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CONSEQUENCES OF THE DART IMPACT ON DIMORPHOS' SPIN STATE AND SURFACE MASS

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Extended Abstract—

Introduction: AIDA (Asteroid Impact & Deflection Assessment) is an international collaboration between NASA and ESA which involves both DART (Double Asteroid Redirection Test, NASA) and Hera (ESA) missions [1]. The target is an asteroid of approximately 160 m in size, named Dimorphos (the secondary of the binary Near-Earth Asteroid (65803) Didymos). 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. We investigate the possible reaction of Dimorphos to the DART collision to be performed in September 2022, under the assumption that it is a spherical gravitational aggregate produced in the formation of the binary system [2, 3]. The very structure of the target is unknown; therefore, we model it by mono- and multi-dispersed distributions of spherical basic elements and by considering irregular components.

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.

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. This, in turn will help in the interpretation of the results of the outcome of the DART impact mission. Also, potentially antipodal escaping mass will be checked to refine the overall momentum multiplication factor ('beta'). Finally, the results may contribute to the interpretation of motion of boulders on the surface of Dimorphos if their tracking will be possible by combination of DART-Liciacube and Hera measurements.

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 [4]). 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 the fraction of kinetic energy (about 1 to 3x10^{-3}) expected to survive once the shattering (non-elastic) phase has dissipated most of the impact kinetic energy [5]. We use conservative values of the restitution coefficient for inter-particle collision (0.3) corresponding to Earth rocks values. We account for different centre and off-centre possible impact geometry compatible with DART nominal impact angle (20º) with respect to the target orbital plane (Fig.1).

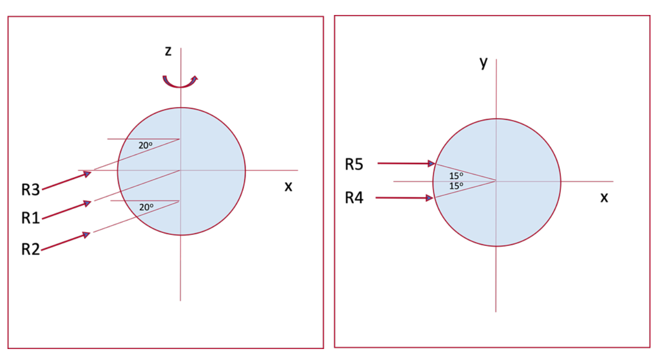

Fig.1. Impact geometries used in numerical experiments.

Our model Dimorphos is a $4.83x10^9$ kg and 80 m radius spherical aggregate made of (a) 100,550 mono-dispersed spherical particles in a close hexagonal packing (CHP) configuration, with particle radius of 1.5 m; (b) multi-dispersed distribution of 100,000 spherical particles, with particle radii ranging from 1 to 2.5 m; (c) 13,600 particles, with particle radii ranging from 2 to 5 m (Fig. 2).

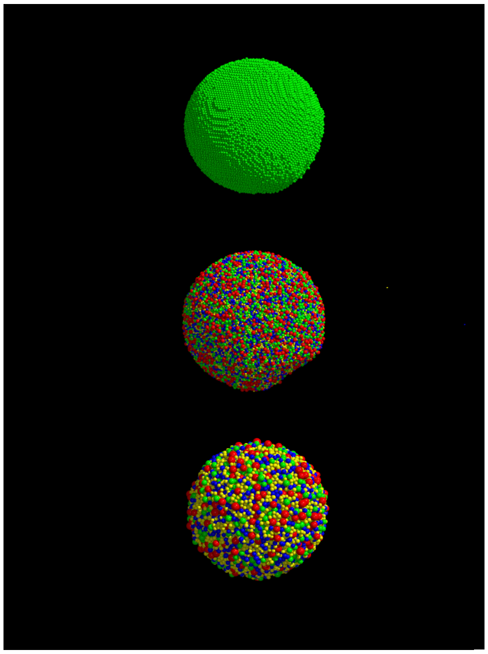

Fig.2. Aggregate distributions (a), (b) and (c) (see text).

Future research will include non-spherical shape for Dimorphos and the presence of the mass of Didymos primary in the system.

<u>Results</u>: We focussed the analysis of our simulation on the change in spin period and direction of the spin axis, tracking of their evolution in time. b) Energy distribution of surface particles capable to lift/move over the surface.

Spin change.

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

i) 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.

ii) The angular momentum vector may be tilted up to 3 deg with respect to initial direction.

iii) Spin vector is tilted with respect to angular momentum vector by about 0.1 deg with motion around the latter following the spin motion.

Surface energy.

iv) The energy and momentum wave seem to reach the surface away from the impact area in different ways depending on internal structure. Mono-dispersed CHP distribution of components damps propagation of both magnitudes and negligible particle motion is measured on the surface. Multi-dispersed distribution results in about 8 times larger amount of energy reaching the surface (Fig.3).

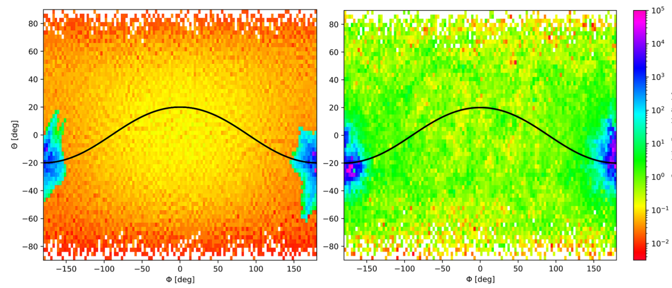

Fig.3. Impact energy reaching the surface of Dimorphos. Total (cumulative) energy in longitude (ϕ) and latitude (Θ) cells is shown for 100,000 mono- (left panel) and multi-dispersed (right panel) distribution of spheres for Dimorphos structure.

vi) Low mass escaping from antipodal impact region is negligible in any case and it does not likely affect *beta* parameter estimation.

v) In the multi-dispersed case, many particles on the surface away from the impact region are able to lift (vertically) at least 0.1 m, these particles may (or not) result in meter-range horizontal displacement. Fig.4 shows the horizontal displacement of these particles after the system reaches a stable state (several hours after the impact). Mass lift and horizontal displacement of hundreds of sizeable particles (diameter > 2 m) over the surface is possible. We also find that many boulders may have horizontal displacement larger than 1.5 meters after 2 min from impact, but no particle has horizontal displacement larger than 3 meters by that time.

The latter result may contribute to the interpretation of (lack of) motion of boulders on the surface of Dimorphos far from impact point. In fact, comparison of DART and Hera images may show displacement of Boulders. This in turn may give information on the internal structure of the body itself. In particular, Licia cubesat released by DART

will take a few pictures of the back side of Dimorphos about 3 min after impact with a resolution of 1.5 m at best. Boulders ranging larger distance may be spotted by Hera lately.

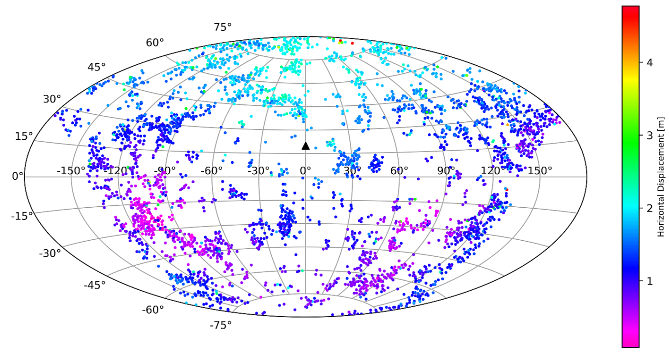

Fig. 4. Multi-dispersed structure. Distribution of boulder horizontal displacement after the system reaches a stable state. The particles are chosen using the criterion that they can lift (vertically) at least 0.1 m on Dimorphos surface away from impact point. Black triangle indicates impact antipodal point.

Such predictions may be of interest in the study of the post-impact dynamics of the system measured by the Hera mission. Next step will analyse estimation of shape deformation.

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