16th SPIG

XVI SUMMER SCHOOL and INTERNATIONAL
SYMPOSIUM on the
PHYSICS OF IONIZED GASES

September 25 -28, 1993. Belgrade, Yugoslavia

CONTRIBUTED PAPERS

&
ABSTRACTS OF INVITED LECTURES AND PROGRESS REPORTS

edited by
M. Milosavljević

1948
1993

Zbornik se objavljuje u čast 45. godina postojanja Instituta „Vinča"

On the occasion of 45th anniversary of the VINČA Institute

Institute of Nuclear Sciences "Vinča"
Belgrade, Yugoslavia

Institute "Braća Karić"
Belgrade, Yugoslavia

ION-ATOM RADIATIVE COLLISIONS AND CONTINUOUS OPTICAL SPECTRA IN HELIUM REACH DB WHITE DWARF ATMOSPHERE

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1. INTRODUCTION

It has been demostrated [1,2] that the contribution of radiative collision processes during $H^+ + H(1s)$- and $He^+(1s) + He(1s^2)$-collisions to the solar- and certain white dwarf- opacities is comparable to the contribution of the known processes of H_2^+ and He_2^+ molecular ion photodissotiation. Moreover, it was found that $H^+ + H(1s)$ radiative collision processes are of significance for particular Solar atmosphere layers, in spite of the fact that they occure in the presence of the very intensive processe of H^- ion photocreation [3].

Since there is not a stable negative atomic ion for helium [4], the influence of the $He^+(1s) + He(1s^2)$ radiative collision processes is expected to be more significant for relatively low temperature ($T < 20000K$) helium plasma than for the corresponding hydrogen case. Consequently we will investigate here in detail the contribution of these processes to the DB white dwarf atmosphere continuous spectra, within the semiclassical approach [2,5].

2. RADIATIVE PROCESSES

The following ion-atom radiative collision processes will be considered

$$He^+(1s) + He(1s^2) \Longleftrightarrow \epsilon_\lambda + He_2^+, \qquad (1a)$$

$$He^+(1s) + He(1s^2) \Longleftrightarrow \epsilon_\lambda + \begin{cases} He^+(1s) + He(1s^2) \\ He(1s^2) + He^+(1s) \end{cases} \qquad (1b)$$

where $\epsilon = 2\pi\hbar c/\lambda$ is the energy of photon with the wavelength λ in the optical spectral range ($300nm \leq \lambda \leq 800nm$).

The contribution of processes (1) to the white dwarf continuous spectra will be compared here with the contribution of the following known radiative processes:
i) free-free radiative transitions during free electron scattering on helium atom:

$$He(1s^2) + e \Longleftrightarrow \epsilon_\lambda + He(1s^2) + e; \tag{2}$$

ii) free-free and free-bound radiative transitions during free electron scattering on positive ions:

$$A^+ + e \Longleftrightarrow \epsilon_\lambda + \begin{cases} A^+ + e \\ A^* \end{cases} \tag{3}$$

where A^* is an atom in an excited state. We use A in Eq.(3) since besides He, the presence of H and other atoms will be taken into account [6].

In order to compare different processes, we will define the ratios F of spectral emissivities ϵ

$$F_{ea}^{ff}(\lambda) = \frac{\epsilon_{ia}(\lambda)}{\epsilon_{ea}^{ff}(\lambda)} \tag{4a}$$

$$F_{ei}(\lambda) = \frac{\epsilon_{ia}(\lambda)}{\epsilon_{ei}(\lambda)} \tag{4b}$$

characterizing relative contribution of the process (1) in comparison with processes (2) and (3) respectively. We note that in the case of local thermal equilibrium, these quantities are also the ratios of the adequatly defined absorption coefficients. The meaninig of indexes is: ei - electron-ion; ia - ion-atom; ea - electron-atom; ff free-free; fb - free-bound.

3. RESULT FOR THE DB WHITE DWARF ATMOSPHERE

The description of the theoretical method and all details of the calculation will be published elsewhere [7]. Our calculations have been performed for DB white dwarf atmosphere using one of models of Koester [6] (the $\log g = 8$ and $T = 12000$ K case in Table 1).

The comparison of (1) and (2) processes contribution is presented in Fig. 1 where the behavior of the quantity $F_{ea}^{ff}(\lambda)$ is shown. We can see that $F_{ea}^{ff}(\lambda)$ increases fast with the temperature increases in the 8000 K$< T <$ 10000 K range, reaches a maximum and

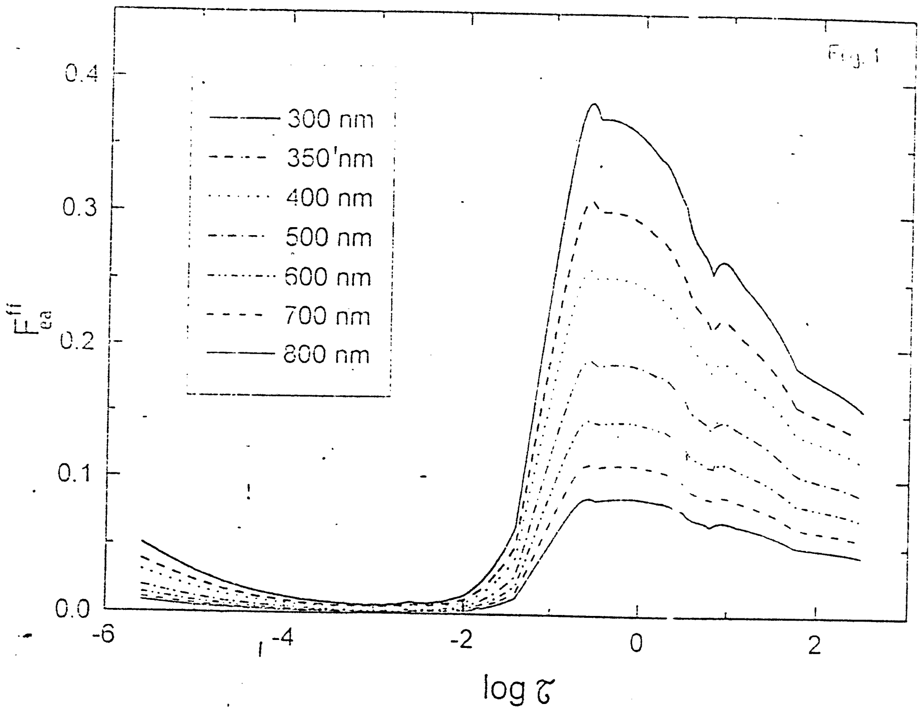
Fig. 1
300 nm
350'nm
400 nm
500 nm
600 nm
700 nm
800 nm
F_{ea}^{ff}
0.4
0.3
0.2
0.1
0.0
-6
-4
-2
0
2
log τ

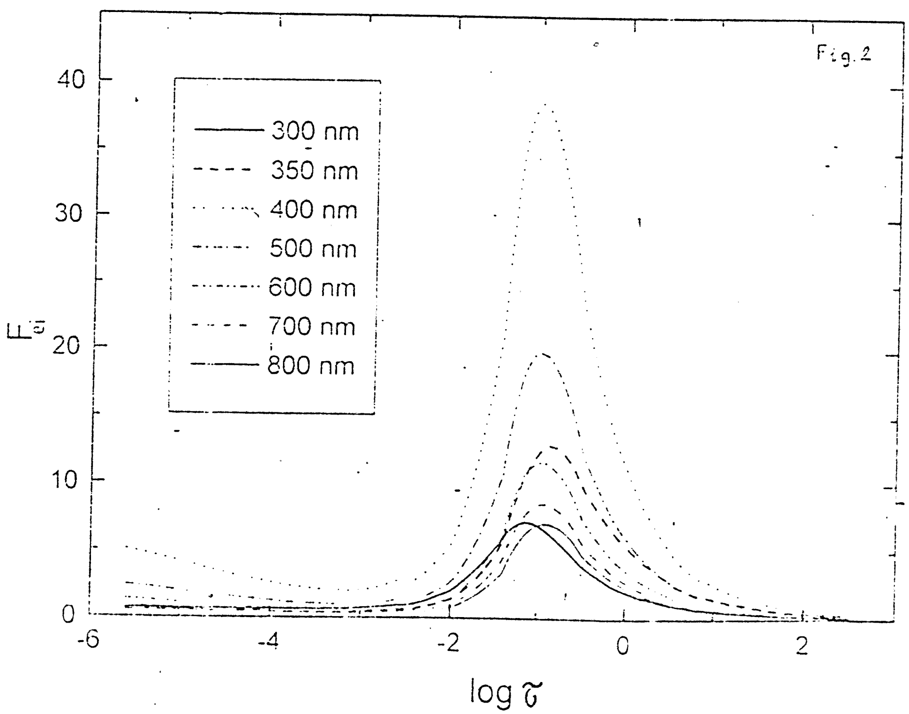
Fig. 2
300 nm
350 nm
400 nm
500 nm
600 nm
700 nm
800 nm
F_{ei}
40
30
20
10
0
-6
-4
-2
0
2
log τ

after them decreases slowly with the further increases of temperature. As a consequence exist a relatively large region (with 8000 K $< T <$ 20000 K) where the quantity $F_{ea}^{ff}(\lambda)$ is within 0.05 - 0.40 range.

The comparison of (1) and (3) processes contribution is presented in Fig. 2 where the behavior of the quantity $F_{ei}(\lambda)$ is shown. We can see that within the 8000 K $< T <$ 20000 K region. $F_{ei}(\lambda)$ has a more pronounced maximum than $F_{ea}^{ff}(\lambda)$. This maximum occures around 10000 K where the quantity $F_{ei}(\lambda)$ is within 5 - 40 range, i.e. two orders of magnitude larger than $F_{ea}^{ff}(\lambda)$. Outside the maximum range, the quantity $F_{ei}(\lambda)$ decreases sharply than $F_{ea}^{ff}(\lambda)$, so that its behavior determines the range where the processes (1) are of interest.

4. CONCLUSION

In Figs. 1 and 2 we can see that the processes (1), not taken into account up to now in DB white dwarf atmosphere research from the spectroscopical point of view, are not negligible within the optical λ range (300 nm $\leq \lambda \leq$ 800 nm) considered. Moreover, in particular layers (8000 K $< T <$ 20000 K), contributions of ion-atom processes (1) and electron-atom processes (2) are comparable and even dominant related to electron-ion processes (3). Consequently, ion-atom processes (1), considered here, should be taken into account for calculations of optical characteristics for particular layers.

REFERENCES

[1] Mihajlov A.A., Dimitrijević M.S., 1986, A&A **155**, 319

[2] Mihajlov A.A., Dimitrijević M.S., 1992, A&A, **256**,305

[3] Mihajlov A.A., Dimitrijević M.S., Ignjatović, Lj.,1993, A&A in press

[4] Massey H.S.W., 1976, Negative Ions, Cambridge University Press, Cambridge

[5] Mihajlov A.A., Popović M.M., 1981, Phys. Rev. A **23**, 1679

[6] Koester D., 1980, A&A Suppl.Ser. **39**, 401

[7] Mihajlov A.A., Dimitrijević M.S., Ignjatović, Lj.,1993, A&A to be published