Stark widths of Ar III spectral lines in the atmospheres of subdwarf B stars

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Abstract
Using semiclassical perturbation approach in impact approximation, we have calculated Stark widths for 32 spectral lines of doubly charged argon (Ar III). Oscillator strengths are calculated using Hartree-Fock method with relativistic correction (HFR) and an atomic model including 17 configurations. Energy levels are taken from NIST database. For perturbing levels for which the corresponding energy does not exist in NIST database, the calculated energies are used. Our widths are compared with the experimental results. The results presented here are of interest for modelling and investigation of stellar atmospheres since argon in different ionization stages is observed in many astrophysical objects. Finally, the importance of Stark broadening mechanism is studied in the atmospheric conditions of sdB stars. Electron impact Stark widths are compared to thermal Doppler widths as a function of temperature and optical depth of atmospheric layers.

Keywords: atomic data; atomic processes; line: profiles; stars: atmospheres

1. Introduction
Stark broadening parameters (width and shift) are of interest for the study of astrophysical and laboratory plasma. Stark Broadening parameters can be used in the determination of temperature and density of laboratory plasma. For example, in Zhou et al. (2009), electron temperature and density are determined simultaneously in a cold argon arc-plasma jet by using Stark broadening of two different emission lines.

Stark broadening is important for modelling and investigation of stellar atmospheres of A and B stars (Popović et al., 2005). Dimitrijević et al. (2007) studied the Stark broadening on the line shapes of Cr II spectral lines observed in stellar atmospheres of middle part of the main sequence. They found that Stark broadening mechanism is very important and should be taken into account, especially in the study of Cr abundance stratification.

Besides main sequence stars, Stark broadening mechanism is important for white dwarfs. Hamdi et al. (2008) considered the broadening on Si VI lines in DO white dwarf spectra. They found that Stark broadening is dominant in broad regions of the considered DO atmospheres. For much cooler DB white dwarfs, Stark broadening is usually the dominant broadening mechanism (Dimitrijević et al., 2011; Simić et al., 2009).

Doubly charged Argon (Ar III) spectral lines are observed in many astrophysical plasmas. In Rodríguez (1999), Ar III lines are used in the determination of abundance in...
galactic H II regions. Blanchette et al. (2008), used Ar III λ 1002.097 Å line in the determination of abundance in hydrogen-rich subdwarf B stars. O’Toole & Heber (2006) obtained high-resolution ultraviolet spectra of five sdB stars using Space Telescope Imaging Spectrograph onboard the Hubble Space Telescope. Abundance of Ar III ion was determined in the studied sdB stars.

Stark widths measurement of Ar III spectral lines are reported in eight works: Platiša et al. (1975); Baker & Burgess (1979); Konjević & Pittman (1987); Purić et al. (1988); Kobilarov & Konjević (1990); Djeniže et al. (1996); Bukvić et al. (2008); Djurović et al. (2011). In Baker & Burgess (1979), Stark broadening parameters were determined in 870-890 Å wavelength interval. In all other works, Stark broadening parameters were determined in 2140-3960 Å wavelength interval.

In this work, we have calculated Stark widths for 32 Ar III spectral lines. We have used semiclassical perturbation approach in impact approximation (Sahal-Bréchot, 1969a,b). Energy levels are taken from NIST database (Ralchenko et al., 2011) and oscillator strengths are calculated using Cowan code (Cowan, 1981). Our Stark widths are compared with the experimental results of (Djurović et al., 2011; Bukvić et al., 2008; Djeniže et al., 1996; Kobilarov & Konjević, 1990; Konjević & Pittman, 1987; Platiša et al., 1975). Finally, the importance of collisions with electrons in atmospheric conditions of subdwarf B (sdB) stars is studied. Electron impact Stark widths are compared with thermal Doppler width as a function of optical depth and as a function of the temperature of atmospheric layers.

2. The impact semiclassical perturbation method

The impact semiclassical perturbation formalism is described in Sahal-Bréchot (1969a,b). The innovations to this formalism are given in Sahal-Bréchot (1974, 1991); Fleurier et al. (1977); Dimitrijević & Sahal-Bréchot (1996). For example in Sahal-Bréchot (1974) the expression of the quadrupole term for complex atoms was given. The profile $F(\omega)$ is Lorentzian for isolated lines:

$$ F(\omega) = \frac{w/\pi}{(\omega - \omega_{if} - d)^2 + w^2} $$

where

$$ \omega_{if} = \frac{E_i - E_f}{\hbar} $$

$i$ and $f$ denote the initial and final states and $E_i$ and $E_f$ their corresponding energies.

The total width at half maximum ($W = 2w$) and shift ($d$) (in angular frequency units) of an electron-impact broadened spectral line can be expressed as:

$$ W = N \int v f(v) dv \sum_{i' \neq i} \sigma_{ii'}(v) + \sum_{f' \neq f} \sigma_{ff'}(v) + \sigma_{el} $$

$$ d = N \int v f(v) dv \int_{R_3}^{R_D} 2\pi \rho d\rho \sin(2\varphi_p) $$

where $N$ is the electron density, $f(v)$ the Maxwellian velocity distribution function for electrons, $\rho$ denotes the impact parameter of the incoming electron, $i'$ (resp. $f'$) denotes the perturbing levels of the initial state $i$ (resp. final state $f$). The inelastic cross section $\sigma_{ii'}(v)$ (resp. $\sigma_{ff'}(v)$) can be expressed by an integral over the impact parameter $\rho$ of the transition probability $P_{ii'}(\rho, v)$ (resp. $P_{ff'}(\rho, v)$) as

$$ \sum_{i' \neq i} \sigma_{ii'}(v) = \frac{1}{2} \pi R_d^2 + \int_{R_3}^{R_D} 2\pi \rho d\rho \sum_{i' \neq i} P_{ii'}(\rho, v). $$

and the elastic contribution is given by

$$ \sigma_{el} = 2\pi R_d^2 + \int_{R_3}^{R_D} 2\pi \rho d\rho \sin^2 \delta + \sigma_r, $$

$$ \delta = (\varphi_p^2 + \varphi_q^2)^{\frac{1}{2}}. $$

The phase shifts $\varphi_p$ and $\varphi_q$ due respectively to the polarization potential ($r^{-4}$) and to the quadrupolar potential ($r^{-3}$), are given in Section 3 of Chapter 2 in Sahal-Bréchot (1969a) and $R_D$ is the Debye radius. All the cut-offs $R_1$, $R_2$ and $R_3$ are described in Section 1 of Chapter 3 in Sahal-Bréchot (1969a). $\sigma_r$ is the contribution of the Feshbach resonances (Fleurier et al., 1977).

The formulae for the ion-impact widths and shifts are analogous to Eqs. (2)-(4), without the Feshbach resonances contribution to the width. For electrons, hyperbolic paths due to the attractive Coulomb force are used, while for perturbing ions the hyperbolic paths are different since the force is repulsive.

Semiclassical perturbation calculations need a relatively large set of oscillator strengths. In this work, oscillator strengths are calculated with the Hartree-Fock relativistic approach using Cowan code (Cowan, 1981) and an atomic model including 17 configurations: $3s^23p^4$, $3s^23p^3nl (nl=4p, 4f, 5p, 5f, 6p, 6f)$ (even parity) and $3s^3p^3$, $3s^23p^3nl'$ ($nl'=3d, 4s, 4d, 5s, 5d, 6g, 6s, 6d, 6g$) (odd parity).

3. Semiclassical perturbation Stark widths and comparison with experiments

Djurović et al. (2011) reported Stark width measurements of 19 Ar III spectral lines. The plasma source was a low-pressure-pulsed arc. Electron densities of $(3.5 - 9.0) \times 10^{16} \text{ cm}^{-3}$ were determined by two-wavelength interferometry method and electron temperature of 16 000 - 24 000 K was measured with the help of the Boltzmann plot technique. All spectral lines for which Djurović et al. (2011) measured Stark parameters belong to the UV region of 2630 - 3960 Å. Authors report that the errors of the measured widths vary from 15% to 50%. In Bukvić et al. (2008), Stark widths measurements of 12 Ar III spectral lines are reported. The plasma source was a mixture of Ar
(72 %) and He (28 %) plasma created in the linear, low pressure, arc discharge. The electron temperature belonging to the interval (26 000 - 30 000 K) was estimated using Boltzmann plot technique. The electron density belonging to the interval (0.16 - 1.68) × 10^{17} cm^{-3} was determined using single laser interferometry technique at the wavelength 6328 Å of the He-Ne laser. According to Bukvić et al. (2008) the Stark widths were measured with 12 % error. Djeniże et al. (1996) reported Stark width measurements of 13 Ar III spectral lines at an electron density of 3.5 × 10^{17} cm^{-3} and electron temperature of 38 000 K. The plasma source was also an argon-helium mixture. Electron density was also measured using laser interferometry at 6328 Å. Electron temperature was measured using Boltzmann plot and ratios of Ar IV to Ar III lines and Ar III to Ar II lines. The uncertainty of the results given by Djeniže et al. (1996) vary from ± 14 % to ± 18 %. Kobilarov & Konjević (1990) gives electron impact widths for six Ar III spectral lines. A low-pressure pulsed arc was used as plasma source. Electron-density was measured using Stark width of He II Pashen-o 4848.7 Å line. Boltzmann plot of O III 3754.21, 3707.24, 3707.75 and 3455.12 Å lines was used for the determination of electron temperature. In Konjević & Pittman (1987), electron impact widths for 11 Ar III spectral lines were reported. Electron density was determined using a He-Ne laser quadrature interferometer operating at 6328 Å. The ratio of 4366.90 and 4369.28 Å O II impurity lines determined electron temperature. Konjević & Pittman (1987) estimated an error of ± 15 % for the widths. Platiša et al. (1975) reported Stark widths of five Ar III spectral lines. Electron density was determined using the same method as in Konjević & Pittman (1987) and electron temperature were determined from the Boltzmann plot of relative intensities of eight Ar II lines. Platiša et al. (1975) estimated that the error of the measured widths is ± 30 %.

In Table 1, we present our electron impact (W_e) and ion impact (W_i) Stark widths (FWHM) with the experimentally determined Stark width (W_{ex}) taken from Djurović et al. (2011); Bukvić et al. (2008); Djeniže et al. (1996); Kobilarov & Konjević (1990); Konjević & Pittman (1987); Platiša et al. (1975). Our Stark widths are calculated using semiclassical perturbation approach in impact approximation (Sahal-Bréchot, 1969a,b). Energy levels needed for this calculation are taken from NIST database (Ralchenko et al., 2011) and oscillator strengths are calculated using Cowan code (Cowan, 1981) and the atomic model previously described. For perturbing levels for which the corresponding energy do not exist in NIST database (Ralchenko et al., 2011), we have used the energies that we have calculated using Cowan code (Cowan, 1981). In NIST database we have found 125 energy levels and 497 classified electric dipole transitions. Among these transitions, only 68 are given with the corresponding oscillator strengths. This number of oscillator strengths is not sufficient to perform a semiclassical perturbation calculation of 32 Stark widths which need a large number of oscillator strengths. So the
use of Cowan code for the calculation of oscillator strengths is very interesting. In Hamdi et al. (2013) and Hamdi et al. (2011), we have used this method for Pb IV and we have determined Stark broadening parameters for 114 spectral lines. In our calculation, only electric dipole (E1) transitions are taken into account. All wavelengths given in Table 1 are taken from NIST database (Ralchenko et al., 2011). For each value given in Table 1, the collision volume (V) multiplied by perturber density (N) is much less than one and the impact approximation is valid. In some cases, 0.1 < N × V < 0.5 and the impact approximation reaches its limit of validity, these values are preceded by an asterisk. The greatest value of N × V, equal to 0.20 has been found for 4p′ 3D2 0 - 4p′ 3P2 transition for collisions with ions. For each transition given in Table 1, our semiclassical perturbation Stark width is \( W_{scl} = W_s + W_e \). Taking into account the plasma composition for each experiment, we have taken as ionic perturber singly ionized helium when we compared with Bukvić et al. (2008) and Djeniž et al. (1996), singly ionized argon when we compared with Djurović et al. (2011) and singly ionized nitrogen when we compared with Platiša et al. (1975). In Kobilarov & Konjević (1990); Konjević & Pittman (1987), electron impact widths were reported, for this reason broadening by collision with ions is not given when we compare with those two authors.

The agreement of our Stark widths with Djurović et al. (2011) values is 35% in average. All our values are greater than Djurović et al. (2011) ones. The lower value of ratio \( \frac{W_{me}}{W_{cal}} \) equal to 0.93 is found for the 3d′ 3D1 0 - 4p′ 3D1 transition. The largest differences between our values and experimental Stark widths of Djurović et al. (2011) are found for 4s' - 4p' transitions as for example for the 4s' 3D2 0 - 4p' 3P2 transition for which the ratio \( \frac{W_{me}}{W_{cal}} \) is equal to 0.67. We notice that this transition is classified by Djurović et al. (2011) as C (errors up to 50%). So, taken into account the accuracy of the experimental results, the agreement with Stark widths of Djurović et al. (2011) is acceptable for all transitions. Very good agreement is found with Bukvić et al. (2008) (8.6 % on average). The greatest difference (31%) between our Stark widths and Bukvić et al. (2008) ones is found for 4s′ 3P 1 0 - 4p′ 3D 2 transition. For the 3d′ 3P 1 0 - 4p′ 3P 1 transition the ratio \( \frac{W_{me}}{W_{cal}} \) is equal to 1. On average, our Stark widths agree with Djeniž et al. (1996) ones within 26%. Besides multiplets arising from 4s, 4p, 4s', 4p', 3d'', 4p'' parent energy levels, results for higher multiplets arising from 5s, 4d', 5s' are also given. An agreement better than 30% is found for these multiplets except for 4p' 3D 3 - 4d' 3P 2 transition, the difference between our calculated Stark width and the measured one is 46%. The agreement between our electron impact Stark widths and the values of Kobilarov & Konjević (1990) is within 35%. In Kobilarov & Konjević (1990), Stark widths are given for two experimental conditions: T = 80 000 K, Ne = 5.8 × 10^{17} cm\(^{-3}\) and T = 110 000 K, Ne = 1 × 10^{18} cm\(^{-3}\). Our results agree better with the experimental Stark widths given for T = 80 000 K and Ne = 5.8 × 10^{17} cm\(^{-3}\). All our Stark widths are greater than Kobilarov & Konjević (1990) ones. Our electron impact Stark widths agree with Konjević & Pittman (1987) ones within 40 %. All our results are greater than Konjević & Pittman (1987) ones. The greatest difference (76%) between our Stark widths and Konjević & Pittman (1987) values is found for the 4s′ 3D 1 0 - 4p′ 3D 3 (\( \lambda = 3480.50 \) Å) transition. In Platiša et al. (1975), measured Stark widths are given for two experimental conditions: T = 21 100 K, Ne = 0.44 × 10^{17} cm\(^{-3}\) and T = 23 080 K, Ne = 0.80 × 10^{17} cm\(^{-3}\). The agreement of our widths with the results of Platiša et al. (1975) is not good specially for T = 23 080 K and Ne = 0.80 × 10^{17} cm\(^{-3}\). For some lines we
found a factor greater than two between our Stark widths and Platiša et al. (1975) ones.

In Fig. 1, we present our electron impact Stark width as a function of electron temperature for the interval (20 000 - 120 000 K) along with experimental values of Djurović et al. (2011); Bukvić et al. (2008); Djeniža et al. (1996); Kobilarov & Konjević (1990); Konjević & Pittman (1987) and Platiša et al. (1975) for the transition 4$s^o$ $^3S_2^o$ - 4$p^o$ $^3P_2$ ($λ=3301.85$ Å). All experimental values are normalized to an electron density of $10^{17}$ cm$^{-3}$. This figure shows that our results over estimate all the experimental values. Fig. 2, Fig. 3 and Fig. 4, are the same as Fig. 1 but for the transitions: 4$s^o$ $^3P_2^o$ - 4$p^o$ $^5D_3$ ($λ=3023.98$ Å), 4$s^o$ $^3D_3^o$ - 4$p^o$ $^3F_4$ ($λ=3336.17$ Å) and 4$s^o$ $^3D_3^o$ - 4$p^o$ $^3D_3$ ($λ=3480.50$ Å) respectively. Fig. 2 shows also that our theoretical Stark widths overestimate the experimental values. We can see also that our width at $T = 30 000$ K is very close to Bukvić et al. (2008) value. In Fig. 3, we can see that our electron impact Stark width underestimate the experimental value of Bukvić et al. (2008) and overestimate all others results. The result of Djeniža et al. (1996) is the closest to our value. Fig. 4 shows that our widths overestimate the experimental values of Djurović et al. (1996); Konjević & Pittman (1987); Platiša et al. (1975) and that our width at $T = 30 000$ K is very close to Bukvić et al. (2008) one. Fig. 1, Fig. 3 and Fig. 4 show a large difference between our widths and Platiša et al. (1975) ones at $T = 23080$ K.

Our results as a function of temperature and electron density will be published elsewhere and will be inserted in the Stark-B database (Sahal-Bréchot et al., 2012), which is a part of Virtual Atomic and Molecular Data Center (Dubernet et al., 2010). Besides the study and investigation of stellar atmospheres, this database is also devoted to the study of laboratory and fusion plasma. For example, Ar III ion spectral lines are observed by Graf et al. (2011) in the spectrum of deuterium plasma in the Alcator C-Mod Tokamak.

4. Stark broadening effect in sdB stars atmospheres

Subdwarf B (sdB) stars are low-mass core helium burning stars with extremely thin hydrogen envelopes located on the extreme horizontal branch of the H-R diagram. The sdB stars have a high effective temperature (20 000 K ≤ $T_{eff}$ ≤ 40 000 K) and gravities (log $g$ ≃ 5 - 6) (see e.g. Ohl et al. (2000)). Ar III spectral lines are observed in subdwarf B star atmospheres (O'Toole & Heber, 2006; Blanchette et al., 2008).

In hot star atmospheres, besides electron-impact broadening (Stark broadening), the important broadening mechanism is the Doppler (thermal) one as well as the broadening due to the turbulence and stellar rotation. Other types of spectral line broadening, such as van der Waals, resonance and natural broadening, are usually negligible. For a Doppler-broadened spectral lines, the intensity distribution is not Lorentzian as for electron-impact broadening but Gaussian, and the full half-width of the spectral lines may be determined by the equation (see e.g. Konjević (1999))

$$W_D[Å] = 7.16 \times 10^{-7} λ[Å] \sqrt{T[K]} M_{Ar}$$

where atomic weight of argon is $M_{Ar} = 39.948$ au.

The importance of Stark broadening mechanism for the Ar III 4$p^o$ $^3P_2^o$ - 5$s^o$ $^3S_2^o$ ($λ = 2170.22$ Å) spectral line in atmospheric conditions of sdB stars is studied. We use the atmospheric models of Jeffery et al. (2001) (http://star.arm.ac.uk/ csj/models/Grid.html) which are plane-parallel line-blanketed model atmospheres for hot stars in local thermal, radiative and hydrostatic equilibrium. The considered atmospheres have the following composition: 0.001
Table 1: Our electron impact Stark widths (FWHM) ($W_e$) and ion impact Stark widths ($W_i$) calculated using SCP approach in impact approximation (Sahal-Bréchot et al., 1969a,b) compared with experimental values of Djurović et al. (2011); Bukvić et al. (2008); Djeniž et al. (1996) ($W_m$). Transitions, wavelengths, electron temperature ($T$) and electron density ($N_e$) are also given. Ref.: a: Djurović et al. (2011); b: Bukvić et al. (2008); c: Djeniž et al. (1996); d: Kobilarov & Konjević (1990); e: Konjević & Pittman (1987); f: Platiša et al. (1975).

| Transition | Term | $\lambda$ (Å) | $T$ (K) | $N_e$ ($10^{17}$ cm$^{-3}$) | $W_m$ (pm) | $W_e$ (pm) | $W_i$ (pm) | Ref. |
|------------|------|----------------|--------|---------------------------|------------|------------|------------|------|
| 4s - 4p    | $^5S_2 - ^3P_3$ | 3285.84 | 22000  | 3.50                      | 46.0       | 56.3       | 4.26       | c    |
|            |      |                |        | 21100                     | 6.4        | 9.13       | e          |      |
|            |      |                |        | 26000                     | 12.2       | 16.1       | e          |      |
|            |      |                |        | 21100                     | 6.4        | 9.13       | 0.49 f     |      |
|            |      |                |        | 23080                     | 8.2        | 15.9       | 0.92 f     |      |
|            | $^5S_0 - ^5P_0$ | 3301.85 | 22000  | 1.00                      | 14.8       | 20.5       | 1.22 a     |      |
| 4s' - 4p'  | $^3D_0 - ^3P_1$ | 2853.30 | 22000  | 1.00                      | 11.9       | 15.4       | 1.63 a     |      |
|            | $^3D_2 - ^3P_1$ | 2855.31 | 22000  | 1.00                      | 12.3       | 15.4       | 1.63 a     |      |
|            |      |                |        | 80000                     | 44.0       | 53.9       | d          |      |
|            |      |                |        | 110000                    | 62.0       | 84.9       | d          |      |
|            | $^3D_2 - ^3P_2$ | 2878.76 | 22000  | 1.00                      | 11.6       | 15.5       | 1.64 a     |      |
|            | $^3D_3 - ^3P_2$ | 2884.21 | 22000  | 1.00                      | 11.2       | 15.6       | 1.65 a     |      |
|            |      |                |        | 80000                     | 45.0       | 54.4       | d          |      |
|            |      |                |        | 110000                    | 66.0       | 85.7       | d          |      |
|            | $^3D_2 - ^3D_3$ | 3472.56 | 30000  | 1.47                      | 32.0       | 28.7       | 2.94 b     |      |
|            | $^3D_3 - ^3D_3$ | 3480.50 | 30000  | 1.47                      | 30.0       | 28.9       | 2.95 b     |      |
|            |      |                |        | 38000                     | 54.0       | 62.1       | 7.32 c     |      |
|            |      |                |        | 21100                     | 5.8        | 10.2       | e          |      |
|            |      |                |        | 21100                     | 5.8        | 10.2       | 0.88 f     |      |
|            |      |                |        | 23080                     | 8.1        | 17.7       | 1.63 f     |      |
|            | $^3D_2 - ^3D_2$ | 3503.58 | 38000  | 3.50                      | 48.0       | 60.6       | 7.38 c     |      |
|            |      |                |        | 80000                     | 53.0       | 77.2       | d          |      |
|            |      |                |        | 110000                    | 78.0       | 121        | d          |      |
|            |      |                |        | 27500                     | 12.4       | 16.7       | e          |      |
|            | $^3D_3 - ^3F_4$ | 3336.17 | 22000  | 1.00                      | 18.5       | 21.5       | 1.98 a     |      |
|            |      |                |        | 30000                     | 1.47       | 31.2       | 27.5       | 2.79 b     |
|            |      |                |        | 38000                     | 3.50       | 56.0       | 59.0       | 6.91 c     |
|            |      |                |        | 21100                     | 6.3        | 9.64       | e          |      |
|            |      |                |        | 26000                     | 12.1       | 16.9       | e          |      |
|            |      |                |        | 21100                     | 6.3        | 9.64       | 0.83 f     |      |
|            |      |                |        | 23080                     | 8.3        | 16.8       | 1.54 f     |      |
|            | $^3D_2 - ^3F_3$ | 3344.75 | 22000  | 1.00                      | 16.6       | 21.4       | 1.98 a     |      |
|            |      |                |        | 30000                     | 1.47       | 32.5       | 27.4       | 2.80 b     |
|            |      |                |        | 38000                     | 3.50       | 54.0       | 58.8       | 6.92 c     |
|            |      |                |        | 26000                     | 12.1       | 16.9       | e          |      |
|            | $^3D_3 - ^3F_3$ | 3352.11 | 30000  | 1.47                      | 30.9       | 27.5       | 2.81 b     |      |
|            | $^3D_1 - ^3F_2$ | 3358.53 | 22000  | 1.00                      | 16.0       | 21.3       | 1.99 a     |      |
|            |      |                |        | 30000                     | 1.47       | 31.1       | 27.4       | 2.81 b     |
|            |      |                |        | 38000                     | 46.0       | 58.9       | 6.96 c     |      |
|            | $^3D_0 - ^3F_2$ | 3361.30 | 30000  | 1.47                      | 31.8       | 27.3       | 3.21 b     |      |
|            | $^3P_2 - ^3P_2$ | 2762.16 | 22000  | 1.00                      | 12.1       | 13.9       | *2.07 a    |      |
|            | $^3P_0 - ^3P_1$ | 2783.60 | 22000  | 1.00                      | 13.3       | 14.1       | *2.09 a    |      |
helium, 0.99741 hydrogen and 0.00047 carbon and nitrogen.

In Figs. 5 and 6, we show Stark and Doppler widths for Ar III 4p $^5P_2 - 5s \, ^5S_0$ ($\lambda = 2170.22$ Å) spectral line as a function of atmospheric layer temperature and as a function of the optical depth (at 4000 Å) respectively. Stark widths are shown for five values of model gravity log $g = 5-6$, $T_{eff} = 22$ 000 K. As we can see in Fig. 5, for the atmosphere with log $g = 6$, Stark broadening is the dominant broadening mechanism for the atmospheric layers for which the temperature is higher than 43 000 K. For the atmosphere with log $g = 5.75$, Stark width is equal to Doppler width for the atmospheric layer with temperature $T \approx 50$ 000 K. For the atmospheres with log $g = 5.50$ and log $g = 5.25$, Stark width is higher than Doppler one only for deep atmospheric layers. For the atmosphere with log $g = 5$, Stark width became comparable to Doppler one for the deeper layer of the atmosphere (at $T = 67638$ K, $W_{Stark} = 0.0565$ Å and $W_{Doppler} = 0.0639$ Å). One should take into account, however, that even when the Doppler width is larger than Stark width, due to different behaviour of Gaussian and Lorentzian distributions, Stark broadening may be important in line wings.

5. Conclusions

In this work we have determined Stark widths for 32 spectral lines of Ar III, our results are in relatively good agreement with many experimental results. The better agreement is found with Bukvić et al. (2008). The largest disagreement is found with Platiša et al. (1975). Comparison between theoretical and experimental results allows to improve both theories and experiments. Our results are shown for five values of model gravity log $g = 5-6$, $T_{eff} = 22$ 000 K.

Table 1: Continued.

| Transition | Term | λ (Å) | T (K) | $N_e$ ($10^{17}$ cm$^{-3}$) | $W_m$ (pm) | $W_e$ (pm) | $W_i$ (pm) | Ref. |
|------------|------|-------|------|----------------------------|--------------|-------------|------------|------|
| 3d$'$ - 3p$'$ | $^3D^0_1 - ^3D^0_2$ | 2631.86 | 22000 | 1.00 | 9.8 | 9.61 | 1.22 | a |
| 3d$'$ - 3p$'$ | $^3D^0_2 - ^3D^0_1$ | 2678.35 | 22000 | 1.00 | 10.3 | 9.70 | 1.33 | a |
| 4p$'$ - 5s$'$ | $^5P^0_1 - ^3P^0_1$ | 3471.29 | 30000 | 1.47 | 31.6 | 26.6 | 5.03 | b |
| 4p$'$ - 5s$'$ | $^5P^0_2 - ^5S^0_2$ | 2166.18 | 38000 | 3.50 | 53.0 | 56.6 | 12.0 | c |
| 4p$'$ - 5s$'$ | $^5P^0_3 - ^5S^0_3$ | 2170.22 | 38000 | 3.50 | 61.0 | 55.8 | 4.78 | c |
| 4p$'$ - 4d$'$ | $^3D^0_3 - ^3P^0_2$ | 2177.19 | 38000 | 3.50 | 56.0 | 55.8 | 4.78 | c |
| 4p$'$ - 4d$'$ | $^3D^0_3 - ^3D^0_2$ | 2133.86 | 38000 | 3.50 | 69.0 | 38.4 | 8.94 | c |

Figure 6: Stark and Doppler widths for Ar III 4p $^5P_2 - 5s \, ^5S_0$ ($\lambda = 2170.22$ Å) spectral line as a function of optical depth. Stark widths are shown for five values of model gravity log $g = 5-6$, $T_{eff} = 22$ 000 K.
show that the use of the Cowan code (Cowan, 1981) for the determination of oscillator strengths needed for SCP calculation of Stark widths is very useful when no experimental data exist. Our study of the Stark broadening in sdB stars shows the importance of this mechanism especially for the atmospheres with high values of log g.

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