REFINEMENT OF PHOBOS EPHEMERIS USING MARS ORBITER LASER ALTIMETER RADIOMETRY. G. A. Neumann[1,2], B. G. Bills[2,3], D. E. Smith[2], M. T. Zuber[1,2], [1] *Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Building 54, 77 Massachusetts Avenue, Cambridge, MA 02139-4307, (neumann@tharsis.gsfc.nasa.gov),* [2] *Laboratory for Terrestrial Physics, Code 920, NASA/Goddard Space Flight Center, Greenbelt, MD 20771,* [3] *Institute for Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093.*

Radiometric observations from the Mars Orbiter Laser Altimeter (MOLA) can be used to improve the ephemeris of Phobos, with particular interest in refining estimates of the secular acceleration due to tidal dissipation within Mars. We have searched the Mars Orbiter Laser Altimeter (MOLA) radiometry data for shadows cast by the moon Phobos, finding 7 such profiles during the Mapping and Extended Mission phases, and 5 during the last two years of radiometry operations. Preliminary data suggest that the motion of Phobos has advanced by one or more seconds beyond that predicted by the current ephemerides, and the advance has increased over the 5 years of Mars Global Surveyor (MGS) operations.

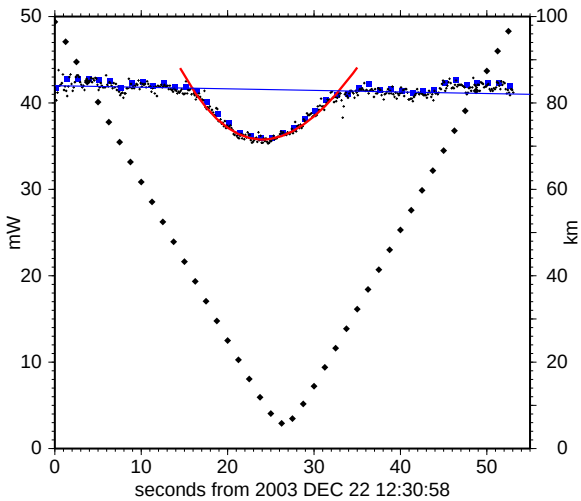

Figure 1: MOLA radiometry, and predicted distance from Phobos' shadow, vs. time. Individual 8-Hz observations (small symbols) are averaged over single MOLA frames (squares). The shadow of Phobos does not completely obscure the Sun, but reduces the light scattered back to the MOLA detector over the course of 16 s. A cubic fit to the observations (red) below the trend line (blue) show that the center of the shadow passes over the MOLA track earlier than the minimum distance predicted by the current ephemeris (diamonds). The misfit provides a constraint on the orbital position of Phobos with respect to MGS.

Although the size and orbital distance of Phobos are such that total solar eclipses never occur on Mars, partial eclipses are common, with an average of 3.22 per day throughout most of each annual cycle [1]. For example, on 2003 DEC 22, 12:31:24 UTC, the center of Phobos' shadow passed through the MOLA detector field-of-view (Figure 1). The ephemeris of Phobos was taken from the file "mar033-7.bsp" provided by the JPL Navigation Ancillary Information Facility (NAIF) prepared by R. A. Jacobson, using the extended Sinclair/Morley Orbital motion model fit to astrometric and Mariner/Viking spacecraft observations. This ephemeris proves remarkably accurate, better than its stated 15 km uncertainty, but a 3-s adjustment in the along-track position (about 6 km) provides a better fit to the shadow. Using MOLA ranging to Phobos in 1998 [2], the ephemeris was estimated to be in error by approximately 1.75 seconds (3.9 km) in the downtrack direction.

While MOLA was primarily designed for active measurement of the martian surface, there is a passive measurement capability as well, that depends on the background light received by the detector from solar illumination of the surface. This capability has been enhanced in resolution by replacing the altimetry in the MOLA telemetry packet with high-rate background counts. The detector images an area on the surface approximately 300 m by 300 m. The noise counts on channels 1 and 2 are now recorded 8 times per second, during which time MOLA travels approximately 375 m, for an along-track resolution of approximately 1/2 km. The measurements were made continuously throughout the mission at a 1 s (3 km) resolution along-track, with a lower average background count rate and therefore lower overall precision.

MGS is in a nearly polar orbit, and Phobos in a nearly equatorial orbit. The ephemeris of the Mars Global Surveyor is known to high precision and the timing of the MOLA instrument can be determined to the 10-ms level. The ratio of their synodic periods is roughly 3.905, so that opportunities arise every 39th orbit of MGS, or every 10th orbit of Phobos. Shadows detected by MOLA are potentially better spatial constraints than astronomical observations, but will need to be carefully modeled. The ground shadow of Phobos in MOLA observations currently puts Phobos more than 2 seconds ahead of Jacobson's model.

The secular acceleration of Phobos [3, 4] has previously been estimated at 0.001247 $^{\circ}yr^{-2}$, leading to an advance in Phobos' orbit relative to a Keplerian model. The advance appears to have increased slightly over the years up to the present. There are also long period terms in the ephemeris (mainly associated with a near resonance between the Martian year and the nodal regression period), and some of them have large enough amplitudes that they could be contributing to the observed discrepancy. The Mars Observer Wide Angle Camera has imaged the Phobos shadow more than a hundred of times. Those observations, if analysed, might help sort out periodic versus secular effects.

MOLA observations will continue for the lifetime of MGS. Another possibility for future measurements is a radio occultation by Phobos of the Mars Exploration Rovers. There are also plans for the PanCam on MER to observe Phobos eclipses.

References

[1] Bills, B. G., and R. Comstock, Solar eclipses on Mars: Spatial and temporal patterns in the motion of the shadow of Phobos, *Eos Trans. AGU*, *84(46)*, Fall Meeting Suppl., Abstract G41B–30, 2003.

[2] Banerdt, W. B., and Neumann, G. A., The topography (and ephemeris) of Phobos from MOLA ranging, (1999) *LPSC*, *XXX*, Abstract 2021.

[3] Jacobson, R. A., S. P. Synott, and J. K. Campbell, The orbits of the satellites of Mars from spacecraft and Earth-based observations, *Astron. Astrophys.*, *225*, 548–554, 1989.

[4] Sinclair, A. T., The orbits of the satellites of Mars determined from Earth-based and spacecraft observations, *Astron. Astrophys.*, *220*, 321–328, 1989.