Publ. Astron. Obs. Belgrade No. 57 (1997), 15 – 18 *Contributed paper*

BROADENING DUE TO COLLISIONS WITH CHARGED PARTICLES OF V V AND V XIII SPECTRAL LINES

MILAN S. DIMITRIJEVIĆ[1] and SYLVIE SAHAL-BRÉCHOT[2]

[1] *Astronomical Observatory, Volgina 7, 11000 Belgrade, Yugoslavia*
E-mail mdimitrijevic@aob.aob.bg.ac.yu

[2] *Observatore de Paris, 92195 Meudon Cedex, France*
E-mail sahal@obspm.fr

Abstract. Using a semiclassical approach, we have calculated electron-, proton-, and He III-impact line widths and shifts for 33 vanadium V multiplets, for perturber densities 10^{14}– 10^{21} cm^{-3} and temperatures T = 50,000 – 500,000 K, and 26 vanadium XIII multiplets, for perturber densities 10^{18}– 10^{22} cm^{-3} and temperatures T = 500,000 – 5,000,000 K.

1. INTRODUCTION

Vanadium is present in stellar and solar plasma, and broadening parameters of its spectral lines for various ionization stages are of interest for the investigation and modelling of such plasma. For stellar plasma conditions with $T_{eff} \geq 10000$K hydrogen is mostly ionized and Stark broadening is the main pressure broadening mechanism. Lines of fourtly charged ions are present in e.g. PG 1159 star atmospheres (Werner et al., 1991), and with the development of space born techniques, the interest for lines of not abundant ions increases. Moreover, for the modelling of subphotospheric layers, higher ionization stages are of interest as well (Seaton, 1997). Consequently, Stark broadening parameters for multiply charged vanadium ion lines are of interest not only for the laboratory plasma research, testing and developping of the Stark broadening theory for shapes of multicharged ion lines, and investigations of regularities and systematic trends (particularly along isoelectronic sequences), but as well for the consideration of stellar plasma.

By using the semiclassical-perturbation formalism (Sahal-Bréchot 1969ab), we have calculated electron-, proton-, and He III-impact line widths and shifts for 33 vanadium V and 26 vanadium XIII multiplets. A short review of the formalism is given e.g. in Dimitrijević *et al.* (1991).

2. RESULTS AND DISCUSSION

Energy levels for vanadium V and vanadium XIII lines have been taken from Bashkin and Stoner (1981). All other details of calculations are given in Dimitrijević and Sahal-Bréchot (1997). Our results for electron-, proton-, and He III-impact line widths

and shifts for 33 vanadium V multiplets, for perturber densities 10^{14}– 10^{21} cm^{-3} and temperatures T = 50,000 – 500,000 K, and 26 vanadium XIII multiplets, for perturber densities 10^{18}– 10^{22} cm^{-3} and temperatures T = 500,000 – 5,000,000 K, will be published elsewhere (Dimitrijević and Sahal-Bréchot, 1997). A sample of results is presented in Tables 1 and 2 for vanadium V and vanadium XIII respectively. We also specify a parameter C (Dimitrijević and S.Sahal-Bréchot, 1984), 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 V V for a perturber density of 10^{16} 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+16cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
V V 4S 4P	50000.	0.237E-02	-0.417E-04	0.480E-04	-0.210E-04
1692.2 A	100000.	0.171E-02	-0.382E-04	0.879E-04	-0.368E-04
C= 0.17E+20	150000.	0.144E-02	-0.452E-04	0.109E-03	-0.479E-04
	200000.	0.128E-02	-0.527E-04	0.127E-03	-0.543E-04
	300000.	0.111E-02	-0.528E-04	0.146E-03	-0.664E-04
	500000.	0.941E-03	-0.466E-04	0.163E-03	-0.771E-04
V V 4S 5P	50000.	0.420E-03	0.173E-05	0.276E-04	0.333E-06
490.9 A	100000.	0.324E-03	0.873E-06	0.384E-04	0.651E-06
C= 0.57E+18	150000.	0.283E-03	0.231E-05	0.422E-04	0.924E-06
	200000.	0.259E-03	0.318E-05	0.447E-04	0.114E-05
	300000.	0.231E-03	0.171E-05	0.478E-04	0.148E-05
	500000.	0.204E-03	0.214E-05	0.516E-04	0.188E-05
V V 5S 5P	50000.	0.420E-01	-0.159E-02	0.215E-02	-0.108E-02
4232.2 A	100000.	0.325E-01	-0.180E-02	0.308E-02	-0.153E-02
C= 0.42E+20	150000.	0.285E-01	-0.192E-02	0.342E-02	-0.181E-02
	200000.	0.262E-01	-0.171E-02	0.367E-02	-0.193E-02
	300000.	0.235E-01	-0.171E-02	0.400E-02	-0.217E-02
	500000.	0.208E-01	-0.160E-02	0.444E-02	-0.246E-02

Table 1 continued

PERTURBER DENSITY = 1.E+16cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
V V 4P 5S	50000.	0.102E-02	0.808E-04	0.271E-04	0.454E-04
826.6 A	100000.	0.756E-03	0.829E-04	0.505E-04	0.637E-04
C= 0.16E+19	150000.	0.647E-03	0.919E-04	0.692E-04	0.746E-04
	200000.	0.587E-03	0.881E-04	0.780E-04	0.799E-04
	300000.	0.517E-03	0.836E-04	0.917E-04	0.891E-04
	500000.	0.445E-03	0.788E-04	0.109E-03	0.101E-03
V V 4P 4D	50000.	0.142E-02	0.211E-04	0.539E-04	0.118E-04
1152.7 A	100000.	0.104E-02	0.172E-04	0.841E-04	0.203E-04
C= 0.74E+19	150000.	0.878E-03	0.229E-04	0.103E-03	0.260E-04
	200000.	0.789E-03	0.272E-04	0.113E-03	0.296E-04
	300000.	0.688E-03	0.257E-04	0.122E-03	0.357E-04
	500000.	0.593E-03	0.220E-04	0.134E-03	0.413E-04
V V 4P 5D	50000.	0.627E-03	0.237E-04	0.484E-04	0.134E-04
553.2 A	100000.	0.482E-03	0.229E-04	0.660E-04	0.196E-04
C= 0.84E+18	150000.	0.423E-03	0.263E-04	0.714E-04	0.236E-04
	200000.	0.389E-03	0.263E-04	0.755E-04	0.258E-04
	300000.	0.350E-03	0.244E-04	0.813E-04	0.287E-04
	500000.	0.312E-03	0.232E-04	0.875E-04	0.328E-04

Table 2

This table shows electron- and proton-impact broadening full half-widths (FWHM) and shifts for V XIII for a perturber density of 10^{19} cm^{-3}.

PERTURBER DENSITY = 1.E+19cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
V XIII3S 3P	500000.	0.154E-01	-0.176E-03	0.162E-03	-0.161E-03
429.5 A	1000000.	0.112E-01	-0.211E-03	0.385E-03	-0.306E-03
C=0.43E+20	1500000.	0.932E-02	-0.228E-03	0.566E-03	-0.413E-03
	2000000.	0.824E-02	-0.207E-03	0.702E-03	-0.501E-03
	3000000.	0.698E-02	-0.205E-03	0.893E-03	-0.604E-03
	5000000.	0.573E-02	-0.194E-03	0.115E-02	-0.765E-03
V XIII3S 4P	500000.	0.106E-02	0.436E-05	0.449E-04	0.592E-05
71.9 A	1000000.	0.785E-03	0.689E-05	0.731E-04	0.111E-04
C=0.47E+20	1500000.	0.665E-03	0.530E-05	0.900E-04	0.148E-04
	2000000.	0.595E-03	0.585E-05	0.101E-03	0.175E-04
	3000000.	0.512E-03	0.578E-05	0.110E-03	0.213E-04
	5000000.	0.430E-03	0.561E-05	0.124E-03	0.261E-04

V XIII3S 5P	500000.	0.122E-02	0.208E-04	0.104E-03	0.283E-04
52.9 A	1000000.	0.922E-03	0.212E-04	0.145E-03	0.422E-04
C=0.13E+20	1500000.	0.794E-03	0.207E-04	0.159E-03	0.517E-04
	2000000.	0.719E-03	0.201E-04	0.170E-03	0.572E-04
	3000000.	0.630E-03	0.200E-04	0.186E-03	0.637E-04
	5000000.	0.540E-03	0.177E-04	0.209E-03	0.725E-04
V XIII4S 4P	500000.	0.297	-0.624E-02	0.114E-01	-0.841E-02
1100.4 A	1000000.	0.222	-0.635E-02	0.191E-01	-0.132E-01
C=0.11E+20	1500000.	0.190	-0.635E-02	0.243E-01	-0.160E-01
	2000000.	0.170	-0.619E-02	0.278E-01	-0.182E-01
	3000000.	0.148	-0.594E-02	0.315E-01	-0.202E-01
	5000000.	0.125	-0.550E-02	0.371E-01	-0.232E-01
V XIII4S 5P	500000.	0.136E-01	0.408E-04	0.106E-02	0.812E-04
169.4 A	1000000.	0.104E-01	0.282E-04	0.146E-02	0.140E-03
C=0.13E+20	1500000.	0.895E-02	0.328E-04	0.160E-02	0.177E-03
	2000000.	0.811E-02	0.269E-04	0.170E-02	0.203E-03
	3000000.	0.712E-02	0.326E-04	0.186E-02	0.243E-03
	5000000.	0.612E-02	0.198E-04	0.210E-02	0.280E-03
V XIII5S 5P	500000.	2.86	-0.923E-01	0.207	-0.144
2237.5 A	1000000.	2.20	-0.844E-01	0.303	-0.201
C=0.22E+20	1500000.	1.91	-0.826E-01	0.341	-0.225
	2000000.	1.74	-0.816E-01	0.373	-0.244
	3000000.	1.53	-0.763E-01	0.425	-0.272
	5000000.	1.32	-0.646E-01	0.508	-0.309

There is not measured or calculated vanadium V and XIII Stark broadening parameters. The corresponding experimental data will be very useful for further development and rafinement of the theory of multicharged ion lines.

References

Bashkin,S., Stoner, J.O.Jr.: 1981, "Atomic Energy Levels and Grotrian Diagrams", Vol. 3, North Holland, Amsterdam.

Dimitrijević, M.S., and Sahal-Bréchot,S.: 1984, *JQSRT* **31**, 301.

Dimitrijević M.S. and Sahal-Bréchot, S.: 1997, *Atomic Data and Nuclear Data Tables* submitted.

Dimitrijević, M.S., Sahal-Bréchot, S. and Bommier,V.: 1991, *Astron. Astrophys. Suppl. Series* **89**, 581.

Sahal-Bréchot, S.: 1969a, *Astron.Astrophys.* **1**, 91.

Sahal-Bréchot, S.: 1969b, *Astron.Astrophys.* **2**, 322.

Seaton, M.J., 1987, *J. Phys. B* **20**, 6363.

Werner, K., Heber, U., Hunger, K., 1991, *Astron. Astrophys.* **244**, 437.