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INTERNAL GRAVITY, SELF-ENERGY, AND DISRUPTION OF ASTEROIDS

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ABSTRACT

The National Aeronautics and Space Administration initiated a new project focused on Planetary Defense on October 1, 2014 (see presentation by Arnold and Burkhard). The new project is funded by NASA's Near Earth Object Program (Lindley Johnson, Program Executive). This presentation describes an effort within one of the four components of the Characterization Task. Specifically, we are modeling the energy required to disrupt potentially hazardous asteroids and comets with realistic shapes. This physics-based model of the energy required to disrupt asteroids and comets will be an input into the other tasks in the ARC project, as well as tasks outside the scope of the ARC project such as different mitigation strategies.

Any solid body such as a comet or asteroid can be approximated to arbitrary accuracy by a polyhedron of sufficient complexity. An analytic formula is known for the gravitational field of any homogeneous polyhedron, but it is widely believed that this formula applies only on the surface or outside of the object. We show instead that this formula applies equally well inside the body.

This enables us to find the internal gravity and potential of several test objects. Knowledge of their interior gravity permits analysis of their internal stresses and strains. Furthermore, knowing a body's internal potential enables us also to find its self-gravitational binding energy, the energy required to disperse all of the body's mass to infinity.

This self-energy is related to Q^*_D, the specific energy required to disrupt a comet or asteroid, especially for objects larger than 100 meters in mean radius. For such gravitationally-dominated objects, Q^*_D scales as the body's mean density times the square of its mean radius, also multiplied by a dimensionless ``form factor'' related to the shape of the object.

For example, the self-energy E of a homogeneous sphere with mass M and radius R is just (3/5) GM**2/R, where G is Newton's constant of universal gravitation. Thus its specific disruption energy Q^*_D is E/M = (3/5) GM/R = (4 π/5) G ρ R**2 ~ 2.513 G ρ R**2, where ρ is its constant density. For comparison, a homogeneous cube of mass M, side S, and density ρ would have E ~ 0.9412 GM**2/S and Q^*_D ~ 0.9412 G ρ S**2. More natural shapes scale similarly.

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