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Detecting Internal Shifts Within Apophis Across its Earth Flyby

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ABSTRACT

On April 13, 2029 the asteroid (99942) Apophis will have a close approach to Earth and be observed with optical telescopes and the DSN's Goldstone planetary radar in the weeks before and after closest approach [1]. This paper will describe how these observations can be leveraged to provide information on Apophis' interior and to detect shifts within its mass distribution due to tidal effects around closest approach.

A driving scientific question related to the Apophis flyby is whether its close Earth passage will induce any global or localized mass redistributions due to tidal forces. It is well understood that the close approach will radically change the tumbling asteroid's spin state and orbit [2], but it is much more controversial whether the flyby will induce any mass redistribution. This question has been studied by numerous researchers (see the summary in [2]) with the conclusion that changes in the surface distribution of material are likely minimal, if they occur at all, but that shifts in the Apophis mass distribution could occur if the asteroid is a multi-component, contact binary asteroid. The current Apophis shape and spin state are consistent with such a morphology [3].

Such shifts within Apophis can be constrained or detected by a combination of radar and optical observations and precise modeling. The Apophis observations will enable the asteroid spin state and moments of inertia to be estimated before and after closest approach, enabling a direct detection of significant shifts within the body, as well as identifying the peak stresses experienced by the asteroid. A previous study and analysis of the asteroid (4179) Toutatis demonstrated this approach using similar radar and optical observations, however the level of precision for Apophis will be improved by orders of magnitude over those demonstrated in [4].

This paper will discuss the accuracy to which the Apophis moment of inertia ratios and center of mass offsets can be estimated, and hence how precisely changes in these mass distribution parameters can be determined. Given that the trajectory and orientation of the asteroid will be precisely known throughout its flyby, it may even be possible to isolate when any such change occurs to constrain the strength of the body. The potential to measure the first tidally induced shift of a small body's mass distribution will open new opportunities for space mission proposals and innovative techniques for probing the interiors of scientifically interesting or hazardous asteroids.

References
[1] J.L. Dotson, et al. Apophis Specific Action Team Report, 2022. Report requested by NASA PSD.
[2] C.J. Benson, D.J. Scheeres, M. Brozovic, S. Chesley, P. Pravec and P. Scheirich. “Spin State Evolution of (99942) Apophis during its 2029 Earth Encounter,” Icarus in press 10/2022.
[3] M. Brozović, et al. Goldstone and Arecibo radar observations of (99942) Apophis in 2012–2013, Icarus 300: 115-128 (2018).
[4] Y. Takahashi, M.W. Busch and D.J. Scheeres. 2013. “Spin State and Moment of Inertia Characterization of (4179) Toutatis,” The Astronomical Journal 146:95, October 2013.

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