Geophysical exploration of asteroids with a surface science package

Hera Community Workshop

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SUPAERO

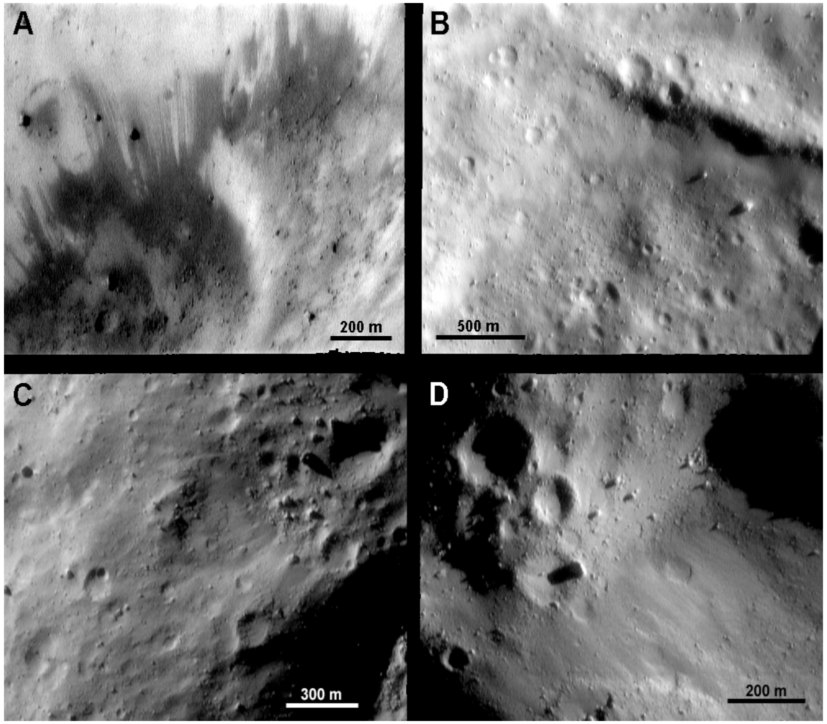
Geophysical exploration of asteroids

- Understanding the internal structure and mechanical properties of asteroids is a major science question
- A primary unknown of hazardous asteroid mitigation ('know your enemy')
- The only way to really understand the mechanical properties of an asteroid is to interact directly with it

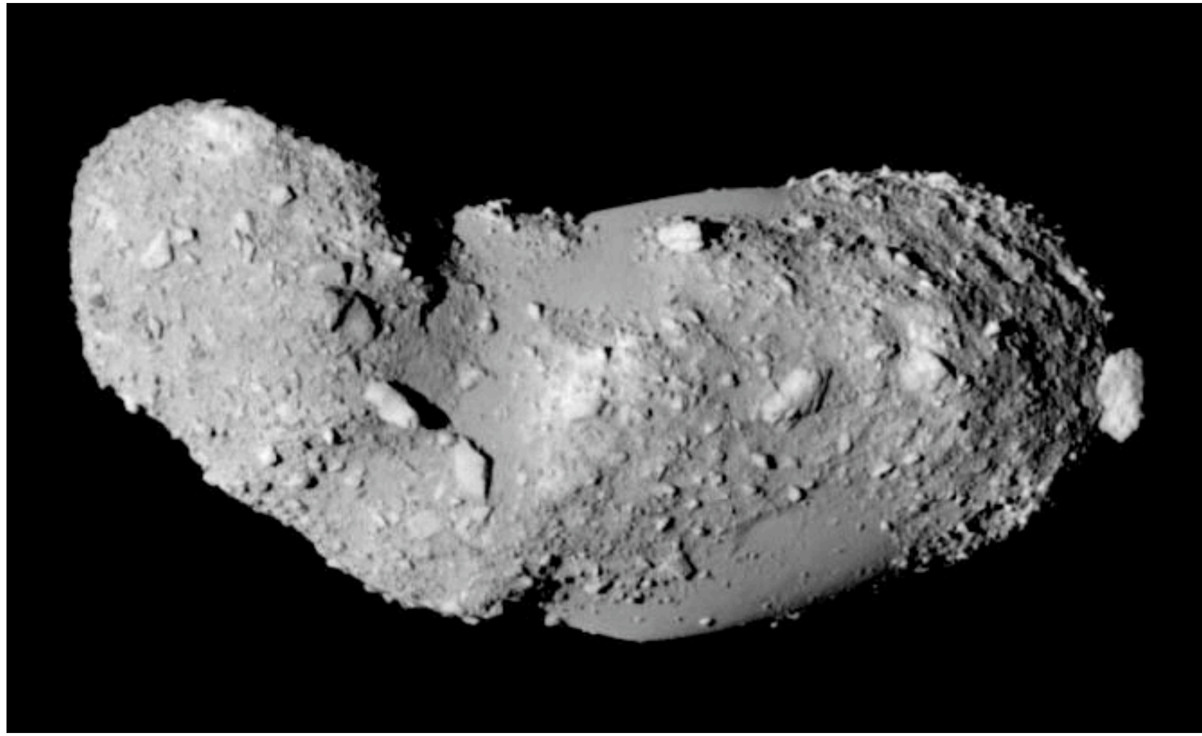
Today I will talk (briefly) about:

- The possibility to perform an in-situ seismic experiment
- A new instrument development that will reach TRL 6/7 within the next 3-4 years
- Interpreting accelerometer data acquired during rebounding/landing

Evidence for seismic activity on asteroids



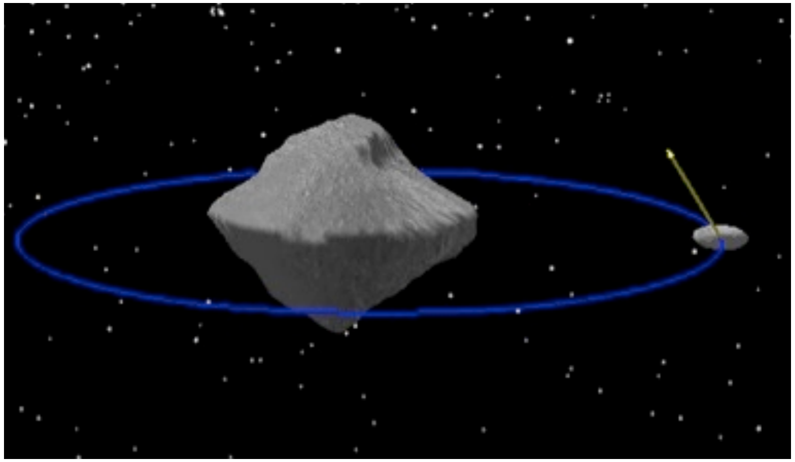
Destabilisation of slopes and regolith migration (Richardson et al., 2005)

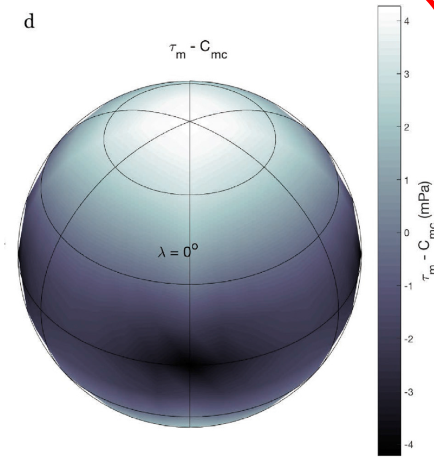


Lack of craters on Itokawa (Saito et al., 2006)

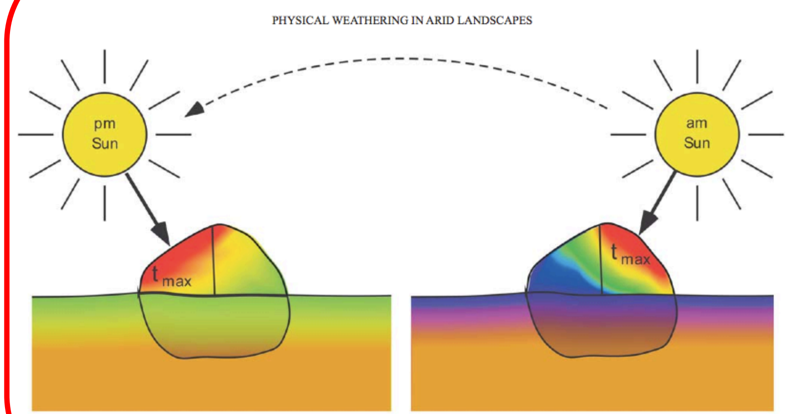
Seismic sources on Didymoon

Tidal deformation





For more information about the frequency of occurrence and seismic moment of these seismic sources on Didymoon see Murdoch et al., PSS (2017)



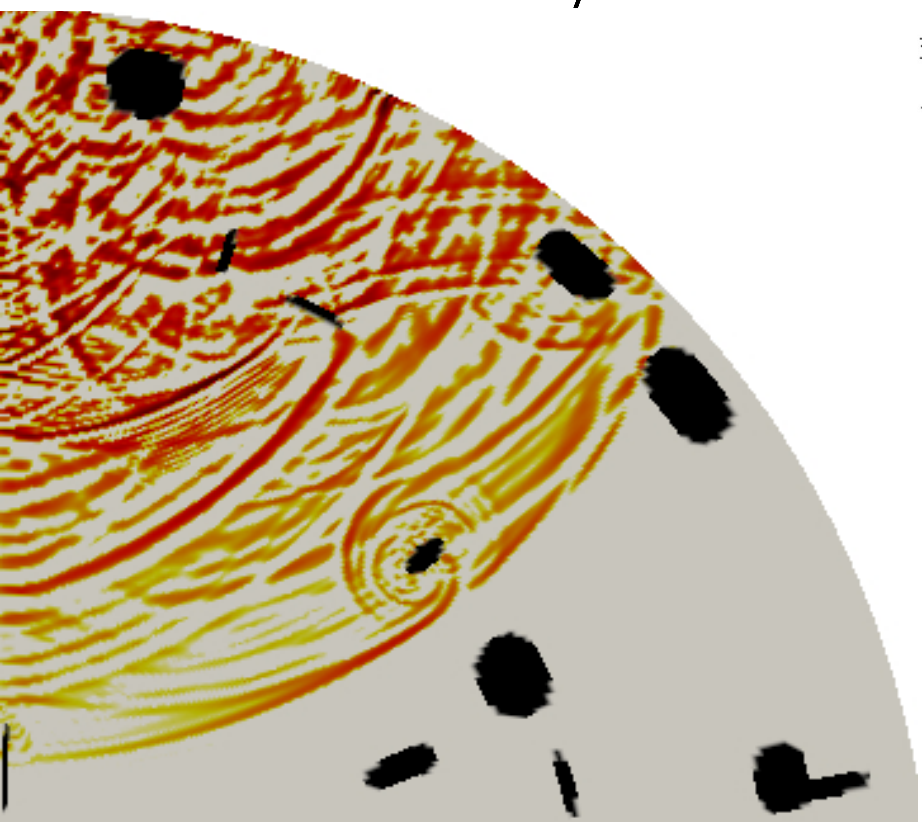
Thermal cracks

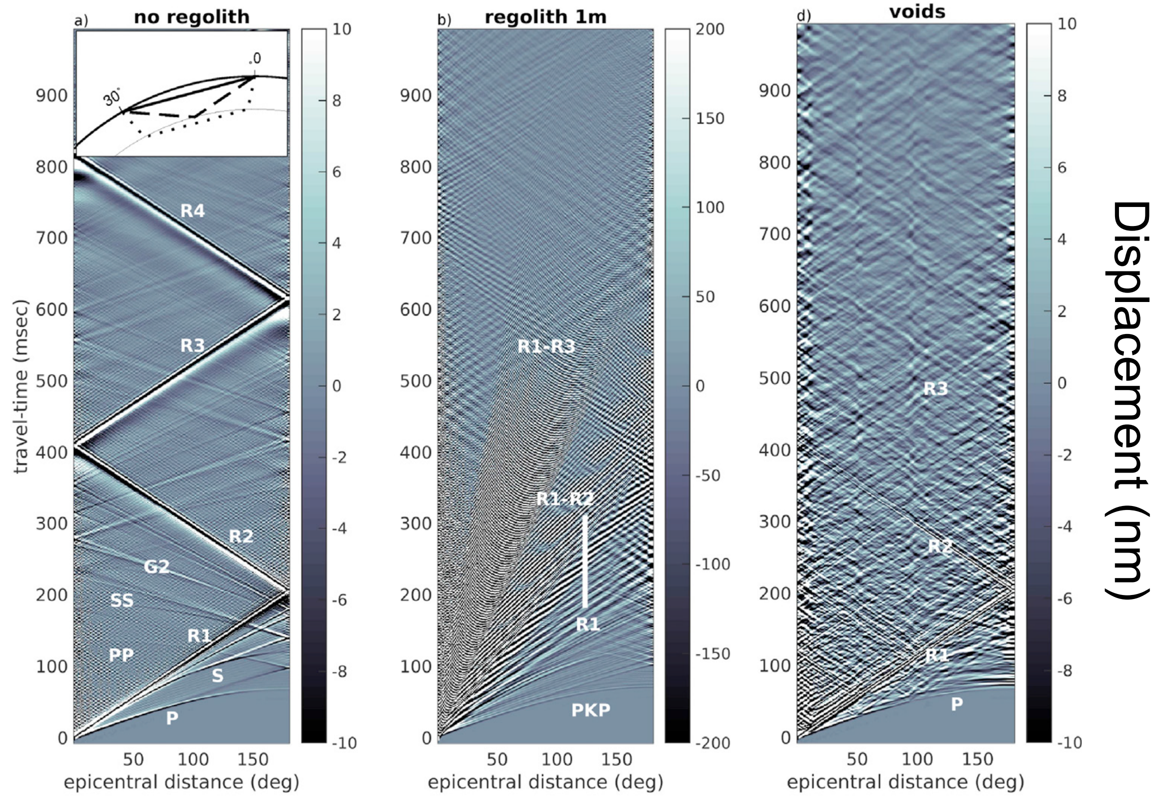
McFadden et al. 2005

Meteoroid impacts

Interpreting the seismic signals

A **regolith layer** results in seismic energy becoming trapped in the regolith due to the strong impedance contrast at the regolith-core boundary

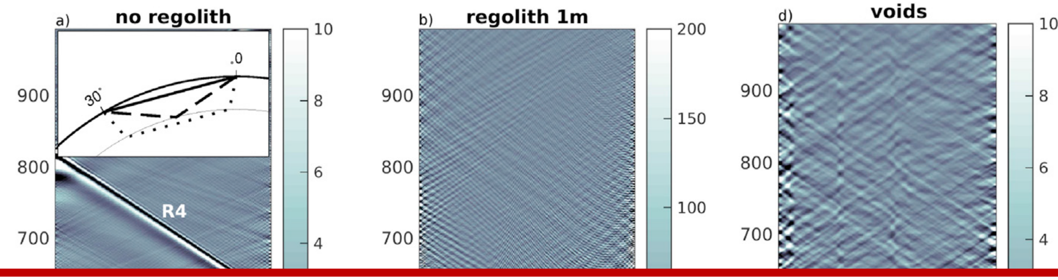




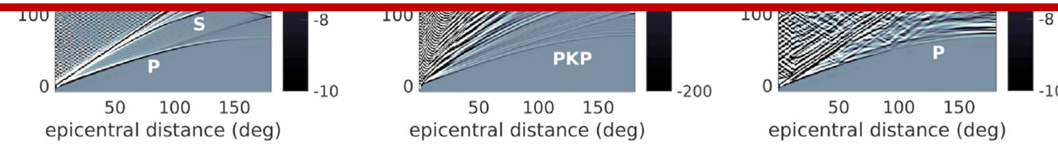
Voids lead to the wave-field becoming more complex and the onsets of seismic waves becoming less clear due to increased scattering

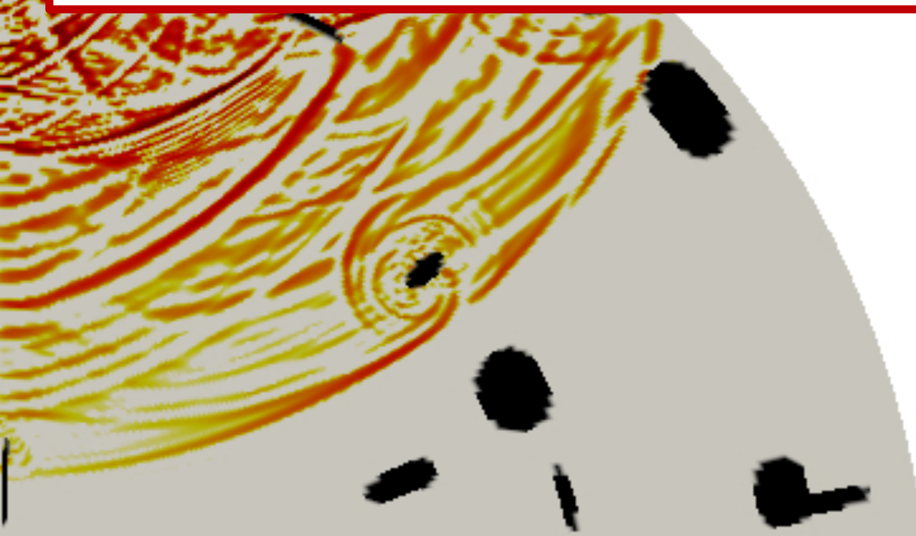
Interpreting the seismic signals

A **regolith layer** results in seismic energy becoming trapped in the regolith due to the strong



Performing a passive seismic experiment on Didymoon could provide information about the **sub-surface and internal structure**, **demonstrate seismology capabilities** on small body surfaces, and could lead to very **unexpected and exciting scientific discoveries**.





Voids lead to the wave-field becoming more complex and the onsets of seismic waves becoming less clear due to increased scattering

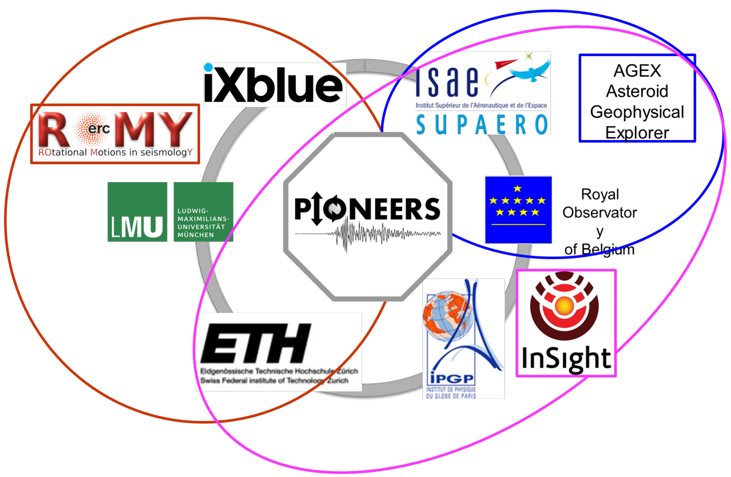
An optical seismometer for asteroid exploration

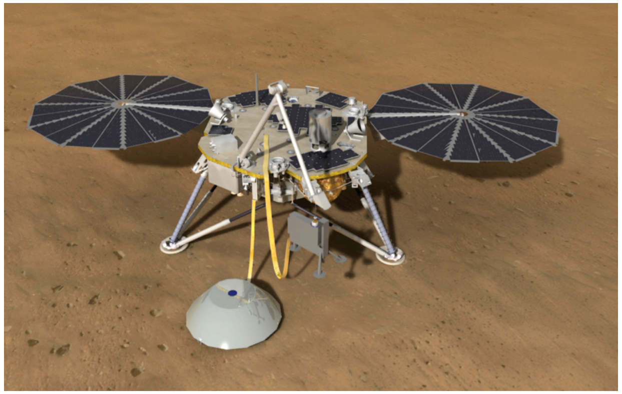
- **P**lanetary **I**nstruments based on **O**ptical technologies for an i**N**novative **E**uropean **E**xploration using **R**otational **S**eismology

- Four year project funded by the EC, start in January 2019; develop an innovative (optical fiber) seismometer that provides 6 degrees of freedom measurements: 3 translational and 3 rotational.

- Expertise from InSight and Earth Rotational Seismology

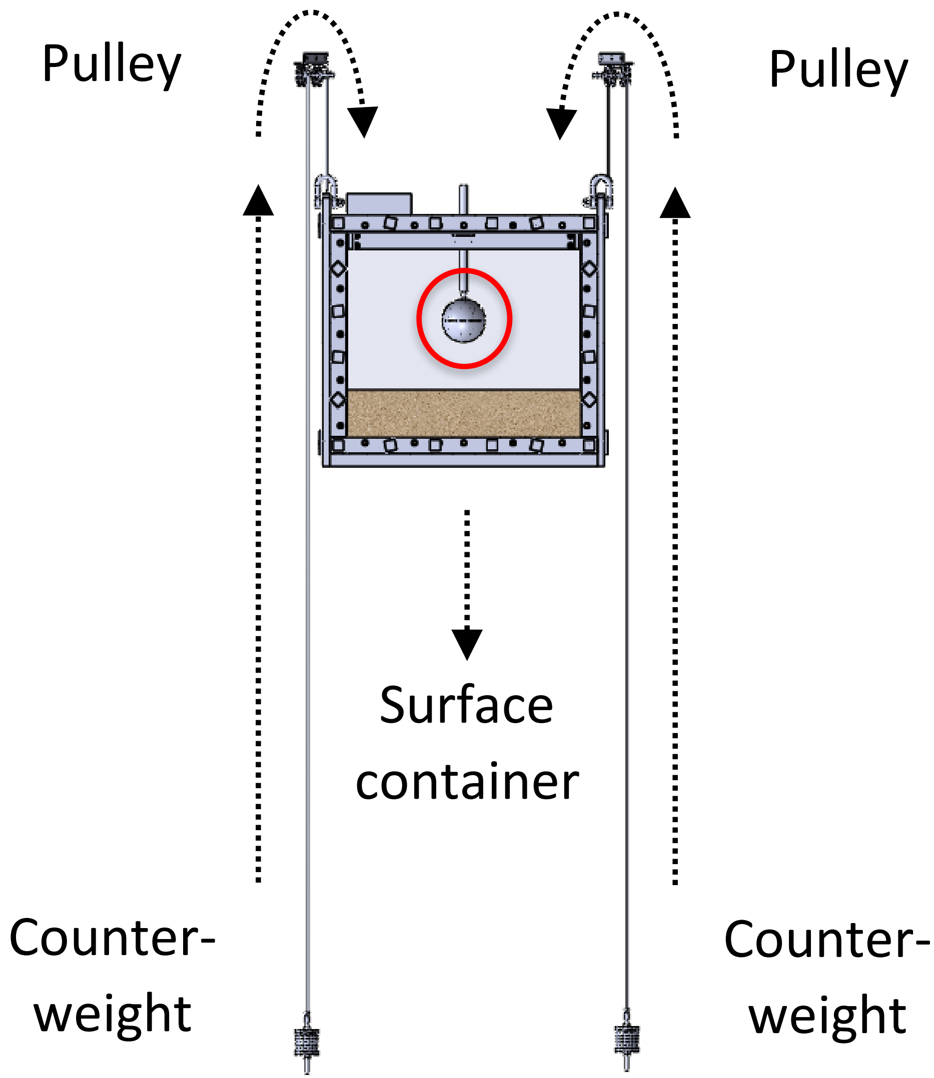
- We will build a <u>reduced scale version</u> specifically dedicated to the exploration of small bodies





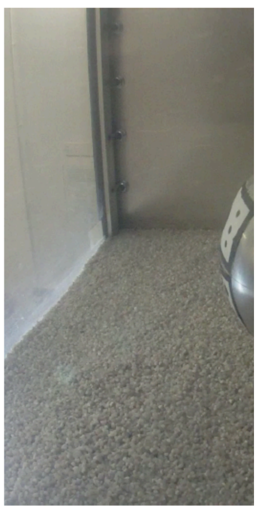
Understanding accelerometer data

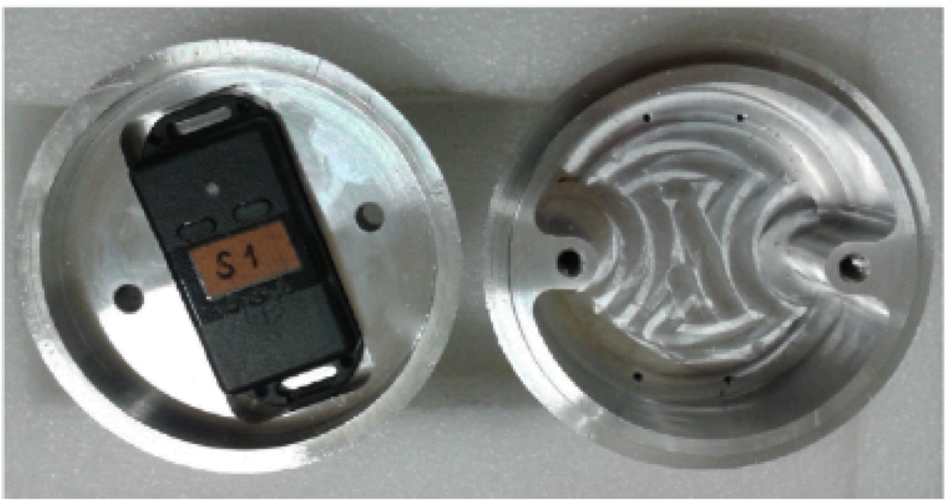
To better understand accelerometer data during asteroid landing/rebounding, we have developed a drop-tower experiment for low-velocity collisions in **which gravity is a variable** (see Sunday et al., RSI, 2016)



ISAE-SUPAERO drop tower

- ✓ Variable and controllable gravity (~0.2 - 1 m/s^2)
- ✓ Lower gravity levels and smaller collision velocities (2 - 40 cm/s) than similar experiments
- ✓ Large experiment, meaning we can do full-scale landing experiments
- ✓ **Accelerometers inside** the projectiles to measure precisely the impact dynamics
- ✓ Easily adaptable to different projectile shapes and sizes



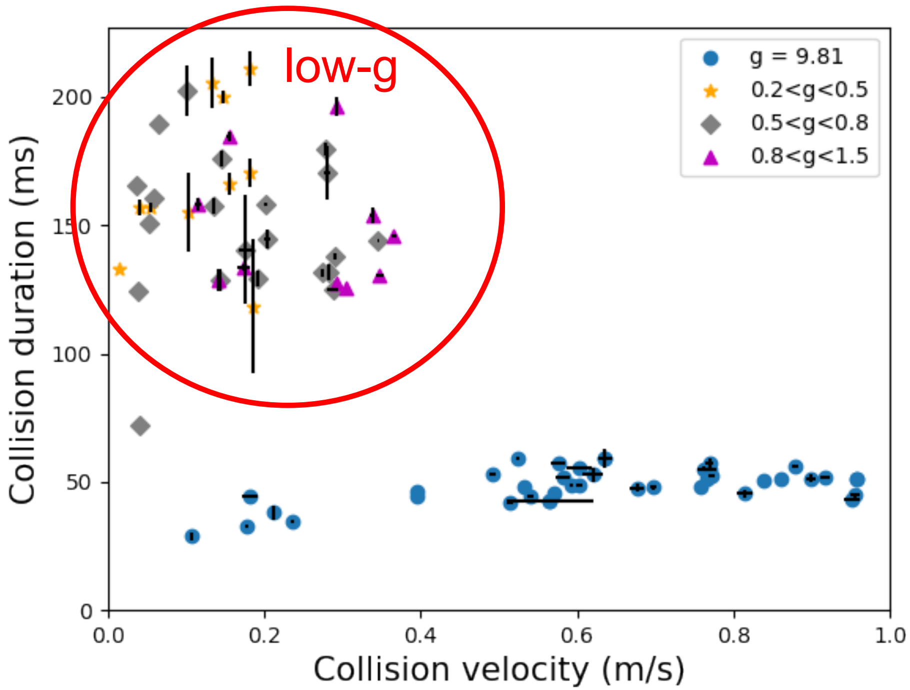


Drop tower experimental results

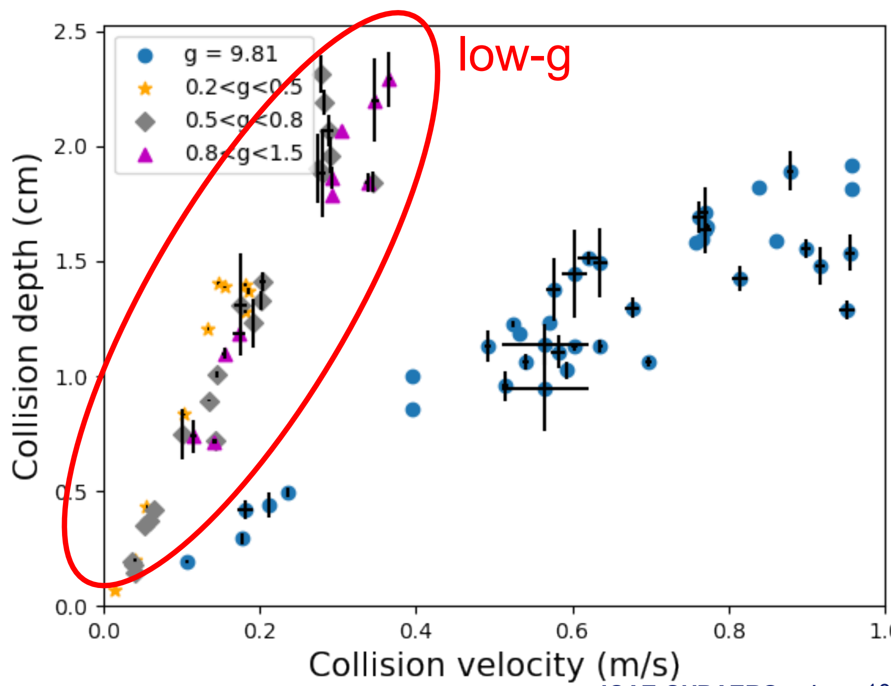
During asteroid rebounding/landing an accelerometer can provide measurements related to the surface mechanical properties e.g., peak acceleration, collision duration, penetration depth

BUT our experiments show that regolith is expected to have a more fluid-like behaviour in low-gravity

Consequences?



Collision duration increases in low-g



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Drop tower experimental results

During asteroid rebounding/landing an accelerometer can provide measurements related to the surface mechanical properties e.g., peak acceleration, collision duration, penetration depth

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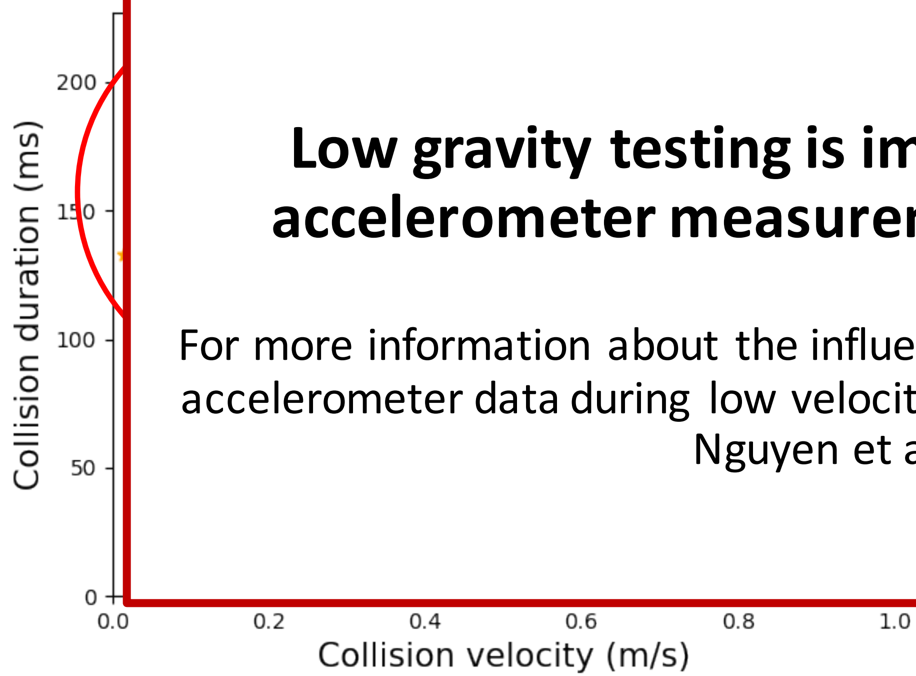
Consequences?

Low gravity testing is important for correctly interpreting accelerometer measurements during rebounding/landing!

For more information about the influence of gravity, particle size, and projectile shape on accelerometer data during low velocity collisions see Murdoch et al., MNRAS, (2017) and Nguyen et al., Submitted to MNRAS.



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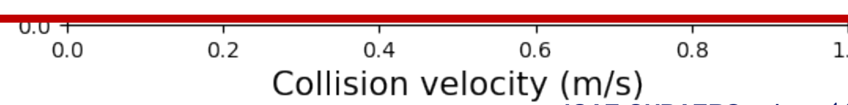

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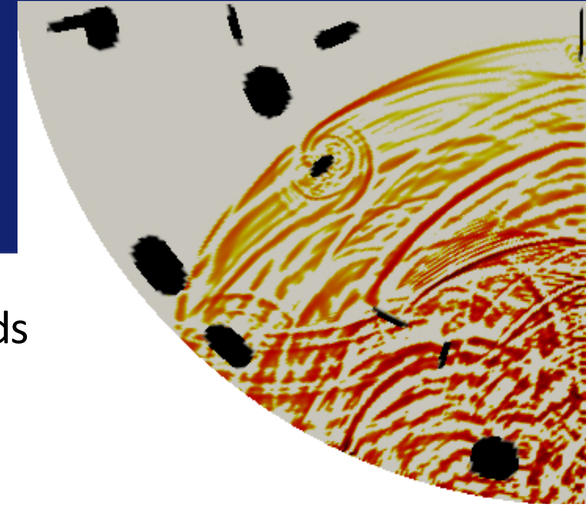
Conclusions



•Understanding the internal structure and mechanical properties of asteroids is a **major science question**

•Performing a passive seismic experiment on an asteroid such as Didymoon could provide information about the **sub-surface and internal structure**, **demonstrate seismology capabilities** on small body surfaces, and could lead to very **unexpected and exciting scientific discoveries** (see Murdoch et al., PSS, 2017).

PIONEERS

•We are currently developing a **new, innovative optical seismometer** for small body exploration - PIONEERS (EC funding, TRL 6/7 by 2023)

•In parallel, to better understand asteroid rebounding/landing, we have developed a novel **drop-tower experiment** for low-velocity collisions in which **gravity is a variable** (see Sunday et al., RSI, 2016)

•Our experimental results highlight the **importance of low gravity testing for correctly interpreting accelerometer measurements** during rebounding/landing (Murdoch et al., MNRAS, 2017; Nguyen et al., Submitted)