MODELING STRENGTH IN GRAVITATIONAL AGGREGATES. D. C. Richardson[1], P. Michel[2], and K. J. Walsh[2], [1]University of Maryland, Department of Astronomy, College Park, MD 20742, USA, dcr@astro.umd.edu, [2]Côte d'Azur Observatory, University of Nice-Sophia Antipolis, UMR 6202 Cassiopée/CNRS, B.P. 4229, 06304 Nice Cedex 4, France.

Introduction: There is growing indirect evidence that asteroids larger than a few hundred meters in diameter are aggregates of smaller cohesive pieces. We call such bodies "gravitational aggregates," because gravity is the principal force holding the body together ([1]). A gravitational aggregate has little or no material cohesion between its components, so it can be disrupted by relatively weak tensile (outward-pointing) forces. Recent observations of the spin rates of asteroids ([2]) suggest that some larger than a few hundred meters in diameter may have a small amount of cohesion ([3]). We have begun to modify our numerical simulation code *pkdgrav* to account for possible weak cohesion between components, using a variety of strength models ([4]). We report on preliminary results here.

Method: In *pkdgrav*, material components are represented as rigid spheres that interact through gravity and collisions. With the new strength models developed so far, a gravitational aggregate is treated either as a rigid body with a maximum allowed stress, or as a pseudo-elastic body with a stretch limit. The former case uses the Euler equations of rigid body rotation with external gravity torques and a treatment of off-axis collisions. The latter case uses a restoring force between neighboring particles. Both approaches lead to different responses to stress induced by rotation.

Results: We have begun to explore these strength models in various contexts. Here we report on simple spin tests, in which the aggregates are given initial spins greatly in excess of the mass-loss spin limit for cohesionless bodies. The rigid model with a maximum allowed stress exhibits an "all-or-nothing" response in this case, since no reshaping can occur before the bonds between components break. In the elastic model, reshaping can occur before mass is lost, leading in some cases to the formation of binary systems. By contrast, in cases without cohesion, the body loses mass isotropically, leaving a single remnant at the center (Fig. 1).

Summary: We have begun the task of adding cohesive strength to our gravitational aggregate models. The stress response is sensitive to the model chosen, and can lead to qualitatively different outcomes compared to the cohesionless case, including fission-like formation of binaries. Much work remains to validate and improve these models, and to explore the vastly larger parameter space that has now been opened.

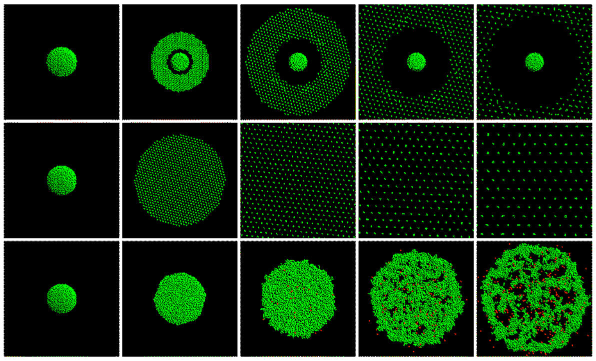

Figure 1: Snapshots of the evolution of three strength cases: cohesionless (top row); rigid failure (middle); elastic failure (bottom). Evolution proceeds from left to right in each row; the snapshots are equally spaced in time. The initial condition was comparable in each case: an oblate aggregate with spin greatly in excess of the cohesionless mass-loss limit (the spin axis is perpendicular to the page). In the cohesionless model, an outer layer is shed, leaving a more slowly spinning central remnant. In the rigid failure model, all bonds break simultaneously and the body disperses. In the elastic model, the body holds together for a while, fragmenting gradually into strands and clumps (in the snapshots, the red particles have been permanently liberated while the green particles still experience an elastic force from their neighbors). This particular case goes on to form a large, roughly spherical remnant with a sizable companion in a near-circular orbit.

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