Precise constraints on the oribit of Phobos and applications to the physics of bodily tides

Mark J. Avara

Mars's satellite Phobos is unique in that it is the most closely orbiting satellite of any of the Solar System planets. While this complicates our picture of its origin, it also enables the exploration of a unique part of parameter space in the dynamics of orbiting bodies. Because it's semi-major axis places it inside synchronous orbit, it experiences a secular acceleration and will shortly (10's of millions of years) be tidally disrupted.

The proximity of Mars to Earth makes Phobos relatively easy to observe and its low altitude makes this a particularly rich system to study luni-tidal interactions. The system constrains both theoretical understanding of the interaction of satellites with their parent bodies as well as our knowledge of the structure of both bodies.

In this talk I will describe how Jacobson (2010) obtained the oribits of Phobos and its sibling Deimos by fitting a numerical integration to nearly all available data on the objects: Earth-based astrometry, space imaging, and the Doppler tracking of the Viking and Phobos 2 spacecraft. From this wealth of data they accurately measure the mass of the satellites, find a geometrical description of the orbits and their changes in time, the Martian tidal quality factor Q, and the secular and figure acceleration of phobos. The secular acceleration is that caused by the response lag of the tide induced by Phobos on Mars and the figure acceleration is a result of Phobos's libration.

I will also describe how placing constraints on the orbital elements of Phobos and Deimos and their evolution at this level of precision enables us to compare the different methods used in the past to determine these values and to compare the differing analytical models for the interaction of Phobos with Mars. For instance, Efroimsky and Lainey (2007) consider the frequency dependence of Q to find the frequency dependence of the geometric lag angle, using Phobos as an example, which determines the secular acceleration magnitude. They use this procedure to determine a longer expected life-time of Phobos by nearly a factor of two compared to previous models. While such changes in our understanding of the dynamical evolution of Phobos give little insight into its origin, they have broader implications for our understanding of tidal interactions in all planetary systems (see Efroimsky and Williams, 2009).

---

[1] Bills, B. G., Neumann, G. A., Smith, D. E., & Zuber, M. T. 2005, Journal of Geophysical Research (Planets), 110, 7004
[2] Efroimsky, M., & Lainey, V. 2007, Journal of Geophysical Research (Planets), 112, 12003
[3] Efroimsky, M., & Williams, J. G. 2009, Celestial Mechanics and Dynamical Astronomy, 104, 257
[4] Jacobson, R. A. 2010, Astron. J. 139, 668
[5] Redmond, J. C., & Fish, F. F. 1964, Icarus, 3, 87