# Hydrodynamic escape of exoplanet atmospheres: Theoretical study of mineral atmospheres of close-in rocky planets with magma surfaces

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Until today, over 1000 exoplanets whose radii are less than 2 Earth radii have been discovered. About 50% of those planets have radiative equilibrium temperatures high enough to melt and vaporize rock. Thus, if rocky like CoRoT-7b, they likely have atmospheres composed of rocky materials (e.g., Schaefer & Fegley 2009, Ito et al.2015). We call such a rocky vapor atmosphere a mineral atmosphere in this study. Recent observation reported on the detection of close-in exoplanets with dusty tails, suggesting that there are hot rocky planets currently losing most parts of their masses (e.g., Rappaport et al. 2012). However, if so, it is puzzling why many hot rocky super-Earths currently detected could have survived such massive mass loss. Until today, while many hydrodynamic simulations of escape of a highly UV irradiated hydrogen-dominated atmosphere were performed for explaining the observationally constrained mass loss rate of close-in gas giants (called hot Jupiters), there are no theoretical studies that investigate the escape of mineral atmospheres on hot rocky exoplanets.
In this study, we focus on the escape of highly-UV irradiated mineral atmosphere on a hot rocky exoplanet with orbit of 0.02 AU during the early stage of a host G-type star with a high UV flux. And, we constructed an 1-D hydrodynamic model of the highly UV-irradiated, mineral atmosphere, including detailed radiative processes and photo- and thermo-chemistry. Then, we assume Na, O, Si, Mg and their ion as gas species in the model atmosphere. Using it for the cases of different planetary masses, we determined the escape rate and outflow structure of the atmosphere. Our results show that the escape is massive enough to be a hydrodynamic/transonic wind, and its flux notably depends on the planetary gravity. At the case of super-Earth (10 Earth-mass), almost all of the incident UV energy is converted into the radiative emission due to electronic transition in alkali metals and alkaline earth metal such as Na and Mg, and the rest of UV energy drives the atmospheric motion. In contrast, at the case of Mars-mass planet (0.1 Earth-mass), the incident visible and FUV energy efficiently drives the atmospheric motion due to the low gravity. As a result, the gravity dependence shows four orders-of-magnitude differences in the mass escaping flux between the case of super-Earth and the case of Mars-mass planets. Our simulation demonstrated that hot rocky exoplanets of 0.1 Earth mass selectively evaporate through the hydrodynamic escape of the mineral atmospheres, but ones with masses larger than one Earth mass survive.

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