DYNAMICS OF EJECTA IN THE DIDYMOS-DIMORPHOS BINARY: SENSITIVITY TO THE SYSTEM PARAMETERS.

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Introduction: The DART spacecraft will impact Dimorphos (the secondary body of the Didymos binary asteroid) to test the kinetic impactor deflection method against possibly hazardous Near Earth Asteroids. The impact crater will be first imaged by the LICIACube spacecraft, hosted as a piggyback and released by DART just before the impact, and then, several years later, by the HERA probe. To fully exploit the wealth of data obtained and to understand the physics of the whole impact experiment it is of paramount importance to properly model the dynamics of the binary system pre- and post-impact and the dynamics of the particles ejected from the impact crater.

In this context a comprehensive model was developed to simulate the outcome of the impact experiment.

The final goal is to study the short (within the DART-LICIACube framework) and medium (the HERA framework) term dynamics of the system and of the ejecta particles with a comprehensive model described in the following section. The expected final output shall be useful to better understand the initial crater evolution and the characterization of the dust environment within the binary system at the time of HERA arrival, exploring also the possibility of the formation of long term stable particles.

The model: The dynamics of the system and the ejecta particles will be studied by means of the following model.

Starting from different iSALE [1,2] cratering simulations of the DART impact [3,4], the initial conditions of the ejecta particles (such as velocity, launch angle, launch position) are defined. Then we produce a 3D representation of the crater by computing the particles elevation (in the topocentric frame at impact location) starting from the Z coordinate given by iSALE (see Fig. 1) and extracting a random azimuth [between 0 and 360 degrees]. Hence, the initial topocentric Cartesian coordinates and velocities of the vectors of each particle are obtained.

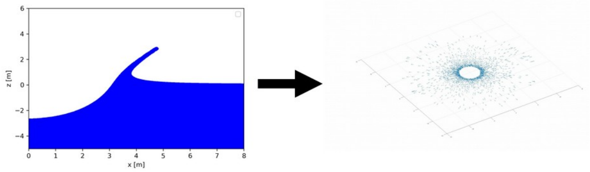

Fig. 1: Example of the generation of a the initial vectors for the ejecta from an iSALE output.

The particles are then propagated with the *Radau* integrator [5] using the following default dynamical model:

- Dimorphos is considered the primary body, with Didymos rotating in an apparent circular (or elliptic, induced by DART impact) orbit around it;
- the gravity field of the primary can be computed either by means of the polyhedral approach [6] for an ad-hoc shape or with an analytical expression for a triaxial ellipsoid [e.g., 7];
- the direct and indirect perturbations of the secondary body are computed assuming either a spherical (default) or an ellipsoidal body;
- the Solar Radiation Pressure (SRP) is computed, including shadows effects;
- for the computation of the area over mass ratio in the SRP effect, the ejecta particles are assumed to be ellipsoids whose axis ratio are extracted from a Gaussian distribution [8] and with a variable rotation rate extracted from a Maxwellian distribution.

As an example of the model performances, in Fig. 2 a brief integration of a few sample spherical particles is shown at two different epochs shortly after the impact. In these cases the destabilizing effect of the secondary body, coupled to the SRP perturbation, leads to a quick escape from the binary system.

Sensitivity analysis: A first step in the project is the need to understand the influence on the system evolution of a set of sub-models and parameters. Beyond the fine tuning of the whole dynamical model itself, the results of such a study are important to assess the accuracy needed in the measurement of the studied parameters to achieve a good representation and understanding of the whole system. The study will concentrate on the following points.

Gravity field. The influence of the gravity field will be explored in a twofold manner. First, the effect of different shapes of the primary on the system evolution will be analyzed. This will be done using different representations of the shapes either as polyhedrons or, for simpler ellipsoidal shapes, by means of analytical expressions [e.g., 6,7]. In particular, given the high computational burden associated with the polyhedron algorithm the possibility to switch to the analytical representation with no significant loss in accuracy (e.g., after a given distance from the primary body) will be explored.

Secondary body effects. As mentioned above, the secondary body is usually considered as spherical. As in the previous item, the specific effects related to the a non-spherical shape of the secondary body will be explored considering a triaxial ellipsoid.

Post-impact orbit effects. The effective total mass and velocity of the ejecta will be used to compute the post-impact, presumably non-circular, orbit of Dimorphos by means of a FTRBP code [9]. The realistic perturbed elliptic orbit will be fed to the simulator as an ephemeris file and thus the influence of the post-impact orbit will be explored as well.

Influence of ejecta shape and rotational motion. Different distributions of the ejecta shape and rotation rates will be explored to assess the influence of these parameters. Firstly the difference w.r.t. the commonly used simple spherical ejecta particles will be assesed and secondly the difference between different specific distributions will be studied.

Location of the impact: the aim of the DART mission is to impact the center of the figure of Didymos as obtained by the probe navigation camera. Nonetheless there is the possibility of an off-center impact. The influence of the impact location on the ejecta evolution will be studied too.

Target composition: In our analysis the target composition translates into different initial conditions (in terms of initial state vectors and size and numerosity of the ejecta). This relevant aspect will be briefly touched here and will be the essence of a separate effort.

Once the sensitivity analysis will be completed and the relevant parameters identified along with their needed accuracy, a massive simulation campaign is foreseen to model the dynamics of a large number of ejecta over different time spans. Due to the significant computational effort required for this task, only a sample of these results will be reported here.

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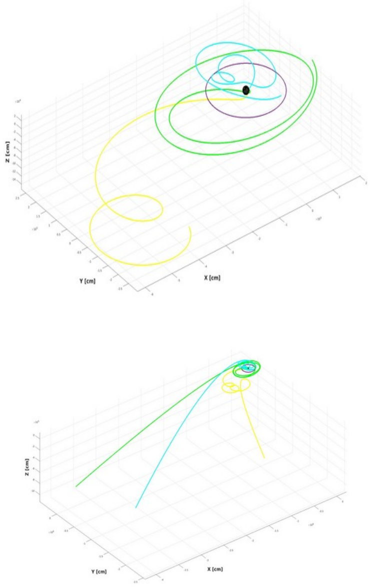

Fig. 2: Example of the evolution of three ejecta particles (yellow, cyan and green lines). The purple circle represents the apparent orbit of Didymos around Dimorphos. The two panels refer to two subsequent sample epochs.

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