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The principal Hugoniot of Bridgmanite: New constraints for planetary interiors

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U.S. DEPARTMENT OF ENERGY

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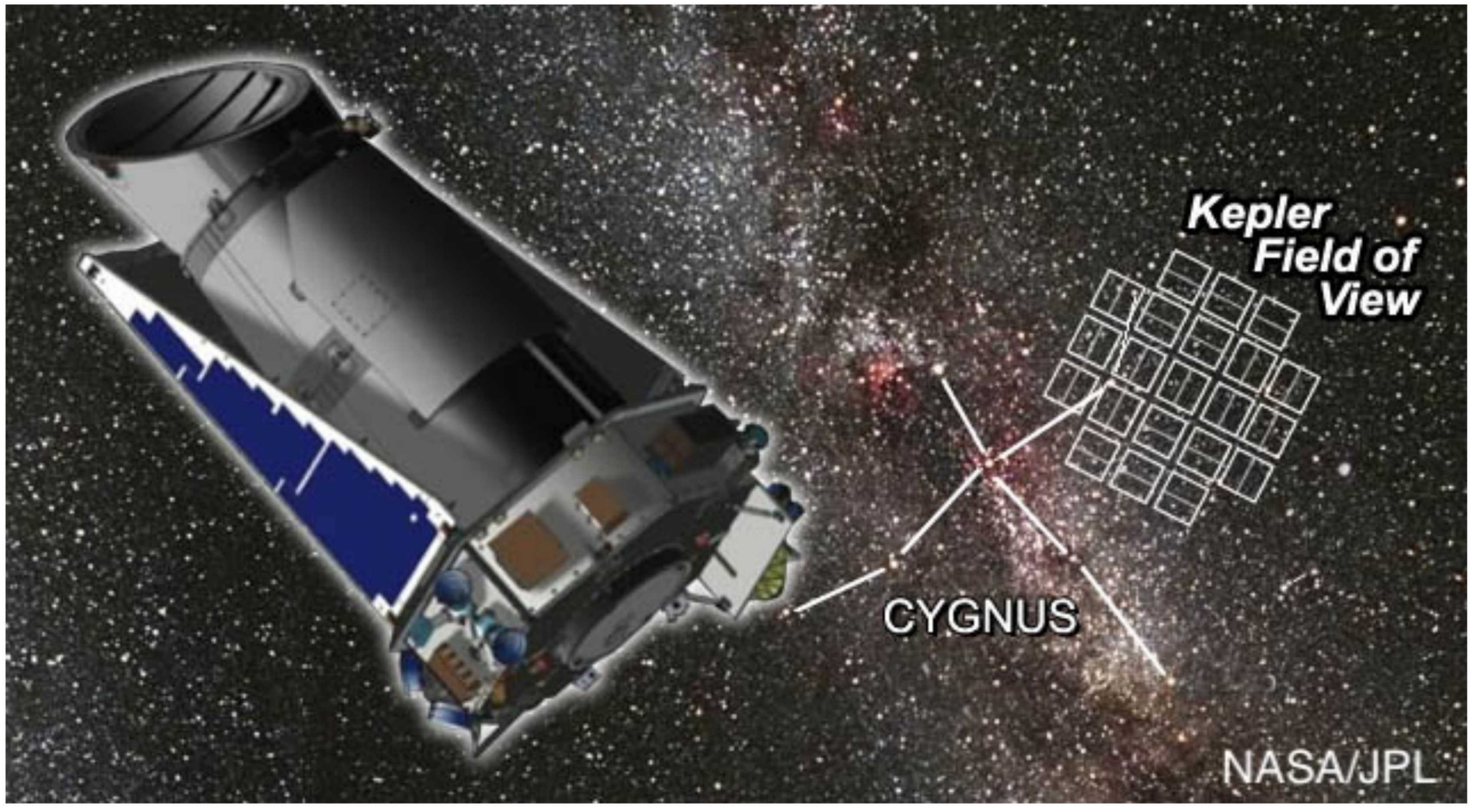
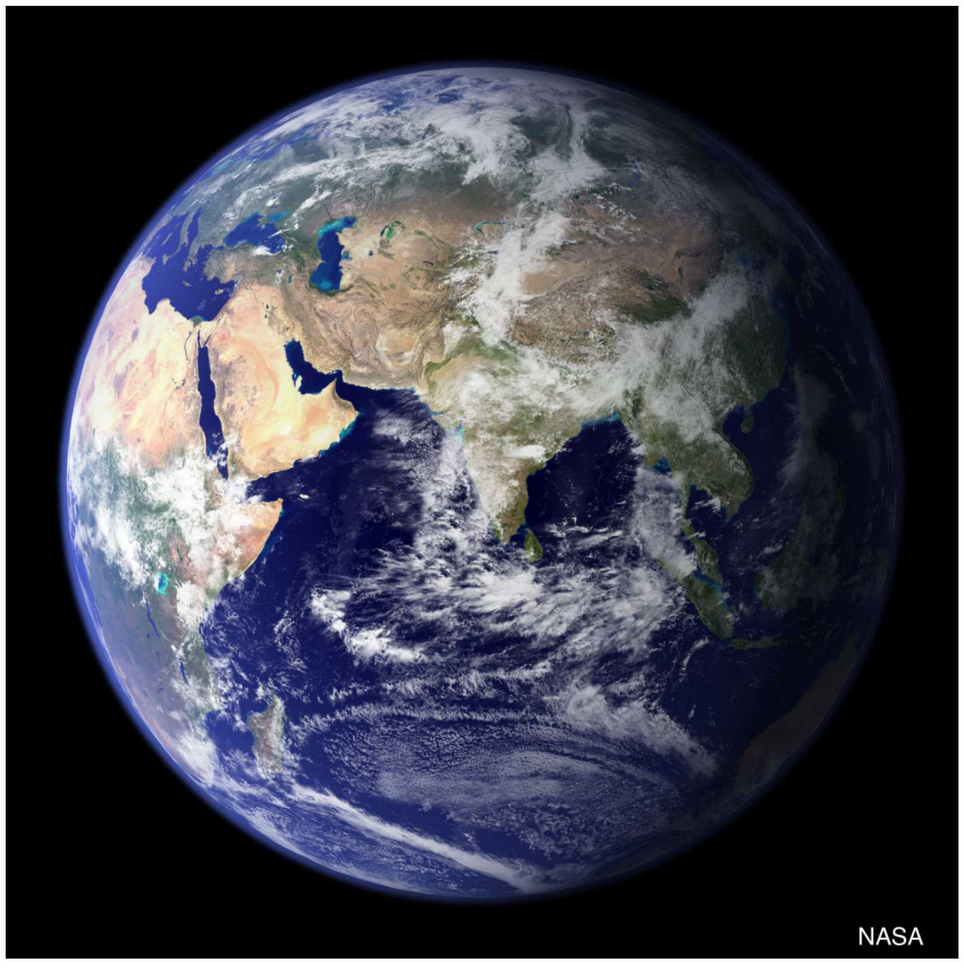
How to go from this:



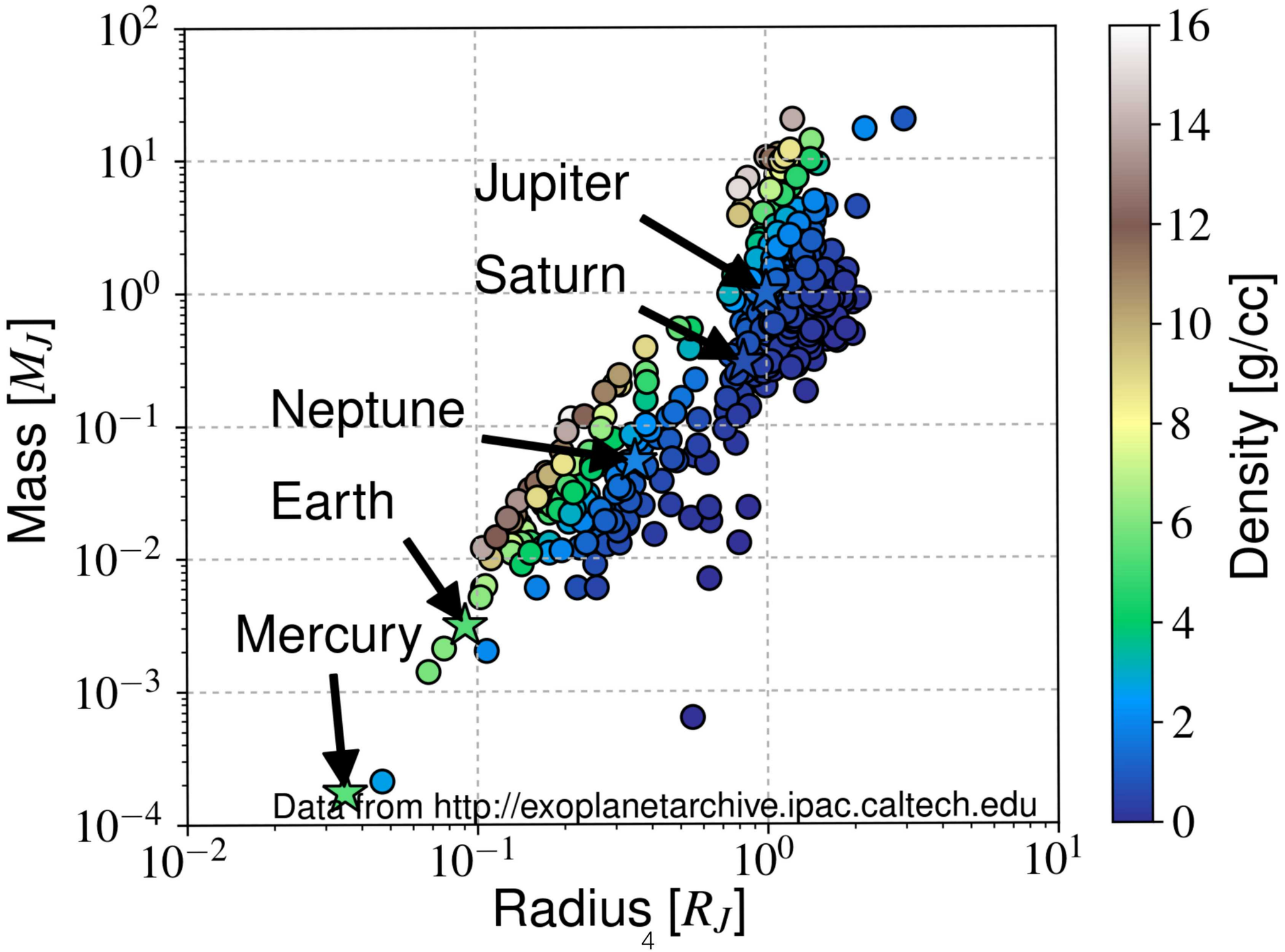
To this:



Planet Earth:

- **Radius 6371 km**
- **Mass 6×10^{25} kg**
- **Surface Temp 270 K**
- **Silicate mantle + iron core**
- **Non-equilibrium atmosphere**
- **Life!**
- **Etc...**

With this:


Jupiter
Saturn
Neptune
Earth
Mercury
Data from http://exoplanetarchive.ipac.caltech.edu
Mass [M_J]
Radius [R_J]
Density [g/cc]
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-2}
10^{-1}
10^0
10^1
16
14
12
10
8
6
4
2
0

The EOS is fundamental

Planet equations:

$$\frac{d\rho}{dr} = -\frac{\rho^2(r)g(r)}{K(r)}$$

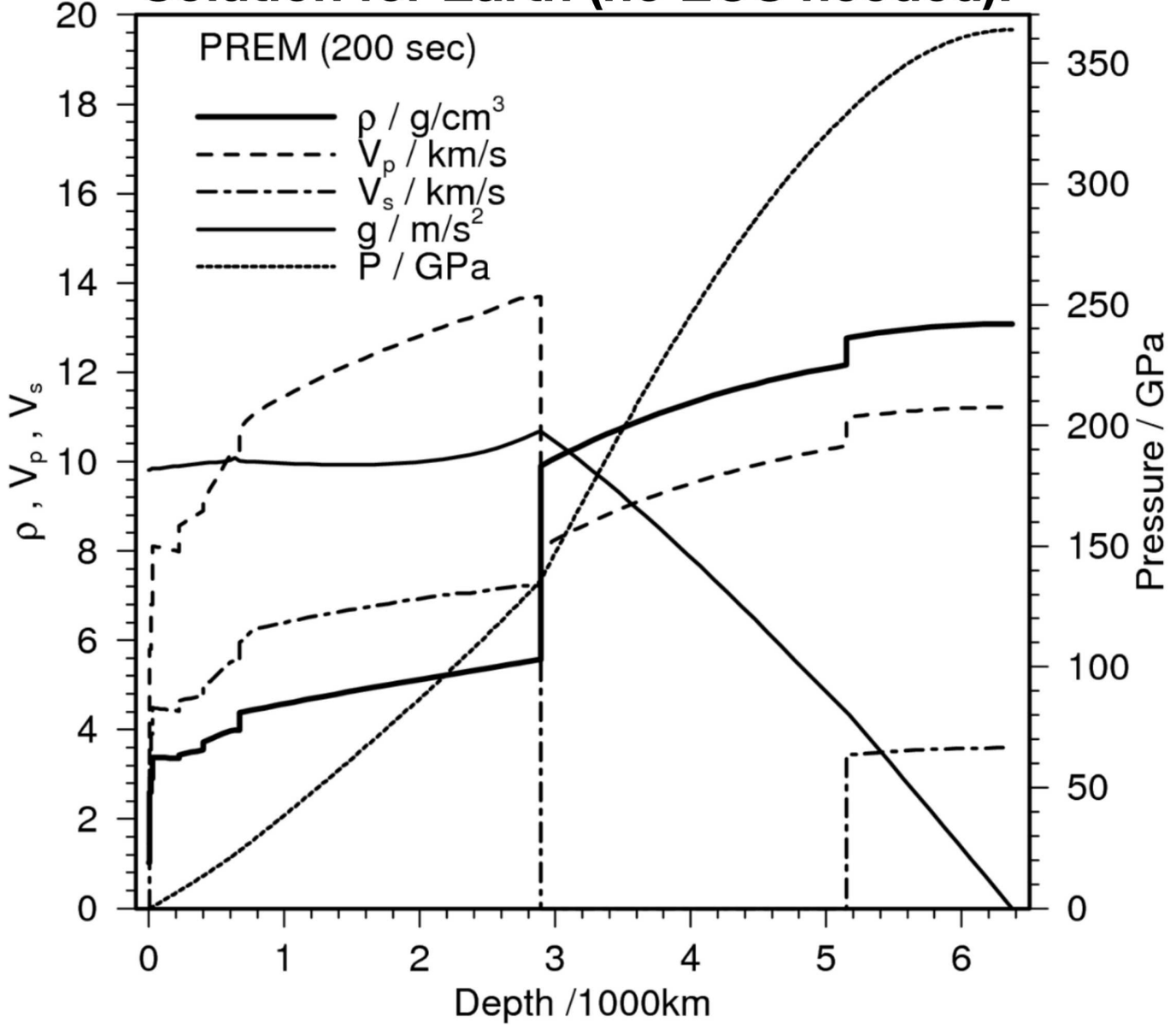
$$g(r) = \frac{4\pi G}{r^2}\int_0^r u^2\rho(u)\,du$$

$$\frac{dT}{dr} = -\frac{\rho(r)g(r)T(r)\gamma(r)}{K(r)}$$

Ingredients to solve:

- **Planet size**
- **Planet mass**
- **EOS *or* seismic data**

Solution for Earth (no EOS needed):



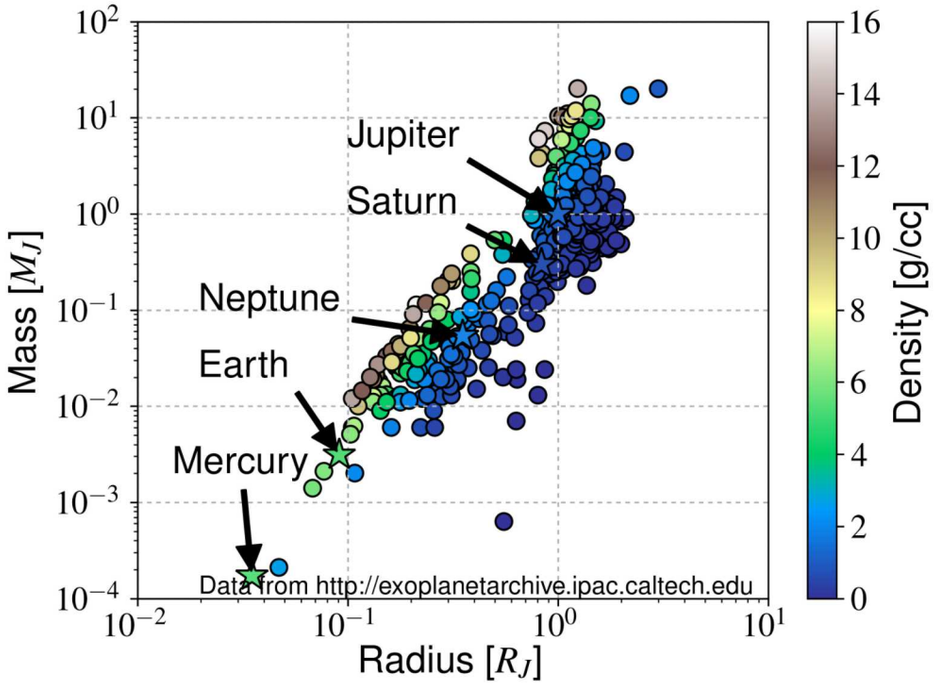
Exoplanet prototypes

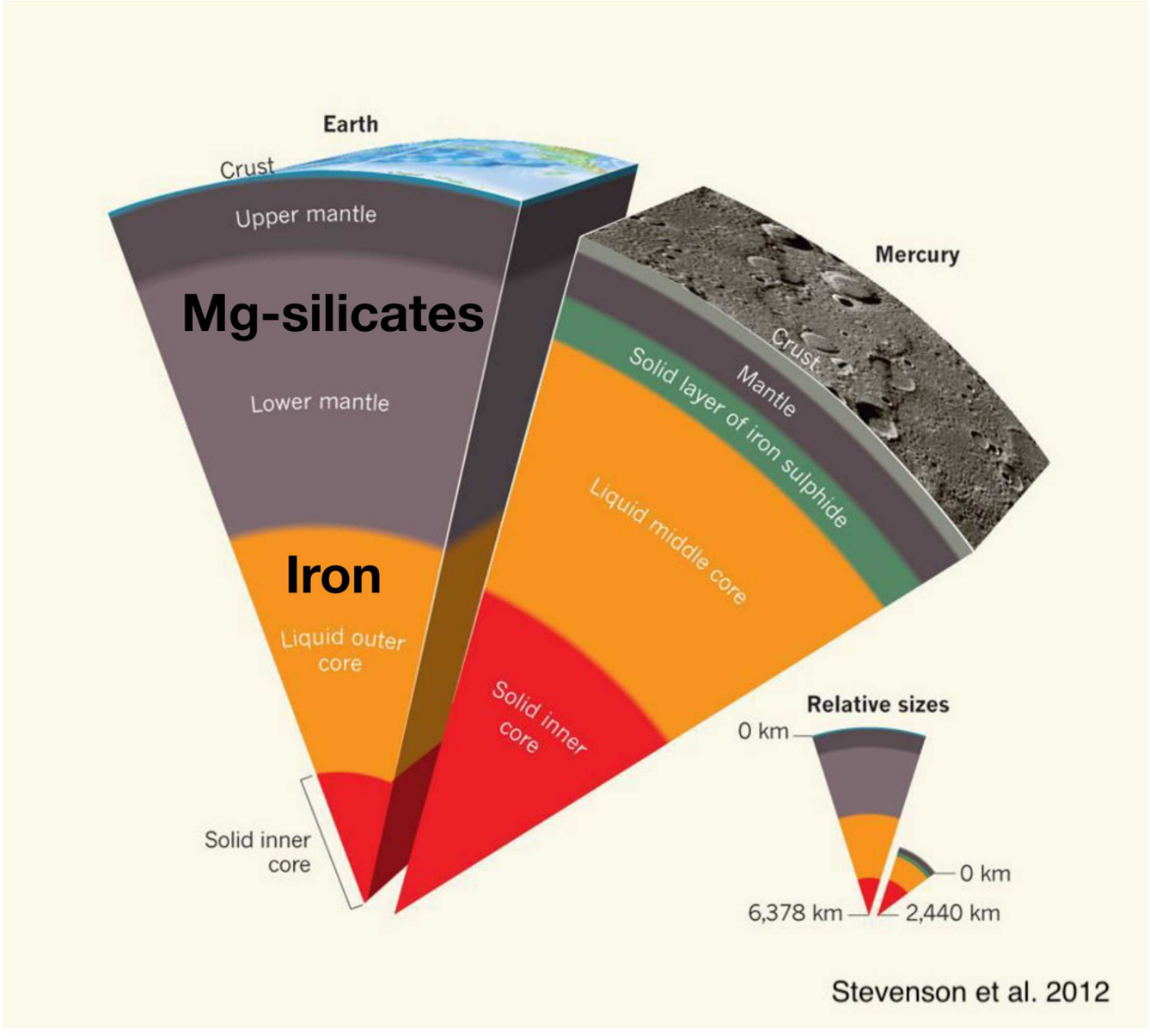
Core mass fraction:

$$\mathrm{CMF} = \frac{M_{core}}{M_{planet}}$$

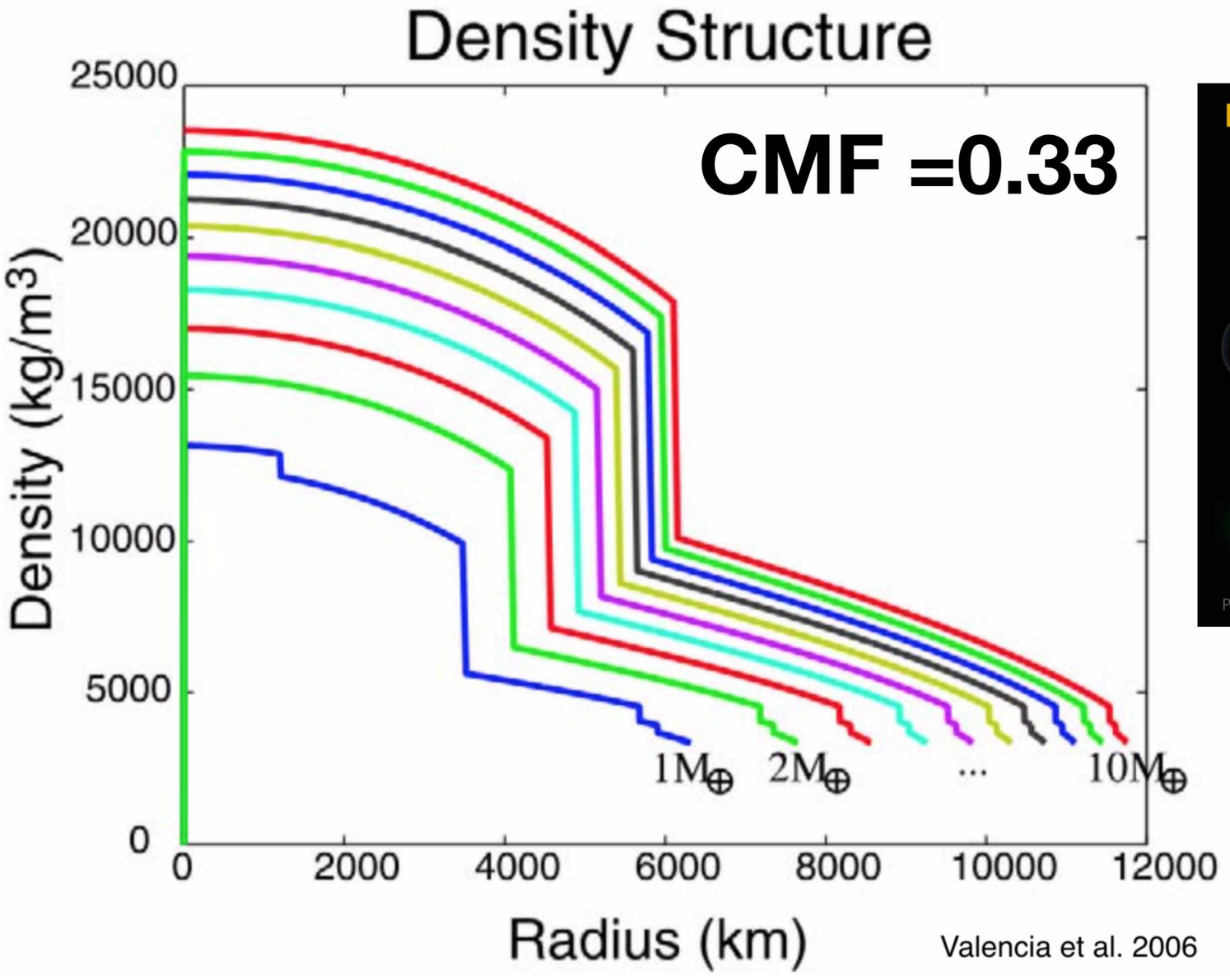
Earth ~0.33

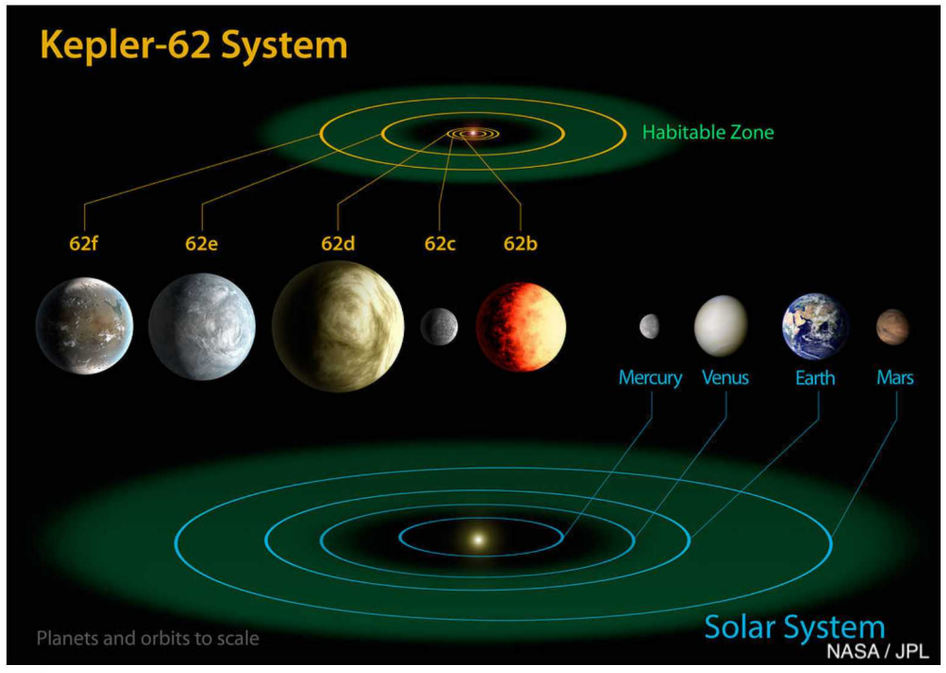
Mercury ~0.66





Exoplanet prototypes



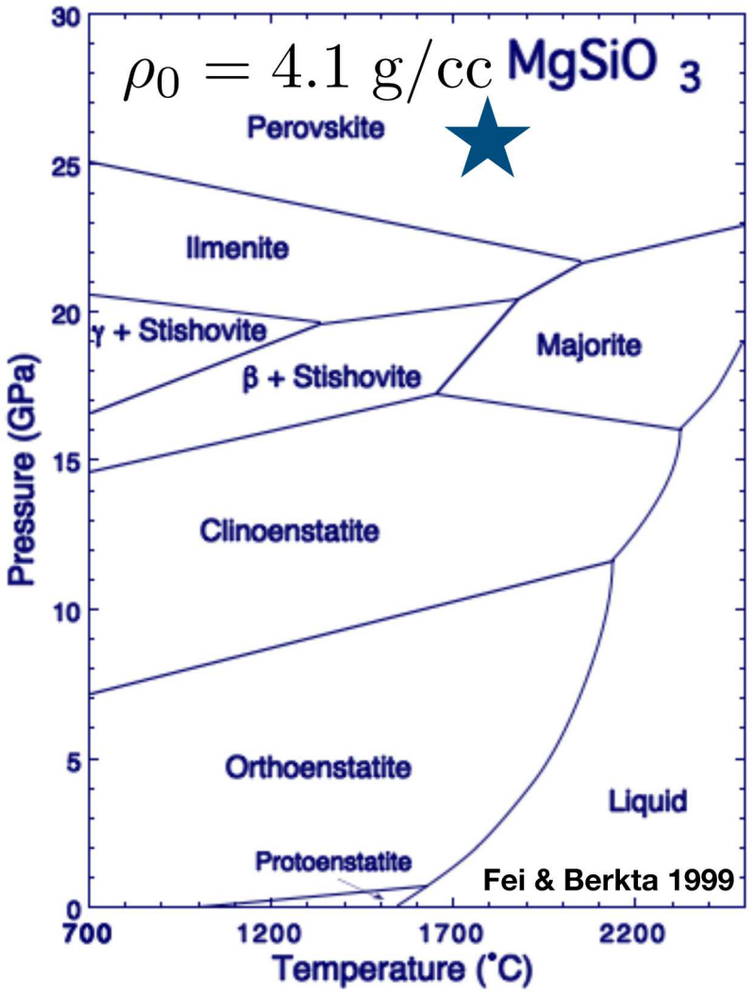


These models rely on EOS extrapolations

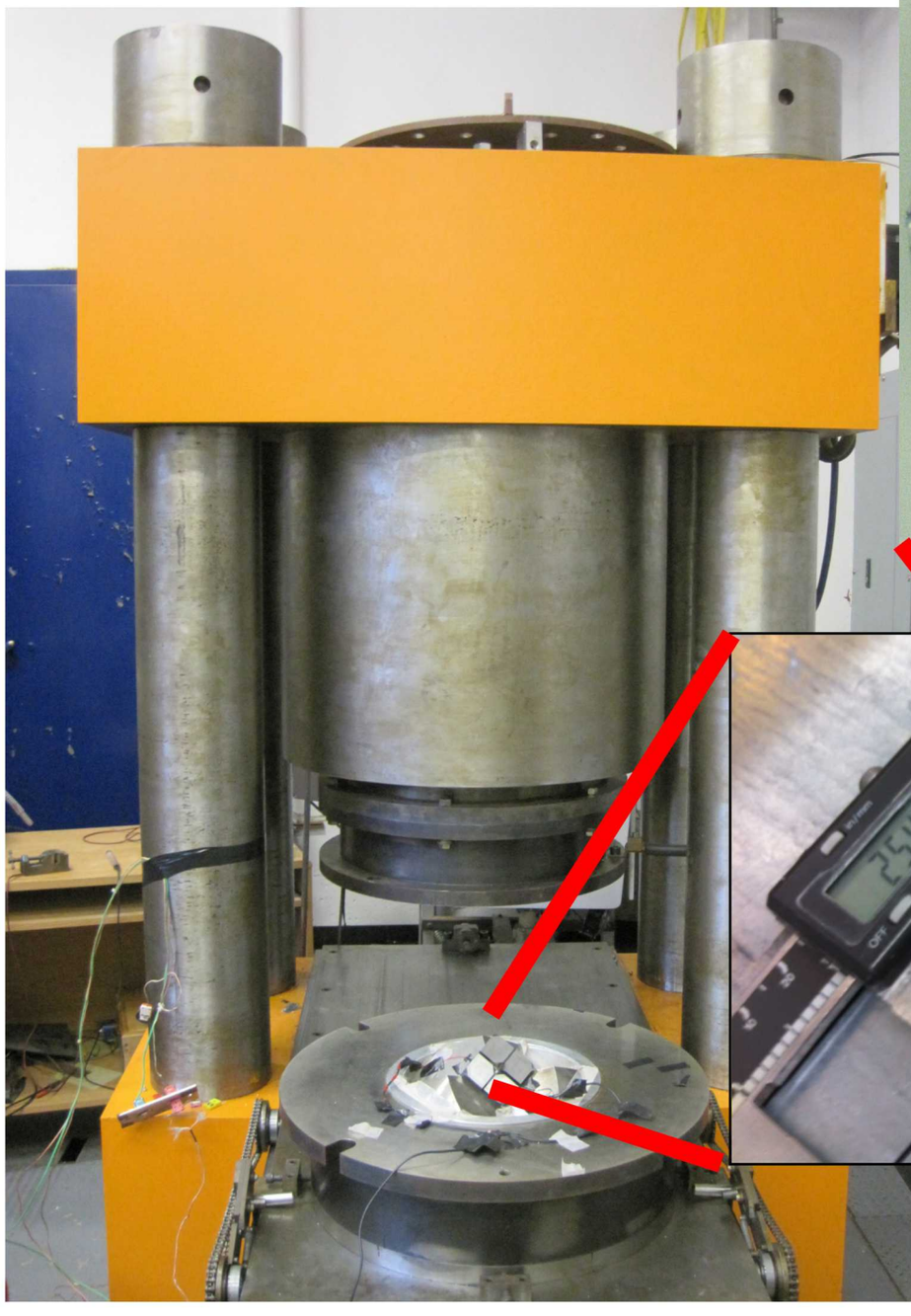
Project Goals

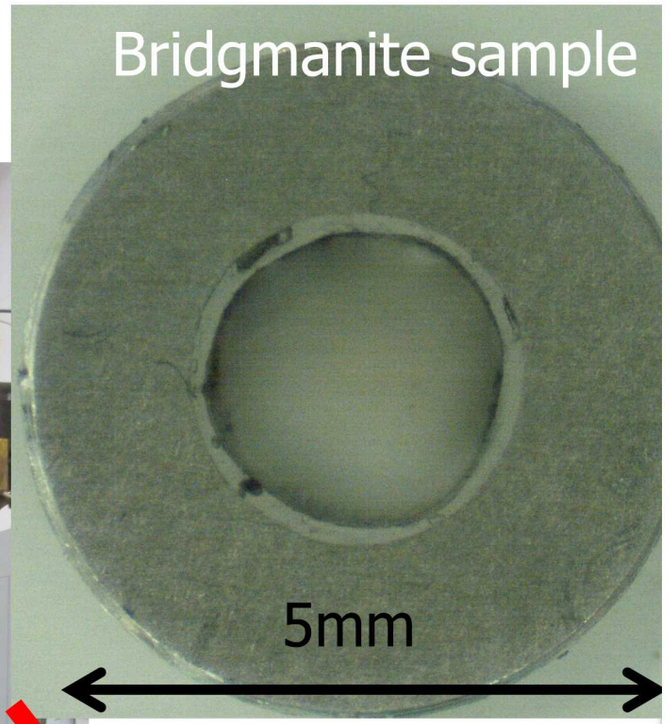
1. **Synthesize bridgmanite $MgSiO_3$ samples**
2. **Obtain Hugoniot states between 200-1000 GPa**
3. **Generate new super-Earth structure models**

Synthesis at CIW GL



- 2-2.5mm disk
- 5 samples/run
- 40 runs

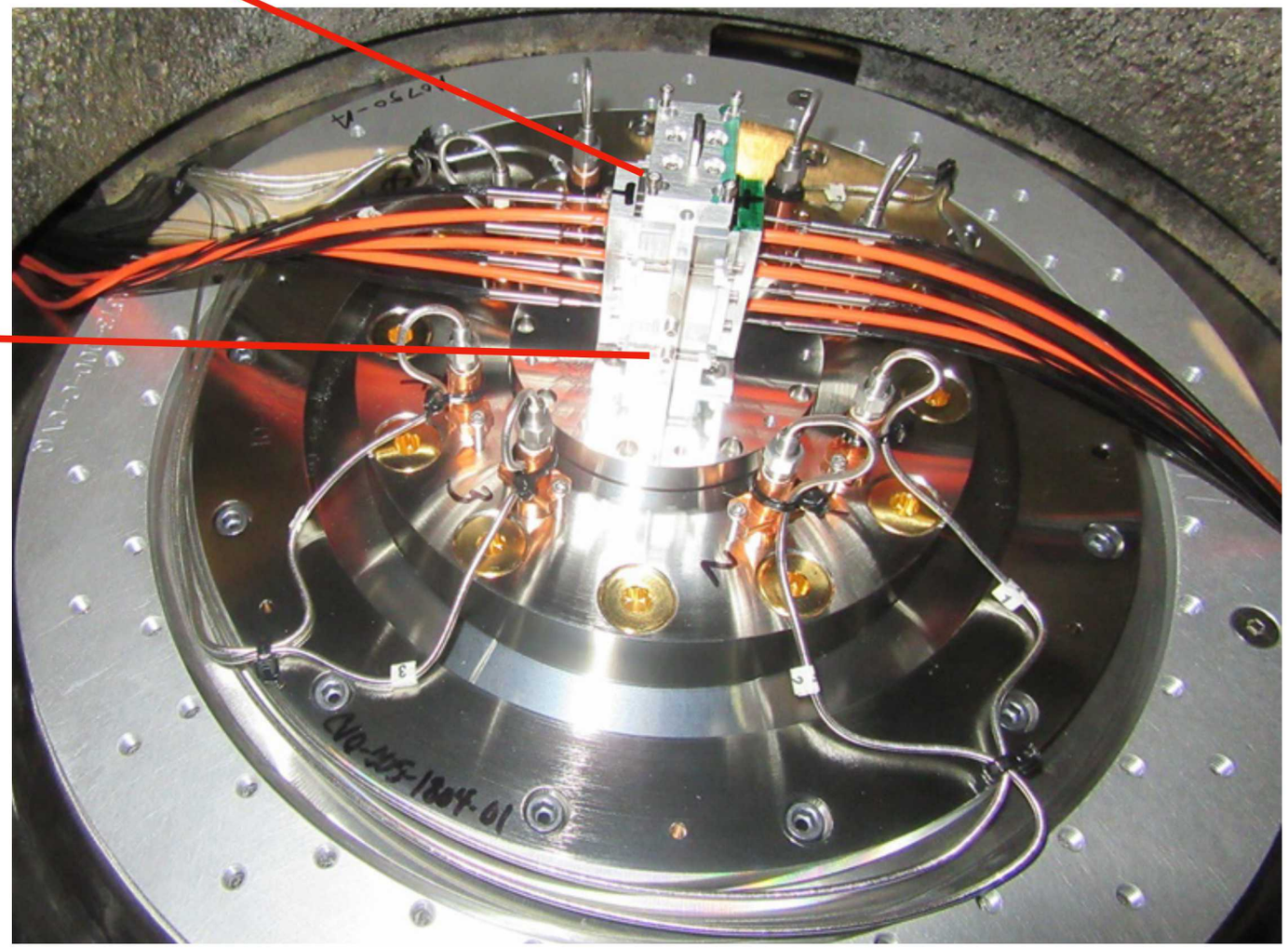


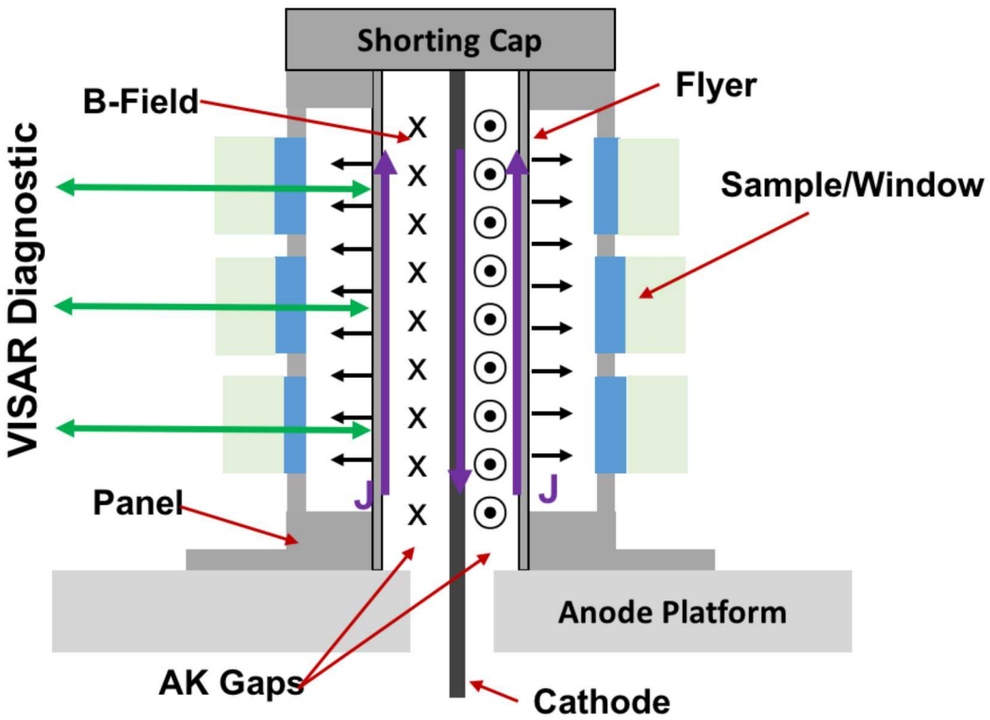


Z Experiment Design

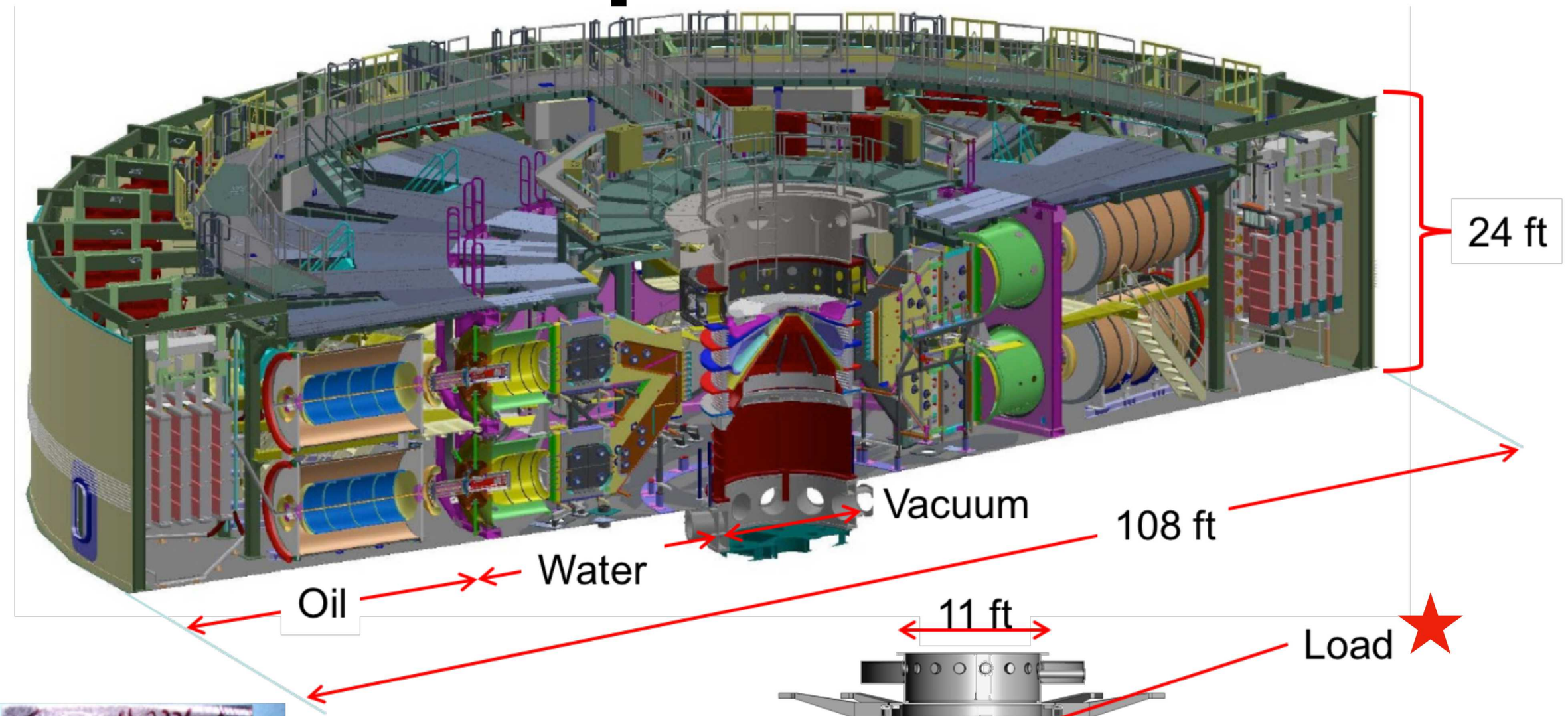
Brigmanite

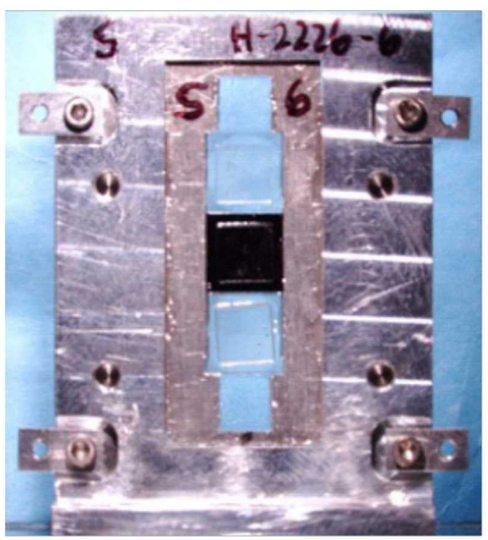
Stripline Assembly

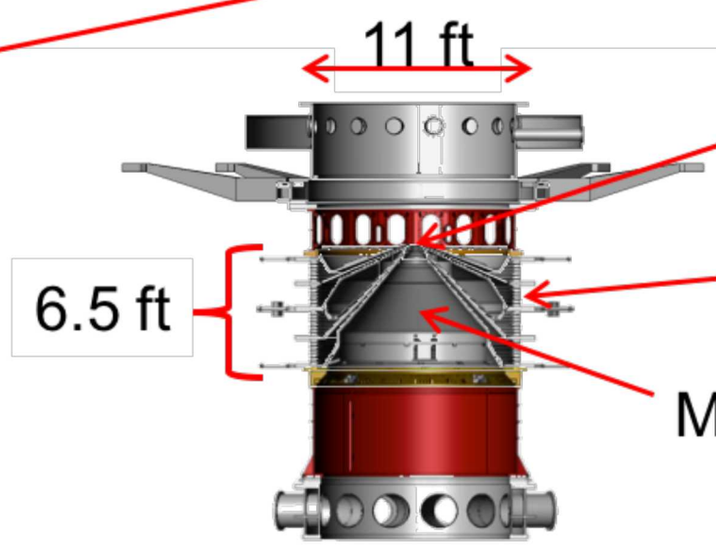




Z Experiments



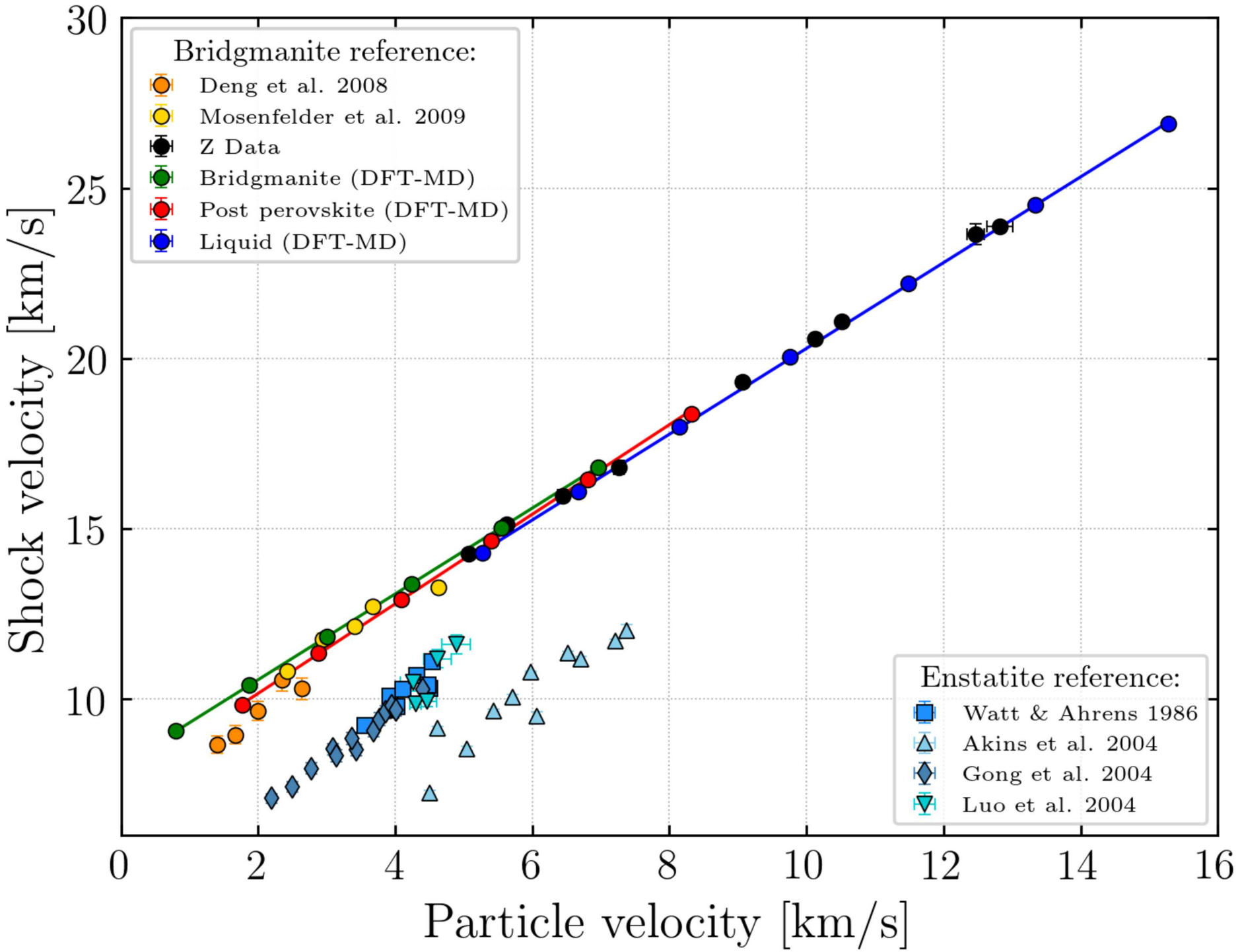




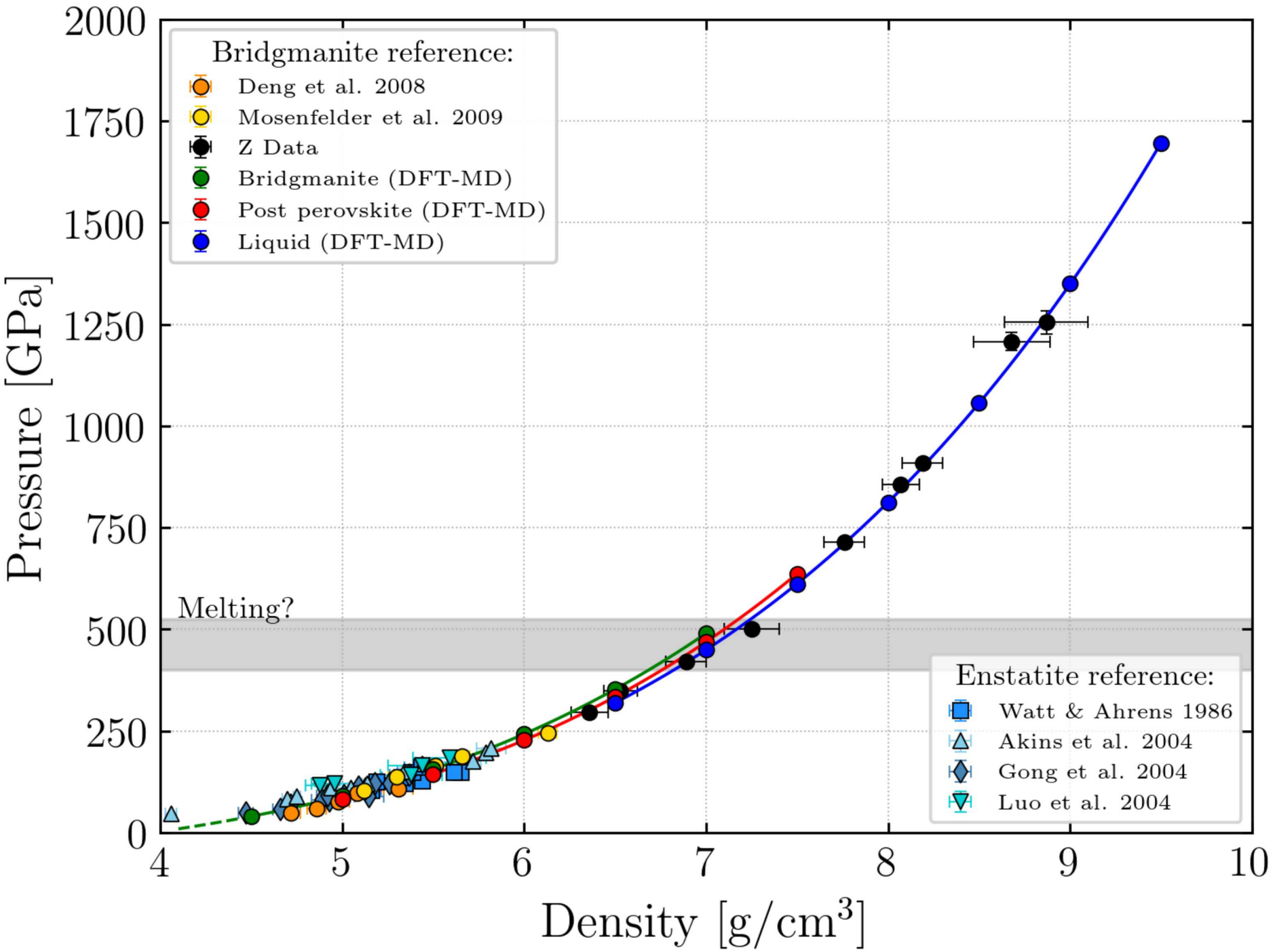
- **2.65 x 10^6 L of oil**
- **1.14 x 10^6 L of water**

Credit: S. Root (SNL)

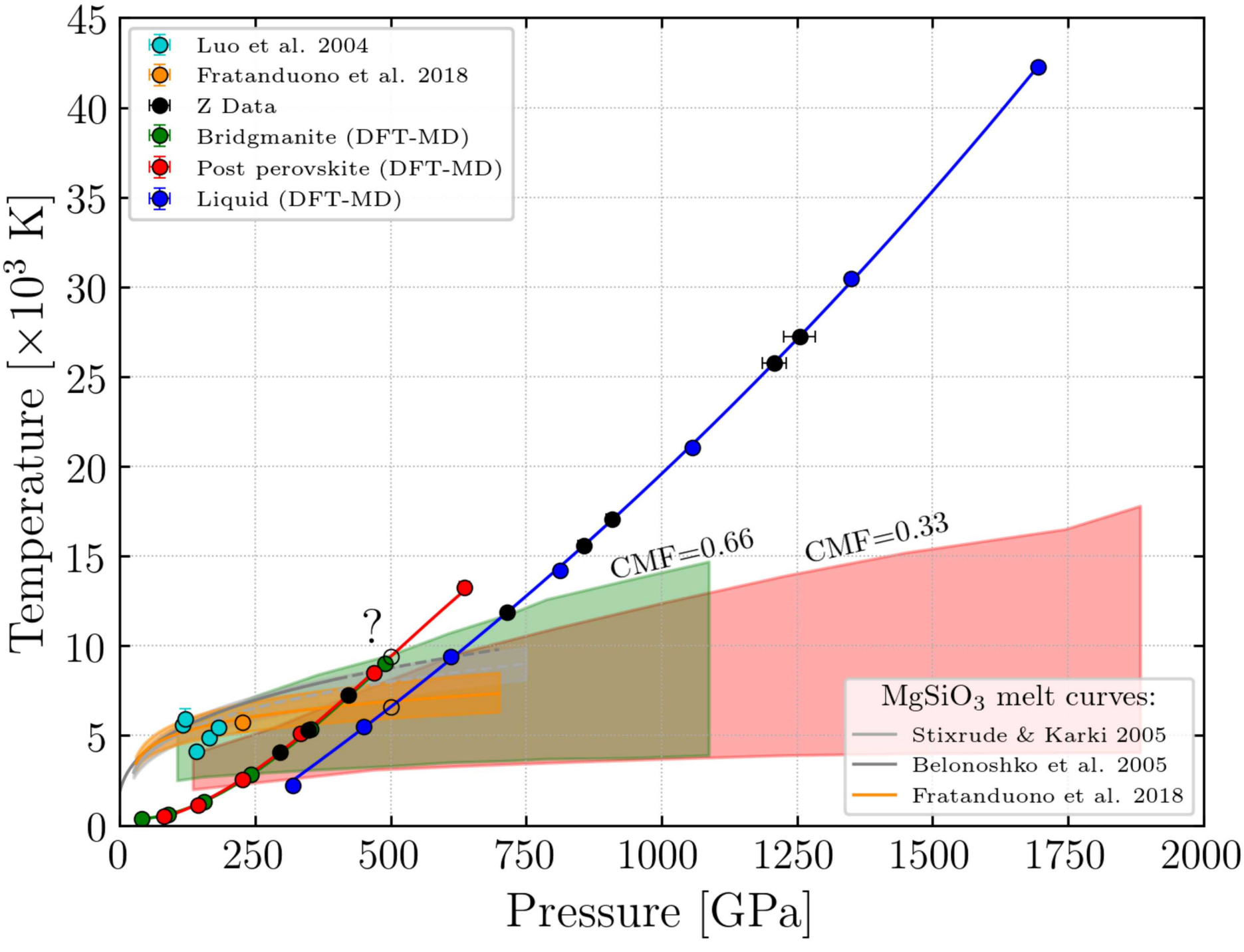
New data to u_p=13 km/s



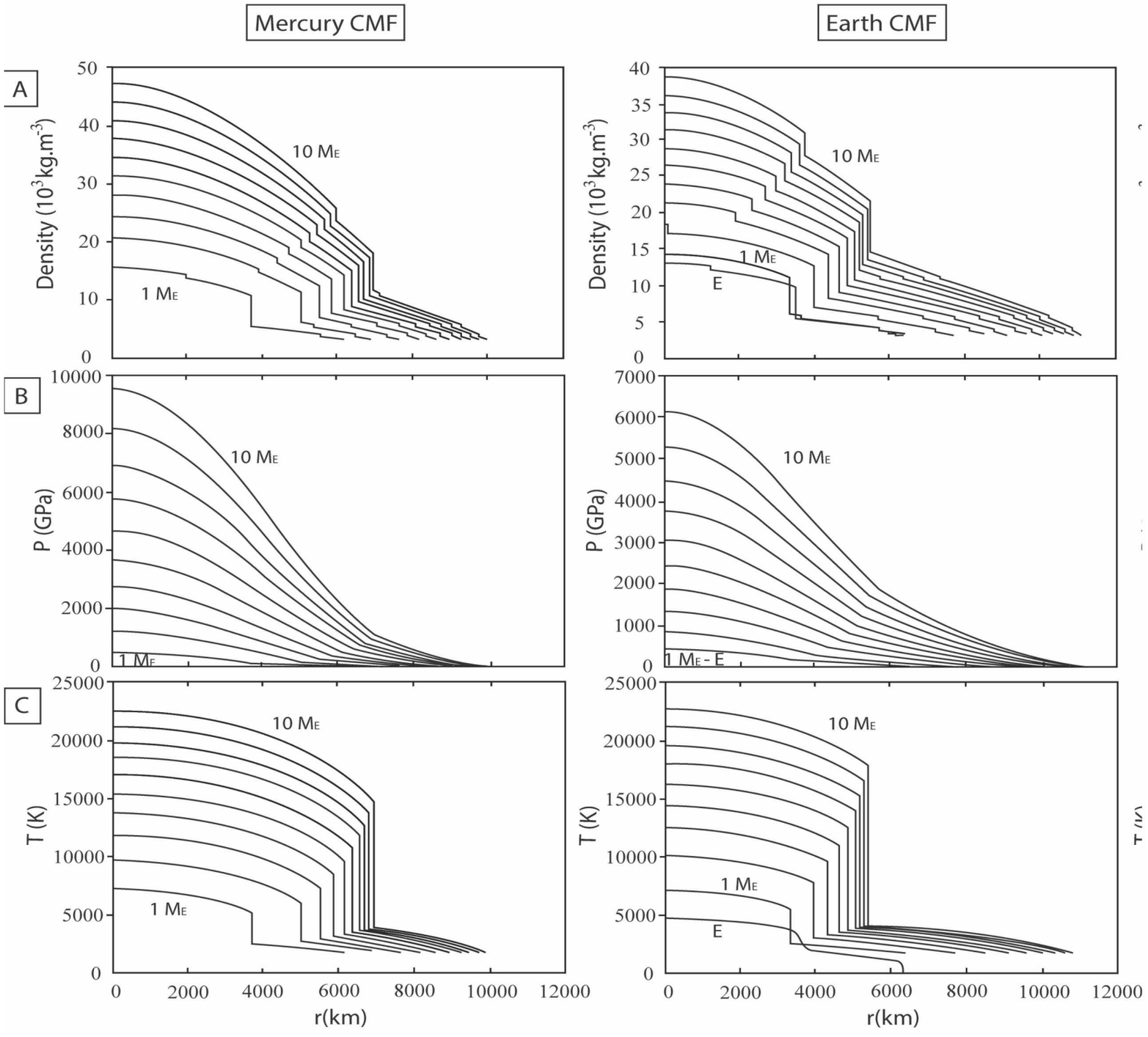
New data to P=1250 GPa



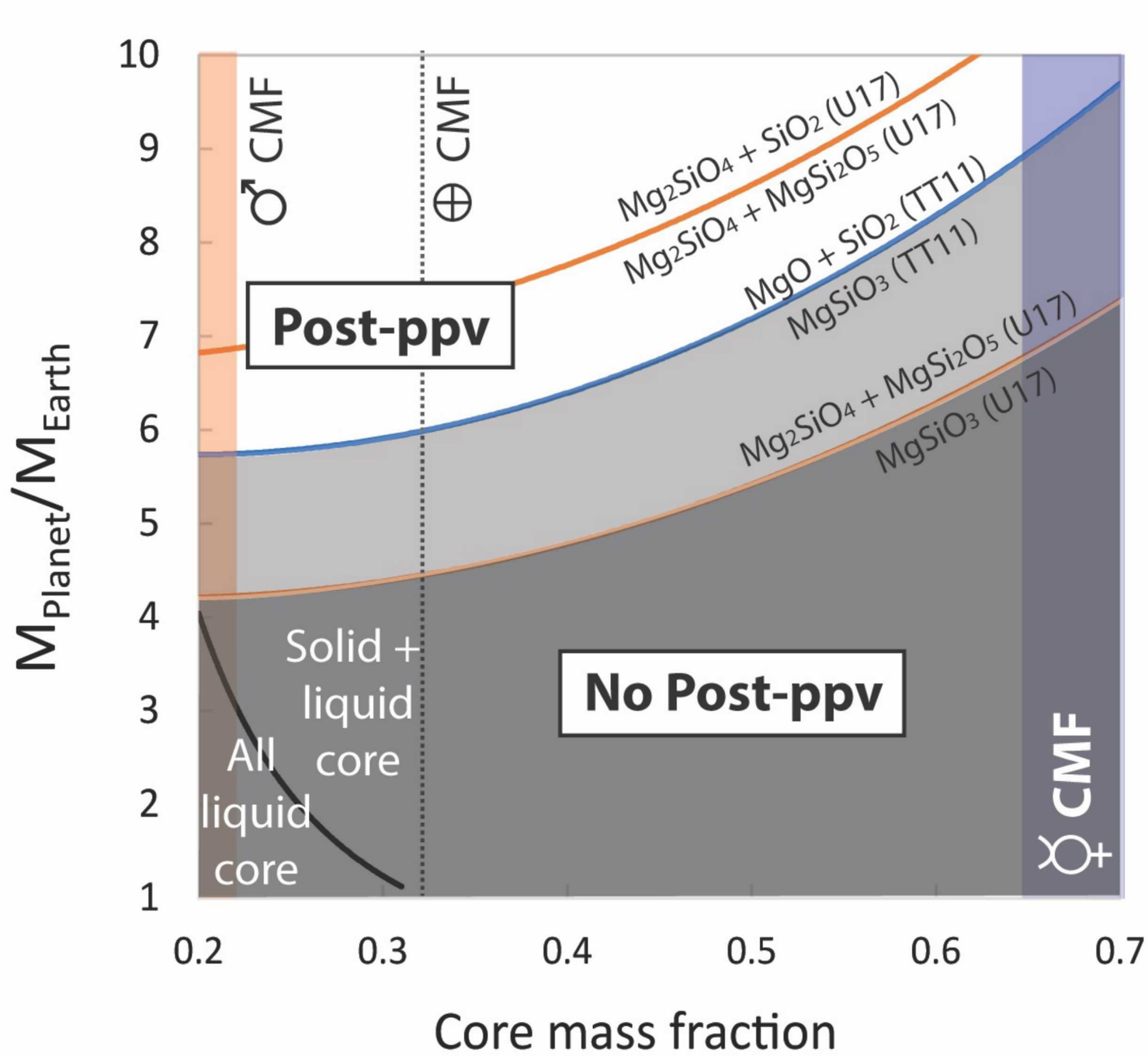
Inferred melting conditions



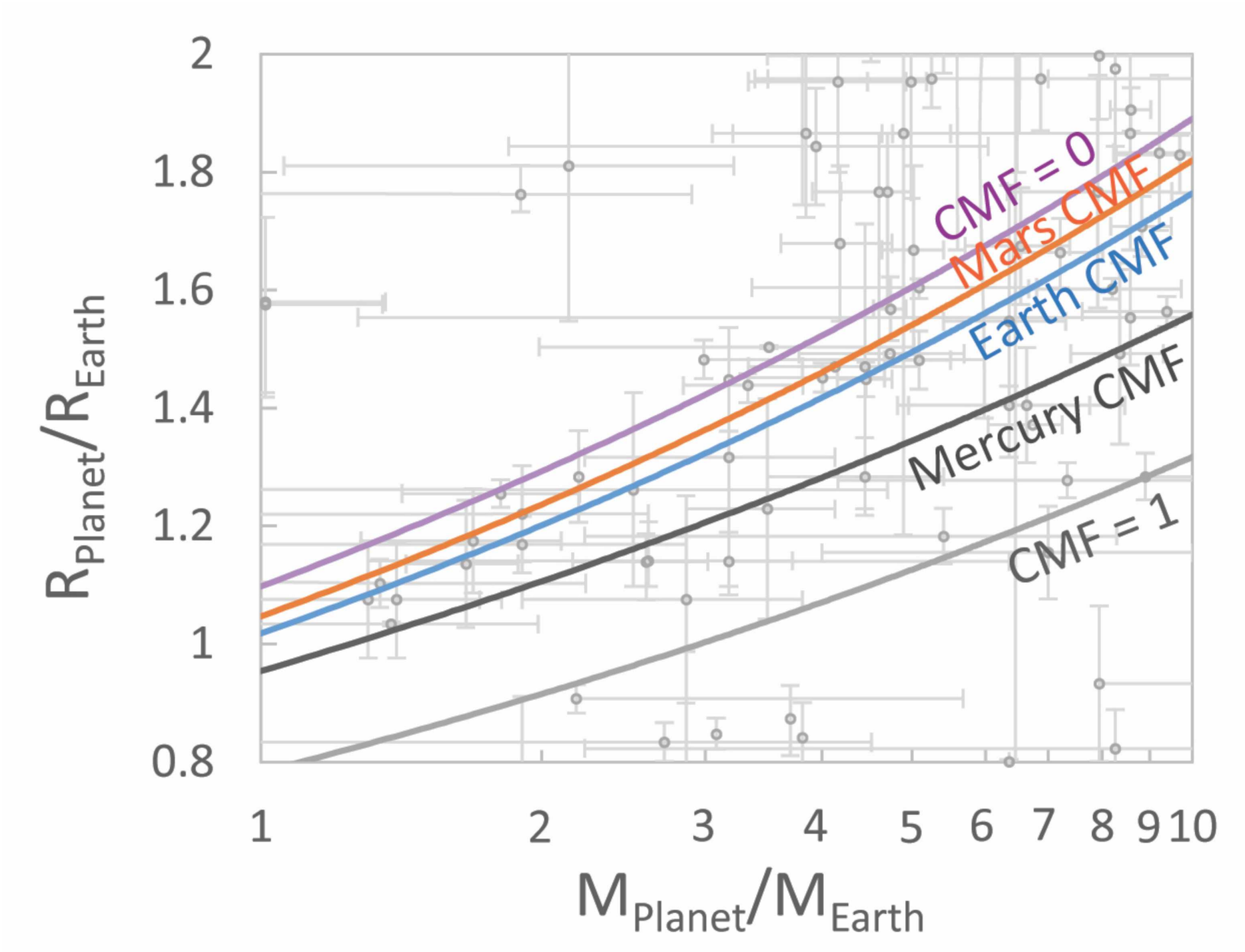
New interior structure models



New interior structure models



New interior structure models



Summary

- **X Shots executed Y shots remaining [ASK CHRIS]**
- **New dataset span 300-1250 GPa**
- **Melting likely occurs ~500 GPa**
- **Sound speed analysis *in progress***
- **New interior structure models *in progress***

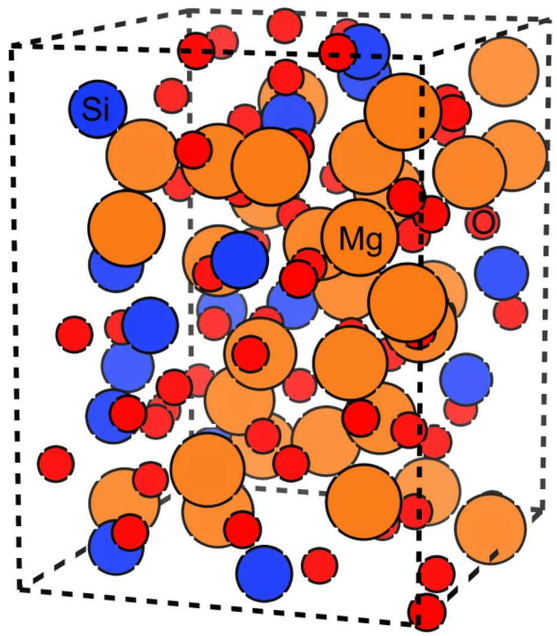
Questions?

Extra slides

DFT-MD Calculations

Two main ideas:

1. **Density, not wfn, is sufficient to describe ground state of system**
2. **Factor SWE into N coupled 3d eqns rather than one 3Nd eqn**



Thermodynamic quantities like *E*, *P*, *T* directly accessible *without assuming material response*!*