DSMC simulations of slow hydrodynamic escape from Mars-like planets

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We have developed a full-particle simulation model of the upper atmosphere of a Mars-like planet. The model incorporates the physics of slow hydrodynamic escape and photochemistry related to atomic C, which strongly affect the evolution of CO_2-dominated atmosphere like Mars.

The intensity of FUV/EUV radiation of the Sun controls the composition of the upper atmosphere of Mars, whose main atmospheric component is CO_2. Tian et al. [2009] showed that the solar EUV radiation 20 times stronger than today (equivalent to the radiation 4.1 Ga) promotes CO_2 dissociation in the upper atmosphere. It leads to the generation of a large amount of atomic C, and atomic C becomes the main component around the exobase under 20EUV condition, which is a minor component at the present-day Mars. In the early stage of the planetary evolution, the FUV/EUV radiation of the central star was strong, so it is crucial to solve atomic C in modeling the evolution of a CO_2-dominated atmosphere.

Tian et al. [2009] also showed that Martian atmosphere exposed to solar EUV radiation 20 times stronger than today was heated and in the slow-hydrodynamic escape regime. It is known that adiabatic cooling associated with a fast upward flow is effective in determining the temperature of the upper atmosphere in the slow-hydrodynamic escape regime. However, our full-particle simulations of the slow-hydrodynamic escape from an Earth-like planet showed that the adiabatic cooling was weakened by kinetic effects due to infrequent intermolecular collisions around the exobase. Therefore, the results of the particle simulation have a higher exobase temperature and exobase altitude than the results of the fluid simulation.

In this presentation, we show the initial results of the density and temperature profiles of the Mars-like atmosphere at 1x, 10x, and 20x the solar EUV radiations than today calculated by a newly developed full-particle model and compare the results with those of the fluid model.

Keywords: Mars-like planet, Atmospheric escape, DSMC simulation