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.
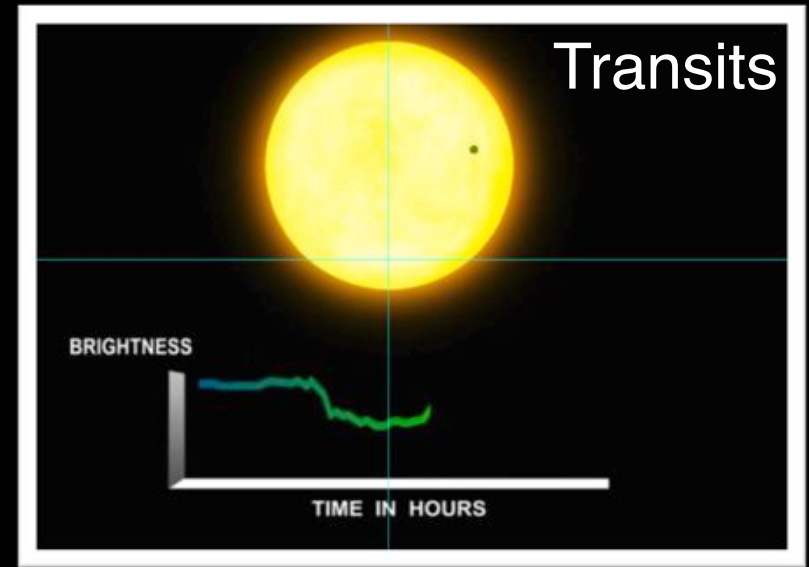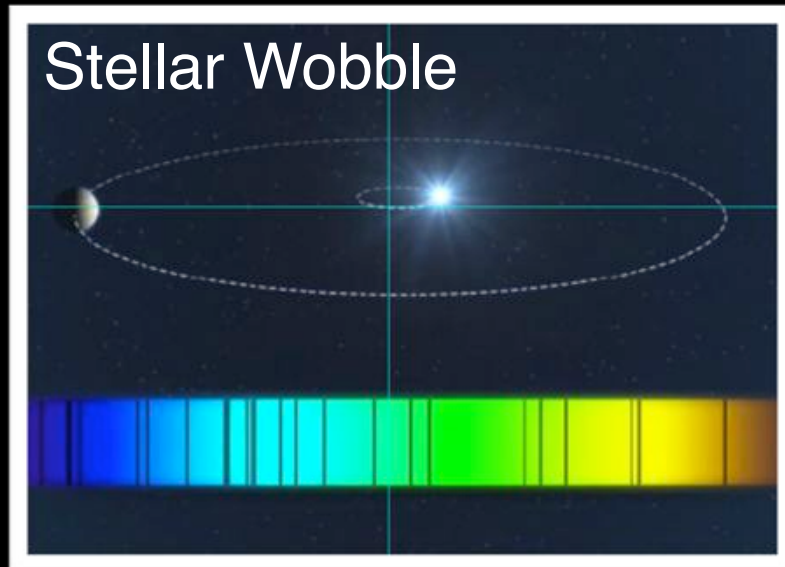
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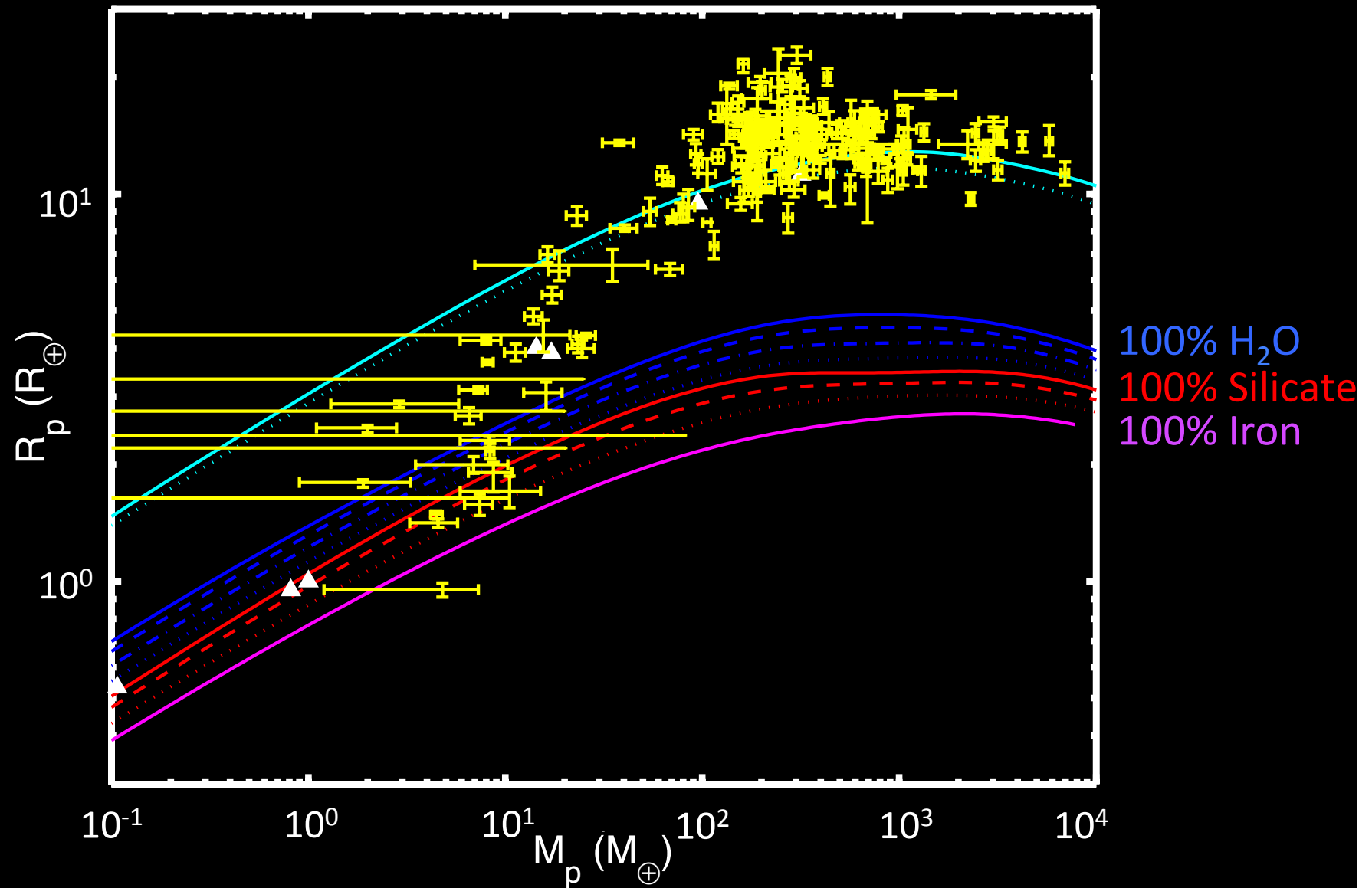# Planets Detected both Dynamically and in Transit are Valuable!

Stellar Wobble

Transits

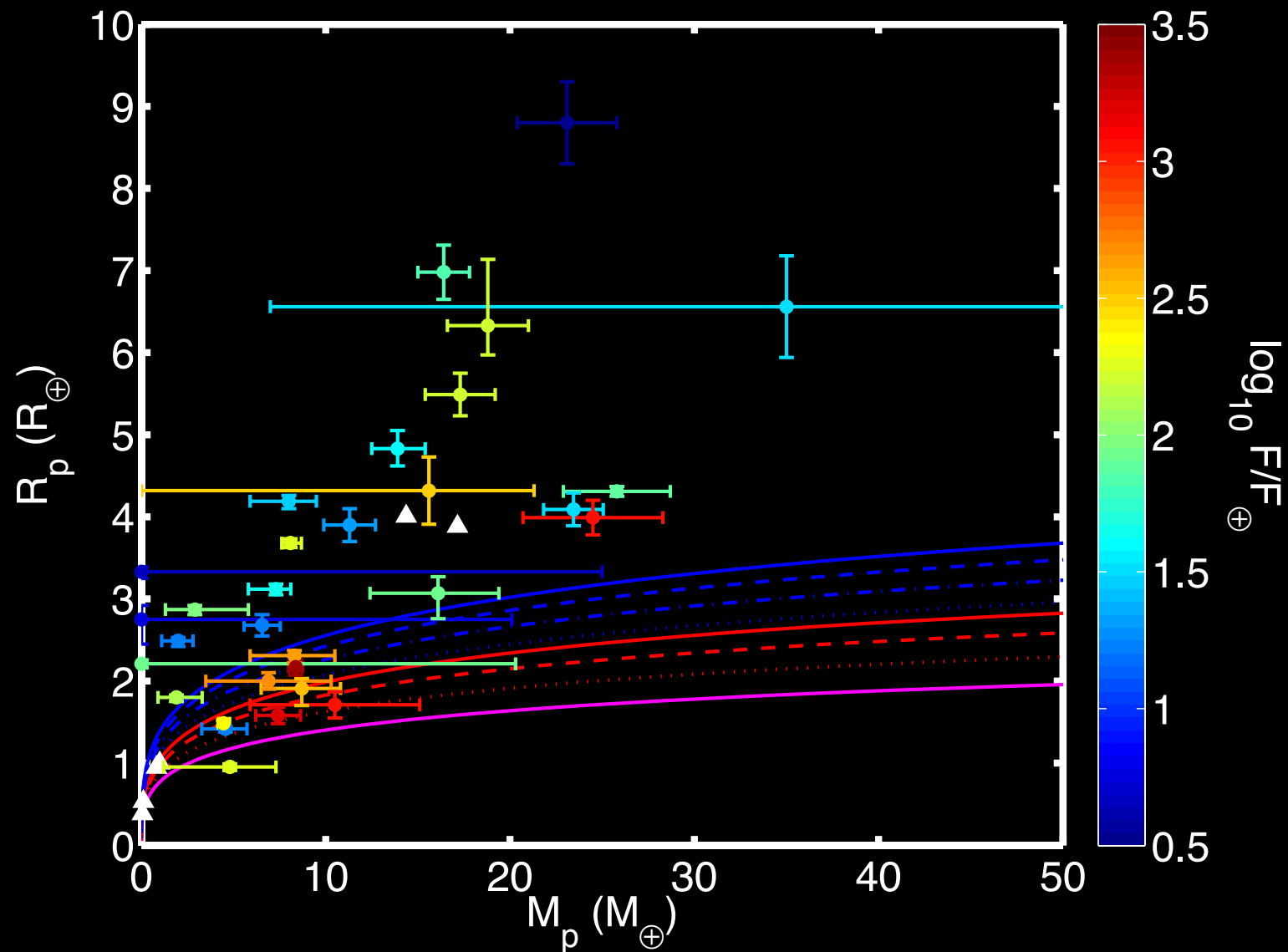BRIGHTNESS

TIME IN HOURS

Planet Mass

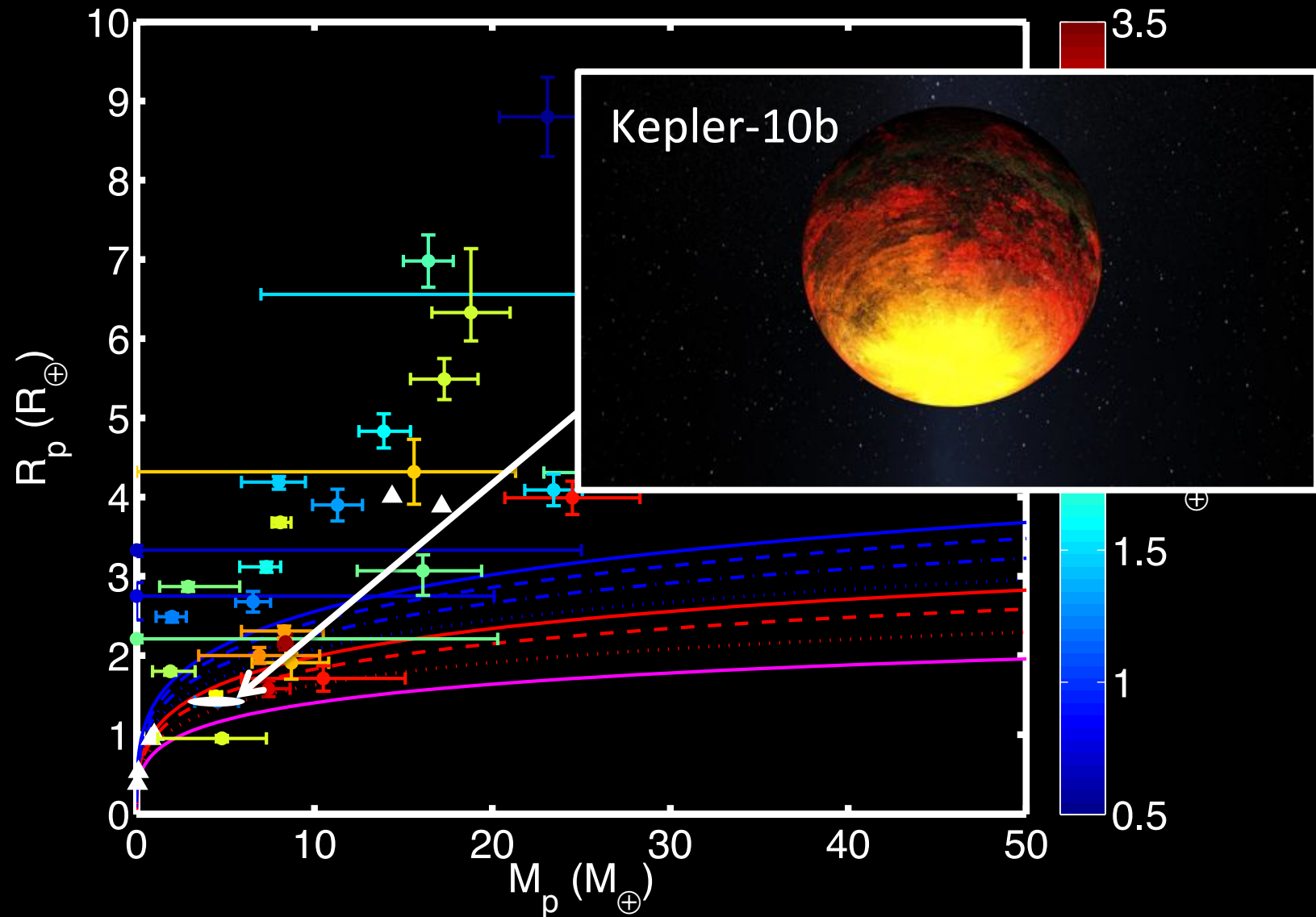Planet Radius

Planet Density

Planet Mass-Radius Diagram

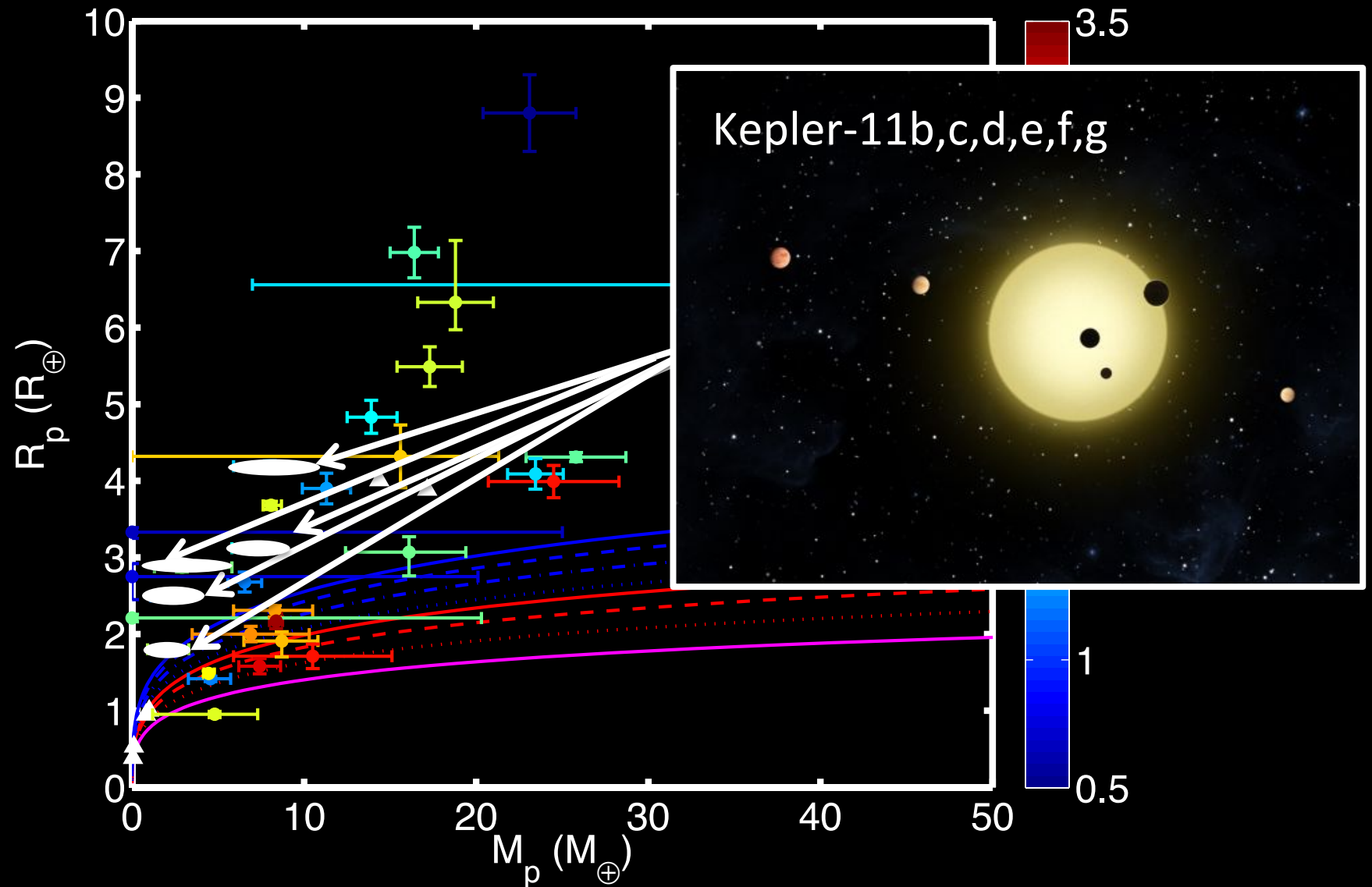Seager et al. (2007) M-R Relations

Adding Incident Flux Dimension

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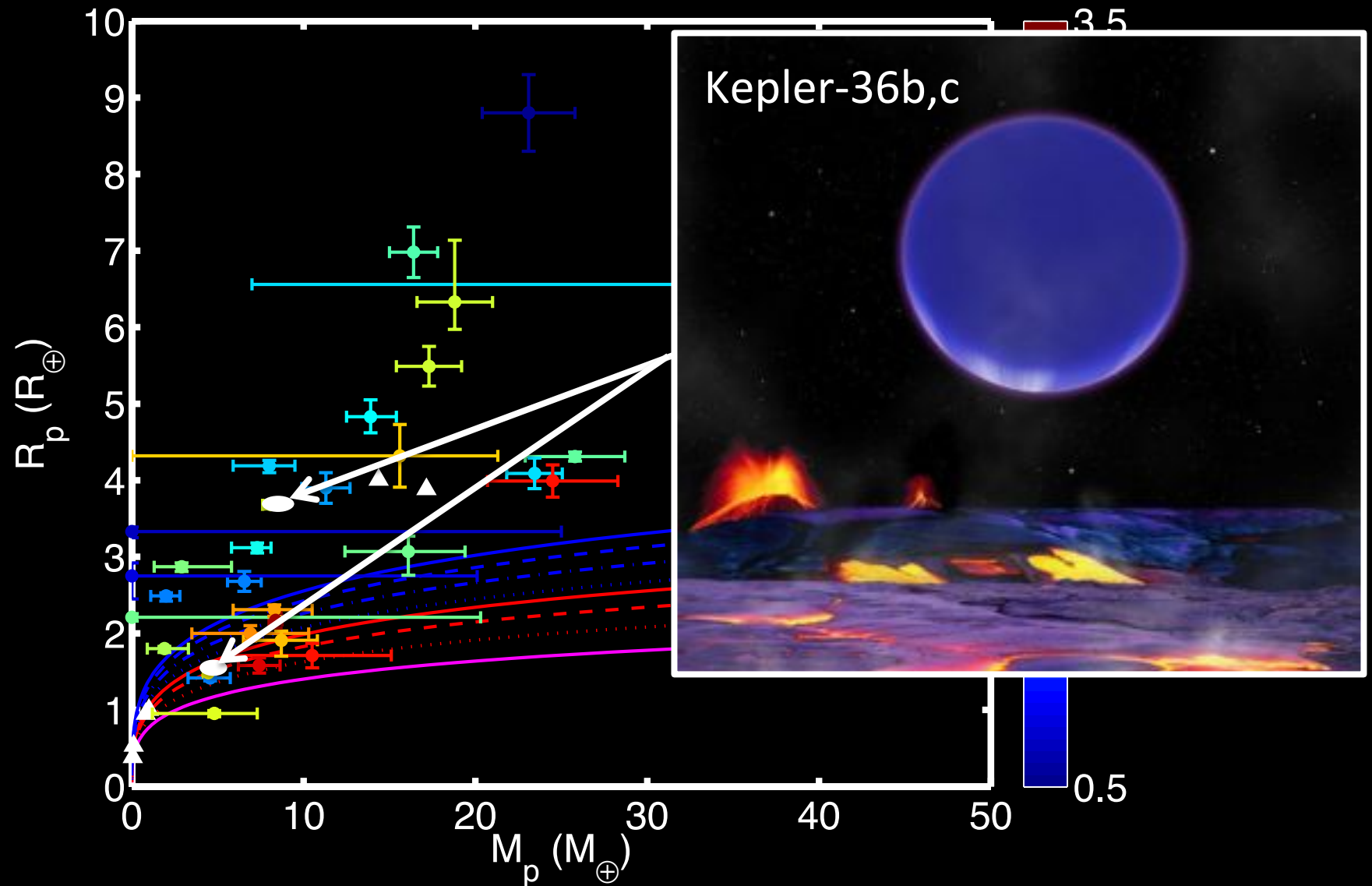
Planet Mass-Radius Diagram

Kepler-10b

R_p ($R_\oplus$)

M_p ($M_\oplus$)

Seager et al. (2007) M-R Relations

Planet Mass-Radius Diagram

Kepler-11b,c,d,e,f,g

Seager et al. (2007) M-R Relations

Planet Mass-Radius Diagram

Kepler-36b,c

R_p ($R_\oplus$)

M_p ($M_\oplus$)

Seager et al. (2007) M-R Relations

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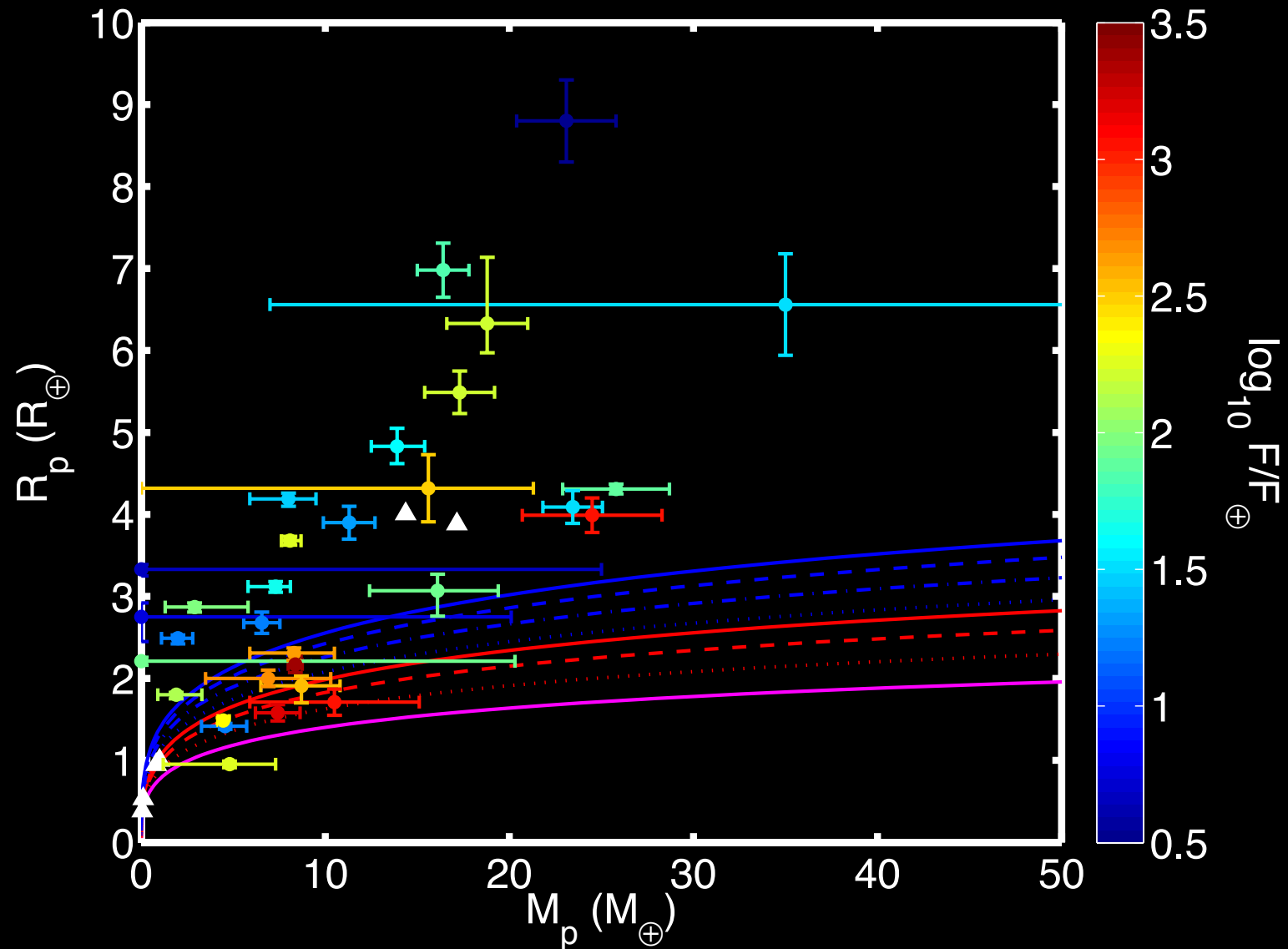
Seager et al. (2007) M-R Relations

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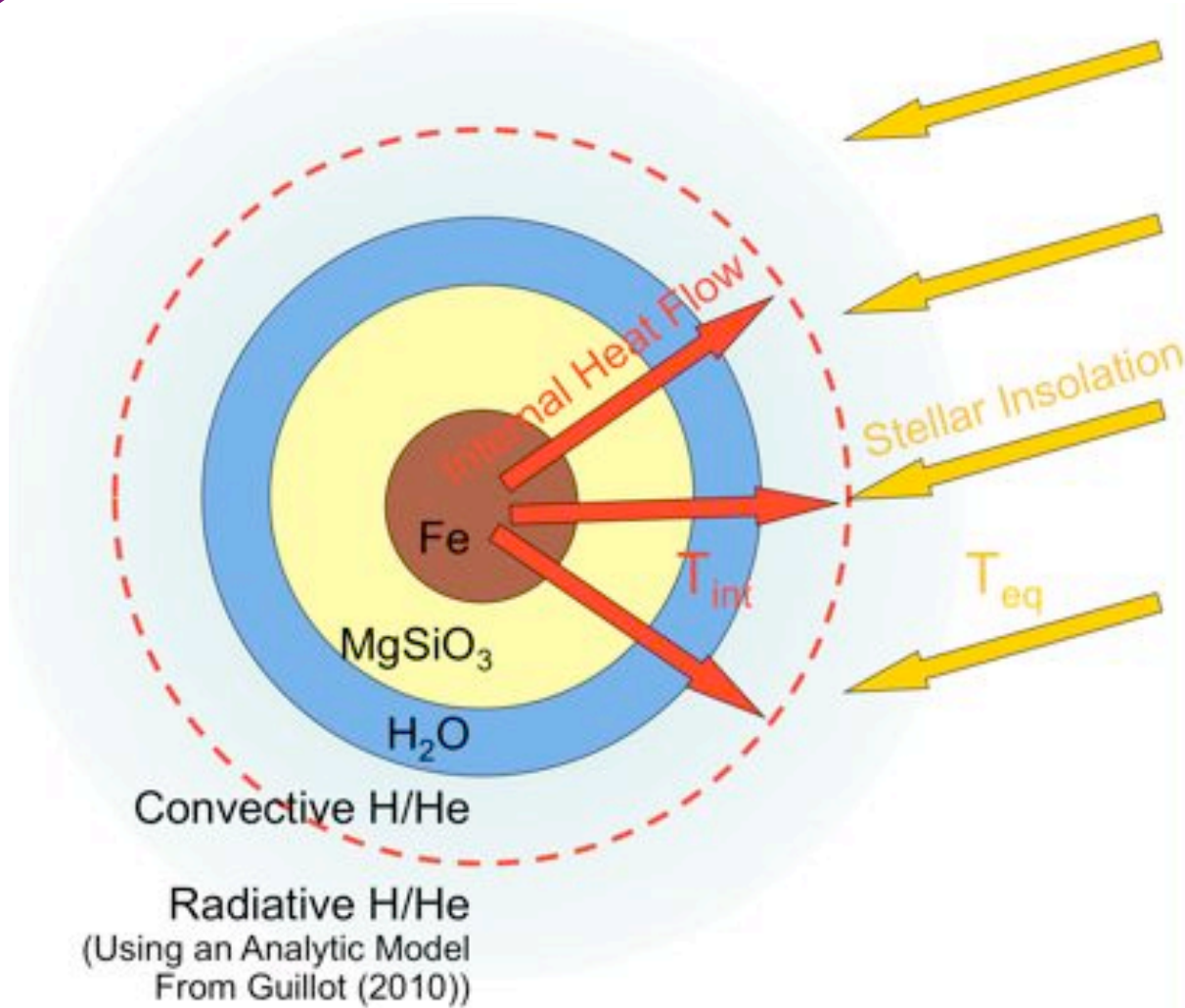- The observed properties of exoplanets show a wide range of diversity.

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Model Overview

Internal Heat Flow

Stellar Insolation

Fe

MgSiO$_3$

H$_2$O

T_{int}

T_{eq}

Convective H/He

Radiative H/He
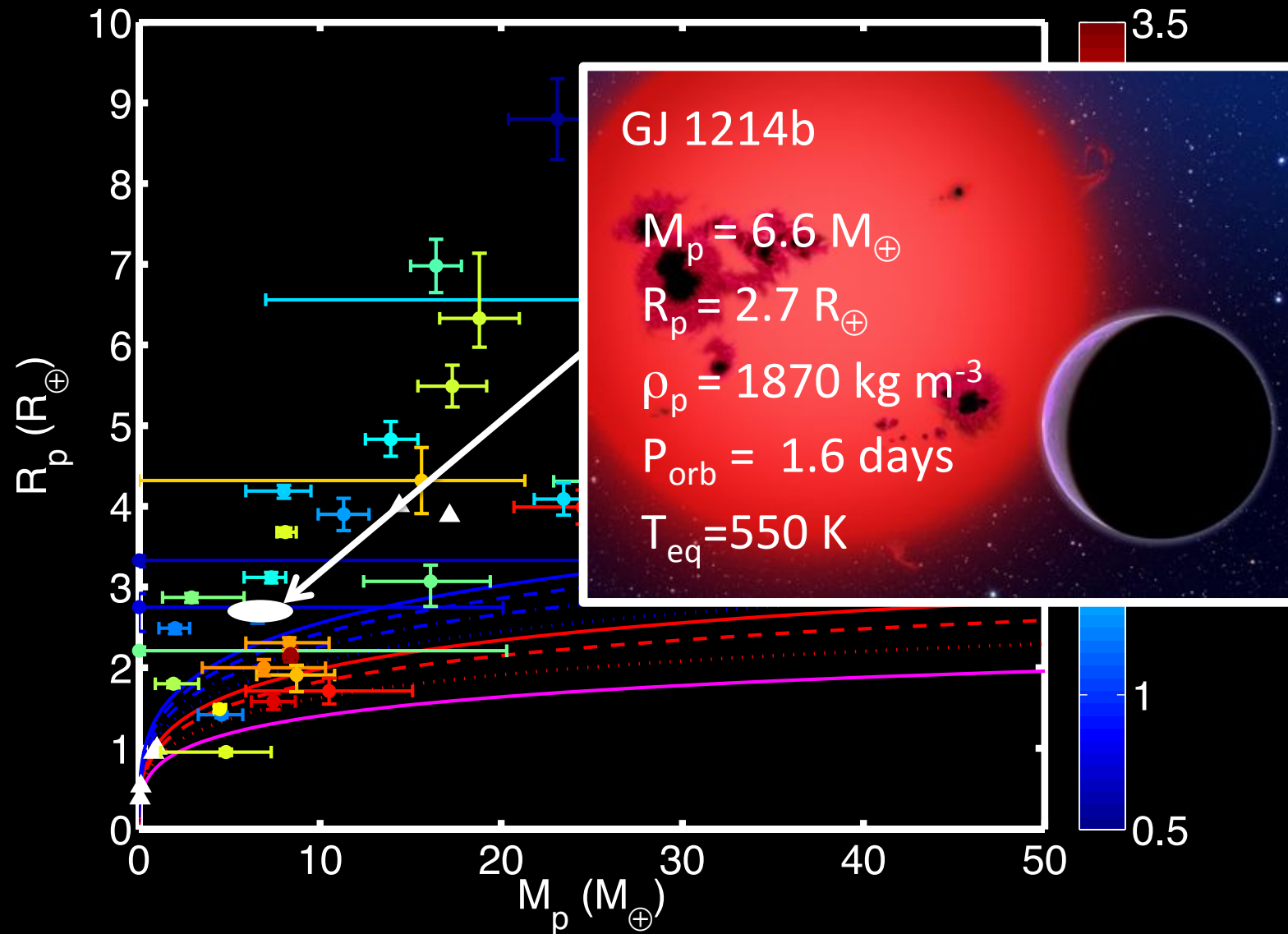(Using an Analytic Model
From Guillot (2010))

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

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

$$\frac{d\tau}{dm} = \frac{\kappa}{4\pi r^2}$$
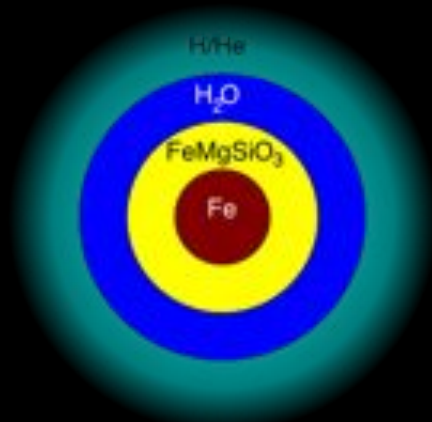
$$\rho = \rho(P, T)$$

Planet Mass-Radius Diagram

GJ 1214b

$M_p = 6.6\ M_\oplus$

$R_p = 2.7\ R_\oplus$

$\rho_p = 1870\ \text{kg m}^{-3}$

$P_{orb} = 1.6\ \text{days}$

$T_{eq} = 550\ \text{K}$

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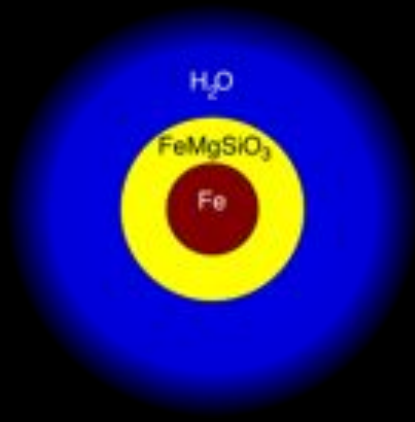
Three Possible Composition Scenarios

Case I: Gas & Ice & Rock

Mini Neptune Scenario

- Gas layer dominated by H/He from the nebula

- Smaller H/He envelope than Neptune (in proportion to planet mass).
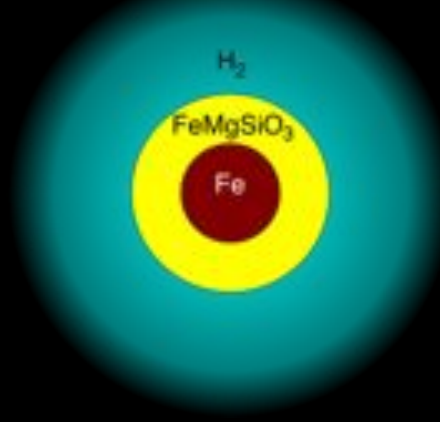
- Requires 10^{-4} to 6.8% H/He by mass

Case II: Ice & Rock only

Water Planet Scenario

- Gas layer dominated by sublimated vapor

- Phases in the envelope: vapor-superfluid-plasma

- Requires at least 47% H_2O by mass.

Case III: Rock only

Rocky Super Earth

- 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).

Rogers & Seager (2010b)
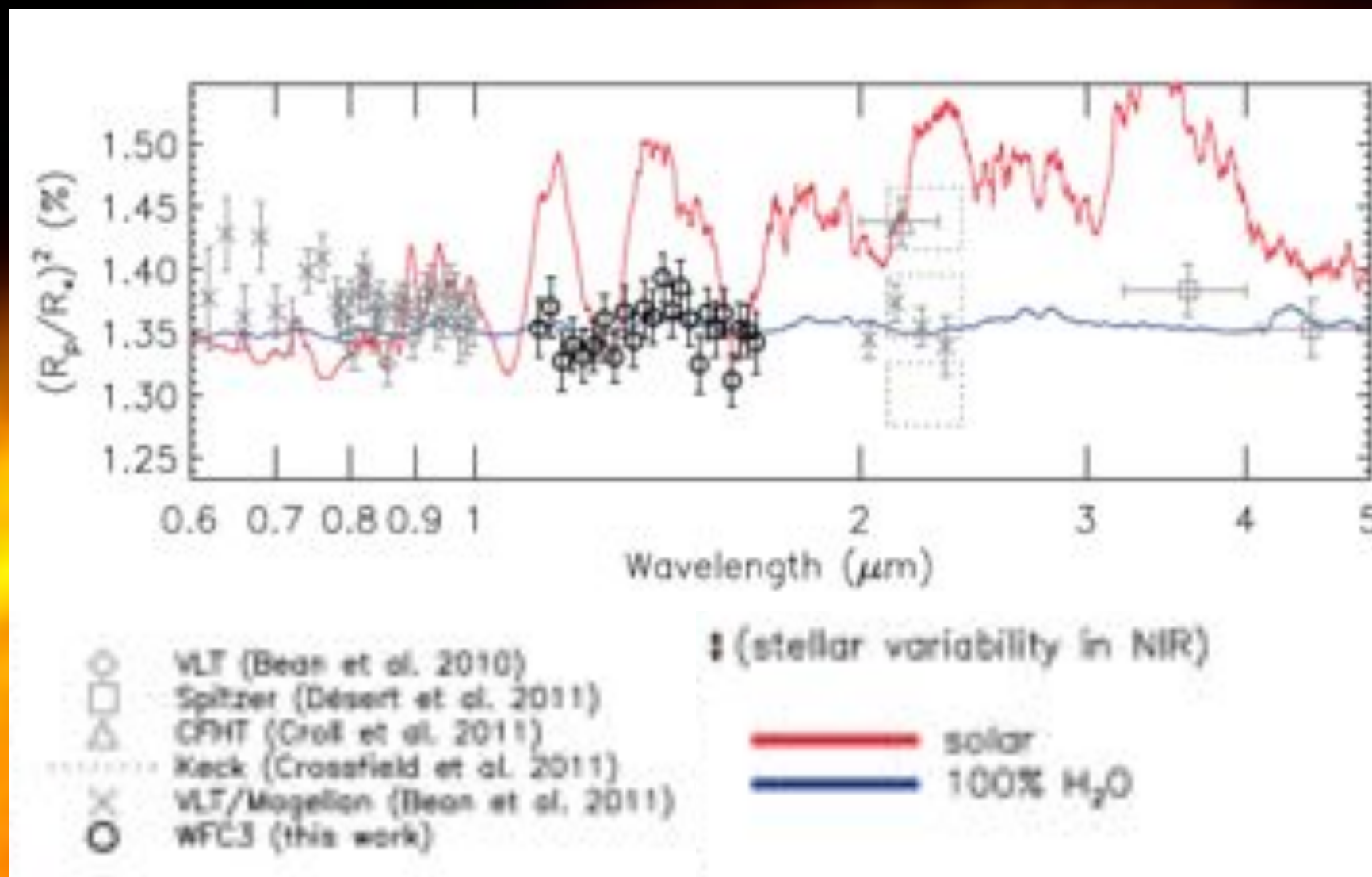
GJ1214b Transmission Spectroscopy

GJ1214b Transmission Spectroscopy

$$H_R = \frac{kT}{m_{ave}\,g}$$
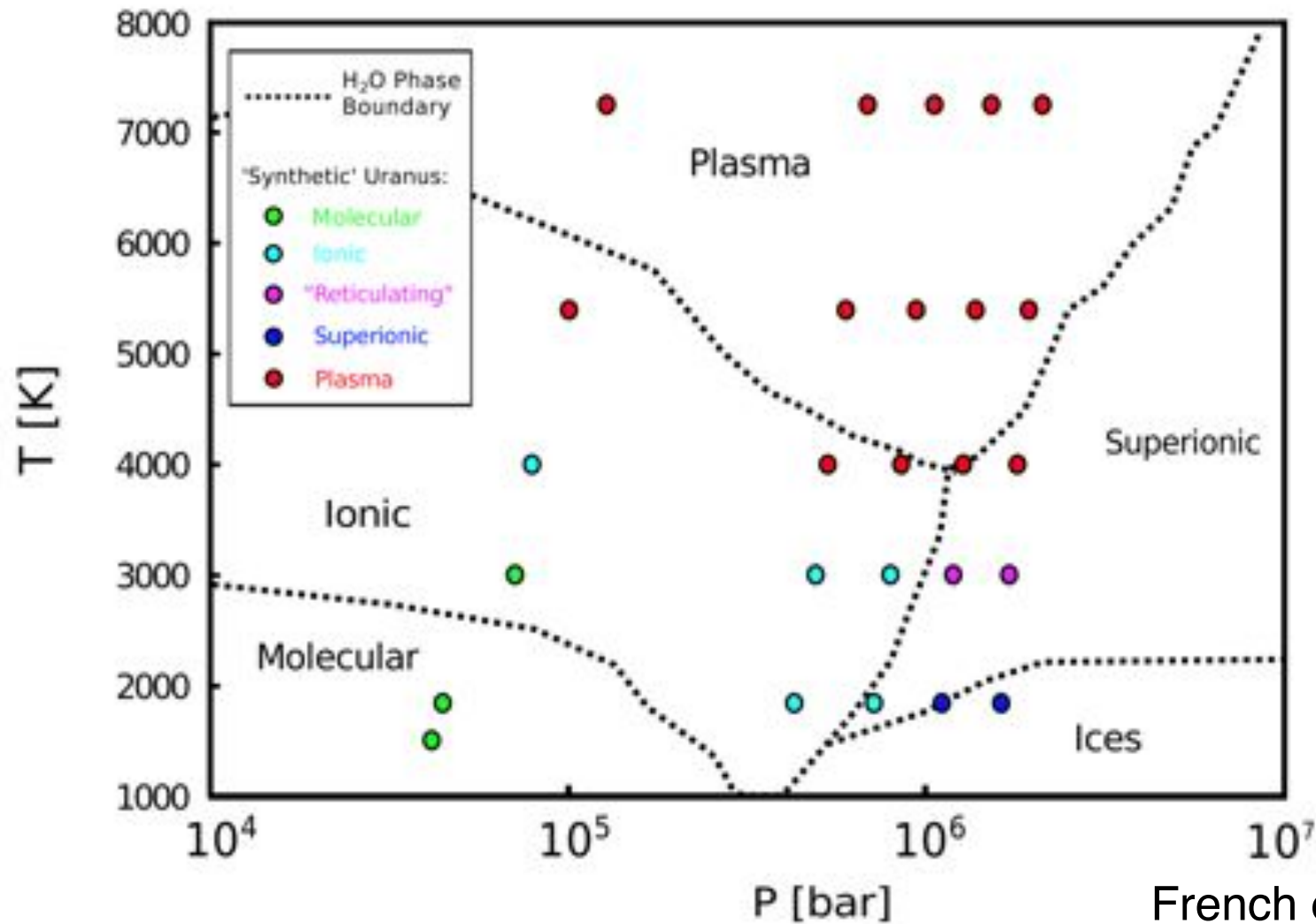
GJ1214b Transmission Spectroscopy

Berta et al. (2012)

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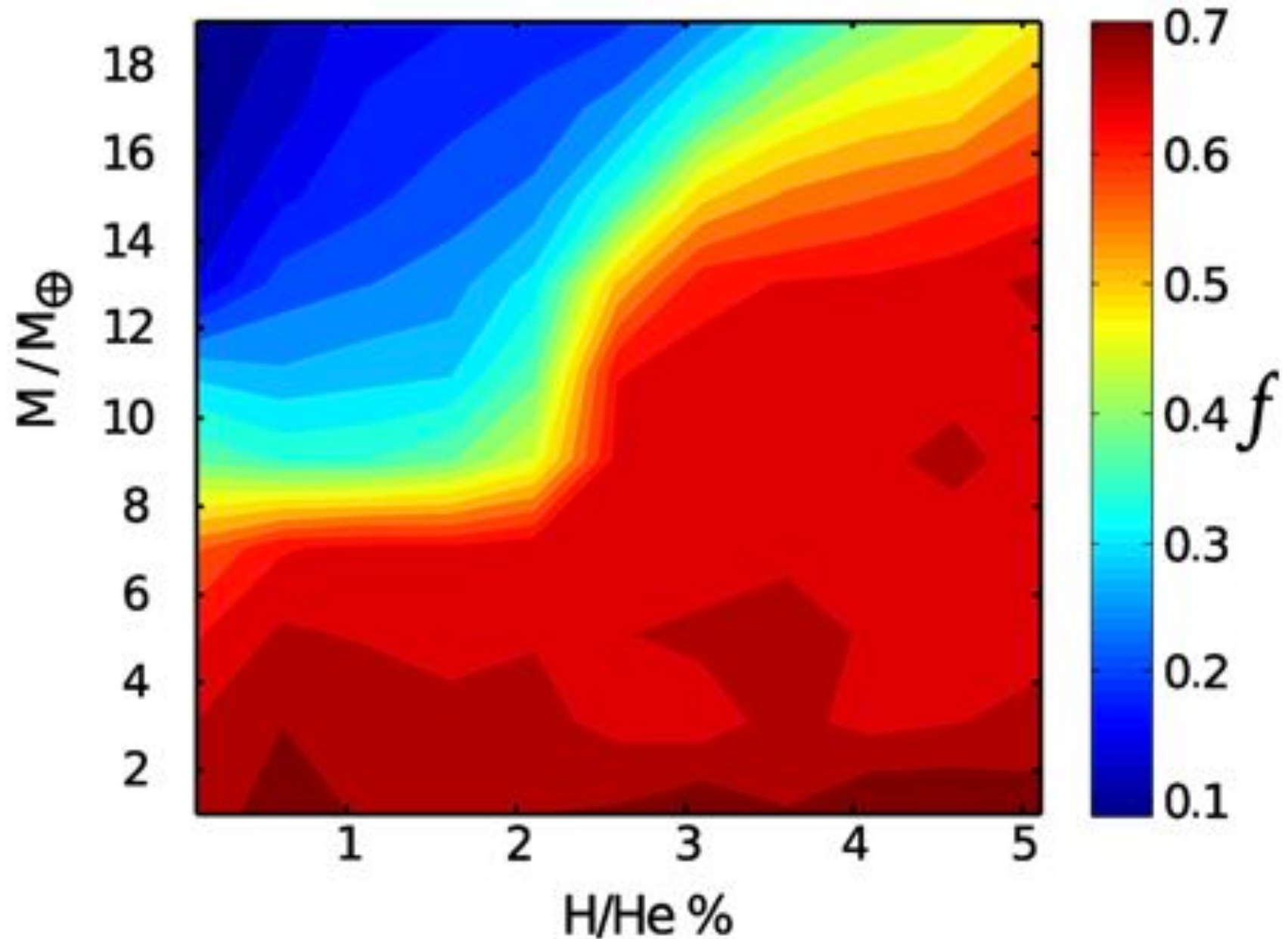
Water Phase Diagram

French et al. (2009)
Chau et al. (2010)
Fig Credit: Tian & Stanley (2013)

Thickness of Potential Dynamo Generating Layer

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