REPEAT-ORBIT INTERFEROMETRIC PRECISION MEASUREMENT OF MERCURY OBLIQUITY.

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Introduction: Repeat-orbit or time-delayed interferometry has been widely used for SAR-based observations of such terrestrial phenomena as flow of glaciers and post-seismic displacements from radar on Earth-orbiting satellites and spacecraft. Repeat-orbit interferometry has also obtained fringes while investigating the measurement of topography of the Moon from Arecibo radar observations (Stacy, 1993). Because of the unique spin-orbit resonance of Mercury, the locus of the subradar point on Mercury crosses over itself many times per year. Moreover, the locus of the subradar track repeats these crossings from year to year over many years. Given the proper geometry, these subradar point crossings offer the opportunity for interplanetary repeat-orbit interferometry via Earth-based radar observations. The ephemerides of Mercury and Earth, and the orientation of the Earth, are all known to sufficiently high-precision with respect to "inertial space" to enable this kind of interferometry. This capability would merely be a curiosity, since Earth-based radar lacks the signal-to-noise to measure planetary-scale topography, except that the technique can be used to measure Mercury's obliquity (and possibly the forced libration in longitude). Combining very accurate measurements of the obliquity and the forced libration in longitude with Mercury-orbiter-based measurements of the low-order and degree Mercury gravity field can place constraints on the size and state of Mercury's fluid core (Peale, 1988; Peale *et al.*, this meeting).

Implications of a Fluid Core: Repeat-orbit interferometry thus holds out the hope that, in combination with improved values of c_{20} and c_{22} for Mercury (from, e.g., MESSENGER), the size and state of a putative fluid core can be determined. Why is it believed that Mercury still has a fluid core today? The idea of the existence of a fluid core is based on the magnetic field observed by Mariner 10 (Ness *et al.*, 1974), which is explained most simply by a dynamo in a currently molten core. If Mercury has such a core, then Peale (1988) has shown that dissipation will carry Mercury to rotational Cassini state 1 (in which the spin vector, the orbit precession angular velocity vector, and the orbit normal vector are all coplanar). The obliquity θ will be close to, but not exactly zero. Under plausible conditions, a libration ϕ in longitude will forced with an 88 day period. The dynamics of Mercury's orbit, along with the Mariner 10 gravity field and associated uncertainties, imply the following ranges according to Peale (1997):

$$1.7 \text{ arcmin} < \theta < 2.6 \text{ arcmin}$$
$$20 \text{ arcsec} < \phi < 60 \text{ arcsec}$$

The size and state of Mercury's core can be deduced from measurement of θ and ϕ along with determination of c_{20} and c_{22} of the gravity field to modest accuracy (Peale, 1997). Radar observations of radar-bright features at the poles of Mercury have improved the limits on the obliquity (Harmon *et al.*, 1994). Further improvements in the knowledge of the obliquity, and measurement of ϕ present a challenging problem in astrometry. Radar imaging of the equatorial regions of Mercury using sub-microsecond bauds may offer a method to measure ϕ that does not require interferometry. Following small radar features over many years may well be the best method for determining ϕ. Such imaging would be done each time the repeat-orbit interferometry was attempted. Additional imaging observations aimed just at measuring ϕ may prove to be necessary.

High Accuracy Interferometry: The repeat-orbit technique uses interferometry between observations of same subradar point on Mercury viewed in precisely the same geometry at greatly different times. The "baseline" is constructed from the two (very slightly different) positions of the observing point on Earth as viewed from Mercury. Figure 1 gives a cartoon of the geometry of the repeat-orbit interferometry. Detailed predictions will be shown for future observations through the year 2009. This technique uses some of the same mathematical formulations as Goldstein *et al.* (1988), and Zebker and Goldstein (1986). For example, the "fringes" for 0.2 microsecond baud voltage samples will appear in the first few Fresnel zones surrounding the subradar point on the two dates, and will begin about an hour before maximum intensity and fade completely over the hour following, if voltage data are obtained at the appropriate times (Goldstein, personal communication, 2000).

In summary, exploration of this technique seems warranted, given the high science value of contributing to constraints on the size and state of Mercury's (assumed) fluid region of its core.

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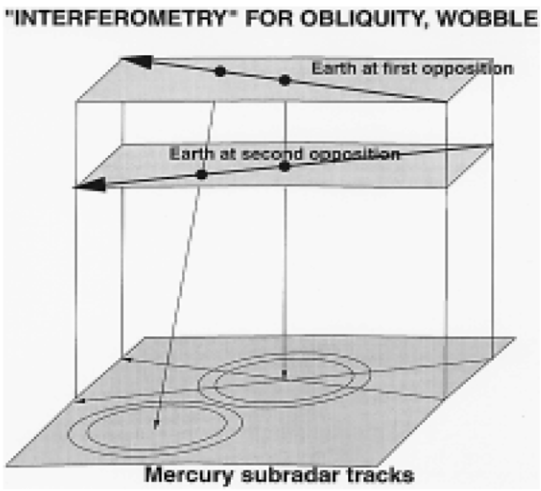

FIGURE 1. Mercury Repeat-Orbit Interferometry