Activating Main Belt Comets by Collisions

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Abstract. Since their identification as a new class of bodies by Hsieh & Jewitt (2006) active asteroids (or Main Belt Comets, MBCs) have attracted a great deal of interest. Given that sublimation of volatile material (presumably water-ice) drives MBC activity, these bodies are candidates for delivering a significant amount of Earth's water. Dynamical studies suggest in-situ formation of MBCs as the remnants of the break-up of large icy asteroids. Also, collisions between MBCs and small objects might have exposed sub-surface water-ice triggering the cometary activity of these bodies. In order to advance the effort of understanding the nature of MBC activation, we investigate these collision processes by simulating the impacts in detail using a smooth particle hydrodynamics (SPH) approach that includes material strength and fracture models. Our simulations cover a range of impact velocities and angles, allowing m-sized impactors to erode enough of an MBCs surface to expose volatiles and trigger its activation. We also vary the material strength of the active asteroid's surface. As expected, depending on the impact energy, impact angle, and material strength we observe different crater depths. Across all scenarios however, our results show that the crater depths do not exceed a few meters. This implies that if the activity of MBCs is due to sublimating water-ice, ice has to exist no deeper than a few meters.

Fundamental Questions

The activity of MBCs is presumed to originate from sublimating water ice

- What is the distribution of water inside these bodies?
  - Prialnik & Rosenberg (2009) suggest that H_2O can only exist at a depth of about 50-150 m beneath the surface
  - Schorghofer (2008) shows that water ice can actually stay within the top few meters just under a thin dusty surface layer

A possible mechanism to trigger MBC activity is the micro-impact of meter-sized bodies onto water-rich kilometer-sized asteroids (e.g., Haghighipour 2009, Hsieh & Jewitt 2006, Maindl et al. 2015)

- What is the typical depth of an impact crater in such collisions for typical impact velocities in the asteroid belt?
- Can such impacts result in exposed subsurface water ice?

Simulations

SCENARIOS

We simulate the collision of a rocky projectile (radius 1 m) with a km-sized target

- The target consists of rock with a water content varying between 0 wt-% and 50 wt-%, the projectile of 100% basaltic rock
- To cover different target material strengths the scenarios include basalt and tuff targets
- Impact velocities vary from 0.25 km/s to 5.3 km/s, impact angles from 0° (head-on) to 60°

METHOD

3D smooth particle hydrodynamics (SPH) including material strength and a fracture model

- Our code (Schäfer 2005, Maindl et al. 2013) implements the full elasto-plastic continuum mechanics model and includes the Grady-Kipp fragmentation model for treating fracture and brittle failure (Grady & Kipp 1980, Benz & Asphaug 1994). A tensorial correction warrants first-order consistency (Schäfer et al. 2007)
- Resolution: approx. 500k SPH particles

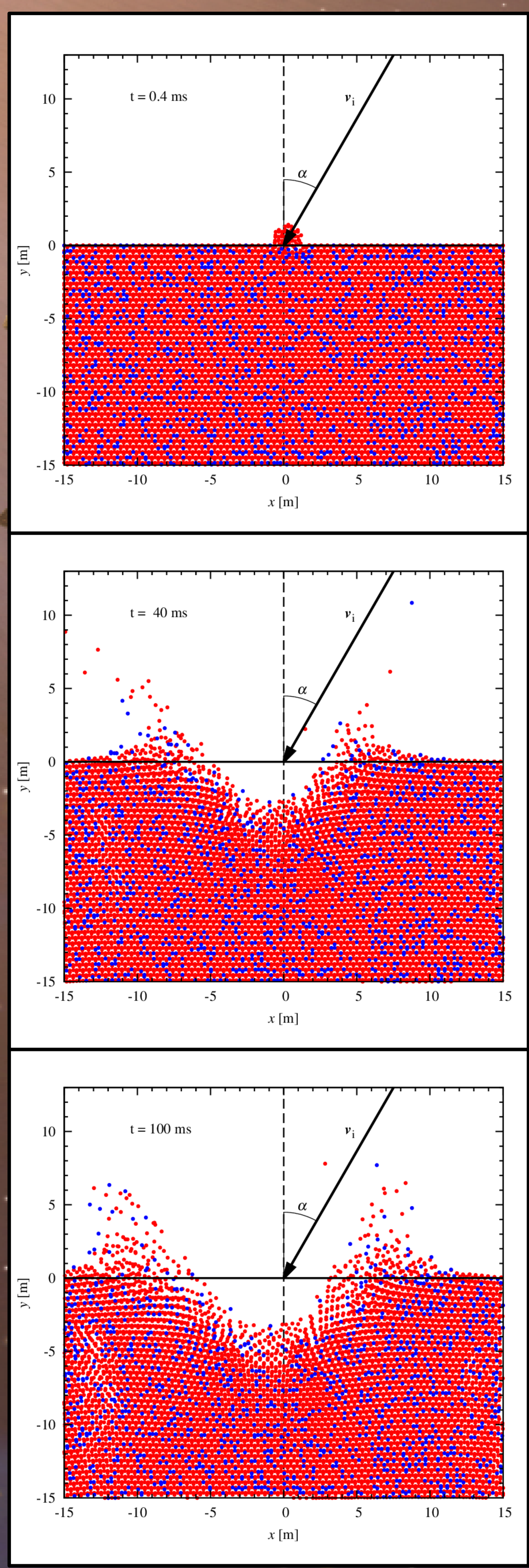

Figure 1. Snapshots of an impact at 4.4 km/s and a 30° angle. The target has 5 wt-% water ice (blue dots), the resulting crater depth is approx. 3.4 m.

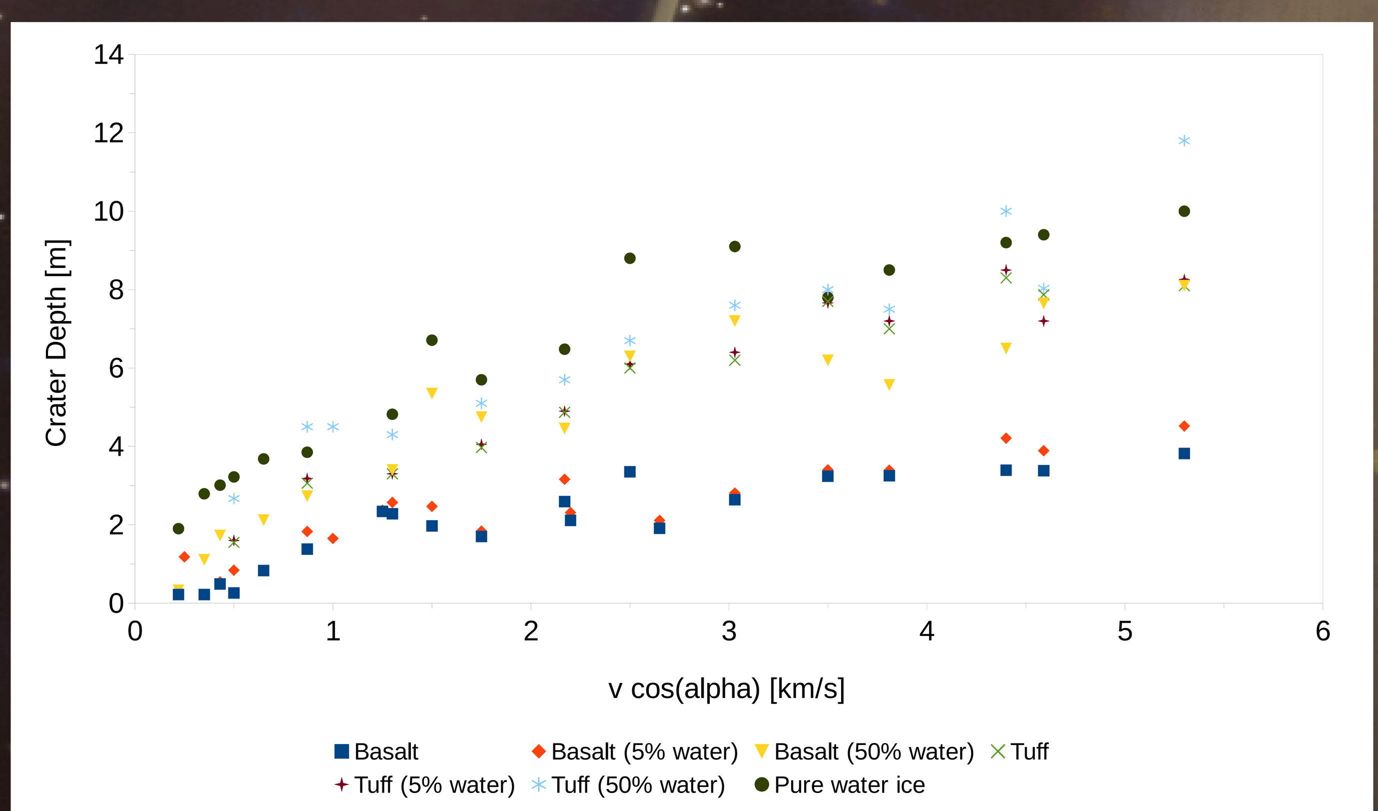

Figure 3. Variations of crater depth in terms of the vertical component of the impact velocity for different target materials. The craters are up to about 12 meters deep.

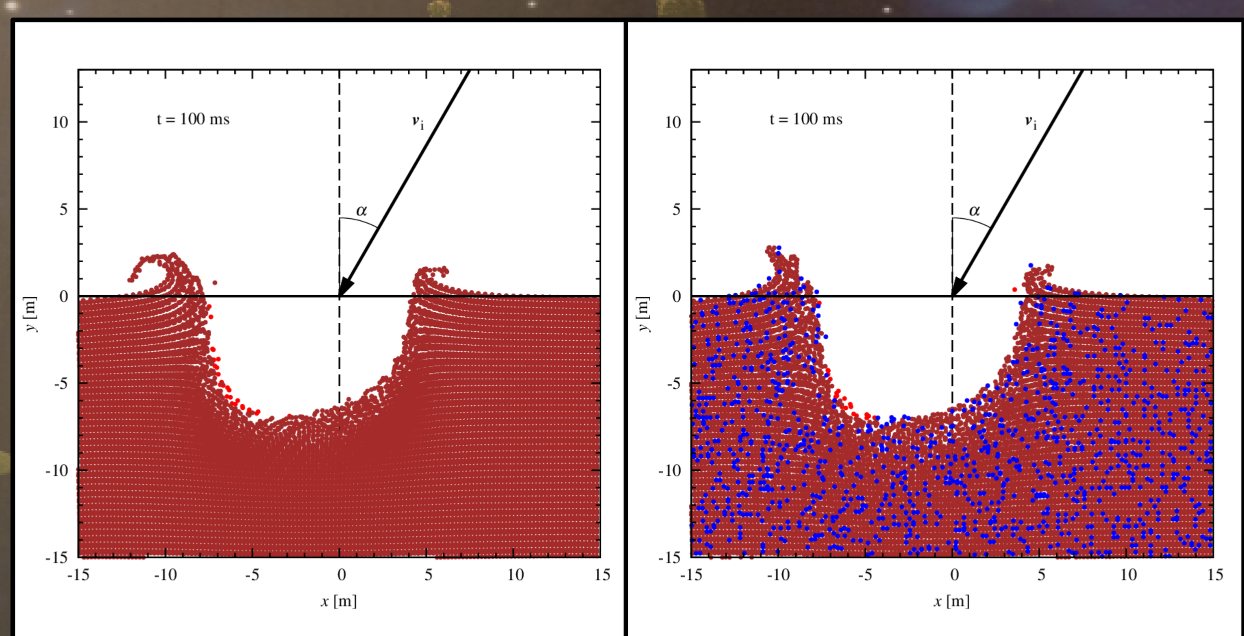

Figure 2. Craters resulting from the same projectile as in Fig. 1 hitting a softer tuff target with water-ice fractions of 0 wt-% (left) and 5 wt-% (right). The resulting crater depths are 7.0 m and 7.2 m, respectively.

Conclusions

- ➔ Crater depths are only a few meters for all values of impact velocity and angle
- ➔ None of our simulations produced craters 50 meters or deeper
- ➔ Our results imply that if the activity of MBCs is due to sublimating water ice, water has to be no deeper than a few meters. This is consistent with the model by Schorghofer (2008)

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Background picture: NASA/JPL-Caltech