GEOPHYSICAL CONSTRAINTS ON THE DEEP INTERIOR OF MARS: PRESENT STATUS AND FUTURE PROSPECTS

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An improved determination of the spin pole precession rate of Mars will contribute greatly to our understanding of the internal structure of the planet. The moment of inertia of Mars is an extremely important global geophysical parameter, whose value is only known with an accuracy of 10%. The polar moment is determined as the ratio of two parameters: the gravitational oblateness, which is known to an accuracy of 0.01%, and the spin axis precession rate, which is known with an accuracy of 10%. Thus, a better determination of the spin precession rate will directly improve knowledge of the moment of inertia, with consequent tightening of constraints on internal density structure and composition. I will review present knowledge of the precession rate, compositional implications of various possible values of the moment of inertia, and near term prospects for improving knowledge of the deep interior of Mars from geodetic observations.

The moment of inertia of Mars is arguably the most important single global geophysical parameter for which a scientifically useful value has not yet been empirically determined. The moment of inertia of a planet can be determined from two related observations: amplitudes of the degree two gravity field coefficients, and rotational responses to known torques. For Mars, the gravitational oblateness is known with a relative error of less than 4 10^{-3} **[1]**. However, the precession rate of the spin pole is only known with an accuracy of about 10% **[2, 3]**. As a result, current estimates of the moment of inertia **[4, 5]** depend on rather ambiguous efforts to partition the observed gravity field into hydrostatic and non-hydrostatic components and then invoke the Darwin-Radau relation to infer the moment of inertia from the hydrostatic component. See **[6, 7, 8]** for discussion of this technique and the problems associated with it. The "standard" value of the moment of inertia of Mars is 0.365 MR^2, where M is the mass, and R is the radius. However, it is very difficult to assess the error in this estimate since alternative partitionings of the gravity field yield values as low as 0.345 MR^2, and the present estimates of the spin axis precession rate suggest that value is closer to 0.325 MR^2.

The mean moment of inertia of a body provides one of only two remotely accessible integral constraints on the radial density profile (total mass, or mean density, is the other). In the absence of seismic constraints, published estimates of Martian internal structure have relied heavily on existing estimates of the moment of inertia **[9, 10, 11, 12, 13]**. Though the numerical uncertainty discussed above may not seem extraordinarily large, the compositional consequences are truly profound. If the moment of inertia of Mars is confirmed to be as low as 0.345 MR^2, the conventional view of mantle with relatively high Fe/Mg would have to be abandoned **[12, 14]**. The most significant benefit in this arena would occur from reducing the uncertainty in the precession rate (and moment of inertia) from the current value of 10% to a value near 1%. Beyond that point, the ambiguities inherent in the compositional inferences from two radial moments make the returns on the investment diminish considerably.

Present observational estimates of the spin axis precession rate come from two sources: astrometric observations of the orbital motions of the natural satellites Phobos and Deimos, extending back to 1877, and range measurements to the Viking landers, extending over the time interval 1976-1983. The astrometric observations yield precession rate estimates of (-8.52 ± 1.63) arcsec/year **[3, 15]** and the Viking range data yield estimates of $(-9.6 + 0.6)$ arcsec/year **[2]**. A combined solution **[2]** yielded a rate estimate of (-8.1 ± 0.5) arcsec/year. The corresponding moment of inertia estimates are $C/MR^2 = (0.325 \pm 0.052)$, (0.289 ± 0.018), and (0.342 ± 0.021), respectively.

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In previous attempts to combine the Viking lander observations and the Phobos and Deimos astrometry, the solutions have suffered from the lack of any observational ties between the data sets. Fortunately, such a tie does exist. On 20, 23 and 27 September 1977, the shadow of Phobos passed over the Viking Lander I site. The eclipses were observed by the on-board cameras. Analysis of the light curves of the eclipses will provide constraints on the path of Phobos across the disc of the Sun, with an expected accuracy of $\pm$100 m. This will allow a much improved combination solution for the spin pole position and precessional motion.

Tracking of artificial satellites in orbit about Mars provides an important additional source of information about the spin pole orientation, via the intermediary of the gravitational field. Recent improvements in knowledge of the gravitational field suggest that it will be possible to re-analyze the Mariner 9 and Viking Orbit data to obtain spin pole constraints in the mid-1970's through early-1980's. When Mars Global Surveyor is in its mapping orbit (starting in January 1998) it will provide significantly improved orbital sensitivity to the spin pole position.

The best near-term prospect for improved knowledge of the spin pole location and precession rate will come from range measurements to the Mars Pathfinder lander. After arrival at Mars in July 1997, it will have the capability to participate in range measurement campaigns similar to those accomplished by Viking. With a single measurement range accuracy of ~10 m, and daily observing sessions during the one month prime mission, this source alone should provide constraints on the spin pole orientation of Mars at the ~1 arcsec level. When this estimate of the late 1990's pole position is compared with the late 1970's position from Viking, the precession rate can be estimated with an accuracy of ~1%.

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