Geophysical Limitations on the Habitable Zone:

Volcanism and Plate Tectonics

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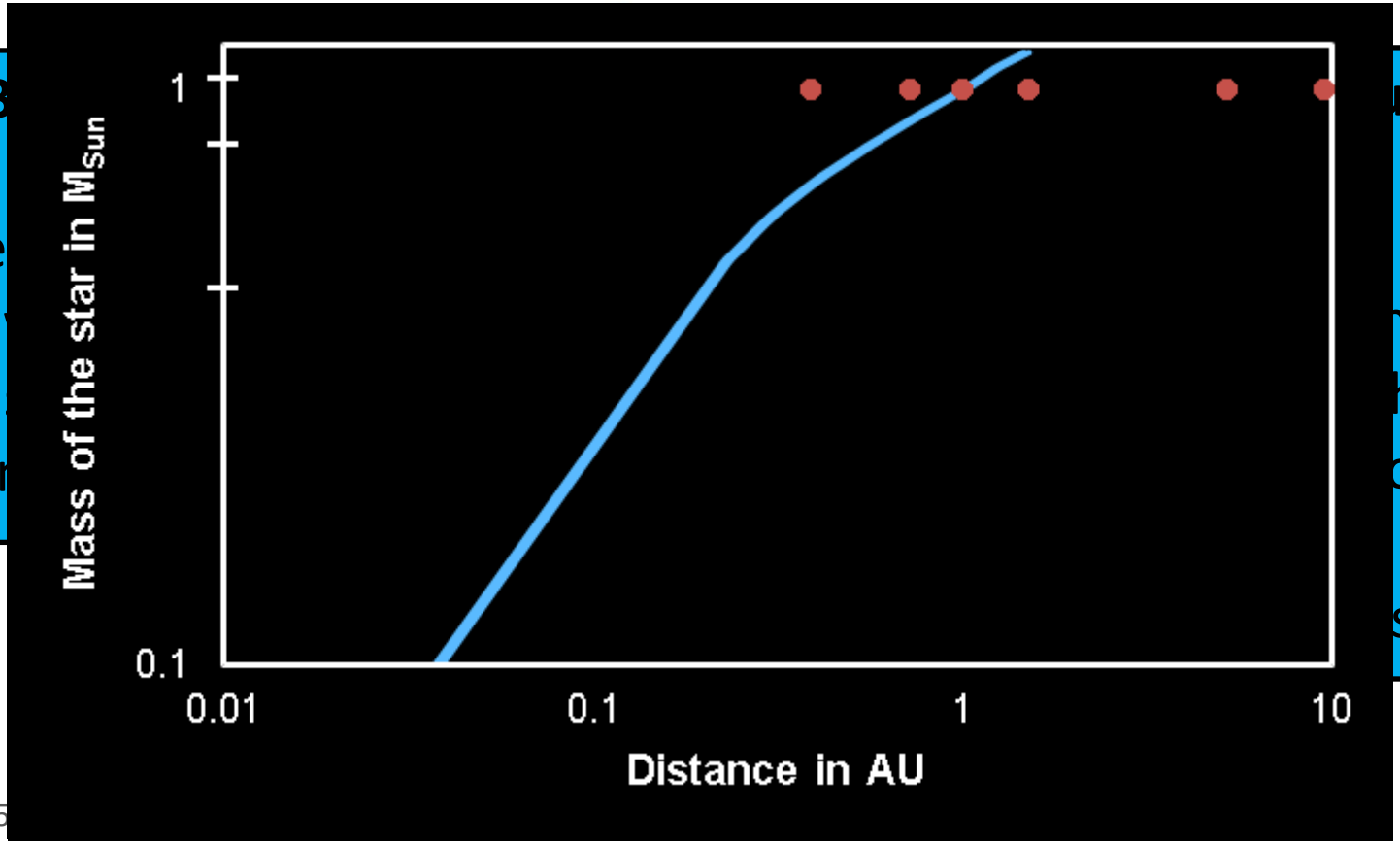
Habitable Zone

For Earth-like planet and mass



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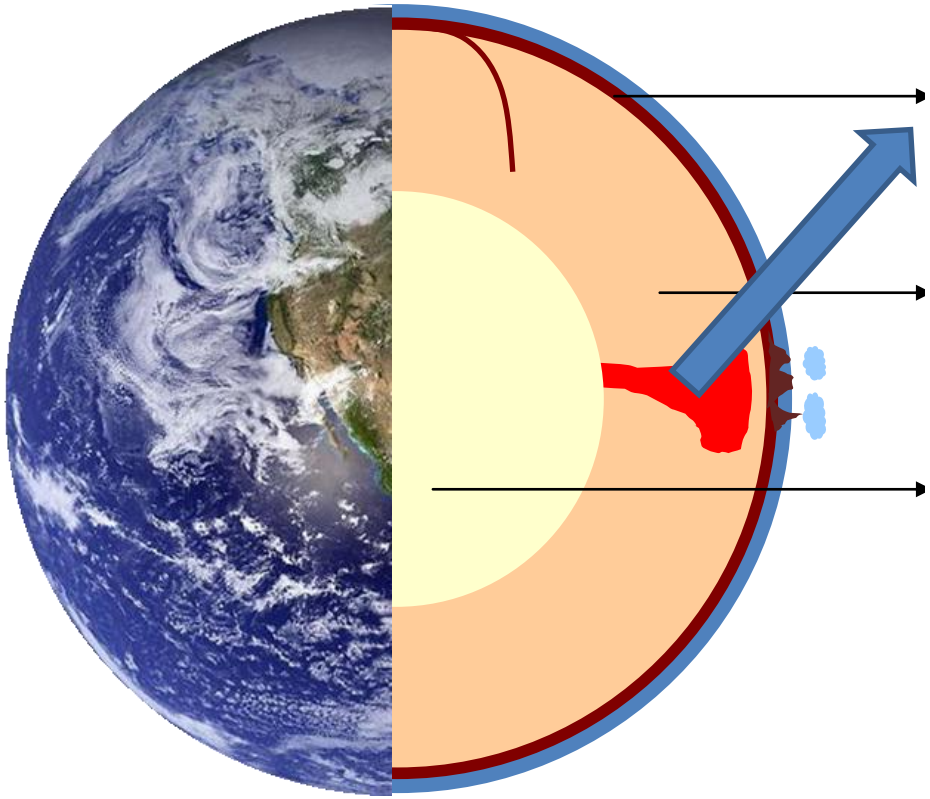
Mowlavi et al., 2012

Mass and Interior Structure

Modelling Terrestrial Planets

Terrestrial = up to 2 Earth sizes / 10 Earth masses

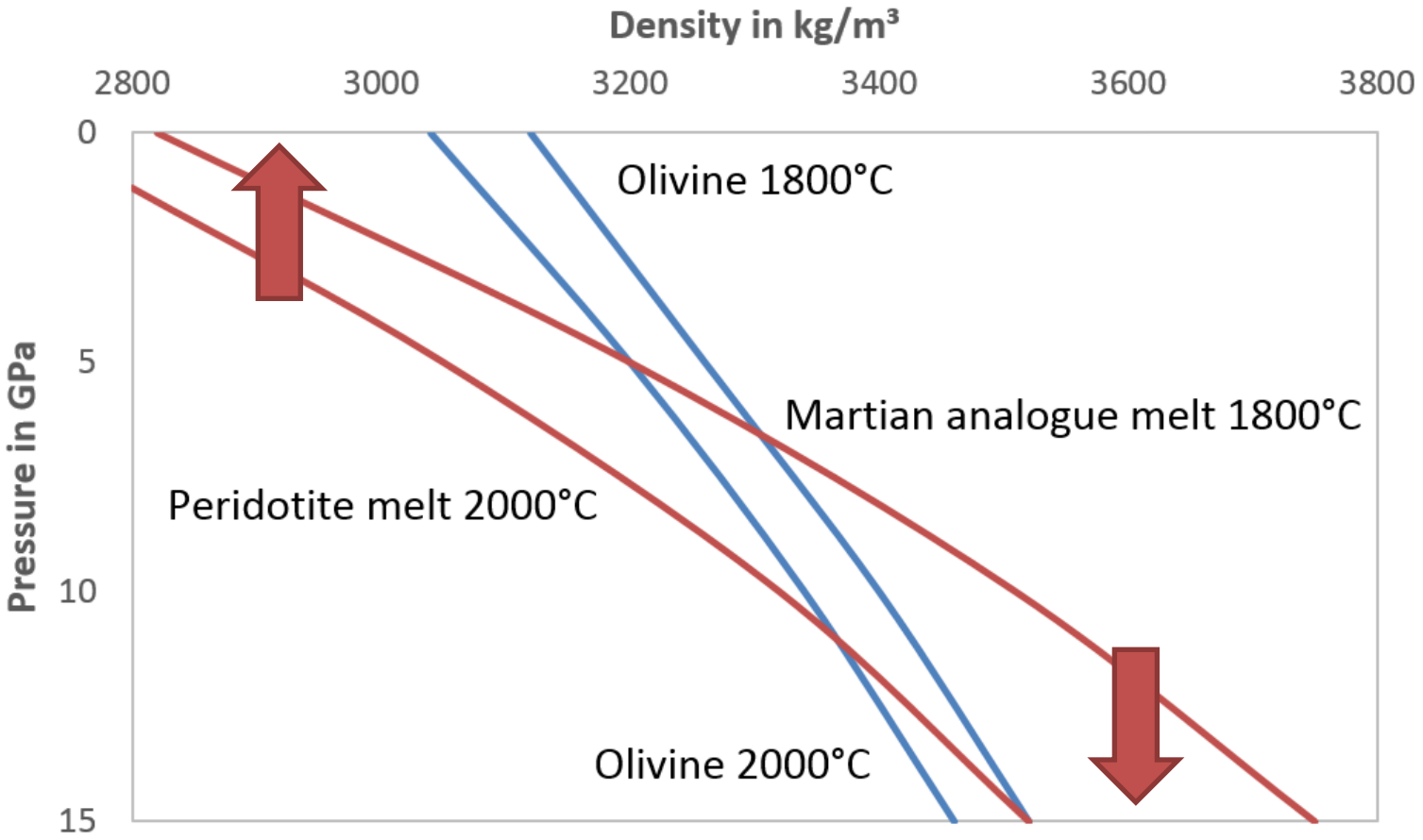


Partial melting in mantle leads to depletion of material

Assume here that melt is immediately extracted to surface with 10%-25% extrusive melt incl. outgassing of volatiles

2D spherical annulus with compressible mantle flow and phase transitions

Melting: Density cross-over



[after Ohtani et al., 1995]

Melt production over time

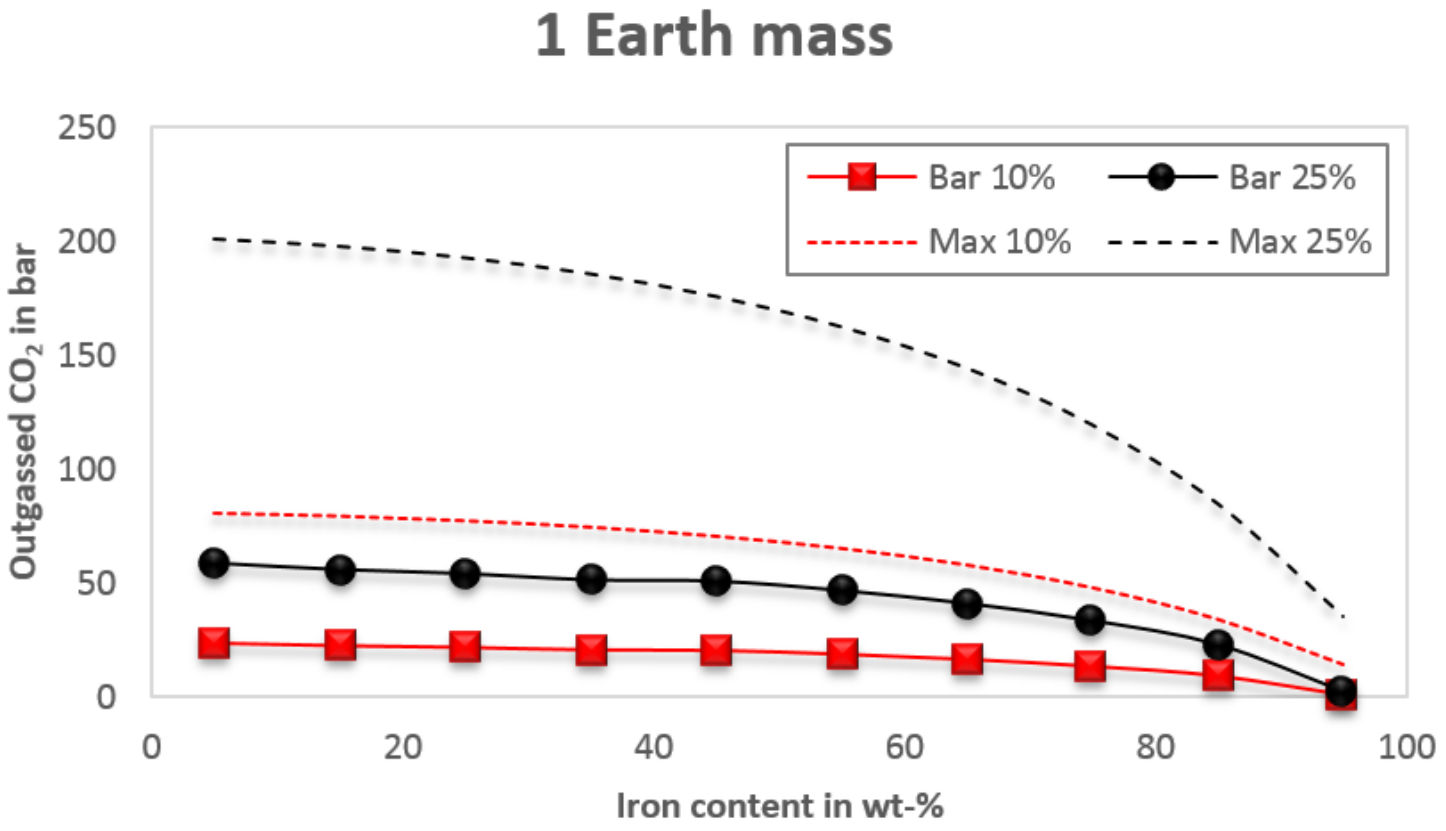
Reference simulation « Earth without plate tectonics »

- Beneath lid on solidus curve, adiabatic profile with depth

Earth-Mass Stagnant Lid Planets

Variation of iron content (assume pure iron, solid core)

Earth-Mass Stagnant Lid Planets



Earth-Sized Plate Tectonics Planets

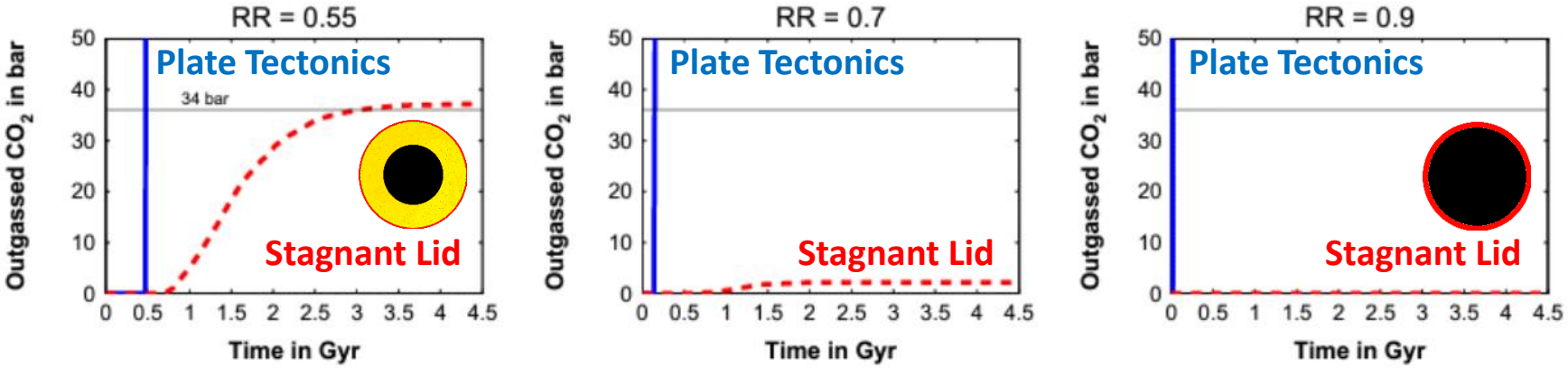


Plate tectonics = sufficient outgassing

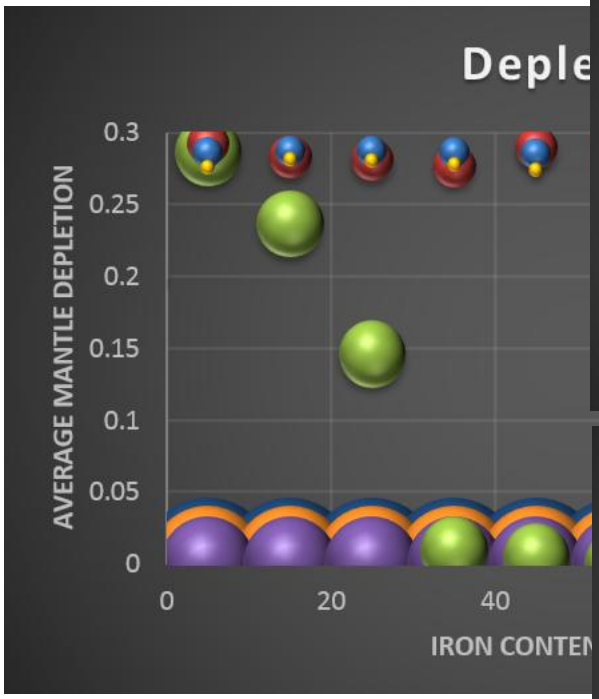
[Noack et al., 2014]

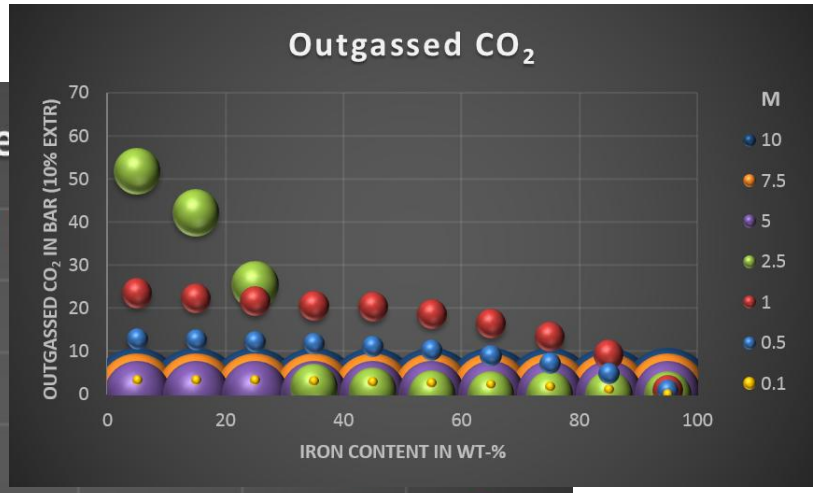
Stagnant Lid Planets: Different Masses

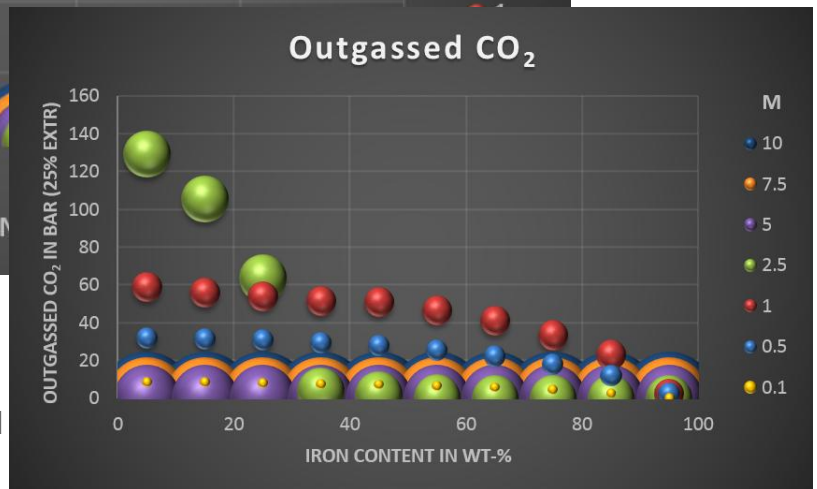
Use Earth-like interior structure (35 wt-% iron)

Different masses and core sizes

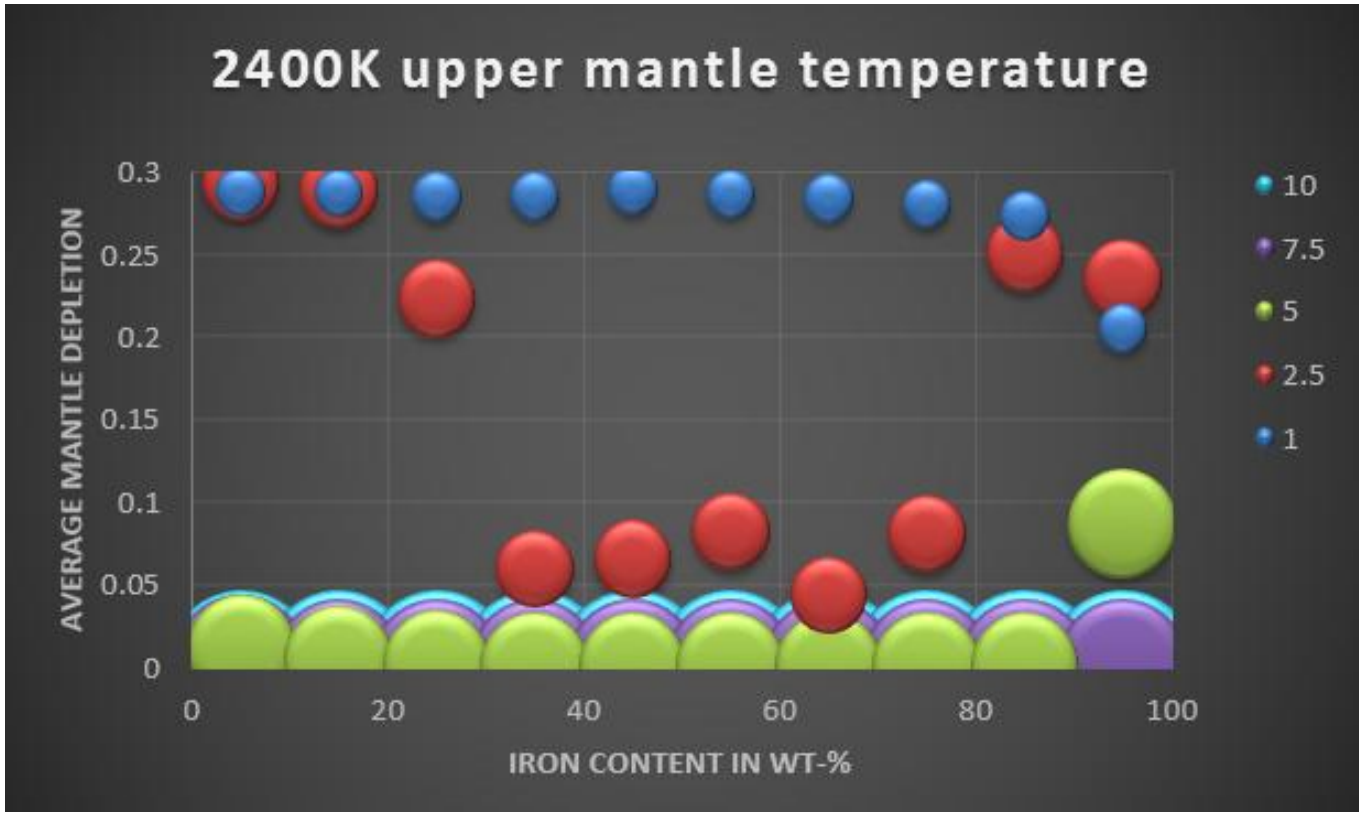
Here 2000K upper mantle temperature







Influence of temperature



…seems to be minor

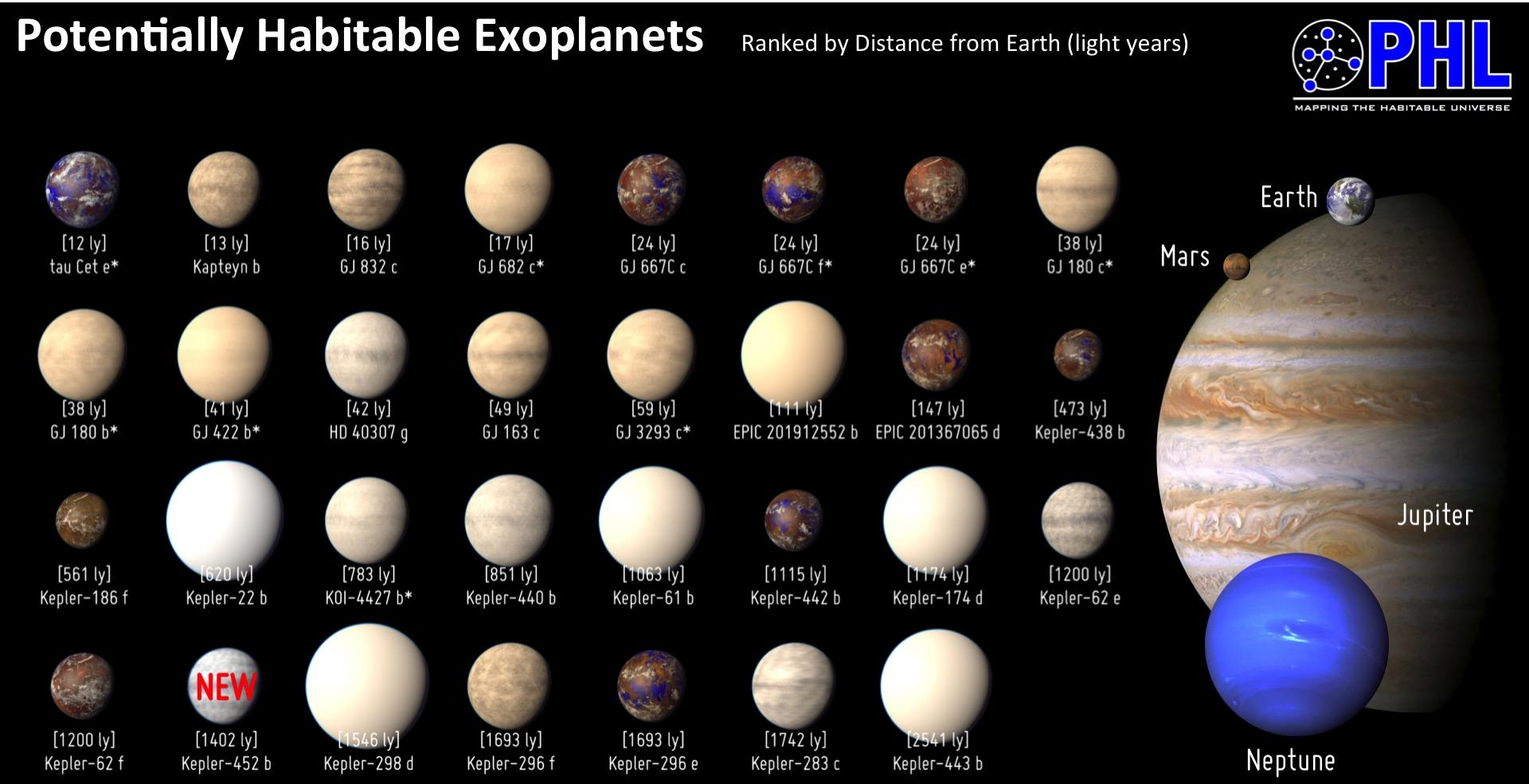
Geophysical constraints for the HZ

- Surface volcanism of Earth-like planets constrained by mass and interior structure (less by temperature)
- Large-massive planets may not outgas a dense-enough secondary atmosphere for the maximum greenhouse limit of the HZ
- A high iron content for planets of Earth-size or larger also leads to less or no outgassing
- Plate tectonics leads to immediate outgassing of several tens of bar CO_2 (independent of planet mass or interior structure) and may also be needed for long-term climate regulation

Planet TOPERS Group

Planet Topers

Current exoplanets: any “good” candidates?



Artistic representations. Earth, Mars, Jupiter, and Neptune for scale. Distance is between brackets. Planet candidates indicated with asterisks.

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) July 23, 2015

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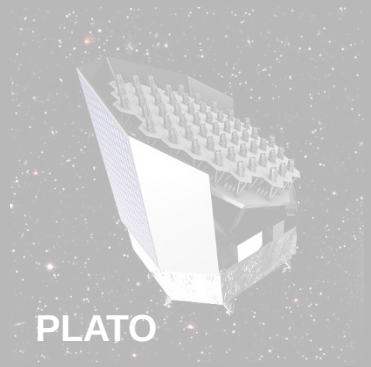
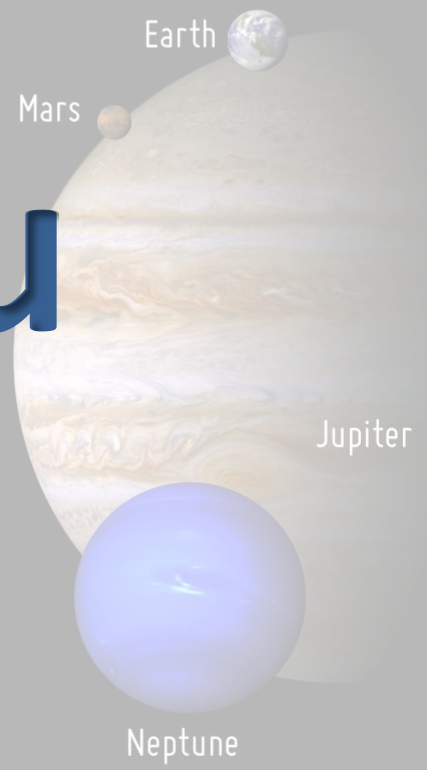
Current exoplanets: any “good” candidates?

Potentially Habitable Exoplanets Ranked by Distance from Earth (light years)

PHL
MAPPING THE HABITABLE UNIVERSE

Thank you





Artistic representations. Earth, Mars, Jupiter, and Neptune for scale. Distance is between brackets. Planet candidates indicated with asterisks.

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) January 16, 2015