UNIVERSITÉ DE GENÈVE
PlanetS

IMPROVING INTERIOR STRUCTURE MODELS OF GIANT PLANETS

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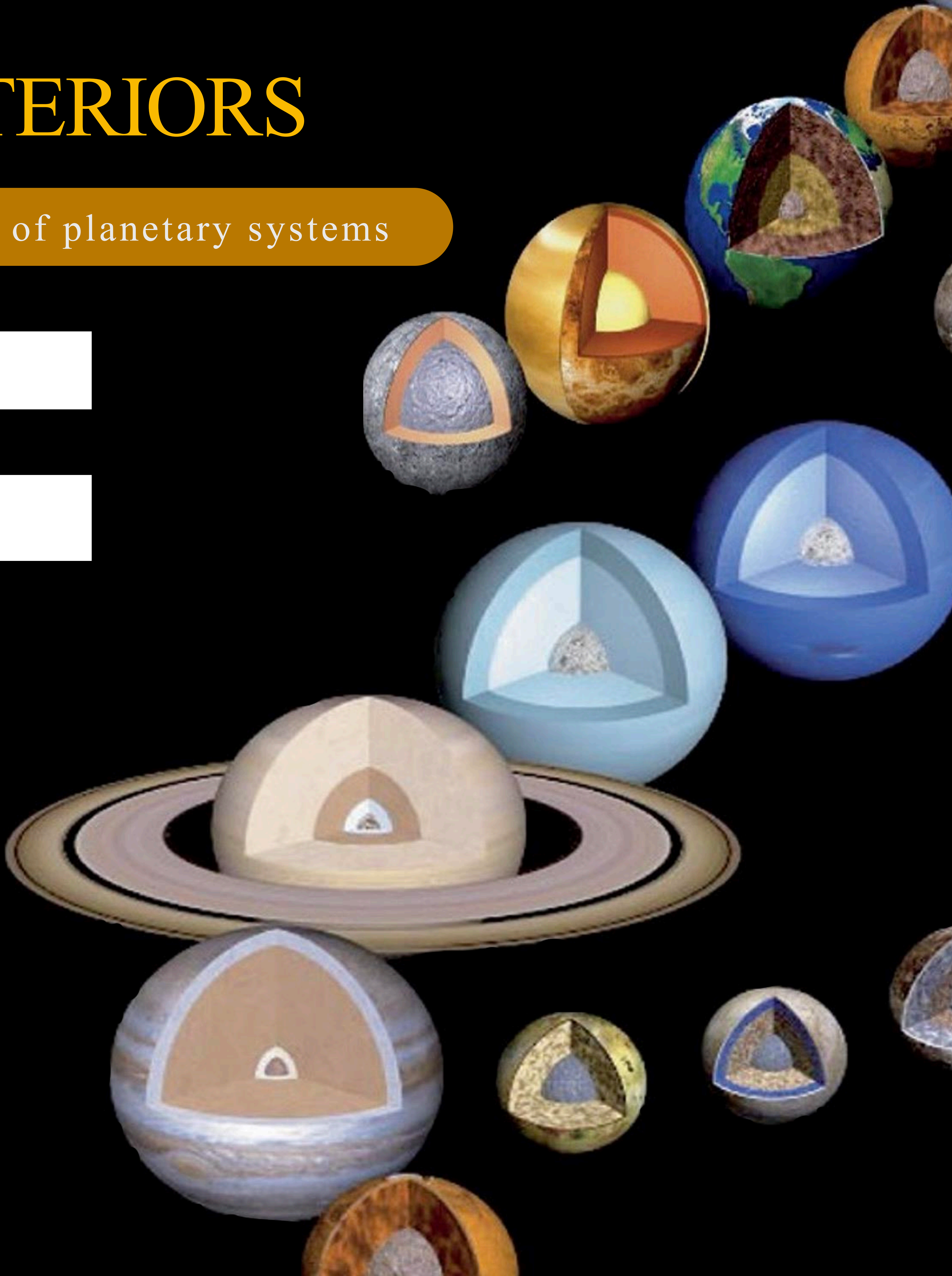
Observatory of Geneva

PLANETARY INTERIORS

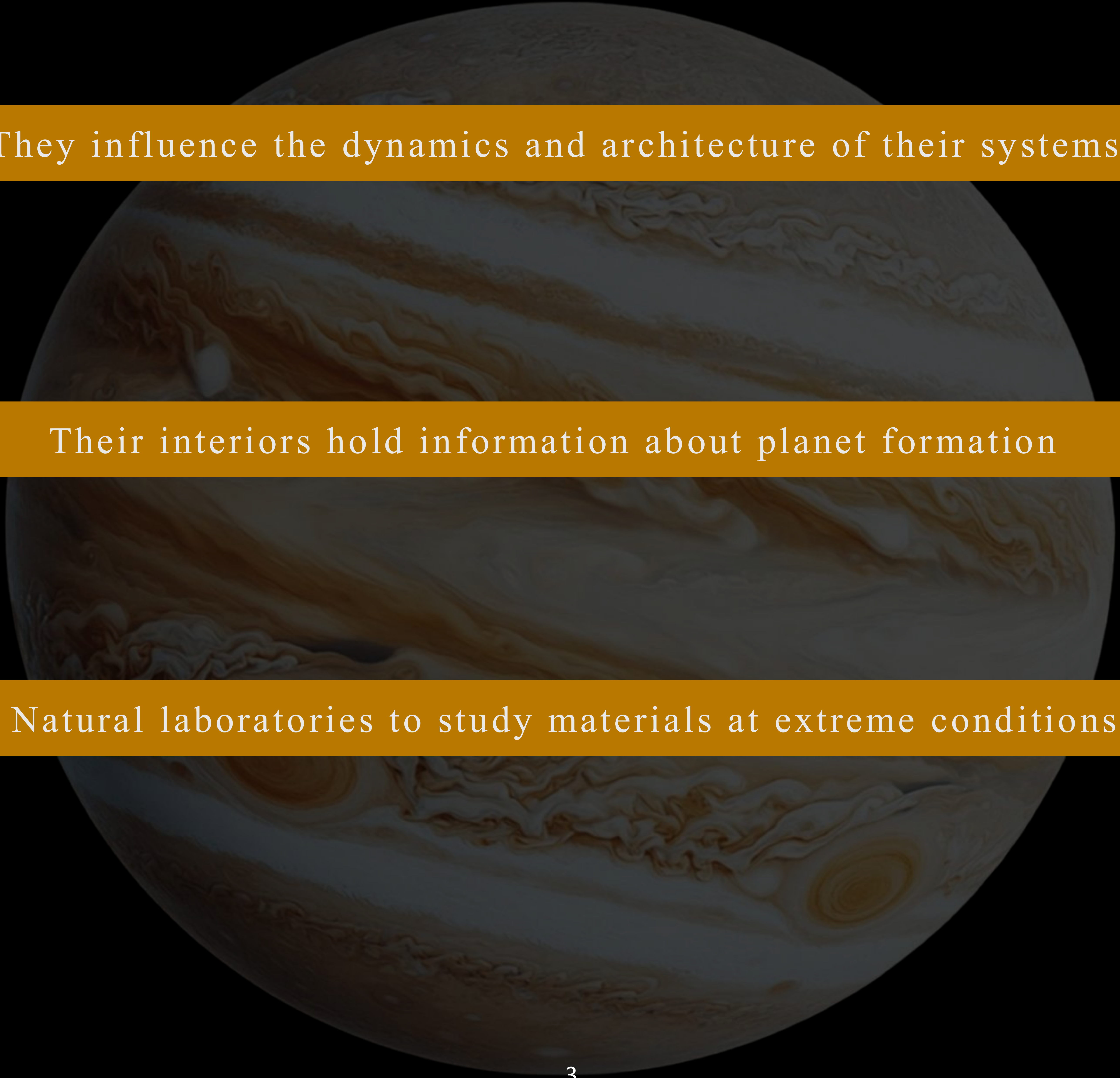
Are crucial for gaining a complete picture of planetary systems

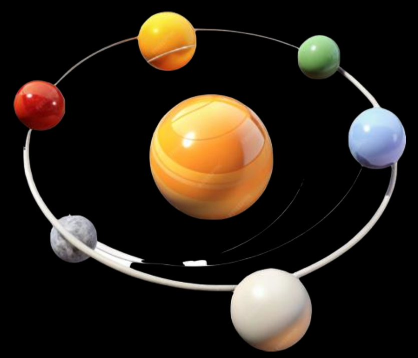
- constrain theories of planet formation and evolution

- Interpret atmospheric observations from transit spectroscopy

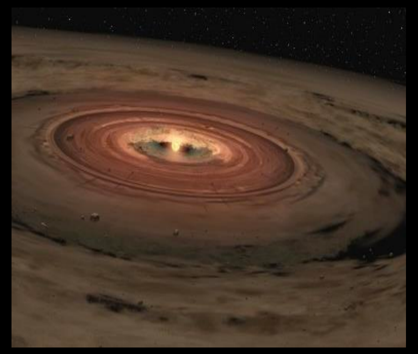


GIANT PLANETS

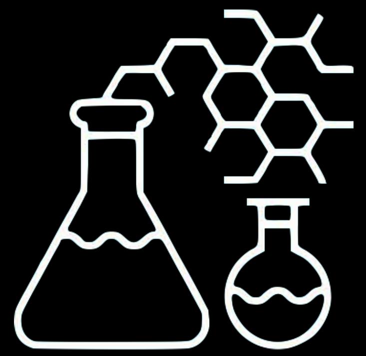




They influence the dynamics and architecture of their systems



Their interiors hold information about planet formation



Natural laboratories to study materials at extreme conditions

Modeling interiors of giant exoplanets

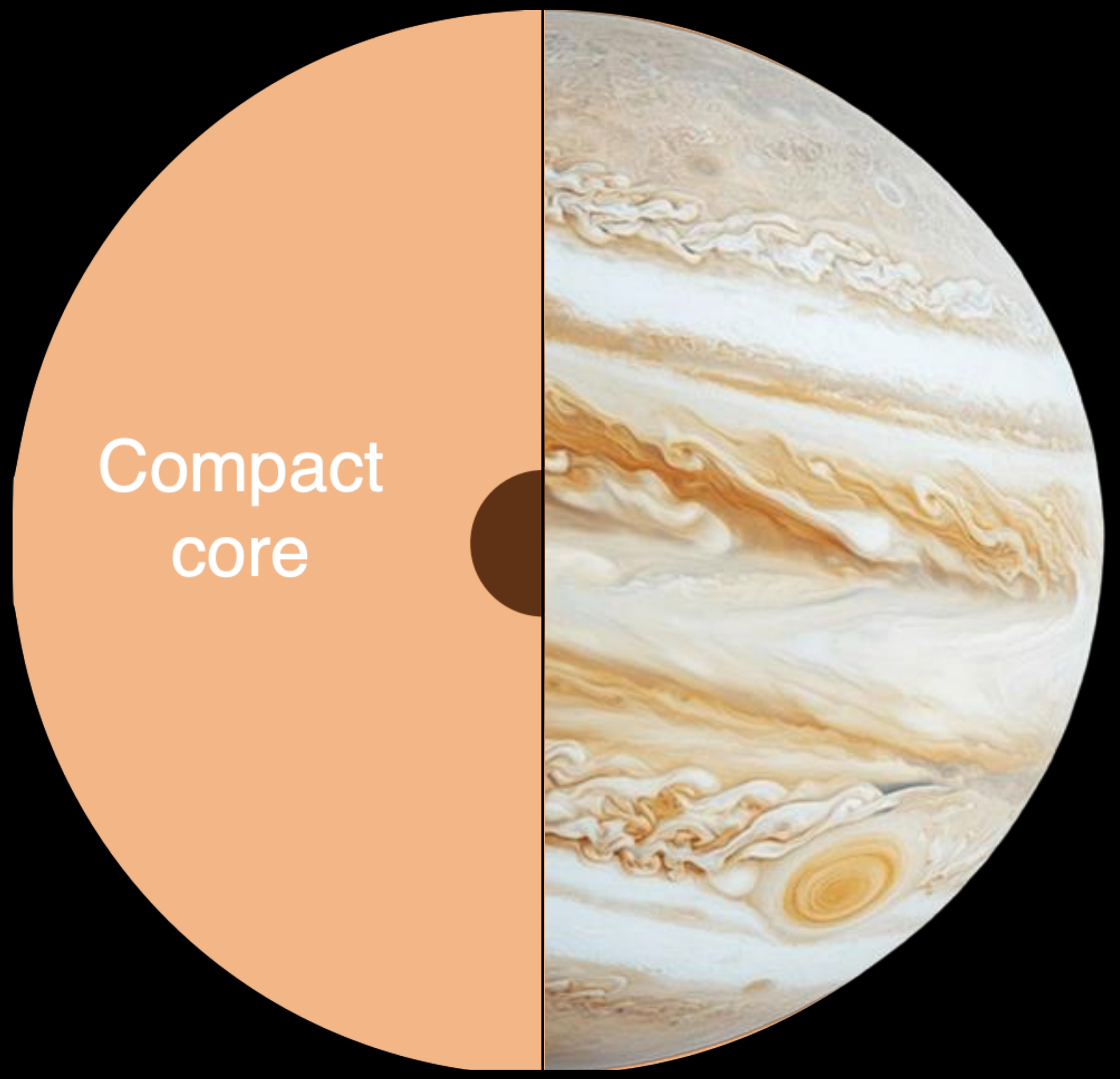
Mass
Radius

Teq
Zatm
Age
⋮

Battley+2024, Acuna+2024,

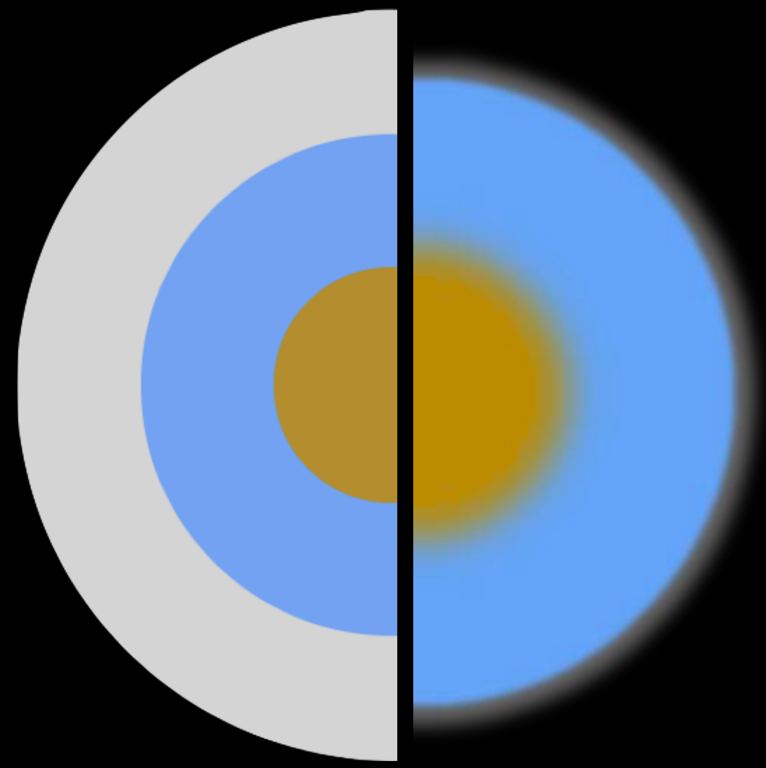
Z

total fraction of heavy elements



M–R is determined by composition & distribution in the interior
(e.g. Baraffe 2008)

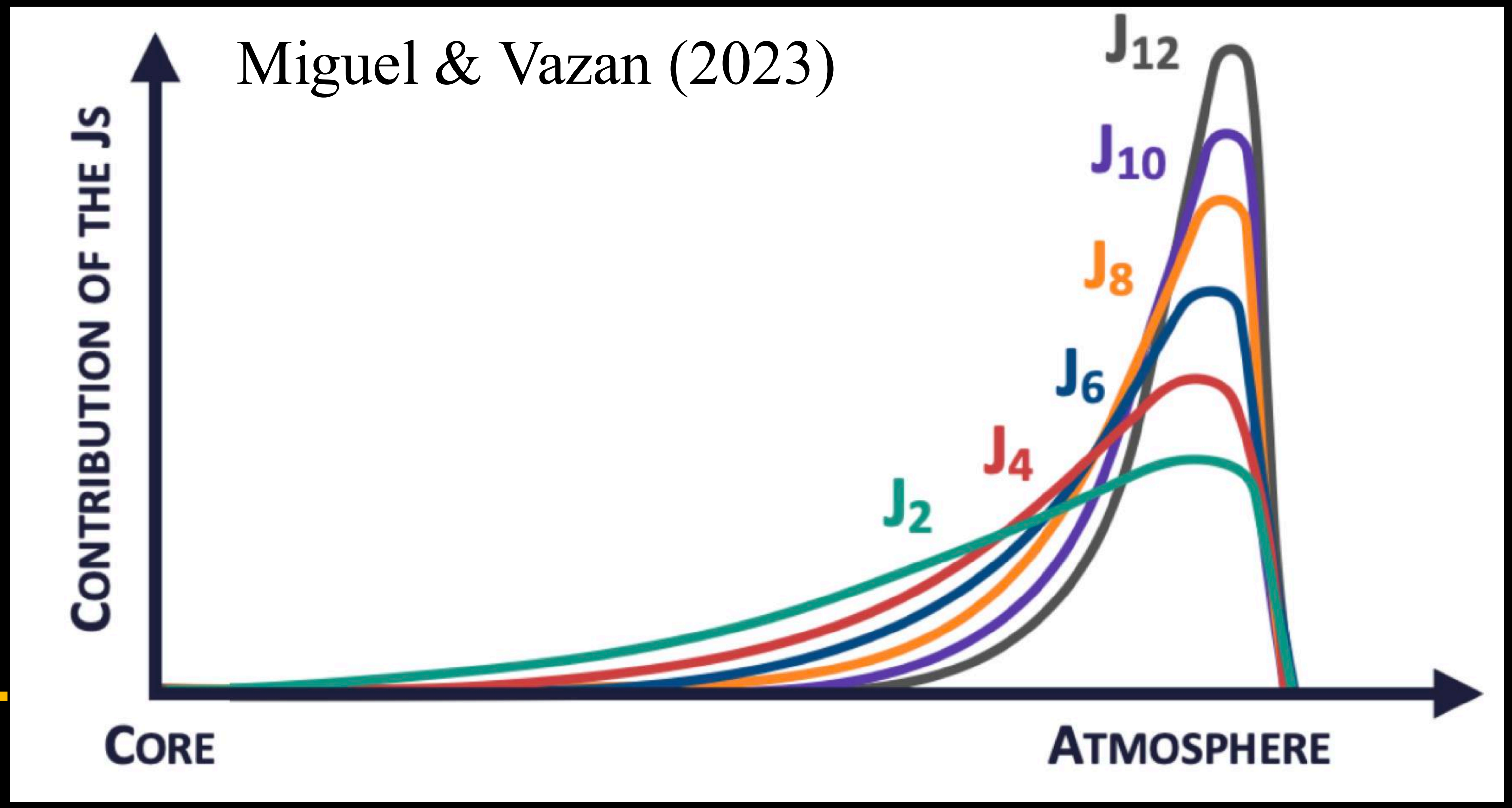
- How are the heavy elements distributed?
- Is there a core, what is its size and mass?



Jupiter's interior

- Mass
- Radius
- T_{eq}
- Z_{atm}
- Age

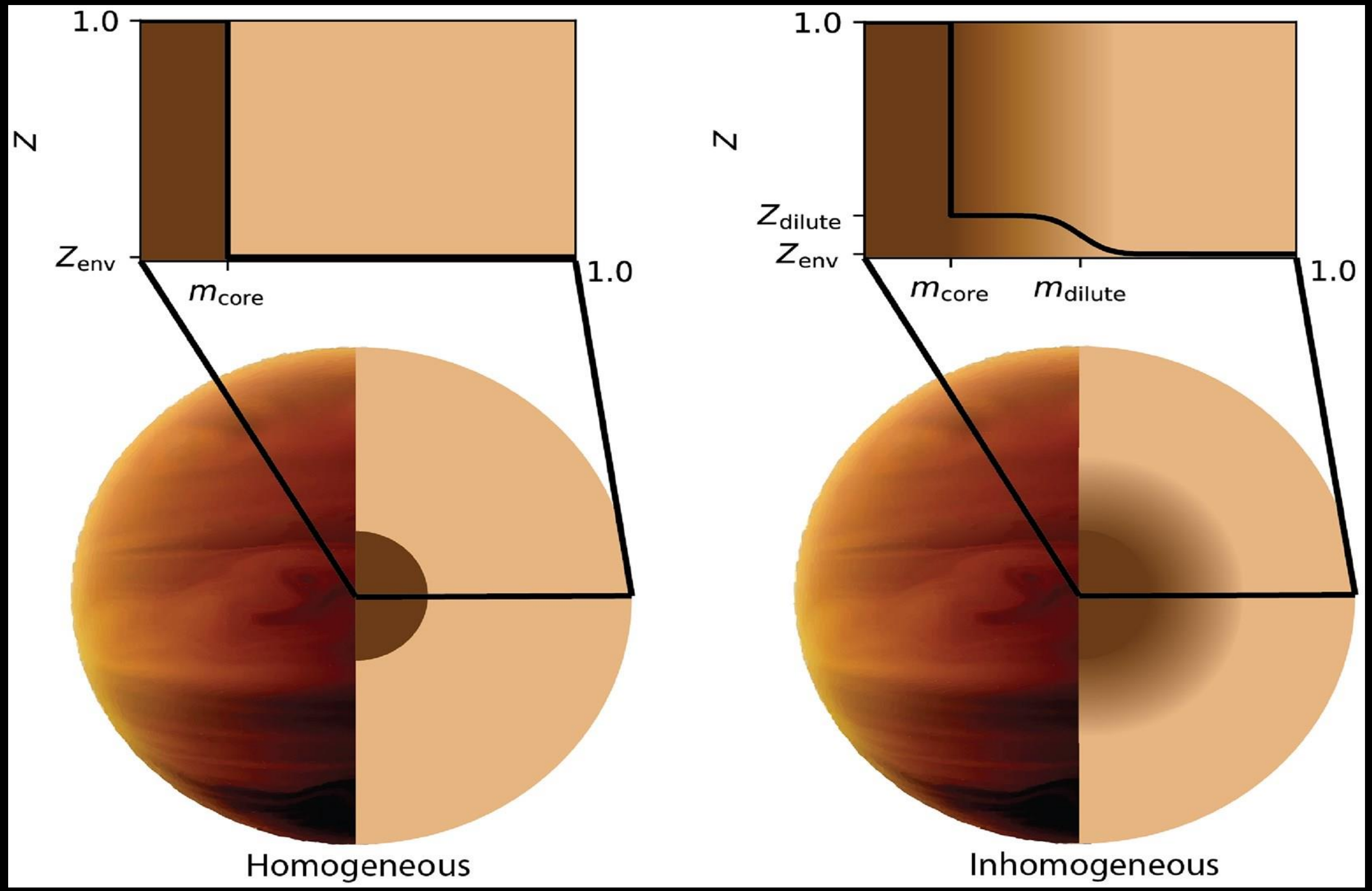
- Rotation rate (Ω)
- Gravity field (Jn)



Durante et al., 2020

J_2 (x10[6])	14696.5735 (0.0017)
k2	0.565 (0.018)

Need to measure



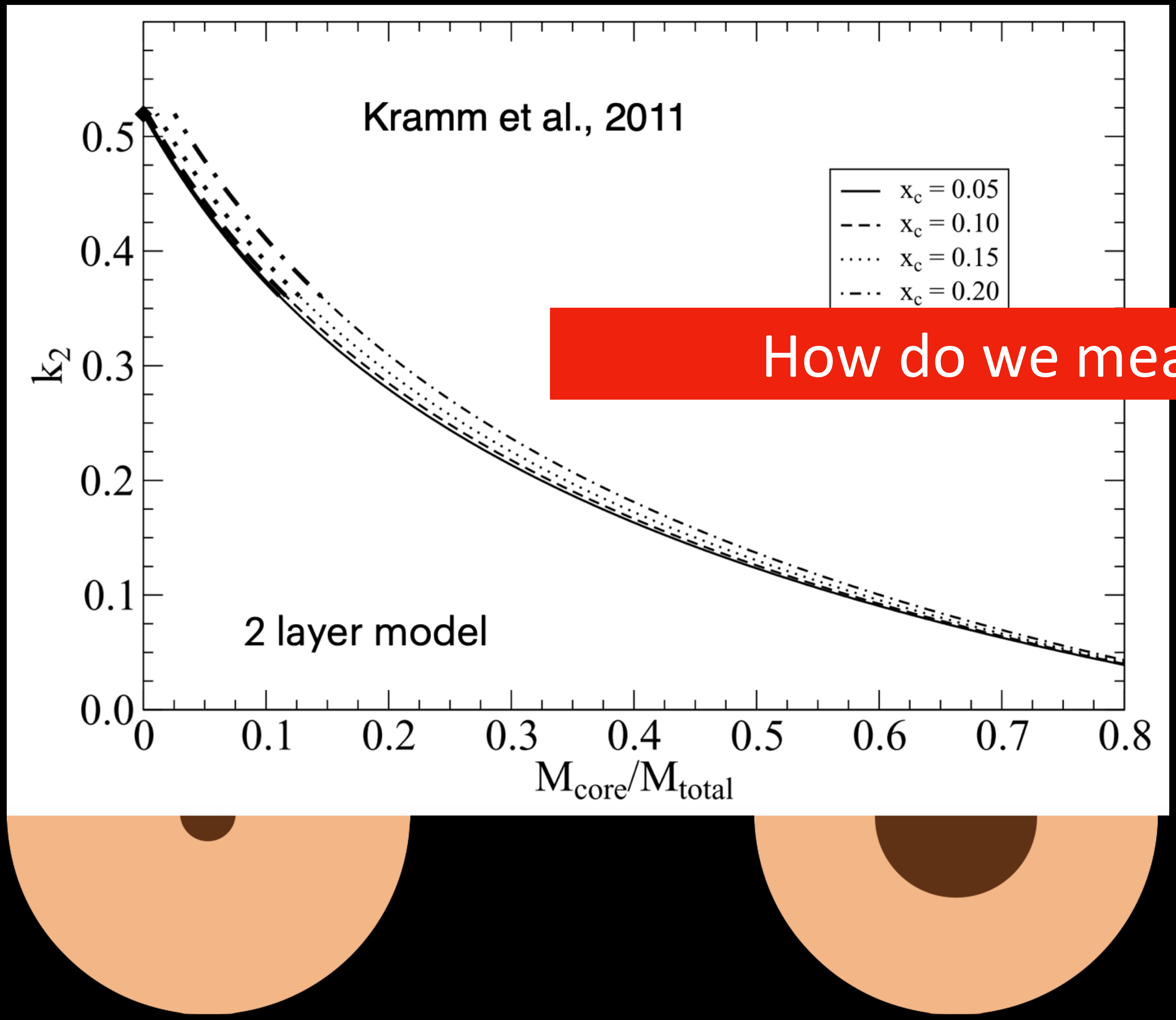
Wahl et al., (2017), Vazan et al. (2018, Miguel et al. (2022), Howard et al.(2023a).

- Are such dilute cores a typical outcome of gas giant formation?
- How does the distribution vary between close-in and far-out giants

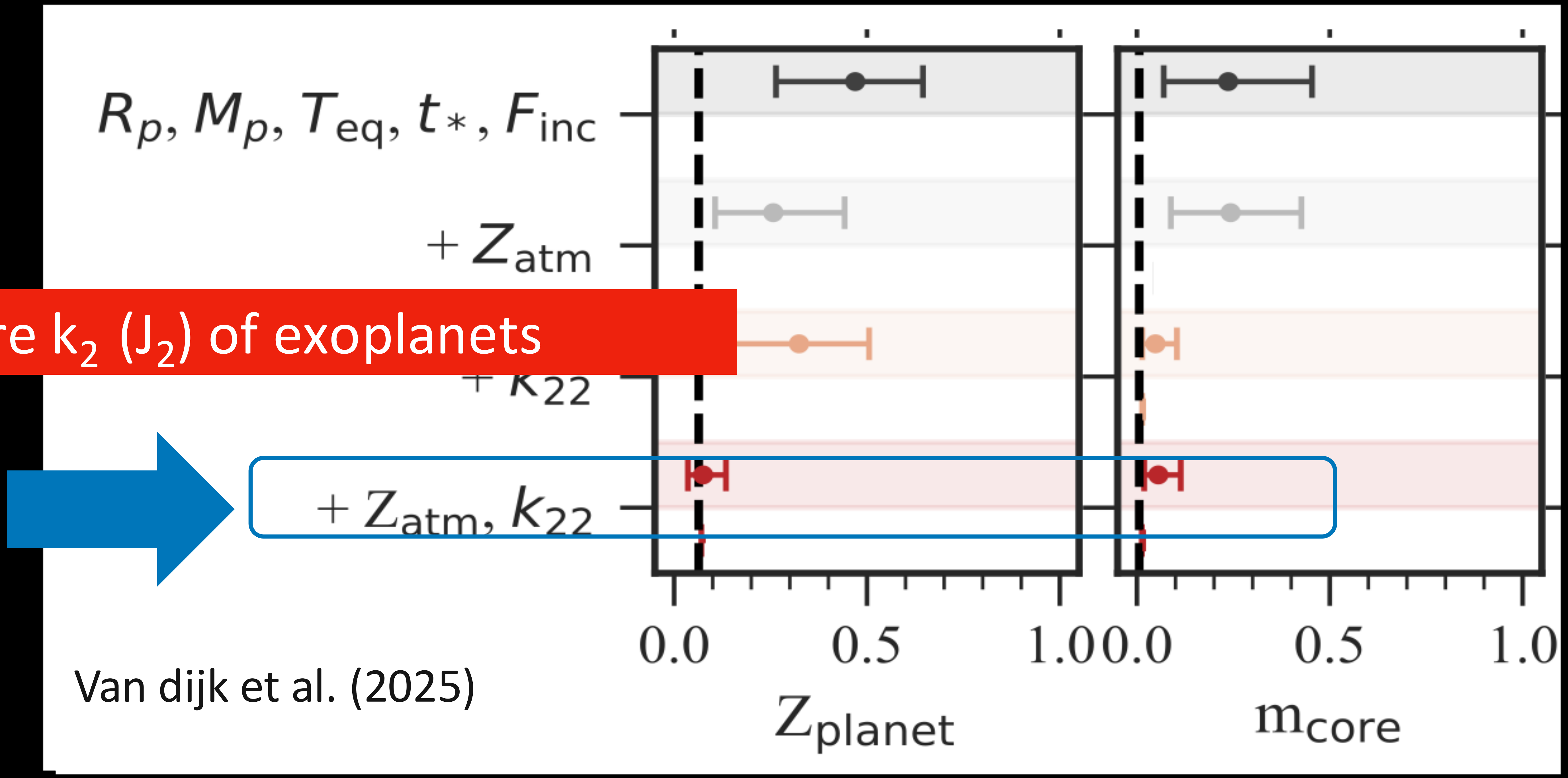
Impact of k_2 on interior retrievals

k2 Love number and interior structure

Batygin et al. (2009), Ragozzine & wolf (2009), Kramm et al. (2011, 2012)

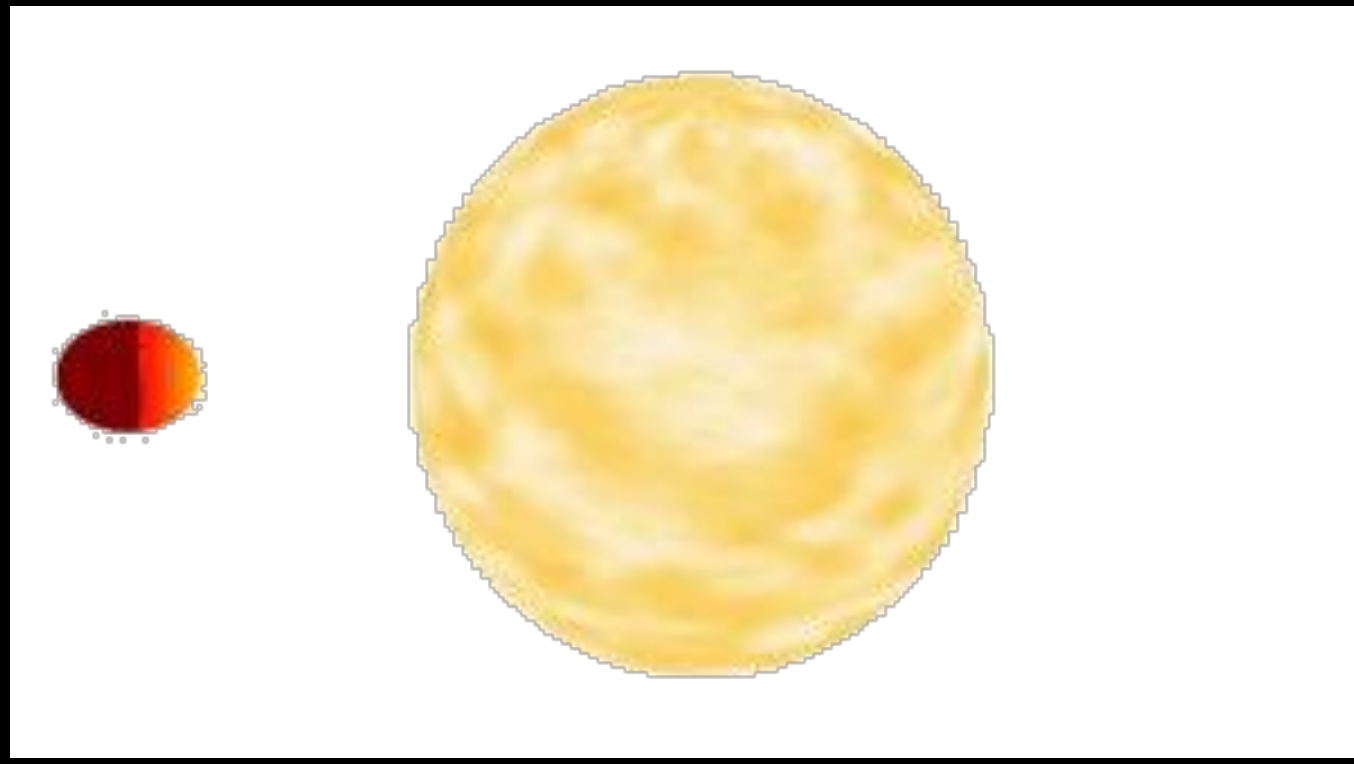


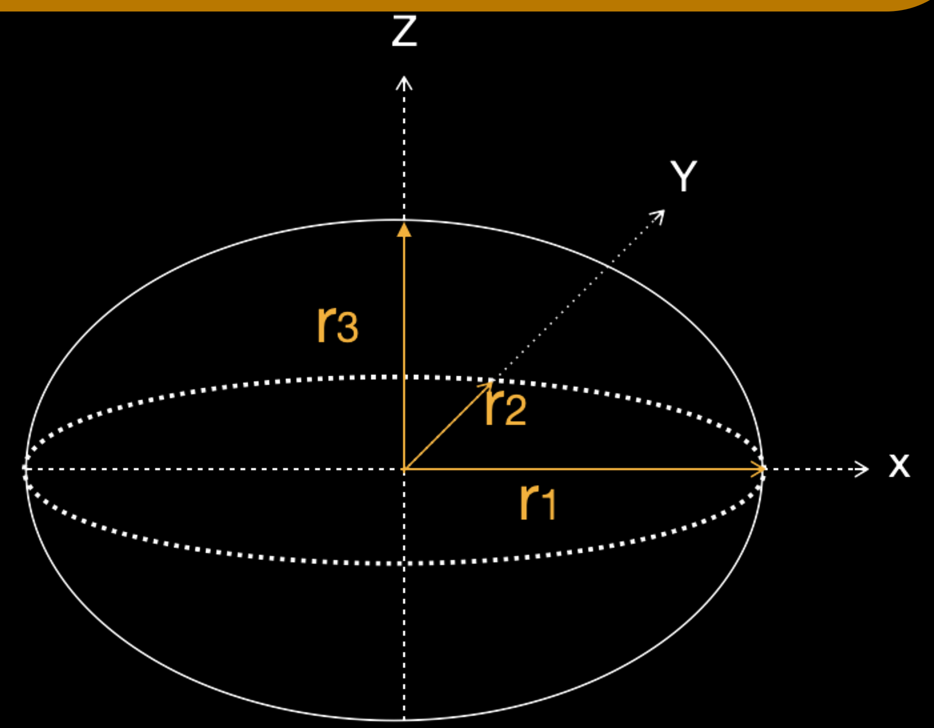
How do we measure k_2 (J_2) of exoplanets



The interior structure of a planet determines how it deforms

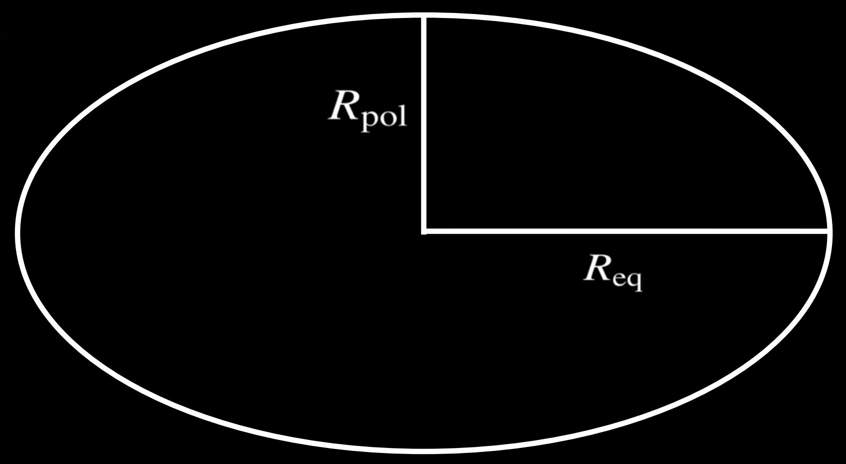
Tidal deformation



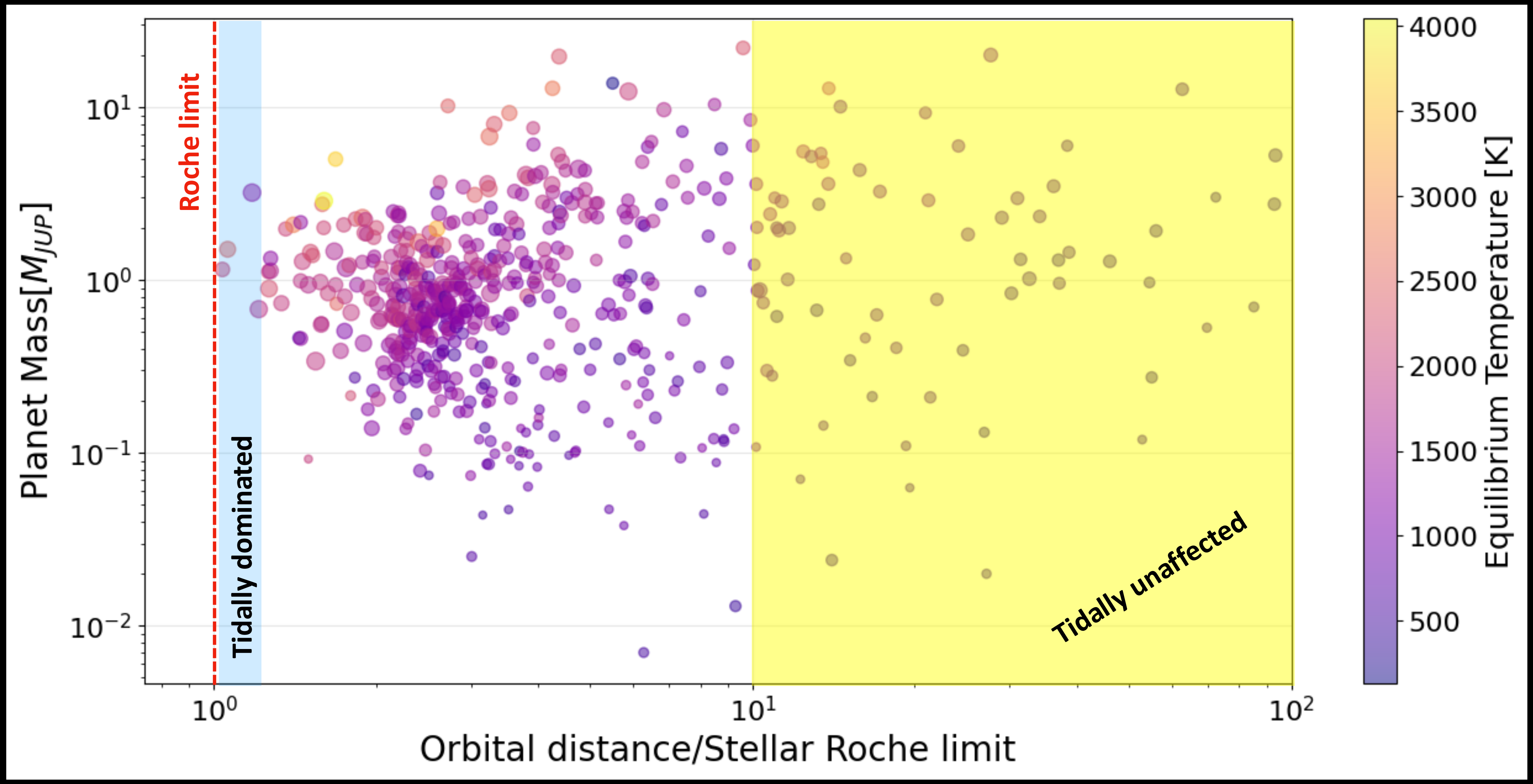


The axes are related by $h_2 = 1 + k_2$
(Correia 2014)

Rotational deformation



$$P_{\rm rot} = 2\pi \sqrt{\frac{R_{\rm eq}^3}{G M_p (2f - 3J_2)}}$$



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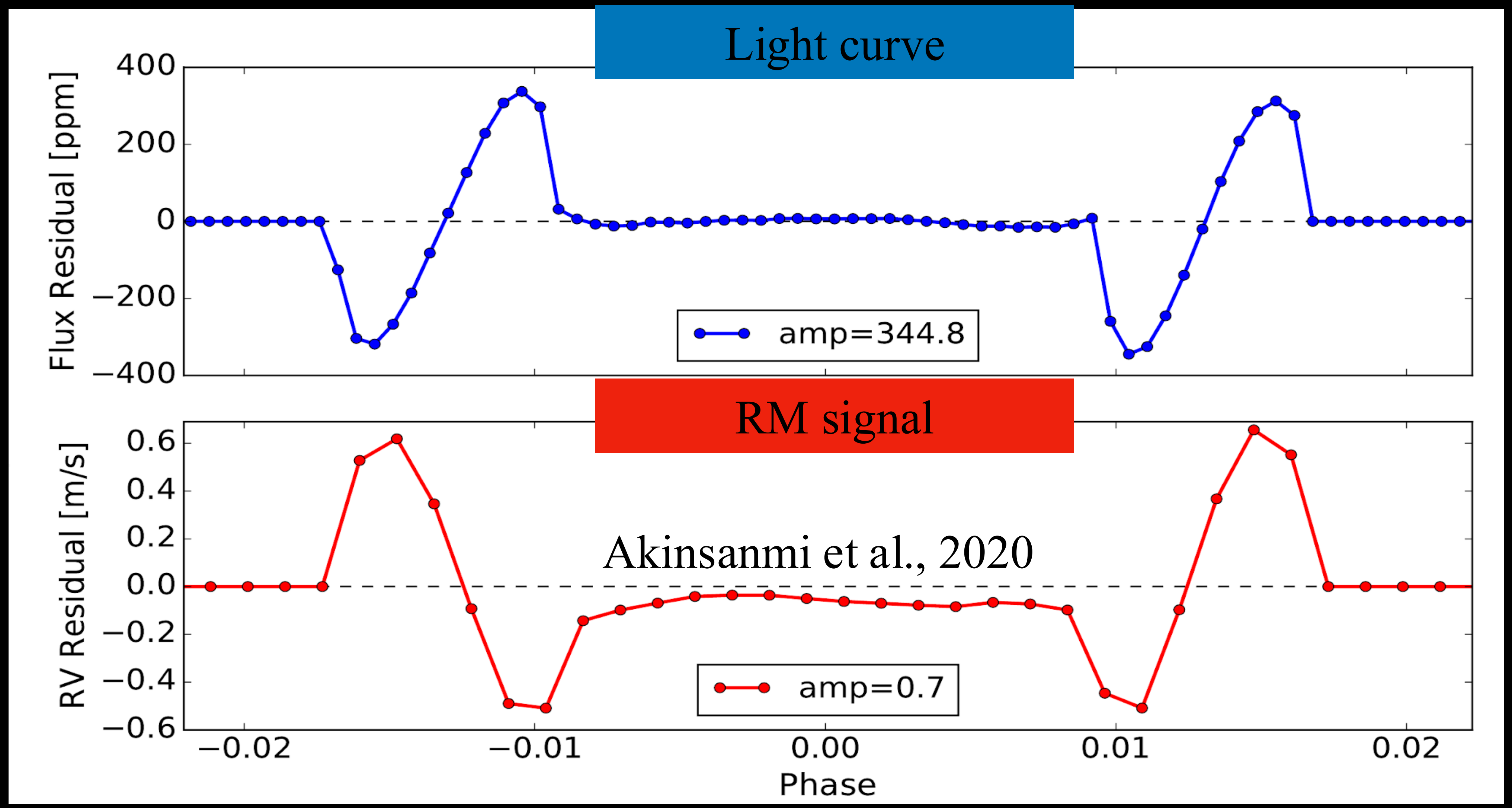
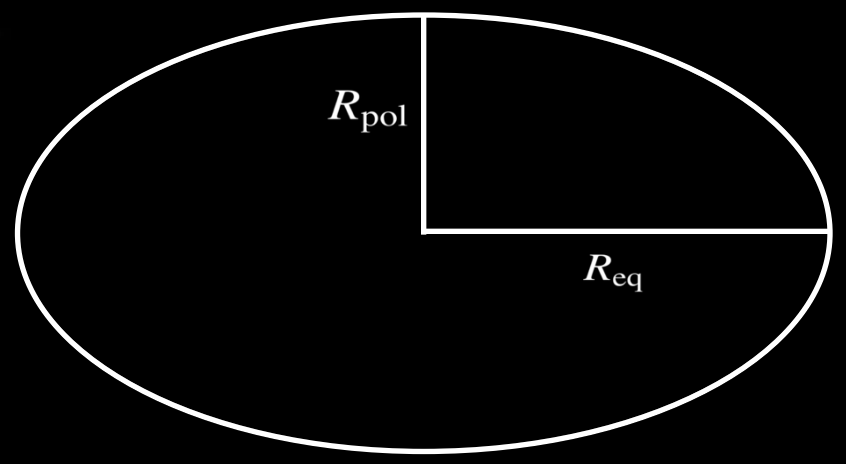
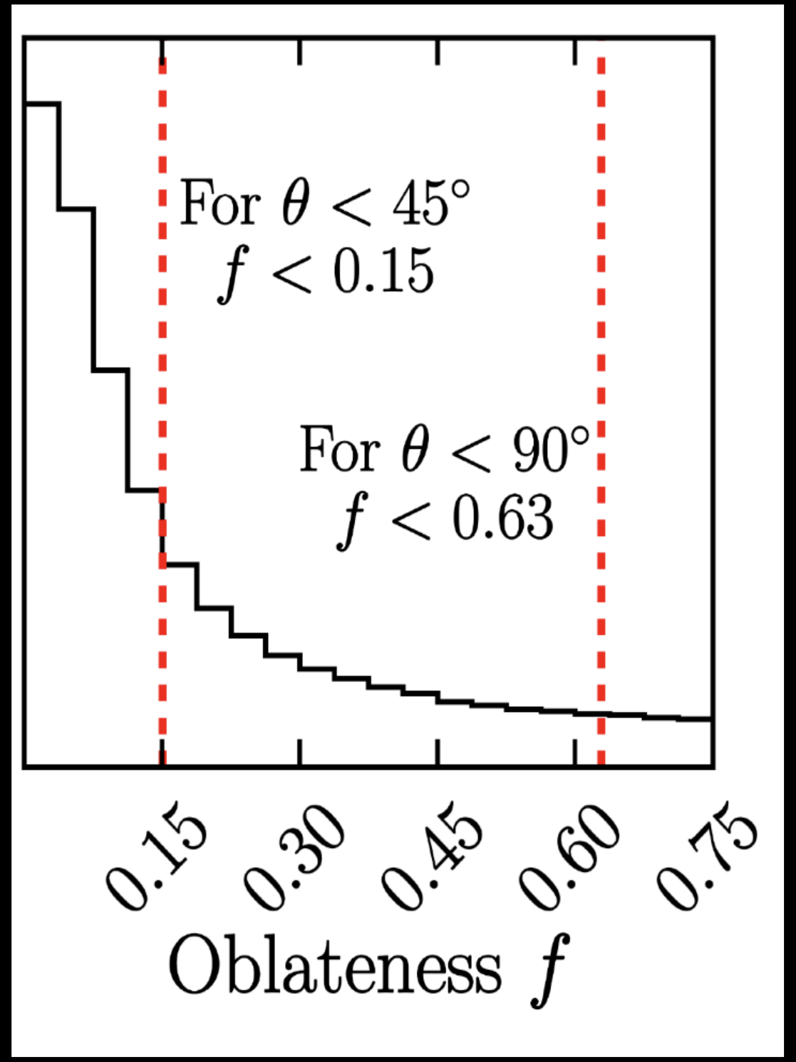


Rotational deformation

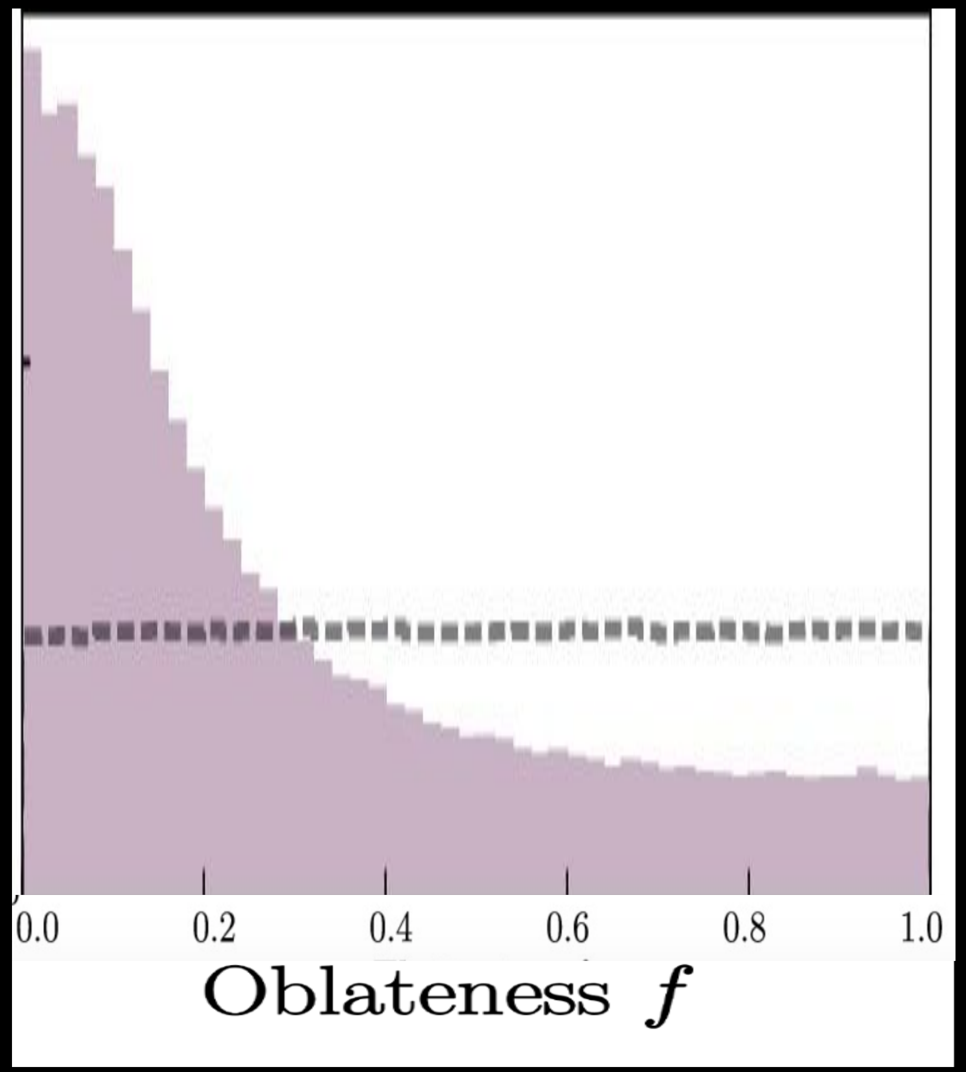


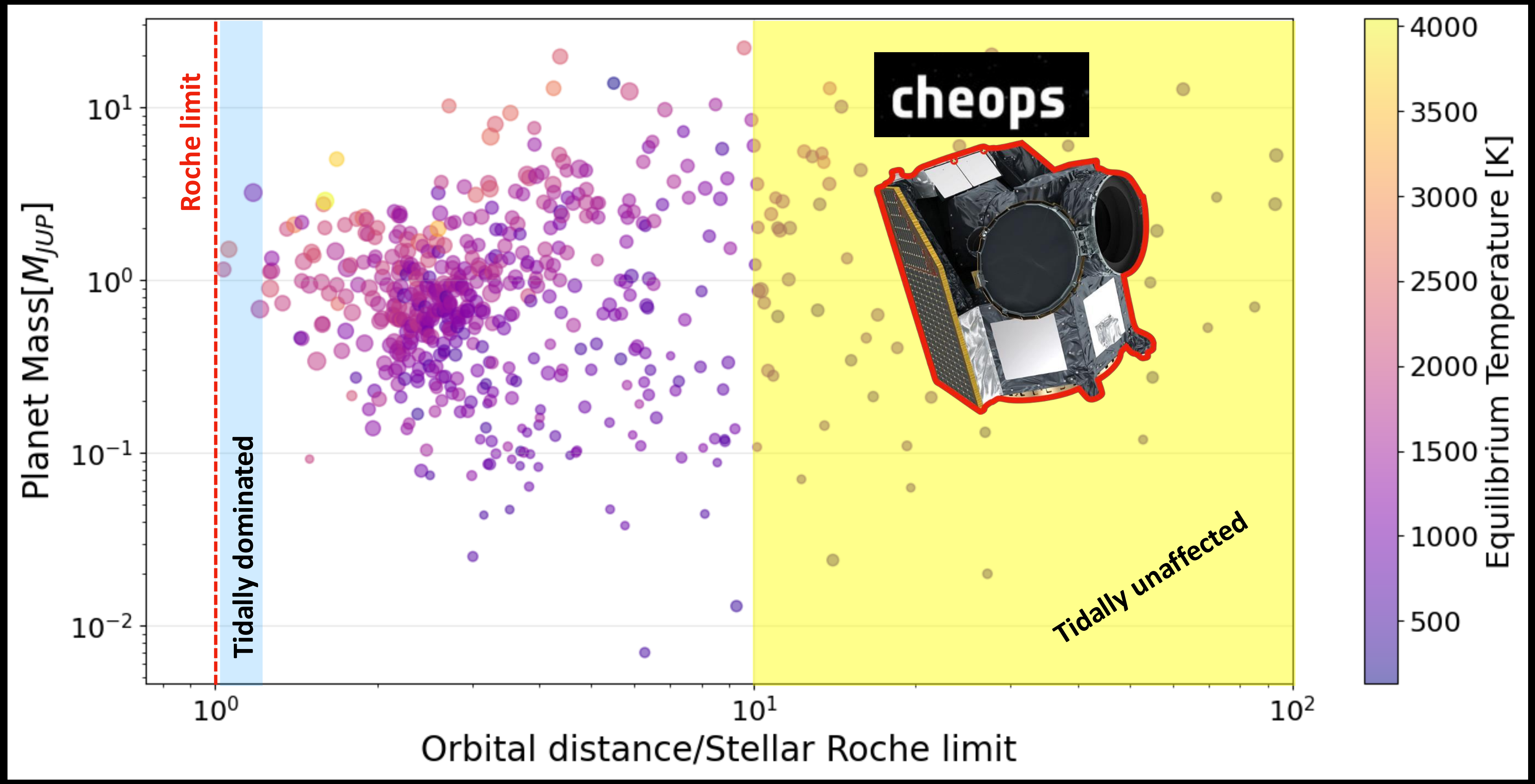
$$P_{\mathrm{rot}} = 2\pi\sqrt{\frac{R_{\mathrm{eq}}^3}{GM_p(2f - 3J_2)}}$$

Kepler-51d
Lammers & Winn (2024)



HIP41378f
Price +2024





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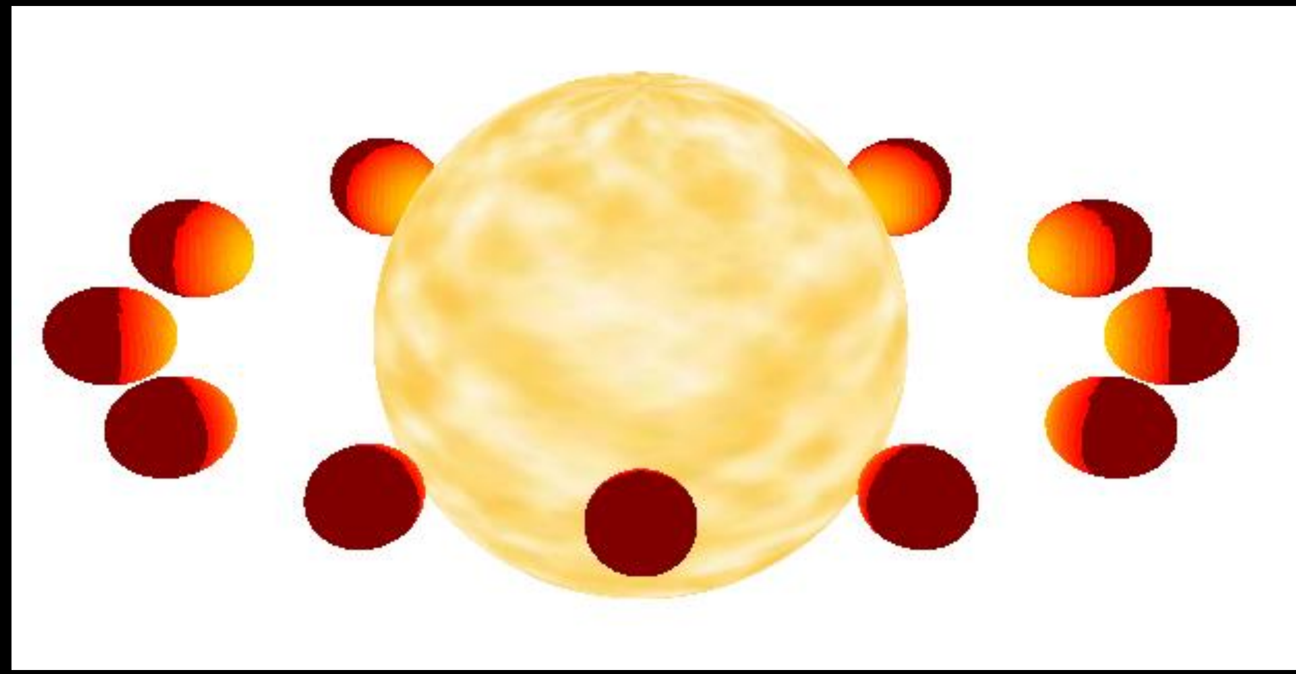
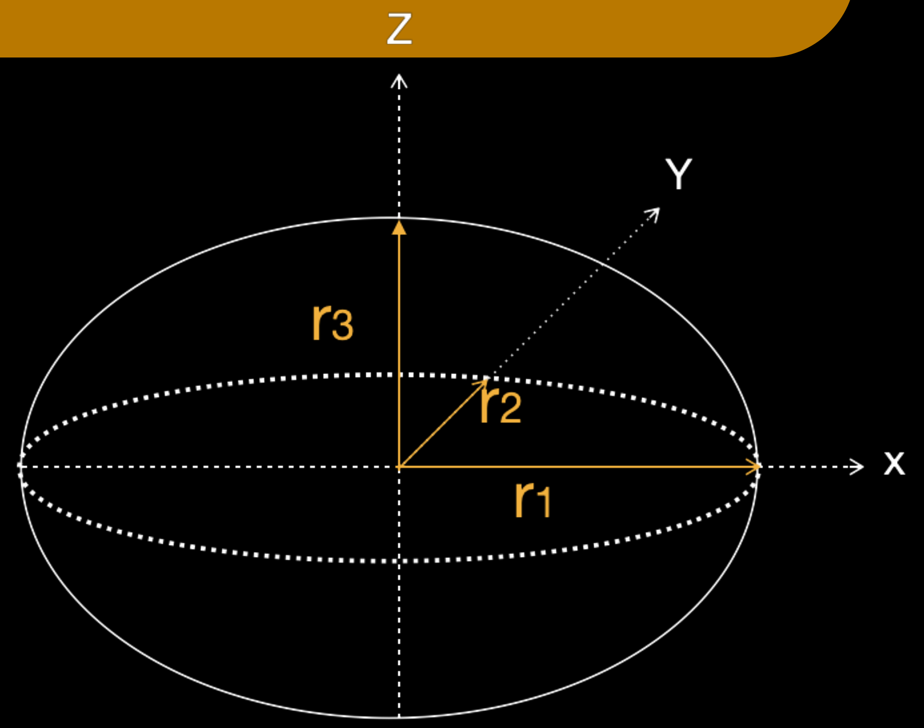
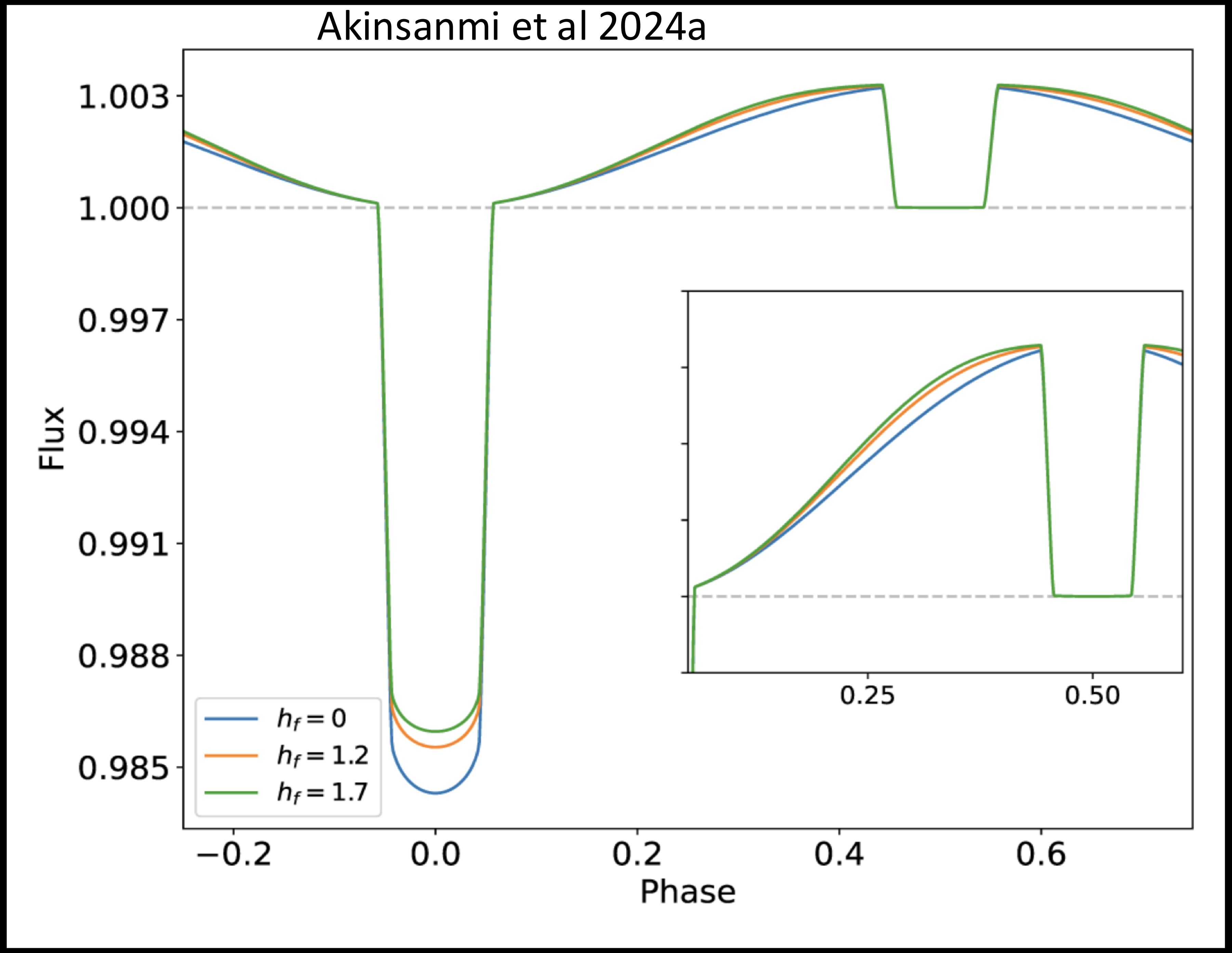
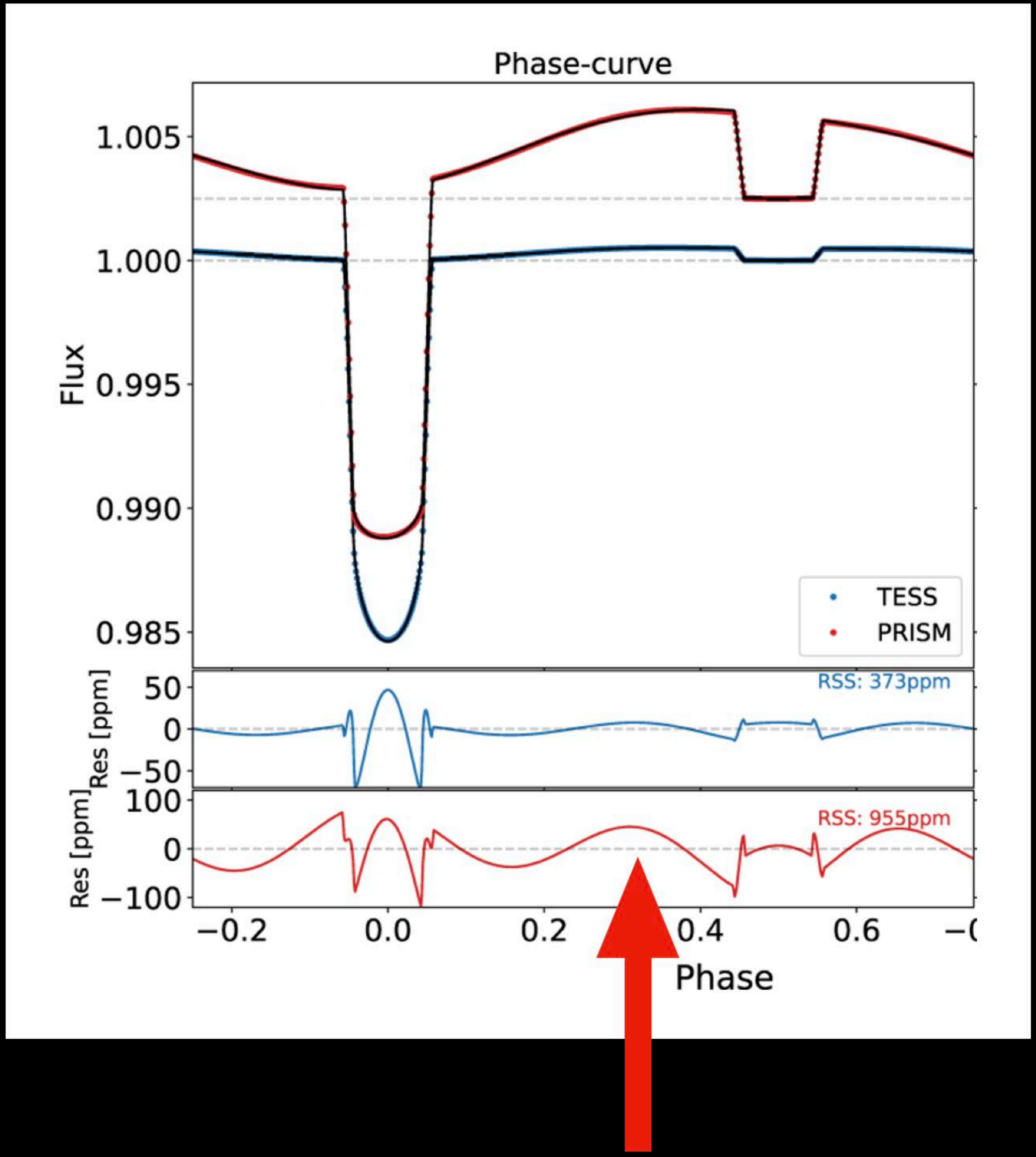
Tidal deformation

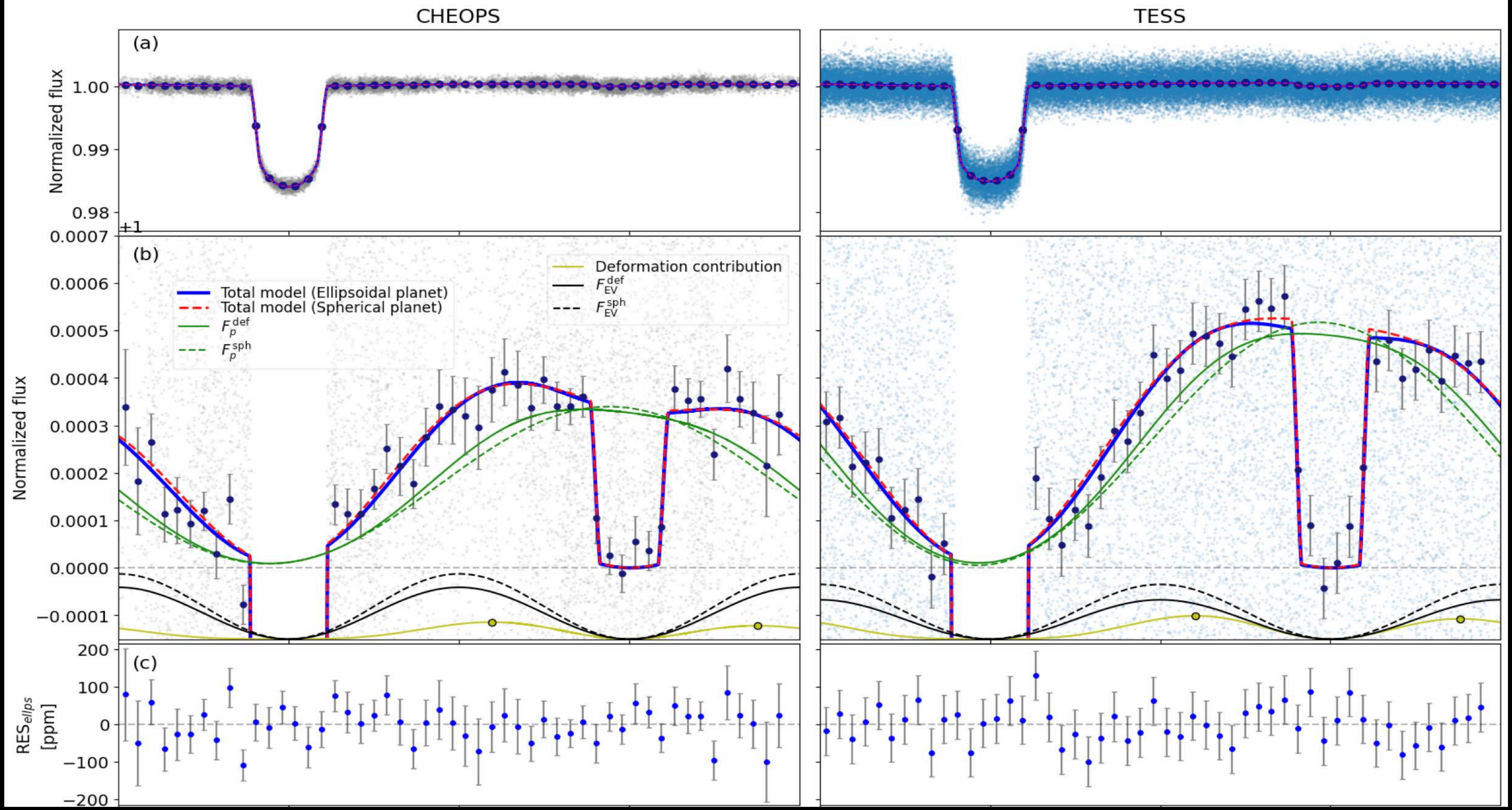


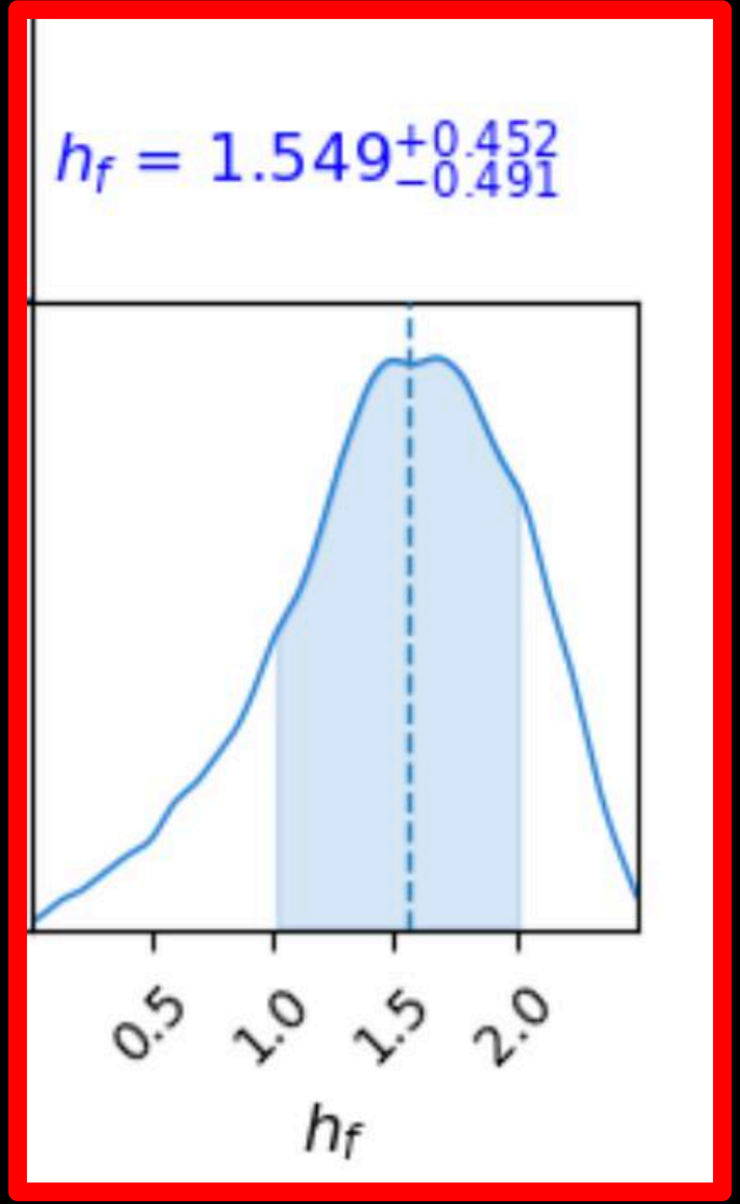




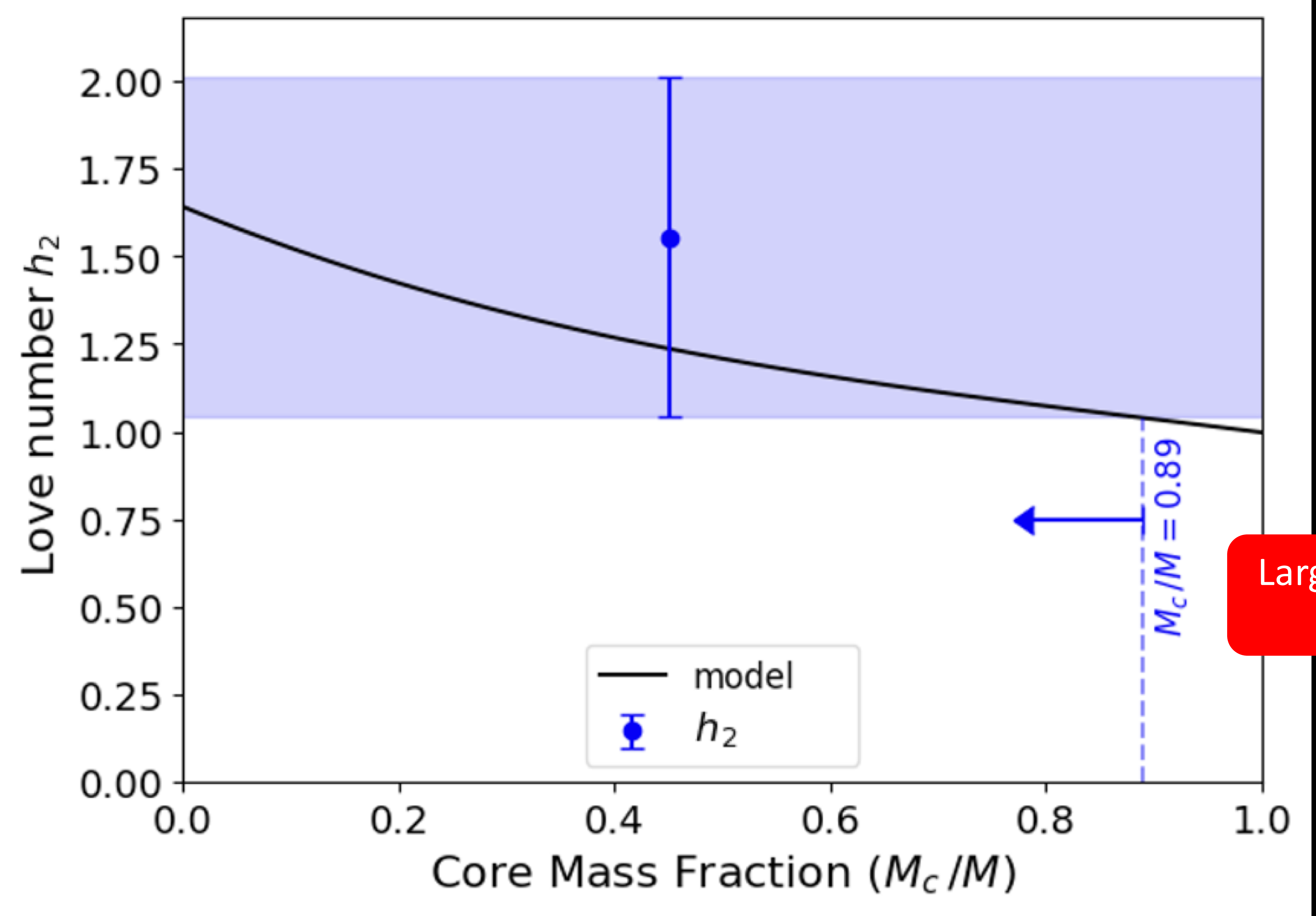


Application of phase curve model to WASP-12b

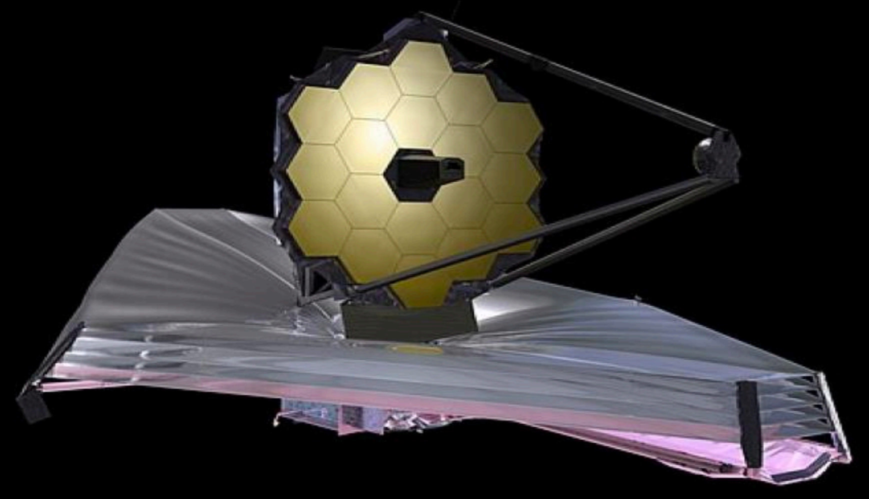




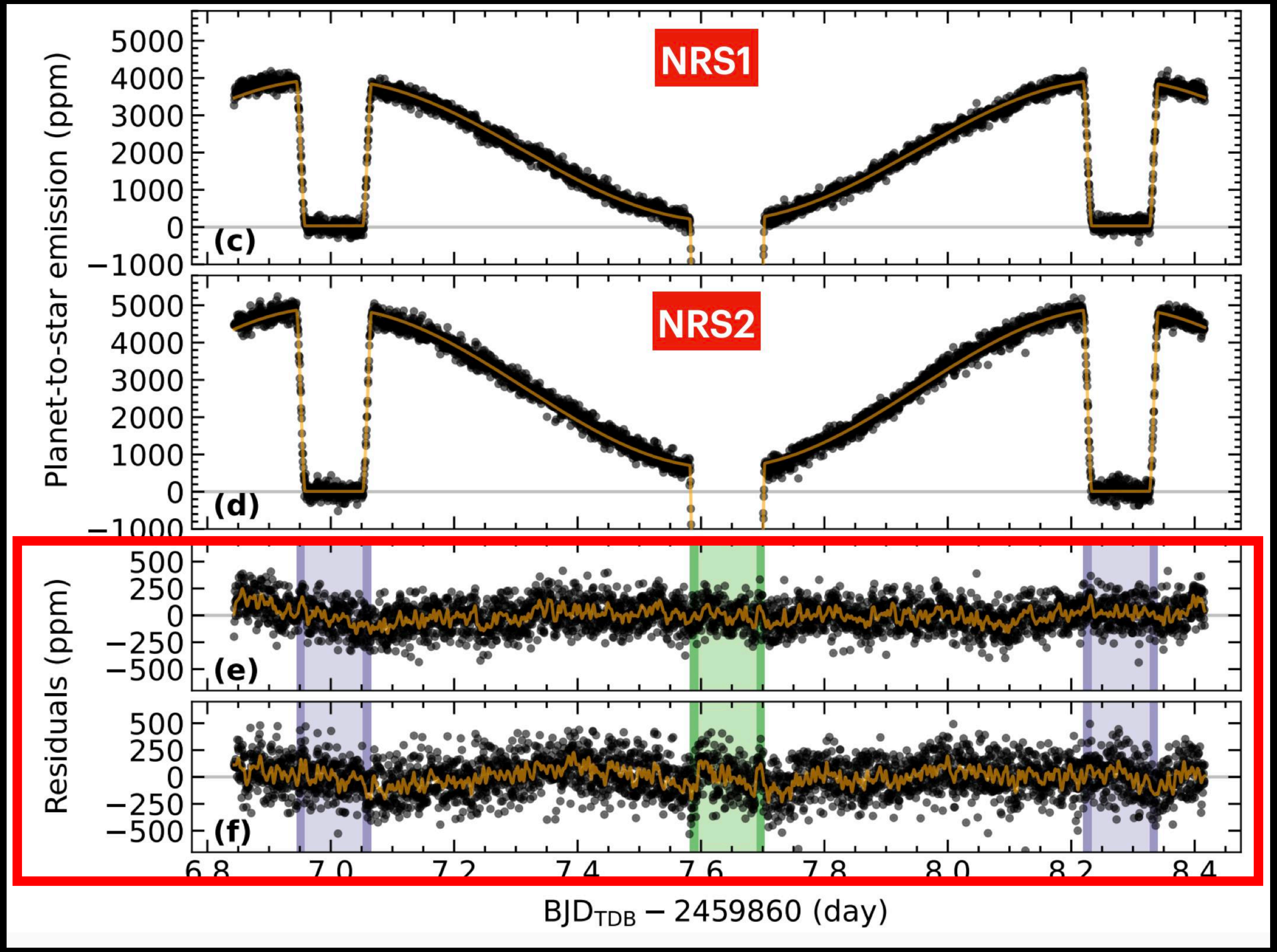
Current Love number measurements are not precise enough

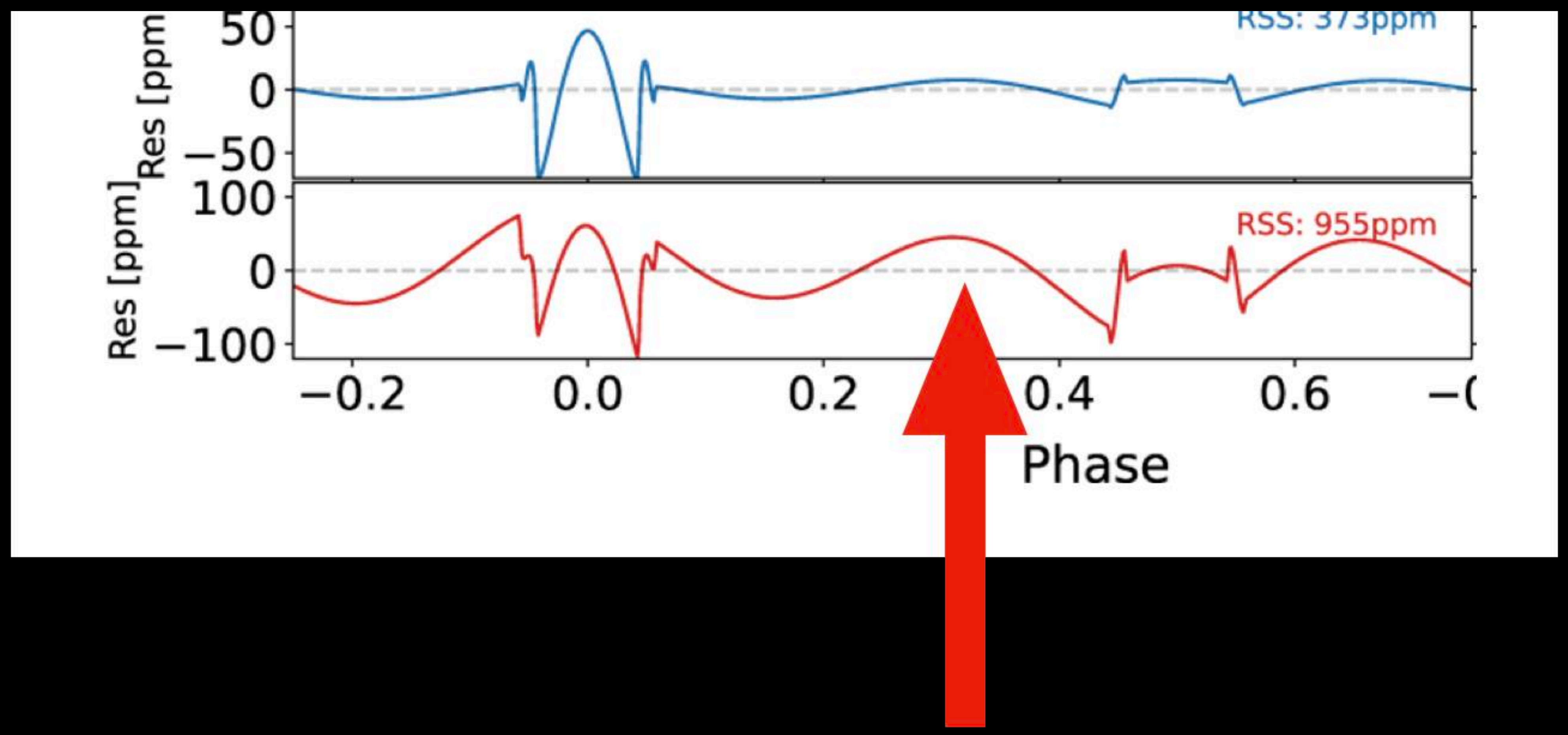


Large upper limit



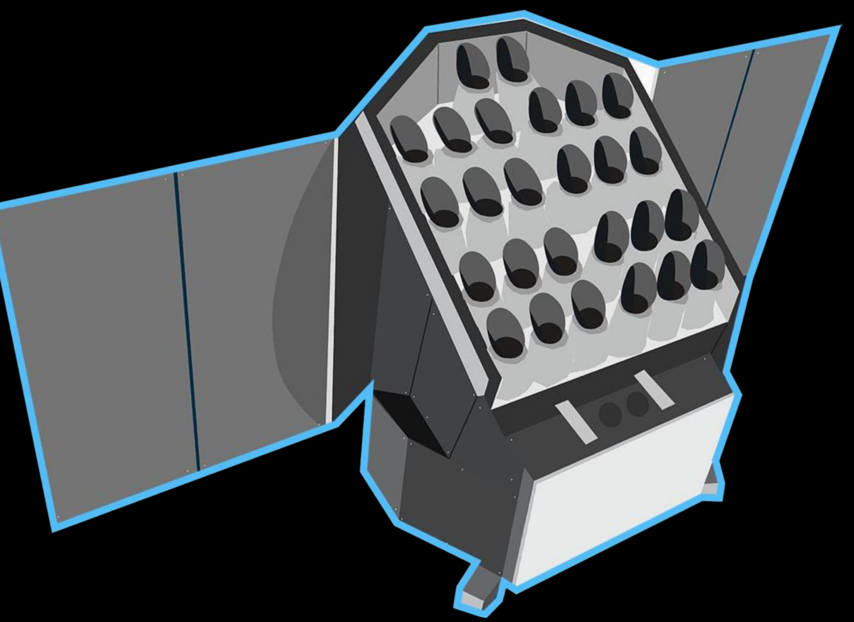
JWST observations



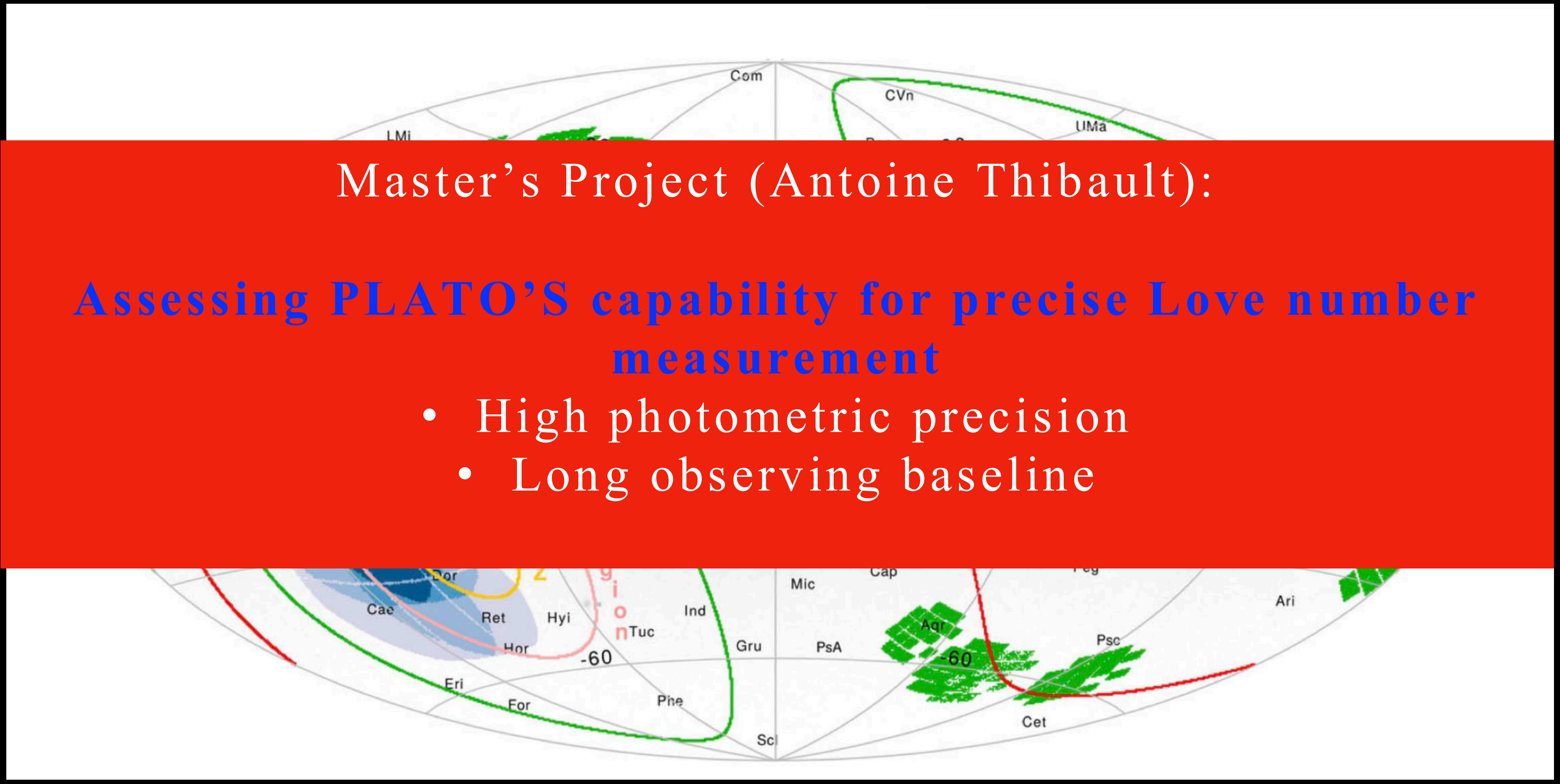


Others:

- Phase curve of WASP-103b
- Transit of WASP-12b



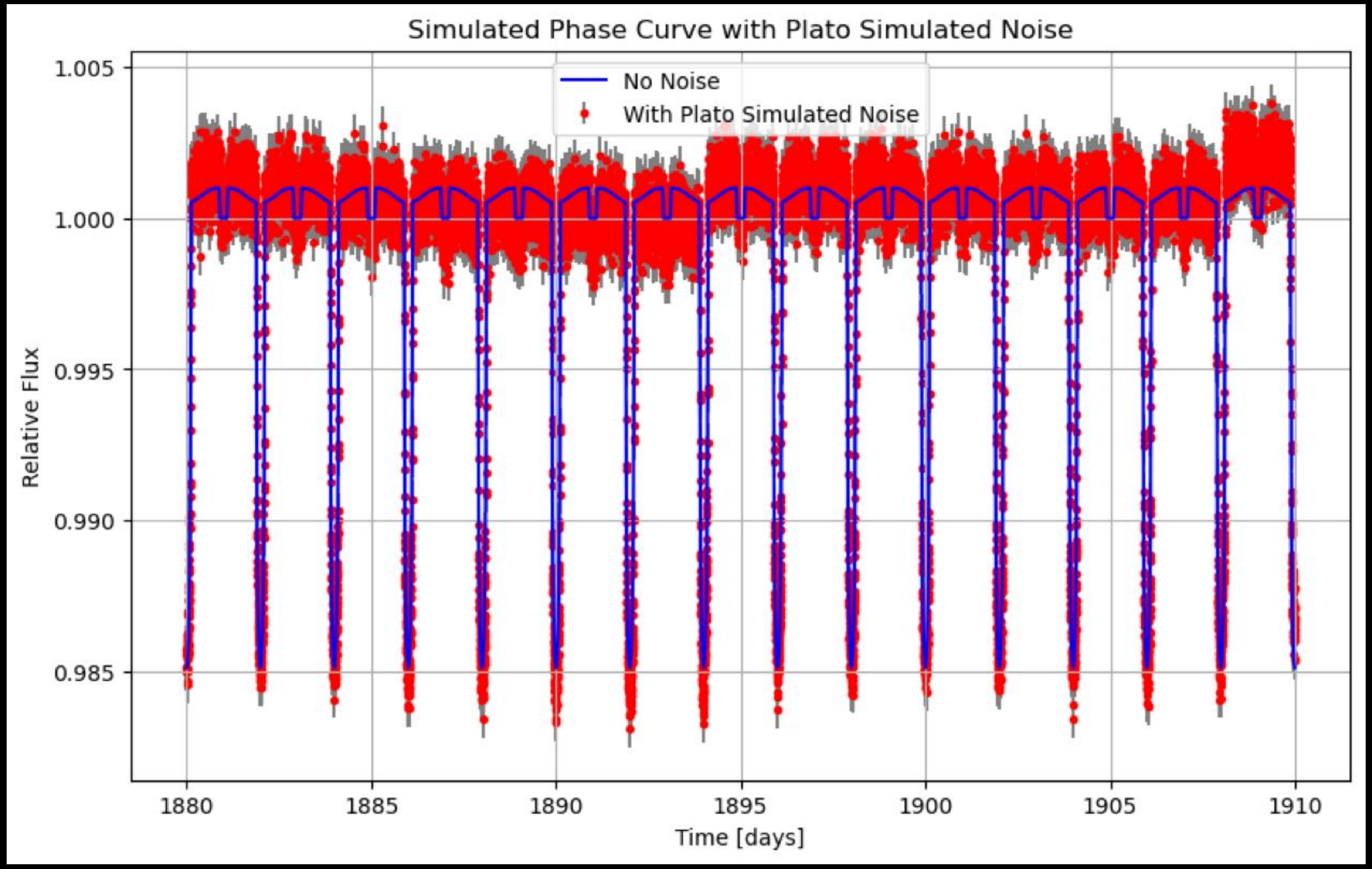
PLATO's Prospect

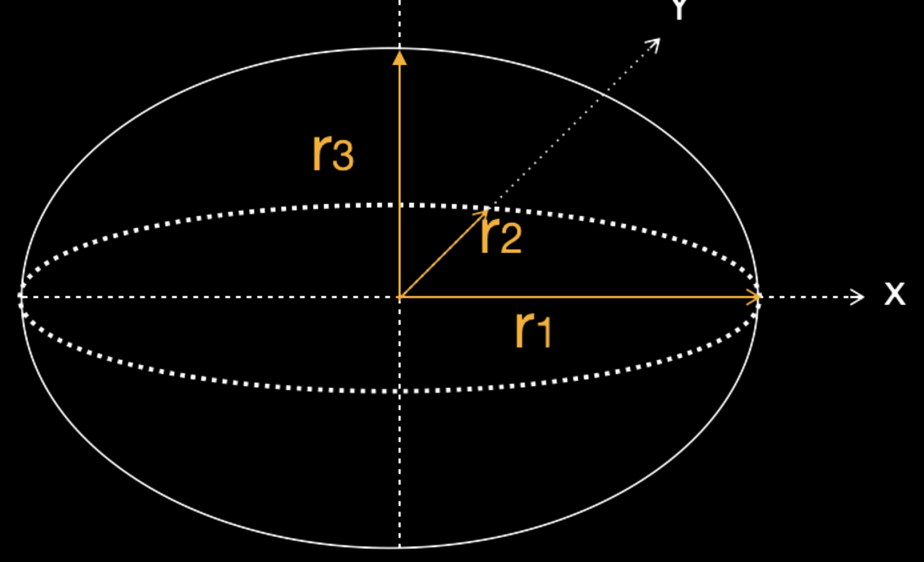


Master's Project (Antoine Thibault):

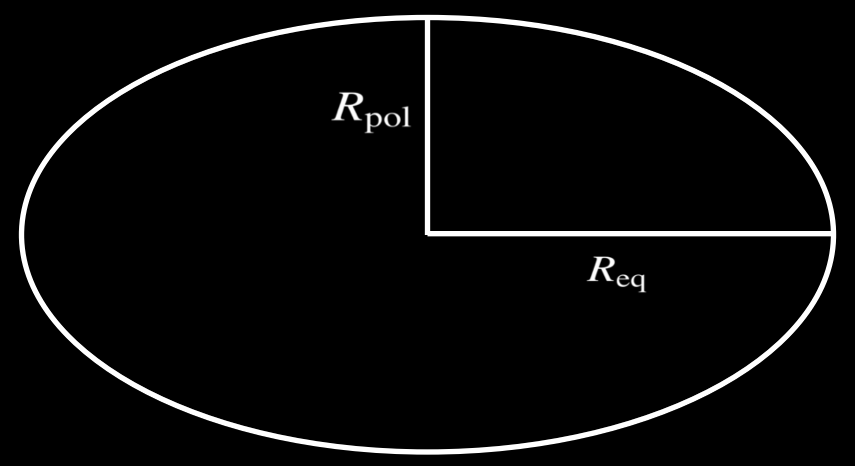
Assessing PLATO'S capability for precise Love number measurement

- High photometric precision
- Long observing baseline





Summary



- Modelling Interior structures of giant exoplanets is challenging due to degeneracies
  - **Measurement of the planet deformation (k_2 & J_2) can alleviate this**
- We are starting to be able to measure Love number from tidal deformation
  - **Phase curves of UHJs allow significant detection, particularly in the NIR**
- With these measurement for different planets, we can **perform comparative analysis** of exoplanet interior structures and **contrast them to solar system giants.**
- Measuring core masses of planets can, in some cases, help **distinguish models of planet formation**