SIMULATING THE EFFECTS OF PARTICLE SHAPE ON THE TIDAL DISRUPTION AND REACCUMULATION OF SMALL SOLAR SYSTEM OBJECTS.

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Introduction: Asteroids and comets can be resurfaced, stretched, reshaped, split into binary or higher multiple systems, or even destroyed by close gravitational encounters with massive objects. While there are many viable approaches to studying tidal disruption, our simulations use the discrete element method (DEM), which models small bodies as rubble-pile collections of distinct pieces.

In the context of granular environments such as those found in rubble-pile bodies, constituent particle shape plays an important role in determining resistance to shear forces [1,2]. Non-spherical constituents tend to interlock and impede the free deformation of a granular medium or rubble-pile body. As a consequence, we expect that rubble piles made up of non-spherical particles will have a greater resistance to shear strength than the equivalent bodies composed of spheres. It may be that the additional shear strength provided by non-spherical components can help to explain how the highly-elongated shapes of objects like `Oumuamua and 2011 AG5 can be maintained so far from their fluid equilibria. We present a scheme for conducting high-resolution, DEM simulations including interparticle friction and non-spherical constituents.

Methods and Code: We use the *N*-body code PKDGRAV, which is highly optimized for calculating gravitational interactions between very large numbers of particles efficiently [3]. PKDGRAV uses a hierarchical tree algorithm that reduces the cost of finding particle neighbors and calculating interparticle gravitational forces. The code is also parallelized.

The PKDGRAV code uses a soft-sphere discrete element method (SSDEM) scheme for handling particle collisions (for other examples of SSDEM see [4,5]). Particles are spherical, and colliding particles are allowed to interpenetrate slightly as a proxy for surface deformation. Contacts are resolved using a spring-dashpot model in which overlaps are detected and result in normal and tangential restoring forces. These forces are modeled as damped springs with user-adjustable spring and damping constants. We also use this approach to calculate forces and torques from static, rolling, and twisting friction. For a more detailed description of the SSDEM implementation in PKDGRAV, see [6,7].

Non-spherical Particles: Instead of constructing polyhedral particles with flat faces and edges, we make use of the existing capabilities of PKDGRAV and model non-spherical particles using a “glued-sphere” approach. We arrange arbitrary numbers of spherical particles in any desired shape and then fix their relative positions so that they behave as a unit, creating rigid, non-spherical aggregates. These arrangements can then be treated as “pseudo-particles,” capturing the physical realism of non-spherical components, but without much of the computational complexity inherent in using polyhedral shapes. As far as we are aware, PKDGRAV is the only code that combines an *N*-body gravity solver and a soft-sphere contact model with an efficient glued-sphere approach to constructing non-spherical particles.

We will detail our implementation of non-spherical DEM particles in the existing PKDGRAV code. In addition, we will present preliminary findings on the effects of particle shape on tidal disruption and reaccumulation.

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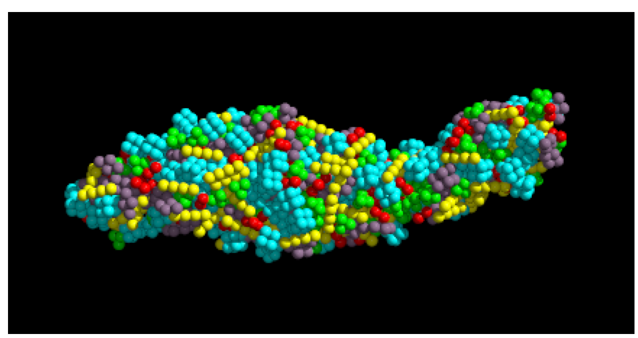

Figure 1. A reaccumulated rubble-pile fragment in the aftermath of a tidal encounter. The fragment is made of non-spherical components, which are color-coded by shape.