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EPSC Abstracts
Vol. 16, EPSC2022-418, 2022
Europlanet Science Congress 2022

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Short-period, low-mass planets have been found to often display inflated atmospheres [1]. Here, we investigate the interior structure of such planets with a moderate water budget using a fully self-consistent planet interior model [2, 3], where water can exist in supercritical state. This has been done by increasing the working range of an existing interior model, allowing us to explore the 0.2-2.3 Earth mass range. We consider planets with water mass fractions (WMF) ranging from 0.01% to 5% and irradiation temperatures between 500 and 2000K. Moreover, we consider three possible internal compositions; a pure rocky interior, an Earth-like core mass fraction (0.325) and a Mercury-like core mass fraction (0.7).

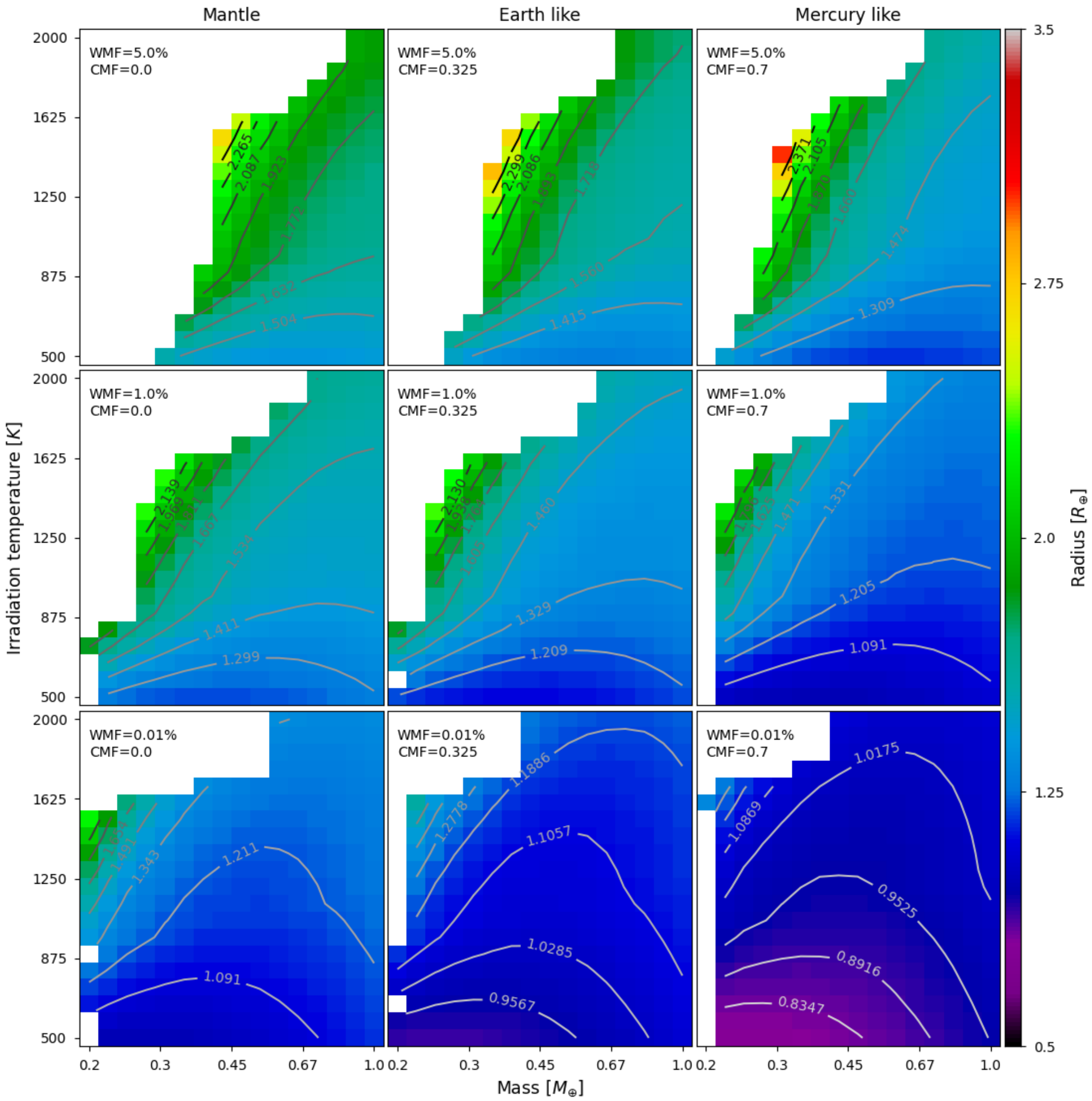

Figure 1: Computed planetary radii Rp at the transiting depth of 20mbar as a function of planetary mass and irradiation temperature. Columns correspond to different core mass fractions (0, 0.325, 0.7, from left to right) while rows correspond to different water mass fractions (5%, 1%, 0.01%, from top to bottom). Any missing data correspond to cases where the atmosphere is hydrostatically unstable.

We find that at higher masses, the planet radius increases with the planet mass, and the radii for planets with supercritical water are greater than if water was in a condensed phase. An important mass of water can also result in a notable compression of the refractory layers (up to 0.1 Earth radius for a WMF of 5%). At lower masses, we find that the steam atmosphere inflates, and becomes gravitationally unstable when the scale height of the atmosphere exceeds ~0.1 times the planetary radius. We propose to use this H/Rp ratio as a stability criterion for steam atmospheres.

Our data can be used to estimate the maximum WMF that can be retained by a planet given its mass, irradiation temperature and interior composition. For a given mass and temperature, a large part of the planets considered here can be stable even if constituted of 100% water. As the temperature increases or as the mass decreases, the surface gravity of a 100% water planet becomes too weak to retain the steam atmosphere. It is then possible to estimate the maximum WMF under which the atmosphere is stable.

Our results show that planets under 0.9 Earth masses should typically present unstable hydrospheres. We also find that a sharp transition exists between a planet able to hold a 100% water atmosphere and an unstable one, as the H/Rp stability criterion exceeds 0.1. Additionally, we note that this class of planets is a viable explanation of the current Super-Puff category without invoking instrumental limitations, as the mass of water molecules induces a more inflated atmosphere than H/He planets.

References:

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