DYNAMICS OF THE EJECTA CLOUD PRODUCED BY A KINETIC IMPACT ON THE SECONDARY OF THE BINARY ASTEROID DIDYMOS: A CONTRIBUTION TO THE AIDA SPACE PROJECT.

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Introduction: To understand the fate of ejecta from a hypervelocity impact is one of the purposes of the NEOShield-2 project, funded by the European Commission in its program Horizon 2020 [1]. It is likewise an aim of the Asteroid Impact & Deflection Assessment (AIDA) space project in collaboration with ESA and NASA. This mission, which is under Phase-A/B1 study at ESA and Phase-A study at NASA until summer 2016, plans to characterize the secondary of the near-Earth binary asteroid 65803 Didymos and to perform a deflection test using a kinetic impactor in 2022 [2]. ESA is tasked with the design of an orbiting spacecraft, Asteroid Impact Mission (AIM), and NASA is tasked with the design of a kinetic impactor, Double Asteroit Redirect Test (DART).

We present here the first step of a study to build an informative model assessing the probable trajectories of the ejecta produced by an impact in the context of a asteroid binary system. A detailed dynamical model is developed based on systematic analysis of the effects of the various processes that can act on the ejecta cloud. This model can then be applied to any binary asteroid pair or to single asteroids, and it can also be used for a more general study aimed at understanding the effects of natural impacts. We apply our methodology directly to the AIDA scenario, in support of the Phase A/B1 study at ESA.

Mechanical Environment: The effects from different forces felt by the particles of the ejecta cloud are analyzed in the context of the Didymos system. The physical and dynamical properties of the bodies of the Didymos binary are derived from observations [3] or from analysis of similar systems [4]. The gravitational effects of celestial bodies (the Sun, planets, and binary components) and radiative perturbations are evaluated. The solar tides and solar radiation pressure are found to be the two major forms of perturbations, and are greatly dependent on the their trajectories. On the other hand, the effects of planetary tides and drag forces are relatively weak and can thus be ignored.

Numerical Methodology: A closed system including the binary components, the ejecta cloud and the Sun is defined. The influences of solar gravity and solar radiation pressure are considered, and the ejecta are assumed to have no effect on the binary system. The binary motion is thus governed entirely by the two bodies' mutual gravity and their solar perturbations.

A two-stage approach is proposed to track the evolution of the ejecta cloud: I. The motion of the binary system around the Sun is solved in advance, and the evolution of both components, i.e., positions, velocities, orientations, and rotational speeds, are recorded within a specified time span. II. The second stage includes a series of simulations in which massless tracer particles are introduced into the environment composed of the Sun and the binary, which move according to their predetermined motions. Tracer particles are sampled from the initial ejecta set that includes particles of different sizes and launching states.

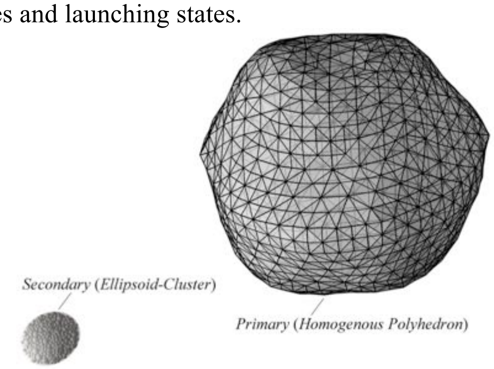

Fig. 1 The models of Didymos' primary and secondary.

To assess the gravity from the two binary members, we assume that the primary is a homogeneous polyhedron with its surface composed of triangular meshes [5] and that the secondary's interior, assumed to have a rubble-pile structure, is discretized into a cluster of solid spheres (see Fig. 1). The binary motion is then computed by solving an equation with 14 degrees of freedom.

Full-scale Test: We ran a full-scale test of our numerical model, in which we simulate the fate of the ejecta produced by the DART impact on the secondary of Didymos in 2022. It serves as a part of the study of the group working on ejecta-dynamics model scenario of AIDA [6]. Our simulations show where and how the ejecta cloud evolves (see Fig. 2) for the considered initial conditions, which rely on scaling laws.

The simulations describe general patterns of motion of an evolving ejecta cloud, which is used to assess the potential hazard to an observing spacecraft around Didymos. The ejecta evolution proves to be violent at first. However, this period is short-lived, and is followed by a more stable stage, during which remaining ejecta are gradually thinned out. The solar radiation pressure is found to be efficient in segregating grains by their sizes within just a few hours after impact, quickly clearing out the smallest grains. The danger posed by small-size ejecta (< 1 mm) is quickly mitigated by solar radiative accelerations. Remaining particles steadily disperse in a generally uniform manner, with most eventually accreting onto either of the components, and the rest being ejected out of the system. The binary asteroid Didymos system proves to be efficient at cleaning ejecta, especially for those moving near the mutual orbital plane; the risk to a spacecraft close to the system is significantly mitigated in two weeks time after the impact. A considerable quantity of the ejecta will eventually accrete onto the surfaces of Didymos' two components, which might lead to a measurable optical alteration for remote observation. Solar radiation pressure is found to play an important role in post-impact processes and in the cleanup of small-size particles around Didymos.

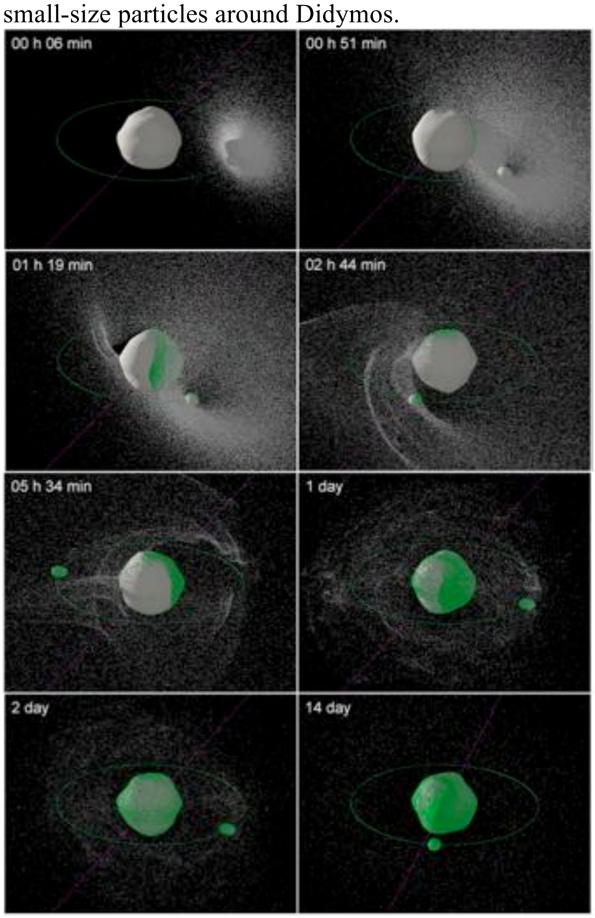

Fig. 2 Snapshots of the time evolution of ejecta cloud near Didymos (view size ~ 4.6 km). The binary and heliocentric orbits are marked with solid lines of color green and purple, respectively. Fictitious large particle size is adopted for visual enhancement, and the accreted particles are colored in green.

References: [1] Schwartz S.R. et al. (2016) *Advances in Space Research,* in press, doi: 10.1016/j.asr.2015.12.042. [2] Cheng A.F. et al. (2016) *Planetary & Space Sci.,* accepted. [3] Michel P. et al. (2016) *Advances in Space Research,* submitted. [4] Walsh K.J. et al. (2012) *Icarus* **220**, 514. [5] Pravec P. et al. (2006), *Icarus* **181**, 63. [6] Schwartz S.R. et al. (2016) 47th LPSC, LPI Contribution, submitted.

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