Using hydrocode simulations to reproduce observations of the DART impact

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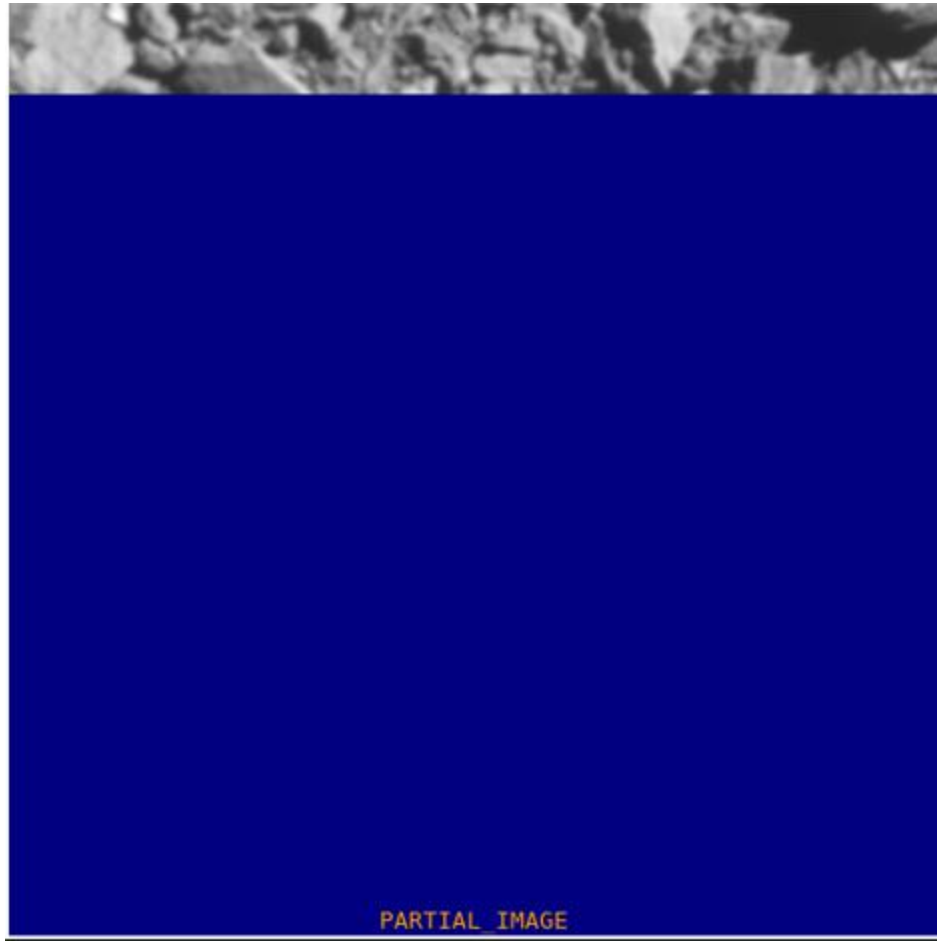
A little over six months ago, DART smashed into an asteroid

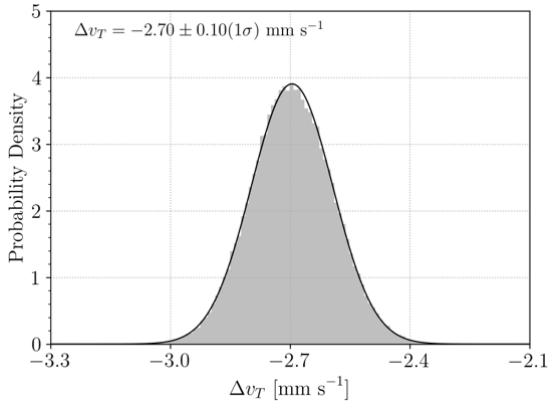
Incomplete transfer of the final image from the DRACO camera



Key observations to reproduce in impact simulations

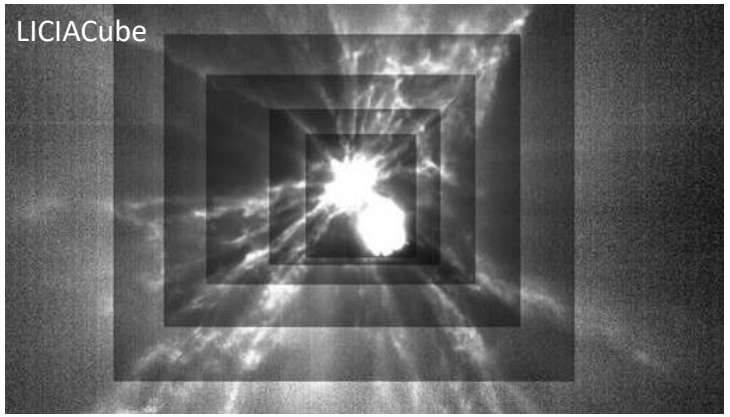
Boulder, boulders, and boulders

dV = 2.7 mm/s

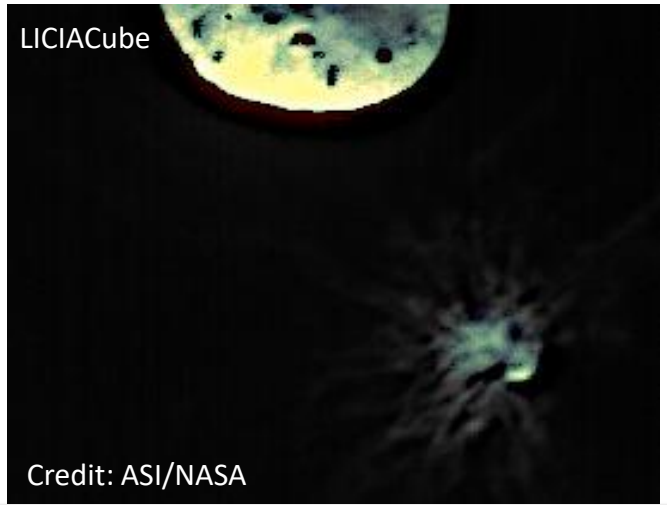


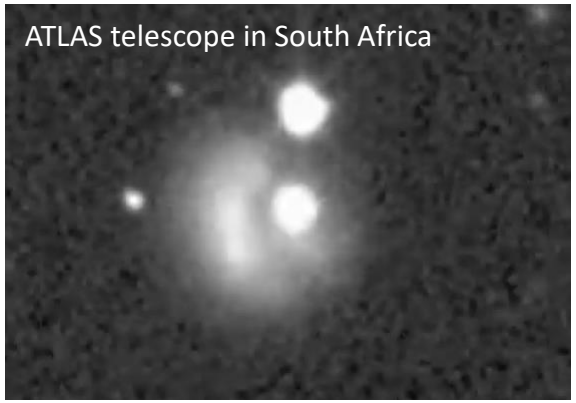
Cheng et al., 2023, *Nature*
Based on observations by Thomas et al., 2023, *Nature*

Ejecta details: morphology, plumes, mass estimates, production longevity…

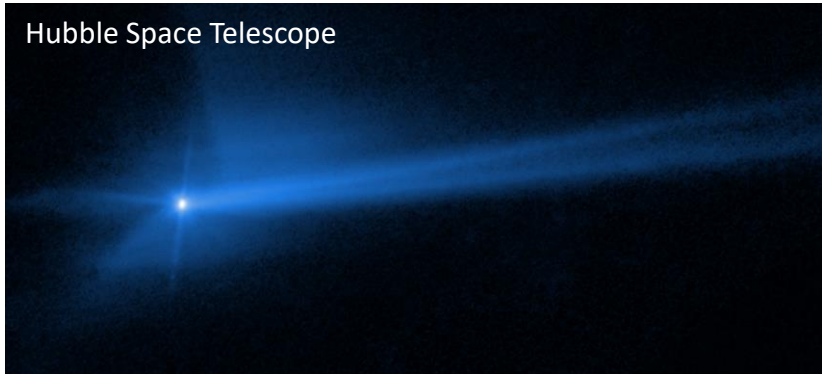


Credit: ASI/NASA/Johns Hopkins APL



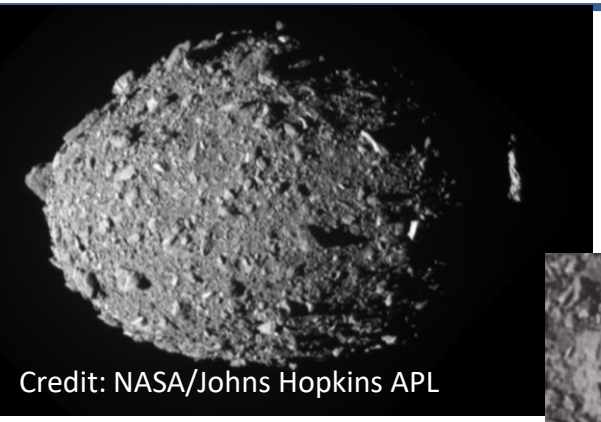


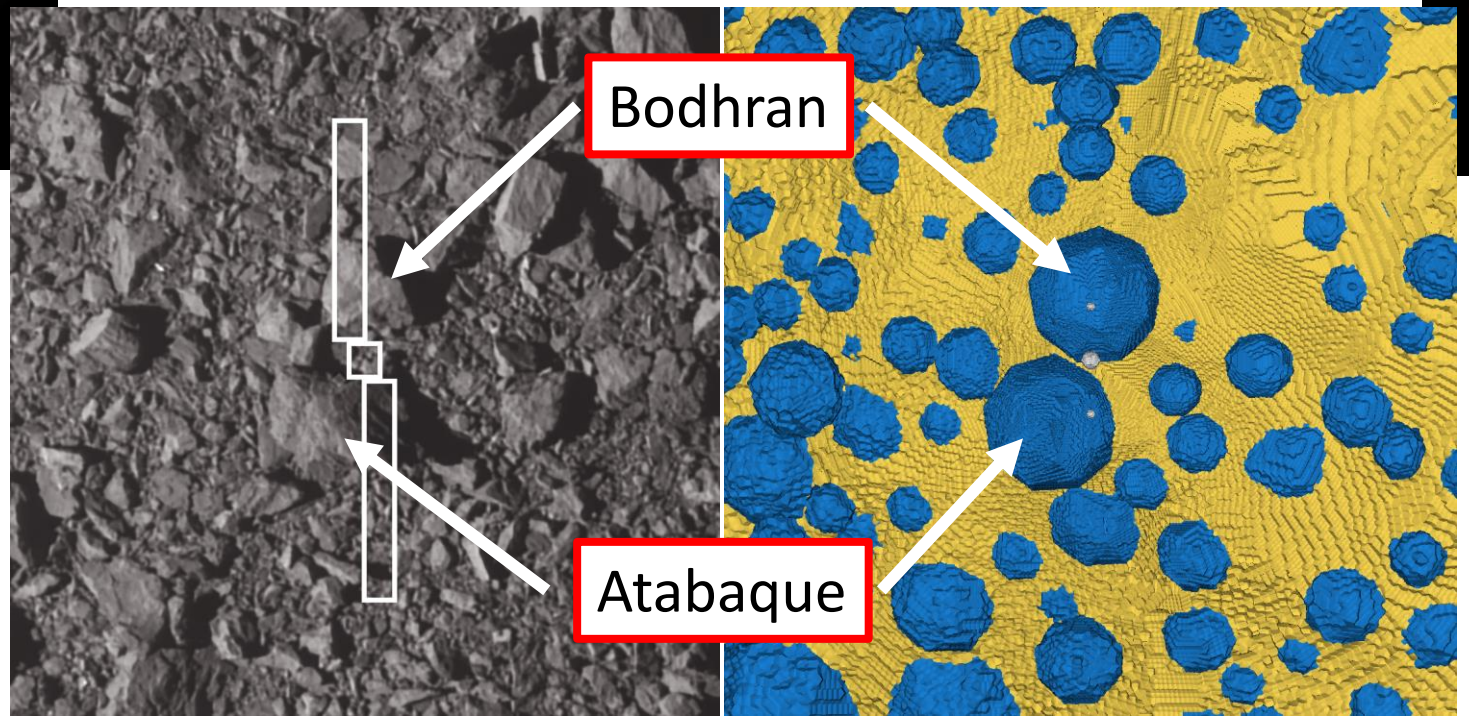
Credit: Asteroid Terrestrial-impact Last Alert System (ATLAS) Project, University of Hawai'i

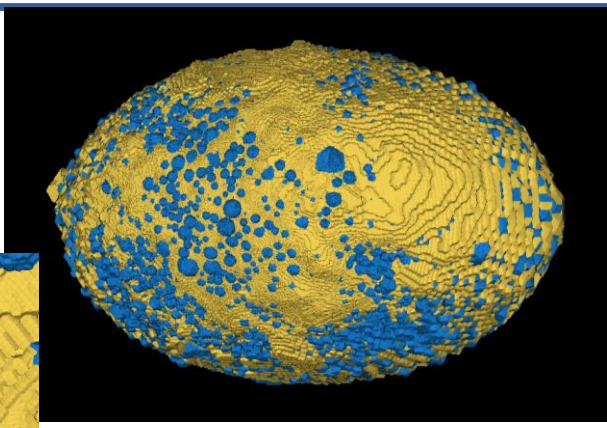


Credit: Science – NASA/ESA/STScI/Jian-Yang Li (PSI)
Image Processing – Joseph DePasquale (STScI)

Simple reproductions of Atabaque and Bodhran in Spheral





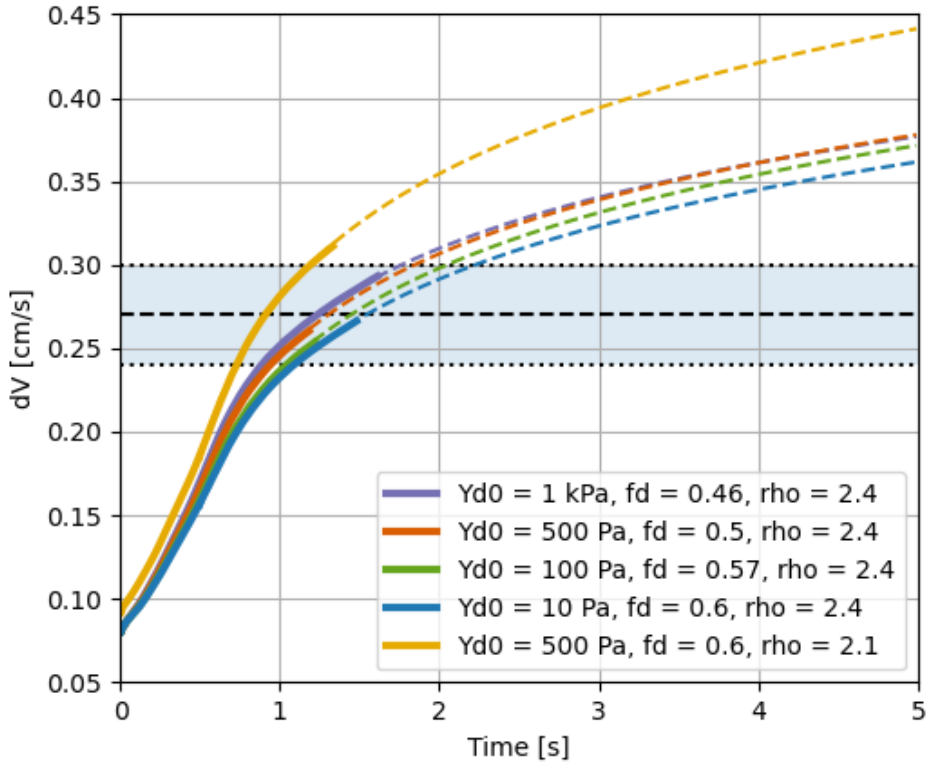


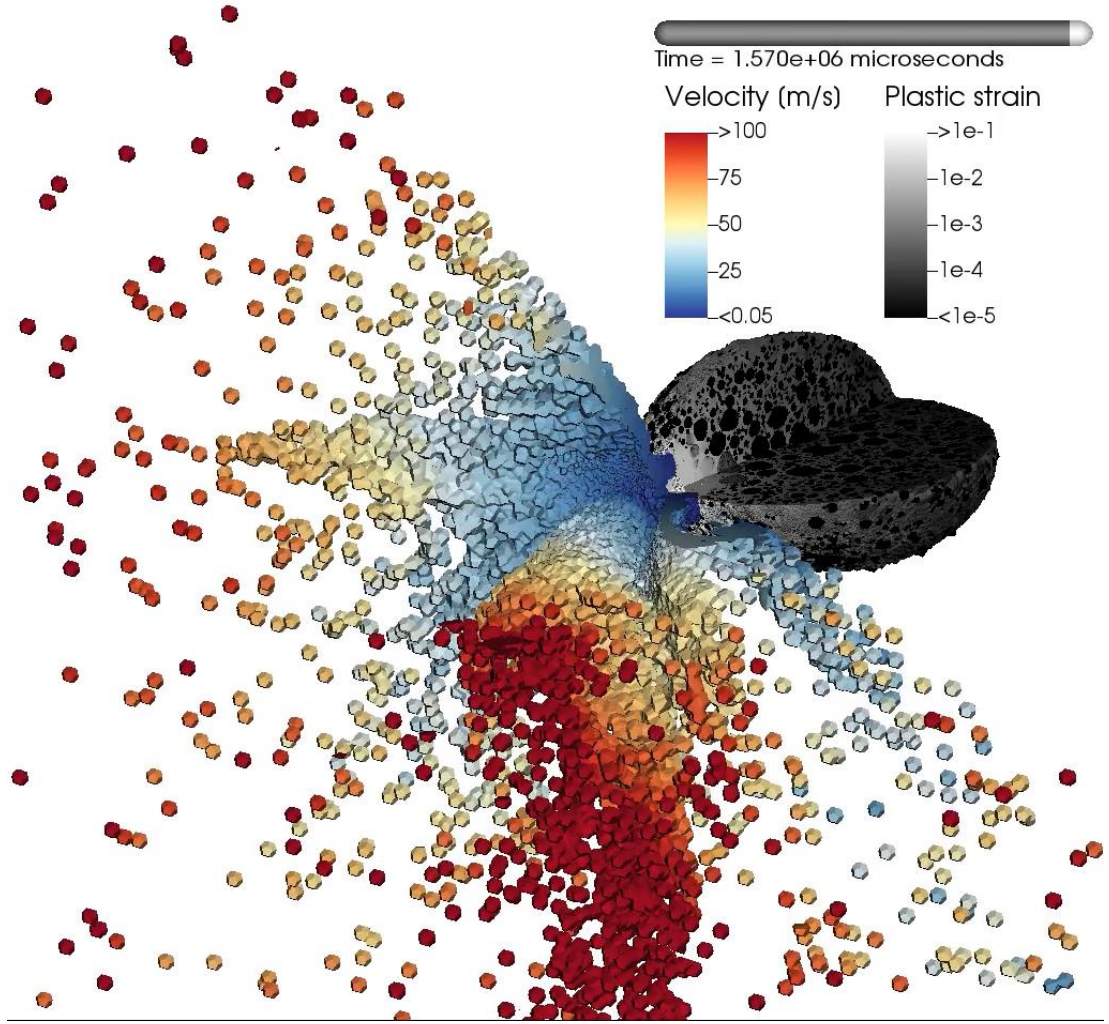
See Stickle et al. poster for more!

For this set-up, many options for matrix properties overshoot target velocity

5 cm resolution at impact site

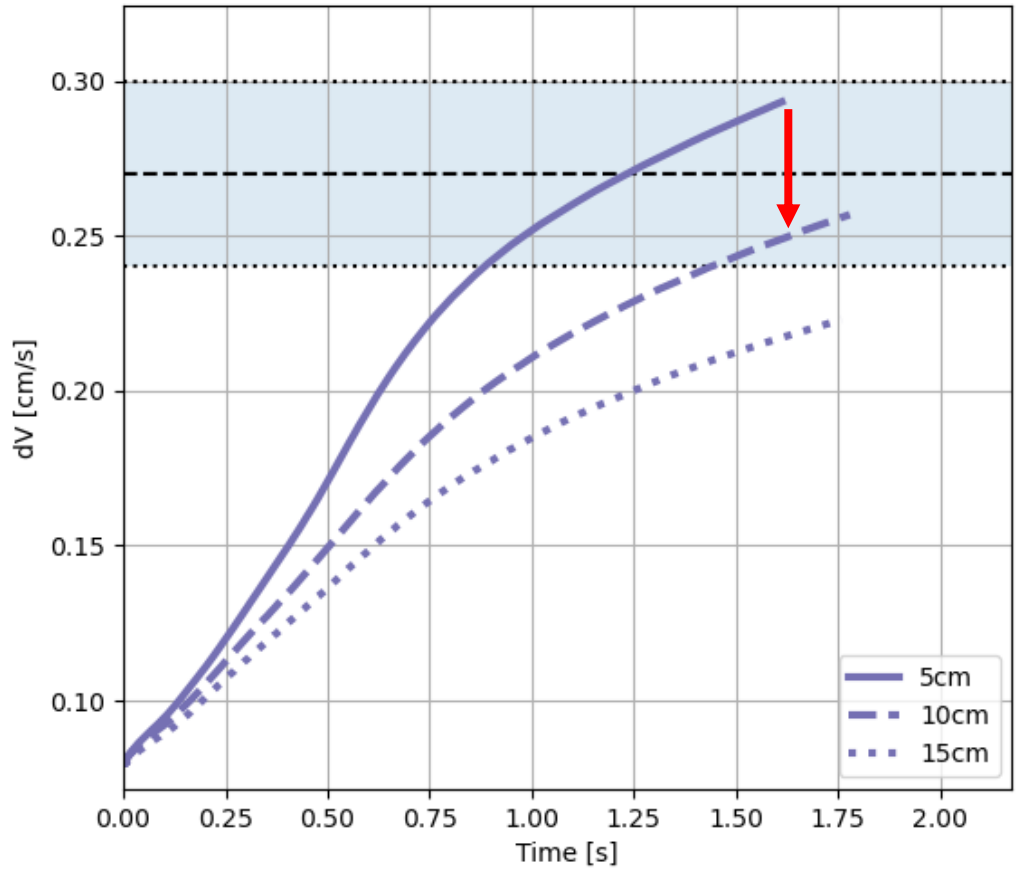
Constant boulder properties (e.g., strength, porosity, etc.)





See Stickle et al. poster for more!

Under-resolving simulations can lead to significant differences in deflection magnitude



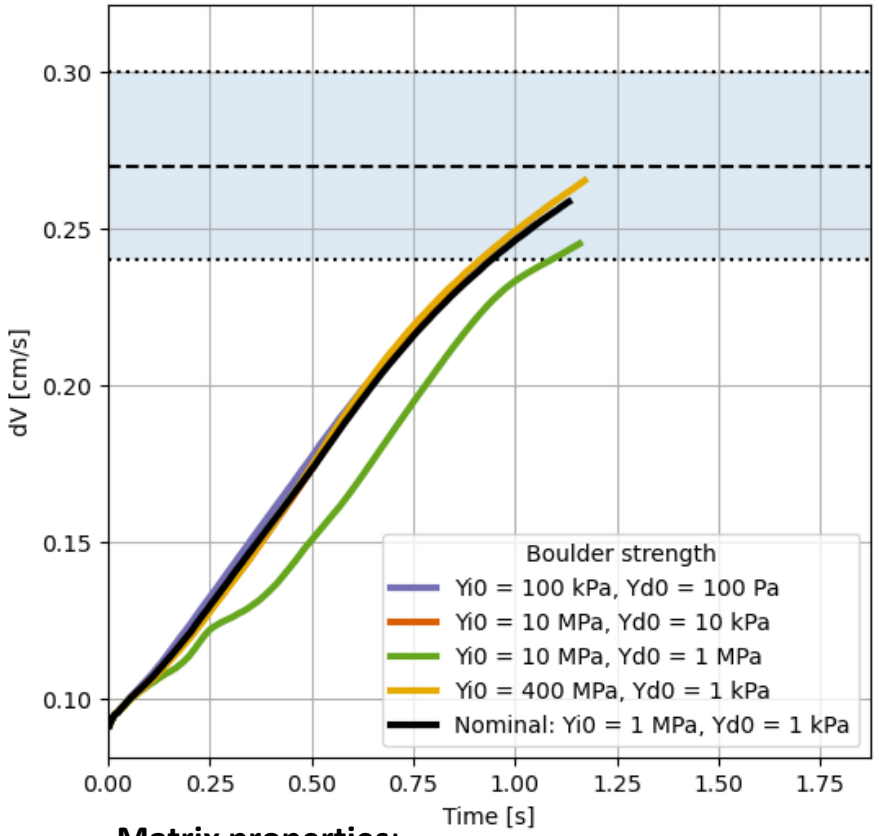
Matrix properties:
Yd0 = 1 kPa
fd = 0.47
ϕ = 0.4

For our assumed properties, we're looking for a substantial **undershoot at 10 cm** to get something that will **work at 5 cm**

See Stickle et al. poster for more!

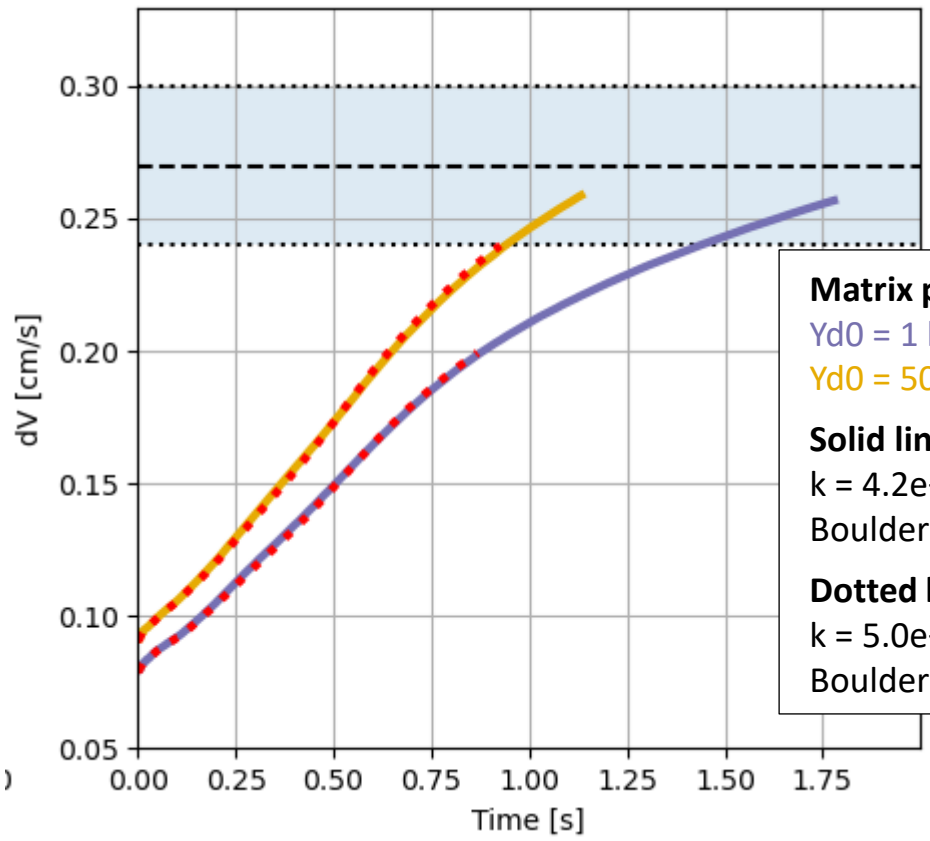
A variety of boulder strengths don't substantially change deflection magnitude

Boulder yield strength



Matrix properties:
Yd0 = 1 kPa, fd = 0.47, ϕ_m = 0.4

Boulder tensile strength



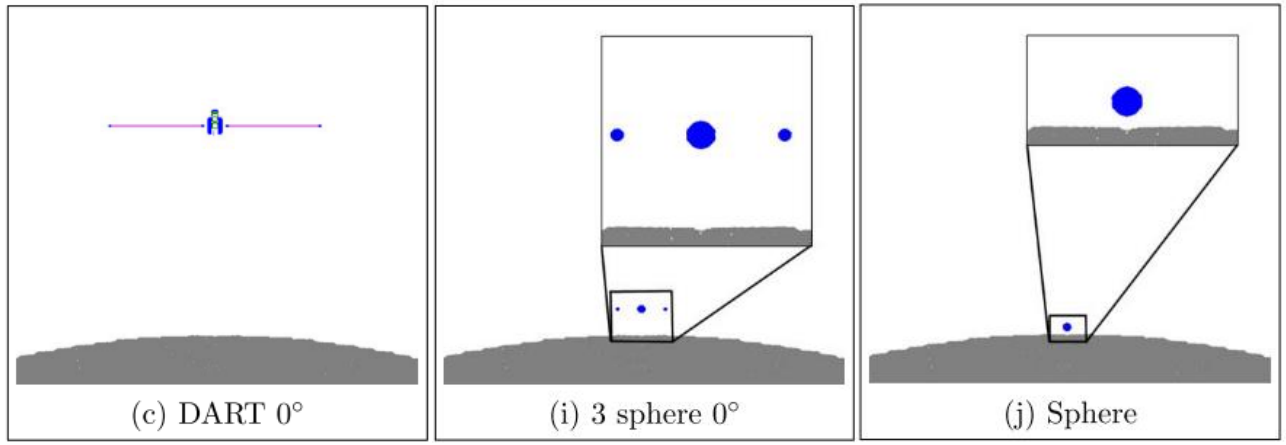
Matrix properties:
Yd0 = 1 kPa, fd = 0.47, ϕ_m = 0.4
Yd0 = 500 Pa, fd = 0.6, ϕ_m = 0.58

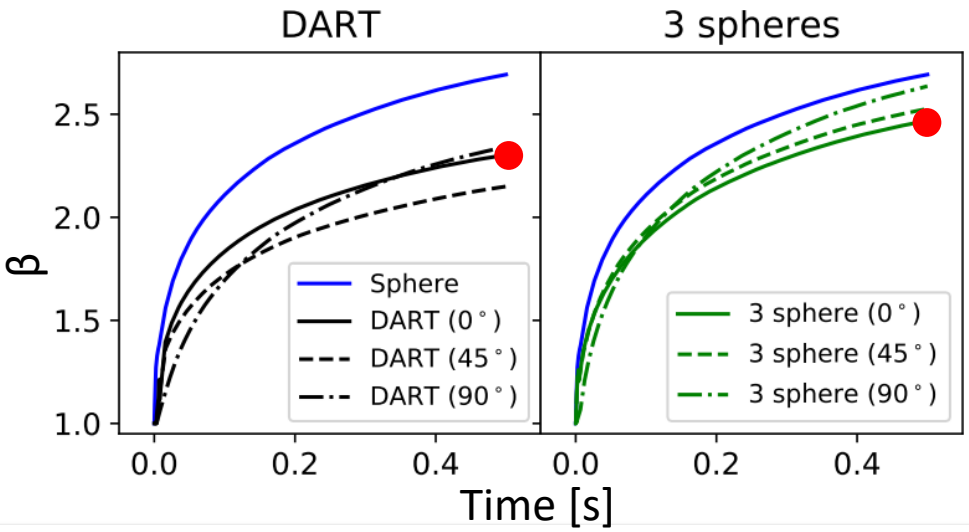
Solid lines:
k = 4.2e+25, m = 5.93
Boulder tensile strength ~ 500 kPa

Dotted lines:
k = 5.0e+24, m = 9.0
Boulder tensile strength ~ 20 MPa

Impactor geometry has a larger effect for rubble piles than homogenous targets

Owen et al., 2022, *PSJ*



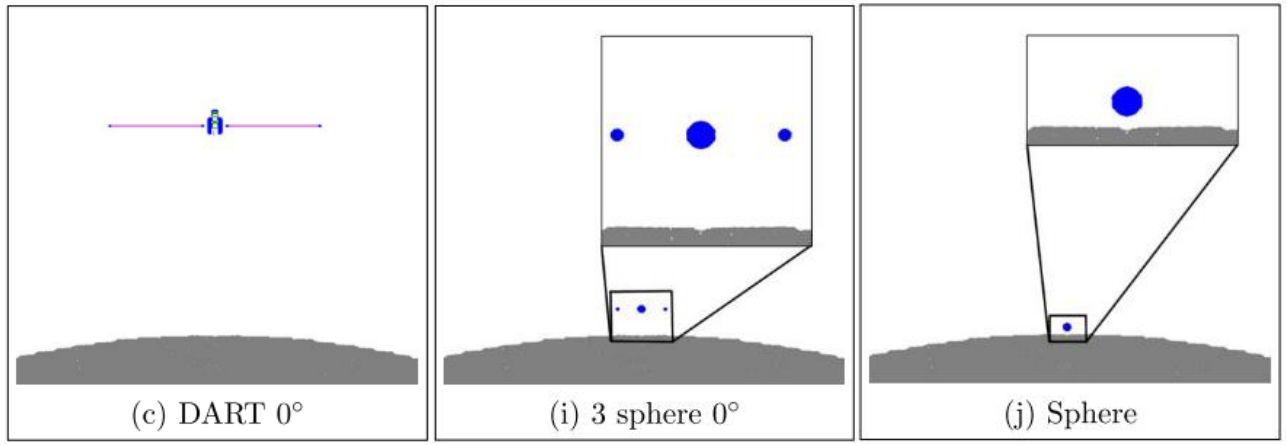


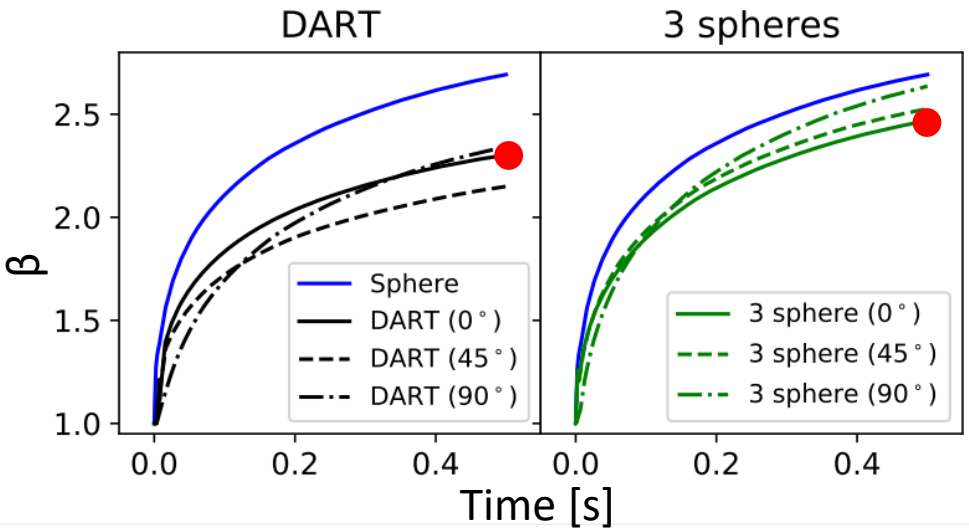
Difference in β of ~4% for 3-sphere vs DART with 0° angle

Same magnitude for dV

Impactor geometry has a larger effect for rubble piles than homogenous targets

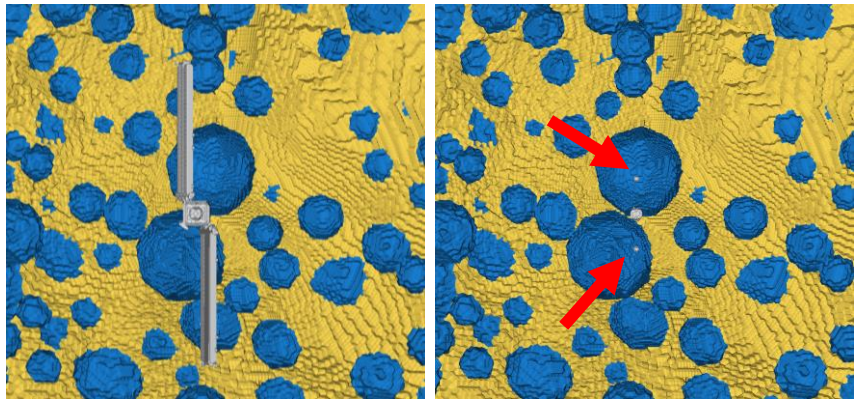
Owen et al., 2022, *PSJ*

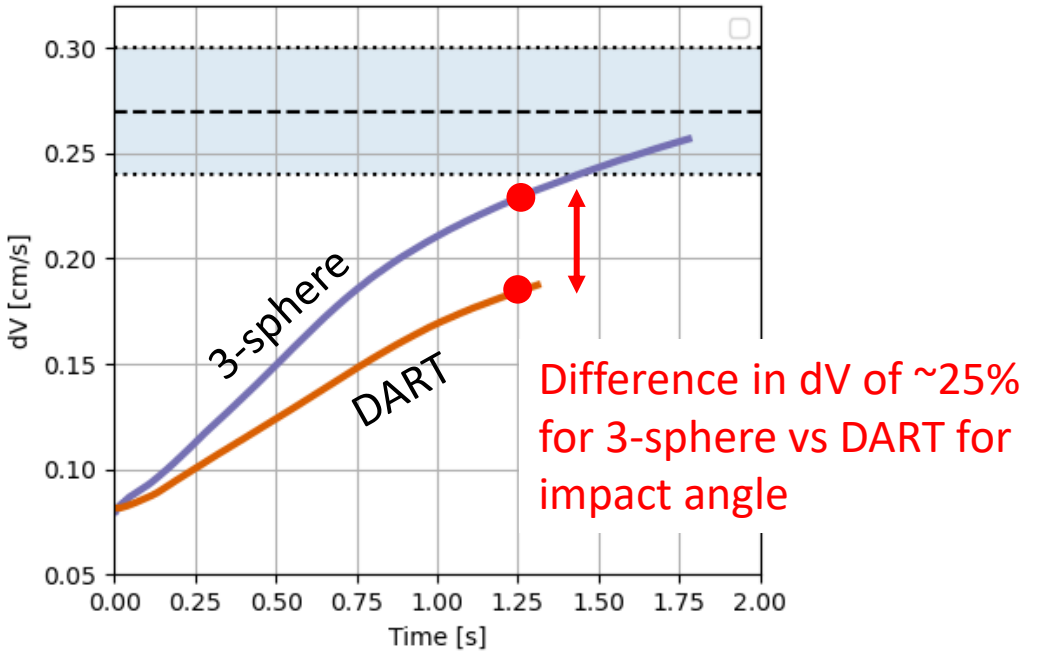




Difference in β of ~4% for 3-sphere vs DART with 0° angle

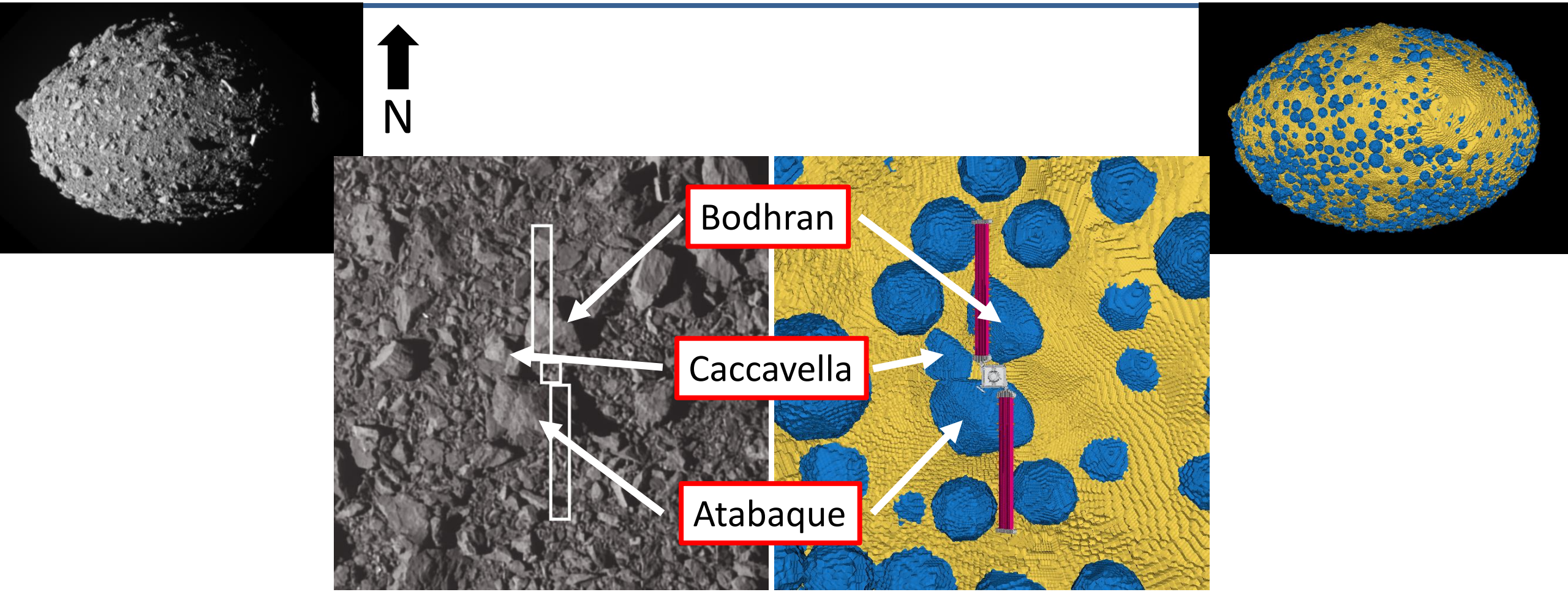
Same magnitude for dV



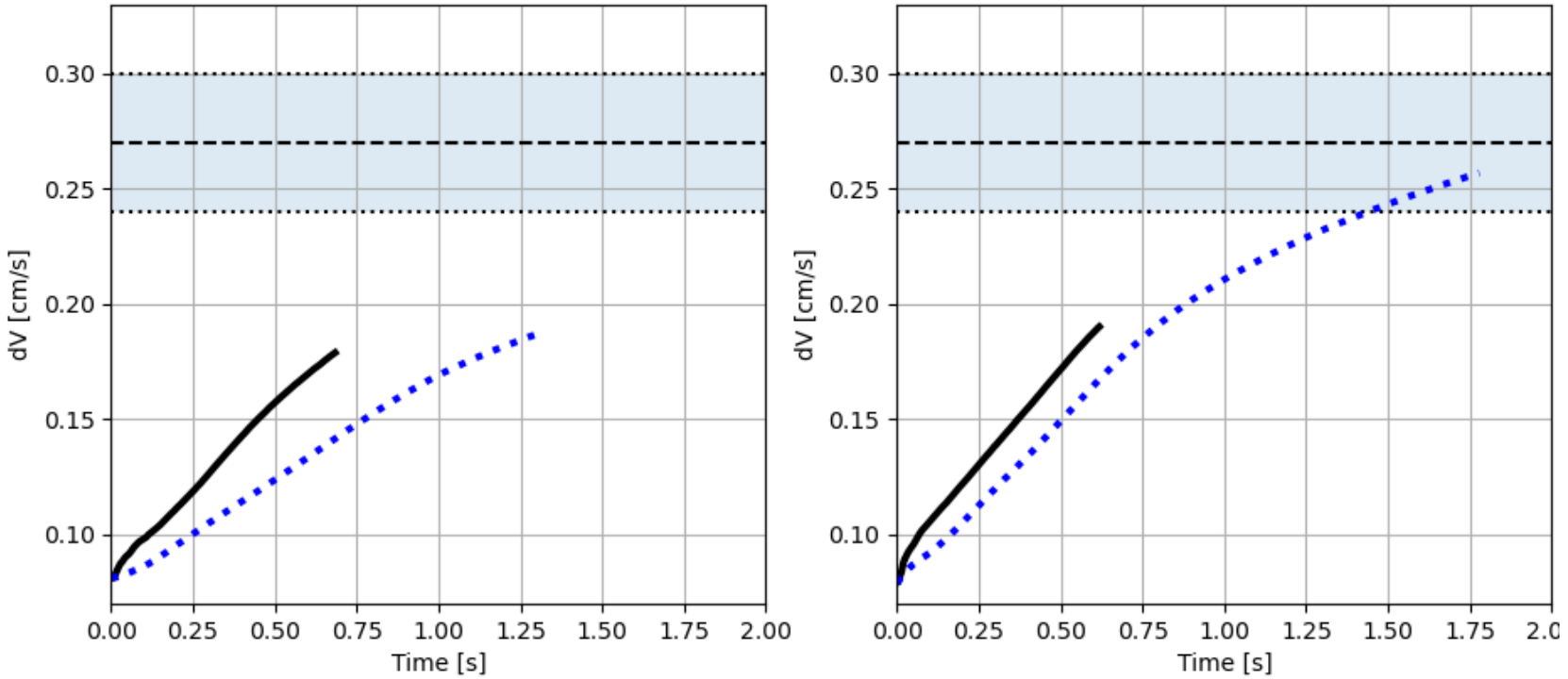


Difference in dV of ~25% for 3-sphere vs DART for impact angle

Making better boulders: Atabaque, Bodhran, and Caccavella



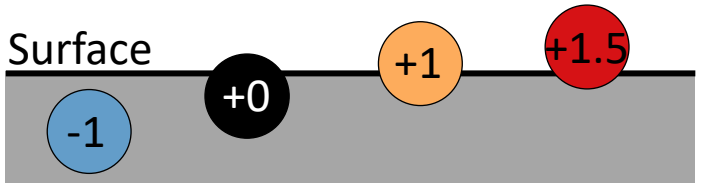
Precise boulder geometry influences deflection magnitude

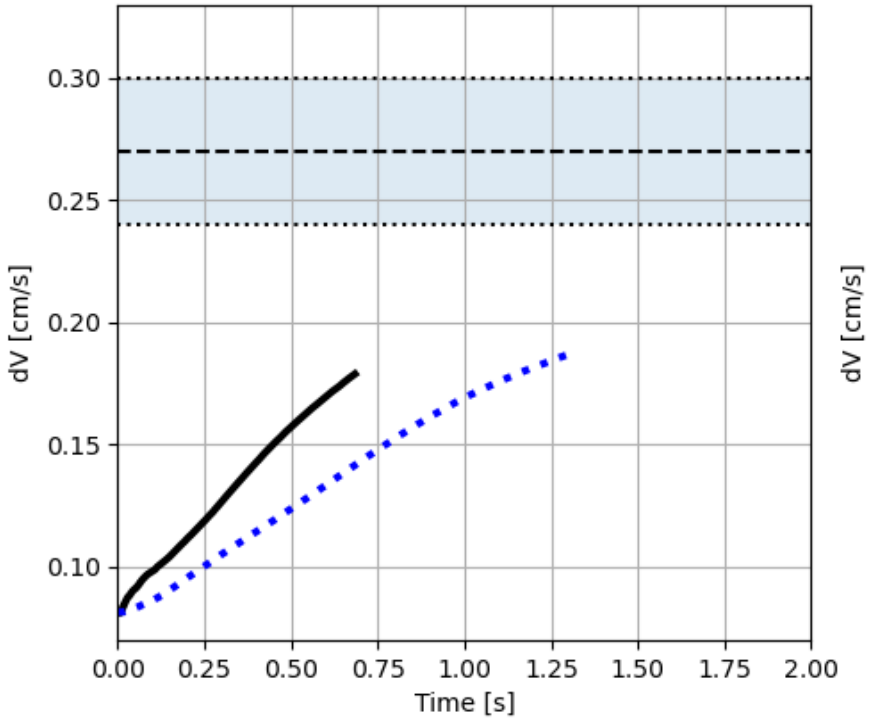


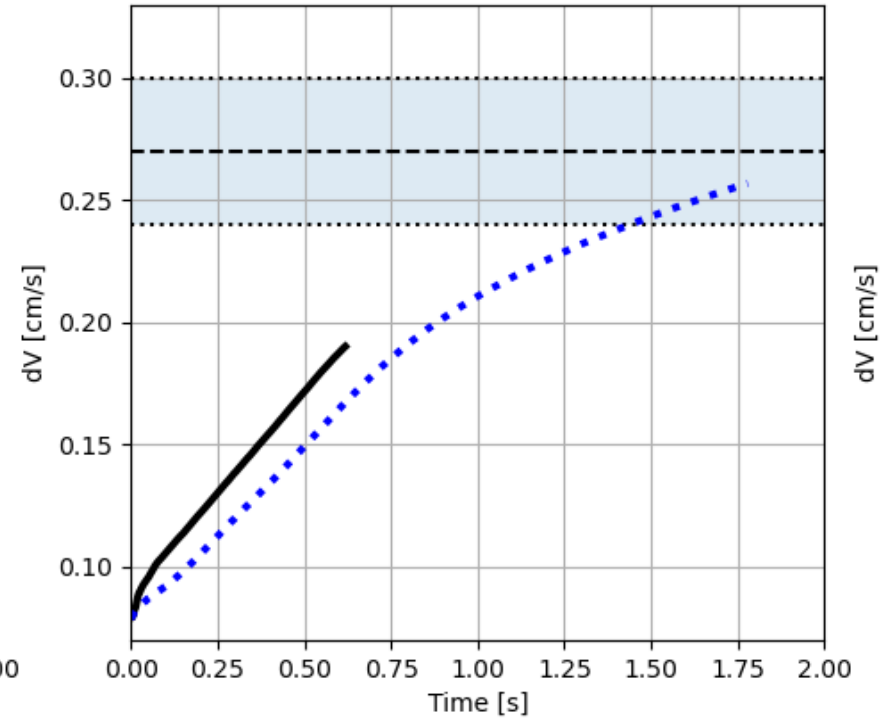
Old boulder arrangement

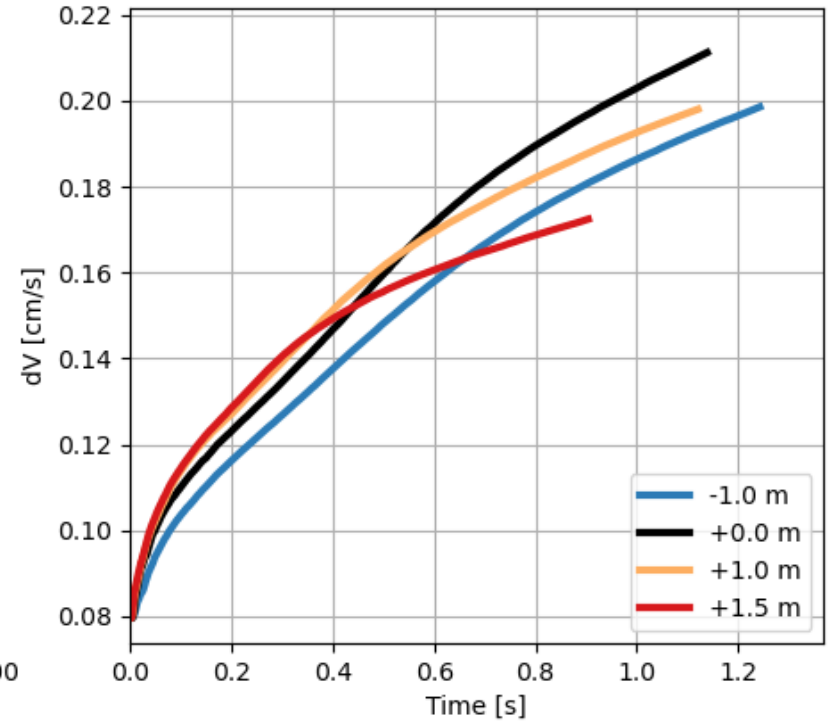
New boulder arrangement

Precise boulder geometry influences deflection magnitude









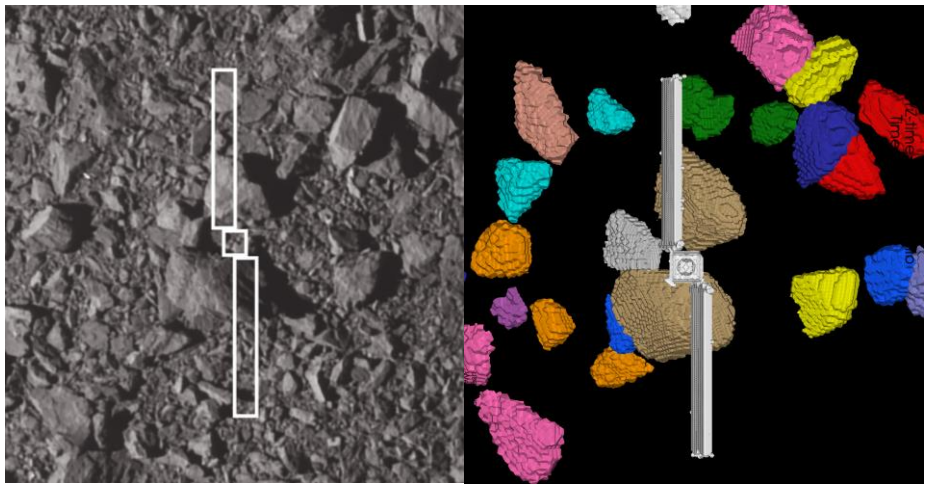
Old boulder arrangement

New boulder arrangement

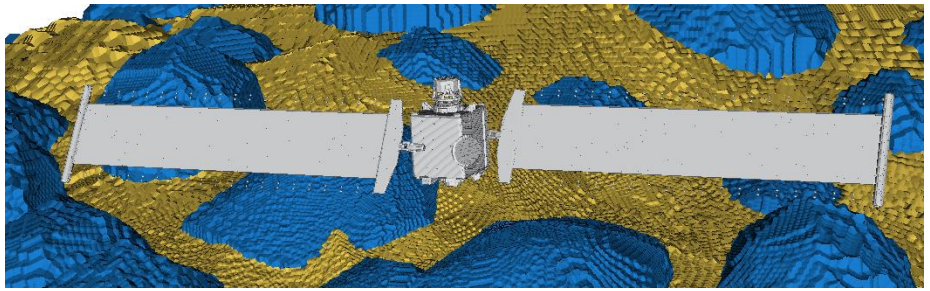
Inspired by Collins et al. (2023, LPSC)

DART provided essential constraints for deflection simulations

More impact site boulders



Hi-res spacecraft



- Some observations are easy to reproduce
  - Filaments in ejecta curtain
  - Relatively wide cone angle of ejecta curtain
  - Large mass of ejecta
- Others have been harder to reproduce
  - Many sims have very high deflection! But we need to reconcile ejecta production longevity and dV.
- Impactor choice is extra important for rubble piles
  - Solar panel “wing” representation may need improvement for 3-sphere analog into boulders
- Many avenues to explore
  - Weak surface + strong interior?
  - Internal boulder arrangement?
  - EOS uncertainty?
  - And more!

Questions?