

Terrestrial Exoplanet Internal Structure Constraints Enabled by Comprehensive Stellar Characterization

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Know Thy Star, Know Thy Planet 2
5 February 2025



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Alejandro
Ross



Henrique
Reggiani

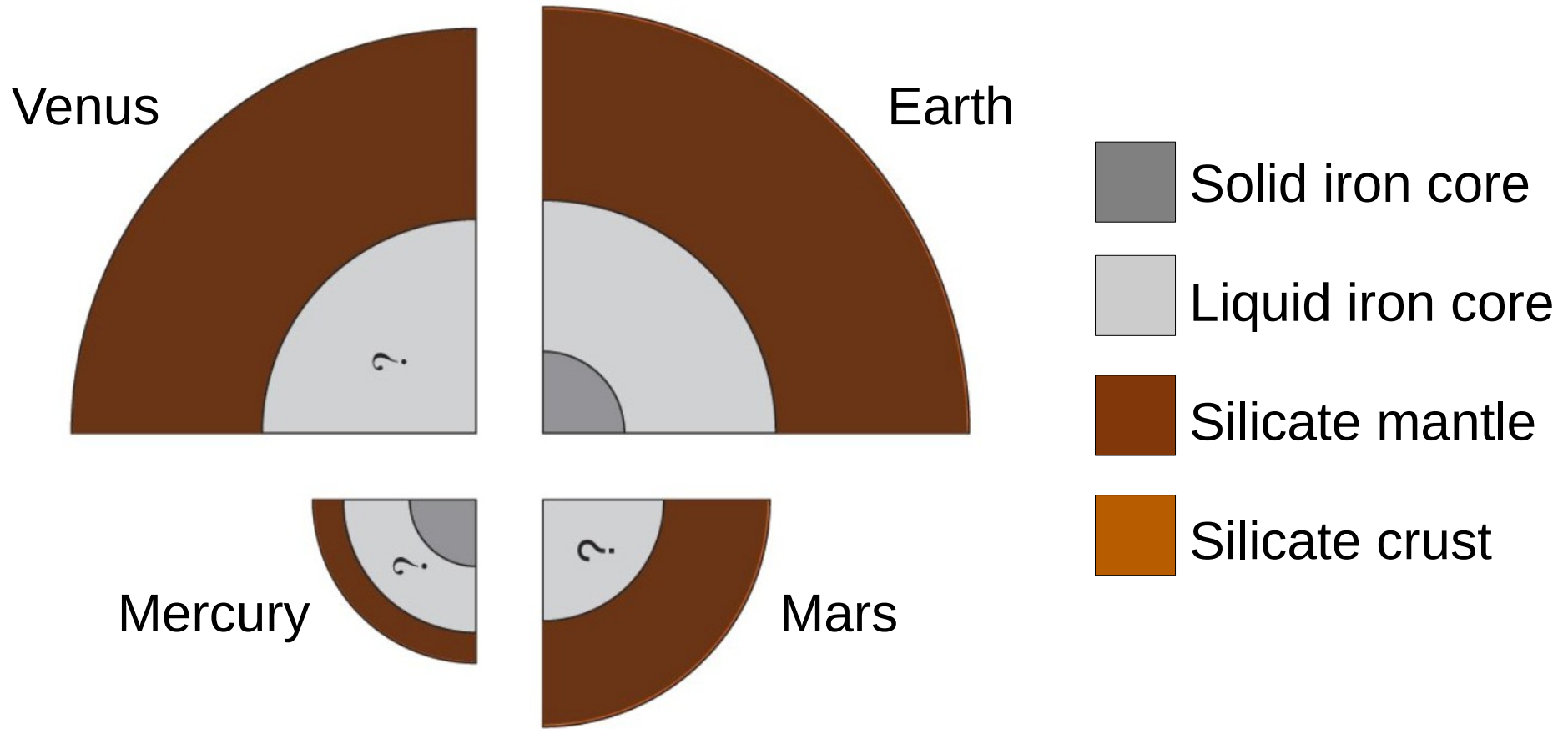


Ross, Reggiani, Schlaufman, et al. (2025, submitted)

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Terrestrial Planet Interior Structure

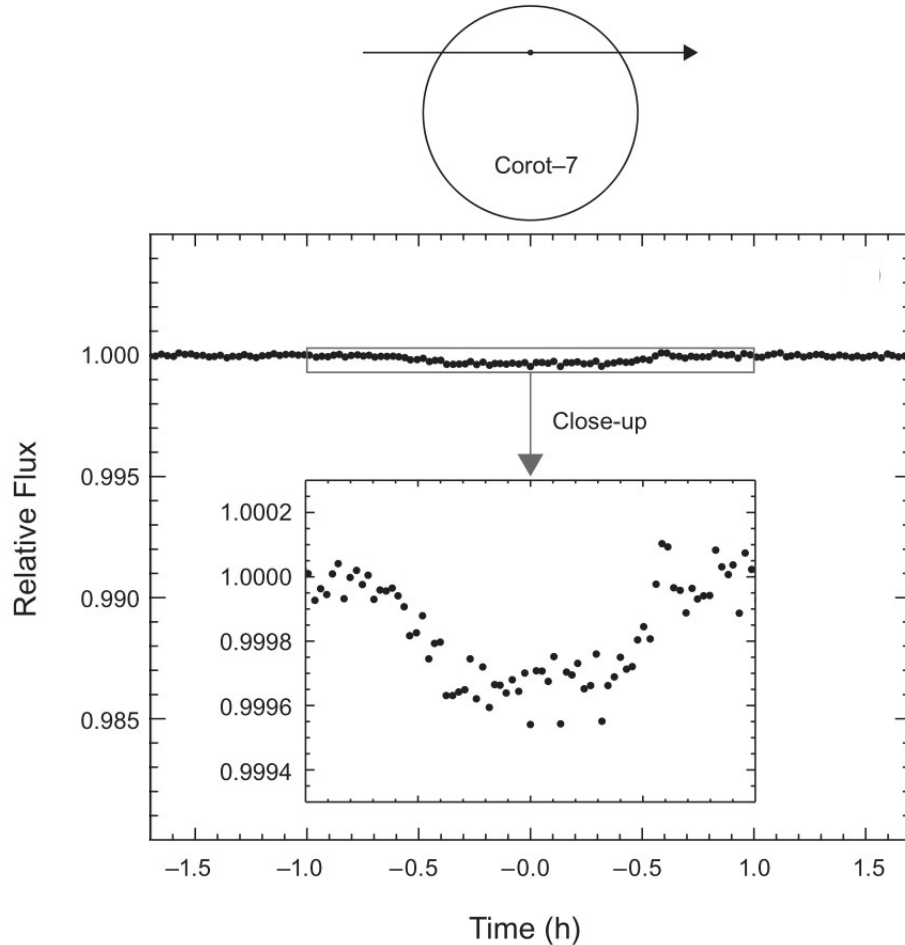
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Adapted from Salyk & Lewis (2020)

Terrestrial Exoplanet Radii

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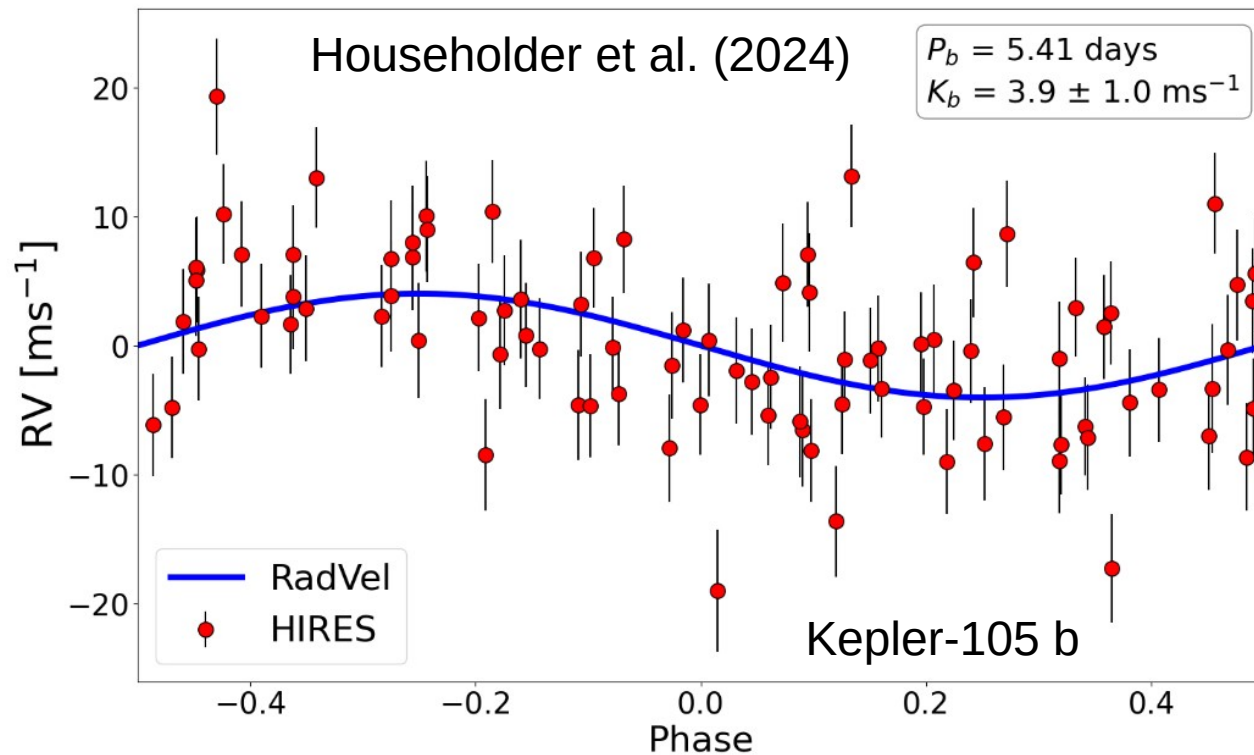
$$\delta \approx \left(\frac{R_p}{R_*} \right)^2$$

-  Measured
-  Inferred
-  Desired

Adapted from Winn (2010)

Terrestrial Exoplanet Masses

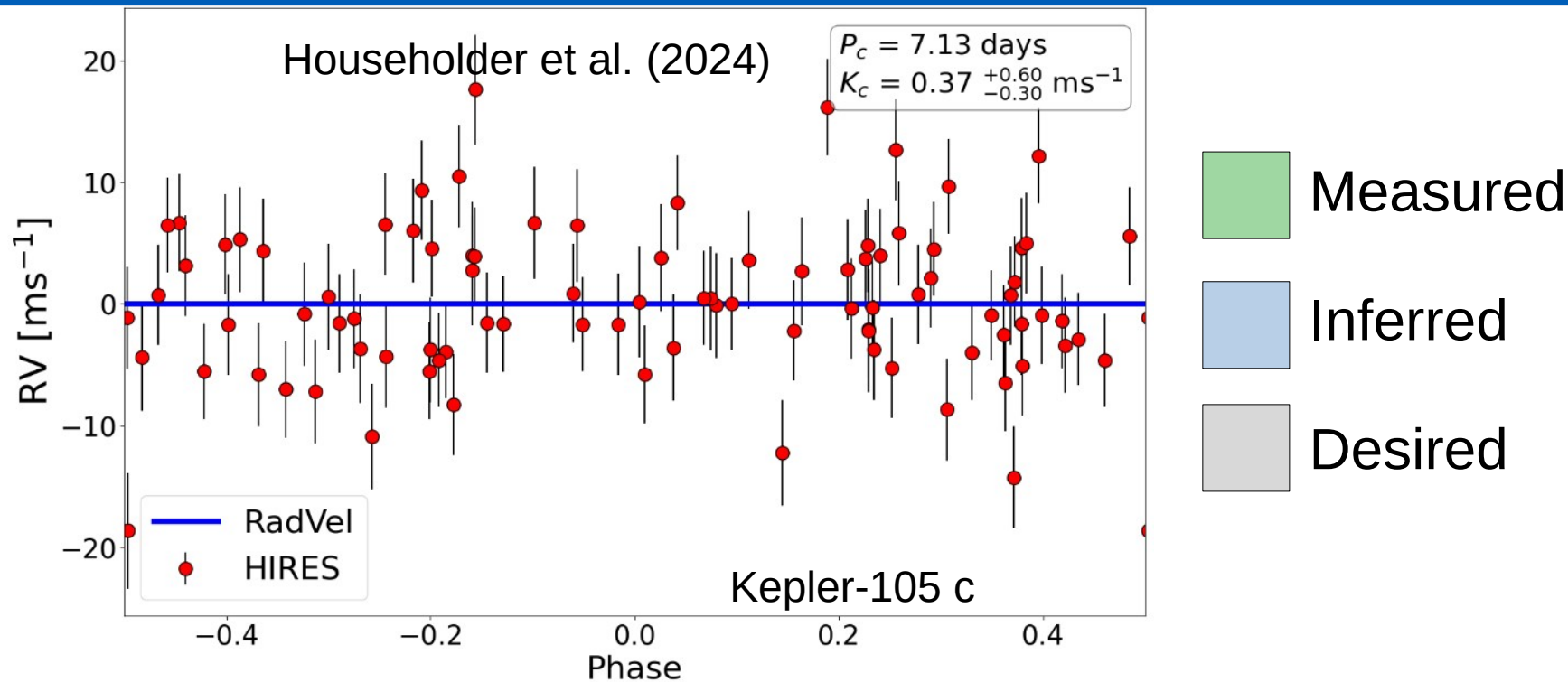
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$$\frac{M_p}{M_{\oplus}} = \frac{\sqrt{1 - e^2}}{\sin i} \left(\frac{K}{3.32 \text{ m s}^{-1}} \right) \left(\frac{M_*}{M_{\odot}} \right)^{2/3} \left(\frac{P}{10 \text{ days}} \right)^{1/3}$$

Terrestrial Exoplanet Masses

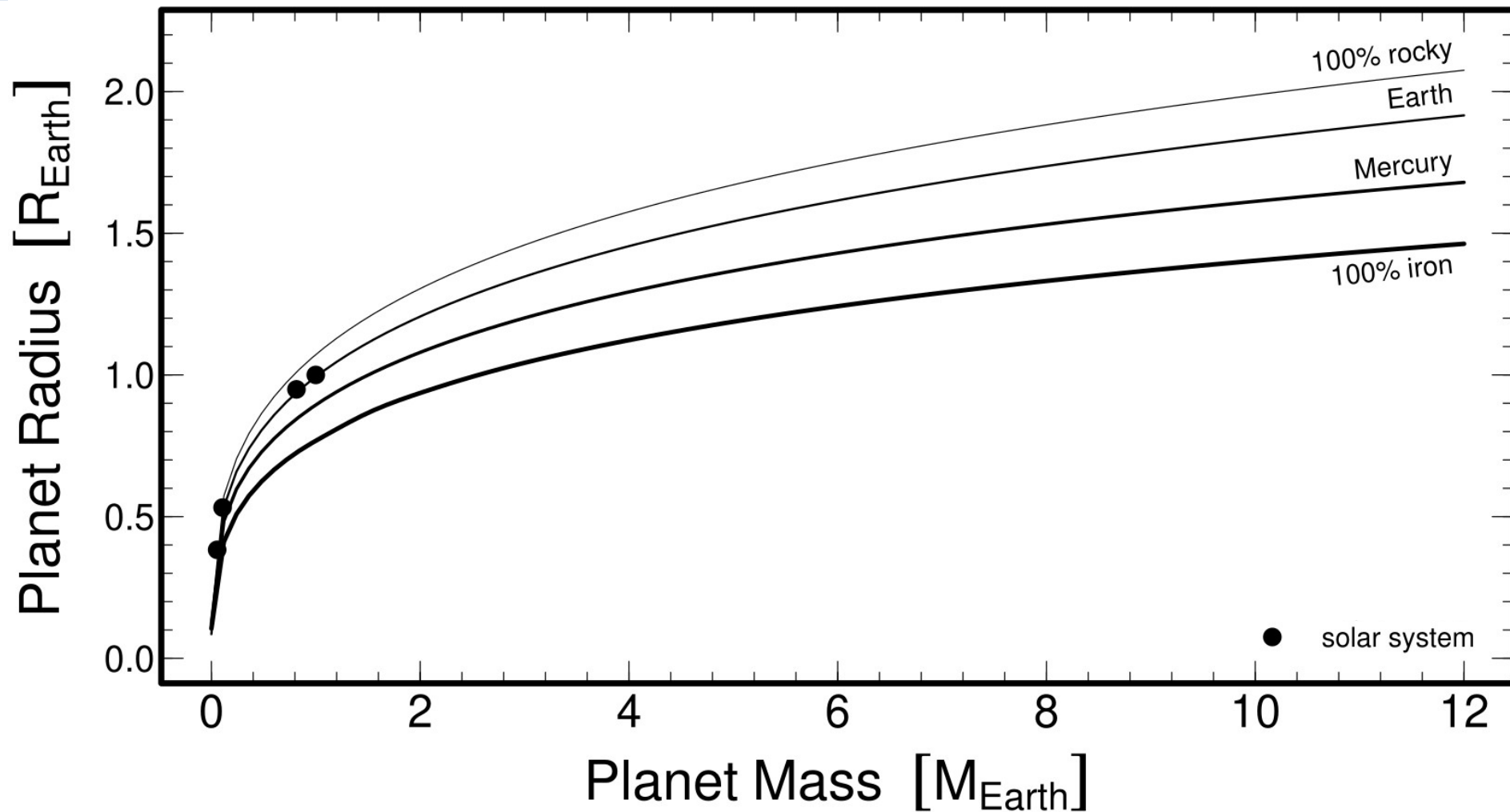
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$$\frac{M_p}{M_{\oplus}} = \frac{\sqrt{1 - e^2}}{\sin i} \left(\frac{K}{3.32 \text{ m s}^{-1}} \right) \left(\frac{M_*}{M_{\odot}} \right)^{2/3} \left(\frac{P}{10 \text{ days}} \right)^{1/3}$$

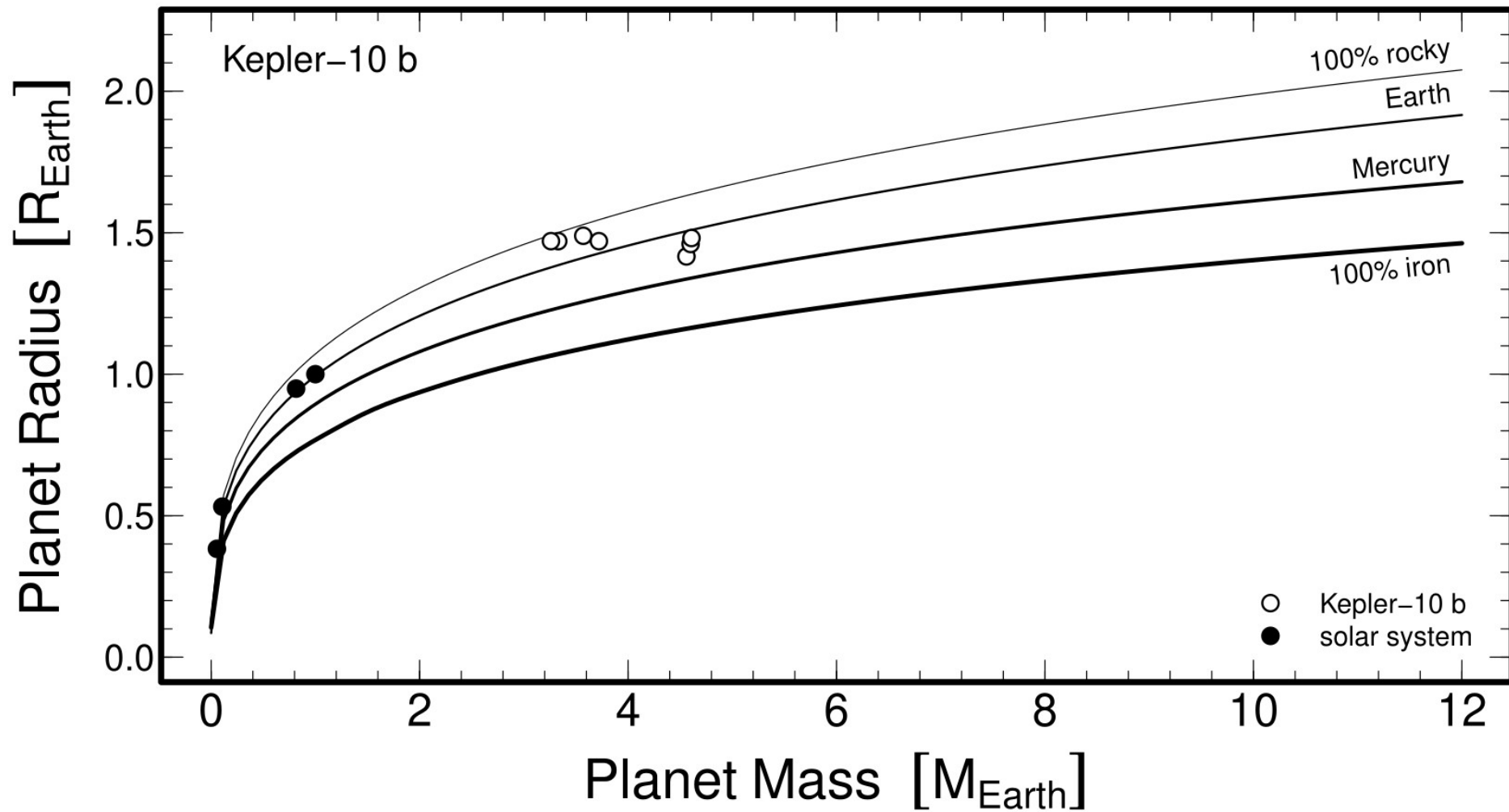
Terrestrial Mass—Radius Relation

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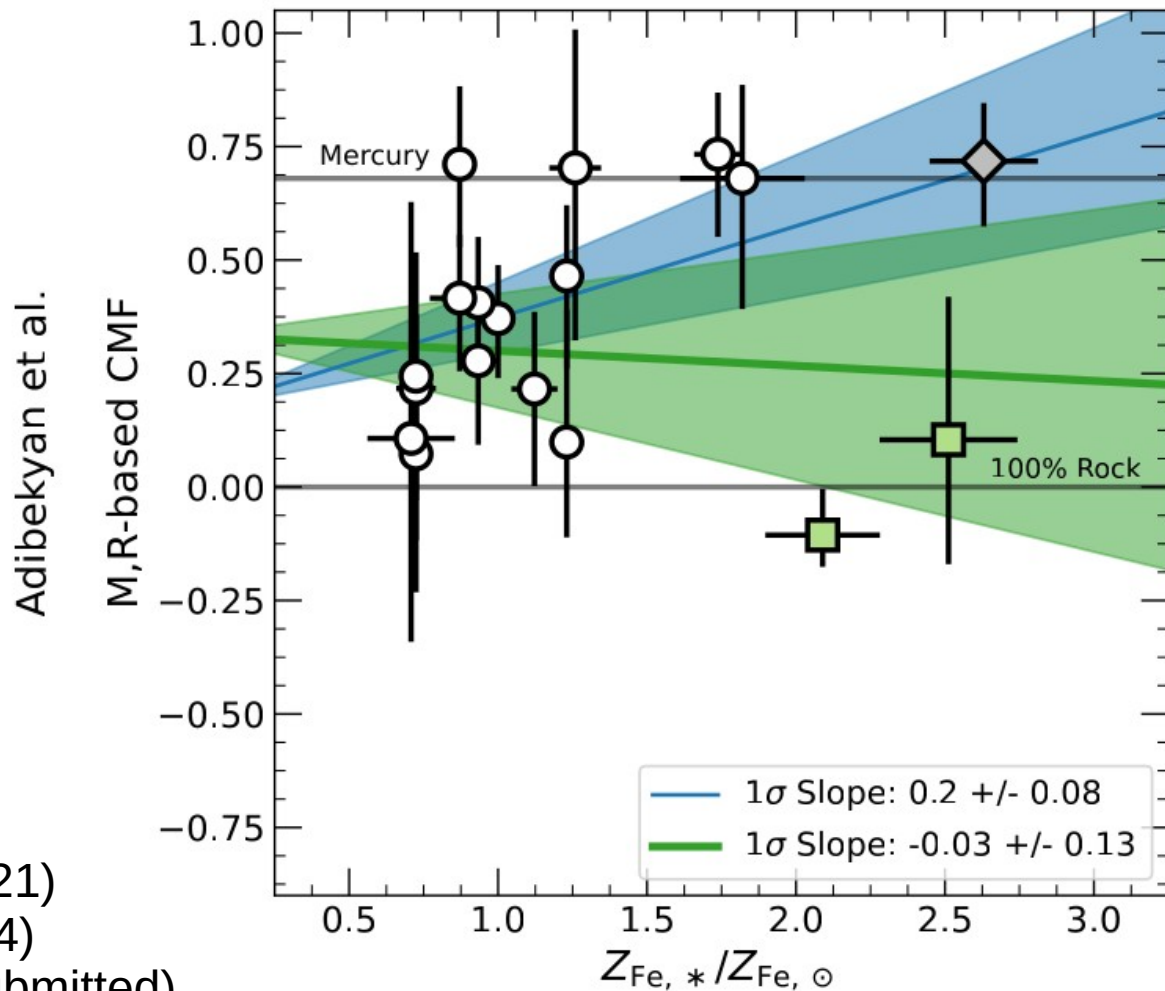
Terrestrial Mass—Radius Relation

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Z—Core Mass Fraction Relation?

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Adibekyan et al. (2021)

Brinkman et al. (2024)

Ross et al. (2025, submitted)

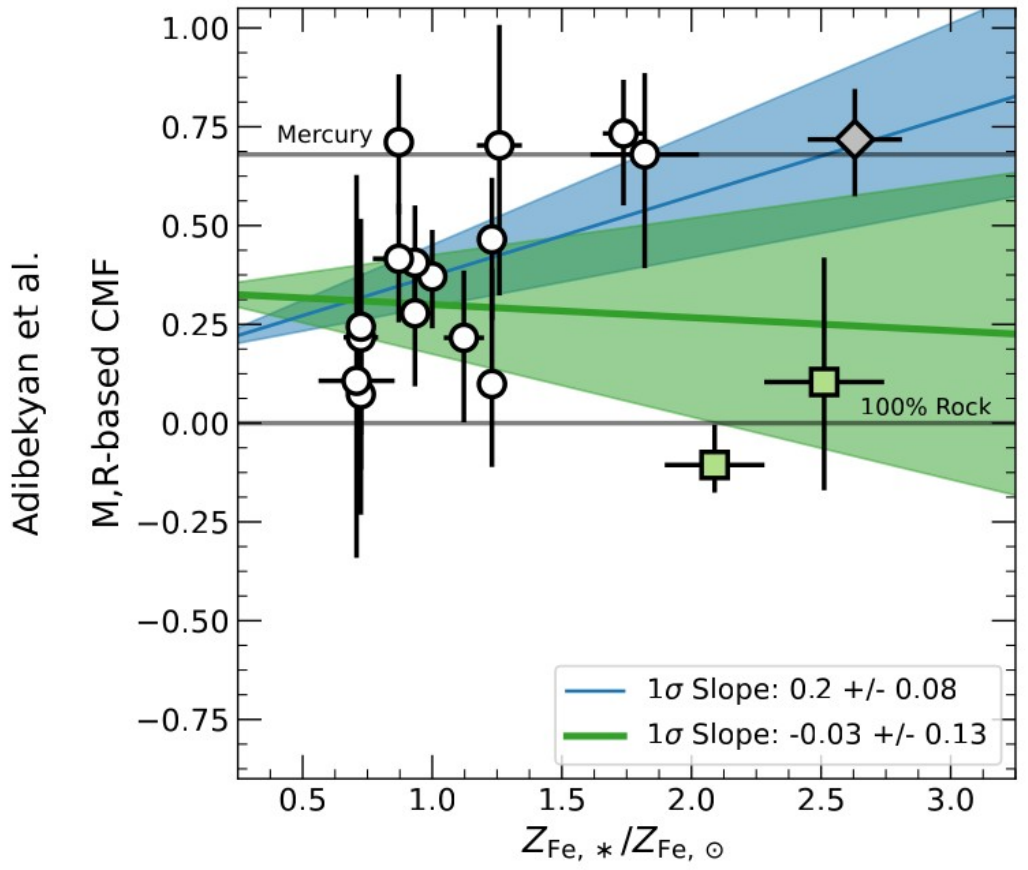
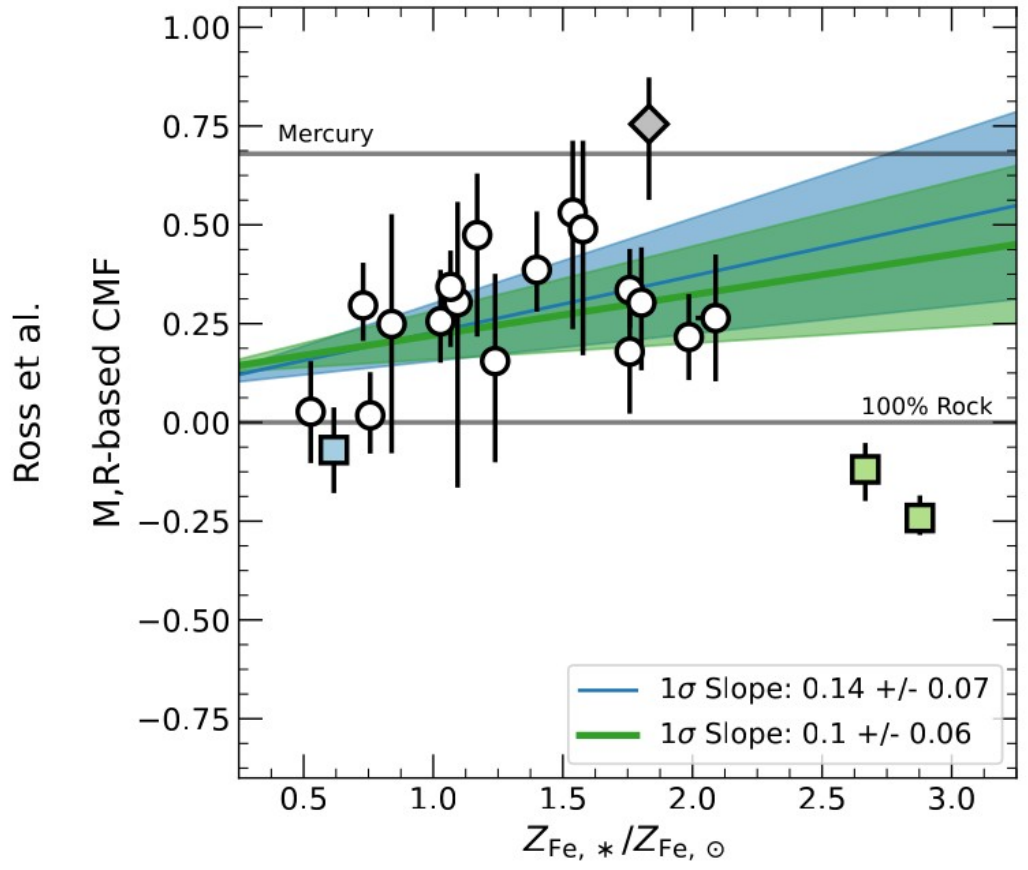
- (1) Infer photospheric (e.g., T_{eff} , $\log g$, $[\text{Fe}/\text{H}]$) and fundamental stellar parameters (e.g., age, mass, radius) by joint analysis of astrometry, photometry, and spectroscopy
- (2) Infer stellar abundances using photospheric stellar parameters
- (3) Infer planet parameters using fundamental stellar parameters to infer planet mass and radius using observables

Reggiani et al. (2022)

Ross et al. (2025, submitted)

Z—Core Mass Fraction Relation

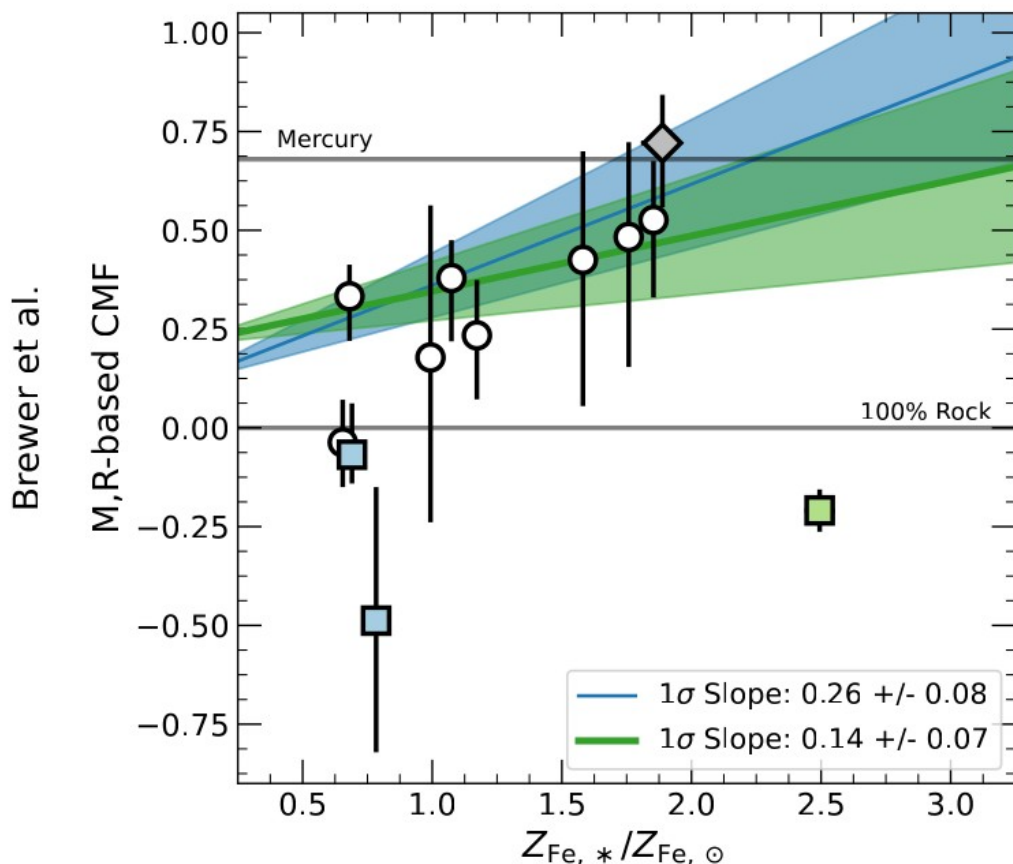
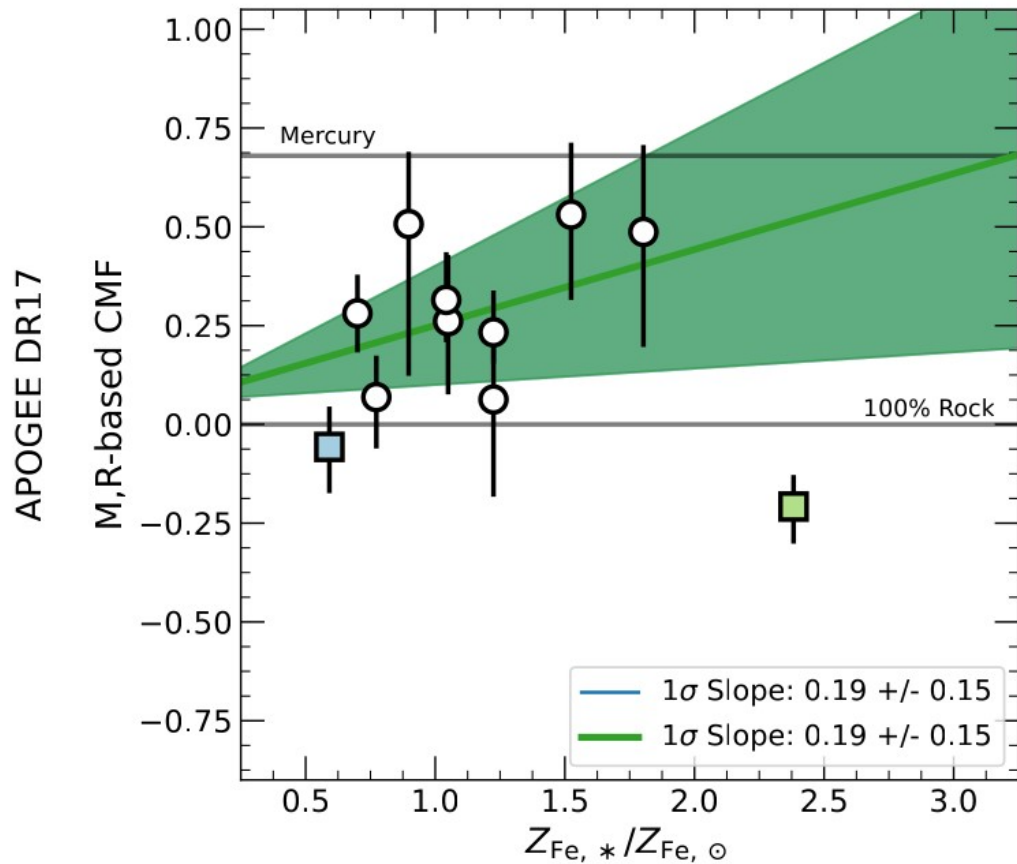
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Ross et al. (2025, submitted)

Z—Core Mass Fraction Relation

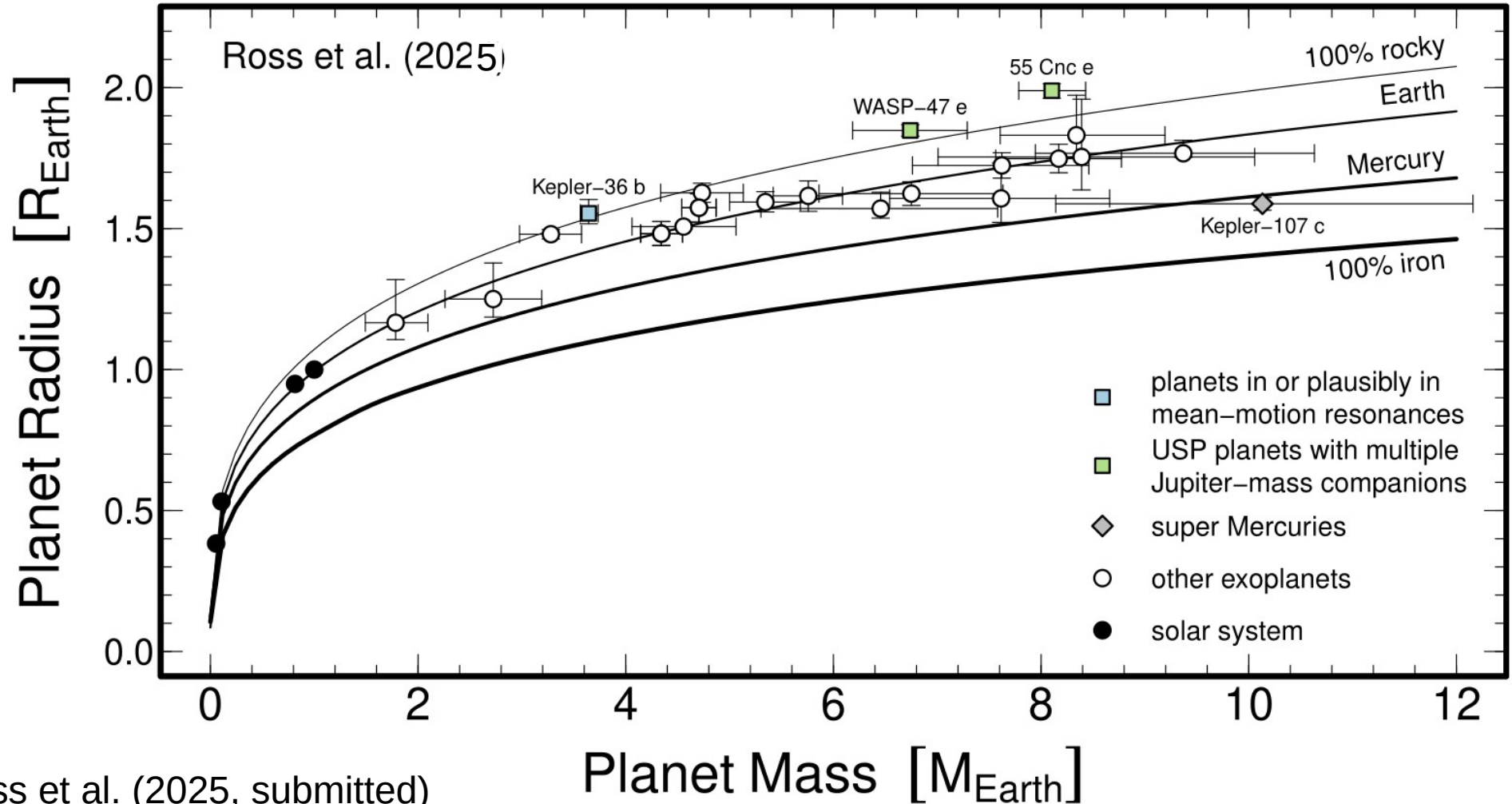
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Ross et al. (2025, submitted)

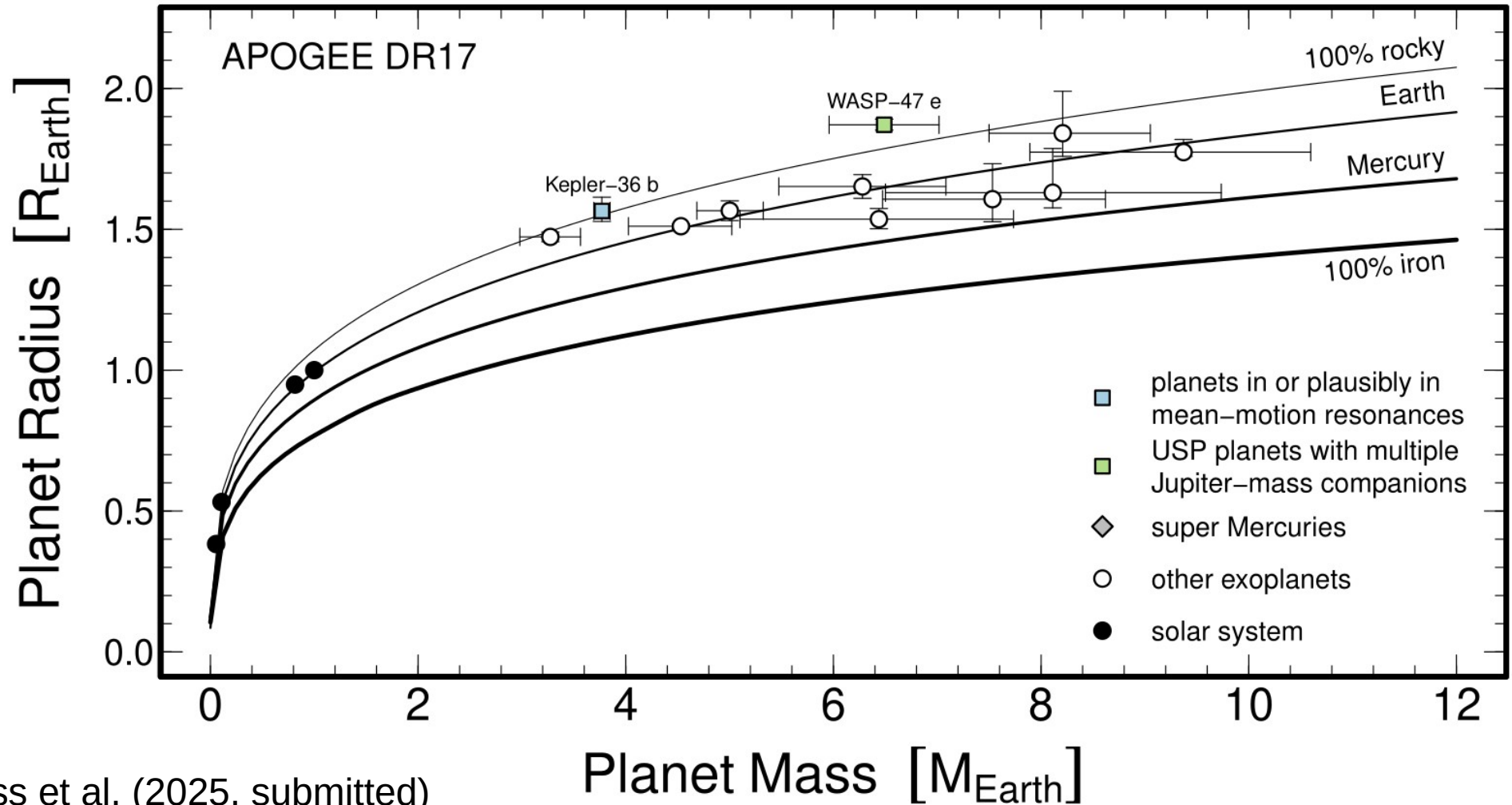
Mass—Radius Relation

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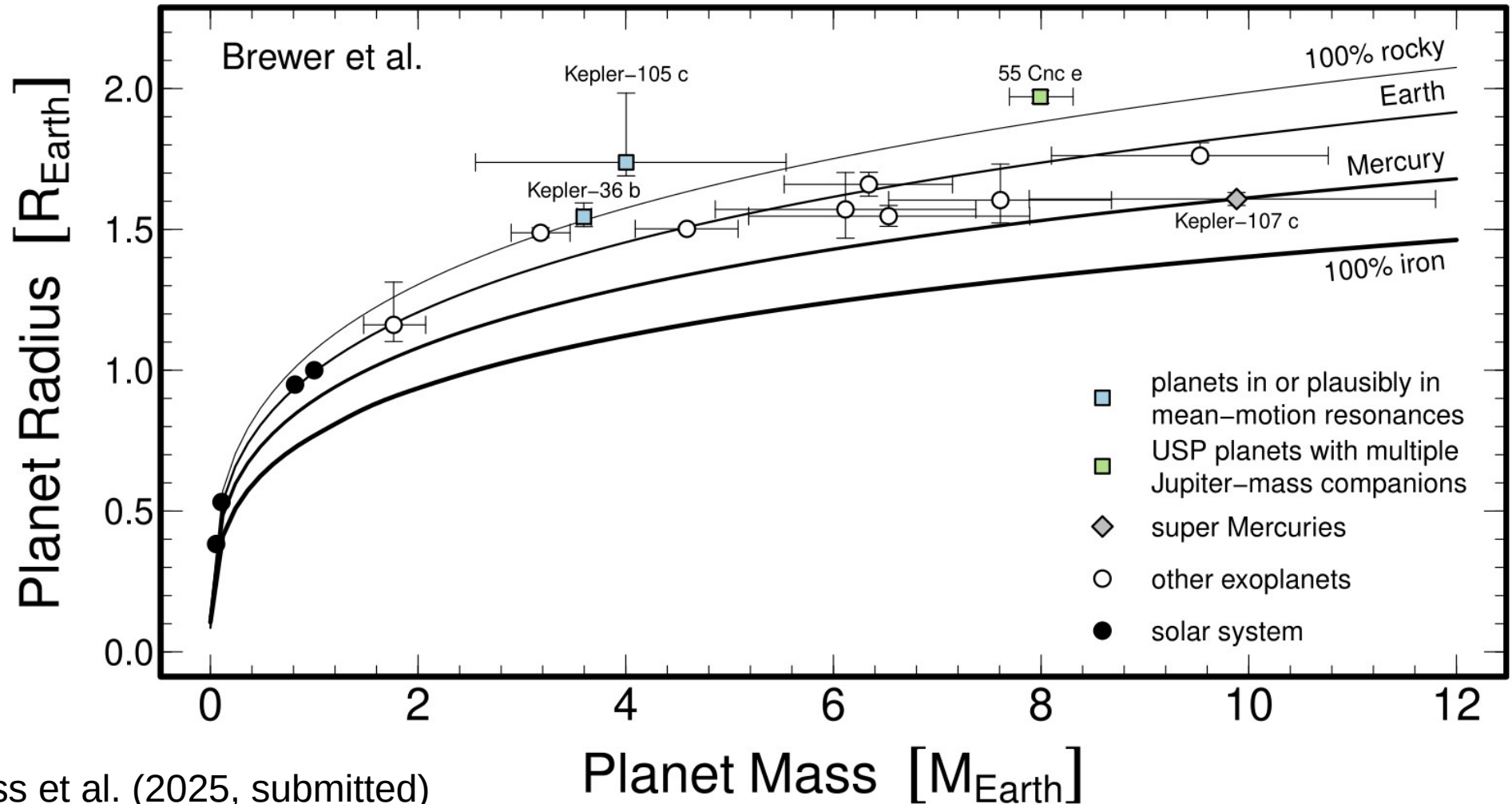
Mass—Radius Relation

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Mass—Radius Relation

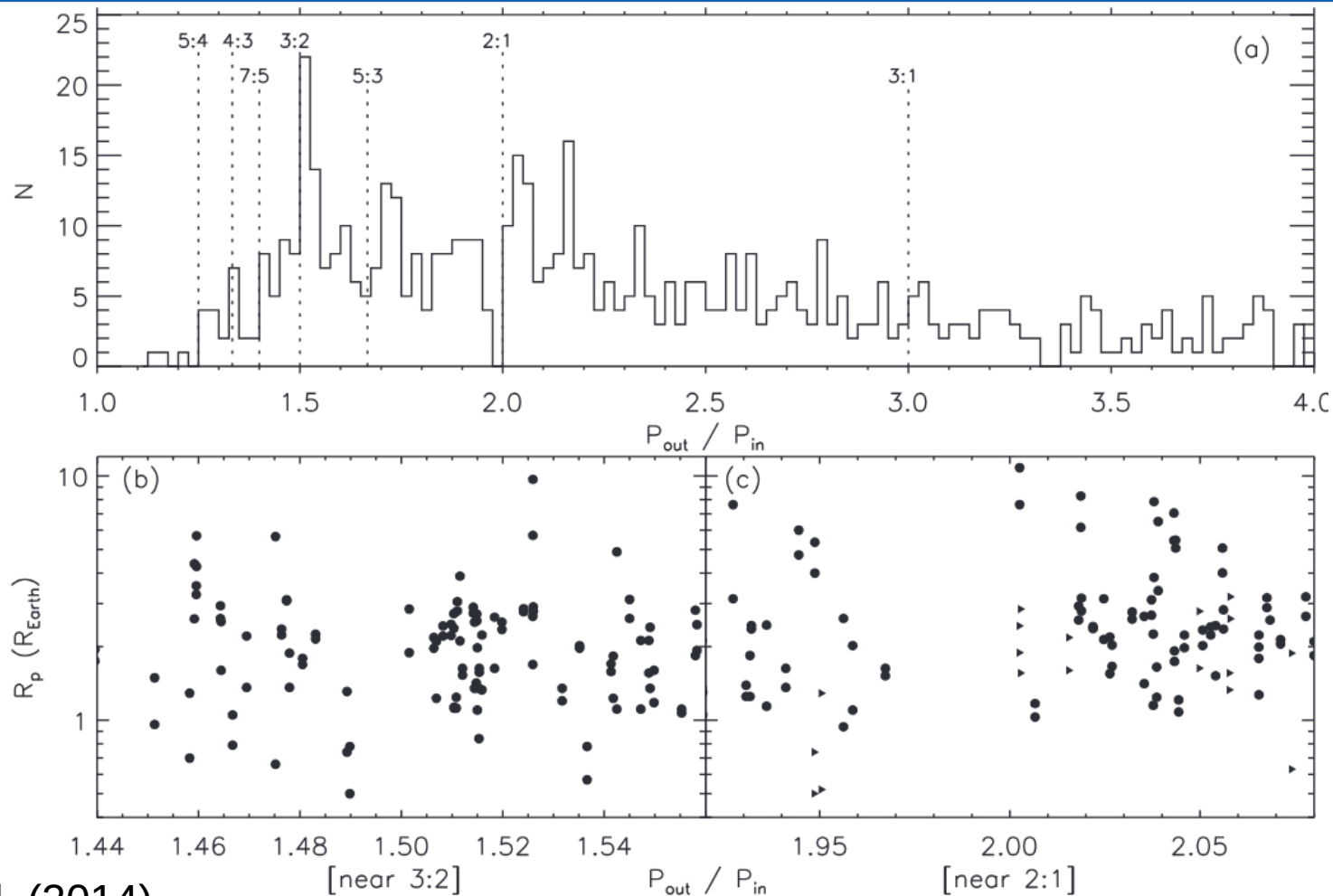
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Ross et al. (2025, submitted)

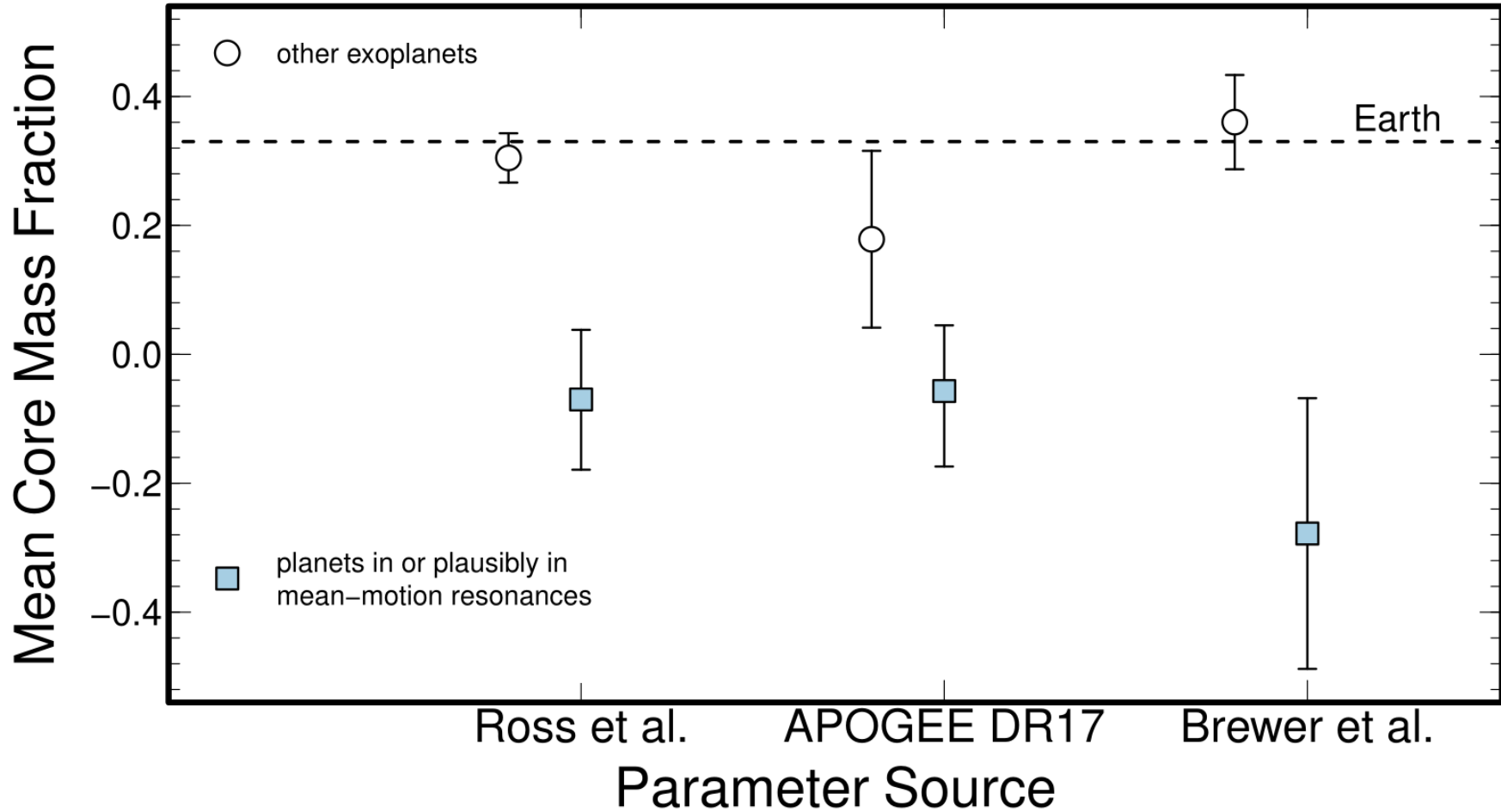
Mean-motion Resonant Planets

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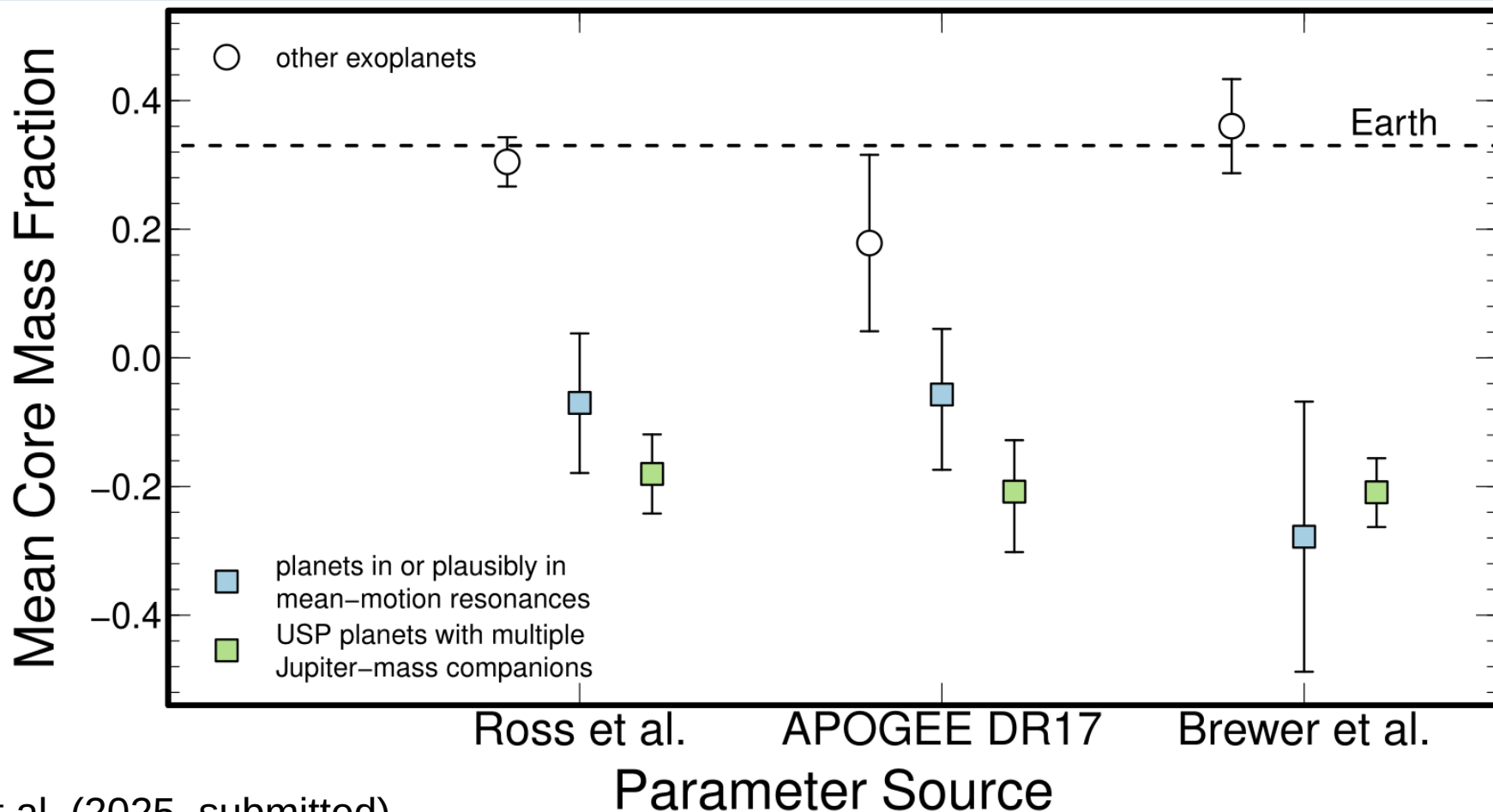
Resonant Planets are Water Rich

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55 Cnc e/WASP-47 e are Special

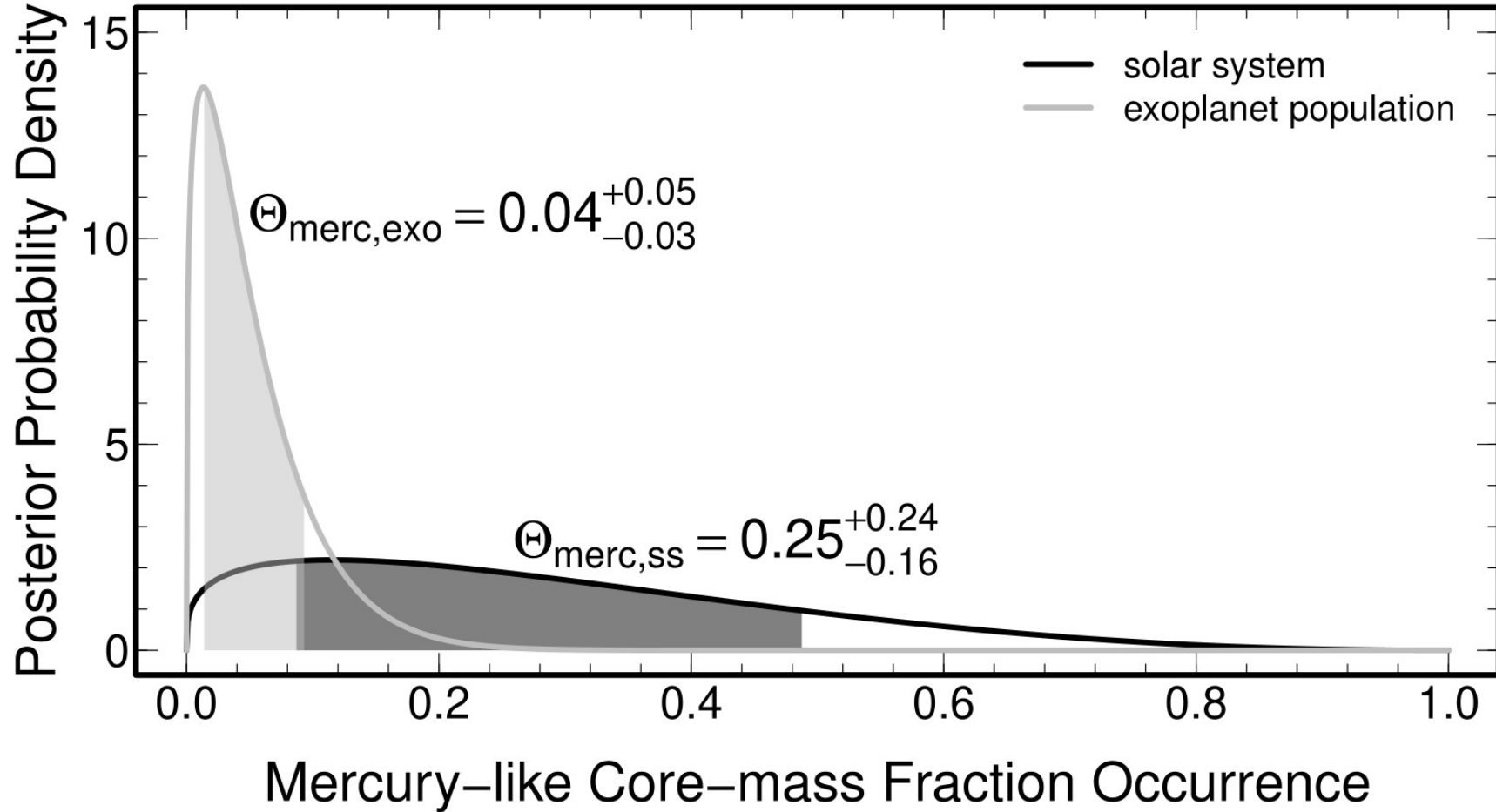
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Ross et al. (2025, submitted)
See also Hansen & Zink (2015)

Super-Mercury Occurrence

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- (1) The core masses of terrestrial planets increase with host star metallicity, and this effect is not a consequence of the existence of a distinct population of super-Mercuries.
- (2) Terrestrial exoplanets in mean-motion resonances are significantly less dense than the rest of the terrestrial exoplanet population. We propose that they are water-rich planets that experienced long-distance Type I migration.
- (3) 55 Cnc e/WASP-47 e are significantly less dense than the rest of the terrestrial exoplanet population. We propose that they were the cores of now tidally disrupted mini-Neptunes.
- (4) These conclusions are robust to stellar parameter inference approach.