火星からの酸素流出率の太陽紫外線強度依存性

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A simulation study of solar EUV control of oxygen escape from Mars with a DSMC model

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I developed a one-dimensional multi-species Martian exosphere Direct Simulation Monte Carlo (DSMC) model and investigated the response of oxygen escape rate from Mars to different solar EUV flux. I estimated oxygen escape rates due to the dissociative recombination of $O_2{}^+$ at the subsolar region. The yields are given for three different solar EUV intensities. These calculations were done by DSMC method using Lennard-Jones intermolecular potential. I assume a photochemical equilibrium as a density of $O_2{}^+$ and electron.

Around the exobase, there exists a transitional domain (between collision and collision less domains) where the collision frequency is not high enough to maintain equilibrium in the flow but the momentum exchange in a collision between atmospheric molecules is still important. The DSMC method is a standard numerical method for solving such a rarefied gas flow. In this method, the flow is represented by the positions and velocity components of many simulated particles, which obey the underlying physical law governing real flow. Its solutions converge to Boltzmann equation solutions in the limit of infinite number of simulated particles, and vanishing cell size and time interval.

The dissociative recombination of $O_2{}^+$ in the ionosphere is the important source for the present Martian oxygen corona. The dissociative recombination reaction produces two fast neutral oxygen atoms with a total kinetic energy equivalent to the ionization potential of molecular oxygen minus the sum of the excitation energies of the atoms. Although some oxygen atoms created are quickly thermalized by a series of collisions with the ambient neutral gases, a fraction of the population produced form the hot oxygen corona.

Hot oxygen atoms produced by dissociative recombination of $O_2{}^+$ have been escaping during Martian history. According to the evolving EUV luminosity model of solar-type stars, the solar EUV intensity was about 6 times its present value in a very early epoch. Over the last few decades, a number of model calculations have been performed using past solar EUV conditions, and they show the escape rate strongly dependent on the solar EUV flux. These calculations were performed assuming an isotropic collision. In this paper, I recalculate the oxygen escape rate due to dissociative recombination of $O_2{}^+$ for past conditions using more accurate intermolecular collision model and discuss a relation between oxygen escape rate and solar EUV flux.