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Stark broadening of spectral lines of multicharged ions of astrophysical interest

XX. O VII and Mg XI spectral lines*

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Abstract. Using a semiclassical perturbation approach, we have calculated electron−, proton−, and He III−impact line widths and shifts for 14 O VII and 18 Mg XI multiplets. For O VII, perturber densities are 10^{17}− 10^{23} cm^{-3} and temperatures $T = 100000 - 2000000$ K. For Mg XI, perturber densities are 10^{18}− 10^{24} cm^{-3} and temperatures $T = 500000 - 5000000$ K. For lower perturber densities, the Stark broadening parameters are proportional to the perturber density.

Key words: line: profiles-atomic data — plasmas

1. Introduction

The investigation of the influence of impacts with charged particles (Stark broadening) on spectral line shapes of oxygen and magnesium in various ionization stages is of importance for a number of problems in astrophysics, physics and technology. For example, Stark broadening parameters for such ions are needed for the modeling and theoretical considerations of subphotospheric layers (Seaton 1987), for stellar abundance determinations, opacity calculations, diagnostic of laser produced, fusion and laboratory plasmas. Data on O VII spectral lines are of interest for the interpretation and modelling of some hot star spectra as PG1159 type stars (Werner et al. 1991). The additional interest for such data is due to 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. Griem & Moreno 1990; Fill & Schöning 1994).

This paper is the twentieth of a series devoted to the research of Stark broadening parameters of spectral lines of multicharged ions (see Dimitrijević & Sahal-Bréchot 1995 and references therein, as well as Dimitrijević & Sahal-Bréchot 1996a,b, 1997, 1998a-d). Within the frame of our project (see e.g. Dimitrijević 1996) to obtain as large as possible set of reliable semiclassical Stark broadening data needed for the investigation, diagnostics and modeling of various plasmas in stellar and solar physics, laboratory, laser physics, fusion research, and various devices, we have calculated within the semiclassical-perturbation formalism (Sahal-Bréchot 1969a,b), electron-, proton-, and He III-impact line widths and shifts for 14 O VII and 18 Mg XI multiplets.

2. Results and discussion

For the consideration of the influence of charged particle-impacts on spectral lines (Stark broadening), the semiclassical perturbation formalism has been used, which, as well as the corresponding computer code (Sahal-Bréchot 1969a,b), have been updated and improved several times (Sahal-Bréchot 1974; Fleurier et al. 1977, Dimitrijević & Sahal-Bréchot 1984; Dimitrijević et al. 1991; Dimitrijević & Sahal-Bréchot 1996b). Short reviews of the method of calculations, with the discussion of improvements and validity criteria, have been published several times as e.g. in Dimitrijević & Sahal-Bréchot (1996c) and Dimitrijević (1996). The atomic energy levels needed for calculations, have been taken from Isler et al. (1993) for O VII, and from Martin & Zalubas (1980) for Mg XI. The oscillator strengths have been calculated within the Coulomb approximation (Bates & Damgaard 1949, and the tables of

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* Tables 1 and 2 are only available in electronic form at the CDS via anonymous ftp (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

Oertel & Shomo 1968). For higher levels, the method of Van Regemorter et al. (1979) has been used.

Our results for electron−, proton−, and He III−impact line widths and shifts for 14 O VII and 18 Mg XI multiplets are shown in Tables 1 and 2 (accessible only in electronic form), for perturber densities $10^{17} - 10^{23}$ cm^{-3} and temperatures $T = 100000 - 2000000$ K for O VII and for perturber densities $10^{18} - 10^{24}$ cm^{-3} and temperatures $T = 500000 - 5000000$ K for Mg XI. The complete set of data is given for the perturber density of 10^{19}cm^{-3} in both cases, while for lower densities, only data needed for better interpolation are given. Stark broadening parameters for densities lower than tabulated, or for transitions not tabulated for perturber densities lower than 10^{19} cm^{-3}, are proportional to the perturber density. Moreover, we present in Tables 1 and 2 as well, a parameter c (Dimitrijević & 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 Tables 1 and 2, the collision volume (V) multiplied by the perturber density (N) is much less than one and the impact approximation is valid (Sahal-Bréchot 1969a,b). Values for $NV > 0.5$ are not given and values for $0.1 < NV \leq 0.5$ are denoted by an asterisk. When the impact approximation is not valid, the ion broadening contribution may be estimated by using the quasistatic approach (Sahal-Bréchot 1991 or Griem 1974). In the region between where neither of these two approximations is valid, a unified type theory should be used. For example in Barnard et al. (1974), a simple analytical formula for such a case is given. The accuracy of the results obtained decreases when broadening by ion interactions becomes important.

One may conclude from Tables 1 and 2, that for multicharged ion lines like O VII and Mg XI lines, ion broadening is not always a small correction to the linewidth, as it is e.g. for singly- and doubly-charged ions, but it is often comparable or even dominant for temperatures of the order of 1000000 K or larger. One should note as well that shifts due to He III- and proton-impacts become dominant in comparison to electron - impact ones.

The presented results may be useful for a number of problems in stellar and laboratory plasma research, modeling and diagnostic. They are also of interest for investigation and modeling of fusion and laser-produced plasmas, as well as for the investigation and modeling of soft X-ray lasers. Such results also have an interest for further development and refinements of the Stark broadening theory for multicharged ion line shapes and different theoretical considerations, particularly for the investigation of systematic trends of Stark broadening parameters along isoelectronic sequences.

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