Influence of porosity on impulsive asteroid mitigation scenarios

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Eric B. Herbold, David Dearborn, Paul Miller

Lawrence Livermore National Laboratory

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Two Types of Asteroids Composed of Many Parts

Gravitational Aggregates

Example: Asteroid 25143 Itokawa

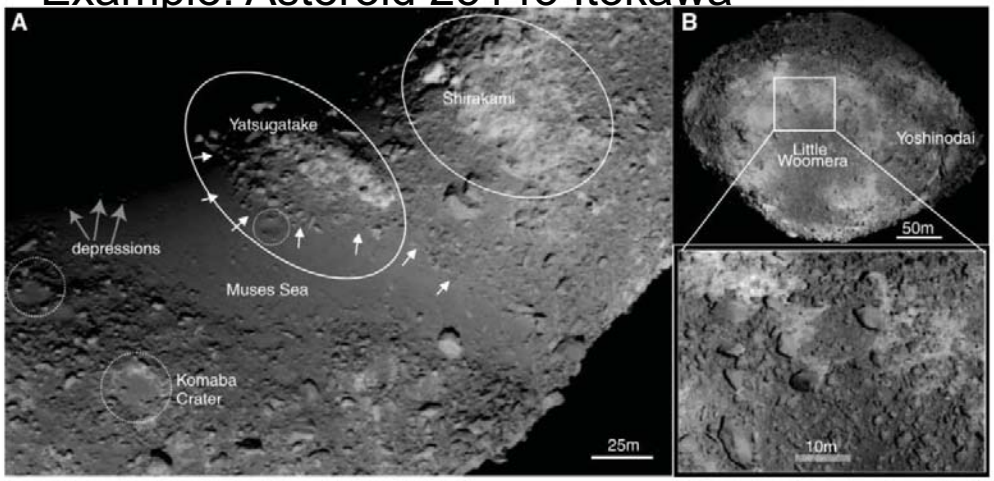


Image from J. Saito, et al, "Detailed Images of Asteroid 25143 Itokawa from Hayabusa", Science **312**, 1341 (2006)

Measurements

Mass = 3.58 10^{10} kg

Density = 1.95 g/cc

Porosity = 40%

Measurements from S. Abe, et al, "Mass and Local Topography Measurements of Itokawa by Hayabusa", Science **312**, 1344 (2006)

*Other examples are:
Mathilde [AF Cheng, Adv. Sp. Res, **33**, 1558 (2004)]
Castalia [Asphaug, et al, Nature, **393**, 437 (1998)]

Fractured Consolidated Body

Example: Eros

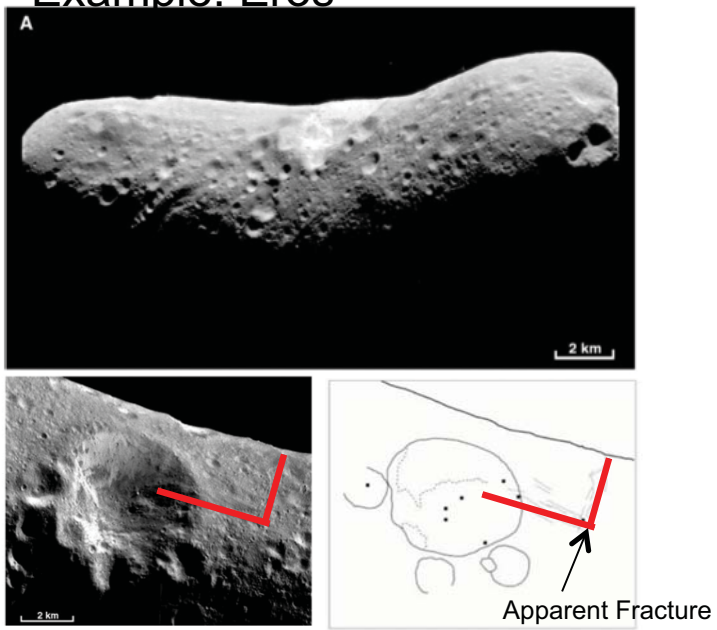


Image from J. Veverka, et al, "NEAR at Eros: Imaging and Spectral Results", Science **289**, 2088 (2000)

Measurements

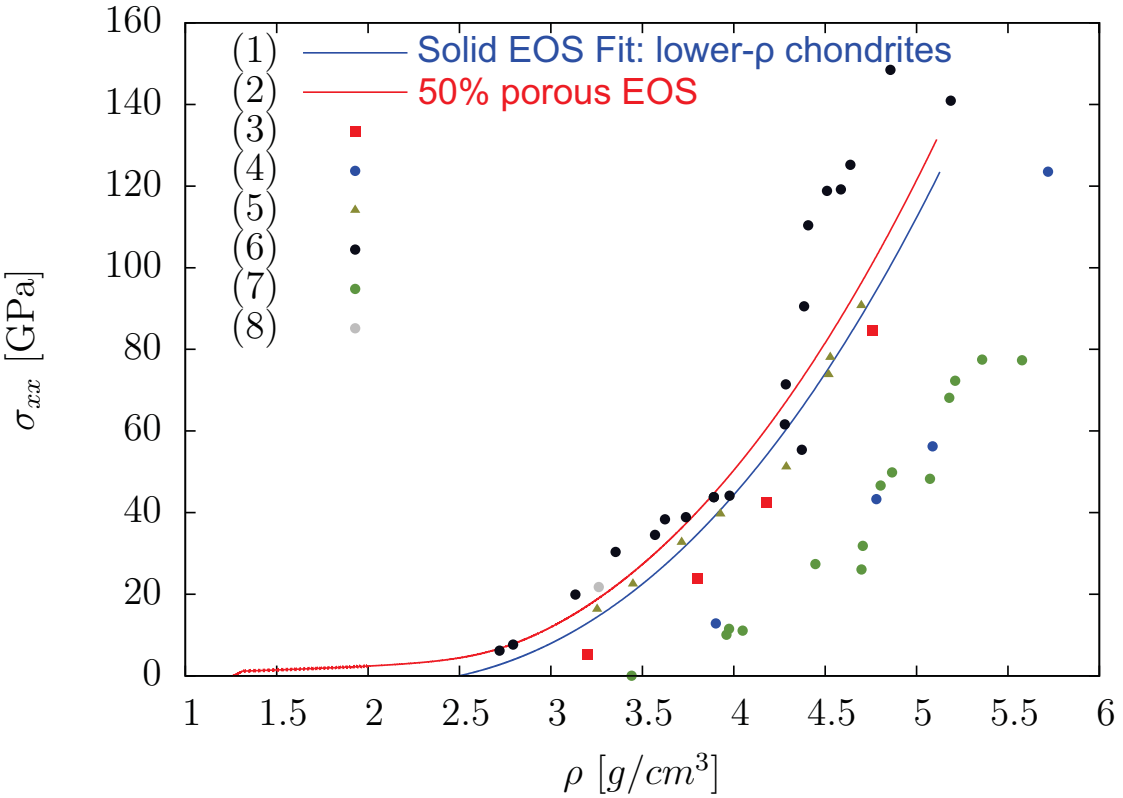
Mass = 6.81 10^{15} kg

Density = 2.67 g/cc

Porosity = 10-30%

Measurements from J. Veverka, et al, "NEAR at Eros: Imaging and Spectral Results", Science **289**, 2088 (2000)

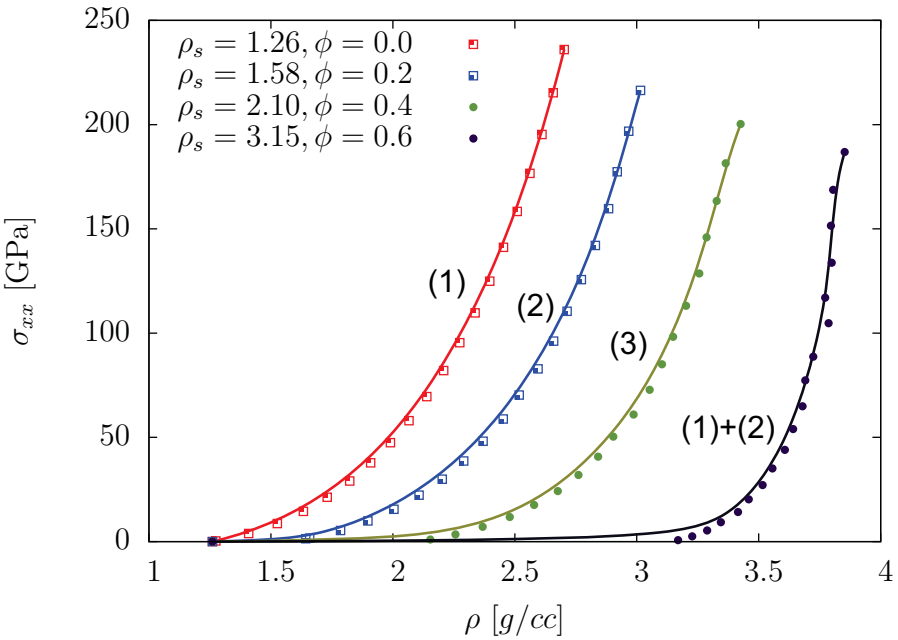
We are currently investigating advancements in EOS and constitutive models for asteroids



- Murchison (Anderson et al., 1998)
- Serpentine (Mader et al., 1980)
- Antigorite (Tyburczy et al., 1991)
- Lizardite (Tyburczy et al., 1991)
- Bruderheim (Anderson et al., 1998)
- H6 chondrite Kernouve (Schmitt, 2000)

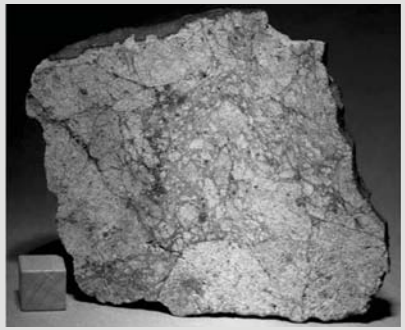
- Asteroid regolith: developing new thermomechanical constitutive models
- Strength coupled to EOS for chondritic materials

Asteroid initial density will be known more accurately than its compressibility

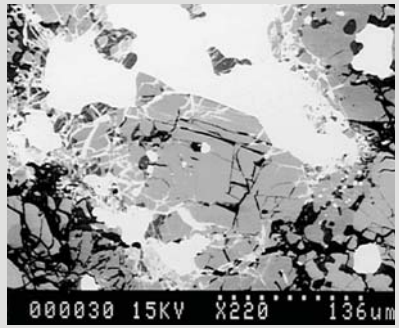


- 4 simulated materials with the same overall density (different levels of porosity).
- 1D planar shock results from 1-20 km/s shown for each material.
- Blowoff momentum from a standoff explosion or hypervelocity impact

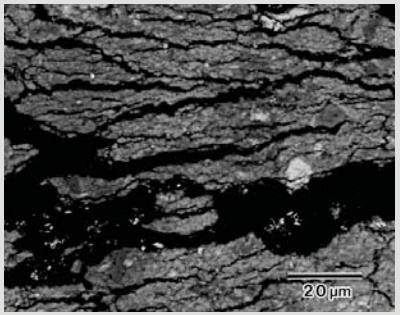
Example Chondrite Morphologies



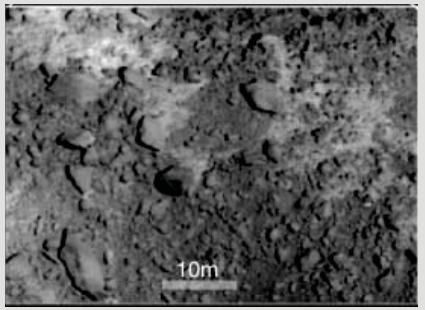
(1) Binzel, et. al., Icarus (2009)



(2) Consolmagno, et. Al. Chemi der Erde (2008)



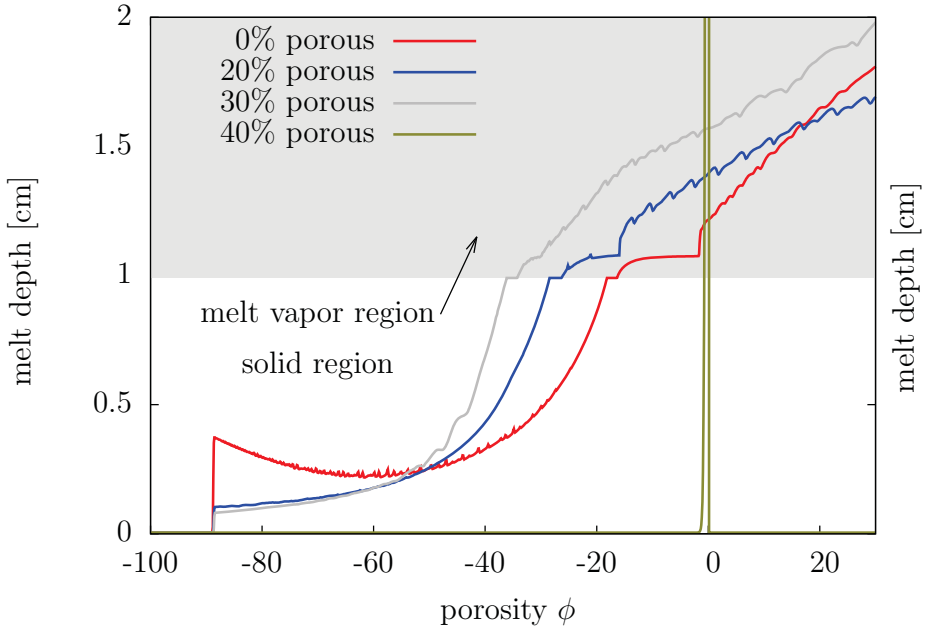
(3) Tomeoka, et. al., Geochimica et Cosmochimica Acta (1999)

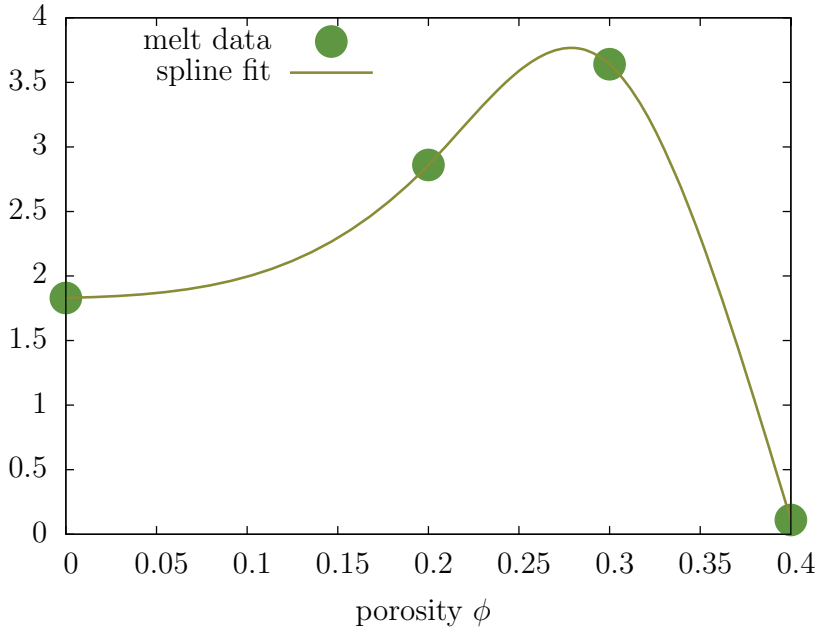


(4) Saito, et. al., Science (2006)

NEA population mostly LL chondrites [Vernazza, Nature (2008)]

Porous compaction may increase melt depth up to a precipitous drop





- Stronger shocks observed in low porosity materials
- Melt depth increases for porosities from 0-30% for our materials with ρ_0=1.26 g/cc.

- Shock wave not generated for 40% or 60% porous material with

Estimation of Boulder Sizes in Simulated Asteroids

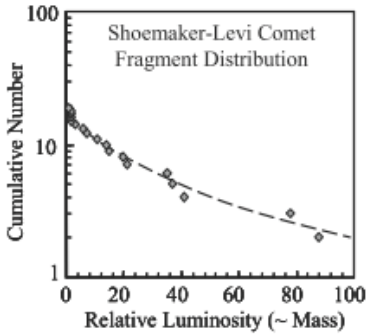


Image from D.E. Grady, "Length scales and size distributions in dynamic fragmentation", Int J Frac **163**, 85 (2010)

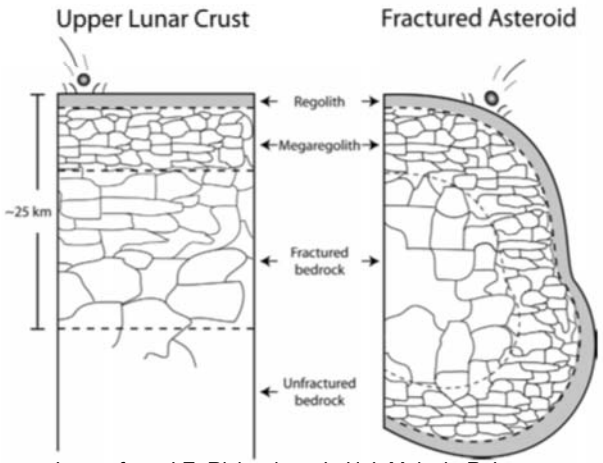


Image from J.E. Richardson Jr, H.J. Melosh, R.J. Greenberg, D.P. Obrien, Icarus, **179**, 325 (2005).

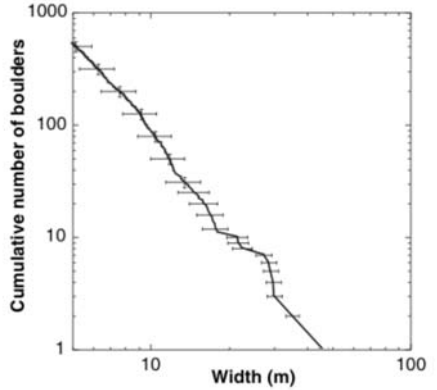
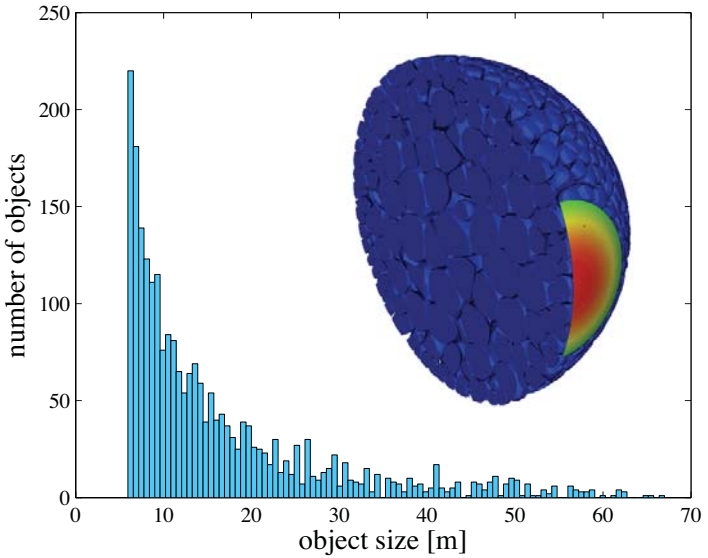


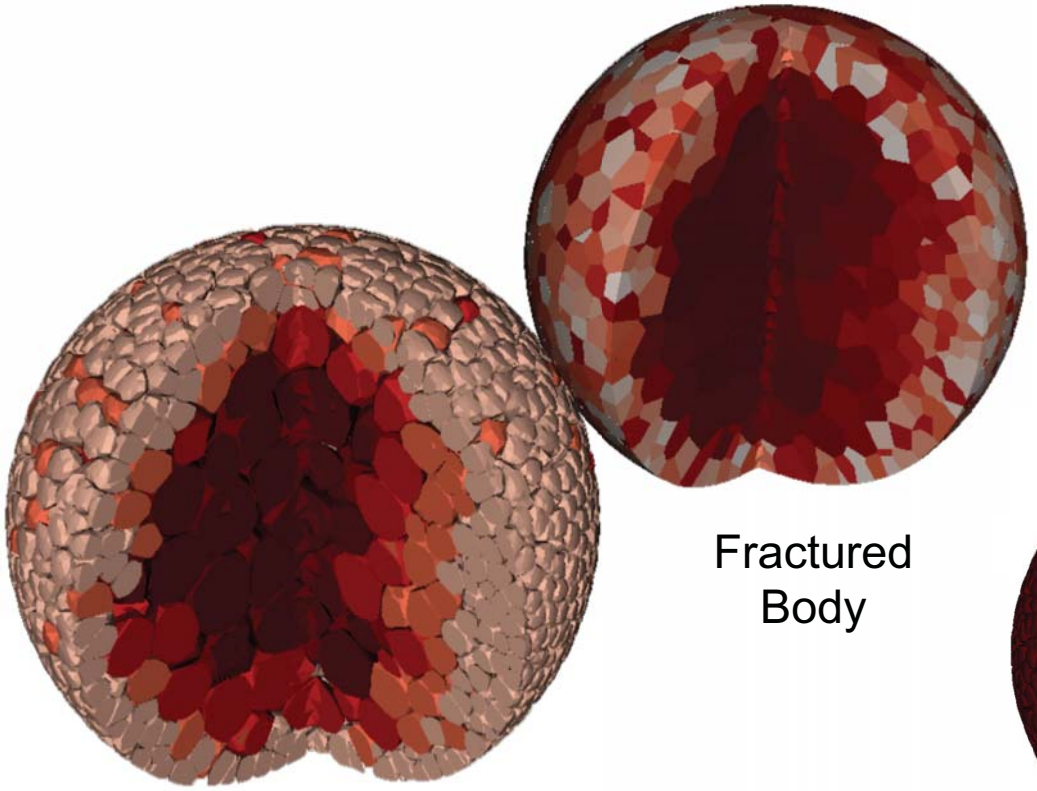
Fig. 2. Cumulative boulder size distribution on the surface of Itokawa. Horizontal axis shows the width

Image from J. Saito, et al, "Detailed Images of Asteroid 25143 Itokawa from Hayabusa", Science **312**, 1341 (2006)



Object composed of 2380 pieces

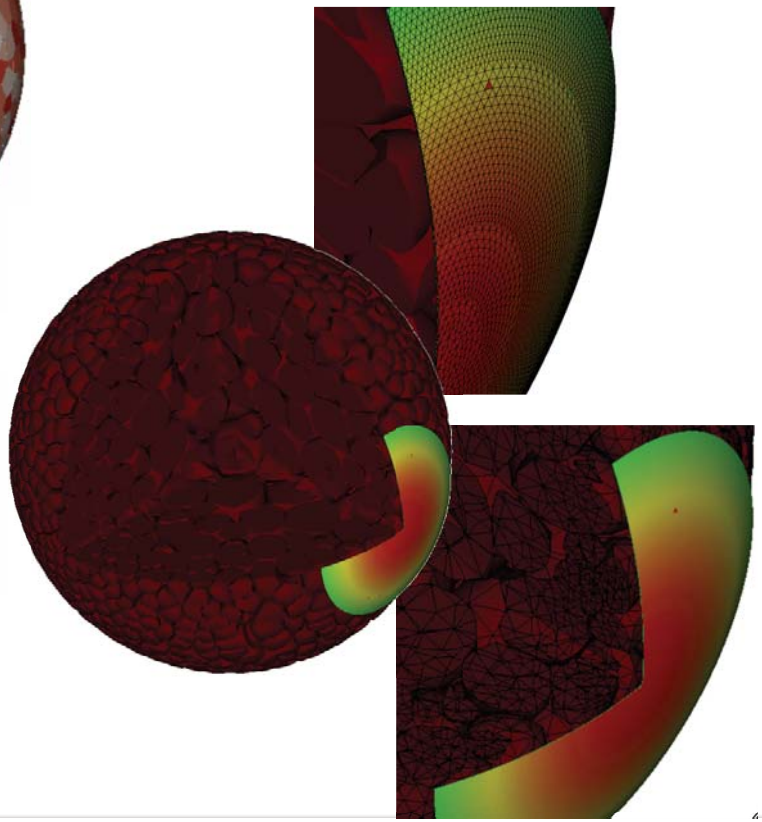
We can model fractured bodies and gravitational aggregates (rubble piles)



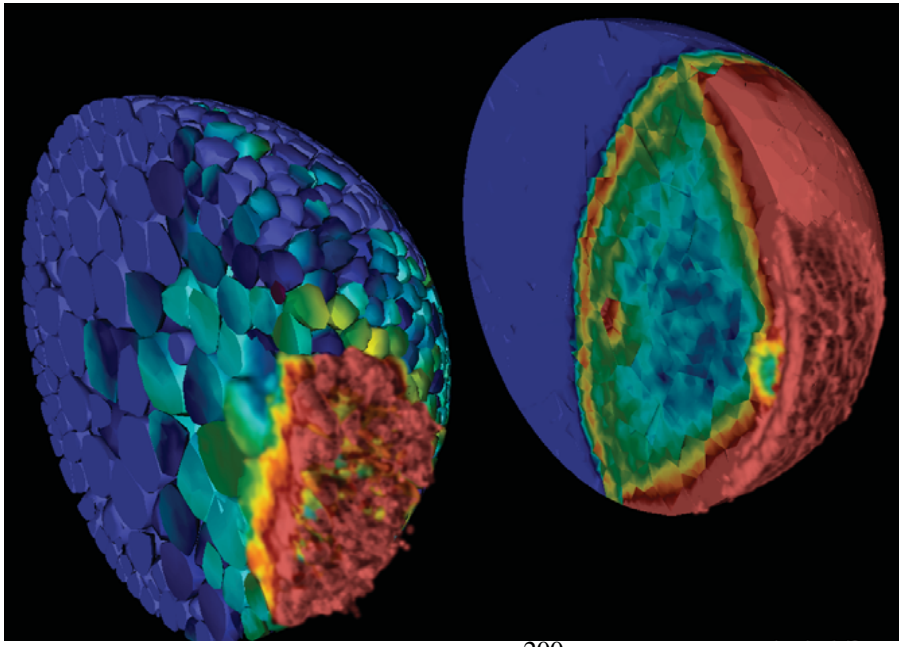
Fractured Body

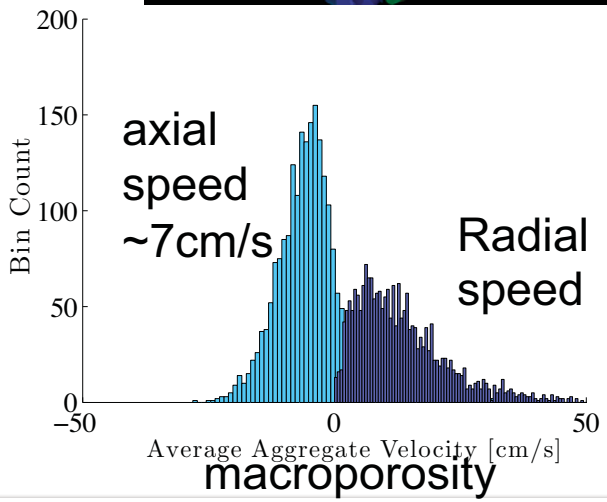
Gravitational Aggregate

Initial conditions: Energy deposited into regolith “cap”

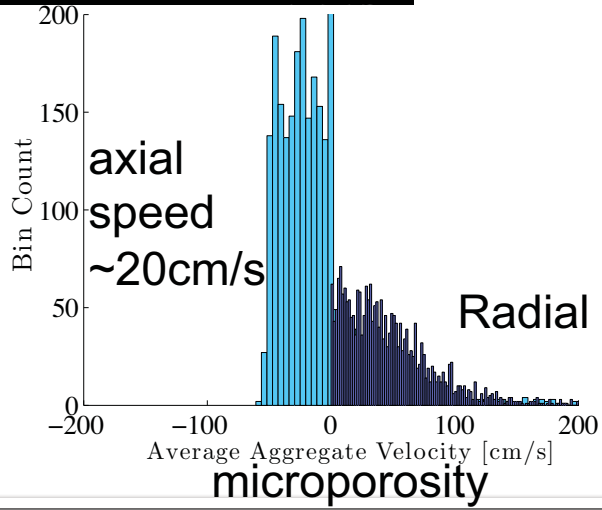


5.4 kt deposition results show better coupling for microporous object





macroporosity



microporosity

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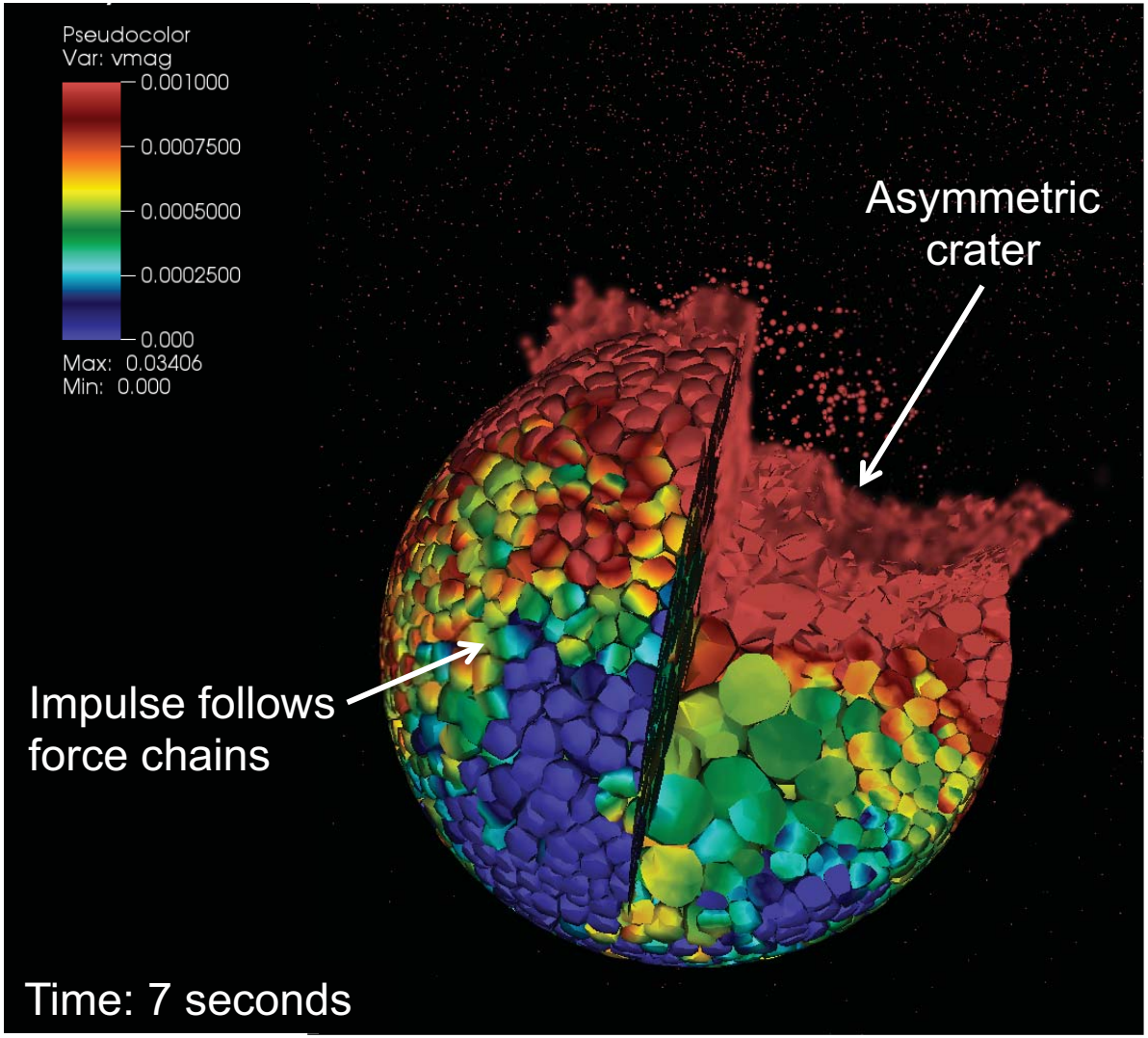

Conclusions

- For impacts and stand-off explosions alike, high porosity (micro, macro or combined) may prohibit shock wave generation.
- Comparing 4 materials with different porosities, a shock was not produced for porosities above 40%. This affects the melt depth by over an order of magnitude in 1d simulations.
- The internal structure of asteroid objects affects the dispersion of fragments meaning that if external symmetry is observed one should not necessarily expect a linear response (i.e. may generate rotation due to internal structure too)