

REVISITING MODELING MERCURY'S INTERIOR STRUCTURE WITH CONSTRAINTS FROM MAGNETICS. S. Goossens¹ and W. Kuang², ¹NASA Goddard Space Flight Center, Planetary Geology, Geophysics, and Geochemistry Laboratory, Greenbelt, MD 20771, USA (sander.j.goossens@nasa.gov), ²NASA Goddard Space Flight Center, Geodesy and Geophysics Laboratory, Greenbelt, MD 20771, USA (weijia.kuang-1@nasa.gov).

Introduction: NASA's MERcury Surface, Space ENvironment, GEOchemistry, and Ranging (MESSENGER) mission provided many new insights into the formation and evolution of the enigmatic innermost planet [1], yet it also opened new lines of investigation. Of particular interest for this work are Mercury's interior structure and the existence of an intrinsic magnetic field that is generated by convection in its fluid core (dynamo). Modeling Mercury's interior structure has resulted in tight bounds on the size of its liquid core, yet questions remain, for example, concerning the existence of a possible inner core (*e.g.*, [2]; [3]) and the state of Mercury's mantle (*e.g.*, [4]). Most of the Mercury dynamo models employ complicated structures, such as a stably stratified outer portion of the core, to account for the observed weak field [5]. Although a recent analysis [6] found that a thermally stable layer formed in all their successful evolution models of Mercury's interior (constrained by crustal thickness, contraction, and energy considerations for the possibility of the existence of a dynamo), this was only the case for a very limited number of models, all with a thick layer at the top of the liquid core.

Here, we revisit our earlier analysis of Mercury's interior [7], using the polar moment of inertia, the mantle moment, mass, and tidal response as expressed by the Love number k_2 as constraints. We update our modeling with recent results concerning the Fe-Si system [8], and by considering additional constraints at the core-mantle boundary from dynamo modeling.

Analysis and Results: Following our earlier work [7] we model Mercury as a radially symmetric planet in hydrostatic equilibrium, consisting of a solid inner core, a liquid outer core, a mantle, and crust. We numerically integrate equations for the pressure, gravity, and temperature to obtain self-consistent radial profiles. From these profiles we compute the model's mass, moments of inertia, and tidal response, which serve as measurements in a Markov Chain Monte Carlo (MCMC) analysis to map the distribution of model parameters that fit these measurements within their associated errors. We use the values for mass, moments of inertia, and Love number from [2].

In our models the core is composed of iron with silicon as the additional light element. We use equations of state for FeSi to determine the density at local pressure and temperature. For the temperature, we assume an isothermal inner core and an adiabatic outer core. The mantle and crust are assumed to be of constant density. To compute a model's tidal response, we assume a

temperature and pressure dependent viscosity profile in the mantle.

In our previous analysis, the radius of the solid inner core was a free parameter in the MCMC simulations. This can result in thermodynamical inconsistencies, as the local

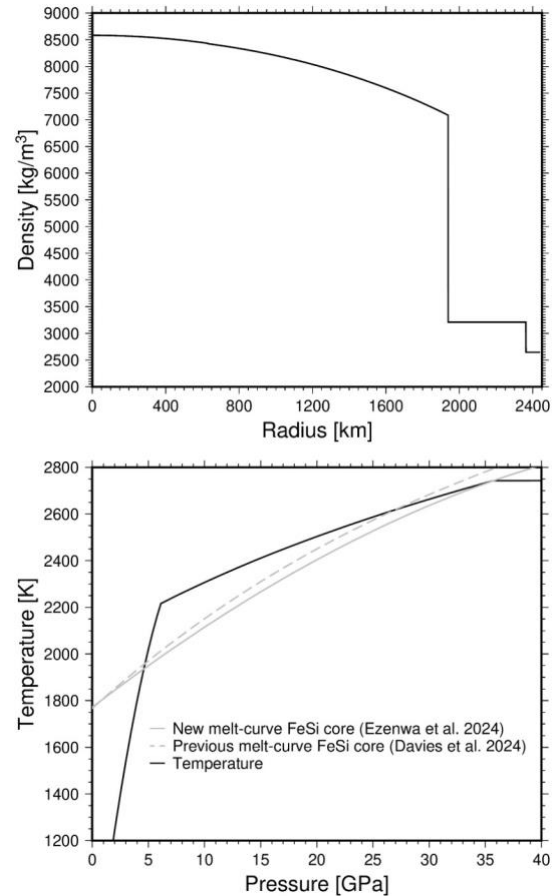


Figure 1. Profiles of radius vs density (top) and pressure vs temperature (bottom) for a sample interior model. The inner core size is determined by the melt-curve (indicated with a dashed line).

pressure and temperature might indicate that the state of the core is liquid while it is assumed to be solid, and vice versa. In this analysis, we use recent results for the melt-curve of FeSi [8] to determine the state of the core locally, thus eliminating a parameter in the MCMC analysis as well as eliminating the possibility of thermodynamical inconsistencies. We combined the results presented in [6] with those in [8] to fit a polynomial that prescribes the FeSi melt temperature as a function of pressure and weight percentage of Si. We show an example of a density profile and of a temperature-pressure profile in Figure 1.

Our analysis also reconsiders temperature profiles in the core to accommodate additional thermal conditions consistent with Mercury’s magnetic properties, *e.g.*, the temperature differences between the inner core boundary (ICB) and the core-mantle boundary (CMB) that are from the full-scale Mercury dynamo simulation results of which the generated magnetic fields display the characteristics of the observed Mercury’s interior magnetic field [9].

Outlook: Our updated analysis provides interior models that are more internally consistent than models from our earlier analysis, by considering local conditions based on recently updated melt curves. In addition, we consider constraints from full-scale dynamo modeling. These constraints influence the resulting distributions of parameters such as CMB temperature, weight percentage of Si in the core, and solid inner core radius. This study could provide well-defined boundary conditions for more elaborate evolution modeling, and in addition it could provide a pathway to model convection in Mercury’s mantle, thus addressing outstanding questions concerning its state.

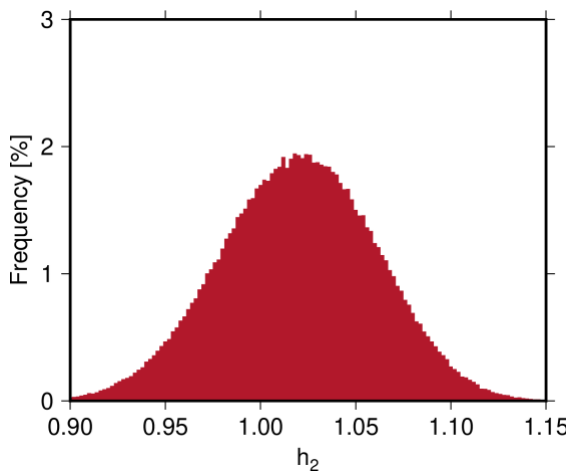


Figure 2. Example of a prediction for the displacement Love number h_2 , which could be measured by BepiColombo.

Our modeling can also provide initial model estimates of, for example, the displacement Love number h_2 (see Figure 2 for an example) and dissipation within Mercury, as expressed by the quality factor Q determined from the tidal phase lag, both of which could be determined using data from the BepiColombo mission [10,11,12].

Acknowledgments: Support for this research was provided by NASA’s Planetary Science Division Research Program, through ISFM work package Planetary Geodesy at Goddard Space Flight Center.

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