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Mercury's moment of inertia from spin and gravity data

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Rotation studies coupled with gravity measurements provide powerful probes of planetary interiors (e.g., Munk and MacDonald 1960, Peale 1976, Lambeck 1980, Wahr 1988, Dickey et al 1994). Peale (1976) has shown that measurements of Mercury's obliquity and amplitude of longitude librations, together with a knowledge of the second-degree coefficients of the gravity field, can illuminate the size and state of the core.

Over the past ten years we have used the Goldstone Solar System Radar (GSSR) in conjunction with the Green Bank Telescope (GBT) to characterize the spin state and interior of Mercury. We implemented a technique (Holin et al, 1988, 1992) that provides instantaneous spin rate measurements with 10 ppm fractional precision and spin axis orientation at the arcsecond level. On the basis of measurements at 21 distinct epochs between 2002 and 2006, we found observational evidence that Mercury closely follows a Cassini state and that it exhibits forced librations in longitude, as predicted by theory. The amplitude of the librations indicates that the mantle of Mercury is decoupled from a molten outer core (Margot et al 2007). A long-period (~12 year) libration signature may be present in the data.

Analysis of the radio science signal from the MESSENGER spacecraft (Solomon et al, 2001) has provided measurements of the low-degree gravitational harmonics with a precision of better than 1% (Smith et al, 2012). The combination of spin and gravity data permits a determination of the polar moment of inertia of the entire planet and that of the outer librating shell. The moments can be used with interior models (Hauck et al, 2004, 2007) to arrive at an estimate of the core size. The core size error budget indicates that the precision of the ground-based estimates of obliquity and librations will ultimately dictate the quality of the core size determination, as well as the attendant inferences regarding the interior structure, thermal evolution, and magnetic field generation of the planet.

Spin measurements obtained since 2006 are being used to (1) refine the determination of the obliquity and of the libration amplitude; (2) confirm the presence or absence of a long-period libration component; (3) quantify deviations of the pole from the strict Cassini state. Departures from the expected spin orientation can provide information about core properties and dynamics. Such an offset in the spin orientation of the Moon has been used to quantify dissipation in the lunar interior, with both dissipation due to solid-body tides and dissipation at a liquid core/solid body boundary playing a role (Yoder 1981, Williams et al 2001).

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