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Calculations of the collisional widths of several Ar I spectral lines

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Abstract. The interactions between the emitter atoms and neutral atoms in the ground state in pure argon have been examined. The Van der Waals, Lennard-Jones and Kaulakys potentials have been used. The width calculations have been performed within the framework of the impact theory. Neutral argon spectral lines 522.1, 549.6, 603.2, 518.8, 591.2, 560.7, and 737.2 nm (nd → 4p, for n = 7 - 4); 641.6 nm (6s → 4p); and 696.5 nm (4p → 4s) were studied.

Key words. Atomic processes: Atomic processes:Collisional broadening - Stars: line profiles: Plasma: diagnostics - Discharges: surface waves

1. Introduction

The knowledge of the interatomic potential between an excited and a ground-state atom and the collisional broadening of spectral lines are useful mainly in astrophysics and plasma diagnostics. The shape of a spectral line emitted or absorbed by the plasma is a convenient test for theoretical models. The review of Allard & Kielkopf (1982) give a comprehensive insight into the developments in both theoretical and experimental aspects of these processes.

Several authors have reported measurements on argon (nd → 4p, for n = 7 - 4), (6s → 4p) and (4p → 4s) (Zagornaev & Khakhaev 1983; Wolnikowski et al. 1993; Moussounda & Ranson 1987). They used a simple long-range interaction potential (van der Waals) to interpret their results.

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Short-range interaction potential (Lennard-Jones) proposed by Hindmarsh & Farr (1972) has been applied in Wolnikowski et al. (1993), and Moussounda & Ranson (1987). Kaulakys potential (Kaulakys 1984) has been used in Wolnikowski et al. (1993). It was found that for the spectral line with small effective quantum number n* of the upper energy level of the corresponding transition the van der Waals potential is adequate. For higher n*, however, it fails as it leads to broadening and shifts values much different from the measured ones.

2. Theory

In this work the calculations of the collisional broadening using different potentials have been performed. The comparison of the obtained results has been carried out. A model for the long-range interaction between the excited atom and the atom in the ground state is van der Waals potential:

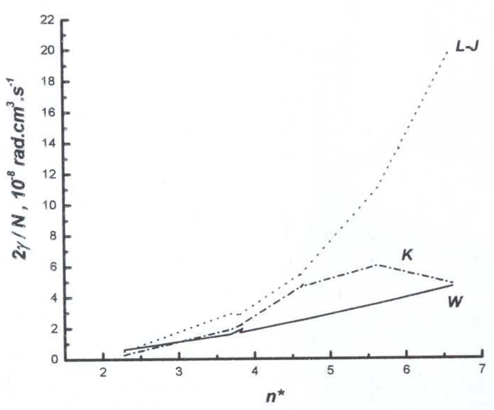

Fig. 1. Collisional broadening of Ar I lines at gas temperature of 2000 K and pressure of 1 atm as a function of the effective quantum number of the upper state (full line - Van der Waals potential, dotted line - Lennard-Jones potential and dash-dott line - Kaulakys potential).

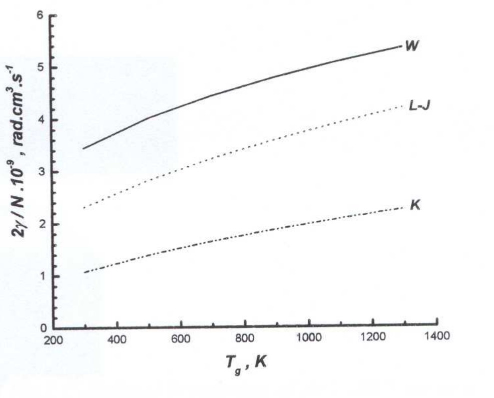

Fig. 2. Collisional broadening of Ar I 696,5 nm as a function of the gas temperature (full line - Van der Waals potential, dotted line - Lennard-Jones potential and dash-dott line - Kaulakys potential) at gas pressure of 50 Torr.

$$V(R) = -C_6 R^{-6}.$$

Lennard-Jones potential involve a short-range interaction too:

$$V(R) = C_{12} R^{-12} - C_6 R^{-6}.$$

For spectral lines including highly excited energy levels, i.e. those corresponding to large values of the principle quantum number, Kaulakys potential can be applied. The potential of the interaction between the Rydberg atom and the neutral atomic particle consist of the polarization attractions and the short-range interaction between the electron and perturber. The polarization attraction V_{pol} is:

$$V_{pol}(\boldsymbol{R}, \boldsymbol{r}) = -\frac{\alpha}{2R^4} + \alpha \frac{R^2 - (\boldsymbol{R} \cdot \boldsymbol{r})}{R^3 |\boldsymbol{R} - \boldsymbol{r}|^3} - \frac{\alpha}{2|\boldsymbol{R} - \boldsymbol{r}|^4},$$

$$|\boldsymbol{R} - \boldsymbol{r}| > r_0$$

where $\boldsymbol{R}$ and $\boldsymbol{r}$are the location of the perturber and the coordinate of the optical electron, respectively, r_0 is the distance of the short-range interaction between the electron and perturber, α is the polarizability. The first term in the equation is the polarization attraction between the perturber and the core of the Rydberg atom. The second term is the interaction between the Rydberg electron and dipole momentum of the perturber induced by the core of the Rydberg atom. The last term represents the electron-perturber polarization attraction. The short-range interaction between the electron and the perturber causes the electron-atom scattering and, for an atom with small polarizability is approximated by a Fermi pseudopotential:

$$V_e(\boldsymbol{r} - \boldsymbol{R}) = 2\pi L \delta(\boldsymbol{r} - \boldsymbol{R}),$$

where L is the scattering length.

3. Results

Results for the broadening of 9 argon lines as a function of the gas temperature, gas pressure and effective quantum number (Fig.1) have been obtained.

The calculations of the collisional width have been performed according our experimental conditions in the pressure range 0-200 Torr (Fig.2) (Christov et al. 1999; Christova et al. 2000) and at the atmospheric pressure (Christova & Calzada 2000; Christova et al. 2004).

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