

SPH simulations for space defense

Maximilian Rutz

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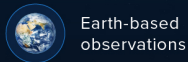
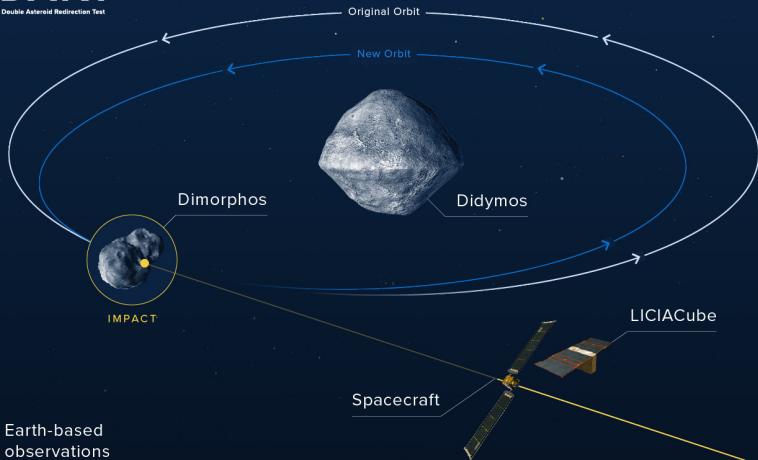
Roadmap

1 Dart and Hera missions

2 SPH setup

3 SPH results

Dart and Hera missions



Dart Mission

- Launch in July 2021 on a SpaceX Falcon 9
- Impact in fall 2022
- Impact at 0.04 au to Earth, 15x Earth-Moon, 1/10x Earth-Mars
- Observations with LICIACube and earth based telescopes

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- Launch in 2024
- Arrival in 2026
- Why a second mission?
 - Dust cloud after impact
 - Reduce uncertainty of orbital shift
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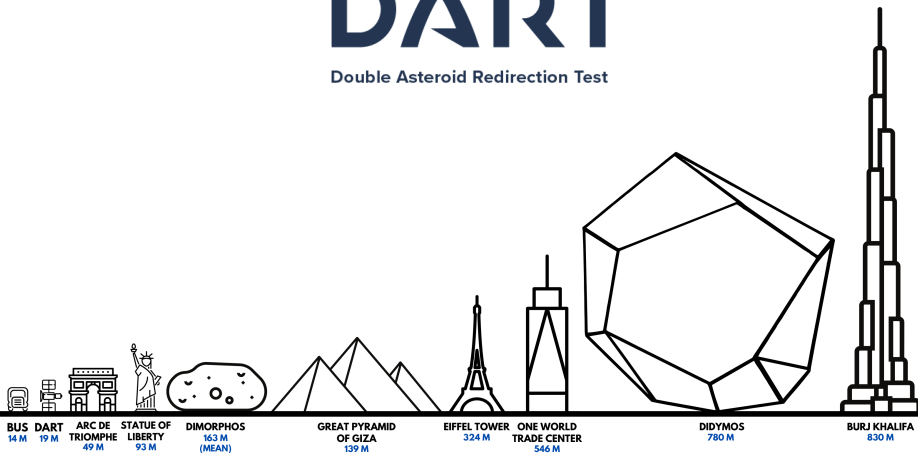
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DART

Double Asteroid Redirection Test



SPH setup

Simulation goals

Compare numerical results with observations to:

- 1 test numerical codes
- 2 identify target properties through parameter studies

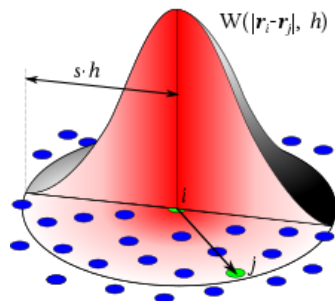
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Smoothed Particle Hydrodynamics

- gridfree method
- particles move through space with a velocity
- particles carry physical quantities like density, pressure or energy
- hydrodynamic/continuum mechanics equations can be solved for every particle
- spatial resolution



Simulation scenario

Target:

- 160 meter diameter
- important parameters such as porosity and strength unknown

Impactor:

- 500 kg mass
- 6 km/s impact velocity
- main body $1.3 \times 1.2 \times 1.2$ meter

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Miluphcuda solid models

- fragmentation for brittle materials
- p- α porosity model
- shear strength
- no self gravity

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Initial conditions

IMAGE 1st frame

Initial conditions

Target:

- basalt
- 20 meter diameter halfsphere
- constant smoothing length in center

Impactor:

- aluminum
- 0.75 meter diameter sphere
- 6 km/s impact velocity
- 500 kg mass
- same smoothing length as center of target

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SPH results

Beta factor

Momentum change because of ejecta: $\beta = 1 + \frac{p_{\text{ejecta}}}{p_{\text{impactor}}}$

Particles considered ejecta:

- 1 impactor diameter above surface
- absolute velocity above gravitational escape velocity
- positive velocity in z direction

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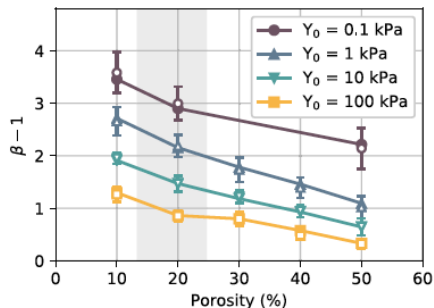
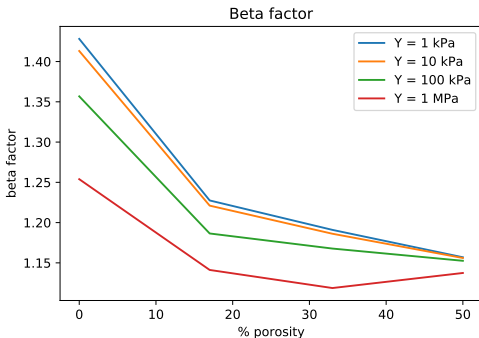


Table 1. Results from Spherical calculations for material with various compositions

Material	Porosity	Strength	Density g/cm ³	Δv (cm/s)	β
Granite	0.2	1 MPa	2.16	0.099	1.353
Basalt	0.2	1 MPa	2.16	0.102	1.391
Pumice	0.2	1 MPa	2.16	0.093	1.277
Granite	0.4	1 MPa	1.62	0.126	1.288

Beta factor other literature Stickle

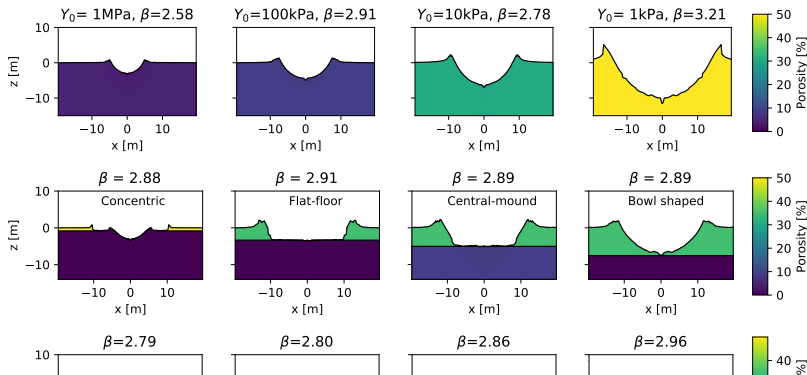
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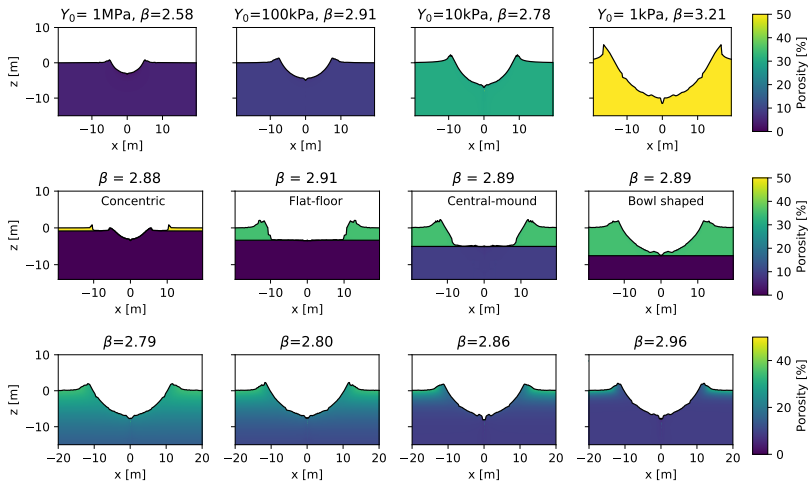
The DART impact into different targets can produce the same β , but different craters.

Measurements of **both** β and crater size/morphology **together** can be diagnostic of target properties.



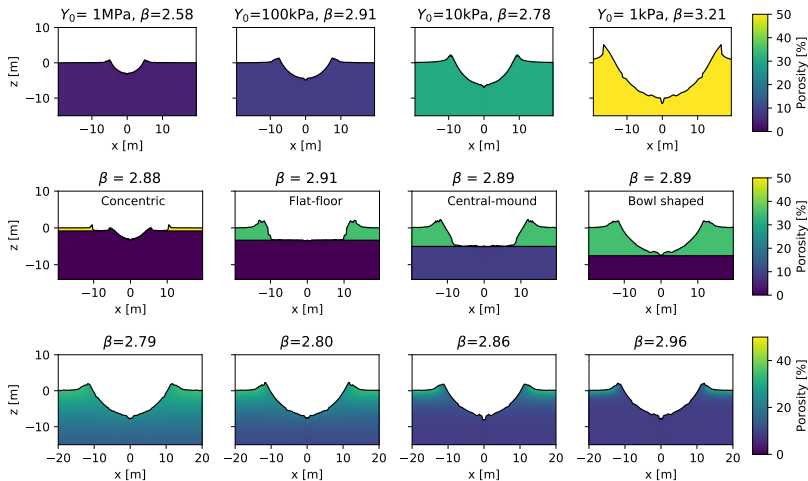
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Personal observations about SPH

- A lot of individual physics implementable
- interaction between physical models within a code can get complex
- Many different codes available
- Difficult to reproduce and compare results between different codes
- Dart setup could be useful as benchmark for solid models

Sources and additional information

Illustrations taken from Dart and Hera websites:

- <https://dart.jhuapl.edu/>
- <https://www.nasa.gov/planetarydefense/dart>
- https://www.esa.int/Safety_Security/Hera

Papers:

- "Modeling impact outcomes for the Double Asteroid Redirection Test (DART) mission", Stickle et al., Procedia Engineering 2017
- "The role of asteroid strength, porosity and internal friction in impact momentum transfer", Raducan et al., Icarus 2019