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On the Stark Broadening of Visible Ar I Lines for Astrophysical Plasma Analysis and Modelling

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Abstract. Stark broadening parameters (width and shift) of Ar I 696.5 nm spectral line have been calculated within the semi-classical perturbation approach and presented here as a part of our investigation of Ar I 522.1, 549.6, 518.6, 603.2, 560.7 and 696.5 nm lines corresponding to the transitions $3p^5nd$ - $3p^54p$ for n = 7-5 and 4p' - 4s. The considered lines are in the optical part of the spectrum which is particularly interesting for astrophysics. Results obtained are compared with available experimental and theoretical data. The validity of impact approximation for ion perturbers is considered as well.

1 Introduction

With the development of space-born spectroscopy, the importance of atomic data, including the Stark broadening parameters, for trace elements like argon, increases. For example argon is found in CVn binary σ^2 Coronae Borealis [1], and "Chandra's" X-ray spectra of young supernovas 1998S and 2003bo revealed argon over-abundance [2]. Recently, argon lines are observed in the optical spectrum of the Be star Hen 2-90 [3], as well as in planetary nebulae and H II regions in the two dwarf irregular galaxies Sextans A and B [4]. Also argon abundance has been determined from spectral lines, *e.g.* for LSE 78, an extreme helium star [5], for the similar star BD-9^{o}4395 [6], for DY Cen [7] and γ Peg [8], as well as for the Sun [9]. Consequently, Stark line broadening parameters for neutral and ionized argon are of interest for the modelling and investigation of astrophysical plasmas. Particularly significant are lines within the optical spectral range and we will investigate here Stark broadening of just such lines of neutral argon.

The Stark broadening parameters (width and shift) of six Ar I spectral lines within the optical part of the spectrum: 522.1, 549.6, 518.6, 603.2, 560.7 and

696.5 nm corresponding to the transitions $3p^5nd$ - $3p^54p$ for n = 7-5 and 4p' - 4s have been calculated within the semi-classical perturbation approach [10, 11] (see also updates in [12]). The detailed results will be given elsewhere [13] together with the comparison of calculated and experimental data of other authors, as well as with detailed discussion of various limits of the applicability. We will present and analyze here, as an example, data for 696.5 nm Ar I spectral line.

2 Results and Discussions

The values of energy levels and oscillator strengths (j-L coupling), which enter in the expressions of the semi-classical cross-sections and the A parameter, have been taken from NIST database [14] for the Ar I 696.5 nm spectral line.

The calculations have been made for a grid of temperatures 2.5×10^4–5.0×10^4 K and for an electron density of 10^{14} cm^{-3}. In Figures 1 and 2 are compared our results for Ar I 696.5 nm with available theoretical and experimental results, divided in two groups according to the value of C_1, validity criterion of the impact approximation (impact criterion), introduced in [11].

The impact approximation is always valid for electron collisions for all temperatures at densities of interest because the corresponding values of C_1 are very small compared to unity. In Figure 1 are compared with theory experimental

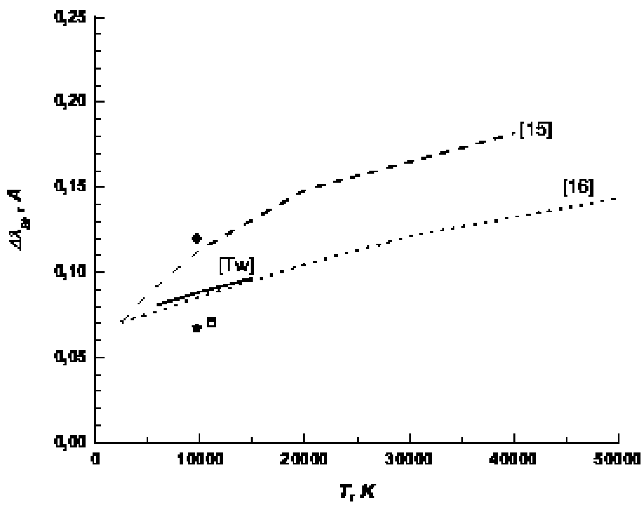

Figure 1. Stark full widths at half maximum of Ar 696.5 nm versus the temperature for the validity criterion of the impact approximation for ions $C_1 < 0.1$. Theoretical and experimental values are normalized to the electron density of 10^{16} cm^{-3}. In square brackets are reference numbers and Tw means this work. Experimental widths are: – filled circle [17]; – filled asterisk [18]; – half filled square [19].

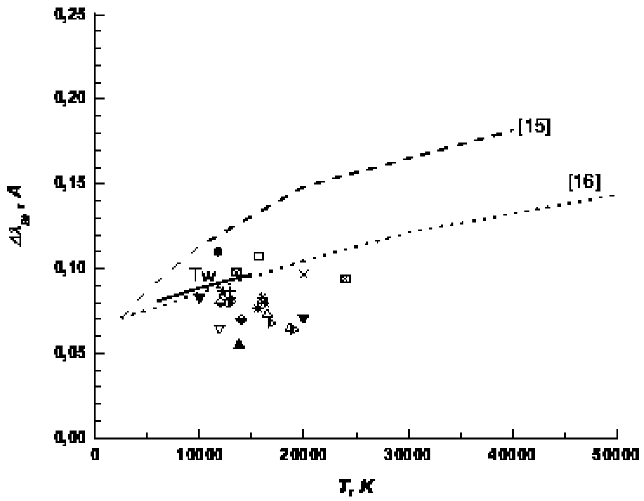

Figure 2. Stark full widths at half maximum of Ar 696.5 nm versus the temperature for the validity criterion of the impact approximation for ions $C_1 > 0.1$. Theoretical and experimental values are normalized to the electron density of 10^{16} cm^{-3}. In square brackets are reference numbers and Tw means this work. Experimental widths are: – full circle [17]; – inverse filled triangle [20]; - filled triangle [21]: – inverse empty triangle [22]; – empty square [23]; – empty triangle on inverse filled triangle [24]; – x [25]; – x within a square [26]; – empty asterisk, averaged value from [26]; – half filled triangle [27]; – filled asterisk [18]; – + [16]; – half filled circle [28]; – empty circle [29]; – empty triangle [30]; – eight rays star [31].

Stark widths where C_1 for ions is less than 0.1, *i.e.* where impact approximation for ions is valid, and in Figure 2 data where C_1 for ions is larger than 0.1. We can see that C_1 is larger than 0.1 for the majority of experimental data. In Figure 3, ratios of experimental widths and calculated ones here and in [16] by using semiclassical perturbation theory of Sahal-Bréchot, as well as the corresponding ratios of experimental widths and calculations in [15] according to Griem's theory versus the parameter C_1 for ion perturbers are presented. This figure illustrates the range of parameter C_1 values for 696.5 nm experimental data. One can see that the Griem's theory overestimates the experimental Stark widths in average. We note that the Ar I 696.5 nm line is one of the most used argon lines for the diagnostic purpose, it is well isolated, visible and intense. This line is suitable to measure the electron density over 1×10^{16} cm^{-3}. As one can see in Figure 3 experimental determinations of its Stark widths have often been performed at the conditions of the transitional range from impact to quasistatic approximation for the ions. Consequently, the theoretical study of Stark broadening within this range is of particular interest.

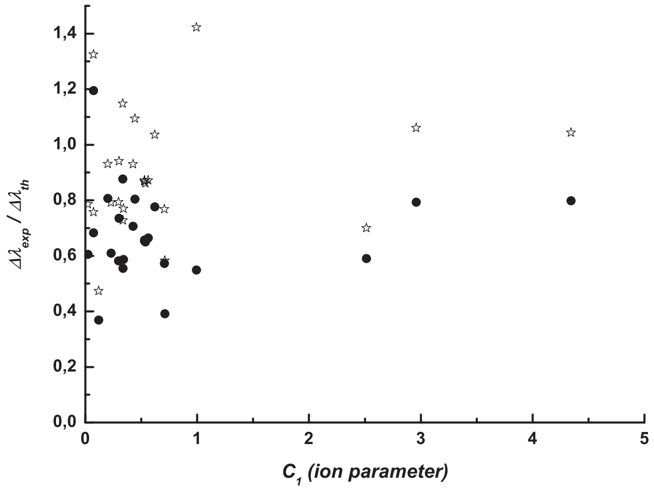

Figure 3. Ratio of experimental and theoretical (filled circles - according to Griem's theory [15], and asterisks – Sahal-Bréchot theory (this work and [16]) Stark widths for Ar I 696.5 nm versus the validity criterion of the impact approximation for ions (the impact approximation for ions is valid if the parameter C_1 is small compared to unity).

Acknowledgments

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