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INFLUENCE OF THE POLARIZATION POTENTIAL ON THE STARK BROADENING OF NEUTRAL LINES IN THE ADIABATIC LIMIT

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We set up a model for a charged-perturber - emitter interaction in the region of small velocities, where the impact approximation[1] within the Lindholm and Foley theory may be applied. Deviations from the uniform motion of the perturber in the presence of the polarization potential of an excited atom[2] have been taken into account, what can give rise to focusing and defocusing effects, depending of the sign of the Stark quadratic constant C_4.

So, if $C_4>0$, there appears a critical impact parameter (atomic units are used): $\rho_c=(4C_4/E)^{1/4}$, where E is the energy of the perturber. For $\rho<\rho_c$ all collisions can be regarded as "destructive" and as such ignored. Then one finds for the half-width and the shift:

$$w-id = (2\pi^5 C_4^2 v)^{1/3} N_p (\eta_c/8-i)\eta_c^{1/3}, \qquad \eta_c = \pi(C_4 Em^2)^{1/4}/8$$

where N_p, v and m are density, mean velocity and mass of the perturber, respectively, and η_c is the phase shift calculated along a straight-line trajectory with $\rho = \rho_c$. It follows then that the ratio $|d|/w\to\infty$ as $v\to 0$, as different from the limiting value $\sqrt{3}$, predicted by the usual adiabatic theory.

When $C_4<0$ there exists no critical impact parameter, but calculations show, nevertheless, that in the zero-temperature limit one obtaines:

$$|d|/w \sim (-C_4 Fm^2)^{-1/4}, \qquad v\to 0$$

Hence, the shift-to-width ratio tends to infinity, again, in the zero-temperature limit.

Thus it is shown that in the absence of a quadrupole moment of the excited atom, back-reaction of the emitter on the perturber causes a drastic change in the low-temperature behaviour of w and d of neutral lines in plasmas. If broadening of the lower level of transition is accounted for the same conclusion still holds.

This work has been partially supported by RZN of SR Serbia.

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JENAM-95

Joint European and National Astronomy Meeting

(4th European and 39th Italian Astronomical Society Meeting)

25-29 September 1995

Catania, Italy

PROGRESS IN EUROPEAN ASTROPHYSICS

Facilities, New Instruments & Technologies, Science Challenges

ABSTRACTS

Catania Astrophysical Observatory

1995

On the Stark Broadening of Mg II Spectral Lines

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Lines of ionized magnesium are present in the solar and stellar spectra and the corresponding Stark broadening parameters are of interest for their analysis as well as for the diagnostic of solar and stellar plasma. Due to the fact that with the increase of the principal quantum number increases the importance of the Stark broadening as well, the corresponding Stark widths and shifts are of importance for the structure of solar atmosphere diagnostics,
5 as well as for the consideration of other star atmospheres.

By using the semiclassical-perturbation formalism, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 52 Mg II multiplets. Here, we present and discuss the results for Mg I, along with a comparison with experimental data and other theoretical results.

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ABSTRACTS

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1995

Stark Broadening of C V Spectral Lines of Astrophysical Interest

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Line profiles study of carbon ions in different ionization stages is of particular astrophysical interest, since such lines are present in stellar atmospheres. For studies as *e.g.* numerical modelling of stellar plasma or abundance determinations, data on C V lines are of importance. Stark broadening parameters are needed especially for hot and dense stars. A good example are PG 1159 pre-white dwarfs with effective temperature 100,000 - 140,000 K where carbon and helium are the dominant constituents (C/He = 0.5, Werner *et al.* 1991). Other astrophysical applications have been pointed out in more detail in Dimitrijević and Sahal - Bréchot, 1992). Stark broadening of C V lines are as well of interest for the diagnostic of laser-produced plasma and for the research of regularities and systematic trends.

By using the semiclassical-perturbation formalism, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 25 C V multiplets, in order to continue our research of multiply charged ion line Stark broadening parameters. A summary of the formalism is given in Dimitrijević *et al.* (1991).

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KVAZIKLASIČNO I KLASIČNO ODREDJIVANJE PRESEKA ZA RASEJANJE ČESTICA NA ODSEČENOM KULONOVOM POTENCIJALU

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Kako teorijska istraživanja, tako i interpretacija eksperimentalnih rezultata u fizici plazme, u atomskoj fizici (atomski i jonski sudarni procesi) i td., veoma često se zasnivaju na modelnim potencijalima interakcije naelektrisanih čestica. Pri proučavanju procesa elektron-jonskih i jon-jonskih sudara u plazmi, najčešće su korišćeni potencijali tipa Debajevog i Kulonov potencijal odsečen na jedan ili drugi način, na odredjenoj udaljenosti od centra rasejanja. Ovde se razmatra slučaj odsečenog Kulonovog potencijala kod koga je potencijalna energija interakcije data izrazom:

$$U_c(r) = \begin{cases} -e^2/r + e^2/r_c , & r \leq r_c \\ 0 , & r > r_c \end{cases}$$

gde je r rastojanje od početka fiksiranog koordinatnog sistema, a r_c je zadati parametar. U plazmi se potencijal ovakvog oblika (kao i Debajev) može koristiti pri modelnom opisivanju efekata ekraniranja polja jona (elektrona) od strane naelektrisanih čestica iz njegove okoline. Radijus ekraniranja pri tome može da bude tretiran i kao radijus korelacije čestica, a potencijal interakcije U_c kao efektivni potencijal u slučaju rasejanja elektrona (negativnih jona) na ekraniranim jednostruko jonizovanim pozitivnim jonima. U ovom radu su ispitivane mogućnosti primene kvaziklasičnih i klasičnih metoda pri odredjivanju efikasnih preseka za elastično rasejanje i za prenos impulsa. Dobijeni rezultati uporedjeni su sa rezultatima tačnog kvantnomehaničkog proračuna i pokazano je da u oblasti: $\varepsilon \gtrsim e^2/r_c$, gde je ε energija slobodnog elektrona kvaziklasični i klasični (uslučaju odredjivanja transportnog preseka) metodi, koji daju rezultate u analitičkom obliku, obezbedjuju potrebnu tačnost odredjivanja preseka.

МИНИСТЕРСТВО ОБЩЕГО И ПРОФЕССИОНАЛЬНОГО
ОБРАЗОВАНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ
МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ ТЕХНИЧЕСКИЙ
УНИВЕРСИТЕТ им. Н.Э.БАУМАНА

НИИ ЭНЕРГЕТИЧЕСКОГО МАШИНОСТРОЕНИЯ
МГТУ им. Н.Э.БАУМАНА

РОССИЙСКАЯ АКАДЕМИЯ НАУК

ОТДЕЛЕНИЕ ФИЗИКО-ТЕХНИЧЕСКИХ ПРОБЛЕМ
ЭНЕРГЕТИКИ РАН

IV МЕЖГОСУДАРСТВЕННЫЙ СИМПОЗИУМ ПО РАДИАЦИОННОЙ ПЛАЗМОДИНАМИКЕ

ТЕЗИСЫ ДОКЛАДОВ

МОСКВА
1997

STARK WIDTHS FOR 4s – 4p TRANSITIONS OF Cu III

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From the analyisis of 11 Hg-Mn star spectra [1], it follows that copper is clearly overabundant in 10 stars. Hg-Mn stars are hot stars where Stark broadening is the main pressure broadening mechanism. Also, knowledge of Stark broadening parameters is of interest for the investigation of laboratory plasma. Spectral lines of Cu III and Cu IV are of particular interest for the diagnostic and modelling of plasma created in electromaganetic macro particle accelerators (see e.g. Ref. 2), where in experimental work, the plasma is usually created by Cu or Al foil evaporation. Stark width for six Cu IV, $4s-4p$ multiplets of interest for such plasma have been calculated within the modified semiempirical approach [3] in Ref. 4. Here we present Stark widths for six multiplets of Cu III calculated by using the modified semiempirical approach [3] (for the case of complex heavy ions see also Ref. 5).

Atomic energy levels for calculation have been taken from [6]. Oscillator strengths have been calculated by using method given in Ref. 7 and the tables from Ref. 8.

Our results for Stark widths (FWHM) of Cu III spectral lines are presented in Table 1. There is not mesaured or other calculated data for Cu III.

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Table I. Stark widths (FWHM) of Cu III spectral lines for an electron density of $10^{23}m^{-3}$ as a function of temperature. The averaged wavelength of the multiplet is denoted by $\bar{\lambda}$

Transition	T (K)	W (nm)
$4s^4F - 4p^4F^0$	5000.	.241E-02
	10000.	.169E-02
	20000.	.118E-02
$\lambda = 160.16$ nm	30000.	.957E-03
	40000.	.823E-03
	50000.	.733E-03
	60000.	.667E-03
	70000.	.618E-03
	80000.	.580E-03
	90000.	.549E-03
	100000.	.524E-03
	125000.	.480E-03
	150000.	.453E-03
$4s^4F - 4p^4G^0$	5000.	.257E-02
	10000.	.181E-02
	20000.	.126E-02
$\lambda = 166.77$ nm	30000.	.102E-02
	40000.	.878E-03
	50000.	.782E-03
	60000.	.712E-03
	70000.	.660E-03
	80000.	.619E-03
	90000.	.586E-03
	100000.	.559E-03
	125000.	.512E-03
	150000.	.482E-03
$4s^4F - 4p^4D^0$	5000.	.270E-02
	10000.	.190E-02
	20000.	.133E-02
$\lambda = 171.68$ nm	30000.	.107E-02
	40000.	.922E-03
	50000.	.821E-03
	60000.	.748E-03
	70000.	.693E-03
	80000.	.649E-03
	90000.	.615E-03
	100000.	.587E-03
	125000.	.537E-03
	150000.	.506E-03

Transition	T (K)	W (nm)
$4s^2F - 4p^2D^0$	5000.	.276E-02
	10000.	.194E-02
	20000.	.135E-02
$\lambda = 167.62$ nm	30000.	.109E-02
	40000.	.941E-03
	50000.	.839E-03
	60000.	.764E-03
	70000.	.708E-03
	80000.	.664E-03
	90000.	.629E-03
	100000.	.601E-03
	125000.	.552E-03
	150000.	.522E-03
$4s^2F - 4p^2F^0$	5000.	.275E-02
	10000.	.193E-02
	20000.	.135E-02
$\lambda = 167.30$ nm	30000.	.109E-02
	40000.	.937E-03
	50000.	.834E-03
	60000.	.760E-03
	70000.	.704E-03
	80000.	.661E-03
	90000.	.626E-03
	100000.	.598E-03
	125000.	.549E-03
	150000.	.519E-03
$4s^2F - 4p^2G^0$	5000.	.294E-02
	10000.	.206E-02
	20000.	.144E-02
$\lambda = 174.44$ nm	30000.	.117E-02
	40000.	.100E-02
	50000.	.893E-03
	60000.	.814E-03
	70000.	.754E-03
	80000.	.707E-03
	90000.	.670E-03
	100000.	.640E-03
	125000.	.588E-03
	150000.	.555E-03

МИНИСТЕРСТВО ОБЩЕГО И ПРОФЕССИОНАЛЬНОГО ОБРАЗОВАНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ
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РОССИЙСКАЯ АКАДЕМИЯ НАУК

ОТДЕЛЕНИЕ ФИЗИКО-ТЕХНИЧЕСКИХ ПРОБЛЕМ ЭНЕРГЕТИКИ РАН

IV МЕЖГОСУДАРСТВЕННЫЙ СИМПОЗИУМ ПО РАДИАЦИОННОЙ ПЛАЗМОДИНАМИКЕ

ТЕЗИСЫ ДОКЛАДОВ

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1997

ON THE STARK BROADENING OF P IV SPECTRAL LINES

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INTRODUCTION

Stark broadening parameters of P IV lines are of interest not only for the plasma diagnostic but for the research of regularities and systematic trends and theoretical considerations as well. Consequently, Stark widths for P IV $4s^1S$ - $4p^1P^o$, $4s^3S$ - $4p^3P^o$ and $3p^3P^o$ - $3d^3D$ multiplets have been determined [1-3] within the modified semiempirical approach [4], Griem's semiempirical approach [5], symplified semiclassical approach (Eq. 526 in Ref. 6) and its modification [4].

In order to continue our research of Stark broadening parameters needed for the investigation of astrophysical and laboratory plasmas and to provide the needed Stark broadening data, we have calculated within the semiclassical-perturbation formalism [7,8] electron-, proton-, and He III-impact line widths and shifts for 114 PIV multiplets. Here wi will present the comparison of our results with other available theoretical data [2,3].

RESULTS AND DISCUSSION

A summary of the formalism is given in Ref. 9. All details of calculations and obtained Stark broadening parameters will be presented at conference and published elsewhere [10].

In Table 1, present semiclassical Stark full widths at half maximum (WDSB) in Å are compared with the calculations in Refs. 2 and 3 by using the modified semiempirical approach [4] (WMSE), Griem's semiempirical approach [5] (WSE), symplified semiclassical approach (Eq. 526 in Ref. 6) (WG) and its modification [4] (WGM). One can see that the best agreement is with the results obtained by using the symplified semiclassical approach.

TABLE I

Present semiclassical Stark full widths at half maximum (WDSB) in Å compared with the calculations of Dimitrijević [2,3] by using the modified semiempirical approach [4] (WMSE), Griem's semiempirical approach [5] (WSE), symplified semiclassical approach (Eq. 526 in Ref. 6) (WG) and its modification [4] (WGM).

PERTURBER DENSITY = 1.E+17cm-3

TRANSITION	T(K)	WDSB(A)	WG(A)	WGM(A)	WSEM(A)	WSE(A)
P IV 4S 4P	10000.	0.714	0.653	0.363	0.565	0.264
4250.9 A	20000.	0.502	0.477	0.279	0.399	0.186
C= 0.43E+21	40000.	0.367	0.360	0.229	0.282	0.132
	80000.	0.280	0.285	0.202	0.215	---
	160000.	0.225	0.238	0.188	0.183	---
P IV 4S 4P	10000.	0.411	0.385	0.216	0.330	0.158
3356.9 A	20000.	0.291	0.281	0.165	0.233	0.112
C= 0.34E+21	40000.	0.210	0.211	0.134	0.165	0.790E-01
	80000.	0.159	0.166	0.117	0.121	0.648E-01
	160000.	0.127	0.138	0.108	0.100	---
P IV 3P 3D	10000.	0.743E-02	0.573E-02	0.477E-02	0.350E-02	0.260E-02
826.3 A	20000.	0.521E-02	0.417E-02	0.350E-02	0.248E-02	0.184E-02
C= 0.46E+20	40000.	0.375E-02	0.313E-02	0.267E-02	0.175E-02	0.130E-02
	80000.	0.271E-02	0.248E-02	0.216E-02	0.124E-02	0.920E-02
	160000.	0.200E-02	0.211E-02	0.190E-02	0.873E-03	0.690E-03

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IV Serb. Bulg. Astron. Conf.
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Program and Abstracts

Invited lecture

REDUCTION OF ASTROGEODETIC DETERMINATIONS ON THE UNIQUE SYSTEMS

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Determinations in geodetic astronomy, namely, determination of time, longitude, latitude and azimuth from star observations, have been made during a long period by different persons. Positions of observed stars have been taken from different catalogues and in different reference systems. In order that results of such determinations will be mutually comparable, it is necessary to make the reduction of stellar positions on the unique reference system. Consequently, results of astrogeodetic determinations will also be reduced to the same system. Starting from the fact that the position of a point is determined only related to something, it is possible to calculate systematic differences of particular catalogues and catalogues used for the materialisation of the chosen reference system. Obtained stellar positions-, and proper movements - systematic errors, enable the changement from standard epoch on another one (the moment of observation), so that stellar positions are reduced to a single system. The proposed model is checked at three classical methods of geodetic astronomy and applied to results of general Stevan Bošković's astrogeodetic determinations, made in the first decade of the XX century.

Invited lecture

FULLERENES AND ASTRONOMY

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Carbonaceous dust in the interstellar medium may show strong diversity and might include not only amorphous carbon but also a variety of components like hydrogenated amorphous carbon, soot, quenched-carbonaceous condensate, diamonds and other so that is pointed out the relation of formation of PAHs, bucky tubes and fullerenes to such dust. We note as well that the astrophysically motivated investigations of the chemistry of carbon stars resulted with the discovery of the C_{60} molecule, first and the most interesting representative of such molecules. Here is presented a review of astronomical researches connected with fullerenes as for example the search for interstellar and circumstellar ones or presence of such molecules in meteorites brechias of impact craters on Earth and impact traces on spacecrafts. Also, their connection with the problem of the diffuse interstellar and circumstellar absorption lines will be discussed. Particular attention will be payed to the search for polyynes in interstellar space which resulted in the formulation of investigation of chemistry of carbon stars and in discovery of fullerenes.

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Program and Abstracts

Poster paper

WATER IN ASTRONOMY AND PLASMA PHYSICS AND A PROJECT FOR RELATED RESEARCH

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The importance of water, the dissolvent without whom our kind of life would be impossible, is obvious and the research of all aspect of this compound is of great interest for many sciences. In astronomy, water is found in comets, Jovian satellites, on the Mars... The first molecule to be detected by radio astronomy methods, was the radical OH in 1963. Some OH sources in interstellar H II regions show strong H_2O emission as well. Their H_2O emission is variable, with intensity changes occuring in periods of months and days. In such regions temperature is around 10000 K and ion density around 5000 ions on m^3. Waters molecules are found and in OH-IR stars, which are probably dust enshrouded Myras having period 600 - 2000 days, and are not visible optically. Recently, water molecules have been detected in the mid-infrared (11-12 microns) spectrum of Arcturus, a K2IIIp giant star (Ryde, N., et al. 2003). Moreover, water at 22,235 MHz (1,35 cm) is one of the well known cosmic masers. Plasma obtained from H_2O is of interest and for investigations of underwater discharges, some aspects of electrolysis research, and for various treatments of water. In this contribution, our project for investigations of plasma-water interaction, plasma containing water molecules, or obtained in the presence of water molecules, of interest for astronomy, laboratory physics and technology, will be discussed.

Poster paper

TEMPORAL VARIABILITY OF THE GRB LIGHT CURVE

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The inner engines of Gamma Ray Bursts (GRBs) are well hidden from direct afterglow observations. However, the variability of GRB light curves at beginning of GRB event can bring us information about the nature of the inner engines. Here, we will present a numerical model which can synthesize light curves in the first phase of GRB in the high density environment. At the beginning we assume that an inner engine creates a lot of small mass shock waves which are spreading isotropically and after short period of time (a couple of seconds) disappearing in the surrounding media. This process causes creation of a massive shock wave which interacts with surrounding media and produces the GRB afterglow. The peaks in the light curve arise in the moment of mutual shocks interaction. We have modeled light curves from a given dynamics, by assuming synchrotron radiation mechanism

IV Serb. Bulg. Astron. Conf.
Belgrade 21–24. April 2004.
Program and Abstracts

Poster paper

ON THE STARK BROADENING OF F III LINES IN WHITE DWARF ATMOSPHERES

ZORAN SIMIĆ, MILAN S. DIMITRIJEVIĆ, LUKA Č. POPOVIĆ
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In order to provide the Stark broadening parameters for F III spectral lines, we made first of all a model of F III atom, with symplified energy level structure, facilitating and optimizing our further considerations. We applied full semiclassical perturbation method only to the astrophysically most important, resonance transition, since for other lines there is no enough complete set of atomic data for such calculations. Consequently, for additional ten multiplets, the modified semiempirical method has been applied, and only Stark widths have been calculated. On the basis of obtained results, the influence of Stark broadening mechanism on F III lines in DA white dwarfs has been investigated. The obtained results demonstrate that it is more important than in A-type star atmospheres, and that it should be taken into account for spectrum analysis and synthesis.

Poster paper

ON THE STARK BROADENING OF Cd I LINES

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For the determination of chemical composition and plasma diagnostic of stellar atmospheres, as well as for radiative transfer, plasma modelling and stellar spectra interpretation and synthesis, Stark broadening parameters are of interest, especially for A-type stars and some white dwarfs, or pre dwarfs like PG-1195 type ones. In order to provide the Stark broadening data for neutral cadmium spectral lines, we have calculated within the semiclassical perturbation theory, Stark broadening parameters (width and shift) for 19 Cd I multiplets in UV and V and for 24 multiplets in infra red spectral ranges, for temperatures between 2500 K and 50 000 K, particularly interesting for stellar plasma investigations. Our theoretical values have been compared with existing experimental, and other theoretical values.

Poster paper

ON THE EXPERIMENTAL AND THEORETICAL INVESTIGATIONS OF F II STARK BROADENING

ALEKSANDAR SREĆKOVIĆ[1], SRDJAN BUKVIĆ[1], STEVAN DJENIŽE[1], MILAN S. DIMITRIJEVIĆ[2]

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Stark widths (W) and shifts (d) of 5 singly ionized fluorine (F II) spectral lines within the $3s - 3p, 3s' - 3p'$ and $3d - 4f$ transitions have been measured in a linear, low-pressure, pulsed arc discharge created in SF_6 plasma at 30400 − 33600 K electron temperatures and at $(2.75 - 2.80) \times 10^{23}$ m^{-3} electron densities. The widths and shifts have also been calculated using the semiclassical perturbation formalism (SCPF) (taking into account the impurity of energy levels, i.e. that the atomic energy levels are expressed as a mix of different configurations due to the configuration interaction). Calculations have been performed for temperatures between 5 000 K and 100 000 K for the for electrons, protons and helium ions as perturbers. Our measured and theoretical Stark parameters are compared with existing experimental and theoretical data. Tolerable agreement was found among them.

Poster paper

CALIBRATION OF THE DIAMETER TULLY-FISHER RELATION AS TOOL FOR DISTANCE DETERMINATION TO SPIRAL EDGE-ON GALAXIES

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The luminosity - HI line width relation of (Tully and Fisher 1977), hereafter TFR, is a widely used tool in the observational cosmology. Today, with the advent of the CCDs, the application of the TFR becomes more efficient. In this work we present calibrated TFR for the diameters of well studied nearby galaxies in B-band (from Macri et al. 2000) and apply it on the sample of 120 edge-on galaxies Karachentsev et al. (1992). The calibration was made after reducing the linear diameters of the calibrators into edge-on view. Using the derived TFR, the distances to the galaxies from the target sample are calculated and compared with kinematic distances. The distance modulus error, of the derived calibration is about 0.45 mag, and the relative distance error is 21%.

9th Cambridge Workshop

COOL STARS
STELLAR SYSTEMS AND THE SUN

Dedicated to the memory of Olin C. Wilson

PROGRAM and ABSTRACTS

Florence (Italy), October 3 - 6, 1995

On the Stark Broadening of Mg I Spectral Lines in Solar and Stellar Spectra

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Lines of neutral magnesium are present in the Solar spectrum and the corresponding Stark broadening parameters are of interest for their analysis as well as for the diagnostic of solar plasma. Especially the infrared lines of Mg I have been observed in the solar spectrum at Kitt Peak and during the Atmos experiment on Spacelab. Due to the suitability of these lines for the solar atmosphere investigations (see e.g. Van Regemorter & Hoang-Binh 1993) and to the fact that with the increase of the principal quantum number increases the importance of Stark broadening as well, the corresponding Stark widths and shifts are of importance for the structure of the solar atmosphere research and solar plasma diagnostic. Stark broadening data for Mg I lines are also of interest for laboratory plasma research and have been investigated experimentally and theoretically several times.

By using the semiclassical-perturbation formalism we have calculated here electron-, proton-, Mg II-, Si II-, Fe II-, and Ar II-impact line widths and shifts for 267 Mg I multiplets , in order to provide the needed Stark broadening parameters for all important perturbers for investigation and modelling of solar plasma. A summary of the formalism is given in Dimitrijević *et al.* (1991). Regemorter & Hoang Binh (1993) have been discussed recently the important simplification of theory for solar Rydberg lines corresponding to the transitions between nearly degenerate states. We check and discuss here this approximation. Moreover, our calculations of Stark full widths for Mg I $5g^1G$ - $6h^1H$ and $6g^1G$ - $7h^1H$ transitions have been compared with available simpler calculations. We hope that the comprehensive set of Stark broadening parameters of Mg I lines will enable the better use of Mg I spectral lines for solar plasma research.

Dimitrijević, M.S.,Sahal-Bréchot,S., & Bommier,V.,1991, A&AS 89, 581.
Regemorter, van H., Hoang Binh Dy, & Prud'homme,M. 1979, J.Phys.B 12, 1073

МАТЕМАТИЧКИ ФАКУЛТЕТ
УНИВЕРЗИТЕТ У БЕОГРАДУ

НАЦИОНАЛНИ ЦЕНТАР
ЗА ДИГИТАЛИЗАЦИЈУ

МАТЕМАТИЧКИ ИНСТИТУТ
СРПСКЕ АКАДЕМИЈЕ
НАУКА И УМЕТНОСТИ

Девета национална конференција с међународним учешћем

НОВЕ ТЕХНОЛОГИЈЕ И СТАНДАРДИ: ДИГИТАЛИЗАЦИЈА НАЦИОНАЛНЕ БАШТИНЕ 2010

МАТЕМАТИЧКИ ФАКУЛТЕТ, УНИВЕРЗИТЕТ У БЕОГРАДУ

Београд, Србија, 16-17. јун 2010

Скуп финансијски подржавају:
Министарство за науку и технолошки развој Републике Србије
Математички факултет, Универзитет у Београду
Математички институт САНУ
Пројекат "Примена информационих технологија у дигитализацији националне и културне баштине", број пројекта 13017

AccessIT : preparing our cultural institutions to contribute digital content in Europe

Rob Davies
MDR Partners, London

The speaker will present the work of the AccessIT project, funded under the European Union's Culture and Media programme, to extend skils in the creation and management of digital libraries to people working in cultural institutions at local level, in three countries of South East Europe: Greece, Serbia and Turkey. The project is an adjunct to the Europeana Local Best Practice Network under the European Digital Libraries Initiative.One of its outcomes will be the creation of a repository of digital content metadata in Serbia for ingestion by Europeana. The presenter will introduce a new online training course for the purpose of training professionals to make content available for harvesting by Europeana and will discuss plans for the accreditation of this training.

Електронска издања београдских астрономских институција

Милан С. Димитријевић
Астрономска опсерваторија, Београд

Са електронским издаваштвом започео сам на Астрономској опсерваторији 2006. године. Мотиви су били двојаки. Са једне стране, желео сам да радови из књига које сам уредио и са конференција које сам организовао буду доступни преко великих међународних база података као што је Насин АДС. Са друге пак, електронско издање омогућује да се сачува, и уврсти у библиотеке, виртуалне библиотеке и базе података као што је Српска виртуелна опсерваторија и материјал који не иде у књиге, као што су велики број фотографија, видео записи и презентације предавача, при чему су рецимо фотографије у облику погодном за штампање и коришћење у другим публикацијама. Дугорочнији циљ је да дигитализујемо зборнике са свих конференција које смо организовали и приредимо и њихова званична електронска издања, која ће имати ЦИП Народне библиотеке и ISBN број, а у која ће бити укључен и онај постојећи матерјал кога нема у папирној верзији, или је тамо одштампан неквалитетно.

До данас су публикована 22 компакт диска и ДВДа, а издавачи су били Астрономска опсерваторија, Астрономско друштво „Руђер Бошковић“, Друштво астронома Србије и Природњачко друштво „ГЕА“ из Вршца. Они се предају библиотекама, као што је Народна библиотека, Библиотека Матице српске, Библиотека Париске опсерваторије, Насином АДСу, Националном центру за дигитализацију и другим институцијама, библиотекама и базама података.

Подаци о изабраним електронским издањима према ЦИП запису

1. Развој астрономије код Срба, IV, Београд 22-26. април 2006. [Електронски извор], Development of Astronomy among Serbs IV, уредник Милан С. Димитријевић, организатор Астрономско друштво “Руђер Бошковић”, диск припремили Милан С. Димитријевић и Татјана Милованов. – Електронско изд. – Београд: Астрономско друштво “Руђер Бошковић”, Астрономска опсерваторија, 2007 (Београд: Астрономско друштво “Руђер Бошковић”). - 1 електронски оптички диск (CD-ROM).

2. I HUNGARIAN-YUGOSLAV ASTRONOMICAL CONFERENCE, Baja, Hungary, 26-27. April, 1995 [Електронски извор], edited by Istvan Vince, Milan S. Dimitrijevic and Lajos Balazs ; CD prepared by Milan S. Dimitrijevic and Tatjana Milovanov. - Belgrade: Astronomical Observatory, 2008 (Belgrade: Astronomical Observatory). - 1 електронски оптички диск (CD-ROM).

3. LINE SHAPES INVESTIGATIONS IN YUGOSLAVIA AND SERBIA [Електронски извор]: (BIBLIOGRAPHY AND CITATION INDEX), Истраживање облика спектралних линија у Југославији и Србији : (библиографија и индекс цитата), Milan S. Dimitrijević. - CD prepared by Milan S. Dimitrijevic and Tatjana Milovanov. - Belgrade: (Belgrade: Astronomical Observatory), Belgrade 2009 - 1. електронски оптички диск (CD-ROM) (Електронски извор је електронска верзија истоимених књига 1-5 публикованих у едицији "Публикације Астрономске опсерваторије у Београду").

4. ABSTRACTS, PRESENTATIONS AND PHOTOS [Електронски извор] The First Summer School in Astronomy and Geophysics, August 6-11, 2007, Belgrade, Serbia ; eds. Milan S. Dimitrijević, Nadežda Pejović, Anđelka Kovačević, organized by Faculty of Mathematics, Belgrade. CD prepared by Milan S. Dimitrijević and Tatjana

PRELIMINARY PROGRAM

	Sreda, 16. 06.	**Wednesday**
8:30 – 9:15	**Registracija**	**Registration**
9:15 – 9:30	**Svečano otvaranje**	**Opening ceremony**
9:30 - 10:55	predsedavajući – chairman:	**Zoran Ognjanović**

- 9:30 - 9:55 **Smile Markovski**
  O nacionalnoj strategiji digitizacije kulturnog nasledja u Makedoniji - perspektive i dileme
- 9:55 - 10:10 **Žarko Mijajlović**
  O projektu Primena informacionih tehnologija u digitalizaciji naučnog i kulturnog nasleđa
- 10:10 - 10:25 **Irini Reljin, Milena Jocić, Stefana Janićijević**
  Analog to Digital TV Transition in the Republic of Serbia
- 10:25 - 10:40 **Andreja Samčović**
  Tehnike za kodovanje kod digitalnog bioskopa
- 10:40 - 10:55 **Branislav Tomić**
  Lexicon Palaeoslovenico — Graeco-Latinum digitalization and conversion into web application

10:55 - 11:20	**pauza**	**coffee break**
11:20 - 12:30	predsedavajući – chairman:	**Tamara Butigan**

- 11:20 - 11:45 **Rob Davies**
  AccessIT : preparing our cultural institutions to contribute digital content in Europe

- 11:45 - 12:00 **Pavel Pavlov, Maria Nisheva-Pavlova, Anton Iliev, Klimentina Rousseva, Nadezhda Apostolova**
  Authoring Tools for an Academic Digital Library
- 12:00 - 12:15 **Maria Nisheva-Pavlova, Pavel Pavlov**
  Methods and Tools Supporting the Lifecycle of Rich Digital Content
- 12:15 - 12:30 **Marija Bogdanović, Nenad Jeremić**
  Baza podataka Srpske retrospektivne bibliografije knjiga: 1868-1944

12:30 - 13:05 poster sekcija, pauza poster section, coffee break

- **Aleksandar Pejović**
  O rezultatima nekih projekata digitalizacije u Srbiji
- **Nadežda Pejović, Aleksandar Valjarević,Žarko Mijajlović**
  Digitized astronomical works of Serbian Authors

13:05 - 14:30 predsedavajući – chairman: **Vesna Vučković**

- 13:05 - 13:30 **Dunja Seiter-Šverko**
  Synergy between analog and digital formats in the space of cultural heritage (on the example of Republic of Croatia)
- 13:30 - 13:45 **Poposki Dimitar**
  The Republic of Macedonia National Strategy for the Digitization of Cultural Heritage – the way toward an Information Literate Society
- 13:45 - 14:00 **Bojan Marinković, Zoran Ognjanović, Tamara Butigan Vučaj**
  Programski sistem za realizaciju kataloga digitalnih kolekcija
- 14:00 - 14:15 **Maja Nikolova**
  Digitalizacija istorije školstva
- 14:15 - 14:30 **Slađana Milojević**
  Digitalizacija dokumentacije Zavoda za zaštitu spomenika kulture grada Beograda – Retrospektiva dosadašnjih aktivnosti na digitalizaciji dokumentacije

14:30 - 16:00 **pauza** **coffee break**

16:00 - 17:45 predsedavajući – chairman: **Dragan Blagojević**

- 16:00 - 16:15 **Vesna Aleksandrović**
  Bulbul pjeva – zvuci bosanske duše sa starog gramofona
- 16:15 - 16:30 **Marija Dumnić**
  Projekat „Digitalizacija i katalogizacija Fonoarhiva Muzikološkog instituta SANU“: dosadašnja iskustva i perspektive
- 16:30 - 16:45 **Stevo Šegan, Vladimir Zeković**
  Understanding Audio Digitization: Audio History, Preservation, Reconstruction and Reformatting
- 16:45 - 17:00 **Vesna Aleksandrović, Ivan Pešić**
  Data Mining – Revealing the Sound Recordings Metadata Meaning
- 17:00 - 17:15 **Snežana Negovanović**
  Digitalna fotografija, proces rada za potrebe fotodokumentacije kulturno-istorijskog nasleđa
- 17:15 - 17:30 **Dragana Rusalić**
  Urban Performans As Part of the Intangible Heritage: Dilemmas, Challenges, Problems and Perspectives of Archiving Contemporary Visual Arts Through Digitization Process
- 17:30 - 17:45 **Goran Gavrilović, Ana Josipović, Nada Jevremović, Srđan Kosovac**
  Muzejski informacioni sistem Srbije - MISS, Muzejska WEB aplikacija ETERNITAS

	Četvrtak, 17. 06.	**Thursday**
8:45 - 9:00	**kafa**	**coffee**
9:00 - 10:30	predsedavajući – chairman:	**Nenad Mitić**

- 9:00 - 9:15 **Vesna Vučković**
  Digitalni vodeni žig u digitalnim slikama i elektronskim knjigama
- 9:15 - 9:30 **Sanja Rajić**
  Digitalizacija u srednjoškolskoj nastavi
- 9:30 - 9:45 **Sanja Životić**
  Registar digitalizovane kulturne baštine
- 9:45 - 10:00 **Mirjana Mijajlović, Angelina Stojanović, Jelena Vasić**
  Pregled razvoja i primena digitalizacije u Muzeju grada Beograda na primerima stručnog muzejskog arhiva sa fototekom i terenskom arheološkom dokumentacijom
- 10:00 - 10:15 **Jelena Glišović**
  Digitalizacija i bibliotekarstvo: Između autorskih prava i slobode pristupa
- 10:15 - 10:30 **Aleksandra Fostikov, Stefana Janićijević**
  New technologies and reconnaissance historical- geography and toponymical research of Toplica “land” with photo session in software Photosynt

10:30 - 11:00	**pauza**	**coffee break**
11:00 - 12:40	predsedavajući – chairman:	**Saša Malkov**

- 11:00 - 11:25 **Milan S. Dimitrijević**
  Elektronska izdanja beogradskih astronomskih institucija
- 11:25 - 11:40 **Nadežda Pejović**
  Digitalizovane knjige Đorđa Stanojevića

- 11:40 - 11:55 **Sonja Vidojević, Stevo Šegan, Slaviša Milisavljević, Biljana Samardžija, D. Marčeta**
  Serbian Astronomical School: last 70 years of Identity

- 11:55 - 12:10 **Jelena Hadži-Purić, Gordana Pavlović-Lažetić, Ana Vukadinović, Bojana Mitrović, Miloš Vojinović, Igor Valjević, Miloš Đurić**
  "Aleksandar Popović" – digitization, storage and retrieval

- 12:10 - 12:25 **Nada Đorđević**
  Digitalna baza tekstualnih podataka

- 12:25 - 12:40 **Dragana Milunović**
  Skriveno blago biblioteka Srbije: virtuelna izložba najdragocenijih eksponata iz zavičajnih zbirki javnih biblioteka u Srbiji

12:40 - 13:10 **pauza** **coffee break**

13:10 - 14:40 predsedavajući – chairman: **Nadežda Pejović**

- 13:10 - 13:25 **Duško Vitas, Miljana Mladenović, Stana Ristić, Gordana Pavlović-Lažetić, Miloš Utvić**
  Digitalni dokumenti u procesima leksikografske obrade

- 13:25 - 13:40 **Jovan Krstić**
  Kriminalitet mržnje i zaštita kulture

- 13:40 - 13:55 **Snežana Nenezić, Miljko Veljković**
  Digitalizacija odabranih naslova književnih dela iz fonda Zavičajne zbirke Narodne biblioteke Kruševac

- 13:55 - 14:10 **Milorad Jovanović, Miljenko Prohaska**
  Savremeni sistemi zaštite i arhiviranja kulturne baštine zasnovani na visokosofisticiranoj opremi za digitalizaciju raznorodnih materijala

- 14:10 - 14:25 **Boris Horošavin**
  Mogućnost primene tehnologije trodimenzionalne vizuelizacije u oblasti zaštite nepokretnih kulturnih dobara

- 14:25 - 14:40 **Zoran Miljenović**
  Srpska arheologija na trodimenzionalnom putu

LIST OF PARTICIPANTS

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9-th INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES

July 25 – 29, 1988
Toruń, Poland

ABSTRACTS

of Contributed Papers

Nicholas Copernicus University Press
Toruń 1988

ON THE STARK BROADENING OF Si IV LINES: REGULARITIES WITHIN SPECTRAL SERIES

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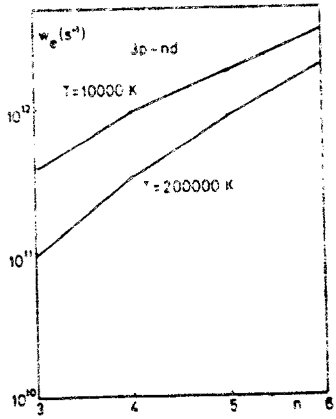
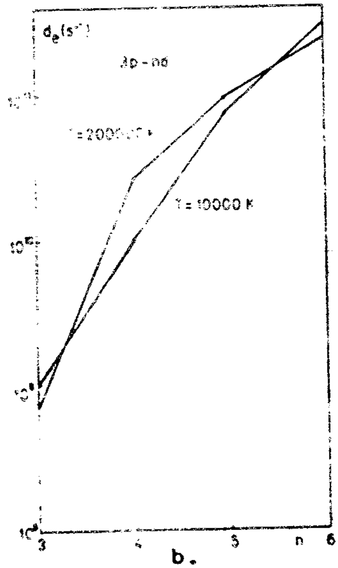
Due to its high abundance, silicon is very interesting for astrophysicists as well as in the laboratory plasma diagnostics, since it is often present as impurity. Using the semiclassical-perturbational formalism [1,2] we have calculated electron- and proton-impact line widths and shifts of 36 Si IV multiplets, and our results are compared with available theoretical and experimental data. The results obtained have also been used to continue our investigation of systematic trends among Stark-broadening parameters within spectral series [3-6].

In Fig. 1, the behaviour of electron- and proton-impact full halfwidths and shifts within $3p\,^2P^o - nd\,^2D$ series for different plasma temperatures (10000 and 200000 K) is presented as an example. By inspecting energy separation between the upper level and the principal perturbing levels (see Grotrian diagrams in Ref. 7) we find that this value decrease gradually within a spectral series. Thus, we obtain a gradual change of Stark broadening parameters as expected.



a.



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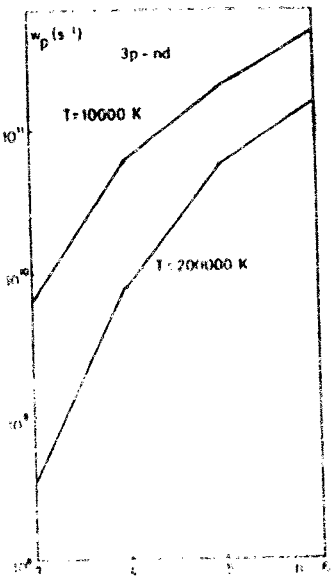
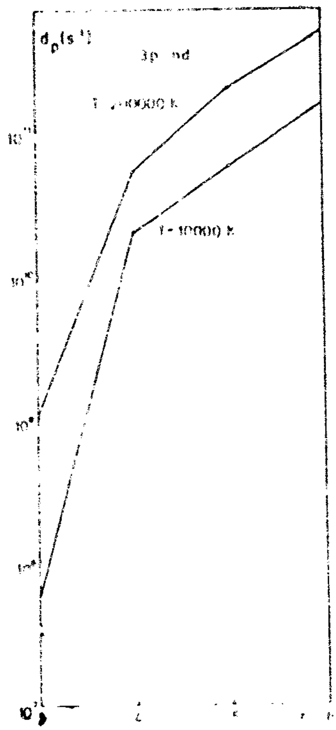


c.

Fig. 1. Stark broadening parameters for Si IV $3p^2P^o$–nd^2D lines as a functionof the principal quantum number of the initial level (n) for T=10000K and 200000 K at $N_e=10^{17}cm^{-3}$. a) Ele-



d.

ctron-impact full halfwidth, b) electron-impact shift, c) proton-impact full halfwidth, d) proton-impact shift.

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9-th INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES

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ABSTRACTS

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Nicholas Copernicus University Press
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LINE WIDTH REGULARITIES AND SYSTEMATIC TRENDS DUE TO COLLISIONS WITH NEUTRAL PERTURBERS

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Regularities and systematic trends of the Stark broadening parameters of isolated, non-hydrogenic spectral lines in plasmas have been studied recently in a number of papers (see e.g. Ref. 1 and references therein). The aim of such studies is to find out if regularities and systematic trends are apparent to such a degree that accurate interpolation of new data as well as the critical evaluation of published data and preliminary experimental results are possible. In this contribution, we try to investigate if such regularities are also apparent in the case of spectral lines broadened by neutral atom impacts, excluding here the case of resonance broadening.

Broadening of a line depends firstly on the dynamics of the collisions with perturbing particles and on the collective effects of all perturbers. Consequently, differences between e.g. low density and high density cases arise. On the other hand, broadening depends also on particle properties. On the basis of atomic structure considerations, similarities should exist within a given spectrum, for line widths within a multiplet, supermultiplet and, to a lesser degree, within a transition array. Furthermore, a regular behaviour of line widths is expected within a spectral series, for corresponding transitions in homologous emitters, and in isoelectronic sequences. Regularities and similarities in line widths are expected also considering different perturbing atom properties such as the polarizability. Dependence of line width on the ionization potential may also be investigated.

In order to find out if regularities and similarities due to particle

Table 1. Examples for supermultiplets and transition arrays. Experimental data of Smith and Raggett, 1984 [4]. Perturber is He and T=2500 K. The w is half halfwidth.

Designation	Multiplet	λ (Å)	w/N(10^{20} rad s^{-1}/cm^{-3})
Ca I 4s3d-3d(^{2}D)4p'	$^3D-^3F^o$	6460.3	0.749
	$^3D-^3D^o$	5592.5	1.13
	$^3D_1-^1D_2$	6449.8	0.851
	$^1D_2-^1D_2$	7148.2	0.627
	$^1D_2-^3P_1$	5717.	1.83

Table 2. Examples for multiplets and homologous atoms.

Transition	λ (Å)	T(K)	w/N (10^{20} rad s^{-1}/cm^{-3}) Ar	Kr	Xe	Ref. (perturbers)
Li I $2s^2S-2p^2P^o$	6707.8	400	0.498	0.615	0.695	(5)
		600	0.460	0.607	0.691	(6)
Na I $3s^2S-3p^2P^o$	5895.9	450	0.796	0.693	0.840	(7)
			0.699	0.780	0.856	(8)
		475	0.796		0.758	(9)
	5890.0	450	0.608	0.679	0.711	(7)
			0.641	0.722	0.825	(8)
		475	0.651		0.668	(9)
K I $4s^2S-4p^2P^o$	7664.9	410	0.337	0.394	0.468	(10)
	7699.0	410	0.413	0.391	0.467	(10)
Rb I $5s^2S-5p^2P^o$	7947.6	320	0.298	0.298	0.343	(11)
	7800.2	320	0.316	0.275	0.362	(11)
Cs I $6s^2S-6p^2P^o$	8943.5	295	0.235	0.238	0.257	(12)
	8521.1	295	0.301	0.143	0.760	(12)

properties are apparent in the case of line broadening due to neutral non-resonant collisions, we analyzed critically selected experimental data [2]. In table 1 are given examples for similarities of line widths within supermultiplets and transition arrays, in table 2 for multiplets and homologous atoms, and in table 3 for a spectral series. The polarisability of the rare gas atoms increase monotonically with increasing atomic mass, and it can be seen that as one would expect, the measured widths, in general also increase with increasing polarisability.

Table 3. An example for spectral series. Perturber is Xe.

Transition	(K)	T(K)	Half halfwidth (w/N) (10^{20} rad s^{-1}/cm^{-3})	Ref.
Cs $6s\,^2S_{1/2}-6p\,^2P_{1/2}$	8943.50	295	1.09	(12)
Cs $6s\,^2S_{1/2}-7p\,^2P_{1/2}$	4593.20	395	3.14	(13)
Cs $6s\,^2S_{1/2}-8p\,^2P_{1/2}$	3889.	450	5.43	(14)

This is an indication that the longer-range part of the radiator-perturber interaction is dominant. The main exception to this rule is the case of helium perturbers. Here, the short range part of the interaction dominates and this is not directly related to the polarisability at all, c.f. Ref. 3.

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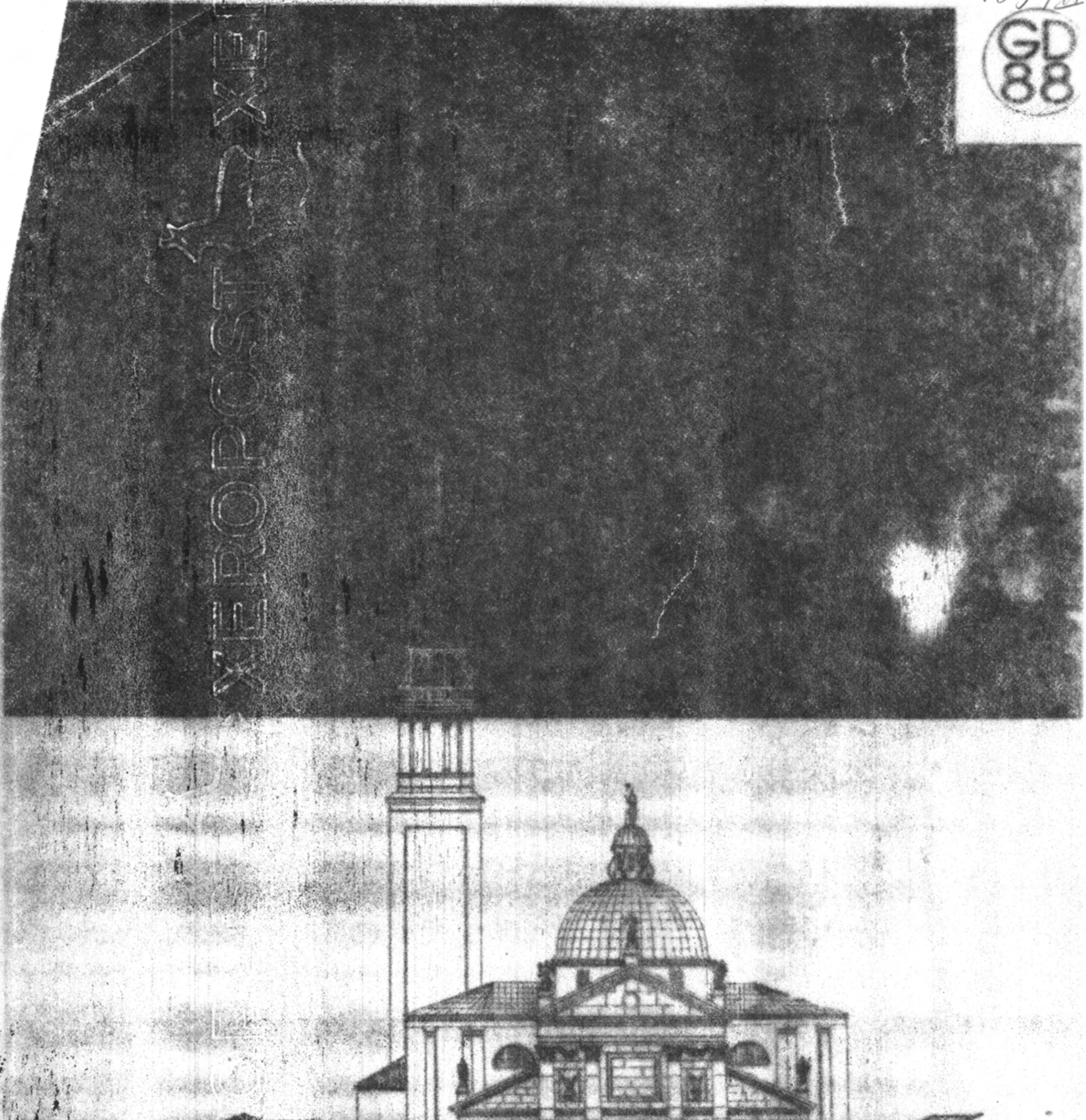

IX INTERNATIONAL CONFERENCE ON GAS DISCHARGES AND THEIR APPLICATIONS

VENEZIA, 19-23 SEPTEMBER 1988

ABSORPTION OF ELECTRO-MAGNETIC RADIATION DURING COLLISIONS BETWEEN LITHIUM ATOMS AND IONS IN LOW TEMPERATURE PLASMA

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On the basis of the semiclassical adiabatic method radiation processes (emission and absorption of electromagnetic radiation) during ion-atomic collisions at thermal velocities have been studied previously (Mihajlov, 1981; Mihajlov, 1986). Mihajlov (1986) obtained results for hydrogene plasma. Recently however, processes of radiation transfer in alkaline metal plasma at low temperatures (i.e. at relatively low degrees of ionization) but at high atom densities, become more interesting. Consequently, in this paper, absorption of electro-magnetic radiation during ion-atom collisions in low temperature plasma has been studied.

In such plasma, absorption of radiation can be caused, among other processes, by the photodissociation of molecular ions:

$$AB^{+} + \hbar\omega \longrightarrow A^{+} + B \qquad \text{1a)}$$

Besides this process we take into account absorption of the radiation by quasimolecular complexes (originating in ion-atomic collisions) as well:

$$A + B^{+} + \hbar\omega \longrightarrow A^{+} + B \qquad \text{1b)}$$

Here, A and B are atoms while A^{+}, B^{+} are the corresponding ions. In a number of cases, processes 1a) and 1b) could be treated as separate channels of unique process of photoabsorption.

We studied symmetrical case when in relations 1a) and 1b) A and B are identical atoms(A≡B, $I_A \equiv I_B$, where $I_{A,B}$ is the ionization potential).

Such case is realized for example in low temperature alkaline metal plasma. Of special interes are dense, low temperature weakly ionized alkaline metal plasma (before all in connection with MHD energy conversion etc). In this paper we conseder the case of lithium plasma. Processes corresponding to the processes 1a) and 1b) in this case are the following.

$$Li_2^{+} + \hbar\omega \longrightarrow Li^{+} + Li \qquad \text{2a)}$$

$$Li^{+} + Li \longrightarrow Li + Li^{+} \qquad \text{2b)}$$

The absorption coefficient of radiation caused by the processes 2a) and 2b) is determined in semiclassical approximation. In low temperature plasmas, we found that our relations are the simplest in the case of the dissociative-recombination equilibrium. In this case, very important in praxis, the absorption coefficient can be normalized to the unity concentrations of atoms Li and ions Li^{+}. We determined the total effect of absorption of radiation due to both processes. We also found the frequency and the temperature regions in which either process 2a) or 2b) has predominant role.

In the processes 2a) or 2b) a photon of frequency ω is absorbed by ion-atomic complex. In the symmetrical case that we study, the complex is either represented by collisional complex Li + Li^{+} or by molecular ion Li_2^{+}. Due to absorption of the pnoton, transition between initial (lower) and final (upper) electronic state of the complex occurs. In the case of alkaline metals, Σ_g is atomic initial state and Σ_u is its final state. For the fixed inter-nuclear distances we will denote with $V_1(R_\omega)$ and $V_2(R_\omega)$ the energies of these states respectively. Photons with frequencies laying in the interval $(\omega, \omega + d\omega)$ are absorbed by the ion-atomic complexes with inter-nuclear distances in the interval $(R_\omega, R_\omega + dR_\omega)$. Here, R_ω is the root of the equation: $\hbar\omega = V_2(R) - V_1(R)$. We limit ourselves only to the range of $\omega(R_\omega)$ for which $V_1(R_\omega) < 0$.

The total absorption coefficient which is the result of parallel action of both processes 2a) and 2b) is given with the following expression:

$$K_\omega(T) = 6.25 \cdot 10^{-43} \cdot (R_\omega^4/\delta) \cdot \exp[-X_\omega(T)] \qquad (3)$$

Absorption coefficients due to an action of either process 2a) or 2b) are given with relations:

$$K_\omega^{(a)}(T) = K_\omega(T) \cdot \Gamma(3/2, -X_\omega(T)) / \Gamma(3/2) \qquad (4a)$$

$$K_\omega^{(b)}(T) = K_\omega(T) \cdot \gamma(3/2, -X_\omega(T)) / \Gamma(3/2) \qquad (4b)$$

In the expressions above $X_\omega(T) \equiv V_1(R_\omega)/kT$, $\delta \equiv (I_{Li}/Ry)^{1/2}$ and R_ω is given in atomic units. Values for $V_{1,2}(R)$ are taken from Konowalow (1984). Due to the normalization of absorption coefficient, its dimension is cm^5.

The results obtained are presented in tables 1 and 2. Results of this work make possible to determine the temperature dependence of spectral absorption coefficient and relative influence of molecular ion photodissociation channel in comparison to the influence of the channel for photoabsorption due to ion-atom collisions.

TABLE 1 Total absorption coefficient

$\lambda \times 10^5$ [cm]	$K \times 10^{39}$ [cm^5]			
	2000 K	2500 K	4000 K	5000 K
3.31	18.9	8.57	2.62	1.77
3.90	1207	292	34.7	17.1
5.02	1963	506	66.1	33.5
6.01	1260	380	62.9	34.5
7.13	926	317	63.3	37.0
10.4	464	204	59.7	39.6

TABLE 2 Ratio of absorption coefficients

$\lambda \times 10^5$ [cm]	$K^{(b)}/K$ (%)			
	2000 K	2500 K	4000 K	5000 K
3.31	5.24	10.0	26.9	36.9
3.90	0.27	1.00	7.23	13.1
5.02	0.36	1.26	8.24	14.5
6.01	0.75	2.78	11.5	18.9
7.13	1.34	4.00	14.9	23.3
10.4	4.63	9.03	25.2	35.1

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Joint European and National Astronomy Meeting

JENAM-2000

9th European and 5th Euro-Asian Astronomical Society Conference

ABSTRACTS

Moscow, Russia, May 29 – June 3, 2000

velocity fields are essential different in active regions. At the same time the down flows entropy are roughly the same for all the investigated active regions. There is no correlation between the magnetic field entropy, the integral magnetic flows or flares activity.

STRUCTURE AND SHAPE OF THE SOLAR CORONA AUG. 11, 1999 AND THEIR CONNECTION WITH THE SOLAR ACTIVITY

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The solar corona Aug 11, 1999 consists from bent wings, helmet-like structures, linear streams, numerous powerful and thin rays which are radial oriented with regard to the Sun. E-corona has bigger development of activity than the W-corona that is the significant E/W-asymmetry of the corona exists. The shape of the solar corona is close to the maximal classical type. The brightness distribution in the corona shows that the corona has the shape close to the spherically-symmetrical one. Only close to the Southern pole of the Sun there is less bright region which probably is connected with the existence here of the polar coronal hole. This fact and other circumstances are evidence of the noticeable N/S-asymmetry of the corona. The Northern hemisphere is more active than the Southern one that is the N-hemisphere is close to its maximal shape of development. We think that the maximum of activity of the present 23-cycle of the solar activity in the N-hemisphere can be shortly (in late 1999 or in early 2000) but in the S-hemisphhere the maximum of activity can be in early 2001. The connection of the structure and the shape of the corona with the heliospheric current sheet is discussed.

THE SOLAR CORONAL PLASMA MOTIONS AND THE SOLAR CYCLE

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The solar coronal plasma motions and their connection with the solar cycle are investigated. Own authors interferometric observations of coronal emission lines are used. Results from more than 80 reports for the observational period since 1956–1999 have been analysed to study the dependence of the velocity values on the solar cycle phase. Matter velocities in the solar corona and transition region have been obtained by different methods by analysing of the line profiles and motions of coronal structures in picture plane. The observations were used in visible, UV, radio and X-rays. The maximum values of the velocities correspond to the solar activity maximum. The highest velocities from 100 km/s to 2000 km/s are connected with active events such as flares, surges, eruptive prominences and loops, rooted in the bright X-ray points. So the probability of the observations of the large velocities is higher during the maximum phase of the solar cycle.

INTERPRETATION OF THE LARGE-SCALE SOLAR MAGNETIC FIELD MEASUREMENTS USING THE LINE RATIO TECHNIQUE

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Measurements of the large-scale magnetic field strength, obtained by the magnetograph of the STOP telescope at the Sayan observatory,are interpreted in the framework of 2-component model. Observations in FeI 5247.1A, 5250.2A, 5250.6A and NiI 5137 A are used.The theoretical magnetic field strength ratio in these lines are calculated. By means of comparison of experimental data and calculated data the true value of the magnetic field strength and the filling factor are inferred.

CONCERNING TIME VARIATION OF SOLAR MAGNETIC FIELDS IN OBSERVATIONS WITH LOW SPATIAL RESOLUTION

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Great interest has invariably been expressed by researchers in time variations of solar magnetic fields, especially within the context of their correlation with acoustic oscillations. Recent trends, however, are toward increased interest in such studies because of the enhanced possibilities of ground-based observations, as well as in connection with the advent of qualitatively new, highly accurate data from SOHO. However, previous works were based primarily on observations made in regions with a strong magnetic field, specifically in sunspots (see, for example, relevant papers in ASP Conf. Ser., 1999, v.184,pp.113–147). However, the subject of analysis in this paper involves time series of low spatial resolution observations of magnetic fields, obtained with the multichannel spectro-polarimeter of the Sayan observatory's STOP telescope. More specifically, an analysis is made of the power spectra of the various characteristics in the distributions of Stokes I and V parameters in different spectral lines in the neighborhood of the FeI 525.02 nm. In addition, we discuss some instrumental-methodological problems inherent in research of this kind.

ON THE STARK BROADENING PARAMETERS FOR SOLAR PLASMA RESEARCH

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In general, Stark broadening is the main pressure broadening mechanism for stars with the effective temper-

atures higher or around 10000K, when the hydrogen is mainly ionized. Such conditions together with the charged particles density high enough that Stark broadening is not negligible in comparison with Doppler broadening, exist in A-type, B-type and white dwarf star atmospheres. However, in some cases, Stark broadening data may be of interest as well for cooler stars like Sun. First of all such data are of interest for modelling and consideration of subphotospheric layers and also for spectral lines involving Rydberg states. The aim of this contribution is to discuss the present status of Stark broadening for non-hydrogenic emitters/absorbers (quadratic Stark effect).

MAGNETIC ACTIVITY OF YOUNG STARS WITH ACCRETION DISCS

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Submitted by: Gorbenko Elena E.
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Magnetic Activity of Young Stars with Accretion Disks Alexander E. Dudorov, Elena E. Gorbenko The base mechanisms of magnetic field origin of young stars are discussed. The main attention is paid to the theory of the fossil magnetic field. It is shown that young stellar objects and new-born stars should have the quite strong fossil magnetic field. The geometry of the fossil field depends on the conditions of star formation and may has three type forms: open, dipolar or quadrupolar ones. The formation of magnetospheres of young stars is described. The model of magnetic stars with magnetic accretion disks is developed in which both types of magnetic fields have the fossil nature. The three type of magnetic activities are possible in the frame of this model: atmospheric, magnetospheric and disks ones. The main features of this three type of activities are discussed.

ON THE RELATIONSHIP BETWEEN ACTIVE REGIONS AND LARGE-SCALE ZONAL MAGNETIC FIELD OF THE SUN

Erofeev D.V.
Submitted by: Erofeev Dmitry Viktorovich
(kram@ml.ussuriisk.ru)

Due to inclination of their axes to parallels of latitude, active regions form a latitude-time distribution of magnetic field which correlates with the large-scale zonal magnetic field of the Sun both on the time scale of the 22-yr cycle and on the shorter time scale of 2–3 years. The time-dependent spherical harmonical coefficients $a_l(t)$ of the magnetic field associated with active regions has been compared with those of the large-scale magnetic field, $b_l(t)$. Spectral analysis of $a_l(t)$ shows that anti-symmetric harmonics (odd l) are dominated by the 22-yr variation, while symmetric harmonics (even l) indicate a series of resonant modes which oscillate with periods of 2–3.5 years, like harmonics of the large-scale magnetic field examined by Stenflo and Vogel (*Nature*, V. 319, 1986). However, the resonant oscillation of $a_l(t)$ correspond to larger values of the spherical harmonic degree l (i.e. a shorter scale of magnetic field) as compared to $b_l(t)$.

ON THE ONSET OF CMES IN THE SOLAR CORONA

Filippov B.P., Den O.G., Koutchmy S., Shilova N.S.
Submitted by: Filippov Boris (bfilip@izmiran.troitsk.ru)

A pre-eruptive stage of coronal mass ejections is discussed. Many CMEs originate from coronal streamers while others happen in the regions without any streamer. We believe that for the some class of CMEs, the problem of the onset of the ejection is the problem of the lost of the quiescent filament equilibrium. Magnetic flux rope related with a filament should manifests itself in the coronal structures before eruption. Indeed, in high resolution white-light eclipse images, as well as in EUV and X-ray images we are able to recognize formations which can be interpreted as the helical flux tubes of the rope in different projections. On the other hand, the twisted structure of the filament loop in the core of the CME at times is visible in the field of view of orbital coronographs up to the distances of several solar radii. As far as filaments are easily accessible for observations, the regions where CMEs could originate are more or less known. We propose a method to estimate the stability of any observed filament and the probability of its eruption.

NEW ARGUMENTS OF INFLUENCE OF SOLAR ACTIVITY ON THE COMETARY BRIGHTNESS OUTBURST PROCESSES

Filonenko V.S., Churyumov K.I.
Submitted by: FILONENKO Vitaly Sergeevich
(filonenko@astron.kharkov.ua)

On the basis of investigations of detailed light curves of comets the following new results were obtained. 1. Influence of solar activity and changes of parameters of solar wind on the light curves of comets Halley, Churyumov-Gerasimenko and IRAS-Araki-Alcock was found for the first time. 2. A new phenomenon in the outburst activity of comet Tempel 2 was discovered: brightness outbursts occured on the one same heliocentric distances during three appearances of the comet. It is shown that this phenomenon is typical for all observed comets. It is a new observational criterion for choice a real mechanism of cometary outburst activity. 3. On the basis of investigation of dependencies between orbital and physical characteristics of comets has been found that the comet belong to one or another photometric clasters according to comet's age and level of solar activity during this appearance of comet. 4. A quasi-periodicity of cometary outburst activity with mean period T=$6.8^d \pm 0.6^d$ was found. Note that 4T $\approx 27^d$ is mean rotation period of Sun. This is a new argument of solar activity influence on the cometary outburst activity.

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is also available. It is used features with well-known wavelengths as reference points in these spectra. Intensity calibration is applied to all spectra by means of artificial standard of brightness registered in every spectrum realization. In that case the spectral atmospheric extinction can be defined from observations of spectrophotometric standard stars. The database application using facilities of WinSockets provides network access to the spectral data through the Internet. The application was developed in the frame of the client/sever model. The Stream Socket communications between client and server sides are used. It also supports Dynamic Data Exchange conversation in server mode.

THE COMPARING OF SOME TYPES OF COLOR EMULSIONS FOR PHOTOGRAPH OF DEEP SKY OBJECTS

Borisov G.V.
Submitted by: Borisov Gennadij Vladimirovich (borisov@sai.crimea.ua)

It is presented the color photos of selected astronomical objects obtained at Crimea telescopes with apertures from 20cm to 60cm. Some types of photoemulsion have been compareed at taking the photographs of deep sky objects. It has been received that FUJI-emulsion is better for the reproduction of color balance at green-blue spectral region, and KODAK-emulsion — at red light.

AUTOMATIC EXTRACTION AND CLASSIFICATION OF LOW-DISPERSION OBJECTIVE PRISM STELLAR SPECTRA IN STAR-FORMING REGIONS OF SMC

Bratsolis E., Maragoudaki F., Bellas-Velidis I., Dapergolas A., Kontizas E., Kontizas M.
Submitted by: Bratsolis Emmanuel (ebrats@astro.noa.gr)

Low dispersion objective prism images have been used to classify the spectral types of stellar populations. The automated method for the classification was developed by us and is described in details by Bratsolis et al. (1998 A&AS, 133, 293) and Bratsolis et al. (2000 A&AS, 142, 339). The distribution of early and late type stars inside the stellar complexes and their surrounding regions can lead to important clues on the star formation mechanism that governs the galaxy. An investigation of stellar complexes in the SMC has been carried out, using digitized direct UKST plates. This method was developed by Maragoudaki et al. (1998 A&A, 338, L29).

THE HIPPARCOS CATALOGUE POSITIONS AND OBSERVATIONS WITH THE BELGRADE MERIDIAN CIRCLE

Dacic M., Cvetkovic Z., Olevic D.
Submitted by: Dacic Miodrag D. (mdacic@aob.bg.ac.yu)

By 1993 there were intensive observations with the Meridian Circle of Belgrade Observatory by applying the classical differential method. For the purpose of analysing the accuracy of the determinations of star positions the positions in four observational star catalogues are compared with those in the Hipparcos Catalogue. The obtained results show that the star positions in our observational catalogues have no systematic errors, but the random errors of the differences are large which is to be expected when the classical observations are concerned. The errors of the Ondrejov PZT Catalogue are significantly smaller than those of the others, but it should be borne in mind that the stars were observed within a very narrow declination zone.

DESIGNATIONS OF ASTRONOMICAL SOURCES

Dickel H.R., IAU Task Group on Designations
Submitted by: Dickel Hélène Ramseyer (hdickel@nfra.nl)

In an effort to promote clear and unambiguous identification of all astronomical objects outside the Solar System, the IAU Task Group on Designations attempts to clarify existing astronomical designations and reviews, updates, and advertises the IAU Recommendations for Nomenclature (http://cdsweb.u-strasbg.fr/iau-spec.html). Some of the recent developments undertaken by the Task Group include establishment of a "Registry for New Acronyms" (http://cdsweb.u-strasbg.fr/cgi-bin/DicForm) and an Electronic Forum on Designations of Stellar Companions (http://aries.usno.nav.mil/ad/wds/iaumcm.html) in preparation for a Multi-Commission Meeting on the topic being held at the IAU General Assembly in August 2000. These and other activities will be presented.

BELDATA — DATABASE OF BELGRADE ASTRONOMICAL OBSERVATORY

Dimitrijevic M.S., Popovic L.C., Milovanovic N.
Submitted by: Dimitrijevic Milan S. (mdimitrijevic@aob.bg.ac.yu)

We have started to develope on the Belgrade Astronomical observatory the BELDATA database. Our intention is that this database include: 1) Stark broadening parameters data set; 2) Spectra of AGN's; 3) Observations made on Belgrade Astronomical observatory; 4) Abstracts of papers printed in Serbian Astronomical Journal and Publications of Astronomical Observatory. Acces to the BELDATA database is possible through Internet with 24 hour online support on address http://www.aob.bg.ac.yu/BELDATA. The aim of this contribution is to describe BELDATA database and its content, as well as our plans for its further development.

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"asymptotic parabola" (AP) and "running parabola" (RP) fits. These methods were developed by the authors and show the minimal errors in the determination of moments and magnitudes of extrema. AP fit allows to determine characteristics of extrema using a relatively small quantity of points and, in some cases, allows to decrease an effect of season gaps. The RP fit is more sensitive to an instability of the light curve which often appears in the Mira variables. As the result of our research, several groups of the Miras with typical light curve variations were distinguished and some regularities in these variations were found.

FAINT OBJECT SPECTRAL CAMERA FOR 2.6M TELESCOPE OF BYURAKAN OBSERVATORY

Movsessian T.A., Boulesteix J., Gach J.-L., Zaratsian S., Balayan S., Zakarian M.
Submitted by: Movsessian Tigran Akop (tigmov@bao.sci.am)

The optical design and observational possibilities of Faint Object Spectral Camera (ByuFOSC) for 2.6m telescope of Byurakan Observatory are presented. Instrument is mounted in Prime Focus on УBonnetteФ pointing-guiding system. The main part of the instrument is focal reducer with parallel beam, which submits a possibility to use different dispersing instruments. Instrument works in different modes — imagery, long-slit, slitless and scanning Fabri-Perot. The scientific applications in of instrument in these modes are presented.

INTEGRAL FIELD SPECTROGRAPH VAGR FOR 2.6M TELESCOPE OF BYURAKAN OBSERVATORY

Movsessian T.A., Gach J.-L., Zhamkotsin F., Boulesteix J.
Submitted by: Movsessian Tigran Akop (tigmov@bao.sci.am)

The integral field spectrograph VARG was designed and made in byurakan Observatory in 1999 on the analogy of TIGER spectrograph based on an original concept of G.Courtes. The Spectrograph is intended for 3D spectrophotometery of extended astronomical objects with medium spectral resolution on 2.6-m Telescope of Byurakan Observatory. This review discuss the optical design and gives the main characteristics of the instrument. The examples of scientific applications are presented to highlight the new possibilities offered by integral field spectrophotometry.

UNIFIED SET OF EVOLUTIONARY TRACKS

Myakutin V.I.
Submitted by: Myakutin Valery (vmyakutin@inasan.rssi.ru)

A set of evolutionary tracks for Population I stars in mass range 0.075–120 solar masses is compiled from published data for a wide range of metallicity and presented. The set includes both recently computed pre-MS and hydrogen burning stages. For evolutionary calculation purposes the tracks are unified and self-described.

A CCD SPECTROHELIOGRAPH

Nikulin I.F.
Submitted by: Nikulin Igor Fedorovich (nikulin@sai.msu.ru)

Two-dimensional monochromatic images of the Sun are obtained using a CCD array installed instead of the exit slit. The solar image is scanned at the entrance slit by a step motor. Number of scans determining the frame size, integration time as well as corresponding data reduction to get spectroheliograms is controlled by a computer. Finally, a spectrograph combined with a CCD array operates as a narrow passband filter in the range 0.35–1.2 mkm corresponding to the spectral sensitivity of the array. Observations in the light of hydrogen, ionized calcium, neutral helium (IR), sodium, etc. lines were made on the tower solar telescope of the Sternberg Astronomical Institute. Angular resolution of about 1 arc second is achieved for the passband of 0.3Å.

DATA MANAGEMENT FOR THE ESA PLANCK MISSION: FROM SUPPORT TO INSTRUMENT GROUND TESTS TO THE PRODUCTION OF FINAL RESULTS

Pasian F., et al.
Submitted by: Pasian Fabio (pasian@ts.astro.it)

Planck is the M3 mission of ESA's Horizon 2000+ programme, and is expected to be launched in early 2007. The data management aspects for the mission include processing and archiving of ground test data, simulations of instrumental effects on observations, production of simulated data, sampling and quantization effects, data compression, handling of telemetry and telecommands, calibration of raw data, creation of frequency maps, separation of astrophysical components. The effects on data quality of technical choices and constraints, and the computational challenges will be discussed.

THE IMPORTANCE OF ELECTRON-IMPACT BROADENING IN HOT STAR ATMOSPHERES: THE CASE OF Zr II AND Zr III LINES

Popovic L.C., Milovanovic N., Dimitrijevic M.S.
Submitted by: Dimitrijevic Milan S. (mdimitrijevic@aob.bg.ac.yu)

The influence of the electron-impact mechanism on line shapes and equivalent widths in hot star atmospheres has been considered. The electron-impact broadening effect influence on abundance determination of zirconium has been discussed.

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alent of two images of 6000 x 6000 pixels that will be read out in 10 seconds. Due to the number of pixel-per-second that the twin cameras will produce, tasks like handling, archiving and reducting the so produced data is a non-trivial problem to solve. The solutions that we think to adopt will be presented.

STARK BROADENING OF HEAVY ELEMENT SPECTRAL LINES IN HOT STARS: Au II, Co II, Ti II AND Co III

Tankosic D., Popovic L.C., Dimitrijevic M.S.
Submitted by: Dimitrijevic Milan S. (mdimitrijevic@aob.bg.ac.yu)

In hot star atmospheres, Stark broadening mechanism is the main pressure broadening mechanism. An interesting application where such mechanism is of interest is the modeling and investigation of subphotospheric layers. Consequently, for the investigation and modeling of the Hg-Mn star and other type of hot star atmospheres, the Stark broadening parameters for Au II, Co II, Ti II and Co III spectral lines are needed. Here we present Stark broadening data for Au II λ=174.048nm, Co II λ=230.785nm, Ti II λ=376.132nm and 27 Co III spectral lines (from a^6D-z^6D^o and a^6D-z^6F^o Co III multiplets), as a function of temperature, calculated by using the modified semiempirical approach. Also, considering that Au II λ=174.048nm, Co II λ=230.785nm and Ti II λ=376.132nm lines have been used for gold, cobalt and titanium abundance determination in HgMn stars, we have tested the influence of Stark broadening mechanism on widths of these lines for an A type star atmosphere, as well as DA and DB white dwarfs.

WIDE-FIELD PLATE DATABASE: THE BUCHAREST PLATE CATALOGUE

Tsvetkov M., Stavinschi M., Stavrev K., Tsvetkova K., Bocsa G., Popov V.
Submitted by: Tsvetkova Katya Petrova (katya@skyarchive.org)

In connection with the creation of an European plate store the up-to-date development of the Wide-Field Plate Database (http://www.skyarchive.org) and, in particular, the organization of the Bucharest archives, are presented. In the WFPDB an information for 338 archives with 2 031 948 plates can be found, the European archives being 231 with 1 139 224 plates, stored in 58 observatories. The Bucharest plate archives include 10533 plates. The primary aims of the observations were to obtain accurate positions for asteroids (78% of all plates) and to serve for different observational campaigns. However the scientific potential of the archives is much larger, with possibilities for investigations of bright visual binaries, long-term variability of the Pleiades red dwarf stars, and potentially hazardous near Earth asteroids. Since 1996 the Bucharest plate catalogue is incorporated in the WFPDB installed in CDS in Strasbourg with an on-line search possible through the VizieR system at address http://vizier.u-strasbg.fr/cats/VI.htx. Results from the scanning of selected plates with the PDS 1010 of the Sofia Sky Archive Data Center will be also presented.

ORGANIZATION OF THE DATA BASE OF SPECTRAL ENERGY DISTRIBUTIONS OF RADIO GALAXIES

Verkhodanov O.V., Kopylov A.I., Verkhodanova N.V., Zhelenkova O.P., Chernenkov V.N., Parijskij Yu.N., Soboleva N.S., Temirova A.V.
Submitted by: Verkhodanov Oleg (vo@sao.ru)

The project of the informational system creation on the problem of evolution of radio galaxies, as a part of the "Big Trio" project aimed on studing of distant radio galaxies, is designed. This system being developed at present at the server with address http://sed.sao.ru will allow a user to operate with simulated curves of spectral energy distributions (SED) to estimate ages and redshifts by photometry data. Authors use SEDs of several models for different types of galaxies. The input forms contain information about input filters or wavelengths and corresponding magnitudes. Another possibilities are supposed to be supported: sorted bibliographical collection of papers for different stages of radio galaxy evolution, archive of radio galaxies data in different wavelength ranges. The HTTP and e-mail access is organized to this system. A result is supposed to be written in ASCII tables and sent to users. This work has been supported by the Russian Foundation of Basic Research (grant No 99-07-90334).

THE LARGEST RADIO ASTRONOMICAL DATABASE CATS: EXTRAGALACTIC FACILITIES

Verkhodanov O.V., Trushkin S.A., Chernenkov N.V., Andernach H.
Submitted by: Verkhodanov Oleg (vo@sao.ru)

The authors describe the largest existing publicly accessible radio source database CATS (astrophysical CATalogs Support system). CATS contains more than 250 catalogs of objects detected in different (but mostly radio) wavelength ranges. These include catalogs from the largest extragalactic existing surveys, like NVSS, FIRST, WENSS, TXS, GB6, IRAS, ROSAT, PGC, MCG, etc. and allows the user to operate with them. Thus CATS allows to draw samples of objects to study a great variety of astrophysical problems. Among the options accessible to CATS users we mention (1) Request short descriptions of each catalog, or print a list of catalogs covering the required sky areas. (2) Select objects from one or more catalogs by coordinate, flux, spectral index, frequency, etc. (3) Select objects from one or more catalogs for many sky patches defined by position and size (e.g. for cross-ID with other catalogs). e-mail (cats@sao.ru), or anon. FTP. Batch requests to extract objects from large lists of sky regions are supported via e-mail. Standard formats of input and output of CATS

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cepted for publication in the regular journals and bearing on the field of obtaining of atomic and molecular data and their using for the astrophysical investigations are planned to be presented, The information on new atomic data catalogues and data bases or their modifications will be also given. Scientific news, including the information on planned Atomic and Molecular data Conferences and Meetings, will find their place in the journal.

COSMOL DATABASE

Kuznetsova L.A.
Submitted by: Kuznezova Ludmila Alekseevna (lakuz@laser.chem.msu.ru)

The database Collisions of Small Molecules, or COSMOL for short, has been created at the Department of Chemistry of Moscow State University. It serves for compilation of experimental and theoretical investigations on the collisions of molecules with electrons, positrons, photons, atoms and molecules (excluding chemical reactions). The following processes are compiled: excitation, ionization, dissociation, electron attachment, elastic scattering of electrons, relaxation, quenching. These data are compiled from the papers published from 1989 to the present, but some more early and important papers are also included. The database is searchable by molecule, by colliders, by process, by studied parameters, by author.

THE RADEN DATA BANK

Kuznetsova L.A.
Submitted by: Kuznezova Ludmila Alekseevna (lakuz@laser.chem.msu.ru)

The RADEN data bank produced at the Department of Chemistry of Moscow State University is designed as well to accumulate published information on radiative parameters of diatomic molecules, as to analyse it and recommend the more reliable values. The bank consists of two parts: Reference-Information-System (RIS) and Recommended-Data-System (RDS) operating under the control of an interactive program. RIS serves for compiling of experimental researches and ab initio calculations of following parameters: potential curves, dipole moments, electronic transition moments, oscillator strengths, Einstein coefficients, Franck-Condon factors and lifetimes of excited states. Now these data are compiled for about 3500 molecular electronic states and transitions. The database bibliography covers above 3700 publications from 1960 up to now. The Reference-Information-System is accessible for users through the Internet system. The Recommended-Data-System serves to accumulate and calculate recommended values of radiative parameters of diatomic molecules.

STATISTICAL EQUILIBRIUM OF EuII IN STELLAR ATMOSPHERES AND ATOMIC DATA NEEDED

Mashonkina L.
Submitted by: Mashonkina Lyudmila Ivanovna (Lyudmila.Mashonkina@ksu.ru)

Statistical equilibrium of EuII in cool stellar atmospheres is first considered. 32 nonet and septet energy levels of EuII known from laboratory experiments are included into the model atom. The first problem is missing low excited quintuplet, triplet and singlet levels that have to increase the EuII partition function. The second one is missing high excited levels that have to couple the EuII levels to the EuIII ground state. Neglecting these levels cause wrong NLTE effects for the EuII levels. Many test calculations have been performed to estimate an error due to missing levels. Departures from LTE for EuII are due to radiative pumping the low excited terms from the ground state electron reservoir resulting in an underpopulation of the EuII ground state and overpopulation of the excited terms. So, the EuII spectral lines are weakened compared with the LTE case. NLTE effects are not so large due to close coupling the low excited terms to each other. In terms NLTE abundance corrections they consist of 0.04 dex for the Sun.

DIELECTRONIC CHEMI-IONIZATION AND CHEMI-RECOMBINATION ATOMIC PROCESSES IN STELLAR ATMOSPHERES

Mihajlov A.A., Dimitrijevic M.S., Ignjatovic Lj., Djuric Z.
Submitted by: Dimitrijevic Milan S. (mdimitrijevic@aob.bg.ac.yu)

Semiclassical methods for dielectronic chemi-ionization and chemi-recombination atomic processes rate coefficient determination, are presented in this contribution. Moreover, the results of the mentioned rate coefficient calculations for conditions characteristic for stellar atmospheres weakly ionized layers, are presented as well. It was shown that in the considered cases of stellar atmospheres hydrogen and helium plasmas, the considered processes may have important or even dominant role in comparison with other ionization-recombination processes, for highly excited atomic states populations. Obtained results may be used for the modelling of equilibrium as well as non-equilibrium weakly ionized plasma within the large range of electronic and atomic temperatures.

BELDATA — THE DATABASE OF BELGRADE ASTRONOMICAL OBSERVATORY

Milovanovic N., Popovic L.C., Dimitrijevic M.S.
Submitted by: Milovanovic Nenad D. (nmilovanovic@aob.bg.ac.yu)

In early-type stars like B and A stars and white dwarfs, Stark broadening is the main pressure broadening mechanism, and the corresponding Stark broadening parameters are of interest for a number of investigations related to stellar opacities, stellar atmospheres modelling and investigations, abundance determinations, interpretation and modelling of stellar spectra, investigation and modelling of subphotospheric layers and laboratory plasma research. In a series of papers, large scale calculations of Stark broadening parameters for a number of spectral lines of various emitters performed on Belgrade Observatory have been published. Our calculations have been performed within the semiclassical perturbation formalism for transitions when a sufficiently complete set of reliable atomic data exist and within the semiempirical approach when low accuracy result is obtained due to small amount of experimental atomic data for atoms and ions. To provide these calculations for scientific community we established BELDATA (Belgrade Astronomical Database). This database is directly connected with Internet to provide easy and fast access for world wide users.

APPROXIMATIONS FOR CROSS SECTIONS OF ELECTRON IMPACT EXCITATION FROM METASTABLE ATOMIC STATES

Mityureva A.A., Ponomarenko G.A., Smirnov V.V.
Submitted by: Mityreva Alla Alexandrovna (Alla.Mit@paloma.spbu.ru)

Metastable states of noble gases can accumulate significant part of energy and have large cross sections of electron impact excitation but this process is less investigated in comparison with excitation from ground state. Cross section values of different working groups can differ and hence the problem of choosing suitable data arises. Besides, there is the problem to join different data sets corresponding to different energy ranges. It may be necessary to obtain rate constant of electron impact excitation. To solve these problems we have proposed approximation of energy dependencies of electron impact cross sections. It must be emphasized that the main feature of our approach is applying this approximation not only to one particular data set but to all available cross section values. This fact allows us to join data sets of different energy ranges and obtain some average value of cross section.

ESTIMATION OF PATH INTEGRAL BY SADDLE-POINT METHOD

Mityureva A.A., Ponomarenko G.A., Smirnov V.V., Semenov A.N.
Submitted by: Mityreva Alla Alexandrovna (Alla.Mit@paloma.spbu.ru)

We develop path integral method for studies of electron-atomic collision processes. We report about our studies of estimation of path integrals by saddle point method. In many cases hamiltonian either is not analytical function or it's domain of analyticity has complicated topology. For example, rectangular potential is not analytical and Coulombe interaction has branch point. To overcome this problem we proposed to make transform to Fock-Bargmann representation. In this representatio for wide set of wavefunctions and operators (bou operators included) their symbols are entier analy functions, i.e. has all singularities at infinity and there are no obstructions for integration dom form in saddle point method. We tested this for the problem of one dimensional tunneling.

NEW METHOD FOR DETERMINATIO PROBABILITY OF THE COLLISION PROCESSES BETWEEN EXCITED A AND IONS, WITH ELECTRONS

Piotrovskii Yu.A.
Submitted by: Piotrovskii Yurii Alexandrovich (piotrov@paloma.spbu.ru)

The collision between excited atoms and ions wit electrons is one of the most significant proce energy redistribution between the excited st electron gun of the closed geometry offers t possibility to measure the rate constants for type of collisions because of independent varia direct excitation rate and that of the energy processes. Under the pulse excitation condit number density of slow electrons increases fr ginning of the pulse just linearly while that o ones is constant. The slow electons distributio eters may be calculated and/or measured One yse the spectral line brightness on time and co electron/atom collisions rate with that of the decay.

STAR LASER

Piotrovskii Yu.A., Tolmachev Yu.A.
Submitted by: Tolmachev Yurii Alexandrovich (Yurii.Tolmach@paloma.spbu.ru)

Nonstationary processes in a star atmosphere sidered for the case to form the excited level pop formation. As a result, the pencil-like active can be formed and the spontaneous emission cation can exist. Strong local inhomogeneitie atmosphere of the Sun are considered for an of such an active zone. Mechanism for the se citation of atomic levels is proposed. Esti given for the excited atoms concentration an tive medium length needed for quasi-laser bea formation. Comparison with some experim and observations are given.

THE VIENNA ATOMIC LINE DATA

Piskunov N., Ryabchikova T.A., Weiss W.W.
Submitted by: Piskunov Nikolai (piskunov@a

We will describe the current status of the Vien Line Database (VALD). VALD currently is collection of atomic data for astronomical spe Specialized extraction tools help selecting tant in different physical environments. The

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THE IMPORTANCE OF ELECTRON-IMPACT BROADENING IN HOT STAR ATMOSPHERES: THE CASE OF Zr II AND Zr III LINES

Popovic L.C., Milovanovic N., Dimitrijevic M.S.
Submitted by: Popovic Luka C.
(lpopovic@aob.bg.ac.yu)

The influence of the electron-impact mechanism on line shapes and equivalent widths in hot star atmospheres has been considered. The electron-impact broadening effect influence on abundance determination of zirconium has been discussed.

ON THE POSSIBILITY OF NUCLEOSYNTHESIS OF R-ELEMENTS IN THERMONUCLEAR SUPERNOVAE

Ptitsyn D.A.
Submitted by: Ptitsyn Dimitri A.
(dptitsyn@inasan.rssi.ru)

On the basis of nucleosynthetic calculations it is shown that r-elements between the first and the second peaks of the cosmic abundance curve can be produced in the central zones of a thermonuclear supernova, provided the neutron excess of the matter $\eta = (N - Z)/(N + Z)$ reaches the value of about 0.21 in those zones.

SIMULATION OF INTERSTELLAR SCATTERING AND COMPARISON WITH THE OBSERVATIONAL RESULTS

Semenkov K.V., Masolkin S.I.
Submitted by: Semenkov Kirill Valerievich
(kirill@anubis.asc.rssi.ru)

Numerical model of pulsar radio impulses scattering is built. Comparison of modelling results (i.e decorrelation bandwiths, temporal parameters of scattered impulses, autocorrelation functions) with the observed ones is performed.

OPTICAL PHOTOMETRY OF THE PSR B0656+14 AND ITS NEIGHBOURHOOD

Shibanov Yu.A., Koptsevich A.B., Sokolov V.V., Zharikov S.V., Pavlov G.G, Komarova V.N., Kurt V.G.
Submitted by: Shibanov Yuri (shib@stella.ioffe.rssi.ru)

We present BVRI observations of the nearby middle-aged radio pulsar PSR B0656+14 and its neighbourhood with the 6-meter telescope at the Special Astrophysical Observatory. Available optical and near infrared data obtained with the Hubble Space Telescope are also incorporated into our analysis. We found that in the BVRI and near infrared region the broad-band spectrum of the pulsar show a complicated behaviour accompanied by excesses in the F187W/NICMOS, and apparently in the VRI bands. This is in contrast to the known monotonous increase of the pulsar flux in near-UV towards the Rayleigh-Jeans extrapolation of the thermal spectrum seen from this neutron star in soft X-rays. The broad-band spectrum of PSR B0656+14 is qualitatively different from generally flat and featureless spectra of younger Crab-like pulsars. We also identified three faint, $V \sim 24.8 - 26^m$, extended objects in the $5'' \times 5''$ pulsar neighbourhood. All of them are likely distant background galaxies and and hardly can be associated with a pulsar wind nebular.

THE MULTIPUPIL FIBER SPECTROSCOPY OF THE CRAB-PULSAR NEIGHBOURHOOD

Shibanov Yu.A., Koptsevich A.B., Zharikov S.V., Afanas'ev V.L., Dodonov S.N.
Submitted by: Shibanov Yuri (shib@stella.ioffe.rssi.ru)

We present the optical spectroscopy of the Crab-pulsar neighbourhood made with the Multipupil Fiber Spectrograph at the 6m telescope of the SAO RAS. $12'' \times 24''$ field centred at the pulsar position was observed with the spatial resolution $\sim 1.5''$ in the 4600 – 5100Å spectral range with $\delta\lambda \sim 1$Å. Strong, $S/N \sim 20 - 50$, blue and redshifted [OIII] λ5007 emissions are seen in in this field with velocities $\sim \pm 1500$km s^{-1}. We analysed the morphology of the field at different wave bands and found that the images in the continuum, blue, and redshifted [OIII] components strongly differ from each other. The images constructed with narrow filters centred at the blue and redshifted components indicate for a first time the presence of a cylindrical cone-like rotating structure around the pulsar. This structure is centred at the pulsar position, it rotates contra-clockwise around its axis, which coincides with the Crab nebular symmetry and/or pulsar rotation axis. The structure is not seen in the continuum, but it appears to be associated with the symmetric halo-like and torus-like structures around the rotation axis to the northwest of the pulsar.

THE RADIO EMISSION OF THE MAGNETAR SGR 1900+14

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The characteristics of the radio emission of the soft-gamma-ray repeater SGR 1900+14, discovered at 111 MHz in Pushchino Radioastronomy Observatory are reported. The results of the timing analysis, obtained during 1999 – april 2000 observations, the measured breaking index, the mechanism of slow-down luminosity and the derived value of superstrong magnetic field of this magnetar are discussed.

TO THE CONNECTION BETWEEN LOW AND HIGH ENERGY PHOTONS RADIATED IN PULSAR MAGNETOSPHERE

Sobolev Ya.M.
Submitted by: Sobolev Yakov Mikhailovich
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Curvature radiation, which has the same nature as syn-

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ISPITIVANJE VAN DER VALSOVE FORMULE U HOMOLOGNOM NIZU

M.S. Dimitrijević
Astronomska opservatorija, Beograd

G. Peach
Department of Physics and Astronomy, University College, London

Astrofizičari često koriste Van der Valsovu formulu za procenu širenja spektralnih linija sudarima sa neutralnim atomima. U ovom saopštenju su analizirani najpouzdaniji eksperimentalni podaci za širenje rezonantnih linija alkalija, da bi se proučilo postojanje sistematskog trenda za širenje linija i analizirala primenljivost Van der Valsove formule u ispitivanom homolognom nizu.

AN INVESTIGATION OF VAN DER WAALS FORMULA WITHIN A HOMOLOGOUS SEQUENCE

M.S. Dimitrijević
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Van der Waals formula is often used by astrophysicsts for the evaluation of neutral atom-impact broadening of spectral lines. In this communication, most reliable experimental data for the broadening of alkaline resonant lines are analyzed, in order to study the existence of a systematic trends for line widths and to analyse the applicability of the Van der Waals formula within the homologous sequence examinated.

KRITIČKA PROCENA PODATAKA O ŠIRENJU LINIJA ZA ASTROFIZIČARE

Milan S. Dimitrijević
Astronomska opservatorija, Beograd

U predavanju se diskutuju kriterijumi i metodi za izbor pouzdanih podataka o širenju spektralnih linija za potrebe astrofizičara. Najpre se uporeduju mogućnosti kvantno mehaničkog, semiklasičnog i klasičnog metoda u istraživanju oblika spektralnih linija, zatim se razmatra korišćenje rezultata istraživanja regularnosti i sistematskih trendova za kritički izbor podataka i na kraju, diskutuje se kritička procena eksperimentalnih podataka.

CRITICAL SELECTION OF LINE BROADENING DATA FOR ASTROPHYSICISTS

Milan S. Dimitrijević
Astronomska opservatorija, Beograd

The criteria and methods for the selection of reliable theoretical and experimental data for the astrophysical needs are discussed. First, we compare the possibility of the quantum mechanical, the semiclassical and the classical methods in line shapes investigations. Second, we consider the investigation of regularities and systematic trends as a tool for critical data selection and third, we discuss the critical estimation of experimental data.

THE PHYSICS OF IONIZED GASES

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BEOGRAD, YUGOSLAVIA

STARK BROADENING OF S III AND S IV LINES

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INTRODUCTION

Experimental studies of the Stark broadening of non-hydrogenic ionised atom lines were concentrated to the investigation of the spectral lines of singly ionised atoms.[1)] First paper which gives the results for Stark widths of multiply ionised atom (carbon III and IV) lines and reports in the same time independent measurements of the electron concentration and temperature was published 1972.[2)] Since than experimental data for Ar III, Ar IV, N III, O III, Si III (for the references see ref. 1) Cl III[3)] and Si IV.[4)] These experimental data were compared mostly with the theoretical results obtained from Griem's semiempirical formula[5)] and the agreement within ± 100% is found.

The aim of this paper is to supply Stark broadening data for the spectral lines of S III and S IV. The experimental results will be compared with the results obtained using various theoretical approximations.

THEORY

The main problem in calculating theoretical line widths of S III and S IV lines arises from the lack of data for energy levels, in particular, for possible higher perturbing levels. Therefore, we have to use theoretical approaches wich require only data for the nearest perturbing levels. First we used Griem's semiempirical formula[5)] in the version where all energy levels were treated lumped together. This is, however, a reasonable approximation in case of investigated S III and S IV lines since sufficiently large energy gaps exist between nearest perturbing levels and initial and final energy level of the investigated line.

For evaluation of the line widths we also used semiclassical theoretical approach for multiply ionised atoms[6] with lower level broadening included in the weak collision term.

EXPERIMENT

The plasma source was a low-pressure pulsed arc consisted of a pyrex tube of 24 mm internal diameter with a distance between electrodes equal 20 cm. The discharge was driven by a 150 μF condenser bank charged to 1.4 kV. During the experiment, a continuous flow of nitrogen-sulphurhexafluoride 10:1 mixture was sustained at a pressure of 0.15 torr.

The light from the pulsed arc was observed end-on by a photomultiplier monochromator system (with 1 m focal length and inverse linear dispersion of 4.16 $\AA mm^{-1}$). This instrument has a measured instrumental halfwidth of 0.046 Å with 10 μm slit width. Scanning of the S III and S IV lines was acomplished by repeated pulsing of the arc while advancing the monochromator in steps of 0.02 Å.

A helium-neon interferometer at 6328 Å (with plane external mirror) was used to determine the peak axial electron density of 2.1×10^{16} cm^{-3} $\pm$ 12%.

The electron temperature of 23700 K $\pm$ 15% was determined from the Boltzmann plot of the relative intensities of four S III lines; the transition probabilities were taken from the book of Wiese et al.[8] The quoted electron temperature and density were taken at the peak of electron density where all the measurements of the line profiles were performed.

Great care was taken to ensure that line self-absorption did not affect our line shape determination. This was achieved by careful examination of line intensities and lineshapes while SF_6 was gradually diluted with nitrogen.

The experimentally observed line profiles consists of two parts: electron impact broadening (Lorentzian) and Doppler and instrumental (Gaussian), since other broadening mechanisms can be neglected in our experimental conditions. To obtain the

Stark profile from the measured one it was neccessary to use a deconvolution procedure.[9)]

RESULTS AND DISCUSSION

The experimentally determined full halfwidths w_m of S III and S IV lines (in Angstrems), at an electron concentration of 2.1×10^{16} cm^{-3} and electron temperature of 23700 K are given in Table 1. The estimated measurement error for these linewidths is ± 18%. In this table, for the same experimental conditions, are also given theoretical results: w_{se} semiempirical formula[5)] and w_{sc} equation 526 from ref. 6.

TABLE 1

Ion	Transition	λ [Å]	w_m [Å]	w_{se} [Å]	w_{sc} [Å]
S III	$4s\,^3P-4p\,^3S^o$	3717.78	0.07_4	0.029	0.073
		3662.01	0.07_3	0.029	0.073
		3656.61	0.07_3	0.029	0.073
	$4p\,^3P-4d\,^3D^o$	2964.80	0.08_1	0.029	0.069
		2950.23	0.08_1	0.029	0.069
S IV	$4s\,^2S-4p\,^2P^o$	3097.46	0.04_5	0.016	0.045
		3117.75	0.04_8	0.016	0.045

Experimental conditions: $N_e = 2.1 \times 10^{16}$ cm^{-3},
$T_e = 23700$ K

From the comparison of the data in table 1 one can notice good agreement between experiment and semiclassical results. Semiempirical formula, however, gives too narrow linewidths.

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ON THE BEHAVIOUR OF HALF-WIDTHS AND SHIFTS OF NEUTRAL LINES IN THE ZERO-TEMPERATURE LIMIT

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Institute of Physics, Belgrade, Yugoslavia

As has been recognized by modern Stark broadening theories[1] both elastic and inelastic collisions contribute to the line broadening in plasmas. However, in the low temperature limit, when the average electron velocity v becomes small, contributions of the excitational scattering gradually decrease and in the adiabatic limit only elastic and deexcitational processes can take place. One may, therefore, make use of the Lindholm and Foley adiabatic theory,[2] which requires knowledge of the elastic scattering phase shifts only. On the other hand, the electron - excited - atom scattering requires a more elaborate treatment in the low energy region, since the motion of the impact electron is considerably perturbed by the long-range potential of the emitter. The influence of the electron motion along a hyperbolic path on the Stark broadening of ion lines has been examined by Roberts and Davis in the low temperature region.[3] Recently, we have studied the back-reaction of the long-range potentials of a neutral atom and its effects on the calculated half-widths and shifts within the GBKO theory.[4] We present here some analytical results for w and d obtained in the adiabatic limit.

In the absence of a permanent quadrupole moment of an excited atom, the dominant potential term in the asymptotic region is the dipole polarization potential

$$V_i(r) = \frac{\alpha_i}{2r^4}, \quad \alpha_i = \frac{2}{3}\sum_{j\neq i}\frac{|\langle j|r|i\rangle|^2}{E_j - E_i} \qquad (1)$$

where index i refers to the upper state of the transition and j

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to the perturbing levels. Depending on the distribution of the latter, α_ℓ can assume both positive and negative values.[5] Here we present results for the case $\alpha_\ell > 0$.

There appears a critical impact parameter[4]

$$\rho_c = \frac{(4\alpha_\ell)^{1/4}}{\sqrt{v}} \qquad (2)$$

which separates two distinct families of the electron trajectories. However, it is convenient to distinguish three regions of the impact parameter ρ, as indicated in Figure 1.

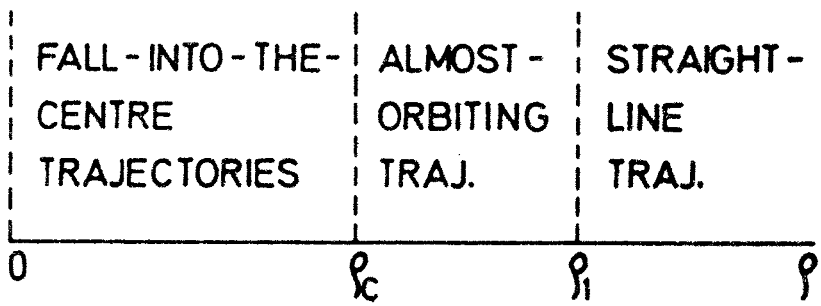

Figure 1. Regions of the impact parameter ρ (not in scale).

For $\rho<\rho_c$ the electron moves towards the excited atom (focusing effect) and thus disturbs the latter beyond any perturbational treatment (strong collisions). We therefore disregard this inner region in the adiabatic treatment. For $\rho_c<\rho<\rho_1$ electron trajectories are almost orbits around the emitter, and both the deflection angle and the semiclassical phase shift η increase indefinitely as $\rho \to \rho_c$. At the critical impact parameter ρ_c, η has a logarithmic singularity

$$\eta_{\tilde{\rho}\to 1} \sim \frac{2\sqrt{2}}{\pi}\left(\ln \frac{16\tilde{\rho}^4}{\tilde{\rho}^4-1}\right)\eta^{(o)}, \quad \tilde{\rho} \equiv \frac{\rho}{\rho_c} \tag{3}$$

where $\eta^{(o)}$ is the phase shift calculated along the straight-line trajectory

$$\eta^{(o)} = \frac{\pi\alpha_i}{4v\rho^3} \tag{4}$$

However, as can be seen from the formula[2]

$$w - id = 2\pi N_e v \int_{\rho_{min}}^{\rho_{max}} (1 - e^{i\eta})\rho d\rho \tag{5}$$

where N_e is the electron density and w and d are the half-width and the shift of the line respectively, large η do not contribute to the integral due to the fast oscillations of the integrand. Furthermore, since we usually have $1 \ll \rho_c \lesssim \rho_1$,[4] we take $\rho_{min} \sim \rho_1$ in eq(5). For $\rho > \rho_1$ the trajectories differ insignificantly from straight lines and we have $\eta \sim \eta^{(o)}$. Taking ρ_{max} to be infinite, one obtains

$$w-id = 3^{-1}2^{-1/3}\pi^{5/3}\alpha_i^{2/3}v^{1/3}N_e \int_0^{\eta_c} (1-e^{i\eta})\eta^{-5/3}d\eta, \quad \eta_c \equiv \pi(4\alpha_i)^{1/4}v^{1/2}/16 \tag{6}$$

In the limit when $v \to 0$, η_c becomes small and after expanding the exponential function under the integral, one gets, retaining the leading terms only:

$$w - id \sim A\left(\frac{1}{8}\eta_c - i\right)\eta_c^{1/3}, \quad A \equiv 2^{-1/3}\pi^{5/3}\alpha_i^{2/3}v^{1/3}N_e \tag{7}$$

yielding finally

$$\frac{|d|}{w} \sim \frac{8}{\eta_c}, \quad v \to 0 \tag{8}$$

The value of $|d|/w$ tends thus to infinity as the temperature goes to zero. This result is to be compared with the usual value of $\sqrt{3}$.[6] On the other hand, eq.(7) almost recovers the well known result: $|d|/w \sim 8.1$ by putting $\eta_c \sim 1$ (the Weisskopf cut-off). As can be seen, the focusing effect changes the adiabatic limit dramatically.

One can easily include the lower level broadening by substiting α_i by $(\alpha_i - \alpha_f)$ in eq. (6), except in the expression for n_c, which depends essentially on α_i only.

More general case for any charged perturber and for $\alpha_i < 0$ also, will be published elsewhere.

This work has been supported by RZN of SR Serbia.

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$H\delta$, $H\gamma$, $H\beta$, Mg I b triplet, He I D_3, Na I D_2 & D_1, $H\alpha$ and Ca II IR triplet, as well as other metallic lines that could be in emission during flares.
We study all these spectral features, both the line emission and profile. The dependence on the age and rotation rate of the level of chromospheric activity in the quiescent state is also analyzed.

3.16 SATELLITE ABSORPTION COMPONENTS OF THE UV SPECTRAL LINES SIIV, CIV, NV AND NIV IN THE ATMOSPHERE OF THE OE STAR HD 175754

E. Danezis[1], A. Antoniou[1], L. Popovic[2], M. Dimitrijevic[2], E. Lyratzi[1], D. Nikolaidis[1], A. Soulikias[1], & E. Theodossiou[1]

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Abstract In this paper we present a study of the UV resonance lines SiIV, CIV, NV and the NIV line (λ 1718.80 Å) of the Oe star HD 175754, using 7 spectrograms, taken by IUE, between September 1978 and August 1981. We used the method proposed by Danezis et al. (2003), with which we can study the velocity fields of the complex atmospherical regions where the lines which present SACs or DACs are created, as well as their ξ value, which is an expression of the optical depth. We calculated the apparent rotation (V_{rot}) and expansion/contraction radial velocities (V_{exp}) of these density regions. In the case of the SiIV doublet there exist three absorbing regions of rotation velocity with the mean values of 746 km/s, 371 km/s, 194 km/s and one emitting region rotating with 422 km/s. The respective values of the apparent radial velocity of all these regions are about -1555 km/s, -1726 km/s, -1761 km/s and 469 km/s. In the case of the CIV doublet there exist two absorbing regions of rotation velocity with the mean values of 1500 km/s and 830 km/s and one emitting region rotating with 359 km/s. The respective values of the apparent radial velocity of all these regions are about -1522 km/s, -1560 km/s and +729 km/s. In the case of the NV doublet there exist two absorbing regions of rotation velocity with the mean values of 2000 km/s, 484 km/s and one emitting region rotating with 545 km/s. The respective values of the apparent radial velocity of all these regions are about -1629 km/s, -1725 km/s and 242 km/s. In the case of the NIV line there exist two absorbing regions of rotation velocity with the mean values of 345 km/s and 141 km/s and one emitting region rotating with 142 km/s. The respective values of the apparent radial velocity of all these regions are about -72 km/s, -27 km/s and +489 km/s. We also present the relation between these parameters and their evolution with time. We see that these values are almost constant with time.

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3.17 SATELLITE ABSORPTION COMPONENTS OF THE UV SPECTRAL LINES SIIV, CIV, NV AND NIV IN THE ATMOSPHERE OF THE OE STAR HD 66811 (ζPUP)

E. Danezis[1], E. Lyratzi[1], L. Popovic[2], M. Dimitrijevic[2], G. Christou[1], A. Soulikias[1], & A. Antoniou[1]

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[2] Astronomical Observatory of Belgrade, Volgina 7, 11160 Belgrade, Serbia and Montenegro

Abstract In this paper we present a study of the UV resonance lines SiIV, CIV, NV and the NIV line (λ 1718.80 Å) of the Oe star HD 175754, using 7 spectrograms, taken by IUE, between 1979 and 1995. We used the method proposed by Danezis et al. (2003), with which we can study the velocity fields of the complex atmospherical regions where the lines which present SACs or DACs are created, as well as their ξ value, which is an expression of the optical depth. We calculated the apparent rotation (V_{rot}) and expansion/contraction radial velocities (V_{exp}) of these density regions. In the case of the SiIV doublet there exist three absorbing regions of rotation velocity with the mean values of 402 km/s, 734 km/s, 145 km/s and one emitting region rotating with 222 km/s. The respective values of the apparent radial velocity of all these regions are about -2111 km/s, -1532 km/s, -711 km/s and +473 km/s. In the case of the CIV doublet there exist three absorbing regions of rotation velocity with the mean values of 754 km/s, 786 km/s and 189 km/s and one emitting region rotating with 753 km/s. The respective values of the apparent radial velocity of all these regions are about -1486 km/s, -2224 km/s -114 km/s and +958 km/s. In the case of the NV doublet there exist three absorbing regions of rotation velocity with the mean values of 603 km/s, 607 km/s, 507 km/s and one emitting region rotating with 498 km/s. The respective values of the apparent radial velocity of all these regions are about -2054 km/s, -935 km/s, -1335 km/s and +1504 km/s. In the case of the NIV line there exist four absorbing regions of rotation velocity with the mean values of 562 km/s, 585 km/s, 586 km/s and 87 km/s and one emitting region rotating with 457 km/s. The respective values of the apparent radial velocity of all these regions are about -1332 km/s, -952 km/s, -640 km/s -308 km/s and +486 km/s. We also present the relation between these parameters and their evolution with time. We see that these values are almost constant with time.

3.18 UTM, A UNIVERSAL TRANSIT MODELLER

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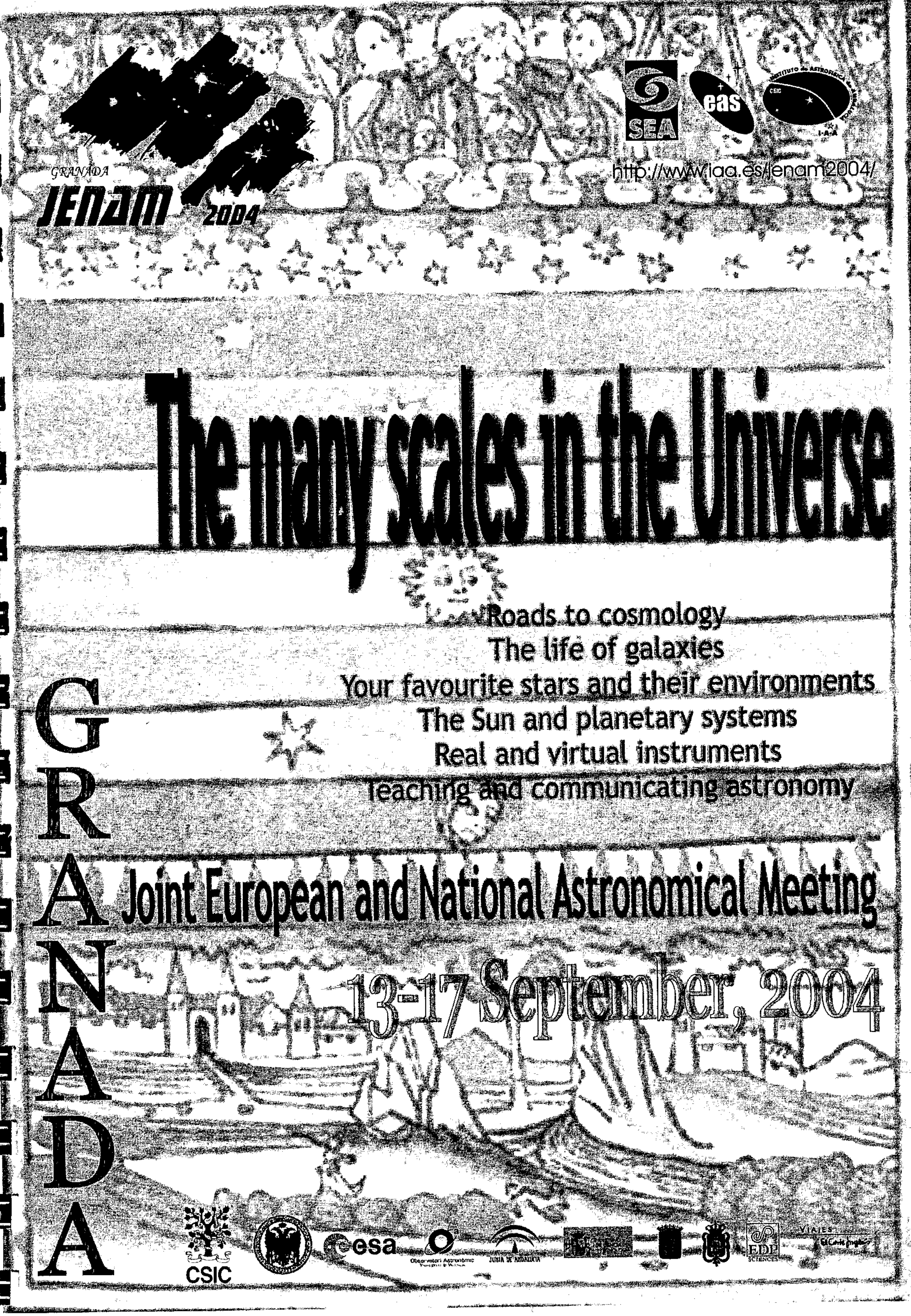
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3.20 GRB021004: COMPLETING THE LIGHT CURVE

A. de Ugarte Postigo, A.J. Castro-Tirado, J. Gorosabel, et al.

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Abstract At 12:06 UT of the 4th of October of 2002 a Gamma-Ray Burst (GRB) was observed by the HETE-2 satellite. The detection was immediatelly sent as an alert to many ground based observatories that began observations in different wavelenghts several minutes later.

Here we present a compilation of unpublished multicolour photometric data, with which a further analysis of GRB021004 has been made. Our study covers the full GRB history, from the early stages, two hours after the burst, down to the underlying host galaxy more than a year after, paying special attention to the nature of the different bumps that where detected in the light curve.

3.21 ON THE CONTRIBUTION OF COLLISIONS WITH CHARGED PARTICLES TO THE GA I LINE PROFILES IN CHEMICALLY PECULIAR STARS

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Abstract Results of Stark broadening (broadening by collisions with charged particles) investigations of neutral gallium spectral lines are of interest for different problems in astrophysics as e.g. for stellar spectra analysis and synthesis, for gallium abundance determination (Smith 1996) and opacity calculations. Spectral lines of this element are present in the Solar and stellar spectra. For example Jaschek & Jaschek (1987) have found gallium lines not only in the spectra of HgMn, Si-4200 and He-weak chemically peculiar stars but also in the spectra of a few stars otherwise classified as normal. Dworetsky (1993) reports on neutral gallium lines in A-type star spectra, and Ryabchikova & Smirnov (1994) in the spectrum of HgMn star Kappa Cancri. Smith (1995) investigated anomalous gallium line profiles in HgMn stars and found evidence for chemical stratification in their atmospheres. To the astrophysical importance of gallium spectral lines, contributes the fact that this element is often overabundant in chemically peculiar stars, which is for HgMn stars discussed in Dworetsky et al. (1998). Zverko & Zboril (1989) tried to derive the gallium abundance of 53 Tau from Ga I 4032.98 Å and 4172.06 Å - spectral lines and Smith (1996) reports on elemental abundance of gallium in normal late-B and HgMn stars. In Smith (1995,1996) has been concluded that HgMn stars have enhanced gallium abundances, and Zboril & Berrington (2001) have published the Non-LTE gallium equivalent widths for the most prominent gallium transitions as identified in real spectra and in (hot) mercury-manganese stars. Data on Stark broadening param-

eters are also significant for the calculation of opacity coefficients in stellar interiors and envelopes. For example Rogers & Iglesias (1992) developed the OPAL code for opacity calculations, where line broadening effects (including Stark broadening) are included, as well as gallium spectral lines. We calculated within the semiclassical perturbation approach (Sahal-Bréchot, 1969a,b), Stark broadening parameters due to impacts with electrons and protons for 18 Ga I transitions, for perturber density of 1×10^{14}cm-3, typical for stellar atmosphere conditions and temperatures from 2,500 up to 50,000 K. The obtained results have been compared, when possible, with the experimental results and the semiclassical calculations of N'Dollo and Fabry (1987), and with estimates of Lakicevic (1983) based on the regularities and systematic trends Stark. The obtained results and the comparison with the mentioned experimental and theoretical data will be published in Dimitrijevic et al. (2004). Our results have been used also for the investigation of the influence of collisions with charged particles (Stark broadening mechanism) on spectral line shapes in stellar atmospheres. Namely, we have calculated for our and N'Dollo & Fabry (1987) results Stark widths for a Kurucz's (1979) A type star (T_{eff} = 10000 K, log g = 4) atmosphere model and compared them with Doppler ones. Results obtained as a function of the Rosseland optical depth show that photospheric layers exist where Doppler and Stark widths are comparable and where the Stark width is dominant which is of interest to take into account when for example the stratification of gallium across the stellar photosphere is considered. Also, obtained results show that for transitions involving energy levels with higher principal quantum numbers, the importance of Stark broadening mechanism increases. This is due to the fact that with the increase of the principal quantum number of the upper level of the transition, the difference between this, and the closest perturbing energy level decreases, resulting in the increase of the Stark broadening influence. The new experimental evaluations of Stark broadening parameters for Ga I spectral lines, especially at higher temperatures, will be certainly of interest not only from the theoretical point of view but also for astrophysical and laboratory plasma diagnostics and modeling.

3.22 OPTICALLY VARIABLE SOURCES MONITORED BY THE OMC

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THE EUROPEAN WEEK OF ASTRONOMY AND SPACE SCIENCE

Abstract Book
(Version 2.0)

Lisbon, 6-10 September 2010

Edited by André Moitinho, Eduardo Amôres, Vladan Arsenijevic, Joana Ascenso, Rui Azevedo

General Topic

GeneralTopic

On Alfvén waves in the solar wind

L.M.B.C. Campos

The propagation of Alfvén waves in the solar wind is affected by: (i) the radial mean flow velocity, that exceeds the wave speed beyond the critical point; (ii) the radial variation of mass density; (iii) the non-uniformity of the magnetic field. These waves are not sinusoidal because of non-uniform moving background, and do not satisfy equipartition of energies. It is shown that: (i) the magnetic energy tends to dominate the kinetic energy; (ii) that an initial white noise spectrum tends to a Kraichnan spectrum resembling hydromagnetic turbulence; (iii) that waves can be reflected or absorbed at the critical level where the wave speed equals the mean flow speed. These properties depend on the solar wind profile, e.g. are distinct for the 'solar breeze'.

On the genation of magneto-acoustic-gravity-inertial (MAGI) waves in stars

L.M.B.C. Campos

The generation of waves in stars is affected by: (i) the compressibility of the gas (acoustics); (ii) the ionization of the fluid or plasma (magnetism); (iii) the stratification in layers (gravity); (iv) Coriolis forces due to rotation (inertial effects). These four effects (i-iv) are generally coupled, leading to magneto-acoustic-gravity-inertial (MAGI) waves. The wave equation describing the propagation of MAGI waves is obtained: its source terms specify generation by turbulence and inhomogeneities; its solution leads to a radiation law for the wave energy flux.

A statistical study of the UV Mg II resonance lines' parameters in 20 Be stars

A. Antoniou, E. Danezis, E. Lyratzi, L. C. Popović, M. S. Dimitrijević

In this paper, using the GR model, we analyze the UV Mg II resonance lines in the spectra of 20 Be stars of different spectral subtypes, taken with IUE, in order to detect the presence of Satellite

Absorption Components (SACs) and Discrete Absorptions Components (DACs). From this analysis we can calculate the values of a group of physical parameters, such as the apparent rotational and radial velocities, the random velocities of the thermal motions of the ions, as well as the column density and the Full Width at Half Maximum (FWHM) of the independent regions of matter which produce the main and the satellites components of the studied spectral lines. Finally, we present the relations between these physical parameters and the effective temperature of the studied stars.

On The Gravitodynamics of Moving Bodies

A. W. Mol

It is known that Einstein's General Theory of Relativity, as usually understood at the present time, which had started from a profound but simple physical concept, the equivalence principle, when applied to the universe through the standard FL cosmology with its currently accepted λCDM model introduced a increasing list of freely specifiable parameters. Though they become more and more precise these realizations have been achieved at the expense of simplicity. In the present work we propose a generalization of Newton's gravitational theory from the original works of Heaviside and Sciama that encompasses both approaches and accomplishes in a simpler way than the standard cosmological approach. The established formulation describes the local gravitational field related to the observables and effectively implements the Mach's principle in a quantitative form that retakes the Dirac's large number hypothesis. As a consequence of the equivalence principle and the application of this formulation to the observable universe, we obtain as an immediate result that Omega is 2. We construct a dynamic model for a galaxy without dark matter, which fits well with the recent observational data, in terms of a variable effective inertial mass that reflects the present dynamic state of the universe and that replicates from first principles, the phenomenology proposed in MOND. The remarkable aspect of these results is the connection of the effect dubbed dark matter with the dark energy field, which makes us possible to interpret it as longitudinal gravitational waves.

North-south asymmetry of Ca II K regions determined from OAUC spectroheliograms: 1996 - 2006

Dorotovic I., J. Rybak, A. Garcia, P. Journoud

The level and evolution of solar activity (SA) is not identical in the northern and southern Sun's hemispheres. This fact was repeatedly confirmed in the past by analysis of a number of long-term observations of various solar activity indices. Therefore, north-south asymmetry (NSA) is a significant tool in analysis of the long-term SA variations. This paper presents a software tool to determine the NSA of the area of bright chromospheric plages, as measured in the Ca II K3 spectroheliograms registered since 1926 in the Observatório Astronómico da Universidade de Coimbra, Portugal, as well as evolution of surface areas in the period of 1996 - 2006. The algorithm of the program is limited to determining the total area of bright features in the emission line of Ca II K3 defining the threshold value of the relative brightness, but it does not perceive differences in the brightness of individual chromospheric features. A comparison and cross-correlation with the N-S asymmetries found for the sunspots and coronal green line brightness is added. In the near

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future we intend to: 1) determine the NSA of area of bright chromospheric Ca II K3 regions back to the year 1926, 2) compare the evolution of surface area in the period 1970 to 2006 with the evolution of the index of magnetic observatory Mt. Wilson and Kitt Peak, which would enable to construct a proxy reconstruction of the magnetic index also back to 1926. Since 2007 are new spectroheliograms recorded using a CCD camera and therefore we will in future address this issue also for the period of 2007 - present.

Impact of solar activity on the growth of pine trees (Pinus cembra: 1610-1970; Pinus pinaster: 1910-1989)

Surovy P., Dorotovic I., Karlovsky V., Lousada J. L., Rodrigues J. C., Rybansky M., Fleischer P.

Many studies indicate that the solar activity (SA) can affect tree growth induced by changes in climatic conditions on Earth's surface evoked due to SA variations. In previous work (Surovy et al., 2008), we found that cork oak (Quercus suber L.) bark growth was lower in the period of maximum of the 23rd SA cycle (2000-2002) than in the SA minimum period (around 1996). In this work we focused on a similar analysis of the data for the annual growth of cembra pine (Pinus cembra) grown in the North-east of Slovakia. The database covers the period of 1406 - 1970, but sunspot data (minima and maxima), is only available since 1610 at the NGDC site, moreover, the most reliable sunspot numbers data are only from 1749. The results of this analysis confirm the fact observed in the previous work, i.e. negative impact of high SA on cembra pine growth, but it should be noted, however, that the statistical significance of results is low. We applied also wavelet analysis to data on the evolution of tree growth, the results indicate periodic variations in the growth period of about 25 years (duration of approximately two solar cycles or one magnetic cycle, respectively), also periodicities of 30, 35, and 70 years were observed. A negative impact of the SA was also observed, in the growth of an 90 year-old maritime pine (Pinus pinaster) tree grown in the North of Portugal. The width of the annual rings was smaller in the years of maximum SA; furthermore it was found that it is the latewood growth that it is affected while the earlywood growth is not affected, as a corollary the percent of late wood also shows a significative negative correlation with SA.

Broad Absorption Lines with DACs and SACs in the spectra of PG 0946+301 and PG 1254+047

Lyratzi, E. Danezis, L. C. Popović, M. S. Dimitrijević and A. Antoniou

Assuming that the Broad Absorption Line Regions - BALR are composed of a number of successive independent absorbing density layers, which have the random, rotational and radial velocity, we investigate the physical properties of Broad Absorption Line Regions (BALRs) of the BALQSOs PG 0946+301 (Z=1.216) and PG 1254+047 (Z=1.024) by applying GR model on their spectra. Specifically, we study the C IV 1548.187, 1550.772 A and Si IV 1393.755, 1402.77 A as well as the Lya ? 1215.68 A spectral line and the N V 1238.821, 1242.804 A, UV resonance lines. The observed peculiar profiles of these lines can be explained by the DACs and SACs phenomena, as they are created by a number of components. Finally, we calculate some kinematical parameters such as the apparent radial (Vrad) and rotational (Vrot) velocities of the regions where the studied lines are created, as well as the random velocities (Vrand) of the studied ions.

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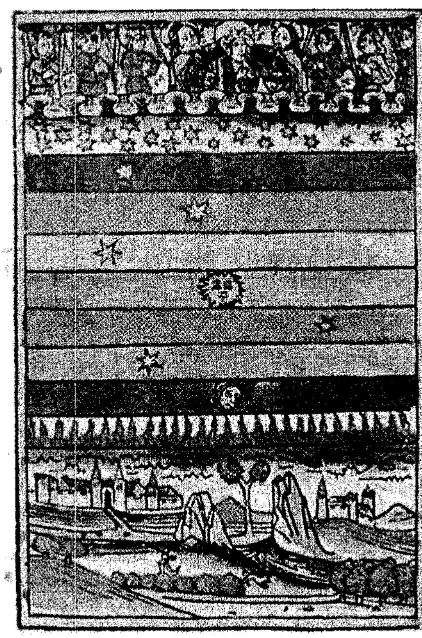

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3P16

Satellite Absorption Components (SACs) of the UV spectral lines NV, CIV, NIV and SiIV in the atmosphere of the Oe star HD 175754

E. Danezis[1], E. Lyratzi[1], L. Č. Popović[2], M. S. Dimitrijević[2], E. Theodossiou[1], M. Stathopoulou[1], A. Antoniou[1] & A. Soulikias[1]

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Introduction

HD 175754 is a luminous supergiant star of spectral type O8IIf with effective temperature T_{eff}=31800±1100 °K (Morossi & Crivellari, 1980). Costero & Stalio (1981) and Costero et al (1981) studied the NV, SiIV and CIV profiles of this star and compared them with the profiles of similar type stars' spectra. They found individuality, which implies different structures and dynamics of the atmospheric layers above the photosphere. Carrasco et al. (1981) reported only small changes in the UV resonance line profiles. They interpreted them in terms of variations in dynamics and density/ionization structure of the stellar wind. Lamers et al (1982) noted the possibility of the presence of satellite components superimposed on the wide P Cygni profiles of the UV resonance lines. Finally, Franco et al (1983) studied the P Cygni profiles of the above resonance lines of HD 175754 observed at different epochs and they reported variability at the secondary satellite component. They proposed two different mechanisms for the explanation of the variability, namely, a thermal mechanism in a hot region at Tc=2·10⁵ °K which produces the principal stationary component and a mechanism which gives rise to the secondary component by ionization of cooler high velocity stellar material from X-rays coming from inner coronal region.

In this paper we present the study of the superionized regions in the gaseous envelope of HD 175754 (Lamers et al. 1982 and Franco et al. 1983), based on the proposed by Danezis et al. (2003) model for the structure of the SACs regions in the early type atmospheres. This model presupposes that the regions, where these spectral lines are formed, are not continuous but consist of a number of independent absorbing density layers of matter, a number of emission regions and an external general absorption region. By this model, we calculate the apparent radial expansion/contraction velocities (V_{exp}), the apparent rotational velocities (V_{rot}), as well as an expression of the optical depth (ξ), for all the independent density regions of the superionized regions in the gaseous envelope of HD 175754. Finally, we calculate the variations of the above mentioned parameters, in the time period between 1978 and 1981.

Method of spectral analysis

In order to study the physical structure and the existence of SACs phenomena in the regions where these lines are created we used the model proposed by Danezis et al. (2002b, 2003a). This model presupposes the existence of independent density layers of matter in these regions. With this method we can calculate the apparent rotation (V_{rot}) and expansion/contraction radial velocities (V_{exp}) of these density regions, as well as their ξ value, which is an expression of the optical depth. The final function which reproduces the complex line profile is:

$$I_\lambda = \left[I_{\lambda 0} \prod_i \exp\{-L_i \xi_i\} + \sum_j S_{\lambda e} \left(1 - \exp\{-L_{ej} \xi_{ej}\}\right) \right] \exp\{-L_g \xi_g\}$$

L_i, L_{ej}, L_g: are the distribution functions of the absorption coefficients $k_{\lambda i}$, $k_{\lambda ej}$, $k_{\lambda g}$ respectively. Each L depends on the values of the apparent rotation velocity as well as of the apparent expansion/contraction radial velocity of the density shell, which forms the spectral line (V_{rot}, V_{exp}) and

ξ: is an expression of the optical depth.

Observational Data

The data we used are the 7 spectra of HD 175754 taken with the IUE satellite with the Short Wavelength range Prime camera (SWP) at high resolution (0.1 to 0.3 Å). Our data are presented in the table 1.

In these spectra we studied the structure of the spectral lines SiIV λλ 1393.755 Å, 1402.77 Å, CIV λλ 1548.185 Å, 1550.774 Å, NIV λ 1718.551 Å and NV λλ 1238.821 Å, 1242.804 Å.

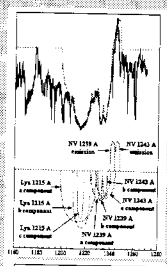
The calculated values of the apparent rotational and radial velocities correspond to the regions, where the Satellite Absorption Components (SACs) are created, and not to the star. Specifically, these values correspond to the density regions which result when streams of matter are twisted and form strings that produce blobs, puffs or bubbles.

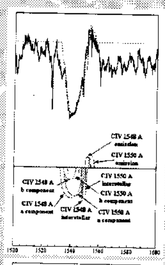
Table 1

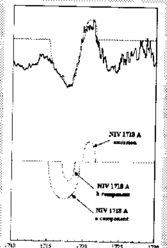
Camera	Date
Swp 02813	30/09/1978
Swp 04901	09/04/1979
Swp 06269	23/08/1979
Swp 09320	20/06/1980
Swp 13591	27/03/1981
Swp 13728	16/04/1981
Swp 14803	24/08/1981

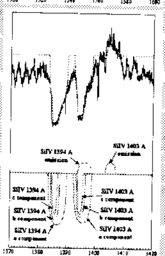
Figures

The best fit is not just the graphical composition of some components (line profiles). The reproduced feature is the result of the final function of the model. In these figures we present some best fits of the star HD 175754's spectra, which present SACs. The black line presents the observed spectral line's profile and the red one the model's fit. We also present all the components which contribute to the observed features, separately.









Conclusions

1. By applying the proposed by Danezis et al. (2003), model we are able to reproduce the profiles of all the spectral lines of the star HD 175754 with great accuracy. This means that the coronal model allowing the existence of successive, independent density shells of matter represents accurately the structure of the gaseous envelope of HD 175754.
2. The best fit of all lines derived by the model we described leads to the conclusion that the layer of matter in the region we studied {33eV (SiIV)-78 eV(NV)} is structured as the model describes:
   i) An area of gas consisting of i independent absorbing layers of matter.
   ii) One emitting layer of matter.
   iii) Occasionally, an external absorption layer of matter.
3. It is interesting to point out that in the regions we study there exist successive shells which move radially with velocities between -1760 km/s and 730 km/s, and rotate with velocities between 140 km/s and 2000 km/s.
4. Apparent rotational and radial velocities of each layer of matter show an insignificant variation between the three different spectra we used.

Acknowledgements

This research project is progressing at the University of Athens, Department of Astrophysics - Astronomy and Mechanics, under the financial support of the Special Account for Research Grants, which we thank very much. This work was also supported by Ministry of Science through the projects P1195 (Influence of collisional processes on astrophysical plasma line shapes) and P1195 (Astrophysical spectroscopy of extragalactic objects.

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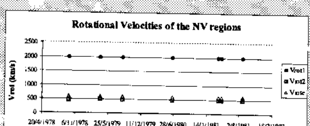

Diagram 1: Apparent rotational velocities of all the SACs as a function of time. The rotational velocity of the first and the second SAC is about 2000 km/s and 484 km/s, respectively. The emission's rotational velocity presents the value of 600 km/s.

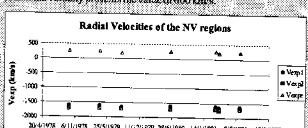

Diagram 2: Apparent radial velocities of all the SACs as a function of time. The radial velocity of the first and the second SAC is about -1630 km/s and -1725 km/s, respectively. The emission's radial velocity presents the value of 242 km/s.

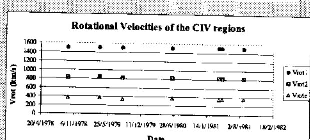

Diagram 3: Apparent rotational velocities of all the SACs as a function of time. The rotational velocity of the first and the second SAC is about 1500 km/s and 830 km/s, respectively. The emission's rotational velocity presents the value of 360km/s.

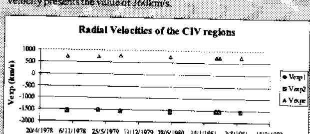

Diagram 4: Apparent radial velocities of all the SACs as a function of time. The radial velocity of the first and the second SAC is about -1522 km/s and -1560 km/s, respectively. The emission's radial velocity presents the value of 730 km/s.

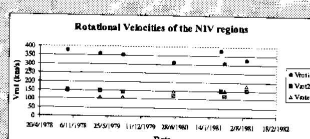

Diagram 5: Apparent rotational velocities of all the SACs as a function of time. The rotational velocity of the first SAC is about 345 km/s. The second SACs and the emission's rotational velocity present the value of 140 km/s.

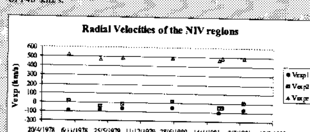

Diagram 6: Apparent radial velocities of all the SACs as a function of time. The radial velocity of the first and the second SAC is about -72 km/s and -15 km/s, respectively. The emission's radial velocity presents the value of 490 km/s.

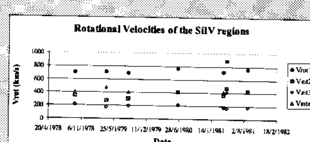

Diagram 7: Apparent rotational velocities of all the SACs as a function of time. The rotational velocity of the first, the second and the third SAC is about 746 km/s, 370 km/s and 194 km/s, respectively. The emission's rotational velocity presents the value of 422 km/s.

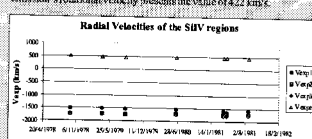

Diagram 8: Apparent radial velocities of all the SACs as a function of time. The radial velocity of the first, the second and the third SAC is about -1556 km/s, -1726 km/s and -1760 km/s, respectively. The emission's radial velocity presents the value of 470 km/s.

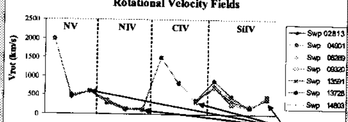

Diagram 9: Apparent rotational velocities of all the SACs as a function of the distance from the star.

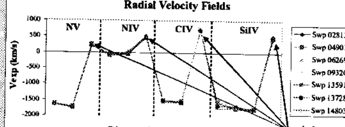

Diagram 10: Apparent radial velocities of all the SACs as a function of the distance from the star.

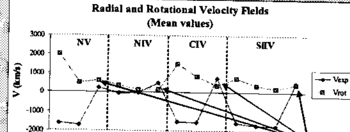

Diagram11: Mean values of the apparent rotational and radial velocities of all the SACs as a function of the distance from the star.

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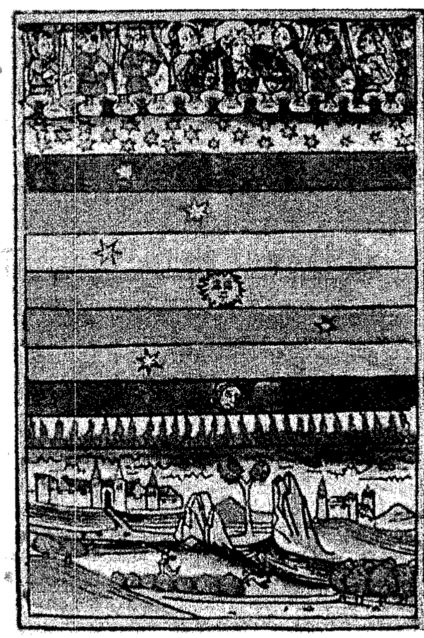

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THE MANY SCALES IN THE UNIVERSE

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Edited by

J.C. del Toro Iniesta, E.J. Alfaro,
J.G. Gorgas, E. Salvador-Solé
and H. Butcher

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Satellite Absorption Components (SACs) of the UV spectral lines NV, CIV, NIV and SiIV in the atmosphere of the Oe star HD 66811 (ζPup)

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Introduction

The hottest of the bright Of stars is ζ Puppis, for which Walborn (1972) gave the spectral type O4I(n)f. Conti and Leep (1974) classified it as O4ef, while Lesh (1972) retained the historic type of O5f.

The main parameters of the star were summarized by Lamers and Morton (1976). The determination of the effective temperature yields large problems. The value derived from the angular diameter and the UV flux distributions is T_e = 32510 ± 1930 °K according to Code et al. (1976) or 31900 ± 1800 °K according to Brune et al. (1979). These values are similar to those of the later type stars ζ Oph (O9.5V) and τ Sco (B0V) and seem, therefore, much too low. A higher T_e value (50000 °K) and log(g)=4.0 was found from a study of COPERNICUS observations of the helium spectrum by Snijders and Underhill (1975), who compared observations of HeII lines with non-LTE predictions obtained for assumed non-LTE-plane-parallel model atmospheres by Auer and Mihalas (1972).

Lamers and Morton (1976) gave a detailed description of P Cygni profiles in ζ Puppis using high resolution spectral scans obtained with the COPERNICUS satellite. Rocket-UV spectra of ζ Puppis has been described by Carruthers (1968), Morton et al. (1969), Stecher (1970), Smith (1970) and Burton et al. (1973, 1975). An absolutely calibrated rocket spectrum (12 to 15 Å resolution) was obtained by Brune et al. (1979). These investigations revealed strong P Cygni lines of C IV, N IV N V, O IV, Si IV, S IV and S VI in the far ultraviolet. Additionally, Snijders and Underhill (1975) analyzed the He II observed by the COPERNICUS satellite along with those available from ground-based spectra. Finally, Franco et al. (1983) found line profile variability in ζ Puppis and suggested that two different mechanisms could produce the observed ionization stages.

In this paper we apply the model proposed by Danezis et al. (1984, 1991, 2000, 2003), for the outer atmosphere of Oe and Be stars to the star HD 66811 (ζ Puppis) and we present some first results deriving from this application. This model allows the existence of many absorption shells or many independent density regions, considers that the expanding outer atmosphere consists of some absorbing and some emitting regions and concludes to a function for the spectral line, able to reproduce the profiles of all the spectral lines with great accuracy.

Method of spectral analysis

In order to study the physical structure and the existence of SACs phenomena in the regions where these lines are created we used the model proposed by Danezis et al. 2003a). This model presupposes the existence of independent density layers of matter in these regions. With this method we can calculate the apparent rotation (V_{rot}) and expansion/contraction radial velocities (V_{exp}) of these density regions, as well as their ξ value, which is an expression of the optical depth. The final function which reproduces the complex line profile is:

$$I_\lambda = \left[I_{\lambda 0} \prod_i \exp\{-L_i \xi_i\} + \sum_j S_{\lambda j}\left(1 - \exp\{-L_{ej}\xi_{ej}\}\right) \right] \exp\{-L_g \xi_g\}$$

L_i, L_{ej}, L_g: are the distribution functions of the absorption coefficients $k_{\lambda i}$, $k_{\lambda ej}$, $k_{\lambda g}$ respectively. Each L depends on the values of the apparent rotation velocity as well as of the apparent expansion/contraction radial velocity of the density shell, which forms the spectral line (V_{rot}, V_{exp}) and

ξ: is an expression of the optical depth.

Observational Data

This project is based on three different spectra of ζ Pup (HD 66811), which are listed below:

- SWP 05963 (27-7-1979)
- SWP 33538 (16-5-1988)
- SWP 53460 (17-1-1995)

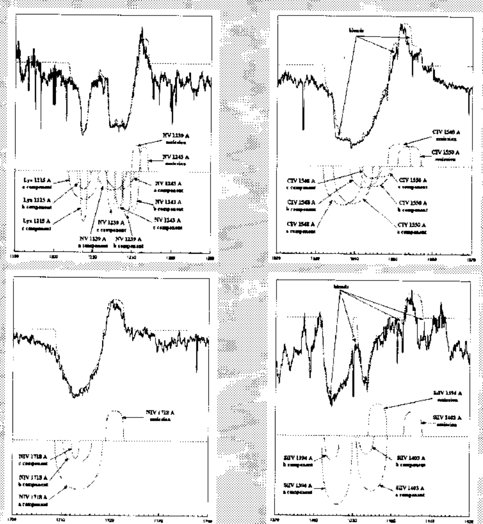
These spectra have been taken with the IUE satellite with the Short Wavelength range Prime camera (SWP) at high resolution (0.1 to 0.3 Å).

We study the structure of the spectral lines of:

- N V λλ 1238,821, 1242,804 Å
- C IV λλ 1548,155, 1550,774 Å
- N IV λ 1718,80 Å
- Si IV λλ 1393,755, 1402,730 Å

Figures

The best fit is not just the graphical composition of some components (line profiles). The reproduced feature is the result of the final function of the model. In these figures we present some best fits of the star HD 66811's spectra, which presents SACs. The black line presents the observed spectral line's profile and the red one the model's fit. We also present all the components which contribute to the observed features, separately.



Conclusions

1. By applying the proposed by Danezis et al. (2003), model we are able to reproduce the profiles of all the spectral lines of the star HD 66811 (ζ Puppis) with great accuracy. This means that the coronal model allowing the existence of successive, independent density shells of matter represents accurately the structure of the gaseous envelope of ζ Puppis.
2. The best fit of all lines derived by the model we described leads to the conclusion that the layer of matter in the region we studied {33eV (Si IV)-78 eV(N V)} is structured as the model describes:
   i) An area of gas consisting of i independent absorbing layers of matter.
   ii) One emitting layer of matter.
   iii) Occasionally, an external absorption layer of matter.
3. It is interesting to point out that in the regions we study there exist successive shells which move radially with velocities between -2200 km/s and 822 km/s, and rotate with velocities between 133 km/s and 1783 km/s.
4. Apparent rotational and radial velocities of each layer of matter show an insignificant variation between the three different spectra we used.

Acknowledgements

This research project is progressing at the University of Athens, Department of Astrophysics - Astronomy and Mechanics, under the financial support of the Special Account for Research Grants, which we thank very much. This work was also supported by Ministry of Science through the projects P1195 (Influence of collisional processes on astrophysical plasma line shapes) and P1195 (Astrophysical spectroscopy of extragalactic objects.

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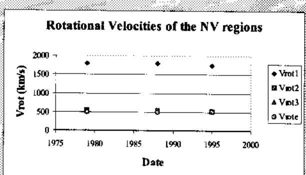

Diagram 1: Apparent rotational velocities of all the SACs as a function of time. The rotational velocity of the first SAC is about 1783 km/s. The second and third SACs' rotational velocities present the value of 533 km/s. The emission's rotational velocity is about 507 km/s.

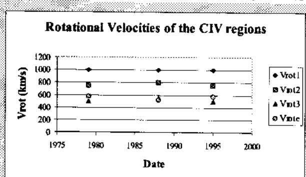

Diagram 3: Apparent rotational velocities of all the SACs as a function of time. The rotational velocity of the first, the second and the third SAC is about 1000 km/s, 767 km/s and 517 km/s, respectively. The emission's rotational velocity presents the value of 553 km/s.

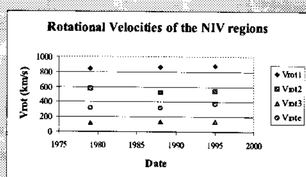

Diagram 5: Apparent rotational velocities of all the SACs as a function of time. The rotational velocity of the first, the second and the third SAC is about 860 km/s, 547 km/s and 133 km/s, respectively. The emission's rotational velocity present the value of 340 km/s.

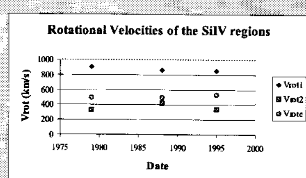

Diagram 7: Apparent rotational velocities of all the SACs as a function of time. The rotational velocity of the first and the second SAC is about 873 km/s and 363 km/s, respectively. The emission's rotational velocity presents the value of 510 km/s.

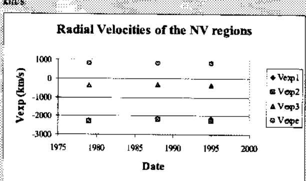

Diagram 2: Apparent radial velocities of all the SACs as a function of time. The radial velocity of the first, the second and the third SAC is about -2190 km/s, -2250 km/s and -347 km/s, respectively. The emission's radial velocity presents the value of 822 km/s.

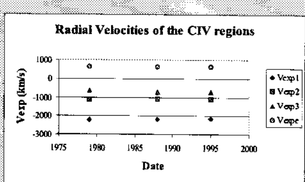

Diagram 4: Apparent radial velocities of all the SACs as a function of time. The radial velocity of the first, the second and the third SAC is about -2195 km/s, -1100 km/s and -690 km/s, respectively. The emission's radial velocity presents the value of 633 km/s.

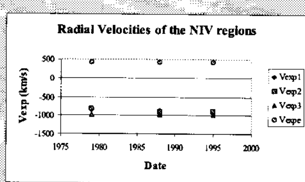

Diagram 6: Apparent radial velocities of all the SACs as a function of time. The radial velocity of the first, the second and the third SAC is about -890 km/s, -876 km/s and -986 km/s. The emission's radial velocity presents the value of 428 km/s.

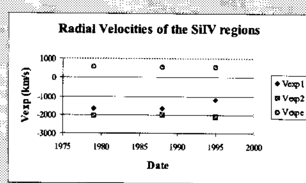

Diagram 8: Apparent radial velocities of all the SACs as a function of time. The radial velocity of the first and the second SAC is about -1525 km/s and -2060 km/s. The emission's radial velocity presents the value of 584 km/s.

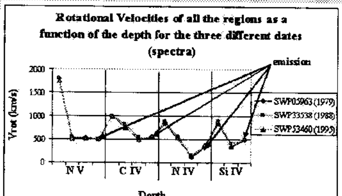

Diagram 9: Apparent rotational velocities of all the SACs as a function of the distance from the star.

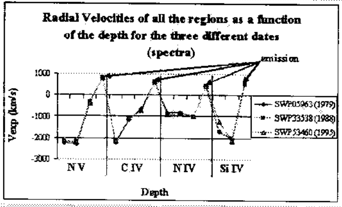

Diagram 10: Apparent radial velocities of all the SACs as a function of the distance from the star.

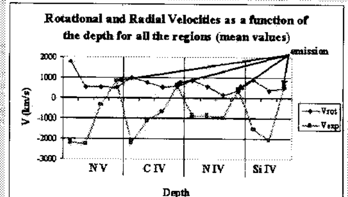

Diagram 11: Mean values of the apparent rotational and radial velocities of all the SACs as a function of the distance from the star.

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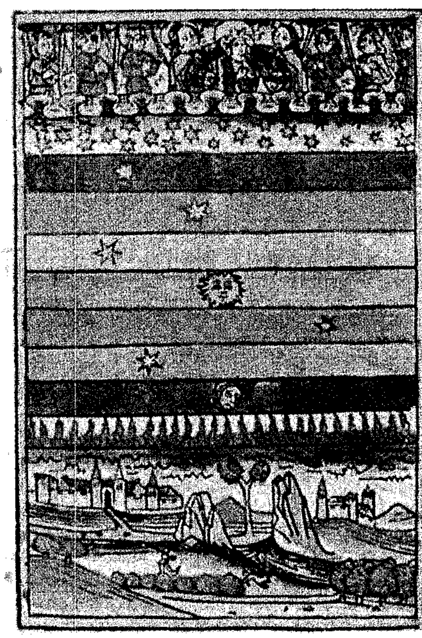

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The complex structure of the SiIV λλ 1393.755, 1402.73 Å regions of 42 BeV stars

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Introduction

The ultraviolet resonance lines of SiIV (λλ 1393.755, 1402.77 Å) arise from the transition $3s^2S$-$3p^2P^0$. This doublet is usually an intense feature in the spectra of early type stars and provides us with a useful tool for the study of the stellar atmosphere's structure. Thus, it has been studied by many researchers. The profile of the resonance lines seem to depend on the spectral subtype and the luminosity class, (Snow 1977), so it has been proposed that the doublet may be a significant tool for the spectral classification (Walborn & Nichols-Bohlin 1987; Prinja 1990). It has been observed that the lines present decreasing strength from the earliest to the latest spectral subtypes. Panek & Savage (1976) and Henize et al. (1976, 1981) observed that they disappear in the spectra of Be stars later than B3. However, Marlborough (1982), Marlborough & Peters (1982) and Slettebak (1994) observed the doublet may be observed in stars as cool as B8. Many researchers have studied the existence of Satellite Absorption Components (SACs or DACs), which accompany the SiIV resonance lines in the spectra of Be stars and which are of circumstellar or interstellar origin (Underhill 1974, 1975; Snow 1977; Lamers & Snow 1978; Gathier et al. 1981; Lamers et al. 1982; Marlborough 1977, 1982; Snow et al. 1979; Henrichs et al. 1983; Hack et al. 1983; Codina et al. 1984; Hubeny et al. 1985, 1986; Danezis 1984, 1986; Danezis et al. 1991; Sahade et al. 1984; Sahade & Brandi 1985; Hutsemekers 1985; Aydin et al. 1988; Doazan et al. 1988; Bruhweiler et al. 1989; Sapar & Sapar 1992; Ferero 1998, Lyratzi et al. 2003). Finally, the SiIV doublet is an indicator of mass-loss effects in B stars, especially when asymmetries appear in both of the resonance lines (Snow & Marlborough 1976; Snow & Morton 1976; Lamers & Snow 1978; Henrichs et al. 1983).

Besides, Kondo et al. (1981) studied the binary system U Cephei. They observed shallow and broad absorption lines of SiIV in the star's spectra from which they calculated a rotation velocity of about 300 km/s, which led them to associate the lines with the photosphere of the B star. They reported variations of the total absorption, perhaps due to hot regions on the B star and gas streaming effects. By comparing with the far-UV spectra of B stars, they found that the SiIV and CIV doublet lines are too strong for a B7 star, while they are comparable to a B0-1 star. They suggested that "the SiIV and CIV lines arise from the region above the conventional photosphere, where the infalling matter from the gas stream gives rise to a pseudophotosphere, whose temperature is higher than that of the photosphere observed from the ground. This pseudophotosphere may exist primarily along the equatorial, region of the BV star". They mentioned that the resonance lines of SiIV and CIV show effects of gas streaming and, possibly, hot regions on the B star, which are due to the hot gas stream of low density leaving the G star and orbiting about 270° around the B star, before escaping from the system. Finally, they suggested that "the absence of emission indicates that the total volume occupied by the gas stream having significant densities is smaller than the volume of the B star".

Also, Codina et al. (1984) studied the UV spectra of the B0.5 IIIe star HD 110432, and observed "broad absorption photospheric lines, narrow absorption lines of high ionized species displaced to the short wavelengths, indicating velocities of about -1350 km/s and very narrow absorption lines of interstellar origin". They calculated a rotation velocity of about 360±40 km/s. As the resonance doublets of SiIV and CIV are asymmetric with extended blue wings, they probably indicate a tenuous expanding envelope. For the narrow absorption lines (SACs) of high ionized species such as SiIV, CIV and NV, they proposed that "they could originate in matter ejected occasionally by the star due to some kind of photospheric activity. In this line of thought, such an ejection is probably a localized phenomenon not associated with the whole surface of the star (blob)". Concerning the "blobs", they proposed that the gas inside them is probably hot, not necessarily in ionization equilibrium and that the ionization is caused by collisional processes.

Sapar & Sapar (1992) studied the UV spectra of η CMa and found that the SiIV resonance lines show changes in their profiles, suggesting the presence of some shell condensations moving with time-dependent radial velocities. They observed "blue-shifted satellite components belonging to expanding shell condensations", with radial velocities -360 km/s, -180 km/s, -110 km/s and -30 km/s. They proposed accelerating expansion of the shell, as they calculated greater radial velocities for the shell components than those from earlier observations by Underhill (1974, 1975). They attributed the presence of strong unshifted resonance line components of SiIV to a hot circumstellar gas cloud. They concluded to such behavior being the result of "an extended expanding envelope having dense shells which move away from the star and have different velocities".

In this paper we present a statistical study of the UV SiIV resonance lines λλ 1393.755, 1402.73 Å in the spectra of 42 BeV stars. Our study is based on the model proposed by Danezis et al. (2003) and our purpose is to extract the limits of the values of the apparent rotation and radial velocities (Vrot, Vexp) and to check whether there exists a common physical structure for the atmospherical regions which create the Satellite Absorption Components (SACs) or the SiIV resonance lines in the spectra of all the BeV stars. It is essential to perform such a study in a great number of stars, in order to accept that the proposed model gives satisfactory results and is able to describe the structure of these atmospherical regions.

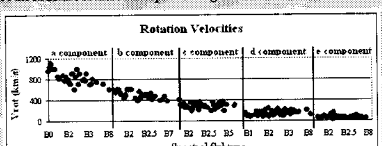


Diagram 1: Apparent rotation velocities of all the SACs as a function of the spectral subtype. Five levels of rotation velocity are presented with the mean values of 830 km/s, 492 km/s, 285 km/s, 137 km/s and 51 km/s. The observed dispersion may be due to the different values axis inclination of the regions where the SACs are created.

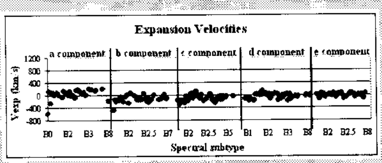
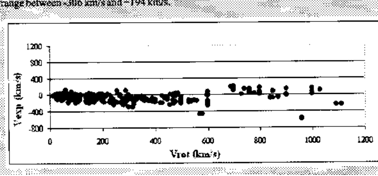


Diagram 2: Apparent expansion/contraction velocities of all the SACs as a function of the spectral subtype. The values of the expansion/contraction velocity of all the SACs lie in the range between -306 km/s and +194 km/s.



Method of spectral analysis

In order to study the physical structure and the existence of SACs phenomena in the regions where these lines are created we used the model proposed by Danezis et al. (2002b, 2003a). This model presupposes the existence of independent density layers of matter in these regions. With this method we can calculate the apparent rotation (V_{rot}) and expansion/contraction radial velocities (V_{exp}) of these density regions, as well as their ξ value, which is an expression of the optical depth. The final function which reproduces the complex line profile is:

$$I_\lambda = \left[I_{\lambda 0} \prod_i \exp\{-L_i \xi_i\} + \sum_j S_{\lambda e} \left(1 - \exp\{-L_{ej} \xi_{ej}\}\right) \right] \exp\{-L_g \xi_g\}$$

L_i, L_{ej}, L_g: are the distribution functions of the absorption coefficients $k_{\lambda i}$, $k_{\lambda ej}$, $k_{\lambda g}$ respectively. Each L depends on the values of the apparent rotation velocity as well as of the apparent expansion/contraction radial velocity of the density shell, which forms the spectral line (V_{rot}, V_{exp}) and

ξ: is an expression of the optical depth.

Observational Data

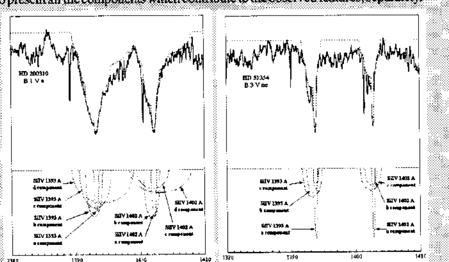
The data we used are the SiIV resonance lines of 42 BeV stars. The stars' spectrograms have been taken with IUE satellite with the Short Wavelength range Prime camera (SWP) at high resolution (0.1 to 0.3 Å). The spectral types of the studied stars have been taken by the SIMBAD database (Centre de Donnees Astronomiques de Strasbourg (CDS), Strasbourg, France). Our data are presented in the following Table.

Table

Star	Spectral Type	Camera	Star	Spectral Type	Camera
HD 206773	B0 V : pe	Swp 18753	HD 32343	B2.5 V e	Swp 06932
HD 200310	B1 V e	Swp 10853	HD 37967	B2.5 V e	Swp 21491
HD 212571	B1 V e	Swp 07009	HD 65875	B2.5 V e	Swp 06544
HD 35439	B1 V pe	Swp 07716	HD 187811	B2.5 V e	Swp 19937
HD 44458	B1 V pe	Swp 18306	HD 191610	B2.5 V e	Swp 08600
HD 200120	B1.5 V nne	Swp 09458	HD 208682	B2.5 V e	Swp 19935
HD 30076	B2 V e	Swp 20844	HD 20336	B2.5 V ne	Swp 19934
HD 32991	B2 V e	Swp 14840	HD 60855	B2/B3 V	Swp 21915
HD 50083	B2 V e	Swp 15958	HD 51354	B3 ne	Swp 16547
HD 58050	B2 V e	Swp 16536	HD 25940	B3 V e	Swp 07011
HD 164284	B2 V e	Swp 08614	HD 45725	B3 V e	Swp 28106
HD 41335	B2 V ne	Swp 08604	HD 183362	B3 V e	Swp 31218
HD 52721	B2 V ne	Swp 25377	HD 208057	B3 V e	Swp 05909
HD 58343	B2 V ne	Swp 08605	HD 205637	B3 V : p	Swp 07008
HD 148184	B2 V ne	Swp 07753	HD 217543	B3 V pe	Swp 31186
HD 194335	B2 V ne	Swp 19938	HD 22192	B5 V e	Swp 08593
HD 202904	B2 V ne	Swp 08601	HD 138749	B6 V nne	Swp 09124
HD 65079	B2 V ne&	Swp 53980	HD 192044	B7 V e	Swp 28251
HD 28497	B2 V : ne	Swp 08594	HD 22780	B7 V ne	Swp 20846
HD 45995	B2 V nne	Swp 09936	HD 18552	B8 V ne	Swp 55906
HD 10516	B2 V pe	Swp 08592	HD 199218	B8 V nne	Swp 30071

Figures

The best fit is not just the graphical composition of some components (line profiles). The reproduced feature is the result of the final function of the model. In these figures we present the fitted SiIV resonance lines of the BeV stars HD 200310 and HD 31354. The black line presents the observed spectral line's profile and the red one the model's fit. We also present all the components which contribute to the observed features, separately.



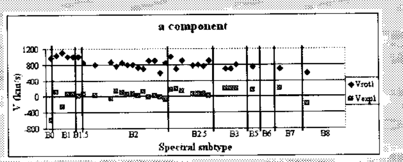


Diagram 4: Apparent rotation and expansion/contraction radial velocities of the first SAC as a function of the spectral subtype. The first SAC's rotation and expansion/contraction velocities present a uniform fluctuation around the values of 830 km/s and +31 km/s respectively.

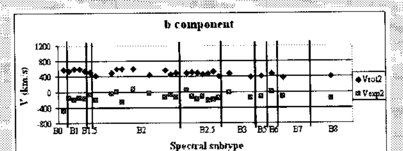
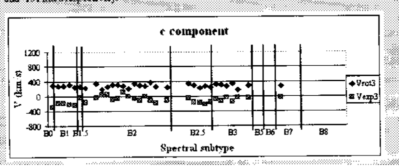


Diagram 5: Apparent rotation and expansion/contraction radial velocities of the second SAC as a function of the spectral subtype. A uniform fluctuation is also presented in the second SAC's rotation and expansion/contraction velocities around the values of 492 km/s and -131 km/s respectively.



Conclusions

We applied the method described above, on the SiIV resonance lines in 42 BeV stellar spectra and we calculated the apparent rotation and radial velocities, in order to extract some general physical lows for the SiIV region of BeV stars. Some interesting results inferred from the investigations are the following:

1. The proposed rotation model gives satisfactory results for the regions where the SiIV λλ 1393.755, 1402.73 Å resonance lines are created.

2. The absorption atmospherical regions where the SiIV resonance lines are created are formed of five independent density layers of matter, which rotate and move radially with different expansion velocities and which do not appear, though, to all the 42 BeV stars we studied. These regions present five apparent rotation velocity groups of 51 km/s, 137 km/s, 285 km/s, 492 km/s, 830 km/s. The apparent expansion/contraction radial velocities of these regions are about -25 km/s, -54 km/s, -105 km/s, -131 km/s and +31 km/s, respectively. These calculated values lead us to accept that the SiIV resonance lines of the BeV stellar spectra present Satellite Absorption Components.

3. We observe that the apparent rotation velocities of the five density regions present a uniform fluctuation with the spectral subtype, which we could not accept as accidental. We detected that there exists a relation among the parameters V_{rot} and V_{exp}.

Acknowledgements

This research project is progressing at the University of Athens, Department of Astrophysics - Astronomy and Mechanics, under the financial support of the Special Account for Research Grants, which we thank very much. This work was also supported by Ministry of Science through the projects P1195 (Influence of collisional processes on astrophysical plasma line shapes) and P1195 (Astrophysical spectroscopy of extragalactic objects.

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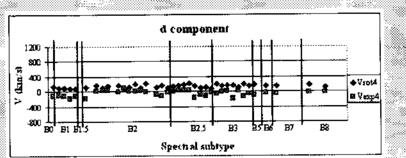

Diagram 7: Apparent rotation and expansion/contraction radial velocities of the forth SAC as a function of the spectral subtype. The forth SAC's rotation and expansion/contraction velocities fluctuate around the values of 137 km/s and -54 km/s respectively.

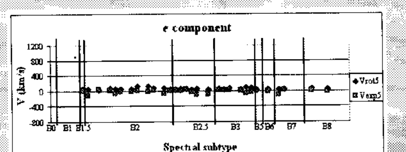

Diagram 8: Apparent rotation and expansion/contraction radial velocities of the fifth SAC as a function of the spectral subtype. The fifth SAC's rotation and expansion/contraction velocities fluctuate around the values of 51 km/s and -25 km/s respectively.

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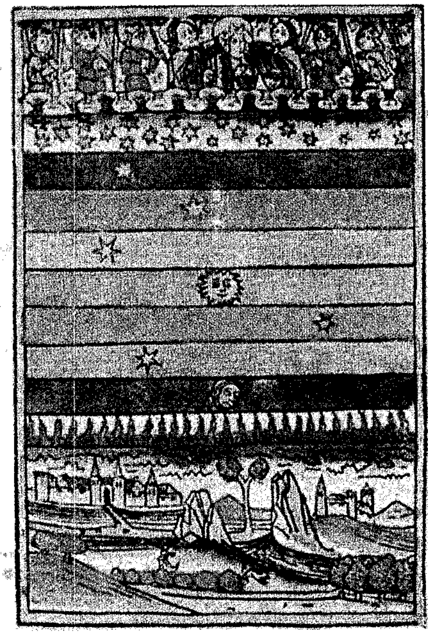

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ON THE CONTRIBUTION OF COLLISIONS WITH CHARGED PARTICLES TO THE Ga I LINE PROFILES IN CHEMICALLY PECULIAR STARS

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Abstract Stark broadening of the 18 Ga I transitions has been analyzed within the framework of the semiclassical perturbation method. Results obtained have been compared with available experimental and theoretical data and used for the consideration of the influence of the Stark broadening effect in stellar atmospheres.

Keywords: Line:profiles-atomic data-atomic processes-line:formation-stars:atmospheres

1. Introduction

Results of Stark broadening (broadening by collisions with charged particles) investigations of neutral gallium spectral lines are of interest for different problems in astrophysics as e.g. for stellar spectra analysis and synthesis, for gallium abundance determination (Smith 1996) and opacity calculations. Spectral lines of this element are present in the Solar and stellar spectra. For example Jaschek & Jaschek (1987) have found gallium lines not only in the spectra of HgMn, Si-4200 and He-weak chemically peculiar stars but also in the spectra of a few stars otherwise classified as normal. Dworetsky (1993) reports on neutral gallium lines in A-type star spectra,and Ryabchikova & Smirnov (1994) in the spectrum of HgMn star Kappa Cancri. Smith (1995) investigated anomalous gallium line profiles in HgMn stars and found evidence for chemical stratification in their atmospheres. To the astrophysical importance of gallium spectral lines, contributes the fact that this element is often overabundant in chemically peculiar stars, which is for HgMn stars discussed in Dworetsky et al. (1998). Zverko & Zboril (1989) tried to derive the gallium abundance of

53 Tau from Ga I 4032.98 Aand 4172.06 A- spectral lines and Smith (1996) reports on elemental abundance of gallium in normal late-B and HgMn stars. In Smith (1995,1996) has been concluded that HgMn stars have enhanced gallium abundances, and Zboril & Berrington (2001) have published the Non-LTE gallium equivalent widths for the most prominent gallium transitions as identified in real spectra and in (hot) mercury-manganese stars. Data on Stark broadening parameters are also significant for the calculation of opacity coefficients in stellar interiors and envelopes. For example Rogers & Iglesias (1992) developed the OPAL code for opacity calculations, where line broadening effects (including Stark broadening) are included, as well as gallium spectral lines.

2. Results and Discussion

We calculated within the semiclassical perturbation approach (Sahal-Brechot, 1969a,b), Stark broadening parameters due to impacts with electrons and protons for 18 Ga I transitions, for perturber density of $10^{14}cm^{-3}$, typical for stellar atmosphere conditions and temperatures from 2,500 up to 50,000 K. The obtained results have been compared in Figs. 1-3 with the experimental results and the semiclassical calculations of N'Dollo and Fabry (1987), and with estimates of Lakicevic (1983) based on the regularities and systematic trends. The obtained results and the comparison with the mentioned experimental and theoretical data will be published in Dimitrijevic et al. (2004). Our results have been used also for the investigation of the influence of collisions with charged particles (Stark broadening mechanism) on spectral line shapes in stellar atmospheres. Namely, we have calculated for our and N'Dollo & Fabry (1987) results Stark widths for a Kurucz's (1979) A type star (T_{eff} = 10000 K, log g = 4) atmosphere model and compared them with Doppler ones. Results obtained as a function of the Rosseland optical depth show that photospheric layers exist where Doppler and Stark widths are comparable and where the Stark width is dominant which is of interest to take into account when for example the stratification of gallium across the stellar photosphere is considered. Also, obtained results show that for transitions involving energy levels with higher principal quantum numbers, the importance of Stark broadening mechanism increases. This is due to the fact that with the increase of the principal quantum number of the upper level of the transition, the difference between this, and the closest perturbing energy level decreases, resulting in the increase of the Stark broadening influence. The new experimental evaluations of Stark broadening parameters for Ga I spectral lines, especially at higher temperatures, will be certainly of interest not only from the theoretical point of view but also for astrophysical and laboratory plasma diagnostics and modeling.

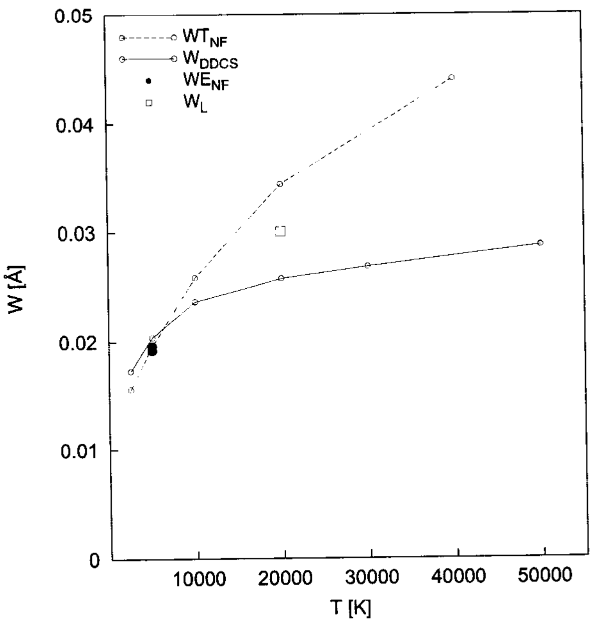

Figure 1. Stark full widths at half maximum W[A] for Ga I $4p^2P^o$ - $5s^2S$ multiplet in function of T[K]. Theoretical calculations: W_{DDSC} - present work; WT_{NF} - N'Dollo & Fabry (1987); W_L - Lakicevic (1983). Experimental data: WE_{NF} - N'Dollo & Fabry (1987).

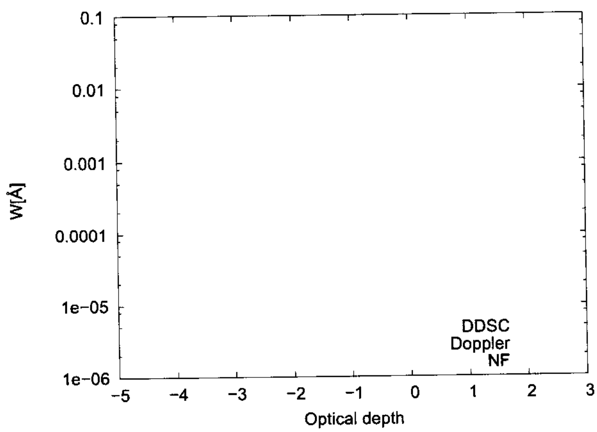

Figure 2. Stark and Doppler widths for Ga I $4p^2P^o$ - $5s^2S$ multiplet as a function of optical depth (Teff=10 000K, log g=4.0). DDSC - present work, NF - N'Dollo & Fabry (1987).

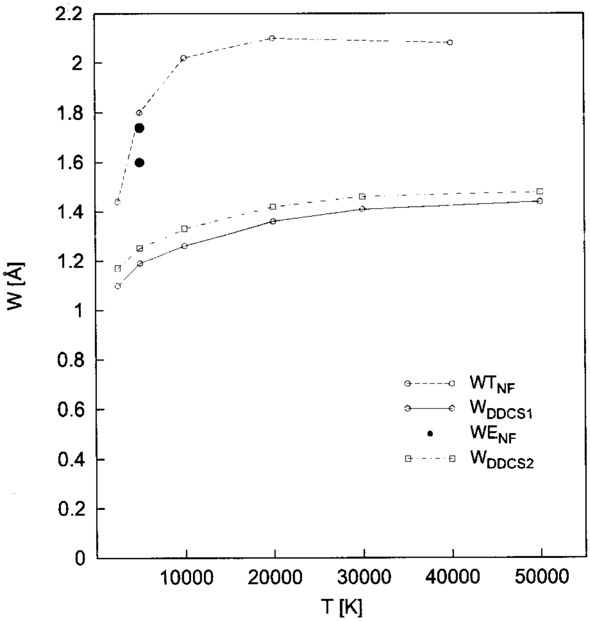

Figure 3. Stark full widths at half maximum W[A] for Ga I $5s^2S$ - $6p^2P^o$ multiplet in function of T[K]. Theoretical calculations: W_{DDCS1} - present values for transition $S_{1/2}$ - $P^o_{1/2}$; W_{DDCS2} - present values for transition $S_{1/2}$ - $P^o_{3/2}$; WT_{NF} - N'Dollo & Fabry (1987). Experimental data: WE_{NF} - N'Dollo & Fabry (1987).

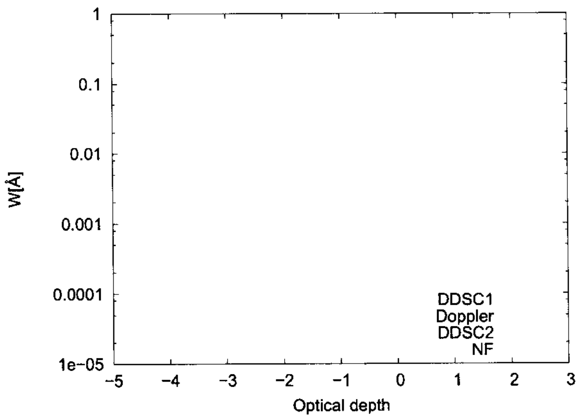

Figure 4. Stark and Doppler widths for Ga I $5s^2S$ - $6p^2P^o$ multiplet as a function of optical depth (Teff=10 000K, log g=4.0). DDSC1 - present values for transition $S_{1/2}$ - $P^o_{1/2}$, DDSC2 - present values for transition $S_{1/2}$ - $P^o_{3/2}$, NF - N'Dollo & Fabry (1987).

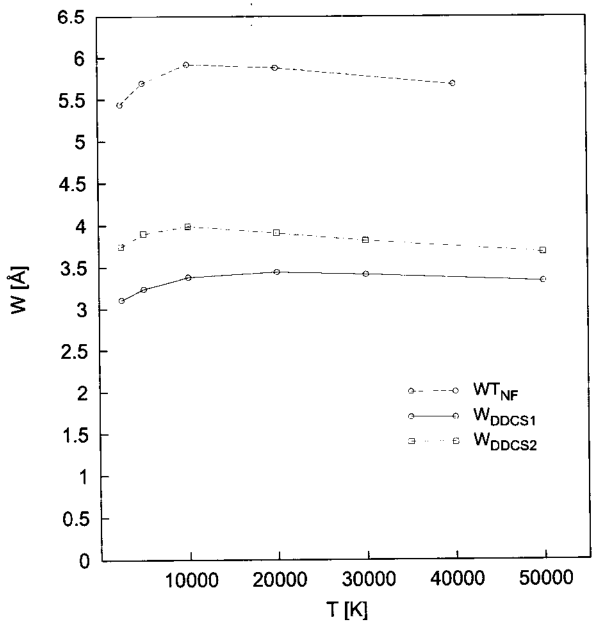

Figure 5. Stark full widths at half maximum W[A] for Ga I $5s^2S$ - $7p^2P^o$ multiplet in function of T[K]. Theoretical calculations: W_{DDCS1} - present values for transition $S_{1/2}$ - $P^o_{1/2}$; W_{DDCS2} - present values for transition $S_{1/2}$ - $P^o_{3/2}$; WT_{NF} - N'Dollo & Fabry (1987).

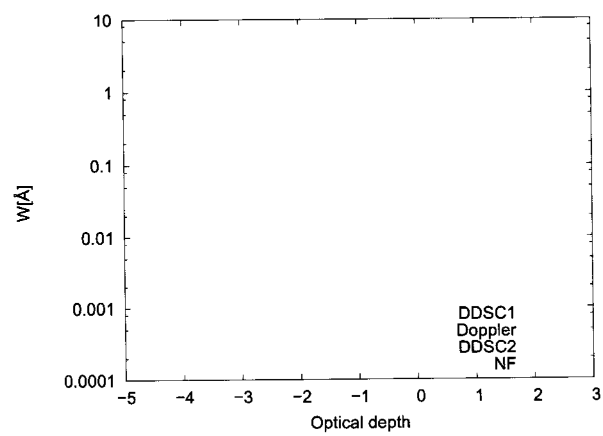

Figure 6. Stark and Doppler widths for Ga I $5s^2S$ - $7p^2P^o$ multiplet as a function of optical depth (Teff=10 000K, log g=4.0). DDSC1 - present values for transition $S_{1/2}$ - $P^o_{1/2}$, DDSC2 - present values for transition $S_{1/2}$ - $P^o_{3/2}$, NF - N'Dollo & Fabry (1987).

Table 1. Electron-, proton-impact broadening parameters for Ga I for perturber density of 10^{14} cm^{-3} and temperatures from 2500 up to 50 000 K. Transitions and wavelengths (λ in A) are also given in the table. By dividing C by the corresponding full width at half maximum (Dimitrijevic et al. 1991), we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used. The validity of the impact approximation has been estimated for data shown in this table, by checking if the collision volume (V) multiplied by the perturber density (N) is much less than one (Sahal-Brechot 1969a,b).

Perturbers are:		*Electrons*		*Protons*	
Transition	*T(K)*	*Width(A)*	*Shift(A)*	*Width(A)*	*Shift(A)*
Ga I $4p^2P^o$-$5s^2S$	2500	0.173E-03	0.142E-03	0.438E-04	0.400E-04
	5000	0.204E-03	0.166E-03	0.488E-04	0.450E-04
4125.8 A	10 000	0.236E-03	0.196E-03	0.546E-04	0.506E-04
C=0.14E+18	20 000	0.257E-03	0.223E-03	0.610E-04	0.569E-04
	30 000	0.268E-03	0.209E-03	0.652E-04	0.608E-04
	50 000	0.287E-03	0.204E-03	0.708E-04	0.662E-04
Ga I $4p^2P^o$-$4d^2D$	2500	0.311E-03	-0.181E-03	0.757E-04	-0.452E-04
	5000	0.311E-03	-0.176E-03	0.793E-04	-0.509E-04
2921.0 A	10 000	0.315E-03	-0.163E-03	0.838E-04	-0.572E-04
C=0.14E+17	20 000	0.330E-03	-0.129E-03	0.894E-04	-0.644E-04
	30 000	0.339E-03	-0.117E-03	0.933E-04	-0.689E-04
	50 000	0.341E-03	-0.988E-04	0.990E-04	-0.751E-04
Ga I $4p^2P^o$-$5d^2D$	2500	0.124E-02	-0.762E-03	0.297E-03	-0.221E-03
	5000	0.128E-02	-0.678E-03	0.322E-03	-0.251E-03
2484.0 A	10 000	0.135E-02	-0.496E-03	0.351E-03	-0.285E-03
C=0.25E+16	20 000	0.140E-02	-0.375E-03	0.386E-03	-0.321E-03
	30 000	0.138E-02	-0.303E-03	0.410E-03	-0.343E-03
	50 000	0.135E-02	-0.219E-03	0.445E-03	-0.375E-03
Ga I $5s^2S$-$5p^2P^o$	2500	0.504E-02	0.368E-02	0.170E-02	0.954E-03
	5000	0.581E-02	0.339E-02	0.177E-02	0.107E-02
12005.6 A	10 000	0.696E-02	0.268E-02	0.186E-02	0.121E-02
C=0.24E+18	20 000	0.889E-02	0.155E-02	0.197E-02	0.136E-02
	30 000	0.100E-01	0.105E-02	0.205E-02	0.146E-02
	50 000	0.112E-01	0.508E-03	0.216E-02	0.159E-02
Ga I $5s^2S_{1/2}$-$6p^2P^o_{1/2}$	2500	0.110E-01	0.808E-02	0.273E-02	0.210E-02
	5000	0.119E-01	0.818E-02	0.297E-02	0.239E-02
6415.2 A	10 000	0.126E-01	0.732E-02	0.326E-02	0.271E-02
C=0.18E+17	20 000	0.136E-01	0.555E-02	0.359E-02	0.305E-02
	30 000	0.141E-01	0.464E-02	0.382E-02	0.327E-02
	50 000	0.144E-01	0.363E-03	0.414E-02	0.357E-02

Table 1. Continued.

Perturbers are:		*Electrons*		*Protons*	
Transition	*T(K)*	*Width(A)*	*Shift(A)*	*Width(A)*	*Shift(A)*
Ga I $5s^2S_{1/2}$-$6p^2P^o_{3/2}$	2500	0.117E-01	0.855E-02	0.286E-02	0.223E-02
	5000	0.125E-01	0.854E-02	0.313E-02	0.254E-02
6398.3 A	10 000	0.133E-01	0.754E-02	0.344E-02	0.289E-02
C=0.16E+17	20 000	0.142E-01	0.573E-02	0.380E-02	0.326E-02
	30 000	0.146E-01	0.476E-02	0.404E-02	0.349E-02
	50 000	0.148E-01	0.369E-02	0.439E-02	0.381E-02
Ga I $5s^2S_{1/2}$-$7p^2P^o_{1/2}$	2500	0.311E-01	0.216E-01	0.732E-02	0.591E-02
	5000	0.324E-01	0.198E-01	0.811E-02	0.684E-02
5361.3 A	10 000	0.133E-01	0.163E-01	0.903E-02	0.783E-02
C=0.40E+16	20 000	0.338E-01	0.124E-01	0.101E-01	0.890E-02
	30 000	0.344E-01	0.994E-02	0.109E-01	0.957E-02
	50 000	0.333E-01	0.694E-02	0.119E-01	0.105E-01
Ga I $5s^2S_{1/2}$-$7p^2P^o_{3/2}$	2500	0.375E-01	0.248E-01	0.898E-02	0.735E-02
	5000	0.390E-01	0.216E-01	0.100E-01	0.855E-02
5349.6 A	10 000	0.399E-01	0.115E-01	0.112E-01	0.981E-02
C=0.28E+16	20 000	0.391E-01	0.129E-01	0.126E-01	0.112E-01
	30 000	0.382E-01	0.102E-01	0.136E-01	0.120E-01
	50 000	0.368E-01	0.693E-02	0.151E-01	0.132E-01
Ga I $5p^2P^o$-$5d^2D$	2500	0.419E-01	-0.259E-01	0.914E-02	-0.688E-02
	5000	0.450E-01	-0.263E-01	0.992E-02	-0.782E-02
13004.3 A	10 000	0.479E-01	-0.241E-01	0.108E-01	-0.886E-02
C=0.68E+17	20 000	0.500E-01	-0.202E-01	0.119E-01	-0.999E-02
	30 000	0.507E-01	-0.175E-01	0.127E-01	-0.107E-03
	50 000	0.509E-01	-0.143E-01	0.138E-01	-0.117E-03
Ga I $4d^2D$-$5p^2P^o$	2500	0.253	0.147	0.608E-01	0.389E-01
	5000	0.284	0.168	0.642E-01	0.440E-01
59974.3 A	10 000	0.308	0.175	0.685E-01	0.496E-01
C=0.60E+19	20 000	0.327	0.161	0.736E-01	0.558E-01
	30 000	0.338	0.144	0.772E-01	0.597E-01
	50 000	0.351	0.122	0.823E-01	0.651E-01
Ga I $4d^2D$-$6p^2P^o_{1/2}$	2500	0.946E-01	0.649E-01	0.220E-01	0.168E-01
	5000	0.103	0.681E-01	0.239E-01	0.192E-01
17885.8 A	10 000	0.110	0.639E-01	0.262E-01	0.217E-01
C=0.14E+18	20 000	0.115	0.542E-01	0.289E-01	0.245E-01
	30 000	0.117	0.467E-01	0.307E-01	0.263E-01
	50 000	0.118	0.365E-01	0.333E-01	0.287E-01

Table 1. Continued.

Perturbers are:		*Electrons*		*Protons*	
Transition	*T(K)*	*Width(A)*	*Shift(A)*	*Width(A)*	*Shift(A)*
Ga I $4d^2D\text{-}6p^2P^o_{3/2}$	2500	0.990E-01	0.678E-01	0.228E-01	0.177E-01
	5000	0.107	0.701E-01	0.249E-01	0.202E-01
17754.4 A	10 000	0.114	0.647E-01	0.273E-01	0.229E-01
C=0.12E+18	20 000	0.119	0.544E-01	0.302E-01	0.258E-01
	30 000	0.120	0.465E-01	0.321E-01	0.277E-01
	50 000	0.121	0.360E-01	0.349E-01	0.302E-01
Ga I $4d^2D\text{-}7p^2P^o_{1/2}$	2500	0.148	0.100	0.342E-01	0.275E-01
	5000	0.154	0.908E-01	0.378E-01	0.319E-01
11553.5 A	10 000	0.161	0.733E-01	0.421E-01	0.365E-01
C=0.18E+17	20 000	0.163	0.506E-01	0.472E-01	0.415E-01
	30 000	0.162	0.364E-01	0.507E-01	0.446E-01
	50 000	0.157	0.268E-01	0.557E-01	0.488E-01
Ga I $4d^2D\text{-}7p^2P^o_{3/2}$	2500	0.177	0.114	0.416E-01	0.341E-01
	5000	0.184	0.970E-01	0.464E-01	0.396E-01
11499.2 A	10 000	0.188	0.766E-01	0.519E-01	0.454E-01
C=0.13E+17	20 000	0.184	0.511E-01	0.586E-01	0.517E-01
	30 000	0.180	0.344E-01	0.632E-01	0.556E-01
	50 000	0.173	0.257E-01	0.701E-01	0.610E-01
Ga I $5d^2D\text{-}6p^2P^o_{1/2}$	2500	24.0	14.7	4.83	3.68
	5000	26.0	14.6	5.26	4.20
231830.3 A	10 000	27.3	13.2	5.77	4.77
C=0.22E+20	20 000	28.7	10.0	6.38	5.39
	30 000	29.3	8.31	6.79	5.78
	50 000	29.3	6.75	7.38	6.31
Ga I $5d^2D\text{-}6p^2P^o_{3/2}$	2500	30.6	18.8	6.12	4.70
	5000	33.0	18.5	6.68	5.37
256416.8 A	10 000	34.6	16.5	7.33	6.10
C=0.26E+20	20 000	36.2	12.5	8.11	6.90
	30 000	36.8	10.3	8.64	7.40
	50 000	36.7	8.25	9.42	8.07
Ga I $5d^2D\text{-}7p^2P^o_{1/2}$	2500	1.81	1.15	0.385	0.309
	5000	1.91	1.08	0.427	0.358
37979.6 A	10 000	1.99	0.890	0.475	0.410
C=0.20E+18	20 000	2.02	0.624	0.532	0.466
	30 000	2.00	0.491	0.571	0.501
	50 000	1.95	0.336	0.628	0.548

Table 1. Continued.

Perturbers are:		*Electrons*		*Protons*	
Transition	*T(K)*	*Width(A)*	*Shift(A)*	*Width(A)*	*Shift(A)*
Ga I $5d^2D-7p^2P^o_{3/2}$	2500	2.08	1.30	0.454	0.370
	5000	2.18	1.14	0.506	0.430
37398.7 A	10 000	2.23	0.917	0.566	0.494
C=0.14E+18	20 000	2.19	0.620	0.639	0.562
	30 000	2.15	0.486	0.689	0.605
	50 000	1.07	0.310	0.764	0.663

Acknowledgments

This work is a part of the project GA 1195 "Influence of collisional processes on astrophysical plasma lineshapes", supported by Ministry of Science and Environment Protection of Serbia.

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GRANADA

SEA · eas · IAA · CSIC · esa · Observatori Astronòmic · Junta de Andalucía · EDP Sciences · Viajes El Corte Inglés

Abstract Kyiv Planetarium is the oldest public astronomy education institution in Ukraine and one of the biggest planetariums in the territory of the former USSR. It was founded in 1952. The idea of its establishment belonged to the famous ukrainian astronomer Sergey Vsehsvyatsky, professor of the Kyiv National University. Today Planetarium takes very important part in popularization of knowledge about Nature and Space in Ukraine. It provides a great variety of lectures and programs for individuals, family visitors and pupils, helping to learn school program in astronomy, geography and natural history, widening it. Main activities, directions of development, and problems in astronomy education in Ukraine are discussed. We are open for experience exchange and are interested in establishment of contacts with other planetariums, technical and natural history museums, other public outreach organizations worldwide.

6.12 70 YEARS OF ASTRONOMICAL SOCIETY "RUDJER BOŠKOVIĆ" - AN INTERESTING EXPERIENCE IN ASTRONOMICAL EDUCATION, POPULARIZATION AND ASTRONOMERS AMATEUR'S ORGANIZATION

M. S. Dimitrijević

Astronomical Observatory, Volgina 7, 11160 Belgrade, Serbia

Abstract The largest and the oldest organization of amateur-astronomers in Serbia is the Astronomical Society "Rudjer Bošković" in Belgrade (Kalemegdan, Gornji Grad 16, 11000 Belgrade), which in the course of 70 years of its existence was spreading astronomical knowledge in our country. The founding meeting was held on 22 April 1934. The first Society's President was Djordje Nikolić (1934-1936) and the second Vojin Djuričić (1936-1941), the governer of the State Mortgage Bank. In 1935 Society started publishing the first periodical for the popularization of science in Serbia "Saturn", "the periodical for astronomy, meteorology, geophysics and geodezy which purpose is to be useful to national culture", published in 12 issues per year up to the end of 1940. In 1953 the Society, jointly with the Aeronautical Association of Yugoslavia, started publishing the periodical for astronomy and aeronautics (currently for astronomy) "Vasiona" (Universe). The first editor in chief of "Saturn" was Djordje Nikolić (1935), and of "Vasiona", Nenad Dj. Janković (1953-1972). Thanks to the exertion of Pero Djurković, Radovan Danić and Nenad Janković with the authorities concerned, the Society obtained for itself the permises in the Despot Tower at Kalemegdan where, on 20 December 1964 was solemny opened the People's Observatory, whose regular activity started in June 1965. The Society managed also to procure a Zeiss planetarium, which was installed in an old spacious steam bathhouse - Turkish Hamam - in the Kalemegdan Donji Grad. The Planetarium started operating in 1969, being formally opened on 17 February 1970. It is included in the educational system and around 15 000 pupils, students and other visitors per year,

attend lectures and projections in it. The Society organized also three conferences on the history of astronomy and astronomy in culture and was the co-organizer of the IV Serbian-Bulgarian astronomical conference. It is worth to note the organization of the astronomical-astronautical exhibition in 1954, which after Belgrade was also in other cities and for example in Sombor was visited by around 7000 persons. This exhibition initiated the foundation of branches of the Society in other towns, and the most successful became in 1974 the Astronomical Society "Novi Sad", ADNOS. In order to contribute to the education and to popularization of astronomy the Society organizes every year in the spring and in the autumn an astronomical seminar for beginners, manifestations "The Belgrade astronomical weekend" in June and "The summer astronomical meetings" in August-September, occasional lectures on astronomy, observations of celestial objects and events, and special observational excursions out of Belgrade. The aim of this contribution is to present activities of Astronomical society "Rudjer Bošković", its Observatory, Planetarium and journal, and discuss the experience accumulated during 70 years of its existence and the future work.

6.13 EXPERIENCIAS PERSONALES EN LA ENSENANZA UNIVERSITARIA DE ASTRONOMIA

S. Ninković

Astronomical Observatory, Volgina 7, 11160 Beograd-74, Serbia and Montenegro

Abstract Desde ultimo tiempo en Serbia (tambien generalmente en Serbia y Montenegro) existen dos universidades que pertenecen al estado y donde se enseña astronomía: en Belgrado y en Novi Sad. Puesto que el autor participa en las ambas - en Belgrado en curso de doctorado en Novi Sad en los estudios normales - su intencion es la de presentar sus experiencias personales

6.14 COMMUNICATING ASTRONOMY: HERACLITUS TO HAWKING

V. Trimble

University of California

Abstract Astronomy (thought of roughly as applied geometry) formed part of the ancient Greek quadrivium. From that time to the present, a subset of astronomers have tried valiantly to explain to their patrons and sponsors (from Rudolph II to modern taxpayers) what they are doing and why. Some have been extraordinarily good at this, to the point where their reputations as communicators transcended their status as scientists. Camille Flammarion and Carl Sagan come immediately to mind. Others were dismal failures (Kepler perhaps an example, though far from the worst). The talk will explore small portions of this history, with some focus on how the problem

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NRAO / AUI / NSF. Image courtesy of NRAO/AUI Photo: Matthew L. Abbondanzio

University *of* Hertfordshire UH esa eas ESO Science & Technology Facilities Council EADS

It is now clear that the properties and evolution of galaxies are closely linked to the growth of their central supermassive black holes. Over the coming decades, a number of future facilities (e.g. JWST, ALMA, E-ELT) will intensively observe the starlight from the very earliest galaxies, which form at z=6-10. However, X-ray observations are required to reveal the extent of accretion activity in the earliest supermassive black holes. I will present new measurements of the evolution of the X-ray luminosity function (XLF) of AGN, probing to the limits of current observatories, and accounting for the uncertainties in redshift measurements and the incompleteness of high-redshift samples. I will then discuss the potential of the International X-ray Observatory (IXO) to detect low-luminosity AGN at z>6, in this early epoch of galaxy formation. I will present the results of simulations to determine the sensitivity of IXO observations, put forward a prospective observing programme and predict the numbers of detected AGN based on extrapolations of the XLF evolution at lower redshifts.

Tuesday
3:10pm

Synergies between Future X-ray and Infrared Facilities

F. Fiore (INAF-OAR)

I will discuss possible synergies between future X-ray missions and present and future infrared and sub-mm facilities such as Spitzer, Herschel, WISE, JWST and ALMA.

Q-P01

Probing Accretion Disk Properties with Long-Term X-Ray Light-Curves

P. Charles (SAAO), Marissa Kotze

I will summarise the importance of all-sky monitors on X-ray astronomy missions, with particular emphasis on RXTE, for studying the long-term, superorbital variations seen in a variety of X-ray binaries. These modulations can provide significant constraints on the physical properties of accretion discs, e.g. the 35d cycle in Her X-1 and related objects are interpreted as irradiation-driven, tilted, precessing accretion discs. Others show more complex light curves, with the period changing on timescales >1000d, and allow an investigation of the disc stability criteria. We propose a categorisation of these variability properties into several different types, based on their observed characteristics.

Q-P02

On the Stark Broadening of Ar XV X rays

M. Dimitrijevic (Astronomical Observatory), A. Kovacevic, Z. Simic, S. Sahal-Brechot

With the development of satellite born spectroscopy, the spectral lines of trace elements become astrophysically significant and for example, far UV lines of Ar VII were discovered recently in the spectra of very hot neutral stars of planetary nebulae and white dwarfs. In order to provide Stark broadening data in X-ray wavelength region, of interest for modelling and analysis of astrophysical plasmas in extreme conditions, we performed semiclassical calculations of Stark broadened line widths and shifts for 8 Ar XV multiplets with wavelengths less than 10 nm.

Q-P03

Breaking the Record: Discovery of the Most Luminous Ultra-luminous X-Ray Source

S. Farrell (University of Leicester), N. A. Webb, D. Barret, O. Godet & J. M. Rodrigues

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NRAO / AUI / NSF. Image courtesy of NRAO/AUI Photo: Matthew L. Abbondanzio

This will be presented as part of the online suite of resources iCosmo available at http://www.icosmo.org

Wednesday
3:20pm

VAMDC: Virtual Atomic and Molecular Data Centre

N. Walton (IoA, Cambridge), M L Dubernet (LPMAA, Paris), N J Mason (Open), N Piskunov (Upsalla), the VAMDC Consortium

The Virtual Atomic and Molecular Data Centre (VAMDC) aims to build a secure, documented, flexible and interoperable e-science environment-based interface to existing Atomic and Molecular (AM) data. The VAMDC will be built upon the expertise of existing AM databases, data producers and service providers with the specific aim of creating an infrastructure that is easily tuned to the requirements of a wide variety of users in academic, governmental, industrial or public communities.

VAMDC will be enabled by the utilisation of the excellent grid and Virtual Observatory data and application infrastructure that has been created across Europe by initiatives such as the Euro-VO and EGEE. VAMDC will commence in July 2009.

This presentation will provide a brief overview of the project, aims and objectives, and describe the key infrastructure that will be created during he project lifetime.

T-P01

The Virtual Meteor Observatory (VMO) of the International Meteor Organization

G. Barentsen (Armagh Observatory), Detlef Koschny (ESA/RSSD), Rainer Arlt (IMO)

Meteor science is concerned with very small particles in the Solar System. The investigation of meteoroids, their origin and their orbital dynamics tells a lot about the next-larger classes of objects - asteroids and comets. Studies of meteor showers are in most cases of statistical nature; large quantities of individual meteor observations are necessary to arrive at meaningful conclusions. The advent of Virtual Observatories in space science is ideally timed with observational advances in data recording in meteor science. The International Meteor Organization (IMO) participates in this advent with the creation of a VO-enabled data centre for meteor science: the Virtual Meteor Observatory (VMO).

T-P02

The Project of Serbian Virtual Observatory and the Connection with VAMDC

D. Jevremovic, M. S. Dimitrijevic, L. C. Popovic, M. Dacic, V. Protic-Benisek, E. Bon, V. Benisek, A. Kovacevic, S. Sahal-Brechot

We present and discuss the project of Serbian Virtual Observatory. The digitization and publication in VO of around 15000 photo plates archivated on Belgrade Asttronomical observatory, as well as stella catalogues produced in Serbia, and digitization of astronomical publications, is in progress. Also, together with french colleagues, in progress is the development of the database STARK-B with Stark broadening data of interest for stellar spectra analysis and modelling, produced during more of 30 years of French-Serbian collaboration. It will enter in VAMDC - Virtual Atomic and Molecular Data Center, MOLAT and SerVO.

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The Armenian program of the IYA-2009 relates to an increase of activity of the professional, amateur, popular astronomy and astronomical education. Beside the IYA-2009 main projects, a number of other activities are planned. A webpage has been created at http://www.aras.am/IYA_2009.htm and the program is given with regular updates of the news and events. An Armenian Astronomical Council will be created to coordinate all astronomical activities, which have in fact been developed randomly, including the professional institutions (Byurakan Astrophysical Observatory (BAO), Yerevan State University (YSU), etc.), school astronomy and Olympiads, amateur astronomers, publishers, etc. Series of seminars "Astronomy and other fields of science" for various students in Byurakan during the whole year, an Astronomical Summer School for the YSU students in Byurakan for students of the YSU Department of Physics, the Armenian Astronomical Society (ArAS) annual meeting with an emphasis on the IYA-2009 will be organized. Publication of a DVD "Encyclopaedia of the Armenian astronomy" is planned, as well as a lot of other materials (booklets, sky maps, calendars, postcards, etc.). The school program includes visits to schools by professional astronomers for popular lectures and visits of pupils in Byurakan. There is a large mass media program too, including a meeting of professional astronomers and journalists in Byurakan.

Wednesday
11:40am

Science Outreach in Benin (West Africa) for the IYA 2009

A. Alapini (University of Exeter), Didier Pelat (Observatoire de Paris), Pascal Galais (CEA), Oscar Kiche (Astronomy Club Orion-Benin), Calixte Alapini (ONG-Acetrose), Romain Alapini (ONG-Acetrose)

Through the mixing of culture, the mixing of ages and the international transfer of knowledge in astronomy, the IYA 2009 is an exceptional opportunity to broaden minds and trigger interest in science among the young generations across the globe.

Since a first outreach mission in Benin for the total solar eclipse of 2006, we have been involved in a collaborative effort aiming at raising awareness of science through astronomy among children in urban and rural areas of Benin. For the IYA, we go a step further. 14 of us are returning to Benin, we will meet 6 local organisers and will visit schools and universities across the country aiming to reach more than a thousand of Benin's citizens. We will man science activities for children and teachers, observing sessions for all ages, and we will give conferences at the universities.

We wish to share with the broader community our experience on science outreach in a developing country. We present our activities in Benin for the IYA 2009, starting by describing how this collaboration began, how it is developing and the benefits and difficulties we encounter in this project.

Wednesday
12:00pm

Society of Astronomers of Serbia, Astronomical Society "Rudjer Boskovic" and IYA 2009

A. Kovacevic (Faculty of Mathematics University of Belgrade), M. S. Dimitrijevic

We will present Society of Astronomers of Serbia and the oldest society of professional and amateur astronomers in Serbia, Astronomical Society "Rudjer Boskovic", founded in 1934. We will review briefly their history and activities with particular attention to the activities, plans and programs for the IYA 2009.

Wednesday
2:00pm

Galileo Teacher Training Programme

University of Hertfordshire

In association with the International Year of Astronomy 2009

Book of Abstracts

European Week of Astronomy and Space Science

20-23 April 2009

University of Hertfordshire, UK

Incorporating RAS NAM 2009
and EAS JENAM 2009

www.jenam2009.eu

The programme includes UK Solar Physics and MIST meetings, ESA and ESO plenaries, multiple parallel science sessions and symposia on

- **The next era in radio astronomy: the pathway to SKA**
- **The standard cosmological models - successes and challenges**
- **Understanding substellar populations and atmospheres: from brown dwarfs to exo-planets**
- **The life cycle of dust**
- **Multi-wavelength high redshift surveys**
- **Three decades of gravitational lenses**
- **The IYA 2009 in Europe**

NRAO / AUI / NSF. Image courtesy of NRAO/AUI Photo: Matthew L. Abbondanzio

The Armenian program of the IYA-2009 relates to an increase of activity of the professional, amateur, popular astronomy and astronomical education. Beside the IYA-2009 main projects, a number of other activities are planned. A webpage has been created at http://www.aras.am/IYA_2009.htm and the program is given with regular updates of the news and events. An Armenian Astronomical Council will be created to coordinate all astronomical activities, which have in fact been developed randomly, including the professional institutions (Byurakan Astrophysical Observatory (BAO), Yerevan State University (YSU), etc.), school astronomy and Olympiads, amateur astronomers, publishers, etc. Series of seminars "Astronomy and other fields of science" for various students in Byurakan during the whole year, an Astronomical Summer School for the YSU students in Byurakan for students of the YSU Department of Physics, the Armenian Astronomical Society (ArAS) annual meeting with an emphasis on the IYA-2009 will be organized. Publication of a DVD "Encyclopaedia of the Armenian astronomy" is planned, as well as a lot of other materials (booklets, sky maps, calendars, postcards, etc.). The school program includes visits to schools by professional astronomers for popular lectures and visits of pupils in Byurakan. There is a large mass media program too, including a meeting of professional astronomers and journalists in Byurakan.

Wednesday
11:40am

Science Outreach in Benin (West Africa) for the IYA 2009

A. Alapini (University of Exeter), Didier Pelat (Observatoire de Paris), Pascal Galais (CEA), Oscar Kiche (Astronomy Club Orion-Benin), Calixte Alapini (ONG-Acetrose), Romain Alapini (ONG-Acetrose)

Through the mixing of culture, the mixing of ages and the international transfer of knowledge in astronomy, the IYA 2009 is an exceptional opportunity to broaden minds and trigger interest in science among the young generations across the globe.

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We will present Society of Astronomers of Serbia and the oldest society of professional and amateur astronomers in Serbia, Astronomical Society "Rudjer Boskovic", founded in 1934. We will review briefly their history and activities with particular attention to the activities, plans and programs for the IYA 2009.

Wednesday
2:00pm

Galileo Teacher Training Programme

Astronomische Gesellschaft
Abstract Series No. 18, 2001

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Hamburg 2001

SC 12

Milutin Milanković (1879–1958) and his Contribution to the European Astronomy

Milan S. Dimitrijević
(Astronomical Observatory, Volgina 7, 11160 Belgrade, Yugoslavia)

Milutin Milanković (Dalj, May 28, 1879 – Belgrade, December 12, 1958), former director of the Belgrade Astronomical observatory and vice president of the Serbian Academy of Sciences and Arts, is the most distinguished Serbian astronomer of the XX century. In honour to his scientific achievements in astronomy a crater on the far side of the Moon (coordinates $+170^o$, $+77^o$) was given his name at the 14th IAU General Assembly in Brighton in 1970. His name is given also to a crater on Mars (coordinates $+147^o$, $+55^o$) at the 15th IAU General Assembly in Sidney in 1973. In 1982 a small planet, provisorily designated 1936 GA, discovered in 1930 by M. Protić and P. Djurković, received its permanent name: 1605 Milanković.

Milutin Milanković went down in the history of science as the man who explained the phenomenon of the Ice Ages by slow changes of the Earth insolation in consequence of changes of the Earth's axis inclination and of those of the parameters of the Earth's motion round the Sun. Milanković elucidated also the history of the Earth's climate as well as that of other planets, being in addition the author of the mathematical theory of climate and of the Earth's pole motion. His scientific results, life and activities will be discussed in this contribution.

SC 13

Eugen Goldstein and his Laboratory Work at the Berlin Observatory

Michael Hedenus
(Oberdorfstraße 16, 69253 Heiligkreuzsteinach, Germany)

At the end of the 19th century the astronomer and director of the Berlin Observatory, Wilhelm Foerster, started an extraordinary research project: He asked the physicist Eugen Goldstein to examine the nature of electricity in space experimentally.

Eugen Goldstein (1850–1930) was one of the most deserving pioneers in the field of electricity, e. g. he discovered the canal rays and he introduced the term "cathode ray". He became assistent at the Berlin Observatory and his official duty was the research on relations between electricity and cosmic phenomena. As a result Goldstein successfully reproduced comet tails in gas discharge tubes.

My speech is about the biography of Eugen Goldstein and his work at the Berlin Observatory. I will discuss some of his experiments and show a reproduction of his artificial comet tails.

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Hamburg 2001

P 114

Search for Weak Magnetic Fields in DBZ and DBAZ White Dwarfs

S. Friedrich (Astrophysikal. Institut Potsdam, An der Sternwarte 16, 14482 Potsdam)
S. Jordan, D. Koester
(Institut f. Theoretische Physik u. Astrophysik, Universität Kiel, 24098 Kiel)

It is widely accepted that metals detected in the spectra of a few cool white dwarfs cannot be of primordial origin and therefore must be accreted from the interstellar medium. However the observed abundances of hydrogen in the atmospheres of these stars are much too low to be compatible with the high accretion rates inferred from metal accretion if solar abundances are assumed. It was therefore proposed that metals are accreted in the form of grains onto a slowly rotating, weakly magnetized white dwarf, whereas ionized hydrogen is repelled at the Alfven radius.

In order to test this hypothesis we obtained circular polarization spectra of two metal line white dwarfs (GD40 and L745-46A) with the VLT-UT1 and FORS1 to search for such magnetic fields. Within the errors ($\pm 0.1\%$ and $\pm 0.3\%$ for L745-46A and GD40, respectively) we could not find signatures of a magnetic field in the spectra of any of the two stars. If we exclude the possibility, that we are looking on the magnetic equator of a pure magnetic dipole, in which case the components of the magnetic field along the line of sight completely cancel and no circular polarization can be detected, we conclude, that the field strength of the magnetic field on both stars must be well below the 10^5 Gauss required by theory.

We could confirm an Hα line in the flux spectrum of GD40, which was found by Greenstein & Liebert (ApJ 360, 662) and determine the hydrogen abundance in the stellar atmosphere which is a factor of 100 to 1000 below the value expected from accretion with solar abundances.

P 115

Influence of Ion-atom Colisional Quasimolecular Complexes on DB White Dwarf Plasma Properties

M.S. Dimitrijević
(Astronomical Observatory, Volgina 7, 11160 Belgrade, Yugoslavia)
A.A. Mihajlov
(Institute of Physics, Pregrevica 118, 11080 Zemun, Yugoslavia)

In a series of papers we have analized the influence of colisional processes in weakly ionized stellar and laboratory plasmas (ion-atom radiative and chemi-recombination/chemi-ionization processes) involving symmetrical, positive quasimolecular collisional complexes on the different plasma properties as for example continuous spectra characteristics and excited atom population distribution function.

Our results shows that for $T_{eff} \leq 16{,}000$ K DB white dwarf photosphere continuous spectra are formed under the important influence of the ion-atom radiative processes, and that for $\lambda \leq 400$ nm, such processes may influence significantly the energetic balance and optical characteristics (opacity and optical depth) of DB white dwarf atmospheric layers where $\log(\tau) \leq 1$. The results suggest that it is necessary to include ion-atom radiative processes for the DB white dwarf atmosphere modeling from the beginning and not as an a posteriori correction, since they change the reference optical depths for the tabulated model parameters. Our results suggest as well, that the chemi-recombination and inverse chemi-ionization processes should be included as well in the modeling of weakly ionized layers in helium rich DB white dwarf atmospheres.

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Hamburg 2001

P 116

Stark Widths of Astrophysically Important O III Spectral Lines

Milan S. Dimitrijević
(Astronomical Observatory, Volgina 7, 11160 Belgrade, Yugoslavia)
Aleksandar Srećković and Stevan Djeniže
(Faculty of Physics, University of Belgrade, PO Box 368, 11001 Belgrade, Yugoslavia)

Stark broadening parameters of spectral lines are of importance in astrophysics for a number of different cases, as stellar plasma diagnostics, abundace determination, analysis and synthesis of stellar spectra, modeling of stellar plasma, radiative transfer calculations etc. They might be of interest for a variety of plasma conditions, from molecular and ionized interstellar hydrogen clouds up to the neutron star atmosferes. However, they are particularly of interest for A and B type stars, pre white dwarfs like PG 1159 type stars and white dwarfs

It is obvious astrophysical importance of such data for spectral lines of oxygen in various ionization stages, due to its high cosmical abundance. In present contribution, the Stark widths of seven O III spectral lines, in five multiplets, have been determined experimentally and theoretically. They have been measured at electron densities between 1.66 10^{23} m^{-3} and 2.80 10^{23} m^{-3} and electron temperatures between 17 000 K and 54 000 K in a linear pulsed-arc discharge in N_2 + O_2 and CO_2 plasmas. The above mentioned species have been calculated using the semiclassical perturbation formalism. Our measured and calculated Stark widths values are compared to existing calculated and experimental data. The results of our analysis allow us to recommend O III 375.47 nm, 375.72 nm, 298.38 nm, 407.39 nm and 408.11 nm lines for stellar and laboratory plasma diagnostics.

P 117

Ionized Neon Spectral Lines Stark Widths for Stellar Plasma Research and Modeling

Milan S. Dimitrijević
(Astronomical Observatory, Volgina 7, 11160 Belgrade, Yugoslavia)
Vladimir Milosavljević and Stevan Djeniže
(Faculty of Physics, University of Belgrade, PO Box 368, 11001 Belgrade, Yugoslavia)

Neon is the most abundant element in the Universe after H, He, O and C and it is one of products of hydrogen and helium burning in orderly evolution of stellar interiors. After hydrogen, helium and carbon burning periodes in massive stars starts neon burning. Stark broadening parameters of Ne II spectral lines are of importance in astrophysics for a number of different cases and they might be of interest for white dwarf spectra consideration and plasma modeling as well since in stars with $T_{eff} \geq 10{,}000$ K, the Stark broadening is the main pressure broadening mechanism. Even for cooler stars Stark broadening data are of interest for the consideration of subphotospheric layers and for Rydberg atoms where optical electron in higly excited state is weakly bound to the core and significantly influenced by relatively weak external electrid fields.

We have determined experimentally here, Stark widths of 42 Ne II lines from 24 multiplets for T = 31 000 K and 34 500 K and electron densities 0.95 and 1.83 10^{23} m^{-3}. We have performed as well semiclassical perturbation calculations for 39 lines from 22 multiplets, providing the reliable Ne II Stark widths needed for stellar plasma research.

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P 256

Development of Astronomy in Serbia in the 20th Century

Milan S. Dimitrijević
(Astronomical Observatory, Volgina 7, 11160 Belgrade, Yugoslavia)

A short review of the developement of astronomy in Serbia from the foundation of Department of Astronomy and Meteorology in 1884 and of Belgrade Astronomical observatory in 1887 up to now is given.

Certainly the central place within the history of Serbian astronomy in 20th century has the Belgrade Astronomical observatory, his history and development, as well as the foundation and development of studies of astronomy at the Belgrade University. The particular merit for the development of astronomy in Serbia has Milan Nedeljković, whose contribution will be discussed. Moreover, the contribution of other astronomers as Djordje Stanojević, the first serbian astrophysicist, Milutin Milanković , who gave the astronomical solution to the quartenary ice ages problem and others will be considered as well as the development of Serbian Astronomical society and of amateur astronomy.

P 257

The Origin of the Common Yearly Counting in the Julian and Gregorian Calendar with Special Attention to the Ancient Astronomy and World View

Sepp Rothwangl
Graz, Austria; calendersign@teleweb.at

Because of a new consideration and recently revealed new facts and documents it is maintained that Dionysius Exiguus fixed the common Christian yearly count with the aim to mark the begin and end of the age of Pisces. By incorporating of three factors, he precalculated the conjunction of all naked eye planets including Sun and Moon of May 2000. He figured it out with the help of so called eternal planet boards and a "plotting year calculation" (Zieljahrberechnung). Then he determined the year 1 A.D. exactly 1999 years before it, due the medieval assumed constant of precession, (66 2/3 years each degree), that was base of calculation of later Arabian and Persian astronomers. Thus he linked the "Platonic Year" with the "Greatest Year". He did this in order to fulfil the Christian belief of the return of the Lord during a planetary position which is equivalent to the Greek Symposium or the start of the Kali Yuga, calculated by the Indian astronomer Aryabhata. For both calculations actually the alignment of all planets of year 531 CE was the base.

In his late antique religious and astronomical world view Dionysius determined the yearly counting such a way, that the year 2000 (2nd millennium) of his count should mark the end of the age of Pisces (ICHTHYS) and the religiously prophesied Christian end time.

INTERNATIONAL ASTRONOMICAL UNION

XXVIth GENERAL ASSEMBLY

August 14-25, 2006
Prague, Czech Republic

ABSTRACT BOOK

Prague Congress Centre
5 května 65, Prague 4

JD04-1 Poster

AGB Stars: Testing Carbon Loss Via The Ultraviolet Lines

Yu.V. Milanova[1], A.F. Kholtygin[2]

[1]*Saint-Petersburg State University, Saint-Petersburg, Russia,* [2]*Astronomical Institute of Saint-Petersburg State University, Saint-Peterburg, Russia*

A method is proposed to determine the realistic abundances of carbon in planetary nebulae based on the actual distribution functions of errors in measuring line intensities. Fluctuations both in temperature and in mass density in a nebula are taken into account. The C abundances and the amplitudes of temperature and density fluctuations for the large sample of PNe are given. The intensity of the ultraviolet lines of C ions are used for determining the more exact abundances.

These abundances are probably the most reliable in the present time and give estimations of the primordial CNO abundances at the epoch when the progenitors of PNs are formed. Basing on the newly carbon abundances the total mass losses of carbon during AGB stage of evolution are estimated.

JD04-2 Poster

On The Origin Of Two-Shell Supernova Remnants

V.V. Gvaramadze

Sternberg Astronomical Institute, Moscow, Russia

It is known that proper motion of massive stars causes them to explode far from the geometric centers of their wind-driven bubbles and thereby affects the symmetry of the resulting diffuse supernova remnants (SNRs). We use this fact to explain the origin of SNRs consisting of two partially overlapping shells (e.g. 3C 400.2, Cygnus Loop, Kes32, etc.), whose unusual morphology is usually treated in terms of the collision (or superposition) of two separate SNRs or breakout phenomena in a region with a density discontinuity.

We propose that a SNR of this type is a natural consequence of an off-centered cavity supernova (SN) explosion of a moving massive star, which ended its evolution near the edge of the main-sequence (MS) wind-driven bubble. Our proposal implies that one of the shells is the former MS bubble reenergized by the SN blast wave. The second shell, however, could originate in two somewhat different ways, depending on the initial mass of the SN progenitor star. It could be a shell swept-up by the SN blast wave expanding through the unperturbed ambient interstellar medium if the massive star ends its evolution as a red supergiant (RSG). Or it could be the remainder of a pre-existing shell (adjacent to the MS bubble) swept-up by the fast progenitor's wind during the late evolutionary phases if after the RSG phase the star evolves through the Wolf-Rayet phase. In both cases the resulting (two-shell) SNR should be associated only with one (young) neutron star (thus one can somewhat improve the statistics of neutron star/SNR associations since the two-shell SNRs are quite numerous). We discuss several criteria to discern the SNRs formed by SN explosion after the RSG or WR phase.

JD04-3 Poster

Analysis Of The High Temperature Region In Be Stars

A. F. Torres, A. E. Ringuelet

Universidad Nacional de La Plata, Facultad de Ciencias Astronómicas y Geofísicas, La Plata, Argentina

The High Temperature Region (HTR) that surrounds the photospheres of Be stars is studied in order to derive observational constraints for modelling Be stars, in particular for the region where superionization takes place.

50 Be stars, representative of a considerable range of temperature, were chosen. From archival, high-dispersion IUE spectra, different lines that originate in the HTR region were considered, namely the resonance lines of Si IV, C IV and Al III, and He II □1640. Equivalent widths (corrected for photospheric contribution), optical depths, atom columns and expansion velocities were measured. From this observational data several correlations between different observables were obtained.

These correlations permit us to discuss the geometry, density distribution and heat input of the lines formation regions (LFRs). The major results can be summarised as follows:

1) The circumstellar material contributes to the resonance lines of Si IV, C IV, Al III and to the He II □1640 at all inclination angles.

2) In Si IV, C IV and Al III the equivalent widths have a tendency to increase in objects with high rotational velocities.

3) Si IV and C IV equivalent widths are also correlated to the kinetic energy of the expansion velocity. This means that dissipation of mechanical energy is one of the heating mechanisms.

4)On the basis of the expansion velocities and the line profiles, we establish a sequence for the LFRs: The LFR of He II is at the base of the wind and the closest to the central star. The LFRs of Si IV and C IV are inmersed in the stellar wind. The LFR of Al III is an interface between the HTR and the cool envelope.

The analysis followed in this work is completely model-independent. Consequently, these results could be useful to decide which are the facts that are to be considered when modelling Be stars.

JD04-4 Poster

Long Term Variability Of The Coronal and Post – Coronal Regions Of The Oe Star HD 93521

A. Antoniou[1], E. Danezis[1], E. Lyratzi[1], D. Nikolaidis[1], L. C. Popovic[2], M. S Dimitrijevic[2]

[1]*University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Panepistimioupoli, Zographou 157 84, Athens, Greece,* [2]*) Astronomical Observatory, Volgina 7, 11160, Belgrade, Yugoslavia (Serbia and Montenegro)*

Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the C IV, N IV and N V spectral lines of the star HD 93521 which is a relatively bright, very rapidly rotating O9.5V star (Conti & Ebbets, 1977; Hobbs et al., 1982; Lennon et al., 1991).

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of the star HD 93521, taken with I.U.E. from 1979 until 1995 and we examine the timescale variations of the physical parameters, stated below.

Results: As a first result we detect that the above spectral lines consist of one or more Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the time scale variation of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the column density, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their time scale variations, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-5 Poster

Hyper Ionization Phenomena In The C IV Region Of 20 Oe Stars

A. Antoniou[1], E. Danezis[1], E. Lyratzi[1], D. Nikolaidis[1], L. C. Popovic[2], M. S. Dimitrijevic[2]

[1]*University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Panepistimioupoli, Zographou 157 84, Athens,*

Greece, [2]Astronomical Observatory, Volgina 7, 11160, Belgrade, Yugoslavia (Serbia and Montenegro)

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Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of 20 Oe stars, taken with I.U.E. and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype.

Results: As a first result we detect that the C IV resonance lines consist of one to five Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the values of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the column density, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-6 Poster

Hyper Ionization Phenomena In The N IV Region Of 20 Oe Stars

A. Antoniou[1], E. Danezis[1], E. Lyratzi[1], D. Nikolaidis[1], L. C. Popovic[2], M. S. Dimitrijevic[2]

[1]University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Panepistimioupoli, Zographou 157 84, Athens, Greece, [2]Astronomical Observatory, Volgina 7, 11160, Belgrade, Yugoslavia (Serbia and Montenegro)

Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the N IV spectral line of 20 Oe stars of different spectral subtypes.

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of 20 Oe stars, taken with I.U.E. and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype.

Results: As a first result we detect that the N IV spectral line consists of one or two Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the values of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the column density, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-7 Poster

Hyper Ionization Phenomena In The N V Region Of 20 Oe Stars

A. Antoniou[1], E. Danezis[1], E. Lyratzi[1], D. Nikolaidis[1], L. C. Popovic[2], M S. Dimitrijevic[2]

[1]University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Panepistimioupoli, Zographou 157 84, Athens, Greece, [2]Astronomical Observatory, Volgina 7, 11160, Belgrade, Yugoslavia (Serbia and Montenegro)

Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the N V resonance lines of 20 Oe stars of different spectral subtypes.

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of 20 Oe stars, taken with I.U.E. and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype.

Results: As a first result we detect that the C IV resonance lines consist of one to four Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the values of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the column density, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-8 Poster

High resolution spectroscopy of halo stars in groundbased UV.

V.Klochkova, G.Zhao, S.Ermakov, V.Panchuk.

V.G. Klochkova[1], S.V. Ermakov[1], V.E. Panchuk[1], G. Zhao[2]

[1]Special Astrophysical Observatory, Nighnij Arkhyz, Russia, [2]National Observatories of CAS, Beijing, China

For the first time an atlas of high spectral resolution (R = 60000)

CCD-spectra in the low studied wavelenghth range 3500-5000ÅÅ is presented for 4 stars with values of metallicity -3.0<[Fe/H]<-0.6, temperatures 4750<Te<5900K and surface gravity 1.6<log g<5.0. Based on these spectral data we determined model atmosphere parameters and calculated abundances of 29 chemical elements or their ions.

JD04-9 Poster

Study of Hα regions in 120 Be-type stars

E. Lyratzi[1], E. Danezis[1], A. Antoniou[1], D. Nikolaidis[1], L. C. Popovic[2], M. S. Dimitrijevic[2]

[1]University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Athens, Greece, [2]Astronomical Observatory, Belgrade, Yugoslavia (Serbia and Montenegro)

Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the shape of Hα line in the spectra of 120 Be-type stars.

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the stellar spectrographs of 120 Be stars, which were taken by Andrillat & Fehrenbach (1982) and Andrillat (1983) (resolution 5,5 and 27 Å) with the telescope of 152 cm in the Observatory of Haute Provence and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype and the luminosity class.

Results: We found that in the Be-type stellar atmospheres, there are two regions that can produce the Hα Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). The first one lies in the chromosphere and the second one in the cool extended envelope. With the above method we calculate: a) For the chromospheric absorption components we calculated the optical depth as well as the rotational and radial velocities of the independent regions of matter which produce the main and the satellites components. b) For the emission and absorption components which are created in the cool extended envelope we calculated the FWHM, the optical depth and the radial velocities of the independent regions of matter which produce the main and the satellites components.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype and luminosity class, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis

JD04-10 Poster

The complex structure of the Si IV λλ 1393.755, 1402.77 Å regions of 68 Be-type stars

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[1]University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Athens, Greece, [2]Astronomical Observatory, Belgrade, Yugoslavia (Serbia and Montenegro)

Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the Si IV resonance lines in the spectra of 68 Be-type stars of all the spectral subtypes and luminosity classes.

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of 68 Be stars, taken with I.U.E. and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype.

Results: We found that the absorption atmospherical regions where the Si IV resonance lines originated may be formed of one to five independent density layers of matter which rotate with different velocities, producing one to five Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the values of the apparent rotational and radial velocities, as well as the optical depth of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-11 Poster

A New Approach For DACs And SACs Phenomena In The Atmospheres Of Hot Emission Stars

D. Nikolaidis[1], E. Danezis[1], E. Lyratzi[1], L. C. Popovic[2], M. S. Dimitrijevic[2], A. Antoniou[1], E. Theodossiou[1]

[1]University of Athens, Faculty of Physics, Department of Astrophysics, Astronomy and Mechanics, Athens, Greece, [2]Astronomical Observatory, Belgrade, Yugoslavia (Serbia and Montenegro)

Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines. This fact is interpreted by the existence of two or more independent layers of matter, in the region where the spectral lines are formed. Such a structure is responsible for the formation of a series of satellite components (DACs or SACs) for each spectral line (Bates & Halliwell, 1986, Danezis et al. 2003, 2005).

Method: In this paper we present a mathematical model reproducing the complex profile of the spectral lines of Oe and Be stars that present DACs or SACs. This model presupposes that the regions, where these spectral lines are formed, are not continuous but consist of a number of independent absorbing or emitting density layers of matter and an external general absorption region. In this model we assume that the line broadening is due to the random motion of the ions and the rotation of the density regions that produce the spectral line and its satellite components. With this method we can calculate the values of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy and finally the column density of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Results: In order to check the above spectral line function, we calculated the rotational velocity of HeI λ 4387.928 Å absorption line in the spectra of five Be stars, using two methods, the classical Fourier analysis and our model. The values of the rotational velocities, calculated with Fourier analysis, are the same with the values calculated with our method.

Discussion: We point out that the new and important aspect of this method is the values' calculation of the above parameters using the DACs or SACs theory.

JD04-12 Oral presentation

High mass stars: starbursts

R.M. González Delgado

Instituto de Astrofísica de Andalucía, Granada, Spain

Starbursts are the preferred place where massive stars form; the main source of thermal and mechanical heating in the interstellar medium, and the factory where the heavy elements form. Thus, starbursts play an important role in the origin and evolution of galaxies. Starbursts are bright at ultraviolet (UV) wavelengths, and after the pioneering IUE program, high spatial and spectral resolution UV observations of local starburst galaxies, mainly taken with HST and FUSE, have made relevant contributions to the following issues: a) The determination of the initial mass function in violent star forming systems in low and high metallicity environments, and in dense (e.g. in stellar clusters) and diffuse environments. b) The modes of star formation: Starburst clusters are an important mode of star formation. c) The role of starbursts in AGN. d) The interaction between massive stars and the interstellar and intergalactic media. e) The contribution of starbursts to the reionization of the universe.

Despite the very significant progress obtained over the past two decades of UV observations of starbursts, there are important problems that still need to be solved. High-spatial resolution UV observations of nearby starbursts are crucial to further progress in understanding the violent star formation processes in galaxies, the interaction between the stellar clusters and the interstellar medium, and the variation of the IMF. Thus, a new UV mission furnished with an intermediate spectral resolution long-slit spectrograph with high spatial resolution and high UV sensitivity is required to further progress in the study of starburst galaxies and their impact on the evolution of galaxies.

JD04-13 Poster

Eta Carinae: What we have learned from HST/STIS in the UV

TR Gull

NASA/GSFC/EUD, Greenbelt, United States

The Luminous Blue Variable, Eta Carinae is revealing many answers to its mysteries by high spatial resolution in the visible and the ultraviolet. Studies with the STIS from 1998.0 to 2004.3 show major changes in the stellar and nebular spectra that track with the 2024-day period first noted by A. Damineli in the visible and followed by M. Corcoran via RXTE X-Ray monitoring.

We will show examples of the stellar and nebular spectra indicating changes in the central source, likely a massive binary system and indicating the response of the nebular ejecta, which is the >12 solar mass

New Deal in European Astronomy: Trends and Perspectives

JENAM

2003 BUDAPEST

25-30 August

Abstracts

– Posters –

07P01

The "Changeling" UV Spectrum of Mira B

M. Karovska, B. Wood, & J. Raymond

The Mira AB system belongs to a class of detached binaries in which a compact object accretes mass from the wind of a cool giant or supergiant. The emission from Mira B is generally assumed to be from a white dwarf surrounded by an accretion disk fed by Mira A's massive wind. Mira B dominates the UV emission from the Mira AB system.

We report here the results from our long-term (>15 years) study of the UV emission from Mira B. The spectra of Mira B show significant changes, especially in the past decade. The most recent HST STIS observations of Mira B (1999) showed that the UV spectrum is dominated by numerous narrow H2 lines which were not detected in the previous HST observations from 1995, or in any of the numerous observations of Mira B by IUE from more than ten years ago. In addition, the continuum fluxes of our HST/STIS spectra are well below those detected by IUE and previous HST observations. These dramatic changes in Mira B's UV spectrum suggest a possible disruption of the accretion disk.

Future UV observations of this and other interacting binaries are critical for determining the origin of the significant UV variability and for understanding the accretion processes in wind accreting systems.

07P02

Broadening of Ga I UV Lines due to Collisions with Charged Particles

D. S. Milan, D. Miodrag, C. Zorica & S. Zoran

Neutral Gallium spectral lines are significant for CP star spectra analysis, where the influence of collisions with charged particles on spectral line shapes should be taken into account. Moreover, with development of space born spectroscopy, good quality high resolution spectra of trace elements like Ga I become more and more available increasing interest for the corresponding line broadening parameters. We analyze in this contribution, the influence of collisions with electrons and ions on UV Ga I spectral line shapes. Analysis has been performed within the semi-classical perturbation approach and line broadening parameters for astrophysically important spectral lines have been provided.

New Deal in European Astronomy:
Trends and Perspectives

JENAM
2003 BUDAPEST
25-30 August

Abstracts

07P03

Importance of Collisions with Charged Particles for Stellar UV Line Shapes: Cd III

N. Milovanovic, M. S. Dimitrijevic, L. C. Popovic & Z. Simic

Influence of collisions with charged particles on Cd III UV stellar lines has been disscused along HR diagram. Within the modified semiempirical approach line broadening parameters have been obtained for most important Cd III UV lines of interest for stellar spectroscopy. Since with the development of space born spectrographs, like Goddard High Resolution Spectrograph on Hubble Space Telescope, even data for trace elements become more and more important, we hope that new data on Cd III UV lines will be of interest for spectroscopy of hot astrophysical plasmas.

Kiel/CCP7 WORKSHOP

on

ATMOSPHERES OF EARLY-TYPE STARS

September 18–20, 1991

University of Kiel, Germany

POSTER ABSTRACTS

P V.3

ION-ATOM COMPLEXES AND THE RECOMBINATION IN STELLAR PLASMA

A.A.Mihajlov[1,2] and M.S.Dimitrijević[2,1]

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We will demonstrate in this contribution the significance of the combined study of the following processess

$$A_2^+ + e - A + A^*(n) \quad (1a)$$

$$A + A^+ + e - \begin{cases} A + A^*(n) \\ A^*(n) + A \end{cases} \quad (1b)$$

in the study of the recombination of ions and electrons in weakly ionized stellar plasmas, and will provide the corresponding rate coefficients for the H and He case. Here A denotes atom, A^+ and A_2^+ atomic and molecular ions, $A^*(n)$ atom excited to the level of principal quantum number n, and e denotes electron.

In the present work the rate coefficients for processes (1a) and (1b) for the case $n \gg 1$ are determined using resonant energy transfer model within electronic components of the atomic systems considered (Mihajlov and Janev, 1981) for the hydrogen and helium case for conditions in stellar atmospheres. In the hydrogen case we provide data for $T \lesssim 10000K$. In the helium case the rate coefficients are calculated and analysed for $T \lesssim 30000K$ what is of particular interest for non DA white dwarfs with helium dominated atmospheres.

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Kiel/CCP7 WORKSHOP

on

ATMOSPHERES OF EARLY-TYPE STARS

September 18–20, 1991
University of Kiel, Germany

POSTER ABSTRACTS

STARK BROADENING PARAMETERS FOR SPECTRAL LINES OF MULTICHARGED IONS IN STELLAR ATMOSPHERES: C IV, N V, O VI LINES AND REGULARITIES WITHIN AN ISOELECTRONIC SEQUENCE

P V.4

M.S.Dimitrijević[1], and S.Sahal-Bréchot[2]

[1]*Astronomical Observatory, Volgina 7, 11050 Beograd, Yugoslavia*

[2]*Laboratoire "Astrophysique, Atomes et Molecules" Departement Atomes et Molecules en Astrophysique Unite associee au C.N.R.S. No 812 Observatoire de Paris-Meudon, 92190 Meudon, France*

For the investigationsof hot star atmospheres it is of interest to know Stark broadening data for multiply charged ion lines as C IV, N V, OVI (see e.g. Werner, Heber and Hunger, 1991). In order to provide a method for quick interpolation of new data along an isoelectronic sequence it is of interest to investigate if a sufficiently regular behaviour of Stark broadening parameters along such a sequence exists. Moreover, Stark broadening of spectral lines has been taking a new interest in astrophysics (Seaton, 1987), owing to the recent development of researches on the physics of stellar interiors: in subphotospheric layers, the modellisation of energy transport needs the knowledge of radiative opacities and thus, certain atomic processes must be known with accuracy.

The present paper concerns C IV, N V and O VI lines.Beyond the interest for the stellar atmospheres investigation and the modellisation of stellar interiors, the knowledge of C IV Stark broadening parameters is of great importance for a number of problems in astrophysics and plasma physics, since carbon has a high cosmical abundance and is present as impurity in many laboratory plasma sources. In order to provide reliable data for the mentioned lines broadened by collisions with all important charged perturbers in stellar plasmas, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 39 C IV (Dimitrijević et al, 1991a), 39 Si IV (Dimitrijević et al, 1991b) and 30 O VI multiplets (Dimitrijević and Sahal-Bréchot, 1992), using the semiclassical-perturbation formalism (Sahal-Bréchot, 1969ab).

The obtained results were used to investigate the behaviour of Stark broadening parameters within the isoelectronic sequencee in order to examine the use of such behaviour for the interpolation of new data of interest for the stellar plasma investigations.

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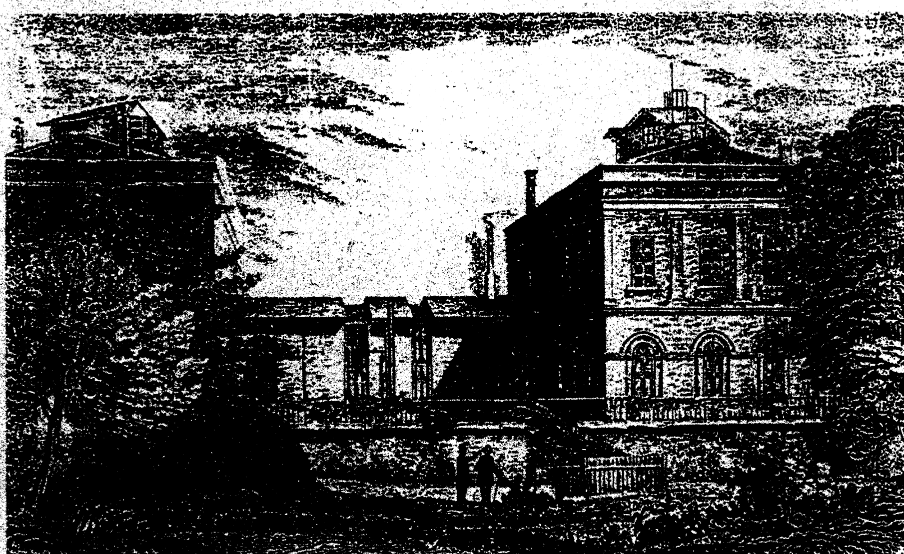
Workshop on

Laboratory and Astronomical High Resolution Spectra

Brussels, Belgium, August 29 - September 2, 1994

in honour of the 150th birthday of Charles FIEVEZ
(May 13, 1844 - February 2, 1890)
the pioneer of astronomical spectroscopy in Belgium

ABSTRACTS



Workshop on

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ABSTRACTS

Scientific Organizing Committee

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On the Stark Broadening of Mg I lines from Solar and Laboratory Plasmas

M. S. Dimitrijević[1], *S. Sahal-Bréchot*[2]

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Lines of neutral magnesium are present in the solar spectrum and the corresponding Stark broadening parameters are of interest for their analysis as well for the diagnostic of solar plasma. Especially the infrared lines of Mg I have been observed in the solar spectrum at Kitt Peak and during the Atmos experiment on Spacelab (Brault & Noyes 1983, Farmer & Norton 1989, Jefferies 1991). Due to the suitability of these lines for the solar atmosphere investigations (see e.g. Van Regemorter & Hoang-Binh 1993), and to the fact that with the increase of the principal quantum number increases the importance of the Stark broadening as well, the corresponding Stark widths and shifts are of importance for the structure of the solar atmosphere diagnostics. Moreover, Stark broadening parameters of the neutral magnesium lines are important for the diagnostics of laboratory plasmas as well.

By using the semiclassical-perturbation formalism we have calculated electron-, proton-, ionized helium-, ionized magnesium-, ionized silicon- and ionized iron-impact line widths and shifts for 267 Mg I multiplets, in order to continue our effort to provide to astrophysicists the needed Stark broadening data. A summary of the formalism is given in Dimitrijević et al. (1991). Here, we present and discuss the obtained results, and also the comparison with other, approximate calculations (Van Regemorter & Hoang-Binh 1993).

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МЕЖДУНАРОДНАЯ ОБЩЕСТВЕННАЯ ОРГАНИЗАЦИЯ
АСТРОНОМИЧЕСКОЕ ОБЩЕСТВО
EURASIAN ASTRONOMICAL SOCIETY

МЕЖДУНАРОДНОЕ СОТРУДНИЧЕСТВО В ОБЛАСТИ АСТРОНОМИИ: СОСТОЯНИЕ И ПЕРСПЕКТИВЫ

25 мая – 2 июня 2002 г.

Москва
АстрО
2002

jump at the CMB and CMB flattening, excitation and maintenance mechanism of the free libration and free core nutation, core-mantle different rotation).

ОПРЕДЕЛЕНИЕ НЕТЕПЛОВЫХ СКОРОСТЕЙ В СОЛНЕЧНОЙ КОРОНЕ ПО ЭМИССИОННЫМ ЛИНИЯМ 5303 И 6374 А СОЛНЦЕ И ПЛАНЕТЫ

Делоне А.Б., Порфирьева Г.А., Якунина Г.В.
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Проблема исследования нетепловых скоростей в солнечной короне в прямую связана с определением температуры излучающей области. При всех возможных принимаемых температурах всегда существуют нетепловые скорости. Рассматривается связь их величин с магнитным полем.

ИСПОЛЬЗОВАНИЕ РЕЗУЛЬТАТОВ, ПОЛУЧЕННЫХ НА КОСМИЧЕСКОМ ТЕЛЕСКОПЕ, ДЛЯ НАЗЕМНЫХ СПЕКТРАЛЬНЫХ ИССЛЕДОВАНИЙ

Денисюк Э.К., *АФИФ, Казахстан*

Обсуждается проблема исследования переменности широкой компоненты линии H_α в сейфертовской галактике NGC 4151. Для отделения наложенных на нее узких эмиссионных линий H_α и [NII] 6548 и 6584 анг. используются результаты наблюдений этого объекта на орбитальном телескопе им. Хаббла. Привлекаются как прямые изображения, полученные с высоким угловым разрешением, так и данные спектральных наблюдений, выполненных с узкой (шириной 0.1 сек.дуги) щелью.

ЛИНИИ ИНФРАКРАСНОГО ТРИПЛЕТА КАЛЬЦИЯ CAII НА СОЛНЦЕ И ХРОМОСФЕРНО АКТИВНЫХ КАРЛИКАХ G8

Дивлекеев М.И.
Государственный астрономический ин-т им. П.К.Штернберга, Россия

Исследованы профили линий ИК триплета кальция CaII в различных образованиях на Солнце. Остаточная интенсивность в ядрах этих линий во флоккулах сильно зависит от активности флоккулов. Как было показано Linsky (1979), заполнение ядра линии 8542E в звездах позднего класса может быть использовано как качественный индикатор хромосферной активности. Таким образом, остаточная интенсивность линий ИК триплета CaII может служить индикатором активности Солнца.

SPECTRAL LINE SHAPES IN ASTROPHYSICS

Dimitrjevic Milan S. *Astronomical Observatory, Belgrade, Serbia, Yugoslavia*

Stark broadening research in Yugoslavia is a developed research field, which has a critical mass of scientists. Spectral line shapes investigations in Yugoslavia and Serbia within 1962–2000 period has been reviewed in this contribution, with the special emphasis on the results of collaboration with colleagues from Russia, Belarus and Ukraine and with an analysis of the astrophysical applications of results of Serbian authors, and the use of their results by colleagues from Russia, Ukraine, Belarus and Eastern-European countries. Such analysis might show not only obtained results but also possibilities and common interest for future collaborations. Particular attention has been paid to the semi-classical method and the modified semi-empirical method as well as to the use in astrophysics of results and achievements in Stark broadening research of the Belgrade school.

МЕЖДУНАРОДНАЯ ОБЩЕСТВЕННАЯ ОРГАНИЗАЦИЯ
АСТРОНОМИЧЕСКОЕ ОБЩЕСТВО
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МЕЖДУНАРОДНОЕ СОТРУДНИЧЕСТВО В ОБЛАСТИ АСТРОНОМИИ: СОСТОЯНИЕ И ПЕРСПЕКТИВЫ

25 мая – 2 июня 2002 г.

Москва
АстрО
2002

сти звездообразования в туманности Ориона с угловым разрешением, соответствующим 0.05 а.е. Обнаружены структуры, сопутствующие формированию звезд: аккреционные диски и джеты. В AGN объектах 1803+784 и 3C 345 исследованы области ядер, установлено поглощение синхротронного излучения релятивистских частиц джетов в окружающей ионизованной среде.

THE INTERNATIONAL COLLABORATION OF BAO IN THE FIELD OF ACTIVE GALAXIES

Mickaelian A.M., *Byurakan astronomical Observatory, Armenia*

Since 1997, an international cooperation between the Byurakan Observatory and Observatoire de Haute-Provence (France) scientists is active in the field of extragalactic astronomy. 9 scientific trips have been carried out in the framework of this collaboration. On the basis of new quasars of the First Byurakan Survey (FBS), the most complete sample of bright QSOs has been constructed and their surface density is re-estimated. More than 1200 new galaxies from the IRAS PSC catalog have been revealed and investigated. On the basis of fine analysis of the emission spectral lines profiles, work on revealing of narrow lines and classification of broad-line AGNs is conducted. This was impossible before because of presence of broad component emission lines. A new subtype of AGNs has been separated.

THE INFLUENCE OF CHEMI-IONIZATION AND CHEMI-RECOMBINATION COLLISION PROCESSES ON THE CHARACTERISTICS OF PLASMA IN THE LOW TEMPERATURE LAYERS OF THE SOLAR ATMOSPHERE

Mihailov A.A.[1], Ignjatovic Lj.M.[1], Popovic L.C.[2], Dimitrijevic M.S.[2]
[1]*Institute of Physics, Beograd, Yugoslavia*
[2]*Astronomical Observatory, Beograd, Yugoslavia*

In this work we studied a group of chemi-ionization and chemi-recombination processes as a factor of influence on the electron density and population of Rydberg states of hydrogen atoms in low temperature layers of solar atmosphere (photosphere and a part of chromosphere). The chemi-ionization processes occur in collisions of two hydrogen atoms, where one of them is in the ground, and the second is in high excited state, while the chemi-recombination processes occur during the free electron scattering on collisional hydrogen ion-atom complexes, as well as on hydrogen molecular ions in weakly bounded ro-vibrational states. These processes have been treated in the frame of semi-classical approximation, which were developed in several previous papers. Their influence on parameters of solar atmosphere has been investigated using of complex modeling procedure. Comparison of results of calculation, performed with inclusion of chemi-ionization/ recombination [illegible] without [illegible] em [illegible] are very important, and have to be taken into account in modeling of low temperature layers of solar atmosphere.

АСТРОНОМИЯ В РФФИ: ДИНАМИКА РАЗВИТИЯ ЗА 10 ЛЕТ

Минин В.А., *РФФИ, Россия*

Рассмотрена динамика развития астрономических исследований, выполненных по грантам РФФИ. Дано библиографическое описание астрономии (на основе данных РФФИ). Исследовано международное соавторство российских астрономов.

Российский фонд фундаментальных исследований

Научный совет РАН по проблеме «Физика низкотемпературной плазмы»

ГОУ ВПО «Петрозаводский государственный университет»

Институт теплофизики экстремальных состояний РАН

Институт электрофизики и электроэнергетики РАН

ФИЗИКА НИЗКОТЕМПЕРАТУРНОЙ ПЛАЗМЫ – 2007

Материалы Всероссийской (с международным участием) конференции

(24–28 июня 2007 г.)

Том 1

Петрозаводск
Издательство ПетрГУ
2007

Том первый

Секции:

Элементарные процессы в плазме

Диагностика плазмы

Кинетика низкотемпературной плазмы

Компьютерное моделирование НТП

Приложения НТП

THE INFLUENCE OF THE RESONANT NON-ELASTIC ATOM-RYDBERG ATOM COLLISION PROCESSES ON THE CHARACTERISTICS OF WEAKLY IONIZED PLASMA

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Introduction

In this work the chemi-ionization processes in symmetric atom-Rydberg atom collisions, as well as the inverse chemi-recombination processes, there are in the centre of attention. Here we keep in mind the atom-atom collision ionization processes

$$A^{*}(n) + A \rightarrow e_k + A^{+} + A \quad (1)$$

$$A^{*}(n) + A \rightarrow e_k + A_2^{+} \quad (2)$$

and corresponding electron-ion-atom recombination processes

$$e_k + A^{+} + A \rightarrow A^{*}(n) + A \quad (3)$$

$$e_k + A_2^{+} \rightarrow A^{*}(n) + A \quad (4)$$

where $A^{*}(n)$ is an atom in the highly excited (Rydberg) state with the principal quantum number $n \gg 1$, A and A^{+} – the corresponding parents atom and its positive ion in their ground states, A_2^{+} – the molecular ion in the ground electronic state, and e_k – the free electron with energy ε_k. In the previous period primarily the processes (1) and (2), in the cases when A is an alkali atom, were investigated [1–16]. Apart of that, the processes (1)–(4), in the cases when $A = H$ and He, were investigated also [17–19]. All chemi-ionization processes were treated by means of semi-classical method based on the mechanism of the resonant energy exchange within the electron component of the considered collision system, introduced into consideration in [20]. This mechanism is illustrated by Fig. 1, where U_1 and U_2 denote the potential curves of the ground and the first excited electronic state of molecular ion A_2^{+}. First of all, the mentioned papers were devoted to determination of the cross-sections and the corresponding rate-coefficients for the processes (1)–(4).

Beside of chemi-ionization and chemi-recombination processes, the processes of (n-n')-mixing in symmetric atom-Rydberg atom collisions, namely

$$A^{*}(n) + A \rightarrow \begin{cases} A^{*}(n+p) + A, \\ A + A^{*}(n+p), \end{cases} \quad (5)$$

$$A^{*}(n) + A \rightarrow \begin{cases} A^{*}(n-p) + A, \\ A + A^{*}(n-p), \end{cases} \quad (6)$$

where $p \geq 1$, were investigated in previous period, but only sporadically. Here we will mention only two papers where the mentioned resonant mechanism was introduces and studied [20, 21]. The main aim of these papers was also determination of the corresponding cross-sections.

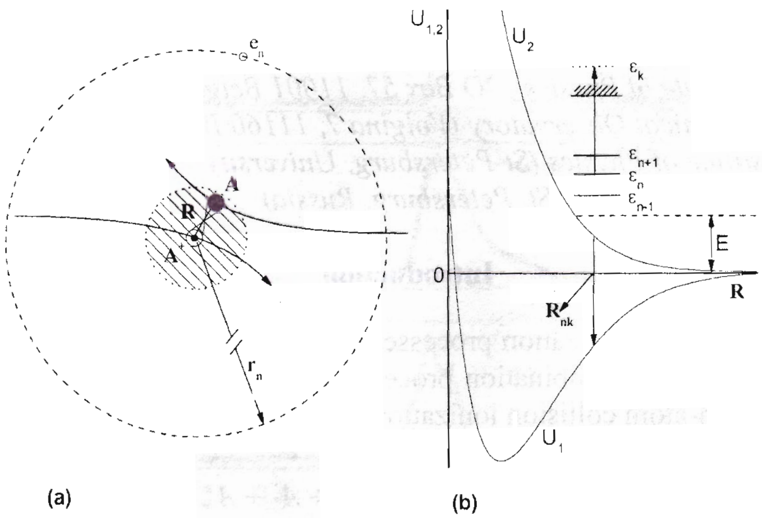

Fig. 1. (a) Schematic illustration of $A^*(n) + A$ collision (the region of the inter-nuclear distance R where the outer electron is collectivized is shaded); (b) Schematic illustration of the simultaneous resonant transitions of the outer electron from the initial bound to the final free state and the sub-system $A^+ + A$ from initial excited to the final ground electronic state

In the last few years significant attention was devoted to the investigation of processes (1)–(6) from the aspect of their influence to inner-plasma kinetics and optical characteristics of weakly-ionized laboratory and astrophysics gaseous plasmas. Just from such an aspect these processes are considered in this work.

Results and discussion

Recently, in [22] was presented the significance of processes (1)–(4) with $A = Na$ for different astrophysical plasmas and for so called photo-resonant plasmas (see also [23]). In [22] it was suggested that for the applications of processes (1)–(4) in the cases of alkali atoms one should use the rate coefficients determined in [12] and [16], while in the case of $A = H$ and He – the rate coefficients determined in [18] and [19]. In connection let us draw attention that the rate coefficients from [18] and [19] were already applied for the solar photosphere and for photospheres of some DB white dwarfs, where it was noticed that the processes (1)–(4) with $A = H$ and He dominate in comparison with other relevant ionization-recombination processes [24, 25]. Because of that, the influence of that processes with $A = H$ on $H^*(n)$ atom populations was investigated by means of code PHOENIX in the case of photosphereM dwarfs [26]. Major result of this work is that including of the processes (1)-(4) in the model changes the calculated values of the mentioned populations up to 50 %. This is illustrated by Fig. 2 which shows the behavior of the quantity $\zeta(n)$, i. e. the ratio of the populations calculated with and without inclusion of chemi-ionization and chemi-recombination processes. Since these processes, influence also to the electron density in the considered photosphere, they should influence simultaneously to the intensities and the shapes of hydrogen spectral lines. This impressive confirms the results shown in Figs. 3a and 3b, which relate to the shapes of H_ε and Pa_ε lines determined with and without of processes (1)–(4).

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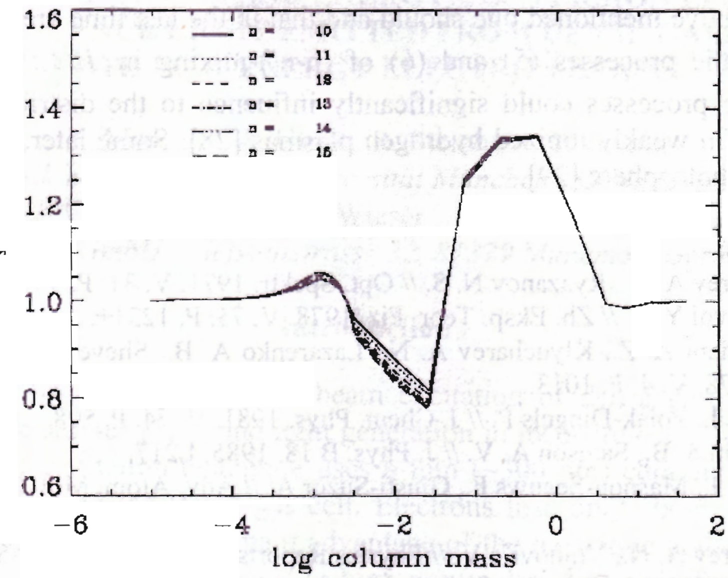

Fig. 2. The behaviour of the population ratio $\zeta(n)$ for $10 \le n \le 15$ as a function of the column mass

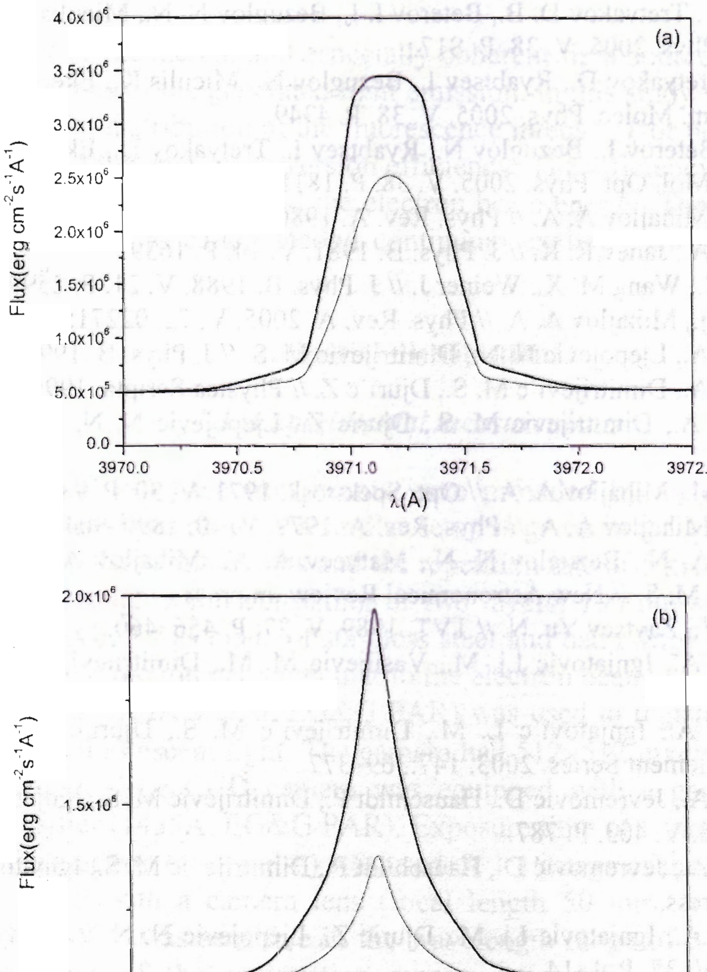

Fig. 3. Line profiles with (wide) and without (thin) inclusion of chemi-ionization and chemi-recombination processes for H_ε (a) and Pa_ε (b) lines from the atmosphere described in text

Apart of above mentioned one should add that in the last time are obtained first results in connection with the processes (5) and (6) of (n-n')-mixing in $H^{*}(n)+H$ collisions, which suggest that these processes could significantly influence to the distribution of excited states atom populations in weakly ionized hydrogen plasmas [28]. Some later, this was confirmed for the case of solar photosphere [29].

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СОДЕРЖАНИЕ

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The second international seminar of the South-Eastern Branch of the European Astronomical Society

"NEW RESULTS IN STELLAR PHYSICS"

3–5 October 2002, Timişoara

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Romanian Academy – Timişoara Branch
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Hip 38684 (CL Lyn) is a short period variable (P ~ 1.59 days), classified as Algol-type binary star.

In the absence of spectroscopic observations a q-search was made and the obtained values were adopted in our subsequent analysis, performed with the latest version of the W-D code. Moreover, taking into account all available information (spectral types, color indices B-V & V-I) for the system, the value of the temperature of its primary component was assumed.

THE ECLIPSING SYSTEM AW UMa: OBSERVATIONS AT KRYONERION AND BUCHAREST

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In this paper photoelectric observations of the contact binary AW UMa are presented, analyzed and discussed.

The observations were carried out with the 48-inch Cassegrain reflector at the Kryonerion Astronomical Station of the National Observatory of Athens, Greece, as well as with the 50cm Cassegrain telescope of the Bucharest Observatory.

From the individual observational points normal ones were calculated and the corresponding light curves were analyzed using the Binary Maker program.

STARK BROADENING IN S III SPECTRUM OF INTEREST FOR STELLAR PLASMAS

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Stark broadening data are of interest for abundance determination, stellar spectra synthesis and interpretation, stellar atmospheres modeling, opacity calculations etc. Spectral lines of Sulfur in various ionization stages are of interest for e.g. CP stars research. In this contribution, Stark widths and shifts of four doubly ionized Sulfur (S III) spectral lines in the 4s-4p transition have been measured in a SF_6 plasma created in the linear, low pressure, pulsed arc discharge at about 35 000 K electron temperature and 2.8 10^{23} m^{-3} electron density. Mentioned parameters have been calculated using semiclassical perturbation formalism (SCPF) taking into account new atomic data. Our new data are compared to the existing experimental values and theoretical predictions made on the basis of various approximations.

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TRANSITION PROBABILITIES IN Kr II SPECTRUM, OF INTEREST FOR HIGH RESOLUTION STELLAR SPECTRA ANALYSIS

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For the analysis and modeling of stellar spectra, abundances determination and stellar plasma analysis, *gf* values related to the transition probabilities are essential. Moreover, due to development of space born astronomical techniques and devices like Goddard High Resolution Spectrograph on the Hubble space telescope the spectral lines of trace elements like krypton, are observed and the corresponding atomic data are of the increasing interest. On the basis of the relative line intensity ratio (RLIR) method transition probability values of the spontaneous emission (Einstein's *A* values) of 14 transitions in the singly (Kr II) ionized krypton spectra have been obtained relatively to the reference *A* values related to the 435.548 nm, belonging to the most intensive transitions in the Kr II spectra. Mentioned *A* values have been calculated also using the Coulomb approximation (CA) method taking into account new atomic data for Kr II energy levels. The linear, low pressure, pulsed arc operated in krypton discharge has been used as an optically thin plasma source at 17 000 K electron temperature and 1.65 10^{23} m^{-3} electron density. Our experimental and calculated relative *A* values have been compared to the existing ones. We hope that our results will be of interest for the research of krypton abundances and analysis of its spectra and transitions in astrophysical conditions.

ON THE STARK BROADENING OF Ne III SPECTRAL LINES OF INTEREST FOR STELLAR ATMOSPHERES RESEARCH

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The Stark broadening data of Ne III spectral lines are of interest for diagnostic, modeling and investigation of stellar plasma. Namely, from such data, it is possible to obtain the basic plasma parameters, such as the electron temperature and electron density. Moreover, neon is the most abundant element in the universe after H, He, O and C, and it is for example one of products of hydrogen and helium burning in the orderly evolution of stellar interiors. Also, after H-, He-, and C-burning periods end in massive stars, neon burning starts. Consequently, Ne III Stark broadening data are of interest for abundance determination, stellar spectra synthesis and interpretation, stellar atmospheres modeling, opacity calculations etc. Five experiments deal with the Ne III Stark width measurements and eight papers contain results of theoretical calculations. Due to significance of neon for stellar, but as well for laboratory and technological plasmas, it is of interest to provide corresponding Stark broadening data, especially for resonance lines and for lines originating from low lying energy terms. In this contribution we present the results of our calculations within the semiclassical – perturbation formalism electron-, proton-, and ionized helium-impact line widths and shifts for 6 Ne III multiplets. The obtained results have been compared with available experimental and theoretical data.

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CHEMI-IONIZATION AND CHEMI-RECOMBINATION PROCESSES IN HELIUM RICH WHITE DWARF ATMOSPHERES

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The influence of the chemi-ionization processes during the collision of Rydberg helium atom with the helium atom in the ground state, and the inverse chemi-recombination processes on the populations of the helium atom Rydberg states in DB white dwarf atmospheres (with the effective temperature from 12 000 K up to 20 000 K and log g = 7 and 8) has been considered. In order to do so, these processes have been considered paralelly with the known ionization and recombination processes, namely the processes of the electron-electron-ion recombination, the Rydberg helium atom ionization by free electron impact, and electron-ion photorecombination. As the quantitative characteristics of the influence of the above mentioned processes one takes ratios of their contributions to populations of the helium atom Rydberg states. The analysis of the obtained results shows that the symmetrical chemi-ionization and chemi-recombination processes should be treated as factors of the significant influence on the populations of the helium atom Rydberg states in the considered DB white dwarfs atmospheres, and must be taken into account for their modeling.

PMS VERSUS POST-MS

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Close to the main sequence the HR diagram is confusing, as stars of similar global properties but with different stages of evolution occupy the same position. Both binaries and pulsating stars with different evolutive stages were discovered in this area.

In some cases the young PMS stars are recognized through specific characteristics – for instance the presence of nebulosity or high degree of activity. These phenomena must be applied to discriminate between binary systems.

An alternative is to take advantage of seismical information whenever it is possible. In this case the discrimination between PMS and POST-MS is possible using differences in their oscillatory frequency distributions in the low frequency range.

THE LOCAL STELLAR VELOCITY DISTRIBUTION OF THE GALAXY

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In the solar-neighbourhood, older stars have larger random velocities than younger ones. It is argued that the increase in velocity dispersion with time (the heating process) is

СРПСКА АКАДЕМИЈА НАУКА И УМЕТНОСТИ
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ПРИРОДНЕ И МАТЕМАТИЧКЕ НАУКЕ У СРБА ДО 1918.

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ПРИРОДНЕ НАУКЕ У СРБИЈИ ДО 1914. ГОДИНЕ

NATURAL SCIENCES IN SERBIA UNTIL 1914

САЖЕТАК: У раду је приказан развој природних наука у Србији у XIX веку и првим годинама XX века, до Првог светског рата. Најпре су се развиле „националне науке", науке корисне за државу, односно науке које су се односиле на упознавања земље и њених природних богатстава (ботаника, зоологија, минералогија, геологија). Остале науке (хемија, физика, математика, астрономија) развиле су се касније и њихов развој текао је спорије јер се сматрало да нису корисне за земљу и да за њих не треба школовати већи број људи и трошити знатнија материјална средства. Научни радови и друге карактеристике научног развоја вредновани су једнаким критеријумима (радови објављени у научним часописима, постојање научних институција и часописа, школовање младих истраживача).

Кључне речи: природне науке, развој у 19. веку, ботаника, зоологија, минералогија, геологија, метеорологија, географија, хемија, математика, физика, механика, астрономија

SUMMARY: This paper gives an outline of the development of natural sciences in Serbia in the nineteenth century and at the beginning of the twentieth century, up until World War I. First, there was a development of „national sciences", the ones that were useful to the country, i.e. sciences which referred to exploration of the earth and its natural resources (botany, zoology, mineralogy, geology). Other sciences (chemistry, physics, mathematics, astronomy) developed later and their progress took more time as it was considered that they were of no use to the country and that therefore not many people were necessary to be educated for them and that no great financial means were to be spent on them. Scientific papers and other characteristics of scientific development were evaluated by the same criteria (the papers published in scientific journals, the existence of scientific institutions and journals, education of the young researchers).

Key words: natural sciences, 19th century development, botany, zoology, mineralogy, geology, meteorology, geography, chemistry, mathematics, physics, mechanics, astronomy

УВОД

Последњих деценија XIX века у Србији су скоро све природне науке биле заступљене. Поједине науке достигле су висок степен развоја: наши научници били су чланови европских друштава и објављивали су радове у познатим научним часописима, а у Београду су оснивана научна и стручна друштва, покретани часописи, обучавани млади истраживачи, вођена стручна дискусија, негована критичка мисао.

Само неколико деценија раније ништа од тога није се могло наслутити. Тридесетих година XIX века у Србији су сви становници били неписмени, није било школâ, ни законâ, ни судовâ, ни других установâ. Само одважни појединци одазивали су се позиву просветних власти и долазили из Аустроугарске (Војводине) да раде у тек основаној гимназији (1830, односно 1833), а затим у Лицеју.

Шта се догодило за то пола века? Како је тако брзо измењена структура државе и створена интелектуална клима која је подстицала на рад и све брже приближавала Србију модерној Европи?

Можда се интелектуална енергија, вековима конзервирана, нагло разасула и изнедрила један број даровитих младих људи који су се трудили да за кратко време надокнаде све оно што је у другим земљама неговано и развијано вековима? Необразовани и полуписмени државници имали су бистру сељачку памет која их је нагонила да помажу највредније и најталентованије младе људе, да их шаљу у најбоље школе и по повратку у земљу да их постављају на одговарајуће функције. Мада су први државници имали на уму добро образоване службенике који ће стварати модерну правну државу, млади који су се враћали с европских универзитета знали су да је за напредак земље потребна култура и наука. И они су не само новостечено знање доносили са собом него све што су видели у великом свету покушавали су да пренесу у своју земљу. А у том свету они су научили како функционише држава, како се стварају културне и научне установе, како се припрема интелектуална елита која је у стању да комуницира с европском културном и научном јавношћу. Осамдесетих и деведесетих година XIX века у Београду се сакупио један број младих људи с највишим дипломама француских, немачких и швајцарских школа, великог знања, енергије и креативности, препуни националног заноса и патриотизма. Трудили су се да у земљи без научне традиције развију науку, оснују неопходне институције, окупе истраживачке тимове и ураде оно што су у другим земљама годинама радили бројни научници и стручњаци кроз школе и одговарајуће установе.

Ово јединствено раздобље у историји наше науке није дуго трајало јер се, можда због ратова и других догађаја, исцрпла интелектуална енергија, самопоуздање и самосталност, тада карактеристични за сваког нашег научника.

Зашто су поједине науке биле развијеније од других и како су у појединим областима настајале школе и науке диференцирале, док су у другим научним областима радили само појединци, без помоћника и без великих средстава?

Од природних наука на Лицеју је најпре, уз математику, предавана физика. Први професори физике и математике нису се бавили научним радом, написали су добре уџбенике, а развој науке почео је тек крајем века. С друге стране, биолошке науке (ботаника, зоологија), затим геологија и минералогија, утемељене су доласком Панчића на Лицеј 1853. године. Све поменуте науке, под називом јестаственица, Панчић је предавао до осамдесетих година, када су их преузели његови ученици.

Разлога за неуједначен развој наукâ било је више, али највише утицаја имали су општи погледи и атмосфера у земљи који су фаворизовали поједине области, а занемаривали друге. Требало је истражити земљу, флору, фауну, климу, и све што је било непознато и што је требало открити и с тим упознати наш свет и Европу. Први учени људи окупљени у Друштву српске словесности и Српском ученом друштву сматрали су да треба развијати „националне науке”, а не непотребно трошити енергију и новац на науке од којих земља нема користи. Ни касније овај став није много измењен. Пред крај живота, фебруара 1888, у тестаментарном писму упућеном члановима Академије наука, Панчић је препоручио академицима да се ограниче „на оне науке које се Српства и Јужног Словенства, а нарочито земаља балканског полуострва тичу”.

БИОЛОШКЕ НАУКЕ

БОТАНИКА

Развој биолошких наука утемељио је *Јосиф Панчић* (1814—1888) педесетих и шездесетих година XIX века. Главна област његових истраживања био је биљни свет Србије и околних земаља. И пре доласка на Лицеј 1853. године он се бавио ботаничким истраживањима, а поставши професор ботанике, зоологије, геологије, минералогије и агрономије потпуно се одао науци, односно истраживању природног богатства земље. Осим биљног света, он је проучавао инсекте, мекушце, птице, рибе, минерале, стене, минералне воде.[1]

Србија је била неистражена у погледу флоре и фауне, и на картама Европе за Србију недостајали су ови подаци. Овакву слику Панчић је желео да измени и да европској научној јавности прикаже проучену флору Србије и тако је укључи у европске ботаничке научне токове.

Флористичка и таксономска истраживања подразумевају тачну научну идентификацију и регистровање свих биљних врста, јер је то основ за каснија модернија и комплекснија истраживања. Панчић је био систематичан и егзактан научник и да би испунио свој задатак морао је да обиђе све крајеве Србије и околних земаља (планине Бугарске, Црне Горе и Приморја). На својим путовањима сакупљао је и идентификовао флору, налазио кључ за њену идентификацију и објављивао радове и монографије на основу којих је Србија врло брзо сврстана у земље с богатом и разноврсном флором.

Прве резултате својих флористичких истраживања објавио је тек 1856. године, у својој 42. години, десет година по доласку у Србију. Већ у првом раду обухватио је 1806 врста самониклих биљака које расту у Србији, међу којима пет нових врста (три се и данас воде као самосталне биљне врсте) и 31 нови таксон на нивоу варијетета и форме (22 је до данас задржало своју систематску вредност).

Са италијанским ботаничарем Визијанијем (Roberto de Visiani) објавио је у Венецији студију од три дела *Plantae serbicae rariores aut novae* (1862, 1866, 1870) која садржи 30 нових биљних врста откривених у Србији (19 је задржало систематску вредност, 7 је стекло нижу систематску вредност, а четири су синоними са већ познатим врстама).

Живећи и радећи у Београду најбоље је познавао флору његове околине. Године 1865. објавио је прво издање *Флоре у околини београдској* које је садржавало 1057 цветница разврстаних у 427 биљних родова. До краја његовог живота изашло је још пет издања, а 1892. и шесто издање у којем је било 1156 биљних врста.

[1] Никола Диклић, *Јосиф Панчић*, у: *Живот и дело српских научника*, уредник М. Сарић, САНУ, Биографије и библиографије, Књига 1, Београд, 1996 (даље: *Живот и дело српских научника*), 1—63; Будислав Татић, *Ботаника (1854—1904)*, у: *Наука и техника у Србији друге половине XIX века*, Крагујевац, 1998, 789—803; Будислав Татић, *Ботаничке науке у Србији током друге половине XIX века*, у: *145 година биологије и 25 година молекуларне биологије у Србији*, Београд, 1998, 75—93.

У књизи *Шумско дрвеће и шибље у Србији* (1871) описао је 189 врста дрвећа и шибља, међу којима три нове врсте (15 страног порекла).

У *Die Flora der Serpentinberge in Mittel-Serbien* (1895) извршио је анализу целокупне серпентинске флоре.

У књизи *Живи песак у Србији и биље што на њему расте* обрадио је вегетацију и флору живог песка у српском Подунављу, од Рама до утока Тимока у Дунав. Наведене су укупно 262 врсте биљака, од којих 58 цветница.

Синтезу својих истраживања дао је у *Флори Кнежевине Србије* (1874, *Додатак* 1884). Ова књига, са 2422 биљне врсте, штампана и на латинском језику, показала је да је Србија земља са богатом и комплексном флором. У првом делу дао је 16 нових врста које је сам открио, обрадио, описао и дао им називе, а у *Додатку* још 12. По обиму и значају ова монографија може се упоредити са класичним европским флористичким делима са којима се и данас равноправно цитира, односно подаци из ње користе се у радовима који се односе на флору Балкана, а била је основ и за *Флору СР Србије* у издању САНУ (1970—1986). Доживела је шест издања и служила је и као ђачки уџбеник.

Једно од Панчићевих најзначајнијих открића јесте оморика (1876), нова четинарска врста која представља реликт из терцијарног доба, ендемска врста за којом је неуморно трагао 20 година.

Путујући по Црној Гори и по Бугарској Панчић је сакупио материјал за флору Црне Горе (1874) и флору Бугарске (1883, 1886).

Године 1887—1888. Панчић је начинио списак на српском и латинском језику свих биљних врста нађених до тада у Србији, укупно 2393, и разаслао школама у Србији и страним ботаничарима и ботаничким институцијама.

Панчић нема велики број научних радова: 15 радова и 10 књига монографског карактера. Већина радова и књига штампана је у Србији, али су писана на немачком или латинском језику како би била доступна страној јавности. Међутим, свака његова публикација је обимног и богатог садржаја и представља значајно дело за ботанику Србије. Његови радови били су основ за сва каснија истраживања и развој различитих ботаничких и зоолошких дисциплина.

У току четрдесетогодишњег рада Панчић је открио 121 нову биљну врсту, 50 нових варијетета и 7 нових форми биљака. Од 121 врсте 11 је приказано без неопходних описа (због чега нису научно верификоване), 64 су деградиране у систематском смислу и одређен им је нижи систематски статус на нивоу подврсте, варијетета и форме или су изједначене као синоними са већ познатим биљним врстама, а неколико врста се временом „изгубило" јер нису публиковане у флористичким радовима. Тако је до данас своју систематску вредност задржало 46 врста, међу којима неколико значајних реликтних и ендемских врста. У последње време неке од деградираних врста су новим истраживачким методама поново анализиране и враћене на ниво врсте како је то Панчић установио.

Панчићев рад представља прва права научна истраживања код нас, а сâм Панчић првог комплетног научника који је делао у Србији. Објављивао је радове и на страном језику и у страним часописима, учествовао на међународним скуповима, био члан страних друштава и академијâ наукâ, одржавао везе с познатим научницима (аустријским, немачким, италијанским, мађарским), вршио размену материјала са страним колегама, у збиркама европских природњачких и ботаничких музеја проверавао своја флористичка открића, обилазио ботаничке баште и упознавао се с њиховим уређењем и одржавањем. У Београду је основао експерименталну лабораторију — Ботаничку башту, а у ботаничка истраживања увео је један број својих ђака, касније професора средњих школа, који су наставили истраживања флоре Србије и објављивали радове (М. Симић, Д. Катић, Н. Ранојевић, Ђ. Илић, Љ. Давидовић, А. Јовановић, М. Бобић).

Живојин Јуришић (1863—1921), професор средње школе, био је Панчићев следбеник. Бавио се истраживањем цветницâ, испитивао флору Бугарске, Босне и Македоније, а дао је и допринос истраживању маховина. Објављивао је радове у нашим часописима.[2]

Лекар *Сава Петровић* (1839—1889) истраживао је флору околине Ниша и нашао неколико нових цветница.[3]

Лујо Адамовић (1864—1935), један од најбољих познавалаца наше флоре и вегетације (неки наводе да је после Панчића најзаслужнији за систематику биљака), кратко време је предавао на Великој школи (1901—1905), али је и пре и после тога објављивао радове везане за истраживања наше земље. Најважније дело, о вегетацији балканских земаља (Лајпциг, 1909), имало је велики значај за познавање флоре и вегетације овог дела Европе. Један број врста које је открио до данас је задржао свој статус (13), док је известан број врста претрпео ревизију и промену статуса (15). До Првог светског рата објавио је 44 рада и две монографије. Ци-

[2] Б. Татић, *Ботаника*, 797.

[3] Новица Ранђеловић, *Сава Петровић*, у: *Живот и дело српских научника*, Књига 3, 1998, 73—92.

тира се у свим радовима из области фитогеографије и флористике који се односе на Балканско полуострво.[4]

Недељко Кошанин (1874—1934) од доласка на Универзитет 1906. године обављао је опсежна, савремена флористичка, таксономска, систематска и фитогена истраживања. Рад у области флористике започео је истраживањем алги и маховинâ, а наставио проучавањем виших биљака. Описао је 265 таксона алги, међу њима две нове врсте. Описао је и проучио 11 врста цветницâ нових за науку, од којих се осам одржало до данас. Својим радовима употпунио је сазнања о флори наше земље и Балкана и омогућио успостављање флористичких везâ између балканске флоре и других области, пре свега предње Азије и Медитерана. У систематска и флористичка истраживања уносио је и физиолошки и еколошки аспект. Бавио се и фитогеографским проучавањем јужне Србије као и многим другим крајевима земље.

Његови радови су често цитирани, сарађивао је са страним научницима и био члан неколико страних ботаничких друштава.

Од укупно 43 научна рада, до Првог светског рата објавио је 19 радова, од тога 10 у страним часописима.[5]

ЗООЛОШКЕ НАУКЕ

Први научни зоолошки рад у Србији објавио је 1847. године Аћим Медовић, лекар, који је по налогу власти пет месеци провео у Ђердапу проучавајући голубачку мушицу. Извештај о овом истраживању објавио је у *Срйским новинама*, али су резултати доспели у европску јавност преко приказа у Бечкој академији наука.[6]

Међутим, пионирски рад у фаунистичким истраживањима започео је Панчић. Саставио је прве кључеве за детерминацију скакаваца и кичмењака Србије, открио је неколико нових врста животиња. Значајно де-

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4 Будислав Татић, *Лујо Адамовић*, у: *Живоӣ и дело срӣских научника*, Књига 2, 1997, 209—235.

5 Милоје Сарић, *Недељко Кошанин*, у: *Живоӣ и дело срӣских научника*, Књига 2, 1997. 437—467; Војислав Петровић, Милорад Јанковић, Иво Савић, *Срӣска академија наука и умеӣносӣи и развој биолоѓије*, САНУ, 1989, 163.

6 Миодраг Јовановић, *Аћим Медовић, ӣисац ӣрвоѓ научноѓ зоолошкоѓ рада у Кнежевини Србији*, у: *Пола века науке и ӣехнике у обновљеној Србији 1804—1854*, Крагујевац, 1996. 178—182; Милоје Сарић, *Доӣринос чланова Друшӣва срӣске словесносӣи, Срӣскоѓ ученоѓ друшӣва и Срӣске краљевске академије у обласӣи ӣољоӣривреде и биолоѓије у XIX веку*, у: *Наука и ӣехника у Србији друѓе ӣоловине XIX века*, Крагујевац, 1998, 605—607; Миодраг Јовановић, *Правци развоја биолоѓије код Срба у ӣрвој ӣоловини 19. века*, у: *Природне и маӣемаӣичке науке у Срба у 18. и ӣрвој ӣоловини 19. века*, Нови Сад, 1995, 331—337.

ло *Грађа за фауну Кнежевине Србије* (1869) садржавало је студију свеукупних животињских врста и њихову распрострањеност у Србији. Монографија *Рибе у Србији* (1860) обухватила је преко 90 врста, студија *Птице у Србији по аналитичком методу* (1867) обухватила је 303 врсте, док је у делу *Ортоптере у Србији* (1883) описао 137 врста, од којих две нове.[7]

Иако се зоолошким истраживањима бавио успут, уз ботаничка истраживања, Панчић је припремао ученике за овај посао. Године 1878. њега је на Великој школи наследио лекар Лазар Докић, после кога се смењују још два лекара, Ђорђе Јовановић и Војислав Ђорђевић.[8]

Тек доласком зоолога *Живојина Ђорђевића* (1896), школованог у Женеви, Берлину и Паризу, почињу модерна фаунистичка истраживања. Ђорђевић је објавио радове о протозоама, црвима, зглавкарима, мекушцима и кичмењацима, језерском планктону Македоније, хидрахиндрама и голубачкој мушици. У својој дугој научној каријери (1898—1957), објавио је више од 70 научних радова, а до Првог светског рата 12. Радове је објављивао у *Гласу СКА* и истовремено у немачким и француским часописима.[9]

Ђорђевић је посебно припремао вредне и даровите студенте за истраживачки рад, а њихове резултате објављивао у публикацији *Радови из Зоолошког завода*. Неки од њих остали су на Универзитету и наставили да се баве научним радом.

ГЕОЛОШКЕ НАУКЕ

Прва геолошка истраживања у Србији обавили су страни стручњаци. Барон Хердер је на позив кнеза Милоша 1835. године десет недеља путовао по Србији испитујући тло, руднике, изворе, стене, минерале. Годину дана касније слична истраживања, али боље припремљена, извео је Ами Буе.[10] Резултати његовог рада дуго су служили као основ за даља геолошка истраживања.

[7] Божидар Ћурчић, *Зоолошке науке у Србији друге половине XIX века*, у: *145 година биологије и 25 година молекуларне биологије у Србији*, Београд, 1998, 47—75.

[8] Исто, 68.

[9] Војислав Петровић, Милорад Јанковић, Иво Савић, *Српска академија наука и уметности и развој биологије*, САНУ, 1989, 170; Божидар Ћурчић, *Живот и дело академика Живојина Ђорђевића*, Monogr. Inst. Zool. Fac. Biol. Univ. Belgrade, 5 (у штампи).

[10] Видојко Јовић, *Геолошка испитивања у обновљеној Србији (1804—1854)*, у: *Пола века науке и технике у обновљеној Србији 1804—1854*, Крагујевац 1996, 182—192; Зоран Петковић, *Стање и развој рударства у обновљеној Србији (1804—1854)*; у: *Пола века науке и технике у обновљеној Србији 1804—1854*, Крагујевац, 1996, 404—414; Александар Грубић, *Ге-*

На својим путовањима по Србији Јосиф Панчић је истраживао и геолошки састав, рудоносне појаве, минералне воде, сакупљао и обрађивао фосиле, стене и минерале. Многе податке уносио је у своје ботаничке радове, а у уџбенику из минералогије и геологије (1867) навео је педесетак наших минерала, двадесетак стена и неколико примера из наше стратиграфије. Основао је Минералошко-геолошки кабинет у којем се 1880. налазило 4086 примерака, са 1600 минерала, стена и фосила из Србије, што је било неопходно за каснија геолошка истраживања.

Систематски научни рад у овој области предузео је Панчићев ученик *Јован Жујовић* (1856—1936) 1880. године.[11] Свестрано образован у Паризу и припремљен за озбиљан и свеобухватан научни рад он је за десет година окупио сараднике за теренска истраживања и основао све потребне институције: Студентски семинар (1883), геолошку библиографију Балканског полуострва (1886), Геолошки завод (1889), *Геолошке анале Балканског полуострва* (1889), Српско геолошко друштво (1891), а 1893. је покренуо идеју о формирању Комитета за детаљну геолошку карту Србије. Поред организационог рада и раног сагледавања потреба за свеукупно научно делање, Жујовић је журио да обучи младе истраживаче и утемељи геолошку науку, како би упознао домаћу и страну јавност са основама геолошког састава Србије, што би допринело да земљу ослободи сфере аустроугарске научне доминације.

У *Геолошким аналима Балканског полуострва*, једином геолошком часопису на Балканском полуострву, штампани су резултати геолошких истраживања, оригинални научни радови његових ученика. Жујовић је желео да обавести европску научну јавност о резултатима рада београдске геолошке школе и првих пет бројева часописа у целини је преведено на стране језике.

ологија у Срба у 18. и првој половини 19. века, у: *Природне и математичке науке у Срба у 18. и првој половини 19. века*, Нови Сад, 1995, 127—135; Видојко Јовић, *Геологија у Срба у првој половини 19. века*, у: *Природне и математичке науке у Срба у 18. и првој половини 19. века*, Нови Сад, 1995, 229—233.

[11] Александар Грубић, *Јован Жујовић*, у: *Живот и дело српских научника*, Књига 1. 1996, 291—359; Петар Стевановић, *Развитак геолошких наука у Српској академији наука и уметности*, САНУ, 1989, 100—159; Александар Грубић, *Геологија у Србији током друге половине XIX века*, у: *Наука и техника у Србији друге половине XIX века 1854—1904*, Крагујевац, 1996, 77—87; Видојко Јовић, *Геолошка испитивања у Србији 1854—1904*, у: *Наука и техника у Србији друге половине XIX века 1854—1904*, Крагујевац, 1996, 237—239; Александар Грубић, *Геологија у Срба 1850—1918*, у: *Природне и математичке науке у Срба 1850—1918*, Нови Сад, 2001, 35—59; К. Петковић, *Жујовићево доба и доба његових савременика — формирање српске геолошке школе и науке*, у: *Геологија Србије, историјски развој*, Завод за регионалну геологију и палеонтологију Рударско-геолошког факултета, Београд, 1977, 39—57; Видојко Јовић, *Из историје геологије у Србији*, Београд, 2003.

Прво истраживање обавио је у петрографској лабораторији Collège de France на колекцији стена из Анда и објавио рад у Београду 1880, а затим монографију у Паризу 1884. године.

Као Панчић, и он је обилазио Србију обављајући истраживања на терену, али истовремено и у лабораторији. Започео је са новим округима на југу Србије (1884), наставио истраживања по целој Србији, па и суседним државама.

Жујовићев научни рад је разноврстан и залази у више грана геологије: петрографија, регионална или топографска геологија, минералогија, стратиграфија, општа геологија, геолошко картирање. Поред геолошких карата и великог броја саопштења у *Записницима Српског геолошког друштва*, до Првог светског рата објавио је осам радова у издањима Академије наука, 13 радова у *Геолошким аналима Балканског полуострва* и два рада у страним часописима. Разлог за невелики број радова јесте његова кратка научна каријера: од 1900. године он се претежно бавио политиком.

Најзначајнији радови су му геолошке карте Краљевине Србије (1886, 1887, 1893) и *Геологија Србије*, први и други део (*Топографска геологија*, 1893; *Еруптивне стене*, 1900). У овој обимној монографији описан је геолошки састав терена Србије по географским областима и геолошким формацијама, односно приказани су сви резултати о регионалној геологији српских планина. На овај начин Србија је ушла у мали број европских земаља које су геолошки биле проучене у XIX веку. У другом делу, који представља допуну и потврду геологије приказане у првом делу, Жујовић је дао детаљни макроскопски опис свих тада познатих еруптивних стена Србије, као и њихову класификацију.

У студији *Ламирофири у Србији* (1888) Жујовић је описао лампрофире, жичне стене из околине Београда и високе Шумадије (Рипањ, Ресник, Пиносава, Бањица, планина Рудник), дајући њихове минералошке и структурне особине.

Добар организатор и далековид у сагледавању научних потреба, он је за кратко време ишколовао младе сараднике, слао их на специјализације у европске центре и припремио их за нове дисциплине. Затим је извршио велике организационе промене на Великој школи које су се, свакако, одразиле и на научни развој. Већ 1889. године одвојио је посебну Катедру за минералогију и петрографију, којом је руководио његов ученик Сава Урошевић, а 1891. издвојио је и Катедру за палеонтологију, којом је руководио његов ученик Светолик Радовановић. Тако су се после његових прегледних, обухватних и детаљних радова убрзо појавили радови његових ученика који су се односили на специјалне петрографске, палеонтолошке, тектонске студије о појединим областима или формацијама.

Међу његовим ученицима најзначајнији су Јован Цвијић, Димитрије Антула, Алекса Станојевић, Сава Урошевић, Јеленко Михаиловић, Владимир Петковић, Михаило Живковић, Цветко Поповић, Светолик Радовановић, Живко Јоксимовић, Милан Петковић, Светолик Стевановић, Милош Динић. Са њим су сарађивали и рударски стручњаци који су резултате својих радова саопштавали у Српском геолошком друштву или у Семинару Катедре геологије.

Светолик Радовановић (1863—1928),[12] заједно са Савом Урошевићем и Петром Павловићем, припада првој генерацији Жујовићевих ђака. Најпре је радио као државни геолог, а 1897. изабран је за професора Велике школе. Бавио се фундаменталним и примењеним геолошким истраживањима. Његова докторска дисертација одбрањена у Бечу 1891, уједно његов први рад из геологије и палеонтологије, јесте стратиграфска и палеонтолошка студија лијаса код Рготине у источној Србији. И касније је испитивао уске стратиграфске јединице, као што је лијас код Добре на Дунаву, догер и келовеј у околини Црнајке и Вршке чуке, један нови белемнит из Црнајке и са Гребена и др. Поред стратиграфских детаља, његови радови садрже и палеонтолошке описе фосила које је открио и сакупљао у истраживаним локалитетима. Ови радови, као и први описи терцијарних фосила П. Павловића, представљају почетке развоја палеонтологије.

Због издвајања меотског ката и слатководне горње олигоценске творевине, као и још неких тектонских чињеница које подржавају могућност постојања великих навлака (шаријажа) у пределима источне Србије, С. Радовановић је прихватао теорију шаријажа и први пут је применио (по узору на румунског геолога Г. Мургочија) у тумачењу тектонског склопа источне Србије. Радовановић је обраћао посебну пажњу на угљоносне терене у тим областима, класификовао их је и утврдио да су различите геолошке старости. Дао је и прву класификацију минералних вода у Србији.

Мада спада у наше најзначајније геологе, није објавио много радова: две монографије (једна са П. Павловићем) и два рада у издању Српске краљевске академије, 10 радова у *Геолошким аналима Балканског полуострва*, један рад у француском часопису (као и 37 саопштења у Српском геолошком друштву, штампаних у *Записницима Српског геолошког друштва*).

[12] Александар Грубић, *Светолик Радовановић*, у: *Живот и дело српских научника*, Књига 2, 1977, 105—149.

Петар Павловић (1864—1938),[13] гимназијски професор, дугогодишњи управник Природњачког музеја, кустос Геолошког завода и асистент за палеонтологију, био је геолог и палеозоолог. Највећи допринос дао је у уским областима палеонтологије и геологије уопште. Бавио се пионирским истраживањима фосилне и рецентне фауне и описао већи број нових таксона и одредио им научне називе.

Систематски је сакупљао и проучавао пужеве и начинио збирку са 450 локалитета у Србији и Македонији која садржи 183 врсте. На основу проучавања те колекције објавио је два обимнија рада (1911. и 1912) у којима је описао 10 нових врста, пет варијетета и једну нову форму. Затим је 1913. године описао један нови савремени род са новом типском врстом. Највећи допринос дао је познавању малакофауне, обогативши је са 75 врста нових за Србију.

У палеонтологији описао је три нове врсте фораминифера, 57 каспибракичних врста мекушаца из панонског ката и 87 слатководних језерских врста мекушаца.

Поред великог броја саопштења у *Записницима Српског геолошког друштва*, до Првог светског рата објавио је тридесетак радова, највећи број у *Геолошким аналима Балканског полуострва* и шест у издањима Академије наука.

Димитрије Антула (1870—1924),[14] поред рада на примењеној и рудничкој геологији, обавио је биостратиграфска проучавања формација јуре и креде. Он је радове објављивао на немачком језику, у издањима бечких институција. Нарочито су значајни његови радови о развићу кредних творевина на Кавказу.

По упутствима Жујовића проблемима специјалних грана геологије бавили су се В. Петковић (радови на проучавању доње и горње креде источне Србије), А. Станојевић, М. Петковић и др.

Сава Урошевић (1863—1930)[15] највише се бавио петрографијом, и то гранита и кристаластих шкриљаца. Проучио је скоро све гранитоидне масиве у Србији, контактно-метаморфне промене које су гранитоиди изазвали на околним стенама, многе кристаласте шкриљце и неке ретке минерале.

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[13] Никола Пантић, Војислав Васић, *Петар С. Павловић*, у: *Живот и дело српских научника*, Књига 2, 1977, 151—207; Гордана Јовановић, *Значај терцијарне збирке Петра Павловића*, у: *Природне и математичке науке у Срба 1850—1918*, Нови Сад, 2001, 109—115.

[14] Александар Грубић: *Димитрије Антула*, у: *Живот и дело српских научника*, САНУ, Књига 7, 2001, 121—168.

[15] Видојко Јовић, Јован Карамата, *Сава Урошевић*, у: *Живот и дело српских научника*, Књига 4, 1998, 67—90.

У првим радовима о петрографији Цера (1899), Венчаца, Букуље, Вагана (1900) и Борање (1903) приказао је особине гранитоида на овим планинама и, нарочито детаљно, контактно-метаморфне појаве изазване гранитоидном интрузијом. Затим је истраживао контактно-метаморфне појаве на Копаонику (1908). Испитивања је проширио на североисточну Србију, Поречко-печку, Текијску и Сипску област (1909). Касније је испитивао кристаласте шкриљце и граните Црног врха, Јухора (1911, 1912), Сталаћких брда, Ђуниских висова, Буковика, Рожња и Јастрепца (радове објавио после рата). У Жујовићевој *Геологији Србије* написао је поглавље о гранитоидима и серпентинима у Србији.

У приступној академској беседи дао је синтезу свог вишегодишњег рада и изложио модерно схватање о постанку метаморфних стена и кристаластих шкриљаца (1911).

Обилазећи руднике у Србији нашао је многе минерале непознате код нас. Испитујући оптичке особине петрогених минерала у поларизационом микроскопу (1889) проучио је и описао „продорне близанце" код биотита из гранит-порфира у Џепу и андезита из Брестовачке Бање (1897) и назвао их „српским близанцима".

До Првог светског рата објавио је петнаестак радова, и то пет у издањима Академије наука, два у немачком часопису и девет у *Геолошким аналима Балканског полуострва*. Такође, има већи број саопштења у *Записницима Српског геолошког друштва.*

Осим С. Урошевића, и С. Стевановић је кристалографски проучавао неке минерале са наших терена, М. Петковић је проучавао стене Шар-планине и геологију крушевачког басена и обода, М. Динић је проучавао вулканске стене из околине Софије и кристаласте шкриљце Балкана, а А. Станојевић је испитивао еруптивне стене Рајца, бигра из Градашнице.[16]

Светолик Стевановић (1869—1953)[16a] први се бавио кристалографским испитивањима минерала. Објавио је десетак радова из минералогије и кристалографије у немачким часописима, већину пре Првог светског рата.

Владимир Петковић (1873—1935),[17] први геолог који је докторирао на Београдском универзитету 1908, бавио се стратиграфским, тектонским

16 Александар Грубић, *Геологија у Србији током друге половине XIX века*, у: *Наука и техника у Србији друге половине XIX века 1854—1904*, Крагујевац, 1996, 82—83.

16a Видојко Јовић, *Светолик П. Стевановић*, у: *Живот и дело српских научника*, Књига 8, 2002, 107—127.

17 Предраг Николић, *Владимир К. Петковић*, у: *Живот и дело српских научника*, Књига 3, 1998, 375—415.

и палеонтолошким проблемима, посебно изучавањем кредних формација. У докторској тези бавио се геолошким проблемима Тупижнице, а касније је рад проширио на друге терене источне Србије. Пред Први светски рат у раду *Голт у Србији* (1913) дао је синтезу теренских, упоредних проучавања више локалитета у Србији. Од тридесетак радова (25 радова, две монографије и 7 листова геолошких карата, 1903—1935), до Првог светског рата објавио је шест радова (два у *Геолошким аналима Балканског полуострва*, два у издањима Академије наука, један у *Гласнику Српског географског друштва* и један у оквиру Цвијићеве студије).

Прва минералошка истраживања обављали су и хемичари. *Сима Лозанић* (1847—1935)[18] анализирао је и описао нови минерал *авалит* (1884), а десет година касније анализирао и извео хемијске формуле за минерале *милошин* и *александролит*. Фотографским огледима испитивао је радиоактивност минерала у Србији и утврдио да само живине руде са Авале имају радиоактивне примесе. *Милорад Јовичић* (1868—1937)[19] анализирао је и описао минерале хрома и титана и на основу хемијског састава дефинисао нову руду хрома *хромитит*. Јовичић је описао и појаве молибдена и хрома у Србији.

У области геохемије Сима Лозанић је анализирао београдске пијаће воде и минералне воде српских бања, а касније су тај рад наставили *Марко Леко* (1853—1932),[20] Марко Николић и Александар Зега (1860—1926).[21] У неким случајевима је утврђена радиоактивност вода (Леко, 1911), чак у београдском водоводу, што је Леко повезао с вулканским стенама на Авали и радиоактивношћу авалског цинабарита. Леко је утврдио и радиоактивност терми Нишке Бање, Рибарске Бање, а нарочито Сокобање (присуство радиоактивних еманација).

У хемијској лабораторији Велике школе анализе минерала, руда и минералних вода обављали су Сима Лозанић, Милорад Јовичић, Петар Илић, Михаило Благојевић, а у Државној хемијској лабораторији Марко Леко, Александар Зега, Бранко Ановић, Марко Николић, Радомир Мајсторовић, Н. Прљевић и др.[22]

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[18] Снежана Бојовић, *Сима Лозанић*, у: *Живот и дело српских научника*, Књига 1, 1996, 199—261.

[19] С. Бојовић, *Милорад Јовичић*, у: *Живот и дело српских научника*, Књига 2, 1997, 371—396.

[20] С. Бојовић, *Марко Леко*, у: *Живот и дело српских научника*, Књига 4, 1998, 33—65.

[21] С. Бојовић, *Александар Зега (1860—1926)*, у: *Живот и дело српских научника*, Књига 3, САНУ, 1998.

[22] С. Бојовић, *Историја хемије у Србији до Другог светског рата*, у: *Хемија и хемијска индустрија у Србији*, СХД, Београд, 1997, 1—72.

МЕТЕОРОЛОГИЈА

Године 1848. *Владимир Јакшић* (1824—1899),[23] вративши се са школовања из Аустрије и Немачке, почео је у својој кући на Сењаку да врши свакодневна мерења температуре ваздуха, затим дневне количине падавина и, најзад, климатске карактеристике. Ова мерења обављао је пуне 52 године, све до краја живота 1899. године. Прве резултате рада објавио је већ 1851. у *Гласнику Друштва српске словесности*, а затим наставио да објављује резултате (1851—1856). У својим дневницима осматрања, климатолошким и статистичким радовима, Јакшић је оставио драгоцене белешке о климатским, фенолошким и хидролошким појавама. Оставио је прве податке о колебању нивоа реке Саве код Београда. Такође се трудио да приносе у пољопривреди доведе у везу с метеоролошким чиниоцима и указивао је на значај метеорологије за пољопривреду и друге делатности, и већ тада установио основне црте наше климе.

Поред мерења у Београду, Јакшић је организовао метеоролошке станице и по другим местима. Године 1857. у Србији је радило 27 метеоролошких станица, а осматрачи су били учитељи. Претпоставља се да је тада то била најгушћа метеоролошка мрежа у Европи. Инструменте постављене на станицама Јакшић је набавио од бечког Централног метеоролошког завода, који је тада располагао најбољим метеоролошким инструментима у средњој Европи. Јакшић је написао и упутства за рад на станицама и то је било прво тимско експериментално истраживање изведено у Србији. Оригиналне књиге Јакшићевих мерења и осматрања чувају се у Хидрометеоролошком заводу Србије.

Објавио је више радова из климатологије и статистике у *Гласнику СУД* у којима је описао основне особине времена и климе у Србији. Његовим одласком на другу дужност полако се ова мрежа гасила и пропадала.

Четврт века касније, пионирски рад Владимира Јакшића наставио је *Милан Недељковић*.[24]

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[23] Федор Месингер, *Метеорологија у 100 година активности Српске академије наука и уметности*, САНУ, 1989, 55—63; Наталија Јанц, *Владимир Јакшић — оснивач метеоролошких станица у обновљеној Србији*, у: *Пола века науке и технике у обновљеној Србији 1804—1854*, Крагујевац, 1996, 169—178; Милан Димитријевић, *Астрономија и физика у Срба у 18. и првој половини 19. века*, у: *Природне и математичке науке у Срба у 18. и у првој половини 19. века*, Нови Сад, 1995, 31.

[24] Исто; Љерка Опра, *Милан Недељковић*, у: *Живот и дело српских научника*, Књига 3, 1998, 131—174; Милорад Ђокић, *Оснивање и прве године рада Опсерваторије Велике школе у Београду*, у: *Наука и техника у Србији друге половине XIX века*, Крагујевац, 1998, 133—148: Наталија Јанц, *Развој метеоролошке службе у Србији током друге половине 19. века*, у: *Наука и техника у Србији друге половине XIX века*, Крагујевац, 1998, 166—178; Милан

Милан Недељковић (1857—1950) као државни стипендиста у Француској студирао је астрономију и физику (метеорологију), а затим радио неколико година у водећим француским астрономским и метеоролошким установама. На Великој школи је од 1884. предавао метеорологију и астрономију. Његовим залагањем основана је за Велику школу Опсерваторија за астрономију и метеорологију 1887 (привремена), односно 1891 (стална). Тако је Катедра за астрономију и метеорологију добила своју радионицу — истраживачки центар и створени су услови и за скромни астрономски рад. Међутим, Недељковић се посветио метеорологији, а Опсерваторија је служила само за метеоролошка испитивања.

Недељковић је проширио метеоролошку мрежу Србије на више од 200 станица. Из Париза и Берлина набавио је комплетан прибор за 12 станица и издао Метеоролошка упутства за мерења.

Почетком 1902. почео је са специјалним мерењима температуре тла до дубине од 24 метра и микроклиматског слоја ваздуха до висине од 2 метра изнад Земљине површине. Ова мерења су обављана на 34 разна нивоа и далеко су превазилазила оквире и најбоље вођених метеоролошких опсерваторија у свету.

Године 1907. за доцента за климатологију и метеорологију на Универзитету у Београду изабран је *Павле Вујевић* (1881—1966).[25] Он је студирао и докторирао у Бечу, а затим је на Универзитету у Берлину и Метеоролошкој опсерваторији у Потсдаму употпунио своја знања из метеорологије.

На основу резултата осматрања вршених под руководством Недељковића Вујевић је написао неколико радова о топлотном стању тла и из области температуре најнижих слојева ваздуха. Ти радови су постали класични у савременој метеоролошкој литератури.

У својим првим радовима обрадио је и анализирао Недељковићева мерења и дао је приказ и објашњења за неколико значајних микроклиматских појава. Затим је за Међународну географску унију скупио и објавио 293 записа из црквених и других рукописа о времену у нашим и суседним крајевима у периоду од XIV до XIX века.

Павле Вујевић је дао значајне прилоге хидрографији, нарочито студијом о Тиси. Проучавао је крупне климатске промене у Србији, па и на

Димитријевић, *Астрономија у Срба 1850—1918*, у: *Природне и математичке науке у Срба 1850—1918*, Нови Сад, 2001, 61—64; Ђуро Радиновић и Федор Месингер, *Метеорологија, Природно-математичке науке данас и у будућности*, САНУ, ПМФ, Београд, 1989, 65—87.

[25] Томислав Ракићевић, *Павле Вујевић*, у: *Живот и дело српских научника*, Књига 4, 1998, 139—174; Љерка Опра, *Павле Вујевић — први европски хидролог и балкански климатолог*, у: *Природне и математичке науке у Срба 1850—1918*, Нови Сад, 2001, 199—209.

целом Балканском полуострву. Испитивао је и утицаје околних мора на топлотне прилике у унутрашњости полуострва, посебно у Македонији.

ГЕОГРАФСКЕ НАУКЕ

Све до XIX века географско познавање српских земаља било је оскудно, мада су велике силе биле заинтересоване за ове терене. У првој половини XIX века објављено је више аустријских карата и списа; Вук Караџић је приказао неке делове земље, у *Гласнику Друштва српске словесности* изашло је тридесетак прилога са описима мањих локалитета, али је све то било непотпуно, често с пуно нетачности, јер су аутори или били нестручни или нису довољно познавали земљу. У другој половини века објављене су две веће монографије о Србији (М. Милићевића 1876. и В. Карића 1888), али и то су били само описи и констатовање појединих географских чињеница и појава.[26]

Мада је географија била важна дисциплина, зато што је требало Европу упознати са Србијом и њеним народом, а истовремено становницима Србије пружити основна знања о земљи и њеном положају на Балканском полуострву, географија није предавана на Великој школи и њом су се све до појаве Јована Цвијића углавном бавили аматери (писци, лекари, војна лица).

Доласком *Јована Цвијића* (1865—1927) на Велику школу 1893. географија је веома брзо постала једна од најразвијенијих наука, а он, по мишљењу многих, најзначајнији наш научник. За кратко време саставио је програм будућих комплексних истраживања, окупио и обучио сараднике, основао институције, покренуо публикације. За најталентованије ученике организовао је семинар, односно допунске студије (данашњим језиком речено последипломске студије), где је обучавао младе људе и уводио их у научни рад, поучавао их у писању радова и подстицао их да објављују резултате свог истраживачког рада. Радови су објављивани у *Српском етнографском зборнику* Српске краљевске академије.[27]

[26] Душан Дукић, *Развој географских наука у САНУ (1886—1984)*, САНУ, 1989, 204—249; Томислав Ракићевић, *Заснивање географије као науке о обновљеној Србији*, у: *Пола века науке и технике у обновљеној Србији 1804—1894*, Крагујевац, 1996, 444—455; Томислав Ракићевић, *Географска наука у Србији друге половине XIX века*, у: *Наука и техника у Србији друге половине XIX века*, Крагујевац, 1998, 566—576; Томислав Ракићевић, *Географија у Срба у 18. и првој половини 19. века*, у: *Природне и математичке науке у Срба у 18. и првој половини 19. века*, Нови Сад, 1995, 99—109; Милорад Васовић, *Стање и перспективе наше географије*, у: *Природно-математичке науке данас и у будућности*, САНУ, ПМФ, Београд, 1989, 119—131.

[27] Милорад Васовић, *Јован Цвијић*, у: *Живот и дело српских научника*, Књига 2, 1997, 235—322.

Већ својом докторском тезом у којој се бавио морфологијом краса Цвијић је признат у европској науци. У области краса (или карста) извршио је детаљну класификацију површинских крашких облика (шкрапа, вртача, увала и поља насталих растварањем кречњачких стена, па и дејством тектонских покрета). Цвијићеве карстолошке студије имале су велики утицај у европској науци, па су српски изрази увала, поље, хум, понор и други прихваћени као општи научни термини. Већину резултата из области краса изложио је још 1893. у студији *Das Karstphänomen*, која се и данас сматра значајним делом светске карстологије. У низу других радова разматрао је постанак и развитак наших крашких поља, подземну хидрографију и типове кречњачких терена, постављајући низ нових и оригиналних принципа.

И у област глацијације унео је значајне новине. Пре њега се тврдило да на балканским планинама није постојало ледено доба. Међутим, Цвијић је још 1896. године открио глацијалне трагове на бугарској планини Рили. Затим је наставио истраживања на планинама Босне и Херцеговине, Црне Горе, Македоније, Грчке и Румуније, где је такође нашао трагове глацијације. На основу тих истраживања објавио је више радова (*Трагови старих глечера на Рили*, 1897; *Глацијалне и морфолошке студије о планинама Босне, Херцеговине и Црне Горе*, 1899; *L'époque glaciaire dans la Péninsule des Balkans*, 1900).

Током седмогодишњег истраживања по Грчкој, Македонији, Бугарској и Старој Србији дошао је до закључака о постанку планина на Балкану на основу којих је издвојио посебне планинске системе (*Die tektonische Vorgänge in der Rodopenmasse*, *Die dinarische Scharung*, *Структура и подела Балканског полуострва*, 1901, 1902).

На путовањима по Балканском полуострву Цвијић је прикупио податке на основу којих је засновао хипотезу о Панонском језеру и његовом отицању преко Ђердапа на исток. Уз то је установио да су у неогену постојала многобројна језера по котлинама средишњих и јужних делова полуострва која су отекла у Егејско море Вардаром као средишном одводницом.

Цвијићево добро познавање природних наука, али и радознали дух и научничка оштроумност омогућили су му да споји природне и друштвене науке. Обилазећи пешице или на коњу Србију и околне земље он је запажао и објашњавао појаве које нико до тада није на тај начин обједињавао и синтезом физичких и друштвених елемената и појава засновао је антропогеографију као науку. Из ове области објавио је низ радова у којима је разматрао културне зоне, географски распоред и миграције становништва, облике привредног живота, положај и типове насеља, типове кућа и етнопсихичке особине Јужних Словена.

Почетком XX века почео је припреме за писање великих синтетичких студија из геоморфологије и антропогеографије које је објавио после рата.

Како је Цвијић неговао и физичку географију (посебно геоморфологију) и антропогеографију, своје ученике је и усмеравао на те две области. Тако су се Петар Јанковић, Михаило Богићевић и Сима Милојевић определили за геоморфологију, Јован Ердељановић, Светозар Томић, Радомир Илић, Тодор Радивојевић, Михаило Драгић, Боривоје Дробњаковић, Петар Шобајић и Шпиро Солдо за антропогеографију (касније Ердељановић и Дробњаковић за етнологију), Драгутин Дероко и Радоје Дединац за картографију, а Антоније Лазић за картографско илустровање.[28]

У Географском заводу су једанпут недељно одржавани семинари на којима је Цвијић својим ученицима давао упутства за научно-истраживачки рад и на којима су они саопштавали резултате својих истраживања на терену о којима се затим дискутовало. Цвијић је имао много сарадника и у народу. На основу његових штампаних упутстава бистри и способни појединци из читаве Србије и Црне Горе, делом и из Босне и Херцеговине и Македоније, прикупљали су и слали му податке о становништву, привреди, насељима.

У периоду 1894—1908. Цвијић је издао пет свезака првог географског часописа на Балканском полуострву *Преглед географске литературе о Балканском полуострву*. Године 1910. основао је Српско географско друштво које од 1912. издаје свој *Гласник* и друга издања.

ХЕМИЈСКЕ НАУКЕ[29]

Михаило Рашковић (1827—1872), наш први хемичар и професор на Лицеју и Великој школи, средином педесетих година основао је и добро опремио хемијску лабораторију у којој се бавио примењеном хемијом.

Из ове лабораторије, коју је наследио *Сима Лозанић* (1847—1935) 1872. године, потекли су Лозанићеви научни радови из скоро свих обла-

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[28] Милорад Васовић, *Јован Цвијић*, 249.

[29] Хемија није разматрана у већој мери јер је аутор о хемијској науци већ писао на основу критеријума примењених у овој студији. О хемијској науци видети у: С. Бојовић, *Хемија у Србији у 19. веку*, Научна књига, Београд, 1989; С. Бојовић, *Сима Лозанић*, Принцип, Београд, 1996; С. Бојовић, *Сима Лозанић*, у: *Живот и дело српских научника*, Књига 1, 1996, 199—261; С. Бојовић, *Милорад Јовичић*, у: *Живот и дело српских научника*, Књига 2, 1997, 371—396; С. Бојовић, *Марко Леко*, у: *Живот и дело српских научника*, Књига 4, 1998, 33—65; С. Бојовић, *Михаило Рашковић (1827—1872)*, у: *Живот и дело српских научника*, Књига 1, 1996, 65—96.

сти хемије, пре свега из органске хемије и електрохемије. До Првог светског рата објавио је више од 50 научних радова у водећим европским часописима. Неки од тих радова се и данас цитирају.

Лозанић је први научник у Србији који се бавио истраживањима која нису имала непосредне користи за земљу, којима наша интелектуална јавност није била наклоњена и није им придавала велики значај. У нашој средини Лозанић је био познат по својим анализама минералних и пијаћих вода, агрикултурним радовима, анализама минерала, руда и метеорита. Његови научни радови имали су мало одјека међу његовим савременицима, иако су оставили видног трага у европској науци.

Други значајан хемичар *Марко Леко* (1853—1932) до доласка у Србију објавио је неколико радова из органске хемије значајних за структурну теорију, који се наводе у историјама хемије. Али, по доласку у београдску Државну хемијску лабораторију окренуо се примењеној хемији и објављивао радове у часописима за примењену хемију. Неке његове аналитичке методе ушле су у немачке уџбенике и приручнике.

Милорад Јовичић (1868—1937), ђак Симе Лозанића, објавио је око стотину радова из органске и неорганске хемије, углавном у страним часописима. Неки од његових радова дуго су цитирани, али је Јовичић више био познат и признат у иностранству него у земљи.

МАТЕМАТИЧКЕ НАУКЕ

Математика је континуирано предавана на Лицеју, касније Великој школи, од самог оснивања. Први професор математике, Атанасије Николић, написао је и прве уџбенике математике, био је и председник Друштва српске словесности, али је сматрао да се не треба посвећивати научном раду и губити време бавећи се некорисним стварима.[30]

Први квалификовани наставник математике Коста Алковић предавао је тридесет година математику, али се није бавио науком.[31]

[30] Миодраг Томић, *Математичке науке*, у: *Српска академија наука и уметности и развој науке и уметности у Срба*, Књига 1, Стогодишњица Српске академије наука и уметности 1886—1986, Београд, 1999 (даље: САНУ, 1999) 13—35; Јован Кечкић, *Математички уџбеници Атанасија Николића*, у: *Пола века науке и технике у обновљеној Србији 1804—1854*, Крагујевац, 1996, 217—227; Павле Перишић, *Математика у обновљеној Србији*, у: *Пола века науке и технике у обновљеној Србији 1804—1854*, Крагујевац, 1996, 386—404; Милена Јовановић, *Атанасије Николић као парадигма*, у: *Природне и математичке науке у Срба 1850—1918*, Нови Сад, 2001, 115—123; Милоје Сарић, Зора Сарић, *Атанасије Николић*, у: *Живот и дело српских научника*, Књига 7, 2001, 1—27.

[31] Катица (Стевановић) Хедрих, *Константин Коста Алковић*, у: *Живот и дело српских научника*, Књига 3, 1998, 33—70.

Прву математичку расправу у *Гласнику Српског ученог друштва* објавио је инжењер Димитрије Стојановић 1869. године. Ова, као и још две касније расправе (1870, 1878) нису оригинални научни радови већ се у њима расправља о објављеним резултатима.[32] Седамдесетих и осамдесетих година још неколико расправа објавили су Љубомир Клерић (1874, 1877), Димитрије Нешић (1878, 1882, 1883, 1885, 1888) и Петар Живковић (1883, 1884, 1885, 1889. и касније), без већег значаја и без научних резултата јер су били „ван тока математичке науке онога доба".[33]

Димитрије Нешић (1836—1904), школован у Бечу и Карлсруеу, предавао је математику на Великој школи више од 30 година (1862—1894). За то време објавио је десет расправа у *Гласнику СУД* и *Гласу СКА*, углавном из математичке анализе (1878—1892); последњих неколико радова су нешто веће вредности него претходни, али и они без оригиналних резултата. Сви радови штампани су само на српском језику.[34]

Петар Живковић (1847—1924), гимназијски професор, школован на Политехничкој школи у Цириху (математика, механика и физика), у *Гласнику СУД* и *Гласу СКА* објавио је укупно десет радова, до Првог светског рата седам (1883—1898). Бавио се релативно елементарним питањима из области синтетичке, аналитичке и елементарне диференцијалне геометрије. Радови су објављени само на нашем језику и нису имали већег одјека у јавности.[35]

Богдан Гавриловић (1863—1947) изабран је за професора Велике школе 1887. године. Студирао је и докторирао у Будимпешти, а усавршавао се на универзитетима у Немачкој, Швајцарској и Француској. Објављивао је радове из алгебре, геометрије и теорије функција. У оквиру алгебарских истраживања бавио се комбинаториком, теоријом бројева и линеарном алгебром. Надовезивао се на радове најпознатијих математичара и за рад бирао актуелне теме. Међутим, сви радови су објављени на српском језику, па су тако остали непознати страној јавности, а нису оставили великог трага ни у београдској математичкој школи. Радове је објавио у кратком временском периоду од седам година (1900—1907). До Првог светског рата, уз тезу и две књиге, објавио је још 15 радова (три у *Раду ЈАЗУ* и 12 у *Гласу СКА*).[36]

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[32] Миодраг Томић, *Математичке науке*, 14.

[33] Миодраг Томић, *Математичке науке*, у: *Српска академија наука и уметности и развој науке и уметности у Срба*, САНУ, Београд, 1989, 14.

[34] Бошко Јовановић, Јеленка Петковић, *Димитрије Нешић*, у: *Живот и дело српских научника*, Књига 3, 1998, 1—31.

[35] Душан Адамовић, *Петар Живковић*, у: *Живот и дело српских научника*, Књига 1, 1996, 181—196.

[36] Жарко Мијајловић, *Богдан Гавриловић*, у: *Живот и дело српских научника*, Књига 2, 1997, 71—102.

Тек доласком *Михаила Пешровића* (1868—1943)[37] почео је развој математике као науке. Петровић је најплоднији, најразноврснији и најоригиналнији наш математичар, први математичар чији су радови имали одјека у европској јавности. Бавио се разноврсним областима и своје радове објављивао је у страним часописима.

Углавном се бавио класичном анализом (у оно време то је била модерна анализа) која се може разврстати у диференцијалне једначине, теорије функција и алгебру (интегрални и диференцијални рачун).

Петровић се школовао на Сорбони, код најпознатијих математичара оног времена који су се бавили класичном анализом. Као ђак те школе, Петровић је наставио да се бави истом проблематиком, али због њене завршне фазе и његови резултати, иако добри и креативни, пре су се надовезивали на постојеће радове него што су у већој мери отварали нове проблеме.

Петровићеве оригиналне математичке дисциплине остале су без већег утицаја, јер ни феноменологија ни теорија спектара нису озбиљније заинтересовале математичаре. У сваком броју *Гласа СКА* налазило се по неколико његових радова које је већ објавио у иностранству, што је у оно време било уобичајено.

Већ резултати његове докторске тезе, објављене на Сорбони 1894. и штампани као посебан рад (*Comptes rendus*, 118, 1894), који се односе на диференцијалне једначине, били су запажени и ушли су у познати уџбеник Е. Пикара (E. Picard, *Traité d'Analyse III*, Paris, 1896).

Петровић није имао стрпљења за дужи и систематичнији рад. Отварао је проблеме, али се на њима није дуго задржавао, нестрпљиво је прелазио на нове, остављајући другима да их даље решавају и уопштавају. Тако и његов први рад, који он није дубље разрађивао, био је предмет проучавања многих математичара и касније је решен у општем случају.

Област рада у којој се највише задржао јесте теорија диференцијалних једначина. Из тог периода најзначајнија је његова монографија *Intégration qualitative des équations differentielles*, објављена у француском часопису у Паризу (*Mémorial des Sciences mathématiques*, Paris, 1931), у којој су садржани најважнији резултати о проблемима диференцијалних једначина. Петровићев рад о сингуларним решењима диференцијалних једначина првог реда наводи се у неколико књига и уџбеника.

У области теорија функција постигао је најзначајније резултате, пре свега по оригиналним идејама и доказима, резултатима изведеним на

[37] Јован Кечкић, *Михаило Пешровић Алас*, у: *Живош и дело срūских научника*, Књига 2, 1997, 325—370.

једноставан и елегантан начин. Увео је више нових специјалних функција које имају разне примене у анализи, посебно приликом описивања решења неких класа диференцијалних једначина. И ове Петровићеве радове допуњавали су, проширивали и уопштавали познати математичари.

Петровић је покушао да заснује две нове математичке дисциплине: математичку феноменологију и нумеричке спектре. Почетком XX века почео је да размишља о применама математичких принципа на многобројне природне феномене. То је почетак његове математичке феноменологије којој је посветио велики део своје научне активности. У књизи *Елементи математичке феноменологије* (1911) поставио је основе нове научне дисциплине — опште феноменологије и, посебно, математичке феноменологије.

Иза њега је остало укупно 527 библиографских јединица, односно 393 рада, не рачунајући поновљена објављивања. Од укупно 257 радова, око 200 су научни, од тога је око 60 објављено до Првог светског рата. Као што је већ поменуто, већину радова је објављивао и у страним и у нашим часописима.

Петровић је учествовао на међународним конгресима (око 40), његове радове цитирали су највећи ондашњи математичари, сарађивао је са страним научницима, био је члан више страних академија наука и великог броја научних друштава.

Кроз семинаре учио је своје ђаке да се служе литературом (снабдевао је библиотеку актуелним часописима) и најбоље међу њима уводио у научни рад, чиме је отпочео стварање математичке школе. До Првог светског рата код М. Петровића су одбрањена два доктората: Младен Берић (1912) и Сима Марковић (1913). Тако је он на време припремио своје наследнике (игром случаја обојица су рано напустили Универзитет).

ФИЗИЧКЕ НАУКЕ

Као и математика, и физика је предавана на Лицеју од 1839. године. Први професори били су добро образовани интелектуалци, али неквалификовани физичари. Први, донекле стручан професор Коста Алковић (1836—1909) завршио је Политехнику у Бечу, али за тридесет година рада на Великој школи (1862—1892) није објавио ниједан научни рад. Тако се физика рано развила као школска дисциплина, написани су уџбеници и основан физички кабинет, али наука се није развијала.

Ђорђе Станојевић (1858—1921), школован у Берлину и Паризу, пре доласка на Велику школу радио је у астрофизичким лабораторијама у Немачкој и Француској и објавио је неколико радова из астрофизике

По доласку на Велику школу за професора експерименталне физике (1893) покушао је да објави астрофизичке радове у Академији наука, али су радови одбијени. Тиме је углавном престало његово интересовање за фундаменталну науку. У области физике „практиковао је огледе из фотографије, оптике и високофреквентних струја". Бавио се физиолошком фотометријом и централним силама у природи.[38]

Стеван Марковић (1860—1945), први доктор физичких наука код нас, није се бавио науком.[39]

Милорад Поповић је објавио неколико радова из физике.

МЕХАНИКА

Љубомир Клерић (1844—1910), рударски инжењер и први професор теоријске механике, седамдесетих и осамдесетих година објавио је прве радове из механике у *Гласнику СУД*.

Штампао је тридесетак радова, углавном у издањима Академије наука, највише из кинематике, неколико из статике, а има и описа конструкција разних инструмената за математику и механику.[40]

Од 1889. године рационалну механику предавао је Мијалко Ћирић, али се није бавио научним радом.

Неколико радова објавио је почетком XX века Коста Стојановић.[40]

Пред избијање балканских ратова на Универзитету је почео да предаје *Милутин Миланковић* (1879—1958), инжењер, механичар, математичар, астроном и геофизичар. На Техничкој великој школи у Бечу студирао је грађевинску технику и докторирао 1904 (први Србин који је стекао докторат техничких наука). У првим радовима објављеним у Бечу извео је основне једначине за одређивање арматуре бетонских носача, а од 1911. почео се интересовати за проблеме соларних климатских утица-

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[38] Стеван Коички, *Развој физике код Срба*, САНУ, 1989, 63—74; Милан Димитријевић, *Астрономија у Срба 1850—1918*, у: *Природне и математичке науке у Срба 1850—1918*, Нови Сад, 2001, 64—67; Марија Шешић, Петар Миљанић, *Живот и дело Ђорђа М. Станојевића — астроном, физичар, електроинжењер*, у: *Природне и математичке науке у Срба 1850—1918*, Нови Сад, 2001, 271—285; Марија Шешић, Петар Миљанић, *Ђорђе Станојевић*, у: *Живот и дело српских научника*, САНУ, Књига 7, 2001, 29—67.

[39] Ђорђе Мушицки, *Развој физике на Великој школи у Београду и почеци наставе теоријске физике*, у: *Развој и техника у Србији друге половине XIX века*, Крагујевац, 1998, 400—401.

[40] Катица (Стевановић) Хедрик, *Љубомир Клерић*, у: *Живот и дело српских научника*, Књига 1, 1996, 129—178; Татомир Анђелић, *Развој механике у оквиру САН*, САНУ, 1989; Александар Петровић, *Коста Стојановић*, у: *Живот и дело српских научника*, Књига 7, САНУ, 2001, 69—118.

јâ и температура на планетама и објављивао је радове из математике и механике, а пре свега геофизике и астрофизике.[41]

У исто време у Београд је дошао и Иван Арновљевић и почео да објављује радове на немачком језику.[42]

АСТРОНОМИЈА[43]

О раном интересу за астрономију, још средином XIX века, сведоче преводи астрономских чланака у часописима, календарима и посебним брошурама. Али, за развој ове научне дисциплине било је још рано, а, с друге стране, астрономски инструменти, нарочито опсерваторијски, били су веома скупи.

Милан Недељковић, који се углавном бавио метеорологијом, набавио је шест мањих инструмената положајне астрономије и два часовника, али, сем повремених и ретких одређивања тачног времена, другог астрономског рада није било.

Астрономски део триангулације земље, крајем XIX и почетком XX века, извела је војска.

Ђорђе Станојевић (1858—1921), као питомац Министарства војног, био је на специјализацији у неколико најпознатијих европских астрономских опсерваторија (Потсдам, Хамбург, Медон, Гринич, Кју, Пулково, 1883—1887) и учествовао у експедицијама, у Русији (1887) за посматрање потпуних Сунчевих помрачења, и Сахари (1889/90) за проучавање линија у спектру Земљине атмосфере. Његови први радови, објављени у издањима Париске академије наука, јесу из области астрофизике. То су уједно и његови једини радови из те области.

Прве радове из астрономије (небеске механике) у *Гласу СКА* објавио је 1909. године *Милутин Миланковић*. До Првог светског рата штампао је неколико радова из небеске механике и започео истраживања из астрономске климатологије, науке коју је он створио током наредних деценија и где је достигао светску славу.

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41 Никола Пантић, *Милутин Миланковић*, у: *Живот и дело српских научника*, Књига [illegible], САНУ, 2001, 171—223.

42 Наталија Наерловић-Вељковић, *Иван Арновљевић*, у: *Живот и дело српских научника*, Књига 2, 1997, 397—435.

43 Јован Симовљевић, *Астрономија у Српској академији наука и уметности*. САНУ 1989, 45—55; Драгутин Ђуровић, Мирјана Вукићевић Карабин, *Астрономија јуче, данас и сутра*, у: *Природно-математичке науке данас и у будућности* (приредили: Ж. Чековић и Ђурић), САНУ и ПМФ, Београд, 1989, 47—57.

ЗАКЉУЧАК

Због потребе упознавања рудног богатства у Србији су и пре 1853. године вршена геолошка истраживања (барон Хердер и Ами Буе), цртане географске карте, извођена метеоролошка мерења. У страним музејима постојале су колекције минерала и стена прикупљених од странаца који су првих деценија века пролазили кроз Србију, или од стручњака који су испитивали земљу на позив српских власти.

Педесетих година Панчић је започео ботаничка истраживања којима се бавио до краја живота (1888). Тај рад наставили су његови ђаци којих је било и на Великој школи и у средњим школама. Панчић је вршио и зоолошка, геолошка и минералошка истраживања, а достојно су га наследили Живојин Ђорђевић, Јован Жујовић и Сава Урошевић.

Географија, веома важна не само за Србију већ и за Европу, није се развијала као наука све до деведесетих година, до појаве Јована Цвијића. Међутим, он је за неколико година надокнадио све оно што је изостало у претходном периоду и почетком XX века Цвијић и српске земље били су већ добро познати научном свету Европе. Тако су ботаника, зоологија, геологија, минералогија, географија крајем XIX и почетком XX века биле развијене науке, имале су одговарајуће институције, стручна друштва, часописе, тимове истраживача.

Крајем четрдесетих година XIX века Владимир Јакшић почео је да се бави климатологијом Србије, а резултате свог рада објавио је педесетих година. Његов рад наставио је Милан Недељковић осамдесетих година.

Остале науке, физика, хемија, математика, астрономија, морале су да чекају настанак интелектуалне климе, долазак једног броја солидно образованих младих људи који су се трудили да научним радом подигну углед и значај Србије у свету.

Најпре се хемија развила као наука. Доласком Симе Лозанића на Велику школу 1872. настављен је развој примењене хемије, започет с М. Рашковићем 1853, али је врло брзо заснована и наука, зато што је Лозанић објављивао радове у нашим и страним часописима из свих области хемије.

Деведесетих година на Велику школу дошао је Михаило Петровић Алас. У првих десет година објавио је педесетак радова из различитих области математике у европским часописима и тиме уврстио Србију у земљу с развијеном математичком науком.

У исто време свој рад у Србији почео је физичар Ђорђе Станојевић. Мада је у Париској академији наука објавио неколико радова из астрономије, у Србији још није било разумевања за такву врсту истраживања и он је свој рад касније усмерио на индустријализацију и електрификацију земље. Тако су физика и астрономија биле једине области у којима у то време није било значајнијих научника.

Дакле, у XIX веку развијале су се науке важне за проучавање и упознавање земље, науке од којих је земља имала користи. Такве науке су подстицане, за њих је издвајан новац, ангажовани млади истраживачи, научници су добијали највећа признања и похвале. Осталим наукама није поклањана већа пажња, а и када је писано о научницима који су се бавили хемијом, астрономијом, физиком наглашаван је њихов рад у примењеним областима, а занемаривана фундаментална истраживања.

СРПСКА АКАДЕМИЈА НАУКА И УМЕТНОСТИ
ОГРАНАК У НОВОМ САДУ
ПРИРОДНО-МАТЕМАТИЧКИ ФАКУЛТЕТ У НОВОМ САДУ
МАТИЦА СРПСКА

Зборник радова научног скупа

ПРИРОДНЕ И МАТЕМАТИЧКЕ НАУКЕ У СРБА ДО 1918.

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ДОПРИНОС АТАНАСИЈА СТОЈКОВИЋА СТВАРАЊУ СРПСКЕ ТЕРМИНОЛОГИЈЕ У ФИЗИЦИ И ДРУГИМ ЕГЗАКТНИМ НАУКАМА

CONTRIBUTION OF ATANASIJE STOJKOVIĆ IN THE CREATION OF SERBIAN TERMINOLOGY IN PHYSICS, BUT ALSO IN OTHER EXACT SCIENCES

САЖЕТАК: Први аутори научних дела на језицима бројчано малих народа постају, имплицитно, и творци научне терминологије на дотичном језику. У овом раду покушаћемо да уочимо неке од доприноса Атанасија Стојковића, аутора првог уџбеника физике на (славено)српском језику, стварању српске терминологије у првом реду у физици, али и у другим егзактним наукама.

Кључне речи: Атанасије Стојковић, историја физике, научна терминологија

SUMMARY: The first authors of the scientific works on different languages corresponding to the smaller nations, automatically become the creators of the scientific terminology for the language spoken by the respective nation. In this paper we try to outline some of the contributions that Atanasije Stojkovic (the author of the first student book in Physics written in Slav-Serbian language) had in the creation of the Serbian terminology mainly in Physics, but also in other exact sciences.

Key words: Atanasije Stojkovic, history of Physics, scientific terminology

1. ПРИСТУП

Пре но што се прихватио писања првог уџбеника физике на (славено)српском језику,[1] Атанасије Стојковић се суочио са једним нимало лаким проблемом (специфичним свим пионирима у некој научној области): са недостатком стручне терминологије у домену *естественице*, јер је „фисика наука всјех својств и сил сотворених вешчеј и всјех их дејствији" (III. 272).[2] Но, свестан овог чињеничног стања, Стојковић није устукнуо, већ се јуначки латио посла, издавши за три године по један том књиге.

Већ из самог наслова тротомне књиге Стојковића види се да је намера аутора била не само да прикаже и објасни физичке појмове и законе, већ и да их учини што разумљивијим и приступачнијим тадашњим читаоцима, користећи прост народни језик.

У „Предисловију к читатељу" првог тома („части" или „частице") *Фисике*, на 1. страни он каже: „Многи од наших учених, јесу у времја објавленија Фисике чудилисе, како сам ја оваково дело на себе узети могао: **видећи да у нас много речеј не има кое су у Фисики потребне**" (подвукао — Д. Ј. П.)

Затим у наставку излаже и своју стратегију писања ове књиге: „Читатели ће мои многе *рјечи нове* у овој книги наићи. Ово е *нуждно* било и *потребно*. Всјака нова вешч има ново свое наименование. Ја сам се трудио способњејша изреченија тражити и всјакое тако јасно истолковати, колико е у моих силах било. Списатели всјех народов себи то право присвојили есу, у оскудности онакових рјечениј, која би мњение их совершено исказала, нова *ковати*. Ја сам од овога права — но колико сам могао менше — употребление творио. Зато ја уверен ес(а)м, да ни едно новое имја, чрез течение цјеле књиге, наитисе нече, кое би оном невразумително било, кои о вешчи со вниманием разсуждавати буде. Между тим, признавајући слабости мoју и знајући, да у роду нашему мужеј довољно има, кои би за едно или друго поњатие лучшее и удоборазумителнејшее рјеченије нашли: прошу, да би онаково мени предложили. Ја ћу всегда с благодарним сердцем оно примити и от него употребление творити. Из приложених немецких и латинских рјеченији всјакиј може разумјети, что сам ја казати хоћо." (Предисловије, стр. 8—9).

Овде нам, донекле и указује на порекло литературе којом се служио, а то су углавном књиге на латинском и немачком језику, које је

[1] Атанасије Стојковић, *Фисика — простим језиком списана за род Славено-Сербскиј*, Будим, Писмени Кралевскаго Университета, Перваја част, 1801; Другаја част, 1802; Третја част, 1803.

[2] У обележавању цитата из *Фисике* користићемо Стојковићев начин, који је он образложио у *Регистру* („Первое Римско число значит част Фисике, второе Арабское, лист").

свакако имао на располагању у току свог образовања, почев од родне Руме, па преко Шопрона, Сегедина и Братиславе, све до Универзитета у Гетингену, где је и докторирао.

Од претходника, учених Срба, свакако да је Стојковић, иако жали што није „силу *Раичева* и сладост *Обрадовичева* језика соединити могао" (Предисловие, стр. 9), морао познавати *Вечити календар* Захарија Орфелина[3] књига која садржи и 182 странице посвећене физици,[4] па је, вероватно, известан број стручних речи преузет из те књиге. Чини се да је Атанасије Стојковић детаљно проучио ову књигу овог „сербског Диогена", чим се упушта у научну полемику око неких тема изнетих тамо (I. 140).

Углавном, новоуведене речи дате су *курзивом*, а у загради је дат латински, немачки или, најчешће, оба назива. Међутим, као методолошки приступ, Стојковић користи курзив и да би подвукао друге речи које он сматра важним за изложену тематику.

У употреби нове терминологије Стојковић није апсолутиста, већ читаоцу оставља извесну слободу лингвистичке надградње, као, на пример, када каже: „Ја мислим да тон на нашем језику значит *глас*. Между тим, всјакому остает свобода вместо гласа читати тон, ако види, да му је тако разумитељније" (II. 270).

Понекад, при увођењу нових термина, он даје и своје образложење: „скакајушчији истоћници" ... „Ја волим овако назвати она художества водна, где вода у висину скаче (Springbrunnen) нежели бунар, из коего вода у висину избија" (II. 295).

Има ситуација када неки појам ни сам Стојковић не зна како да преведе, али ипак некако треба пресудити: „Находисе едињ камењ, коего Греци Електрон, Латини Електрум, Немци Brenstein или Agatstein наричу. Како се Сербски зове ја не знам. Чини ми се да до сад о њему ни разговора било није, а о чему људи не разговарајусе, оному и имена не знају. Ја ћу га називати Електр" (II. 317) и даље ... „Турци (га) називајут Ћиприбар" (Регистар, стр. 5).

[3] Захарија Орфелин, *Вечити календар*, Беч, 1783.

[4] Милан С. Димитријевић, *Астрономија и физика у Србији у XVIII и првој половини XIX века*, Зборник радова научног скупа „Природне и математичке науке у Срба у 18. и првој половини 19. века", Нови Сад, 26—27. јуни 1995, стр. 27.

Др Атанасије Стојковић, писац, професор физике на Универзитету у Харкову. Портрет је урадио Павел Ђурковић, сликар (Баја, 1772 — Одеса ? око 1830) и налази се у Галерији Матице српске у Новом Саду[5] (ГМС/У 380)

2. КАТЕГОРИЈЕ НОВОУВЕДЕНИХ РЕЧИ

У тако обимном раду у три тома, од укупно око 1000 страница текста и цртежа, са „поправљенијем и додатцима" и „регистром на све три части Фисике", природно је да постоји велики број новоуведених стручних речи. У овом раду односићемо се само на појмове везане за физику, без да се заустављамо на анализу других наука које у својој књизи Атанасије Стојковић обрађује (астрономија, метеорологија, минералогија).[6, 7] Такође, нећемо се бавити славено-сербским језиком и оценама у којој мери он задовољава циљ књиге (то препуштамо лингвистима).

[5] Дарко В. Капор и Јован П. Шетрајчић, *Физика, 6. разред основне школе*, Завод за уџбенике и наставна средства, Београд, 2002.

[6] Милан С. Димитријевић, *нав. дело*, стр. 25—32.

[7] Наталија Јанц, *Просветитељски допринос Атанасија Стојковића у области метеорологије*, Зборник радова научног скупа „Природне и математичке науке у Срба у 18. и првој половини 19. века", Нови Сад, 26—27. јуни 1995, стр. 161—178.

Што се терминологије из физике тиче, пратићемо увођење и коришћење основних појмова физике, основних закона физике и називе за мерне инструменте.

А. Основни појмови физике

Фисика или *естественица* (I. 6) проучава *сушчества* (substantiae), која могу бити двогуба: *Духови* (spiritus) „која способност мислити имају", односно *материје* (materia), а Стојковић ће радије употребљавати словенску реч *вечшество* (I. 5). *Тела* или *телеса* могу бити *проста* (simplicia) или *сложена* (composita) (I. 6). „Ово све *естествено* или *натурално* бива." (I. 8).

Као општа својства тела истичу се: *протјаженије* (тј. просторност), *непроницаемост* (непроницљивост, непробојност), *скважност* (порозност), *делимост* (дељивост), *сојузност* (кохезија), *движност* (покретљивост, мобилност), *тјажест* (тежина) (I. 15).

Свако тело има своју „*фигуру* (то јест *образ*)" (I. 16) и *масу* (I. 19), а због дејства силе *сојузности* (I. 24), тела могу бити *упруга* (elastica) или *неупруга* (I. 26).

Кретање или „*движение* ест премјенение мјеста", што претпоставља разматрање и других тела „с коима ми оно сравнивамо" (I. 29), што би данас рекли — референцијални систем. Кретање је релативно, то јест „*двогубо, истиное* и *видимое*". „При видимому движенију оно тело ест у покоју, коему ми движеније приписујемо." (I. 30).

При кретању, тело прелази *пут* или *направленије* (данас кажемо: путања или трајекторија[8]), јер „тело кое се движе *пут* имати мора." (I. 55). Ако „*дивидирамо*" „*простор* с *временом*" (I. 38) добићемо „*скорост*" (брзину) (I. 31).

Важно својство тела јесте њихова „*леност* (inertia)" (I. 39), а такође и „*важест*" (pondus, Gewicht), тј. „различное притискивание телес" (I. 57), а тела у покрету поседују и „*количество движенија*" или „*величину движенија*" или „*величину удара*" (I. 52), што би данас рекли — импулс.

У сваком случају, кретање може бити „*равнообразно*" (uniformis), а оно „*неравнообразно*" (diformis) дели се на „*скорјашчеје*" (acceleratus) и „*поздњашчеје*" (retardatus) (I. 48). Такође, може бити „*просто*" или „*сложено*" (I. 45).

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[8] Љубо Мићуновић, *Савремени лексикон страних речи и израза*, Завод за уџбенике и наставна средства, Београд, 1991.

„От два тела (равне величине) оно је *тјажејше*, кое више масе има" (I. 57), а „*средоточије тјажести* ест она точка у телу, около кое все части тела у равновесију есу" (I. 68).

У другом тому, Атанасије Стојковић се бави „*оптиком*" (II. 60) у којој су важне појаве „*отбитие*" (II. 53) (одбијање, рефлексија) и „*преломление*" (II. 50) (преламање, рефракција), док са тачке гледишта оптике површине и „*огледала*" могу бити „*равна*", „*узвишена*" (испупчена, конвексна) или „*изглубљена*" (издубљена, конкавна[9]) (II.58). За сочива користи појам „*зажигатељнаја стакла*" (Brennglas) или, пак, само „*стакла*" (II. 57). А „... она стакла која су од обе стране *узвишена* предмете *увеличавају*. Она на против того, која су на крајеви *дебља* нежели у среди, то ест која су *изглубљена* от обе стране, представљају нам предмете *мењше*." (II. 57). Такође, користи и појам „*увеличитељное стакло* или *Микроскоп*" (II. 57).

„*Примечаније*. О свјетје и законах его, о преломленији, и отбитији свјета различније красне, но весма тјажке Математическе науке дјејствујут." (II. 60).

Када се односи на извор топлоте, Стојковић користи реч „*теплотник* (Warmestof, caloricum)", у смислу „теплотворное вешчество" (II. 110), а температуре тела изражене су у „степенима топлоте", односно „степенима студени". За степене користи још и реч „градуси" (II. 124). Пренос топлоте, односно загревање, је за Стојковића „сообшчение теплоти (communication caloris)" (II. 134), док тела могу бити подвргнута „растопленију", па тако разликујемо „тјажкотечна" од „легкотечних" тела (II. 130).

Гасовита тела су „воздухоподобна" (II. 129), а она „из којих је извађен ваздух", тј. „праздна од ваздуха" јесу „воздухопраздна" (II. 167). То се постиже користећи „воздушни насос (Luftpumpe)" (II. 166) и „стаклено звоно" или „реципијент" (II. 168). Иначе, ... „Воздух је таково тело кое се даде весма притиснути (стиснути, сжимати, zusammendrucken, comprimare)" (II. 170). Ваздух може да буде чист или „кислотворij (oxygenius)" (II. 225), за разлику од запаљивог ваздуха који се „у новој Химии нариче" ... „*водороднij* или водотворнij (Gas hydrogenium)" (II. 229). ... „Ове просте и перве неразрушиме частице наричусе Стихије Химическије (Elementa chimica)." (II. 220). Штетан по жива бића је „угљенокислиj ваздух (aer fixus, acidus cabonicus)" (II. 229).

Дефиниција звука у *Фисици* гласи: „Всјакое дјејствије кое на наш слух бива наричесе *звук*." (II. 266), а за појам осцилације Стојковић користи речи „трепшчујушче движеније (oscillare)" (II. 268). „Ако трепе-

[9] Љубо Мићуновић, *нав. дело.*

шчушчеје тела движеније правилно бива, то ест: всјакое движеније у равном *почти* времену, то се звук нариче *звоњ* (Klang)", ... који се разликује од „*шума*" или „*лупе* (trepitus, tumultus)" (II. 269). „Звоњ звука может бити различниј, *толстиј*, то ест дебелиј, *средниј, тонкиј*", док „отношеније високости и нискости звона ест *глас* (тон, Ton, tonus)." (II. 270).

У електрицитету говори о „електрическој материји" (II. 318) и о електричној сили која дејствује између тела подвргнута „тренију" и која „наричусе *тела електрическаја*" (II. 318). Код таквих тела „ест електрическа материја *первоначална* или *својствена*". Када таква тела „у сојуз дојду со електрическими телеси", тада је њихова „електрическаја материја" „сообшчена" (II. 319). Ова тела „проводе ју далше и зато се наричу *проводители*" (II. 320).

По „материји електрическој", тела се могу налазити „тројаким образом". Прво, у „естественному состојанију", када тело „толико материје електрическе у себи има, колико ему пристоит". „Второе состојаније наричу Фисики *положително* (positiv), третје отрицателно (negativ)" (III. 51).

Такође, у 84. параграфу говори се о „магнетическој материји" и о „магнетима" (II. 327).

Б. Формулисање основних закона физике

Иако Атанасије Стојковић не прецизира ком се узрасту његова књига обраћа, из предговора, али и по списку пренумераната види се да ју је наменио широком кругу читалаца. На самом почетку он каже да је то наука „која се поперве у осмој школи предаје" (Предисловије, стр. 3), па се да закључити да се обраћа и мањим узрастима ученика. У прилог овој тврдњи стоји како горенаведено *Примечаније* у вези са оптиком, тако и чињеница да у сва три тома књиге се уопште не појављује ниједна физичка формула. Чак и када је приморан, да би поткрепио своје излагање, да прибегне математичком рачуну, он то ради детаљно описујући кораке рачунања, без употребе математичких формула (види, на пример, (II. 48) и (II. 64—67)).

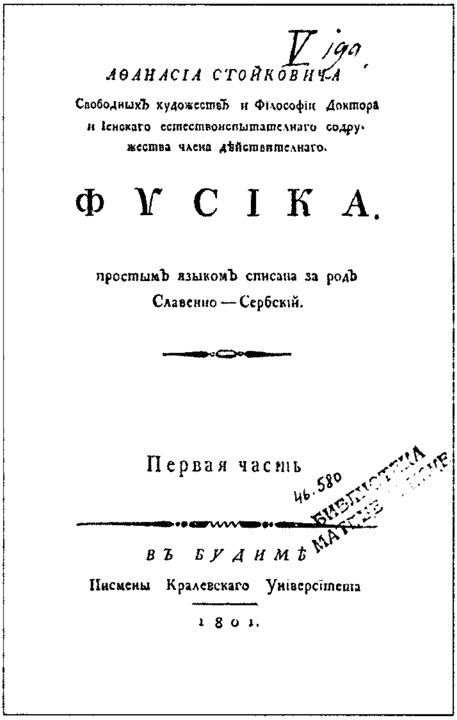
Зато није наодмет да размотримо неколико примера формулисања основних закона физике (којих, додуше, у књизи нема много), упоређујући их са данашњом формулацијом.

Као илустрацију терминологије у години 1801. дајемо „первиј закон, по коему движение бива": „*Всјако тело, кое е едањ пут у покоју, мора дотле у покоју бити, док от какове друге вњешне силе у движенију не постависе.*" (I. 40).

„Барометар" (I. 23), (II. 179), „насос воздушниј" (I. 62), „топломерник" или „термометар" (II. 120), који може бити „Дребелскиј или воздушниј" (II. 121), „Беренхајтскиј" (II. 126) или „Ромурскиј" (II. 126), „манометар" (II. 210), „дасиметр (густиномеритељ)" (II. 210), „влажномеритељ" (II. 213) или „хигрометр" (Регистар, стр. 17), „вјетромерник (anemometer), орудие коим се скорост движенија вјетра мери" (II. 261), „цјев глаголанија" (II. 278) и „цјев слишанија (tuba auditoria)" (II. 279), „призма" (III. 91), представљају само неколико од мерних (опитних) инструмената коришћених у физици онога доба.

3. ПОРЕКЛО НОВОУВЕДЕНИХ РЕЧИ

Имајући у виду како националну припадност аутора (Србин, а у ширем смислу Словен или „Славен"), тако и стручно усавршавање у домену природних наука (пре свега на Универзитету у Гетингену), логично је што, у објашњењу старијих појмова и тражењу нових, Стојковић користи реч или кованицу у духу славено-српског језика. У већини случајева он даје (у загради) и немачки назив, али и латински (који је још увек, у природним наукама тадашње епохе, био „званични" научни језик). Иначе, Атанасије Стојковић је добро знао латински и грчки, затим немачки, италијански и мађарски, нешто словачки и чешки, а вероватно и јеврејски, по тврдњама научника који су истраживали његов живот и дело.[16]


V/190
АѲАНАСІА СТОЙКОВИЧА

Свободныхъ художествъ и Философіи Доктора и Іенскаго естествоиспытателнаго содружества члена дѣйствителнаго.

ФУСІКА.

простымъ языкомъ списана за родъ Славенно — Сербскій.

Первая часть

ВЪ БУДИМѢ

Писмены Кралевскаго Университета

1801.

Фисика **Атанасија Стојковића**
(штампана 1801, 1802. и 1803. године)

Тамо где није нашао згодну реч у народном говору, он ју је сковао налик на немачку, латинску или чак руску реч, пошто је све те језике добро познавао. Као примере наво-

[16] Ристо Ковијанић, *Српски писци у Братислави и Модри XVIII века*, Зборник Матице српске за књижевност и језик, Нови Сад, 1973.

димо: *„натурално”* (природно) (II. 64), *„дивидирати”* (поделити), *„квоцијент”* (количник), *„лењост”* (инерција), *„потвјесно* или *перпендикуларно”*, *„равнитељ* (Gleicher)” (екватор) (I. 184), *„трјасеније земљи”* (земљотрес) (I. 292) *„нафта”* (I. 301), *„прилив”* (плима), *„отлив”* (осека) (II. 16), *„вихр (вијор)”* (вртлог) (II. 260), *„суптилна”* (II. 291). Није тешко уочити језичко порекло ових речи.

Неки су од ових назива и данас у употреби у српском научном језику, претрпевши мале фонетске измене, у складу са правилима садашњег српског језика. Други се, пак, стручни називи у неизмењеном облику и данас користе у руској терминологији физике: *„движеније”*, *„скорост”*, *„количество движенија”*, *„насос”*, *„проводители”*, *„воздухоподобниј”*, што јасно говори о њиховом пореклу у случају Стојковићеве књиге.

Узгред да напоменемо да се у својој *Фисици* Стојковић бавио и другим наукама: астрономијом, метеорологијом, минералогијом, географијом, зоологијом (неке од њих су се, истини за вољу, тек касније искристалисале као посебне науке), па је природно да је он морао и у тим областима људскога сазнања да створи и уведе неке речи. На пример, из астрономије (*„звезде неподвижне и подвижне”*, *„зодијак”*, *„еклиптика”*, *„равноденствије”*, *„затамњење сунца”*, *„оризонт”*, *„полуденник”* (подневак, меридијан[17]), *„сјена* или *сенка”*), из метеорологије (*„барометар* („Славенски би могли *тјажетомјерником* назвати.”)”, *„тиск”*, *„влажномеритељ”*, *„парокружие* или *атмосфера”*), из географије (*„компас”*, *„оризонт”*).

4. ЗАКЉУЧНЕ ПРИМЕДБЕ

Анализа тако обимног дела као што је *Фисика* Атанасија Стојковића, са тачке гледишта порекла коришћене терминологије, јесте колико сложен подухват, толико и занимљив. Сложеност проблематике састоји се у томе што је тешко (поготову нама из дијаспоре) доћи до других књига из тог домена и тог периода, да би се могло пратити кретање, односно преузимање, неких речи и термина специфичних, у нашем случају, физици.

Иако не у потпуности на одговарајућем нивоу, књига *Фисика*, боље рећи њен аутор, Атанасије Стојковић има ту заслугу да је храбро кренуо да прокрчи пут (релативно) каснијим покушајима такве врсте, стварајући или адаптирајући српску терминологију физике (и других сродних егзактних наука) можда у периоду када је српском народу то било најпотребније. Свакако да је Стојковићева књига, са свим њеним не тако ве-

[17] Љубо Мићуновић, *нав. дело.*

ликим недостацима и пропустима, била корисна многим генерацијама ученика. Забележен је податак да је у периоду од децембра 1839. године до септембра 1841. професор Антоније Арнот Арновљев предавао физику на тада „највишем научном заводу” — Лицеју, по књизи Атанасија Стојковића.[18] То само илуструје временску непревазиђеност ове књиге, све до објављивања *Начела физике* Вука Маринковића 1851. године.

У недостатку адекватне терминологије на српском језику, природно је дакле било да се Стојковић сналази како се најбоље разуме, прибегавајући страној (руској, немачкој, латинској) терминологији и, адаптирајући је духу нашег народног језика. Сматрамо да је у том послу у великој мери и успео. Вероватно је и то разлог географске распрострањености ове књиге.

Стојковић је у својој књизи увео и доста кованица. Неке од тих речи су се сачувале у истоветном фонетском облику, неке су временом адаптиране у духу савременог српског језика, а неке су, природно, временом нестале и нису више у употреби, њихово милозвучје има само заслугу да нам дочарава неко давно прохујало време.

Позитивно је, по нашем мишљењу, упорно настојање Атанасија Стојковића да осамостали српску терминологију у домену физике и сродних егзактних наука, дајући јој, тамо где је било могуће, национални печат. У великој мери он је то и успео. Чак и да је само то једини допринос *Фисике* Атанасија Стојковића било би довољно, имајући у виду економски, политички, научни и културни ниво нашега народа при крају XVIII века у овим крајевима.

Све у свему, Стојковићева *Фисика*, насупрот више од два века од њеног објављивања, остаје и даље не само лако и интересантно штиво за широки спектар читалаца, већ се може сматрати и каменом-темељцем наставе физике у Срба.[19]

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[18] Милан С. Димитријевић, *нав. дело*, стр. 30.

[19] Душан Ј. Попов, *Камен-темељац природних наука у Срба: „Фисика" Атанасија Стојковића*, Зборник радова I. Међународног научно-развојног симпозијума „Стваралаштво као услов привредног развоја Нове технологије и технике у служби човека", Београд, 10—11. октобар 1996, стр. 1.159—1.166.

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АСТРОНОМИЈА У СРБА 1850—1918.

ASTRONOMY BY SERBS 1850—1918

САЖЕТАК: У раду је дат преглед развоја астрономије у Срба од 1850. до 1918. године. Свакако централно место у овом периоду има оснивање Астрономске и метеоролошке опсерваторије 1887. године, и оснивање Катедре за астрономију са метеорологијом, што је посебна заслуга Милана Недељковића. Поред тога, посебна пажња је посвећена Ђорђу Станојевићу, првом српском астрофизичару, који у деветнаестом веку први објављује праве научне радове из физике Сунца и спектроскопије у часопису Француске академије наука. Разматрају се такође текстови из астрономије у календарима, алманасима и часописима, популаризација астрономије, као и покушаји за реформу Јулијанског календара.

Кључне речи: астрономија, Астрономска опсерваторија, астрофизика, историја астрономије, Милан Недељковић, Ђорђе Станојевић, популаризација астрономије, реформа календара

SUMMARY: A short review of the development of astronomy among Serbs from 1850 up to — 1918 is given. Certainly the central place within this period has the foundation of the Astronomical and meteorological observatory in 1887, and the foundation of Department of astronomy and meteorology, with the particular merit for this of Milan Nedeljković. Moreover, a particular attention has been paid to Djordje Stanojević, the first serbian astrophysicist, who is the first Serb in the nineteenth century publishing the astrophysical scientific papers in the journal of French academy of science. Texts on astronomy in calendars, almanachs and journals, popularization of astronomy and attempts to reform Julian calendar, have been considered as well.

Key words: astronomy, Astronomical observatory, astrophysics, history of astronomy, Milan Nedeljković, Djordje Stanojević, popularization of astronomy, calendar reform

1. ДЕВЕТНАЕСТИ ВЕК

У другој половини деветнаестог века створен је кадар и друштвена клима који су омогућили да астрономија на овим просторима постане права наука и нађе своје место у средњим школама и на Великој школи. У овом периоду оснива се Астрономска и метеоролошка опсерваторија 1887. године, као и Катедра за астрономију са метеорологијом, јављају се први научни и популаризаторски радови у данашњем смислу, први школски уџбеници и настаје аматерска астрономија код нас.

Године 1849. долази по позиву за професора Лицеја Вук Маринковић (1807—1859). Он предаје физику од 1849. до 1859. године и први од професора физике на Лицеју пише свој уџбеник *Начела физике*, који објављује 1851. године, где се налазе и астрономски садржаји. Он астрономију вероватно већ од 1849. године предаје уз физичку географију.

Међу писцима који састављају уџбенике за гимназије са укљученим астрономским садржајем налази се Емилијан Берберовић (1849—1889), који је у својој *Календарографији или науци о календару* објавио 1881. године корисна упутства о састављању календара[1]. Проблеме у вези са састављањем календара са низом таблица и упутстава за практичну примену излаже и Јован Драгашевић (1836—1915) у уџбенику *Кронографија* објављеном 1874. голине. Он 1875. године објављује и уџбеник *Космометрија* у коме се описује како се одређује време, географске координате и магнетска деклинација, а намењен је слушаоцима Војне академије и Техничког факултета. Астрономски дурбин који од 1847. године постоји у збирци физичких инструмената на Лицеју[2] вероватно је коришћен за изучавање астрономских садржаја.

У другој половини деветнаестог века издавачка делатност се шири и низ календара, алманаха и часописа доноси прилоге из астрономије, који имају едукативну и популаризаторску функцију.

Занимљиво је да се и један свештеник, Ђорђе (Гаврило) Поповић (Баја, 1811—Београд, 1871) бавио популарисањем астрономије. Године

[1] Ненад Ђ. Јанковић, *Преглед историје астрономије у Југословенским земљама*, у: Бранислав М. Шеварлић, *Историја астрономске науке од Њутновог доба до наших дана*, Универзитет у Београду, Београд (1986), 143.

[2] Јован Симовљевић, *Астрономија*, у: *Четрдесет година Природно-математичког факултета у Београду*, Београд (1987), 166.

1850. издао је књигу *Астрономија или наука о звездама*. Јанковић[3] наводи да се „по који астрономски чланак може наћи и у популарним делима" *Огледи умне науке* од Јована Петрова и *Општа знања сваком човеку нуждна* од Петра Радовановића. У Црној Гори, у часопису *Луча* (јануар 1896, год. II, св. II, стр. 32—35) Душан В. Тодоровић, студент Петроградског универзитета, објављује чланак *Неколико ријечи о животу на другим свјетилима*.

У разматраном периоду појављује се код Срба и аматерска астрономија. Као једног од првих астронома аматера у нашим крајевима можемо сматрати Јована (Јулијана) Чокора (Баја, 21. I/2. II 1810—Сремски Карловци, 10. или 13. VI 1871)[4]. Он је у Сремским Карловцима направио малу опсерваторију, а израђивао је и сунчане сатове. Аматерски су се бавили астрономијом и Ђорђе Максимовић (1838—1881), лекар, Петар Манојловић Селим, официр и дипломата, Лазар Комарчић, књижевник и писац нашег првог научно-фантастичног романа *Једна угашена звезда*,[5] Сретен Хаџић, педагог и други[6].

2. ОСНИВАЊЕ АСТРОНОМСКЕ И МЕТЕОРОЛОШКЕ ОПСЕРВАТОРИЈЕ И КАТЕДРЕ ЗА АСТРОНОМИЈУ СА МЕТЕОРОЛОГИЈОМ

Милан Недељковић (Београд, 27. IX 1857—Београд, 21. XII 1950), као „приправник за физику и математику на Великој школи" подноси 16. VIII 1878. године Министарству просвете молбу да студије завршене у земљи настави у иностранству и то физику и астрономију, а осим тога аналитичку или рационалну механику и математику. Министар Бошковић тражи од ректора мишљење које стиже 12. VI 1879. План студија према овом мишљењу је следећи: „1) да у Паризу слуша две године предавања из инфинитезималног рачуна, рачуна вероватноће, математичке физике, метеорологије, рационалне и аналитичке механике, више геодезије и астрономије; 2) треће године да се веџба на Париској астрономској и метеоролошкој опсерваторији и слуша специјална предавања из астрономије и метеорологије, поглавито о теорији и употреби астрономских и метеоролошких инструмената; 3) прву половину четврте године да пробави у Лондону, а другу половину у путовању, обилазећи најважније астрономске и метеоролошке станице." Ово мишљење су потпи-

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[3] Ненад Јанковић, *Астрономија код Срба*, Енциклопедија Југославије I, Лексикографски завод ФНРЈ, Загреб (1955), 223.

[4] Ненад Јанковић, *нав. дело*, 223.

[5] Лазар Комарчић, *Једна угашена звезда*, Штампарија Д. Димитријевића, Београд (1902).

[6] Ненад Јанковић, *нав. дело*, 223.

сали Јосиф Панчић, Коста Алковић, Сима Лозанић, Љубомир Клерић, Димитрије Нешић и Димитрије Стојановић[7]. Тиме га ово мишљење усмерава у ствари на студије астрономије и метеорологије и ради њих је као државни питомац послат у Француску.

Године 1863, законом о устројству Велике школе, астрономија је заборављена, али је изменама и допунама овог закона 1880. године уведена као посебан предмет на Природнословно-математичком одсеку Филозофског факултета Велике школе, а требало је да је слушају и студенти технике. Ова одлука је спроведена у дело тек 1884. године, када се Милан Недељковић вратио са школовања у Француској, на коме је био од јуна 1879. до јула 1884. Управо 17. VII 1884. године, министар правде Димитрије Маринковић (1835—1911), у својству заступника министра просвете и црквених дела, саопштава одлуку Главног просветног савета „да се космографија у строжијем, научном смислу одвоји од географије и пренесе као засебан предмет у седми разред гимназија и реалака". Милан Андоновић, професор Велике школе (1849—1926) и Јован Ђорђевић, професор Учитељске школе, задужени су да саставе програм. Године 1888. Милан Андоновић је написао *Космографију*, уџбеник за овај предмет. Она је у једном периоду била најпотпунији уџбеник за овакво градиво.

После повратка са школовања, Милан Недељковић је краљевим указом од 21. X 1884. године постављен за суплента за астрономију и метеорологију и поверена му је Катедра за астрономију са метеорологијом Велике школе, коју држи пуних четрдесет година, до свог другог пензионисања 1924. године. Једини прекид био је када је Милан Недељковић први пут био у пензији од 5. јула 1899. до 31. октобра 1900. године[8], када је Катедра за астрономију са метеорологијом поверена Ђорђу Станојевићу. Недељковић је по Уредби из 1896. године предавао астрономију као стручни предмет у Математичко-физичком одсеку. Астрономија је сведена на помоћну науку и изостављена из професорских испита изменом Уредбе од 30. IX 1900. године. Ништа се не мења ни оснивањем Универзитета 1905. године. Од 1906. астрономија је помоћни предмет прве студијске групе Филозофског факултета, а М. Недељковић је ванредни професор. Године 1909. за ванредног професора примењене математике, по позиву долази из Беча доктор технике, грађевински инжењер Милутин Миланковић (Даљ, 28. V 1879—Београд, 12. XI 1958),

[7] Ненад Ђ. Јанковић, *Милан Недељковић, професор Велике школе и оснивач њене Опсерваторије*, у: *Сто година Астрономске опсерваторије у Београду*, Publ. Obs. Astron. Belgrade, 36, (1989), 107.

[8] Перо Ђурковић, *Седамдесет пет година рада Астрономске опсерваторије у Београду*, Publ. Obs. Astron. Belgrade, 12, (1968), 15.

који је први код нас, у оквиру овог предмета, започео наставу из небеске механике.

Недељковић није написао уџбеник за астрономију, већ су студенти користили *Космографију* Милана Андоновића[9]. У рукопису је остала *Практична астрономија за ученике Велике школе*, и преводи метеорологије од Ван Бебера[10], астрономије од Волфа[11], *Теоријске астрономије* од Уотсона (Watson)[12] и *Теоријске метеорологије* од В. Ферела (W. Ferrel)[13], као и делимични превод Секијеве (Secchi) књиге о звезданој астрономији[14]. У оквиру педагошког и популаризаторског рада Милана Недељковића свакако треба поменути и његову популарну књижицу *Свет и Халејева комета*, издату 1910. године.

После повратка из иностранства, Недељковић почиње и борбу за оснивање Астрономске и метеоролошке опсерваторије, подухват који је, уочивши за њега повољне околности, крунисао успехом. Акт о оснивању потписао је министар просвете и црквених дела Краљевине Србије Милан Кујунџић Абердар, 26. марта (7. априла) 1887. године, а Милан Недељковић је одређен за првог управника Астрономске и метеоролошке опсерваторије. Овај датум узима се као датум оснивања Астрономске опсерваторије у Београду, једне од најстаријих научних установа у Србији и јединог самосталног астрономског института у Југославији, а историја њеног развоја је важан део историје науке и културе на овим просторима. Оснивањем ове установе[15], која је представљала основну базу за развој астрономске науке код нас, дат је снажан подстрек и постављене су основе за развој ове науке.

Првог маја 1887. године Недељковић почиње са радом у Провизорној опсерваторији у закупљеној кући породице Гајзлер. Овде је Опсерваторија радила до првог маја 1891. године, када се преселила у за то време довршену сопствену зграду, данашњу Метеоролошку опсерваторију у Карађорђевом парку, у чијем се мањем музејском простору, од прославе

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[9] Ненад Ђ. Јанковић, *Преглед историје астрономије у Југословенским земљама*, у: Бранислав М. Шеварлић, *Историја астрономске науке од Њутновог доба до наших дана*, Универзитет у Београду, Београд (1986), 143.

[10] W. J. Van Bebber, *Handbuch der ausübenden Witterungskunde*, Stuttgart (1885—1886).

[11] Rudolf Wolf, *Geschichte der Astronomie neuerer Zeit*, München (1877).

[12] J. C. Watson, *Theoretical Astronomy*, Philadelphia (1868).

[13] Ненад Ђ. Јанковић, *Милан Недељковић, професор Велике школе и оснивач њене Опсерваторије*, у: *Сто година Астрономске опсерваторије у Београду*, Publ. Obs. Astron. Belgrade, 36 (1989), 107.

[14] A. Secchi, *Les étoiles, Essai d'astronomie sidérale*, Paris (1879).

[15] Оснивање и развој су описани у раду: Милан С. Димитријевић, *110 година Астрономске опсерваторије*, у: *Развој астрономије код Срба*, уредници М. С. Димитријевић, J. Милоградов-Турин, Л. Ч. Поповић, Publ. Astron. Obs. Belgrade 56 (1997), 9.

стогодишњице оснивања 1987. године, налази једна соба посвећена почецима астрономске науке у Југославији.

Недељковић је на челу Опсерваторије од 26. марта (7. априла) 1887. године до 30. јануара 1924. године. Изузетак представља само период од 5. јула 1899. до 31. октобра 1900. године, када је био у пензији због политичких разлога, тј. због Ивандањског атентата на краља Милана, који је краљ Александар искористио за обрачун са својим политичким противницима. У то време на његовом месту био је Ђорђе Станојевић (Неготин, 7. IV 1858—Париз, 24. XII 1921), први српски астрофизичар, други руководилац Астрономске и метеоролошке опсерваторије, ректор Универзитета у Београду, велики популаризатор астрономије и науке уопште, човек који је увео електрично осветљење у Београду, Ужицу, Лесковцу, Чачку, дарујући тако тим градовима светлост, градитељ прве српске хидроцентрале, пионир индустрије расхладних уређаја, иницијатор организовања комитета за хладноћу и међународне организације за технику хлађења у Паризу 1903. године. Он је и пионир фотографије у боји у Србији.

Осим свог значаја за метеорологију, Астрономска и метеоролошка опсерваторија Милана Недељковића колевка је и сеизмолошких и геомагнетских истраживања код Срба. Крајем 1903. године Недељковић позајмљује инструменте за геомагнетска мерења од Теге Миклош Конкоља, оснивача Астрономске опсерваторије у Будимпешти, и гради земномагнетски павиљон. Захваљујући Конкољу, Недељковић 1903. године добија и сеизмограф, који следеће године поставља у посебан павиљон. Посматрања се обављају редовно и за ове потребе подиже се на Ташмајдану зграда данашњег Сеизмолошког завода 1906. године. Ову активност преузима Недељковићев помоћник Јеленко Михајловић (Врбица, 11. I 1869—Београд, 10. X 1956), који од 1896. године ради на Опсерваторији.

3. ЂОРЂЕ СТАНОЈЕВИЋ, ПРВИ СРПСКИ АСТРОФИЗИЧАР

Ђорђе Станојевић, први српски астрофизичар, други руководилац Астрономске и метеоролошке опсерваторије, рођен је у Неготину 7. априла 1858. године. У родном граду, где је завршио основну школу и нижу гимназију, данас постоји његова спомен-соба. Као питомац Министарства војног у периоду од 1883. до 1887. био је на студијама, специјализацији и раду на најпознатијим астрономским и метеоролошким опсерваторијама Европе: у Берлину (Универзитет), Потсдаму (астрофизичка опсерваторија), Хамбургу (метеоролошка централа), Паризу (Сорбона), Медону (Париска опсерваторија за физичку астрономију), Гриничу, Кјуу и Пулкову[16]. У овом периоду, Станојевић се опредељује за астрофизику и бира физику Сунца за своју научну област.

У Медону ради код оснивача ове опсерваторије, чувеног астрофизичара Жансена и ту почиње да се бави озбиљним научним радом на пољу физике Сунца и спектроскопије. Године 1885. објављује свој први прави научни рад *Спектрална анализа елемената у Земљиној атмосфери*[17] у *Часопису Париске академије наука*. Следеће 1886. године, у овом реномираном научном часопису излазе његови радови *О пореклу фотосферске мреже на Сунцу*[18] и *О спектру апсорпције кисеоника*[19]. Године 1887. излази научни рад *О директној фотографији барометарског стања атмосфере Сунца*[20]. Ови његови научни радови из астрофизике објављени у издањима Париске академије наука су први прави научни радови из ове области код Срба[21].

При крају свога боравка у Паризу, августа 1887, учествује као изасланик Париске опсерваторије[22] у експедицији за посматрање потпуног помрачења Сунца 19. августа 1887. године у Русији (Петровск), о чему објављује извештај у *Часопису Париске академије*[23]. Временске прилике му нису ишле на руку, па се потпуно помрачење могло видети само 20—25 секунди.

Године 1887, по повратку у земљу, постаје професор физике и механике на Војној академији. Париска опсерваторија га позива да учествује у француској експедицији која ће испитивати Сунце у Сахари, где остаје три месеца (1891—1892). Године 1893, после пензионисања Косте Алковића, постаје професор експерименталне физике на Великој школи где постаје директор Физичког института. У периоду од 1909. до 1913. био је декан Филозофског факултета а од 1913. до 1921. године ректор Универзитета. На улици у Паризу, где борави ради проучавања неких

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16 Јован Симовљевић, *Астрономија*, у: *Четрдесет година Природно-математичког факултета у Београду*, Београд (1987), 166; Ђорђе Мушицки и Ђорђе Басарић, *Физика*, у: *Четрдесет година Природно-математичког факултета у Београду*, Београд (1987), 196.

17 Djordje M. Stanojević, *Analyse spectrale des éléments de l'atmosphère térèstre*, Communication à l'Academie des Sciences de Paris, 100 (1885), 752.

18 Djordje M. Stanojević, *Sur l'origine du résau photosphérique Solaire*, Communication à l'Academie des Sciences de Paris 102 (1886), 853.

19 Djordje M. Stanojević, *Sur le spectre d'absorption de l'Oxygéne*, Communication à l'Academie des Sciences de Paris, 102 (1886), 1024.

20 Djordje M. Stanojević, *Sur la photographie directe de l'état barometrique de l'atmosphère Solaire*, Communication à l'Academie des Sciences de Paris, 104 (1887), 1263.

21 Ненад Ђ. Јанковић, *Преглед историје астрономије у Југословенским земљама*, у: Бранислав М. Шеварлић, *Историја астрономске науке од Њутновог доба до наших дана*, Универзитет у Београду, Београд (1986), 143.

22 Драган Трифуновић, *Дело Ђорђа М. Станојевића у светлу открића Николе Тесле*, у: Ђорђе М. Станојевић, *Никола Тесла и његова открића*, Београд (1976).

23 Djordje M. Stanojević, *L'éclipse totale du Soleil du 19 aout 1887, observé en Russie (Pétrowsk)*, Communication à l'Academie des Sciences de Paris, 106 (1888), 43.

решења у ваздухопловној техници, умире изненада услед срчаног удара 24. децембра 1921. године.

Када је Милан Недељковић први пут био у пензији од 5. јула 1899. до 31. октобра 1900. године[24], управник Београдске опсерваторије постаје Ђорђе Станојевић. Њему је поверена и Катедра за астрономију са метеорологијом.

Његови научни резултати су толико изнад нивоа тадашње научне јавности у Србији, да тек основана Српска краљевска академија одбија да публикује његове радове из физике Сунца[25]. Разочаран он практично напушта научни рад на пољу астрофизике. У издањима Париске академије објављује још само прегледни чланак *Садашње стање фотографије Сунца*[26].

У каснијем раду се опредељује за физику и практичне проблеме електрификације и индустријализације Србије. Он изводи електрификацију Београда, Ужица, Лесковца, Чачка, Зајечара... Учествује у изградњи прве хидроцентрале у Србији код Ужица. На Великој школи организује ремонтну службу за електромоторе. Уводи код нас фотографију у боји и објављује књигу са оваквим фотографијама *Србија у сликама*[27]. Наставља да се бави озбиљним научним радом у физици, па му после прекида од девет година поново почињу да излазе научни радови у *Часопису Париске академије наука*, али из експерименталне физике[28].

Очаран лепотама ноћног неба пише научно-популарну књигу *Звездано небо независне Србије*.[29] У предговору млади Станојевић, наш први велики популаризатор астрономије у модерном а не у просветитељском „доситејевском" духу, излаже свој credo речима: „Ништа није грешније него знати неку истину а не хтети је казати и другоме, који је не зна и у свом незнању лута тамо-амо, машајући се често и за највећу погрешку."[30] Популаризацијом астрономије почиње да се бави још као студент па у периоду од 1880. до 1883. године објављује деветнаест научно-популарних чланака из астрономије у *Просветном гласнику* (9), *Вас-*

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[24] Перо Ђурковић, *нав. дело*, 15.

[25] Ђорђе М. Станојевић, *Сунчеве фотосферске мреже пред Краљевско-Српском Академијом природних наука*, Београд (1888).

[26] Djordje M. Stanojević, *L'état actuel de la photographie du Soleil*, Communication à l'Academie des Sciences de Paris, 108 (1889), 724.

[27] Ђорђе М. Станојевић, *Србија у сликама (фотографски снимци)*, Београд (1901).

[28] Библиографија његових радова у астрономским наукама је у: Драган Трифуновић, *Стваралаштво Ђорђа Станојевића у астрономским наукама*, Васиона, XLII, бр. 1—2 (1994), 23; а целокупна библиографија у: Д. Трифуновић, М. Димић, *Библиографија радова Ђорђа М. Станојевића*, у: Ђорђе М. Станојевић, *Никола Тесла и његова открића*, Београд (1976), као и у: Драган Трифуновић, *Ђорђе Станојевић професор и ректор Универзитета у Београду — живот и дело*, Свеске, књ. 1, Београд (1997).

[29] Ђорђе М. Станојевић, *Звездано небо независне Србије*, Београд (1882).

[30] Ђорђе М. Станојевић, *нав. дело*, стр. VI.

йишачу (5), *Побрашимсшву* (3), *Србадији* (1) и *Ошаџбини* (1)[31]. Године 1887. објављује научно-популарну књижицу *Васионска енергија и модерна физика*,[32] а 1888. године у *Ошаџбини* велики чланак *Небо и његов склоп*[33]. У *Шемашизму Краљевине Србије* за 1891. и 1892. годину пише одељак *Небо у години*, као и у *Државном календару Краљевине Србије* за 1894. и 1895. годину. У овој публикацији у периоду од 1901. до 1914. године редовно пише прилог *Сшари и нови календар и година.*

Ђорђе Станојевић, први српски астрофизичар, други директор Астрономске опсерваторије, ректор Универзитета у Београду, велики популаризатор астрономије и науке уопште, градитељ прве српске хидроцентрале и пионир фотографије у боји има велико и значајно место у историји науке, технике и културе српског народа.

4. РЕФОРМА КАЛЕНДАРА

Више прегалаца на пољу астрономије бавило се у разматраном периоду и реформом Јулијанског календара. Православни Срби, наиме, нису усвојили Грегоријански календар, који је у Аустрију и Мађарску увео цар Рудолф Други, као ни друге православне земље све до почетка двадесетог века. У средњем веку су године рачунате по цариградској ери, од стварања света, а почињале су 1. септембра или ређе 1. марта. Татомир Миловук у књижици *План најновији и обшши један свију хришћана васеленски календар*, Нови Сад, 1865, предлаже да се у Јулијанском календару месецима са 31 даном одузме један дан а месецима са 30 дана у Грегоријанском календару дода по један дан — фебруару два, па би разлика која постоји нестала. Овај наивни план остаје без одјека, али Мојсије Пајић у три предавања у Бечу 1866. године предлаже да година почиње равнодневицом, сваке године на подневку који је 87 или 87,2 степена западније од оног од претходне године, тако да свака година има 366 дана, али последњи дан траје само 5 ч 48 м или 5 ч 49 м[34].

Крајем XIX века у Србији предлаже реформу Јулијанског календара Ђорђе Станојевић 1892. године[35], али је његов предлог да се сваке 128. године изостави по један дан остао без подршке. У књизи објављеној у

[31] Драган Трифуновић, *Сшваралашшво Ђорђа Сшанојевића у асшрономским наукама*, Васиона, XIII, бр. 1—2 (1994), 23.

[32] Ђорђе М. Станојевић, *Васионска енергија и модерна физика*, Београд (1887).

[33] Ђорђе М. Станојевић, *Небо и његов склоп*, Отаџбина, 7, књ. 19 (1888), 1.

[34] Ненад Јанковић, *Сшав Срба йрема реформи календара*, Зборник радова VII Националне конференције астронома Југославије, Публикације Астрономског друштва „Руђер Бошковић", бр. 4, Београд (1985), 103.

[35] Djordje M. Stanojević, *Le calendrier normal*, (1908); Ђорђе М. Станојевић, *Нешачно йразновање Васкрсења у йравославној цркви и реформа календара*, Београд (1908).

Београду 1898. године *Предлог за изравнање Јулијанског и Грегоријанског календара и сметње томе*, Љубомир Узун-Мирковић (1832—1905) предлаже изједначавање Грегоријанског и Јулијанског календара, тако што би се у току 1898. и 1899. од јула одузела 2 дана, а од августа, септембра, октобра и децембра по један дан, што би уклонило разлику која је у то време износила 12 дана.

Године 1900. Недељковић објављује свој рад *Projet de réforme du calendrier* (Предлог за реформу календара)[36]. Осим усклађивања календара са тропском годином, он жели и да пролеће увек почиње 21. марта, а уколико би оно почињало 22. марта он би ту годину учинио преступном и тако почетак пролећа вратио на 21. Таквим рачуном добија низ преступних година: 1900, 1904, 1908, 1913, 1921... Он увиђа ману оваквог рачунања, да преступне године нису у правилним размацима, па даје и други предлог у коме је свака четврта година преступна. Да би то постигао он претвара из преступних у просте године које се завршавају са две нуле, осим оних које је израчунао до 12000. године, али сада почетак пролећа не пада увек 21. марта.

Од 1900. до 1921. године, професор гимназије Максим Трпковић (Орланци код Кичева, 15. XI 1864—Београд, 3/16. XII 1924) објављује низ радова у којима установљава да се разлика између јулијанске и тропске године (време између два узастопна проласка Земље кроз пролећну или гама тачку) повећа за 7 дана у току 900 година. Да би се овај вишак дана елиминисао он предлаже да преступне буду само оне године са две нуле на крају које подељене са 9 дају остатак 0 или 4. Максим Трпковић 1900. године штампа у Београду књигу *Реформа календара.* Такође у *Годишњем извештају Реалке за 1894—1895* (Београд, 1895, 25—40) објављује *Нешто о даљинама звезда (некретница) и склопу васионе.* Трпковићев календар, који је дорадио и усавршио Милутин Миланковић, усвојен је од стране православне цркве 1923. године у Истамбулу.

ЗАКЉУЧАК

У периоду од 1850. до 1918. астрономија је на нашим просторима доживела велики успон и постала модерна наука, која се негује на Универзитету и предаје у средњим школама и на факултету, наука у оквиру које се врше научна истраживања и објављују научни радови. Осим научних радова Ђорђа Станојевића, треба поменути и радове: *Соко-Бања,*

[36] Milan Nedeljković, *Projet de réforme du calendrier*, Imprimerie Royale de Serbie, Belgrade (1900); Милан Недељковић, *О календару*, одштампано из *Новог живота*, Народна самоуправа а.д., Београд (1923).

први метеорит у Србији од Јосифа Панчића (*Гласник Српског учених друштва*, 1880, XLVIII), *Јелички метеорит*, од Јована Жујовића (*Геолошки анали*, 1890), као и чланке о спектроскопији, фотометрији и фотографији у астрономији од Јеленка Михајловића[37]. На крају овог периода, са Астрономском опсерваторијом у Београду, Катедром за астрономију и метеорологију на Београдском универзитету и створеним кадром и друштвеном климом, астрономија је у двадесетом веку могла да настави свој успон на овим просторима, тако да су створени услови да и Срби узму учешће у муњевитом развоју ове науке која је омогућила да човек ступи ногом на Месец и тако закорачи ка звездама.

[37] N. Banjac, *Scientific and professional activity of Professor Jelenko M. Mihajlović (1869—1956)*, Serbian Astronomical Journal, 160 (1999), 75.

СРПСКА АКАДЕМИЈА НАУКА И УМЕТНОСТИ
ОГРАНАК У НОВОМ САДУ
УНИВЕРЗИТЕТ У НОВОМ САДУ
МАТИЦА СРПСКА

Зборник радова научног скупа

ПРИРОДНЕ И МАТЕМАТИЧКЕ НАУКЕ У СРБА У 18. И У ПРВОЈ ПОЛОВИНИ 19. ВЕКА

Нови Сад, 26 – 27. јуни 1995.

НОВИ САД, 1995

АСТРОНОМИЈА И ФИЗИКА У СРБИЈИ У XVIII И ПРВОЈ ПОЛОВИНИ XIX ВЕКА

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Кратак садржај: *У раду је дат кратак преглед развоја астрономије и физике у нашим крајевима у XVIII и првој половини XIX века, са освртом и на почетке метеорологије.*

Кључне речи: историја астрономије, историја физике, историја метеорологије

ASTRONOMY AND PHYSICS WITH THE SERBS IN THE 18TH AND THE FIRST HALF OF THE 19TH CENTURY

Abstract: *A short history of the developement of astronomy and physics in Serbia in the 18th and the first half of the 19th century as well as a short account of the beginning of meteorology is presented .*

Key words: history of astronomy, history of physics, history of meteorology.

Осамнаести век

У осамнаестом веку код Срба се једино Руђер Бошковић бави као научник физиком и астрономијом. Остали прегаоци баве се овим наукама у просветитељском Доситејевском смислу, док се у првој половини деветнаестог века постављају основе за развој физике, астрономије и метеорологије код Срба. У то време развој астрономије је од превасходног интереса пре свега за поморство па није чудно да најпознатије опсерваторије граде управо и велике поморске силе, па се, на пример, једна од најпознатијих у Америци и зове Поморска опсерваторија. У нашим крајевима подстицај за интерес према астрономији и метеорологији пружа пољопривреда и код нашег народа, који се у овом сложеном историјском периоду бори за опстанак, ослобођење и стварање своје државе, астрономски садржај доминира међу разматраним наукама, нарочито у осамнаестом веку управо због интереса пољопривредно оријентисаног становништва за календар, смену годишњих доба и појаве на небу.

У овом периоду у нашим крајевима обавља астрономска посматрања болоњски гроф Луиђи [Алојзије] Фердинанд Марсиљи (Luigi [Aloysius] Ferdinandus Marsigli) (1658-1730)[1]. Војник по професији а научник по вокацији, изузетни човек универзалног духа, плодове својих истраживања објављује у Амстердаму 1726. године у монументалном шестотомном делу Danubius Pannonico - Mysicus, observationibus geographicis, astronomicis, hydrographicis, historicis, physicis. Први том је посветио Мађарској, Србији и осталим земљама које леже на обалама ове реке; други том обухвата археологију ових земаља; трећи геологију; четврти, пети и шести рибе, птице и остале животиње. У последњем тому даје и каталог биљака и приказ притока2. У другом делу првог тома описује, уз подробне цртеже, своје астрономске радове објављене код нас у јуну и јулу 1696. године. На ушћу Драве у Дунав и у тврђави у Тителу одредио је - користећи астрономске методе - месне географске ширине, висине Сунца у меридијану, посматрао Јупитер и његова четири сателита, скицирао тадашњи изглед Месеца. Са моста на Црној Бари, код Бачког Градишта је посматрао Јупитер и његове пратиоце, нацртао карту тада видљивог дела Месеца. Код Сенте је посматрао, опет, Јупитер и његове пратиоце, док је у Жабљу поново нацртао карту Месеца у фази[3]. Дело грофа Марсиљија, човека енциклопедијске ширине, сврстава га у ред личности од изузетног значаја за историју науке у XVIII веку на нашим просторима.

Као прво „астрономско" занимање у Београду, може се навести посао мувекита, верског службеника који се стара о тачном времену за молитве и одређује правац ка Меки. У мувекитханама (сахатницама) које су оснивали или вакуфи или богати султанови намесници, тачно време се одређивало мерењем висине Сунца помоћу астролаб-квадранта (руб'тахта).[4] Мувекит ради у Београду од 1741. у џамији султана Махмуда у Горњем граду уз коју је била медреса са библиотеком, а касније бива премештен у Хусеин Ћехајину џамију.[5]

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[1] Dr Constant von Wurzbach, Biographisches Lexikon, 17. Theil, Wien (1867), 16

[2] Dr Constant von Wurzbach, nav. delo, 17-18

[3] Божидар Д. Јовановић, Astronomy in Vojvodina, Publ.Obs.Astron. de Belgrade, No. 33 Beograd (1985), 96

[4] Јасминко Мулаомеровић, Мувекитхане - прве астрономске институције у Босни и Херцеговини, Зборник радова VII Националне конференције астронома Југославије, Публикације Астрономског друштва „Руђер Бошковић" No. 4, Београд (1985), 25.

[5] Радмила Тричковић, Варош после 1740. године, Историја Београда I, уредник В. Чубриловић, Просвета, Београд (1974), 668.

У исто време, у латинској школи у Сремским Карловцима, велики путник, песник и богослов а на крају архимандрит Јован Рајић (11.XI 1726 – 11.XII 1801) предаје астрономију од 1749 до 1768. године, а сачувана су и његова скрипта за тај предмет.[6] Интересантно је напоменути да у то време Руђер Бошковић предаје астрономију у Римском колегијуму и да је рукопис предавања одржаних школске 1754/55. године сачуван и налази се у Централној националној бибилиотеци Виторио Емануело у Риму.[7] У српској православној великој гимназији у Сремским Карловцима предаје се астрономија од 1798. до 1825. године по Валховом уџбенику из 1794. године, написаном на немачком језику, а елементи астрономије налазе се и у математичкој географији и физици.[8]

Календари

О интересу за астрономију, физику и метеорологију сведоче разни преводи или прераде текстова из ових наука. Осим тога, астрономски садржај налази се и у календарима који на српском језику почињу да се штампају у другој половини XVIII века. Почев од 1765. па до краја XVIII века има их једва дванаестак, док се средином XIX века само у једној години штампа толики број различитих календара.[9]

Први српски календари, месецослови, штампају се у Млецима, Бечу, Будиму и Темишвару, а тек тридесетих година XIX века Милошева Србија добија штампарије, па се на насловним странама календара почињу јављати и Београд и Крагујевац. Овакви календари су ширили и популарисали астрономска знања у нашем народу, објављујући не само времена изласка и заласка Сунца, дужину дана, Месечеве мене, почетак годишњих доба и видљивост планета, него и чланке о небеским појавама и другим астрономским темама који се на другом месту нису могли наћи на српском језику.

У Млецима Павле Соларић штампа свој календар 1813. године, а Захарије Орфелин (1726-1785) објављује Вечити календар 1783. године[10] у Бечу. Поред астрономског дела он садржи и 182 странице посвећене физи-

[6] Ненад Јанковић, Астрономија у делима Јована Рајића, Зборник радова VII Националне конференције астронома Југославије, Публикације Астрономског друштва „Руђер Бошковић" No. 4, Београд (1985), 77.

[7] Ивица Мартиновић, Биљешке Бошковићевих предавања из астрономије академске године 1754/1755, Зборник радова VII Националне конференције астронома Југославије, Публикације Астрономског друштва „Руђер Бошковић" No. 4, Београд (1985), 91.

[8] Божидар Јовановић, Нећемо корачати у XVIII век, Дневник, 14. VII (1990),2.

[9] Ненад Б. Јанковић, Астрономија у српским штампаним календарима до 1900., САНУ Посебна издања DCXXVIII, Одељење Природно-математичких наука, књ. 70, Београд (1994).

[10] Божидар Д. Јовановић, Војводина и Војвођани у популаризацији астрономије до 1941. године, Зборник радова VII Националне конференције астронома Југославије, Публикације Астрономског друштва „Руђер Бошковић Но. 4, Београд (1985), 117.

ци. Астрономски и физички део писан је према уџбенику Адама Данијела Рихтера, директора гимназије у Цитави, Lehrbuch einer für Schulen fasslichen Naturlehre, zum Gebrauch bey Vorlesungen, Fulda 1776.[11,12] У Бечу 1792. године свој календар објављује и Стефан Новаковић.[13]

Велики број календара на српском језику штампан је и у Будиму, почевши од 1799. када је Славеносербскија печатни при Краљевском Университ., штампан Месјацослов. У Будиму је штампан 1801. Календар или Прогностикон у преводу Государа Дамијана Каулиција, Месјацослов митрополита Стратимировића (1807) и други .[14]

Међу првим календарима у Београду налазе се Забавник (1833) Димитрија Давидовића и Београдска лира (1833). Давидовићев забавник се штампа у разним местима са прекидима од 1815. до 1836. године. Он први међу календарима употребљава (1815) народне називе за Венеру (Даница, Зорњача, Вечерњача), а у једном од издања (1820) јавља се чланак Астрономија, у коме је дат кратак преглед небеских тела.[15]

Атанасије Николић (Бачки Брестовац 1803 – Београд 1882.) покреће 1831. године календар Ружицу, а од 1831. до 1837. године издаје Домовни и обштеполезни календар.[16] Од 1836. године па до 1850., „при Књажеско – Србској типографији" штампа се Месецослов, а у Новом Саду се појављује „печатан код г. Павла Јанковића" а после код његове удовице, Ружични венац (1839).[17]

Од 1826. до 1834. са прекидом од 1830. до 1833. године Вук Стефановић Караџић издаје Даницу са занимљивим календарским делом. Димитрије Пантелеон Тирол (Чаково 1793 – Темишвар 1857) објављује 1837. и 1838. године у Београду Уранију заједно са „сотрудницима" Јованом С. Поповићем, Јованом Стејићем и Симом Милутиновићем. У Темишвару, Тирол објављује Банатски алманах (1827 и 1828). Осим тога, он објављује и Месецослове за 1836, 1837. и 1842. годину.[18] Александар Андрић од 1846. до 1859. године уређује и издаје календар Зимзелен у коме саопштава где ће се која планета налазити.

На Цетињу, Димитрије Милаковић издаје календар Грлицу 1835-1839, с тим што је 1837. године уредник био Петроније Лујановић. У првој књизи овог календара за 1835. годину налази се саопштење о Халејевој комети.

11 Божидар Д. Јовановић, нав. дело, 117.
12 Ненад Б. Јанковић, нав. дело, 6.
13 Ненад Б. Јанковић, нав. дело.
14 Ненад Б. Јанковић, нав. дело.
15 Ненад Б. Јанковић, нав. дело, 6.
16 Божидар Д. Јовановић, нав. дело, 117.
17 Ненад Б. Јанковић, нав. дело.
18 Божидар Д. Јовановић, нав. дело, 117.

Осим тога, у библиотеци Петра I коју је Његош наследио налазе се и наслови из земљописа, физике, математике и геометрије.

Мада многи календари не прате увек довољно развој астрономских знања, има и много супротних примера који су омогућили нашим људима да прате напредак астрономије и буду правовремено обавештени о значајним појавама на небу. Тако је долазак Халејеве комете најављен 1835. године на време. Српска јавност је 1836. године упозната и са Енкеовом кометом, као и са открићем Нептуна 1848. године.

Просветитељи

Научни живот на нашим просторима на крају осамнаестог и почетком деветнаестог века обележен је просветитељским духом Доситеја Обрадовића, за кога је наука била првенствено средство које је користио у циљу просвећивања народа и сузбијања сујеверја и различитих заблуда.

Најзначајнији међу писцима који су следили овакав доситејевски дух био је Атанасије Стојковић (1733-1832), доктор филозофије и члан немачких учених друштава. Мада је на нашем подручју делао веома кратко, од 1799. када се враћа са студија у Немачкој до свог одласка у Русију 1804., где постаје професор Универзитета у Харкову[19], оставио нам је поред неколико полукласичних ода и четири прозна дела (Кандор или откровеније египетских таин, Аристид и Наталија, Сербски секретар и Фисика), међу којима је најзначајнија и најпознатија тротомна Фисика.

Ово капитално дело писано славеносербским језиком остало је дуго времена непревазиђено и донело Стојковићу славу и ауторитет које није помрачила ни његова борба против Вука. Фисика даје систематско излагање о природним појавама и законима. Осим физике обухвата и све друге природне науке осим хемије, па се у њој налазе и поглавља посвећена астрономији и метеоролошким појавама.

Текстове из астрономије, физике и метеорологије објављују Павле Соларић (Ново гражданско землеописаније, 1804), Василије Будић (Земљеописаније – 1824), Павле Кенгелац (Кикинда 1766 – Темишвар 1834) Јестествословије (Будим 1811), Еустахија Арсић (Ириг 1776 – Арад 1843) Полезнаја размишленија о четирих годишних временах Будим 1816), Пантелејмон Михајловић, Енциклопедија (Будим 1818) и други. Занимљиво је да се и један свештеник, Ђорђе (Гаврило) Поповић (Баја 1811 – Београд 1871) бавио популарисањем астрономије. Године 1850. издао је књигу Астрономија или наука о звездама.

[19] Јован Деретић, Славеносербски списатељ Атанасије Стојковић, Атанасије Стојковић: Аристид и Наталија, Фисика, Нолит, Београд (1973).

Прва половина деветнаестог века

Прва половина деветнаестог века је период у коме су постављене основе за развој метеорологије и физике у Србији и створена клима која ће омогућити и каснији развој астрономије.

Настава физике у Србији почиње са првом генерацијом ученика Лицеја 1839. године. У току две године на лицеју су ђаци слушали девет предмета и међу њима од природних наука једино физику на другој години. Први привремени професор физике на Лицеју био је Константин Бранковић који је физику предавао само два месеца, од октобра до децембра 1839. године.[20]

Први стални професор физике био је Антоније Арнот Арновљев (1798-1841). Од децембра 1839. године до септембра 1841. он предаје физику по књизи Фисика Атанасија Стојковића. Он започиње и прикупљање физичких апарата за своја предавања па је на тај начин започео формирање збирке физичких инструмената, прве школске збирке код нас.[21] После њега наставу физике су држали Јован Рајић, само око месец дана, и Георгије Мушицки, од октобра 1841. до марта 1843.[22]

Први привремени професор физике на лицеју Константин Бранковић, поново на неколико месеци преузима наставу физике после оставке Георгија Мушицког. После њега, професор физике постаје Јанко Шафарик, професор словенске филологије и историје, који предавања из физике држи од 1843. до 1849. године а у његово време, од 1847. године у збирци физичких инструмената на лицеју постоји и астрономски дурбин.33 Године 1849. долази по позиву за професора лицеја Вук Маринковић (1807-1859). Он на Лицеју предаје физику од 1849. до 1859. године и први од професора физике на Лицеју, пише свој уџбеник, Начела физике, који објављује 1851. године. Он је знатно увећао физичку збирку на Лицеју, а од посебног значаја је и његов рад на стварању српске научне терминологије за природне науке.

У наставном плану Лицеја из 1844. године нема астрономије и метеорологије, али их вероватно већ од 1849. године Вук Маринковић предаје уз физичку географију. Астрономски садржај налази се у уџбеницима Прва початија исчислителного јестественаго земљеписанија, Јована Стери-

[20] Ђорђе Мушицки, Ђорђе Басарић, Физика, Четрдесет година Природно – математичког факултета у Београду, Београд (1987), 196.

[21] Ђорђе Мушицки, Ђорђе Басарић, нав. дело, 196.

[22] Јован Симовљевић, Астрономија, Четрдесет година Природно – математичког факултета у Београду, Београд (1987), 166. Треба напоменути да Ђорђе Мушицки и Ђорђе Басарић, (нав. дело, 196) у истој књизи кажу да се пре Вука Маринковића који је дошао 1849. физичка збирка Лицеја састојала „од свега неколико примитивних уређаја и једног малог микроскопа“.

је Поповића из 1845., Астрономија или наука о звездама, Гаврила Поповића из 1850. и у Начелима физике Вука Маринковића из 1851. године. Астрономски дурбин који од 1847. године постоји у збирци физичких инструмената на Лицеју вероватно је коришћен за изучавање астрономских садржаја.

Средином деветнаестог века, као и у другим државама Европе, и у Србији почиње да се развија метеорологија. Вративши се са школовања у Немачкој и Аустрији, Владимир Јакшић (1824-1899), професор Лицеја, члан Друштва сербске словесности и касније начелник статистичког одељења Министарства финансија и оснивач статистике у Србији, почиње 1848. да врши редовна свакодневна метеоролошка мерења и осматрања у Београду (од 1. јануара 1848. до краја 1899. године).[23]

Јакшићева метеоролошка станица налазила се на Сењаку у близини Маркарнице (данас улица Краља Вукашина број 8). Он мери температуру ваздуха помоћу „сторазделног топлописа“ и бележи временске услове „соразмерност погоде“, а од 1850. и дневне количине падавина. Године 1855. прикључује своме програму и мерења психрометром. Његове оригиналне белешке чувају се у Метеоролошкој опсерваторији на западном Врачару.[24]

Већ после три године посматрања, Јакшић 1851. године у Гласнику Друштва сербске словесности објављује прве резултате. У овом и низу других радова објављених у Гласнику Друштва сербске словесности (1851, 1854, 1855, 1856) и Државопису Србије (1863), Јакшић даје „читаву студију о „местној клими“ Београда, поредећи је са климом у местима ближе полутару, односно ближе Северном полу, са континенталном и приморском климом и са климом места која имају приближно исту температуру „одсеком (просечну) годишњу, односно у поједина годишња доба.“[25]

У овом периоду, Јакшић започиње и са организовањем прве метеоролошке мреже у Србији. Тако је већ 1856. године у Србији радило двадесет добро организованих метеоролошких станица и то у Топчидеру, Шапцу, Ваљеву, Тополи, Неменикућама, Паланци, Пожаревцу, Мајданпеку, Неготину, Јагодини, Крагујевцу, Брусници, Чачку, Ужицу, Рашкој, Карановцу (данас Краљево), Крушевцу и Алексинцу.[26]

На крају разматраног периода у Србији је створен кадар и друштвена клима која ће омогућити да у другој половини деветнаестог века израсту прави научници који ће дати свој допринос развоју научне мисли.

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[23] Зоран Поповић, 100-година Метеоролошке опсерваторије у Београду, Васиона, XXXV (1987), 7.

[24] Боривоје Добриловић, Ненад Ђорђевић, Метеорологија, Четрдесет година Природно – математичког факултета у Београду, Београд (1987), 252.

[25] Боривоје Добриловић, Ненад Ђорђевић, нав. дело, 252.

[26] Зоран Поповић, нав. дело, 7.

ROLE OF CHEMI-IONIZATION AND CHEMI-RECOMBINATION COLLISION PROCESSES IN PLASMA OF SOLAR ATMOSPHERE

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1 Introduction

In several previous papers [1-3], chemi-recombination processes during the free electron scattering on the quasi-molecular collisional complexes $H(1s) + H^+$ and molecular ions H_2^+ in the weakly bound rhovibrational states, have been introduced and investigated. It was assumed that these molecular ions are in the ground electronic state $X^2\Sigma_g^+(1s\sigma_g)$. The mentioned chemi-recombination processes are

$$H_2^+ + e \Rightarrow H^*(n) + H(1s), \qquad (1a)$$

$$H(1s) + H^+ + e \Rightarrow H^*(n) + H(1s), \qquad (1b)$$

where $H^*(n)$ denotes hydrogen atom in a highly excited (Rydberg) state with the principal quantum number $n \leq 4$. It has been shown that in partially ionized plasma the processes (1a) and (1b) may be significant for the $H^*(n)$ atom populations.

In this paper we will consider the (1a,b) processes from the aspect of their influence on $H^*(n)$ atom populations of solar photosphere and lower part of chromosphere. We point out here that the taking into account of these processes may be particularly important when the conditions of LTE, concerning the excited atom population distribution function, are not satisfied. Such situation exist just for the above mentioned parts of the solar atmosphere (due to their small optical depth). The principal aim of this paper is to show that, for particular layers of the solar atmosphere, the chemi - recombination processes (1a,b) could be comparable or sometimes even more important that the processes of the electron - electron - ion recombination as well as with the processes of electron - ion photorecombination, which have a particularly important role in the solar atmosphere, so that they also must be taken into account when modelling the solar atmosphere.

2 Results and discussion

In accordance with Refs.[1-3] recombination processes (1a,b) will be treated as the result of the energy exchange within the electronic component of the $H_2^+ + e$ or $H + H^+ + e$ system, which is caused by dipole interaction of the electron e with the ion - atomic subsystem H_2^+ or $H + H^+$.

In order to estimate the importance of the (1a,b) chemi - recombination processes, we will compare them at first with the photorecombination processes

$$H^+ + e \Rightarrow H^*(n) + h\nu, \qquad (2)$$

for the $n \geq 4$ range. As a quantitative characteristic of the relative influence of the (1a,b) chemi - recombination processes and the photorecombination processes (6) we will use the quantity

$$F_{phr}^{(ab)}(4;8) = \frac{\Sigma_4^8 I_r^{(ab)}(n;T)}{\Sigma_4^8 I_{phr}(n;T)}, \qquad (3)$$

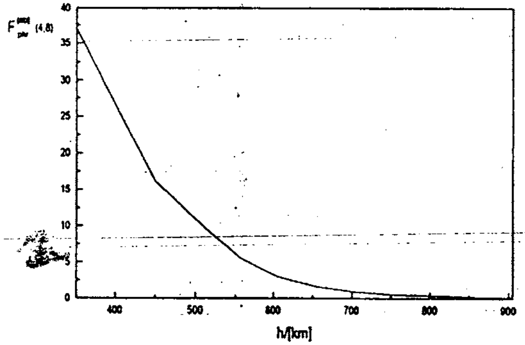

Figure 1. The behaviour of the quantity $F_{phr}^{(ab)}(4;8)$, given by the Eq. (3), as a function of height h.

where $I_{phr}(n;T)$ denotes the photorecombination flux conditioning the process (6) for given n and $I_r^{ab}(n;T)$ the total chemi-recombination flux. In order to determine the $F_{phr}^{(ab)}(4;8)$ values, the Eqs (2-4) from Refs. [4] have been used for $\Sigma_4^8 I_r^{(ab)}(n;T)$ calculations, while $\Sigma_4^8 I_{phr}(n;T)$ is estimated on the basis of data from Ref.[5]. Fig. 1 illustrates the behavior of the $F_{phr}^{(ab)}(4;8)$ quantity for 350 km $\leq h \leq$ 905 km. We show only this height range, since for h >905 km the values of quantity $F_{phr}^{(ab)}(4;8)$ decrease below 0.01, while for h <350 km these values continue to increase monotonically. One can see in Fig. 1 that above arround 700 km the influence of the (1a,b) processes is much smaller in comparison with the photorecombination processes ($F_{phr}^{(ab)}(4;8) < 0.1$). For 650 km $< h <$ 700 km the influence of both processes is comparable and for $h <$ 650 km the (1a,b) chemi - recombination processes are dominant in comparison with the photorecombination processes (2) for $n \geq 4$.

This conclusion is not connected with our choice of the $n = 8$ as the upper limit of the considered n values region. Namely, our estimates performed in order to check this conclusion show that if we change even only $\Sigma_4^8 I_{phr}(n;T)$ with the sum for all $n \geq 4$, which have sense for given T and $N(e)$, the ratio values on the Eq. (2) right side will be changed around 20 percent. It is clear that this change will be even smaller if $\Sigma_4^8 I_r^{(ab)}(n;T)$ in the Eq. (3) will be changed in the adequate way.

In the next step we will compare the (1a,b) chemi-recombination processes with the electron - electron - ion recombination processes

$$H^+ + e + e \Rightarrow H^*(n) + e, \qquad (4)$$

for the same $n \geq 4$ range. As a quantitative characteristic of the relative influence of the (1a,b) chemi - recombination processes and the electron - electron - ion recombination processes (4) we will first of all use the quantity

$$F_{eei}^{(ab)}(4;8) = \frac{\Sigma_4^8 I_r^{(ab)}(n;T)}{\Sigma_4^8 I_r^{eei}(n;T)}, \tag{5}$$

where $I_r^{eei}(n;T)$ denotes the electron - electron - ion recombination flux conditioning the process (4) for given n, taken here in the form

$$I_r^{eei}(n) = \alpha_r^{eei}(T) N(e)^2 N(H^+). \tag{6}$$

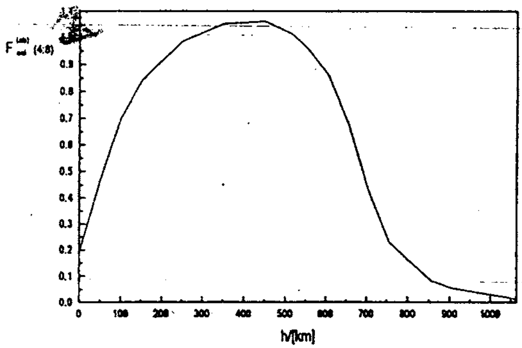

Figure 2. The behaviour of the quantity $F_{eei}^{(ab)}(4;8)$, given by the Eq. (5), as a function of height h.

For determination of the $F_{eei}^{(ab)}(4;8)$ values, the $\alpha_r^{eei}(T)$ rate coefficients have been calculated here by using the corresponding expressions in Ref.[6]. The behavior of the $F_{eei}^{(ab)}(4;8)$ quantity for 0 km $\leq h \leq$ 1065 km illustrates Fig. 2. This Fig. shows that around 450 km, the (1a,b) chemi - recombination processes become even more influent than the electron - electron - ion recombination processes (4), while within 0 km $\leq h \leq$ 750 km range both processes are comparable ($F_{eei}^{(ab)}(4;8) > 0.2$). For $h <$ 0km and $h >$ 750km, the influence of the chemi - recombination processes becomes small in comparison with electron - electron - ion recombination processes ($F_{eei}^{(ab)}(4;8) < 0.1$ for $h < -25$km and $h >$ 850km).

Besides the $F_{eei}^{(ab)}(4;8)$ quantity, we will introduce also the quantities

$$f_{eei}^{(ab)}(n) = \frac{I_r^{(ab)}(n;T)}{I_r^{eei}(n;T)},$$

characterizing the relative influence of the (1a,b) chemi - recombination processes in comparison with the electron - electron - ion recombination processes (4), on the $H^*(n)$ atom populations for the given n. With help of Eq. (4), where $N(e)$ and $N(H^+)$ are the electron and proton densities, we have that

$$f_{eei}^{(ab)}(n) = \frac{K_r^{(ab)}(n,T)}{\alpha_r^{eei}(T)}\frac{N(1)}{N(e)}. \quad (7)$$

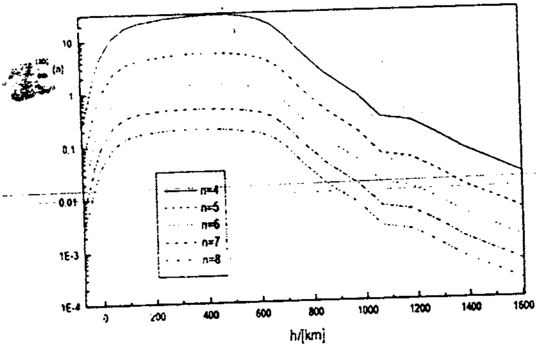

Figure 3. The behaviour of the quantities $f_{eei}^{(ab)}(n)$, given by the Eq. (7), as a function of height h for $n = 4-8$.

where $N(1)$ is the density of $H(1s)$ atoms and $K_r^{ab}(n;T)$ the total chemi-recombination rate coefficient. Here, the ratio $N(1)/N(e)$ may be replaced with $[N(e)/N(H)]^{-1}$, for the $h \leq 750$km range, practically without the decrease of accuraccy. The behavior of the $f_{eei}^{(a\bar{b})}(n)$ quantities as a function of height h for $n = 4-8$ is shown in Figure 3. One can see in Fig. 3 that for n values considered, the chemi - recombination processes are comparable with the electron - electron - ion recombination processes (for $n = 6-8$) or dominant (for $n = 4, 5$) within a wide h range which lower limit changes for different n from -75 km up to 50 km and the upper one from 650 km up to 750km. For $n = 4$ and 5 the h range where the relative influence of the chemi - recombination processes remains comparable, is up to around 1200km.

The specific significance of the $f_{eei}^{(ab)}(n)$ quantities lies is in the fact that they are in the same time ratios of the total fluxes $I_{tot}^{(ab)}(n;T)$ and $I_{tot}^{eei}(n;T)$ characterizing the influence of the ionization processes inverses to the (1a,b) and the (4) recombination process. Namely, in the partially ionized plasma, the (1a,b) chemi - recombination processes occure together with the inverse chemi - ionization processes due to $H^*(n) + H(1s)$ collisions, while the electron - electron - ion processes (4) occure together with the impact ionization processes due to $H^*(n) + e$ collisions. The influence of these inverse processes on the $H^*(n)$ atom populations may be characterized by the corresponding ionization fluxes $I_i^{(ab)}(n)$ and $I_i^{eei}(n)$. The total fluxes $I_{tot}^{(ab)}(n;T)$ and $I_{tot}^{eei}(n;T)$ are than being expressed as

$$I_{tot}^{(ab)}(n;T) = I_r^{(ab)}(n;T) - I_i^{(ab)}(n;T), \qquad I_{tot}^{eei}(n;T) = I_r^{eei}(n;T) - I_i^{eei}(n;T).$$

On the basis of Ref.[3], when $T_e = T_a = T$, these total fluxes may be presented in the form

$$I_{tot}^{(ab)}(n;T) = I_r^{(ab)}(n;T)[1-\eta(n)], \qquad I_{tot}^{eei}(n;T) = I_r^{eei}(n;T)[1-\eta(n)],$$

where is $\eta(n) = N(n)/N_{eq}(n)$, $N(n)$ is the density of the $H(n)^*$ atoms and $N_{eq}(n)$ is the equilibrium density which corresponds to the electron density N_e and the proton density $N(H^+)$ from the same model. From here follows that for the considered Solar plasma is valid that

$$f_{eei}^{(ab)}(n) = \frac{I_{tot}^{(ab)}(n,T)}{I_{tot}^{eei}(n,T)}.$$

Obtained results show that the (1a,b) chemi - recombination processes evidently have an important role in the large region around the temperature minimum in the Solar atmosphere, where they are comparable or dominant in relation to the other recombination processes. Within this range they may be a quite significant factor contributing to the smaller decrease from LTE. Consequently, this shows the necessity of the inclusion of the (1a,b) processes in the modelling of the weakly ionized layers in the Solar atmosphere.

For Solar and stellar atmosphere models where $T_e = T_a = T$, the expressions (2-4) from Ref.[4] for the (1a,b) chemi - recombination processes total rate coefficient $K_r^{(ab)}(n,T)$ may be used. However, for atmosphere models where the equality of T_e and T_a is not assumed, the corresponding tables and the general expressions for partially ionized nonequilibrium hydrogen plasma are given in Ref.[3].

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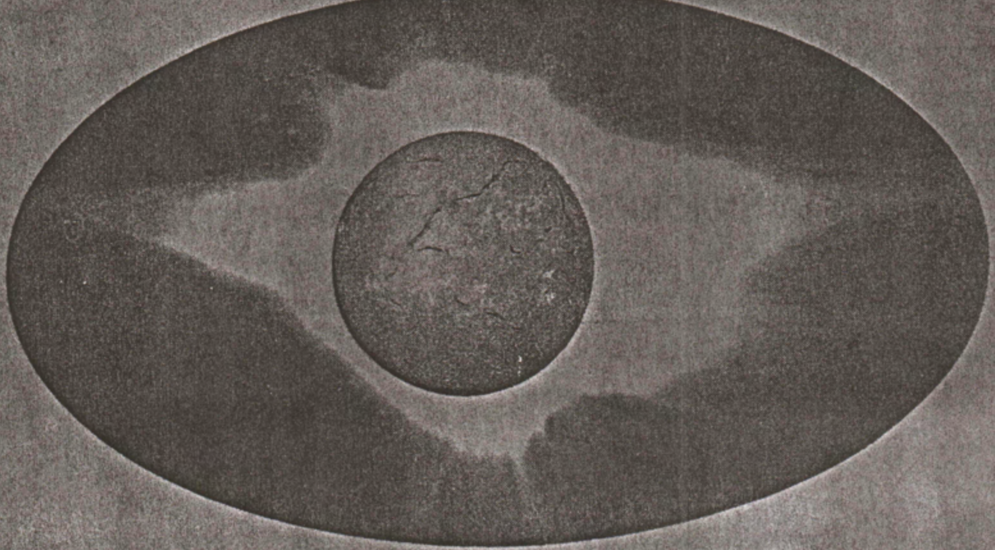

Новый цикл активности Солнца: наблюдательный и теоретический аспекты

Тезисы
Конференции, посвящённой
50-летию
Горной Астрономической Станции
ГАО РАН

24-29 июня 1998 г.

полярный дрейф границ зональной структуры начался в середине 1996 года и его начало совпало с началом нового цикла пятен. Средняя скорость дрейфа с 1996 по 1998 г. составляла 5 м/с и не отличалась от средней скорости полярного дрейфа в период с 1880 по 1990 г. Обсуждается связь и соотношение между полярным и экваториальным дрейфом крупномасштабных магнитных полей.

СВОЙСТВА КОЛЕБАНИЙ В ПРОТУБЕРАНЦАХ

Г. П. Машнич, В. С. Башкирцев

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По результатам наблюдений лучевых скоростей в протуберанцах получены временные и пространственные характеристики колебаний, на основе которых выделены три типа колебаний в этих объектах. Авторы полагают, что источник квазичасовых колебаний находится в нижележащих слоях солнечной атмосферы. Правильность такого предположения доказывает наличие высокой корреляции гелиоширотной зависимости величины квазичасового периода в фотосфере, хромосфере и протуберанцах.

Работа выполнена при поддержке Российского Фонда Фундаментальных Исследований грант 960216647 и Государственного фонда поддержки ведущих научных школ грант 961596733.

ROLE OF CHEMI-IONIZATION AND CHEMI-RECOMBINATION COLLISION PROCESSES IN PLASMA OF SOLAR PHOTOSPHERE

A. A. Mihajlov[1], Lj. M. Ignjatovic[1], and M. S. Dimitrijevic[2]

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Influence of atom-atom chemi-ionization and electron-ion-atom chemi-recombination Collision Processes on the population of excited states of hydrogen atoms in plasma of solar photosphere is studied using some of standard models of the solar chromosphere and photosphere. These processes are treated within a framework of semiclassical theory developed earlier. It is shown that these processes are significant for plasma kinetics under conditions typical for solar photosphere, and are important for coming close to equilibrium distribution of population of excited hydrogen atoms.

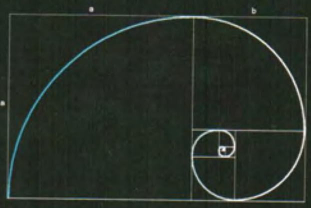
СОЛНЕЧНЫЙ ЦИКЛ КАК СЛЕДСТВИЕ НЕРАДИАЛЬНЫХ ПУЛЬСАЦИЙ СОЛНЦА

В. П. Михайлуца

Горная астрономическая станция ГАО РАН

Аргументируется существование нерадиальных пульсаций Солнца с азимутальными гармоническими числами ($l = 3; 5, m = 2$). Эти пульсации образуют 22-х летний зонально-секторный (диполь-квадрупольный) цикл фонового магнитного поля и являются "точными часами" солнечной цикличности. Генератор пульсаций — солнечное ядро. Часть нерадиальных мод — инерционные волны — захватываются в радиативной зоне Солнца и проявляются на поверхности как: а) секторно-полушарная асимметрия числа групп пятен и полярных факелов; б) пространственно-временные малые деформации (± 0,2 угловых секунд) солнечного радиуса; в) модуляции магнитного потока фонового магнитного поля. Диполь-квадрупольный цикл фонового магнитного поля — основа пятенного цикла, образующегося, как и общепринято, в основании конвективной зоны.

International Congress



The Dialogue between Science & Religion in the Orthodox World

25 - 27 September 2008

Bucharest, Romania

Romanian Academy,
Calea Victoriei 125, Bucharest

Faculty of Orthodox Theology,
Sf. Ecaterina str. 2, Bucharest

have fallen? In the Siberian camp, nearby the northern pole, where he executed his sentence, my uncle was preaching first to the birds and to the beasts, then to the people. This was a sign that the Church was with him, that it did not remain in Zloti. This was a sign that the Church is not a simple building, but a living being. From the experience of the former USSR, of which the actual Republic of Moldova was a part, I would find myself entitled to state that: I do not believe in the meaning of the revolutions which stimulate the most the human vices and which animalize the human being, instead of perfecting him. I believe too that there is no point for a revolution if it could not improve the inside of the human being. The other ones are regrettable losses of time, human lives and hopes. I also believe that it is not quite the society that should be changed, but rather the human being from within, including with the help of scietific data.

It is not the economical differences between our countries and the Occident that is frightening, but the interval between our mentalities. I see the unity of a forthcoming Europe into a recovered harmony between religion and science, an important step for its spiritual unity.

Orthodox Church and Astronomy in Common Fight against Astrological Superstition

Milan S. Dimitrijevic
Serbia

In the fight against superstition and credulity Orthodox Church and Astronomical science have a common adversary - Astrology. In this common task, the Orthodox Church and Astronomy are partners which could help mutually to educate people and suppress superstition.

A number of cannons of the Orthodox Church as for example 24th canon of Ankir council (314 AD), 36th canon of Laodice council (360 AD), canons of holy Basil the Great and of Gregory of Nyssa condemn any fortune-telling and their techniques including astrology. In canons 65 and 72 of holy Basil the Great fortune-telling, which is the destruction of human liberty, equals with murder.

Astrology attacks human liberty and free will. Decisions which a man makes himself are ceded to an astrologer. A free man becomes in such a way astrologer's "client" without liberty to make decisions according to his own free will, without astrologer. In such a way a man also throw away the responsibility.

For example Holy Maxim the Greek says: "If by movements of stars and by their conjunctions we receive the gifts of God, than our reason and the free will of our souls depend on zodiacal properties, and by them are directed toward the virtue or toward the culpable life, and than the apostolic sermon becomes needless, and our faith becomes needless...Nobody than should care about virtue or to try to avoid vices... Such one should not have the fear of the Judge since his justification will be that he is forced by the evil master who against his will forced him to different vices."

We will discuss here the disagreement of Astrology with modern science and with Orthodoxy and review the arguments of Orthodox Church and Astronomy against this superstitious belief.

KNOWLEDGE AS THE RESULT OF GOING BEYOND SCIENCE AND RELIGION

Liviu Druguş
Romania

What is beyond science and religion, after going between them and across them? In my opinion the transdisciplinary results of these trips is knowledge, more knowledge and better and clearer knowledge. The paper is a bit challenging one by wondering if "science" and "religion are the right words we need to describe our attempts to more clear and precise knowledge. My hypothesis is that underlining the links, similarities and differences between Science and Religion, we risk forgetting to go beyond them. My proposal is to pick up the barrier between them and to start to think them together, far beyond any institutional arrangements, group interests or individual ambitions. Of course, many others are working to this project. I am describing here only some remarks and (new?) proposals

THE UNCREATED ENERGIES AND THE MYSTERY OF CREATION

Victor Eugen Gelan
Romania

In the present paper, I will point out the importance of the doctrine of the uncreated energies, as it is exposed in the writings of Gregory Palamas. The isihast theology is fundamental in the orthodox thinking, which conceives the world as a creation of God. Even though this teaching is explicitly exposed for the first time in the writings of Gregory Palamas, it was also a system of thought and a way of life in the first centuries of the Christian era. The roots of this doctrine are to be found in the Gospels and in the mystic experience of uniting with God. Understanding this doctrine of the Church Fathers concerning uncreated energies implies on the one hand understanding the world, and on the other hand understanding the relation between the Creator and his creation.

Can the world as a creation of God be known by means of sciences? Is it possible for the scientific thinking to pass beyond showing us how the world is and finally tell us what the world is? The scientific activity is concerned only with the descriptive level or is it concerned with understanding too? Is it concerned only with the "how" of the things or with their "why" as well? Can the theological doctrine of the uncreated energies be at the same time of any interest for the scientific understanding and explanation of the world?

The relation between science and theology can be reconsidered from the point of view of the uncreated energies. Both theology and science are concerned with the reality humans are dealing with, of which they are part and that they are trying to understand better. We can talk about many realities or many levels of the same reality. The way the human subject experiences reality differs from the different levels of the same reality as described by theology and science. Those levels are parts of the same reality only because they relate to the same general human conscience.

Nicolae Dabija

(B. 1948), writer, historian of literature and politician from the Republic of Moldova, a honorary member of the Romanian Academy since 2003. As chief editor of the weekly magazine Literatura si Arta issued by the Writers' Union from the Republic of Moldova he took an important part in the struggle for national renaissance within the republic. In 1988-1989 the weekly magazine led by Dabija was the most important publication which sustained the return of the "moldavian language" to the Latin writing, the acknowledgement of the identity between the moldavian language and Romanian one and the proclaiming of the latter as an official language in the SSR of Moldavia. In its glorious times, the weekly magazine Literatura si Arta was crossing the issue border of 150,000 copies. Nowadays, the same weekly magazine is forced to call for sponsors in order to survive.

Milan S. Dimitrijevic

He is an astronomer. 1994 – 2002: director of Belgrade Astronomical Observatory; 1987 – 2002: editor in chief of Serbian Astronomical Journal; 1982 – 2005 president of the Astronomical Society "Rudjer Boškovic", co-president of the Working group on line broadening of the IAU Commission 14 for Atomic and Molecular data, now at Belgrade Astronomical Observatory. Scientific interest include influence of collisions with charged particles on stellar spectral line shapes, collisional processes and chemical reactions in stellar atmospheres, astrophysical spectra, history of astronomy, astronomy in culture and popularization and education of astronomy.

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Victor Eugen Gelan

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10th ICSLS

International Conference on Spectral Line Shapes

ABSTRACTS

University of Texas, Department of Physics, Austin, TX 78712
June 25 – 29, 1990

AN EXAMINATION OF REGULARITIES IN NEUTRAL ATOM BROADENING

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Regularities and similarities in the widths of spectral lines perturbed by neutral atoms have been studied in order to find out if they are apparent to such a degree that they can be used to obtain data by interpolation and hence provide a tool for the critical evaluation of new experimental results. The principal results on the clearly identified regularities will be published soon[1].

The Van der Waals result for the theoretical half-half width, w(theory), has been used in conjunction with the critically selected data of Allard and Kielkopf[2], w(experiment), to search for regularities in transitions along a spectral series and for corresponding transitions in homologous emitters. The dependence of line widths on the perturber properties has also been examined.

We define the quantity

$$f(C_6,\mu,T) = C_6^{2/5}(T/\mu)^{3/10},$$

where C_6 is the Van der Waals coefficient, μ is the reduced mass of the emitter-perturber system, T is the temperature and all quantities are in atomic units. Results for the resonance transitions of the alkalis perturbed by rare gases are shown in figure 1. The scatter of the data about the average value of w(experiment)/w(theory) is less for larger values of $f(C_6,u,T)$, which corresponds to larger values of C_6 and hence to where the longer-range part of the interatomic potential becomes dominant in determining the width. Our results also show that better agreement between theory and experiment is obtained if the Van der Waals formula is multiplied by a factor of about 1.25-1.5. This can be explained by studying figure 2 where accurate potentials, V(R), for Na-Ne are plotted as a ratio to their asymptotic value, $-C_6/R^6$. It is seen that true convergence to the Van der Waals limit only occurs for R > 50 a.u., a much larger value of R than is often assumed, but that the curves have a maximum at much lower values of R. This behaviour is typical of all alkali-rare gas interactions.

Work is in progress on the development of a new simple formula for the line width that is an improvement on the pure Van der Waals formula. All the long-range polarisation terms in the emitter-perturber interaction are included with the Van der Waals potential being regained in the limit of large R. Preliminary results are shown in figure 3 for the data of figure 1 but with w(theory) being the new simple formula. The results are very encouraging, since

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PROCEEDINGS OF THE V SYMPOSIUM OF BELARUS, SERBIA AND MONTENEGRO ON PHYSICS AND DIAGNOSTICS OF LABORATORY AND ASTROPHYSICAL PLASMAS (PDP-V'2004)

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M I N S K
2004

НАЦИОНАЛЬНАЯ АКАДЕМИЯ НАУК БЕЛАРУСИ
ИНСТИТУТ МОЛЕКУЛЯРНОЙ И АТОМНОЙ ФИЗИКИ

ТРУДЫ V СИМПОЗИУМА БЕЛАРУСИ, СЕРБИИ И ЧЕРНОГОРИИ ПО ФИЗИКЕ И ДИАГНОСТИКЕ ЛАБОРАТОРНОЙ И АСТРОФИЗИЧЕСКОЙ ПЛАЗМЫ (ФДП-V'2004)

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CONTENTS

INVITED LECTURES

ON THE STARK BROADENING OF Cr I LINES IN STELLAR ATMOSPHERES

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1. Introduction

The Stark broadening is the most significant pressure broadening mechanism for A and B stars and this effect should be taken into account in investigation, analysis and modeling of their atmospheres. In our previous works /1-3/ we have shown that the Stark effect may change the spectral line equivalent widths by 10-45%, hence neglecting this mechanism, a significant error in abundance determinations may be introduced. On the other hand, high resolution spectra allow us to study different broadening effects using line profiles.

Neutral chromium spectral lines have been observed for example in Beta CrB (Coronae Borealis) chemically peculiar Ap star. This star shows strong abundance anomalies and there is no a certain answer for this reason.

The aim of this contribution is to calculate Stark broadening of 9 Cr I spectral lines from $4p^7P^o$-$4d^7D$ multiplet using the semiclassical perturbation approach /4,5/, include the obtained results in the synthetic spectrum of Beta CrB, together with the proposed here Cr and Fe stratifications, and compare the obtained results with observations.

2. Results and discussion

All details of the semiclassical perturbation approach /4,5 / used here for the Stark broadening parameter calculations and the analysis of the obtained results will be presented in /6/. Our results for electron-, proton-, and ionized helium-impact line widths and shifts for the nine Cr I spectral lines for a perturbed density of of $1,0\times10^{14}$ cm^{-3} and temperatures from 2,500 up to 50,000 K will be published elsewhere /6/. As a sample, only data for elerctron-, and proton-impact broadening for three lines are shown in Table 1.

Model atmosphere calculations as well as calculations of the absorption coefficients were made with the ATLAS9 code written by R.L. Kurucz /7/. The

Table 1. Stark broadening parameters for Cr I $4p^7P^o$-$4d^7D$ spectral lines. This table shows electron- and proton-impact broadening parameters for Cr I, for a perturber density of $1,0x10^{14}$ cm^{-3} and temperatures from 2,500 up to 50,000 K. The quantity C, when divided by the corresponding full width at half maximum, gives an estimate for the maximum perturber density for which tabulated data may be used. The asterisk identifies cases for which the collision volume multiplied by the perturber density (the condition for validity of the impact approximation) lies between 0.1 and 0.5. For higher densities, the isolated line approximation used in the calculations breaks down. Width denotes full line width at half maximum and *Shift line shift in 0.1 nm.*

		Electrons		Protons	
Transition	T [K]	Width 0.1 nm	Shift 0.1 nm	Width 0.1 nm	Shift 0.1 nm
Cr I $4p^7P^o{}_2$- $4d^7D_1$ 527,75nm	2500	0.890E-2	-0.205E-2	0.461E-2	-0.379E-2
	5000	0.772E-2	-0.146E-2	0.551E-2	-0.437E-2
	10000	0.665E-2	-0.104E-2	0.678E-2	-0.505E-2
	20 000	0.548E-2	-0.767E-3	0.832E-2	-0.592E-2
	30 000	0.493E-2	-0.660E-3	0.951E-2	-0.651E-2
	50 000	0.431E-2	-0.559E-3	0.993E-2	-0.719E-2
Cr I $4p^7P^o{}_2$- $4d^7D_2$ 527,72nm	2500	0.193E-1	-0.216E-2		
	5000	0.164E-1	-0.155E-2		
	10000	0.136E-1	-0.108E-2		
	20 000	0.111E-1	-0.790E-3	*0.717E-1	-0.298E-1
	30 000	0.983E-2	-0.675E-3	*0.702E-1	-0.273E-1
	50 000	0.841E-2	-0.569E-3	*0.664E-1	-0.239E-1
Cr I $4p^7P^o{}_2$- $4d^7D_3$ 527,67nm	2500	0.240E-1	-0.939E-3	*0.216E-1	-0.138E-1
	5000	0.210E-1	-0.677E-3	*0.253E-1	-0.170E-1
	10000	0.178E-1	-0.473E-3	*0.274E-1	-0.193E-1
	20 000	0.147E-1	-0.401E-3	0.280E-1	-0.193E-1
	30 000	0.131E-1	-0.393E-3	0.283E-1	-0.180E-1
	50 000	0.112E-1	-0.393E-3	0.289E-1	-0.155E-1

next step is the calculation of the outward flux at corresponding wavelengths points using the given model. For this purpose we used SM, code written by Khan /8/. This code allows to calculate synthetic spectra of early and intermediate type of stars taking into account magnetic field effects and stratification of chemical elements. We used a model of Beta CrB calculated by ATLAS9 code with T_{eff} = 8000 K, log g = 4.3, without convection. Magnetic field is 8000 Gauss.

Stratification is determined from a number of intervals with more or less strong Cr and Fe lines. The found stratification profiles are shown in Fig. 1. The comparison of observed and calculated Cr I lines is shown in Figs. 2 and 3.

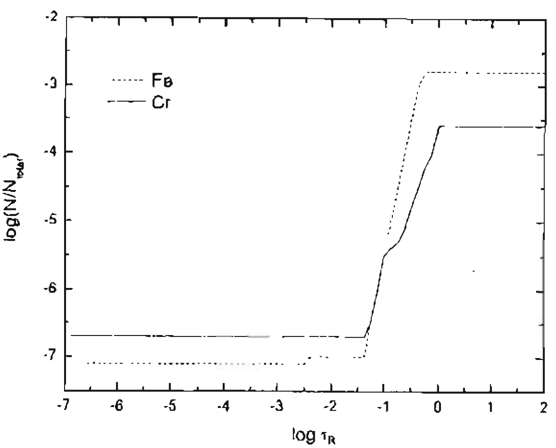

Figure 1. Proposed Cr and Fe abundance distribution in the atmosphere of Beta CrB star.

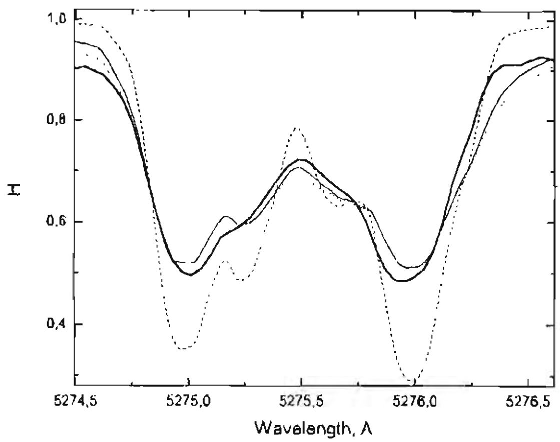

Figure 2. A comparison between the observed Cr I line profiles in the spectrum of Ap star Beta CrB (thick line) and synthetic spectra calculated with the obtained Stark widths and shifts and Cr, Fe abundance stratifications (thin line), with the same Stark parameters but for homogeneous Si distribution (dashed line), and with Stark width calculated by approximate formulae for the same stratification (dotted line). X- and Y-coordinates are wavelenghths and surface fluxes (normalized to unity).

3. Conclusions

We have calculated Stark broadening parameters for Cr I spectral lines from $4p^7P^o$-$4d^7D$ multiplet and investigated the influence of Stark broadening effect in stellar atmosphere for these lines. From our investigation we can conclude: (i) The calculated value of Stark widths as well of shifts can be quiet

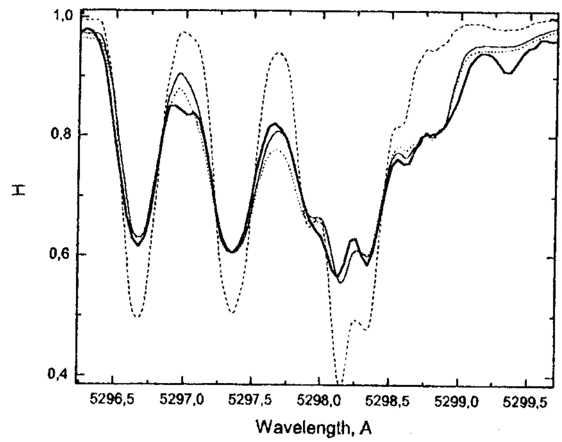

Figure 3. The same as in Fig. 2 but for the region around 5298 A.

different for the different lines, although these belong to the same multiplet. (ii) The contribution of the proton collision to the line width and shift are significant, and it may be depending on the temperature comparable or sometimes even larger than the electron-impact contribution. (iii) The agreement with observations is much better if Stark broadening and stratification are taken into account.

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ON THE STARK BROADENING OF THE Kr II 469.4 nm, Ar II 476.5 nm AND Ar II 480.6 nm LINES

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1. Introduction

In this work, the full semi-classical perturbation approach /1,2/ has been applied for the determination of Stark broadening parameters of the Kr II 469.4nm, Ar II 476.5 nm and Ar II 480.6 nm lines, and a jointly laser physical application of the results obtained; namely the role of Stark broadening on the mode properties of hollow cathode excited noble gas mixture lasers is discussed.

2. Stark broadening parameters calculation

All details of the semiclassical perturbation approach /1,2 / used here for the Stark broadening parameter calculations and the comparison of obtained results with existing experimental and theoretical calculations (see /3/ and references therein) will be presented in /4/. We note only that we checked the influence of the missing Kr II 7p levels and found it not important. Determined Stark broadening parameters for the Kr II 469.4nm, Ar II 476.5 nm and Ar II 480.6 nm lines are shown in Tables 1-3 respectively.

3. Stark broadening in hollow cathode laser discharges

Ionic lines can be effectively excited in a hollow cathode (HC) discharge due to the presence of high energy electrons. It has been used since 1970 for the excitation of a lot of noble gas-metal vapor and noble gas mixture ion lasers /5/.

An interesting feature of the HC lasers is that they oscillate usually in a single axial mode without any optical selection. This property has been attributed to the large homogeneous line-width due to the relatively large filling pressures. Recent studies have shown, however, that - in several cases - pressure broadening is not large enough to explain single mode operation /6/, and Stark broadening has also to be taken into account /7/. Therefore it seemed to be reasonable to study the role of Stark effect at the He-Kr^+ 469.4 nm and He-Ar^+ 476.5 nm HC lasers /8,9/.

3.1. The HC laser discharge.

For laser purposes the discharge inside the cathode is used for the excitation. Different HC geometries are applied; most frequently "longitudinal" or "transversal" systems /10/. The typical pressure in the tube is 10-25 mbar. In

Table 1. Stark widths **W** (full widths at half maxima) and shifts **d** for the Kr II 469.4 nm line. Perturber density: $1{,}0\times10^{14}$ cm^{-3}. The perturbers are electrons, protons and ionized Krypton.

		Electrons		Protons		Ionized Krypton	
Transition	T [K]	Width 10^{-3} nm	Shift 10^{-4} nm	Width 10^{-5} nm	Shift 10^{-5} nm	Width 10^{-5} nm	Shift 10^{-5} nm
Kr II 5p-6s	1000	0,339	1,03	0,0492	0,159	0,200	0,147
	2000	0,251	0,782	0,158	0,313	0,348	0,245
	5000	0,167	0,622	0,455	0,564	0,546	0,370
	10 000	0,118	0,564	0,755	0,771	0,654	0,443
	20 000	0,0921	0,452	0,998	0,924	0,765	0,525
	50 000	0,0788	0,362	1,32	1,16	0,919	0,642

Table 2. Stark widths w (full widths at half maxima) and shifts d for the Ar II 476.5 Å line. Perturber density:$1{,}0\times10^{14}$ cm^{-3}. The perturbers are electrons, protons and ionized Argon.

		Electrons		Protons		Ionized Argon	
Transition	T [K]	Width 10^{-3} nm	Shift 10^{-4} nm	Width 10^{-5} nm	Shift 10^{-6} nm	Width 10^{-5} nm	Shift 10^{-6} nm
Ar II $4s^2P$-$4p^2P^o$	1000	0,193	0,429	0,0348	0,249	0,131	0,248
	2000	0,132	0,362	0,0919	0,520	0,250	0,497
	5000	0,0859	0,248	0,241	1,18	0,408	0,957
	10 000	0,0633	0,195	0,370	1,82	0,482	1,32
	20 000	0,0474	0,149	0,485	2,50	0,544	1,61
	50 000	0,0368	0,112	0,594	3,20	0,599	2,03

Table 3. Stark widths w (full widths at half maxima) and shifts d for the Ar II 480.6 nm line. Perturber density: $1{,}0\times10^{14}$ cm^{-3}. The perturbers are electrons, protons and ionized Argon.

		Electrons		Protons		Ionized Argon	
Transition	T [K]	Width 10^{-3} nm	Shift 10^{-3} nm	Width 10^{-5} nm	Shift 10^{-4} nm	Width 10^{-5} nm	Shift 10^{-6} nm
Ar II $4s^4P$-$4p^4P^o$	1000	0,147	0,161	0,0250	0,132	0,0980	0,132
	2000	0,110	0,125	0,0669	0,277	0,194	0,272
	5000	0,0728	0,103	0,183	0,662	0,331	0,567
	10 000	0,0544	0,0741	0,288	1,10	0,399	0,810
	20 000	0,0410	0,0571	0,391	1,54	0,452	1,03
	50 000	0,0317	0,0453	0,470	2,05	0,502	1,31

Table 4. Line-broadening data for the Kr II 496.4 nm, Ar II 476.5nm and 480.6 nm lines in He-Kr and He-Ar hollow cathode laser discharges. Typical plasma parameters at ~100mA/cm^2 current density and 23 hp pressure: N_e~6x10^{13} cm^{-3} and T_e~2300 K

	Kr II 469.4nm [MHz]	Ar II 476.5nm [MHz]	Ar II 480.6nm [MHz]	Remark
Pressure broadened natural line-width at 23 hp (measured at 50mA/cm^2 current density) /8,9/	490	585	141	Stark line-width at these experimental conditions deduced (factor: 0.35)
Stark line-width at laser conditions (23hp, ~100 mA cm^{-2})	199	101	83	Calculated from the present theoretical data
Homogeneous (pressure broadened natural + Stark) line-width	689	686	224	
Inhomogeneous (Doppler) line-width at laser conditions	1400	2100	2100	Estimated value based on experimental data at lower current densities /8,9/
Ratio of homogeneous and inhomogeneous line-widths	0.49	0.33	0.11	

a HC discharge the electron energy distribution function has generally a nearly Maxwellian low energy part with a high energy tail. The mean energy of the low energy part amounts to E_e = 0.1 – 1 eV, while the high energy tail can rise up to the cathode voltage which is commonly several hundred V. For laser excitation the high energy tail is of importance, but concerning Stark broadening the low electron energy part is important: It was found experimentally that in a HC laser discharge - in the middle of the cathode - *the electron density amounts to* N_e = *5.10^{13} - 10^{14}cm^{-3}, about two order of magnitude larger, than that in the positive column of a glow discharge /11/.* Different model calculations and measurements are available (see e.g. /12/). *Gill and Webb* /12/, however, have found, that in noble gas-metal vapour systems N_e is about a factor of two larger, than that in pure noble gas systems. Therefore especially for the He–Kr and He-Ar gas mixtures in a transversal hollow cathode discharge tube with 20 - 25 mbar filling pressure and at ~100mA cm^{-2} current density on the cathode surface, E_e ~ 0.2 eV and N_e ~ 6 x10^{13} cm^{-3} can be assumed as a good estimation.

3.2. Line broadening data for the Kr^+ and Ar^+ lines in HC laser discharges

Results are summarized in Table 4. The line-widths are given in frequency units typically used in this field. Stark line-widths are calculated at a perturber density N_e~6x10^{13} cm^{-3} and electron temperature T_e~2300 K. The pressure broadened natural line-widths given in row 3 had been measured earlier /8,9/ and have to be corrected now with the Stark line-widts at the discharge tube used. (The smaller current density and off-centre observation direction together resulted here in a decreasing factor of 0.35 compared to the Stark line-widths at laser conditions.).

4. Discussion

For single mode operation of a laser - according to Troickij /13/ - the ratio of homogeneous and inhomogeneous line-widths should be larger than ~0.3 – 0.32. It can be stated that this condition is fulfillled at both laser transition. But while for the He-Kr II 469.4 nm laser the earlier assumption remains valid, i.e. pressu re broadening is enough large to explain the single mode operation of this laser, at the He-Ar II 476.5 nm laser - like at the He-Cd II 537.8 nm laser /7/ - Stark broadening also has to be taken into account to explain this property. At the Ar II 480.6 nm (not laser) transition both line-widths are significantly smaller.

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PHYSICS OF FORMATION OF FeII LINES OUTSIDE LTE

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STARK BROADENING OF THE Fe II LINES IN THE SOLAR AND STELLAR SPECTRA

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ABSTRACT. Recently developped modified semiempirical approach (Dimitrijević and Konjević, 1980, 1986; Dimitrijević and Kršljanin, 1986) is applied to the Stark broadening calculation of Fe II lines in the Solar spectrum and the spectrum of Am 15 Vulpeculae.

1. INTRODUCTION

In stellar atmospheres calculations the collisional broadening parameters for a large number of various elements are required and they are often unavailable. Moreover, in O and B stars and white dwarfs atmospheres the Stark effect is the main pressure broadening mechanism. In A stars atmospheres its influence is very important and even in atmospheres of relatively cool stars as the Sun, where the line broadening caused by collisions with neutral perturbers is dominant, for higher number of spectral series the Stark effect may compete with neutral perturber interaction with emitter (Vince et al, 1985). A convenient method for Stark broadening calculations in astrophysics in the cases when more sophysticated calculations are avoided (e.g. lack of atomic data, complex spectra, large scale calculations or rough estimates) is the modified semiempirical approach (Dimitrijević and Konjević, 1980, 1981; 1986; Dimitrijević and Konjević, 1986). Tables of calculated Stark widths of prominent lines of some doubly- and triply-charged ions are given by Dimitrijević and Konjević (1981).

Recently, a detailed model atmosphere analysis of the Am 15 Vulpeculae star is carried out (Yo-ichi Takeda, 1984) in plasma conditions where the Stark broadening is not negligible. For a number of lines of more complex atoms, published Stark broadening data have not been found by the author of the mentioned article. Here are given the simple Stark broadening calculations of Fe II lines from the spectrum of Am 15 Vulpeculae and Solar spectrum in order to demonstrate the aplicability of the modified semiempirical method for such kind of the calculations in the case of more complex atoms and to provide also the Stark broadening data for some Fe II lines of

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astrophysical interest.

2. THE MODIFIED SEMIEMPIRICAL APPROACH

In order to reduce the input set of atomic data and to extend the applicability of semiempirical method published by Griem (1968) to higher stages of ionization, Dimitrijević and Konjević (1980) separated the transitions with $\Delta n = 0$ and introduced for them different Gaunt factor. Transitions with $\Delta n \neq 0$ are summed separately. half-half width w and shift d of ion spectral line broadening by Stark effect become now

$$w + id = N \frac{4\pi}{3} \frac{\hbar^2}{m^2} \left(\frac{2m}{\pi kT}\right)^{1/2} \frac{\pi}{\sqrt{3}} \sum_{j=i,f} \{ \vec{R}^2_{k,k+1} [\tilde{g}(x_{k,k+1}) + i\epsilon_j \tilde{g}_{sh}(x_{k,k+1})] + \vec{R}^2_{k,k-1} [\tilde{g}(x_{k,k-1}) - i\epsilon_j \tilde{g}_{sh}(x_{k,k-1})] \} + \sum_{j'} (\vec{R}^2_{jj'})_{\Delta n \neq 0} [g(x_j) + i\epsilon_j g_{sh}(x_j)] - 2i\epsilon_j [\sum_{\Delta E_{jj'} < 0} (\vec{R}^2_{jj'})_{\Delta n \neq 0} g_{sh}(x_{jj'})] \quad (1)$$

Here $k = \ell_j$, i and f denote the initial and final levels $\epsilon_j = +1$ if $j = i$ and -1 if $j = f$ and $\vec{R}^2_{jj'} = |\langle j|\vec{r}|j'\rangle|^2$. Gaunt factors g, $\tilde{g}$, g_{sh} and $\tilde{g}_{sh}$ are given as a function of x in the Table 1. Also $x_{jj'} = 3kT/2\Delta E_{jj'}$, $x_j = 3kTn_j^{*3}/4Z^2E_H$ where E_H is the hydrogen ionization energy.

Table 1.

	x	≤ 1	2	3	5	10	30	100
	g	0.2	0.2	0.24	0.33	0.56	0.98	1.33
	$\tilde{g}$	0.7	-1.1/Z+g					
	g_{sh}	0.2	0.25	0.32	0.45	0.66	0.82	0.87
Z = 2	$\tilde{g}_{sh}$	0.35	0.40	0.47	0.58	0.70	0.82	0.87
Z = 3	$\tilde{g}_{sh}$	0.53	0.54	0.57	0.62	0.70	0.82	0.87
Z = 4	$\tilde{g}_{sh}$	0.62	0.63	0.63	0.65	0.70	0.82	0.87
Z 4	$\tilde{g}_{sh}$	0.88 - 1.1/Z+0.01+0.01x/Z;				x ≤ 100		

$$\sum_{j'} (\vec{R}^2_{jj'})_{\Delta n \neq 0} \simeq \left(\frac{3n^*_j}{2Z}\right)^2 \frac{1}{9}(n^{*2}_j + 3\ell^2_j + 3\ell_j + 11) \quad (2)$$

and

$$R^2_{jj'} = \left(\frac{3n^{*2}_j}{2Z}\right)\frac{\ell_>}{2\ell+1}(n^2_\ell - \ell^2_>)\phi^2(n_{\ell-1}, n_\ell, \ell)$$

For all cases when $3kT/2\Delta E_{jj'} \lesssim 2$ one can use the values $g = g_{sh} = 0.2$ and $\tilde{g} = \tilde{g}_{sh} = 0.9 - 1.1/Z$. Furthermore, one can put in Eqs. 1 and 2 $\phi^2 = 1$ what is a reasonable assumption for $\Delta n = 0$ (see e.g. Griem, 1974 p. 31) since the exact values of ϕ^2 usually range between 0.8 and 1. If one performs summation in Eq. (1) it is easy to obtain

$$w(\mathring{A}) = 0.2215\cdot 10^{-8} \frac{\lambda^2(cm)N(cm^{-3})}{T^{1/2}} \sum_{j=i,f} \left[(\vec{R}^2_{jj'} + \frac{\tilde{g}_{th} g_{th}}{g_{th}} \cdot \left(\frac{3n^*_j}{2Z}\right)^2 (n^{*2}_j - \ell^2_j - \ell_j - 1)\right] \quad (3)$$

Since the contribution to the total line width of transitions with $\Delta n \neq 0$ does not exceed 25%, and it is compensated by assuming $\phi^2 = 1$, we can neglect them and finally obtain

$$w(\mathring{A}) = 1.1076\cdot 10^{-8} \frac{\lambda^2(cm)N(cm^{-3})}{T^{1/2}}\left(0.9 - \frac{1.1}{Z}\right) \sum_{j=i,f} \left(\frac{3n^*}{2Z}\right)^2 \cdot (n^{*2}_j - \ell^2_j - \ell_j - 1) \quad (4)$$

With analogous simplifications for the shift from Eq.(1) one may obtain

$$d(\mathring{A}) = 1.1076\cdot 10^{-8} \frac{\lambda^2(cm)N(cm^{-3})}{T^{1/2}}\left(0.9 - \frac{1.1}{Z}\right) \sum_{j=i,f} \left(\frac{3n^*_j}{2Z}\right)^2 \frac{\epsilon_j}{2\ell_j+1} \{(\ell_j+1)|n^{*2}_j - (\ell_j+1)^2| - \ell_j(n^{*2}_j - \ell^2_j)\} \quad (5)$$

If all levels $\ell_{i,f} \pm 1$ exist, an additional summation may be performed in Eq. (5) obtaining

$$d(\mathring{A}) = 1.1076 \cdot 10^{-8} \frac{\lambda^2(cm) N(cm^{-3})}{T^{1/2}} \left(0.9 - \frac{1.1}{Z}\right) \frac{9}{4Z^2} \sum_{j=i,f} \frac{n_j^{*2} \varepsilon_j}{2\ell_j + 1} \cdot$$

$$\cdot (n_j^{*2} - 3\ell_j^2 - 3\ell_j - 1) \qquad (6)$$

In order to test the modified semiempirical approach, selected experimental data for 36 multiplets (7 different ion species) of doubly-, and 7 multiplets (4 different ion species) of triply-charged ions were compared with linewidths calculated according to Eq. (1). The average values of the ratios of measured to calculated widths are as follows: for doubly-, 1.06 ± 0.31 and for triply-charged ions 0.91 ± 0.42 (Dimitrijević and Konjević, 1980).

Furthermore, in order to test the equations obtained for low temperature limit of modified semiempirical formula, comparison is made between the linewidth result from Eq. (1) and (4) and previously mentioned selected experimental results (Dimitrijević and Konjević, 1980), in the cases when Eq. (4) may be applied. The average ratio of experimental and calculated values from Eqs. (1) and (4) are 1.01 and 1.04 respectively (Dimitrijević and Konjević, 1986).

Recently, the modified semiempirical theory is applied to the most intensive lines of Ti II and Mn II observed in the Solar spectrum (Dimitrijević, 1982), in order to test the applicability of the approach to the case of more complex transitions and heavier elements. The obtained agreement between this approach and more sophysticated semiclassical calculations indicates that this method can be used for estimation of electron width for heavier elements.

3. RESULTS

In Table 2, electron impact full halfwidths (W_{MSE}) for 3 Solar multiplets ($a^4H - z^4F^o$, $a^6D - z^6D^o$, and $b^4F - z^4F^o$) and 3 multiplets observed in the spectrum of Am 15 Vulpeculae (Yo-ichi Takeda, 1984) ($b^4P - z^4F^o$, $b^4F - z^4D^o$, and $b^4P - z^4D^o$) are given for different electron temperatures (T) and for $N_e = 10^{17}$ cm^{-3}.

We hope that the presented method will be useful for Stark broadening calculations of Fe II lines especialy in the cases when we need an extensive set of data with good average accuracy and when the accuracy of each particular value is not so important.

Table 2. Electron impact full halfwidths (W_{MSE}) in Angströms for selected Solar lines and lines from the spectrum of Am 15 Vulpeculae (see the text) for different temperatures (T) and at the electron concentration 10^{17} cm^{-3}.

Ion	Transition (mult. No.) wavelength (Å)	T(K)	W_{MSE} (Å)
Fe II	$a^4H - z^4F^o$	5000	0.249
	(32)	10000	0.176
	λ = 4300.15 Å	20000	0.124
		40000	0.0880
Fe II	$a^6D - z^6D^o$	5000	0.0856
	(UV 1)	10000	0.0605
	λ = 2611.41 Å	20000	0.0428
		40000	0.0303
Fe II	$b^4F - z^4F^o$	5000	0.278
	(37)	10000	0.196
	λ = 4564.89 Å	20000	0.139
		40000	0.0982
Fe II	$b^4P - z^4F^o$	5000	0.250
	(28)	10000	0.177
	λ = 4293.11 Å	20000	0.125
		40000	0.0884

Fe II	$b^4F - z^4D^o$	5000	0.277
	(38)	10000	0.196
	λ = 4558.73 Å	20000	0.139
		40000	0.0995
Fe II	$b^4P - z^4D^o$	5000	0.281
	(27)	10000	0.199
	λ = 4558.73 Å	20000	0.141
		40000	0.0995

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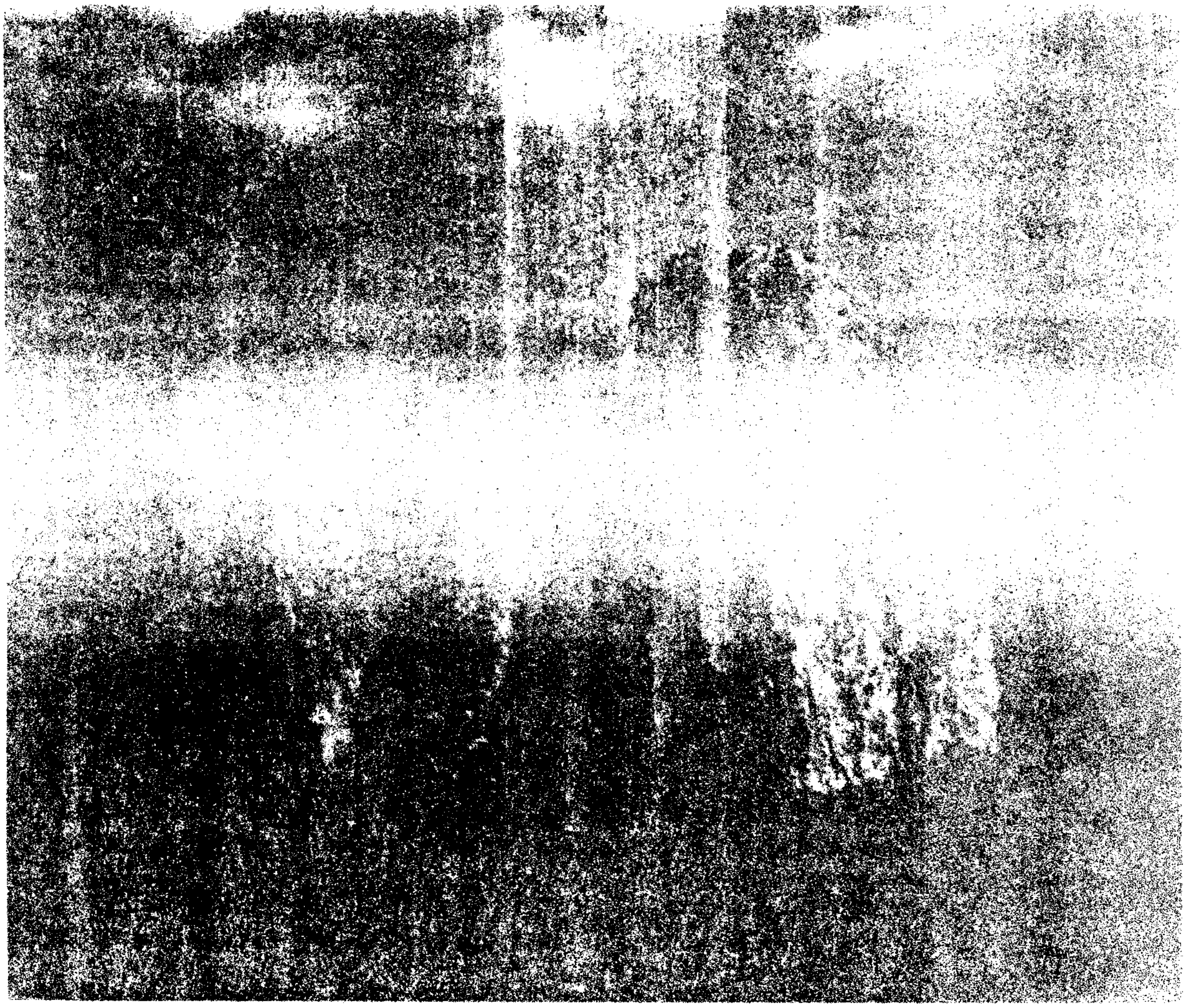
ABSTRACTS OF PAPERS



ISTITUTO ASTROFISICA SPAZIALE (FRASCATI)
OSSERVATORIO ASTRONOMICO CAPODIMONTE (NAPOLI)

STARK BROADENING OF SPECTRAL LINES IN THE SPECTRUM OF Am 15 VULPECULAE

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Investigation of the Stark broadening of atomic and ionic lines is important for the estimation of the physical conditions in the stellar atmospherae. Stark broadening data are also required for determination of the abundance of elements and for evaluations of the radiative transfer through stellar interior. In such a case data for a great number of lines are often needed. Recently, a modified version of the Stark broadening theory is published (Dimitrijević and Konjević, 1980; 1986; Dimitrijević and Kršljanin, 1986), usefull especially for such large scale calculations with a good average accuracy. Here, this theory is applied to the most intensive lines of Fe II observed in the spectrum of Am 15 Vulpeculae, in order to test the applicability of the approach to the case of Fe II lines.

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Semi-Classical and Modified Semi-Empirical Impact Stark Broadening Calculations of Singly Ionized Oxygen Spectral Lines

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Abstract. Using the semi-classical approach by Sahal-Bréchot [1-2] and the modified semiempirical approach by Dimitrijevic and Konjevic [3], we have calculated Stark broadening widths and shifts for OII multiplets using the needed oscillator strengths from the sophisticated atomic structure data base TOPbase. Then we have compared our results with experimental data and those calculated by Griem [4].

1 Introduction

The charged oxygen (OII) atoms, as emitters or absorbers, are especially important due to their presence in many kinds of cosmic sources of radiation.
Using the semi-classical impact perturbation theory [1-2], we calculated widths and shifts of singly ionized oxygen (OII) spectral lines and compared with experimental results and those calculated by Griem [4].
Energy levels and oscillator strengths have been taken from TOPbase [5].
We also calculated modified semiempirical widths using the formalism of Dimitrijevic and Konjevic [3], where the mean square radius is expressed in terms of the oscillator strengths for the contribution of the collisional transitions with $\Delta n=0$ and hydrogenic approximation is used for $\Delta n\neq 0$.
In this work the calculation of widths and shifts of some lines are obtained for the first time [6-8].

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2 Semi-Classical and Semiempirical Formalism

$$W_{SC} = 2w = \int_0^{+\infty} vf(v)dv\left(\sum_{j\neq i}\sigma_{ij}(v) + \sum_{j'\neq f}\sigma_{fj'}(v) + \sigma_{el}\right) \quad (1)$$

$$d = N\int_0^{+\infty} vf(v)dv\int_{R_D}^{R_1} 2\pi\rho d\rho \sin^2\phi_p \quad (2)$$

In order to minimize the needed atomic data and to extend its validity to multiply charged ion lines, we use the modified semiempirical formula of Dimitrijevi and Konjevic [3].

For _n=0

$$R_{ij}^2 = \frac{f_{ij}\lambda_{ij}(cm^{-1})}{303.7} \quad (3)$$

Where f_{ij} is the oscillator strength between levels *i* and *j*, and for _n≠0, we use the hydrogenic approximation.

$$W_{line} = \left(\frac{\lambda}{\langle\lambda\rangle}\right)^2 W \quad (4)$$

$$d_{line} = \left(\frac{\lambda}{\langle\lambda\rangle}\right)^2 d \quad (5)$$

In the above expression, , d and $\langle\lambda\rangle$ are values for the multiplet, and W_{line}, d_{line} and λ refer to a particular line within the multiplet.

3 Applications to OII spectral lines

Table 1. $W_{m.}$ experimental Stark widths of del Val et al. [9]; W_e is the electronic width calculated by Mahmoudi et al. [6]; W_{SC} is the semi-classical values calculated by Mahmoudi et al. [6]; the semiempirical data $W_{MSE.}$ calculated by Mahmoudi et al. [8] and the semi-classical value of Griem [4] W_{eG}. for the transition array $2p^2(1D)3p$ -$2p^2(1D)3d$

Multiplet	(Å)	T_e(K)	N_e (cm^{-3}) 10^{17}	W_m (Å)	W_e (Å)	W_{SC} (Å)	W_{MSF} (Å)	W_{eG} (Å)
$^4p\text{-}^4p^0$	4349.43	40000	1.0	0.253	0.249	0.287	0.263	0.219
	4336.86	40000	1.0	0.202	0.248	0.285	0.261	0.218
	4366.89	40000	1.0	0.248	0.251	0.289	0.265	0.221
	4345.56	40000	1.0	0.258	0.249	0.286	0.261	0.218
	4319.63	40000	1.0	0.261	0.246	0.283	0.259	0.216
	4317.14	40000	1.0	0.256	0.246	0.283	0.259	0.216

Table 2. Same as Table 1 for the shifts, d_e is the electronic shift calculated by Mahmoudi et al. [7]

Multiplet	(Å)	T_e(K)	N_e (cm^{-3}) 10^{17}	d_m (Å)	d_e (Å)	d_{eG} (Å)
$^4p\text{-}^4p^0$	4349.43	40000	1.0		0.0084	
	4336.86	40000	1.0		0.0084	
	4366.89	40000	1.0		0.0085	
	4345.56	40000	1.0		0.0084	
	4319.63	40000	1.0		0.0083	
	4317.14	40000	1.0		0.0083	

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French-Serbian Collaboration on the Stark Broadening of Spectral Line Shapes

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Abstract. The importance of having a large set of Stark broadening data is presented. Then, a short review of French-Serbian collaboration on the theoretical calculations (within the frame of the semiclassical perturbation approach) of Stark broadening of nonhydrogenic spectral line shapes is presented, with a bibliography of results published in international journals.

1 Introduction and discussion of the interest for obtaining a large set of Stark broadening data

Stark broadening research has been a developed research field in France and Serbia for many years. Its often-interdisciplinary significance provides a good basis for scientific collaboration. The aim of this paper is to display the results of French-Serbian collaboration on the Stark broadening of nonhydrogenic emitter spectral lines modelisation by using the semiclassical perturbation approach. Stark broadening data are of interest not only for laboratory, laser-produced, fusion and technological plasmas research, modeling and diagnostics, but also in astrophysics, e.g. for the modelisation of white dwarfs and hot stars of B and A type, determination of chemical abundances of elements from equivalent widths of absorption lines, estimation of the radiative transfer through stellar plasmas, especially in subphotospheric layers, and for opacity calculations. Stark broadening is also important for the study of radio recombination lines from molecular and ionized hydrogen clouds, radiative acceleration considerations, stellar nucleosynthesis research and other astrophysical topics.

It is obvious that stellar spectroscopy depends on a very extensive list of elements and line transitions with their atomic and line broadening parameters, and efforts to obtain as large as possible data set are additionally stimulated by the development of space astronomy, since with instruments like Goddard High Resolution Spectrograph (GHRS) on Hubble Space Telescope, an extensive amount of high

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quality spectroscopic information has been and will be collected.
Development of computers also stimulates the need for a large amount of atomic and spectroscopic data. A good example for the need of an extensive set of atomic and spectroscopic data including Stark broadening is the modeling of stellar atmospheres. For example, PHOENIX computer code for the stellar atmospheres modeling includes a database containing 42 millions atomic/ionic and molecular spectral lines.

2 On the French-Serbian collaboration: Valorization of the semi-classical perturbation computer codes for obtaining a large set of data

This collaboration started in 1978 with a post doc stay of M. S. Dimitrijevic in Meudon. This was the beginning of very fruitful collaboration in this research field, resulting up to now in 60 articles in international journals listed here [1-26] and several hundred publications in national journals and proceedings of international and national conferences. Examples of obtained results are e.g. the first calculation of Stark broadening parameters within the quantum mechanical strong coupling method for a nonhydrogenic neutral emitter spectral lines, performed for Li I 2s S – 2p P transition [1], the investigations of Stark broadening parameters behaviour within spectral series (e.g. Refs. 5, 8, 9) and isoelectronic sequences [13], or investigation of Solar Rydberg Mg I lines [17]. Also, in order to complete as much as possible Stark broadening data needed for astrophysical and laboratory plasma research and stellar opacities calculations we made and are still making a continuous effort to provide Stark broadening data for a large set of atoms and ions. Modelisation has been updated and improved several times [2,8,9,17].
For the development of French-Serbian collaboration in this research field, an important contribution of Alain Lesage was also the donation of his shock tube to Belgrade university. The collaboration with him resulted in the common publications with one of us (MSD – Ref. 11), but also with Jagos Puric, Nikola Konjevic, Slobodan Manola, Milivoje Cuk, Vida Knezevic and others.

In this collaboration participated also Truong Bach, Marie-Christine Artru, Yves Vitel, Maurice Skowronek, Veronique Bommier, Marko Popovic, Miodrag Dacic, Zoran Simic and Zorica Cvetkovic.

We also have plans to organize the obtained results in a database. This project, the creation of the database of Belgrade Astronomical observatory "BelData" started, and the Internet address of the "BelData" database is http://www.aob.bg.ac.yu/BELDATA. Another project, the database MOLAT (http://molat.obspm.fr), is under construction at the Paris Observatory and concerns atomic and molecular data of astrophysical interest. We are planning to join our efforts in this domain.

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Importance of Collisions with Charged Particles for Stellar UV Line Shapes: Cd III

Nenad Milovanović*, Milan S. Dimitrijević, Luka Č. Popović and Zoran Simić

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Abstract. Stark broadening parameters, widths and shifts, for spectral lines of doubly-ionized cadmium (Cd III) have been calculated using the modified semi-empirical approach (MSE). Widths and shifts of the spectral lines are given for temperature range of 5 000 K - 60 000 K and an electron density of 10^{23} m^{-3}. The influence of collisions with charged particles on Cd III UV stellar lines along the HR diagram and in DA white dwarf atmospheres is discussed.

1 Introduction

Spectral lines of multiply charged heavy elements are present in the UV spectra of early-type stars, especially in spectra of chemically peculiar (CP) ones. Investigation of these lines is important for example for spectral lines synthesis, diagnostics and modelling of laboratory and stellar plasma, abundance determination and opacity calculation.

2 Method of calculation and results

We used the modified semiempirical approach (MSE) [1,2]. The accuracy of the MSE calculations for spectral line widths is around 50% [1]. Error in obtained shifts with MSE calculations is within 50% of the corresponding width values.
Doubly-ionized cadmium (Cd III) belongs to Palladium isoelectronic sequence with the ground state electronic configuration $4d^{10}$ $^1S_0$ and ionization potential of 302200±50 cm^{-1}. Atomic data needed for our MSE calculation were taken from [3]. They observed Cd III spectra in UV spectral range from 50 to 210 nm with 6.65 and 10.7 meters normal-incidence vacuum spectrograph.

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The calculated Stark widths and shifts of Cd III spectral lines for 84 spectral lines, where 22 belong to $4d^9$ 5s – $4d^9$ 5p and 62 to $4d^9$ 5p – $4d^9$ 5d transitions are given in [4].

3 Disscusion

In Fig. 1 Stark (FWHM) and Doppler widths for Cd III 5p $^3F^o_3$ – 5d $^3G_3$ (λ=144.754 nm) spectral line as a function of atmospheric layer temperatures are shown. Stark widths are shown for 8 atmospheric models with effective temperatures T_{eff}=7000 - 30000 K, corresponding to spectral classes (Sp) from F0 to B0, logarithm of surface gravity log g=4 and turbulent velocity v_t=0 km/s. In Fig. 1 one can see that Stark widths are larger than Doppler ones for stars with lower effective temperatures. For stars with higher effective temperatures Stark broadening is more important than Doppler one for deeper atmospheric layers (higher layer temperature T).

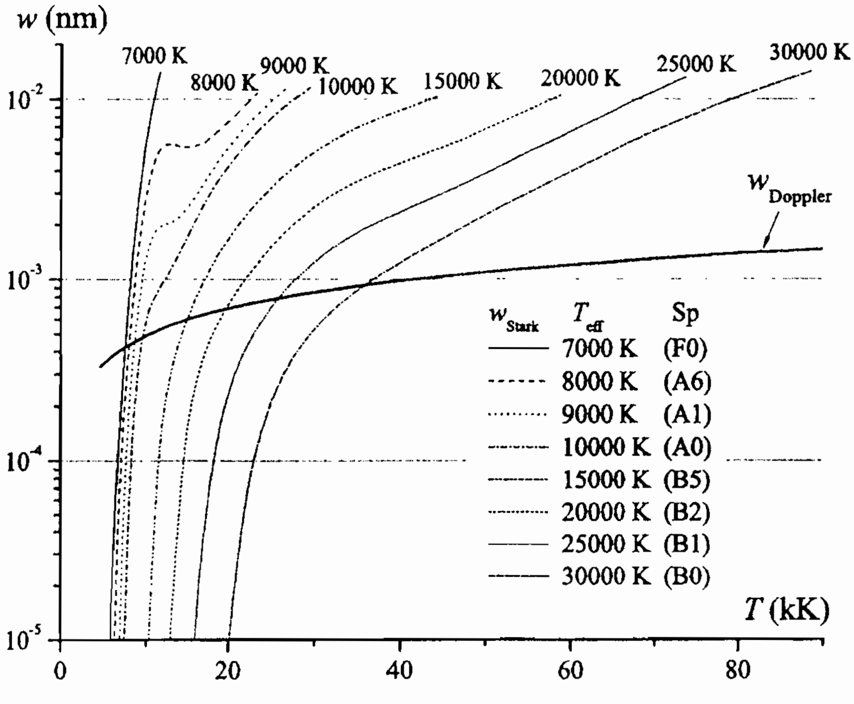

Figure 1. *Stark widths (FWHM) (thinner lines) and Doppler width (thicker line) for Cd III λ=144.754 nm spectral line as a function of atmospheric layer temperatures.*

In order to compare Stark and Doppler broadening we have calculated spectral line widths for Cd III λ=144.754 nm for DA white dwarfs atmospheres. Models were taken from [5]. We note that DA dwarfs are helium and metal underabundant.
As one can see in Fig. 2 Stark broadening is by one or two order of magnitudes higher than Doppler one. Also with the increases of the pressure, electron density or effective temperature in DA white dwarf models the importance of Stark broadening increases as well.

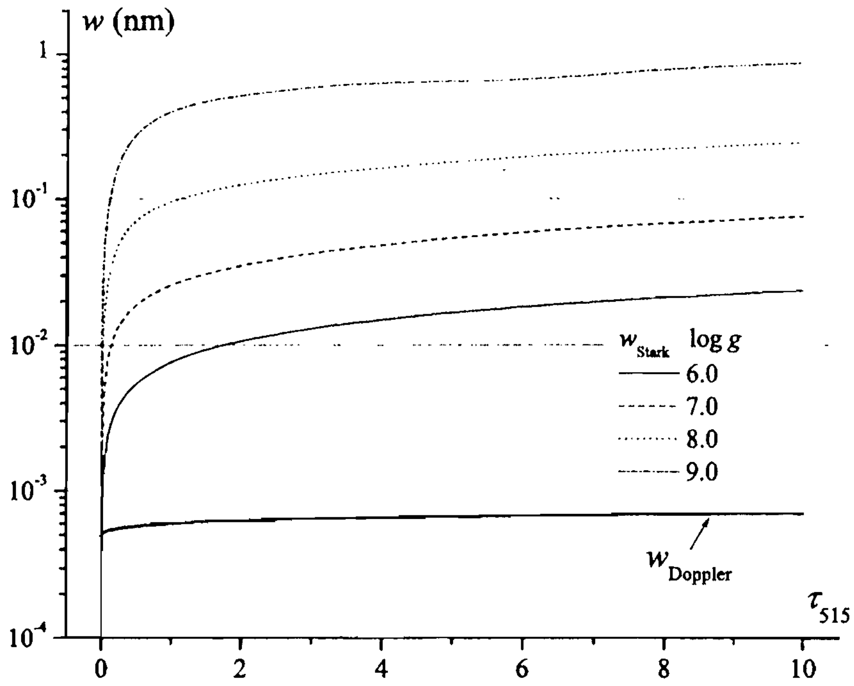

Figure 2. *Stark and Doppler widths for Cd III λ=144.754 nm spectral line as a function of optical depth for standard wavelength λ_{st}=505 nm for DA white dwarfs. Widths are given for 4 values of logarithm of surface gravity log g=6 - 9. Effective model temperature is T_{eff}=10 kK.*

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The Complex Structure of the MgII λλ 2795.523, 2802.698 Å Regions of 64 Be Stars

E. Lyratzi[1*], E. Danezis[1], L. C. Popovic[2], M. S. Dimitrijevic[2], E. Theodossiou[1], D. Nikolaidis[1], A. Antoniou[1] & A. Soulikias[1]

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[2] *Astronomical Observatory of Belgrade, Volgina 7, 11160 Belgrade, Serbia and Montenegro*

Abstract. In this paper we present a statistical study of the UV MgII resonance lines in 64 Be stars' spectra, using the method proposed by Danezis et al. (2003). With this method we can study the velocity fields of the complex atmospherical regions of MgII resonance lines λλ 2795.523, 2802.698 Å, which present SACs or DACs. We found that there exist three levels of rotational velocity with the mean values of 143 km/s, 60 km/s and 31 km/s. The respective mean values of the apparent radial velocity are -19 km/s, -13 km/s and -2 km/s.

1 Introduction

The MgII resonance lines present a peculiar profile in the Be stellar spectra and have been studied by many researchers [1-15]. They have observed the existence of absorption components shifted to the violet or the red side of the main spectral line [2-5], [8-13], [15]. These components have been named Discrete Absorption Components (DACs) [1] or Satellite Absorption Components [6]. When the components are quite narrow, they cannot be photospheric, but of circumstellar or interstellar origin [14]. In any case, the whole feature of the MgII resonance lines is not the result of a uniform atmospherical region, but the components are created in different regions, which rotate and move radially with different velocities. As de Jager et al. [7] proposed, in the late B supergiants variable mass loss occurs, due to "occasional stellar "puffs" superposed on a more or less regular wind". They proposed that "there are concentrations of low-ionization species in the stellar wind as a result of the occurrence of significant density variations".

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2 Data and Results

The data we used are the MgII resonance lines of 64 Be stars. The stars' spectrograms have been taken with IUE satellite with the Long Wavelength range Prime and Redundant cameras (LWP, LWR) at high resolution (0.1 to 0.3 Å).

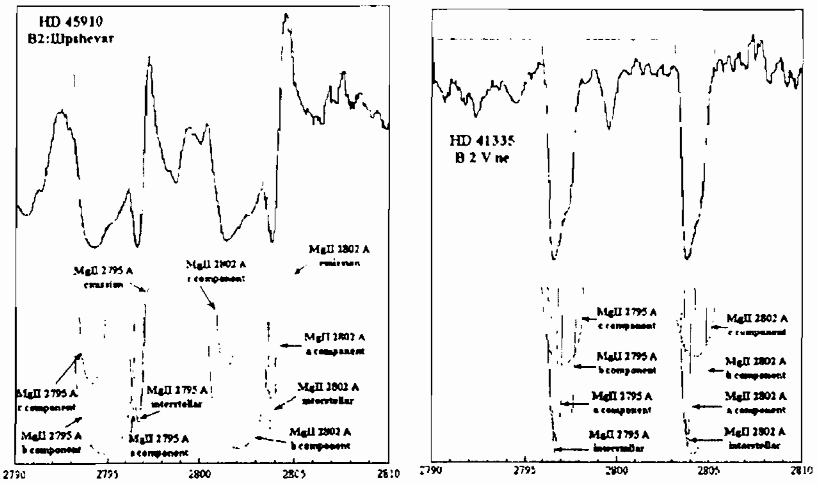

***Figure 1** : The MgII resonance lines fittings of the star HD 45910, which presents DACs and of the star HD 41335, which presents SACs.*

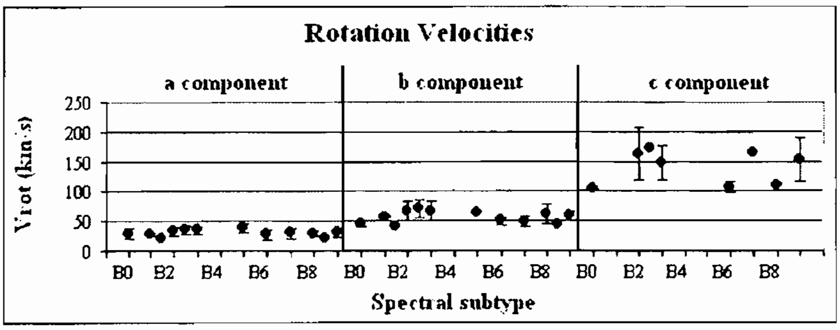

***Figure 2** : Mean values of the apparent rotational velocities of the three SACs as a function of the spectral subtype. Three rotational velocity groups are presented, with the mean values of 31 km/s, 60 km/s, and 143 km/s. All these velocity groups do not appear in all the studied Be stellar spectra.*

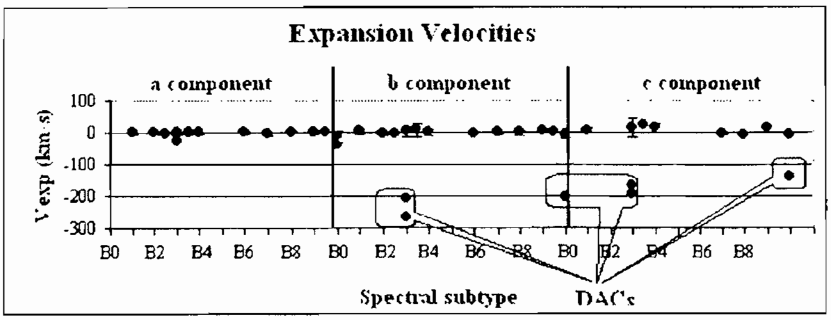

Figure 3 *: Mean values of the apparent radial velocities of all the SACs as a function of the spectral subtype. The apparent radial velocity of all the SACs present the values of -2 km/s, 0 km/s and +9 km/s. In the case of the stars that present DACs, the apparent radial velocity is about -227 km/s and -169 km/s.*

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The Complex Structure of the SiIV λλ 1393.755, 1402.73 Å Regions of 42 BeV

E. Lyratzi[1*], E. Danezis[1], L. C Popovic[2], M. S. Dimitrijevic[2], E. Theodossiou[1], D. Nikolaidis[1], A. Antoniou[1] & A. Soulikias[1]

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Abstract. In this paper we present a statistical study of the UV SiIV resonance lines in 57 BeV stars' spectra, using the method proposed by Danezis et al. (2003). With this method we can study the velocity fields of the complex atmospherical regions of SiIV resonance lines λλ 1393.73, 1402.73 Å, which present SACs or DACs. We found that there exist five levels of rotation velocity with the mean values of 830 km/s, 492 km/s, 285km/s, 137 km/s and 51 km/s. The values of the apparent radial velocity of all SACs lie in the range between -306 km/s and +194 km/s.

1 Introduction

The ultraviolet resonance lines of SiIV (λλ 1393.755, 1402.77 Å) are usually intense features in the spectra of early type stars and provides us with a useful tool for the study of the stellar atmosphere's structure. Thus, it has been studied by many researchers [1-33]. The profile of the resonance lines seems to depend on the spectral subtype and the luminosity class [29], so it has been proposed that the doublet may be a significant tool for the spectral classification [23], [33]. It has been observed that the lines present decreasing strength from the earliest to the latest spectral subtypes. Panek & Savage [22] and Henize et al. [11], [12] observed that they disappear in the spectra of Be stars later than B3. However, Marlborough [20], Marlborough & Peters [21] and Slettebak [26] pointed that the doublet may be observed in stars as cool as B8. Many researchers have studied the existence of Satellite Absorption Components (SACs or DACs), which accompany the SiIV resonance lines in the spectra of Be stars and which are of circumstellar or

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interstellar origin [1-5], [7-10], [13-20], [24], [25], [29-32]. Finally, the SiIV doublet is an indicator of mass-loss effects in B stars, especially when asymmetries appear in both of the resonance lines [13], [17], [27], [28].

2 Data and Results

The data we used are the SiIV resonance lines of 42 BeV stars. The stars' spectrograms have been taken with IUE satellite with the Short Wavelength range Prime camera (SWP) at high resolution (0.1 to 0.3 Å).

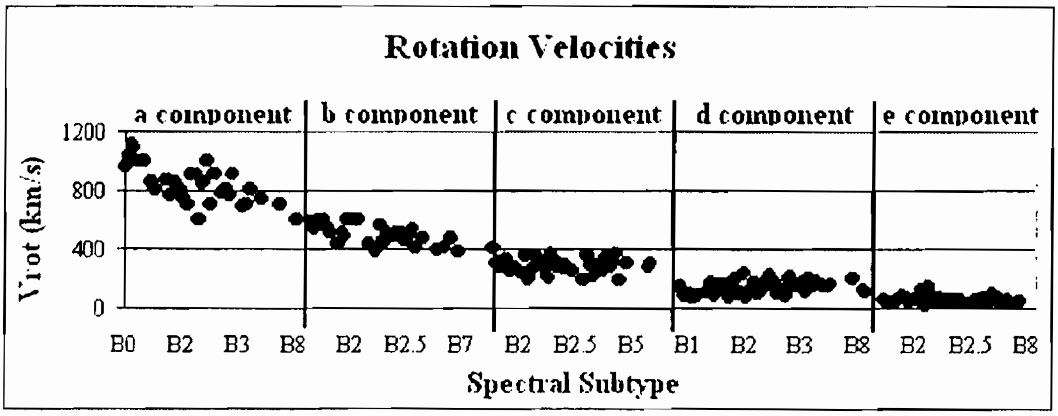

***Figure 2** : Apparent rotation velocities of all the SACs as a function of the spectral subtype. Five levels of rotation velocity are presented with the mean values of 830 km/s, 492 km/s, 285km/s, 137 km/s and 51 km/s.*

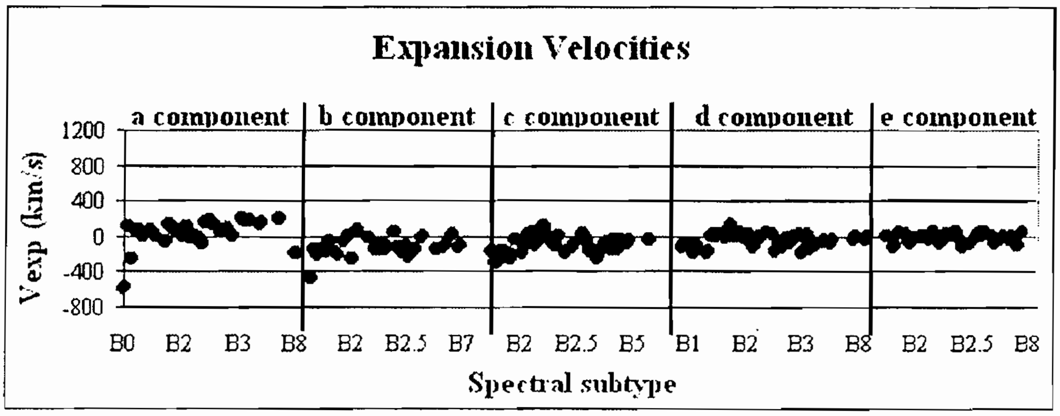

***Figure 3** : Apparent expansion/contraction velocities of all the SACs as a function of the spectral subtype. The values of the expansion/contraction velocity of all the SACs lie in the range between -306 km/s and +194 km/s.*

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Collisions with Charged Particles for Stellar Four Times Ionized Silicon Line Shapes

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Abstract. Stark broadening parameters, widths and shifts, for 16 Si V multiplets calculated with energy and oscillator strengths obtained with the SUPERSTRUCTURE code have been calculated using the semiclassical perturbation approach. Widths and shifts of the spectral lines were given for temperature range of 50 to 500 kK and electron density 10^{23} m^{-3}. The influence of collisions with charged particles on Si V strong singlet spectral line $2p^6\ ^1S_0 - 2p^5 3s\ ^1P^o_1$ (λ=11.7853 nm) along the HR diagram is discussed.

1 Introduction

We have computed Si V Stark broadening parameters within the semiclassical formalism [1,2] by using oscillator strengths from SUPERSTRUCTURE code in order to provide new Stark broadening data of astrophysical interest. Additionally, we have performed the same calculations using for needed atomic data the Coulomb approximation method [3], in order to estimate the error introduced in the Stark broadening parameters due to uncertainties of oscillator strength values due to the use of the Coulomb approximation. The obtained data have been used to investigate the influence of Stark broadening effect on Si V spectral lines along the HR diagram.

2 Method of calculation

The energy levels of Si V are calculated using the general atomic structure code SUPERSTRUCTURE developed at the University College in London [4]. The wave

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functions are determined by diagonalization of the non-relativistic Hamiltonian using orbitals calculated in a scaled Thomas-Fermi-Dirac-Amaldi (TFDA) potential. The relativistic corrections: spin-orbit, mass, Darwin and one-body, are introduced according to the Breit-Pauli approach [5]. By combining the SUPERSTRUCTURE code, calculating energy levels and oscillator strengths, and the code for semiclassical perturbation Stark broadening calculations [1,2], we obtained possibility to calculate Stark broadening parameters ab initio.

By using atomic energy levels obtained by SUPERSTRUCTURE code, we have calculated also oscillator strengths with the help of the Coulomb approximation with quantum defect of Bates and Damgaard [3]. If we compare results for Stark widths obtained with oscillator strengths calculated with SUPERSTRUCTURE and by using Bates and Damgaard approximation, the average ratio of Stark widths with Coulomb and SUPERSTRUCTURE oscillator strengths is 1.09 for T = 50 kK and 1.10 for 500 kK.

3 Results and disscusion

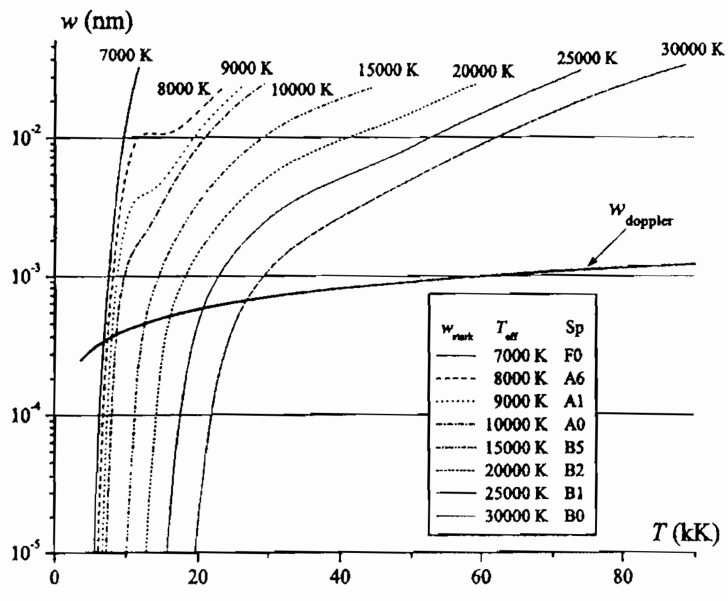

Figure 1. *Stark widths (FWHM) (thinner lines) and Doppler width (thicker line) for Si V* $2p^6\ {}^1S_0 - 2p^5 3s\ {}^1P^o_1$ *(*λ*=11.7853 nm) spectral line as a function of atmospheric layer temperatures. Stark widths are shown for 8 atmospheric models with effective temperatures* T_{eff}*= 7000 – 30000 K, corresponding to spectral classes (Sp) form F0 to B0, log g = 4.0 and turbulent velocity* $v_t = 0$ *km* s^{-1}*.*

Comparison of Stark and Doppler broadening for Si V $2p^6\ ^1S_0$ $2p^53s\ ^1P^o_1$ (λ=11.7853 nm) resonance spectral line is illustrated in Fig. 1.
In Fig. 1. one can see that Stark widths are larger than Doppler ones for stars with lower effective temperatures. For stars with higher effective temperatures, Stark broadening is more important than Doppler one for deeper atmospheric layers (larger layer temperature T).

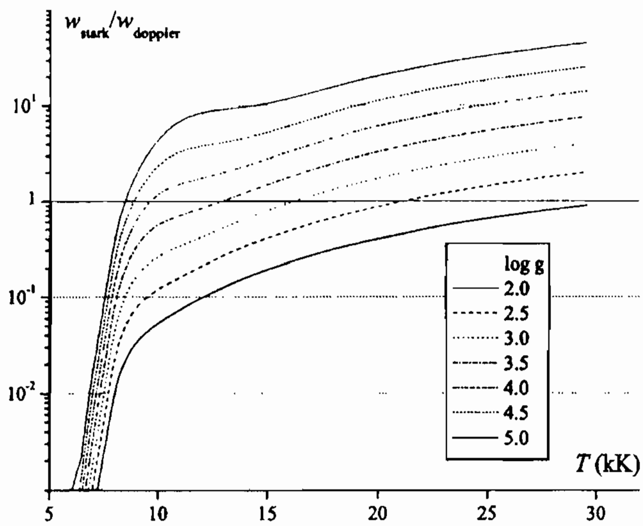

Figure 2. *Same as Fig. 1. but ratio of Stark and Doppler widths are shown for 7 values of model gravity log g = 2 – 5,* T_{eff} *= 10000 K and* $v_t = 0$ *km* s^{-1}.

The Stark broadening in stellar atmospheres with higher values of surface gravity is significantly larger than Doppler broadening (Fig. 2.). For stars with surface gravity log g = 2, Stark broadening is comparable to Doppler widths only for deeper hot atmospheric layers. For upper parts of stellar atmospheres Stark widths rapidly decrease and for layer temperature $T \approx$ 6000-7000 K Stark widths are several magnitudes lower than Doppler ones for all shown values of surface gravity log g.

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December 1996

Stark broadening of Ge III and Ge IV lines

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Abstract

Stark broadening with data for a large number of transitions in many atomic and ionic spectra are needed for astrophysical and physical modeling of stellar and laboratory plasma. Stark broadening mechanism is important in hot stars with $T_{eff} \gtrapprox 10000$ K, where it is the main pressure broadening mechanism. However, Stark broadening of lines originating from energy levels with large principle quantum numbers may be important even for cooler stars. Consequently providing of Stark broadening parameters for a large number of transitions for many atoms and ions is needed. Spectral lines of ionized germanium (Ge II , Ge III) are present in hot star spectra, as e.g. in the β Ori (Selvelli et al. 1977) spectrum. Here we present Stark width calculations for several UV Ge III and Ge IV spectral lines.

1 Calculations and results

For the calculation, the modified semi-empirical approach developed by Dimitrijević & Konjević (1980) and Dimitrijević & Kršljanin (1986) has been used. Atomic energy levels needed for calculation have been taken from Moore's tables (1971). For Ge IV lines the oscillator strengths from Migdalek (1977) have been used. In Table 1 we present results of our calculation of Stark widths for Ge III and Ge IV lines. For these ions there are no experimental Stark broadening data for comparison.

Table 1: Stark full width (FWHM) of Ge III and Ge IV spectral lines. The electron density is 10^{23}m^{-3}. The averaged wavelength of the multiplet is denoted by $\overline{\lambda}$

transition	T (K)	W (nm)
$4s^2\ ^1S - 4p^1P^0$ Ge III $\lambda = 108.8$ nm	5000.	.798E-03
	10000.	.560E-03
	20000.	.391E-03
	30000.	.316E-03
	40000.	.272E-03
	50000.	.242E-03
$4p^1P^0 - 4d^1D$ Ge III $\lambda = 188.3$ nm	5000.	.365E-02
	10000.	.255E-02
	20000.	.177E-02
	30000.	.142E-02
	40000.	.122E-02
	50000.	.109E-02
$4p^1P^0 - 5s^1S$ Ge III $\lambda = 132.3$ nm	5000.	.514E-02
	10000.	.359E-02
	20000.	.252E-02
	30000.	.209E-02
	40000.	.187E-02
	50000.	.173E-02
$4d^1D - 4f^1F^0$ Ge III $\lambda = 152.5$ nm	5000.	.532E-02
	10000.	.367E-02
	20000.	.257E-02
	30000.	.218E-02
	40000.	.202E-02
	50000.	.195E-02
$4p^3P^0 - 4d^3D$ Ge III $\lambda = 100.3$nm	5000.	.919E-03
	10000.	.640E-03
	20000.	.442E-03
	30000.	.356E-03
	40000.	.308E-03
	50000.	.277E-03
$4p^3P^0 - 5s^3S$ Ge III $\lambda = 104.9$ nm	5000.	.221E-02
	10000.	.155E-02
	20000.	.108E-02
	30000.	.882E-03
	40000.	.772E-03
	50000.	.705E-03

Table 1. (continued)

transition	T (K)	W (nm)
$4s^2S - 4p^2P^0$ Ge IV $\overline{\lambda} = 120.2$ nm	5000.	.122E-02
	10000.	.857E-03
	20000.	.601E-03
	30000.	.488E-03
	40000.	.420E-03
	50000.	.374E-03
$4s^2S - 5p^2P^0$ Ge IV $\overline{\lambda} = 44.0$ nm	5000.	.336E-03
	10000.	.236E-03
	20000.	.165E-03
	30000.	.134E-03
	40000.	.116E-03
	50000.	.105E-03
$4p^2P^0 - 4d^2D$ Ge IV $\overline{\lambda} = 92.9$ nm	5000.	.893E-03
	10000.	.626E-03
	20000.	.436E-03
	30000.	.353E-03
	40000.	.303E-03
	50000.	.270E-03
$5s^2S - 5p^2P^0$ Ge IV $\overline{\lambda} = 359.5$ nm	5000.	.375E-01
	10000.	.263E-01
	20000.	.184E-01
	30000.	.149E-01
	40000.	.130E-01
	50000.	.118E-01
$4d^2D - 5p^2P^0$ Ge IV $\overline{\lambda} = 275.3$ nm	5000.	.145E-01
	10000.	.102E-01
	20000.	.709E-02
	30000.	.575E-02
	40000.	.498E-02
	50000.	.448E-02
$5p^2P^0 - 6s^2S$ Ge IV $\overline{\lambda} = 232.7$ nm	5000.	.333E-01
	10000.	.233E-01
	20000.	.165E-01
	30000.	.138E-01
	40000.	.125E-01
	50000.	.117E-01

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CHEMI-IONIZATION AND CHEMI-RECOMBINATION RATE COEFFICIENTS FOR STELLAR ATMOSPHERES CONDITIONS

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Abstract

In this work a precedingly developed semiclassical theory for the chemi-ionization processes, during $A^*(n)+A$ slow collisions, and the inverse chemi-recombination processes, during $e+A_2^+$ and $e+A^++A$ scattering, has been improved. Such modified theory was applied for the calculation of the rate coefficients of these processes for plasma conditions relevant to atmospheres of helium rich white dwarfs (A = He) and for Solar atmospheres (A = H).

1 INTRODUCTION

In several articles [1-7; see also 8-11], the following chemi-ionization and chemi-recombination processes have been considered in conditions relevant to weakly ionized astrophysical and laboratory plasmas:

- the processes of $A^*(n)+A$ chemi-ionization [1-5]

$$A^*(n)+A \Longrightarrow e+A_2^+, \tag{1a}$$

$$A^*(n)+A \Longrightarrow e+A+A^+, \tag{1b}$$

- the inverse $e+A_2^+$ and $e+A^++A$ chemi-recombination processes [3-7]

$$e+A_2^+ \Longrightarrow A^*(n)+A, \tag{2a}$$

$$e+A^++A \Longrightarrow A^*(n)+A, \tag{2b}$$

where $A^*(n)$ is the atom in the highly excited state, n - the corresponding principal quantum number ($n \gg 1$), and A, A^+ and A_2^+ - atom, atomic ion and the molecular ion in their ground electronic states.

The considered chemi-ionization and chemi-recombination processes (1a,b) and (2a,b) are produced by the dipole interaction of the ion-atom subsystem of the considered system with the outer electron [1, 2, 6 and 7]. These processes have been considered using a quasistatic model based on the semiclassical adiabatic approximation for heavy particle collisions. Within this theory it was assumed that considered atomic system can change its electronic state only once during the collision and that the probability of this change is small enough. These assumptions are correct for sufficiently large principal quantum number n, but theirs applicability decreases with the decrease of n. However, all excited atomic states are important for the (1a,b) and (2a,b) processes in the conditions relevant to weakly ionized layers of the star atmospheres. This is clearly illustrated by the results presented in the recent paper regarding Solar atmosphere [12]. Because of that, we have modified used theory so it could be applied for all excited atomic states, except for the states with $n = 2, 3$, where one of the multichannel methods must be applied.

2 RESULTS AND DISCUSSION

The description of the previously developed theory is given in detail in previous papers [1, 2, 6 and 7]. Because of that, here we have given only few necessary facts. Within this theory processes (1a,b) and (2a,b) are considered in such conditions when it's possible to treat them in the following manner:

$$A^*(n) + A \Longrightarrow (A^* + A)^{in}_{qm} \Longrightarrow e + (A^* + A)^{fin}_{qm} \Longrightarrow e + A + A^+/e + A_2^+,$$

$$e + A^+ + A/e + A_2^+ \Longrightarrow e + (A + A^+)^{in}_{qm} \Longrightarrow (A^* + A)^{fin}_{qm} \Longrightarrow A^*(n) + A,$$

where the lower index qm denotes that the corresponding collisional atomic system is considered to be the quasimolecular complex, upper indexes in and fin denote that the system is in its initial or final electronic state. All the necessary characteristics are determined (with the help of this theory) for the ionization processes, while for the recombination processes the corresponding characteristics are obtained from the principle of the thermodynamic balance. Let $P^{fin}_{in}(t)$ be the probability that the transition $(A^* + A)^{in}_{qm} \Longrightarrow e + (A^* + A)^{fin}_{qm}$, in the case of the considered chemi-ionization process, has occured before the moment t, when the system is moving along the given trajectory. In the previously developed theory $P^{fin}_{in}(t)$ was determined from the equation $dP^{fin}_{in}/dt = W(R(t))$, where the $W(R)$ is the number of transitions $(A^* + A)^{in}_{qm} \Longrightarrow e + (A^* + A)^{fin}_{qm}$ per unit time, for the given internuclear distance R. Within this approach, which is valid for the $n \gg 1$, the amplitude of the initial electronic state is considered to be constant. This approximation is treated here as the Born approximation. Consequently, the chemi-ionization and chemi-recombination rate coefficients calculated in this way are denoted by $K^{(B)}_{i,r}(n)$. For the lower n it becomes necessary to take into account the change of the mentioned amplitude along the given trajectory. In this work, this is accomplished

Table 1: Chemi-ionization rate coefficients $K_i^{(B)}(n)[cm^3/s]$:

n	T[K] 3000	5000	7000	9000
4	0.51271E-09	0.12173E-08	0.18230E-08	0.23144E-08
5	0.59690E-09	0.10776E-08	0.14247E-08	0.16822E-08
6	0.53318E-09	0.82770E-09	0.10208E-08	0.11574E-08
7	0.43109E-09	0.60937E-09	0.71964E-09	0.79523E-09
8	0.33577E-09	0.44568E-09	0.51105E-09	0.55495E-09
9	0.25865E-09	0.32825E-09	0.36853E-09	0.39520E-09
10	0.19940E-09	0.24476E-09	0.27047E-09	0.28734E-09

Table 2: Chemi-ionization rate coefficients $K_i(n)[cm^3/s]$:

n	T[K] 3000	5000	7000	9000
4	0.25255E-09	0.60058E-09	0.91289E-09	0.11795E-08
5	0.39835E-09	0.72875E-09	0.97886E-09	0.11730E-08
6	0.41996E-09	0.66062E-09	0.82481E-09	0.94491E-09
7	0.37209E-09	0.53161E-09	0.63333E-09	0.70488E-09
8	0.30544E-09	0.40872E-09	0.47160E-09	0.51466E-09
9	0.24280E-09	0.31002E-09	0.34963E-09	0.37624E-09
10	0.19089E-09	0.23539E-09	0.26097E-09	0.27794E-09

Table 3: Chemi-recombination rate coefficients $K_r(n)^{(B)}[cm^6/s]$:

n	T[K] 3000	5000	7000	9000
4	0.55330E-27	0.16396E-27	0.84374E-28	0.53727E-28
5	0.30826E-27	0.11150E-27	0.62047E-28	0.41131E-28
6	0.20849E-27	0.83857E-28	0.48606E-28	0.32889E-28
7	0.15572E-27	0.66597E-28	0.39499E-28	0.27030E-28
8	0.12319E-27	0.54705E-28	0.32892E-28	0.22656E-28
9	0.10107E-27	0.45981E-28	0.27881E-28	0.19279E-28
10	0.85037E-28	0.39308E-28	0.23962E-28	0.16608E-28

Table 4: Chemi-recombination rate coefficients $K_r(n)[cm^6/s]$:

n	T[K] 3000	5000	7000	9000
4	0.27255E-27	0.80888E-28	0.42250E-28	0.27382E-28
5	0.20572E-27	0.75401E-28	0.42629E-28	0.28680E-28
6	0.16422E-27	0.66929E-28	0.39270E-28	0.26851E-28
7	0.13441E-27	0.58098E-28	0.34762E-28	0.23959E-28
8	0.11206E-27	0.50169E-28	0.30354E-28	0.21011E-28
9	0.94882E-28	0.43428E-28	0.26451E-28	0.18354E-28
10	0.81407E-28	0.37803E-28	0.23120E-28	0.16065E-28

by calculating the $P_{in}^{fin}(t)$ from the equation $dP_{in}^{fin}/dt = (1 - P_{in}^{fin})W(R(t))$. The corresponding chemi-ionization and chemi-recombination rate coefficients are denoted here by $K_{i,r}(n)$. The necessity of such approach for lower n is illustrated in the Tables 1 - 4, where the values of $K_{i,r}^{(B)}(n)$ and $K_{i,r}(n)$ are given for the case of hydrogen plasma with the $4 \leq n \leq 10$ and the plasma temperature $T = 3000, 5000, 7000$ and $9000K$. One should pay attention that the rate coefficients $K_i^{(B)}(n)$ and $K_i(n)$ characterize both the chemi-ionization processes (1a) and (1b) together, and similarly, the rate coefficients $K_r^{(B)}(n)$ and $K_r(n)$ characterize both the chemi-recombination processes (2a) and (2b) together.

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Hexameron of Saint Basil the Great and cosmological views of his time

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1. Introduction

One of the most important works of Basil the Great, Archbishop of Caesarea and Saint of the Eastern and Western Christian Church (330–379 A.D.), consists of his nine Speeches on the Hexameron[1], where, using the scientific knowledge of his time, accompanied by a brilliant theological justification, he tries to prove the truth of cosmological events, described in the biblical book of Genesis.

2. The studies of Basil the Great

Basil the Great (330–379 A.D.), Archbishop of Caesarea and a Saint of the Eastern and Western Christian Church, was born at Neocaesarea in Pontus, into a wealthy family of intellectuals. His father was a rich attorney and a teacher of

[1] Hexameron is a Greek word meaning six days, and represents a work with comments on the description of the world's Creation in six days according to the biblical book of Genesis).

Considering the Speeches of Saint Basil from the point of view of the history of science, this work is one of the most important sources of knowledge concerning the dominant astronomical, and general scientific, views of that epoch, written by someone (Saint Basil) who had scientific and astronomical knowledge, formed in the wide region around the Mediterranean sea.

In the present work, we will present and analyze some questions concerning the cosmological ideas and the notion of time during the time of Saint Basil, on the basis of Hexameron.

rhetoric, while two of his seven brothers, Gregory and Peter, became bishops of the Eastern Orthodox Christian Church at the cities of Nissa and Sevastea respectively.

Saint Basil started his basic studies at Neocaesarea and continued them at Caesarea, where he became a close friend of Gregory Theologue. At Caesarea he probably met Julian, the later Emperor of the Eastern Roman Empire. The cycle of his basic studies was completed at Constantinople, where he was a student of the famous orator Levanius.

For his great moral and spiritual virtues, as well as for his general contribution, the Christian Church canonized Basil and his memory is honored by the Eastern Orthodox Church on January the 1st and 30th, together with two other holy Fathers, Gregory Theologue and John Chrysostom, and by the Western Christian Church on June the 14th.

3. Saint Basil's cosmological considerations

In the first one, as in all other Speeches, when the science, and especially astronomy, of that epoch is concerned, the expressed views can be considered as a harmonic match of the astronomical and, in general, the scientific views of the ancient Greeks, the Babylonians and the Egyptians, also found in the ancient Jewish literature. These views were prevalent in the Middle East and Mesopotamia, regions visited by Saint Basil, when he was a young scholar.

According to views expressed in "Hexameron", Basil the Great is aware of the spherical shape of the Earth, and he identifies the north and the south geographical pole. He also knows the star cycles, the zodiacal cycle, the existence of the fixed stars on the northern hemisphere, the notions of geographical latitude and longitude, the declinations and the time needed for each planet to traverse its orbit.

Interesting is his justification of the Aristotelian view of that time, that the Earth is in the centre of the Universe:

"Earth, they say, has taken over the centre of everything and since it has the same distance from all outer points, not having any place to lean on, it necessarily remains in its place, since the similarity all around it makes its inclination at some specific point completely impossible. This central position, they say, has Earth not by chance or by incident, but it is natural and essential for it. Since heaven possesses the ultimate position upwards, the weights we shall assume, they say, are falling from above from every direction and they are going to gather in the middle, and at the point to which the parts are directed, it is obvious that there will the entire set condense. If now, the stones and the woods and everything that comes from Earth are brought downwards, there will also be the proper position of the entire Earth...

So do not show admiration if Earth does not incline to anywhere, since its natural position is the middle. Because it is an unavoidable need for Earth to remain in its place and not to abandon it, thus breaking the laws of nature."[2]

[2] Basil the Great, 1990, *Homilies*.

In the richness of information we can derive from the first Speech of Saint Basil's *Hexameron*, we would discuss here six passages referring to ideas which constitute the subject of cosmology and essence of time.

We should remark also, after analysis of all Saint Basil's Speeches in the *Hexameron*, that these views are not personal conclusions of the Great Father, but a recording of scientific thoughts of Saint Basil's time, presented by a deep connoisseur of astronomy and the physical sciences of that epoch. This opinion is also justified by the fact that in all of his Speeches, Saint Basil, beginning to express scientific views, uses the phrase "as they say".

3.1. What existed before the Creation of the perceivable Universe?

According to Saint Basil:

"Apparently, before this world there was something that our mind may conceive theoretically, but which stayed out of this narration as it was not proper for people still learning and infantile in knowledge. There was a situation older than the genesis of the world, corresponding to the ultramundane powers, a situation beyond time, eternal, everlasting. And in this situation, the builder and creator of everything moulded his creations..."[3]

We see that according to Saint Basil, the Universe was not born out of nothing, but it came out of *something* which existed before this Universe. But where could Saint Basil have this information from?

1. Saint Basil lived and acted during the 4th century A.D., when the Egyptian papyri of Oxyrhynchus (written in the 2nd century A.D.) were in use. This means that the Great Father of the Christian Church was in the position to know of Alcman's cosmogonic views, referred to in papyrus no. 2390, since he had been in that region for one year during his studies. According to those views, the Universe was born out of some pre-existing material.[4]

2. According to the refuting pamphlet[5], of Tertullian *Adversus Hermogenem*, his contemporary Hermogenes, who came from Northern Africa, spread the dominant consideration of that time, i.e. the existence of three theories about the issue of God's relation to the World. According to the first, God created the world out of nothing, while in the second theory, the world was created by God from His own substance. According to the third theory, in God existed eternal matter of which He made the world.

Saint Basil, who probably knew these contemporary theories, agrees with the third view, although Tertullian, according to his writings *Adversus Hermogenem*, *De Censu Animae* and *De Anima*, was against it.

[3] Basil the Great, 1990, *Homilies*.

[4] Danezis and Theodossiou, 1999, *A presocratic...*, 125.

[5] Kordatos, 1975, *Jesus Christ...*, 226.

One should point out that Hermogenes himself rejected the first two theories, after analyzing all three of them, using the method of *reductio ad absurdum*. He supported the view that man's soul has its beginning and origin from the eternal matter, which existed before the Creation of the Universe.[6]

We note here, that ideas opposite to the Christian doctrine of Creation *ex nihilo* were present at that time, since it was not codified before the adoption of what we call the Nicene Creed. Although this Creed was partly formulated, as its name suggests, at the Council of Nicea, in 325 A.D., before Saint Basil was born, it received its final form only at the Council of Chalcedon, in 451 A.D., after the death of Saint Basil. Consequently, it is not surprising that at that epoch, Saint Basil, Hermogenes, and the Alexandrine Fathers (especially such as Origen), did not subscribe to the doctrine and held different ideas.

3.2. Time before the Creation of the world

The cited sentence "...There was a situation older than the genesis of the world, corresponding to the ultramundane powers, a situation beyond time, eternal, everlasting",[7] is particularly interesting.

Apparently, Saint Basil expresses in his first Speech, before Saint Augustine (Aurelius Augustinus, 354–430 A.D.), the opinion that the state before the Creation of the Universe was beyond the measurable human or Newtonian time, eternal and everlasting.

Saint Augustine, bishop of Hippo in Northern Africa, one of the greatest Christian philosophers and Father of the religious ideas of the Western World, worked also on the essence of the structure of time, often with views similar to that of Saint Basil. His ideas have as a starting point Plato's and Aristotle's views about time. The 11th book of the *Confessions*,[8] contains a brilliant analysis of the motion of time. His initial question was: "What was God doing before the Creation of the World?". Saint Augustine's answer is that such a question is meaningless, since before the World's Creation there was not any feeling of the "substance that people call time". Time and the centuries are the results of His entire Creation. For God there is no time but eternity in the sense of the achronal (undated or timeless) existence, where the concepts of past, present and future are meaningless.

These positions of Saint Augustine, a contemporary of Saint Basil,[9] originate from the prevalent views of that time, in the region where the Great Father of the Church acted. One should not forget that Saint Augustine, the bishop of a region in Northern Africa, probably knew Hermogenes' and Saint Basil's views as well.

[6] Kordatos, 1975, *Jesus Christ...*, 226.

[7] Basile de Césarée, 1968, *Homelies...*, 86–522.

[8] *Confessiones*, Ch. 14–37

[9] By the time Saint Basil died, Saint Augustine was about 25 years old.

3.3. Time as the measure of aging

In another passage of the first Speech in *Hexameron*, Saint Basil defines the time as a measure of aging, underlying its different meaning for humans and for God:

"... the stream of time, always in a hurry, flows away and never ceases its motion. Or is time not like this? The past has disappeared, the future has not arrived yet and the present escapes our perception, before we understand it? ... Thus (time) was necessary for the bodies of animals and plants, which are by some need bound to a stream and held together by the motion leading to creation or destruction, determined by the nature of time which has a particular aspect according to the changing things."[10]

Consequently, Saint Basil comes before Saint Augustine to the conclusion that time is not identical with motion, but it measures it through the effect of destruction caused by time.

3.4. The achronal Creation

Concerning the notion and nature of time, of interest is also the next passage of the first Speech:

"... Or perhaps because the creation took place instantaneously and without any time interference, therefore it is said in the beginning He created, since the beginning has neither parts nor dimensions, as the beginning of a road is not a road yet and the beginning of a house is not a house, so the beginning of time is not time nor is the minimal part of it. If someone has objections and supports the view that the beginning is time, let him know that he will be forced to divide this beginning into those parts of time which are the start, the middle and the end. But to invent a beginning of time is completely ridiculous and he who bisects the beginning shall produce two beginnings instead of one, or rather infinitely many, since whatever has been bisected can be divided to more ad infinitum."[11]

We see that, according to Saint Basil's consideration, the Universe was born achronally, i.e. the time is a result of the Creation of the perceivable Universe. This view is similar to Alcman's opinion, described in the Oxyrhynchus papyrus No. 2390.[12] As we have already mentioned, Saint Augustine expresses a similar position a little later, as he concludes that, due to this fact, the question about what was God doing before the Creation is meaningless.

3.5. The multiple Universes

A fifth remark can be made through the next passages of the first Speech:

"Therefore in their opinion, that the universes are ungoverned and unruled traveling randomly, they were deceived by their atheism which they had inside

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[10] Basil the Great, 1990, *Homilies...*

[11] *Ibidem.*

[12] Danezis and Theodossiou, 1999, *A presocratic...*, 125.

them".[13] And further: "...His creative power is not confined within the measures of one world only, but it is infinitely greater".[14]

With these passages, Saint Basil discusses the question: Is our Universe unique in the context of natural Creation?

In this question an interesting answer, not in accordance with theological sense, is given. There is an infinite number of Universes similar to our own.

It is interesting that today cosmological considerations exist like those of Andrei Linde and Jayant Narlikar, discussing the existence of a Multiversum consisting of separate Universes, i.e. the possibility of Creation of many Universes in the context of a wider Creation than can be perceived by us.

3.6. The Universe with a beginning

Finally a sixth passage of the first Speech comes to a philosophical ground as far as a Universe with a beginning is concerned. It states:

"Thus, man does not imagine that everything you see has no beginning and because the bodies moving in the sky have circular orbits — as with a usual look we do not easily conceive the beginning of a circle — does not think that the bodies moving circularly have by nature no beginning...

... do not be deceived that the world is unruled and interminable (without beginning and end) by the fact that their motion is regular and nothing interrupts it...

...What has begun at some instant in time, it is necessary to end at another instant. If it has a beginning, do not doubt about its end".[15]

According to the previous considerations of Saint Basil, based on the scientific knowledge of that period, since the perceivable Creation has a beginning it will surely have an end. This means that neither the Universe nor its age are infinite. In this way, long before Aleksandr Aleksandrovich Friedman (1888–1925) and abbé Georges Eduard Lemaître (1894–1966), the vision existed in Mediterranean cultures of a Universe finite in space and time, as reported by Saint Basil. However, we should not forget that he reconciles in a theologically and philosophically elegant way the Universe with a beginning, with the existence of our perceivable

Universe and an infinite number of other Universes as well.

Acknowledgements: We are grateful to Professor Alan Batten for suggestions and comments which considerably improved our paper and to Dr. David Asher for very useful comments and kind help.

[13] Basile de Césarée, 1968, *Homelies...*, 86–522.

[14] *Ibidem.*

[15] *Ibidem.*

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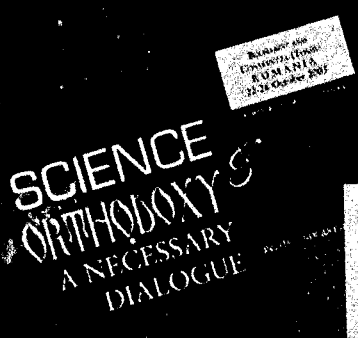

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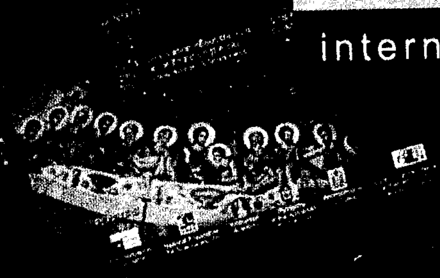

Cosmological Implications of the "Hexameron" of Saint Basilius the Great

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Basilius the Great, Archbishop of Caesarea and Saint of the Eastern and Western Christian Church (330-379 A.D.), was born at Neocaesarea of Pontos by a wealthy family of intellectuals in 330 A.D. At the age of 21, Basilius came to Athens, the main centre of university studies of the time, where the famous philosophical schools founded by Plato and Aristotle were still operating. At these schools were teaching the distinct sophists of the time, Emaerius and Proaeraesius. In Athens, Basilius took classes of rhetoric, grammar, philosophy, dialectics, astronomy, geometry, arithmetic, and, to a lesser degree, medicine. That cycle of studies was completed within four years, after which he returned to Caesarea (356 A.D.). After his return to Cappadocia and a five year-period of ascetic isolation and meditation, Basilius was ordained a priest (364) and finally became Archbishop of Caesarea after the death of Eusebius.

For his great moral and spiritual virtues as well as for his general social contribution, the Christian Church has declared Basilius a Saint and his memory is honored by the Eastern Orthodox Church on January, the 1st and 30th, together with two other holy Fathers, Gregorius Theologus and Ioannis Chryssostomus, and by the Western Christian Church on June, the 14th.

One of the most important works of Basilius the Great constitutes his nine Speeches on the Hexameron where, through the scientific knowledge of his time accompanied by a brilliant theological justification, he tries to prove the truth of cosmological events, as are those described in the biblical book of Genesis.

Considering the speeches of Saint Basilius from the point of view given by the history of science, we wish to indicate that this work is one of the most important sources of knowledge as far as the dominant views in the field of

Astronomy and, in general, in the field of the sciences of that era, are concerned.

The truth of this indication is evident if one takes into account that, the astronomical views in the Hexameron are stated, by someone (Saint Basilius) who had a deep knowledge of science and astronomy being formed in the wide region around the Mediterranean sea.

In the present work, being a small part of a wider project concerning the investigation of the physical knowledge during the time of Saint Basilius as it is deducted from the Hexameron, we shall examine some pioneering ideas developed by the Great Father of the Christian Church, which can constitute the beginning of a series of considerations for the historians of Astronomy.

Theology and Modern Physics

Emmanuel Danezis[1], *Efstratios Theodosiou*[1], *Ioannis Gonidakis*[1], *Milan S. Dimitrijevic*[2]

[1] National and Kapodestrian University of Athens, School of Physics, Department of Astrophysics, Astronomy and Mechanics

[2] Belgrade Astronomical Observatory

A distinctive characteristic of the modern theological reality, which is developing in Western societies, is the effort to confute the metaphysical views of the Christian Theology through the expression of ideas that are mainly based on the findings of the Exact Sciences (Antiretic-Objectionable Theology). The exact scientific way of thinking nowadays takes for granted that the current scientific knowledge, will inevitably be expanded, corrected, completed, and some ideas even annulated in the future under the pressure of new dramatic scientific discoveries. Thus, scientists from other fields, that are not familiar with the reality stated above, should not support their theological considerations on perishable and temporary views that may be overruled, once the scientific facts they are based on overrule themselves.

Antiretic Theology is based, in many cases, on scientific views of the 17th century that are no longer valid. We should mention that, due to this fact, the theological schools should study in depth the new Exact Sciences achievements and adapt their objections upon them, pursuing their antiretic work. In fact, we suggest that the theologians should follow the model of the Christian Church Fathers and become experts of the exact sciences of

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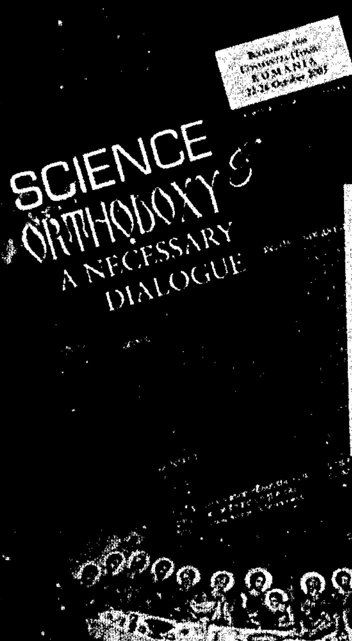

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Emergence, Discovery and a Platonic Perspective on complex systems

Pranab Das
Physics Department. Elon University, USA

The expression "emergent property", though expressive of the novelty reflected in complex systems, risks mis-construing the fundamental nature of dynamics. This paper offers an alternative formulation reflecting the "discovery" of existence in potential of such properties"

On the Reform of Julian Calendar on Ecumenical Congress in Constantinopole in 1923

Milan S. Dimitrijević[1] and Efstratios Theodossiou[2]
[1]Astronomical Observatory, Belgrade, Serbia and Montenegro
[2]Faculty of Physics, University of Athens Panepistimiopolis, Athens, Greece

Patriarch Meletios IV, the head of the Orthodox Churches, was convening an ecumenical congress in Constantinople in May 1923, where one of the principal points was the reform of the Julian calendar. On the Congress attended Greek, Russian, Romanian and Serbian Churches, and representatives of Serbian and Romanian Orthodox Churches submitted two elaborated propositions for calendar reform.

In Serbian delegation were Metropolitan of Montenegro and Coast Gavrilo Dožić, who later become Patriarch of Serbian Orthodox Church, and Milutin Milanković, one of the greatest Serbian scientists, later vice-president of Serbian Academy of Sciences and Arts, and Director of Belgrade Astronomical Observatory, who explained by astronomical reasons the phenomenon of Ice Ages, elucidated the history of Earth's climate as well as that of other planets, being in addition the author of the

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mathematical theory of climate and of the Earth's pole motion. They came on the Congress with the proposition of calendar reform which author was Maksim Trpković. He proposed the intercalation rule that the secular years whose number of the centuries divided with 9 gives the remainders 0 or 4 will be leap years. In such a way 7 days will be omitted from 9 centuries, so that the calendar will be closer to the tropical year than Gregorian, and equinox will be always on 21 March or very close.

In Romanian delegation were Archimandrite Julius Scriban and senator Dragici. They came with the following proposal of the calendar reform. The year has 364 days, full 52 weeks, so that every date has a fixed, always the same day in the week. March, June, September and December have 31 days and other months 30 days. An additional week which number of days corrects the difference with tropical year, is added every 5 years between 31 June and 1 July. The first day of Easter is fixed on 29 April and all other holidays become fixed. The unsigned proposition senator Dragici presented to Congress as his, but he told to Milanković that the author is baron Bedeus from Sibiu, who is not an orthodox, so that is inconvenient that his name is on proposition to Congress of Orthodox Churches.

In scientific commission formed to examine two projects were Milutin Milankovic, senator Dragici and Archimandrit Scriban, but both propositions were rejected by Congress as inconvenient and Milutin Milanković obtained task to elaborate a new one. He proposed a new intercalation rule, that secular years are leap years only provided that the number of centuries they belong to, divided by 9 yields the remainder 2 or 6. In such a way he obtained the calendar more precise than Gregorian one but identical with this up to 2800. He underlined that the advantage is that Orthodox Church has not accepted the calendar of the Catholic Church and that it is in principle better than Gregorian.

Also, Anthimos Metropolitan of Viziys proposed to determine the exact date of Easter by astronomical methods with the help of Observatories and Universities in Athens, Belgrade, Bucharest and Pulkovo.

Milutin Milanković made the final redaction of the calendar reform adopted on the Congress, which was signed by Patriarch Meletos IV, Metropolitan of Kyzikos, Kalinikos, Archbishop of North America, Alexander, Metropolitan of Montenegro and Coast Gavrilo Dožić, Metropolitan of Nicaea, Vasilios, Metropolitan of Durachion, Jakub, Archimandrite Julius Scriban, and Professors V. Antoniadis and Milutin Milanković. In this contribution we will discuss this calendar reform.

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SCIENCE AND RELIGION
Antagonism or Complementarity?

An international symposium organized within the framework of

Science and Spiritual Quest

A programme of the

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Science and the Spiritual Quest II

8-11 November 2001, Bucharest, Romania

The symposium is organized in collaboration with

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and

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Opening session: November 8th, 2001, 9 a.m.
Aula of the Romanian Academy, Bucharest, Calea Victoriei 125
The remainder of the symposium will be held in the conference hall of the Institut Français de Bucarest, 77 Bd. Dacia

Need and Usefulnes of a Revised Creation Theology: Chaos Theology

Sjoerd L. BONTING
Netherlands

Dialogue of science and theology is not only possible, but is greatly needed. A sound creation theology is crucial for this purpose. The 1800-year old creatio ex nihilo doctrine is untenable on five points: conceptual, biblical, scientific, theological, and the unsolved problem of evil.

From the biblical idea of creation from chaos and continuing creation with a remaining element of chaos, together with the physical theory of chaos events speaker has developed a revised creation theology, called 'chaos theology'.

Principles are: creation from initial chaos, remaining chaos element operating in continuing creation, abolished on last Day; chaos element is source of evil. Chaos events constitute opening for God to guide his continuing creation to fulfillment.

Chaos theology provides interesting parallels with current cosmological insights. It can renew traditional theological thinking about God's action in the world, incarnation and salvation in Jesus Christ, original sin, and offer a theology of disease.

Cosmological Fine-tuning, Two Versions of the Design Hypothesis and Physical Eschatology

Milan M. ĆIRKOVIĆ
Yugoslavia

The Design hypothesis for explanation of the anthropic coincidences so ubiquitous in cosmology and fundamental physics is examined in light of the two basic philosophical conceptions vis-a-vis temporal becoming. As is well-known, there is a famous division into A- and B-theories of time, the former asserting physical reality of temporal becoming ("tensed"), and the latter rejecting it as an artifact of human cognition ("tenseless" or "atemporal"). It is shown that, accordingly, there are two basic versions of the Design hypothesis, which correspond to the two basic relationship of fine-tuning agents with temporal phenomena we observe in the universe. Therefore, the status of cosmological *final* boundary conditions is different in these two approaches. The most interesting issue concerns the principal possibility of discriminating between the two versions using the recent advances in cosmology and, in particular, physical eschatology – the nascent astrophysical discipline dealing with future evolution of astronomical objects. In any case, this investigation may serve better delineation between the two main contenders in the field of anthropic reasoning: the Design hypothesis and the Multiverse hypothesis.

Science and Religion: Complementarity in the Fight against Astrology

Milan S. DIMITRIJEVIC
Yugoslavia

In a discussion of antagonism or complementarity of science and religion it is interesting to consider also the complementarity of religious and scientific arguments in the perpetuous fight against astrology. In this fight the Holy Bible and the Christian Church may be important partners to astronomers, and astronomers might help to the Church to decrease the influence of astrology.

It is difficult to defite the superstitious belief in astrology completely, since in comparison with other magic practicers and fortellers of events, astrologists with they use of some mathematical formulas, observational data and methods which looks as scientific ones, look very scientifically to non educated people. The astrology however is in disagreement with Christian religion and with the increase of the influence of religion often decrease the influence of astrology.

For example, in the Serbia in XIX century when the influence of the Ortodox Church was dominant, in practically all calendars, astrological nonsensses have been condamned and for example in one of them is written: "Allmighty God rules the World and not planets which are only creation of His hands. Such belief existed long time ago in old Egipt among nonbelivers, who believed that planets rule the human destiny and the World". In the Holy Bible, in Deuteronomy (Moses V); 10-12, old Moses advices his people: "There should not be found in you any one who is... a practicer of magic, or anyone who looks for omens ... or a professional forteller of events... For everybody doing these things is something detestable to God, and on account of these detestable things your Good is driving them away from before you..."

It is interesting that today in the epoch when man made his first steps towards stars we have 184000 registered astrologists in France, 200000 in Japan and armies of astrologists in other countries, taking money from superstitious people. Does contribute to this also the fact that the influence of Religion now is smaller than in XIX century? If a beliver read in the Holy Bible in Genesis, in Chapter 25 (25-26) concerning the birth of E'sav and Jacob that Jacob "come out and his hand was holding onto the heel of E'sav" and see so different destiny of these twins, will he believe also in astrological horoscops based on positions of celestial objects in the time of birth?

In this contribution I will summarize arguments from Bible against astrology and their complementarity with scientific arguments in order to provide a better preparation for perpetuous common fight of religion and science against superstition.

About two rational and scientific arguments to accept divinity

Dan D. FARCAS
Romania

1. An *astronomic* argument. A conservative estimate, using a Drake-like equation, gives that our Galaxy could bear around 10000 technological civilizations, as ours. At least 100 of them, we hope, can survive for a very long time, maybe millions of years, becoming supercivilizations. As the age of our Universe is, at least, 15 billions of years, and the conditions were different in different zones, some supercivilizations could be born hundreds of millions of years ago. Even with spaceships we can build today, such a supercivilization could visit Earth in the past. But in such a great time span is almost impossible to not discover some new principles of physics, some new states of substance, other dimensions, subcuantic properties etc. to avoid the limitation of speed of light for long distance communication and transport.

The Universe we observe has about 100 billion galaxies. But the Universe could be still much older, much wider and much more complex than we can observe or even imagine. Therefore, even we were too optimistic, the probability that such supercivilization exist, voyaging without restrictions of speed of light, is 0.99999... Such a supercivilization should be here, on Earth; even we do not acknowledge it. As it was observed, it is not possible for humans to distinguish between the acts of such a supercivilization and magic. We can add as well the sacred, holy and divine.

2. An *epistemological* argument. Humans get knowledge about the reality through theories and other kinds of models: verbal, mathematical, graphical etc. All of these instruments are limited by the inherent limits of language, logic and, finally, of the human mind. Therefore, no such model could be perfect. Consequently, in many complex domains of knowledge, several alternative models or theories were developed; they can contradict each other in some parts, but we can not dismiss any of them, until they contradict clearly the observations or the experiments made in the real world. As an example, we can not get rid of the hypothesis of divinity (even all the dogmas have some anecdotal, but not intrinsic, contradictions) simply because we can not organize the experiments to prove that divinity does not exist.

Faced with the plurality of alternative theories, a rational person has a choice: (1) to act using only one model (theory etc.), considered the best, for example the scientific approach, or (2) to use all of them - to act keeping in mind the suggestions of each of these theories, maybe with a weight attributed to them. As no theory is perfect, the second method could be more rational. This means, for example, that in many situations we can act considering simultaneously science and religion.

Nicolas Paulesco – l'unité entre la science et la tradition

Constantin GALERIU
Romania

La personne humaine, sollicitée à se réaliser sur de multiples plans de l'existence, porte également en elle, impérativement, le désir de l'unité. Cela correspond à la nature de son facteur essentiel – l'âme, qui, en rapport avec l'existence organique du corps, nous est révélé en tant que "*simple et indivisible dans le dispersé, illimité dans le rassemblé, changeant en tant que mû et mû en tant qu'ayant un but vers quoi il est*

Mariana BIRLAN. Teacher of Physics, 14 years experience of teaching in High School, Student in "Sciences Teaching" of Paris 7 University. Interest topics: Physics, Religion, comparative study of teaching methods.

Mirel BIRLAN. PhD. in Astronomy, Ph.D. in Physics, Engeneer CNRS, Observatoire de Paris-Meudon. Associate astronomer Astronomical Institute of the Romanian Academy. Interest topics: planetology, astronomy, history of Physics, informatics, epistemology.

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Sjoerd L. BONTING. Speaker studied biochemistry at the Univ. of Amsterdam. After receiving a Ph.D. degree in 1952, he spent 13 years in the USA at various universities and the National Institutes of Health, Bethesda. From 1965-85 he was professor and chairman, Dept. of Biochemistry, Univ. of Nijmegen, the Netherlands. From 1985-93 he worked as a scientific consultant at NASA-Ames Research Centre, California on preparations for biological research on the International Space Station. He studied theology 1957-63, and was ordained priest in the Episcopal Church at Washington Cathedral in 1964. He founded and served four Anglican congregations for English-speaking persons in the Nether-lands, 1965-85. Since 1993 he has been writing and lecturing on science-theology issues,
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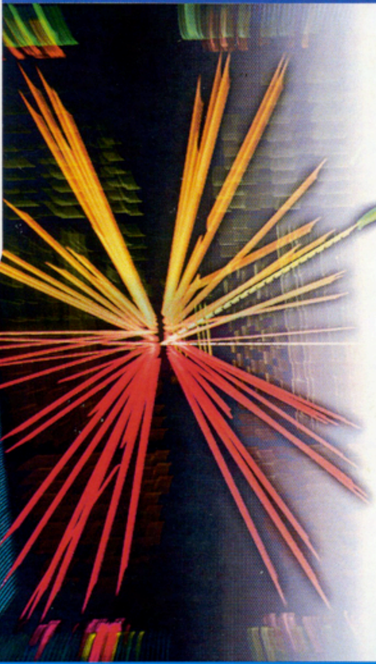

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envisager un accélérateur laser-plasma pour la physique des particules. Les voies de recherche et développement à l'étude actuellement seront brièvement présentées.

MC08b-05

Table Ronde: L'accélérateur, un instrument du futur?

R. ALEKSAN[a], E. MONNIER[b]
[a] *CEA/Saclay, Gif sur Yvette - FRANCE* , [b] *CPPM, Marseille - FRANCE*

Discussion sur les compétences qui seront nécessaires en physique des accélérateurs à l'avenir par rapport aux compétences actuelles, mise en commun des ressources techniques, collaborations entre laboratoires et communautés....

Mini-colloque 9 : Astrophysique de laboratoire aux basses énergies

Session MC09a

« Physico-chimie à basse température »

jeudi 04 juillet 2013 de 14:30 à 16:30

MC09a-01 | *Conférence invitée*

VAMDC: Infrastructure internationale d'échange pour les données de physique atomique et moléculaire

ML. DUBERNET[a]
[a] *Observatoire de Paris, Meudon - FRANCE*

VAMDC (http://www.vamdc.eu) a un role de valorisation des données expérimentales et théoriques de physique atomique et moléculaire, données qui ont un impact pour de nombreux domaines tels l'astrophysique, la physique de l'atmosphère, l'environnement, les plasmas, la chimie de combustion, la santé, les sciences cliniques. Concrètement VAMDC met à disposition des bases de données dans un format uniforme, développe des standards de description des données, des briques logicielles ainsi que des logiciels utilisateurs. A ce jour VAMDC regroupe une trentaine de bases de données internationales, qui sont en particulier accessibles depuis son portail http://portal.vamdc.eu. Nous montrerons la valeur ajoutée scientifique qu'apporte VAMDC à la distribution des données de physique atomique et moléculaire, et insisterons dans le cadre du mini-colloque 9 sur les aspects concernant l'astrophysique de laboratoire aux basses énergies.

Au-delà de cette infrastructure logicielle VAMDC s'organise en consortium avec des activités qui vont au-delà des acteurs de la recherche (producteurs ou utilisateurs de données de physique atomique et moléculaire). VAMDC veut effectivement développer ses partenariats avec le monde de l'éducation, le monde industriel, les éditeurs de journaux scientifiques, les institutions, les agences, les citoyens. VAMDC se développe et s'organise pour répondre aux objectifs de l'horizon 2020 de l'Europe, et pour devenir un facteur de croissance économique, de transmission de l'information scientifique avec un impact sur l'éducation et sur le rayonnement de la science auprès du public.

MC09a-02

Virtual laboratory astrophysics in the framework of VAMDC: the Stark-B database

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"Stark broadening" theories and calculations have been extensively developed for about 50 years. Accurate spectroscopic diagnostics and modelling require the knowledge of numerous collisional line profiles.

Nowadays, the access to such data via an on line database becomes essential. The aim of STARK-B is to reply to this need. It is a collaborative project between the Astronomical Observatory of Belgrade (AOB) and the "Laboratoire d'Etude du Rayonnement et de la matière en Astrophysique" (LERMA). It is a database of widths and shifts of isolated lines of atoms and ions due to electron and ion impacts that we have calculated and published in international refereed journals. It is devoted to modelling and spectroscopic diagnostics of stellar atmospheres and envelopes, laboratory plasmas, laser equipments and technological plasmas. Hence, the domain of temperatures and densities covered by the tables is wide and depends on the ionization degree of the considered ion.

STARK-B has been fully opened to the international community since fall 2008. We have just finished to enter our published semiclassical data (more than 150 papers). We are now beginning to insert calculations resulting from the Modified SemiEmpirical method, (about 50 papers). We will also feed the database with future new published results.

STARK-B [1] is a part of VAMDC [2]. VAMDC (Virtual Atomic and Molecular Data Centre) *"is a Consortium of Databases & Services Providers that has built a unified, secure, documented, flexible and interoperable e-science environment-based interface to its members A+M databases"* (sic, [2]). *"VAMDC Consortium has been funded by VAMDC Project* [3] *and SUP@VAMDC Grants* [4]. *VAMDC project (2009-2012) aims at building an interoperable e-infrastructure for the exchange of atomic and molecular data"* (sic, [3]).

We will present the state of development of the STARK-B database VAMDC node at the Conference. We will also show how to use STARK-B and the VAMDC software.

References

[1] http://stark-b.obspm.fr
[2] http://www.vamdc.eu
[3] http://www.vamdc-project.vamdc.eu/
[4] http://www.sup-vamdc.vamdc.eu/

MC09a-03 | *Conférence invitée*

Physico-chimie des glaces interstellaires

P. THEULÉ[a], F. DUVERNAY[a], G. DANGER[a], F. MISPELAER[a], P. ROUBIN[a], T CHIAVASSA[a]
[a] *Aix-Marseille Université, Marseille - FRANCE*

Les grains interstellaires joue un rôle important dans la formation de H_2 et des molécules complexes. Les différents processus mis en œuvre dans la physico-chimie des grains interstellaires (accrétion, désorption, diffusion, réseau de réactions chimiques thermiques et photochimiques,...) vont pouvoir augmenter ou limiter la complexité moléculaire dans le milieu interstellaire, notamment dans les régiosn de formation d'étoiles.

Des expériences en laboratoire sur des analogues de grain interstellaire permettent de comprendre et de modéliser ces processus physico-chimiques .

Nous allons passer l'état actuel de nos connaissances, voir quels sont les défis et quelles expériences devraient améliorer notre compréhension de la physico-chimie des grains interstellaires.

MC09a-04

Comprendre la formation et les propriétés des aérosols de Titan en laboratoire avec l'expérience PAMPRE

T. GAUTIER[a], N. CARRASCO[a], C. SZOPA[a], A. MAHJOUB[a], B. FLEURY[a], PR. DAHOO[a], E. HADAMCIK[a], G. CERNOGORA[a]
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Mini-colloque 9 : Astrophysique de laboratoire aux basses énergies

P052

Stark broadening parameters of B IV spectral lines

M. DIMITRIJEVIC[a], M. CHRISTOVA[b], Z. SIMIC[a], S. SAHAL-BRECHOT[c], A. KOVACEVIC[d]

[a] Astronomical Observatory, Belgrade - SERBIE , [b] Department of Applied Physics, Technical University, Sofia - SERBIE , [c] Observatoire de Paris, Meudon - SERBIE ; [d] Department of Astronomy, Faculty of Mathematics, Belgrade - SERBIE

Abundance determinations of light elements Li, Be, and B in a number of stars provide data on the astrophysical processes that can both produce and destroy them, so that the corresponding data on boron, including data on line profiles, are of interest for testing models of stellar interiors and evolution. Also we note that boron spectral lines are observed in hot stars, where Stark broadening, i.e. broadening by impacts with charged particles, is an important line broadening mechanism. Stark broadening of B IV spectral lines is of interest for modelling of subphotospheric layers and in plasma conditions such as those of white dwarf atmospheres. It is also useful for laboratory plasma diagnostic as well as for analysis and synthesis of B IV spectra in laboratory and astrophysical plasmas.

Within the frame of semiclassical perturbation theory, we have calculated Stark broadening parameters for 185 B IV lines for temperatures from 20 000 K to 500 000 K and for a greed of electron densities. The obtained results have been used to examine the regular behaviour of Stark broadening parameters within various spectral series, since the established regularities might be used for interpolation of new data and to quickly check the data found in literature or during experiments. Additionally, the results have been used to compare Stark and Doppler broadening importance in stellar atmospheres.

The results will be included in the STARK-B database containing theoretical Stark broadening parameters [1], which is a part of VAMDC - Virtual Atomic and Molecular Data Center [2].

Here, a part of obtained results will be presented.

References

[1] http://stark-b.obspm.fr

[2] http://www.vamdc.eu

P053

Détermination des propriétés de l'atmosphère des naines brunes froides et des planètes extrasolaires par l'étude quantique des spectres d'absorption des métaux alcalins perturbés par les gaz rares

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Les raies de résonnance des métaux alcalins élargies par pression en présence des atomes perturbateurs d'atomes de gaz rares et, plus précisément, les structures de satellites dans les ailes lointaines ont, très récemment, fait l'objet de plusieurs études théoriques et de mesure expérimentales. Les investigations spectroscopiques des planètes extrasolaires et le diagnostique de l'atmosphère des naines brunes froides nouvellement découvertes ont incité la communauté scientifique à effectuer des calculs de haute qualité et procéder à des mesures précises pour la détermination des paramètres et caractéristiques physiques et chimiques de leurs environnements [1, 2, 3, 4, 5].

L'analyse théorique et purement quantique des spectres de photo absorption des alcalins (ns-np) perturbés par les gaz rares a été réalisée en particulier dans les travaux [3, 4, 5]. Les résultats obtenus sont essentiellement basés sur la précision des courbes d'énergie des dimères alcalin-gaz rare et sur les moments dipolaires de transition qui assurent les transitions quantiquement permises. Pour cela nous avons déterminé les états électroniques: le fondamental X $^2\Sigma^+$ et les excités A $^2\Pi$et B $^2\Sigma$ correspondant à l'interaction des atomes alcalins dans l'état ns ^2S ou np ^2P avec les atomes d'hélium dans leur état $1s^2$ ^1S ainsi que les moments dipolaires relatifs.

Les coefficients d'absorption réduits calculés montrent l'apparition dans l'aile bleue du spectre d'absorption d'un satellite dans le domaine de température 500-3000 K et sont en bon accord avec d'autres études théoriques et mesures expérimentales [3, 4, 5].

References

[1] A. Burrows, Nature **433**, 261 (2005)

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[5] H. Boutarfa, K. Alioua, M. Bouledroua, A.R. Allouche, M. Aubert-Frécon, A **86**, 052504 (2012)

P054

Zeeman Spectroscopy of NiH : Landé factors of ?=3/2 electronic states

H. HARKER[a], C. RICHARD[a], G. TOURASSE[a], P CROZET[a], A. ROSS[a]

[a] Institut Lumière Matière - Université Claude Bernard Lyon 1 & CNRS (UMR 5306), Villeurbanne - FRANCE

We present laboratory determined molecular Landé factors of the NiH molecular radical, as a model for transition hydrides found in cool stellar atmospheres (sunspots and brown dwarfs). In particular, measurements of Zeeman patterns in NiH (17000 18000 cm^{-1}) obtained through high resolution laser excitation and dispersed fluorescence in the presence of an external magnetic field (< 1 Tesla) combined with literature values for the $X_1{}^2\Delta_{5/2}$ ground state Landé factors[1] [McCarthy et al. JCP 107 (1997) 4179] have allowed us to elucidate the often peculiar magnetic responses of individual rotational levels in this molecule and to determine effective electronic Landé factors for several Ω=3/2 electronic states. We report molecular Landé factors for Ω=3/2 electronic states that exhibit remarkably strong variations with J and with parity as well as an electronic state that exhibits an unexpected isotopologue-dependent Zeeman response at low J. These observations provide evidence for extensive mixing between electronic states and deviation from Hund's case (a) coupling. We also report polarization dependent discrepancies between experimental and theoretical spectral intensities [Berdyugina and Solanki A&A 385 (2002) 701]. This study of NiH has provided reliable data for possible use in stellar spectropolarimetry, and prepared us for the more challenging near IR Zeeman study of FeH, which is considered a more likely molecular probe of magnetic fields in sunspots and on cool stars (T>3000K) (c.f. Poster P. CROZET).

P055

Zeeman laser spectroscopy of FeH in the gas phase and spectropolarimetric sunspot measurements at THEMIS

P. CROZET[a], A. ROSS[b], N. ALLEQ[a], A. LOPEZ ARISTE[c], C. LE MEN[c], B. GELLY[c]

[a] ILM Institut Lumière Matière, UMR 5306 (CNRS/UCBL Lyon1), Villeurbanne - FRANCE , [b] ILM Institut Lumière Matière, UMR 5306 (CNRS/UCBL Lyon1), Villeurbanne - FRANCE , [c] THEMIS Télescope Héliographique pour l'Etude du Magnétisme et des Instabilités Solaires, CNRS UPS 853, LA LAGUNA TENERIFE - FRANCE

Zeeman broadened lines in the near IR band of FeH have been suggested as a magnetic probe of cool stellar atmospheres [1], but measurements of the Zeeman response were lacking , this response is also notoriously difficult to predict because of extensive interstate mixing [2]. We report results from a laser spectroscopy experiment developed in Lyon (c.f Poster H. Harker). FeH radicals are produced with a DC discharge and injected in a locally homogeneous field, calibrated *in situ* with Ar I atomic lines. The 869 nm (1-0) and 989 nm (0-0) absorption bands in the F $^4\Delta_\Omega$ - X $^4\Delta_\Omega$ system are probed by laser-induced fluorescence. We have recorded survey scans at zero field, to measure Λ-doubling separations, unresolved in earlier work [3,4]; then Zeeman splittings or profiles in magnetic fields up to 0.5 Tesla for J"<11½ have been measured, extending significantly the first laboratory investigations [5]. Landé factors were then

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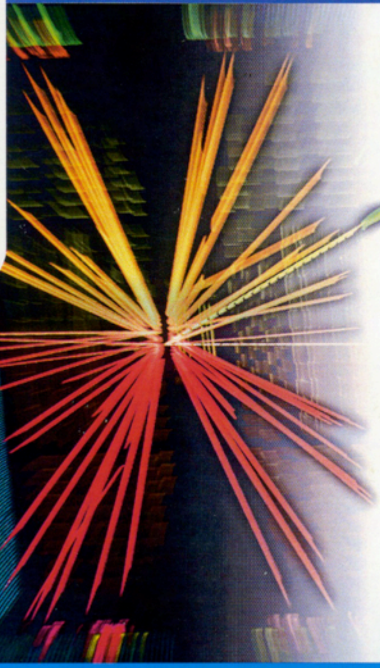

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Mini-colloque 9 : Astrophysique de laboratoire aux basses énergies

P052

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P054

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ABSTRACTS

On the Existence between Light and Darkness
Radu CONSTANTINESCU & Gelu CALINA

There will be an approach of the issues related to the impact that concepts of the light and darkness have on our existence in general; at the level of human being (spiritually); at the level of human society and the one of the Universe as a whole. The approach will consider the interdisciplinary perspective searching for answers for a set of „big questions" from different points of views: those of physicists, theologians, social and human sciences, etc. Some examples of basic questions: Light means energy/information. Has „dark matter" clear epistemological significance? More light means more energy. More energy might generate „black holes" (see the experiment LHC – GENEVA). Can the light generate darkness? On the microscopic level, the matter generates the light through creation/annihilation precesses

Church and Science in Common Fight against Superstition
Milan S. DIMITRIJEVIC

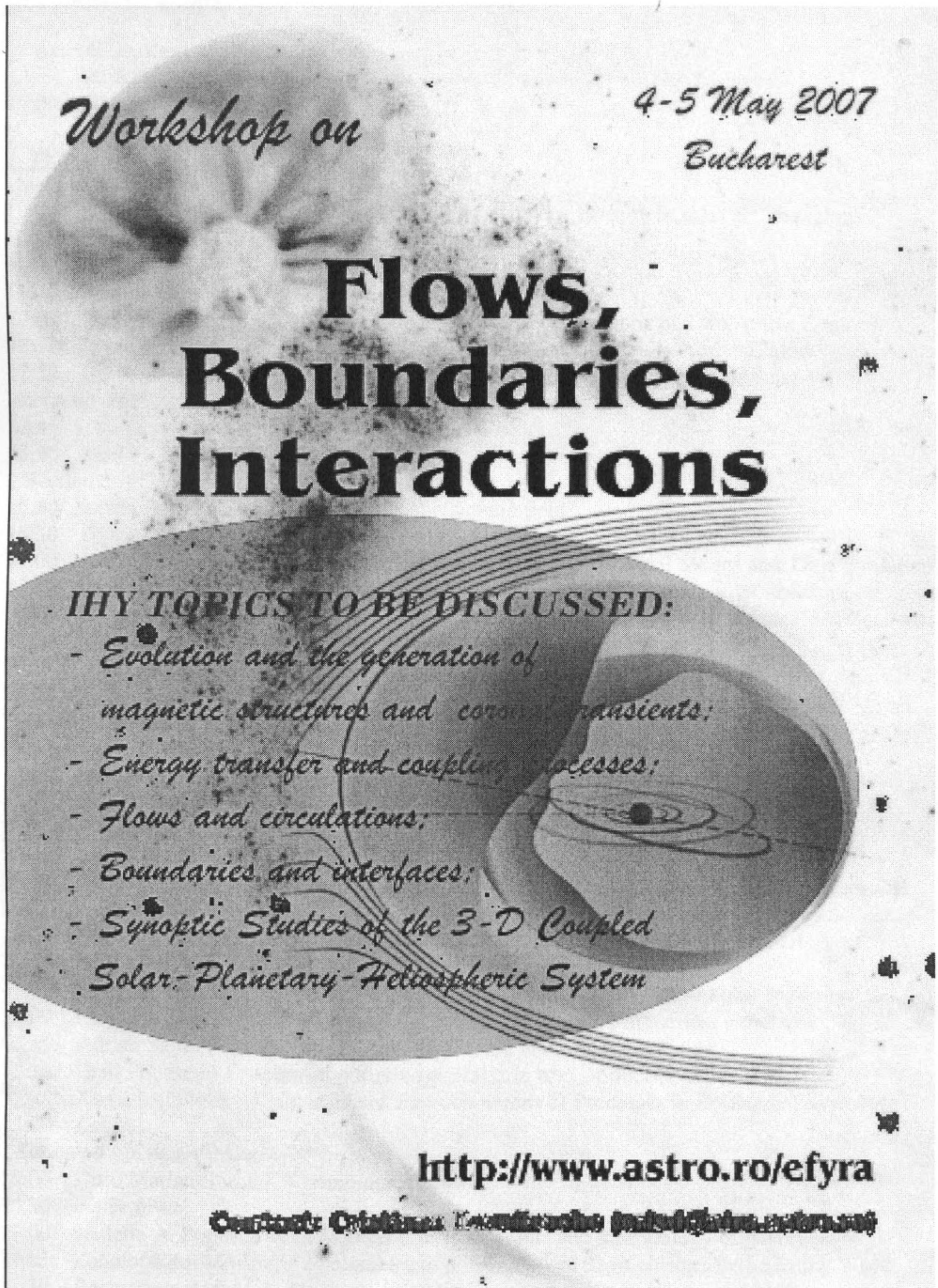
Scientific and Religious arguments together are more successful in perpetuous fight of Religion and Science against superstition, for the liberty of human will. It will be discussed common interest and importance of the joint action against practices based on superstition like astrology, numerology, palmistry, and similar activities which may result that someone loose initiative to make himself his decisions by free will. It will be discussed possible actions like round tables, lectures, articles and TV and Radio emissions and arguments and possible strategies.

IDEAS

1. Church and Science in common fight against superstition
2. Scientific theories on the beginning of the Universe
3. Eschatology of the Universe
4. The development of the idea of the multiplicity of inhabitable worlds and possibility for communications with other civilizations.
5. The secret of the big silence of cosmos. Where are they?

Informational Cosmology. Transdisciplinary Aspects
Adrian IOSIF

The main ways of the research: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Flows,
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- Energy transfer and coupling processes;
- Flows and circulations;
- Boundaries and interfaces;
- Synoptic Studies of the 3-D Coupled
Solar-Planetary-Heliospheric System
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Photometry of poorly studied open clusters in the Milky Way

Zabolotskikh M.V., Glushkova E.V., Spiridonova O.I., Koposov S.E.

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BVRI CCD photometric survey of poorly studied galactic open star clusters in the direction to Perseus spiral arm was performed with 1-meter Zeiss telescope of SAO RAS. DAOPHOT package and Padova theoretical isochrones have been applied to King18.

Stochastization time in star clusters

Rastorguev A.S., Sementsov V.N.

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We show that passage to a statistical description of stellar systems is possible when considering the evolution on time scales longer than t_m ($t_m^5 = t_d^4\ t_c$), where t_d is the mean dynamical (Keplerian) time and t_c is the two-particle collisional relaxation time.

ON THE COMMON INFLUENCE OF STARK BROADENING AND HYPERFINE STRUCTURE IN STELLAR SPECTRA: Mn II LINES

L. Ch. Popovic (1), M. S. Dimitrijevic(1), M. Dacic (1), Z. Simic (1), A. Kovacevic (2),

S. Sahal-Brechot (3)

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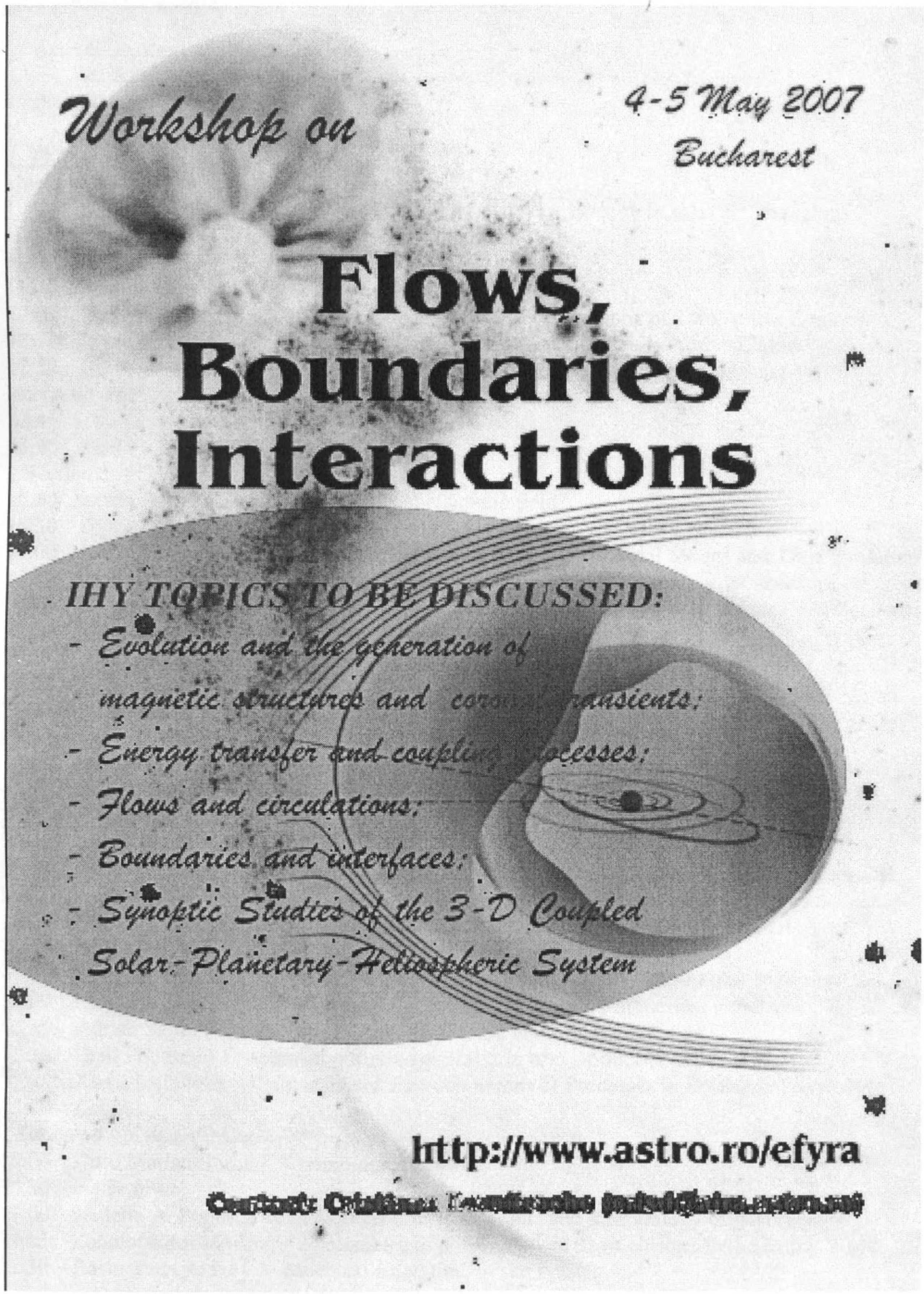
Ionized manganese lines are of interest for the analysis and modeling of stellar spectra as well as for the modeling and consideration of subphotospheric layers. Recently, a disagreement of up to 5.7 times is found between experimental and calculated Stark widths and shifts of Mn II lines. As one of possible reasons, the hfs splitting was assumed. In order to do so, we performed more sophisticated calculations for six Mn II lines, by using the semiclassical perturbation theory. Moreover, we made a detailed analysis of the influence of hfs splitting on the considered experimental results. The obtained data and conclusions are of interest for a number of problems in stellar and Solar physics, like spectrum analysis and synthesis, radiative transfer, and modellisation of subphotospheric layers.



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Te I STARK BROADENING DATA FOR STELLAR PLASMA ANALYSIS

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Email: andjelka@matf.bg.ac.yu
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In spite of the fact that tellurium is one of the least abundant element in the Earth's litosphere, its cosmic abundance is larger than for any element with atomic number greater than 40, and its spectral lines are observed in stellar spectra. Since the significance of trace elements spectral data, including Stark broadening parameters, increases with the development of space-born spectroscopy we investigate here theoretically the influence of collisions with charged particles on spectral lines of neutral tellurium. By using the semiclassical perturbation method, Stark widths and shifts of four Te I spectral lines, of interest for modellisation, investigation and diagnostic of stellar plasma have been obtained.

INFLUENCE OF COLLISIONS WITH CHARGED PARTICLES ON SOLAR TYPE STARS SPECTRA - INVESTIGATIONS ON BELGRADE ASTRONOMICAL OBSERVATORY

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Broadening of spectral lines by collisions with charged particles (Stark broadening) will be considered and analyzed with a particular emphasis on the solar type stars. Also will be reviewed and discussed theoretical methods for the determination of Stark broadening parameters, developed on the Belgrade Astronomical observatory and in Serbia, as well as the results of theoretical determination of such data and its applicability to stellar plasma research.

Papapetrou Energy-Momentum Complex for a Stringy Black Hole Solution

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The aim of this paper is to evaluate the energy distribution of a stringy black hole solution with the Papapetrou energy-momentum complex. The space-time under consideration describes the dual solution known as the magnetic black hole solution. The energy distribution depends on the mass M and charge Q of the magnetic black hole. In the limit Q-->8594; 0 the expression of the energy reduces to that obtained in the case of the Schwarzschild black hole when the Schwarzschild Cartesian coordinates are used.

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STARK BROADENING OF SINGLY IONIZED CALCIUM LINES

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1 Introduction

Calcium is among the most abundant elements in stellar plasmas after hydrogen and helium. Particularly important for stellar spectral analysis are the well known resonance lines of Ca II, which are present in all spectra starting with B−type stars and reaching maximal intensity in stars of the K0 spectral type. Consequently, knowledge of reliable Ca II Stark−broadening parameters is of great importance for detailed investigation of stellar atmospheres, as well as for opacity research. Furthermore, Ca II lines are of particular interest for investigations of laboratory plasmas, since calcium is often present as an impurity. By using the semiclassical−perturbation formalism [1,2], we have calculated electron−, proton−, and ionized helium−impact line widths and shifts for 28 Ca II multiplets. A summary of the formalism is given in Ref. 3.

2 Results and discussion

Here, we present in Table 1 and discuss a comparison with experimental data [4−14] while the tables of Ca II Stark broadening parameters will be published elsewhere [15,16]. We see that for most of experiments the widths fall within the error bars of both methods. Additional reliable experimental data for the 4s−4p Ca II widths, especially at lower temperatures, will be of interest.

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Table 1. Comparison between the experimental Stark full half–halfwidths of Ca II lines (Wm) with different calculations. Semiclassical calculations: WDSB–present results; WJBG – Jones, Benett and Griem (1971)[18,19]; WHC – Hildum and Cooper (1971)[13]; quantum–mechanical calculations: WQ – Barnes (1971)[16] and Barnes and Peach (1970)[17]; N =electron densitv.

Transition	λ(A)	T(K)	N/10+17(cm-3)	Wm(A)	Wm/WDSB	Wm/WJBG	Wm/WHC	Wm/WQM	Ref.
3d-4p	8542.09	13000	1.08	0.95	0.91	0.64		1.10	4
	8662.14	13000	1.08	0.95	0.91	0.64		1.10	4
4s-4p	3933.66	11400	0.40	0.039	0.45	0.33	0.41	0.42	6
		11600	0.64	0.079	0.57	0.43	0.52	0.54	6
		12240	0.80	0.0914	0.53	0.41	0.49	0.51	7
		13000	1.08	0.235	1.04	0.78	0.95	0.99	4
		13350	1.32	0.180	0.65	0.50	0.60	0.63	7
		16000	1.00	0.16	0.81	0.62	0.75	0.78	8
		17500	10.0	10.0	5.15	3.95	4.81	5.05	9
		19000	1.00	0.172	0.91	0.69	0.51	0.45	10
		25100	1.00	0.22	1.22	0.92	1.15	1.25	11
		28000	1.00	0.25	1.40	1.07	1.32	1.44	8
		29200	1.00	0.18	1.01	0.78	0.95	1.05	11
		30000	2.35	0.24	0.58	0.47	0.53	0.63	9
	3968.47	7450	1.00	0.210	0.82	0.67	----	----	5
		12240	0.80	0.0846	0.49	0.38	0.46	0.47	7
		13000	1.08	0.235	1.04	0.78	0.95	0.99	4
		13350	1.32	0.161	0.59	0.44	0.54	0.56	7
		16000	1.00	0.16	0.81	0.62	0.75	0.78	8
		17500	10.0	10.3	5.31	4.07	4.95	5.20	9*
		18560	1.00	0.188	0.98	0.75	0.93	1.04	13
		25100	1.00	0.20	1.11	0.84	1.04	1.14	11
		28000	1.00	0.25	1.40	1.07	1.32	44	8
4p-5s	3736.20	7500	10.0	18.2	2.37	2.98			9
		10000	1.00	0.69	1.03	1.00			14
		13000	1.12	0.79	1.21	0.94			4
		25100	1.00	0.30	0.63	0.53			11
	3706.03	10000	1.00	0.70	1.04	1.01			14
		13000	1.12	0.79	1.21	0.94			4
		17500	10.0	13.7	2.68	2.24			9
4p-4d	3179.33	13000	1.13	0.66	1.40	1.03			4
	3158.87	13000	1.13	0.66	1.40	1.03			4
		25100	1.00	0.32	0.90	0.74			11
		29200	1.00	0.30	0.87	0.71			11
	3181.28	13000	1.13	0.66	1.40	1.03			4

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MODIFIED SEMIEMPIRICAL FORMULA FOR THE ELECTRON-IMPACT WIDTH OF IONIZED ATOM LINES: THEORY AND APPLICATIONS

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1. Introduction

In 1968, Griem [1] suggested a simple semiempirical impact approximation based on Baranger's [2] original formulation, together with the use of an effective Gaunt-factor approximation proposed by Seaton [3] and Van Regemorter [4]. For singly ionized atoms, this semiempirical formula agrees on the average within ± 50% with experiments [5]. For multiply ionized atoms, the agreement becomes worse and few attempts have been made to extend the applicability of this approach to higher ionisation stages [6-9]. This extension was done by adjustments of the effective Gaunt factors and by taking into account also the complexities of particular atomic structures (deviations from LS coupling, configuration mixing and optically forbidden transitions. Some limitations of these attempts [6-9] have been discussed recently by Dimitrijević and Konjević [10].

In this paper a modification of the semiempirical formula is reported and numerous theoretical calculations of line widths of ionized atoms are presented. The results of comparisons with other theoretical approaches and experiments are also given.

2. Theory

Within the impact approximation, Baranger [2] derived a quantum-mechanical expression for the width of an isolated ion line:

$$W = N\{v\,[\sum \sigma_{i'i} + \sum_{f'} \sigma_{f'f}]\}_{av} + W_{e\ell}\ , \qquad (1)$$

where W is the full half-width (FWHM) in units of angular frequency and N is the electron concentration. The symbols $\sigma_{i'i}$ and $\sigma_{f'f}$ represent the inelastic cross sections for collisional transitions to i′, f′ from initial (i) and final (f) levels, respectively, of the optical transition. $W_{e\ell}$ is the line width induced by elastic collisions. The averaging in Eq. (1) has to be performed over the electron velocity (v) distribution.

Within the framework of the dipole approximation, one may use Bethe′s relation [11]

$$\sigma_{j'j} = \frac{8\pi}{3} \lambda^2 \vec{R}^2_{j'j} \frac{\pi}{\sqrt{3}} g \qquad (2)$$

to evaluate inelastic cross sections. In this expression $\lambda = \hbar/mv$ is the reduced de Broglie wavelength of an electron and $\vec{R}^2_{j'j}$ (in units of the Bohr radius a_o) is the square of the coordinate operator matrix element summed over all components of the operator, the magnetic substates of total angular momentum J′, and averaged over the magnetic substates of J.

For higher electron temperatures, Griem [1] assumed that the contribution of elastic collisions to the line width [cf.Eq. (1)] can be neglected. The same author [1] made an attempt to take elastic collisions into account in the low temperature limit by using the threshold value of the inelastic cross section below the threshold. The Stark line width can then be calculated from the well known semiempirical formula [1]

$$W = N \frac{8\pi}{3} \frac{\hbar^2}{m^2} \left(\frac{2m}{\pi kT}\right)^{1/2} \frac{\pi}{\sqrt{3}} \left[\sum_{i'} \vec{R}^2_{i'i}\, g\left(\frac{E}{\Delta E_{i'i}}\right) + \sum_{f'} \vec{R}^2_{f'f}\, g\left(\frac{E}{\Delta E_{f'f}}\right)\right] \quad (3)$$

Here, $E = 3kT/2$ is the energy of the perturbing electron and $\Delta E_{j'j} = [E_{j'}-E_j]$ is the energy difference between levels j and j'; $g(x) = 0.20$ for $x \leq 2$ and $g(x) = 0.24, 0.33, 0.56, 0.98$, and 1.33 for $x = 3,5,10,30$, and 100.

If the nearest perturbing level in Eq. (3) is so far from E_i or E_f that the condition $E/\Delta E_{j'j} \leq 2$ is satisfied, g becomes a costant [1]. Then, the summation in Eq. (3) can be performed straightforwardly leading to considerable simplification of the relation. The line width (FWHM) in Å units then becomes

$$W(\text{Å}) = 0.4430 \cdot 10^{-8} \frac{\lambda^2(\text{cm})\, N(\text{cm}^{-3})}{T^{1/2}} (\vec{R}^2_{ii} + \vec{R}^2_{ff}), \qquad (4)$$

$$\vec{R}^2_{jj} = \sum_{j'} \vec{R}^2_{j'j} \simeq \frac{1}{2}\left(\frac{n_j}{Z}\right)^2 [5n_j^2+1 - 3\ell_j(\ell_j+1)], \qquad (5)$$

where n_j is the effective principal and ℓ_j the orbital angular momentum quantum number, while (Z-1) is the ionic charge.

As we have pointed out previously, the semiempirical relation agrees on the average within ±50% with experimenal data for singly-ionized atoms. However some authors (see e.g. Kobzev [6]) already pointed out that the constant threshold value of the Gaunt factor for all kinds of transitions was not always an adequate choice. On the other hand Griem [5] suggested that the unmodified semiempirical formula can be used for multiply--ionized atoms as well, but with an accuracy of ±100 %. However, the comparison with the experimental values of line widths of doubly- and triply-ionized atoms [6-9, 12-15] shows that the theoretical results are systematically lower. This observation is an indication that the threshold value of 0.2 for the Gaunt factor is rather small for higher ionization stages.

For the transitions with the principal quantum number n unchanged, Kobzev [16] suggested an empirical value of $g = 0.9-1/Z$ at threshold. We have adopted this suggestion. Therefore, in Eq. (3), the contribution of the collisional transitions with $\Delta n = 0$ is treated separately. For higher electronic energies, the Gaunt factor is calculated from the following equation:

$$\tilde{g}(x) = 0.7 - 1.1/Z + g(x). \tag{6}$$

If one uses Eq. (3) to calculate Stark line widths, a lack of atomic data causes difficulties in the evaluation of necessary matrix elements. These difficulties are especially serious for multiply-ionized atoms for which data on higher perturbing levels are sometimes completely missing in the literature. To overcome this problem, we have separated the transitions with $\Delta n = 0$. Also, the LS coupling approximation is assumed. In this case, only two matrix elements are calculated: one for the transition array $\ell \to \ell+1$ ($R^2_{\ell,\ell+1}$) and the other for $\ell \to \ell-1$ ($R^2_{\ell,\ell-1}$). The same technique has been used by Griem [5] for semiclassical calculations of multiply charged ion line widths.

Equation (3) becomes now

$$W = N \frac{8\pi}{3} \frac{\hbar^2}{m^2} \left(\frac{2m}{\pi kT}\right)^{1/2} \frac{\pi}{\sqrt{3}} \Bigg[\vec{R}^2_{\ell_i,\ell_i+1}\, \tilde{g}\left(\frac{E}{\Delta E_{\ell_i,\ell_i+1}}\right) + \vec{R}^2_{\ell_i,\ell_i-1}\, \tilde{g}\left(\frac{E}{\Delta E_{\ell_i,\ell_i-1}}\right) + \vec{R}^2_{\ell_f,\ell_f+1}\, \tilde{g}\left(\frac{E}{\Delta E_{\ell_f,\ell_f+1}}\right) + \vec{R}^2_{\ell_f,\ell_f-1}\, \tilde{g}\left(\frac{E}{\Delta E_{\ell_f,\ell_f-1}}\right) + \sum_{i'} (\vec{R}^2_{ii'})_{\Delta n \neq 0} \cdot g\left(\frac{3kTn_i^3}{4Z^2E_H}\right) + \sum_{f'} (\vec{R}^2_{ff'})_{\Delta n \neq 0}\, g\left(\frac{3kTn_f^3}{4Z^2E_H}\right) \Bigg], \tag{7}$$

$$\vec{R}^2_{\ell,\ell'} \simeq \left(\frac{3n}{2Z}\right)^2 \frac{\max(\ell,\ell')}{2\ell+1} \left[n^2 - \max{}^2(\ell,\ell')\right] \phi^2, \tag{8}$$

$$\sum_{j'} (\vec{R}^2_{jj'})_{\Delta n \neq 0} \simeq \left(\frac{3n_j}{2Z}\right)^2 \frac{1}{9} \left(n_j^2 + 3\ell_j^2 + 3\ell_j + 11\right). \tag{9}$$

For the inelastic part in Eq. (7) the nearest perturbing level is estimated from

$$\Delta E_{n,n+1} \approx 2Z^2 E_H / n^3 .$$

At high temperatures, say $3kT/2\Delta E > 50$, all Gaunt factors in Eq. (7) are calculated in accordance with the GBKO high temperature limit [17], viz.

$$\tilde{g}_{j'j} = g_{j'j} = \frac{\sqrt{3}}{\pi} \left[\frac{1}{2} + \ln \left(\frac{2Z\ kT}{n_j^2\ \Delta E_{j'j}}\right)\right]. \tag{10}$$

3. Results and comparisons with experiments

In order to estimate the accuracy of the theoretical results a detailed comparison with available experimental data for doubly and triply ionized atoms [12-14, 33-37] has been performed in Ref. 18; a summary is given in Table 1. A comparison has also been made with experiments for singly ionized atom lines and three typical examples are given in Fig. 1.

Table 1. Average ratios of measured and calculated linewidths for various doubly and triply ionized atoms

Element	T_e [K]	W_m/W_{SEM}	W_m/W_{SE}
CIII	60000	1.29	1.21
NIII	24300	0.92	1.71
OIII	25400	1.05	1.90
SiIII	25600	0.67	1.08
SIII	28500	1.16	1.65
ClIII	24200	1.01	1.68
AIII	21100	0.99	1.57
average ratio:		1.06 ± 0.31	1.53 ± 0.46

Element	T_e [K]	W_m/W_{SEM}	W_m/W_{SE}
CIV	60000	1.50	2.57
SiIV	25600	0.66	1.15
SIV	28500	0.80	1.65
AIV	21500	0.76	1.24
average ratio:		0.91±0.42	1.56±0.85

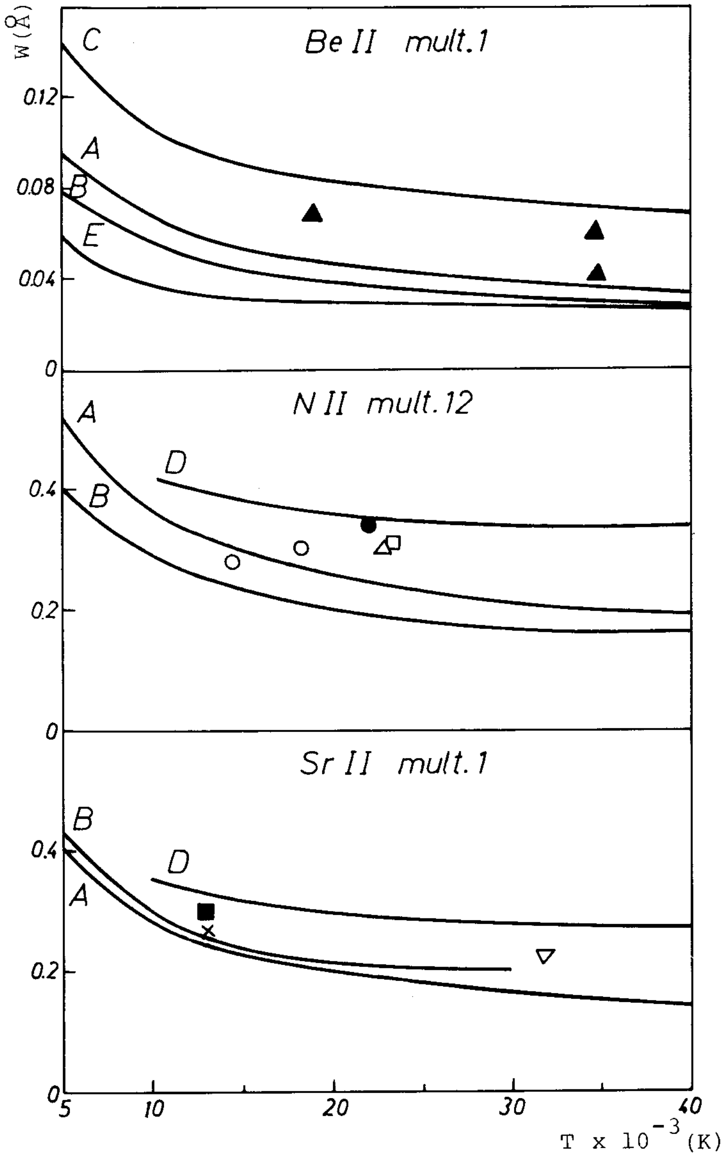

FIG.1. Measured and calculated full halfwidths for singly ionized atoms, normalized to an electron density of $1\times10^{17}cm^{-3}$, as a function of electron temperature. Curves: A:W_{SEM}; B:W_{SE}; C:W_{SC}-Jones et al [38]; D:W_{SC}-our calculations; E:quantum mechanical results with exchange by Sanchez et al [39]. Experimental points: ▲-Sanchez et al [39]; ●-Berg et al [40]; △-Jalufka and Craig [41]; o-Konjević et al [42]; □-Popović et al [43]; ■-Fleurier et al [44]; ▽-Hadžiomerspahić et al [45]; Theoretical points: x - Fleurier et al [44]

The results of numerous theoretical calculations of the electron impact line widths of prominent, isolated lines of BeIII through AIII and BIV through AIV are given in Table 2, where under W_{SEM} results are given obtained from eqs. (7) - (10), W_{SE}: eqs. (4) and (5). For the sake of comparison the same table contains the results W_G of a semiclassical formula (see Ref. 5, eq. 526 on p. 279, and the details of the calculations in Ref. 18) and its modified form [18], W_{GM}.

It is not necessary to discuss here uncertainties from the approximations involved in our calculations since the criteria for their application are given in detail elsewhere (see e.g. Ref. 5).

Additional errors which are not inherent to the theoretical approaches described above are related to the calculation of matrix elements and the lack of atomic data.

For evaluation of the radial integrals, the tables of Bates and Damgaard [14, 20] have been used. The cases when an atomic state with equivalent electrons is the principal one are avoided. If such a state is the perturbing one, corresponding coefficients of fractional parentage [21] are included whenever possible.

Data for atomic energy levels were taken from references 22 - 28. Some additional information is available for SIII [29], NaIII [30, 31] and PIII [32]. The results for multiplets 4UV, 5UV, 2 and 6 of AIV are probably less accurate since the data for the 4d level are missing.

TABLE 2. This table lists electron impact full half widths of isolated lines from doubly and triply ionized atoms from beryllium through argon at an electron density of $1x10^{17}$ cm^{-3} and electron temperatures T from 10.000 to 80.000K. Transition and averaged wavelength for the multiplet (in angström units) are also given. Under W_{SEM} and W_{SE} are given semiempirical results obtained from eqs. (7-10) and (4-5) respectively. W_{GM} are semiclassical results obtained from eqs.(11-15) in Ref. 18 (with 1.4 instead of 5-(4.5/Z) on the right-hand-side of eq.(12)in Ref. 18), and W_G are the results from eqs. (11-15) in Ref. 18. The value for 3kT/2ΔE represents the ratio of the thermal electron energy at 10.000K to the energy difference to the nearest perturbing level.

Element/Transition	T (K)	W_{SEM} (Å)	W_{SE} (Å)	W_{GM} (Å)	W_G (Å)
BE III $2s^1S-2p^1P^o$	10000	0.227	0.128	0.197	0.282
	20000	0.160	0.904-1	0.155	0.210
λ= 6141.0	30000	0.131	0.738-1	0.139	0.181
3kT/2ΔE=0.64	40000	0.117	0.711-1	0.131	0.165
	80000	0.947-1		0.117	0.136
BE III $2s^3S-2p^3P^o$	10000	0.701-1	0.402-1	0.617-1	0.874-1
	20000	0.496.1	0.284-1	0.471-1	0.644-1
λ= 3721.8	30000	0.405-1	0.232-1	0.414-1	0.548-1
3kT/2ΔE=0.39	40000	0.351-1	0.201-1	0.383-1	0.493-1
	80000	0.263-1	0.175-1	0.333-1	0.399-1
B III $2s^2S-2p^2P^o$	10000	0.191-1	0.115-1	0.176-1	0.244-1
	20000	0.135-1	0.815-2	0.131-1	0.178-1
λ= 2066.3	30000	0.110-1	0.665-2	0.113-1	0.150-1
3kT/2ΔE=0.22	40000	0.953-2	0.576-2	0.103-1	0.134-1
	80000	0.674-2	0.408-2	0.867-2	0.106-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
B III $4p\,^2P^o$-$5d\,^2D$	10000	9.88		6.72	7.74
	20000	8.29		6.08	6.62
λ = 4243.6	30000	7.44		5.68	6.04
3kT/2ΔE = 390.	40000	6.83		5.39	5.66
	80000	5.81		4.66	4.79
B III $4d\,^2D$-$5f\,^2F^o$	10000	12.2		7.62	8.15
	20000	9.85		6.76	7.00
λ = 4487.5	30000	8.66		6.24	6.38
3kT/2ΔE = 1000.	40000	7.90		5.86	5.96
	80000	6.39		4.96	5.01
B IV $2s\,^1S$-$2p\,^1P^o$	10000	0.396-1	0.200-1	0.367-1	0.481-1
	20000	0.280-1	0.141-1	0.277-1	0.353-1
λ = 4499.4	30000	0.228-1	0.115-1	0.240-1	0.299-1
3kT/2ΔE = 0.46	40000	0.198-1	0.999-2	0.220-1	0.268-1
	80000	0.152-1		0.187-1	0.214-1
B IV $2s\,^3S$-$2p\,^3P^o$	10000	0.269-1	0.136-1	0.201-1	0.316-1
	20000	0.190-1	0.958-2	0.150-1	0.228-1
λ = 2823.4	30000	0.155-1	0.782-2	0.129-1	0.191-1
3kT/2ΔE = 0.29	40000	0.134-1	0.678-2	0.117-1	0.169-1
	80000	0.966-2	0.513-2	0.986-2	0.131-1
C III $2p\,^3P^o$-$3s\,^3S$	10000	0.344-2	0.184-2	0.314-2	0.463-2
mult. 5UV	20000	0.243-2	0.130-2	0.244-2	0.344-2
λ = 538.2	30000	0.198-2	0.106-2	0.218-2	0.295-2
3kT/2ΔE = 0.48	40000	0.172-2	0.920-3	0.203-2	0.267-2
	80000	0.139-2		0.180-2	0.218-2
C III $3s\,^3S$-$3p\,^3P^o$	10000	0.523	0.263	0.410	0.642
mult. 1	20000	0.370	0.187	0.329	0.482
λ = 4648.8	30000	0.308	0.169	0.299	0.416
3kT/2ΔE = 1.0	40000	0.274		0.283	0.379
	80000	0.229		0.256	0.313

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
C III $3s'\,^1P^o-3p'\,^1D$	10000	0.486	0.230	0.377	0.589
mult. 7	20000	0.346	0.167	0.314	0.451
λ = 4326.0	30000	0.300		0.292	0.394
3kT/2ΔE = 1.1	40000	0.280		0.281	0.363
	80000	0.249		0.260	0.307
C III $3p\,^1P^o-3d\,^1D$	10000	0.736	0.410	0.716	0.991
mult. 2	20000	0.521	0.290	0.564	0.745
λ = 5696.0	30000	0.430	0.253	0.506	0.644
3kT/2ΔE = 0.89	40000	0.384		0.474	0.588
	80000	0.315		0.422	0.489
C III $3p\,^1P^o-4d\,^1D$	10000	0.172		0.180	0.233
	20000	0.139		0.158	0.189
λ = 1531.8	30000	0.124		0.148	0.170
3kT/2ΔE = 6.9	40000	0.115		0.142	0.159
	80000	0.103		0.128	0.137
C III $4p\,^3P^o-5d\,^3D$	10000	3.16		2.83	3.80
mult. 10	20000	2.77		2.54	3.10
λ = 3609.3	30000	2.62		2.40	2.80
3kT/2ΔE = 8.3	40000	2.49		2.31	2.62
	80000	2.16		2.08	2.24
C IV $2s\,^2S-2p\,^2P^o$	10000	0.728-2	0.383-2	0.570-2	0.873-2
mult.1UV	20000	0.515-2	0.271-2	0.417-2	0.627-2
λ = 1549.1	30000	0.421-2	0.221-2	0.353-2	0.522-2
3kT/2ΔE = 0.16	40000	0.364-2	0.192-2	0.318-2	0.460-2
	80000	0.258-2	0.135-2	0.257-2	0.350-2
C IV $2s\,^2S-4p\,^2P^o$	10000	0.295-2		0.232-2	0.354-2
mult. 3UV	20000	0.246-2		0.202-2	0.277-2
λ = 244.9	30000	0.220-2		0.190-2	0.245-2
3kT/2ΔE = 5.2	40000	0.207-2		0.183-2	0.227-2
	80000	0.169-2		0.169-2	0.193-2

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
C IV $2p^2P^o-3s^2S$	10000	0.227-2	0.949-3	0.164-2	0.278-2
mult. 6UV	20000	0.161.2	0.671-3	0.128-2	0.204-2
λ = 419.6	30000	0.131-2	0.548-3	0.114-2	0.174-2
3kT/2ΔE = 0.61	40000	0.116-2	0.509-3	0.107-2	0.156-2
	80000	0.936-3		0.954-3	0.125-2
C IV $2p^2P^o-4d^2D$	10000	0.570-2		0.449-2	0.536-2
mult. 9UV	20000	0.450-2		0.397-2	0.445-2
λ = 289.2	30000	0.390-2		0.370-2	0.403-2
3kT/2ΔE = 110.	40000	0.352-2		0.352-2	0.377-2
	80000	0.272-2		0.309-2	0.321-2
C IV $3s^2S-3p^2P^o$	10000	0.776	0.320	0.495	0.880
mult. 1	20000	0.571		0.402	0.656
λ = 5804.9	30000	0.484		0.369	0.564
3kT/2ΔE = 2.2	40000	0.440		0.352	0.511
	80000	0.368		0.325	0.419
C IV $4d^2D-5f^2F^o$	10000	2.13		1.24	1.38
mult. 14UV	20000	1.73		1.12	1.18
λ = 2524.4	30000	1.52		1.04	1.08
3kT/2ΔE = 1000.	40000	1.38		0.983	1.01
	80000	1.10		0.847	0.860
N III $2p^2P^o-3s^2S$	10000	0.202-2	0.108-2	0.185-2	0.272-2
mult. 4 UV	20000	0.143-2	0.801-3	0.143-2	0.201-2
λ = 452.1	30000	0.116-2		0.127-2	0.172-2
3kT/2ΔE = 1.1	40000	0.101-2		0.118-2	0.155-2
	80000	0.783-3		0.104-2	0.127-2
N III $3s^2S-3p^2P^o$	10000	0.333	0.173	0.261	0.408
mult. 1	20000	0.236	0.125	0.205	0.304
λ = 4097.3	30000	0.192		0.183	0.260
3kT/2ΔE = 1.1	40000	0.167		0.172	0.235
	80000	0.131		0.154	0.192

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
N III $3s^4P^o-3p^4P$	10000	0.236	0.121	0.188	0.292
mult. 5	20000	0.167	0.853-1	0.149	0.218
λ = 3367.3	30000	0.137	0.730-1	0.134	0.188
$3kT/2\Delta E$ = 0.81	40000	0.121		0.127	0.170
	80000	0.966-1		0.114	0.140
N III $3p^2P^o-3d^2D$	10000	0.415	0.236	0.413	0.565
mult. 2	20000	0.294	0.167	0.319	0.421
λ = 4640.6	30000	0.240	0.136	0.283	0.362
$3kT/2\Delta E$ = 0.48	40000	0.208	0.118	0.263	0.328
	80000	0.163		0.230	0.270
N IV $3s^3S-3p^3P^o$	10000	0.213	0.906-1	0.135	0.242
mult. 1	20000	0.151	0.641-1	0.105	0.177
λ = 3480.8	30000	0.124	0.535-1	0.929-1	0.150
$3kT/2\Delta E$ = 0.74	40000	0.108	0.499-1	0.869-1	0.134
	80000	0.837-1		0.776-1	0.107
N IV $3p^3P^o-3d^3D$	10000	0.735	0.353	0.588	0.904
mult. 4	20000	0.520	0.250	0.454	0.666
λ = 7117.0	30000	0.427	0.213	0.401	0.566
$3kT/2\Delta E$ = 0.74	40000	0.379	0.211	0.373	0.509
	80000	0.304		0.329	0.411
O III $3s^3P^o-3p^3D$	10000	0.230	0.122	0.183	0.283
mult. 2	20000	0.163	0.863-1	0.142	0.209
λ = 3762.3	30000	0.133	0.705-1	0.126	0.179
$3kT/2\Delta E$ = 0.63	40000	0.115	0.641-1	0.118	0.161
	80000	0.866-1		0.104	0.131
O III $3s^3P^o-3p^3S$	10000	0.185	0.981-1	0.148	0.229
mult. 3	20000	0.131	0.694-1	0.115	0.169
λ = 3326.6	30000	0.107	0.566-1	0.102	0.144
$3kT/2\Delta E$ = 0.63	40000	0.925-1	0.514-1	0.952-1	0.130
	80000	0.693-1		0.844-1	0.106

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
O III $3s\,^3P^o-3p\,^3P$	10000	0.158	0.839-1	0.127	0.197
mult. 4	20000	0.112	0.594-1	0.985-1	0.146
λ = 3041.5	30000	0.914-1	0.485-1	0.879-1	0.124
3kT/2ΔE = 0.63	40000	0.792-1	0.440-1	0.821-1	0.112
	80000	0.595-1		0.728-1	0.912-1
O III $3s\,^1P^o-3p\,^1D$	10000	0.171	0.877-1	0.137	0.213
mult. 6	20000	0.121	0.620-1	0.109	0.159
λ = 2983.8	30000	0.989-1	0.506-1	0.978-1	0.136
3kT/2ΔE = 0.58	40000	0.865-1	0.466-1	0.921-1	0.124
	80000	0.673-1		0.828-1	0.102
O III $3s\,^5P-3p\,^5D^o$	10000	0.223	0.118	0.177	0.275
mult. 21	20000	0.158	0.836-1	0.138	0.203
λ = 3706.1	30000	0.129	0.683-1	0.122	0.174
3kT/2ΔE = 0.39	40000	0.112	0.591-1	0.114	0.157
	80000	0.841-1	0.513-1	0.101	0.127
O III $3s\,^5P-3p\,^5S^o$	10000	0.126	0.673-1	0.103	0.158
mult. 22UV	20000	0.891-1	0.476-1	0.796-1	0.117
λ = 2678.2	30000	0.728-1	0.389-1	0.708-1	0.997-1
3kT/2ΔE = 0.46	40000	0.630-1	0.337-1	0.660-1	0.901-1
	80000	0.473-1		0.585-1	0.732-1
O III $3p\,^3P-3d\,^3D^o$	10000	0.245	0.144	0.252	0.339
mult. 14	20000	0.173	0.102	0.193	0.252
λ = 3712.5	30000	0.141	0.830-1	0.169	0.216
3kT/2ΔE = 0.39	40000	0.122	0.719-1	0.157	0.195
	80000	0.907-1	0.625-1	0.136	0.160
O III $3p\,^5D^o-3d\,^5F$	10000	0.196	0.113	0.204	0.273
mult. 25	20000	0.139	0.800-1	0.156	0.202
λ = 3453.0	30000	0.113	0.653-1	0.137	0.173
3kT/2ΔE = 0.39	40000	0.982-1	0.566-1	0.126	0.157
	80000	0.727-1	0.480-1	0.109	0.128

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
O III $3d\,^3P^o - 4p\,^3S$	10000	0.321	0.171	0.300	0.437
mult. 20UV	20000	0.227	0.121	0.240	0.330
λ = 2601.6	30000	0.188	0.112	0.216	0.285
3kT/2ΔE = 0.95	40000	0.168		0.203	0.260
	80000	0.134		0.181	0.215
O III $3d\,^1F^o - 4p\,^1D$	10000	0.356	0.179	0.333	0.483
mult. 21UV	20000	0.262	0.148	0.272	0.369
λ = 2558.1	30000	0.227		0.249	0.322
3kT/2ΔE = 1.5	40000	0.210		0.236	0.295
	80000	0.175		0.213	0.247
O IV $2p\,^2P^o - 3s\,^2S$	10000	0.596-3	0.270-3	0.453-3	0.746-3
mult. 4UV	20000	0.421-3	0.191-3	0.342-3	0.543-3
λ = 279.8	30000	0.344-3	0.156-3	0.297-3	0.456-3
3kT/2ΔE = 0.32	40000	0.298-3	0.135-3	0.273-3	0.406-3
	80000	0.217-3	0.105-3	0.235-3	0.319-3
O IV $2p\,^2P^o - 3d\,^2D$	10000	0.330-3	0.195-3	0.451-3	0.556-3
mult. 5UV	20000	0.233-3	0.138-3	0.336-3	0.408-3
λ = 238.5	30000	0.190.3	0.112-3	0.288-3	0.345-3
3kT/2ΔE = 0.36	40000	0.165-3	0.973-4	0.262-3	0.310-3
	80000	0.117-3	0.792-4	0.219-3	0.249-3
O IV $3s\,^4P^o - 3p\,^4D$	10000	0.168	0.721-1	0.106	0.190
mult. 3	20000	0.119	0.510-1	0.812-1	0.139
λ = 3374.3	30000	0.968-1	0.416-1	0.714-1	0.117
3kT/2ΔE = 0.39	40000	0.838-1	0.360-1	0.663-1	0.104
	80000	0.622-1	0.294-1	0.583-1	0.820-1
O IV $3p\,^4P - 3d\,^4D^o$	10000	0.310	0.152	0.252	0.385
mult. 9	20000	0.219	0.107	0.192	0.282
λ = 4792.5	30000	0.179	0.875-1	0.167	0.238
3kT/2ΔE = 0,50	40000	0.155	0.758-1	0.154	0.213
	80000	0.119		0.133	0.170

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
O IV $3p^2D-3d^2D^o$	10000	0.400	0.193	0.323	0.495
mult. 11	20000	0.283	0.137	0.246	0.363
λ = 5339.5	30000	0.231	0.112	0.216	0.307
3kT/2ΔE = 0.56	40000	0.202	0.101	0.200	0.276
	80000	0.156		0.174	0.221
F III $3s^4P_6-3p^4P^o_6$	10000	0.119	0.660-1	0.975-1	0.148
	20000	0.839-1	0.467-1	0.748-1	0.109
λ = 2916.3	30000	0.685-1	0.381-1	0.659-1	0.930-1
3kT/2ΔE = 0.33	40000	0.593-1	0.330-1	0.612-1	0.837-1
	80000	0.430-1	0.258-1	0.535-1	0.676-1
F III $3s^4P-3p^4D^o$	10000	0.134	0.743-1	0.110	0.167
mult. 1	20000	0.949-1	0.525-1	0.842-1	0.123
λ = 3124.4	30000	0.775-1	0.429-1	0.742-1	0.105
3kT/2ΔE = 0.33	40000	0.671-1	0.371-1	0.689-1	0.944-1
	80000	0.489-1	0.294-1	0.603-1	0.761-1
F III $3s^2P_4-3p^2P^o_4$	10000	0.130	0.684-1	0.105	0.162
	20000	0.918-1	0.483-1	0.822-1	0.120
λ = 2811.4	30000	0.750-1	0.395-1	0.733-1	0.103
3kT/2ΔE = 0.53	40000	0.651-1	0.346-1	0.686-1	0.929-1
	80000	0.488-1		0.611-1	0.759-1
F III $3s^2P-3p^2D^o$	10000	0.160	0.843-1	0.129	0.198
mult. 2	20000	0.113	0.596-1	0.101	0.147
λ = 3176.9	30000	0.924-1	0.487-1	0.897-1	0.126
3kT/2ΔE = 0.53	40000	0.801-1	0.426-1	0.840-1	0.114
	80000	0.603-1		0.748-1	0.929-1
NE III $3s^3S^o-3p^3P$	10000	0.965-1	0.540-1	0.800-1	0.121
mult. 12UV	20000	0.683-1	0.382-1	0.612-1	0.892-1
λ = 2678.2	30000	0.557-1	0.312-1	0.538-1	0.758-1
3kT/2ΔE = 0.32	40000	0.483-1	0.270-1	0.498-1	0.682-1
	80000	0.348-1	0.200-1	0.434-1	0.549-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
NE III $3s'^3D^o-3p'^3F$	10000	0.832-1	0.474-1	0.697-1	0.105
	20000	0.588-1	0.335-1	0.532-1	0.771-1
λ = 2612.4	30000	0.480-1	0.274-1	0.466-1	0.654-1
3kT/2ΔE = 0.29	40000	0.416-1	0.237-1	0.431-1	0.588-1
	80000	0.297-1	0.176-1	0.374-1	0.472-1
NE III $3p^5P_7-3d^5D^o_9$	10000	0.685-1	0.452-1	0.803-1	0.103
	20000	0.484-1	0.319-1	0.606-1	0.760-1
λ = 2163.8	30000	0.395-1	0.261-1	0.527-1	0.649-1
3kT/2ΔE = 0.27	40000	0.342-1	0.226-1	0.483-1	0.586-1
	80000	0.243-1	0.162-1	0.412-1	0.477-1
NE IV $3s^4P-3p^4D^o$	10000	0.608-1	0.281-1	0.404-1	0.703-1
	20000	0.430-1	0.199-1	0.303-1	0.509-1
λ = 2361.5	30000	0.351-1	0.162-1	0.262-1	0.426-1
3kT/2ΔE = 0.25	40000	0.304-1	0.141-1	0.240-1	0.378-1
	80000	0.215-1	0.994-2	0.204-1	0.293-1
NE IV $3s'^2D-3p'^2F^o$	10000	0.588-1	0.270-1	0.390-1	0.679-1
	20000	0.416-1	0.191-1	0.292-1	0.492-1
λ = 2289.1	30000	0.339-1	0.156-1	0.253-1	0.412-1
3kT/2ΔE = 0.39	40000	0.294-1	0.135-1	0.231-1	0.366-1
	80000	0.208-1	0.106-1	0.197-1	0.284-1
NA III $3s^4P-3p^4P^o$	10000	0.667-1	0.390-1	0.570-1	0.846-1
	20000	0.472-1	0.276-1	0.432-1	0.621-1
λ = 2515.6	30000	0.385-1	0.225-1	0.377-1	0.526-1
3kT/2ΔE = 0.26	40000	0.333-1	0.195-1	0.348-1	0.472-1
	80000	0.237-1	0.141-1	0.300-1	0.378-1
NA III $3s^4P-3p^4D^o$	10000	0.545-1	0.319-1	0.469-1	0.695-1
	20000	0.385-1	0.226-1	0.355-1	0.510-1
λ = 2232.5	30000	0.315-1	0.184-1	0.310-1	0.432-1
3kT/2ΔE = 0.26	40000	0.272-1	0.159-1	0.286-1	0.388-1
	80000	0.193-1	0.114-1	0.246-1	0.311-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
NA III $3s^4P-3p^4S^o$	10000	0.441-1	0.260-1	0.384-1	0.568-1
	20000	0.311-1	0.184-1	0.291-1	0.417-1
λ = 1971.5	30000	0.254-1	0.150-1	0.254-1	0.353-1
$3kT/2\Delta E$ = 0.26	40000	0.220-1	0.130-1	0.234-1	0.317-1
	80000	0.156-1	0.928-2	0.201-1	0.254-1
NA III $3s^2P-3p^2D^o$	10000	0.689-1	0.408-1	0.591-1	0.879-1
	20000	0.487-1	0.289-1	0.449-1	0.645-1
λ = 2458.9	30000	0.398-1	0.236-1	0.392-1	0.547-1
$3kT/2\Delta E$ = 0.26	40000	0.345-1	0.204-1	0.361-1	0.491-1
	80000	0.244-1	0.146-1	0.311-1	0.393-1
NA III $3s^2P-3p^2P^o$	10000	0.593-1	0.351-1	0.512-1	0.760-1
	20000	0.419-1	0.248-1	0.388-1	0.558-1
λ = 2247.4	30000	0.342-1	0.203-1	0.339-1	0.473-1
$3kT/2\Delta E$ = 0.26	40000	0.296-1	0.176-1	0.312-1	0.424-1
	80000	0.210-1	0.125-1	0.269-1	0.340-1
MG IV $3s^4P-3p^4S^o$	10000	0.199-1	0.969-2	0.140-1	0.236-1
	20000	0.140-1	0.685-2	0.104-1	0.170-1
λ = 1477.8	30000	0.115-1	0.559-2	0.892-2	0.142-1
$3kT/2\Delta E$ = 0.20	40000	0.993-2	0.484-2	0.810-2	0.126-1
	80000	0.702-2	0.342-2	0.678-2	0.972-2
MG IV $3p^4S^o_4-3d^4P_6$	10000	0.238-1	0.133-1	0.230-1	0.324-1
	20000	0.169-1	0.941-2	0.170-1	0.236-1
λ = 1548.1	30000	0.138-1	0.768-2	0.145-1	0.198-1
$3kT/2\Delta E$ = 0.16	40000	0.119-1	0.665-2	0.132-1	0.176-1
	80000	0.843-2	0.470-2	0.109-1	0.138-1
AL III $3s^2S-3p^2P^o$	10000	0.303-1	0.193.1	0.277-1	0.398-1
mult. 1UV	20000	0.214-1	0.136-1	0.208-1	0.291-1
λ = 1857.4	30000	0.175-1	0.111-1	0.180-1	0.246-1
$3kT/2\Delta E$ = 0.19	40000	0.151-1	0.963-2	0.165-1	0.220-1
	80000	0.107-1	0.681-2	0.140-1	0.175-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
AL III $3s^2S-4p^2P^o$	10000	0.136-1	0.837-2	0.138-1	0.199-1
mult. 2UV	20000	0.964-2	0.592-2	0.107-1	0.148-1
λ = 696.0	30000	0.787-2	0.483-2	0.953-2	0.127-1
3kT/2ΔE = 0.60	40000	0.684-2	0.446-2	0.886-2	0.115-1
	80000	0.525-2		0.777-2	0.940-2
AL III $3s^2S-5p^2P^o$	10000	0.238-1	0.145-1	0.254-1	0.361-1
mult. 3UV	20000	0.169-1	0.115-1	0.204-1	0.274-1
λ = 560.4	30000	0.144-1		0.184-1	0.238-1
3kT/2ΔE = 1.3	40000	0.131-1		0.173-1	0.217-1
	80000	0.111-1		0.154-1	0.180-1
AL III $4s^2S-4p^2P^o$	10000	1.48	0.859	1.20	1.87
mult. 2	20000	1.04	0.607	0.951	1.40
λ = 5705.9	30000	0.852	0.496	0.856	1.20
3kT/2ΔE = 0.60	40000	0.751	0.462	0.805	1.09
	80000	0.616		0.720	0.895
AL III $4p^2P^o-4d^2D$	10000	1.45		1.37	1.90
mult. 3	20000	1.14		1.14	1.47
λ = 4523.2	30000	0.996		1.04	1.30
3kT/2ΔE = 5.7	40000	0.909		0.983	1.19
	80000	0.764		0.876	1.00
AL III $4f^2F^o-5d^2D$	10000	4.42		4.14	5.25
mult. 6	20000	3.77		3.60	4.25
λ = 4701.6	30000	3.38		3.35	3.82
3kT/2ΔE = 10.	40000	3.16		3.18	3.56
	80000	2.65		2.83	3.03
AL III $4d^2D-6f^2F^o$	10000	5.92		4.82	5.40
	20000	5.01		4.27	4.58
λ = 2762.8	30000	4.50		3.95	4.15
3kT/2ΔE = 320.	40000	4.20		3.72	3.87
	80000	3.53		3.18	3.25

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
SI III $3p^3P^o-4s^3S$	10000	0.175-1	0.109-1	0.165-1	0.242-1
mult. 6UV	20000	0.124-1	0.772-2	0.129-1	0.180-1
λ = 996.1	30000	0.101-1	0.630-2	0.114-1	0.154-1
$3kT/2\Delta E$ = 0.48	40000	0.876-2	0.546-2	0.106-1	0.139-1
	80000	0.702-2		0.936-2	0.114-1
SI III $4s^3S-4p^3P^o$	10000	0.728	0.438	0.604	0.932
mult. 2	20000	0.514	0.310	0.473	0.693
λ = 4560.1	30000	0.420	0.253	0.422	0.594
$3kT/2\Delta E$ = 0.48	40000	0.364	0.219	0.395	0.538
	80000	0.289		0.350	0.438
SI III $4s^1S-4p^1P^o$	10000	1.25	0.736	1.02	1.59
mult. 4	20000	0.887	0.520	0.811	1.19
λ = 5739.7	30000	0.724	0.468	0.729	1.02
$3kT/2\Delta E$ = 0.97	40000	0.640		0.686	0.927
	80000	0.518		0.613	0.760
SI III $4p^3P^o-4d^3D$	10000	0.762	0.456	0.746	1.06
mult. 5	20000	0.546	0.347	0.590	0.800
λ = 3801.4	30000	0.463		0.529	0.691
$3kT/2\Delta E$ = 1.3	40000	0.411		0.496	0.630
	80000	0.342		0.438	0.520
SI III $4p^3P^o-5s^3S$	10000	0.793	0.438	0.680	1.04
mult. 6	20000	0.571	0.326	0.555	0.792
λ = 3237.8	30000	0.500		0.507	0.688
$3kT/2\Delta E$ = 1.2	40000	0.458		0.481	0.628
	80000	0.409		0.433	0.521
SI IV $3s^2S-3p^2P^o$	10000	0.141-1	0.733-2	0.104-1	0.170-1
mult. 1UV	20000	0.995-2	0.518-2	0.764-2	0.122-1
λ = 1396.7	30000	0.812-2	0.423-2	0.651-2	0.102-1
$3kT/2\Delta E$ = 0.15	40000	0.703-2	0.366-2	0.588-2	0.902-2
	80000	0.497-2	0.259-2	0.484-2	0.691-2

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
SI IV $3p^2P^o-3d^2D$	10000	0.109-1	0.659-2	0.116-1	0.156-1
mult. 3UV	20000	0.768-2	0.466-2	0.856-2	0.114-1
λ = 1126.4	30000	0.627-2	0.380-2	0.730-2	0.955-2
$3kT/2\Delta E$ = 0.18	40000	0.543-2	0.329-2	0.659-2	0.851-2
	80000	0.384-2	0.233-2	0.541-2	0.670-2
SI IV $4s^2S-4p^2P^o$	10000	0.605	0.281	0.388	0.700
mult. 1	20000	0.428	0.199	0.298	0.512
λ = 4097.9	30000	0.349	0.162	0.263	0.432
$3kT/2\Delta E$ = 0.43	40000	0.302	0.140	0.245	0.386
	80000	0.230		0.216	0.305
SI IV $4p^2P^o-4d^2D$	10000	0.467	0.233	0.355	0.576
mult. 2	20000	0.346		0.281	0.429
λ = 3160.3	30000	0.297		0.253	0.367
$3kT/2\Delta E$ = 2.5	40000	0.267		0.237	0.332
	80000	0.213		0.211	0.270
SI IV $4d^2D-5p^2P^o$	10000	1.20	0.576	0.866	1.46
mult. 3	20000	0.884		0.692	1.09
λ = 3766.0	30000	0.763		0.625	0.930
$3kT/2\Delta E$ = 2.5	40000	0.701		0.589	0.841
	80000	0.593		0.529	0.683
SI IV $5p^2P^o-6s^2S$	10000	3.37	1.46	2.29	4.03
mult. 4	20000	2.55	1.27	1.89	3.03
λ = 4323.5	30000	2.24		1.74	2.61
$3kT/2\Delta E$ = 1.7	40000	2.12		1.66	2.37
	80000	1.84		1.51	1.93
SI IV $5d^2D-6f^2F^o$	10000	8.34		6.03	7.67
mult. 5	20000	7.09		5.39	6.34
λ = 4212.4	30000	6.39		5.04	5.71
$3kT/2\Delta E$ = 140.	40000	5.97		4.80	5.32
	80000	4.91		4.22	4.49

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
P III $4s^2S-4p^2P^o$	10000	0.531	0.326	0.446	0.682
mult. 3	20000	0.375	0.230	0.347	0.507
λ = 4230.4	30000	0.306	0.188	0.309	0.434
$3kT/2\Delta E$ = 0.44	40000	0.265	0.163	0.289	0.392
	80000	0.206		0.255	0.319
P III $4s^4P^o-4p^4P$	10000	0.462		0.388	0.594
mult. 9	20000	0.327		0.301	0.441
λ = 3943.5	30000	0.267		0.268	0.377
$3kT/2\Delta E$ = 8.9	40000	0.231		0.250	0.341
	80000	0.176		0.220	0.277
P III $4p^2P^o-4d^2D$	10000	0.477	0.297	0.491	0.683
mult. 4	20000	0.349		0.390	0.516
λ = 3228.8	30000	0.296		0.350	0.447
$3kT/2\Delta E$ = 1.7	40000	0.269		0.328	0.408
	80000	0.219		0.290	0.339
P IV $4s^3S-4p^3P^o$	10000	0.330	0.158	0.216	0.385
mult. 1	20000	0.233	0.112	0.165	0.281
λ = 3355.9	30000	0.191	0.912-1	0.144	0.237
$3kT/2\Delta E$ = 0.35	40000	0.165	0.790-1	0.134	0.211
	80000	0.121	0.648-1	0.117	0.166
P IV $4s^1S-4p^1P^o$	10000	0.565	0.264	0.363	0.653
mult. 2	20000	0.399	0.186	0.279	0.477
λ = 4249.6	30000	0.326	0.152	0.246	0.403
$3kT/2\Delta E$ = 0.44	40000	0.282	0.132	0.229	0.360
	80000	0.215		0.202	0.285
S III $3d^3P_o-4p^3P$	10000	0.216	0.135	0.221	0.301
mult. 2	20000	0.153	0.954-1	0.168	0.223
λ = 3346.2	30000	0.125	0.779-1	0.147	0.190
$3kT/2\Delta E$ = 0.41	40000	0.108	0.675-1	0.135	0.171
	80000	0.773-1		0.116	0.139

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
S III $3d^3P^o-4p^3S$	10000	0.205	0.128	0.209	0.286
mult. 3	20000	0.145	0.904-1	0.159	0.212
λ = 3233.4	30000	0.119	0.738-1	0.139	0.181
$3kT/2\Delta E$ = 0.40	40000	0.103	0.640-1	0.128	0.163
	80000	0.736-1		0.110	0.132
S III $3d^3D^o-4p^3P$	10000	0.302	0.193	0.309	0.421
mult. 8	20000	0.214	0.137	0.235	0.312
λ = 3950.5	30000	0.175	0.112	0.206	0.266
$3kT/2\Delta E$ = 0.46	40000	0.151	0.966-1	0.189	0.240
	80000	0.108		0.162	0.195
S III $3s^3P^o-4p^3D$	10000	0.472	0.277	0.388	0.598
mult. 4	20000	0.334	0.196	0.303	0.444
λ = 4287.1	30000	0.273	0.160	0.270	0.380
$3kT/2\Delta E$ = 0.46	40000	0.236	0.139	0.252	0.343
	80000	0.183		0.223	0.280
S III $4s^3P^o-4p^3P$	10000	0.389	0.229	0.322	0.495
mult. 5	20000	0.275	0.162	0.251	0.368
λ = 3840.0	30000	0.225	0.132	0.223	0.314
$3kT/2\Delta E$ = 0.45	40000	0.194	0.115	0.208	0.284
	80000	0.148		0.184	0.231
S III $3s^3P^o-4p^3S$	10000	0.364	0.214	0.302	0.465
mult. 6	20000	0.258	0.152	0.235	0.345
λ = 3692.3	30000	0.210	0.124	0.209	0.295
$3kT/2\Delta E$ = 0.45	40000	0.182	0.107	0.195	0.266
	80000	0.138		0.173	0.217
S IV $3p^2P^o-4s^2S$	10000	0.396-2	0.202-2	0.306-2	0.503-2
	20000	0.280-2	0.143-2	0.231-2	0.366-2
λ = 553.1	30000	0.229-2	0.117-2	0.201-2	0.308-2
$3kT/2\Delta E$ = 0.32	40000	0.198-2	0.101-2	0.185-2	0.275-2
	80000	0.144-2	0.784-3	0.159-2	0.217-2

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
S IV $4s^2S-4p^2P^o$	10000	0.245	0.118	0.162	0.287
mult. 1	20000	0.173	0.838-1	0.123	0.209
λ = 3104.1	30000	0.141	0.684-1	0.107	0.176
3kT/2ΔE = 0.35	40000	0.122	0.592-1	0.991-1	0.156
	80000	0.886-1	0.476-1	0.861-1	0.123
CL III $3d^4P-4p^4P^o$	10000	0.286	0.175	0.288	0.392
mult. 7	20000	0.202	0.123	0.218	0.290
λ= 4045.8	30000	0.165	0.101	0.190	0.246
3kT/2ΔE = 0.47	40000	0.143	0.873-1	0.174	0.222
	80000	0.102		0.149	0.179
CL III $4s^4P-4p^4D^o$	10000	0.284	0.171	0.238	0.363
mult. 1	20000	0.201	0.121	0.184	0.268
λ= 3629.0	30000	0.164	0.987-1	0.163	0.229
3kT/2ΔE = 0.47	40000	0.142	0.855-1	0.151	0.206
	80000	0.106		0.133	0.167
CL III $4s^4P-4p^4P^o$	10000	0.246	0.148	0.207	0.315
mult. 2	20000	0.174	0.104	0.160	0.233
λ = 3330.9	30000	0.142	0.853-1	0.141	0.199
3kT/2ΔE = 0.42	40000	0.123	0.739-1	0.132	0.179
	80000	0.908-1		0.116	0.145
CL III $4s^4P-4p^4S^o$	10000	0.226	0.135	0.190	0.290
mult. 3	20000	0.160	0.956-1	0.147	0.214
λ = 3160.1	30000	0.130	0.781-1	0.130	0.183
3kT/2ΔE = 0.40	40000	0.113	0.676-1	0.121	0.165
	80000	0.831-1		0.106	0.134
CL III $4s^2P-4p^2D^o$	10000	0.314	0.194	0.266	0.404
mult. 5	20000	0.222	0.137	0.206	0.299
λ = 3739.4	30000	0.181	0.112	0.182	0.255
3kT/2ΔE = 0.53	40000	0.157	0.982-1	0.170	0.231
	80000	0.118		0.149	0.187

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
CL III $4s\,^2P-4p\,^2P^o$	10000	0.243	0.157	0.212	0.318
mult. 6	20000	0.172	0.111	0.164	0.236
λ = 3300.9	30000	0.140	0.905-1	0.145	0.201
3kT/2ΔE = 0.45	40000	0.121	0.784-1	0.135	0.182
	80000	0.897-1		0.118	0.147
CL III $4s'\,^2D-4p'\,^2F^o$	10000	0.271	0.165	0.229	0.348
mult. 10	20000	0.192	0.117	0.177	0.257
λ = 3543.8	30000	0.157	0.953-1	0.156	0.219
3kT/2ΔE = 0.59	40000	0.136	0.859-1	0.145	0.198
	80000	0.100		0.128	0.160
CL III $4s'\,^2D-4p'\,^2D^o$	10000	0.252	0.153	0.213	0.324
mult. 11	20000	0.178	0.108	0.165	0.240
λ = 3394.2	30000	0.146	0.885-1	0.146	0.204
3kT/2ΔE = 0.55	40000	0.126	0.785-1	0.135	0.184
	80000	0.932-1		0.119	0.149
CL III $4s'\,^2D-4p'\,^2P^o$	10000	0.204	0.123	0.173	0.263
mult. 11UV	20000	0.144	0.871-1	0.134	0.195
λ = 2975.4	30000	0.118	0.711-1	0.118	0.166
3kT/2ΔE = 0.45	40000	0.102	0.616-1	0.110	0.150
	80000	0.748-1		0.963-1	0.121
CL IV $4s\,^3P^o-4p\,^3D$	10000	0.162	0.991-1	0.122	0.200
	20000	0.114	0.701-1	0.924-1	0.146
λ = 3082.2	30000	0.933-1	0.572-1	0.806-1	0.123
3kT/2ΔE = 0.32	40000	0.808-1	0.496-1	0.743-1	0.110
	80000	0.589-1	0.391-1	0.643-1	0.870-1
CL IV $4s\,^3P^o-4p\,^3P$	10000	0.131	0.819-1	0.100	0.164
	20000	0.924-1	0.579-1	0.760-1	0.119
λ = 2767.6	30000	0.755-1	0.473-1	0.662-1	0.101
3kT/2ΔE = 0.32	40000	0.653-1	0.409-1	0.609-1	0.899-1
	80000	0.472-1	0.314-1	0.526-1	0.710-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
A III 3d"$^3P^o$-4p"^3P	10000	0.164	0.114	0.183	0.238
mult. 6	20000	0.116	0.806-1	0.139	0.176
λ = 3432.6	30000	0.949-1	0.658-1	0.120	0.150
3kT/2ΔE = 0.42	40000	0.822-1	0.570-1	0.110	0.135
	80000	0.583-1		0.938-1	0.110
A III 4s$^5S^o$-4p^5P	10000	0.208	0.128	0.178	0.268
mult. 1	20000	0.147	0.906-1	0.137	0.198
λ = 3296.6	30000	0.120	0.740-1	0.120	0.169
3kT/2ΔE = 0.35	40000	0.104	0.641-1	0.112	0.152
	80000	0.763-1	0.522-1	0.978-1	0.123
A III 4s'$^3D^o$-4p'^3D	10000	0.238	0.144	0.200	0.304
mult. 2	20000	0.168	0.102	0.155	0.225
λ = 3492.1	30000	0.137	0.832-1	0.137	0.192
3kT/2ΔE = 0.37	40000	0.119	0.720-1	0.127	0.173
	80000	0.877-1	0.603-1	0.111	0.140
A III 4s'$^3D^o$-4p'^3F	10000	0.221	0.134	0.187	0.283
mult. 3	20000	0.156	0.946-1	0.144	0.209
λ = 3344.8	30000	0.128	0.772-1	0.127	0.178
3kT/2ΔE = 0.37	40000	0.110	0.669-1	0.118	0.161
	80000	0.813-1	0.553-1	0.104	0.130
A III 4s"$^3P^o$-4p"^3D	10000	0.141	0.807-1	0.117	0.178
mult. 4	20000	0.100	0.571-1	0.898-1	0.131
λ = 3041.4	30000	0.816-1	0.466-1	0.791-1	0.112
3kT/2ΔE = 0.40	40000	0.707-1	0.404-1	0.733-1	0.100
	80000	0.513-1		0.641-1	0.810-1
A IV 4s^4P-4p$^4D^o$	10000	0.117	0.716-1	0.888-1	0.145
mult. 4UV	20000	0.829-1	0.506-1	0.670-1	0.106
λ = 2810.9	30000	0.677-1	0.413-1	0.583-1	0.891-1
3kT/2ΔE = 0.29	40000	0.586-1	0.358-1	0.536-1	0.795-1
	80000	0.422-1	0.271-1	0.461-1	0.626-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
A IV $4s\,^4P-4p\,^4P^o$	10000	0.102	0.631-1	0.781-1	0.127
mult. 5UV	20000	0.721-1	0.446-1	0.589-1	0.926-1
λ = 2617.5	30000	0.588-1	0.364-1	0.512-1	0.780-1
3kT/2ΔE = 0.29	40000	0.510-1	0.315-1	0.470-1	0.696-1
	80000	0.365-1	0.234-1	0.404-1	0.548-1
A IV $4s\,^2P-4p\,^2D^o$	10000	0.133	0.813-1	0.101	0.165
mult. 2	20000	0.943-1	0.575-1	0.761-1	0.120
λ = 2925.4	30000	0.770-1	0.469-1	0.663-1	0.101
3kT/2ΔE = 0.31	40000	0.667-1	0.407-1	0.610-1	0.905-1
	80000	0.482-1	0.313-1	0.526-1	0.714-1
A IV $4s'\,^2D-4p'\,^2F^o$	10000	0.114	0.701-1	0.868-1	0.142
mult. 6UV	20000	0.806-1	0.496-1	0.654-1	0.103
λ = 2769.2	30000	0.658-1	0.405-1	0.569-1	0.868-1
3kT/2ΔE = 0.29	40000	0.570-1	0.350-1	0.523-1	0.775-1
	80000	0.410-1	0.263-1	0.449-1	0.610-1

4. Discussion and conclusions

From the results shown in Table 2, it appears that, for the specified temperature and electron density regions, agreement of modified semiempirical and semiclassical results with experiments is quite good. The errors seem to be random and are caused by uncertainties in both, calculations and experiments. The average values of the ratios of measured to calculated widths of ionized atoms are as follows: for doubly-ionized atoms, $R_{SEM} = 1.06 \pm 0.32$, $R_{SE} = 1.53 \pm 0.46$, $R_{GM} = 0.96 \pm 0.24$, $R_G = 0.72 \pm 0.19$; for triply-ionized atoms, $R_{SEM} = 0.91 \pm 0.42$, $R_{SE} = 1.56 \pm 0.85$, $R_{GM} = 1.08 \pm 0.41$, $R_G = 0.72 \pm 0.32$. The indicated error represents an average quadratic error calculated from $\sigma = \sqrt{\sum_{i=1}^{m} \Delta_i^2/m(m-1)}$ where Δ_i is the difference between the i-th average ratio for the multiplet and the average ratio for all multiplets.

The principal deficiency in the comparisons of theoretical results for doubly and triply ionized atoms with experiments comes from the lack of experimental line widths at higher electron temperatures.

At the present time there are not enough experimental data to show which modified approach is the better one, especially at high temperatures. If one draws a conclusion based on a single experiment for CIII and CIV lines [12], the modified semiclassical approach seems to describe the experiment better. However, it should be emphasized here that there is little difference between the results derived from the modified and unmodified semiclassical expressions at high electron temperatures.

From the examples in Fig. 1 it seems that the modified semiempirical formula agrees better with the experiments for singly ionized atom lines, than its unmodified version. This one may expect, since in most investigated examples the semiempirical formula can be used in "lumped together" form [1]. In these cases one can always count on higher accuracy of our modified version. However, for intermediate electron energies it is always better to take into account all perturbing levels separately.

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MODIFIED SEMIEMPIRICAL FORMULA FOR THE ELECTRON-IMPACT WIDTH OF IONIZED ATOM LINES: THEORY AND APPLICATIONS

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1. Introduction

In 1968, Griem [1] suggested a simple semiempirical impact approximation based on Baranger's [2] original formulation, together with the use of an effective Gaunt-factor approximation proposed by Seaton [3] and Van Regemorter [4] . For singly ionized atoms, this semiempirical formula agrees on the average within ± 50% with experiments [5]. For multiply ionized atoms, the agreement becomes worse and few attempts have been made to extend the applicability of this approach to higher ionisation stages [6-9]. This extension was done by adjustments of the effective Gaunt factors and by taking into account also the complexities of particular atomic structures (deviations from LS coupling, configuration mixing and optically forbidden transitions. Some limitations of these attempts [6-9] have been discussed recently by Dimitrijević and Konjević [10].

In this paper a modification of the semiempirical formula is reported and numerous theoretical calculations of line widths of ionized atoms are presented. The results of comparisons with other theoretical approaches and experiments are also given.

2. Theory

Within the impact approximation, Baranger [2] derived a quantum-mechanical expression for the width of an isolated ion line:

$$W = N\{v\,[\Sigma\,\sigma_{i'i} + \Sigma_{f'}\,\sigma_{f'f}]\}_{av} + W_{e\ell}\,, \qquad (1)$$

where W is the full half-width (FWHM) in units of angular frequency and N is the electron concentration. The symbols $\sigma_{i'i}$ and $\sigma_{f'f}$ represent the inelastic cross sections for collisional transitions to i′, f′ from initial (i) and final (f) levels, respectively, of the optical transition. $W_{e\ell}$ is the line width induced by elastic collisions. The averaging in Eq. (1) has to be performed over the electron velocity (v) distribution.

Within the framework of the dipole approximation, one may use Bethe′s relation [11]

$$\sigma_{j'j} = \frac{8\pi}{3}\lambda^2\,\vec{R}^2_{j'j}\,\frac{\pi}{\sqrt{3}}\,g \qquad (2)$$

to evaluate inelastic cross sections. In this expression $\lambda = \hbar/mv$ is the reduced de Broglie wavelength of an electron and $\vec{R}^2_{j'j}$ (in units of the Bohr radius a_o) is the square of the coordinate operator matrix element summed over all components of the operator, the magnetic substates of total angular momentum J′, and averaged over the magnetic substates of J.

For higher electron temperatures, Griem [1] assumed that the contribution of elastic collisions to the line width [cf.Eq.(1)] can be neglected. The same author [1] made an attempt to take elastic collisions into account in the low temperature limit by using the threshold value of the inelastic cross section below the threshold. The Stark line width can then be calculated from the well known semiempirical formula [1]

$$W = N\,\frac{8\pi}{3}\,\frac{\hbar^2}{m^2}\,\left(\frac{2m}{\pi kT}\right)^{1/2}\frac{\pi}{\sqrt{3}}\,\left[\sum_{i'}\vec{R}^2_{i'i}\,g\left(\frac{E}{\Delta E_{i'i}}\right) + \sum_{f'}\vec{R}^2_{f'f}\,g\left(\frac{E}{\Delta E_{f'f}}\right)\right] \qquad (3)$$

Here, $E = 3kT/2$ is the energy of the perturbing electron and $\Delta E_{j'j} = [E_{j'} - E_j]$ is the energy difference between levels j and j'; g(x) = 0.20 for x≤2 and g(x) = 0.24, 0.33, 0.56, 0.98, and 1.33 for x = 3,5,10,30, and 100.

If the nearest perturbing level in Eq. (3) is so far from E_i or E_f that the condition $E/\Delta E_{j'j} \lesssim 2$ is satisfied, g becomes a costant [1]. Then, the summation in Eq. (3) can be performed straightforwardly leading to considerable simplification of the relation. The line width (FWHM) in Å units then becomes

$$W(\text{Å}) = 0.4430 \cdot 10^{-8} \frac{\lambda^2(\text{cm})\, N(\text{cm}^{-3})}{T^{1/2}} (\vec{R}^2_{ii} + \vec{R}^2_{ff}), \quad (4)$$

$$\vec{R}^2_{jj} = \sum_{j'} \vec{R}^2_{j'j} \simeq \frac{1}{2}\left(\frac{n_j}{Z}\right)^2 [5n_j^2 + 1 - 3\ell_j(\ell_j + 1)], \quad (5)$$

where n_j is the effective principal and ℓ_j the orbital angular momentum quantum number, while (Z-1) is the ionic charge.

As we have pointed out previously, the semiempirical relation agrees on the average within ±50% with experimenal data for singly-ionized atoms. However some authors (see e.g. Kobzev [6]) already pointed out that the constant threshold value of the Gaunt factor for all kinds of transitions was not always an adequate choice. On the other hand Griem [5] suggested that the unmodified semiempirical formula can be used for multiply--ionized atoms as well, but with an accuracy of ±100 %. However, the comparison with the experimental values of line widths of doubly- and triply-ionized atoms [6-9, 12-15] shows that the theoretical results are systematically lower. This observation is an indication that the threshold value of 0.2 for the Gaunt factor is rather small for higher ionization stages.

For the transitions with the principal quantum number n unchanged, Kobzev [16] suggested an empirical value of g = = 0.9-1/Z at threshold. We have adopted this suggestion. Therefore, in Eq. (3), the contribution of the collisional transitions with $\Delta n = 0$ is treated separately. For higher electronic energies, the Gaunt factor is calculated from the following equation:

$$\tilde{g}(x) = 0.7 - 1.1/Z + g(x). \tag{6}$$

If one uses Eq. (3) to calculate Stark line widths, a lack of atomic data causes difficulties in the evaluation of necessary matrix elements. These difficulties are especially serious for multiply-ionized atoms for which data on higher perturbing levels are sometimes completely missing in the literature. To overcome this problem, we have separated the transitions with $\Delta n = 0$. Also, the LS coupling approximation is assumed. In this case, only two matrix elements are calculated: one for the transition array $\ell \to \ell+1\,(R^2_{\ell,\ell+1})$ and the other for $\ell \to \ell-1\,(R^2_{\ell,\ell-1})$. The same technique has been used by Griem [5] for semiclassical calculations of multiply charged ion line widths.

Equation (3) becomes now

$$W = N\,\frac{8\pi}{3}\,\frac{\hbar^2}{m^2}\left(\frac{2m}{\pi kT}\right)^{1/2}\frac{\pi}{\sqrt{3}}\Bigg[\vec{R}^2_{\ell_i,\ell_i+1}\,\tilde{g}\left(\frac{E}{\Delta E_{\ell_i,\ell_i+1}}\right) + \vec{R}^2_{\ell_i,\ell_i-1}\,\tilde{g}\left(\frac{E}{\Delta E_{\ell_i,\ell_i-1}}\right) + \vec{R}^2_{\ell_f,\ell_f+1}\,\tilde{g}\left(\frac{E}{\Delta E_{\ell_f,\ell_f+1}}\right) + \vec{R}^2_{\ell_f,\ell_f-1}\,\tilde{g}\left(\frac{E}{\Delta E_{\ell_f,\ell_f-1}}\right) + \sum_{i'}(\vec{R}^2_{ii'})_{\Delta n\neq 0}\cdot g\left(\frac{3kTn_i^3}{4Z^2E_H}\right) + \sum_{f'}(\vec{R}^2_{ff'})_{\Delta n\neq 0}\,g\left(\frac{3kTn_f^3}{4Z^2E_H}\right)\Bigg], \tag{7}$$

$$\vec{R}^2_{\ell,\ell'} \simeq \left(\frac{3n}{2Z}\right)^2\frac{\max(\ell,\ell')}{2\ell+1}\left[n^2-\max^2(\ell,\ell')\right]\phi^2, \tag{8}$$

$$\sum_{j'} (\vec{R}^2_{jj'})_{\Delta n \neq 0} \simeq \left(\frac{3n_j}{2Z}\right)^2 \frac{1}{9} \left(n_j^2+3\ell_j^2+3\ell_j+11\right). \quad (9)$$

For the inelastic part in Eq. (7) the nearest perturbing level is estimated from

$$\Delta E_{n,n+1} \approx 2Z^2 E_H/n^3 \quad .$$

At high temperatures, say $3kT/2\Delta E > 50$, all Gaunt factors in Eq. (7) are calculated in accordance with the GBKO high temperature limit [17], viz.

$$\tilde{g}_{j'j} = g_{j'j} = \frac{\sqrt{3}}{\pi} \left[\frac{1}{2} + \ell n \left(\frac{2Z\ kT}{n_j^2\ \Delta E_{j'j}}\right)\right]. \quad (10)$$

3. Results and comparisons with experiments

In order to estimate the accuracy of the theoretical results a detailed comparison with available experimental data for doubly and triply ionized atoms [12-14, 33-37] has been performed in Ref. 18;a summary is given in Table 1. A comparison has also been made with experiments for singly ionized atom lines and three typical examples are given in Fig. 1.

Table 1. Average ratios of measured and calculated linewidths for various doubly and triply ionized atoms

Element	T_e [K]	W_m/W_{SEM}	W_m/W_{SE}
CIII	60000	1.29	1.21
NIII	24300	0.92	1.71
OIII	25400	1.05	1.90
SiIII	25600	0.67	1.08
SIII	28500	1.16	1.65
ClIII	24200	1.01	1.68
AIII	21100	0.99	1.57
average ratio:		1.06 ± 0.31	1.53 ± 0.46

Element	T_e [K]	W_m/W_{SEM}	W_m/W_{SE}
CIV	60000	1.50	2.57
SiIV	25600	0.66	1.15
SIV	28500	0.80	1.65
AIV	21500	0.76	1.24
average ratio:		0.91±0.42	1.56±0.85

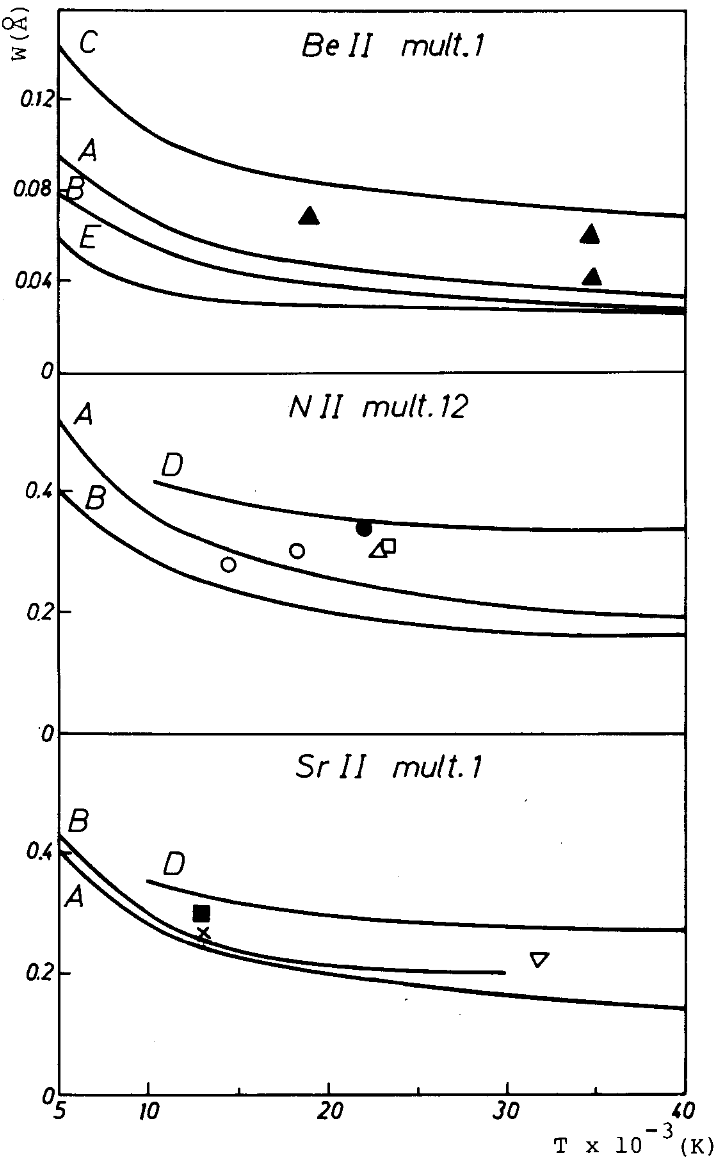

FIG.1. Measured and calculated full halfwidths for singly ionized atoms, normalized to an electron density of $1 \times 10^{17} cm^{-3}$, as a function of electron temperature. Curves: A: W_{SEM}; B: W_{SE}; C: W_{SC}-Jones et al [38]; D: W_{SC}-our calculations; E: quantum mechanical results with exchange by Sanchez et al [39]. Experimental points: ▲-Sanchez et al [39]; ●-Berg et al [40]; Δ-Jalufka and Craig [41]; o-Konjević et al [42]; □-Popović et al [43]; ■-Fleurier et al [44]; ∇-Hadžiomerspahić et al [45]; Theoretical points: x - Fleurier et al [44]

The results of numerous theoretical calculations of the electron impact line widths of prominent, isolated lines of BeIII through AIII and BIV through AIV are given in Table 2, where under W_{SEM} results are given obtained from eqs. (7) - (10), W_{SE}: eqs. (4) and (5). For the sake of comparison the same table contains the results W_G of a semiclassical formula (see Ref. 5, eq. 526 on p. 279, and the details of the calculations in Ref. 18) and its modified form [18], W_{GM}.

It is not necessary to discuss here uncertainties from the approximations involved in our calculations since the criteria for their application are given in detail elsewhere (see e.g. Ref. 5).

Additional errors which are not inherent to the theoretical approaches described above are related to the calculation of matrix elements and the lack of atomic data.

For evaluation of the radial integrals, the tables of Bates and Damgaard [14, 20] have been used. The cases when an atomic state with equivalent electrons is the principal one are avoided. If such a state is the perturbing one, corresponding coefficients of fractional parentage [21] are included whenever possible.

Data for atomic energy levels were taken from references 22 - 28. Some additional information is available for SIII [29], NaIII [30, 31] and PIII [32]. The results for multiplets 4UV, 5UV, 2 and 6 of AIV are probably less accurate since the data for the 4d level are missing.

TABLE 2. This table lists electron impact full half widths of isolated lines from doubly and triply ionized atoms from beryllium through argon at an electron density of $1x10^{17}$ cm^{-3} and electron temperatures T from 10.000 to 80.000K. Transition and averaged wavelength for the multiplet (in angström units) are also given. Under W_{SEM} and W_{SE} are given semiempirical results obtained from eqs. (7-10) and (4-5) respectively. W_{GM} are semiclassical results obtained from eqs.(11-15) in Ref. 18 (with 1.4 instead of 5-(4.5/Z) on the right-hand-side of eq.(12)in Ref. 18), and W_G are the results from eqs. (11-15) in Ref. 18. The value for $3kT/2\Delta E$ represents the ratio of the thermal electron energy at 10.000K to the energy difference to the nearest perturbing level.

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
BE III $2s^1S-2p^1P^o$	10000	0.227	0.128	0.197	0.282
	20000	0.160	0.904-1	0.155	0.210
λ= 6141.0	30000	0.131	0.738-1	0.139	0.181
$3kT/2\Delta E$=0.64	40000	0.117	0.711-1	0.131	0.165
	80000	0.947-1		0.117	0.136
BE III $2s^3S-2p^3P^o$	10000	0.701-1	0.402-1	0.617-1	0.874-1
	20000	0.496.1	0.284-1	0.471-1	0.644-1
λ= 3721.8	30000	0.405-1	0.232-1	0.414-1	0.548-1
$3kT/2\Delta E$=0.39	40000	0.351-1	0.201-1	0.383-1	0.493-1
	80000	0.263-1	0.175-1	0.333-1	0.399-1
B III $2s^2S-2p^2P^o$	10000	0.191-1	0.115-1	0.176-1	0.244-1
	20000	0.135-1	0.815-2	0.131-1	0.178-1
λ= 2066.3	30000	0.110-1	0.665-2	0.113-1	0.150-1
$3kT/2\Delta E$=0.22	40000	0.953-2	0.576-2	0.103-1	0.134-1
	80000	0.674-2	0.408-2	0.867-2	0.106-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
B III $4p\,^2P^o$-$5d\,^2D$	10000	9.88		6.72	7.74
	20000	8.29		6.08	6.62
λ = 4243.6	30000	7.44		5.68	6.04
3kT/2ΔE = 390.	40000	6.83		5.39	5.66
	80000	5.81		4.66	4.79
B III $4d\,^2D$-$5f\,^2F^o$	10000	12.2		7.62	8.15
	20000	9.85		6.76	7.00
λ = 4487.5	30000	8.66		6.24	6.38
3kT/2ΔE = 1000.	40000	7.90		5.86	5.96
	80000	6.39		4.96	5.01
B IV $2s\,^1S$-$2p\,^1P^o$	10000	0.396-1	0.200-1	0.367-1	0.481-1
	20000	0.280-1	0.141-1	0.277-1	0.353-1
λ = 4499.4	30000	0.228-1	0.115-1	0.240-1	0.299-1
3kT/2ΔE = 0.46	40000	0.198-1	0.999-2	0.220-1	0.268-1
	80000	0.152-1		0.187-1	0.214-1
B IV $2s\,^3S$-$2p\,^3P^o$	10000	0.269-1	0.136-1	0.201-1	0.316-1
	20000	0.190-1	0.958-2	0.150-1	0.228-1
λ = 2823.4	30000	0.155-1	0.782-2	0.129-1	0.191-1
3kT/2ΔE = 0.29	40000	0.134-1	0.678-2	0.117-1	0.169-1
	80000	0.966-2	0.513-2	0.986-2	0.131-1
C III $2p\,^3P^o$-$3s\,^3S$	10000	0.344-2	0.184-2	0.314-2	0.463-2
mult. 5UV	20000	0.243-2	0.130-2	0.244-2	0.344-2
λ = 538.2	30000	0.198-2	0.106-2	0.218-2	0.295-2
3kT/2ΔE = 0.48	40000	0.172-2	0.920-3	0.203-2	0.267-2
	80000	0.139-2		0.180-2	0.218-2
C III $3s\,^3S$-$3p\,^3P^o$	10000	0.523	0.263	0.410	0.642
mult. 1	20000	0.370	0.187	0.329	0.482
λ = 4648.8	30000	0.308	0.169	0.299	0.416
3kT/2ΔE = 1.0	40000	0.274		0.283	0.379
	80000	0.229		0.256	0.313

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
C III $3s\,^1P^o-3p\,^1D$	10000	0.486	0.230	0.377	0.589
mult. 7	20000	0.346	0.167	0.314	0.451
λ = 4326.0	30000	0.300		0.292	0.394
3kT/2ΔE = 1.1	40000	0.280		0.281	0.363
	80000	0.249		0.260	0.307
C III $3p\,^1P^o-3d\,^1D$	10000	0.736	0.410	0.716	0.991
mult. 2	20000	0.521	0.290	0.564	0.745
λ = 5696.0	30000	0.430	0.253	0.506	0.644
3kT/2ΔE = 0.89	40000	0.384		0.474	0.588
	80000	0.315		0.422	0.489
C III $3p\,^1P^o-4d\,^1D$	10000	0.172		0.180	0.233
	20000	0.139		0.158	0.189
λ = 1531.8	30000	0.124		0.148	0.170
3kT/2ΔE = 6.9	40000	0.115		0.142	0.159
	80000	0.103		0.128	0.137
C III $4p\,^3P^o-5d\,^3D$	10000	3.16		2.83	3.80
mult. 10	20000	2.77		2.54	3.10
λ = 3609.3	30000	2.62		2.40	2.80
3kT/2ΔE = 8.3	40000	2.49		2.31	2.62
	80000	2.16		2.08	2.24
C IV $2s\,^2S-2p\,^2P^o$	10000	0.728-2	0.383-2	0.570-2	0.873-2
mult.1UV	20000	0.515-2	0.271-2	0.417-2	0.627-2
λ = 1549.1	30000	0.421-2	0.221-2	0.353-2	0.522-2
3kT/2ΔE = 0.16	40000	0.364-2	0.192-2	0.318-2	0.460-2
	80000	0.258-2	0.135-2	0.257-2	0.350-2
C IV $2s\,^2S-4p\,^2P^o$	10000	0.295-2		0.232-2	0.354-2
mult. 3UV	20000	0.246-2		0.202-2	0.277-2
λ = 244.9	30000	0.220-2		0.190-2	0.245-2
3kT/2ΔE = 5.2	40000	0.207-2		0.183-2	0.227-2
	80000	0.169-2		0.169-2	0.193-2

Element/Transition		T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
C IV	$2p\,^2P^o-3s\,^2S$	10000	0.227-2	0.949-3	0.164-2	0.278-2
	mult. 6UV	20000	0.161.2	0.671-3	0.128-2	0.204-2
	λ = 419.6	30000	0.131-2	0.548-3	0.114-2	0.174-2
	$3kT/2\Delta E$ = 0.61	40000	0.116-2	0.509-3	0.107-2	0.156-2
		80000	0.936-3		0.954-3	0.125-2
C IV	$2p\,^2P^o-4d\,^2D$	10000	0.570-2		0.449-2	0.536-2
	mult. 9UV	20000	0.450-2		0.397-2	0.445-2
	λ = 289.2	30000	0.390-2		0.370-2	0.403-2
	$3kT/2\Delta E$ = 110.	40000	0.352-2		0.352-2	0.377-2
		80000	0.272-2		0.309-2	0.321-2
C IV	$3s\,^2S-3p\,^2P^o$	10000	0.776	0.320	0.495	0.880
	mult. 1	20000	0.571		0.402	0.656
	λ = 5804.9	30000	0.484		0.369	0.564
	$3kT/2\Delta E$ = 2.2	40000	0.440		0.352	0.511
		80000	0.368		0.325	0.419
C IV	$4d\,^2D-5f\,^2F^o$	10000	2.13		1.24	1.38
	mult. 14UV	20000	1.73		1.12	1.18
	λ = 2524.4	30000	1.52		1.04	1.08
	$3kT/2\Delta E$ = 1000.	40000	1.38		0.983	1.01
		80000	1.10		0.847	0.860
N III	$2p\,^2P^o-3s\,^2S$	10000	0.202-2	0.108-2	0.185-2	0.272-2
	mult. 4 UV	20000	0.143-2	0.801-3	0.143-2	0.201-2
	λ = 452.1	30000	0.116-2		0.127-2	0.172-2
	$3kT/2\Delta E$ = 1.1	40000	0.101-2		0.118-2	0.155-2
		80000	0.783-3		0.104-2	0.127-2
N III	$3s\,^2S-3p\,^2P^o$	10000	0.333	0.173	0.261	0.408
	mult. 1	20000	0.236	0.125	0.205	0.304
	λ = 4097.3	30000	0.192		0.183	0.260
	$3kT/2\Delta E$ = 1.1	40000	0.167		0.172	0.235
		80000	0.131		0.154	0.192

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
N III $3s^4P^o-3p^4P$	10000	0.236	0.121	0.188	0.292
mult. 5	20000	0.167	0.853-1	0.149	0.218
λ = 3367.3	30000	0.137	0.730-1	0.134	0.188
3kT/2ΔE = 0.81	40000	0.121		0.127	0.170
	80000	0.966-1		0.114	0.140
N III $3p^2P^o-3d^2D$	10000	0.415	0.236	0.413	0.565
mult. 2	20000	0.294	0.167	0.319	0.421
λ = 4640.6	30000	0.240	0.136	0.283	0.362
3kT/2ΔE = 0.48	40000	0.208	0.118	0.263	0.328
	80000	0.163		0.230	0.270
N IV $3s^3S-3p^3P^o$	10000	0.213	0.906-1	0.135	0.242
mult. 1	20000	0.151	0.641-1	0.105	0.177
λ = 3480.8	30000	0.124	0.535-1	0.929-1	0.150
3kT/2ΔE = 0.74	40000	0.108	0.499-1	0.869-1	0.134
	80000	0.837-1		0.776-1	0.107
N IV $3p^3P^o-3d^3D$	10000	0.735	0.353	0.588	0.904
mult. 4	20000	0.520	0.250	0.454	0.666
λ = 7117.0	30000	0.427	0.213	0.401	0.566
3kT/2ΔE = 0.74	40000	0.379	0.211	0.373	0.509
	80000	0.304		0.329	0.411
O III $3s^3P^o-3p^3D$	10000	0.230	0.122	0.183	0.283
mult. 2	20000	0.163	0.863-1	0.142	0.209
λ = 3762.3	30000	0.133	0.705-1	0.126	0.179
3kT/2ΔE = 0.63	40000	0.115	0.641-1	0.118	0.161
	80000	0.866-1		0.104	0.131
O III $3s^3P^o-3p^3S$	10000	0.185	0.981-1	0.148	0.229
mult. 3	20000	0.131	0.694-1	0.115	0.169
λ = 3326.6	30000	0.107	0.566-1	0.102	0.144
3kT/2ΔE = 0.63	40000	0.925-1	0.514-1	0.952-1	0.130
	80000	0.693-1		0.844-1	0.106

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
O III $3s^3P^o$-$3p^3P$	10000	0.158	0.839-1	0.127	0.197
mult. 4	20000	0.112	0.594-1	0.985-1	0.146
λ = 3041.5	30000	0.914-1	0.485-1	0.879-1	0.124
3kT/2ΔE = 0.63	40000	0.792-1	0.440-1	0.821-1	0.112
	80000	0.595-1		0.728-1	0.912-1
O III $3s^1P^o$-$3p^1D$	10000	0.171	0.877-1	0.137	0.213
mult. 6	20000	0.121	0.620-1	0.109	0.159
λ = 2983.8	30000	0.989-1	0.506-1	0.978-1	0.136
3kT/2ΔE = 0.58	40000	0.865-1	0.466-1	0.921-1	0.124
	80000	0.673-1		0.828-1	0.102
O III $3s^5P$-$3p^5D^o$	10000	0.223	0.118	0.177	0.275
mult. 21	20000	0.158	0.836-1	0.138	0.203
λ = 3706.1	30000	0.129	0.683-1	0.122	0.174
3kT/2ΔE = 0.39	40000	0.112	0.591-1	0.114	0.157
	80000	0.841-1	0.513-1	0.101	0.127
O III $3s^5P$-$3p^5S^o$	10000	0.126	0.673-1	0.103	0.158
mult. 22UV	20000	0.891-1	0.476-1	0.796-1	0.117
λ = 2678.2	30000	0.728-1	0.389-1	0.708-1	0.997-1
3kT/2ΔE = 0.46	40000	0.630-1	0.337-1	0.660-1	0.901-1
	80000	0.473-1		0.585-1	0.732-1
O III $3p^3P$-$3d^3D^o$	10000	0.245	0.144	0.252	0.339
mult. 14	20000	0.173	0.102	0.193	0.252
λ = 3712.5	30000	0.141	0.830-1	0.169	0.216
3kT/2ΔE = 0.39	40000	0.122	0.719-1	0.157	0.195
	80000	0.907-1	0.625-1	0.136	0.160
O III $3p^5D^o$-$3d^5F$	10000	0.196	0.113	0.204	0.273
mult. 25	20000	0.139	0.800-1	0.156	0.202
λ = 3453.0	30000	0.113	0.653-1	0.137	0.173
3kT/2ΔE = 0.39	40000	0.982-1	0.566-1	0.126	0.157
	80000	0.727-1	0.480-1	0.109	0.128

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
O III $3d^3P^o$-$4p^3S$	10000	0.321	0.171	0.300	0.437
mult. 20UV	20000	0.227	0.121	0.240	0.330
λ = 2601.6	30000	0.188	0.112	0.216	0.285
3kT/2ΔE = 0.95	40000	0.168		0.203	0.260
	80000	0.134		0.181	0.215
O III $3d^1F^o$-$4p^1D$	10000	0.356	0.179	0.333	0.483
mult. 21UV	20000	0.262	0.148	0.272	0.369
λ = 2558.1	30000	0.227		0.249	0.322
3kT/2ΔE = 1.5	40000	0.210		0.236	0.295
	80000	0.175		0.213	0.247
O IV $2p^2P^o$-$3s^2S$	10000	0.596-3	0.270-3	0.453-3	0.746-3
mult. 4UV	20000	0.421-3	0.191-3	0.342-3	0.543-3
λ = 279.8	30000	0.344-3	0.156-3	0.297-3	0.456-3
3kT/2ΔE = 0.32	40000	0.298-3	0.135-3	0.273-3	0.406-3
	80000	0.217-3	0.105-3	0.235-3	0.319-3
O IV $2p^2P^o$-$3d^2D$	10000	0.330-3	0.195-3	0.451-3	0.556-3
mult. 5UV	20000	0.233-3	0.138-3	0.336-3	0.408-3
λ = 238.5	30000	0.190.3	0.112-3	0.288-3	0.345-3
3kT/2ΔE = 0.36	40000	0.165-3	0.973-4	0.262-3	0.310-3
	80000	0.117-3	0.792-4	0.219-3	0.249-3
O IV $3s^4P^o$-$3p^4D$	10000	0.168	0.721-1	0.106	0.190
mult. 3	20000	0.119	0.510-1	0.812-1	0.139
λ = 3374.3	30000	0.968-1	0.416-1	0.714-1	0.117
3kT/2ΔE = 0.39	40000	0.838-1	0.360-1	0.663-1	0.104
	80000	0.622-1	0.294-1	0.583-1	0.820-1
O IV $3p^4P$-$3d^4D^o$	10000	0.310	0.152	0.252	0.385
mult. 9	20000	0.219	0.107	0.192	0.282
λ = 4792.5	30000	0.179	0.875-1	0.167	0.238
3kT/2ΔE = 0,50	40000	0.155	0.758-1	0.154	0.213
	80000	0.119		0.133	0.170

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
O IV $3p^2D-3d^2D^o$	10000	0.400	0.193	0.323	0.495
mult. 11	20000	0.283	0.137	0.246	0.363
λ = 5339.5	30000	0.231	0.112	0.216	0.307
3kT/2ΔE = 0.56	40000	0.202	0.101	0.200	0.276
	80000	0.156		0.174	0.221
F III $3s^4P_6-3p^4P^o_6$	10000	0.119	0.660-1	0.975-1	0.148
	20000	0.839-1	0.467-1	0.748-1	0.109
λ = 2916.3	30000	0.685-1	0.381-1	0.659-1	0.930-1
3kT/2ΔE = 0.33	40000	0.593-1	0.330-1	0.612-1	0.837-1
	80000	0.430-1	0.258-1	0.535-1	0.676-1
F III $3s^4P-3p^4D^o$	10000	0.134	0.743-1	0.110	0.167
mult. 1	20000	0.949-1	0.525-1	0.842-1	0.123
λ = 3124.4	30000	0.775-1	0.429-1	0.742-1	0.105
3kT/2ΔE = 0.33	40000	0.671-1	0.371-1	0.689-1	0.944-1
	80000	0.489-1	0.294-1	0.603-1	0.761-1
F III $3s^2P_4-3p^2P^o_4$	10000	0.130	0.684-1	0.105	0.162
	20000	0.918-1	0.483-1	0.822-1	0.120
λ = 2811.4	30000	0.750-1	0.395-1	0.733-1	0.103
3kT/2ΔE = 0.53	40000	0.651-1	0.346-1	0.686-1	0.929-1
	80000	0.488-1		0.611-1	0.759-1
F III $3s^2P-3p^2D^o$	10000	0.160	0.843-1	0.129	0.198
mult. 2	20000	0.113	0.596-1	0.101	0.147
λ = 3176.9	30000	0.924-1	0.487-1	0.897-1	0.126
3kT/2ΔE = 0.53	40000	0.801-1	0.426-1	0.840-1	0.114
	80000	0.603-1		0.748-1	0.929-1
NE III $3s^3S^o-3p^3P$	10000	0.965-1	0.540-1	0.800-1	0.121
mult. 12UV	20000	0.683-1	0.382-1	0.612-1	0.892-1
λ = 2678.2	30000	0.557-1	0.312-1	0.538-1	0.758-1
3kT/2ΔE = 0.32	40000	0.483-1	0.270-1	0.498-1	0.682-1
	80000	0.348-1	0.200-1	0.434-1	0.549-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
NE III $3s'^3D^o-3p'^3F$	10000	0.832-1	0.474-1	0.697-1	0.105
	20000	0.588-1	0.335-1	0.532-1	0.771-1
λ = 2612.4	30000	0.480-1	0.274-1	0.466-1	0.654-1
3kT/2ΔE = 0.29	40000	0.416-1	0.237-1	0.431-1	0.588-1
	80000	0.297-1	0.176-1	0.374-1	0.472-1
NE III $3p^5P_7-3d^5D^o_9$	10000	0.685-1	0.452-1	0.803-1	0.103
	20000	0.484-1	0.319-1	0.606-1	0.760-1
λ = 2163.8	30000	0.395-1	0.261-1	0.527-1	0.649-1
3kT/2ΔE = 0.27	40000	0.342-1	0.226-1	0.483-1	0.586-1
	80000	0.243-1	0.162-1	0.412-1	0.477-1
NE IV $3s^4P-3p^4D^o$	10000	0.608-1	0.281-1	0.404-1	0.703-1
	20000	0.430-1	0.199-1	0.303-1	0.509-1
λ = 2361.5	30000	0.351-1	0.162-1	0.262-1	0.426-1
3kT/2ΔE = 0.25	40000	0.304-1	0.141-1	0.240-1	0.378-1
	80000	0.215-1	0.994-2	0.204-1	0.293-1
NE IV $3s'^2D-3p'^2F^o$	10000	0.588-1	0.270-1	0.390-1	0.679-1
	20000	0.416-1	0.191-1	0.292-1	0.492-1
λ = 2289.1	30000	0.339-1	0.156-1	0.253-1	0.412-1
3kT/2ΔE = 0.39	40000	0.294-1	0.135-1	0.231-1	0.366-1
	80000	0.208-1	0.106-1	0.197-1	0.284-1
NA III $3s^4P-3p^4P^o$	10000	0.667-1	0.390-1	0.570-1	0.846-1
	20000	0.472-1	0.276-1	0.432-1	0.621-1
λ = 2515.6	30000	0.385-1	0.225-1	0.377-1	0.526-1
3kT/2ΔE = 0.26	40000	0.333-1	0.195-1	0.348-1	0.472-1
	80000	0.237-1	0.141-1	0.300-1	0.378-1
NA III $3s^4P-3p^4D^o$	10000	0.545-1	0.319-1	0.469-1	0.695-1
	20000	0.385-1	0.226-1	0.355-1	0.510-1
λ = 2232.5	30000	0.315-1	0.184-1	0.310-1	0.432-1
3kT/2ΔE = 0.26	40000	0.272-1	0.159-1	0.286-1	0.388-1
	80000	0.193-1	0.114-1	0.246-1	0.311-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
NA III $3s^4P-3p^4S^o$	10000	0.441-1	0.260-1	0.384-1	0.568-1
	20000	0.311-1	0.184-1	0.291-1	0.417-1
λ = 1971.5	30000	0.254-1	0.150-1	0.254-1	0.353-1
3kT/2ΔE = 0.26	40000	0.220-1	0.130-1	0.234-1	0.317-1
	80000	0.156-1	0.928-2	0.201-1	0.254-1
NA III $3s^2P-3p^2D^o$	10000	0.689-1	0.408-1	0.591-1	0.879-1
	20000	0.487-1	0.289-1	0.449-1	0.645-1
λ = 2458.9	30000	0.398-1	0.236-1	0.392-1	0.547-1
3kT/2ΔE = 0.26	40000	0.345-1	0.204-1	0.361-1	0.491-1
	80000	0.244-1	0.146-1	0.311-1	0.393-1
NA III $3s^2P-3p^2P^o$	10000	0.593-1	0.351-1	0.512-1	0.760-1
	20000	0.419-1	0.248-1	0.388-1	0.558-1
λ = 2247.4	30000	0.342-1	0.203-1	0.339-1	0.473-1
3kT/2ΔE = 0.26	40000	0.296-1	0.176-1	0.312-1	0.424-1
	80000	0.210-1	0.125-1	0.269-1	0.340-1
MG IV $3s^4P-3p^4S^o$	10000	0.199-1	0.969-2	0.140-1	0.236-1
	20000	0.140-1	0.685-2	0.104-1	0.170-1
λ = 1477.8	30000	0.115-1	0.559-2	0.892-2	0.142-1
3kT/2ΔE = 0.20	40000	0.993-2	0.484-2	0.810-2	0.126-1
	80000	0.702-2	0.342-2	0.678-2	0.972-2
MG IV $3p^4S^o_4-3d^4P_6$	10000	0.238-1	0.133-1	0.230-1	0.324-1
	20000	0.169-1	0.941-2	0.170-1	0.236-1
λ = 1548.1	30000	0.138-1	0.768-2	0.145-1	0.198-1
3kT/2ΔE = 0.16	40000	0.119-1	0.665-2	0.132-1	0.176-1
	80000	0.843-2	0.470-2	0.109-1	0.138-1
AL III $3s^2S-3p^2P^o$	10000	0.303-1	0.193.1	0.277-1	0.398-1
mult. 1UV	20000	0.214-1	0.136-1	0.208-1	0.291-1
λ = 1857.4	30000	0.175-1	0.111-1	0.180-1	0.246-1
3kT/2ΔE = 0.19	40000	0.151-1	0.963-2	0.165-1	0.220-1
	80000	0.107-1	0.681-2	0.140-1	0.175-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
AL III $3s^2S-4p^2P^o$	10000	0.136-1	0.837-2	0.138-1	0.199-1
mult. 2UV	20000	0.964-2	0.592-2	0.107-1	0.148-1
λ = 696.0	30000	0.787-2	0.483-2	0.953-2	0.127-1
$3kT/2\Delta E$ = 0.60	40000	0.684-2	0.446-2	0.886-2	0.115-1
	80000	0.525-2		0.777-2	0.940-2
AL III $3s^2S-5p^2P^o$	10000	0.238-1	0.145-1	0.254-1	0.361-1
mult. 3UV	20000	0.169-1	0.115-1	0.204-1	0.274-1
λ = 560.4	30000	0.144-1		0.184-1	0.238-1
$3kT/2\Delta E$ = 1.3	40000	0.131-1		0.173-1	0.217-1
	80000	0.111-1		0.154-1	0.180-1
AL III $4s^2S-4p^2P^o$	10000	1.48	0.859	1.20	1.87
mult. 2	20000	1.04	0.607	0.951	1.40
λ = 5705.9	30000	0.852	0.496	0.856	1.20
$3kT/2\Delta E$ = 0.60	40000	0.751	0.462	0.805	1.09
	80000	0.616		0.720	0.895
AL III $4p^2P^o-4d^2D$	10000	1.45		1.37	1.90
mult. 3	20000	1.14		1.14	1.47
λ = 4523.2	30000	0.996		1.04	1.30
$3kT/2\Delta E$ = 5.7	40000	0.909		0.983	1.19
	80000	0.764		0.876	1.00
AL III $4f^2F^o-5d^2D$	10000	4.42		4.14	5.25
mult. 6	20000	3.77		3.60	4.25
λ = 4701.6	30000	3.38		3.35	3.82
$3kT/2\Delta E$ = 10.	40000	3.16		3.18	3.56
	80000	2.65		2.83	3.03
AL III $4d^2D-6f^2F^o$	10000	5.92		4.82	5.40
	20000	5.01		4.27	4.58
λ = 2762.8	30000	4.50		3.95	4.15
$3kT/2\Delta E$ = 320.	40000	4.20		3.72	3.87
	80000	3.53		3.18	3.25

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
SI III $3p^3P^o$-$4s^3S$	10000	0.175-1	0.109-1	0.165-1	0.242-1
mult. 6UV	20000	0.124-1	0.772-2	0.129-1	0.180-1
λ = 996.1	30000	0.101-1	0.630-2	0.114-1	0.154-1
3kT/2ΔE = 0.48	40000	0.876-2	0.546-2	0.106-1	0.139-1
	80000	0.702-2		0.936-2	0.114-1
SI III $4s^3S$-$4p^3P^o$	10000	0.728	0.438	0.604	0.932
mult. 2	20000	0.514	0.310	0.473	0.693
λ = 4560.1	30000	0.420	0.253	0.422	0.594
3kT/2ΔE = 0.48	40000	0.364	0.219	0.395	0.538
	80000	0.289		0.350	0.438
SI III $4s^1S$-$4p^1P^o$	10000	1.25	0.736	1.02	1.59
mult. 4	20000	0.887	0.520	0.811	1.19
λ = 5739.7	30000	0.724	0.468	0.729	1.02
3kT/2ΔE = 0.97	40000	0.640		0.686	0.927
	80000	0.518		0.613	0.760
SI III $4p^3P^o$-$4d^3D$	10000	0.762	0.456	0.746	1.06
mult. 5	20000	0.546	0.347	0.590	0.800
λ = 3801.4	30000	0.463		0.529	0.691
3kT/2ΔE = 1.3	40000	0.411		0.496	0.630
	80000	0.342		0.438	0.520
SI III $4p^3P^o$-$5s^3S$	10000	0.793	0.438	0.680	1.04
mult. 6	20000	0.571	0.326	0.555	0.792
λ = 3237.8	30000	0.500		0.507	0.688
3kT/2ΔE = 1.2	40000	0.458		0.481	0.628
	80000	0.409		0.433	0.521
SI IV $3s^2S$-$3p^2P^o$	10000	0.141-1	0.733-2	0.104-1	0.170-1
mult. 1UV	20000	0.995-2	0.518-2	0.764-2	0.122-1
λ = 1396.7	30000	0.812-2	0.423-2	0.651-2	0.102-1
3kT/2ΔE = 0.15	40000	0.703-2	0.366-2	0.588-2	0.902-2
	80000	0.497-2	0.259-2	0.484-2	0.691-2

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
SI IV $3p\,^2P^o - 3d\,^2D$	10000	0,109-1	0.659-2	0.116-1	0.156-1
mult. 3UV	20000	0.768-2	0.466-2	0.856-2	0.114-1
λ = 1126.4	30000	0.627-2	0.380-2	0.730-2	0.955-2
3kT/2ΔE = 0.18	40000	0.543-2	0.329-2	0.659-2	0.851-2
	80000	0.384-2	0.233-2	0.541-2	0.670-2
SI IV $4s\,^2S - 4p\,^2P^o$	10000	0.605	0.281	0.388	0.700
mult. 1	20000	0.428	0.199	0.298	0.512
λ = 4097.9	30000	0.349	0.162	0.263	0.432
3kT/2ΔE = 0.43	40000	0.302	0.140	0.245	0.386
	80000	0.230		0.216	0.305
SI IV $4p\,^2P^o - 4d\,^2D$	10000	0.467	0.233	0.355	0.576
mult. 2	20000	0.346		0.281	0.429
λ = 3160.3	30000	0.297		0.253	0.367
3kT/2ΔE = 2.5	40000	0.267		0.237	0.332
	80000	0.213		0.211	0.270
SI IV $4d\,^2D - 5p\,^2P^o$	10000	1.20	0.576	0.866	1.46
mult. 3	20000	0.884		0.692	1.09
λ = 3766.0	30000	0.763		0.625	0.930
3kT/2ΔE = 2.5	40000	0.701		0.589	0.841
	80000	0.593		0.529	0.683
SI IV $5p\,^2P^o - 6s\,^2S$	10000	3.37	1.46	2.29	4.03
mult. 4	20000	2.55	1.27	1.89	3.03
λ = 4323.5	30000	2.24		1.74	2.61
3kT/2ΔE = 1.7	40000	2.12		1.66	2.37
	80000	1.84		1.51	1.93
SI IV $5d\,^2D - 6f\,^2F^o$	10000	8.34		6.03	7.67
mult. 5	20000	7.09		5.39	6.34
λ = 4212.4	30000	6.39		5.04	5.71
3kT/2ΔE = 140.	40000	5.97		4.80	5.32
	80000	4.91		4.22	4.49

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
P III $4s\,^2S-4p\,^2P^o$	10000	0.531	0.326	0.446	0.682
mult. 3	20000	0.375	0.230	0.347	0.507
λ = 4230.4	30000	0.306	0.188	0.309	0.434
$3kT/2\Delta E$ = 0.44	40000	0.265	0.163	0.289	0.392
	80000	0.206		0.255	0.319
P III $4s\,^4P^o-4p\,^4P$	10000	0.462		0.388	0.594
mult. 9	20000	0.327		0.301	0.441
λ = 3943.5	30000	0.267		0.268	0.377
$3kT/2\Delta E$ = 8.9	40000	0.231		0.250	0.341
	80000	0.176		0.220	0.277
P III $4p\,^2P^o-4d\,^2D$	10000	0.477	0.297	0.491	0.683
mult. 4	20000	0.349		0.390	0.516
λ = 3228.8	30000	0.296		0.350	0.447
$3kT/2\Delta E$ = 1.7	40000	0.269		0.328	0.408
	80000	0.219		0.290	0.339
P IV $4s\,^3S-4p\,^3P^o$	10000	0.330	0.158	0.216	0.385
mult. 1	20000	0.233	0.112	0.165	0.281
λ = 3355.9	30000	0.191	0.912-1	0.144	0.237
$3kT/2\Delta E$ = 0.35	40000	0.165	0.790-1	0.134	0.211
	80000	0.121	0.648-1	0.117	0.166
P IV $4s\,^1S-4p\,^1P^o$	10000	0.565	0.264	0.363	0.653
mult. 2	20000	0.399	0.186	0.279	0.477
λ = 4249.6	30000	0.326	0.152	0.246	0.403
$3kT/2\Delta E$ = 0.44	40000	0.282	0.132	0.229	0.360
	80000	0.215		0.202	0.285
S III $3d\,^3P_o-4p\,^3P$	10000	0.216	0.135	0.221	0.301
mult. 2	20000	0.153	0.954-1	0.168	0.223
λ = 3346.2	30000	0.125	0.779-1	0.147	0.190
$3kT/2\Delta E$ = 0.41	40000	0.108	0.675-1	0.135	0.171
	80000	0.773-1		0.116	0.139

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
S III $3d\,^3P^o-4p\,^3S$	10000	0.205	0.128	0.209	0.286
mult. 3	20000	0.145	0.904-1	0.159	0.212
λ = 3233.4	30000	0.119	0.738-1	0.139	0.181
$3kT/2\Delta E$ = 0.40	40000	0.103	0.640-1	0.128	0.163
	80000	0.736-1		0.110	0.132
S III $3d\,^3D^o-4p\,^3P$	10000	0.302	0.193	0.309	0.421
mult. 8	20000	0.214	0.137	0.235	0.312
λ = 3950.5	30000	0.175	0.112	0.206	0.266
$3kT/2\Delta E$ = 0.46	40000	0.151	0.966-1	0.189	0.240
	80000	0.108		0.162	0.195
S III $3s\,^3P^o-4p\,^3D$	10000	0.472	0.277	0.388	0.598
mult. 4	20000	0.334	0.196	0.303	0.444
λ = 4287.1	30000	0.273	0.160	0.270	0.380
$3kT/2\Delta E$ = 0.46	40000	0.236	0.139	0.252	0.343
	80000	0.183		0.223	0.280
S III $4s\,^3P^o-4p\,^3P$	10000	0.389	0.229	0.322	0.495
mult. 5	20000	0.275	0.162	0.251	0.368
λ = 3840.0	30000	0.225	0.132	0.223	0.314
$3kT/2\Delta E$ = 0.45	40000	0.194	0.115	0.208	0.284
	80000	0.148		0.184	0.231
S III $3s\,^3P^o-4p\,^3S$	10000	0.364	0.214	0.302	0.465
mult. 6	20000	0.258	0.152	0.235	0.345
λ = 3692.3	30000	0.210	0.124	0.209	0.295
$3kT/2\Delta E$ = 0.45	40000	0.182	0.107	0.195	0.266
	80000	0.138		0.173	0.217
S IV $3p\,^2P^o-4s\,^2S$	10000	0.396-2	0.202-2	0.306-2	0.503-2
	20000	0.280-2	0.143-2	0.231-2	0.366-2
λ = 553.1	30000	0.229-2	0.117-2	0.201-2	0.308-2
$3kT/2\Delta E$ = 0.32	40000	0.198-2	0.101-2	0.185-2	0.275-2
	80000	0.144-2	0.784-3	0.159-2	0.217-2

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
S IV $4s^2S-4p^2P^o$	10000	0.245	0.118	0.162	0.287
mult. 1	20000	0.173	0.838-1	0.123	0.209
λ = 3104.1	30000	0.141	0.684-1	0.107	0.176
3kT/2ΔE = 0.35	40000	0.122	0.592-1	0.991-1	0.156
	80000	0.886-1	0.476-1	0.861-1	0.123
CL III $3d^4P-4p^4P^o$	10000	0.286	0.175	0.288	0.392
mult. 7	20000	0.202	0.123	0.218	0.290
λ= 4045.8	30000	0.165	0.101	0.190	0.246
3kT/2ΔE = 0.47	40000	0.143	0.873-1	0.174	0.222
	80000	0.102		0.149	0.179
CL III $4s^4P-4p^4D^o$	10000	0.284	0.171	0.238	0.363
mult. 1	20000	0.201	0.121	0.184	0.268
λ= 3629.0	30000	0.164	0.987-1	0.163	0.229
3kT/2ΔE = 0.47	40000	0.142	0.855-1	0.151	0.206
	80000	0.106		0.133	0.167
CL III $4s^4P-4p^4P^o$	10000	0.246	0.148	0.207	0.315
mult. 2	20000	0.174	0.104	0.160	0.233
λ = 3330.9	30000	0.142	0.853-1	0.141	0.199
3kT/2ΔE = 0.42	40000	0.123	0.739-1	0.132	0.179
	80000	0.908-1		0.116	0.145
CL III $4s^4P-4p^4S^o$	10000	0.226	0.135	0.190	0.290
mult. 3	20000	0.160	0.956-1	0.147	0.214
λ = 3160.1	30000	0.130	0.781-1	0.130	0.183
3kT/2ΔE = 0.40	40000	0.113	0.676-1	0.121	0.165
	80000	0.831-1		0.106	0.134
CL III $4s^2P-4p^2D^o$	10000	0.314	0.194	0.266	0.404
mult. 5	20000	0.222	0.137	0.206	0.299
λ = 3739.4	30000	0.181	0.112	0.182	0.255
3kT/2ΔE = 0.53	40000	0.157	0.982-1	0.170	0.231
	80000	0.118		0.149	0.187

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
CL III $4s^2P-4p^2P^o$	10000	0.243	0.157	0.212	0.318
mult. 6	20000	0.172	0.111	0.164	0.236
λ = 3300.9	30000	0.140	0.905-1	0.145	0.201
3kT/2ΔE = 0.45	40000	0.121	0.784-1	0.135	0.182
	80000	0.897-1		0.118	0.147
CL III $4s'^2D-4p'^2F^o$	10000	0.271	0.165	0.229	0.348
mult. 10	20000	0.192	0.117	0.177	0.257
λ = 3543.8	30000	0.157	0.953-1	0.156	0.219
3kT/2ΔE = 0.59	40000	0.136	0.859-1	0.145	0.198
	80000	0.100		0.128	0.160
CL III $4s'^2D-4p'^2D^o$	10000	0.252	0.153	0.213	0.324
mult. 11	20000	0.178	0.108	0.165	0.240
λ = 3394.2	30000	0.146	0.885-1	0.146	0.204
3kT/2ΔE = 0.55	40000	0.126	0.785-1	0.135	0.184
	80000	0.932-1		0.119	0.149
CL III $4s'^2D-4p'^2P^o$	10000	0.204	0.123	0.173	0.263
mult. 11UV	20000	0.144	0.871-1	0.134	0.195
λ = 2975.4	30000	0.118	0.711-1	0.118	0.166
3kT/2ΔE = 0.45	40000	0.102	0.616-1	0.110	0.150
	80000	0.748-1		0.963-1	0.121
CL IV $4s^3P^o-4p^3D$	10000	0.162	0.991-1	0.122	0.200
	20000	0.114	0.701-1	0.924-1	0.146
λ = 3082.2	30000	0.933-1	0.572-1	0.806-1	0.123
3kT/2ΔE = 0.32	40000	0.808-1	0.496-1	0.743-1	0.110
	80000	0.589-1	0.391-1	0.643-1	0.870-1
CL IV $4s^3P^o-4p^3P$	10000	0.131	0.819-1	0.100	0.164
	20000	0.924-1	0.579-1	0.760-1	0.119
λ = 2767.6	30000	0.755-1	0.473-1	0.662-1	0.101
3kT/2ΔE = 0.32	40000	0.653-1	0.409-1	0.609-1	0.899-1
	80000	0.472-1	0.314-1	0.526-1	0.710-1

Element/Transition	T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
A III 3d"$^3P^o$-4p"^3P	10000	0.164	0.114	0.183	0.238
mult. 6	20000	0.116	0.806-1	0.139	0.176
λ = 3432.6	30000	0.949-1	0.658-1	0.120	0.150
3kT/2ΔE = 0.42	40000	0.822-1	0.570-1	0.110	0.135
	80000	0.583-1		0.938-1	0.110
A III 4s$^5S^o$-4p^5P	10000	0.208	0.128	0.178	0.268
mult. 1	20000	0.147	0.906-1	0.137	0.198
λ = 3296.6	30000	0.120	0.740-1	0.120	0.169
3kT/2ΔE = 0.35	40000	0.104	0.641-1	0.112	0.152
	80000	0.763-1	0.522-1	0.978-1	0.123
A III 4s'$^3D^o$-4p'^3D	10000	0.238	0.144	0.200	0.304
mult. 2	20000	0.168	0.102	0.155	0.225
λ = 3492.1	30000	0.137	0.832-1	0.137	0.192
3kT/2ΔE = 0.37	40000	0.119	0.720-1	0.127	0.173
	80000	0.877-1	0.603-1	0.111	0.140
A III 4s'$^3D^o$-4p'^3F	10000	0.221	0.134	0.187	0.283
mult. 3	20000	0.156	0.946-1	0.144	0.209
λ = 3344.8	30000	0.128	0.772-1	0.127	0.178
3kT/2ΔE = 0.37	40000	0.110	0.669-1	0.118	0.161
	80000	0.813-1	0.553-1	0.104	0.130
A III 4s"$^3P^o$-4p"^3D	10000	0.141	0.807-1	0.117	0.178
mult. 4	20000	0.100	0.571-1	0.898-1	0.131
λ = 3041.4	30000	0.816-1	0.466-1	0.791-1	0.112
3kT/2ΔE = 0.40	40000	0.707-1	0.404-1	0.733-1	0.100
	80000	0.513-1		0.641-1	0.810-1
A IV 4s^4P-4p$^4D^o$	10000	0.117	0.716-1	0.888-1	0.145
mult. 4UV	20000	0.829-1	0.506-1	0.670-1	0.106
λ = 2810.9	30000	0.677-1	0.413-1	0.583-1	0.891-1
3kT/2ΔE = 0.29	40000	0.586-1	0.358-1	0.536-1	0.795-1
	80000	0.422-1	0.271-1	0.461-1	0.626-1

Element/Transition		T(K)	W_{SEM}(Å)	W_{SE}(Å)	W_{GM}(Å)	W_G(Å)
A IV	$4s\,^4P-4p\,^4P^o$	10000	0.102	0.631-1	0.781-1	0.127
	mult. 5UV	20000	0.721-1	0.446-1	0.589-1	0.926-1
	λ = 2617.5	30000	0.588-1	0.364-1	0.512-1	0.780-1
	$3kT/2\Delta E$ = 0.29	40000	0.510-1	0.315-1	0.470-1	0.696-1
		80000	0.365-1	0.234-1	0.404-1	0.548-1
A IV	$4s\,^2P-4p\,^2D^o$	10000	0.133	0.813-1	0.101	0.165
	mult. 2	20000	0.943-1	0.575-1	0.761-1	0.120
	λ = 2925.4	30000	0.770-1	0.469-1	0.663-1	0.101
	$3kT/2\Delta E$ = 0.31	40000	0.667-1	0.407-1	0.610-1	0.905-1
		80000	0.482-1	0.313-1	0.526-1	0.714-1
A IV	$4s'\,^2D-4p'\,^2F^o$	10000	0.114	0.701-1	0.868-1	0.142
	mult. 6UV	20000	0.806-1	0.496-1	0.654-1	0.103
	λ = 2769.2	30000	0.658-1	0.405-1	0.569-1	0.868-1
	$3kT/2\Delta E$ = 0.29	40000	0.570-1	0.350-1	0.523-1	0.775-1
		80000	0.410-1	0.263-1	0.449-1	0.610-1

4. Discussion and conclusions

From the results shown in Table 2, it appears that, for the specified temperature and electron density regions, agreement of modified semiempirical and semiclassical results with experiments is quite good. The errors seem to be random and are caused by uncertainties in both, calculations and experiments. The average values of the ratios of measured to calculated widths of ionized atoms are as follows: for doubly-ionized atoms, $R_{SEM} = 1.06 \pm 0.32$, $R_{SE} = 1.53 \pm 0.46$, $R_{GM} = 0.96 \pm 0.24$, $R_G = 0.72 \pm 0.19$; for triply-ionized atoms, $R_{SEM} = 0.91 \pm 0.42$, $R_{SE} = 1.56 \pm 0.85$, $R_{GM} = 1.08 \pm 0.41$, $R_G = 0.72 \pm 0.32$. The indicated error represents an average quadratic error calculated from $\sigma = \sqrt{\sum_{i=1}^{m} \Delta_i^2 / m(m-1)}$ where Δ_i is the difference between the i-th average ratio for the multiplet and the average ratio for all multiplets.

The principal deficiency in the comparisons of theoretical results for doubly and triply ionized atoms with experiments comes from the lack of experimental line widths at higher electron temperatures.

At the present time there are not enough experimental data to show which modified approach is the better one, especially at high temperatures. If one draws a conclusion based on a single experiment for CIII and CIV lines [12], the modified semiclassical approach seems to describe the experiment better. However, it should be emphasized here that there is little difference between the results derived from the modified and unmodified semiclassical expressions at high electron temperatures.

From the examples in Fig. 1 it seems that the modified semiempirical formula agrees better with the experiments for singly ionized atom lines, than its unmodified version. This one may expect, since in most investigated examples the semiempirical formula can be used in "lumped together" form [1]. In these cases one can always count on higher accuracy of our modified version. However, for intermediate electron energies it is always better to take into account all perturbing levels separately.

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ON THE SYSTEMATIC TRENDS OF STARK BROADENING PARAMETERS OF ISOLATED LINES IN PLASMAS

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1. Introduction

A number of recently published papers have been devoted to the investigation of the regularities and systematic trends of the Stark broadening parameters of isolated, non-hydrogenic spectral lines in plasmas [1-15]. According to the approach to this problem one can divide all published papers in three groups. In one group [3, 10] regularities were searched among the experimental results and the conclusions were drawn on the basis of the analysis of the configuration of atomic energy levels and transition probabilities. The investigations of regularities and systematic trends of another group of authors strongly rely on the existing semiclassical and semiempirical theories although comparisons with the experimental results are made as well [1, 2, 5, 8, 9, 12, 13, 15]. A third group of papers [4, 6, 7, 14] reports experimental results related to the study of systematic trends, e. g. line widths and shifts of the same transition of homologous atoms, line widths and shifts within multiplet etc.

Here, one should point out that on the basis of the comparison of experiment and theory for neutral and singly ionized atom lines, good average agreement is found: semiclassical results agree within ±20 % [16] with experiment while semiempirical results for singly ionized atoms are in agreement within 50 % with experimental data [16]. Therefore, to discuss further systematic trends for neutral and singly ionized atoms, in the first approximation one can use existing theories only and avoid numerous comparisons with the experiments.

In this paper we investigate regularities and systematic trends which can be derived from the existing theories of the Stark broadening of isolated non-hydrogenic lines in plasmas.

At the beginning we shall confine our discussion to the semiclassical theory [16] of the Stark broadening. The analysis will be later extended to the other theoretical approaches.

To facilitate further discussion we shall start with a general expression for the Stark line width w and shift d in the frame of the dipole approximation:

$$w + id \propto N_e < v^{-1} \sum_{jj'} \vec{R}^2_{jj'} \left[A\left(\frac{\rho\omega_{jj'}}{v}\right) + iB\left(\frac{\rho\omega_{jj'}}{v}\right) \right]_{\rho v} > ; \quad jj' = ii; \ ff' \qquad (1)$$

where N_e is the electron concentration, v electron velocity, $\vec{R}_{jj'}$ matrix element of optical electron coordinate operator, A and B are Stark broadening functions [16] , ρ impact parameter and $\omega_{jj'}$ energy difference between levels j,j'. From the analysis of relation (1) one may conclude that certain regularities and systematic trends on the basis of plasma as well as atomic physics are to be expected. The dependence of Stark widths and shifts on plasma parameters (electron density and to a minor extent electron temperature) is very explicit and proven in a number of experiments. However, in expression (1) the atomic physics factors are involved in a rather complicated way so it is not clear explicitely what type of regularities should be expected. Here we shall further discuss only systematic trends and regularities which are induced by atomic physics constants used for evaluation of Stark broadening parameters.

2. Similarities within a given spectrum

From the analysis of relation (1) one may conclude that similar Stark broadening parameters within a given spectrum and under the same experimental conditions are to be expected for all lines for which energy differences between atomic states and corresponding matrix elements are approximately the same. Therefore similarities and systematic trends can be expected between Stark broadening parameters of the lines within a multiplet, supermultiplet and transition array.

Multiplet: For all lines within a multiplet, functions A and B in expression (1) are practically the same. The difference may come only through the values of matrix elements R^2_{ii} and R^2_{ff}. However, within the dipole and LS coupling approximation, the sum of all matrix elements for transitions which begin or end on the level LJ does not depend on characteristics of a particular line within the multiplet. If all other quantities in relation (1) are nearly equal this summation can be performed straightforwardly. In such a case relation (1) is the same for each particular line within the multiplet.

Differences between Stark broadening parameters of the lines within a multiplet may be appreciable in cases where: a) energy separation of the levels within the multiplet can not be disregarded in comparison with energy separation to the nearest perturbing level, and b) if higher order interactions (quadrupole and higher) and interference terms are important.

Differences within a multiplet induced by the effects designated by b) should not exceed $\pm$ 10 %. However, separation of energy levels may induce large differences within a multiplet. A good example are the AII UV lines 289.2 nm and 294.3 nm which belong to the same multiplet. For these, the measured line widths differ by more than 50 %: $W_{289.2}$ = 0.0163 nm, $W_{294.3}$ = 0.0101 nm [17]. These differences can be easily explained qualitatively on the basis of the analysis of the energy levels and the energy separation to the nearest perturbing level, Fig. 1. In the case of the λ = 289.2 nm line the nearest perturbing level $3d'\,^2D_{3/2}$ to the upper level $4p'\,^2P^o_{3/2}$ is so close in comparison with the energy separation from $3d'\,^2D_{5/2}$ to $4p'\,^2P^o_{3/2}$ for the λ = 294.3 nm line that one expects a larger line width. Theoretical calculations by Hey [17] have proven quantitatively this expectation.

Here, one should emphasize that exceptions like the previous one are very rare and the Stark broadening parameters should be practically the same within a multiplet. This was also proven experimentally in a number of high precision experiments (see e.g. Refs. 4, 6, 18). In cases when differences within a multiplet exceed the experimental error of the measurements a care-

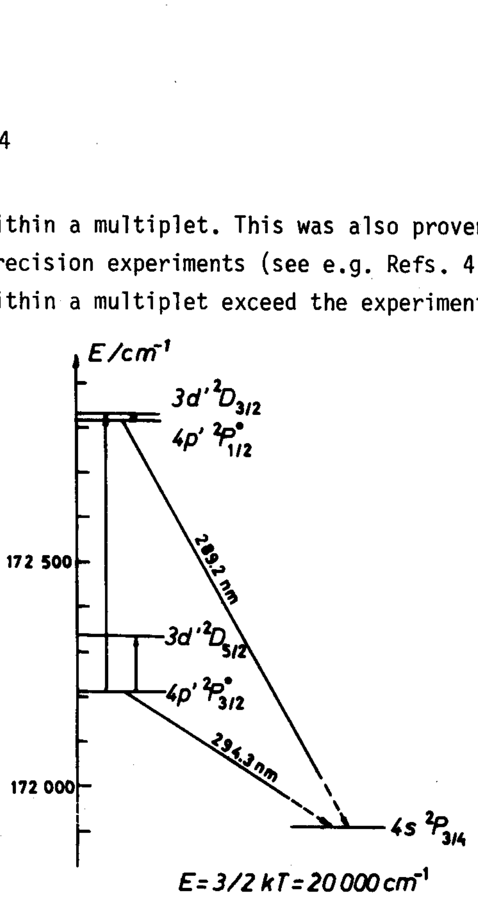

FIG. 1. Part of Ar II - level diagram taken from Behringer and Thoma [17].

Table 1. Experimentally determined full halfwidths W_m, the ratios of measured [20] and calculated [16,19] halfwidths W_m/W_{th} and oscillator strengths f_{ik} for the main transition [21].

Transition array	Designation (mult. no.)	λ(Å)	W_m(Å)	W_m/W_{th}	f_{ik}
OII $2p^23s-2p^2(^3P)3p$	$^4P-^4D^o$ (1)	4649.14	0.11_9	0.69	0.5
		4650.84	0.12_3	0.72	
	$^4P-^4P^o$ (2)	4366.90	0.11_5	0.93	0.297
		4317.14	0.11_4	0.92	
	$^4P-^4S^o$ (3)	3712.75	0.10_6	1.09	0.123
		3727.33	0.10_0	1.03	
	$^2P-^2D^o$ (5)	4414.91	0.13_9	0.93	
	$^2P-^2P^o$ (6)	3973.26	0.11_8	0.803	

ful analysis of the causes of these differences should be performed.

Supermultiplet: On the basis of the similar considerations we have used for multiplets Stark broadening parameters of all lines in a supermultiplet should be approximately equal. This regular behaviour, however, is not expected to be as close as for the multiplet case.

Here, one should notify that on the basis of the analysis of the computed line widths for neutral and singly ionized atom lines [16, 19] one may argue with this conclusion since in some cases differences within supermultiplet go up to factor of two. Our analysis showed that this was induced by large differences of the oscillator strength (f values) for the main transition which enter directly into the above mentioned calculations by Jones et al. [16, 19]. For all other perturbing levels these authors use only one matrix element for every nl-$n'l'$ transition. An example is given in Table 1. Here, the discrepancy between theoretical results [16, 19] and experiment [20] increases with the growth of f value for the main transition.

It should be underlined that one can not always perform so simple an analysis on the basis of f values since this quantity enters not only in the sum of matrix elements but also, after averaging over ρ in the strong collision term and the Stark broadening functions.

Transition array. Stark parameters of all lines within a transition array should be roughly the same (see e.g. example in Table 1). However, all remarks given for a supermultiplet are even more pronounced here.

3. Regularities within homologous atoms and ions

Since atoms with the same number of electrons in outer shells possess similar and regularly varying atomic structures they should suffer approximately the same broadening effects, or exhibit systematic trends if respective transitions are compared under the same experimental conditions. An example for earth-alkaline atoms is given in Table 2 which may be used to illustrate the importance of experimental conditions (electron temperature) for the derivation of systematic trends.

Table 2. Theoretical full-halfwidths [16] and their ratios at different electron temperatures

Element	Transition	W[Å] at $1x10^{16}cm^{-3}$	
		5000 K	40000 K
Be II	$2s\,^1S - 2p\,^1P^o$	$1.424x10^{-3}$	$0.300x10^{-2}$
Mg II	$3s\,^1S - 3p\,^1P^o$	$7.96x10^{-3}$	$1.192x10^{-2}$
W_{Mg}/W_{Be}		4.89	3.97

4. Regularities within isoelectronic sequence

All atomic parameters (ionization potential, oscillator strengths, energy level structure) which enter Stark broadening formulae change regularly along the isoelectronic sequence and therefore it seems that Stark broadening parameters should change regularly as well. It should be notified however, that various effects which influence line broadening (spin-orbit interaction, the contribution of quadrupole and higher order interactions, change in energy levels distribution due to relativistic effects, importance of ion broadening etc.) depend, for higher ionization stages, in a different way upon Z. Thus, extrapolations from determined systematic trends should be done with precautions.

5. Usefulness of various theoretical approaches for investigation of systematic trends

Semiclassical approach [16]. Very useful for all types of investigations of systematic trends and regularities. However, due to various approximations the comprehensive numerical results of Jones et al. [16, 19] are useful only for investigations of homologous atoms.

Semiempirical formula [22]. There is no sense to use this very crude approach, in all cases wheresemiclassical results [16,19] exist. It can -

not be used for a study of isoelectronic sequences since the Gaunt factor dependence upon the ionization stage is not well known.

Adiabatic approach [16]. Good for lower temperatures (in scale of $kT/\Delta E$ where k is Boltzmann constant, T is the electron temperature and ΔE is the energy separation to the nearest perturbing level). It is very convenient that all atomic parameters are included via atomic polarisability α:

$$W_{neutrals} \propto (\alpha_i - \alpha_f)^{2/3}$$
$$W_{ions} \propto (\alpha_i - \alpha_f)^{2/5}$$

where α_i and α_f are polarisabilities of the initial and final state of the electron transition.

Here one should stress once more that Stark broadening parameters are not atomic constants. Therefore, the validity of systematic trends and regularities is limited to the experimental conditions for which they are derived.

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STARK BROADENING OF He I LINES OF ASTROPHYSICAL INTEREST : REGULARITIES WITHIN SPECTRAL SERIES AND INFLUENCE OF DEBYE SHIELDING

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By using a semiclassical-perturbation formalism for the Stark broadening of atomic lines, we have calculated electron and proton impact linewidths and shifts of 36 neutral He I lines as the continuation of our previous work (1). These Stark broadening parameters have been calculated for lines originating from upper energy levels with $4 < n < 10$, and for an electron density of 10^{13} cm^{-3}, typical of stellar atmospheres.

The obtained results have then been used for an investigation of the Stark broadening parameters behaviour within spectral series. The results confirm previous conclusions (1, 2) : for lines belonging to a given spectral series, the electron impact width increases gradually with the increasing principal quantum number of the upper state. We obtain the same conclusion for proton-impact widths. For the shifts we find that the upper level contribution increases gradually within a spectral series if $R_D > R_3$ (the strong collision cutoffs R_1, R_2, R_3 and the Debye cutoff R_D are described in ref. 3). In the case $R_D < R_3$ the shift is zero. The shift can be negative (blue) for the lower members of a series, owing to the larger polarization of the lower level of the transition; on the other hand, for the higher members of the series it becomes positive (red), owing to the gradual increase of the upper level contribution.

In order to investigate the influence of Debye shielding on the electron impact width and shift, we have calculated line widths and shifts for several lines as a function of the electron density. The quantities of inte-

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rest for the physical discussion are the ratios $\frac{R_D}{R_1}$, $\frac{R_D}{R_2}$, $\frac{R_D}{R_3}$ or the differences between R_D and R_1, R_2 or R_3. The influence of Debye shielding becomes large when R_D approaches R_1, R_2 or R_3. In that case the derived widths and shifts are very sensitive to the cutoffs. This implies that all the Stark broadening calculations based on semiclassical perturbation theories become doubtful when Debye shielding effects become important. Refinement of the calculations, by introducing for instance a Debye-Hückel potential should be vain, owing to the failure of the semiclassical perturbation treatment. In fact, a statistical quantum theory, which should take into account in a coherent way both close-coupling collisional and collective effects becomes necessary.

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STARK BROADENING OF K I: REGULARITIES WITHIN SPECTRAL . .ES

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Stark broadening parameters for potassium lines are useful for a number of problems in plasma diagnostics, astrophysics, technology of high-pressure discharge lamps etc. Using the semiclassical-perturbation formalism [1,2], we have calculated Stark broadening parameters for 50 neutral K lines. Besides electron-impact widths and shifts, Stark broadening due to proton-impacts (for astrophysical purposes) and Ar II-impacts (for laboratory plasma diagnostics) have been calculated. The results obtained have also been used to continue our investigation of systematic trends among Stark broadening parameters within spectral series[3-5].

As an example of results obtained, in Figs 1a,b the behaviour of electron-impact full halfwidths and shifts within $4s\,^2S-np\,^2P^o$ series is illustrated for different plasma temperatures (2000 and 30,000 K). By inspecting energy separations between the upper level and the principal perturbing levels (see Grotrian diagrams in Ref. 6) we find that this value decrease gradually within a spectral series. Moreover in Figs. 1c and 1d the contributions of elastic, inelastic (for upper level only) and strong collisions to the line widths within the spectral series considered are presented for T=2000 and 30,000 K and we can see that they also change gradually. Thus we obtain a gradual change of Stark broadening parameters as expected.

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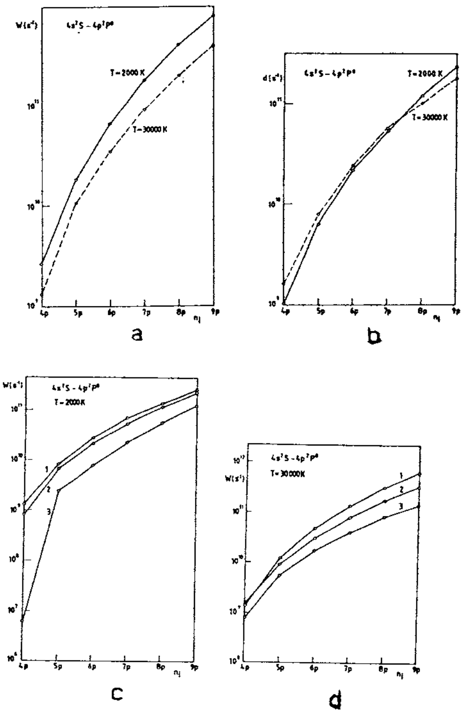

Fig. 1. Electron-impact broadening parameters for K I $4s\,^2S-np\,^2P^o$ lines as a function of n_l for T=2000 and 30,000 K at $N_e=10^{15}$ cm^{-3}. a) full halfwidth b) shift c) full halfwidth due to elastic-1, strong-2, and inelastic (only for upper level) collisions-3, at T=2000 K d) as in 1c but at 30,000 K.

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MODIFIED SEMIEMPIRICAL ESTIMATES OF ION LINES STARK BROADENING I.THEORY

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In 1968 Griem suggested a simple semiempirical formula [1] useful for singly charged ion lines. This method has been modified recently in order to avoid extensive set of input atomic data and to appropriate for multiply charged ion line widths [2,3] and shifts [4]. Tables of calculated Stark widths of prominent lines of some doubly and triply charged ions are given in [3]. At the low temperature limit simple analytical expressions have been derived [5] too. Here the complete modified semiempirical method is presented. In order to reduce the input set of atomic data and to extend the applicability of semiempirical method [1] to higher stages of ionization, Dimitrijević and Konjević [2] separated the transitions with $\Delta n = 0$ and introduced for them different Gaunt factor. Transitions with $\Delta n \neq 0$ are summed separately. Half-half width w and shift d of ion spectral line broadened by Stark effect become now

$$w + id = N \frac{4\pi}{3} \frac{\hbar^2}{m^2} \left(\frac{2m}{\pi kT}\right)^{1/2} \frac{\pi}{\sqrt{3}} \sum_{j=i,f} \{\vec{R}^2_{k,k+1} [\tilde{g}(x_{k,k+1}) +$$

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$$i\varepsilon_j \tilde{g}_{sh}(x_{k,k+1})] + R^2_{k,k-1}[\tilde{g}(x_{k,k-1}) - i\varepsilon_j \tilde{g}_{sh}(x_{k,k-1})] + \quad (1)$$

$$\Sigma(\vec{R}^2_{jj'})_{\Delta n\neq 0}[g(x_j) + i\varepsilon_j g_{sh}(x_j)] - 2i\varepsilon_j[\Sigma_{\Delta E_{jj'}<0}(\vec{R}^2_{jj'})_{\Delta n\neq 0} g_{sh}(x_{jj'})]\}$$

Here $k = \ell_j$, i and f denote the initial and final levels $\varepsilon_j = +1$ if $j = i$ and -1 if $j = f$ and $\vec{R}^2_{jj'} = |\langle j|\vec{r}|j'\rangle|^2$. Gaunt factors g, $\tilde{g}$, g_{sh} and $\tilde{g}_{sh}$ are given as a function of x in the table. Here $x_{jj'} = 3kT/2\Delta E_{jj'}$; $x_j = 3kTn_j^3/4Z^2E_H$ where E_H is the hydrogen ionization energy.

	x	≤1	2	3	5	10	30	100
	g	0.2	0.2	0.24	0.33	0.56	0.98	1.33
	$\tilde{g}$	0.7	$-1.1/Z+g$					
	g_{sh}	0.2	0.25	0.32	0.45	0.66	0.82	0.87
Z = 2	$\tilde{g}_{sh}$	0.35	0.40	0.47	0.58	0.70	0.82	0.87
Z = 3	$\tilde{g}_{sh}$	0.53	0.54	0.57	0.62	0.70	0.82	0.87
Z = 4	$\tilde{g}_{sh}$	0.62	0.63	0.63	0.65	0.70	0.82	0.87
Z > 4	$\tilde{g}_{sh}$	0.88	$-1.1/Z+0.01$	$+0.01x/Z$;		x≤100		

When the nearest perturbing level is so far that $3kT/2|\Delta E_{jj'}| \leq 2$ is satisfied, Eq.(1) may be considerably simplified [5]. In the following paper [6] the described method is used for the evaluations of Stark broadening parameters of ionized atom lines.

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MODIFIED SEMIEMPIRICAL ESTIMATES OF ION LINES STARK BROADENING II. APPLICATION

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The modified semiempirical method presented in the preceding paper [1] is used here for the calculation of Stark widths and shifts of singly -, doubly - and triply - charged ion lines. The expression for width (Eq. (1) [1]) is tested in Ref. [2] on a set of experimental data for 36 multiplets of doubly and 7 multiplets of triply charged ions. The average values of the ratios of measured to calculated widths are 1.06 ± 0.31 for doubly - and 0.91 ± 0.42 for triply charged ions. In order to test simplified form of Eq.(1) [1] derived for the low temperature limit [3] we compared with the results of comprehensive width calculations for doubly and triply ionized atoms [4] in which Eq.(1) [1] is used. The discrepancy did not exceed ±30% in average. Furthermore, comparison is made between simplified Eq.(1) [1] with available experimental results in cases when low temperature limit of Eq.(1) [1] may be applied. The average ratio of experimental and calculated values is 1.04, while this ratio is 1.01 when Eq.(1) [1] is used. In Table 1 are compared experimental results w_m for analogous transi-

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tions of doubly ionized inert gases [4] with results from Eq.(1) [1] and its simplified form for the low temperature limit, LTL Eq.(1):

$$w(\mathring{A})=2.215\cdot 10^{8}\,\frac{\lambda^{2}(cm)N(cm^{-3})}{T^{1/2}}\left(0.9-\frac{1.1}{Z}\right)\sum_{j=i,f}\left(\frac{3n_j}{2Z}\right)^{2}(n_j^{2}-\ell_j^{2}-\ell_j-1)$$

On the basis of the presented results we believe that modified simiempirical method is adequate when evaluating a large number of ion line widths and shifts or when rapid estimates are required.

TABLE 1

ION	WAVELENGTH (Å)	TEMP. (K)	FULL WIDTH IN Å AT $N=1\times10^{17}cm^{-3}$ w_m	$w_{Eq.(1)}$	$w_{LTLEq.(1)}$
NeIII	2677.90	34000	0.063	0.052	0.049
	2678.64	34000	0.063	0.052	0.049
ArIII	3509.33	27500	0.160	0.153	0.174
	3514.18	27500	0.148	0.153	0.174
KrIII	3564.23	26000	0.160	0.168	0.194
XeIII	3780.98	27000	0.222	0.235	0.267

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SIMPLE CONVERGENT FORMULA FOR ESTIMATING STARK WIDTHS AND SHIFTS FOR NEUTRAL AND IONIC LINES

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ABSTRACT

Formula for estimating Stark widths and shifts of neutral and ionized atom lines have been derived from a convergent theory that avoids the computation of minimum impact parameter.

1. INTRODUCTION

In stellar atmosphere calculations, collisional broadening parameters for large number of lines of various elements are required. To obtain these data, one can use the semi-classical or the quantum mechanical approaches[1] which both require elaborate calculations even for one line.

For neutral atom lines the simplified semi-classical methods[2-5] are very convenient.*

For charged ion lines, one can use the modified semi-empirical (M.S.E.) approach for width[6] and shift[7] calculations.

2. GENERAL FORMULA

We extend our previous formula for Stark broadening of neutral atom lines[5] to ion case using a new collision functions with two parameters because the straight path trajectory is changed in a hyperbolic one with excentricity ε. We start with the convergent Bassalo-Cattani-Walder (B.C.W.) theory[8-9], and according to S. A. Freudenstein and J. Cooper[3], we have approximated the velocity average by $\bar{v} = \sqrt{\frac{3kT}{m}}$ where T is the temperature and m the electron mass. The half-half width w and shift d are then given by :

$$w + id = N\,\bar{v}^3 \sum_{jj'} \frac{f_{jj'}(T)}{g_j\,\omega_{jj'}^2} \qquad (1)$$

with

$$f_{jj'}(T) = \int_o^\infty z\left[1 - \exp\left\{-i g_j \alpha_{jj'}(z,\bar{v})\right\}\right] dz \quad (2)$$

and

$$\alpha_{jj'}(z,\bar{v}) = \frac{2}{3}\frac{e^4}{\hbar^2}\frac{\mathrm{R}_{jj'}^2 \omega_{jj'}^2}{\bar{v}^4}\left[\frac{B_s(z,\xi) - iA_s(z,\xi)}{z^2}\right] \quad (3)$$

ξ is a dimensionless parameter ($\xi = \frac{a\omega_{jj'}}{\bar{v}}$ where $a = Z\frac{e^2}{m\bar{v}^2}$ and Z is the ion charge) .

3. SIMPLIFIED COLLISION FUNCTIONS

For neutral lines, the collision functions[10,11] A(z) and B(z) vanishes at large z :

$$A(z \gg 1) \approx \pi z \exp(-2z) \text{ and } B(z \gg 1) \approx \frac{\pi}{4z} \quad (4)$$

They approach one and zero respectively for $z=0$: $A(z \ll 1) \approx 1$ and $B(z \ll 1) \approx 0$,
so we propose new simplfied collision functions as :

$$A_s(z) = A_s(z,\xi=0) = (1+\pi z)\exp(-2z) \text{ and } B_s(z) = B_s(z,\xi=0) = \frac{\pi z}{4(1+z^2)} \quad (5)$$

For ion lines, the variables (δ,ε) are used in the original definition of the collision functions[12-14], the variables (δ,ξ) are also used and the factor $\frac{\varepsilon^2-1}{\varepsilon^2} = \frac{z^2}{z^2+\xi^2}$ is introduced to preserve the same form for atomic and ionic expressions[15] ($z = \sqrt{\varepsilon^2-1}\,\xi$, $\delta = \xi(\varepsilon-1)$). For small ξ , we have the asymptotic expressions :

$$A(z \ll 1,\xi) \approx (1+\pi\xi)\frac{z^2}{z^2+\xi^2} \text{ and } B(z \ll 1,\xi) = 0 \quad (6)$$

$$A(z \gg 1,\xi) \approx \pi z \exp(-2z+\pi\xi)\frac{z^2}{z^2+\xi^2} \text{ and } B(z \gg 1,\xi) \approx \frac{\pi}{4z}\frac{z^2}{z^2+\xi^2} \quad (7)$$

We propose the simplified functions which are valid for small ξ and large ε :

$$A_s(z,\xi) = \frac{z^2}{z^2+\xi^2}(1+\pi z)\exp\left[-2z + 2\xi\, Arctg\left(\frac{z}{\xi}\right)\right] \text{ and } B_s(z,\xi) = \frac{\pi z^3}{4(1+z^2)(z^2+\xi^2)} \quad (8)$$

This simplified A_S and B_S functions for small ξ and large ε, simplify also the convergent formula in the astrophysicaly interesting case of close dominating perturber levels and high temperature.

4. CONCLUSION

This simple convergent formula might be of interest for opacity calculations or stellar atmosphere modelisations.

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STARK BROADENING OF CIV LINES OF LARGE PRINCIPAL QUANTUM NUMBER : REGULARITIES WITHIN SPECTRAL SERIES

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1 Introduction

We have calculated recently, Stark broadening data for 39 C IV multiplets[1,2]. Our tables however are not sufficiently complete for the investigation of[3,4] PG 1159 stars . The PG 1159 stars are hot hydrogen deficient pre−white dwarfs with effective temperature 100,000 − 140,000K and carbon and helium as the dominant constituents (C/He= 0.5)[4]. Due to the high surface gravity (log g= 7) Stark broadening is an important line broadening mechanism and Stark broadening data are needed for NLTE model atmosphere analysis[4] and other stellar plasma investigations. Moreover, Stark broadening data in far and extreme ultraviolet, for lines originating from transitions between energy levels with large principal quantum number and low lying levels will become important for astrophysics in the near future due to the Extreme Ultraviolet Explorer (EUVE) and the Far Ultraviolet Spectroscopy Explorer (FUSE) missions.

Here, we present and discuss the results for C IV multiplets of large principal quantum number, along with a discussion of the Stark broadening parameter regularities within spectral series .

2 Results and discussion

In order to provide the needed data for stellar plasma analysis, Stark broadening parameters for C IV[1,2] , Si IV, N V, O VI, Sc III and Ti IV lines (see Ref. 5 and Refs. therein), have been calculated recently, using the semiclassical − perturbation formalism.[6,7] In order to provide needed Stark broadening data for research of PG 1159 stars and for the analysis of results of EUVE and FUSE missions, we have calculated here, electron−, proton−, and ionized helium−impact line widths and shifts for 69 C IV multiplets of large principal quantum number, as functions of temperature and perturber density.

The obtained set of results has been used for the analysis of systematic trends in spectral series. In Figures 1−2, the electron full halfwidth and shift within $2p^2P^0 - ns^2S$ series are reported. By inspecting the energy separation between the upper level and the principal perturbings levels, we find that this separation decreases gradually within a spectral series. We obtain as a consequence, a gradual change of the Stark widths as in the case analysed in Ref. (1) when the upper level was a p level. In Figs 3 and 4 the case of C IV $np^2P^0 - 9s^2S$ transitions, i.e. the case when the upper level does not changes is presented. We can see that particularly in the case of shift the changes

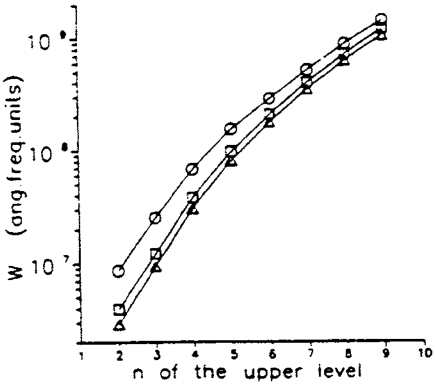

Fig. 1. Electron – impact full half widths (in angular frequency units) for the C IV $2p^2P^0 - ns^2S$ lines as a function of n for T = 20,000 K (○); 100,000 K (□) and 200,000 K (△) at N = 10^{13} cm^{-3}.

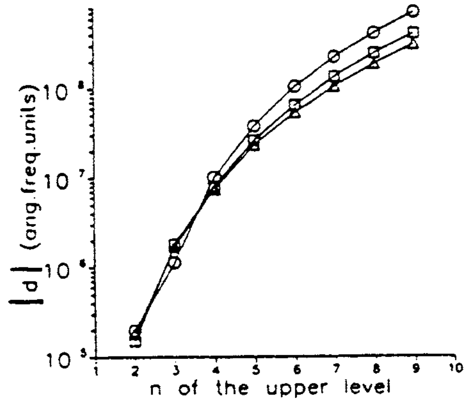

Fig. 2. As in Fig.1 but for the electron – impact shift.

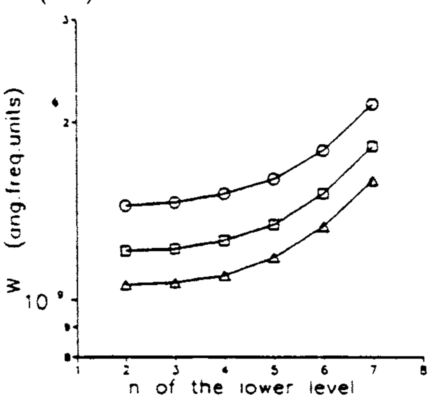

Fig. 3. As in Fig. 1. but for the C IV $np^2P^0 - 9s^2S$ electron– impact width.

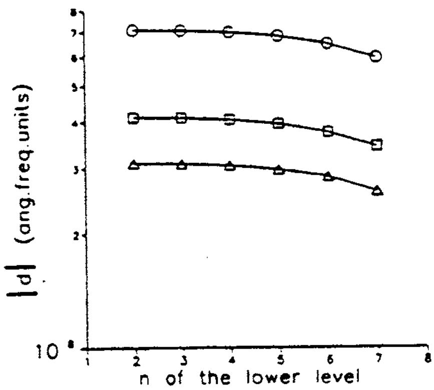

Fig. 4. As in Fig.1 but for the C IV $np^2P^0 - 9s^2S$ electron– impact shift.

of Stark broadening parameters are relatively small, permitting the interpolation of new data or critical evaluation of mutual consistency of existing data.

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REGIONAL MEETING
ON SOLAR PHYSICS

SOLAR RESEARCHES IN THE SOUTH-EASTERN EUROPEAN COUNTRIES: PRESENT AND PERSPECTIVES

24 - 28 April 2001, Bucharest, Romania

PROGRAMME
AND ABSTRACTS

CCD Solar Observations

E. C. Matei

Astronomical Institute of the Romanian Academy, Str.Cutitul de Argint 5, O.P. 28, Ro-75212

The paper presents a history of the CCD using in astronomy as well as some technics for improvement of the image quality. There are disccused the difficulties met in chromospheric observations with a SBIG ST7 CCD camera through H_α filter using the PC. It also presents few image acquisition problems.

Solar Physics during the Last Three Decades at Astronomical Observatory in Belgrade

I. Vince

Astronomical Observatory, Volgina 7, 11050 Beograd, Yugoslavia

Solar research at Belgrade Astronomical Observatory occasionally performed since the foundation of our Institute in 1887. But, from 1968 until now we permanently carried out experimental and theoretical solar research. In this invited lecture I'll present our main scientific results and our planes for the next several years. Based on this lecture I will propose a scientific cooperation program in solar physics research between South-Eastern European Countries.

Solar Plasma and Stark Broadening Investigations

M. S. Dimitrijevic

Astronomical Observatory, Volgina 7, 11160 Belgrade, Yugoslavia

Broadening due to interaction between emitter and charged particles (Stark broadening) is dominant in a number of cases of astrophysical interest. Here, the importance of Stark broadening for

Solar plasma research will be discussed in details. In cooler star atmospheres as e.g. Solar one, Stark broadening may be important. Namely the influence of Stark broadening within a spectral series increases with the increase of the principal quantum number of the upper level and Stark broadening contribution may become significant for Rydberg atoms and ions where the optical electron is weakly bound to the core, so that e.g. high member Balmer series lines may be used as a

We discuss also the case of Solar infrared Mg lines and the importance of Stark broadening for subphotospheric layers modeling and considerations.

SOLAR AND STELLAR PHYSICS THROUGH ECLIPSES

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Volkan BAKIŞ, *Çanakkale University, Department of Physics*, bakisv@physics.comu.edu.tr

TITLE: Discovery of New Variable Stars at Çanakkale University Observatory

AUTHOR(S): V. Bakış, H. Bakış, O. Demircan, E. Budding, A. Erdem, C. Çiçek, C.

ABSTRACT: We present discovery of three variable stars at Çanakkale University Observatory. Methods of data reduction and detecting magnitude variations of stars in the series of ccd images are discussed.

Julyan CARTWRIGHT, *CSIC – Granada, Spain*, julyan@lec.csic.es

TITLE: Pulsating The Morphologies of Ices in the Solar System

AUTHOR(S): J. Cartwright

ABSTRACT: Ice, the solid phase of water, is ubiquitous in the universe. Understanding ice helps us to comprehend water, a simple triatomic molecule, but one with much complex behaviour, and vital and fundamental to the living world. Icy particles in the stratosphere are implicated in ozone depletion chemistry, and as such play an important part in determining the climate on Earth. Ice may be involved in the origin of life itself; amino acids have been created on ice under the conditions of the interstellar medium of space, suggesting that the precursors of life, or even life itself, could have arrived here on Earth from space, from comets or meteorites. This presentation will review the presence of icy films throughout the solar system; their morphologies, physics, and chemistry.

Vladan A. ČELEBONOVIĆ, *Institute of Physics, Center for Experimental Physics*, vladan@phy.bg.ac.yu

TITLE: Basics of Dense Matter Physics and Applications to Astronomy

AUTHOR(S): V. A. Čelebonović

ABSTRACT: The aim of this paper is to present basic notions of dense matter physics and some of its applications to geophysics and astronomy. Topics covered in the paper include: basic observational data, fundamental ideas of static high pressure experiments, notions of theoretical dense matter physics, and finally some details about theoretical work on dense matter physics and its astronomical applications in Serbia.

Michel DENNEFELD, *Institut d'Astrophysique (IAP-Paris)*, dennefel@iap.fr

TITLE: Telescope Access Possibilities Within Europe

AUTHOR(S): M. Dennefeld

ABSTRACT: -

Milan DIMITRIJEVIC, *Astronomical Observatory Belgrade*, mdimitrijevic@aob.bg.ac.yu

TITLE: Stark Broadening of Spectral Lines for Solar and Stellar Plasma Research

AUTHOR(S): M. S. Dimitrijevic

ABSTRACT: Broadening due to interaction between emitter and charged particles (Stark broadening) is of interest for solar and stellar plasmas but also even for extreme conditions in interstellar molecular clouds or neutron star atmospheres. It is first of all interesting for hotter stars like A-type stars, PG1195-type stars and white dwarfs, where the hydrogen, the main constituent of stellar atmospheres is mainly ionized, and among collisional broadening mechanisms for spectral lines, the dominant is the Stark effect. Even in cooler star atmospheres as e.g. Solar one, Stark broadening may be important. For example, its influence within spectral series increases with the increase of the principal quantum number of the upper level and consequently, its contribution may become significant even in the Solar spectrum. It is also important for the study of subphotospheric layers. Here we will give a review of problems in solar and stellar plasma investigations where Stark broadening data are of interest.

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AND ABSTRACTS

A Development of the Solar Physics in Bulgaria

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In this paper, we trace the history of Solar Physics in Bulgaria from the early period of the Bulgarian astronomy, via the epoch when the Institute of Astronomy of the Bulgarian Academy of Sciences was established, to the present time when the Solar Physics Section of the Institute of Astronomy is actively working. Three main topics of the solar researches in Bulgaria (solar activity, solar eclipses and theoretical activities) are presented. Several important results, obtained during different years, are considered and discussed. The activities of other solar research of the Departments of the Bulgarian Academy of Sciences are also considered.

Influence of Chemi-Ionization and Chemi-Recombination Processes on the Plasma Kinetics in the Solar Atmosphere

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In several papers we have introduced and investigated, chemi-recombination processes during the free electron scattering on the quasi-molecular collisional complexes H(1s)+H ion and molecular hydrogen ions in the weakly bound rhovibrational states, as well as H ion - H atom radiative processes of charge exchange and association during H and H(1s) collisions.

We discuss and present here results of our investigations of the influence of such radiative processes on continuous electromagnetic emission (absorption) optical spectrum of Solar photosphera and chromosphera. Our results show that these processes not taken into account up to now, should be taken into account for modelisation of generation and transfer of continuous electromagnetic radiation in particular layers of Solar photosphera and chromosphera, although they make only a negligible contribution to the emergent cotinuous spectrum of the Sun.

We present and discuss also results of our considerations of the influence of the H atom - H ion - e and H molecular ion - e chemi - recombination processes on the highly excited hydrogen atom population in the photosphere and lower part of the chromosphere. It has been shown that these chemi - recombination processes have an important role in the large region around the temperature minimum in the Solar atmosphere, where they are comparable to the other relevant recombination processes, or even dominant and that they should be taken into account for the modelling of the weakly ionized layers in the Solar atmosphere.

22nd Summer School and International Symposium on the Physics of Ionized Gases

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ABSTRACTS OF INVITED LECTURES, TOPICAL INVITED LECTURES and PROGRESS REPORTS

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Belgrade, 2004

Some Spectroscopic Methods for Astrophysical Plasma Research

L. Č. Popović*, M. S. Dimitrijević*, E. Mediavilla†, E. Danezis**, E. Lyratzi**, E. Bon*, D. Ilić‡, P. Jovanović*, E. Theodossiou** and M. Dačić*

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The emission lines of active galactic nuclei (AGNs) are produced over a wide range of distances from the central continuum source and under a wide range of physical and kinematical conditions (see e.g. [1,2] and references therein). The line strengths, their widths, and shapes, are powerful tools for emitting gas diagnostics in different parts of the emitting region of an AGN. Generally, the emission line region in AGNs can be divided into two regions; the broad-line region (BLR) emits very complex broad lines (FWHM~several 1000 km/s) of low ionized atoms and neutrals, and the narrow-line region (NLR) emits the narrow lines (FWHM~several 100 km/s), mainly high ionized atoms from forbidden transitions. The physics in the broad-line region (BLR) is more complicated than in the narrow-line region (NLR).

Here we will present some of spectroscopic method for emission gas research in the BLR of AGNs: (1) we will demonstrate the possibility to use the Boltzmann-plot method to estimate of physical conditions in the BLRs [3]; (2) we will discuss the applicability of so called "Gaussian method" for spectral line shape investigation of NLRs and BLRs [3,4,5]; (3) we will present a method for fitting of the line profiles with a kinematically complex model.We apply a two-component model assuming that the line wings originate in a very broad line region (VBLR) and the line core in an intermediate line region (ILR) of AGNs. The VBLR is assumed to be an accretion disk and the ILR a spherical emission region [6]; (4) Also, a model for fitting of broad absorption lines in quasars will be discussed [7,8].

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Stark Broadening of Neutral Cadmium Spectral Lines

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Abstract. Stark broadening parameters, widths and shifts, for 13 Cd I multiplets in UV and V spectral ranges have been calculated using the semiclassical perturbation method. Obtained results have been compared with available experimental and theoretical data.

INTRODUCTION

Spectral lines of neutral cadmium are of astrophysical interest, since such lines are present in stellar atmospheres. The Cd I Stark broadening parameters are needed especially for chemically peculiar (CP) stars, for example 68 Tauri [1] where neutral cadmium is overabudant.

Here, we will calculate within the semiclassical perturbation approach, Stark broadening parameters of 13 Cd I transitions, for conditions typical for astrophysical and laboratory plasmas. The obtained results will be compared with available experimental and theoretical values.

RESULTS AND DISCUSSION

Stark broadening parameters (the full line at half maximum-w and the line shift-d) of neutral cadmium were determined by using the semiclassical perturbation formalism. This formalism, as well as the corresponding computer code [2, 3], have been updated and optimized several times [4, 5, 6, 7]. The calculation procedure, with the discussion of updatings and validity criteria, has been briefly reviewed in [8]. Atomic energy levels needed for calculations have been taken from [9]. The oscillator strengths have been calculated within the Coulomb approximation [10], and the tables [11]. For higher levels, the method [12] has been used.

Results for electron-, and proton-impact broadening parameters for 13 Cd I transitions for perturber density of 10^{16} cm^{-3} and temperatures from 2 500 K up to 50 000 K are shown in Table 1.

TABLE 1. Electron-, and proton-impact broadening parameters for Cd I spectral lines, for perturber density 10^{16} cm^{-3} and temperatures from 2 500 K up to 50 000 K. Transitions and averaged wavelenghts for the multiplet (in nm) are also given. By dividing C (cm^{-3} 10^{-1} nm) by the corresponding full width at half maximum [6], we obtain an estimate of the maximum perturber density for which the line may be treated as isolated and tabulated data may be used. For values shown in the Table, impact approximation is valuable. When it is not the case, such values are omitted.

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T (K)	WIDTH (10^{-1} nm)	SHIFT (10^{-1} nm)	WIDTH (10^{-1} nm)	SHIFT (10^{-1} nm)
6s ^{3}S^o – 7p ^{3}P^o	2500	1.75	1.17		
	5000	1.87	1.15		
740.09nm	10000	2.00	0.999	0.516	0.367
C=0.20E+19	20000	2.16	0.757	0.572	0.443
	30000	2.22	0.630	0.609	0.487
	50000	2.26	0.475	0.662	0.544
6s ^{3}S^o – 7p ^{3}P^1	2500	1.82	1.21		
	5000	1.94	1.18		
738.70nm	10000	2.06	1.02	0.533	0.380
C=0.18E+19	20000	2.21	0.772	0.592	0.460
	30000	2.27	0.641	0.631	0.506
	50000	2.30	0.480	0.687	0.565
6s ^{3}S^o – 7p ^{3}P^2	2500	2.05	1.33		
	5000	2.17	1.26		
734.82nm	10000	2.30	1.07		
C=0.14E+19	20000	2.41	0.815	0.668	0.521
	30000	2.44	0.669	0.714	0.575
	50000	2.44	0.489	0.781	0.643
6s ^{3}S^o – 8p ^{3}P^o	2500	3.93	2.22		
	5000	4.13	2.24		
611.79nm	10000	4.36	1.94		
C=0.62E+18	20000	4.55	1.53		
	30000	4.58	1.27		
	50000	4.53	0.920		
6s ^{3}S^o – 8p ^{3}P^1	2500	4.10	2.28		
	5000	4.31	2.28		
611.32nm	10000	4.53	1.96		
C=0.57E+18	20000	4.70	1.55		
	30000	4.71	1.28		
	50000	4.64	0.922		
6s ^{3}S^o – 8p ^{3}P^2	2500	4.65	2.52		
	5000	4.87	2.36		
610.08nm	10000	5.10	2.01		
C=0.44E+18	20000	5.15	1.58		
	30000	5.10	1.30		
	50000	4.97	0.918		
6s ^{3}S^o – 9p ^{3}P^o	2500				
	5000	8.33	3.75		
560.84nm	10000	8.86	3.24		
C=0.28E+18	20000	9.15	2.61		
	30000	.9.11	2.16		
	50000	8.92	1.52		

TABLE. 1. Continued.

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T (K)	WIDTH (10^{-1} nm)	SHIFT (10^{-1} nm)	WIDTH (10^{-1} nm)	SHIFT (10^{-1} nm)
6s $^3S^o$ – 9p $^3P^1$	2500				
	5000	8.64	3.76		
560.62nm	10000	9.17	3.24		
C=0.26E+18	20000	9.40	2.61		
	30000	9.34	2.16		
	50000	9.12	1.51		
6s $^3S^o$ – 9p $^3P^2$	2500				
	5000	9.58	3.68		
560.03nm	10000	10.1	3.20		
C=0.20E+18	20000	10.2	2.56		
	30000	10.0	2.10		
	50000	9.71	1.47		
6s $^3S^o$ – 10p $^3P^o$	2500				
	5000				
534.09nm	10000				
C=0.11E+18	20000	17.7	3.61		
	30000	17.6	2.99		
	50000	17.1	2.09		
5p $^3P^o$ – 6s $^3S^o$	2500	0.321E-01	0.255E-01	0.812E-02	0.673E-02
	5000	0.380E-01	0.300E-01	0.905E-02	0.783E-02
494.13nm	10000	0.436E-01	0.353E-01	0.101E-01	0.900E-02
C=0.17E+20	20000	0.472E-01	0.387E-01	0.113E-01	0.102E-01
	30000	0.502E-01	0.394E-01	0.120E-01	0.110E-01
	50000	0.531E-01	0.356E-01	0.131E-01	0.121E-01
5p $^3P^o$ – 7s $^3S^o$	2500	0.689E-01	0.485E-01	0.149E-01	0.113E-01
	5000	0.800E-01	0.576E-01	0.167E-01	0.139E-01
319.31nm	10000	0.884E-01	0.660E-01	0.188E-01	0.164E-01
C=0.25E+19	20000	0.949E-01	0.664E-01	0.211E-01	0.189E-01
	30000	0.101	0.649E-01	0.225E-01	0.205E-01
	50000	0.108	0.545E-01	0.245E-01	0.226E-01
5p $^3P^o$ – 8s $^3S^o$	2500	0.160	0.105	0.328E-01	0.208E-01
	5000	0.184	0.127	0.369E-01	0.277E-01
282.21nm	10000	0.203	0.139	0.415E-01	0.341E-01
C=0.94E+18	20000	0.231	0.135	0.466E-01	0.404E-01
	30000	0.246	0.118	0.498E-01	0.442E-01
	50000	0.278	0.982E -01	0.543E-01	0.491E-01

In Table 2, our results are compared with existing experimental results [13] for Cd I 5p $^3P^o$ – 6s $^3S^o$ spectral line. With w_m are denoted experimental full widths at half maximum in (nm), with w_{th} our theoretical results and with $w_{th'}$ theoretical results [14] determined by the GBKO theory [15].

The experimental widths of Cd I 5p $^3P^o$ – 6s $^3S^o$ multiplet were determined [13] by using spark discharges in tube with $Cd(CH_3)_2$ and $Cd(C_2H_5)_2$ for perturber density normalized at the value of 10^{17} cm^{-3} and for temperature of 11 100 K.

Our results are in disagreement with experimental results [13], for 5p $^3P^o$ – 6s $^3S^o$ multiplet, as well as the theoretical results [14]. In ref. [16] the selfabsortion is indicated as a possible reason for this.

TABLE 2. Experimental-w_m [13], and theoretical values of Stark widths (w_{th}-our results, $w_{th'}$-[14]) for Cd I 5p $^3P^o$ – 6s $^3S^o$ multiplet.

TRANSITION	λ(nm)	w_m(nm)	w_{th}	$w_{th'}$
	508.58	0.367	6.41	6.34
5p $^3P^o$ – 6s $^3S^o$	479.99	0.384	7.53	6.63
	467.82	0.174	3.59	3.00

The new experimental determinations of Stark broadening parameters will be of interest for comparison with our and other theoretical data and will be useful for research and modelling of astrophysical plasmas.

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ABSTRACTS OF INVITED LECTURES, TOPICAL INVITED LECTURES and PROGRESS REPORTS

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Collisions with Charged Particles for Stellar Si V Lines Shapes

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Abstract. Stark broadening parameters, widths and shifts, for 16 multiplets calculated with energy and oscillator strengths obtained with the SUPERSTRUCTURE code of the Si V lines have been calculated using the semiclassical perturbation approach. Widths and shifts of the spectral lines were given for temperature range of 50 to 500 kK and electron density 10^{23} m^{-3}. The influence of collisions with charged particles on Si V strong singlet spectral line $2p^6\ ^1S_0 - 2p^5 3s\ ^1P^o_1$ (λ=11.7853 nm) along the HR diagram and standard models of DA and DB white dwarfs is discussed.

INTRODUCTION

We have computed Si V Stark broadening parameters within the semiclassical formalism [1,2] by using oscillator strengths from SUPERSTRUCTURE code in order to provide new Stark broadening data of astrophysical interest. Additionally, we have performed the same calculations using for needed atomic data the Coulomb approximation method [3], in order to estimate the error introduced in the Stark broadening parameters due to uncertainties of oscillator strength values due to the use of the Coulomb approximation.

The obtained results will be published elsewhere [4].

METHOD OF CALCULATION

The energy levels of Si V are calculated using the general atomic structure code SUPERSTRUCTURE developed at the University College in London [5]. The wave functions are determined by diagonalization of the non-relativistic Hamiltonian using orbitals calculated in a scaled Thomas-Fermi-Dirac-Amaldi (TFDA) potential. The relativistic corrections: spin-orbit, mass, Darwin and one-body, are introduced according to the Breit-Pauli approach [6] in intermediate coupling LSJ. By combining the SUPERSTRUCTURE code, calculating energy levels and oscillator strengths, and the code for semiclassical perturbation Stark broadening calculations, we obtained possibility to calculate Stark broadening parameters *ab initio*.

By using atomic energy levels obtained by SUPERSTRUCTURE code, we have calculated also oscillator strengths with the help of the Coulomb approximation with quantum defect of Bates and Damgaard [3]. If we compare results for Stark widths obtained with oscillator strengths calculated with SUPERSTRUCTURE and by using Bates and Damgaard approximation, the average ratio of Stark widths with Coulomb and SUPERSTRUCTURE oscillator strengths is 1.09 for T = 50 kK and 1.10 for 500 kK. Since, in Stark broadening calculations we use a set of atomic data where a particular oscillator strength value is not always critical, obtained result confirm that the Bates and Daamgard approximation may be useful for Stark broadening calculations in the case of ions as Si V, when more reliable data are not available.

We used obtained Stark widths to investigate influence of Stark and Doppler broadening along Hertzsprung-Russell (HR) diagram and in atmospheres of DA and DB white dwarfs. More detailed example of this calculation, for Cd III spectral lines, are given in [7]. The calculations were performed for solar element abundance atmospheric models given in [8].

RESULTS AND DISSCUSION

Comparison of Stark and Doppler broadening for Si V $2p^6\ {}^1S_0 - 2p^5 3s\ {}^1P^o{}_1$ (λ=11.7853 nm) resonance spectral line is illustrated in Fig. 1.

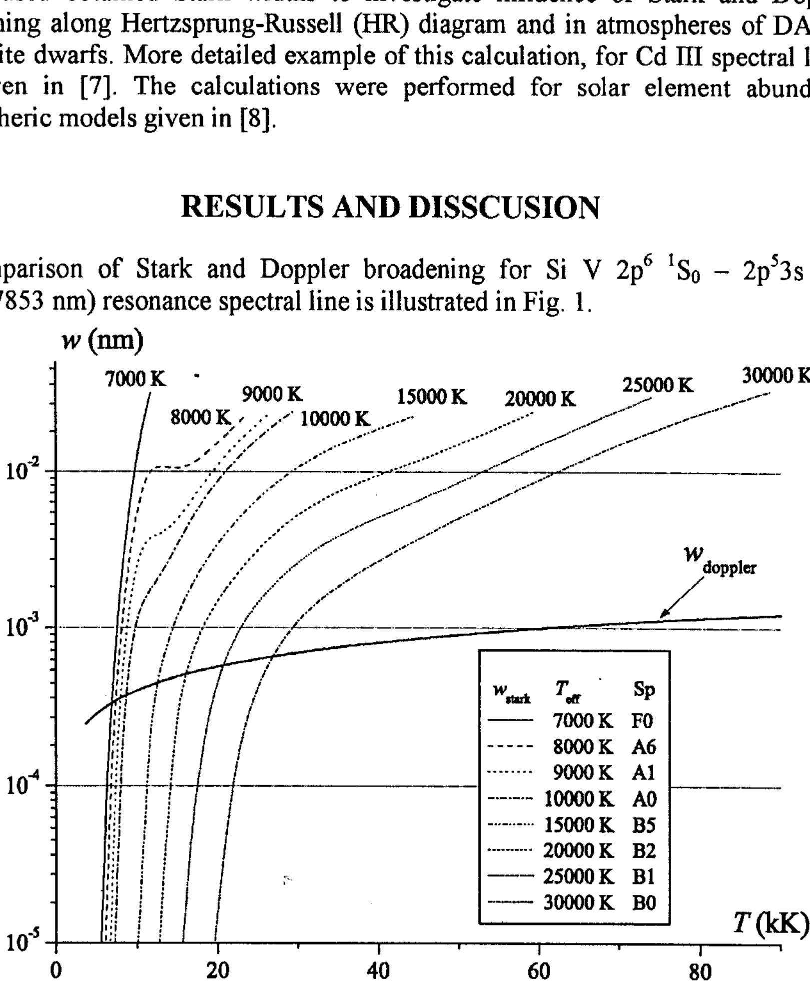

FIGURE 1. Stark widths (FWHM) (thinner lines) and Doppler width (thicker line) for Si V $2p^6\ {}^1S_0 - 2p^5 3s\ {}^1P^o{}_1$ (λ=11.7853 nm) spectral line as a function of atmospheric layer temperatures. Stark widths are shown for 8 atmospheric models with effective temperatures T_{eff} = 7000 – 30000 K, corresponding to spectral classes (Sp) form F0 to B0, log g = 4.0 and turbulent velocity v_t = 0 km s^{-1}.

In Fig. 1. one can see that Stark widths are larger than Doppler ones for stars with lower effective temperatures. For stars with higher effective temperatures, Stark broadening is more important than Doppler one for deeper atmospheric layers (larger layer temperature T).

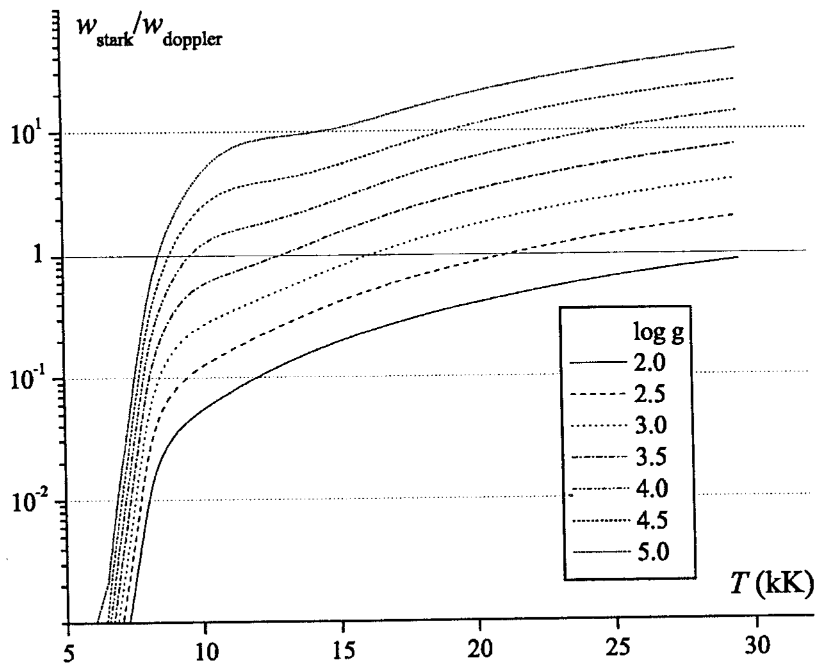

FIGURE 2. Same as Fig. 1. but ratio of Stark and Doppler widths are shown for 7 values of model gravity log g = 2 – 5, T_{eff}= 10000 K and turbulent velocity v_t = 0 km s^{-1}.

The dependence of Stark and Doppler broadening on atmospheric layer temperature for 7 values of surface gravity is shown in Fig. 2. The Stark broadening in stellar atmospheres with higher values of surface gravity is significantly larger than Doppler broadening. For stars with surface gravity log g = 2, Stark broadening is comparable to Doppler widths only for deeper hot atmospheric layers. For upper parts of stellar atmospheres (T < 10000 K) Stark widths rapidly decrease and for layer temperature $T \approx$ 6000-7000 K Stark widths are several magnitudes lower than Doppler ones for all shown values of surface gravity log g.

To compare Stark and Doppler broadening we have calculated spectral line widths for Si V λ=11.7853 nm for DA and DB white dwarf atmospheres [9]. DA dwarfs are helium and metal underabundant and DB white dwarfs are helium and metal overabundand compared to hydrogen. As one can se in Fig. 3. Stark broadening is by one or two order of magnitudes higher than Doppler one. With the increase in pressure, electron density or effective temperature in DA and DB white dwarf models, the importance of Stark broadening increases as well.

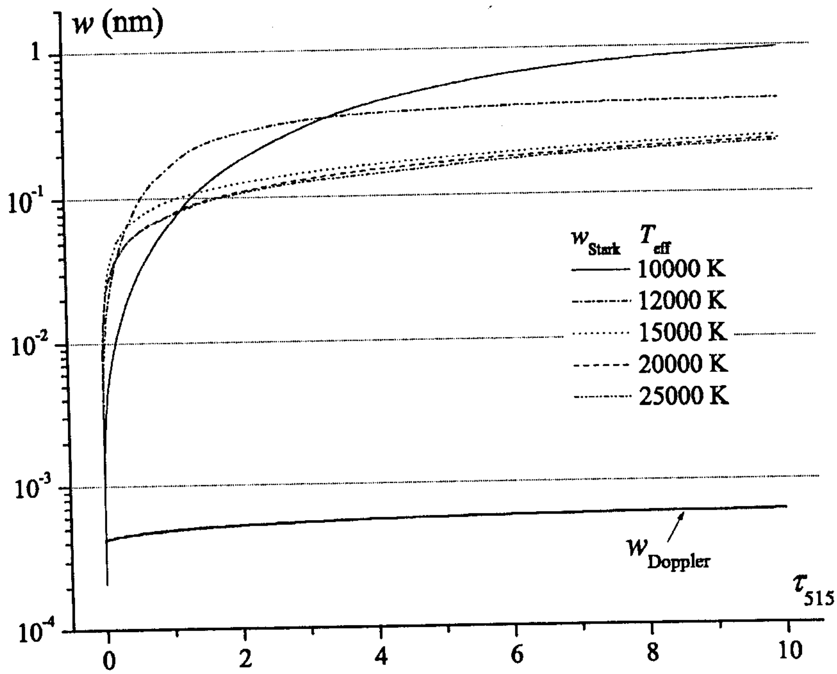

FIGURE 3. Stark and Doppler widths for Si V $2p^6\ ^1S_0 - 2p^53s\ ^1P^o_1$ (λ=11.7853 nm) spectral line as a function of optical depth for standard wavelength λ_{st} = 515 nm for DA white dwarfs. Widths are given for 5 values of effective temperature T_{eff} = 10000 – 25000 K and log g = 8.

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ABSTRACTS OF INVITED LECTURES, TOPICAL INVITED LECTURES and PROGRESS REPORTS

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On Stark Widths of Ar I Lines in the Optical Part of the Spectrum

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Abstract. Stark widths of six Ar I spectral lines in the optical part of the spectrum, corresponding to the $3p^5nd \rightarrow 3p^54p$ (n = 7-5) and $4p' \rightarrow 4s$ transitions, were calculated using the semi-classical perturbation approach. The obtained results were compared with other theoretical and experimental data.

Keywords: Stark broadening, Line broadening, Plasma diagnostics.
PACS: 95.30.Dr, 32.70.Jz

CALCULATIONS

Using the semi-classical perturbation formalism within the impact approximation [1-3], Stark broadening of argon lines in the visible part of the spectrum,

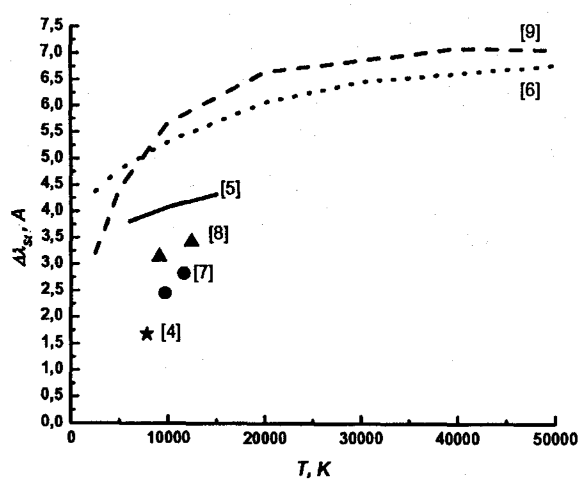

FIGURE 1. Stark full widths at half maximum of Ar I 549.6 nm versus the temperature: theoretical and experimental values are normalized to the electronic density of 10^{16} cm^{-3}.

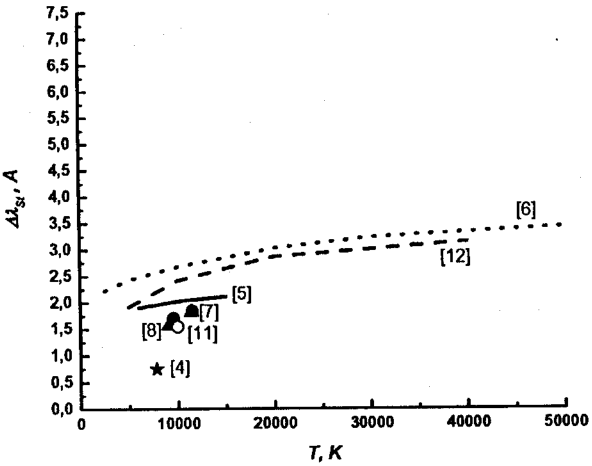

FIGURE 2. Stark full widths at half intensity maximum of Ar I 603.2 nm versus the temperature: theoretical and experimental values are normalized to the electronic density of $10^{16}\,cm^{-3}$.

corresponding to the $3p^5nd \rightarrow 3p^54p$ (n = 7-5) and $4p' \rightarrow 4s$ transitions have been calculated for temperatures within the (2.5-5.0) $x10^4$ K range and for a perturber density of $10^{14}\,cm^{-3}$. All data concerning to the used method and to the details of calculations will be published elsewhere. Some preliminary results with basic explanations are presented in Refs. [5, 6, 10]. Here, the obtained results will be compared with other theoretical and experimental data. We note here that our results in Refs. [5] and [10] are for a particular line within a multiplet and from Ref. [6] for a multiplet.

RESULTS AND DISCUSSION

In Figs.1-2 our calculations of the Stark widths of argon 549.6 and 603.2 nm spectral lines in pure argon gas are compared with those, published by Griem [9, 12] and with the available experimental ones.

In Table 1 we compare our Stark width results with other theoretical and experimental ones. The corresponding experimental conditions and references for all studied spectral lines are given as well.

One can see that the agreement with the experimental data is better for the calculations for a particular line than for the multiplet as a whole. Obtained theoretical results are in good agreement with ones from Refs. [9,12] but lower. Theoretical Stark widths, obtained here as well as from Refs. [9,12] are higher than experimental ones.

TABLE 1. Experimental and theoretical Stark broadening.					
λ, nm	n_e.10^{16}, cm^{-3}	T, K	Δλth, A°	Δλ^{exp}, A°	Ref.
522.1	1.0	7800		3.18	[4]
	1.0	10 000	8.16		[5]
	1.0	10 000	9.92		[6]
549.6	1.1÷5.3	9650÷11600		2.7÷15.0	[7]
	0.63÷7.3	9100÷12350		1.97÷25.0	[8]
	1.0	7800		1.68	[4]
	1.0	10 000	5.68		[9]
	1.0	10 000	4.08		[5]
	1.0	10 000	5.31		[6]
518.8	0.63÷4.7	9100÷11450		1.26÷11.0	[8]
	1.0	7800		1.09	[4]
	1.0	10000	1.77		[10]
603.2	1.0÷5.0	9550÷11500		1.7÷9.2	[7]
	0.63÷4.7	9100÷11450		0.98÷8.55	[8]
	1.0	7800		0.75	[4]
	1.6	10 000		2.47	[11]
	1.0	10 000	2.41		[12]
	1.0	10 000	2.02		[10]
	1.0	10 000	2.67		[6]
560.7	0.63÷7.3	9100÷12400		0.77÷9.43	[8]
	1.0	7 800		0.72	[4]
	1.0	10 000	1.38		[10]
696.5	1.2÷6.0	9700÷11800		0.14÷0.63	[13]
	14.5	13 800		0.80	[14]
	4.8 ÷ 19.6	1e4 ÷ 2e4		0.40 ÷ 1.40	[15]
	1.2 ÷ 7.7	9700÷12250		0.08 ÷ 0.66	[16]
	10.0	13 000		0.81	[11]
	60 ÷ 100	1.65÷1.87e4		4.4 ÷ 6.5	[17]
	6.0	11 900		0.4	[18]
	3.3	13 000			[19]
	10.0	13 000		0.814	[20]
	3.8	13 000		0.33	[21]
	5.5	17 000			[19]
	10.0	1.35÷2.65e4		0.97	[22]
	3.8	13 000		0.33	[21]
	10.0	15 660		1.07	[23]
	6.7	15 6000		0.519	[24]
	7.0	16 000		0.58	[24]
	7.1	16200		0.57	[24]
	12.1-19.7	13.5-24.0e3		1.18-1.85	[20]
	10	12750		0.8	[25]
	20-10	14.0-12.0e3		1.4-0.8	[26]
	57-80	16.8-19.0e3		3.9-5.1	[27]
	1.0	10 000	11.34e-2		[9]
	1.0	10 000	8.57e-2		[21]
	1.0	10 000	8.86e-2		[5]

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Cowan Code And Stark Broadening Of Spectral Lines

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Abstract. We present Stark broadening parameters (widths) of 5 multiplets of S II and 3 multiplets of S III calculated using modified semi-empirical approach (MSE). Needed atomic data (energy levels) have been calculated using *ab initio* Cowan code. Comparison of energy levels of S II and S III calculated by Cowan code and energy levels taken from NIST atomic spectra database is given. We also present comparison of FWHM Stark widths calculated by using MSE and experimental widths.

Keywords: Stark broadening, *ab initio* calculations, atomic spectra, atomic data.
PACS: 32.60.+i, 31.15.Ar, 32.30.-r, 95.30.Ky

INTRODUCTION

Stark broadening of spectral lines is the dominant pressure broadening mechanism in hot, early-type, stars and white dwarf atmospheres. This type of broadening might also be important in interstellar molecular and ionized hydrogen clouds and in cooler stars such as solar type ones for transitions involving higher principal quantum numbers.

The electron-impact broadening data are needed for various problems in astrophysics and physics, as e.g. for diagnostic and modeling of laboratory and stellar plasma, investigation of its physical properties and for abundance determination. These investigations provide us with useful information for modeling of stellar evolution. As an example, the abundances study in stellar atmospheres provides evidences for the chemical composition of the stellar primordial cloud, processes occurring within the stellar interior, and the dynamical processes in stellar atmosphere.

STARK BROADENING OF SPECTRAL LINES

There are several methods used to calculate Stark broadening parameters.

Advanced calculation of the Stark broadening parameters using the strong-coupling quantum-mechanical method [1-9] is so complicated that only a limited amount of data for spectral lines originating from low-lying transitions can be calculated adequately.

Semi-classical method [10-12] (see also a review of obtained results in [13]) needs a large amount of atomic data, energy levels and oscillator strengths. This method is not applicable in an adequate way to the Stark broadening calculation of atoms and ions because there is insufficient number of reliable atomic data.

Modified semi-empirical approach (MSE, [14,15]) includes explicitly only levels with $\Delta n = 0$ and $l'_{if}=l_{if} \pm 1$, where n is the principal quantum number, l is the orbital quantum number and i and f denote initial and final level, respectively. Levels with $\Delta n \neq 0$ are combined and approximately estimated, so that for Stark broadening parameter calculations we need less atomic data then in the semi-classical method. The accuracy of the MSE calculations for spectral line widths is around ±50% [14].

In order to obtain higher accuracy of Stark broadening parameters using MSE calculations we need to have large and reliable amount of atomic data (energy levels, oscillator strengths, etc.). These atomic data can be experimental and theoretical. Experimental data are rare and hard to obtain due to complexity and difficulty in experiments. Theoretical calculations of atomic data are *ab initio* calculations and several of programs packages exist as Cowan code, ATSP (MCHF atomic structure calculations), etc. Here we used Cowan code for atomic data calculations.

COWAN CODE

Cowan code [16] is a suite of four programs that calculates atomic structures and spectra via the superposition-of-configuration method.

The programs are:

1. RCN - calculates one-electron radial wavefunctions (bound or free) for each of any number of specified electron configurations, using the Hartree-Fock or any of several more approximate methods.
2. RCN2 - is an interface program that uses the output wave-functions from RCN to calculate the configuration-interaction Coulomb integrals (R_k) between each pair of interacting configurations, and the electric-dipole (E1) and/or electric quadrupole (E2) radial integrals between each pair of configurations.
3. RCG - sets up energy matrices for each possible value of the total angular momentum J, diagonalizes each matrix to get eigenvalues (energy levels) and eigenvectors (multi-configuration, intermediate-coupling wavefunctions in various possible angular-momentum-coupling representations), and then computes M1 (magnetic dipole), E2, and/or E1 radiation spectra, with wavelengths, oscillator strengths, radiative transition probabilities, and radiative lifetimes.
4. When higher accuracy results are desired, RCE can be used to vary the various radial energy parameters E_{av}, F_k, G_k, zeta, and R_k to make a least-squares fit of experimental energy levels by an iterative procedure. The resulting least-squares-fit parameters can then be used to repeat the RCG calculation with the improved energy levels and (presumeably) wavefunctions.

Using Cowan code, we calculated atomic data for singly- and doubly-ionized sulfur (S II and S III).

RESULTS AND DISCUSSION

Singly-ionized sulfur has ground state $[Ne]3s^2 3p^3$ $^4S^o_{3/2}$ and ionization energy of 188 200 cm^{-1} while doubly-ionized sulfur has ground state $[Ne]3s^2 3p^2$ $^3P_0$ and ionization energy of 280 900 cm^{-1}.

Some energy levels of S II and S III multiplets calculated with Cowan code (E_{CC}) and energy levels taken from NIST atomic spectra database (E_{NIST}) are shown in Table 1.

TABLE 1. Energy levels of S II and S III multiplets calculated with Cowan code (E_{CC}) and energy levels taken from NIST atomic spectra database (E_{NIST}).

Element	Configuration	Term	E_{CC} (cm^{-1})	E_{NIST} (cm^{-1})
S II	$3p^2$ (^3P) 4s	^4P	110187.36	110004.94
		^2P	113156.63	113286.88
	$3p^2$ (^3P) 3d	^4F	110500.32	110511.56
		^4D	114375.86	114237.38
		^2F	114954.43	115079.36
	$3p^2$ (^3P) 4p	$^4D^o$	128238.30	128287.40
		$^4P^o$	130045.96	129984.44
		$^2D^o$	130865.49	130968.76
S III	3p 4s	$^3P^o$	146823.52	146960.62
	3p 4p	^3D	147856.40	147689.05
		^3S	174196.63	174037.69
	3p 5s	$^3P^o$	210653.26	210339.26

As one can see, there is good agreement between E_{CC} and E_{NIST} for S II and S III.

Using complete energy levels of S II and S III calculated using Cowan code combined with experimental energy levels taken from NIST database we have been calculated Stark broadening parameters (FWHM) with MSE method. In Table 2. are shown some of our results for 5 multiplets of S II and 3 multiplets of S III. In this table, our calculations are compared with experimental widths taken from [17].

TABLE 2. FWHM Stark width of 5 multiplets of S II and 3 multiplets of S III.

Element	Transition array	Multiplet	λ (nm)	w_{MSE} (nm)	w_{exp} (nm)	ref.
S II	$3p^2$ 3d – $3p^2$ 4p	^4F – $^4D^o$	560.615	0.0304	0.038	[18]
		^4D – $^4P^o$	630.548	0.0963	0.101	[18]
		^2F – $^2D^o$	631.269	0.103	0.084	[18]
	$3p^2$ 4s – $3p^2$ 4p	^4P – $^4D^o$	545.386	0.0301	0.031	[19]
		^2P – $^2D^o$	564.702	0.0424	0.0316	[20]
S III	3p 4s – 3p 4p	$^3P^o$ – 3D	433.271	0.0401	0.0428	[20]
	3p 4p – 3p 5s	^3D – $^3P^o$	250.815	0.0410	0.0402	[21]
		^3S – $^3P^o$	278.549	0.0396	0.038	[21]

Reference in Table 2. is given for experimental Stark widths (w_{exp}). Calculated Stark widths (w_{MSE}) were adjusted for corresponding temperature and electron density of experimental widths (see e.g. [22,23]).

This method of Stark width calculation can be widely used in getting more accurate results were extensive set of data are needed.

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On Stark Broadening Parameters for Se III Lines in Laboratory and Stellar Plasma

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Abstract. Using the modified semiempirical approach, Stark widths for three Se III transitions were calculated. For these lines, the full semiclassical perturbation approach is not applicable in an adequate way due to the lack of reliable atomic data. Results are obtained as a function of temperature, for perturber density of 10^{17} cm^{-3}. Obtained results are used for an analysis of the influence of Stark broadening for A type star and DB white dwarf atmospheres conditions.

INTRODUCTION

With the development of new techniques, importance of data on trace element spectra like Se increases. Also, the knowledge of Stark broadening parameters is of interest for the investigation of laboratory and technological plasmas.

Selenium, a trace element without an astrophysical significance before, is now detected in the atmospheres of cool DO white dwarfs [1,2].

Here we present Stark widths for three transitions of Se III calaculated by using the modified semiempirical approach [3,4]. Obtained theoretical results are used here to consider the influence of Stark broadening on spectral line shapes for A type stars and DB white dwarf atmospheres conditions

RESULTS AND DISCUSSIONS

Atomic energy levels needed for calculation of Se III Stark line widths were taken from [5].

The results obtained within the modified semiempirical method ([3]; see also the review of inovations and applications in [4]) for the Stark widths (full width at half maximum) due to electron-impacts, for three Se III transitions are shown in Tables 1 respectively for perturber density of 10^{17} cm^{-3} and temperatures from 10000 K up to 300000 K.

In Fig. 1, Se III 5s $^3P^o$ - 5p ^3D (λ=3815.5 A), line widths due to Stark and thermal Doppler broadening mechanisms are compared as functions of Rosseland optical depth corresponding to 10000-30000 K temperature range, for an A type star atmosphere model with T_{eff} = 10000 K and log g = 4.5 [6]. One should take into account that due to differences between Lorentz (Stark) and Gauss (Doppler) line intensity distributions, Stark broadening may be more important on line wings in comparison with the thermal Doppler one, even when it is smaller in the central part.

TABLE 1. This table shows Se III electron-impact broadening parameters (full width at half maximum W) obtained by the modified semiempirical method [3] for perturber density of 10^{17} cm^{-3} and temperatures from 10000 up to 300000 K.

Transition	T(K)	Width(A)
5s $^3P^o$ - 5p ^3D 3815.5 Å	10000	0.377
	20000	0.267
	50000	0.169
	100000	0.134
	200000	0.119
	300000	0.116
5s $^3P^o$ - 5p ^3P 3534.1 Å	10000	0.321
	20000	0.227
	50000	0.144
	100000	0.113
	200000	0.101
	300000	0.981E-01
5s $^3P^o$ - 5p ^3S 3271.0 Å	10000	0.273
	20000	0.193
	50000	0.122
	100000	0.958E-01
	200000	0.857E-01
	300000	0.831E-01

The influence of the Stark broadening on Se III spectral lines for DB white dwarf plasma conditions was investigated for 5s $^3P^o$ - 5p ^3D (λ=3815.5 A) by using the corresponding model with T_{eff} = 15000 K and *log* g = 7 up to 9 [7]. For the considered model atmosphere of the DB white dwarfs the prechosen optical depth points at the standard wavelength λ =5150 A (τ_{5150}) are used in [7] and here, as the difference to the A type star model [6], where the Rosseland optical depth scale (τ_{Ross}) was taken. As one can see in Fig. 2, for the DB white dwarf atmosphere plasma conditions, thermal Doppler broadening has much less importance in comparison with the Stark broadening mechanism.

The Stark broadening parameters obtained here, contribute also to the creation of a set of such data for as large as possible number of spectral lines, of significance for a number of problems in astrophysical, laboratory and technological plasma research.

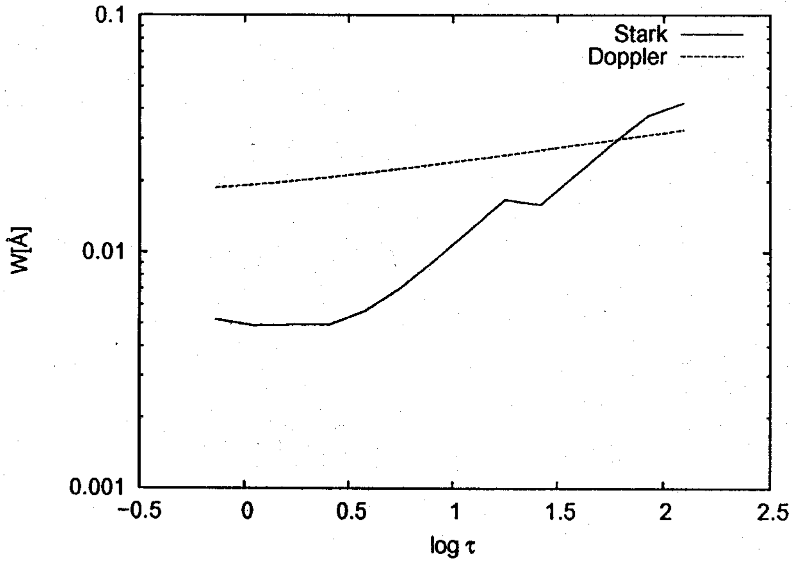

FIGURE 1. Thermal Doppler and Stark widths for Se III spectral lines 5s ^{3}P° - 5p ^{3}D (λ=3815.5 Å), for an A type star atmosphere model with T_{eff} = 10000 K and *log* g = 4.5, as a function of the Rosseland optical depth.

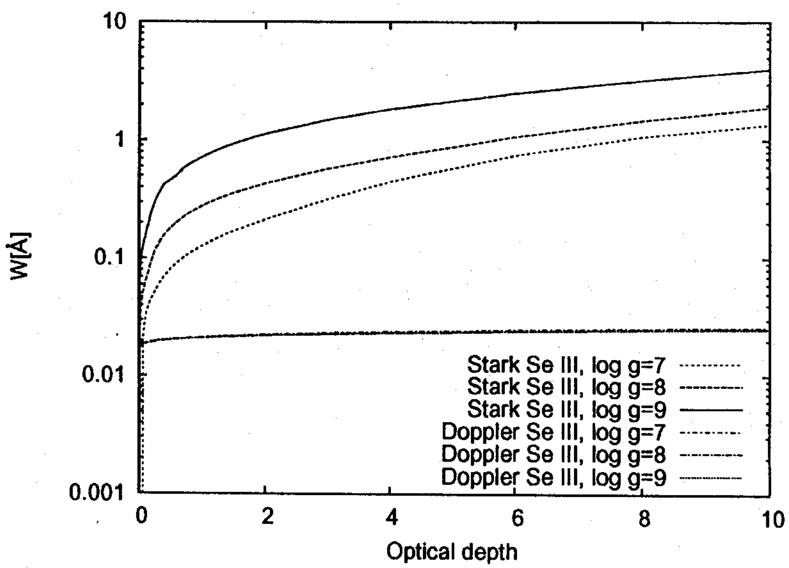

FIGURE 2. Thermal Doppler and Stark widths for Se III spectral lines 5s ^{3}P° - 5p ^{3}D (λ=3815.5 Å), for a DB white dwarf atmosphere model with T_{eff} = 15000 K and *log* g = 7 up to 9, as a function of optical depth τ_{5150}.

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Influence of chemi-ionization and chemi-recombination processes on Hydrogen line shapes in M dwarfs

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Abstract. We study an influence of chemi-ionization and chemi-recombination processes on the population of higher levels and consequently on profiles of Hydrogen lines in the atmospheres of late type (M) stars. Modeling, using general stellar atmosphere code PHOENIX reveals importance of inclusion of such processes.

Keywords: atomic processes - molecular processes - Stars: atmosphere
PACS: 34.70+e, 97.10.Ex

INTRODUCTION

In previous papers [1, 2] we demonstrated the influence of a group of collisional chemi-ionization and chemi-recombination processes on the excited atom populations in Hydrogen plasmas with the ionization degree less than 10^{-3}. We studied the ionization processes

$$H^*(n)+H--->e+H^++A, \quad (1)$$

$$H^*(n)+H--->e+H_2^+, \quad (2)$$

and correspondent inverse recombination processes

$$e+H^++H--->H^*(n)+H, \quad (3)$$

$$e+H_2^+--->H^*(n)+H, \quad (4)$$

where $H=H(1s)$, $H^*(n)$ is the hydrogen atom in the excited state with the principal quantum number n, H_2^+ - the molecular ion in the ground electronic state, and e - free electron.

We applied the same methodology to show the importance of these processes in the Solar atmosphere [3] and atmospheres of cool stars [4]. We compared these processes with the efficiency of the ionization and recombination electron-atom and electron-ion processes

$$e+H^*(n)--->e+H^++H, \quad (5)$$

$$e+e+H^+--->e+H^*(n), \quad (6)$$

$$e+H^+--->\varepsilon_\lambda+H^*(n). \quad (7)$$

where ε_λ denotes the energy of the emitted photon.

Moreover, in [5] we demonstrated the influence of the processes similar to the processes (1) - (4) on the excited atom populations in weakly ionized helium plasma and shown the importance of chemi-ionization and chemi-recombination processes in atmospheres of some DB white dwarfs.

Major result of previous work was that it is very important to include mentioned processes as the population numbers can differ for up to 50% [4].

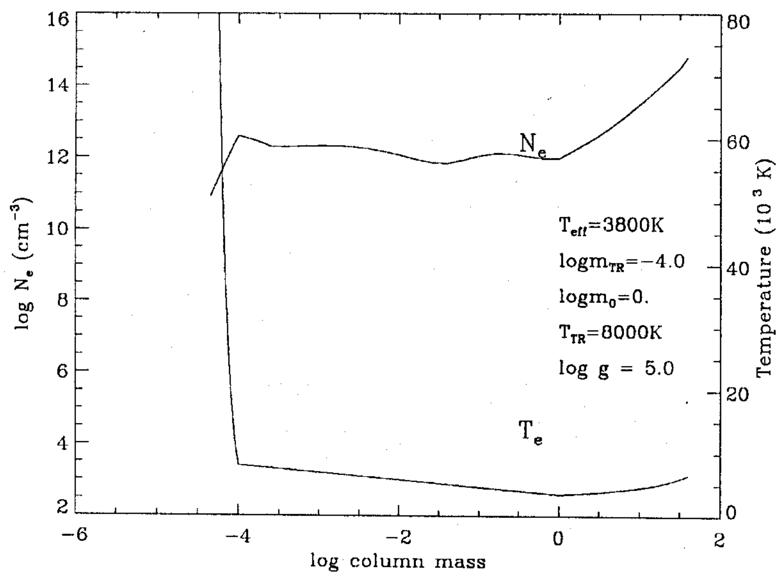

FIGURE 1. Structure of model atmosphere - Temperature and electron density vs column mass

RESULTS OF MODELING AND DISCUSSION

We use the general stellar atmosphere code PHOENIX [6, 7, 8] for our modeling. This code has an advantage that apart for solving the atmospheric structure, it also calculates output spectra, so changes in population levels are reflected on line shapes.

Theory we used in previous work has a shortcoming that it is not applicable for the levels $n \leq 4$. That means that collisional processes are not completely accounted for lower levels of Hydrogen atom. To overcome this problem we introduced in PHOENIX collisional rates from [9].

The procedure similar to one used in [4] was applied. Basic atmosphere has an effective temperature of 3800K, with chromosphere and transition region appearing at logarithm column mass of 0.0 and -4.0 respectevly and temperature at the bottom of transition region fixed at 8000K. This basic atmosphere is shown in Fig.1.

Atmospheric structure was iterated until changes in populations of levels of atomic Hydrogen were less than 1%.

In Figs.2-5 we show the final line profiles of H_α, H_δ, H_ε and $Pa\varepsilon$ with and without inclusion of new processes.

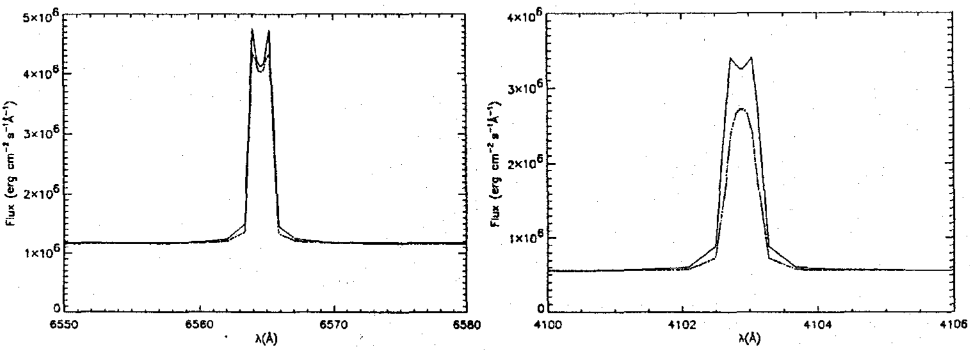

FIGURE 2. Line profiles with (full) and without (dashed) inclusion of chemi-ionization and chemi-recombination processes for H_α (left) and H_δ (right) lines from the atmosphere described in text and shown in Fig. 1

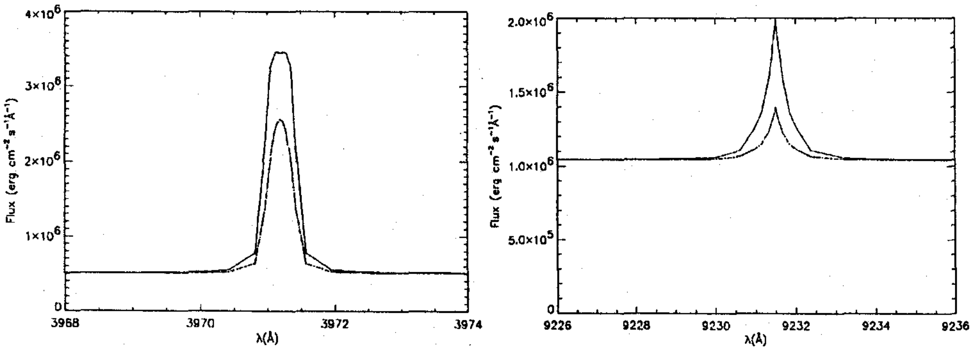

FIGURE 3. Same as in Fig.2 for H_ε and Pa_ε

As one can see there is significant change in line profiles, so it is very important to include chemi-ionization and chemi-recombination processes in modeling of atmospheres of late type stars, especially if one wants to use line profiles as diagnostics of stellar chromospheres.

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The SACs Broadening

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Abstract. As we know, some spectral lines of many Oe and Be stars present Discrete Absorption Components (DACs) or Satellite Absorption Components (SACs). The presence of SACs can broaden the spectral line and we call this phenomenon SACs broadening. The recently published Gaussian-Rotation model enables to study many parameters of the regions that construct this kind of spectral lines. In this paper we indicate that we can detect the same phenomena in the spectra of many quasars and that we can study them with this method.

Keywords: Hot emission stars, quasars, models, DACs, SACs.
PACS: 97.10.Ex, 97.10.Fy, 97.20.Ec, 97.30.Eh, 98.54.Aj

INTRODUCTION

Into a stellar atmosphere or a disc that exist around hot emission stars, an absorption line can originate from several regions that present the same temperature. From each of these regions an absorption component arises.

The line profile of each of these absorption components is a function of a group of physical parameters, as the radial, the rotational, the random velocities and the optical depth of the region that produce the specific components of the spectral line.

These spectral lines are named Discrete Absorption Components (DACs), if they are discrete [1].

DACs are discrete but not unknown absorption spectral lines. They are spectral lines of the same ion and the same wavelength as a main spectral line, shifted at different , as they are created in different density regions which rotate and move radially with different velocities [2,3].

In this paper we indicate the existence of the DACs phenomenon in the spectra of some quasars. We propose that a similar phenomenon, which we call SACs phenomenon, is one of the reasons of the broadening and the complex structure of the observed spectral lines of hot emission stars and quasars.

THE DACs PHENOMENON IN QUASARS

DACs are lines, easily observed, when the regions that give rise to such lines, rotate with low velocities and move radially with high velocities.

In Fig. 1 we can see the Mg II doublet in the UV spectrum of HD 45910. In these line profiles we can see the main spectral lines and a group of DACs at the blue side of each one of them. Below the spectra we can see the components that create the observed features.

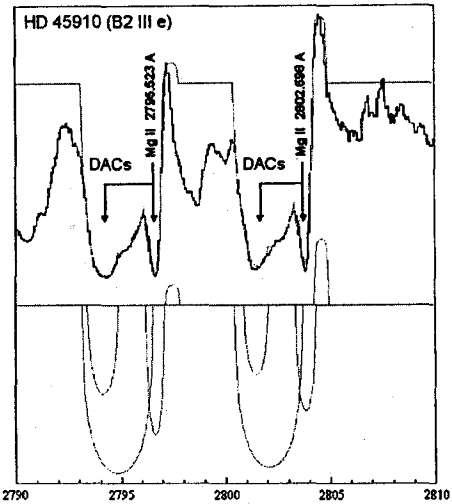

FIGURE 1. Presence of DACs in the Mg II resonance lines of the Be star HD 45910.

It is very important to point out that we can detect the same phenomenon in the spectra of many quasars. In Fig. 2 we can see the C IV doublet of the quasar PG 0946+301. The values of radial displacements and the ratio of the line intensities indicate that the two observable C IV features present a similar DACs phenomenon as in the case of the spectra of hot emission stars.

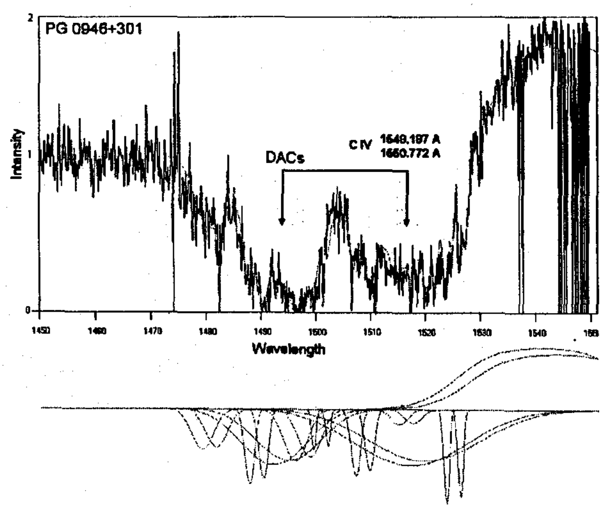

FIGURE 2. Presence of DACs in the C IV resonance lines of the quasar PG 0946+301.

THE SACs BROADENING

However, if the regions that give rise to such lines, rotate with large velocities and move radially with small velocities, the produced lines have large widths and small shifts.

As a result they are blended among themselves as well as with the main spectral line and thus they are not discrete. In such a case the name Discrete Absorption Components is inappropriate and we use only the name Satellite Absorption Components (SACs) [2,3]. The present of SACs can broaden the line shape and we call this phenomenon SACs broadening.

In Fig. 3 we observe the SACs phenomenon in the doublet of Mg II in the case of the Be star HD 41335. Below the spectra we can see the components that create the observed features.

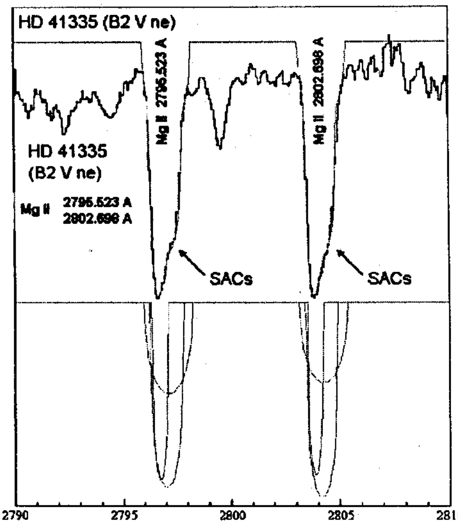

FIGURE 3. Presence of SACs in the Mg II resonance lines of the Be star HD 41335

As we know, around the hot emission stars and the quasars we can detect extensive disc. However, the disc model is not able to reproduce the profiles of many spectral lines.

The question that we examine is the possibility to explain the very complex structure of the spectral lines in many quasars, using the SACs phenomenon. The first conclusions are very promising.

In Fig. 4 we can see the complex structure of C IV doublet and the Si IV, C IV doublet in the spectra of the quasar PG 1700+518 and H 1413+1143 respectively. Below the spectra we can see the components that create the observed features.

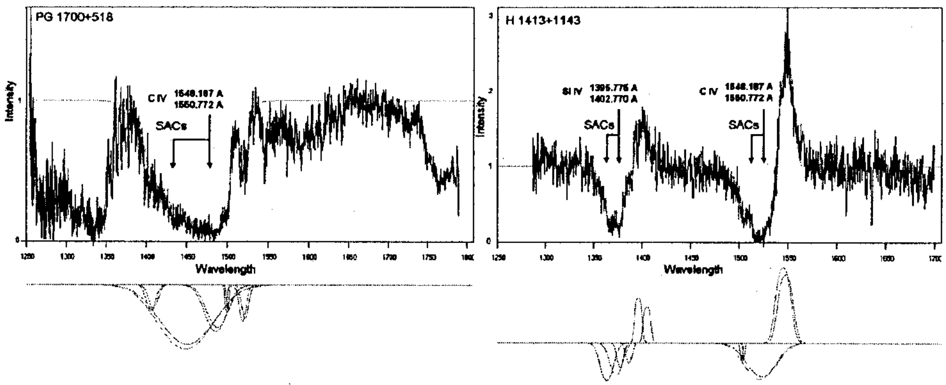

FIGURE 4. Presence of SACs in the C IV resonance lines of the quasar PG 1700+518 and in the Si IV and C IV resonance lines of the quasar H 1413+1143.

CONCLUSIONS

As we see, the presence of SACs can broaden the line shapes and we call this phenomenon SACs broadening. An important point is that we can detect DACs or SACs phenomena not only in the spectra of hot emission stars but also in the spectra of many quasars.

This means that we can study all these line shapes with GR model [4,5].

ACKNOWLEDGMENTS

This research project is progressing at the University of Athens, Department of Astrophysics, Astronomy and Mechanics, under the financial support of the Special Account for Research Grants, which we thank very much. This work also was supported by Ministry of Science and Environment Protection of Serbia, through the projects "Influence of collisional processes on astrophysical plasma line shapes" and "Astrophysical spectroscopy of extragalactic objects".

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ABSTRACTS OF INVITED LECTURES, TOPICAL INVITED LECTURES and PROGRESS REPORTS

Editors

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Belgrade, 2006

The Photospheric And The Respective Si IV Regions' Rotational Velocities In 27 Be Stars

E. Lyratzi[1], E. Danezis[1], D. Nikolaidis[1], A. Antoniou[1], L. . Popovi [2], M. S. Dimitrijevi [2] and E. Theodossiou[1]

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Abstract. It is known that some spectral lines of many Oe and Be stars present Discrete Absorption Components (DACs) or Satellite Absorption Components (SACs). Recently, we presented a method to study many parameters of the regions that create this kind of spectral lines. In this paper, using this method, we study the relation between the rotational velocities of the Si IV regions of 27 Be stars and their photospheric rotational velocities.

Keywords: Be stars, DACs, SACs, rotational velocity, photospheric rotational velocity.
PACS: 97.10.Ex, 97.10.Fy, 97.10.Kc, 97.20.Ec, 97.30.Eh

INTRODUCTION

A significant phenomenon in the spectra of hot emission stars is the existence of Discrete Absorption Components (DACs) [1] or Satellite Absorption Components (SACs) [2,3].The appearance of these components results to the complex profile of many spectral lines in the spectra of Oe and Be stars. The difference between the DACs and SACs phenomena is explained in [2-6].

In this paper we study the relation between the rotational velocities of the Si IV regions of 27 Be stars and their photospheric rotational velocities, using the method described in [4], where the C IV regions in 20 Oe stars have been analysed. Finally, we compare the results of the Si IV regions of 27 Be stars and the C IV regions in 20 Oe stars.

THE RELATION BETWEEN THE PHOTOSPHERIC AND THE RESPECTIVE Si IV REGIONS ROTATIONAL VELOCITIES OF 27 Be STARS

This study is based on the analysis of 27 Be stellar spectra taken with the IUE – satellite (IUE Database http://archive.stsci.edu/iue). We examine the complex structure of the Si IV resonance lines (1393.755 , 1402.77). Our sample includes all the subtypes from B0 to B8. The values of the photospheric rotational velocities are taken from the catalogue [7].

We found that the Si IV spectral lines consist of three components in 7 stars, four in 15 stars and five in 5 stars. The ratio V_{rot}/V_{phot} of the first to fifth detected components as a function of the photospheric rotational velocity (V_{phot}) is presented in Figs. 1a to 5a, respectively. In such a way we obtain an indication of how much the rotational velocity of the specific Si IV layer is higher than the apparent rotational velocity of the star. In Figs. 1b - 5b the respective ions' random velocities (V_{rand}) are presented as a function of the photospheric rotational velocity, where V_{rot} is the rotational velocity of the successive Si IV regions that form each of the considered components. We observe that the dispersion of the random velocities decreases from the first to the fifth component.

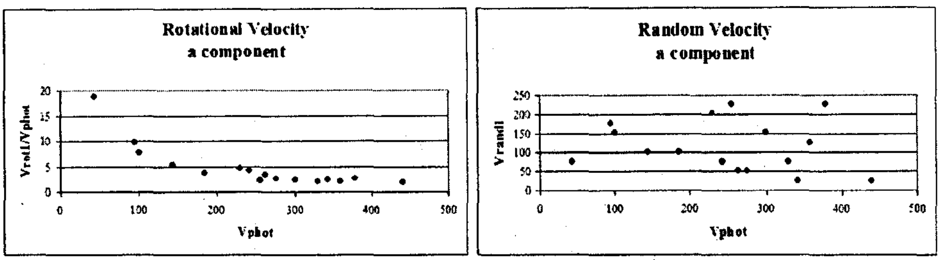

FIGURE 1a, b.: The ratio V_{rot}/V_{phot} (left) and the ions' random velocities (right) as a function of the photospheric rotational velocity V_{phot} of the first component in the sample of 27 Be stars.

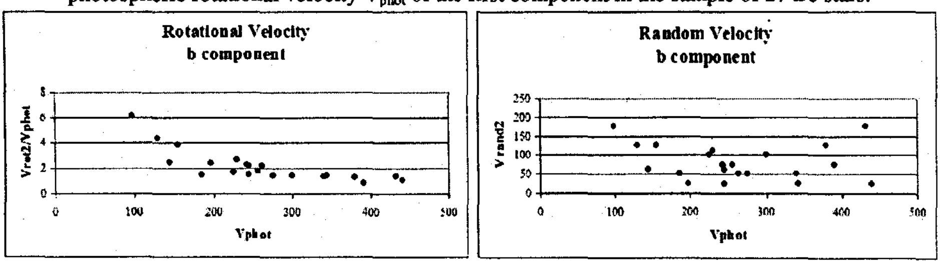

FIGURE 2a, b.: The ratio V_{rot}/V_{phot} (left) and the ions' random velocities (right) as a function of the photospheric rotational velocity V_{phot} for the second component in the sample of 27 Be stars.

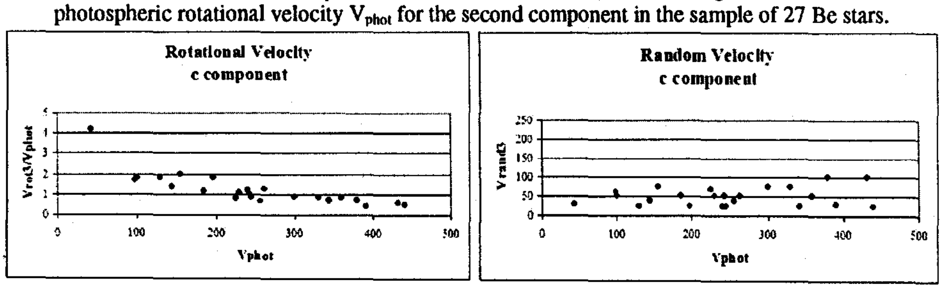

FIGURE 3a, b.: The ratio V_{rot}/V_{phot} (left) and the ions' random velocities (right) as a function of the photospheric rotational velocity V_{phot} for the third component in the sample of 27 Be stars.

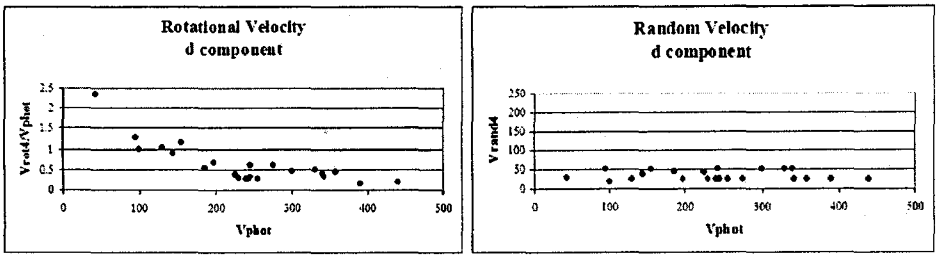

FIGURE 4a, b.: The ratio V_{rot}/V_{phot} (left) and the ions' random velocities (right) as a function of the photospheric rotational velocity V_{phot} for the fourth component in the sample of 27 Be stars.

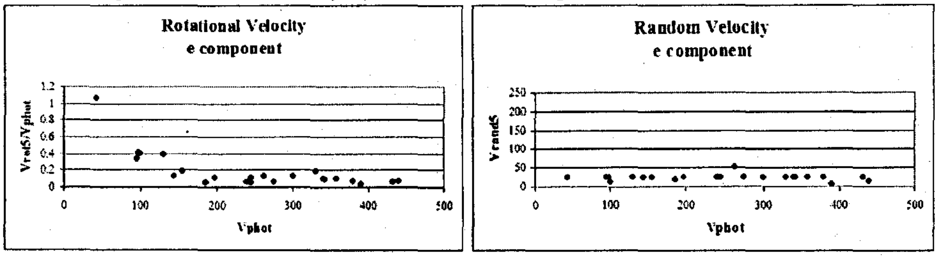

FIGURE 5a, b.: The ratio V_{rot}/V_{phot} (left) and the ions' random velocities (right) as a function of the photospheric rotational velocity V_{phot} for the fifth component in the sample of 27 Be stars.

RESULTS

Our results are very similar with the ones extracted from the study of the C IV regions in 20 Oe stars [4]. The Si IV resonance lines are composed of three four of five components, depending on the star. This means that there exist three to five independent density regions responsible for the creation of these components. The difference with the case of the C IV resonance lines in the spectra of 20 Oe stars, is that they are composed of two, three or four components. However, in both cases, in each region and for each component there exists a logarithmic relation between the ratio V_{rot}/V_{phot} and the photospheric rotational velocity V_{phot}. For the satellite components of the Si IV resonance lines, the maximum ratio V_{rot}/V_{phot} varies from 19, for the first to 1 for the fifth component (Figs. 1a - 5a). The same phenomenon appears in the case of the C IV resonance lines in 20 Oe stars, where the maximum ratio V_{rot}/V_{phot} varies from 40, for the first to 5 for the fourth component [4].This variation may be due to the inclination of the stellar axis. In order to test the validity of our model we check, for all the studied stars, whether the ion's random velocities of each Si IV component, are constant and do not depend on this angle, as it is theoretically expected. Our results confirm this phenomenon, meaning that the mean values of the ions' random velocities are almost constant (Figs. 1b, 2b, 3b, 4b, 5b). The same results are also extracted from the study of the C IV regions in 20 Oe stars [4].

ACKNOWLEDGMENTS

This research project is progressing at the University of Athens, Department of Astrophysics, Astronomy and Mechanics, under the financial support of the Special Account for Research Grants, which we thank very much. This work also was supported by Ministry of Science and Environment Protection of Serbia, through the projects "Influence of collisional processes on astrophysical plasma line shapes" and "Astrophysical spectroscopy of extragalactic objects".

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The Photospheric And The Respective C IV Regions' Rotational Velocities In 20 Oe Stars

A. Antoniou[1], E. Danezis[1], E. Lyratzi[1], D. Nikolaidis[1],
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Abstract. It is known that some spectral lines of many Oe and Be stars present Discrete Absorption Components (DACs) or Satellite Absorption Components (SACs). Recently, we developed a method to study many parameters of the regions that create this kind of spectral lines. Using this method, we study here the relation between the rotational velocities of the C IV regions of 20 Oe stars and their photospheric rotational velocities.

Keywords: Oe stars, DACs, SACs, rotational velocity, photospheric rotational velocity.
PACS: 97.10.Ex, 97.10.Fy, 97.10.Kc, 97.20.Ec, 97.30.Eh

INTRODUCTION

As it is already known, some of the spectral lines of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complex profile of the spectral lines [1]. The DACs are not unknown absorption spectral lines, but spectral lines of the same ion and the same wavelength as a main spectral line, shifted at different , as they are created at different density regions which rotate and move radially with different velocity [2,3].

However, if the regions that give rise to such lines rotate with large velocities and move radially with small velocities, the produced lines have large widths and small shifts. As a result, they are blended among themselves as well as with the main spectral line and thus they are not discrete. In such a case the name Discrete Absorption Components is inappropriate and we use only the name SACs (Satellite Absorption Components). We presented a model able to reproduce the complex profile of DACs or SACs and a method to study many parameters of the regions that create this kind of spectral lines [2,3].

In this paper, using the proposed method [2-5] and, using I.U.E - spectra we study the relation between the rotational velocities of the C IV regions of 20 Oe stars and their photospheric rotational velocities.

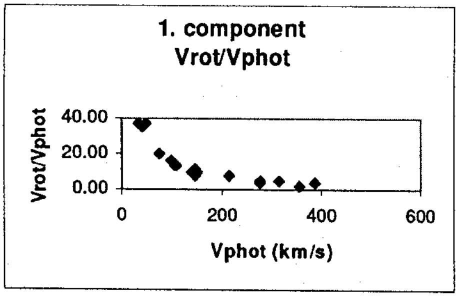
THE GAUSSIAN-ROTATIONAL MODEL (GR-MODEL)

Using GR model [2-5] we can calculate many parameters of the regions that create spectral lines which present DACs or SACs, as the apparent rotational and radial velocities, the Gaussian deviation of the ions' random motions, the random velocities of these motions, as well as the optical depth, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy and the product of the Source function S and the optical depth of the independent regions of matter, which produce the main line and the discrete or satellites components (DACs, SACs) of the studied spectral lines.

THE RELATION BETWEEN THE PHOTOSPHERIC AND THE RESPECTIVE C IV REGIONS ROTATIONAL VELOCITIES OF 20 Oe STARS

This study is based on the analysis of 20 Oe stellar spectra taken with the IUE – satellite (IUE Database http://archive.stsci.edu/iue). We examine the complex structure of the C IV resonance lines (1548.155 , 1550.774). Our sample includes the subtypes O4 (one star), O6 (four stars), O7 (five stars), O8 (three stars) and O9 (seven stars). The values of the photospheric rotational velocities are taken from the catalogue [6].

In our study we detect that the C IV spectral lines consist of two components in 9 stars, three in 7 stars, four in 3 stars and five in one star. In Figs. 1a, 2a, 3a and 4a we present the ratio V_{rot}/V_{phot} of the first, second, third and fourth detected component as a function of the photospheric rotational velocity (V_{phot}). This ratio indicates how many times the rotational velocity of the specific C IV layer is higher than the apparent rotational velocity of the star. In Figs. 1b, 2b, 3b and 4b we present the respective ions' random velocities (V_{rand}) as a function of the photospheric rotational velocity, where V_{rot} is the rotational velocity of the successive C IV regions that create each of these components.



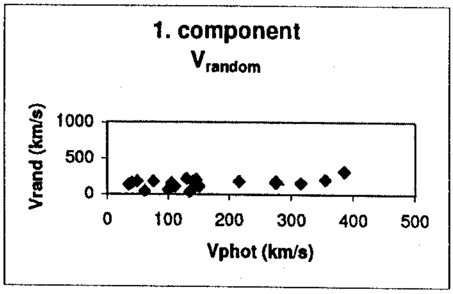


FIGURE 1a, b. The ratio V_{rot}/V_{phot} (left) and the ions' random velocities (right) as a function of the photospheric rotational velocity V_{phot} of the first component in the sample of 20 Oe stars.

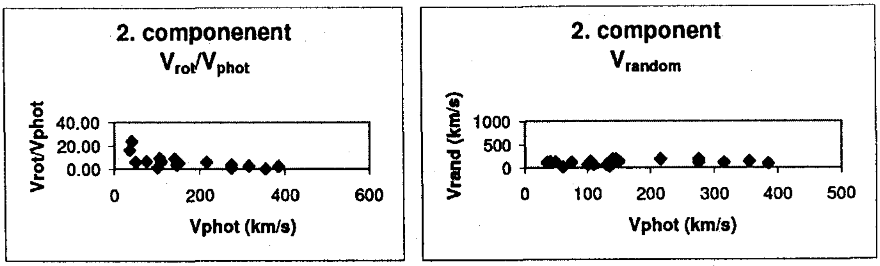


FIGURE 2a, b. The ratio V_{rot}/V_{phot} (left) and the ions' random velocities (right) as a function of the photospheric rotational velocity V_{phot} for the second component in the sample of 20 Oe stars.

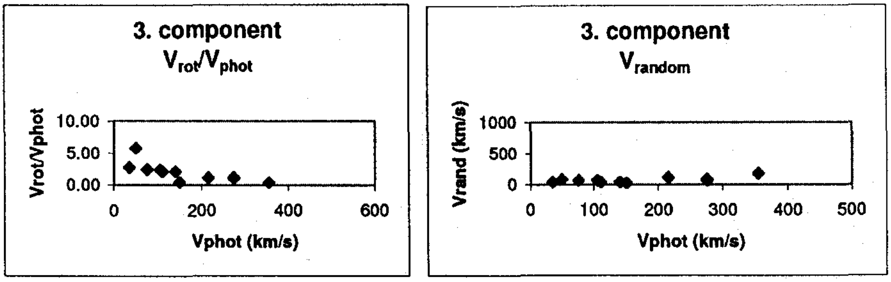


FIGURE 3a, b. The ratio V_{rot}/V_{phot} (left) and the ions' random velocities (right) as a function of the photospheric rotational velocity V_{phot} for the third component in the sample of 20 Oe stars.

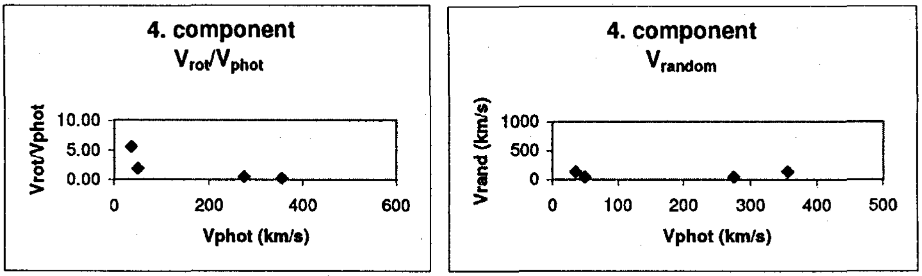


FIGURE 4a, b. The ratio V_{rot}/V_{phot} (left) and the ions' random velocities (right) as a function of the photospheric rotational velocity V_{phot} for the fourth component in the sample of 20 Oe stars.

RESULTS

In each region and for each component we can conclude that there exists a logarithmic relation between the ratio V_{rot}/V_{phot} and the photospheric rotational velocity V_{phot}. The maximum ratio V_{rot}/V_{phot} varies from 40, for the first to 5 for the fourth component (Figs. 1a, 2a, 3a, 4a). A possible explanation of this situation is the inclination of the stellar axis. In order to test the validity of our model we check, for all the studied stars, whether the ion's random velocities of each C IV component, are constant and do not depend on this angle, as it is theoretically expected. Our results confirm this phenomenon, meaning that the mean values of the ions' random velocities are almost constant (Figs. 1b, 2b, 3b, 4b).

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Editors

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Belgrade, 2006

A Study Of DACs And SACs Regions In The Atmospheres Of Hot Emissions Stars

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Abstract. The presence of Discrete Absorption Components (DACs) or Satellite Absorption Components (SACs) is a very common phenomenon in the atmospheres of hot emission stars and their result is the complex line profiles of these stars. The shapes of these lines are interpreted by the existence of two or more independent layers of matter nearby a star. These structures are responsible for the formation of a series of satellite components for each spectral line. Here we present a model reproducing the complex profile of the spectral lines of Oe and Be stars which psesent the DACs and SACs phenomenon. Generally, this model gives a line function for the complex structure of the spectral lines that present DACs or SACs. This line function includes a function L that considers the kinematics (geometry) of an independent region. In the calculation of the function L we have considered the rotational velocities of the independent regions, as well as the random velocities within them. This means that the function L is a synthesis of the Rotation distribution and a Gaussian one. Finally, with this method we can calculate the optical depth ( ) and the column density (d) of each independent density region.

Keywords: Hot emission stars, models, DACs.
PACS: 97.10.Ex, 97.10.Fy, 97.20.Ec, 97.30.Eh

INTRODUCTION

One of the most important phenomena in the spectra of hot emission stars is the DACs (Discrete Absorption Components) phenomenon [1].

DACs are discrete but not unknown absorption spectral lines. They are spectral lines of the same ion and the same wavelength as a main spectral line, shifted at different , as they are created in different density regions which rotate and move radially with different velocities [2,3]. DACs are lines, easily observed, when the regions that give rise to such lines, rotate with low velocities and move radially with high velocities. However, if the regions, that give rise to such lines, rotate with large velocities and move radially with small velocities, the produced lines are quite broadened but have small shifts. As a result they are blended among themselves as well as with the main spectral line and thus they are not discrete. In such a case the name Discrete Absorption Component is inappropriate and we use only the name SACs (Satellite Absorption Components) [4,5].

DESCRIPTION OF THE MODEL

The Line Profile Function

Some years ago our research team proposed a new model to explain the complex structure of the density regions of hot stars, where the spectral lines that present SACs or DACs are created [2,3].

The main hypothesis of this model is that the atmospherical region where a specific line is created is not continuous, but it is composed of a number of successive independent absorbing density regions, a number of emission regions and an external general absorption region.

By solving the radiation transfer equations through a complex structure, as the described one, we conclude to a function for the line profile, able to give the best fit for the main spectral line and its Satellite Components in the same time (Eq. 1).

$$I_\lambda = \left[I_{\lambda 0} \prod_i e^{-\tau_{ai}} + \sum_j S_{\lambda ej} \left(1 - e^{-\tau_{ej}}\right) \right] e^{-\tau_g} \qquad (1)$$

where: I_0: is the initial radiation intensity, S_{ej} is the source function, which, at the moment when the spectrum is taken, is constant and $e^{-\tau_{ai}}$, $S_{\lambda ej}\left(1 - e^{-\tau_{ej}}\right)$, $e^{-\tau_g}$ are the distribution functions of the absorption, emission and general absorption lines, respectively. This function I does not depend on the geometry of the regions which create the observed feature.

The Spherical Symmetry Hypothesis

In order to include in Eq. (1) some kinematical parameters such as the rotational and the radial velocities, we have to suppose a geometrical hypothesis. If we choose the spherical symmetry hypothesis, Eq. (1) becomes:

$$I_\lambda = \left[I_{\lambda 0} \prod_i e^{-L_{ai}\xi_{ai}} + \sum_j S_{\lambda ej} \left(1 - e^{-L_{ej}\xi_{ej}}\right) \right] e^{-L_g \xi_g} \qquad (2)$$

where: I_0: is the initial radiation intensity, L_{ai}, L_{ej}, L_g: are the distribution functions (Rotation distribution) of the absorption coefficients k_{ai}, k_{ej}, k_g, respectively and is the optical depth in the center of the line.

In the present work we propose an approach of the problem, where we calculate L as a function of the rotational and the random velocities (see [4,5]).

Calculation Of The New Distribution Function (Gauss-Rotation)

Let us consider a spherical shell moving radially and a point A_i in its equator (see Fig. 1a). If the laboratory wavelength of a spectral line that arises from A_i is $_{lab}$, the observed wavelength will be $_0 = {}_{lab} + {}_{rad}$ where $_{rad}$ is the radial displacement.

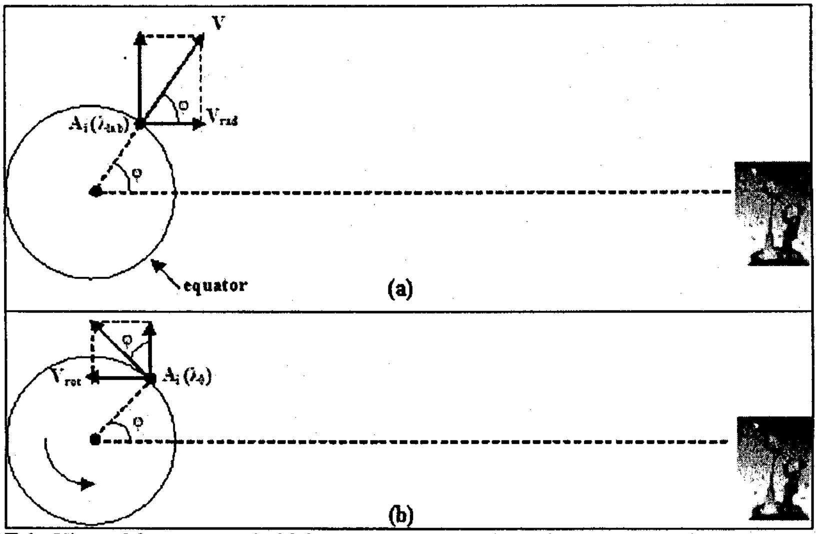

FIGURE 1. View of the equator of a blob. We can see the radial velocity (V_{rad}) of the point A_i, which results to the radial displacement ($_{rad}$) (a) and the rotational velocity (V_{rot}) which results to the width ($_{rot}$) (b).

If the spherical density region rotates (see Fig. 1b), we will observe a displacement $_{rot}$ and the new wavelength of the center of the line $_i$ is $\lambda_i = \lambda_0 \pm \Delta\lambda_{rot}$, where $\Delta\lambda_{rot} = \lambda_0 z \sin\varphi$ and $z = \frac{V_{rot}}{c} = \frac{\Delta\lambda_{rot}}{\lambda_0 \sin\varphi}$, where V_{rot} is the observed rotational velocity of the point A_i.

This means that $\lambda_i = \lambda_0 \pm \lambda_0 z \sin\varphi = \lambda_0(1 \pm z\sin\varphi)$ and if $-\frac{\pi}{2} < \varphi < \frac{\pi}{2}$ then $\lambda_i = \lambda_0(1 - z\sin\varphi)$.

If we consider that the spectral line profile is a Gaussian distribution we have: $P(\lambda) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\left[\frac{\lambda-\kappa}{\sigma\sqrt{2}}\right]^2}$ where is the mean value of the distribution and in the case of the line profile it indicates the center of the spectral line that arises from A_i. This means that $P(\lambda) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\left[\frac{\lambda-\lambda_0(1-z\sin\varphi)}{\sigma\sqrt{2}}\right]^2} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{[\lambda-\lambda_0(1-z\sin\varphi)]^2}{2\sigma^2}}$. For all the semi-equator we have $L(\lambda) = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{[\lambda-\lambda_0(1-z\sin\varphi)]^2}{2\sigma^2}} \cos\varphi d\varphi$. If we make the transformation $\sin\varphi = x$ and $u = \frac{\lambda-\lambda_0(1-zx)}{\sqrt{2}\sigma}$, then $L(\lambda) = \frac{1}{\lambda_0 z\sqrt{\pi}} \int_{\frac{\lambda-\lambda_0(1+z)}{\sigma\sqrt{2}}}^{\frac{\lambda-\lambda_0(1-z)}{\sigma\sqrt{2}}} e^{-u^2} du$ or

$$L(\lambda)=\frac{1}{\lambda_0 z\sqrt{\pi}}\left[\int_0^{\frac{\lambda-\lambda_0(1-z)}{\sigma\sqrt{2}}} e^{-u^2}du-\int_0^{\frac{\lambda-\lambda_0(1+z)}{\sigma\sqrt{2}}} e^{-u^2}du\right]$$

and $L(\lambda)=\frac{\sqrt{\pi}}{2\lambda_0 z}\left[erf\left(\frac{\lambda-\lambda_0(1-z)}{\sqrt{2}\sigma}\right)-erf\left(\frac{\lambda-\lambda_0(1+z)}{\sqrt{2}\sigma}\right)\right]$.

The distribution function from the semi-spherical region is

$$L_{final}(\lambda)=\frac{\sqrt{\pi}}{2\lambda_0 z}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}}\left[erf\left(\frac{\lambda-\lambda_0}{\sqrt{2}\sigma}+\frac{\lambda_0 z}{\sqrt{2}\sigma}\cos\theta\right)-erf\left(\frac{\lambda-\lambda_0}{\sqrt{2}\sigma}-\frac{\lambda_0 z}{\sqrt{2}\sigma}\cos\theta\right)\right]\cos\theta d\theta \quad (3)$$

(Method Simpson).

Eq. (3) gives the final distribution function, which is a synthesis of the Rotation distribution and a Gaussian one.

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ABSTRACTS OF INVITED LECTURES, TOPICAL INVITED LECTURES and PROGRESS REPORTS

Editors

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Institute of Physics
Belgrade, Serbia

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The flux ratio of the [OIII] $\lambda\lambda$ 4959, 5007 Å lines in AGNs: measurements vs. theory

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Abstract.
Here we present the measurements of the flux ratio of the [OIII] $\lambda\lambda$ 4959, 5007 Å emission lines for the sample of 62 AGNs, obtained from SDSS Database and from the published observations. We selected the sample using the criteria of high signal to noise ratio and the same line shapes of 4959 and 5007 lines. We found that the flux ratio is 2.99±0.08, which is in a good agreement with the theoretical value of 2.98 given by Leisy and Zeippen (2000).

Keywords: AGN, NLR, line profiles, [OIII] lines, flux ratio
PACS: 95.30.Ky, 98.54.Cm, 95.75.Fg, 98.62.Ra

INTRODUCTION

The forbidden [OIII] $\lambda\lambda$ 4958.911, 5006.843 Å spectral emission lines are extremely bright in the spectra of photoionized nebulae and in the spectra of the Narrow Line Region (NLR) of AGNs. NLR is fotoionized gas region surrounding the accreting super massive black hole in the center of an AGN. In the diffuse conditions found in nebulae and NLRs, atoms and ions could survive a long time without undergoing collisions. This means that there is sufficient time for excited metastable states to decay, which explains forbidden line emissions. These lines could not be observed in the laboratory where it was not possible to produce collision-free conditions over that timeframe. This transition is strongly forbidden for electric dipoles by the Laporte rule, so the observed transitions are electric quadripole or magnetic dipole ones [1].

Since transitions are strongly forbidden and since both lines originate on the same energy level, both lines have exactly the same emission line profile. Their flux ratios depend only on atomic properties - the energy differences between the fine structure levels and Einstein A-coefficients. External physical condition as density, temperature and velocities, have no influence on flux ratios [2].

The aim of this paper is to measure the [OIII] 4959, 5007 flux ratio in an AGN sample and to compare the obtained results with theoretical ones and with results obtained up to now, only for planetary nebulae, demonstrating that and AGN spectra might be used for such purpose with the appropriate accuracy. The actual value of the lines flux ratio may be useful in spectral analysis of observational datasets.

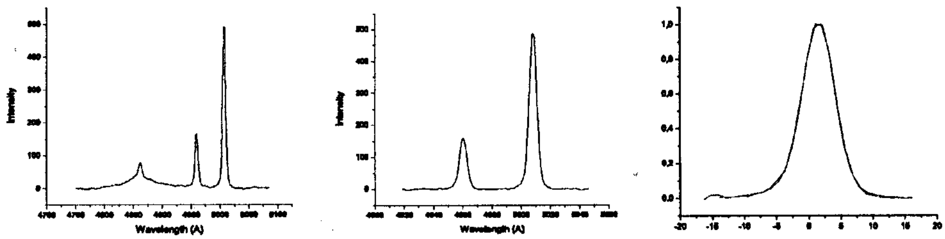

FIGURE 1. Example of the selected spectrum (SDSS J082308.29+42252000.00) with the same shapes of the [OIII] $\lambda\lambda$ 4959, 5007 Å lines.

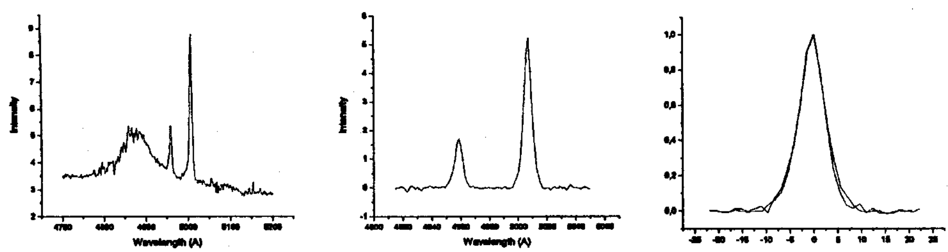

FIGURE 2. Example of the spectrum (PKS 2135-14) where the line shapes are slightly different.

THE LINE RATIO

Up to now, all direct flux ratio measurements of the [OIII] $\lambda\lambda$ 4959, 5007 Å lines have been made for planetary nebulae spectra. Also, these ratios were obtained in some papers as by-product, analyzing spectra of quasars or galaxies, or were used as a checking method.

The theoretical work of Galavis et al. [3] gives an [OIII] $\lambda\lambda$ 4959, 5007 Å flux ratio of 2.89. On the other hand, Storey and Zeippen [4] obtained theoretical value of 2.98, taking into account the higher order relativistic corrections for the magnetic dipole operator calculations.

Using planetary nebulae spectra, Rosa [5] measured a flux ratio of 3.03±0.03, while measurements of Iye et al. [6] give a value of 3.17±0.04, and that of Leisy and Dennefeld [7] 3.00±0.08.

Bahcall et al. [2], used spectra of quasars obtained from the Sloan Digital Sky Survey (SDSS) Early Data Release, to test the time dependence of the fine structure constant. As a by-product, they measured line flux ratio value of 2.99±0.02.

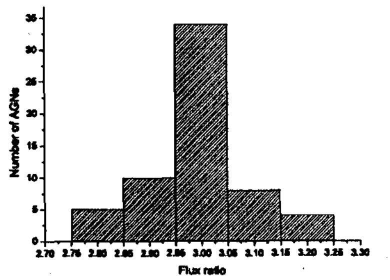

FIGURE 3. Histogram showing the distribution of the measured flux ratio of the initial 62 AGNs sample.

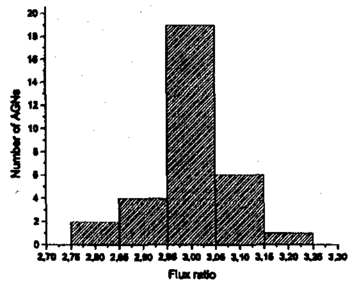

FIGURE 4. Histogram showing the distribution of the measured flux ratio of the final 32 AGNs sample.

THE SAMPLE AND MEASUREMENTS

We selected our AGN sample spectra, with high signal to noise ratio, from the latest Date Release Four (DR4) of the SDSS Database and from observations described in paper of Marziani et al. [8]. We subtracted the continuum by using DIPSO software, and in some spectra we subtracted the H_β and FeII emission lines which contaminate the [OIII] $\lambda\lambda$ 4959, 5007 Å lines.

After that we compared the [OIII] $\lambda\lambda$ 4959, 5007 Å line profiles (see Figs. 1 and 2) by DIPSO software and we selected our initial sample of 62 AGNs by using the criteria that the shapes of 5007 and 4959 lines are the same or different in a small percent.

From the initial sample of 62 AGNs, a number of 32 AGNs satisfy the criteria that the line profiles of both [OIII] lines are identical (Figure 1). The rest of spectra have slightly different line shapes (Figure 2). We measured the flux ratio for initial sample of 62 spectra and for final sample of 32 spectra. Here we present a histogram of the flux ratio values of the initial sample (Figure 3) and the final sample (Figure 4).

RESULTS AND CONCLUSIONS

For the initial sample of 62 objects we found flux ratio 2.99±0.10, and for the final sample of 32 AGNs a value of 2.99±0.08. The obtained flux ratios in both case are in reasonable agreement with the theoretical predictions by Storey and Zeippen (2000). We showed here that the spectra of AGNs could be also used for checks of such theoretical calculations.

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TRENDS IN PHYSICS EPS-7

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O I LINES FORMATION IN STELLAR ENVELOPES

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Two intense infrared triplets of neutral oxygen ($2p^3$ 4s $^3S_1^o$ - $2p^3$ 3p $^3P_{0,1,2}$, λ = 13165 Å and $2p^3$ 3d $^3D_{1,2,3}$ - $2p^3$ 3p $^3P_{0,1,2}$, λ = 11127 Å) have been recently observed in the emission spectrum of the Be type star γ Cas (Ref. 1) with the Canada - France - Hawaï 3 m 60 telescope. Both multiplets have the same lower term 3p ^3P. The triplet 3p ^3P - 3s $^3S^o$ λ = 84465 Å, has been observed for a long time in the emission spectrum of Be stars (e. g. ref. 2). Bowen (ref. 3) showed that that emission line results in a radiative pumping mechanism, due to the coïncidence of the wavelength of O I $2p^3$ 3d ^3D - $2p^4$ ^3P with that of Ly β of hydrogen (the so-called Bowen mechanism). However, such a mechanism cannot be invoked for the formation of O I 13165, even it can be responsible for O I 11127 Å.

In order to investigate the formation of O I 13165 Å the following processes have been considered for populating te 4s $^3S_1^o$. level :

- $2p^4$ ^3P - $2p^3$ 3d $^3D^o$ photoexcitation by Ly β
- $2p^4$ ^3P - $2p^3$ 4d $^3D^o$ photoexcitation by Ly γ followed by cascades towards 4s $^3S^o$ (4d - 4p - 4s).
- 3d $^3D^o$ - 4p ^3P collisional excitation transfer by electrons and protons followed by cascades towards 4s $^3S_1^o$.
- 3d $^3D^o$ - 4s $^3S_1^o$ direct collisional excitation transfer by electrons and protons.

The results of our analysis, using the model of Poeckerf and Marlborough (ref. 4) for the γ Cas envelope model indicate that the considered lines are formed in the initial part of the envelope and that the collisional coupling 3d $^3D^o$ - 4p ^3P - 4s $^3S_1^o$ is predominant for populating the 4s $^3S_1^o$ level.

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ON THE STARK BROADENING OF C IV LINES

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Stark broadening parameters for 10 C IV lines been calculated using a semiclassical perturbational formalism (1, 2) for temperature and pressure conditions of recent experiments which have provided new data (3). The results are compared with those obtained by means of the modified semiempirical method (4), which is simpler.

Table 1. Comparison of semiclassical (DSB) and modified semiempirical (DK) : calculations of full widths at half intensity (W) for Stark broadened C IV lines. $N_e = 5 \times 10^{17}$ cm^{-3}, T = 10 ev.

Term	λ (Å)	W_{DSB}(Å)	W_{DK}(Å)
3s-3p	5801/5811	2.69	1.8
3p-4s	1230	0.22	0.2
3s-4p	948.1	0.17	0.16
3p-4d	1107.6	0.24	0.23
3p-4f	1106.5	0.15	0.12
3d-4f	1169.	0.15	0.12
4p-5s	2698.	2.97	3.7
4p-5d	2405.	3.33	4.0
4d-5f	2524.4	3.11	3.8
4f-5g	2530.	1.55	1.6

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ТОМ LXXV

ТЕЗИСЫ ДОКЛАДОВ

на Всероссийской астрономической конференции ВАК-2004 «ГОРИЗОНТЫ ВСЕЛЕННОЙ»

К 250-летию Московского Государственного университета
им.М.В.Ломоносова (1755–2005)

Москва
2004

весьма редкое, по теоретическим оценкам, явление – одиночную черную дыру, выброшенную из кратной системы черных дыр в ядре гигантской эллиптической галактики и аккрецирующую газ при прохождении сквозь диск спиральной галактики.

ФОТОМЕТРИЧЕСКАЯ МНОГОКОМПОНЕНТНАЯ МОДЕЛЬ ГАЛАКТИКИ

Кутузов С.А., Марданова М.А.

Для нахождения распределения яркости по изображению внешней галактики используется уравнение переноса излучения в интегральной форме. Коэффициент поглощения принимается пропорциональным плотности масс пылевой составляющей, которая моделируется гомотетическим сфероидальным распределением. Коэффициент изотропного излучения принимается пропорциональным пространственной плотности звездной составляющей. Она моделируется непрерывной суперпозицией сфероидальных компонентов с различными сферичностями. Задание весовой функции позволяет получать значительное многообразие эквилюменит. Для законов пылевой и звездной плотностей принимаются аналитические выражения со свободными параметрами. Оценки параметров находятся путем аппроксимации наблюдаемой яркости. Моделируя отношение масса/светимость и используя кривую вращения, можно строить динамическую модель галактики. Рассмотрены примеры.

ПАНОРАМНАЯ СПЕКТРОСКОПИЯ ГАЛАКТИК С ПЕРЕМЫЧКАМИ

Моисеев А.В.

Обсуждаются результаты наблюдений на 6-м телескопе САО РАН выборки дисковых галактик с центральными перемычками (барами). Применение методов панорамной спектроскопии позволило детально изучить ряд эффектов, связанных с динамической выделенностью центральных (килопарсековых) областей изучаемых галактик. Основное внимание уделяется следующим проблемам: анизотропия дисперсии скоростей звездного компонента; объекты типа бар-в-баре; околоядерные диски (в том числе – ортогональные к плоскости внешнего диска) и мини-спиральные образования в центральных областях перемычек.

ПАРАМЕТРЫ СПИРАЛЬНОЙ СТРУКТУРЫ ГАЛАКТИКИ ПО ДАННЫМ О РАССЕЯННЫХ ЗВЕЗДНЫХ СКОПЛЕНИЯХ

Попова М.Э., Локтин А.В.

По 447 РЗС разных возрастов, разделенных на 13 перекрывающихся возрастных групп, определены положения спиральных рукавов Галактики в разные моменты времени. Графики $\ln R(T)$ и $\theta(T)$, где T – средний возраст каждой группы РЗС в млн.лет, R– галактоцентрическое расстояние и θ– галактоцентрический угол, показали, что скопления всех возрастных групп "чувствуют" спиральное возмущение. При этом расстояния между спиральными ветвями для скоплений разного возраста, вплоть до возраста 10^9 лет оказываются приблизительно одинаковыми. Угловая скорость вращения спирального узора равна 22 ± 2 пк/млн.лет/кпк.

МОДЕЛЬ ДЛЯ ОБЛАСТИ ОБРАЗОВАНИЯ ШИРОКИХ ЛИНИЙ ПОГЛОЩЕНИЯ В BAL-КВАЗАРАХ

Попович Л.Ч., Danezis E., Lyratzi V., Димитрийевич М.С., Theodossiou E.

Спектр BAL-квазаров обычно интерпретируется как широкополосный континуум от центральной машины плюс широкие эмиссионные линии от области образования широких эмиссионных линий (BLR). Континуум исходит от области рядом с центром квазара, а широкие абсорбционные линии накладываются в отдельной области, вне центра, называемой областью образования широких линий поглощения (BALR). Предполагая, что BALR состоит из множества последовательных независимых поглощающих плотных слоев, которые имеют постоянную вращательную и радиальную скорости, мы развили модель для BALR. Модель может обеспечить нас основными параметрами BALR (скорости вращения и расширения и оптическая толща). В данном докладе мы представим результаты приложения модели к ультрафиолетовому спектру BALQSO PG0946+301.

АНАЛИЗ КРИВЫХ БЛЕСКА ИЗБРАННЫХ БЛАЗАРОВ В ДИАПАЗОНЕ ОТ 4.8 ДО 37 ГГЦ

Пятунина Т.Б., Кудрявцева Н.А., Габузда Д.К., Эрштад С.Г., Аллер М.Ф., Аллер Х.Д., Терасранта Х.

Результаты многолетнего VLBA мониторинга структуры избранных блазаров на частотах 22 и 43 ГГц, обеспечившего рекордное пространственное ($\sim$ 0.15 мсек дуги) и временное ($\sim$ 0.1 года) разрешение, а также теоретические исследования структуры джетов и их эволюции убедительно свидетельствуют о том, что простейшая схема "одно возмущение – одна компонента" не соответствует реальности. Становится все более очевидным, что единичное первичное возмущение в основании джета порождает сложную последовательность событий, включающую стационарные и сверхсветовые компоненты, быстрые основные компоненты и более медленные сопровождающие. Каждое из этих событий находит свое отражение в переменности, а прецессия джета, сложная структура магнитного поля и взаимодействие с неоднородностями среды еще более усложняют наблюдаемую картину. В связи с

…АДОКС РЕЛАКСАЦИИ В ДИНАМИКЕ ГАЛАКТИК: PRO И CONTRA

…ков Л.П.

…уммируются аргументы, которые подтверждали бы в настоящее время существование …радокса релаксации» («основного парадокса классической звездной динамики» по К.Ф. …одникову), т.е. противоречие между практической бесконечностью времени релакса… по теории Джинса–Чандрасекара и признаками того, что в галактиках произошли ста…тически необратимые изменения. Обсуждаются возможные возражения на эти аргумен… В частности, анализируются: форма распределения звездных скоростей в Галактике, …иверсальность строения галактик, проблема равнораспределения по энергии и зависи…мость дисперсии звездных скоростей от возраста.

…N THE MICROLENSING INFLUENCE ON SPECTRA OF LENSED QSOs: THEORY …ND OBSERVATIONS

…опович Л.Ч., Йованович П., Димитрийевич М.С., Дачич М.Д.

ГАМБУРГ-САО ОБЗОР ДЛЯ ПОИСКА НИЗКОМЕТАЛЛИЧНЫХ ГАЛАКТИК (HSS-LM)

Пустильник С.А., Engels D., Прамский А.Г., Kniazev A., Ugryumov A., Hagen H.-J.

HSS-LM – обзор галактик с очень сильными эмиссионными линиями (EW(5007)> 150 – 200Å) в южной галактической полусфере, в области неба с площадью 3500 кв.град. Одна из целей – поиск галактик с очень низкой металличностью (12+log(O/H)<7.65). Такие галактики очень редки, составляя не более (1–2)% от всех известных голубых компактных галактик (BCG), и являются кандидатами в молодые галактики. Другая цель – получить большую выборку BCG с хорошо измеренным содержанием кислорода и известной функцией селекции, для того, чтобы вывести распределение галактик по этому параметру, и сопоставить полученные данные с моделями хим.эволюции. Представляются промежуточные итоги, по завершению наблюдений около 75% предварительно отобранных эмиссионных галактик (около 160, из них O/H определено для 120). Открыто 5 галактик с очень низкой металличностью.

ГЛУБОКАЯ ФОТОМЕТРИЯ В ОПТИЧЕСКОМ И БЛИЖНЕМ ИК ДИАПАЗОНАХ ГАЛАКТИК С ОЧЕНЬ НИЗКОЙ МЕТАЛЛИЧНОСТЬЮ. ИХ ЭВОЛЮЦИОННЫЙ СТАТУС ПО ДАННЫМ О ВОЗРАСТАХ НАИБОЛЕЕ СТАРЫХ ЗВЕЗД

Пустильник С.А., Фиоктистова И.С., Vanzi L., Князев А.Ю.,

Одно из перспективных направлений в изучении эволюционного статуса галактик с очень низкой металличностью, которые не разрешаются на отдельные звезды, это – анализ цветов областей галактик на периферии, где вклад излучения компактной области бурного звездообразования мал. Мы представляем результаты глубокой фотометрии в фильтрах BVRI, а также узком фильтре H-alpha для нескольких таких BCG. Для части объектов мы получили также глубокие изображения в фильтрах JHK. Комплексный анализ полученных данных указывает, что цвета звезд на периферии нескольких BCG являются весьма голубыми. Сравнение этих цветов с модельными (PEGASE.2) приводит к выводу, что эти объекты могут быть молодыми галактиками, с возрастами менее 500 млн. лет.

МОЛОДЫЕ ГАЛАКТИКИ В БЛИЖНЕЙ ВСЕЛЕННОЙ: ПОЧЕМУ ЗВЕЗДООБРАЗОВАНИЕ В НИХ ВСЕ-ТАКИ НАЧАЛОСЬ?

Пустильник С.А., Прамский А.Г., Фиоктистова И.С., Князев А.Ю., Chengalur J.

Многие голубые компактные галактики с очень низким содержанием металлов ($Z < 1/20 Z_{sun}$) рассматриваются как кандидаты в локальные молодые галактики. В частности, I Zw 18, SBS 0335–052 E и W являются вероятными молодыми галактиками с возрастами менее 500 млн. лет. Теоретические модели предсказывают возможное существование очень устойчивых газовых протогалактик, которые могли остаться в таком состоянии до современной эпохи. Если наблюдаемые немногочисленные молодые галактики – это и есть те самые очень устойчивые протогалактики, то почему в них все-таки недавно началось образование звезд? Мы показываем, что в большой доле таких карликовых галактик имеет место взаимодействие (или даже слияние) с близким объектом сравнимой массы. Это приводит к потере устойчивости, коллапсу газа и включению первой вспышки звездообразования. Имеются ли альтернативные механизмы, приводящие к вспышкам звездообразования в молодых галактиках, пока не ясно, но описанный механизм является реально наблюдаемым по крайней мере в трети таких объектов.

КВАЗИОДНОВРЕМЕННЫЕ РСДБ И РАТАН-600 НАБЛЮДЕНИЯ АКТИВНЫХ ЯДЕР ГАЛАКТИК

Пушкарев А.Б., Ковалев Ю.Ю., Самодуров В.А., Молотов И.Е., Нечаева М.Б., Горшенков Ю.Н., Туккари Дж., Хонг Ш., Куик Д., Доугхерти Ш., Лю Ш.

В рамках проекта LFVN в ноябре-декабре 1999 года были проведены РСДБ наблюдения ряда квазаров и объектов типа BL Lacertae на частоте 1.66 ГГц. В эксперименте

• Александр Бугров, получив увольнение от крестьянского общества, стал своекоштным студентом физико-математического факультета Императорского Московского Университета в 1811 г.
• Прошения, поданные А.Бугровым Министру Народного Просвещения графу А.К. Разумовскому и попечителю Московского Университета П.И. Голенищеву-Кутузову, по поводу получения средств на приобретение в С.-Петербурге астрономических инструментов, книг и таблиц для Московского Университета в 1815 году.
• Сдача Бугровым 10 мая 1819 г. экзамена на степень кандидата физико-математического отделения.
• Организация А.Бугровым устройства солнечных часов на восстановленном здании Московского Университета (Моховая, 11).
• Защита А. Бугровым 9 февраля 1821 г. диссертации «Об эллиптическом движении небесных тел» на степень магистра отделения физико-математических наук.
• Принятие 7 сентября 1821 г. на заседании Совета Университета решения о посылке магистра Бугрова в чужие края (Германию и Францию) на два года для усовершенствования в астрономии.
• Трагическая гибель 28-летнего А. Бугрова 13 октября 1821 года.

ПУЛКОВСКИЙ ВЫПУСКНИК С.П. БОШКОВИЧ И ЕГО ОПРЕДЕЛЕНИЕ ВРЕМЕНИ, ШИРОТ И АЗИМУТОВ В СЕРБИИ В НАЧАЛЕ XX СТОЛЕТИЯ

Дачич М.Д.

Stevan P. Boskovič finished in Serbia the Military academy, and in 1892, came in Russia with a Serbian state grant. He was the first officer of Serbian army sent on the specialization in higher geodesy and positional astronomy. From 1897 up to 1899 he was on Pulkovo observatory, where he obtains the knowledge and the practice on fundamental astronomy and astrometry. The exceptionally long military and scientific career of Stevan P. Boskovič, began in late XIX century in the Kingdom of Serbia, was continued in the Kingdom of Yugoslavia, to be finished in the Federative People's Republic of Yugoslavia. His fruitful activity was devoted to geodesy and cartography in the framework of which a large part concerns the astronomical determinations of time, latitude and of azimuth at points on the soils of Serbia and Yugoslavia, along with the longitude determination. A special importance attaches to his efforts at establishing a continuity of these works in the region of Balkan Peninsula and a link between our networks and those of Europe.

THE MOST DISTINGUISHED SERBIAN ASTRONOMER MILUTIN MILANKOVIC – ON THE OCCASION OF 125th ANIVERSARY OF HIS BIRTH

Димитрийевич М.С.

The most distinguished Serbian astronomer Milutin Milankovic (Dalj, May 28, 1879 – Belgrade, December 12, 1958), which name have a crater on the far side of the Moon, a crater on Mars and asteroid 1605, went down in the history of science as the man who explained the phenomenon of the Ice Ages by slow changes of the Earth insulation in consequence of changes of the Earth's axis inclination and of those of the parameters of the Earth's motion round the Sun. He elucidated the history of the Earth's climate as well as that of planet Mars, being in addition the author of the mathematical theory of climate and of the Earth's pole motion. He promoted the Celestial Mechanics by introducing into it the vector calculus, making besides several original contributions to the solution of the three-body. Milankovic investigated also the History of Astronomy and was a great popularizer of science. At the Orthodox Church Council in 1923 in Istanbul, he submitted the proposal concerning the reform of the calendar, providing for a more exact calendar than the Gregorian one. The calendar of Milankovic use now a part of Orthodox churches.

In this contribution, his life and contribution to astronomy is presented and analyzed.

ОСНОВНЫЕ ВЕХИ ИСТОРИИ АСТРОНОМИИ В КАЗАНИ

Дубяго И.А., Нефедьев Ю.А.

Начало преподавания астрономии в Казани уходит своими корнями ещё к Казанской гимназии, на базе которой и был открыт Университет, получивший от нее как всю материальную часть, так и состав преподавателей и слушателей. В докладе рассмотрены основные вехи развития астрономии в Казани, связанные с отдельными историческими личностями. Многие из них занимали высокие руководящие посты. Так А.А. Яковкин член-корреспондент АН УССР был директором ГАО АН УССР, проф. Д.Я. Мартынов долгое время руководил крупнейшим астрономическим учреждением страны – московским институтом им.Штернберга, член-корреспондент АН СССР В.А. Крат возглавлял ГАО АН СССР в Пулково.

Казанская школа астрономов заслужила мировое признание в области теоретической астрономии, фундаментальной астрономии, исследованиями Луны, участием в международной службе широты, в области исследования переменных звезд, теоретической астрофизики и многих других направлениях.

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ТЕЗИСЫ ДОКЛАДОВ

на Всероссийской астрономической конференции ВАК-2004 «ГОРИЗОНТЫ ВСЕЛЕННОЙ»

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весьма редкое, по теоретическим оценкам, явление – одиночную черную дыру, выброшенную из кратной системы черных дыр в ядре гигантской эллиптической галактики и аккрецирующую газ при прохождении сквозь диск спиральной галактики.

ФОТОМЕТРИЧЕСКАЯ МНОГОКОМПОНЕНТНАЯ МОДЕЛЬ ГАЛАКТИКИ

Кутузов С.А., Марданова М.А.

Для нахождения распределения яркости по изображению внешней галактики используется уравнение переноса излучения в интегральной форме. Коэффициент поглощения принимается пропорциональным плотности масс пылевой составляющей, которая моделируется гомотетическим сфероидальным распределением. Коэффициент изотропного излучения принимается пропорциональным пространственной плотности звездной составляющей. Она моделируется непрерывной суперпозицией сфероидальных компонентов с различными сферичностями. Задание весовой функции позволяет получать значительное многообразие эквилюменит. Для законов пылевой и звездной плотностей принимаются аналитические выражения со свободными параметрами. Оценки параметров находятся путем аппроксимации наблюдаемой яркости. Моделируя отношение масса/светимость и используя кривую вращения, можно строить динамическую модель галактики. Рассмотрены примеры.

ПАНОРАМНАЯ СПЕКТРОСКОПИЯ ГАЛАКТИК С ПЕРЕМЫЧКАМИ

Моисеев А.В.

Обсуждаются результаты наблюдений на 6-м телескопе САО РАН выборки дисковых галактик с центральными перемычками (барами). Применение методов панорамной спектроскопии позволило детально изучить ряд эффектов, связанных с динамической выделенностью центральных (килопарсековых) областей изучаемых галактик. Основное внимание уделяется следующим проблемам: анизотропия дисперсии скоростей звездного компонента; объекты типа бар-в-баре; околоядерные диски (в том числе – ортогональные к плоскости внешнего диска) и мини-спиральные образования в центральных областях перемычек.

ПАРАМЕТРЫ СПИРАЛЬНОЙ СТРУКТУРЫ ГАЛАКТИКИ ПО ДАННЫМ О РАССЕЯННЫХ ЗВЕЗДНЫХ СКОПЛЕНИЯХ

Попова М.Э., Локтин А.В.

По 447 РЗС разных возрастов, разделенных на 13 перекрывающихся возрастных групп, определены положения спиральных рукавов Галактики в разные моменты времени. Графики $\ln R(T)$ и $\theta(T)$, где T – средний возраст каждой группы РЗС в млн.лет, R– галактоцентрическое расстояние и θ– галактоцентрический угол, показали, что скопления всех возрастных групп "чувствуют" спиральное возмущение. При этом расстояния между спиральными ветвями для скоплений разного возраста, вплоть до возраста 10^9 лет оказываются приблизительно одинаковыми. Угловая скорость вращения спирального узора равна 22 ± 2 пк/млн.лет/кпк.

МОДЕЛЬ ДЛЯ ОБЛАСТИ ОБРАЗОВАНИЯ ШИРОКИХ ЛИНИЙ ПОГЛОЩЕНИЯ В BAL-КВАЗАРАХ

Попович Л.Ч., Danezis E., Lyratzi V., Димитрийевич М.С., Theodossiou E.

Спектр BAL-квазаров обычно интерпретируется как широкополосный континуум от центральной машины плюс широкие эмиссионные линии от области образования широких эмиссионных линий (BLR). Континуум исходит от области рядом с центром квазара, а широкие абсорбционные линии накладываются в отдельной области, вне центра, называемой областью образования широких линий поглощения (BALR). Предполагая, что BALR состоит из множества последовательных независимых поглощающих плотных слоев, которые имеют постоянную вращательную и радиальную скорости, мы развили модель для BALR. Модель может обеспечить нас основными параметрами BALR (скорости вращения и расширения и оптическая толща). В данном докладе мы представим результаты приложения модели к ультрафиолетовому спектру BALQSO PG0946+301.

АНАЛИЗ КРИВЫХ БЛЕСКА ИЗБРАННЫХ БЛАЗАРОВ В ДИАПАЗОНЕ ОТ 4.8 ДО 37 ГГЦ

Пятунина Т.Б., Кудрявцева Н.А., Габузда Д.К., Эрштад С.Г., Аллер М.Ф., Аллер Х.Д., Терасранта Х.

Результаты многолетнего VLBA мониторинга структуры избранных блазаров на частотах 22 и 43 ГГц, обеспечившего рекордное пространственное ($\sim$ 0.15 мсек дуги) и временное ($\sim$ 0.1 года) разрешение, а также теоретические исследования структуры джетов и их эволюции убедительно свидетельствуют о том, что простейшая схема "одно возмущение – одна компонента" не соответствует реальности. Становится все более очевидным, что единичное первичное возмущение в основании джета порождает сложную последовательность событий, включающую стационарные и сверхсветовые компоненты, быстрые основные компоненты и более медленные сопровождающие. Каждое из этих событий находит свое отражение в переменности, а прецессия джета, сложная структура магнитного поля и взаимодействие с неоднородностями среды еще более усложняют наблюдаемую картину. В связи с

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...АМБУРГ-САО ОБЗОР ДЛЯ ПОИСКА НИЗКОМЕТАЛЛИЧНЫХ ГАЛАКТИК (HSS–LM)

...устильник С.А., Engels D., Прамский А.Г., Kniazev A., Ugryumov A., Hagen H.-J.

HSS-LM – обзор галактик с очень сильными эмиссионными линиями (EW(5007)> 150 – 200Å) в южной галактической полусфере, в области неба с площадью 3500 кв.град. Одна из целей – поиск галактик с очень низкой металличностью (12+log(O/H)<7.65). Такие галактики очень редки, составляя не более (1–2)% от всех известных голубых компактных галактик (BCG), и являются кандидатами в молодые галактики. Другая цель – получить большую выборку BCG с хорошо измеренным содержанием кислорода и известной функцией селекции, для того, чтобы вывести распределение галактик по этому параметру, и сопоставить полученные данные с моделями хим.эволюции. Представляются промежуточные итоги, по завершению наблюдений около 75% предварительно отобранных эмиссионных галактик (около 160, из них O/H определено для 120). Открыто 5 галактик с очень низкой металличностью.

ГЛУБОКАЯ ФОТОМЕТРИЯ В ОПТИЧЕСКОМ И БЛИЖНЕМ ИК ДИАПАЗОНАХ ГАЛАКТИК С ОЧЕНЬ НИЗКОЙ МЕТАЛЛИЧНОСТЬЮ. ИХ ЭВОЛЮЦИОННЫЙ СТАТУС ПО ДАННЫМ О ВОЗРАСТАХ НАИБОЛЕЕ СТАРЫХ ЗВЕЗД

Пустильник С.А., Фиоктистова И.С., Vanzi L., Князев А.Ю.,

Одно из перспективных направлений в изучении эволюционного статуса галактик с очень низкой металличностью, которые не разрешаются на отдельные звезды, это – анализ цветов областей галактик на периферии, где вклад излучения компактной области бурного звездообразования мал. Мы представляем результаты глубокой фотометрии в фильтрах BVRI, а также узком фильтре H-alpha для нескольких таких BCG. Для части объектов мы получили также глубокие изображения в фильтрах JHK. Комплексный анализ полученных данных указывает, что цвета звезд на периферии нескольких BCG являются весьма голубыми. Сравнение этих цветов с модельными (PEGASE.2) приводит к выводу, что эти объекты могут быть молодыми галактиками, с возрастами менее 500 млн. лет.

МОЛОДЫЕ ГАЛАКТИКИ В БЛИЖНЕЙ ВСЕЛЕННОЙ: ПОЧЕМУ ЗВЕЗДООБРАЗОВАНИЕ В НИХ ВСЕ-ТАКИ НАЧАЛОСЬ?

Пустильник С.А., Прамский А.Г., Фиоктистова И.С., Князев А.Ю., Chengalur J.

Многие голубые компактные галактики с очень низким содержанием металлов ($Z < 1/20Z_{sun}$) рассматриваются как кандидаты в локальные молодые галактики. В частности, I Zw 18, SBS 0335–052 E и W являются вероятными молодыми галактиками с возрастами менее 500 млн. лет. Теоретические модели предсказывают возможное существование очень устойчивых газовых протогалактик, которые могли остаться в таком состоянии до современной эпохи. Если наблюдаемые немногочисленные молодые галактики – это и есть те самые очень устойчивые протогалактики, то почему в них все-таки недавно началось образование звезд? Мы показываем, что в большой доле таких карликовых галактик имеет место взаимодействие (или даже слияние) с близким объектом сравнимой массы. Это приводит к потере устойчивости, коллапсу газа и включению первой вспышки звездообразования. Имеются ли альтернативные механизмы, приводящие к вспышкам звездообразования в молодых галактиках, пока не ясно, но описанный механизм является реально наблюдаемым по крайней мере в трети таких объектов.

КВАЗИОДНОВРЕМЕННЫЕ РСДБ И РАТАН-600 НАБЛЮДЕНИЯ АКТИВНЫХ ЯДЕР ГАЛАКТИК

Пушкарев А.Б., Ковалев Ю.Ю., Самодуров В.А., Молотов И.Е., Нечаева М.Б., Горшенков Ю.Н., Туккари Дж., Хонг Ш., Куик Д., Доугхерти Ш., Лю Ш.

В рамках проекта LFVN в ноябре-декабре 1999 года были проведены РСДБ наблюдения ряда квазаров и объектов типа BL Lacertae на частоте 1.66 ГГц. В эксперименте

• Александр Бугров, получив увольнение от крестьянского общества, стал своекоштным студентом физико-математического факультета Императорского Московского Университета в 1811 г.
• Прошения, поданные А.Бугровым Министру Народного Просвещения графу А.К. Разумовскому и попечителю Московского Университета П.И. Голенищеву-Кутузову, по поводу получения средств на приобретение в С.-Петербурге астрономических инструментов, книг и таблиц для Московского Университета в 1815 году.
• Сдача Бугровым 10 мая 1819 г. экзамена на степень кандидата физико-математического отделения.
• Организация А.Бугровым устройства солнечных часов на восстановленном здании Московского Университета (Моховая, 11).
• Защита А. Бугровым 9 февраля 1821 г. диссертации «Об эллиптическом движении небесных тел» на степень магистра отделения физико-математических наук.
• Принятие 7 сентября 1821 г. на заседании Совета Университета решения о посылке магистра Бугрова в чужие края (Германию и Францию) на два года для усовершенствования в астрономии.
• Трагическая гибель 28-летнего А. Бугрова 13 октября 1821 года.

ПУЛКОВСКИЙ ВЫПУСКНИК С.П. БОШКОВИЧ И ЕГО ОПРЕДЕЛЕНИЕ ВРЕМЕНИ, ШИРОТ И АЗИМУТОВ В СЕРБИИ В НАЧАЛЕ XX СТОЛЕТИЯ

Дачич М.Д.

Stevan P. Boskoviĉ finished in Serbia the Military academy, and in 1892, came in Russia with a Serbian state grant. He was the first officer of Serbian army sent on the specialization in higher geodesy and positional astronomy. From 1897 up to 1899 he was on Pulkovo observatory, where he obtains the knowledge and the practice on fundamental astronomy and astrometry. The exceptionally long military and scientific career of Stevan P. Boskoviĉ, began in late XIX century in the Kingdom of Serbia, was continued in the Kingdom of Yugoslavia, to be finished in the Federative People's Republic of Yugoslavia. His fruitful activity was devoted to geodesy and cartography in the framework of which a large part concerns the astronomical determinations of time, latitude and of azimuth at points on the soils of Serbia and Yugoslavia, along with the longitude determination. A special importance attaches to his efforts at establishing a continuity of these works in the region of Balkan Peninsula and a link between our networks and those of Europe.

THE MOST DISTINGUISHED SERBIAN ASTRONOMER MILUTIN MILANKOVIC – ON THE OCCASION OF 125th ANIVERSARY OF HIS BIRTH

Димитрийевич М.С.

The most distinguished Serbian astronomer Milutin Milankovic (Dalj, May 28, 1879 – Belgrade, December 12, 1958), which name have a crater on the far side of the Moon, a crater on Mars and asteroid 1605, went down in the history of science as the man who explained the phenomenon of the Ice Ages by slow changes of the Earth insulation in consequence of changes of the Earth's axis inclination and of those of the parameters of the Earth's motion round the Sun. He elucidated the history of the Earth's climate as well as that of planet Mars, being in addition the author of the mathematical theory of climate and of the Earth's pole motion. He promoted the Celestial Mechanics by introducing into it the vector calculus, making besides several original contributions to the solution of the three-body. Milankovic investigated also the History of Astronomy and was a great popularizer of science. At the Orthodox Church Council in 1923 in Istanbul, he submitted the proposal concerning the reform of the calendar, providing for a more exact calendar than the Gregorian one. The calendar of Milankovic use now a part of Orthodox churches.

In this contribution, his life and contribution to astronomy is presented and analyzed.

ОСНОВНЫЕ ВЕХИ ИСТОРИИ АСТРОНОМИИ В КАЗАНИ

Дубяго И.А., Нефедьев Ю.А.

Начало преподавания астрономии в Казани уходит своими корнями ещё к Казанской гимназии, на базе которой и был открыт Университет, получивший от нее как всю материальную часть, так и состав преподавателей и слушателей. В докладе рассмотрены основные вехи развития астрономии в Казани, связанные с отдельными историческими личностями. Многие из них занимали высокие руководящие посты. Так А.А. Яковкин член-корреспондент АН УССР был директором ГАО АН УССР, проф. Д.Я. Мартынов долгое время руководил крупнейшим астрономическим учреждением страны – московским институтом им.Штернберга, член-корреспондент АН СССР В.А. Крат возглавлял ГАО АН СССР в Пулково.

Казанская школа астрономов заслужила мировое признание в области теоретической астрономии, фундаментальной астрономии, исследованиями Луны, участием в международной службе широты, в области исследования переменных звезд, теоретической астрофизики и многих других направлениях.

ВАК–2013

Всероссийская астрономическая конференция

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Санкт-Петербург

ШИРОКОПОЛОСНЫЕ ПРИЕМНЫЕ ФАР СВЧ ДИАПАЗОНА: РЕАЛИЗАЦИЯ ДИАГРАММООБРАЗУЮЩИХ СХЕМ НА БАЗЕ ЭЛЕМЕНТОВ АНАЛОГОВОЙ ФОТОНИКИ

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В докладе обсуждается решение задачи диаграммоформирования в широкополосных (частотное перекрытие – до 3-х и более октав) многоэлементных фазированных антенных решетках (ФАР) СВЧ диапазона с применением элементной базы аналоговой фотоники. Варианты построения оптических ДОС для ФАР и их достоинства в последние 10-15 лет широко обсуждаются в литературе [1-2]. На основе анализа публикаций различных исследовательских групп нами выбраны несколько схем оптических ДОС, реализующих подход true time delay beamforming (TTD) – диаграммоформирование с истинно временными задержками в диапазоне частот до 12-15 ГГц, перспективных с точки зрения возможности их реализации с применением представленной на рынке элементной базы фотоники. В докладе приводятся методика и результаты расчета основных рабочих характеристик оптических ДОС: отношения сигнал/шум, динамического диапазона, пороговой чувствительности, важных для различных применений приемных антенных решеток, в том числе и для радиоастрономии.

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ИОН-АТОМНЫЕ АБСОРБЦИОННЫЕ ПРОЦЕССЫ В ФОТОСФЕРЕ СОЛНЦА НАД СОЛНЕЧНЫМИ ПЯТНАМИ

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В продолжение предыдущих исследований ион-атомных абсорбционных процессов в УФ и ЭУФ областях спектра в атмосфере спокойного Солнца эти процессы рассматриваются в фотосфере Солнца над солнечными пятнами. Мы имеем в виду абсорбционную перезарядку в симметричных ($H+H^+$) и строго несимметричных ($H+X^+$) ион-атомных столкновениях и фотодиссоциацию соответствующих молекулярных ионов (H_2^+ и HX^+), где X означает атом одного из металлов. В этой работе все абсорбционные процессы исследуются при условиях, характеризирующих релевантную модель солнечных пятен, принимая X=Na, Si, Al, Mg и Ca. Эффективность рассмотренных ион-атомных абсорбционных процессов сравнивается с эффективностью конкурирующих процессов, включая процессы фотоионизации атомов присутствующих металлов. Цель этого исследования – показать, что в упомянутых спектральных областях ион-атомные абсорбционные процессы влияют на непрозрачность фотосферы Солнца над солнечными пятнами настолько значительно, что заслуживают быть включенными в соответствующие модели солнечной фотосферы.

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SP08 - 201

STARK SHIFTS DEPENDENCE ON THE UPPER LEVEL IONISATION POTENTIAL AND THE REST CORE CHARGE OF THE EMITTER WITHIN ns-np TRANSITION ARRAYS

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Stark shift simultaneous dependence on the upper level ionization potential and rest core charge of the emitter has been evaluated and discussed. It has been verified that the found relations, connecting Stark broadening parameters with upper level ionization potential and rest core charge of the emitters for particular electron temperature and density, can be used for prediction of Stark line width and shift data in case of ions for which observed data, or more detailed calculations, are not yet available. Stark widths and shifts published data are to demonstrate the existence of other kinds of regularities within similar spectra of different elements and their ionization stages. The emphasis is on the Stark parameter dependence on the upper level ionization potential and on the rest core charge for the lines from similar spectra. The found relations connecting Stark shift parameters with upper level ionization potential, rest core charge and electron temperature were used for a prediction of new Stark broadening data, thus avoiding much more complicated procedures.

SP08 - 202

STARK WIDTHS IN THE F II 3S' – 3P' TRANSITION

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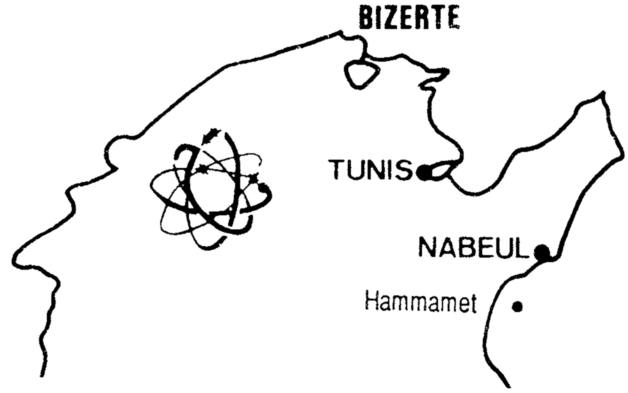
Stark FWHM (full-width at half intensity maximum, W) of four singly ionised fluorine (F II) spectral lines (410.917 nm, 354.177 nm, 429.918 nm and 320.274 nm) in $2p^33s'$ - $2p^3(^2D^0)3p'$ transition have been measured in a linear, low-pressure, pulsed arc discharge created in SF_6 plasma at 30 400 – 33 600 K electron temperatures and at (2.75-2.80) 10^{23} m^{-3} electron densities. The measured Stark widths have been compared with our theoretical data obtained within the semiclassical perturbation formalism (SCPF).

الجمعية التونسية للفيزياء

Société Tunisienne de Physique



الملتقى القومي الخامس للبحث في الفيزياء

Cinquième Colloque National de Recherche en Physique

الحمامات 17، 18 و 19 مارس 1995

Hammamet 17, 18 et 19 Mars 1995

Vème COLLOQUE NATIONAL DE RECHERCHE EN PHYSIQUE

Fonctions d'élargissement Stark pour les émetteurs neutres et ionisés

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Résumé

L'élargissement Stark d'une raie spectrale émise par un émetteur plongé dans un plasma est couramment calculé dans le cadre de la théorie semi classique avec l'approximation d'impact. La contribution du terme d'interaction dipolaire, au second ordre de perturbation, fait intervenir les fonctions de largeur et de déplacement notées respectivement A et B.

L'opérateur d'élargissement électronique, dont les parties réelle et imaginaire donnent la largeur et le déplacement, est proportionnel au produit du carré de l'intégrale radiale et de la fonction A + i B intégrée sur les paramètres de la collision.

Ces fonctions, ainsi que les fonctions a et b obtenues après intégration sur le paramètre d'impact, ont été étudiées pour les émetteurs neutres par Seaton en 1962, Griem et al. en 1962. Pour les émetteurs ionisés, ces fonctions sont calculées par Burgess en 1964, Bréchot en 1967, Feutrier en 1968, S. Bréchot en 1969 et Klarsfeld en 1970.

Plus récemment, des expressions de ces fonctions sont déduites par Kissami et Fleurier en 1988, Dimitrijevic et Ben Nessib en 1990, Dimitrijevic et S. Bréchot en 1992 et Ben Nessib, Ben Lakhdar et Dimitrijevic en 1993.

Dans ce travail, nous présentons une nouvelle expression analytique simple de la fonction A déduite des formes asymptotiques qui pour les émetteurs neutres ne s'écarte que de 5% de l'expression exacte. Son domaine de validité est évalué pour les émetteurs ionisés.

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STARK BROADENING OF Ni II SPECTRAL LINES

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The first experimental determination of Ni II Stark widths and shifts has been performed recently [1]. By using the semiclassical-perturbation formalism [2,3,4] we have calculated Stark broadening parameters for two lines withins Ni II a^4F - z^4G^o multiplet.

Table 1. Comparison of experimental and theoretical Stark widths (FWHM) and shifts for Ni II lines within the a^4F - z^4G^o multiplet at an electron density of 5.5 10^{17} cm^{-3} and temperature of 17000 K. W_M, d_M - experimental widths(FWHM) and shifts [1]; W_{DSB}, d_{DSB} - present semiclassical electron - impact widths(FWHM) and shifts; W_{ArII}, d_{ArII} - present semiclassical Ar II - impact widths and shifts; W_{MSE} - by using the MSE method [5]; W_{SMSE} - by using the SMSE method [6].

Wave-length (Å)	W_m (Å)	d_m (Å)	W_{DSB} (Å)	d_{DSB} (Å)	W_{ArII} (Å)	d_{ArII} (Å)	W_{MSE} (Å)	W_{SMSE} (Å)
2264.5	0.056	0.022	0.031	-0.00032	0.0025	-0.00013	0.018	0.015
2270.2	0.050	-	0.030	-0.00038	0.0025	-0.00014	0.018	0.014

In Table 1 the present semiclassical full half-widths have been compared with experimental results [1] as well as with results of present calculations by using the modified semiempirical approach (MSE-Ref. 5) and its symplified version (SMSE-Ref.6). The differences between theory and experiment are such that a new experiment is of interest.

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RADIATIVE SYMMETRICAL ION-ATOM COLLISIONS AS AN ADDITIONAL SOURCE OF CONTINUOUS RADIATION FROM WEAKLY-IONIZED PLASMA

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We consider the processes of radiative ion-atom photoassociation/photodissociation $A^+ + A \Longleftrightarrow h\nu + A_2^+$ and radiative charge transfer $A^+ + A \Longleftrightarrow h\nu + A + A^+, A^+ + A$ where A, A^+ and A_2^+ denote an atom and the corresponding atomic and molecular ions. The reactions have been treated in the semiclassical and quasi static [1-3] approximations in the case where the optically active shell of A has been assumed to contain s-electrons only. These radiative processes are particularly important for weakly-ionized plasmas. In such plasmas, ion-atom collisions are predominantely slow ($v << 1$ au) and the radiation processes can be accurately modelled in the approximation of two molecular electronic terms.

The semiclassical differential cross sections for spontaneous photon emission induced by the ion-atom collision have been first obtained. In the approximations adopted, the differential cross sections can be presented in an analytical form convenient for applications. The cross sections have then been used to determine the spectral intensity of spontaneous emission and the corresponding absorption spectral coefficients. The theory is applicable to equilibrium as well as non-equilibrium plasmas. For LTE, the resulting coeffcients are also presented analytically.

The numerical calculations have been carried out for A = H and He in the temperature domain $4000\ K \leq T \leq 20000\ K$ and for A = Li and Na in the domain $T \leq 4000\ K$, within the optical range $200 \leq \lambda \leq 800$ nm. We have also studied the effect of pressure in the H and He plasmas. The λ and T ranges where ion-atom radiative processes significantly contribute to the total continuous radiation from plasma, have been established. The ion-atom radiative processes are found to be particularly important if the stabe A^- atomic ions do not exist, *i.e.* in the helium plasmas, among the atomic speices presently studied.

The reported results are new for the helium and alkaline plasmas while for the hydrogenic plasma they cover an extended range of plasma parameters which is of current experimental interest but has not been previously studied.

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VOLUME
4 D

STARK BROADENING OF NII, NIII and NIV LINES

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A critical review[1] of all available experimental data on the Stark widths and shifts of non-hydrogenic lines of singly ionized atoms indicated that measured widths are generally in a fairly good agreement (within ±20%) with comprehensive semiclassical theory developed by Griem and coworkers[2,3]. Experimental results for singly-ionized nitrogen fit well in this picture. Until recently, only single experimental paper has reported Stark broadening data of four doubly-ionized nitrogen lines[4]. However, for the comparison with this experiment semiclassical theoretical data were not available.

Recently a new experimental study of the Stark broadening of prominent NII, NIII and NIV ion lines at high electron density and elevated electron temperature 58000K has been reported[5]. Direct comparison of these results with other experimental[4,6-8] and theoretical data[2,3] for 3s-3p and 3p-3d transitions of NII indicates typical discrepancy of the order of two. Results for the transitions 3s-3p (multiplet no.1) of doubly-ionized nitrogen are compared with a single available experimental linewidth[4] and discrepancy goes up to factor of three.

In order to clarify this, rather large discrepancy with other experiments and the theory we have performed an additional analysis of the experimental procedure and the results reported in Ref. 5. A number of the theoretical linewidths are also evaluated. Results of this analysis and comparisons of theoretical and experimental results will be presented at the Conference.

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STARK LINE WIDTHS OF SOME LITHIUM ISOELECTRONIC SEQUENCE IONS

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An investigation of line widths of highly ionized atoms has many important applications. Recent advances in fusion research have made possible detailed spectral observation of thermonuclear plasmas[1] and the application of Stark broadening data to diagnose the compression of the pellet implosion plasmas[2]. Also, an interpretation of the physical conditions in astrophysical plasmas depends on the accurate knowledge of the line shapes. Lithium-like ions are often present as contaminants in fusion research plasmas. They are also identified in many stellar objects[3,4].

In this study we calculated Stark widths for resonance lines of some ions from the lithium-isoelectronic sequence. Calculations have been performed according to (i) the semiclassical approach (eq. 526 in ref.5), (ii) its modified version[6] and (iii) the modified semiempirical theory[6]. In some cases, detailed semiclassical calculations were also carried out. Dependence of Stark line widths from radiator charge Z is investigated, and the validity of the applied theories for radiators with $z > 3$ is discussed, too.

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VOLUME 4 D

SEMICLASSICAL CALCULATIONS OF THE STARK WIDTHS OF CIII AND CIV

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In spite of the importance of Stark broadening parameteres for investigations of laboratory and stellar plasmas, theoretical results for the multiply charged ions, calculated according to the most widely used version of the semiclassical theory[1,2] do not exist. In this study, the semiclassical theory[1,2] has been used for calculating CIII and CIV Stark line widths, that have been the subject of experimental study[3]. The results obtained are presented in Table 1. Here, W_{SC} are semiclassical line width (FWHM), W_m are experimental values[3], W_G - approximative semiclassical calculations (according to eq. 526 in ref. 2) performed by Griem[2] and W_{SEM} modified semiempirical calculations[4].

As one can see from the Table 1 all results compare better for CIII than for CIV, where semiclassical results are consistently higher.

Table 1.

Transition	λ(Å)	W_m(Å)	W_{SC}(Å)	W_G(Å)	W_{SEM}(Å)
CIII $3s\,^3S-3p\,^3P^o$	4647.4	0.95	1.7	1.4	0.98
$3s'\,^1P^o-3p'\,^1D$	4325.7	2.1	2.0	1.3	1.0
$3p\,^1P^o-3d\,^1D$	5696.0	1.9	2.4	2.0	1.4
$3p\,^1P^o-4d\,^1D$	1531.8	0.43	0.74	0.49	0.42
$3d\,^1D-4f\,^1F^o$	2162.9	0.46	0.66	0.60	0.27
$4p\,^3P^o-5d\,^3D$	3609.3	6.2	9.0	7.3	9.4
$4f\,^1F^o-5g\,^1G$	4187.0	4.1	4.3	5.3	3.2
CIV $2s\,^2S-2p\,^2P^o$	5801.5	1.6	2.9	1.7	1.6
$3s\,^2S-3p\,^2P^o$	1548.2	0.024	0.048	0.016	0.012

Experimental conditions: T = 60000K; $N_e = 4\times10^{17}\,cm^{-3}$

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ВЕСНИК

УДРУЖЕЊЕ УНИВЕРЗИТЕТСКИХ ПРОФЕСОРА И НАУЧНИКА СРБИЈЕ година XIX број 20, јануар 2009.

МИЛУТИН МИЛАНКОВИЋ И ТАЈНА ЛЕДЕНИХ ДОБА

Др Милан С. Димитријевић*

Милутин Миланковић (Даљ, 28. мај 1879. – Београд, 12. децембар 1958), потпредседник Српске академије наука, руководилац београдске Астрономске опсерваторије и ректор Универзитета у нашој престоници, у историју науке ушао је као човек који је објаснио појаву ледених доба, спорим променама у осунчавању Земље услед различитих утицаја због којих се мења нагиб Земљине осе и карактеристике њеног кретања око Сунца. Растумачио је и историју климе на Земљи и дао теорију о померању њених полова, што је, како данас знамо, последица померања континенталних плоча. Унапредио је небеску механику у коју је увео векторски рачун, а аутор је и неколико оригиналних доприноса решавању проблема три тела. Бавио се и питањем реформе календара, предложивши његово побољшање. Дао је значајан допринос популаризацији науке и организацији астрономије код нас.

Миланковић започиње каријеру у Бечу као грађевински инжењер где убрзо постаје виши инжењер. На позив да дође у Србију и допринесе образовању свога народа, напушта европски Беч и долази у отаџбину да помогне њеном развоју. Министар просвете и црквених послова Љубомир Стојановић потписује 9. септембра 1909. године указ о постављењу Милутина Миланковића за ванредног професора Примењене математике, коју су чиниле Рационална механика, Небеска механика и Теоријска физика. Тако Миланковић долази у Србију, у Београд, и започиње универзитетску каријеру.

Милутин Миланковић
(рад Паје Јовановића)

Почетком *XX* века, велика научна загонетка било је постојање четири велика ледена доба у Европи у последњих шест стотина хиљада година. Имена Вирм, Рис Миндел и Гинц добила су по именима речица у Баварској и Швајцарској где су нађени њихови трагови. Последње се завршило пре нешто више од десет хиљада година, а у највећим налетима хладноће на многим местима у Европи било је као данас на Антарктику.

Милутин Миланковић, по доласку у Београд 1909. године, почиње рад на истраживању астрономских узрока који утичу на настанак ледених доба. Сматрао је да до оваквих појава могу да доведу три узрока.

(а) Промене нагиба Земљине осе између 22° и 24,5° са периодом од 41.000 годину, услед чега се мењају услови осунчавања на некој изабраној тачки на површини наше планете.

Да бисмо разумели зашто је ова промена значајна, замислимо шта би било када такав нагиб не би постојао. Онда би у току целе године на свакој тачки на Земљи било увек исто годишње доба. На северу би била вечита зима што би довело до ширења леденог покривача и његовог продирања ка југу. У Европи би завладало стално ледено доба. Овакве екстремне ситуације треба само да покажу колико су и много мање промене од 2,5 степена важне за климу.

(в) Прецесија услед које се пролећна или гама тачка (тачка на небу у којој се привидно налази Сунце у тренутку почетка пролећа) помера дуж привидне годишње Сунчеве путање, са периодом од 22.000 година, што утиче на трајање годишњих доба.

На своме путу око Сунца Земља се понаша као чигра, која се споро врти и њена оса описује површину купе. Ова појава назива се прецесија. На њу утиче и Месец који изазива додатно "тетурање" наше планете које се назива нутација. Како то може да утиче на количину топлоте која нам долази од Сунца?

Ако би неко поставио питање када је наша планета најближа Сунцу, колико њих би одговорило да је то зими, године 2009. 4. јануара? Али управо због тога, она се брже креће него лети када је најдаља од наше звезде (4. јула), па у Европи најхладније годишње доба траје седам дана и четрнаест часова краће него најтоплије. Али услед прецесије, то ће се мењати и наступиће време када ће трајати дуже.

Наставак на 2. страни

*Аутор је научни саветник у Атрономске опсертаворије, Београду

УНИВЕРЗИТЕТСКИ ВЕСНИК

ЛИСТ УДРУЖЕЊА УНИВЕРЗИТЕТСКИХ ПРОФЕСОРА И НАУЧНИКА СРБИЈЕ

Година XIX, број 20

април 2009.

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МИЛУТИН МИЛАНКОВИЋ И ТАЈНА ЛЕДЕНИХ ДОБА

Др Милан С. Димитријевић

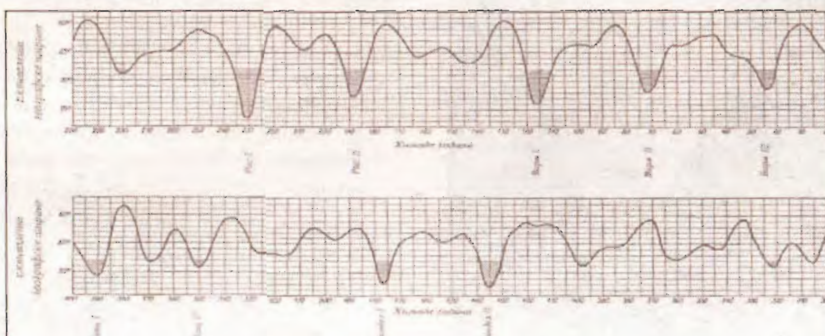
Настанак са 1. стране

Наиме топлији део године у Европи је време када се Сунце привидно креће од пролећне до јесење тачке, односно од пролећне до јесење равнодневице. Пролећна тачка се креће дуж привидне путање Сунца, односно у стварности се помера место на елиптичној путањи Земље када почиње пролеће. Ако пролеће почиње када је Земља најближе или најдаље од Сунца, топлија и хладнија половина године су исте дужине. Ако је она најближа Сунцу у сред зиме или лета, разлика у трајању топлије и хладније половине године је највећа.

(б) Промена ексцентричности Земљине путање око Сунца од једног до шест процената, са периодом од 100.000 година, услед чега се мења удаљеност од Сунца што има утицај и на трајање годишњих доба.

Мада су промене који сваки од наведених узрока изазива мале, када сва три делују заједнички, њихов утицај постаје значајан.

Проблем који је стајао пред Миланковићем био је и како посматрати деловање ових утицаја, односно шта мерити. Он је уочио да су за настанак



Миланковићева крива осунчавања. На апсциси је време од данашњег тренутка обележеног са 0 д до 600.000 година уназад, а на ординати је еквивалентна ширина која показује којој данашњој географској ширини одговара осунчавање на ширини 65о у неком тренутку прошлости.

ледених доба много значајнија хладна лета него хладне зиме. Наиме у Сибиру, где температура зими иде и до –50°C а лети до +30°C нема глечера пошто високе летње температуре изазивају топљење снега. А велики

љају само у добу које геолози зову квартар, а не тако изразито и раније, Миланковић 1932. године формулише диференцијалну једначину кретања Земљиних полова. Данас знамо да је то уствари последица померања континенталних плоча. Он налази да се пре око 300 милиона година северни пол налазио у Тихом океану, а и данас се креће према свом крајњем, равнотежном положају у Сибиру, близу места где река Печора утиче у Северни ледени океан.

Осим тога, Миланковић је узео у обзир да када ледено доба почне и снег и лед се нагомилају до неке висине, средња температура, која је на планинама све нижа и нижа како се више пењемо почиње да опада како висина леденог покривача расте. Зато када он достигне довољну висину, ледено доба ће трајати све док опет три удружена астрономска узрока не доведу до промене климе.

Миланковић је своје решење тајне ледених доба имао разасуто у 28 чланака и увидео је потребу да сe научној јавности стави на располагање једна јединствена публикација. Зато је настало његово најзначајније дело, Канон осунчавања Земље и његовог утицаја на проблем ледених доба, написано на немачком језику, у коме је дао комплетно решење ове загонетке. То је капитално научно дело, монографија која укључује резултате ис-

нства", као и љубав према таквој историји.

У књизи Техника у току давних векова са жаљењем констатује да "док би дела светске историје напунила велику библиотеку, најважнија дела историје математике, астрономије и физике могу се сместити у ма којој личној библиотеци". За разлику од светске историје, према Миланковићу, у повесници науке уместо наследних владара, главну улогу играју они који су своје место у историји освојили снагом духа и напомиње да се "вределo упознати изближе са њима! Зато се моја лична библиотека из године у годину обогаћивала делима из историје егзактних наука и њихових примена".

Написао је Историју астрономске науке од њених почетака до 1727, која је први пут објављена 1948. године. У овој занимљивој и веома лепо документованој књизи, која је истовремено и уџбеник, обухватио је период од првих почетака астрономске науке па до Њутнове смрти 1727. године. Он ту даје и оригинални научни допринос, "као што је на пример рашчишћавање улоге Аристарха у развоју хелиоцентричне мисли или доказ да је Аполоније створио своју знамениту теорију епицикала полазећи од хелиоцентризма, а не од геоцентризма, као што се пре њега сматрало".

Своје изванредно дело у области популаризације астрономске науке, књигу Кроз васиону и векове, почео је да пише у лето 1925. године у Аустрији. У периоду од 1926. до 1928. године објављивао га је у наставцима у "Летопису Матице српске", а као књига штампана је 1928. Превео је на немачки 1936. године при чему је прерадио и знатно проширио текст, а друго немачко издање изашло је у Лајпцигу 1939. Вредно је напоменути да је ова књига у немачким школама улазила у обавезну лектиру. Занимљиво писана у облику писама са обиљем података о историји астрономије и њеним проблемима, вероватно је наша највише објављивана књига из области популаризације науке.

На сабору Православне цркве у Цариграду, 1923. године, прихваћен је предлог српског астронома Милути-

ред.проф. Факултета за специјалну едукацију и рехабилитацију
(у пензији)

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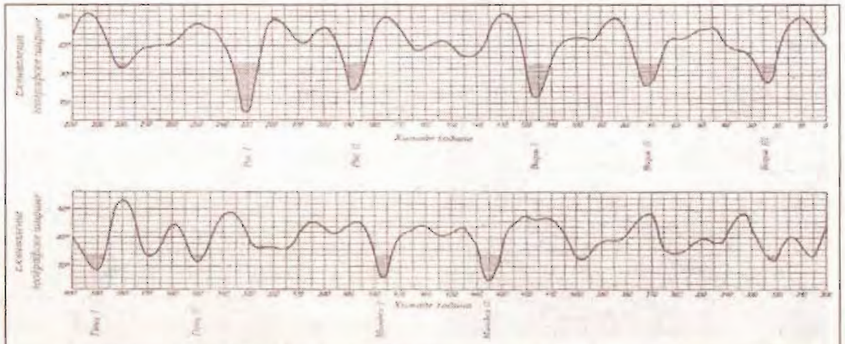
мерити. Он је уочио да су за настанак



Миланковићева крива осунчавања. На апсциси је време од данашњег тренутка обележеног са 0 g до 600.000 година уназад, а на ординати је еквивалентна ширина која показује којој данашњој географској ширини одговара осунчавање на ширини 65о у неком тренутку прошлости.

ледених доба много значајнија хладна лета него хладне зиме. Наиме у Сибиру, где температура зими иде и до –50°C а лети до +30°C нема глечера пошто високе летње температуре изазивају топљење снега. А велики део Гренланда, где је зими око –10°C а лети +8°C, је под снегом и ледом. Зато Миланковић рачуна како се у току последњих 600.000 година мења географска ширина тачке која у току лета прими од Сунца онолико топлоте колико данас прима тачка на 65о географске ширине, односно којој данашњој географској ширини одговара осунчавање на ширини 65° у неком тренутку прошлости. На слици видимо да је у највећем налету хладноће у току прве фазе леденог доба Рис, тачка која се налазила на 65° географске ширине (Исланд, Архангелск), примала количину Сунчеве топлоте као данас тачка на 77° (Шпицберг, Земља Фрања Јосифа у Северном леденом океану).

Тако је Миланковић добио своју чувену криву осунчавања Земље, која је у првобитном облику била са много ужим минимумима. Они су се у потпуности поклапали са геолошки установљеним леденим добима и свим њиховим фазама.

Главна питања оних који су оспоравали ове резултате била су: Зашто је до изразитих и дуготрајних ледених доба у Европи долазило само у последњих 600.000 година а не и раније? Зашто су ледена доба трајала веома дуго, а минимуми које показује Миланковићева крива су много ужи?

Да би одговорио на прво питање – зашто се ледена доба у Европи јав-

настало његово најзначајније дело, Канон осунчавања Земље и његовог утицаја на проблем ледених доба, написано на немачком језику, у коме је дао комплетно решење ове загонетке. То је капитално научно дело, монографија која укључује резултате истраживања, претходно публиковане у 28 научних радова. У овој монографији они су сакупљени у целину, заједно са новим анализама и додацима и са бројним примерима и применама. У Канону Миланковић даје математичку теорију климе на Земљи (која се може применити и на друге планете), објашњава порекло и узроке настанка ледених доба и даје своју теорију померања Земљиних полова.

Канон је грчка реч у значењу правило, пропис, мерило или узор. Употребљава се и да означи књигу или списе који су проглашени за аутентичне, као што је то Свето писмо. Миланковић је и именом свога дела хтео да покаже да иза резултата изложених у њему не стоје претпоставке и апроксимације, него да су то универзалне законитости. У предговору каже да је један од разлога и што је Ополцер тако назвао своје чувено дело у коме је дао податке о помрачењима Сунца и Месеца у прошлости и будућности.

Миланковић је посебну пажњу посвећивао историји науке – Интерес за историју науке. У својим Успоменама, доживљајима и сазнањима, истиче "да се свака наука може само онда у потпуности схватити када се упозна њен постанак и постепени развитак" и описује како се у њему "зачела мисао да је историја наука највеличанственији део целе историје човеча-

хелиоцентричне мисли или доказ да је Аполоније створио своју знамениту теорију епицикала полазећи од хелиоцентризма, а не од геоцентризма, као што се пре њега сматрало".

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На сабору Православне цркве у Цариграду, 1923. године, прихваћен је предлог српског астронома Милутина Миланковића за реформу Јулијанског календара. Он је предложио правило да су преступне године које се завршавају са две нуле само ако број векова који садрже подељен са 9 даје остатак 2 или 6. На тај начин уместо 3 дана у 4 столећа, као што је то у Јулијанском календару, треба одузети 7 дана у 9 столећа. То значи да би само 2 од 9 година којима се завршавају столећа биле преступне. На пример 2000. година којом се завршава XX век је преступна пошто је 20:9=18 и остатак је 2. Миланковићев предлог се у средњем разликује од праве тропске године за 0,000002 дана.

Милутин Миланковић је најзнаменитији српски астроном, а по некима и наш најистакнутији научник. У прилог томе треба истаћи да је за разлику од Николе Тесле и Михајла Пупина који су до својих открића дошли у иностранству, Миланковић светску славу стекао радећи у Београду, у својој скромној соби у Капетан Мишином здању.

У част његових научних достигнућа на пољу астрономије, на XIV конгресу Међународне астрономске уније у Брајтону, један кратер на невидљивој страни Месеца добио је његово име. На XV конгресу ове организације у Сиднеју, његово име је добио и један кратер на Марсу, а 1982. је мала планета, коју су 1936. открили Милорад Протић и Перо Ђурковић, добила име 1605 Миланковић.

5th International Conference on

GAS DISCHARGES

University of Liverpool
11-15 September 1978

Rapporteur's Reports

8.8 Effect of collisions on the low frequency oscillations in a plasma with negative ions

by M. V. Popovic, M. Dimitryevic and M. Platisa

The waves considered by these authors are drift waves. These arise when one has a density gradient in a magnetic field, in this case in the x and z directions respectively. The inhomogeneity has an associated current perpendicular to the magnetic field. The dispersion relation is then different from that of a uniform plasma.

The authors consider the case where negative ions are also present, a situation which can be produced in a Q-machine. In the present paper the effects of collisions are included and viscosity terms are also included, for the ions. Quasi-neutrality has been assumed, since low frequency waves are being studied. The continuity equations and the equations of motion are employed for the three species (electrons, positive ions and negative ions). Looking for wave solutions which travel at an arbitrary angle to the magnetic field leads to a system of 12 equations. Some results are presented for the case of propagation along the magnetic field, where the number of simultaneous equations is reduced to 6. The plots show the phase velocity of the wave, normalized in terms of the drift velocity of the positive ions, as a function of the ratio of negative to positive ions. The results appear to show, for the parameters chosen, that the negative ions only influence the dispersion when collisions are taken into account. Unstable solutions are also found when collisions are taken into account.

The calculations are for Caesium or Potassium positive ions coexisting with chlorine negative ions. Such mixtures can be produced in a Q-machine, since chlorine has a high electron affinity (3.6 - 3.8 eV). The rapporteur is not entirely clear about the motivation for the work, since the situation seems to be very contrived.

One question for the authors is the following: does the treatment in the absence of collisions differ greatly from kinetic theory treatment using the Vlasov equation?

TRENDS IN PHYSICS

5th GENERAL CONFERENCE

of the

EUROPEAN PHYSICAL SOCIETY

in collaboration with the Turkish Physical Society

Istanbul, 7-11 Sept. 1981

abstracts

CLASSICAL INVESTIGATIONS OF $e^+ + H \rightarrow H^+ + e^- + e^+$ REACTION NEAR THE THRESHOLD

M. S. Dimitrijević[†] and P. Grujić[‡]

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Electron - hydrogenic target collisions near the ionizational threshold have been extensively studied in the last decade. The high symmerty of the final configuration of a double escape has enabled rigorous analytical treatments to be carried out, both within classical[1] and semiquantum mechanical approaches (e.g. Ref. 2). The classical trajectory method has provided, apart of confirming threshold laws, a number of additional informations about relevant physical quantities around the threshold.[3]

Because of the great difference between positron and proton masses, the single escape configuration possesses different degree of symmetry compared with two-electron (double escape) case. As shown by Klar,[4] in the case of the zero total angular momentum dominant contribution to the ionization probability near the threshold comes from a colinear motion, with the electron approximately half-way between positron and proton.

In the present calculations we use somewhat different initial configurations from all previous set-ups, which all were restricted to the plane case. This time the total angular momentum has been chosen to be 1 au, thus allowing positronium to be formed without transfering a large angular momentum to the nucleus. As shown in Fig. 1, the resulting angular momentum lies in O_{xy} plane, with the major axis of the atomic electron Keplerian orbit on O_z axis. Further, we choose to vary the initial position of the target electron and examine corresponding ionization interval.[3] For that purpose the three-body classical computer code by Abrines _et al._[5] has been used, modified appropriately for the problem at hand.

The atomic electron orbit is specified initially by three Euler angles,[5] eccentricity $\varepsilon = 2^{-\frac{1}{2}}$ and the ground state energy $E_n = -1/2$ au. The program then solves a set of Newton's equtations and provides a final state configuration. Double precision mode has been used, so that relative error in the total energy is typically less than 1 %. The initial time parameter t is varied within the atomic period T = 2π, and the particle final energies are plotted as functions of t. Generally an ionization interval is extremely small and graphical interpolation of the numerical results must be employed in determining its length. As a rule an ionization interval appears situated between a direct-scattering region and a t-interval which leads to the positronium formation.

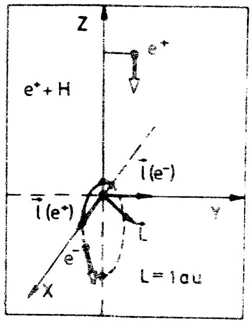

Figure 1. Initial configuration of e^+ - H system.

Besides the very threshold law, we examine the energy, mutual angle and angular momenta distribution functions, in particular their dependence of the total energy. Computations are in progress and we hope to present results at the Conference.

We are inebted to Professor I. Percival, Dr N. Valentine and Dr D. Banks for providing us with their original computer code. We thank Professor H. Klar for his kind sending to us his analytical results prior to publication. This work has been supported by the Research Fund of RZ of Serbia.

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SIXTH ANNUAL CONFERENCE

ON

SPECTRAL LINE SHAPES

JULY 11-16, 1982

University of Colorado
Boulder

ON THE STARK BROADENING OF NON-HYDROGENIC SPECTRAL LINES OF HEAVY ELEMENTS IN PLASMAS

N. Konjević and M.S. Dimitrijević
Institute of Applied Physics
11071 Beograd, P.O.Box 58, Yugoslavia

In both comparisons |1,2| of selected experimental data for the Stark line widths of isolated non-hydrogenic lines with semiclassical theoretical results (helium through calcium and cesium) by Griem and coworkers |1,3| fairly good agreement (within ±20%) is found. Although experimental data for heavier elements were available |2| at that time, there were no theoretical data to compare with.

Since, semiclassical results (an extension of above mentioned data |1,3|.) for spectral lines of some elements heavier than calcium became available recently |4| we were able to performe comparison with experiment. This comparison revealed large discrepancy with theory previously undetected for lighter elements |1,2|. Critical analysis of experimental data indicates that in most of cases experiment is to be blamed for this discrepancy.

The details of this analysis will be presented at the conference.

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Division of Conferences/Institutes
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SIXTH ANNUAL CONFERENCE

ON

SPECTRAL LINE SHAPES

JULY 11-16, 1982

University of Colorado
Boulder

STARK BROADENING PARAMETERS FOR INFRARED LINES OF He I

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An accurate knowledge of the Stark broadening of atomic and ionic lines are of great importance for spectroscopy of astrophysical and laboratory plasmas, as well as for opacity calculations. Reliable line broadening data for helium, the most wide spread element after hydrogen, are of particular interest for a number of problems in astrophysics and plasma physics. We have performed here semi-classical calculations of Stark broadening parameters for a large number of infrared He I lines. The basis for calculations is the computer code of Sahal-Bréchot which evaluates electron-impact and ion broadening parameters of isolated lines using the semi-classical perturbation approach [1].

The obtained comprehensive set of Stark broadening data has been used to investigate Stark broadening regularities within spectral series. This has been made in order to investigate if systematic trends among Stark broadening parameters within a spectral seria are apparent : in that case accurate interpolation of new data and critical evaluation of experimental results could be done (see e.g. [2, 3]).

Finally, the obtained numerical results are compared with other existing calculations [4-7] when available.

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5TH IC SLS

FIFTH INTERNATIONAL CONFERENCE ON

SPECTRAL LINE SHAPES

BERLIN (WEST) JULY 7-11, 1980

PROGRAM AND ABSTRACTS

MODIFIED SEMIEMPIRICAL FORMULA FOR THE ELECTRON - IMPACT WIDTH OF IONIZED ATOM LINES

M. Dimitrijević and N. Konjević

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In 1968 Griem suggested simple semiempirical approach for evaluation of electron impact Stark line-widths of singly ionized atoms [1]. This approach is based on Baranger's quantum-mechanical impact approximation [2] with the effective Gaunt factor approximation as proposed by Seaton [3] and Van Regemorter [4]. The comparison of semiempirical results with the experiment indicated for singly ionized atoms an average agreement within ±50% [5]. Griem proposed that the same formula with effective Gaunt factor threshold value of 0.2 can be used for multiply ionized atoms with an accuracy ±100%. However, the comparison with the experimental line widths of doubly and triply ionized atoms shows theoretical results systematically lower (see e.g. refs. 6 and 7 and references therein). This is an indication that threshold value of 0.2 for Gaunt factor is rather small for higher ionisation stages.

In semiempirical formula, first, we have separated transitions to the perturbing levels in three groups: a) $\Delta n=0$, $\ell\to\ell+1$ b) $\Delta n=0$, $\ell\to\ell-1$ and c) $\Delta n\neq0$ and within each group matrix elements are treated lumped together. For the transitions with $\Delta n=0$:

$$\tilde{g}\left(\frac{E}{\Delta E_{jj'}}\right) = 0.7 - \frac{1.1}{Z} + g\left(\frac{E}{\Delta E_{jj'}}\right)$$

where $g\left(\frac{E}{\Delta E_{jj'}}\right)$ is the effective Gaunt factor. For the transitions with $\Delta n\neq0$ the energy separation to the nearest perturbing level $E_{n,n+1}$ is taken as

$$\Delta E_{n,n+1} \approx \frac{2Z^2 E_H}{n^3}$$

FC3

At higher electron temperatures, Gaunt factor is derived from the GBKO high temperature limit

$$\tilde{g}_{jj'} = \frac{\sqrt{3}}{\pi} \left[\frac{1}{2} + \ln \left(\frac{2ZkT}{n_j^2 \, \Delta E_{jj'}}\right)\right]$$

The average ratios of experimental, W_m, and theoretical results (modified W_{SEM}, and unmodified semiempirical formula W_{SE}) are given in the table.

Element	T_e |K|	W_m/W_{SEM}	W_m/W_{SE}
CIII	60000	1.29	1.21
NIII	24300	0.92	1.71
OIII	25400	1.05	1.90
SiIII	25600	0.67	1.08
SIII	28500	1.16	1.65
ClIII	24200	1.01	1.68
AIII	21100	0.99	1.57
average ratio:		1.06 ± 0.31	1.53 ± 0.46
CIV	60000	1.50	2.57
SiIV	25600	0.66	1.15
SIV	28500	0.80	1.65
AIV	21500	0.76	1.24
average ratio:		0.91 ± 0.42	1.56 ± 0.85

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FIFTH INTERNATIONAL CONFERENCE ON

SPECTRAL LINE SHAPES

BERLIN (WEST) JULY 7-11, 1980

PROGRAM AND ABSTRACTS

ON THE SYSTEMATIC TRENDS OF STARK BROADENING PARAMETERS OF ISOLATED LINES

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A number of recently published papers have been devoted to the investigation of the regularities in the Stark widths of isolated lines in plasmas [1-10]. According to the approach to this probleme one can devide all published work in two groups. In one group [3,6] regularities are discussed from the point of view of atomic structure involved, while in the other group analysis of regularities strongly rely to the existing semiempirical theory [1,2,4,5,8-10]. The aim of this paper is to discuss and critically evaluate latter approach.

First it should be underlined that all theoretical Stark width formulae imply regularities and systematic trends from the point of view of atomic physics. The expressions for neutral and ion lines contain the same two basic atomic quantities: 1. excitation energies or, more specifically, energy differences between upper and lower states of the transition between interacting atomic states, and 2. dipole (and quadrupole) matrix elements (radial integrals) for interacting states.

Second, on the basis of the comparison of the experiment and the theory for neutral and singly ionized atom lines, good average agreement is found: semiclassical results agree within $\pm$20% [11-13] with experiment while semiempirical results for singly ionized atoms are in agreement within 50% with experimental data [11]. Therefore, to discuss further systematic trends within neutral and singly ionized atoms in the first approximation one can use existing theories only and avoid numerous comparisons with the experiments.

For the space reasons, the results of this analysis is impossible to present here and it will be discussed in details at the conference.

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Volume 22D

ELECTRON IMPACT BROADENING PARAMETERS FOR V II LINES

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Spectral lines of singly charged vanadium ion are present in Solar as well as in stellar spectra [1-4]. The V II lines are mostly formed within layers (photosphere or subphotosphere) of stellar atmospheres with higher electron density. Consequently, electron impact broadening mechanism may be of importance, especialy for hot stars (A and B stars) as well as for white dwarfs. Due to the lack of reliable atomic energy levels and transition probabilities for this emitter, it is correct to apply approximate methods for Stark broadening parameter calculations. One of these methods is the modified semiempirical approach [5,6], applied here. In order to provide a set of atomic data needed for different astrophysical problems, as e.g. opacity calculations, we have calculated Stark broadening parameters for many astrophysically important elements (see e.g. [7]) by using this approach.

We present in this paper Stark full widths (FWHM) and shifts for 24 transitions of V II calculated by using the modified semiempirical approach, as a function of temperature, for the electron density of $10^{23}m^{-3}$. The atomic energy levels needed for calculations were taken from Ref. 8.

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ELECTRON IMPACT BROADENING PARAMETERS FOR Ti XI AND Ti XII SPECTRAL LINES

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A number of problems in solar and stellar physics, plasma physics and technology (see e.g. Ref. 1) depends on a comprehensive set of reliable data on the influence of impacts with charged particles on spectral line shapes, i.e. on the Stark broadening parameters. For example, Stark broadening parameters for multiply charged ions are needed for the modelling and theoretical considerations of subphotospheric layers [2], as well as for the examination of radiative transfer. Such data for multiply charged ion lines are of additional interest as well due to the development of soft X-ray lasers, where Stark broadening data are needed to calculate gain values, model radiation trapping and to consider photoresonant pumping schemes [3,4]. Of course such data are also useful for the rafinemant and checking of theory, as well as for the consideration of systematic trends along isoelectronic sequences. Titanium in various ionization stages are present in stellar plasma. For example 7 Ti IV lines have been found in the τ Sco spectrum [5]. One should mention as well that Stark broadening parameters for 10 Titanium IV multiplets, have been calculated recently [6] within the semiclassical perturbation approach [7,8].

As the continuation of our project (see e.g. Ref. 9) to make available to astrophysicists and physicists an as large as possible set of reliable semiclassical Stark broadening data needed for the investigation, diagnostics and modeling of various plasmas in stellar and solar physics, abundance detrminations, opacity calculations, modeling and consideration of subphotospheric layers, diagnostics and investigation of laboratory plasma,as well as for laser physics, fusion research, and various devices as e.g. light sources, we have calculated within the semiclassical-perturbation formalism [7,8], electron-, proton-, and He III-impact line widths and shifts for 4 Ti XI and 27 Ti XII multiplets.

Presented results are the first Stark broadening data concerning titanium XI and XII spectral lines. We hope that the presented data will be of interest for a number of problems in physics and astrophysics.

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THE ELECTRON-IMPACT BROADENING PARAMETERS FOR Ti III SPECTRAL LINES

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Investigations of Stark line broadening parameters are important for a number of problems in laboratory and astrophysical plasma research as e.g. analysis and synthesis of stellar spectra and interpretation of particular lines, stellar opacity calculations and abundance determination. A set of the electron- impact broadening data, needed for different physical and astrophysical problems, for many ionized elements have been calculated by using the semiclassical perturbation formalism (see e.g. Ref. 1), and the modified semiempirical approach (Ref.2, for emitters with complex spectra see also Refs. 3, 4, 5).

The spectral lines for Titanium, in different ionization stages, are presented in stellar plasma. Stellar Ti II lines have been considered e.g. in Ref. 6. Stark broadening data for 10 Ti IV multiplets [7], 4 Ti XI multiplets and 27 Ti XII multiplets [8] have been calculated within the semiclassical perturbation formalism. In order to complete data on Stark broadening parameters for Ti lines we present here electron-impact broadening parameters for Ti III spectral lines belonging to the 4s-4p transitions. Due to the lack of reliable atomic energy levels needed for the full semiclassical approach, calculations were performed by using the modified semiempirical approach, for an electron density of $10^{23} m^{-3}$ and the temperature range T=5000-50000 K. Energy levels for Ti III lines were taken from Ref. 9, while oscillator strengths have been calculated by using Bates–Damgaard method [10]. In order to analyze the influence of the different oscillator strength data to electron-impact broadening results, we performed the same calculations by using measured oscillator strength data from Ref. 11. We found that the results obtained taking into account the calculated oscillator strengths by using Bates-Damgaard method and are around 50% smaller than results obtained with the measured oscillator strength data from Ref. 9.

We hope that results of our calculation will be of interest for physical and astrophysical plasma consideration.

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VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (VAMDC) AND STARK-B DATABASE

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Abstract: Virtual Atomic and Molecular Data Center (VAMDC) is an European FP7 project with aims to build a flexible and interoperable e-science environment based interface to the existing Atomic and Molecular data. The VAMDC will be built upon the expertise of existing Atomic and Molecular databases, data producers and service providers with the specific aim of creating an infrastructure that is easily tuned to the requirements of a wide variety of users in academic, governmental, industrial or public communities. In VAMDC will enter also STARK-B database, containing Stark broadening parameters for a large number of lines, obtained by the semiclassical perturbation method during more than 30 years of collaboration of authors of this work (MSD and SSB) and their co-workers. In this contribution we will review the VAMDC project, STARK-B database and discuss the benefits of both for the corresponding data users.

1. VIRTUAL OBSERVATORIES AND SERBIAN VIRTUAL OBSERVATORY

For various applications in astrophysics, atmospheric physics, fusion, environmental sciences, combustion chemistry, and in industrial applications from plasmas and lasers to lighting, a reliable, critically selected set of atomic and molecular data is needed. However, the available data present in literature and databases are presented in different, non-standardized ways, so that their adequate exploitation is often difficult.

The need for a large amount of atomic and molecular data is in particular stimulated by the development of satellite astronomy, providing a huge amount of high quality astronomical spectra. This development produced an information avalanche and leaded to the creation of huge data collections as e. g. IUE and HST archive, or Sloan Digital Sky Survey SDSS, containing spectra of ~ 230 million objects.

In order to solve the problem of analysis and mining of such amount of data, the idea of Virtual Observatory was formulated at the end of 2000. It was realized as the FP5 project Astrophysical Virtual Observatory – AVO, the origin of European Virtual Observatory - EURO-VO (http://www.euro-vo.org), who started in 2001.

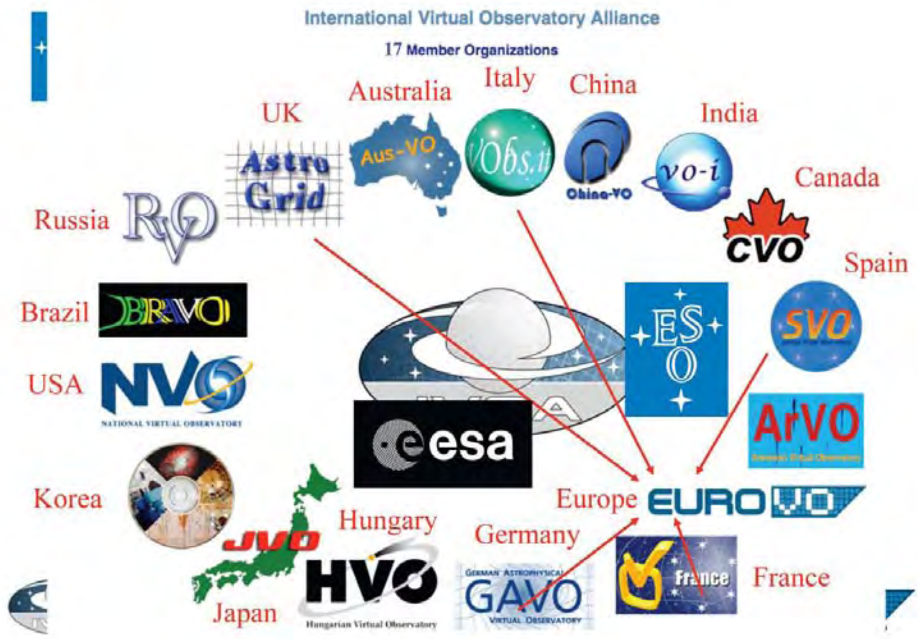


Fig. 1. International Virtual Observatory Alliance.

In order to coordinate the international collaboration in this field and develop and adopt the needed corresponding standards, International Virtual Observatory Alliance (IVOA, http://www.ivoa. net) was formed in June of 2002.

Serbia entered in such activities by creating SerVO - Serbian virtual observatory (http://servo.aob.rs/~darko), funded through the project TR13022 by Ministry of Science and Technological Development of Republic of Serbia (Jevremović et al., 2009, 2012). After establishing SerVO, our objective is to join

IVOA, if possibly on the interoperability meeting in Nara, Japan, 7-11 of December 2010, and the EuroVO. Our plan is also to establish SerVO data Center for digitizing, archiving and publishing in VO format photo-plates (Tsvetkova et al., 2009) and other data produced at Belgrade Astronomical Observatory and to develop tools for visualization of the corresponding data. Two of us (MSD-SSB) work on the development of STARK-B - Stark broadening data base containing, as the first step, our results for Stark broadening parameter determination obtained within the semiclassical perturbation approach, in VAMDC and VO compatible format. A mirror site of this database will be a part of SerVO. Also, within the frame of SerVO will be a mirror site for DSED (Darthmouth Stellar Evolution Database, Dotter et al., 2007, 2008) in the context of VO.

2. VAMDC – VIRTUAL ATOMIC AND MOLECULAR DATA CENTER

The need for an efficacious and adequate search and mining for available atomic and molecular data, highly fragmented and provided in different non standardized formats, which was an obstacle for their suitable use, leaded to the VAMDC idea. In order to make the search of atomic and molecular data efficacious, we need the search engines that must look “everywhere” for the needed A&M dat and to create an accessible and interoperable e-infrastructure.

This is in fact the main objective of Virtual Atomic and Molecular Data Center (VAMDC – Dubernet et al., 2010), a FP7 funded project which started on July 1st 2009 with budget of 2.9 MEuros over 42 months. The above mentioned objectives will be achieved by upgrading and integrating European (and wider) A&M database services and catering for the needs of variety of data users in science, research and development, and industry. In order to establish a better communication between data producers, data users and databases developers, one of the important VAMDC aims is also the creation of a forum for discussion of the corresponding subjects, as well as to organize the training of potential users in European Research Area and wider.

The VAMDC can be understood as a publisher infrastructure (Fig. 2), which will deploy yellow pages (registries) in order to find resources, design user applications, build data access layers above databases to provide unified outputs from these databases, and connect its infrastructure to the grid.

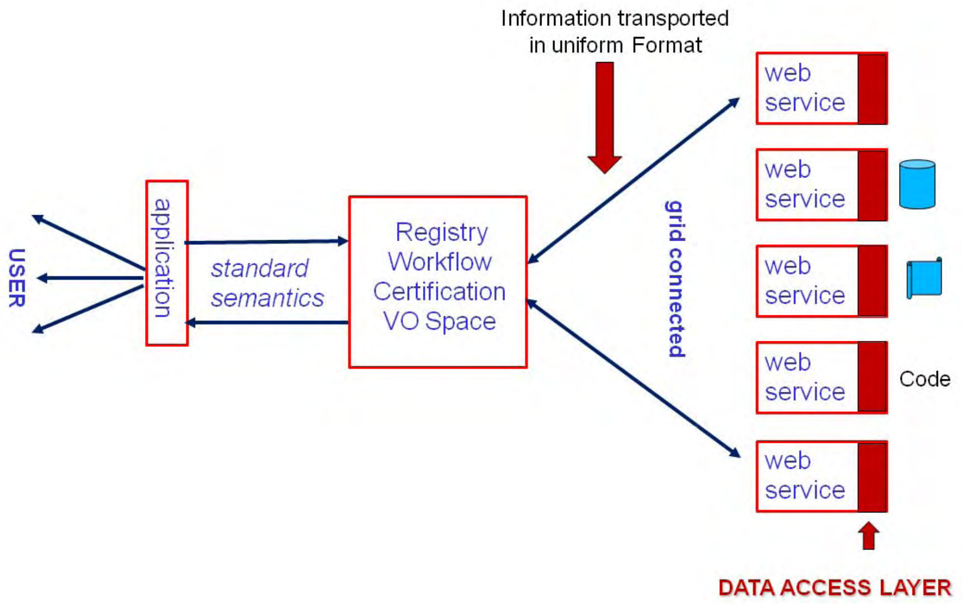


Fig. 2. Schematic diagram of the VAMDC infrastructure; note that it is a distributed system.

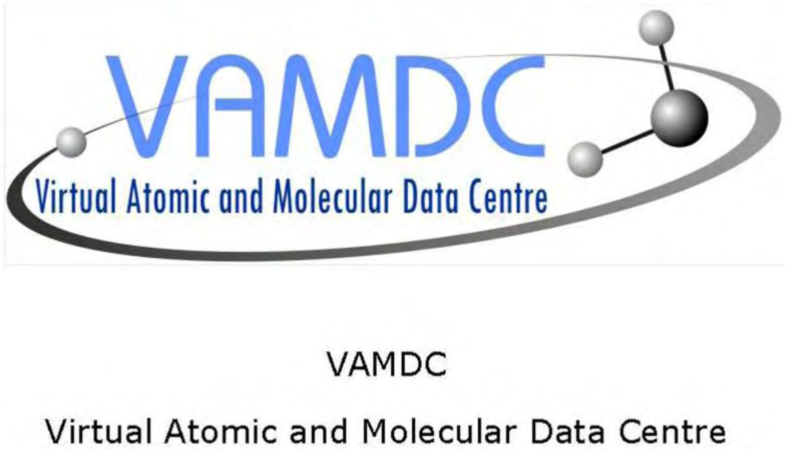


Fig. 3. VAMDC logo.

Project leader is Marie-Lise Dubernet from Observatoire de Paris and core consortium is made of 15 institutions with 24 scientific groups from France, Serbia, Russia, England, Austria, Italia, Germany, Sweden and Venezuela.

Partners in the Consortium of the Project are: 1) The coordinator, Centre National de Recherche Scientifique - CNRS (Université Pierre et Marie Curie, Paris; Observatoire de Paris; Université de Reims; Université Joseph Fourier de Grenoble, Université de Bordeaux 1: Université de Bourgogne, Dijon; Université Toulouse 3); 2) The Chancellor, Masters and Scholars of the University of Cambridge – CMSUC; 3) University College London – UCL; 4) Open University – OU (Milton Keynes, England); 5) Universitaet Wien - UNIVIE; 6) Uppsala Universitet – UU; 7) Universitaet zu Koeln – KOLN; 8) Istituto Nazionale di Astrofisica – INAF (Catania, Cagliari); 9) Queen's University Belfast – QUB; 10) Astronomska Opservatorija - AOB (Belgrade, Serbia); 11) Institute of Spectroscopy RAS – ISRAN (Troitsk, Russia); 12) Russian Federal Nuclear Center - All-Russian Institute of Technical Physics - RFNC-VNIITF (Snezhinsk, Chelyabinsk Region, Russia); 13) Institute of Atmospheric Optics - IAO (Tomsk, Russia); 14) Corporacion Parque tecnologico de Merida – IVIC (Merida, Venezuela); 15) Institute for Astronomy RAS - INASAN (Moscow, Russia).

External VAMDC partner is also NIST – National Institute for Standards and Technology in Washington.

The VAMDC facilities are dedicated to the various users in Astronomy, Plasma science, Atmospheric Science Radiation science and Fusion community as well as Industries using technological plasmas and Lightning industry

The basis of VAMDC e-infrastructure are the included databases upon which are actually:

VALD database (Kupka et al., 1999) of atomic data for analysis of radiation from astrophysical objects (http://vald.astro.univie.ac.at/).

CHIANTI (Dere et al., 2009), an atomic database for the analysis of optically thin collisionally ionised astrophysical plasmas. (http://sohowww.nascom.nasa.gov/solarsoft, http://www.damtp.cam.ac.uk/user/astro/chianti/)

EMol Database, at the Open University in Milton Keynes (Mason, 2007), containing critically evaluated measured and calculated cross sections for electron interactions with molecular systems, and a suite of semi-empirical theoretical methods for the corresponding evaluation when there are currently no experimental data.

CDMS - Cologne Database for Molecular Spectroscopy (http://www.ph1.uni-koeln. de/ vorhersagen/) provides recommendations for spectroscopic transition frequencies and intensities for atoms and molecules of astronomical interest and for studying the Earth atmosphere. It is cross correlated with its US counterpart, the JPL Jet Propulsion Laboratory Submillimeter Catalogue (http://spec.jpl.nasa.gov/) (Müller et al., 2005).

BASECOL database (Dubernet et al., 2004) (http://basecol.obspm.fr) contains excitation rate coefficients for ro-vibrational excitation of molecules by electrons, He and H_2.

GhoSST (Grenoble astrophysics and planetology Solid Spectroscopy and Thermodynamics, http://ghosst.obs.ujf-grenoble.fr) database service, offers spectroscopic laboratory data on molecular and atomic solids and liquids from the near UV to the far-infrared.

UMIST - University of Manchester Institute of Science and Technology (UMIST) database for astrochemistry (Millar et al., 1991; Woodall et al., 2007) (http://www.udfa.net/), provides reaction rate data and related software for chemical kinetic modelling of astronomical regions.

KIDA - KInetic Database for Astrochemistry will contain data on chemical reactions used in the modelling of the chemistry in the interstellar medium and in planetary atmospheres (http://kida.obs.u-bordeaux1.fr).

PAHs (Polycyclic Aromatic Hydrocarbon) and carbon clusters spectral database (http://astrochemisty.ca.astro.it/database/) in Cagliari, developed in collaboration of CESR (Centre d'Etude Spatiale des Rayonnements) with CNRS (Malloci et al., 2007).

LASP (Laboratorio di Astrofisica Sperimentale) Database (http://web.ct.astro.it/weblab/ dbindex.html#dbindex) at the INAF (Istituto Nazionale di Astrofisica) - Catania Astrophysical Observatory, contains (i) infrared (IR) spectra of molecules in the solid phase (ii) IR optical constants of molecules in the solid phase and after processing with energetic ions; (iii) band strengths of the IR absorption bands ; and (iv) density values of frozen samples.

Spectr-W^3 (Faenov et al., 2002) atomic database (http://spectr-w3.snz.ru), created in collaboration between the Russian Federal Nuclear Centre All-Russian Institute of Technical Physics (RFNC VNIITF - Snezhinsk, Chelyabinsk Region, Russia) and the Institute for High Energy Densities of the Joint Institute for High Temperatures of the Russian Academy of Sciences (IHED JIHT RAS - Moscow). It lists experimental, calculated, and compiled data on ionization potentials, energy levels, wavelengths, radiation transition probabilities and oscillator strengths, and also parameters for analytic approximations for electron-collision cross-sections and rates for atoms and ions.

The V.E. Zuev Institute of Atmospheric Optics (IAO) in Tomsk (http://www.iao.ru/) hosts the following databases:

CDSD - The Carbon Dioxide Spectroscopic Databank (Perevalov and Tashkun, 2008) (http://cdsd.iao.ru and ftp://ftp.iao.ru/pub/CDSD-2008).

S&MPO - Spectroscopy & Molecular Properties of Ozone) relational database (Rothman et al., 2009) (http://ozone. iao.ru and http://ozone.univ-reims.fr/), developed in collaboration with the University of Reims.

"Spectroscopy of Atmospheric Gases" (http://spectra.iao.ru), containing HITRAN (Rothman et al., 2009) , GEISA (Jacquinet-Husson et al., 2008) and HITEMP (Rothman et al., 2010) databases.

W@DIS – Water Internet @ccessible Distributed Information System (http://wadis.saga.iao.ru) lists experimental water-vapour spectroscopy data from the literature and calculated line lists.

Databases under the management of Corporacion Parque tecnologico de Merida – IVIC (Instituto Venezoelano de Investigaciones Scientificas) and CeCalCULA (Centro Nacional de Cálculo Científico de la Universidad de Los Andes).

TIPTOPbase (Cunto et al., 1993) located at the Centre de Données astronomiques de Strasbourg, France (http://cdsweb.u-strasbg.fr/topbase/home.html), contains:

TOPbase: Atomic data computed in the Opacity Project, namely LS-coupling energy levels, gf-values and photo ionization cross sections for light elements ($Z \leq 26$) of astrophysical interest.

TIPbase: Intermediate-coupling energy levels, A-values and electron impact excitation cross sections and rates for astrophysical applications ($Z \leq 28$), computed by the IRON Project.

OPserver (Mendoza et al., 2007), located at the Ohio Supercomputer Center, USA, (http://opacities.osc.edu/), a remote, interactive server for the computation of mean opacities for stellar modelling using the monochromatic opacities computed by the Opacity Project.

Within VAMDC e-infrastructure are also:

XSTAR database (Bautista and Kallman, 2001), used by the XSTAR code (http://heasarc.gsfc.nasa.gov/ docs/software/ xstar/xstar.html) for modelling photo ionised plasmas.

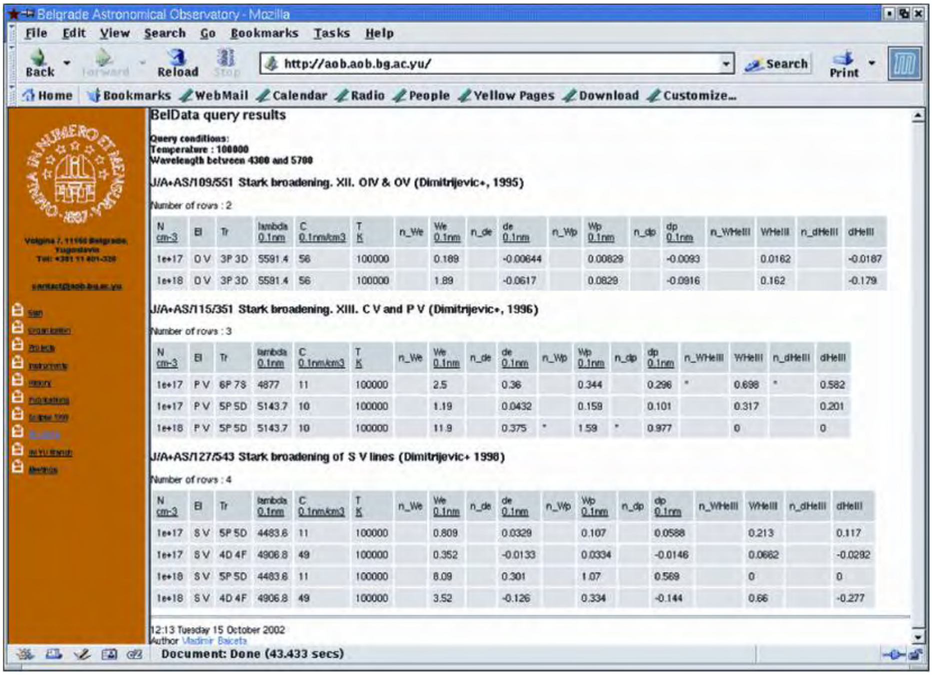
HITRAN - HIgh-resolution TRANsmission molecular absorption database (Rothman et al., 2008) (http://www.cfa. harvard.edu/hitran/).

GEISA - Gestion et Etude des Informations Spectroscopiques Atmosphériques database (Jacquinet-Husson et al., 2008) (http://ara.lmd.polytechnique.fr/index.php?page=geisa-2 or http://ether.ipsl.jussieu. fr/etherTypo/ ?id=950) is a computer accessible database system, designed to facilitate accurate and fast forward, calculations of atmospheric radiative transfer.

HITEMP, a high temperature extension to HITRAN (Rothman et al., 2010) containing data for water, CO_2, CO, NO and OH.

3. STARK-B DATABASE

The STARK-B database (http://stark-b.obspm.fr) (Sahal-Bréchot, 2010), is created in collaboration between Laboratoire d’Etude du Rayonnement et de la matière en Astrophysique of the Observatoire de Paris-Meudon and the Astronomical Observatory of Belgrade, and it enters also in the VAMDC e-infrastructure. It contains the theoretical widths and shifts of isolated lines of atoms and ions due to collisions with charged perturbers, obtained within the impact approximation (Stark broadening). At this stage it contains results obtained using the semiclassical perturbation approach (Sahal-Bréchot, 1969ab, for optimization of computer code and updates see e.g. Sahal-Bréchot, 2010; Dimitrijević, 1996).



BelData query results

Query conditions:
Temperature : 100000
Wavelength between 4300 and 5700

J/A+AS/109/551 Stark broadening. XII. OIV & OV (Dimitrijevic+, 1995)

Number of rows : 2

N cm-3	El	Tr	lambda 0.1nm	C 0.1nm/cm3	T K	n_We	We 0.1nm	n_de	de 0.1nm	n_Wp	Wp 0.1nm	n_dp	dp 0.1nm	n_WHeIII	WHeIII	n_dHeIII	dHeIII
1e+17	O V	3P 3D	5591.4	56	100000		0.189		-0.00644		0.00829		-0.0093		0.0162		-0.0187
1e+18	O V	3P 3D	5591.4	56	100000		1.89		-0.0617		0.0829		-0.0916		0.162		-0.179

J/A+AS/115/351 Stark broadening. XIII. C V and P V (Dimitrijevic+, 1996)

Number of rows : 3

N cm-3	El	Tr	lambda 0.1nm	C 0.1nm/cm3	T K	n_We	We 0.1nm	n_de	de 0.1nm	n_Wp	Wp 0.1nm	n_dp	dp 0.1nm	n_WHeIII	WHeIII	n_dHeIII	dHeIII
1e+17	P V	6P 7S	4877	11	100000		2.5		0.36		0.344		0.296	*	0.698	*	0.582
1e+17	P V	5P 5D	5143.7	10	100000		1.19		0.0432		0.159		0.101		0.317		0.201
1e+18	P V	5P 5D	5143.7	10	100000		11.9		0.375	*	1.59	*	0.977		0		0

J/A+AS/127/543 Stark broadening of S V lines (Dimitrijevic+ 1998)

Number of rows : 4

N cm-3	El	Tr	lambda 0.1nm	C 0.1nm/cm3	T K	n_We	We 0.1nm	n_de	de 0.1nm	n_Wp	Wp 0.1nm	n_dp	dp 0.1nm	n_WHeIII	WHeIII	n_dHeIII	dHeIII
1e+17	S V	5P 5D	4483.6	11	100000		0.809		0.0329		0.107		0.0588		0.213		0.117
1e+17	S V	4D 4F	4906.8	49	100000		0.352		-0.0133		0.0334		-0.0146		0.0662		-0.0292
1e+18	S V	5P 5D	4483.6	11	100000		8.09		0.301		1.07		0.569		0		0
1e+18	S V	4D 4F	4906.8	49	100000		3.52		-0.126		0.334		-0.144		0.66		-0.277

12:13 Tuesday 15 October 2002
Author Vladimir Bajceta

Fig. 4. Output from the old BELDATA database.

STARK-B may be useful for modelling and spectroscopic diagnostics of stellar atmospheres and envelopes, as well as for laboratory plasmas, analysis of laser produced plasma and laser equipment design and development, fusion plasma and technological plasmas. The database is currently developed in Paris, and a mirror site is planned in Belgrade, within the frame of SerVO. It is described in detail in Sahal-Bréchot (2010).

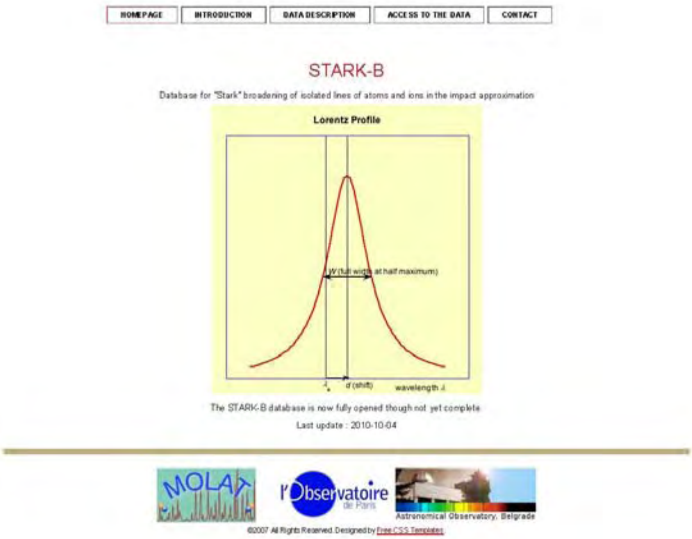


Fig. 5. The homepage of STARK-B.

On Belgrade Astronomical Observatory was created previously, as a precursor of STARK-B and SerVO, BELDATA database with Stark broadening parameters as its main content. A history of BELDATA can be traced in Popović et al. (1999ab), Milovanović et al. (2000ab), Dimitrijević et al. (2003) and, Dimitrijević and Popović (2006).

The participants of AOB (Astronomical Observatory – Belgrade) VAMDC Node are: Milan S. Dimitrijević, Luka Č. Popović, Andjelka Kovačević, Darko Jevremović, Zoran Simić, Edi Bon and Nenad Milovanović.

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Our ambition is that in the future, Group for Astrophysical spectroscopy and SerVO become a VAMDC regional center, in particular since it is expected that VAMDC, as an example of the global collaborations and innovations in e-science, will become one of major European cyber-infrastructures with a world wide impact.

Acknowledgments

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THE Fe II LINES IN AGN SPECTRA

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Abstract. We present a study of optical Fe II emission in 302 AGNs selected from the SDSS. We group the strongest Fe II multiplets into three groups according to the lower term of the transition (b ^4F, a ^6S and a ^4G terms). We calculate an Fe II template which takes into account transitions into these three terms and an additional group of lines, based on a reconstruction of the spectrum of I Zw 1. This Fe II template gives a more precise fit of the Fe II lines than other templates. We notice that the ratios of blue, red, and central parts of the iron shelf depend on some spectral properties as continuum luminosity and FWHM Hβ. We examine the dependence of the well-known anti-correlation between the equivalent widths of Fe II and [O III] and we found possible connection with the Baldwin effect.

1. INTRODUCTION

There are many unresolved questions concerning optical Fe II (λλ4400-5400 Å) lines. Some of them are: geometrical place of the Fe II emission region in AGN, processes of excitation which produce Fe II emission, as well as some correlations of the Fe II lines and other AGN spectra properties which need a physical explanation. It is established that the Fe II emission depends on the radio, X and IR parts of the continuum and also some correlations with other lines in spectra are observed (for review see Lipari and Terlevich, 2006). One of the most interesting is the relation between equivalent widths of the Fe II and [O III] lines, which physical background is still not explained (see Boroson and Green, 1992).

In this paper, we investigate the Fe II emitting region by analyzing the correlations between the optical Fe II lines and the other emission lines within a sample of 302 AGN from the SDSS. To do this, we construct an Fe II template. The strongest Fe II multiplets within the λλ4400-5400 Å range are sorted into three groups, according to the lower terms of the transitions. We analyze relationships between ratios of Fe II line groups and other spectral properties, as well as anticorrelation between EW Fe II and EW [O III].

2. THE SAMPLE AND ANALYSIS

Spectra for our data sample are taken from the 7th data release (Abazajian et al., 2009) of the Sloan Digital Sky Survey (SDSS). We used an SQL search to obtain the best sample of AGN spectra, with following requirements: high signal to noise ratio (S/N>20), good pixel quality, high redshift confidence (zConf > 0.95) and with z < 0.7, negligible contribution from the stellar component (EW CaK 3934 Å, Mg 5177 Å and Hd 4102 Å > -1).

Spectra are corrected for Galactic reddening, using procedure described in paper Schlegel et al. (1998). Continuum emission is substracted by DIPSO software.

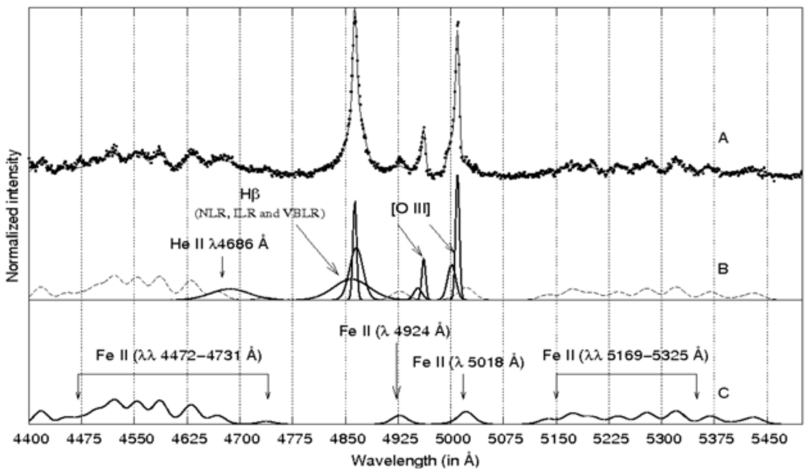

Figure 1. Example of fit of the SDSS J141755.54+431155.8 in the λλ4400-5500 Å range.

We fit all considered lines in λλ4400-5500 Å range (Fe II, [O III], Hβ), with a sum of Gaussian functions of different shifts, widths and intensities, which reflects physical conditions of emission regions where those components arise (see Fig. 1). We assume that Balmer lines have three components: NLR, ILR and VBLR (Ilić et al., 2006; Bon et al., 2006 ; Hu et al., 2008), and we fited them with three Gaussians of different width and shift. Optical Fe II lines were fited with calculated template.

3. RESULTS

The Fe II template

We calculated the Fe II template, using the 50 Fe II emission lines, identified as the strongest within the λλ4400-5500 Å range. The 35 of them are separated in the three line groups according to their lower level of transition: $3d^6$ (^{3}F2)4s ^{4}F, $3d^5 4s^2$ ^{6}S and $3d^6$ (^{3}G)4s ^{4}G (in further text F, S and G group of lines).

The lines from three line groups describe about 75% of Fe II emission in observed range (λλ4400-5500 Å), but about 25% of Fe II emission can not be explained with permitted lines which excitation energies are close to these of lines from the three line groups.

In order to complete the template for missing 25%, we selected 15 lines which probably arise with some of these mechanisms, from Kurutcz database (http://kurucz.harvard.edu/linelists.html). The selected lines have wavelengths on missing parts, strong oscillator strengh and their energy of excitation goes up to ~11 eV. Relative intensities of these 15 lines are obtained from I Zw 1 spectrum by making the best fit together with Fe II lines from the three line groups.

We have assumed that each of lines can be represented with a Gaussian, described by width (W), shift (d) and intensity (I). Since all Fe II lines from the template probably originate in the same region, with the same kinematical properties, values of d and W are the same for all Fe II lines in the case of one AGN, but intensities are assumed to be different. We suppose that relative intensities between the lines within one line group (F, S and G) can be obtained as:

$$\frac{I_1}{I_2} = (\frac{\lambda_2}{\lambda_1})^3 \frac{f_1}{f_2} \cdot \frac{g_1}{g_2} \cdot e^{-(E1-E2)/kT}$$

where I_1 and I_2 are intensities of the lines with the same lower level of transition, λ_1 and λ_2 are line wavelengths, g_1 and g_2 are corresponding statistical weights, and f_1 and f_2 are oscillator strengths, E_1 and E_2 are energies of upper level of transitions, k is Boltzman constant and T is the excitation temperature.

According to that, the template of Fe II is described by 7 parameters of fit: parameter of the width, parameter of the shift, four parameters of intensity – for F, S, G and group of lines obtained from I Zw 1 object, as well as excitation temperature.

We applied this template to our sample of 302 AGNs from SDSS database, and we found that the template can satisfactorily fit the Fe II lines.

The ratios of Fe II line groups vs. other spectral properties

Since line intensities and their ratios are indicators of physical properties of the plasma where those lines arise, we have investigated relations among the ratios of Fe II line groups with various spectral properties. The F, S and G line groups correspond approximately to the blue, central and red part of the iron shelf, respectavely.

We find that the ratios of different parts of the iron shelf (F/G, F/S, and G/S) depend on some spectral properties such as: continuum luminosity and Hβ FWHM. Also, it is noticed that spectra with Hβ FWHM greater and less than ~3000 km/s have different properties which is reflected in significantly different coefficients of correlation between the parameters.

We found that all three ratios (F/G, F/S and G/S) are in significant correlation with FWHM Hβ for subsample with FWHM Hβ > 3000 km/s. The obtained coefficients of correlation are: F/G vs. FWHM Hβ (r = 0.36, P = 1.2E-5), F/S vs. FWHM Hβ (r = 0.59, P = 1.3E-14) and G/S vs. FWHM Hβ (r = 0.44, P = 6.1E-8).

No correlations between these parameters are observed for subsample with FWHM Hβ < 3000 km/s. Also, we found the correlation between F/G ratio and continuum luminosity $\log(L_{5100})$, which is more significant for FWHM Hβ < 3000 km/s subsample: r = - 0.51, P = 5.7E-12. The correlation between F/S and $\log(L_{5100})$ is also observed (r = - 0.41, P = 7.9E-8), for the same subsample.

EW Fe II vs. EW [O III]

One of the problems mentioned in the introduction is the anti-correlation between the equivalent widths of the [O III] and Fe II lines which is related to Eigenvector 1 in the analysis of Boroson and Green (1992). Some physical causes proposed to explain Eigenvector 1 correlations are: (a) Eddington ratio L/L_{Edd}, (b) black hole mass M_{BH}, and (c) inclination angle (for detailed review see Kovačević et al., 2010). Wang et al. (2006) suggested that EV1 may be related to AGN evolution.

We confirmed the EW Fe II vs. EW [O III] anti-correlation in our sample (r = - 0.39, P < 0.0001, see Fig 2).

To try to understand the EW Fe II vs. EW [O III] anti-correlation, we examined its relationship to continuum luminosity. We examined the relations of equivalent widths of Fe II and [O III] lines vs. L_{5100}. We confirmed a strong Baldwin effect (see Baldwin, 1977) for [O III] lines (r = - 0.43, P = 4E-15), and an inverse Baldwin effect for EW Fe II lines (r = 0.30, P = 2E-7), i.e. we found that as continuum luminosity increases, EW Fe II also increases, but EW [O III] decreases (see Fig 3). In Fig 3, objects with redshift within range z < 0.1 are denoted with open squares, 0.1< z < 0.2 with filled triangles, 0.2 < z < 0.3 with open circles, 0.3 < z < 0.4 with filled squares, 0.4 < z < 0.5 with open triangles, 0.5 < z < 0.6 with filled circles and 0.6 < z < 0.7 with stars.

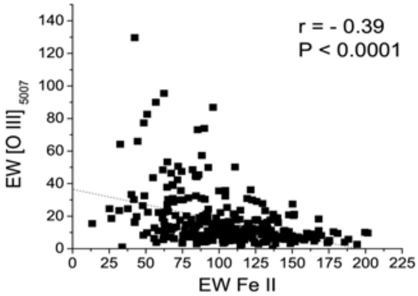

Figure 2. Relationship between the EW [O III] l5007 Å vs. EW Fe II.

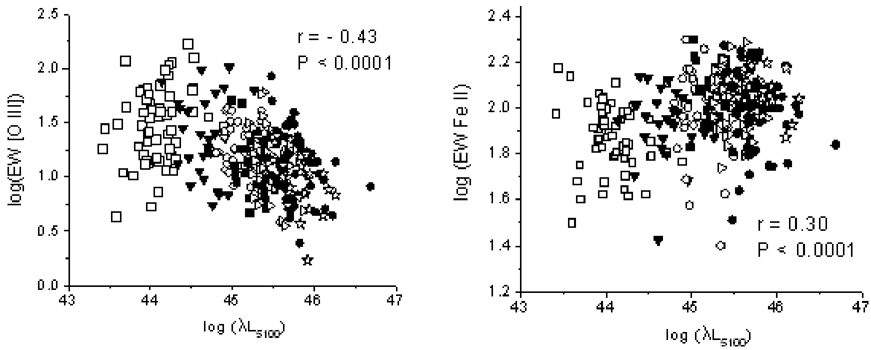

Figure 3. The Baldwin effect significant for the [O III] lines (left panel), while an inverse Baldwin effect is detected for the optical Fe II lines (rigth panel).

This implies that the EW Fe II - EW [O III] anti-correlation may be influenced by Baldwin effect for [O III] and an inverse Baldwin effect for Fe II lines. Also, in our analysis we found that the strength of the Baldwin effect depends on the FWHM Hβ of the sample. Note that FWHM Hβ is one of the parameters in Eigenvector 1.

The origin of the Baldwin effect is still not understood and is a matter of debate. The increase of the continuum luminosity may cause a decrease of the covering factor, or changes in the spectral energy distribution (softening of the ionizing continuum) which may result in the decrease of EWs. The inclination angle may also be related to Baldwin effect. The physical properties which are usually considered as a primary cause of the Baldwin effect are: M_{BH}, L/L_{Edd}, and changes in gas metalicity. Also, a connection between Baldwin effect and AGN evolution is possible (for detailed review see Kovačević et al., 2010).

Conclusions

1. We have proposed an optical Fe II template for the λλ4400-5500 Å range, which consists of three groups of Fe II multiplets, grouped according to the lower terms of transitions (F, S and G), and an additional group of lines reconstructed from the I Zw 1 spectrum. We found that template can satisfactorily fit the Fe II lines.
2. We find that the ratios of different parts of the iron shelf (F/G, F/S, and G/S) depend of some spectral properties such as: continuum luminosity and Hβ FWHM. Also, it is noticed that spectra with Hβ FWHM greater and less than ~3000 km/s have different properties which is reflected in significantly different coefficients of correlation between the parameters.
3. We confirm in our sample the anti-correlation between EW Fe II and EW [O III] which is related to Eigenvector 1 (EV1) in Boroson and Green (1992) and we examined its dependence on the continuum luminosity. We found an inverse Baldwin effect for Fe II lines, and Baldwin effect was confirmed for the [O III] lines. Since EW Fe II increases, and EW [O III] decreases with increases of continuum luminosity, the observed EW Fe II vs. EW [O III] anti-correlation is probably due to the same physical reason which causes the Baldwin effect. Moreover, it is observed that the coefficients of correlation due to Baldwin effect depend on Hβ FWHM range of a sub-sample, which also implies the connection between the Baldwin effect and EV1.

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STARK-B DATABASE VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (VAMDC) AND DATA FOR WHITE DWARF ATMOSPHERES ANALYSIS

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Abstract. In a number of papers we have demonstrated the importance of Stark broadening mechanism for the modeling and synthesizing of lines observed in spectra of white dwarf atmospheres. We also determined a number of Stark broadening parameters of interest in particular for DB and DO white dwarf plasmas investigations. Now, work on their inclusion in STARK-B database and in Virtual Atomic and Molecular Data Center, an FP7 european project, as well as in Serbian Virtual Observatory is in progress. We review here the part of this work of interest for white dwarf atmospheres analysis.

1. INTRODUCTION

Virtual Atomic and Molecular Data Center (VAMDC) aims at building an interoperable e-Infrastructure for the exchange of atomic and molecular data. In a number of papers we have demonstrated the importance of Stark broadening mechanism for the modelling and synthesizing of lines observed in spectra of white dwarf atmospheres. We determined Stark broadening parameters for trace element: Te I, Cr II, Mn II, Au II, Cu III, Zn III, Se III, In III and Sn III of interest particularly for DB and DO white dwarf plasmas investigations. Now, work on their inclusion in STARK-B database and in Virtual Atomic and Molecular Data Center, an FP7 european project, as well as in Serbian Virtual Observatory is in progress.

As an example of this work, we will show here Stark broadening parameters for two Mn II lines and their relevance for white dwarf spectra analysis and synthesis.

2. RESULTS AND DISCUSSIONS

Calculations have been performed within the semiclassical perturbation formalism, developed and discussed in detail in Sahal-Breéchot 1969a,b. This formalism, as well as the corresponding computer code, have been optimized and updated several times (Sahal-Breéchot 1974, Dimitrijević and Sahal-Bréchot 1984, Dimitrijević et al. 1991).

Using the semiclassical perturbation method we obtained Stark widths and shifts for six Mn II lines (Popović et al. 2008) for perturber density of $10^{17}cm^{-3}$ and temperatures from 5000 to 100000 K. Here, as an example we will show data for two of them 2594.5 and 2950.1 Å. The needed atomic energy levels were taken from Bashkin and Stoner 1982. The oscillator strengths required were calculated using the Coulomb approximation method described by Bates and Damgaard 1949 and the tables of Oertel and Shomo 1968. For higher levels, the method described by van Regemorter et al. 1979 was applied. As an example of obtained results, Stark widths and shifts for these lines are given in Table 1.

Table 1: Electron-impact broadening parameters (full width at half maximum W and shift d) for Mn II (Popović et al. 2008) for perturber density of 10^{17}cm^{-3} and temperatures from 5000 to 100000 K.

Transition	T(K)	W(Å)	d(Å)
	5000	0.128	0.236E-03
	10000	0.948E-01	-0.996E-03
a ^{7}S - z ^{7}P^o	20000	0.702E-01	-0.116E-02
2594.5Å	30000	0.598E-01	-0.956E-03
	50000	0.507E-01	-0.128E-02
	100000	0.435E-01	-0.118E-02
	5000	0.226	-0.394E-01
	10000	0.165	-0.302E-01
a ^{5}S - z ^{5}P^o	20000	0.121	-0.234E-01
2950.1Å	30000	0.102	-0.193E-01
	50000	0.884E-01	-0.168E-01
	100000	0.800E-01	-0.137E-01

In order to investigate the importance of Stark broadening mechanism in DA and DB white dwarf atmospheres the atmospheric models of Wickramasinghe 1972, with T_{eff} = 15000-25000 K and log g=8, are used. Here, g is the gravitational acceleration on the stellar surface and log g=8 means that g = 10^8 m/s. Calculated thermal Doppler and Stark widths as a function of optical depth, for Mn II a ^{5}S - z ^{5}P^o (2950.1 Å), are compared in Figs. 1 and 2. for DA and DB white dwarfs plasma conditions. As in Wickramasinghe 1972, optical depth points at the standard wavelength 5150 Å are used. As one can see, for DB white dwarf atmospheres the Stark broadening mechanism is more important than for the DA white dwarf atmospheres, especially for atmospheric layers with the optical depth larger or approximatively equal to 0.1, where the Stark width is up to one or two orders of magnitude larger than the thermal Doppler width.

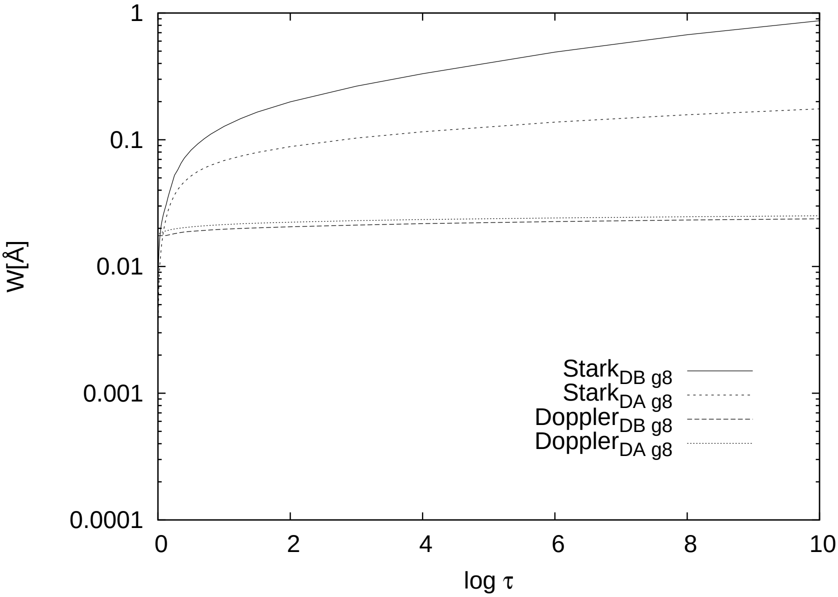

Figure 1. Thermal Doppler and Stark widths for Mn II spectral line a ^{5}S - z ^{5}P^o (2950.1Å) as a function of optical depth for DA and DB white dwarf models with T$_{eff}$=15000 K and log g=8.

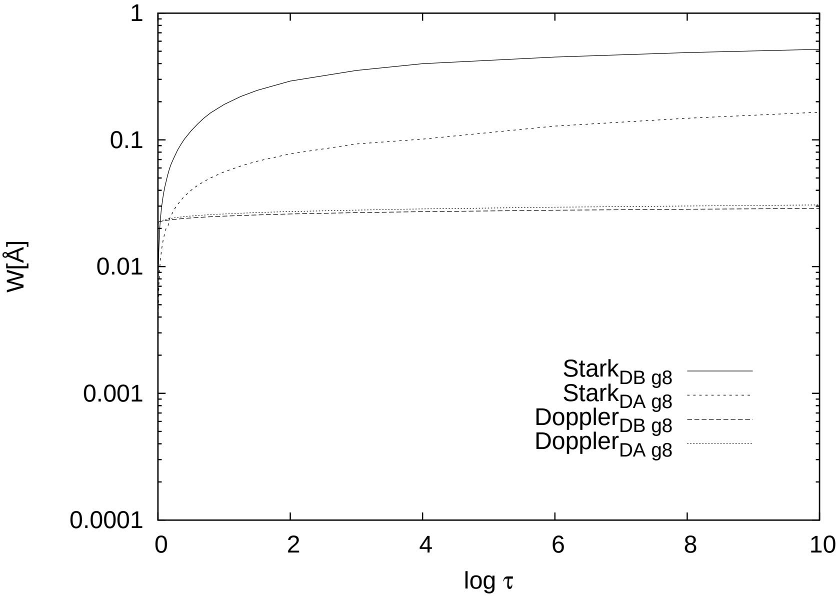

Figure 2. Thermal Doppler and Stark widths for Mn II spectral line a ^{5}S - z ^{5}P^o (2950.1Å) as a function of optical depth for DA and DB white dwarf models with T$_{eff}$=25000 K and log g=8.

Acknowledgements

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ON THE STARK BROADENING OF Ar XV SPECTRAL LINES

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Abstract. In order to provide Stark broadening data in X-ray and far UV wavelength region, of interest for modelling and analysis of astrophysical plasmas in extreme conditions, we performed calculations of Stark broadened line widths and shifts for Ar XV using the semiclassical perturbation theory.

1. INTRODUCTION

New X ray space telescopes like "Chandra" enable the observation and analisys of cosmic X ray sources with such accuracy that the need for spectroscopic data on trace elements in this wavelength range increases. For example, far UV lines of Ar VII were discovered recently in the spectra of very hot central stars of planetary nebulae and white dwarfs (Werner et al. 2007), indicating the astrophysical interest for atomic and line broadening data for this element in various ionization states. Such data are also of interest for laboratory, laser produced and fusion plasma investigations.

In order to provide Stark broadening data in X-ray wavelength region, of interest for modelling and analysis of astrophysical plasmas in extreme conditions, we have performed semiclassical calculations of Stark broadened line widths and shifts for 8 Ar XV multiplets with wavelengths less than 100 Å. As an example of obtained results, here are presented Stark broadening parameters for three ArXV singlets, for electron density of 10^{20}cm^{-3} and electron temperatures from 500000 K up to 6000000K.

2. THEORY

For determination of Stark broadening parameters, the semiclassical perturbation formalism, developed and discussed in detail by Sahal-Bréchot 1969a,b, was used. This formalism, as well as the corresponding computer code, has been optimized and updated several times (Sahal-Bréchot 1974, Dimitrijević and Sahal-Bréchot 1984, Dimitrijević et al. 1991).

Within this formalism, the full width of an isolated spectral line of a neutral emitter broadened by electron impact (W) can be expressed in terms of cross sections for elastic and inelastic processes as

$$W = \frac{\lambda^2}{\pi c} N \int v f(v) dv (\sum_{i' \neq i} \sigma_{ii'}(v) + \sum_{f' \neq f} \sigma_{ff'}(v) + \sigma_{el} + W_R), \tag{1}$$

and the corresponding line shift d as

$$d = \frac{\lambda^2}{2\pi c} N \int v f(v) dv \int_{R_3}^{R_D} 2\pi \rho d\rho \sin 2\phi_p. \tag{2}$$

Here, λ is the wavelength of the line originating from the transition with initial atomic energy level i and final level f, c is the velocity of light, N is the electron density, $f(v)$ is the Maxwellian velocity distribution function for electrons, ρ denotes the impact parameter of the incoming electron, and ϕ_p is the phase shift due to the polarization potential. The inelastic cross sections $\sigma_{jj'}(v)$ (where $j = i$ or f) and elastic cross section σ_{el} are determined according to Chapter 3 in Sahal-Bréchot 1969b. The cut-offs (needed for the calculation of inelastic and elastic cross sections and the shift), included in order to maintain for the unitarity of the S-matrix, and to take into account Debye screening are described in Section 1 of Chapter 3 in Sahal-Bréchot 1969b. W_R gives the contribution of the Feshbach resonances Fleurier et al. 1977 and this term is zero if the emitters are neutral atoms. Other differences between neutral and ionized emitters is that for calculations of the cross sections rectilinear perturber paths are taken for neutral ones and hyperbolic paths for ionized species.

The formulae for the ion-impact broadening parameters are analogous to the formulae for electron-impact broadening. We note that the fact that the colliding ions could be treated using impact approximation in the far wings should be checked, even for stellar atmosphere densities.

3. RESULTS AND DISCUSSIONS

Using the semiclassical perturbation method we obtained Stark widths and shifts for eight Ar XV multiplets for a perturber density of 10^{20}cm^{-3} and temperatures from 500 000 up to 6 000 000 K. The needed atomic energy levels were taken from Bhatia and Landi 2008 and the energy of ionization of Ar XV from NIST database. The oscillator strengths required were calculated using the Coulomb approximation method described by Bates and Damgaard 1949 and the tables of Oertel and Shomo 1968. For higher levels, the method described by van Regemorter et al. 1979 was applied. As an example of obtained results, Stark widths and shifts for three singlet lines are given in Table 1. The quantity C (given in Å cm^{-3}), when divided by the corresponding full width at half maximum, gives an estimate for the maximum perturber density for which the line may be treated as isolated and the tabulated data may be used. WIDTH(Å) denotes the full line width at half maximum in Å, while SHIFT(Å) denotes line shift in Å. We note that, in the wings, the impact approximation for ions should be checked and that ions will be quasi-static in the far wings. For perturber densities lower than those tabulated here, Stark broadening parameters vary linearly with perturber density. The nonlinear behaviour of Stark broadening parameters at higher densities is the consequence of the influence of Debye shielding and was analyzed in detail in Dimitrijević and Sahal-Bréchot 1984.

Table 1: This table shows electron-impact broadening parameters for Ar XV for perturber density of 10^{20}cm^{-3} and temperatures from 500 000 up to 6 000 000 K. Transitions and wavelengths (Å) are also given in the Table. By dividing C by the corresponding full width at half maximum (Dimitrijević et al., 1991), we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used. The validity of the impact approximation has been estimated for data shown in this table, by checking if the collision volume (V) multiplied by the perturber density (N) is much less than one (Sahal-Bréchot, 1969a,b).

PERTURBERS ARE:		ELECTRONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)
Ar XV 2s^{1}S-3p^{1}P^o	500000.	0.521E-03	-0.763E-06
24.7 Å	750000.	0.430E-03	0.325E-06
C= 0.38E+20	1000000.	0.377E-03	0.110E-06
	2000000.	0.277E-03	0.598E-06
	3000000.	0.233E-03	0.545E-06
	6000000.	0.176E-03	0.105E-05
Ar XV 2s^{1}S-4p^{1}P^o	500000.	0.783E-03	0.759E-05
18.8 Å	750000.	0.656E-03	0.786E-05
C= 0.12E+20	1000000.	0.580E-03	0.805E-05
	2000000.	0.439E-03	0.801E-05
	3000000.	0.376E-03	0.808E-05
	6000000.	0.293E-03	0.682E-05
Ar XV 3s^{1}S-3p^{1}P^o	500000.	0.133E-01	0.124E-04
74.6 Å	750000.	0.112E-01	0.259E-05
C= 0.18E+21	1000000.	0.994E-02	0.811E-05
	2000000.	0.756E-02	0.103E-04
	3000000.	0.650E-02	0.117E-04
	6000000.	0.509E-02	0.561E-05

There is no experimental or other theoretical data for the comparison with the calculated Stark broadening parameters of Ar XV spectral lines. Detailed analysis of the obtained results will be given elsewhere.

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INVESTIGATIONS OF THE INFLUENCE OF COLLISIONAL PROCESSES ON THE ASTROPHYSICAL PLASMA SPECTRA AT ASTRONOMICAL OBSERVATORY (PERIOD 2008-2009)

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Abstract. The review of activities on the project 146001 "Influence of collisional processes on the astrophysical plasma spectra", supported by the Ministry of Science and Technological development of Serbia, from 1st of January 2008 up to 31st of December 2009 is given, together with the bibliography of published works.

Investigations made within the frame of the Project "Influence of collisional processes on spectra of astrophysical plasma" concern plasma in astrophysics, laboratory and technology. Particular attention has been paid to the investigation of spectral line profiles, of interest for the diagnostics and modelling of stellar plasma, plasma in laboratory and technological plasma, broadened by collisions with charged particles (Stark effect). Semiclasical perturbation and Modified semiempirical methods were used, developed, tested and investigated. They were applied for determination of Stark broadening parameters, and obtained results were used for the investigation of its influence in stellar atmospheres.

Participants of the Project published 8 papers in leading international journals (the upper third of Science Citation Index (SCI) list), namely in (with the number of published papers in the brackets) Astronomy and Astrophysics (1), Astrophysical Journal (3), Astrophysical Journal Supplement Series (1), Monthly Notices of the Royal Astronomical Society (2), Spectrochimica Acta B (1). In the rest of journals from SCI list as New Astronomy (1), New Astronomy Review (5) and European Journal of Physics D (1) were published 7 articles and in international journals which are not on SCI list and in books of international publishers 18 works.

Other results are: Invited lectures on international conferences published in books of international publishers (2) and in conference proceedings (2), monographs published in Serbia (1), articles in national journals and books (16), contributions in proceedings of international conferences (17), published invited lectures at national conferences (2), contributions in proceedings of national conferences (22), abstracts of invited lectures on international conferences (10), abstracts of presentations on international conferences (49), abstracts of invited lectures on national conferences (3), book reviews in international journals (1) abstracts of presentations on national conferences (3). Within the considered period Zoran Simić defended his PhD Thesis.

In total, project participants published 139 bibliographical items, 83 connected with project and 56 not.

Participamts of the Project organized four conferences and one summer school, giving and in this way contribution to the development of scientific collaboration. They are:

1. « DEVELOPMENT OF ASTRONOMY AMONG SERBS V», Belgrade, 18 – 22. April 2008, Chairman of the Scientific Committee M. S. Dimitrijević, members of the Local Organizing Committee M. Dačić, M. S. Dimitrijević.
2. 6th SERBIAN-BULGARIAN ASTRONOMICAL CONFERENCE, Belgrade, 7 – 11. May, 2008, Co-Chairman of the Scientific Committee M. S. Dimitrijević, members M. Dačić, D. Jevremović, Chair of the Local Organizing Committee A. Kovačević, members M. Dačić, M. S. Dimitrijević, N. Milovanović, Z. Simić.
3. 24TH SUMMER SCHOOL AND INTERNATIONAL SYMPOSIUM ON THE PHYSICS OF IONIZED GASES - [SPIG 2008], August 25-29, 2008, Novi Sad, Serbia, Co-Chairman of the Local Organizing Committee M. S. Dimitrijević, members A. Kovačević, M. Dačić, N. Milovanović, Z. Simić.
4. THE SECOND SUMMER SCHOOL IN ASTRONOMY, September 29 – October 1, 2008, Belgrade, Serbia, Co-Chairman of the Scientific Committee M. S. Dimitrijević, Chair of the Local Organizing Committee A. Kovačević, members M. Dačić, Z. Simić (This School is in official program for the celebration of 200 years from the foundation of the University of Belgrade).
5. 7TH SERBIAN CONFERENCE ON SPECTRAL LINE SHAPES IN ASTROPHYSICS, June 15-19, 2009, Zrenjanin, Serbia; Co-Chairman of the Scientific Committee M. S. Dimitrijević, member D. Jevremović, Chairman of the Local Organizing Committee D. Jevremović, members M. Dačić, M. S. Dimitrijević, A. Kovačević, Z. Simić

Project participants also contributed to the organization of the following conferences:

1. «DJORDJE STANOJEVIĆ – LIFE AND WORK - On the occasion of 150 years from his birth", Novi Sad, 10-11 October 2008, M. S. Dimitriević – Editor of Proceedings and memeber of Scientific Organizing Committee.
2. 1ST WORKSHOP: ASTROPHYSICAL WINDS AND DISKS. SIMILAR PHENOMENA IN STARS AND QUASARS, Platamonas, Greece, September

3-8, 2009, Co-Vice chairman of the Scientific Committee M. S. Dimitrijević, members A. Kovačević, Z. Simić

3. XV NATIONAL CONFERENCE OF ASTRONOMERS OF SERBIA, Belgrade, October 2-5, 2008, member of the Local Organizing Committee A. Kovačević,
4. INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES, 15-20 June 2008, Valladolid, Spain, member of the Scientific Committee M. S. Dimitrijević

From 2008 to 2009, seven researchers were working on this project, six from Belgrade Astronomical Observatory and Andjelka Kovačević from Faculty of Mathematics. The leader of the project during the considered period (1st of January 2008 – 31st of December 2009) was M. S. Dimitrijević, and the participants are:

1. Miodrag Dačić (born 1946) total 20 RM (Research Months)
2. Milan S. Dimitrijević (born 1947) total 24 RM
3. Darko Jevremović (born 1968) total 18 RM
4. Andjelka Kovačević (born 1972) total 16RM
5. Nenad Milovanović (born 1979) total 24 RM
6. Zoran Simić (born 1967) total 24 RM
7. Dragana Tankosić (born 1968) total 8 RM

During two years, seveen participants were engaged for 134 research months, i.e. 11.2 years. The average age was around 46 years (or the average year of birth 1963.9).

The Ministry of Science and Technological Development of Serbia, accepted the project in accordance with the call for projects announced in 2005, and the detailed financial structure of this project during the considered period is shown below.

2009.	
• 1. Salaries for the researchers	8 121 038 RSD
• 2. Expenses of the institution	2 320 320 RSD
• 3. Direct expenses of the Project	596 654 RSD
Sub-Total	11 038 012 RSD
2008.	
• 1. Salaries for the researchers	6 009 281 RSD
• 2. Expenses of the institution	2 001 003 RSD
• 3. Direct expenses of the Project	890 952 RSD
Sub-Total	8 901 236 RSD
Total 2008 - 2009.	**19 939 248 RSD**
(~210 000 EUR – 1 EUR = 95 RSD)	

Decisions on overhead costs were made by director, of Astronomical observatory and they were used for administration and for general expenses of the Institution. While decisions concerning expenses for travels, international collaboration, equipment, and material were made on the Project level.

During 2008. and 2009. years, the investigations of the influence of collisional processes on astrophysical plasma spectra were performed in several directions. The research of the influence of Strak broadening on spectra of chemically peculiar A type stars and white dwarfs have been continuated. The common influence of Stark broadening effect and of hyperfine structure on the lines of ionized manganese has been considered, it was shown when these effects are important and how they can be taken into account. (Popović et al., 2008, New Astronomy, **13,** 85).

It has been investigated the dependence on temperature of Stark broadening in stellar spectra and proposed an improved method to take into account this dependence, for the calculation of stellar atmosphere models and in laboratory plasma diagnostics (Zmerli et al., 2008, European Journal of Physics D **48,** 389).

The influence of Stark broadening at very hot (effective temperature from 40000 to 100000 K) and dense white DO dwarfs was considered, and applying the code for the calculation of atomic structure, were *ab initio* determined Strak broadening parameters for Si VI spectral lines (Hamdi et al., 2008, Monthly Notices of the Royal Astronomical Society, **387,** 871).

The spectrum of the GJ 117 star was observed with 2,7 m telescope on Mc Donalds observatory. Analyzing it by modeling of stellar atmosphere with PHOENIX code was established that $^{6}Li/^{7}Li$=0.05+/-0.02. Also was analyzed the mechanism of creation of lithium in this star (Christian et al., 2008, Astrophysical Journal, **686**, 542).

It was worked on the development of the Dartmouth database for investigation of stellar evolution and for this purpose was investigated and calculated the evolutionary history of some types of stars (Dotter et al., 2008, Astrophysical Journal Supplement Series, **178**, 89).

Since the effects of the changement of chemical composition of stellar populations were investigated on the element by element basis on the stellar evolutionary tracks and isochrones to the end of the red giant branch, now are incorporated the fully consistent synthetic stellar spectra with those isochrone models in predicting integrated colors, Lick indices, and synthetic spectra. Older populations display element ratio effects in their spectra at higher amplitude than younger populations (Lee et al., 2009, Astrophysical Journal, 694, 902).

A series of synthetic spectra was elaborated and published and radiative transfer for broad absorption iron lines of low ionization degree was analyzed at active galactic nuclei. Obtained results support the idea that FeLoBALs may be an evolutionary stage in the development of more ``ordinary" QSOs. (Casebeer et al., 2008, Astrophysical Journal, **676**, 857).

Variability of galaxy optical spectra has been investigated (Shapovalova et al., 2008, Astronomy and Astrophysics, **486** (1), 99-111).

The total and relative contribution to the atmospheric opacity of DB white dwarfs within UV and VUV regions has been determined (Ignjatović et al., 2009, Monthly Notices of the Royal Astronomical Society, **396,** 2201).

A method for the determination of gas temperature in argon – helium microwave plasma on atmospheric pressure, with the help of Van der Waals broadening of spectral lines in optical part of the spectrum, has been elaborated, and the most convenient lines for this purpose have been found (Muñoz et al., 2009, Spectrochimica Acta B **64,** 167).

Furthermore, Stark broadening of spectral lines was analyzed for Serbian Virtual Observatory (Jevremović et al., 2009, New Astronomy Review, **53**, 222), and has been worked on kinematics of broad line region at quasars (Lyratzi et al., 2009, New Astronomy Review, **53**, 179), interpretation of complex profiles of spectral lines in stellar spectra (Danezis et al., 2009, New Astronomy Review, **53**, 214), Stark broadening of spectral lines of chemically peculiar stard (Simić et al., 2009, New Astronomy Review, **53**, 246) and on analyzis of emission lines variability at active galactic nuclei (Shapovalova et al., 2009, New Astronomy Review, **53**, 246).

This are only the most important results and the rest can be seen from bibliography of published papers, presented here.

Certainly the largest success and recognition of Project's results is that, together with our partners from France, England, Austria, Sweden, Italy, Russia and Venezuela we obtained FP7 project "Virtual Atomic and Molecular Data Center.

Additionally, the successful collaboration with Paris Observatory, and UUniversities, Observatories and Institutes in Athens, Cordoba, Paris, Lion, Sankt Petersburg, Moscow, Nizhnyj Arkhiz, London, Belfast, Darthmouth, Groningen, Washington, Oklahoma, Alabama, Wichita, Wisconsin, Georgia, California, Hanover, Göttingen, Sao Paolo, Montreal, Mexico and Tunis, was achieved as well as with the Institute of Astronomy in Sofia (the project SASA-BAS) and with Department of Applied Physics of the Technical university in Sofia, what can be seen from the list of published papers given here.

Also, M. S. Dimitrijević was the supervisor of PhD Thesis of Zoran Simić, defended on 15th of July of 2008.

Within the frame of Project it has been worked and on development of STARK-B database together with Sylvie Sahal-Bréchot and Nicolas Moreau from Paris observatory.

BIBLIOGRAPHY OF SCIENTIFIC WORKS OF PARTICIPANTS OF THE PROJECT 146001 WITHIN THE PERIOD 2008-2009

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ELECTRICAL CONDUCTIVITY OF PLASMAS OF DB WHITE DWARFS ATMOSPHERES

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Abstract. The static electrical conductivity of plasma was calculated by using the modified random phase approximation and semiclassical method, adapted for the case of dense, partially ionized plasma of DB white dwarf atmospheres. were performed for the range of plasma parameters of interest for DB white dwarf atmospheres with effective temperatures $1 \cdot 10^4\text{K} \lesssim T_{eff} \lesssim 3 \cdot 10^4\text{K}$.

1. INTRODUCTION

The data on electrical conductivity of plasma of stars with a magnetic field or moving in the magnetic field of other component in a binary system (see e.g. Zhang et. al., 2009; Potter and Tout, 2010; Rodriguez-Gill et al., 2009) could be of significant interest, since they are useful for the study of thermal evolution of such objects (cooling, nuclear burning of accreted matter) and the investigation of their magnetic fields. Electrical conductivity was particularly investigated for solar plasma, since it is of interest for the consideration of various processes in the observed atmospheric layers, like the relation between magnetic field and convection, the question of magnetic field dissipation and the energy released by such processes (see e.g. Kopecký 1970 and references therein).

An additional interest for data on electrical conductivity in white dwarf atmospheres may be stimulated by the search for extra-solar planets. Namely Jianke et al. (1998) have shown that a planetary core in orbit around a white dwarf may reveal its presence through its interaction with the magnetosphere of the white dwarf. Such an interaction will generate electrical currents that will directly heat the atmosphere near its magnetic poles. Jianke et al. (1998) emphasize that this heating may be detected within the optical wavelength range as H_α emission. For investigation and modelling of mentioned electrical currents, the data on electrical conductivity in white dwarf atmospheres will be useful.

One of the most frequently used approximations for the consideration of transport proprieties of different plasmas is the approximation of "fully ionized plasma" (Spitzer 1962, Radke et al. 1976, Adamyan et al. 1980, Kurilenkov and Valuev 1984, Ropke and Redmer 1989, Djurić et al. 1991, Nurekenov et al. 1997, Zaika et al. 2000, Esser et al. 2003). It was shown that the electrical conductivity of fully ionized plasmas can be successfully calculated using the modified random-phase approximation (RPA) (Djurić et al. 1991, Adamyan et al. 1994a,b) in the region of strong and moderate non-ideality, while the weakly non-ideal plasmas were successfully treated within semiclassical approximation (SC) (Mihajlov et al. 1993, Vitel et al. 2001). In practice, even the plasmas with the significant neutral component are treated as fully ionized ones because of simplification of the considered problems, (Ropke and Redmer 1989, Esser and Ropke 1998, Zaika et al. 2000, Esser et al. 2003). However, our preliminary estimations have shown that such an approach is not applicable for the helium plasmas of DB white dwarf atmospheres described in Koester (1980) where the influence of neutral component can not be neglected.

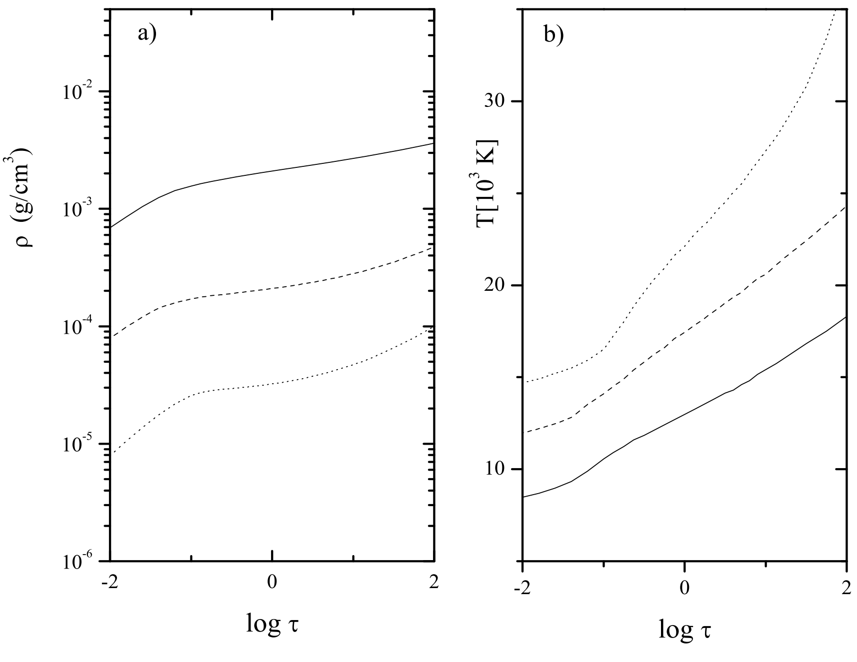

Figure 1. DB white dwarf atmosphere models with log $g = 8$ and T_{eff}=12000K (full curve), T_{eff}=16000K (dashed curve) and T_{eff}=20000K (dotted curve) from Koester (1980): (a) The mass densities; (b) The temperatures, as functions of Rosseland opacity τ.

Consequently, an adequate method for calculations of electrical conductivity of dense, partially ionized helium plasmas is developed here and all details are published in Srećković et al. (2010). This method represents a generalization of methods developed in Djurić et al. (1991) and Mihajlov et al. (1993), namely modified RPA and SC methods, and gives a possibility to estimate the real contribution of the neutral component to the static electrical conductivity of the considered helium plasmas in wide ranges of the mass densities (ρ) and temperatures (T).

The calculations were performed for the helium plasma in the state of local thermodynamical equilibrium with given ρ and T in regions $1 \cdot 10^4\mathrm{K} \lesssim T \lesssim 1 \cdot 10^5\mathrm{K}$ and $1 \times 10^{-6}\mathrm{g/cm}^3 \lesssim \rho \lesssim 2\mathrm{g/cm}^3$. For the calculations of plasma characteristics of DB white dwarf atmospheres the data from Koester (1980) were used. All results are given in Srećković et al. (2010) and here only the application to DB white dwarf atmospheres will be shown.

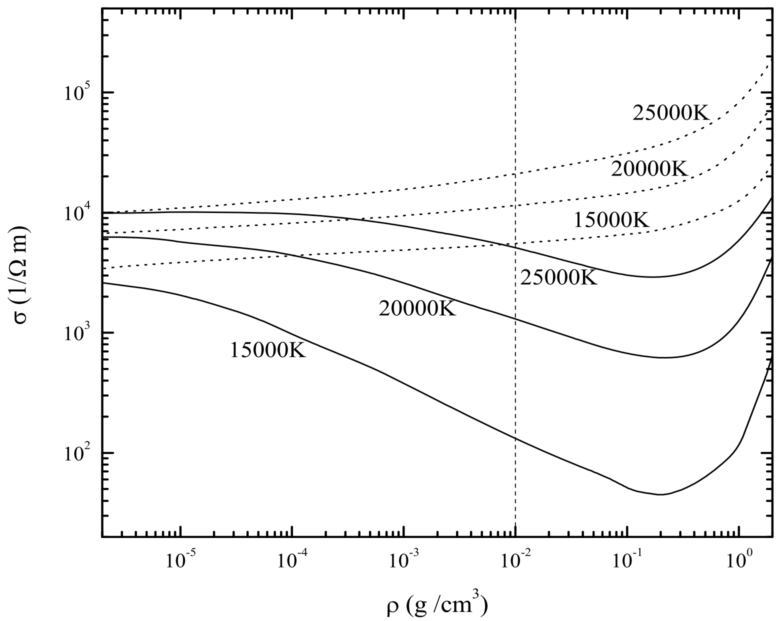

Figure 2. Static electrical conductivity σ of dense He plasmas as a function of mass density ρ (full curves), compared to the Coulomb part of conductivity (dashed curves). The area between the two vertical dashed lines marks the region which is of interest for DB white dwarfs.

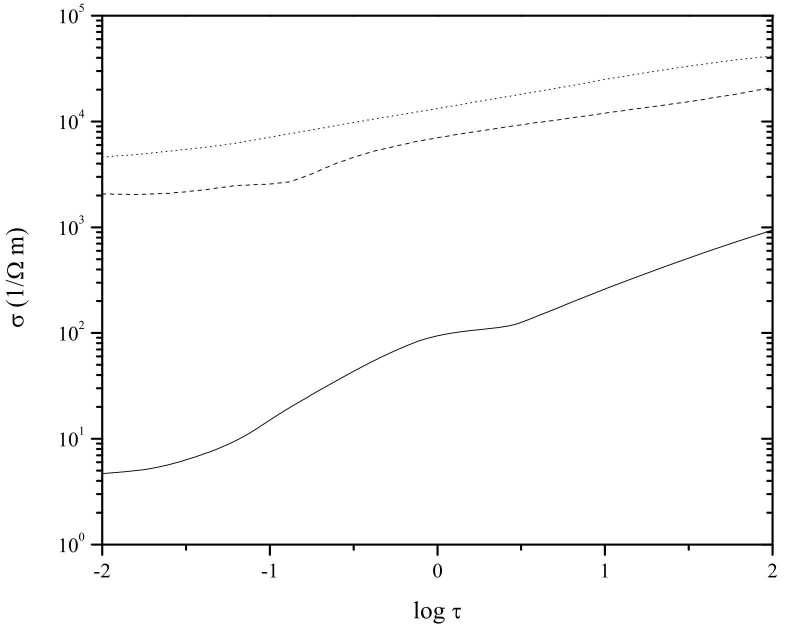

Figure 3. Electrical conductivity σ as a function of the logarithm of Rosseland opacity τ for DB white dwarf atmosphere models with log $g = 8$ and T_{eff}=12000K (full curve), T_{eff}=16000K (dashed curve) and T_{eff}=20000K (dotted curve).

2. RESULTS AND DISCUSSION

In order to apply our results to the study of DB white dwarf atmosphere plasma properties, helium plasmas with electron (N_e) and atom (N_a) densities and temperatures (T), characteristic for atmosphere models presented in the literature (Koester 1980), are considered here. So, the behaviour of ρ and T for models with the logarithm of surface gravity log g =8 and the effective temperature T_{eff} =12000K, 16000K and 20000K is shown in Fig. as a function of Rosseland opacity τ. As one can see, these atmospheres contain layers of dense helium plasma. In order to cover reliably the considered plasma parameter range, we tested our method for the calculation of the plasma electrical conductivity within a wider range of mass density 1×10^{-6}g/cm$^3 \lesssim \rho \lesssim 2$g/cm^3 and temperature $10000K \lesssim T \lesssim 30000K$.

The influence of neutral atoms on the electrical conductivity of helium plasma is shown in Fig. . In this figure the electrical conductivities for T = 15000, 20000 and 25000K are given as functions of mass density ρ. The range between the two vertical dashed lines corresponds to the conditions in the considered DB white dwarf atmospheres. Two groups of curves are presented in this figure: a) the dashed ones, obtained neglecting the influence of atoms, i.e. with $\nu_{ea} = 0$; b) the full line curves calculated including the influence of atoms. First, one should note that the behaviour of these two groups of curves is qualitatively different: the first one increases constantly with increasing ρ, while the other group of curves decreases, reaches a minimum, and then starts to increase with increasing ρ. One could explain such behaviour of the electrical conductivity by the pressure ionization. This figure also clearly shows when the considered plasma can be treated as "fully ionized".

The developed method was applied to the calculation of plasma electrical conductivity for the models of DB white dwarf atmospheres presented in Fig. . The results of the calculations are shown in Fig. . Let us note a regular behaviour of the static electrical conductivity which one should expect regarding the characteristics of DB white dwarf atmospheres.

The method developed and published in Srećković et al. (2010) represents a powerful tool for research into white dwarfs with different atmospheric compositions (DA, DC etc.), and for the investigation of some other stars (M type red dwarfs, Sun etc.). Finally, this method provides a basis for the development of methods to describe the other transport characteristics which are important for the study of all the mentioned astrophysical objects, such as the electronic thermo-conductivity in the star atmosphere layers with large electron density, electrical conductivity in the presence of strong magnetic fields and dynamic (high frequency) electrical conductivity.

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SERBIAN VIRTUAL OBSERVATORY AND VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (VAMDC)

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Abstract. In this lecture we review recent developments in Serbian Virtual Observatory (SerVO) as well as its relation with the European FP7 project: Virtual Atomic and Molecular Data Center - VAMDC. Main components of SerVO are going to be the archive of photographic plates, database of Stark broadening parameters and stellar evolution database. Photographic plates were obtained at Belgrade Observatory from 1936 to 1996. Data for Stark broadening were obtained using semiclassical perturbation and modified semiempirical theories mainly in collaboration with Paris Observatory, and we are organizing them now in the STARK-B database, which will enter also in VAMDC, and will have a mirror site in SerVO. Serbian Virtual Observatory will contain as well a mirror of Darthmouth Stellar evolution database with improvements and VO compatible outputs.

1. VIRTUAL OBSERVATORIES AND SERBIAN VIRTUAL OBSERVATORY

The creation of datasets, connected with the space missions, in the NASA centers in early 90´s, and the huge quantity of data obtained in large all sky surveys (2MASS and SDSS) in the mid-90´s, available for the general use, posed the problem how to organize their search and use them for scientific investigations. The idea of virtual observatory originated from the efforts to solve this problem. Today, the objective of virtual observatories is not only to find, retrieve and analyze astronomical data from ground and space based telescopes worldwide, but also to combine research in different areas of astrophysics, like e.g. multi wavelength astrophysics, archival research, survey astronomy… They also provide data analysis techniques, common standards, wide network bandwidth and state of the art analysis tools. For the differences of classic observatories which have telescopes for gathering electromagnetic radiation or particles, instruments for analyzing and recording as well as different facilities for support of operation, the virtual observatories consist of data centers, loads of astronomical data, software systems and processing capabilities.

International Virtual Observatory Alliance (**IVOA**, www.ivoa.net), is formed in June of 2002, with objective to facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating virtual observatory. So its activity mainly focuses on the development and establishing of standards. The current set of standards as well as recommended ways of implementing them can be found at http://www.ivoa.net/Documents/.

European Virtual Observatory - EuroVO is an organization which aims at deploying VO in Europe. It is organized in three main parts:

Facility center (VOFC) provides the EURO-VO with a centralized registry for resources, standards and certification mechanisms as well as community support for VO technology take-up and dissemination and scientific program support using VO technologies and resources.

Technology center (VOTC) coordinates a set of research and development projects on the advancement of VO technology, systems and tools in response to scientific and community requirements.

Data Center alliance (DCA) is an alliance of European data centers who will populate the EURO-VO with data, provide the physical storage and computational fabric and who will publish data, metadata and services to the EURO-VO using VO technologies.

Serbian Virtual Observatory (SerVO – http://servo.aob.rs/~darko/**)** is a project, whose funding was approved through a grant TR13022 from Ministry of Science and Technological development of Republic of Serbia aiming to achieve the following goals:

1) establishing SerVO and join the EuroVO and IVOA;

2) establishing SerVO data Center for digitizing and publishing in VO photo-plates from the archive of AOB, and publishing other observational, theoretical, and simulated data obtained at Serbian observatories or by staff of Serbian observatories;

3) development of tools for visualization of data.

2. PHOTO PLATES

International Astronomical Union adopted in 2000 a resolution, which stated that all historic observations should be preserved, digitized and made available for use of wide astronomical community.[1] In particular photographic plates, which have a special historical, as well as scientific, significance for the astronomy.

From the mid-thirties till mid-nineties of the last century, photographic plates had been one of the recording media for the observations at the Astronomical Observatory in Belgrade, one of the oldest scientific institutions in Serbia, founded in 1887. From this period, more than fifteen thousand archived plates exist, and one of the main goals of SerVO for the beginning, is to digitize them and publish in the VO compatible format.

During this period of around sixty years, were used photo plates: Kodak (103aO, 2aO, 103aJ, 103aF), Ferrania Pancro anti-halo, Agfa Astro-Platten, Peruts Emulsion, Gevaert Super Chromosa, ORWO ZU 2 and ZU 21, Ilford etc, and variety of objects were observed.

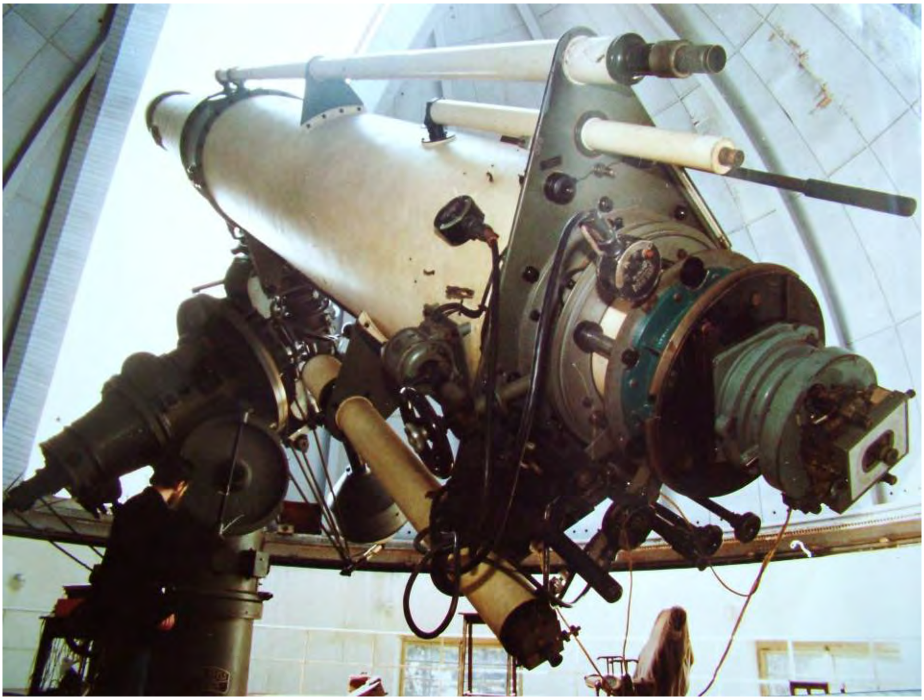

Fig. 1. Zeiss refractor (65 cm) of the Belgrade Astronomical Observatory.

[1] Resolution B3 of XXIVth International Union General Assembly, http://www.iau.org/static/publications/ib88.pdf p.40

For the beginning we are scanning plates with medium resolution (i.e. 1200 dpi) and prepare them for publication in VO compatible format. After completion of this 'preview' phase, we will scan them with high resolution (4800 dpi). In this phase, since the preview will be accessible on the SerVO, we will scan in priority the asked by the users. An example of a scanned plate is given in Fig. 3.

Fig. 2. Zeiss astrograph. M. B. Protitch and his asisstantn M. Simić (1936).

Fig. 3. Scanned photographic plate (from the very early datasets).

The meta data on each plate will contain: plate number, date and time, instrument, observer, coordinates, coordinates of guiding star, method of observations, exposure time, focal length, type and format of plate, air temperature and quality of exposure etc. Meta data are extracted from hand written records. The first results in archiving of photographic plates were presented in Protić-Benišek et al. (2006). Together with standard software (SQL, JAVA, Perl etc.), some EURO-VO tools will be used to build appropriate database. Handling will be achieved using linux Software RAID array with Linux Volume Manager.

3. SerVO – BELDATA - STARK-B

Theoretical data of interest for the modellisation and interpretation of various phenomena and objects in astronomy, are fairly new addition in the context of Virtual Observatory. The staff of Belgrade Observatory produced a large quantity of theoretical data for Stark broadening parameters (line width and shift), obtained mainly within the framework of fruitful collaboration with Observatoire de Paris in Meudon (MSD and SSB), lasting more than thirty years. This line broadening mechanism is generated by interaction of emitting/absorbing atoms and ions with charged particles.

The first attempt to organize these data, as well as other data existing at the Astronomical Observatory in a database, was the BELDATA project (Dimitrijević et al., 2003), the precursor of SerVO and its main content was database on Stark broadening parameters, which after intensification of collaboration between two of us (MSD and SSB) on the realization of this idea not in Belgrade but in Paris, and engagement of an informaticist (Nicolas Moreau) became STARK-B. This database is devoted to modellisation and spectroscopic diagnostics of stellar atmospheres as well as to laboratory plasmas, laser equipments, fusion and technological plasmas.

In the first stage, STARK-B (http://stark-b.obspm.fr) contains data determined using the semiclassical-perturbation approach developed by Sahal-Bréchot (1969ab; 1974), and the corresponding code, supplemented in Fleurier et al. (1977) and, Dimitrijević and Sahal-Bréchot (1984). The accuracy of the data varies from about 15-20 percent to 40 percent, depending on the complexity of the spectrum, degree of excitation of the upper level, and on the quality of the used atomic structure entering the calculation of scattering S-matrix leading to the widths and shifts. The more the upper level is excited, the semiclassical approximation is more suitable, but it is more difficult to find a sufficiently complete set of input atomic data. We note that the STARK-B database is included in the FP7 project European Virtual Atomic and Molecular Data Center (VAMDC). The data can be retrieved in two manners: as a text file or in VO table format.

4. DSED IN SerVO

Members of the group for Astrophysical spectroscopy (DJ) participated also in the development of Dartmouth Stellar Evolution Database which has been recently published (Dotter et al., 2007, 2008). It consists of evolutionary tracks and isochrones for initial stellar mass from one tenth to four solar masses. They were evolved from pre-main sequence state to either of runaway fusion or 100 Gyrs. One of us (DJ) contributed to this project calculating the outer boundary conditions for the atmospheric structures using general stellar atmosphere code PHOENIX. Using this kind of boundary conditions allows an easy generation of various parameters for population synthesis (i.e. colors , low dispersion spectra of star clusters and galaxies). We intend to add an option of "VO table output" for the whole set of data and host a mirror site at SerVO.

5. VAMDC – VIRTUAL ATOMIC AND MOLECULAR DATA CENTER

In order to enable an efficacious, productive and convenient search and mining of available atomic and molecular data and their adequate use, a FP7 founded project: Virtual Atomic and Molecular Data Centre (VAMDC – Dubernet et al., 2010), started on July 1 2009 with a budget of 2.9 MEuros over 42 months. Its aim are to build accessible and interoperable e-infrastructure for atomic and molecular data upgrading and integrating European (and wider) A&M database services and catering for the needs of variety of data users in science, research and development, and industry; creation of search engines that must look "everywhere" in order to map A&M Universe; and creation of a forum of data producers, data users and databases developers, as well as the training of potential users in European Research Area and wider.

VAMDC
Virtual Atomic and Molecular Data Centre

VAMDC

Virtual Atomic and Molecular Data Centre

Fig. 4. VAMDC logo.

Project leader is Marie-Lise Dubernet from Observatoire de Paris and core consortium is made of 15 institutions with 24 scientific groups from France, Russia, England, Austria, Italia, Germany, Sweden, Serbia, and Venezuela.

Partners in the Consortium of the Project are: 1) The coordinator, Centre National de Recherche Scientifique - CNRS (Université Pierre et Marie Curie, Paris; Observatoire de Paris; Université de Reims; Université Joseph Fourier de Grenoble, Université de Bordeaux 1: Université de Bourgogne, Dijon; Université Toulouse 3); 2) The Chancellor, Masters and Scholars of the University of Cambridge – CMSUC; 3) University College London – UCL; 4) Open University – OU (Milton Keynes, England); 5) Universitaet Wien - UNIVIE; 6) Uppsala Universitet – UU; 7) Universitaet zu Koeln – KOLN; 8) Istituto Nazionale di Astrofisica – INAF (Catania, Cagliari); 9) Queen's University Belfast – QUB; 10) Astronomska Opservatorija - AOB (Belgrade, Serbia); 11) Institute of Spectroscopy RAS – ISRAN (Troitsk, Russia); 12) Russian Federal Nuclear Center - All-Russian Institute of Technical Physics - RFNC-VNIITF (Snezhinsk, Chelyabinsk Region, Russia); 13) Institute of Atmospheric Optics - IAO (Tomsk, Russia); 14) Corporacion Parque tecnologico de Merida – IVIC (Merida, Venezuela); 15) Institute for Astronomy RAS - INASAN (Moscow, Russia).

External VAMDC partner is also NIST – National Institute for Standards and Technology in Washington.

The main users of VAMDC facilities will be Astronomy, Plasma science, Atmospheric Science Radiation science and Fusion community as well as Industries using technological plasmas and Lightning industry

Acknowledgments

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2008

ATOMIC DATA AND STARK BROADENING PARAMETERS FOR DO WHITE DWARF ATMOSPHERES RESEARCH: Si VI

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Introduction

Accurate Stark broadening parameters are important to obtain a reliable modelisation of stellar interiors. The Stark broadening mechanism is also important for the investigation, analysis, and modelling of B-type, and particulary A-type, stellar atmospheres, as well as for white dwarf atmospheres (see e.g. /1,2/).

Silicon, in various ionization stages, is detected in the atmospheres of DO white dwarfs /3/. Si VI lines have been observed as well for example in coronal line regions of planetary nebulae NGC 6302 and 6537 /4/.

We note that due to the lack of atomic data, most of the reported sophisticated semiclassical Stark broadening parameters relate to spectral lines of neutral and low ionization stages. In previous papers /5,6/, we calculated Stark broadening parameters of quadruply ionized silicon and neon using SUPERSTRUCTURE /7,8/ and Bates & Damgaard method /9/ for oscillator strengths and we found that the difference is tolerable.

In this work we obtained fine-structure energy-levels, transition probabilities and oscillator strengths for Si VI ion. The atomic structure code SUPERSTRUCTURE was used, which allows for configuration interaction, relativistic effects and semi-empirical term energy corrections. Calculated energies and oscillator strengths are used to provide Stark broadening parameters due to electron, proton, and ionized helium-impact of Si VI lines.

The method and results

The atomic model used to calculate energies of terms or levels and transition probabilities include 26 configurations. Configuration interaction (CI) effects were fully taken into account. For each radial orbital $P_{nl}(r)$, the potential can be adjusted using a parameter called λ. In the present case, those n and l-dependent scaling parameters λ_{nl} were determined variationally by optimizing the weighted sum of the term energies. The P_{nl} are orthogonalised to each other such that the function P_{n1l} is orthogonalised to the function P_{n2l} when $n_2<n_1$. Relativistic corrections are included in Breit-Pauli Hamiltonian (H_{BP}) as perturbation to the non relativistic Hamiltonian (H_{nl}). H_{BP} contains the one electron operators for the mass correction, the Darwin contact term, the spin-orbit interaction in the field of the nucleus and the two electron operators for spin-orbit, spin-other orbit, and spin-spin interactions. We also use the so-called term energy corrections (TEC) /10/ in which the Hamiltonian matrix is empirically adjusted to give the best agreement between experimental energies and the final calculated term energies including the relativistic effects. In practice, the TEC for a given term is simply the difference between the calculated and measured energy of the lowest level in the multiplet.

Stark broadening parameter calculations have been performed within the semiclassical perturbation method. A detailed description of this formalism with all the innovations is given in /11-17/.

Discussion

In atmospheres of very hot stars like DO dwarfs, besides electron-impact broadening (Stark broadening) the important broadening mechanism is a Doppler (Thermal) one as well as the broadening due to the turbulence and stellar rotation. Other types of spectral line broadening, such as van der Waals, resonance and natural broadening, are negligible. For a Doppler-broadened spectral lines, the intensity distribution is not Lorentzian as for electron impact broadening but Gaussian.

We used the obtained Stark broadening parameters for Si VI to demonstrate the importance of Stark broadening in stellar atmospheres comparing them to the Doppler broadening. In Fig 1. Stark (FWHM) and Doppler widths for Si VI λ=122,67 nm spectral line as a function of atmospheric layer temperatures are shown. Stark widths are shown for 6 atmospheric models (from /18/) with effective temperatures T_{eff}= 50,000 K-100,000 K and logarithm of surface gravity log g=8. We can see in Fig 1. that Stark broadening is more important than Doppler broadening for deeper atmospheric layers for all effective temperatures. For WD with effective temperature T_{eff} = 50,000 K, Stark and Doppler widths are equal for temperature layer $T \approx$ 70,000 K and for WD with effective temperature T_{eff} = 100,000 K, Stark and Doppler are equal for temperature layer $T \approx$ 125,000 K. One should take into account however, that even when the Doppler width is larger than Stark width, due to different behaviour of Gaussian and Lorentzian distributions, Stark broadening may be important in line wings.

In Fig 2. we present Stark (FWHM) and Doppler widths for Si VI (λ=122,67 nm) spectral line as a function of Rosseland optical depth for the same atmospheric models as in Fig 1.

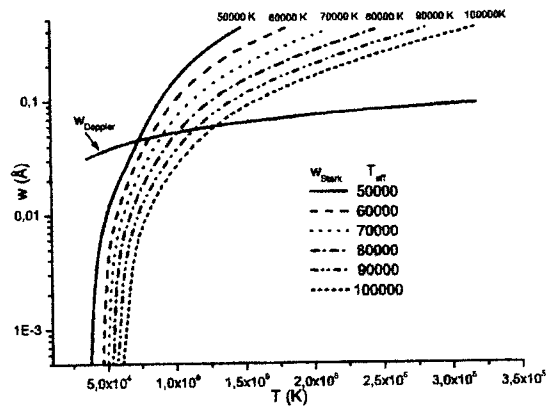

Fig 1. Stark and Doppler widths for Si VI $2p^4(^3P)3s\ ^2P$ - $2p^4(^3P)3p\ ^2D^o$ (λ=122,67 nm) spectral line as a function of atmospheric layer temperatures. Stark widths are shown for 6 atmospheric models with effective temperature T_{eff}= 50,000 K-100,000 K and log g=8. DO white dwarfs atmosphere models were taken from /18/.

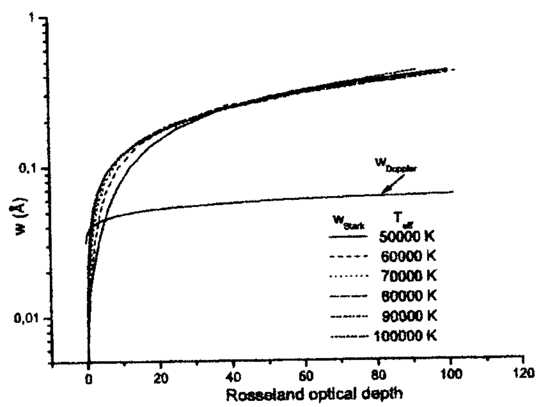

Fig 2. As in Fig 1. but in function of the Rosseland optical depth.

The obtained results for Si VI (atomic and Stark broadening data) are published in /19/.

Acknowledgments

We would like to thank C.J. Zeippen for providing his version of SUPERSTRUCTURE code. This work is a part of the projects 146001 "Influence of collisional processes on astrophysical plasma line shapes" and 146002 "Astrophysical Spectroscopy of Extragalactic Objects" supported by the Ministry of Science of Serbia.

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DATABASES AND EXTRAGALACTIC ASTROPHYSICAL SPECTROSCOPY (Invited talk)

LUKA Č. POPOVIĆ

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Spectroscopy is a powerful tool for investigation of extragalactic objects. Esepcially in investigations of the central part of Active Galactic Nuclei (AGNs) which represent one the most powerful sources in the Universe. In this talk, I will present some recent investigations of spectral properties of AGNs by using the data from Sloan Digital Sky Survey. Also, an overview of useful databases for extragalactic spectroscopical investigation will be given.

BAYESIAN PROBABILITY THEORY IN ASTRONOMY:
TIMING ANALYSIS OF NEUTRON STARS (Invited talk)

VALERI HAMBARYAN[1]

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We will present a Bayesian statistical approach to the data sets collected by XMM-Newton and Chandra X-ray observatories of neutron stars. It will include methodical aspects of short and long term variations with periodic and variable signal detection and parameter estimation. A comparison of Bayesian and classical approaches will be discussed.

SERBIAN VIRTUAL OBSERVATORY AND VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (VAMDC)

DARKO JEVREMOVIĆ[1], MILAN S. DIMITRIJEVIĆ[1], LUKA Č. POPOVIĆ[1], MIODRAG DAČIĆ[1], VOJISLAVA PROTIĆ BENIŠEK[1], EDI BON[1], NATAŠA GAVRILOVIĆ[1], JELENA KOVAČEVIČ[1], VLADIMIR BENIŠEK[1], ANDJELKA KOVAČEVIČ[2], DRAGANA ILIĆ[2], SYLVIE SAHAL-BRÉCHOT[3], KATYA TSVETKOVA[4], ZORAN SIMIĆ[1]. MIODRAG MALOVIĆ[5]

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In this lecture we review recent developments in Serbian Virtual Observatory (SerVO) as well as its relation with the european FP7 project: Virtual Atomic and Molecular Data Center. Main components of SerVO are going to be the archive of photographic plates, database of Stark broadening parameters and stellar evolution database. Photographic plates were obtained at Belgrade Observatory from 1936 to 1996. Data for Stark broadening were obtained using semiclassical perturbation and modified semiempirical theories. The STARK'B database will enter also in VAMDC. SerVO will contain also Stellar evolution database, a mirror of Darthmouth evolution database with improvement and VO compatible outputs.

CLASSICAL APPROACHES OF INFORMATICS TO ASTRONOMICAL IMAGES PROCESSING

DIMO DIMOV[1], MILCHO TSVETKOV[2], YULIANA GORANOVA[3, 2]

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Major interests of the Bulgarian Astroinformatics project (Kounchev, Tsvetkov, Dimov et al. 2009) are directed towards images obtained by scanning of astronomical wide photo plates and especially towards the ones produced up to about the middle of last century or earlier. Naturally, the waste majority of these plates are related to astronomical methods, approaches and tools that are no more in use, for instance – the star chain plates for flare objects recovering (Aniol et al. 1990), the plates artificially enriched by an auxiliary measuring grid, etc. Nevertheless, the astronomers are currently well interested in these images just because of their information is unique and dated to the past. Most of the archive astronomical images are covered by a high (and irregular) level of noise caused by atmospheric disturbances over the used telescopes of ground installation. The diffraction distortions that are intrinsic for the optical telescopes often cause so called hallo effects around brighter object in the images (Starck, Murtagh 2002). The telescope identification data (cf. its distortions' model) as well as the time and position of the sky quadrant of observation are usually written on the plate itself, which means that it is possible these data to be partially and/or irreparably lost. Thus, the canonical task for registration of a given plate image towards a (contemporarily) stellar catalog (Bertin, Arnouts 1996), is naturally modified into a nonstandard task of the „lost in space" type (Kolomenkin et al. 2004).

The current presentation is going to analyze classical methods, approaches and techniques that can be successfully applied in the computer processing of the above mentioned astro-images, namely: approaches for adaptive binarization (or segmentation by intensity) of stellar objects, projection techniques to localize stellar chains and/or to isolate the

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relevant to the quality of the photometric results expected from such observations taken with the telescopes of the Bulgarian National astronomical observatory Rozhen. Based on IRAF routines only, we present an algorithm making use of transparency profiles of stars with known magnitudes. The support of the Bulgarian National Science Fund grant DO-02-273 is appreciated.

THE Fe II EMISSION LINES IN AGN SPECTRA

JELENA KOVAČEVIĆ, LUKA Č. POPOVIĆ, MILAN S. DIMITRIJEVIĆ

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We present a study of the optical Fe II emission in 302 AGNs selected from the SDSS. The strongest Fe II multiplets are grouped into three groups according to the lower term of the transition which correspond approximately to the blue, central, and red part of the "iron shelf" around Hβ. We construct the Fe II template based on those three multiplet groups and one additional group of lines obtained from I Zw 1 object. This Fe II template enables more precise fit of the Fe II lines than usually used templates. We notice that the blue, red, and central parts of the iron shelf have different relative intensities in different objects. Their ratios depend on continuum luminosity, FWHM Hβ, the velocity shift of Fe II, and the Hα/Hβ flux ratio. We analyse the correlations between Fe II line properties and other spectral parameters, and we find different correlations for subsamples with FWHM Hβ greater and less than 3000 km/s.

SEARCHING FOR PERIODICITIES IN AGN

ANDJELKA KOVAČEVIĆ[1], LUKA Č. POPOVIĆ[2]

[1]*Department of Astronomy, Faculty of Mathematics, Studentski trg 16, 11000 Belgrade, Serbia*
[2]*Astronomical Observatory Belgrade, Volgina 7, 11060 Belgrade, Serbia*

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Active Galactic Nuclei (AGNs) often show high variability in the spectral lines and continuum. This variability may be periodical, that may indicate a binary black hole in the center of some AGNs. Here we analyze some methods for periodicity searching in the optical AGN spectra. We apply the methods to the long term observations in the case of several

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observational network. Such collected data are placed in to the sophisticated databases to be accessible for detailed analyze among the scientist. In this paper we have examined the actual databases for Gamma Ray Bursts events, their organization and accessibility. Also, we reviewed the actual process of acquiring the data from satellites and observational network.

CONCEPTS OF CLOUD COMPUTING

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[1] Institute of Mathematics and Informatics, Bulgarian Academy of Sciences
[2] Institute of Astronomy, Bulgarian Academy of Sciences

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The Cloud Computing is a new trend in the network based computing. Its overview and basic concepts are presented here. The different layers and services of cloud computing are explained together with a discussion of their benefits and limitations.

STARK-B DATABASE VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (VAMDC) AND DATA FOR WHITE DWARF ATMOSPHERES ANALYSIS (Invited talk)

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In a number of papers we have demonstrated the importance of Stark broadening mechanism for the modeling and synthesizing of lines observed in spectra of white dwarf atmospheres. We also determined a number of Stark broadening parameters of interest for DA, DB and DO white dwarf plasmas investigations. Now, work on their inclusion in STARK-B database and in Virtual Atomic and Molecular Data Center, an FP7 european project, as well as in Serbian Virtual Observatory is in progress. We review here the part of this work of interest for white dwarf atmospheres analysis.

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P O S T E R S:

SOCIETY OF ASTRONOMERS OF SERBIA, ASTRONOMICAL SOCIETY "RUDJER BOŠKOVIĆ" AND INTERNATIONAL YEAR OF ASTRONOMY

ANDJELKA KOVAČEVIĆ[1], MILAN S. DIMITRIJEVIĆ[2],
TATJANA MILOVANOV[2]

[1]*Department for Astronomy, Faculty for Mathematics, Studentski Trg 16, 11000 Belgrade, Serbia*
[2]*Astronomical Observatory Belgrade, Volgina 7, 11060 Belgrade, Serbia*

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We will present Society of Astronomers of Serbia, and the oldest society of professional and amateur astronomers in Serbia, Astronomical Society "Rudjer Boskovic", founded in 1934.

We will review briefly their history and activities with particular attention to the activities concerning International Year of Astronomy in Serbia.

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SOME ASPECTS OF CIRCULAR RESTRICTED THREE BODY PROBLEM FROM DIFFERENTIAL GEOMETRY POINT OF VIEW

DUŠAN MARČETA

Department of astronomy, Faculty of mathematics, University of Belgrade, Belgrade, Serbia

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This poster considers differential geometry methods for determining local geometrical parameters of zero–velocity curves (ZVC) and surfaces (ZVS) in the circular restricted three-body problem (CR3BP) and emphasizes some interesting characteristics. The obtained results indicate some principles in distribution of local geometrical parameters along ZVC and ZVS and their influence on orbital motion.

SPECTROSCOPICAL INVESTIGATIONS OF EXTRAGALACTIC OBJECTS AT ASTRONOMICAL OBSERVATORY (PERIOD 2008 – 2009)

LUKA Č. POPOVIĆ

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Here we give an overview of the activities on the project P146002 (Astrophysical Spectroscopy of Extragalactic Objects) financed by the Ministry of Science and Technological Development of Serbia. Scientific and other activity of researchers on the project are described. Also, we give a list of references which are published by participants of the project in the 2008/2009 period.

ON THE STARK BROADENING OF Ar XV SPECTRAL LINES

MILAN S. DIMITRIJEVIĆ[1], ANDJELKA KOVAČEVIĆ[2],
ZORAN SIMIĆ[1], SYLVIE SAHAL-BRECHOT[3]

[1]*Astronomical Observatory Belgrade, Volgina 7, 11060 Belgrade, Serbia*
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Satellite born spectroscopy creates an increasing need for data on the spectral line profiles of trace elements, which become astrophysically more and more significant. For example, far UV lines of Ar VII were discovered recently in the spectra of very hot neutral stars of planetary nebulae and white dwarfs and Ne VIII lines in H-deficient pre-white dwarf stars. In order to provide Stark broadening data in X-ray and far UV wavelength region, of interest for modelling and analysis of astrophysical plasmas in extreme conditions, we performed calculations of Stark broadened line widths and shifts for 8 Ar XV multiplets using the semiclassical perturbation theory.

INVESTIGATIONS ON THE INFLUENCE OF COLLISIONAL PROCESSES ON THE ASTROPHYSICAL PLASMA SPECTRA AT ASTRONOMICAL OBSERVATORY (PERIOD 2008-2009)

MILAN S. DIMITRIJEVIĆ

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The review of activities on the project 146001 “Influence of collisional processes on the astrophysical plasma spectra”, supported by the Ministry of Science and Technological development of Serbia from 1st January 2008 up to 31st December 2009 is given, together with the bibliography of published works.

OBSERVATIONS OF M81 GALAXY GROUP IN NARROW BAND [SII] AND Hα FILTERS. II

MILICA ANDJELIĆ[1], KONSTANTIN STAVREV[2], BOJAN ARBUTINA[1], DRAGANA ILIĆ[1], DEJAN UROŠEVIĆ[1]

[1]*Department of Astronomy, Faculty of Mathematics, University of Belgrade, Serbia*
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We present preliminary results of the observations made with 2m RCC telescope at NAO Rozhen, using narrow band [S II] and Hα filters. The main target was to identify supernova remnant and HII region candidates in interaction regions in M81 galaxy group, particularly in the NGC 3077 galaxy. Tidal interaction between galaxies in this group, as well

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MILICA ANDJELIĆ[1], KONSTANTIN STAVREV[2], BOJAN ARBUTINA[1], DRAGANA ILIĆ[1], DEJAN UROŠEVIĆ[1]

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The aim of the present talk is to give an account of the achievements during the first stage of the Astroinformatics project, www.astroinformatics.eu, DO-02-275 with Bulgarian National Science Foundation.

VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (VAMDC) AND STARK-B DATABASE

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Virtual Atomic and Molecular Data Center (VAMDC) is an European FP7 project with aims to build a flexible and interoperable e-science environment based interface to the existing Atomic and Molecular data. The VAMDC will be built upon the expertise of existing Atomic and Molecular databases, data producers and service providers with the specific aim of creating an infrastructure that is easily tuned to the requirements of a wide variety of users in academic, governmental, industrial or public communities. In VAMDC will enter also STARK-B database, containing Stark broadening parameters for a large number of lines, obtained by the semiclassical perturbation method during more than 30 years of collaboration of authors of this work and their coworkers. In this contribution we will review the VAMDC project, STARK-B database and discuss the benefits of both for the corresponding data users.

THE ASTROMATIC SOFTWARE SUITE (Invited talk)

EMMANUEL BERTIN[1]

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The purpose of the Astr*O*matic project is to provide the global astronomy community with open-source software, for processing large quantities of imaging data in a consistent and fully automated way. Astr*O*matic software packages have been developed through the years in the framework of various imaging surveys and data processing pipelines (e.g. TERAPIX, DESDM). After a hands-on overview of the different tasks that can be performed by Astr*O*matic software, I will focus on the ongoing development efforts in the field of automated source morphometry.

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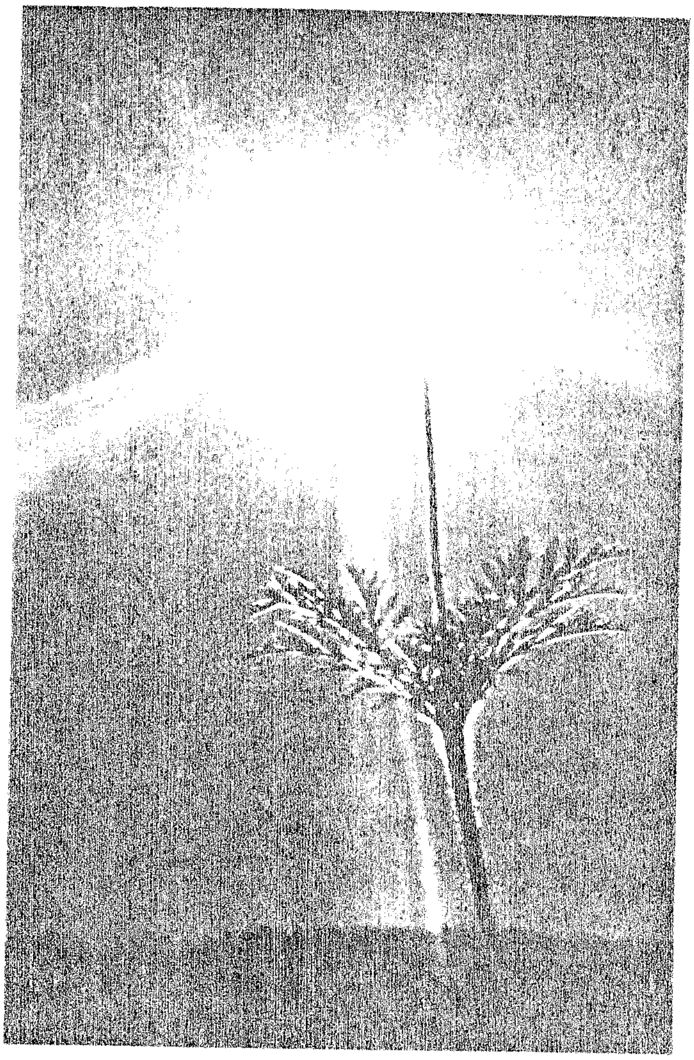
SEVENTH INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES

AUSSOIS (FRANCE) June 11–15, 1984



SCIENTIFIC PROGRAM AND ABSTRACTS

STARK BROADENING OF He I LINES OF ASTROPHYSICAL INTEREST : REGULARITIES WITHIN SPECTRAL SERIES AND INFLUENCE OF DEBYE SHIELDING

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By using a semiclassical-perturbation formalism for the Stark broadening of atomic lines, we have calculated electron and proton impact linewidths and shifts of 36 neutral He I lines as the continuation of our previous work (1). These Stark broadening parameters have been calculated for lines originating from upper energy levels with $4 < n < 10$, and for an electron density of 10^{13} cm^{-3}, typical of stellar atmospheres.

The obtained results have then been used for an investigation of the Stark broadening parameters behaviour within spectral series. The results confirm previous conclusions (1, 2) : for lines belonging to a given spectral series, the electron impact width increases gradually with the increasing principal quantum number of the upper state. We obtain the same conclusion for proton-impact widths. For the shifts we find that the upper level contribution increases gradually within a spectral series if $R_D > R_3$ (the strong collision cutoffs R_1, R_2, R_3 and the Debye cutoff R_D are described in ref. 3). In the case $R_D < R_3$ the shift is zero. The shift can be negative (blue) for the lower members of a series, owing to the larger polarization of the lower level of the transition; on the other hand, for the higher members of the series it becomes positive (red), owing to the gradual increase of the upper level contribution.

In order to investigate the influence of Debye shielding on the electron impact width and shift, we have calculated line widths and shifts for several lines as a function of the electron density. The quantities of interest for the physical discussion are the ratios $\frac{R_D}{R_1}$, $\frac{R_D}{R_2}$, $\frac{R_D}{R_3}$ or the differences between R_D and R_1, R_2 or R_3. The influence of Debye shielding becomes large when R_D approaches R_1, R_2 or R_3. In that case the derived widths and shifts are very sensitive to the cutoffs. This implies that all the Stark broadening calculations based on semiclassical perturbation theories become doubtful when Debye shielding effects become important. Refinement of the calculations, by introducing for instance a Debye-Hückel potential should be vain, owing to the failure of the semiclassical perturbation treatment. In fact, a statistical quantum theory, which should take into account in a coherent way both close-coupling collisional and collective effects becomes necessary.

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SEVENTH INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES

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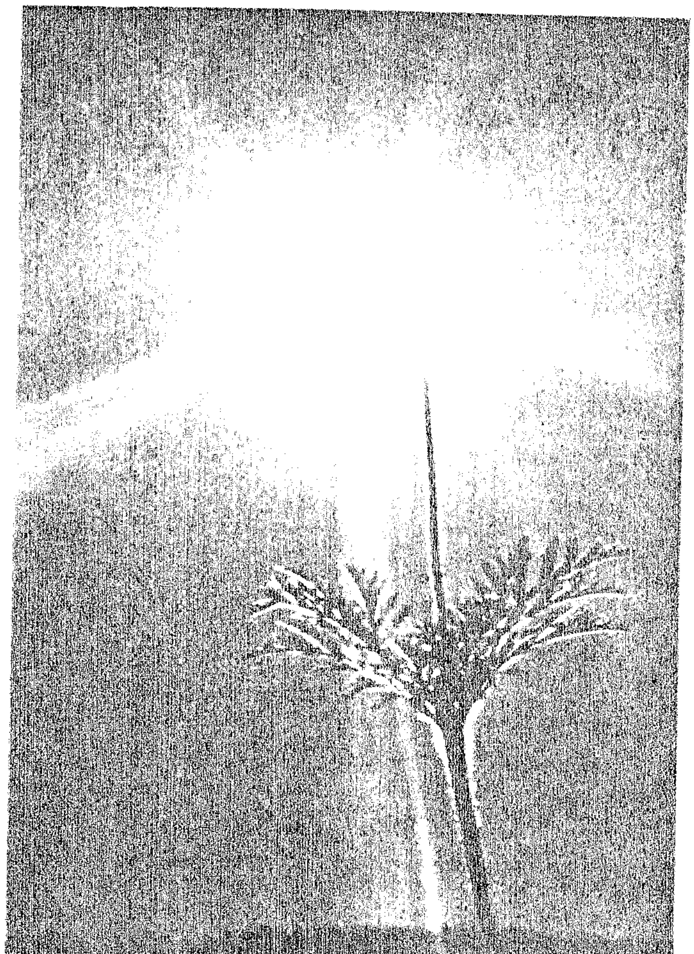

SCIENTIFIC PROGRAM AND ABSTRACTS

COLLISION BROADENING AND SOLAR LIMB EFFECT: Na I $3p^2P^o-ns^2S$ LINES

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Careful measurements of the Fraunhofer lines show a small but systematic red shift across the solar disk (as compared with their wavelength at the centre) reaching a maximum on the limb. Theoretical explanations of this effect are based mainly on two hypotheses (see 1 and Refs. therein). According to the radial-current hypothesis the limb-effect is caused by the existence of rising elements of the gas in the solar atmosphera while the pressure broadening hypothesis explains the observed line shifts as a result of collisions between the absorbing atoms and surrounding particles. As a preliminary result of our study of the influence of collisions on the limb effect, we present here calculations for Na I $3p^2P^o-ns^2S$ series.

We calculated line shifts within Na I $3p^2P^o - ns^2S$ series using the Smirnov-Roueff exchange potential, which takes into account the overlap at intermediate distances of the electronic orbitals (2,3). Results are presented in Fig. 1 together with our calculations using Lenard-Jones (4) and Van der Waals potentials, We can see that the shift rises gradually within this spectral series and that the Lenard-Jones potential is not good for the higher series members.

Our calculations of relative line shifts across the solar disk using HSRA model of the solar atomsphera (5) are compared with simple radial-current theory predictions (1) in Fig. 2. For Stark shift calculations we used data from Ref. 6. We can see that for Na I $3p^2P^o-6s^2S$ line the influence of pressure broadening on the limb effect is substantial. Moreover the significant red shift on the limb due to collisions contributes to the so called supergravitational effect.

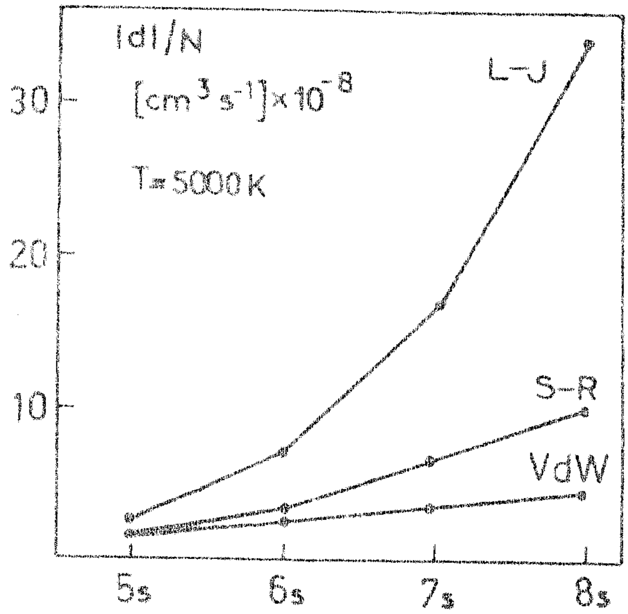

Fig. 1

Line shifts |d|/N [rad $cm^3 s^{-1}$] due to collisions with hydrogen atoms within Na I $3p^2P^0$-ns^2S series calculated using Na-H interaction potentials: S-R-Smirnov-Roueff potential (red); VdW-Van der Waals (red), L-J Lenard Jones (blue).

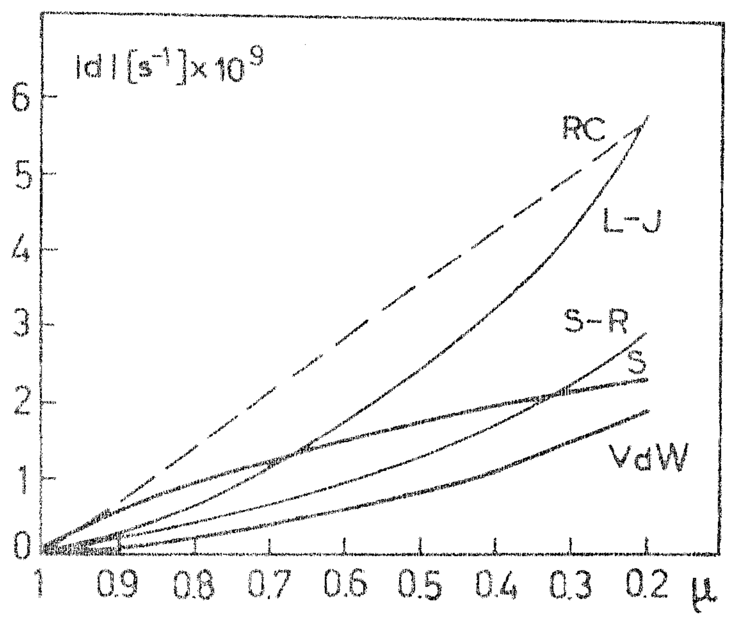

Fig. 2

Relative spectral line shifts (shift in the Solar disk centre is taken as zero) for Na I $3p^2P^0$-$6s^2S$ line as a function of the position angle (μ = cos Ø) of observed points. S-R; VdW and L-J have the same meaning as in the Fig.1, S denotes shift due to the collisions with electrons (red) and RC the blue shift according to the simple radial-current theory (see e.g.1)

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EIGHTH EUROPEAN SECTIONAL CONFERENCE ON ATOMIC AND MOLECULAR PHYSICS OF IONIZED GASES

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CONFERENCE ABSTRACTS

ON THE ELECTRON-IMPACT BROADENING FOR THE RESONANCE LINES OF THE ALKALIS

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Homologous atoms and ions (as e.g. neutral alkalis) often exhibit similar atomic structures. Therefore the electron-impact broadening parameters should exhibit similarities for analogous atomic transitions which differ only by the addition of an electron shell, and systematic trends such as gradual variations are expected in such cases (see e.g. Ref. 1). In order to analyse such similarities for homologous atoms we have computed contributions of various collisional processes to the impact Stark broadening of neutral alkali resonance lines. We have performed also an analysis of the contribution of different angular momenta of the colliding electron to the linewidth and shift. All details of calculations may be found elsewhere[2,3] Results obtained are presented in Tables 1-3.

Table 1. Relative contributions w_ℓ/w for the various angular momenta ℓ of the colliding electron for the semiclassical half halfwidths of ns - np resonance lines of different alkalis at the temperature T = 2500 and 20000 K.

ℓ	Li	Na	K	Rb	Cs	Li	Na	K	Rb	Cs
0	0.383	0.296	0.223	0.184	0.160	0.117	0.085	0.058	0.047	0.049
1	0.383	0.455	0.425	0.393	0.359	0.247	0.226	0.166	0.140	0.106
2	0.167	0.174	0.237	0.279	0.244	0.191	0.199	0.171	0.158	0.139
3	0.044	0.046	0.067	0.086	0.120	0.139	0.130	0.123	0.119	0.103
4	0.014	0.015	0.023	0.030	0.056	0.104	0.098	0.099	0.097	0.081
5	0.005	0.007	0.009	0.012	0.026	0.068	0.074	0.083	0.082	0.073
10	0.000	0.001	0.001	0.001	0.002	0.009	0.012	0.022	0.027	0.034
	T = 2500 K					T = 20000 K				

Table 2. Relative contributions, d_ℓ/d for the various angular momenta ℓ of the colliding electron for the semiclassical shifts of ns - np resonance lines of different alkalis at the temperature t = 2500 and 20000 K.

	Li	Na	K	Rb	Cs	Li	Na	K	Rb	Cs
0	0.201	0.036	0.023	0.009	0.007	0.089	-0.017	-0.010	-0.002	-0.002
1	0.408	0.324	0.206	0.129	0.138	0.211	0.108	0.007	-0.022	0.002
2	0.144	0.230	0.266	0.249	0.229	0.153	0.137	0.098	0.076	-0.019
3	0.071	0.117	0.145	0.171	0.155	0.105	0.117	0.103	0.087	-0.145
4	0.041	0.069	0.087	0.105	0.105	0.072	0.090	0.092	0.085	-0.059
5	0.027	0.045	0.057	0.070	0.074	0.056	0.072	0.078	0.076	-0.007
10	0.007	0.012	0.014	0.017	0.019	0.018	0.028	0.035	0.037	0.052
			T = 2500 K					T = 20000 K		

Table 3. Relative contributions of inelastic (w_{in}), strong (w_s) and elastic (w_{el}) collisions to the half halfwidth of ns-np resonance lines of alkalis.

	Li	Na	K	Rb	Cs	Li	Na	K	Rb	Cs
w_{in}/w	0.402	0.241	0.250	0.207	0.316	0.630	0.552	0.613	0.616	0.687
w_s/w	0.532	0.566	0.573	0.587	0.542	0.409	0.420	0.397	0.380	0.373
w_{el}/w	0.598	0.759	0.750	0.793	0.684	0.370	0.448	0.387	0.384	0.313
			T = 2500 K					T = 20000 K		

By inspecting Tables 1-3 we can see that gradual variation for each ℓ exist and that for heavier alkalis higher ℓ are more important. We founf also that a gradual variation shew all examined processes.

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8th EUROPEAN MEETING ON SOLAR PHYSICS
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Final Programme & Abstracts

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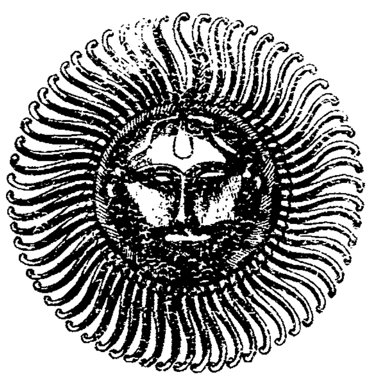

the oscillation mode. Hence resonant damping of the p-modes by coupling to local Alfvén waves is mainly important for modes propagating predominantly along the magnetic fieldlines.

1.13 OBSERVATIONS OF SUNSPOT UMBRAL OSCILLATIONS

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A sunspot is a unique laboratory to investigate the dynamics of a magnetized atmosphere and of magneto-atmospheric waves in particular (Staude, 1994). Both the German Vacuum Tower Telescope (VTT) and the Gregory-Coudé Telescope (GCT) at the Spanish Observatorio del Teide / Tenerife have been used to obtain two-dimensional observations of oscillations in the photospheric layers of sunspot umbrae. At both telescopes circular polarization optics have been used to get time series of CCD data with Stokes ($I \pm V$) line profiles. At the GCT the area of the sunspot has been scanned by shifting the spectrograph slit while several spectral lines can be observed simultaneously (Landgraf, 1995); at the VTT the Fabry-Perot interferometer from Göttingen has been used to get two-dimensional pictures directly and to scan through the line profile (Horn et al., 1996).

After a short description of both methods, including a discussion of their advantages and shortcomings, some preliminary results are presented. The spectra of velocity oscillations show the known features of closely packed power peaks in bands of periods around 3 min (strengthened), 5 min (weakened with respect to the quiet Sun), and possibly at 20 min; there are clear differences between different positions in the umbra. Reliable oscillations of the umbral magnetic field could not be discovered: apparent oscillations are not correlated with the velocity oscillations but rather produced by variations of the umbral intensity contrast due to fluctuations of parasitic stray light.

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1.14 Be III STARK BROADENING DATA FOR THE INVESTIGATION OF SUBPHOTOSPHERIC LAYERS

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Stark broadening of multicharged ion spectral lines is of interest for the Solar physics owing to the recent development of research on the physics of the stellar interiors (Seaton, 1987). Such data are especially of interest for the investigation and modelling of subphotospheric layers. The Be III Stark broadening parameters are additionally interesting, since the surface content (abundance) of Be, involves problems correlated with nucleogenesis, mixing between the atmospheres and the interior, and stellar structure and evolution (Boesgaard, 1988). Line profiles of Be in various ionization stages, are of interest for Solar and stellar opacity calculations as well (Seaton, 1988). Moreover, Stark broadening of Be III lines is of interest for the investigation and diagnostic of hot and dense laboratory plasma, and for the research of regularities and systematic trends.

By using the semiclassical-perturbation formalism (Sahal-Brechot 1969ab), we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 12 Be III multiplets, in order to continue our research of multiply charged ion line Stark broadening parameters. A summary of the formalism is given in Dimitrijevic, & Sahal-Brechot (1996). Here, we will present and discuss the obtained results as well as the comparison with available simpler estimates.

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1.15 THE VARIATION OF THE TOTAL NUMBER OF SOLAR FLARES AND THE NEUTRINO FLUX VARIATIONS

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The method of successive approximations has been used in order to compute periodicities, the phases and the amplitudes of the variation of the solar neutrino flux N (count d^{-1}), measured from the detection rate ^{37}Ar, at the Homestake solar neutrino experiment for the time period 1964-1990. Periodicities of 12 and 2 years have been computed. The following relation has been found:

$$N^{cal} = 0.7sin\frac{2\pi}{24}(t-1969) + 0.7sin\frac{2\pi}{24}(t-1979) + 0.4sin\frac{2\pi}{4}(t-1971)$$

$$-0.4sin\frac{2\pi}{4}(t-1973) - 0.47sin\frac{2\pi}{4}(t-1975) - 0.23sin\frac{2\pi}{4}(t-1978) - 0.25sin\frac{2\pi}{4}(t-1981)$$

$$-0.25sin\frac{2\pi}{4}(t-1983) - 0.35sin\frac{2\pi}{4}(t-1985) - 0.05sin\frac{2\pi}{4}(t-1987)$$

The same periodicities have been found by the same method for the number of total flares and the number of sunspots. We can conclude probable relation between the neutrino magnetic moment that is responsible for the variation of the neutrino flux and the solar magnetic field that is responsible for the total number of sunspots and the number of flares.

1.16 A COMPARISON BETWEEN THE EMISSION MEASURE OF THE SUN AND SOME RS CVn BINARIES

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The Emission Measure (EM) analysis method is a valuable tool in the study of the atmospheres of late–type stars. Employing this method on data collected by the IUE and EUVE satellites, we obtain information about the amount of emitting material for a wide range range of temperatures (and hence height) from the chromosphere all the way up to the corona. The RS CVn–type of binary stars exhibit all the phenomena usually associated with Solar magnetic activity (eg. spots; spectral emission lines originating from the chromosphere, TR, and corona; many orders of magnitude higher X-ray emission; extremely hot coronae and frequent flaring) in very pronounced way. A comparison between the RS CVn stars and the Solar case is presented here.

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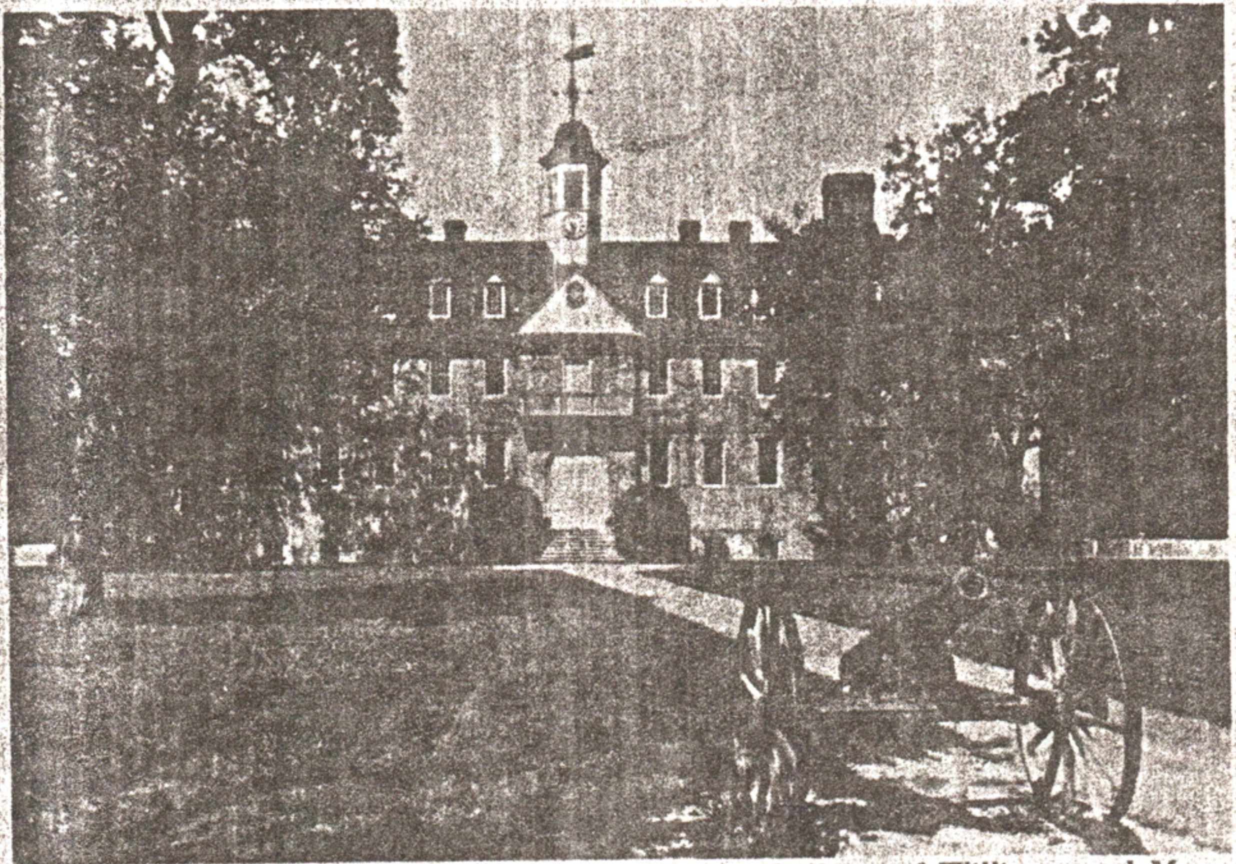
EIGHTH INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES



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Program And Abstracts

MODIFIED SEMIEMPIRICAL ESTIMATES OF ION LINES STARK BROADENING I.THEORY

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In 1968 Griem suggested a simple semiempirical formula [1] useful for singly charged ion lines. This method has been modified recently in order to avoid extensive set of input atomic data and to appropriate for multiply charged ion line widths [2,3] and shifts [4]. Tables of calculated Stark widths of prominent lines of some doubly and triply charged ions are given in [3]. At the low temperature limit simple analytical expressions have been derived [5] too. Here the complete modified semiempirical method is presented. In order to reduce the input set of atomic data and to extend the applicability of semiempirical method [1] to higher stages of ionization, Dimitrijević and Konjević [2] separated the transitions with $\Delta n = 0$ and introduced for them different Gaunt factor. Transitions with $\Delta n \neq 0$ are summed separately. Half-half width w and shift d of ion spectral line broadened by Stark effect become now

$$w + id = N \frac{4\pi}{3} \frac{\hbar^2}{m^2} \left(\frac{2m}{\pi kT}\right)^{1/2} \frac{\pi}{\sqrt{3}} \sum_{j=i,f} \{\vec{R}^2_{k,k+1} [\tilde{g}(x_{k,k+1}) +$$

$$i\varepsilon_j \tilde{g}_{sh}(x_{k,k+1})] + R^2_{k,k-1}[\tilde{g}(x_{k,k-1}) - i\varepsilon_j \tilde{g}_{sh}(x_{k,k-1})] + \qquad (1)$$

$$\Sigma(\vec{R}^2_{jj'})_{\Delta n\neq 0}[g(x_j) + i\varepsilon_j g_{sh}(x_j)] - 2i\varepsilon_j [\sum_{\Delta E_{jj'}<0} (\vec{R}^2_{jj'})_{\Delta n\neq 0} g_{sh}(x_{jj'})]\}$$

Here $k = \ell_j$, i and f denote the initial and final levels $\varepsilon_j = +1$ if $j = i$ and -1 if $j = f$ and $\vec{R}^2_{jj'} = |\langle j|\vec{r}|j'\rangle|^2$. Gaunt factors g, $\tilde{g}$, g_{sh} and $\tilde{g}_{sh}$ are given as a function of x in the table. Here $x_{jj'} = 3kT/2\Delta E_{jj'}$; $x_j = 3kTn_j^{*3}/4Z^2E_H$ where E_H is the hydrogen ionization energy.

	x	≤1	2	3	5	10	30	100
	g	0.2	0.2	0.24	0.33	0.56	0.98	1.33
	$\tilde{g}$	0.7	$-1.1/Z+g$					
	g_{sh}	0.2	0.25	0.32	0.45	0.66	0.82	0.87
Z = 2	$\tilde{g}_{sh}$	0.35	0.40	0.47	0.58	0.70	0.82	0.87
Z = 3	$\tilde{g}_{sh}$	0.53	0.54	0.57	0.62	0.70	0.82	0.87
Z = 4	$\tilde{g}_{sh}$	0.62	0.63	0.63	0.65	0.70	0.82	0.87
Z > 4	$\tilde{g}_{sh}$	0.88	$-1.1/Z+0.01$	$+0.01x/Z$;			$x\leq 100$	

When the nearest perturbing level is so far that $3kT/2|\Delta E_{jj'}|\leq 2$ is satisfied, Eq.(1) may be considerably simplified [5]. In the following paper [6] the described method is used for the evaluations of Stark broadening parameters of ionized atom lines.

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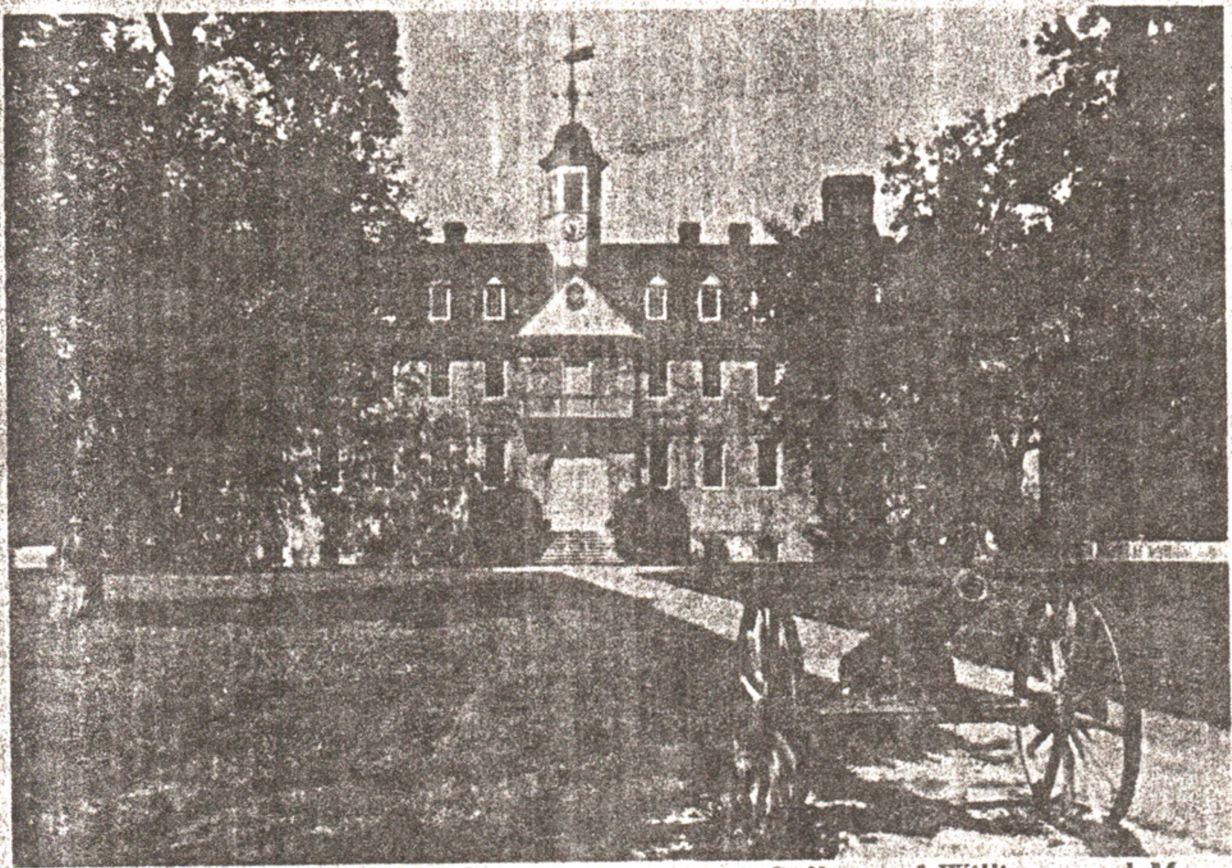

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Program And Abstracts

DIFFERENTIAL Fe I LIMB EFFECT AROUND λ=630.2 nm

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It is confirmed recently [1] that the pressure broadening is an important contribution to the solar limb effect for some NaI lines. Here, our intention is to obtain observational data for FeI solar lines and to study the influence of pressure broadening, in order to find cases where pressure broadening and convective motion contributions may be well separated. Such cases may be suggested for study of motions in solar photosphera.

Solar disk was observed with the solar spectrograph of Belgrade Observatory at 5 heliocentric angles during 14 days in VIII/IX 1984. The distances among 4 spectral lines: FeI 630.15 nm and 630.25 nm as well as telluric lines O_2 630.20 nm and 630.28 nm were measured with PDS 2020 GM machine of Münster University. Four to nine spectrograms at each disk positions were measured and averaged to yield a daily spectral line position. The line position was defined as the vertex of a parabola fitted to the lower 30% of the line depth. All line position differences were averaged also in time (14 days) and one FeI differential limb effect curve was evaluated for all four (N,E,S,W) radii of the solar disk (Fig. 1). The wavelength distance of FeI lines (circles in Fig. 1) decreases with increasing of the heliocentric angle, θ. The overall change, for $0\leq\sin\theta\leq0.79$, amounting to 115 fm corresponds to about 50 ms^{-1} in line-of-sight velocity units. As expected, the distance of the two telluric lines is nearly constant (squares in Fig. 1).

We calculated pressure broadening contribution using HSRA solar atmosphera model. Shift produced by apsorber-neutral atom collisions are calculated

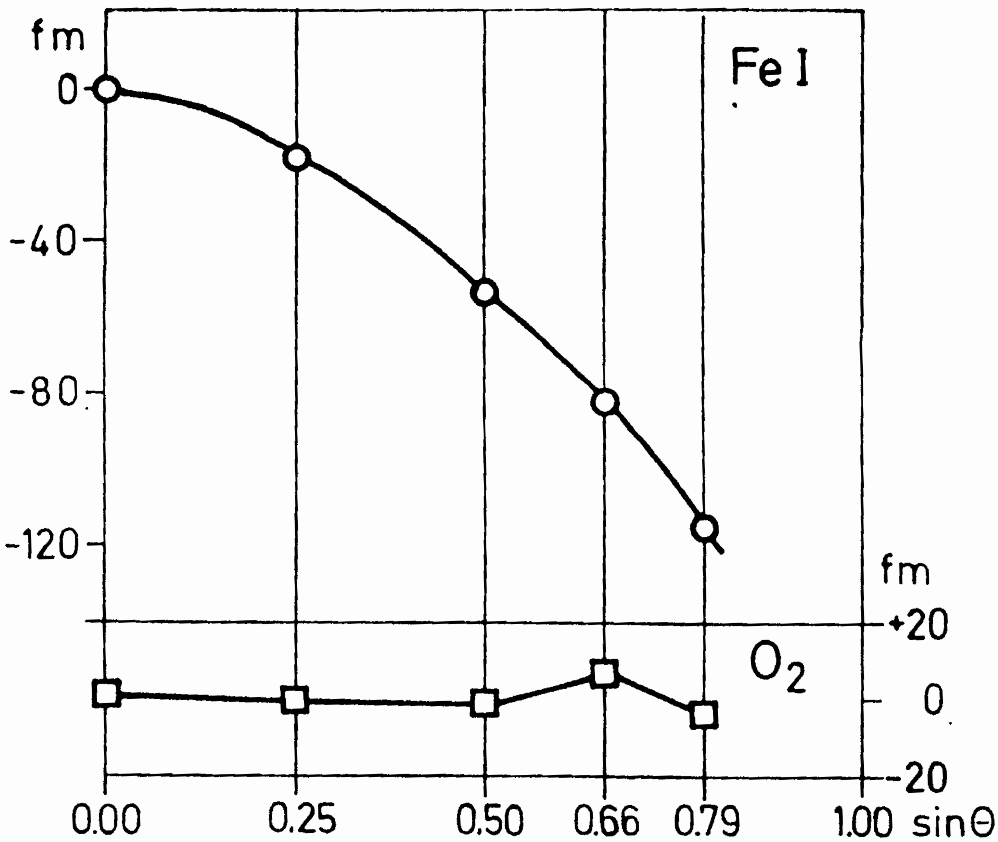

Fig. 1. Relative wavelength shifts of FeI and O_2 lines.

using Lennard-Jones potential while Stark broadening contribution is estimated approximatively. The pressure broadening contribution to FeI 630.15 nm line is 7.5 m/s at the solar disk center. The contribution to the limb effect of each FeI observed line is 1.0 m/s and to the differential limb effect is completely negligible. Therefore, these lines may be used for studies of convective motions with confidence. Consequently, the observed differential limb effect (Fig. 1) is probably caused only by some velocity fields.

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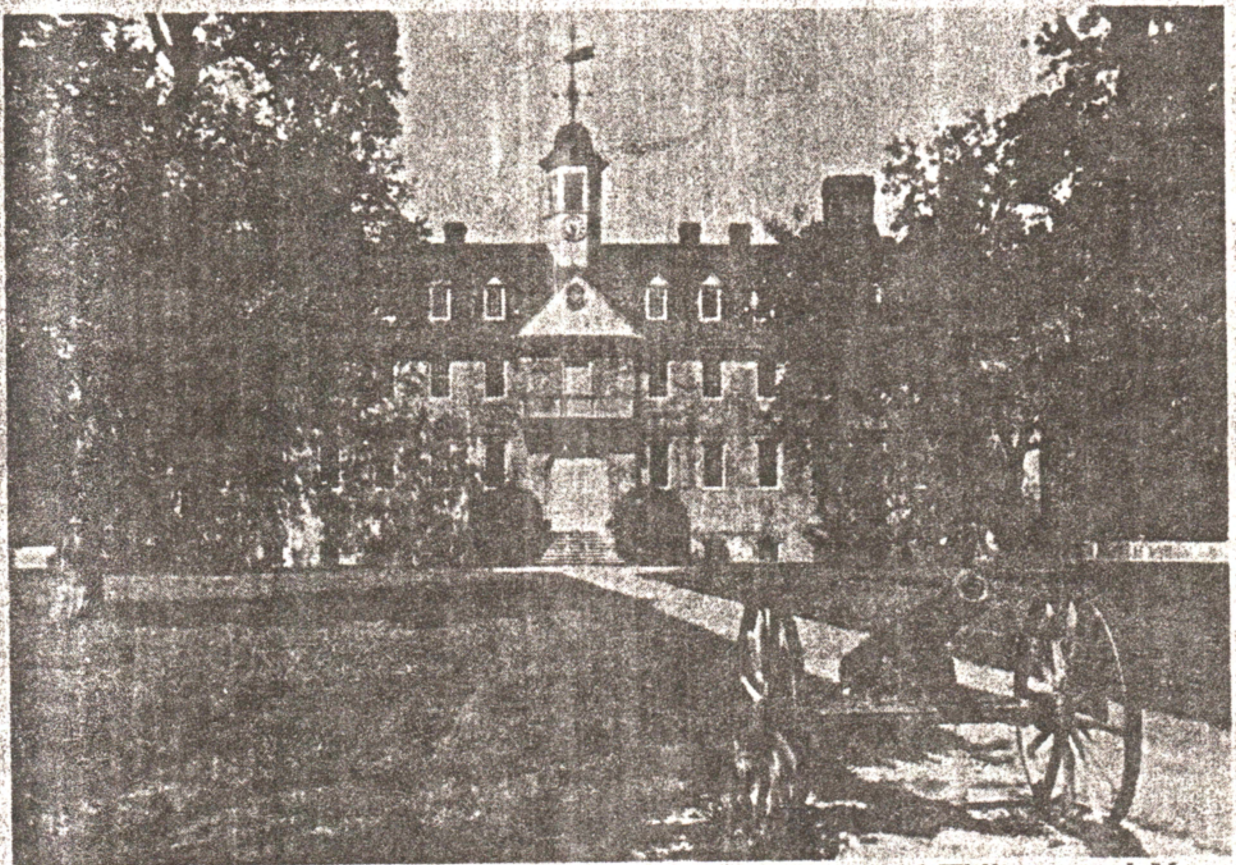
EIGHTH INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES



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Program And Abstracts

MODIFIED SEMIEMPIRICAL ESTIMATES OF ION LINES STARK BROADENING II. APPLICATION

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The modified semiempirical method presented in the preceding paper [1] is used here for the calculation of Stark widths and shifts of singly -, doubly - and triply - charged ion lines. The expression for width (Eq. (1) [1]) is tested in Ref. [2] on a set of experimental data for 36 multiplets of doubly and 7 multiplets of triply charged ions. The average values of the ratios of measured to calculated widths are 1.06 ± 0.31 for doubly - and 0.91 ± 0.42 for triply charged ions. In order to test simplified form of Eq.(1) [1] derived for the low temperature limit [3] we compared with the results of comprehensive width calculations for doubly and triply ionized atoms [4] in which Eq.(1) [1] is used. The discrepancy did not exceed ±30% in average. Furthermore, comparison is made between simplified Eq.(1) [1] with available experimental results in cases when low temperature limit of Eq.(1) [1] may be applied. The average ratio of experimental and calculated values is 1.04, while this ratio is 1.01 when Eq.(1) [1] is used. In Table 1 are compared experimental results w_m for analogous transi-

tions of doubly ionized inert gases [4] with results from Eq.(1) [1] and its simplified form for the low temperature limit, LTL Eq.(1):

$$w(\mathring{A}) = 2.215\cdot 10^{8}\,\frac{\lambda^{2}(cm)\,N(cm^{-3})}{T^{1/2}}\left(0.9-\frac{1.1}{Z}\right)\sum_{j=i,f}\left(\frac{3n_j}{2Z}\right)^{2}\left(n_j^{2}-\ell_j^{2}-\ell_j-1\right)$$

On the basis of the presented results we believe that modified simiempirical method is adequate when evaluating a large number of ion line widths and shifts or when rapid estimates are required.

TABLE 1

ION	WAVELENGTH (Å)	TEMP. (K)	FULL WIDTH IN Å AT $N=1\times10^{17}cm^{-3}$		
			w_m	$w_{Eq.(1)}$	$w_{LTLEq.(1)}$
NeIII	2677.90	34000	0.063	0.052	0.049
	2678.64	34000	0.063	0.052	0.049
ArIII	3509.33	27500	0.160	0.153	0.174
	3514.18	27500	0.148	0.153	0.174
KrIII	3564.23	26000	0.160	0.168	0.194
XeIII	3780.98	27000	0.222	0.235	0.267

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savez društava matematičara, fizičara
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VIII kongres

MATEMATIČARA, FIZIČARA I ASTRONOMA JUGOSLAVIJE

SAOPŠTENJA

KONGRES MFAJ
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PRIŠTINA

23 — 27. septembar 1985.

Prezime i ime Sadžakov Sofija
Adresa 11050 Beograd, Volgina br.7
Sekcija A-2 Dinamika i fizika zvezda i Sunca
Naziv rada Sistematske greške sopstvenih kretanja u katalozima GC, IKŠZ i AGK3.

REZIME:

Autori:
Sadžakov Sofija, Dačić Miodrag

Rezime:

Izvršeno je poredjenje pomenutih kataloga sa posmatračkim katalogom KŠZ uradjenom u Beogradu, i izvedene sistematske greške. Na osnovi u dobijenih rezultata data je ocena tačnosti sopstvenih kretanja u katalozima GC, IKŠZ i AGK3.

Prezime i ime Anatolij A. Mihajlov[1,2] Milan S. Dimitrijević[2,1]
Adresa 1) Institut za fiziku, P.fah 57, 11001 Beograd 2) Astronomska opservatorija, Volgina 7, 11050 Beograd
Sekcija A-2
Naziv rada Uticaj jon-atomskih sudara na apsorpciju zračenja u atmosferama zvezda A tipa

REZIME:

Poznato je da u atmosferama zvezda A tipa značajan doprinos apsorpciji u kontinuumu daje proces

$$H_2^+ + \hbar\omega \rightarrow H + H^+ \qquad (1)$$

Istovremeno sa ovim procesom može doći i do apsorpcije fotona na jon-atomskim kompleksima

$$H + H^+ + \hbar\omega \rightarrow \begin{cases} H + H^+ \\ H^+ + H \end{cases} \qquad (2)$$

U radu je pokazano da prilikom proučavanja spektara zvezda A tipa ovi procesi moraju biti posmatrani zajedno i da u infracrvenom delu spektra proces (2) postaje značajniji od procesa (1). Takodje su odredjeni i odgovarajući koeficijenti apsorpcije.

7th International Conference on the Physics of Highly Charged Ions HCI-94

Book of Abstracts

September 19 - 23, 1994
Technische Universität Wien
Vienna, Austria

PROF. MILAN DIMITRIJEVIĆ
ASTRONOMSKA OBSERVATORIJA
BEOGRAD / YUGOSLAVIA

Editors

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Electron Emission from LiF under Impact of Multicharged Ions

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Multicharged ion (MCI) induced electron emission strongly rises with projectile charge. It might thus be related to the predicted /1/ but not yet clearly demonstrated /2/ process of "Coulomb explosion". Thin LiF films were bombarded in UHV with singly and multiply charged ions from an ECR source /3/ at ion velocities $v_i \leq 5x10^5$ m/s. Absolute total electron yields were derived by measuring electron emission statistics /4/. In comparison with clean metal surfaces /4/, the potential emission is less efficient and the kinetic emission (KE) starts at a lower threshold. Then the KE yield rises steeply with v_i before levelling off above $2x10^5$ m/s. Some interpretations of these results will be given.

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We60

STARK BROADENING OF Na IX SPECTRAL LINES

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The needs for diagnostics of laser produced plasma and the development of fusion research and UV astronomy from space as well as the development of researches on the physics of stellar interiors, increases the significance of the Stark broadening of multiply charged ion lines in physics and astrophysics.

By using the semiclassical-perturbation formalism, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 8 Na IX multiplets, in order to continue our research of multiply charged ion line Stark broadening parameters, with the special emphasis on the lithium isoelectronic sequence. Moreover, the influence of the perturber charge on the ion broadening contribution has been investigated and discussed.

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ON THE STARK BROADENING OF Si XII SPECTRAL LINES

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Due to the simplicity (one optical electron), Stark broadening parameters for spectral lines for ions within the lithium isoelectronic sequence have particular importance for the investigation of regularities and systematic trends. Results of such investigations are of interest for asquisition of new data by interpolation and for critical evaluation of existing experimental and theoretical data, particularly in plasma research and astrophysics.

By using the semiclassical-perturbation formalism, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 9 Si XII multiplets. Here, we present and discuss the obtained results as well as the Stark broadening parameter behaviour within the lithium isoelectronic sequence.

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Ne III and Ne IV LINE PRODUCTION IN ACTIVE GALACTIC NUCLEI

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1s-photoionization of atomic neon is accompagnied by outer shell excitation and ionization. The simultaneous K and L electron ionization, which represents 16% of the single K electron ionization, produces Ne IV states by KL-LLL Auger decays. In astrophysical situations where a thin plasma is exposed to energetic photons, these Ne IV excited states give rise to soft X-ray lines with intensities of the same order of magnitude as the main Ne III lines resulting from the $1s2s^2 2p^6$ K-LL Auger decay. Experimental and theoretical data on Auger and radiative rates, allow us to estimate some Ne II, Ne III and Ne IV relative soft X-ray line intensities (350-600 Å).

3/II

PHYSICS OF IONIZED GASES 1976

contributions

dubrovnik, aug. 27 - sept. 3

j. stefan institute, ljubljana

3.23 STARK BROADENING OF F II LINES

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The available experimental Stark broadening data of singly and multiply ionized atom lines have been recently critically evaluated (1,2). From both reviews one can notice that reliable experimental results for singly ionized atoms are missing for some elements completely, even in two first periods of periodic system of elements: alkaline metals, boron, fluorine, phosphorus and neon.

The intention of this work is to supply Stark broadening data for some prominent lines of singly ionized fluorine. The experimental results will be compared with available theoretical results (2) and calculated values obtained from various theoretical approximations.

Experiment

The experimental apparatus and procedure were described in more details previously (3). The plasma source was a low pressure (0.1 Torr) pulsed arc 20 cm long with Pyrex discharge tube 24 mm i.d. The light from pulsed arc end-on was observed shot-by-shot with 1 m monochromator, McPherson, Model 2051 (inverse linear dispersion in the first order 4.15 Å/mm) equiped with photomultiplier tube EMI 6255B. Measured instrumental half-width with 10 μ slits was 0.047 Å.

In order to obtain optically thin plasma of F II lines, freon 12 was diluted with argon. The ratio freon 12 to argon 1:11 was determined after a number of experiments in which freon 12 was gradually diluted while line shapes and line intensities within multiplets were measured.

Stark profiles were deduced from experimental ones using standard deconvolution procedure for gaussian and dispersion profile (4).

A helium-neon laser interferometer with plane external mirror was used to measure the axial electron density. The electron temperature was determined from the Boltzmann plot of relative intensities of Cl III lines.

Results and Discussion

Experimentally determined full halfwidths of F II lines in Å units at an electron concentration of 5.8×10^{16} cm^{-3} ± 7% and electron temperature of 24200 K ± 10% are given in Table 1. The estimated error of these line widths are typically ±17%.

For the same experimental conditions two sets of theoretical data were calculated and they are also given in the table. Semiclassical results of our calculations for the line widths according to the theory of Baranger (5) with hyperbolic perturber - path trajectories are introduced in table under W_{thB}. The results obtained from combination of Baranger's approach with GBKO straight perturber path approximation for high perturber velocities (6,7) are introduced in table under W_{thCO}. Most of the details and further references for the theoretical calculations can be found in our previous paper (3). For the first multiplet of F II in table under W_{thG} is also given theoretical result obtained from semiclassical, hyperbolic perturber path calculation (2).

The agreement between experiment and theoretical semiclassical calculations for singly ionized fluorine lines is well within the limits of experimental error, while the results based on Baranger's theoretical approach W_{thB} are systematically higher. It follows from this comparison that Baranger's perturber path approximation (hyperbolic trajectories) is not adequate for singly ionized atoms.

TABLE 1

Transsition array	Designation (mult.No.)	wavelength Å	W_m (Å)	W_{thG} (Å)	W_{thB} (Å)	W_{thCO} (Å)
$2p^3 3s-2p^3(^4S^o)3p$	$^5S^o-^5P$ (1)	3847.10	0.11_8	0.113	0.171	0.118
		3849.99	0.11_7	0.113	0.171	0.118
$2p^3 3s'-2p^3(^2D^o)3p'$	$^3D^o-^3D$ (5)	4109.17	0.11_2	-	0.177	0.090
		4119.22	0.11_0	-	0.177	0.090
	$^1D^o-^1F$ (7)	4299.17	0.11_8	-	0.203	0.100

Experimental conditions $N_e = 5.8 \times 10^{16}$ cm^{-3}, T = 24200 K

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NEW TRENDS in ASTRONOMY and ASTROPHYSICS

ABSTRACTS

European Space Agency
Agence spatiale européenne

On Stark broadening of Y III spectral lines for stellar plasma research

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Spectral lines of yttrium are observed in spectra of hot stars, as e.g. in the spectrum of ϕ Her, o And and Sirius, where Stark broadening is the principal pressure broadening mechanism. Moreover, yttrium is commonly associated with slow-neutron-capture nucleosynthesis in stellar interiors. Consequently, Y III lines are of interest for the diagnostic and modelling of stellar plasmas.

Recently, Popović and Dimitrijević (1996) have calculated within the modified semiempirical approach, electron - impact broadening parameters for astrophysically important ns-np transitions of singly charged yttrium ion. While for Y II ions it is not possible to perform more sophysticated semiclassical - perturbation calculations with the appropriate accuracy, due to the lack of reliable atomic data, such calculations are possible for Y III ion spectral lines. In order to provide the corresponding Stark broadening data, we have calculated within the semiclassical-perturbation formalism electron-, proton-, and ionized - helium-impact line widths and shifts for 32 Y III multiplets, for perturber densities relevant for stellar atmospheres and subphotospheric layers research and temperatures T = 10,000 − 300,000 K. There is not measured or calculated Y III Stark broadening parameters. The corresponding experimental data for Stark broadening of doubly charged Yttrium ions will be very useful for further development and rafinement of the theory of multicharged ion lines.

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ABSTRACTS

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Broadening due to collisions with charged particles of V V lines in hot star plasmas

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Vanadium spectral lines are observed in Solar and stellar spectra and consequently data on their shapes are of interest for astrophysics, particularly now with the development of satellite astronomy.

For analysis of a number of hot stars atmospheres and for the consideration of subphotospheric layers, Stark broadening data are of interest, since the Stark broadening is the main pressure broadening mechanism in atmospheres of e.g. white dwarfs, A type stars, PG1159 type stars etc. Forthly and fiftly charged ion lines are dominant in PG1159 type star spectra and they are also important for the modelling of subphotospheric layers and for analysis of radiation transfer through such layers.

In order to provide the corresponding Stark broadening data, for fourthly charged vanadium lines, we have calculated within the semiclassical-perturbation formalism electron-, proton-, and ionized - helium-impact line widths and shifts for 28 V V multiplets, for perturber densities relevant for stellar atmospheres and subphotospheric layers research and temperatures T = 50,000 – 1,000,000 K.

There is not measured or calculated V V Stark broadening parameters for comparison. Consequently, the corresponding experimental determinations will be of interest.

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ABSTRACTS

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The influence of ion - atom complexes on the stellar plasma kinetic and optical characteristics of stellar atmospheres

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In several previous papers (see e.g. Mihajlov et al. 1995,1996 and references therein), processes involving quasi-molecular ion-atom complexes have been considered for plasma coditions relevant for DB white dwarfs. These processes are chemi-recombination processes and the inverse chemi-ionization processes

$He_2^+ + e \Longleftrightarrow He^*(n) + He(1s^2)$,

$He(1s^2) + He^+(1s) + e \Longleftrightarrow He^*(n) + He(1s^2)$,

as well as the ion-atom processes of photoassociation and photodissociation and the inverse processes of the photoemission and photoabsorption charge exchange

$He^+(1s) + He(1s^2) \Longleftrightarrow \epsilon_\lambda + He_2^+$,

$He^+(1s) + He(1s^2) \Longleftrightarrow \epsilon_\lambda + He^+(1s) + He(1s^2)$

It is shown here that in DB white dwarf atmospheres, the mentioned chemi-recombination/ionization processes influence simultaneously on $He^*(n)$ atom populations and on free electron energy distribution.

It is shown in this contribution as well, that for $T_{eff} \leq 16000$ K, DB white dwarf photospheres continuous spectra are formed under the important influence of the considered ion-atom radiative processes. Obtained results show that ion-atom radiative processes may influence significantly on the energetic balance and optical characteristic (opacity and optical depth) of DB white dwarf atmospheric layers where $\log(\tau) \leq 1$. Especially important is the influence on the optical depth values calculated with and without taking into account the considered ion - atom radiative processes. These suggest the necessity to include ion-atom radiative processes for the white dwarf atmosfere modeling from the beginning and not as an *a posteriori* correction, since they change the reference optical depth greed for the tabulated model parameters.

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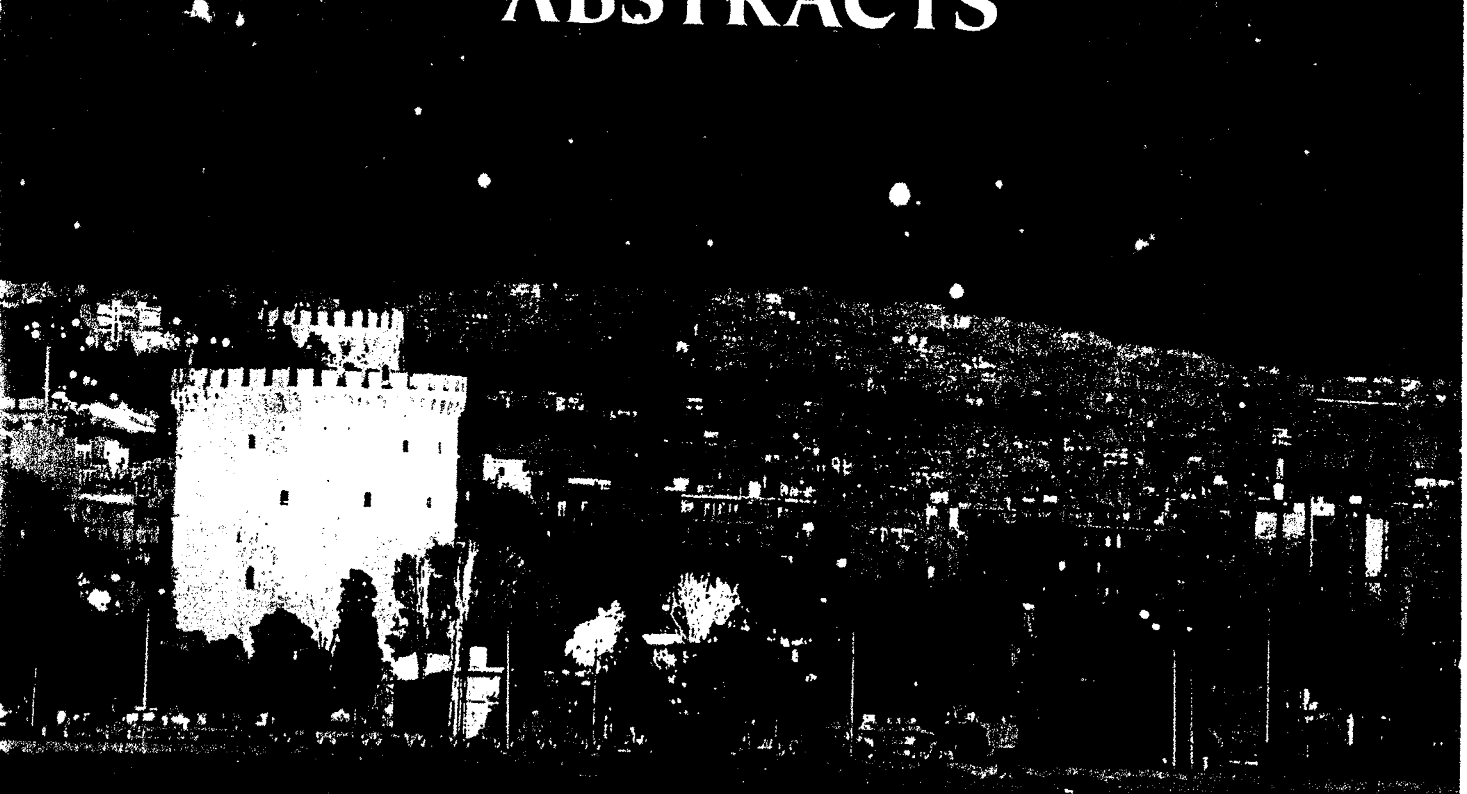

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Chemi-ionization and chemi-recombination processes influence on excited atom populations in Solar atmospheres

A. A. Mihajlov[1,2], M. S. Dimitrijević[2], Lj.M. Ignjatović[1] and M.M. Vasiljević[1]

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In several previous papers (see e.g. Mihajlov et al. 1996 and references therein), chemi-recombination processes during the free electron scattering on the quasi-molecular collisional complexes $H(1s)+H^+$ and molecular ions H_2^+ in the weakly bound rhovibrational states, have been introduced and investigated, as well as the inverse chemi-ionization processes. It has been shown that in partially ionized plasma, the mentioned processes

$$H_2^+ + e \Leftrightarrow H^*(n) + H(1s),$$
$$H(1s) + H^+ + e \Leftrightarrow H^*(n) + H(1s),$$

may be significant for the $H^*(n)$ atom populations.

We investigate here, the influence of these chemi - recombination and of the inverse chemi-ionization processes on the highly excited hydrogen atom population in the Solar photosphere and lower part of the chromosphere. Our result is that the considered processes have an important role in the large region around the temperature minimum in the Solar atmosphere, where they are comparable to the other relevant recombination and ionization processes, or even dominant and that they should be taken into account for the modelling of the weakly ionized layers in the Solar atmosphere.

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NEW TRENDS in ASTRONOMY and ASTROPHYSICS

ABSTRACTS

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Electron-impact broadening mechanism in Hg-Mn star atmospheres: Stark widths for Mn II lines

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The analyses of Hg-Mn star spectra are shown that Manganese is clearly overabundant in this type of CP stars. Hg-Mn stars are hot stars where Stark broadening is the main pressure broadening mechanism and the knowledge of the Stark broadening parameters for astrophysically interesting spectral lines, is needed for the stellar atmosphere investigations and modelling.

Here we present Stark widths for six transitions of Mn II calculated by using the modified semiempirical approach. As an example, how much the electron-impact broadening mechanism influences on the spectral line shapes from Hg-Mn star atmospheres, we have compared thermal Doppler and Stark widths for the model of a hot star (T_{eff} = 12000 K and log$g$=4.0).

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APSTRAKTI RADOVA

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PRIBLIŽNI METODI ZA DOBIJANJE PARAMETARA ŠTARKOVOG ŠIRENJA

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Prilikom istraživanja u astrofizici i fizici često je potrebno poznavati parametre Štarkovog širenja spektralnih linija.Ovi parametri mogu se pouzdano odrediti u izvesnom broju slučajeva,koristeći veoma složeni kvantno mehanički prilaz ili nešto jednostavnije semiklasične teorije.

Za rešavanje čitavog nza problema (kao što je na primer prenos zračenja u zvezdanim atmosferama) nije neophodno veoma precizno odredjivanje parametara Štarkovog širenja svake pojedinačne linije, već je dovoljno da za veći broj linija tačnost bude u srednjem dobra. Pored takvih problema gde su potrebni podaci za veliki broj linija, aproksimativni prilazi su neophodni i za istraživanje linija u kompleksnim spektrima, gde su složenije teorije često neprimenljive u praksi, ili zbog niza dodatnih aproksimacija daju rezultate ponekad čak i manje tačnosti nego aproksimativne.

U predavanju će se dati pregled istraživanja metoda koji omogućuju relativno brzu procenu širine i pomaka spektralnih linija proširenih sudarima sa elektronima i jonima. Biće izloženi rezultati istraživanja semiempirijskog prilaza, istraživanja regularnosti i sistematskih trendova, kao i rezultati pokušaja da se dobiju jednostavne formule na osnovu ovakvih istraživanja. Na kraju će se dati kratki pregled istraživanja oblika spektralnih linija u Jugoslaviji.

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STARKOVO ŠIRENJE DUŽ HOMOLOGNOG NIZA ALKALNIH METALA

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Širenje spektralnih linija sudarima sa elektronima i jonima u plazmi niskih temperatura, značajno je u astrofizici pre svega za proučavanje zvezdanih atmosfera, na primer prilikom odredjivanja hemijske zastupljenosti pojedinih elemenata na osnovu analize spektara zvezda. Prilikom rešavanja ovog problema, potrebno je poznavanje parametara širenja velikog broja linija, pri čemu je bitna dobra srednja tačnost za ceo skup linija a ne tačnost svakog pojedinog podatka.

Nedavno je objavljena približna semiklasična metoda (1) za odredjivanje parametara Starkovog širenja linija neutralnih atoma. Koristeći rezultate istraživanja zavisnosti Starkove širine i pomaka od jonizacionog potencijala (vidi 2 i reference u ovom radu) razradjen je približni metod za dobijanje širine i pomaka spektralnih linija duž homolognog niza neutralnih atoma (3). U ovom radu daje se prikaz razvijenog metoda i njegova primena na linije homolognog niza alkalnih metala.

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5th International Colloquium on Atomic Spectra and Oscillator Strengths for Astrophysical and Laboratory Plasmas

POSTER PAPERS

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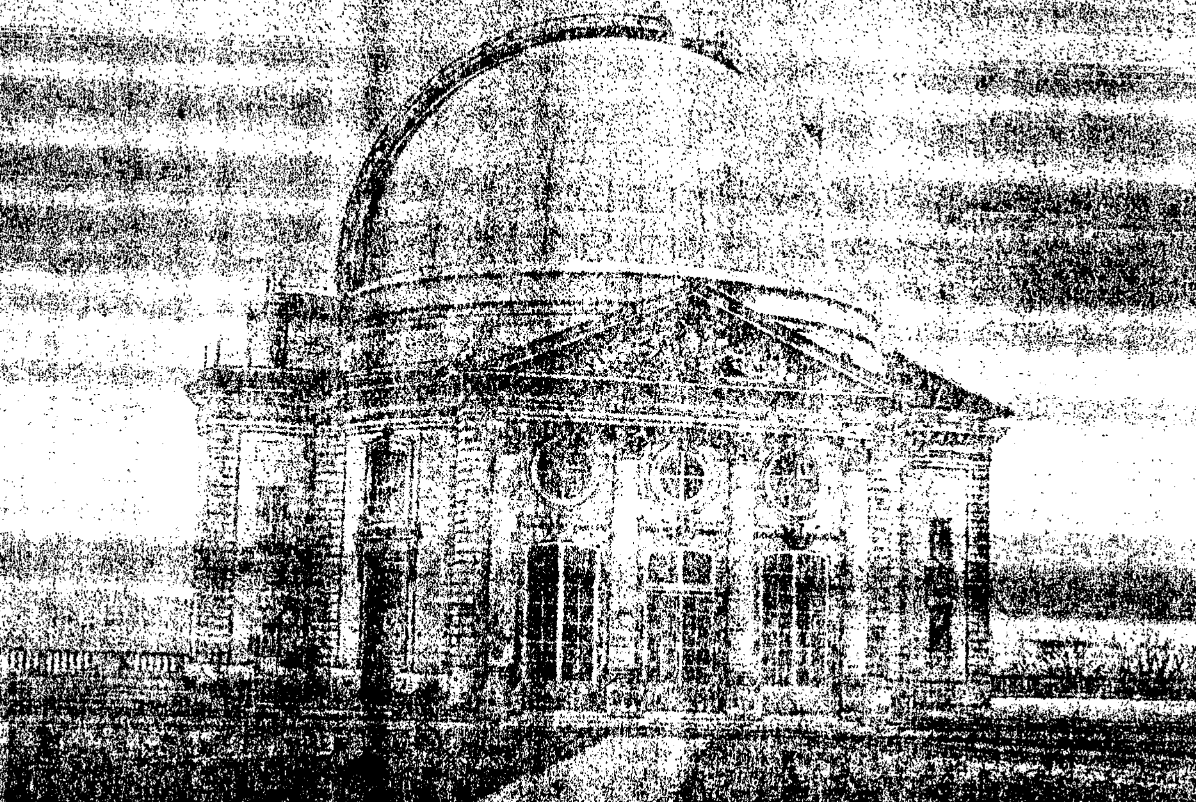

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VI SERBIAN-BELARUSSIAN SYMPOSIUM ON PHYSICS AND DIAGNOSTICS OF LABORATORY & ASTROPHYSICAL PLASMA

Belgrade, 22.-25. August 2006

Abstracts of invited lectures and posters

Eds. M. Ćuk, M. S. Dimitrijević and N. Milovanović

Faculty of Physics, University of Belgrade
Center for Science and Technology Development, Belgrade
Astronomical Observatory, Belgrade

BELGRADE, 2006

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AND DIAGNOSTICS OF LABORATORY & ASTROPHYSICAL PLASMA

was organized by

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PROGRAM OF THE CONFERENCE

22. 8. 2006. Tuesday

09:30 Registration
10:00 Opening ceremony

Chairman: J. Purić
10:30 A. P. Voitovich
INTRINSIC RADIATIVE COLOR CENTERS IN ALKALI HALIDES CRYSTALS AND FILMS: FORMATION AND APPLICATIONS
11:00 M. S. Dimitrijević
COLLISIONS WITH CHARGED PARTICLES AND SPECTRAL LINE SHAPES IN ASTROPHYSICAL PLASMAS – RESEARCH ON BELGRADE ASTRONOMICAL OBSERVATORY 2002-2005

11:30 Coffee pause

Chairman: A. P. Voitovich
12:00 A. Chernyvski, A. Byk, V. Goncharov, V. Zakhozhy, I. Kravtsevich, A. Sikalenka, O. Tarazevich
AUTOMATED ANALYSIS OF THE PLASMA FORMATIONS WITH 100 ns TIME RESOLUTION
12:30 I. P. Dojčinović, M. M. Kuraica, J. Purić
SILICON SINGLE CRYSTAL SURFACE MODIFICATION BY COMPRESSION PLASMA FLOW ACTION

13:00 Lunch pause

Chairman: M. S. Dimitrijević
15:00 V. Goncharov, K. Kazadayeu
LASER-PLASMA PRODUCTION OF WATER SUSPENSIONS WITH NANOPARTICLES OF METALS
15:30 D. Jevremović, A. Dotter, E. Baron
MODELS OF STELLAR ATMOSPHERES FOR EVOLUTIONARY MODELLING

16:00 Coffee pause

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16:30 N. V. Tarasenko, V. S. Burakov, A. V. Butsen, A. A. Nevar, N. A. Savastenko, P. Ya. Misakov
LASER ABLATION AND ELECTRICAL DISCHARGE PLASMAS IN LIQUIDS FOR FABRICATION OFNANOSIZED PARTICLES

17:00 Lj. Hadžievski
DYNAMICS OF WEAKLY RELATIVISTIC ELECTROMAGNETIC SOLITONS IN LASER-PLASMAS

17:30 M. Ivković, S. Jovićević, R. Žikić, N. Konjević
APPLICATIONS OF NON-HYDROGENIC SPECTRAL LINES FOR LOW ELECTRON DENSITY PLASMA DIAGNOSTICS

23. 8. 2006. Wednesday

Chairman: A. Chernyavski

09:30 A. N. Chumakov, N. A. Bosak, A. M. Kuzmitsky, A. M. Petrenko, V. V. Shkurko, M. Sambuu
EFFECTIVE REGIMES OF LASER PLASMA FORMATION FOR FILMS DEPOSITIONS AND SPECTROCHEMICAL ANALYSIS OF MATERIALS

10:00 M. Dačić
CONNECTION OF RADIO-INTERFEROMETRIC WITH OPTICAL OBSERVATIONS AND CREATION OF A NEW REFERENCE FRAME FOR POSITION DETERMINATION OF CELESTIAL OBJECTS

10:30 Coffee pause

Chairman: M. Ćuk

11:00 E. Ershov-Pavlov, K. Catsalap, V. Rozantsev, Yu. Stankevich, K. Stepanov
EMISSION SPECTRA OF LASER-INDUCED PLASMAS AT ELEMENTAL ANALYSIS OF SOLIDS: MEASUREMENT AND MODELING RESULTS

11:30 N. M. Sakan, V. A. Srećković, V. M. Adamyan, I. M. Tkachenko, A. A. Mihajlov
THE METHODS FOR DETERMINATION OF HF CHARACTERISTICS OF NONIDEAL PLASMA

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16:00 Poster section

19:00 Conference dinner

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LASER-PLASMA JETS IN SCATTERING IRRADIATION OF THE LIGHT GATE

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EXCESSIVE DOPPLER BROADENING OF HYDROGEN AND DEUTERIUM BALMER LINES IN A HOLLOW CATHODE GLOW DISCHARGES

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11:00 F. Krčma, V. Mazánková, I. Soural
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11:30 S. V. Gaponenko
MODIFICATION OF SPECTROSCOPIC TRANSITIONS IN MESOSCOPIC STRUCTURES: CAN IT SHED NEW LIGHT ON ELECTROMAGNETIC VACUUM?

12:00 V. I. Arkhipenko, A. A. Kirillov, L. V. Simonchik, S. M. Zgirouski
THE CATHODE LAYER CHARACTERISTICS OF THE NORMAL DC ATMOSPHERIC PRESSURE GLOW DISCHARGE

13:00 Lunch pause

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15:00 S. Raikov, V. Burakov, E. Dovnar-Zapolskaya, V. Kiris, E. Klyachkovskaya, N. Kozhukh
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15:30 M. Jelić, S. Kuhn, J. Duhovnik
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16:00 Coffee pause

Chairman: M. Dačić

16:30 N. A. Bosak, A. N. Chumakov, Yu. A. Stankevich
SELECTION OF SOLID PROPELLANT FOR LASER PLASMA ENGINE

16:00 M. Puzyrev, D. Ismailov, S. Petrov
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17:30 L. Č. Popović, P. Jovanović
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25. 8. 2006. Friday

Excursion

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INVITED LECTURES

Invited lecture

THE CATHODE LAYER CHARACTERISTICS OF THE NORMAL DC ATMOSPHERIC PRESSURE GLOW DISCHARGE

V. I. Arkhipenko, A. A. Kirillov, L. V. Simonchik, S. M. Zgirouski

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There is large increasing interest in atmospheric pressure glow discharges (APGDs) because they can be used for a wide range of technological applications without the need of vacuum systems. Some of fundamental properties of APGD plasmas have been characterized experimentally including discharge dynamics, optical emission, and densities of charged particles and excited species, but the experimental cathode fall parameters of the APGD have not been determined. To a lesser extent the APGD have also been studied numerically. Results of these numerical studies agree favorably with the macroscopic features of measured discharge current and voltage. Theoretical models offer useful tools to understand atmospheric glow discharges, but precision of model results isn't high due to an imperfect data of elementary processes rates, especially, large uncertainties in the electron yield per ion for practical cathodes. That is why the results of every model calculation need experimental testing.

There are a lot of experimental data relatively the normal cathode fall and current density in the low pressure glow discharges (LPGD) presented in well-known books [1-4], for example. But there are a few references where the experimental cathode fall parameters of the APGD are presented. The increase of the gas pressure up to atmospheric leads to a decrease in the dimensions of the characteristics of glow discharge regions and to the sharp increase in the heat release in the cathode region. A determination of the normal cathode fall and current density of the different APGDs and their examination using scaling laws are important current research topics and necessary for further optimization of the different APGD applications.

The cathode fall parameters were investigated in details for the self-sustained normal dc APGD in helium with the steel cathode in [5]. The objectives of this work are to determine both the cathode fall and current density in self-sustained normal dc APGDs in other gases, namely, argon, neon, nitrogen, air and their mixtures with helium. At the same time the different cathode materials are used as well.

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Invited lecture

SELECTION OF SOLID PROPELLANT FOR LASER PLASMA ENGINE

N. A. Bosak[1], A. N. Chumakov[1], Yu. A. Stankevich[2]

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Possibility of jet thrust creation at laser action on absorbing condensed mediums was revealed many years ago (G.A. Askaryan, 1962, A. Kantrowitz, 1972). But only now the idea of laser propulsion has chance of using for control of micro- and nano-satellites movement. Such satellite needs obtaining the strictly verified impulses for its orbits correction. One of the promising directions of solving this problem is creation of laser-plasma engine of ablative type with solid-state working substance (solid propellant). The important characteristic of laser engine is its working resource which depends on used solid propellant. This report is devoted to optimal selection of solid propellant based on experimental determination of specific mass-removal of various materials irradiated by pulsed laser in vacuum.

Dependences of specific mass removal on laser radiation power density were studied by experimental and numerical methods. The experimental results were obtained for number of metals (Al, Bi, brass), for graphite and composites (glass fibre and carbon fibre plastics, sol-gel glass SiO_2 containing 40 % of graphite particles) irradiated in vacuum ($P_0 = 2\cdot10^{-2}$ mm Hg) by Nd:YAG laser (1064 nm wavelength, ~20 ns and ~200 μs pulse duration, irradiance in the range of 1 – $2\cdot10^4$ MW/cm^2). The simulation results, which were obtained for Al and graphite samples, are compared to the experimental ones, for the range of power density 30 –10^4 MW/cm^2. It was found out that experimental dependences of specific mass removal on laser radiation power density are characterized by areas with dominance evaporative or explosive mechanism of target destruction. Obtained results showed mainly evaporative regime of graphite and brass destruction for laser irradiances 30-600 MW/cm^2 that comes with specific mass removal ensuring necessary resource for created laser plasma microengine.

Invited lecture

AUTOMATED ANALYSIS OF THE PLASMA FORMATIONS WITH 100 ns TIME RESOLUTION

A. Chernyvski, A. Byk, V. Goncharov, V. Zakhozhy,
I. Kravtsevich, A. Sikalenka, O. Tarazevich

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The camera was developed and created for the purpose of linear and array image registration. It has a time resolution of 100 ns and 14-bit video signal coding. The maximum storage time is equal to 3 ms. The working spectral range lies between 200 nm and 800 nm. The camera is assembled on a base of an electrical optical transducer of The Moscow Electric-Bulb Factory as well as on a base of a P-22 matrix produced by firm “Electron”, which is situated in St. Petersburg. The matrix has 1 000 × 1 000 pixels format. The developed camera is employed in scientific investigations, conducted in The Atomic and Molecular Physics Institute of The Academy of Sciences of Belarus.

Invited lecture

EFFECTIVE REGIMES OF LASER PLASMA FORMATION FOR FILMS DEPOSITIONS AND SPECTROCHEMICAL ANALYSIS OF MATERIALS

A. N. Chumakov[1], N. A. Bosak[1], A. M. Kuzmitsky[1], A. M. Petrenko[1],
V. V. Shkurko[1], M. Sambuu[2]

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[2]Belarussian State University

The action of intensive laser radiation on absorbing condensed mediums results in formation of laser plasma which is widely used both for deposition of thin films in vacuum, and for spectrochemical analysis of materials. The method of pulsed laser deposition in vacuum provides obteining of high velocities of condensation up to 10^4–10^8 nm/s with good enough reproducibility of chemical composition of irradiated material in deposited films. However, efficiency of such deposition essentially depends on repetition rate of laser pulses. With increase of repetition rate of laser pulses the conditions of laser plasma formation and its subsequent gasdynamic motion are being modified, that results in change of spatially-temporal distribution of plasma parameters and conditions of films deposition. In present work, the capabilities of effective formation of laser plasma are explored at multi-pulsed high-frequency ($f \leq 50$ kHz) laser action on materials and features of pulsed laser deposition of films and coatings on various substrates in vacuum, including in the presence of external electrical field, are investigated.

It was established on the basis of complex experimental researches and numerical calculations of pulse-periodic laser action on metals and carbon materials that the interaction of individual plasma formations initiate changes of conditions for plasma deposition on a substrate only for repetition rates of laser pulses more than 10–20 kHz in vacuum and 1–5 kHz in atmospheric air. Diamond-like and conductive carbon films on various substrates are obtained experimentally at irradiation of graphite by pulsed solid-state laser generating on 1060 nm wavelength with repetition rates of laser pulses up to 20 kHz. Multiple growth of carbon films deposition velocity is found out for intensities of external electrical field exceeding 3 kV/cm. The dependence of structure and electrical conductivity of deposited coatings on the direction and intensity of external electrical field is established. This result can find application for deposition diamond-like and conductive carbon films. The new possibilities for development of LIBS technique for material analysis are revealed using double pulse laser action at two wavelengths of laser radiation.

Invited lecture

CONNECTION OF RADIO-INTERFEROMETRIC WITH OPTICAL OBSERVATIONS AND CREATION OF A NEW REFERENCE FRAME FOR POSITION DETERMINATION OF CELESTIAL OBJECTS

Miodrag Dačić

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It is undispensable, for observations of stars and other objects for the needs of astrophysical investigations, to know their positions as much precisely as possible. The development of long base radio-interferometry enabled the connection of radio-interferometric and optical observations, and consequently, the connection of reference frame for extra galactic radio sources, which positions are practically unchanged for a number of decades. In such a way, a new reference frame of high accuracy is obtained, where coordinates of observed objects are given.

Invited lecture

COLLISIONS WITH CHARGED PARTICLES AND SPECTRAL LINE SHAPES IN ASTROPHYSICAL PLASMAS – RESEARCH ON BELGRADE ASTRONOMICAL OBSERVATORY 2002-2005

Milan S. Dimitrijević

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The project "Influence of collisions with charged particles on astrophysical plasma spectral line shapes" was financialy supported by Ministry of Science and Environment protection of Republic of Serbia under the contract number GA-1195, starting with 2002 up to 2005. The contract 146001 for the project under the same name is signed also for the 2006-2010 period. The objective of this contribution is to review the results obtained up to now and to discuss the future plans. Since our main scientific activity was realized through this project our aim is to inform Belarussian colleagues on our achievments and directions of future activities in order to stimulate the development of Serbian – Belarussian collaboration within this research field.

Invited lecture

SILICON SINGLE CRYSTAL SURFACE MODIFICATION BY COMPRESSION PLASMA FLOW ACTION

I. P. Dojčinović[1,2], M. M. Kuraica[1,2], J. Purić[1,2]

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Modification of silicon single crystal surface by the action of nitrogen quasistationary compression plasma flow (CPF) generated by magnetoplasma compressor is studied. It was found that during single pulse surface treatment regular fracture features are obtained on the Si (111) and Si (100) surface in the target central part. Some of these regular structures can become free from the underlying bulk, formed as blocks ejected from the surface. Also, oriented silicon periodic structures are produced in the target periphery part. These surface phenomena are results of specific conditions during CPF interaction with silicon surface. High plasma flow energy density, large dynamic pressure, thermodynamic parameters gradients and induced magnetic field on treated surface cause rapid heating and melting of surface layer, as well as surface fracturing, long existence of molten layer and fast cooling and recrystalisation.

Invited lecture

EMISSION SPECTRA OF LASER-INDUCED PLASMAS AT ELEMENTAL ANALYSIS OF SOLIDS: MEASUREMENT AND MODELING RESULTS

E. Ershov-Pavlov[1], K. Catsalap[1], V. Rozantsev[1], Yu. Stankevich[2], K. Stepanov[2]

[1]Institute of Molecular and Atomic Physics, Minsk, Belarus
[2]Heat and Mass Transfer Institute, Minsk, Belarus

Results are presented of a numerical simulation of laser-induced plasma plumes and of their emission spectra as applied to the elemental analysis of solids by the LIBS technique. The plasma plumes have been considered, which are generated by 1.06 µm laser pulses of a nano-second duration and GW/cm^2 power density at single- and double-pulse excitation modes. The laser beam is supposed to fall normally to the sample surface. The modeling of the plume plasma parameters consist of a solution of the thermal, hydrodynamics and optical problems at the laser beam action on a solid sample. The numerical code allows investigating the dynamics of two-dimensional erosion plumes supposing their axial symmetry.

Resulting space and time distributions of parameters in the laser-induced plasmas are used for the calculation of the emission spectra of the plumes at a chosen exposition time. The emission spectra are simulated for a side-on observation case.

The simulation results obtained for an Al-sample are compared to the experimental ones, measured at the conditions of common LIBS applications: Q-switched Nd:YAG laser, 1064 nm wavelength, ~10 ns pulse duration, irradiance in the range of 10^9 W/cm^2.

The comparative study is realized for the emission spectra of the plasma plumes induced at single- and double-pulse excitation modes, which allows examining main reasons of the observed efficiency increase of the LIBS at the elemental analysis using the double-pulse excitation mode.

Invited lecture

LASER-PLASMA PRODUCTION OF WATER SUSPENSIONS WITH NANOPARTICLES OF METALS

V. Goncharov, K. Kazadayeu

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The methods of nanoparticle objects producing and controlling of their characteristics are eveloping at the present time. Physical and chemical properties of matter in this range of sizes differ both from individual ions and atoms properties and from solid properties. The application of nanoparticles is of interest of such fields as medicine, electronics, chemical industry, optics and i.e.

The nickel nanoparticles water suspense was obtained by penetration of the metallic target erosion products in water medium. The masking of the of drop-liquid particles beam allowed to realize spatial separation of the lager(1-100 μm) and the smaller(10-100 nm) particles. The erosion laser jet was obtained by the acting average intensity laser irradiation at the nickel target, using Nd-glass laser (λ=1.064 nm).

The method of laser probing was used to determine the effective nickel particle sizes and their number concentration in water suspense. This results are proved by the data of atomic-power and electronic microscopy.

Invited lecture

LASER-PLASMA JETS IN SCATTERING IRRADIATION OF THE LIGHT GATE

V. Goncharov, K. Kazadayeu, M. Puzyrev, D. Slavashevich

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The methods of laser treatment of materials are widespread at the present time. The using of methods with maximal mass removing is more suitable to maximize the speed of laser treatment. The dominating mass removed from the target is due to the hydrodynamic mechanism of drop-liquid phase formation.

Non-luminous laser erosion products and the dynamics of their recession were investigated with an employment with light gating (probing) pulse of ruby laser. It was experimentally showed, that the drop-liquid particles, formed by the hydrodynamic mechanism appear in laser jet only after laser irradiation intensity decreasing at our conditions. The drop-liquid particles move on the small angle (~12 º) to target surface in case of large irradiated spot (erosion crater diameter is much lager than its deepness).

The small (nanosize) drop-liquid target particles appeared in laser jet during the whole time of the acting laser pulse. They move perpendicularly to the target surface. This fact can be applied for the spatial separation of the small particles (formed by the mechanism of volume evaporation) and large particles (- hydrodynamic mechanism).

Invited lecture

DYNAMICS OF WEAKLY RELATIVISTIC ELECTROMAGNETIC SOLITONS IN LASER-PLASMAS

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Relativistic EM solitons are coherent spatially localized structures self-trapped by a locally modified plasma refractive index via relativistic electron mass increase and an electron density drop due to the ponderomotive force of an intense laser light [1]. A train of relativistic EM solitons is typically found to form behind the intense laser pulse front. Relativistic electromagnetic (EM) solitons in laser driven plasmas were analytically predicted and found by PIC (particle-in-cell) simulations [2] [3], [4]. It has been estimated that, for ultra-short laser pulses, up to 40% of the laser energy can be trapped by relativistic solitons, creating a significant channel for laser beam energy conversion.

In this work, we treat a case of a linearly polarized laser light. In laser-plasma interactions, relativistic Lorentz force sets electrons into motion, generating coupled longitudinal-transverse wave modes. These modes in the framework of a weakly relativistic cold plasma approximation in one-dimension, can be well described by a single dynamical equation of the generalized nonlinear Schrödinger type [1], with two extra nonlocal terms. Conserved quantities and solution for the moving solitons are analytically calculated in an closed form. Stability of the solitons is studied analytically and numerically. The instability threshold dependent on the soliton self-frequency and velocity is obtained. The dynamics of the stable and unstable solitons are studied numerically. For an isolated soliton, our analysis shows that the soliton motion downshifts the soliton eigenfrequency and decreases its amplitude. The effect of the soliton velocity on the stability is analytically predicted and checked numerically. Results show shifting of the stability region toward larger amplitudes in comparison to the standing soliton case [5]. Rich dynamics with examples of (un)stable soliton propagation and breather creation and formation of unstable cusp-type structures is exposed numerically. These results are compared with the one for a standing (non-moving) relativistic EM soliton case [1]. Further, we address a soliton stability as a base for our understanding of a complex soliton-pair interaction, which critically depends on solitons amplitude, velocity and a mutual phase relation. [6]

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[5] A. Mančić, Lj. Hadžievski and M.M. Škorić, *Phys. Plasmas* **13**, 052309 (2006)
[6] A. Mančić, Lj. Hadžievski, M.S. Jovanović, M.M. Škorić and K. Mima, *J. Plasma Physics* (2006)

Invited lecture

APPLICATIONS OF NON-HYDROGENIC SPECTRAL LINES FOR LOW ELECTRON DENSITY PLASMA DIAGNOSTICS

M. Ivković, S. Jovićević, R. Žikić, N. Konjević

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This work comprises an analysis of optical emission spectroscopy (OES) techniques and results of their application for diagnostics of middle and low electron densities (N_e) in low temperature plasmas. In this review, discussion will be limited primarily to the applications of the non-hydrogenic spectral lines. For analysis of hydrogenic spectral lines more details can be found in recent review [1] and in references cited therein.

These techniques became, in some cases when it is not convenient to seed plasma with hydrogen, the most sensitive and often the only possible plasma diagnostics tool. The following OES diagnostic techniques based on use of: 1) Stark – widths and shifts of ion spectral lines, 2) Stark parameters and shape of atom spectral lines, 3) line shape of helium lines atom with forbidden components and 4) molecular nitrogen bandheads intensities are considered.

Within this work all these techniques are studied, critically evaluated, tested and applied for diagnostics of microwave induced discharges (MIP), low pressure pulsed arcs or capillary discharge. The importance of electron temperature for electron density diagnostics is considered also. The experimental difficulties and necessary precautions required whenever Stark broadening parameters have to be determined or used for plasma diagnostics purposes will be examined and result applied.

For OES studies of low pressure pulsed arcs and capillary discharge, the electron density determination by fitting the shape of non-hydrogenic atomic and ion spectral lines is critically evaluated. In these plasma sources the study of ion lines widths along carbon sequence and comparison with theories are also performed. Neutral atom lines asymmetry and new techniques for an ion-broadening parameter measurement was discussed too. Special attention was devoted to the application of approximate experimental formulas connecting parameters of the helium atom lines with forbidden components and electron density.

New technique for low electron density diagnostics [2] based on molecular nitrogen bandhead intensities was demonstrated in MIP and further theoretical and experimental studies suggested.

[1] M.Ivković, S.Jovićević and N.Konjević, *Spectrochimica Acta* B **59**, 591, (2004).
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Invited lecture

NOTES ON THE ROLE OF REACTIVE FIELD EFFECTS OF THE PARTICLE ACCELERATION TO THEIR COLLECTIVE MOTION IN PINCHED PLASMAS IN NATURE AND EXPERIMENTS

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Reactive field due to particle acceleration is one of the most intriguing and controversial phenomena in classical mechanics and classical electrodynamics (see e.g., [1,2]). The appearance of reactive field is apparently easy to understand within a simple pictures based on the retarding fields of moving particles, and seems to be a very universal one in both sub-atomic and cosmological scales (e.g., [3]). It gives nice interpretations of the magnetic field, which turns out to be just a consequence of potential field sources in the space-time structure [4,5]. The Einstein equivalence between the mass and energy was discovered within this theory well before his work on the mass-energy equivalence (e.g., [1]). This theory is also well aligned with the zero point fluctuating field theory [6]. Unfortunately, the pragmatic success of quantum mechanics, which itself yields excellent results (we may say: too formal, i.e., without a real understanding), somehow damped the further development of this branch of physics during the previous and current centuries. In this lecture we would like to point out the relevance of reactive forces in classical electrodynamics to macroscopic systems with strong particle accelerating fields. The test case we propose here is a system consisting of a spherical shell of charged particles accelerated in radial direction in an external field (in general of arbitrary nature), which generates the stationary reactive electric field E_{acc} that we calculate as:

$$E_{acc} = \frac{Q}{4\pi\varepsilon_0}\frac{a}{R}\frac{1}{c^2}I(\frac{r}{R}),$$

where, Q is the total charge within the spherical shell of an instant radius R, a is the acceleration, ε_0 and c are the vacuum permeability and the speed of the light, respectively, and $I(r/R)$ is an integral over the spherical angle, (which is finite in the range $0 < r < \infty$ with a sharp maximum of the order of unity for $r = R$). In the case of a number of N particles with elementary charge e and mass m_e (e.g., electrons), accelerated in an external electrostatic field E_{ext} the last formula yields the result $E_{acc} = N\frac{r_0}{R}E_{ext}$, where $r_0 = e^2/(4\pi\varepsilon_0 m_e c^2) = 2.8179\times10^{-15}m$ is the classical (or Compton) electron radius. This last expression could have dramatic consequences to plasma systems in nature, laboratory and fusion devices, which are characterized by enough high number of accelerated particles. Namely, the reactive acceleration can strongly compete the external electrostatic force and so could be interpreted as a kind of "electrostatic" confinement mechanism. In addition, consequences of the present approach to subatomic scales should be reinvestigated in a new consistent manner, leading to a reanimation of classical electrodynamics so as to establish the quantum theory only as a special case of the first principles of the nature.

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Invited lecture

MODELS OF STELLAR ATMOSPHERES FOR EVOLUTIONARY MODELLING

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In our contribution we will review recent modelling of stellar atmospheres using general stellar atmosphere code PHOENIX.. A grid of over four thousand models has been built with temperatures in the range from 3000-10000K, Z from -2.5 to +0.5 and different alpha element enhancement (from -0.2 to +0.8). Application to the better understanding of boundary condition between inner stellar structure and atmosphere and its consequences to the evolutionary modeling will be discussed.

Invited lecture

SHORT LIVE AFTERGLOW IN PURE NITROGEN AND NITROGEN CONTAINING TRACES OF METHANE AND OXYGEN

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The nitrogen post-discharge has been a subject of many studies for a relatively long time [1, 2]. The relaxation processes of atomic and various metastable molecular states created during an active discharge lead to the common thermal equilibrium. Besides the collisional processes, the light emission plays a significant role in the thermalization.

The first period (up to about 5 ms) of the post-discharge in the pure nitrogen is characterized by a strong decrease of the light emission. After that, a strong light emission at about 5 – 14 ms after the end of the active discharge (known as a short live afterglow or "pink afterglow") can be observed in pure nitrogen only. It is represented by a strong increase of the pink light emission at decay times of about 5 – 8 ms in the pure nitrogen, while the yellow-orange color is characteristic for the other parts of the nitrogen afterglow. The effect of the nitrogen pink afterglow can be studied only in pure nitrogen and various traces (especially containing carbon [4] and oxygen [5]) quench it. These impurities form during the discharge (both active and post-discharge) various species that significantly change the post-discharge kinetics whiles their influence on the active discharge can be negligible if they are in concentrations under 0.1 %.

The work presents results obtained during spectroscopic observations of DC flowing post-discharges of pure nitrogen plasma and nitrogen plasma containing traces of methane and oxygen. The plasma have been studied by the emission spectroscopy of three nitrogen spectral systems, two CN spectral systems (when methane is added) and two NO bands (with oxygen impurities).

First, the quenching of the nitrogen pink afterglow by the methane traces was studied. It was shown that the maxima of the pink afterglow intensities for all three nitrogen bands were decreasing proportionally to the increase of the methane concentration. The position of the maximal pink afterglow emission was also linearly shifted to later decay times. In the case of oxygen addition into the pure nitrogen flow, the pink afterglow quenching was observed, too. The nitrogen first negative system showed a similar dependence of the maximal pink afterglow intensity on oxygen concentration as in the case of methane impurity but the effect was about one order lower. The other nitrogen systems were not significantly influenced by oxygen traces. The pink emission maximal intensity was shifted to shorter decay times, it means in contrary to the methane impurity.

On the basis of the experimental results, the appropriate kinetic model of the plasma generated in pure nitrogen and in nitrogen with methane traces was designed. The specific state-to-state energy transfer reactions between the studied states were presented. The kinetic model of nitrogen-oxygen mixture is contemporary under preparation.

Acknowledgement
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Invited lecture

DIODE-PUMPED SOLID-STATE LASERS WITH CONTROLLED PARAMETERS FOR SPECTROSCOPIC APPLICATIONS

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Possibilities of control of frequency, polarization and spatial characteristics of portable LD pumped solid-state lasers have been investigated. The lasing wavelengths were within the 1.06 (Nd^{3+}:YAG and $Nd^{3+}:YVO_4$ active media) and 1.5 µm (boro-silico-phosphate glass co-activated by Er,Yb ions) spectral regions. Two active medium excitation schemes (longitudinal pumping by radiation of laser diodes and transversal pumping by laser diode arrays) were used in the experiments.

Tuned single- or double frequency lasing modes have been revealed for the LD longitudinally pumped Nd^{3+}:YAG laser with composite optical resonator. It was shown that the change in the pump radiation polarization azimuth can led to that in the lasing frequency spectrum similar to action of spectral selector. The method of realization of the linear polarized output laser radiation based on selection of the transversal pump configuration has been proposed.

The output radiation beam quality parameter M^2 for the longitudinally pumped powerful $Nd^{3+}:YVO_4$ lasers and for the transversally pumped erbium glass lasers has been investigated depending on the active medium excitation power P and the extent of overlapping of the pump and lasing areas. It has been determined that in the case of a considerable excess of the lasing mode cross-section area in comparison to that for the pump radiation the radiation focusing limit size is increased noticeably. The regular regions of abrupt rising of the beam quality parameter were shown up on the background of the monotonous $M^2(P)$ dependence. The interpretation of this effect is presented. Conditions providing optimal spatial characteristics of laser radiation for the focusing system are discussed.

The data obtained are analyzed in the view of creation of powerful tunable laser radiation emitters for spectroscopy application and plasma sources.

Invited lecture

THE SHAPE OF Fe Kα LINE EMITTED BY ACTIVE GALACTIC NUCLEI: MICROLENSING EFFECTS

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The Fe Kα line is emitted from an accretion disk around a massive black hole located in the center of Active Galactic Nuclei (AGN). Here we present a model of the Fe Kα emitting accretion disk in Kerr metrics. We discuss the different Fe Kα line shapes as a function of different disk parameters. Moreover, the influence of microlensing on the Fe Kα line shape will be presented.

Invited lecture

PROPERTIES OF THE DIAMOND-LIKE CARBON FILMS DEPOSITED BY THE LASER-PLASMA METHOD ON GLASS, SILICON AND QUARTZ SUBSTRATES

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Diamond films are very promising materials for use in high temperature/high power electronics. These films pose a high thermal conductivity, a high degree of chemical inertness and have a band gap of about 5 eV. Diamond-like carbon films were deposited by laser ablation of graphite, using Nd-glass laser (λ=1.06 μm). Films were deposited in vacuum. The pressure was equal to 10^{-3} Pa. In the experiment different types of substrates were used (glass, quartz, bronze, silicon). Films were deposited using 2 – 8 J laser radiation energy range. Raman spectroscopy method was used to investigate the structure of the films for mentioned above types of substrates. Obtained spectra were analyzed on a presence of Lorentzian approximated D and G peaks. It provided us with information about structure of these films for different substrates in terms of sp3/sp2 content. Thicknesses of obtained films were also examined. It was discovered that they are almost independent on a types of substrates for examined set of materials.

Invited lecture

SPACE-TIME-RESOLVED OPTICAL EMISSION SPECTROSCOPY OF LASER ABLATION PLASMA FOR MICROANALYSIS OF UNIQUE SOLID SAMPLES

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Laser ablation of solid samples is an analytical technique, which combines sampling and atomization in one step. Therefore, direct and rapid spectrochemical microanalysis without any sample preparation is possible. In spite of the many advantages of laser ablation for spectrochemical analysis the main problem remains the lack or absence of certified solid reference materials especially for nontechnological materials such as unique museum exhibits. Moreover, even the small differences in matrixes and surface properties of analyzed materials as compared with the reference samples as well as the possible variations in ablation laser energy must be thoroughly taken into account. Therefore, during the last decade different approaches have been undertaken to overcome or at least to discriminate the above mentioned problems in the most widely spread laser ablation based analytical technique, namely laser-induced breakdown spectroscopy (LIBS).

Thus, the achievement of the main goal of the last time attempts to make LIBS really quantitative is based on the development of absolute or so-called calibration-free (CF) algorithm of LIBS, which is in turn based on the perfection of optical diagnostics of pulsed plasma. In this work further development of CF LIBS and its approbation for microanalyses of a material of unique solid samples on an example of determination of component concentrations of the bronze and gold alloys, flint glasses, fragments of jeweller ornaments of an archaeological origin, and pigments from easel paintings have been carried out. Detailed structural characterization and identification of key chemical constituents can uncover important information on historical and artistic significance of artworks. A major concern when an analysis is to be performed on valuable objects, such as museum exhibits is the preservation of its integrity and aesthetic value. LIBS can be regarded as a nearly nondestructive technique. In addition, the technique has the capability of providing depth-profiling information.

In particular, the LIBS technique has been applied for the microanalysis of pigment materials from the different sections of the well-known easel paintings “Landscape of Pool with an Obelisk and Ruins of an Aqueduct” and “Garden of Borghese Villa in Rome” of the famous French artist Hubert Robert (1733-1808). These old paintings from the National Art Museum of Republic of Belarus require thorough investigations of the pigments for confirmation of their originality taking into account the rich biography of the paintings. Obtained quantitative data on elemental composition of the selected pigment microsamples from all paint layers including the ground layer alongside with art and historical examinations have formed the base for the exact identification of the originality of the tested paintings.

Invited lecture

THE METHODS FOR DETERMINATION OF HF CHARACTERISTICS OF NONIDEAL PLASMA

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In the presented work, the results obtained on the base of the modified RPA methods are discussed. In considerations are taken the static conductivity, HF conductivity, refraction, reflection coefficients etc., the numerical method retrospective. The possibility of application of the used methods in the extremely nonideal plasma is discussed. Apart of that, the alternative methods of calculation of dynamic characteristics of nonideal plasma, that uses a much simpler numerical procedure, are presented also. The results obtained by all metioned methods are compared with each another and with presently available data.

Invited lecture

EXCESSIVE DOPPLER BROADENING OF HYDROGEN AND DEUTERIUM BALMER LINES IN A HOLLOW CATHODE GLOW DISCHARGES

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The shape of Balmer lines in hollow cathode gas discharges operated with hydrogen or deuterium and hydrogen gas mixtures with inert gases exibit unusual multicomponent behaviour, see e.g. Figs 1-7 in [1]. The origin of narrowest part of the profile is related to the Doppler broadening of the thermalized excited hydrogen atoms H^* in the negative glow region of the discharge. Broader middle part of the line profile is related to excited hydrogen atoms generated in electron collisions with H_2. The pedestal of the line profile is very broad indicating that energetic excited hydrogen atoms having energies larger than hundreds of electron volts are generated in discharge. The presence of large energy excited hydrogen atoms implies that fast hydrogen atoms H_f of even higher energy exist in the discharge [2]. As pointed out already, the origin of narrow- and medium-width part of line profile may be explained on the bases of well-established processes.

The sound explanation of the broadest part - pedestal of line profile offers the sheath-collision model. In this model ions H^+ and H_3^+ are accelerated in a high-voltage discharge sheath and produce fast H atoms in charge transfer/dissociation collisions with the matrix gas – molecular hydrogen. The fast H atoms are then excited and scattered in another collision. The same excitation process is occurring with H atoms backscattered from the cathode [3-5]. In the Ar-H_2 discharge, the contribution of H^+ ion is negligible in comparison with that of H_3^+ ion, see e.g. [3,6]. The latter ions fragment in collisions with matrix gas or at the cathode surface generating H_f atoms of lower energy and consequently lower energy excited atoms H^* are produced.

The details of recent experimental studies of excessive Doppler broadening of hydrogen and deuterium Balmer lines in hollow cathode glow discharges [1,7,8] will be reviewed and discussed at the Conference.

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Invited lecture

LASER ABLATION AND ELECTRICAL DISCHARGE PLASMAS IN LIQUIDS FOR FABRICATION OF NANOSIZED PARTICLES

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The capabilities of two techniques (laser ablation and electrical discharges in liquids) for fabrication of metallic and composite nanoparticles with laser-induced size modification were analyzed.

The properties of Ag, Au and Cu as well as bimetallic Ag-Cu and Ag-Au nanoparticles synthesized in different liquids (water, acetone, ethanol) were examined. Experiments were made by using two 10 Hz pulsed Nd:YAG lasers, operating at 1064 nm and 532 nm. It was shown that both the mean size of the nanoparticles and their stability could be controlled by proper selection of the parameters of laser ablation and post irradiation such as temporal delays between pulses, laser fluence and a combination of radiation wavelengths.

Metallic nanoparticles (e.g., W, Ti) and their carbides were synthesized by pulsed arc and spark discharges submerged in liquids using the appropriate combinations of pairs of metallic and graphite electrodes. The discharges with 3.5 – 4.5 A average current at a repetition rate of 100 Hz were produced in ethanol and distilled water. The formed nanoparticles were examined by UV/VIS absorption spectroscopy, TEM and XRD. In particular, it was found that WC particles with an average diameter of 7 nm could be prepared at the rate of approximately 10 mg/min in pulsed spark discharge submerged in ethanol. It is expected, that the obtained results will find applications in the synthesis of new materials with modified properties, in the fabrication of catalysts etc.

Invited lecture

INTRINSIC RADIATIVE COLOR CENTERS IN ALKALI HALIDES CRYSTALS AND FILMS: FORMATION AND APPLICATIONS

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Alkali halides (AH) crystals, containing radiative color centers (CCs), are widely applied as active and passive laser media. They are also used in optoelectronics and in radiation dosimetry. Among them, lithium fluoride (LiF) crystals and films with CCs have found the most successful applications. LiF samples can be colored by irradiation with ionizing radiation, as X-rays, γ-rays, elementary particles and ions.

The processes of CCs formation under LiF irradiation with ionizing radiation and electrons are considered in the report. Charged particles are appeared into the crystals or films during their irradiation. The most numerous and important particles are electrons, fluorine ions, shifted from the lattice site into the interstitial position, and positively charged vacancies F^{+}, positioned on the lattice sites where the fluorine ions were situated before shifting. All of these particles are moving inside the crystal or film. Their diffusion results in the CCs formation.

The formation processes and efficiency hardly depend on the temperature during and after irradiating and the temperature of particles mobility. The formation features which depend upon these temperatures are discussed in the report. Two cases are considered: a) irradiating temperature is higher than temperature of vacancies mobility, b) irradiation temperature is lower than temperature of vacancies mobility but temperature of annealing which followed the irradiation is higher than last one. The difference in the CCs formation processes is noted for these two cases.

The particularities of the CCs formation processes in a bulk, a near-surface layer, a film, nano-sized structures of LiF crystals are given. They are determined by concentrations of electrons, vacancies, different kinds of traps and ratio of electrons and vacancies concentrations.

The examples of CCs applications are presented. Lasers, optoelectronics, dosimetry are considered as an illustration of such applications.

POSTERS

Contributed paper

STUDIES AND CHARACTERIZATION OF QUASI-STATIONARY COMPRESSION PLASMA FLOWS GENERATED BY GAS-DISCHARGE AND EROSIVE PLASMA ACCELERATORS

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The results of investigations on compression plasma flows generated by gas-discharge magnetoplasma compressors and erosive plasmadynamic systems are presented. Electron temperature and plasma concentration in such quasi-stationary plasma accelerators (plasma guns) both were measured with spatio-temporal resolution. The characterization of quasi-stationary plasma flows was conducted using the dynamic coefficients specifically introduced. These coefficients were calculated based on the temporal evolution of the electron density and temperature in plasma obtained in these experiments.

Contributed paper

OBTAINING OF SILICON REGULAR FORMATIONS WITH NANOSTRUCTURED METAL COATINGS ON SEMICONDUCTOR WAFERS SUBJECTED TO COMPRESSION PLASMA FLOW

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The priority results on the substantial structural-phase semiconductor modification obtained with the use of compression plasma flows are presented. In particular, the formation of bulk (cylinder-like) regular submicron/nanoscale structures on the silicon wafers simultaneously with the deposition of nanostructured metal coatings that completely cover a surface including bulk structures are discussed.

The deposition of nanostructured coatings on a silicon surface under the action of the compression plasma flow loaded by highly dispersed metal particles is shown to feature the formation (in the target near-surface area) of stable metal clusters 50-300 nanometers in size which later, at a final stage of the discharge, precipitate on a silicon surface to form a monolayer of the particles linked to each other. Such a process may be caused by the interaction between metal particles under conditions of sufficiently quick change in properties of decaying near-surface plasma, which provides the formation of the bound state of the particles.

Contributed paper

VARIATIONS OF ABNORMAL GLOW DISCHARGE PROPERTIES WITH CATHODE HEATING

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In this paper the influence of cathode temperature on abnormal glow discharge properties is examined. A Grimm type glow discharge with no cathode cooling, operating in argon was used. Spectral line intensities of argon and cathode material are measured simultaneously with cathode temperature and were observed to change significantly. Change of discharge voltage with measured cathode temperature is also reported. The behavior of the discharge was the same for two different cathode materials. Variations of the discharge properties may be attributed to the rise of gas temperature due to the heat transfer form the cathode.

Contributed paper

SPECTROSCOPIC MEASUREMENTS OF NITROGEN COMPRESSION PLASMA FLOW ELECTRON DENSITY AND TEMPERATURE

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Magnetoplasma compressor with a semi-transparent electrode system that operates in the ion current transfer regime is studied. The thermodynamic parameters of the discharge and the compression plasma flow generated in N_2 + 5% H_2 mixture at 500 Pa pressure with input energy 4.9 kJ have been measured. Special construction of the accelerator electrode system enable the electrode shielding by the self-magnetic field resulting in protection from the erosion. Fully predominant N II spectrum is observed in the compression plasma flow during quasistationary phase. The plasma flow velocity and electron temperature maximum values are measured close to 35 km/s and 4 eV, respectively. It was found that electron density values are close to $2 \cdot 10^{16}$ cm^{-3} during discharge quasistationary phase.

Contributed paper

CLEAVAGE OF SILICON SINGLE CRYSTAL SURFACE PRODUCED BY COMPRESSION PLASMA FLOW ACTION

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Modification of silicon single crystal surface by the compression plasma flow (CPF) action is studied. It has been found that during single pulse surface treatment regular fracture features are obtained on the Si (111) and Si (100) surface in the target central part. Some of these regular structures can become free from the underlying bulk, formed as blocks ejected from the surface. These surface phenomena are results of specific conditions during CPF interaction with silicon surface.

Contributed paper

CLOSE ENCOUNTERS WITH ASTEROID (704) INTERAMNIA

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Results of the search for close encounters between asteroid (704) Interamnia and 13000 numbered asteroids for period 1996-2051 are presented. A multistep numerical procedure has been used to derive the parameters of close encounters.

Contributed paper

PECULIARITIES OF THE MOTION OF SIZABLE DUST GRAINS IN COMETARY ATMOSPHERES

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We performed a simulation of trajectories of sizable dust grains with consideration for two specific points found on phase plane of cm-sized dust particles. The specific points correspond to positions of equilibrium, one point located further from the nucleus corresponding to stable equilibrium. The possibility of the capture of dust particles in the zone of stable equilibrium points is established on the basis of hydrodynamical modelling of spherically symmetric gas flow with consideration for Knudsen boundary layer of a cometary nucleus. We derived estimations of parameters (the sizes and initial speed) of dust particles which can be accumulated, the estimations depending on heliocentric distance of a comet. However, the probability of the process of ballistics accumulation is low in the stationary atmosphere of a comet. A qualitative analysis of the action of atmosphere dynamical properties on trajectories of sizable dust grains having two specific points is carried out by the method of stage-by-stage consideration. We inferred that the probability of the capture of sizable dust particles and of their accumulation in the stable equilibrium zone increased in this case. Parameters of dust particles being captured and the accumulation rate depend on physical and chemical properties of the nucleus and on an orbit of a comet.

Contributed paper

THE MERIDIONAL DRIFT OF SOLAR MAGNETIC STRUCTURES

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The drift of structures of the general magnetic field and activity zones with the solar cycle activity is analysed. The expressions linking the drift velocity of magnetic structures with the difference of their plasma density are derived. It is shown that the rotation of the Sun leads to the separate of magnetic structures into lighter and more heavy ones in comparison to the surrounding plasma. The drift of the sunspot zones toward the equator owing to the rotation of the Sun is possible under the condition that magnetic structures with sunspots are more heavy structures. At the same time the structures of the general magnetic field are bound to be to drift towards the polar zones. The difference of plasma densities in these structures is calculated on the basis of the observational drift velocity of magnetic structures. The mean strength of the magnetic field in the structures of the general magnetic field that corresponds to the difference of the plasma density is found to be 31.5 mT.

Contributed paper

EXPERIMENTAL STUDY OF A HOLLOW CATHODE GLOW DISCHARGE IN HYDROGEN

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[2] *Faculty of Physics, University of Belgrade, 11001 Belgrade, P.O. Box 368, Serbia*

The optical emission spectroscopy is used for the temperature measurement of excited hydrogen atoms T_{exc} from the shape of the Doppler broadened hydrogen H_α line in a titanium hollow cathode glow discharge operated at various pressures of hydrogen. Measurements of molecular rotational and vibrational temperatures have been carried out as well. The rotational temperature is determined from the population of the H_2 excited state $d^3\Pi_u^-$ rotational-vibrational levels ($\nu' = 0$). The vibrational temperature is measured from the H_2 Fulcher-α diagonal bands, $d^3\Pi_u^- \rightarrow a\ ^3\Sigma_g^+$ transition, Q-branches, ν'=2, 3. To reveal the discharge length at various pressures in a hollow cathode, plasma potential probe measurements are performed.

Contributed paper

Contributed paper

COWAN CODE AND STARK BROADENING OF SPECTRAL LINES

Nenad Milovanović, Milan S. Dimitrijević

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We present Stark broadening parameters (widths) of 5 multiplets of S II and 3 multiplets of S III calculated using modified semi-empirical approach (MSE). Needed atomic data (energy levels) have been calculated using *ab initio* Cowan code. Comparison of energy levels of S II and S III calculated by Cowan code and energy levels taken from NIST atomic spectra database is given. We also present comparison of FWHM Stark widths calculated by using MSE and experimental widths.

Contributed paper

A METHOD FOR DETERMINING ORBITS OF SMALL PLANETS AND THEIR 3D REPRESENTATION

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We propose a method for determining elements of orbits of small planets and comets from data obtained by series of measurements. The particular benefit of the method is seen in the easy and accurate determination of the type of the orbit when the measured points are closely arranged on the trajectory of the body. It is done by computing four quantities related to conics that represent trajectories. Also, software is developed for the 3D graphical representation of trajectories and enveloping surfaces that they make in the course of time in the heliocentric coordinate system.

Contributed paper

EVOLUTION OF ACTIVE GALACTIC NUCLEI JETS IN GALACTIC HALOS

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We analyze long-term evolution of jets from their origin in accretion disks of active galactic nuclei to their destruction in far-halos of galaxies. Based on the analytical solutions of RMHD equations we show that magneto-hydrodynamical interactions of charged jet with intergalactic medium are not effective in jet destruction. High stability of jet in the nearest halo region are explained and proved. We show that the only mechanism of jet particles changing their trajectories is their interaction with cold dark matter (CDM) particles in far regions of galactic halos. Numerical simulations result in the most probable candidate for such CDM particles – primordial micro black holes.

Contributed paper

RADIATIVE CHARACTERISTICS OF ACTIVE GALACTIC NUCLEI JETS IN EARLY PROPAGATION STAGES

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Integral and spectral characteristics of active galactic nuclei jets in their early propagation stages are simulated. We analyze two main mechanisms of jet emission: synchrotron emission in the inner regions of jet and Compton scattering of background photons and photons of surrounding sources by jet particles in outer regions. We show only these two mechanisms of jet emission provide the total jet luminosity. Synchrotron emission are effective mainly in radio band of spectrum, Compton one – in hard X-rays and Gamma-rays.

Contributed paper

PLASMACHEMICAL REDUCTION FOR THE CONSERVATION OF ARCHAEOLOGICAL ARTIFACTS

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It was proved that the using of hydrogen plasma allows reduction of chlorinated products as well as oxides from the corrosion layers of archaeological objects [1, 2] Plasmachemical treatment is much more shorter than the mechanical or chemical treatment that have been commonly used till this time. The main advantage of this method is the fact that it is possible to treat the artifact of big size, the hollow artifacts or artifacts with broken relief [1, 3, 4].

Internal iron corrosion layers, surrounding the metallic core, are mainly made of magnetite Fe_3O_4. External corrosion layers consist of oxides, chlorides, α-FeOOH, β-FeOOH, α-Fe_2O_3 in combination with other minerals such as FeOCl, $FeCl_2$, Fe_2SiO_4, $Fe_3(PO_4)_2$ $8H_2O$ etc... Corrosion layers of copper or bronze artifacts include for example Cu_2O, CuO, $Cu(OH)_2$, $Cu_2Cl(OH)_3$, CuS, Cu_2S, $CuFeS_2$ etc…It is well known that especially chlorinated products are dangerous in term of new corrosion attack. The chlorinated products can be decomposed to the chlorides which cause the active corrosion. Our aim is to remove the corrosion layers and to protect the artifacts against new corrosion.

Mechanical and chemical treatment in alcaline sulphite bath is often used to eliminate the chlorides from the layers but it takes several months. In 1980, the plasmachemical method was developed. It is based on the reduction processes in low-pressure RF hydrogen plasma. The original method was changed and improved on the basis of further experience. Originally, gas mixture of methane, hydrogen, nitrogen and argon was used for the treatment at the temperatures of 400 °C. Presently, it is given priority to pure hydrogen use and in some cases, the argon and much lower temperature is used. Depending on the character of the corrosion layer, it can be reduced up to the metal.

It was found that the whole process can be monitored by using optical emission spectroscopy. The optical emission spectra emitted from the discharge were recorded by spectrometer Jobin Yvon with CCD detector. In the spectra, various lines and bands were found. The hydrogen lines and bands as well as OH radical bands were the most intensive. The band and line intensities were observed as a function of the treatment time. It was found that the integral intensity of OH is changed during the reduction process. First, the small increase was observed, then, the intensity decreased. The relation between oxides reduction and OH intensity was found. It could be appreciated that its integral intensity decrease to the value of 10 % of its maximum corresponds to the „end“ of the cycle of the reduction process. For the removal of corrosion layers and for their reduction to the metal it is necessary to apply several treatment steps which are combined with the soft mechanical cleaning and desalination in the LiOH solution or in the distilled water. The desalination process was controlled by the determination of chloride concentration in the solution using the titration method.

Moreover, the model samples of corrosion layers were made and treated in our experiments, too. The results obtained during the treatment were compared. It was also found that the simlified monitoring device would be useful for the purpose of practical conservation in the museum. The device consists of lens, 3, interference filter, UV sensitive photodiode, low noise amplifier, AD converter, grounded box and digital signal output.

Furthermore, the x-ray diffraction analysis was provided during our experiments. The results show the strong decrease of the chloride content in the layer during the treatment. We also observed the difference between the layer composition at the treatment begin and the composition identified after several hours of treatment. The analyses of corrosion layers in the dependence of the plasma treatment condition will be subject of further studies.

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[4] Dalard F., Gourbeyre Y., Degrigny C., *Studies in Conserv.* **47** (2002) 117.

Contributed paper

STUDY OF A PULSE ARC DISCHARGE USED FOR DIAMOND-LIKE COATING DEPOSITION

I. P. Smyaglikov[1], E. I. Tochitsky[2], V. G. Tatur[2], N. I. Chubrik[1]
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Carbon plasma flows for deposition of diamond-like films are generated with the help of four-electrode system with graphite cathode and self-recovering thin-film conductor of an ignition device in a vacuum chamber with residual pressure down to $5 \cdot 10^{-5}$ Torr. The pulse-periodic carbon arc discharge is considered at discharge current of 4–10 kA, duration of pulses of 100–200 ms and the pulse repetition rate of up to 30 Hz. The form and amplitude of voltage and current of pulses of igniting, supporting and main discharges, and the form of light pulse in various zones of the discharge were measured. The information on reproducibility of the arc discharge of short duration was obtained as well.

AUTHORS INDEX

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PROGRAMME & ABSTRACTS

Heron Press Sofia

Activities at Belgrade Astronomical Observatory on Collecting of Data and Their Organization in a Database

Milan S. Dimitrijevic, Luka C. Popovic
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For a number of problems in astronomy and physics a large number of different data is needed, so that the organization of such data in databases is obviously of interest. Problems where such databases are particularly important, are for example modelings of stellar atmospheres as well as of different laboratory and technological plasmas, spectra synthesis and radiative transfer calculations. In order to complete as much as possible Stark broadening data needed for astrophysical and laboratory plasma research and stellar opacities calculations, we are making a continuous effort to provide Stark broadening data for a large set of atoms and ions. Since the organization of obtained data in a database is useful to scientific community, we are also making a continuous effort to develop in Astronomical Observatory a database "BELDATA", which will contain Stark broadening data, but also in the future stellar catalogues published in Astronomical observatory and publications of Astronomical observatory. Moreover, on Belgrade Astronomical Observatory and other old observatories, a large amount of photographic plates with observational data are stored. An international effort is to digitalize such plates and include them in Sofia and Belgrade databases. In Belgrade, work on databases with various data of interest for physicists but also for astronomers is also in course in the Institute of Physics. Laboratory for Gaseous Electronics has been trying for several years to set up a database for swarm data and the cross sections normalized to swarms. Also, plans are to include numerous measurements of various collision cross-sections between electrons and various molecules performed in Belgrade. In this contribution we will discuss the organization of various data of interest for astronomers and physicists in databases. Also, activities at Belgrade astronomical observatory on collecting data and their organization in the database BELDATA with the discussion of some similar activities in the Institute of physics, will be presented.

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Thursday, 28 April

PLATE DIGITIZATION SESSION 3

Chairman: P. Kroll

08:30–08:40 Opening of Day 2

08:40–09:00 *Rene Hudec*: Astrophysics with Astronomical Archival Plates

09:00–09:20 *Magda Stavinschi*: Astronomical Heritage Databases. A Case Study

09:20–09:40 *Nikolai Samus*: Moscow Astronomical Plate Archive: Contents, Digitization, Current and Possible Applications

09:40–10:00 *Milan Dimitrijevic*: Activities at Belgrade Astronomical Observatory on Collecting of Data and Their Organization in a Database

10:00–10:20 *Tatyana Sergeeva*: MAO NAS of Ukraine Plate Archive: Towards to WFPDB Integration

10:20–10:40 *COFFEE BREAK*

PLATE DIGITIZATION SESSION 4

Chairman: R. Hudec

10:40–11:00 *Thierry Pauwels*: A Tool for Identifying Astronomical Plates

11:00–11:20 *Katya Tsvetkova*: Catalogue of Wide-Field Plate Archives: Version 5.0

11:20–11:40 *Andre Csillaghy*: The VO in Sunlight

11:40–12:00 *Poster Session Talks*

12:00–14:00 *LUNCH BREAK*

IMAGE SEQUENCE PROCESSING SESSION 1

Chairman: F. Murtagh

14:00–14:30 *Rafael Molina*: Super Resolution Reconstruction of Multispectral Images

14:30–15:00 *Nikolaos Galatsanos*: Spatial Segmentation of Image Sequences Based on Their Time Activity

15:00–15:30 *Ognyan Kounchev*: Compression of Astronomical Images by Means of Polyspline Wavelets

18:20–18:30 *COFFEE BREAK*

Activities at Belgrade Astronomical Observatory on Collecting of Data and Their Organization in a Database

Milan S. Dimitrijevic, Luka C. Popovic
Astronomical Observatory, Volgina 7, 11160 Belgrade 74, Serbia & Montenegro

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Activities at Belgrade Astronomical Observatory on Collecting of Data and their Organization in a Database*

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Astronomical Observatory, Volgina 7, 11160 Belgrade, Serbia

Abstract

The importance of databases in astronomy and physics, with examples of exceptionally complex calculations needing a large number of data, has been discussed, as well as ways to organize and present the collected data. Activities at Belgrade astronomical observatory on collecting of data and their organization in a database with the discussion of some similar activities in the Institute of physics in Belgrade, are presented.

1 Significance of databases in astrophysics

Different problems in physics and astrophysics, need a large number of various data, and their organization in databases is important for many problems, as for example modelling of stellar atmospheres, laboratory and technological plasmas, spectra synthesis and radiative transfer calculations.

The interest for a very extensive list of atomic, collisional and line broadening data is particularly stimulated by the development of space astronomy where an extensive amount of spectroscopic information over large spectral regions of all kind of celestial objects has been and will be collected with increasing resolution. Development of computers and special softwares (as *e.g.* SYNTH, CLODLY, PHOENIX *etc.*) also stimulated the need for a large amount of atomic, spectroscopic, and other data needed for modelling and investigations of different laboratory and astrophysical plasmas, as well as for plasmas in technology, light sources, fusion research, laser produced plasmas, *etc.*

Particularly large number of data is needed for example for opacity calculations. An illustrative example might be the research of opacities for classical

*Support from the Ministry of Science and Environment protection of Serbia for the projects GA-1195 "Influence of collisional processes on astrophysical plasma lineshapes" and GA-1196 "Astrophysical Spectroscopy of Extragalactic Objects" is gratefully acknowledged.

Cepheide models [1], where 11 996 532 spectral lines have been taken into account (45 H lines, 45 He, 638 C, 54 N, 2 390 O, 16 030 Ne, 50 170 Na, 105 700 Mg, 145 200 Al, 133 700 Si, 12 560 Ar, 11 530 000 Fe).

Interesting investigations which become possible with the development of computer technology, are calculations of equivalent width changes with the age in starburst stellar clusters and galaxies [2]. In this Ref. the change of particular hydrogen and helium lines equivalent widths during 500 million years, has been calculated for the galaxy as a whole, taking into account the spectra of different stars. Calculations have been done in two steps. First, the population of stars of different spectral types, as a function of age are calculated, and then the profiles of the lines are synthesized by adding the different contributions from stars.

For calculations with the multi-purpose stellar atmosphere code PHOENIX (version 13.13 [3–7]), combined molecular line list includes about 550 million molecular lines [8]. The lines are selected for every model from the master line list at the beginning of each model iteration to account for changes in the model structure. Both atomic and molecular lines are treated with a direct opacity sampling method. The pre-computed opacity sampling tables are *not* used, but instead the relevant LTE background lines are dynamically selected from master line lists at the beginning of each iteration for every model and the contribution of every line is summed within a search window to compute the total line opacity at arbitrary wavelength points.

An additional good example is that in order to obtain data for oscillator strengths and atomic energy levels for one million transitions of interest for stellar and solar opacity calculations, as well as data on photo ionization cross sections and line broadening parameters, Seaton has organized in 1984 the international "Opacity project" [9]. The result of ten years long efforts was not only a book and a series of papers, but also the international TOP Database [10, 11] containing mostly data on oscillator strengths and atomic energy levels.

In astronomy, a large amount of observational data is published in various stellar catalogues. The most spectacular one was made after the mission of the astrometrical satellite born telescope. In the honor of the Greek astronomer who made the first stellar catalogue, this telescope is named to associate his name – HIPPARCOS – HIgh Precision PARallaxe COllecting Satellite. It was launched on August 1989, and worked up to March 1993. With the telescope with a mirror of 29 cm, precise measurements of positions, parallaxes and proper motions of 118 000 stars were performed, and the result is a very precise stellar catalogue with the same name, covering all celestial sphere. Additionally a less precise catalogue with data for around 500 000 stars, named Tycho was produced. These data are also organized in a database.

2 Different Kinds of Collected Data and the Way of Their Representation

There are several approaches to collect the useful data which might be organized in databases.

a) First of all one can collect the references or the references with citations, which may be published as a book but also organized as a database, like for example Science Citation Index. M. S. Dimitrijević collected and published in five volumes [12–16] bibliography and citation index on spectral line shape research in Yugoslavia and Serbia from the first article published in 1962, concluding with the year 2000. He also collected and published similar data for Serbian astronomers [17].

b) Data collections from literature or other sources are also of interest as for example the well known tables of the Oak Ridge National Laboratory containing data in atomic and molecular and discharge physics (see for example [18]).

c) Critically evaluated set of data is particularly useful as for example Critically evaluated Stark broadening data published by Nikola Konjević and his co-workers [19–25]. When compiled data are presented, a useful information is also the data source with authors.

d) In astronomy, a large amount of observational data is published in different stellar catalogues. Such catalogues are published in Belgrade Astronomical Observatory by Sofija Sadžakov, Miodrag Dačić, Zorica Cvetković, Dušan Šaletić, Georgije Popović, Milan Mijatov, Djordje Teleki, Djura Božičković and Veselka Trajkovska [26–31, 33–38]. Our intention is to organize them in the future in a database.

e) On Belgrade Astronomical Observatory and other old observatories, a large amount of photographic plaques with observational data are stored. An international effort is to digitalize such data and organize them as databases available to the international scientific community.

f) Journals and publications may be also put in a database, enabling a search through key words.

3 Activities in Belgrade on Data Collection and Organization and the Experience with their Organization in Databases

In Belgrade, the production collection and critical evaluation of data needed for modelling and research of various processes occurs in several laboratories. Such data may be organized in databases and some attempts in this direction have been done.

a) Nikola Konjević with co-workers published several reviews with critically evaluated Stark broadening data [19–25], which are very suitable for creation of a database.

b) Ratko Janev published critical collection of data on collisional cross – sections [39] and lately, with the experience obtained in Belgrade, he worked on the collection of data and their organization in a database in International Atomic Agency in Vienna.

c) Laboratory for Gaseous Electronics led by Zoran Petrović has been trying for several years to set up a database for swarm data and the cross sections normalized to swarms.

d) The group led until his death by Milan Kurepa has performed numerous measurements of various collisional cross-sections between electrons and various molecules. Bratislav Marinković has attempted to join Z. Petrović to form a joint database with the data from the Institute of Physics in Belgrade.

e) Such activities on Belgrade Astronomical Observatory will be reviewed in the following section.

4 Activities in Belgrade Astronomical Observatory on Data Collection and Organization and the Experience with their Organization in Databases

During the time, a more and more larger amount of observational data is accumulated on astronomical observatories, and today exist different international projects for their digitalization and collection in databases or virtual observatories. On Belgrade astronomical observatory, around 10 000 photographic plates with observational data exist, and we also mentioned and published stellar catalogues [26–31, 33–38]. Additionally data on around 7000 observed double stars are collected [40] becoming an unavoidable reference for double system orbits considerations. It should be noted that Zoran Knežević takes part in the development, maintenance and amelioration of the international internet service AstDyS, who became a referent service for determinations of orbital elements of all known asteroids and standard data source for the observation planning.

Besides the mentioned bibliographies with citation indexes concerning spectral line shapes research in Yugoslavia and Serbia (1962–2000) [12–16] and astronomy in Serbia in the XX century [17], on Belgrade astronomical observatory for years is performed work on the investigation and determination of Stark broadening parameters of spectral lines. In order to provide Stark broadening data needed for investigation and modelling of astrophysical and laboratory plasmas Milan S. Dimitrijević and Sylvie Sahal-Bréchot, to whom recently joined Miodrag Dačić, Zorica Cvetković and Nebil Ben Nessib from Tunisia, presented in a series of papers results of determinations of these quantities [41] within the semiclassical perturbation approach [42]. Up to now, results for 79 He, 62 Na, 51 K, 61 Li, 25 Al, 24 Rb, 3 Pd, 19 Be, 270 Mg, 31 Se, 33 Sr, 14 Ba, 189 Ca, 32 Zn, 6 Au, 48 Ag, 18 Ga, 28 Ca II, 30 Be II, 29 Li II, 66 Mg II, 64 Ba II, 19 Si II, 3 Fe II, 2 Ni II, 22 Ne II, 12 B III, 23 Al III, 10 Sc III, 27 Be III, 5 Ne III, 32 Y III, 20 In III, 2 Tl III, 2 Ne IV, 10 Ti IV, 39 Si IV, 90 C IV, 5 O IV, 114 P IV, 2 Pb IV, 19 O V, 30 N V, 25 C V, 51 P V, 34 S V, 16 Si V, 26 V V, 30 O VI, 21 S VI, 2 F VI, 14 O VII, 10 F VII, 10 Cl VII, 20 Ne VIII, 4 K VIII, 9 Ar VIII, 6 Kr VIII, 4 Ca IX, 30 K IX, 8 Na IX, 57 Na X, 48 Ca X, 4 Sc X, 7 Al XI, 4 Si XI, 18 Mg XI, 4 Ti XI, 10 Sc XI, 9 Si XII, 27 Ti XII, 61 Si XIII and 33 V XIII multiplets are published.

In order to complete as much as possible such data, Milan S. Dimitrijević, Luka Č. Popović, Vladimir Kršljanin, Dragana Tankosić, Nenad Milovanović, Saša Simić, Zoran Simić, Miodrag Dačić and Predrag Jovanović used the modified semiempirical approach [44] for emitters where atomic data are not sufficiently complete to perform an adequate semiclassical perturbation calculation. Stark line widths and in some cases also shifts of the following emitters spectral lines were calculated: Ar II, Fe II, Pt II, Bi II, Zn II, Cd II, As II, Br II, Sb II, I II, Xe II, Mn II, La II, Au II, Eu II, V II, Ti II, Kr II, Na II, Y II, Zr II, Sc II, Nd II, Be III, B III, S III, C III, N III, O III, F III, Ne III, Na III, Al III, Si III, P III, S III, Cl III, Ar III, Mn III, Ga III, Ge III, As III, Se III, Zn III, Mg III,La III, V III, Ti III, Bi III, Sr III, Cu III, Co III, Cd III, B IV, Cu IV, Ge IV, C IV, N IV, O IV, Ne IV, Mg IV, Si IV, P IV, S IV, Cl IV, Ar IV, V IV, Ge IV, C V, O V, F V, Ne V, Al V, Si V, N VI, F VI, Ne VI, Si VI, P VI, and Cl VI.

In order to facilitate the use of these data we started development of the database BelData [45]. The first phases of its design and elaboration are finished. Database serving as the web interface support has been designed and finished, as well as the web interface for data access and the corresponding search. Also is designed and elaborated database for Stark broadening parameters (line widths and shifts) obtained by using semiclassical perturbation formalism. This year we started collaboration with the database MOLAT at Paris observatory with the objective to obtain two mirrors, one in Belgrade and one in Paris.

Actually the database contains catalogues of data for Ag I, Al I, Al III, Al XI, Ar VIII, B III, Ba I, Ba II, Be I, Be II, Be III, C IV, C V, Ca I, Ca II, Ca IX, Ca X, Cd I, Cl VIII, F VI, F VII, He I, In II, In III, K I, K VIII, K IX, Kr VIII, Li I, Li II, Mg I, Mg II, Mg IX, N V, Na I, Na IX, Na X, Ne VIII, O IV, O V, O VI, O VII, P IV, P V, Pb IV, Rb I, S V, S VI, Sc III, Sc X, Sc XI, Se I, Si IV, Si V, Si XI, Si XII, Si XIII, Sr I, Sr III, Ti III, Ti IV, Ti XI, Ti XII, V V, V XIII, Y III and Zn I. Relational databases have been realized by using MySQL server. Web interface has been realized in PHP, Java Script and HTML.

Besides the data on Stark broadening parameters, we plan to include in this base stellar catalogues produced on Belgrade Astronomical Observatory [26–31, 33–38], as well as digitalized photographic plates in collaboration with Miltcho Tsvetkov (Wide Field Photographic Observations Database in Sofia). This part of the work is governed in Belgrade by Vojislava Protić-Benišek. It is planned that the third part of this database will be devoted to the active galaxies spectra. We will include in the database spectra of galaxies in FITS format, observed on Crimea by K. K. Chuvaev, as well as the set of active galaxies spectra observed with Isaac Newton telescope of the North European

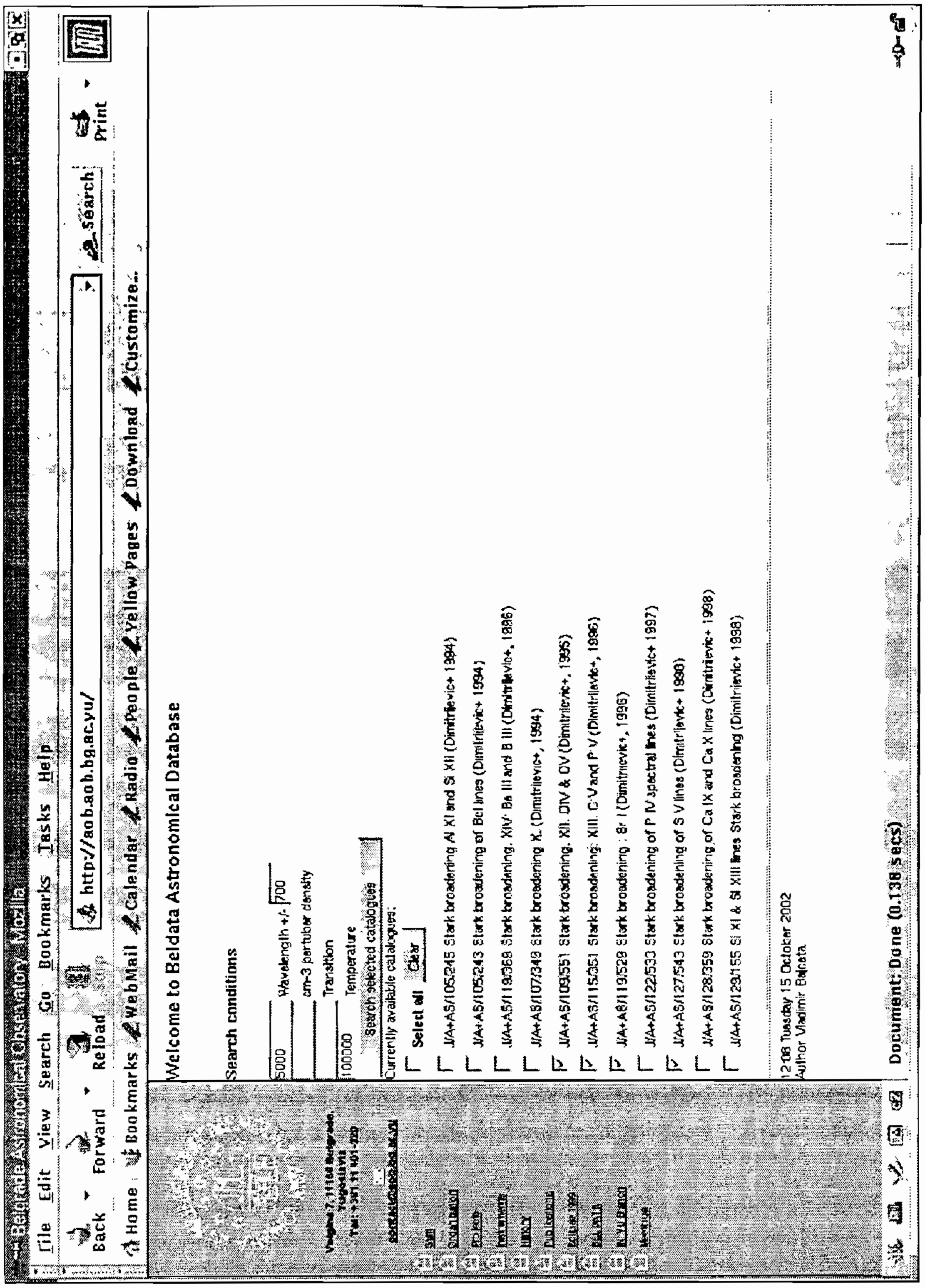

Figure 1. BelData search form.

Observatory on Canary islands, from 21 to 25. 1. 2002, covering spectral region of Balmer series. It was observed 12 active galaxies (Mrk 1040, 3c120, NGC 3227, PG 1116+215, NGC 4253, Mrk 110, Mrk 141, REJ 1034+393, 3c273, Mrk 817, Mrk 493, Mrk 841) [46]. In this part of the database we will include

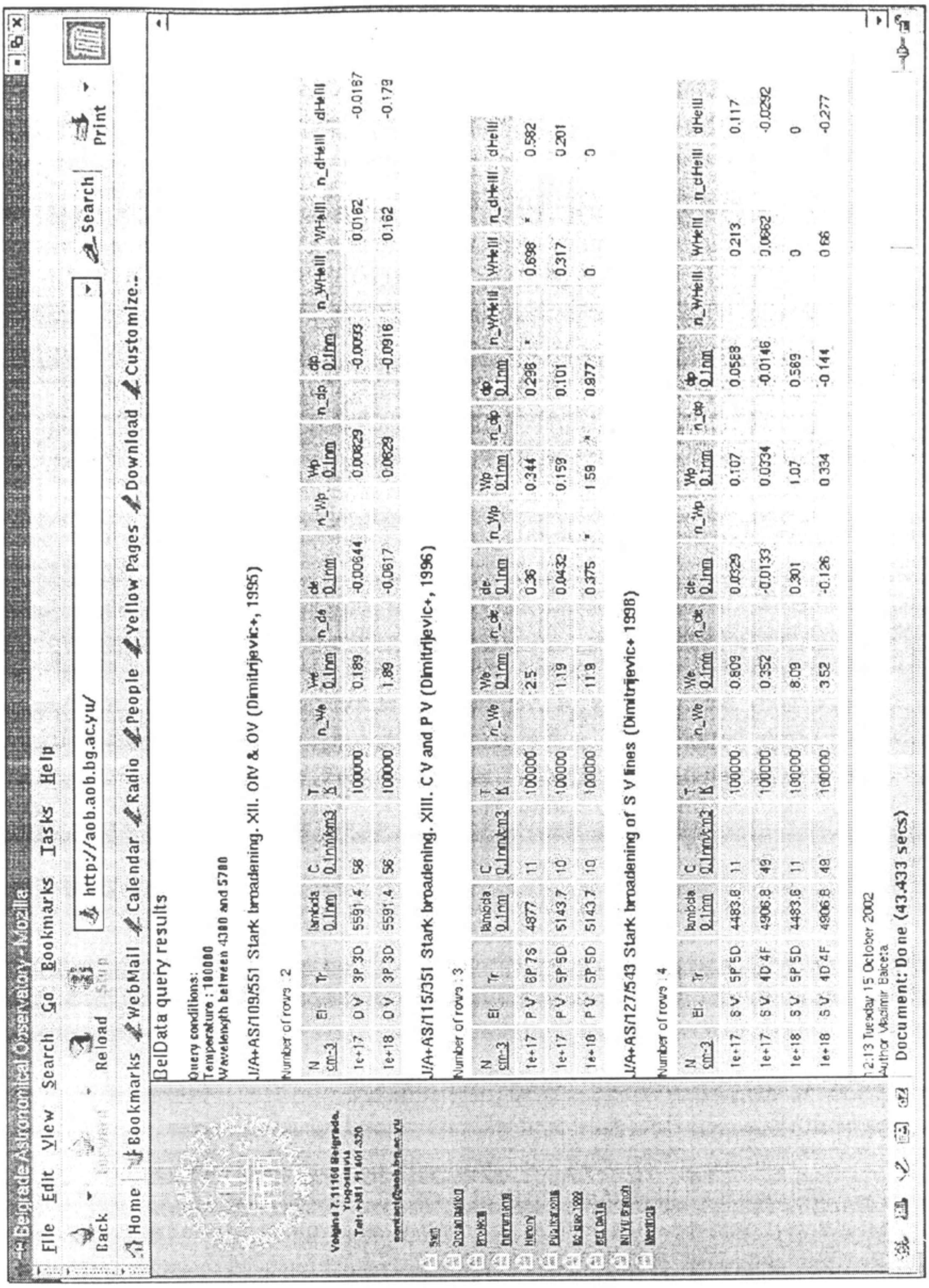

Figure 2. Query results.

all other future observations as well.

In Figure 1 is shown the opening page of the database with list of catalogues and search conditions. We show here as an example, the search for Stark broadening data for a part of the optical spectral region (5000 Å± 700Å and a temperature of T = 100 000 K, typical for PG1159 type stars. In Figure 2, the result of the query is shown.

Besides the database MOLAT of Paris observatory, we developed also a collaboration with the following databases:

a) Astrophysical Data System (http//adswww.harvard.edu/BOBeo) where Serbian Astronomical Journal is available.

b) VALD2 database from Vienna Observatory. Prof. Werner Weiss provided help in education on database creation for Nenad Milovanović and we coordinate databse organization so that two bases will be complementary.

c) Wide Field Photographic Observations Database (WFPDB, http://skyarchive.org), created in Sofia by Milcho Tsvetkov. An agreement on cooperation in digitalization and organization in a database of old photographic plaques on Belgrade Astronomical Observatory is in preparation.

We hope that the development of such databases will be useful for the scientific community.

Acknowledgments

Support from the Ministry of Science and Environment protection of Serbia for the projects GA-1195 “Influence of collisional processes on astrophysical plasma lineshapes” and GA-1196 “Astrophysical Spectroscopy of Extragalactic Objects” is gratefully acknowledged.

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V JUGOSLOVENSKI SKUP

IZ FIZIKE ATOMSKIH SUDARA

Kopaonik, 2-4 juni, 1987.

APSTRAKTI SAOPŠTENJA

Organizator:

OOUR Fizika i meteorologija

Prirodno-matematički fakultet

Beograd

Dr Danica Cvejanović

UTICAJ SUDARNIH PROCESA NA PROFILE LINIJA NATRIJUMA U SUNČEVIM I ZVEZDANIM SPEKTRIMA

Ištvan Vince i Milan S. Dimitrijević

ASTRONOMSKA OPSERVATORIJA
Beograd, Volgina 7.

Prilikom istraživanja spektara astrofizičke plazme često je veoma važno kvalitativno i kvantitativno poznavati, kako na formiranje absorpcionih linija utiču sudarni procesi. Čak i kada u opštem slučaju ovi procesi nisu dominantni u poređenju sa uticajem različitih makroskopskih i mikroskopskih kretanja, kod pojedinačnih spektralnih linija njihov uticaj može biti značajan.[1]

Cilj ovog saopštenja je da se prikažu rezultati analize uticaja nerezonantnih sudara sa vodonikovim atomima na spektralne linije natrijuma u uslovima zvezdane plazme. Kao primer uzeli smo spektralne linije koje su posmatrane u Sunčevom spektru a posebno smo se osvrnuli na spektralne serije i analizu uticaja sudarnih procesa u njima.

Izvršeno je i istraživanje uticaja sudara sa atomima vodonika, elektronima i protonima na pomake Fraunhoferovih linija duž Sunčevog diska kao i analiza uticaja ovih procesa na neke od natrijumovih linija koje mogu biti korišćene za određivanje brzinskih polja u konvektivnoj zoni.

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MEHANIZMI FORMIRANJA LINIJA NEUTRALNOG KISEONIKA U ZVEZDANIM OMOTAČIMA

Milan S.Dimitrijević

Astronomska opservatorija, Volgina 7, 11050 Beograd.

Često se u emisionim spektrima Be zvezda vide intenzivne linije neutralnog kiseonika[1,2]. Ovaj tip zvezda rotira veoma brzo tako da u okolni prostor izbacuje vodonik te se formira omotač, koji se prostire i do više desetina zvezdanih radijusa. Za razliku od apsorpcionih spektara običnih B zvezda, u ovakvim Be zvezdama vide se emisione linije koje nastaju u omotaču.

Nedavno su u emisionom spektru Be zvezde γ Cas posmatrana dva intenzivna tripleta neutralnog kiseonika $3p\,^3P-4s\,^3S^o$ (λ=13165 Å) i $3d\,^3D^o-3p\,^3P$ (λ=11127 Å) u bliskoj infracrvenoj oblasti. Da bi se ustanovilo koji su mehanizmi formiranja linija odgovorni za njihov nastanak i na taj način utvrdilo u kome delu zvezdanog omotača one nastaju, razmotreni su sledeći mehanizmi:

- Naseljavanje nivoa $3d\,^3D^o$ pomoću vodonikove linije L_β , koja ima istu talasnu dužinu kao i linija $2p^4\,^3P-3d\,^3D^o$ neutralnog kiseonika.
- Naseljavanje nivoa $4d\,^3D^o$ pomoću vodonikove linije L_γ, koja ima istu talasnu dužinu kao i linija $2p^4\,^3P-4d\,^3D^o$ neutralnog kiseonika i zatim naseljavanje nivoa $4s\,^3S^o$ kaskadnim prelazima.
- Naseljavanje nivoa $4s\,^3S^o$ sudarima, putem dipolnih prelaza $3d\,^3D^o-4p\,^3P$ i $4p\,^3P-4s\,^3S^o$.
- Naseljavanje nivoa $4s\,^3S^o$ kvadrupolnim prelazom $4s\,^3S^o-3d\,^3D^o$.

Prilikom razmatranja, usvojen je model omotača i zvezde γ Cas, koji su razradili Poeckert i Marlborough[3]. Rezultati analize pokazuju da razmatrane linije O I nastaju na početku zvezdanog omotača na rastojanju do dva radijusa zvezde od fotosfere.

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5th Serbian Conference on Spectral Line Shapes in Astrophysics

PROGRAM AND ABSTRACTS

eds. Milan S. Dimitrijević and Luka Č. Popović

Prirodnjačko društvo "Gea" Vršac

Vršac 2005

V Serbian Conference on Spectral Line Shapes in Astrophysics (V SCSLSA)
6-10 June 2005, Vršac, Serbia

Organized by Belgrade Astronomical Observatory and
"Gea" Vršac

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V Serb. Conf. on Spectral Line Shapes in Astrophysics
Vršac, 6-10. June, 2005.
Program and Abstracts

Invited lecture

A NEW MODELING APPROACH FOR DACs AND SACs REGIONS IN THE ATMOSPHERES OF HOT EMISSION STARS

E. DANEZIS[1], D. NIKOLAIDIS[1], E. LYRATZI[1], L.Č. POPOVIĆ[2], M.S. DIMITRIJEVIĆ[2], E. THEODOSSIOU[1] and A. ANTONIOU[1]

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The presence of Discrete Absorption Components (DACs) or Satellite Absorption Components (SACs) is a very common phenomenon in the atmospheres of hot emission stars (see Danezis et al. 2003, Lyratzi & Danezis 2004) and result to the complex line profiles of these stars. The shapes of these lines are interpreted by the existence of two or more independent layers of matter nearby a star. These structures are responsible for the formation of a series of satellite components for each spectral line. Here we will present a model reproducing the complex profile of the spectral lines of Oe and Be stars with DACs and SACs (Danezis et al. 2003, Lyratzi & Danezis 2004). In general, this model has a line function for the complex structure of the spectral lines with DACs or SACs and include a function L that considers the kinematic (geometry) of an independent region. In the calculation of the function L we have considered the rotational velocities of the independent regions, as well as the random velocities within them. This means that the new function of L is a synthesis of the rotational distribution and a physical Gaussian. Finally, we calculate the optical depth (τ) and the column density (d) of each independent density region.

References

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Lyratzi, E. and Danezis, E. 2004, AIP Conference Proceedings 740, pp. 458-473 [THE PHYSICS OF IONIZED GASES: 22nd Summer School and International Symposium on the Physics of Ionized Gases, Bajina Bašta, 23-27 August 2004, eds. Lj. Hadzijevski, T. Grozdanov, N. Bibić].

CONFERENCE PROGRAMME

Monday, 06. 06. 2005.

9:00-12:00 *Transportation (from Belgrade to Vršac by bus) and accommodation of participants.*

12:00-12:30 Opening Ceremony

Chairman: *M.S. Dimitrijević*

12:30-13:00 John Danziger: THE ROLE OF LINE PROFILES IN ANALYZING SPECTRA OF SUPERNOVAE

13:00-13:30 Zoran Petrović: ANOMALOUS DOPPLER BROADENING OF HYDROGEN LINES DUE TO EXCITATION BY FAST NEUTRALS IN LOW PRESSURE TOWNSEND DISCHARGES

13:30-15:30 *Lunch*

Chairman: *Z. Petrović*

15:30-16:00 Albert Ellingboe: WHISTLER WAVE - PARTICLE INTERACTION IN A TEMPERATE IONOSPHERE-LIKE PLASMA

16:00-16:30 Nebil Ben Nessib: INTERACTION POTENTIALS FOR SPECTRAL LINE SHAPES IN PLASMA

16:30-16:45 Zoran Simić: INFLUENCE OF IMPACTS WITH CHARGED PARTICLES ON Cd I AND F III SPECTRAL LINES IN STELLAR PLASMA

16:45-17:00 Walid Mahmoudi: SEMI-CLASSICAL AND MODIFIED SEMI-EMPIRICAL IMPACT STARK BROADENING CALCULATIONS OF SINGLY-IONIZED CARBON AND OXYGEN SPECTRAL LINES

17:00-17:15 Vladimir Milosavljević: MEASURED STARK SHIFTS OF Kr I LINE PROFILES IN THE 5s-5p AND 5s-5p' TRANSITIONS

17:15-17:30 Sergey Kharintsev: FRACTIONAL OSCILLATOR AND ANOMALOUS BROWNIAN MOTION IN THE THEORY OF SPECTRAL LINE BROADENING AND SHIFT

17:30-18:00 *Coffee break*

Chairwoman: *D. Calzada-Canalejo*

18:00-18:15 Magdalena Christova: STARK BROADENING OF Ar I SPECTRAL LINES EMITTED IN SURFACE-WAVE SUSTAINED DISCHARGES

18:15-18:30 Haykel Elabidi: ELECTRON IMPACT BROADENING OF MULTICHARGED NEON SPECTRAL LINES

18:30-18:45 Bratislav M. Obradović: THE EXTERNAL MAGNETIC FIELD INFLUENCE ON THE HYDROGEN BALMER LINES PROFILES IN ELECTRIC DISCHARGES

18:45-19:00 Nenad Milovanović: THE STARK BROADENING EFFECT IN HOT STAR ATMOSPHERES: Tl II

19:00-19:30 Welcome cocktail

Tuesday, 07. 06. 2005.

Chairman: *E. Barron*

9:00-9:30 France Allard: THE IMPORTANCE OF ALKALI LINE BROADENING IN BROWN DWARF ATMOSPHERES

9:30-10:00 Gillian Peach: LINE SHAPES FOR THE SPECTRA OF BROWN DWARFS

10:00-10:30 Emanuil Danezis: A NEW MODELING APPROACH FOR DACs AND SACs REGIONS IN THE ATMOSPHERES OF HOT EMISSION STARS

10:30-11:00 Denis Shulyak: ATMOSPHERES OF CP STARS: MAGNETIC FIELD EFFECTS

11:00-11:30 *Coffee break*

Chairman: *A.F. Zakharov*

11:30-12:00 Andrei Lobanov: RADIO SPECTROSCOPY OF ACTIVE GALACTIC NUCLEI

12:00-12:30 Stefano Ciroi: THE HIDDEN NATURE OF NARROW-LINE SEYFERT 1 GALAXIES

12:30-12:45 Dragana Ilić: THE STRUCTURE OF THE BLR AND NLR IN AGN Mrk 817

12:45-13:00 Alexey Moiseev: SCANNING FABRY-PEROT INTERFEROMETER IN THE EXTRAGALACTIC RESEARCHES

13:00-13:15 Edi Bon: KINEMATICS AND VARIABILITY OF III Zw 2 BROAD LINE EMISSION REGION

13:15-13:30 Srdjan Samurović: DETECTION OF DARK MATTER IN EARLY-TYPE GALAXIES WITH X-RAY HALOES USING ABSORPTION SPECTRAL LINES

13:30-15:30 *Lunch*

Chairman: *L. Wisotzki*

15:30-16:00 Alexander F. Zakharov: BLACK HOLES: THEORY VERSUS OBSERVATIONS - ANALYSIS OF THE Fe K_α LINES AND PRECISE ASTROMETRICAL OBSERVATIONS

16:00-16:30 Cristina Abajas: INFLUENCE OF GRAVITATIONAL MICROLENSING ON BROAD EMISSION LINES OF QUASARS

16:30-16:45 Predrag Jovanović: MICROLENSING EFFECT ON Fe Kα LINE AND X-RAY CONTINUUM IN THE CASE OF THREE GRAVITATIONALLY LENSED QUASARS: MG J0414+0534, QSO 2237+0305 and H1413+117

16:45-17:00 Eleni Chatzichristou: MULTI-WAVELENGTH SURVEYS OF OBSCURED AGN

17:00-17:30 *Coffee break*

Chairman: *M. Roth*

17:30-18:00 Lutz Wisotzki: QUASAR ABSORPTION LINES AND THE INTERGALACTIC MEDIUM

18:00-18:15 Marko Krčo: HINSA AS A TOOL FOR STUDYING DARK CLOUDS AND STAR FORMATION

18:30-20:30 Poster presentation (5 min per poster)

Chairman: *N. Ben Nessib*

M. Christova, V. Gagov and I. Koleva: CALCULATIONS OF THE COLLISIONAL NEUTRAL LINE WIDTHS OF SEVERAL Ar I LINES

F. Di Mille, P. Rafanelli, S. Ciroi, V.L. Afanasiev and S.N. Dodonov: SPECTROPHOTOMETRIC STUDY OF NEARBY SEYFERT NUCLEI

Milan S. Dimitrijević, Tanya Ryabchikova, Luka Č. Popović, Denis Shulyak and Sergey Khan: ON THE INFLURENCE OF STARK BROADENING OF Cr I LINES IN THE Cr-RICH Ap STAR β CrB ATMOSPHERES

G. Djurašević, D. Dimitrov, B. Arbutina, B. Albayrak and S.O. Selam: A STUDY OF CLOSE BINARY SYSTEM EE Cet

Anton Dorodnitsyn and Igor Novikov: LINE-DRIVEN WINDS NEAR BHs

N. Gavrilović, S. Jankov, P. Mathias and P. De Cat: INVESTIGATION OF ROTATIONAL VELOCITY OF E-PERSEI (EPSILON-PERSEI)

Rafik Hamdi and Nébil Ben Nessib: ELECTRIC DIPOLE TRANSITION PROBABILITIES IN Al IV AND Al V IONS

Daniela Korcakova and Jiri Kubat: EMERGENT LINE PROFILES FROM RAPIDLY ROTATING STARS

Ana Lalović and Ištvan Vince: THE REDUCTION OF ECLIPSING BINARY STARS SPECTRA OBSERVED AT ROZHEN OBSERVATORY

A. Sáinz, M.D. Calzada, M.C. García: GAS TEMPERATURE FROM LINE BROADENING IN A NEON MICROWAVE PLASMA AT ATMOSPHERIC PRESSURE

A. Sáinz, I. Santiago, M.C. García and M.D. Calzada: SELF-ABSORPTION EFFECTS IN THE EQUIVALENT WIDTH OF THE SPECTRAL LINES IN A NEON MICROWAVE PLASMA AT ATMOSPHERIC PRESSURE

I. Santiago, M. Pineda, M.C. García and M.D. Calzada: VOIGT DAMPING PARAMETER OF THE SPECTRAL LINES EMITTED BY A PLASMA FLAME AND A PLASMA COLUMN GENERATED BY MICROWAVE AT ATMOSPHERIC PRESSURE

Zoran Simić, Luka Č. Popović, Milan S. Dimitrijević and Miodrag D. Dačić: ON THE STARK BROADENING PARAMETERS FOR Cu III AND Zn III LINES IN A TYPE STAR ATMOSPHERES

A.A. Smirnova, A.V. Moiseev and V.L. Afanasiev: STUDYING OF SOME SEYFERT GALAXIES BY THE METHODS OF PANORAMIC SPECTROSCOPY

A.Yu. Vorobyev, S.S. Kharintsev and M.Kh. Salakhov: ANALYTICAL CURVES REDUCTION BY USING FRACTIONAL DERIVATIVE SPECTROMETRY

C. Yubero, M.D. Calzada and M.C. García: COMPUTER-SIMULATED BALMER-ALPHA LINE PROFILE FOR CALCULATING THE ELECTRON NUMBER DENSITIES

Besma Zmerli, Nébil Ben Nessib and Milan S. Dimitrijević: TEMPERATURE DEPENDANCE OF NON HYDROGENIC ATOM-LINES STARK WIDTHS

Wednesday, 08.06.2005.

Chairman: *J. Purić*

10:00-10:30 Valiants M. Astashynski: SPECTROSCOPIC STUDY OF PLASMA FLOWS CREATED BY A MAGNETOPLASMA COMPRESSOR

10:30-11:00 Dolores Calzada-Canalejo: SPECTROSCOPY OF THE DISCHARGES CREATED AND MAINTAINED BY A SURFACE-WAVE

11:00-11:30 Coffee break

Chairman: *J. Danzinger*

11:30-12:00 Martin Roth: 3D SPECTROSCOPY OF EMISSION LINE SPECTRA OF PLANETARY NEBULAE: DIAGNOSTIC TOOLS FROM THE MILKY WAY TO NEARBY GALAXIES AND BEYOND

12:00-12:30 Edward Baron: OVERVIEW OF SUPERNOVA MODELING WITH PHOENIX

12:30-14:00 *Lunch*

14:00-19:00 *Visiting orthodox and catholic churches in Vršac, monastery Mesić, Vršac's Tower (at the top of Vršac's mountains)*

20:00-23:00 *Visiting the wine cellar in the village Gudurica with testing local wines. Conference dinner will be in the wine cellar*

Thursday, 09.06.2005

Chairwoman: *G. Peach*

11:00-11:30 Peter Hauschildt: EFFECTS OF LINE PROFILES IN T DWARFS

11:30-12:00 Mikhail Sachkov: PULSATIONS IN THE ATMOSPHERES OF Ap STARS

12:00-12:15 Olga Atanacković-Vukmanović: SOLUTION OF NLTE LINE TRANSFER PROBLEM BY USE OF A FORTH-AND-BACK IMPLICIT Λ ITERATION

12:15-12:30 Milan Zboril: HELIUM LINE SHAPE ANALYSIS IN B TYPE STARS

12:30-13:45 Darko Jevremović: ^{6}Li IN THE ATMOSPHERES OF ACTIVE COOL STARS

13:45-15:30 *Lunch*

Chairman: *P. Hauschild*

15:30-16:00 Ljubinko M. Ignjatović: PROCESSES OF ATOM-ATOM (n - n') - MIXING INFLUENCE ON HYDROGEN ATOM RYDBERG STATES POPULATIONS IN STELLAR ATMOSPHERES

16:00-16:30 Evagelia Lyratzi: A NEW APPROACH FOR THE STRUCTURE OF Hα REGIONS IN 120 Be STARS

16:30-16:45 Nikola Vitas: HEIGHTS OF FORMATION OF Mn I SPECTRAL LINES BROADENED BY HYPERFINE STRUCTURE

16:45-17:00 Derek Homeier: MOLECULAR LINE WIDTHS AT STELLAR ATMOSPHERE CONDITIONS

17:00-17:30 *Coffee break*

Chairman: *E. Danezis*

17:30-18:00 Slobodan Ninković: GLOBULAR CLUSTERS OF THE MILKY WAY: THEIR FATE AND CHEMICAL COMPOSITION

18:00-18:15 Nenad Sakan: THE APPLICATION OF THE CUT-OFF COULOMB POTENTIAL FOR THE CALCULATION OF A CONTINUOUS SPECTRA OF DENSE HYDROGEN PLASMA

Chairmen: *M. S. Dimitrijević, L. Č. Popović*

18:15-19:00 Discussion about conference, next SCSLSA, all participants are invited to take part.

Friday, 10. 06. 2005.

Excursion: Smederevo Fortress (1420), monastery Manasia (1407), Resava cave, waterfall Lisine

Back to Belgrade around 21:00

AUTHORS' INDEX

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SERBIAN Conference on Spectral Line Shapes in Astrophysics (V SCSLSA) (5th ; 2005 ; Vršac)

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COBISS.SR-ID 122797580

Invited lecture

PROCESSES OF ATOM – ATOM (n – n')-MIXING INFLUENCE ON HYDROGEN ATOM RYDBERG STATES POPULATIONS IN STELLAR ATMOSPHERES

LJUBINKO M. IGNJATOVIĆ[1], ANATOLIJ A. MIHAJLOV[1] and MILAN S. DIMITRIJEVIĆ[2]
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The $(n - n')$-mixing processes in $H^*(n) - -H(1s)$ collisions, have been considered from the aspect of their influence on of the $H^*(n >> 1)$ atom states in the weakly ionized layers of stellar atmospheres. These processes have been treated by the mechanism of the resonant energy exchange within the electron component of the considered collisional system. It was shown that these processes must have significant influence in comparison with corresponding electron-atom collision processes, on the populations of hydrogen Rydberg atoms in Solar photosphere and lower chromosphere (ionization degree of the order of 10^{-4}). From obtained results follows that the examinated $(n - n')$ mixing processes have to be included in the modelisation of Solar and cooler stars atmospheric plasma.

Invited lecture

RADIO SPECTROSCOPY OF ACTIVE GALACTIC NUCLEI

ANDREI LOBANOV
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Radio spectroscopy offers a number of tools for studying a large variety of astrophysical phenomena, ranging from stars and their environment to interstellar and intergalactic medium, active galactic nuclei (AGN) and distant quasars. Main targets of extragalactic radio spectroscopy are molecular and dust material in galaxies, HII regions, and maser emission originating in the dense, circumnuclear regions. These studies cover all galactic types and span an impressive range of angular scales and distances. Molecular emission, hydrogen absorption and maser lines have become the tools of choice for making an assessment of physical conditions in the nuclear regions of galaxies. In this contribution, some of the recent advances in the aforementioned fields will be reviewed and discussed in connection with future radio astronomical facilities.

V Serb. Conf. on Spectral Line Shapes in Astrophysics
Vršac, 6-10. June, 2005.
Program and Abstracts

Invited lecture

A NEW APPROACH FOR THE STRUCTURE OF Hα REGIONS IN 120 Be STARS

E. LYRATZI[1], E. DANEZIS[1], D. NIKOLAIDIS[1], L.Č. POPOVIĆ[2],
M.S. DIMITRIJEVIĆ[2], E. THEODOSSIOU[1] and A. ANTONIOU[1]

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The spectra of a fraction of Oe and Be stars have Discrete Absorption Components (DACs) or Satellite Absorption Components (SACs) which create complex line profiles of these stars. The shapes of these lines are interpreted by the existence of two or more independent layers of matter nearby a star. These structures are responsible for the formation of a series of satellite components for each spectral line. First, here we will shortly present a model reproducing the complex profile of the spectral lines of Oe and Be stars with DACs and SACs (Danezis et al. 2003, Lyratzi & Danezis 2004). In general, this model has a line function for the complex structure of the spectral lines with DACs or SACs and include a function L that considers the kinematic (geometry) of an independent region. We have developed the model considering random velocities in the calculation of the function L. With this modification, the model can explain the complex structure of all line forming independent regions, until the regions where the Mg II lines are created. However, with this model it is not possible to explain the structure of the Hα forming region, i.e. the model cannot appropriate fit the complex Hα line profiles of Be stars. Here we will present a new approach of the model which is able to explain the complex structure of Hα regions. The new approach of the model is based on a synthesis of Hα lines using the fact that sub-regions have random, radial and rotation velocities, but also that some atomic (collisional) processes can contribute to the line wings (it brings a Voigt profile). Moreover, we study Hα lines of a sample of 120 Be stars and we obtained the radial and rotational velocities of the independent regions in which the satellite components are created. Finally, we calculate the optical depth (τ) and the column density (d) of each independent density region and we discuss the correlations between obtained parameters of sub-regions in the sample.

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Short talk

STARK BROADENING OF Ar I SPECTRAL LINES EMITTED IN SURFACE WAVE SUSTAINED DISCHARGES

M. CHRISTOVA[1], M.S. DIMITRIJEVIĆ[2] and S. SAHAL-BRÉCHOT[3]

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The Stark parameters (the widths and shift) of six Ar I spectral lines in pure argon: 522.1, 549.6, 603.2, 518.8, 560.7 nm ($nd \rightarrow 4p$, for $n = 7 \div 5$) and 696.5 nm ($4p' \rightarrow 4s$) have been calculated within the semi-classical perturbation approach [1-3].

Surface wave's discharges (SWDs) have been successfully employed in various fields of science and technology, including materials processing, elemental analysis, abatement of harmful gases, and more recently, sterilization of medical devices. Operating at atmospheric pressure we have used emission spectroscopy to determine the electron density of SWDs from the Stark broadening of the emitted argon lines [4].

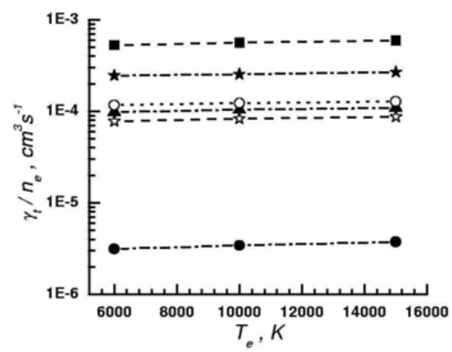

Fig. 1. *The ratio of the total width to the electron density ($n_e = 10^{14} cm^{-3}$) as a function of the electron temperature T_e for the studied Ar I lines (■ 522.1, * 549.6, ○518.6, ▲603.2, *560.7, ●696.6 nm)*

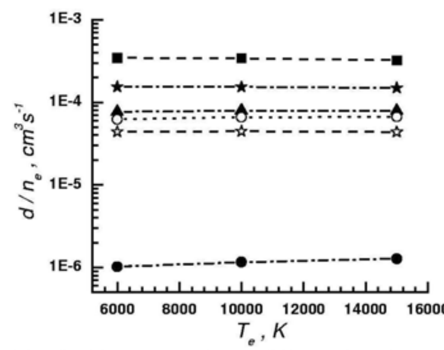

Fig. 2. *The ratio of the shift to the electron density ($n_e = 10^{14} cm^{-3}$) as a function of the electron temperature T_e for the studied Ar I lines (■ 522.1, * 549.6, ▲518.6, ○ 603.2, *560.7, ●696.6 nm)*

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V Serb. Conf. on Spectral Line Shapes in Astrophysics
Vršac, 6-10. June, 2005.
Program and Abstracts

Short talk

ELECTRON IMPACT BROADENING OF MULTICHARGED NEON SPECTRAL LINES

HAYKEL ELABIDI[1], NÉBIL BEN NESSIB[1] and MILAN S. DIMITRIJEVIĆ[2]
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Stellar and laboratory plasma diagnostic, atomic abundances, opacity calculations, all have led to a need for knowledge about Stark broadening of multicharged ion spectral lines. Sophisticated quantum-mechanical and semiclassical methods (Griem 1974) exist, but they often require a considerable labor even for the evaluation of a single line width. Moreover, when quick estimate is needed, the approximate approaches may be very useful.

One such approximate method is the modified (Dimitrijević and Konjević 1980, 1981) semi-empirical (Griem 1968) formula suitable for singly as well as for multiply charged ion lines, based on the Gaunt factor approximation for inelastic cross sections (Griem 1968). Since the Gaunt factor is proportional to the collision strength, it is of interest to use the collision strength data in the modified semi-empirical formula (Dimitrijević and Konjević 1980) in order to obtain more accurate results.

In this work, instead of the semi-empirical Gaunt factor used in Dimitrijević and Konjević (1980, 1981), more accurate electron impact excitation collision strengths, obtained in the distorted wave approximation in LS coupling, were used. We note also that we take into account the elastic collision contribution to the width by calculating the collision strengths at the threshold energy and extrapolating them below the threshold as in Griem (1968) and, Dimitrijević and Konjević (1980). It has been shown that the elastic contribution to the line width becomes less important with the increase in temperature (Ralchenko et al. 1999).

We have applied this method to the calculation of Stark line widths of two ions, Ne VII and Ne VIII. The comparison with experiments and other theoretical approaches indicates that this method can be used successfully for Stark line width calculations.

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Short talk

MEASURED STARK SHIFTS OF Kr I LINE PROFILES IN THE 5s-5p AND 5s-5p' TRANSITIONS

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On the basis of the precisely recorded 10 neutral krypton (Kr I) line shapes in the 5s–5p and 5s–5p' transitions, it has been obtained the Stark shift (d) of the neutral krypton (Kr I) spectral lines. These lines have been studied in a linear, low–pressure, optically thin pulsed arc discharge operated in pure krypton. The line shapes are measured at 17 000 K electron temperature (T) and at 16.5×10^{22} m^{-3} electron density (N). The mentioned plasma parameters have been measured using independent experimental diagnostics techniques, as well as from the line deconvolution procedure. The separate electron and ion contributions from the total Stark shift (d_t), i.e. d_e and d_i have been obtained and represent the first experimental data in this field.

On the basis of the observed asymmetry of the Stark broadened line profile it has been deduced the ion broadening parameters which describe the influence of the ion static (A) and the ion–dynamical effect on the shift (E) of these 10 Kr I line shapes. The ion–dynamical parameters of the measured Kr I line shape are the first data in this field, too.

Short talk

THE STARK BROADENING EFFECT IN HOT STAR ATMOSPHERES: Tl II

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Electron-impact broadening is the main pressure broadening mechanism in the hot star atmospheres. Satellite ultraviolet spectral lines observations made by e.g. International Ultraviolet Explorer (IUE) and Goddard High Resolution Spectrograph (GHSR) installed at Hubble Space Telescope provided much better possibilities for the investigations of the trace elements spectral line in stellar atmospheres. Consequently, Stark broadening parameters data for such lines become of interest for stellar spectra interpretation, analysis and modelling as well as for abundance determination.

In order to provide the needed spectroscopic data for singly ionized Thallium spectral lines we present Stark broadening parameters for Tl II spectral lines calculated within the modified semiempirical approach. Calculations were performed within temperature range 5000K-50000K and for an electron density of 10^{23}m^{-3}.

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Vršac, 6-10. June, 2005.
Program and Abstracts

Poster paper

ON THE INFLURENCE OF STARK BROADENING OF Cr I LINES IN THE Cr-RICH Ap STAR β CrB ATMOSPHERES

MILAN S. DIMITRIJEVIĆ[1], TANYA RYABCHIKOVA[2,3], LUKA Č. POPOVIĆ[1,4], DENIS SHULYAK[5] and SERGEY KHAN[5]

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Chromium is one of the most anomalous elements in Ap stars. It was shown to be concentrated in the deeper atmospheric layers in Ap stars β CrB and in γ Equ, where electron density is high enough to favor the Stark broadening mechanism, the most significant pressure broadening mechanism for A and B stars. Most Cr I, and Cr II, lines in the optical spectral region have rather small Stark damping constants so no measurable Stark wings appeared. However, Cr I, lines from $4p - 4d$ transitions are known to have fairly large Stark damping constants according to calculations made by Kurucz.

We present here new calculations of Cr I Stark line widths and shifts based on the semi-classical perturbation approach of Sylvie Sahal-Bréchot. Electron-, proton-, and ionized helium-impact line widths and shifts for nine Cr I spectral lines from the $4p^7P^0 - 4d^7D$ multiplet, were calculated for a perturber density of 10^{14} cm^{-3} and for temperatures T = 2,500 − 50,000 K.

The results were used to investigate the influence of Stark broadening effect on Cr I line shapes in the atmosphere of the Cr-rich Ap star β CrB. In spite of the rather large Stark damping constants, the effect is not observable in stars with solar Cr abundance. In hot stars where electron and proton densities are high, the Cr I, lines considered here are generally very weak, while in cooler stars (solar type) other broadening effects are more significant where these lines are strong enough. The only chance to look at Stark effect is in stratified atmosphere of a Cr-rich Ap star, such as the well known magnetic star β CrB.

Our analysis of the Cr-rich Ap star β CrB line shapes was based on its spectrum obtained in February 1998 with the MuSiCoS spectropolarimeter mounted on the 2 m telescope at Pic du Midi observatory (R=35000).It was found (Dimitrijević et al, 2005) that the contribution of proton and He ii collisions to the line width and shift is significant and comparable, and is sometimes even larger than electron-impact contribution depending of the electron temperature. Moreover, not only the Stark line width, but also the Stark shift may contribute to the blue as well as to the red asymmetry of the same line depending on the electron-, proton-, and He ii density in stellar atmosphere. The results were used to investigate the influence of Stark broadening effect on Cr i line shapes in the atmosphere of the Cr-rich Ap star β CrB.

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V Serb. Conf. on Spectral Line Shapes in Astrophysics
Vršac, 6-10. June, 2005.
Program and Abstracts

Poster paper

ON THE STARK BROADENING PARAMETERS FOR Cu III AND Zn III LINES IN A TYPE STAR ATMOSPHERES

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Stark broadening of ion and atom lines is of interest in the investigation of laboratory and astrophysical plasma. With the development of space-born spectroscopy, observations of spectral lines of trace elements like copper and zinc, become available. From the analysis of 11 Hg-Mn star spectra (Jacobs and Dworetsky, 1981) for example, it follows that copper is clearly overabundant in 10 of investigated stars. Zinc spectral lines are present as well in stellar spectra (see e.g. Adelman 1994, Cowley et al. 2000, Ryabchikova et al. 2000).

The knowledge of Stark broadening parameters is also of interest for the investigation of laboratory and technological plasmas. For example, Spectral lines of Cu III and Cu IV are of particular interest for the diagnostic and modelling of plasma created in electromagnetic macro particle accelerators where in experimental work, the plasma is usually created by Cu or Al foil evaporation. Also, doubly charged zinc ion is a member of the nickel isoelectronic sequence, known to include possible candidates for development of ultraviolet lasers.

Here we present Stark widths for six transitions of Cu III and six transitions of Zn III calaculated by using the modified semiempirical approach (Dimitrijevi and Konjevi 1980). Obtained theoretical results are used to consider the influence of Stark broadening for A type star atmospheres conditions.

Obtained results demonstrate that in A type star atmospheres exist layers where the influence of Stark broadening on Cu III and Zn III line shapes is important in comparison with Doppler broadening. The obtained Stark broadening parameters contribute also to the creation of a set of such data for as large as possible number of spectral lines, of significance for a number of problems in laboratory, technological and astrophysical plasma research.

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V Serb. Conf. on Spectral Line Shapes in Astrophysics
Vršac, 6-10. June, 2005.
Program and Abstracts

Poster paper

COMPUTER-SIMULATED BALMER-ALPHA LINE PROFILE FOR CALCULATING THE ELECTRON NUMBER DENSITIES

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In general, the profile of the spectral lines observed in cold plasmas with a low density and at pressures of over 100 Torr, can be approximated well enough by means of Voigt type functions. This function is the result of the convolution of a gaussian function with a lorentzian function. In this way, by using a model permitting us to fit the Voigt function and intermediate theories, it is possible to obtain fundamental parameters characterizing the plasma (electron density and temperature, gas temperature, etc.)

In the present work, we have fitted the experimental profiles of the Hydrogen Balmer serie lines to a simulated profile obtained from the theoretical Stark profiles given by Gigosos *et al*[M.A. Gigosos, M.A. Gonzlez and V. Cardeoso: Spectrochim. Acta B **58** (2003) 1489.]. by means of the Model Microfield Method. For this treatment it is necessary to find out the most important effects causing the line broadening in our "low density plasmas": Van der Waals, Doppler, instrumental and Stark broadening.

This study was carried out for the first Hydrogen Balmer series line (H_α), this being the most problematic line because it depends heavily on the electron temperature and has a strong broadening by ion dynamics. This method permits the inclusion of ion dynamics effects and also to take into account the difference between T_e and T_g existing in the plasma, by means of the reduced mass, μ. (In our Ar-H plasma with $T_e = 6500$K y $T_g = 1400$K, μ is approximately 4). The best simulated profile corresponded to the convolution between a Van der Waals profile for a gas temperature of 1400 K ($\approx$ 0.035), a Gaussian profile (Doppler+Instrumental) of approximately 0.02 nm and a Stark profile for a μ equal to 4 and an electron density of $\approx 4 - 5 \cdot 10^{14}\text{cm}^{-3}$, with a 95% approximation to the experimental profile.

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Program and Abstracts

Poster paper

TEMPERATURE DEPENDENCE OF NON HYDROGENIC ATOM-LINES STARK WIDTHS

BESMA ZMERLI[1], NÉBIL BEN NESSIB[1] and MILAN S. DIMITRIJEVIĆ[2]

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We investigate in the present work the temperature dependence of Stark widths for neutral atom spectral lines in order to find a more precise method for scaling with temperature than sometimes used dependence $T^{-1/2}$, which is often inadequate particularly for Stark broadening of neutral emitter lines.

We propose here a method which provides better possibilities for scaling with temperature. In order to demonstrate the applicability of this scaling, we have applied it to Stark line widths of He I, Mg I, and Ar I. The present results concerns the data at a perturber density $10^{16} cm^{-3}$ and (temperature = 2.510^3 - 5.010^4 K).

In order to obtain a better method for the scaling of Stark broadening parameters with temperature we have used formulae for estimating Stark widths of neutral atom lines based on the simple method of Freudenstein and Cooper and its generalization (i) for the cases where there are more than one important perturber level and (ii) for the shifts, by Dimitrijević and Konjević.

We present results for temperature scalings of Stark half-halfwidths with the proposed method, which are compared with width calculations according to the semiclassical perturbation formalism (versions of Sahal-Bréchot and Griem, Baranger, Kolb and Oertel)and with results obtained with symplified methods of Freudenstein and Cooper, and of Dimitrijević and Konjević.

FACULTY OF MATHEMATICS
UNIVERSITY OF BELGRADE

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The Tenth National Conference

Digitization of national heritage

Belgrade, Serbia, September 22-23, 2011

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BOOK OF ABSTRACTS

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Астрономска опсерваторија, Београд

ЕЛЕКТРОНСКА ИЗДАЊА БЕОГРАДСКИХ АСТРОНОМСКИХ ИНСТИТУЦИЈА 2010-2011

Електронско издаваштво у српским астрономским институцијама започели смо на Астрономској опсерваторији 2006. године и детаљно приказали период закључно са 2009, у Прегледу НЦД, бр. 17 (2010, стр. 17-24). У том периоду су публикована 22 компакт диска и ДВДа, а издавачи су били Астрономска опсерваторија, Астрономско друштво „Руђер Бошковић“, Друштво астронома Србије и Природњачко друштво „ГЕА“ из Вршца. Овде ћемо приказати наставак активности на објављивању астрономских садржаја и текстова у дигитализованом облику, у 2010. и 2011. години.

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STARK BROADENING OF Al III LINES IN THE ARC OF ELECTRODYNAMIC MACROPARTICLE ACCELERATOR

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INTRODUCTION

The arc plasma created in the electrodynamic macroparticle accelerator ("rail gun") is an interesting example of a cool and very dense plasma [1]. Moreover, the diagnostic of such a plasma is very difficult. In the previous paper [2], the Stark broadening in the "rail gun" with Cu plasma has been analyzed. In the arc plasma Cu III ions are the most abundant but Cu IV ions are also present and are more convenient for the diagnostic purposes, since their lines are less influenced by selfabsorption. Moreover, the spectrum of Cu IV is more convenient from the theoretical point of view for the Stark broadening calculations than the Cu III spectrum. Consequently, we can obtain more reliable data.

In the present case, Al III ions are the most abundant and Al IV ions are also present. However, in the Ne-like Al IV spectrum there is not convenient lines in the visible part of the spectrum (see e.g. the corresponding Grotrian diagrams in [3]). On the contrary, in the case of Al III lines such lines exist and moreover there is sufficiently of atomic data for a reliable semiclassical calculation. Consequently, as a difference from the previous article [2], where for the Stark broadening calculation for Cu IV lines the modified semiempirical method [4] has been used, the more sophisticated semiclassical-perturbation formalism [5,6] has been applied here for the calculation of line widths and shifts for 9 Al III multiplets.

METHOD AND RESULTS OF CALCULATION

Within the framework of the semiclassical perturbational formalism used here [5,6], the full halfwidth (W) and shift (d) of an electron-impact broadened isolated spectral line can be expressed as:

$$W = N\int_0^\infty v f(v)dv\Big(\sum_{i'\neq i}\sigma_{ii'}(v)+\sum_{f'\neq f}\sigma_{ff'}(v)+\sigma_{el}\Big)+W_R$$

$$d = N\int_0^\infty v f(v)dv\int_{R_{min}}^{R_D}2\pi\rho d\rho \sin(2\varphi_p)$$

Here, N is the electron density, R_D Debye cut-off, f(v) the Maxwellian velocity distribution function for electrons, ρ denotes the impact parameter of incoming electron, i and f denote the initial and final states, and i', f' their corresponding perturbing states, while W_R gives the contribution of Feshbach resonances [7]. With $\sigma_{jj'}(v)$ and σ_{el} are denoted the corresponding inelastic and elastic cross sections and with φ_p the phase shift due to polarization potential. All additional details concerning calculation, as well as the cut-off parameter R_{min}, may be found in Refs. [5,6] and [8].

Energy levels for Al III lines have been taken from [3]. Oscillator strengths have been calculated by using the method of Bates and Damgaard (Coulomb approximation) [9] and the corresponding tables in Ref. [10]. For higher levels, the method described in Ref. [11] has been used. Our results are shown in Table 1 for perturber density $10^{17}cm^{-3}$ and temperatures of T = 10000, 15000, 20000, 50000 and 100000 K. We also specify a parameter c [12], which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the full half width at half maximum (W). For each value given in Table 1, the collision volume (V) multiplied by the perturber density (N) is much less then one and the impact approximation is valid [5,6].

[illegible] broadening parameters for Al III lines (full width at half maximum W and shift d) for perturber density of $10^{17}cm^{-3}$ and temperatures from 10,000K to 100,000K. Transitions and averaged wavelengths for the multiplet (in Å) are also given. By using c (see Eq.5 in Ref.8) we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

Transition	T(K)	W(Å)	d(Å)
3S - 3P 1857.4Å $c=1.9\cdot10^{20}$	10 000 15 000 20 000 50 000 100 000	$0.519\cdot10^{-1}$ $0.427\cdot10^{-1}$ $0.371\cdot10^{-1}$ $0.240\cdot10^{-1}$ $0.179\cdot10^{-1}$	$0.903\cdot10^{-5}$ $-0.139\cdot10^{-3}$ $-0.322\cdot10^{-3}$ $-0.349\cdot10^{-3}$ $-0.400\cdot10^{-3}$
3S - 4P 696.0Å $c=8.5\cdot10^{18}$	10 000 15 000 20 000 50 000 100 000	$0.164\cdot10^{-1}$ $0.138\cdot10^{-1}$ $0.122\cdot10^{-1}$ $0.898\cdot10^{-2}$ $0.757\cdot10^{-2}$	$0.110\cdot10^{-3}$ $0.192\cdot10^{-3}$ $0.320\cdot10^{-3}$ $0.258\cdot10^{-3}$ $0.366\cdot10^{-3}$
3P - 3D 1609.8Å $c=7.2\cdot10^{19}$	10 000 15 000 20 000 50 000 100 000	$0.451\cdot10^{-1}$ $0.375\cdot10^{-1}$ $0.328\cdot10^{-1}$ $0.216\cdot10^{-1}$ $0.165\cdot10^{-1}$	$-0.105\cdot10^{-3}$ $0.261\cdot10^{-3}$ $0.574\cdot10^{-3}$ $0.545\cdot10^{-3}$ $0.702\cdot10^{-3}$
3P - 4D 893.3Å $c=1.5\cdot10^{18}$	10 000 15 000 20 000 50 000 100 000	$0.491\cdot10^{-1}$ $0.425\cdot10^{-1}$ $0.386\cdot10^{-1}$ $0.297\cdot10^{-1}$ $0.251\cdot10^{-1}$	$0.330\cdot10^{-2}$ $0.384\cdot10^{-2}$ $0.401\cdot10^{-2}$ $0.386\cdot10^{-2}$ $0.362\cdot10^{-2}$
3P - 4S 1382.6Å $c=3.3\cdot10^{19}$	10 000 15 000 20 000 50 000 100 000	$0.582\cdot10^{-1}$ $0.474\cdot10^{-1}$ $0.415\cdot10^{-1}$ $0.286\cdot10^{-1}$ $0.232\cdot10^{-1}$	$0.115\cdot10^{-1}$ $0.791\cdot10^{-2}$ $0.750\cdot10^{-2}$ $0.573\cdot10^{-2}$ $0.494\cdot10^{-2}$
3D - 4F 1935.9Å $c=6.8\cdot10^{18}$	10 000 15 000 20 000 50 000 100 000	0.192 0.164 0.147 0.108 $0.890\cdot10^{-1}$	$-0.552\cdot10^{-2}$ $-0.603\cdot10^{-2}$ $-0.563\cdot10^{-2}$ $-0.583\cdot10^{-2}$ $-0.408\cdot10^{-2}$
3D - 4P 3606.2Å $c=2.3\cdot10^{20}$	10 000 15 000 20 000 50 000 100 000	0.434 0.367 0.327 0.242 0.205	$0.244\cdot10^{-2}$ $0.368\cdot10^{-2}$ $0.660\cdot10^{-2}$ $0.536\cdot10^{-2}$ $0.777\cdot10^{-2}$
4S - 4P 5706.9Å $c=5.7\cdot10^{20}$	10 000 15 000 20 000 50 000 100 000	1.43 1.19 1.07 0.814 0.707	$-0.470\cdot10^{-1}$ $-0.520\cdot10^{-1}$ $-0.487\cdot10^{-1}$ $-0.503\cdot10^{-1}$ $-0.482\cdot10^{-1}$
4P - 4D 4524.9Å $c=3.7\cdot10^{19}$	10 000 15 000 20 000 50 000 100 000	1.41 1.22 1.12 0.879 0.761	$0.683\cdot10^{-1}$ $0.833\cdot10^{-1}$ $0.828\cdot10^{-1}$ $0.842\cdot10^{-1}$ $0.741\cdot10^{-1}$

CONCLUSION

The presented Stark broadening parameters of most important Al III lines give possibility for diagnostic research of arc plasma created in the electrodynamic macroparticle accelerator. Together with previously investigated Cu IV lines [2], these data enable diagnostic considerations of plasmas created in principal devices of such kind.

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International Conference on Spectral Line Shapes

ABSTRACTS

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June 25 – 29, 1990

SIMPLE CONVERGENT FORMULAE FOR ESTIMING STARK WIDTHS OF NEUTRAL ATOM LINES

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ABSTRACT

Simple analytical expressions for estimation of Stark widths of neutral atoms have been derived from the convergent theory who avoid the calculation of the minimum impact parameter. Obtained formulae have been applied to HeI lines and compared to others calculations

GENERAL FORMULA

We develop a simplified convergent method, using a mean velocity, where w+i d is writen as :

$$w + i\,d = N_e\ \bar{v}^{3} \sum_{jj'} \frac{f_{jj'}(T)}{g_j\ \omega_{jj'}^{2}}$$

with

$$f_{jj'}(T) = \int_0^{\infty} z\ [\ 1 - \exp\{ - i\ g_j\ \alpha_{jj'}\ (z\ ,\ \bar{v}\ )\ \}\ ]\ dz \qquad (1)$$

and

$$\alpha_{jj'}\ (z\ ,\bar{v})\ = \frac{2}{3}\ \frac{e^4}{\hbar^2}\ \frac{R_{jj'}^{2}\ \ \omega_{jj'}^{2}}{\bar{v}^{\ 4}} \left(\frac{B_s(z_{jj'}) - iA_s(z_{jj'})}{z^2}\right) \qquad (2)$$

where $A_s(z)$ and $B_s(z)$ are the simplified collision functions fitted numerically with an expression of the form :

$$A_s(z) = e^{-2z}\ (\ a + b\ z\ )\ \text{and}\ B_s(z) = c\ z^2\ \mathrm{Log}\left(\ 1 + \frac{d}{z^3}\right) \qquad (3)$$

Where a=0.90, b=3.12, c=1.4 and d= 0.7

COMPARISON WITH OTHER CALCULATIONS OF WIDTHS

In table I, we compare our results with these obtained by using semi-classical[1,2,3,4] and other simplified[5,6] methods.

Table I Electron impact half-halfwidths for HeI lines as a function of temperature at electron density of 10^{16} cm^{-3}

		Semi-classical formula			Simplified formula		
		Cutoff		Conv.	Cutoff		Conv.
	T (°K)	W_{BG} ref.1 (Å)	W_{DSB} ref.2,3 (Å)	W_{BCW} ref.4 (Å)	W_{FC} ref.5 (Å)	W_{DK} ref.6 (Å)	W_{DBN} this work (Å)
He 4438 Å	5000	1.41	1.24	1.265	1.34	1.46	1.44
2^1P-5^1S	10000	1.57	1.16	1.406	1.64	1.77	1.71
	20000	1.65	1.18	1.488	1.72	1.85	1.47
	40000	1.62	1.22	1.481	1.60	1.72	1.18
He 6678 Å	5000	0.423	0.370	0.3954	0.948	0.468	0.319
2^1P-3^1D	10000	0.386	0.347	0.3576	0.825	0.428	0.308
	20000	0.349	0.314	0.3128	0.696	0.389	0.243
	40000	0.318	0.288	0.2683	0.573	0.344	0.179

CONCLUSION

It seems clearly that this simplified convergent formulae presented here will be useful for astrophysicists in the cases when a large number of Stark broadening data with a good average precision is needed. Also this approch has permitted us to avoid the determination of the minimum impact parameter.

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ABSTRACTS

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PLASMA BROADENING OF BrI AND II LINES FROM $(^1D_2)np$ LEVELS

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ABSTRACT

Systematic experimental and theoretical study of Stark broadening of BrI and II lines from $(^1D_2)np$ levels has been performed.

INTRODUCTION

Recently, results of a study of the Stark broadening and shift of halogen atom lines in a plasma of a wall stabilized arc have been reported[1,2,3]. Comparison between experimental results and simple theoretical calculations has shown large discrepancy for BrI lines from $(^1D_2)5p\,^2P^0$ not detected for the lines of other transitions of halogen atoms[1,2,3]. In order to trace the causes of this puzzling discrepancy we performed systematic experimental and theoretical study of plasma broadening of spectral lines from $(^1D_2)np$ levels of BrI and II.

EXPERIMENTAL RESULTS AND COMPARISONS

As a plasma source we used wall stabilized arc[1,2,3]. Experimental procedure and plasma diagnostics techniques were described elsewhere[1,2,3]. Details of theoretical calculations are given in refs. 4,5 and 6. Comparison of experimental results for BrI and II lines given in Table I together with theoretical data [4,5,6] shows better agreement with calculations from a simple theoretical approach (see ratios w_m/w_{SSC} in Table I). However, both sets of theoretical calculations show large discrepancy with the experiment for the lines of BrI originating from $(^1D_2)5p\,^2P^0$ level. None of the results for other transitions (see Table I) including line from BrI $(^1D_2)5p\,^2D^0$ bear any resemblance to the transitions from $(^1D_2)5p\,^2P^0$ levels. Since in our theorteical calculations only dipole allowed transitions were taken into account an attempt is made to explain this large discrepancy by the influence of forbidden transition.

Table I Experimental data for full-halfwidths w_m in Å units. Experimental results are compared with theoretical ones calculated using semiclassical method[4,5] w_{sc} and simplified semiclassical approach[6] w_{ssc}.

TRANSITION	T (K)	N ($10^{16}cm^{-3}$)	w_m (Å)	w_m/w_{sc}	w_m/w_{ssc}
BrI					
$(^3P_2)5s\,^4P_{3/2} - (^1D_2)5p\,^2P^0_{3/2}$	9800	3.25	1.06	7.16	2.92
$(^3P_1)5s\,^2P_{3/2} - (^1D_2)5p\,^2P^0_{3/2}$	9800	3.15	1.09	5.83	2.44
$(^3P_0)5s\,^2P_{1/2} - (^1D_2)5p\,^2P^0_{1/2}$	9800	3.15	0.85	4.08	1.62
$(^1D_2)5s\,^2D_{5/2} - (^1D_2)5p\,^2D^0_{5/2}$	9600	2.80	0.98	2.59	1.02
II					
$(^3P_2)5d[1]_{3/2} - (^1D_2)6p[2]^0_{3/2}$	9300	2.00	1.43	2.40	1.52
$(^3P_2)5d[3]_{5/2} - (^1D_2)6p[2]^0_{5/2}$	9400	2.20	1.69	2.57	1.68
$(^3P_2)6s[2]_{5/2} - (^1D_2)6p[3]^0_{7/2}$	9400	2.30	0.29	3.42	1.71
$(^3P_2)5d[3]_{5/2} - (^1D_2)6p[3]^0_{7/2}$	9300	2.00	1.47	2.50	1.62

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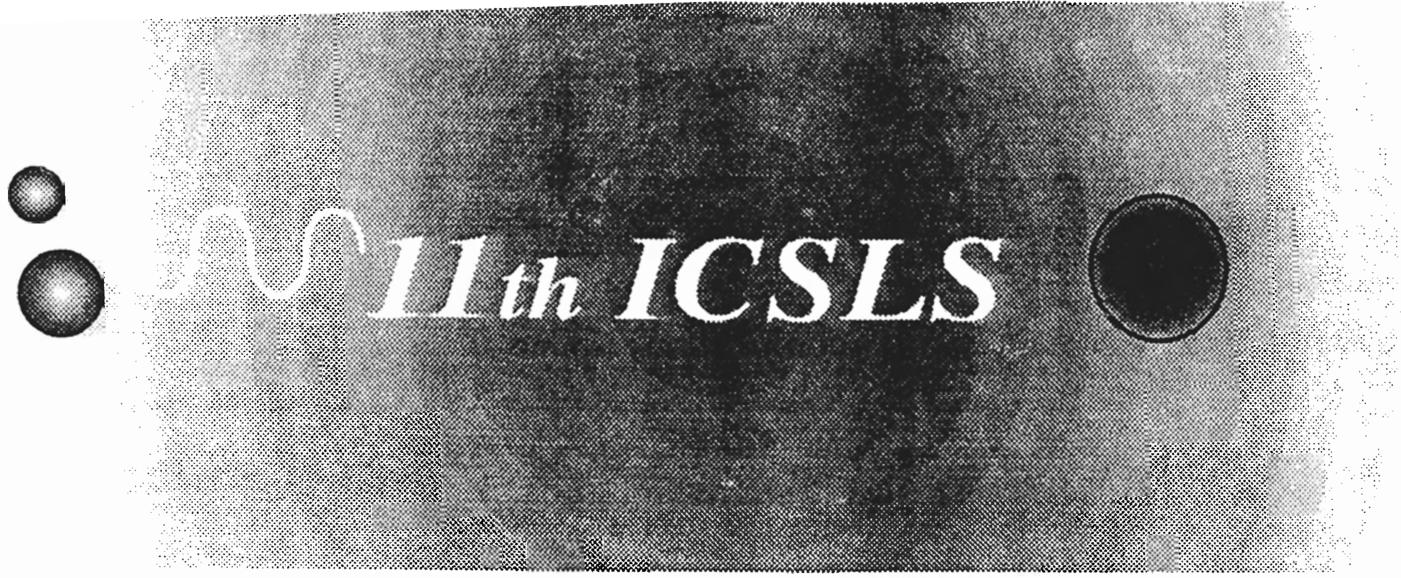

ELEVENTH INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES

CARRY LE ROUET (FRANCE)

June 8-12 1992

SCIENTIFIC PROGRAM AND ABSTRACTS

SIMPLE CONVERGENT FORMULA FOR ESTIMATING STARK WIDTHS AND SHIFTS FOR NEUTRAL AND IONIC LINES

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ABSTRACT

Formula for estimating Stark widths and shifts of ionized atom lines have been derived from a convergent theory that avoids the computation of the minimum impact parameter.

1. INTRODUCTION

In stellar atmosphere calculations, collisional broadening parameters for large number of lines of various elements are required. To obtain these data, one can use the semi-classical or the quantum mechanical approches[1] which both require elaborate calculations even for one line.

For neutral atom lines the simplified semi-classical methods[2-5] are very convenient.

For charged ion lines, one can use the modified semi-classical (M.S.E) approach for widths[6] and shifts[7] calculations.

2. GENERAL FORMULA

We extend our previous formula for neutral atom[5] to ions using a new collision functions with two parameters because the straight path trajectory is changed in a hyperbolic one with excentricity ε. We start with the convergent Bassalo-Cattani-Walder (B.C.W) theory[8-9], and according to S. A. Freudenstein and J. Cooper[3], we have approximated the velocity average by $\bar{v} = \sqrt{\frac{3kT}{m}}$ where T is the temperature and m the electron mass. The half-halfwidth w and shift d are then given by :

$$w + i\,d = N\ \bar{v}^{3} \sum_{jj'} \frac{f_{jj'}(T)}{g_j\, \omega^2_{jj'}} \tag{1}$$

with

$$f_{jj'}(T) = \int_0^{\infty} z[1 - \exp\{-ig_j\, \alpha_{jj'}(z,\bar{v})\}]\, dz \tag{2}$$

and

$$\alpha_{jj'}(z,\bar{v}) = \frac{2}{3}\frac{e^4}{h^2}\frac{\mathbf{R}_{jj'}^{2}\omega^2_{jj'}}{\bar{v}^{4}}\left[\frac{B_S(z,\xi) - i\,A_S(z,\xi)}{z^2}\right] \tag{3}$$

ξ is a dimentionless parameter : $\xi = a\,\omega_{jj'}/\bar{v}$ where $a = Z\,e^2/m\bar{v}^2$

3. SIMPLIFIED COLLISION FUNCTIONS

For neutral lines, the collision functions[10,11] A(z) and B(z) vanishes at large z :

$$A(z \gg 1) \sim \pi z \exp(-2z) \text{ and } B(z \gg 1) \sim \frac{\pi}{4z} \quad (4)$$

They approch one and zero respectively for z=0 : $A(z \ll 1) \sim 1$ and $B(z \ll 1) \sim 0$, so we propose new simplified collision functions as :

$$A_S(z) := (1+\pi z) \exp(-2z) \text{ and } B_S(z) := \frac{\pi z}{4(1+z^2)} \quad (5)$$

For ion lines, the variables (δ, ε) are used in the original definition of the collision functions[12-14], the variables (δ, ξ) are also used and the factor $\frac{\varepsilon^2-1}{\varepsilon^2} = \frac{z^2}{z^2+\xi^2}$ is introduced to preserve the same form for atomic and ionic expressions[15] ($z = \sqrt{\varepsilon^2 - 1}\, \xi$, $\delta = \xi\, (\varepsilon-1)$)

For small ξ , we have the asymptotic expressions :

$$A(z \ll 1, \xi) \sim (1+\pi\xi) \frac{z^2}{z^2+\xi^2} \text{ and } B(z \ll 1, \xi) \sim 0 \quad (6)$$

$$A(z \gg 1, \xi) \sim \pi z \exp(-2z+\pi\xi) \frac{z^2}{z^2+\xi^2} \text{ and } B(z \gg 1, \xi) \sim \frac{\pi}{4z} \frac{z^2}{z^2+\xi^2} \quad (7)$$

We propose the simplified functions which are valid for small ξ and large ε :

$$A_S(z,\xi) := \frac{z^2}{z^2+\xi^2} (1+\pi z) \exp[-2z+2\xi \mathrm{Arctg}(z/\xi)] \text{ and } B_S(z,\xi) := \frac{\pi z^3}{(z^2+\xi^2)(1+z^2)} \quad (8)$$

4. CONCLUSION

The simple convergent formula presented here might be useful in astrophysics calculations for neutral and ionic lines.

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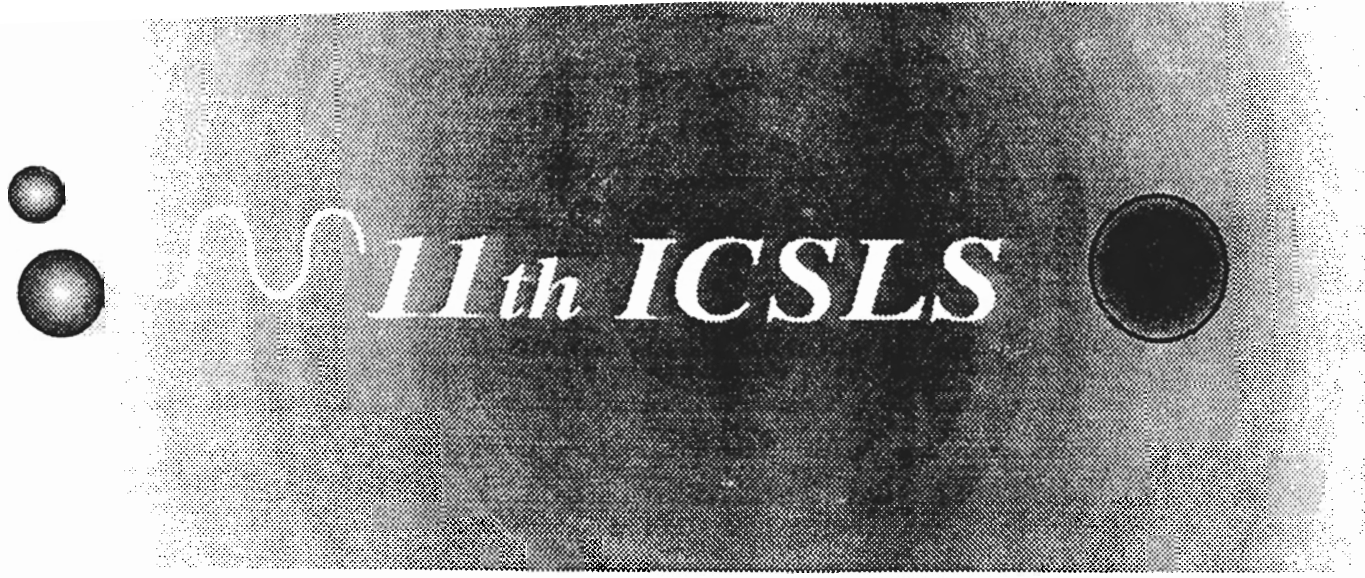

ELEVENTH INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES

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SCIENTIFIC PROGRAM AND ABSTRACTS

Stark Broadening of Singly Ionized Calcium Lines

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1 Introduction

Calcium is among the most abundant elements in stellar plasmas after hydrogen and helium. Particularly important for stellar spectral analysis are the well known resonance lines of Ca II, which are present in all spectra starting with B–type stars and reaching maximal intensity in stars of the K0 spectral type. Consequently, knowledge of reliable Ca II Stark–broadening parameters is of great importance for detailed investigation of stellar atmospheres, as well as for opacity research. Furthermore, Ca II lines are of particular interest for investigations of laboratory plasmas, since calcium is often present as an impurity. By using the semiclassical–perturbation formalism [1,2], we have calculated electron–, proton–, and ionized helium–impact line widths and shifts for 28 Ca II multiplets. A summary of the formalism is given in Ref. 3.

2 Results and discussion

Here, we present in Table 1 and discuss a comparison with experimental data [4–14] while the tables of Ca II Stark broadening parameters will be published elsewhere [15,16]. We see that for most of experiments the widths fall within the error bars of both methods. Additional reliable experimental data for the 4s–4p Ca II widths, especially at lower temperatures, will be of interest.

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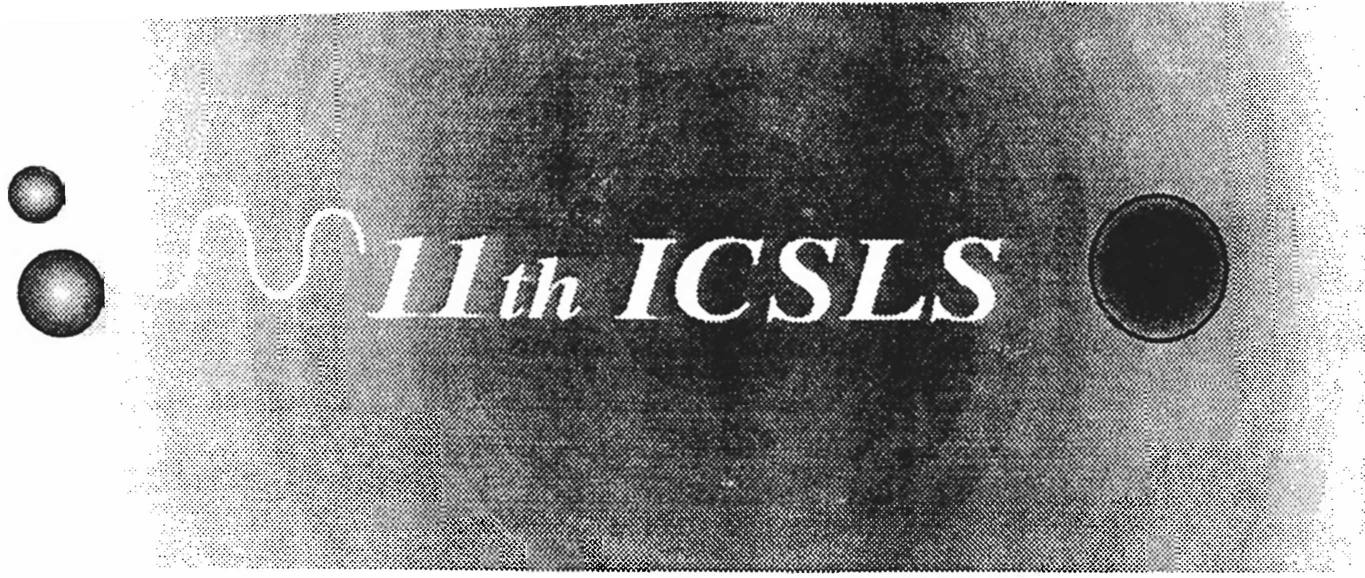
Table 1. Comparison between the experimental Stark full half–halfwidths of Ca II lines (Wm) with different calculations. Semiclassical calculations: WDSB–present results; WJBG – Jones, Benett and Griem (1971)[18,19]; WHC – Hildum and Cooper (1971)[13]; quantum–mechanical calculations: WQ – Barnes (1971)[16] and Barnes and Peach (1970)[17]; N =electron densitv.

Transition	λ(A)	T(K)	N/10+17(cm-3)	Wm(A)	Wm/WDSB	Wm/WJBG	Wm/WHC	Wm/WQM	Ref.
3d-4p	8542.09	13000	1.08	0.95	0.91	0.64		1.10	4
	8662.14	13000	1.08	0.95	0.91	0.64		1.10	4
4s-4p	3933.66	11400	0.40	0.039	0.45	0.33	0.41	0.42	6
		11600	0.64	0.079	0.57	0.43	0.52	0.54	6
		12240	0.80	0.0914	0.53	0.41	0.49	0.51	7
		13000	1.08	0.235	1.04	0.78	0.95	0.99	4
		13350	1.32	0.180	0.65	0.50	0.60	0.63	7
		16000	1.00	0.16	0.81	0.62	0.75	0.78	8
		17500	10.0	10.0	5.15	3.95	4.81	5.05	9
		19000	1.00	0.172	0.91	0.69	0.51	0.45	10
		25100	1.00	0.22	1.22	0.92	1.15	1.25	11
		28000	1.00	0.25	1.40	1.07	1.32	1.44	8
		29200	1.00	0.18	1.01	0.78	0.95	1.05	11
		30000	2.35	0.24	0.58	0.47	0.53	0.63	9
	3968.47	7450	1.00	0.210	0.82	0.67	....	....	5
		12240	0.80	0.0846	0.49	0.38	0.46	0.47	7
		13000	1.08	0.235	1.04	0.78	0.95	0.99	4
		13350	1.32	0.161	0.59	0.44	0.54	0.56	7
		16000	1.00	0.16	0.81	0.62	0.75	0.78	8
		17500	10.0	10.3	5.31	4.07	4.95	5.20	9
		18560	1.00	0.188	0.98	0.75	0.93	1.04	13
		25100	1.00	0.20	1.11	0.84	1.04	1.14	11
		28000	1.00	0.25	1.40	1.07	1.32	44	8
4p-5s	3736.20	7500	10.0	18.2	2.37	2.98			9
		10000	1.00	0.69	1.03	1.00			14
		13000	1.12	0.79	1.21	0.94			4
		25100	1.00	0.30	0.63	0.53			11
	3706.03	10000	1.00	0.70	1.04	1.01			14
		13000	1.12	0.79	1.21	0.94			4
		17500	10.0	13.7	2.68	2.24			9
4p-4d	3179.33	13000	1.13	0.66	1.40	1.03			4
	3158.87	13000	1.13	0.66	1.40	1.03			4
		25100	1.00	0.32	0.90	0.74			11
		29200	1.00	0.30	0.87	0.71			11
	3181.28	13000	1.13	0.66	1.40	1.03			4



ELEVENTH INTERNATIONAL CONFERENCE ON SPECTRAL LINE SHAPES

CARRY LE ROUET (FRANCE)

June 8-12 1992

SCIENTIFIC PROGRAM AND ABSTRACTS

Stark Broadening of C IV Lines of Large Principal Quantum Number: Regularities Within Spectral Series

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1 Introduction

We have calculated recently, Stark broadening data for 39 C IV multiplets[1,2]. Our tables however are not sufficiently complete for the investigation of[3,4] PG 1159 stars . The PG 1159 stars are hot hydrogen deficient pre–white dwarfs with effective temperature 100,000 – 140,000K and carbon and helium as the dominant constituents (C/He= 0.5)[4]. Due to the high surface gravity (log g= 7) Stark broadening is an important line broadening mechanism and Stark broadening data are needed for NLTE model atmosphere analysis[4] and other stellar plasma investigations. Moreover, Stark broadening data in far and extreme ultraviolet, for lines originating from transitions between energy levels with large principal quantum number and low lying levels will become important for astrophysics in the near future due to the Extreme Ultraviolet Explorer (EUVE) and the Far Ultraviolet Spectroscopy Explorer (FUSE) missions.

Here, we present and discuss the results for C IV multiplets of large principal quantum number, along with a discussion of the Stark broadening parameter regularities within spectral series .

2 Results and discussion

In order to provide the needed data for stellar plasma analysis, Stark broadening parameters for C IV[1,2] , Si IV, N V, O VI, Sc III and Ti IV lines (see Ref. 5 and Refs. therein), have been calculated recently, using the semiclassical – perturbation formalism.[6,7] In order to provide needed Stark broadening data for research of PG 1159 stars and for the analysis of results of EUVE and FUSE missions, we have calculated here, electron–, proton–, and ionized helium–impact line widths and shifts for 69 C IV multiplets of large principal quantum number, as functions of temperature and perturber density.

The obtained set of results has been used for the analysis of systematic trends in spectral series. In Figures 1–2, the electron full halfwidth and shift within $2p^2P^0 - ns^2S$ series are reported. By inspecting the energy separation between the upper level and the principal perturbings levels, we find that this separation decreases gradually within a spectral series. We obtain as a consequence, a gradual change of the Stark widths as in the case analysed in Ref. (1) when the upper level was a p level. In Figs 3 and 4 the case of C IV $np^2P^0 - 9s^2S$ transitions, i.e. the case when the upper level does not changes is presented. We can see that particularly in the case of shift the changes

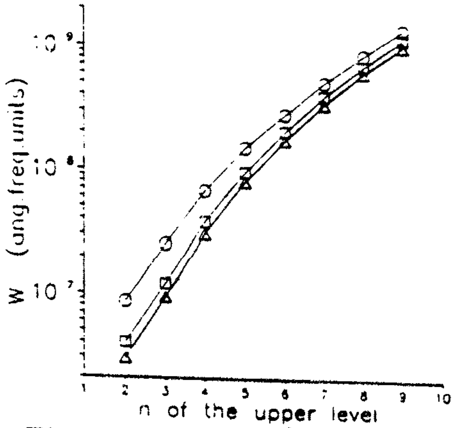

Fig. 1. Electron – impact full half widths (in angular frequency units) for the C IV $2p^2P^0 - ns^2S$ lines as a function of n for T = 20,000 K (○); 100,000 K (□) and 200,000 K (△) at N = 10^{13} cm^{-3}.

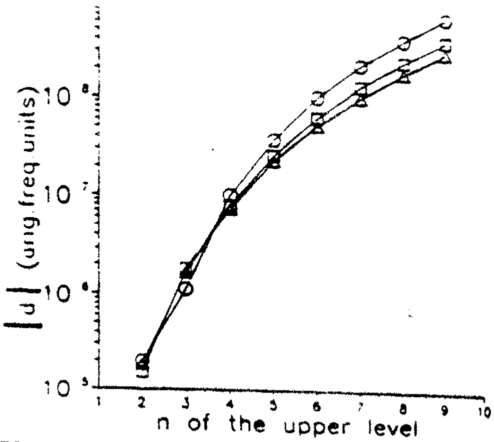

Fig. 2. As in Fig.1 but for the electron - impact shift.

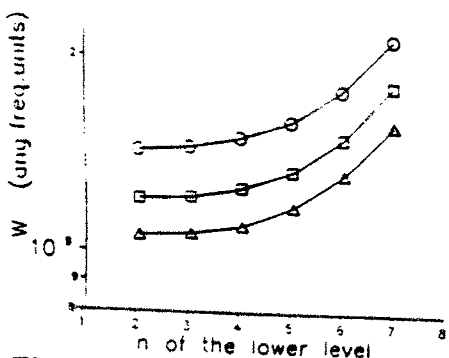

Fig. 3. As in Fig. 1. but for the C IV $np^2P^0 - 9s^2S$ electron– impact width.

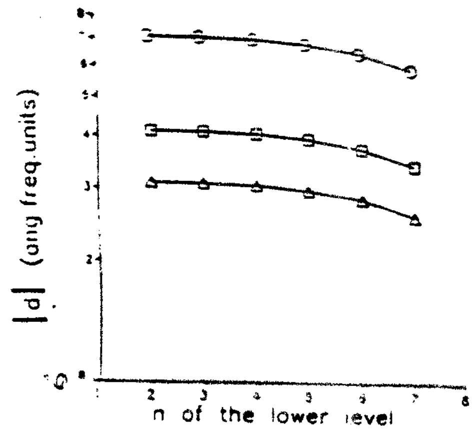

Fig. 4. As in Fig.1 but for the C IV $np^2P^0 - 9s^2S$ electron– impact shift.

of Stark broadening parameters are relatively small, permitting the interpolation of new data or critical evaluation of mutual consistency of existing data.

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ABSTRACT BOOK

12TH European Regional Astronomy Meeting of the International Astronomical Union (IAU)

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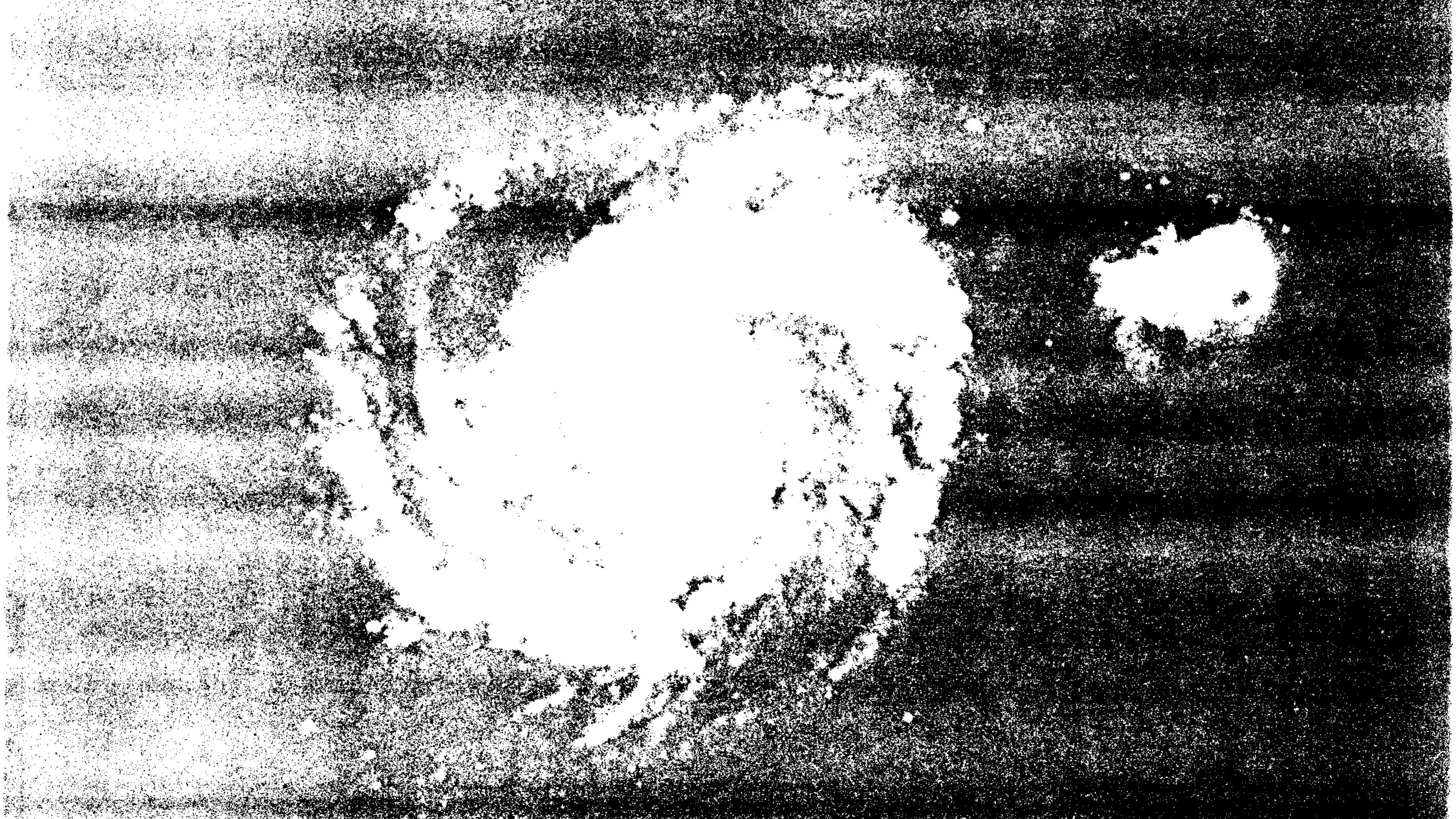

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INFLUENCE OF H - H^- COLLISIONS ON THE CONTINUUM ABSORPTION SPECTRA OF COOL STARS

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Recently[1], it has been shown that for the interpretation of continuum absorption spectra of A type stars the processes $H_2^+ + \hbar\omega \to H + H^+$ and $H + H^+ + \hbar\omega \to H + H^+$ must be considered together when their contribution is comparable. In the case of cooler stars H_2^- ion contribution is very important especially in the case of M-type stars. Consequently it is of interest to examine the simultaneous process:

$$\hbar\omega + H_2^- \to H + H^- \qquad (1a)$$

$$\hbar\omega + H + H^- \to \begin{cases} H + H^- \\ H^- + H \end{cases} \qquad (1b)$$

and to determine their relative contributions to the total absorption coefficient for processes 1a and 1b tohether.

Using the results of Refs. 1,2 appropriated for the case considered, spectral intensity of the continuum electromagnetic radiation caused by any of the processes $H_2^- + \hbar\omega \to H + H^-$ (a) and $H + H^- + \hbar\omega \to H + H^-$ (b), or total (b) is:

$$S_\omega^{(ab)}(T) = S_\omega^{(a)}(T) + S_\omega^{(b)}(T)$$

$$S_\omega^{(a)}(T) = S_\omega^{(ab)}(T)\gamma\left\{\frac{3}{2}, \frac{|U_g(R_\omega)|}{kT}\right\}/\Gamma(3/2) \qquad (2)$$

$$S_\omega^{(a)}(T) = S_\omega^{(ab)}(T)\Gamma\left\{\frac{3}{2}, \frac{|U_g(R_\omega)|}{kT}\right\}/\Gamma(3/2)$$

where R_ω is determined from[2]:

$$\hbar\omega = U_u(R_\omega) - U_g(R_\omega), \qquad (3)$$

and $\Gamma(x)$, $\gamma(x,y)$ and $\Gamma(x,y)$ are complete and incomplete gamma functions. $U_u(R_\omega)$ and $U_g(R_\omega)$ are the corresponding energies of electron states Σ_u^+ and Σ_g^- in H_2^-, taken from Ref. 3.

In Ref. 1 it is shown that the relative contribution of e.g. the process 1b to the total absorption coefficient $K_\omega^{(ab)}(T)$ for both processes is:

$$X(b)(\omega,T) = K_\omega^{(b)}(T)/K_\omega^{(ab)}(T) = S_\omega^{(b)}(T)/S_\omega^{(ab)}(T). \quad (4)$$

Our results for λ = 10000 Å and for temperatures of interest for stellar atmospheres research are presented in Fig. 1. One can see that even at t = 2000 K the simultaneous treatment of both processes is important for the interpretation of stellar continuum absorption spectra.

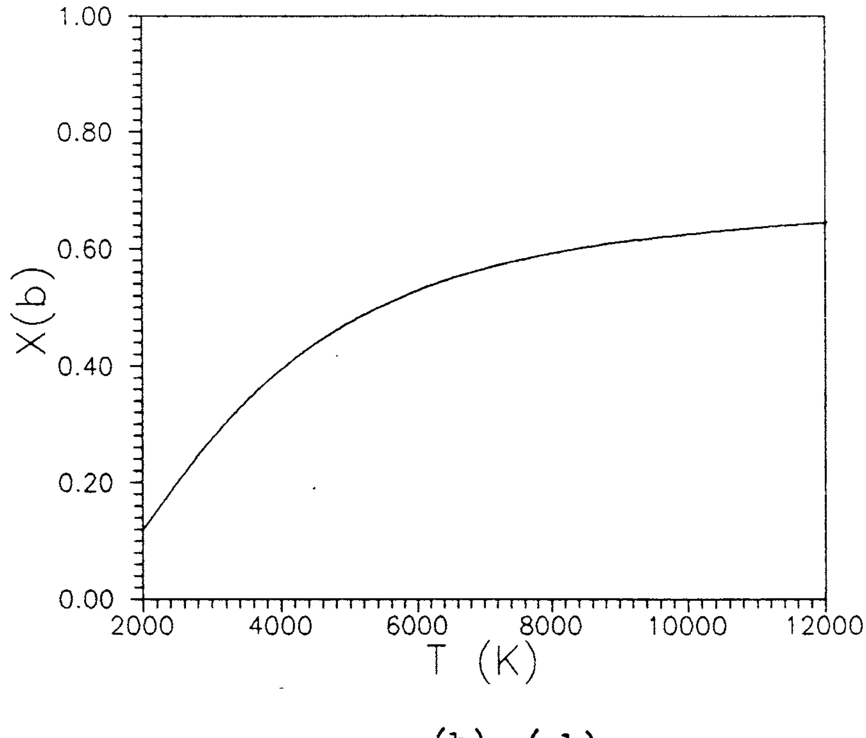

Fig. 1. The $X(b) = K_\omega^{(b)}/K_\omega^{(ab)}$ as a function of T.

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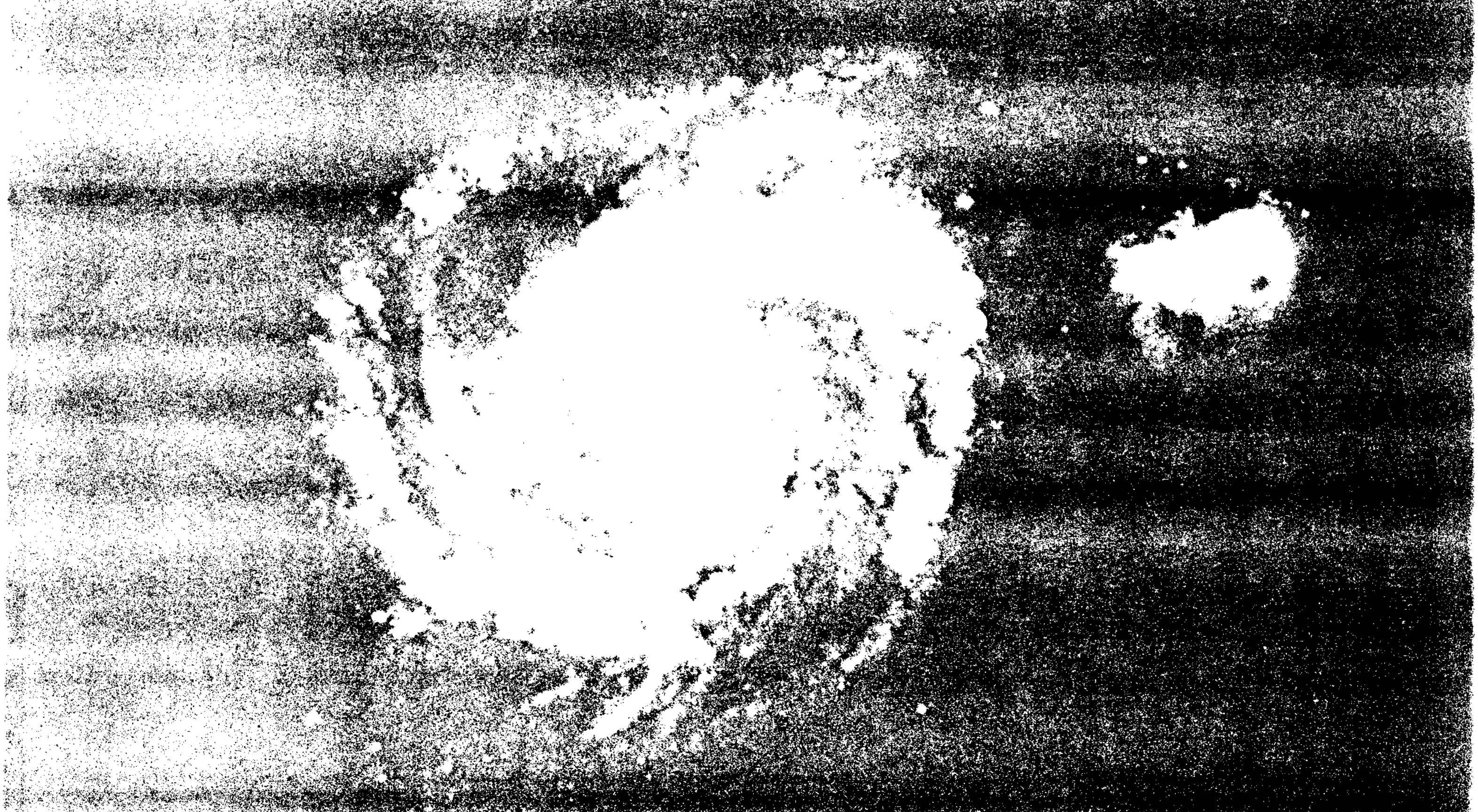

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PROFILES OF NEUTRAL LITHIUM LINES: BROADENING BY CHARGED PARTICLES

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Profiles of neutral lithium lines are of interest for astrophysicists since the surface content (abundance) of Li involve problems correlated with nucleogenesis and with mixing between atmosphere and interior (Boesgaard, 1988). They might be also of interest for the study of extremely strong Li I features observed in a number of C and S stars (Boesgaard, 1988) and for the investigations connected with the evidence of the deep Li depletions in the mid-F stars, first observed in the Hyades (Boesgaard and Tripico, 1986). Even for study of stars in the late stages of evolution the Stark broadening might be of interest since its influence increases with an increase in the principal quantum number (n) of the initial energy level (Vince, Dimitrijević, Kršljanin, 1985) because the bond between the optical electron and the core becomes weaker and the influence of external electric microfields increases.

Using semiclassical-perturbation formalism (Sahal-Bréchot, 1969a,b) and a Stark-broadening computer code derived from this method, we have calculated electron-, proton- and ionized helium-impact line widths and shifts for 61 neutral lithium multiplets as a function of temperature and perturber density. As a sample of results in Table 1 are presented Stark broadening parameters for the astrophysically most interesting 2s-2p line as well as for three other lines.

It is interesting also to investigate how the emission line widths change with the change of the principal quantum number of the final state. Our analysis shows that in the case of $ns^2S - 7p^2P^o$ lines, line width in angular frequency units is practically

Table 1. Stark widths (FWHM) and shifts for Li I multiplets.

PERTURBER DENSITY= 0.1D+14					
		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
2S - 2P	2500	0.230E-04	-0.588E-05	0.113E-04	-0.165E-05
6709.6 A	5000	0.234E-04	-0.691E-05	0.113E-04	-0.185E-05
C= 0.55D+20	10000	0.254E-04	-0.755E-05	0.113E-04	-0.208E-05
	20000	0.319E-04	-0.745E-05	0.113E-04	-0.233E-05
	30000	0.378E-04	-0.646E-05	0.113E-04	-0.249E-05
	40000	0.428E-04	-0.581E-05	0.113E-04	-0.262E-05
2S - 3P	2500	0.122E-03	0.859E-04	0.323E-04	0.272E-04
3233.6 A	5000	0.130E-03	0.741E-04	0.355E-04	0.306E-04
C= 0.37D+18	10000	0.140E-03	0.586E-04	0.392E-04	0.344E-04
	20000	0.142E-03	0.449E-04	0.435E-04	0.387E-04
	30000	0.142E-03	0.360E-04	0.463E-04	0.414E-04
	40000	0.141E-03	0.299E-04	0.484E-04	0.434E-04
2S - 4P	2500	0.399E-03	0.268E-03	0.101E-03	0.885E-04
2742.0 A	5000	0.420E-03	0.218E-03	0.112E-03	0.100E-03
C= 0.12D+18	10000	0.444E-03	0.171E-03	0.125E-03	0.113E-03
	20000	0.441E-03	0.122E-03	0.139E-03	0.127E-03
	30000	0.435E-03	0.937E-04	0.149E-03	0.136E-03
	40000	0.429E-03	0.747E-04	0.156E-03	0.143E-03
2S - 5P	2500	0.103E-02	0.661E-03	0.263E-03	0.230E-03
2563.1 A	5000	0.109E-02	0.499E-03	0.292E-03	0.262E-03
C= 0.52D+17	10000	0.114E-02	0.399E-03	0.326E-03	0.296E-03
	20000	0.111E-02	0.252E-03	0.365E-03	0.334E-03
	30000	0.109E-02	0.184E-03	0.390E-03	0.358E-03
	40000	0.107E-02	0.139E-03	0.409E-03	0.376E-03

the same for all members. This is the consequence of the much smaller importance of the lower level broadening contribution. This might be of interest in astrophysics and for quick estimates. In such cases the only difference is due to the difference in the wavelengths and we can scale from one available result other series members.

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ABSTRACTS

OF

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Department of Physics

University of Toronto

Toronto, Canada

TEMPERATURE DEPENDENCE OF THE TRIPLY IONIZED OXYGEN STARK WIDTHS

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INTRODUCTION

Broadening and shift of spectral lines in plasmas are subject of numerous experimental studies. Unfortunately, most of the reported data are from the measurements at a single electron temperature or in the best case the results are taken in a small temperature range. Tne lack of the experimental data in a wider temperature range makes a detailed test of the Stark broadening theoretical calculations unreliable. Furthermore, without the knowledge of the line width and shift dependence upon electron temperature comparison of the experimental results obtained at different plasma conditions becomes very difficult.

The aim of this paper is to supply the experimental and theoretical data for the widths of the prominent triply ionized oxygen lines in a large electron temperature range. The reported experimental results together with other experimental data will be used for the testing of various theoretical calculations.

THEORY

By using the semiclassical-perturbation formalism[1] we have calculated electron-, proton-, and ionized helium-impact line widths for O IV $3s^2S$-$3p^2P^0$ and $3p^2P^0$-$3d^2D$ multiplets and the results are given in Table 1.

TABLE 1.

		PERTURBER		
		Electrons	Protons	Ionized He
Transition	T [K]	Width [A]	Width [A]	Width [A]
3s-3p	40000	1.100e-01	2.380e-02	3.250e-03
3066.4 [A]	70000	8.560e-02	3.660e-03	4.420e-03
c=0.28e21	100000	7.410e-02	4.440e-03	5.200e-03
	170000	6.100e-02	5.630e-03	5.880e-03
3p-3d	40000	1.170e-01	2.230e-03	3.080e-03
3410.9 [A]	70000	9.100e-02	3.620e-03	4.310e-03
c=0.34e21	100000	7.840e-02	4.410e-03	5.200e-03
	170000	6.420e-02	5.850e-03	6.050e-03

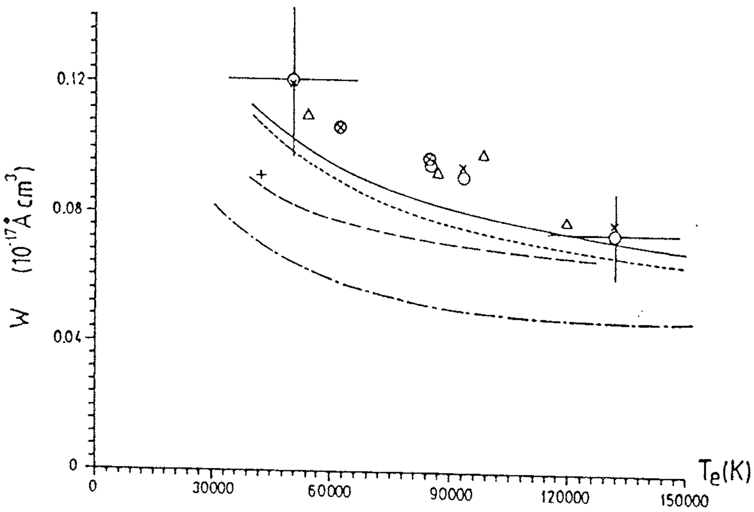

Fig 1. Full Stark widths (refered to an density of $10^{17}cm^{-3}$) for the O IV 3s-3p multiplet vs electron temperature. Theory: ___, semiclassical, electrons + He^{+} impact widths, ..., semiclasical, electrons only (see Table 1.), _. _, semiclassical aproximation[5,4], _._, modified semiempirical formula[5].

EXPERIMENT AND COMPARISONS

The Stark widths of the O IV lines belonging to the multiplets form Table 1 are measured in the plasma (initial gas mixture $He:O_2$=98.6:1.4) of a low preasure pulsed arc. Electron densities in the range $(2.1-6.4)\times10^{17}cm^{-3}$ were determined from the width of the He II P_α line while electron temperatures between 50800 and 131800 K are measured from the Boltzman plot of O IV line intensities. Our experimental results for $3s^2S-3p^2P^0$ multiplet are compared in Fig.1 with other experiments[2,3] and our semiclassical results from Table 1. For comparison other simplified theoretical approaches[4,5] are taken as well.

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INFLUENCE OF THE OSCILLATOR STRENGTHS ON THE STARK BROADENING OF Rb I LINES

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INTRODUCTION

Neutral Rubidium Stark-broadening parameters are of significance for laboratory plasma research [1] as well as for Solar and stellar spectroscopy, since Rb I lines have been observed in solar and stellar spectra[2]. By using the semiclassical-perturbation formalism[3,4], we have calculated electron-, proton-, and ionized argon-impact line widths and shifts for 24 Rb I multiplets. The obtained results for Stark broadening parameters will be published elsewhere[5]. Here, we will discuss the results for Rb I, along with a comparison with experimental data and other theoretical results. We will discuss moreover, the influence of the oscillator strength (**f**) values on the obtained results.

RESULTS AND DISCUSSION

In Table I, the present results with Ar II -impact contribution included, are compared with experimental data[1]. In all cases we added to Stark broadening parameters due to electron-impacts, our results for Ar II - impact broadening. We see that the agreement between experimental and theoretical values is particularly good for shifts.

In order to see the influence of oscillator strength values on the results, calculations have been repeated with oscillator strengths calculated by using relativistic single- configuration Hartree-Fock method with allowance for core polarization, which have been taken from Table IV (values denoted as RHF+CP) in Ref. 6, and with oscillator strengths from Ref. 7, where allowance for configuration mixing and for spin-orbit interaction has been made. Different availlable results for the needed oscillator strengths are compared in Table IV of Ref. 5. One can see that the most important difference is for 5p-5d transition where with the Bates and Damgaard method the value of 0.731 have been obtained while in Refs. 6 (Table IV, values under RHF+CP) and 7 we have 0.0396 and 0.0265 respectively. In Ref. 8, several effective single-, and multiple-parameter model potentials have been compared, and for the critical 5p-5d transition the corresponding **f**-value varies between 0.0396 and 0.360. In Ref. 8

authors concluded that there is no significant improvement in computed oscillator strengths and sometimes even deterioration of accuracy is observed for more sophysticated calculations. We can see in Table I that the best agreement with experimental data is for oscillator strengths obtained within the Coulomb approximation, while in the case of more sophysticated f-values even the sign of shift is different from the experimental one. This is maybe a consequence of the fact that within the Coulomb approximation we have a summation over the complete and consistent set of atomic data. If we use better oscillator strength values for particular transition, the final result is not always better since this consistency might be disturbed if we use a mix of values from different sources.

Table I Comparison between the experimental Stark full half-widths (W) and shifts (d) of Rb I lines within the $5s^2S - 5p^2P^o$ multiplet with different calculations. The meaning of indexes is : m experimental values of Purić et al (1977)/1/; DSB-present results; fMB-present results with the oscillator strengths taken from table IV (values denoted as RHF+CP) in Ref.6; fW-present results with oscillator strengths taken from Ref.7. The electron density N is equal to $10^{17}cm^{-3}$.

λ (Å)	T (K)	Wm (Å)	WDSB (Å)	WfMB (Å)	WfW (Å)	dm (Å)	dDSB (Å)	dfMB (Å)	dfW (Å)
7800.2	15000	1.66	1.31	1.09	1.08	0.52	0.59	-0.31	-0.23
	17500	1.70	1.35	1.13	1.13	0.50	0.57	-0.32	-0.25
	20800	1.76	1.42	1.18	1.18	0.47	0.54	-0.34	-0.26
	26000	1.92	1.51	1.25	1.26	0.51	0.50	-0.35	-0.28
7947.6	15000	1.82	1.31	1.09	1.08	0.55	0.59	-0.31	-0.23
	17500	1.92	1.35	1.13	1.13	0.53	0.57	-0.32	-0.25
	20800	2.00	1.42	1.18	1.18	0.50	0.54	-0.34	-0.26
	26000	2.20	1.51	1.25	1.26	0.45	0.50	-0.35	-0.28

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Contributed Papers
Part I

PHENOMENA IN IONIZED GASES 1977

XIII INTERNATIONAL CONFERENCE ON PHENOMENA IN IONIZED GASES
XIII ICPIG
DDR BERLIN 1977

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CURVILINEAR TRAJECTORIES AND STARK BROADENING OF HYDROGEN LINES

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Recently we have investigated influence of noncoulombic long range potentials on the broadening of neutral lines of plasma for nonhydrogenic emitters,/1/,/2/. In this contribution we present some results for several hydrogen lines, obtained by taking into account permanent dipole, quadrupole, and polarization potentials of the excited atom. This interaction makes the impact electron path deviate from the rectilinear one, in a similar manner as in case of charged emitters. We investigate influence of these deviations on line profiles in the far wings, within the Unified Theory of Greene et al. /3,a,b/.

The interaction potential between an excited hydrogen atom and a slowly moving electron can be represented in the asymptotic region by (atomic units are used throughout) :

$$V(r)=P/2r^2-Q/2r^3-\alpha/2r^4 \qquad (1)$$

where P is twice the permanent dipole of the atom: $P = 3n(n_2-n_1)$ in the presence of an external electric field, Q is the quadrupole moment and α is dipole polarizability, /4/; n,n_1,n_2 are parabolic quantum numbers.

Here we assume that the projections P and Q onto Z axis, which passes through the emitter and perturbing electron, remain constant during collision. This assumption should be a reasonable approximation for not too close collisions and not very fast impact electrons/2/.

As an illustration of the effect of an excited atom on the electron motion, several electron paths in the field of n=2 hydrogen states are plotted in Figure 1.

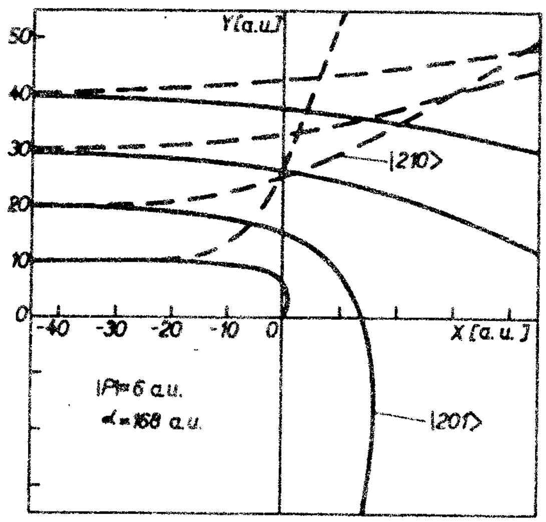

Figure 1. Electron trajectories in the hydrogen long range potential; ——— : P<0, - - - - : P>0. Electron velocity at infinity: k=0.187 a.u.; Q=0.

As can be seen in Figure 1, deviations from straight line paths are considerable for smaller impact parameters, for which strong collisions may take place.

In order to investigate possible effect on the line profile, we have carried out some calculations for a number of hydrogen lines. For this use has been made of the Unified Theory (classical paths) of Greene et al. /3,a,b/, (whose notation we are following closely), basically developed for hydrogenic ions. We modified their approach by substituting Coulomb interaction by V(r) from eq. (1). Special attention has been paid to the far wing region, where the asymptotic expansion should be valid. Relative deviation:

$$\Lambda_\alpha^{PQ} = (f(\Delta\omega)_A - f(\Delta\omega))/f(\Delta\omega)_A \qquad (2)$$

of the Fourier transform $f(\Delta\omega)$ of relevant thermal average function F(t), /3,b/ :

$$f(\Delta\omega)\underset{\Delta\omega\to\infty}{\sim}|\gamma|^{3/2}(e^{x^2}\mathrm{erfc}(x)+2x/\sqrt{\pi})/\Delta\omega^{5/2} \quad (3)$$

from asymptotic values has been calculated, with x given in our case by :

$$x^2=(-P\frac{\Delta\omega}{|\gamma|}+Q(\Delta\omega/|\gamma|)^{3/2}+\alpha(\Delta\omega/|\gamma|)^{3/2})/2kT \quad (4)$$

where $\Delta\omega$ is separation from the line centre and

$$|\gamma| = ((P)_{up}-(P)_{low})/2 \quad (5)$$

Numerical results for H_{11} line are presented in Figure 2. Two Δ_α^{PQ} elements are plotted only, the other two, differing from them in P parameter, being very close. As can be seen from Fig. 2, relative deviations amount up to approximately 17% in the outmost wing region.

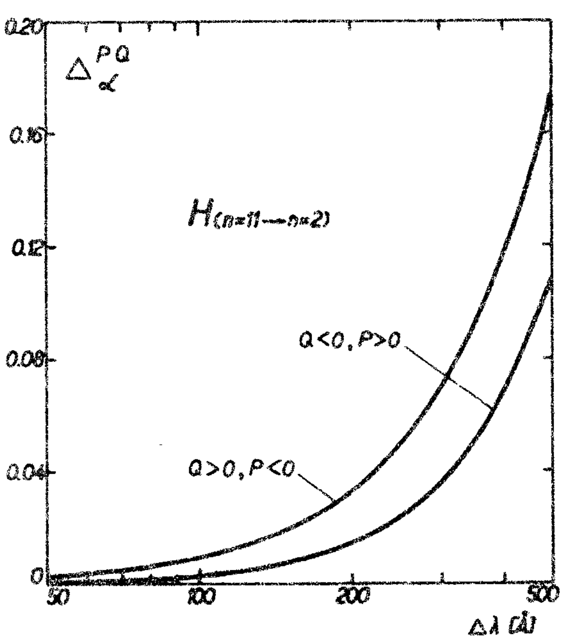

Figure 2. Relative deviations Δ_α^{PQ} for a specific term of n=11→n=2 hydrogen line.

Calculations have been carried out for several other lines as well :

L_α: $\Delta\lambda$=50 Å, |210>→|100>, Δ_α^{PQ} = 0.0013

L_δ: $\Delta\lambda$=30 Å, |510>→|100>, Δ_α^{PQ} = 0.0052

L_{11}: $\Delta\lambda$=25Å, |11 1 0>→|100|, Δ_α^{PQ} = 0.069

L_δ: $\Delta\lambda$=300Å, |501>→|210>, Δ_α^{PQ} = 0.0021

|510>→|210>, Δ_α^{PQ} = 0.0042

where $\Delta\lambda$ is separation from line centre and atomic states are designated by $|nn_1n_2>$.

From these results one may conclude that the effect is most prominent at lines with high upper principal quantum numbers, but negligible for most intensive plasma lines. Of course, in case of ionized emitters this effect should be even less noticable, since it is Coulomb interaction which dominates electron-ion scattering.

The work has been supported by RZN of SR Serbia.

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CONSIGLIO NAZIONALE DELLE RICERCHE

13th International Conference on SPECTRAL LINE SHAPES

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BANCA TOSCANA

PLASMA BROADENING OF SPECTRAL LINES ALONG THE ISOELECTRONIC SEQUENCE OF BERYLLIUM

B.Blagojević*, M.V.Popović*, N.Konjević* and M.S.Dimitrijević**

The Stark width dependence of BII, CIII, NIV and OV $3s^3S-3p^3P^o$ transitions upon the ion emitter charge has been studied experimentally in the plasma of a low pressure pulsed arc and theoretically using the impact semiclassical method.

Plasma electron densities are determined from the width of the HeII P_α line while electron temperatures are measured from the relative line intensities. To estimate the influence of different ions to the width of investigated lines, evaluations of plasma composition data are performed and, in conjunction with our theoretical results, the contribution of ion broadening was estimated.

In the studied electron temperature range and within the estimated uncertainties the experimental Stark widths agree well with the results of our semiclassical electron impact widths. The only exception are BII lines where the experimental Stark widths agree better with modified semiempirical formula. For the conditions of the present experiment, estimated contribution of the ion broadening has never exceeded seven percents of the total width. So within the precision of this experiment it was not possible to detect its presence with certainty.

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BANCA TOSCANA

ON THE STARK BROADENING OF Mg II SPECTRAL LINES

M. S. Dimitrijević* and S.Sahal – Bréchot**

In order to provide the needed Stark broadening data, we have calculated within the semiclassical - perturbation formalism electron-, proton-, and ionized helium-impact line widths and shifts for 67 Mg II multiplets, as functions of perturber densities and temperatures. Here we discuss the obtained results, along with a comparison with experimental and other theoretical data.

It was concluded in Konjević *et al.* (1984), that the results of Goldbach et al. (1982) and Roberts and Barnard (1972), which adequately account for the critical factors, provide the most reliable data for the Mg II 3s - 3p resonance lines. These results are in accordance with the strong coupling quantum mechanical calculations (Bely and Griem, 1970; Barnes, 1971) and about two times smaller than results of full semiclassical calculations (present results and results from Jones *et al.* 1971). One should be noted that the semi - classical method gives often results of lower accuracy for resonance lines, especially for lower temperatures, since for the appropriate inclusion of the various short range effects, the full quantum mechanical approach is needed. For non - resonant lines there is much less data. which are additionaly of lower accuracy. Our results are in excellent agreement with experimental results of Chapelle and Sahal - Bréchot (1970) for Mg II 3d - 4f transition, which has the best accuracy for non - resonant lines according to Konjević *et al.*, (1984).

One can see that there are less experimental data for the shift and that they are of lower accuracy. It is difficult to make a final conclusion since even the sign of experimental shifts are different. A new high precision measurement would be very useful.

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BANCA TOSCANA

ON THE STARK BROADENING OF B III SPECTRAL LINES

MilanS.Dimitrijević* and Sylvie Sahal - Bréchot**

By using the semiclassical-perturbation formalism, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 27 B III multiplets, for perturber densities 10^{17} - $10^{21}cm^{-3}$ and temperatures T = 10,000 - 300,000K, in order to continue our research of multiply charged ion line Stark broadening parameters.

The unique experimental result convenient for comparison, are the Stark widths of two lines within the B III $2s^2S$ - $2p^2P^o$ multiplet, measured by Srećković *et al.* (1993) in a linear, low - pressure pulsed arc operating in O_2. They found a large disagreement between they Stark widths and results (Dimitrijević and Konjević, 1981), obtained within the modified semiempirical approach (Dimitrijević and Konjević 1980). For B III 2065.77 Å line, they found that the ratio of measured to theoretical Stark width is 7.8 and for 2067.23 Å line 6.7 for the temperature of 48000 K at an electron density of 2.55 x $10^{17}cm^{-3}$. Corresponding ratios with our results with ionized oxygen-impact broadening included, are 3.9 and 3.5 respectively, which is better but not satisfying.

We may compare available theoretical results for B III $2s^2S$ - $2p^2P^o$ multiplet for the temperature of 160000 K at an electron density of 1 x $10^{17}cm^{-3}$. Our full width at half maximum W = 0.0103 Å, and the agreement is closest with calculations of Dimitrijević and Konjević (1981) by using the symplified semiclassical approach of Griem (1974, Eq. 526), which obtained W = 0.00892 A. Within the modified semiempirical approach (Dimitrijević and Konjević 1980), same authors obtained W = 0.00449 Å, which is two times smaller. Within the close coupling quantum mechanical approach Seaton (1988) obtained W = 0.00602 Å, which is also in disagreement with experiment and our calculations. In order to clarify the situation, particularly since B III $2s^2S$ - $2p^2P_o$ multiplet is important for the consideration of Stark broadening parameters within the lithium isoelectronic sequence, we recomend a new experimental determination of Stark broadening parameters particularly for this multiplet.

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BANCA TOSCANA

STARK WIDTHS FOR Sc II, Y II and Zr II SPECTRAL LINES

L. Č. Popović* and M.S.Dimitrijević*

Spectral lines of Sc II, Y II and Zr II are present in spectra of hot stars, as e. g. in spectra of ϕ Her ($T_{ef} \approx 11500$ K, log$g$=3.5) and o And ($T_{ef} \approx 9500$ K,log$g$=3.5) (Adelman & Lanz 1987) as well as in other hot stars.

The electron impact broadening mechanism is the main pressure broadening mechanism in the hot star atmospheres ($T_{ef} \gtrapprox 10000$), and it is of interest especially for A type stars and white dwarfs.

We have calculated Stark widths for 18 transitions of Sc II, Y II and Zr II, which are needed for stellar atmospheres investigations, by using the modified semiempirical approach (Dimitrijević & Konjević 1980). Calculations were carried out for $ns - np$ transitions from 6 multiplets for each of considered ions. We have selected only such multiplets where it was possible to calculate Stark widths within the usual accuracy of the modified semiempirical approch, and where it is not possible to use more elaborate methods (as e.g. semiclasical one), due to the lack of atomic data.

In the case of these ions, there is not measured Stark broadening parameters, only the simple estimates of Lakićević (1983) based on regularities and systematic trends were published for Sc II ($a^3D - z^3F^0$) and Zr II ($a^4F - z^4G^0$). Comparison of our calculated Stark widths with the estimates given by Lakićević (1983) are shown bellow:

Transition	$(FWHM)_1$ this paper	$(FWHM)_2$ Lakićević (1983)	$(FWHM)_1/(FWHM)_2$
Sc II ($a^3D - z^3F^0$)	0.0107 nm	0.0091 nm	1.17
Zr II ($a^4F - z^4G^0$)	0.00761 nm	0.0084 nm	0.91

As one can see, our calculated Stark widths are in good agremeent with the simple estimates of Lakićević (1983).

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XIII NATIONAL CONFERENCE OF YUGOSLAV ASTRONOMERS

Belgrade, 17 – 20 October 2002

ABSTRACTS

AN INTERACTIVE SPECTRUM SYNTHESIZER (ISS)

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We are developing an application for graphical comparison of observed and synthetic spectra (ISS). Synthetic spectrum calculation is done by SPECTRUM. Stellar Spectral Synthesis Program by Richard O. Gray. This program computes line profiles under LTE condition in the given wavelength interval using a stellar (solar) atmosphere model. a spectral line data list (wavelength. energy levels. oscillator strengths. and damping constants). a file that contains data for atoms and molecules. as well as a data file for hydrogen line profiles calculation. ISS offers a simple interface for viewing and changing any atomic parameter SPECTRUM used for line profile calculation. enabling quick comparison of the new synthetic line profile against the observed one. This way parameters like oscillator strengths and van der Walls damping constants can be improved. achieving a better agreement with the observed spectrum.

TRANSITION PROBABILITIES IN Kr III SPECTRUM, OF INTEREST FOR HIGH RESOLUTION STELLAR SPECTRA ANALYSIS

Stevan Đeniže[1], Vladimir Milosavljević[1] and Milan S. Dimitrijević[2]

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On basis of the relative line intensity ratio (RLIR) method transition probability values of the spontaneous emission (Einstein's A values) of 10 transitions in doubly (Kr III) ionized krypton spectra have been obtained relative to the reference A value related to the 324.569 nm Kr III. most intensive transition in the Kr III spectra. Our Kr III transition probability values are the first data obtained experimentally using the RLIR method. Mentioned A values have been calculated also using the Coulomb approximation (CA) method taking into account new atomic data for Kr III energy levels. The linear. low pressure. pulsed arc operated in krypton discharge was used as an optically thin plasma source at 17 000 K electron temperature and 1.65 10^{23} m^{-3} electron density. Our experimental and calculated relative A values have been compared to the existing ones.

STARK SHIFTS IN THE S III SPECTRUM

Aleksandar Srećković, Stevan Đeniže and Srđan Bukvić

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The doubly ionized sulfur (S III) spectral lines play an important role in astrophysics. Thus, the knowledge of the Stark broadened and shifted S III line characteristics are necessary for various cosmic plasma modelling or diagnostic purpose. To the knowledge of the authors no experimental or theoretical Stark shifts (d) data of the S III lines exist. The aim of this paper is to present the first measured d values for six prominent S III spectral lines belonging to the 3d - 4p transition at 31 200 K electron temperature and 2.8410^{23} m $^{-3}$ electron density. The Stark shifts were measured in a SF_6 plasma created in the linear, low pressure, pulsed arc discharge.

DATABASE BELDATA, PRESENT STATE AND PLANS FOR FUTURE DEVELOPMENT

Milan S. Dimitrijević, Luka Č. Popović, Edi Bon, Vladimir Bajčeta, Predrag Jovanović and Nenad Milovanović

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The project of the realization of the database BELDATA includes creation and development of the database for: a) Stark broadening parameters obtained by the fellows of the group of Astrophysical spectroscopy; b) spectra of active galaxies; c) stellar catalogues observed and derived in Belgrade; d) abstracts of papers (and later full papers) appeared in publications of the Belgrade Astronomical Observatory.

The first phases of the design and elaboration of the astronomical database BELDATA are finished. Database serving as the web interface support has been designed and finished, as well as the web interface for data access and the corresponding search. Also is designed and elaborated database for Stark broadening parameters (line widths and shifts) obtained by using semiclassical perturbation formalism. Actually the database contains catalogues of data for Be I, Sr I, Be III, B III, O IV, P IV, C V, O V, P V, S V, Ne VIII, Ca IX, Ca X, Al XI, Si XI, Si XII, Si XIII. Relational databases have been realized by using MySQL server. Web interface has been realized in PHP, Java Script and HTML.

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ABSTRACTS

TRANSITION PROBABILITIES IN THE Kr II SPECTRUM

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Recent investigations of the Planetary Nebulae spectra (Dinerstein, 2001), demonstrated that krypton is one of the most abundant among elements with $Z > 32$, and with the development of space techniques, even trace elements in stellar spectra become of interest. On the basis of the relative line intensity ratio method, transition probability values of the spontaneous emission (Einstein's A values) of 14 transitions in the singly (Kr II) ionized krypton spectra have been obtained relative to the reference A values related to the 435.548 nm Kr II, the most intensive transition in the Kr II spectrum. The mentioned A values have been calculated also by using the Coulomb approximation method, taking into account the new atomic data for Kr II energy levels. The linear, low pressure pulsed arc operated in krypton discharge was used as an optically thin plasma source at 17000 K electron temperature and 1.65 $10^{23}\mathrm{m}^{-3}$ electron density. Our experimental and calculated relative A values have been compared to the existing ones.

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STARK BROADENING OF NEUTRAL GERMANIUM SPECTRAL LINES IN ASTROPHYSICAL PLASMA

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The interest for atomic data on as much as possible larger number of emmiters/absorbers, increased considerably last years, since with space born spectrographs, one obtains stellar spectra with such resolution that a large number of different spectral lines may be indentified. As an example, in the spectrum of Przybylski's star Cowley et al. (2000) identified lines belonging to 75 various atom/ion species. Data on the Stark broadening of neutral germanium spectral lines is of interest for laboratory as well as for astrophysical plasma research as e.g. for germanium abundance determination. Consequently, Stark broadening of Ge I lines has been investigated several times experimentally and theoretically (see e.g. Sarandaev et al. 2000 and references therein). Here, we will calculate within the semiclassical perturbation approach, Stark broadening parameters of 5 Ge I multiplets within the $4s^24p^2$ - $4s^24p5s$ transition array, for conditions typical for astrophysical plasma. The obtained results will be compared with available experimental and theoretical values.

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ABSTRACTS

INFLUENCE OF STARK BROADENING WITHIN Be III SPECTRAL SERIES

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Spectral lines of light elements are present in stellar atmospheres and the study of their profiles is of interest for stellar atmospheres research. Stark broadening parameters for 12 Be III multiplets of interest for stellar plasma research, have been published in Dimitrijević and Sahal-Bréchot (1996). Recently, the spectrum of Be III has been reexamined (Jupen et al. 2001), and the data for new atomic energy levels enable the determination of Stark broadening parameter for additional transitions. In this contribution, Stark broadening parameters of 52 additional Be III multiplets have been determined within the semiclassical perturbation approach. The obtained results have been used to study regularities and systematic trends within spectral series, in order to establish possibilities for interpolation of new data, and for critical evaluation of existing experimental and theoretical results.

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STARK BROADENING OF F III LINES IN STELLAR PLASMA

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With the development of space technology and satellite born astronomical instruments, astrophysical interest for data on trace elements increases. Here, we investigate the Stark broadening in F III spectrum for stellar atmospheres plasma conditions. By using the modified semiempirical approach (Dimitrijević and Konjević, 1980), Strak broadening data for 9 F III multiplets have been calculated. Moreover, for the F III $2s^2 2p^3\ ^4S^o$ - $3s^4P$ resonant transition, calculations have been performed within the semiclassical perturbation approach. The obtained results have been used also for the investigation of the influence of Stark broadening effect on F III lines in stellar atmospheres.

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TRAJECTORY EFFECTS ON THE PHASE SHIFT IN THE IMPACT APPROXIMATION

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Basic assumptions: We consider the semiclassical phase shift in spectral line during atom-perturber collision in plasma following the assumptions: (*i*) trajectory of perturber is specified in the classical path approximation ; collisions are (*ii*) binary, and (*iii*) adiabatic; (*iv*) the impact parameter ρ is much larger than size of a target; (*v*) shift of the atomic energy (or the line frequency) follows the routine power law. We do not use the rectilinear-trajectory hypothesis, but we take into account effects of curvilinearity of the perturber trajectory as a result of the back reaction in the field of a net charge induced in the perturbered (macroscopically neutral) particle.

Formalism: For our purposes we explicitly distinguish expressions for electrostatic potential interactions V and the corresponding shift $\triangle E$ of the atomic energy states, vs. distance R:

$$V_l(R) = C_l R^{-l}, \qquad \triangle E(R) = C_n R^{-n}. \tag{1}$$

Following the above assumptions, phase shift induced in the perturbed atom during history of the collision is given by [1]

$$\eta_{n,l}(\rho) = \frac{2C_n}{v} \int_{R_{max}}^{\infty} \frac{R\,dR}{R^n \sqrt{R^2(1 - V_l(R)/E) - \rho^2}} \tag{2}$$

in conventional designations. If $C_l = 0$, then Eq. (2) reduces to the ordinary rectilinear result[2], being $\eta_n^0(\rho)$.

Impact of the trajectory effects on the phase shift and on broadening of neutral atom lines has recently been considered by Dimitrijević [3,4] (see therein for further references), under the particular condition $n = l$ for $n = 2, 3,$ and4. In general $l \neq n$, and the phase shift depends on two numbers (n, l), and not on one of them (n) only. We consider cases when both, one, or none of the interacting particles are charged macroscopically or have permanent dipole moment.

Intermolecular potentials and corresponding shifts ΔE: Survey of the (n,l) combinations of physical interest for weak interactions [1,6–7].

n:l	interaction	solution - ref.	n:l	interaction	solution -ref.
2:3	q-pc	1	4:4	d-pc	3,4,1
2:4	d-pc	1	5:5	VdW, d-d	–
3:3	res, d-d	3,4	6:3	VdW, d-d	–
4:3	q-pc	–	6:6	VdW, d-d	–

Abbreviations: d – dipole, q – quadrupole, pc – point charge, res – resonance, VdW – Van der Waals.

Exemplary results: $n = 2,\ l = 3.$

$$\eta_{2,3}(\rho) = \frac{2C_2}{v}\int_{x_1}^{\infty}\frac{dx}{\sqrt{(x-x_1)(x-x_2)(x-x_3)x}} = \eta_2^0\frac{4\sqrt{3}F(\varphi,k)}{\pi\sqrt{\sqrt{3}\sin 2\xi + 3\cos 2\xi}}, \quad (3)$$

where $F(\varphi,k)$ is the elliptic integral of the first kind,

$$x_1' = 2\cos\xi, \qquad x_2' = -(\cos\xi + \sqrt{3}\sin\xi),$$
$$x_3' = \sqrt{3}\sin\xi - \cos\xi, \qquad x_4' = 0,$$

$$x_i' = x_i/(\rho/\sqrt{3}), \qquad i = 1,\ldots,4,$$
$$\xi = (\arccos\delta)/3, \qquad \delta = C_3/\left[2E(\rho/\sqrt{3})^3\right]. \quad (4)$$

When $C_3 > 0$ (repulsive forces), $x_2 < x_3 < x_4 < x_1$,

$$\varphi = \arcsin\left[x_2/(x_2 - x_1)\right],$$
$$k^2 = \left[(x_1 - x_2)x_3\right]/\left[(x_1 - x_3)x_2\right]. \quad (5)$$

When $C_3 < 0$ (attractive forces), $x_2 < x_4 < x_3 < x_1$,

$$\varphi = \arcsin\left[(x_2 - x_3)/(x_2 - x_1)\right],$$
$$k^2 = \left[(x_1 - x_2)x_3\right]/\left[(x_3 - x_2)x_1\right]. \quad (5')$$

At the limit of $\delta \to 0$ we have $\eta_{2,3} \to \eta_2^0$. Run of the ratio $\eta_{2,3}/\eta_2^0$ as a function of δ is illustrated in Fig. 1.

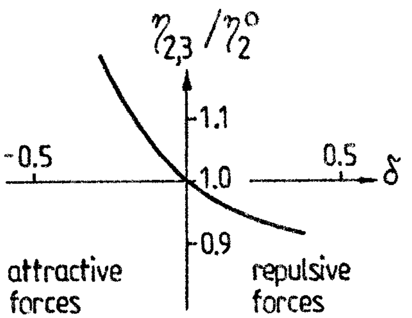

Fig. 1. $\eta_{2,3}/\eta_2^0$ as a function of the perturbation parameter δ.

$n = 2$, $l = 4$.

$$\eta_{2,4} = \frac{C_3}{v} \int_{R^2_{max}}^{\infty} \frac{dx}{\sqrt{(x - x_1)(x - x_2)x}} = \eta_2^0 \frac{2\rho}{\pi\sqrt{x_2}} K(k), \tag{6}$$

$$x_{1,2} = (\rho^2/2)\left[1 \mp (1 + \beta)^{1/2}\right],$$

$$\beta = 4C_4/(E\rho^4), \qquad k = (x_1/x_2)^{1/2}. \tag{7}$$

K(k) – the complete elliptic integral of the first kind. When $\beta \to 0$, $\eta_{2,4} \to \eta_2^0$.

$n = 6$, $l = 3$.

$$\eta_{6,3}(\rho) = \frac{2C_6}{v} \int_{x_1}^{\infty} \frac{dx}{x^4\sqrt{(x - x_1)(x - x_2)(x - x_3)x}}. \tag{8}$$

The quantities as in (4–5′) are relevant here. The final solution of Eq. (8) for $C_3 < 0$, as an example :

$$\eta_{6,3} = \frac{2C_6 g}{v x_3^4}\left[V_0 + 4\left(\frac{x_1}{x_3} - 1\right)V_1 + 6\left(\frac{x_1}{x_3}\right)^2\left(1 - \frac{x_3}{x_1}\right)^2 V_2 + \right.$$
$$\left. + 4\left(\frac{x_1}{x_3}\right)^3\left(1 - \frac{x_3}{x_1}\right)^3 V_3 + \left(\frac{x_1}{x_3}\right)^4\left(1 - \frac{x_3}{x_1}\right)^4 V_4\right], \tag{9}$$

$$
\begin{aligned}
V_0 &= K(k)\,, \\
V_1 &= \Pi(\pi/2, \alpha^2, k)\,, \\
V_2 &= \left[2(\alpha^2-1)(k^2-\alpha^2)\right]^{-1}\left[\alpha^2 E(k) + (k^2-\alpha^2)K(k) + \right. \\
&\qquad \left. + (2\alpha^2k^2 + 2\alpha^2 - \alpha^4 - 3k^2)\Pi(\pi/2,\alpha^2,k)\right]\,, \\
V_3 &= \left[4(1-\alpha^2)(k^2-\alpha^2)\right]^{-1}\left[k^2K(k) + 2(\alpha^2k^2+\alpha^2-3k^2)\Pi(\pi/2,\alpha^2,k) + \right. \\
&\qquad \left. + 3(\alpha^4 - 2\alpha^2k^2 - 2\alpha^2 + 3k^2)V_2\right]\,, \qquad (10) \\
V_4 &= \left[6(1-\alpha^2)(k^2-\alpha^2)\right]^{-1}\left[3k^2\Pi(\pi/2,\alpha^2,k) + 4(\alpha^2k^2+\alpha^2-3k^2)V_2 + \right. \\
&\qquad \left. + 5(\alpha^4 - 2\alpha^2k^2 - 2\alpha^2 + 3k^2)V_3\right]\,, \\
g &= 2/\sqrt{x_1(x_3-x_2)}\,, \\
\alpha^2 &= (x_1-x_2)/(x_3-x_2)\,, \\
&\alpha^2 \neq 1, \qquad k^2 \neq \alpha^2, \qquad x_3 \neq 0;
\end{aligned}
$$

$E(k), \Pi(\pi/2, \alpha^2, k)$ – complete elliptic integrals of the second and the third kind.

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ION LINE STARK BROADENING IN STELLAR PLASMAS

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In stellar atmospheres calculations the collisional broadening parameters for a large number of lines of various elements are required and they are frequently unavailable. Moreover, in O and B stars and white dwarfs atmospheres the Stark effect is the main pressure broadening mechanism. Even in atmospheres of relatively cool stars as the Sun, where the line broadening caused by collisions with neutral perturbers in dominant, for higher number of spectral series the Stark effect may compete with neutral perturber interaction with emitter[1]. A convenient method for Stark broadening calculations in astrophysics in the cases when more sophysticated calculations are avoided (e.g. lack of atomic data, large scale calculations or rough estimates) is the modified semiempirical approach[2-5]. Tables of calculated Stark widths, of prominent lines of some doubly - and triply-charged ions are given in Ref.3. By inspecting these tables one can notice that for typical conditions in hot stars and white dwarfs atmospheres ($T \sim 10^4$K) the threshold value of the Gaunt factor may be often used in the modified semiempirical approach for most of intense lines in doubly - and triply-charged ion spectra. When such situation occurs the semiempirical method permits considerable simplification[6]. The aim of this paper is to obtain in analytical form the low temperature limit of modified semiempirical formulae[2,5] which can be useful for simple estimates of Stark broadening parameters of singly and multiply charged ion lines in plasmas.

According to the modified semiempirical method,[2-5] the half - halfwidth w and shift d (in angular frequency units) of spectral line broadened by the Stark effect may be expressed

$$w+id=N\frac{4\pi}{3}\frac{h^2}{m^2}\left(\frac{2m}{\pi kT}\right)^{1/2}\frac{\pi}{\sqrt{3}}\sum_{j=i,f}\{\vec{R}^2_{k,k+1}[\tilde{g}(x_{k,k+1})+$$

$$+i\varepsilon_j\tilde{g}_{sh}(x_{k,k+1})]+\vec{R}^2_{k,k-1}[\tilde{g}(x_{k,k-1})-i\varepsilon_j\tilde{g}_{sh}(x_{k,k-1})]\}+ \quad (1)$$

$$+\sum_{j'}(\vec{R}^2_{jj'})_{\Delta n\neq 0}[g(x_j)+i\varepsilon_j g_{sh}(x_j)]-2i\varepsilon_j[\sum_{\Delta E_{jj'}<0}(\vec{R}^2_{jj'})_{\Delta n\neq 0}g_{sh}(x_{jj'})]$$

Here, $k = \ell_j$, i and f denote the inital and final levels $\varepsilon_j = +1$ if $j = i$ and -1 if $j = f$. The sum of relevant matrix elements $\vec{R}^2_{jj'}$ for $\Delta n \neq 0$ is

$$\sum_{j'}(\vec{R}^2_{jj'})_{\Delta n\neq 0} \simeq \left(\frac{3n_j^*}{2Z}\right)^2\frac{1}{9}(n_j^{*2}+3\ell_j^2+3\ell_j+11) \quad (2)$$

and $R^2_{jj'} = \left(\frac{3n_j^{*2}}{2Z}\right)\frac{\ell_>}{2\ell+1}(n_\ell^2-\ell_>^2)\phi^2(n_{\ell-1},n_\ell,\ell)$

where n^* is the effective principal and ℓ the orbital quantum number and Z-1 the ionic charge, Gaunt factors g and g_{sh} are defined by Griem[6], $\tilde{g}$ in Ref.2 and $\tilde{g}_{sh}$ in Ref.5, $x_{jj'} = 3\,kT/2|\Delta E_{jj'}|$ and $x_j = 3kTn_j^{*3}/4Z^2E_H$ (E_H is the hydrogen ionization energy) while ϕ is the Bates and Damgaard factor.

For all cases when $3kT/2\Delta E_{jj'}\lesssim 2$ one can use the values $g = g_{sh} = 0.2$ and $\tilde{g} = \tilde{g}_{sh} = 0.9-1.1/Z$. Furthermore, one can put in Eqs.1 and 2 $\phi^2 = 1$ what is a reasonable assumption for $\Delta n = 0$ (see e.g. Ref.7, p.31) since the exact values of ϕ^2 usually range between 0.8 and 1. If one performs summation in Eq.(1) it is easy to obtain

$$w(\mathring{A})=0.2215\cdot 10^{-8}\frac{\lambda^2(cm)N(cm^{-3})}{T^{1/2}}\sum_{j=i,f}[(\vec{R}^2_{jj'}+\frac{\tilde{g}_{th}-g_{th}}{g_{th}}\cdot$$

$$\cdot\left(\frac{3n_j^*}{2Z}\right)^2(n_j^{*2}-\ell_j^2-\ell_j-1)] \quad (3)$$

Since the contribution to the total line width of transitions with $\Delta n \neq 0$ does not exceed 25%, and it is compensated by assuming $\phi^2 = 1$, we can neglect them and finally obtain

$$w(\mathring{A})=1.1076\cdot10^{-8}\ \frac{\lambda^2(cm)N(cm^{-3})}{T^{1/2}}(0.9-\frac{1.1}{Z})\sum_{j=i,f}(\frac{3n^*}{2Z})^2\cdot$$

$$\cdot(n_j^{*2}-\ell_j^2-\ell_j-1) \qquad (4)$$

With analogous simplifications for the shift from Eq.(1) one may obtain

$$d(\mathring{A})=1.1076\cdot10^{-8}\ \frac{\lambda^2(cm)N(cm^{-3})}{T^{1/2}}(0.9-\frac{1.1}{Z})\sum_{j=i,f}(\frac{3n_j^*}{2Z})^2\frac{\varepsilon_j}{2\ell_j+1}$$

$$\{(\ell_j+1)|n_j^{*2}-(\ell_j+1)^2|-\ell_j(n_j^{*2}-\ell_j^2)\} \qquad (5)$$

If all levels $\ell_{i,f}\pm1$ exist, an additional summation may be performed in Eq.(5) obtaining

$$d(\mathring{A})=1.1076\cdot10^{-8}\frac{\lambda^2(cm)N(cm^{-3})}{T^{1/2}}(0.9-\frac{1.1}{Z})\frac{9}{4Z^2}\sum_{j=i,f}\frac{n_j^{*2}\varepsilon_j}{2\ell_j+1}\cdot$$

$$\cdot(n_j^{*2}-3\ell_j^2-3\ell_j-1) \qquad (6)$$

In order to test the equations obtained for low temperature limit of modified semiempirical formula, we compared first the results from Eq.(4) with the results of comprehensive width calculations for doubly and triply ionized atoms[3] in which Eq.(1) is used. The discrepancy did not exceed ±30% in average. Furthermore, comparison is made between the line width results from Eq.(1) and (4) and experimental results from Tables 1 and 2 in Ref.2, in the cases when Eq.(4) may be applied. The average ratio of experimental and calculated values from Eqs.(1) and (4) are 1.01 and 1.04, respectively. In Table 1 are given the results obtained from Eqs.(1) and (4) together with the recently measured Starkwidths of analogous transitions of doubly ionized inert gases.[8]

On the basis of the results presented here, we believe that the simple formulae (4) and (5) should be adequate when astrophysicists require a large number of ion line widths due to Stark broadening, or when rapid estimates are required.

ION	WAVELENGTH (Å)	TEMP. (K)	FULL WIDTH IN Å AT $N=1\times10^{17}$ cm^{-3}		
			w_m	$w_{Eq.(1.)}$	$w_{LTLEq.(1)}$
NeIII	2677.90	34000	0.063	0.052	0.049
	2678.64	34000	0.063	0.052	0.049
ArIII	3509.33	27500	0.160	0.153	0.174
	3514.18	27500	0.148	0.153	0.174
KrIII	3564.23	26000	0.160	0.168	0.194
XeIII	3780.98	27000	0.222	0.235	0.267

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MODIFIED SEMIEMPIRICAL ESTIMATES OF ION LINES STARK SHIFTS: SPECTRA OF HOT DA WHITE DWARFS

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Introduction: In 1968 Griem suggested a simple semiempirical formula[1] very useful for calculation of the singly charged ion lines Stark broadening. This method has been modified recently in order to avoid an extensive set of input atomic data and appropriated also for multiply charged ion line widths[2,3].

In this paper we give modified semiempirical formula for calculation of ion line Stark shifts.[4] Using the formula obtained, the shift of Si III $3s3p\,^3P^O-3p^2\,^3P$ multiplet in the hot DA white dwarf atmospheres is estimated as well as the influence of pressure effects on the mass determination from the gravitational red shift.

Theory: In order to reduce the input set of atomic data we separated the transitions with $\Delta n=0$ introducing for them a different Gaunt factor. Transitions with $\Delta n\neq 0$ are summed separately. Shift (d) of a spectral line broadened by Stark effect now becomes

$$d = N\frac{4\pi}{3}\frac{\hbar^2}{m^2}\left(\frac{2m}{\pi kT}\right)^{1/2}\frac{\pi}{\sqrt{3}}\sum_{j=i,f}\Big\{\hat{R}^2_{k,k+1}\,\varepsilon_j\,\tilde{g}_{sh}(x_{k,k+1})-\hat{R}^2_{k,k-1}\,\varepsilon_j\,\tilde{g}_{sh}(x_{k,k-1})\; +$$

$$+\sum_{j'}\left(\hat{R}^2_{jj'}\right)_{\Delta n\neq 0}\varepsilon_j\,g_{sh}(x_j)-2\varepsilon_j\Big[\sum_{\Delta E_{jj'}<0}\left(\hat{R}^2_{jj'}\right)_{\Delta n\neq 0}g_{sh}(x_{jj'})\Big]\Big\} \qquad (1)$$

Here, $k=\ell_j$, i and f denote the initial and final levels, $\varepsilon_j=+1$ if j=i and -1 if j=f. The sum of relevant matrix elements $\hat{R}^2_{jj'}$ for $\Delta n\neq 0$ is

$$\sum_{j'} (\hat{R}^2_{jj'})_{\Delta n \neq 0} \approx \left(\frac{3n_j^*}{2Z}\right)^2 \frac{1}{9} (n_j^{*2} + 3l_j^2 + 3l_j + 11) \quad (2)$$

where n^* is the effective principal- and l orbital- quantum number and Z-1 is the ionic charge.

If there are perturbing levels with $|\Delta E_{jj'}| \ll |\Delta E_{n,n+1}|$, the contribution of each such level to the line shift should be calculated as

$$\delta_j = \pm \varepsilon_j (\hat{R}^2_{jj'}) \left[g_{sh}\left(\frac{3kT}{2\Delta E_{jj'}}\right) \mp g_{sh}\left(\frac{3kT}{2\Delta E_{n_j,n_j+1}}\right)\right] \quad (3)$$

where the lower sign corresponds to $\Delta E_{jj'} < 0$.

Gaunt factor g_{sh} for Z=2 is determined by Griem[1] and given in Ref.1. We determined Gaunt factors $\tilde{g}_{sh}$ (for $\Delta n=0$) presented in Table as a function of x. Here, $x_{jj'} = 3kT/2|\Delta E_{jj'}|$; $x_j = 3kT n_j^{*3}/4ZE_H$ where E_H is the hydrogen ionization energy.

x		1	2	3	5	10	30	100
$\tilde{g}_{sh}$	Z=2	0.35	0.40	0.47	0.58	0.70	0.82	0.87
	Z=3	0.53	0.54	0.57	0.62	0.70	0.82	0.87
	Z=4	0.62	0.62	0.63	0.65	0.70	0.82	0.87
	Z>4	0.88-1.1/Z+0.01x/Z ; x≤100						

When the nearest perturbing level is so far that $3kT/2|\Delta E_{jj'}| \lesssim 2$ is satisfied, Eq.(1) may be considerably simplified[5].

Application to hot DA white dwarfs spectra: Here, we present possible shifts of the lines of the Si III metastable-like (UV 4) $3s3p\,^3P^0 - 3p^2\,^3P$ multiplet (λ=129.89nm), one of the prominent features in UV spectra of hot stars, and often present in hot white dwarfs spectra[6,7], calculated according to the derived formula, and using the set of pure hydrogen model atmospheres of Wesemael et al.[8] All calculations were performed for the typical value of surface gravity of white dwarfs log g=8. The results are presented in Fig.1. The right ordinate axes shows the possible influence of pressure effects on

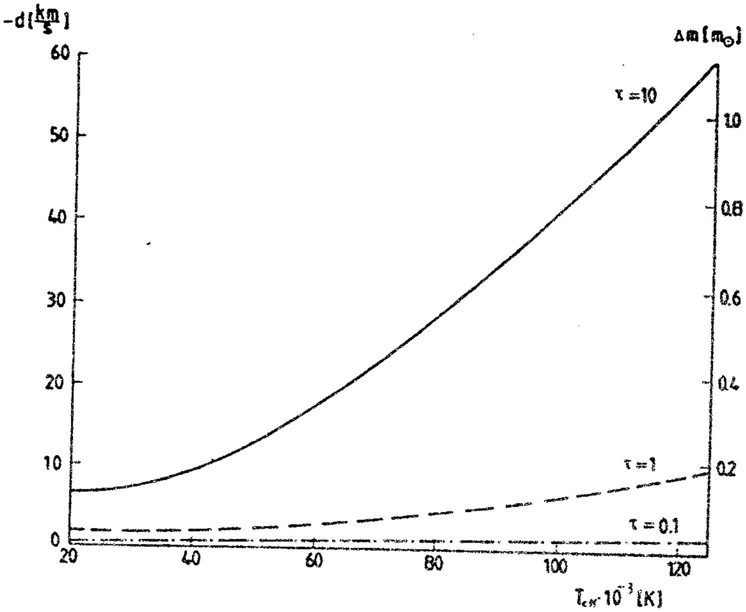

Fig.1. Shift (d) for Si III $3s3p^3P^O$-$3p^{23}P$ multiplet as a function of the effective temperature T_{eff} and the Rosseland optical depth τ .The right ordinate shows the influence of the shift on the hot DA white dwarf mass determination (Δm) in units of solar mass ($m_\odot$).

determination of the mass of a white dwarf (in units of solar mass) from gravitational red shift. (For these estimations we used the mean radius of DA white dwarfs R=0.012 in units of solar radius from Koester et al.[9] According to the same authors, the mean mass of the DA white dwarfs is 0.58 solar masses.)

One can conclude that lines examined are suitable for gravitational red shift measuring, if they are formed high enaugh in the white dwarf atmosphere. Besides, they can show significant asymetry. The blue shift of the lines suggests caution in measuring of mass-flow from the atmospheres of white dwarfs. In all cases mentioned, the Stark broadening parameters are necessary for accurate determinations.

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Друштво физичара Србије

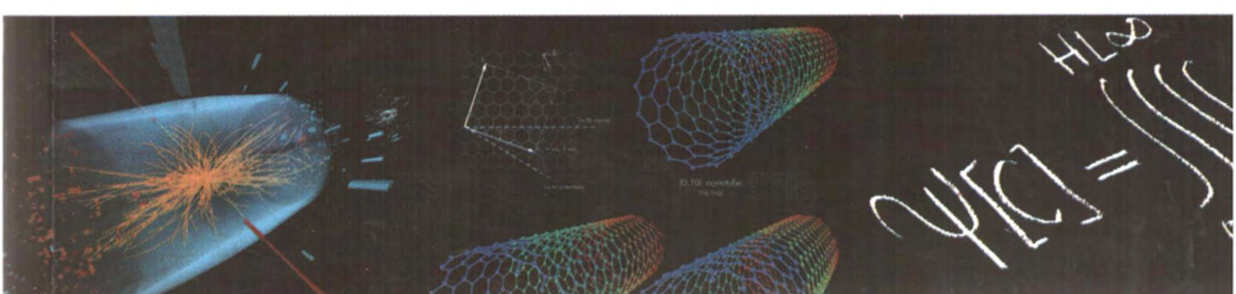
XII КОНГРЕС ФИЗИЧАРА СРБИЈЕ

28. април – 2. мај 2013, Врњачка Бања, Србија

ЗБОРНИК РАДОВА

Усмена предавања, предавања по секцијама, усмена и постер саопштења

Београд 2013.



СПЕКТРИ АКТИВНИХ ГАЛАКТИЧКИХ ЈЕЗГАРА: КИНЕМАТИЧКЕ ВЕЗЕ ИЗМЕЂУ ЕМИСИОНИХ РЕГИОНА

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Апстракт. Активна галактичка језгра (АГЈ) се могу посматрати у свега 5-10% галаксија у Васиони. Веома велика енергија коју израче ови објекти, која их чини видљивим и на великим космолошким растојањима, настаје услед процеса акреције материје у супермасивну црну рупу која се налази у центру. Спектри АГЈ су веома богати јаким емисионим линијама чији облици могу бити веома сложени, са израженим асиметријама, које представљају одраз физичких и кинематичких особина емисионих региона. У овом раду је проучавано око 300 спектара активних галактичких језгара. Анализом облика емисионих линија, као и тражењем веза између параметара линија, истраживане су кинематичке везе између различитих емисионих области.

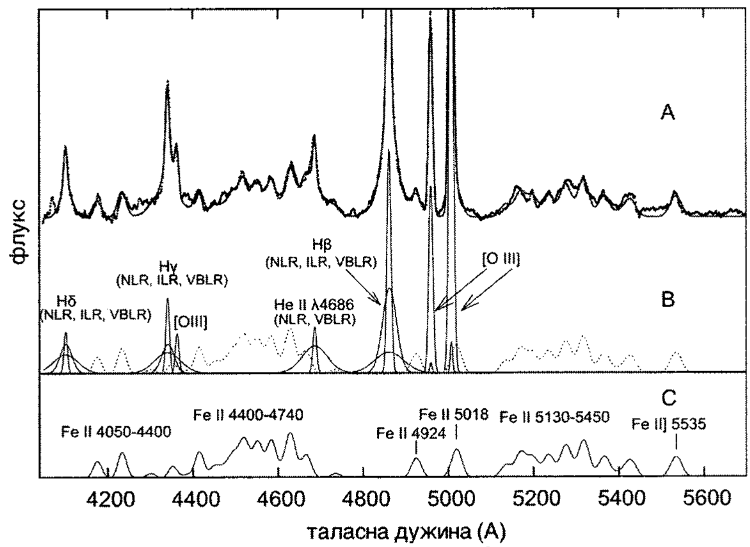
1. УВОД

Активна галактичка језгра (у даљем тексту АГЈ) која се могу посматрати у свега 5-10% галаксија у Васиони, карактерише изузетно висока луминозност, која може бити више хиљада пута већа од луминозности језгара нормалних галаксија. Претпоставља се да интензивно зрачење код АГЈ настаје из процеса акреције материје у супермасивну црну рупу која се налази у центру, при чему се ослобађа велика енергија. На акрециони диск, који окружује црну рупу, надовезује се фотојонизовани гас који се креће великим турбулентним брзинама (~5000 km/s) и чија је густина 10^8-10^{11} cm^{-3} (тзв. широколинијски регион). У овој области настају широке емисионе линије. Широколинијски регион је окружен торусом прашине на који се наставља тзв. усколинијски регион, који карактерише мања густина (10-10^3 cm^{-3}) и мање брзине турбулентног кретања гаса (~500 km/s). У овом региону настају уске емисионе линије. Концентрација у оба ова региона је одређена на основу присуства/одсуства забрањених и полузабрањених линија у спектру АГЈ, а температура је процењена на интервал 10000-25000 K. Приликом проласка енергије израчене из акреционог диска кроз гас који окружује црну рупу, настаје врло богат спектар АГЈ. За разлику од спектра обичних галаксија, који се састоји од мноштва танких апсорпционих линија које потичу са звезда које сачињавају ту галаксију, спектри АГЈ се одликују јаким зрачењем континуума на који су суперпониране врло уочљиве емисионе, широке и уске линије. Те линије доминирају спектром АГЈ и имају велике ширине, за које се сматра да су последица доплеровског ширења (турбулентно и ротационо кретање гаса), те се стога изражавају у km/s. Линије које настају у усколинијском региону имају просечне ширине ~500 km/s, док су ширине оних које настају у широколинијском региону ~5000 km/s. Осим турбулентног кретања гаса, као и оног услед ротације око црне рупе, често постоји и усмерено кретање гаса, које се осликава као померај ка плавом или ка црвеном линија или њихових компоненти. Емисионе линије у АГЈ често имају врло сложене облике (поготово широке линије), који представљају одраз кинематичких и физичких услова који владају у гасу који их емитује.

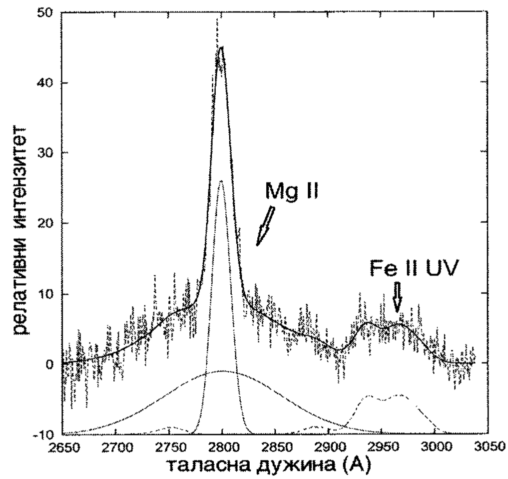
У овом раду су анализирани спектри 294 АГЈ у оптичком и ултраљубичастом домену, у циљу проучавања кретања емисионог гаса, и лоцирања појединих емисионих региона у структури АГЈ. Анализиране су ширине и помераји различитих линија, и њихових компоненти, које указују на кинематичке услове који владају у њиховим емисионим регионима. На тај начин, покушали смо утврдити на којем месту у сложеној структури АГЈ настају проучаване линије, са посебним освртом на линије оптичког и UV гвожђа, у вези којих постоји више отворених питања (види Kovačević et al. 2010).

2. УЗОРАК СПЕКТАРА И АНАЛИЗА

Узорак АГЈ спектара коришћен у овом истраживању је преузет са Sloan Digital Sky Survey (SDSS) базе (Data Release 7, Abazajian et al. 2009). Уз помоћ SQL (Structural Query Language) изабрани су спектри који одговарају потребама истраживања. Критеријуми за избор су били да спектри имају висок однос сигнала наспрам шума (С/Ш>25), да немају лоше пикселе, нити јаке апсорпционе линије које се преклапају са емисионим, да имају и уске и широке емисионе линије (АГЈ типа 1), јаке Hβ и Mg II, и да им је космолошки црвени помак у опсегу: $0.4< z <0.64$, како би биле обухваћене све емисионе линије од интереса за истраживење. Коначан узорак износи 294 АГЈ. Затим су спектри кориговани за Галактичко поцрвењење, космолошки црвени помак и одузета је емисија континуума (поступак описан у Kovačević et al. 2010). Спектри су фитовани χ^2 минимализационим поступком (Popović et al. 2004) у два опсега: λλ2650-3050 Å (линије UV Fe II, Mg II 2798 Å) и λλ4000-5500 Å ([O III] 4959, 5007 Å, Балмерове линије Hβ, Hγ и Hδ, и оптичке линије Fe II). Све емисионе линије су фитоване са Гаусијанима јер се претпоставља да Доплерово ширење доминира. За описивање сложених профила Балмерових линија, [O III] и Mg II, коришћено је више Гаусијана, јер се због сложеног облика ових линија претпоставља да њихови различити делови долазе из кинематички другачијих региона, што се осликава кроз различите ширине и помераје Гаусијана. Балмерове линије су фитоване са три Гаусијана: један уски, који представља емисију из усколинијског региона (NLR компонента, од енг. Narrow Line Region), и два широка који описују емисију из различитих слојева широколинијског региона (ILR компонента, од енг. Intermediate Line Region и VBLR од енг. Very Broad Line Region). ILR компонента описује језгро, а VBLR крила Балмерових линија (види Kovačević et al. 2010). Помераји и ширине за ове



СЛИКА 1. Пример фита у оптичком домену (4000-5600 Å): (А) посматрани спектар (тачке) и најбољи фит (пуна линија), (В) декомпозиција спектра на компоненте линија, (С) издвојен шаблон гвожђа.



СЛИКА 2. Пример фита у UV домену (2650-3050 A).

три компоненте су исти за све три проучаване Балмерове линије унутар истог спектра. Моштво линија Fe II, које формирају неправилне структуре у оптичком, као и UV домену, фитоване су шаблонима гвожђа, чија конструкција је детаљно описана у радовима: Popović et al. 2013, Shapovalova et al. 2012, Kovačević et al. 2010 (за шаблон оптичког гвожђа) и Popović et al. 2003 (за шаблон гвожђа у UV домену). Све линије оптичког Fe II имају исту ширину и померај, јер се претпоставља да долазе из истог емисионог региона. Исто важи и за линије гвожђа у UV домену. Пример фита АГЈ спектра у оптичком и UV домену приказан је на сликама 1 и 2.

3. РЕЗУЛТАТИ И ДИСКУСИЈА

Фитовањем узорка од 294 АГЈ спектра, добијени су подаци о ширинама и померајима разматраних емисионих линија и њихових компоненти. Испитано је постојање корелација између ових параметара, у циљу утврђивања кинематичких веза између емисионих региона, са посебним освртом на линије оптичког и UV гвожђа. Анализом корелација између Доплерових ширина разматраних емисионих линија и њихових компоненти (види Табелу 1), уочава се постојање корелације између ширина оптичког Fe II, UV Fe II, ширине компоненте која описује језгро Mg II и ILR компоненте Балмерових линија (која такође описује њихово језгро, види Слику 1).

ТАБЕЛА 1. Спирманови коефицијенти корелације између Доплерових ширина емисионих линија. NLR Бл, ILR Бл и VBLR Бл су компоненте Балмерових линија. Коефицијенти корелације са P<1E-10, су написани подебљаним словима.

	Fe II опт.	Fe II UV	NLR Бл	ILR Бл	VBLR Бл	Mg II јез.	Mg II крила
Fe II опт.	1	**0.39**	-0.24	**0.58**	0.19	**0.57**	**-0.37**
Fe II UV	**0.39**	1	-0.10	**0.39**	0.20	**0.49**	**-0.43**
NLR	-0.24	-0.10	1	0.01	-0.04	-0.18	0.10
ILR	**0.58**	**0.39**	0.01	1	**0.35**	**0.60**	-0.28
VBLR	0.19	0.20	-0.04	**0.35**	1	0.21	-0.11
Mg II језгро	**0.57**	**0.49**	-0.18	**0.60**	0.21	1	-0.30
Mg II крила	**-0.37**	**-0.43**	0.10	-0.28	-0.11	-0.30	1

Такође, средње ширине ових компоненти за дати узорак су приближно сличне, са мањим одступањем језгра Mg II (Fe II оптичко: 2340 km/s, UV Fe II: 2530 km/s, језгро Mg II: 1590 km/s и ILR Бл: 1930 km/s), док средње ширине уске компоненте – NLR Бл (308 km/s), и компоненте које описују крила Hβ (4370 km/s) и крила Mg II (7760 km/s), значајно одступају. Са друге стране, када се анализирају помераји датих линија, уочава се корелација између помераја језгра Mg II и ILR Бл (r=0.44), као и између језгра Mg II и UV Fe II (r=0.41).

Поменуте корелације указују на кинематичку повезаност емисионих региона у којима настају оптичке и UV Fe II линије, као и оних у којим настају језгра Mg II и Балмерових линија, што занчи да је место њиховог настанка вероватно спољашњи слој широколинијског региона (ILR), док крила Mg II и Балмерових линија вероватно настају у дубљим слојевима, ближе црној рупи. Даље истраживење је потребно како би се објасниле још неке уочене корелације попут негативне корелације између ширине крила Mg II линија и ширине оптичких и UV Fe II линија (види Табелу 1).

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Друштво физичара Србије

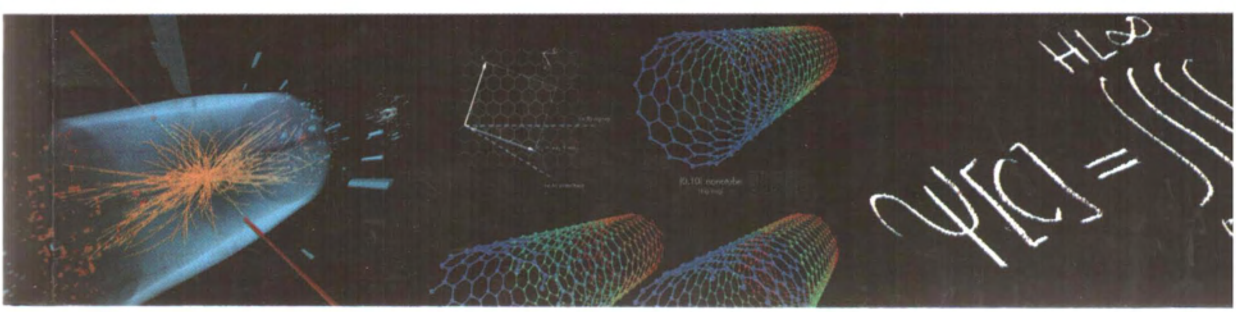
XII КОНГРЕС ФИЗИЧАРА СРБИЈЕ

28. април – 2. мај 2013, Врњачка Бања, Србија

ЗБОРНИК РАДОВА

Усмена предавања, предавања по секцијама, усмена и постер саопштења

Београд 2013.



ЕКСЦИТАЦИОНИ И ДЕЕКСЦИТАЦИОНИ ПРОЦЕСИ У АТОМ-RYDBERG АТОМ СУДАРИМА У АТМОСФЕРАМА БЕЛИХ ПАТУЉАКА БОГАТИМ ХЕЛИЈУМОМ

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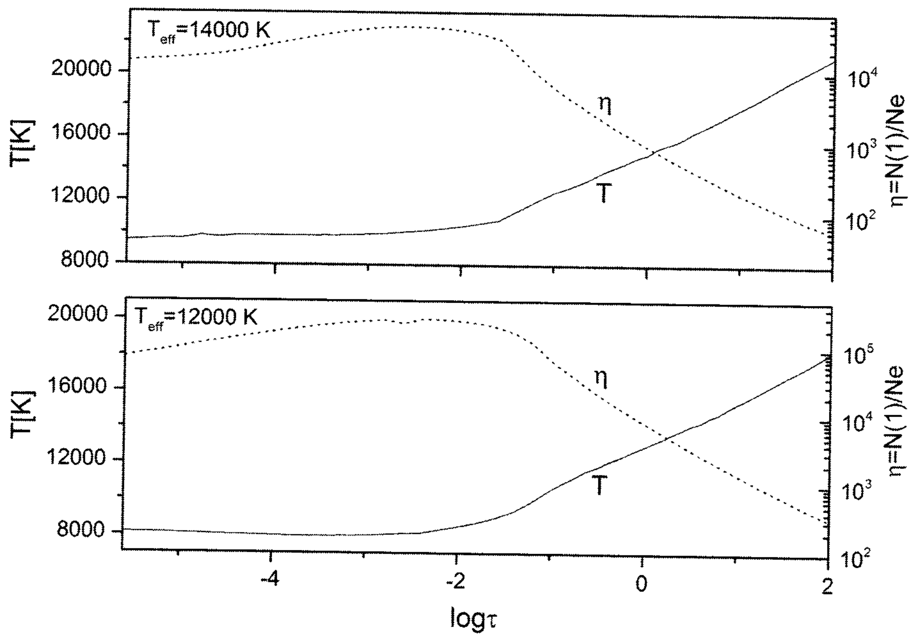
Апстракт. У овом раду циљ нам је да покажемо значај нееластичних ексцитационих и деекцитатионих процеса у $He^{*}(n)$ + $He(1s^{2})$ сударима са главним квантним бројем $n \geq 3$ за класу атмосфера белих патуљака богате хелијумом. Упоредићемо ефикасност ових процеса са познатим нееластичним електрон - $He^{*}(n)$ атом процесима у посматраним атмосферама. Показали смо да се у значајним деловима разматраних атмосфера, које садрже слабо јонизоване слојеве (степен јонизације $\leq 10^{-3}$), утицај испитиваних атома - Rydberg атом сударних процеса на популацију побуђених атома хелијума доминантан или бар упоредив са утицајем конкурентних електрон - $He^{*}(n)$ атом процеса.

1. УВОД

Овај рад је настак наших претходних истраживања нееластичних $A+A^{*}(n)$ атом-Rydberg атом сударних процеса (где је главни квантни број $n >> 1$ и A атом у основном стању), који могу утицати на популацију побуђених атома у различитим звезданим атмосферама. Разматрамо процесе који се могу интерпретирати као резултат резонантне размене енергије између дела система $A+A^{+}$, у којем је A^{+} кор Rydberg атома $A^{*}(n)$, и спољашњег електрона овог атома. Постоје две групе оваквих процеса. Прву групу представљају хеми-јонизациони процеси који повезују блок атомских Ридберг стања са континумом [1]. Другу групу представљају такозвани (n-n') mixing процеси т.ј. процеси ексцитације и деексцитације који доводе до прелаза између Rydberg стања са главним квантним бројевима n и $n' \neq n$ [2].

Хеми-јонизациони процеси при $A+A^{*}(n)$ сударима, заједно са својим инверзним процесима, су проучавани за случајеве A=H и A=He на примеру звезданих атмосфера. У радовима [3,4] проучаван је утицај ових процеса на популацију побуђених атома водоника и спектралних профила линија у атмосфери М црвених патуљака (T_{eff} = 3800K). У радовима [1,5] испитиван је потенцијални утицај ових процеса на популацију побуђих атома водоника и хелијума у атмосфери Сунца и неких ДБ белих патуљака.

Међутим, могућ утицај (n-n') mixing процеса у $A+A^{*}(n)$ сударима на популацију побуђених атома у звезданим атмосферама је само испитиван за случај A=H и то у контексту Сунчеве атмосфере [6]. Резултати ових истраживања су показала да је ефикасност ових процеса у већем делу Сунчевог фотосфере доминантна у односу на ефикасност релевантних конкурентних ексцитационих и деекцитатион процесима за n=4,5 и 6, и може се поредити са њима за n=7 и 8. Као природан наставак ових радова је истраживање (n-n') mixing процеса за случај класе атмосфера белих патуљака богате хелијумом.



СЛИКА 1. Параметри (температура T –пуна линија и η=N(1)/Ne -испрекидана) за моделе атмосфера ДБ белих патуљака са log g = 8 и T_{eff} = 12000 K и 14000 K у функцији log τ.

2. ТЕОРИЈСКИ МОДЕЛ

У овом раду, користећи моделе атмосфера из [7], ефикасности ексцитационих

$$He^*(n) + He = \begin{cases} He^*(n' = n+p) + He, & p \geq 1, \\ He + He^*(n' = n+p), & p \geq 1, \end{cases} \quad (1)$$

и инверзних процеса деекцитације

$$He^*(n) + He = \begin{cases} He^*(n' = n-p) + He, & 0 < p \leq n-3, \\ He + He^*(n' = n-p), & 0 < p \leq n-3, \end{cases} \quad (2)$$

(где су n+p и n-p главни квантни бројеви финалног Rydberg стања) су упоређени за $3 \leq n \leq 8$ са ефикасношћу релевантних конкурентних процеса. Овде, пре свега мислимо на добро познате електрон-побуђен-атом сударне ексцитационе тј. деексцитационе процесе

$$He^{*}(n)+\vec{e}=He^{*}(n\pm p)+\vec{e}'. \qquad (3)$$

Потребни прорачуни су извршени користећи моделе из [7] за атмосфере ДБ белих патуљака са log g = 8 и T_{eff} = 12000,14000 K. Процеси (1,2) се карактеришу ексцитационим и деекцитационим рејт коефицијентима $K_{n;n+p}(T)$ и $K_{n;n-p}(T)$. Сви потребни изрази су дати у [2,8]. Конкурентски електрон-Rydberg атом процеси (3) се описују коефицијентом $\alpha_{n;n\pm p}(T_e=T)$ са изразима датим у [9,10]. За процену релативне ефикасности процеса (1) и (2) и конкурентских процеса (3), довољно је испитати понашање величина $F_n^{(+)}$ и $F_n^{(-)}$ у разматраним атмосферама ДБ белих патуљака, који су дати изразима

$$F_n^{(+)}=\frac{\sum_{p=1}^{5}K_{n,n+p}\cdot N(n)\cdot N(1)}{\sum_{p=1}^{5}\alpha_{n,n+p}\cdot N(n)\cdot N_e}=\frac{\sum_{p=1}^{5}K_{n,n+p}}{\sum_{p=1}^{5}\alpha_{n,n+p}}\cdot\eta,\ \mathrm{n}\geq 3, \qquad (4)$$

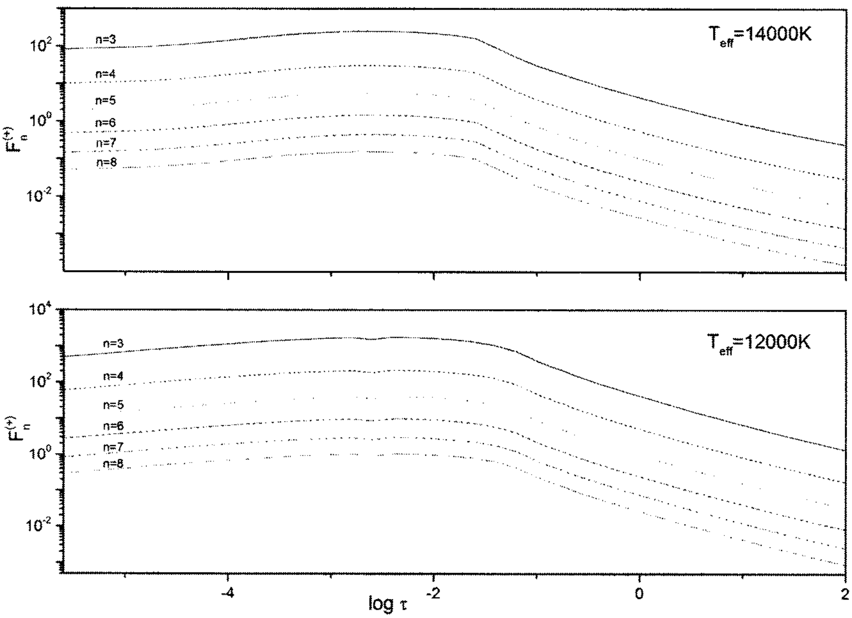
и

$$F_n^{(-)}=\frac{\sum_{p=1}^{n-3}K_{n,n-p}\cdot N(n)\cdot N(1)}{\sum_{p=1}^{n-3}\alpha_{n,n-p}\cdot N(n)\cdot N_e}=\frac{\sum_{p=1}^{n-3}K_{n,n+p}}{\sum_{p=1}^{n-3}\alpha_{n,n+p}}\cdot\eta,\ \mathrm{n}\geq 4, \qquad (5)$$

где су $N(n), N(1), N_e$ концентрације свих Rydberg атома хелијума у стањима са датим $n\geq 3$, конц. атома хелијума у основном стању и концентрације слободних електрона, респективно. Производи $K_{n,n-p}\cdot N(n)\cdot N(1)$ и $\alpha_{n,n-p}\cdot N(n)\cdot N_e$ су парцијални атом – и електрон Rydberg атом ексцитациони тј. деексцитациони флуксеви. Фактор $\eta\equiv N(1)/Ne\cong(\mathrm{stepen\ jonizacije})^{-1}$ и његово понашање у посматраним атмосферама ДБ белих патуљака је представљено на слици 1.

3. РЕЗУЛТАТИ И ДИСКУСИЈА

На Сл. 2. је приказано понашање величине $F_n^{(+)}$ са $3\leq n\leq 8$ за случај атмосфера ДБ белих патуљака описаним моделима из [7] за log g = 8 и T_{eff} = 12000 K и T_{eff} = 14000 K у функцији log τ (Rosseland optical depth). Слика недвосмислено показује, да се у случају атмосфера ДБ белих патуљака са T_{eff} = 14000 K, ексцитациони процеси (1) за 3 ≤ n ≤ 8 морају узети у обзир као нови важан фактор који утиче на популацију хелијум Rydberg атома. Слика 2 показује да је у деловима атмосфере где је степен јонизације $\leq 10^{-3}$, процеси (1) са n = 3,4 и 5 су доминантни у односу на процесе (3), а за n = 6 и 7 су доминантни у деловима где јонизација степен је $\leq 10^{-4}$, а у преосталим деловима њихова је ефикасност упоредива са ефикасношћу процеса (3). Чак ефикасност процеса (1) са n = 8 је у близини, или бар упоредива са, ефикасност процеса (3) у деловима где је степен јонизације $< 10^{-4}$. Истих закључци важе за величину $F_n^{(-)}$ за $4 \leq$ n $\leq$ 8. Дакле, следи да процесе (1) свим средствима треба узети у обзир у сваком будућем не-ЛТЕ моделу атмосфера ДБ белих патуљастих са сличним параметрима.



СЛИКА 2. Понашање величина $F_n^{(+)}$ за $3 \leq n \leq 8$, дате једначином (4).

ЗАХВАЛНИЦА

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I A U

U N E S C O

XI INTERNATIONAL SCHOOL FOR YOUNG ASTRONOMERS

SEPTEMBER 17 - OCTOBER 8, 1980, HVAR, SR CROATIA, YUGOSLAVIA

P R O G R A M

ZAGREB, JULY, 1980

LECTURE COURSES

Z.Ceplecha (Z.C.): "Interplanetary Matter"	10 hours
B.Cester (B.C): "Evolution of Binary Systems"	10 hours
M.Hack (M.H.) : "Spectroscopy"	6 hours
R.van Helden (R.v.H.) : "Practical Astronomy"	28 hours
C.de Jager (C.J.): "Astrophysics from Space"	8 hours
J.Kleczek (J.K.): "Solar Physics"	10 hours
E.Müller (E.M.): "Astronomical Spectroscopy"	10 hours
G.Munch (G.M.): "Planets and Satellites"	10 hours
P.Pismis (P.P.): "Galaxies"	4 hours
P.Pismis (P.P.): Interstellar Matter"	4 hours
C.Sanchez - Magro (S.M.): "Astronomical Technics"	14 hours
H.Schmidt (H.S.): "Cosmic Electrodynamics"	12 hours
V.Vujnović (V.V.): "Atomic Physics and Spectra Formation"	4 hours

SEMINARS

A.Cadež (A.Č.): "Black Holes"	2 hours
V.Čadež (V.Č.): "Solar Radio Bursts"	2 hours
M.Dimitrijević (M.D.): "Stark Broadening and its Astrophysical Applications"	3 hours
M.Vukičević-Karabin: "The Photospheric Velocity Fields and Relevant Effects	2 hours
G.Pichler (G.P.): "Quasistatic Line Wing and Collisional Redistribution of Radiation by Neutral particles"	3 hours
V.Ruždjak(V.R.): "Solar Granulation Metrology via Coherent Optical Fourier Analysis	2 hours

STARK BROADENING AND ITS ASTROPHYSICAL APPLICATIONS

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Spectral analysis of line and continuum radiation from cosmical plasmas is often the main source of information for an astronomer. Typical astrophysical problems for which an investigation of line shapes induced by interaction with particles and fields is important, are: diagnostic of cosmical plasmas, radiative transfer in the stelar plasma, determination of abundances of elements from profiles of absorption lines and investigation of radio recombination lines in ionized hydrogen regions.

In this lecture, various line broadening mechanisms and their astrophysical and practical implications will be discussed. Also, a review of modern theoretical methods for the calculation of Stark broadening parameters will be given, with an emphasis on approximative methods, useful for large scale calculations. Available experimental data obtained from laboratory plasmas, will be critically examinated.

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ENERGY DISTRIBUTION IN THE NEAR-THRESHOLD POSITRON IMPACT IONIZATION OF ATOMS

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The rapid development of the experimental technique and the resulting increase of the experimental data has greately stimulated theoretical investigations of the positron-atom collisions[1]. The expected positron (and electron) energy differential cross section is investigated in two papers[2,3]. Klar has shown that the energy distribution cross section is flat[2]. On the other hand, Dimitrijević and Grujić[3] have found by numerical calculations of the classical equation, an abrupt decrease in the energy distribution cross section for $\mathcal{E}_+/E \lesssim 0.65$ corresponding to the actual formation of the positronium. In this paper, we will examine the energy distribution function for several particularly choosen $\mathcal{E}_+, \mathcal{E}_-$ energies.

Let electron and positron recede from the residual ion of charge Z (atomic units are used throughout) along a common straight line, with distances from the ion: r_+, r_-. Corresponding Newton's equations are

$$\ddot{r}_+ = Z/r_+^2 - (r_+ - r_-)^{-2} \qquad (1)$$
$$\ddot{r}_- = -Z/r_-^2 + (r_+ - r_-)^{-2}$$

We may assume that for the given particle energies r_+ and r_- may be expressed as

$$r_+ = r + \nabla$$
$$r_- = \gamma^2 r - \frac{1}{\gamma}\nabla$$

Let at a particular moment be

$$\mathcal{E}_+ = \alpha E, \; \mathcal{E}_- = (1-\alpha)E, \; r_+ = r, \; r_- = \gamma^2 r$$
$$\mathcal{E}_+ = \frac{1}{2}\dot{r}_+^2 + Z/r_+ - \frac{1}{2(r_+ - r_-)} \qquad (2)$$
$$\mathcal{E}_- = \frac{1}{2}\dot{r}_-^2 - Z/r_- - \frac{1}{2(r_+ - r_-)}$$

From eqs.(2) one can see that the following relation must be satysfied

$$\gamma = [(1-\alpha)/\alpha]^{1/2}$$

From eqs.(1) follows that a stationary sollution must satysfy also the relation

$$z(1 - 3\gamma + 4\gamma^2 - 3\gamma^3 + \gamma^4) - \gamma^2 = 0$$

For Z=1

$$(a-\gamma)\left(\frac{1}{a} - \gamma\right)\left(1 + \frac{a-4}{a+1}\gamma + \gamma^2\right) = 0$$

One can see that exist only one physical solution a=0.46431 corresponding to the saddle point. We will suppose that near the Wannier point[4] the solution (which satysfy eqs.(1)) has the form:

$$r_+ = a t^{2/3} + c\, t^{\mu}$$

$$r_- = \gamma a t^{4/3} - \frac{c}{\gamma} t^{\mu}$$

One can show (see, e.g. Ref.4) that the energy distribution is given by dC/dE or dC/dα.

Now we will examine the shape of the energy distribution near several specialy choosen points.

a) Near the saddle point

$$\frac{\varepsilon}{E-\varepsilon} = \frac{\alpha}{1-\alpha} = \frac{\dot{r}_+^2}{\dot{r}_-^2} = \frac{A + CB}{\gamma^2 A - CB}$$

$$C = \frac{A}{B}\left[(\gamma^2+1)\alpha - 1\right], \quad A = \frac{4}{9} a^2 t_W^{-2/3}, \quad B = \frac{4 a \mu}{3} t_W^{\mu - 4/3}$$

$$\frac{dC}{d\alpha} = \frac{A}{B}(\gamma^2+1) = const$$

b) Near the point $\alpha = 0.65$, $\gamma = 0.734$

$$\frac{\alpha}{1-\alpha} = \left(\frac{1}{2}\dot{r}_+^2 - \frac{1}{2(r_+ - r_-)}\right) \Big/ \left(\frac{1}{2}\dot{r}_-^2 - \frac{1}{2(r_+ - r_-)}\right)$$

$$C = \{A[(\gamma^2+1)\alpha - 1] + (1-2\alpha)F\} / (B + G - 2\alpha G)$$

$$F = 3A/4a^3(1-\gamma), \quad G = 3(1+\gamma)B/4a^3\mu\gamma(1-\gamma)^2$$

$$\frac{dC}{d\alpha} = [(\gamma^2+1)AB - 2FB + (\gamma^2 - 1)AG] / (B + G - 2\alpha G)^2$$

For $\alpha = 0.65$, $B+G-2\alpha G = 0.04$.

c) The case $r_+ \approx r_-$, $\tilde{\omega} \approx 1$

Using the preceeding procedure one obtains that $C = 0$ and $dC/d\alpha = 0$ for this case.

It appears that the energy distribution is flat near the saddle point (case a) and equals zero near the conditions for the positronium formation (case c). Near the point $\alpha = 0.65$ the distribution is not flat and $dC/d\alpha$ has a singular point.

Acknowledgement

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AN OLD TWO-ELECTRON - SYSTEM MODEL REVISITED

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In 1921 Langmuir proposed two classical models as candidates for helium atom.[1] Those models failed to provide satisfactory ground-state energy, partly because of inadequate quantization rules applied. Recently,[2] we have reexamined both models in the light of modern semiclassical theory. Here, we present some of results obtained for the so called oscillatory (L2) model, which consists of two electrons undergoing motion in a manner similar to the bending mode oscillations of XYX type molecules, with the charge Z as Y, and electrons as X atoms. Numerical solutions reveal that the electron move on segments of circles, whose centres appear displaced from the

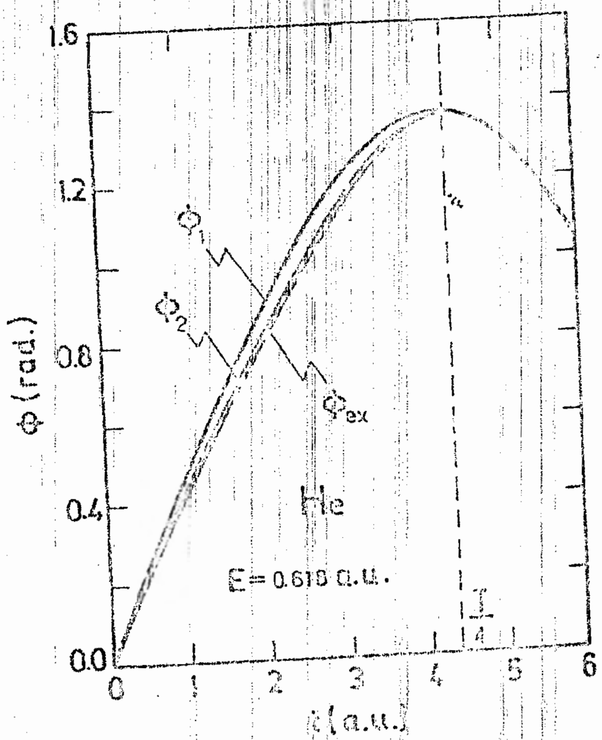

Fig. 1. Numerical (ϕ_{ex}) and approximate analytical solutions for the angular coordinate of an electron (see text).

origin by ρ, along Ox axis, with maximum angle with respect to Ox axis ϕ_{max}. In Fig. 1 exact numerical solution is shown, as well as approximate analytical expressions, for Z=2 (neutral atom):

$$\phi_1(t)=\phi_{max}\sin(2\pi\frac{t}{T}),\quad T\text{-period} \qquad (1)$$

$$\phi_2(t)=\{1-2(\phi_{max}-1)(\frac{t}{T})^{1/2}\}\sin(2\pi\frac{t}{T}) \qquad (2)$$

As the charge Z increases, two centres tend to merge, whereas as ϕ_{max} approaches $\pi/2$, thus making both electrons move along a common circle in the limit $Z\to\infty$, stopping at $\pi/2$, moving back to $\phi=0$, then to $\phi=-\pi/2$, and so forth, see Fig. 2, where r_o denotes the initial (minimum) distance from the origin at Z. The stability of the configuration has been

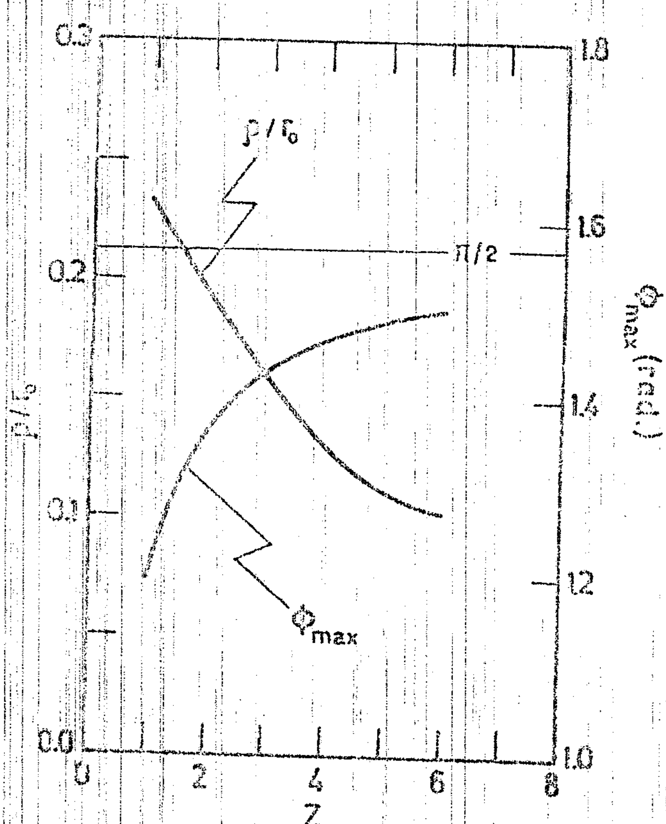

Fig. 2. Helium-like system model parameters, as function of the nuclear charge Z, from the numerical calculations.

examined, making use of the perturbative approach, applied previously for the $(Z + e^- + e^+)$ system.[3] It is found that for the total angular momentum L=0, the model remains an essentially plane configuration, with instability along the radial coordinate. However, unlike the first model (L1) oscillator-like configuration is non separable and no solutions valid for the

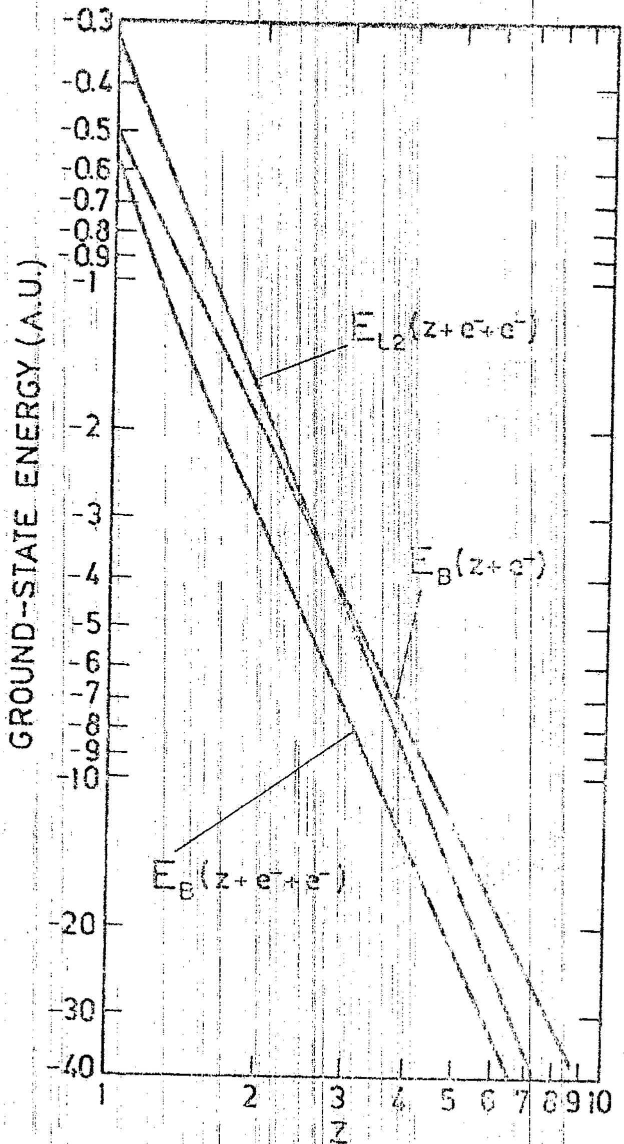

Fig. 3. Ground-state semiclassical energies for L2 model, Bohr's planetary model and Bohr's hydrogen-like ions.

whole period can be found for the deviations from the reference orbit. In order to evaluate the energy spectra, we first calculate the action function [4]

$$S_n=\oint_C(p_x dx + p_y d_y)=(n+\ell/4)h, \quad n=0,1,2,... \qquad (3)$$

where C is the actual (closed) electron orbit and ℓ is the number of turning points (in our case: 4). By applying the scaling laws

$$r\to\lambda r, \quad S\to\sqrt{\lambda}S, \quad E\to E/\lambda \qquad (4)$$

where λ is a real parameter, we evaluate first proper action, and then the corresponding energy levels E_n. In Fig. 3 we have plotted ground levels (n=1) against the charge Z. As can be seen for Z<2.75 the lowest states appear embeded into continuum, unstable against the autoionization

$$He(n=1) \to He^+(n=1) + e \qquad (5)$$

Evidently, as $Z\to\infty$, calculated ground-state energies approach the corresponding Bohr's levels. We conclude that L2 models appear inferior to Bohr's planetary atoms and calculated states can at best show up as resonances in the elastic electron -hydrogenic ions scattering.

This work has been supported in part by RZN of Serbia.

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DETERMINATION OF THE CROSS SECTION FOR ELASTIC SCATTERING OF THE ELECTRONS ON CUT OFF COULOMB POTENTIAL IN QUASI CLASSICAL METHOD

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In few previous papers[1,2] concerning the investigations into dense plasma, the features of diffusion of electrons on the potential $U_c(r)$ were investigated, where

$$U_c(r) = \begin{cases} -1/r + 1/r_c, & r \leq r_c, \\ 0, & r > r_c. \end{cases} \tag{1}$$

Here r is the distance from the beginning of the fixed coordinate system and r_c the parameter which has the meaning of a screening radius. The method of partial waves[3] which is the most apropriated in a range of low electron energy was used (at $\varepsilon \lesssim 1/r_c$, where ε is the energy in atomic units). However at higher energies, especially when r_c is relatively large, the calculations become too cumbersomes. Since the results are not analytic, the method mentioned above, could not be used in dense plasma investigations. The results obtained show the possibility of the application of more simple quasi classical method in a range

$$\varepsilon > 1/r_c, \tag{2}$$

which is quite often important in plasma conditions.

In this paper we applied quasi classical modification of the partial waves method. The purpose of this paper is to show possibilities of the application of this method for describing elastic scattering of electrons on the potential (1) in energetic range (2). One should take account that this method gives analytical results, and could be easily applied for transport cross sections determinations in dense plasmas.

As in ordinary partial waves method we begin from radial Shrodinger's equation

$$\left[d^2/dr^2 - 2U_c(r) + \ell(\ell+1)/r^2 + 2\mathcal{E}\right]\cdot R_{\mathcal{E},\ell}(r) = 0, \quad (3)$$

where ℓ is orbital quantum number. $R_{\mathcal{E},\ell}(r)$ describes the solution of the eq. (3) which satisfies an ordinary condition[3] when $r = r_c$. When $r \to \infty$ the solution is proportional to $\sin(kr - \ell\pi/2 + \delta_\ell(k;r_c))$, where $k = (2\mathcal{E})^{0.5}$, and $\delta_\ell(k;r_c)$ is so called phase shift. The aim is to determine δ_ℓ since differential and total cross sections are given by eqs:

$$\sigma_\Omega(\theta;\mathcal{E}) = \left[\frac{1}{2k}\sum_{\ell=0}^{\infty}(2\ell+1)\sin 2\delta_\ell\cdot P_\ell(\cos\theta) + \frac{1}{k}\sum_{\ell=0}^{\infty}(2\ell+1)\sin\delta_\ell^2\cdot P_\ell(\cos\theta)\right], \quad (4)$$

$$\sigma_{tot}(\mathcal{E}) = \sum_{\ell=0}^{\infty}\sigma_\ell(\mathcal{E}) \qquad \sigma_\ell(\mathcal{E}) = \frac{2\pi}{\mathcal{E}}\sin^2\delta_\ell, \quad (5)$$

where $P_\ell(\cos\theta)$ are the legandre polynomials, $\sigma_\ell(\mathcal{E})$ are partial cross sections, and θ is the scattering angle.

In quasi classical case $\ell(\ell+1)$ is replaced by $(\ell+\frac{1}{2})^2$ and δ_ℓ is defined in the following manner:

$$\delta_\ell(k;r_c) = \int_{r_0}^{r_c}\left[2(\mathcal{E} - U_c(r)) + \frac{\ell(\ell+1)}{2r^2}\right]^{0.5}dr - \int_{r_1}^{r_c}\left[2\left(\mathcal{E} - \frac{\ell(\ell+1)}{2r^2}\right)\right]^{0.5}dr, \quad (6)$$

where r_0 and r_1 are classical turning points for $\mathcal{E}$ and ℓ given. Here r_1 refers to the case of free motion. In the case of potential (1) the result of the integration in eq. (6) is:

$$\delta_\ell = (A + B) - (C + D), \quad (7)$$

where

$$A = \left[2\,\varepsilon_c \cdot r_c^2 + 2 r_c - \mu^2\right]^{0.5}, \quad \varepsilon_c \equiv \varepsilon - 1/r_c, \ \mu \equiv \ell + 1/2; \qquad (8a)$$

$$B = \begin{cases} (2\varepsilon_c)^{-0.5} \cdot \ln\left\{\left[2\varepsilon_c(2\varepsilon_c \cdot r_c^2 + 2r_c - \mu^2)\right]^{0.5} + 2\varepsilon_c \cdot r_c + 1\right\} \cdot \\ \left[1 + 2\varepsilon_c \cdot \mu^2\right]^{-0.5}, \quad \varepsilon > 1/r_c, \\ \left[2 r_c - \mu^2\right]^{0.5}, \quad \varepsilon = 1/r_c, \\ (2\varepsilon_c)^{-0.5} \cdot \arccos\left[(2\varepsilon_c r + 1)\cdot(2\varepsilon_c \mu^2 + 1)^{-0.5}\right], \quad \varepsilon < 1/r_c; \end{cases} \qquad (8b)$$

$$C = \left[2\varepsilon r_c^2 - \mu^2\right]^{0.5} - \mu \cdot \arccos\left[\mu \cdot \left(r_c (2\varepsilon)^{0.5}\right)^{-1}\right]; \qquad (8c)$$

$$\mathcal{D} = \mu \cdot \arccos\left\{\left[\mu^2 - r_c\right] \cdot \left[r_c(1 + 2\varepsilon_c \cdot \mu^2)\right]^{-0.5}\right\}. \qquad (8d)$$

Eqs. (4) and (5) together with eqs. (7) and (8) solve completely the problem of determinating differential and total cross section for elastic electron scattering on the potential (1), since in quasi classical case in (4) and (5) is enough to take the members with $\ell \leq \ell_{max}(\varepsilon; r_c)$ where

$$\ell_{max}(\varepsilon; r_c) = Ent\left(2\varepsilon \cdot r_c^2 - 0.5\right).$$

When $\ell > \ell_{max}$, $\delta_\ell = 0$ in accordance with (6). The results obtained shows fig. 1, which presents the behaviour of total cross section determined by ordinary partial waves method (curve I) and with help of quasi classical method, described here (curve II). We should pay attention that in fig. 1 are given values of cross section devided with πr_c^2 in the case when $r_c = 10$. It is obvious that for $\varepsilon \geq 0.5/r_c$ quasi classical results converge to the results of ordinary partial waves method. When $\varepsilon > 1/r_c$, the difference becomes negligable.

Our conclusion is that for $\varepsilon \geq 1/r_c$ ordinary partial waves method could be successfuly replaced by its quasi classical modification presented here.

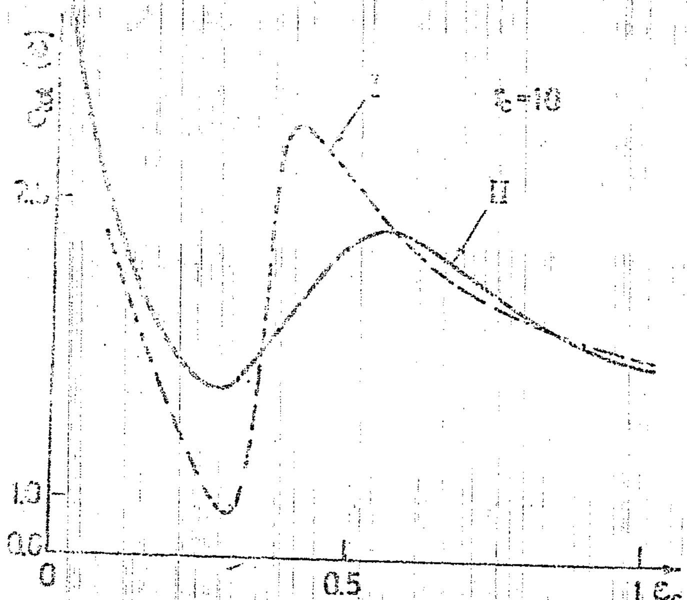

Fig. 1

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DETERMINATION OF ELECTRICAL CONDUCTIVITY OF PLASMA BY THE USE OF CLASSICAL TRANSPORT CROSS SECTIONS CALCULATED ON THE BASIS OF THE CUT OFF COULOMB POTENTIAL MODEL

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The two components, indispensable for the calculation of conductivity, are the distribution function of free electrons on impulses (in the presence of electric field), and transport cross sections (cross sections for transport of impulses when there is scattering of electrons on ions, atoms, etc.).

We shouldn't stay on the first of them, considering that the distribution function $f(v;E)$, where E is the electric field intensity, could be taken in the form[1]:

$$f(v;E) = f_0(v) + f_1(v)\cdot\cos\Theta, \tag{1}$$

where

$$f_0(v) = N_e(2\pi kT/m)^{-3/2}\exp(-mv^2/2kT), \tag{2a}$$

$$f_1(v) = (eE/m)\,df_0(v)/dv\,(N_i v\sigma_{tr}(v))^{-1}, \tag{2b}$$

Θ is the angle between the directions of the electric field and the speed. Further, we consider that $N_e = N_i$. By $\sigma_{tr}(v)$ we denote the cross section for transport of impulses by the electron scattering on ions.

Now, if j is the electric density, then[1]:

$$j = -(4\pi/3)e\int_0^\infty v^3 f_1(v)\,dv,$$

from which it follows, in accordance with (2a) and (2b), that

$$j = \left[(4e^2/m)(3(2\pi kT/m)^{1/2})^{-1}\int_0^\infty \frac{x\exp(-x)\,dx}{\sigma_{tr}(kTx)}\right]E, \tag{3}$$

where $x = (mv^2/2)/(kT)$, and the transport cross section is taken to be the energy function.

It follows from (3) that $j = \sigma^{tr}(T)E$, where $\sigma^{tr}(T)$ denotes the expression in square brackets on the right side.

In accordance with definition, $\sigma^{tr}(T)$ is the plasma conductivity, the determination of which is the aim of the present paper.

The problem is limited to the determination of transport cross section.

Since at large ... and relatively low ... there are conditions when using Debye potential is not justified[2], there is a question of a choice of another potential model. In the present case we use the screening Coulomb potential[3,4]

$$U_c(r) = \begin{cases} -e^2/r + e^2/r_c, & r \le r_c, \\ 0, & r > r_c, \end{cases} \tag{4}$$

where r is the distance of electron from the origin of the fixed coordinate system, and r_c is the screening radius, which is the parameter.

We consider $kTr_c/e^2 \gg 1$, so that the range where $\mathcal{E} < e^2/r_c$, (where $\mathcal{E}$ is the energy of the free electron), is not of importance. The performed investigations show that, when $\mathcal{E} \gtrsim e^2/r_c$, the electron scattering on potential (1) nearly exactly describes the quasi-classical method, which enables the transport cross section determination in analytical form. Nevertheless, the resulting expressions are too clumsy. Considering that these are the first potential (4) applications, we chose another more simple classical method which gives the transport cross section in a very simple form:

$$\sigma^{(cl)}_{(tr)}(\mathcal{E}) = \pi r_c^2 (2/s_c)\left[1 + (1 - s_c)s_c^{-1}\ln(1 - s_c)\right], \tag{5}$$

where $s_c \equiv 4\mathcal{E}_c(1 - \mathcal{E}_c)$, and $\mathcal{E}_c \equiv r_c$. Figure 1 shows the behaviour of the reduced (devided by πr_c^2) transport cross sections in quasi-classical - curves I and II, and classical - curve III, cases. It is obvious that there is a very good agreement of classical and quasi-classical results when $\mathcal{E} \gtrsim 0.5/r_c$. From (3) and (5) it follows:

$$\sigma^{tr}(T) = (4e^2/3m)\left[\pi r_c^2 (2\pi kT/m)^{1/2}\right]^{-1} \chi(T_c), \tag{6}$$

where $T_c = kTr_c/e^2$, and $\chi(T_c)$ is the universal function, given by expression:

$$\chi(T_e) = \int_0^\infty \frac{x \exp(-x)\,dx}{\tilde{\sigma}_{tr}^{el}(x \cdot T_e)}$$

where $\tilde{\sigma}_{tr}^{el} \equiv \sigma_{tr}^{el} \cdot (\pi r_c^2)^{-1}$. The electron - electronic scattering should be taken into account by introducting Spitcer's factor $\gamma = 1.72^{-1}$, and coductivity, in this case, should be denoted by $\sigma_\gamma^*(T)$, where $\sigma_\gamma^*(T) \equiv \sigma^*(T)\cdot\gamma$. Figure 2 shows the results of theoretical calculations[5,6] (Spitcer, Kakljugin, Norman), experimental results[2] and the intervals in which the determined $\sigma_\gamma^*(r_c)$ changes with the corresponding changes of the parameter $\varkappa \equiv r_c/r_D$, where r_D is Debye radius. From the above mentioned results it follows, that, by the appropriate choice of r_c, a good agreement of experimental and here obtained conductivity could be achieved. The importance of this result is that the parameter r_c could be determined independently (from optical measurements), and then conductivity is determined automaticaly, without any other presumption in connection with the screening mechanism.

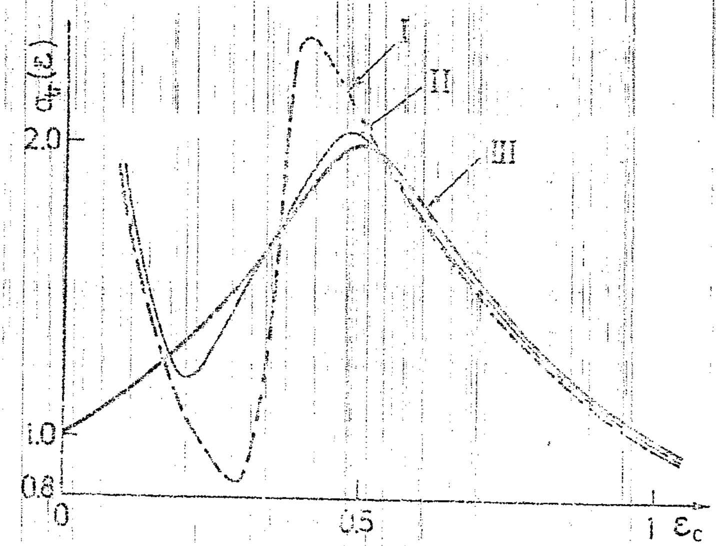

Fig. 1

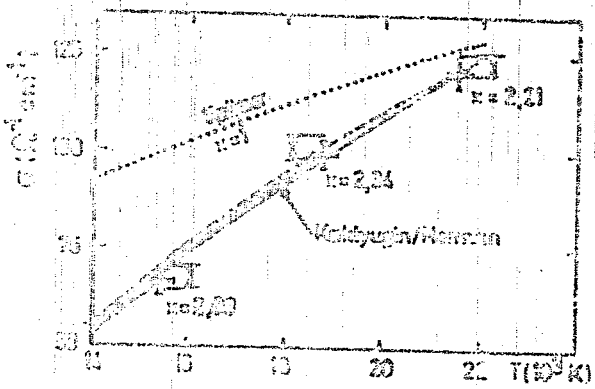

Fig. 2

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THE TRAJECTORY EFFECT AND BROADENING OF NEUTRAL ATOM LINES

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Within the semiclassical and the classical formalism for the calculation of neutral atom spectral line shapes within the impact approximation, the trajectory of the perturber is commonly represented by a straight line. At low temperatures the effect of back reaction of the neutral emitter on a perturbing particle may become noticeable and consequently deviations of the perturber motion from the uniform one should be taken into account[1-4]. Here, the phaseshifts due to collisions with a perturbing particle moving in a $\pm C_n r^{-n}$ (n=2,3 and 4) potential (- is for an attractive and + for a repulsive potential) are evaluated.

Using polar coordinates, the motion of the perturbing particle is decribed by[5]:

$$\dot{\theta} = \rho v / r^2$$

$$\dot{r} = v\left(1 - \frac{\rho^2}{r^2} - \frac{2V(r)}{Mv^2}\right)^{1/2} \qquad (1)$$

The phaseshift is

$$\eta = \frac{2C_n}{v} \int_{r_m}^{\infty} \frac{dr}{r^n (r^2 - \rho^2 - r^2 V(r)/E_0)^{1/2}} \qquad (2)$$

where r_m is the largest of the positive roots of the denominator.

In some cases integration in (2) may be performed easily. For the considered potential $V(r) = \pm C_n r^{-n}$ and for n=2 (the linear Stark effect) we obtain:

$$\eta = \eta^0 \left(1 + \frac{C_n}{\rho^2 E_0}\right)^{-1/2} \qquad \eta^0 = \frac{\sqrt{\pi}\,\Gamma[(n-1)/2] C_n}{\Gamma(n/2) v_0 \rho^{n-1}} \qquad (3)$$

The case n=3 corresponds to the resonance broadening. The solution of equation (2) is obtained in the following form:

$$\eta = \eta^0 \frac{2\rho^2}{b[a(b-c)]^{1/2}}\left[K(k) + \left(\frac{b}{a} - 1\right)\Pi(k^2, k)\right] \qquad (4)$$

$$k^2 = \frac{b(a-c)}{a(b-c)}$$

Here, K and Π are the complete elliptic integrals of the first and third kind, respectively and $a = (2\rho/\sqrt{3})\cos(\phi/3)$; $b = (2\rho/\sqrt{3})\cos((\phi + 4\pi)/3)$; $c = (2\rho/\sqrt{3})\cos((\phi + 2\pi)/3)$; $a > b > c$ are roots of the denominator in the integral in equation (2), and:

$$\cos\phi = -(\rho_c/\rho)^3 \qquad (5)$$

$$\rho_c = \sqrt{3}(C_3/Mv)^{1/3}.$$

Since the potential is attractive, if the impact parameter of the incoming electron is smaller than ρ_c, the atoms 'fall' into each other. In such a case one must resort to a more realistic emitter-perturber potential which accounts for a number of short range effects.

For n=4 (the quadratic Stark effect) the potential may be attractive or repulsive, depending on the sign of the quadratic Stark constant C_4 of the target.

For the attractive case one has:

$$\eta = \eta^0 \frac{4\rho^3}{\pi a b^2}(K(k) - E(k))$$

$$a, b = (\rho^2/2)\{1 \pm [1 - (1/\tilde{\rho})]^{1/2}\}$$

$$\tilde{\rho} = (\rho/\rho_c)^4$$

$$k = b/a$$

$$\rho_c = (8|C_4|/v^2)^{1/4} \qquad (6)$$

where E(k) is the complete elliptic integral of the second kind.

For the repulsive case[3]

$$\eta = \eta^0 \frac{16}{\pi}\tilde{\rho}\sqrt{\beta}\left(E(k) - \frac{\beta+1}{2\beta}K(k)\right)$$

$$\beta^2 = 1 + \tilde{\rho}^{-1} \qquad k^2 = \frac{\beta - 1}{2\beta}. \qquad (7)$$

As we can see, in the case of a repulsive potential the introduction of a non-uniform motion of the perturbing electron eliminates the problem of the minimum impact parameter, a crucial difficulty in the low-temperature region.

For n=6 the integration in equation (2) is also straightforward but the solution is so cumbersome that numerical integration appears easier.

As an example we consider here the He $(3^1P^o-2^1S)$, λ=5017Å (multiplet 4) line, which has a large and negative quadratic Stark constant for the upper state of the transition[3]. In fig 1 the e-He(3^1P) scattering phaseshifts obtained according to: a) exact solution of eq. (2) (η_l), b) straight path case (η_l^o), and c) Vallés et al.[1] (η_l') are presented. One can see that for $\rho > \rho_c$ the approximate treatment is in good agreement with the exact solution of eq.(2), but differs considerably in the region $\rho < \rho_c$, where the proposed approximation is not applicable. In the case considered the potential is repulsive due to the negative quadratic Stark constant, and the phase shift (η_l) does not diverge for small impact parameters. Consequently, in the adiabatic impact theory of Stark broadening where the integration over ρ is needed in order to obtain the line width (w) and shift (d), the large discrepancy between η_l' and η_l for $\rho<\rho_c$ may be a problem.

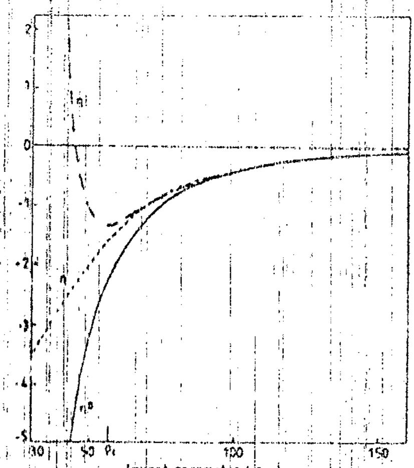

Figure 1. e-He(3^1P) scattering phaseshifts for plasma at T = 5000 K.

For the He I($3^1P^o-2^1S$) line for T = 5000 K and electron density $N_e = 10^{16}$ cm^{-3}, the half-half width w = 0.400 Å, using the exact solution of eq. (2) whereas the ordinary adiabatic theory calculations[6] with straight-line perturber paths provide the value 0.367 Å, and using the approximate solution[1] we obtain the value w = 0.206 Å. The semiclassical method[6] yields 0.378 Å. Finally we can conclude that in the region $\rho < \rho_c$ method proposed in ref. 1 is not applicable. This is especially important for the repulsive potential, since in such cases the contribution of the perturbers with $\rho < \rho_c$ is substantial.

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KNJIGA APSTRAKATA

The Eleventh National Conference

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BOOK OF ABSTRACTS

način poslovanja, politički život, kulturu i zauvek promenio način na koji radimo, učimo, komuniciramo, živimo. Zadnje decenije desila se još jedna digitalna revolucija romantičnog naziva „Računarski oblak“ ili „Cloud computing“.

Kao pojam u razvoju može da se definiše kao model koji omogućava jednostvani mrežni pristup određenom skupu resusrsa, bez obzira da li su u pitanju mrežni resursi, aplikacije ili servisi koji su brzo dostupni za upotrebu. Sinhronizacija sadržaja i korisnika na Cloud-u dala je nove dimenzije korišćenju Interneta. Uz pomoć Cloud-a svi ti sadržaji su dostupni i na računaru, i notebook-u, tabletu ili mobilnom telefonu, a po potrebi i svima onima sa kojima su umreženi, odnosno sinhronizovani.Zbog svojih pozitivnih karakteristika razvija se velikom brzinom i svakodnevno dobija sve veći broj korisnika širom sveta - od javnih preduzeća, vlada, škola, kompanija, do poslovnih ljudi, studenata i mnogih drugih. To je „oblak” na informatičkom nebu, računarska infrastruktura koja svojim korisnicima nudi mogućnost skladištenja informacija, korišćenje softvera i aplikacija po principu servisa, kao i nove načine obrade i korišćenja podataka.

Deo kulturne baštine predstavalja i arhivska građa koja u sebe uključuje i mnogobrojne fotografije. Osavremenjivanje rada arhivske službe u skaldu sa razvojem moderne tehnologije, pojava elektronskih oblika zapisa i novih oblika medjuljudske komunikacije omogućili su veću dostupnost arhivske gradje. Tako digitalizovana gradja, koja se čuva u institucijama zaštite kao i u privatnim kolekcijama, postaje dostupna mnogobrojnim korisnicima.Korišćenjearhivske gradje,koja sadrži veliki broj raznovrsnih informacija, u naučne i druge svrhemože biti olakšano i ubrzano primenom Cloud computing-a. Pored toga, umrežavanje i upotreba mrežnih resursa može da utiče na smanjenje troškova obrade i njene primene.

Cilj ovog rada je da ukaže na mogućnost korišćenja digitalnih zapisa u procesu zaštite kulturne baštine kao i na primenu računarskog oblaka koji olakšava njenu dostupnost i ubrzava razmenu informacija.

Милан С. Димитријевић, Јован Алексић
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ЕЛЕКТРОНСКА ИЗДАЊА СРПСКИХ АСТРОНОМСКИХ ИНСТИТУЦИЈА И ДРУШТАВА 2011-2012

У астрономским институцијама и друштвима у Србији, електронско издаваштво је започето 2006. Године. Период закључно са 2009, детаљно је приказан у Прегледу НЦД, бр. 17 (2010, стр. 17-24). У том периоду су публикована 22 компакт диска и ДВДа, а издавачи су били Астрономска опсерваторија, Астрономско друштво „Руђер Бошковић“, Друштво астронома Србије и Природњачко друштво „ГЕА“ из Вршца. Наставак ове активности у 2010. и делу 2011, приказан је у раду саопштеном на Десетој конференцији „Нове технологије и стандарди: Дигитализација националне баштине“, који је у штампи у Прегледу НЦД. Овде ћемо дати преглед резултата добијених у оквиру ове активности у другом делу 2011. и првом делу 2012. године.

14. SUMMER SCHOOL & INTERNATIONAL SYMPOSIUM ON THE PHYSICS OF IONIZED GASES '88

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STARK BROADENING OF NOBLE GAS IONS AS A FUNCTION OF THE IONIZATION POTENTIAL

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For the investigation and diagnostic method for plasmas created in laboratory, as well as in astrophysical sources, Stark broadening data are often very useful. In the cases where a very good accuracy of each particular result is not needed, but a good average accuracy for a number of data is only required, methods for simple estimates may be of interest. Such methods are also useful for critical evaluation of various published data or for interpolation of new data.

In this work we derrive a simple formula for quick estimate of Stark widths within the ionized noble gas homologous sequence, starting from the modified semiempirical method.[1]

When the nearest perturbing level j' is sofar from the initial or final energy level j = i,f that $x_{jj'} = E/\Delta E_{j'}-E_j| \leq 2$ is satisfied, the modified semiempirical formula may be considerably simplified[2]

$$w(\text{Å}) = 2.2151\cdot 10^{-8}\ \frac{\lambda^2(\text{cm})\ N(\text{cm}^{-3})}{T^{1/2}(\text{K})}\ \cdot$$

$$\left(0.9 - \frac{1.1}{Z}\right)\sum_{j=i,f}\left(\frac{3n_j}{2Z}\right)^2\left(n_j^2-\ell_j^2-\ell_j-1\right) \qquad (1)$$

Here, N and T are the electron density and electron temperature respectively, E = 3kT/2 is the energy of perturbing electron, Z-1 is the ionic charge and n is the effective principal quantum number. Such case is of particular interest for astrophysical purposes, low temperatures and for transitions between low lying levels.

In the case of singly charged ions, we obtained the following form for the Eq.(1):

$$W(\text{Å}) = 1.74439 \cdot 10^{-8} \frac{\lambda^2(\text{cm})\, N(\text{cm}^{-3})}{T^{1/2}(\text{K})} \cdot \sum_{j=i,f} \frac{E_H}{I_o - E_j}\left(\frac{4E_H}{I_o - E_j} - \ell_j^2 - \ell_j - 1\right) \qquad (2)$$

where I_o is the ionization energy and E_i, E_f energies of initial and final levels respectively.

In the case of $ns\,^4P - np\,^4P^o$ transitions in Ne II, Ar II, Kr II, Xe II homologous sequence $\ell \to \ell - 1$ transition does not exist for the final level so we will neglect the lower level broadening contribution in Eq. (2). Moreover, we found empirically that between the energy of $np\,^4P^o$, $np\,^4D^o$ or $ns\,^4P$ levels (E_p or E_s), of Ne II, Ar II, Kr II, Xe II homologous sequence (where n=3 for Ne II, 4 for Ar II ...) and I_o there exist a relationship, which may be approximatively expressed as $E = a + bI_o$. Corresponding a and b coefficients are given in Table 1.

Now, for the case considered of singly charged noble gas ion ns-np transitions, Eq. (2) becomes

$$W(\text{Å}) = 1.7444 \cdot 10^{-8} \frac{\lambda^2(\text{cm})\, N(\text{cm}^{-3})}{T^{1/2}(\text{K})} \frac{E_H}{I_o(1-b_p) - a_p}\left[\frac{4E_H}{I_o(1-b_p) - a_p} - 3\right] \quad (3)$$

where a_p and b_p are corresponding a and b coefficients for $np\,^4P^o$ and $np\,^4D^o$ levels. From Eq. (3) follows that the full Stark widths within the homologous sequence examined may be expressed as a function of the ionization potential I_o and plasma condition parameters. The values obtained using Eq. (3) are compared with recently published experimental values[3,4] obtained at low (Table 2) and high density (Table 3). We can see that at high densities, experimental and theoretical values compare better than at low densities. However, if we devide (W/λ^2 values with the normalization factor

$$NF = \frac{E_H}{I_o(1-b_p) - a_p}\left[\frac{4E_H}{I_o(1-b_p) - a_p} - 3\right] \qquad (4)$$

we can see from Tables 2 and 3 that obtained values are nearly

Table 1

Values of the coefficients of the linear relation between the level energy and the ionization potential I_o (in cm^{-1}) for each interacting level

E_j	$a(cm^{-1})$	b
$np\,^4P^o$	-31477.666	0.838242
$np\,^4D^o$	-29487.069	0.84120377
$ns\,^4P$	-39149.403	0.77998322

Table 2

Low density case. Normalized values of the experimental widths[3] ($N=10^{17}cm^{-3}$, T=10000 K) devided by λ^2 compared with simple theoretical estimates (Eq. (3)). Ratios of the normalized widths devided by the normalization factor NF are also given.

Line	λ (Å)	$\frac{w}{\lambda^2}$ (10^{-8} Å^{-1}) measured	$\frac{w}{\lambda^2}$ (10^{-8} Å^{-1}) theoretical	$w/\lambda^2 NF$ (10^{-8} Å^{-1})
Ar II	4847.87	1.46	0.99	0.25
Ar II	4348.06	1.92	1.11	0.30
Xe II	4844.33	1.98	1.60	0.22
Xe II	5419.15	2.29	1.60	0.25

Table 3

Same as in Table 2 but for high density case.

Line	λ (Å)	$\frac{w}{\lambda^2}$ (10^{-8} Å^{-1}) measured	$\frac{w}{\lambda^2}$ (10^{-8} Å^{-1}) theoretical	$w/\lambda^2 NF$ (10^{-8} Å^{-1})
Ar II	4847.87	1.26	0.99	0.22
Ar II	4348.06	1.59	1.11	0.24
Xe II	4844.33	1.82	1.60	0.20
Xe II	5419.15	1.82	1.60	0.20

constant in low density as well as in high density case. This demonstrates a regular behaviour between Stark widths within the homologous sequence examined. Moreover, this regularity is conserved also in the high density case.

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Line widths due to neutral non-resonant collisions within a homologous sequence: an investigation of the Van der Waals formula

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The broadening of a line depends on the dynamics of the collisions with perturbing particles as well as on the collective effects of all the perturbers. Consequently, differences between low density and high density cases arise. On the other hand, broadening depends also on particle properties. On the basis of atomic structure considerations, similarities should exist within a given spectrum, for line widths within a multiplet, supermultiplet, and to a lesser degree, within a transition array. Furthermore, a regular behaviour of line widths is expected within a spectral series, for corresponding transitions in homologous emitters, and in isoelectronic sequences. Regularities and similarities in line widths are expected to depend also on different perturbing atom properties such as the polarisability. Dependence of line width on ionization potential may also be investigated. In this communication the most reliable experimental data for the alkali resonant lines are analysed in order to search for systematic trends and the applicability of the van der Waals formula is examined within a homologous sequence. Only data of high photometric precision are included, no photographic measurements are used. Also the only measurements given are those for which instrumental effects and other possible sources of broadening have been subtracted.

In figure 1 measured half-half widths w(experiment) are presented for the resonance lines of Li (Gallagher, 1975; Smith and Collins, 1976; Lwin et al, 1977), Na (McCartan and Farr, 1976) and K (Lwin et al, 1977) perturbed by rare gases. The theoretical half-half width is

$$w(\text{theory}) \propto C_6^{2/5}\left(\frac{T}{\mu}\right)^{3/10}$$

where C_6 is the van der Waals constant, μ is the reduced mass of the emitter-perturber system, and N and T are the number density of perturbers and the temperature (see Peach, 1981). Here we have used the coefficient C_6 obtained by averaging over the degenerate levels, as described by Al-Saqabi and Peach (1987). The polarisability of the rare gas atoms and consequently C_6, increases with increasing atomic mass and it can be seen that the measured widths do in general increase with increasing polarisability along the homologous sequence. This is an indication that the long-range part of the radiator-perturber interaction becomes relatively more dominant. However particularly interesting is the case of neon. If line widths are considered to be a function of polarisability only, one obtains a pronounced irregular minimum for neon explained as 'expected on the basis of the Ramsauer-Townsend effect' by Kielkopf (1980). However this anomaly disappears almost completely when the full dependence on all the physical parameters are taken into account as in figure 1. The results are more dispersed for He and Ne perturbers because the short range part of the interaction is also important and this is not directly related to polarisability at all. It also appears that for heavier perturbers better agreement between theory and experiment is obtained if the van der Waals formula is multiplied by a factor of about 1.25. This can possibly be explained by studying figure 2 where accurate potentials for Na-Ne (Peach, unpublished) are plotted as a ratio to their asymptotic limit. This shows that true convergence to the van der Waals limit only occurs for R > 50 a.u., a much larger value of R than is often assumed, but that the curves have maxima at much lower values of R.

In the course of preparing this paper an error has been discovered in the phase factor in equation (34) of Al-Saqabi and Peach (1987). This has the effect of making the line widths predicted by the average profile approximation slightly less rather than slightly greater than those given by the average level approximation.

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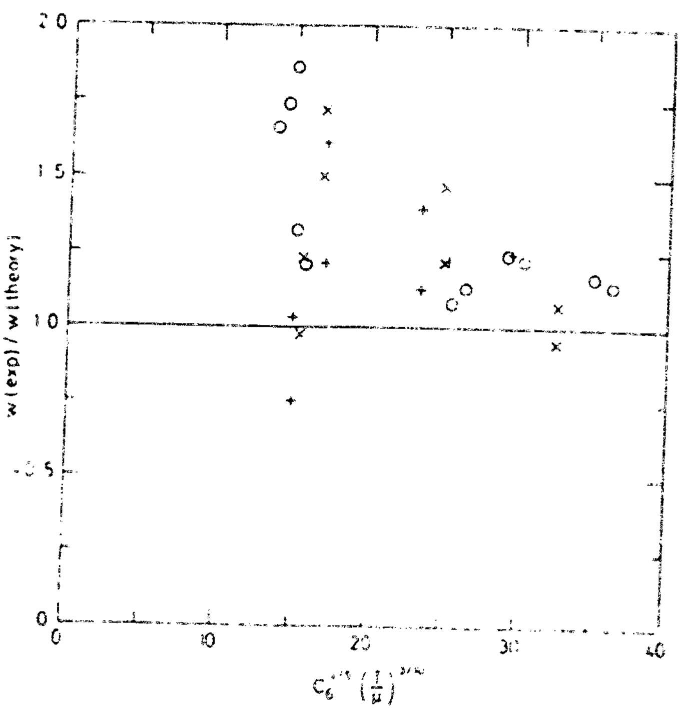

Figure 1. The ratio w(experiment)/w(theory) as a function of $C_6^{1/6}\left(\frac{T}{\mu}\right)^{3/10}$ evaluated in atomic units (c.f. Allen, 1973).

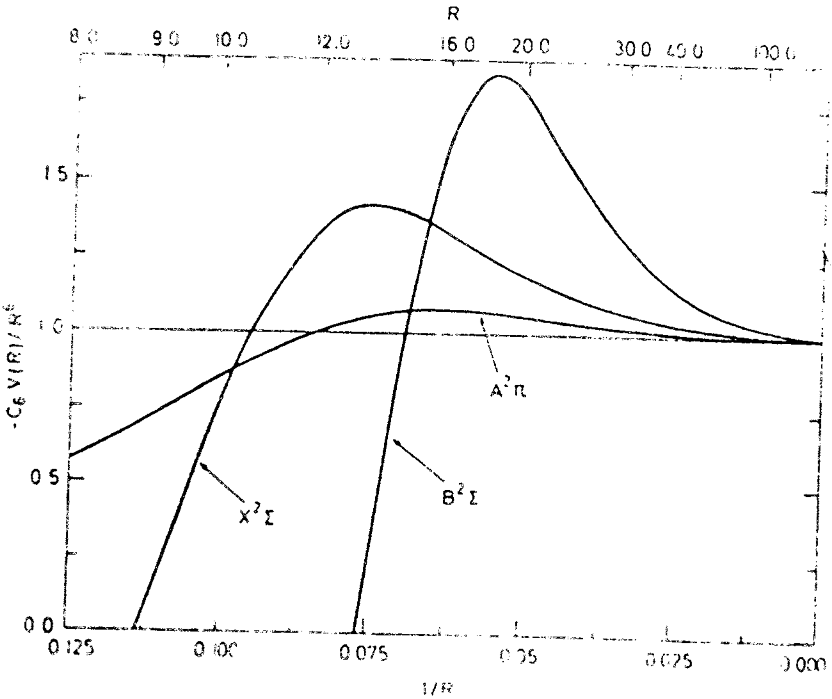

Figure 2. The adiabatic potentials for the $X^2\Sigma$, $B^2\Sigma$ and $A^2\Pi$ for the system Na-Ne plotted as a ratio to their asymptotic form, $-C_6/R^6$.

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THE INFLUENCE OF DEBYE SHIELDING ON THE STARK WIDTS AND SHIFTS OF ION LINES IN THE ADIABATIC LIMIT

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In spite of the fact that the case where only adiabatic collisions are important is not frequent, the adiabatic limit is important in Stark broadening theory for the following reasons. First of all, strong collisions contribution is one of the most critical points in any semiclassical theory of Stark broadening. Strong collisions which are, roughly speaking adiabatic[1] are often of the same importance as weak collisions or even dominant. Second, the adiabatic approximation is very important for the GBKO theory[2] for neutral atom lines, where it is assumed that the theory of Lindholm[3] and Foley[4] is correct in the adiabatic limit. The same is assumed in the case of singly charged ion lines[5], for the adiabatic limit obtained by Roberts and Davis[6]. Third, in the semiclassical perturbation formalism of Sahal-Bréchot[7,8], elastic collisions contribution is estimated using the adiabatic theory. Moreover, when the impact approximation for ion broadening is valid, an adiabatic approach is commonly used.

The classical adiabatic approach for Stark broadening of ion lines is developed by Roberts and Davis[6] from the theory of Lindholm and Foley[3,4] with the assumption that Debye screening is not important. However, for higher densities, as well as for lines originating from more excited atomic states, such assumption is often not justified. The aim of this paper is to obtain the frequency shift and the shift to width ratio in the adiabatic limit, taking into account Debye shielding and using the Coulomb cut-off potential.

Using polar coordinates, and atomic units, the motion of the perturbing particle is described by[9]:

$$\dot{\theta} = \rho v / r^2$$

$$\dot{r} = v\left(1 - \frac{\rho^2}{r^2} - \frac{2V(r)}{v^2}\right)^{1/2}$$

Here, v is the perturber velocity, ρ the impact parameter, and

$$V(r) = \begin{cases} -\frac{1}{r} + \frac{1}{r_D}, & r < r_D \\ 0, & r \geq r_D \end{cases}$$

the Coulomb cut-off potential[10], suitable especialy for a non-ideal plasma. Introducing the Weisskopf radius $\rho_o = (C_4/v)^{1/3}$ where C_4 is the quadratic Stark coefficient, $Z = Z_{ion}/\rho_o v^2$ is a measure of the ratio of perturber potential energy to kinetic energy, and $k = \rho/\rho_o$, the phase shift induced during the collision is

$$\eta = 2\rho_o^3 \int_{r_o}^{r_D} \frac{dr}{r^3\sqrt{Rr^2 + 2Z\rho_o r - K^2\rho_o^2}}, \tag{1}$$

where r_o is the largest of positive roots of the denominator, r_D the Debye radius and $R = (1 - \frac{2}{v^2 r_D})$.

The solution of Eq. (1) is:

$$\eta = \frac{\pi}{2K^3}\left\{R + \frac{2}{\pi}\left(R + \frac{3Z^2}{K^2}\right)\mathrm{arctg}\,\frac{Zr_D - K^2\rho_o}{K\sqrt{Rr_D^2 + 2Z\rho_o r_D - K^2\rho_o^2}} + \right. \tag{2}$$

$$\left. + \frac{3Z^2}{K^2} + \frac{2}{\pi}\left(\frac{\rho_o K}{r_D^2} + \frac{3Z}{Kr_D}\right)\sqrt{Rr_D^2 + 2Z\rho_o r_D - K^2\rho_o^2}\right\}$$

For $r_D \to \infty$ Eq. 2 becomes identical with the solution of Roberts and Davis[6]

$$\eta = \frac{\pi}{2K^3}\left\{1 + \frac{2}{\pi}\left(1 + \frac{3Z^2}{K^2}\right)\mathrm{arctg}\left(\frac{Z}{K}\right) + \frac{3Z^2}{K^2} + \frac{6Z}{\pi K}\right\}. \tag{3}$$

and in the high temperature limit ($v \to \infty$, i.e. $z \to 0$ and $\rho_0 \to 0$) Eq. (2) reduces to the Lindholm-Foley result, $\eta = \pi/2k^3$. In the low velocity limit

$$\eta = \frac{3\pi z^2}{k^5}\left\{1 + \frac{k}{\pi}\sqrt{\frac{2\rho_0}{r_D z}}\right\} \approx \frac{3\pi z^2}{k^5}$$

Stark width w and shift d can now be expressed as

$$w(z) + i\,d(z) = 2\pi N_e v \rho_0^2 \int_0^{k_D} \left\{1 - \exp[-i\,\eta(z,k,\rho_0,r_D)]\right\} k\,dk$$

where $k_D = r_D/\rho_0$. If one express the integral over k as $\int_0^\infty - \int_{k_D}^\infty$ and one makes a rough estimate of the second integral, one obtains in high temperature limit:

$$w + id = 2\pi N_e v \rho_0^2 \left\{\frac{1}{3}\left(\frac{\pi}{2}\right)^{2/3} \frac{\pi e^{i\pi/3}}{\sin(\frac{2\pi}{3})\,\Gamma(5/3)} - \frac{\pi^2}{48 k_D^6} - i\,\frac{\pi}{6 k_D^3}\right\}$$

In low temperature limit:

$$w + id = 2\pi N_e v \rho_0^2 \left\{\frac{(3\pi z^2)^{2/5}}{5} \frac{\pi e^{i\pi/5}}{\sin(\frac{2\pi}{5})\,\Gamma(\frac{7}{5})} - \frac{9\pi^2 z^4}{20 k_D^{10}} - i\,\frac{3\pi z^2}{5 k_D^5}\right\}$$

We can see that d/w ratio is not constant as if Debye shielding is neglected but $d/w = f(k_D/Z)$. The obtained correction may be neglected in the high temperature limit where $k \to \infty$ but it is important in the low temperature limit where $v \to 0$, $Z \to \infty$ and $k \to 0$.

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COMPARISON BETWEEN CALCULATED AND MEASURED STARK WIDTHS OF C IV LINES

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For a number of astrophysical as well as physical applications, the knowledge of C IV Stark broadening parameters is very important due to its high cosmical abundance and its presence as impurity in many laboratory plasma sources. Using the semiclassical-perturbation formalism[1,2] we have calculated electron-, and proton-impact line widths and shifts for 38 C IV multiplets. In this paper our results are compared with available experimental results[3-6] and with results obtained using the modified semiempirical approach.[4,7,8]

In Table 1, our results (W_{DSB}) are compared with existing experimental values [3-6] and with existing calculations[4,7] using the modified semiempirical method[8]. In the paper of Bötcher et al[6] two experimental values are given. One assuming impact and other assuming quasistatic approximation. Both are presented in Table 1. We can notice a good agreement between semiclassical-perturbation and much simpler modified semiempirical results especialy good for higher transitions. However, in the case of 3s-3p and particularly 2s-2p transition, the considerable difference exist, due to the contribution of series of resonances below the threshold for inelastic excitation. Since such contribution is included in the modified semiempirical approach in the empirical part chosen to be in average in accordance with existing experiments, these results are in better agreement with experiments than the semiclassical ones. Further, present calculations are in good agreement with calculations[9] using the

Table 1. Experimental Stark widths (W_M) compared with the theory. The W_{DSB} are present semiclassical calculations; W_{MSE} are calculations[4,7] using the modified semiempirical approach[8]. Experimental data are: a- El-Farra, Hughes (1983)[4]; b- Bogen (1972)[3]; c- Ackermann et al (1985)[5]; d- Bötcher et al (1987): d1-collisional case; d2- static case.

Transition	λ (Å)	T (K)	N_e (10^{17} cm^{-3})	W_m (Å) (Ref.)	W_{DSB} (Å)	W_{MSE} (Å)
$2s\,^2S-2p\,^2P^o$	1548.20	53.000	15	0.043(a)	0.15	0.044
		58.000	4	0.024(b)	0.038	0.012
	1550.77	53.000	15	0.063(a)	0.15	0.044
		58.000	4	0.024(b)	0.038	0.012
$3s\,^2S-3p\,^2P^o$	5801.33	53.000	15	6.2(a)	10.8	6.5
		58.000	4	1.6(b)	2.76	1.6
		116.000	5	2.8(c)	2.69	1.8
	5811.98	53.000	15	6.0(a)	10.8	6.5
		58.000	4	1.6(b)	2.76	1.6
		116.000	5	2.8(c)	2.69	1.8
$3p\,^2P^o-4s\,^2S$	1230.	116.000	5	0.58(c)	0.22	0.2
$3s\,^2S-4p\,^2P^o$	948.1	116.000	5	0.4(c)	0.17	0.16
$3p\,^2P^o-4d\,^2D$	1107.6	113.700	4.7	0.10(d1)	0.23	
				0.12(d2)		
		116.000	5	0.53(c)	0.24	0.23
		124.000	7.7	0.18(d1)	0.36	
				0.23(d2)		
$3p\,^2P^o-4f\,^2F$	1106.5	116.000	5	0.35(c)	0.15	0.12
$4p\,^2P^o-5s\,^2S$	2698	116.000	5	5.4(c)	2.97	3.7
$3d\,^2D-4f\,^2F^o$	1169	53.000	15	0.62(a)	0.53	0.58
		113.700	4.7	0.060(d1)	0.14	
				0.070(d2)		
		116.000	5	0.4(c)	0.15	0.12
		124.000	7.7	0.12(d1)	0.22	
				0.15(d2)		
$4p\,^2P^o-5d\,^2D$	2405	116.000	5	10.0(c)	3.33	4.0
$4d\,^2D-5f\,^2F^o$	2524.4	116.000	5	8.4(c)	3.11	3.8
		124.000	7.7	1.0(d2)	4.54	
$4f\,^2F^o-5g\,^2G$	2530	116.000	5	4.2(c)	1.55	1.6
		124.000	7.7	1.0(d2)	2.28	

semiclassical method of Griem[10]. This is also illustrated in Figs. 1-3, where various theoretical and experimental data have been compared.

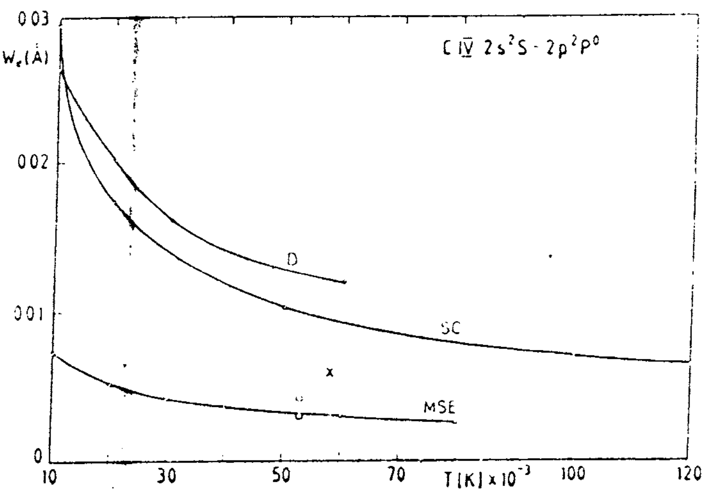

Fig. 1. Full halfwidths for the C IV $2s^2S-2p^2P^0$ multiplet as a function of electron temperature: N = $10^{17}cm^{-3}$ Experimental points:X- Bogen (1972)[3];⊙- El-Farra, Hughes (1983)[4];+- Ackermann et al (1985)[5]; Δ - Bötcher et al (1987)[6], coll. approx.;∇- static approx. Calculations: SC- semiclassical (present); MSE - modified semiempirical; D- Dimitrijević (1988)[9]

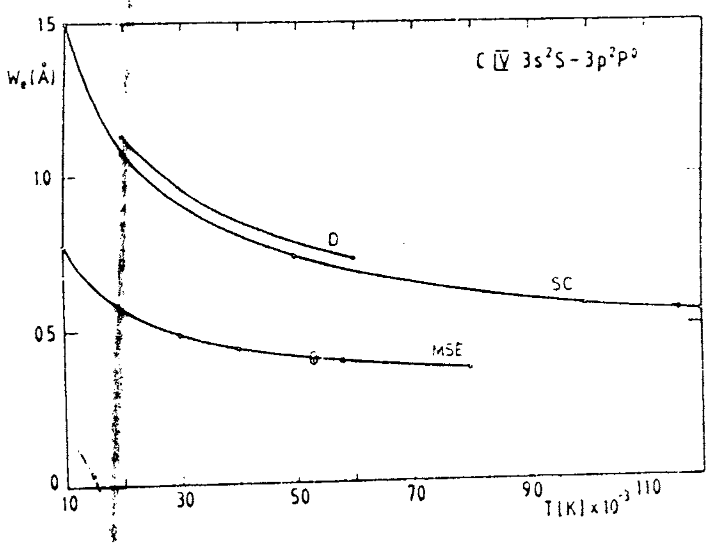

Fig. 2. Same as in Fig. 1 but for C IV $3s^2S-3p^2P^0$ multiplet

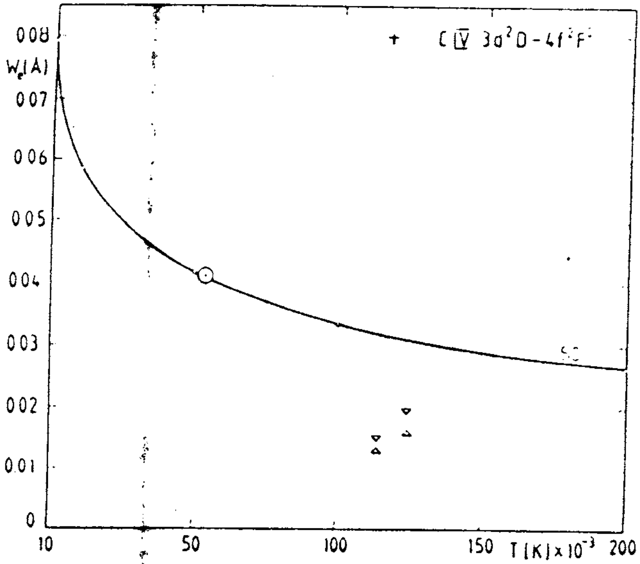

Fig. 3. Same as in Fig. 1 but for C IV $3d^2D-4f^2F^o$ multiplet

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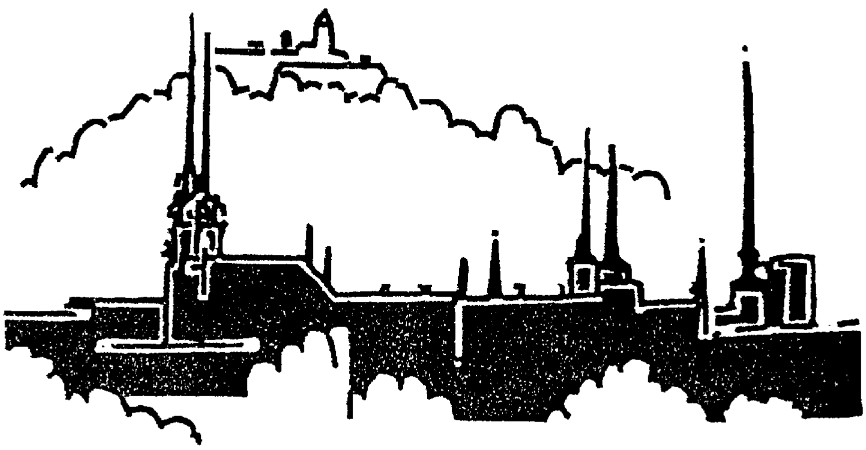

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EUROPEAN VIRTUAL ATOMIC AND MOLECULAR DATA CENTER - VAMDC

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Abstract: Virtual Atomic and Molecular Data Center (http://www.vamdc.eu, VAMDC), described here, is an European Union funded FP7 project with the objective to create a secure, documented, flexible and interoperable e-science environment-based interface to existing atomic and molecular data. It will also provide a forum for dissemination and training of potential users. The contribution of the Belgrade node is STARK-B database (http://stark-b.obspm.fr), developing together with LERMA-Observatoire de Paris-Meudon, containing Stark broadening parameters. The database is currently developed in Paris, and a mirror-site is planned in Belgrade, within the frame of SerVO - Serbian virtual observatory (http://www.servo.aob.rs/~darko).

Keywords: atomic data, molecular data, databases, e-science, virtual observatories

Introduction

Atomic and Molecular data are of critical importance in many research fields in astrophysics, atmospheric physics, fusion, environmental sciences, combustion chemistry, and in industrial applications from plasmas and lasers to lighting. In spite of this, it is not easy to obtain a needed critically selected set of such data. Namely in various sources they are provided in different ways, without common standards, using different units, often without critical evaluation, anonymously and without indications of the method or theory for their production.

As the principal problems for an adequate search and atomic and molecular data mining, one could enumerate: a) Lack of standards and common guidelines; b) Interoperability problem; c) Data exchange problem; d) Overlapping of efforts; e) Need of hiring computer engineers since the majority of developers are Astronomers, Physicists, Chemists; f) Data identification problem, since XML schemata keys are needed not only for data exchange but also for data identification; g) Need for a critical evaluation of data; h) Often lack of primary source of data and description how they are produced.

The need to solve the above mentioned problems and to provide facilities for a productive search and data mining, leaded to the idea to create a Virtual Atomic and Molecular Data Center (VAMDC – [1]), accepted as a FP7 founded project, which started on July 1 2009, with a duration of 42 months.

Here, we will describe the FP7 VAMDC Project and its connections with STARK-B database for parameters of Stark broadening of spectral lines (http://stark-b.obspm.fr), as well as with Serbian Virtual Observatory (SerVO - http://www.servo.aob.rs/~darko).

VAMDC – Virtual Atomic and Molecular Data Center

The aim of VAMDC project is to build a secure, documented, flexible, easily accessible and interoperable e-infrastructure, and upgrade and integrate Atomic and Molecular database services in order to satisfy the needs of the users of such data in science, research and development, governmental institutions, industry and general public. This will be done by implementing a VAMDC interface for access the principal databases with heterogeneous data, which are created for different purposes and users. Also, VAMDC will enable data queries across multiple databases, aimed for various research fields. In addition, the objective of VAMDC is also to create a forum of data producers, data users and databases developers, as well as to organize the corresponding tutorials and training of potential users. In such a way, VAMDC will involve users and producers in the development and use of its facilities and resources and will enable data publishing and control of quality of implemented atomic and molecular data.

Project leader is Marie-Lise Dubernet from Observatoire de Paris and core consortium is made of 15 institutions with 24 scientific groups from France, Serbia, Russia, England, Austria, Italy, Germany, Sweden and Venezuela. The coordinator of the Project is, Centre National de Recherche Scientifique - CNRS (Université Pierre et Marie Curie, Paris; Observatoire de Paris; Université de Reims; Université Joseph Fourier de Grenoble, Université de Bordeaux 1: Université de Bourgogne, Dijon; Université Toulouse).

Fig. 1: VAMDC logo.

External VAMDC partner is also NIST – National Institute for Standards and Technology in Washington.

The databases, which represent the core of the VAMDC e-infrastructure are the following: VALD database of atomic data for analysis of radiation from astrophysical objects (http://vald.astro.univie.ac.at/); CHIANTI, an atomic database for spectroscopic diagnostics of optically thin collisionally ionised astrophysical plasmas (http://sohowww.nascom.nasa.gov/ solarsoft, http://www.damtp.cam.ac.uk/user/astro/chianti/); EMol Database at the Open University in Milton Keynes, containing a comprehensive listing of critically evaluated and regularly updated measured and calculated cross sections for electron interactions with molecular systems; CDMS - Cologne Database for Molecular Spectroscopy (http://www.ph1.uni-koeln. de/ vorhersagen/); BASECOL database (http://basecol.obspm.fr) containing excitation rate coefficients for ro-vibrational excitation of molecules by electrons, He and H_2; GhoSST (Grenoble astrophysics and planetology Solid Spectroscopy and Thermodynamics, http://ghosst.obs.ujf-grenoble.fr), offering spectroscopic laboratory data on molecular and atomic solids and liquids from the near UV to the far-infrared; UMIST - University of Manchester Institute of Science and Technology (UMIST) database for astrochemistry (http://www.udfa.net/), providing reaction rate data and related software for chemical kinetic modelling of astronomical regions; KIDA - KInetic Database for Astrochemistry containing data on chemical reactions used in the modelling of the chemistry in the interstellar medium and in planetary atmospheres (http://kida.obs.u-bordeaux1.fr); PAHs (Polycyclic Aromatic Hydrocarbon) and carbon clusters spectral database (http://astrochemisty.ca.astro.it/database/) in Cagliari; LASP (Laboratorio di Astrofisica Sperimentale) Database (http://web.ct.astro.it/weblab/ dbindex.html#dbindex) at the INAF (Istituto Nazionale di Astrofisica) - Catania Astrophysical Observatory, containing atomic data for molecules in the solid phase; Spectr-W^3 atomic database (http://spectr-w3.snz.ru), listing experimental, calculated, and compiled data on ionization potentials, energy levels, wavelengths, radiation transition probabilities and oscillator strengths, and also parameters for analytic approximations for electron-collision cross-sections and rates for atoms and ions; CDSD - The Carbon Dioxide Spectroscopic Databank (http://cdsd.iao.ru and ftp://ftp.iao.ru/pub/CDSD-2008), containing calculated spectral line parameters for seven isotopologues of carbon dioxide; S&MPO - Spectroscopy & Molecular Properties of Ozone) database (http://ozone.iao.ru and http://ozone.univ-reims.fr/), containing spectral line parameters for the ozone molecule, experimental UV cross-sections, information on ozone's molecular properties, updated reference lists as well as programs for user applications; "Spectroscopy of Atmospheric Gases" (http://spectra.iao.ru); W@DIS - Water Internet @ccessible Distributed Information System (http://wadis.saga.iao.ru), listing experimental water-vapour spectroscopy data; TOPbase (http://cdsweb.u-strasbg.fr/topbase/ topbase.html), listing atomic data computed in the Opacity Projec, TIPbase (http://cdsweb.u-strasbg.fr/tipbase/home.html), with atomic data computed by the IRON Project, and OPserver, located at the Ohio Supercomputer Center, USA, (http://opacities.osc.edu/), a remote, interactive server for the computation of mean opacities for stellar modelling using the monochromatic opacities computed by the Opacity Project; XSTAR database, used by the XSTAR code (http://heasarc.gsfc.nasa.gov/ docs/software/ xstar/xstar.html) for modelling photoionised plasmas; HITRAN - HIgh-resolution TRANsmission molecular absorption database (http://www.cfa.harvard.edu/hitran/); GEISA - Gestion et Etude des Informations Spectroscopiques Atmosphériques (Management and Study of Atmospheric Spectroscopic Information) database (http://ara.lmd.polytechnique.fr/index.php?page=geisa-2 or http://ether.ipsl.jussieu.fr/etherTypo/?id=950); HITEMP, a high temperature extension to HITRAN (To access the HITEMP data: ftp to cfa-ftp.harvard.edu; user = anonymous; password = e-mail address); STARK-B database (http://stark-b.obspm.fr) of the theoretical widths and shifts of isolated lines of atoms and ions due to collisions with charged perurbers, obtained within the impact approximation. Details on references for particular databases could be found in Refs. [1, 2].

The VAMDC facilities will be useful for a number of topics in Astronomy, Plasma science, Atmospheric science, Radiation science, Fusion community, Industries using technological plasmas, as e.g. lasers, etching, and Lighting industry and will provide an adequate tool for an easier and more efficacious data mining and search of the needed atomic and molecular data.

STARK-B database

The development of STARK-B databse, which enters in VAMDC e-infrastructure, is in progress in Laboratoire d'Etude du Rayonnement et de la matière en Astrophysique of the Observatoire de Paris-Meudon in collaboration with the Astronomical Observatory of Belgrade. It contains Stark line broadening parameters (widths and shifts) obtained within the impact approximation using the semiclassical perturbation approach [3,4], during the more than 30 years lasting collaboration between two of us (SSB – MSD). All later optimizations and updating of the computer code, are described for example in Ref. [5].

STARK-B [6] is aimed for modelling and spectroscopic diagnostics of stellar atmospheres and envelopes, as well as for laboratory plasmas, laser equipment, inertial fusion plasma and technological plasmas. The database is currently developed in Paris, and a mirror-site is planned in Belgrade.

SerVO – Serbian Virtual Observatory

The mirror-site of the STARK-B database which will be in the AOB VAMDC node, will be a part of the SerVO - Serbian virtual observatory (http://www.servo.aob.rs/~darko). SerVO started as a project TR13022, accepted by the Ministry of Science and Technological Development of Republic of Serbia [7], from April 1st 2008. From the 1st January of 2011, it is financed by the Ministry of

Education and Science through the project III44002 "Astroinformatics and virtual observatories". After establishing SerVO and starting to digitize and archive photo plates [8] and other astronomical data produced at Belgrade Astronomical Observatory, the aims are i) To work on the development of SerVO and to join the EuroVO and IVOA; b) To develop SerVO data Center which will work on the digitizing, archiving and publishing in VO format of 14,500 photo-plates archived on Belgrade Astronomical observatory, obtained between 1936 and 1996, as well as stellar catalogues produced in Serbia; c) To work on the development of tools for visualization of data; d) Make a regional node of Virtual Atomic and Molecular Data Center – VAMDC; e) Make a mirror-site of STARK-B; f) Make a mirror-site for DSED - Darthmouth Stellar Evolution Database [9] in the context of VO.

VAMDC, STARK-B and SerVO are examples of new facilities in e-science. Especially VAMDC which is expected to become legal entity and one of the major European cyber-infrastructures. We plan to develop further the Serbian VAMDC node with an aim to become a regional center for this activity, and a forum for A&M data users and producers in South Eastern Europe, as well as an organizer of tutorials and trainings for students and potential users.

Acknowledgments

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XIX ICPEAC

CANADA 1995

NINETEENTH INTERNATIONAL CONFERENCE ON THE PHYSICS OF ELECTRONIC AND ATOMIC COLLISIONS

SCIENTIFIC PROGRAM AND ABSTRACTS OF CONTRIBUTED PAPERS

WHISTLER, BRITISH COLUMBIA
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26 JULY - 1 AUGUST 1995

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J.B.A. MITCHELL, J.W. McCONKEY, C.E. BRION

ELECTRON-ION-ATOM AND ELECTRON-MOLECULAR ION RECOMBINATION IN HYDROGEN PLASMA

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In the previous papers [1] [2] a semiclassical method for the determination of the rate coefficients of the di-electronic recombination processes

$$H_2^+ + \tilde{e} \Longrightarrow H + H^*(n), \quad (1a)$$

$$H + H^+ + \tilde{e} \Longrightarrow H + H^*(n), \quad (1b)$$

has been presented. Here $\tilde{e}$ is free electron, $H = H(1s)$, $H^*(n)$ - atom in high excited state with the principal quantum number n, H_2^+ - weakly bound molecular ion in the electronic ground state $(1\Sigma_g^+)$ and $H + H^+$ denotes quasi-molecular collisional complex.

The aim of this paper is to demonstrate that such recombination processes, neglected up to now as a source of highly excited atoms, may have important or even dominant role in comparison with alredy known recombination processes. In order to do so we will consider relatively weakly ionized hydrogen plasma (the ionization degree less or equal to 10^{-3}), characterized by electronic and atomic temperatures T_e and T_a, where $T_a \leq T_e$. The contribution of the recombination processes (1a,b) to the $H^*(n)$ atom population we will compare with the contribution of the electron - electron - ion recombination processes

$$H^+ + \tilde{e} + \tilde{e} \Longrightarrow H^*(n) + \tilde{e}. \quad (2)$$

We will define the recombination fluxes of reaction (1a), (1b) and (2) as

$$\begin{aligned} I_n^{(a)}(T_a, T_e) &= K_n^{(a)}(T_a, T_e) N(e) N(H^+) N(H), \\ I_n^{(b)}(T_a, T_e) &= K_n^{(b)}(T_a, T_e) N(e) N(H^+) N(H), \\ I_n(T_e) &= \alpha_n(T_e) N(e)^2 N(H^+), \end{aligned}$$

where $K_n^{(a)}(T_a, T_e)$, $K_n^{(b)}(T_a, T_e)$ and $\alpha_n(T_e)$ are the rate coefficients of the recombination processes (1a),(1b) and (2) respectively. The rate coefficient α_n is determined here by semiempirical expression from [4].

In according to Refs. [1] [2] we have that $K_n^{(a)} = K_n^{(DR)}[N(H^+)N(H)/N(H_2^+)]^{-1}$. This gives possibility to express recombination flux $I_n^{(ab)}(T_a, T_e)$, characterizing the total contribution of processes (1a) and (1b), as

$$I_n^{(ab)}(T_a, T_e) = K_n^{(ab)}(T_a, T_e) N(e) N(H^+) N(H),$$

where $K_n^{(ab)}(T_a, T_e) \equiv K_n^{(a)}(T_a, T_e) + K_n^{(b)}(T_a, T_e)$

Relatively influence processes (1a,b) in comparison with process (2) is characterized by ratio

$$\frac{I_n^{(ab)}}{I_n} = \frac{K_n^{(ab)}}{\alpha_n} \frac{N(H)}{N(e)}.$$

Behaviour of the quantity $I_n^{(ab)}/I_n$ in the case $n = 4$ and $N(H)/N(e) = 100$ is ilustrated on Figure 1.

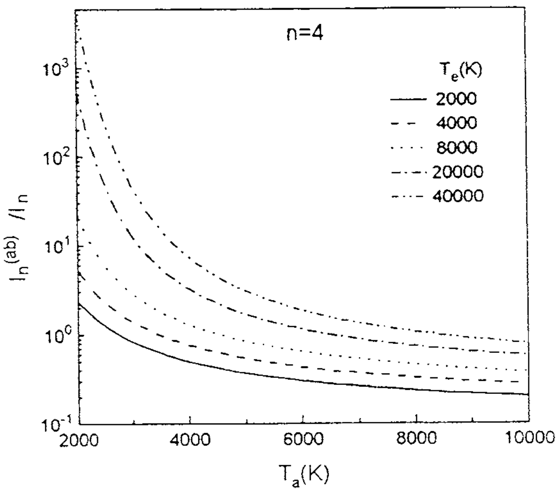

Figure 1: Behaviour of the quantity $I_n^{(ab)}/I_n$ in the case $n = 4$ and $N(H)/N(e) = 100$

We can see that processes (1a,b) are important as a source of high excited atoms. Also, it is necessary to take into account these processes in modelling of weakly ionized plasmas.

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J.B.A. MITCHELL, J.W. McCONKEY, C.E. BRION

BROADENING OF Li II LINES BY COLLISIONS WITH CHARGED PARTICLES

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Charged particle - impact broadening parameters for singly charged lithium lines are of interest not only for the diagnostic of laboratory and astrophysical plasmas but for the theoretical considerations as well, since the He-like Li II spectrum is suitable for theoretical research. They are particularly of interest for the examination of *e.g.* regularities and systematic trends within He isoelectronic sequence.

Table 1. This table shows electron-impact broadening parameters for Li II for a perturber density of 10^{17} cm^{-3} and temperatures from 5,000 up to 40,000 K. Transitions and averaged wavelengths for the multiplet (in Å) are also given. If one divides c value with the Stark width value, we obtain an estimate for the maximum perturber density (in cm^{-3}) for which the line may be treated as isolated and tabulated data may be used.

TRANSITION	T(K)	WIDTH(A)	SHIFT(A)
Li II 1S- 2P	5000.	0.557E-03	0.391E-04
199.3 A	10000.	0.395E-03	0.401E-04
C= 0.41E+18	20000.	0.286E-03	0.274E-04
	40000.	0.211E-03	0.175E-04
Li II 1S- 3P	5000.	0.282E-02	-0.308E-03
178.0 A	10000.	0.228E-02	-0.246E-03
C= 0.15E+17	20000.	0.189E-02	-0.236E-03
	40000.	0.161E-02	-0.197E-03
Li II 2S- 2P	5000.	2.37	-0.141
9584.1 A	10000.	1.69	-0.134
C= 0 [illegible]6E+21	20000.	1.25	-0.111
	40000.	0.974	-0.121
Li II 2S- 3P	5000.	0.196	-0.265E-01
1420.9 A	10000.	0.158	-0.209E-01
C= 0.97E+18	20000.	0.131	-0.182E-01
	40000.	0.112	-0.165E-01
Li II 2P- 3S	5000.	0.188	0.810E-01
1755.3 A	10000.	0.147	0.633E-01
C= 0.92E+19	20000.	0.127	0.521E-01
	40000.	0.114	0.414E-01

By using the semiclassical-perturbation formalism[1,2], we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 29 Li II multiplets. A summary of the formalism is given in Ref. 3. Here, we present and discuss the results for Li II, along with a comparison with other theoretical results[4].

Energy levels for Li II lines have been taken from Ref. 5. In addition to electron-impact full halfwidths and shifts, Stark-broadening parameters due to proton- and ionized-helium impacts have been calculated. As a part of our results, electron - impact broadening parameters for a perturber density of 10^{17}cm^{-3} and temperatures T = 5,000 - 40,000 K, are shown in Table 1. We also specify a parameter c[6] which, when it is divided by the corresponding electron-impact full width at half maximum, gives an estimate for the maximum perturber density for which the line may be treated as isolated.

If one compares our results for electron-impact full half widths and shifts within the $2s^3S$ - np^3P^o series with semiclassical results of Jones *et al.*[4], one can see a gradual change of Stark broadening parameters permitting the interpolation of new data or critical evaluation of mutual consistency of existing data. The agreement between present calculation and calculations of Jones *et al.*[4] is better at higher temperatures, when the inelastic contribution to the width dominates, than at lower ones, when differences in cut-off procedure and the symmetrization influence are more significant.

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ON THE ELECTRON-IMPACT BROADENING OF O IV LINES

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Oxygen lines are of considerable interest for the laboratory plasma diagnostic and, due to high cosmical abundance of oxygen, ofparticular interest for the analysis of stellar spectra. In order to investigate the influence of electron impacts on triply charged oxygen ion spectral lines, we have calculated within the semiclassical-perturbation formalism [1,2] electron-, proton-, and He III-, -impact line widths and shifts for 5 O IV multiplets.

Energy levels for O IV lines have been taken from Ref. 3. In addition to electron-impact full halfwidths and shifts, Stark-broadening parameters due to proton-, and He III- impacts have been calculated.

A part of our results for 5 O IV multiplets,the electron-impact broadening parameters, are shown in Table 1, for perturber densities $10^{17}cm^{-3}$ and temperatures T = 20,000 - 200,000K. We also specify a parameter c [4], which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding electron-impact full width at half maximum. The accuracy of the results obtained decreases when broadening by ion interactions becomes important.

The analysis of present results and comparison with available experimental and theoretical data will be published elsewhere[5]

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Table 1. This table shows electron-impact broadening parameters for O IV, for perturber density of $10^{17}cm^{-3}$ and temperatures from 20,000 to 200,000 K. Transitions and averaged wavelengths for the multiplet (in Å) are also given. By using c^4, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

Transition	T(K)	Width (Å)	Shift (Å)
O IV 2P 3S	20000.	0.609E-03	0.158E-04
279.9 Å	50000.	0.362E-03	0.330E-04
C= 0.26E+19	100000.	0.266E-03	0.358E-04
	200000.	0.205E-03	0.383E-04
O IV 2P 3D	20000.	0.477E-03	-0.138E-04
238.5 Å	50000.	0.303E-03	-0.198E-05
C= 0.17E+19	100000.	0.221E-03	0.814E-06
	200000.	0.167E-03	0.343E-06
O IV 3S 3P	20000.	0.155	-0.141E-02
3066.4 Å	50000.	0.991E-01	-0.237E-02
C= 0.28E+21	100000.	0.741E-01	-0.233E-02
	200000.	0.578E-01	-0.270E-02
O IV 3P 3D	20000.	0.162	-0.244E-02
3410.9 Å	50000.	0.106	-0.205E-02
C= 0.34E+21	100000.	0.784E-01	-0.211E-02
	200000.	0.607E-01	-0.220E-02
O IV 3D 4F	20000.	0.306E-01	-0.666E-03
1067.8 Å	50000.	0.208E-01	-0.539E-03
C= 0.30E+19	100000.	0.160E-01	-0.572E-03
	200000.	0.129E-01	-0.336E-03

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STARK BROADENING OF O VI LINES

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1. INTRODUCTION

Stark broadening of spectral lines has been taking a new interest in astrophysics [1], owing to the recent development of researches on the physics of stellar interiors: in subphotospheric layers, the modellisation of energy transport needs the knowledge of radiative opacities and thus, certain atomic processes must be known with accuracy. At these high temperatures (10^5 K or more) and densities (10^{17} -10^{21} cm^{-3}) the matter is mostly ionized: therefore Stark broadening of strong multicharged ionic lines plays a non-negligible role in the calculation of the opacities, especially in the UV.

The present paper concerns O VI lines. Beyond the interest for the modellisation of stellar interiors, the knowledge of O VI Stark broadening parameters is of great importance for a number of problems in astrophysics and plasma physics, since oxygen has a high cosmical abundance and is present as impurity in many laboratory plasma sources. In order to provide reliable data for O VI lines broadened by collisions with charged perturbers in stellar plasmas, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 31 O VI multiplets, using the semiclassical-perturbation formalism [2,3].

2. RESULTS AND DISCUSSION

All details of the calculation procedure has been described in details in [4] and will not be repeated here. Energy levels for O VI lines have been taken from [5]. Oscillator strengths have been calculated using the method of Bates and Damgaard [6] and tables of Oertel and Shomo [7]. For higher levels, the method described by Van Regemorter et al.[8] has been used.

A sample of our results is shown in Table 1 for a perturber density 10^{17} cm^{-3} and temperatures of T = 100,000; 150,000; 200,000; 300,000; 500,000 and 800,000 K. We also specify a parameter c [9] which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by 2W.

In the case of 3s-3p O VI multiplet, at T = 145.000 K and electron density 1.8 10^{18} cm^{-3} , for the ful width at half maximum,the experiment [10] gives 2.78Å our calculations 1.67Å, quantum mechanical [11] 1.01Å. In Ref. [10], the experimental data for the considered multiplet have been compared with the calculations based upon

Table 1. This table gives electron-, impact broadening parameters for O VI lines, for perturber densities of 10^{17} cm^{-3} and temperatures from 100,000 K to 800,000 K. Transitions and averaged wavelengths for the multiplet(in Å) are also given.By dividing c and 2W, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used. The asterisk identifies cases for which the collision volume multiplied by the perturber density (the condition for validity of the impact approximation) lies between 0.1 and 0.5.

PERTURBER DENSITY = 0.1D+18

TRANSITION	T(K)	ELECTRONS WIDTH(Å)	SHIFT(Å)
OVI 2S-2P	100000.	0.144E-02	-0.329E-04
1033.8 Å	150000.	0.118E-02	-0.324E-04
C= 0.10E+21	200000.	0.105E-02	-0.310E-04
	300000.	0.869E-03	-0.345E-04
	500000.	0.694E-03	-0.386E-04
	800000.	0.572E-03	-0.362E-04
OVI 2S-3P	100000.	0.121E-03	0.262E-05
150.1 Å	150000.	0.102E-03	0.227E-05
C= 0.19E+18	200000.	0.910E-04	0.215E-05
	300000.	0.779E-04	0.202E-05
	500000.	0.647E-04	0.191E-05
	800000.	0.551E-04	0.166E-05
OVI 2S-4P	100000.	0.218E-03	0.905E-05
115.8 Å	150000.	0.188E-03	0.895E-05
C= 0.47E+17	200000.	0.170E-03	0.872E-05
	300000.	0.148E-03	0.843E-05
	500000.	0.126E-03	0.696E-05
	800000.	0.108E-03	0.577E-05
OVI 2S-5P	100000.	0.441E-03	0.262E-04
104.8 Å	150000.	0.385E-03	0.252E-04
C= 0.20E+17	200000.	0.351E-03	0.241E-04
	300000.	0.309E-03	0.208E-04
	500000.	0.264E-03	0.170E-04
	800000.	0.229E-03	0.148E-04
OVI 2S-6P	100000.	0.848E-03	0.596E-04
99.7 Å	150000.	0.747E-03	0.550E-04
C= 0.29E+21	200000.	0.684E-03	0.492E-04
	300000.	0.604E-03	0.421E-04
	500000.	0.518E-03	0.354E-04
	800000.	0.450E-03	0.313E-04

four approximate theoretical approaches (which gives 1.36Å [12], 1.13Å [13],1.01Å [14] (1.28Å [15]), and 2.16 Å [16]. Moreover, the empirical scaling relations [17, 18] gives 2.24Å.

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MODIFIED SEMIEMPIRICAL STARK SHIFT EXAMINATION: I. ArII STARK LINE SHIFTS

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The modified semiempirical (MSE) method for ion lines Stark widths /1,2/ and shifts /3/ calculation has shown to be a convenient method for simple and fast estimation of Stark broadening parameters with good average accuracy (see e.g./4/ and references therein). Because of the generally smaller possibilities of theory in the case of line shifts, we performed extensive quantitative testing of MSE Stark shifts on the basis of comparison with reliable experimental data. This contribution contains the analysis of ArII Stark shifts. In the subsequent paper /5/ we present Stark shifts in the homologous sequence of alcali-like singly charged ions.

According to /1-3/ transitions with $\Delta n=0$ are treated separately with a different Gaunt factor and the Stark shift of a spectral line can be expressed as /3/:

$$d = \frac{4\pi}{3}\frac{\hbar^2}{m^2}\left(\frac{2m}{\pi kT}\right)^{1/2}\frac{\pi}{\sqrt{3}}\sum_{j=i,f}\Big\{\hat{R}^2_{k,k+1}\varepsilon_j\tilde{g}_{sh}(x_{k,k+1}) - \hat{R}^2_{k,k-1}\varepsilon_j\tilde{g}_{sh}(x_{k,k-1}) + \sum_{j'}(\hat{R}^2_{jj'})_{\Delta n\neq 0}\varepsilon_j g_{sh}(x_j) - 2\varepsilon_j\Big[\sum_{\Delta E_{jj'}<0}(\hat{R}^2_{jj'})_{\Delta n\neq 0}\, g_{sh}(x_{jj'})\Big]\Big\} \quad (1)$$

Here, $k=\ell_j$, i and f denote the initial and final levels, $\varepsilon_j=+1$ if $j=i$ and -1 if $j=f$; $x_{jj'}=3kT/2|\Delta E_{jj'}|$; $x_j=3kTn_j^{*3}/4ZE_H$ where E_H is the hydrogen ionization energy, n^* is the effective principal quantum number and Z-1 is the ionic charge. All relevant Gaunt factors are tabulated in /3/. The matrix elements can be calculated in accordance with Coulomb approximation /6/. If there are perturbing levels with $|\Delta E_{jj'}| \ll |\Delta E_{n,n+1}|$, the contribution of each such level to the line shift should be calculated as

$$d_j = \pm\,\varepsilon_j(\hat{R}^2_{jj'})\left[g_{sh}(x_{jj'}) \mp g_{sh}(x_j)\right] \quad (2)$$

where the lower sign corresponds to $\Delta E_{jj'}<0$.

For the testing of MSE method for the Stark shifts estimation in the case of complex ions, the most suitable are ArII lines since for this emiter the most extensive reliable ion lines Stark shifts experimental data set exists. On the basis of critical reviews of experimental data /7,8/ we took into account 8 experiments /9-16/ with about 170 line shift measurements in 47 multiplets of ArII. When possible, we compared our results with semiclassical calculations of Jones et al./17/ also. Complete analysis together with extensive tabulations will be published elsewhere /4,18/. The representative results are shown here, in Tables 1 and 2 and in Figs. 1-3.

Table 1. Mean ratios of measured to theoretical ArII Stark shifts for different multiplets, together with standard deviations and numbers of line shifts involved. SC are the semiclassical results /17/ and MSE are the present results.

Transition (multiplet)			S C	M S E
3d–4p	4D–4PO	(1)	0.72±0.11(12)	2.05±0.34(12)
	4D–4DO	(2)	0.74±0.29(10)	1.66±0.70(10)
4s–4p	4P–4PO	(6)	1.62±0.41(22)	1.36±0.38(22)
	4P–4DO	(7)	1.38±0.51(24)	1.63±0.64(24)
	4P–2DO	(8)		0.64±0.42(2)
	4P–4SO	(10)	1.00 (1+4[1])	1.23±1.20(4+1[1])
	2P–2DO	(14)	0.36±0.10(6)	0.85±0.22(6)
	2P–2PO	(15)		0.45±0.14(6+3[1])
	2P–2SO	(17)		0.84±0.27(4)
4s'–4p'	2D–2FO	(31)		1.11±0.11(5)
4p–4d	4PO–4D	(44)		1.66±0.09(4)
	4DO–4D	(54)	0.75±0.09(9)	1.44±0.18(9)
	4DO–4P	(57)		1.19±0.12(4)
	2PO–2P	(83)	0.59±0.06(3)	0.83±0.09(3)
	4SO–4P	(90)	0.91±0.04(3)	1.28±0.06(3)
4p–5s	4PO–4P	(42)	0.98±0.12(6)	1.14±0.14(6)

Table 2. Mean ratios of measured to theoretical ArII Stark shifts for all experiments considered. Notation is the same as in Table 1.

Experiment (Ref.No.)	S C	M S E
/9/	0.94±0.33(16+2[1])	1.35±0.74(25)
/10/	1.54±0.62(15)	1.92±0.81(16+6[1])
/11/	0.96±0.50(47+2[1])	1.53±1.40(106+1[1])
/12/	1.02±0.10(2)	1.38±0.06(2)
/13/	0.80±0.40(4)	1.12±0.37(4)
/14/	0.46±0.10(2)	0.72±0.10(2)
/15/		1.00±0.00(2)
/16/	1.44±0.26(12)	1.10±0.14(12)
Mean	**1.02±0.34**	**1.26±0.34**

[1]Theory predicts the opposite sign.

Mean measured to theoretical Stark shift ratio of the MSE results, for 165 line shift measurements is 1.38±0.60, with 6 results with opposite signs of the shifts. The same ratio of the semiclassical results /17/ for 98 line shifts is 1.06±0.53 with 4 results with opposite signs. This ratio is even better if one averages mean ratios for individual experiments (Table 2). Our results

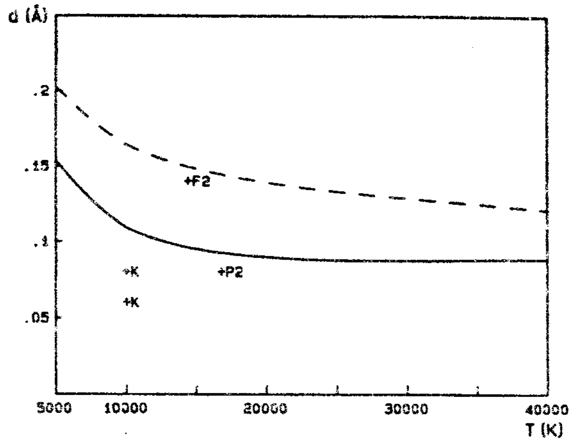

Fig.2. Stark shifts for MgII 3p2P0-4s2S multiplet. Notation is the same as in Fig.1.

We calculated MSE Stark shifts for alcali-like ions using this improvement also (results denoted with MSE1). MSE1 results differ from MSE ones only if transitions with $g_{sh}^{(1)}$ or $g_{sh}^{(3)}$ strongly dominate in line shift calculations. Even in the cases when contributions of $g_{sh}^{(1)}$ and $g_{sh}^{(3)}$ transitions are mixed MSE1 results can be practicaly equal to MSE ones. As shown in Table 3 and in Figs. 3 and 4, in the case of alcali-like singly charged ions MSE1 considerably improves the accuracy of MSE results for p-d multiplets. MSE1 mean experimental to theoretical line shift ratio is 1.39 ± 0.80 (with 3 theoreticaly predicted results with opposite sign and 3 zero results) i.e. it only slightly differs from the original MSE result.

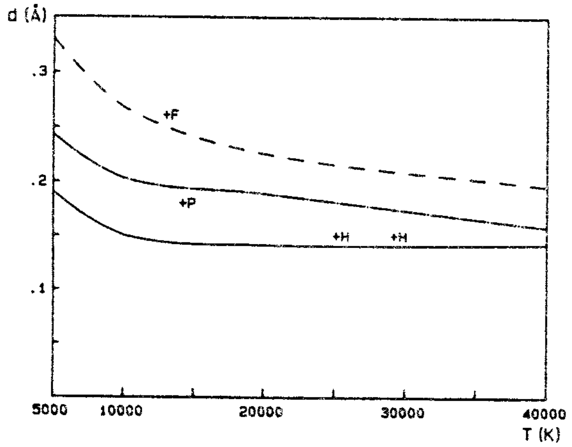

Fig.3. Stark shifts for CaII 4p2P0-4d2D multiplet. Notation is the same as in Fig.1.

One can conclude that MSE approach gives satisfactory results for the Stark shifts of alcali-like singly charged ions. In some particular cases these results can be improved with Gaunt factors presented here. Especialy encouraging are the good results achieved for heavy ions because the complex emiters are difficult to be treated with more sophysticated theoretical approaches.

Table 3. Mean ratios of measured to theoretical Stark shifts for different multiplets. MSE1 are MSE calculations with eqs. (1-3). Other symbols have the same meaning as in Table 1.

Transition		S C	M S E	M S E 1
BeII	2s-2p	1.01±0.25(4)	2.45±0.67(4)	2.55±0.70(4)
MgII	3s-3p	0.57±0.00(2+3^{1})	(2^{1}+3^{2})	(2^{1}+3^{2})
	3p-3d	0.82 (1)	(1^{1})	2.17 (1)
	3p-4s	0.64±0.22(6)	0.97±0.33(6)	0.93±0.34(6)
CaII	4s-4p	0.43±0.21(13)	2.05±1.01(13)	2.11±1.05(13)
	4p-5s	0.75±0.27(10)	1.04±0.38(10)	1.08±0.40(10)
	4p-4d	0.88±0.17(6)	1.45±0.34(6)	1.09±0.21(6)
SrII	5s-5p	0.54±0.11(4)	1.82±0.30(4)	1.90±0.33(4)
	5p-5d		2.20±0.36(4)	0.94±0.07(4)
	5p-6s		0.53±0.00(3)	0.51±0.05(3)
BaII	6s-6p	0.30±0.06(4)	0.93±0.19(4)	0.90±0.21(4)
	5d-6p	(3^{1})	1.21±0.06(3)	1.20±0.06(3)
	6p-6d	0.48±0.09(2)	1.34±0.04(2)	0.64±0.14(2)

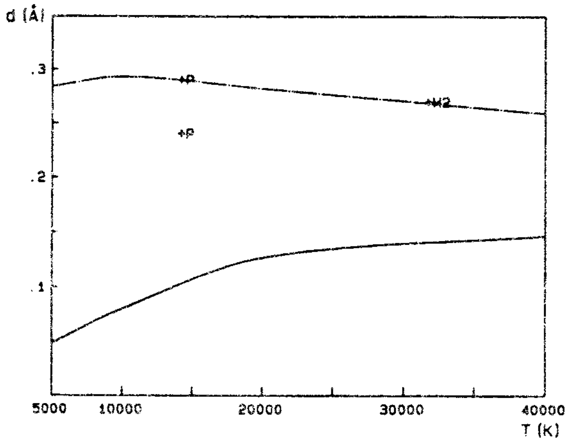

Fig.4. Stark shifts for SrII 5p2P0-5d2D multiplet. Notation is the same as in Fig.1.

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MODIFIED SEMIEMPIRICAL STARK SHIFT EXAMINATION: II. ALCALI-LIKE SINGLY CHARGED ION LINES STARK SHIFTS

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This contribution continues quantitative analysis of the reliability of the modified semiempirical (MSE) method for estimation of ion lines Stark shifts /1/ (see also the preceeding paper /2/). Using the MSE approach, results with good average accuracy in the case of ArII line shifts have been obtained in preceeding papers /2-4/.

The homologous sequence of alcali-like singly charged ions is experimentaly relatively well studied. Critical compilations of the experimental data /5,6/ list about 70 reliable Stark line shift data in 13 multiplets from 9 experiments /7-15/ for BeII, MgII, CaII, SrII and BaII ions. We performed MSE calculations covering all these data and then we made comparisons with experimental results and with semiclassical calculations of Jones et al./16/. Results of these comparisons are given numericaly in Tables 1-3 and few representative cases are displayed in Figs. 1-4.

Mean experimental to theoretical Stark shift ratio of MSE results for 61 line shift measurements is 1.51±0.80 with 4 results with opposite signs of the shifts and 3 results where the theoreticaly predicted shift is zero. The same ratio of the semiclassical results /16/ for 54 line shifts is 0.63±0.28 with 7 results with opposite signs. These averagings were done without experiment /12/ because of the largest discrepancy of its results with the theory (see Table 1). Simmilar values are obtained by averaging the mean results for individual experiments (Table 1).

Table 2 shows that MSE results better agree with experiments for heavy ions than for light ones, unlike the semiclassical results /16/.

MSE formula for the Stark shifts (eq.1. in /2/) treats all perturbing levels with $\Delta n \neq 0$ via the same Gaunt factor for all types of transitions, g_{sh}, as used by Griem /17/. For somewhat more refined analysis, on the basis of calculations /18/, instead of g_{sh} one can suggest Gaunt factor depending on the type of transition viz.

$g_{sh}^{(1)} = 0.5 g_{sh}$ for s-p transitions (1)

$g_{sh}^{(2)} = g_{sh}$ for p-s transitions (2)

$g_{sh}^{(3)} = 2 g_{sh}$ for p-d and other allowed types of transitions. (3)

Table 1. Mean ratios of measured to theoretical alcali like singly charged ions Stark shifts for all experiments considered, together with standard deviations and numbers of line shifts involved. SC are the semiclassical calculations /16,5,6/ and MSE are the present results.

Experiment (Ref.No.)	S C	M S E
/7/	0.59±0.15(14+2[1])	1.56±0.86(20)
/8/	0.72±0.26(11+2[1])	1.84±0.94(15+1[2])
/9/	0.69±0.30(16)	1.43±0.33(13+1[1]+2[2])
/10/	0.22±0.13(4)	1.18±0.78(4)
/11/	0.42±0.06(2+1[1])	0.64±0.09(2+1[1])
/12/	2.21±0.56(3)	4.15±1.17(3)
/13/	0.19 (1)	0.81 (1)
/14/	0.58±0.07(2)	0.80±0.10(2)
/15/	1.16±0.14(2)	1.58±0.18(2)
Mean	**0.75±0.58** (0.57±0.29)[3]	**1.55±1.00** (1.23±0.41)[3]

[1] Theory predicts the opposite sign.
[2] Theoretically predicted shift is zero.
[3] Without experiment /12/.

Table 2. Mean ratios of measured to theoretical Stark shifts for different alcali-like ions. Notation is the same as in Table 1.

Ion	S C	M S E
BeII	1.01±0.25(4)	2.45±0.67(4)
MgII	0.65±0.20(9+4[1])	0.97±0.33(6+4[1]+3[2])
CaII	0.63±0.29(29)	1.58±0.86(29)
SrII	0.54±0.11(4)	1.52±0.71(11)
BaII	0.36±0.11(6+3[1])	1.12±0.22(9)

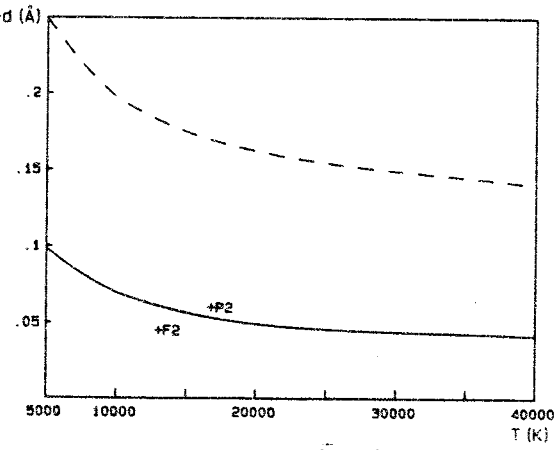

Fig.1. Stark shifts for BaII 6s2S-6p2P0 multiplet. Theoretical curves: --- according to /16/, —— present method, -.- present method with eqs.(1-3). Experimental points: P-/7/, H-/8/, F-/9/, K-/11/. Numbers of line shifts with the same experimental values are indicated.

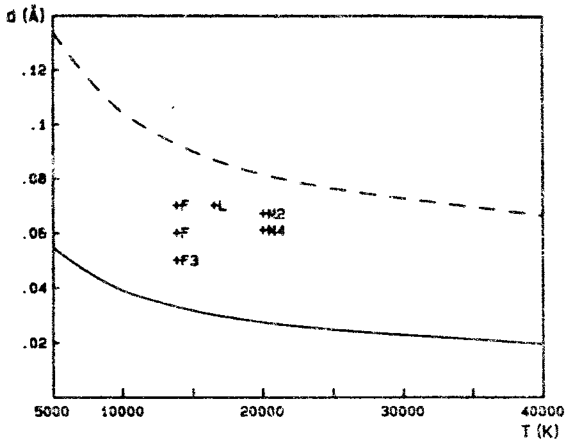

Fig.1. Stark shifts for ArII 3d4D-4p4PO multiplet. Theoretical curves: --- ref./17/, —— present results. Experimental points: F-ref./9/, L-/10/, M-/11/, J-/13/, C-/14/, S-/16/. Numbers of line shifts with the same experimental values are also indicated.

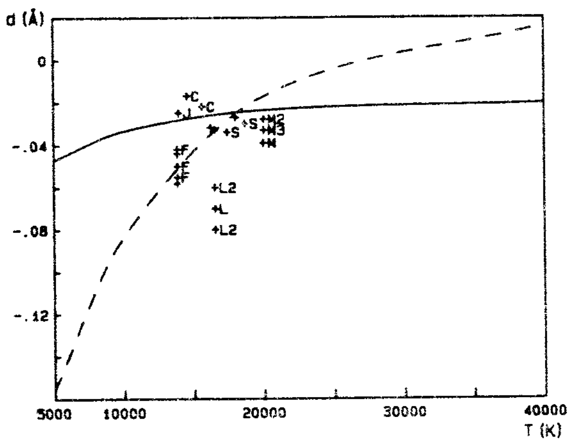

Fig.2. Stark shifts for ArII 4s4P-4p4DO multiplet. Notation is the same as in Fig.1.

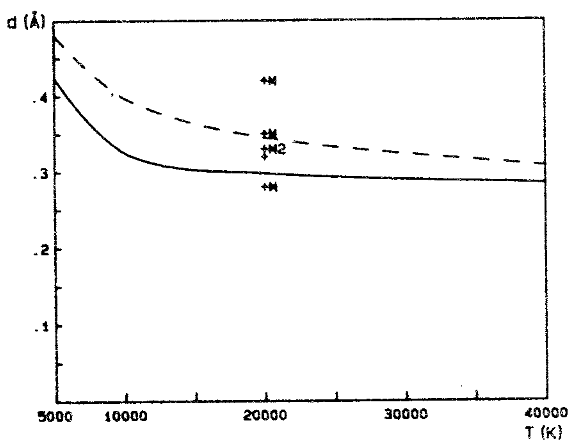

Fig.3. Stark shifts for ArII 4p4pO-5s4P multiplet. Notation is the same as in Fig.1.

for forbidden multiplets and for multiplets with jl coupling involved show the same average accuracy. Because of the considerable simplicity of MSE method, the accuracy achieved for ArII Stark shifts is very encouraging.

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Contributed Papers 2

Tuesday 11th July 1989

ON THE SEMICLASSICAL STARK WIDTHS OF C IV LINES

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Introduction

Several papers have been published recently [1-11] treating Stark broadening of C IV . Moreover, carbon is an astrophysically very important element due to its high cosmical abundance. Broadening of C IV lines, according to the number of the cited references one of the "hot topics" of line shape investigations, is also very important for the laboratory plasma diagnostics, since the carbon is present as impurity in many laboratory plasma sources. Using the semiclassical - perturbation formalism [12,13], we have calculated electron- and proton-impact line widths and shifts for 38 C IV multiplets. As an example of the results obtained, in this paper we present numerical results and analysis of Stark broadening data for two C IV multiplets, where a number of different theoretical and experimental data exist.

Results and discussion

In Table 1, our results for C IV $2s^2S-2p^2P^o$ and $3s^2S-3p^2P^o$, Stark widths (FWHM) with (W_{DSB}), and without (W_{DSB1}) the resonance contribution, are compared with existing experimental values [1-3,6,10] and with the calculations using [9] the modified semiempirical method [14] . We can notice that the resonant contribution, which is only a rough correction, present a substantional part, especially in the case of $2s^2S-2p^2P^o$ multiplet, and that calculations without this contribution agree better with existing experimental values and with quantum mechanical results [11] given in Table 2a.

In Tables 2a and 2b, different calculations of C IV lines are compared with our results. Besides our present calculations with (W_{DSB}) and without (W_{DSB1}) resonances, the recent strong coupling quantum mechanical results (W_{QM}) by Seaton [11], the semiclassical calculations [8] according to Griem's method [15] , approximative semiclassical calculations [7] according to Eq. 526 in Ref. [15] (in original version (W_G), and with modifications (W_{GM}) [14]) and calculations [9] using the modified semiempirical method [14] are presented. We can underline the good agreement of W_{MSE} and W_G with W_{GM}. The agreement of W_{DSB1} and W_{QM} is better for $3s^2S-3p^2P^o$ multiplet, since the semiclassical method is not so good for the ground state, very

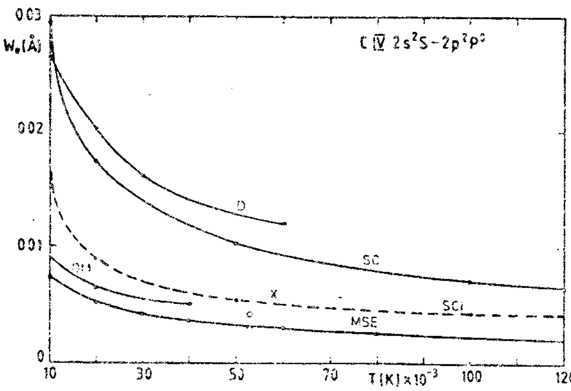

Fig. 1. Full halfwidths for the C IV 2s-2p multiplet as a function of electron temperature: $N=10^{17} cm^{-3}$. Experimental points: X- Bogen (1972) [1]; ⊙ - El-Farra, Hughes (1983) [2]; +- Ackermann et al (1985)[3]; ● - Böttcher et al (1988)[6]; ▲- Djeniže et al (1988)[10]. Calculations: SC- semiclassical (present); SCl- semiclassical without the resonance contribution (present); QM- quantum mechanical (Seaton, 1988) [11] ; D- Dimitrijević(1988) [8]; MSE- modified semiempirical (Dimitrijević 1988)[9].

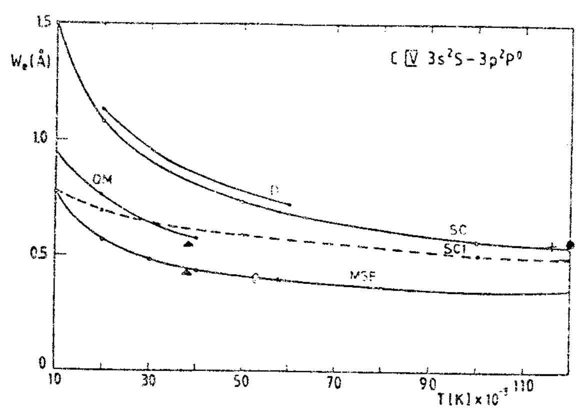

Fig. 2. Same as in Fig. 1 but for C IV $3s^2S-3p^2P^o$ multiplet.

Table 1. Experimental Stark widths (W_M) compared with the theory. The W_{DSB} are present semiclassical calculations; W_{DSB1} are present calculations without the resonant contribution. W_{MSE} are calculations [9] using the modified semiempirical approach [14]. Experimental data are: a- El-Farra, Hughes (1983) [2]; b- Bogen (1972) [1]; c- Djeniže et al (1988) [10]; d- Ackermann et al (1985) [3]; e- Bötcher et al (1988) [6]. Full halfwidths at $N_e = 10^{17} cm^{-3}$ are given.

λ(Å)	T(K)	W_M(Å)(Ref)	W_{DSB}(Å)	W_{DSB1} (Å)	W'_{MSE} (Å)
1548.20	53000	0.29-2(a)	0.10-1	0.54-2	0.30-2
	58000	0.60-2(b)	0.95-2	0.53-2	0.29-2
1550.77	53000	0.42-2(a)	0.10-1	0.54-2	0.30-2
	58000	0.60-2(b)	0.95-2	0.53-2	0.29-2
5801.33	38000	0.55(c)	0.83	0.63	0.46
	53000	0.41(a)	0.72	0.59	0.41
	58000	0.40(b)	0.69	0.58	0.40
	116000	0.56(d)	0.54	0.50	0.36
	145000	0.56(e)	0.52	0.46	0.34

Table 2a. Comparison between different semiclassical and quantum mechanical calculations The W_{DSB} are present semiclassical calculations with resonant contribution and W_{DSB1} without. W_D- Dimitrijević (1988) [8]; W_{QM}- quantum mechanical (Seaton, 1988) [11]. Full halfwidths (FWHM) for C IV lines at $N_e=10^{17} cm$ are given.

Mult.	T(K)	W_{DSB} (Å)	W_{DSB1} (Å)	W_D (Å)	W_{QM} (Å)
2s-2p	10000	0.295-1	0.166-1	0.26-1	0.890-2
	20000	0.173-1	0.892-2	0.20-1	0.653-2
	30000	-	-	0.16-1	-
	40000	-	-	-	0.511-2
	50000	0.103-1	0.552-2	-	-
	60000	-	-	0.12-1	-
	100000	0.717-2	0.442-2		
	200000	0.512-2	0.370-2		
3s-3p	10000	0.150+1	0.787	1.57	0.957
	20000	0.108+1	0.700	1.14	0.764
	30000	-	-	0.954	-
	40000	-	-	-	0.579
	50000	0.735	0.595	-	-
	60000	-	-	0.730	-
	100000	0.567	0.507	-	-
	200000	0.448	0.424	-	-

Table 2b. Comparison between different approximative approaches. W_{MSE}-modified semiempirical approach (Dimitrijević, 1988) [9] ; W_G and W_{GM}-Griem's approximative semiclassical, original and modified version respectively (Dimitrijević, 1988) [7]. Full halfwidths (FWHM) for C IV lines at $N_e = 10^{17} cm^{-3}$ are given

Mult.	T(K)	W_{MSE} (Å)	W_G (Å)	W_{GM} (Å)
2s-2p	10000	0.728-2	0.873-2	0.570-2
	20000	0.515-2	0.627-2	0.417-2
	40000	0.364-2	0.460-2	0.318-2
	80000	0.258-2	0.350-2	0.257-2
	160000	0.187-2	0.281-2	0.224-2
3s-3p	10000	0.776	0.880	0.495
	20000	0.571	0.656	0.402
	40000	0.448	0.511	0.352
	80000	0.368	0.419	0.325
	160000	0.325	0.359	0.307

important in the case of $2s^2S-2p^2P^o$ multiplet.

The case of line shift is more complicated. The only existing experimental value [10] has different sign from quantum mechanical [11] and our semiclassical prediction.

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Contributed Papers 2

Tuesday 11th July 1989

ON THE STARK BROADENING OF Si IV LINES: INFLUENCE OF DIFFERENT COLLISIONAL PROCESSES

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Silicon is often present as impurity in laboratory plasmas and, due to its high abundance, it is also very interesting for astrophysicists. In order to provide Stark broadening data for diagnostic purposes in stellar and laboratory physics, we have calculated electron- and proton-impact line widths and shifts of 36 Si IV multiplets, by using the semiclassical-perturbational formalism [1,2]. In order to investigate the influence of various collisional processes on the Stark broadening, we have calculated also the contribution of elastic inelastic and strong collisions. The needed Si IV energy levels were found in [3].

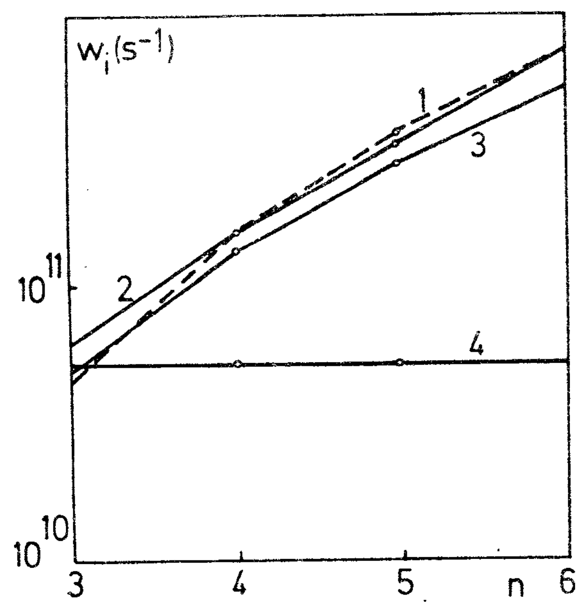

Fig. 1a. Influence of different collisional processes on the Stark widths of Si IV $3s^2S-np^2P^o$ (n=3,4,5,6) lines at electron density $10^{17}cm^{-3}$ and T=50000K. With w_i are denoted different contributions to the Stark width: 1-strong collisions; 2-inelastic, upper level; 3-elastic; 4-inelastic, lower level.

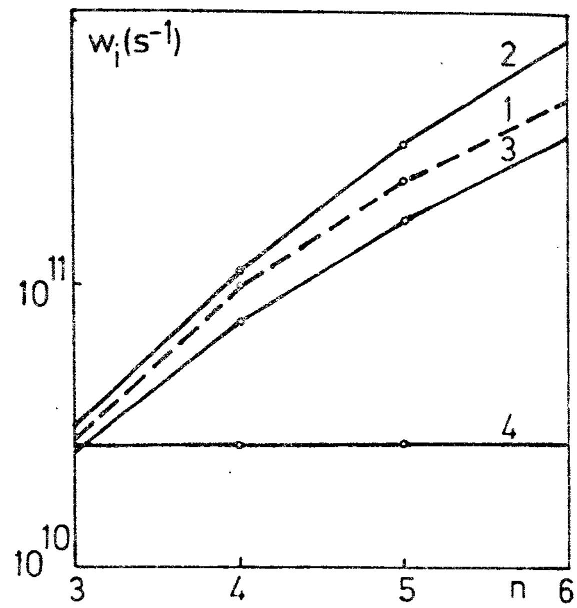

Fig. 1b. Same as 1a but for T=200000 K.

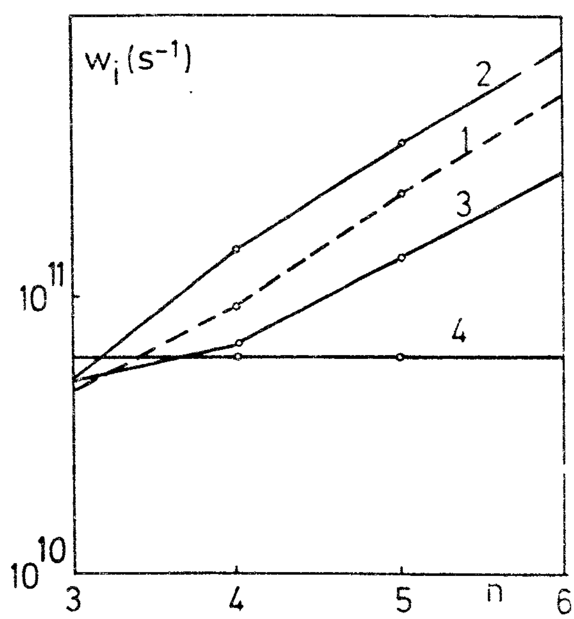

Fig. 2a. Same as 1a but for Si IV $3p^2P^o-nd^2D$

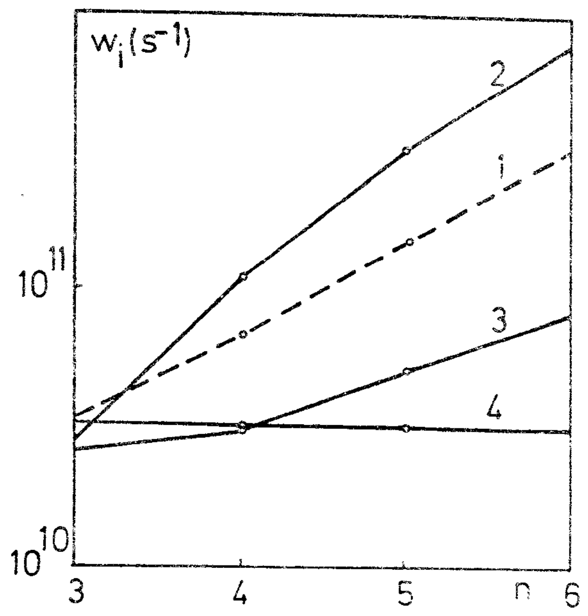

Fig. 2b. Same as 2a but for T=200000 K.

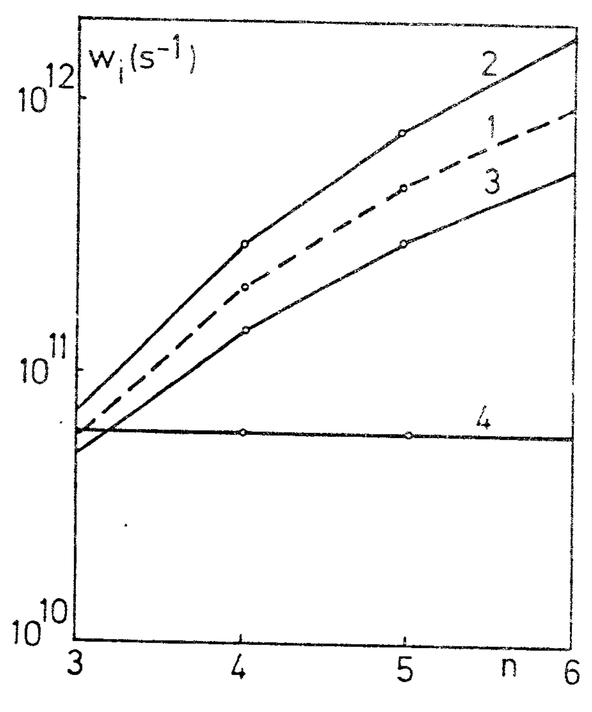

Fig. 3a. Same as 1a but for Si IV $3p^2P^o$–nd^2D

Stark widths due to elastic, inelastic and strong collisions for Si IV $3s^2S$–np^2P^o; $3p^2P^o$–ns^2S and $3p^2P^o$–nd^2D lines (n=3,4,5,6) at T=50000K and 200000K are presented in Figs. 1-3. Strong collision contribution is the sum of strong elastic and strong inelastic ones, while in the case of elastic and

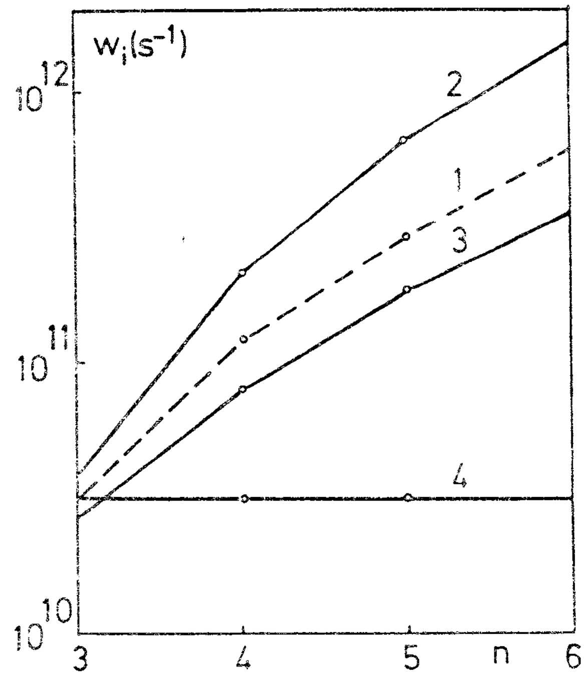

Fig. 3b. Same as 3a but for T=200000K.

inelastic collisions, e.g. elastic is the sum of strong- and weak-elastic contributions. One can see that in the case of $3p^2P^o$–ns^2S and $3p^2P^o$–nd^2D transitions, the contribution of the inelastic collisions is larger and consequently, the semiclassical approximation is better, than in the case of $3s^2S$–np^2P^o transitions. One can see also, that in the case of $3s^2S$–np^2P^o at 50000 K, contribution of strong collisions, which can not be described within the semiclassical approximation, is even dominant for the higher members of the spectral series.

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Contributed Papers 2

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STARK BROADENING ALONG A HOMOLOGOUS SEQUENCE OF EARTH ALKALI -METAL ION LINES

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Introduction

For astrophysical purposes, e.g. for elemental abundance analysis or opacity calculations, data for a large number of spectral lines for various elements and ionization stages are needed. Consequently, methods for a simple estimate of Stark broadening parameters with a good average accuracy for a large number of lines, may be useful.

Another possibility for the critical estimation of experimental values and interpolation of new Stark broadening data, is the investigation of regularities and systematic trends. (e.g. [1] and references therein). For example, a systematic behaviour of Stark broadening parameters, such as gradual variations, are expected in the case of homologous atoms and ions, which exhibit similar atomic structures.

Recently, has been demonstrated [2] that in the case of neutral atom lines, one can find a normalization factor for analogous transitions, which enables to interpolate along the homologous sequence. In this work we derive an analogous formula for ion lines using the earth alkali-metal ion homologous sequence as an example.

Theory

When the nearest perturbing level j' is so far from the initial or final energy level j = i,f that $x_{jj'} = E/|E_{j'} - E_j| \leq 2$ is satisfied, the modified semiempirical formula [3] may be considerably simplified [4].

$$W(\text{Å}) = 2.2151 \times 10^{-8} \frac{\lambda^2(\text{cm})\, N(\text{cm}^{-3})}{T^{1/2}(\text{K})} \times$$

$$\times \left(0.9 - \frac{1.1}{Z}\right) \sum_{j=i,f} \left(\frac{3 n_j}{2Z}\right)^2 (n_j^2 - \ell_j^2 - \ell_j - 1) \quad (1)$$

Here, N and T are the electron density and electron temperature respectively, E=3kT/2 is the energy of perturbing electron, Z-1 is the ionic charge and n is the effective principal quantum number. Such case is of particular interest for astronomical purposes, low temperatures and for transitions between low lying levels.

In the case of singly charged ions, we obtained the following form for the Eq. (1)

$$W(\text{Å}) = 1.7439 \times 10^{-8} \frac{\lambda^2(\text{cm})\, N(\text{cm}^{-3})}{T^{1/2}(\text{K})} \times$$

$$\times \sum_{j=i,f} \frac{E_H}{I_0 - E_j} \left(\frac{4E_H}{I_0 - E_j} - \ell_j^2 - \ell_j - 1\right) \quad (2)$$

where I_0 is the ionization energy and E_i, E_f energies of initial and final levels respectively.

In some cases there exists a linear relationship between the analogous energy level E_j within a homologous sequence and I_0 [2,5].

$$E_j = a_j + b_j I_0 \quad (3)$$

The coefficients a_j, b_j may be determined empirically for the analogous energy levels within a homologous sequence. Now Eq. (2) becomes

$$W(\text{Å}) = 1.7444 \times 10^{-8} \frac{\lambda^2(\text{cm})\, N(\text{cm}^{-3})}{T^{1/2}(\text{K})} \times$$

$$\times \sum_{j=i,f} \frac{E_H}{I_0(1-b_j) - a_j} \left[\frac{4E_H}{I_0(1-b_j) - a_j} - \ell_j^2 - \ell_j - 1\right] \quad (4)$$

From Eq. (4) follows that the full Stark widths for analogous transitions within homologous radiator spectra may be expressed as a function of the ionization potential I_0 and plasma condition parameters. Moreover, we can see that the sum on the right hand side of Eq. (4) may be used as a normalization factor for the critical examination of homologous experimental values devided by λ^2. If ratio of such values and the normalization factor is nearly constant within homologous sequence (at plasma conditions when the used assumptions are valid), we may expect that the available data set is consistent.

We may neglect the lower level contribution in the normalization factor, since this contribution is often negligible and moreover one may expect that the regular behaviour within the homologous sequence is similar for both levels in most cases. The normalization factor is now

$$NF = \frac{E_H}{I_o(1-\ell_i)-a_i}\left[\frac{4E_H}{I_o(1-\ell_i)-a_i} - \ell_i^2 - \ell_i - 1\right] \quad (5)$$

If we have Stark widths for several homologous transitions, we may interpolate a new value by calculating

$$W' = 1.7444\ 10^{-8}\ \frac{\lambda^2(cm)\ N(cm^{-3})}{T^{1/2}(K)}\ NF \quad (6)$$

and than, multiplying the obtained result with the averaged ratio of experimental and calculated values:

$$W = W'\left(\frac{W_{exp}}{W'}\right)_{av} \quad (7)$$

In such a way we also correct the neglecting of the lower level broadening contribution.

Results and discussion

The proposed method is applied to the np - (n+1)s transitions of the earth-alkali ions. We found that the linear relation (Eq. 3) between the ionization potential and the energy levels of interest exist for the case considered. In table 1 we present experimental Stark widths compared with our estimates. We can see that a selfconsistent Stark broadening data set for homologous transitions is obtained. This indicates that the interpolation of new data (e.g. for Sr II from Table 1) may be successful.

Table 1. Normalized values of the experimental full halfwidths (W) at N = 10^{17} cm^{-3} and T = 10000 K, devided by λ^2, compared with simple theoretical estimates: a - obtained using Eq. (6); b- results under a, multiplied with the averaged ratio of experimental and theoretical data. Experimental data are from [6] and [7] for Mg II; [6] and [8] for Ca II and [9] for Ba II.

Element/λ (Å)	$\frac{W}{\lambda^2}$ (10^{-8} Å^{-1}) exp.	th.-a	b
Mg II 2928.75	4.4	3.2	4.1
	4.1	3.2	4.1
2936.54	4.4	3.2	4.1
	4.2	3.2	4.1
Ca II 3706.03	5.9	4.5	5.7
	5.1	4.5	5.7
3736.20	5.8	4.5	5.7
	4.9	4.5	5.7
Ba II 4899.9	7.1	5.6	7.1
4524.9	7.2	5.6	7.1

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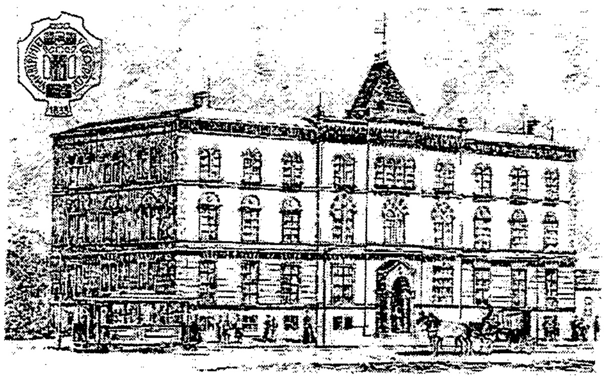

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On the Stark broadening of K IX lines

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ON THE STARK BROADENING OF Ti XII LINES

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Abstract. Using a semiclassical approach, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 27 Ti XII multiplets, for perturber densities $10^{18}-10^{23}$ cm^{-3} and temperatures T = 500,000 – 6,000,000 K.

1. INTRODUCTION

Atomic data on titanium, including Stark broadening parameters of its spectral lines for various ionization stages are of interest for research and modeling of stellar plasma, since this element is present in stars. Particularly Stark broadening data for higher ionization stages are of interest for the consideration of subphotospheric layers [1]. Such data are as well of interest e.g. for fusion plasma research and for investigations of systematic trends along isoelectronic sequences.

By using the semiclassical-perturbation formalism [2,3], we have calculated electron-, proton-, and He III-impact line widths and shifts for 27 titanium XII multiplets. A description of the used formalism is given e.g. in Refs. 4 and 5.

2. RESULTS AND DISCUSSION

Energy levels for titanium XII lines have been taken from Ref. 6. All other details of calculations are given in Ref. 7. Our results for electron-, proton-, and He III-impact line widths and shifts for 27 titanium XII multiplets, for perturber densities $10^{18}-10^{23}$ cm^{-3} and temperatures T = 500,000 – 6,000,000 K, will be published elsewhere [7]. We present here in Table 1, only a sample of data for perturber density of 10^{19} cm^{-3}. We also specify a parameter C [8], which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding full width at half maximum.

Table 1. This table shows electron- and proton-impact broadening full half-widths (FWHM) and shifts for Ti XII for a perturber density of 10^{19} cm^{-3} and temperatures from 500,000 up to 6,000,000 K. By deviding C with the full linewidth, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
TiXII3S 3P	500000.	0.193E-01	-0.226E-03	0.289E-03	-0.252E-03
466.9 A	750000.	0.160E-01	-0.267E-03	0.473E-03	-0.367E-03
C=0.47E+22	1000000.	0.141E-01	-0.306E-03	0.630E-03	-0.464E-03
	2000000.	0.105E-01	-0.285E-03	0.105E-02	-0.718E-03
	4000000.	0.798E-02	-0.275E-03	0.152E-02	-0.988E-03
	6000000.	0.689E-02	-0.272E-03	0.173E-02	-0.110E-02
TiXII3S 4P	500000.	0.149E-02	0.882E-05	0.810E-04	0.111E-04
82.2 A	750000.	0.125E-02	0.108E-04	0.106E-03	0.160E-04
C=0.56E+20	1000000.	0.111E-02	0.107E-04	0.123E-03	0.197E-04
	2000000.	0.848E-03	0.102E-04	0.159E-03	0.293E-04
	4000000.	0.668E-03	0.957E-05	0.185E-03	0.398E-04
	6000000.	0.588E-03	0.857E-05	0.203E-03	0.442E-04
TiXII3S 5P	500000.	0.174E-02	0.370E-04	0.177E-03	0.491E-04
60.7 A	750000.	0.149E-02	0.345E-04	0.215E-03	0.612E-04
C=0.15E+20	1000000.	0.133E-02	0.345E-04	0.234E-03	0.708E-04
	2000000.	0.105E-02	0.327E-04	0.270E-03	0.897E-04
	4000000.	0.852E-03	0.299E-04	0.314E-03	0.108E-03
	6000000.	0.763E-03	0.264E-04	0.339E-03	0.120E-03
TiXII4S 4P	500000.	0.386	-0.950E-02	0.191E-01	-0.130E-01
1204.5 A	750000.	0.326	-0.993E-02	0.252E-01	-0.170E-01
C=0.12E+23	1000000.	0.291	-0.894E-02	0.299E-01	-0.193E-01
	2000000.	0.226	-0.875E-02	0.401E-01	-0.259E-01
	4000000.	0.179	-0.815E-02	0.499E-01	-0.310E-01
	6000000.	0.158	-0.713E-02	0.573E-01	-0.344E-01

Table 1 continued

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
TiXII4S 5P	500000.	0.197E-01	0.827E-04	0.180E-02	0.152E-03
194.8 A	750000.	0.168E-01	0.351E-04	0.218E-02	0.207E-03
C=0.15E+21	1000000.	0.151E-01	0.607E-04	0.236E-02	0.251E-03
	2000000.	0.119E-01	0.506E-04	0.271E-02	0.348E-03
	4000000.	0.970E-02	0.408E-04	0.316E-02	0.433E-03
	6000000.	0.869E-02	0.374E-04	0.343E-02	0.481E-03
TiXII5S 5P	500000.	3.79	-0.128	0.326	-0.213
2455.8 A	750000.	3.27	-0.125	0.405	-0.264
C=0.25E+23	1000000.	2.95	-0.122	0.443	-0.292
	2000000.	2.36	-0.118	0.543	-0.349
	4000000.	1.92	-0.974E-01	0.673	-0.416
	6000000.	1.72	-0.836E-01	0.768	-0.456
TiXII3P 4S	500000.	0.159E-02	0.105E-03	0.586E-04	0.131E-03
108.8 A	750000.	0.134E-02	0.114E-03	0.105E-03	0.167E-03
C=0.98E+20	1000000.	0.120E-02	0.108E-03	0.129E-03	0.191E-03
	2000000.	0.923E-03	0.105E-03	0.230E-03	0.249E-03
	4000000.	0.726E-03	0.982E-04	0.311E-03	0.299E-03
	6000000.	0.636E-03	0.879E-04	0.365E-03	0.331E-03
TiXII3P 5S	500000.	0.128E-02	0.167E-03	0.144E-03	0.228E-03
71.8 A	750000.	0.110E-02	0.162E-03	0.210E-03	0.278E-03
C=0.21E+20	1000000.	0.999E-03	0.160E-03	0.266E-03	0.302E-03
	2000000.	0.797E-03	0.154E-03	0.362E-03	0.362E-03
	4000000.	0.642E-03	0.132E-03	0.477E-03	0.432E-03
	6000000.	0.567E-03	0.115E-03	0.543E-03	0.471E-03

Table 1 continued

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
TiXII3P 6S	500000.	0.182E-02	0.302E-03	0.394E-03	0.474E-03
61.2 A	750000.	0.160E-02	0.302E-03	0.489E-03	0.537E-03
C=0.84E+19	1000000.	0.146E-02	0.295E-03	0.559E-03	0.579E-03
	2000000.	0.118E-02	0.274E-03	0.722E-03	0.690E-03
	4000000.	0.962E-03	0.223E-03	0.946E-03	0.799E-03
	6000000.	0.851E-03	0.193E-03	0.105E-02	0.864E-03

Presented results are the first Stark broadening data concerning titanium XII spectral lines. We hope that such data will be of interest for astrophysical and laboratory plasma research, as well as for the theoretical considerations of systematic trends along isoelectronic sequences and for fusion plasma research.

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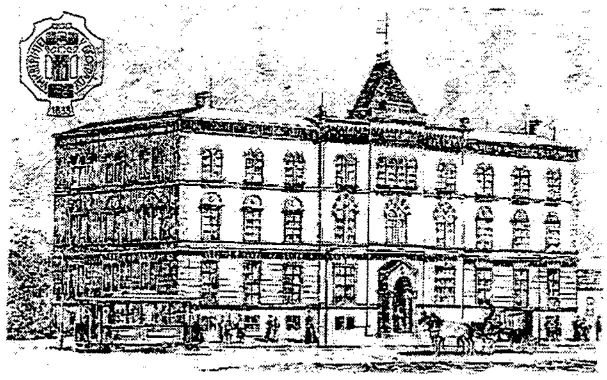

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On the Stark broadening of K IX lines

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ON THE STARK BROADENING OF K IX LINES

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Abstract. Using a semiclassical approach, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 30 K IX multiplets, for perturber densities 10^{18}– 10^{22} cm^{-3} and temperatures T = 200,000 – 5,000,000 K.

1. INTRODUCTION

Spectral lines of potassium are present in Solar [1] and stellar spectra [2], as e.g. in SN 1987 A ejecta [3]. Potassium is a product of alpha processes - neutron capture on slow time scale, and the data on the spectral line broadening parameters of potassium in various ionization stages are of interest for the considering and modelling of subphotospheric layers [4]. Such data are as well of interest for the fusion plasmas and laser-produced plasmas research and for the investigation of soft X-ray lasers (see e.g. Refs. 5 and 6).

By using the semiclassical-perturbation formalism [7,8], we have calculated electron-, proton-, and He III-impact line widths and shifts for 30 potqssium IX multiplets. A description of the used formalism is given e.g. in Refs. 9 and 10.

2. RESULTS AND DISCUSSION

Energy levels for potassium IX lines have been taken from Ref. 11. All other details of calculations are given in Ref. 12. Our results for electron-, proton-, and He III-impact line widths and shifts for 30 potassium IX multiplets, for perturber densities 10^{18}– 10^{22} cm^{-3} and temperatures T = 200,000 – 5,000,000 K, will be published elsewhere [12]. We present here in Table 1, only a sample of data for perturber density of 10^{19} cm^{-3}. We also specify a parameter C [13], which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding full width at half maximum.

Table 1. This table shows electron- and proton-impact broadening full half-widths (FWHM) and shifts for K IX for a perturber density of 10^{19} cm^{-3} and temperatures from 200,000 up to 5,000,000 K. By deviding C with the full linewidth, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used. Values for $0.1 < NV \leq 0.5$ are denoted by an asterisk.

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
K IX 3S 3P	200000.	0.664E-01	-0.800E-03	0.649E-03	-0.479E-03
626.3 A	500000.	0.433E-01	-0.861E-03	0.186E-02	-0.114E-02
C=0.63E+22	1000000.	0.323E-01	-0.971E-03	0.301E-02	-0.180E-02
	2000000.	0.248E-01	-0.902E-03	0.424E-02	-0.248E-02
	3000000.	0.215E-01	-0.867E-03	0.472E-02	-0.277E-02
	5000000.	0.182E-01	-0.817E-03	0.542E-02	-0.319E-02
K IX 3S 4P	200000.	0.738E-02	0.494E-04	0.304E-03	0.407E-04
131.7 A	500000.	0.499E-02	0.731E-04	0.544E-03	0.905E-04
C=0.10E+21	1000000.	0.384E-02	0.608E-04	0.687E-03	0.133E-03
	2000000.	0.305E-02	0.569E-04	0.784E-03	0.177E-03
	3000000.	0.271E-02	0.590E-04	0.846E-03	0.197E-03
	5000000.	0.236E-02	0.491E-04	0.926E-03	0.224E-03
K IX 3S 5P	200000.	0.903E-02	0.159E-03	0.732E-03	0.168E-03
98.8 A	500000.	0.635E-02	0.195E-03	0.105E-02	0.293E-03
C=0.28E+20	1000000.	0.506E-02	0.191E-03	0.121E-02	0.373E-03
	2000000.	0.414E-02	0.184E-03	0.136E-02	0.451E-03
	3000000.	0.373E-02	0.164E-03	0.144E-02	0.496E-03
	5000000.	0.330E-02	0.137E-03	0.156E-02	0.551E-03
K IX 4S 4P	200000.	1.44	-0.266E-01	0.509E-01	-0.300E-01
1657.9 A	500000.	0.991	-0.342E-01	0.950E-01	-0.541E-01
C=0.17E+23	1000000.	0.775	-0.324E-01	0.123	-0.735E-01
	2000000.	0.623	-0.314E-01	0.147	-0.881E-01
	3000000.	0.554	-0.281E-01	0.165	-0.977E-01
	5000000.	0.483	-0.238E-01	0.190	-0.111

Table 1 continued

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
K IX 4S 5P	200000.	0.104	0.380E-03	0.759E-02	0.567E-03
319.4 A	500000.	0.737E-01	0.337E-03	0.109E-01	0.115E-02
C=0.30E+21	1000000.	0.590E-01	0.432E-03	0.123E-01	0.160E-02
	2000000.	0.484E-01	0.424E-03	0.139E-01	0.197E-02
	3000000.	0.436E-01	0.318E-03	0.147E-01	0.218E-02
	5000000.	0.386E-01	0.257E-03	0.160E-01	0.247E-02
K IX 5S 5P	200000.	15.1	-0.492	0.965	-0.566
3448.3 A	500000.	10.9	-0.481	1.45	-0.886
C=0.34E+23	1000000.	8.78	-0.460	1.74	-1.08
	2000000.	7.23	-0.411	2.10	-1.29
	3000000.	6.51	-0.362	2.31	-1.40
	5000000.	5.73	-0.298	2.59	-1.51
K IX 3P 4S	200000.	0.923E-02	0.502E-03	0.197E-03	0.472E-03
185.4 A	500000.	0.634E-02	0.650E-03	0.580E-03	0.839E-03
C=0.21E+21	1000000.	0.493E-02	0.611E-03	0.102E-02	0.110E-02
	2000000.	0.392E-02	0.585E-03	0.135E-02	0.132E-02
	3000000.	0.346E-02	0.545E-03	0.156E-02	0.147E-02
	5000000.	0.297E-02	0.466E-03	0.190E-02	0.164E-02
K IX 3P 5S	200000.	0.780E-02	0.887E-03	0.561E-03	0.860E-03
121.5 A	500000.	0.562E-02	0.926E-03	0.119E-02	0.132E-02
C=0.43E+20	1000000.	0.450E-02	0.896E-03	0.159E-02	0.162E-02
	2000000.	0.366E-02	0.823E-03	0.205E-02	0.191E-02
	3000000.	0.325E-02	0.729E-03	0.238E-02	0.209E-02
	5000000.	0.280E-02	0.607E-03	0.274E-02	0.229E-02

There is not experimental data concerning the Stark broadening of K K IX spectral lines. Exists however, a prediction for K IX $4s^2S$ - $4p^2P^o$ Stark width [14], obtained with the help of established regularities of the Stark widths along Na isoelectronic sequence. For T = 500 000 K and an electron density of 10^{17} cm^{-3}, Djeniže and Labat

(1996) obtained for the Stark full width (FWHM) the value of 0.0057±25% Å, while the present result is 0.0099 Å. We hope that the presented data will be of interest for some problems in stellar and laboratory plasma research, especially for subphotospheric layers consideration, investigation and modeling of fusion and laser-produced plasmas, and of soft x-ray lasers, as well as for the checking and development of the Stark broadening theory for multicharged ion line shapes, as e.g. for investigations of systematic trends along isoelectronic sequences.

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THE PHYSICS OF IONIZED GASES

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SEMIEMPIRICAL STARK LINEWIDTHS OF ALKALI LIKE IONS

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For evaluation of Stark widths and shifts of non-hydrogenic spectral lines of ionized atoms, various theoretical approaches have been used[1]. Most of these approaches require a considerable labor even for the evaluation of a single linewidth. Whenever large number of theoretical data of the linewidths are required (e.g. opacity evaluations) tedious calculations can be avoided if one uses simple approximative formulas.

In 1968. Griem[2] suggested simple semiempirical impact approximation based upon Baranger's original formulation together with the effective Gaunt factor approximation as proposed by Seaton and Van Regemorter. For singly ionized atoms semiempirical formula agrees in average within 50% with the experiment[1]. For multiply ionized atoms the agreement becomes worse and few attempts have been made to extend the applicability of this approach to higher ionization stages[3,4].

The aim of this paper is to test the applicability of recently derived effective Gaunt factor values[5] for evaluation of Stark widths of alkali like ions. To achieve this in semiempirical formula we have separated transitions to the perturbing levels in three groops: a) $\Delta n=0$, $\ell\to\ell+1$ b) $\Delta n=0$, $\ell\to\ell-1$ and c) $\Delta n\neq0$ and within each group matrix elements are treated lumped together. For the transitions with $\Delta n=0$ effective Gaunt factor g is calculated from the following expression[5]

$$g = (1 - \frac{1}{Z_e})(0.7 + \frac{1}{n})\ [0.6+0.25\ \ell n(\frac{E}{\Delta E_{ij}})] \qquad (1)$$

Here Z_e is the effective charge ι ion and n is the principal quantum number. For transitions w.th $\Delta n \neq 0$, g=0.2 at threshold is retained and the energy separation to the nearest perturbing level $E_{n,n+1}$ is taken as

$$\Delta E_{n,n+1} \approx \frac{2Z^2 E_H}{n^3} \quad .$$

At higher electron temperatures, Gaunt factor for transitions with $\Delta n \neq 0$ is derived from the GBKO high temperature limit

$$g(T) = \frac{\sqrt{3}}{\pi} \left[\frac{1}{2} + \ln \left(\frac{nKT}{ZE_H} \right) \right]$$

For the space reasons, only results for an average ratio of experimental, W_m, and theoretical results for singly and triply ionized atoms are given:

singly ionized: $W_m/W_{th} = 1.20$ $W_m/W_{g=0.2} = 1.27$

triply ionized: $W_m/W_{th} = 1.24$ $W_m/W_{g=0.2} = 1.86$

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AN INVESTIGATION OF e - He DOUBLE IONIZATION NEAR THE THRESHOLD: THE CLASSICAL TRAJECTORIES METHOD

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Nonstatistical classical trajectories calculations have been carried out in order to investigate some features of double ionization for e-He collisions, for the impact electron energies: $2 < E_e < 6.5$ eV. The computer code due to Abrines et al.[1] has been modified for that purpose, so that motion of three identical charged particles in the presence of Coulomb field can be treated. The integration subroutine has been converted to double precision so as to achieve high acuracy, which has been better than 99% in the total energy computed. As in earlier calculations, the total angular momentum of the system was chosen to be zero (plane case). In addition, He nucleus was assumed infinitely heavy. The extended Bohr's He model (see, e.g.[2]), shown in Fig. 1, has been adopted, with the ground energy -83.31 eV, as compared with experimental value -78.98 eV. This model assures a good numerical stability for e-He collisions.

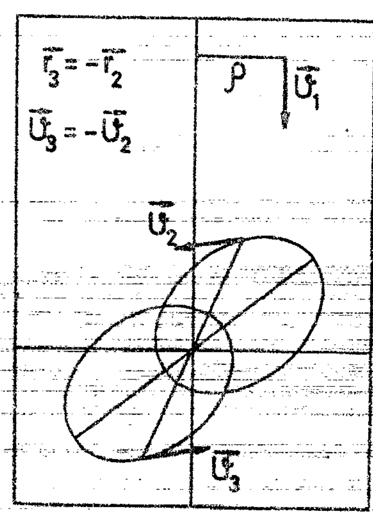

Figure 1. Classical model for the electron-helium collisions.

Ionization intervals along the time parameter axis (see, e.g.[3]), have been examined for a number of the impact energies and the typical results are shown in Fig. 2. Numerical results reveal several interesting features: 1. Final configurations possess axial, rather than central symmetry. 2. The energy distributions appear uniform, but do not cover the entire possible range (O,E). 3. Angular momenta of "symmetrical electrons" acquire large values (with approximately equal magnitudes), as different from the third electron, moving along the axis of symmetry.

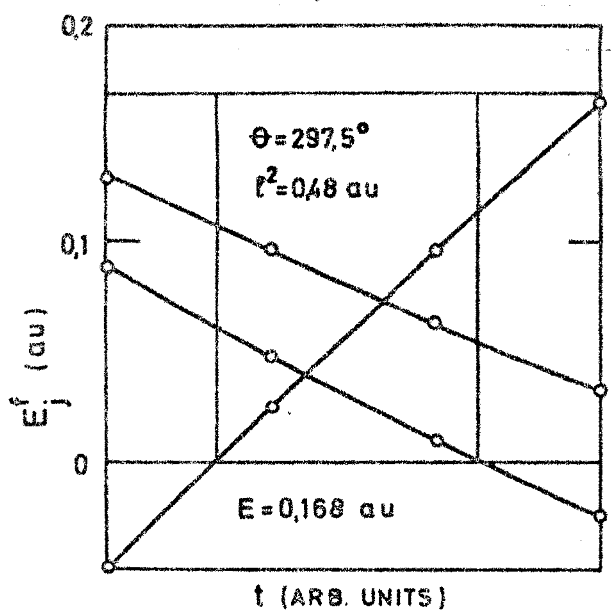

Figure 2. Electron final energies in the double ionization threshold vicinity.

Capability of the present method for deriving the ionization threshold law, as well as the relevant experimental situation, will be discussed.

We are grateful to Professor I. Percival and Dr. N. Valentine for providing us with the original computer code. Thanks are due to Dr. S. Cvejanović, who participated at an early stage of the modification of the program, and for valuable comments.

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The Project for the Stark Broadening Parameter Determination within the Modified Semiempirical Approach: Ag II

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Investigations of the Stark line broadening parameters are important for a number of problems in laboratory and astrophysical plasma research as e.g. analysis and synthesis of stellar spectra and modeling of stellar atmospheres and spectra. The Belgrade group (M. S. Dimitrijevic, L. C. Popovic, V. Krsljanin, D. Tankosic and N. Milovanovic) uses the modified semiempirical approach [1] in order to complete a set of the Stark broadening data in the case when the energy level data, needed for the reliable semiclassical calculation, are not completed. Up to now, this group has performed Stark broadening parameter calculations for Ar II, Fe II, Pt II, Bi II, Zn II, Cd II, As II, Br II, Sb II, I II, Xe II, La II, Au II ,Eu II,Ti II, Kr II, Na II ,Y II, Zr II, Sc II, Ra II, Be III, B III, S III, C III, N III, O III, F III, Ne III, Na III, Al III, Si III, P III, S III, Cl III, Ar III, Mn III, Ga III, Ge III, As III, Se III, Zn III, Mg III, La III, V III, Ti III, Bi III, Sr III, Cu III, Co III, B IV, Cu IV, Ge IV, C IV, N IV, O IV, Ne IV, Mg IV, Si IV, P IV, S IV, Cl IV, Ar IV, V IV, Ge IV, C V, O V, F V, NeV, Al V, Si V, N VI, F VI, Ne VI, Si VI, P VI and Cl VI spectral lines [2], using the modified semiempirical approach.

Here we present the Stark broadening data for 44 Ag II spectral lines calculated within the modified semiempirical approach. Calculations were performed for an electron density of 10^{23} m^{-3}, within the temperature range 5000-50000 K. Energy level data were taken from Ref. [3]. Oscillator strengths have been calculated by using the method of Bates and Damgaard [4]. As an example, in Table 1 the Stark broadening parameters for the $5s^1D_2 - 5p^1P_1^o$ Ag II spectral line, as a function of temperature, are shown.

Table 1

Element	Transition	T (K)	W (nm)	d (nm)
Ag II	$5s^1D_2 - 5p^1P_1^o$ λ= 228.07nm	5000	0.659E-02	-0.127E-03
		10000	0.459E-02	-0.812E-04
		20000	0.318E-02	-0.440E-04
		30000	0.256E-02	-0.237E-04
		40000	0.221E-02	-0.926E-05
		50000	0.199E-02	-0.399E-05

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STARK WIDTHS AND SHIFTS OF THE Kr III SPECTRAL LINES

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In this work we will present measured and calculated Stark FWHM (full-width at half intensity maximum, W) and Stark shift (d) values of eleven Kr III spectral lines. Stark width values of seven Kr III lines from these were not known before. The present d values of Kr III lines are the first publication, with reliably determined plasma parameters, in this topic.

Measurements have been performed at 17 000 K electron temperature and 1.65×10^{23} m^{-3} electron density in krypton plasma created in the linear, low pressure pulsed arc discharge [1-3]. The W and d values have been calculated within the frame of the modified semiempirical method [4-7] for the electron temperature range between 10 000 K and 70 000 K.

Table 1. Measured Stark FWHM (W_m) and shift (d_m) values for the Kr III lines at an electron temperature (T) of 17 000 K and electron density (N) of 1.65×10^{23} m^{-3}. W_m/W_{th} presents the ratio between our measured (W_m) and calculated (W_{th}) values. Positive shift is toward the red [3].

Transition	Multiplet	λ [nm]	W_m [nm]	d_m [nm]	W_m/W_{th}
5s-5p	$^5S^o_2$-$^5P_1$	335.19	0.0308	0.0032	1.09
	$^5S^o_2$-$^5P_2$	332.58	0.0290	0.0031	1.04
	$^5S^o_2$-$^5P_3$	324.57	0.0300	0.0026	1.13
	$^3S^o_1$-$^3P_2$	350.74	0.0328	0.0020	0.99
5s'-5p'	$^3D^o_2$-$^3D_2$	343.95	0.0306	0.0021	1.01
	$^3D^o_1$-$^3F_2$	326.85	0.0261		1.20
	$^3D^o_3$-$^3F_4$	326.49	0.0214	0.0015	0.99
	$^3D^o_3$-$^3P_2$	302.44	0.0280	0.0011	0.91
5s"-5p"	$^3P^o_2$-$^3D_3$	337.49	0.0480	0.0013	1.45
	$^3P^o_2$-$^3P_2$	304.69	0.0395	0.00	1.45
4d"-5p"	$^3D^o_2$-$^3D_3$	302.23	0.0455	0.00	

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Stark Broadening Effect and Zirconium Conflict Problem

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.The elctron-impact broadening is the main pressure broadening mechanism in early-type star atmospheres [1]. The available abundance analysis show that about 10% - 20% of A and B type stars have abundance anomalies (CP stars). Study of HgMn stars show that Zirconium is often overabundant in these stars. Zirconium abundance determination from Zr II and Zr III lines is quite different in HgMn star x Lupi [2,3]. This effect is so called "zirconium conflict" and it was supposed that this difference is probably due to non adequate use of theoretical stellar models, e.g. if the influence on non-LTE effects or diffusion are not taken into account [3]. In order to investigate this conflict we, have calculated Stark broadening widths for two Zr II and Zr III lines using Modified Semiempirical Method [4,5]. After that, we have synthesized the line profiles using SYNTH code and Kurucz's ATLAS9 code for stellar atmosphere model (T_{eff}=10000 K, log g=4.0) which is similiar with atmosphere of x Lupi star [6]. In the table below we present ratios of equivalent widths (EW) of two Zr II and Zr III lines calculated with Stark broadening effect $(EW)_{ST}$ and without it $(EW)_O$ as a function of zirconium abundance.

$\log(N_{Zr}/N_H)$	Zr II 232.4 nm $(EW)_{ST}/(EW)_O$	Zr II 138.85 nm $(EW)_{ST}/(EW)_O$	Zr III 194.104 nm $(EW)_{ST}/(EW)_O$	Zr III 194.025 nm $(EW)_{ST}/(EW)_O$
-6.0	1.06194	1.07319	1.17196	1.21052
-6.5	1.03249	1.03775	1.09889	1.13592
-7.0	1.01660	1.01936	1.04868	1.07268
-7.5	1.00926	1.01037	1.02325	1.03549
-8.0	1.00473	1.00594	1.01151	1.01749

As one can see from table the electron-impact broadening effect is more important in the case of higher abundance of zirconium. The EW increases with abundance for all lines, but EW for Zr III is more sensitive than for Zr III lines. It may cause error in abundance determination in the case where Stark broadening effect is not taken into account. Although the zirconium conflict in HgMn star x Lupi cannot be explained only by this effect, one should take into account that this effect may cause errors in abudance determination.

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DETERMINATION OF ELECTRICAL CONDUCTIVITY OF PLASMA ON THE BASIS OF THE CUT - OFF COULOMB POTENTIAL MODEL

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Introduction

Determination of local electro-conductivity, based on measurements of obtained plasma parameters, is still based on a chosen model and depends on it. This considers the model way of describing collective effects which are conditions for ecranizing of a field of ions by electrical particles that surround it. Usually, the Debye potential is used as a model potential. However, when electronic density grows in relatively low temperature of plasma, we have the range in which using of the Debye potential isn't justified any more. (For example, when $N_e=1,41\cdot10^{18}$ cm^{-3} and T= 13750 K $N_D=2$)(Ref. 1) Because of that there is a question of choice of some other model. One of the simpliest is the screened Coulomb potential(Refs. 2,3)

$$U_c(r)=\begin{cases} -e^2/r + e^2/r_c, & r \le r_c, \\ 0, & r > r_c, \end{cases} \quad (1)$$

where r is the distance between electron and the origin of the fixed coordinate system, and r_c is the screening radius, which is the parameter.

This potential is used when determining electroconductivity, but its application is a bit harder because for every single case it requires numerical calculation.

In this paper we should show that this potential could be very useful for interpretation of experimental results. At the same time, we should show that its application requires only a determination of a parameter which replaces the parameters of the Coulomb type of logarithm, and so on, and which could be tabled in a such way that it could be easily used for concrete estimation. We should pay attention longer to the case of fully ionized hydrogenical plasma.

Basis of the calculations

A component that is necessary when calculating electroconductivity is an electron distribution function in the presence of the electric field. We will take it as:

$$f(v;E)=f_0(v)+f_1(v)\cos\theta, \quad (2a)$$

where

$$f_0(v)=N_e(2\pi kT/m)^{-3/2}\exp(-mv^2/2kT), \quad (2b)$$

$$f_1(v)=(eE/m)df_0(v)/dv\left[N_i v\sigma_{tr}(v)\right]^{-1}, \quad (2c)$$

θ is the angle between the direction of the electric field and the speed. Further, we consider that $N_e=N_i$: By $\sigma_{tr}(v)$ we denote the cross section for transport of impulses by the electron scattering on ions.

Now, if j is the current density, then(Ref.4)

$$j=-(4\pi/3)e\int_0^\infty v^3 f_1(v)dv, \quad (3)$$

from which it follows, in accordance with (2a) and (2b), that:

$$j=(4e^2/m)\left[3(2\pi kT/m)^{1/2}\right]^{-1}\int_0^\infty \frac{x\exp(-x)dx}{\sigma_{tr}(kT\,x)}E, \quad (4)$$

where $x=(mv^2/2)/(kT)$, and the transport cross section is taken to be the energy function.

From these it follows that:

$$j=\sigma^*(T)E \quad (5)$$

where $\sigma^*(T)$ is the plasma conductivity which we write by expression:

$$\sigma^*(T)=(4e^2/3m)\left[\pi r_c^2(2\pi kT/m)^{1/2}\right]^{-1}\chi(T_c), \quad (6)$$

where T_c=kTr_c/e^2, and $\chi(T_c)$ is the universal undimensional function, given by expression:

$$\chi(T_c)=\int_0^\infty\frac{x\exp(-x)dx}{\tilde{\sigma}^{cl}_{tr}(x\cdot T_c)} \quad (7)$$

where $\tilde{\sigma}^{cl}_{tr}\equiv\sigma^{cl}_{tr}\cdot(\pi r_c^2)^{-1}$. The electron-electron scattering should be taken into account by introducing Spitcer's factor $\gamma = 1.72^{-1}$, and conductivity, in this case, should be denoted by $\sigma^*_\gamma(T)$, where $\sigma^*_\gamma(T)\equiv\sigma^*(T)\gamma$.

The usage of the Spitcer's factor for e - e scattering seems to be inconsistency, and the authors of the paper are conscious of that. The excuse for that is that, in the paper, there is the limited aim - to show that with a corresponding choice of cut-off radius, it could be possible to obtain an agreement of the experiment and the calculation. Because of that, it is aimless to calculate more precisely, already in this phase, the influence of e - e scattering. It is needed in the further theoretical research, to obtain that influence in consistent way, as well as it is the case with e - i scattering.

In the case of the potential (1) the simpliest expression for transport cross section is obtained using the classical method. So, it follows that:

$$\sigma_{(tr)}=\pi r_c^2\,\tilde{\sigma}_{(tr)} \quad (8)$$

where:

$$\tilde{\sigma}^{(cl)}_{(tr)}(\varepsilon)=(2/S_c)\left[1+(1-S_c)\,S_c^{-1}\ln(1-S_c)\right], \quad (9)$$

where $S_c\equiv4\varepsilon_c(1-\varepsilon_c)$, $\varepsilon_c\equiv\varepsilon\cdot r_c$, and ε is the energy of the free electron.

However, the performed qantuum -mechanical calculations show that the expression for transport cross sections (9) is very good for the energy range of the strike electrons $\varepsilon > \frac{0.5}{r_c}$.

In the last paper (Ref.4) we showed that in obtaining transport cross section, there was a very good agreement of the classical and the quantuum-mechanical methods results, when $\varepsilon \gtrsim 0.5/r_c$.

Here we consider $kTr_c/e^2 >> 1$, so that the range where $\varepsilon < e^2/r_c$ is not of importance. This gives a possibility of the determination of the factor (7) with help of analitical expression (9), under these presumptions.

Results of the calculations

Results of the calculations of the factors could be given in a table for the determined concentration of electric particles and temperature, taking $x=r_c/r_D$, as a parameter, where r_D is the Debye radius for determined n_e and T. As example, there are given the values for three concentrations and temperatures in the range of $1<x<4$ (Table 1).

We also show (Ref.4) that the results of theoretical estimations, (Refs.5,6) experimental results (Ref.1) and the intervals in which the determined $\sigma^*_\gamma(T_c)$ change with the corresponding changes of the parameter $x \equiv r_c/r_D$, where r_D is the Debye radius. From the above mentioned results it follows that, by the appropriate choice of r_c, a good agreement of experimental and here obtained conductivities could be achieved. The importance of this result is that the parameter r_c could be determined independently (from optical measurements), and then conductivity is determined automaticaly, without any other presumption in connection with the screening mechanism.

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Table 1:

x	T= 15400 K n_e=0.34*		T= 18750 K n_e=1.41*		T= 21500 K n_e=1.51*	
	r_c	S_c	r_c	S_c	r_c	S_c
1.0	124.5	65.589	106.0	70.813	109.7	95.349
1.1	136.9	73.516	116.6	83.608	120.7	112.55
1.2	149.4	91.302	127.2	97.239	131.6	131.00
1.3	161.8	104.93	137.8	111.77	142.6	150.69
1.4	174.3	119.40	148.4	127.20	153.6	171.60
1.5	186.7	134.68	159.0	143.50	164.5	193.70
1.6	199.1	150.78	169.6	160.67	175.5	217.00
1.7	211.6	167.68	180.2	178.71	186.5	241.47
1.8	224.o	185.38	190.8	197.59	197.4	267.10
1.9	236.5	203.87	201.4	217.31	208.4	293.89
2.0	248.9	223.14	212.0	237.87	219.4	321.82
2.1	261.4	243.18	222.6	259.26	230.3	350.89
2.2	273.8	264.00	233.2	281.47	241.3	281.08
2.3	286.3	285.57	243.8	304.49	252.3	412.39
2.4	298.7	307.90	254.4	328.33	263.3	444.81
2.5	311.2	330.99	265.0	352.97	256.1	332.17
2.6	323.6	354.82	275.6	378.40	285.2	512.94
2.7	336.1	379.39	286.2	404.63	296.2	548.65
2.8	348.5	404.71	296.8	431.65	307.1	585.43
2.9	360.9	430.75	307.4	459.46	318.1	623.29
3.0	373.4	457.53	318.0	488.05	329.1	662.23
3.1	385.8	485.03	328.6	517.41	340.0	702.22
3.2	398.3	513.26	339.2	547.54	351.0	743.28
3.3	410.7	542.20	349.8	578.45	362.0	785.39
3.4	423.2	571.86	340.4	610.11	372.9	828.55
3.5	435.6	602.23	371.0	642.55	383.9	872.76
3.6	448.1	633.31	381.6	675.73	394.9	918.01
3.7	460.5	665.10	392.2	709.68	405.8	964.29
3.8	473.0	697.59	402.8	744.37	416.8	1059.9
3.9	485.4	730.78	413.4	779.82	427.8	1059.9
4.0	497.9	764.67	424.0	816.01	438.8	1109.3

*x.10^{18} cm^{-3}

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APPROXIMATIVE ELECTRON- AND PROTON-IMPACT LINE WIDTHS WITHIN A SPECTRAL SERIES

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Modern quantum-mechanical and semiclassical Stark broadening theories (see e.g. Ref. 1) require a considerable labour even for the evaluation of a single line width. In the cases when more sophysticated methods are not necessary or not applicable (e.g. because of the lack of reliable atomic data) various approximative formulae may be used. An additional possibility for estimation or critical evaluation of Stark broadening data (see e.g.Ref. 2) offers also the knowledge about regularities and systematic trends of Stark broadening parameters.

The purpose of this paper is twofold: (i) to investigate the electron- and proton-impact line widths within spectral series and (ii) to find if Stark widths within a spectral series can be estimated with a simple formula.

Using the semiclassical-perturbation formalism for the estimate of Stark broadening parameters of neutral atom lines[3,4] we have calculated electron and proton impact widths for He I resonance lines.[5] As we can see from Fig. 1, the energy differences between the upper level and the principal interacting levels decrease with the principal quantum number of the upper level, n, thus a gradual increase of electron- and proton-impact width for He I $1s^2S\text{-}np^1P$ spectral series is expected. This is confirmed by our results presented in Figs. 2 and 3.

We can try to estimate electron-impact widths (FWHM) within a spectral series starting from the approximative expression for He I lines:[6]

$$W \approx \frac{8\pi}{3\bar{v}} \left(\frac{\hbar}{m}\right)^2 N\left\{\frac{\ell+1}{2\ell+1} \frac{9}{4} n^2\left[n^2-(\ell+1)^2\right]\left(\frac{1}{2} + \ln\left|\frac{2\,kT}{n^2\hbar\omega_{\ell,\ell+1}}\right|\right) + \frac{\ell}{2\ell+1} \frac{9}{4} n^2(n^2-\ell^2)\left(\frac{1}{2} + \ln\left|\frac{2\,kT}{n^2\hbar\omega_{\ell,\ell-1}}\right|\right)\right\} \quad (1)$$

Within a spectral series, the condition $n \gg \ell+1$ is always satisfied for sufficiently large n, thus:

$$W \approx \frac{6\pi}{\bar{v}} \left(\frac{\hbar}{m}\right)^2 Nn^4\left[\frac{1}{2} + \ln \frac{2kT}{n^2\hbar} - \frac{\ell+1}{2\ell+1} \ln\omega_{\ell,\ell+1} - \frac{\ell}{2\ell+1}\ln\omega_{\ell,\ell-1}\right] \quad (2)$$

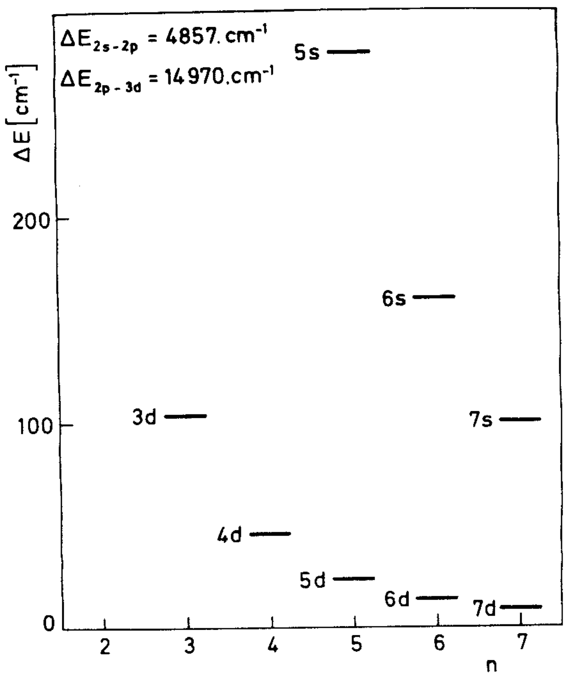

Fig. 1. The energy separation between the upper level and principal perturbing levels for He I resonance lines.

If the both level splittings are less than the plasma frequency $\omega_p = (4\pi Ne^2/m)^{1/2}$ (and this is satisfied for n sufficiently large) the expression becomes particularly simple.

$$W \approx \frac{6\pi}{\bar{v}}\left(\frac{\hbar}{m}\right)^2 Nn^4\left[\frac{1}{2} + \ln \frac{2kT}{\hbar\omega_p n^2}\right] \quad (3)$$

Thus we can see that for higher members of a spectral series, the electron-impact width depends on n as $A(N,T)n^4 \times (B(N,T) - 2\ln n)$.

Results obtained according to Eqs. 2 and 3 are presented in Fig. 2 (the broken lines) and they agree with the semiclassical calculations.

For the estimation of ion broadening, two methods are widely used. According to one of them[7], the influence of ion broadening can be estimated within the quasistatic approximation and the total width (W_t) is obtained as

$$W_t = W + W_c, \text{ where}$$
$$W_c = 1.75\, A\, (1 - 0.75\, R)\, W. \quad (4)$$

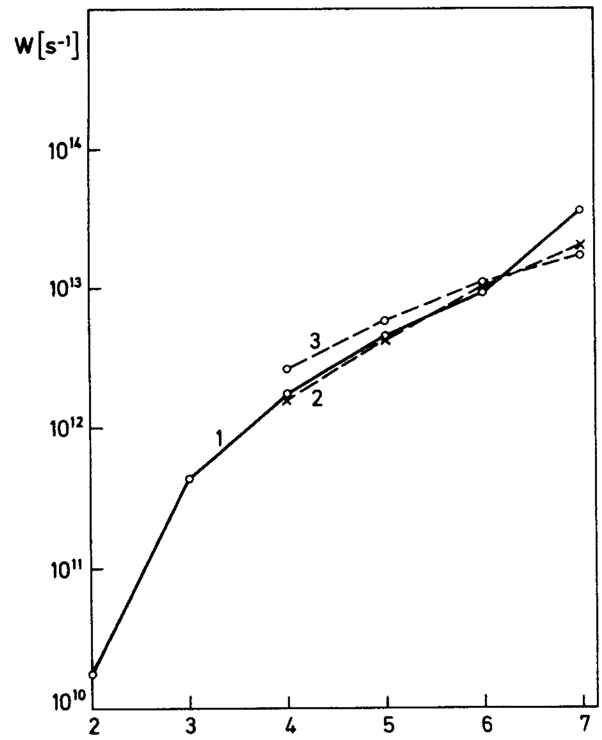

Fig. 2. Electron-impact full halfwidths for HeI $1s^1S-np^1P^o$ lines as a function of n. $N_e = 10^{16}$ cm^{-3} and T = 10000 K. Curves: 1 - semiclassical calculations; 2 - approximative calculations according to Eq. 2; 3 - approximative calculations according to Eq. 3.

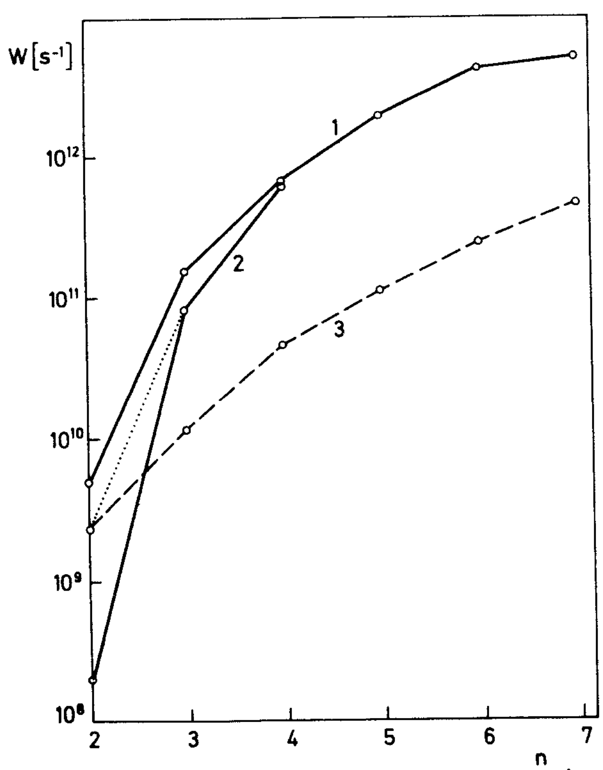

Fig. 3. Proton-impact full halfwidths for HeI $1s^1S-np^1P^o$ lines as a function of n. $N_e = 10^{16}$ cm^{-3} and T = 10000 K. Curves: 1 - semiclassical calculations; 2 - quasistatic estimates; 3 - quadrupol broadening estimates.

Here, W is the electron-impact width and A and R are parameters defined e.g. in Ref. 1. According to the second method[1] the ion width (FWHM) can be approximated by the quadrupol width:

$$W_i \approx 4\pi N_p[(n_i^2-n_f^2)^2\hbar a_o/Z^2m]Z_p \qquad (5)$$

It is suggested also[1] that as the ion broadening correction, the larger of W_c and W_i should be used.

In the Figs. 3 and 4, various results for proton broadening within two He I series are presented. We can see that the larger of widths obtained according to Eqs. 4 and 5 agrees with the semiclassical calculations in both cases.

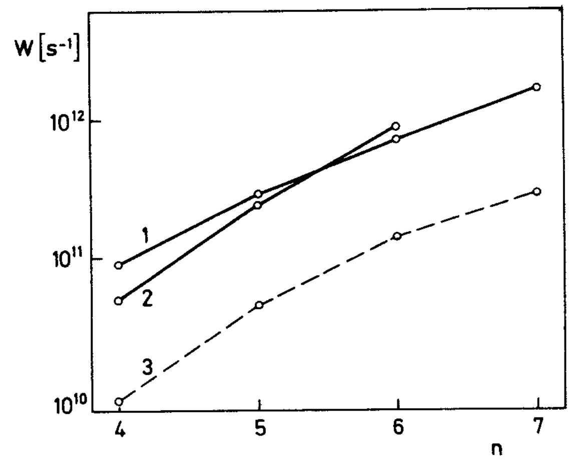

Fig. 4. Same notation as in Fig. 3, but for HeI $3p^3P^o-ns^3S$ lines and for T = 5000 K.

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SEMICLASSICAL CALCULATION OF He I STARK BROADENING PARAMETERS

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Using a semiclassical approach for the Stark broadening of atomic lines, we have calculated electron and proton impact line widths and shifts of 56 neutral helium lines.[1] In addition to the larger number of included lines and the wider temperature range, we have used also a semiclassical approach[2,3] which differs in several respects from the other large scale calculations of neutral helium lines.[4,5]

On the basis of the presently obtained comprehensive set of results, we have attempted also to find out if systematic trends among Stark broadening parameters within a spectral series are apparent: thus accurate interpolation of new data and critical evaluation of experimental results could be done.

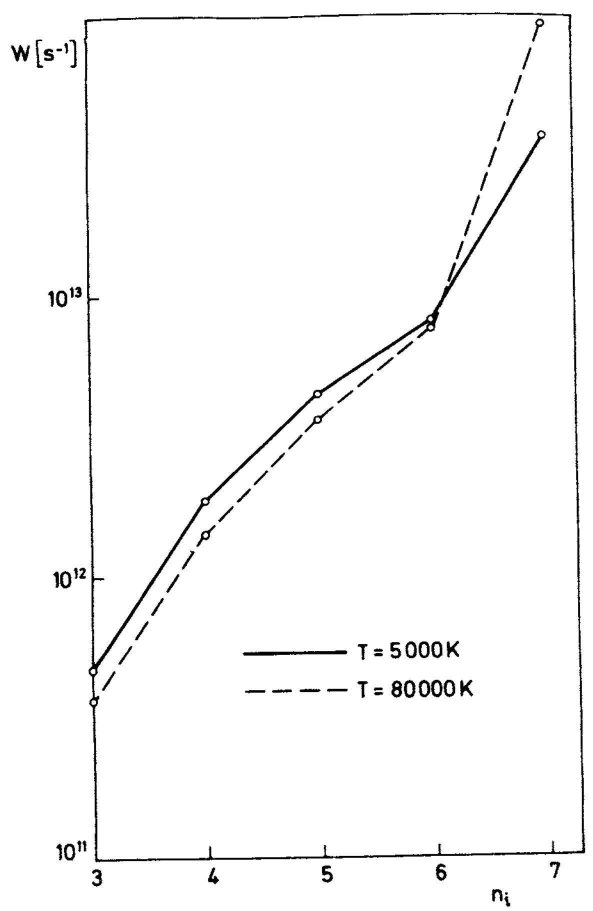

Fig. 1. The Stark halfwidth for He I $2s^1S-np^1P^o$ lines as a function of n_i for T = 5000 and 40000 K.

As a small part of obtained results, we present in Table 1 Stark broadening parameters for He I (singlet) lines in the range 2500 Å $\leq\lambda\leq$ 7000 Å. In this Table, $2W_e$ is the electron full halfwidth and d_e is the shift of a spectral line.

For the He I 5016 Å line we compare our results with different experimental detterminations of the Stark width.[6-16] This comparison is presented in Table 2 and we can see that the disagreement between our results and the most reliable experimental values lies within the limits of 10%.

We used our set of results to investigate also width regularities within a spectral series. As we can see from Fig. 1 a regular increase of width values exists within $2s^1S-2p^1P^o$ series.

Table 2. Various experimental results for the He I 5016 Å line compared with the present calculations.

Author	Year	W_{meas}/W_T
1) Wulff[6]	(58)	0.85
2) Berg et al.[7]	(62)	1.01
3) Bötticher et al.[8]	(63)	1.33-1.11
4) Lincke[9]	(64)	1.01
5) Greig et al.[10]	(68)	1.35
6) Greig and Jones[11]	(70)	1.42-1.38
7) Kusch[12]	(71)	1.96-2.19
8) Diatta et al.[13]	(74)	1.06
9) Einfeld and Sauerbrey[14]	(76)	2.01
10) Chiang et al.[15]	(77)	1.12
11) Kelleher[16]	(81)	1.09

Table 1. Stark broadening parameters for He I (singlet) lines in the range 2500 Å $\leq \lambda \leq$ 7000 Å, at an electron density of 10^{16} cm^{-3}.

Transition	T[K]	$2W_e$[Å]	d_e[Å]
$2s^1S-3p^1P^o$ 5015.68 Å	5000	.627	-.236
	10000	.597	-.179
	20000	.568	-.132
	30000	.549	-.110
	40000	.532	-.950-1
	80000	.487	-.666-1
$2s^1S-4p^1P^o$ 3964.73 Å	5000	1.54	-.459
	10000	1.48	-.345
	20000	1.40	-.249
	30000	1.34	-.208
	40000	1.29	-.179
	80000	1.16	-.126
$2s^1S-5p^1P^o$ 3613.64 Å	5000	3.07	-.757
	10000	3.10	-.574
	20000	3.00	-.432
	30000	2.87	-.354
	40000	2.77	-.306
	80000	2.50	-.211
$2s^1S-6p^1P^o$ 3447.59 Å	5000	5.09	-.881
	10000	5.63	-.627
	20000	5.64	-.335
	30000	5.49	-.189
	40000	5.34	-.109
	80000	4.89	.708-2
$2s^1S-7p^1P^o$ 3354.55 Å	5000	22.5	7.32
	10000	35.7	14.6
	20000	41.5	21.2
	30000	45.4	24.9
	40000	48.5	27.6
	80000	57.5	34.3
$2p^1P^o-4s^1S$ 5047.74 Å	5000	1.05	.730
	10000	1.09	.745
	20000	1.11	.668
	30000	1.13	.584
	40000	1.14	.528
	80000	1.12	.417
$2p^1P^o-6s^1S$ 4168.97 Å	5000	5.83	3.12
	10000	6.37	3.43
	20000	6.82	3.49
	30000	6.97	3.50
	40000	6.99	3.50
	80000	6.77	3.39
$2p^1P^o-7s^1S$ 4023.97 Å	5000	7.98	.534
	10000	11.4	.590
	20000	15.0	.569
	30000	17.6	.524
	40000	20.1	.480
	80000	29.8	.380
$2p^1P^o-8s^1S$ 3935.91 Å	5000	1.25	.882
	10000	26.3	.949
	20000	101.	.884
	30000	146.	.794
	40000	178.	.721
	80000	256.	.571
$2p^1P^o-3d^1D$ 6678.15 Å	5000	.714	.249
	10000	.666	.222
	20000	.602	.180
	30000	.565	.162
	40000	.538	.144
	80000	.485	.106
$2p^1P^o-4d^1D$ 4921.93 Å	5000	2.60	.436
	10000	2.48	.368
	20000	2.24	.298
	30000	2.08	.252
	40000	1.96	.221
	80000	1.69	.162
$2p^1P^o-5d^1D$ 4387.93 Å	5000	.361	.665
	10000	5.10	.558
	20000	4.81	.450
	30000	4.53	.382
	40000	4.31	.336
	80000	3.75	.250
$2p^1P^o-6d^1D$ 4143.76 Å	5000	.637	.924
	10000	.580	.856
	20000	8.69	.775
	30000	8.36	.707
	40000	8.04	.656
	80000	7.14	.528
$2p^1P^o-7d^1D$ 4009.27 Å	5000	31.1	10.4
	10000	38.1	20.7
	20000	43.5	29.7
	30000	47.1	34.6
	40000	65.8	38.0
	80000	77.4	46.7

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SEMIEMPIRICAL STARK SHIFTS OF ION LINES

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For the calculation of Stark broadening parameters sophysticated quantum-mechanical and semiclassical methods [1] exist, but they often require a considerable labour even for the evaluation of a single line width. Moreover, when there are not enough reliable atomic data for more involved calculations, or when quick estimate is needed, the approximate approaches may be very useful.

One such approach is the Griem's semiempirical method[2](based on the effective Gaunt factor approximation[3,4]) developed for widths and shifts of singly charged ions. The main disadvantages of this method are: (i) one must have atomic data for a sufficiently complete set of perturbing levels, (ii) for transitions with $\Delta n = 0$ Gaunt factors (g) at threshold are larger than o.2[5], and (iii) the method is appropriated only for singly charged ions. Modified semiempirical method for line widths of singly and multiply charged ions is published recently[6,7]. The aim of this paper is to present an improved semiempirical method for line shifts.

Within the semiempirical approach the shift d may be expressed as [2]:

$$d = 8\left(\frac{\pi}{3}\right)^{3/2}\frac{\hbar a_0}{m} N_e \left(\frac{E_H}{KT}\right)^{1/2} \sum_{i'f'} \left[\frac{\Delta E_{ii'}}{|\Delta E_{ii'}|} \times |\langle i'|\frac{\vec{r}}{a_0}|i\rangle|^2 \bar{g}_{sh}\left(\frac{3KT}{2|\Delta E_{ii'}|}\right) - \frac{\Delta E_{ff'}}{|\Delta E_{ff'}|} |\langle f'|\frac{\vec{r}}{a_0}|f\rangle|^2 \bar{g}_{sh}\left(\frac{3KT}{2|\Delta E_{ff'}|}\right)\right]$$

Effective Gaunt factor for widths ($\bar{g}$) and shifts ($\bar{g}_{sh}$) are related to each other by a Cauchy integral (dispersion) relation[2]. The electron concentration is N_e, $\Delta E_{jj'}$ is the energy difference between the initial (i) or final (f) and corresponding perturbing energy levels (i′,f′), E_H is the ionization energy of hydrogen and $\vec{r}$ is the coordinate vector of the optical electron.

In order to avoid the need for a comprehensive set of atomic data, we have separated transitions to perturbing levels in three groups: a) $\Delta n = 0,\ \ell \to \ell + 1$, b) $\Delta n = 0,\ \ell \to \ell - 1$ and c) $\Delta n \neq 0$. For transitions with $\Delta n = 0$, Kobzev[5] suggested for Gaunt factor an empirical value of $\bar{g}_{th} = 0.9 - 1.1/Z$ at the threshold. Starting from this value and using the dispersion relation[2], and average estimates with b_2 Stark broadening functions[1] (for hyperbolic at low and straight perturber paths at high temperatures), we obtained $\tilde{g}_{sh}$ for $\Delta n = 0$ transitions presented in Fig. 1. For singly charged ions $\tilde{g}_{sh} = 0.35$ for $x \leq 1$ and $\tilde{g}_{sh}(x) = 0.40;\ 0.47\ 0.53;\ 0.58;0.61;\ 0.64;\ 0.66;\ 0.68;\ 0.70;\ 0.78;\ 0.82;\ 0.84;\ 0.85;\ 0.86;$ o.86 for x = 2,3,4,5,6,7,8,9,1o,20, 30,40,60,80, and 100.

At high temperature limit all

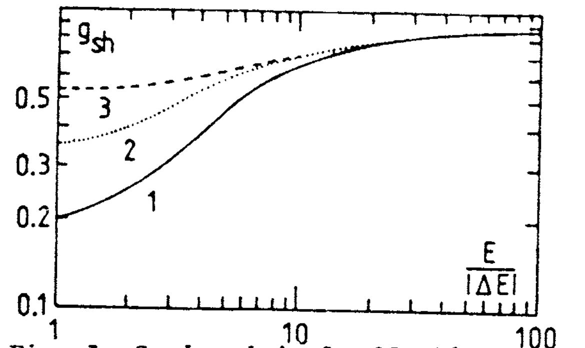

Fig. 1. Semiempirical effective Gaunt factors for shifts: 1 - $\bar{g}_{sh}$ from Ref. 2; 2 - $\tilde{g}_{sh}$ for $\Delta n=0$, for singly charged ions; 3 - $\tilde{g}_{sh}$ for $\Delta n=0$, for doubly charged ions.

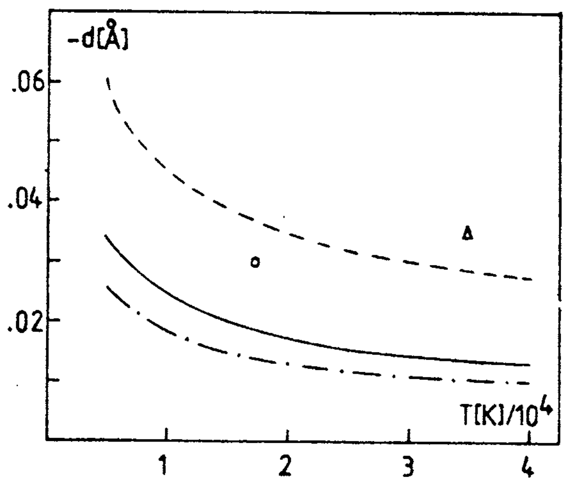

Fig. 2. Stark shifts for BeII 2s-2p multiplet. Calculations:—— modified semiempirical;—·— semiempirical according to Griem [2] ;- - - semiclassical Jones et al [8]; Experimental points: o -Purić, Konjević [9]; Δ-Hadžiomerspahić et al.[10]; ×-Fleurier et al.[11]; + -Roberts Barnard [12] ; ▼ -Helbig, Kusch [13] ; ▲ -Hühn, Kusch [14]

Gaunt factors for the shift are $\sqrt{3}/2$.

For transitions with $\Delta n \neq 0$ $\bar{g}_{sh}$ given by Griem [2] is retained. This group is separated in three parts. All transitions are firstly summed and corresponding matrix elements are treated lumped together. The energy separation is taken as $\Delta E_{jj'} = \Delta E_{n,n+1} = 2Z^2 E_H / n_j^{*3}$, where Z=2 for singly charged ions and n^* is the effective principal quantum number. In practicaly

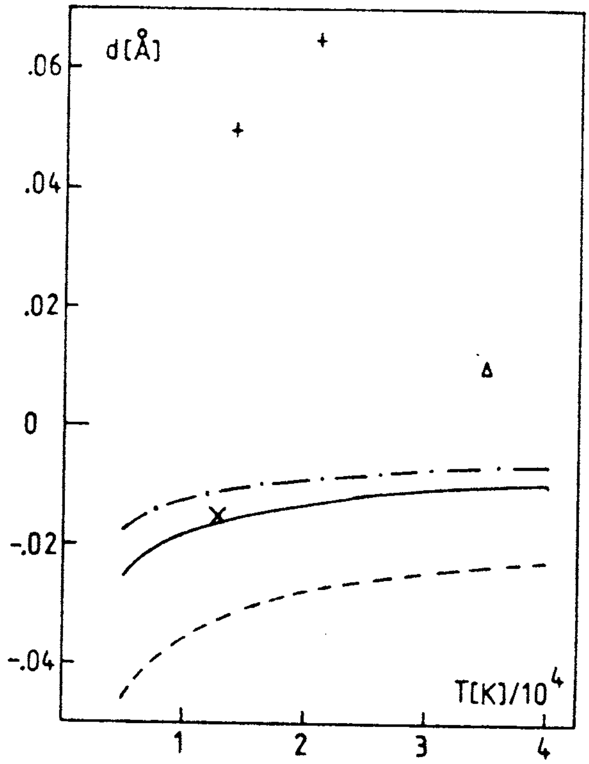

Fig. 3. As in Fig. 2 but for MgII 3s-3p multiplet

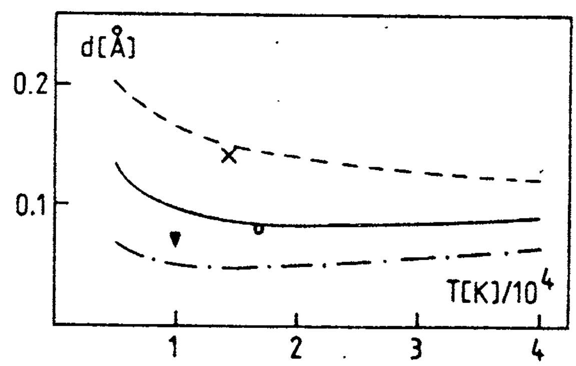

Fig. 4. As in Fig. 2 but for MgII 3p-4s multiplet

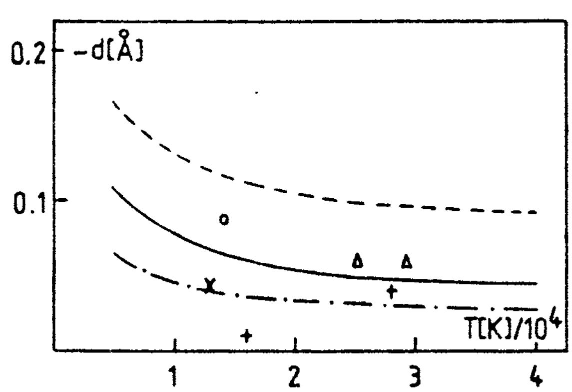

Fig. 5. As in Fig. 2 but for CaII 4s-4p multiplet

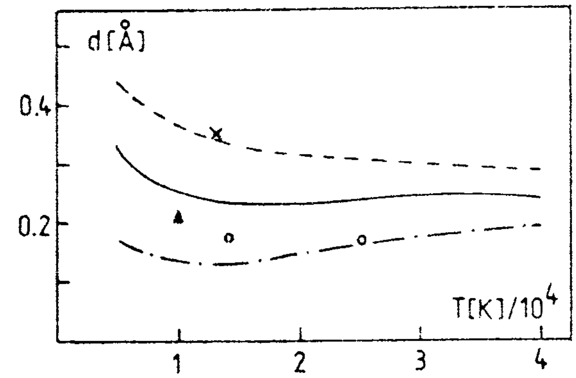

Fig. 6. As in Fig. 2 but for CaII 4p-5s multiplet

all examined experiments [9-14] the obtained $\overline{g}_{sh}$ is below the threshold. So, we can use $\overline{g}_{th}$ for this group. From the sum obtained we have subtracted the group of transitions with $\Delta E_{jj'}<0$ and, if exist, transitions strongly violating the approximation used for $\overline{g}_{sh}$. The obtained relation is:

$$d = N_e \frac{8\pi}{3} \frac{\hbar^2}{m^2} \left(\frac{2m}{\pi kT}\right)^{1/2} \frac{\pi}{\sqrt{3}} \Big[\hat{R}^2_{l_i,l_i+1} \cdot \tilde{g}_{sh}\left(\frac{E}{\Delta E_{l_i,l_i+1}}\right) - \hat{R}^2_{l_i,l_i-1} \tilde{g}_{sh}\left(\frac{E}{\Delta E_{l_i,l_i-1}}\right) - \hat{R}^2_{l_f,l_f+1} \tilde{g}_{sh}\left(\frac{E}{\Delta E_{l_f,l_f+1}}\right) + \hat{R}^2_{l_f,l_f-1} \cdot \tilde{g}_{sh}\left(\frac{E}{\Delta E_{l_f,l_f-1}}\right) + \sum_{i'} (\hat{R}^2_{ii'})_{\Delta n \neq 0} \overline{g}_{sh}(x_i) - 2 \sum_{\substack{i' \\ \Delta E_{ii'}<0}} \hat{R}^2_{ii'} \overline{g}_{sh}\left(\frac{E}{\Delta E_{ii'}}\right) - \sum_{f'} (\hat{R}^2_{ff'})_{\Delta n \neq 0} \cdot \overline{g}_{sh}(x_f) + 2 \sum_{\substack{f' \\ \Delta E_{ff'}<0}} \hat{R}^2_{ff'} \overline{g}_{sh}\left(\frac{E}{\Delta E_{ff'}}\right)$$

where with $\hat{R}$ are denoted corresponding matrix elements [6], and $x_j = E/\Delta E_{jj'}$. The obtained relation is compared with various experimental data [9-14] and with semiclassical [8] and unmodified semiempirical (performed by

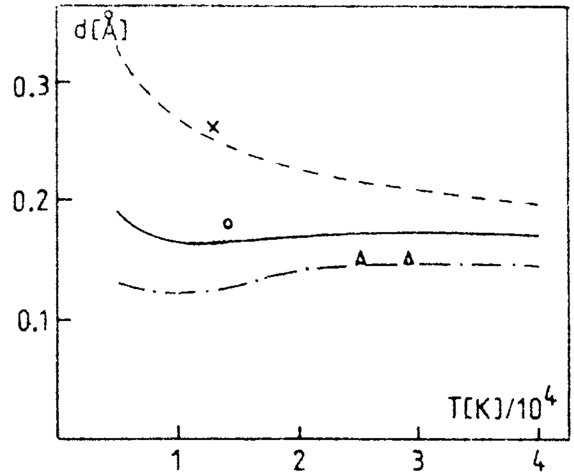

Fig. 7. As in Fig. 2 but for CaII 4p-4d multiplet

authors according to [2]) calculations in Figs. 2-7. We can see that the method proposed here, give an accuracy comparable with more sophysticated methods.

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The Figs. 2-7 should be replaced by the following ones:

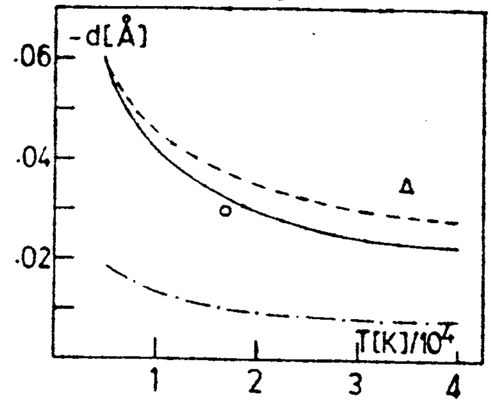

Fig. 2

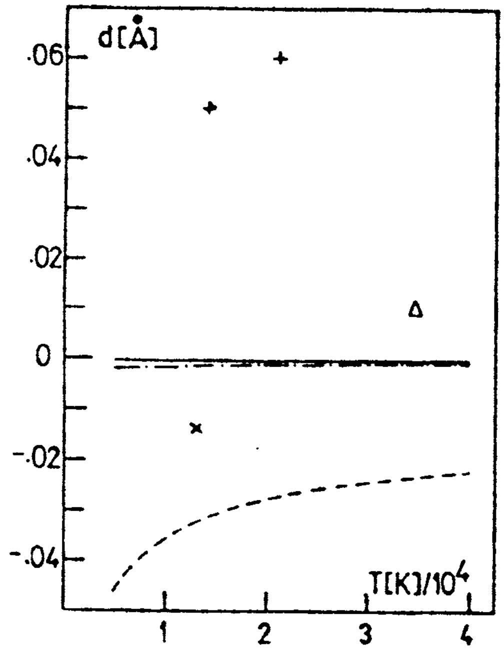

Fig. 3

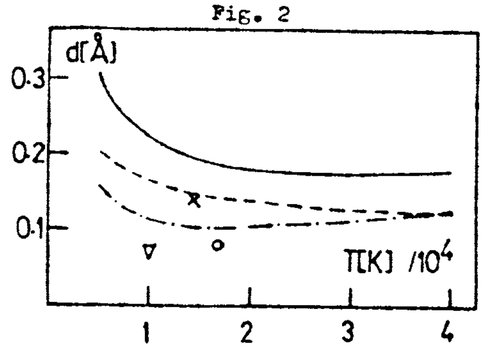

Fig. 4

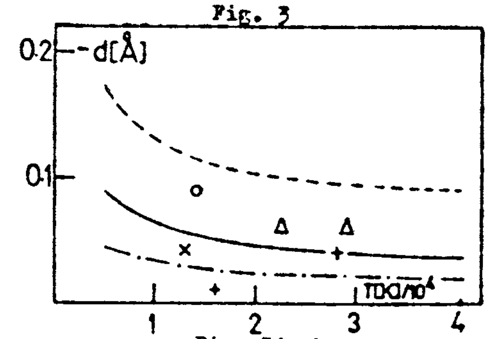

Fig. 5(up)

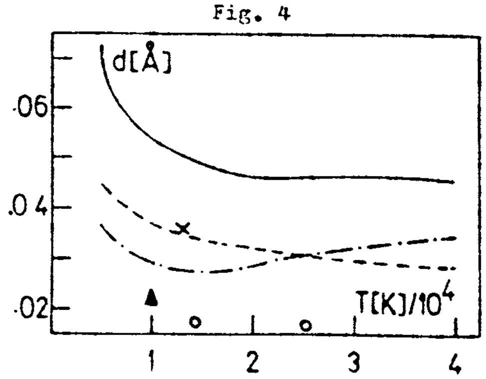

Fig. 6

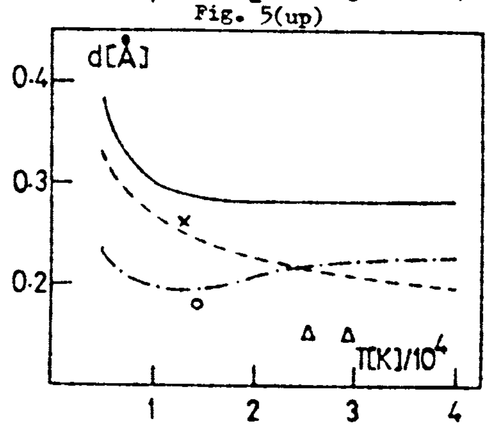

Fig. 7(right)

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STARK BROADENING OF Na I LINES: REGULARITIES WITHIN A SPECTRAL SERIES

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Using the semiclassical-perturbation formalism [1,2], we have calculated electron and proton impact line widths and shifts of 30 Na I lines[3]. On the basis of our comprehensive results, we have attempted to find out if systematic trends among Stark-broadening parameters within Na I spectral series are apparent [4,5]. If this is the case, accurate interpolations and critical evaluations of experimental results became feasible.

Results

In Fig. 1, our results for the Na I $3s^2S - 3p^2P^o$ multiplet (λ= 5891.8 Å) are compared with available theoretical [6,7,8] and experimental [9, 10] data. In both experiments considered [9,10] perturbing ion was singly ionized argon.

In some cases, in literature exists a controversy concerning impact or quasistatic character of ionic contribution to the line profile. We can see from Fig. 1 that data of Ref. [9] are in perfect agreement with our calculations with static ions. On the other hand, line widths of Ref. [10] agree better with numerical results, if the ionic contribution is treated within the impact approximation. Since the difference between the results with static and impact treatment of ionic contribution is measurable, a high precision measurement

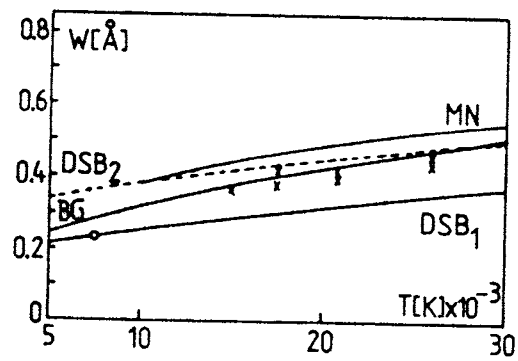

Fig. 1 Full halfwidths for Na I 3s-3p multiplet as a function of T; N = 10^{16} cm^{-3}. Experimental points: o, Baur and Cooper [9] x, Purić et al. [10]. Calculations: BG, Benett and Griem [7], MN, Mazure and Nollez [8], DSB_1, present calculations (quasistatic ion broadening), DSB_2, present calculations (impact ion broadening).

of Stark broadening data at various temperatures will be very interesting for Na I 3s-3p multiplet in order to see the true character of ionic contribution.

Discussion of regularities and conclusion

It was shown earlier [11] that, for lines belonging to a spectral

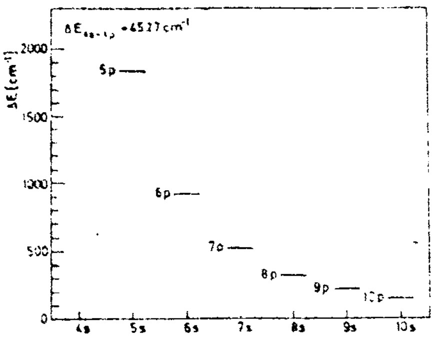

Fig. 2

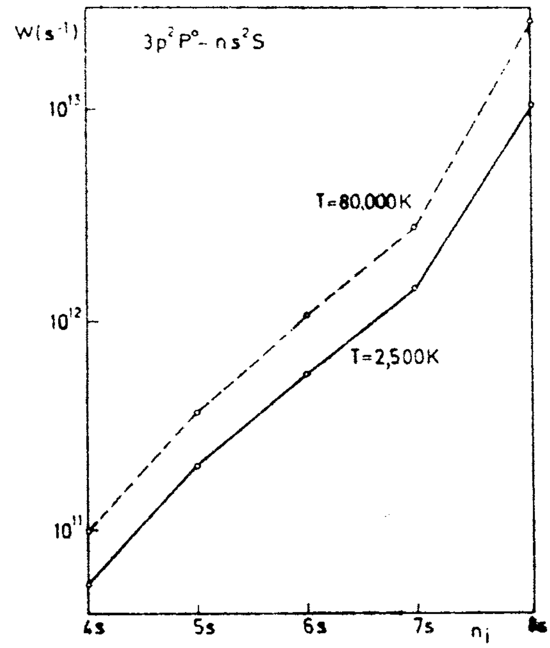

Fig. 3 Electron-impact full halfwidths as a function of n at N = 10^{16} cm^{-3}.

series, one should expect a gradual increase in the electron impact width with increasing principal quantum number of the upper state. Recently, on the basis of comprehensive numerical results for Stark broadening of He I lines it was shown [4,5] that for lines belonging to a spectral series, electron and proton impact width increases gradually with increasing principal quantum number of the upper state. The electron and proton impact shift changes gradually within a spectral series if Debye shielding effects are negligible. If the shift is negative (blue) for lower members of a series due to the larger polarization of the lower level of the transition, for higher members of the series it becomes positive (red) owing to the gradual increase of the upper level contribution. We continue here this investigation using the present results for Na I lines.

By inspecting energy separations between the upper level and the principal perturbing levels for 3p–ns series (Fig.2), we find that this value decreases gradually within a spectral series. Thus, we expect a gradual change of the Stark broadening parameters.

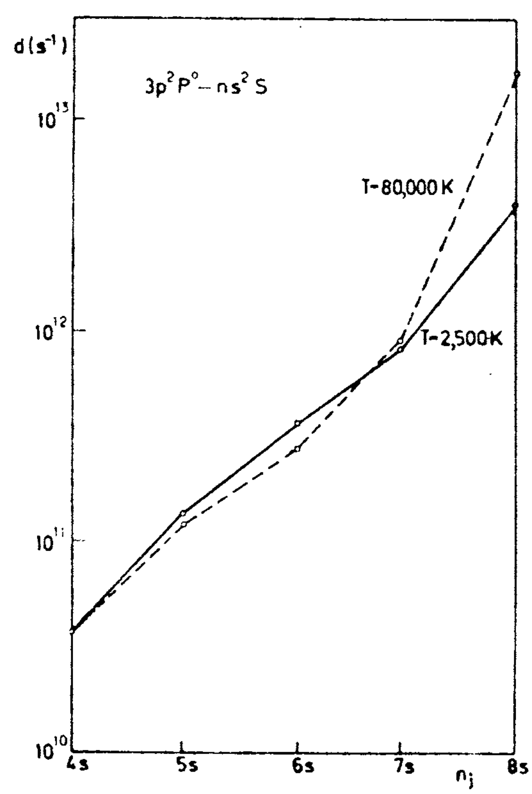

Fig. 4 Same as in Fig. 3 but for electron-impact shift

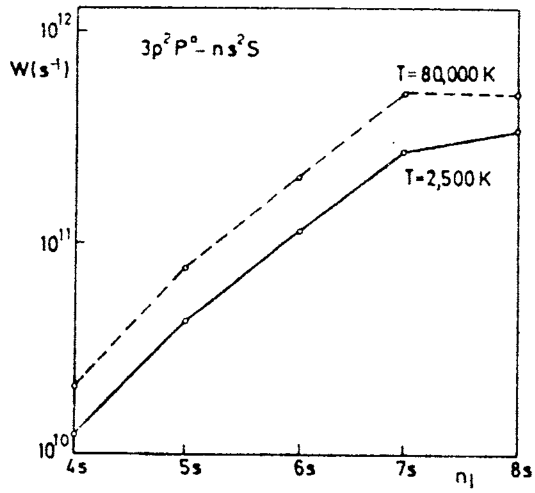

Fig. 5 Same as in Fig. 3 but for proton-impact full halfwidth

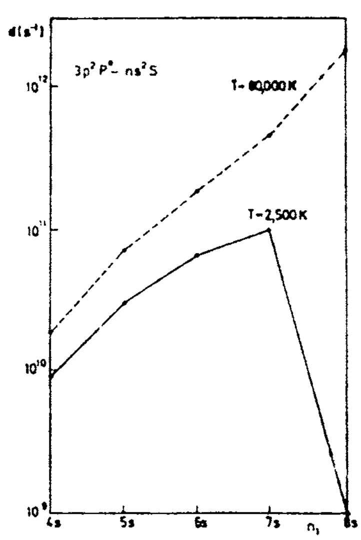

Fig. 6 Same as in Fig. 3 but for proton-impact shift

The electron and proton impact broadening parameters (in angular frequency units) as a function of the principal quantum numbers of the upper level (n_i) are shown in Figs. 3 -6. In practically all cases we can see a gradual increase of the Stark broadening parameters with the increase of the n_i. The unique exception is the proton-impact shift at 2500 K which is equal to zero for 3p-8s line due to the influence of Debye shielding.

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XVIII INTERNATIONAL CONFERENCE ON
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ABSTRACTS
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VOLUME II

EDITED BY

T. ANDERSEN B. FASTRUP F. FOLKMANN H. KNUDSEN

ION-ATOM RADIATIVE COLLISIONS IN THE SOLAR ATMOSPHERE

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1. INTRODUCTION

The continuum opacity of the solar atmosphere in the visible range is dominated by radiation exchange in formation and dissociation of the H^- ion[1]. However other processes involving atoms and positive ions may also play a role in the opacity. The purpose of the present paper is to evaluate the contribution of some ion-atom radiative collision processes to the opacity of the solar atmosphere. We will limit ourselves to the optical part of the electromagnetic spectrum (350 to 1250 nm) where the theory of the processes involved can be considered as correct.

2. ATOMIC AND MOLECULAR RADIATIVE PROCESSES IN THE SOLAR ATMOSPHERE.

The following positive ion-atom radiative collision processes of radiative charge exchange and of ion-atom photoassociation of molecular ion will be treated here:

$$H^+ + H \leftrightarrow \varepsilon_\lambda + \begin{cases} H + H^+, \\ H_2^+ \end{cases} \qquad (1)$$

where all atomic particles are in their electronic ground states and $\varepsilon_\lambda = 2\pi\hbar c/\lambda$ is the energy of the photon with the wavelength λ.

The contribution of processes (1) to the opacity of the solar atmosphere will be compared here with the contribution of the following known radiative processes: i) free-free and free-bound process involving a positive ion; ii) free-free processes in the field of an atom; iii) free-bound processes in the field of an atom (first of all formation and dissociation of H^-).

We will define ratios F of emissivities ε characterizing relative contribution of the process (1) in comparison with processes (i), (ii) and (iii) respectively. In the case of local thermal equilibrium, these ratios are also the ratios of the corresponding absorption coefficients. We now proceed to calculating the quantities F.

3. RESULT FOR THE SOLAR ATMOSPHERE AND DISCUSSION

All detailes of calculations are given in Ref.2. Results obtained have been applied to the solar atmosphere using the solar photospheric model of Maltby et al.[3] (their Table 11, photosheric reference model) for altitudes (h) lower than 605 km and chromospheric model of Vernazza et al.(1981) (their model C) for higher altitudes.

The comparison of (1) and (i) processes contribution shows two maxima, one in the photosphere and the other one in the chromosphere.

The comparison of the contribution of processes (1) with that one of the processes (ii) shows photospheric and chromospheric maxima of the corresponding F values located in the same height range. These maxima however are of smaller intensity.

Our calculations shows as well that the values of $F^{fb}_{ea}(\lambda)$ parameter change from 0.15 up to 0.05 in the -100 km ≤ h ≤ 50km, decrease slowly up to around 700 km and increases steply up to 0.1. After 700 km they increase very slowly for all λ considered.

Results obtained show that the processes (1), not taken into account up to now in photosphere and chromosphere research from the spectroscopical point of view, are not negligible and that in particular layers it becomes in fact even comparable with processes (iii), the most important for continuous emission (absorption) spectrum formation for the height range considered. We want to draw attention that our results show as well that the inclusion of radiative charge exchange processes together with H_2^+ photodissociation results in a combined contribution to the total absorption spectrum of around 10 per cent for particular photospheric and chromospheric layers of the Sun, in spite of the fact that only 10^{-2}-10^{-4} of hydrogen is ionized.

We have estimated (for hydrogen) the relative importance of processes (1) on the total optical depth of solar atmosphere in the range 0 km ≤ h ≤ 1065 km, as well as on the emergent intensity (see e.g. Ref. 1). The calculations have been performed for radial rays. This shows that the contribution of processes (1) changes the optical depth of the atmospheric layer considered (photosphere and lower chromosphere) from 3.5 up to 1.5 per cent when λ varies from 400 nm up to 800 nm.

Such an optical depth change is not negligible for sophisticated calculations. However it does not influence significantly the emergent intensity. Our calculations show that for the photosphere (0 km ≤ h ≤ 605 km), the change of emrgent intensity is between 0.28 to 0.14 per cent for λ between 500 and 800 nm. In this layer for $\lambda \geq$ 500 nm, the source function may be approximated by a Planck function, as used here.

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VOLUME II

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T. ANDERSEN B. FASTRUP F. FOLKMANN H. KNUDSEN

RADIATIVE ION-ATOM PROCESSES AS A SOURCE OF CONTINUAL EM-RADIATION FROM LOW TEMPERATURE HELIUM PLASMA

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1. INTRODUCTION

In this paper we will apply to helium plasma case, recently developed[1] semiclassical approach for total and partial spectral coefficient calculation in the case of radiative ion-atom recombination and radiative charge exchange

$$He^+(1s) + He(1s^2) \longleftrightarrow \hbar\omega + \begin{cases} He_2^+ \\ He + He^+ \end{cases} \quad (1)$$

processes, where He_2^+ ion is in the ground state ($^1\Sigma_u$).

We will limit ourselves in further to the visible spectral range as well as to the near ultraviolet and near infrared ranges and to temperatures of $T \lesssim 3\ 10^4$ K.

Our objective is to investigate the relative importance of the radiative processes (1) comparing with other processes occuring in the plasma. The comparison will be done with electron-atom (free-bound and free-free electron transitions in collisions with He^+) and electron-ion (free-free electron transitions in collisions with He, with the subsequent excitation of the target atom) collisional processes. These reactions are generally known to be important contributors to the continuum radiation emitted from plasmas.

2. RESULTS AND DISCUSSION

We discuss here our results of calculations of total and partial emission spectral coefficients for ion-atom recombination and radiative charge exchange (1) processes for helium plasma. All details of calculations are given in detail in Ref. 1.

As an illustration, in Fig. 1 is shown the ratio of the total spectral density due to ion-atom collisions, to the radiation spectral density due to electron-ion scatterinf in helium plasma as a function of temperature and wavelength for the ratio of He to electron densities equal to 5×10^3.

The obtained results show that processes (1) dominate over the electron-ion source of continuous electromagnetic radiation in a wide range of plasma conditions. Apart from laboratory plasmas, similar conditions take place also in some astrophysical plasmas, mainly in the helium enriched DB white dwarfs where hydrogen had been partially or completely burnt up in the course of the star evolution. According to our results, the processes (1) may compete not only with the electron-ion reactions mentioned above, but also with the mentioned electron-atom reactions.

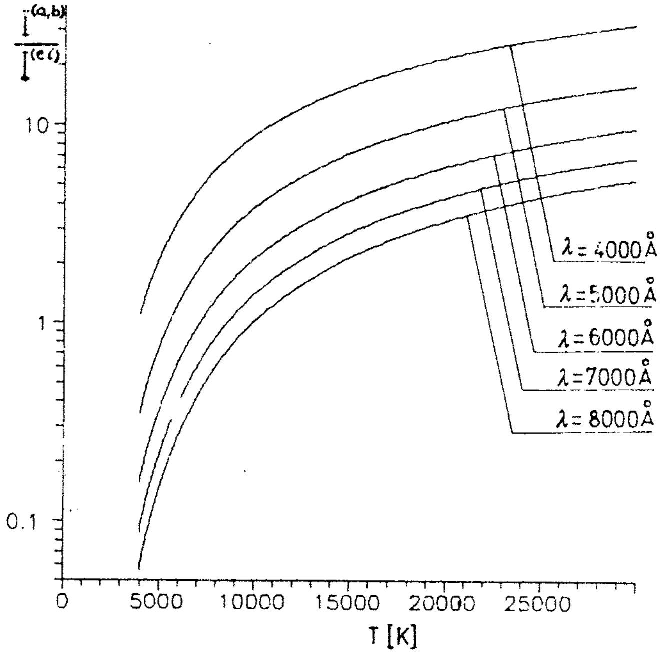

Fig. 1. The ratio of total spectral density $I^{(ab)}(\lambda,T)$ caused by ion - atom collisions and radiation spectral density $I^{(ei)}(\lambda,T)$ caused by electron-ion scattering in plasma as a function of temperature (T) and wavelength (λ), for $N_{He}/N_e = 5\ 10^3$.

3. CONCLUSION

We can conclude that in the case of helium plasma one must particularly be carefull concerning the continuous EM-radiation spectrum nature. Namely, from our results follows that at typical values of electron and atom component ratio in helium plasma, radiation processes (1) might completely determine the character of spontaneous EM-radiation spectrum. We expect to find applications of this theory in diagnostics of laboratory plasmas and analysis of radiation from helium-rich stars such, for instance, as the DB white dwarfs.

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ABSTRACTS OF INVITED LECTURES AND PROGRESS REPORTS

UNIVERSITAS STUDIORUM NEOPLANTENSIS

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STARK BROADENI : OF SPECTRA LIN S ALONG THE ISOELE RONIC SEQUENCES OF LITHIUM A D BERYLLIUM

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1. INTRODUCTION

The Stark widths of the $3s^2S$-$3p^2P^0$ tran ions along the isoelectronic sequence of lithium (BIII, CIV, NV, OVI) and the $3s^3S$-$3p^3$ ransitons along the isoelec onic sequence of beryllium (BII, CIII, NIV, OV) have bee tudied theoretically using i act semiclassical method and experimentally observed in the asma of a low pressure puls d arc. The plasma electron densities were determined from width of the HeII P line hile the electron temperatures were measured from the rel e line intensities. To estim the influence of different ions to the Stark width of lines, aluation of the plasma co osition data was performed and in conjunction with our t retical results contribution f ion broadening estimated.

2. THEORY

By using the semiclassical-perturbation malism [1] we have calcula d electron and all relevant perturbing ions impact broadenin arameters for the $3s^2S$-$3p^2P^0$ transitions along the isoelectronic sequences of lithium and f he $3s^3S$-$3p^3P^0$ transition along the isoelectronic sequence of beryllium. Energy levels neede for these calculations have been taken from [2]. Oscillator strengths were calculated by usi the method described in [3], see also [4]. The contribution of higher energy levels is estim d as in [5].

3. EXPERIMENT

The experimental apparatus (see Figu 1.) and procedure a desc ed in [6] so only minimum details will be given here. The li source was a low pressure pulsed arc with a quartz discharge tube 10 mm internal dia er. The distance betw en al minum electrodes was 161 mm, and 3 mm diameter holes we ocated at the center of both ectrodes to allow was 161 mm, and 3 mm diameter holes were located at the center of both electrodes to allow endon plasma observations. All plasma observations are performed with 1-m monochromator with inverse linear dispersion 8.33 Å/mm in the first order of the diffraction grating, equipped with the photomultiplier tube and a stepping motor. The discharge was driven by a 15.2 μF low inductance capacitor charged to V = 3 or 4.8 kV, pressure of the gas mixture p = 1.7 or 3.0 torr, continuous flow of the gas mixture was sustained composition: 0.5 % to 4 % of investigated gas in He. The stepping motor and the oscilloscope are controlled by a personal computer, which was also used for data acquisition. Recordings of the spectral line shapes were performed shot-by-shot. At each wavelength position of the monochromator time evolution and decay of the plasma radiation were recorded by the oscilloscope. Eight such signals were averaged at each wavelength.

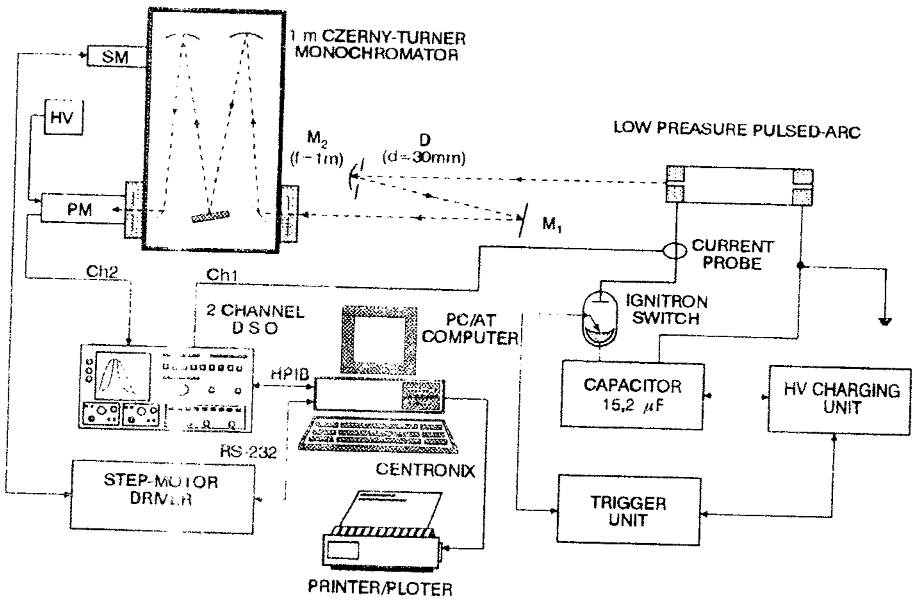

Figure 1. The experimental setup.

To construct the line profiles these averaged signals at different wavelengths and at various times of the plasma existence were used to construct line profiles. Spectral line profiles were recorded with instrumental half widths of 0.165 Å. To determine the Stark half width from the measured profile, a standard deconvolution procedure for the Lorentzian (Stark) and Gaussian (instrumental+Doppler) profiles was used.

4. EXPERIMENTAL RESULTS AND DISCU ION

The experimental results for Stark widths a comparisons with theoretical results are given for the $3s^2S$-$3p^2P^0$ transitions along lithium oelectronic sequence (Figure 2.) and for the $3s^3S$-$3p^3P^0$ transitions along beryllium isoel ronic sequence (Figure 3.). In order to evaluate contribution of ion impact widths it wa ecessary to compute plasma composition data for the conditions of width measurements (el ron density and temperature).

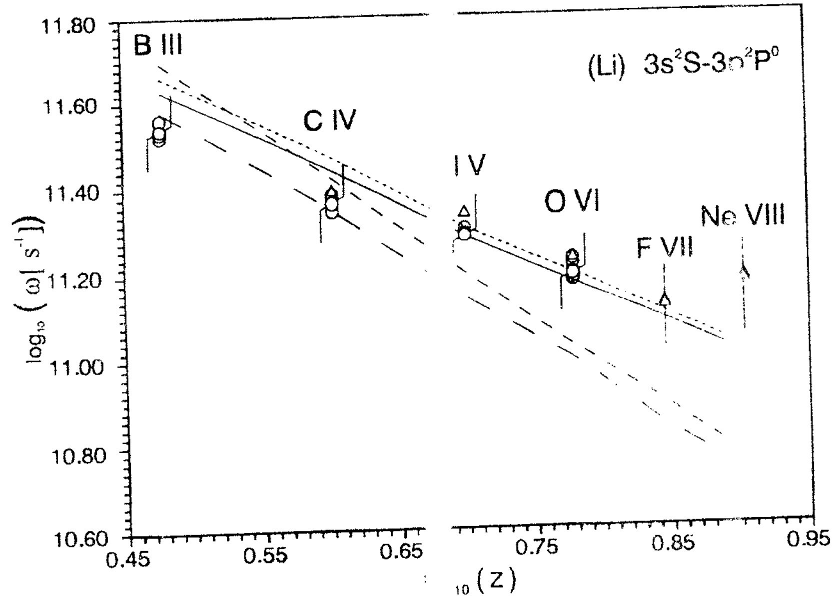

Figure 2. Stark widths Li-like spectral lines n angular frequency units) as function of $\log_{10}Z$ for $3s^2S$-$3p^2P^0$ multiplets. Theory: ··· , semiclassical electrons + ions impact widths, ——, semiclassical electrons only; - , semiclassical approximation (Eq.(526) taken from [8]); -- — --, modified semi pirical formula [7]. Experiment: O, our data; Δ, Glenzer et al [9,10].

In the studied electron temperature range d within the estimated uncertainties the experimental Stark widths agree well with th results of our semiclassical electron impact widths. The only exception are BII lines wh the experimental Stark widths agree better with modified semiempirical formula [7]. F the conditions of the present experiment, estimated contribution of the ion broadening s never exceeded seven percents of the total width. So within the precision of this experi nt it was not possible to detect its presence with certainty.

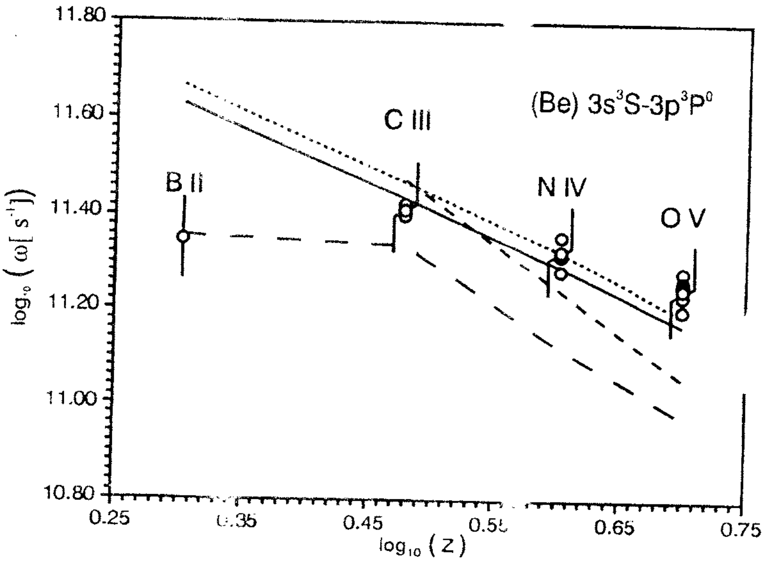

Figure 3. Stark widths Be-like spectral lines (in angular frequency units) as function of $\log_{10}Z$ for $3s^3S$-$3p^3P^0$ multiplets. Theory: ········· , semiclassical electrons + ions impact widths, ——, semiclassical electrons only; - - -, semiclassical approximation (Eq.(526) taken from [8]); — — —, modified semiempirical formula [7]. Experiment: O, our data.

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ABSTRACTS OF INVITED LECTURES AND PROGRESS REPORTS

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ON THE STARK BROADENING OF P IV SPECTRAL LINES

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Abstract. Using a semiclassical approach, we have calculated electron–, proton–, and He III–impact line widths and shifts for lines within triply charged phosphorus spectrum. The obtained results have been compared with other available calculations.

INTRODUCTION

As the continuation of our effort to provide needed data for the analysis of laboratory and astrophysical plasmas (see Ref. 1 and references therein), we started the investigation of the Stark broadening of P IV lines. Stark broadening parameters of P IV lines are of interest not only for the plasma diagnostic but for the research of regularities and systematic trends and theoretical considerations as well. Consequently, Stark widths for P IV $4s^1S$ - $4p^1P^o$, $4s^3S$ - $4p^3P^o$ and $3p^3P^o$ - $3d^3D$ multiplets have been determined [2,3,4] within the modified semiempirical approach [5], Griem's semiempirical approach [6], symplified semiclassical approach (Eq. 526 in Ref. 7) and its modification[5].

By using the semiclassical-perturbation formalism [8,9], we started to determine electron-, proton-, and He III-impact line widths and shifts for P IV, in order to continue our research of multiply charged ion line Stark broadening parameters.

RESULTS AND DISCUSSION

A summary of the formalism is given in Ref. 10. All details of calculations will be given elsewhere [11]. Here, in Table 1, we present only a sample of results obtained for perturber density of 10^{17} cm^{-3} and temperatures T = 50,000 - 500,000K. We also specify a parameter c [12], which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding electron-impact full width at half maximum.

In Table 2, present semiclassical Stark full widths at half maximum (WDSB) in Å are compared with the calculations in Refs. 3 and 4 by using the modified semiempirical approach [5] (WMSE), Griem's semiempirical approach [6] (WSE), symplified semiclassical approach (Eq. 526 in Ref. 7) (WG) and its modification [5] (WGM). One can see that the best agreement is with the results obtained by using the symplified semiclassical approach.

TABLE I

This table shows electron-, proton-, and He III-impact broadening full half - widths (FWHM) and shifts for P IV for a perturber density of 10^{17} cm^{-3} and temperatures from 50,000 up to 500,000 K. By deviding c with the full linewidth, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

PERTURBER DENSITY = 1.E+17cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
P IV 3S 3P	50000.	0.438E-02	-0.181E-04	0.101E-03	-0.281E-05
950.7 A	100000.	0.316E-02	-0.212E-04	0.178E-03	-0.563E-05
C= 0.81E+20	150000.	0.264E-02	-0.183E-04	0.218E-03	-0.825E-05
	200000.	0.236E-02	-0.161E-04	0.251E-03	-0.106E-04
	300000.	0.203E-02	-0.190E-04	0.280E-03	-0.143E-04
	500000.	0.173E-02	-0.228E-04	0.308E-03	-0.192E-04
P IV 3S 4P	50000.	0.193E-02	0.386E-[illegible]	0.146E-03	0.127E-04
388.3 A	100000.	0.148E-02	0.247E-[illegible]	0.196E-03	0.212E-04
C= 0.35E+19	150000.	0.130E-02	0.394E-[illegible]	0.211E-03	0.256E-04
	200000.	0.119E-02	0.418E-[illegible]	0.222E-03	0.296E-04
	300000.	0.107E-02	0.348E-[illegible]	0.237E-03	0.345E-04
	500000.	0.943E-03	0.342E-[illegible]	0.254E-03	0.393E-04
P IV 4S 4P	50000.	0.334	-0.111E-[illegible]	0.186E-01	-0.101E-01
4250.9 A	100000.	0.260	-0.161E-[illegible]	0.257E-01	-0.140E-01
C= 0.43E+21	150000.	0.229	-0.152E-[illegible]	0.283E-01	-0.157E-01
	200000.	0.211	-0.140E-[illegible]	0.302E-01	-0.170E-01
	300000.	0.190	-0.141E-[illegible]	0.329E-01	-0.189E-01
	500000.	0.169	-0.133E-[illegible]	0.367E-01	-0.216E-01
P IV 3P 4S	50000.	0.678E-02	0.591E-	0.241E-03	0.366E-03
776.4 A	100000.	0.507E-02	0.677E-	0.417E-03	0.508E-03
C= 0.14E+20	150000.	0.438E-02	0.696E-	0.533E-03	0.566E-03
	200000.	0.399E-02	0.659E-	0.604E-03	0.613E-03
	300000.	0.353E-02	0.634E-	0.699E-03	0.685E-03
	500000.	0.305E-02	0.600E-	0.823E-03	0.770E-03
P IV 3P 3D	50000.	0.607E-02	0.193E-	0.265E-03	0.911E-04
877.5 A	100000.	0.446E-02	0.172E-	0.397E-03	0.146E-03
C= 0.30E+20	150000.	0.380E-02	0.197E-	0.473E-03	0.177E-03
	200000.	0.344E-02	0.215E-	0.503E-03	0.201E-03
	300000.	0.302E-02	0.207E-	0.548E-03	0.226E-03
	500000.	0.263E-02	0.196E-	0.604E-03	0.260E-03
P IV 3P 4D	50000.	0.496E-02	-0.209E-	0.429E-03	-0.264E-03
525.9 A	100000.	0.390E-02	-0.178E-	0.559E-03	-0.355E-03
C= 0.14E+19	150000.	0.344E-02	-0.180E-	0.624E-03	-0.395E-03
	200000.	0.316E-02	-0.183E-	0.673E-03	-0.426E-03
	300000.	0.283E-02	-0.170E-	0.753E-03	-0.474E-03
	500000.	0.249E-02	-0.144E-	0.839E-03	-0.526E-03

Table 1 continued

PERTURBER DENSITY = 1.E 7cm-3

TRANSITION	T(K)	ELECTRO WIDTH(A	SHIFT(A)	PROTONS WIDTH(A)	SHIFT(A)
P IV 4P 4D	50000.	0.164	-0.757E-02	0.147E-01	-0.701E-02
2645.1 A	100000.	0.131	-0.605E-02	0.181E-01	-0.935E-02
C= 0.35E+20	150000.	0.116	-0.668E-02	0.199E-01	-0.104E-01
	200000.	0.108	-0.680E-02	0.213E-01	-0.113E-01
	300000.	0.976E-	-0.615E-02	0.232E-01	-0.125E-01
	500000.	0.868E-	-0.544E-02	0.254E-01	-0.139E-01
P IV 3D 4P	50000.	0.101	0.211E-03	0.763E-02	-0.242E-03
2606.3 A	100000.	0.774E-	-0.218E-03	0.100E-01	-0.433E-03
C= 0.16E+21	150000.	0.680E-	0.196E-03	0.108E-01	-0.570E-03
	200000.	0.626E-	0.123E-03	0.113E-01	-0.651E-03
	300000.	0.565E-	-0.102E-03	0.121E-01	-0.793E-03
	500000.	0.503E-	-0.129E-04	0.128E-01	-0.935E-03
P IV 3D 4F	50000.	0.287E-	0.917E-03	0.188E-02	0.153E-02
1405.0 A	100000.	0.220E-	0.876E-03	0.278E-02	0.211E-02
C= 0.99E+19	150000.	0.192E-	0.870E-03	0.317E-02	0.235E-02
	200000.	0.176E-	0.802E-03	0.344E-02	0.253E-02
	300000.	0.157E-	0.704E-03	0.388E-02	0.279E-02
	500000.	0.138E-	0.601E-03	0.454E-02	0.315E-02
P IV 4D 4F	50000.	9.43	0.593	0.840	0.623
19996.3 A	100000.	7.48	0.527	1.09	0.789
C= 0.20E+22	150000.	6.63	0.541	1.23	0.881
	200000.	6.12	0.540	1.34	0.954
	300000.	5.51	0.497	1.51	1.06
	500000.	4.87	0.432	1.72	1.17
P IV 4S 4P	50000.	0.191	-0.501E-02	0.110E-01	-0.380E-02
3356.9 A	100000.	0.147	-0.615E-02	0.149E-01	-0.543E-02
C= 0.34E+21	150000.	0.129	-0.653E-02	0.162E-01	-0.640E-02
	200000.	0.119	-0.581E-02	0.171E-01	-0.684E-02
	300000.	0.107	-0.585E-02	0.184E-01	-0.767E-02
	500000.	0.951E-0	-0.552E-02	0.201E-01	-0.872E-02
P IV 3P 4S	50000.	0.355E-0	0.341E-03	0.110E-03	0.186E-03
630.8 A	100000.	0.262E-0	0.351E-03	0.200E-03	0.262E-03
C= 0.12E+20	150000.	0.224E-0	0.386E-03	0.274E-03	0.298E-03
	200000.	0.204E-0	0.367E-03	0.308E-03	0.323E-03
	300000.	0.180E-0	0.348E-03	0.362E-03	0.358E-03
	500000.	0.155E-0	0.328E-03	0.429E-03	0.405E-03
P IV 3P 3D	50000.	0.337E-0	0.624E-05	0.137E-03	0.857E-06
826.3 A	100000.	0.245E-0	0.105E-04	0.217E-03	0.172E-05
C= 0.46E+20	150000.	0.206E-0	0.715E-05	0.266E-03	0.257E-05
	200000.	0.184E-0	-0.564E-05	0.294E-03	0.338E-05
	300000.	0.159E-0	0.963E-05	0.317E-03	0.481E-05
	500000.	0.136E-0	0.114E-04	0.346E-03	0.697E-05

TABLE II

Present semiclassical Stark full widths at half maximum (WDSB) in Å compared with the calculations of Dimitrijević [3,4] by using the modified semiempirical approach [5] (WMSE), Griem's semiempirical approach [6] (WSE), symplified semiclassical approach (Eq. 526 in Ref. 7) (WG) and its modification [5] (WGM).

PERTURBER DENSITY = 1.E+17cm-3

TRANSITION	T(K)	WDSB(A)	WG(A)	WGM(A)	WSEM(A)	WSE(A)
P IV 4S 4P	10000.	0.714	0.653	0.363	0.565	0.264
4250.9 A	20000.	0.502	0.477	0.279	0.399	0.186
C= 0.43E+21	40000.	0.367	0.360	0.229	0.282	0.132
	80000.	0.280	0.285	0.202	0.215	---
	160000.	0.225	0.238	0.188	0.183	---
P IV 4S 4P	10000.	0.411	0.385	0.216	0.330	0.158
3356.9 A	20000.	0.291	0.281	0.165	0.233	0.112
C= 0.34E+21	40000.	0.210	0.211	0.134	0.165	0.790E-01
	80000.	0.159	0.166	0.117	0.121	0.648E-01
	160000.	0.127	0.138	0.108	0.100	---
P IV 3P 3D	10000.	0.743E-02	0.573E-02	0.477E-02	0.350E-02	0.260E-02
826.3 A	20000.	0.521E-02	0.417E-02	0.350E-02	0.248E-02	0.184E-02
C= 0.46E+20	40000.	0.375E-02	0.313E-02	0.267E-02	0.175E-02	0.130E-02
	80000.	0.271E-02	0.248E-02	0.216E-02	0.124E-02	0.920E-02
	160000.	0.200E-02	0.211E-02	0.190E-02	0.873E-03	0.690E-03

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ABSTRACTS OF INVITED LECTURES AND PROGRESS REPORTS

Editors:
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PROCESSES INVOLVING ION-ATOM COMPLEXES IN WEAKLY IONIZED LABORATORY AND ASTROPHYSICAL PLASMAS

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In a number of papers (see Refs. 1-10 and references therein), the following processes involving symmetrical, positive ion - atom collisional quasi - molecular complexes have been considered in weakly ionized laboratory and astrophysical plasmas: (i) the photodissociation of molecular ion and the processes of the photoabsorption charge exchange; (ii) the ion-atom photoassociation of molecular ion and the processes of the photoemission charge exchange; (iii) recombination during electron scattering on molecular ions, and on ion-atom complexes; (iv) processes of $A^*(n) + A$ chemi-ionization. These processes have been considered using a quasistatic model based on the semiclassical adiabatic approximation for heavy particle collisions [1,3,5], and it was shown the significance of the combined study of the both processes given under (i) or (ii) or (iii) or (iv). The method has been applied in detail to hydrogen and helium plasmas, that are representatives of two different optical types of gaseous medium. The hydrogen and helium case has been analyzed for conditions of solar atmosphere and atmospheres of helium rich DB white dwarfs.

We will present here a review of our results and will discuss the importance of the processes (i) - (iv) for the analysis and modelling of weakly ionized plasmas in laboratory and stellar conditions.

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ABSTRACTS OF INVITED LECTURES AND PROGRESS REPORTS

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PROCESSES OF $H - H^+ -$ AND $H_2^+ - e$ RECOMBINATION IN THE L N-TEMPERATURE LAYERS OF SUN AT OSPHERE

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Introductio

In several previous p pers [1, 2, 3] we have take to consideration dielectron chemi- recombination processes during the free electron s tering on the symmetrical quasi-molecular ion-atom complexes $H(1s) + H^+$ and we y bound molecular ion H_2^+ in the electronic ground state

$$H_2^+(1\Sigma_g) + e \Rightarrow H^*(n) + H(1s), \qquad (1a)$$

$$H(1s) + H^+ + e \Rightarrow H^*(n) \quad H(1s), \qquad (1b)$$

where $H^*(n)$ represents hydrogen atom in excited ate, with the principal quantum number $n \geq 4$. Then, in the paper [4] we showed that ch recombination processes could be of importance for low temperature astrophysical asmas. In this paper we consider recombination processes (1a,b) in connection with t plasma of low-temperature layers of sun atmosphere (photosphere and lower part of c mosphere). The principal aim of this paper is to show that these processes must be ta into account when modeling the mentioned layers of sun atmosphere, together with th processes of the electron-electron-ion recombination

$$H^+ + e + e \Rightarrow H^*(n) \quad , \qquad (2)$$

whose importance for low-temperature plasmas is ve well known [5, 6].

* * *

In papers [1, 2] it was shown that processes (1a), ch fall into the class of processes of disociative recombination, and processes (1b) have ilar intensities in the conditions characteristic for weakly ionized plasmas, and there must always be considered together, namely as the cannels (a) and (b) of the rec bination process (1) as a whole. Then, in the paper [3] the recombination processes (were considered from the aspect of their influence on the population of the atoms H^* for $4 \leq n \leq 10$ in equilibrium and nonequilibrium hydrogen plasmas, in the tempera e domain $2000 - 10000K$ for the atomic particles, and temperature domain 2000−3000 for the electrons. That is why in that paper processes (1) were considered together wit e processes of electron-electron-ion recombination (2). On that basis in the paper [3] showed that the influence of the processes (1) on the populations of excited atoms in sma, whose degree of ionization is $\leq 10^{-2}$, is either as important as the influence of cesses (2), or is even dominant. These facts show why the ole of recombination proces of type (1), in the kinetics of of low-temperature astrophysical plasmas, especially the sma of sun atmosphere, deserves the special attention.

Theory

In previous papers recombination processes were treated within semiclassical approximation. The expressions for rate coefficients of recombination processes (1a,b) represent one of the basic results of those papers. We denote that coefficcients by $K_r^{(a,b)}(n, T_a, T_b)$, and the total rate coefficient by $K_r^{(ab)}(n, T_a, T_b) = K_r^{(a)} + K_r^{(b)}$. In accordance with [3] these coefficients are given by the expressions

$$K_r^{(a,b)}(n, T_a, T_e) = C_r(n, T_e) \int_0^{R_n} exp\left[-\frac{\varepsilon(R)}{kT_e} - \frac{U_1(R)}{kT_a}\right] X^{(a,b)}(R, T_a)\frac{R^4\, dR}{a_0^5}, \quad (3)$$

$$K_r^{(ab)}(n, T_a, T_e) = C_r(n, T_e) \int_0^{R_n} exp\left[-\frac{\varepsilon(R)}{kT_e} - \frac{U_1(R)}{kT_a}\right] \frac{R^4\, dR}{a_0^5}, \quad (4)$$

where $U_1(R)$ and $U_2(R)$ are the adiabatic terms of the ground ($1\Sigma_g$) and the first excited ($1\Sigma_u$) electronic state of the molecular ion H_2^+, whose values are taken from [7], and

$$\varepsilon(R) = U_2(R) - U_1(R),$$

$$X^{(a)}(R, T_a) = 1 - X^{(b)}(R, T_a),$$

$$X^{(b)}(R, T_a) = \begin{cases} \Gamma\left[\frac{3}{2}; -\frac{U_1(R)}{kT_a}\right]\Gamma^{-1}(\frac{3}{2}), & \text{if } U_1(R) < 0, \\ 1, & \text{if } U_1(R) \geq 0, \end{cases} \quad (5)$$

while the coefficient $C_r(n, T_e)$ is given by the expression

$$C_r(n, T_e) = \frac{(2\pi)^{5/2}}{3\sqrt{3}} \frac{(\hbar e a_0)^2}{m^{3/2}} \frac{exp(I_n/kT_e)}{(kT_e)^{3/2}} n^{-3}, \quad (6)$$

where $I_n = R_y/n^2$ is the ionization potental of the $H^*(n)$ atom. The upper integration limit R_n, for the values of $n = 4, 5, 6, 7, 8$, has the values R_n =5.535, 6.091, 6.533, 6.902, 7.218, respectively.

Results and discussion

In paper [8], where the standard chromospheric model (model C) is given, among other data temperatures $T(h)$ are given, as well as concentrations of free electrons $N_e(h)$, concentrations of protons $N_p(h)$ and concentrations $N_n(h)$ of the hydrogen atoms in the states with $1 \leq n \leq 8$, as a function of height h in the range $-75 \leq h \leq 2543\, km$. This enables us, for the given range h, to determine the equilibrium concentrations $N_n^{eq}(h)$ of the atoms $H^*(n)$ which respond to $T(h)$, $N_e(h)$ i $N_p(h)$, and then the values of ratio $N_n(h)/N_n^{eq}(h)$. Here, the values of that ratio are given in Table 1, for $4 \leq n \leq 8$ and $-75 \leq h \leq 905\, km$. This table shows that in the given range h the values of ratio significantly differ from 1, which shows the important deviations of distribution functions for populations of excited states of hydrogen atoms from the equilibrium distribution. Because of this fact, the question of relative importance of processes (1), which has not been considered up until now, to the processes (2) becomes important. Now, we denote by

Table 1: Values of ratio … $h)/N_n^{eq}(h)$

h(km)	T(K)	4	5	6	7	8
905	5755	1.1996	1.0563	1 170	.9710	.9683
855	5650	1.1747	1.0392	1)15	.9560	.9537
755	5280	1.0444	.9547	. i02	.8899	.8889
705	5030	.9362	.8795	. i68	.8318	.8321
655	4730	.8011	.7878	i49	.7641	.7659
605	4420	.6752	.7004	:05	.6981	.7015
555	4230	.6190	.6661	.)36	.6720	.6755
515	4170	.6195	.6745	)31	.6795	.6828
450	4220	.6884	.7405	. i46	.7357	.7380
350	4465	.8518	.8812	)37	.8564	.8572
250	4780	.9771	.9862	)98	.9479	.9478
150	5180	1.0323	1.0397	1 397	.9973	.9967
100	5455	1.0290	1.0438	1 444	1.0042	1.0035
50	5840	1.0273	1.0260	1 416	1.0040	1.0035
0	6420	1.0191	1.0359	366	1.0029	1.0024
-25	6910	1.0167	1.0326	.335	1.0022	1.0016
-50	7610	1.0161	1.0303	.309	1.0024	1.0021
-75	8320	1.0154	1.0285	291	1.0031	1.0027

Table 2: Values of ratio $I_{r;n}^{(ab)}(h)/I_{r;n}^{e}(h)$

h(km)	T(K)	n				
		4	5	6	7	8
905	5755	.1403E+01	.2822E+00	.7 0E-01	.2838E-01	.1184E-01
855	5650	.2056E+01	.4112E+00	.1)E+00	.4109E-01	.1712E-01
755	5280	.5975E+01	.1166E+01	.3 iE+00	.1139E+00	.4718E-01
705	5030	.1129E+02	.2163E+01	.5 E+00	.2078E+00	.8566E-01
655	4730	.1843E+02	.3447E+01	.9 3E+00	.3236E+00	.1326E+00
605	4420	.2418E+02	.4393E+01	.1 2E+01	.4015E+00	.1635E+00
555	4230	.2758E+02	.4913E+01	.1 5E+01	.4410E+00	.1788E+00
515	4170	.2950E+02	.5220E+01	.1 1E+01	.4657E+00	.1886E+00
450	4220	.3063E+02	.5449E+01	.1 5E+01	.4886E+00	.1981E+00
350	4465	.2948E+02	.5380E+01	.1)E+01	.4938E+00	.2013E+00
250	4780	.2666E+02	.5007E+01	.1 1E+01	.4720E+00	.1937E+00
150	5180	.2185E+02	.4234E+01	.1 3E+01	.4107E+00	.1699E+00
100	5455	.1780E+02	.3516E+01	.9 5E+00	.3472E+00	.1443E+00
50	5840	.1141E+02	.2307E+01	.6)E+00	.2330E+00	.9734E-01
0	6420	.4478E+01	.9335E+00	.2 9E+00	.9710E-01	.4087E-01
-25	6910	.1926E+01	.4103E+00	.1 2E+00	.4360E-01	.1845E-01
-50	7610	.6350E+00	.1390E+00	. 2E-01	.1515E-01	.6454E-02
-75	8320	.2419E+00	.5416E-01	. 4E-01	.6038E-02	.2588E-02

$$I^{(ab)}_{r;n}(h) = K^{(ab)}_r(T(h))N_e(h)N_p(h)N_1(h), \quad I^e_{r;n}(h) = K^e_r(T(h))N^2_e(h)N_p(h)$$

the recombination fluxes which, for given n and given h, are caused by the chemi-recombination processes (1) and processes of electron-electron-ion recombination (2), respectively. Here, $K^{(ab)}_r(T)$ is given by the expressions (4), (5) and (6) for $(T_e = T_a = T)$, and the values of rate coefficients of electron-electron-ion recombination $K^e_r(T)$ are determined by the expressions from the paper [9]. The relative importance of the processes (1) and (2), for given h, is characterised by the values of the ratio $I^{(ab)}_{r;n}(h)/I^e_{r;n}(h)$, and these values are presented in the Table 2 for the $4 \leq n \leq 8$ and $-75 \leq h \leq 905\,km$.

From the Table 2 one can see that, for every n from the domain $4 \leq n \leq 8$, there exist a rather wide region of heights in which the value of the ratio $I^{(ab)}_{r;n}(h)/I^e_{r;n}(h)$ is greater or close to 0.1, and that this region gets wider with the decrease of n, with the appearance of subregion in which the value of ratio $I^{(ab)}_{r;n}(h)/I^e_{r;n}(h)$ is greater or close to 1. Furthermore, for $n = 4$ and 5 one can notice that in some regions of h chemi-recombination processes (1) become dominant in the comparison with the processes of the electron-electron-ion recombination (2), because in that regions ($-25 \leq h \leq 855\,km$ for $n = 4$ and $50 \leq h \leq 750\,km$ for $n = 5$) the ratio $I^{(ab)}_{r;n}(h)/I^e_{r;n}(h)$ is the several times greater then 1. This clearly shows that chemi-recombination processes (1) must be taken into account when modeling the low-temperature layers of sun atmosphere.

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ABSTRACTS OF INVITED LECTURES AND PROGRESS REPORTS

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ON THE STARK BROADENING C Ba II SPECTRAL LINES

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Abstract. Using a semiclassical approach, : have calculated electron–, proton–, and ionized helium–impact line widths and shif: for 64 Ba II multiplets for perturber densities 10^{15}– 10^{18} cm^{-3} and temperatures T = 5)0 – 100,000 K. Obtained results have been compared with available experimental and t :oretical data.

INTRODUCTION

Ionized barium lines are of interest for the ıvestigation of laboratory as well as astrophysical plasmas. Stark broadening of Ba II es has been considered experimentally and theoretically in a number of articles. Kato al. [1] investigated wavelength shifts of Ba II lines emitted by an inductively coupled ıasma. Manning et al. [2] performed a study of the effect of pressure and electron de. ty on wavenumber position for Ba II lines. Experimental Stark broadening paramete: :or ionized barium lines of Jaeger [3], Purić & Konjević [4], Hadžiomerspahić et al. [5 and of Fleurier et al. [6], have been critically reviewed in Refs. 7 and 8.

Stark widths of Ba II lines have been calcul: d by Cooper & Oertel [9] within the semiclassical approa. taking into account hyper. ic classical perturber paths and lower level broadening. For Ba II 1, 2, 3, and 4 multipl. they give full width at half maximum (FWHM) values of 0.42 Å, 0.84 Å, 1.02 Å and 1.20 respectively, but without the electron temperature specified. Ba II lines have been co :dered theoretically as well by Davis [10], for research of a laser - generated barium pl: ıa, by Sahal - Bréchot [11] within the semiclassical - perturbation formalism and by Fle :r et al. [6] within the same formalism but with the effect of Feshbach resonances inclu :d. The semiclassical calculations by using the theoretical approach developed by Gri et al. [12] and further improved and described in detail in Refs. 13 and 14, were per. :med by Purić et al. [15]. For Ba II $6s^2S$ - $6p^2P^o$ multiplet, at an electron density of N = 10^{17} cm^{-3} and electron temperature T=15000 K, they obtain FWHM = 0.428 Å. In R :. 7 and 8 the theoretical comparison data have been calculated by W.W.Jones (priva communication in Ref. 7), by using the same method. Stark broadening parameters : 3a II mult. 1 and 2, for T = 16000 K have been calculated also by Gorchakov & Demki 16] within the semiclassical approach of Vainshtein & Sobel'man [17]. Griem's semiem :ical formula [18] has been applied to Ba II lines in Refs. 5, 6 and 19. Moreover, Dim. :ijević & Konjević [19] performed for Ba II $6s^2S$-$6p^2P^o$ multiplet 1, linewidth calculat ıs within the modified semiempirical method [20] and within the same approach but w a the Gaunt factor derived from Ref. 21 for the perturbing transitions without the ch. :e of the principal quantum number, Lakićević [22] estimated line widths and shifts fo: ›a II $6s^2S$ - $6p^2P^o$ multiplet for T =

TABLE I

Experimental Stark f widths at half maximum (W) and shifts (dm) in Å compared with theory. The Wth a dth are present semi - clas cal calculations. Experimental values: (a) - Fleurier et (1977) [6]; (b) - Jaeger (1969) [3]; (c) - Purić & Konjević (1972) [4]; (d) - Hadžiom pahić et al. (1973) [5].

Transition (Mult.)	Wavelength	T(K)	Ne [10(+17) cm(-3)]	Wm [A]	Wth [A]	dm [A]	dth [A]	Ref.
5d-6p (2)	6141.72	13000	1.13	0.50	0.91	-	-	a
		13200	1	1.58	0.80	-	-	b
		16800	1	-	-	0.07	0.002	c
		27100	1	0.28	0.62	-	-	d
		31700	1	0.28	0.59	-	-	d
	6496.9	16800	1	-	-	0.07	0.002	c
		27100	1	0.28	0.62	0.05	0.002	d
		31700	1	0.28	0.59	-	-	d
	5853.7	13200	1	1.32	0.80	-	-	b
6s-6p (1)	4554.03	13000	1.13	0.49	0.58	-0.050	-0.095	a
		13200	1	0.80	0.51	-	-	b
		16800	1	-	-	-0.06	-0.076	c
		27100	1	0.26	0.39	-	-	d
	4934.09	13000	1.13	0.49	0.58	-0.050	-0.095	a
		13200	1	0.94	0.51	-	-	b
		16800	1	-	-	-0.07	-0.076	c
		27100	1	0.24	0.39	-	-	d
6p-6d (4)	4130.6	13200	1	1.24	1.07	-	-	b
	4166.0	13200	1	1.26	1.07	-	-	b
	3891.8	16800	1	-	-	0.26	0.49	d
		31700	1	0.28	0.93	0.33	0.40	d
6p-7s (3)	4899.9	13200	1	1.48	1.10	-	-	b
	4524.9	13200	1	1.28	1.10	-	-	b

20000 K, on the basis of the Stark broadening pai ieter dependence on the ionization potential from the lower level of the correspondir. :ransition. By using Ba II 4899.9 Å and 4524.9 Å lines as example, Dimitrijević & ɔpović [23] demonstrated a simple method (developed for neutrals by Vitel et al. [: . suitable for critical evaluation of existing data and interpolation of new Stark wid s along homologous sequences, by using a normalization factor for analogous transitic .

In order to continue our research of Stark broad .ng parameters needed for the investigation of astrophysical and laboratory plasmas ai. to provide the needed Stark broadening data, we have calculated within the semicl ical-perturbation formalism [11,25] electron-, proton-, and ionized helium-impact line dths and shifts for 64 Ba II multiplets.

RESULTS AND DISCUSSION

A summary of the formalism and all details of .lculations are given in Refs. 25-28. We note here that the inelastic collision contribut .ı is included in the ion-impact line widths.

In addition to electron-impact full halfwidths d shifts, Stark-broadening parameters due to proton-, and He II- impacts have beer. alculated. Our results for 64 Ba II multiplets, for perturber densities 10^{15}– 10^{18} cm^{-3} ; .l temperatures T = 5,000 – 100,000 K, will be published elsewhere [27].

In Table 1 our results are compared with the ;xperimental results [3-6], critically selected in Refs. 7 and 8. One can see that large ifferences between particular experiments and between theory and experiment exist. 'he agreement exist between widths of Fleurier et al. [6], which experiment was critic .y estimated [8] to have the highest accuracy among Ba II experimental data, and our sults for $6s^2S$ - $6p^2P^o$ multiplet. For the shift, the best agreement is with results of Puri(Konjević [4] for the same multiplet.

Our results for Stark width are in agreement ith the semiclassical calculations of Cooper and Oertel [9] as well as with the semicl ical calculations by using the theoretical approach developed by Griem et al. [12-1 performed by W.W. Jones (private communication in Ref. 7), and Purić et al. [15]. (· Stark width calculation are also in agreement within the error bars of the methods v .ı various semiempirical calculations [5,6,19] as well as with simple Stark width estimate 22]. For Ba II $6s^2S$ - $6p^2P^o$ multiplet, Lakićević [22] obtained FWHM = 0.50 Å at an e. :ron density of N_e = 10^{17} cm^{-3} and electron temperature T=20000 K, and our result i).43 Å.

Our results for the shift are in agreement wi: ı the error of the method with the semiclassical calculations of W.W. Jones (private c. ımunication in Ref. 7), but in strong desagreement with calculations in Ref. 16, perfor :d within the semiclassical approach of Vainshtein & Sobel'man [17], with semiempirica alculations in Ref. 4 and with simple estimates [22]. New high precision measurements Stark broadening parameters for Ba II lines will be of interest for the development of tl retical methods for heavy atoms and ions.

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ION-ATOM COLLISIONS AND ELECTRON RECOMBINATION IN ASTROPHYSICAL HYDROGEN PLASMA

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Introduction

Besides the interaction between diatomic molecular ions and colliding atom - atomic ion complexes with radiation in plasma, it is obviously actual and the problem of their interaction with free electrons. Recently has been presented and applied to hydrogen case a quasiclassical method for the calculation of total and partial recombination rate coefficients for the following processes (Mihajlov et al. 1992):

$$A_2^+ + \bar{e} \Longrightarrow A + A^*(n) \tag{1a}$$

$$A + A^+ + \bar{e} \Longrightarrow \begin{cases} A + A^*(n) \\ A^*(n) + A \end{cases} \tag{1b}$$

where A denotes a neutral atom in ground state, A^+ and A_2^+ atomic and molecular ions in ground states, $A^*(n)$ atom excited to the level with the principal quantum number n, and $\bar{e}$ denotes free electron. Processes (1a) and (1b) are important recombination channels in weakly ionised stellar plasmas, for temperatures $T < 10000K$.

In this contribution we present an approximate method, derived from previous one for the case $n \gg 1$. In the case of hydrogen, this method agrees within several percents with previous one for $n > 10$ and converges very quckly. The method is based on tables with results of more sophysticated calculations for a particular $n \gg 1$ ($n = 4$ in the present case), which are a starting point for a simple interpolation to higher n cases.

THEORY AND DISCUSSION

The electron energy ϵ is calculated in the $A + A^+$ complex center of mass reference frame, temperature T_a of the ion-atom component.

The recombination rate coefficient $K_n^{(a,b)}$ for the processes (1a) and (1b) is written as with electron temperature T_e. (We note that T_e is not in a general case equal to the atom temperature T_a.)

On the basis of the results given in Mihajlov and Janev (1981); Mihajlov and Dimitrijević (1992) we have $K_n^{(a,b)}$ in the form

$$K_n^{(a,b)}(T_a, T_e) = C_n(T_a, T_e) \int_{\epsilon_n}^{\epsilon_{max}} \frac{e^{-\epsilon/kT}}{\gamma\epsilon} R_\epsilon{}^4 e^{-U_1(\epsilon)/kT_a} X^{(a,b)}(\epsilon, T_a) d\epsilon \qquad (2)$$

where

$$C_n(T_a, T_e) = \frac{8\pi^{5/2}}{3\sqrt{6}} \frac{1}{n^3(kT)^{3/2}} \exp\left(\frac{|\epsilon_n|}{kT}\right)$$

$$X^{(a)}(\epsilon, T_a) = \Phi(\sqrt{Z}) - \frac{2}{\sqrt{\pi}} Z \exp(-Z)$$

$$X^{(b)}(\epsilon, T_a) = 1 - X^{(a)}(\epsilon, T_a)$$

$$Z = -\frac{U_1(R_\epsilon)}{kT_\epsilon} \qquad (3)$$

where T_e is electron temperature (We note that T_e is not in a general case equal to the atom temperature T_a.), Φ is the error function (Abramowitz and Stegun, 1972), and all quantities in the Eqs. (2,3) are in atomic units. The internuclear distance R_ϵ as a function of ϵ is determined from the equation

$$\epsilon = U_2(R_\epsilon) - U_1(R_\epsilon)$$

where it is assumed that the electron recombination occurs in the close vicinity of the resonant internuclear distance R_ϵ. Here ϵ is the energy difference between the final

In the hydrogen case, the proposed method is correct for $n \geq 4$ in this case (see the corresponding discussion in Mihajlov et al 1992).

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PROCEEDINGS

ON THE IONIZED IRON LINES STARK BROADENING IN PLASMAS

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Fe II lines are present in solar and stellar spectra and for their analysis or the calculations of synthetic spectra corresponding Stark broadening data are of importance. Stark broadening data for Fe II lines are of significance for laboratory plasma as well, since the iron is often present as impurity in various plasmas.

The strongest Fe II lines correspond to 4s-4p and 3d-4p transitions in $3d^6nl$ and $3d^54snl$ configurations, covering some 1500 observed lines and accounting for the main part of the intensity of the Fe II spectrum. However, if one wishes to perform a more sophisticated calculations it is not easy to collect the sufficiently complete energy level set and to avoid the additional difficulties due to configuration interaction and violation of the LS selection rules. The best situation is just with 4s-4p sextets, which Stark broadening parameters have been determined experimentally in [1], where the sufficiently complet energy level set exists and there is not pronounced configuration interactions or critical violations of the LS selection rules, so that the semiclassical calculations may provide more reliable Stark broadening parameters.

By using the semiclassical-perturbation formalism [2,3] we have calculated Stark broadening parameters for singly-ionized iron a^6D - z^6P^o, a^6D - z^6D^o and a^6D - z^6F^o multiplets. Perturbers are electrons and protons.

RESULTS AND DISCUSSION

All details of calculations will be given elsewhere [4]. Results for a^6D - z^6P^o, a^6D - z^6D^o and a^6D - z^6F^o multiplets, covering 34 lines within 2328.11-2632.108 A° range, are shown in Table 1.

In Table 2 the present theoretical full half-widths have been compared with experimental results [1] as well as with the calculations from Ref. [5] performed by using the modified semiempirical approach [6] and with simple theoretical estimates [7] based on regularities and systematic trends. For the experiment from Ref. 1, SF_6 has been used as a working gas. Since the ionized sulphur has the lower ionization potential and the corresponding linewidth is larger, full half width due to S II- impacts has been presented in Table 2 as an upper limit of ion broadening contribution. We can see that semiclassical calculations with the ion broadening contribution included, give larger widths than experiment but within the error bars of theory and experiment. Taking into account the complexity of the Fe II spectrum, the results in ref. 5 obtained by using the modified semiempirical method [6] are in satisfactory agreement with the experimental values. The agreement of simple estimates [7] with experimental and semiclassical values is encouraging as well.

PERTURBER DENSITY = $10^{17} cm^{-3}$

TRANSITION	T(K)	ELECTRONS WIDTH(A)	ELECTRONS SHIFT(A)	PROTONS WIDTH(A)	PROTONS SHIFT(A)
Fe II a^6D-z^6F	5000.	0.117	0.262E-03	0.169E-02	-0.546E-04
2392.9 A	10000	0.854E-01	-0.325E-03	0.313E-02	-0.121E-03
C= 0.21E+21	30000.	0.519E-01	-0.304E-03	0.519E-02	-0.323E-03
	50000.	0.432E-01	-0.411E-03	0.571E-02	-0.436E-03
	100000.	0.362E-01	-0.398E-03	0.638E-02	-0.599E-03
	150000.	0.336E-01	-0.391E-03	0.669E-02	-0.664E-03
Fe II a^6D-z^6D	5000.	0.137	0.158E-03	0.173E-02	-0.196E-03
2611.4 A	10000.	0.993E-01	-0.138E-02	0.329E-02	-0.422E-03
C= 0.26E+21	30000.	0.600E-01	0.113E-02	0.562E-02	-0.972E-03
	50000.	0.496E-01	-0.153E-02	0.620E-02	-0.124E-02
	100000.	0.411E-01	-0.146E-02	0.696E-02	-0.155E-02
	150000.	0.380E-01	-0.145E-02	[illegible]	-0.172E-02
Fe II z6D-z6P	5000.	0.112	0.135E-03	[illegible]	-0.362E-04
2334.8 A	10000.	0.816E-01	-0.211E-03	0.310E-02	-0.806E-04
C= 0.19E+21	30000.	0.498E-01	-0.222E-03	0.509E-02	-0.224E-03
	50000.	0.414E-01	-0.278E-03	[illegible]	-0.314E-03
	100000.	0.347E-01	-0.285E-03	0.625E-02	-0.435E-03
	150000.	0.323E-01	-0.274E-03	0.625E-02	0.490E-03

Table 1: This table shows Stark broadening full half-widths (FWHM) and shifts for Fe II for a perturber density of $10^{17} cm^{-3}$ and temperatures from 5 000 up to 150 000 K. Perturbers are electrons and protons. By deviding c with the full linewidth, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

Transition	Wavelength [A]	T [10^4K]	N [10^{17}cm^{-3}]	WM[A]	We[A]	WSII[A]	WDK[A]	WP[A]
a^6D-z^6D^o	2598.37	3.00	1.95	0.070	0.117	0.0130	0.068	0.126
		2.90	1.64	0.058	0.100	0.0109	0.059	0.108
		2.80	1.06	0.044	0.066	0.0070	0.038	0.072
	2607.52	3.00	1.95	0.100	0.117	0.0130	0.068	0.126
		2.90	1.64	0.076	0.100	0.0109	0.059	0.108
		2.90	1.27	0.058	0.077	0.0084	0.045	0.084
	2611.87	3.00	1.95	0.096	0.117	0.0130	0.068	0.126
		2.90	1.64	0.090	0.100	0.0109	0.059	0.108
		2.80	1.06	0.072	0.066	0.0070	0.038	0.070
	2613.82	3.00	1.95	0.088	0.117	0.0130	0.068	0.126
		2.90	1.64	0.072	0.100	0.0109	0.059	0.108
		2.80	1.06	0.044	0.066	0.0070	0.038	0.070
	2617.62	3.00	1.95	0.084	0.117	0.0130	0.068	0.126
		2.90	1.64	0.072	0.100	0.0109	0.059	0.108
		2.80	1.06	0.050	0.066	0.0070	0.038	0.070
a^6D-z^6F^o	2373.74	2.80	1.06	0.062	0.057	0.0065	0.034	0.064
	2382.04	3.00	1.95	0.090	0.101	0.0121	0.060	0.114
		2.90	1.64	0.080	0.086	0.0101	0.051	0.098
		2.80	1.06	0.048	0.057	0.0065	0.034	0.064

Table 2: Comparison of experimental and theoretical Stark widths (FWHM) at corresponding electron densities N, and temperatures T. WM - experimental widths (FWHM) of Purić *et al.* [1]; We - present semiclassical widths (FWHM) for electron-impact broadening; WSII - present semiclassical widths (FWHM) for SII- impact broadening; WDK - Dimitrijević [5]; WP - Purić *et al.* [7].

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PROGRAMME & ABSTRACTS

QUANTITATIVE ESTIMATES OF DOPPLER AND LORENTZ BROADENING FROM SPECTRAL LINE PROFILE

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It is well known that the Doppler broadening and Lorentz one can be determined from a spectral line profile emitted by plasma and measured for example by means of the Fabry-Perot interferometer. To estimate the parameters the least squares method has been used frequently. Knowing in advance for a concrete model statistical quantities such as confidence intervals and correlation coefficients, a chance exists that the parameters will be evaluated with reasonable precision. First attempt to do such analysis of the problem from this point of view will be presented.

ON THE IONIZED IRON LINES STARK BROADENING IN PLASMAS

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The research of neutral and ionized iron spectra is of great importance for the investigations of stellar plasma. This is an element witho high abundance and its role is important in various processes in stellar plasma. Fe II lines are present in solar and stellar spectra and for their analysis or the calculations of synthetic spectra corresponding Stark broadening data are of importance. Stark broadening data for Fe II lines are of significance for laboratory plasma as well, since the iron is often present as impurity in various plasmas.

The strongest Fe II lines correspond to 4s-4p and 3d-4p transitions in $3d^6nl$ and $3d^54snl$ configurations, covering some 1500 observed lines and accounting for the main part of the intensity of the Fe II spectrum. However, if one wishes to perform a more sophisticated calculations it is not easy to collect the sufficiently complete energy level set and to avoid the additional difficulties due to configuration interaction and violation of the LS selection rules. The best situation is just with 4s-4p sextets, which Stark broadening parameters have been determined experimentally in [1], where the sufficiently complet energy level set exists and there is not pronounced configuration interactions or critical violations of the LS selection rules, so that the semiclassical calculations may provide more reliable Stark broadening parameters.

By using the semiclassical-perturbation formalism [2] we have calculated Stark broadening parameters for singly-ionized iron a^6D - z^6P^o, a^6D - z^6D^o and a^6D - z^6F^o multiplets. Perturbers are electrons, protons and a singly charged perturber with the mass equal to 35 a.u. corresponding to the averaged mass of perturbing ions in Solar atmosphere. The obtained results have been compared with experimental data and simpler evaluations.

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IMPROVED ALGORITHM FOR INTERPRETATION OF LANGMUIR PROBE DATA

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In this work we present an improved algorithm for interpretation of single Langmuir probe characteristic. The main focus of the improvements is given to the case when the electron energy distribution function (EEDF) cannot be approximated by a maxwellian one. In these circumstances (and, of course, in case of a maxwellian EEDF too) our program offers the determination of the electron density n_e and electron "effective temperature" V_{eff} by using integration of the measured EEDF, i.e. by using the formulae

$$n_e = \frac{2^{3/2} m_e^{1/2}}{e_0^{3/2} A_p} \int_0^\infty I_e''(V)\, V^{3/2}\, dV$$

$$V_{eff} = \frac{2}{3} \frac{\int_0^\infty I_e''(V)\, V^{3/2}\, dV}{\int_0^\infty I_e''(V)\, V^{1/2}\, dV}$$

where m_e, e_0 are the electron mass, charge respectively and A_p is the area of the probe. In case that the EEDF can be approximated by "standard distribution", i.e. the EEDF of the form

$$f^*(\varepsilon) = const\ \varepsilon_p^{3/2} \exp\left[-\varepsilon^k/\left(k\, \varepsilon_p^k\right)\right] ,$$

where k is a rational number ≥ 1 and ε_p is the most probable electron energy the computer fit of the standard EEDF to the measured data can be made prior to the integration procedure. In addition, the case of a "double temperature" distribution, i.e. the EEDF which can be approximated by two maxwellian EEDF's with different temperatures (case found e.g. in an argon RF discharge at low pressures) can be treated by the presented algorithm; first the computer fit is made in an interactive manner and then the electron density and electron "effective temperature" is calculated using the above described "integral evaluation"of the probe characteristic.

XIV

NATIONAL CONFERENCE OF ASTRONOMERS OF SERBIA AND MONTENEGRO

BOOK OF ABSTRACTS

October 12 – 15, 2005

Belgrade

Serbia and Montenegro

NICEPHOROS GREGORAS THE GREATEST BYZANTINE ASTRONOMER AND SERBS

Efstratios Th. Theodossiou[1], **Vassilios N. Manimanis**[1] **and Milan S. Dimitrijević**[2]

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In the wider Greek area no eminent astronomer appeared after the great Claudius Ptolemy. For ten centuries after Ptolemy we can distinguish only one: Nicephoros Gregoras (1295–1360). The monk Nicephoros Gregoras is considered along with his teacher, Theodoros Metochites, one of the most significant scholarly figures of Byzantium. Gregoras was first to propose, in 1324, a correction to the calculation of the Easter and to Julian calendar similar to the one adopted later, in 1582, by the Pope Gregory XIII. This proposition and, more obviously, his dispute with St. Gregorios Palamas, created problems in the relations of Gregoras with the Church, leading to desecration of his corpse by the fanatic crowd. It is interesting that he was in diplomatic mission in 1326 to Milutin, King of the Serbs, who had married the granddaughter of the Emperor Andronicus II Palaelologous, Simonida. Moreover, in 1334, the Emperor Andronicus III entrusted Gregoras with a diplomatic mission to the new King of the Serbs Stephan Dushan, bearing peace proposal to end the hostilities between the Serbs and the Byzantines. Gregoras is also author of the famous "Byzantine History", composed of 37 books. Its 7 leading chapters give a short account of the events from 1204 to 1320, while the rest 30 covers extensively the period from 1320 up to 1359. This book is also important for the history of the medieval Serbia. In this contribution we (Efstratios Th. Theodossiou, Vassilios N. Manimanis and Milan S. Dimitrijević) will elucidate life and works of the great Byzantine astronomer, historician and philosopher Nicephoros Gregoras.

ASTRONOMY EDUCATION IN SERBIA AND MONTENEGRO 2002-2005

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Astronomy education in Serbia and Montenegro is reviewed with special attention paid to the changes introduced from June 1, 2002 to June 1, 2005.

NATIONAL CONFERENCE OF XV ASTRONOMERS OF SERBIA

XV National Conference of Astronomers of Serbia

Belgrade, 2-5 October 2008

BOOK OF ABSTRACTS

Eds. Olga Atanacković, Zorica Cvetković and Dragana Ilić

Faculty of Mathematics

Astronomical Observatory

Belgrade 2008

XV NATIONAL CONFERENCE OF ASTRONOMERS OF SERBIA
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Book of abstracts, eds. O. Atanacković, Z. Cvetković, D. Ilić
Faculty of Mathematics and Astronomical Observatory, Belgrade, 2008

Short talk

DJORDJE STANOJEVIĆ IN ASTRONOMY AND ASTROPHYSICS

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A review of contributions of Djordje Stanojević (1858-1921) to Astronomy and Astrophysics is presented on the occasion of 150 years since his birth.

Short talk

DJORDJE STANOJEVIĆ IN WORKS OF JULES JANSSEN

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Jules Janssen (Paris 1824 - Meudon 1907) is well known as the founder of the "Observatoire d'Astronomie Physique de Paris (sis à Meudon). He was also professor and collaborator of Djordje Stanojević, the first Serbian astrophysicist, rector of the Belgrade University and the second person on the head of Belgrade Astronomical Observatory, the first builder of hydro power plants in Serbia, the author of the first color fotography and the first book with color fotographies (Srbija u slikama - Serbia in photos) in Serbia, pioneer of electrification and industrialization of our country. His articles in the journal of the French Academy of Sciences (Comptes Rendus de l'Academie des Sciences) are in the Serbian Astronomy the first modern scientific papers. They are presented and commented in Academy by Jules Janssen, who also mentions Stanojević in his works in various contexts. In this contribution, presence of Djordje Stanojević in contributions of Jules Janssen and his comments on Stanojević's work in Comptes Rendus are analyzed. Also, the work and life of Jules Janssen are presented briefly.

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Poster

ACTIVITIES OF THE GROUP FOR ASTRONOMICAL SPECTROSCOPY 2005-2008

M. S. Dimitrijević[1], L. Č. Popović[1], D. Jevremović[1], M. Dačić[1], P. Jovanović[1], A. Kovačević[2], S. Simić[3], D. Ilić[2], Z. Simić[1], E. Bon[1], N. Gavrilović[1], J. Kovačević[1], N. Milovanović[1] and D. Tankosić[1]

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Fellows of the Astronomical Spectroscopy Group are participants of projects "Influence of collisions with charged particles on astrophysical plasma spectra", "Spectroscopy of extragalactic objects" and "Serbian Virtual Observatory", working together on the spectroscopy of cosmic plasmas, like Active Galactic Nuclei and stellar atmospheres. First two projects are supported by Ministry of Sciences of Serbia, and the third is proposed for funding to this Ministry as technological project. Within the 2005-2008 period fellows of the Group published more than 100 papers in peer reviewed international publications, among them 8 in ApJ, 2 in ApJS, 6 in MNRAS, 3 in PASJ, 3 in New Astronomy, 2 in New Astronomy Review, 2 in Rev. Mex. Astron. Astrophys., 2 in PASP, 2 in Astron. Nachrichten etc. They organized 5 conferences (5^{th} and 6^{th} Serb. Conf. Spect. Line Shapes in Astrophys, Development of Astronomy among Serbs 4 and 5, and 6^{th} Serb. Bulg. Astron. Conf.) and one school. We have also international collaboration with France, Greece, Italy, Russia, Germany, Tunisia, Spain and Bulgaria and within the considered period we had almost one hundred visits of foreign scientists and students. In this contribution we will present results of our activities within the considered period.

XV SUMMER SCHOOL and INTERNATIONAL SYMPOSIUM on the PHYSICS OF IONIZED GASES

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ASYMPTOTIC BEHAVIOUR OF THE STARK BROADENING A AND a FUNCTIONS FOR ATTRACTIVE HYPERBOLIC PATHS

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When the impact approximation is used within the semiclassical, Stark broadening theory[1-3] the time developement of the emiter-perturber system is contained in the so called Stark broadening functions[1-3], A, a, B and b. In the case of hyperbolic paths (attractive interaction), for the calculation of the linewidth we need the function

$$A(\xi,\varepsilon)=(\xi\varepsilon)^2\exp(\pi\xi)\{|K_{i\xi}(\xi\varepsilon)|^2+$$
$$+[(\varepsilon^2-1)/\varepsilon^2]|K'_{i\xi}(\xi\varepsilon)|^2\}, \quad (1)$$

where $K_{i\xi}(x)$ and $K'_{i\xi}(x)$ are a modified Bessel function of imaginary order and its derivative, ε is the perturber-path eccentricity

$$\xi=(e^2/\hbar v)(\hbar\omega_{ii'}/mv^2), \quad (2)$$

in the case of i and i′energy levels of a singly ionized radiator, and

$$a(\xi,\varepsilon)=\exp(\pi\xi)\xi\varepsilon K_{i\xi}(\xi\varepsilon)|K'_{i\xi}(\xi\varepsilon)| \quad (3)$$

In the case when $\xi>10$, the following assymptotic relations have been proposed by Klarsfeld[4] for $A(\xi,\varepsilon)$ and $a(\xi,\varepsilon)$:

$$A(\xi,\varepsilon)=\pi^{1/2}\varepsilon^{3/2}\{2\exp(-i\pi/3)\xi^{2/3}G_1(\zeta)-[(\tfrac{1}{8\varepsilon}-\tfrac{21}{40})G_0(\zeta)-$$
$$-\tfrac{11}{40}\zeta G_1(\zeta)-\tfrac{3}{10}\zeta^2G_2(\zeta)]\} \quad (4)$$

where

$$G_n\equiv\int_0^\infty dt\, t^{n+1/2}\exp(\zeta t-t^3/3)$$

$$\zeta\equiv 2\exp(2\pi i/3)(\varepsilon-1)\xi^{2/3}$$

and

$$a(\xi,\varepsilon)=\pi^{1/2}\varepsilon^{1/2}\{G_0(\zeta)+\tfrac{1}{2}\exp(i\pi/3)\xi^{-2/3}[(\tfrac{9}{20}-\tfrac{3}{4\varepsilon})\zeta G_0(\zeta)+$$
$$+\tfrac{3}{10}\zeta^2G_1(\zeta)+(\tfrac{1}{20}+\tfrac{3}{4\varepsilon})G_2(\zeta)]\} \quad (5)$$

We tested these expressions for a large range of ξ and ε values and found that when ε is close to 1 ($\delta = \xi(\varepsilon - 1)$ small) the proposed rxpressions are not good. Developing $K_{i\xi}(\xi\varepsilon)$ and $|K'_{i\xi}(\xi\varepsilon)|$ in series[5] for the case of $\xi \gg 1$ and $\delta = \xi(\varepsilon-1) = O(\xi\varepsilon)^{1/3}$ one obtains

$$K_{i\xi}(\xi\varepsilon) = \frac{\sqrt{3}}{6} e^{-\pi\xi/2}\Big[\Gamma(1/3)\Big(\frac{6}{\xi\varepsilon}\Big)^{1/3} - \Gamma\Big(\frac{2}{3}\Big)\Big(\frac{6}{\xi\varepsilon}\Big)^{2/3}\delta + \Gamma\Big(\frac{4}{3}\Big)\Big(\frac{6}{\xi\varepsilon}\Big)^{4/3} \times$$
$$\times \frac{\delta}{3}\Big(\frac{\delta^2}{2} + \frac{1}{5}\Big) - \frac{\Gamma(5/3)}{8}\Big(\frac{6}{\xi\varepsilon}\Big)^{5/3}\Big(\frac{\delta^4 + \delta^2}{3} + 1/35\Big)\Big]$$

$$|K'_{i\xi}(\xi\varepsilon)| = \sqrt{\frac{3}{2}}\, e^{-\pi\xi/2}\Big(\frac{6}{\xi\varepsilon}\Big)^{2/3}\Big[2\Gamma\Big(\frac{2}{3}\Big) + \Big(\frac{6}{\xi\varepsilon}\Big)^{2/3}\Big(-\Gamma(4/3)(\delta^2 + \frac{2}{15})$$
$$+ \frac{1}{5}\Gamma\Big(\frac{1}{3}\Big)\Big) + \frac{6}{\xi\varepsilon}\Big(\Gamma(5/3)\frac{\delta}{6}(1 + 2\delta^2) - \frac{2}{9}\delta\,\Gamma\Big(\frac{2}{3}\Big)\Big)\Big]. \qquad (6)$$

A and a functions calculated using the proposed asymptotic relations, are compared with our calculations using Klarsfeld's expressions, in Table 1. One can see that for small δ values, the proposed relations give good results contrary to the Eqs. 4,5.

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Table 1. A and a functions.

ξ	δ	A(Eq.6)	A(Eq.4)	a(Eq.6)	a(Eq.5)
15.0	0.000E+00	10.9	0.000E+00	1.88	0.299
15.0	0.100E-01	11.0	13.5	1.87	1.87
15.0	0.200E-01	11.1	11.0	1.86	1.86
15.0	0.300E-01	11.2	11.1	1.86	1.82
15.0	0.400E-01	11.2	11.2	1.45	1.83
15.0	0.500E-01	11.3	11.3	1.84	1.83
15.0	0.600E-01	11.4	11.4	1.82	1.82
15.0	0.700E-01	11.5	11.5	1.83	1.82
15.0	0.800E-01	11.6	11.6	1.82	1.81
15.0	0.900E-01	11.7	11.7	1.81	1.80
15.0	0.100	11.7	11.7	1.80	1.80
15.0	0.200	12.4	12.4	1.72	1.72
15.0	0.300	12.9	12.9	1.64	1.64
0.100E+04	0.000E+00	167.	0.000E+00	1.82	0.182E-01
0.100E+04	0.100E-01	168.	0.595E-10	1.82	0.332E-12
0.100E+04	0.200E-01	168.	31.9	1.81	0.337
0.100E+04	0.300E-01	168.	208.	1.81	1.34
0.100E+04	0.400E-01	169.	213.	1.81	1.79
0.100E+04	0.500E-01	169.	186.	1.81	1.79
0.100E+04	0.600E-01	170.	170.	1.81	1.74
0.100E+04	0.700E-01	170.	168.	1.81	1.73
0.100E+04	0.800E-01	170.	170.	1.40	1.74
0.100E+04	0.900E-01	171.	171.	1.80	1.75
0.100E+04	0.100	171.	172.	1.80	1.76
0.100E+04	0.200	175.	175.	1.78	1.77
0.100E+04	0.300	178.	178.	1.77	1.76
0.100E+04	0.400	181.	181.	1.75	1.74
0.100E+04	0.500	184.	184.	1.73	1.73
0.100E+04	0.600	187.	187.	1.71	1.71
0.100E+04	0.700	190.	190.	1.69	1.69
0.100E+04	0.800	192.	192.	1.67	1.67
0.100E+04	0.900	194.	194.	1.65	1.65
0.100E+04	1.00	197.	197.	1.63	1.63

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ON THE STARK BROADENING OF Cu I LINES - THE INFLUENCE OF THE OSCILLATOR STRENGTH VALUES

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The spectral line shapes of neutral cuprum are often of importance for diagnostic purposes in laboratory plasmas. Moreover, the atomic structure of Cu I is simillar to iron, one of the astrophysically most interesting heavy element. In most semiclassical calculations, when a large number of oscillator strength values for different perturbing transitions are needed, the Coulomb approximation is used. It is of interest to investigate how the departure from this approximation influences on Stark broadening parameters in the case of a heavy element with a complex spectrum, such as Cu I.

Table 1. Line broadening parameters in Å for perturber density of $10^{16} cm^{-3}$

NE= 0.1D+17

TRANSITION	T(K)	ELECTRONS 2WE(A)	DE(A)	PROTONS 2WI(A)	DI(A)	IONIZED Cu 2WI(A)	DI(A)
4P - 5S 8041.0 A	2500.	0.113	0.780E-01	0.264E-01	0.204E-01	0.175E-01	0.105E-01
	5000.	0.131	0.936E-01	0.291E-01	0.238E-01	0.189E-01	0.127E-01
	10000.	0.146	0.113	0.321E-01	0.274E-01	0.204E-01	0.149E-01
	20000.	0.157	0.117	0.356E-01	0.312E-01	0.221E-01	0.172E-01
	30000.	0.169	0.118	0.379E-01	0.336E-01	0.232E-01	0.186E-01
	80000.	0.202	0.859E-01	0.440E-01	0.399E-01	0.264E-01	0.223E-01
4P - 6S 4515.1 A	2500.	0.183	0.127	0.396E-01	0.289E-01		
	5000.	0.214	0.155	0.444E-01	0.360E-01		
	10000.	0.234	0.178	0.498E-01	0.429E-01		
	20000.	0.251	0.179	0.559E-01	0.499E-01		
	30000.	0.262	0.163	0.598E-01	0.541E-01		
	80000.	0.316	0.121	0.705E-01	0.651E-01	0.396E-01	0.359E-01
4P - 4D 5197.9 A	2500.	0.187	-0.840E-01	0.394E-01	-0.264E-01		
	5000.	0.203	-0.555E-01	0.431E-01	-0.320E-01		
	10000.	0.220	-0.311E-01	0.474E-01	-0.377E-01		
	20000.	0.219	-0.113E-01	0.522E-01	-0.435E-01		
	30000.	0.219	0.815E-03	0.554E-01	-0.471E-01		
	80000.	0.217	0.723E-02	0.647E-01	-0.564E-01	0.396E-01	-0.312E-01
4P - 5D 4050.4 A	2500.	1.03	0.418E-01				
	5000.	1.04	0.777E-02				
	10000.	1.02	0.831E-02				
	20000.	0.982	0.484E-02				
	30000.	0.941	-0.659E-02				
	80000.	0.830	-0.103E-01				

Table 2. Same as in Table 1, but with oscillator strengths from Ref. 1, when availlable.

NE= 0.1D+17

TRANSITION	T(K)	ELECTRONS 2WE(A)	DE(A)	PROTONS 2WI(A)	DI(A)	IONIZED Cu 2WI(A)	DI(A)
4P – 5S 8041.0 A	2500.	0.207	0.160	0.503E-01	0.399E-01	0.295E-01	0.195E-01
	5000.	0.255	0.187	0.562E-01	0.475E-01	0.328E-01	0.246E-01
	10000.	0.298	0.215	0.628E-01	0.552E-01	0.364E-01	0.296E-01
	20000.	0.325	0.232	0.702E-01	0.634E-01	0.405E-01	0.346E-01
	30000.	0.335	0.231	0.751E-01	0.684E-01	0.431E-01	0.376E-01
	80000.	0.354	0.196	0.882E-01	0.817E-01	0.503E-01	0.453E-01
4P – 6S 4515.1 A	2500.	0.184	0.127	0.397E-01	0.290E-01		
	5000.	0.215	0.153	0.445E-01	0.360E-01		
	10000.	0.236	0.174	0.500E-01	0.430E-01		
	20000.	0.254	0.173	0.560E-01	0.500E-01		
	30000.	0.266	0.165	0.600E-01	0.54[illegible]E-01		
	80000.	0.317	0.121	0.706E-01	0.653E-01	0.397E-01	0.360E-01
4P – 4D 5197.9 A	2500.	0.197	-0.102	0.418E-01	-0.283E-01		
	5000.	0.200	-0.827E-01	0.460E-01	-0.346E-01		
	10000.	0.215	-0.580E-01	0.507E-01	-0.407E-01		
	20000.	0.222	-0.388E-01	0.560E-01	-0.471E-01		
	30000.	0.226	-0.270E-01	0.595E-01	-0.510E-01		
	80000.	0.235	-0.919E-02	0.695E-01	-0.611E-01	0.421E-01	-0.338E-01
4P – 5D 4050.4 A	2500.	1.03	0.420E-01				
	5000.	1.04	0.866E-02				
	10000.	1.02	0.101E-01				
	20000.	0.983	0.762E-03				
	30000.	0.941	-0.187E-02				
	80000.	0.830	-0.391E-02				

In this contribution, two different sets of oscillator strengths have been used: (i) calculated within Coulomb approximation and (ii) from the critical selection of best availlable results.[1]

Using the semiclassical-perturbational formalism[2,3] we have calculated widths (FWHM) (2W) and shifts (D) due to different charged perturbers, for selected Cu I multiplets. Results obtained using different oscillator strength sets are presented in Tables 1 and 2. We can conclude: (i) that the shift is more sensitive than the width; (ii) in the case of line widths, the results obtained using the coulomb approximation are correct when the contribution of allowed transitions is dominant and (iii) the significant difference in the case of 8041 Å multiplet is due to the influence of $4s^{2}\,{}^{2}D$-4p transition.

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September 3 - 7, 1990. Dubrovnik, Yugoslavia

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abstracts of invited lectures and progress reports

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SEMICLASSICAL AND APPROXIMATE METHODS FOR STARK-BROADENING INVESTIGATIONS OF ASTROPHYSICAL AND LABORATORY SPECTRA

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The growing interest in studying Stark broadening of spectral lines is motivated by the important role of these data for a number of astrophysical and physical problems as e.g. opacity calculations, abundance analysis, spectral analysis of stellar and solar radiation, as well as the diadnosis of astrophysical and laboratory plasmas. Here is presented a review of semiclassical calculations of Stark broadening parameters and comparison of different semiclassical procedures is discussed, as well as the agreement with critically selected experimental data and more sophysticated close coupling calculations.

We also give a review of approximate methods for the calculation of Stark broadening parameters, usefull especially in such astrophysical problems where large scale calculations and analyses must be performed and where a good average accuracy is expected.

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ELECTRON ELASTIC SCATTERING ON THE CUT-OFF COULOMB AND DEBYE POTENTIAL.

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The influence of electrostatic screening in plasma in the processes of electron scattering on positive ions has up until the present, most often been considered through the model method. This implies the introduction of some effective screening of the Coulomb potential. One of the best known is Debye potential:

$$U_D(r) = -\frac{e^2}{r}\exp\left(-\frac{r}{r_0}\right), \qquad (1)$$

where e is electron charge. Potential (1) is an example of a limitless potential range. At the same time, limited range potentials are used as in the case of the cut-off Coulomb potential:

$$U_C(r) = \begin{cases} e^2\left(-\frac{1}{r} + \frac{1}{r_0}\right), & r < r_0 \\ 0, & r > r_0 \end{cases} \qquad (2)$$

These models are used equally in different areas of plasma physics[1,2]. Bearing in mind research in the transport and optical characteristics of plasma[3,4], we have carried out comparative calculations of total and transport cross-sections for the elastic scattering of electrons at potentials (1) and (2). Calculations have been carried out for electron energy up to 5eV, which corresponds to temperatures $T \simeq 60000K$. The radius of screening r_0 was varied in the interval 10-100(a.u.), which corresponds to electron densities $N_e = 2\cdot10^{18}-2\cdot10^{21}cm^{-3}$. Total cross-section for elastic scattering at potential (1), for the same r_0 and ε_0 (ε_0 is electron energy given in $1/r_0$ units), are larger in order of magnitude of the cross-section for scattering at potential (2). This results should be born in mind wherever elastic scattering plays a role (for e.g. Stark broadening of ion spectral lines). The transport cross-section for electron scattering at potential (1), in units πr_0^2 of fixed ε_0, practically do not depend of r_0 when ε_0 > 0.1. The same is true for potential (2) when ε_0 > 0.5. Because of this, we will take that transport cross-section $\sigma_{tr}^{D,C} = \pi r_0^2 f^{D,C}(\varepsilon_0)$. Function $f^{D,C}(\varepsilon_0)$ are illustrated by Table 1. The Table 1 shows that differences between σ_{tr}^{C} and σ_{tr}^{D} are small when ε_0 > 1.5. The difference grows with the decrease of ε_0 and becomes significant when ε_0 < 1. It follows, therefore, that the question of choice concerning the kind of screening potential becomes one of great importance in ranges Ne and T where $e^2/r_0 \sim kT$, especially when describing the transport characteristics of plasma.

The calculations of total and transport cross-section for the scattering of electrons at potentials (1) and (2) were carried out by the method of partial waves. The authors wish to thank prof. C.J.Joachain who very kindly allowed them to use the required program.

Table 1

ε_0	.5	.6	.7	.8	.9	1.0	1.2	1.4	1.5	1.6	1.8	2.0
f^C	1.83	1.67	1.45	1.25	1.09	.95	.75	.61	.55	[illegible]	.42	.36
f^D	2.81	2.22	1.80	1.49	1.26	1.08	.83	.66	.59	[illegible]	.45	.38

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ABSTRACTS

of papers presented at the

20th Conference on Stellar Astronomy of Czech and Slovak Professional Astronomers

and

International Conference on Variable Star Research

Brno, Czech Republic
November 5–9, 1997

Ranked in alphabetic order of first author's name.

Determination of Distances to Novae

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The methods of determination of distances to classical novae are discussed. Methods are based on: 1. Trigonometric parallaxes. 2. Galactic rotation. 3. Strengths of interstellar lines. 4. Estimate of absolute magnitude at maximum using different absolute magnitude — rate of decline relationships and evaluation of interstellar extinction by various methods. 5. The absolute magnitude 15 days following maximum. 6. The plateau of constant bolometric luminosity. 7. Nebular expansion parallaxes. 8. Light echoes.

A Period Study of the Eclipsing Binary V566 Ophiuchi

Cnota, R. (presented by J. Speil)
Polskie towarzystwo miłośników astronomii

Roche Potentials for Non–synchronously Rotating and Elliptically Orbiting Close Binary

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In this contribution we discuss a problem of asynchronous rotation of hot components in symbiotic binaries. We derive an analytical form for the first approximation of the binary potential. We present an approximation derived from the numerical study of the Roche model for close binary stars and provide a formula which minimises the error between analytical and approximate equations for suitable range of input parameters. The presented approach offers a simple application of this case for a wider community.

Stark Broadening Parameters for Stellar Plasma Research: Bi III Lines

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Data on Stark broadening of stellar spectral lines are important for the consideration of various physical processes in stellar plasmas and for modelling and interpretation of stellar spectra. They are also of interest for the consideration of radiative transfer through subphotospheric layers, but also for the laboratory and fusion plasmas and laser produced plasmas research. The development of space born high precision spectroscopy provides an additional interest for lines of trace elements.

In order to provide the needed Stark broadening parameters, a project to calculate within the semiclassical–perturbation formalism and the modified semiempirical approach such data, is in course. We will summarize the achievements and objectives and as an example we will present the

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results of our calculations of Bi III lines within the semiclassical-perturbation and the modified semiempirical approaches.

An Analysis of the Dwarf Novae OY Car Light Curves Obtained during its Superoutburst in April 1992.

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Photometric observations of the dwarf-novae *OY Car*, made during its superoutburst in April 1992 (Bruch et al.,1996), are analysed via a model by Djurašević (1996) for synthesising of the light curves of a cataclysmic variable.

The model considers the radial and azimuthal temperature distributions in the disc that is formed around a white dwarf as a result of an intensive matter exchange between the components. A complex hot-spot structure and a radial temperature profile in the disk enable a successful interpretation of asymmetric and deformed light curves characteristic for such systems. An inverse problem method by Djurašević (1992), adapted to this model, is applied in analysing of the observed light curves.

Synthetic light curves, obtained by solving the inverse problem, provided a good fit to the observations. This shows that the proposed model can be used to estimate the system's parameters.

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A Photometric Study of the Early-type Binary BF Aurigae

Djurašević, G.[1], Demircan, O.[2], Özdemir, S.[2], Tanriver, M.[2], Müyesseroglu, Z.[2], Ak, H.[2], Albayrak, B.[2]

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The UBV observations of the massive binary *BF Aur* were made at the Ankara University Observatory during 1988, 1989 and 1996. The asymmetry of the light curves, arising from unequal height of successive maxima, indicates that the system is active. By analysing these observations in the framework of the Roche model (including the presence of bright regions on the components) one obtains a semidetached configuration of the system, with the cooler secondary component filling its Roche lobe. The analysis of the light curves yields consistent solutions for mass ratio $q = m_2/m_1$ somewhat less than one. The influence of the mass transfer on the change of the system-orbital-period is relatively small. The upward parabolic character of the $O - C$ diagram (Zhang et al., 1993) indicates a mass transfer from the less massive secondary to the more massive primary. This inturn requires the less massive secondary to fill its Roche lobe. This is consistent with our solution.

Based on these facts we introduced the following working hypothesis. At the place where the gas stream from the secondary falls on the primary, relatively small in size but a high temperature contrast active hot-spot (hs) region is formed. As a result of the heating effect caused by the irradiation of the hot-spot region, on the secondary's side facing the hot spot a bright-spot (bs) region is formed. The bright-spot region is larger in size but with significantly lower temperature

XX. ICPEAC

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MO 157

ON THE ELECTRON-IMPACT BROADENING OF S V LINES

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One of important applications of the electron - ion or electron - atom collision theory is the investigation of the influence of emitter/absorber collisions with electrons on spectral line shapes. The first step in such investigations is to solve the perturbing electron - emitter/absorber binary collision problem, and than to make corresponding averages over characteristics of the ansamble of perturbers, in order to obtain the electron - impact broadening parameters of a spectral line. Consequently the development of electron - impact broadening theory is strongly dependent on the development of electron - ion/atom collision theory, and represent an interesting application and an additional method for the indirect experimental or observational (stellar spectra) investigations of such theories.

Table 1. Electron-impact broadening parameters for S V, for perturber density of 10^{18} cm^{-3}. By dividing C by the corresponding full width at half maximum, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

Transition	T (K)	$W(\AA)$	$d(\AA)$
3S-3P	20000.	0.407E-01	0.424E-04
$\lambda = 786.5\AA$	50000.	0.261E-01	-0.133E-03
C= 0.79E+21	100000.	0.186E-01	-0.185E-03
	150000.	0.153E-01	-0.168E-03
	300000.	0.114E-01	-0.204E-03
	500000.	0.941E-02	-0.205E-03
3S-4P	20000.	0.147E-01	-0.176E-03
$\lambda = 286.1\AA$	50000.	0.950E-02	0.737E-04
C= 0.24E+20	100000.	0.700E-02	0.546E-04
	150000.	0.595E-02	0.622E-04
	300000.	0.467E-02	0.102E-03
	500000.	0.401E-02	0.843E-04
3S-5P	20000.	0.167E-01	0.232E-03
$\lambda = 223.3\AA$	50000.	0.119E-01	0.411E-03
C= 0.85E+19	100000.	0.947E-02	0.397E-03
	150000.	0.843E-02	0.468E-03
	300000.	0.706E-02	0.431E-03
	500000.	0.630E-02	0.410E-03
4S-4P	20000.	2.84	-0.228E-01
$\lambda = 3398.3\AA$	50000.	1.83	-0.514E-01
C= 0.34E+22	100000.	1.37	-0.528E-01
	150000.	1.17	-0.627E-01
	300000.	0.935	-0.551E-01
	500000.	0.809	-0.543E-01

Electron - impact broadening parameters for S V lines are of interest not only for the laboratory plasma research and for testing and developping of electron - impact broadening theory for shapes of multicharged ion lines, but as well for the consideration of subphotosperic layers and atmospheres of hot stars. They are also of importance for the considerations of regularities and systematic trends particularly along isoelectronic sequences. Moreover, recently, S V spectral lines have been observed in spectra of some sdO stars[2], where the electron - impact broadening is the main pressure broadening mechanism. Consequently, data on the shape of S V spectral lines are of interest for the modelling and interpretation of sdO star spectra as well.

This contribution is the continuation of our efforts (see Ref. 1 and references therein) to provide to plasma physicists and astrophysicists electron - impact broadening parameters needed for the research of astrophysical and laboratory plasmas, as well as plasmas in various plasma devices in technology. Within the semiclassical - perturbation formalism[3,4] we have calculated electron-, proton-, and He III-impact line widths and shifts for 34 S V multiplets, for perturber densities 10^{17}– 10^{21} cm^{-3} and temperatures T = 20,000 – 1,000,000 K. A sample of the obtained results is shown in Table 1, while the complete report will be published in Refs. 5 and 6.

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ON THE STARK BROADENING WITHIN A SPECTRAL SERIES

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In the preceeding paper of this conference, the semiclassical-perturbation calculation of Stark broadening parameters for 31 O VI multiplets has been reported [1]. The obtained comprehensive set of data is used here to investigate the behaviour of Stark broadening parameters within a spectral series. The results of such investigation may be used for the interpolation of new data as well as for the critical evaluation of published results or quick estimations during experiment.

The behaviour of electron-, and proton-impact widths and shifts within 2s-np series of O VI (n is the principal quantum number) is presented in Figs. 1-4. Since the gap between higher level of the transition and the closeset perturbing levels decreases in the spectral series with the increase of n, their influence becomes larger as well as the corresponding Stark broadening parameters. We can see that Stark broadening widths and shifts increase regularly.

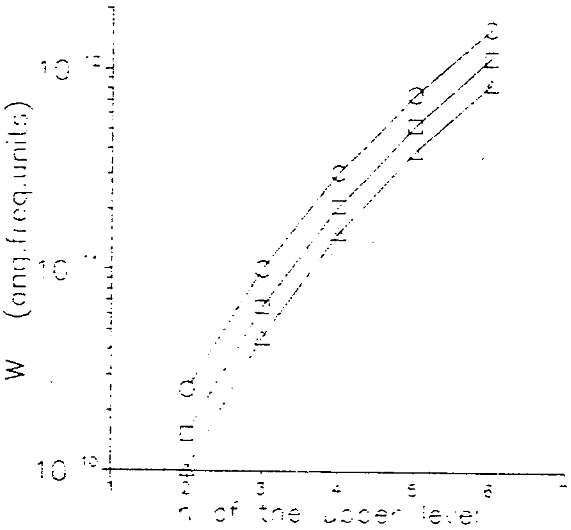

Fig.1. Electron-impact widths within O VI 2s - np (n=2,3,4,5,6) series as a function of the principal quantum number of the upper level (n). The perturber density is 10^{17} cm^{-3} and temperatures: ○ - 100.000 K; □ - 300.000 K; Δ - 800.000 K.

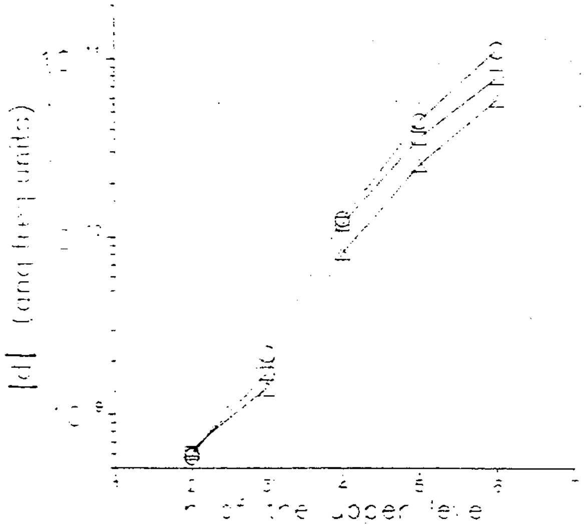

Fig.2. The same as in Fig.1 but for the electron-impact shift.

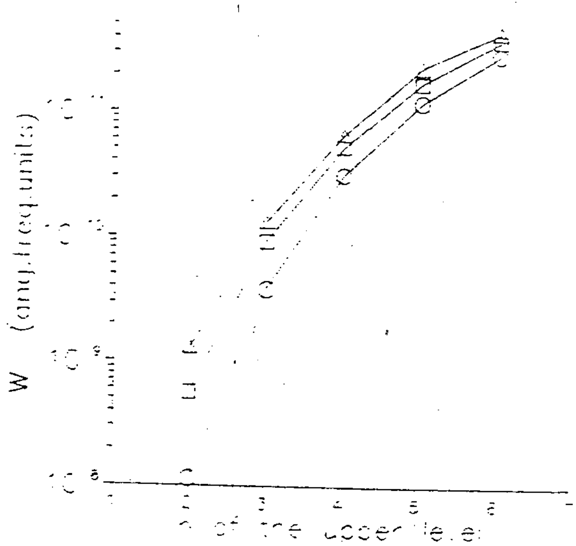

Fig.3. The same as in Fig.1 but for the proton-impact width.

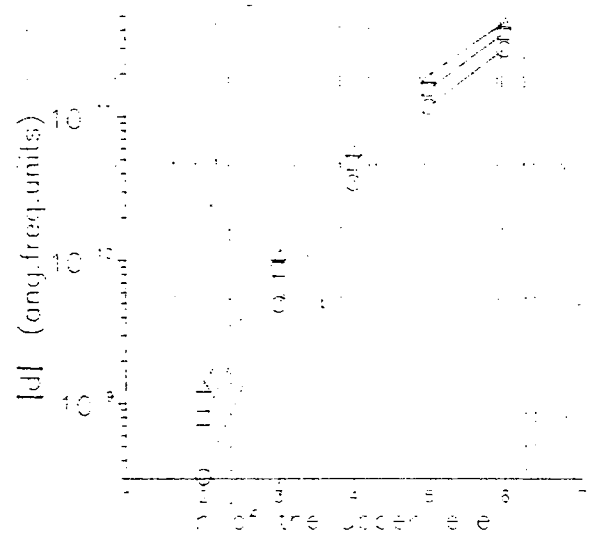

Fig.4. The same as in Fig.1 but for the proton-impact shift.

In order to investigate the influence of various collisional processes, we have calculated also the contribution of inelastic, elastic and strong collisions.The results for T= 100.000, 300.000, and 800.000K are presented in Figs. 5-7. Strong collision contribution is the sum of strong elastic and strong inelastic ones, while in

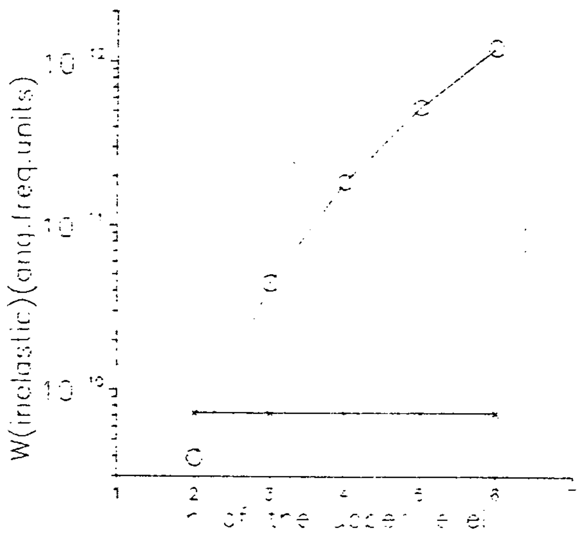

Fig.5 The inelastic contribution to the electron-impact width within O VI 2s - np series as a function of the principal quantum number of the upper level (n). The perturber density is 10^{17} cm^{-3} and temperature 100.000 K. With O is denoted the upper level-, and with x the lower level - contribution.

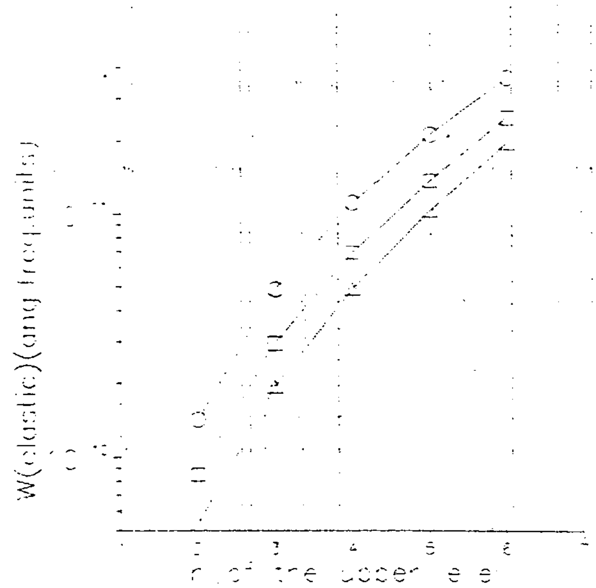

Fig.6. The same as in Fig.1 but for the elastic contribution to the electron-impact width.

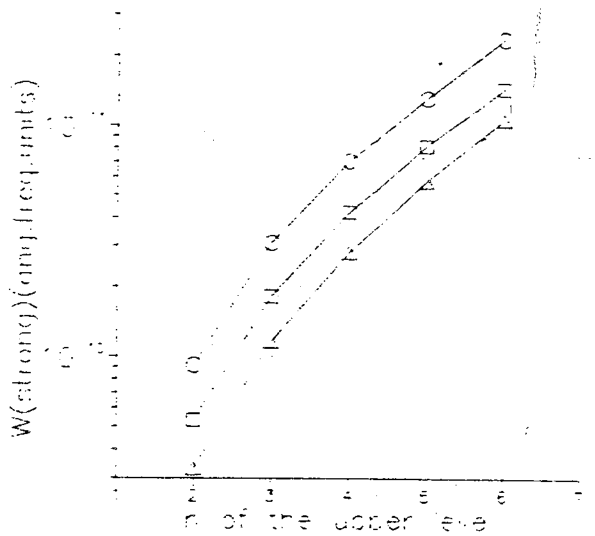

Fig.7. The same as in Fig.1 but for the strong contribution to the electron-impact width.

the case of elastic and inelastic collisions, e.g. elastic is the sum of strong-, and weak-elastic contributions. We can see that all contributions increase regularly with the increase of n.

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BROADENING OF SPECTRAL LINES DUE TO ATOMIC COLLISIONS AT PRESENCE OF THE BACK REACTION

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1 Introduction

In the previous paper [1] extensive the phase shift calculations have been performed taking into account the trajectory effect, resulting from the back reaction within self-consisting field of interacting neutral systems of radiator and perturber, practically for all physically interesting cases. The above-cited calculations have been evaluated within the binary adiabatic impact approximation using the classical path approach, and the leading terms in the multipole interactions bending the perturber trajectory.

Semiclassical calculations of the spectral line shape parameters using the leading terms of the multipole expansions of both the frequency shift and the back reaction, have been performed in numerous papers (e.g. Refs. 2-4). Particularly, in case of lines susceptible to the quadratic Stark effect, the above calculational model was used including the screening effects simultaneously [5,6].

It is a well-known fact that in case of the van der Waals type interactions the parameters of the line shape, calculated using simple power one-term attractive potential, do not fit the measurements and the astrophysical observations, nor give correct broadening to shift ratio (e.g. [7,8]). In that case usage of the first term of a multipole expansion solely could hardly be adequate for deep levels and is worse approximation for higher excited states for which at least short range repulsive term must be added [8]. In the present calculations of the line shape parameters at presence of the back reaction we take into account more exact multipole expansion in the frequency shift under the interatomic perturbations. To this end we use the Lennard-Jones potential $V(R) = \hbar C_6/R^6 + \hbar C_{12}/R^{12}$ and the phase shift calculation published in our previous paper [1].

2 Results and conclusions

The phase shift [1], calculated according to the above assumptions,

$$\eta_{(6+12),6}(\rho, v) = \frac{2}{v} \sum_{n=6,12} (\Delta C_n) \int_{R_{mes}}^{\infty} \frac{dR}{R^{n-1}\sqrt{R^2(1 - \frac{\hbar C_6}{R^6 E_0}) - \rho^2}}, \quad (1)$$

following to [1] becomes

$$\eta_{(6+12),6}(\rho, v) = \sum_{n=6,12} (\Delta C_n/v\rho^{n-1}) 3^{(n-1)/2} X J_{(2-n)/2}. \quad (2)$$

Details, and in particular the recurrent expressions XJ_m for auxiliary integrals, in the forthcoming paper [1]. In the quasi-classical adiabatic limit, the half-half width (w) and shift (d) are expressed via the phase shift η as follows:

$$w + id = N \int v f(v) dv \int 2\pi\rho d\rho [1 - exp(-i\eta)]. \quad (3)$$

ΔC_n in Eqs. (1) and (2) denotes the difference of the interaction constants of the upper (u) and lower (l) levels; for C_6 in the denominator of Eq. (1) we assume C_6 corresponding to the upper level of the line transition ([3]; however, see also [9]).

In Table 1 the input data of the investigated lines of neutral thallium are gathered after Dygdala [10]. The interaction constants C_6 and C_{12} are calculated by this author using relativistic Dirac-Hartree-Fock wave-functions for the case when the perturber gas is neonium.

Table 1: The input data.

Line [nm]	Transition	$C_6 * 10^{31}$ [$cm^6 rad\ s^{-1}$] u	$C_6 * 10^{31}$ [$cm^6 rad\ s^{-1}$] l	$C_{12} * 10^{74}$ [$cm^{12} rad\ s^{-1}$] u	$C_{12} * 10^{74}$ [$cm^{12} rad\ s^{-1}$] l
535.0	$7s\ ^2S_{1/2}$ - $6p\ ^2P^{3/2}$	-1.78	-0.46	6.62	0.061
377.6	$7s\ ^2S_{1/2}$ - $6p\ ^2P^{1/2}$	-1.78	-0.35	6.62	0.036

In Table 2 the line-width and shift measurements as an example are compared with proper results of the calculations within the physical models of different level of refinement. The measurements refer to proper case when the lines are broadened by the foreign perturbing gas of Ne, at temperature $T = 855$ K and concentration of neonium $N \cong 10^{17} cm^{-3}$. The measurements have been made in Ref. 10 and by authors cited therein.

Table 2: The calculated and measured line shape parameters (w in the upper line, and d in the lower one) of Ta I at unitary concentration N of the perturber Ne gas (the data in units $10^{-20} cm^{-1}/atoms\ cm^{-3}$; the standard deviation is of the order of 0.1).

Line [nm]	Calculations vdW	Calculations L-J	Calculations (vdW)BR	Calculations (L-J)BR	measurements (see [10])		
535.0	1.82	1.72	**1.27**	**0.75**	1.11	1.49	1.45
	-0.68	-0.08	**-0.68**	**-0.27**	-0.24	-0.32	-0.34
377.6	1.96	1.64	**1.32**	**1.03**	1.15	1.64	1.30
	-0.71	-0.09	**-0.70**	**-0.40**	-0.17	-0.26	

The numbers printed in bold type, i.e. those in the columns within the headlines (vdW)BR and (L-J)BR, are the line parameters (w and d) calculated within the presented formalism taking into account the frequency splitting by the simple van der Waals or Lennard-Jones potential, respectively, and the back reaction described by the leading term of a power expansion of the potential.

In our opinion the back reaction model with L-J potential describes the line shift d enough correctly, but in the case of the line width w there is an ambiguity due to faultiness of control of the perturber trajectory at small atom-perturber distances. Our present model provides for the perturber capture at distances smaller than R_{max} (see Eq. (1)). Thus, in the present statistic all events with $R < R_{max}$ are do not taken into account. Rough estimation using Lorentz-Weisskopf cross section give contribution of these events to w in (L-J)BR case as follows: 0.56 and 0.64 for 535.0 and 377.6 nm lines, respectively, in units as in the caption of Tab. 2. Realistic results should fall between w (L-J)BR and the sum with the above numbers.

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Contributed Papers 6

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SIMPLE ESTIMATES OF STARK BROADENING PARAMETERS ON THE BASIS OF REGULARITIES AND SYSTEMATIC TRENDS ALONG THE PERIODIC TABLE

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1. INTRODUCTION

The experimental determination of Stark widths, as well as the existing theoretical data, can not satisfy the need, especially in astrophysics. Therefore, it is of interest to exploit any possible theoretical approach who might provide simple relations e.g. from the systematic trends found in the Stark broadening data. An approximate approach, based on the found systematic trends in Stark broadening parameters, has been developed in a series of articles (see e.g. [1,2] and references therein), in the case of neutral atoms and single charged ion resonances and offresonances (ns - np transitions: $\Delta n = 0,1$ for resonances and $n = n + 1$ for offresonances; n is the main quantum number of the ground energy level of a corresponding emitter). In the present work, we apply this approach to doubly and triply charged ion resonant and offresonant spectral lines.

The proposed method is based on the fact, demonstrated firstly in [3], that the Stark widths and shifts exibit a systematic dependence on the ionization potential, upper or lower energy level of the corresponding transition when measured from the ionization limit and not from the ground level (In order to avoid the misunderstanding we will call in further the positive value of such quantity (χ) "the upper" or "lower level ionization potential" respectively).
Moreover, a systematic dependence has been found also on the net core charge (z) of the emitter as seen by the electron undergoing transition. Since the simple relations based on such trends may be useful in astrophysics, when Stark broadening data for a lot of lines are needed, we have tried here to obtain and analyze such relations. Therefore, the Stark parameter dependences on χ and z are deduced here from the large scale semi-classical [4] or semi-empirical [5]. and modified semiempirical [6,7] calculations.

2. THEORY

The relations for line width (W) and shift (d) following from the proposed method are [3]

$$W=N_e f(T) a_1 z^{c_1} \chi^{-b_1} \qquad (1)$$

$$d=N_e f(T) a_2 z^{c_2} \chi^{-b_2} \qquad (2)$$

For lower temperatures of astrophysical interest, f(T) tends to be $f(T) = T^{-1/2}$ in the case of ionized emitters(see e.g.[4]). The Eqs. (1) and (2) are to be used: (i) in the case of the lines originating from the same type of transition (e.g. resonances or offresonances) within one stage of ionization, (ii) within particular isoelectronic sequences and (iii) within a given isonuclear sequences.

For the same plasma conditions and for the exactly analogous transitions within the different atomic spectra the corresponding a as well as b constants are similar. Consequently, we can determine empirically, from experiments or more sophysticated calculations, averaged empirical values for $A=aN_e f(T)$ and b.

In the case of ion lines, at low temperature limit we can scale the obtained empirical values to other temperatures by using $T^{-1/2}$ dependence (for validity conditions see e.g. [4],). In the case of higher temperatures the dependence on temperature is weaker. In some cases, when only an estimate is needed and temperature do not vary too much we can use an averaged empirical value for a temperature range taking into account that the accuracy is lower. Moreover, we can always try to fit w

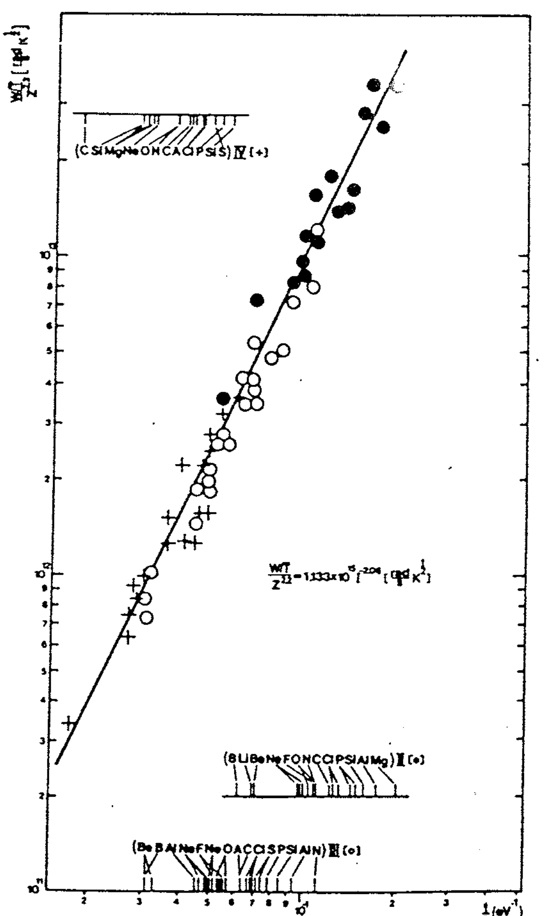

Fig. 1

or d with an $f(x) = \alpha x^{\beta}$ expression. In astrophysics w is sometimes successfully represented as $w = aT^{b}$ in order to make easier the use of data for the whole temperature range within a model of the stellar atmosphera. Here, we propose the expressions 1-2 of the type

$$w, d = A\ \chi^{-b}, \qquad (3)$$

suitable for the calculations of new data by an interpolation if we determine the needed coefficients from the known Stark parameter values within the particular stage of ionization.

One can try to obtain the corresponding analytical expressions for coefficients A, b in Eq. (3) starting from a more refined theory (see e.g.[7] . Such way may provide usable analytical expressions only with additional approximations and for special cases. The other way, used here, is to try to obtain the proposed simple relations from the large set of results of more sophysticated calculations, in order to prove that Stark broadening parameters may be fitted with the proposed relations and to obtain the corresponding a and b coefficients on the basis of existing semiclassical and modified semiempirical calculations. Also, one attempt has been undertaken to find a generalized relation which appropriately fit the existing theoretical and experimental data within several ionization stages.

3 RESULTS AND DISCUSSION

Equations (1) and (2) have been verified using the existing theoretical results and the procedure described in [1] . i.e. plotting the W wersus χ data on a log-log graph, for a specific temperature and $N_e = 10^{17} cm^{-3}$, and a linear regression is used in order to get the A = a N f(T), b and c coefficients of equations (1) and (2). The data we have used for that, are the Stark parameter values calculated by [4] in the case of the neutral atoms for the resonance transitions, and in the case of the singly ionized atoms for resonance and off-resonance $((n_o+1)s - (n_o+1)p$ transitions where n_o is the principal quantum number of the ground state of the emitter).. In the case of doubly and triply charged ions, the data obtained in [7] where the modified semiempirical formula [6] has been used. All Stark broadening parameters are full width at half maximum (FWHM) in angular frequency units normalized to the electron density $10^{17} cm^{-3}$.

Our analysis of the semiclassical [4] or modified semiempirical [6] results, shows that for $T = 10000K$ and $N = 10^{17} cm^{-3}$, $b = 3.67 \pm 17\%$ and $A = 1.1\ 10^{13}$ (if χ is expressed in eV and w in angular frequency units) for the neutral atom resonances. In the case of neutrals, Eq(1) and Eq. (3) are identical. However we can use Eq. (3) for the ion lines also. The corresponding A and b coefficients for other considered cases (neutrals, singly-, doubly-, and triply-charged ion lines will be given in [9]. By using the coefficients given in [9] and Eq. (3) we can obtain new data for other lines belonging to the same type of transition knowing the corresponding χ and plasma conditions (N, T) only.

The analysis of the simultaneous Stark broadening parameter dependence on the z and χ for off resonance transitions of ions from Li to Ar in the three successive stages of ionization (II, III and IV), has been made and the equation (1) with empirically determined coefficients becomes

$$w[rad/s] = 0.01133\ [T\ (K)]^{-1/2} N_e(cm^{-3})\ z^{2.2}\ [\chi(eV)]^{-2.06} \qquad (4)$$

as demonstrated in Fig. 1, where theoretical data from [4] and [7] have been used. The theoretical data fit the linear regression formula given by Eq. (4) with a correlation factor of 0.98. Since all availlable data fit this relation so closely, we hope that such equation can be used for the prediction of Stark width parameters for spectral lines belonging to the same type of transitions, especially for astrophysical purposes.

4. CONCLUSION

It has been found that the relations given by the Equations (1-4) are very convenient for the prediction of new Stark broadening data, avoiding much more complicated procedures, or in the cases when accurate atomic data are missing. Moreover, the described method gives good possibilities for the quick estimation of the reliability of the performed measurements and other published data on line broadening parameters [10].

Finally, we might conclude that, the described approach might be used for the predictions of missing Stark broadening data in the case of singly, doubly and triply charged ions. For astrophysical purposes, where sometimes the missing widths are estimated as ten times the classical width (see e.g. [11]) the described method might be used for rough predictions even for higher ionization stages,or heavier element lines. We hope that such simple relation will be useful especially in astrophysics where for opacity calculations and stellar atmospheres investigations a large number of line broadening parameters is required.

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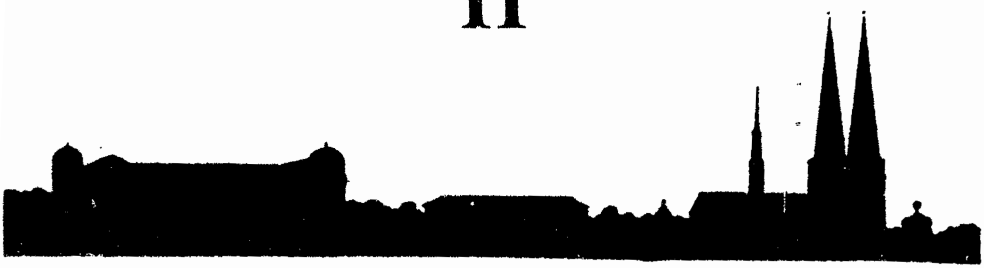

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14 D

STARK BROADENING OF Li (I) LINES: REGULARITIES WITHIN A SPECTRAL SERIES

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Stark broadening parameters for neutral lithium are of interest in plasma spectroscopy /1/ and might be employed in deducing the electron concentration of a high-density plasma /2/. Profiles of neutral lithium lines are also of interest for astrophysicists, since the surface content (abundance) of Li involve problems correlated with nucleogenesis and with mixing between atmosphere and interior /3/.

Using a semiclassical-perturbation formalism /4, 5/ and a Stark broadening computer code derived from this method, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 61 lithium multiplets /6, 7/, as a function of temperature and perturber density. The obtained extensive and self-consistent set of data, has been used also for the continuation of our research of regularities within spectral series (see e.g. Ref. 8).

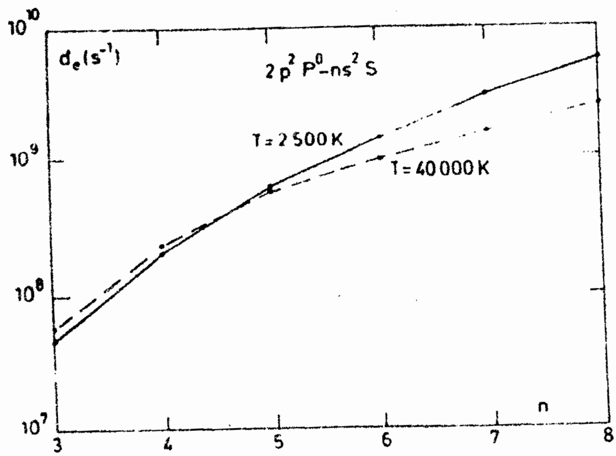

Fig. 1. Electron full halfwidths for Li (I) $2p^2P^o - ns^2S$ lines as a function of n_i for T = 2,500 and 40,000 K at $N_e=10^{13}$ cm^{-3}.

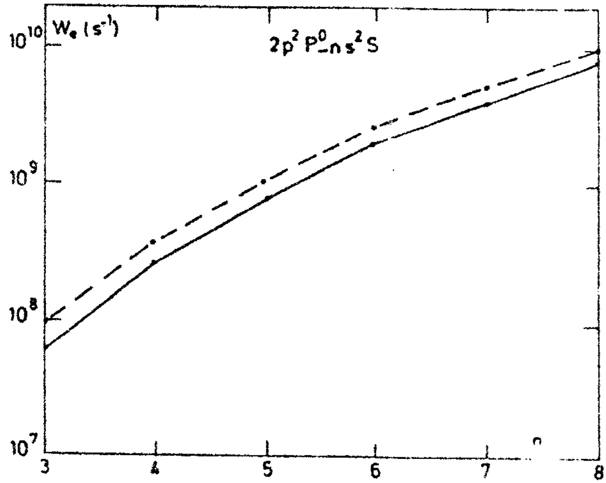

Fig. 2. As in Fig. 1 but for the electron-impact shift.

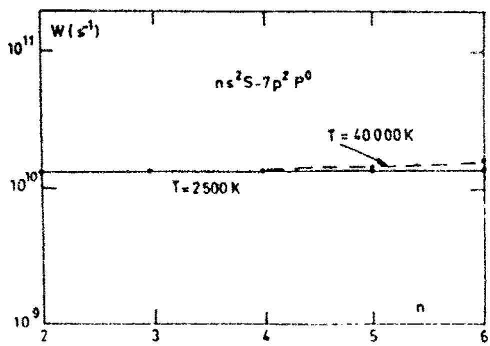

Fig. 3. As in Fig. 1 but for electron-impact full halfwidths for Li (I) $ns\,^2S - 7p\,^2P^0$ lines.

Since the energy separations betwsen the upper level and the principal perturbing levels for the $2p^2P^o - ns^2S$ series decrease gradually, we expect a gradual and regular change of the Stark-broadening parameters /8/. We can see in Figs. 1 - 2 that this is the case for electron-impact widths and shifts within $2p^2P^o$-ns^2S series.

It is interesting also to analyse how the emission line widths change with the change of the principal quantum number of the final state. One can see in Fig. 3 that in the case of $ns^2S - 7p^2P^o$ lines, line width in angular frequency unit is practically the same for all members. The largest difference is for 6s-7p transition where line widths are 1.51 $10^{10}s^{-1}$ for T = 2,500 K and 1.67 $10^{10}s^{-1}$ for T=40,000 K (in comparison with 1.43 $10^{10}s^{-1}$ and 1.41 $10^{10}s^{-1}$ for 2s-7p line). This is the consequence of the much smaller importance of lover level broadening contribution.

This mighz be of interest in astrophysics and for quick estimates. In such cases the only difference is due to the difference in the wavelengths and we can scale from one available result other series members.

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Abstract Book

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JD1.031 P

Laboratory Studies of Atomic Ion VUV Emission Spectra of Astrophysical Interest

W.-Ü L. Tchang Brillet et al.
DAMAp, UMR 8588 du CNRS, Observatoire de Paris-Meudon, also University Paris 6

Laboratory studies of the emission spectra of multiply (two to five times) charged atomic ions are being carried out in the VUV wavelength region ($50-300nm$) motivated by the recent space missions (HST, SOHO and FUSE). The spectrogrammes are produced using vaccum spark sources and high resolution normal incidence vacuum spectrograph. The precision of $\Delta\lambda = \pm 0.0003-0.0005nm$ obtained on wavelengths lead to reliable identification of the spectral lines and to the determination of the atomic energy levels. The atomic configurations are interpreted by parametric calculations giving rise to improved transition probabilities. Ions of the iron (Mn, Fe) and platinum groups (Au, Os) have been investigated involving international collaborations (Institute of Spectroscopy of Troitsk, University of Amsterdam, University of Liège, University of Antigonish, NIST). Future projects concern ions of rare earth elements.

Co-author: *J.-F. Wyart, Laboratoire Aimé Cotton, CNRS II*

JD1.032 P

Doubly Hollow Lithium with Even Parity

J.-C. Chang et al.
National Hsinchu Teachers' College, Taiwan

The energy of double hollow lithium states with even parity are calculated with the saddle-point method. The energy shift and width of those resonance states are calculated with the saddle-point complex-rotation method. The partial Auger width is studied for each single open channel as well as for the fully coupled open channels. The predicted Li $[3s3p^2]\,^2P$ resonance energy and width are 176.294 and 0.3992 eV, respectively. The predicted Li $[3s3p^2]\,^2D$ resonance energy and width are 175.582 and 0.2626 eV, respectively. Some other resonances are studied as well.

Co-author: *Kwong T. Chung*

JD1.033 P

BelData - An Atomic Database for Astrophysical Purpose

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In early-type stars like B and A stars and white dwarfs, Stark broadening is the main pressure broadening mechanism, and the corresponding Stark broadening parameters are of interest for a number of investigations related to stellar plasma. One may mention as examples calculation of stellar opacities, stellar atmospheres modeling and investigations, abundance determinations, interpretation and modeling of stellar spectra and investigation and modeling of subphotospheric layers.

In order to provide the Stark broadening parameters for astrophysical purposes extensive calculations of a large number of radiators have been performed at Astronomical Observatory in Belgrade. The BelData, the data base which contents this Stark broadening parameters, has as a goal to provide the faster and easier access to the data.

In the paper the present status and future plans of the BelData will be discussed.

Co-authors: *M. S. Dimitrijević and N. Milovanović*

JD1.034 P

The electron-impact broadening parameters for Pd II spectral lines.

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Spectral lines of palladium in various ionization stages are observed in spectra of different type stars. For example spectral lines of neutral palladium are present in solar spectrum, while Pd II spectral lines are observed in Hg Mn star ξ Lupi spectra. Consequently, experimental and theoretical spectroscopic data are needed for the analysis and modeling of such lines, as well as for atmosphere investigation and modeling of such stars. Among the required spectroscopic data, Stark broadening data are of interest especially for hot stars as e.g. for Hg-Mn stars and white dwarfs.

There is not experimental data on the Stark broadening of ionized palladium. However, Stark broadening parameters for Pd II λ=136.33nm have been estimated by Lakićević (1983), based on regularities and systematic trends.

In order to provide Stark broadening data for singly ionized palladium we have calculated, by using the modified semiempirical approach, the corresponding data for Pd II lines, belonging to the $5s'''^2G$-$5p'''^2F^o$ multiplet. Calculation were performed for an electron density of $10^{23}m^{-3}$ and within the temperature range of 5000K-50000K.

Co-authors: *M. S. Dimitrijević and L. Č. Popović*

JD1.035 P

Stark Broadening Effect in Hot Star Atmospheres: Tl II

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Electron-impact broadening is the main pressure broadening mechanism in the hot star atmospheres. Satellite ultraviolet spectral lines observations made by e.g. International Ultraviolet Explorer (IUE) and Goddard High Resolution Spectrograph (GHSR) installed at Hubble Space Telescope provided much better possibilities for the investigations of the trace elements spectral line in stellar atmospheres. Consequently, Stark broadening parameters data for such lines become of interest for stellar spectra interpretation, analysis and modelling as well as for abundance determination.

In order to provide the needed spectroscopic data for singly ionized Thallium spectral lines we present Stark broadening parameters for Tl II spectral lines calculated within the modified semiempirical approach. Calculations were performed within temperature range 5000K-50000K and for an electron density of $10^{23}m^{-3}$.

These calculated data, together with other Stark broadening parameters for various elements, will be included in Belgrade Astronomical Database (BELDATA) on Internet address www.aob.bg.ac.yu.

Co-authors: *M. S. Dimitrijević and L. Č. Popović*

JD1.036 P

A Project for large-scale Stark broadening Data Calculation: Cd I

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In order to complete as much as possible Stark broadening data needed for astrophysical and laboratory plasma research and stellar opacities calculations we are making a continuous effort to provide reliable Stark broadening data for a large set of atoms and ions. Our calculations are performed within the semiclassical - perturbation formalism, for transitions when a sufficiently complete set of reliable atomic data exist and the good accuracy of obtained results is expected. Extensive calculations have been performed, up to now for a large number of various radiators, and now we try to organize the obtained results in the BELDATA database (www.aob.bg.ac.yu). As the continuation of our project, we have calculated within the semiclassical-perturbation formalism, electron-, proton-, and ionized helium-impact line widths and shifts for 48 neutral cadmium lines, as a function of temperature and perturber density. Results are compared with other experimental and theoretical data. Besides the presentation of new results, our intention is to review our previous work as well.

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Stark Broadening Parameters for Stellar Plasma Research: Bi III Spectral Lines

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Abstract. Stark widths (FWHM) for 5 Bi III transitions, for the electron density of $10^{23}\,m^{-3}$ and temperatures from 5000 K up to 500000 K have been calculated by using the modified semiemprical approach.

Key words: spectral lines; profiles – atomic and molecular data

1. Introduction

Data on Stark broadening of stellar spectral lines are important for the consideration of various physical processes in stellar plasmas and for modelling and interpretation of stellar spectra. They are also of interest for the consideration of radiative transfer through subphotospheric layers, as well as for the laboratory and fusion plasmas and laser produced plasmas research. The development of space born high precision spectroscopy provides an additional interest for lines of trace elements.

Our objective is to provide to astrophysicists as well as for plasma physicists and others interested in such data, an as large as possible set of reliable Stark broadening parameters. We apply the semiclassical perturbation approach (Sahal-Bréchot, 1969ab), when the relevant reliable atomic data needed for the calculations with appropriate accuracy exist. If such set of atomic data is not sufficiently complete, or the semiclassical perturbation method can not be applied in an appropriate way, we apply the modified semiempirical approach, developed by Dimitrijević and Konjević (1980). For the case of ions with complex spectra the improvement was done by Popović and Dimitrijević (1996ab).

Within the semiclassical perturbation method, extensive calculations have been performed, up to now (Dimitrijević, 1996) for a number of radiators, and consequently, Stark broadening parameters for 79 He, 62 Na, 51 K, 61 Li, 25 Al, 24 Rb, 3 Pd, 19 Be, 270 Mg, 31 Se, 33 Sr, 14 Ba, 28 Ca II, 30 Be II, 29 Li II, 66 Mg II, 64 Ba II, 19 Si II, 3 Fe II, 2 Ni II, 12 B III, 23 Al III, 10 Sc III, 27 Ba III, 32 Y III, 10 Ti IV, 39 Si IV, 90 C IV, 5 O IV, 114 P IV, 19 O V, 30 N V, 25 C V, 51 P V, 33 V V, 30 O VI, 21 S VI, 10 O VII, 10 F VII, 20 Ne VIII, 4 Ca IX, 8 Na IX, 48 Ca X, 7 Al XI, 4 Si XI, Si XII, 26 V XIII multiplets become available. Data for particular lines of F I, Ga II, Ga III, Cl I, Br I, I I, Cu I, Hg II, N III, F V and S IV also exist.

The width data for the most intensive lines for the following atom and ion species were calculated by us with the help of the modified semiempirical approach: Sc II, Ti II, Mn II, Fe II, Bi II, Pt II, Zn II, Cd II, As II, Br II, Sb II, I II, Xe II, Y II, Zr II, La II, S III, Be III, B III, C III, N III, O III, F III, Ne III, Na III, Al III, Si III, P III, S III, Cl III, Ar III, Mg III, Mn III, Ga III, Ge III, As III, Se III, La III, Zn III, Cu IV, B IV, C IV, N IV, O IV, Ne IV, Mg IV, Si IV, P IV, S IV, Cl IV, Ar IV, Ge IV, C V, O V, F V, Ne V, Al V, Si V, N VI, F VI, Ne VI, P VI and Cl VI.

Since the accuracy of the shift calculations is lower, shift values are not give when experimental data enabling an additional checking, are not availlable. We will determine here Stark broadening parameters of the Bi III spectral lines. Due to the unsuficient set of reliable atomic energy levels the modified semiempirical method is adequate for Bi III lines Stark broadening calculations, and was applied in this paper.

2. Results and Discussion

The analysis of obtained results and all details of calculations will be published elsewhere (Dimitrijević and Popović, 1998). Here are only presented in Table 1, Stark widths (FWHM) for 5 Bi III transitions, for the electron density of $10^{23}m^{-3}$ and temperatures from 5000. K up to 500000. K. Atomic energy levels needed for calculations have been taken from Moore (1971). We hope that presented results will be of help for various problems of stellar and laboratory plasmas analysis and modeling.

Table 1. Stark full width (FWHM) of Bi III. The electron density is $10^{23}\mathrm{m}^{-3}$. The avaraged wavelength of the multiplet is denoted by $\overline{\lambda}$.

Transition	T (K)	W (nm)
	5000.	.211E-02
	10000.	.148E-02
$6p^2P^0_{3/2} - 7s^2S_{1/2}$	20000.	.103E-02
	50000.	.669E-03
$\lambda = 105.18$ nm	100000.	.548E-03
	250000.	.515E-03
	500000.	.487E-03
	5000.	.359E-02
	10000.	.251E-02
$6p^2P^0_{3/2} - 7s^2S_{1/2}$	20000.	.175E-02
	50000.	.113E-02
$\lambda = 134.61$ nm	100000.	.926E-03
	250000.	.871E-03
	500000.	.828E-03
	5000.	.559E-01
	10000.	.390E-01
$7s^2S - 7p^2P^0$	20000.	.272E-01
	50000.	.179E-01
$\overline{\lambda} = 394.61$ nm	100000.	.150E-01
	250000.	.144E-01
	500000.	.133E-01
	5000.	.369E-01
	10000.	.262E-01
$7s^2S - 8p^2P^0$	20000.	.200E-01
	50000.	.167E-01
$\overline{\lambda} = 165.00$ nm	100000.	.153E-01
	250000.	.126E-01
	500000.	.115E-01
	5000.	1.76
	10000.	1.25
$8s^2S - 8p^2P^0$	20000.	.943
	50000.	.784
$\overline{\lambda} = 956.66$ nm	100000.	.738
	250000.	.622
	500000.	.538

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STARK WIDTHS FOR 4s – 4p TRANSITIONS OF Cu III

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From the analyisis of 11 Hg-Mn star spectra [1], it follows that copper is clearly overabundant in 10 stars. Hg-Mn stars are hot stars where Stark broadening is the main pressure broadening mechanism. Also, knowladge of Stark broadening parameters is of interest for the investigation of laboratory plasma. Spectral lines of Cu III and Cu IV are of particular interest for the diagnostic and modelling of plasma created in electromaganetic macro particle accelerators (see e.g. Ref. 2), where in experimental work, the plasma is usually created by Cu or Al foil evaporation. Stark width for six Cu IV, $4s - 4p$ multiplets of interest for such plasma have been calculated within the modified semiempirical approach [3] in Ref. 4. Here we present Stark widths for six multiplets of Cu III calaculated by using the modified semiempirical approach [3] (for the case of complex heavy ions see also Ref. 6).

Atomic energy levels for calculation have been taken from [7]. Oscillator strengths have been calculated by using method given in Ref. 8 and the tables from Ref. 9.

Our results for Stark widths (FWHM) of Cu III spectral lines are presented in Table 1. There is not mesaured or other calculated data for Cu III.

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Table 1. Stark width (FWHM) of Cu III spectral lines for electron density of $10^{23} m^{-3}$ as a function of temperature. The averaged wavelength of the multiplet is denoted by $\overline{\lambda}$

Transition	T (K)	w (nm)	Transition	T (K)	w (nm)
	5000.	.241E-02		5000.	.276E-02
	10000.	.169E-02		10000.	.194E-02
	20000.	.118E-02		20000.	.135E-02
$4s^4F - 4p^4F^0$	30000.	.957E-03	$4s^2F - 4p^2D^0$	30000.	.109E-02
	40000.	.823E-03		40000.	.941E-03
λ = 160.16 nm	50000.	.733E-03	λ = 167.62 nm	50000.	.839E-03
	60000.	.667E-03		60000.	.764E-03
	70000.	.618E-03		70000.	.708E-03
	80000.	.580E-03		80000.	.664E-03
	90000.	.549E-03		90000.	.629E-03
	100000.	.524E-03		100000.	.601E-03
	125000.	.480E-03		125000.	.552E-03
	150000.	.453E-03		150000.	.522E-03
	5000.	.257E-02		5000.	.275E-02
	10000.	.181E-02		10000.	.193E-02
$4s^4F - 4p^4G^0$	20000.	.126E-02		20000.	.135E-02
	30000.	.102E-02	$4s^2F - 4p^2F^0$	30000.	.109E-02
	40000.	.878E-03		40000.	.937E-03
λ = 166.77 nm	50000.	.782E-03	λ = 167.30 nm	50000.	.834E-03
	60000.	.712E-03		60000.	.760E-03
	70000.	.660E-03		70000.	.704E-03
	80000.	.619E-03		80000.	.661E-03
	90000.	.586E-03		90000.	.626E-03
	100000.	.559E-03		100000.	.598E-03
	125000.	.512E-03		125000.	.549E-03
	150000.	.482E-03		150000.	.519E-03
	5000.	.270E-02		5000.	.294E-02
	10000.	.190E-02		10000.	.206E-02
	20000.	.133E-02		20000.	.144E-02
$4s^4F - 4p^4D^0$	30000.	.107E-02	$4s^2F - 4p^2G^0$	30000.	.117E-02
	40000.	.922E-03		40000.	.100E-02
λ = 171.68 nm	50000.	.821E-03	λ = 174.44 nm	50000.	.893E-03
	60000.	.748E-03		60000.	.814E-03
	70000.	.693E-03		70000.	.754E-03
	80000.	.649E-03		80000.	.707E-03
	90000.	.615E-03		90000.	.670E-03
	100000.	.587E-03		100000.	.640E-03
	125000.	.537E-03		125000.	.588E-03
	150000.	.506E-03		150000.	.555E-03

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ABSTRACT BOOK

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JD04-1 Poster

AGB Stars: Testing Carbon Loss Via The Ultraviolet Lines

Yu.V. Milanova[1], A.F. Kholtygin[2]

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A method is proposed to determine the realistic abundances of carbon in planetary nebulae based on the actual distribution functions of errors in measuring line intensities. Fluctuations both in temperature and in mass density in a nebula are taken into account. The C abundances and the amplitudes of temperature and density fluctuations for the large sample of PNe are given. The intensity of the ultraviolet lines of C ions are used for determining the more exact abundances.

These abundances are probably the most reliable in the present time and give estimations of the primordial CNO abundances at the epoch when the progenitors of PNs are formed. Basing on the newly carbon abundances the total mass losses of carbon during AGB stage of evolution are estimated.

JD04-2 Poster

On The Origin Of Two-Shell Supernova Remnants

V.V. Gvaramadze

Sternberg Astronomical Institute, Moscow, Russia

It is known that proper motion of massive stars causes them to explode far from the geometric centers of their wind-driven bubbles and thereby affects the symmetry of the resulting diffuse supernova remnants (SNRs). We use this fact to explain the origin of SNRs consisting of two partially overlapping shells (e.g. 3C 400.2, Cygnus Loop, Kes32, etc.), whose unusual morphology is usually treated in terms of the collision (or superposition) of two separate SNRs or breakout phenomena in a region with a density discontinuity.

We propose that a SNR of this type is a natural consequence of an off-centered cavity supernova (SN) explosion of a moving massive star, which ended its evolution near the edge of the main-sequence (MS) wind-driven bubble. Our proposal implies that one of the shells is the former MS bubble reenergized by the SN blast wave. The second shell, however, could originate in two somewhat different ways, depending on the initial mass of the SN progenitor star. It could be a shell swept-up by the SN blast wave expanding through the unperturbed ambient interstellar medium if the massive star ends its evolution as a red supergiant (RSG). Or it could be the remainder of a pre-existing shell (adjacent to the MS bubble) swept-up by the fast progenitor's wind during the late evolutionary phases if after the RSG phase the star evolves through the Wolf-Rayet phase. In both cases the resulting (two-shell) SNR should be associated only with one (young) neutron star (thus one can somewhat improve the statistics of neutron star/SNR associations since the two-shell SNRs are quite numerous). We discuss several criteria to discern the SNRs formed by SN explosion after the RSG or WR phase.

JD04-3 Poster

Analysis Of The High Temperature Region In Be Stars

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The High Temperature Region (HTR) that surrounds the photospheres of Be stars is studied in order to derive observational constraints for modelling Be stars, in particular for the region where superionization takes place.

50 Be stars, representative of a considerable range of temperature, were chosen. From archival, high-dispersion IUE spectra, different lines that originate in the HTR region were considered, namely the resonance lines of Si IV, C IV and Al III, and He II λ1640. Equivalent widths (corrected for photospheric contribution), optical depths, atom columns and expansion velocities were measured. From this observational data several correlations between different observables were obtained.

These correlations permit us to discuss the geometry, density distribution and heat input of the lines formation regions (LFRs). The major results can be summarised as follows:

1) The circumstellar material contributes to the resonance lines of Si IV, C IV, Al III and to the He II λ1640 at all inclination angles.

2) In Si IV, C IV and Al III the equivalent widths have a tendency to increase in objects with high rotational velocities.

3) Si IV and C IV equivalent widths are also correlated to the kinetic energy of the expansion velocity. This means that dissipation of mechanical energy is one of the heating mechanisms.

4)On the basis of the expansion velocities and the line profiles, we establish a sequence for the LFRs: The LFR of He II is at the base of the wind and the closest to the central star. The LFRs of Si IV and C IV are inmersed in the stellar wind. The LFR of Al III is an interface between the HTR and the cool envelope.

The analysis followed in this work is completely model-independent. Consequently, these results could be useful to decide which are the facts that are to be considered when modelling Be stars.

JD04-4 Poster

Long Term Variability Of The Coronal and Post – Coronal Regions Of The Oe Star HD 93521

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Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the C IV, N IV and N V spectral lines of the star HD 93521 which is a relatively bright, very rapidly rotating O9.5V star (Conti & Ebbets, 1977; Hobbs et al., 1982; Lennon et al., 1991).

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of the star HD 93521, taken with I.U.E. from 1979 until 1995 and we examine the timescale variations of the physical parameters, stated below.

Results: As a first result we detect that the above spectral lines consist of one or more Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the time scale variation of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the column density, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their time scale variations, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-5 Poster

Hyper Ionization Phenomena In The C IV Region Of 20 Oe Stars

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Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the C IV resonance lines of 20 Oe stars of different spectral subtypes.

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of 20 Oe stars, taken with I.U.E. and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype.

Results: As a first result we detect that the C IV resonance lines consist of one to five Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the values of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the column density, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-6 Poster

Hyper Ionization Phenomena In The N IV Region Of 20 Oe Stars

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Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the N IV spectral line of 20 Oe stars of different spectral subtypes.

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of 20 Oe stars, taken with I.U.E. and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype.

Results: As a first result we detect that the N IV spectral line consists of one or two Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the values of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the column density, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-7 Poster

Hyper Ionization Phenomena In The N V Region Of 20 Oe Stars

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Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the N V resonance lines of 20 Oe stars of different spectral subtypes.

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of 20 Oe stars, taken with I.U.E. and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype.

Results: As a first result we detect that the C IV resonance lines consist of one to four Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the values of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the column density, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-8 Poster

High resolution spectroscopy of halo stars in groundbased UV.

V.Klochkova, G.Zhao, S.Ermakov, V.Panchuk.

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For the first time an atlas of high spectral resolution (R = 60000)

CCD-spectra in the low studied wavelenghth range 3500-5000ÅÅ is presented for 4 stars with values of metallicity $-3.0<[Fe/H]<-0.6$, temperatures $4750<Te<5900K$ and surface gravity $1.6<\log g<5.0$. Based on these spectral data we determined model atmosphere parameters and calculated abundances of 29 chemical elements or their ions.

JD04-9 Poster

Study of Hα regions in 120 Be-type stars

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Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the shape of Hα line in the spectra of 120 Be-type stars.

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the stellar spectrographs of 120 Be stars, which were taken by Andrillat & Fehrenbach (1982) and Andrillat (1983) (resolution 5,5 and 27 Å) with the telescope of 152 cm in the Observatory of Haute Provence and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype and the luminosity class.

Results: We found that in the Be-type stellar atmospheres, there are two regions that can produce the Hα Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). The first one lies in the chromosphere and the second one in the cool extended envelope. With the above method we calculate: a) For the chromospheric absorption components we calculated the optical depth as well as the rotational and radial velocities of the independent regions of matter which produce the main and the satellites components. b) For the emission and absorption components which are created in the cool extended envelope we calculated the FWHM, the optical depth and the radial velocities of the independent regions of matter which produce the main and the satellites components.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype and luminosity class, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis

JD04-10 Poster

The complex structure of the Si IV λλ 1393.755, 1402.77 Å regions of 68 Be-type stars

E. Lyratzi[1], E. Danezis[1], A. Antoniou[1], D. Nikolaidis[1], L. C. Popovic[2], M. S. Dimitrijevic[2]

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Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines (Bates & Halliwell, 1986). In this poster paper we detect the presence of this phenomenon (DACs or SACs) in the Si IV resonance lines in the spectra of 68 Be-type stars of all the spectral subtypes and luminosity classes.

Method: In our study we apply the method proposed by Danezis et al. (2003, 2005) on the spectra of 68 Be stars, taken with I.U.E. and we examine the variations of the physical parameters, stated below, as a function of the spectral subtype.

Results: We found that the absorption atmospherical regions where the Si IV resonance lines originated may be formed of one to five independent density layers of matter which rotate with different velocities, producing one to five Satellite Absorption Components (SACs or DACs, Danezis et al., 2005). With the above method we calculate the values of the apparent rotational and radial velocities, as well as the optical depth of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Discussion: We point out that the new and important aspect of our study is the values' calculation of the above parameters and their variations as a function of spectral subtype, using the DACs or SACs theory. Our results are a successful test of this theory and of Danezis et al. (2003, 2005) proposed method. This study is a part of a Ph. D. Thesis.

JD04-11 Poster

A New Approach For DACs And SACs Phenomena In The Atmospheres Of Hot Emission Stars

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Introduction: As it is already known, the spectra of many Oe and Be stars present Discrete Absorption Components (DACs) which, due to their profiles' width as well as the values of the radial velocities, create a complicated profile of the main spectral lines. This fact is interpreted by the existence of two or more independent layers of matter, in the region where the spectral lines are formed. Such a structure is responsible for the formation of a series of satellite components (DACs or SACs) for each spectral line (Bates & Halliwell, 1986, Danezis et al. 2003, 2005).

Method: In this paper we present a mathematical model reproducing the complex profile of the spectral lines of Oe and Be stars that present DACs or SACs. This model presupposes that the regions, where these spectral lines are formed, are not continuous but consist of a number of independent absorbing or emitting density layers of matter and an external general absorption region. In this model we assume that the line broadening is due to the random motion of the ions and the rotation of the density regions that produce the spectral line and its satellite components. With this method we can calculate the values of the apparent rotational and radial velocities, the Gaussian standard deviation of the random motions of the ions, the random velocities of these motions, as well as the optical depth, the Full Width at Half Maximum (FWHM), the absorbed and the emitted energy and finally the column density of the independent regions of matter which produce the main and the satellites components of the studied spectral lines.

Results: In order to check the above spectral line function, we calculated the rotational velocity of HeI λ 4387.928 Å absorption line in the spectra of five Be stars, using two methods, the classical Fourier analysis and our model. The values of the rotational velocities, calculated with Fourier analysis, are the same with the values calculated with our method.

Discussion: We point out that the new and important aspect of this method is the values' calculation of the above parameters using the DACs or SACs theory.

JD04-12 Oral presentation

High mass stars: starbursts

R.M. González Delgado

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Starbursts are the preferred place where massive stars form; the main source of thermal and mechanical heating in the interstellar medium, and the factory where the heavy elements form. Thus, starbursts play an important role in the origin and evolution of galaxies. Starbursts are bright at ultraviolet (UV) wavelengths, and after the pioneering IUE program, high spatial and spectral resolution UV observations of local starburst galaxies, mainly taken with HST and FUSE, have made relevant contributions to the following issues: a) The determination of the initial mass function in violent star forming systems in low and high metallicity environments, and in dense (e.g. in stellar clusters) and diffuse environments. b) The modes of star formation: Starburst clusters are an important mode of star formation. c) The role of starbursts in AGN. d) The interaction between massive stars and the interstellar and intergalactic media. e) The contribution of starbursts to the reionization of the universe.

Despite the very significant progress obtained over the past two decades of UV observations of starbursts, there are important problems that still need to be solved. High-spatial resolution UV observations of nearby starbursts are crucial to further progress in understanding the violent star formation processes in galaxies, the interaction between the stellar clusters and the interstellar medium, and the variation of the IMF. Thus, a new UV mission furnished with an intermediate spectral resolution long-slit spectrograph with high spatial resolution and high UV sensitivity is required to further progress in the study of starburst galaxies and their impact on the evolution of galaxies.

JD04-13 Poster

Eta Carinae: What we have learned from HST/STIS in the UV

TR Gull

NASA/GSFC/EUD, Greenbelt, United States

The Luminous Blue Variable, Eta Carinae is revealing many answers to its mysteries by high spatial resolution in the visible and the ultraviolet. Studies with the STIS from 1998.0 to 2004.3 show major changes in the stellar and nebular spectra that track with the 2024-day period first noted by A. Damineli in the visible and followed by M. Corcoran via RXTE X-Ray monitoring.

We will show examples of the stellar and nebular spectra indicating changes in the central source, likely a massive binary system and indicating the response of the nebular ejecta, which is the >12 solar mass

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ABSTRACTS

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18D

ON THE STARK BROADENING OF SPECTRAL LINES ALONG THE LITHIUM ISOELECTRONIC SEQUENCE: Ne VIII AND Na IX

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1. INTRODUCTION

The development of UV astronomy from space as well as the development of researches on the physics of stellar interiors /1/, increases the significance of multiply charged ion lines in astrophysics.

By using the semiclassical-perturbation formalism /2/3/, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 20 Ne VIII and 8 Na IX multiplets, in order to continue our research of multiply charged ion line Stark broadening parameters, with the special emphasis on the lithium isoelectronic sequence. A summary of the formalism is given in Ref. /4/. Here, we present and discuss the obtained results. Moreover, the influence of the perturber charge on the ion broadening contribution has been investigated and discussed.

2. RESULTS AND DISCUSSION

The needed oscillator strengths have been calculated by using the method of Bates & Damgaard /5/. For higher levels, the method described by Van Regemorter et al. /6/ has been used. In addition to electron-impact full halfwidths and shifts, Stark-broadening parameters due to proton-, and He III- impacts have been calculated. Our results for 20 Ne VIII and 8 Na IX multiplets, for perturber densities 10^{16} - 10^{22}cm^{-3} and temperatures T = 200,000 - 2,000,000K will be published in Ref. /7/. An analysis of the influence of perturber charge on the ion broadening contribution has been performed as well. Full half widths (W) and shifts (d) due to Na IX collisions with Na ions with the charge between 1 and 9 (Z = 2 - 10) are compared with the electron- and proton-impact widths. When the perturber charge increases, we have that the repulsive force between the emitter and the perturber increases as well. On the other hand, a perturber with higher charge has the stronger influence on the emitter than a perturber with smaller charge at the same distance. For lower temperatures, i.e. smaller perturber velocities, the repulsive force is more effective since the collision duration is larger and highly charged perturber has smaller chance to come closer to the emitter. Consequently, for the lower temperatures (see Fig. 1 as an example) the Stark broadening parameters have smaller change with Z than for T = 10^6K. It has been found as well that shifts are more sensitive to the perturber charge increase than widths.

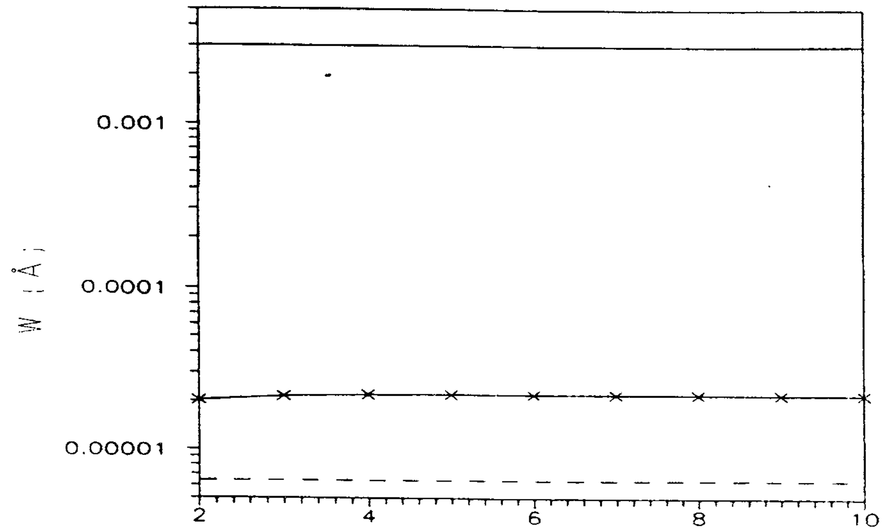

Fig.1. The behavior of W(FWHM)[Å] for Na Z - Na IX impacts (-x-x-x-) (Z=1 for neutrals, 2 for singly charged ions etc). Electron-impact (———) and proton-impact (-----) widths are shown as well. The considered transition is 2s-2p, electron density $10^{17}cm^{-3}$ and temperature 200,000K.

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ABSTRACTS

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STARK WIDTH OF Xe II SPECTRAL LINE

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Stark broadening data of heavy ion lines are of interest for analysis of hot star spectrum, where Stark broadening mechanism is main pressure broadening mechanism. The Xe II spectral lines have been detected in stellar spectra, as e.g. in spectra of κ Cnc (Hg - Mn star), where about 20 lines of Xe II have been observed /1/.

Here we present calculated Stark widths for two Xe II multiplet transitions ($6s^4P - 6p^4P^0$, $6s^4P - 6p^4D^0$) within the modified semiempirical approach /2/. The needed atomic data for calculation have been taken from Refs. /3/4/.

Table 1. Stark full width (FWHM) of Xe II lines as a function of temperature. The electron density is $10^{23}m^{-3}$.

Transition	T(K)	FWHM (nm)	Transition	FWHM (nm)
	5000.	.982E-01		.752E-01
$6s^4P - 6p^4P^0$	10000.	.681E-01	$6s^4P - 6p^4D^0$	.521E-01
	20000.	.475E-01		.364E-01
$\lambda = 584.5$ nm	30000.	.396E-01	$\lambda = 503.7$ nm	.303E-01
	40000.	.358E-01		.275E-01
	50000.	.339E-01		.262E-01

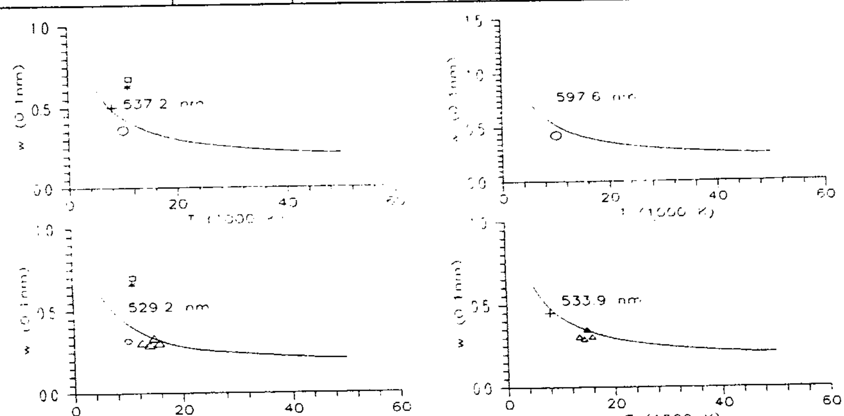

Fig. 1. Stark width (FWHM) of Xe II ($6s^4P - 6p^4P^0$) lines. The full line denots present results calculated by using the modified semiempirical approach. Experimental data are taken from Refs.: (∗) - /5/, (□) - /6/, (o) - /7/, (Δ) - /8/, + - /9/, (▲) - /10/.

In Table 1. Xe II Stark full width (FWHM), for electron density of $10^{23}m^{-3}$ as a function of temperature, have been presented.

In Figs. 1. and 2. our results for Xe II Stark widths have been compared with available experimental data /5/–/10/. As one can see in Figs. 1. and 2. the obtained Stark widths for Xe II lines are in satisfactory agreement with experimental data.

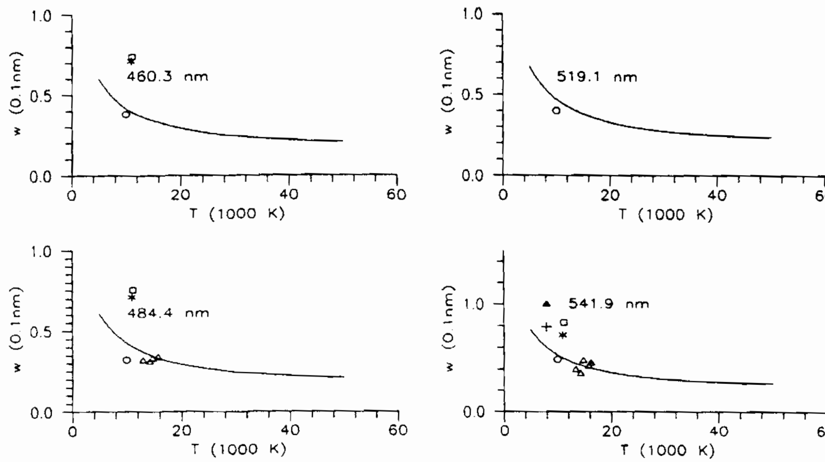

Fig. 2. Same as in Fig. 1., but for $6s^4P - 6p^4D^0$ transitions.

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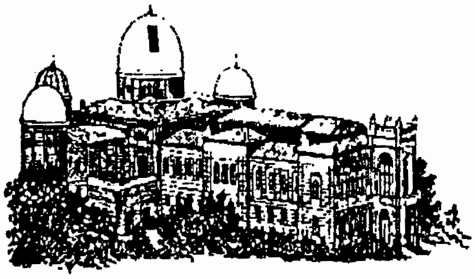

European Working Group on CP Stars

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ABSTRACTS

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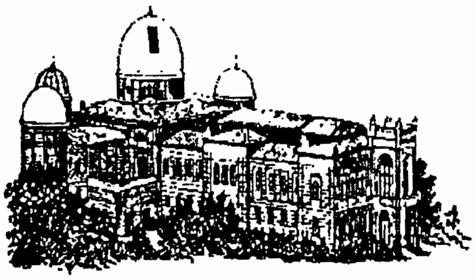
Stark Broadening parameter regularities and interpolation and critical evaluation of data for CP star atmpospheres research: Stark line shifts

M.S. Dimitrijevič, D. Tankosić
Astronomical Observatory, Volgina 7, 11050 Belgrade, Yugoslavia

We will review the experimentally and theoretically established regularities and systematic trends in Stark broadening parameters, with the special emphasis on the line shifts. We will point out as well the possibilities to use such knowledge for the estimates of missing data and for critical evaluation of data existing in the literature.

In order to find out if regularities and systematic trends found to be apparent among experimental Stark line shifts allow the accurate interpolation of new data and critical evaluation of experimental results, the exceptions to the established regularities will be analysed on the basis of critical reviews of experimental data, and reasons for such exceptions will be discussed.



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ABSTRACTS

Supported by the Commission for Astronomy of the Austrian Academy of Sciences

A Program for Electron-Impact Broadening parameter calculations of ionized rare-earth element lines

L.C. Popović, M.S. Dimitrijević
Astronomical Observatory Volgina 7, Belgrade, Serbia – Yugoslavia

In order to provide atomic data needed for astrophysical investigations a set of electron-impact broadening parameters for ionized rare-earth element lines should be calculated. For some transitions of La II and La III we have calculated Stark widths by using the modified semiempirical approach (results presented in Popović and Dimitrijević, 1997, Publ. Astron. Obs. Belgrade **47**, p.123). We are going to calculate the electron-impact broadening parameters of La IV, Ce II, III, IV, Nd II, Pr III, Eu II, III, Er III, Yb II, III and Lu II, III, IV lines. Taking into account that the spectra of these elements are very complex, for calculation we can use only the modified semiempirical approach – MSE or simplified MSE. Here we will present our plans and specify the lines which we may calculate with a satisfied accuracy and discuss the difficulties which may appear in calculation.

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Stark broadening of heavy ion spectral lines in spectra of CP stars

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Abstract

In this paper we present Stark width for nine spectral lines of four heavy ions (Zn II, As II, I II and Bi II). Stark broadening data are calculated within modified semiempirical approach for electron density of $10^{21}m^{-3}$ and electron temperature of 10 000 K and compared with the corresponding Doppler widths and with experimental data. Our results show that Stark broadening widths for some of the investigated heavy ion spectral lines are of the same order of magnitude as Doppler ones in spectra of hot CP stars (e.g. Ap stars).

1 Introduction

A large number of heavy ion spectral lines are present in spectra of CP stars (see e.g. Jacobs and Dworetsky 1982, Sadakane et al. 1988, Fuhrmann 1989, Danezis et al. 1991, etc.).

Stark broadening is dominant pressure broadening mechanism for CP stars with $T_{eff} \geq 10000K$ (see e.g. Popovič et al. 1993a). However Stark broadening of lines originating from energy levels with higher principal quantum numbers may be important even for cooler stars (see e.g. Vince et al. 1985).

In this paper we present calculated Stark widths for nine spectral lines of four heavy ions (Zn II, As II, I II and Bi II) for electron density of $10^{21}m^{-3}$ and electron temperature of 10 000 K which are typical parameters in that part of atmosphere of hot CP stars where those spectral lines are formed. Our calculated Stark widths are compared with corresponding Doppler widths and with available experimental data.

2 Method

For heavy ions, it is often impossible to obtain a sufficiently complete set of atomic data, so the quantum mechanical and semi classical theories are not applicable for Stark broadening calculation in such cases. Consequently we use here the modified semi empirical approach (Dimitrijevič and Konjevič 1980, Dimitrijevič 1988), which is applicable for the lines considered here.

The oscillator strengths needed for calculations (see Popovič et al. 1993b) have been taken from Wiese and Martin (1980), Kunisz (1975) and Gruzdev (1968, 1969) and the atomic energy levels from Moore (1971) and Li and Andrew (1971, 1972). The departure from LS coupling has been taken into account (see Dimitrijevič and Popovič 1993) for np^2

and *npms* terms by representation of the corresponding term as a mixture of singlet and triplet states (in cases of As II and Bi II). The mixing coefficients are given by Gruzdev (1968).

Ion	λ (nm)	$w_{St.}$ (nm)	$w_{Dopp.}$ (nm)
Zn II			
$4s^4S_{1/2} - 4p^2P^0_{1/2}$	206.19	.434E-4	.110E-2
$4p^2P^0 - 4s^2\,{}^2D$	747.44	.516E-3	.398E-2
As II			
$5s^3P^0_0 - 5p^3D_1$	549.92	.575E-3	.274E-2
$5s^3P^0_1 - 5p^3D_1$	562.21	.751E-3	.279E-2
$5s^3P^0_1 - 5p^3D_2$	555.96	.814E-3	.276E-2
I II			
$6s^5S^0 - 6p^5P$	532.63	.654E-3	.203E-2
$6s^3P^0 - 6p^3P$	562.21	.778E-3	.218E-2
Bi II			
$7s^3P^0_1 - 7p^3P_0$	571.90	.121E-2	.170E-2
$7s^3P^0_1 - 7p^3D_2$	520.90	.132E-2	.155E-2

Table 1: Comparison of Stark and Doppler full widths (FWHM) for Zn II, As II, I II and Bi II spectral lines for T=10 000 K and $N_e = 10^{21}m^{-3}$.

3 Results and Conclusions

In Table 1. we present the results of our calculated Stark and Doppler widths (FWHM) for above mentioned nine spectral lines for four heavy ions. From Table 1. follows that Stark broadening of heavy ion spectral lines may be important as for instance in the case of Bi II $\lambda = 520.9nm$ line where Doppler width is comparable to the Stark width.

In Table 2. our results are compared with available experimental data (Miller and Bengston 1980, Purić et al. 1985, Labat et al. 1990, Djeniže et al. 1991). Taking into account the complexity of heavy ion spectrum, theoretical results in comparison with experimental data show satisfactory agreement. We may conclude that in this case the

Ion	Transition	λ (nm)	T(10^3K)	w_{exp}/w_{th}	Ref
Zn II	$4s^2S - 4p^2P^0$	206.2	33.0	1.9	[1]
	$4p^2P^0 - 4s^2\,{}^2D$	747.4	33.0	1.6	[1]
I II	$6s^5S^0 - 6p^5P$	516.1	64.0	1.3	[2]
	$6s^3S^0 - 6p^3P$	562.7	64.0	1.9	[2]
Bi II	$7s^3P^0 - 7p^3P$	571.9	11.0	1.2	[3]
			16.0	2.2	[4]
			20.0	1.1	[4]
	$7s^3P^0 - 7p^3D$	520.9	16.0	1.0	[4]
			20.0	1.6	[4]

Table 2: Comparison of experimental and theoretical Stark widths of heavy ion spectral lines. Experimental data were taken from: [1]-Djeniže et al. (1991), [2]-Labat et al. (1990), [8]-Miller and Bengston (1980), [4]-Purič et al. (1985).

modified semi empirical approach gives satisfactory results, since the average ratio of experimental and theoretical widths is $(w_{exp}/w_{th})_{Av} = 1.5$.

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Discussion:

Ansari: 1. What effect does Stark broadening have on the abundance determination of an element?

Vince: If the line is weak the equivalent width is proportional to the relative abundance, but for strong lines this dependence is more complicated.

Ansari: 2. How are weak lines and strong lines affected by Stark broadening?

Vince: As I know there is no such selection rule. Stark broadening depends on character of transition energy levels and on perturbing energy levels. Usually for higher energy level the Stark broadening parameter is larger.

Budaj: The answer to Ansari;
The uncertainty of determination of Stark broadening should not have an influence for weak - unsaturated lines as the abundances are determined from equivalent widths which depend linearly on element abundances in this case. Another case is for saturated line there stark broadening may cause saturation or desaturations effect and change on equivalent width nonlinearity with element abundance.

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A PROJECT FOR LARGE-SCALE STARK BROADENING DATA CALCULATION: Ca I

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In a series of papers we have performed large scale calculations of Stark broadening parameters for a number of spectral lines of various emitters (see e.g. [1]). In order to complete as much as possible Stark broadening data needed for astrophysical and laboratory plasma research and stellar opacities calculations we are making a continuous effort to provide Stark broadening data for a large set of atoms and ions. Our calculations are performed within the semiclassical - perturbation formalism, for transitions when a sufficiently complete set of reliable atomic data exist and the good accuracy of obtained results is expected.

Extensive calculations have been performed, up to now [1] for a number of radiators, and consequently, Stark broadening parameters for 79 He I, 62 Na, 51 K, 61 Li, 25 Al, 24 Rb, 3 Pd, 19 Be, 270 Mg, 31 Se, 33 Sr, 14 Ba, 28 Ca II, 30 Be II, 29 Li II, 66 Mg II, 64 Ba II, 19 Si II, 3 Fe II, 2 Ni II, 12 B III, 23 Al III, 10 Sc III, 27 Be III, 32 Y III, 20 In III, 2 Tl III, 10 Ti IV, 39 Si IV, 90 C IV, 5 O IV, 114 P IV, 2 Pb IV, 19 O V, 30 N V, 25 C V, 51 P V, 34 S V, 26 V V, 30 O VI, 21 S VI, 2 F VI, 14 O VII, 10 F VII, 10 Cl VII, 20 Ne VIII, 4 K VIII, 4 Ca IX, 30 K IX, 8 Na IX, 57 Na X, 48 Ca X, 4 Sc X, 7 Al XI, 4 Si XI, 18 Mg XI, 4 Ti XI, 10 Sc XI, 9 Si XII, 27 Ti XII, 61 Si XIII and 33 V XIII multiplets become available.

Data for particular lines of F I, B II, C III, N IV, Ar II, Ga II, Ga III, Cl I, Br I, I I, Cu I, Hg II, N III, F V and S IV also exist.

In order to continue our project to provide to physicists and astrophysicists an as much as possible complete set of needed reliable Stark broadening data, we have calculated within the semiclassical-perturbation formalism, electron-, proton-, He II-, Mg II-. Si II-, and Fe II - impact line widths and shifts for 189 neutral calcium lines, as a function of temperature and perturber density. Perturbers selected here, are the main perturbers in solar and stellar atmospheres.

A summary of the formalism has been published several times (see e. g. [2]). Energy levels for have been taken from Ref. 3.

Here, in Table 1, we present only a sample of results obtained.

We hope that the present results will be of interest for the the stellar, laboratory, fusion and laser produced plasma investigation and modeling, as well as for the testing and developing of Stark broadening theory.

Table 1: This table shows electron-impact broadening full half-widths (FWHM) and shifts for Ca I singlets for a perturber density of 10^{16} cm^{-3} and temperatures from 2,500 up to 50,000 K. By deviding C with the full linewidth, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)
4S - 4P	2500.	0.103E-01	0.578E-02
4227.9Å	5000.	0.115E-01	0.665E-02
C= 0.17E+20	10000.	0.124E-01	0.795E-02
	20000.	0.143E-01	0.807E-02
	30000.	0.162E-01	0.724E-02
	50000.	0.193E-01	0.585E-02
5S - 5P	2500.	7.36	3.52
29288.1 Å	5000.	9.21	2.15
C= 0.49E+20	10000.	11.4	0.952
	20000.	12.7	0.146
	30000.	13.4	-0.315
	50000.	14.0	-0.477

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THE ELECTRON-IMPACT BROADENING PARAMETERS FOR Ra II SPECTRAL LINES

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The knowledge of Stark broadening data is important for investigation of laboratory and astrophysical plasma as e.g. for the laboratory plasma diagnostics and investigation, fusion plasma and laser produced plasma research, the stellar atmosphere modeling and abundance determination. The electron-impact broadening parameters for many ionized elements have been calculated by using the semiclassical perturbation formalism [1-3] or the modified semiempirical approach (Ref.4, for the emitters with complex spectra see Ref.5).

Stark broadening parameters of Ra II lines may be of interest for the consideration of regularities and systematic trends. Such data may be of interest as well for eventual laboratory measurements and for comparison with existing simple estimates [6,7]. Namely, Stark widths for $7s^2S - 7p^2P^0$ (λ=381.44 nm), $7p^2P^0 - 8s^2S$ (λ=581.36 nm) and $7p^2P^0 - 7d^2D$ (λ=434.06 nm) Ra II spectral lines have been estimated based on regularities along a homologous sequence of the second group in the periodic system [6]. These values have been compared with Stark widths [6] calculated by using the simplified modified semiempirical approach [8]. Moreover, for the $7s^2S$-$7p^2P^0$ (λ=468.22nm) Ra II line Stark width has been estimated based on regularities and systematic trends [7].

In order to enlarge the existing set of theoretical Stark broadening data, we present here results of Stark broadening parameter calculation for Ra II spectral lines belonging to the $7s^2S$-$7p^2P^0$ and $7p^2P^0$-$8s^2S$ multiplets. Calculations have been performed within the modified semiempirical approach (MSE) for an electron density of 10^{23} m^{-3} and temperature range 5000-50000K. In Table 1 Stark broadening parameters for 7s-7p Ra II transitions are shown. Energy levels for Ra II have been taken from Ref. 9. Oscillator strengths have been calculated by using the Bates-Damgaard method [10].

In Table 2, our results are compared with estimated Stark widths for the $7s^2S$-$7p^2P^0$ (λ=381.44 nm) and $7p^2P^0 - 8s^2S$ (λ=581.36 nm) Ra II spectral lines from Ref 6. as well as with estimated Stark width value from Ref.7, for $7s^2S - 7p^2P^0$ (λ=468.22 nm) Ra II line . Taking into account that the value obtained on the basis of regularities in Refs.6,7 is an approximate one, the ratio is certainly within error bars for such complex spectra and encouraging for the application of such methods.

Table 1. Stark (full) widths (W) and shifts (d) for 7s-7p Ra II transitions at an electron density of $10^{23}m^{-3}$ as a function of temperature.

Transition	$7s\ ^2S - 7p\ ^2P^0$ $\lambda = 468.22$ nm				$7s\ ^2S - 7p\ ^2P^0$ $\lambda = 381.44$ nm			
T(K)	5000	10000	20000	50000	5000	10000	20000	50000
W(nm)	0.0549	0.0381	0.0265	0.0182	0.0401	0.0278	0.0194	0.0136
d(nm)	-0.0188	-0.0135	-0.00756	-0.00719	-0.00899	-0.00639	-0.00456	-0.00286

Table 2. Predicted (full) widths (W_p) for Ra II spectral lines, given from [6,7] for T=20000K and an electron density of $10^{23}m^{-3}$. W_p/W_{MSE} is the ratio of the estimated Stark widths and the values obtained here.

transitions	λ (nm)	W_p (nm)	W_p/W_{MSE}	Ref.
$7s^2S-7p^2P^0$	468.22	0.0470	1.77	7
$7s^2S-7p^2P^0$	381.44	0.0174	0.89	6
$7p^2P^0-8s^2S$	581.36	0.0932	0.64	6

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STARK BROADENING EFFECT IN CP STELLAR ATMOSPHERES: THE CASE OF IONIZED RARE EARTH ELEMENT LINES

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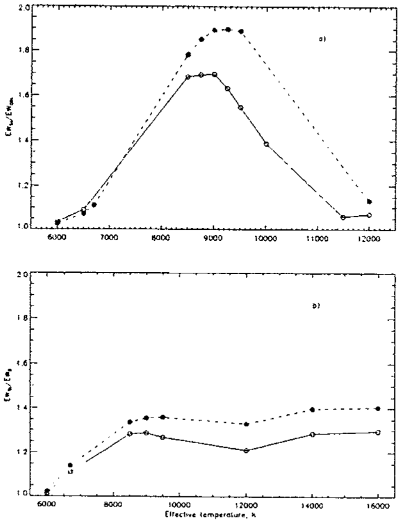
The ionized rare earth element (REE) lines are present in spectra of CP stars in a wide temperature range [1-6] and many review articles on abundances of the REEs exist [1],[4],[7]. Here we have considered Eu II 420.505 nm and Eu III 666.63 nm spectral lines. These lines are usually very strong in the optical spectra of CP stars.

In order to test the importance of the electron-impact broadening effect in stellar atmospheres, we have calcualated Stark widths (W) for Eu II λ=420.505 nm and Eu III λ=666.63 nm by using the modified semiempirical method [8],[9]. We have synthesized also the line profiles using SYNTH code [11] and the Kurucz's ATLAS9 code for stellar atmospheres models [12] in the temperature range of $6000 \leq T_{\rm eff} \leq 16000$ K, and $3.0 \leq \log g \leq 5.0$. We have modified the SYNTH code, which uses $\log W(\,\mathrm{rad\,s^{-1}})$ per electron for T=10000 K as an imput parameter replacing them by three imput parameters: coefficients A_0 and A_1 determining the temperature Stark width dependence (see [10]) and Stark line shift.

Detailed discussion of obtained results will be published in Ref. [10]. A part of our results is presented in Fig. 1(a,b), where the ratio of the equivalent widths of the line calculated with and without Stark broadening effect – $EW_{\rm St}/EW_0$ – is shown as a function of the effective temperature. The calculations were performed for Eu II 420.505 nm (Fig. 1a) and for Eu III 666.63 nm (Fig. 1b) lines with the europium abundance log(Eu/H)= -6.9.

As one can see from Fig. 1(a,b) for Eu II 420.505 nm line the electron impact broadening has its maximum effect for stellar atmospheres with $T_{\rm eff} \approx 8000 - 9000$ K, while for Eu III 666.63 nm line this effect is important for stellar atmospheres with $T_{\rm eff} > 8000$ K and maximum is not present. Different trends in the dependence of the electron broadening effect on effective temperature for two lines may be explained by difference in the ionization potentials of Eu II and Eu III. The ionization potential of Eu II is 11.241 eV, and for higher effective temperatures this ion is practically absent in the layers where the electron impact broadening is important and where Eu III dominates over Eu II. The small minimum around $T_{\rm eff}$=12000 K in Fig.1b may be connected with the specific depth formation of the Eu III line.



A decrease of the Stark broadening effect for Eu II line towards the lower temperatures occures due to rapid decrease of the electron density.

As we can see the Stark broadening becomes to be significant in hot stars, and it should be taken into account in the analysis of stellar spectral lines for the $T_{\rm eff}>7000$ K in particular if europium is overabundant.

Fig. 1. The ratio of equivalent widths for Eu II 420.505 nm line (a) and for Eu III 666.63 nm line (b) calculated with Stark broadening effect ($EW_{\rm St}$) and without it (EW_0) as a function of effective temperature. Results for $\log g$=4.0 and for $\log g$=4.5 are shown by the open circles and full circles respectively.

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