Revised scaling laws for asteroid disruptions

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Models for the evolution of small-body populations (e.g., the asteroid main belt) of the solar system compute the time-dependent size and velocity distributions of the objects as a result of both collisional and dynamical processes. A scaling parameter often used in such numerical models is the critical specific impact energy Q^*_D, which results in the escape of half of the target's mass in a collision. The parameter Q^*_D is called the catastrophic impact energy threshold. We present recent improvements of the Smooth Particle Hydrodynamics (SPH) technique (Benz and Asphaug 1995, Jutzi et al. 2008, Jutzi 2014) for the modeling of the disruption of small bodies. Using the improved models, we then systematically study the effects of various target properties (e.g., strength, porosity, and friction) on the outcome of disruptive collisions (Figure), and we compute the corresponding Q^*_D curves as a function of target size.

For a given specific impact energy and impact angle, the outcome of a collision in terms of Q^*_D does not only depend on the properties of the bodies involved, but also on the impact velocity and the size ratio of target/impactor. Leinhardt and Stewardt (2012) proposed scaling laws to predict the outcome of collisions with a wide range of impact velocities (m/s to km/s), target sizes and target/impactor mass ratios. These scaling laws are based on a "principal disruption curve" defined for collisions between equal-sized bodies: $Q^*_{RD,\gamma=1} = c^* 4/5 \pi \rho G R^2_{C1}$, where the parameter c^* is a measure of the dissipation of energy within the target, R_{C1} the radius of a body with the combined mass of target and projectile and a density $\rho = 1000$ kg/m^3, and γ is the mass ratio. The dissipation parameter c^* is proposed to be 5 ± 2 for bodies with strength and 1.9 ± 0.3 for hydrodynamic bodies (Leinhardt and Stewardt 2012). We will present values for c^* based on our SPH simulations using various target properties and impact conditions. We will also discuss the validity of the principal disruption curve (with a single parameter c^*) for a wide range of sizes and impact velocities. Our preliminary results indicate that for a given target, c^* can vary significantly (by a factor of ~ 10) as the impact velocity changes from subsonic to supersonic.

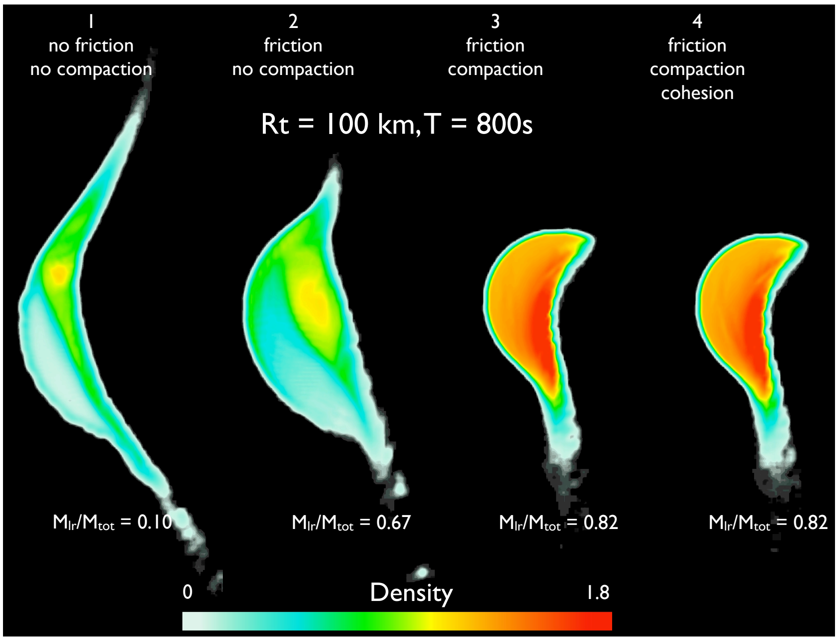

Figure: Cross section of SPH simulations of collisions using $R_t = 100$ km, $R_p = 27$ km, and $v_{imp} = 3$ km/s.

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References: Benz, W. and Asphaug, E. 1995. Comp. Ph. Com. 87, 253–265; Jutzi, M., Benz, W., Michel, P. 2008. Icarus 198, 242–255; Jutzi, M. 2014. Proceedings of the CD8 workshop, Hawaii; Leinhardt, Z.M., Stewart, S.T. 2012. The Astrophysical Journal, 751:32.