Rubble, Rubble, Toil and Trouble

Abstract

In a 2004 paper, Richardson et al.[1] examine the stability of asteroids constructed as self-gravitating aggregates of otherwise unbound 'rubble'. The model used by this work is closely related to a model of asteroids as a collection of smaller, more cohesive bodies, held together exclusively by gravity, with no other binding forces. The friction inherent in such a structure – caused by packing effects, rather than microscopic forces – makes the simple results based on a fluid model inapplicable. A nonrotating rubble pile, for instance, can retain a non-spherical shape in much the same way that a pile of sand in a box will not level out. Using many-body simulations, the authors inspect the stability of such bodies both with and without rotation, determining what shapes may be supported by a rubble pile. Such examinations serve as an implicit test of the cohesionless rubble pile model. Should asteroids be observed in configurations found to be unstable as a rubble pile, they must be supported by an additional cohesion force.

While the 2004 paper makes use of extensive numerical simulations to determine the stable rubble configurations, substantial progress can be made analytically, by describing the rubble as a fluid with a certain non-zero resistance to shear force, characterized by a "friction angle". Larger friction angles correspond to higher resistance to shear forces and, therefore, a wider range of shapes for stable asteroids.

Richardson et al. examine the stability only of "perfect" rubble piles, consisting exclusively of equal-sized, spherical particles. Working from the friction-angle viewpoint, we examine heuristically the effects of including particles of unequal sizes, and well as certain non-spherical shapes.

[1] Richardson et al. *Numerical experiments with rubble piles: equilibrium shapes and spins.* Icarus 173, 349-361 (2005).