PLASMA POLARIZATION SHIFT OF THE RESONANCE LINES OF IONIZED HELIUM

S. VOLONTE*

Astrophysics Research Unit, Culham Laboratory, Abingdon, Berkshire, England

In a recent T–tube experiment, Greig *et al.* (1970) reported the observation of a blue shift of ~0.05 Å for the first member of the resonance series of ionized helium. This was explained as due to some polarization effect in the plasma (Berg *et al.*, 1962; Griem, 1966) and a classical estimate allowing for quantum mechanical effects was presented. The relative wavelength shift of the resonance lines of He II was predicted to be

$$\frac{\Delta\lambda}{\lambda} = -\frac{8\pi}{3}\frac{n^6}{Z^4}a_0^3 N_e \exp\left(\frac{E}{kT}\right), \tag{1}$$

where n is the principal quantum number, a_0 the Bohr radius, N_e the electron density and E is close to the ionization energy of neutral helium. For the plasma condition of their experiment ($N_e = 3\times10^{17}$ cm^{-3}; $kT_e \simeq 4$ eV) the formula gives $\simeq 0.06$ Å, and accounts very well for the measured shift. Our measurements were made using a low inductance T–type shock tube. The filling gas was a mixture of 10% H_2 in helium pre-ionized by a 0.01 μF capacitor at 45 kV and driven by a 0.8 μF capacitor of 45 kV. The observations were made on the reflected shock using a 2 m grazing incidence vacuum spectrograph with a 10 μ entrance slit, built into the expansion tube of the shock-tube. The spectrum was recorded on Kodak SC5 photographic plate and a reference spectrum produced by a microwave source was superimposed on the same plate to allow measurement of the shifts. The instrument profile was approximated by the reference line at the wavelength of interest and resulted in a half-width of $\simeq 0.06$ Å at $\lambda = 256$ Å.

The plasma density and temperature were derived from the width and the line to continuum ratio of the 4686 He II line.

The shifts were measured from the microdensitometer traces of the lines of interest. In order to reduce noise effects, 10 scans were taken at independent positions along each line and averaged numerically to produce 'clean' traces.

Our plasma conditions were

$$N_e \simeq 9\times10^{17}\ \text{cm}^{-3}$$

$$T_e \simeq 45\,000\ \text{K}.$$

We analized the first two members of the resonance series $\lambda = 304$ Å and $\lambda = 256$ Å. No definite conclusions could be drawn for the 304 Å line because of the presence in the wings of O III and N IV lines. However a red shift of 0.032 Å was measured in the second

* Present address: Department d'Astrophysique, Université de Mons, Belgium.

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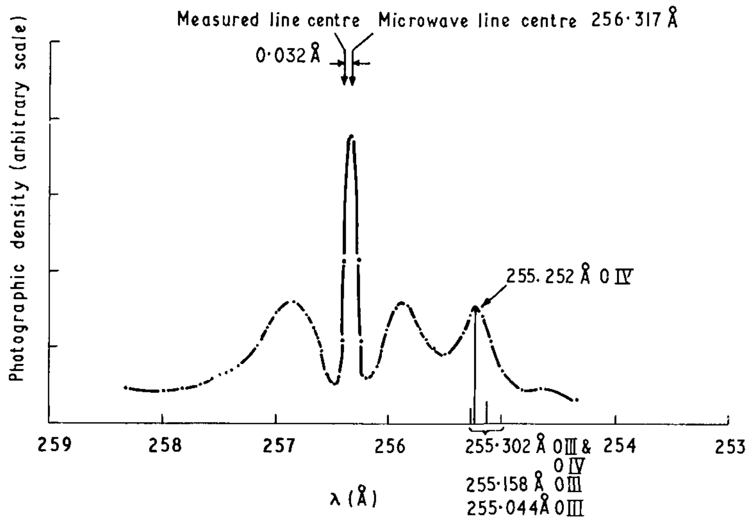

Fig. 1. Profiles of the second ionized helium resonance line. The points plotted are the result of a numerical averaging over 10 scans across the line at independent positions on the photographic plate.

member of the resonance series. This is seen on Figure 1 where the members of perturbing multiplets of O III and O IV are shown with their relative strengths.

Using formula (1) one would predict much larger blue shifts, of the order of a few tenths of an Å, for both lines with our plasma conditions.

References

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DISCUSSION

H.R. Griem: In regard to the interpretation of your measurements we should realize that our experimental line shapes are essentially determined by the profile of the absorption coefficient, while theories tend to deal with the profile of the emission coefficient. In helium plasmas these two profiles are probably not the same as discussed by us mainly in connection with measured line widths.

S. Volonte: Although the emission and absorption profiles might be different, it is important to point out that this effect is then different from the mechanism first proposed to explain the so-called plasma polarization shift.

A.H. Gabriel: It is of interest to note the similarity between this effect, and the satellites in the soft X-ray region which I consider in my paper. Both involve the shift of a line due to the influence of additional perturbers. For the satellites, when only the screening effect of the perturber is allowed for, theory predicts a blue shift. When, however, the transition in the total system, including the perturber, is computed, this becomes a red shift, as actually observed. The incomplete theories proposed so far for plasma polarization shift consider only the screening effects. This may in part explain the predicted blue shift, in contrast to the red shift reported in the present observations.

S. Volonte. It is true that the interactions on the perturbers have been left out in the theories proposed so far for the plasma polarization shift. If they were accounted for, a red shift would be predicted. However, it is important to remark that in connection with this experiment, the observation of a red shift on the third and possibly the higher members of the series, would be of great interest and would in some way support your remark.

H. R. Griem: Unresolved satellite lines associated with the He II resonance line corresponding to $n \gtrsim 5$ and broadened by Stark effect may well be responsible for the shifts of He II 304 Å observed in the laboratory (Greig, J. R., Griem, H. R., Jones, L. A., and Oda, T.: 1970, *Phys. Rev. Letters* **24**, 3). If one assumes that the population ratio of upper and lower states of the satellite lines is well below the population ratio for the parent lines, this mechanism gives a blue-shift of the optically thick emission feature, as does the above mechanism which was connected with the indistinguishibility of He^+ ions in the ground state. Computed profiles for the conditions of Greig *et al.* allowing for both of these mechanisms are shown on Figure 1a.

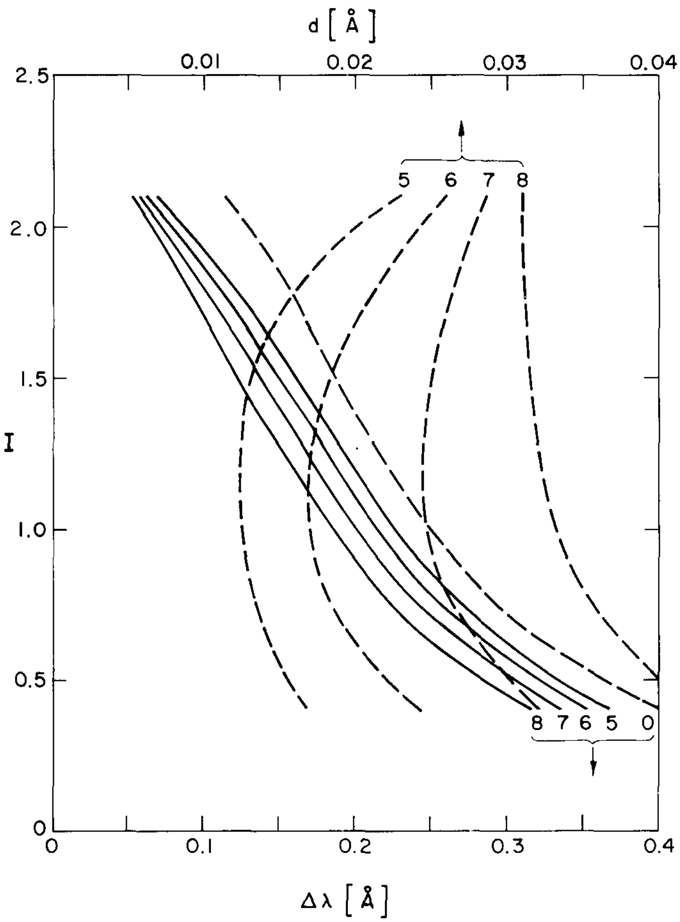

Fig. 1a. Computed optically thick emission profile near 304 Å of a helium plasma of depth 2 cm, electron density 3.10^{17} cm^{-3} and temperature 4 eV. The single dashed curve refers to the blue wing, the solid lines to the red wing, the index being the principal quantum number of the highest number of the satellite line series allowed for. The family of dashed curves gives the blue shift of the median as a function of relative intensity.

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