Publ. Astron. Obs. Belgrade No. 80 (2006), 99 - 104 *Contributed paper*

INFLUENCE OF IMPACTS WITH CHARGED PARTICLES ON Cd I AND F III SPECTRAL LINES IN STELLAR PLASMA

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Abstract. Using a semiclassical perturbation approach, we obtained the Stark broadening parameters of 11 Cd I singlets and 13 triplets in ultra-violet and visible, and 24 Cd I triplets in infra red spectral ranges, for temperatures between 2500 K and 50000 K, and for perturber density of 10^{16}cm^{-3}. Also, we calculated within the same approach Stark broadening parameters for F III 2p^3 ^{4}S^o - 3s ^{4}P resonant line. Moreover, for 10 F III multiplets, Stark line widths have been calculated within the modified semiempirical approach, for temperatures between 10000 K and 300000 K, and for perturber density of 10^{17}cm^{-3}. We compared our Stark broadeninig parameters for Cd I and F III with existing experimental data and other theoretical results, we also investigated the regularity within a spectral series of Cd I 5s^2 ^{1}S - np ^{1}P^o and finally we analyzed the influence of Stark broadening mechanism of neutral cadmium and doubly ionized fluorine in comparison to the Doppler one for an A type star atmosphere.

1. INTRODUCTION

Stark broadening parameters of neutral cadmium and doubly ionized fluorine are of astrophysical interest due to their presence in stellar atmospheres. Abudance analysis for A type stars showed the presence of neutral cadmium in stellar spectra of e.g. 68 Tauri (Adelman, 1994ab) and V816 Centauri (Cowley et al., 2000), in distinction from fluorine cosmic abundance of which is lower.

We note that the line 6438.4696 Å, 5p ^{1}P$^o_1$ - 5d ^{1}D$_2$ is the fundamental wavelength standard on which other standards are based.

Data on Stark broadening parameters for cadmium lines are also of interest for the consideration of regularities and systematic trends, and the corresponding results may be of interest in astrophysics for interpolation of new data and critical evalution of existing ones.

The aims of this paper are: 1) to determine Cd I spectral line widths and shifts, particularly for the cases when Stark broadening parameters are not known well; 2) to obtain results applicable for an analysis of Stark broadening influence on cadmium lines in stellar spectra. In order to analyze difference between neutral and ion emitters we included F III lines, in particular because their Stark broadening was not investigated thoroughly enough, so that the obtained results can be useful from this point of view, as well.

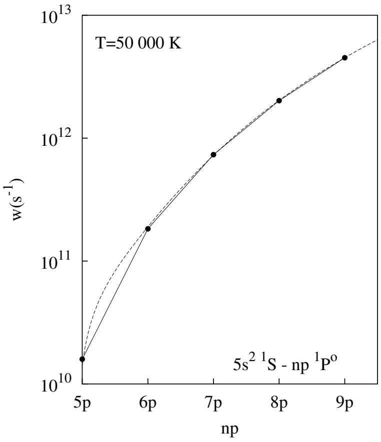

Figure 1: Electron-impact widths for Cd I 5s^2 ^{1}S - np ^{1}P^o spectral series in angular frequency units as a function of main quantum number n for the upper atomic energy level.

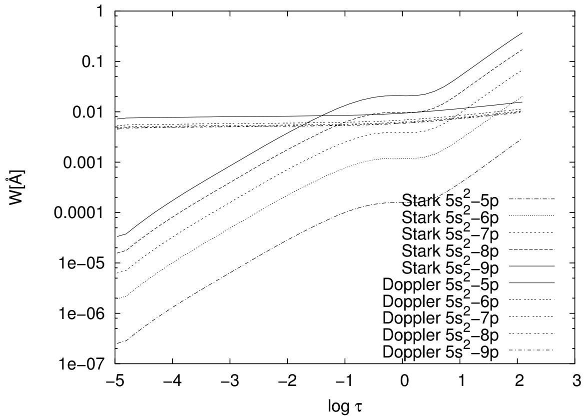

Figure 2: Thermal Doppler and Stark widths for Cd I singlet spectral lines: 5s^2 ^{1}S - 5p ^{1}P^o (2288.7 Å), 5s^2 ^{1}S - 6p ^{1}P^o (1669.3 Å), 5s^2 ^{1}S - 7p ^{1}P^o (1526.9 Å), 5s^2 ^{1}S - 8p ^{1}P^o (1469.4 Å), 5s^2 ^{1}S - 9p ^{1}P^o (1440.2 Å) as a function of Rosseland optical depth.

2. RESULTS AND DISCUSSION

We have calculated within the semiclassical perturbation approach (Sahal-Bréchot, 1969ab) the Stark broadening parameters of 11 Cd I singlets and 13 triplets in ultraviolet and visible, and 24 Cd I triplets in infra red spectral ranges, for temperatures between 2500 K and 50000 K, and for perturber density of 10^{16}cm^{-3} (Simić et al., 2005b; Simić, 2004). Also, we have calculated within the same approach these parameters for F III 2p^3 ^{4}S^o - 3s ^{4}P resonant line (Simić et al., 2005a; Simić, 2004). This formalism, as well as the corresponding computer code, have been updated and

Table 1: Experimental Stark widths - W_m, our theoretical results - W_{th}, theoretical results obtained within GBKO approach - $W_{th'}$.

TRANSITION	λ (Å)	W_m(Å)	W_m/W_{th}	$W_m/W_{th'}$
CdI	5085.8	3.67	6.41	6.34
	4799.9	3.84	7.53	6.63
5p ^{3}P^o - 6s ^{3}S^o	4678.2	1.74	3.59	3.00

optimized several times (Sahal-Bréchot, 1974, 1991; Fleurier et al., 1977; Dimitrijević and Sahal-Bréchot, 1984; Dimitrijević et al., 1991; Dimitrijević and Sahal-Bréchot, 1996). A brief review of the calculation procedure, with the discussion of updatings and validity criteria is given e.g. in Dimitrijević (1996). Moreover, for 10 F III multiplets, line widths have been obtained within the modified semiempirical approach (Dimitrijević and Konjević, 1980), for temperatures between 10000 K and 300000 K, and for perturber density of 10^{17}cm^{-3} (Simić et al., 2005a; Simić, 2004). Atomic energy levels needed for calculations have been taken from Moore (1971). The oscillator strengths have been calculated within the Coulomb approximation (Bates and Damgaard, 1949, and the tables of Oertel and Shomo, 1968). For higher levels, the method of van Regemorter et al. (1979) has been used.

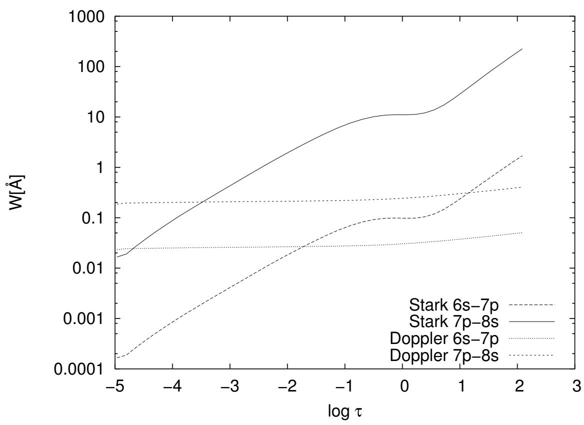

Figure 3: Thermal Doppler and Stark widths for Cd I triplet spectral line: 6s ^{3}S^o - 7p ^{3}P^o (7400.9 Å) and 7p ^{3}P^o - 8s ^{3}S^o (59346.5 Å) as a function of Rosseland optical depth.

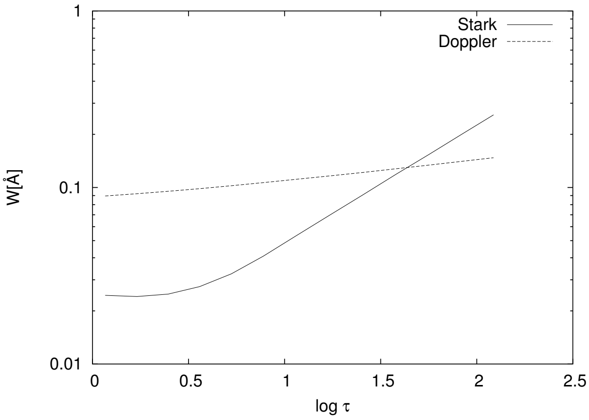

Figure 4: Stark and Doppler widths for F III 4s ^{4}P - 4p ^{4}D^o (8890 Å) as a function of Rosseland optical depth, for an A type stellar atmosphere model with $T_{eff} = 10000$ K and log $g = 4$.

Stark widths (see Table 1) for Cd I 5p ^{3}P^o - 6s ^{3}S^o multiplet have been compared with existing experimental data (Kusch and Oberschelp, 1967). In this experiment Stark widths were determinated by using spark discharge in tube with Cd(CH_3)$_2$ and Cd(C_2H_5)$_2$ for perturber density normalized at value of 10^{17}cm^{-3} and for temperature of 11100 K. Also, for the same multiplet there are theoretical results obtained within GBKO approach (Griem et al., 1962) by Dimitrijević and Konjević (1983). Both theoretical results are in disagreement with experimental results. In Konjević, Dimitrijević and Wiese (1984a) the selfabsortion is indicated as a possible reason for this.

One of the goals of our investigation is to investigate the regularity within a spectral series of Cd I 5s^2 ^{1}S - np ^{1}P^o and then obtain analytical expression which can be useful for estimation of new data. In Fig. 1 electron-impact full half widths - W in angular frequency units, for Cd I 5s^2 ^{1}S - np ^{1}P^o lines as a function of quantum number - n, for T=50000 K at N_e=10^{16} cm^{-3} are shown. We can see gradual change of Stark widths within 5s^2 ^{1}S - np ^{1}P^o spectral series. Such regular behaviour of Stark widths is the consequence of the gradual change of the energy separations between the initial (upper) level and the principal perturbing levels. This function $W(n)$ has been interpolated by third power polynomial (Simić et al., 2005b; Simić, 2004)

$$W(n) = an^3 + bn^2 + cn + d.$$

Here W is a full width at half maximum (FWHM) expressed in rad/s per electron, and constants are a=6.83417 10^{10}, b=-1.05083 10^{12}, c=5.15558 10^{12} and d=-9.83561 10^{12}. Polynomial function is represented by dotted line in Fig. 1. Using the previous expression, the Stark width is estimated for Cd I 5s^2 ^{1}S - 10p ^{1}P^o spectral line for which there is no enough atomic data and we obtained a value of W=8.564 10^{12} s^{-1} i.e. W=0.911 Å.

Stark widths for Cd I within $5s^2\ ^1S$ - np $^1P^o$ spectral series (Simić et al., 2005b; Simić, 2004) have been compared in Fig. 2 with Doppler widths for a model (T_{eff} = 10000 K, log g = 4) of A type star atmosphere (Kurucz's, 1979), close to the conditions for 68 Tauri (T_{eff}=9025 K, log g=3.95) where Stark broadening is of interest for the atmosphere modeling (Adelman, 1994ab). We note also that one of the lines (2288.7 Å) within the first member of this series, the multiplet $5s^2\ ^1S$ - 5p $^1P^o$, has an intensity of 1500 according to the NIST Atomic Spectra Database. Our results are presented as a function of Rosseland optical depth - log τ. As one can see, with an increase of the principal quantum number the importance of Stark broadening in comparison to the Doppler one increases as well. For lines with higher initial quantum number Stark broadening is more than one magnitude larger than Doppler mechanism. The Kurucz's model for the stellar atmosphere has been used for two other spectral lines, the first (7400.9 Å) in optical range and the second (59346.5 Å) in IC range (see Fig. 3.) In Fig. 4 we compared line widths for F III due to Stark and thermal Doppler broadening mechanisms as functions of optical depth corresponding to 10000-30000 K temperature range (Simić et al., 2005a; Simić 2004), for an A type star atmosphere model (T_{eff}=10000 K, log g=4). One should take into account that due to differences between Lorentz (Stark) and Gauss (Doppler) line intensity distributions, Stark broadening may be more important in line wings in comparison with the thermal Doppler one, even when it is smaller in the central part.

Our results show that Stark broadening data for neutral cadmium and doubly ionized fluorine lines are needed for an adequate description of stellar spectra and plasma modeling.

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

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