Johns Hopkins Applied Physics Laboratory

Late-time Nuclear Disruption in the PDC 2021 Scenario

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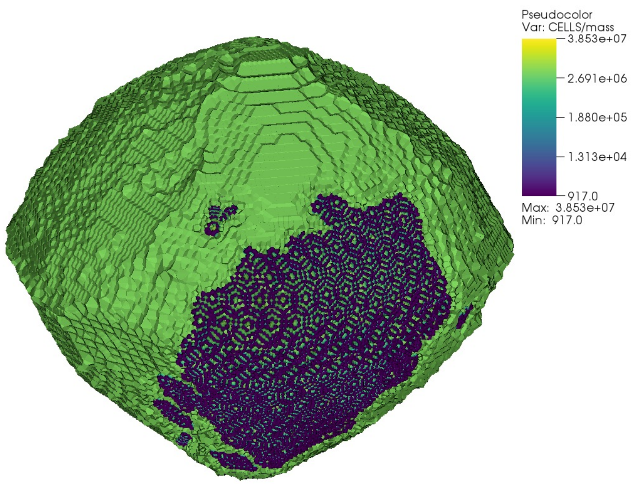
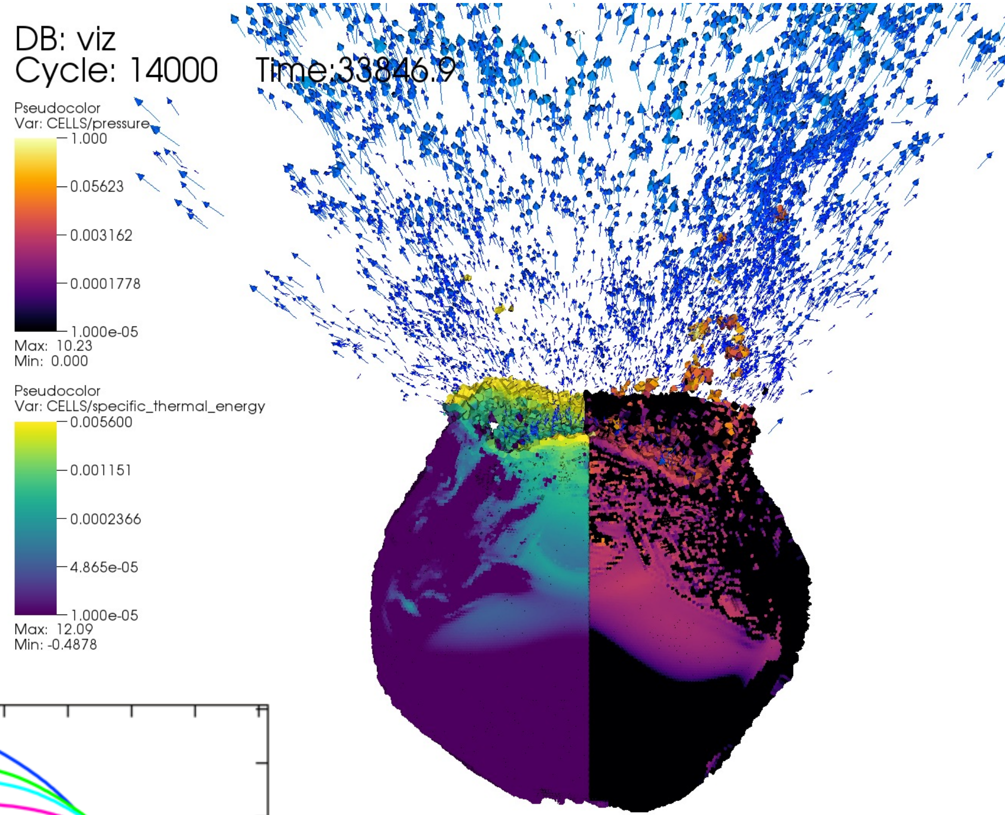
Overview

- Nuclear Disruption of a Fiducial Small Body
- N-Body Methodology
- Results for the PDC 2021 Scenario

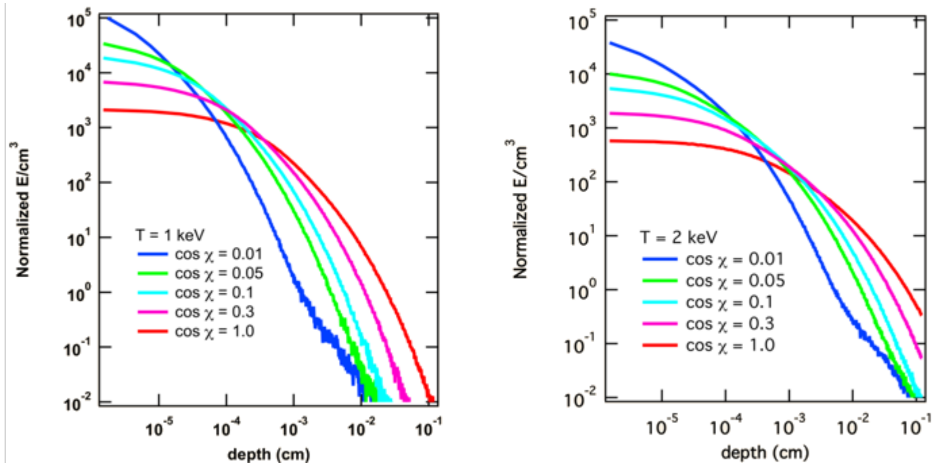
Nuclear Disruption of a Fiducial Small Body

- Simulation conducted with Spheral hydrocode
- 20% scaled model of 101255 Bennu (corresponds to 100 meter diameter)
- Modeled as uniform granite with 25% microporosity; Collins strength model with Tillotson EOS
- Uniform bulk linear resolution (~1.6 meter linear resolution) with ratioed zoning deposition zone for source
- 1 MT device at 15 meter height-of-burst (65 meters from center) at equator
- Consistent with simulation scheme described in Dearborn et al. 2020



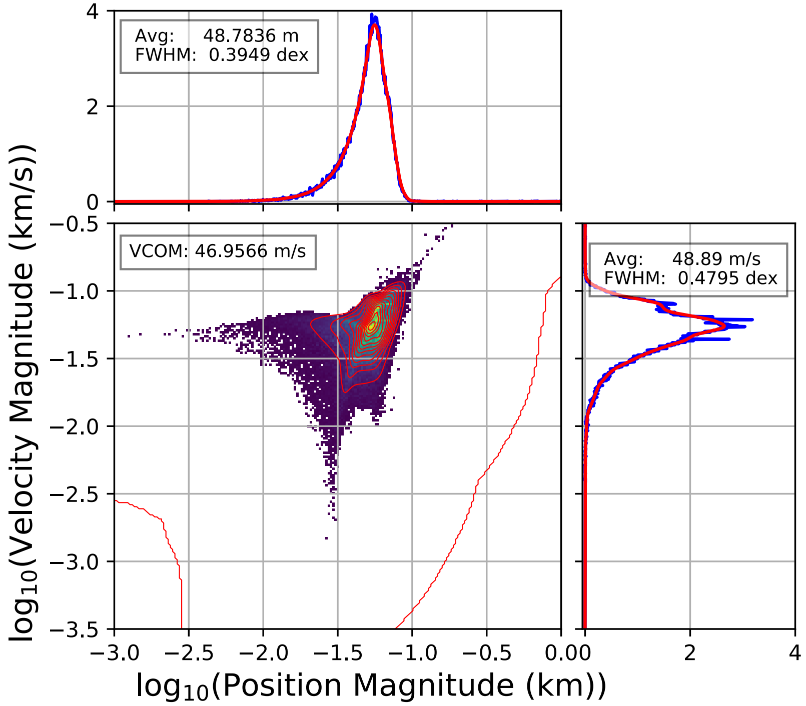


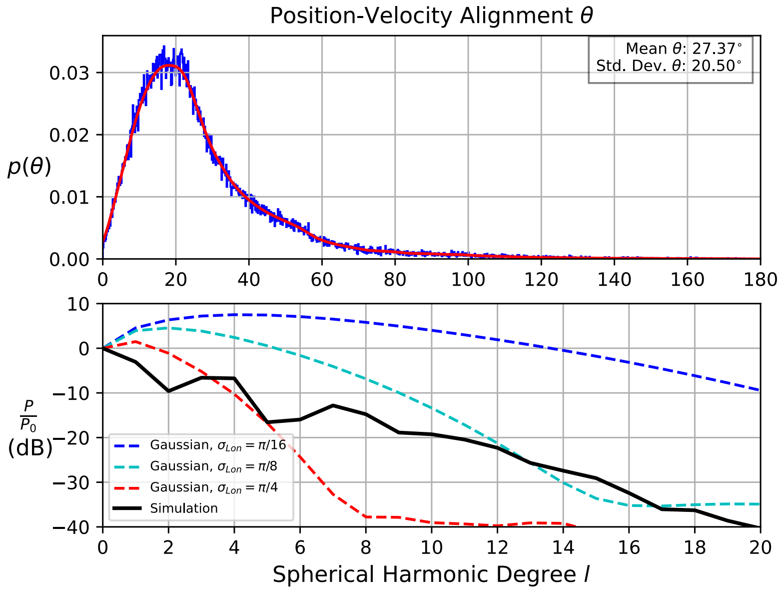
X-ray deposition profile

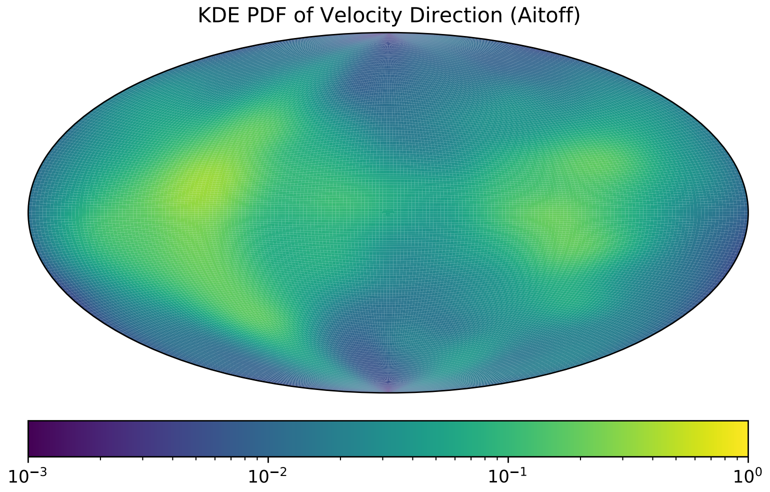


Nuclear Disruption of a Fiducial Small Body

- Simplified treatment of fragmentation: using bulk particles as estimate of disrupted debris field
- Delivered about 60 kT of yield to the target; about 4 kT of this was debris field kinetic energy (~0.35% KE yield efficiency)
- Kinetic Energy/Mass of ~17000 J/kg (much greater than Q^*_D)
- Center of mass velocity (a deflection) of 46.96 m/s
- COM frame expansion velocity (disruption) of 48.89 m/s
- Expansion field in COM frame is nearly uniform and radial
- Details to appear in King et al., submitted to Acta Astronautica



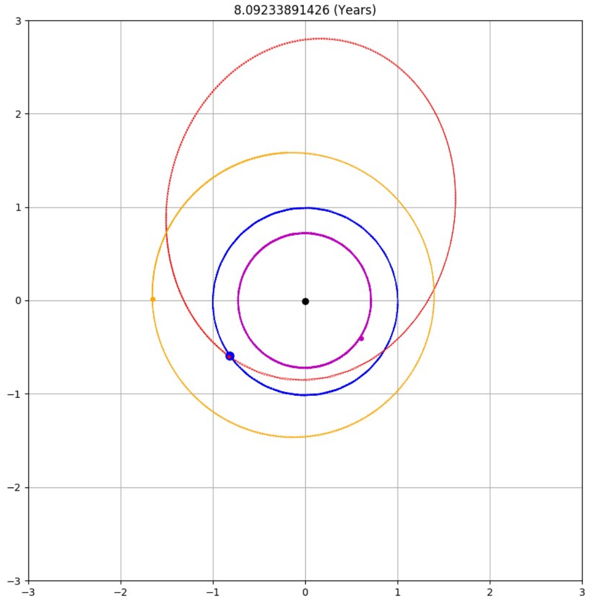


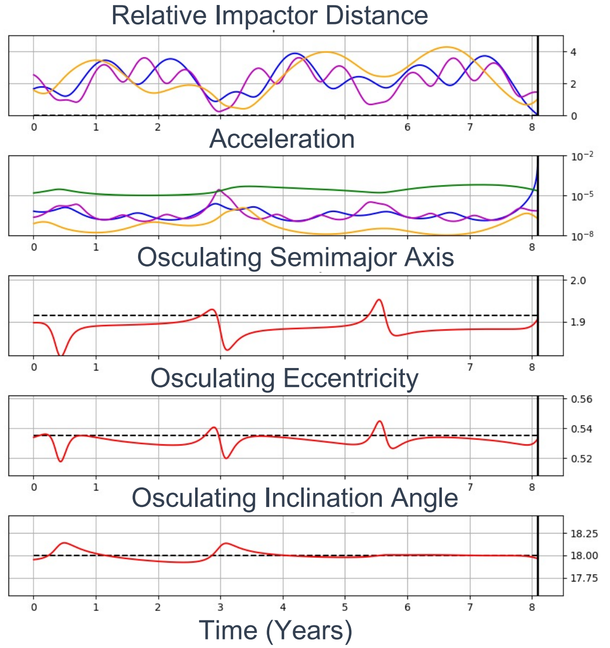


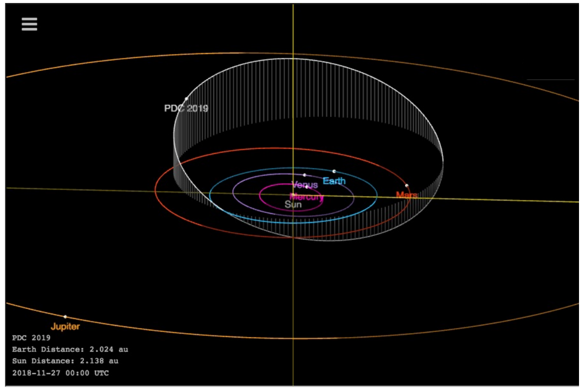
Calculated Deflection: 46.96 m/s
Calculated Disruption: 48.89 m/s

N-Body Methodology

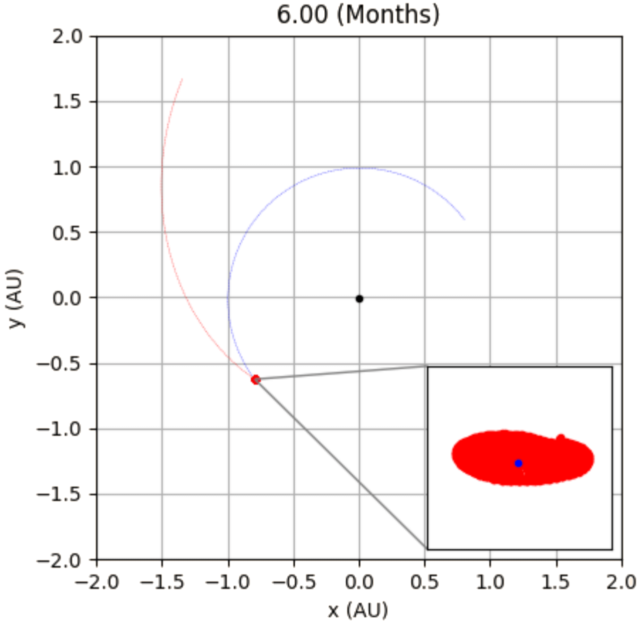
- Approach is to insert an approximate fragment field directly into a realistic N-body model of the solar system and evolve fragment orbits
- Fragment field based on disruption simulation and consists of deflection and disruption components
- Softening is employed to ensure stability and speed; carefully controlled for accuracy bounds
- Care is taken to ensure the initial trajectory results in an impact
- Effects such as gravitational focusing included to orbital evolution accuracy
- Fragment-fragment gravity is included







Example based on the 2019 PDC Scenario

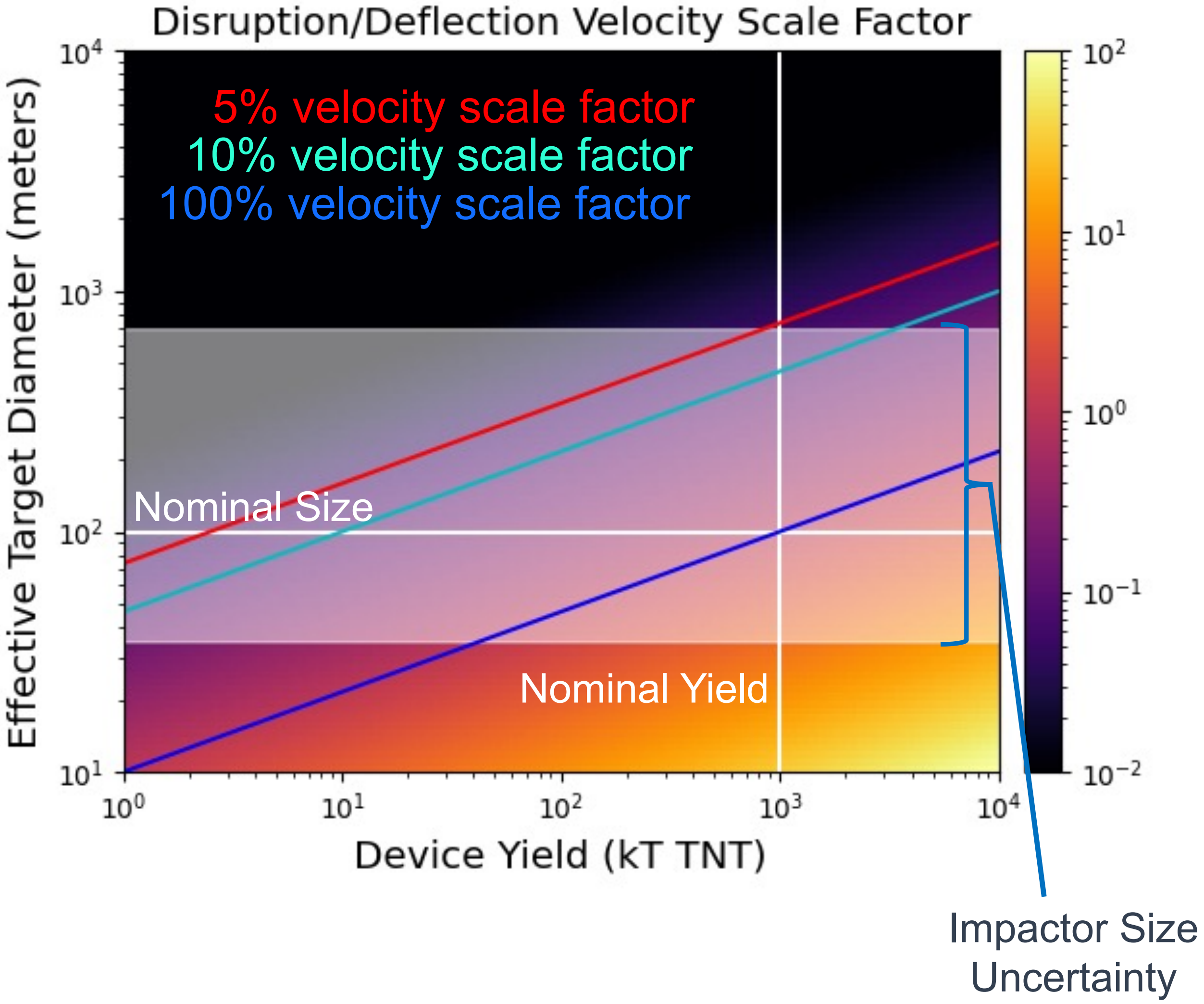


N-Body Methodology

- Can apply a naïve yield scaling to accommodate either different yields or uncertainty in target size

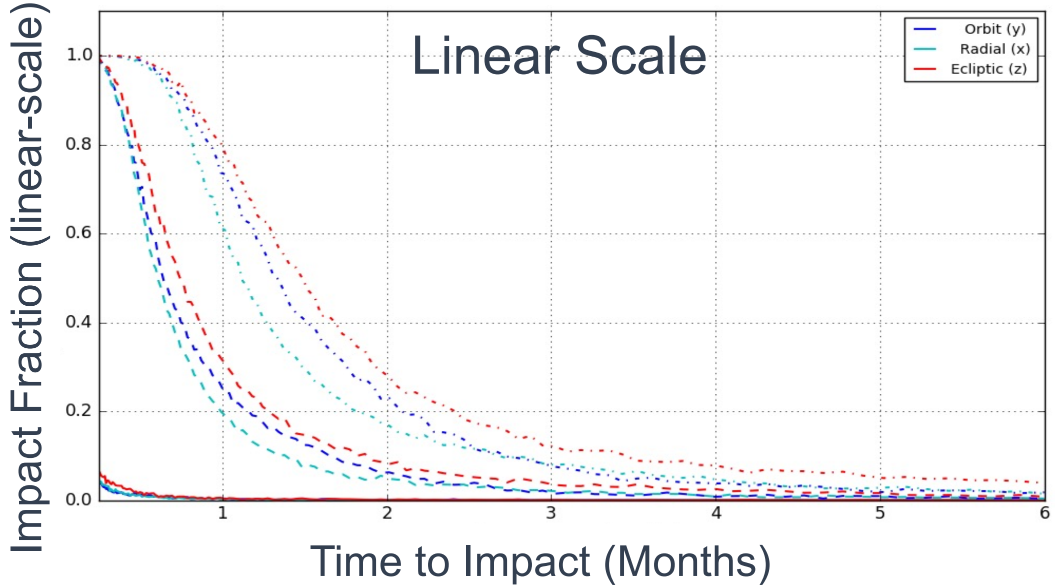
$$\frac{v_{scaled}}{v_{nominal}} = \left(\frac{Y}{1\ MT\ TNT}\right)^{1/2} \left(\frac{D}{100\ m}\right)^{-3/2}$$

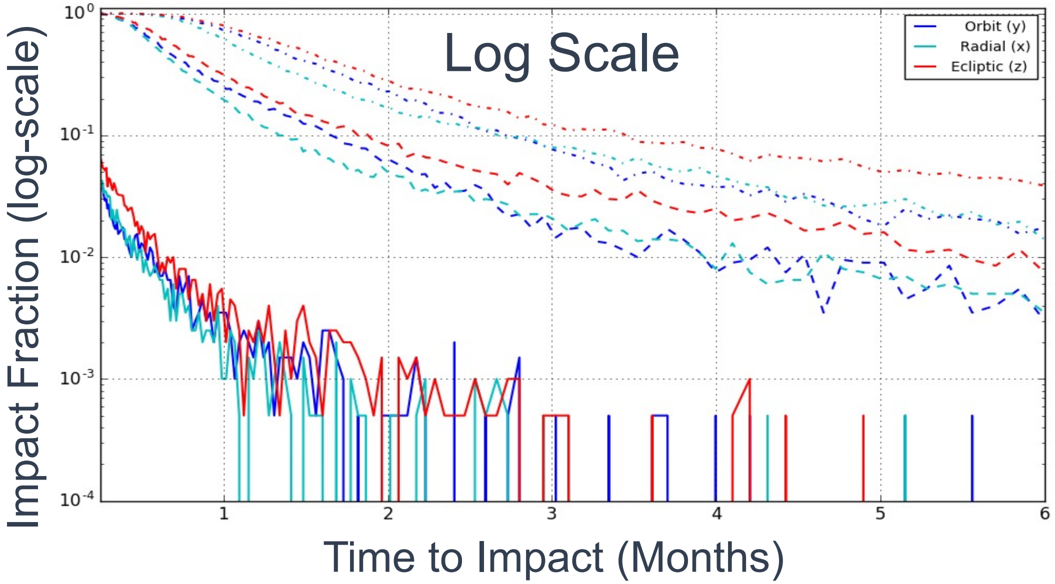
- Study should be repeated with dedicated high-fidelity disruption simulation using best available target data
- Primary metric is the *impact fraction* (quantity of impacting mass relative to total mass)
- This study has been conducted for the PDC 2019 scenario and several other reasonable scenarios and is to appear in King et al., submitted to Acta Astronautica



Results for the PDC 2021 Scenario

- The nominal disruption model can disrupt the impactor efficiently enough to result in only 1% impacting mass by two weeks
  - By 2 months the nominal disruption has likely achieved 0.1% impact fraction, but this estimate is limited by the fragment resolution of our simulations
- The less efficient disruptions require more time before impact to work effectively
  - The 10% scaled disruption achieves impact fraction of 10% by 2 months; 5% scaled disruption requires 3.5 months
- Deflection direction appears to have a modest effect; the strongest performing direction is the radial direction and the weakest is the ecliptic direction





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