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THE MANIFESTATIONS OF THE NON-SYMMETRIC ION–ATOM ABSORPTION PROCESSES IN THE SOLAR ATMOSPHERES IN UV AND VUV REGION

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Abstract. In this work we draw attention to the radiative processes in strongly non-symmetric ion-atom collisions as factors of influence on the opacity of the solar atmosphere in UV and VUV region. For several ion-atom systems, He + H^+ and H + A^+, where A is the atom of one of the metal (Mg, Si, Al etc), some characteristics have been determined, such as molecular potential curves and dipole matrix elements. Here the non-symmetric radiative processes are considered under the conditions characterizing the non-LTE standard model of the solar atmosphere. In this work the calculations of the corresponding spectral absorption coefficients have been performed. It is shown that the examined processes generate rather wide and firm molecular absorption stripes in the UV and VUV regions, whose intensity is comparable and sometimes even larger than the intensity of known one's generated in the H + H^+ radiative collision processes. Due to all these reasons the processes have to be consistently included in standard models of the solar atmosphere.

1. INTRODUCTION

The important influence of some ion-atom radiative collision processes on the optical characteristics of the stellar atmospheres was already established. Here we have in mind the symmetric radiative processes of the photo absorption/emission and radiative charge exchange which can be presented by

$$\varepsilon_\lambda + A_2^+ \leftrightarrow A + A^+ \qquad (1)$$

$$\varepsilon_\lambda + A^+ + A \leftrightarrow A + A^+ \qquad (2)$$

where A = H(1s) or He(1s^2), A^+ and A_2^+ are the corresponding positive, single charged atomic and molecular ions in the ground electronic states, and ε_λ is the photon energy. Previously, it was shown in Mihajlov et al. (1993, 2007) that these processes can influence to the opacity of Solar atmospheres. Nevertheless, the mentioned papers have leaved opened the questions of the significance of the non-symmetric radiative processes.

The main objective of this paper is to draw attention to the possible significance of the non-symmetric radiative processes as factors which influence to the opacity of stellar atmosphere in UV and VUV region. Here we will consider the processes of absorption charge exchange and photo-dissociation of the type

$$\varepsilon_\lambda + AB^+ \leftrightarrow A^+ + B \qquad (3)$$

$$\varepsilon_\lambda + A + B^+ \leftrightarrow A^+ + B \qquad (4)$$

$$\varepsilon_\lambda + A + B^+ \leftrightarrow (AB^+)^* \qquad (5)$$

where B is the ground state atom with the ionization potential I_B which is less than the ionization potential I_A of the atom A, and AB^+ - the corresponding molecular ion in one of the electronic states which are asymptotically correlated with the state of the system A + B^+. One can see that the processes of charge exchange and photo-dissociation i.e. (3) and (4) represent the analogues of the processes (1) and (2), while the process (5) has not it's symmetric analog.

In this paper the strongly non-symmetric radiative processes are investigated under the conditions characterizing the model of the solar atmosphere presented in Vernazza et al. (1981). All needed data for the calculations of the spectral absorption coefficients are provided in tabular form only in chosen models. In accordance with this model is possible that atom A = He(1s^2) and B = H(1s), and A = H(1s) and B = Mg, Si and Al.

We should point out that for the molecular ions HeH^+ and $(HeH^+)^*$ the corresponding potential curves and the dipole matrix elements, as the functions of the internuclear distances, are taken from Green et al. (1974a,b), while for all other considered molecular ions the mentioned quantities are calculated within this manuscript and in Srećković et al. (2011).

The spectral absorption coefficients calculated here, as the function of the local temperature T, wavelength λ, and the particle densities are determined in the region 40 nm ≤ λ ≤ 230 nm.

2. RESULTS AND DISCUSSION

The strongly non-symmetric processes (3)-(5) are schematically shown in Fig. 1, where: bf-, ff-, and fb denote the bound-free, free-free and free-bound radiative transitions; $\Delta I = I_A - I_B$; $E = E_{imp}$ and E'_{imp} are the impact energies of the corresponding ion-atom systems; U_{in} (R) and $U_{fin}(R)$ - are the adiabatic potential curves of the initial and final molecular electronic states; v , v' , J, and J' - the quantum numbers of the corresponding bound ro-vibration and free states.

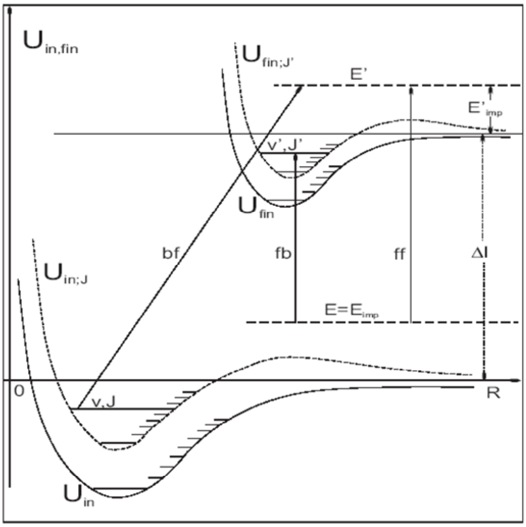

Figure 1: Schematic presentation of the non-symmetric processes (3)-(5) caused by the bf-, ff-, and fb- radiative transitions.

The contribution of the considered non-symmetric ion-atom absorption processes (3) - (5) to the opacity of the solar atmosphere is described here by the spectral absorption coefficient $\kappa_{ia;nsim}(\lambda;\ T)$. The behavior of $\kappa_{ia;nsim}(\lambda;\ T)$ for several values of λ is illustrated by Fig.2, where h is the distance of considered layer from the referent one (h=0) in accordance with Vernazza et al. (1981).

The behavior of the quantity $G = \kappa_{ia;nsim}(\lambda;\ T)/\ \kappa_{ia;tot}(\lambda;\ T)$, where $\kappa_{ia;tot}(\lambda;\ T)$ characterize the total contribution of all ion-atom absorption processes, i.e. (1) - (5), is shown in Fig.3. Then, in Fig.4 is presented the behavior of the quantities $F_{sim} = \kappa_{ia;sim}(\lambda;\ T)/\ \kappa_{ea}(\lambda;\ T)$ and $F_{tot} = \kappa_{ia;tot}(\lambda;\ T)/\kappa_{ea}(\lambda;\ T)$, dash and full lines respectively. Here $\kappa_{ia;sim}(\lambda;\ T)$ characterizes the contribution of the symmetric ion-atom absorption processes (1) and (2), and $\kappa_{ea}(\lambda;\ T)$ - the contribution of the concurrent electron-atom processes i.e. H^- continuum, which were treated until recently as the absolutely dominant.

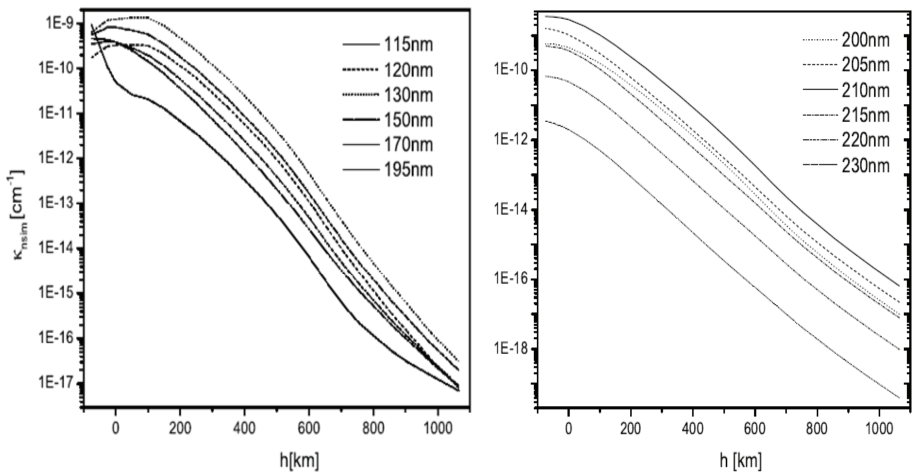

Figure 2: Spectral absorption coefficients $\kappa_{ia;nsim}(\lambda; T)$ as the function of h for the Solar atmosphere for 115 nm $\leq \lambda \leq$ 230 nm.

On the basis of the above mentioned it follows that the non-symmetric absorption processes (3)-(5) should be *ab initio* included in the relevant models.

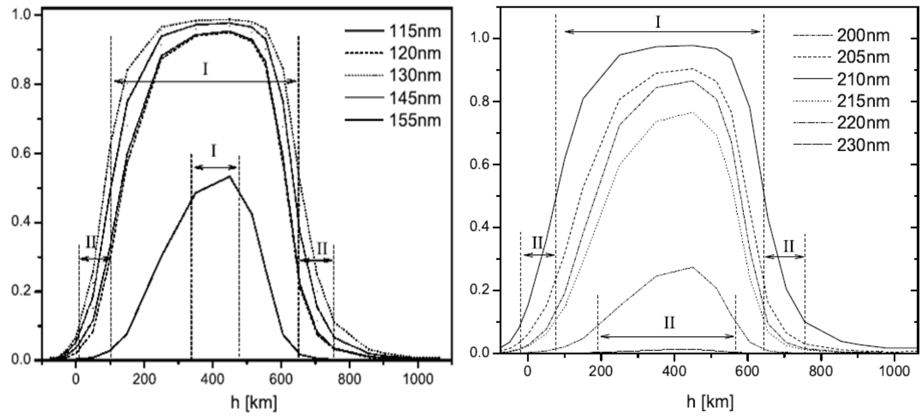

Figure 3: The behavior of the quantity G= $\kappa_{ia;nsim}(\lambda; T)/ \kappa_{ia;tot}(\lambda; T)$ as the function of h for the Solar atmosphere for 115 nm $\leq \lambda \leq$ 230 nm.

Even only the results presented in figures 3 and 4 show that the neglecting of the contribution of the non-symmetric processes (3) - (5) to the opacity of the solar atmosphere, in respect to the contribution of symmetric processes (1) and (2) would caused noticeable errors.

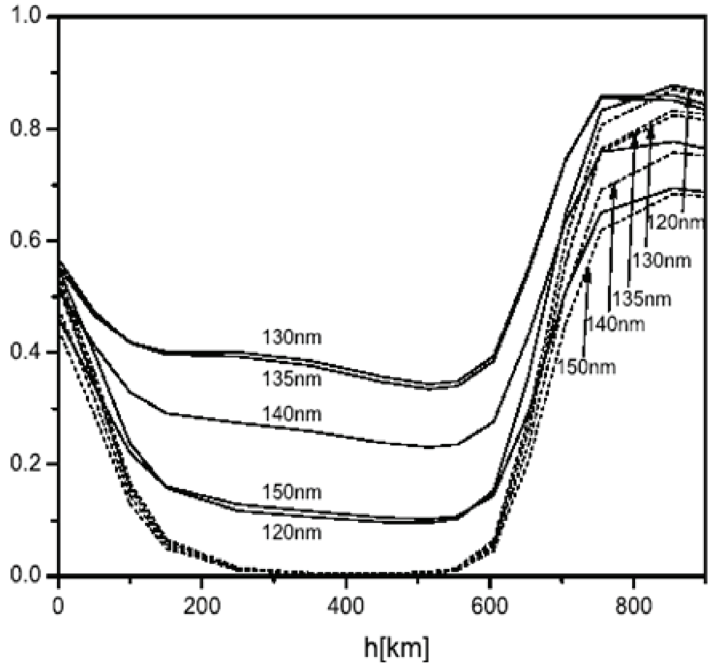

Figure 4: The behavior of the quantities F_{sim} (dash lines) and F_{tot} (full lines) as the function of h for the Solar atmosphere for 115 nm ≤ λ ≤ 230 nm.

Acknowledgments

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