Call for Ideas: NEO Encounter 2029

Determination of asteroid fragmentation energy from an impactor and post-fragmentation dynamics

Executive Summary

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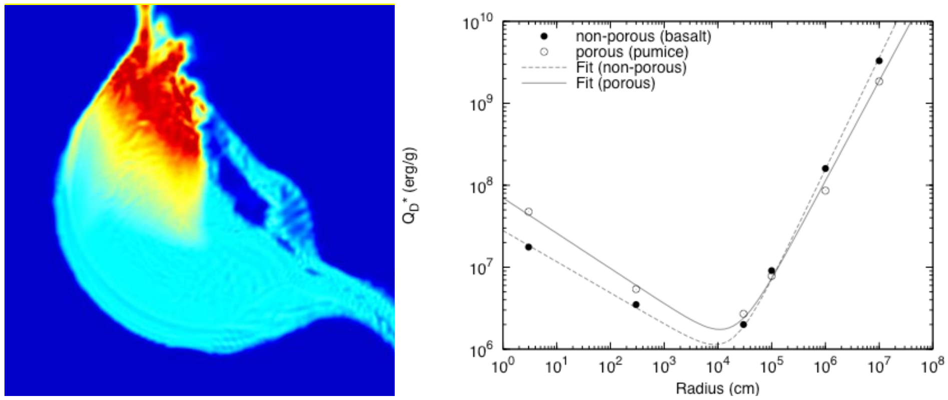
Picture:



Left: Disruption of a 25 km basalt sphere by the impact of a projectile (colours represent velocities of fragments, from negative light blue to positive red): right: impact energy threshold for disruption of a target as a function of its radius for either porous or non-porous targets impacted at 5 km/s.

Motivation:

The aim of this study is to characterize the impact energy threshold that leads to the disruption of a target rather than its deflection as a function of impact velocity and target's internal structure, and to estimate the outcome of such disruption in terms of fragment sizes and ejection velocities.

Methodology:

A mission of deflection using a potential impactor requires making sure that the impact energy given to the projectile will at most deflect the target and not disrupt it. In recent years, we have combined two numerical codes, one computing the fragmentation of a solid body as a result of an impact, the other one computing the gravitational interaction (when non-negligible) of the fragments generated and their eventual reaccumulations. Two models of fragmentation have been developed, one for non-porous bodies, and the other for porous objects that involves the additional process of pore crushing. This allowed us to investigate the impact response of bodies over a wide range of sizes and material properties. Previous works have been concentrated in validating the models, first at laboratory scale, then at larger scales by reproducing successfully observed asteroid families. The impact energy threshold for disruption was also characterized for basalt and ice non-porous bodies.

Results:

We extended the previous work, which determined the impact energy threshold for disruption of non-porous basalt and ice targets to the case of porous bodies. Moreover, we characterized the outcome of these disruptions in terms of fragment size and ejection velocity distributions. The most significant results are:

- In the strength regime, which corresponds to target sizes below a few hundreds of meters, porous targets are more difficult to disrupt that non-porous ones.
- In the gravity regime, while the outcome is controlled purely by gravity and porosity in the case of porous targets, it remains dependent on strength for non-porous ones; therefore one cannot say that non-porous targets are systematically easier or more difficult to disrupt than porous ones, as the outcome highly depends on the assumed strength values.
- The cumulative fragment size distributions can be reasonably fitted by a power-law whose exponent ranges between -2.2 and -2.7 for all target diameters, internal structures and for impact velocities at least in the range 3-5 km/s.
- Although ejection velocities in the gravity regime tend to be higher from porous targets, they remain of the same order as the ones from non-porous ones.

Publications:

- Jutzi, M., Michel, P., Benz, W., and Richardson, D.C., “*Fragment properties at the catastrophic disruption threshold: The effect of the parent body's internal structure*”, Icarus, accepted, 2009.
- Jutzi, M., Michel, P., Benz, W., and Richardson, D.C., “*Fragment Properties at the Catastrophic Disruption Threshold: The Effect of the Parent Body's Internal Structure*”, Bulletin of the American Astronomical Society 41, DPS meeting, Puerto Rico, 2009.
- Michel, P., Jutzi, M. & Benz, W., “*Catastrophic Impact Energy Threshold for Disruption of Small Porous and Non-Porous Asteroids: a Crucial Information for Deflection Strategies*", ESA Proceedings of the 1st IAA Planetary Defense Conference, Grenada (Spain), 2009.
- Michel, P., Jutzi, M., Richardson, D.C., Benz, W., “*Collisional Family Formation and Scaling Laws : Effects of Porosity and Explicit Formation of Spinning Aggregates*”, Bulletin of the American Astronomical Society 40, DPS meeting, Ithaca, 2008.

Highlights:

For the first time, the impact energy threshold for disruption has been characterized using a model of fragmentation adapted to porous materials. A great number of asteroids are expected to be porous, especially those with low albedo. Our ability to characterize the impact response of such bodies is of crucial importance to define adapted deflection strategies. Further work will concentrate on bodies containing macro-porosity (large voids, instead of small pores), the so-called rubble piles, which are believed to dominate bodies whose sizes are larger than a few hundreds of meters.