MERCURY LIBRATIONS MEASURED WITH EARTH-BASED RADAR. J. L. Margot[1], S. J. Peale[2], R. F. Jurgens[3], M. A. Slade[3], I. V. Holin[4], [1]Department of Astronomy, Cornell University, 304 Space Sciences Building, Ithaca, NY 14853, jlm@astro.cornell.edu, [2]University of California, Santa Barbara, [3]Jet Propulsion Laboratory, [4]Space Research Institute.

Introduction: Since May 2002 we have obtained about 20 high-precision measurements of the instantaneous spin rate of Mercury using the radar facilities of Arecibo and Goldstone, and the Robert C. Byrd Green Bank Telescope. The experimental technique relies on the space-time correlation of speckle patterns (Fig. 1) and was first described in [1,2,3,4]. A libration signature which is synchronized to the orbital period of 88 days is clearly detected. Initial data analysis was not entirely satisfactory as it revealed an offset of the angular velocity curve from the expected value of 3/2 the mean orbital motion. While this offset could be indicative of an additional libration component superposed on the 88-day librations, the presence of a significant, long-period libration was unexpected: The damping timescales for a possible ~12 year free libration have been shown to be much smaller than the age of the solar system [5] and the amplitude of a possible ~125 year forced libration has been shown to be small [6]. Further analysis revealed a systematic effect in the conversion between our observable (time lag between two receiving stations) and the desired instantaneous spin rate values. Although this systematic effect was small, corresponding to a surface displacement of less than a centimeter during each observation interval, its removal eliminates the need for an additional libration component and improves the overall fit of the data to theoretical libration curves (reduced chi-squared of order unity). With the removal of the angular velocity offset, our best-fit value of (B-A)/Cm is reduced to (2.00 +/- 0.12) x 10^{-4}, now barely outside the range expected for a solid core using the Mariner 10 measurement of the gravitational harmonic C_{22} and its uncertainties [7]. Monte Carlo simulations that take into account the uncertainties on all parameters reveal that 90% of simulated C_m/C values are less than unity (Fig. 2), suggesting that the core of Mercury is liquid. However, if the existing C_{22} measurement from Mariner 10 is off by more than one sigma (realistic errors of [7]), our libration data may be consistent with a solid core. Updated values of the gravitational harmonic coefficients will be obtained by the MESSENGER mission.

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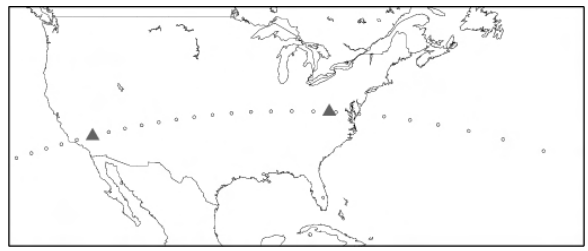

Figure 1: Illustration of the trajectory (circles, 1 s time step) of wavefront corrugations tied to the rotation of a planetary body as observed by two telescopes on Earth (triangles). The time delay for the pattern to reproduce at both stations is a direct measure of the planetary rotation rate.

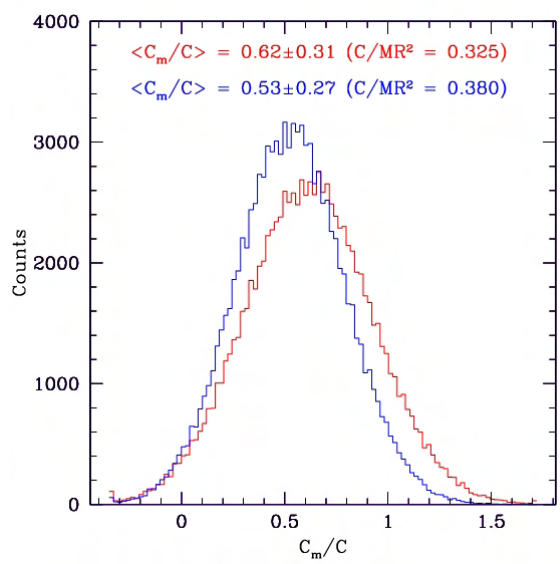

Figure 2: Result of Monte Carlo simulations taking into account uncertainties on all parameters influencing the value of C_m/C, diagnostic of the state of Mercury's core. Values less than unity indicate a liquid core.