PDC2013
Flagstaff, AZ, USA

IAA-PDC13-04-25

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LOWER LIMITS ON NEO DEFLECTION VELOCITIES FROM VAPOR AND BLOW-OFF MOMENTUM

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Keywords: *Asteroid, nuclear, deflection, simulation*

ABSTRACT

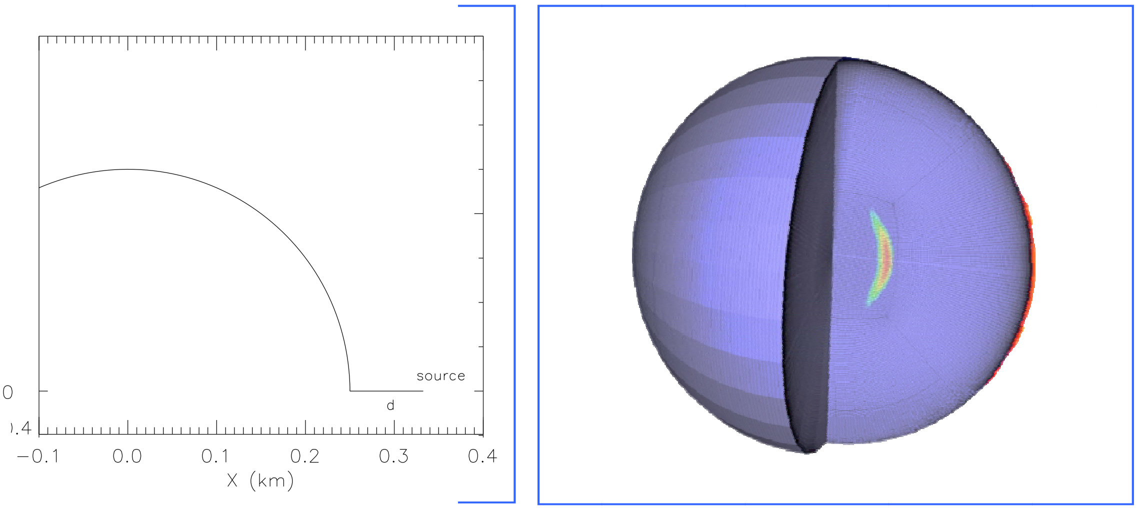
Near-Earth objects (NEOs) on a collision course with Earth that are large or have short warning times warrant the use of nuclear explosives to mitigate the threat. A major source of uncertainty in predicting the response of a specific NEO to a nuclear detonation arises from the unknown, possibly complicated, internal structure of the body. For this reason, we consider non-disruptive events and deflection velocities for NEOs using the momentum of the ejected surface material. We assume the surface properties of an NEO are known and model the response to a standoff nuclear detonation using Arbitrary Lagrangian-Eulerian radiation/hydrodynamics (ALE rad/hydro) simulations. To establish an absolute lower limit on deflection velocities, we measure the momentum of the vaporized surface material. Lower bounds on the deflection velocities are determined as functions of energy and NEO properties. Specifically, we explore the effects of various monochromatic sources (e.g. neutrons, x-rays) and deposited energies as functions of NEO size, composition (e.g. silicon dioxide SiO_2), porosity and strength. Next, as a first order correction to the vapor momentum transfer estimate, we explore deflection velocities resulting from all initially ejected material (vapor and non-vapor) moving at velocities greater than escape velocity from the body. However, the uncertainties arising from the unknown sub-surface structure of NEOs (e.g. complex porosity, composition, strength) require further exploration and quantification, since variance in these parameters directly affects the response of the blow-off.

Two key outputs of the ALE rad/hydro simulations include the mass and momentum of the vaporized material. For verification purposes, these quantities are compared to analytic calculations of energy densities required to take material from vacuum temperature to vapor with a specified kinetic energy distribution. Furthermore, we

explore the deflection velocities resulting from the momentum transfer as functions of source and NEO parameters. We compare these measurements in both the vapor and blow-off cases to the following spherically symmetric analytic approximation for required energy density, ε_0, as a function of desired deflection velocity, source type, standoff distance, and NEO density and size,

$$\varepsilon_0(R,\lambda_{eff},\theta_t,\Delta v_z)_{(erg/cc)} = \frac{2.56\times10^{10}}{\beta}\left(\frac{R_{(km)}}{\lambda_{eff\,(cm)}}\right)^2 \frac{1-\sin\theta_t}{\theta_t}\,\frac{1-\left(2\theta_t/\pi\right)^2}{\sin\theta_t-2\theta_t/\pi}\,\rho_{(g/cc)}\Delta v^2_{z(cm/s)}\left(\frac{g_{\max}}{g(\theta_t)}\right)^2,$$

where R is the radius of the NEO, λ_{eff} is the mean free path of the source, θ_t is the maximum of angle of incidence as measured from the NEO center, Δv_z is the desired
posited energy, ρ is the density of the
ctor. The results from these analyses
nd standoff distance for generic NEO



rad/hydro Calculation Example –
response of a 500 m diameter SiO_2
O (no porosity, no strength) to a
3R standoff 27 kt neutron-source at
t = 0.05 s. The RGB color scale
ws the pressure wave in the asteroid.
red cap shows the change in density
material is ejected from the surface.

This work was funded by the Laboratory Directed Research and Development Program at LLNL under project tracking code 12-EDR-005, and performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-607832.