The Importance of Planet Mass In Assessing Planetary Habitability

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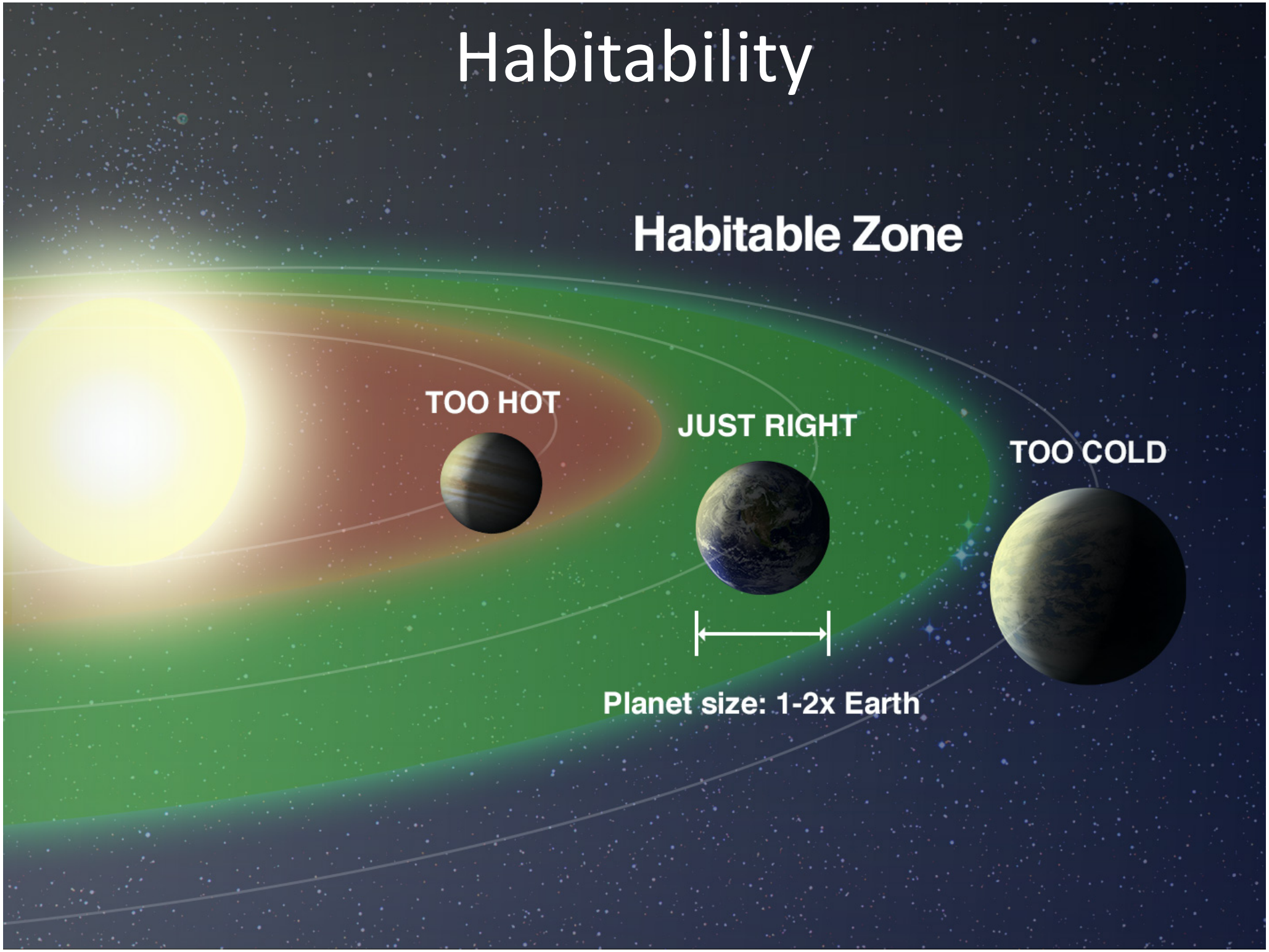
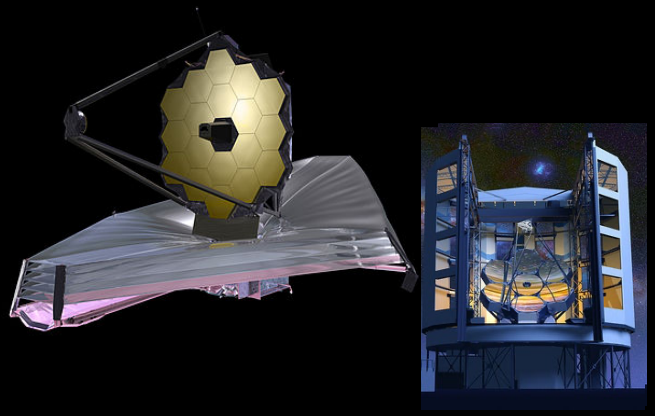
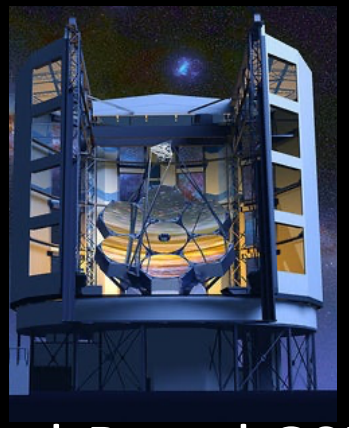
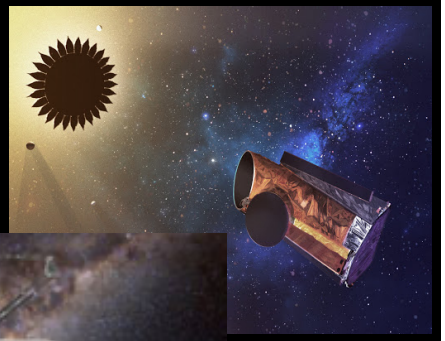
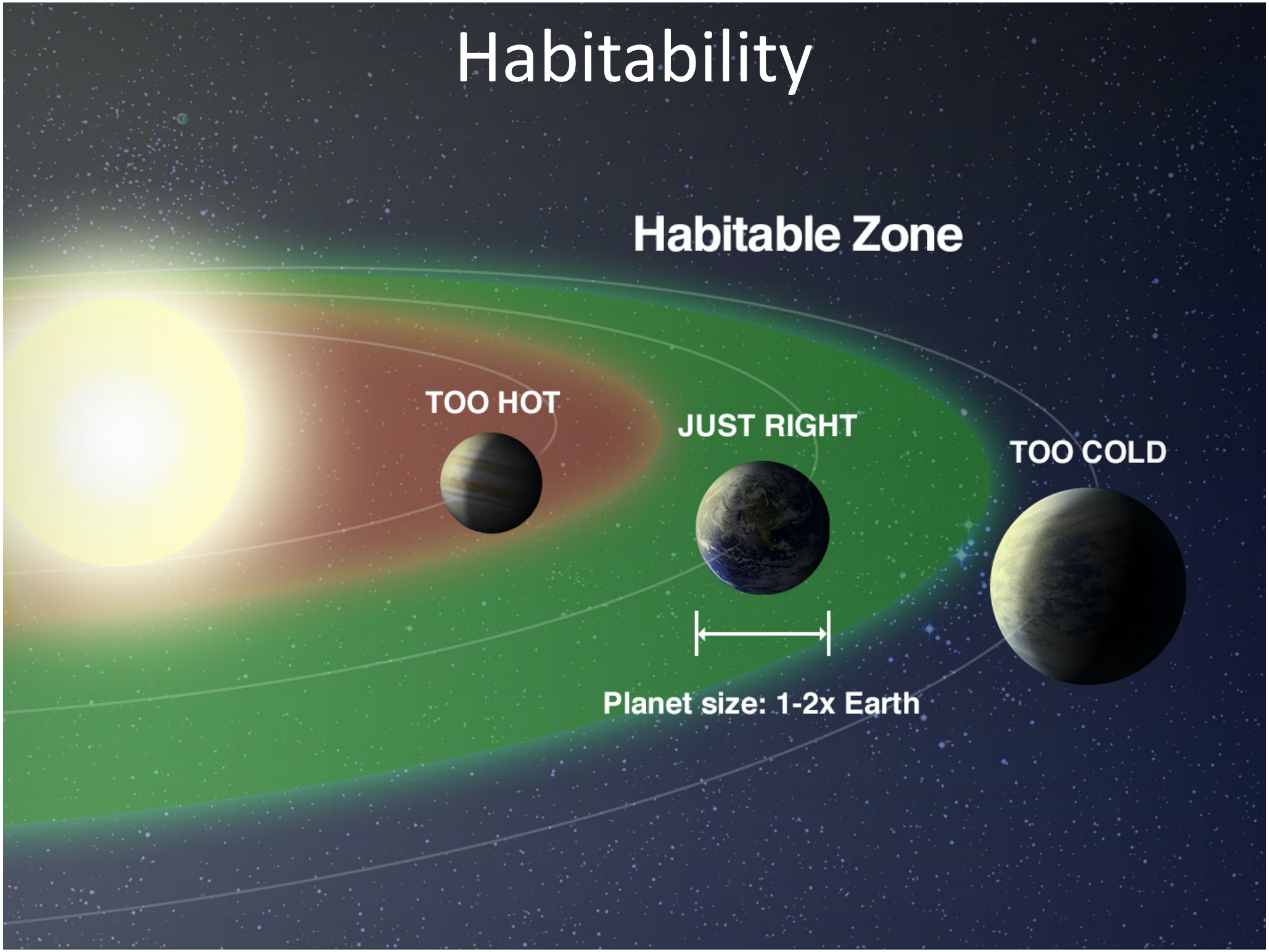
Sagan Summer Workshop 2020


Habitability
Habitable Zone
TOO HOT
JUST RIGHT
TOO COLD
Planet size: 1-2x Earth

Atm Characterization of Habitable Planets

	Transits	Direct Imaging
M dwarf Stars	 JWST & GSMTs	 Ground-Based GSMTs
G-dwarf Stars	Low Probability	  Space-Based HabEx/LUVOIR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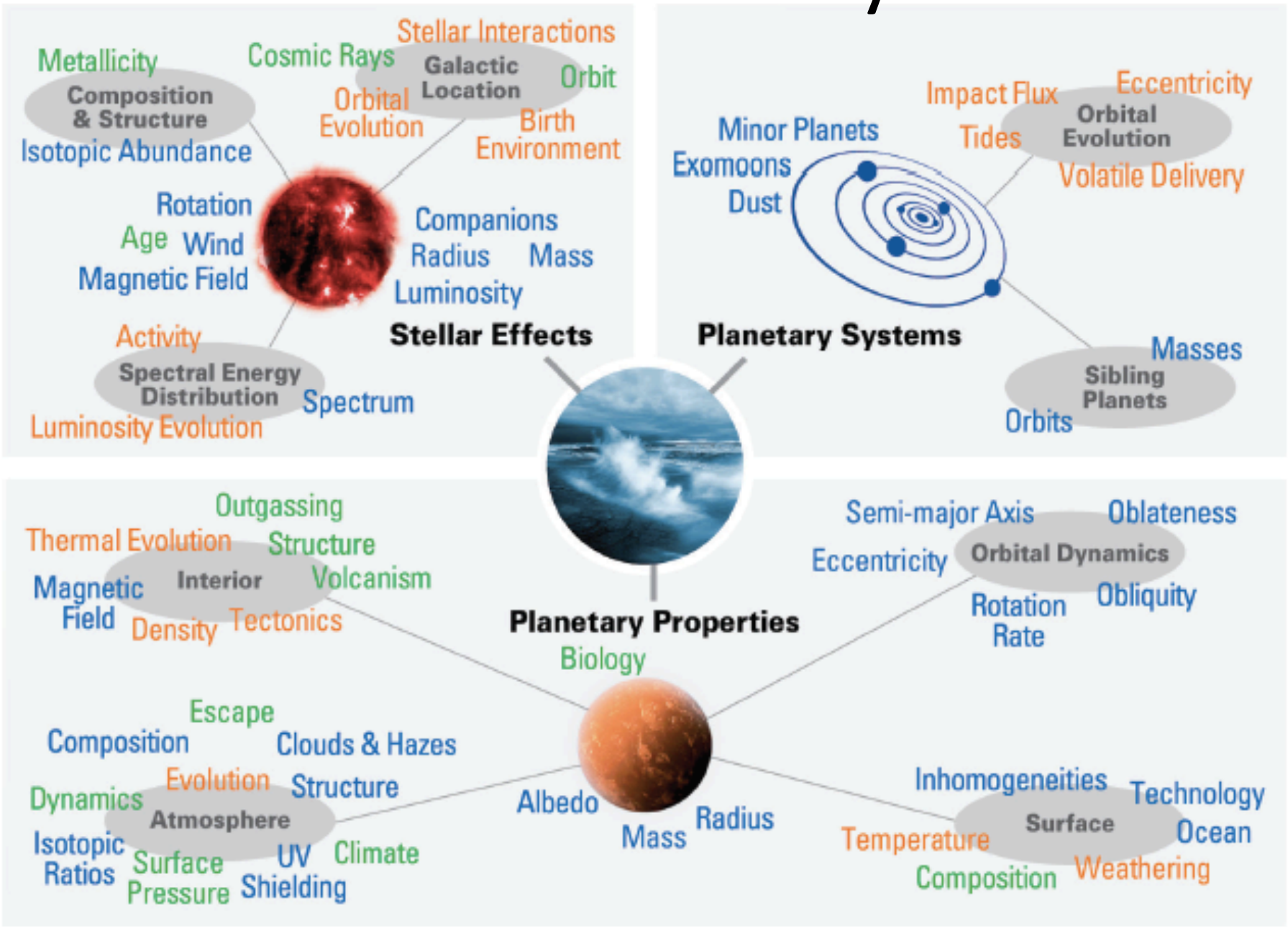
Habitability



Meadows & Barnes (2018)

Observable Observations+Modeling Modeling

Planet Mass measurements are needed…

- To constrain planet compositions, distinguishing terrestrial planets from water-rich planets and mini-Neptunes.
- To determine the planet's surface gravity (log g), which facilitates the retrieval of abundances from atmospheric spectra.
- To assess atmospheric loss rates.
- To assess the planet's thermal evolution (e.g., likelihood of a dynamo magnetic field, geological activity).
- To understand the interactions of the planet with other bodies in the system.
- Because mass is one of the most fundamental properties of any astrophysical body!

Mass measurements are needed to constrain planet compositions

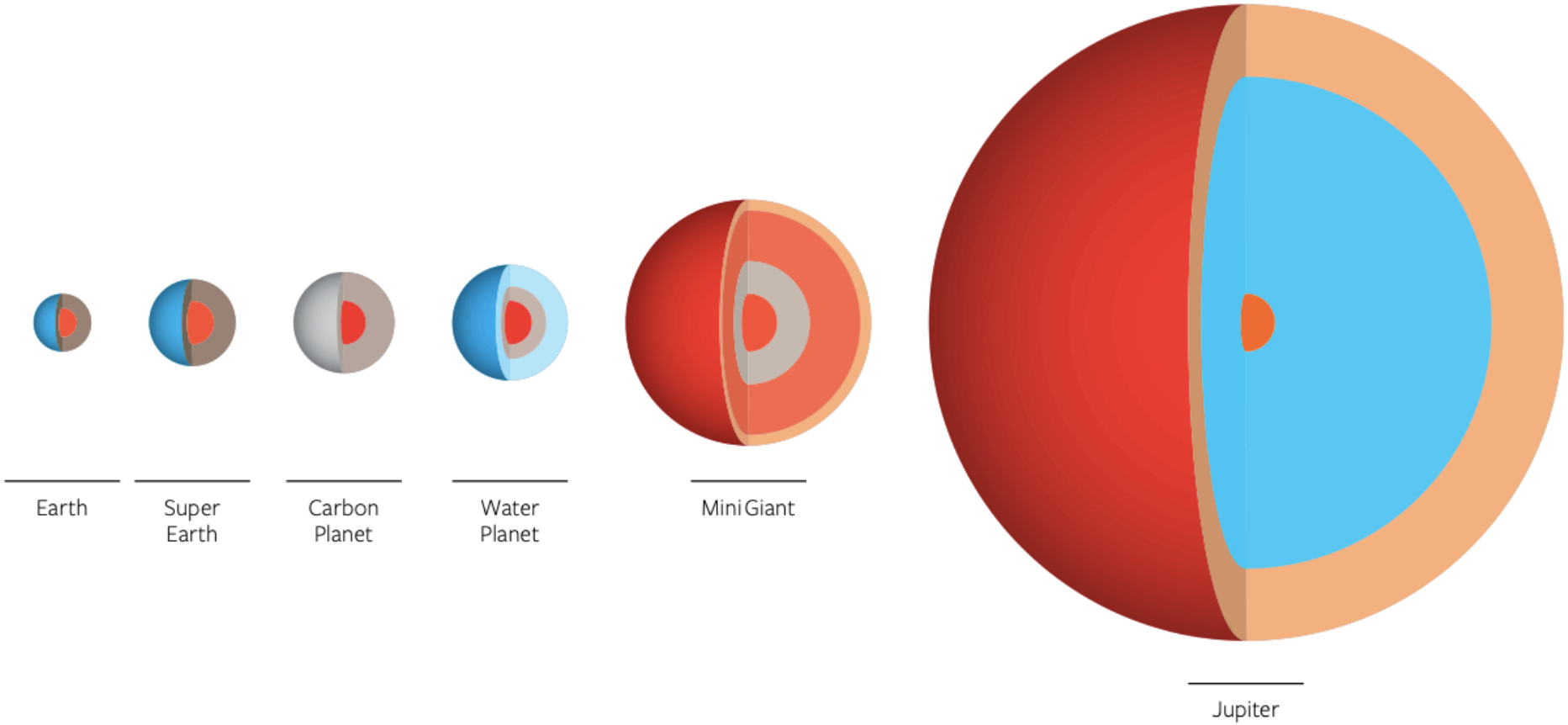


Illustration: Seager (2009)

Mass measurements are needed to constrain planet compositions

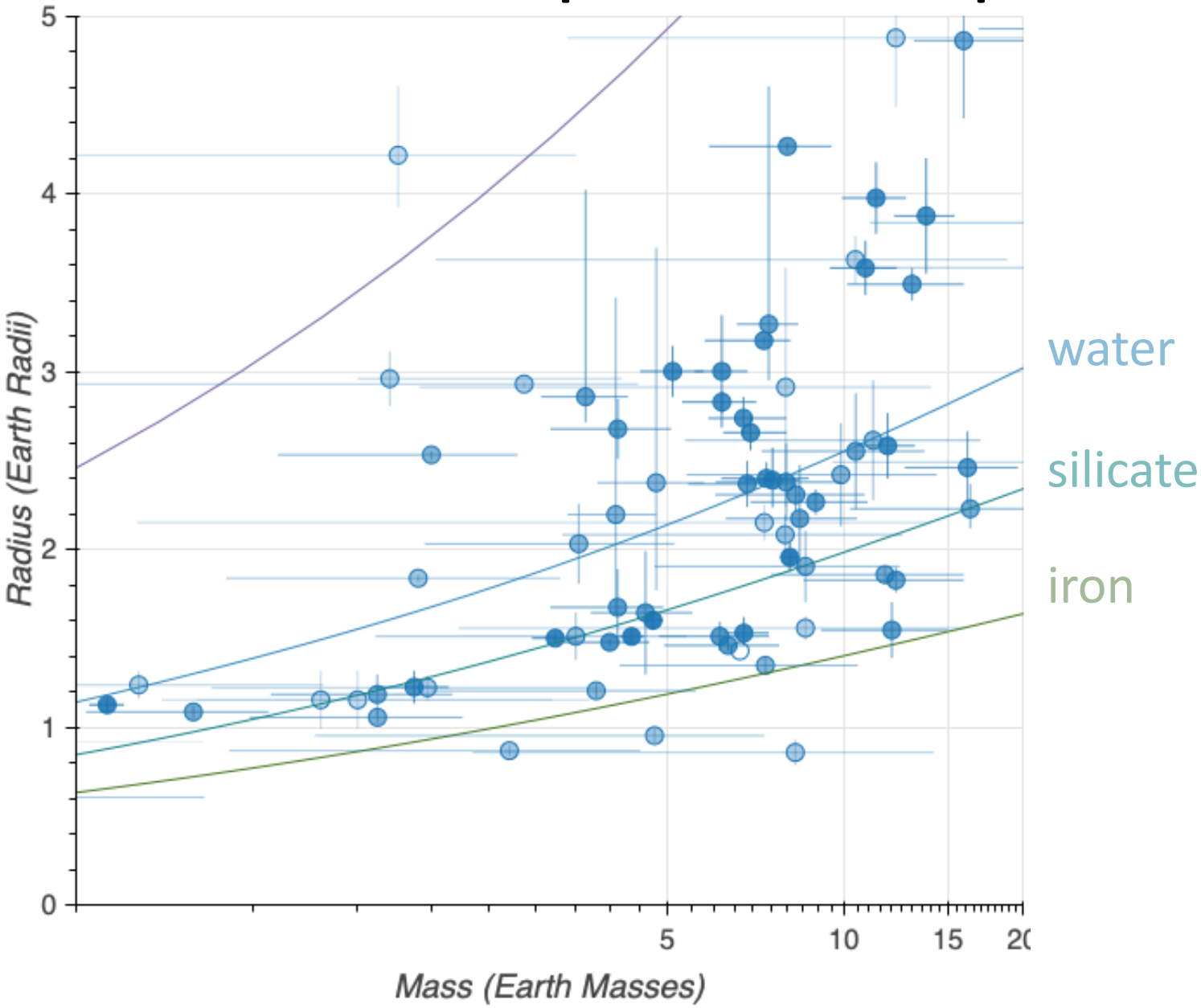
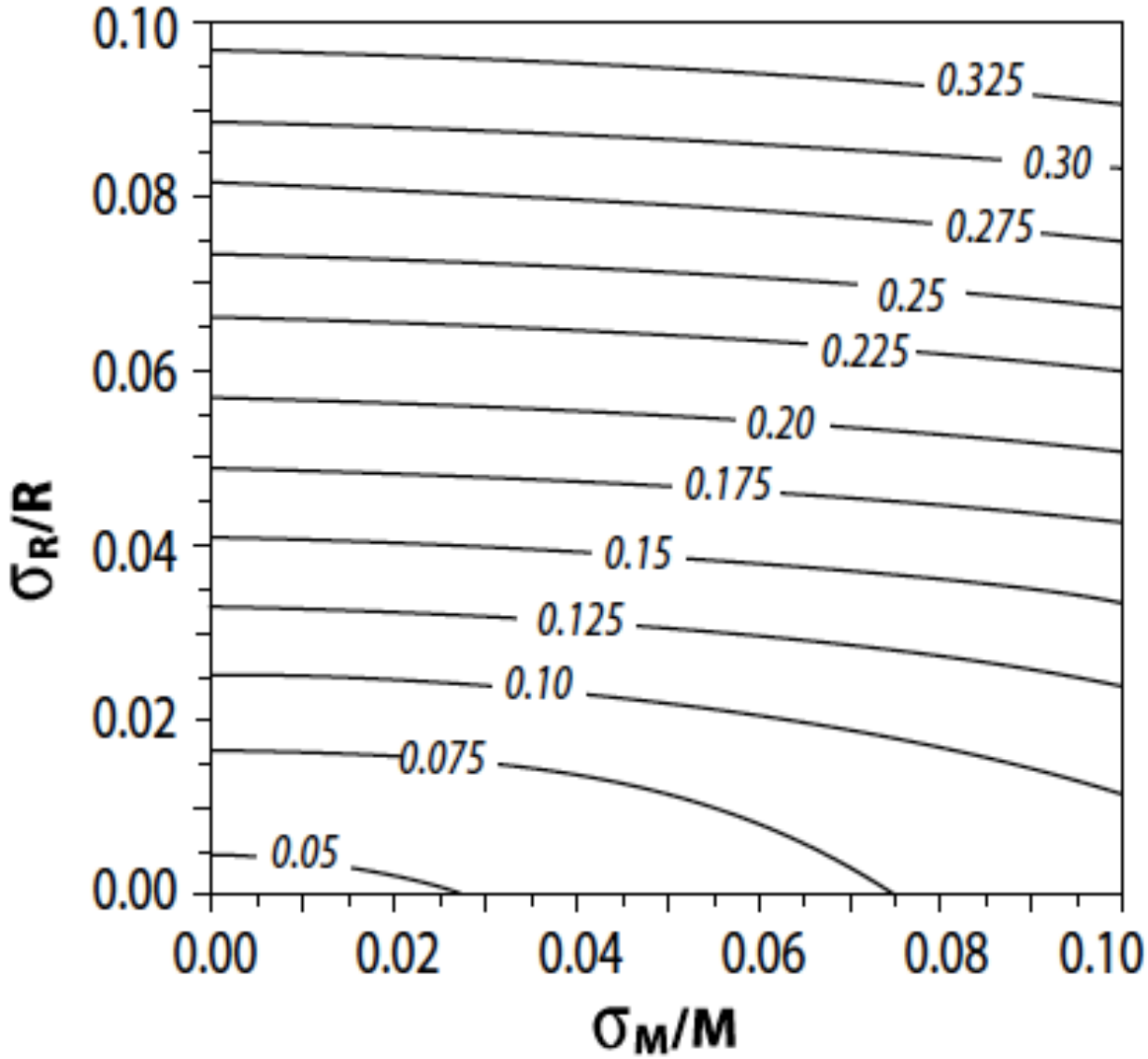


Fig Credit:
Megan Bedell
bedell.space

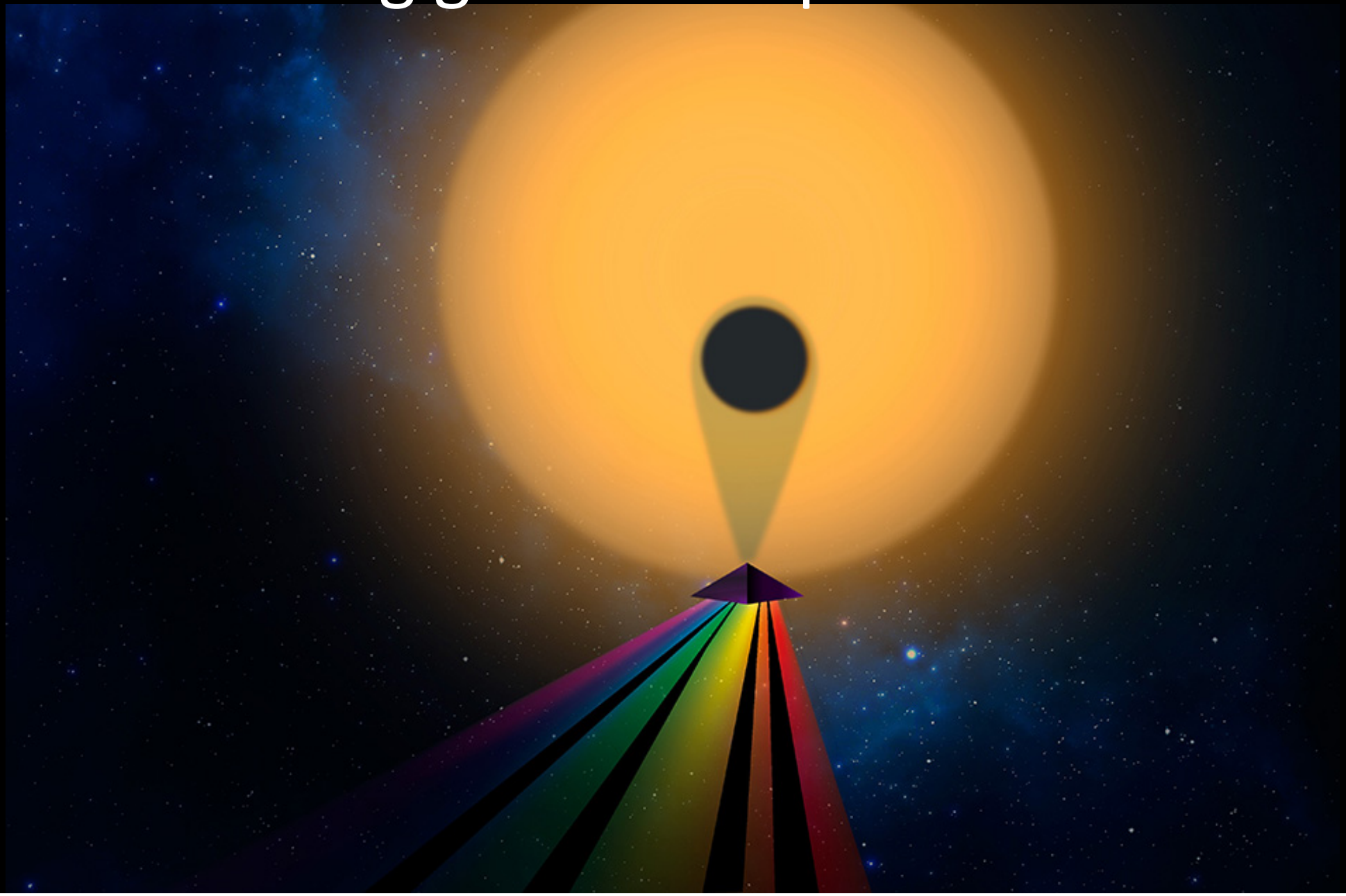
Mass measurements are needed to constrain planet compositions



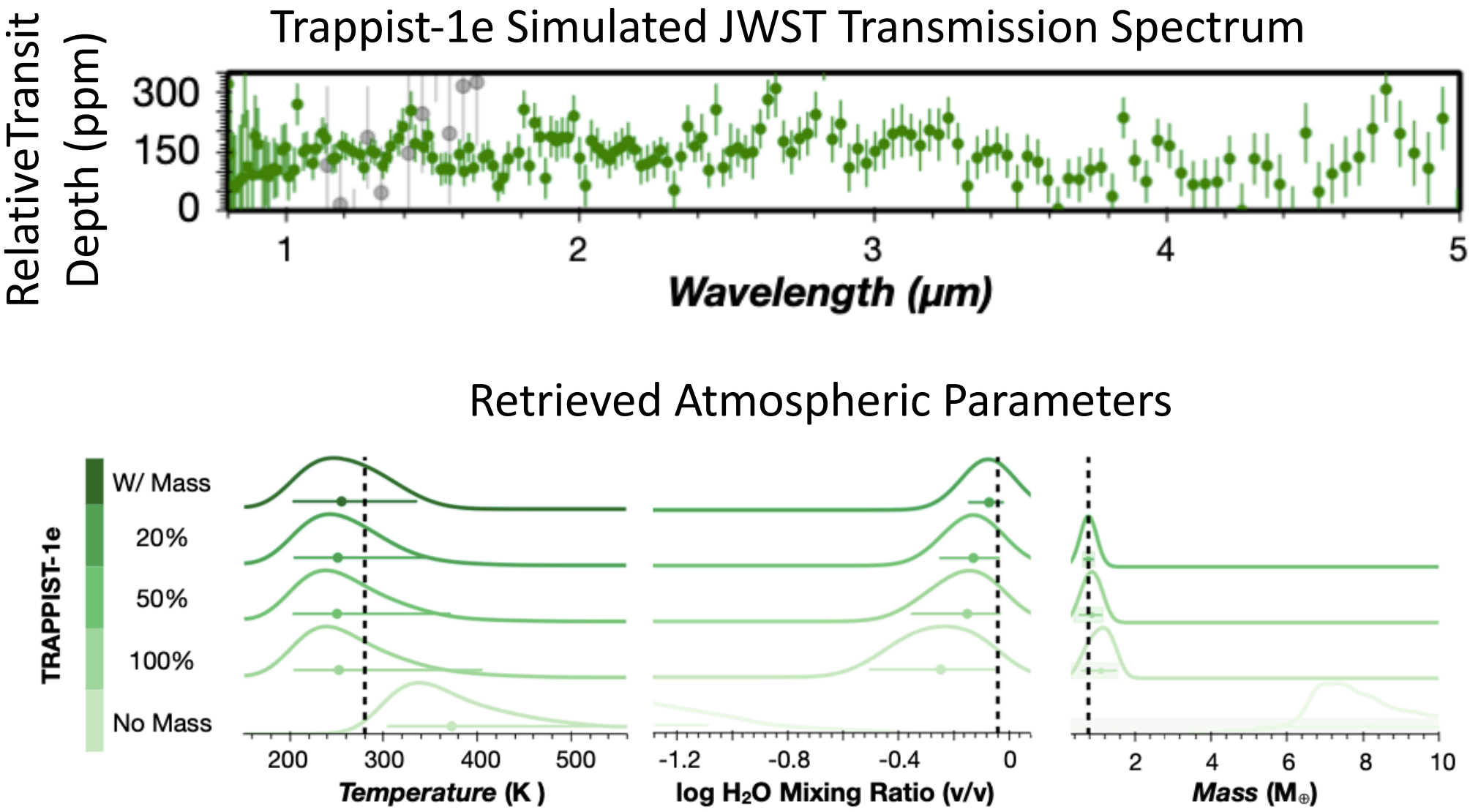
Countours denote relative uncertainty obtained on water mass fraction (for specified precision in R_p and M_p measurements).

Grasset et al. (2009)

Mass measurements are needed to constrain log g for atmosphere retrievals.

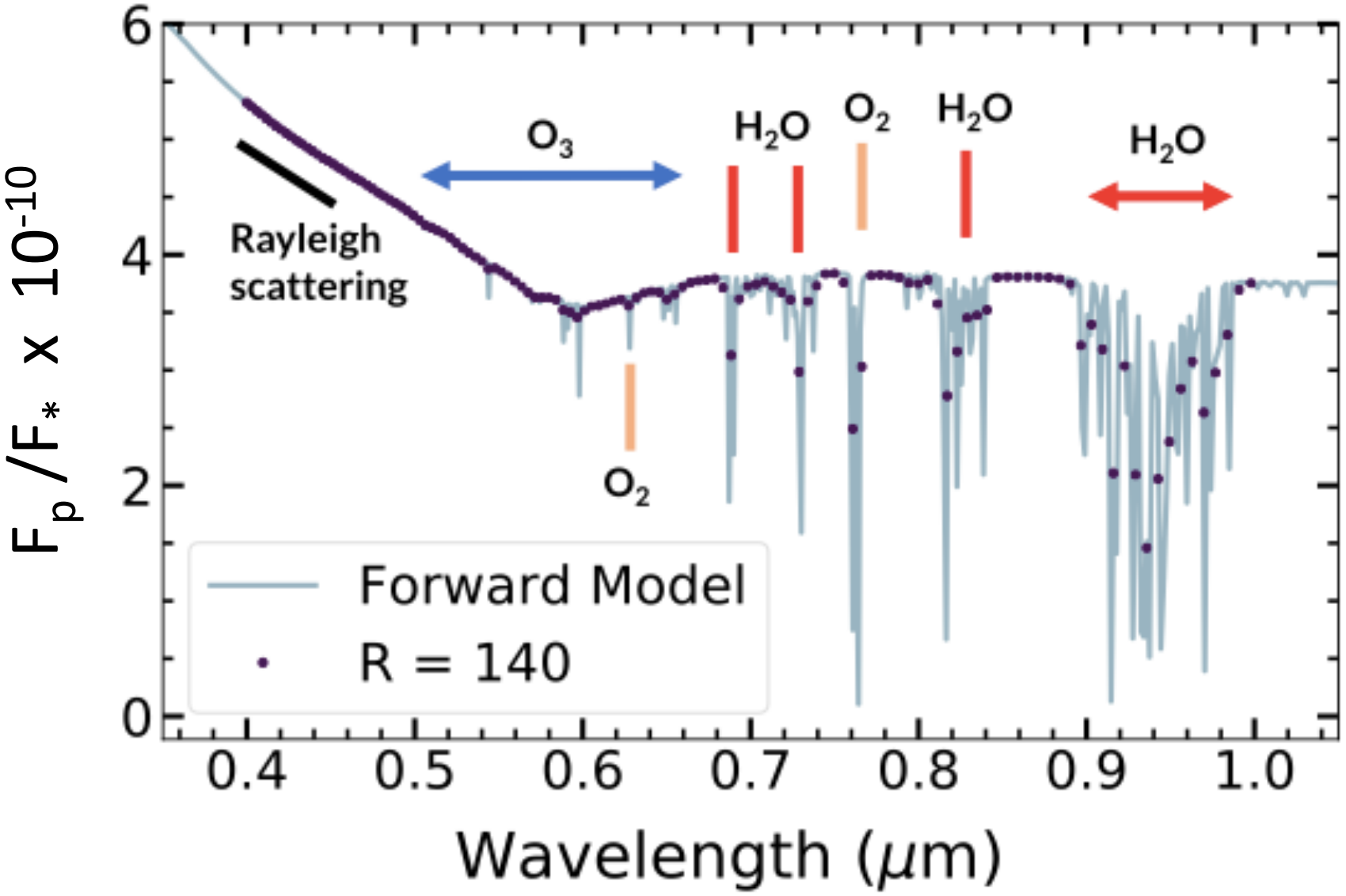


Mass measurements are needed to constrain log g for atmosphere retrievals – transit transmission



Batalha et al. (2020)

Mass measurements are needed to constrain log g for atmosphere retrievals – reflected light imaging



Feng et al. (2018)

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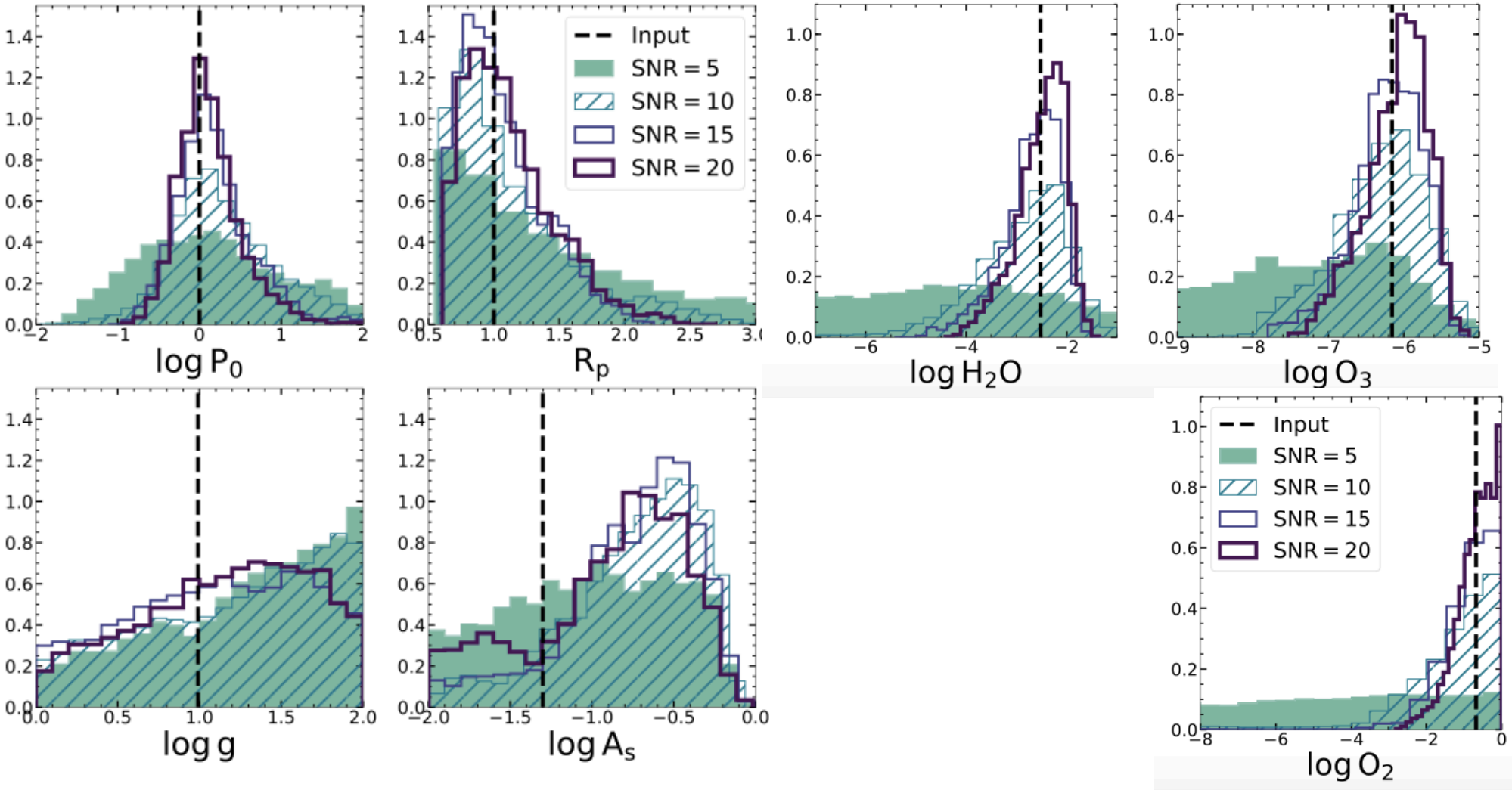
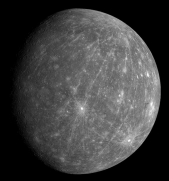


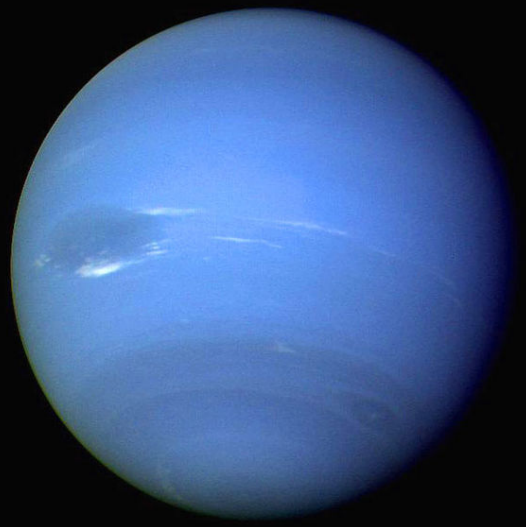
Feng et al. (2018)

Mass measurements are needed to assess atmospheric mass loss rates.



Too Little Atmosphere

Just Right



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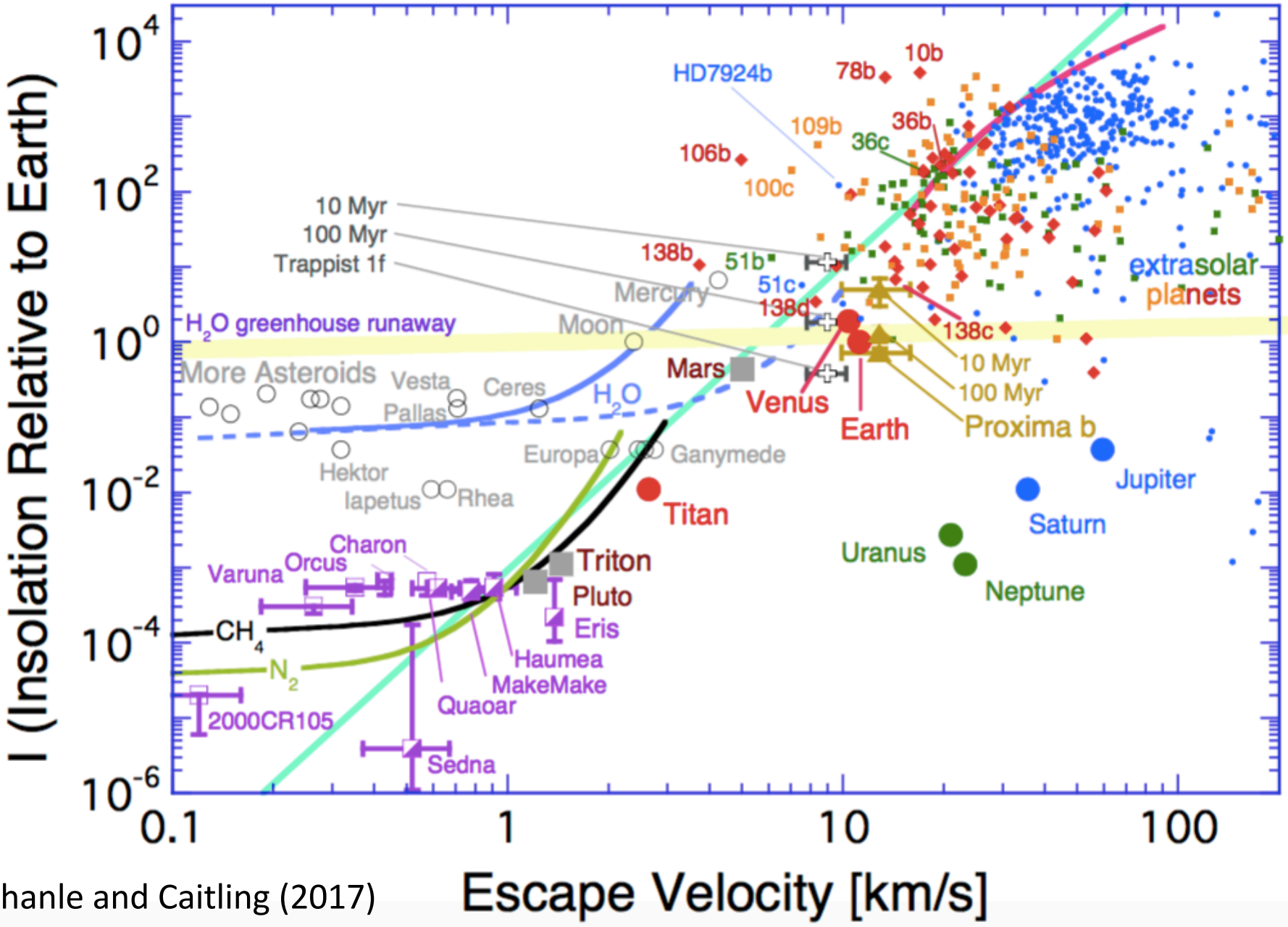
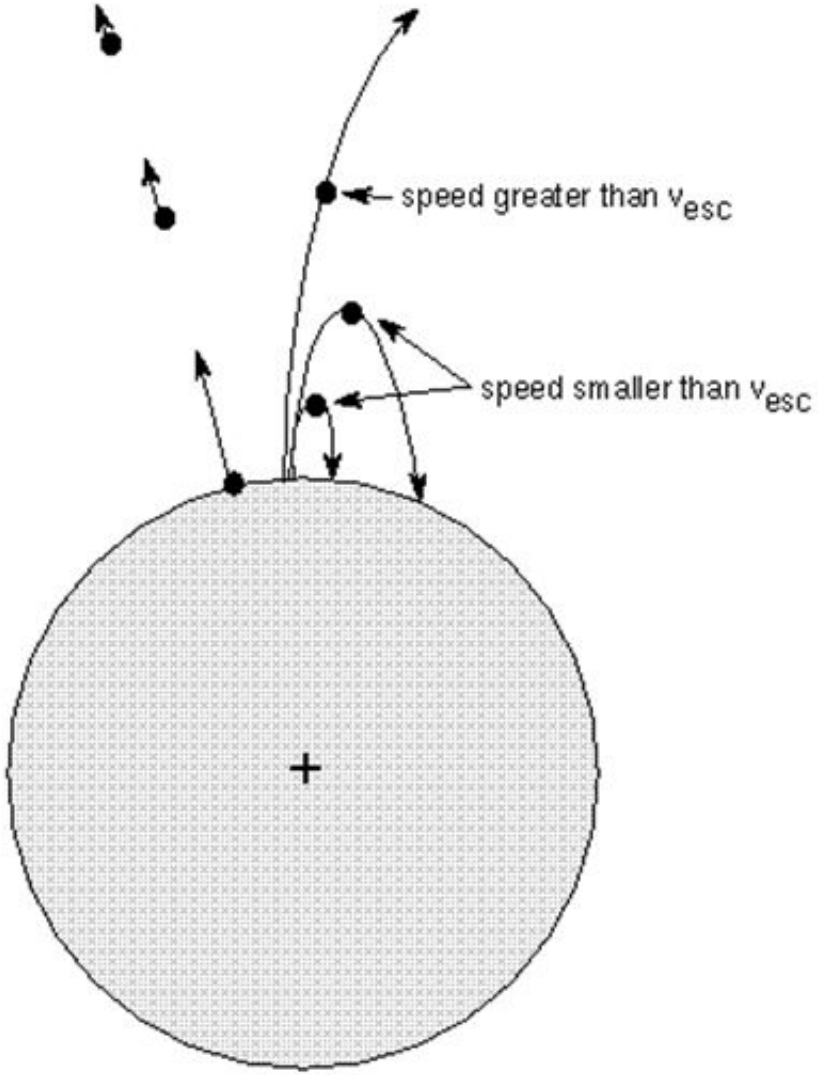


Zhanle and Caitling (2017)

Escape Velocity, v_{esc}

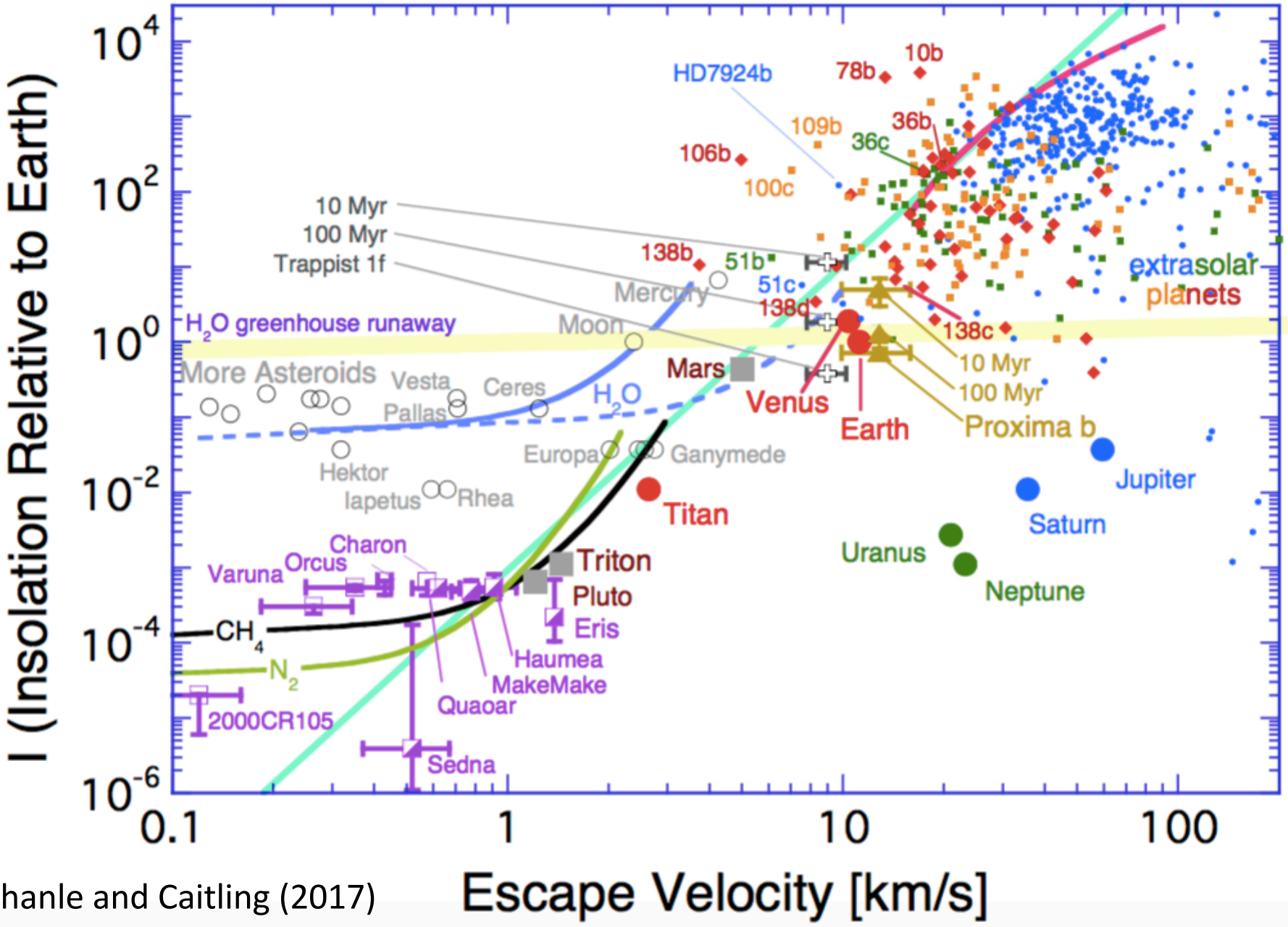


Escape velocity depends on the gravitational potential of the planet

$$\frac{1}{2}mv^2 = \frac{GMm}{r}$$

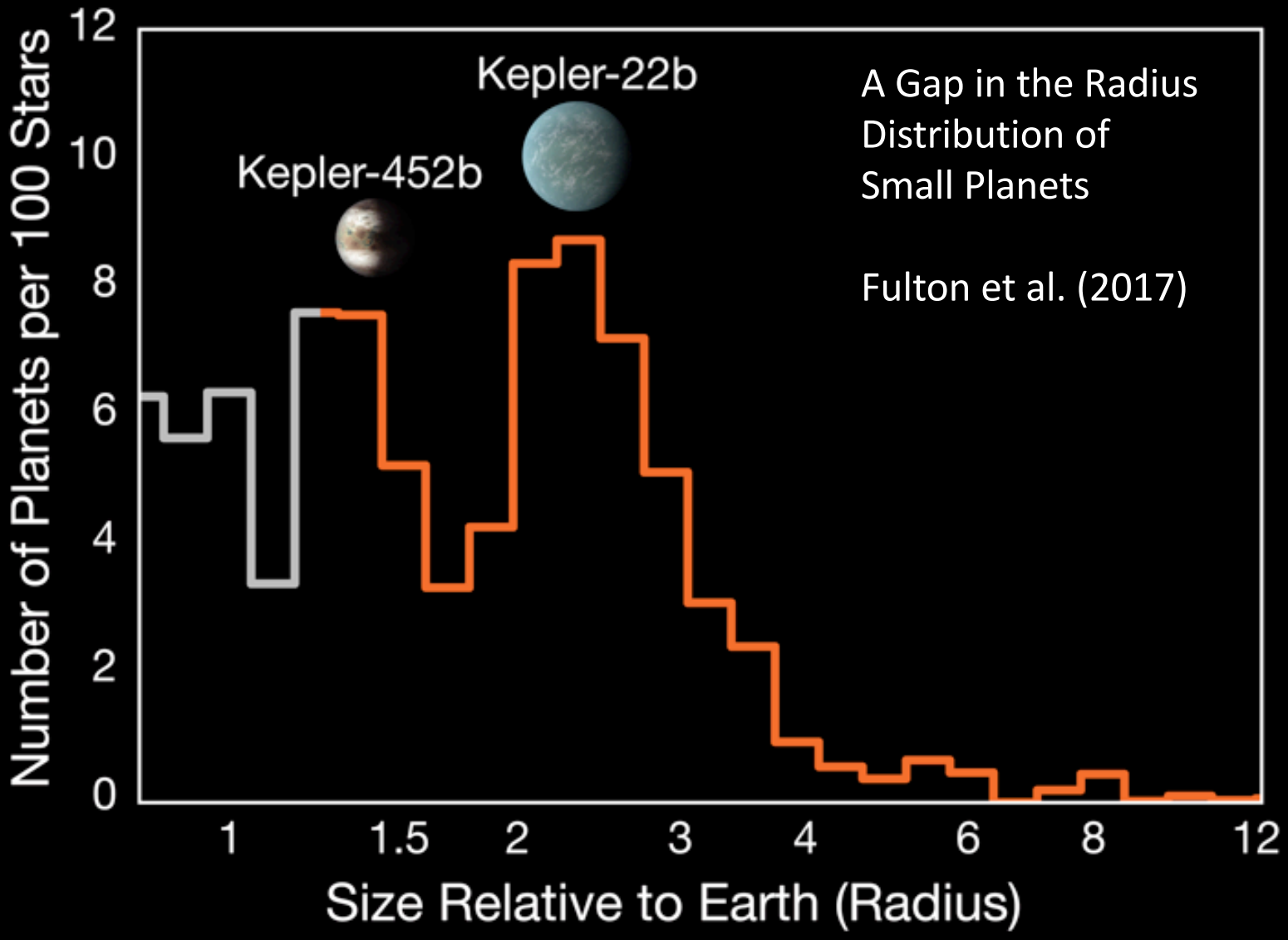
$$v_{escape} = \sqrt{\frac{2GM}{r}}$$

Mass measurements are needed to assess atmospheric mass loss rates.

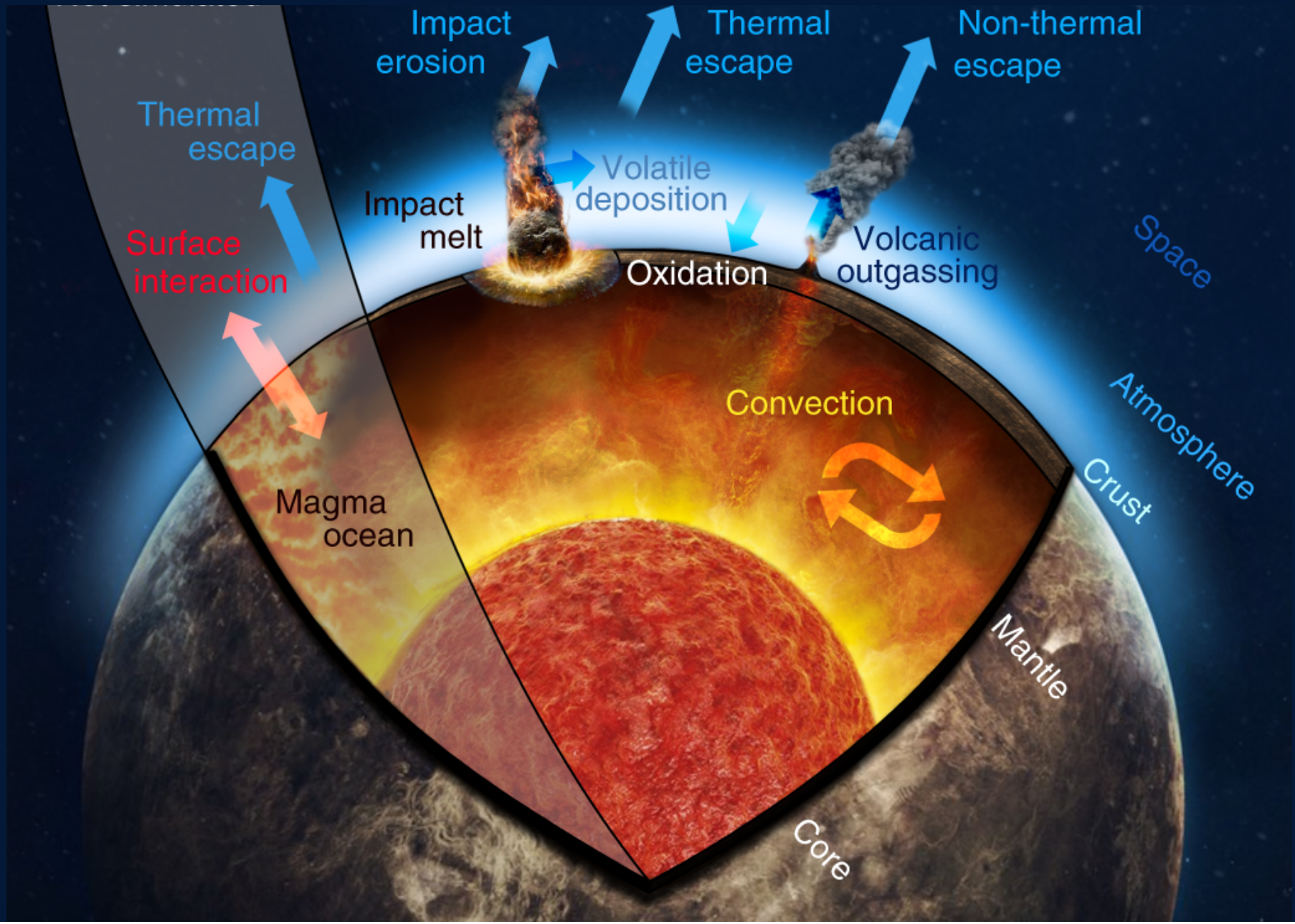


Zhanle and Caitling (2017)

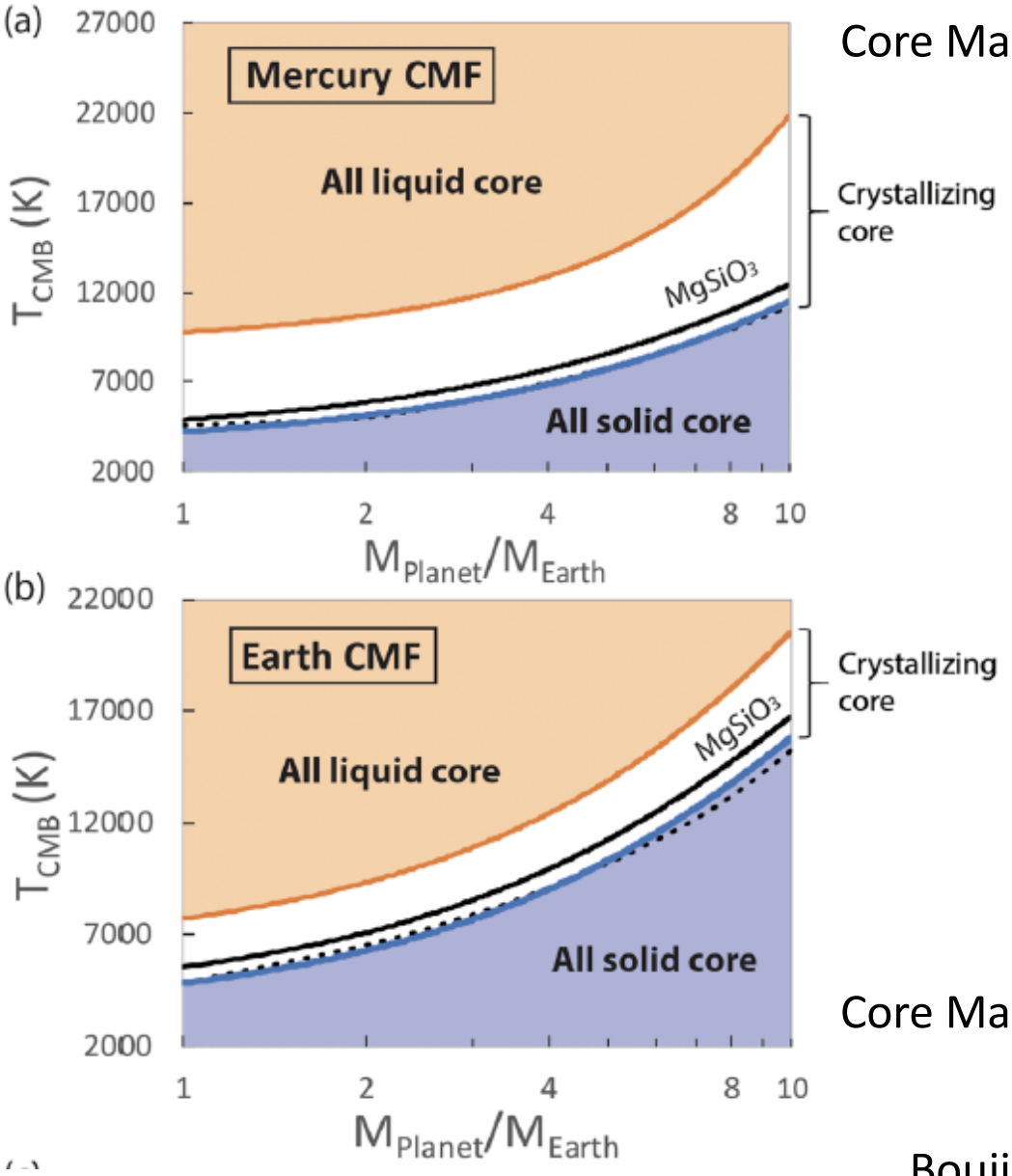
Evidence for Atmospheric Escape Affecting Exoplanets



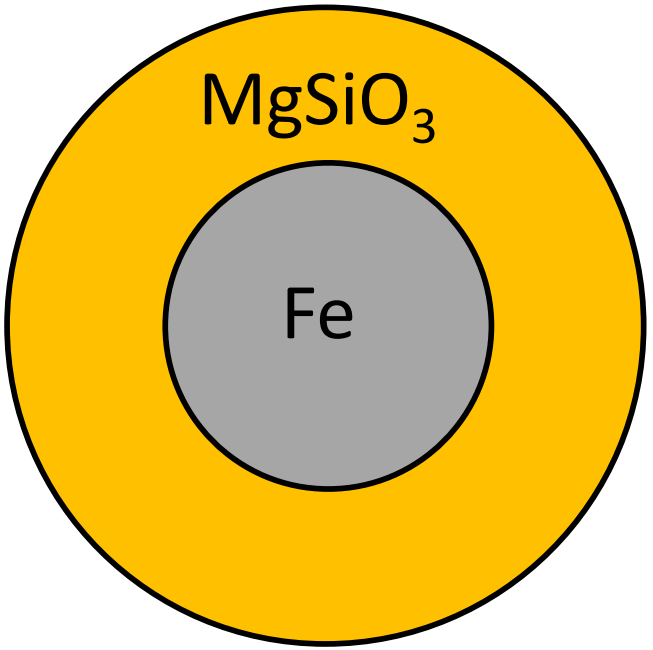
Mass measurements are needed to assess the planet's thermal evolution.



Planet mass affects pressure, and phases within rocky planet interiors.



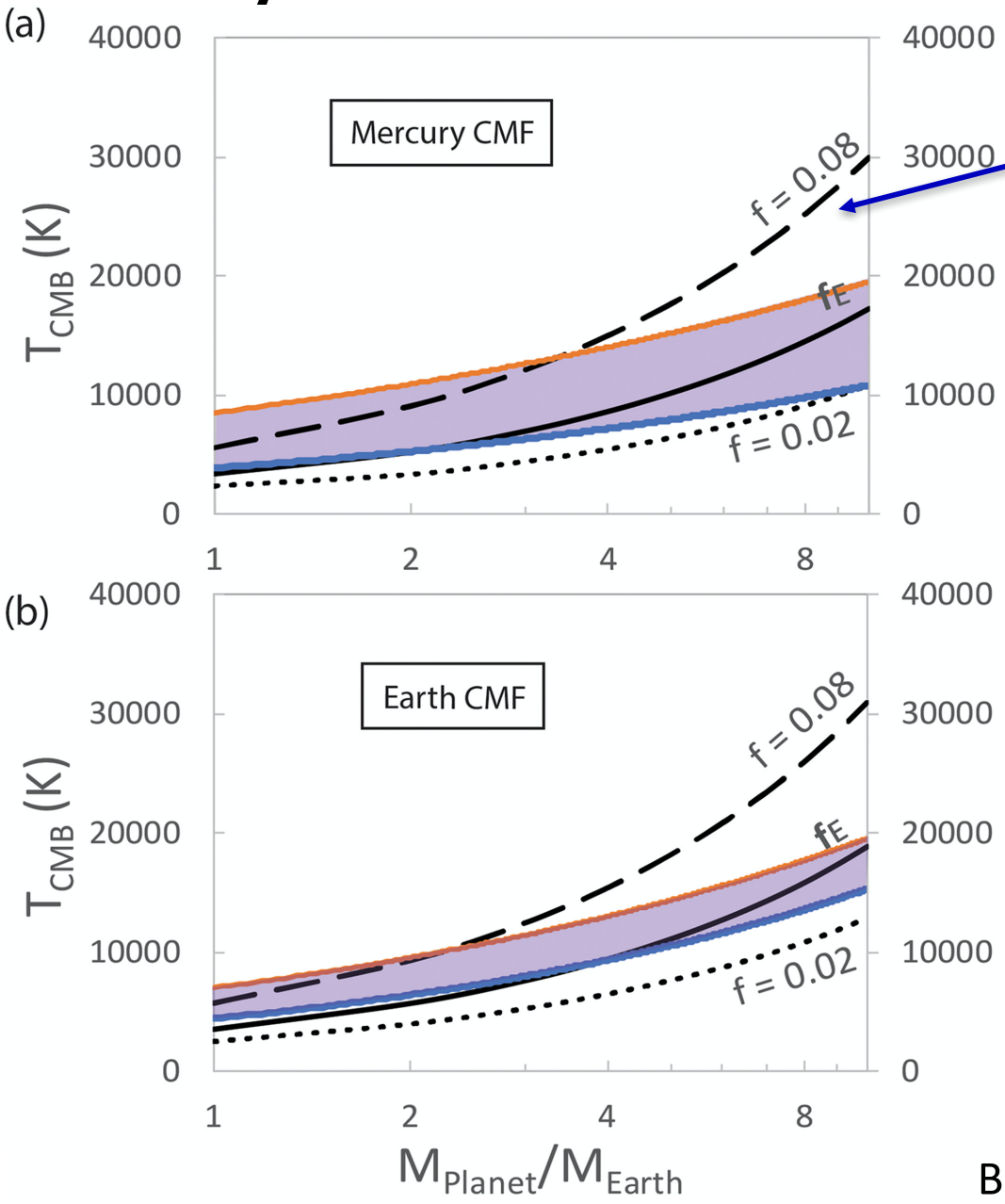
Core Mass Fraction (CMF) = 0.68



Core Mass Fraction (CMF) = 0.32

Boujibar et al. (2020)

Gravitational Potential Energy Released by Rocky Planet Accretion Increases with M_p



f = Fraction of gravitational potential energy released by accretion retained

Boujibar et al. (2020)

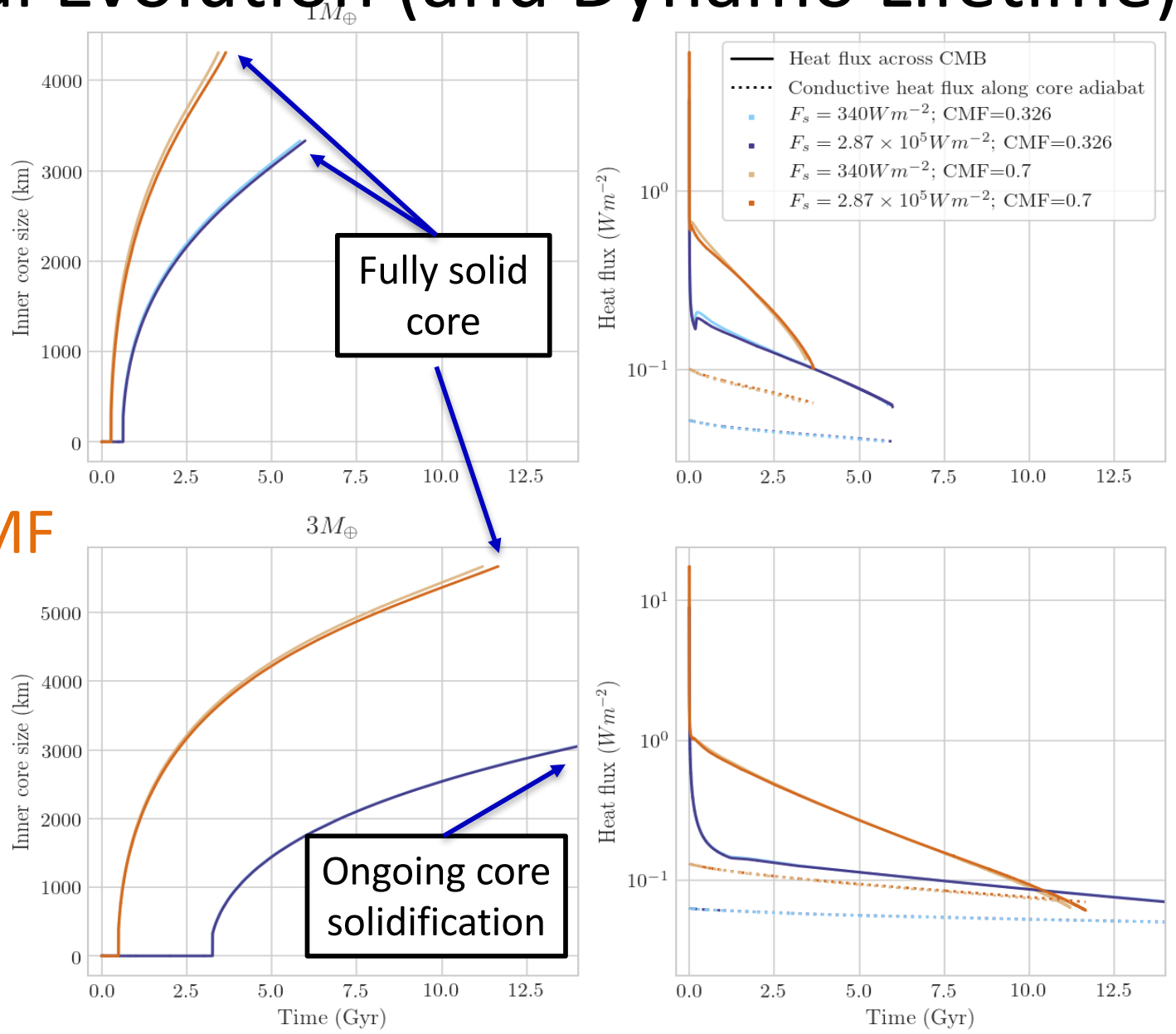
M_p and Iron Core Mass Fraction Affect Planet Thermal Evolution (and Dynamo Lifetime)

1 M_{Earth}

Earth CMF

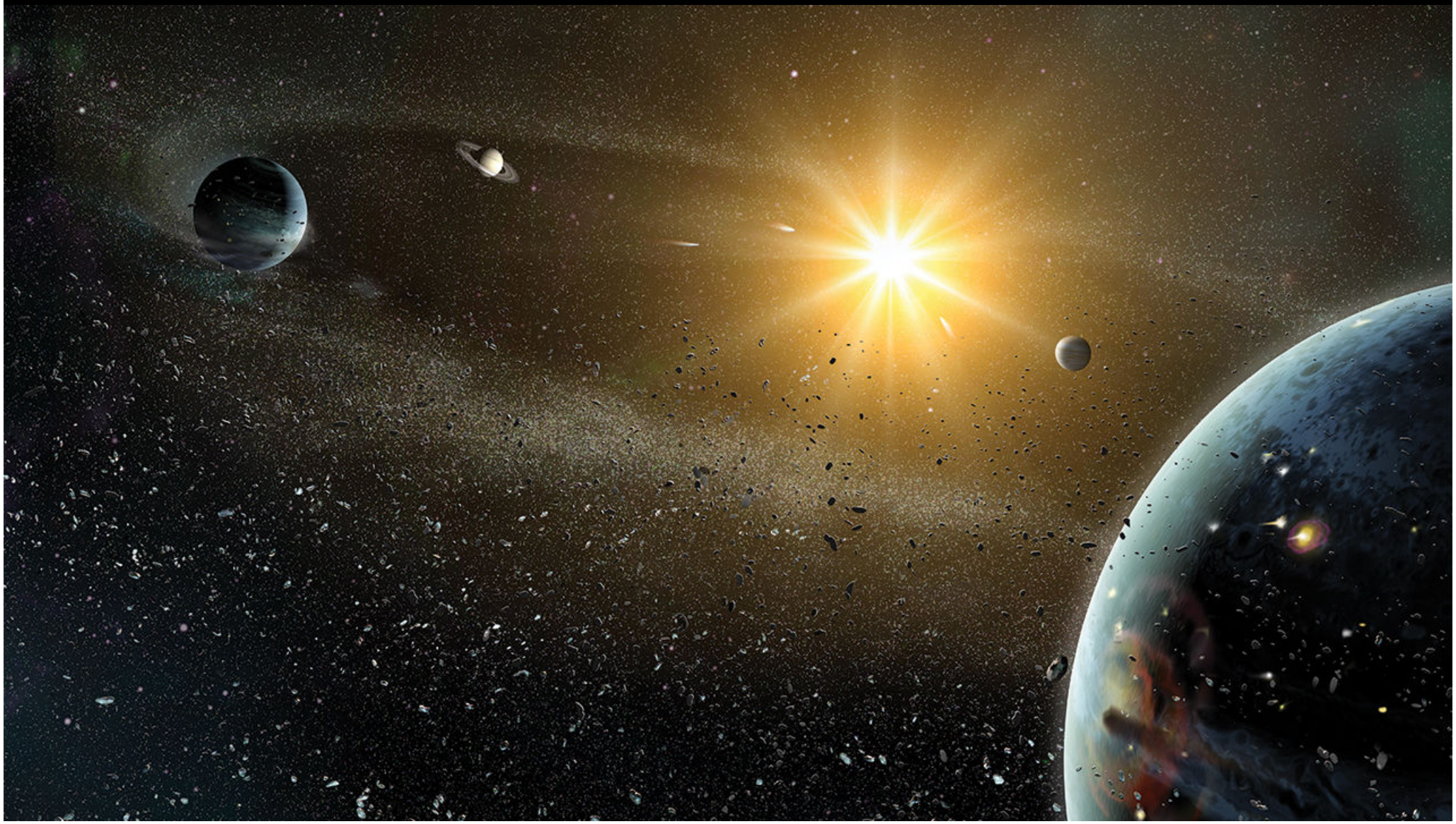
Mercury CMF

3 M_{Earth}

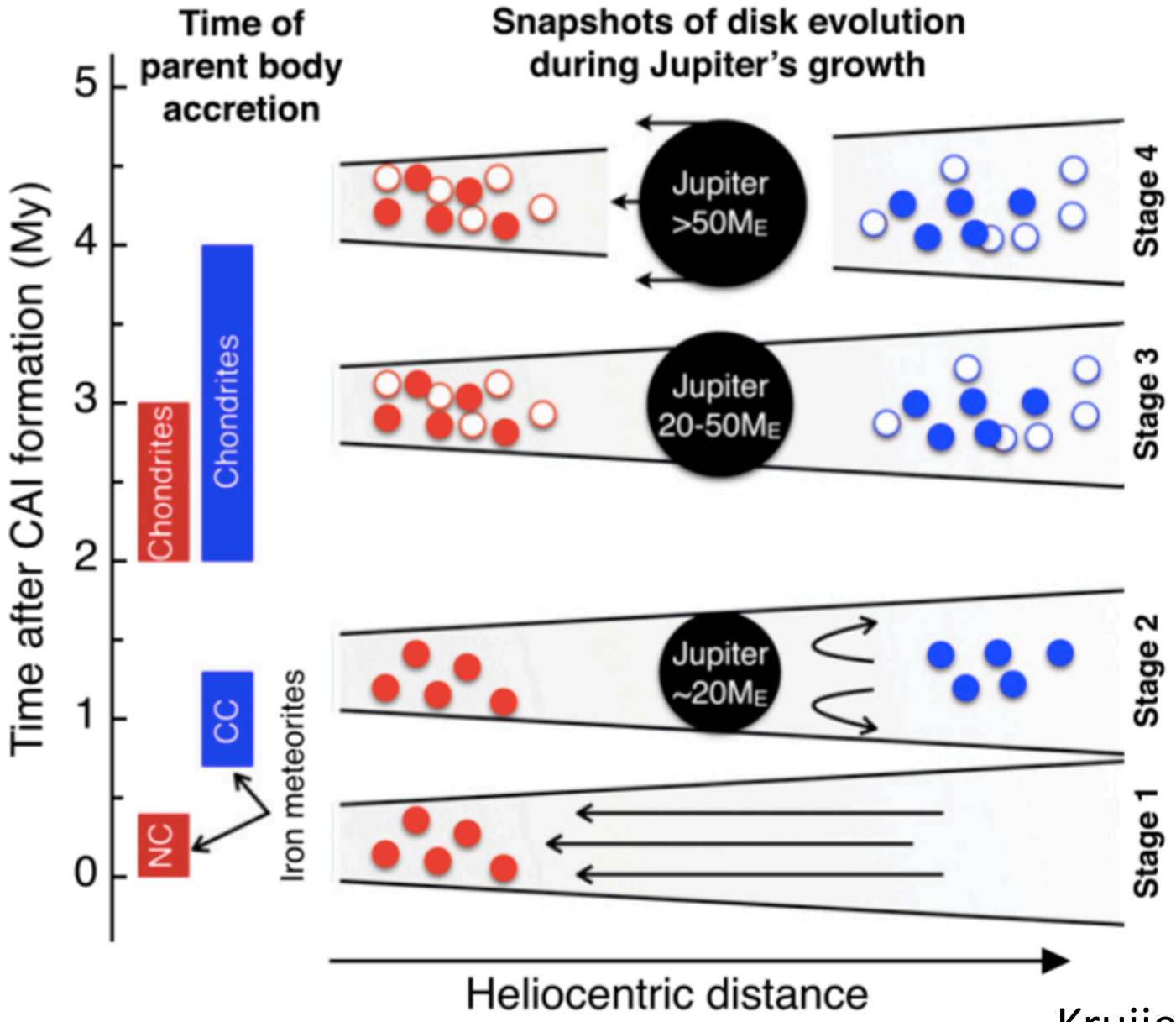


Zhang and Rogers (in prep.)

Mass measurements are needed to understand the planets' interactions with the rest of its system.

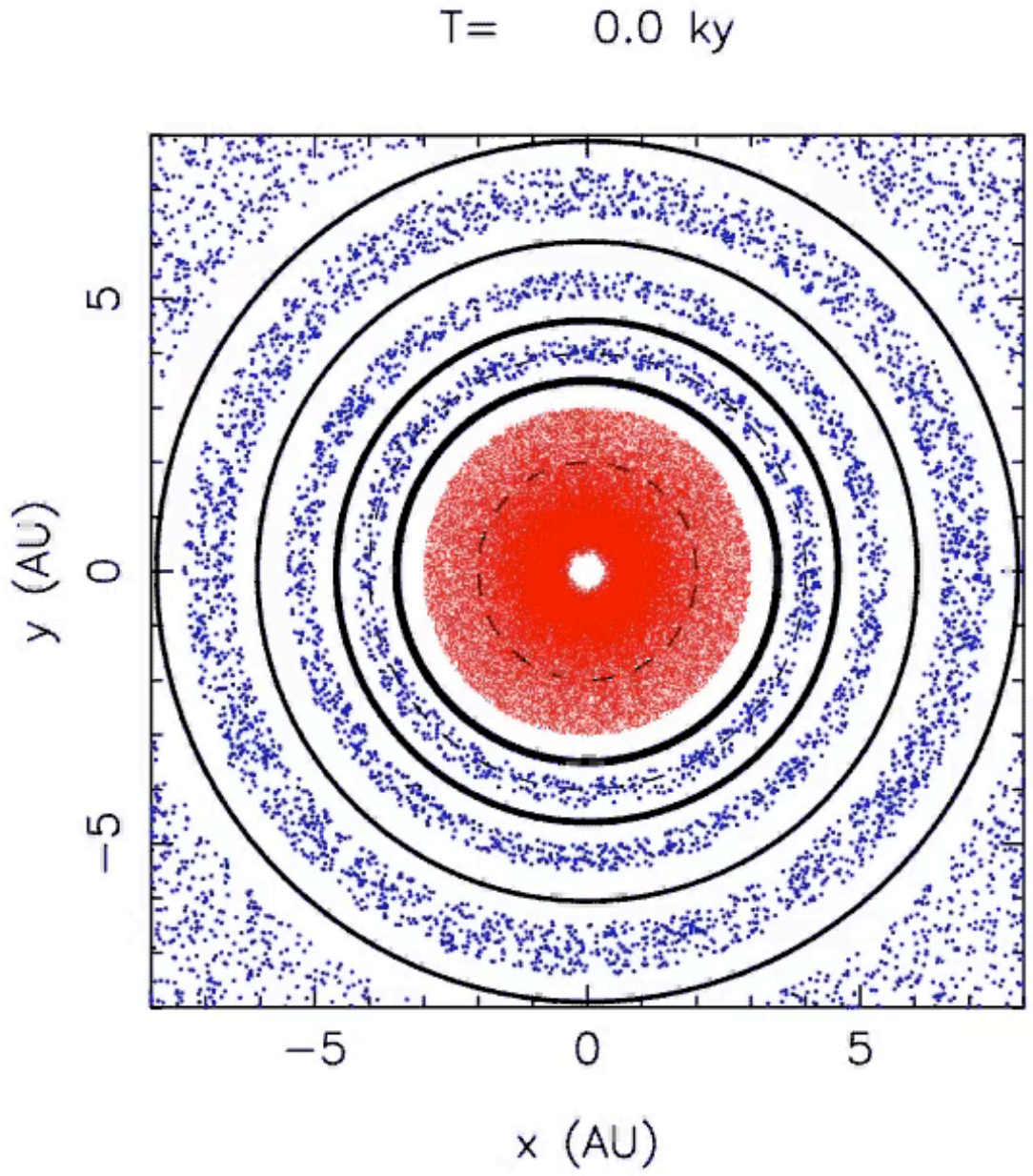


Jupiter and Saturn Analogs Affect Dynamics & Formation of Entire Planetary Systems



Kruijer et al. (2017)

Masses, orbits, and migration histories of giant planets affect volatile delivery to the HZ

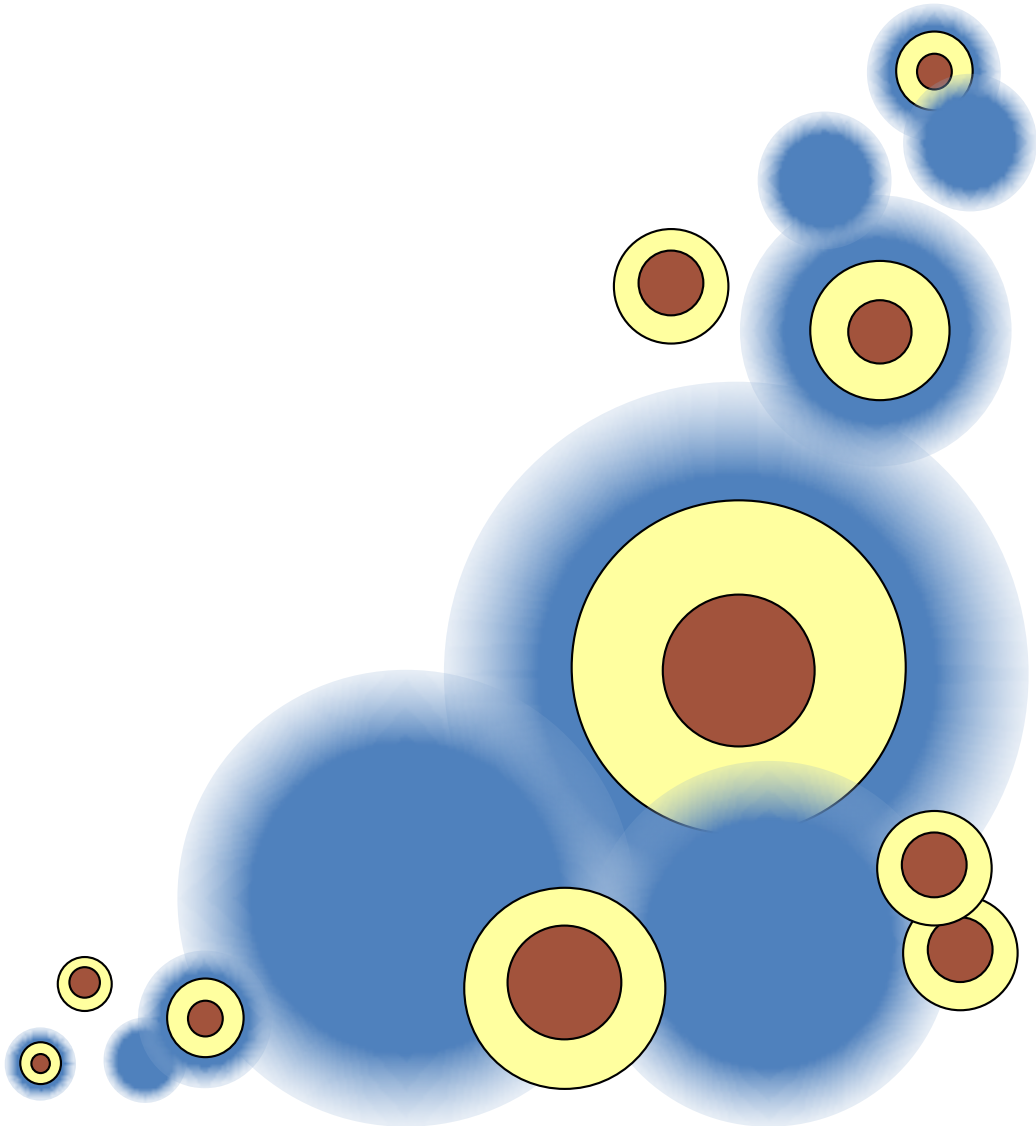


The "Grand-Tack" model for the Solar System

Walsh et al. 2011

- Orbits of gas giants
- Rocky Planetesimals
- Icy Planetesimals

Mass measurements are needed to constrain planet populations



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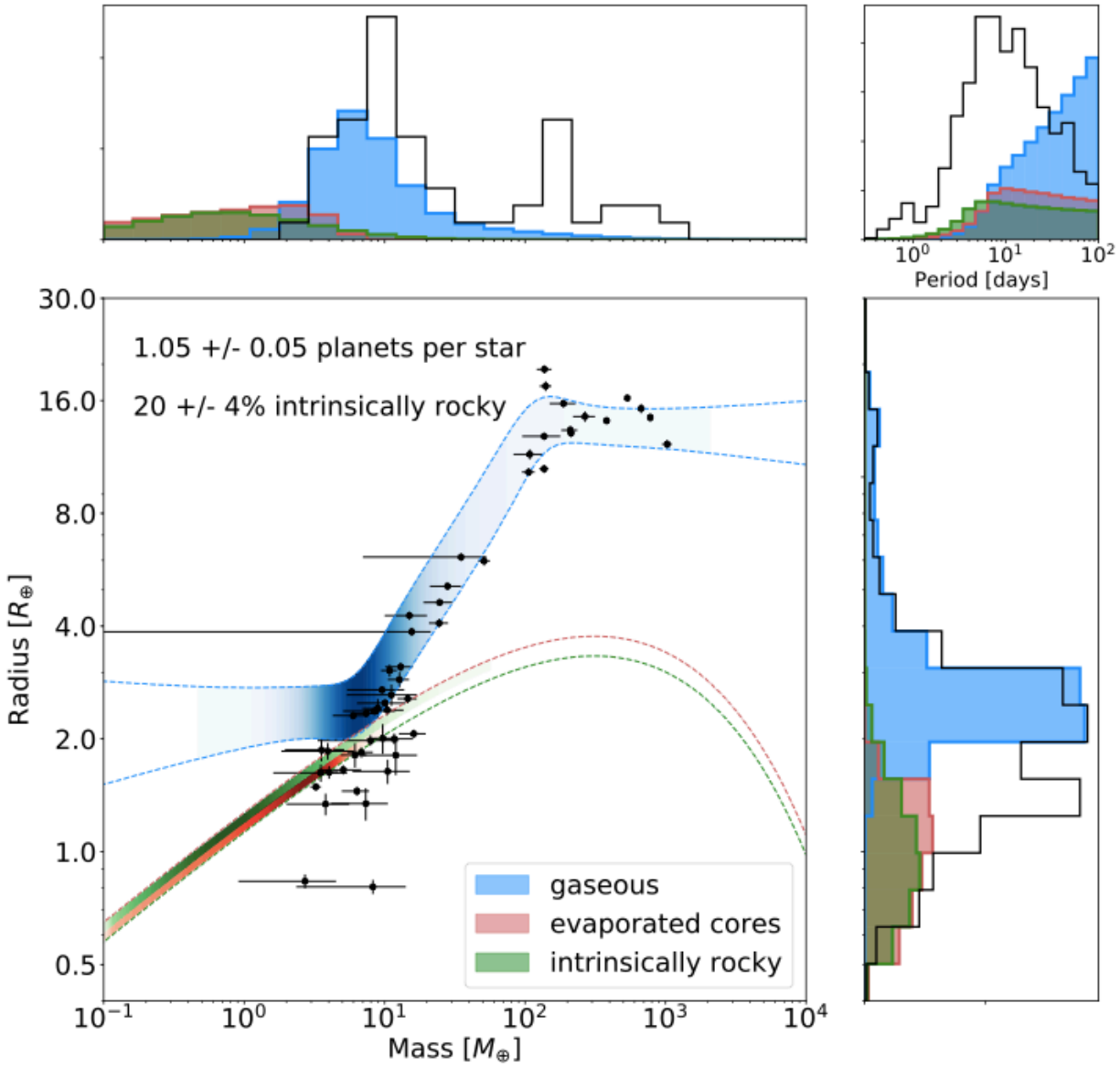
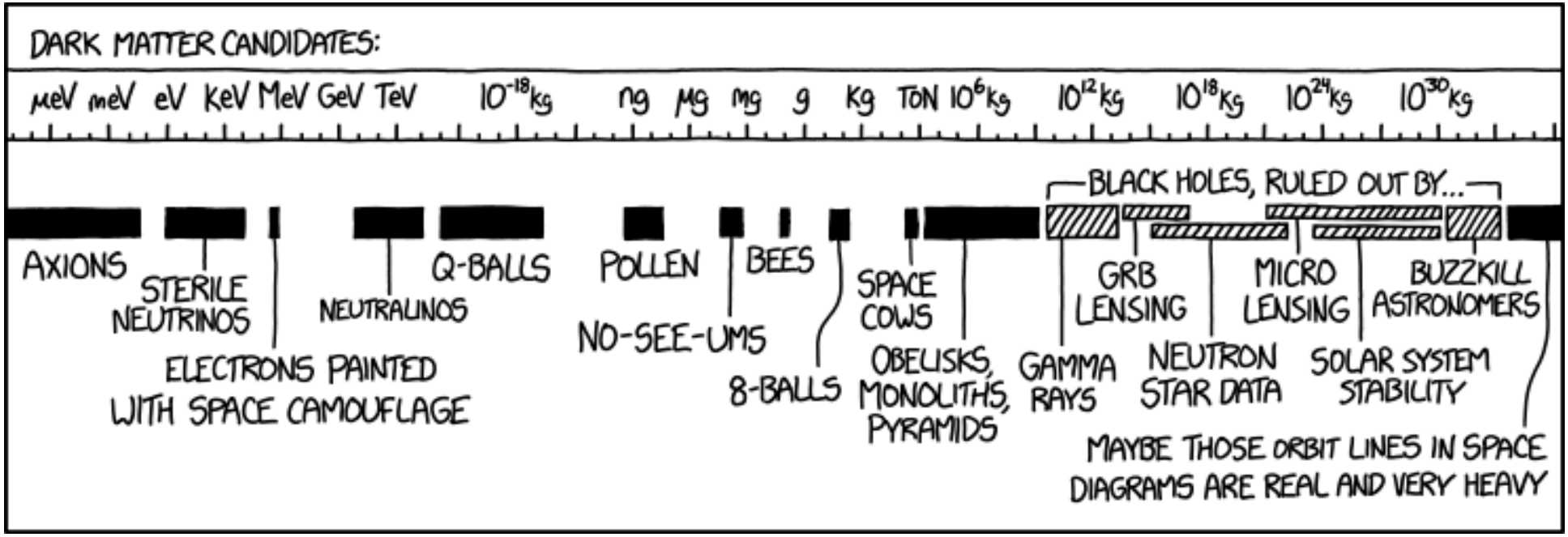


Neil & Rogers (2020) – Joint M_p-R_p-P Distribution of Planets

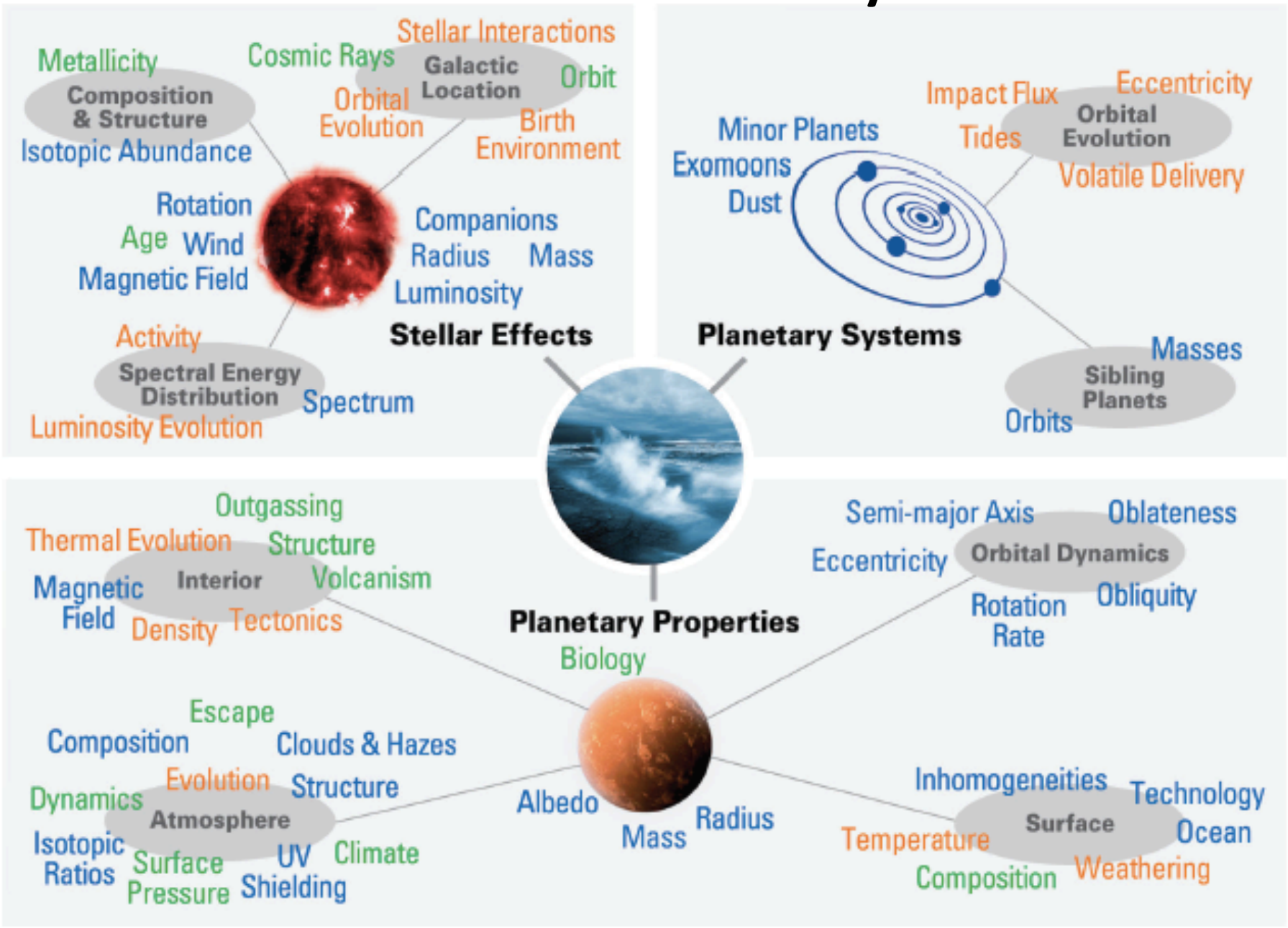
- Characterizing the planet mass distribution helps to inform priors on masses of planets lacking mass measurements
- Identifying compositional trends and sub-populations helps to place individual planets in context

Mass measurements are needed since
mass is a fundamental property of any astrophysical body.



https://xkcd.com/2035/

Habitability



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