Theoretical emission spectra of hot rocky super-Earths: Lack of alkali metals due to atmospheric escape

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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. In addition, previous studies showed that atmospheric loss processes such as atmospheric escape cause selective depletion of Na and K in the atmosphere and magma ocean, because of the high-volatility and low abundance of Na and K in rocks. Also, our new 1-D hydrodynamic model of the highly UV-irradiated mineral atmosphere (Ito & Ikoma, in prep) suggests that the hydrodynamic escape is massive enough to remove completely Na and K during the early stage of the host star. Thus, the detection of a mineral atmosphere would provide definitive evidence that the planet is rocky. Moreover, identifying the mineral atmosphere composition, especially the presence or absence of Na and K, would give constraints on the magma composition which could trace not only the interior but evolution of planets.

In this study, we focus on the temperature-pressure structure and detectability for emission spectra of the mineral atmosphere in hydrostatic equilibrium on a hot rocky super-Earth. Also, we investigate the impact of the selective depletion of Na and K on the thermal structure and emission spectra. In order to investigate it, we use the hydrostatic/radiative/chemical equilibrium atmospheric model for mineral atmospheres (Ito et al. 2015) which calculates the gas-melt equilibrium composition of the mineral atmosphere, vertical thermal structure and secondary eclipse depths. We show our results for higher planetary equilibrium temperature (2500, 3000K) such as CoRoT-7 b and Kepler-10 b. We find that the thermal inversion structure of the mineral atmosphere without Na and K is hotter than that of the atmosphere with Na and K. This is mainly because the atmosphere inefficiently emits photons in visible wavelength region due to the lack of Na and K. Our feasibility assessment demonstrates that identification of mineral atmospheres with and without Na and K on hot rocky super-Earths in secondary transit is possible via observation from space telescopes.

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