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Thermal Escape of the Terrestrial Planet's Atmosphere After Giant Impacts

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The recent works on the planetary formation show that several tens of Mars-sized protoplanets are formed through a successive accretion of planetesimals in the terrestrial planet region. Then, these protoplanets collide each other as their orbit crosses owing to gravitational interaction among them. Therefore, it is generally thought that several giant impacts of Mars-sized planet occur at the late stage of the terrestrial planet formation. Giant impacts cause the various severe phenomena. We focus on volatile elements, especially the materials that form the terrestrial planets' atmosphere and ocean.

In the past works (e.g., Ahrens, 1990, In Origin of the Earth), once a giant impact occurs, the proto-atmosphere is completely lost due to the strong ground motion excited by the shock wave traveling to the planetary interior. Therefore, it is generally thought that the present atmosphere of the terrestrial planets derives from volatile-rich planetesimals and/or comets accreted after the final giant impact (e.g., Owen et al., 2000, In Origin of the Earth and Moon). However, the recent work studied by Genda and Abe (submitted to Icarus, 2002) have demonstrated most of a proto-atmosphere survives such strong ground motion. Therefore, it has indicated that degassed atmosphere and/or gravitationally-attracted solar-type atmosphere during accretion stage of Mars-sized proto-planets play important roles as the source of atmospheric origin.

The surviving atmosphere becomes very hot (5000-10000K). This is because the atmosphere is heated by the planetary surface that is very hot due to the passage of the shock wave, and by the re-accretion of the impactor's fragments that is scattered around the target's planet. There is the possibility that such a very hot atmosphere, especially hydrogen gas is not bounded by the gravity of the planet, and easily lost. Since the atmosphere and surface ground is very hot, the silicate near the surface may be vaporized, and dense atmosphere composed of mixture of proto-atmosphere and silicate vapor is created. It is not clear that the hydrogen gas selectively escape from such a mixed atmosphere. Moreover, this mixed atmosphere itself may escape in the case of small planet, which correspond to the very early giant impact stage. The problems of atmospheric escape are related to the evolution of the isotopic fractionation of the terrestrial atmosphere. In this study, we numerically determine the escape flux of the atmosphere, and discuss the effect of thermal escape on the evolution of the atmosphere.