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# STARK BROADENING PARAMETERS FOR WHITE DWARF ATMOSPHERES RESEARCH

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**Abstract.** Stark broadening parameters of C II lines were determined within 3d-nf series using semiclassical perturbation method. The atomic energy levels needed for calculations were taken from TOPBASE as well as the oscillator strengths, which were additionally calculated using the method of Bates and Damgaard. The both results were compared and only insignificant differences were found. 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/).

## 1. INTRODUCTION

Stark broadening is dominant pressure broadening mechanism in white dwarf atmospheres and it was found that for such stars it is dominant in practically all relevant atmospheric layers (see e.g. Simić et al. 2009, Popović et al. 1999, Tankosić et al. 2003, Hamdi et al. 2008). Consequently, data on spectral line widths broadened by this mechanism are in particular important for analysis, synthesis and interpretation of white dwarf spectra, for radiative transfer considerations, abundance determination, and for the investigation, diagnostics and modelling of plasma of such stars.

If traces of carbon, either as neutral carbon lines or molecular $C_2$ Swan bands are present in white dwarf spectra, they are collectively known as DQ stars. In hotter DQ stars C II spectral lines are also present. For example Thejll et al. (1990) 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. (2007, 2008). 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 line broadening is crucial for this type of white dwarf atmosphere modellisation. At these temperatures and pressures of interest (effective temperatures within 19,000-23,000 K, 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

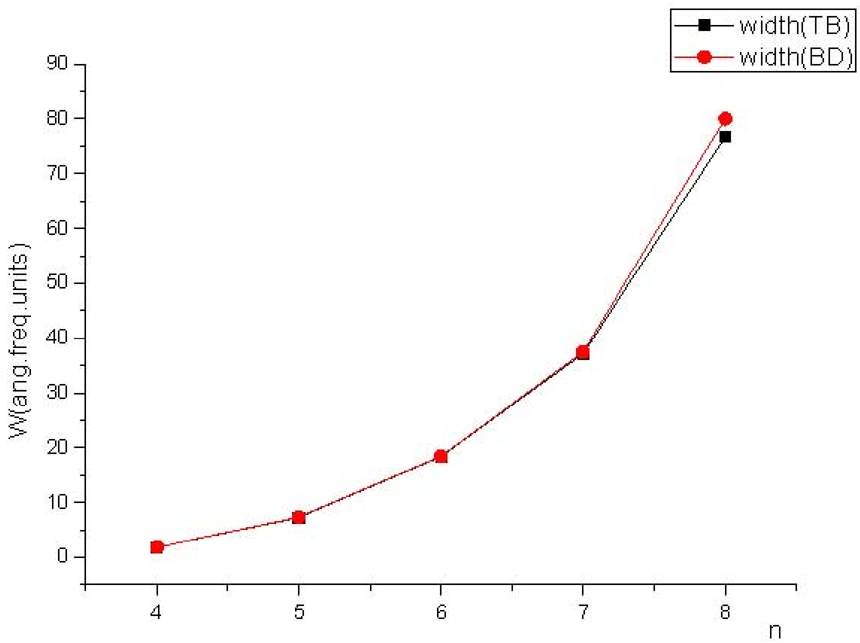


**Figure 1:** Electron-impact full half-widths (in angular frequency units) for C II 3d-nf lines as a function of n for T = 10000 K. The electron density is $10^{14}$ cm$^{-3}$. For the calculation of widths denoted as TB needed energies and oscillator strengths were taken from TOPBASE. The widths denoted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

**Table 1.** C II Stark widths and shifts for 3d-nf series for an electronic density of $N_e$=$10^{14}$ $cm^{-3}$. In the first column, we give transitions, wavelengths for the transitions in Å and C values which, when divided with W, give an estimate for the maximum perturber density for which the line may be treated as isolated. Asterisks denote cases where the impact approximation is not valid.

| Transition | T[K] | $W_e$[Å] | $d_e$ [Å] | $W_{C\ II}$ [Å] | $d_{C\ II}$ [Å] |
|---|---|---|---|---|---|
| 2s2 4f-2s2 3d | 5000. | 0.220E-02 | -0.434E-04 | 0.138E-03 | -0.103E-03 |
| | 10000. | 0.175E-02 | -0.212E-04 | 0.168E-03 | -0.123E-03 |
| 4299.9 Å | 20000. | 0.142E-02 | -0.121E-04 | 0.192E-03 | -0.144E-03 |
| C= 0.15E+17 | 30000. | 0.130E-02 | -0.108E-04 | 0.209E-03 | -0.154E-03 |
| | 50000. | 0.119E-02 | -0.122E-04 | 0.236E-03 | -0.178E-03 |
| | 80000. | 0.110E-02 | -0.649E-05 | 0.241E-03 | -0.184E-03 |
| 2s2 5f-2s2 3d | 5000. | 0.386E-02 | 0.151E-03 | 0.366E-03 | 0.325E-03 |
| | 10000. | 0.349E-02 | 0.194E-03 | 0.463E-03 | 0.381E-03 |
| 3009.9 Å | 20000. | 0.316E-02 | 0.138E-03 | 0.491E-03 | 0.419E-03 |
| C= 0.10E+16 | 30000. | 0.296E-02 | 0.112E-03 | 0.563E-03 | 0.464E-03 |
| | 50000. | 0.273E-02 | 0.110E-03 | 0.670E-03 | 0.497E-03 |
| | 80000. | 0.251E-02 | 0.960E-04 | 0.775E-03 | 0.563E-03 |
| 2s2 6f-2s2 3d | 5000. | 0.693E-02 | 0.532E-03 | 0.962E-03 | 0.804E-03 |
| | 10000. | 0.651E-02 | 0.502E-03 | 0.108E-02 | 0.942E-03 |
| 2588.1 Å | 20000. | 0.605E-02 | 0.350E-03 | 0.123E-02 | 0.114E-02 |
| C= 0.46E+15 | 30000. | 0.574E-02 | 0.314E-03 | 0.128E-02 | 0.114E-02 |
| | 50000. | 0.530E-02 | 0.285E-03 | 0.139E-02 | 0.116E-02 |
| | 80000. | 0.487E-02 | 0.202E-03 | 0.171E-02 | 0.145E-02 |
| 2s2 7f-2s2 3d | 5000. | 0.118E-01 | 0.146E-02* | 0.205E-02* | 0.178E-02 |
| | 10000. | 0.112E-01 | 0.116E-02* | 0.239E-02* | 0.196E-02 |
| 2386.5 Å | 20000. | 0.104E-01 | 0.868E-03 | 0.252E-02 | 0.243E-02 |
| C= 0.25E+15 | 30000. | 0.990E-02 | 0.771E-03 | 0.259E-02 | 0.228E-02 |
| | 50000. | 0.919E-02 | 0.612E-03 | 0.338E-02 | 0.274E-02 |
| | 80000. | 0.846E-02 | 0.420E-03 | 0.330E-02 | 0.285E-02 |
| 2s2 8f-2s2 3d | 5000. | 0.221E-01 | 0.922E-02 | * | * |
| | 10000. | 0.210E-01 | 0.720E-02 | * | * |
| 2271.8 Å | 20000. | 0.195E-01 | 0.547E-02* | 0.593E-02 | 0.553E-02 |
| C= 0.16E+15 | 30000. | 0.183E-01 | 0.465E-02* | 0.779E-02 | 0.595E-02 |
| | 50000. | 0.168E-01 | 0.362E-02* | 0.678E-02 | 0.623E-02 |
| | 80000. | 0.153E-01 | 0.278E-02* | 0.913E-02 | 0.555E-02 |

predominant cause of broadening of CII lines is Stark broadening, i.e. broadening by electron-impact and ion interactions.

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.

## 2. RESULTS AND DISCUSSION

Using semiclassical perturbation approach (Sahal-Bréchot, 1969ab), we have obtained ab initio Stark broadening parameters for 148 C II multiplets. All details of the calculations as well as analysis of obtained results and comparison with existing experimental and theoretical results will be given in Larbi-Terzi et al. (2010). As an example of obtained results, here are given C II Stark widths (FWHM) and shifts for 3d-nf series for an electronic density of $N_e=10^{14}$ cm$^{-3}$. 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 3d-nf 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 differences are insignificant.

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/).

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