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Numerical modelling of the DART impact and the importance of the Hera mission

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Earth is continuously impacted by space debris and small asteroids, and, while large asteroid impacts are uncommon, they could produce a severe natural hazard. NASA's Double Asteroid Redirection Test (DART), set to launch in 2021 [1], aims to test a controlled deflection of a Near-Earth binary asteroid, by impacting the smaller component of the 65803 Didymos asteroid system [2, 3]. The impact will thereby alter the binary orbit period by an amount detectable from Earth [1].

In high velocity impact events the change in momentum of the asteroid ΔL can be amplified by the momentum of crater ejecta that exceeds the escape velocity, which is often expressed in terms of an empirical value, $\beta = \Delta L/(mU)$, where mU is the impactor momentum [4]. The DART mission, together with Earth based measurement, will measure the deflection of the Didymos secondary–Didymoon– and hence, β. However, the amount by which crater ejecta enhances asteroid deflection–that is, the normalised momentum of the escaping ejecta $(\beta - 1)$–has been found to vary significantly depending on the target asteroid's properties and composition [5]. Thus, without knowledge of the surface properties of the Didymos secondary, a measurement of β alone is not sufficient for the purpose of numerical model validation.

For a better constraint of Didymoon's target properties, ESA is planning a rendezvous mission, Hera [1, 6], that has a 2023 planned launch and will arrive at Didymoon several years after the DART impact. The spacecraft will enable us to perform detailed characterisation of the Didymoon volume and surface properties, as well as measure the DART impact outcome, such as change in the binary system orbit or the volume and morphology of the DART impact crater. Here, we discuss the measurements made

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by Hera that should enable us to infer the asteroid surface material properties from the DART impact crater morphology.

We used the iSALE shock physics code [7, 8] to numerically model the DART impact in two and three dimensions. The DART spacecraft structure was modelled as a porous aluminium sphere, impacting a basalt target at 7 km/s. To study the target material response to a possible impact, we considered three distinct target scenarios: a homogeneous porous half-space, layered targets with a porous weak upper layer overlying a stronger bedrock layer, and targets with continuous porosity gradients. For each of these target scenarios we systematically varied the target material properties (e.g. the cohesional strength, porosity or coefficient of internal friction, the layer thickness or the porosity gradient profile) and determined the crater morphology and the momentum carried away by the ejecta, $\beta - 1$.

We found that similar deflection (i.e., similar β values), can be achieved by impacting targets with very different material properties or structures. However, these impacts produce different crater morphologies (Fig. 1). Acquisition of high-resolution images and measurements of the DART impact crater by the Hera mission should therefore allow the asteroid's near-surface properties and structure to be inferred and provide robust validation of impact simulations. Such validation would greatly increase confidence in the numerical predictions of kinetic impact deflection.

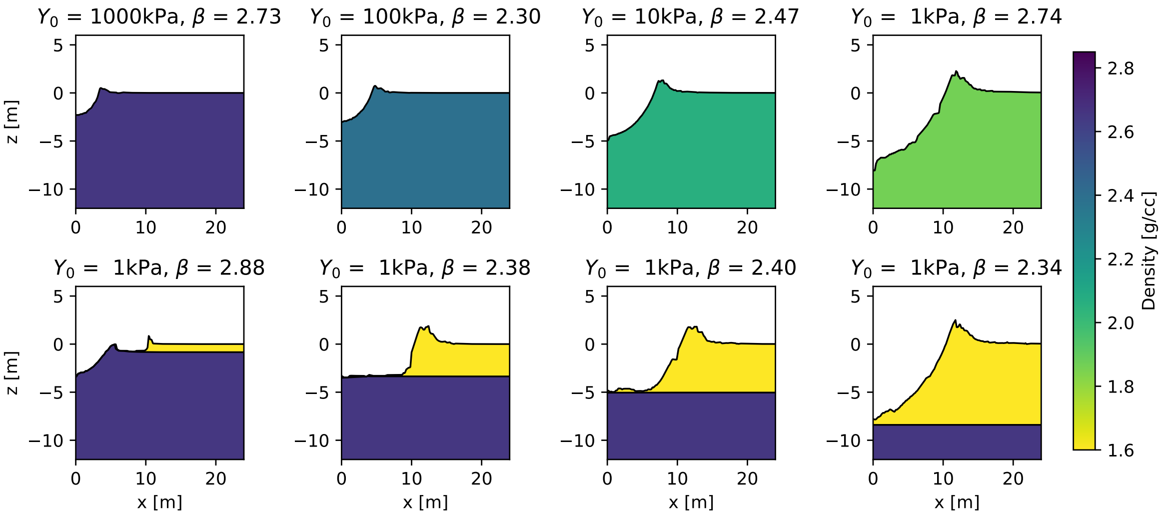

Figure 1: Crater morphologies for eight impacts into targets with different properties that produce a similar total ejected momentum ($2.3 < \beta < 2.9$).

Comments: *Oral presentation*

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