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Stark Broadening Parameters for Neutral Oxygen Spectral Lines

N. Alonizan[1,*], R. Qindeel[1], N. Ben Nessib[1], S. Sahal-Bréchot[2] & Milan S. Dimitrijević[2,3,4]

[1]*Department of Physics and Astronomy, College of Science, King Saud University, P. O. Box 2455, Riyadh 11451, Saudi Arabia.*
[2]*LERMA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, 5 Place Jules Janssen, 92195 Meudon Cedex, France.*
[3]*Astronomical Observatory, Volgina 7, 11060 Belgrade, Serbia.*
[4]*IHIS Techno Experts, Bežanijski put 23, 11080 Belgrade-Zemun, Serbia.*
[*]*e-mail: nalonizan@ksu.edu.sa*

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Abstract. Stark broadening parameters for nine neutral oxygen (O I) lines have been determined within the impact approximation and the semiclassical perturbation method. The atomic data have been taken from the TOPbase and NIST atomic databases. The electron and proton Stark widths and shifts and ion broadening parameter values for these O I lines have been calculated for electron density of 10^{16} cm^{-3} and for 4 different electron temperatures in the range of 5000 K to 40000 K. These Stark broadening parameters are compared with our previous results (Ben Nessib, N. *et al.* 1996, *Physica Scripta*, **54**, 603–613), where we calculated Stark broadening parameters for only four O I spectral lines and where Stark widths and shifts were compared with experimental and theoretical data available in the literature. In the present paper, we have also compared our results with the Griem's book (Griem, H. R. 1974, *Spectral line broadening by plasmas*) and VALD (Ryabchikova, T. *et al.* 2015, *Physica Scripta*, **90**, 054005) values.

Key words. Stark broadening—atomic data—line: profiles—O I.

1. Introduction

Oxygen is an important element for human life, in the microscopic and macroscopic dimensions. It is important because of carbon–nitrogen–oxygen (CNO) nuclear cycle reactions in hot stars and it is the most abundant element after hydrogen and helium in the Universe. It is also present in most plasma laboratory experiments and its spectral lines are important to know for spectroscopic diagnostics. So it is important

to obtain detailed structure information of the atomic oxygen whether experimentally or theoretically. This neutral atom has four electrons in its second orbit in the fundamental state; its fundamental configuration is $2s^2 2p^4$ and is subdivided into 3 even terms: ^3P, ^1D and ^1S. Due to spin–orbit interaction, the ground term ^3P is subdivided into three levels, corresponding to $J = 0$, 1 and 2. $J = 2$ is the ground level.

In a previous work (Ben Nessib *et al.* 1996), within the impact approximation and the semiclassical method (Sahal-Bréchot 1969a, b, 1974), we calculated electron and ion (Ar II) collisional widths and shifts of four spectral lines of O I. The input atomic structure data were taken from the TOPbase atomic structure database and were introduced in the Sahal-Bréchot's semiclassical perturbation (SCP) code. The calculations were performed for temperatures from 5000 up to 40000 K. These data were provided for an electron density of N_e=10^{16} cm^{-3} as a standard value for modeling neutral plasmas, and for the experimental electronic densities as well. We also calculated the quasistatic ion parameter for the four lines. Results were compared with Griem values (Griem 1974) and with different experimental results.

In their paper, Vennes *et al.* (2011) discussed broadening parameters of other lines, other than the four calculated in our previous paper, especially the 7773 Å line. In the present work, we will provide data for this O I λ 7773 Å multiplet and extend our previous work to study Stark broadening of five other spectral lines, using as input the atomic data from the databases TOPbase (Cunto *et al.* 1993) and NIST (Kramida *et al.* 2014) and we will compare our results with the Griem's book values (Griem 1974).

2. Results and discussion

In the SCP method for neutral emitters, the perturber electron moves along a straight line path with impact parameter ρ and velocity v (or kinetic energy $E = \frac{1}{2}\mu v^2$, with μ the reduced mass of the system atom-perturber).

Recently, Sahal-Bréchot *et al.* (2014) gave a review of the SCP method for calculating Stark broadening parameters of isolated lines with all details and references included.

For isolated lines such as the lines of the present study, the full width at half maximum (FWHM) of an electron-impact broadened spectral line is given by the following formulae (Sahal-Bréchot 1969a, b, 1974):

$$W = N_e \int v f(v) \mathrm{d}v \left(\sum_{i' \neq i} \sigma_{ii'}(v) + \sum_{f' \neq f} \sigma_{ff'}(v) + \sigma_{\mathrm{el}} \right), \tag{1}$$

where N_e is the electron density, $v f(v)\mathrm{d}v$ is the Maxwell distribution of the electron velocities, where

$$\sum_{i' \neq i} \sigma_{ii'}(v) = \frac{1}{2}\pi R_1^2 + \pi a_0^2 \frac{8 I_H^2}{E_{\mathrm{sym}} \Delta E_{ii'}} f_{ii'} \frac{\mu}{m_e} \left(a(z_{\min D}) - a(z_{\min 1}) \right), \tag{2}$$

where equation (2) is the sum of the inelastic cross-sections between the initial level i and the perturbing levels i' with an analogous summation for the inelastic

cross-sections between the final level f and its perturbing levels f'. $\sigma_{\rm el}$ represents the contribution of the elastic collisions (see Sahal-Bréchot 1969a and Sahal-Bréchot 2014 for details). $\Delta E_{ii'}$ and $f_{ii'}$ are respectively the energy difference and the oscillator strengths between the levels i and i'. $a(z) = z\,|K_1(z)|\,K_0(z)$, where K_0 and K_1 are the modified first kind Bessel functions of order zero and one.

The energy E, z_1 and z_D of the original semiclassical formulae have been symmetrized in order to satisfy the reciprocity relation (Seaton 1962) and become (Sahal-Bréchot *et al.* (2014) and earlier papers):

$$E_{\rm sym} = \frac{1}{2}(2E - \Delta E_{ii'}), \tag{3}$$

$$z_{\min 1} = \frac{R_1}{a_0}\sqrt{\frac{\mu}{m_e}\sqrt{\frac{E}{I_H}}\frac{\Delta E_{ii'}}{2E - \Delta E_{ii'}}} \tag{4}$$

and

$$z_{\min D} = \frac{R_D}{a_0}\sqrt{\frac{\mu}{m_e}\sqrt{\frac{E}{I_H}}\frac{\Delta E_{ii'}}{2E - \Delta E_{ii'}}}, \tag{5}$$

where R_1 and R_D are respectively the lower and upper (Debye radius) impact parameter cut-offs and they are described in Sahal-Bréchot (1969a).

The elastic cross-sections are expressed by means of the phase shifts due to dipolar and quadrupolar potential (Sahal-Bréchot 1969a; Sahal-Bréchot *et al.* 2014).

The quadrupolar interaction contributes to the elastic part of the width and is expressed by means of the atomic structure coefficients B_i, B_f and B_{if} which have to be determined according to Sahal-Bréchot (1974).

In the present paper, the atomic data used as input for the SCP code are from the on-line atomic database TOPbase (Cunto *et al.* 1993) and from NIST (Kramida *et al.* 2014). TOPbase contains the most complete dataset of LS-coupling term energies, f-values and photoionization cross sections for astrophysically abundant ions (Z = 1–26) that is currently available. They have been computed within the close-coupling approximation (Burke & Seaton 1971) by means of the R-matrix method (Burke *et al.* 1971). NIST database (Kramida *et al.* 2014) contains critically evaluated data for radiative transitions and energy levels in atoms and atomic ions. Data are included for observed transitions of 99 elements and energy levels of 89 elements.

In Table 1, we present our new calculations of the electron impact total widths. W_e(TOPbase), W_e(NIST-LS) and W_e(NIST-LSJ) corresponding to our new calculations using the atomic data from TOPbase, NIST-LS with term averaged energies over J (multiplet energies) and NIST-LSJ energy levels (within a multiplet, only one line, corresponding to the transition with the lowest J values has been taken) compared to our previous results W_e(96) (Ben Nessib *et al.* 1996), to Griem W_e(G) (Griem 1974) and to VALD values W_e(VALD) (Ryabchikova *et al.* 2015), where W_e(VALD) are the widths taken from the VALD database for T = 10000 K and for the other temperatures, we used the proposed VALD scaling formula $W_e(\mathrm{T}) = W_e(10000) \times (\frac{T}{10000})^{1/6}$.

Table 1. Electron impact widths for an electron density of $N_e = 10^{16}$ cm^{-3} and electron temperature from 5000 up to 40000 K. W_e(TOPbase), W_e(NIST-LS) and W_e(NIST-LSJ) are our new calculations using different atomic input data from respectively TOPbase, NIST for the multiplet and a fine structure line, W_e(96) are for the precedent calculations (Ben Nessib *et al.* 1996), W_e(G) are for the Griem values (Griem 1974) and W_e(VALD) are from the VALD database (Ryabchikova *et al.* 2015). Data preceded by an asterisk mean that the impact approximation reaches its limit of validity, $0.1 < C_{\rm impact} \leq 0.5$, and in cells containing '–' symbol values are missing, since the correct semiclassical perturbation calculation can not be performed due to the absence of important perturbing levels in NIST database (see text for details).

Line	T (K)	W_e(G) (Å)	W_e(96) (Å)	W_e(TOPbase) (Å)	W_e(NIST-LS) (Å)	W_e(NIST-LSJ) (Å)	W_e(VALD) (Å)
1304 Å	5000	1.44E-03		1.12E-03	1.08E-03	1.08E-03	1.68E-03
2p−3s	10000	1.64E-03		1.33E-03	1.28E-03	1.29E-03	1.88E-03
$^3P - ^3S^o$	20000	1.89E-03		1.51E-03	1.46E-03	1.46E-03	2.11E-03
	40000	2.16E-03		1.62E-03	1.58E-03	1.55E-03	2.37E-03
989 Å	5000	7.44E-04		8.44E-04	5.57E-04	5.86E-04	8.60E-04
2p−3s	10000	8.46E-04		8.72E-04	6.00E-04	6.33E-04	9.65E-04
$^3P - ^3D^o$	20000	9.36E-04		8.53E-04	6.00E-04	6.34E-04	1.08E-03
	40000	1.10E-03		8.27E-04	5.98E-04	6.30E-04	1.22E-03
7773 Å	5000	4.56E-02		5.52E-02	4.13E-02	4.74E-02	8.04E-02
3s−3p	10000	6.30E-02		6.30E-02	5.23E-02	5.38E-02	9.03E-02
$^5S^o - ^5P$	20000	8.94E-02		8.25E-02	7.12E-02	7.10E-02	1.01E-01
	40000	1.21E-01		1.13E-01	9.70E-02	9.88E-02	1.14E-01
8227 Å	5000	4.76E-02		1.00E-01	6.17E-02	6.90E-02	1.27E-01
3s−3p	10000	7.00E-02		1.10E-01	7.18E-02	8.06E-02	1.43E-01
$^3D^o - ^3D$	20000	1.03E-01		1.23E-01	7.72E-02	8.95E-02	1.60E-01
	40000	1.42E-01		1.40E-01	7.80E-02	9.53E-02	1.80E-01
7157 Å	5000	8.00E-02		7.73E-02	8.64E-02	9.46E-02	1.08E-01
3s−3p	10000	9.62E-02		8.81E-02	7.37E-02	8.15E-02	1.21E-01
$^1D^o - ^1D$	20000	1.20E-01		1.10E-01	7.38E-02	8.32E-02	1.36E-01
	40000	1.49E-01		1.41E-01	7.59E-02	8.97E-02	1.53E-01
3947 Å	5000	9.06E-02	8.69E-02	9.01E-02	6.70E-02	8.19E-02	1.47E-01
3s−4p	10000	1.25E-01	1.07E-01	1.10E-01	7.94E-02	1.01E-01	1.65E-01
$^5S^o - ^5P$	20000	1.64E-01	1.33E-01	1.37E-01	1.02E-01	1.26E-01	1.85E-01
	40000	1.97E-01	1.63E-01	1.67E-01	1.32E-01	1.54E-01	2.08E-01
4368 Å	5000	1.17E-01	1.16E-01	1.16E-01	–	–	1.88E-01
3s−4p	10000	1.60E-01	1.42E-01	1.41E-01	–	–	2.11E-01
$^3S^o - ^3P$	20000	2.14E-01	1.78E-01	1.75E-01	–	–	2.37E-01
	40000	2.62E-01	2.20E-01	2.17E-01	–	–	2.66E-01
5330 Å	5000	5.96E+00	*5.04E+00	*5.12E+00	–	–	4.98E+00
3p−5d	10000	5.84E+00	*4.87E+00	*5.01E+00	–	–	5.59E+00
$^5P - ^5D^o$	20000	5.54E+00	4.60E+00	4.79E+00	–	–	6.28E+00
	40000	5.08E+00	4.27E+00	4.50E+00	–	–	7.05E+00
5436 Å	5000	1.65E+00	1.53E+00	1.44E+00	–	–	2.11E+00
3p−6s	10000	2.00E+00	1.53E+00	1.53E+00	–	–	2.37E+00
$^5P - ^5S^o$	20000	2.40E+00	1.65E+00	1.65E+00	–	–	2.66E+00
	40000	2.68E+00	1.87E+00	1.87E+00	–	–	2.99E+00

Although we have used the same database (TOPBase), it can be noticed that the widths and shifts calculated in the present work are not exactly the same as in the preceding one. This is due to a number of perturbing levels which were smaller in the previous work. One can see from Table 1 that the widths W_e(G) are twenty to thirty per cent different from our TOPbase-SCP values and W_e(VALD) can differ by a factor of two in most cases from ours.

In Table 2, we present our new calculations of the electron impact shifts. d_e(TOPbase) and d_e(NIST-LSJ) correspond respectively to our new calculations using the atomic data from TOPbase and NIST (within a multiplet, only one line, corresponding to the transition with the lowest J values has been taken) compared to our previous results d_e(96) (Ben Nessib *et al.* 1996) and to Griem values d_e(G) (Griem 1974). We also calculate the ion broadening quasistatic parameter A(TOPbase) and A(NIST-LSJ) and compare them to our previous values A(96) and to the Griem 1974 values A(G).

In Table 3, we present our new calculations of the proton impact widths and shifts W_i(TOPbase), d_i(TOPbase), W_i(NIST-LSJ) and d_i(NIST-LSJ) using the atomic input data from TOPbase and NIST, compared to values W_i(96) and d_i(96) from (Ben Nessib *et al.* 1996).

The used reference wavelengths in the tables for the nine lines are from NIST (Kramida *et al.* 2014) and they correspond to the same wavelengths used in Griem's book (Griem 1974) and for the four lines of our previous paper (Ben Nessib *et al.* 1996).

In the tables, data preceded by an asterisk mean that the impact approximation reaches its limit of validity ($0.1 < C_{\rm impact} \leq 0.5$). Cells which only contain an asterisk mean that the impact approximation is not valid, because $C_{\rm impact} > 0.5$ and thus the corresponding data are not provided. In this case the quasistatic approximation should be used (see Ben Nessib *et al.* 1996 for the impact approximation condition definition $C_{\rm impact}$).

Then, using TOPbase energy levels and oscillator strengths, we have studied the influence of the lower cutoff on our electron and ion widths and shifts results. We have compared the results obtained by using the mean radius and mean square radius from the hydrogenic approximation and from the first Cowan atomic structure code RCN (Cowan 1981). We have found that we obtain nearly the same results. So we have not displayed the results obtained with the Cowan code in the present tables. This shows that the choice of the mean radius and of the mean square radius is not very significant for these lines of O I.

By using energy levels and oscillator strengths from NIST with fine structure (LSJ values) or without fine structure (LS values), we have verified that we obtain values with a difference less than the errors of the method of calculation. This was expected because LS coupling is valid and the electronic spin has no time to rotate during collision (see Sahal-Bréchot *et al.* (2014)).

We want to draw attention to the fact that for a reliable result of semiclassical perturbation calculations, we should include for a transition $n_i l_i - n_f l_f$ all perturbing energy levels $n_j l_{j\pm1}, n_{j\pm1} l_{j\pm1}, n_{j\pm2} l_{j\pm1}, j = i, f$ (if their existence is possible). If some of the mentioned perturbing levels are not included, the resulting Stark broadening parameters are underestimated. For example, if for the line 5330 Å we do not include the important levels 5p, 6p and 7p, for $T = 20000$ K instead of W_e(TOPbase) = 4.54 Å, we will obtain the underestimated value

Table 2. Electron impact shifts for an electron density of N_e=10^{16} cm^{-3} and electron temperature from 5000 up to 40000 K. d_e(TOPbase) and d_e(NIST-LSJ) are respectively our new calculations using the atomic input data from TOPbase and NIST for fine structure levels corresponding to the lower J values, d_e(96) are for the precedent calculations (Ben Nessib *et al.* 1996) and d_e(G) are for the Griem values (Griem 1974). Positive shifts are towards the red shifts (larger wavelengths). A(TOPbase) and A(NIST-LSJ) are our new calculations of the quasistatic ion broadening parameter using respectively atomic input data from TOPbase and NIST for fine structure levels corresponding to the lower J values, and A(G) are for the Griem values (Griem 1974). Data preceded by an asterisk mean that the impact approximation reaches its limit of validity, $0.1 < C_{\rm impact} \leq 0.5$, and in cells containing '–' symbol values are missing, since the correct semiclassical perturbation calculation can not be performed due to the absence of important perturbing levels in NIST database (see text for details).

Line	T (K)	d_e(G) (Å)	d_e(96) (Å)	d_e(TOPbase) (Å)	d_e(NIST-LSJ) (Å)	A (G)	A (96)	A(TOP-base)	A(NIST-LSJ)
1304 Å	5000	8.72E-04		9.75E-04	9.49E-04	0.031		0.041	0.040
2p−3s	10000	1.00E-03		1.15E-03	1.11E-03	0.028		0.036	0.036
$^3P - ^3S^o$	20000	1.10E-03		1.30E-03	1.27E-03	0.025		0.033	0.032
	40000	1.10E-03		1.34E-03	1.30E-03	0.023		0.031	0.031
989 Å	5000	4.48E-04		3.95E-04	4.42E-04	0.030		0.034	0.036
2p−3s	10000	5.16E-04		4.00E-04	4.58E-04	0.027		0.033	0.034
$^3P - ^3D^o$	20000	5.66E-04		3.81E-04	4.43E-04	0.024		0.034	0.034
	40000	5.73E-04		3.36E-04	3.93E-04	0.022		0.034	0.034
7773 Å	5000	1.44E-02		1.82E-02	1.83E-02	0.016		0.015	0.017
3s−3p	10000	1.43E-02		1.81E-02	1.83E-02	0.012		0.014	0.015
$^5S^o - ^5P$	20000	1.30E-02		1.35E-02	1.38E-02	0.010		0.011	0.012
	40000	1.08E-02		1.02E-02	1.03E-02	0.008		0.009	0.010
8227 Å	5000	−3.10E-03		−6.60E-04	−3.81E-02	0.005		0.016	0.030
3s−3p	10000	−3.67E-03		2.10E-03	−4.18E-02	0.004		0.015	0.027
$^3D^o - ^3D$	20000	−4.50E-03		2.45E-03	−4.42E-02	0.003		0.014	0.025
	40000	−5.24E-03		2.53E-03	−4.25E-02	0.002		0.013	0.024
7157 Å	5000	4.47E-02		5.14E-02	−3.34E-02	0.035		0.038	0.022
3s−3p	10000	4.87E-02		5.62E-02	−3.90E-02	0.030		0.034	0.025
$^1D^o - ^1D$	20000	4.84E-02		5.58E-02	−4.51E-02	0.026		0.029	0.024
	40000	4.33E-02		4.24E-02	−4.82E-02	0.022		0.024	0.023
3947 Å	5000	−6.80E-03	−1.45E-04	−4.43E-07	−3.39E-04	0.018	0.00	0.017	0.018
3s−4p	10000	−1.72E-02	7.10E-03	7.35E-03	6.77E-03	0.014	0.00	0.015	0.016
$^5S^o - ^5P$	20000	2.98E-02	1.24E-02	1.27E-02	1.19E-02	0.011	0.00	0.013	0.013
	40000	3.97E-02	1.04E-02	1.08E-02	1.02E-02	0.010	0.00	0.011	0.012
4368 Å	5000	3.31E-02	3.72E-02	4.80E-02	–	0.032	0.035	0.036	–
3s−4p	10000	3.56E-02	4.31E-02	5.27E-02	–	0.025	0.031	0.031	–
$^3S^o - ^3P$	20000	3.58E-02	4.44E-02	5.32E-02	–	0.020	0.026	0.027	–
	40000	3.30E-02	3.46E-02	4.14E-02	–	0.018	0.022	0.023	–
5330 Å	5000	2.29E+00	*1.77E+00	*1.78E+00	–	0.282	0.421	0.416	–
3p−5d	10000	1.91E+00	*1.58E+00	*1.57E+00	–	0.286	0.432	0.423	–
$^5P - ^5D^o$	20000	1.53E+00	1.50E+00	1.30E+00	–	0.298	0.452	0.438	–
	40000	1.17E+00	1.33E+00	1.25E+00	–	0.318	0.477	0.459	–
5436 Å	5000	9.21E-01	1.05E+00	1.05E+00	–	0.137	0.152	0.159	–
3p−6s	10000	9.43E-01	1.08E+00	1.08E+00	–	0.118	0.152	0.152	–
$^5P - ^5S^o$	20000	8.76E-01	1.03E+00	1.03E+00	–	0.104	0.144	0.144	–
	40000	7.47E-01	8.27E-01	8.26E-01	–	0.095	0.131	0.131	–

Table 3. Proton impact widths and shifts for an electron density of $N_e = 10^{16}$ cm^{-3} and electron temperature from 5000 up to 40000 K. W_i(TOPbase) and d_i(TOPbase) are our new proton impact widths and shifts calculations using the atomic input data from TOPbase, W_i(NIST-LSJ) and d_i (NIST-LSJ) are our new proton widths and shifts calculations using the atomic input data from NIST for fine structure levels corresponding to the lower J values, $W_i(96)$ and $d_i(96)$ are for the precedent calculations (Ben Nessib *et al.* 1996). Positive shifts are towards the red shifts (larger wavelengths). Data preceded by an asterisk mean that the impact approximation reach its limit of validity, $0.1 < C_{\rm impact} \leq 0.5$, and cells which only contain an asterisk mean that the impact approximation is not valid, because $C_{\rm impact} > 0.5$, and in cells containing '–' symbol values are missing, since the correct semiclassical perturbation calculation can not be performed due to the absence of important perturbing levels in NIST database (see text for details).

Line	T (K)	$W_i(96)$ (Å)	W_i(TOPbase) (Å)	W_i(NIST-LSJ) (Å)	$d_i(96)$ (Å)	d_i(TOPbase) (Å)	d_i(NIST-LSJ) (Å)
1304 Å	5000		2.93E-04	2.84E-04		2.66E-04	2.59E-04
2p−3s	10000		3.29E-04	3.19E-04		3.03E-04	2.95E-04
$^3P - ^3S^o$	20000		3.69E-04	3.58E-04		3.43E-04	3.34E-04
	40000		4.14E-04	4.02E-04		3.87E-04	3.77E-04
989 Å	5000		1.71E-04	1.42E-04		1.53E-04	1.30E-04
2p−3s	10000		1.94E-04	1.60E-04		1.75E-04	1.47E-04
$^3P - ^3D^o$	20000		2.23E-04	1.81E-04		1.98E-04	1.67E-04
	40000		2.60E-04	2.06E-04		2.23E-04	1.88E-04
7773 Å	5000		3.13E-02	2.45E-02		4.97E-03	4.81E-03
3s−3p	10000		3.14E-02	2.46E-02		5.64E-03	5.46E-03
$^5S^o - ^5P$	20000		3.15E-02	2.47E-02		6.37E-03	6.17E-03
	40000		3.16E-02	2.48E-02		7.18E-03	6.96E-03
8227 Å	5000		3.62E-02	2.82E-02		−8.31E-03	−1.08E-02
3s−3p	10000		3.66E-02	2.88E-02		−9.45E-03	−1.23E-02
$^3D^o - ^3D$	20000		3.73E-02	2.95E-02		−1.07E-02	−1.39E-02
	40000		3.85E-02	3.06E-02		−1.21E-02	−1.57E-02
7157 Å	5000		2.94E-02	2.95E-02		1.33E-02	−9.15E-03
3s−3p	10000		3.02E-02	2.98E-02		1.52E-02	−1.04E-02
$^1D^o - ^1D$	20000		3.13E-02	3.02E-02		1.73E-02	−1.18E-02
	40000		3.25E-02	3.07E-02		1.95E-02	−1.34E-02
3947 Å	5000	3.44E-02	3.90E-02	3.34E-02	−3.15E-02	−4.89E-03	−4.73E-03
3s−4p	10000	3.51E-02	3.93E-02	3.36E-02	−3.65E-02	−5.60E-03	−5.42E-03
$^5S^o - ^5P$	20000	3.54E-02	3.94E-02	3.38E-02	−4.18E-02	−6.37E-03	−6.16E-03
	40000	3.55E-02	3.96E-02	3.40E-02	−4.76E-02	−7.21E-03	−6.98E-03
4368 Å	5000	5.17E-02	4.85E-02	–	7.32E-02	1.16E-02	–
3s−4p	10000	5.30E-02	4.91E-02	–	8.62E-02	1.34E-02	–
$^3S^o - ^3P$	20000	5.36E-02	4.96E-02	–	9.96E-02	1.53E-02	–
	40000	5.38E-02	5.02E-02	–	1.14E-01	1.74E-02	–
5330 Å	5000	*	*	*	*	*	
3p−5d	10000	*	*	*	*	*	
$^5P - ^5D^o$	20000	*	*	*	*	*	
	40000	*	*	*	*	*	
5436 Å	5000	*1.98E-01	*	–	*1.03E-01	*	–
3p−6s	10000	2.25E-01	*	–	1.52E-01	*	–
$^5P - ^5S^o$	20000	2.53E-01	*3.83E-01	–	1.96E-01	*3.19E-01	–
	40000	2.84E-01	*4.30E-01	–	2.38E-01	*3.76E-01	–

W_e(TOPbase) = 1.64 Å. For this reason, the values of the Stark widths NIST-LS and NIST-LSJ of the 4368 Å, 5330 Å and 5436 Å lines are not shown in Table 1. For them there is a lack of some perturbing levels in the NIST database which are needed for a reliable SCP calculation.

We present the different results of the electron total impact widths and shifts and ion broadening parameters for the standard electron density of 10^{16} cm^{-3} and for 4 different electron temperatures in the range from 5000 K to 40000 K.

All these data will be put in STARK-B database (Sahal-Bréchot *et al.* 2015). It is a part of VAMDC (Virtual Atomic and Molecular Data Centre, Dubernet *et al.* 2010, Rixon *et al.* 2011), which is an European Union funded collaboration between groups involved in the generation and use of atomic and molecular data.

3. Conclusions

By using atomic data from TOPbase and NIST, and the SCP method and code of Sahal-Bréchot, we have calculated electron and proton impact widths and shifts and quasistatic ion broadening parameters for nine lines of neutral oxygen and compared them with our previous calculations for four lines and with the values from Griem's (1974) book and VALD data.

For calculating Stark broadening parameters, we need energy levels and oscillator strengths. For that, we recommend the atomic data using the NIST-LSJ. If they do not exist or if some levels are missing in NIST, we recommend the use of TOPbase atomic database. We notice that it is a bad idea to complete missing atomic data by data coming from another method, because the oscillator strengths sum rules can be violated and this leads to bad widths and shifts results. In addition, we need the values of $\langle r^2 \rangle$ for the initial and final levels of the transition forming the studied line, and we need the values of $\langle r \rangle$ for all atomic energy levels involved in the calculation (initial, final and perturbing levels). We recommend the use of $\langle r \rangle$ and $\langle r^2 \rangle$ calculated by means of the RCN Cowan code. Concerning the Stark broadening data displayed in the VALD database, they can be used if there is no more reliable calculations, mainly for astrophysical applications using a great number of data, where accuracy of these parameters is not important.

The results obtained here for Stark broadening parameters of neutral oxygen lines will be included in our database STARK-B (Sahal-Bréchot *et al.* 2015).

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