EPSC Abstracts
Vol. 15, EPSC2021-691, 2021
https://doi.org/10.5194/epsc2021-691
Europlanet Science Congress 2021

Effects of DART impact on Dimorphos' spin state and surface motion away from the impact point

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INTRODUCTION

The NASA Double Asteroid Redirection Test (DART) mission is set to impact an asteroid of approximately 160 m in size, named Dimorphos (the secondary of the binary Near-Earth Asteroid (65803) Didymos) in September 2022. Little is known about the shape of the satellite, except available ground-based observations are compatible with a spherical to moderately elongated (b / a < 1.2) shape. Also, one primary goal of this mission is to improve our understanding of the impact momentum multiplication factor ('β'). By checking the potentially antipodal escaping mass, it is possible to refine the estimation of the β factor.

In this work we investigate the possible reaction of Dimorphos to the DART collision, under the assumption that it is a spherical gravitational aggregate produced in the formation of the binary system [1][2]. The very structure of the target is unknown; therefore, we model it by (a) 100,550 mono-dispersed spherical particles in a close hexagonal packing (CHP) configuration; (b) multi-dispersed distribution of 100,000 spherical particles; (c) multi-dispersed distribution of only 13,600 particles.

METHODOLOGY

We perform numerical simulations of the collision event on a stand-alone Dimorphos by using a discrete-element N-body numerical code (PKDGRAV-SSDEM [3]). We do not perform simulations of the shattering phase, we instead concentrate on the effect of the collision on the target, once the shattering phase implying material damage (melting, vaporization, heating, and deformation) is over. Therefore, our synthetic projectile carries the same nominal momentum as the DART spacecraft does, but it delivers to the target only a small fraction of kinetic energy expected to survive once the shattering (non-elastic) phase has dissipated most of the impact kinetic energy [4]. We account for different center and off-center possible impact geometry compatible with DART nominal impact angle (20º) with respect to the target orbital plane (Fig.1).

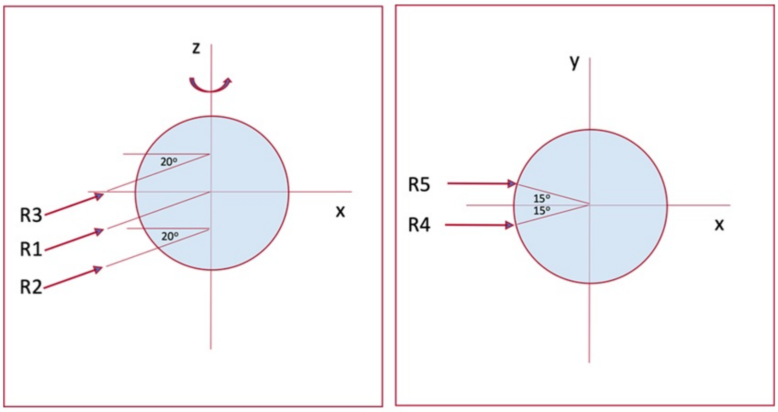

Fig.1. Impact geometries used in numerical experiments.

RESULTS

Here we report on results obtained so far on the effects of the DART impact on Dimorphos in the mono- and multi-dispersed distributions. In particular, we focussed on: a) Changes in spin period and direction of the spin axis, and tracking of their evolution in time. b) Energy distribution of surface particles capable to lift/move over the surface.

Our model of the DART impact in the case of mono- and multi-dispersed distribution of spherical particles shows that:

- Spin period may be changed (decreased) by up to about -30 min in all impact configurations, except for the impact geometry R5 carrying in negative angular momentum. In this case to the system slows down its spin period to +10 min, depending on structure.
- The angular momentum vector may be tilted up to 3 deg with respect to initial direction.
- Spin vector is tilted with respect to angular momentum vector by about 0.1 deg with a precession motion about the latter.

- Negligible mass escaping from antipodal impact region does not substantially affect beta estimation.
- The energy and momentum wave reach the surface away from the impact area so that mass lift and displacement of sizeable particles over the surface are possible.

Such predictions may be of interest in the study of the post-impact dynamics of the system– that will be determined by the Hera mission measurements. Finally, the results may contribute to the interpretation of (lack of) motion of boulders on the surface of Dimorphos away from the impact point. In fact, a comparison of DART- LICIACube and Hera images may show displacement of boulders. This in turn may give information on the internal structure of the body itself.

We are currently modeling non-spherical shape for Dimorphos and the presence of the mass of Didymos primary in the system. On the other hand, instead of using spherical particles as the basic components (or ‘fragments’) of Dimorphos, we plan to apply irregular shapes and the corresponding mass distribution for the fragments. This refinement is expected to better reproduce the actual shear forces between the fragments.

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