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Assessment of resurfacing process on Apophis during the 2029 Earth flyby

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ABSTRACT

Surface modification processes such as solar wind ion implantation, impacts, and sputtering, which are known as space weathering, cause optical variations in an asteroid's surface. On the other hand, resurfacing processes expose fresh, unweathered materials located beneath the surface. While studies have explored these processes for decades, the detailed mechanism of resurfacing is still not well understood. Expected to have the closest Earth flyby on April 13, 2029, (99942) Apophis is considered to be key to resolving a decades-long puzzle of the spectral difference between S-type asteroids and ordinary chondrite meteorites (OCs). During the 2029 Earth flyby, Apophis approaches the Earth at a distance within 6 Earth radii from the Geocenter. It has been proposed that a tidal effect from the Earth may contribute to resurfacing processes on this asteroid, resulting in shape modification and/or landslides, which may expose fresh surface materials. Here, we develop a numerical simulation package for computing the evolution of the gravity slope of Apophis during the 2029 flyby by using the radar observation-driven polyhedron shape model[1]. This shape model has a contact binary shape with an equivalent

diameter of 335.80 m. In simulations, we assume the bulk density to be 2.0 g cm^{-3}, considering the material density of chondrites having 40% porosity[2], and the material distribution to be uniform.

We simulate the orbital and attitude evolution of Apophis to compute the surface slope evolution during the 2029 flyby by using a 4^{th}-order Runge-Kutta integrator implemented in MATLAB. In this analysis, first, the translational motion is computed by starting from March 13, 2019, the position of which is obtained from the JPL Horizons. Second, the angular acceleration of Apophis' attitude is computed by using the Euler equation with a torque driven by the tidal effect from the Earth. Then, the surface slope of Apophis is computed based on the direction of the gravity force, the tidal force from the Earth, and the rotation-driven force on each facet.

The results show that while the gravity slope in some regions of Apophis reaches 45.0 deg even before the 2029 flyby, it rapidly changes 2.16 deg within 46 hr after the closest approach. According to Ballouz et al. (2018), the gravity slope changes up to 2 deg may cause mass-wasting events on the Martian moon, Phobos. Thus, the present analysis supports the idea that Apophis may experience landslides at some magnitude. While our work is consistent with earlier works[3,4], we point out the importance of the shape and the spin state change for the gravity slope variation. We also note that radar observations[1] had weak signal-to-noise ratios, implying the uncertainties of the shape model. A detailed shape model will provide further constraints on resurfacing. Finally, a better understanding of the surface evolution of Apophis during the 2029 flyby will provide useful information for the development of planetary defense technologies.

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4 R. L. Ballouz et al. (2018) arXuv:1809.02520v1.