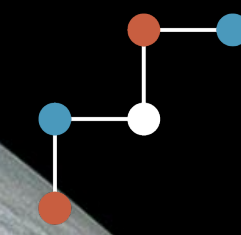




Universität
Zürich ^{UZH}

PlanetS
National Centre of Competence in Research



Schweizerischer
Nationalfonds

Unraveling the origin of giant planets

Henrik Knierim & Ravit Helled
Department of Astrophysics
University of Zurich

OHP, 10.10.2025

Credit: NASA/JPL-Caltech/SwRI/MSSS

(Some) Open Questions

- **Core accretion vs. disk instability**
- **Planetesimals vs. pebbles**
- **Migration vs. in-situ**
- **Hot vs. cold start**

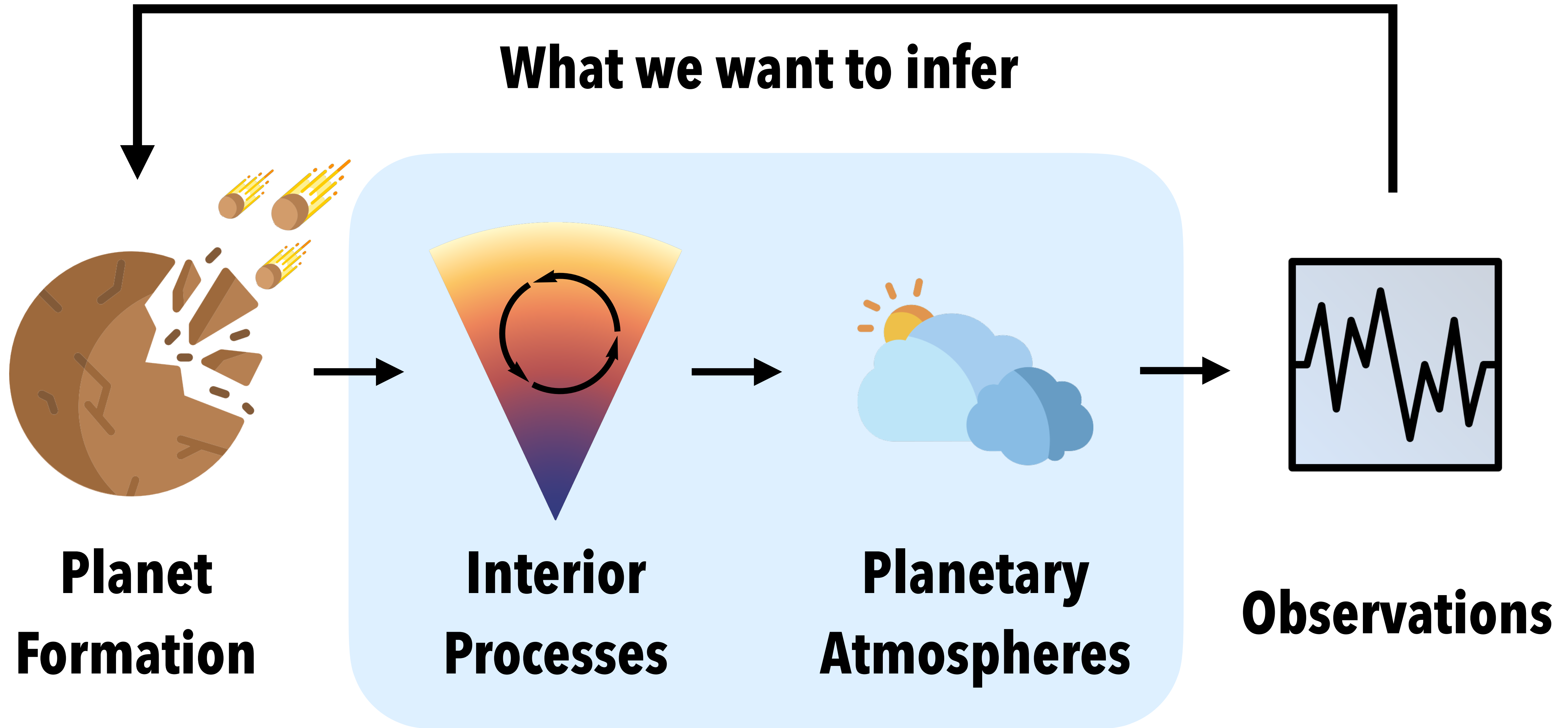
Atmospheric Characterization



Credit: NASA-GSFC, Adriana M. Gutierrez (CI Lab)

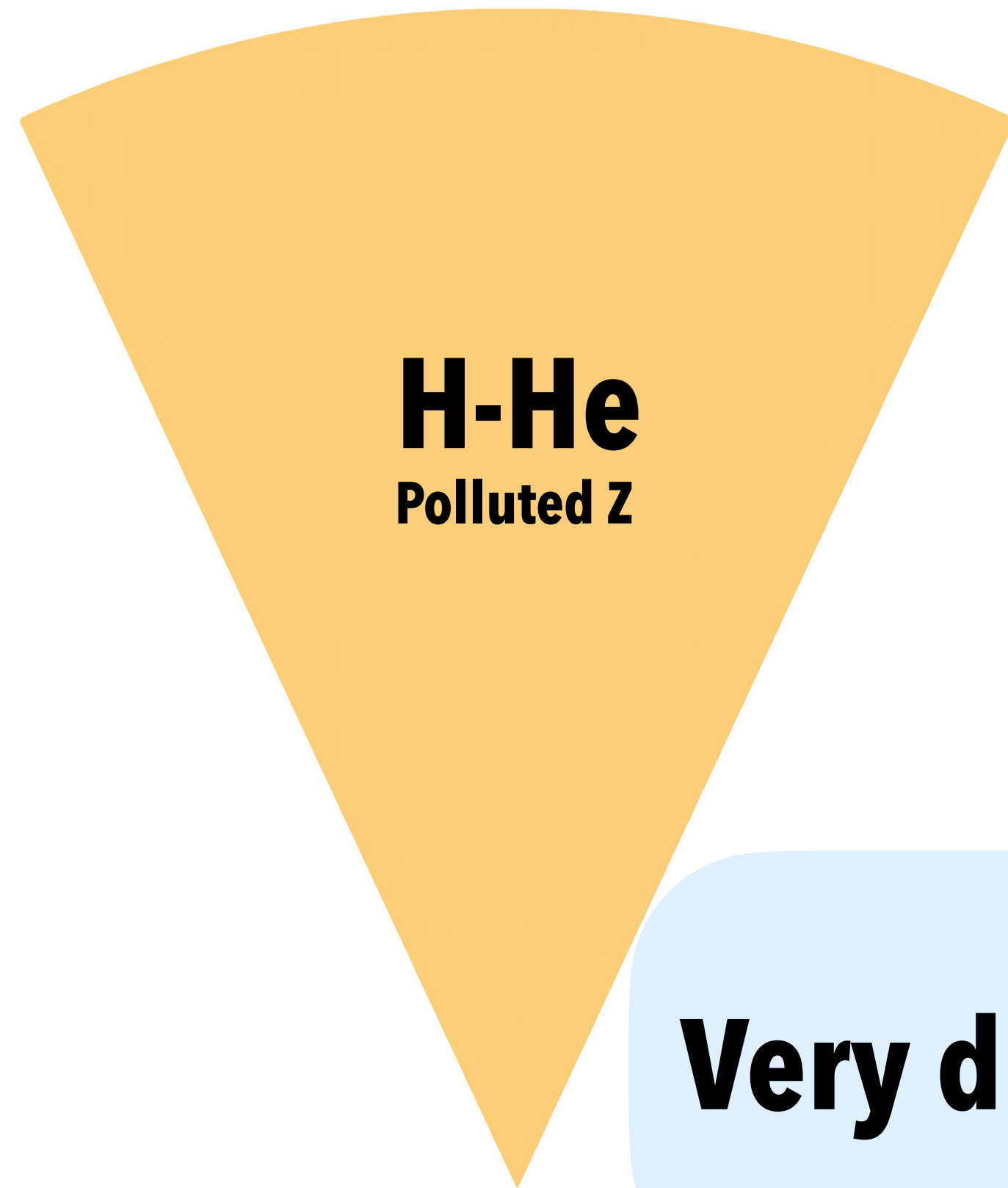
- **Instruments like JWST and soon ARIEL allow for never seen atmospheric characterization of exoplanets.**
- **Detection of molecules, their abundances, atmospheric structure, etc.**

E.g., Coulombe et al. 2023, Nat., Feinstein et al. 2023, Nat., Zieba et al. 2023, Nat., Espinoza et al. 2024, Inglis et. al. 2024, Nat., Saidel et al. 2025

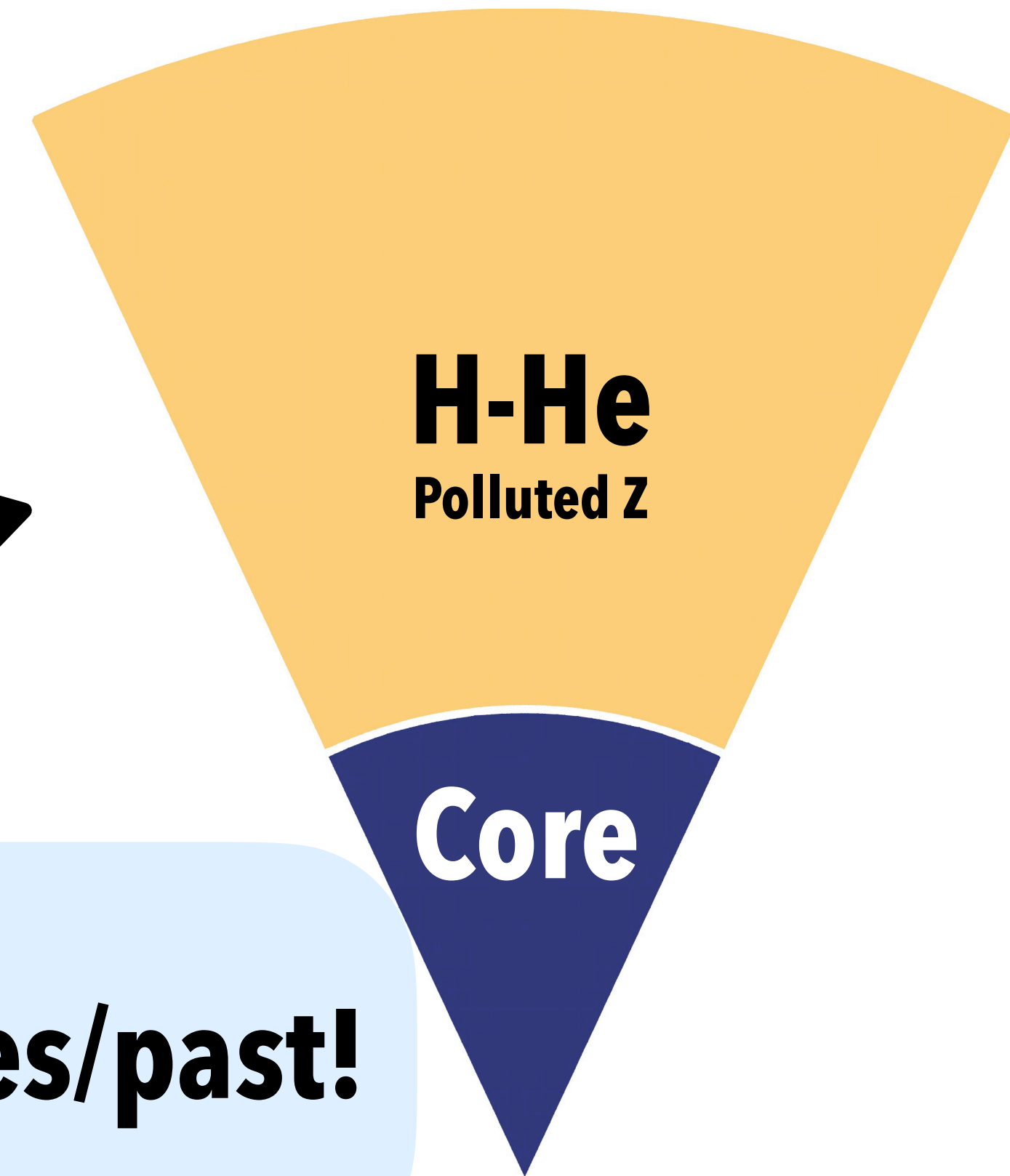


Simplified Interior Models

Homogeneous

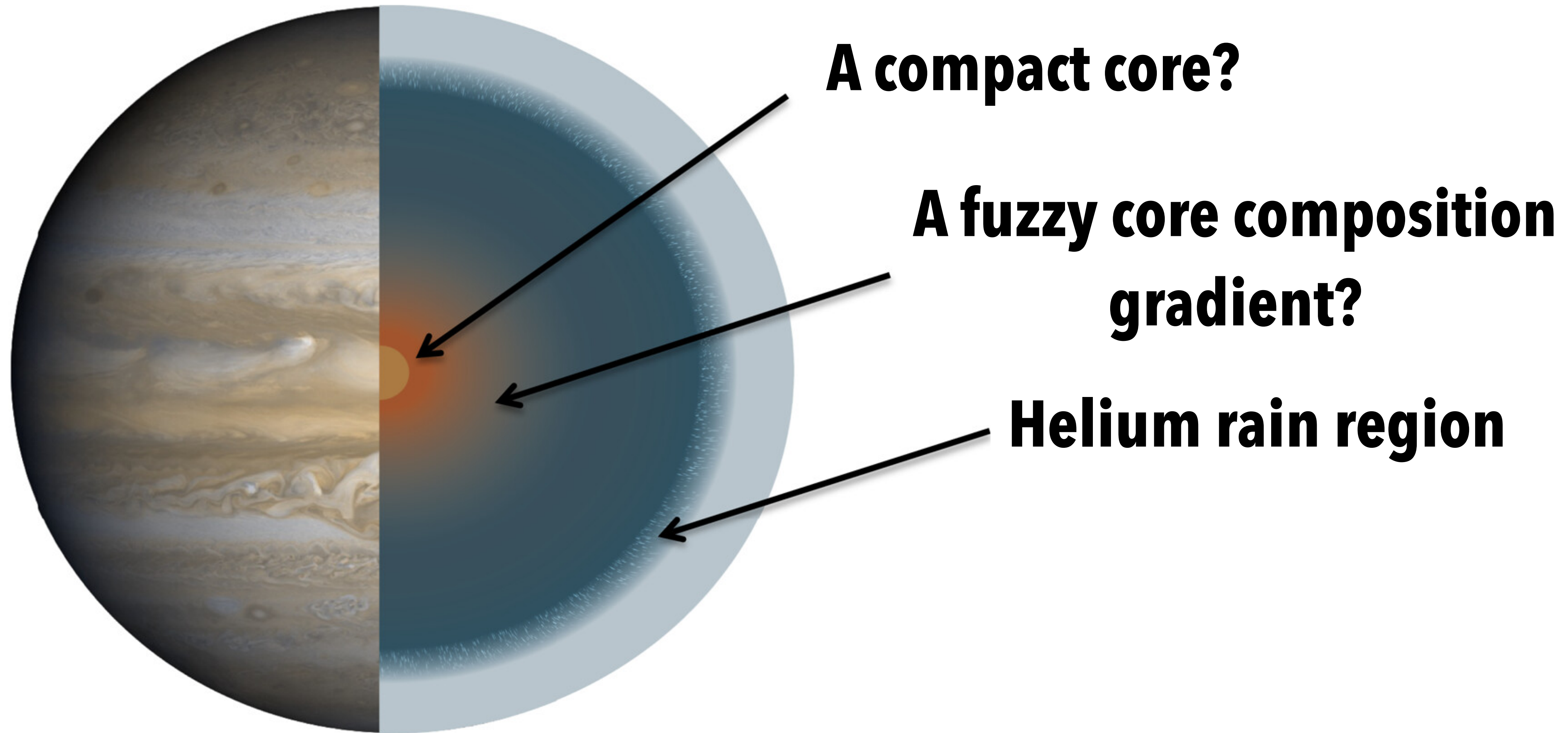


Core + Envelope



Very different properties/past!

Jupiter post-Juno



How do we know what's the case?

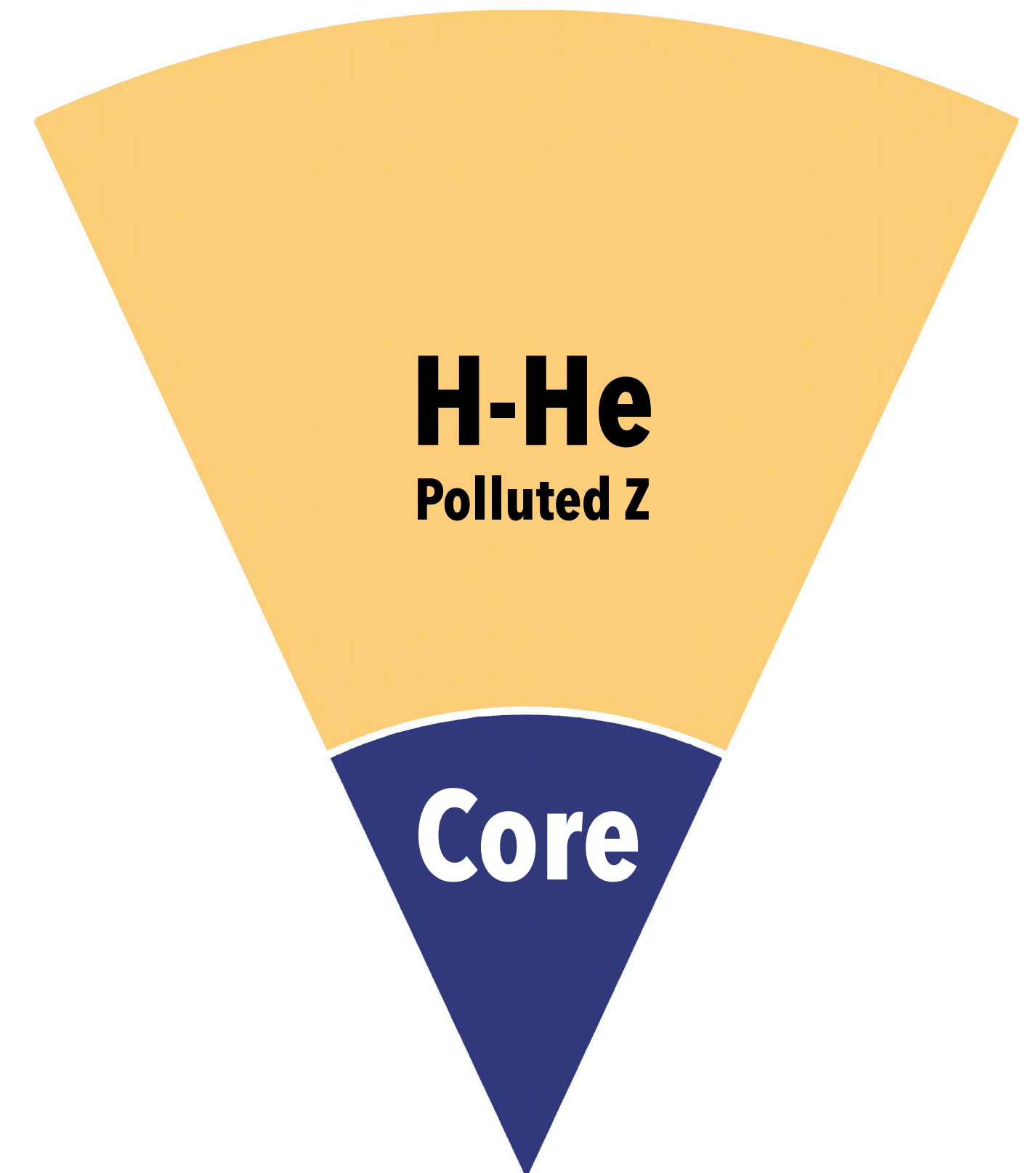
Homogeneous



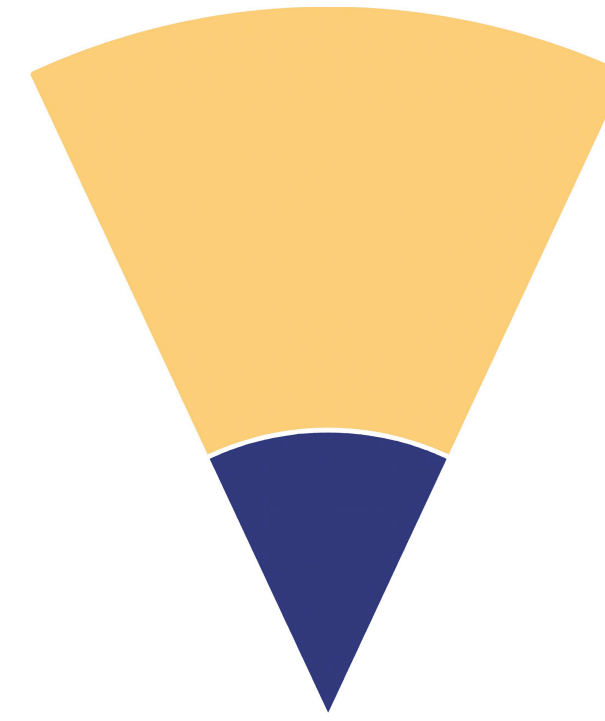
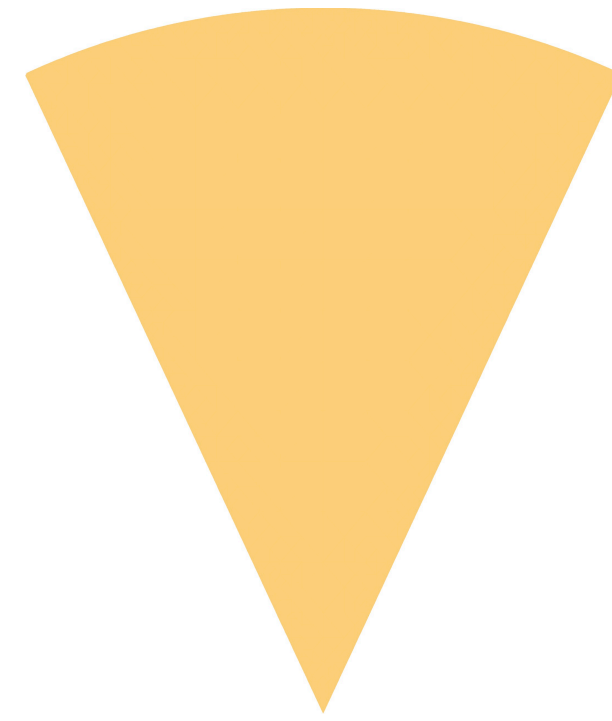
Dilute Core



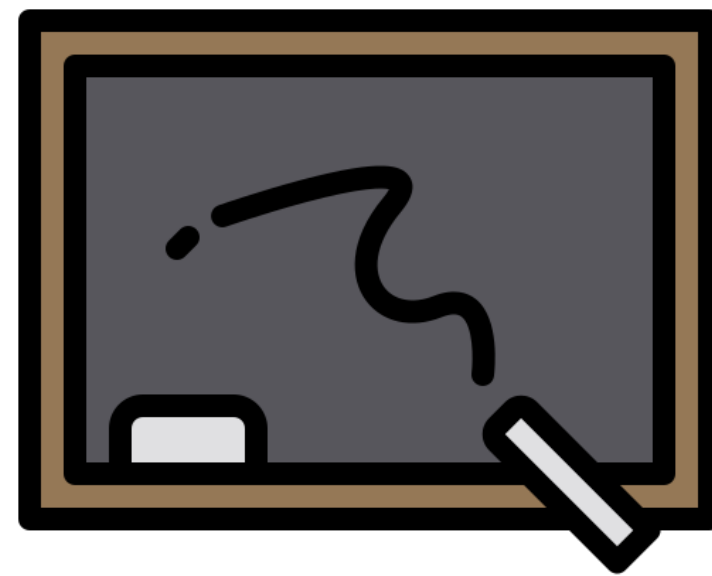
Core + Envelope



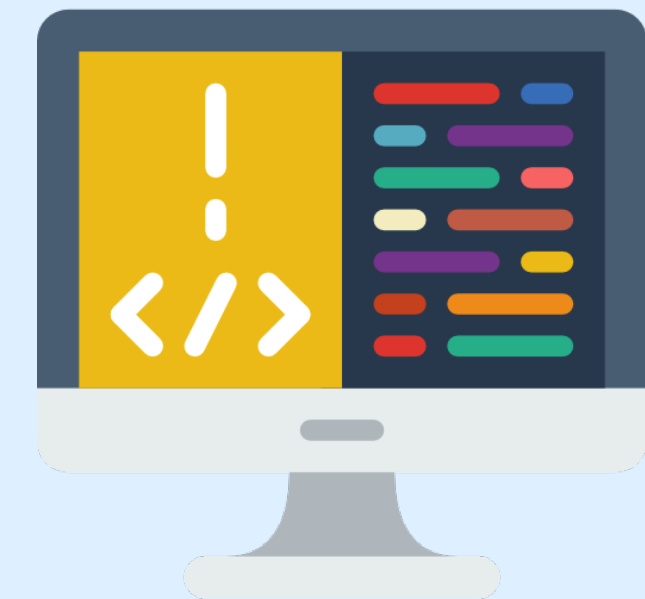
**Interior
Processes**



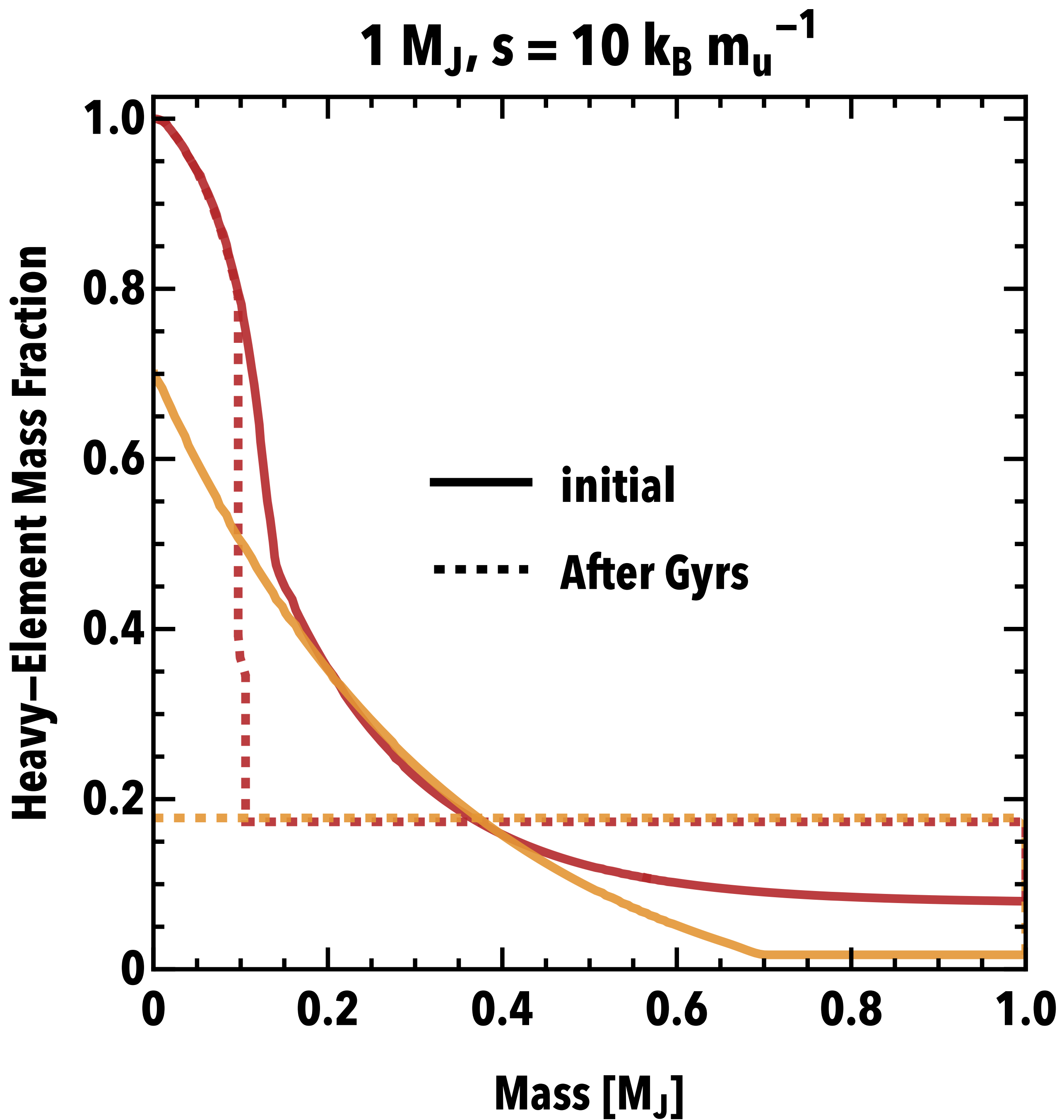
Knierim & Helled 2024



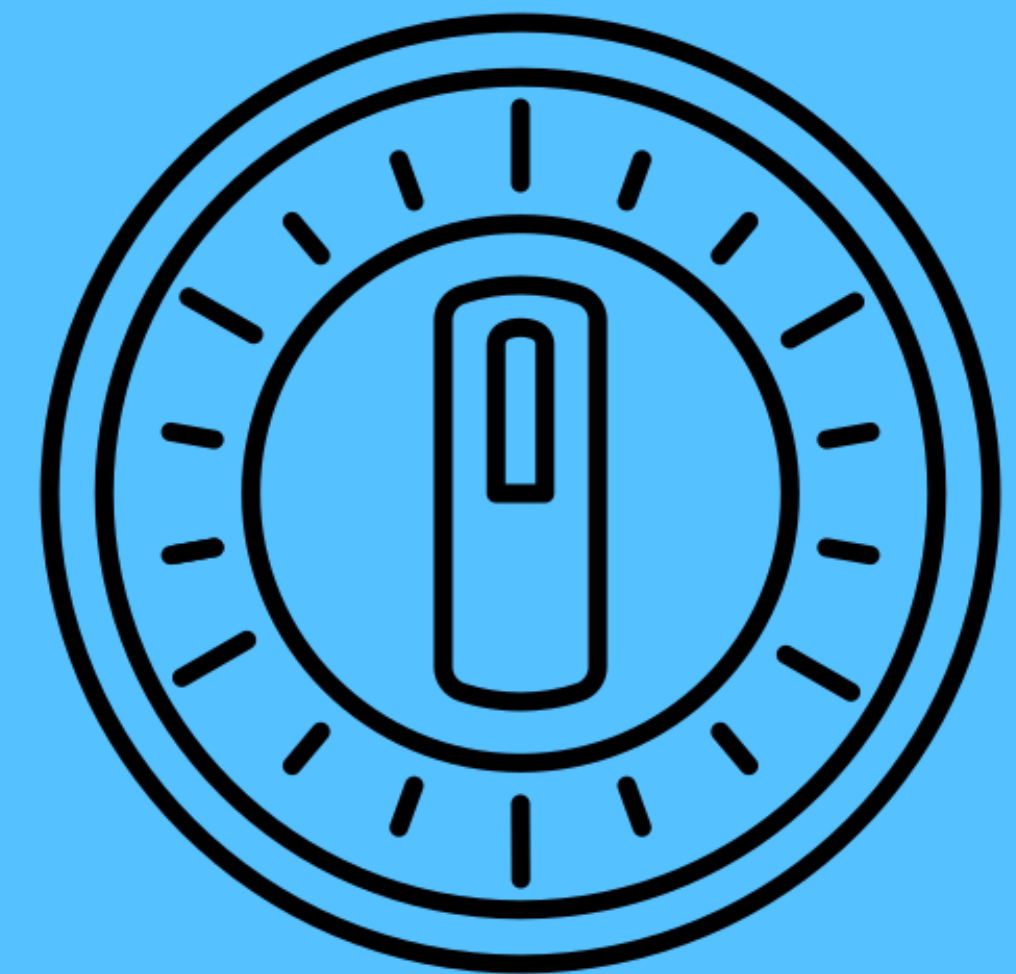
**Analytic
Calculations**



**Numerical
Experiments**

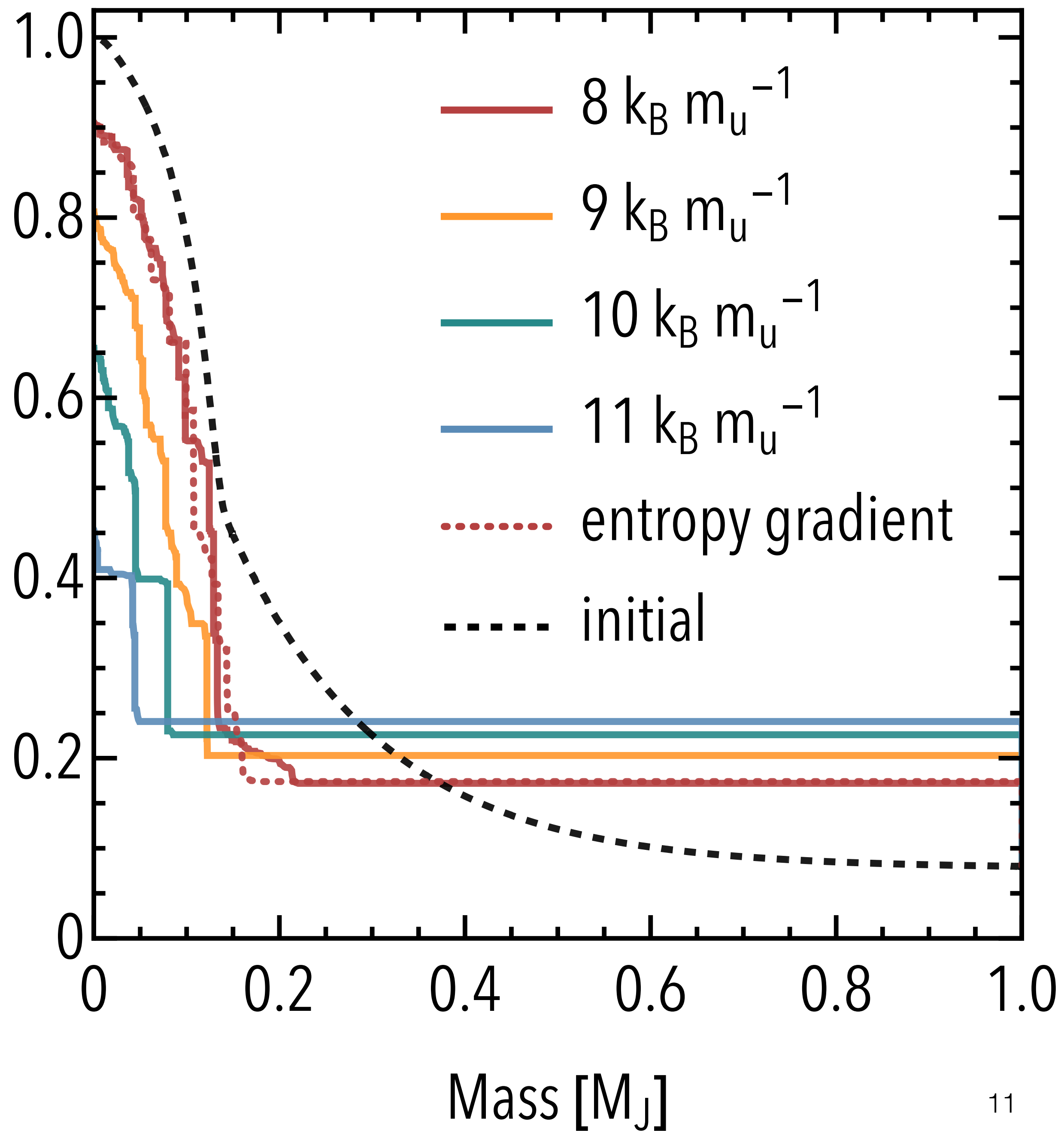


Primordial Composition

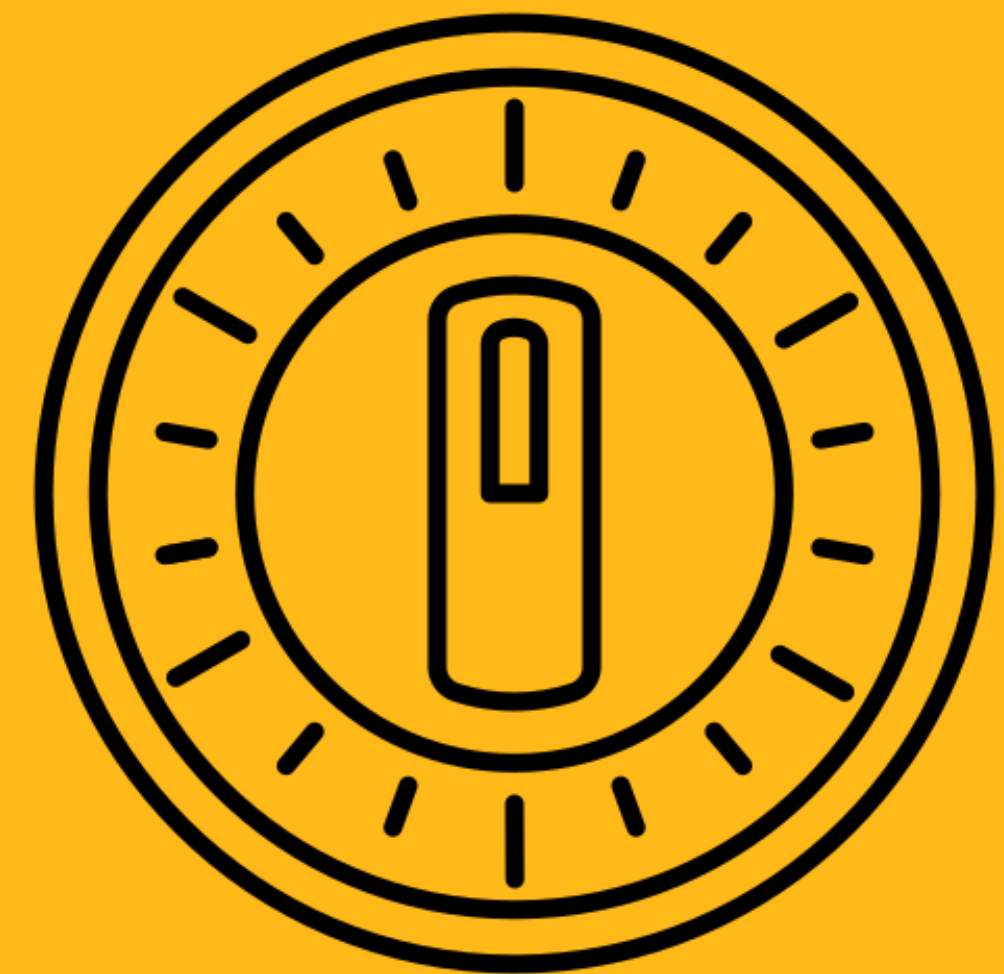


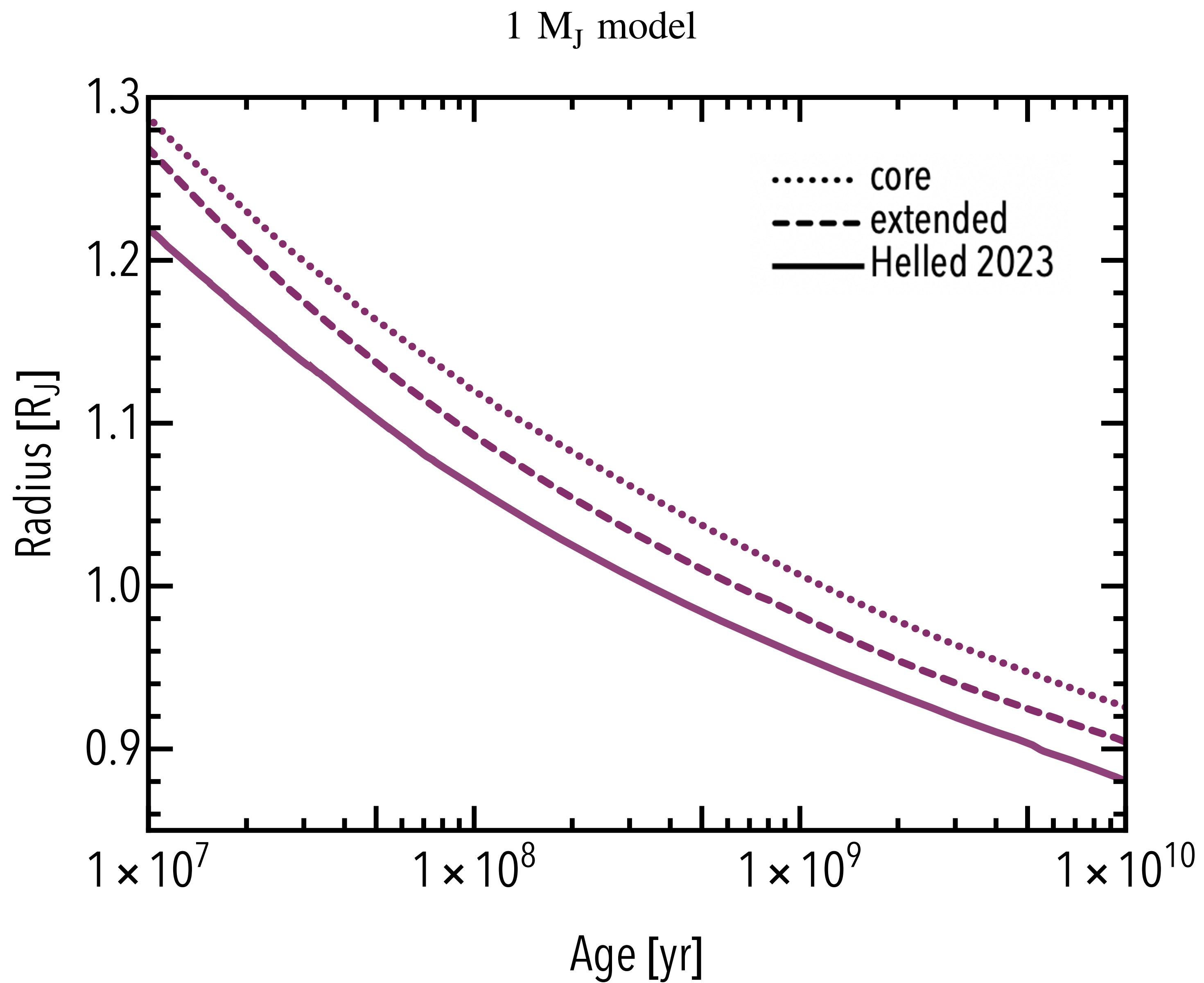
Heavy-Element Mass Fraction

Z after 4.55 Gyr

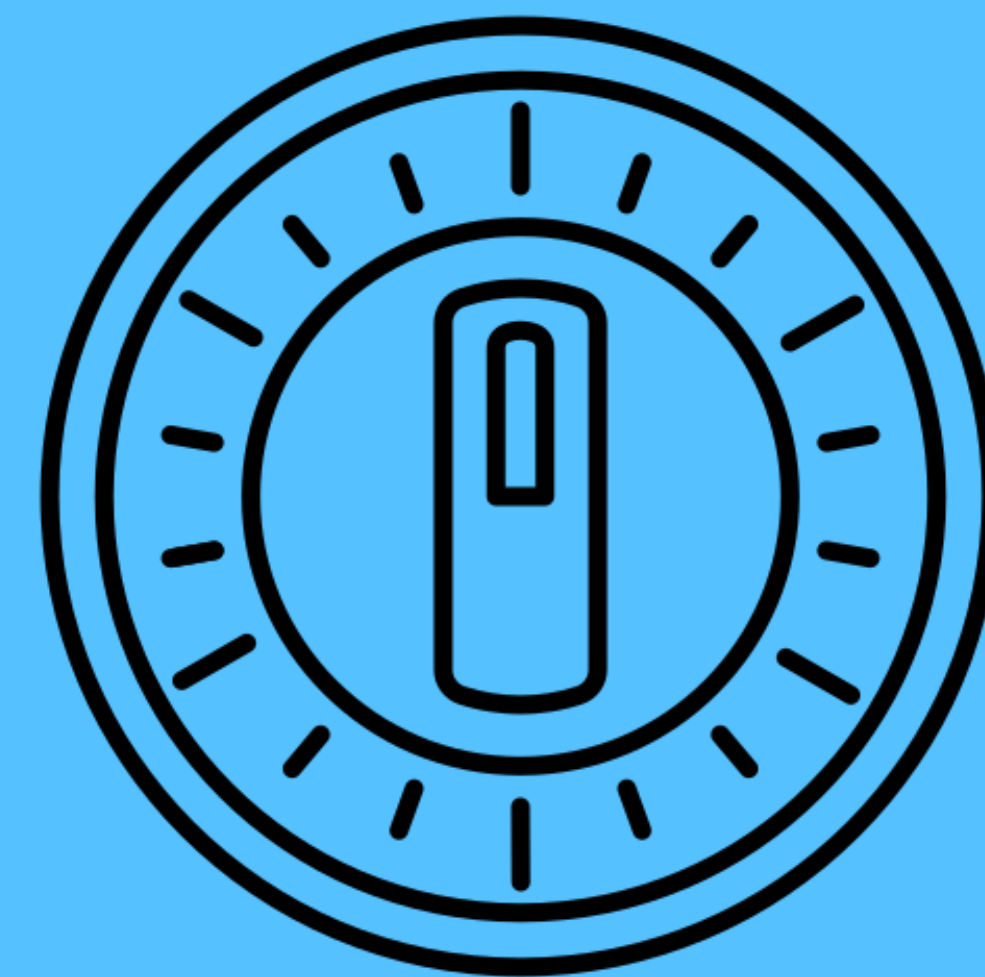


Primordial Entropy

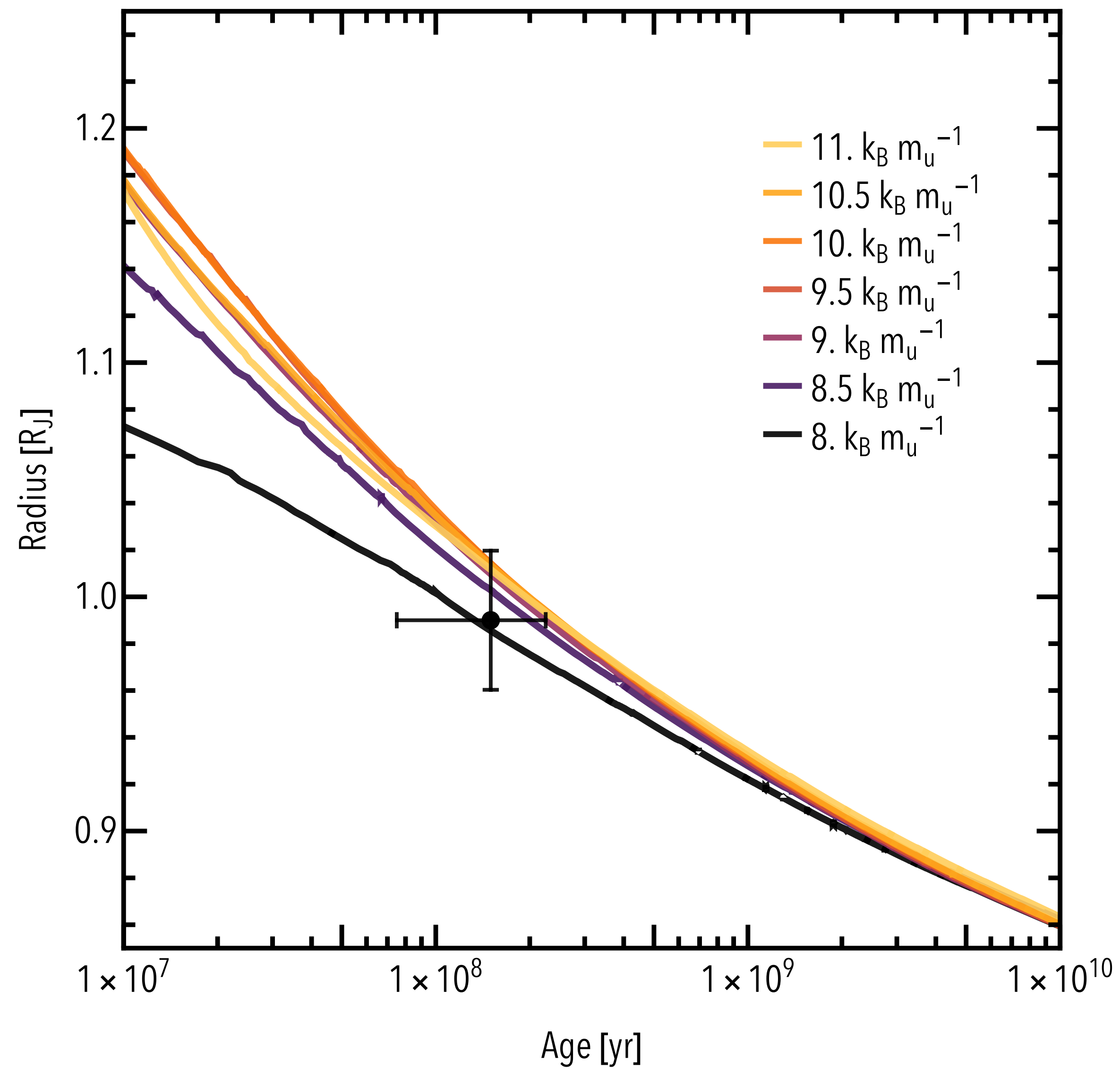




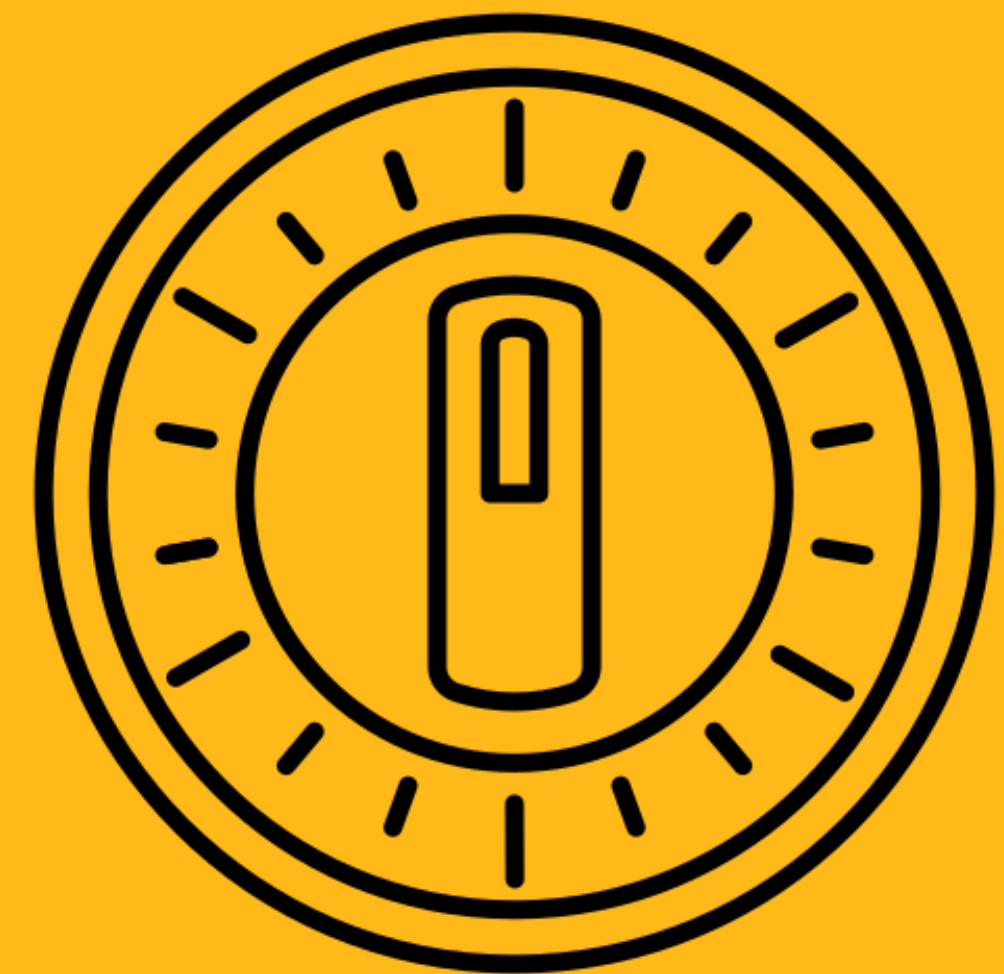
Primordial Composition



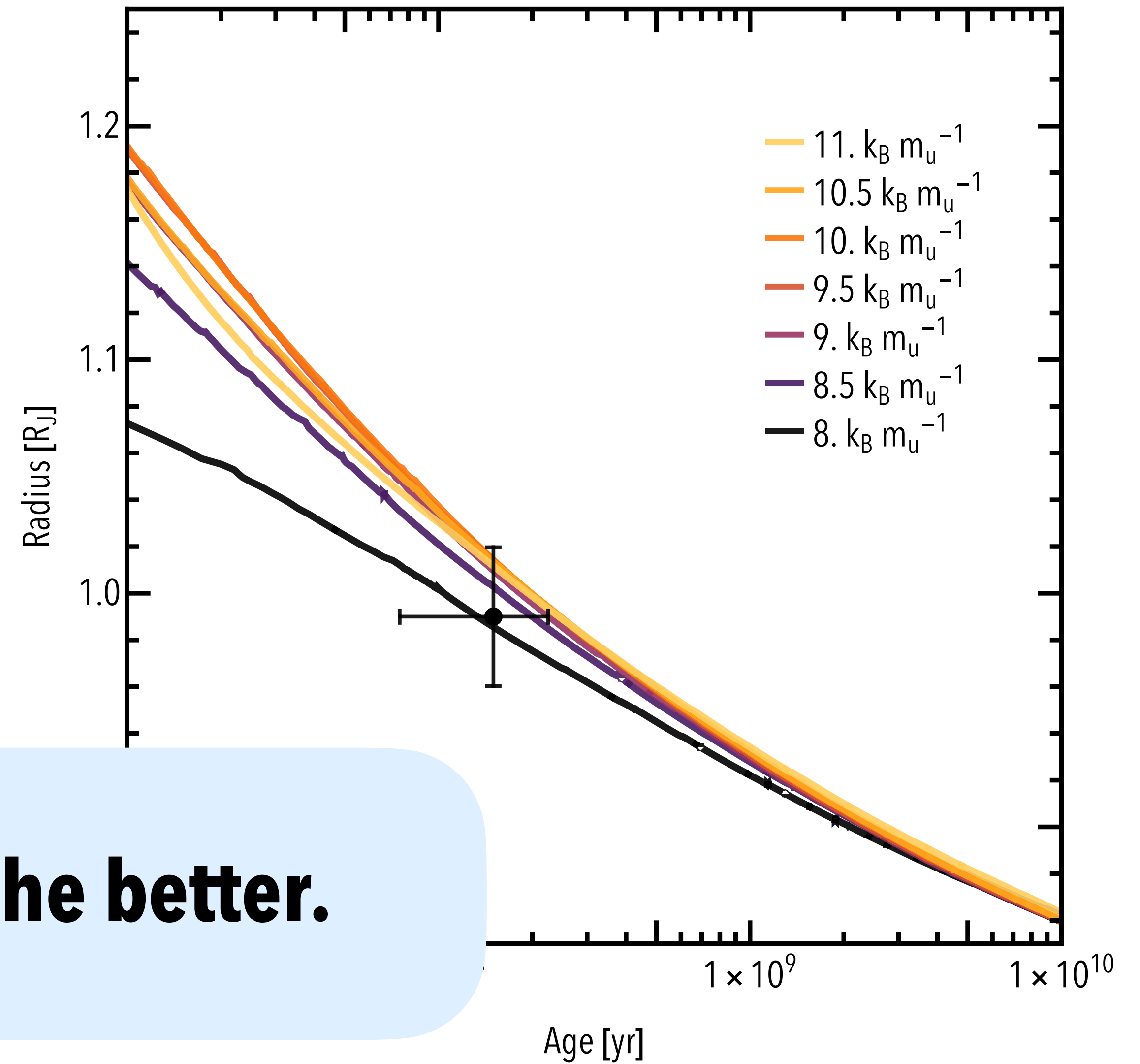
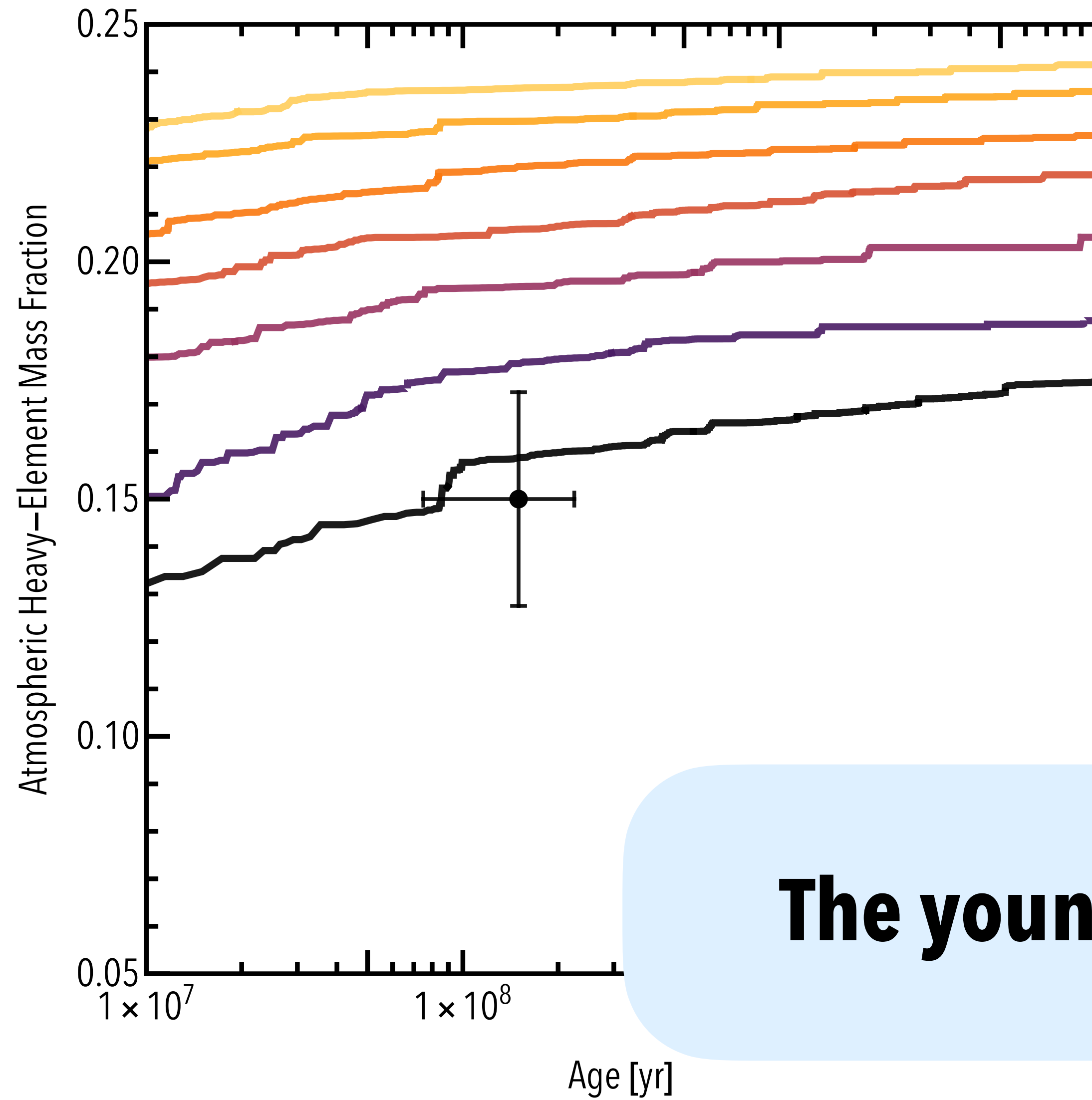
1 M_J Helled 2023 model



Primordial Entropy

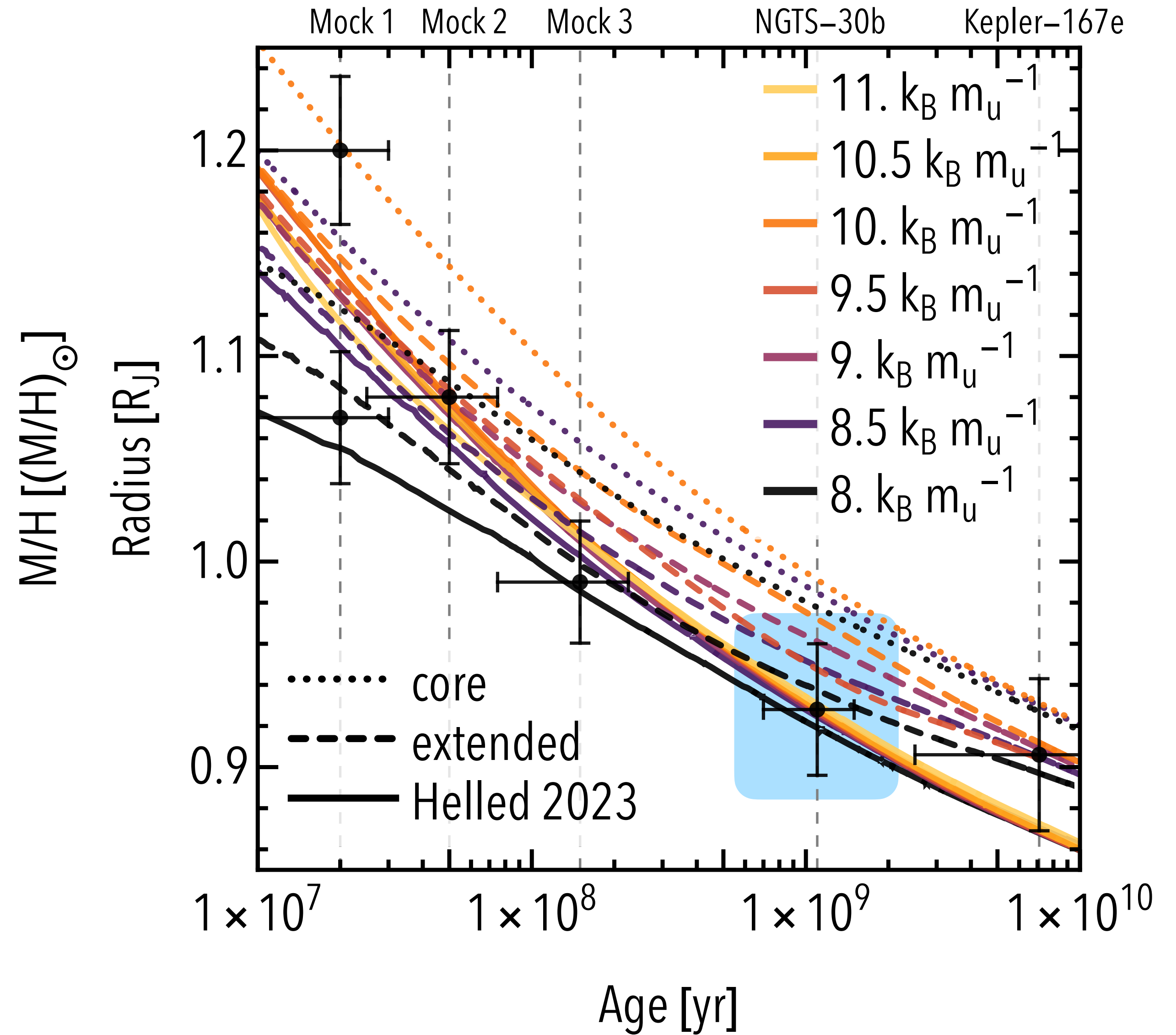
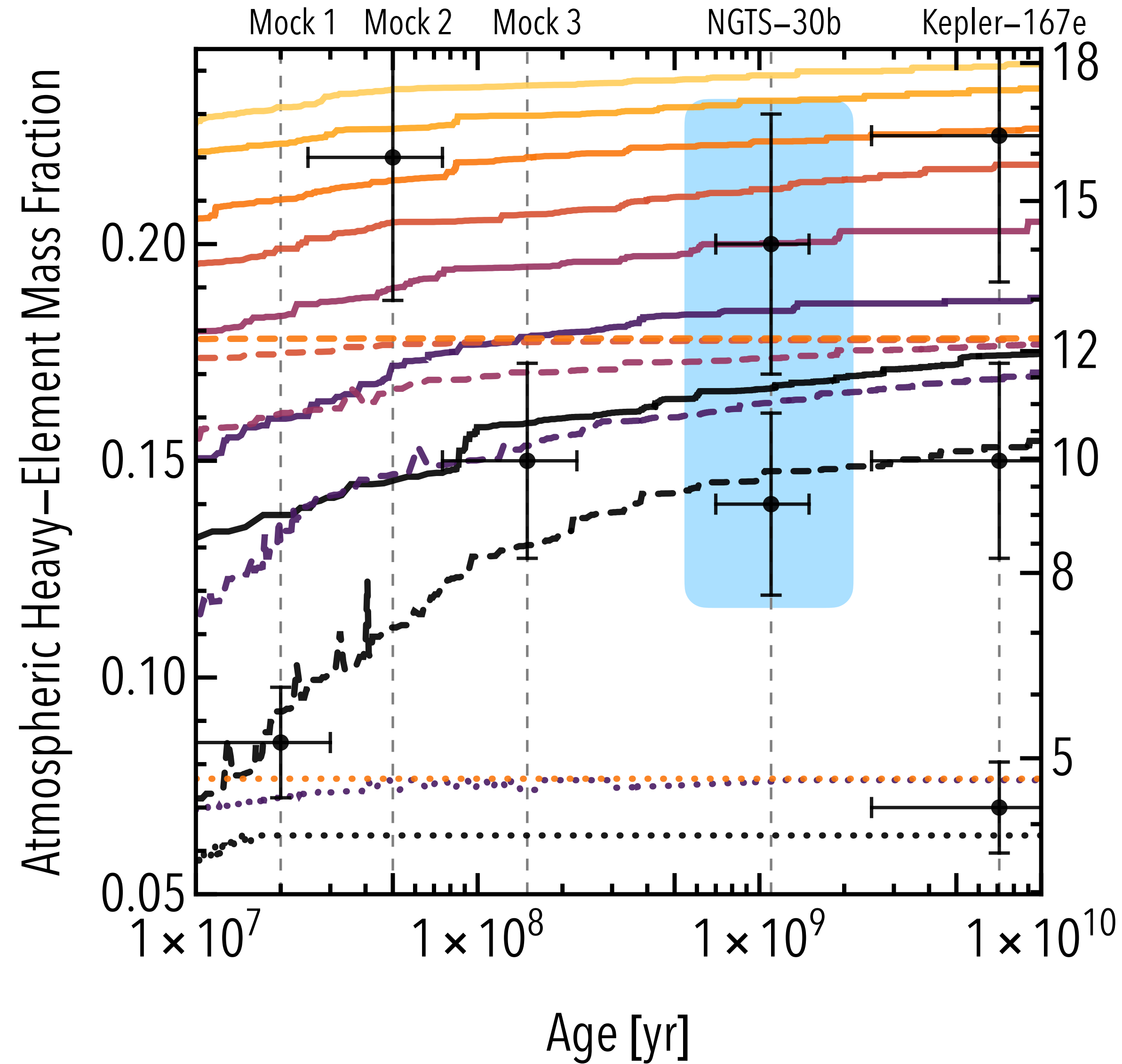


1 M_J Helled 2023 model

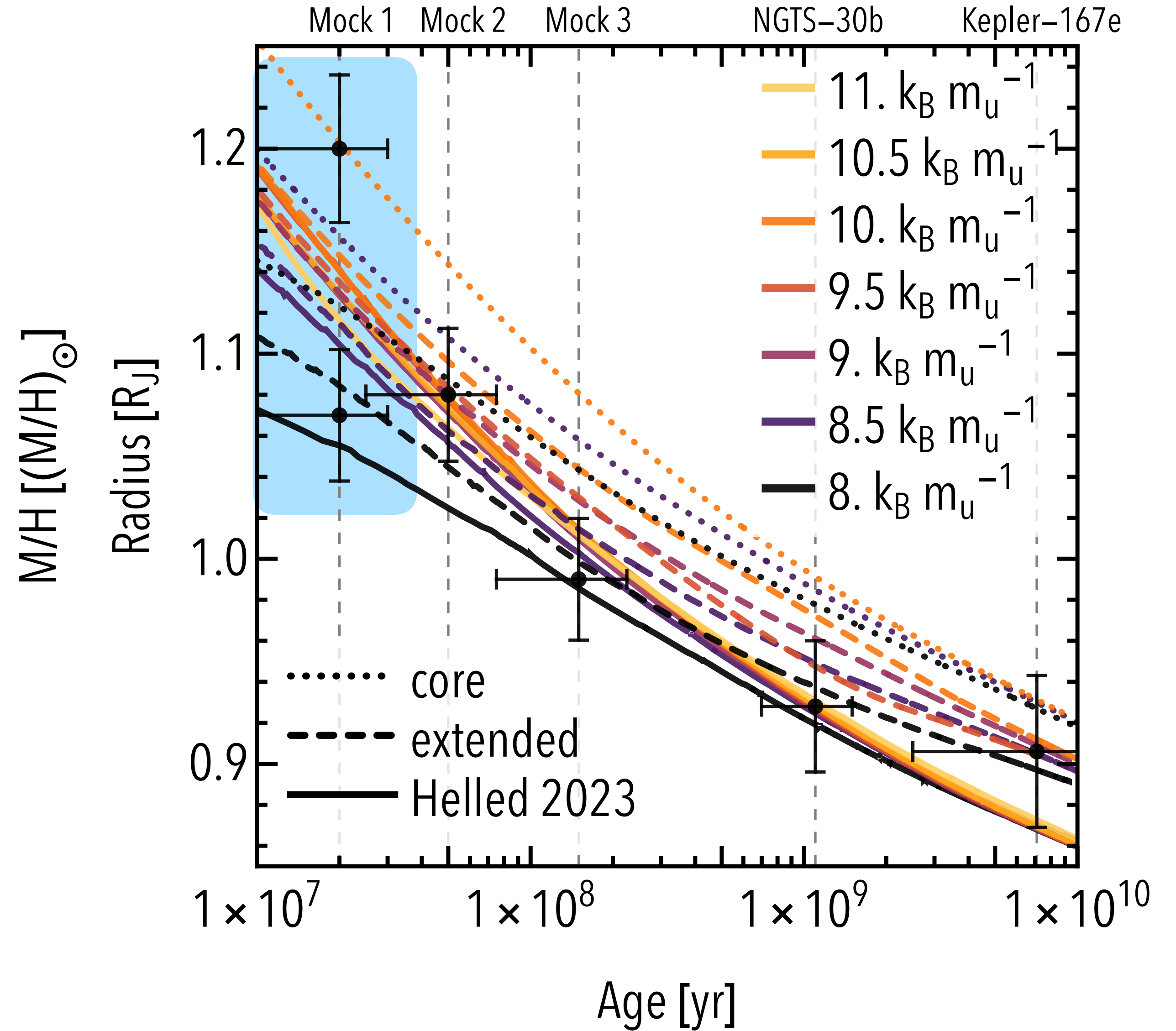
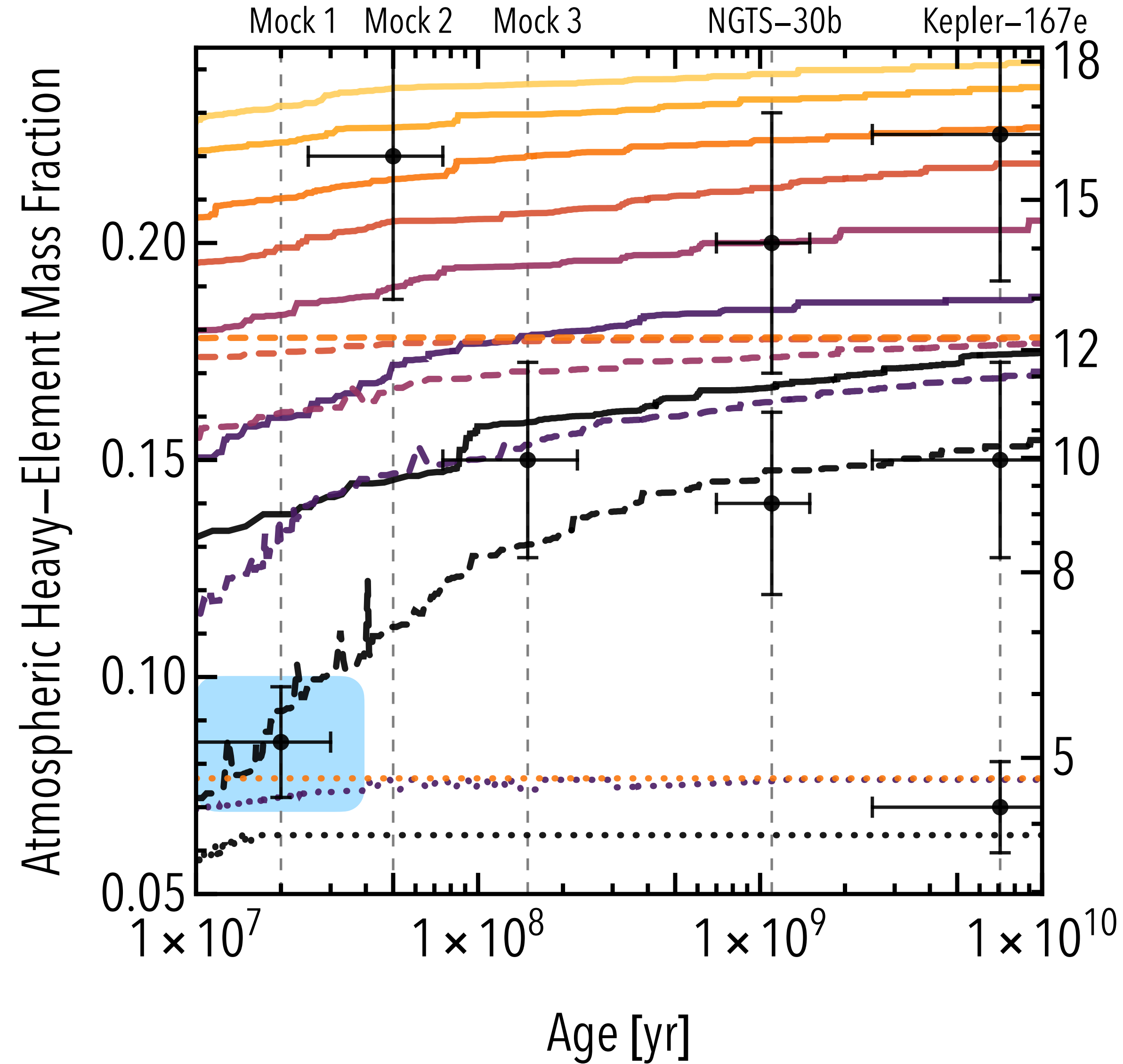


The younger the better.

1 M_J model

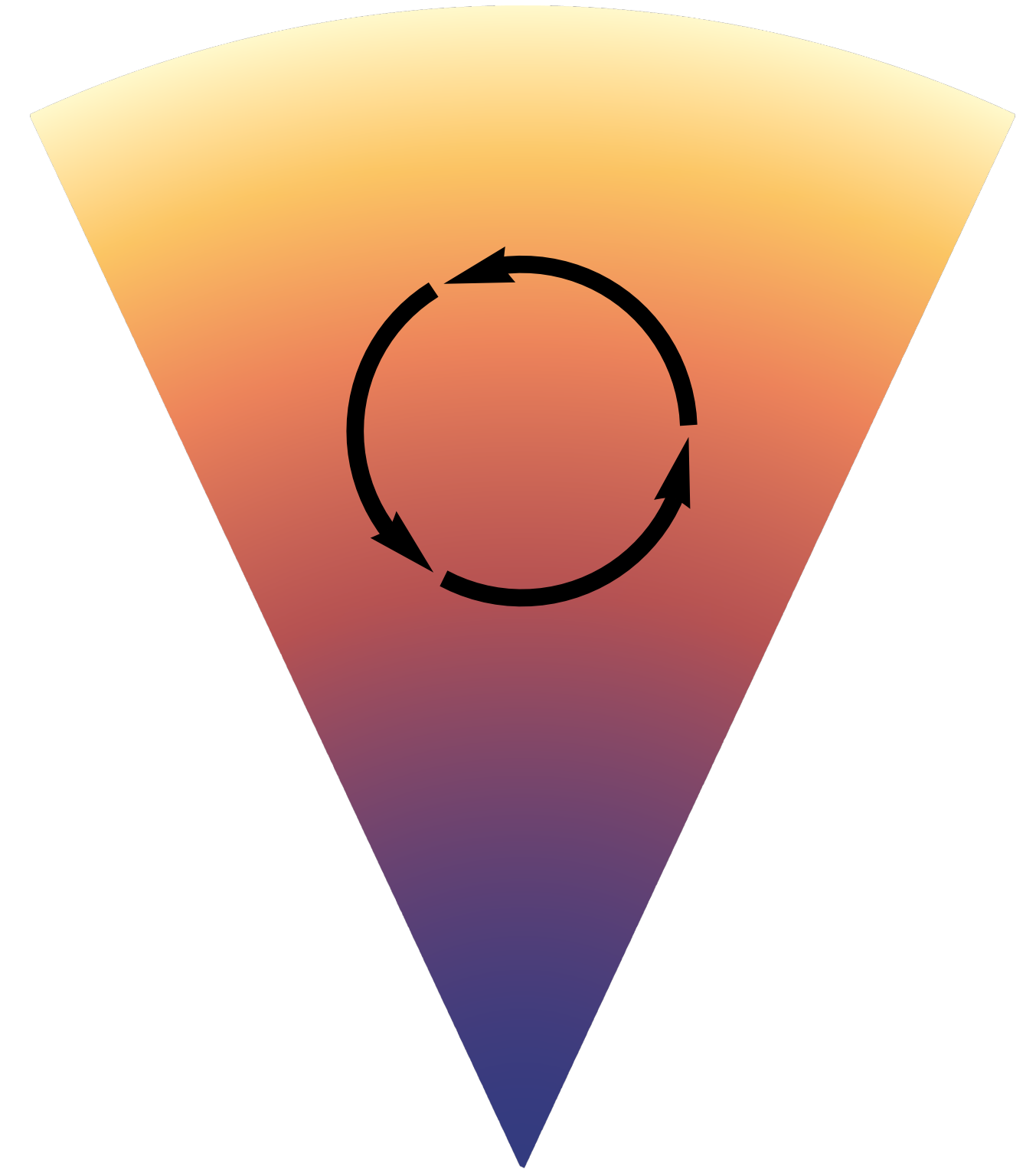


1 M_J model





**Planet
Formation**



**Interior
Processes**

Conclusions

- **Convective mixing is a crucial mechanism that shapes the evolution of a planet.**
- **Mixing allows to infer the primordial state.**
- **Young planets are the perfect targets!**

