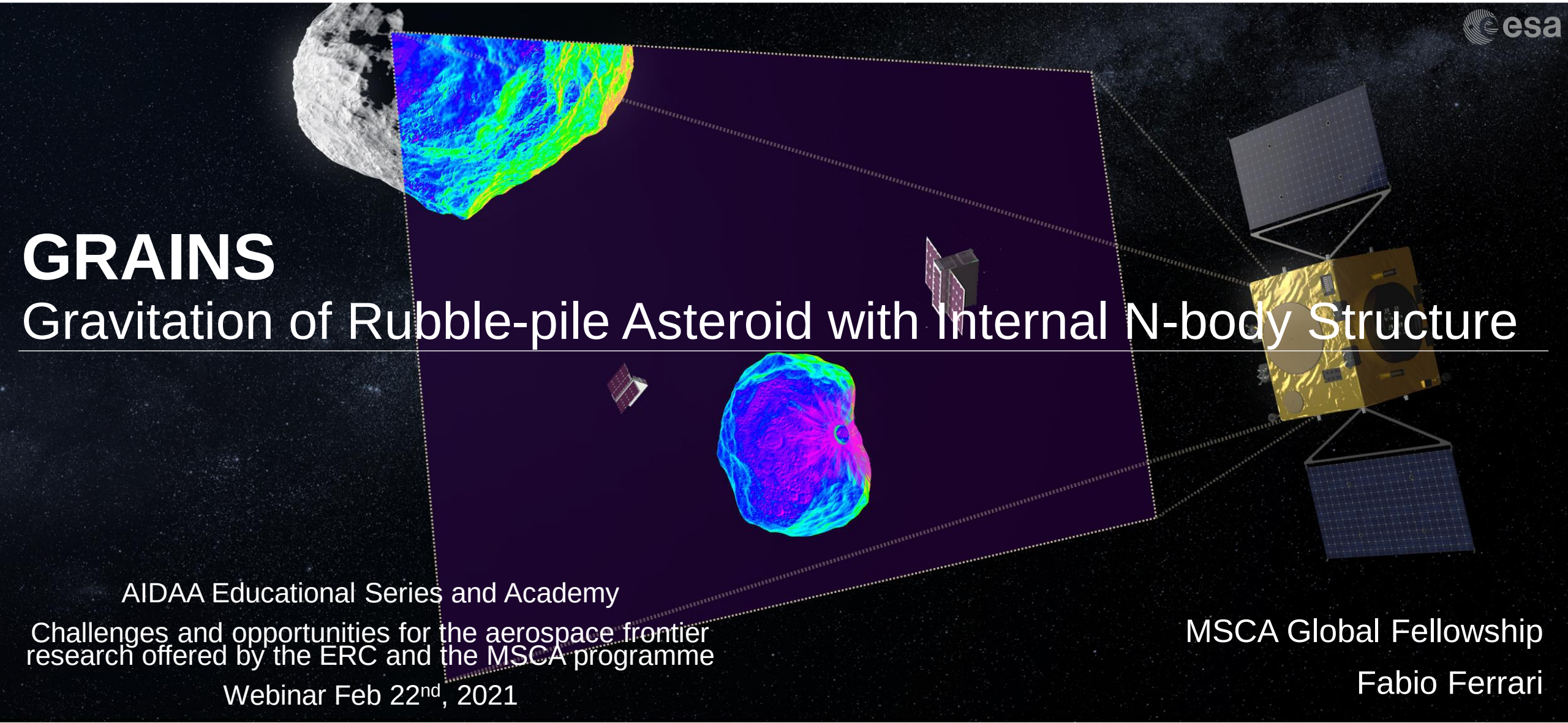


GRAINS

Gravitation of Rubble-pile Asteroid with Internal N-body Structure

AIDAA Educational Series and Academy

Challenges and opportunities for the aerospace frontier research offered by the ERC and the MSCA programme

Webinar Feb 22nd, 2021

MSCA Global Fellowship

Fabio Ferrari

INTRODUCTION
About me

- 2010/2013: B.Sc./M.Sc. **Politecnico di Milano**, Aerospace/Space Engineering
- 2013: Visiting researcher at **Purdue University** (USA)
- 2017: Ph.D. **Politecnico di Milano**, Aerospace Engineering

"Non-Keplerian Models for Mission Analysis Scenarios About Small Solar System Bodies"

- 2018-2020: Marie Skłodowska-Curie GF at **Politecnico di Milano** and **NASA/JPL** (secondment at **OCA-Nice**)

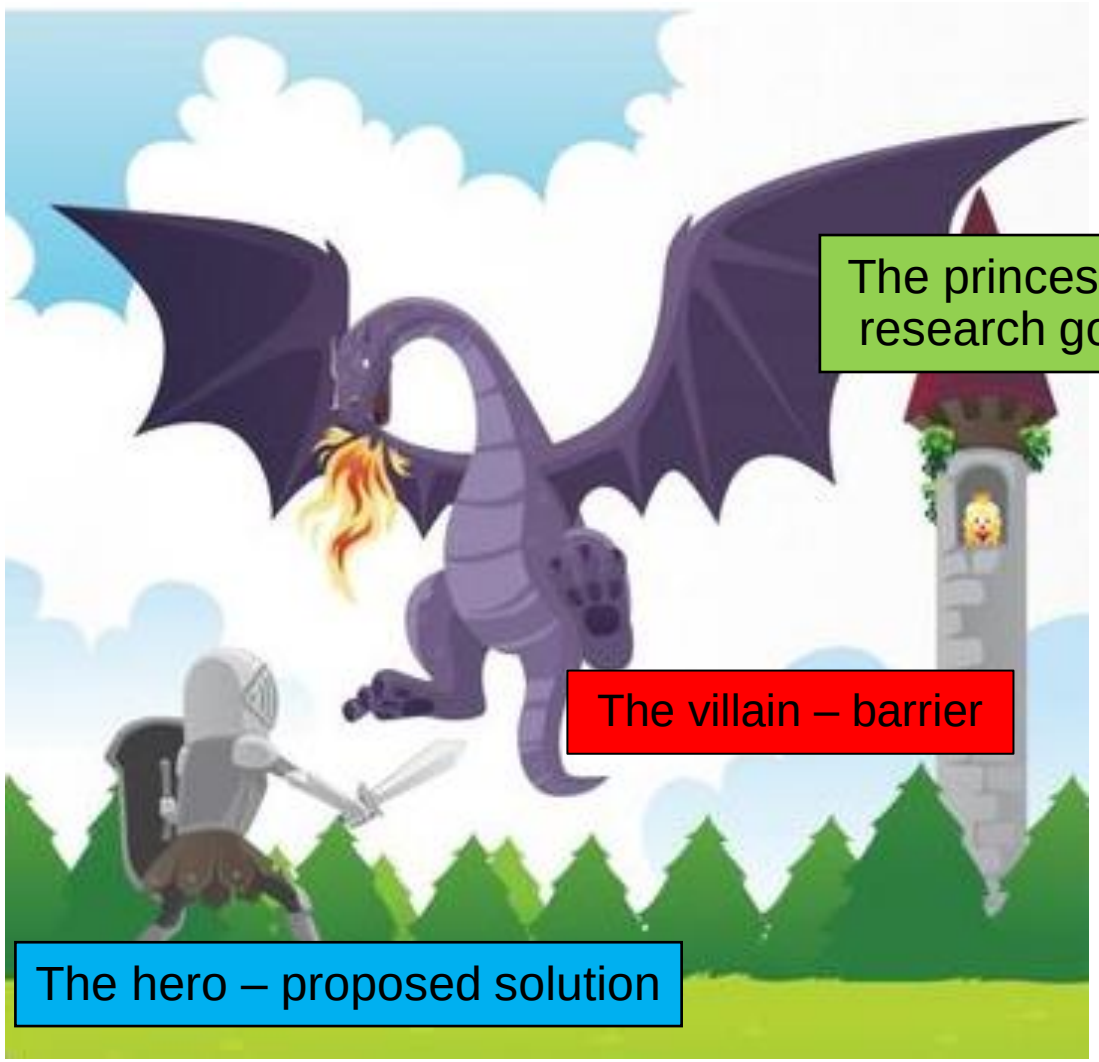
"GRAINS: Gravitation of Rubble-pile Asteroid with Internal N-body Structure"

- 2020-ongoing: Ambizione Fellow at **University of Bern**

"Dynamics and evolution of small bodies in the Solar System"

and Visiting Scientists at **NASA/JPL**

DEVELOPING THE PROJECT'S RESEARCH CONCEPT



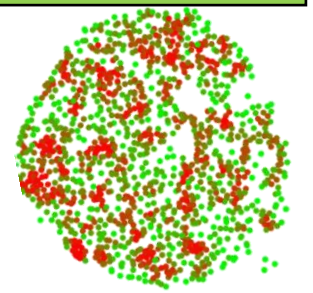
The princess – research goal

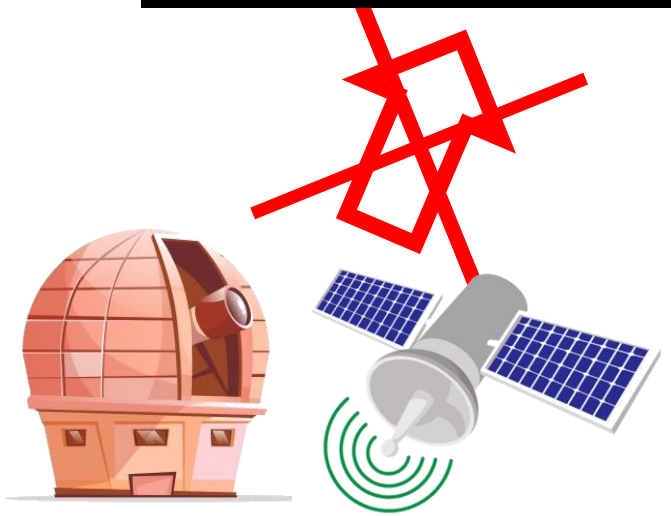
The villain – barrier

The hero – proposed solution

Realistic models of asteroids interior







Not observable remotely and hardly observable in-situ



High-fidelity simulations

RESEARCH GOAL: MOTIVATION

Why asteroids?

IMPACT HAZARD

Search programmes will **detect more asteroids** in the near future

Impact models unproven at asteroid scale

Only natural hazard we can **predict** and **prevent**





SCIENCE

Evolution of the Solar System and binary formation

Understanding the **physics of impacts** and material properties of small asteroids

Properties largely unknown

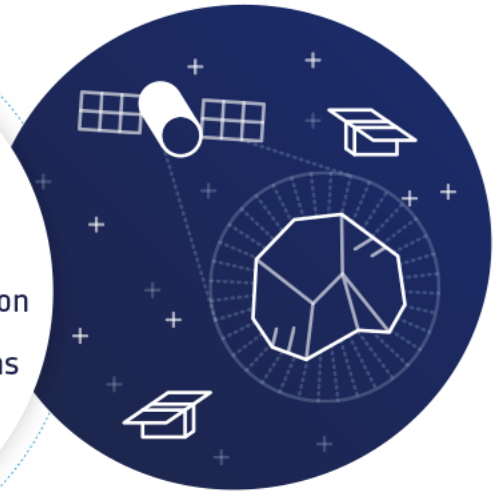
TECHNOLOGY

Onboard spacecraft **autonomy**

Advanced **vision-based** navigation

Deep-space **CubeSats** operations

Stepping stone to future servicing missions





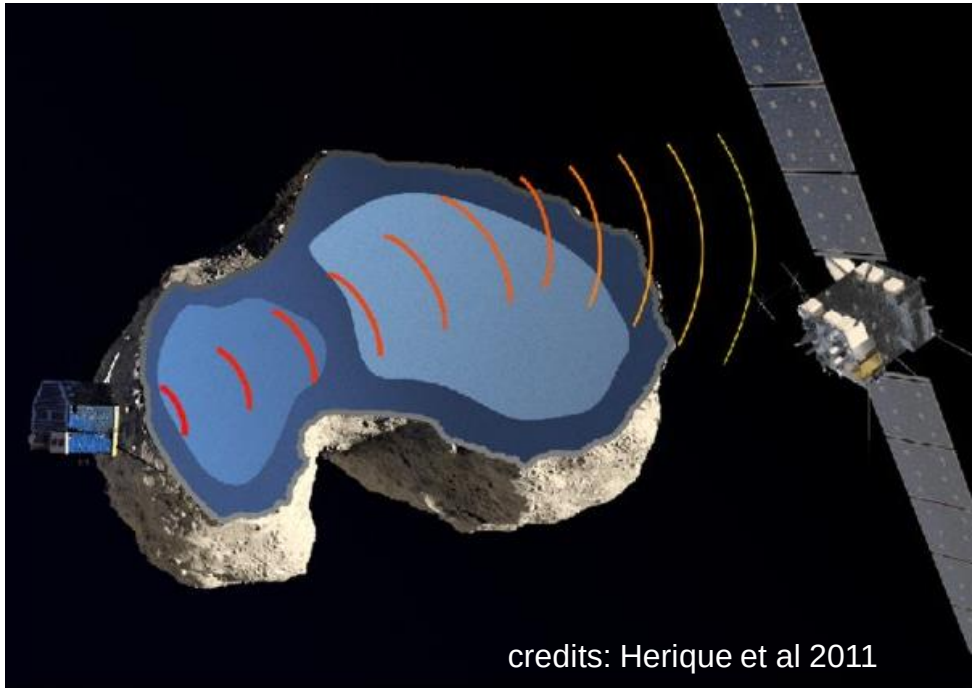
RESOURCES

Increasing **industrial capabilities** for the **potential use** of resources to produce propellant

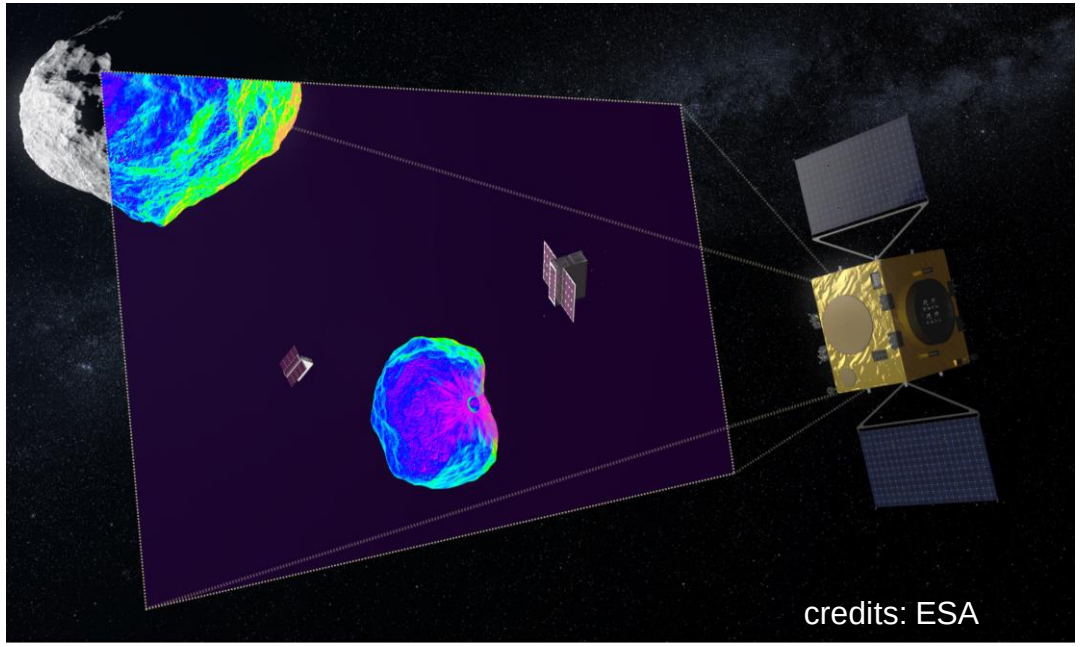
BARRIER: CURRENT LIMITATIONS

- Interior is not observable from ground-based surveys
- Systematic in-situ observation is not practical and is challenging
  - Bi-static radar tomography (two co-operating spacecraft)
  - Seismic experiments (on the surface)

- Only one mission provided data so far (CONSERT aboard Rosetta/Philae)
- Next foreseen in 2027 (Hera/Juventas)



credits: Herique et al 2011



credits: ESA

METHODOLOGY

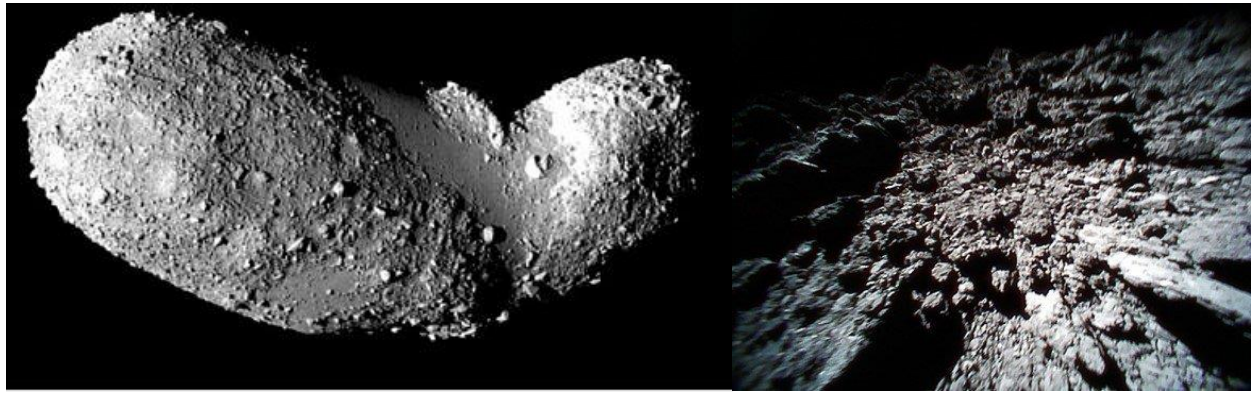
Asteroids between 100 m and 100 km in size are likely gravitational aggregates “rubble pile”

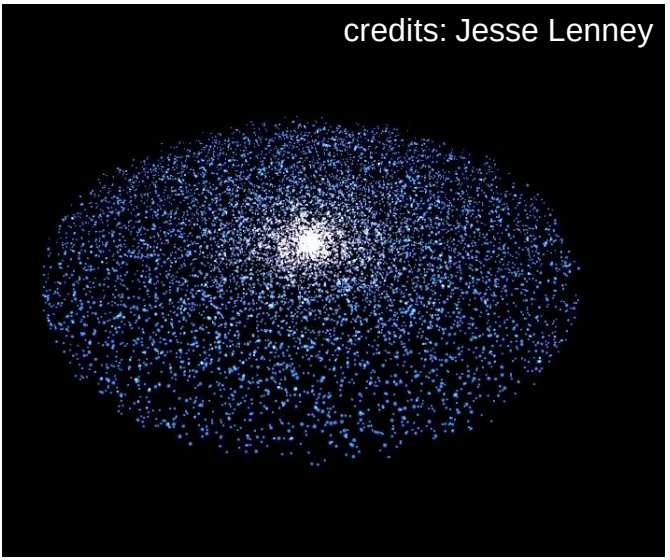
⇩

Simulations between self-gravitating boulders

Credits: JAXA/Hayabusa

Credits: JAXA/ Hayabusa 2/ Minerva-II1-B





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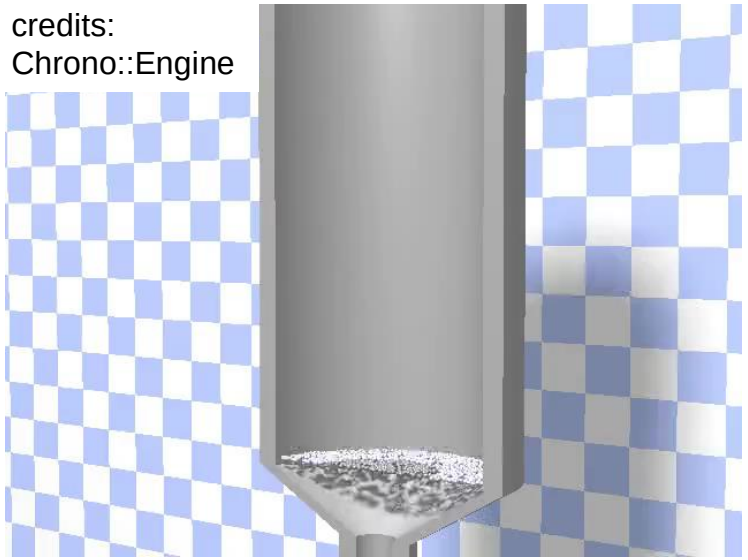

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Cosmological N-body simulations

Granular dynamics simulations

Gravity-granular coupled simulations

METHODOLOGY

Asteroids between 100 m and 100 km in size are likely gravitational aggregates “rubble pile”

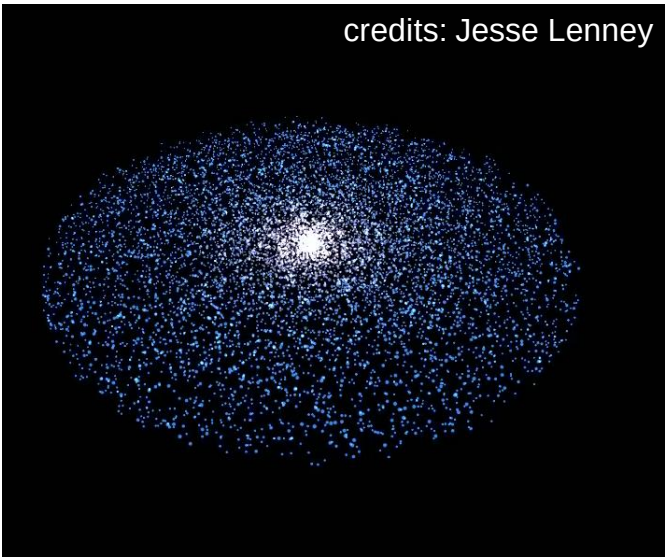
⇩

Simulations between self-gravitating boulders

Advancing the state-of-the-art methods

⇩

First code with self-gravity + contacts using **complex-shaped 6DOF fragments** on a **large scale**



Cosmological N-body simulations

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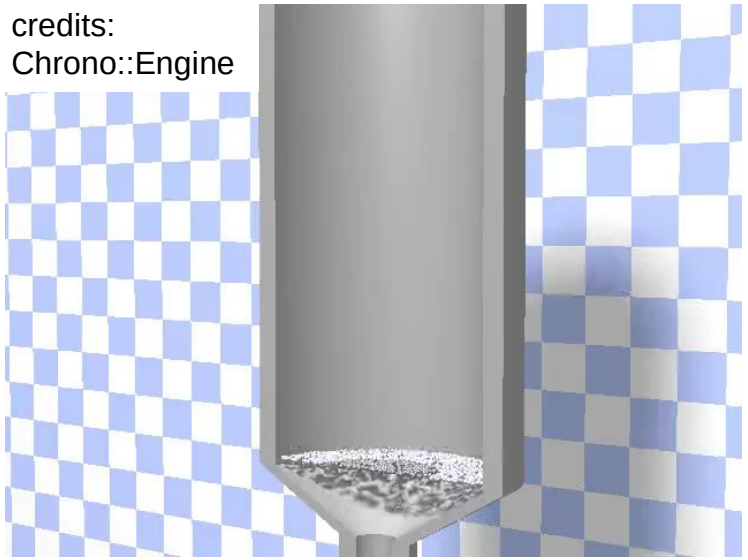

Granular dynamics simulations

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Gravity-granular coupled simulations

GRAINS: KEY FEATURES
Highlights from the evaluation letter

Innovative

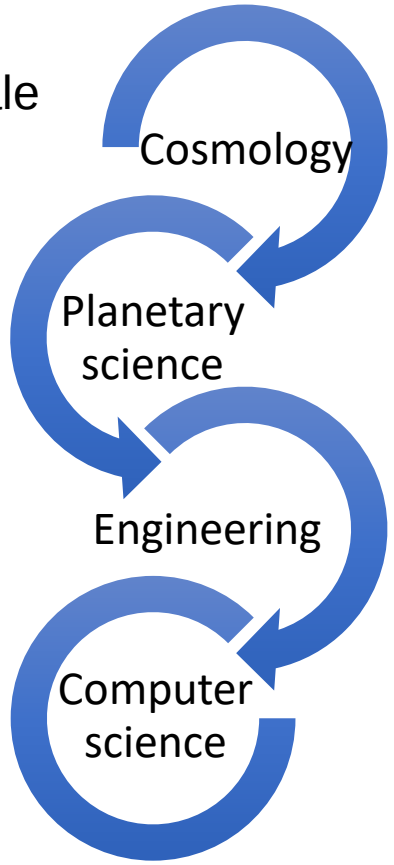
- First code with self-gravity + contacts using complex-shaped 6DOF fragments on a large scale
- Unprecedented high-fidelity simulations

Interdisciplinary

- Methods from cosmology/astrophysics and engineering
- Impact to different communities (planetary science, engineering, astrodynamics)

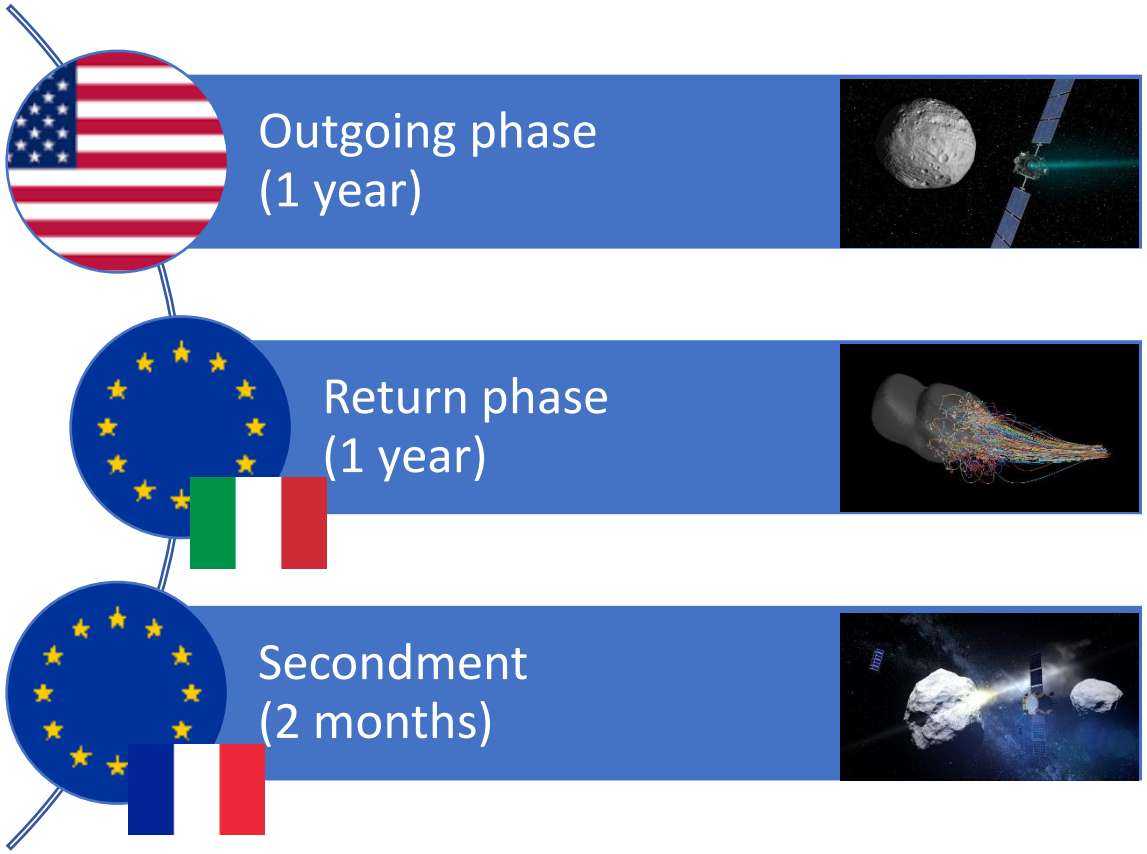
Partner institutions

- To cover all topics and acquire missing knowledge
- To provide computational resources needed
- Involvement in asteroid missions



PARTNER INSTITUTIONS

- Choose institutions to cover all topics and acquire missing knowledge



Jet Propulsion Laboratory
California Institute of Technology

POLITECNICO
MILANO 1863

Observatoire
de la CÔTE d'AZUR

IMPACT ON YOUR CAREER

Training

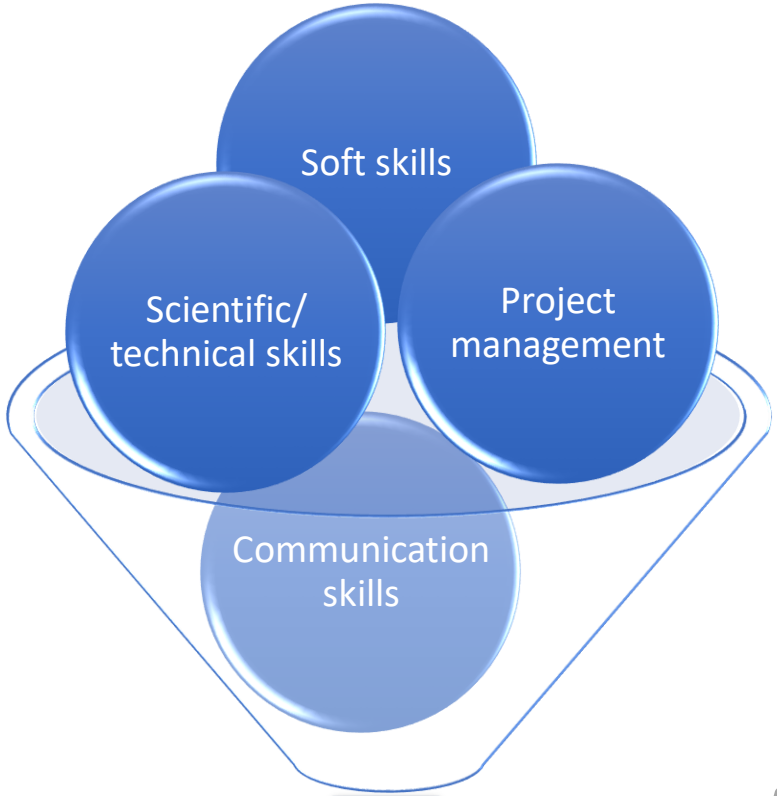
- Learn from the best scientists in relevant fields
- Share and discuss ideas
- Communicate and disseminate
- Learn how to manage a research project

Networking

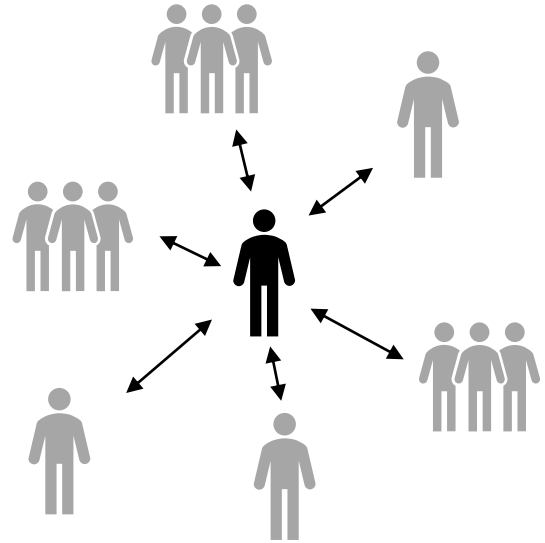
- Recognition as independent scientist
- Building your own connections and collaborations

The value of mobility

- Different perspective
- Different working methods
- Building strong connections
- Personal enrichment







Stronger scientific position

Building your own space in the scientific community

FINAL TIPS TO THE APPLICANT

- Know the scheme you are applying for
- Plan in advance and take your time
- Leave your comfort zone
- Think big
- Defeat the dragon!

