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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 $10^{20}\mathrm{cm}^{-3}$ 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

$$W = \frac{\lambda^2}{\pi c} N \int v f(v) dv \left(\sum_{i' \neq i} \sigma_{ii'}(v) + \sum_{f' \neq f} \sigma_{ff'}(v) + \sigma_{el} + W_R \right), \tag{1}$$

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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