Planetary Interiors and Magnetic Fields: State of the Field and Open Questions

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Main Takeaway Points

• The observed properties of exoplanets show a wide range of diversity.

• Inferences about exoplanet interiors from current observations are fraught with degeneracies.

• Measurements of exoplanet magnetic fields would yield additional constraints on interior models.
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Planets Detected both Dynamically and in Transit are Valuable!

Stellar Wobble

Transits

Planet Mass

Planet Radius

Planet Density
Planet Mass-Radius Diagram

Seager et al. (2007) M-R Relations
Adding Incident Flux Dimension

Seager et al. (2007) M-R Relations
Seager et al. (2007) M-R Relations
Planet Mass-Radius Diagram

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Model Overview

\[
\frac{dr}{dm} = \frac{1}{4\pi r^2 \rho}
\]

\[
\frac{dP}{dm} = -\frac{Gm}{4\pi r^4}
\]

\[
\frac{d\tau}{dm} = \frac{\kappa}{4\pi r^2}
\]

\[
\rho = \rho(P, T)
\]
Planet Mass-Radius Diagram

GJ 1214b

- $M_p = 6.6 \, M_\oplus$
- $R_p = 2.7 \, R_\oplus$
- $\rho_p = 1870 \, \text{kg m}^{-3}$
- $P_{\text{orb}} = 1.6 \, \text{days}$
- $T_{\text{eq}} = 550 \, \text{K}$

Seager et al. (2007) M-R Relations
Three Possible Composition Scenarios

**Case I: Gas & Ice & Rock**

- Gas layer dominated by H/He from the nebula
- Smaller H/He envelope than Neptune (in proportion to planet mass).
- Requires $10^{-4}$ to 6.8% H/He by mass

**Mini Neptune Scenario**

**Case II: Ice & Rock only**

- Gas layer dominated by sublimated vapor
- Phases in the envelope: vapor-superfluid-plasma
- Requires at least 47% H$_2$O by mass

**Water Planet Scenario**

**Case III: Rock only**

- Gas layer dominated by outgassing
- Outgassed atmosphere must be hydrogen-rich (like that outgassed by ordinary H, L, LL and high iron enstatite EH chondrites).

**Rocky Super Earth**

Rogers & Seager (2010b)
GJ1214b Transmission Spectroscopy
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\[ H_R = \frac{kT}{m_{ave}g} \]
GJ1214b Transmission Spectroscopy

Berta et al. (2012)
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Water Phase Diagram

French et al. (2009)
Chau et al. (2010)
Fig Credit: Tian & Stanley (2013)
Thickness of Potential Dynamo Generating Layer
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