VAMDC FP7 project and STARK-B database: C II Stark broadening parameters for white dwarf atmospheres research

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Abstract. Stark broadening parameters of C II lines were determined within 3s-np spectral series within the semiclassical perturbation method. The atomic energy levels needed for calculations were taken from TOPBASE as well as the oscillator strengths, calculated additionally using the Coulomb approximation (the method of Bates and Damgaard). The both results were compared and the disagreement is found only in one case where the configuration mixing allows a forbidden transition to a close perturbing energy level. Calculations were performed for plasma conditions relevant for atmospheres of DQ white dwarfs and for a new type of white dwarfs, with surface composed mostly of carbon, discovered in 2007 by Dufour et al. The aim of this work is to provide accurate C II Stark broadening data, which are crucial for this type of white dwarf atmosphere modellisation. Obtained results will be included in STARK-B database (http://stark-b.obspm.fr/), entering in the FP7 project of European Virtual Atomic and Molecular Data Center VAMDC aiming at building an interoperable e-Infrastructure for the exchange of atomic and molecular data (http://www.vamdc.org/).

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INTRODUCTION

The dominant pressure broadening mechanism in white dwarfs atmospheres is Stark broadening (see e.g. [1, 2, 3, 4]) and data on spectral line Stark broadening parameters are important for modelling of plasma of such stars. Carbon lines are present in spectra of DQ white dwarfs but in hotter DQ stars C II spectral lines are also observed. For example Thejll et al. [5] for the modelling of the spectrum of the carbon rich DQ white dwarf G35-26 (Gr 469, WD 0203+207), used data on the Stark broadening of C II lines.

A new type of white dwarfs has recently been discovered by Dufour et al. [6]. The surface composition of these stars is mostly composed of carbon. There is hardly neither hydrogen nor helium in the atmosphere. In order to understand the origin and evolution of this new type of stars, the determination of gravity is essential, and it is necessary to develop a new generation of accurate models. In fact, the inclusion of accurate spectral

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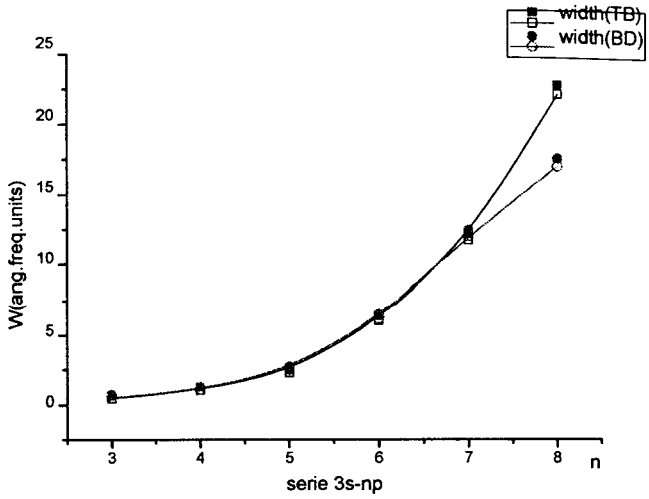

FIGURE 1. Electron-impact full half-widths (in angular frequency units) for C II $3s - np$ lines as a function of n for $T = 10000$ K. The electron density is 10^{14} cm^{-3}. For the calculation of width (TB) needed energies and oscillator strengths were taken from TOPBASE, while the width denoted as BD were calculated using TOPBASE only for energy levels and Oscillator strengths were calculated by using the method of Bates and Damgaard

line broadening is crucial for this type of white dwarf atmosphere modellisation. At these temperatures and pressures of interest (effective temperatures within 19,000-23,000K, electron density within 10^{15}cm^{-3}-10^{18}cm^{-3}), the dominant ion is C II. There is a contribution of C III for the most profound layers or for very hot models but it can be neglected. The predominant cause of broadening of CII lines is Stark broadening, i.e. broadening by electron impact and ion interactions.

In the present work, we calculate the full Stark width at half maximum FWHM and the shift of C II spectral lines due to collisions with electrons and C II ions using the semiclassical perturbation formalism

RESULTS AND DISCUSSION

We have obtained ab initio Stark broadening parameters for 148 C II multiplets within the semiclassical perturbation method [7, 8]. Energy levels and oscillator strengths are taken from the TOPBASE. Results are obtained as a function of temperature. In addition to electron-impact full halfwidths and shifts, Stark broadening parameters due to singly ionized carbon-impacts have been calculated. Thus, we have provided Stark broadening data for all the important charged perturbers in carbon dominated atmospheres of the new type of white dwarfs.

Obtained results will be included in STARK-B database containing Stark broadening parameters obtained theoretically within the semiclassical perturbation approach (http://stark-b.obspm.fr/). entering in the FP7 project of European Virtual Atomic and Molecular Data Center VAMDC aiming at building an interoperable e-Infrastructure for the exchange of atomic and molecular data (http://www.vamdc.org/).

TABLE 1. C II Stark full widths at half intensity maximum (W) and shifts (d) due to electron- (e) and C II-impacts for 3s-np series for an electronic density of $N_e = 10^{14}$ cm^{-3}. In the first column, we give transitions, wavelengths in Å and C values which give an estimate for the maximum perturber density for which the line may be treated as isolated if it is divided by the corresponding full width.

Transition	T [K]	W_e [Å]	d_e [Å]	W_{CII} [Å]	d_{CII} [Å]
$2s^2$ 3p - $2s^2$ 3s	5000.	0.143E-02	-0.281E-04	0.605E-04	-0.648E-05
	10000.	0.106E-02	-0.334E-04	0.814E-04	-0.105E-04
6741.6 Å	20000.	0.848E-03	-0.287E-04	0.924E-04	-0.146E-04
C= 0.63E+18	30000.	0.791E-03	-0.310E-04	0.989E-04	-0.167E-04
	50000.	0.753E-03	-0.348E-04	0.106E-03	-0.191E-04
	80000.	0.729E-03	-0.308E-04	0.109E-03	-0.214E-04
$2s^2$ 4p - $2s^2$ 3s	5000.	0.330E-03	0.657E-04	0.353E-04	0.664E-05
	10000.	0.261E-03	0.451E-04	0.400E-04	0.883E-05
2195.0 Å	20000.	0.234E-03	0.351E-04	0.443E-04	0.106E-04
C= 0.26E+17	30000.	0.230E-03	0.332E-04	0.456E-04	0.117E-04
	50000.	0.230E-03	0.272E-04	0.471E-04	0.132E-04
	80000.	0.232E-03	0.232E-04	0.474E-04	0.143E-04
$2s^2$ 5p - $2s^2$ 3s	5000.	0.410E-03	0.133E-03	0.663E-04	0.143E-04
	10000.	0.349E-03	0.100E-03	0.735E-04	0.171E-04
1700.8 Å	20000.	0.334E-03	0.804E-04	0.772E-04	0.203E-04
C= 0.72E+16	30000.	0.336E-03	0.704E-04	0.778E-04	0.224E-04
	50000.	0.344E-03	0.577E-04	0.804E-04	0.244E-04
	80000.	0.347E-03	0.497E-04	0.801E-04	0.260E-04
$2s^2$ 6p - $2s^2$ 3s	5000.	0.795E-03	0.424E-03	0.144E-03	0.613E-04
	10000.	0.738E-03	0.355E-03	0.153E-03	0.722E-04
1515.9 Å	20000.	0.734E-03	0.297E-03	0.168E-03	0.831E-04
C= 0.17E+16	30000.	0.763E-03	0.258E-03	0.168E-03	0.890E-04
	50000.	0.796E-03	0.217E-03	0.183E-03	0.101E-03
	80000.	0.810E-03	0.181E-03	0.170E-03	0.108E-03
$2s^2$ 7p - $2s^2$ 3s	5000.	0.133E-02	0.726E-03	0.256E-03	0.117E-03
	10000.	0.128E-02	0.642E-03	0.276E-03	0.136E-03
1434.9 Å	20000.	0.134E-02	0.509E-03	0.292E-03	0.153E-03
C= 0.13E+16	30000.	0.140E-02	0.452E-03	0.291E-03	0.166E-03
	50000.	0.146E-02	0.371E-03	0.292E-03	0.185E-03
	80000.	0.149E-02	0.304E-03	0.298E-03	0.186E-03
$2s^2$ 8p - $2s^2$ 3s	5000.	0.222E-02	-0.924E-08	0.414E-03	-0.161E-03
	10000.	0.226E-02	0.710E-04	0.447E-03	-0.186E-03
1387.1 Å	20000.	0.239E-02	0.843E-04	0.460E-03	-0.208E-03
C= 0.30E+15	30000.	0.249E-02	0.917E-04	0.471E-03	-0.222E-03
	50000.	0.259E-02	0.943E-04	0.499E-03	-0.242E-03
	80000.	0.262E-02	0.740E-04	0.513E-03	-0.289E-03

All details of calculations, the complete set of results, analysis and the comparison with existing experimental and other theoretical data will be given elsewhere [9]. As one example of obtained results we used C II Stark broadening parameters within 3s-np spectral series to demonstrate regular behavior of Stark widths within this spectral series and to check the agreement of data obtained using the set of oscillator strengths from TOPBASE and obtained within Bates and Damgaard approximation. In order to see the applicability of the method of Bates and Damgaard for the calculation of C II Stark widths, in Fig. 1 are compared within 3s-np series Stark widths obtained with oscillator strengths taken from TOPBASE (http://cdsweb.u-strasbg.fr/topbase/topbase.html) with those with oscillator strengths calculated using the method of Bates and Damgaard. One can see that the difference exists only for 3s-8p transition. We found that this difference is caused by the doubly excited energy level $2s2p(3P^o)3p$ which is close to the $2s^28p$ level and the configuration mixing allows the transition between. Within the Bates and Damgaard approximation this transition is forbidden and the corresponding oscillator strength value is zero and we used the value of 0.1625. For other energy levels in this spectral series such irregularity is not present and the agreement is very good.

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