DSMC simulations of slow hydrodynamic escape from Earth-like and Mars-like planets

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We have developed full-particle simulation models that solve the slow hydrodynamic escape from Earth-like and Mars-like planets based on the Direct Simulation Monte Carlo (DSMC) method to understand the long-term evolution of the atmospheres of these planets. While hydrodynamic and Jeans escape processes are relatively well understood, the transition between the two, i.e., slow hydrodynamic escape process, has been less thoroughly investigated due to difficulties in its theoretical and numerical treatment. The slow hydrodynamic escape is one of the candidate processes that would have caused the drastic climate change on early Mars and have significantly changed the amount and composition of the atmosphere. The DSMC method is able to self-consistently solve the slow hydrodynamic escape without imposing a priori assumptions on the boundary condition and molecular diffusion. We first developed a full-particle DSMC model of the upper atmosphere of an Earth-like planet and then implemented photochemistry related to atomic carbon for a Mars-like planet. Our simulation results showed that the adiabatic cooling associated with the slow hydrodynamic expansion was weakened due to infrequent intermolecular collisions around the exobase, hence higher exobase temperature and escape rates were obtained than previous fluid models. In this presentation, we will show simulation results of Earth-like and Mars-like atmospheres subject to intense EUV radiation and compare them with fluid models.

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