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ASSESSMENT OF ASTEROID SHAPES PRODUCED AFTER CATASTROPHIC DISRUPTION

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ABSTRACT

In order to understand the origin of spinning top-shapes of asteroids such as KW4, EV5, Bennu and Didymos, we consider an alternate scenario to the YORP spin-up model that is frequently considered the cause of such shapes. We investigate systematically the shapes of all re-accumulated fragments produced by catastrophic disruption of parent bodies that are 0.3 km and greater in diameter. These new fragments eventually become new asteroids of the size that current sample-return missions plan to explore, some of which are top-shaped.

Our numerical investigations of catastrophic disruption were undertaken using an SPH hydrocode that includes a model of fragmentation for porous materials. A range of impact conditions were considered, that varied the parent bodies' strength, size and porosity, and the velocity and size of the projectile. All impact conditions range near the catastrophic threshold, usually designated by Q^*, where half of the target's mass escapes.

The gravitationally dominated phase of reaccumulation of our asteroids is computed using the *N*-body code pkdgrav. At sufficiently slow impact speeds in the *N*-body model, particles are permitted to stick, forming irregular, competent pieces that can gather into non-idealized rubble piles as a result of re-accumulation. Shape and spin information of re-accumulated bodies are thus preserved. Due to numerical expense, this first study uses what we call a hard-sphere model, rather than a soft-sphere spring and dashpot model. This latter model is more commonly used in granular flow simulations for which detailed treatment of the multicontact physics is needed, which is not the case here, and comes at the expense of much smaller timesteps. With the hard-sphere model, there are three supported collision outcomes for bonded aggregates: sticking on contact (to grow the aggregate); bouncing (computed for these generally non-central impacts); and fragmentation (wherein the particles involved become detached from their respective aggregates and proceed to bounce as rigid spheres, possibly releasing more particles). We adjusted the strength of the forming aggregates to the measured strength of materials in the lab, scaled to the aggregate size, by using strength-size scaling rules. We measure the aspect ratio of all resulting aggregates greater than 10 pkdgrav particles in size, after having computed their center of mass and principal axis orientation.

Assessments reveal that most aggregates formed after catastrophic reaccumulation possess axis ratios $b/a \sim 0.82$ and $c/a \sim 0.7$. Top (Didymos, KW4, Bennu) and elongated (Eros, Itokawa) asteroid shapes are not very common. Parent-body porosity, aggregate strength (cohesion), and impact obliquity all appear to enhance the formation of top-shaped asteroids.

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