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Integrated Blowoff and Breakup Calculations for Asteroid Deflection by Nuclear Ablation

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ABSTRACT

Modeling asteroid deflection using x-ray output from a nuclear device requires resolution near 10-100 microns at the asteroid's surface to accurately capture the energy deposition profile[(1)]. We use two different methods to simulate the early-time portion of the problem, when x-ray energy is deposited and material is vaporized, contributing to blow-off momentum: (1) a realistic x-ray spectrum is sourced into a spherical asteroid using a radiation-hydrodynamics code or (2) a blackbody approximation (T = 2 keV) of an x-ray source is deposited in a thin skin of the Bennu shape model, using a specialized node generator in Spheral, an adaptive SPH code[(2,3,4)]. The deposition profile is well-described by an analytical approximation[(5)]. Re-radiation must be estimated *a priori.*

Once the prompt blow-off momentum from vaporization has finished evolving (typically, after a few hundred microseconds), we focus on the shock traveling through the asteroid, which crushes material and contributes to additional solid ejecta. This phase of the problem requires somewhat coarser resolution, so that the

entirety of the 500-m body can be modeled and the simulation can be carried out to a few shock-crossing times (seconds). Spheral is an appropriate code for handling this late-time behavior, due to its benchmarked strength and damage models for geological materials. We are currently developing numerical tools to efficiently remap results from the energy deposition stage to the shock propagation stage. Modeling the entire problem is necessary to (1) quantify any additional contributions to the delivered momentum impulse from ejecta and (2) determine to what extent the asteroid is damaged and any potential risks of unintentional disruption.

While these initial cases are focused on deflecting Bennu-sized asteroids, later runs will treat a variety of asteroid sizes, shapes, compositions, porosities, and strengths. This remapping methodology can also be used for cases where complete disruption is intentional. For smaller asteroids and shorter warning times, the necessary deflection velocity can approach or exceed the escape speed. In such cases, rather than risking production of a poorly-dispersed fragment field, it may be safer to source in a large amount of energy from a proximal explosion and thoroughly rip apart the asteroid. Fully integrated blowoff and breakup calculations are essential for ensuring complete dispersion of asteroid fragments in such scenarios.

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