The ESA Hera mission: planetary defense and science return

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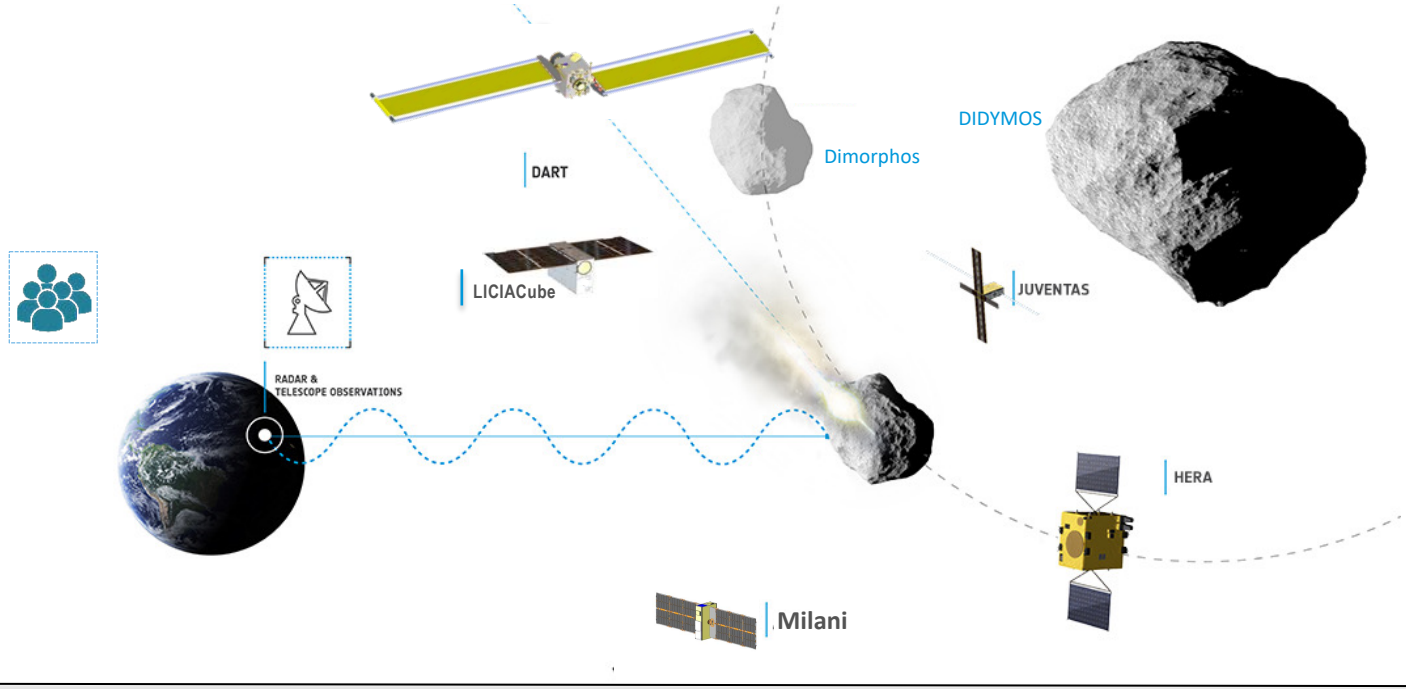
On behalf of the Hera Science Team

7th IAA Planetary Defense Conference

AIDA international collaboration



AIDA

Synergy from

DART

First demonstration of asteroid deflection by kinetic impact on Dimorphos, to change its orbit

with

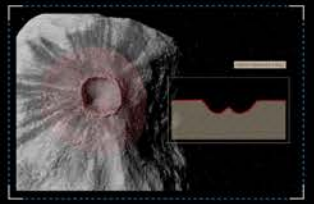
LICIACube

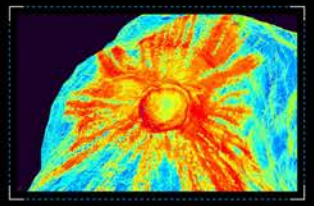
First prompt imaging of the impacted surface, ejecta plume evolution and of the non-impacted hemisphere of Dimorphos

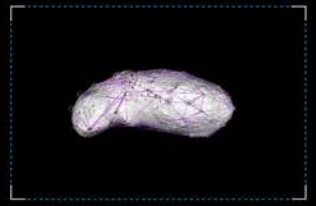
+

Mass of Dimorphos
Detailed dynamical characterization
Detailed investigation of final crater
Overall characterization of the asteroids

Hera mission scenario







08/10 2024
HERA LAUNCH

DETAILED CRATER SHAPE INVESTIGATION

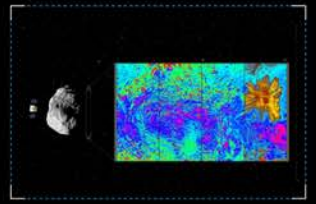
DETAILED SUBSURFACE CRATER INVESTIGATION

AUTONOMOUS PROXIMITY OPERATIONS DEMONSTRATION

MULTI-POINT ASTEROID INVESTIGATION
low-frequency radar, multispectral imager, dust dector, gravimeter.

DIDYMOS

2.3 YEARS CRUISE



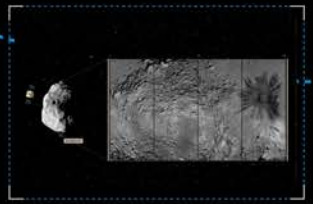
2 x Asteroid Framing Cameras
2 x 6U CubeSats
Laser Altimeter
Thermal Infrared Camera (JAXA)
Hyperspectal Imager

LANDING ON DIDYMOS
MISSISON ENDS

DETAILED CHARACTERISATION PHASE
Measuring surface and interior properties

28/12 2026
ASTEROID ARRIVAL

DIMORPHOS

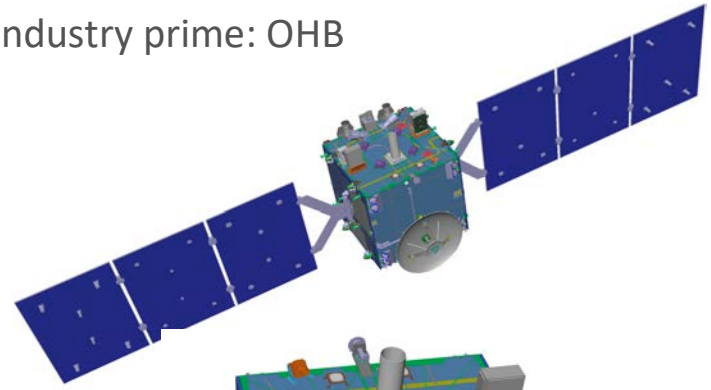


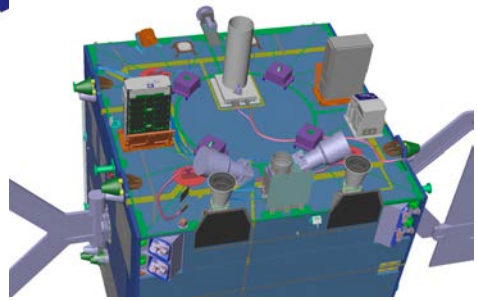
CUBESATS RELEASE

EARLY CHARACTERISATION PHASE
Measuring mass and dynamics

Hera spacecraft, payloads and 2 Cubesats

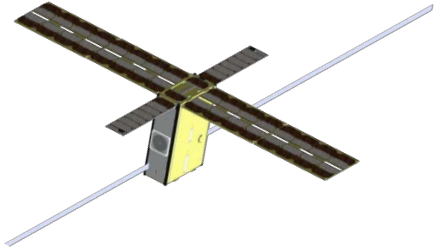
Industry prime: OHB

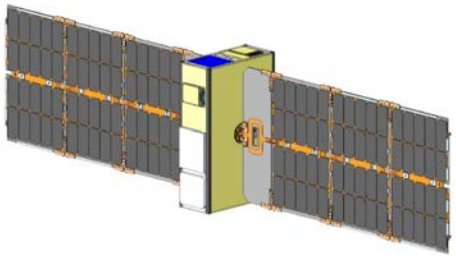




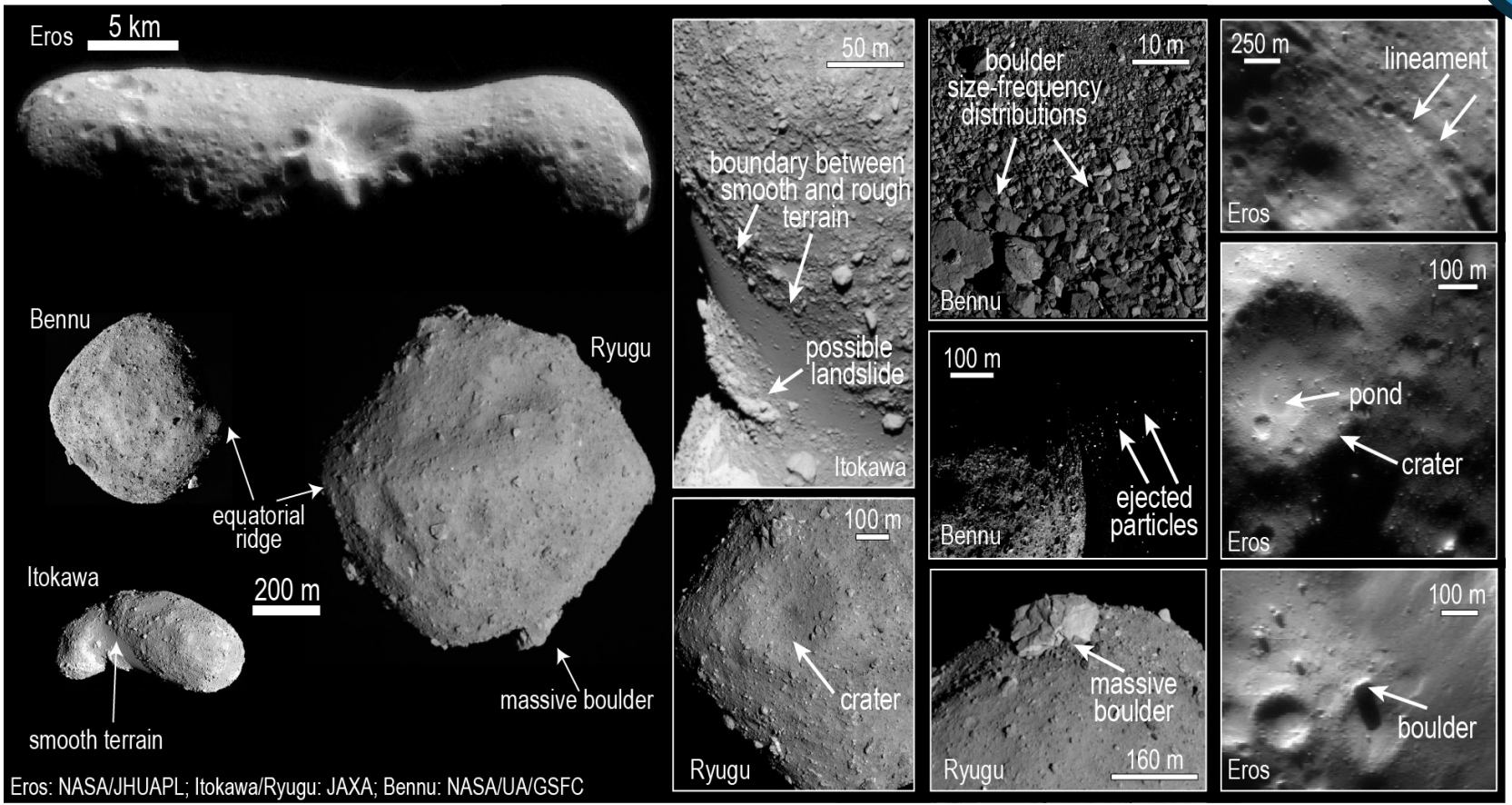
+ ISL and RadioScience

- **Asteroid Framing Camera**
- **LIDAR** (PALT)
- **Thermal Infrared Imager** (TIRI)
- **Hyperspectral Imager** (Hyperscout-H)
- **Juventas Cubesat** (internal structure, gravity field, surface properties)
- **Milani Cubesat** (Mineralogy, space weathering, dust detection, gravity field)

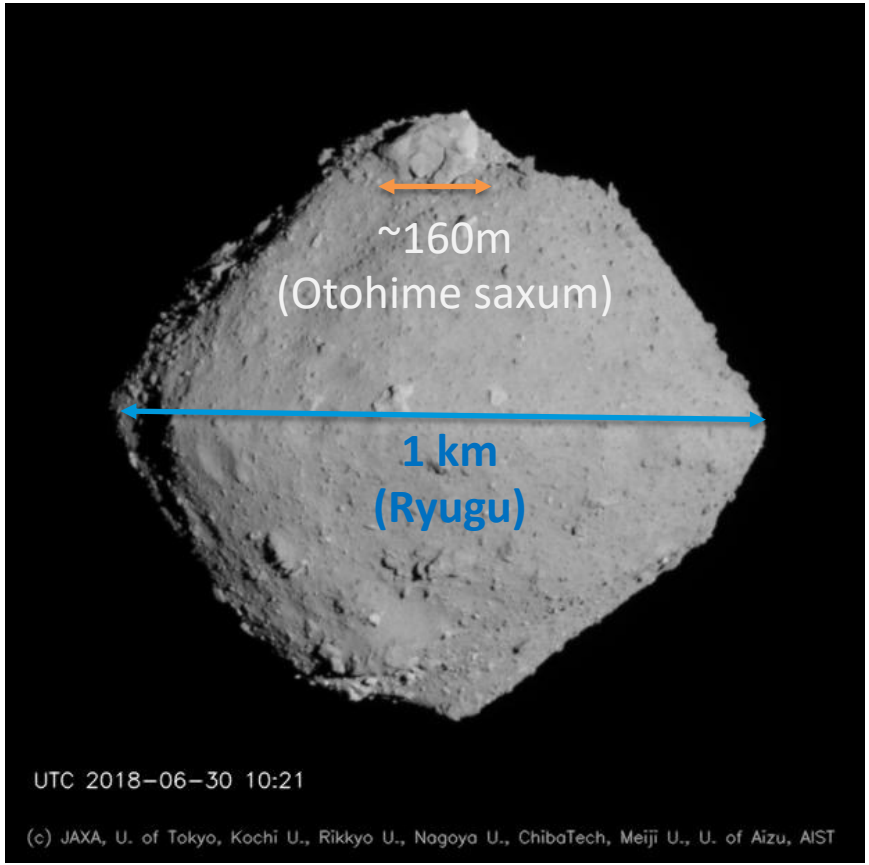


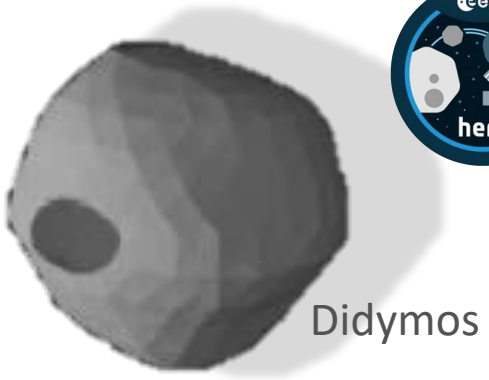


Asteroids:
An incredible and fascinating geological and compositional diversity



Dimorphos vs Ryugu (Hayabusa2)





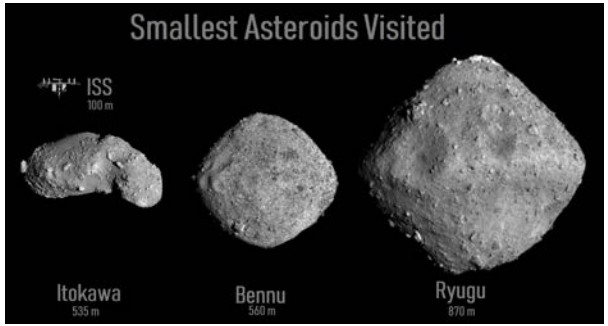
Hera mission firsts

- **First rendezvous** mission to a **binary asteroid**
- **First** characterization of an asteroid in an **intriguing size range**
- **First** radar sounding **(internal structure) of an asteroid**
- **First** full scale **cratering physics experiment** (with DART)

Hera in the context of Hayabusa2 and OSIRIS-REx

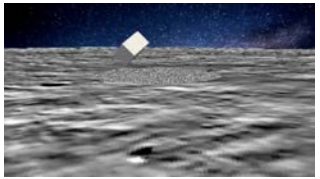
- **First detailed characterization and surface response of 2 primitive asteroids in different gravity conditions**

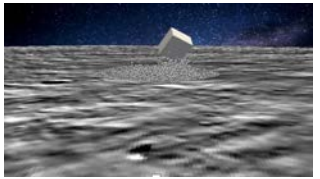
  - Ryugu is 900 meter wide
  - Bennu is 500 meter wide



Credits: NASA/Goddard/University of Arizona

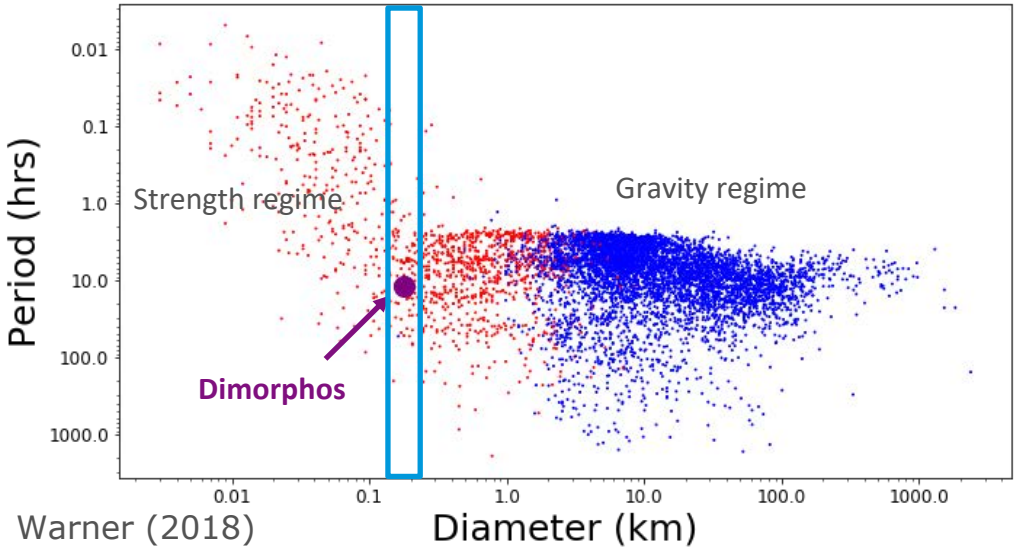
- **Dimorphos is ~ 3 times less wide than Bennu**
  - Another step in low gravity levels
  - **Possibility to understand how some processes scale with gravity down to the low-g of Dimorphos**



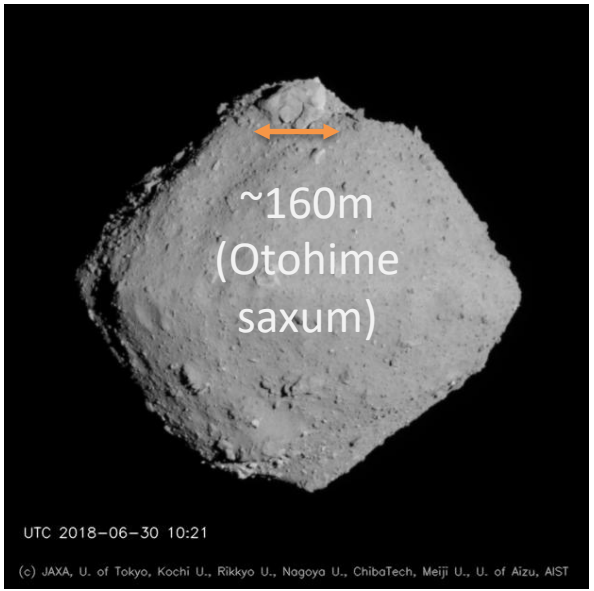


Dimorphos: in a very interesting size range

First detailed characterisation (**including interior**) of an asteroid at the transition between strength (cohesion) and gravity-dominated bodies

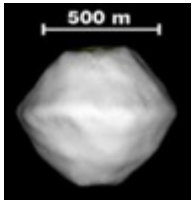


Warner (2018)

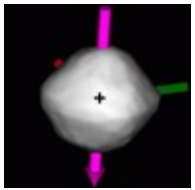


New knowledge in our understanding of asteroid geophysics and impact response (with DART)

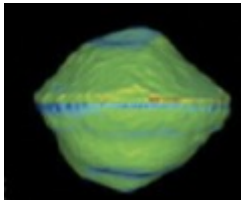
Didymos and the prevalence of « spinning tops »



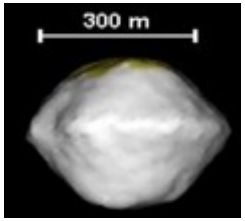
Triple Asteroid 1994 CC Brosovic et al. 2011



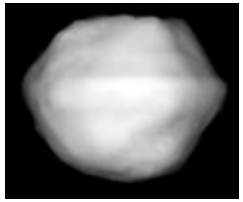
Single Asteroid Bennu Howell et al. 2008, ACM



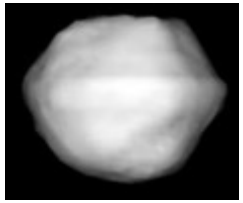
Binary Asteroid 1999 KW4 Ostro et al. 2005



Single Asteroid 2008 EV5 Busch et al. 2011

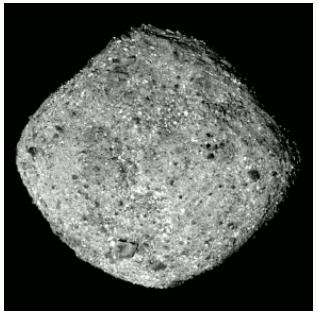


Triple Asteroid 1996 SN263 Becker et al. 2008



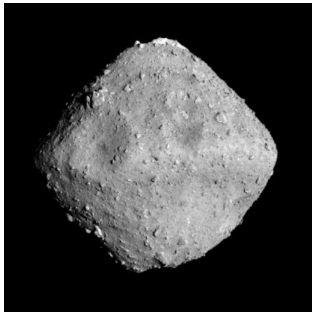
Binary Asteroid 2004 DC Taylor et al. 2008, ACM

Bennu



Credit: NASA

Ryugu



Credit: JAXA, University of Tokyo, et al.

- Ryugu and Bennu are top shapes possibly formed early by disruption/reaccumulation !!! (Michel, P. & Ballouz R.-L. et al. 2020)
- **But both Ryugu and Bennu are single!**
- **What does a top shape binary primary look like?**

First detailed investigation of a binary asteroid

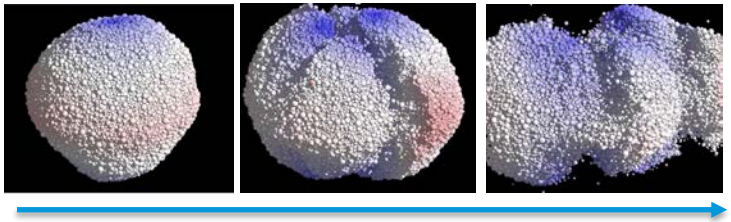
15% of NEAs are binaries

- YORP mass shedding?
- Are Didymos and Dimorphos rubble piles?

Key knowledge to understand Solar System accretion processes

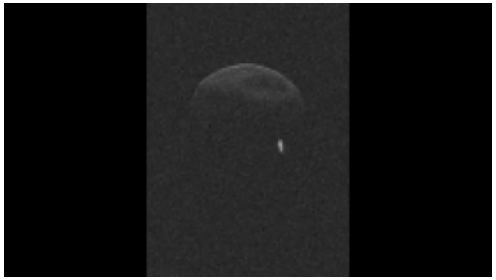
- First asteroid visited near disruption limit
- Insights on formation or disruption of planets

Didymos spin-up evolution



Spin-up

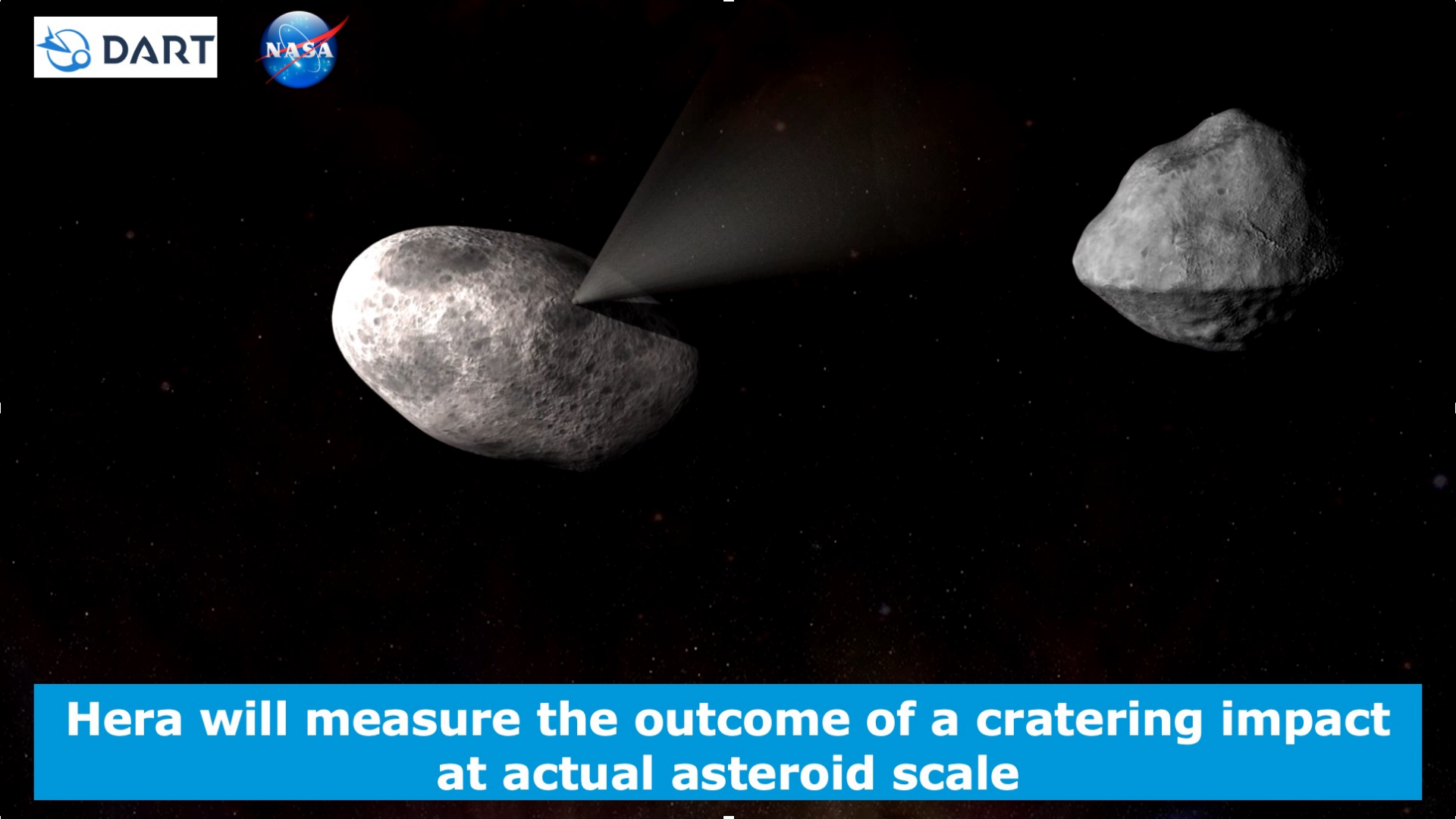
Zhang et al. 2021, Icarus 362



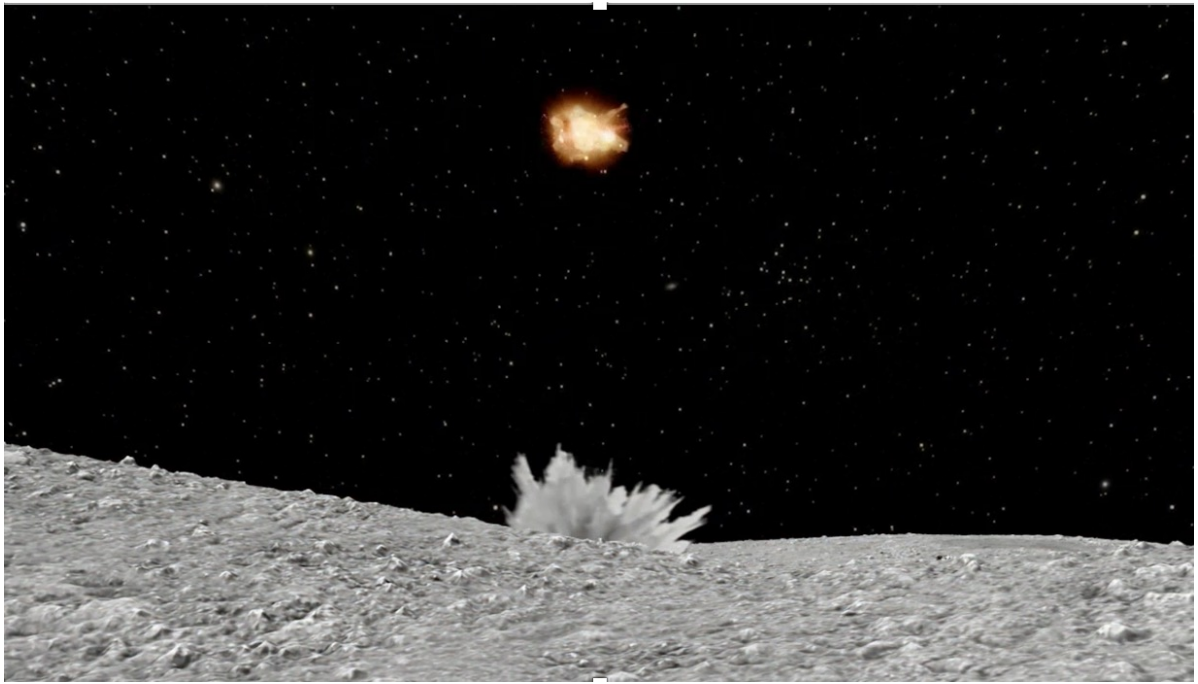
1998 QE2

2004 BL86

2014 JO25

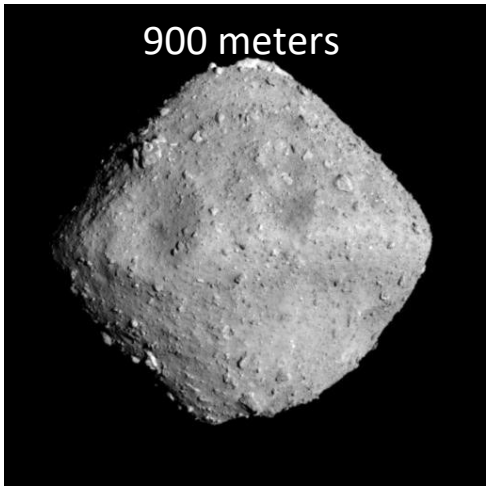

DART
NASA
Hera will measure the outcome of a cratering impact
at actual asteroid scale

Cratering physics: Hayabusa2 versus Hera



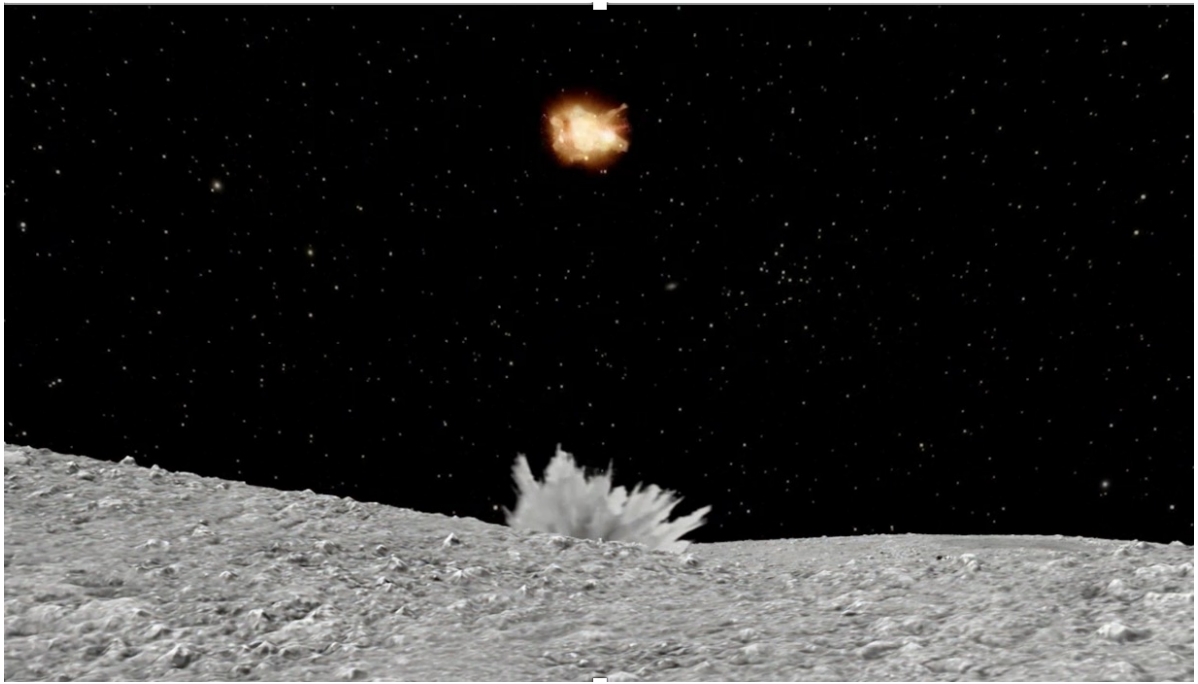
Hayabusa2 Small Carry-on Impactor
April 5, 2019

Arakawa et al. 2020, Science



Credit: JAXA, Univ. Tokyo et al.

Cratering physics: Hayabusa2 versus Hera



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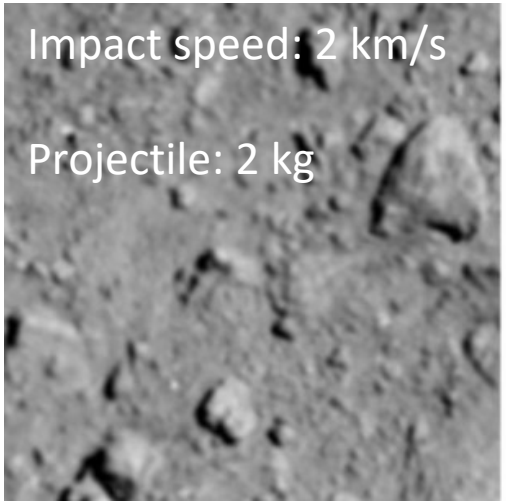
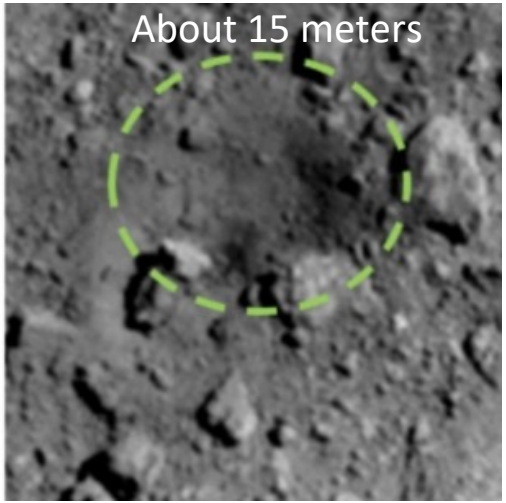
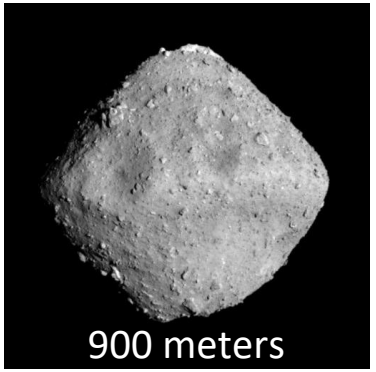






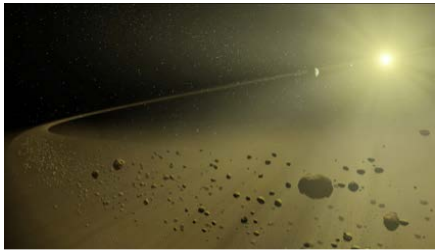
Credit: JAXA, Univ. Tokyo et al.

The large size of the crater can only be explain if the surface has no cohesion, which is a surprize! **Strong implications on surface age**

What about a 165 m-size body? And how does cratering scale with impact speed (from 2 to 6 km/s)?

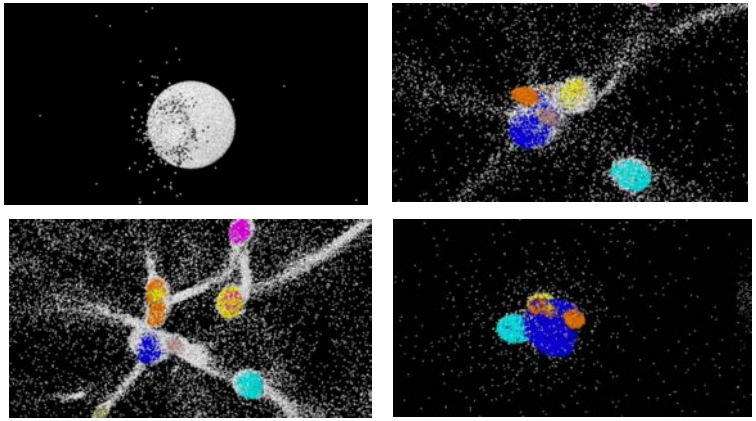
Understanding collisions in space

Planetesimal formation



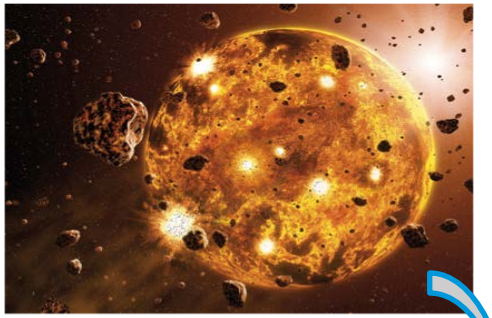
Collisional accretion

EARLY PHASES

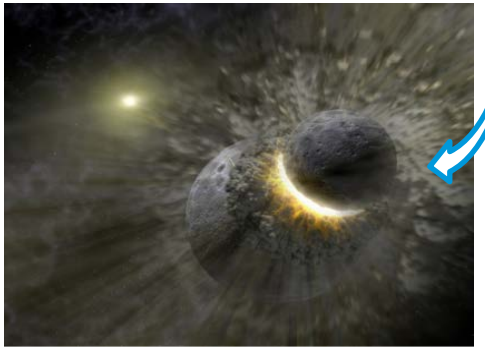


Michel & Richardson 2013

Planet formation



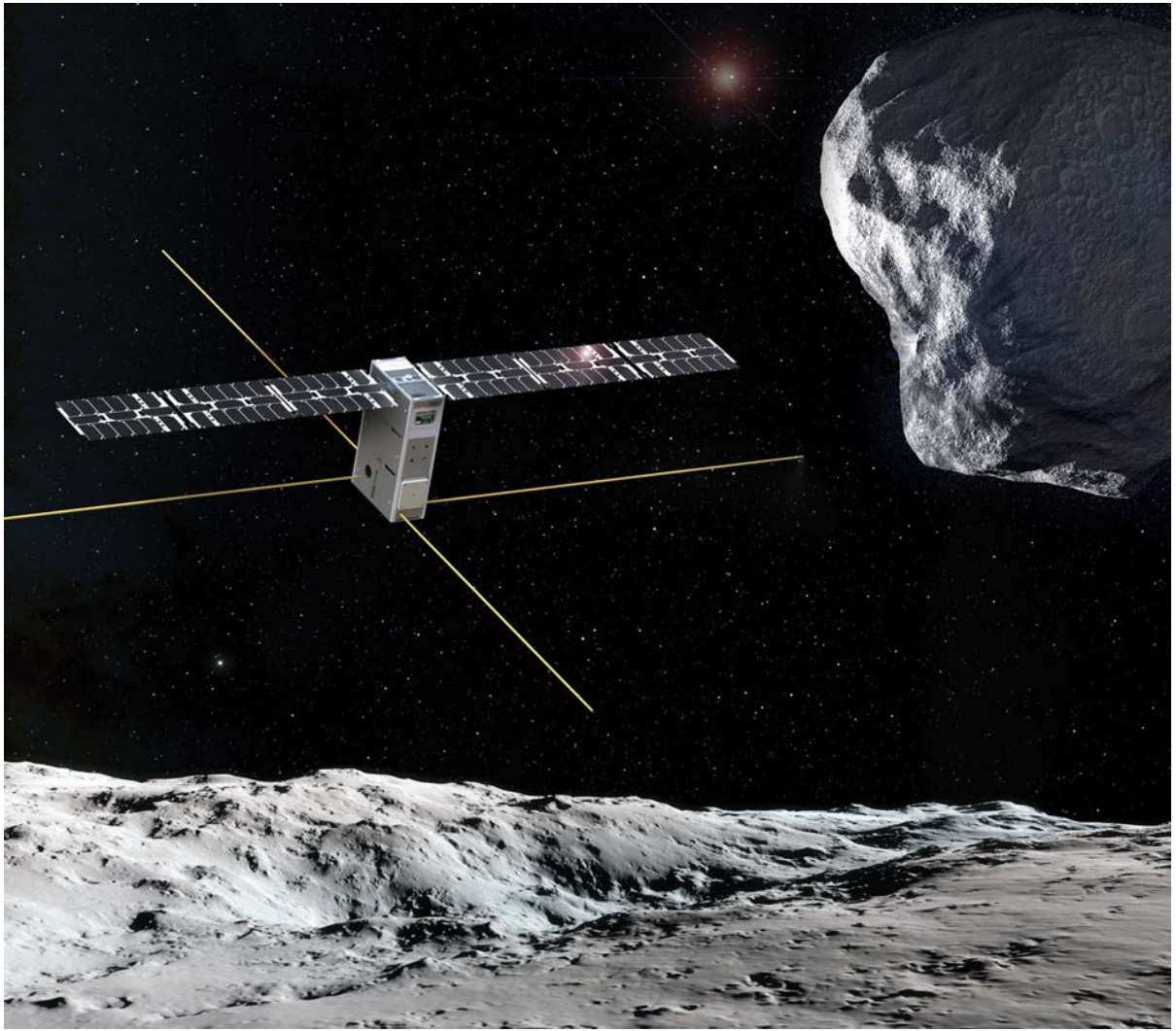
Giant impacts



Asteroid families

Collisional disruption

LATE PHASES



Juventas 6U Cubesat

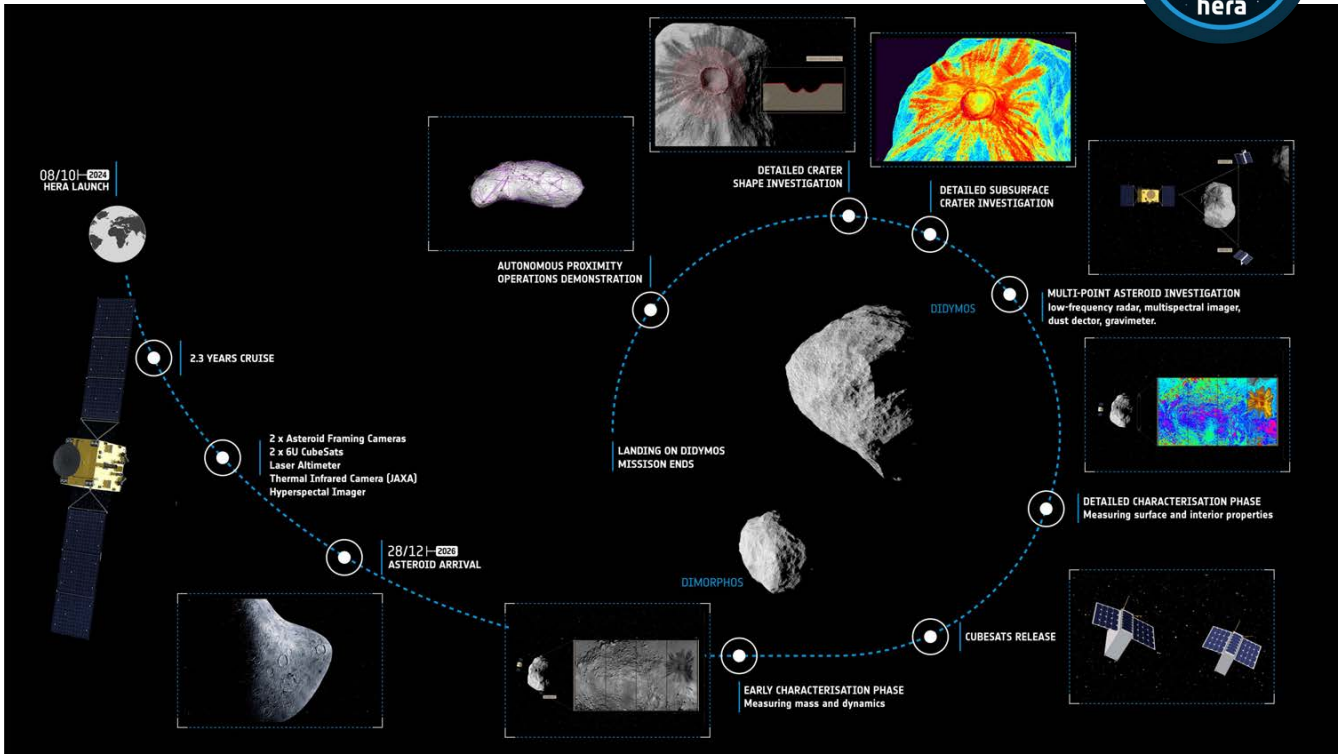
Landing on Dimorphos

- Bouncing properties
- Mechanical properties

Direct interaction with the surface is the only way to determine its often counter-intuitive response!

Hera: a mission of "firsts"

- **First** rendezvous with a binary asteroid and smallest asteroid ever visited
- **First** detailed measurements of asteroid cratering physics in the impact speed regime of asteroid collisions
- **First** deep-space Cubesats for very close asteroid inspection and **first internal structure probing**
- **First** Cubesat landing on a 160 m-size asteroid



Hera: planetary defense and science

Asteroids are fascinating:

- Sources of high interest of different communities (science, planetary defense, mining)
- Whichever is the primary objective to explore them (here, planetary defense), all those communities will benefit from the gained knowledge

Hera is fascinating:

- First binary asteroid rendezvous and full characterisation, including subsurface/interior properties, and documentation of an impact outcome with NASA DART
- European contribution to planetary defense, concretizing ESA's pioneering initiative in the early 2000s starting with the Don Quijotte concept
- Great team and community actively working for it, promising amazing discoveries!

European Commission
HORIZON 2020
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870377.

Hera Science Team

Impacts simulation

Chairs:
Kai Wünnemann
Martin Jutzi

Mission PI:
Patrick Michel

Dynamics

Chairs: Menios Tsiganis
Adriano Campo Bagatin
Sébastien Charnoz

ESA Mission Manager:
Ian Carnelli

ESA project scientist:
Michael Küppers

Data Analysis Exploitation Interpretation

Chairs: Alain Hérique
Jean-Baptiste Vincent
Paolo Tortora
Ozgur Karatekin
Naomi Murdoch

Management Board:
S. Green
A. Fitzsimmons
M. Lazzarin
S. Ulamec

Ground-based observations

Chairs: Petr Pravec
Julia de Leon
Benoît Carry
Colin Snodgrass

+ Operation Group
+ Instrument PIs
+ International (US/Japan) members

Common AIDA (DART +Hera) Working groups

THANK YOU