**Using a Discrete Element Method to Investigate Seismic Response and Spin Change of 99942 Apophis During the 2029 Tidal Encounter.** J. V. DeMartini[1], D. C. Richardson[2], O. S. Barnouin[3], N. C. Schmerr[4], J. B. Plescia[5], P. Scheirich[6], P. Pravec[7], [1]University of Maryland, Physical Sciences Complex, 4296 Stadium Dr., College Park, MD, 20742, USA, jdema@astro.umd.edu, [2]University of Maryland, Physical Sciences Complex, 4296 Stadium Dr., College Park, Md, 20742, USA, dcr@astro.umd.edu, [3]Johns Hopkins University, Building 200, 1101 Johns Hopkins Rd., Laurel, MD, 20723, USA, olivier.barnouin@jhuapl.edu, [4]University of Maryland, Department of Geology, 8000 Regents Dr., College Park, MD 20742, USA, nschmerr@umd.edu, [5]Johns Hopkins University, Building 200, 1101 Johns Hopkins Rd., Laurel, MD 20723, USA, jeffrey.plescia@jhuapl.edu, [6]Academy of Sciences of the Czech Republic, Astronomical Institute, Fricova 298, 251 65 Ondrejov, Czech Republic, petr.scheirich@gmail.com, [7]Academy of Sciences of the Czech Republic, Astronomical Institute, Fricova 298, 251 65 Ondrejov, Czech Republic, petr.pravec@asu.cas.cz.

**Abstract:** Near-Earth Asteroid 99942 Apophis presents a unique opportunity to study the dynamics, bulk properties, and interior structure of a rubble-pile asteroid when it makes its close encounter with the Earth in 2029 [1]. In order to better understand the potential outcomes of a tidal encounter between Earth and Apophis, and to support a potential future mission to Apophis, we perform numerical simulations of the encounter. We represent Earth as a single rigid sphere and the target body as a cohesionless, self-gravitating granular aggregate of identical spheres in a hexagonal-close-packed configuration subject only to gravitational and soft-sphere (elastic) contact forces. The aggregate has material properties similar to that of terrestrial gravel, with an angle of friction of ~45 deg.

We use a radar-derived shape model for the asteroid, along with current best estimates for the orbital solution of Apophis [2] to simulate the encounter trajectory, and perform a large parameter sweep over different potential encounter orientations and bulk densities for the body. We find that the median change in the rotational period for Apophis, sampled for a range of different initial body and spin orientations, is $-1.9$ h (mean $-0.1 \pm 6.0$ (1-σ) hours) during the encounter. Additionally, we measure that the mean of the largest change in axis length among the 3 primary body axes, also sampled over trials with different initial body and spin orientations, is $0.132 \pm 0.066$ mm during the encounter, assuming a bulk Young's modulus of $10^6$ Pa (Fig.. 1). Such strains on the timescale of peak stress during the encounter may be large enough to be detected by an in-situ seismometer (Fig. 2).

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**References:** [1] DeMartini, J.V. et al (2019) *Icarus* 328, 93-103. [2] Brozovic et al (2018) *Icarus* 300, 115-128.

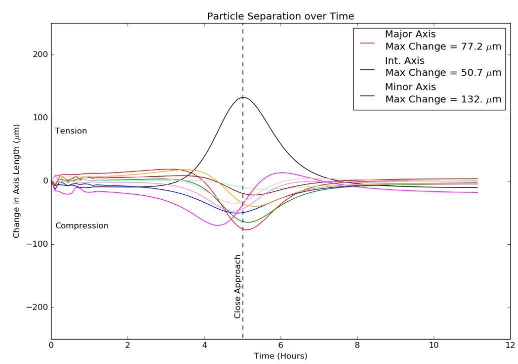


*Figure 1: Distance (μm) measured at each timestep between 10 particle pairs with 3 pairs positioned at the ends of the primary body axes and the rest along 7 random axes throughout the body. This shows the strains across the different axes of the body due to tidal stresses over the course of the encounter.*

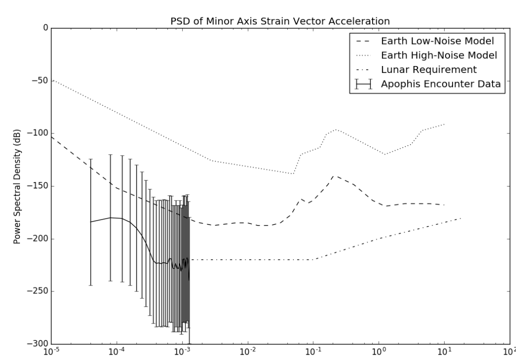


*Figure 2: Power spectrum of expected signal due to tidal strains during the encounter, plotted against Earth noise models and lunar seismology requirement.*