Universität Zürich[UZH]
Departement of Astrophysics

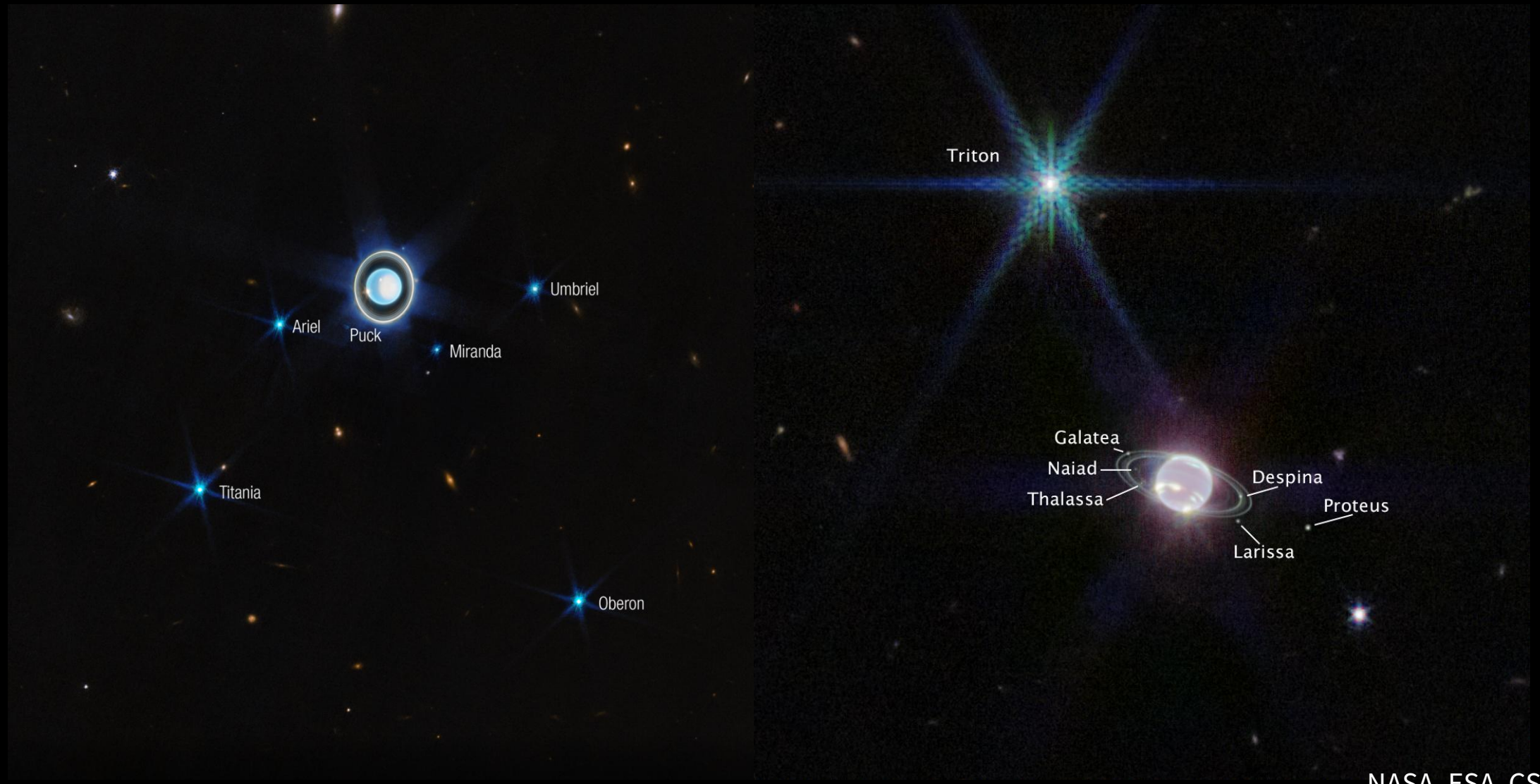
Schweizerischer Nationalfonds

Icy or rocky? Convective or stable?

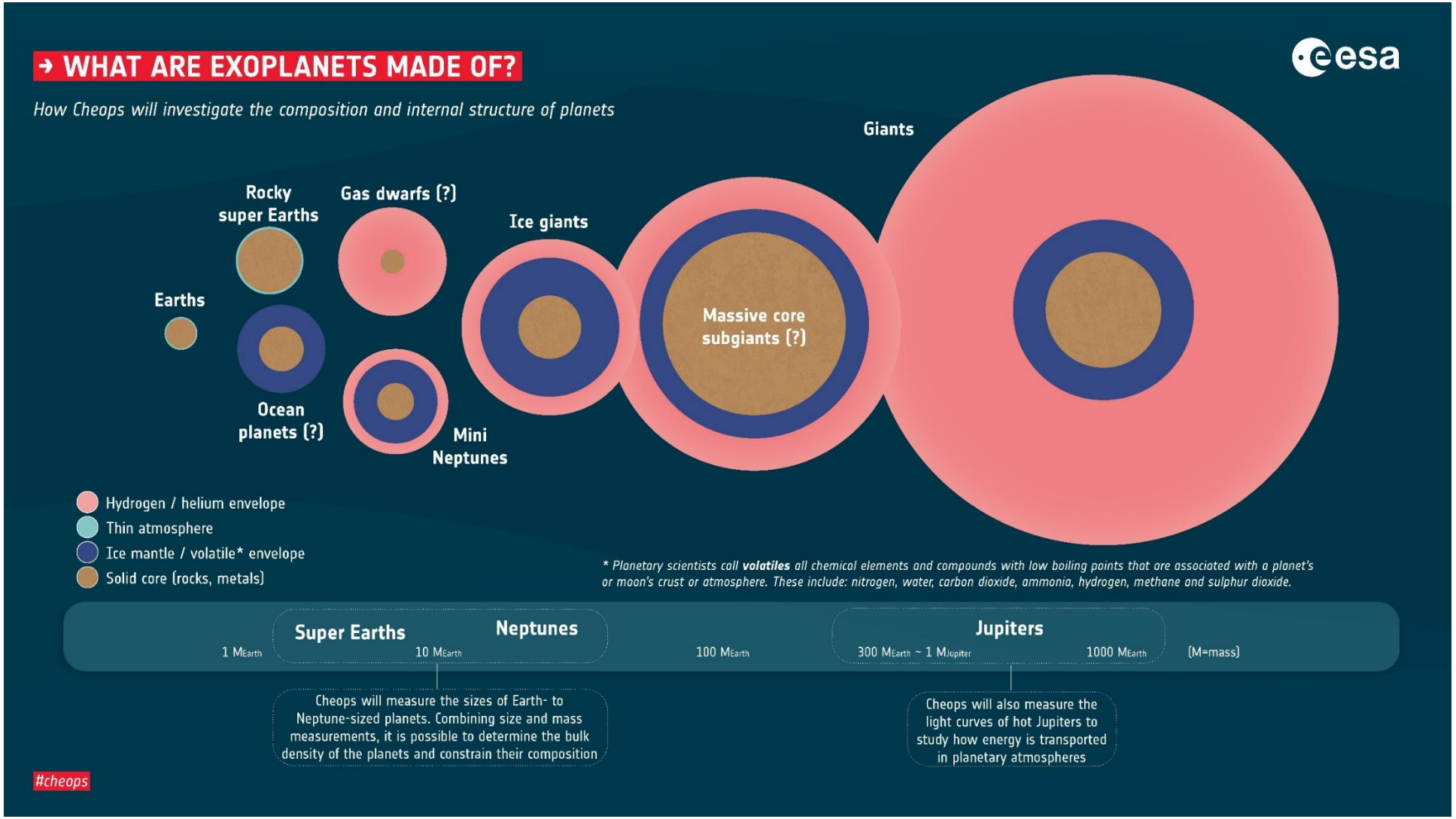
New interior models of Uranus and Neptune

Luca Morf

14 April 2026

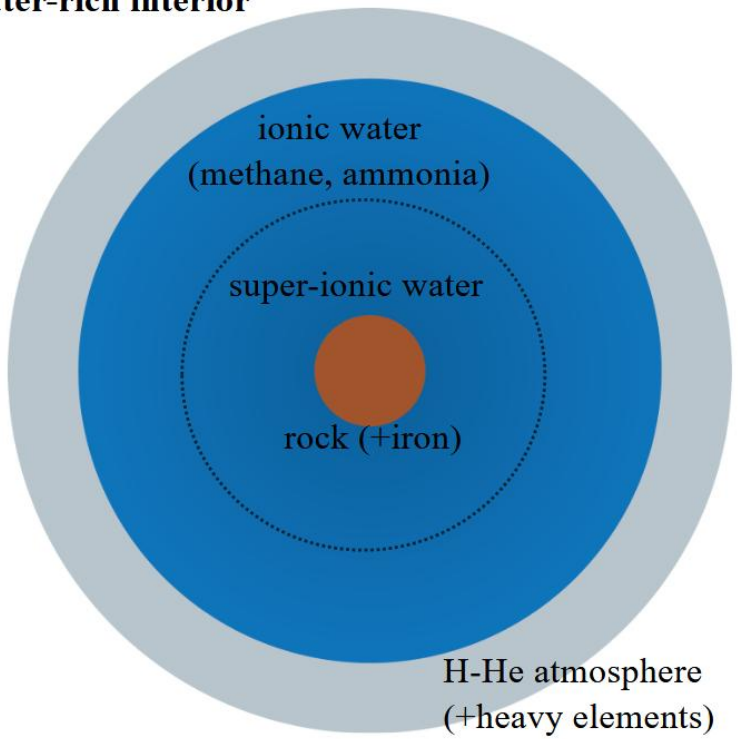


NASA, ESA, CSA, STScI


→ WHAT ARE EXOPLANETS MADE OF?
How Cheops will investigate the composition and internal structure of planets
esa
Earths
Rocky super Earths
Ocean planets (?)
Gas dwarfs (?)
Mini Neptunes
Ice giants
Massive core subgiants (?)
Giants
Hydrogen / helium envelope
Thin atmosphere
Ice mantle / volatile* envelope
Solid core (rocks, metals)
* Planetary scientists call volatiles all chemical elements and compounds with low boiling points that are associated with a planet's or moon's crust or atmosphere. These include: nitrogen, water, carbon dioxide, ammonia, hydrogen, methane and sulphur dioxide.
Super Earths
Neptunes
Jupiters
1 MEarth
10 MEarth
100 MEarth
300 MEarth ~ 1 MJupiter
1000 MEarth
(M=mass)
Cheops will measure the sizes of Earth- to Neptune-sized planets. Combining size and mass measurements, it is possible to determine the bulk density of the planets and constrain their composition
Cheops will also measure the light curves of hot Jupiters to study how energy is transported in planetary atmospheres
#cheops

Traditional Interior Models:

- **Distinct (three) layers**
- **An adiabatic temperature profile**
- **Water-rich interior**



central temperature:
a few 10^3 K

Helled 2025

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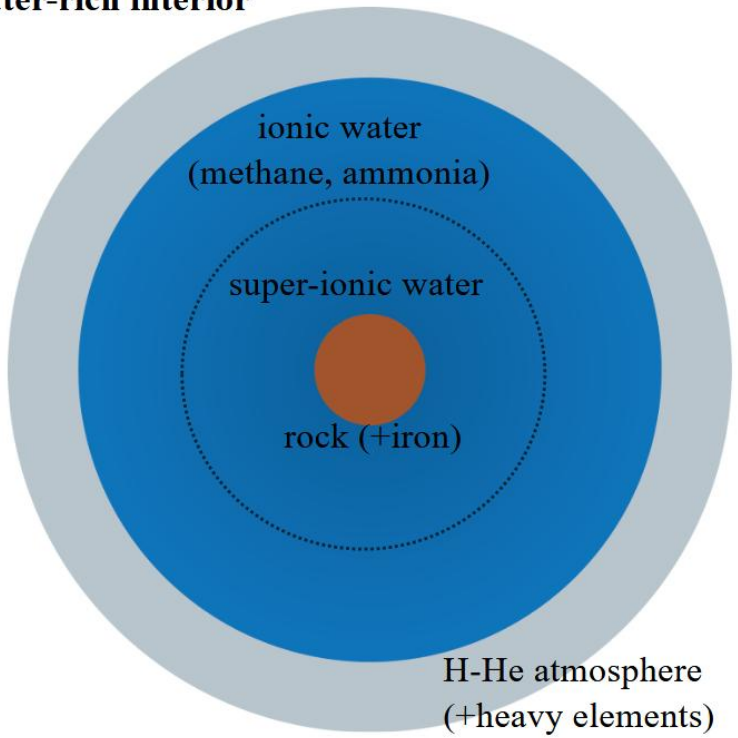
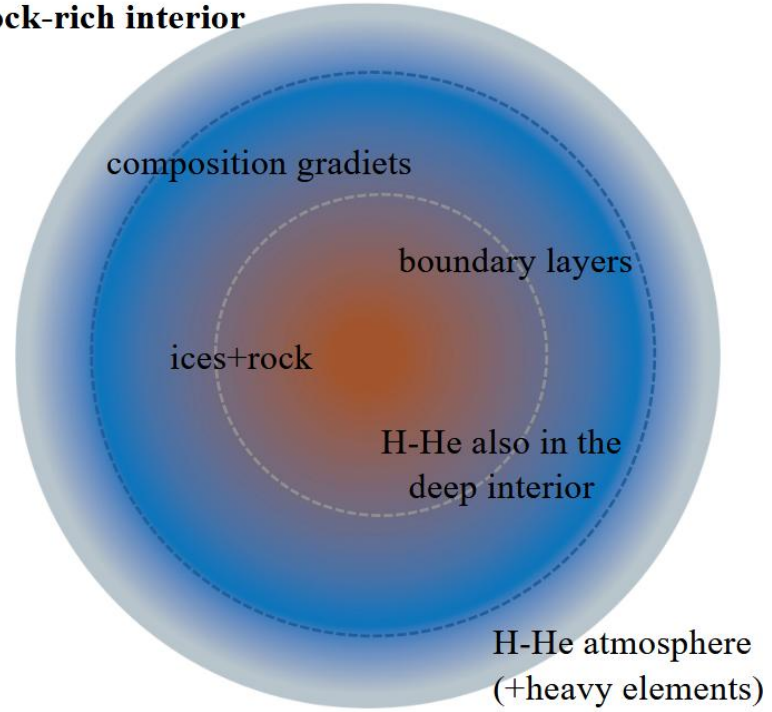


central temperature:
a few 10^3 K

Reality?:

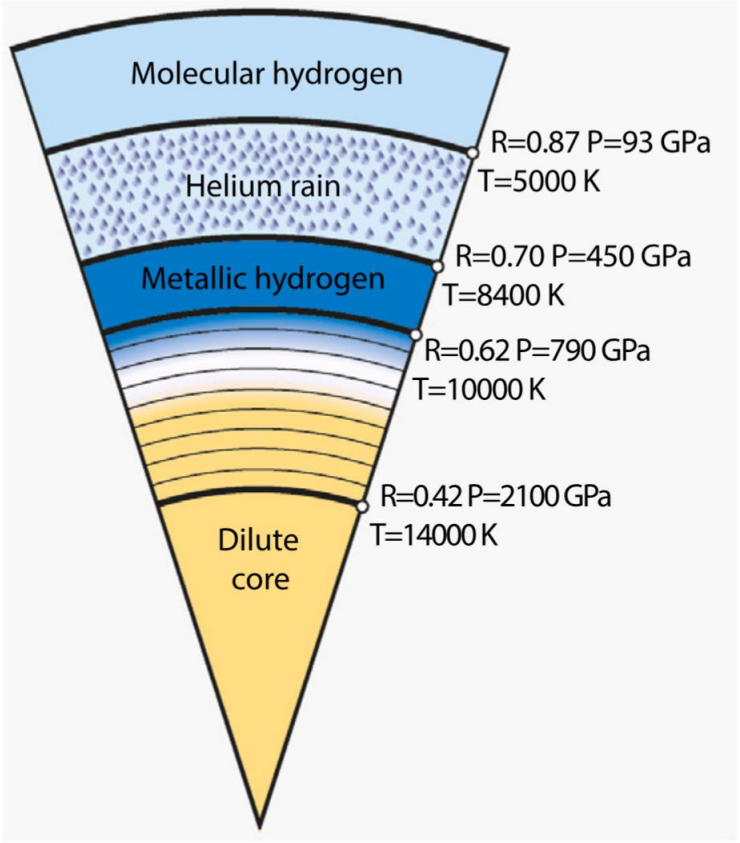
- **Composition gradients (no distinct layers)**
- **A non-adiabatic temperature profile**
- **Boundary layers**
- **Rock-rich interior**



central temperature:
a few 10^4 K

Helled 2025

Jupiter



Militzer and Hubbard 2024

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- We need to relax assumptions!

Empirical approach to interior modelling

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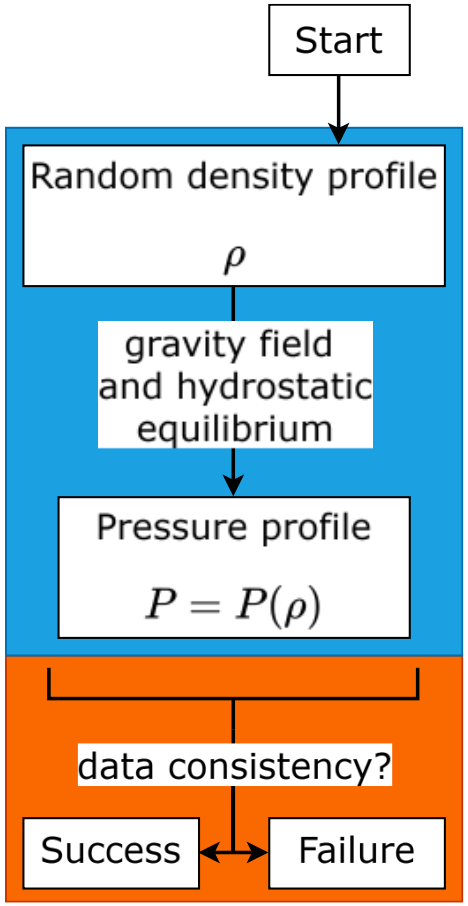
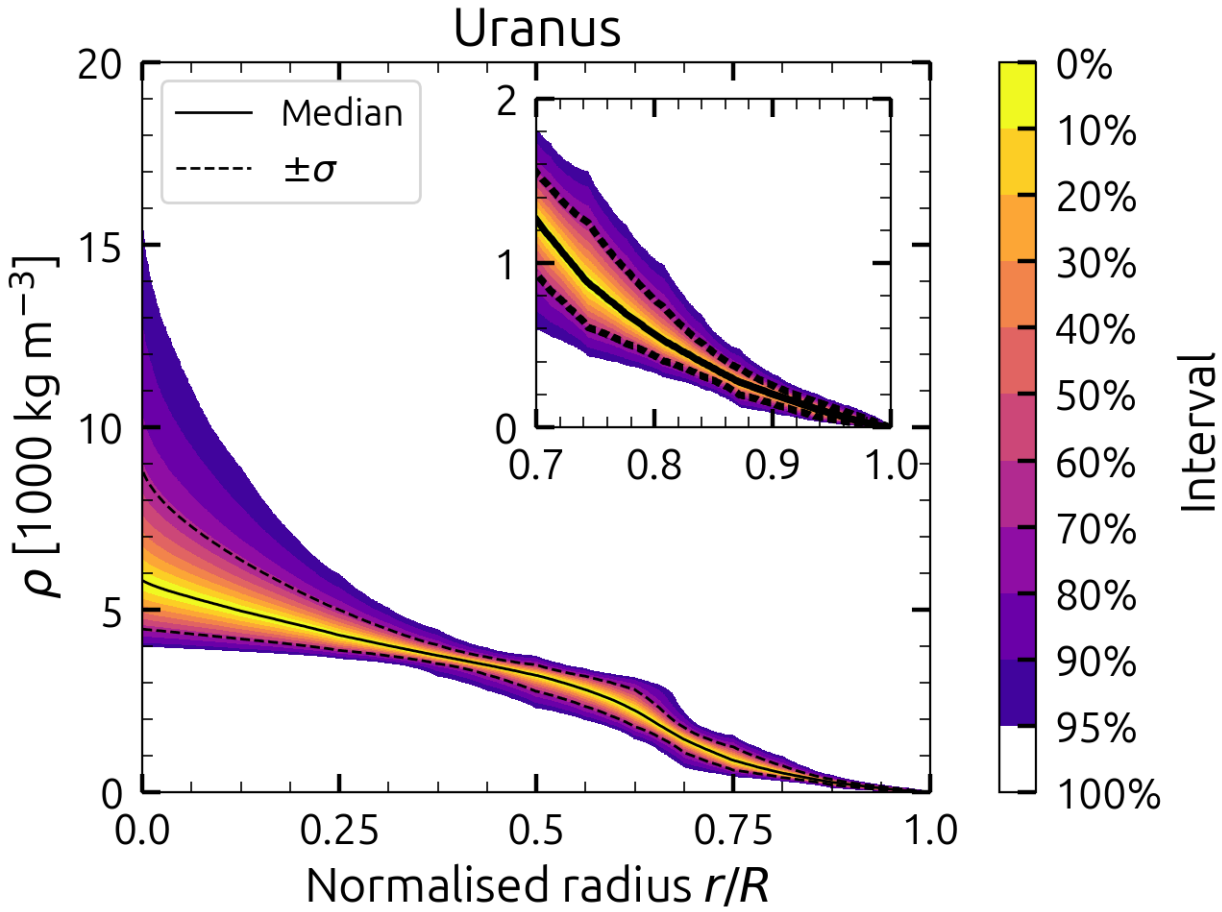
Empirical approach to interior modelling

Minimalist

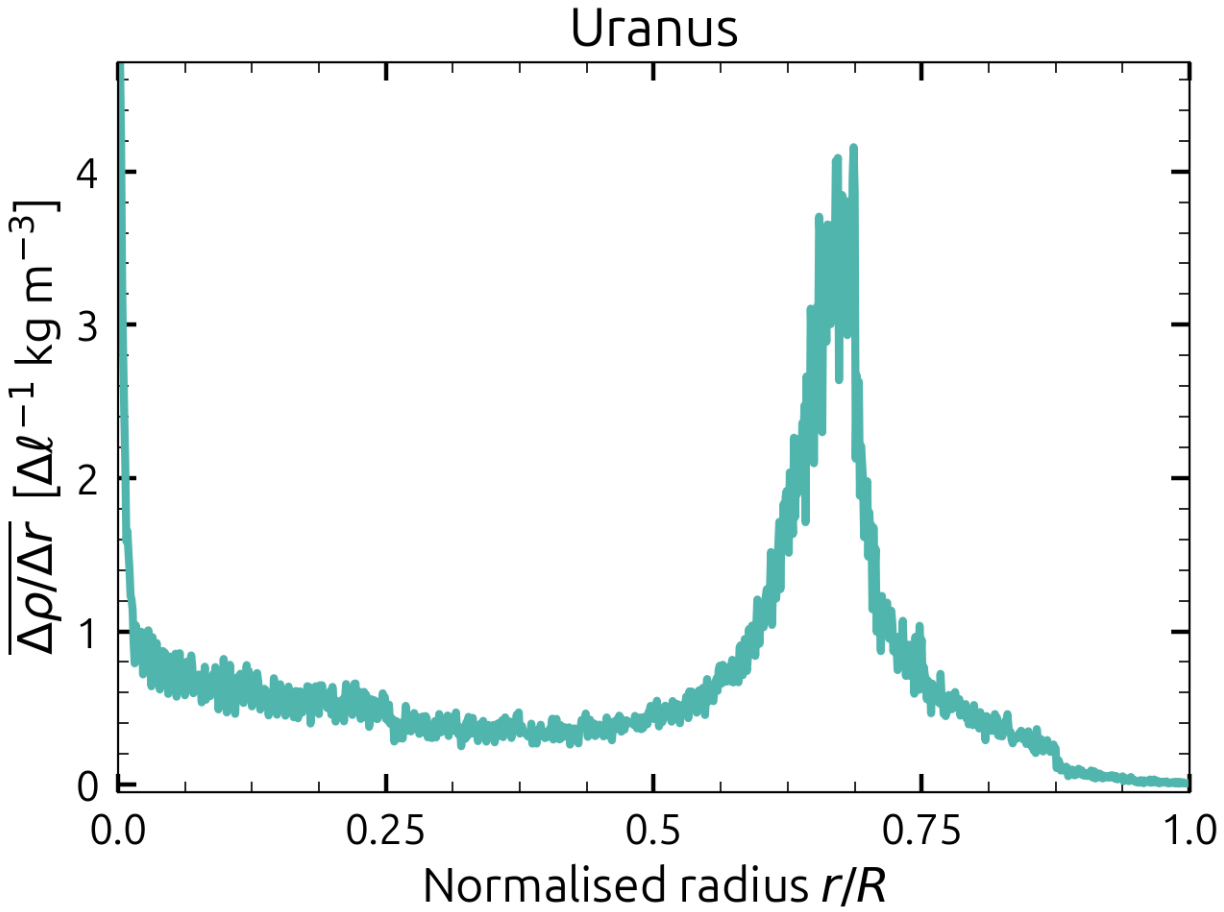


Empirical approach to interior modelling: Minimalist



Wirth, Morf, and Helled 2025

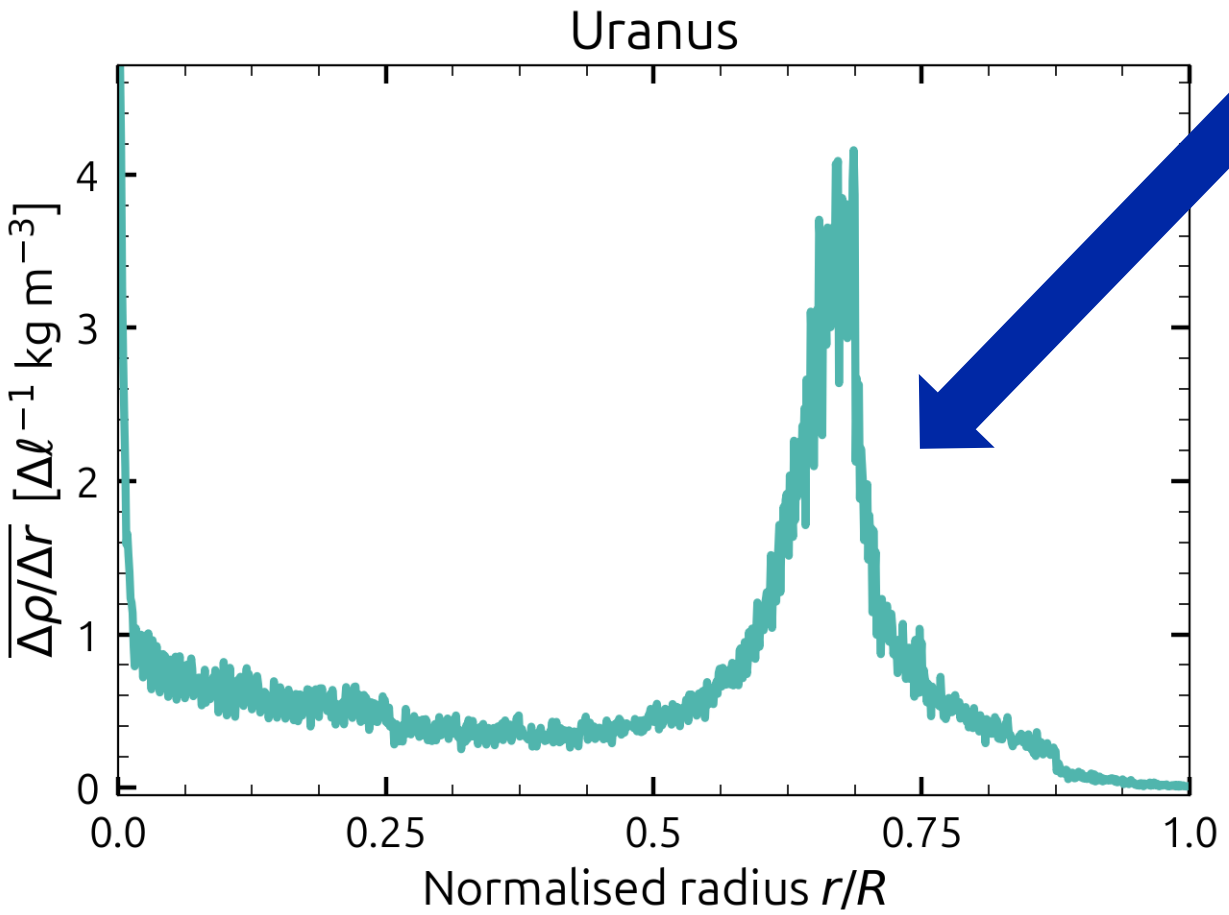
Empirical approach to interior modelling: Minimalist



Wirth, Morf, and Helled 2025

Empirical approach to interior modelling: Minimalist

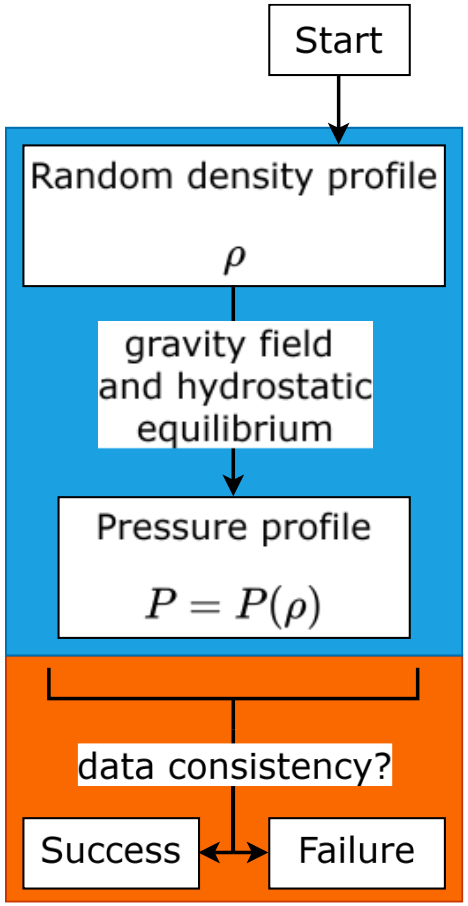
Boundary between layers dominated by H-He and layers dominated by metals?



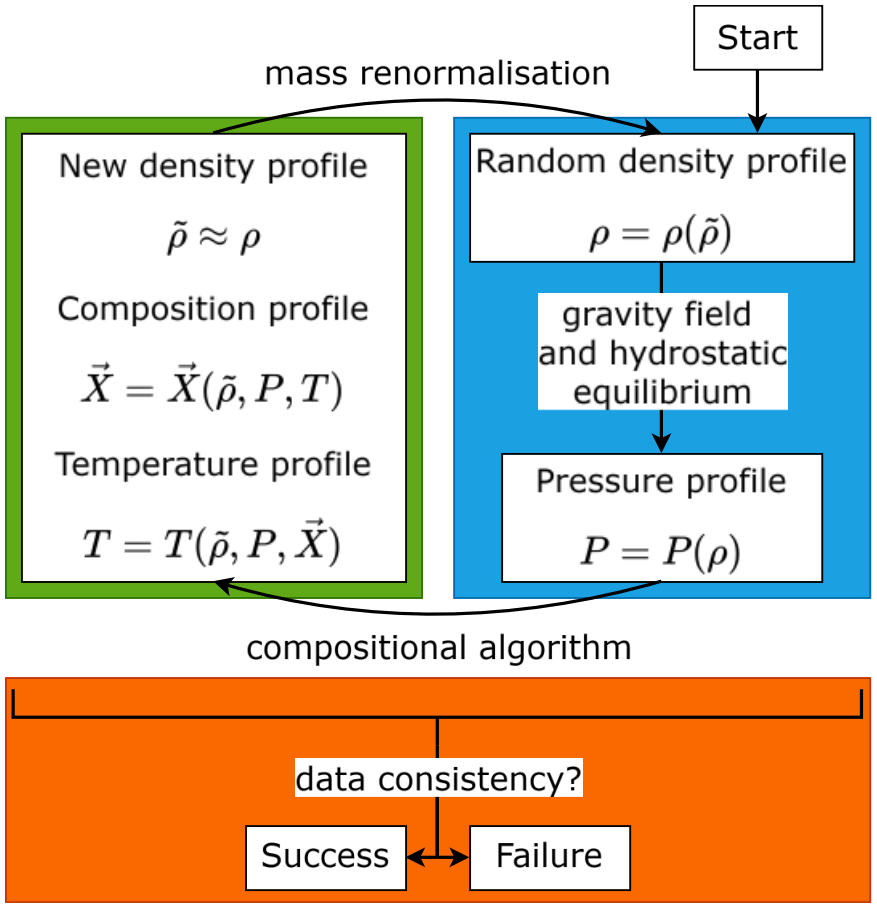
Wirth, Morf, and Helled 2025

Empirical approach to interior modelling

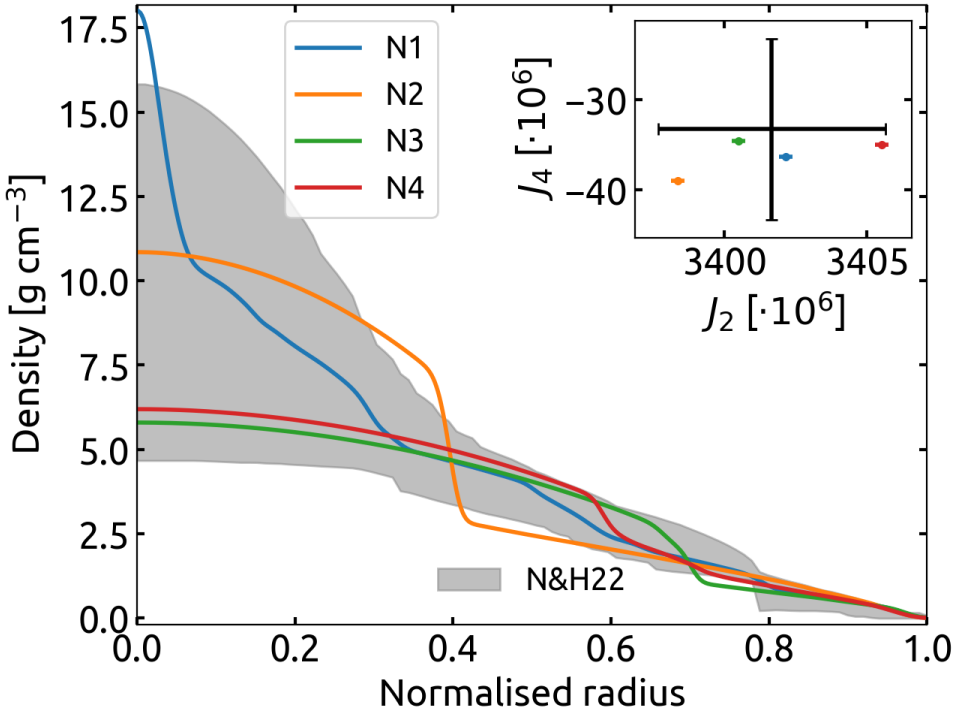
Minimalist

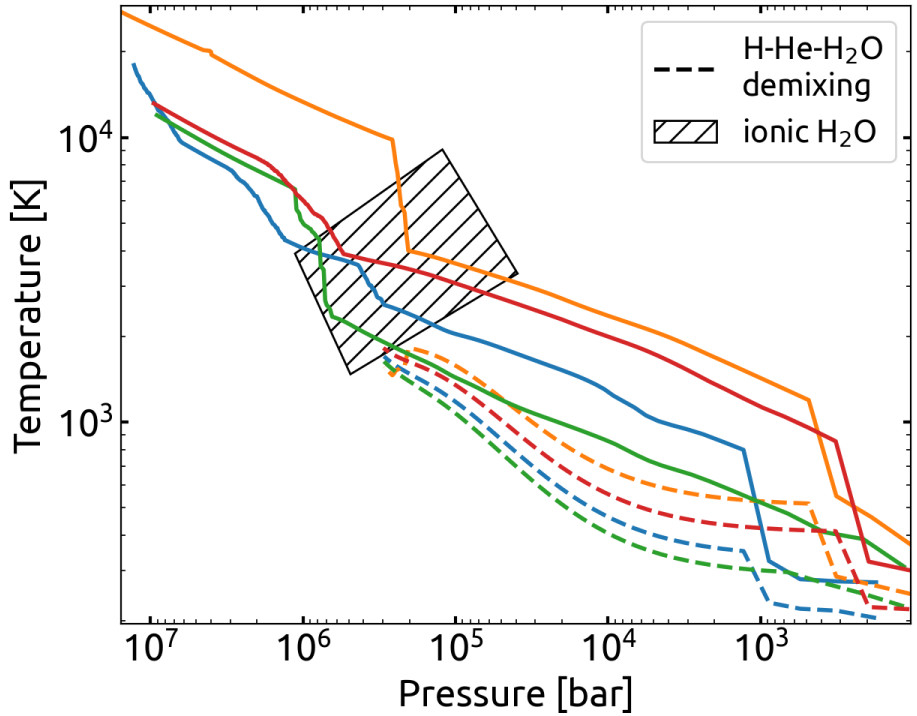


Self-consistent



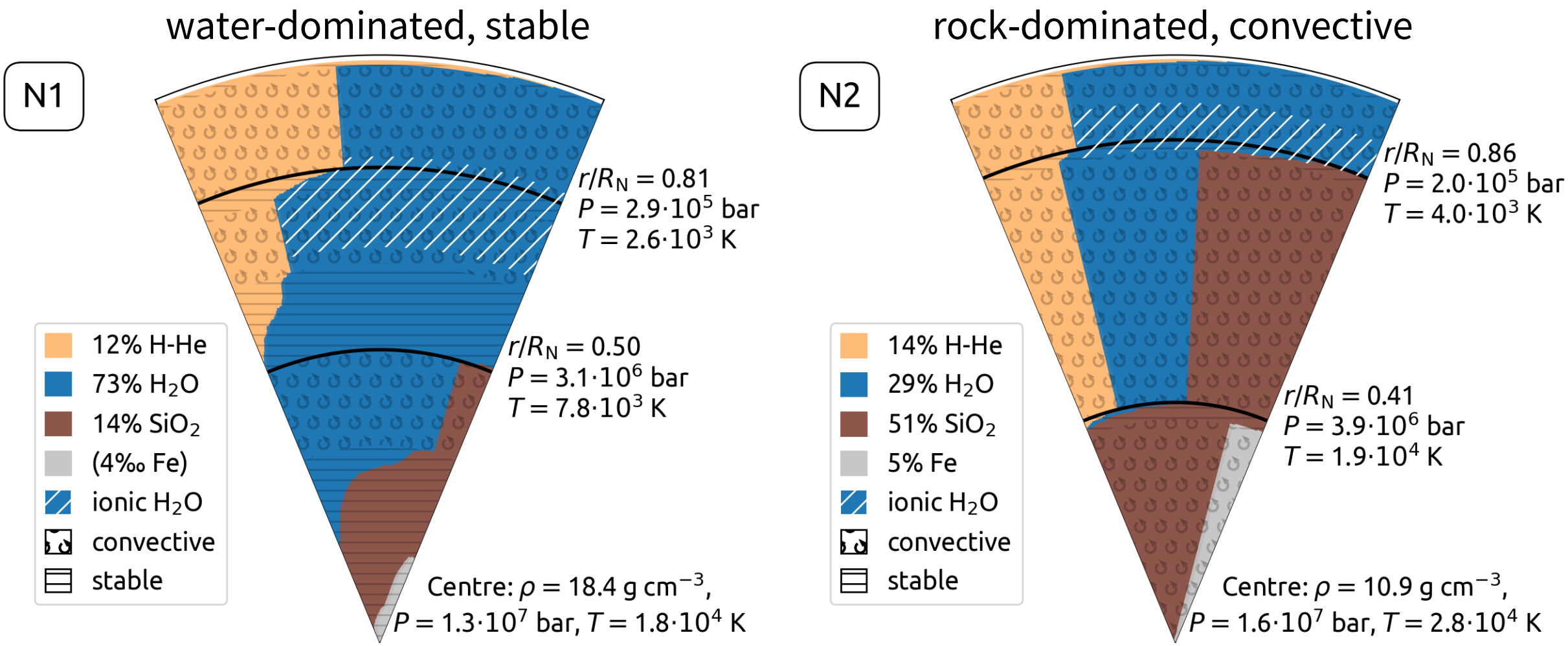
Empirical approach to interior modelling: Self-consistent





Morf and Helled 2025

Empirical approach to interior modelling: Self-consistent



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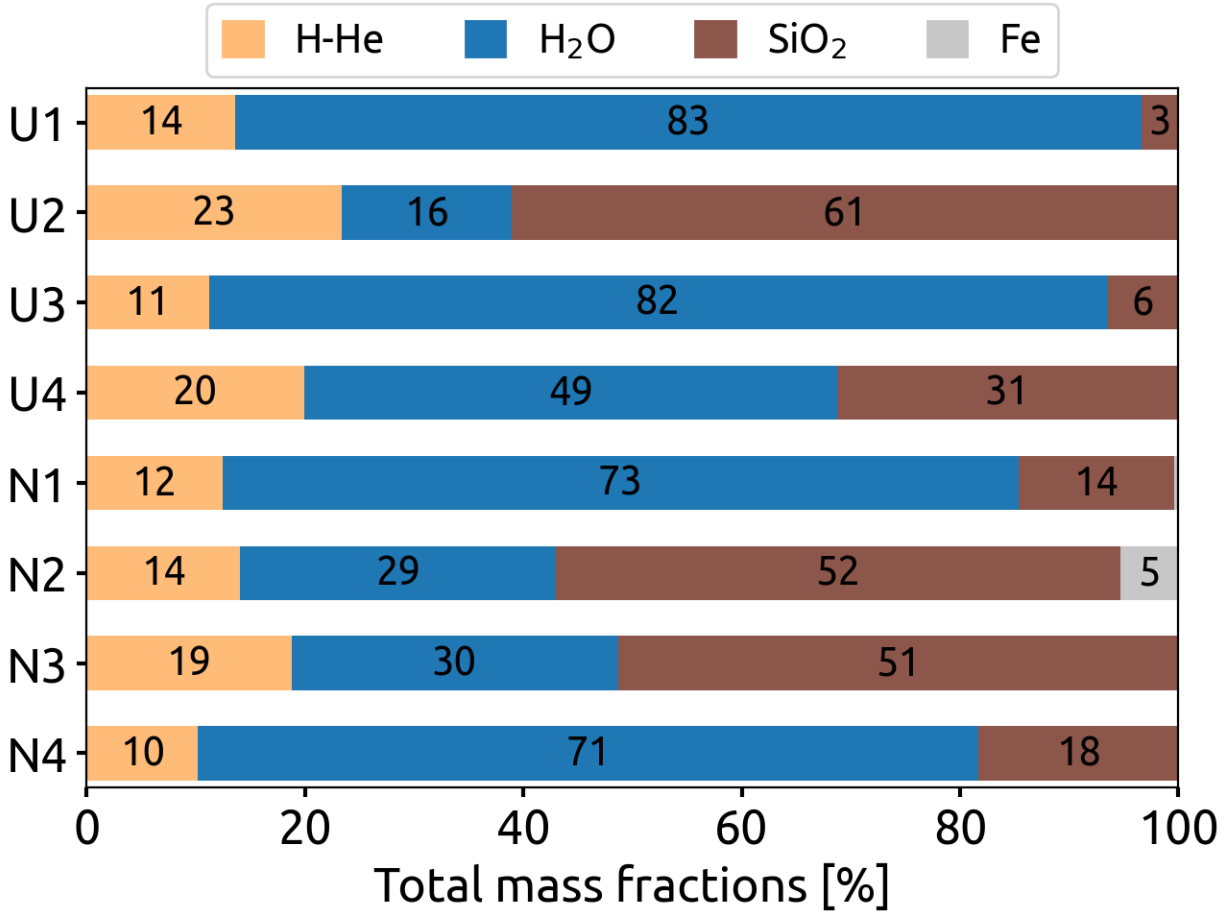
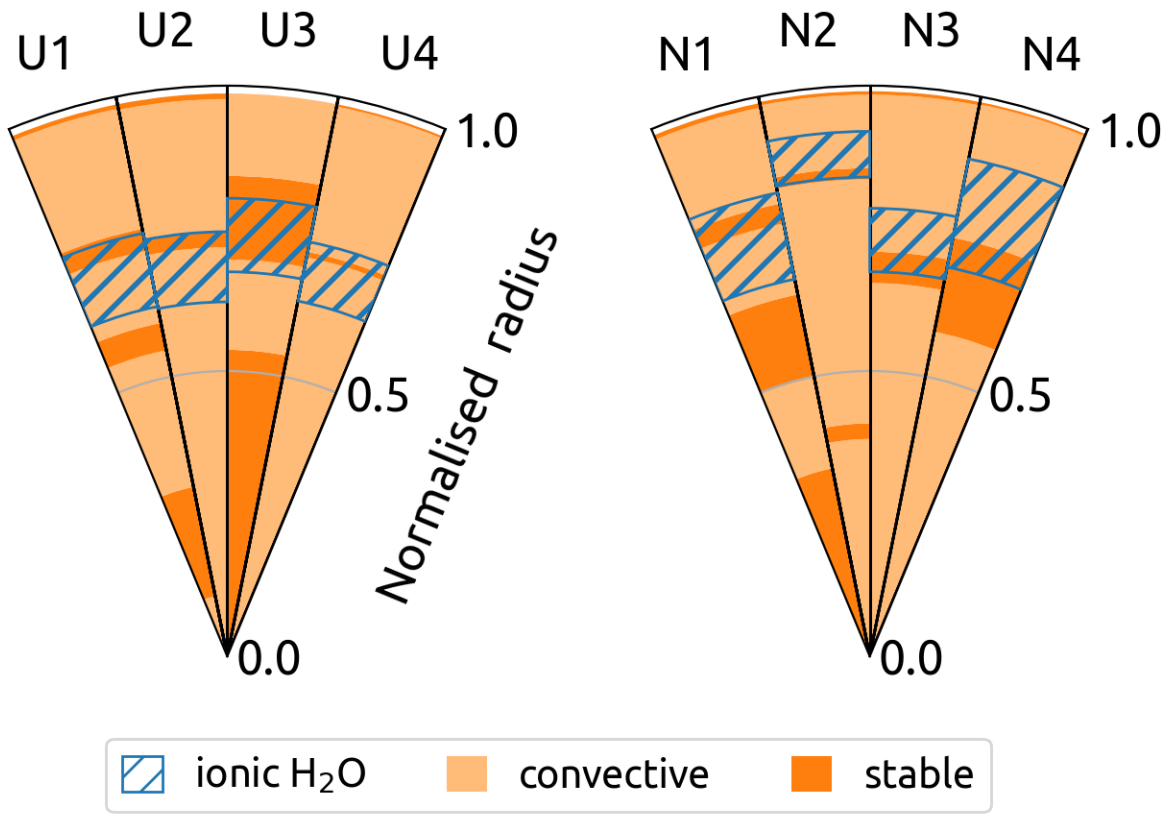
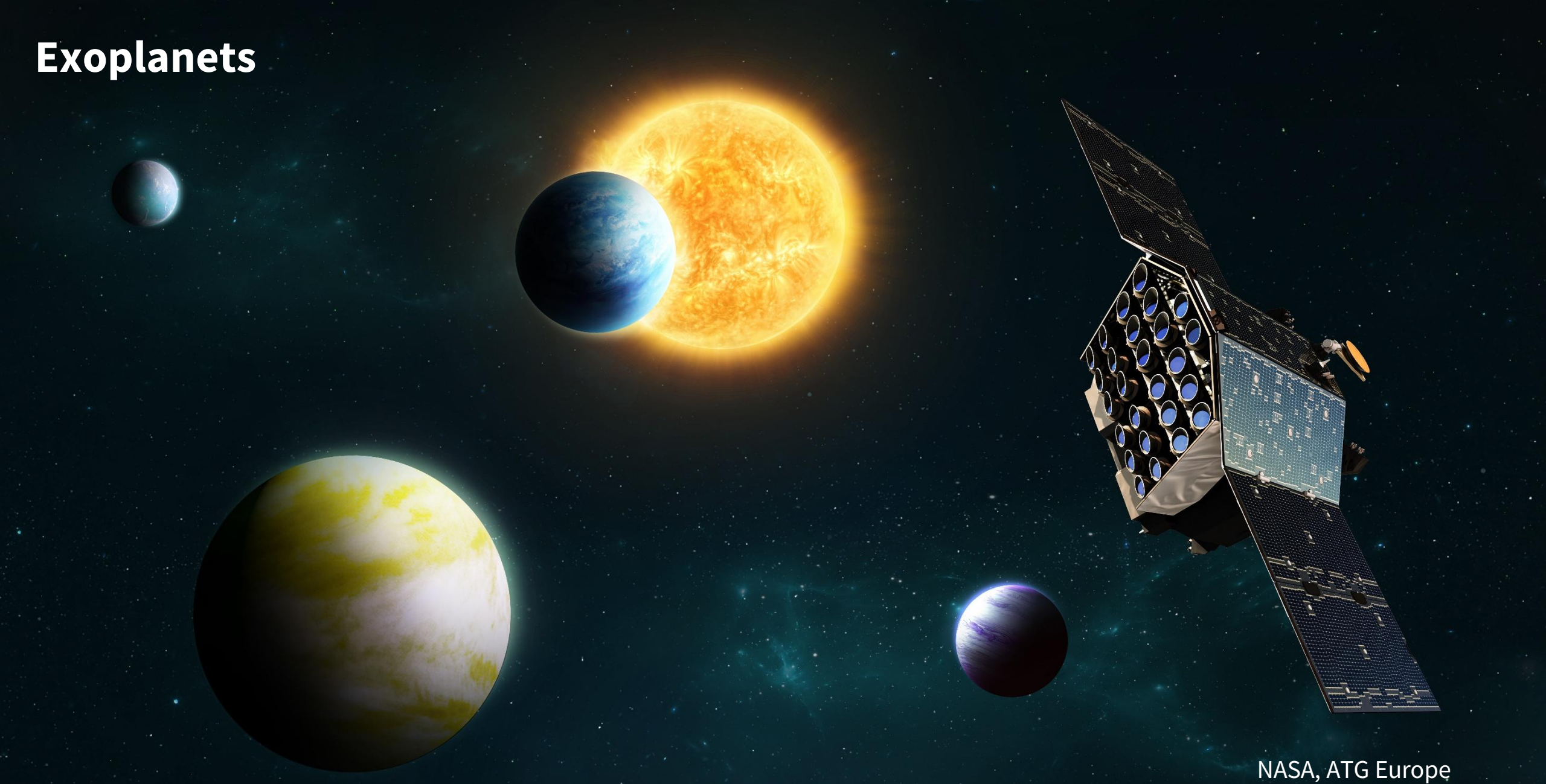




Morf and Helled 2025

Exoplanets



NASA, ATG Europe

K2-18b

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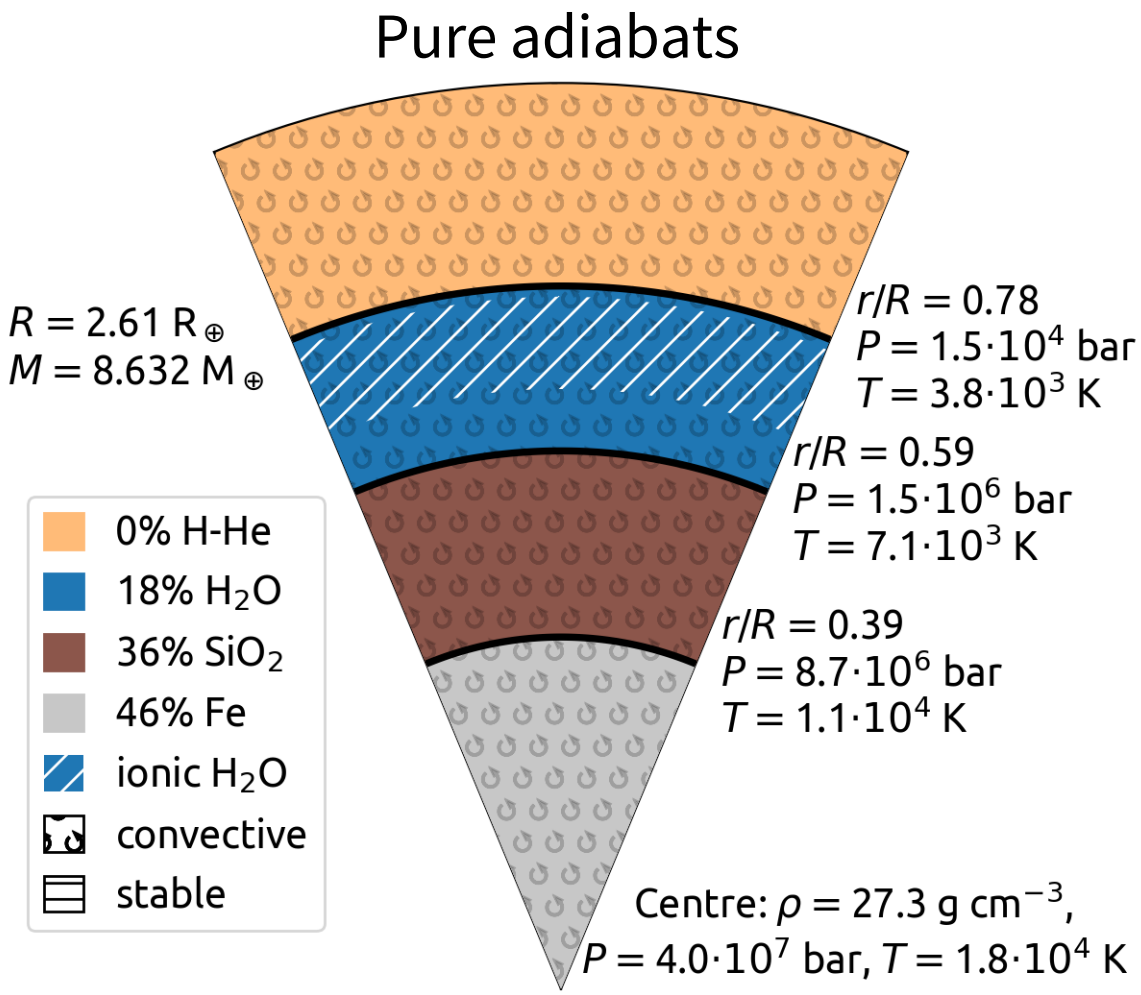
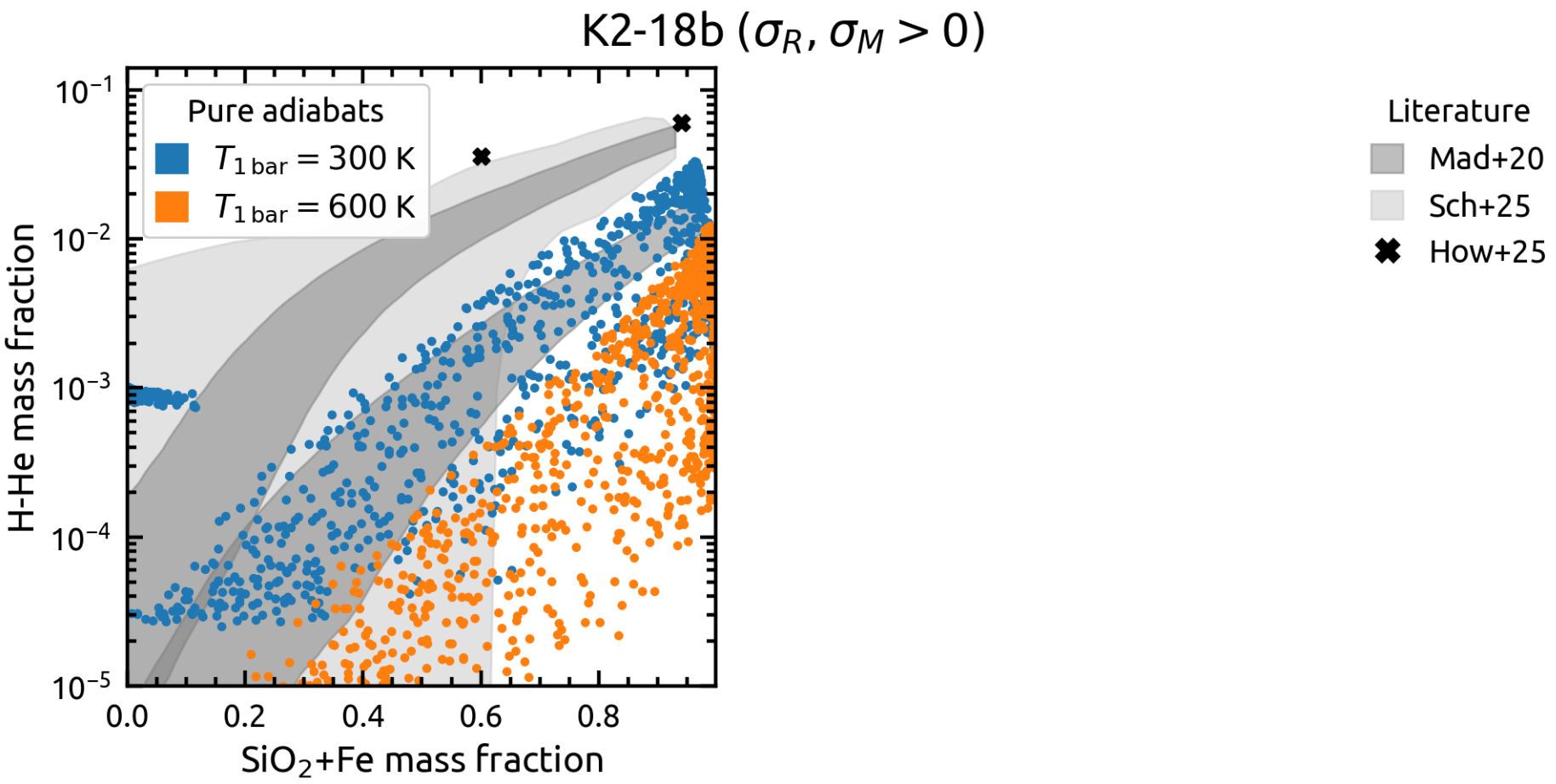
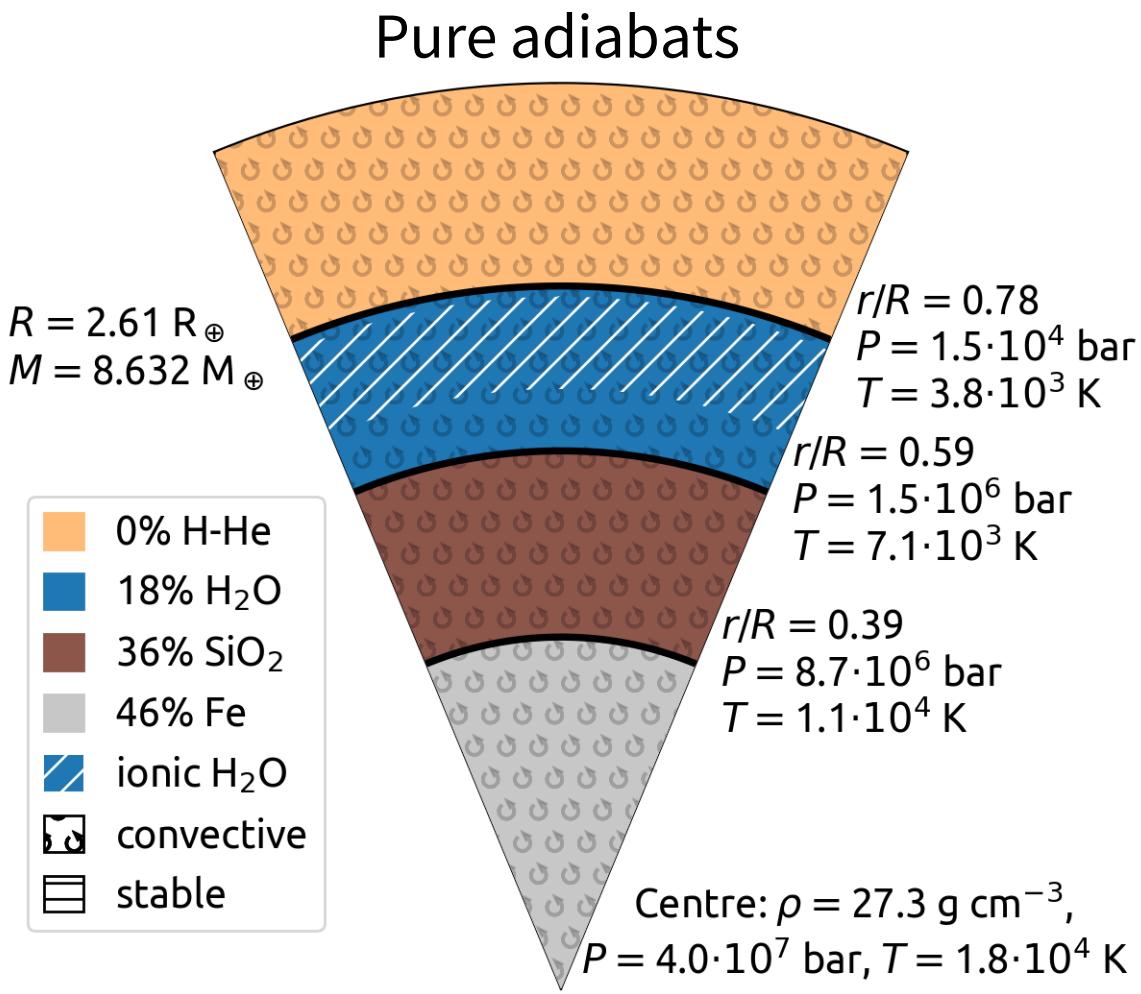


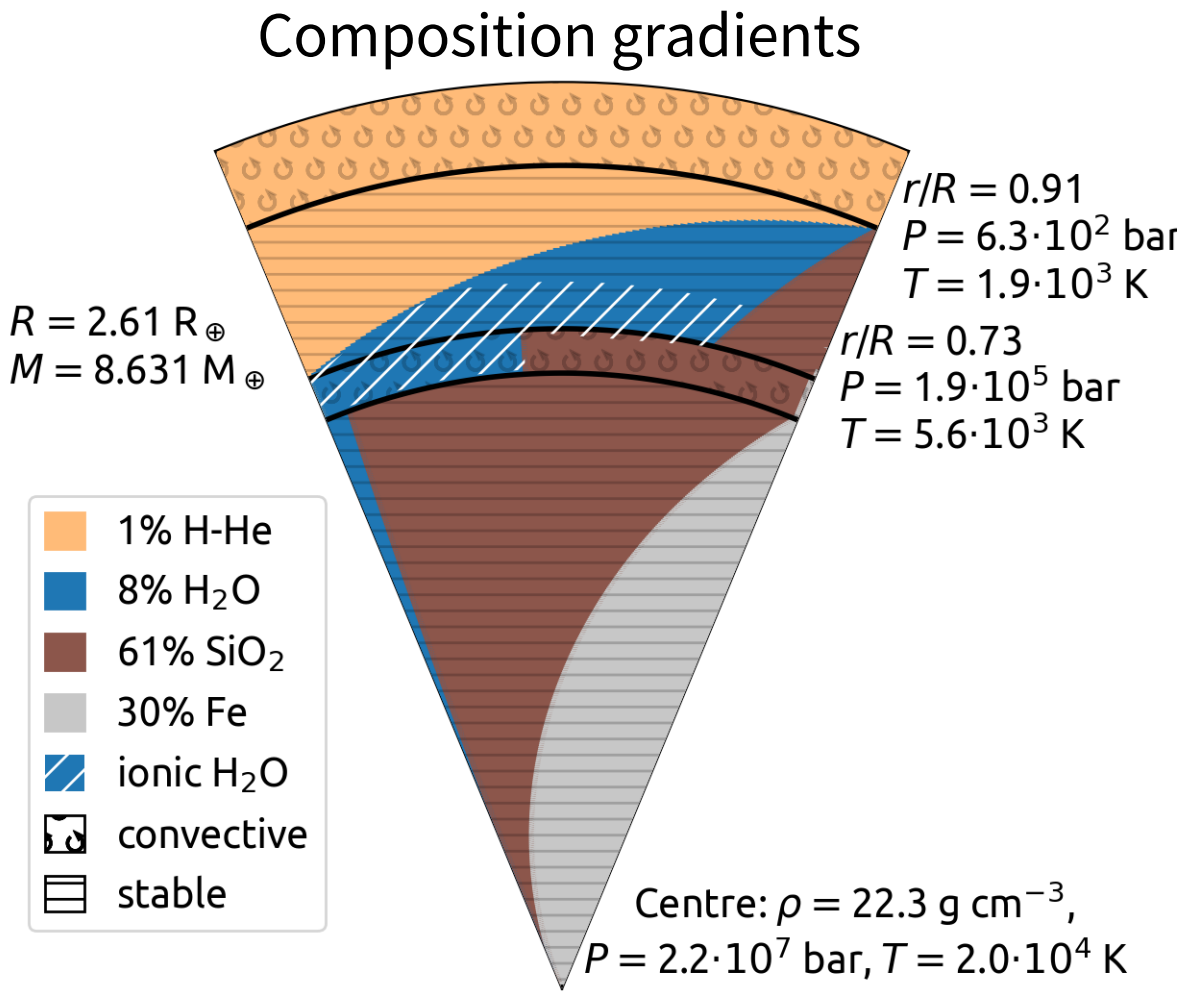
Morf and Helled 2026, in prep.



Morf and Helled 2026, in prep.

K2-18b





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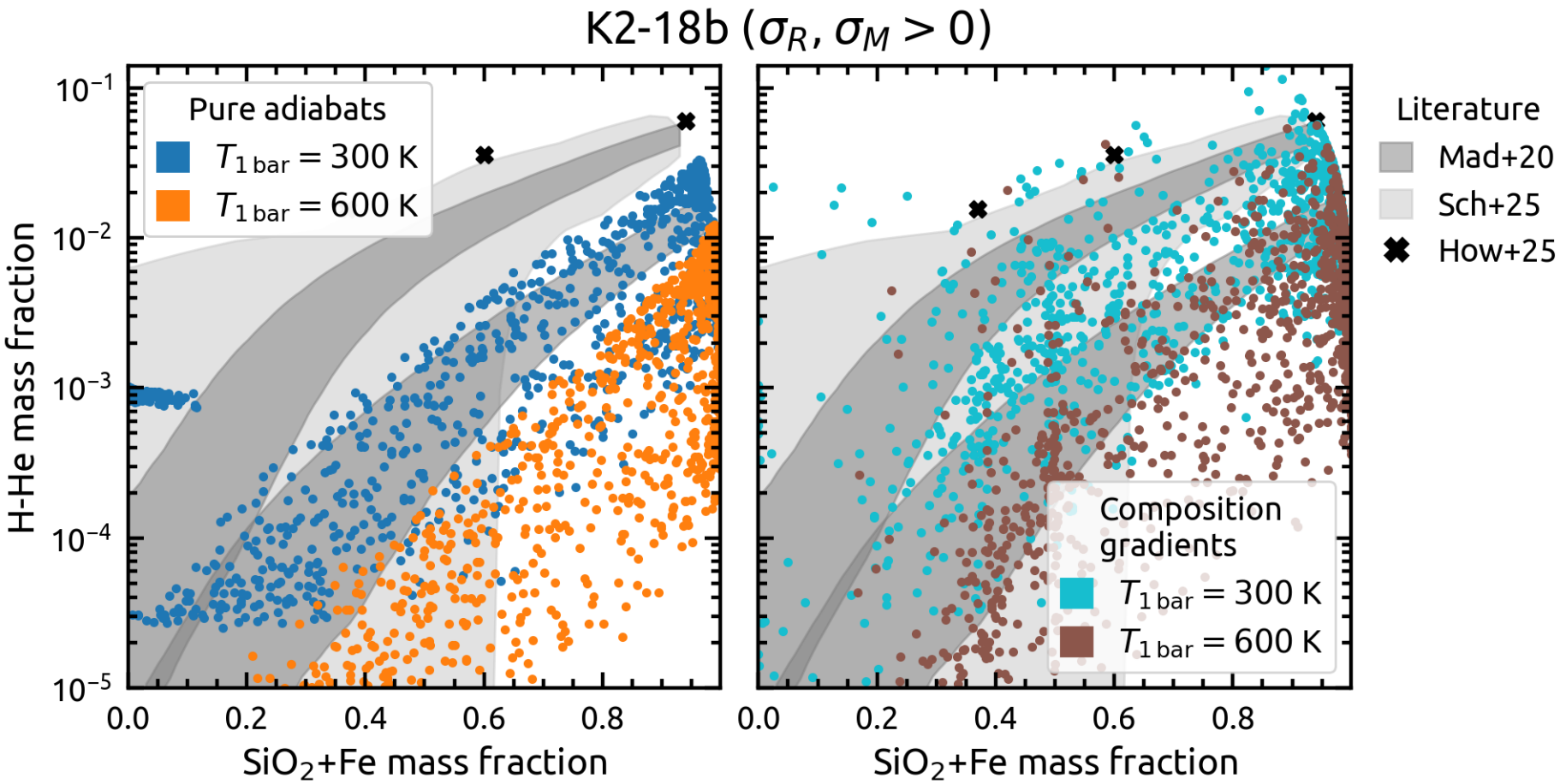

Morf and Helled 2026, in prep.

Conclusions

- Agnosticism allows for more accurate constraints
- Uranus and Neptune could be rocky
- Model assumptions dominate over physical constraints for exoplanet interior modelling

Image Bibliography

- Image of Uranus; NASA, ESA, CSA, STScI.; https://www.nasa.gov/solar-system/nasas-webb-scores-another-ringed-world-with-new-image-of-uranus/
- Image «What are exoplanets made of?»; ESA; https://www.esa.int/ESA_Multimedia/Images/2019/12/Cheops_science_What_are_exoplanets_made_of
- Image «Plato key visual»; ESA, ATG Europe; https://www.esa.int/ESA_Multimedia/Images/2023/05/Plato_key_visual

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