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Understanding the Effect of Rubble Pile Structures on Asteroid Deflection

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ABSTRACT

In the event of an inevitable impact by an asteroid, a kinetic impactor is the most mature line of defense to avert disaster. However, our detailed understanding of this technique is based primarily on large numerical simulations. The upcoming launch of the Double Asteroid Redirection Test (DART) mission will provide the first full-scale test of a kinetic impactor in a planetary defense scenario. This demonstration is vital for understanding the feasibility of deflection via a kinetic impactor while providing a completely unique validation data set. While we must wait to obtain an empirical deflection efficiency from DART, we can begin to explore the parameter space of more complicated asteroid shapes, such as rubble piles, in numerical simulations.

Rubble-pile asteroids have been understood to exist since the late 1970’s. It was not until the two recent Hayabusa missions to Itokawa and Ryugu that the immense variation of asteroidal rubble-pile structures was observed. On Itokawa, portions of the asteroid are covered in fine-grained regolith; on the other hand, Ryugu contains no discernable regolith and is exclusively rubble. These two extremes not only highlight the diversity of asteroids within our Solar System, but also presents

challenges to simulation efforts since these bodies are not nearly as simple as they are sometimes modeled.

To understand the effect of rubble-pile structures on asteroid bodies, we use a novel rubble-pile generator implemented in our Adaptive Smoothed Particle Hydrodynamics (ASPH) code, Spheral++. Using the impactor mass and velocity planned for the DART mission, we can explore how the presence of boulders on the surface or under layers of regolith at the point of impact change the deflection parameter β, which is defined as the enhancement to momentum transfer in excess of a purely inelastic collision. Shown in Figure 1 is an example simulation, run using the rubble-pile features of Spheral++.

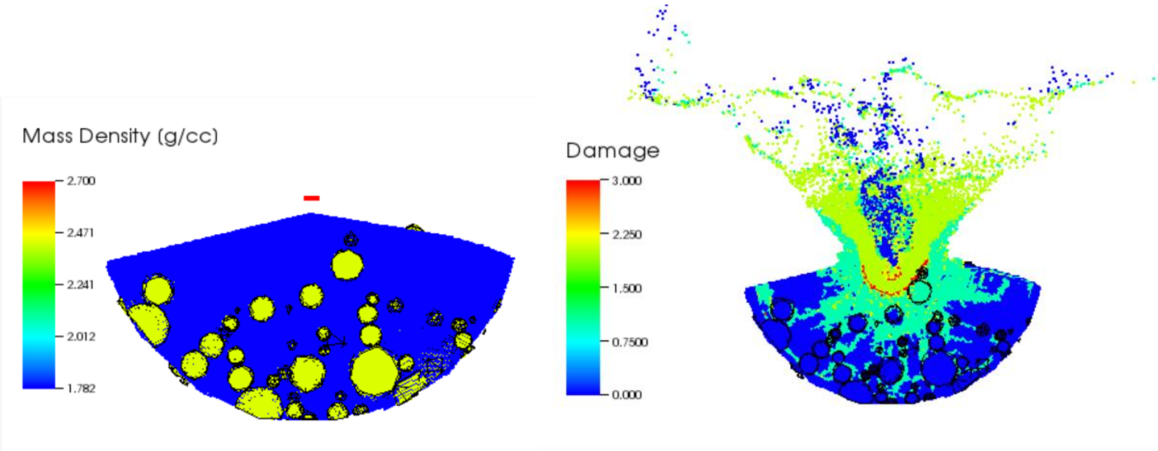

Figure 1: (Left) Initial conditions of the rubble-pile simulation showing the different densities of boulders (yellow) and regolith (blue). Note that the impactor (red) is impacting a region of the body that is primarily regolith in this example. (Right) The damage trace following impact into the rubble-pile body. In both panels, the black outlines represent the locations of the boulders.

These simulations will help to both identify and quantify the uncertainties that arise from impacting a rocky surface covered in varying amounts of porous regolith and boulders. With the results from these simulations, it will be possible to compare against the results of the DART mission, as well as non-rubble-pile simulations, to help interpret the results of the groundbreaking demonstration of a kinetic impactor.

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