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SIMULATION AND ESTIMATION OF THE MASS SHIFTS DURING THE (99942) APOPHIS EARTH FLYBY

Abstract

On April 13, 2029, the asteroid (99942) Apophis, with a diameter of 340 meters, is anticipated to make its approach to Earth, coming within approximately 0.1 lunar distances from the geocenter. While the Apophis close approach has been modeled by several authors, there exist intriguing potential effects that have not been thoroughly examined due to the limited availability of comprehensive models. This includes exploring the response of a bifurcated internal configuration with a neck, also referred to as a contact binary, to tidal stresses. Utilizing delay-Doppler radar images suggesting a bilobed shape for Apophis, this study aims to model the asteroid as a contact binary with a neck, examining stress variations in the neck region that may induce mass shifts. Moreover, we will assess the observability of these potential mass shifts during the close approach event.

To achieve our objectives, we will employ the numerical method known as Contact Dynamics (CD), a discrete element method grounded in non-smooth mechanics, implemented using the open-source software LMGC90. The CD method, notable for its ability to accommodate polyhedral particle systems, will enable us to construct realistic shape models of the bilobate asteroid and simulate the neck region based on existing radar shape data. The scenario for mass shifts in our model considers various factors, including Apophis's precise shape, internal voids, orientation at the closest approach epoch, and the resistance of relative motion in the neck region. To comprehensively investigate the potential shape changes, we will analyze all parameters that may impact the magnitude, with the moment of inertia serving as a crucial index.

The comparison of shape changes from our simulation with possible observation limitations will be conducted. Various observation methods, including lightcurve analysis, delay-Doppler radar, and in-situ spacecraft (Osiris-APEX) measurements, will be involved during the close approach event. We will evaluate the precision of measurements and the number of observations required to detect potential changes. These findings will provide a comprehensive guide for future observation campaigns, enhancing our understanding of Apophis's internal mass distribution during close encounters and shedding light on the dynamics of near-Earth asteroids.