Structure and Composition of super-Earths

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Input: $M$, $P_{surf}$, $T_{surf}$, guess $R$, $g_{surf}$, composition + Vinet EQ

Output: $R$, $\rho(r)$, $P(r)$, $g(r)$, $m(r)$, $/2H_2O$ adiab
rocky super-Earth
Generalized M-R relationship

Radius (km)

max radius

min radius

Venus

Earth

Uranus

Neptune

H2O

Mass

1M⊙ 2M⊙ 4M⊙ 7M⊙ 10M⊙ 15M⊙

0.262(1-0.138 I

Salpeter & Zapolsky 1966
Stevenson 1982
Sotin et al. 2007;
Fortney et al. 2007;
Seager et al. 2007

Earth-like: Fe/Si
Ternary Diagram: Tool to show composition

Silicate Mantle

20% IMF
30% CMF

Terrestrial Side

Fe Core
There is degeneracy in composition.

Valencia et al. 2010
M-R relationship can not tell us about SE composition
Precision in Measurements

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M = 2.5M

--- 4% ΔR and 10% ΔM
-- 4% ΔR and 5% ΔM
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Diagram showing isopleths for Mantle and Core with different precision levels.
Can it retain an atmosphere?

Unlikely

Mass Loss (% of initial):

- $f=0.7$
- $f=0.5$
- $f=0.3$
- $f=0.1$

Energy limited calculation based on:

$R = 1.7 \pm 0.17 \, R_E$, $P = 0.85 \, AU$, $T_{eff} = 2000 K$, ...Mass
$M = 5.5M_E$

$M = 10M_E$
Terrestrial CoRoT-Exo-7b

$R = 1.7 \pm 0.17 \text{ } R_E$

$4 M_E < M < 13 M_E$
Conclusions

degeneracy in composition that can fit the average density.

Detailed model (‘toblerone’ diagram) to infer type from M and R data.

A maximum radius above which the planet is likely volatile rich (H₂O). Below this value the rocky or may not be rocky.

Eff to invest in increasing radius precision
Constraining composition

Silicate Mantle
Plausible Composition

Silicate Mantle

silica

mantle
Plausible Composition
structure of Super-Earths

Super-Earths' mantles are mostly composed of PPV
The M-R relationship is robust to temperature, equation of state and core mass fraction (CMF) according to Vencias et al. 2006. The relationship is given by:

\[ R = a \left( \frac{M}{M_{\odot}} \right)^{0.26} \]