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Preliminary report

ESTIMATION OF ELECTRON-IMPACT LINE WIDTHS FOR SINGLY-, DOUBLY- AND TRIPLY-CHARGED VANADIUM IONS

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SUMMARY: In this paper we present the electron-impact widths for 28 transitions of singly-, doubly-, and triply- ionized vanadium estimated by using the modified semiempirical method. The electron-impact widths have been estimated for the electron density of $10^{23}\mathrm{m}^{-3}$ and presented as a function of electron temperature.

1. INTRODUCTION

Lines of vanadium ions are present in stellar and solar plasma (see e.g. Van't Veer-Mennert et al. 1985, Adelman and Lanz 1987, Sadakane and Ueta 1989, Werner et al. 1991, Kocer et al. 1993, etc.) and atomic and spectroscopic data for its ions are of interest for the investigation and modelling of such plasmas. The electron-impact broadening mechanism is the main pressure broadening mechanism in stellar plasma conditions with $T_{eff} \geq 10000$ K, i.e. for plasma present in A and B-type stars photospheres. Also, it has been found that vanadium is overabundant in some A-type stars (see e.g. Van't Veer-Mennert et al. 1985). Moreover, Stark broadening parameters for singly and multiply charged vanadium ion lines are of interest not only for the astrophysical plasma investigations but also for laboratory plasma research, and the testing and developing of the Stark broadening theory for shapes of multicharged ion lines.

The electron-impact line widths and shifts for 14 vanadium II, 8 vanadium III and 30 vanadium IV multiplets have been calculated (Popović and Dimitrijević 1998) within the modified semiempirical method (Dimitrijević and Konjević 1980, Dimitrijević and Kršljanin 1986, Popović and Dimitrijević 1996). Here we present the estimated electron-impact line widths for additional transitions when the needed atomic energy levels are not complete, but exist some reliably determinated members of multiplet or supermultiplet. For such cases the averaged atomic energy levels have been used.

However, one must take into account that the usual average accuracy of the modified semiempirical (MSE) method might not be achieved for such results. Here we present the electron-impact widths for 13 V II, 9 V III and 6 V IV multiplets estimated on the basis of the modified semiemprical method.

2. RESULTS AND DISCUSSION

The atomic energy levels needed for estimations were taken from Bashkin and Stoner (1975). Oscillator strengths have been calculated by using the method of Bates and Damgaard (1949) and the tables of Oertel and Shomo (1968). In the case of all three ions, incomplet energy data for $4f$ levels caused that the MSE method for the electron-impact widths calculation couldn't be applied in the adequate way. Consequnetly, we used the following approximation: on the bases of given energies of $4f$ levels we estimated the averaged enegy ($<E>$) for a multiplet as

$$<E>=\frac{\sum_{i=1}^{N} E_i \cdot (2J_i+1)}{\sum_{i}^{N}(2J_i+1)},$$

where E_i is the energy of level with corresponding J_i.

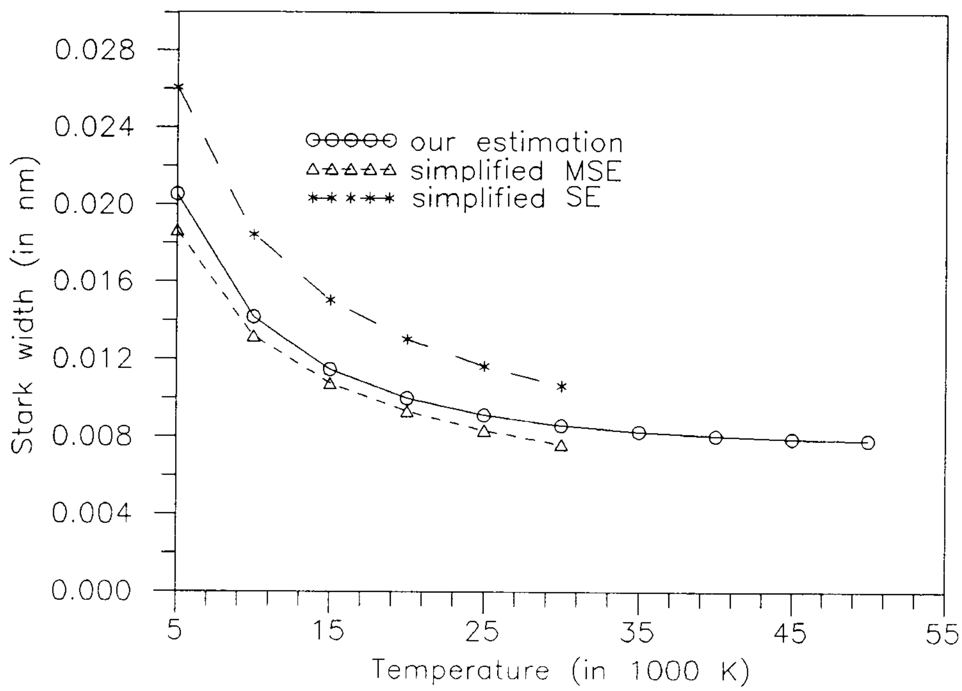

Fig. 1. *Estimated Stark widths (○) for V II $z^5D^0 - e^5P$ ($\overline{\lambda}$=283.26 nm) transition as a function of temperature compared with the results of simplified MSE (Δ) and simplified SE (∗) calculation. The electron density is* $10^{23}\mathrm{m}^{-3}$.

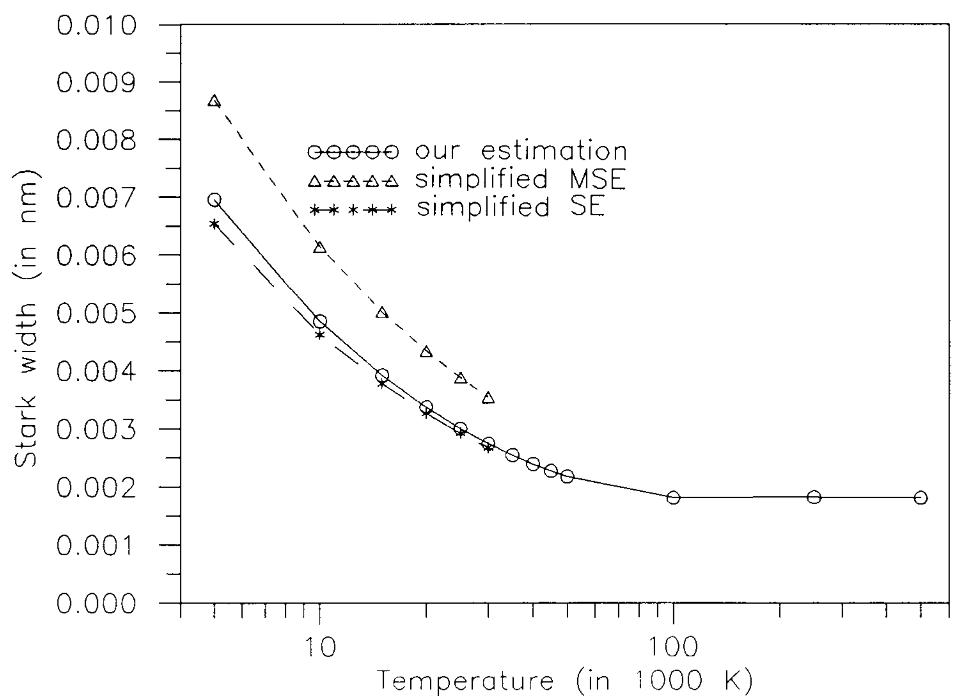

Fig. 2. *Same as in Fig. 1, but for V III $z^4D^0 - e^4P$ ($\overline{\lambda}$=180.00 nm) transition.*

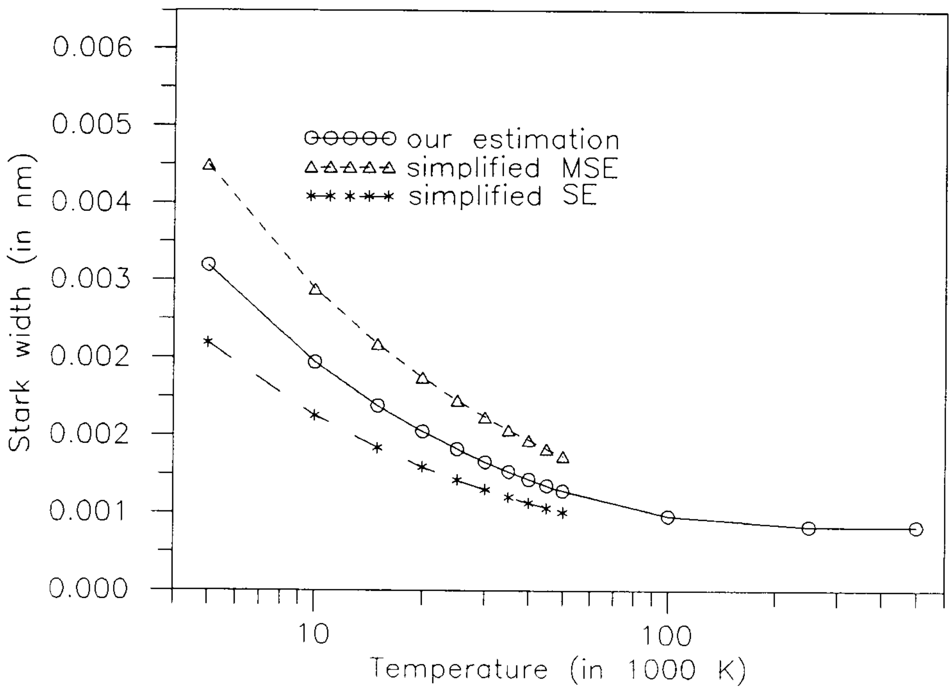

Fig. 3. *Same as in Fig. 1, but for V IV* $z^3P^0 - e^3P$ ($\overline{\lambda}$*=132.98 nm) transition.*

In the case of incomplete levels we took only levels which are given in Bashkin and Stoner (1975), and after that we have varied the averaged energy in an interval of ± 10 % and we have compared the changes of the corresponding Stark widths. Considering that such estimation is taken only for one or two perturbing levels of the upper level in transitions, as a rule we obtained that final results vary slightly (less than ± 5%), i.e. we expect that Stark width error bars are within the frame of the MSE approach accuracy. Moreover, we have compared such calculated widths with the ones obtained by using the simplified MSE – SMSE (Dimitrijević and Konjević 1987) and simplified semiemprical approach – SSE (Griem 1968). In Figs. 1 – 3 Stark widths obtained by our method by using simplified MSE and simplified SE methods are presented.

Stark widths obtained by the described estimation for 13 V II, 9 V III and 6 V IV multiplets as a function of temperature are presented in Table 1. The calculations have been performed for the perturber density of $10^{23}\mathrm{m}^{-3}$.

Table 1. Stark full widths (FWHM – denoted W) of 25 V II – IV multiplets as a function of temperature. The electron density is $10^{23}\mathrm{m}^{-3}$. The averaged wavelength of the multiplet is denoted $\overline{\lambda}$. With an asterisk are denoted values calculated by using the high temperature limit, so that a jump in W value due to the change of the calculation procedure exists.

Transition	T (K)	W (nm)
$z^3D^0 - e^3D$ V II $\overline{\lambda} = 275.58$ nm	5000.	0.185E-01
	10000.	0.128E-01
	20000.	0.905E-02
	30000.	0.784E-02
	40000.	0.741E-02
	50000.	0.726E-02
$z^3D^0 - e^3F$ V II $\overline{\lambda} = 257.04$ nm	5000.	0.183E-01
	10000.	0.126E-01
	20000.	0.903E-02
	30000.	0.795E-02
	40000.	0.757E-02
	50000.	0.746E-02

Transition	T (K)	W (nm)
$z^3F^0 - e^3D$ V II $\overline{\lambda} = 301.77$ nm	5000.	0.232E-01
	10000.	0.160E-01
	20000.	0.113E-01
	30000.	0.980E-02
	40000.	0.923E-02
	50000.	0.903E-02
$z^3F^0 - e^3F$ V II $\overline{\lambda} = 279.68$ nm	5000.	0.298E-01
	10000.	0.222E-01
	20000.	0.185E-01
	30000.	0.178E-01
	40000.	0.175E-01
	50000.	0.169E-01
$z^3F^0 - e^3G$ V II $\overline{\lambda} = 282.38$ nm	5000.	0.224E-01
	10000.	0.155E-01
	20000.	0.110E-01
	30000.	0.968E-02
	40000.	0.919E-02
	50000.	0.904E-02
$z^3G^0 - e^3F$ V II $\overline{\lambda} = 273.52$ nm	5000.	0.283E-01
	10000.	0.211E-01
	20000.	0.176E-01
	30000.	0.169E-01
	40000.	0.167E-01
	50000.	0.161E-01
$z^3G^0 - e^3G$ V II $\overline{\lambda} = 276.11$ nm	5000.	0.212E-01
	10000.	0.147E-01
	20000.	0.105E-01
	30000.	0.918E-02
	40000.	0.872E-02
	50000.	0.858E-02
$z^5D^0 - e^5P$ V II $\overline{\lambda} = 283.26$ nm	5000.	0.205E-01
	10000.	0.142E-01
	20000.	0.100E-01
	30000.	0.860E-02
	40000.	0.806E-02
	50000.	0.784E-02
$z^5D^0 - e^5D$ V II $\overline{\lambda} = 255.96$ nm	5000.	0.181E-01
	10000.	0.125E-01
	20000.	0.898E-02
	30000.	0.794E-02
	40000.	0.760E-02
	50000.	0.751E-02
$z^5D^0 - e^5F$ V II $\overline{\lambda} = 279.55$ nm	5000.	0.205E-01
	10000.	0.142E-01
	20000.	0.100E-01
	30000.	0.861E-02
	40000.	0.808E-02
	50000.	0.787E-02

Transition	T (K)	W (nm)
$z^5F^0 - e^5D$ V II $\overline{\lambda} = 253.32$ nm	5000.	0.178E-01
	10000.	0.123E-01
	20000.	0.882E-02
	30000.	0.780E-02
	40000.	0.746E-02
	50000.	0.737E-02
$z^5F^0 - e^5F$ V II $\overline{\lambda} = 276.40$ nm	5000.	0.201E-01
	10000.	0.139E-01
	20000.	0.981E-02
	30000.	0.845E-02
	40000.	0.792E-02
	50000.	0.771E-02
$z^5G^0 - e^5F$ V II $\overline{\lambda} = 262.25$ nm	5000.	0.174E-01
	10000.	0.120E-01
	20000.	0.848E-02
	30000.	0.732E-02
	40000.	0.688E-02
	50000.	0.671E-02
$z^2F^0 - e^2G$ V III $\overline{\lambda} = 175.92$ nm	5000.	.683E-02
	10000.	.476E-02
	20000.	.330E-02
	50000.	.214E-02
	100000.	.180E-02
	250000.	.183E-02
	500000.	.180E-02
$z^2G^0 - e^2G$ V III $\overline{\lambda} = 188.40$ nm	5000.	.780E-02
	10000.	.543E-02
	20000.	.377E-02
	50000.	.244E-02
	100000.	.205E-02
	500000.	.206E-02*
$z^4D^0 - e^4P$ V III $\overline{\lambda} = 180.00$ nm	5000.	.696E-02
	10000.	.485E-02
	20000.	.337E-02
	50000.	.217E-02
	100000.	.181E-02
	250000.	.182E-02
	500000.	.181E-02
$z^4D^0 - e^4D$ V III $\overline{\lambda} = 190.80$ nm	5000.	.684E-02
	10000.	.476E-02
	20000.	.330E-02
	50000.	.211E-02
	100000.	.175E-02
	250000.	.178E-02
	500000.	.180E-02*

Transition	T (K)	W (nm)
$z^4D^0 - e^4F$ V III $\overline{\lambda} = 172.95$ nm	5000.	.619E-02
	10000.	.431E-02
	20000.	.300E-02
	50000.	.199E-02
	100000.	.172E-02
	250000.	.171E-02
$z^4F^0 - e^4D$ V III $\overline{\lambda} = 183.30$ nm	5000.	.618E-02
	10000.	.430E-02
	20000.	.298E-02
	50000.	.191E-02
	100000.	.159E-02
	250000.	.159E-02
	500000.	.159E-02
$z^4F^0 - e^4F$ V III $\overline{\lambda} = 166.77$ nm	5000.	.565E-02
	10000.	.393E-02
	20000.	.274E-02
	50000.	.182E-02
	100000.	.157E-02
	250000.	.157E-02
	500000.	.157E-02
$z^4F^0 - e^4G$ V III $\overline{\lambda} = 185.47$ nm	5000.	.648E-02
	10000.	.451E-02
	20000.	.313E-02
	50000.	.200E-02
	100000.	.166E-02
	250000.	.168E-02*
	500000.	.170E-02*
$z^4G^0 - e^4F$ V III $\overline{\lambda} = 164.15$ nm	5000.	.583E-02
	10000.	.406E-02
	20000.	.282E-02
	50000.	.187E-02
	100000.	.161E-02
	250000.	.162E-02
	500000.	.159E-02
$z^4G^0 - e^4G$ V III $\overline{\lambda} = 182.24$ nm	5000.	.669E-02
	10000.	.466E-02
	20000.	.323E-02
	50000.	.207E-02
	100000.	.170E-02
	250000.	.171E-02*
	500000.	.171E-02*
$z^1P^0 - e^1S^0$ V IV $\overline{\lambda} = 127.30$ nm	5000.	0.361E-02
	10000.	0.253E-02
	20000.	0.176E-02
	50000.	0.111E-02
	100000.	0.842E-03
	250000.	0.732E-03
	500000.	0.715E-03

Transition	T (K)	W (nm)
$z^1P^0 - e^1P$ V IV $\overline{\lambda} = 160.19$ nm	5000.	0.467E-02
	10000.	0.327E-02
	20000.	0.228E-02
	50000.	0.142E-02
	100000.	0.105E-02
	250000.	0.881E-03
	500000.	0.889E-03
$z^1D^0 - e^1D$ V IV $\overline{\lambda} = 122.65$ nm	5000.	0.285E-02
	10000.	0.200E-02
	20000.	0.139E-02
	50000.	0.871E-03
	100000.	0.655E-03
	250000.	0.564E-03
	500000.	0.559E-03
$z^3P^0 - e^3S$ V IV $\overline{\lambda} = 145.27$ nm	5000.	0.389E-02
	10000.	0.273E-02
	20000.	0.190E-02
	50000.	0.119E-02
	100000.	0.879E-03
	250000.	0.740E-03
	500000.	0.743E-03*
$z^3P^0 - e^3P$ V IV $\overline{\lambda} = 132.98$ nm	5000.	0.336E-02
	10000.	0.235E-02
	20000.	0.164E-02
	50000.	0.102E-02
	100000.	0.770E-03
	250000.	0.664E-03
	500000.	0.661E-03
$z^3D^0 - e^3P$ V IV $\overline{\lambda} = 124.78$ nm	5000.	0.287E-02
	10000.	0.201E-02
	20000.	0.140E-02
	50000.	0.875E-03
	100000.	0.660E-03
	250000.	0.571E-03
	500000.	0.568E-03

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REFERENCES

Adelman, S.J. and Lanz T. eds.: 1987, *Elemental abundance analyses*, the Institut d'Astronomie de l'Université de Lausanne.

Bashkin, S. and Stoner, J.O.Jr.: 1975, *Atomic Energy Levels and Grotrian Diagrams*, Vol. 1, North Holland, Amsterdam.

Bates, D.R. and Damgaard A.: 1949, *Trans. Roy. Soc. London* Ser. A **242**, 101.
Dimitrijević, M.S. and Konjević, N.: 1980, *J. Quant. Spectrosc. Radiat. Transfer*, **24**, 451.
Dimitrijević, M.S. and Kršljanin, V.: 1986, *Astron. Astrophys.* **165**, 269.
Dimitrijević, M.S. and Konjević, N.: 1987, *Astron. Astrophys.* **173**, 345.
Griem, H.R.: 1968, *Phys. Rev.* **165**, 258.
Kocer, D., Adelman, S.J., Bolcal, C. and Mill, G.: 1993, In *Peculiar Versus Normal Phenomena in A-Type and Related Stars* (Eds. M. M. Dworetski, F. Castelli, R. Faraggiana), ASP Conf. Series **44**, 213.
Oertel, G.K. and Shomo, L.P.: 1968, *Astrophys. J. Suppl. Series*, **16**, 175.
Popović, L.Č. and Dimitrijević, M.S.: 1996, *Astron. Astrophys. Supp. Series*, **120**, 373.
Popović, L.Č. and Dimitrijević, M.S.: 1998, *Phys. Scr.* to be published
Sadakane, K. and Ueta, M.: 1989, *Publ. Astron. Soc. Japan*, **41**, 279.
Van't Veer-Mennert, C., Coupry, M.F. and Burkhart, C.: 1985, *Astron. Astrophys.* **146**, 139.
Werner, K., Heber, U. and Hunger, K.: 1991, *Astron. Astrophys.* **244**, 437.

ПРОЦЕНА ШИРИНА ЛИНИЈА УСЛЕД СУДАРА СА ЕЛЕКТРОНИМА ЗА ЈЕДАНПУТ, ДВАПУТ И ТРИПУТ НАЕЛЕКТРИСАНЕ ЈОНЕ ВАНАДИЈУМА

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Претходно саопштење

У раду су дате процењене ширине линија настале услед судара са електронима за 28 прелаза једанпут, двапут и трипут јонизованог ванадијума добијене помоћу модификованог семиемпиријског прилаза. Ширине линија су дате у зависности од температуре за електронску концентрацију од 10^{23} m^{-3}.