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Precise Earth Impact Risk Assessment of PHOs via a Multi-Flyby Mission

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ABSTRACT

The effectiveness of improving the knowledge of Earth collision risk of a potentially Earth impacting asteroid by means of a multi-flyby mission has been analysed. The improvement of the asteroid ephemeris knowledge is achieved via radiometric measurements of the spacecraft from Earth and optical measurements of the asteroid from the spacecraft. The spacecraft trajectory has been designed to be in 1:1 resonance with the chosen target such that repeating encounters and measurement opportunities occur naturally without large intermediate manoeuvres. This also allows for a precise measurement of the asteroid orbital period.

From the 1906 potentially hazardous asteroids known at the time of writing, Apophis has been selected as the main research target due to its extremely close expected Earth encounter on April 13th, 2029: the nominal predicted miss-distance is 38440 km. Data from JPL's HORIZONS has been used as input for a covariance analysis to produce the asteroid position knowledge evolution and the knowledge evolution of the asteroid in Earth's B-plane at the expected close-approach date.

It has been found that, for Apophis, two flybys are sufficient to ensure mission success. After the second set of optical measurements, the orbital period of the asteroid is accurately known, which improves the asteroid position knowledge by roughly two orders of magnitude while improving the diameter of the covariance error ellipse at the expected close-approach date by roughly three orders of magnitude. The 1-sigma error ellipse diameter shrinks from roughly 65000 km to roughly 15 km after two flybys. The analysis shows that for the used spacecraft trajectory the asteroid knowledge evolution is independent from the targeted flyby B-plane parameters. In the case multiple optical measurements are taken during a flyby, the knowledge evolution is found to be close-to independent from the distance to the asteroid when an optical measurement is taken. The results of this study indicate that taking optical measurements during a flyby mission to a potentially Earth impacting asteroid, such as Apophis, is a feasible option to improve the knowledge of the Earth collision uncertainty of that asteroid.

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