Mass-Radius relationships of small, highly irradiated exoplanets with small water mass fractions

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We use a fully self-consistent planet model, based on an internal structure model and an atmosphere model to produce mass-radius relationships for a wide variety of planets with water contents <5%. We look at multiple internal structure compositions, irradiation temperatures and WMFs (Water Mass Fractions). The results show that the contraction of the interior structure is non negligible, the inflation of the atmosphere takes place for planets even with small water contents, and finally this inflation leads to many planets not being able to retain an atmosphere under hydrostatic stability.

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Introduction

This poster presents the results obtained for planets with small water contents. The approach follows the one described in Mousis et al. 2020 and Aguichine et al. 2021.

The discovery of widespread presence of water in the solar system, as well as its detection on Neptune-like exoplanets, raises the possibility that planets with large water contents exist.

Such planets, under the right insolation, would present inflated atmospheres and thus bridge the gap between the super-Earth and sub-Neptune populations without the need to invoke the presence of large H/He enveloppes.

This unified class of planets would then present the aspect of either of the previous categories purely based on their water content and irradiation temperature.

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Methodology

We couple an internal structure model (Brugger et al., 2017) to an atmosphere model (Marcq et al. 2017, 2019) to produce fully self-consistent planets.

We base our computations on a grid of planets with masses ranging from 0.2 to $2.3M_{\oplus}$, WMFs between 0.01% and 5%, irradiation temperatures from 500 to 2000K, and three different internal compositions (pure mantle, Earth like and Mercury like).

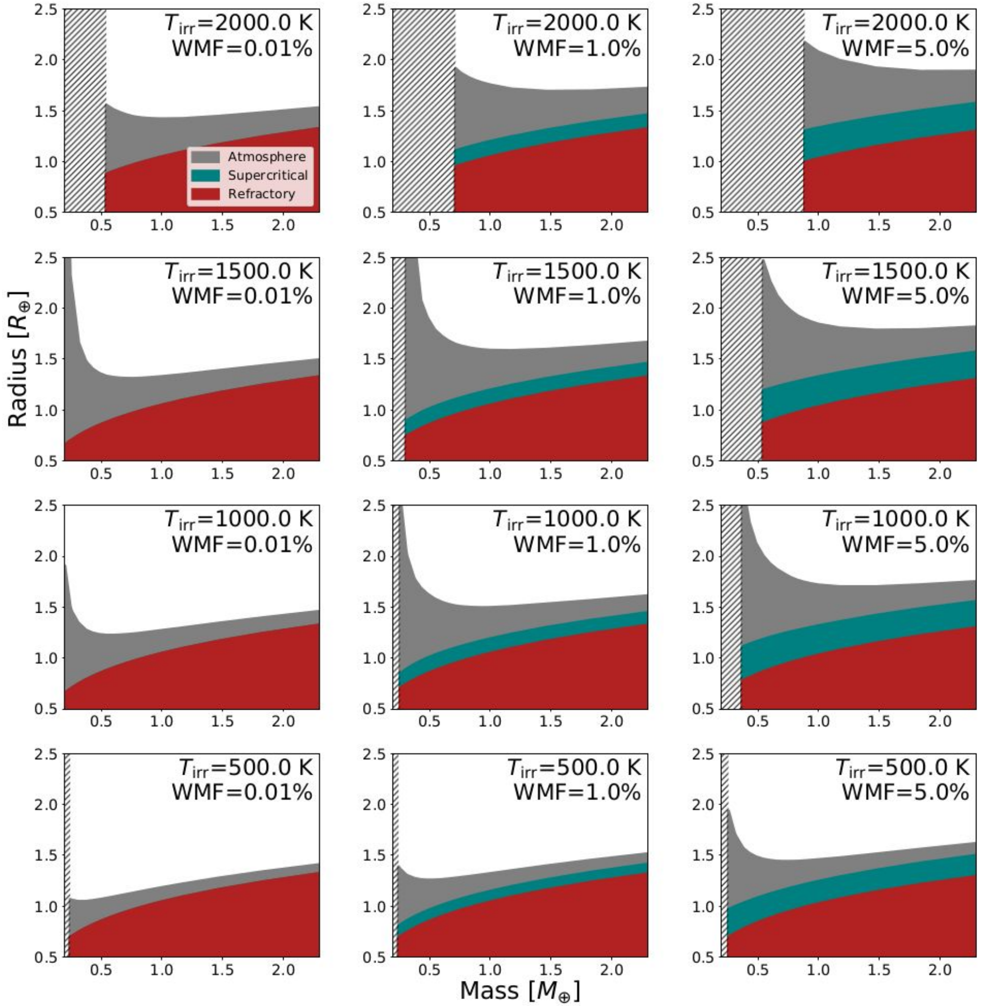
In addition to the internal layers, our models handle water phases from ice to plasma (see Fig.1 in Aguichine et al. 2021).

The models are connected at a given boundary pressure P_b = 300bar, where the relevant parameters (temperature, gravity and water fractions) are passed to each models. This way, we are able to account for the refractory layers contraction, and evaluate the hydrostatic validity of any given atmosphere.

Results

We show that even for WMFs as low as 0.01%, atmospheric inflation can clearly be seen. We also show that many of these planets are not valid from a hydrostatic point of view (hased areas).

We can also clearly see that water in supercritical phase appears even for WMF as low as 1% at any temperature.



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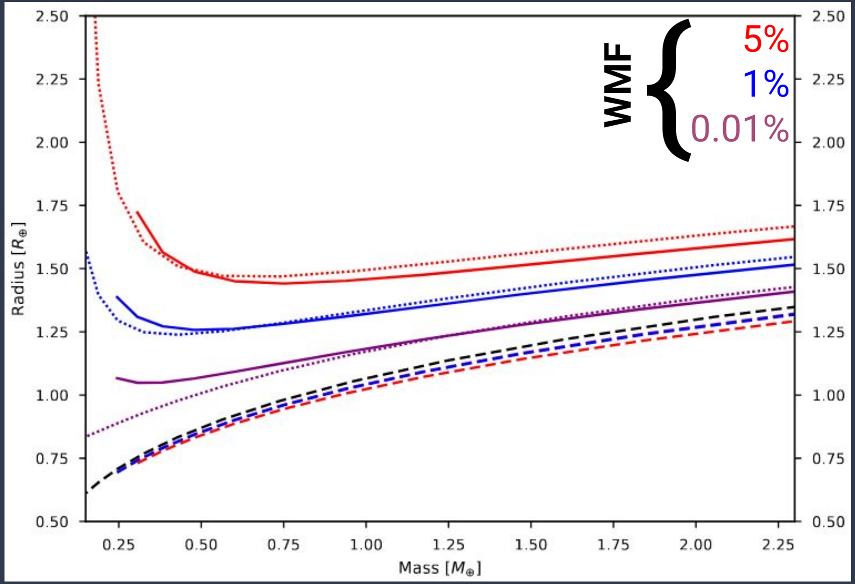
Conclusions

We show that inflation, and hydrostatic instability, exist even for planets with low water contents. We also show that the presence of water in the supercritical state is ubiquitous, and must be accounted for.

We also compare our results to a similar approach, from Turbet et al. 2020, where atmospheric inflation is also evaluated, and results are in agreement for the most part. While their model proposes a mode elaborate atmosphere model; ours makes use of a newer supercritical model, as well as core compression handling. Therefore, our model predicts some planets to be impossible.

Comparison between the mass-radius relationships computed from our model (solid lines) and that of Turbet et al. 2020 (dotted lines) for T_{irr}=500K in the case CMF=0. The colored and black dashed lines correspond to the base of the hydrosphere computed from our approach and that of Turbet et al. 2020 respectively.



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