Changes in Apophis rotation and surface gravity during its 2029 Earth flyby

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Apophis, the Asteroid 2004 MN4 is one of the Near-Earth Object (NEO) with regular and extremely close Earth encounters. With its very close encounter at about 37,000 km above the surface of the Earth in 2029, it has become an important body to study. This close fly-by will be an opportunity to better study this asteroid, especially through the changes in its dynamics and orbit as they are expected to vary significantly due to gravitational interactions with the Earth (Benson et al, 2023; Scheeres et al, 2006; Souchay et al, 2018; Souchay et al, 2014). The variations of orbital parameters, i.e. spin, obliquity, longitudinal and latitudinal librations increase considerably during the closest-approach epoch, which will be observable in real time by ground-based radars and telescopes.

In the work presented here, we used numerical simulations implementing the full-two-body problem (F2BP). The F2BP can fully capture the system's dynamics considering the objects' irregular shapes and the close proximity of the components. The propagator we use is the open source F2BP code GUBAS (Davis et al, 2020). The initial position and speed come from Horizon System from the Jet Propulsion Laboratory, the set of initial orientations from Pravec et al, 2014 and Brozović et al, 2018 and the system is propagated using a LGVI integrator. We base our shape model for Apophis on a radar-based shape model from Brozović et al, 2018 while the Earth is modeled by an ellipsoid of revolution.

We show that for the non-tumbling initial conditions, the fly-by causes several changes. We found up to 35% increase in the rotation speed and a change in the local gravity of up to 3%. Locally, the surface slopes achieved values well above 35° leading to potential landslides (see Figure 1). We continued these simulations starting from when Apophis enters the sphere of influence of Earth until it leaves it, and we propagate the dynamical parameters for multiple initial rotational states (including a tumbling Apophis), densities and shapes. The results show a high dependency on the initial tumbling state for the evolution of the rotational state. Further, the changes in surface slopes and local gravity are more affected by the fly-by for these initial tumbling states. These changes in Apophis rotation and local gravity, are important parameters for planetary defense missions since they provide information on otherwise inaccessible interior and mechanical properties of asteroids.

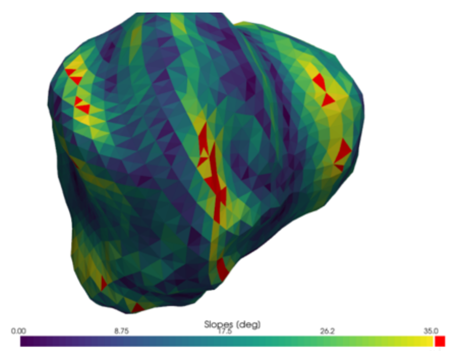

Figure 1: Local slopes at closest encounter.

References

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