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TIDAL ACCELERATION GRAVITY GRADIOMETRY FOR MEASURING ASTEROID GRAVITY FIELD FROM ORBIT

Abstract

Here we describe a novel technique for measuring the gravity field of a planetary body from orbit, and describe how that can be applied to determining the gravity fields of small bodies such as asteroids. Tidal Acceleration Gravity Gradiometry (TAGG)involves measuring the tidal acceleration field at a point offset from the mass-centre of a spacecraft, due to the gravity-gradient field of a nearby planetary body, using an absolute accelerometer. This is enabled by such a space accelerometer that is under development at Gedex, the Vector Gravimeter/Accelerometer (VEGA) instrument. In effect, the combination of a VEGA instrument and the spacecraft itself comprises the TAGG instrument; mounting VEGA on a boom increases the magnitude of the tidal acceleration signal, increasing TAGG measurement sensitivity.

Measuring mass and higher-order gravity field terms from orbit has been done for planets and larger asteroids and comets in the past, using radio tracking systems to measure range-rate versus time between Earth and a spacecraft flying-by or orbiting those bodies. However, while this technique works well for the major planets and for the larger of the minor planets, its performance decreases with the mass of the planetary body, such that it works poorly for small (sub-1 km) asteroids. This is because for smaller bodies, the magnitude of the body's gravity is relatively small, and so the amount of radio doppler signal due to spacecraft trajectory perturbations is also small. In the face of doppler measurement noise, and uncertainties in non-gravitational forces acting on the spacecraft (e.g., solar radiation pressure), the resulting signal to noise ratio is relatively low for small bodies. The same factors similarly limit other techniques used in the past (e.g., using LIDAR to measure spacecraft speed with respect to a body's surface, or measuring range-rate between a pair of satellites co-orbiting around a body).

The TAGG approach is similar to the gravity gradiometer approach used in the Earth-orbiting GOCE mission, but uses much simpler and lower-mass equipment (albeit with lower sensitivity), suitable for carrying on even very small asteroid-rendezvous spacecraft. Here we focus on the case of Didymoon, the 150 m diameter secondary body of 65803 Didymos, for which the AIDA mission desires to know its mass in order to help determine the momentum transfer efficiency during the DART spacecraft impact. We show the expected performance of our new technique in measuring Didymoon's mass, using TAGG aboard ESA's proposed HERA mission to rendezvous with Didymos.