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ASTRONOMY

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Abstract

Full Text

ASTRONOMY

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ULTRAVIOLET RADIATION AND THE EXCITATION OF OXYGEN LINES IN THE CHROMOSPHERE

(Presented by Academician V. G. Fesenkov, 25 VIII 1959)

The OI multiplets, the quintet system $\lambda\lambda$ 7771.95; 7774.18; 7775.39 and the triplet system $\lambda\lambda$ 8446.35; 8446.73; 8447.66, are characterized by a rather high (~ 10 eV) excitation potential of the upper levels. Figure 1 shows a diagram of the energy levels of OI. The lower levels of the multiplets, combining with the neighboring ground level, give the lines $\lambda\lambda$ 1302.2; 1304.8; 1306.0 (triplets) and $\lambda\lambda$ 1355.6; 1358.5—spin-forbidden lines. Both groups of ultraviolet lines have been observed in the solar spectrum by American investigators from rockets ⁽¹⁾. Since the continuous radiation of the Sun in the wavelength interval corresponding to an energy of 10 eV is negligibly small, the source of excitation of the initial levels for $\lambda\lambda$ 8446 and 7774 ($^3P_{2,1,0}$; $^5P_{1,2,3}$) must be electron impact.

However, in the case of the triplets, the mechanism populating the initial level for the emission of λ 8446, the level $^3P_{0,1,2}$, may be a cascade transition from the higher level $^3D_{3,2,1}$, excited by chromospheric radiation in the line L_β 1025.73 Å. Here we are dealing practically with a resonance process: the energy of the 3D level corresponds to λ 1025.77 Å, while the width of the L_β line is slightly less than 1 Å.

This mechanism was first considered by P. S. Shklovsky as applied to oxygen in the Earth's atmosphere ⁽²⁾. But for a number of reasons, up to the present time attempts to detect the twilight flash at λ 8446 expected according to ⁽²⁾ have been unsuccessful.

Let us consider the action of the mechanism described under the conditions of the solar atmosphere. To this end, solving the systems of stationarity equations separately for the triplets and quintets of OI, we find the populations of the initial levels for $\lambda\lambda$ 8446 and 7774 with allowance for the action of L_β -radiation. We shall denote the levels by numerals (Fig. 1), restricting ourselves to consideration of only four of them. Freely bound processes may be neglected for simplicity. The solutions have the form

$$\left(\frac{n_3}{n_1}\right)_{8446} = \frac{A_{43}}{A_{32}A_{41}} (B_{14}\rho_{L_\beta} + b_{13}); \quad (1)$$

$$\left(\frac{n_3}{n_1}\right)_{7774} = \frac{1}{B_{34}\rho_{34}} b_{12}. \quad (2)$$

Here n_1 is the population of the ground level 3P ; A, B are Einstein coefficients; b are coefficients of excitation by electron impact; ρ is the density of the exciting radiation. We note that in deriving (1) and (2) we took into account the inequalities $A \gg B\rho \gg b$ valid for the chromosphere (with the exception of the cases $\rho = \rho_{L_\beta}$ and A for intercombination transitions).

To estimate the magnitudes of the terms in expression (1), we shall assume that the chromospheric radiation in L_β can be represented by black-body radiation with $T \sim 5000^\circ$, the electron temperature and concentration in the lower chromosphere $T_e = 5000^\circ$, $N_e \sim 10^{12} \text{ cm}^{-3}$ (3), and the mean value of the effective cross section for excitation by electron impact of the order of the gaskinetic one. Then, in generally accepted notation,

$$B_{14}\rho L_\beta \sim A_{41}^i W 10^{-\frac{5040}{T} \chi_{14}}, \quad b_{13} \sim N_e \sigma \left(\frac{8kT_e}{\pi m}\right)^{1/2} 10^{-\frac{5040}{T_e} \chi_{13}}, \quad B_{14}\rho L_\beta / b_{13} \sim 10^3. \quad (3)$$

It should be noted that the estimate depends very strongly on the adopted values of the intensity of the L_β -radiation and on the electron temperature of the chromosphere T_e . Nevertheless, in regions of the chromosphere with an increased density of L_β -radiation, the emission lines $\lambda 8446$ must be substantially enhanced.

Fig. 1. Scheme of O I levels. Triplets and quintets

What is the magnitude of the intensity ratio of the chromospheric lines I_{8446}/I_{7774} ? In the absence of excitation of $\lambda 8446$ by L_β -radiation, this quantity should be small. This follows from the metastability of the lower level for $\lambda 7774$, 5S , and from the presence of an effective drain—the permitted transition of excited atoms from the analogous level for $\lambda 8446$, 3S , to the ground level 3P . In the case of the absorption lines $\lambda \lambda 8446$ and 7774 , arising in dense layers of the solar atmosphere, the excitation is determined predominantly by collisions, and I_{8556}/I_{7774} will be close to 1. This is confirmed by an estimate of the equivalent widths with the aid of (4—6).

The excitation properties of the chromospheric lines $\lambda 8446$ open up the possibility of measuring the intensity L_β in various regions of the chromosphere. Despite certain difficulties associated with observations of the very weak infrared O I lines in the chromospheric spectrum outside eclipse, this method has a number of obvious advantages in comparison with rocket observations of L_β .

We note that, because of the large optical thickness of the chromosphere in the lines of the Lyman series, such a method gives information only about the

density of L_{β} -radiation in those layers of the chromosphere where the emission line $\lambda 8446$ is formed.

In setting up observations of this kind it is convenient to record simultaneously $\lambda 8446$ and 7774 , since the intensity ratio, according to (1), (2), and (3), does not depend on the electron concentration and depends significantly more weakly on the electron temperature than does each line separately.

The condition $I_{8446}/I_{7774} > 1$ is a direct indication of additional excitation of $\lambda 8446$ by L_{β} -radiation.

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Note: Figure translations are in progress. See original paper for figures.

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