Probing the link between atmosphere and interior

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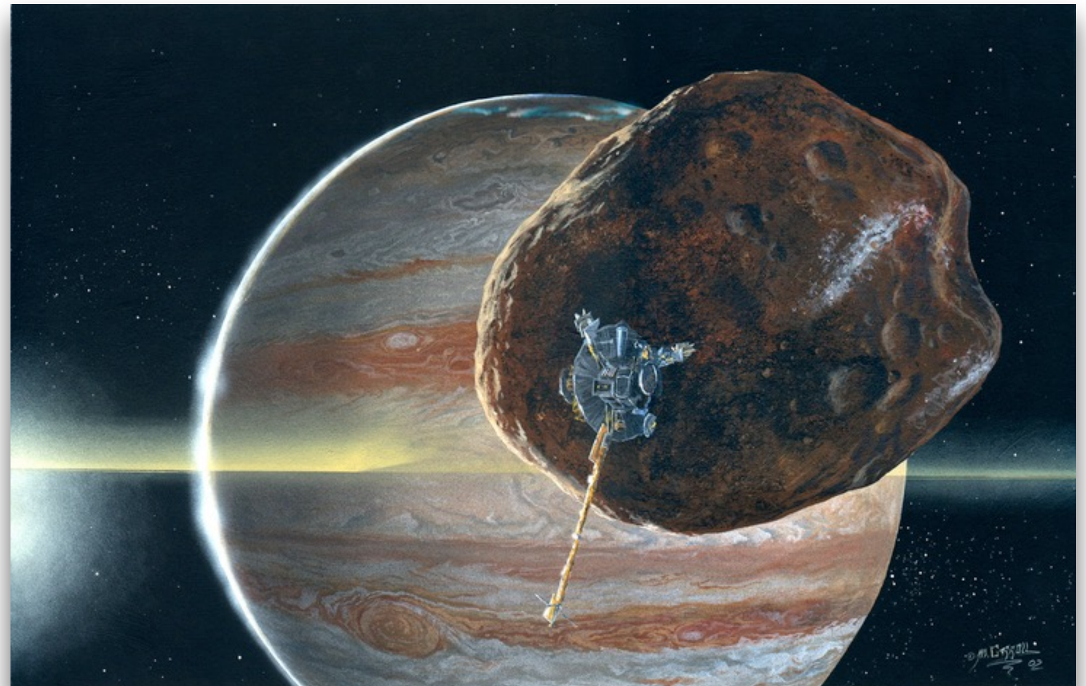
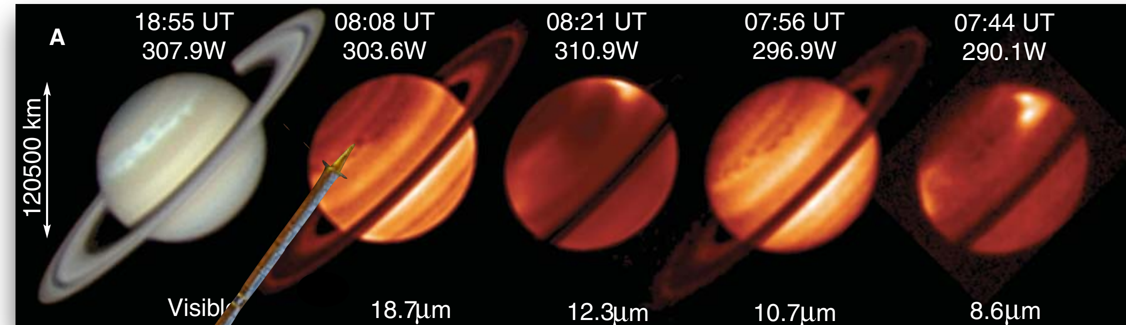
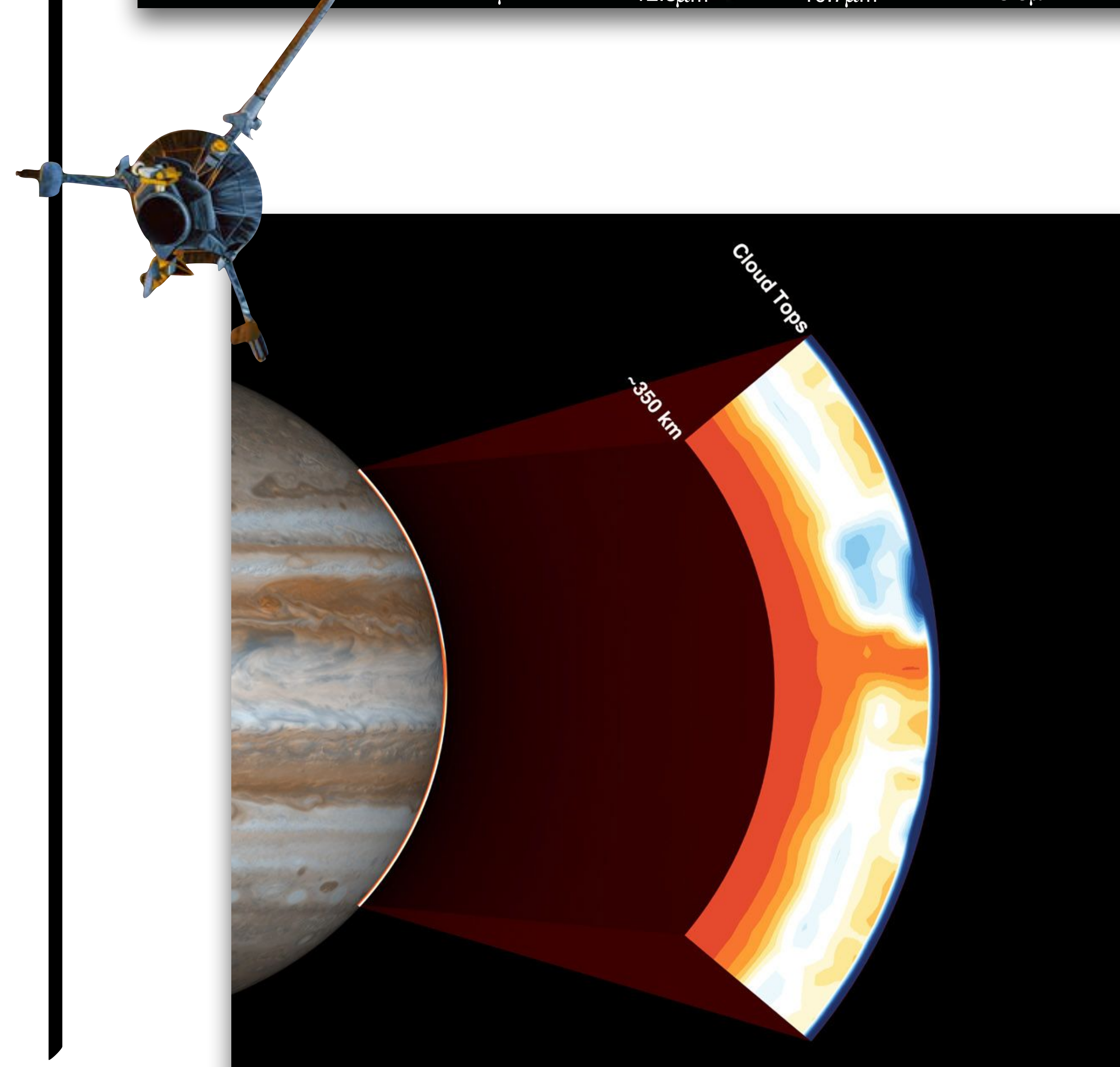
Interiors and atmospheres: two different worlds?



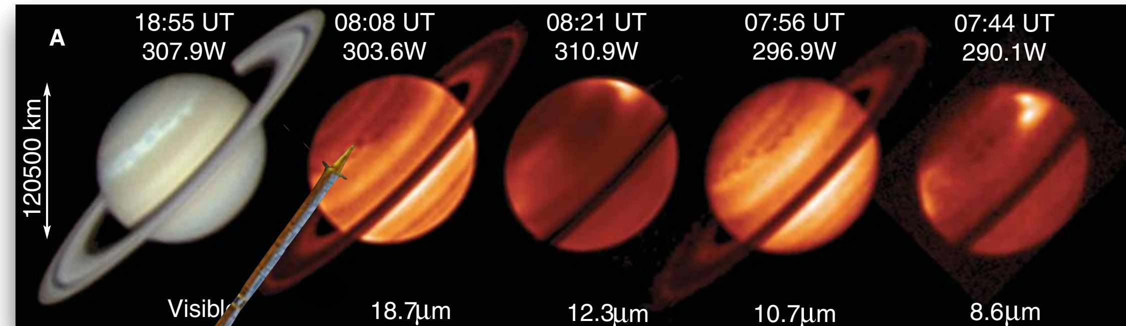


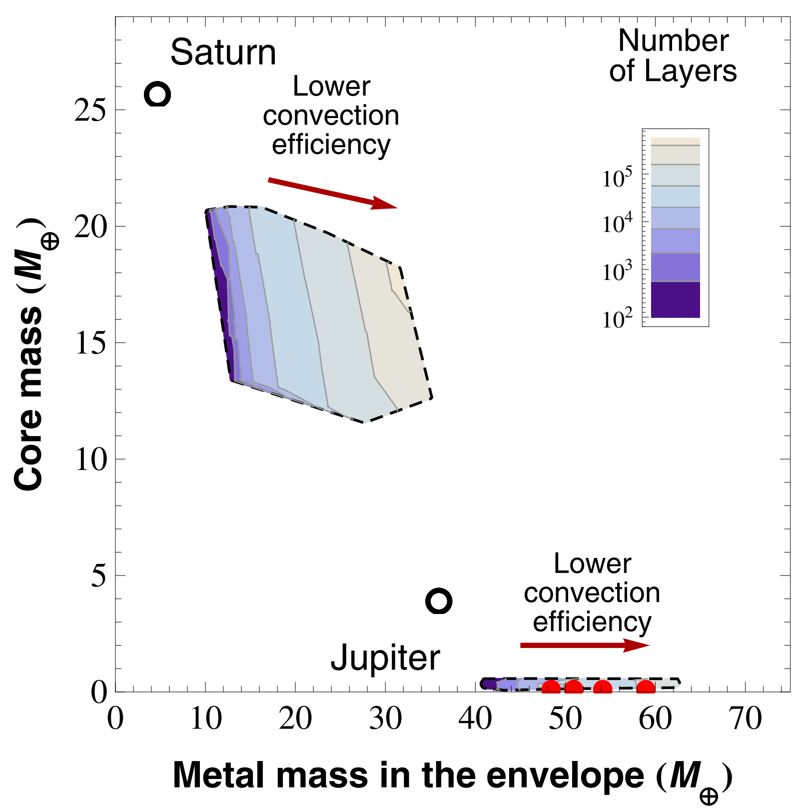


Ammonia map from Bolton et al. (2017)

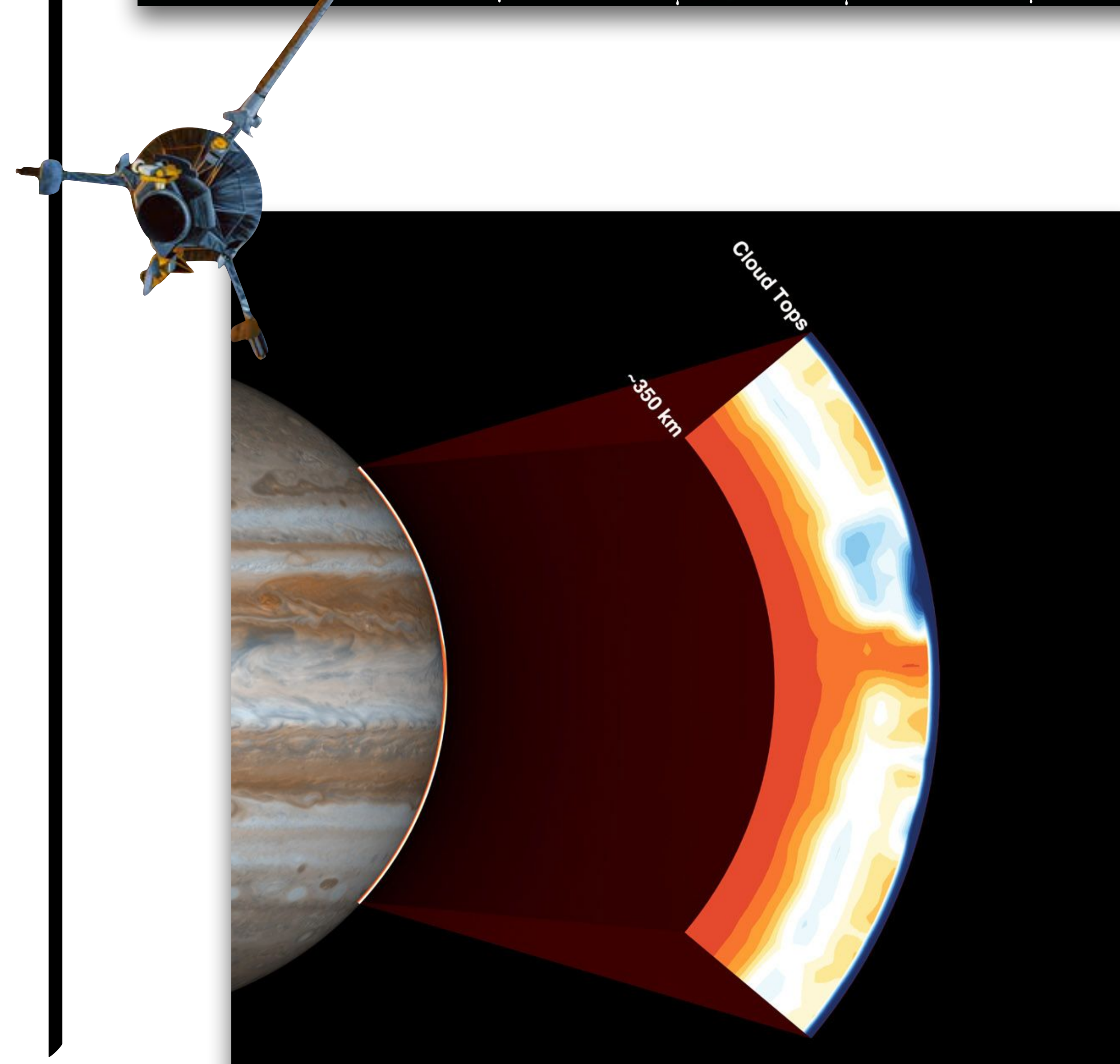
Interiors and atmospheres: two different worlds?

	Jupiter	Saturn
M_p [10^{26} kg]	18.986112(15)	5.684640(30)
R_{eq} [10^7 m]	7.1492(4)	6.0268(4)
R_{pol}[10^7 m]	6.6854(10)	5.4364(10)
P_{rot} [10^4 s]	3.57297(41)	3.83577(47)
T_{1bar} [K]	165.(5)	135.(5)
F_{tot} [W.m^{-2}]	5.44(43)	2.01(14)
$J_2 \times 10^2$	1.4697(1)	1.6332(10)
$J_4 \times 10^4$	–5.84(5)	–9.19(40)





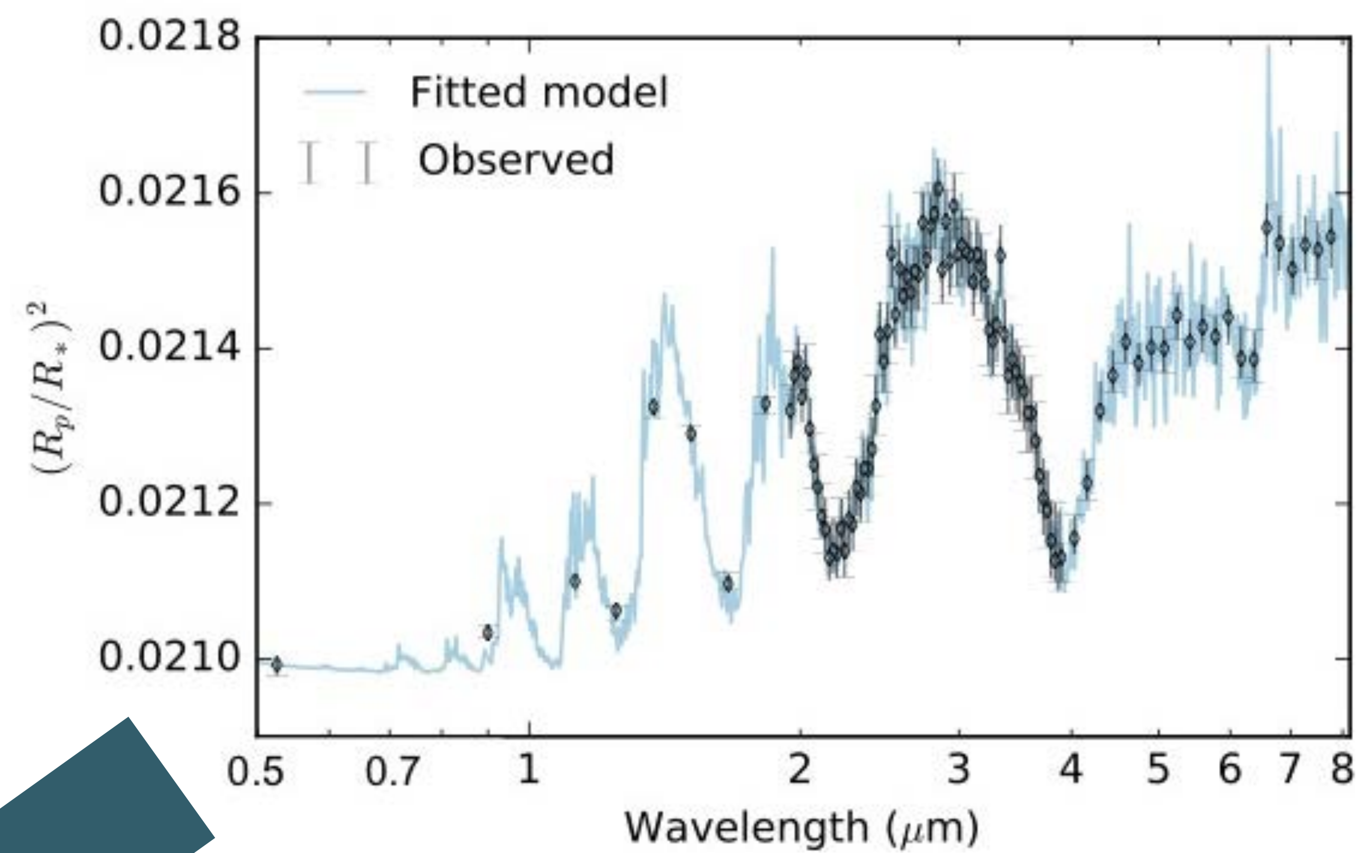
Leconte & Chabrier (2012)

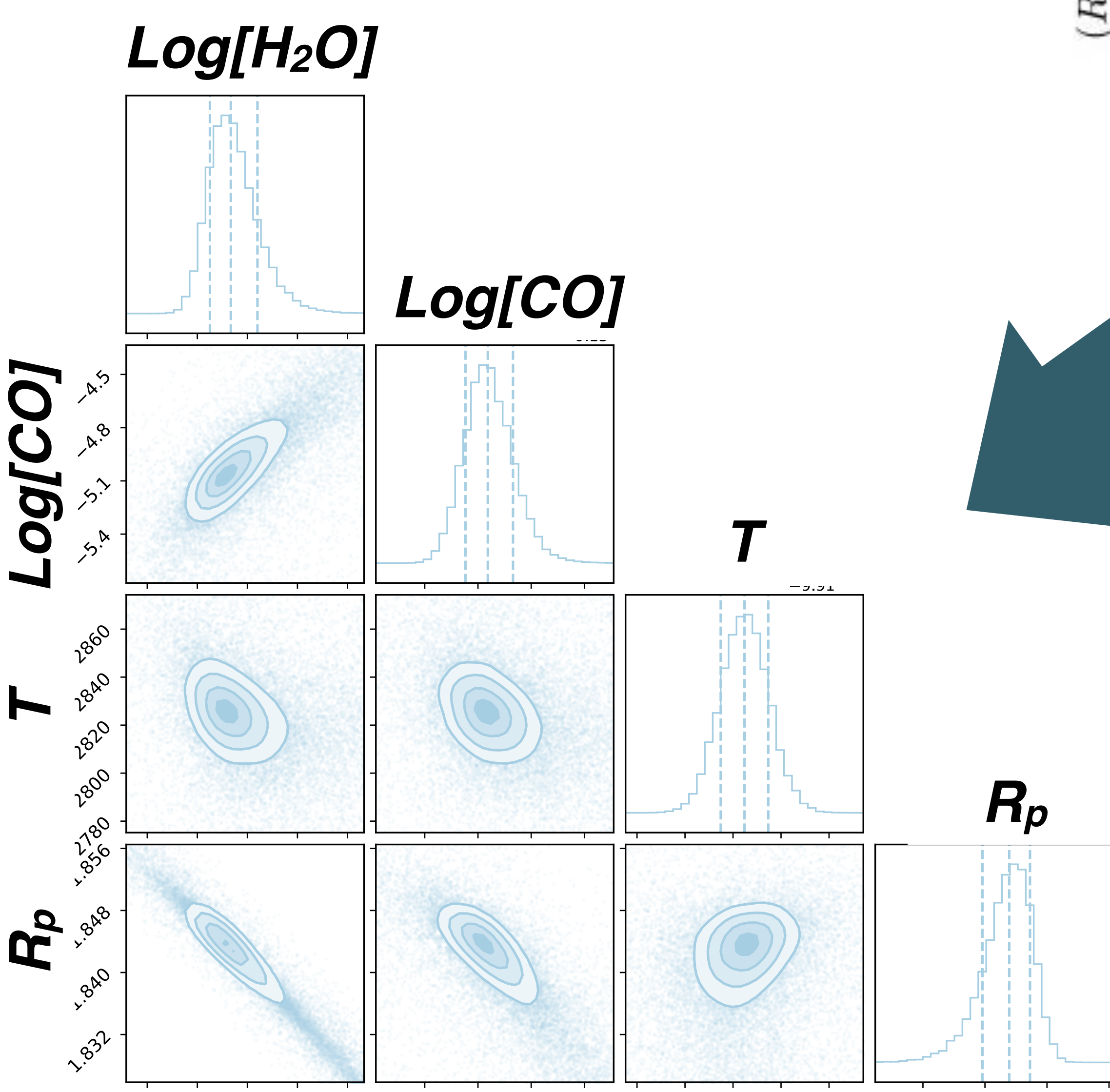


Ammonia map from Bolton et al. (2017)

Interiors and atmospheres: two different worlds?

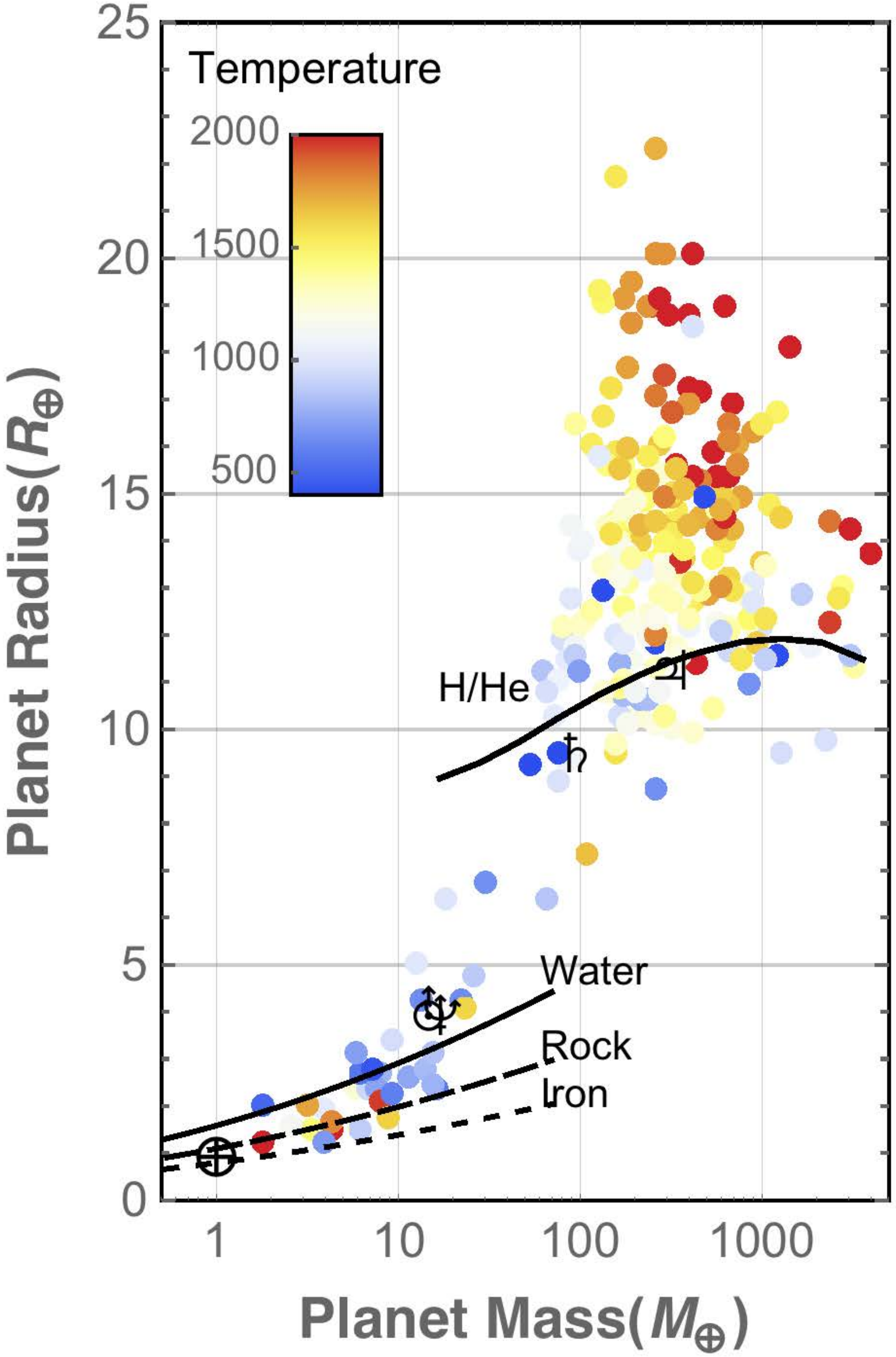
Measure spectral information





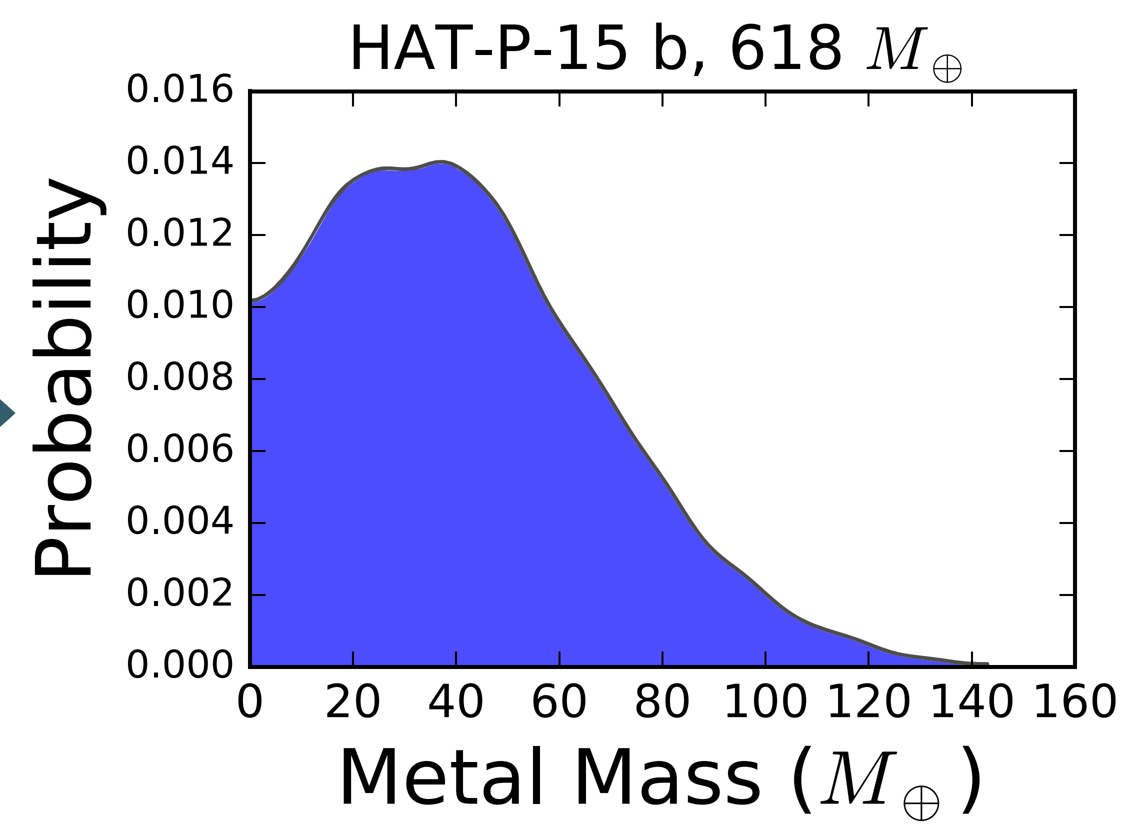
Constrain temperature structure and composition

Interiors and atmospheres: two different worlds?



Model

Interior retrieval!

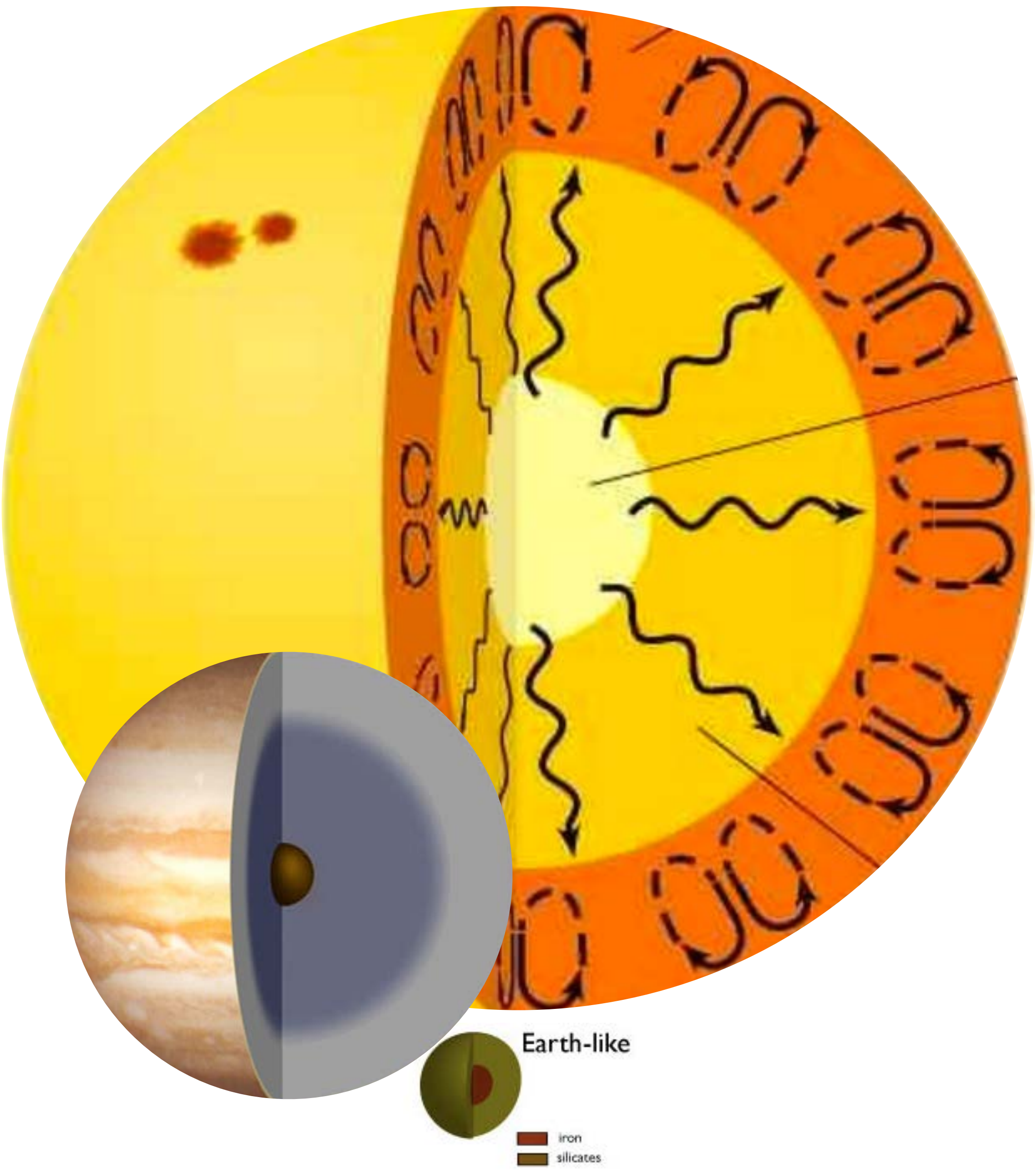


Leconte et al. (2009)
Cabrera et al. (2010)
Miller & Fortney (2011)
Thorngren et al. (2016)

What are the <u>degeneracies</u>?

Can ARIEL help with it?

(Sub)stellar evolution equations



$$\frac{\partial r}{\partial m} = -\frac{1}{4\pi r^2 \rho}$$

$$\frac{\partial P}{\partial m} = -\frac{Gm(r)}{4\pi r^4}$$

$$\frac{\partial l}{\partial m} = \epsilon - T\frac{\partial S}{\partial t}$$

$$\frac{\partial \ln T}{\partial \ln P} = \nabla_T$$

- Boundary conditions:
  - Measured temperature
  - Evolution => Atmosphere model

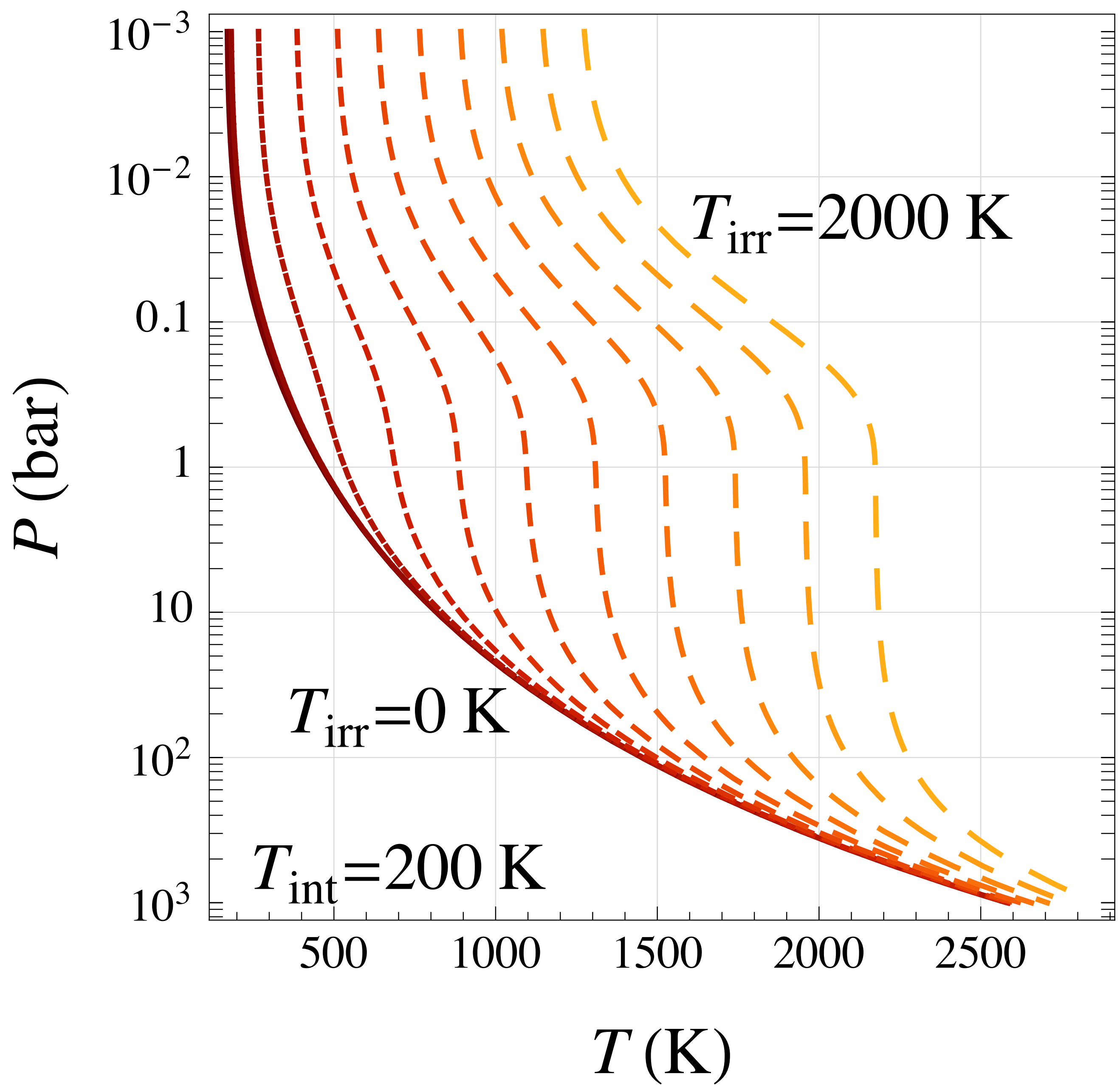
Boundary condition: measuring the atmospheric temperature

★In principle, ARIEL could measure directly the temperature (as in SS)

★But:

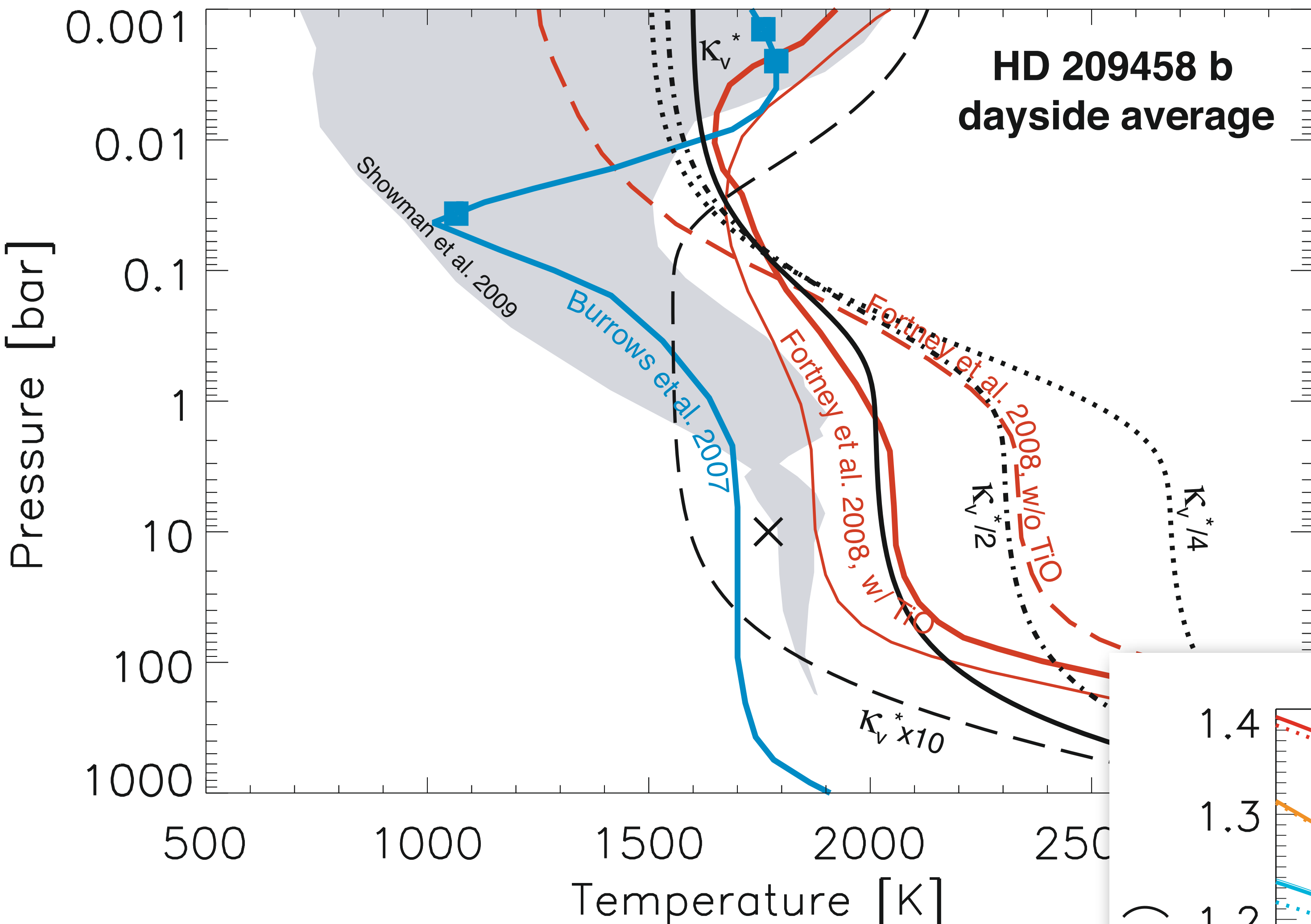
➡Large uncertainties because you need to measure deep

➡Link to the internal adiabat less direct for highly irradiated planets

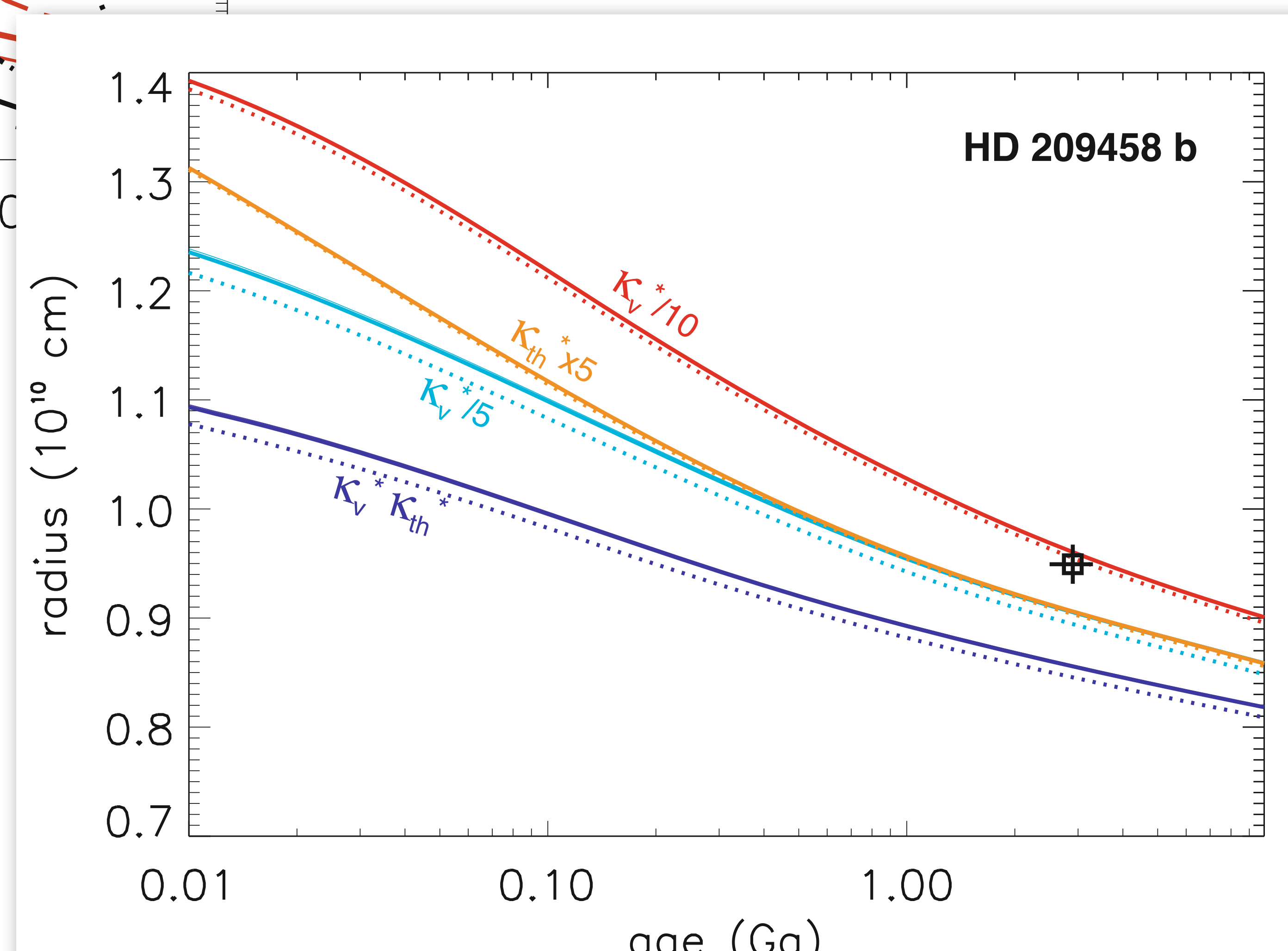


Model based on Guillot (A&A, 2010)

Boundary condition: constraining thermal evolution

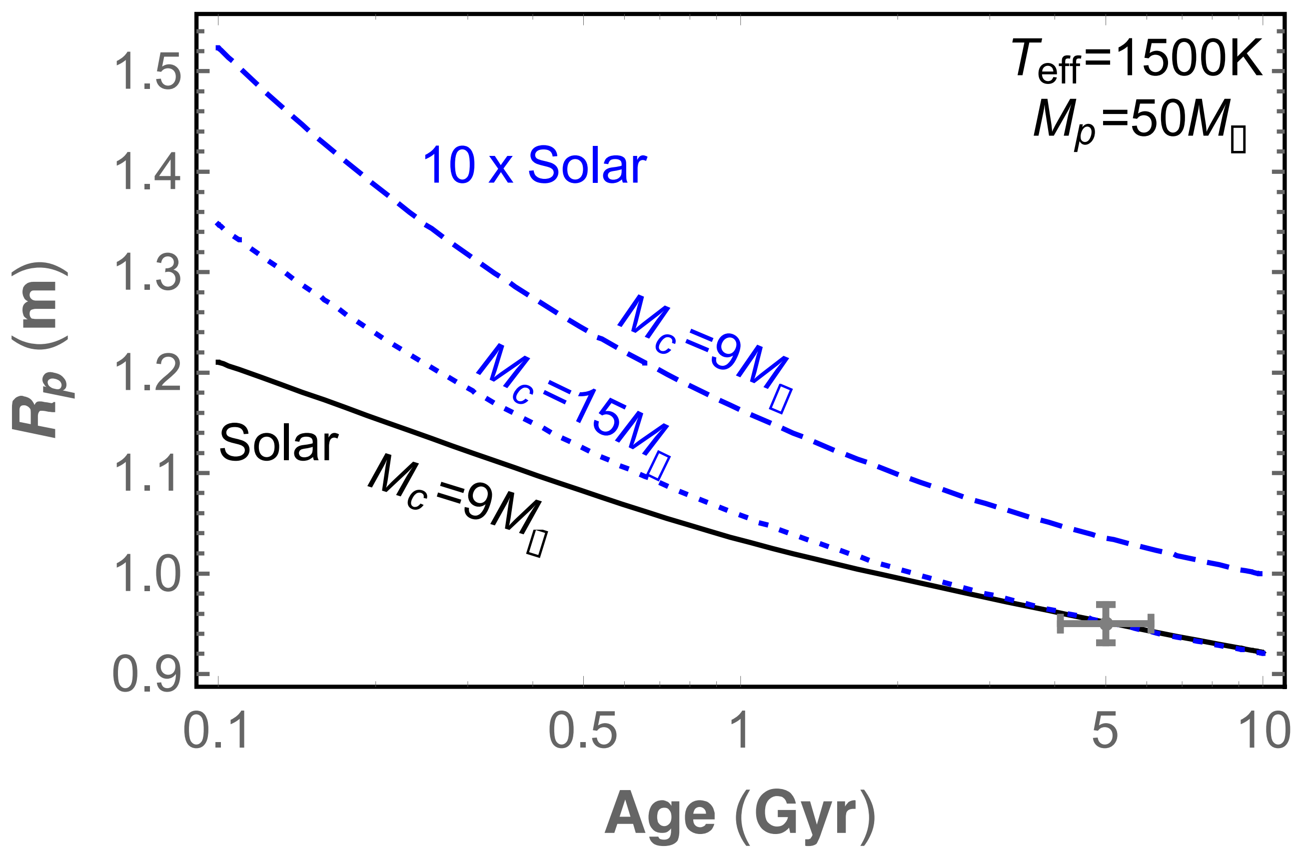


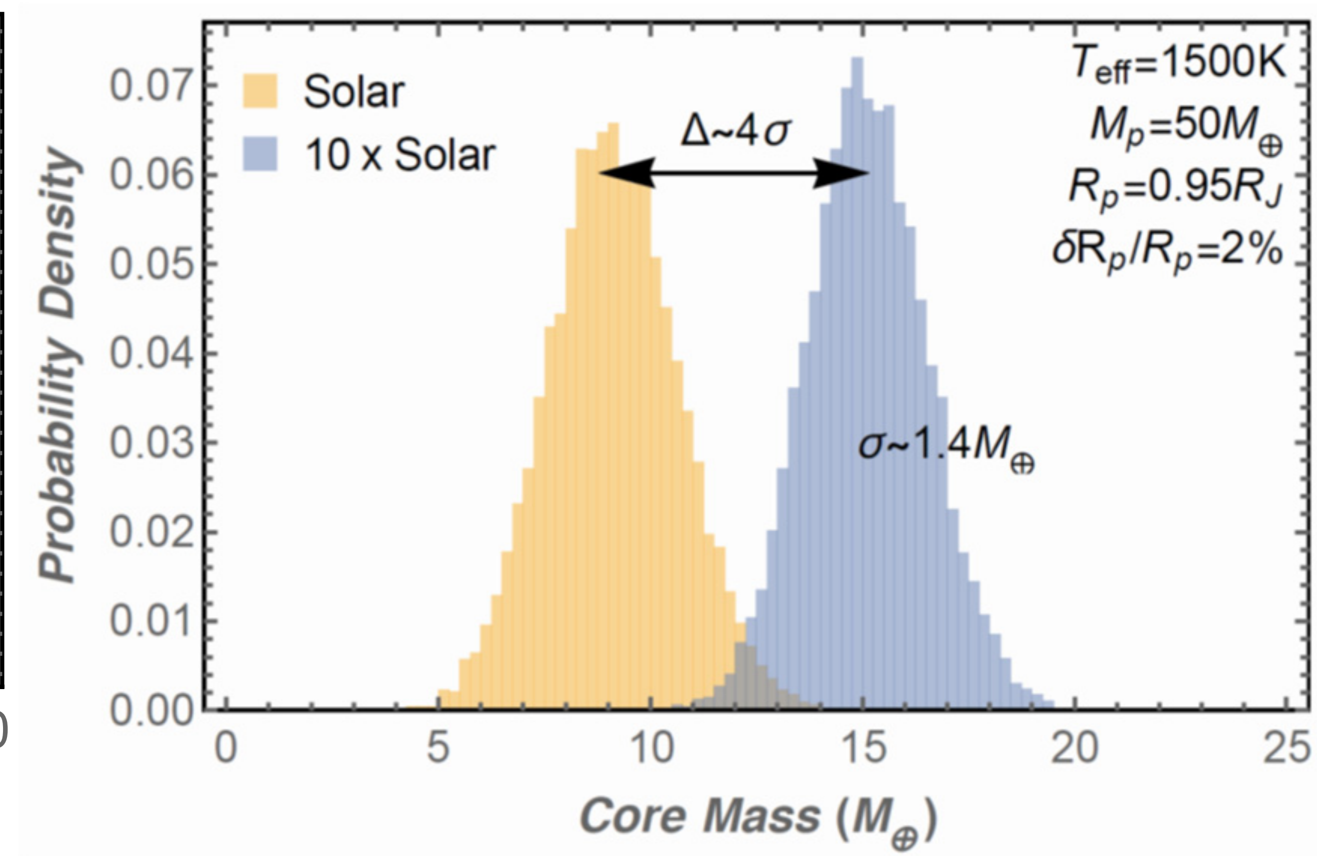
Changing the composition of the atmosphere changes the evolution



Guillot et al. (2010)

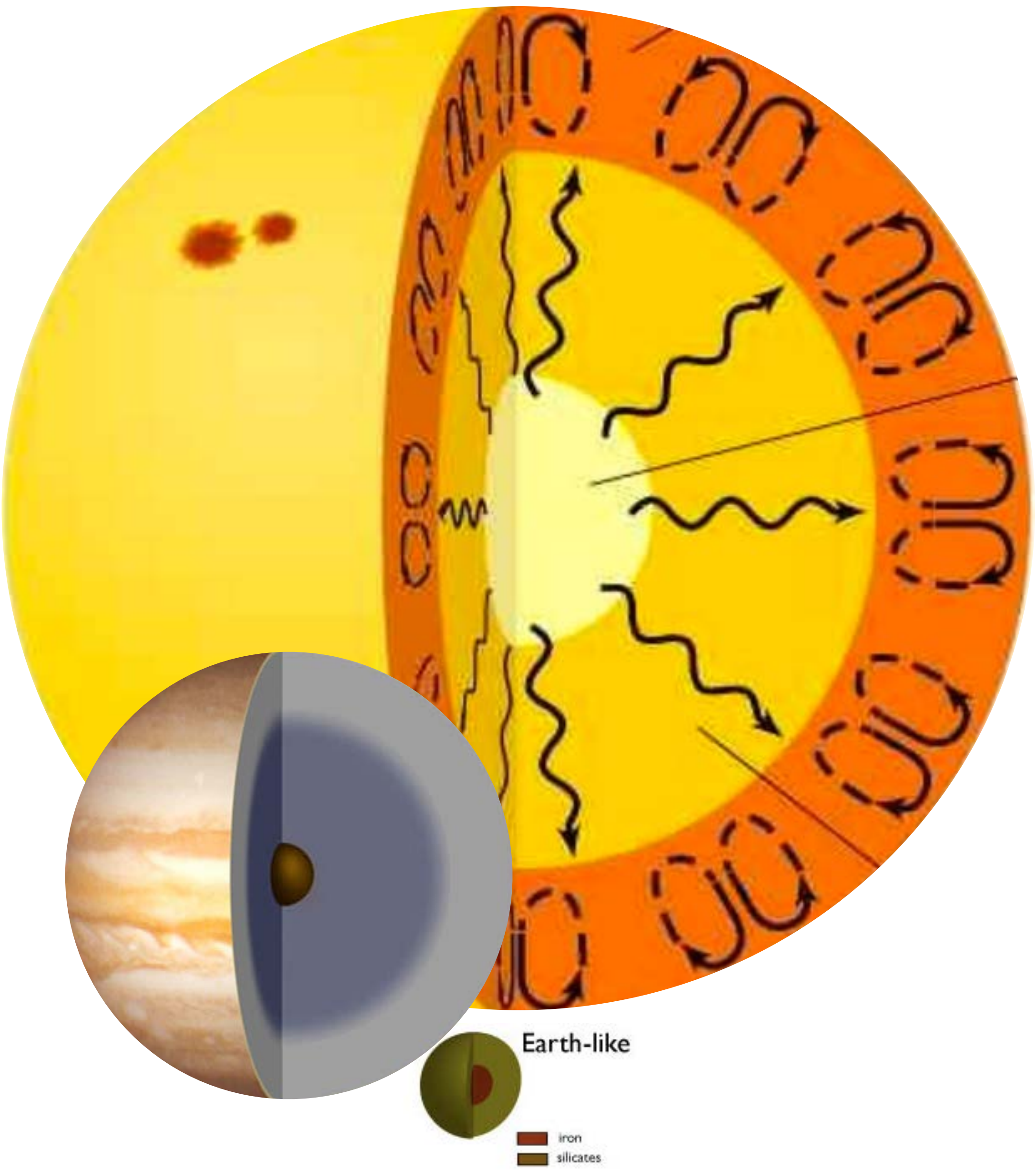
Boundary condition: constraining thermal evolution





Knowing the composition
of the atmosphere
significantly changes the inferred core mass

(Sub)stellar evolution equations



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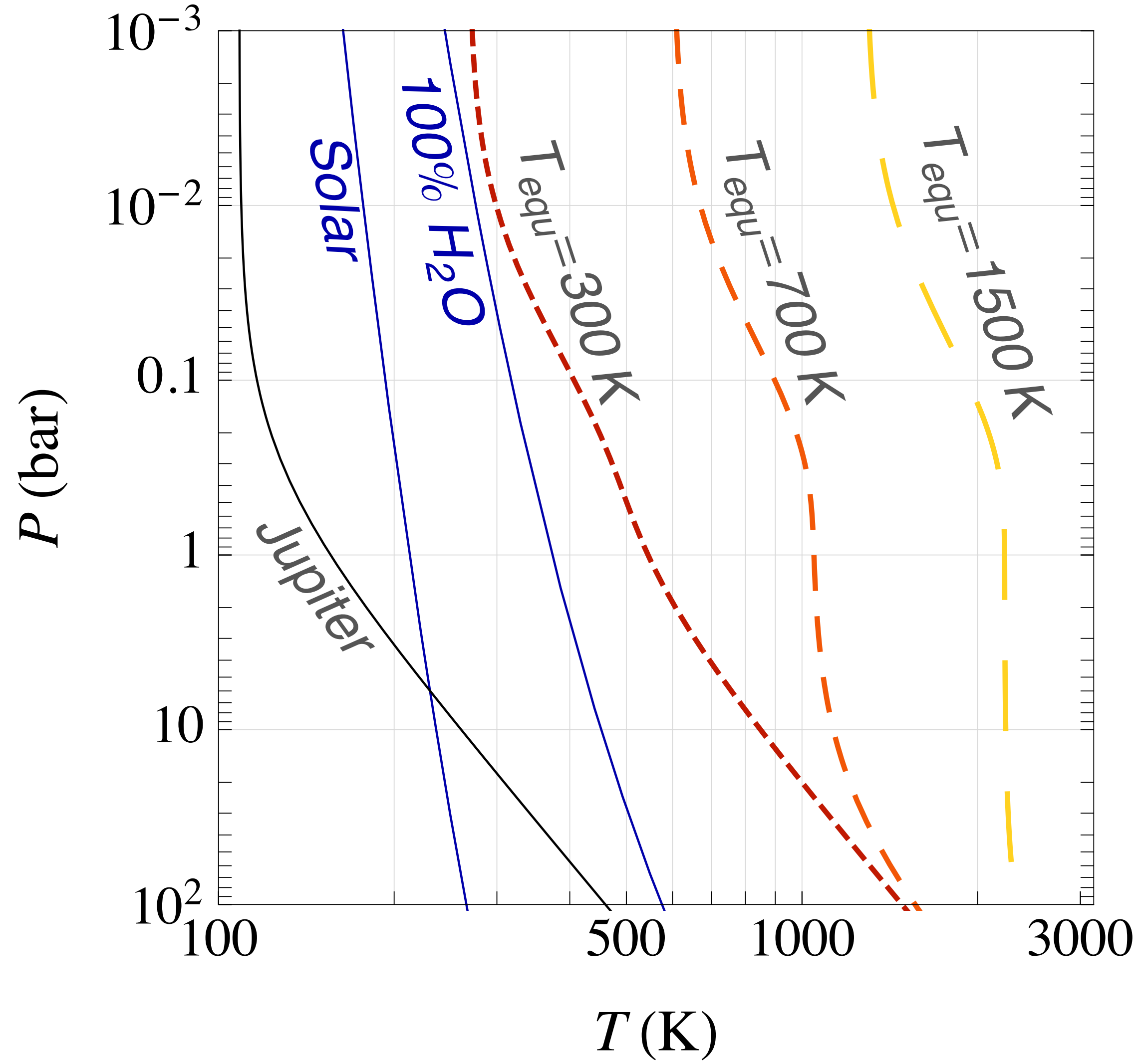
- Boundary conditions:
  - Measured temperature
  - Evolution => Atmosphere model
- Equation of State (Composition)

Is the atmosphere representative of the envelope?



★Compared to Solar System giants:

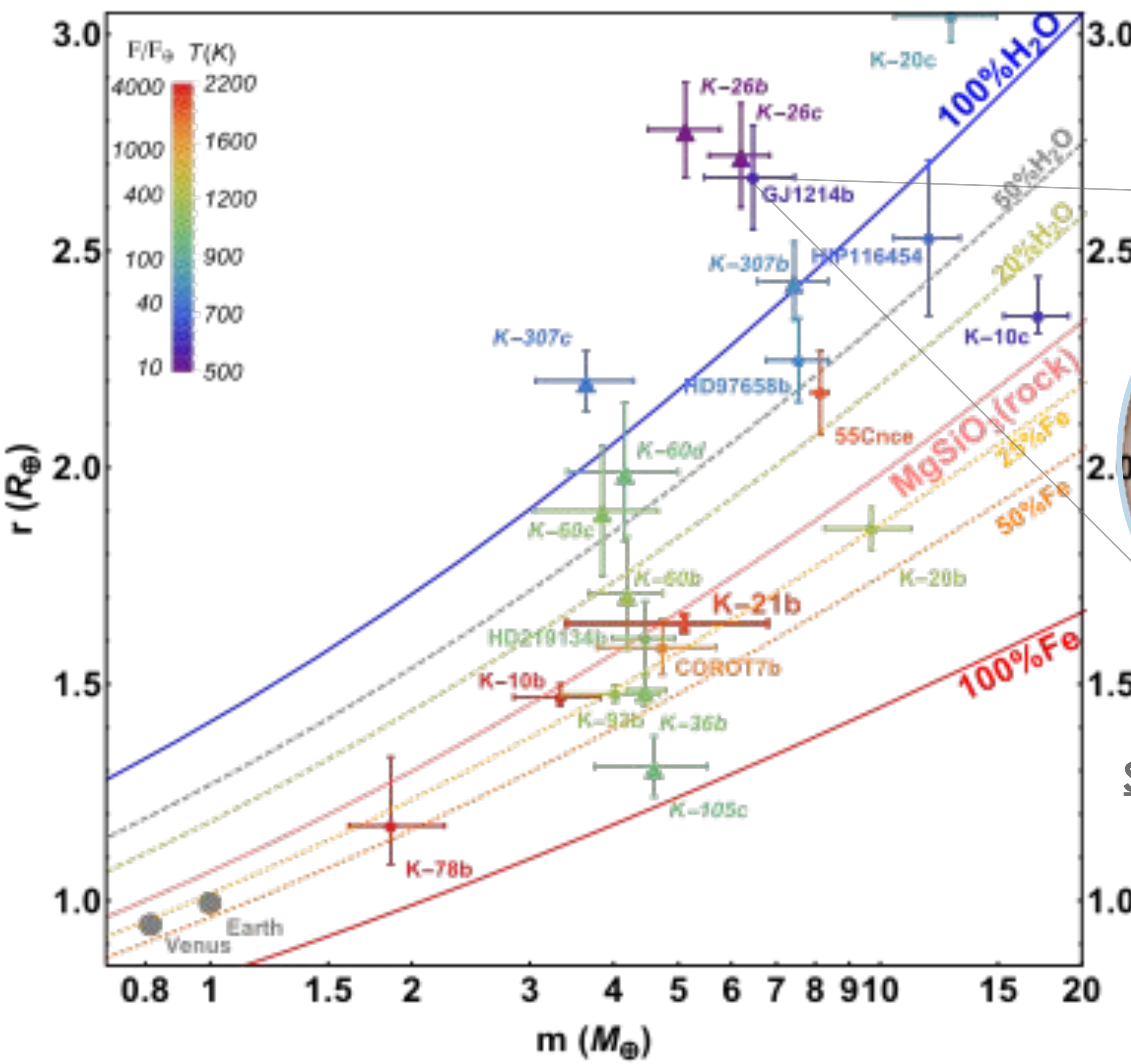
- ★Condensation is less of an issue!
- ★Probably no Helium separation!
- ★We may have access to elemental abundances w/o relying on chemistry

➡Atmospheric composition should be similar to the gaseous envelope

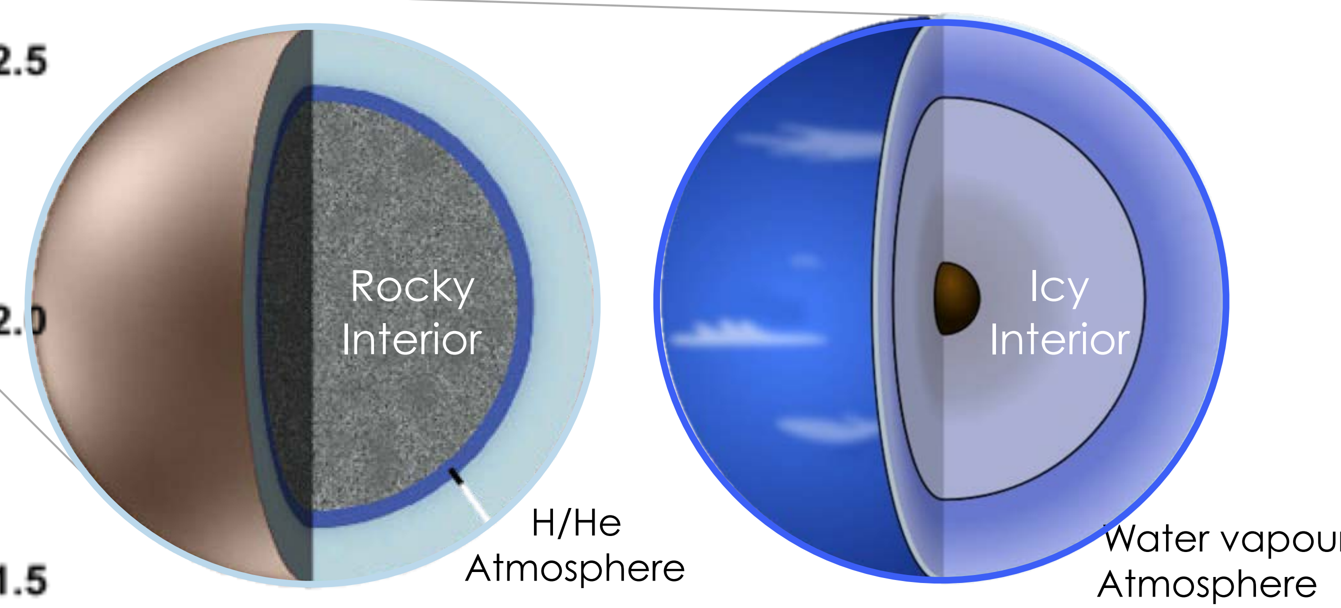
Although we cannot completely rule out inhomogeneities (Leconte et al. (2012), Vazan et al. 2016)

Lifting the envelope composition degeneracy

Mass-Radius observations



Atmospheric composition through ARIEL will clarify the degeneracy

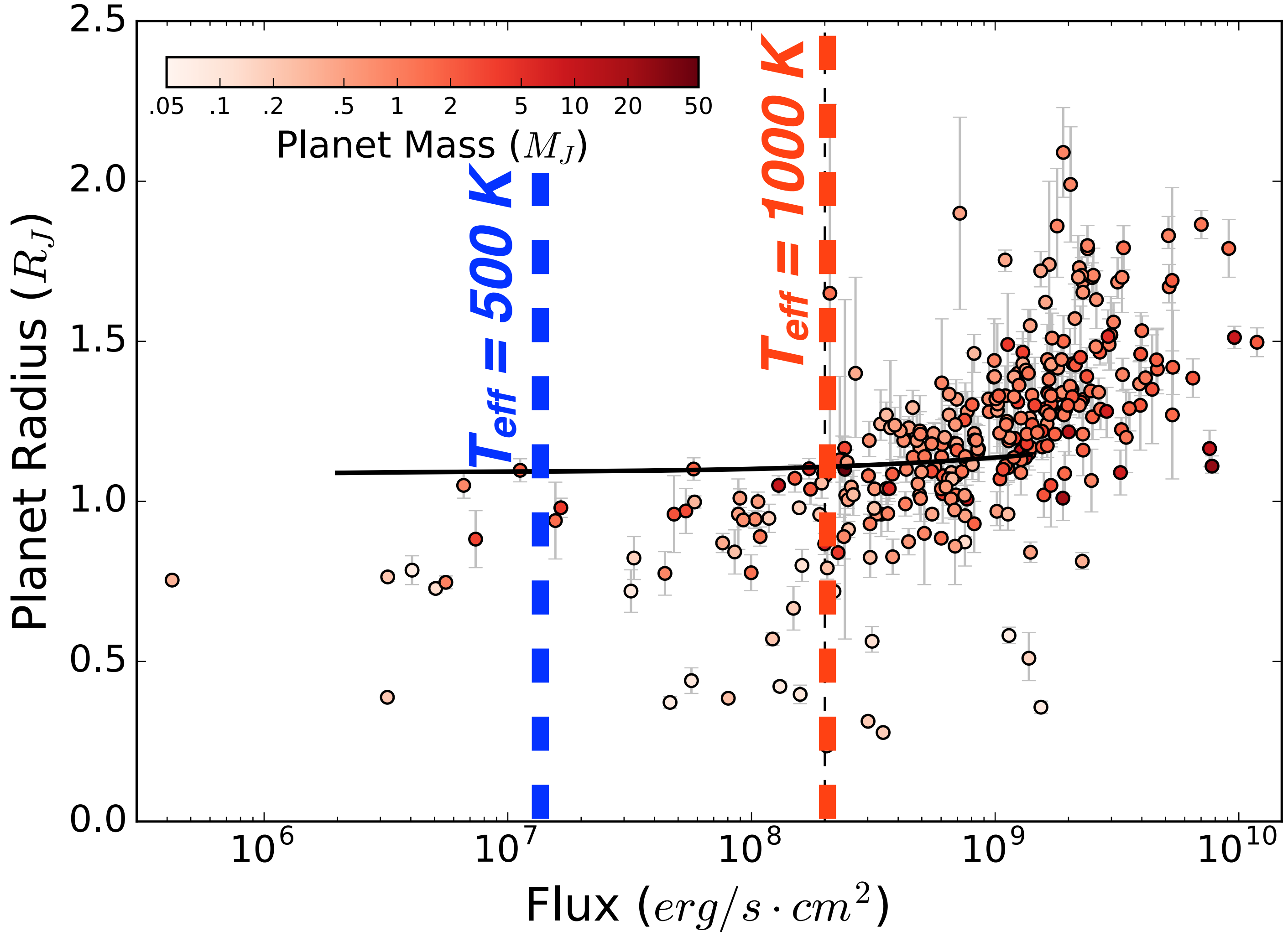


Same mean density – Different atmospheric signatures

Can ARIEL test interior model predictions?

Testing interior model predictions

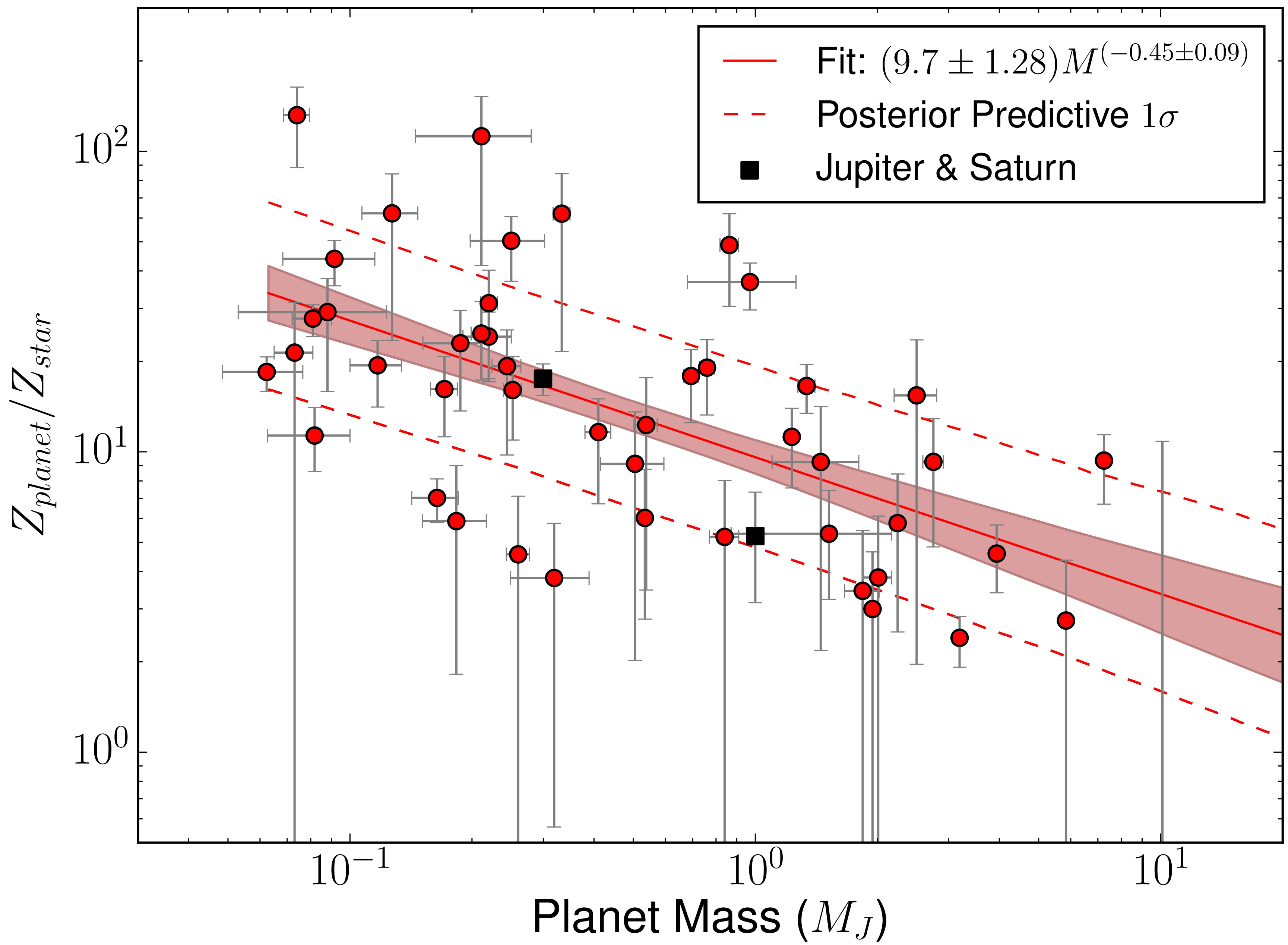
The « warm giant » opportunity



Thorngren et al. (2016)

Testing interior model predictions

The « warm giant » opportunity



Thorngren et al. (2016)

Some conclusions

- ***We need to study the atmosphere to understand the interior***
  - –*Inferences from M-R measurements:*
    - *rely on many assumptions*
    - *show many degeneracies*
- ***By lifting these degeneracies, ARIEL could be seen as a real interior characterization mission!!!***
    - *(although not to the extent of what is done in the Solar system)*
    - *Statistical comparison with interior model*

Thank you