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Orbital evolution of levitated regolith particles in the 65803 Didymos binary system

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ABSTRACT

Operating a spacecraft in a strongly perturbed environment of a binary asteroid system is a challenging task. In this context, risk of collision with free-floating regolith grains is one of the least-studied problems. In light of the near-future exploration of the 65803 Didymos binary system by the Hera probe and the lack of study of orbital evolution of naturally levitated regolith particles in the Didymos system, a method is here proposed to identify such regions of high collision risk. The assessment method comprises (1) determination of regions of regolith levitation from the asteroidal surface, (2) identification of regions of stable motion, i.e., orbital neighborhoods in which particles may survive for extended periods of time, and (3) exploration of the trajectories connecting the initial states upon levitation and the final states in the stable-motion trajectories. Periodic orbits and regions of stable motion are computed through a grid-search method applied in the augmented bicircular problem, i.e., a dynamical model that constitutes an expansion of the bicircular four-body problem by substituting the point-mass gravity fields with spherical-harmonics models of ellipsoidal primaries, applying solar-radiation pressure and third-body perturbances. The investigation of the regions of regolith levitation is conducted using a proximity dynamical model—a modification of the augmented bicircular problem in which the spherical-harmonics gravity field of Didymos is substituted by a mass-concentration model to ensure convergence at the surface of the primary body. The distance between trajectories leading from the off-surface levitation of the grains from the primary body and the trajectories of bounded motion is then assessed. The methodology presented in this work does not render conclusive results with regards to the existence or absence of temporary-capture trajectories in the adopted model. A qualitative evaluation of the expected patterns of motion of regolith particles is

here presented together with a discussion of the key conclusions in the context of in-situ operations planning for the Hera probe. The primary region of hazard to the spacecraft is identified to be the vicinity of the ecliptic plane of the system. As a result of the study, the Hera spacecraft is found to be under hazard of collision with regolith particles (1) in trajectories escaping from the binary system and (2) in long-term chaotic motion after levitation from Didymos. Existence of two dust disks is suggested, where the inner disk spans up to 20 km from the center of the binary system and the outer disk is formed by the particles slowly spiraling out of the binary system. The inner disk is identified as the larger risk to the spacecraft than the outer one due to its chaotic character and significantly larger expected density.

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Comments:

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