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Original scientific paper

MEASURED STARK WIDTHS AND SHIFTS IN THE O IV SPECTRUM

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SUMMARY: Stark widths (W) and shifts (d) of 5 prominent triply ionized oxygen (O IV) spectral lines in 3 multiplets have been measured in oxygen plasma at 42 000 K electron temperature using a linear, low-pressure, pulsed arc discharge as an optically thin plasma source. Obtained W and d values have been compared to available experimental and theoretical data. We found a good agreement among our experimental W and d values and theoretical expectations.

Key words. atomic data – line: profiles

1. INTRODUCTION

Atomic data such as spectral line widths and shifts represent important atomic parameters in astrophysical plasma modelling and diagnostics (Zeippen 1995). The triply ionized (O IV) oxygen spectral lines are present in many cosmic spectra and represent important source of information in various investigations. Recently Heckman et al. (2002) showed that the column density for O IV, in intergalactic medium, is comparable to those seen in O VI. The O IV lines have been used by Doschek and Mariska (2001) in investigations of the lower solar transition region. Telfer et al. (2002) refer to the O IV presence as absorber, in the intergalactic medium. Thus, the triply ionized oxygen spectral line characteristics are useful for diagnostics of astrophysical plasmas. The Stark line width (W) and shift (d) belong to the group of the atomic data which are of interest in astrophysics, especially in the plasmas with electron densities (N) higher than 10^{21} m^{-3} where the Stark effect begins to play an important role in the line broadening mechanism. However, only three works deal with these widths measurements (Purić et al. 1988; Glenzer et al. 1994; Blagojević et al. 1994) and only one work contains measured d values (Blagojević et al. 1996). Existing calculated O IV W and d values are presented in Dimitrijević and Sahal-Bréchot (1994, 1995) and Blagojević et al.(1996) (see Lesage and Fuhr 1999; Konjević et al. 2002; NIST 2003).

In this work we would like to present Stark FWHM (full-width at half intensity maximum, W) and shift (d) of 5 prominent O IV spectral lines belonging to the 3s-3p and 3p-3d transitions at 42 000 K electron temperature (T) is present in many cosmic plasma sources. Namely, existing experimental W and d data are obtained at higher electron temperatures. Our measured values are compared to available experimental and theoretical data.

2. EXPERIMENT

The modified version of the linear low-pressure pulsed arc (Djeniže et al. 2001, 2002; Srećković et al. 2001, 2002) has been used as an optically thin plasma source. A pulsed discharge was driven in a pyrex discharge tube of 5 mm inner diameter and plasma length of 14 cm. The tube has end-on quartz window. On the opposite side of the electrodes the glass tube was expanded in order to reduce erosion of the glass wall and also the sputtering of the electrode material onto the quartz windows. The working gas was pure oxygen at 130 Pa filling pressure in flowing regime. Spectroscopic observation of isolated spectral lines was made end-on along the axis of the discharge tube. A capacitor of 14 μF was charged up to 2.8 kV. The line profiles were recorded using a step-by-step technique with a photomultiplier (EMI 9789 QB) and a grating spectrograph (Zeiss PGS-2, reciprocal linear dispersion 0.73 nm/mm in the first order) system. The instrumental FWHM of 8 pm was determined by using narrow spectral lines emitted by the hollow cathode discharge. The spectrograph exit slit (10 μm) with the calibrated photomultiplier was micrometrically traversed along the spectral plane in small wavelength steps (7.3 pm).The photomultiplier signal was digitized using an oscilloscope, interfaced to a computer. In Fig. 1 O IV spectrum obtained using the described procedure is presented. Intensity of each point is an average value of five successive shots at the same slit position.

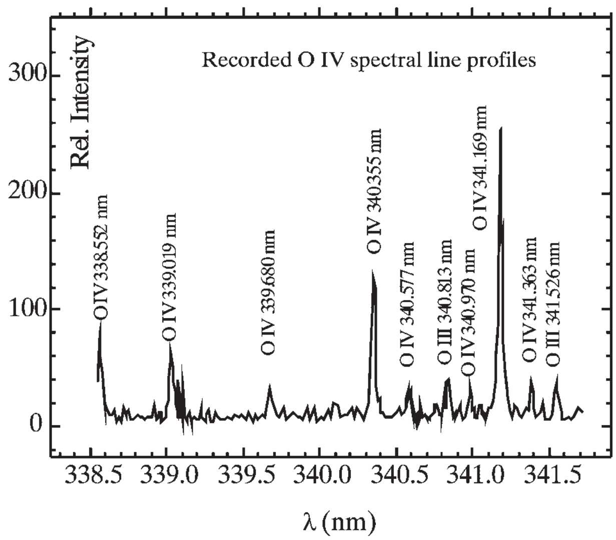

Fig. 1. *Recorded spectrum with several O IV and O III spectral lines at 2 μs after the beginning of the discharge.*

Plasma reproducibility was monitored by the O III and O IV line radiation and by the discharge current (it was found to be within 3%). The plasma parameters were determined using standard diagnostic methods (Rompe and Steenbeck 1967). Thus, the electron temperature was determined from ratios of the relative intensities (Saha equation) of O III (326.08 nm, 372.09 nm and 375.99 nm) and O II (327.05 nm, 372.7 nm and 374.9 nm) spectral lines with an estimated error of ±8%, assuming the existence of LTE, according to the criterion taken from Griem (1974). All necessary atomic data were taken from NIST (2003). The electron temperature decay is presented in Fig. 2. The electron density decay was measured using a well-known single laser interferometry technique for the 632.8 nm He-Ne laser wavelength with an estimated error of ±6%. The electron density decay is presented in Fig. 2, also.

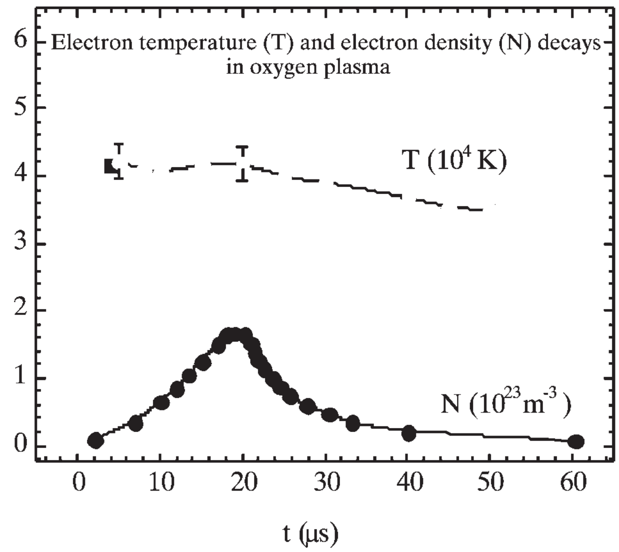

Fig. 2. *Temporal evolution of the electron temperature and density in the decaying plasma.*

3. LINE WIDTH AND SHIFT MEASUREMENTS

The measured profiles were of the Voigt type due to the convolutions of the Lorentzian Stark and Gaussian profiles caused by Doppler and instrumental broadening. For the electron temperature and density presented in our experiment, the Lorentzian fraction was dominant. Van der Waals and resonance (Griem 1974) broadening were estimated to be smaller by more than one order of magnitude in comparison to Stark, Doppler and instrumental broadening. The standard deconvolution procedure (Davies and Vaughan 1963) has been applied using the least squares algorithm. The Stark widths have been measured with ±12% error at a given N and T. The absence of self-absorption was checked using the method described by Djeniže and Bukvić (2001).

The Stark shifts have been measured by monitoring the line center position through the whole plasma decay period (Purić and Konjević 1972). We have made corrections necessary to eliminate the influence of variations in electron temperature during plasma decay (Popović et al. 1992). The Stark shift data have been determined with a ±0.8 pm error at a given N and T.

4. RESULTS AND DISCUSSION

Our measured Stark FWHM (W_m) and shift (d_m) values at 42 000 K electron temperature and 1.65×10^{23} m^{-3} electron density are given in Table 1.

Table 1. Measured O IV W_m (in pm) and d_m (in pm) values at 42 000 K electron temperature and 1.65×10^{23} m^{-3} electron density and their ratios to the calculated ones (Blagojević et al.1996). Positive shift is toward the red.

Transition	λ (nm)	W_m	d_m	W_m/W_{th}	d_m/d_{th}
$3s^2S - 3p^2P^0$	306.343	23.6	2.41	1.05	1.27
	307.160	25.0	2.30	1.11	1.21
$3p^2P^0 - 3d^2D$	340.355	27.0	1.93	1.21	1.23
	341.169	27.0	2.10	1.21	1.33
$3s^4P^0 - 3p^4D$	338.552	–	0.00	–	–

In order to compare the measured Stark FWHM values, we have presented in Fig.3. the existing experimental data set including our results, together with recently published theoretical prediction (Blagojević et al. 1996).

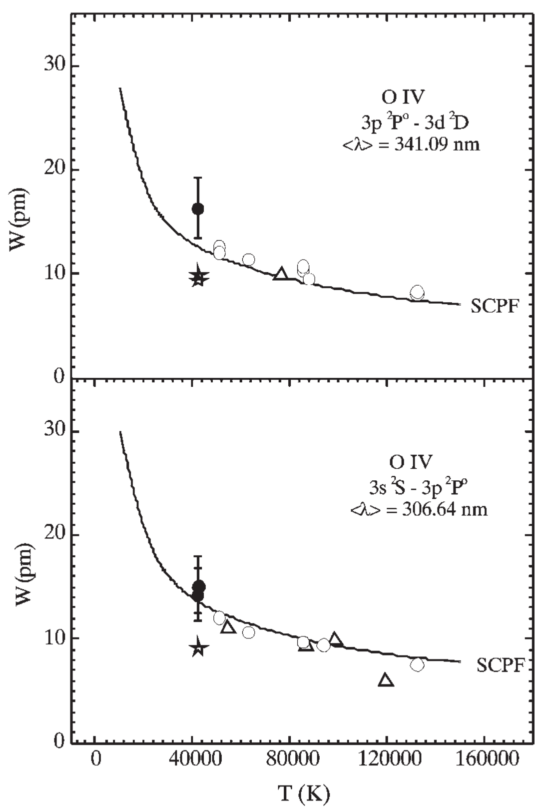

Fig. 3. *Stark FWHM (W) dependence on the electron temperature (T) at 10^{23} m^{-3} electron density. Filled circles (•), represent our experimental data and those of other authors: asterisks (⋆), Purić et al. (1988); open triangles (△), Glenzer et al. (1994) and open circles (◯) Blagojević et al. (1994). SCPF denote calculated W values by Blagojević et al. (1996) for electrons as perturbers only. $< \lambda >$ is the mean wavelength in the multiplet. Error bars* (±18%) *represent the sum of the measured width* (±12%) *and electron density* (±6%) *uncertainties.*

Our W_m data are obtained at the lowest electron temperature (T= 42 000 K) which is often present in many astrophysical light sources. In the case of the 3s-3p transition our W_m values agree (within 10%) with SCPF predictions. Within the 3p-3d transition we have measured about 21% higher W values with respect to the SCPF predictions. It turns out that the inclusion of the ion component (W_i), generated by oxygen ions with different charge (O II, O III, O IV) into the total Stark width could increase the total W values (by a few percent) rendering the agreement between our W_m and W_{SCPF} even better. Unfortunately, the mentioned W_i values have not been calculated within the impact approximation. Their possible inclusion will be well within error bars of the SCPF method (20−30%). Our d_m values have positive sign and lie above d_{th} data (Blagojević et al.1996) at about 26% (on the average). The earlier published experimental d data (Blagojević et al. 1996) have also been positive, but lie about 40% above mentioned theoretical data. It turns out that our measured shift for the 338.552 nm O IV line is the very first published experimental value.

5. CONCLUSION

On the basis of the Table 1. and Fig. 3. one can conclude that the existing Stark width data, including ours, show good agreement with SCPF values. The agreement between our shift data and those calculated by SCPF is tolerable taking into account the difficulties connected with the calculations (Blagojević et al. 1996; Dimitrijević and Sahal-Bréchot 1994,1995). We recommend the 306.343 nm and 307.160 nm O IV spectral lines as lines with convenient Stark parameters for the plasma diagnostical purposes.

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МЕРЕНЕ ШТАРКОВЕ ШИРИНЕ И ПОМЕРАЈИ У СПЕКТРУ O IV

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Оригинални научни рад

Штаркове ширине (W) и помераји (d) пет значајних спектралних линија у спектру троструко јонизованог кисеоника (O IV) из три мултиплета мерене су на електронској температури од 42 000 K у кисеоничкој плазми. Као извор оптичке ретке плазме коришћен је линеарни импулсни лук на ниском притиску. Одређене W и d вредности упоређене су са доступним експерименталним и теоријским подацима. Нађено је добро слагање наших експерименталних W и d вредности са теоријским предвиђањима.