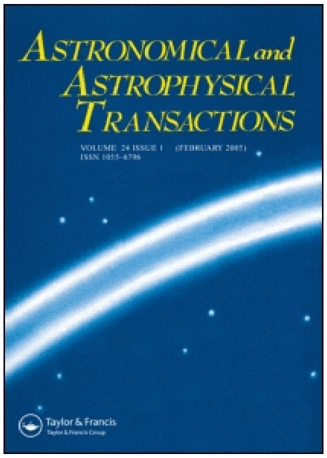

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ON THE POSSIBILITY OF THE EXISTENCE OF SOLAR TRANSITION REGION IONS AT CHROMOSPHERIC TEMPERATURES

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Certain mechanism of helium ionization in the chromosphere under coronal EUV-irradiation used to be extended to ions of the inner chromosphere–corona transition region. It is shown that due to the photoionization by coronal radiation the existence of ions such as C(III)–C(IV) at the temperature $\sim 10^4$ K is possible if the electron density is not greater than $\sim 10^8\ \mathrm{cm}^{-3}$. Such conditions may occur at heights of about 3 to 10×10^3 km inside the cells of the chromospheric network.

KEY WORDS Sun, transition region, ionization

As early as 1945 I. S. Shklovsky noted; "The hard radiation of the corona would penetrate into the lower-lying layers of the solar atmosphere and certainly affect the state of ionization of the latter" (Shklovsky 1945). The idea became of common use nowadays in respect to helium in the chromosphere and prominences: due to the coronal EUV-radiation the helium ionization is realized at the electron temperature $\leqslant 10^4$ K which is not sufficient for impact ionization. However, the mechanism affecting the helium atoms should be valid as well as with other atoms and ions of ionization potential near to that of He(I)–He(II). Such species are the ions of the inner ("cold") part of the chromosphere–corona transition region (TR).

The temperature "boundary" between the inner and outer ("cold" and "hot") parts of the transition region† is defined by an observed minimum of the differential emission measure $ME(T_i)$ at $T_i \approx 10^5$ K (see, for example, Figure 1 in Raymond and Doyle 1981); T_i is the temperature respective to the maximum number density of a certain ion in the case of electron impact ionization. The shape of the $ME(T_i)$ curve at $T > 10^5$ K (outer TR) is well explained by heat conduction from the corona. As concerns the inner TR the interpretation of the $ME(T_i)$ trend meets with serious difficulties. In other words the mechanism of the origin of the inner TR ions can be stated as unknown. One of the possible ways out is seen in the consideration of photoionization by the coronal EUV-radiation.

It is thought implicitly that the electron temperature at the region of existence of an ion of TR is close to T_i; say at the regions of formation of the C(IV) lines

† This is rather to say on existence of the two types of structural elements in the so called transition region: the "cold" and "hot" elements.

the temperature T_e is considered to be of $\sim 10^5$ K. But photoionization by the outer coronal radiation may occur as well at $T_e \ll T_i$, as it takes place with helium. So in general the condition $T_e \approx T_i$ should not be necessary in the inner transition region.

To verify the above reasoning we shall consider the ionization equilibrium of the carbon ions typical for the inner TR in the field of the coronal EUV-radiation at the "chromospheric" temperature of $T_e = 10^4$ K. As a first approximation we shall treat just the most important processes: photoionization from the ground level and recombinations (radiative and dielectronic) to all levels. Then we have the following system of equations:

$$\left.\begin{array}{l} N(i)\phi(i) = N(i+1)\alpha(i+1)n_e \\ \quad (i = 1, 2, 3, 4) \\ \sum_{i=1}^{5} N(i) = N(C) \end{array}\right\} \tag{1}$$

Here $N(1), \ldots, N(5)$—the number density of C(I), ..., C(V) ions respectively; $N(C)$—the total content of all atoms and ions of carbon; $\phi(i)$—the number of events of photoionization from the ground level of the $C(i)$ ion referred to 1 ion per second; $\alpha(i+1)$—coefficient of recombination (sum of all recombinations) for the $C(i+1)$ ion. States of ionization above C(V) can evidently be neglected under the above conditions.

In computing the ϕ-values the photionization cross-sections by Henry (1970) for C(I) and C(II) and by Railman and Manson (1979) for C(III) and C(IV) were used. The solar EUV-fluxes at the Earth's atmosphere boundary relevant to low solar activity are taken from Heroux and Hinteregger (1978). The coefficients of the low-temperature dielectronic recombination are calculated with the data by Nussbaumer and Storey (1983), and coefficients of the radiative recombination with the data by Aldrovandi and Pequignot (1973).

By solving the system of equations (1) we obtain values of relative number density $N(i)/N(C)$ of the ions of C(I)–C(V) as a function of electron density under $T_e = 10^4$ K. Figure 1 presents the ionization curves for the interval of n_e from 10^{10} to $10^6\,cm^{-3}$. We did not take into account the ionization by electronic impact being of concern at our temperature only for the neutral atoms of carbon. Consideration of such a process reduces slightly the number density of C(I) but does not affect the results relevant to the ions of C(II)–C(V).

Figure 1 shows that essentially all the carbon can be exist in the states of C(III) to C(V) through the field of the coronal EUV-radiation even under chromospheric temperature if $n_e \lesssim 10^8\,cm^{-3}$. May such conditions be valid within the chromosphere? Seemingly, yes. Almost all the chromospheric matter above $\sim$2000 km is known to be concentrated in the spicules which are located at the chromospheric network. Inside the network cells and between the spicules the matter density is essentially reduced. For instance, as it follows from our results of the eclipse observations of the K-corona at very close distances from the limb (Gulyaev and Ajmanova 1982), the value of n_e is less than $10^8\,cm^{-3}$ at the height interval of 3 to 10×10^3 km in the space between the spicules. This means that the above mechanism deserves attention relative not only to the helium but also to the ions of the inner transition region. Note that photoionization of the cold

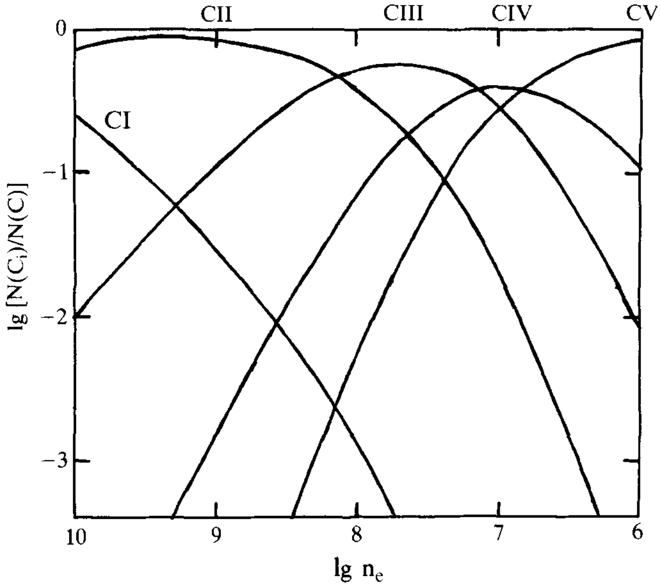

Figure 1 Dependence of the carbon ionization state on the electron density in the coronal EUV-radiation field at the chromosphere level with $T_e = 10^4$ K.

plasma by the outer EUV-radiation with output of ions of the type of C(III)–C(V) represents a phenomenon common in the Universe. The general examples are planetary nebulae and the Galactic halo.

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