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Constraining Mercury's interior structure with geodesy data and its present thermal state

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Recent measurements of Mercury's spin state and gravitational field supplemented by the assumption that the planet's core is made of iron and sulfur give strong constraints on its interior structure. In particular, they allow a precise determination of Mercury's core size and average mantle density. Present geodesy data do, however, almost not constrain the size of the inner core. Interior structure models with a fully molten liquid core as well as models with an inner core almost as large as the core agree with the observations.
Additionally, the observed internally generated magnetic field of Mercury does not preclude the absence of an inner core, since remelting of iron snow inside the core could produce a sufficient buoyancy flux to drive magnetic field generation by compositional convection.

Although sulfur is ubiquitously invoked as being the principal candidate light element in terrestrial planet's cores its abundance in the core depends on the redox conditions during planetary formation. Remote sensing data of Mercury's surface by MESSENGER indicate that Mercury formed under reducing conditions. As a consequence, substantial amounts of other light elements like for example silicon and carbon could be present together with sulfur inside Mercury's core. Compared to sulfur, which does almost not partition into solid iron at Mercury's core conditions, silicon partitions almost equally well between solid and liquid iron whereas a few percent of carbon can partition into solid iron. Therefore, compared to a pure iron-sulfur core, if silicon and carbon are present in the core the density jump at the inner-core outer-core boundary could be smaller and induce a large enough change in the inner-core flattening to alter Mercury's libration amplitude. Moreover, the presence of carbon together with sulfur further reduces the core solidus temperature, potentially delaying the onset of inner core formation. Finally, if both silicon and sulfur are present in sufficient quantities a thin layer much enriched in sulfur and depleted in silicon could form at the top of the core as a consequence of a large immiscibility region in liquid Fe-S-Si at Mercury's core conditions.

The present radius of an inner core depends mainly on Mercury's thermal state and concentration of light elements inside the core. Because of the secular cooling of the planet, at a time in Mercury's evolution the temperature inside the core drops below the core liquidus temperature somewhere in the core, which can lead to the formation of an inner core and to the global contraction of the planet. The amount of contraction depends mainly on the temperature decrease, on the thermal expansion of the materials inside the planet, on the volume of crystallized iron-rich core liquid, and on the volume of crystallized crust.

In this study we use geodesy data (88 day libration amplitude, polar moment of inertia, and tidal Love number), the recent estimate about the radial contraction of Mercury, and thermo-chemical evolution calculations taking into account the formation of the crust, a growing inner core, and modeling the formation of iron-rich snow in the core in order to improve our knowledge about Mercury's inner core radius and thermal state. Since data from remote sensing of Mercury's surface indicate that Mercury formed under reducing conditions we consider models that have sulfur, silicon, and carbon as light elements inside their core.