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Modified semiempirical electron width calculations of singly-ionized oxygen spectral lines⋆

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Abstract. Using a modified semiempirical approach, we have calculated Stark broadening full widths at half maximum for 25 OII multiplets for temperatures from 5000 K up to 80 000 K using the needed oscillator strengths from the sophisticated atomic structure data base TOPbase. Then we compared our results with experimental data for 41 OII spectral lines and with the available semi-classical calculations to test the applied method and the accuracy of the results obtained.

Key words. line: profiles – atomic data

1. Introduction

Charged oxygen (OII) atoms, as emitters or absorbers, are especially important due to their presence in many kinds of cosmic sources of radiation. The abundance of oxygen and the large number of ionized oxygen spectral lines in stellar plasmas make these of great importance for diagnostic purposes. In astrophysics, Stark broadening data are required e.g. for the evaluation of the physical conditions in stellar atmospheres from the analysis of stellar spectra. Further, Stark broadening data are also required for determination of the abundances of elements and for evaluation of radiative transfer through the stellar interior.

For Stark linewidth determination, Griem (1968) suggested a simple semiempirical method based on Baranger's original formulation (Baranger 1958, see also 1962), together with the use of an effective Gaunt-factor approximation proposed by Seaton (1962) and Van Regemorter (1962). For singly ionized atoms, this semiempirical formula agrees on the average within ±50% with experiments (Griem 1974). This formula has been modified by Dimitrijević & Konjević (1980) to minimize the atomic data needed and to extend its validity to multiply charged ion lines. An effort has been made to obtain new Stark broadening data with this modified formula (see Dimitrijević & Popović 2001, and references therein), especially in the case when more sophisticated methods are not adequately applicable due to the lack of needed atomic data.

The aim of this paper is twofold: to provide new Stark broadening data for astrophysically important OII lines and to test the modified semiempirical approach (Dimitrijević & Konjević 1980). Also, we compared our results to available experimental and other theoretical results for OII.

2. Theory

Within the impact approximation, Baranger (1958) derived a quantum-mechanical expression for the width of an isolated line:

$$W = N\left(v\sum_{i'}\sigma_{i'i}(v) + \sum_{f'}\sigma_{f'f}(v)\right)_{\rm av} + W_{\rm el} \quad (1)$$

where W is $FWHM$ (Full Width at Half Maximum) in units of angular frequency and N is the electron concentration. The symbols $\sigma_{i'i}$, $\sigma_{f'f}$ represent the inelastic cross sections for collisional transitions to i', f' from the initial (i) and final (f) levels of the optical transition respectively. $W_{\rm el}$ is the line width induced by elastic collisions. The averaging in Eq. (1) has to be performed over the electron velocity v distribution.

Within the framework of the dipole approximation, one may use Bethe's relation (Bethe 1930)

$$\sigma_{j'j} = \frac{8\pi}{3}\bar{\lambda}^2\overline{R^2_{j'j}}\frac{\pi}{\sqrt{3}}g \quad (2)$$

to evaluate inelastic cross sections. In this expression $\bar{\lambda}$ is the reduced de Broglie wavelength of an electron and $\overline{R^2_{j'j}}$ (in units of the Bohr radius a_0) is the square of the coordinate operator

⋆ Table 3 is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?/A+A/434/773

matrix element summed over all components of the operator, the magnetic substates of total angular momentum J', and averaged over the magnetic substates of J.

For higher electron temperatures, Griem (1968) assumed that the contribution of elastic collisions to the line width can be neglected (cf. Eq. (1)) and made an attempt to take elastic collisions into account in the low temperature limit by extrapolating the threshold value of the inelastic cross section below the threshold. The Stark line width can then be calculated from the well-know semiempirical formula (Griem 1968)

$$W = N\frac{8\pi}{3}\left(\frac{\hbar}{m}\right)^2\left(\frac{2m}{\pi kT}\right)^{\frac{1}{2}}\frac{\pi}{\sqrt{3}} \times\left[\sum_{i'}R^2_{i'i}g\left(\frac{E}{\Delta E_{ii'}}\right)+\sum_{f'}R^2_{f'f}g\left(\frac{E}{\Delta E_{ff'}}\right)\right]. \quad (3)$$

Here, $E = \frac{3kT}{2}$ is the energy of the perturbing electron and $\Delta E_{j'j} = \left[E_{j'} - E_j\right]$ is the energy difference between level j and j' (j and $j' = i, f, i', f'$ where i denotes initial and f final atomic energy level and i', f' are their corresponding perturbing levels), $g(x) = 0.20$ for $x \leq 2$ and $g(x) = 0.24$, 0.33, 0.56, 0.98, and 1.33 for $x = 3$, 5, 10, 30, and 100. Also

$$x = \frac{E}{\Delta E_{jj'}}, \quad (4)$$

$$R^2_{jj} = \sum_{j'}R^2_{j'j} \simeq \frac{1}{2}\left(\frac{n^*_j}{Z}\right)^2\left[5n^{*2}_j + 1 - 3l_j(l_j+1)\right], \quad (5)$$

n^*_j is the effective principal-, and l_j the orbital angular momentum-quantum numbers, while $(Z-1)$ is the ionic charge.

If one uses Eq. (3) to calculate Stark line widths, we need the same set of atomic data as for a more sophisticated semiclassical method, and a lack of atomic data causes the same difficulties for both methods in the evaluation of necessary matrix elements. These difficulties are especially serious for multiply-ionized atoms for which data on higher perturbing levels are sometimes completely missing in the literature. Moreover for multiply charged ions the Griem's semiempirical formula becomes inapplicable. To overcome these problems, Dimitrijević & Konjević (1980) have separated the transitions with $\Delta n = 0$ and with $\Delta n \neq 0$. In the first case, only two matrix elements are calculated for the initial state, one for the transition array $l \rightarrow l+1$ $\left(R^2_{l,l+1}\right)$ and the other for $l \rightarrow l-1$ $\left(R^2_{l,l-1}\right)$. Also, only two matrix elements are needed for the final state. The effective Gaunt factor $\widetilde{g}(x)$ for the transitions with the principal quantum number n unchanged is taken as

$$\widetilde{g}(x) = 0.7 - \frac{1.1}{Z} + g(x). \quad (6)$$

All perturbing levels with $\Delta n \neq 0$ are lumped together and the energy separation to the nearest perturbing level is estimated from

$$\Delta E_{n,n+1} = \frac{2Z^2E_H}{n^{*3}}. \quad (7)$$

At high temperatures (say $x \geq 50$), all Gaunt factors are calculated in accordance with the GBKO high temperature limit (Griem et al. 1962)

$$g_{j'j} = \frac{\sqrt{3}}{\pi}\left[\frac{1}{2} + \ln\left(\frac{2ZkT}{n^{*2}_j\Delta E_{j'j}}\right)\right]. \quad (8)$$

For $\Delta n = 0$

$$R^2_{ij} = f_{ij}\frac{\lambda_{ij}(\text{Å})}{303.7}, \quad (9)$$

where f_{ij} is the oscillator strength between levels i and j, and for $\Delta n \neq 0$

$$\sum_{i'}\left(R^2_{ii'}\right)_{\Delta n\neq 0} \simeq \left(\frac{3n^*_i}{2Z}\right)^2\frac{1}{9}\left(n^{*2}_i + 3l^2_i + 3l_i + 11\right), \quad (10)$$

where l_i is the orbital quantum number of the valence electron. In such a way Dimitrijević & Konjević (1980) extended the validity of the semiempirical method to multiply charged ions, and optimized the needed set of atomic data ensuring that the method is applicable when, due to the lack of atomic data, more sophisticated approaches are not adequately applicable.

When the wavelength of a particular line within the multiplet differs significantly from the average wavelength $\langle\lambda\rangle$ of the whole multiplet, we use the following scaling (Popović et al. 2001):

$$W_{\text{line}} = \left(\frac{\lambda}{\langle\lambda\rangle}\right)^2 W. \quad (11)$$

In the above expression, W and $\langle\lambda\rangle$ are values for the multiplet, and W_{line} and λ refer to a particular line within the multiplet.

3. Results and discussion

The atomic energy levels and oscillator strengths for OII have been taken from TOPbase (Cunto et al. 1993; Zeippen 1995). TOPbase does not provide mean square radii. Therefore we have calculated them by using the oscillator strengths (cf. Eq. (9)) and the effective quantum numbers n^*_i obtained from the TOPbase (cf. Eq. (10)). By using the modified semiempirical approach (Dimitrijević & Konjević 1980), we have calculated Stark broadening widths of forty one OII spectral lines. The obtained Stark *FWHM* values at various electron temperatures and electron densities and comparisons with other experimental and theoretical data are shown in Tables 1 and 2. With W_{m} are denoted the measured widths, W_{MBS} is the electron-impact width calculated by Mahmoudi et al. (2004) on the basis of the semi-classical approach of Sahal-Bréchot (1969a,b), W_{MSE} present calculations with the modified semiempirical approach of Dimitrijević and Konjević (1980) (corresponding to Eqs. (6)-(10)), and W_{eG} the semi-classical approach by Griem (1974).

Table 1. Experimental OII Stark widths W_m (*FWHM*), and different calculations: the semi-classical values calculated by Mahmoudi et al. (2004) W_{MBS}, our data obtained with the modified semiempirical approach (Dimitrijević & Konjević 1980) W_{MSE} and semi-classical values of Griem (1974) W_{eG}. References: a. Platiša et al. (1975); b. del Val et al. (1999); c. Djeniže et al. (1998); d. Blagojević et al. (1999); e. Djeniže et al. (1991), with e* is denoted the line where only the shift is reported by Djeniže et al. (1991) and f. Srećković et al. (2001). The data indicated by † are calculated here and not in the cited paper. The W_{eG} data for T = 60000 K denoted by ⊤ are extrapolated Griem (1974) values from Djeniže et al. (1991).

Multiplet	λ Å	T K	N_e 10^{17} cm^{-3}	W_m Å	W_{MBS} Å	W_{MSE} Å	W_{eG} Å	$\frac{\Delta S}{S}$	Ref.
3s ^{4}P–3p ^{4}D^0	4649.13	25 900	0.52	0.119		0.188	0.172	0.31	a
		40 000	1.0	0.209		0.290	0.314	0.31	b
	4641.81	40 000	1.0	0.223		0.289	0.313	0.31	b
		54 000	2.8	0.620		0.725		0.31	c
	4638.86	40 000	1.0	0.220		0.289	0.312	0.31	b
		54 000	2.8	0.640		0.724		0.31	c
	4650.84	25 900	0.52	0.123		0.188	0.171	0.31	a
		40 000	1.0	0.225		0.291	0.314	0.31	b
^{4}P–^{4}P^0	4349.43	40 000	1.0	0.253	0.249	0.263	0.219	0.32	b
	4336.86	40 000	1.0	0.202	0.248	0.261	0.218	0.32	b
	4366.89	25 900	0.52	0.115	0.147†	0.171	0.124	0.32	a
		40 000	1.0	0.248	0.251	0.265	0.221	0.32	b
	4345.56	40 000	1.0	0.258	0.249	0.262	0.218	0.32	b
	4319.63	40 000	1.0	0.261	0.246	0.259	0.216	0.32	b
	4317.14	25 900	0.52	0.114	0.144†	0.167	0.124	0.32	a
		40 000	1.0	0.256	0.246	0.259	0.216	0.32	b
^{4}P–^{4}S^0	3749.48	54 000	2.8	0.380	0.422	0.489		0.23	c
^{2}P–^{2}D^0	4414.90	18 800	0.31	0.087	0.106	0.128	0.094	0.26	d
		19 100	0.41	0.113	0.139	0.168	0.124	0.26	d
		19 500	0.46	0.133	0.155	0.187	0.138	0.26	d
		19 500	0.39	0.110	0.132	0.159	0.117	0.26	d
		19 800	0.44	0.125	0.147	0.178	0.132	0.26	d
		19 900	0.47	0.135	0.157	0.189	0.141	0.26	d
		25 900	0.52	0.139	0.158	0.184	0.149	0.26	a
	4416.97	18 800	0.31	0.086	0.106	0.128	0.093	0.26	d
		19 100	0.41	0.121	0.140	0.169	0.123	0.26	d
		19 500	0.46	0.130	0.155	0.187	0.138	0.26	d
		19 500	0.39	0.109	0.132	0.159	0.117	0.26	d
		19 800	0.44	0.124	0.147	0.178	0.132	0.26	d
		19 900	0.47	0.132	0.157	0.189	0.140	0.26	d
^{2}P–^{2}P^0	3954.36	25 900	0.52	0.118	0.127	0.157		0.28	a
		54 000	2.8	0.540	0.575	0.622		0.28	c
3p ^{4}D^0 – 3d ^{4}F	4075.86	25 900	0.52	0.122	0.156†	0.158	0.140	0.13	a
		40 000	1.0	0.197	0.270	0.244	0.258	0.13	b
	4072.15	25 900	0.52	0.118	0.156†	0.157	0.140	0.13	a
		40 000	1.0	0.239	0.269	0.244	0.258	0.13	b
	4092.93	25 900	0.52	0.122	0.158†	0.159	0.140	0.13	a
		40 000	1.0	0.213	0.272	0.246	0.260	0.13	b
^{2}D^0–^{4}D	4710.01	60 000	0.81	0.240		0.245		0.08	e
^{2}D^0–^{2}F	4705.35	18 800	0.31	0.115	0.145	0.165	0.126	0.10	d
		19 100	0.41	0.170	0.190	0.216	0.167	0.10	d
		19 500	0.46	0.195	0.212	0.240	0.186	0.10	d
		19 500	0.39	0.146	0.179	0.204	0.157	0.10	d
		19 800	0.44	0.174	0.202	0.228	0.178	0.10	d
		19 900	0.47	0.189	0.215	0.243	0.189	0.10	d
		60 000	0.7	0.240	0.253†	0.228	0.255	0.10	e
^{2}D^0–^{2}D	4395.93	60 000	0.81	0.254		0.238		0.07	e
^{4}S^0–^{4}P	4890.86	54 000	2.8	0.940	0.936	0.919		0.07	c
	4924.53	60 000	0.81	0.232	0.272	0.260	0.336⊤	0.07	e

Table 1. continued.

Multiplet	λ Å	T K	N_e 10^{17} cm^{-3}	W_m Å	W_{MBS} Å	W_{MSE} Å	W_{eG} Å	$\frac{\Delta S}{S}$	Ref.
$^2P^0$–^2P	5206.65	60 000	0.81	0.362		0.364	0.326$^\top$	0.10	e
$^2P^0$–^2D	4955.71	60 000	0.81	0.328	0.328	0.320	0.331$^\top$	0.09	e
3p′ $^2F^0$ – 3d′ ^2G	4185.46	15 700	1.45	0.448	0.595	0.633		0.11	f
		18 300	1.82	0.356	0.706	0.735		0.11	f
		20 500	0.98	0.232	0.364	0.374		0.11	f
		25 900	0.52	0.104	0.177	0.177		0.11	a
	4189.79	15 700	1.45	0.419	0.596	0.634		0.11	f
		18 300	1.82	0.358	0.707	0.737		0.11	f
		20 500	0.98	0.222	0.365	0.375		0.11	f
$^2F^0$–^2F	4448.19	40 000	1.0	0.343		0.308		0.15	b
$^2D^0$–^2D	4327.46	40 000	1.0	0.382		0.314		0.10	b
$^2P^\circ$–^2D	4860.97	60 000	0.81	0.284	0.285	0.336		0.13	e
	4871.52	60 000	0.81	0.284	0.287	0.338		0.13	e
$^2P^0$–^2S	4319.87	60 000	0.81	0.208		0.277		0.06	e
3s′ ^2D–3p′ $^2F^0$	4590.97	25 900	0.52	0.132	0.186†	0.196		0.30	a
		40 000	1.0	0.223	0.319	0.306		0.30	b
	4596.18	25 900	0.52	0.128	0.187†	0.196		0.30	a
		40 000	1.0	0.272	0.320	0.306		0.30	b
		54 000	2.8	0.420	0.843	0.776		0.30	c
	4595.96	54 000	2.8	0.380	0.843	0.776		0.30	c
3p $^2D^0$ – 4s ^2P	3470.67	54 000	2.8	1.00		1.481		0.10	c
$^4P^0$–^4P	3289.98	60 000	0.81	0.344		0.373	0.355$^\top$	0.18	e
$^4S^0$–^4P	3739.76	60 000	0.81	0.426		0.483	0.473$^\top$	0.14	e
$^2P^0$–^2P	3802.98	60 000	0.81	0.418		0.525	0.492$^\top$	0.11	e
3p′ $^2F^0$ – 4s′ ^2D	3270.86	60 000	0.81			0.348		0.09	e*
$^2P^0$–^2D	3729.22	60 000	0.81	0.132		0.499		0.11	e
3d ^4F–4p $^4D^0$	6895.10	60 000	0.81	0.976	1.480	1.777	1.683$^\top$	0.07	e

Table 2. Calculated OII widths for the transition array $2p^2(^3P)3s$ – $2p^2(^3P)3p$: semi-classical (Griem 1974) values W_D calculated by Dimitrijević (1982), semi-classical (Sahal-Bréchot 1969a,b) values W_{MBS} calculated by Mahmoudi, Ben Nessib and Sahal-Bréchot (2004) and our calculation with the modified semiempirical approach (Dimitrijević & Konjević 1980) W_{MSE}. λ_m is the average wavelength for the multiplet.

Multiplet	λ_m Å	T K	N_e 10^{17} cm^{-3}	W_D Å	W_{MBS} Å	W_{MSE} Å
^4P–$^4D^0$	4652	20 000	1.0	0.338		0.423
		30 000	1.0	0.314		0.345
		60 000	1.0	0.294		0.260
		80 000	1.0	0.288		0.244
^4P–$^4P^0$	4341	20 000	1.0	0.294	0.312	0.377
		30 000	1.0	0.274	0.272	0.308
		60 000	1.0	0.258	0.234	0.231
		80 000	1.0	0.254	0.225	0.217
^4P–$^4S^0$	3736	20 000	1.0	0.232	0.192	0.275
		30 000	1.0	0.218	0.169	0.224
		60 000	1.0	0.204	0.149	0.171
		80 000	1.0	0.200	0.145	0.161

Calculated $\frac{\Delta S}{S}$ ratios are also included in the Table 1. This ratio is a measure of the completeness of the set of perturbing levels with respect to the sums of dipole matrix elements and it is calculated from the following relation

$$\frac{\Delta S}{S} = \frac{\sum_{i'} R^2_{ii'} + \sum_{f'} R^2_{ff'} - R^2_{ii} - R^2_{ff}}{R^2_{ii} + R^2_{ff}}, \quad (12)$$

where in the summation enter terms for $\Delta n = 0$ defined by Eq. (9) and terms for $\Delta n \neq 0$ by Eq. (10). For a complete set of perturbing levels, $\frac{\Delta S}{S} = 0$. One can see in Table 1 that in all considered cases $\frac{\Delta S}{S}$ is greater than 0, i.e. the sum in Eq. (12) obtained with the help of Eqs. (9), (10) is larger than the sum (Eq. (5)) within the Coulomb approximation for up to 30%. This demonstrates that the introduction of a fictive common energy level for all perturbing energy levels with $\Delta n \neq 0$ (Eq. (7)) overestimates the theoretical sum rule Eq. (5) by up to 30%, but the agreement with experiments indicates that this is equilibrated by the underestimation of the contribution of elastic collisions.

Table 2 present a comparison of our calculations (W_{MSE}) with theoretical results of Dimitrijević (1982) (W_D) obtained using the semi-classical approach of Griem (1974) and theoretical data (W_{MBS}) calculated by Mahmoudi et al. (2004) using the semi-classical method of Sahal-Bréchot (1969a,b).

One can see from Tables 1 and 2 that the MSE results are in good agreement with experiments and more sophisticated

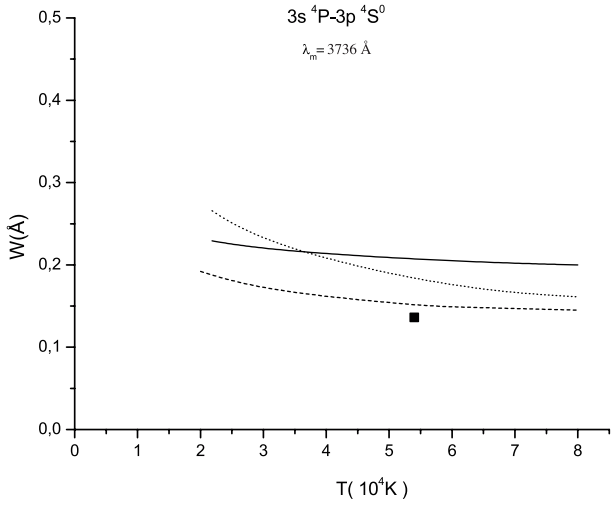

Fig. 1. Theoretical Stark width dependence on electron temperature for an electron density of 1×10^{17} cm^{-3}. ■, Djeniže et al. (1998); the solid line denotes results of Dimitrijević (1982) obtained by the semi-classical theory of Griem (1974); the dashed line denotes data calculated by Mahmoudi et al. (2004) and the doted line denotes our calculation with the modified semiempirical formalism (Dimitrijević & Konjević 1980). $\lambda_{\rm m}$ is the average wavelength for the multiplet.

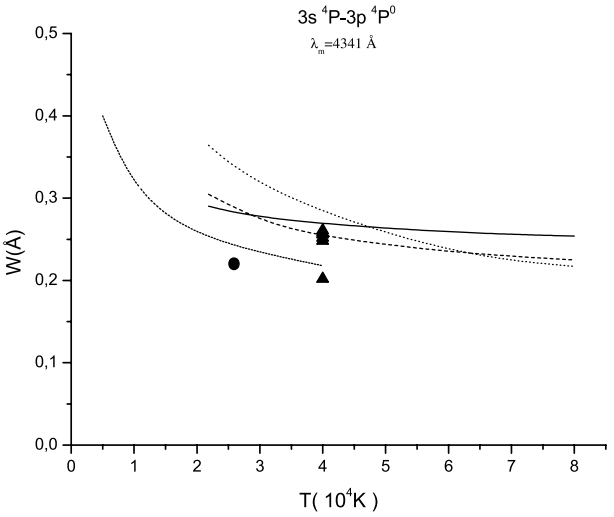

Fig. 2. Theoretical Stark width dependence on electron temperature for an electron density of 1×10^{17} cm^{-3}. •, Platiša et al. (1975); ▲, del Val et al. (1999); the solid line denotes results of Dimitrijević (1982) obtained by the semi-classical theory of Griem (1974); the dashed line denotes data calculated by Mahmoudi et al. (2004); the doted line denotes our calculation with the modified semiempirical formalism (Dimitrijević & Konjević 1980) and the short dashed one denotes the theoretical values of Griem (1974). $\lambda_{\rm m}$ is the average wavelength for the multiplet.

theoretical calculations (Mahmoudi et al. 2004; Griem 1974) for all considered experimental conditions (T and $N_{\rm e}$). Indeed the ratio $\frac{W_{\rm m}}{W_{\rm MSE}}$ and $\frac{W_{\rm m}}{W_{\rm MBS}}$ shows on average an agreement within 20% and 16% respectively. This is well within the error bars of the semiempirical and the modified semiempirical methods estimated to be ±50% (Griem 1974; Dimitrijević & Konjević 1980) which is a very good agreement especially taking into account that the needed atomic data set is much smaller than for more sophisticated semi-classical calculations (Sahal-Bréchot 1969a,b; Griem 1974; Mahmoudi et al. 2004). The exceptions are in the multiplets $2p^2(^1D)3p\ ^2F^0 - 2p^2(^1D)3d\ ^2G$ at 18 300 K, $2p^2(^1D)3s\ ^2D - 2p^2(^1D)3p\ ^2F^0$ at 54 000 K, $2p^2(^3P)3d\ ^4F - 2p^2(^3P)4p\ ^4D^0$ and $2p^2(^1D)3p\ ^2P^0 - 2p^2(^1D)4s\ ^2D$ where the discrepancy between experiment and theoretical calculations is of the order of 50% which is also within the error bars of the semi-classical and the modified semiempirical method.

The results of Table 2 are compared in Figs. 1–3 with available experimental data but we note that the experimental results are for particular spectral lines within a multiplet while the theoretical data are calculated for the multiplet as a whole. One can see that our results obtained with the modified semiempirical method (Dimitrijević & Konjević 1980) are in agreement within the error bars with the experimental data and with more sophisticated semi-classical calculations of Dimitrijević (1982) and Mahmoudi et al. (2004) which demonstrates that this method can be used especially for large scale calculations and when due to lack of the needed atomic data more sophisticated methods are not adequately applicable.

In Table 3 (available only in electronic form at the CDS) our Stark width (*FWHM*) results for 25 OII multiplets calculated for an electron density of 10^{17} cm^{-3} and temperatures of 5000, 10 000, 20 000, 30 000, 60 000 and 80 000 K are given for the modelling, analysis and diagnostics of astrophysical

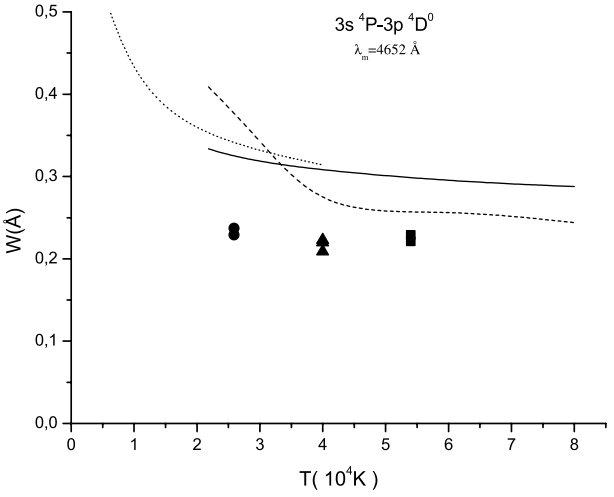

Fig. 3. Theoretical Stark width dependence on electron temperature for an electron density of 1×10^{17} cm^{-3}. •, Platiša et al. (1975); ▲, del Val et al. (1999); ■, Djeniže et al. (1998); the solid line denotes results of Dimitrijević (1982) calculated with the semi-classical theory of Griem (1974); the dashed line denotes our calculation with the modified semiempirical formalism (Dimitrijević & Konjević 1980) and the doted line denotes the theoretical value of Griem (1974). λ_m is the average wavelength for the multiplet.

plasmas. We note also that for lower densities a linear scaling is sufficient. For higher densities, linearity with the electron density may be assumed if the plasma is ideal. The idealness of the plasma can be checked by calculating the number of perturbers in the Debye sphere, i.e. $(4\pi/3)R_{\rm D}^3 N > 1$ or $N < 1.9 \times 10^6 T^3$ cm^{-3} (Dimitrijević et al. 1991), where $R_{\rm D}$ is

the Debye radius. For non-ideal plasmas, the method used here is not suitable. Stark broadening in a strongly correlated plasma has been considered recently by Ben Chaouacha et al. (2004). The other criteria for the applicability of the modified semiempirical approach have been dicussed in detail in Milovanović et al. (2004).

4. Conclusion

We have calculated by using the modified semiemirical method (Dimitrijević & Konjević 1980) Stark widths (*FWHM*) for 25 OII multiplets for an electron density of 10^{17} cm^{-3} and temperatures from 5000 to 80 000 K. In order to test the applicability of the used method, we have compared the results obtained with experimental results for 41 OII spectral lines and with more sophisticated semi-classical calculations of Griem (1974), Dimitrijević (1982) and Mahmoudi et al. (2004). We found that the ratio of experimental and our theoretical values is on average in agreement within 20%, which is well within the estimated error bars of this method (±50%), with several exceptions of the order of 50%. The agreement found between experimental and semi-classical values demonstrates that the method can be used for OII Stark width calculations, especially when more sophisticated methods are not applicable in an adequate way. Consequently, one can expect that the accuracy of the obtained OII Stark width data presented in Table 3 is better on average than that estimated for this method of (±50%).

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