Scan me! Abstract.

NUMERICAL MODELLING OF THE DART IMPACT AND THE IMPORTANCE OF THE HERA MISSION

S. D. Raducan[1], G. S. Collins[1], T. M. Davison[1],

[1]Impact and Astromaterials Research Centre, Department of Earth Science and Engineering, Imperial College London, SW7 2AZ, UK

Scan me! Poster.

DART and Hera missions at Didymoon

- The NASA Double Asteroid Redirection Test (DART) will be the first mission to test a controlled deflection of a near-Earth asteroid, by impacting the moon of Didymos [1, 2]. The change in momentum caused by the impact can be expressed in terms of the multiplication factor β [3]: $\Delta \mathbf{p} = \beta m \mathbf{v}$, where m is the impactor mass and $\mathbf{v}$ is the impactor velocity.
- ESA's Hera mission will arrive at Didymoon several years after the DART impact and will perform detailed measurements that will enable us to validate our numerical models.

Key measurements for model validation:

- DART & Earth obs.:
  - Momentum enhancement, β
  - Bulk density measurements
- Hera:
  - Surface cohesion estimate
  - Morphology and size of the DART crater
  - Asteroid surface survey

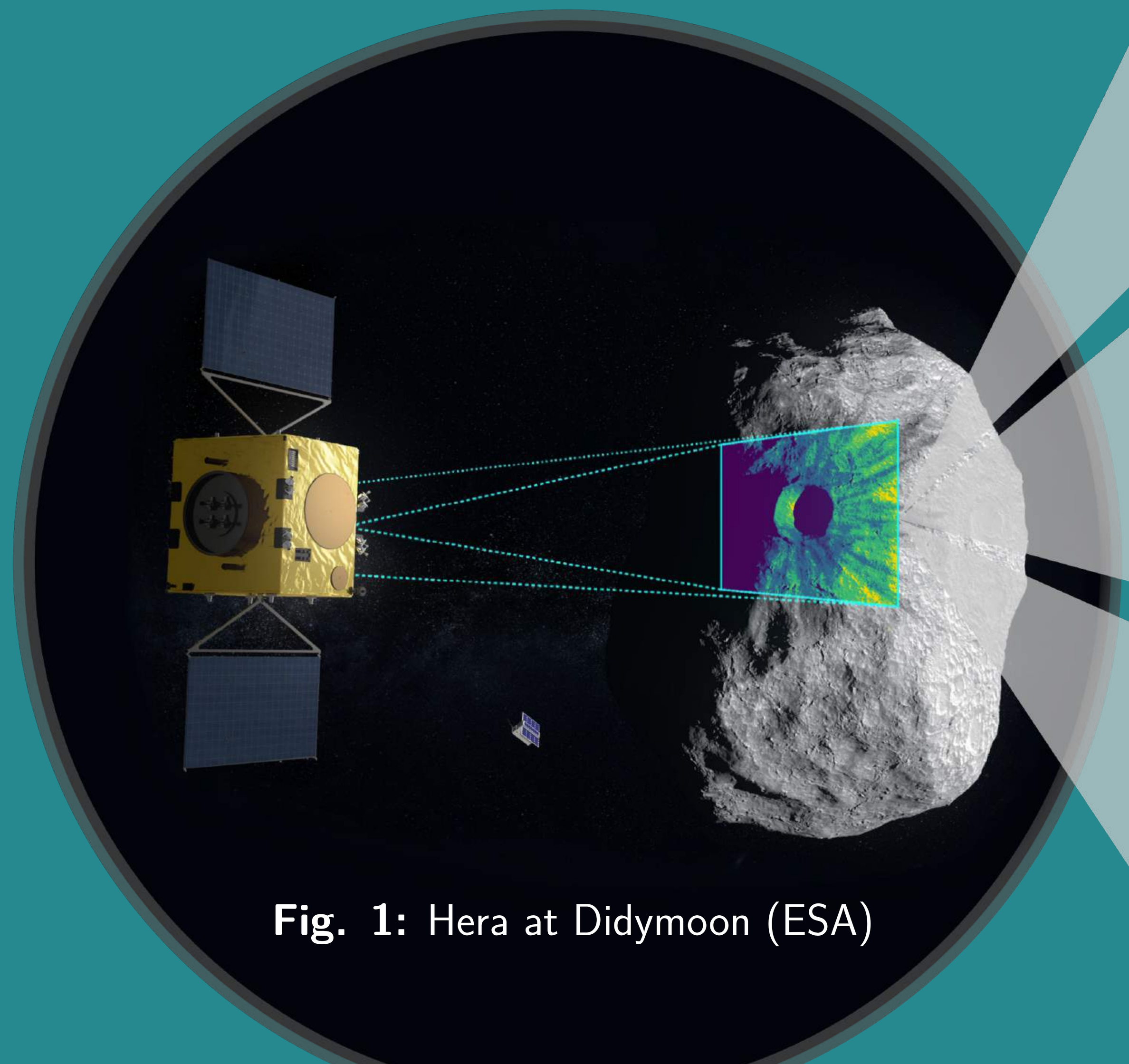

Fig. 1: Hera at Didymoon (ESA)

We used iSALE to model the DART impact

The DART spacecraft was modelled using iSALE [4, 5], as a porous aluminium sphere, impacting a basalt target at 7 km/s. We considered three distinct target scenarios; for each, we systematically varied the target material properties and determined crater morphology and momentum transfer efficiency, β.

References

[1] Cheng, A. F. et al. (2018) Planet. Space Sci, 157:104–115. [2] Michel, P. et al. (2018) Adv Space Res. 62:2261–2272. [3] Holsapple, K. A. Housen, K. R. (2012) Icarus, 221:875–887. [4] Collins, G. S. et al. (2004) Meteorit. Planet. Sci, 39:217–231. [5] Wünnemann, K. et al. (2006) Icarus, 180:514–527. **Acknowledgements:** We gratefully acknowledge the developers of iSALE (www.isale-code.de) and STFC for funding (Grant ST/J001260/1).

Same deflection predicted for different target structures

We found that similar deflection (similar β values), can be achieved by impacting targets with very different material properties or structures. However, these impacts produce different crater morphologies. The Hera mission will acquire high-resolution images and measurements of the DART impact crater which will allow the asteroid's near-surface properties and structure to be inferred and provide robust validation of impact simulations.

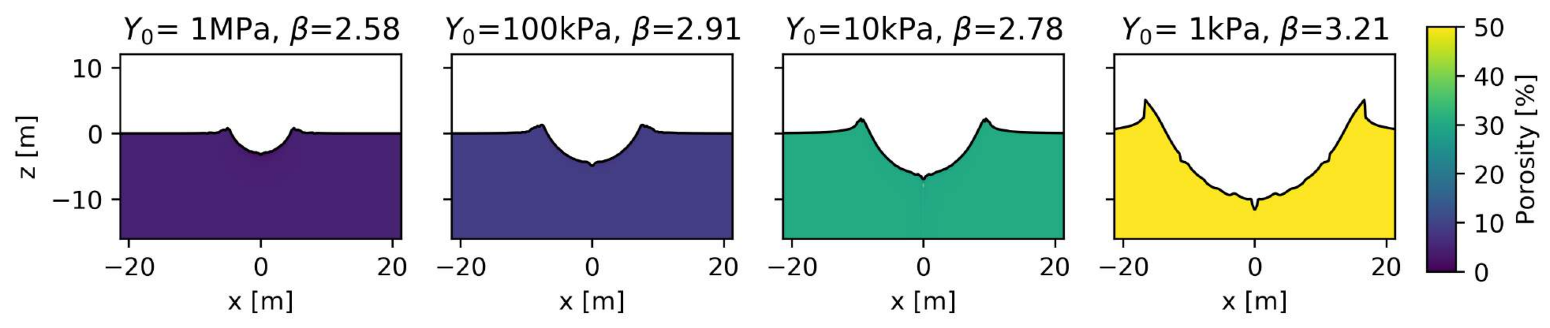

Fig. 2: Crater morphologies for impacts into homogeneous targets with different cohesions and porosities that produce a similar β.

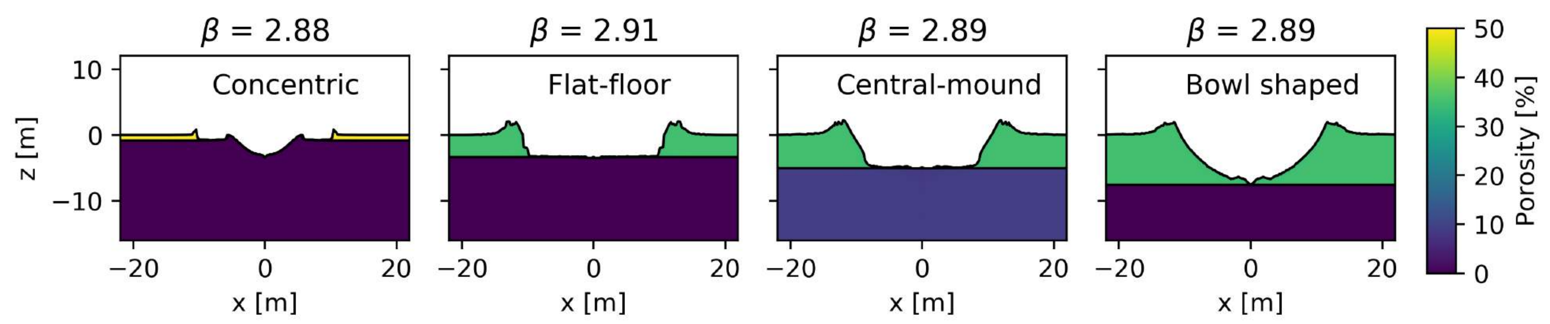

Fig. 3: Crater morphologies for impacts into layered targets with different porosities configurations that produce a similar β.

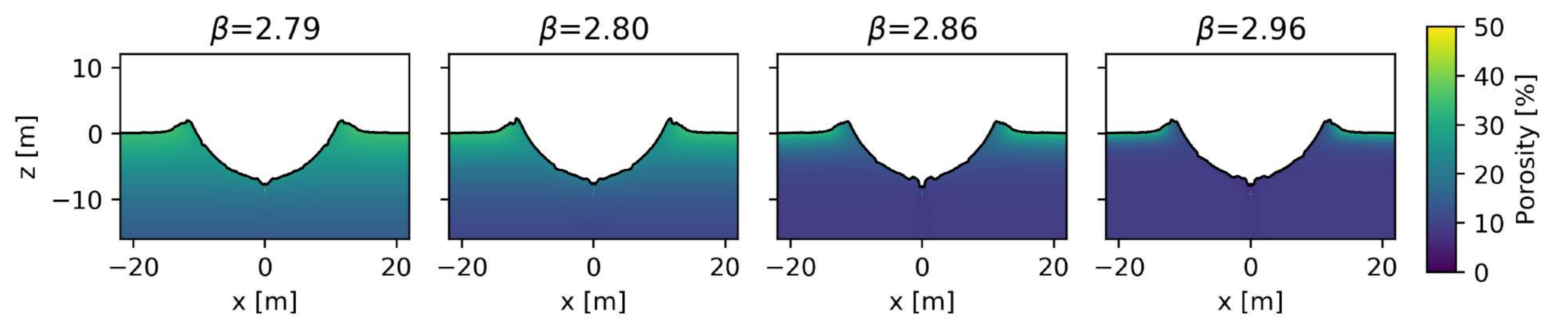

Fig. 4: Crater morphologies for impacts into targets with exponentially decreasing porosity with depth, that produce a similar β.

Conclusion: Hera measurements are vital for validation purposes

- Impacts into a homogeneous porous Didymoon produce $2 < \beta < 4$; The crater size is mainly influenced by the target cohesion;
- Impacts into layered targets produce both amplification and reduction in β. The crater morphology is dependent on the upper layer thickness;
- Impacts into targets with exponentially decreasing porosity produce an amplification in β only for sharp gradients, while the crater size remains unchanged.

a) Homogeneous porous half-space

We varied the cohesional strength of the damaged material, Y_0, between 0.1 and 100 kPa and target porosities between 0% and 50%. All craters formed were bowl shaped and the crater radius and β were highly sensitive to Y_0.

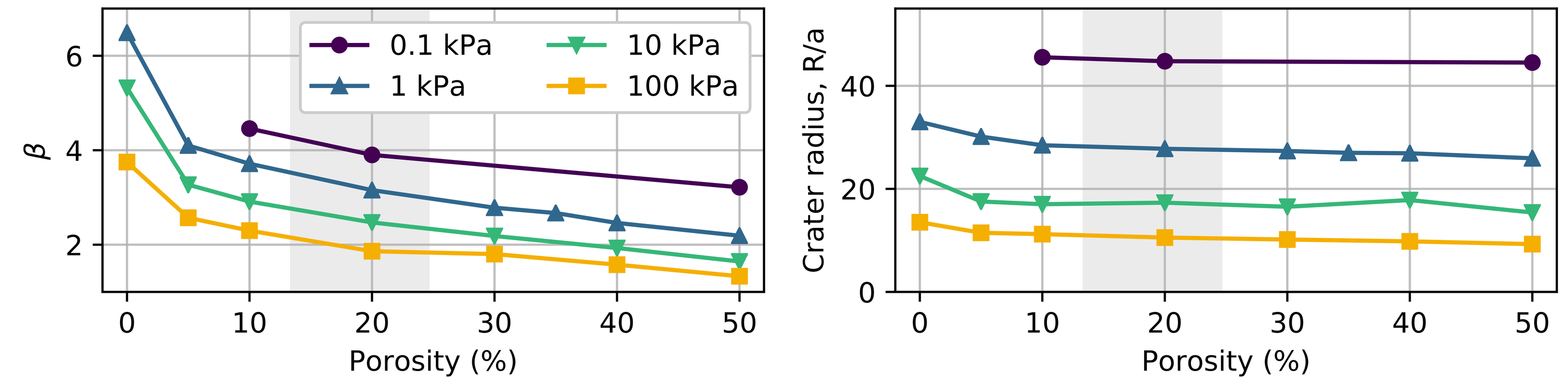

Fig. 5: Momentum enhancement (β) and normalised crater radius (R/a) as a function of porosity for impacts into homogeneous half-space with 0.1 kPa $< Y_0 < 100$ kPa.

b) Two-layer targets

A weak (1 kPa), porous upper layer covering a stronger (100 kPa), less porous substrate. We considered four layer porosity configurations, for which we varied the regolith layer thickness, $1 < h/a < 20$. Depending on h/a, different crater morphologies were produced.

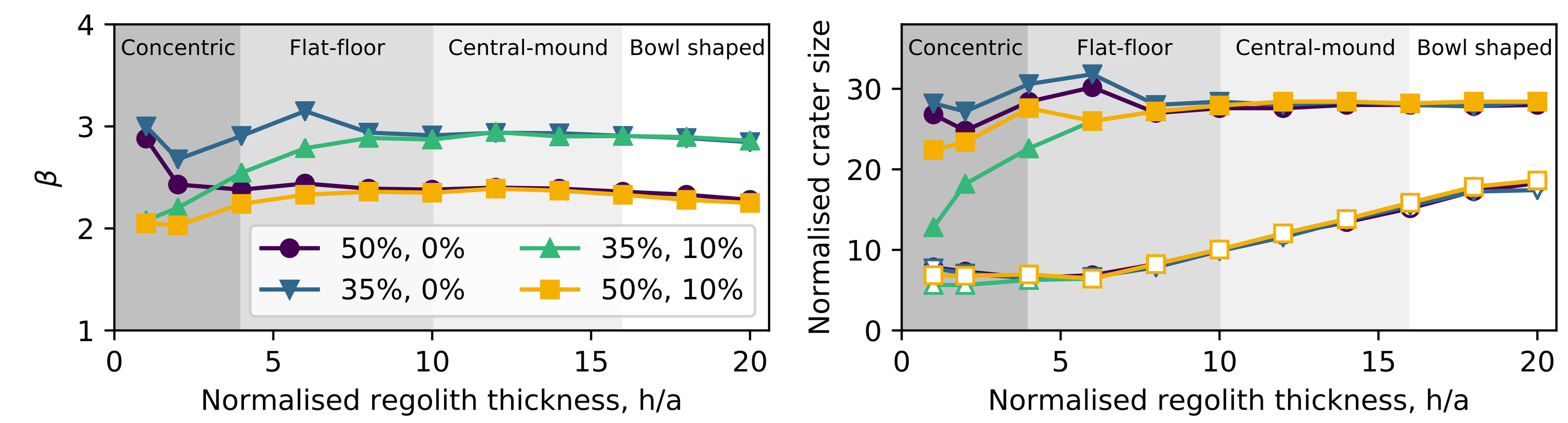

Fig. 6: β and crater size normalised by the impactor radius (crater radius, with filled symbols and crater depth with hollow symbols) as a function of regolith thickness.

c) Targets with exponentially decreasing porosity

Two simulation sets: $\phi_{surface} = 50\%$, $\phi_{min} = 0\%$ and $\phi_{surface} = 35\%$, $\phi_{min} = 10\%$. For each set, we varied the e-folding depth $0.12 < 1/h_\star < 1.2$. The impact produced bowl shaped craters.

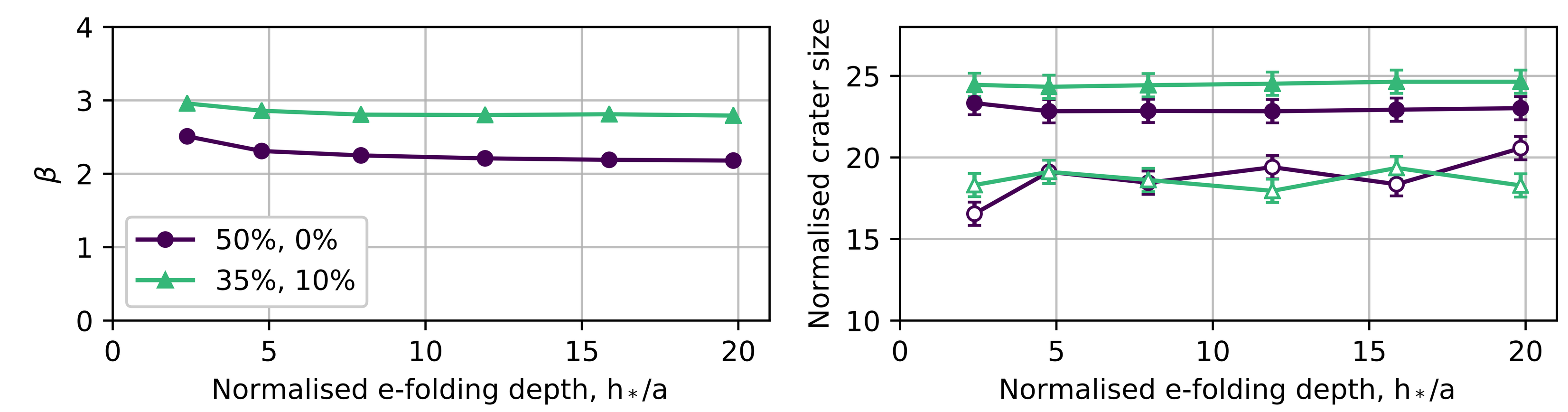

Fig. 7: β and crater size normalised by the impactor radius (crater radius, with filled symbols and crater depth with hollow symbols) as a function of e-folding depth.