Numerical Study of Multi-Component Hydrodynamic Escape: Application to the Water Loss from Early Venus

Takanori Sasaki[1]; Yutaka Abe[2]

[1] Earth and Planetary Sci., Univ Tokyo; [2] Earth Planetary Sci., Univ. Tokyo

http://noinoi.main.jp/

Hydrodynamic escape is one of a few mechanisms that can change the composition of a planetary atmosphere irreversibly. So far, several numerical models have been developed to solve the hydrodynamic escape problem. Previous models, however, is unsatisfactory to apply actual atmospheric evolution quantitatively because they cannot solve transonic solutions or multi component solutions. Here we present the first study on the multi-component time-dependent hydrodynamic equations for transonic neutral gas escape from planetary atmospheres.

The numerical model is the one-dimensional time-dependent non-viscous Euler equations with thermal conduction in spherical geometry. The effects of collisions with other species are included in the momentum equation to solve the multicomponent hydrodynamic escape. We develop the numerical code of hydrodynamic escape using CIP method, which is well suited to solve the transonic flow. A two-dimensional energy deposition calculation method is adapted to provide an accurate approximation of the complicated radiative transfer processes in an extended spherical atmosphere. We also use the power-law fits of solar fluxes against solar age to estimate the energy deposition by solar EUV heating in numerical calculations; the emission of the younger Sun in all wavelength intervals is orders of magnitude larger than the current solar flux.

In this study, we apply the developed numerical model to the escape of hypothetical early Venusian atmosphere to consider the water loss from early Venus. Venus is free of molecular oxygen but it is thought to have contained a primordial water ocean. Present lack of water is considered to be due to photodissociation of H_2O followed by thermal escape of H at early stage. Then, the lack of oxygen on present Venus is puzzling. We apply the numerical code to consider the water loss problem, and determine whether the complete water loss from early Venus can achieve or not.

According to the numerical results, the hydrogen molecules escape more than oxygen molecules from the water-rich Venusian atmosphere all the time. Therefore, the relative abundance of oxygen to hydrogen inevitably increases with time. Moreover,the larger the relative abundance of oxygen to hydrogen is, the harder the oxygen escapes from the Venusian atmosphere, so that the oxygen relative abundance would increase at an accelerating pace. The results indicate that the complete water loss from early Venus by hydrodynamic escape of oxygen is very difficult or almost impossible. How the oxygen concentrate and how the concentrated oxygen was consumed and/or escaped are discussed.