Detection of Tides on Planets and Satellites using Orbiting Spacecraft and Landers

Charles F. Yoder, Jet Propulsion Laboratory, CalTech, Pasadena, CA 91009.

Tide detection on moons and planets other than Earth is generally problematic. Solid body tides have been detected on Venus from perturbations in the orbit of the orbiting Magellan spacecraft using X-band Doppler tracking. The moving tidal bulge is seen in tracking data as a periodic gravity field and is used to deduce a potential EMBED Equation Love number. The observed value (EMBED Equation) is only compatible with a venusian liquid iron core and not a solidified core. A similar solar tidal signal has not yet been observed on Mars from MGS tracking data (X-band Doppler and range and laser altimetry), despite its high accuracy, primarily because the gravity tidal signal is an order of magnitude smaller than that seen by Magellan on Venus. Mars lander tracking data does detect seasonal changes in axial rotation, part of which is due to tidal changes in Mars' oblateness. Unfortunately, seasonal mass redistribution related to the changing polar caps dominates the observed signature and the ice cap history is imperfectly known. Earth tides raised on the moon have been indirectly detected using laser ranging to corner cube reflectors left by Apollo astronauts. It turns out that the largest effect of tides is to alter the lunar obliquity relative to other periodic changes and again the best determined solution parameter is the gravity EMBED Equation Love number, not the surface elevation change or EMBED Equation.

Two planetary satellites may have large liquid bodies either on the surface (Titan) or buried beneath a thin, global ice shell (Europa). The Jovian moon Europa is a particularly attractive candidate for an orbiting spacecraft, since its putative buried ocean is primarily water and might harbor life. Its depth is probably greater then 10km from Galileo magnetometer data and tides are likely near EMBED Equation m. An orbiting spacecraft carrying an X-band radio transponder and laser altimeter can be employed to definitively prove the existence or absence of an ocean, whether it is global in extent or is partially grounded, and determine mean ice shell thickness. The general problem of tide detection on moons and planets other than Earth using remote sensing shall be reviewed using the above examples to illustrate present-day capabilities.