

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

Planetary Defense Conference, April 5th 2023

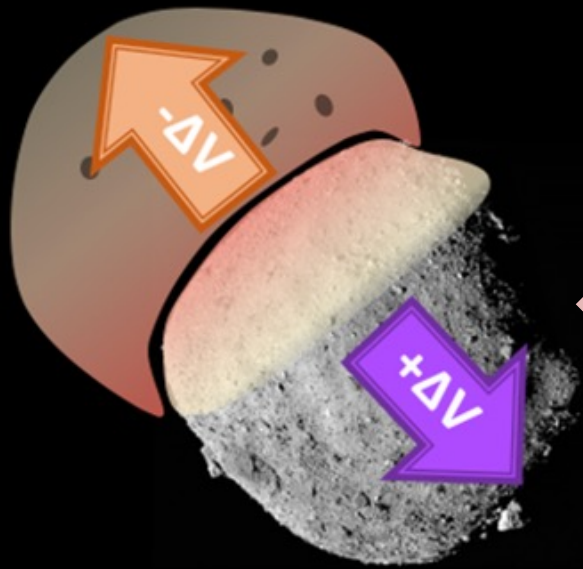
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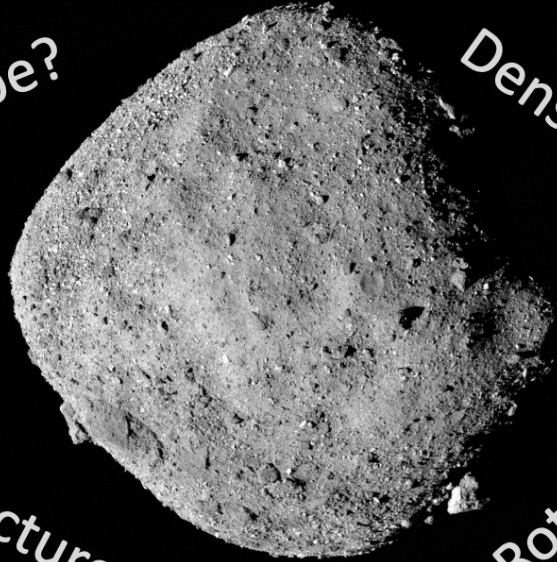


The Nuclear Explosive Option:

Deflection



Mass?
Shape?

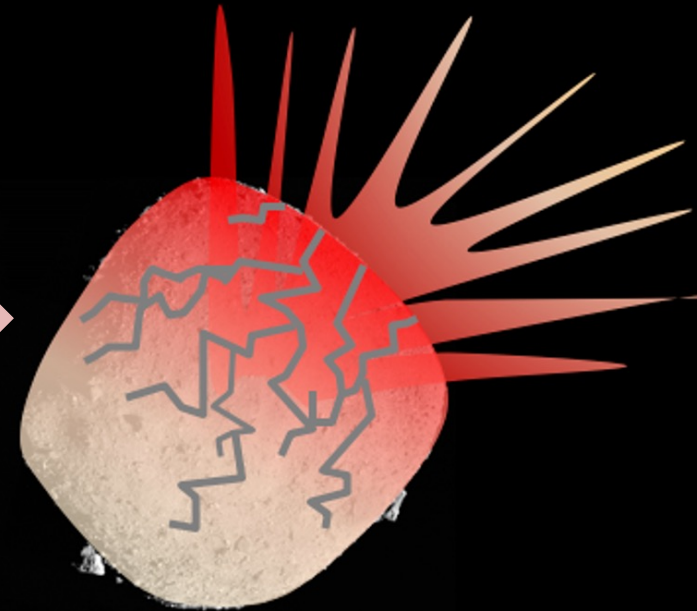


Composition?
Density?

Structure?
Size?

Rotation?

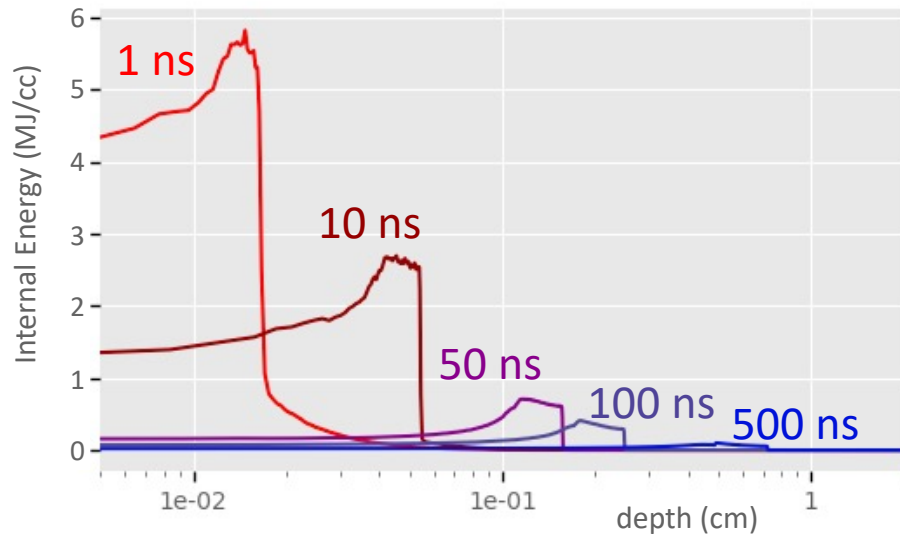
Disruption



A problem with two parts

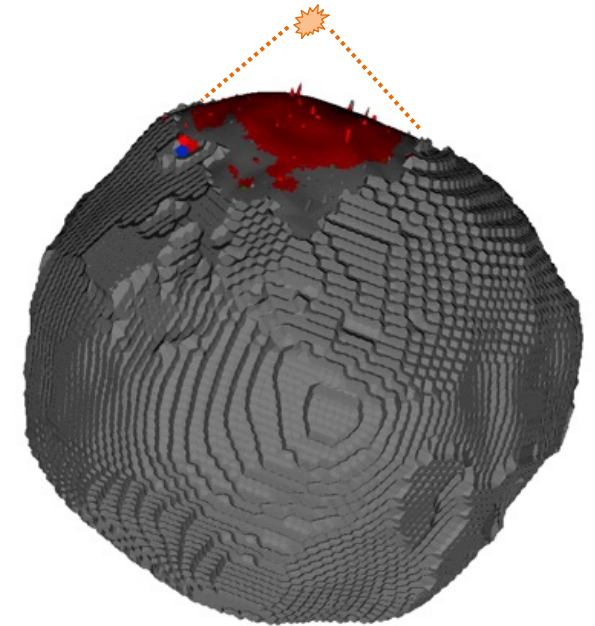
X-Ray Energy Deposition

- 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.



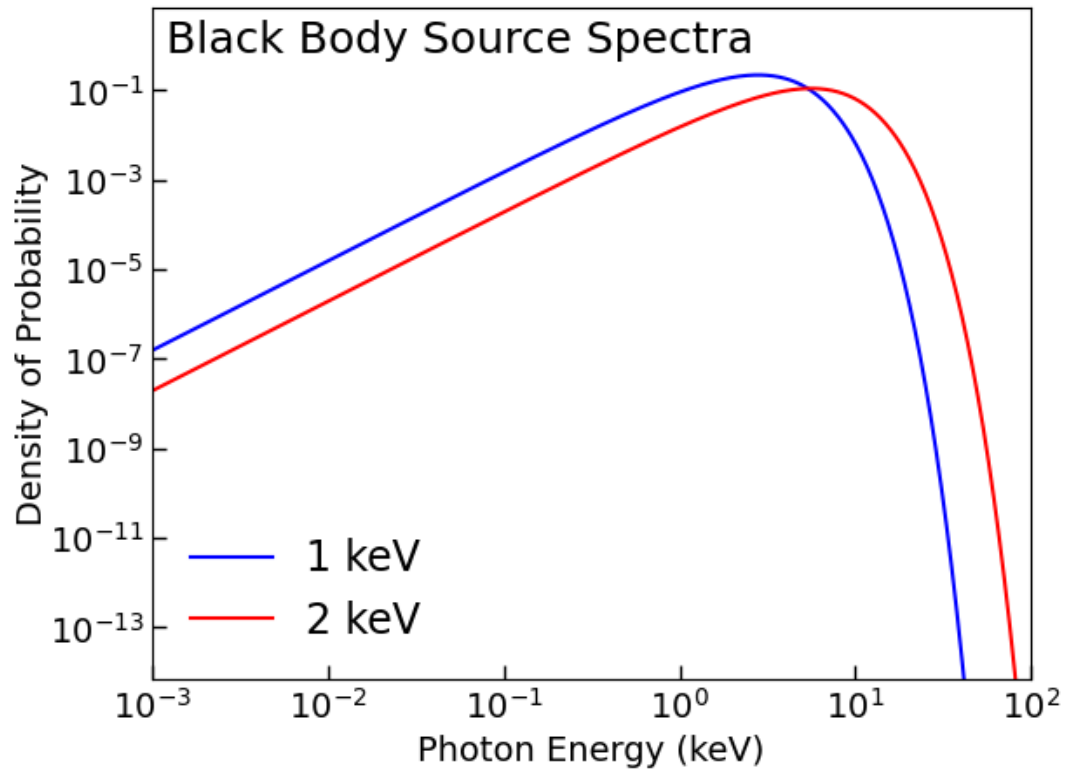
Hydrodynamics

- 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/m²
1 Mt at a 10m Standoff distance
Everything in between
Just barely melting the surface
1e-4 kt/m²

Source Duration: 10 to 100ns*

Material Compositions:

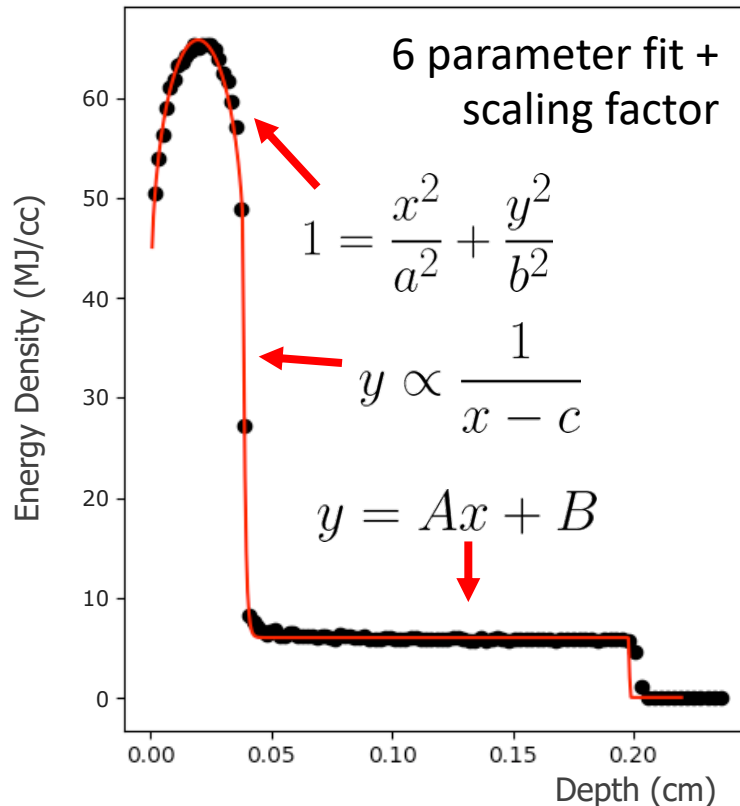
- Quartz (SiO₂)
- Forsterite (Mg₂SiO₄)
- Iron (Fe)
- Ice (H₂O)

(What we have equation of state data for)

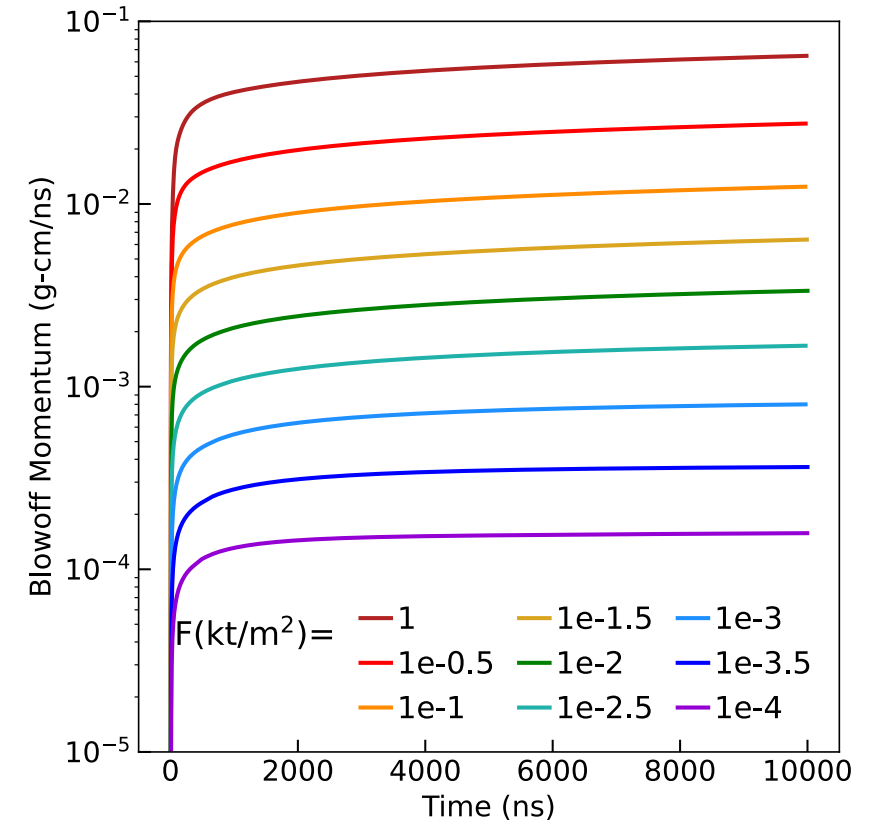


Modeling the X-ray Energy Deposition with Kull

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.

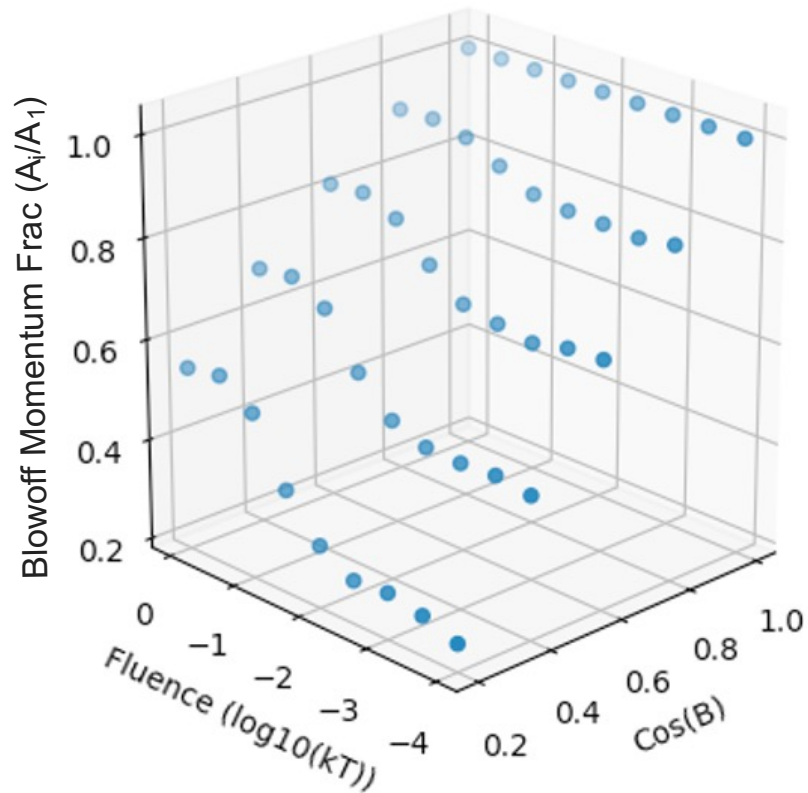


- Started model construction using fits from a base grid:
 - 9 fluence levels
 - 7 source durations
 - 4 materials
 - 2 source spectra
 - All normal incidence
 - No porosity added.
- Blowoff momentum used as metric for accuracy**



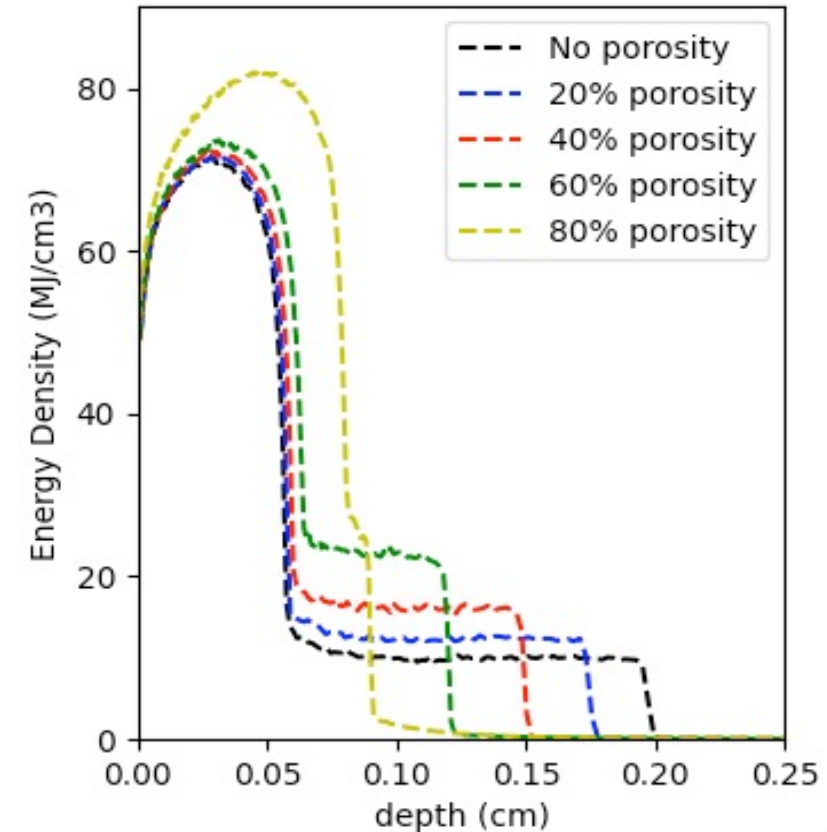
Angle of Incidence/Porosity Construction:

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



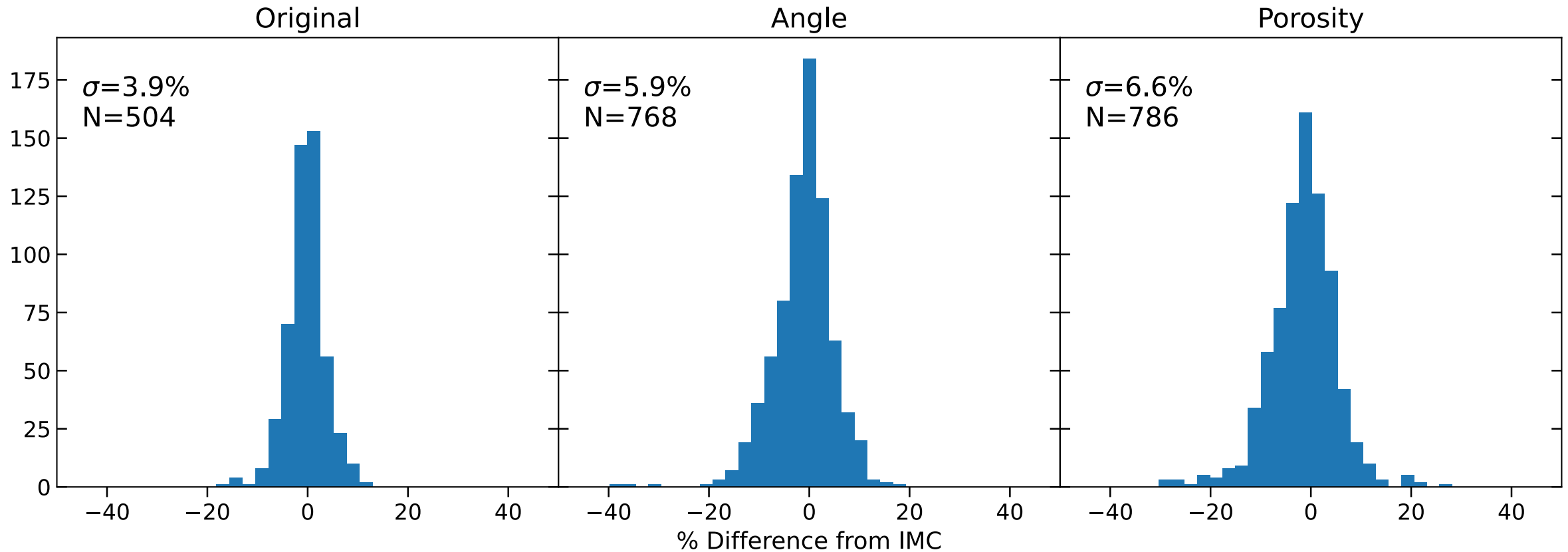
1D Simulation
Construction
Suite: N=768

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



1D Simulation
Construction
Suite: N=786

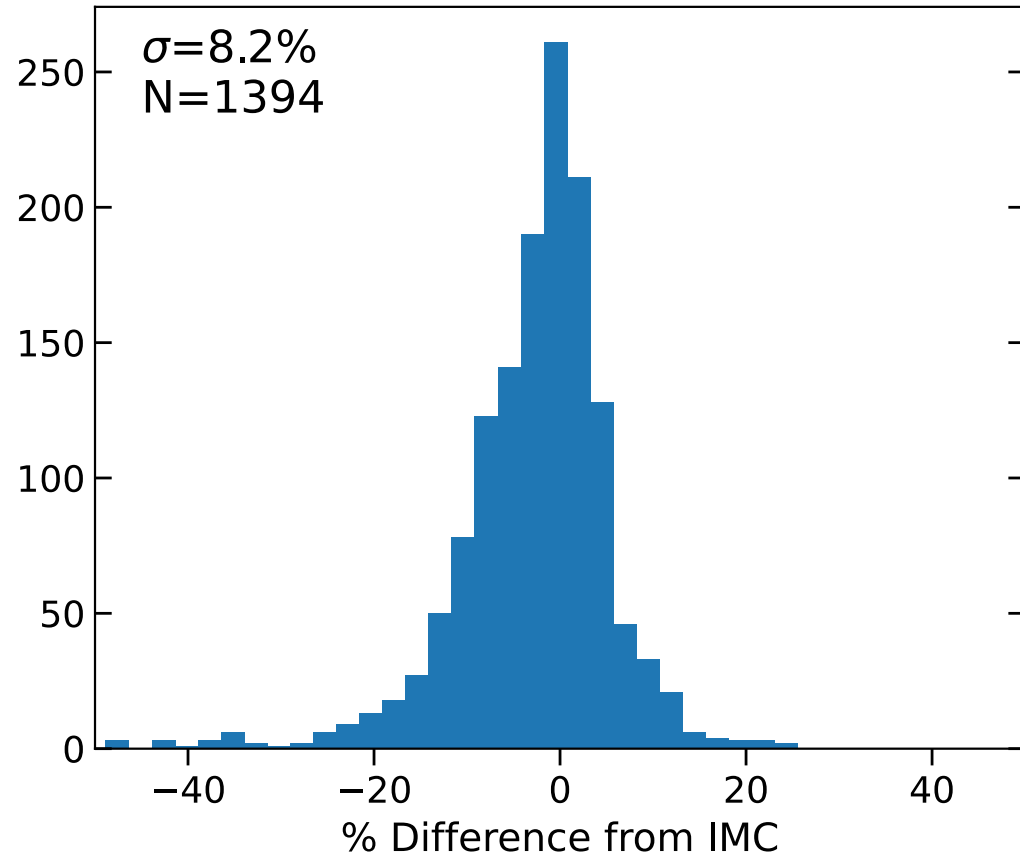
Accuracy Results:



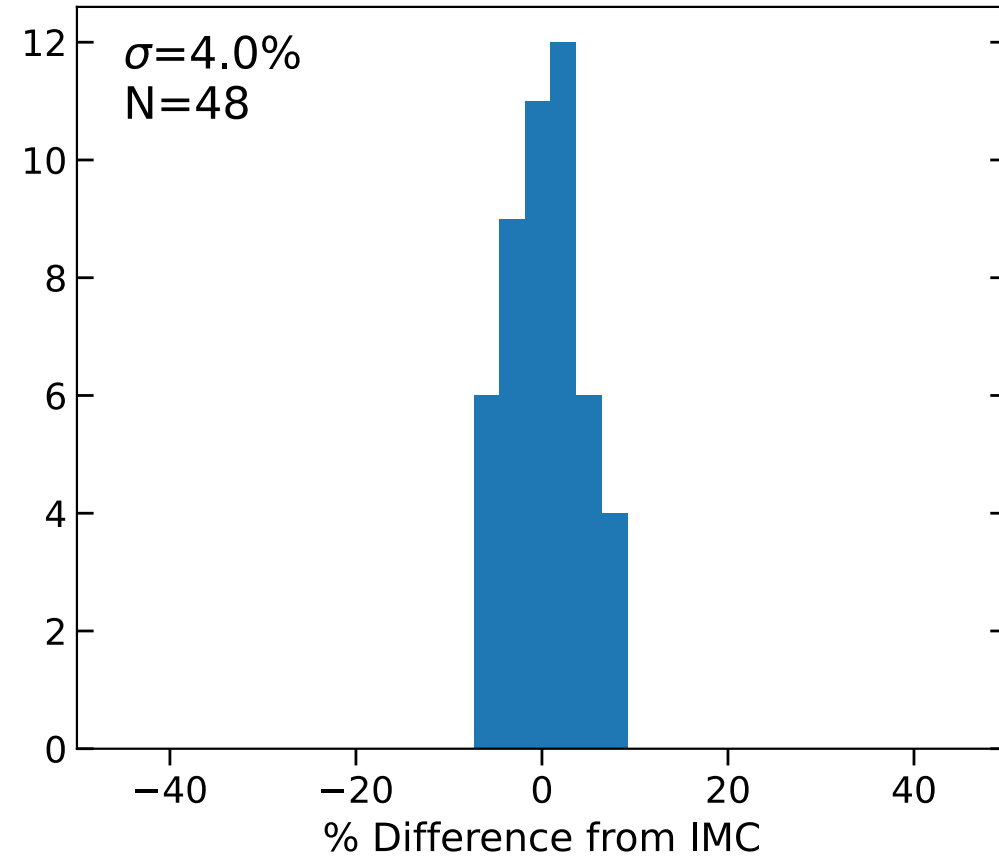
Comparing the original IMC blowoff momentum to a function-initiated simulation yields consistent results!

Accuracy Results:

Angle X Porosity Grid



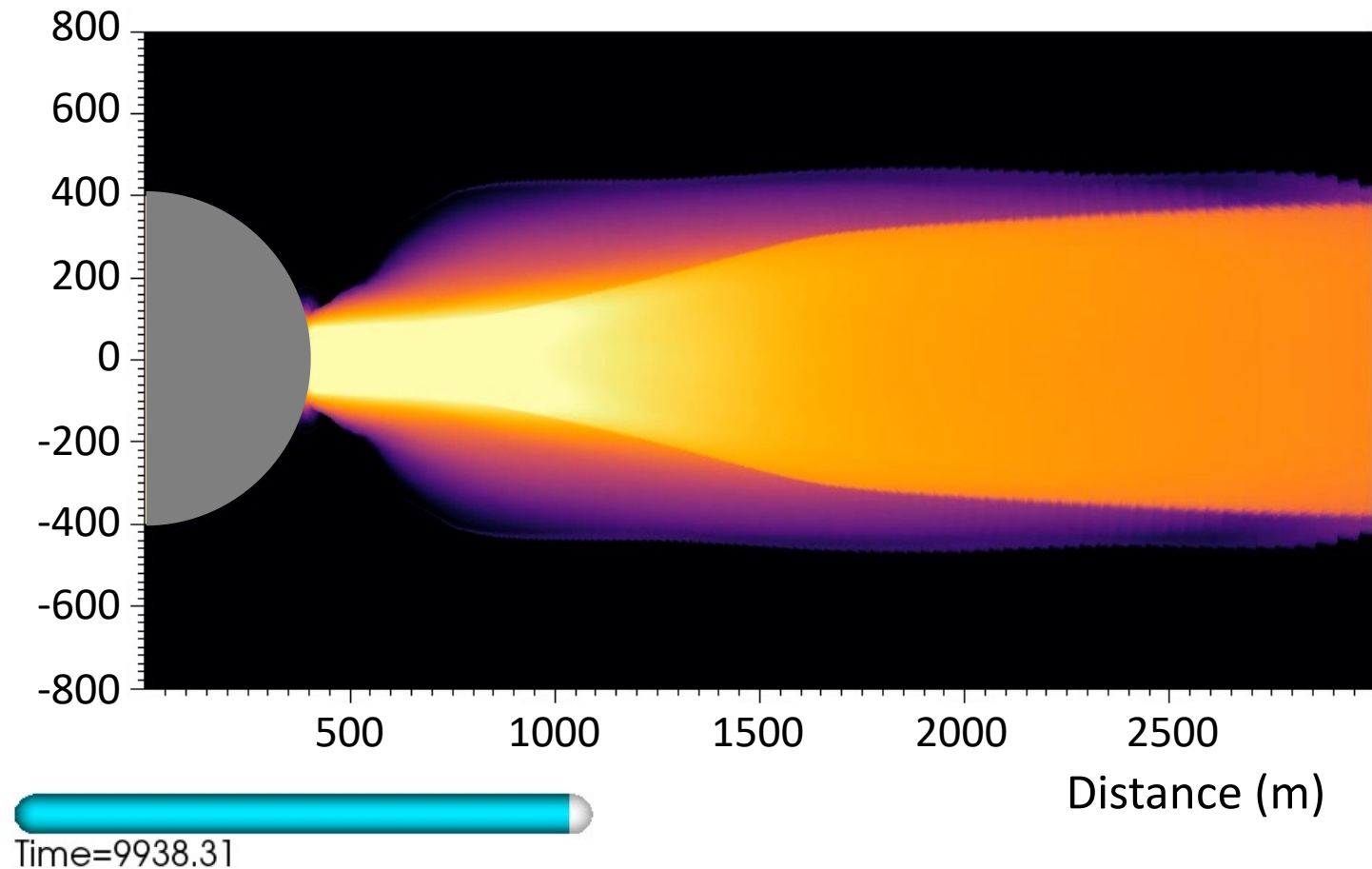
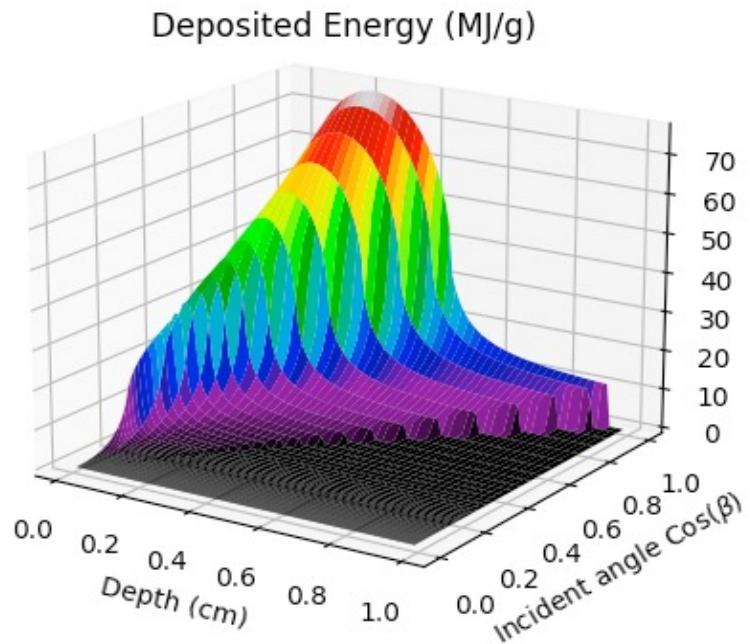
2D Suite



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

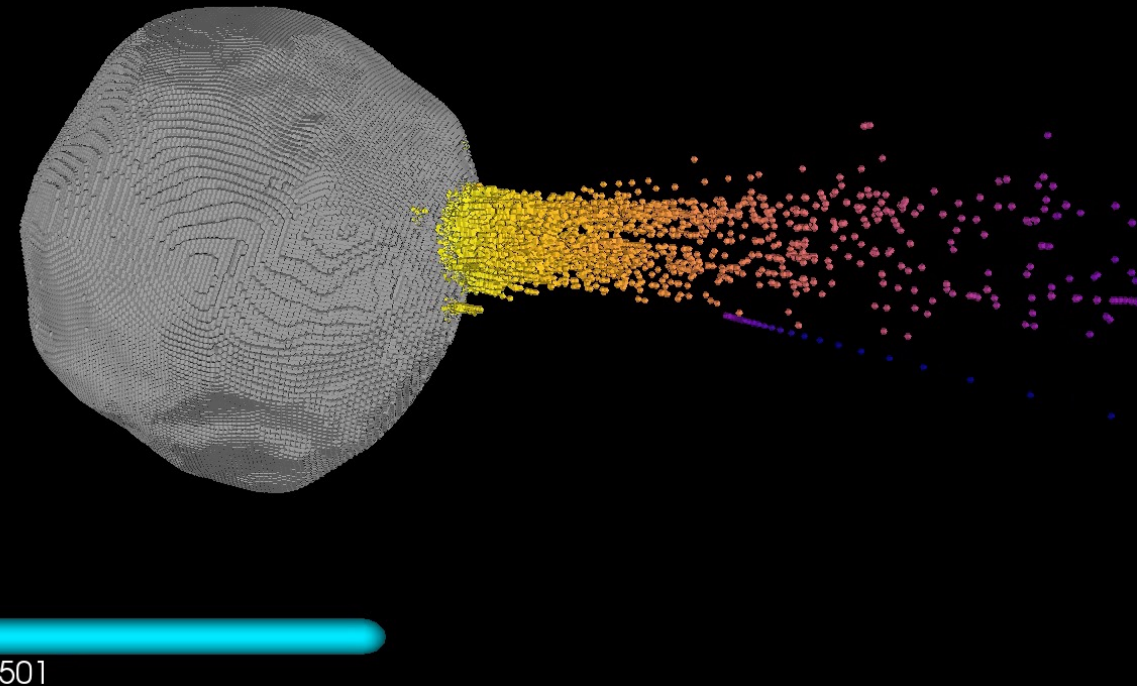
PDC Exercise test with Ares:

- 800m spherical asteroid made of SiO_2 with 21% porosity ($\rho=2.1 \text{ g/cc}$)
- 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



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