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FAST SPINNING PRIMARIES OF NEA BINARIES: THE CASE OF DIDYMOS, AIDA MISSION'S TARGET

Adriano Campo Bagatin[(1)], **Fernando Moreno**[(2)], **and Antonio Molina**[(2,3)]
[(1)]*DFISTS-IUFACyT, Universidad de Alicante, P.O. Box 99, E-03080 Alicante, Spain, Tel.: +34 965909943,*
[(2)]*Instituto de Astrofísica de Andalucía – CSIC, Glorieta de la Astronomía, s/n. E18008, Granada, Tel.: +34 958121311,*
[(3)]*Dept. Física, Universidad de Granada, Avda. del Hospicio, s/n E-18071 Granada Tel.: +34 958243000,*

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ABSTRACT

An increasing number of Near Earth Asteroids (NEAs) in the range of a few hundred meters to a few kilometers in size are found to have relatively high spin rates (less than 4 hr, down to ~2.3 hr, depending on taxonomic type). Due to their high spin rate local acceleration near their equator may in some case be directed outwards so that lift off of near-equatorial material is possible. In particular, this is the case of the primary of the Didymos binary system, target of the AIDA mission. What are the effects of that phenomenon on surface material at any asteroid latitude?

MOTIVATION

Both coherent bodies and gravitational aggregates (GA) (often called "rubble piles") may stand spin rates higher than the critical ones for fluids found by Chandrasekhar [1]. In the case of coherent structures that is due to internal solid state forces while in the case of gravitational aggregates shear strength may easily appear as a consequence of friction among GA components [2] increasing structural yield. Near Earth Asteroids (NEAs) coming from the asteroid belt are believed to be mostly GA in the range ~0.5-1 km to ~50 km [3] due to their collisional history. Once in the inner Solar System, NEAs may undergo spin up evolution through the non-gravitational YORP effect [4] causing their components to disperse, to shed mass or to fission and eventually form binary, multiple systems and asteroid pairs [5, 6]. The end state of those events often is an object spinning above any Chandrasekhar stability limit, kept together by friction and characterized in some case by the presence of an equatorial “bulge”, as shown by radar images [7, 8]. This seems to be the case of the primary bodies of binary systems 1996 FG3 and 1996 KW4, and the single body 2008 EV5, among others. The Didymos primary has been spotted by radar in 2003, even if not at a precision level to evidence any such feature.

In the case of some NEAs, the centrifugal force acting on surface particles and boulders at near-equatorial latitudes may slightly overcome the gravitational pull of the asteroid itself, having the opportunity to leave its surface.

As centrifugal is a contact force, leaving the surface does not mean that particles are lost form the asteroid, in fact, particles leave the surface at negligible velocity and as soon as they lift off they move only under the gravitational field of the asteroid, the non-inertial apparent forces due to rotation, the Sun’s gravity and –in the case of binary systems- the secondary’s gravitational pull. Therefore, particles may levitate for some time, land on the surface and lift off again, repeating this cycle over and over. Alternatively, they may enter orbiting states or even transfer to the secondary. [9] have studied some of the features of this problem, relevant to binary dynamics. Non-inertial and gravitational forces have the same dependence on a given particle mass, their action is then independent on mass itself: small dust particles may leave the surface as well as large boulders. Other forces may act as well on small particles, like electrostatic forces or molecular forces (cohesion), with the likely result to stick them together and still undergo the same effects as dusty clumps. Moreover, small particles may be lost as they undergo solar pressure force able to subtract them to the asteroid’s gravity while they are levitating.

METHODOLOGY

We have collected available data on binary asteroid systems with very good accuracy in spin rate determination and acceptable uncertainties in mass and have catalogued NEA binary systems according to their primary spin.

This study follows and develops researches made by the working group on mechanical properties of the “MarcoPolo-R” mission proposed to ESA in its past M3 call. In that case, the goal was to study regolith lift off features on both 1996 FG3, the former target of the mission, and 2008 EV5, its nominal target.

We have now focussed on two binary systems: Didymos and 1996 FG3. In order to study the dynamics of particles in those systems, we use a numerical code that integrates, by a fourth-order Runge-Kutta method, the equations of motion of individual particles that are ejected from the asteroid surface when centrifugal acceleration is strong enough to overcome local gravity. The equation of motion is written in a non-inertial asteroid-centered reference frame, taking into account the asteroid (and the secondary, in the case of binaries) and solar gravity, radiation pressure, and inertial terms. A version of this code has been successfully tested and applied by Molina et al. [10] to the study of particles in comet environments.

We then study the motion of particles in the 1 μm to 10 cm range in the non-inertial reference frame of the rotating primary, accounting for centrifugal and Coriolis apparent forces as well as the gravitational fields of the primary, the secondary, the Sun and the radiation forces by the Sun itself. The eccentricity of the heliocentric orbit of the system and the obliquity of the system are taken into account.

The dynamics of particles of a wide mass range is calculated during many orbital cycles as a function of their initial position on the asteroid surface for each system under study. A relative mass density of levitating particles is calculated as a function of distance to surface, latitude, and longitude. In the very case of Didymos, the study is being extended and discussed in the ranges of size and mass of the primary.

We present the results of our ongoing study in the case of Didymos.

RESULTS

We find that fine particles are easily swept away from the system by radiation pressure, while large particles may undergo landing and lift off cycles that form a dusty environment above the surface at near-equatorial latitudes. Consequences in the planning of missions to NEAs with similar characteristics can be derived from this study.

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