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ON THE STARK BROADENING OF THE FOUR TIMES IONIZED SILICON SPECTRAL LINES

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Abstract. Using a semiclassical perturbation approach, we have compared Stark broadening parameters for 16 Si V multiplets calculated with oscillator strengths obtained with the SUPERSTRUCTURE code and within the Coulomb approximation. In order to complete Stark broadening data for most important charged perturbers in stellar atmospheres, Stark broadening parameters for proton−, He II−, and Si II−impact line widths and shifts are presented also.

1. Introduction

The semiclassical - perturbation formalism (Sahal-Bréchot, 1969ab) has been used in a series of papers for large scale calculations of Stark broadening parameters for a number of spectral lines of various emitters from neutrals up to twelve time charged ions (see e.g. Dimitrijević, 1997 and references therein). The results of such calculations are of interest for a number of different problems in physics, astrophysics and plasma technology. Results for four-times charged ions, are of interest for the consideration of radiative transfer through subphotospheric layers (Seaton, 1988), for modelling of some hot stars atmospheres as e.g. PG 1159 pre-white dwarfs with effective temperature 100 000 - 140 000 K (Werner and Heber, 1991), as well as for the fusion plasmas and laser-produced plasmas research. 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 (see e.g. Fill and Schöning, 1994 and, Griem and Moreno, 1980), excited an additional interest for such results.

With the development of space-borne spectroscopy, with the possibility to obtain high resolution spectra in a wide weavelength range including X-rays, not detectable

from the Earth's surface, the interest for such results is increasing. For example an analysis of X-ray spectrum of some stars obtained with the high resolution space observatory CHANDRA show spectra which can be rich in emission lines in the soft X-ray region, including Si V lines.

The aim of this contribution is twofold. First of all we want to perform parallel determination of Si V Stark broadening parameters, by using oscillator strengths obtained by using SUPERSTRUCTURE code and the method of Bates and Damgaard (1949, see also Oertel and Shomo, 1968), in order to ascertain what error is introduced in the Stark broadening parameters due to uncerntainties of oscillator strength values and due to the use of Coulomb approximation. Secondly, our aim is to provide new semiclassical Stark broadening data for Si V, whose spectrum is poorly known and it is not possible to obtain a sufficiently complete set of experimental atomic energy levels needed for adequate semiclassical perturbation calculations.

2. RESULTS AND DISCUSSION

The energy levels of SiV are calculated using the general purpose atomic structure code SUPERSTRUCTURE developed at the University College in London and described in Eissner et al. (1974). All details of the calculation procedure of atomic energy levels will be given in Ben Nessib et al. (2003). By using atomic energy levels obtained by SUPERSTRUCTURE code, we have calculated also oscillator strengths with the help of the Coulomb approximation of Bates and Damgaard (1949, see also Oertel and Shomo, 1968).

Stark broadening parameter calculations have been performed within the semiclassical perturbation method (Sahal-Bréchot, 1969ab). A detailed description of this formalism with all inovations and optimizations is given in Sahal-Bréchot (1969ab), Fleurier et al (1974), Dimitrijević and Sahal-Bréchot (1996) and Dimitrijević (1996), and all details of calculation of Stark broadening parameters will be given in Ben Nessib et al. (2003).

The results for 16 Si V multiplets, for electron-impact broadening widths (FWHM - full width at half maximum) and shifts calculated with atomic energy levels obtained using the SUPERSTRUCTURE Code (using the Thomas Fermi potential model) and with oscillator strengths obtained using for the same code and with the Bates and Damgaard method (using the Coulomb approximation) will be published in Ben Nessib et al. (2003). As an example of obtained results, data for 5 multiplets are shown here in Table 1 for a perturber density of $10^{17}\mathrm{cm}^{-3}$ and temperatures from 50,000 up to 500,000 K. Such temperature interval is of interest for modelling and analysis of X wavelength range spectra as spectra obtained by CHANDRA, modelling of some hot stars (e.g. PG 1195 type) atmospheres, subphotospheric layers, soft X ray lasers and laser produced plasma research. Higher temperatures are of interest for fusion plasma research as well as for stellar interiors considerations. We also specify a parameter C (Dimitrijević and 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. For each value given in Table 1 the collision volume (V) multiplied by the perturber density (N) is much less than one and the impact approximation is valid (Sahal-Bréchot, 1969ab).

If we compare results for Stark widths obtained with oscillator strengths calculated with SUPERSTRUCTURE (W_S) and by using Bates and Damgaard Coulomb

Table 1: Electron-impact broadening line widths (FWHM - full width at half maximum) and shifts for Si V calculated with atomic energy levels obtained with SUPERSTRUCTURE code and with oscillator strengths obtained with SUPERSTRUCTURE code (W_S and S_S) and with the Coulomb approximation of Bates and Damgaard (1949)(W_{BD} and S_{BD}). The results bear on perturber densities of 10^{17}cm^{-3} and temperatures from 50,000 up to 500,000 K. Transitions and averaged wavelengths for the multiplet (in $\AA$) are also given. By dividing C by the corresponding full width at half maximum (Dimitrijević and Sahal-Bréchot 1984), 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)	$W_S(A)$	$S_S(A)$	$W_{BD}(A)$	$S_{BD}(A)$
Si V 2P-3S	50000.	0.257E-04	0.543E-06	0.309E-04	0.228E-06
120.4 A	100000.	0.181E-04	0.137E-05	0.211E-04	0.164E-05
C= 0.11E+19	150000.	0.149E-04	0.144E-05	0.172E-04	0.181E-05
	200000.	0.132E-04	0.153E-05	0.153E-04	0.191E-05
	300000.	0.112E-04	0.168E-05	0.130E-04	0.210E-05
	500000.	0.930E-05	0.166E-05	0.108E-04	0.206E-05
Si V 2P-3D	50000.	0.384E-04	-0.244E-06	0.425E-04	-0.709E-06
98.3 A	100000.	0.275E-04	0.253E-06	0.302E-04	0.184E-06
C= 0.54E+18	150000.	0.228E-04	0.367E-06	0.251E-04	0.394E-06
	200000.	0.201E-04	0.268E-06	0.222E-04	0.252E-06
	300000.	0.170E-04	0.323E-06	0.188E-04	0.312E-06
	500000.	0.141E-04	0.425E-06	0.157E-04	0.446E-06
Si V 3S-3P	50000.	0.847E-02	-0.779E-04	0.926E-02	-0.945E-04
1308.0 A	100000.	0.605E-02	-0.107E-03	0.662E-02	-0.132E-03
C= 0.13E+21	150000.	0.503E-02	-0.961E-04	0.551E-02	-0.117E-03
	200000.	0.444E-02	-0.111E-03	0.487E-02	-0.135E-03
	300000.	0.377E-02	-0.120E-03	0.416E-02	-0.146E-03
	500000.	0.313E-02	-0.109E-03	0.347E-02	-0.132E-03
Si V 3S-3P	50000.	0.855E-02	-0.366E-04	0.962E-02	-0.976E-04
1333.2 A	100000.	0.611E-02	-0.546E-04	0.688E-02	-0.137E-03
C= 0.13E+21	150000.	0.507E-02	-0.480E-04	0.572E-02	-0.124E-03
	200000.	0.447E-02	-0.582E-04	0.507E-02	-0.142E-03
	300000.	0.379E-02	-0.593E-04	0.432E-02	-0.152E-03
	500000.	0.314E-02	-0.509E-04	0.361E-02	-0.139E-03
Si V 3S-3P	50000.	0.409E-02	-0.608E-04	0.368E-02	0.116E-04
759.7 A	100000.	0.294E-02	-0.841E-04	0.266E-02	-0.439E-05
C= 0.32E+20	150000.	0.246E-02	-0.763E-04	0.223E-02	0.319E-05
	200000.	0.218E-02	-0.782E-04	0.198E-02	0.936E-05
	300000.	0.186E-02	-0.889E-04	0.170E-02	0.486E-05
	500000.	0.155E-02	-0.888E-04	0.143E-02	0.359E-06

approximation (W_{BD}), the average ratio of W_{BD} and W_S is 1.09 for T = 50 000 K and 1.10 for 500 000 K, confirming the adequacy of Coulomb approximation for Stark broadening calculations in the case of ions as Si V. For shifts disagreements are larger but one should have in view that shifts obtained here are typically 2-3 orders of magnitude smaller than widths. Namely, unlike widths where all important contributions are with a positive sign, for shifts we have in the present case cancellations of important contributions with different signs so that the final accuracy, usually estimated at 20-30 per cent of the width value, is in present case bad.

In conclusion, we see that using the SUPERSTRUCTURE code, one obtains simultaneously a set of energy levels and oscillators strengths, enabling an *ab initio* calculation of Stark broadening parameters. It is suitable particularly for multicharged ions when other theoretical and experimental atomic data are scarse. This work also verifies the use of the Coulomb approximation for oscillator strengths calculations in the Stark broadening calculations for multicharged ions like Si V.

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