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Suprathermal atoms in the upper atmosphere of HD 209458b

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Abstract

The extended hydrogen cloud surrounding the exoplanet HD 209456b was discovered in the space FUV observations with HST/STIS spectrograph [1]. The most interesting results were obtained in the UV range, where observations showed the sufficiently strong weakening of the stellar emission of HD 209458: in the Lyman α line of atomic hydrogen HI 121.6 nm from 5 to 15% depending on the spectral resolution [1], and in the lines of atomic oxygen at 130.4 nm and the ionized carbon at 133.5 nm of 13 and 7%, respectively [2]. In the UV resonance lines, the planetary atmosphere was weakened substantially more than the planet itself, which indicates the presence of an extended atmosphere around HD 209458b. The planet itself shields only 1.5% of stellar radiation in the visible range, which means that the planet is surrounded by a neutral hydrogen cloud as large as about a few planetary radii. These observations were currently interpreted as a signature of an extended exosphere in which the evaporating atomic hydrogen drags other heavy atoms outward [1,2].

The fundamental question of the HD 209458b atmosphere evolution forced by the stellar UV irradiation, inflow of the stellar wind, and tidal forces of the parent star is still intensively investigated. One of the challenges is to explain why the OI and CII observations show almost the same level of transit absorption [2,3] as HI when the abundances of the heavy atoms are at least 3 or more orders of magnitude lower.

To investigate the efficiency of the energy transfer from suprathermal atomic hydrogen to the heavy atoms – C, and O, we use numerical stochastic model [4], in which the formation, kinetics and dynamics of the suprathermal (hot) atomic hydrogen in the extended upper atmosphere of HD 209458b is considered on the molecular level of description.

In this model the suprathermal hydrogen atoms are formed due to: (i) dissociation and dissociative ionization of the molecular hydrogen by the stellar UV radiation; (ii) photoelectron impact dissociation of H_2. It was found [4] that H_2 dissociation processes result in the formation of hydrogen atoms with excess kinetic energies up to a few eVs, and because elastic collisions at suprathermal energies are characterized by the scattering angle distributions strongly peaked at small angles a stable fraction of hot atomic hydrogen can be formed. To calculate the efficiency of the collisional energy transfer from light and high-energy hydrogen atoms to the heavy atoms the numerical model [4] was modified by taken into account the minor species – C, and O. Their space distributions were adopted from the chemical model of HD 209458b [5]. Calculations show that the suprathermal H formed in the upper atmosphere of HD 209458b due to H_2 dissociation processes can be an important energy source for the heavy atoms – C, and O, leading to the formation of their hot fractions.

As it was mentioned in [3], the presence of the suprathermal fraction may translate into the a spectral inflection near ~± 20 km/s from the line center of the OI and CII lines, therefore a future detection of such spectral feature would confirm the direct signature of suprathermal atoms in the upper atmosphere of HD 209458b.

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References

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