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Triply ionized Molybdenum lines in the spectra of the DA-type and the DO-type white dwarfs

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Abstract. Molybdenum is trans-iron element and the most serious problem for the determination of these element abundances is the lack of atomic data. Investigations of the spectrum of the white dwarf RE 0503-289 indicate the presence of lines of multiply ionized elements such as Ga, Kr, Mo and Xe. Extreme overabundances of trans-iron elements are seen in DO white dwarfs, in a temperature range from 49500 K up to 70000 K. In this context, we have considered the lines of triply ionized molybdenum in the spectra of white dwarfs, especially of DA and DO type. Differences in the contributions of spectral line broadening for two different types of white dwarfs are due to different physical conditions, since effective temperatures and surface gravities are different. More than ten 5s - 5p transitions of Mo IV of interest for the calculation of Stark broadening parameters, width and shift, were selected. A simple modified semi-empirical approach by Dimitrijević and Konjević, 1987 was applied. The obtained results may be particularly useful for determination of molybdenum abundances in white dwarfs and for laboratory plasma diagnostics.

Key words: Stark broadening – line profiles – atomic data

1. Introduction

Our knowledge of the abundance of heavy elements in the atmospheres of white dwarfs is not complete. List of elements found in their atmospheres is limited both to those that are naturally rich and to elements with dominant ionization states, which have otherwise strong resonance lines. Analysis of heavy elements in atmospheres of many hot white dwarfs is a demanding and extensive task that necessarily uses all valid parameters obtained in the laboratory as well as theoretical calculations using valid and recognized methods. Therefore, the parameters of the Stark broadening are of great importance for stellar spectroscopy.

In Werner et al. (2012) has been reported the first detection of the noble gases krypton and xenon in a white dwarf. These observations, carried out with the Far Ultraviolet Spectroscopic Explorer, have detected the lines of krypton VI - VII and xenon VI - VII in the ultraviolet spectrum of a hot white dwarf of the type DO with the name RE 0503-289. This star is a hot DO type WD with effective temperature of 70,000 K Dreizler & Werner (1996). Its spectrum is extraordinarily rich in unidentified absorption lines that are not observed in any other WD. Also, they discovered photospheric lines from other multiply ionized elements of the trans-iron group, namely Ga, Ge, As, Se, Mo, Sn, Te and I, of which gallium and molybdenum are new discoveries in white dwarfs as well. In the NIST database can be found 10 Mo VI lines from the FUSE spectral range as it is presented from observations in Werner et al. (2012). During this research were detected the four lines with the highest relative intensity: with wavelengths 995.811, 1038.642, 1047.184, 1182.143 Å and three of them have the largest gf values. It should be noted as well that this element was not detected before in a white dwarfs.

Many heavy elements, such as Ga, Ge, Sn and Pb, have been identified in sdB and sdOB stars by O'Toole (2004) and O'Toole & Heber (2007). In Vennes et al. (2005) was reported the observation of Ge in three H atmospheres of white dwarfs, spectral type DA, where the average abundance is nearly solar. Chayer et al. (2005) reported many heavy elements and molybdenium in the atmospheres of white dwarf, spectral type DO.

New determination of photospheric Mo abundances are obtained by Rauch et al. (2016) from spetral analysis of two type white dwarf, DA and DO. It was identified 12 Mo V and 9 Mo VI lines in the UV spectrum of RE 0503-289 and measured a photospheric Mo abundance of 1.2-3.0 x 10^{-4} (mass fraction, 22 500-56 400 times the solar abundance).

2. Method

We used a simplified modified semiempirical method by Dimitrijević & Konjević (1987), designed for Stark broadening of isolated spectral lines of singly and multiply charged ions in plasma. A more accurate semiclassical perturbation method by Sahal-Bréchot (1969a,b), Sahal-Bréchot et al. (2014) is not applicable in an adequate way due to the lack of a sufficient set of atomic data. It means that there is no data on the entire energy level scheme needed for calculations. The good knowledge on closest perturber levels for both initial and final states for the transition is crucial. The insufficient set of atomic energy levels is an obstacle for application of more precise methods, so the simplified formula was the preferred and only possible method to be used in the described case of the considered Mo IV lines. Full width at half intensity maximum follows the expression given by Dimitrijević & Konjević (1987):

$$w_{smse} = C_{fw} \frac{\lambda^2 N}{\sqrt{T}} \left(0.9 - \frac{1.1}{Z}\right) \sum_{k=i,f} \left(\frac{3n^*_{l_k}}{2Z}\right)^2 \left({n^*_{l_k}}^2 - {l_k}^2 - l_k - 1\right) \qquad (1)$$

where wavelength λ is given in [m], perturber density N in [m^{-3}], temperature T in [K], constant $C_{fw} = 2.21577 \times 10^{-20}$ m^{2}K$^{1/2}$, and full width at half intensity of maximum w_{smse} is in [m]. Initial atomic energy level is denoted by i, and the final with f $(k = i, f)$. Z denotes ion residual charges: $Z = 1$ for neutral, $Z = 2$ for singly ionized, $Z = 3$ for doubly ionized, etc. Effective principal quantum number is labelled $n^*_{l_k}$, where l_k $(k = i, f)$ represents orbital angular momentum quantum number.

Formula used for Stark shift calculation depends on the case. If for transitions with $\Delta n = 0$ all levels with angular momenta $\ell \pm 1$ exist (where n denotes main principal number), summing all the allowed transitions gives the following formula for the shift:

$$d^{(1)}_{smse} \approx C_{sh} \frac{\lambda^2 N}{\sqrt{T}} (0.9 - \frac{1.1}{Z}) \frac{9}{4Z^2} S_1 \tag{2}$$

where $C_{sh} = 1.1076 \times 10^{-20}$ m^{2}K$^{1/2}$ and

$$S_1 = \sum_{k=i,f} \frac{{n^*_{l_k}}^2 \epsilon_k}{2l_k + 1} ({n^*_{l_k}}^2 - 3{l_k}^2 - 3l_k - 1) \tag{3}$$

In the general case, we can determine the shift with:

$$d^{(2)}_{smse} \approx C_{sh} \frac{\lambda^2 N}{\sqrt{T}} (0.9 - \frac{1.1}{Z}) \frac{9}{4Z^2} S_2 \tag{4}$$

where

$$S_2 = \sum_{k=i,f} \frac{{n^*_{l_k}}^2 \epsilon_k}{2l_k + 1} [(l_k + 1)[{n^*_{l_k}}^2 - (l_k + 1)^2] - l_k({n^*_{l_k}}^2 - l_k^2)] \tag{5}$$

where $\epsilon_k = +1$ for $k = i$ and $\epsilon_k = -1$ for $k = f$.

In order to calculate averaged energies, we can use the expression:

$$E = \frac{\sum_J (2J + 1) E_J}{\sum_J (2J + 1)} \tag{6}$$

where E represents averaged energy, E_J energy level and J total angular momentum of a particular energy level.

3. Results and Discussion

Within the framework of this study, we added molybdenum to the elements of heavy metals as a continuation of the previously discussed elements: iridium Simić et al. (2021), rhodium Simić & Sakan (2021), rhenium Simić et al. (2023). The parameters of Stark broadening, widths and shifts, have been obtained for

27 spectral lines of Mo IV. In this case, all the conditions for the application of the simplified modified semi-empirical method are met.

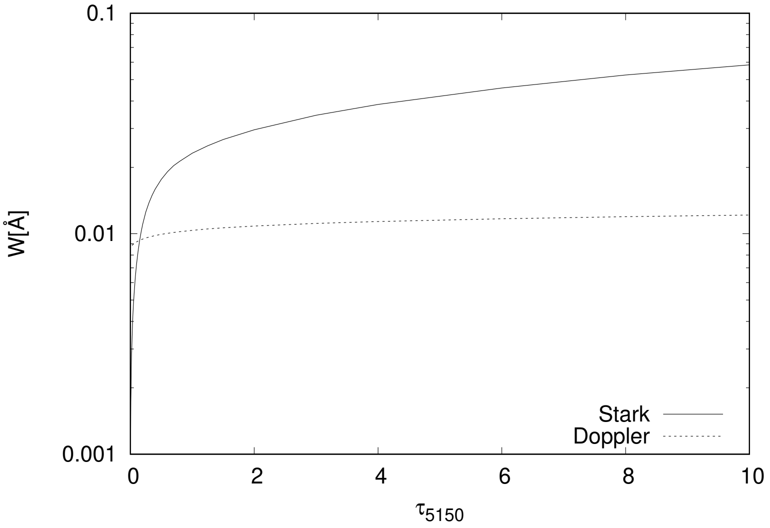

Figure 1. Dependence of electron-impact FWHM and thermal Doppler width on optical depth (τ_{5150}) in the DA White Dwarf atmosphere for Mo IV 5s ^{4}F$_{5/2}$ - 5p ^{4}F$^o_{7/2}$ (λ = 1886 Å) spectral line. Model of DA white dwarf atmosphere Wickramasinghe (1972) is with T_{eff} =15000 K and log g = 8.

Our calculations are performed for an electron density of 10^{17} cm^{-3} and temperatures from 5000 K to 80000 K. The energy levels are taken from Moore (1971). These results for Mo IV spectral lines are presented in Table 1. The first column presents transitions with calculated Ritz wavelengths, which are different from the experimental ones. The corresponding data for the Stark width and shift of a respective Mo IV line are given in Å, and Stark width and shift in angular frequency units in the next two columns, obtained using the formula:

$$W = \frac{\lambda^2}{2\pi c} W\,[\mathrm{s}^{-1}] \qquad \left(d = \frac{\lambda^2}{2\pi c} d\,[\mathrm{s}^{-1}]\right) \tag{7}$$

where c is the light speed. The last column gives 3kT/2ΔE, where ΔE is the energy difference between the nearest perturbing level and the closest of the initial and final levels. The expression 3kT/2ΔE must be less than or equal to two for the method to be valid.

For all considered spectral lines of Mo IV the LS coupling is valid. All notations for atomic energy levels are taken from Moore (1971); Reader et al. (1980); Ralchenko et al. (2005) and NIST database.

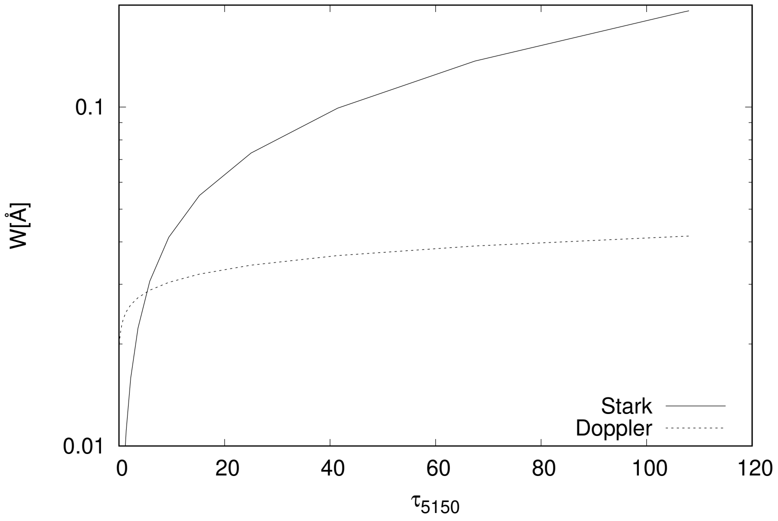

Figure 2. Stark and Doppler widths for Mo IV 5s $^4F_{5/2}$ - 5p $^4F^o_{7/2}$ ($\lambda = 1886$ Å) spectral line as a function of Rosseland optical depth (τ). This atmospheric model for DO type of WD (Wesemael, 1981) include parameters with surface gravity log $g = 6$ and $T_{eff} = 80\ 000$ K.

For correction of widths and shifts for differences due to the difference of experimental (λ_e) and theoretical wavelength or to these differences within a multiplet, one can use the expression:

$$W_e = (\lambda_e/\lambda)^2 W \qquad (d_e = (\lambda_e/\lambda)^2 d) \tag{8}$$

where W_e and d_e are the width and shift for an experimental λ_e, and λ is a theoretical wavelength, with corresponding W and d (the width and shift) in Table 1.

We choose one of Mo IV spectral lines, 5s $^4F_{5/2}$ - 5p $^4F^o_{7/2}$ ($\lambda = 1886$ Å) and we tested how Stark and Doppler width change in a stellar atmosphere with the optical depth. We used the stellar model atmospheres for DA type of white dwarfs with parameters log $g = 8$ and $T_{eff} = 15000$ K Wickramasinghe (1972) and results are presented in Fig.1.

In the introduction of this work, we marked that spectral lines of highly charged molybdenum ions (Mo IV - Mo VII) have been observed in DO white

Table 1. Stark broadening parameters Full Widths at Half Intensity Maximum (W) and shifts (d) for Mo IV spectral lines, for a perturber density of 10^{17} cm^{-3} and temperatures from 5 000 K to 80 000 K.

Transition	T(K)	W$_e$(Å)	d$_e$(Å)	W[s^{-1}]	d[s^{-1}]	3kT/2ΔE
5s - 5p ^{4}F$_{3/2}$ - ^{4}F$^o_{3/2}$ 1966.04 Å	5000	0.8559D-01	-0.1815D-01	0.4171D+12	-0.8847D+11	0.103
	10000	0.6052D-01	-0.1284D-01	0.2949D+12	-0.6256D+11	0.205
	20000	0.4279D-01	-0.9077D-02	0.2085D+12	-0.4423D+11	0.410
	40000	0.3026D-01	-0.6419D-02	0.1475D+12	-0.3128D+11	0.820
	80000	0.2140D-01	-0.4539D-02	0.1043D+12	-0.2212D+11	1.640
5s - 5p ^{4}F$_{3/2}$ - 5p ^{4}F$^o_{5/2}$ 1922.01 Å	5000	0.8242D-01	-0.1728D-01	0.4202D+12	-0.8810D+11	0.100
	10000	0.5828D-01	-0.1222D-01	0.2972D+12	-0.6230D+11	0.200
	20000	0.4121D-01	-0.8639D-02	0.2101D+12	-0.4405D+11	0.401
	40000	0.2914D-01	-0.6109D-02	0.1486D+12	-0.3115D+11	0.802
	80000	0.2060D-01	-0.4319D-02	0.1051D+12	-0.2202D+11	1.603
5s - 5p ^{4}F$_{5/2}$ - ^{4}F$^o_{3/2}$ 1994.67 Å	5000	0.8835D-01	-0.1881D-01	0.4183D+12	-0.8906D+11	0.104
	10000	0.6247D-01	-0.1330D-01	0.2958D+12	-0.6297D+11	0.208
	20000	0.4417D-01	-0.9405D-02	0.2091D+12	-0.4453D+11	0.416
	40000	0.3123D-01	-0.6651D-02	0.1479D+12	-0.3149D+11	0.832
	80000	0.2209D-01	-0.4703D-02	0.1046D+12	-0.2226D+11	1.664
5s - 5p ^{4}F$_{5/2}$ - ^{4}F$^o_{5/2}$ 1949.35 Å	5000	0.8501D-01	-0.1789D-01	0.4214D+12	-0.8869D+11	0.102
	10000	0.6011D-01	-0.1265D-01	0.2980D+12	-0.6271D+11	0.203
	20000	0.4251D-01	-0.8946D-02	0.2107D+12	-0.4434D+11	0.407
	40000	0.3006D-01	-0.6325D-02	0.1490D+12	-0.3136D+11	0.813
	80000	0.2125D-01	-0.4473D-02	0.1054D+12	-0.2217D+11	1.626
5s - 5p ^{4}F$_{5/2}$ - ^{4}F$^o_{7/2}$ 1886.85 Å	5000	0.8054D-01	-0.1666D-01	0.4261D+12	-0.8813D+11	0.098
	10000	0.5695D-01	-0.1178D-01	0.3013D+12	-0.6232D+11	0.197
	20000	0.4027D-01	-0.8329D-02	0.2131D+12	-0.4407D+11	0.394
	40000	0.2847D-01	-0.5889D-02	0.1507D+12	-0.3116D+11	0.787
	80000	0.2013D-01	-0.4164D-02	0.1065D+12	-0.2203D+11	1.574
5s - 5p ^{4}F$_{7/2}$ - ^{4}F$^o_{5/2}$ 1991.37 Å	5000	0.8909D-01	-0.1886D-01	0.4232D+12	-0.8957D+11	0.104
	10000	0.6299D-01	-0.1333D-01	0.2992D+12	-0.6333D+11	0.208
	20000	0.4454D-01	-0.9428D-02	0.2116D+12	-0.4478D+11	0.415
	40000	0.3150D-01	-0.6666D-02	0.1496D+12	-0.3167D+11	0.831
	80000	0.2227D-01	-0.4714D-02	0.1058D+12	-0.2239D+11	1.661
5s - 5p ^{4}F$_{7/2}$ - ^{4}F$^o_{7/2}$ 1926.19 Å	5000	0.8428D-01	-0.1753D-01	0.4279D+12	-0.8901D+11	0.100
	10000	0.5959D-01	-0.1240D-01	0.3026D+12	-0.6294D+11	0.201
	20000	0.4214D-01	-0.8766D-02	0.2139D+12	-0.4451D+11	0.402
	40000	0.2980D-01	-0.6199D-02	0.1513D+12	-0.3147D+11	0.803
	80000	0.2107D-01	-0.4383D-02	0.1070D+12	-0.2225D+11	1.607
5s - 5p ^{4}F$_{7/2}$ - ^{4}F$^o_{9/2}$ 1877.81 Å	5000	0.8081D-01	-0.1658D-01	0.4317D+12	-0.8856D+11	0.098
	10000	0.5714D-01	-0.1172D-01	0.3052D+12	-0.6262D+11	0.196
	20000	0.4040D-01	-0.8290D-02	0.2158D+12	-0.4428D+11	0.392
	40000	0.2857D-01	-0.5862D-02	0.1526D+12	-0.3131D+11	0.783
	80000	0.2020D-01	-0.4145D-02	0.1079D+12	-0.2214D+11	1.567
5s - 5p ^{4}F$_{9/2}$ - ^{4}F$^o_{7/2}$ 1997.14 Å	5000	0.8925D-01	-0.1870D-01	0.4301D+12	-0.9011D+11	0.103
	10000	0.6311D-01	-0.1322D-01	0.3041D+12	-0.6372D+11	0.206
	20000	0.4463D-01	-0.9350D-02	0.2150D+12	-0.4506D+11	0.412
	40000	0.3156D-01	-0.6612D-02	0.1521D+12	-0.3186D+11	0.825
	80000	0.2231D-01	-0.4675D-02	0.1075D+12	-0.2253D+11	1.649
5s - 5p ^{4}F$_{9/2}$ - ^{4}F$^o_{9/2}$ 1926.21 Å	5000	0.8546D-01	-0.1766D-01	0.4339D+12	-0.8967D+11	0.100
	10000	0.6043D-01	-0.1249D-01	0.3068D+12	-0.6340D+11	0.201
	20000	0.4273D-01	-0.8831D-02	0.2169D+12	-0.4483D+11	0.402
	40000	0.3022D-01	-0.6244D-02	0.1534D+12	-0.3170D+11	0.803
	80000	0.2137D-01	-0.4415D-02	0.1085D+12	-0.2242D+11	1.607

Table 1. Continued

Transition	T(K)	W_e(Å)	d_e(Å)	W[s^{-1}]	d[s^{-1}]	3kT/2ΔE
5s - 5p $^2F_{5/2}$ - $^2F^o_{5/2}$ 2231.80 Å	5000	0.1156D+00	-0.2505D-01	0.4371D+12	-0.9472D+11	0.116
	10000	0.8173D-01	-0.1771D-01	0.3091D+12	-0.6697D+11	0.233
	20000	0.5779D-01	-0.1252D-01	0.2185D+12	-0.4736D+11	0.465
	40000	0.4086D-01	-0.8855D-02	0.1545D+12	-0.3349D+11	0.931
	80000	0.2889D-01	-0.6261D-02	0.1093D+12	-0.2368D+11	1.862
5s - 5p $^2F_{5/2}$ - $^2F^o_{7/2}$ 2146.66 Å	5000	0.1082D+00	-0.2303D-01	0.4421D+12	-0.9413D+11	0.112
	10000	0.7647D-01	-0.1628D-01	0.3126D+12	-0.6656D+11	0.224
	20000	0.5408D-01	-0.1151D-01	0.2210D+12	-0.4706D+11	0.448
	40000	0.3824D-01	-0.8141D-02	0.1563D+12	-0.3328D+11	0.895
	80000	0.2704D-01	-0.5757D-02	0.1105D+12	-0.2353D+11	1.791
5s - 5p $^2F_{7/2}$ - $^2F^o_{5/2}$ 2345.95 Å	5000	0.1288D+00	-0.2824D-01	0.4410D+12	-0.9667D+11	0.122
	10000	0.9110D-01	-0.1997D-01	0.3118D+12	-0.6835D+11	0.245
	20000	0.6442D-01	-0.1412D-01	0.2205D+12	-0.4833D+11	0.489
	40000	0.4555D-01	-0.9985D-02	0.1559D+12	-0.3418D+11	0.979
	80000	0.3221D-01	-0.7061D-02	0.1102D+12	-0.2417D+11	1.957
5s - 5p $^2F_{7/2}$ - $^2F^o_{7/2}$ 2252.05 Å	5000	0.1201D+00	-0.2587D-01	0.4460D+12	-0.9608D+11	0.117
	10000	0.8491D-01	-0.1829D-01	0.3154D+12	-0.6794D+11	0.235
	20000	0.6004D-01	-0.1293D-01	0.2230D+12	-0.4804D+11	0.470
	40000	0.4246D-01	-0.9146D-02	0.1577D+12	-0.3397D+11	0.939
	80000	0.3002D-01	-0.6467D-02	0.1115D+12	-0.2402D+11	1.879
5s - 5p $^4F_{3/2}$ - $^4D^o_{1/2}$ 1821.72 Å	5000	0.7545D-01	-0.1536D-01	0.4282D+12	-0.8716D+11	0.095
	10000	0.5335D-01	-0.1086D-01	0.3028D+12	-0.6163D+11	0.190
	20000	0.3772D-01	-0.7678D-02	0.2141D+12	-0.4358D+11	0.380
	40000	0.2668D-01	-0.5429D-02	0.1514D+12	-0.3081D+11	0.760
	80000	0.1886D-01	-0.3839D-02	0.1071D+12	-0.2179D+11	1.520
5s - 5p 5s $^4F_{3/2}$ - 5p $^4D^o_{3/2}$ 1795.73 Å	5000	0.7370D-01	-0.1487D-01	0.4305D+12	-0.8689D+11	0.094
	10000	0.5212D-01	-0.1052D-01	0.3044D+12	-0.6144D+11	0.187
	20000	0.3685D-01	-0.7437D-02	0.2153D+12	-0.4344D+11	0.375
	40000	0.2606D-01	-0.5259D-02	0.1522D+12	-0.3072D+11	0.749
	80000	0.1843D-01	-0.3719D-02	0.1076D+12	-0.2172D+11	1.498
5s - 5p 5s $^4F_{5/2}$ - $^4D^o_{3/2}$ 1819.58 Å	5000	0.7588D-01	-0.1538D-01	0.4317D+12	-0.8747D+11	0.095
	10000	0.5365D-01	-0.1087D-01	0.3053D+12	-0.6185D+11	0.190
	20000	0.3794D-01	-0.7688D-02	0.2158D+12	-0.4374D+11	0.379
	40000	0.2683D-01	-0.5436D-02	0.1526D+12	-0.3093D+11	0.759
	80000	0.1897D-01	-0.3844D-02	0.1079D+12	-0.2187D+11	1.518
5s - 5p $^4F_{5/2}$ - $^4D^o_{5/2}$ 1819.51 Å	5000	0.7587D-01	-0.1537D-01	0.4317D+12	-0.8747D+11	0.095
	10000	0.5365D-01	-0.1087D-01	0.3053D+12	-0.6185D+11	0.190
	20000	0.3794D-01	-0.7687D-02	0.2159D+12	-0.4374D+11	0.379
	40000	0.2683D-01	-0.5435D-02	0.1526D+12	-0.3093D+11	0.759
	80000	0.1897D-01	-0.3843D-02	0.1079D+12	-0.2187D+11	1.518
5s - 5p $^4F_{5/2}$ - $^4D^o_{7/2}$ 1771.35 Å	5000	0.7264D-01	-0.1448D-01	0.4361D+12	-0.8695D+11	0.092
	10000	0.5136D-01	-0.1024D-01	0.3084D+12	-0.6149D+11	0.185
	20000	0.3632D-01	-0.7242D-02	0.2180D+12	-0.4348D+11	0.369
	40000	0.2568D-01	-0.5121D-02	0.1542D+12	-0.3074D+11	0.739
	80000	0.1816D-01	-0.3621D-02	0.1090D+12	-0.2174D+11	1.478
5s - 5p $^4F_{7/2}$ - $^4D^o_{5/2}$ 1856.06 Å	5000	0.7927D-01	-0.1616D-01	0.4335D+12	-0.8835D+11	0.097
	10000	0.5606D-01	-0.1143D-01	0.3065D+12	-0.6247D+11	0.194
	20000	0.3964D-01	-0.8079D-02	0.2167D+12	-0.4418D+11	0.387
	40000	0.2803D-01	-0.5713D-02	0.1533D+12	-0.3124D+11	0.774
	80000	0.1982D-01	-0.4040D-02	0.1084D+12	-0.2209D+11	1.548

Table 1. Continued

Transition	T(K)	W_e(Å)	d_e(Å)	W[s^{-1}]	d[s^{-1}]	3kT/2ΔE
5s -5p $^4F_{7/2}$ - $^4D^o_{7/2}$ 1805.98 Å	5000	0.7581D-01	-0.1521D-01	0.4378D+12	-0.8783D+11	0.094
	10000	0.5361D-01	-0.1075D-01	0.3096D+12	-0.6211D+11	0.188
	20000	0.3791D-01	-0.7604D-02	0.2189D+12	-0.4392D+11	0.377
	40000	0.2680D-01	-0.5377D-02	0.1548D+12	-0.3105D+11	0.753
	80000	0.1895D-01	-0.3802D-02	0.1095D+12	-0.2196D+11	1.507
5s -5p $^4F_{9/2}$ - $^4D^o_{7/2}$ 1850.70 Å	5000	0.8001D-01	-0.1617D-01	0.4400D+12	-0.8893D+11	0.096
	10000	0.5658D-01	-0.1143D-01	0.3112D+12	-0.6289D+11	0.193
	20000	0.4001D-01	-0.8086D-02	0.2200D+12	-0.4447D+11	0.386
	40000	0.2829D-01	-0.5717D-02	0.1556D+12	-0.3144D+11	0.772
	80000	0.2000D-01	-0.4043D-02	0.1100D+12	-0.2223D+11	1.544
5s -5p $^2F_{5/2}$ - $^2D^o_{5/2}$ 2231.79 Å	5000	0.1156D+00	-0.2505D-01	0.4371D+12	-0.9472D+11	0.116
	10000	0.8172D-01	-0.1771D-01	0.3091D+12	-0.6697D+11	0.233
	20000	0.5779D-01	-0.1252D-01	0.2185D+12	-0.4736D+11	0.465
	40000	0.4086D-01	-0.8855D-02	0.1545D+12	-0.3349D+11	0.931
	80000	0.2889D-01	-0.6261D-02	0.1093D+12	-0.2368D+11	1.862
5s -5p $^2F_{5/2}$ - $^2D^o_{7/2}$ 2146.66 Å	5000	0.1082D+00	-0.2303D-01	0.4421D+12	-0.9413D+11	0.112
	10000	0.7647D-01	-0.1628D-01	0.3126D+12	-0.6656D+11	0.224
	20000	0.5408D-01	-0.1151D-01	0.2210D+12	-0.4706D+11	0.448
	40000	0.3824D-01	-0.8141D-02	0.1563D+12	-0.3328D+11	0.895
	80000	0.2704D-01	-0.5757D-02	0.1105D+12	-0.2353D+11	1.791
5s -5p $^2F_{7/2}$ - $^2D^o_{7/2}$ 2252.06 Å	5000	0.1201D+00	-0.2587D-01	0.4460D+12	-0.9608D+11	0.117
	10000	0.8491D-01	-0.1829D-01	0.3154D+12	-0.6794D+11	0.235
	20000	0.6004D-01	-0.1293D-01	0.2230D+12	-0.4804D+11	0.470
	40000	0.4246D-01	-0.9146D-02	0.1577D+12	-0.3397D+11	0.939
	80000	0.3002D-01	-0.6467D-02	0.1115D+12	-0.2402D+11	1.879
5s -5p $^2F_{5/2}$ - $^2G^o_{7/2}$ 2007.05 Å	5000	0.9657D-01	-0.1989D-01	0.4516D+12	-0.9300D+11	0.105
	10000	0.6829D-01	-0.1406D-01	0.3193D+12	-0.6576D+11	0.209
	20000	0.4828D-01	-0.9944D-02	0.2258D+12	-0.4650D+11	0.419
	40000	0.3414D-01	-0.7032D-02	0.1597D+12	-0.3288D+11	0.837
	80000	0.2414D-01	-0.4972D-02	0.1129D+12	-0.2325D+11	1.674
5s - 5p $^2F_{7/2}$ - $^2G^o_{9/2}$ 2028.94 Å	5000	0.1006D+00	-0.2062D-01	0.4605D+12	-0.9435D+11	0.106
	10000	0.7116D-01	-0.1458D-01	0.3256D+12	-0.6672D+11	0.212
	20000	0.5032D-01	-0.1031D-01	0.2302D+12	-0.4718D+11	0.423
	40000	0.3558D-01	-0.7290D-02	0.1628D+12	-0.3336D+11	0.846
	80000	0.2516D-01	-0.5155D-02	0.1151D+12	-0.2359D+11	1.693

dwarfs (Werner et al., 2012) where Stark broadening is usually dominant line broadening mechanism. Here, we used the obtained results to investigate the importance of Stark broadening in DO white dwarf atmospheres. The atmospheric model for DO type of WD (Wesemael, 1981) is for a surface gravity log g = 6 and T_{eff} = 80 000 K. The importance of Stark broadening in DO white dwarf atmospheres is illustrated by comparison of Stark and Doppler line widths in Fig.2.

Our knowledge of the Stark broadening parameters is of great importance for the spectra of White Dwarfs, as we have shown in some of the previous studies Majlinger et al. (2015, 2017); Simić & Sakan (2020); Simić & Sakan (2021), because of all this, the Stark broadening must be taken into consideration when investigating white dwarf atmospheres since our calculations of Mo IV spectral lines show that they are of great importance in DA and DO white dwarf-type atmospheres. Such data are also of interest for investigation, analysis and modelling of stellar, technological and laboratory plasma.

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