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Theoretical threshold mass and radius for close-in low-mass water-rich super-Earths: Implications for the main compositi

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Recent progress in observational technique has enabled us to find many exoplanets that have as small as several to several ten Earth masses and/or Earth radii (hereafter super-Earths). We can obtain the planetary mean densities from measured planetary masses and radii and thereby infer planetary compositions. It has been revealed that low-mass planets with short orbital periods (close-in planets) are diverse in composition. Despite of closeness, there are a significant number of close-in planets that have the potential to be mainly composed of water components (e.g., GJ1214b). Planetary composition is important to understand the planet's evolution and origin. I investigate mass-radius relationships for water-rich close-in planets, including the effects of thermal evolution and mass loss. Since close-in planets are strongly irradiated, they are rather hot and also experience mass loss. Nevertheless, impacts of those effects on the mass-radius relationships for water-rich planets have not been investigated previously. Through the investigation, I intend to derive threshold values for planetary mass and radius and constrain observations that can possess water components. I have calculated the interior structure and evolution of close-in water-rich planets, including the XUV-driven energy-limited hydrodynamic escape. I assume that the planet, orbiting a solar-type star, has three-layer structure: a water-vapor atmosphere, a water mantle and a rocky core from top to bottom. I have realized that the mass loss due to the intense stellar-XUV irradiation has a significant impact on evolution of close-in planets. In particular, water envelopes of the planets with mass of less than a few Earth masses, depending on distance from their host stars, are completely stripped off. I have derived a threshold value of the planet's initial mass below which the planet loses its water mantle completely. This threshold has been obtained as a function of the semi-major axis and other input parameters. The theoretical model of the structure and evolution of close-in water-rich planets in this dissertation predicts the domains in mass-period and radius-period distributions where naked rocky planets or water-rich planets are likely to be detected. This provides an essential piece of information for understanding the origin of close-in low-mass planets.

Keywords: Super-Earth, Mass loss, Interior structure