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Hidden water in magma ocean exoplanets

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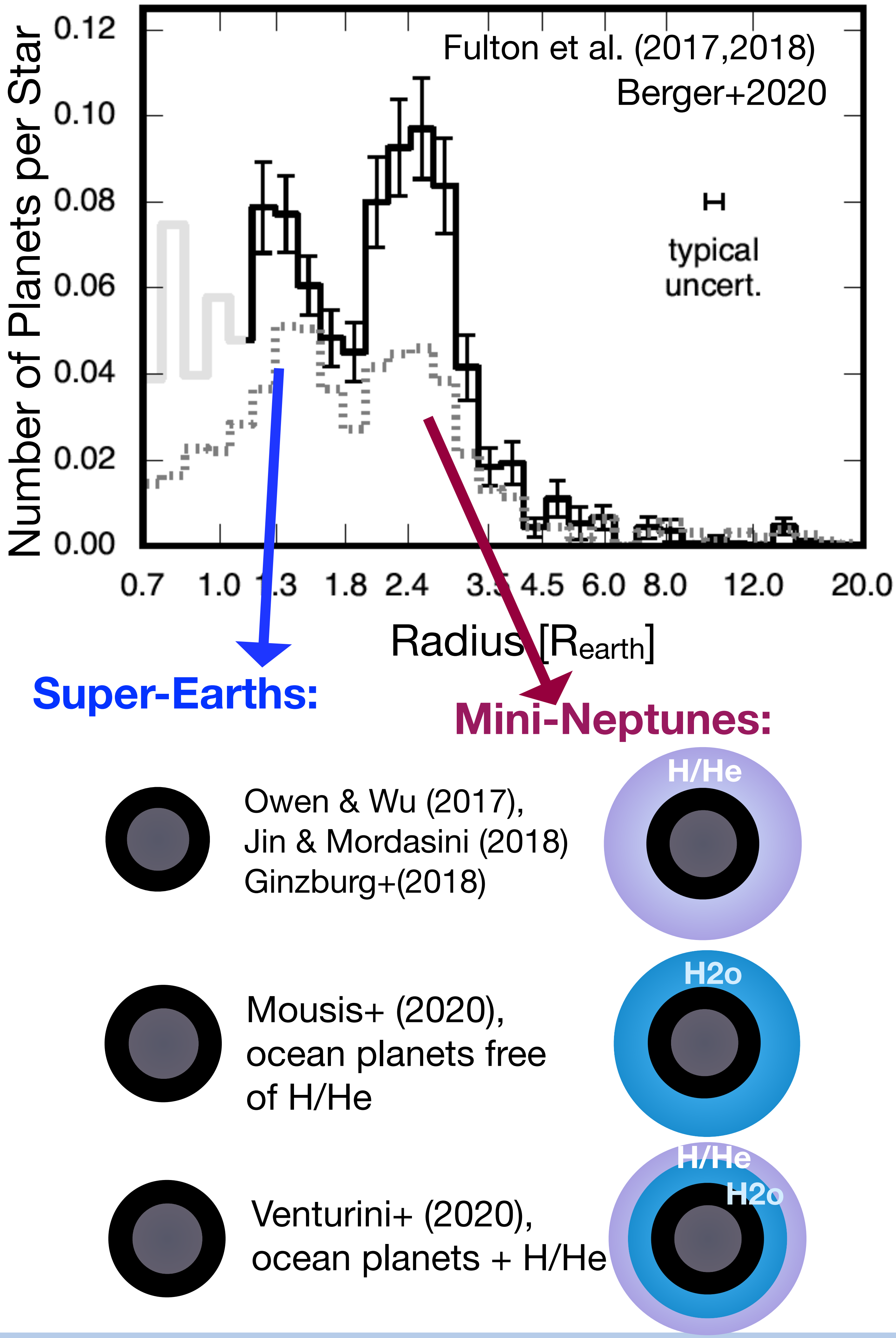


So far, the majority of studies on interior characterization, evolution and formation employ rel. simple structure models: a cold rocky interior with volatile layers on top. This simple model has been used to interpret the bimodality of planet radii - which is among the most important observational constraints.

In recent years, we learned that planet interiors are more complex and the simple model is put in question.

New view on planet interiors

includes chemical reactions between layers & volatile partitioning

magma oceans are common!
mantle rock is molten

magma ocean + primordial H:
water is produced

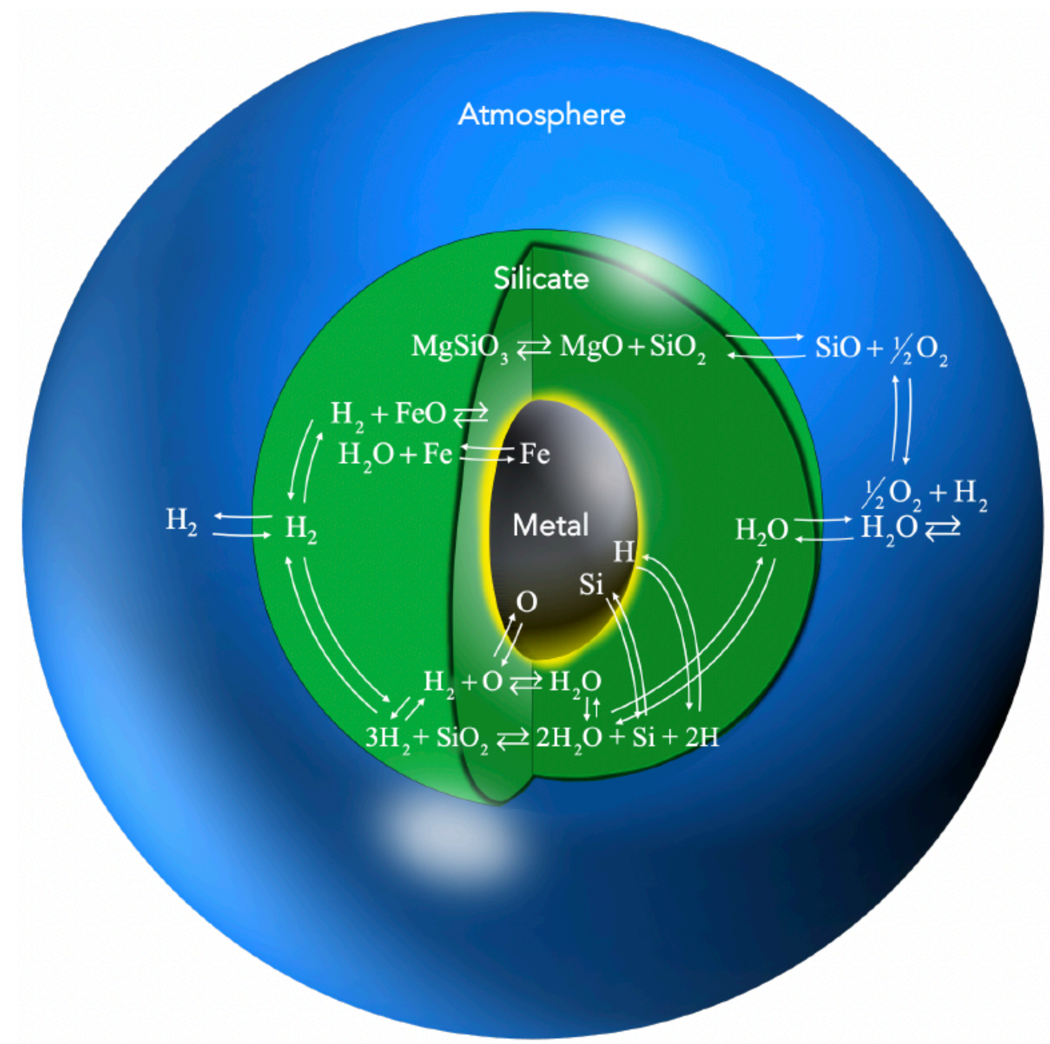
$$\mathrm{FeO_{silicate} + H_{2,gas} \rightleftharpoons Fe_{metal} + H_2O_{gas}}$$

Kite & Schaefer (2021)
Schlichting & Young (arxiv, 2021)
Kimura & Ikoma (2020)

magma ocean + volatiles:
volatiles & magma mix

H2O partitions most efficiently

Olson & Sharp (2019)
Vazan+(2020)
Bower+(2019, 2021)



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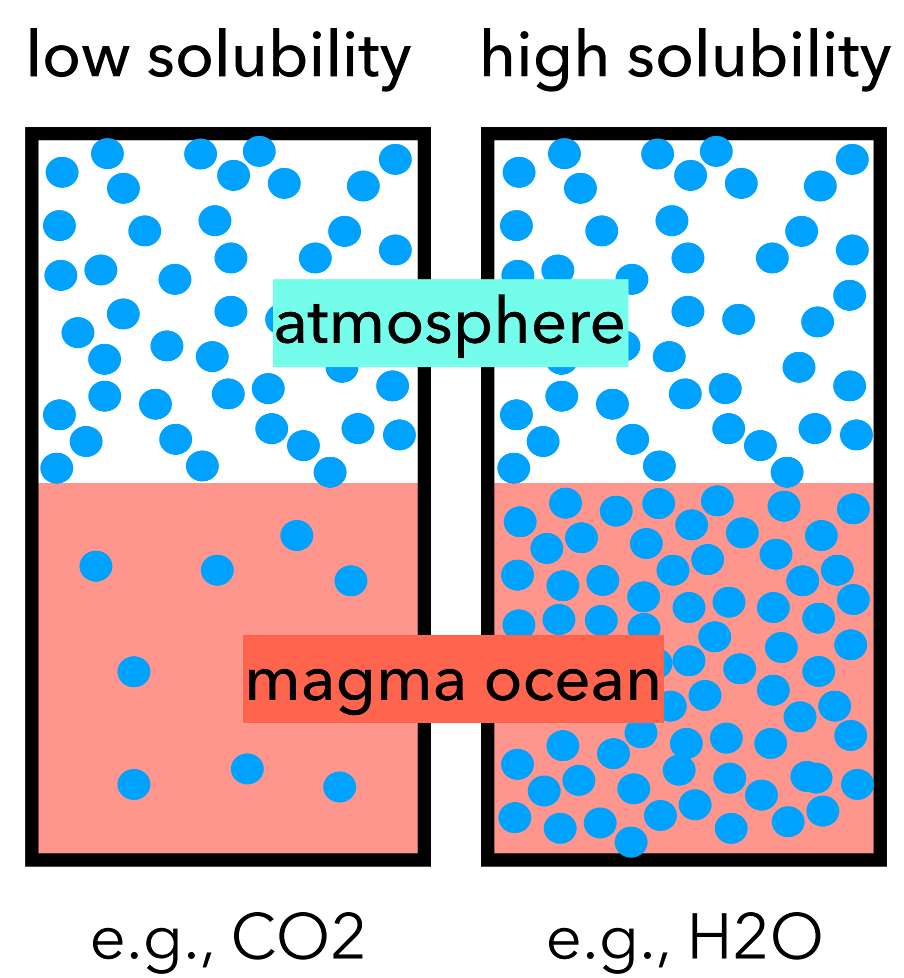
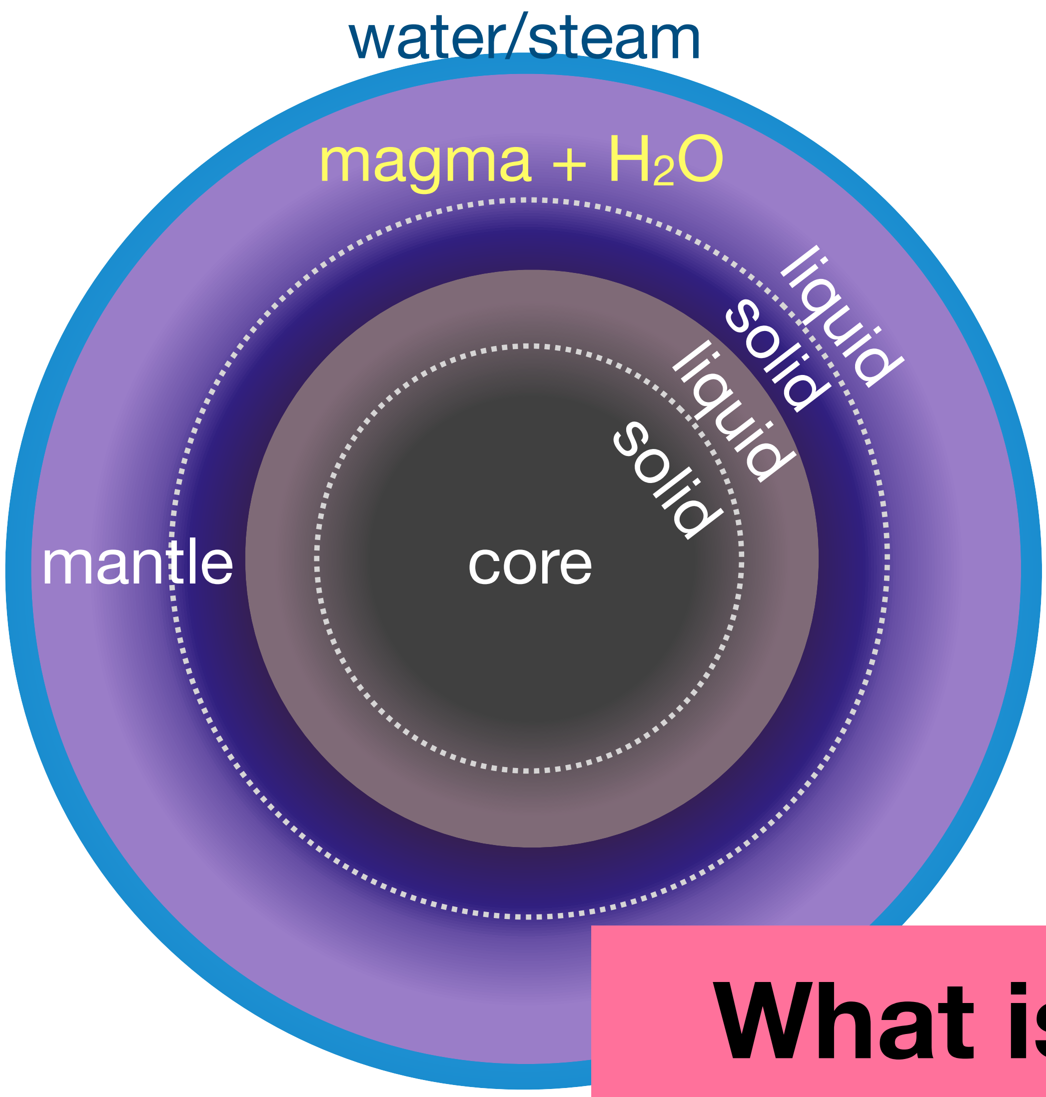
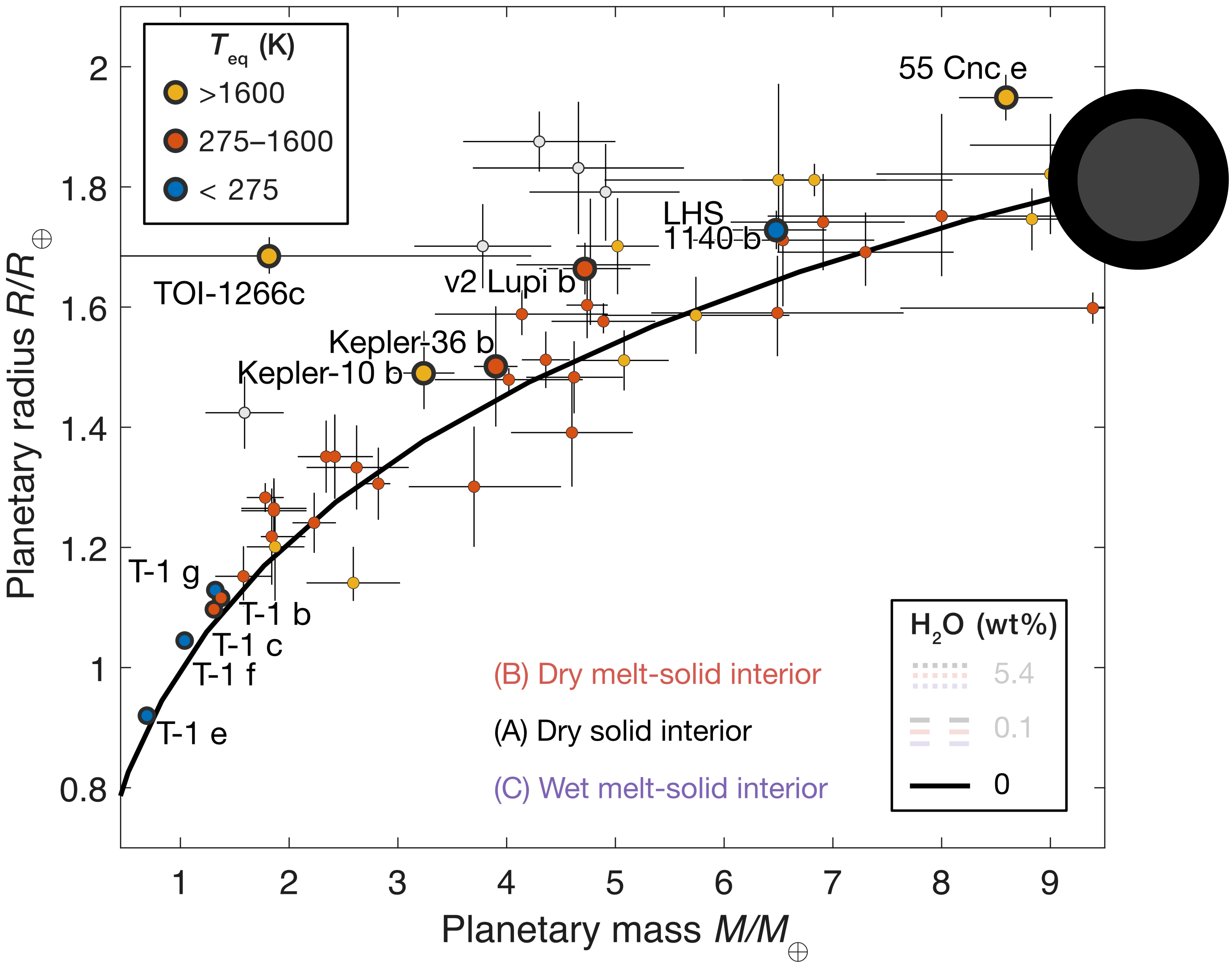


magma oceans can be huge water reservoirs

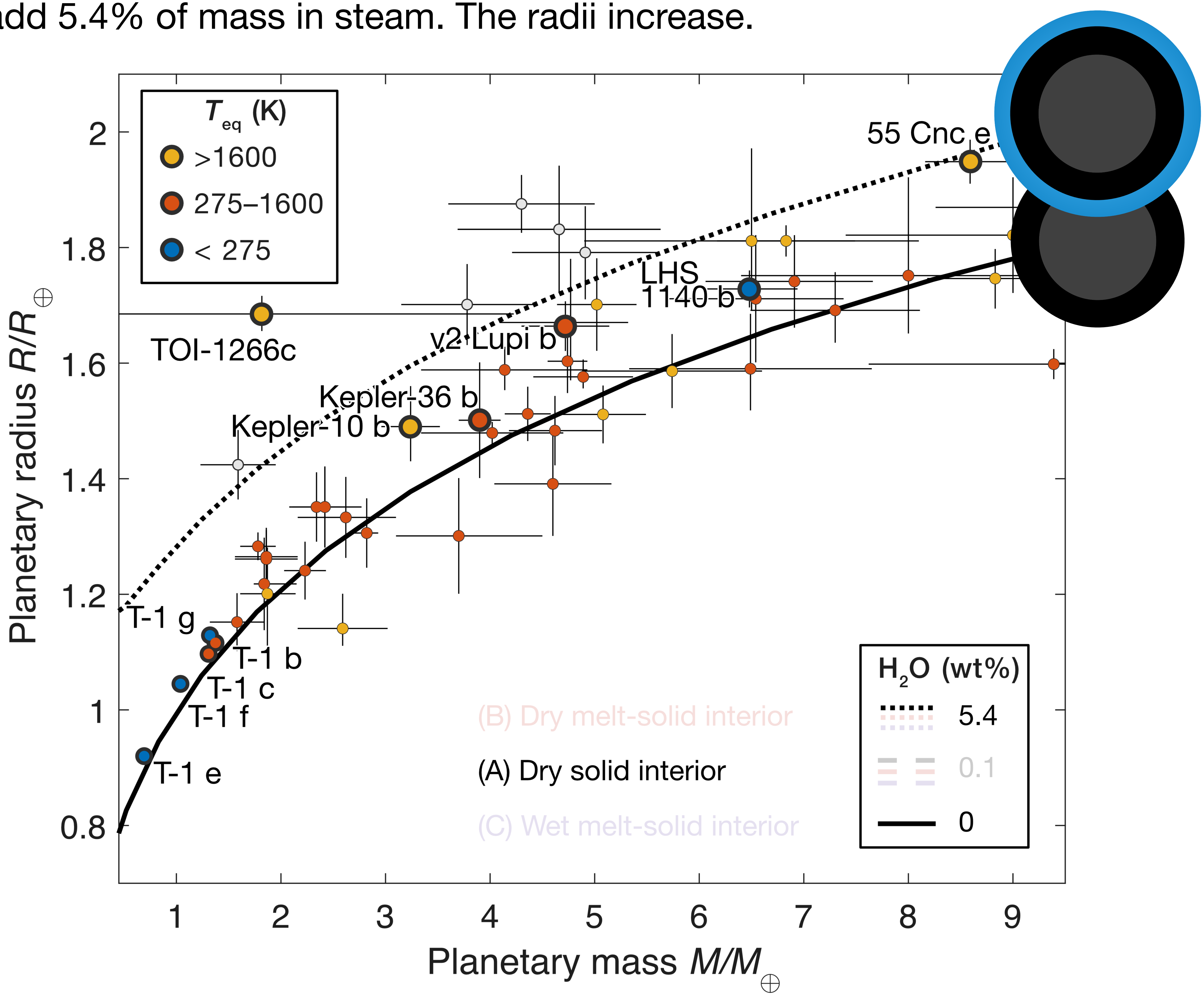


What is the effect on R of deep water reservoirs ?

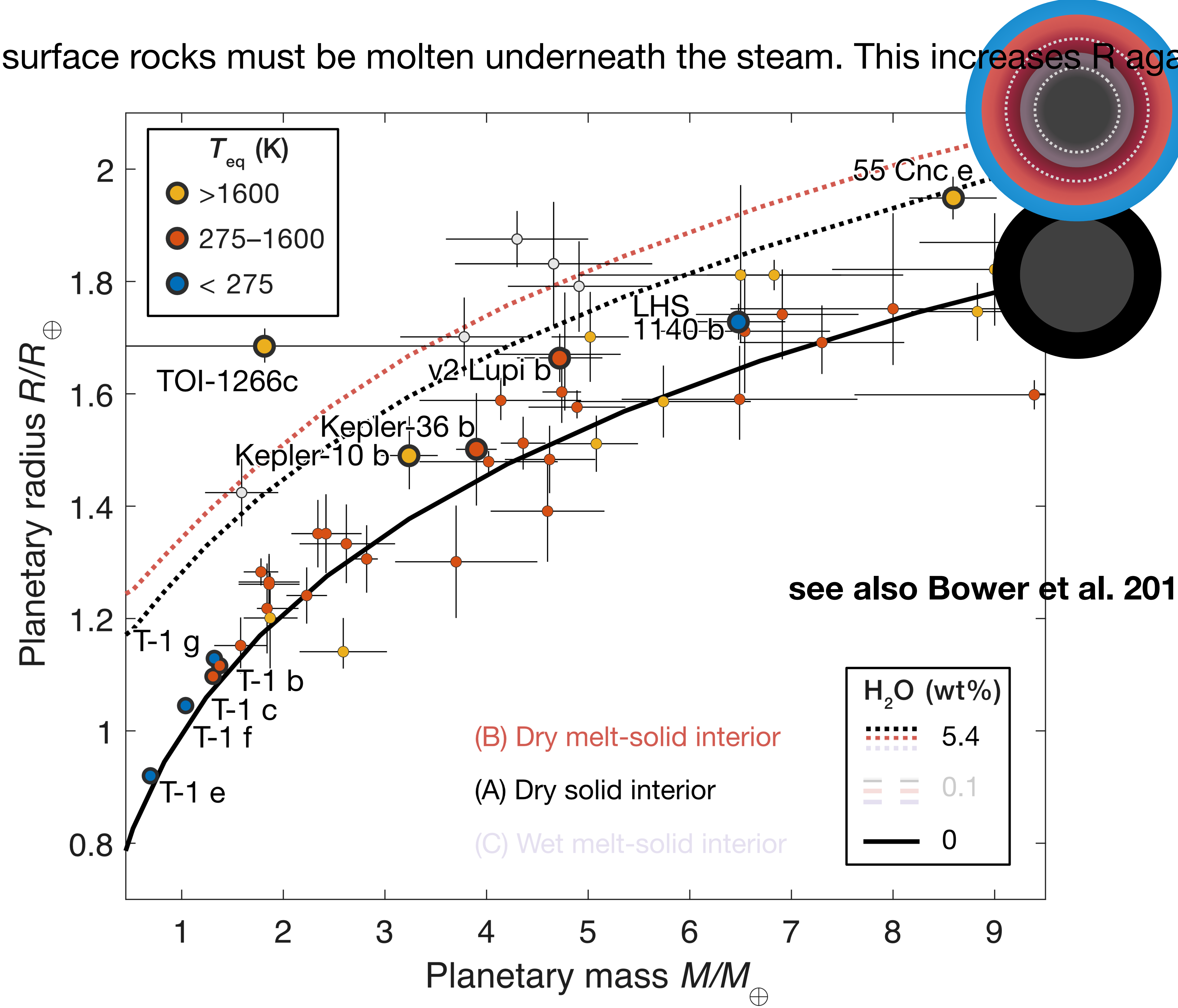
Here I plot a curve for an Earth-like composition, a purely rocky and cold interior.



Now I add 5.4% of mass in steam. The radii increase.

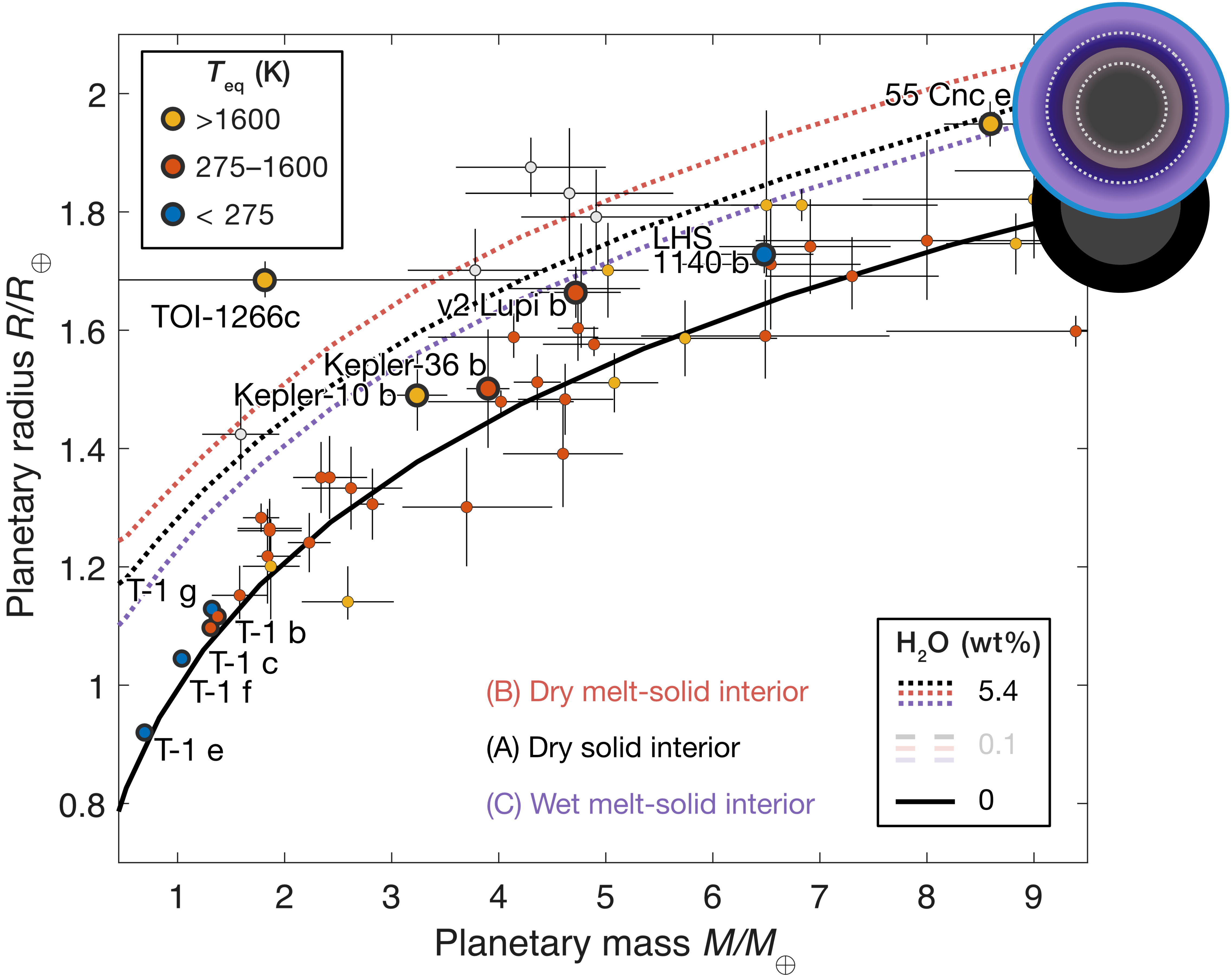


Now the surface rocks must be molten underneath the steam. This increases R again.

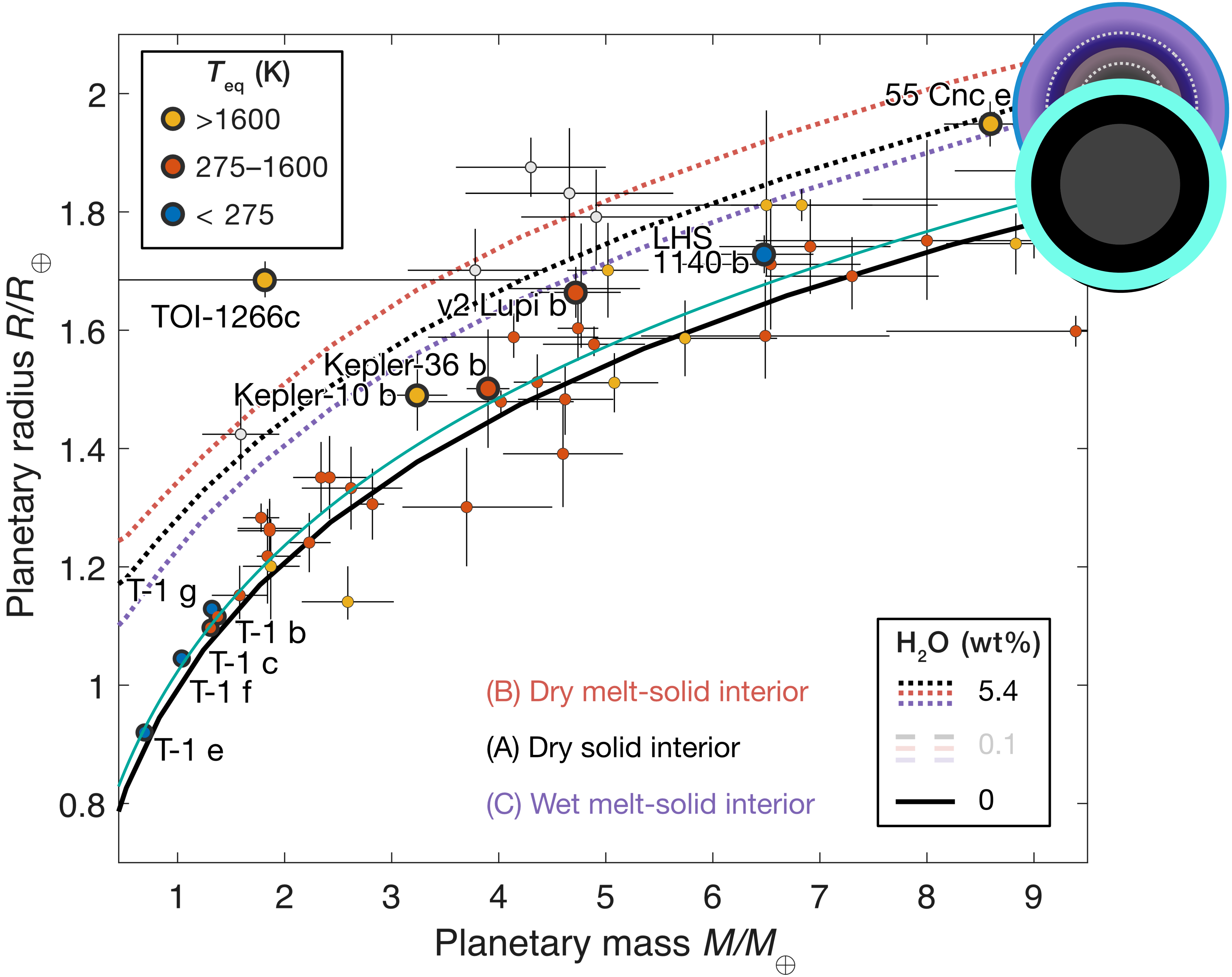


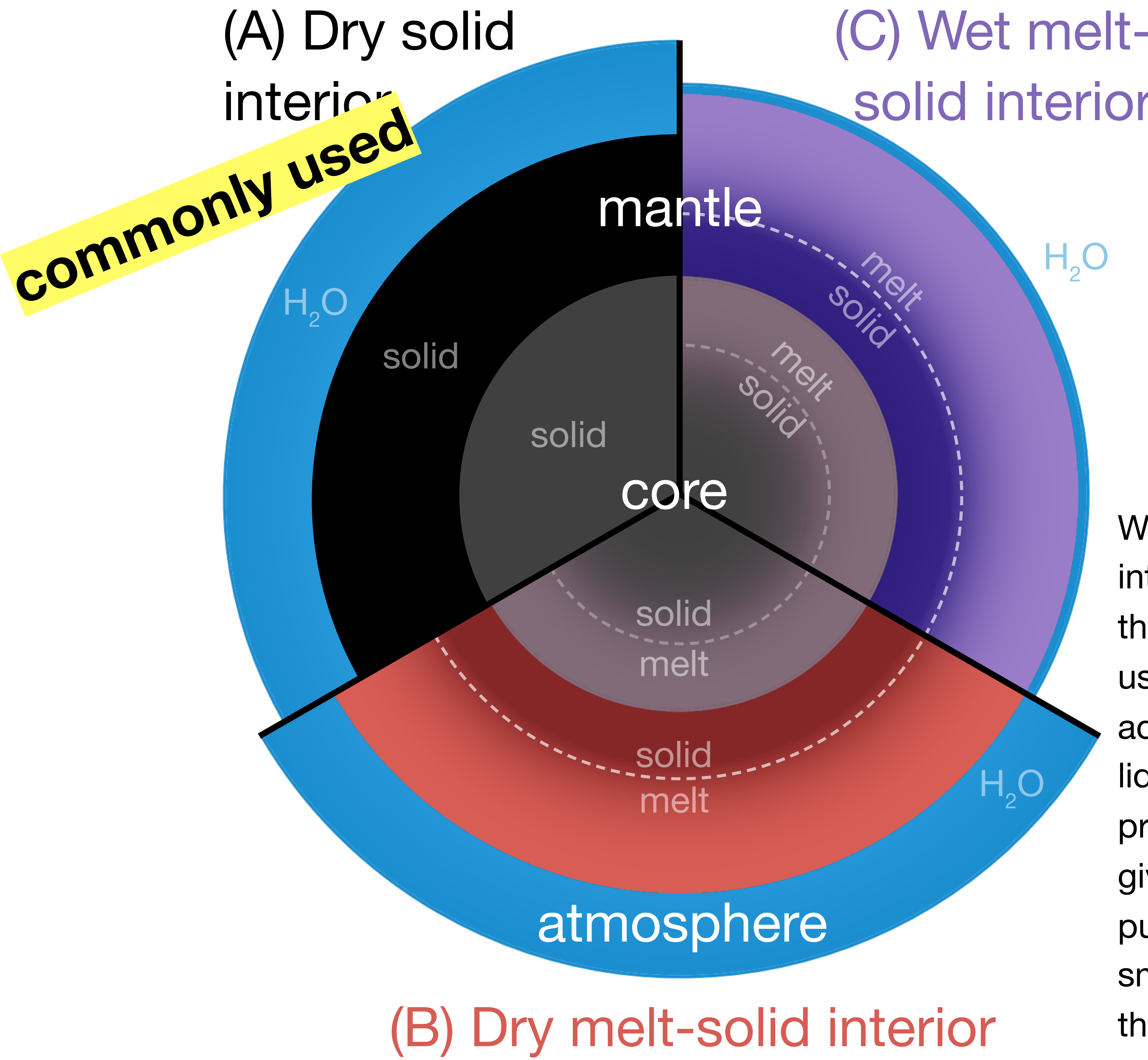
see also Bower et al. 2019

But the water will dissolve into the interior. This decreases R for the purple model.



For comparison: Here a M-R curve for a cold interior with water in form of ice.

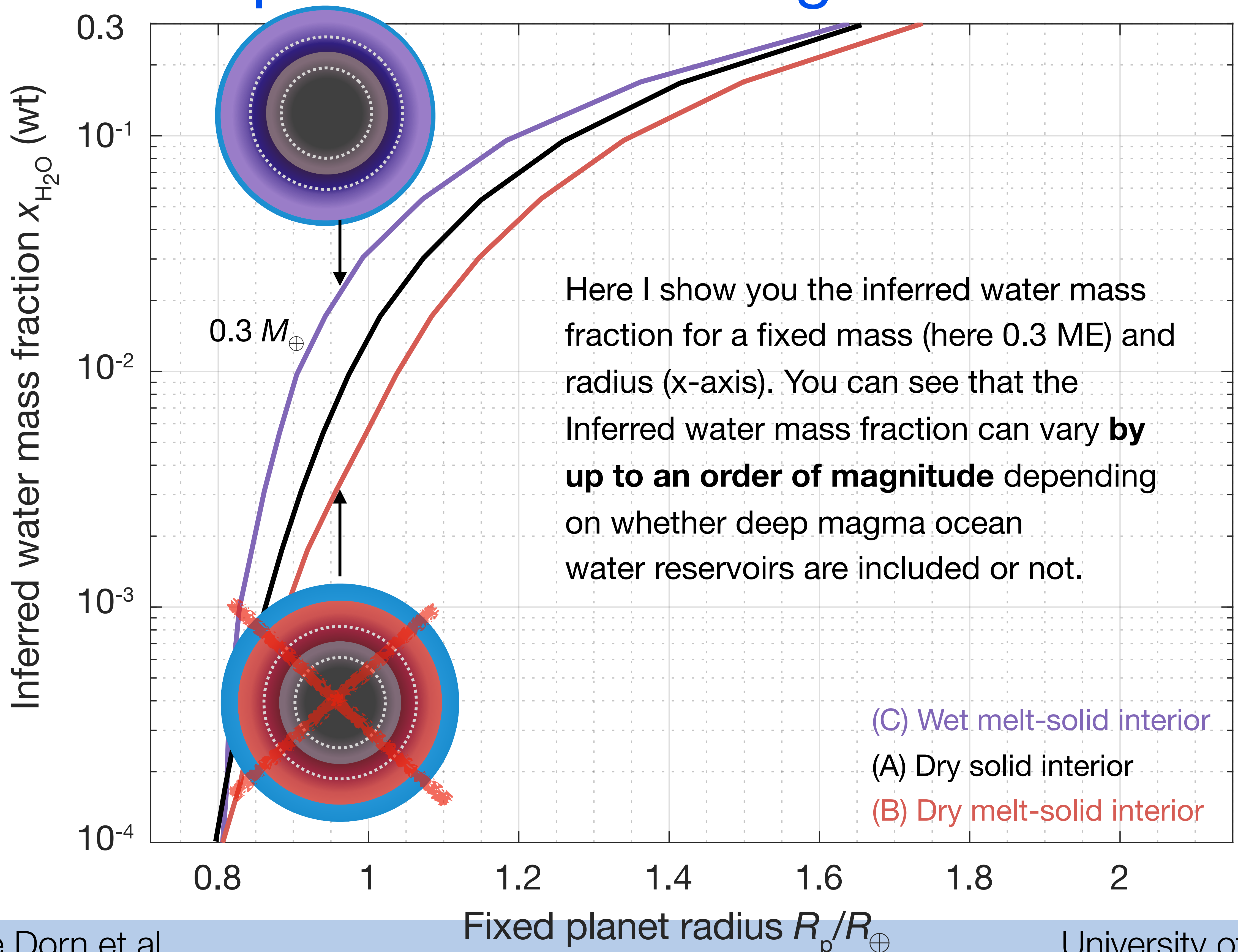




We have compared these 3 interior models. The black is the one which is commonly used. The red model is more advanced as it accounts for liquid rock phases. This model provides the largest radii for a given composition, while the purple model yields the smallest radii and is physically the most accurate.

Effect on inferred water budgets?

up to 1 order of magnitude differences



Here I show you the inferred water mass fraction for a fixed mass (here 0.3 ME) and radius (x-axis). You can see that the Inferred water mass fraction can vary **by up to an order of magnitude** depending on whether deep magma ocean water reservoirs are included or not.

Effect on inferred water budgets?

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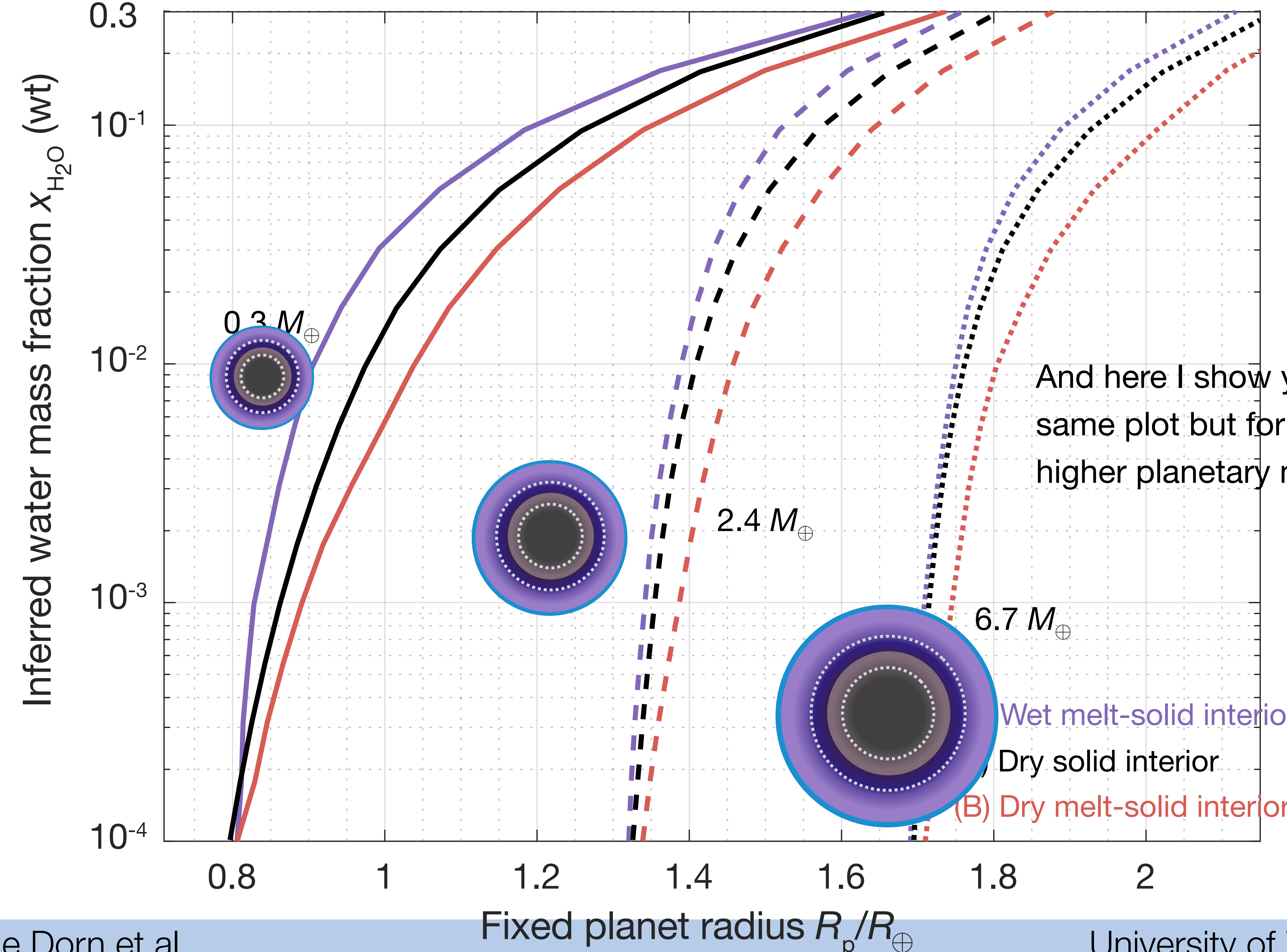
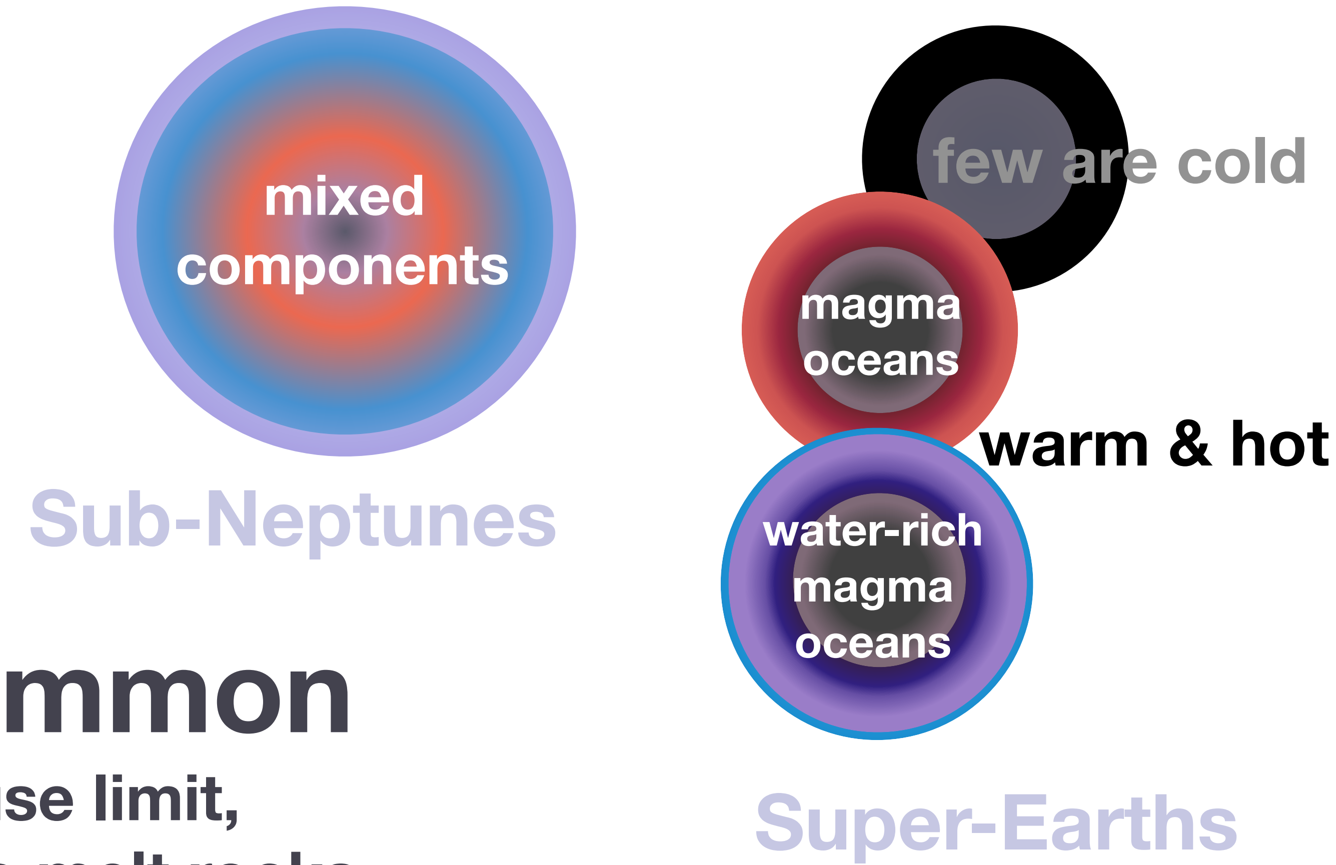


And here I show you the same plot but for few higher planetary masses.

Conclusions



water is common

(accreted & chemically produced)

magma oceans are common

**(3/4 are within the runaway greenhouse limit,
1/4 are hot enough without atmosphere to melt rocks,
few exceptions: Trappist-1, LHS 1140b)**

magma oceans are huge water reservoirs

**(inferred water budget can raise by 1 order of magnitude
compared with previous models)**

-> implications:

- reduced evaporative loss
- sub-stellar water abundances for Neptune atmospheres

Dorn & Lichtenberg (2021)