

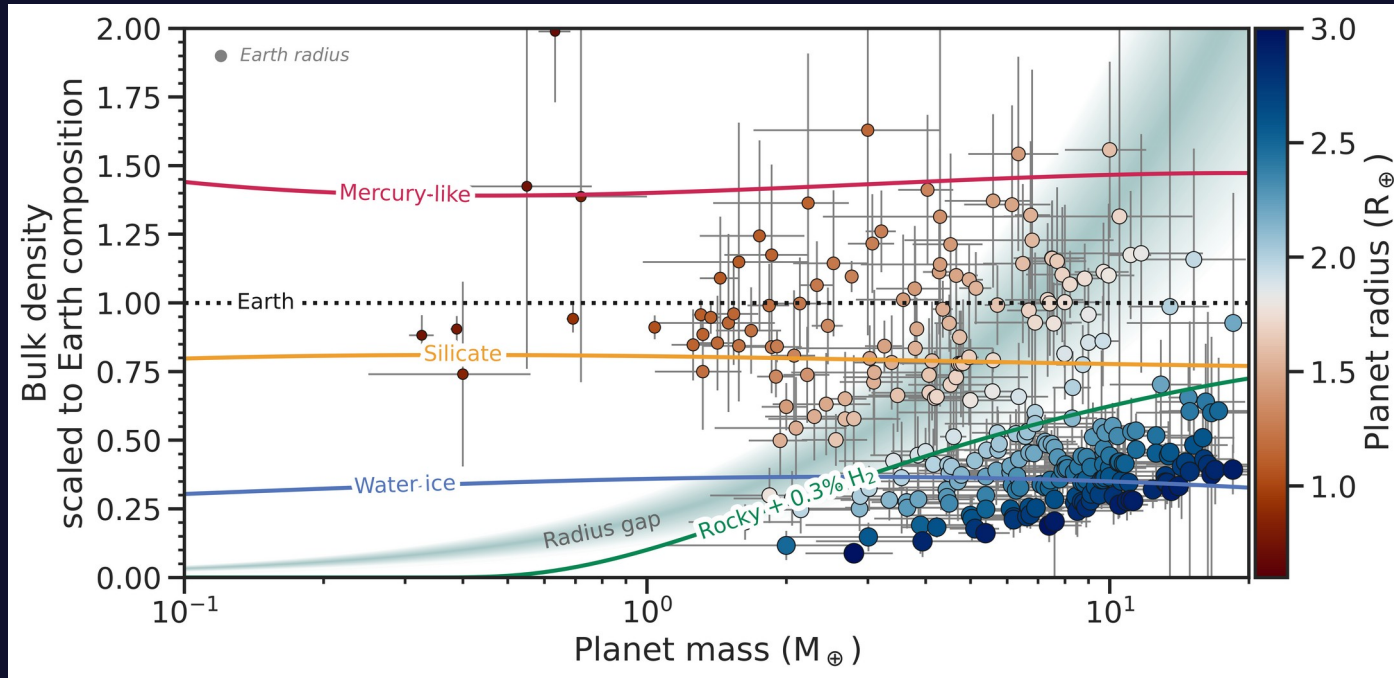
Machine-learning retrievals of rocky exoplanet interiors

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Layers of Understanding 2026

Rocky planets are diverse



Baumeister, Miozzi et al. (2025)

Interior retrieval

Inverse problem

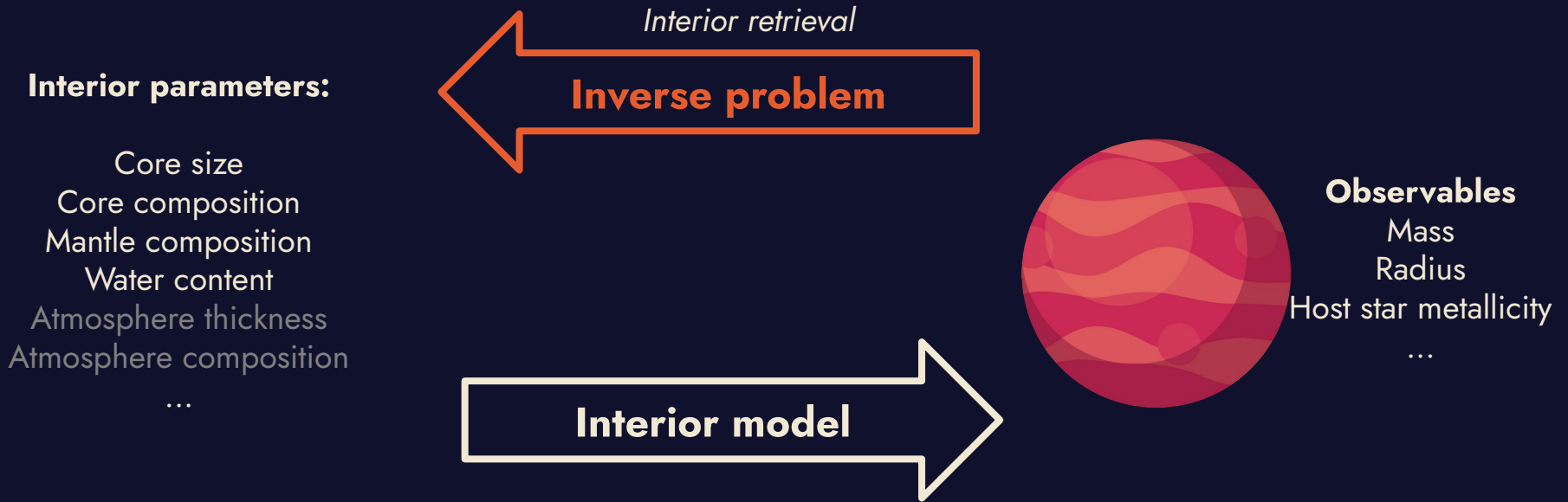
Interior parameters:

- Core size
- Core composition
- Mantle composition
- Water content
- Atmosphere thickness
- Atmosphere composition
- ...



Observables

- Mass
- Radius
- Host star metallicity
- ...

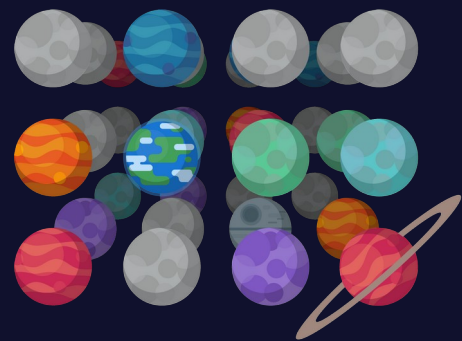


Dorn et al., 2017
10⁵ models at 40–90s per model

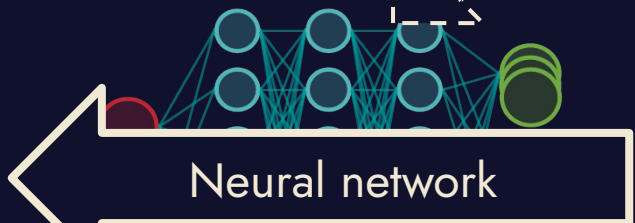
Haldemann et al., 2023
12 hours (28 CPUs)
8.7 days (1 CPU)

Interior parameters:

- Core size
- Core composition
- Mantle composition
- Water content
- Atmosphere thickness
- Atmosphere composition
- ...



Database of random planets with diverse interior structures



EXO-MDN

Baumeister and Tosi (2023)



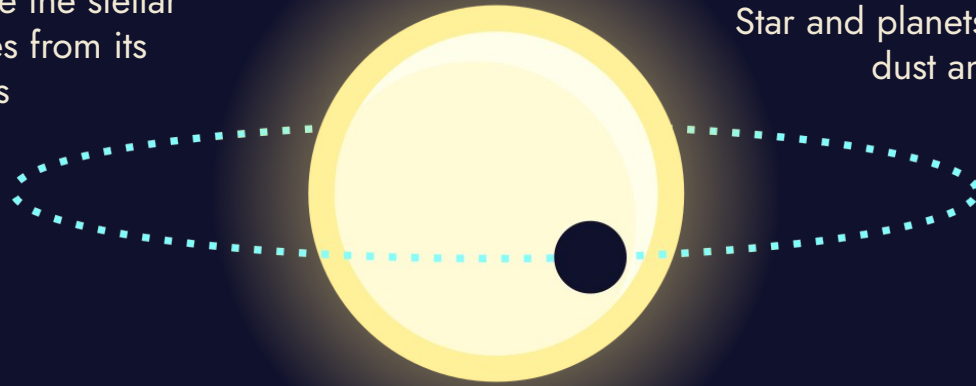
Observables

- Mass
- Radius
- Density
- ...

Using stellar composition as a proxy for planet composition

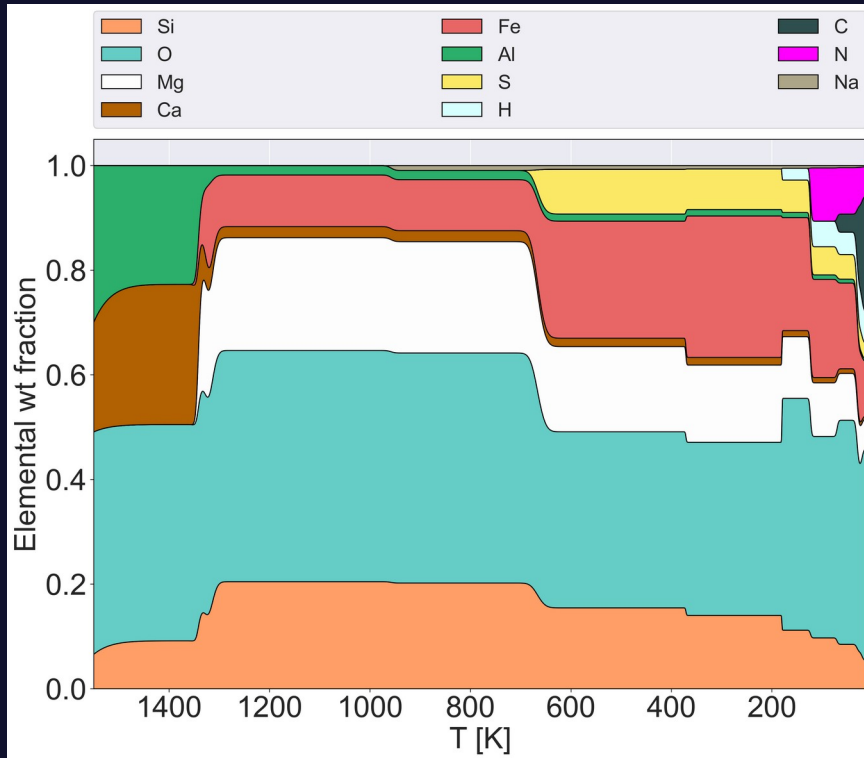
We can directly observe the stellar elemental abundances from its spectral lines

Star and planets form from the same dust and gas cloud



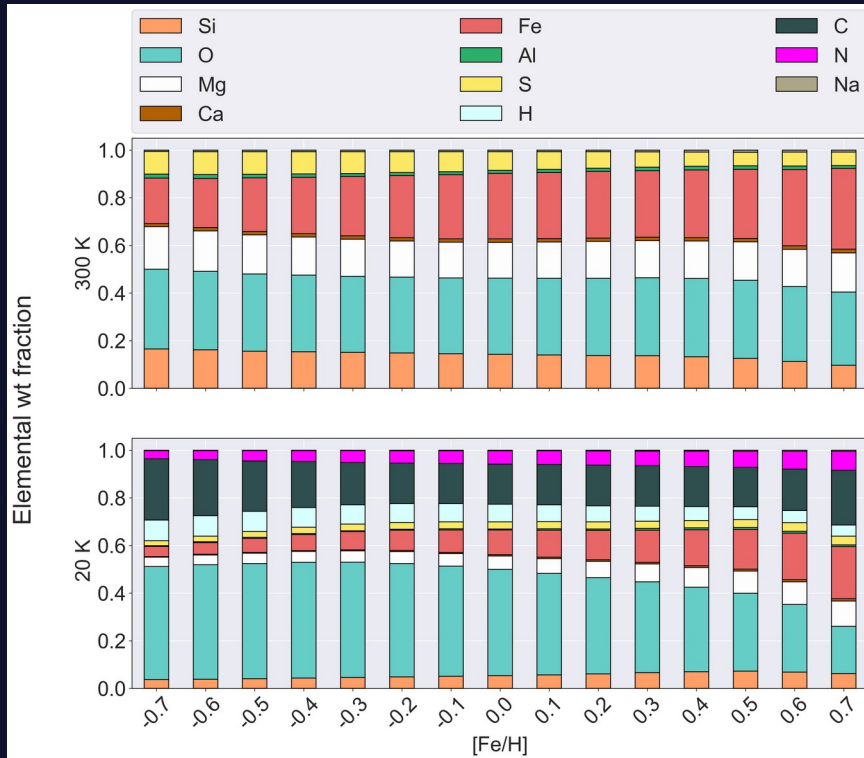
Main rock-forming elements (Mg, Fe, Si, Al, Ca) condense early

Rocky abundance should be mostly unaltered from the stellar abundances



Baumeister, Miozzi et al. (2025)

Composition of planet building blocks depends on their formation location in the protoplanetary disk...



Baumeister, Miozzi et al. (2025)

...and on the metallicity of the
protoplanetary disk



Zahra Ali

Observables:

Planet mass
Planet radius

Stellar mass
Stellar radius
Stellar metallicity [Fe/H]

Orbital distance



Predicted interior parameters:

Core mass/thickness
Mantle mass/thickness
Water mass/thickness

Mantle Mg#
 $Mg/(Mg + Fe)$

Fraction of FeS in core



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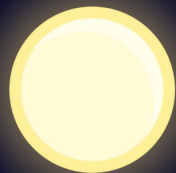
Mantle Mg#
 $Mg/(Mg + Fe)$

Fraction of FeS in core

Mixture Density Network
predicts multimodal probability distributions
instead of discrete values

Generating training data

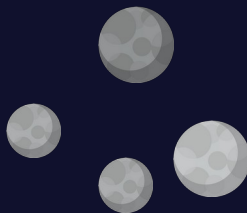
Generate star



- Randomized stellar mass
- Randomized metallicity
- Stellar radius from M-R scalings with random perturbation



Set composition of planet-building blocks



- Randomized equilibrium temperature
- Orbital distance from host star luminosity
- Determine composition via condensation sequence



Calculate planet structure

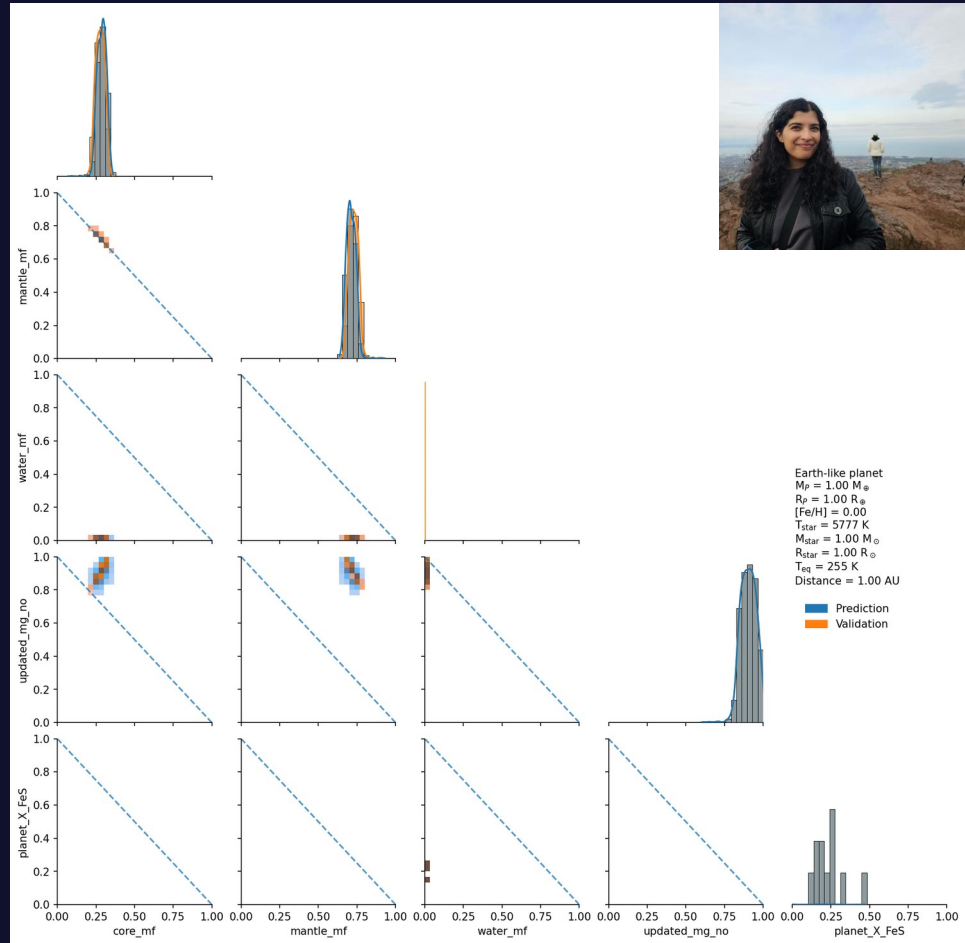


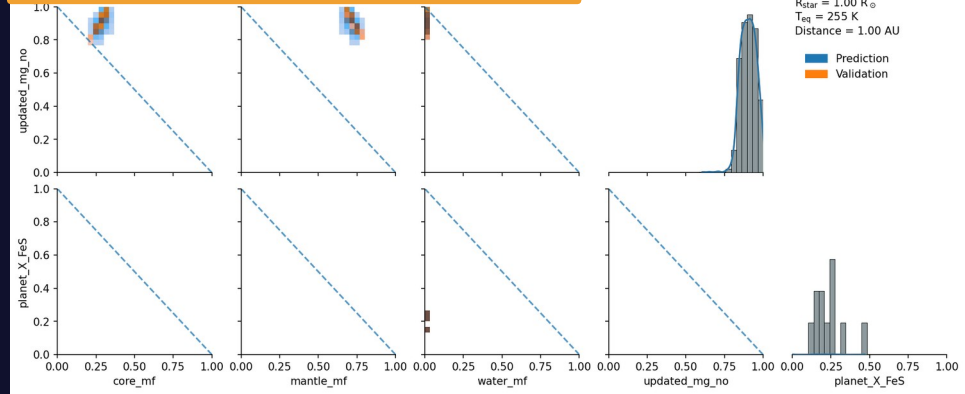
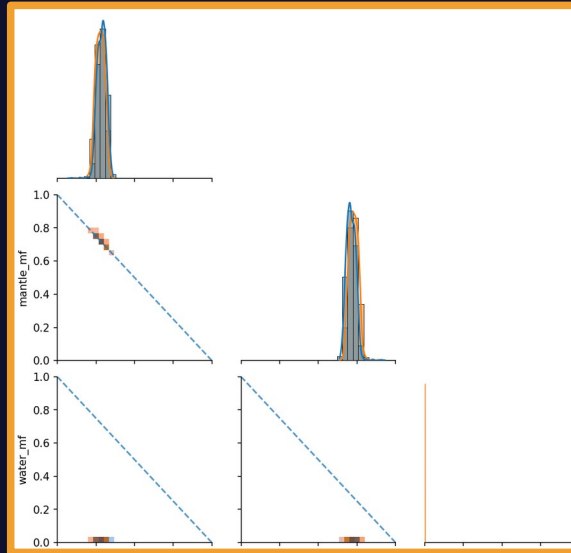
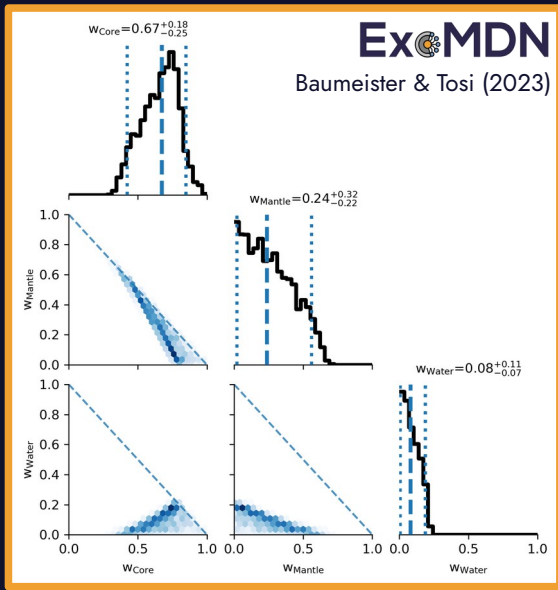
- Randomized planet mass
- Randomized Mg#
- Randomized amount of light elements in core
- Randomized amount of water retained from formation
- Planet radius, core size, and core mass computed with ROWS code (Noack & Lasbleis 2020)

Earth as an exoplanet

Core mass and Mg# are well predicted

Larger uncertainties for core FeS

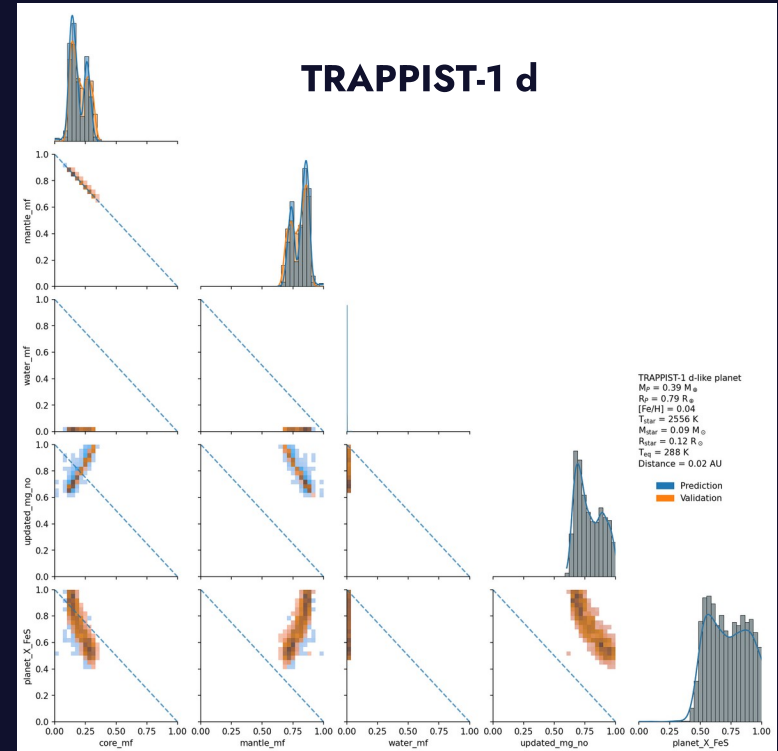
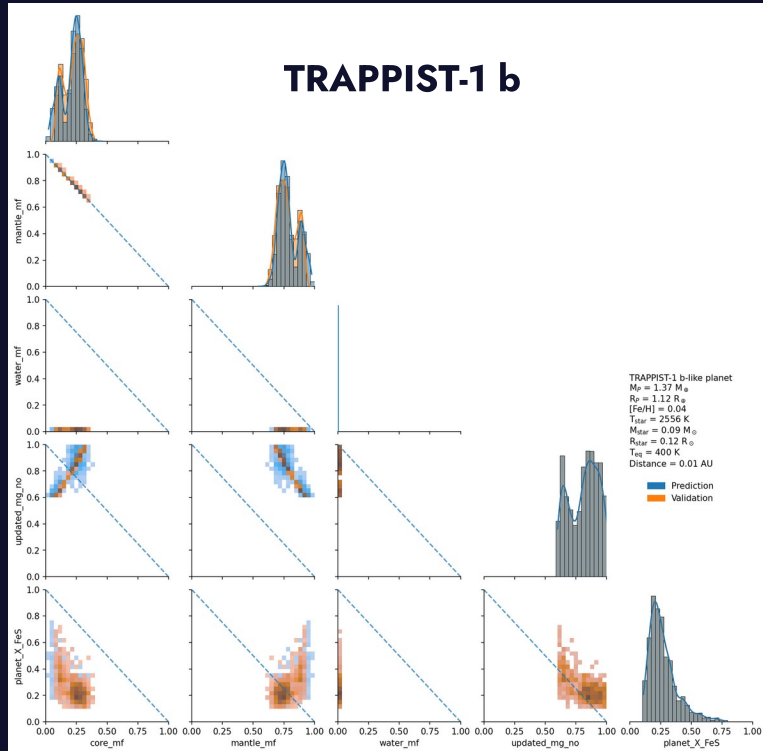




General model from Baumeister & Tosi (2023)

Host star metallicity gives significantly better constraints on core size

TRAPPIST-1 planets show interesting difference in predicted core FeS



Conclusion

- We developed a machine-learning retrieval model tailored to rocky planets
- The model allows instant retrievals of interior parameters based on mass, radius, orbit, and host star properties
- Host star metallicity allows to well constrain the core mass of rocky planets
- *Next: Statistical studies on rocky planet populations*

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Thank you!