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Impact simulations on the rubble pile asteroid (2867) Steins

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Images from the OSIRIS camera system on board the Rosetta spacecraft (Keller et al. 2010) have revealed several interesting features on asteroid (2867) Steins. Its macro porosity of 40%, together with the shape that looks remarkably like a YORP evolved body, both indicate a rubble pile structure. A large crater on the southern pole is evidence for collisional evolution of this rubble pile asteroid.

We have developed a new approach for simulating impacts on asteroid bodies that connects formation history to their collisional evolution. This is achieved by representing the interior as a ‘rubble pile’, created from the gravitational aggregation of spherical ‘pebbles’ that represent fragments from a major disruption event. These ‘pebbles’ follow a power-law size function and constitute the building blocks of the rubble pile. This allows us to explicitly model the interior of rubble pile asteroids in hyper-velocity impact simulations in a more realistic way. We present preliminary results of a study validating our approach in a large series of simulated impacts on a typical small main-belt rubble pile asteroid using the Smoothed Particle Hydrodynamics solver in LS-DYNA.

We show that this approach allows us to explicitly follow the behavior of a single ‘pebble’, while preserving the expected properties of the bulk asteroid as known from observations and experiments (Holsapple 2009).
On the example of Steins, we use this model to relate surface features like the northern hill at 75/100 degrees lon/lat distance to the largest crater (Jorda et al. 2012), or the catena of depletion pits, to the displacement of large fragments in the interior of the asteroid during the impact. We do this by following the movement of pebbles below the surface feature in simulations that recreate the shape of the impact crater. We show that while it is not straightforward to explain the formation of the hill-like structure, the formation of cracks possibly leading to depletion zones can be observed.

References: Keller et al., 2010, Science, 327(5962), pp. 190–193; Jorda et al., 2012, Icarus, vol. 221 (2) pp. 1089-1100; Holsapple, 2009, PSS, 57(2), 127–141.