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NUMERICAL ANALYSIS OF THE IMPACT OF SHADOW ON SPACECRAFT MOTION ABOUT ASTEROID APOPHIS

Abstract

It is well known that solar radiation pressure (SRP) can be a major perturbation for orbits in vicinity to asteroids. However, previous studies on the effects of SRP on spacecraft motion around asteroids have rarely considered the case of possible asteroid's shadow crossings. This study investigates how would the asteroid's shadow crossings affect the orbit stability, especially, the lifetime of a spacecraft orbiting about the asteroid. The numerical model includes perturbations from the third-body gravity, the non-spherical gravitational field of the asteroid and the direct SRP, where the asteroid is modeled as a uniformly rotating ellipsoid, the shadow is also projected by the ellipsoid, and the Cannonball model is used. Considering possible shadow crossings, numerous simulations are conducted applying to orbits about asteroid (99942) Apophis firstly with initial conditions of various sets of semi-major axis, inclination, and longitude of the ascending node. Two types of orbits that are stable enough for maintaining around asteroids without collisions or escapes for the simulated time span have been found: the near-equatorial orbits close to the surface of the asteroid, and the terminator orbits with larger orbital altitudes. Comparisons with the simulations neglecting shadow suggested that, at the low near-equatorial orbits, the accumulation effect of SRP with shadow crossings generally diminishes the deviation of semi-major axis from its initial value compare to cases without shadow. However, the change of the lifetime of the spacecraft becomes more complicated due to the fast-varying force environment, along with the changing sub-satellite altitude on the surface of the ellipsoidal asteroid. It is shown that, at the near-equatorial orbits close to the asteroid, even perturbations from the direct SRP is weaker than that from the non-spherical gravitational field of Apophis, the repeated shadow crossings may still significantly change the lifetime of the spacecraft (from several months to several years). The terminator orbits are not affected, since the orbital plane remains almost perpendicular to the sun line, there are no cases of shadow crossings.