Using Fe-S-Si Internal Structure Models to Study Mercury's Interior

A. H. Dunnigan*[1,2] (dunniga@email.unc.edu), K. M. Soderlund[3], D. Liu[3], G. Steinbrügge[4], A. Rivoldini[5], M. Dumberry[6], G. Schubert[7], H. Cao[7,8], D. M. Schroeder[9]

[1]Department of Physics and Astronomy, University of North Carolina at Chapel Hill, [2]Lunar and Planetary Institute (USRA), [3]Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin, [4]NASA Jet Propulsion Laboratory, California Institute of Technology, [5]Royal University of Belgium, [6]Department of Physics, University of Alberta, Edmonton, [7]Department of Earth, Planetary, and Space Sciences, University of California Los Angeles, [8]Department of Earth and Planetary Sciences, Harvard University [9]Department of Geophysics, Stanford University.

Motivation

While NASA's MESSENGER mission improved many measurements for Mercury, a lack of direct measurement makes it difficult to constrain the interior. We must rely on modeling with geodetic and magnetic constraints to get an idea of what the interior is like.

- How can we better constrain Mercury's interior given known geodetic constraints and hypotheses for how its magnetic field is generated and maintained?

Methods

Geodetic Constraints:

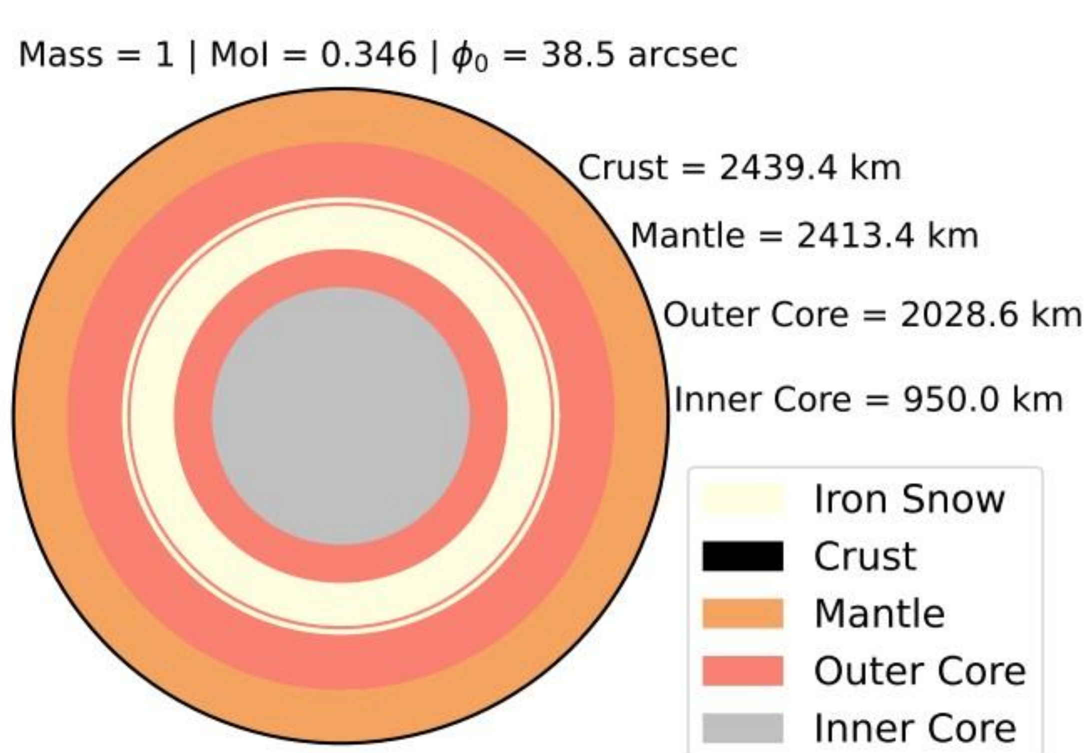
- Mean density ($\bar{\rho}$), obliquity (θ) , libration amplitude (ϕ_0), tidal love number (k_2), normalized moment of inertia ($\tilde{C}$), ratio of the polar moment of inertia of the solid part of Mercury involved in libration and the polar moment of inertia (C_m/C)
- We use $\tilde{C}$ **= 0.346 ± 0.014**, C_m/C = 0.426 ± 0.045, and ϕ_0 = 38.5 ± 1.6 arcsec [1]

Magnetic Constraints:

- Evidence of past and present magnetic field – dynamo
- Dynamo hypothesized to be sustained by iron snow driving convection in the core – creates **snow zones** in outer core fluid

Theoretical models (in Python code) consider the geodetic constraints and compute various models to match them.

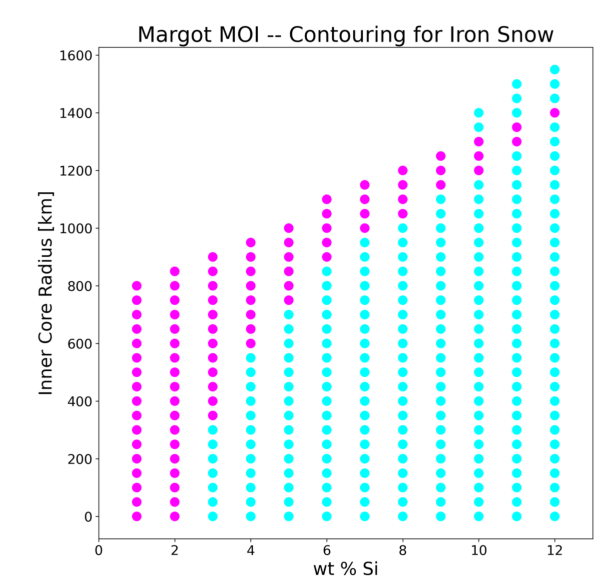
- Previously Fe-S, Fe-Si concentrations [2][3], now Fe-S-Si
- Present-day interior models – use Si as input
- Present-day code outputs radial profiles of temperature, density, S concentration, pressure

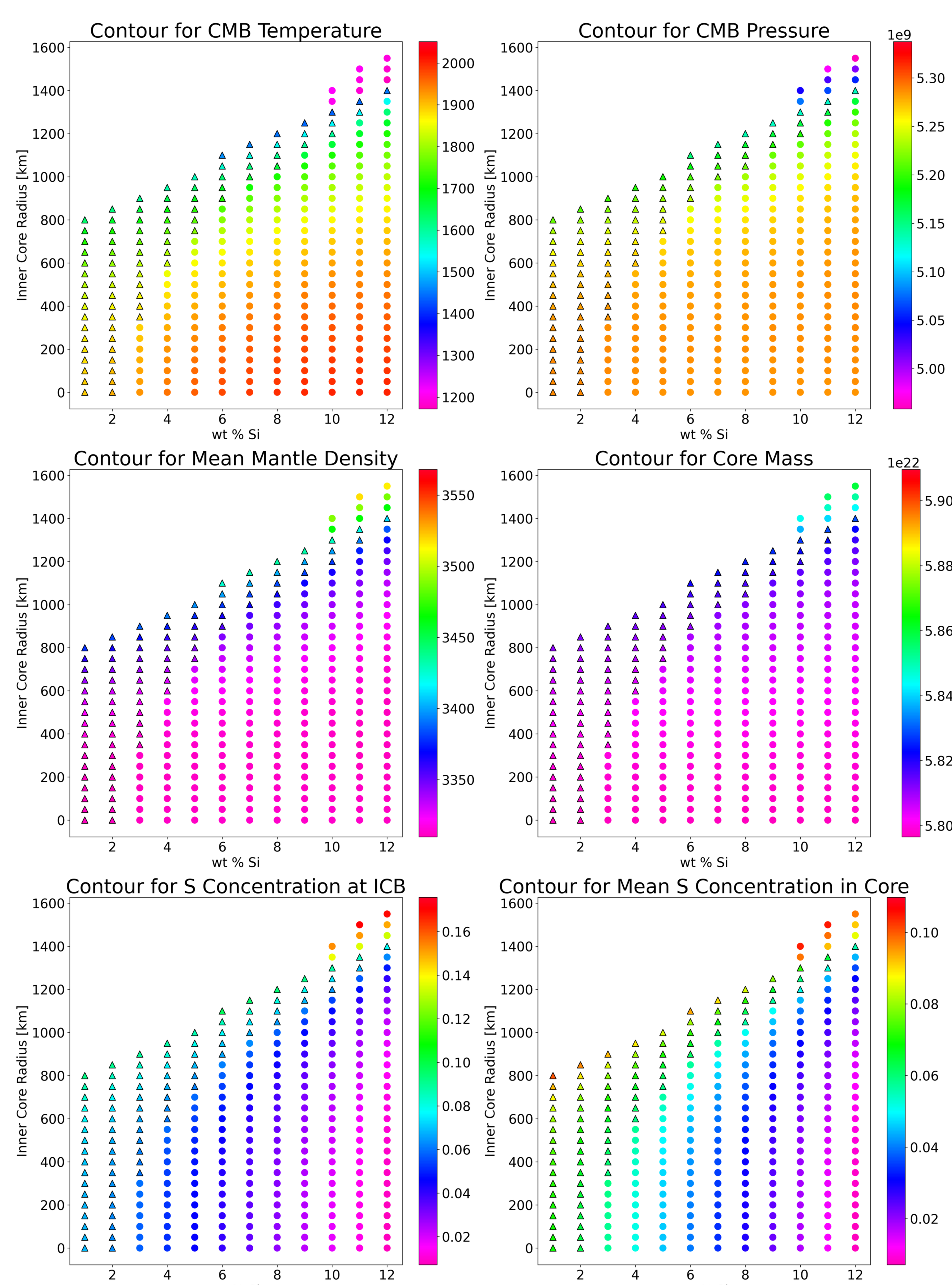


Example of interior structure model set to meet geodetic constraints of Margot et al. (2012) and silicon concentration of 6 wt % Si. Yields inner core radius of 950 km and two iron snow regions.

Results

- Using constraints from Margot et al. (2012)
- Magenta band of models with snow zones, skewed to lower wt % Si and shows increasing inner core radius with increasing wt % Si
- Look at models with snow zones because they are hypothesized to support dynamo that sustains magnetic field





Discussion

Using the assumption that the present day models need snow zones to sustain the magnetic field, we can find likely ranges for interior properties of Mercury.

Property	Range [units]
CMB Temperature	1440 – 1910 [K]
CMB Pressure	5.13 – 5.29 [GPa]
Mean Mantle Density	3310 – 3430 [kg/m^3]
Core Mass	(5.80 – 5.83) × 10^{22} [kg]
S Concentration (ICB)	6 – 10 [wt %]
S Concentration (Core Avg)	5 – 10 [wt %]
Si Concentration	1 – 12 [wt %]
Inner Core Radius	0 – 1400 [km]

Future Work:

- Repeat findings with constraints from Genova et al. (2019)
- Do error analysis for $\tilde{C}$ = 0.346 ± 0.014 to see how models with snow zones change
- Certain snow zone configurations not conducive to generating Mercury's dynamo – method of further constraining models
- Do further analysis on which properties are more likely to be present, especially considering the thermal evolution of Mercury
- Take most likely present day models with snow zones and study their evolution models

Acknowledgments

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[1] Margot et al. (2012) [2] Dumberry & Rivoldini (2015) [3] Steinbrügge et al. (2021)