Geophysical Research Abstracts
Vol. 15, EGU2013-7006, 2013
EGU General Assembly 2013

Interior Structure and Tidal Response of Mercury

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Recent determinations of Mercury's mean density, polar moment of inertia factor, and the inertia of its solid outer shell provide strong constraints on the radius of its liquid core. We present an ensemble of spherically symmetric interior structure models that all satisfy the observational constraints. The models consist of a pure iron solid inner core, a liquid Fe-FeS outer core, a peridotite mantle and a crust predominantly composed of plagioclase. The sulfur content in the outer core, the iron and magnesium content of the mantle, and the crustal thickness vary throughout the ensemble. Comparison of observed and predicted moments of inertia yields admissible ranges for the outer core radius and the mantle density. From this model ensemble we derive geophysical observables that would allow further constraining the interior structure of Mercury in future experiments.

The moment of inertia constraints allow for both forsterite and fayalite rich mantle compositions. Variations of mantle density trade off with crustal thickness and core composition. This non-uniqueness could be resolved using seismic travel time observations: since the P wave velocity of a fayalite mantle is significantly lower than that of the plagioclase-rich crust, a shadow zone arises as a clear discriminant between the two end-member compositions.

The planet's response to solar tidal forcing strongly depends on its interior structure and rheological properties and can be parameterized in terms of the surface body tide Love numbers k_2 and h_2, respectively. We employ the frequency-dependent Maxwell rheology to calculate the body tide Love numbers for the main tidal period (87.97 days) using the density, rigidity and viscosity profiles of our structural models. We obtain values between 0.38 and 0.65 for k_2 and between 0.70 and 1.12 for h_2, respectively, thereby indicating the substantial tidal response of Mercury's interior. Furthermore we find that, via viscosity and rigidity, both k_2 and h_2 are foremost dependent on the mantle composition and less affected by the inner and outer core radii. The peak-to-peak radial displacement amplitudes are predicted to range from 47 cm to 76 cm in polar regions and from 139 cm to 223 cm in equatorial regions, sufficiently large to be detected by laser altimetry from the BepiColombo spacecraft.