Initiating Nuclear Mitigation Mission Simulations with a Simplified X-ray Energy Deposition Model

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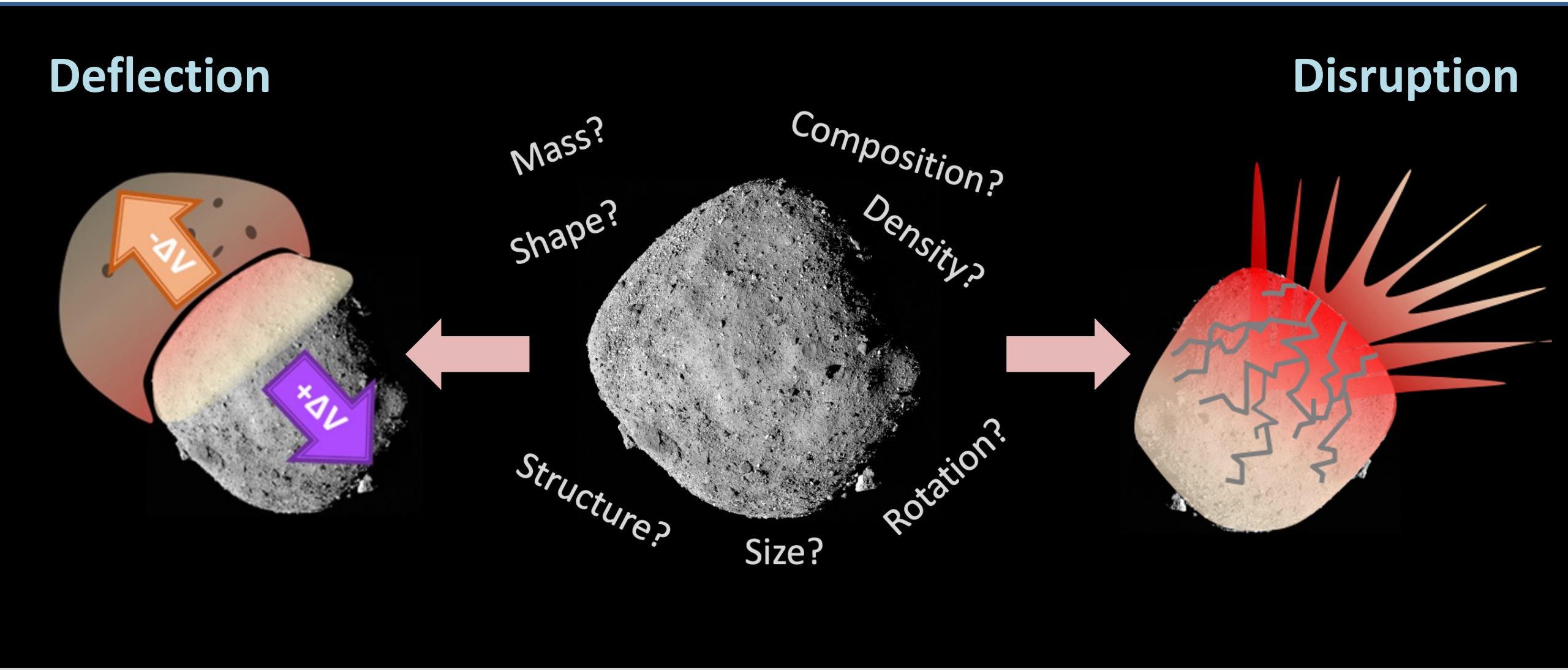
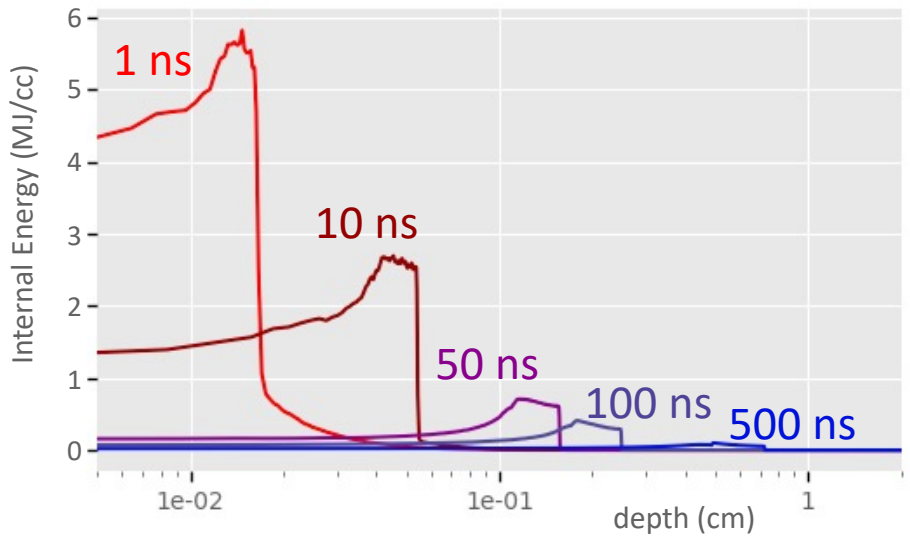
The Nuclear Explosive Option:



A problem with two parts

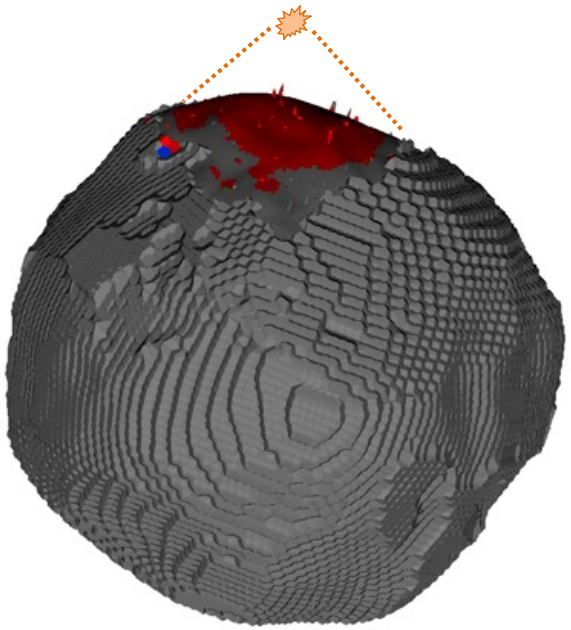
X-Ray Energy Deposition

- X rays illuminate the surface material, causing heating and ionization. Some energy re-radiates away.
- Happens at smaller/faster length/timescales compared to asteroid's motion: requires a full rad-hydro simulation.



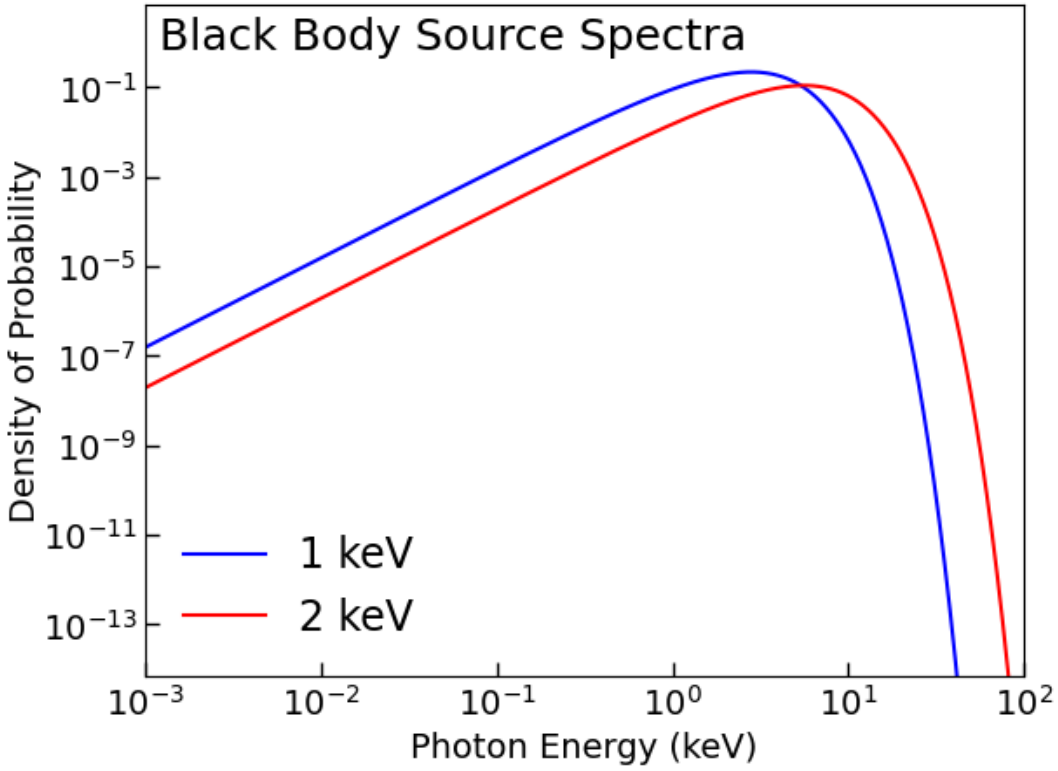
Hydrodynamics

- Everything that happens after the energy deposition.
- Material begins moving and expanding.
- At this point, only a standard hydrocode is needed.



Scope of Study: Sources and Materials

Idealized X-Ray spectra to approximate the source:



Fluence Range:

1 kt/m^2

1 Mt at a 10m Standoff distance

Everything in between

Just barely melting the surface

1e-4 kt/m^2

Source Duration: 10 to 100ns*

Material Compositions:

- Quartz (SiO_2)
- Forsterite (Mg_2SiO_4)
- Iron (Fe)
- Ice (H_2O)

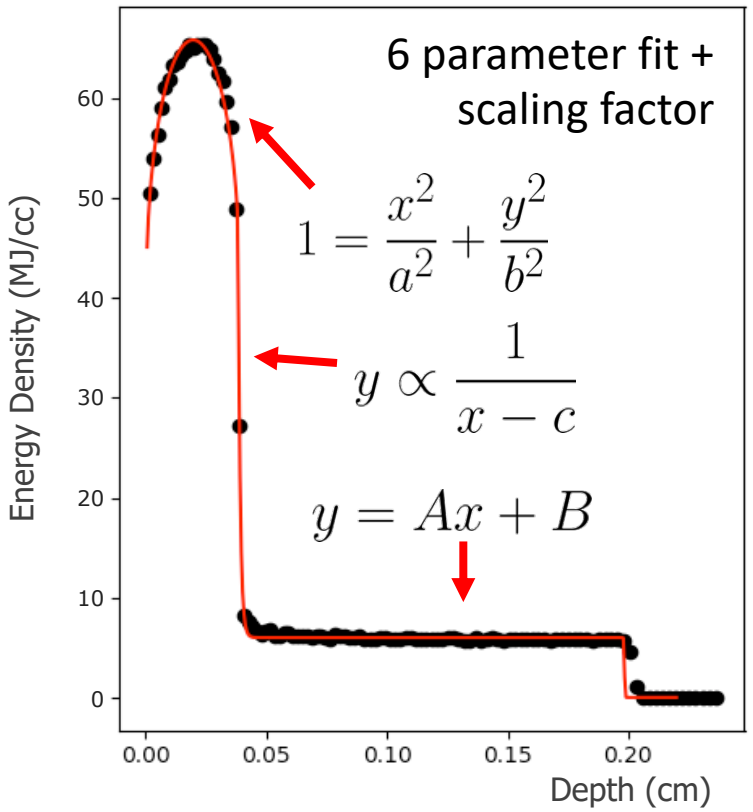
(What we have equation of state data for)

Image credit: Gerwin Koolstra

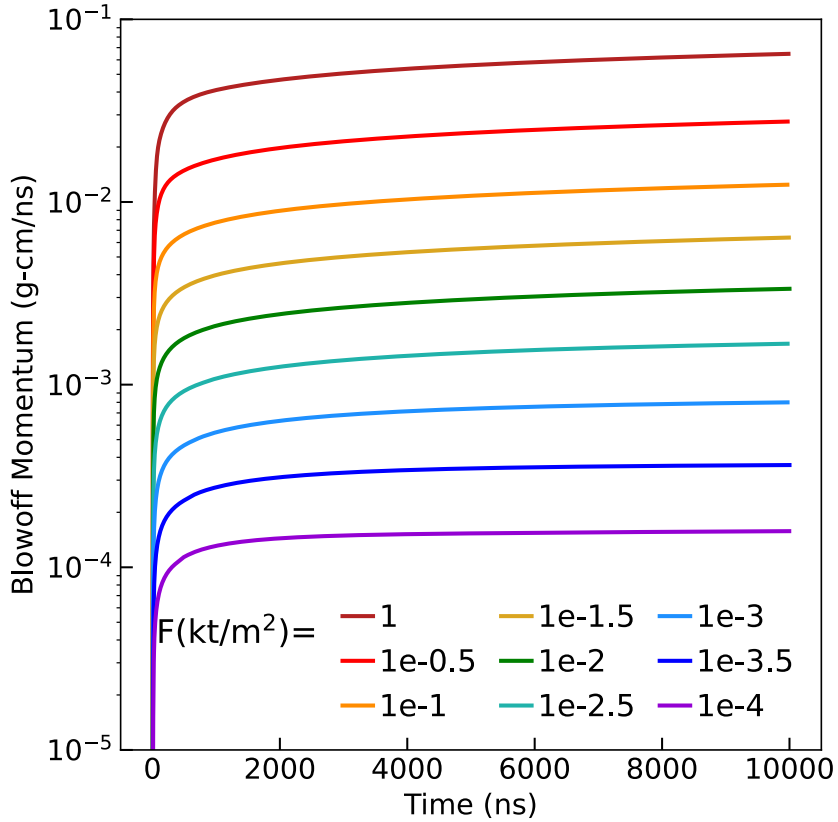
*taken from §1.54 and §1.57 of Glasstone & Dolan 1977

Modeling the X-ray Energy Deposition with Kull

The Kull Multiphysics code is a mesh-based radiation-hydrodynamics code that was developed for High Energy Density Physics. It uses the best-available opacities and includes re-radiation.

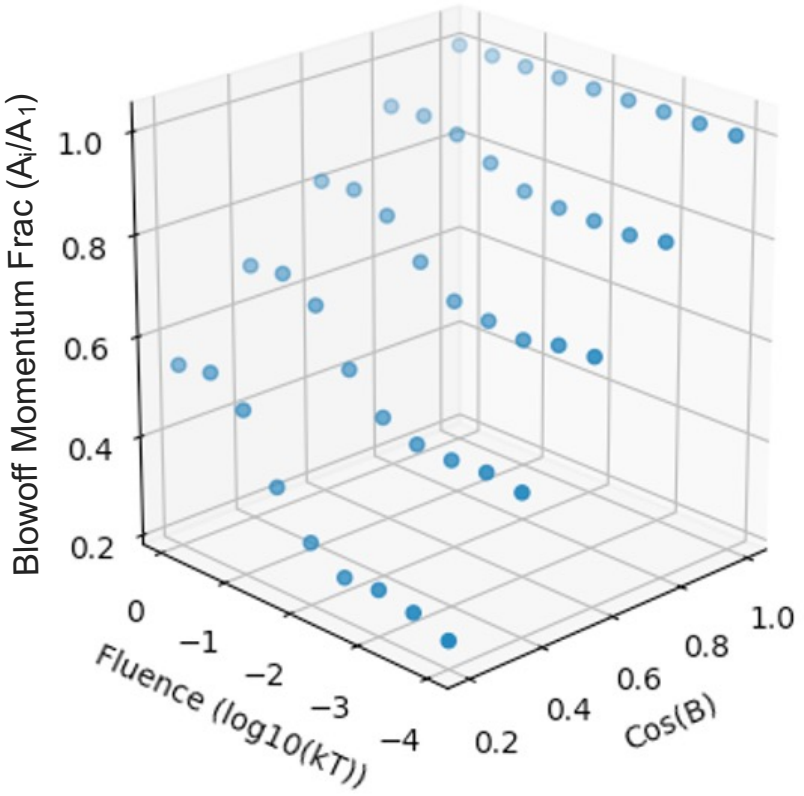


- Started model construction using fits from a base grid:
  - 9 fluence levels
  - 7 source durations
  - 4 materials
  - 2 source spectra
  - All normal incidence
  - No porosity added.
- **Blowoff momentum used as metric for accuracy**



Angle of Incidence/Porosity Construction:

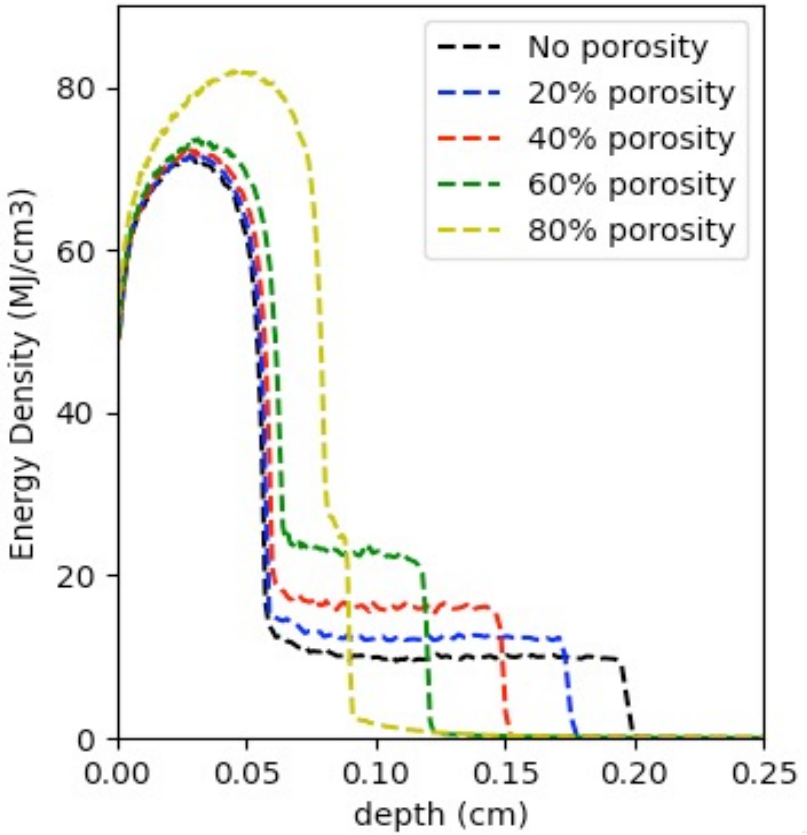
Angle: No shape change: scale down fluence surface "sees" by fraction of reflected photons



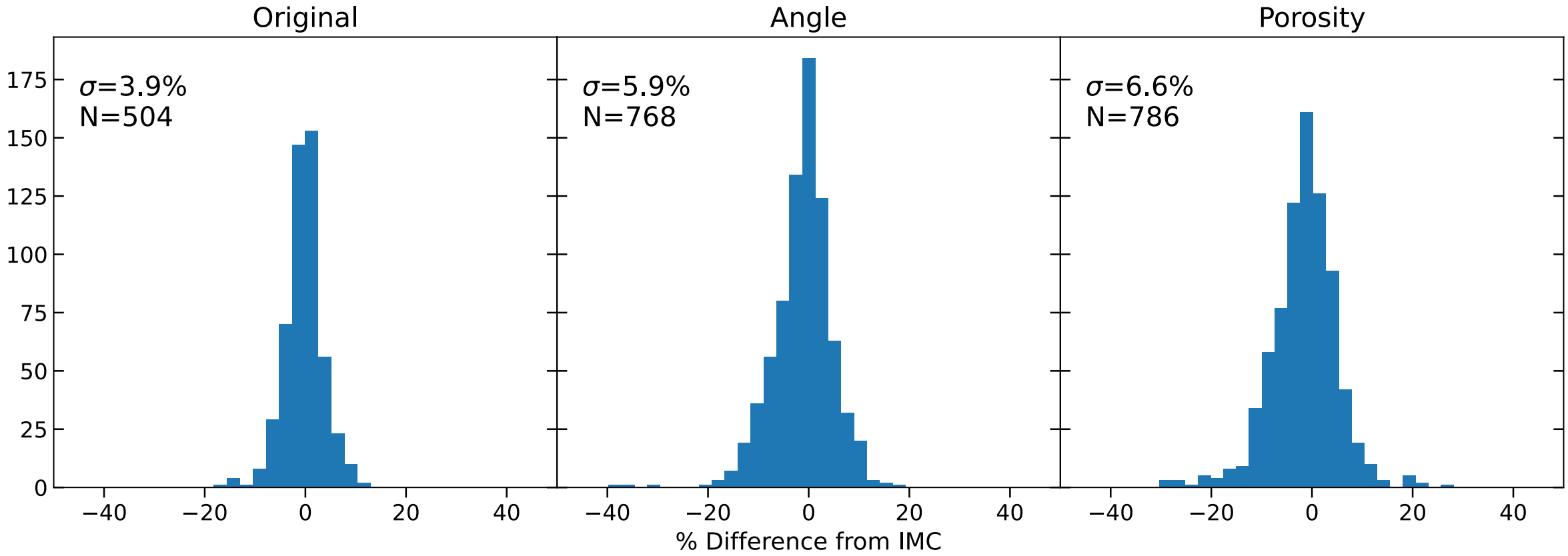
1D Simulation Construction Suite: N=768

Porosity: Some shape change after scaling with density, minor adjustments to the function.

1D Simulation Construction Suite: N=786

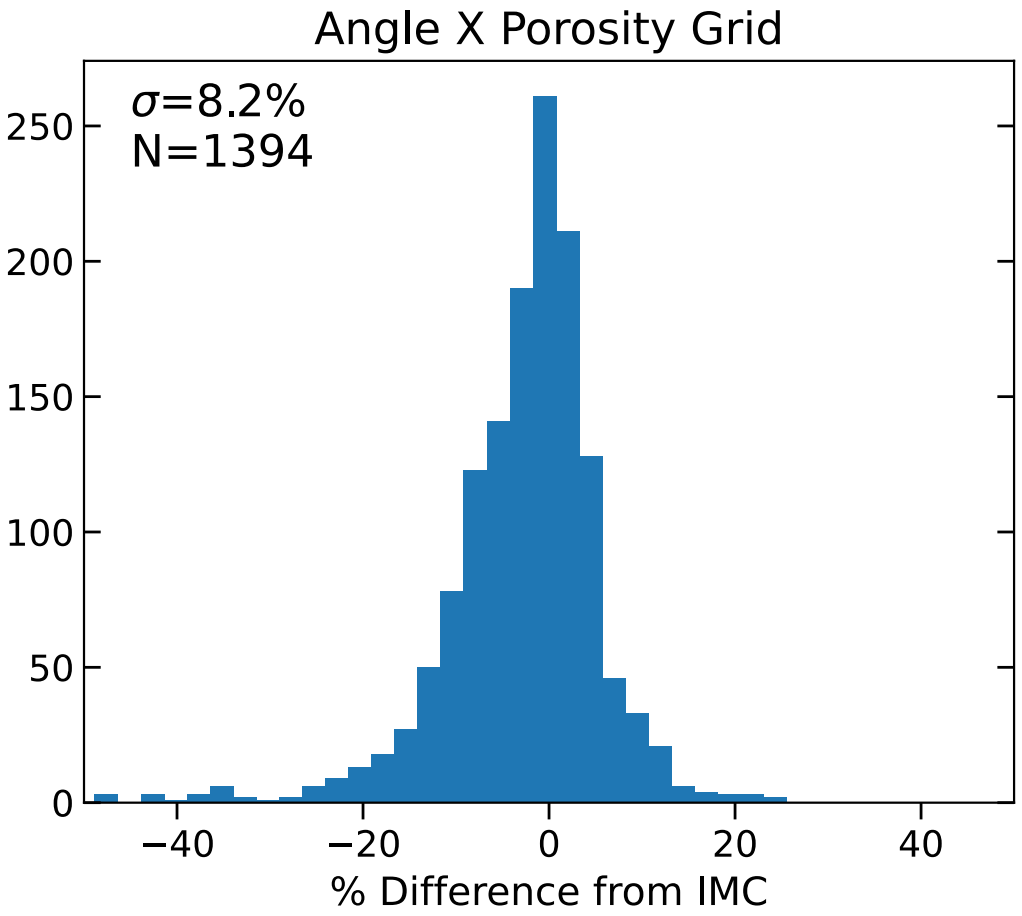


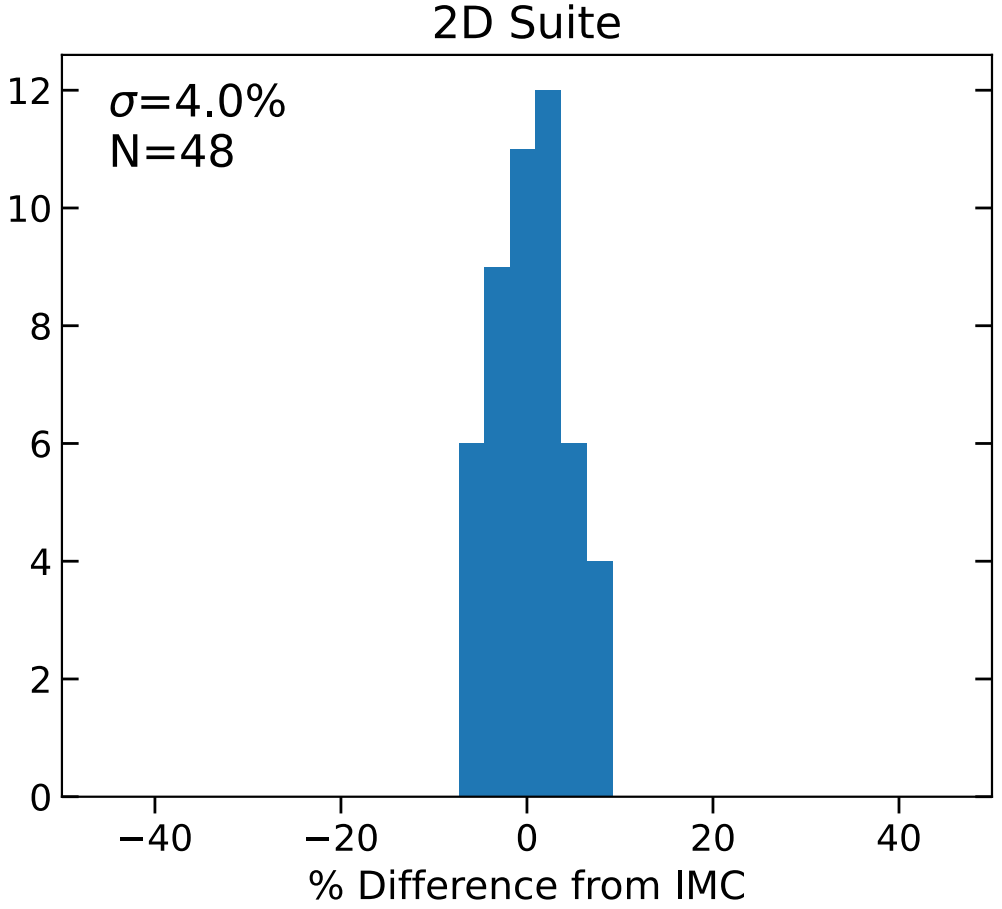
Accuracy Results:



Comparing the original IMC blowoff momentum to a function-initiated simulation yields consistent results!

Accuracy Results:

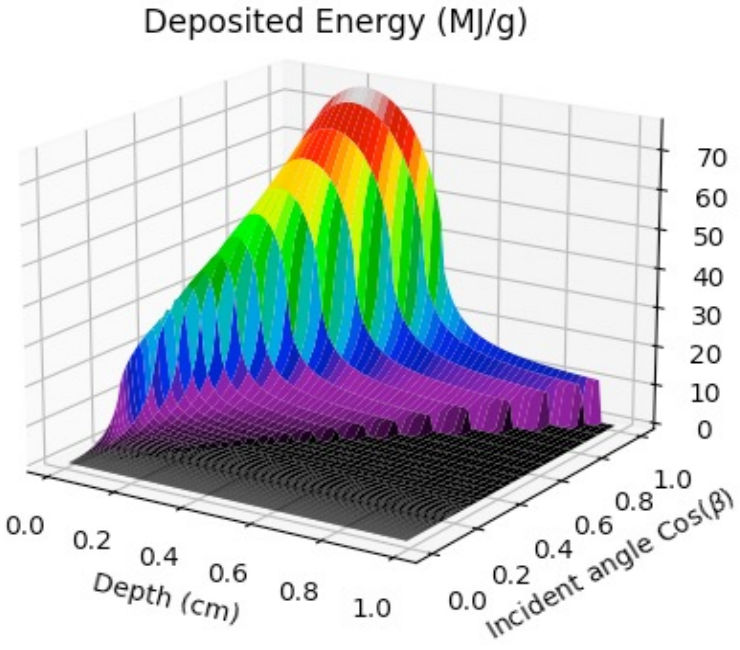


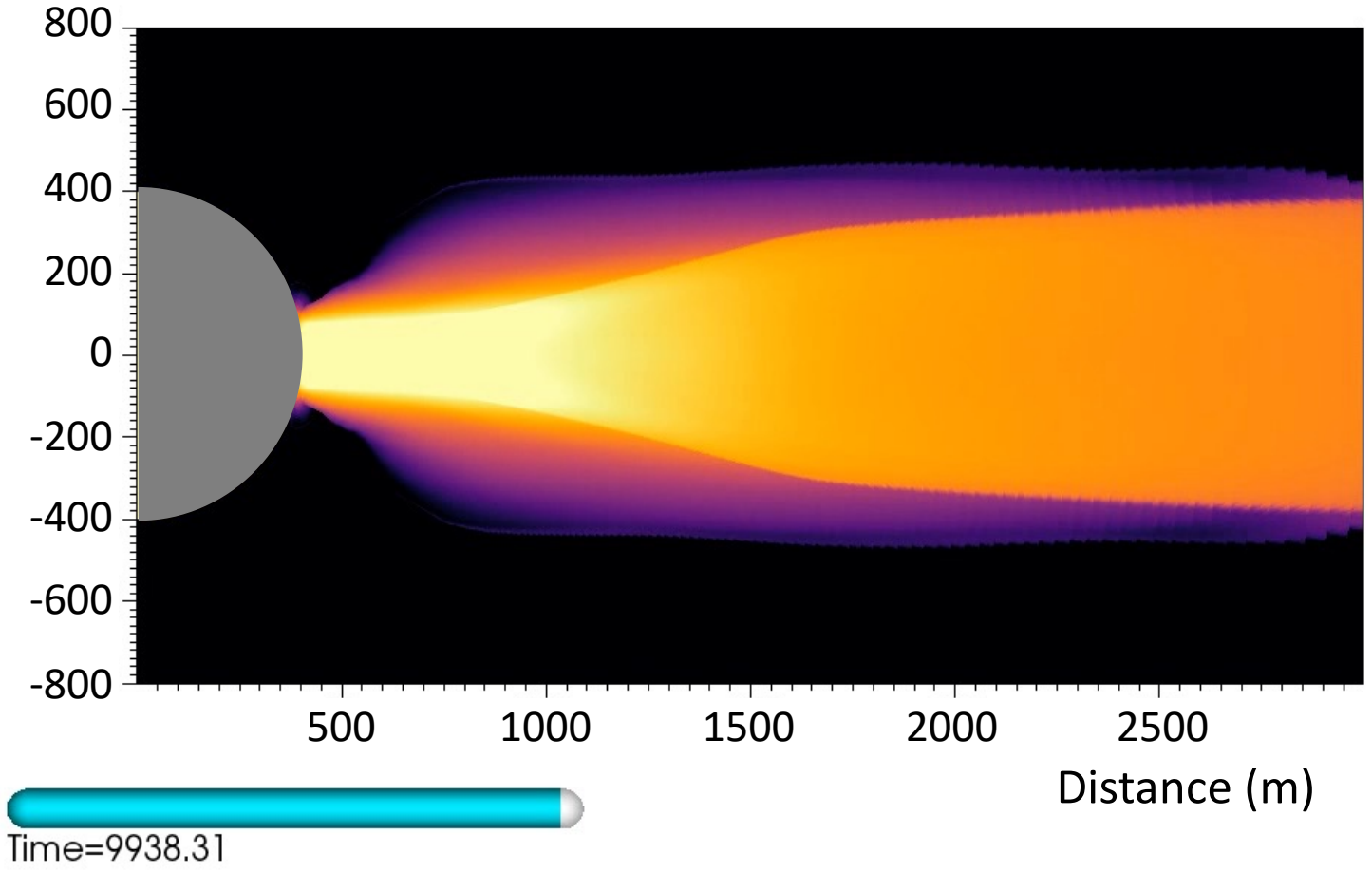


Comparing the original IMC blowoff momentum to a function-initiated simulation yields consistent results!

PDC Exercise test with Ares:

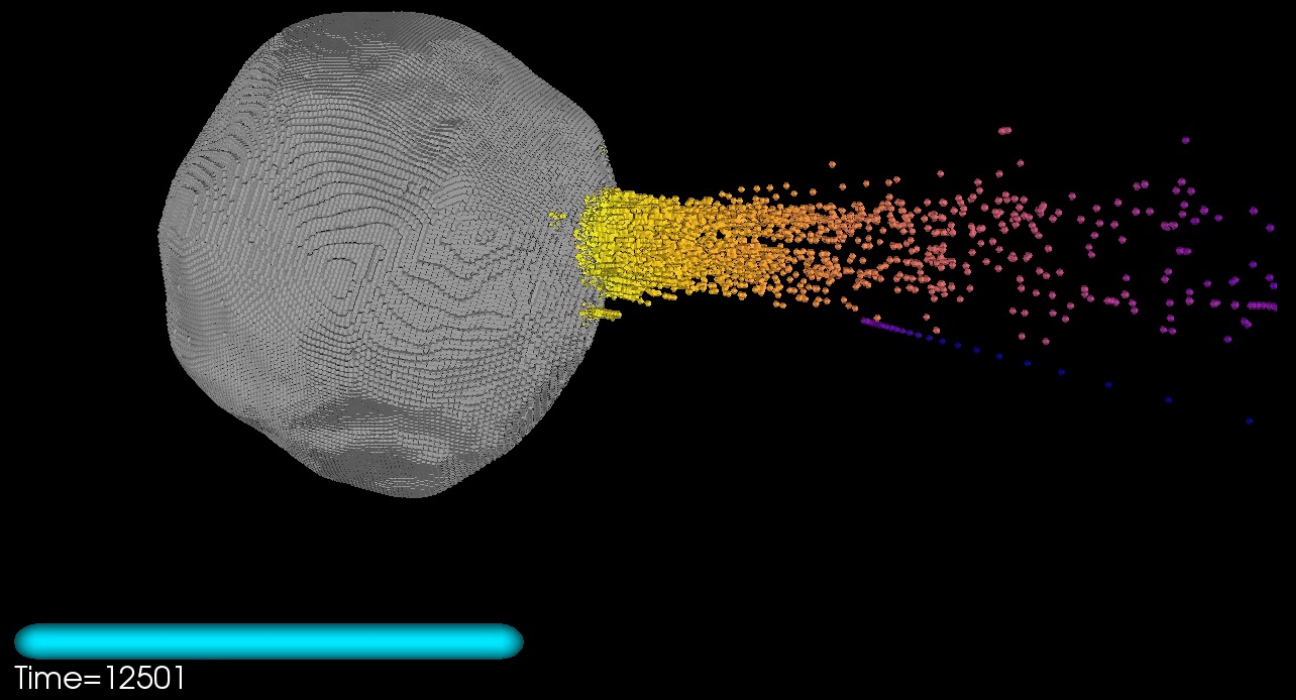
- 800m spherical asteroid made of SiO_2 with 21% porosity (ρ=2.1 g/cc)
- 1 MT Device, 10m Standoff distance, 2keV BB source spectrum.





Next Steps: Spheral

- Continue developing our simulation capabilities for NED missions in Spheral, verify that it works as expected.
- Explore implications of strength/damage
- Attempt to characterize threshold between disruption/deflection
- Incorporate Rubble Pile structure



New X-ray Energy Deposition method to be submitted to Planetary Science Journal