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The Equatorial Shape, Topography, and Gravity of Mercury from the MESSENGER Flybys of 2008

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Abstract

In January and October 2008, the MESSENGER spacecraft passed within 200 km of the surface of Mercury en route to Mercury orbit insertion in March 2011. Data acquired by the laser altimeter and Doppler signals from tracking the spacecraft during these two encounters provided new information on the planet's equatorial shape, near-surface structure, and gravity field.

During both flybys the laser altimeter made range measurements to the surface for approximately 10 minutes along ground tracks 3000 to 4000 km long just south of the planet's equator. The two ground tracks, on opposite sides of the planet, both revealed a crater-studded surface having a long-wavelength topographic slope that appears be a global feature of the planet and not inconsistent with earlier radar measurements. In addition to craters, the altimeter sampled scarps and ridges – dominantly products of planet-wide contraction that accompanied cooling of the interior – whose topographic profiles provide fresh constraints on mechanical models for lithospheric deformation on Mercury.

The tracking of MESSENGER provided new information about Mercury's mass and gravity field. For periods of approximately 30 minutes during both flybys the spacecraft was sensitive to the asphericity of the planet's gravity field, and a preliminary spherical harmonic gravity model (HgM001, to degree and order four) has been developed from the tracking data. The model indicates that the equatorial gravitational ellipticity of Mercury is closely aligned with the prime meridian and also with the long axis of the elliptical shape estimated from the two altimetric profiles and suggested by radar observations acquired during the last four decades. The altimeter data also reveal a several-hundred-meter offset in the center of figure from the center of mass.

During both flybys the orbital perturbations by the Mercury gravity field were larger than anticipated on the basis of the gravity field inferred from observations made during the Mariner 10 flybys of 1974-75. Those perturbations could not be modeled fully by adjustments only to the planet's mass, gravitational flattening, and equatorial ellipticity. The Doppler residuals to the new gravity model suggest that additional gravity information is contained in the tracking data but is not resolved in HgM001. The possibility that Mercury has uncompensated lunar-like mascon anomalies centered on major impact basins is not inconsistent with the observations but cannot be demonstrated from data in hand. Errors in the position of Mercury and in the Doppler tracking data have been ruled out.