Differences in Nuclear Deflection Scenarios with Oddly Shaped Asteroids

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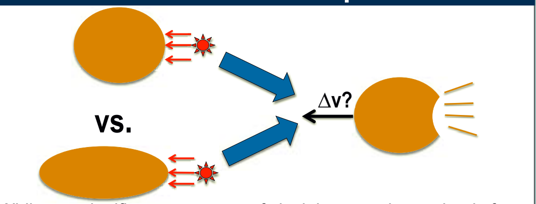
Planetary Defense Conference, Frascati, Italy
April 13-17, 2015

Abstract

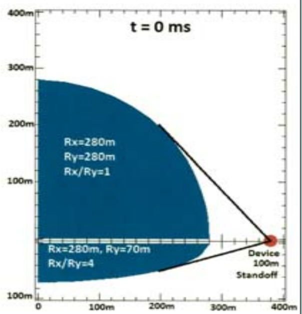
Traditionally, the starting point for any calculation of the nuclear deflection of an asteroid is a spherical approximation. This captures a most of the effects expected, and provides useful scoping data within parameter sets surrounding radiation type and spectrum, as well as material type and composition. However, one also needs to understand how an asteroid with a non-spherical shape will affect the deflection attempt, as all potentially hazardous objects contain some degree of asphericity. This poster discusses several simulations of nuclear deflection on non-spherical objects. Spherical asteroids with a boulder are examined, allowing for the exploration of 'shadowing' effects, and elliptical asteroids with varying degrees of ellipticity are studied.

Problem Setup

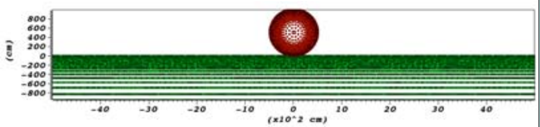


While a significant amount of insight can be gained from examining the deflection of spherical asteroids, most objects are not perfect spheres and do not have smooth surfaces. We examine the effects that generalized-shape features have on deflection during a nuclear deflection attempt, and compare these to the spherical case.

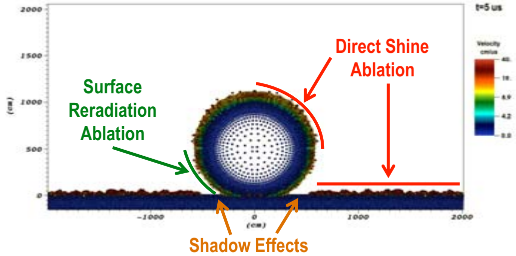
In the first case, we examine elliptical asteroids using the setup at right. A 1-MT device with a 1-keV blackbody x-ray spectrum is placed a varying distance (100 m nominally) from the surface of an asteroid with a nominal 280-m radius. The object's major and minor axes can then be varied to achieve different ellipticities and masses.

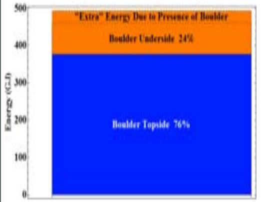


In another case, we use the same device output described above, incident on an asteroid with a 5 m radius boulder on its surface as shown below. This case is run using a smooth-particle hydrodynamic code such that the interaction of the blowoff from the main asteroid and the boulder is well characterized.



Asteroids with Surface Features

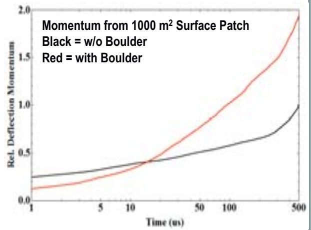


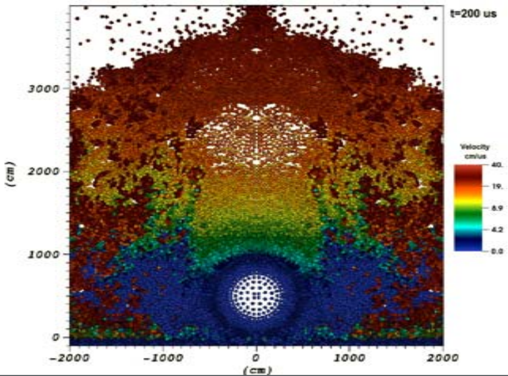


We examined situations where the asteroid surface has a large boulder. X rays from the device deposit directly onto exposed surfaces (direct shine). Due to the boulder, parts of the asteroid are shadowed (shadow effects).

The "direct shine" regions of the asteroid get extremely hot, and re-radiate some energy as x rays in all directions. These deposit on the underside of the boulder (surface reradiation). Of the energy deposited in the boulder, almost ¾ is on the topside, but ¼ is on the underside, and ~10s of GJ of this is "extra" energy that would have been lost to space without the boulder.

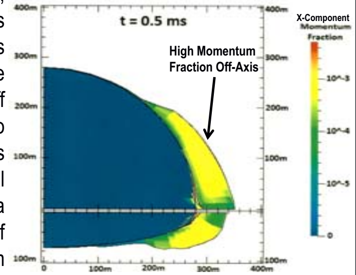
At early times, the boulder shadows parts of the asteroid and reduces the deflection. At late times, debris from the boulder is rocketed into the main asteroid (shown below) and this leads to an enhancement of the deflection momentum applied to the main asteroid (at right).





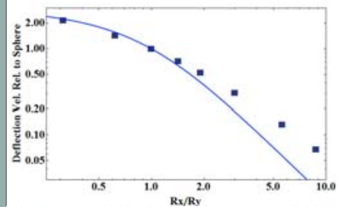
Elliptical Asteroids

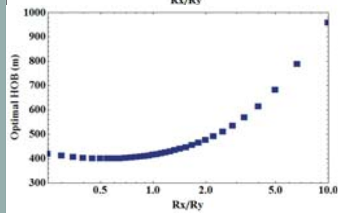
For elliptical asteroids, the shape changes both how energy is deposited and how the resulting blowoff imparts momentum to the body. At ½ ms after, the spherical asteroid (top) has a significant fraction of its momentum from off-axis angles.



The elliptical asteroid (bottom) also gets most of its push from off-axis components, but has less surface area "seen" by the device due to its shape. This leads to a smaller push overall.

Plotted below are data for asteroids with various ellipticities but the same mass, showing the deflection velocity achieved relative to a spherical case. Prolate objects receive a smaller push, up to an order of magnitude different at the extreme, while oblate objects are pushed harder. The solid line relates this to the relative solid angle intercepted from the device.





The shape also affects the optimal distance for the device to be from the object (lower left plot). All prolate objects have larger optimal distances than the spherical case, as this allows the device to shine on more of the object's surface area. Oblate objects generally have smaller optima.

Conclusions

- Shape and surface features can make a significant difference to nuclear deflection scenarios.
- The presence of surface boulders can capture energy that would otherwise be lost to space, and boulder blowoff itself will get rocketed into the asteroid, enhancing deflection.
- Elliptical asteroids will either enhance deflection (oblate shapes) or reduce deflection (prolate shapes), as well as affect the optimal device distance from the object.

LLNL-POST- 669130

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and partially funded by the Laboratory Directed Research and Development Program at LLNL under tracking code 12-ERD-005.