SPH simulations for space defense

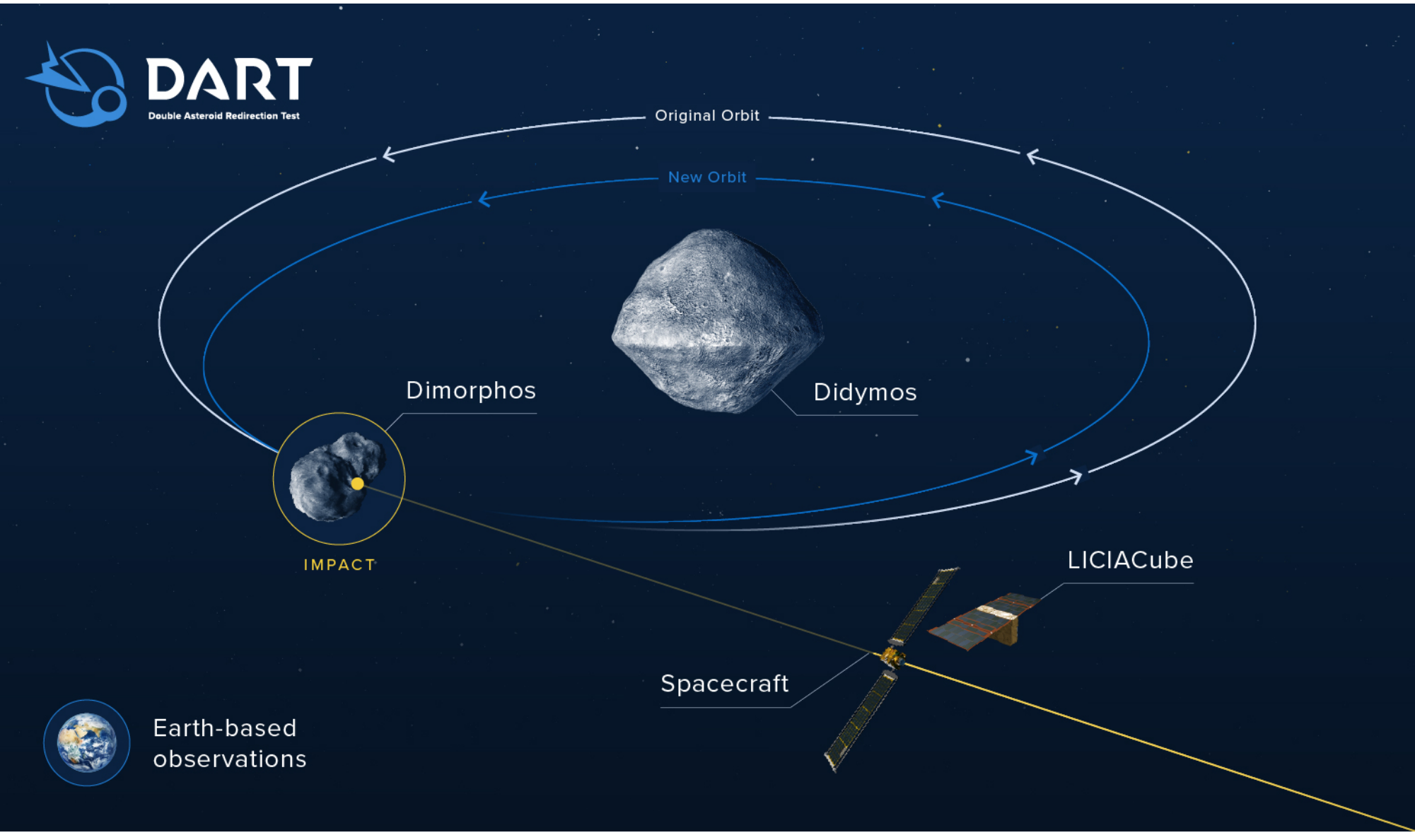
Maximilian Rutz

July 17, 2020

Roadmap

1. Dart and Hera missions
2. SPH setup
3. SPH results

Dart and Hera missions


DART
Double Asteroid Redirection Test
Original Orbit
New Orbit
Dimorphos
Didymos
IMPACT
LICIACube
Spacecraft
Earth-based
observations

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
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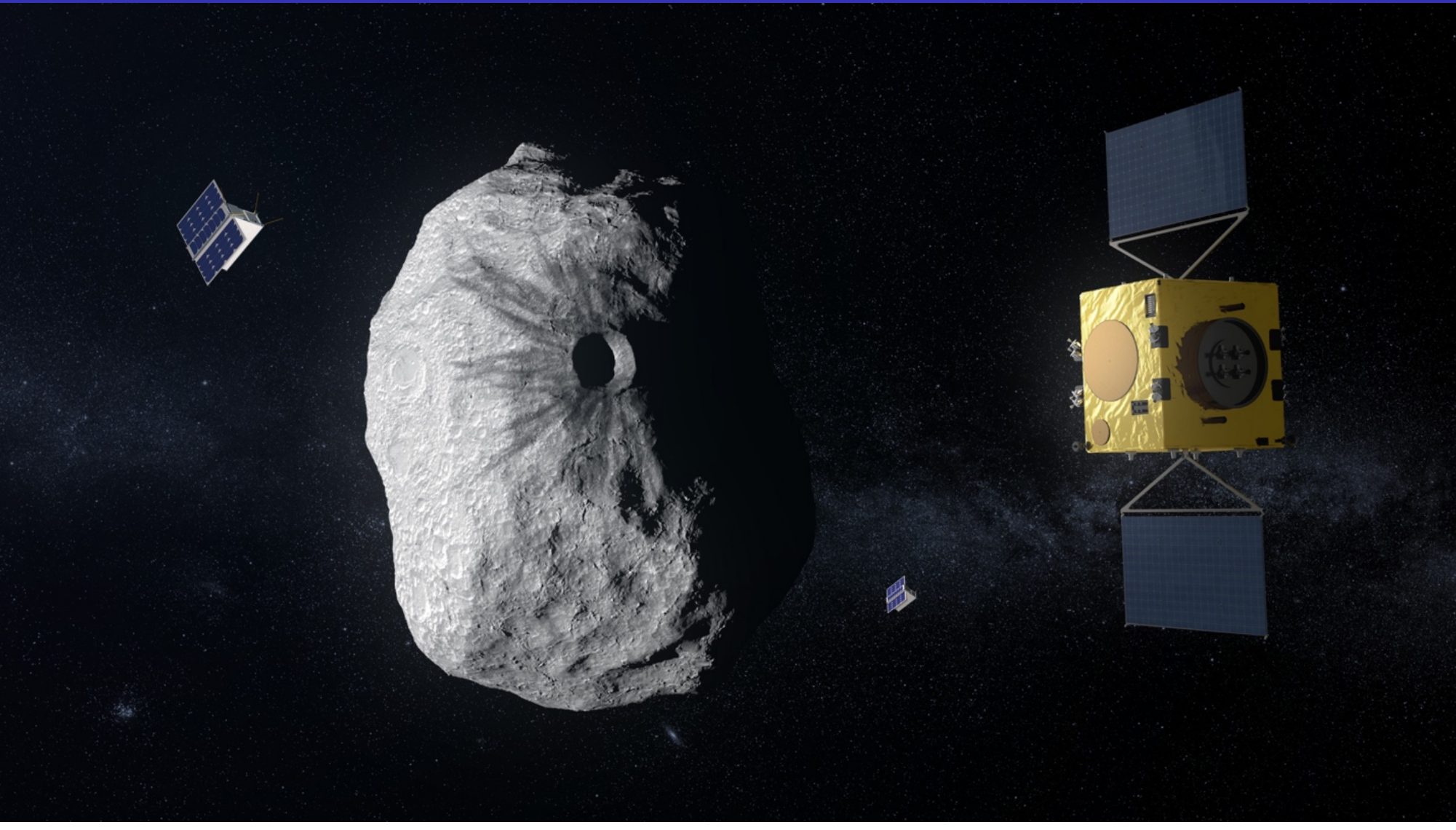
Hera Mission



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- Arrival in 2026
- Why a second mission?
  - Dust cloud after impact
  - Reduce uncertainty of orbital shift
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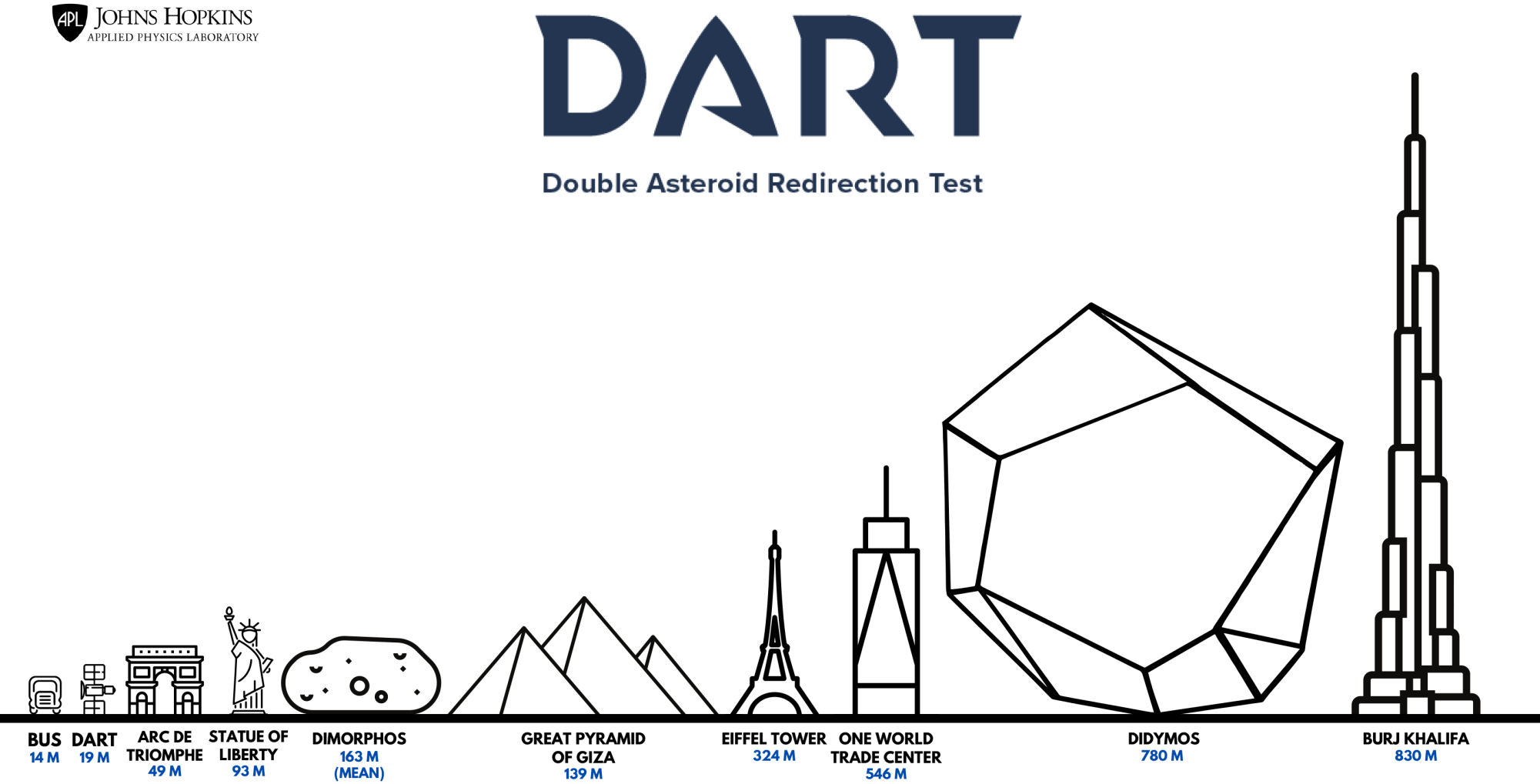
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
DART
Double Asteroid Redirection Test
BUS 14 M
DART 19 M
ARC DE TRIOMPHE 49 M
STATUE OF LIBERTY 93 M
DIMORPHOS 163 M (MEAN)
GREAT PYRAMID OF GIZA 139 M
EIFFEL TOWER 324 M
ONE WORLD TRADE CENTER 546 M
DIDYMOS 780 M
BURJ KHALIFA 830 M

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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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 x 1.2 x 1.2 meter

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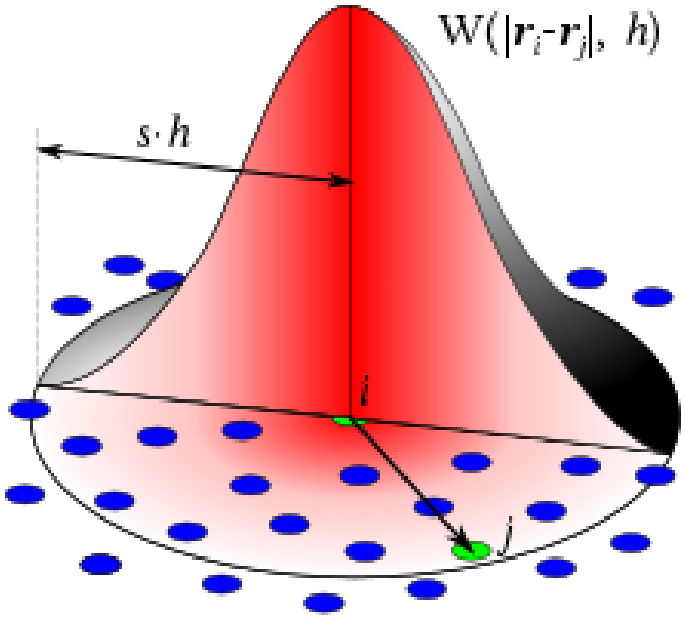
Smoothed Particle Hydrodynamics

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



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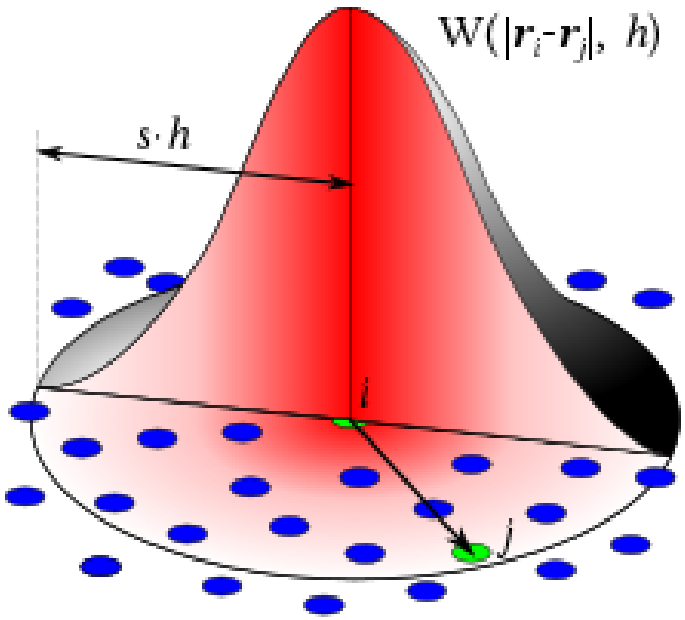

SPH Code

Miluphcuda:

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Miluphcuda setup

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- Runge Kutta fourth order integrator
- no self gravity
- p-α porosity - micro vs macroporosity

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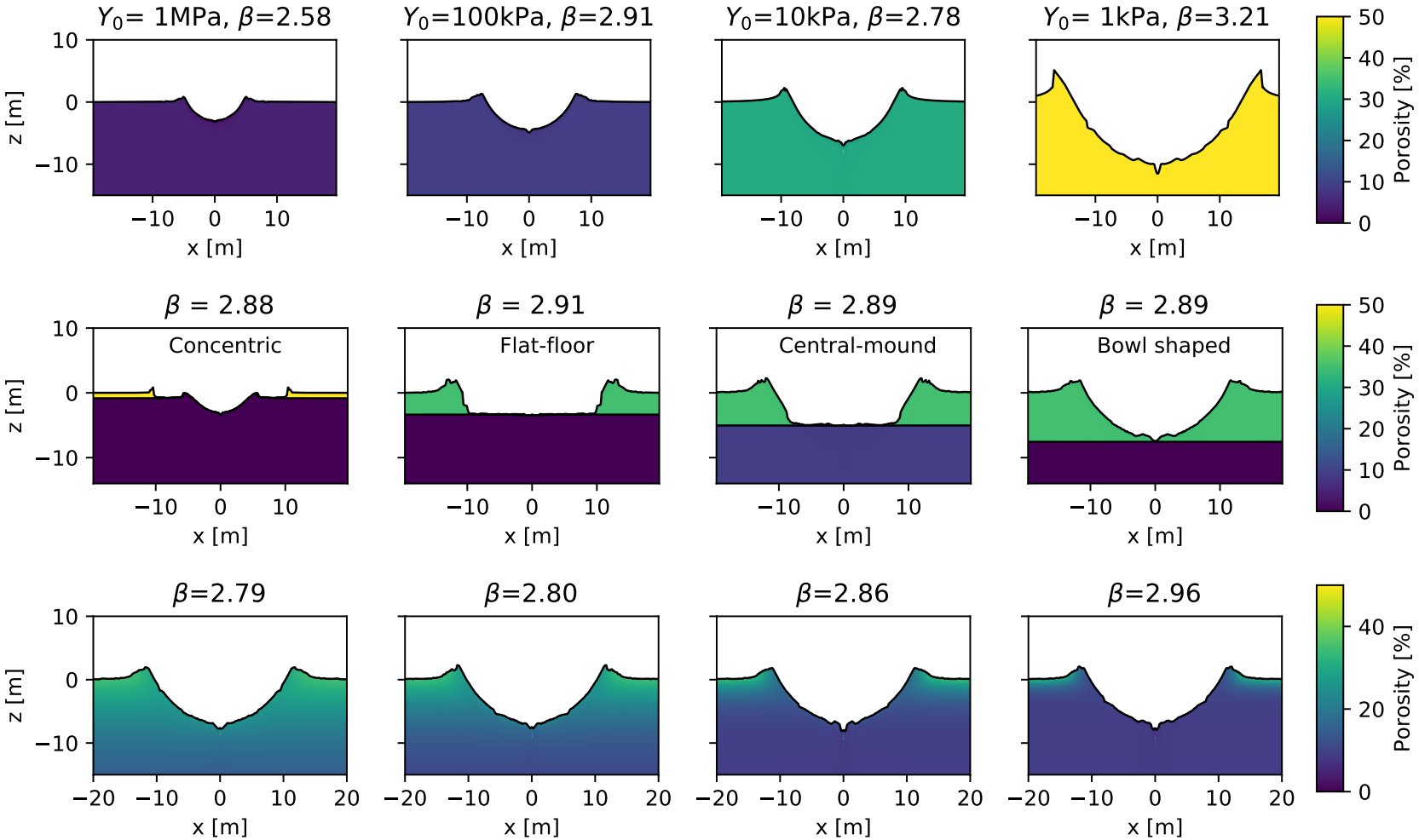
SPH results

Beta factor

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

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.



Raducan et al. (2020), PSS

Personal observations about SPH

- A lot of individual physics implementable
- Many different codes available
- Difficult to reproduce and compare results between different codes
- Dart setup could be useful as benchmark

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