Impact cratering on the Solar System

Sun

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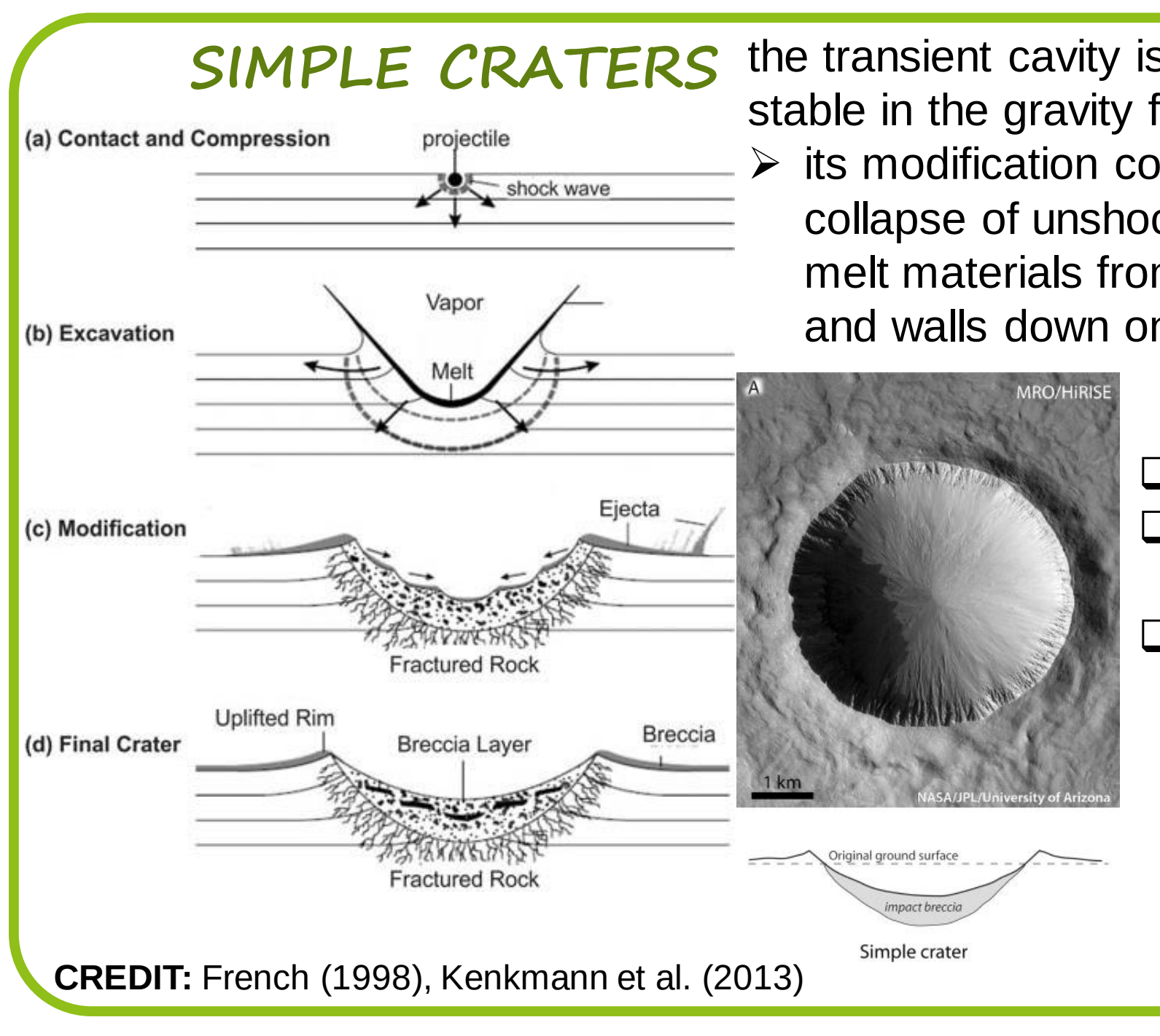
& RSN3

Physics of impact crater formation

SIMPLE CRATERS

the transient cavity is more or less stable in the gravity field
- ➢ its modification consists in the collapse of unshocked and/or melt materials from crater rim and walls down onto the floor

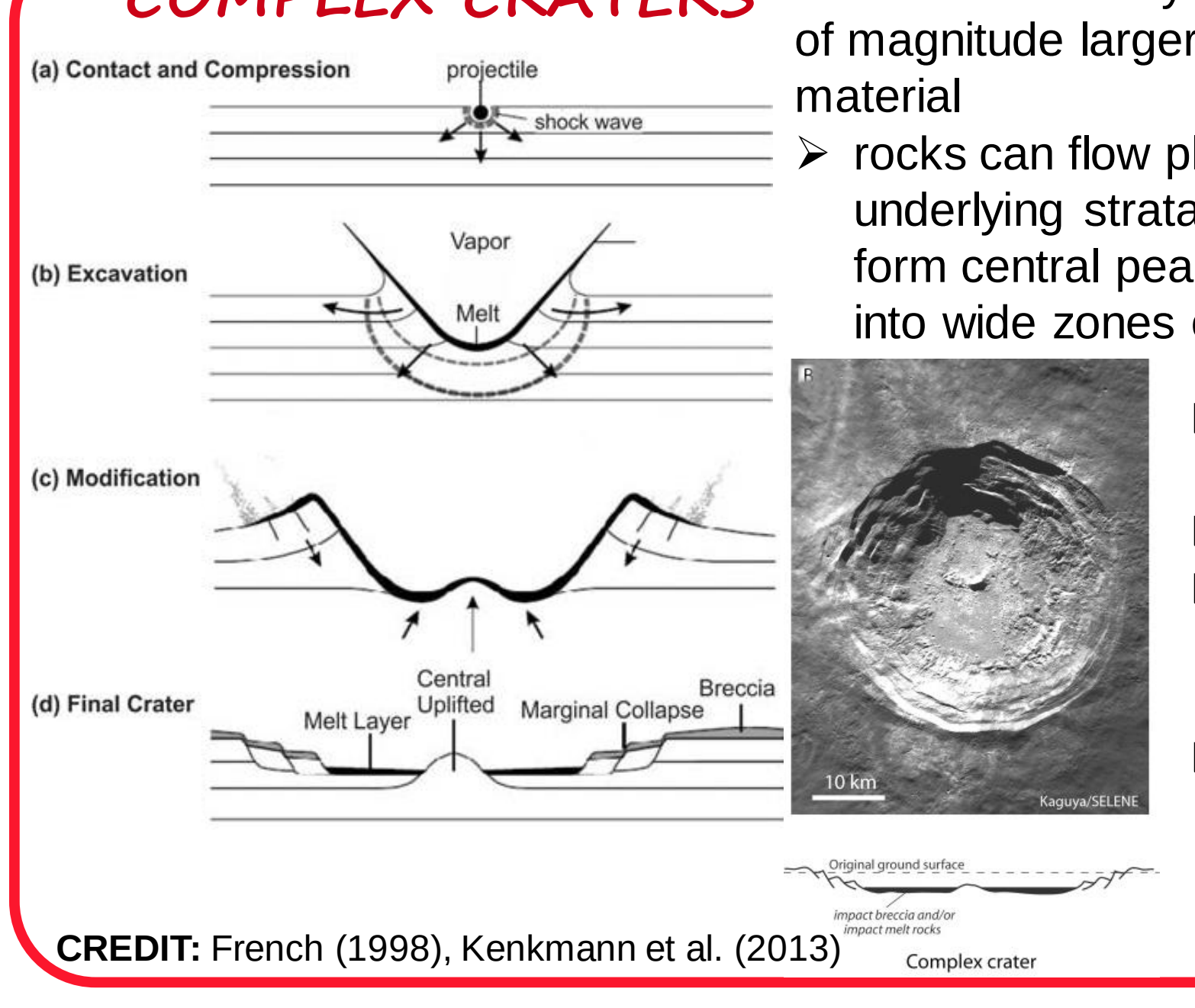


- ☐ bowl shape
- ☐ depth = ~1/5 diameter
- ☐ the floor is covered by a breccia lens

CREDIT: French (1998), Kenkmann et al. (2013)

COMPLEX CRATERS

the transient cavity is subjected to stresses orders of magnitude larger than the failure strength of the material
- ➢ rocks can flow plastically, allowing (i) the underlying strata under the cavity to uplift and form central peaks, and (ii) the rim to collapse into wide zones of stepped terraces



- ☐ the complex morphology onset depends on 1/g
- ☐ slump terraced rims
- ☐ single or multiple central peaks, or central rings at higher diameters
- ☐ relatively flat floor

CREDIT: French (1998), Kenkmann et al. (2013)

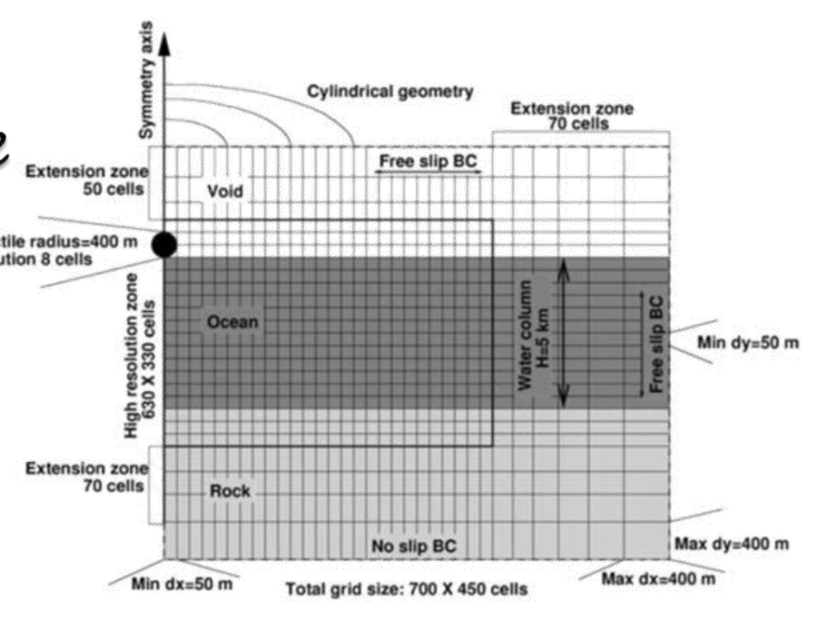
Methods

Code 1:

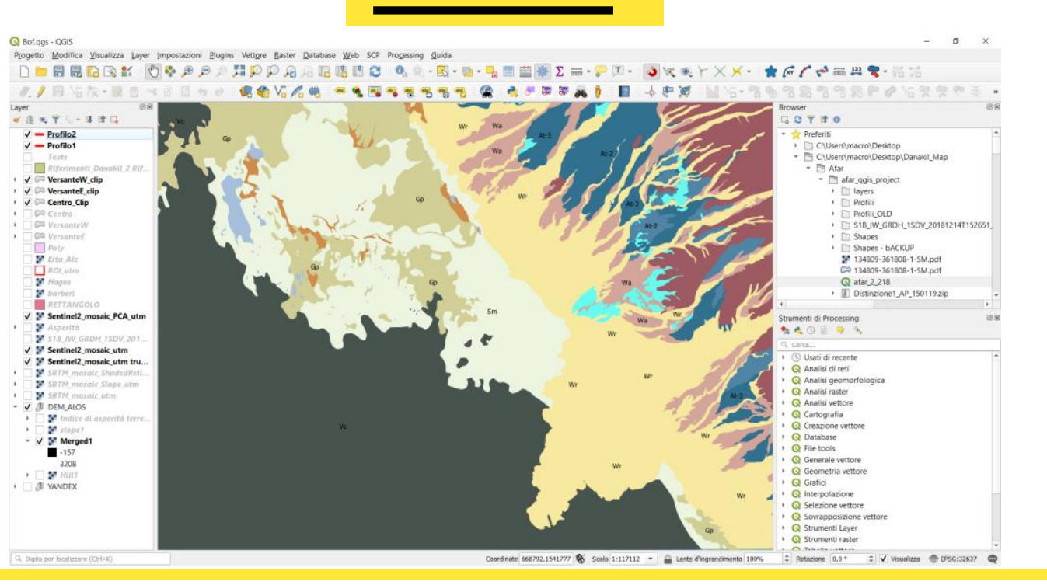
iSALE shock physics code

https://isale-code.github.io

Amsden et al. (1980);
Melosh et al. (1992);
Ivanov et al. (1997);
Collins et al. (2004), (2011);
Wünnemann & Ivanov (2003);
Wünnemann et al. (2006)



Code 2:

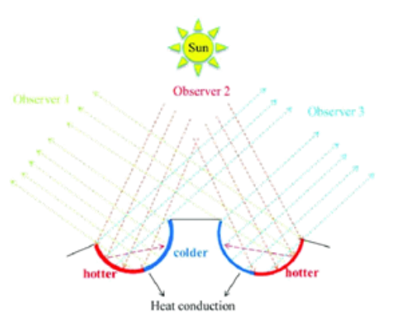


Code 3:

SPICE Toolkit

https://naif.jpl.nasa.gov/naif/toolkit.html

direct solar insolation
+
backscattered light



CREDIT: Yu & Ip (2021)

Project 1: MINI-GRANT 2023 “Origin of water ice on Mercury”

CREDIT:
NASA /
JHU Applied
Physics Lab /
Carnegie Inst.
Washington

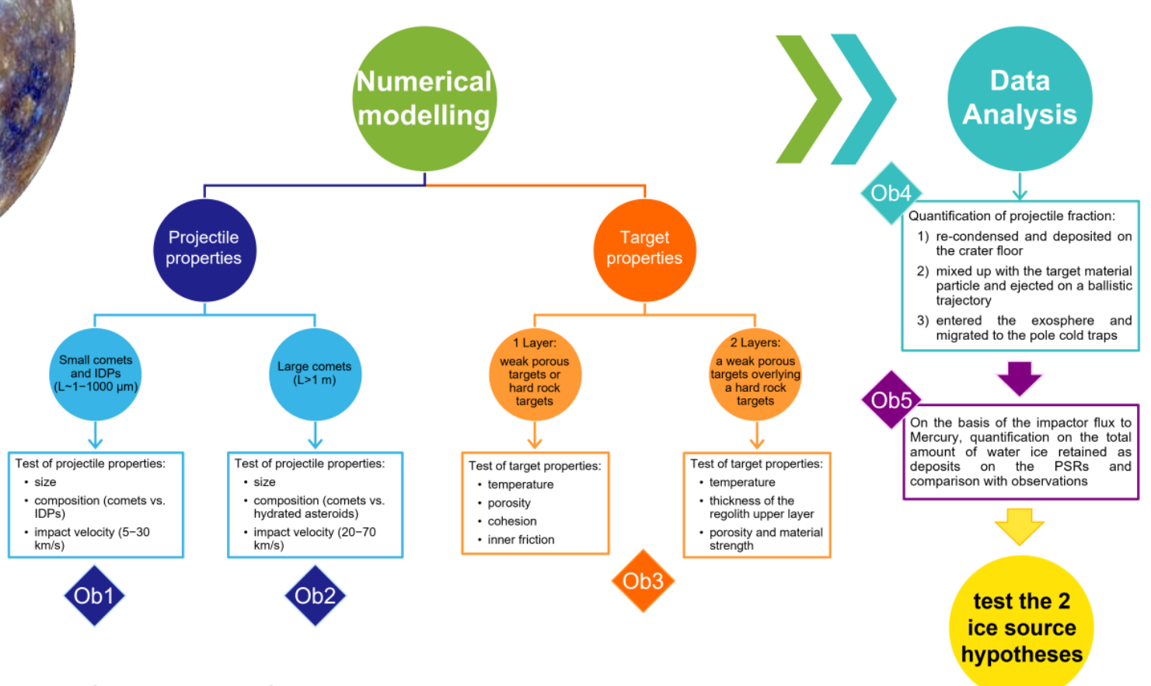
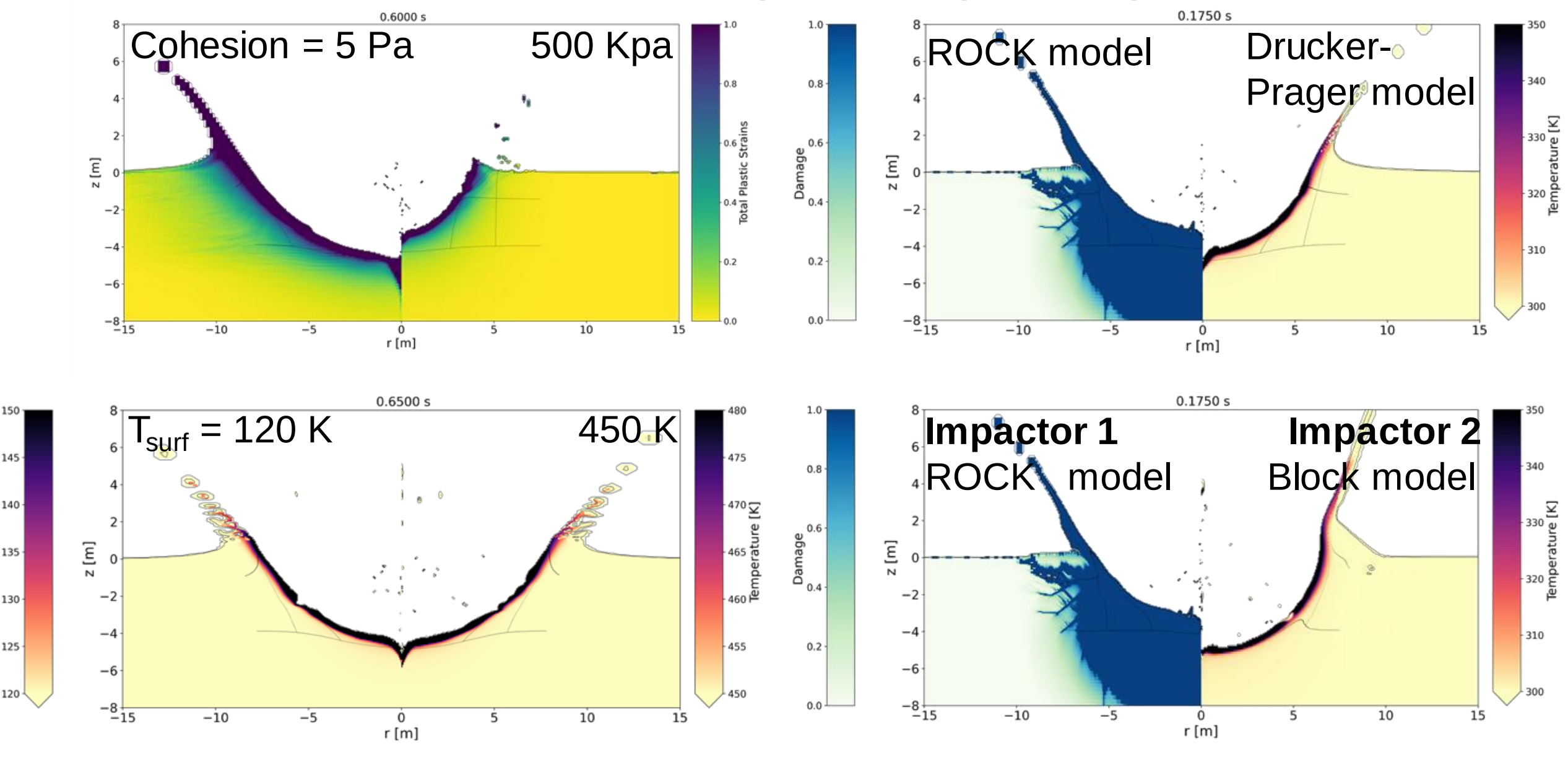


Fig. 1. Conceptual map of the "Mercury-ice" project.

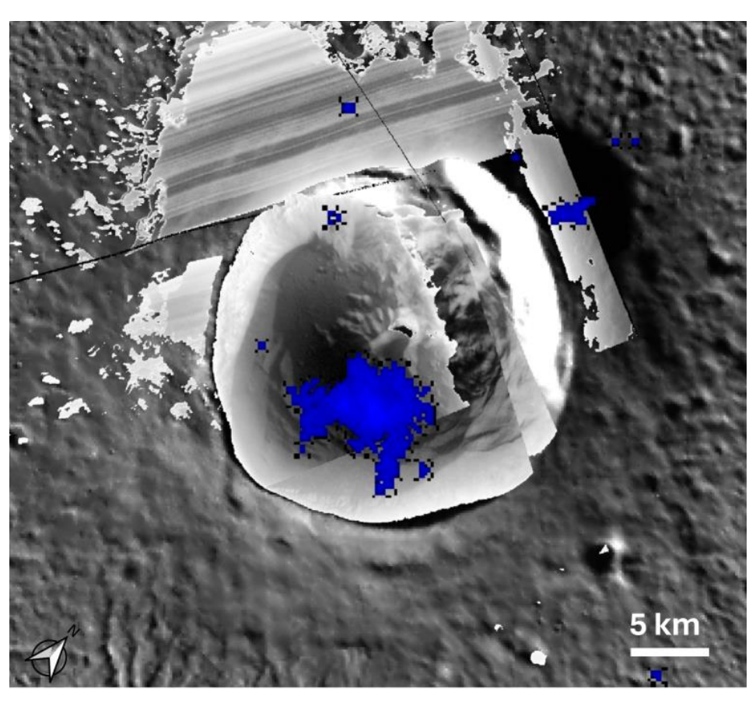
- ➢ water ice deposits within the Permanent Shadowed Regions (PSRs)
  - ☐ images and reflectance measurements highlight the presence of bright and low-reflectance zones with sharp boundaries
  - ☐ thermal modelling suggests that ice deposits can be both exposed at the surface and insulated by 10−30 cm of a carbon-rich material sublimation lag

HYPOTHESES:
1) continuous flux of water-bearing micrometeoroids
   - ➢ **IMPACTOR 1**: L=1 mm to 1 m, v=20 km/s
2) few individual and large impacts of comets and/or hydrated asteroids
   - ➢ **IMPACTOR 2**: L=1 m to 1 km, v=40 km/s

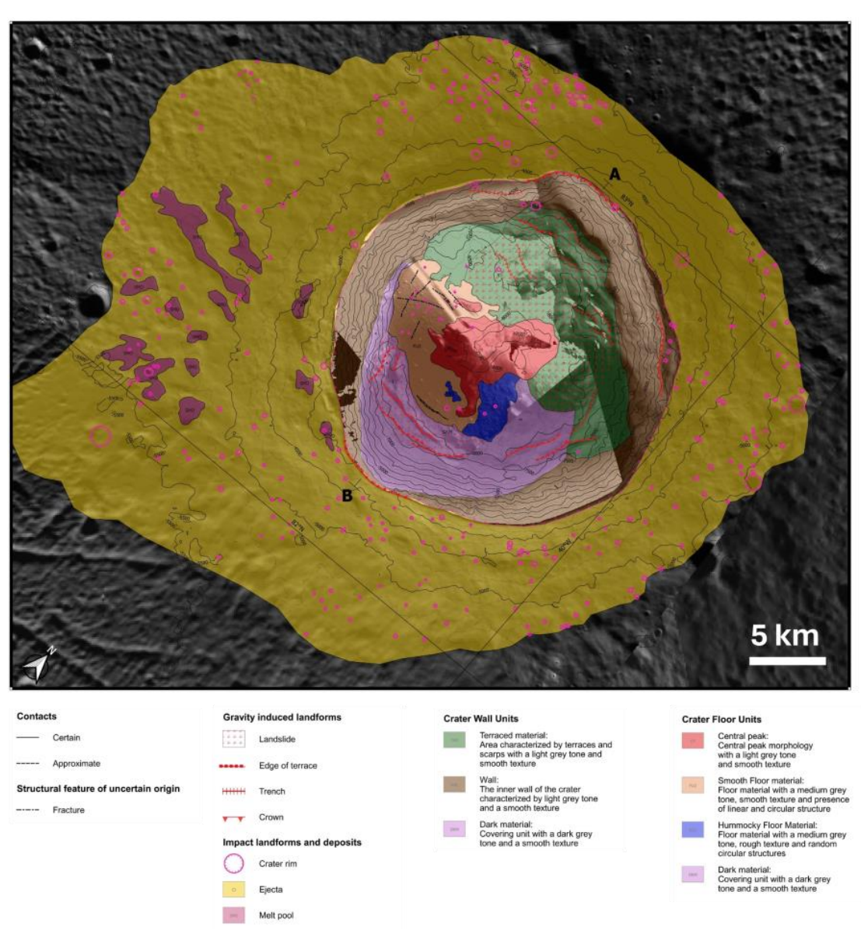
Impactor 1 (L = 1 m):



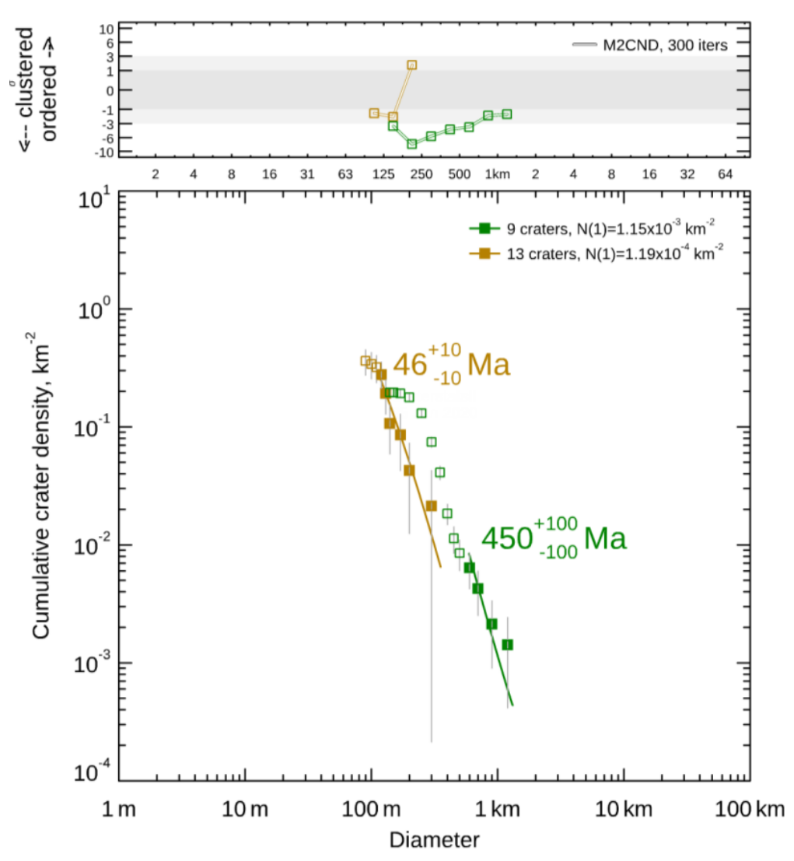
Project 2: Cartography, age determination, impact and thermal modelling of Hermean polar craters



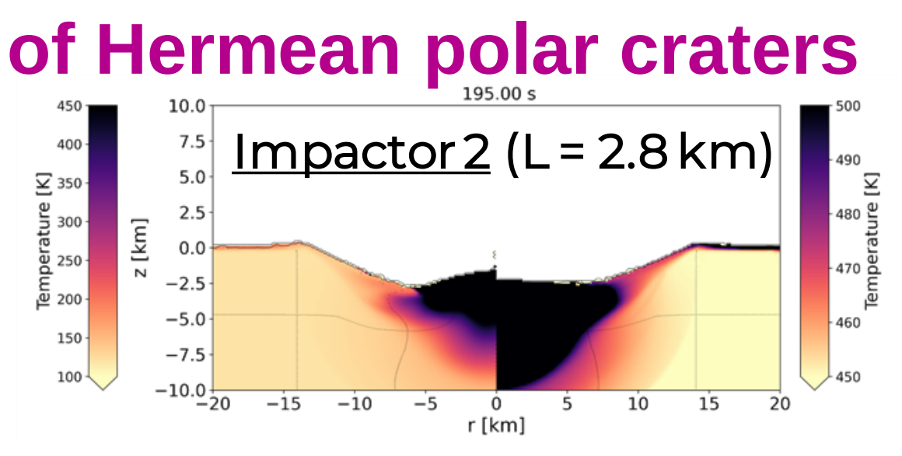
CREDIT: Fuller crater overlapped by the radar bright deposit (in blue).
CREDIT: Harmon et al. (2011)



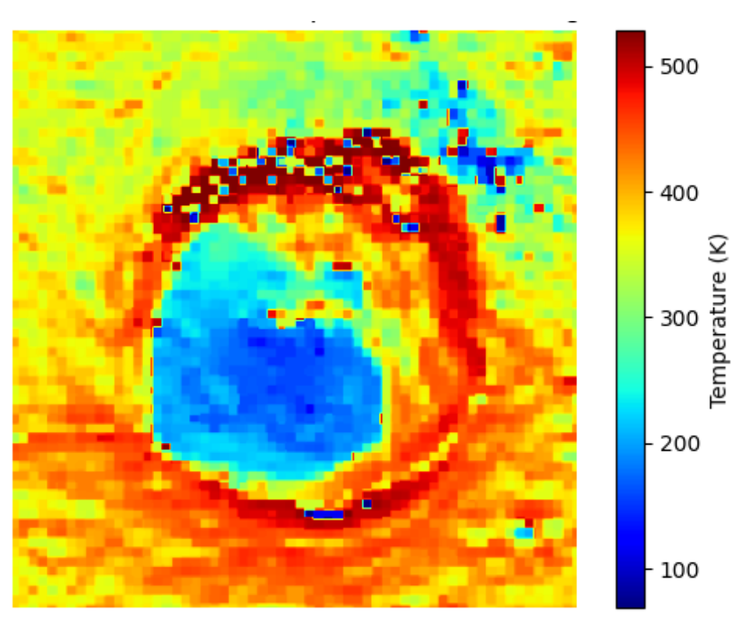
Geological map of Fuller crater taken from Bertoli et al. (in press).



Cumulative size frequency distribution of the crater counted in the floor (yellow) and ejecta (green) units, with age determination.

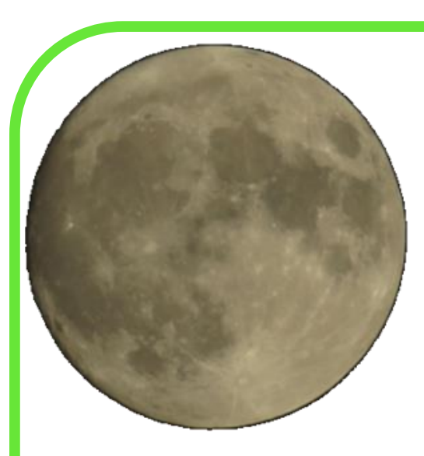


Impact numerical modelling



Thermal modelling

Project 1: “Impact modelling” WG of the LUMIO space mission

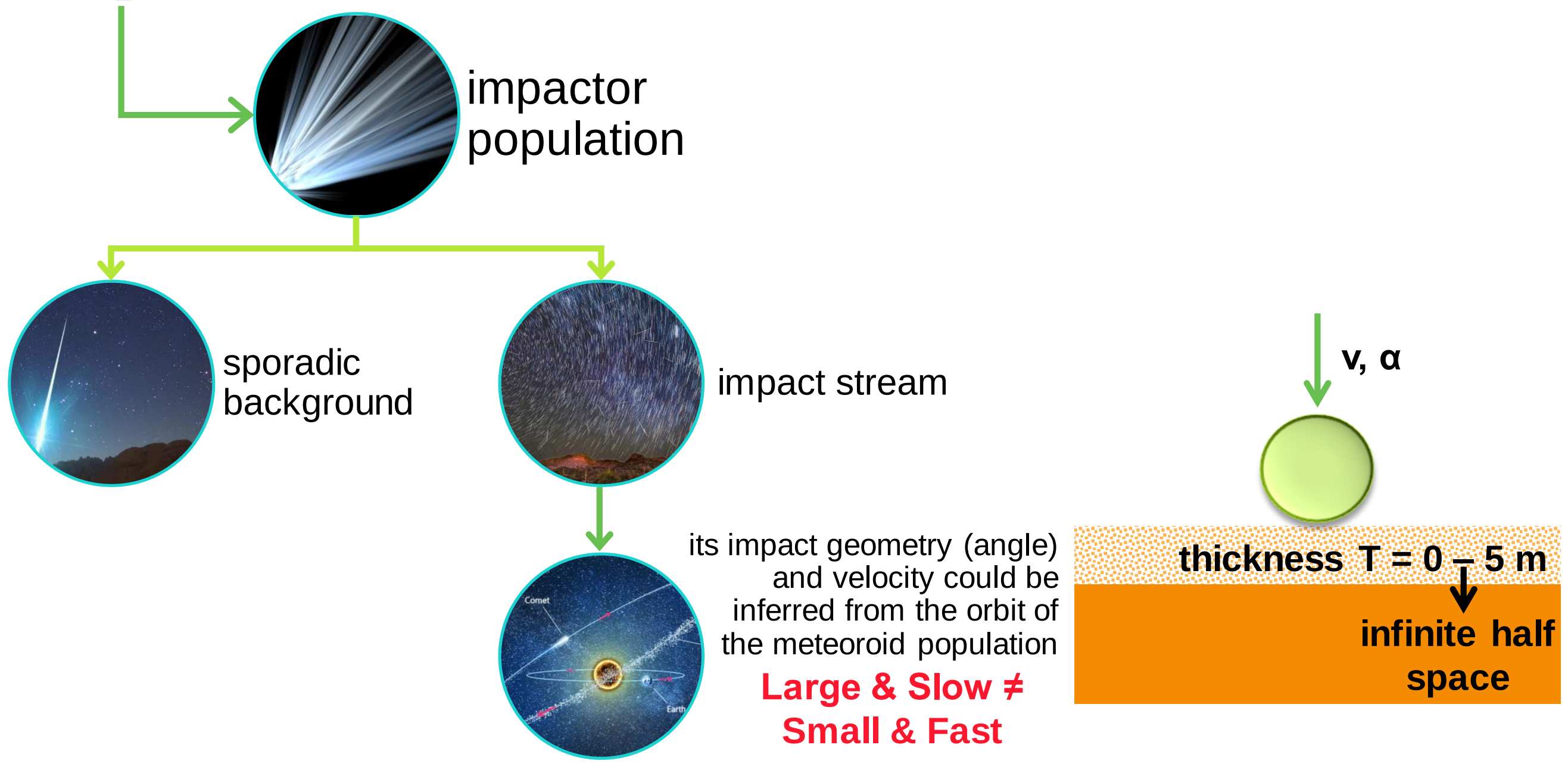


investigate how the impact mass and velocity, as well as the near-surface target properties can affect the final crater morphology

1) to study the impact process via numerical modelling;
2) compare the simulation results with observational data, in order to derive information about the impact area;
3) merge the parametric study into a generalized crater vs. projectile size relation, for varying impact conditions.

LUMIO definition and goals:

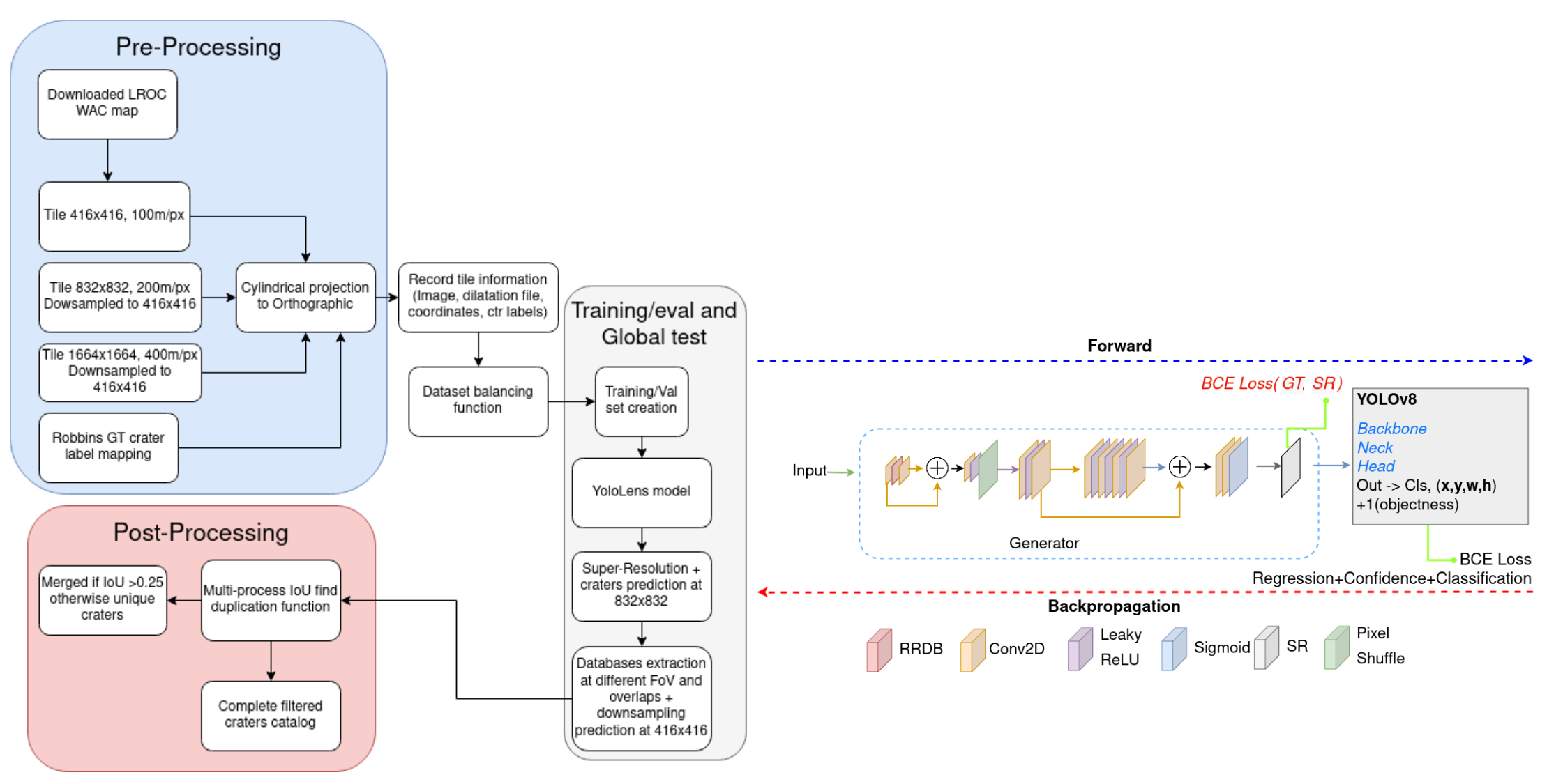
- ✓ a 12U CubeSat that carries the LUMIO-Cam, an optical instrument designed for observations in both the visible and near-infrared spectrum and continuous monitoring and data processing
- ✓ from a quasi-halo orbit at Earth-Moon L2, the mission aims to observe, quantify, and characterize meteoroid impacts on the lunar far side by detecting their flashes

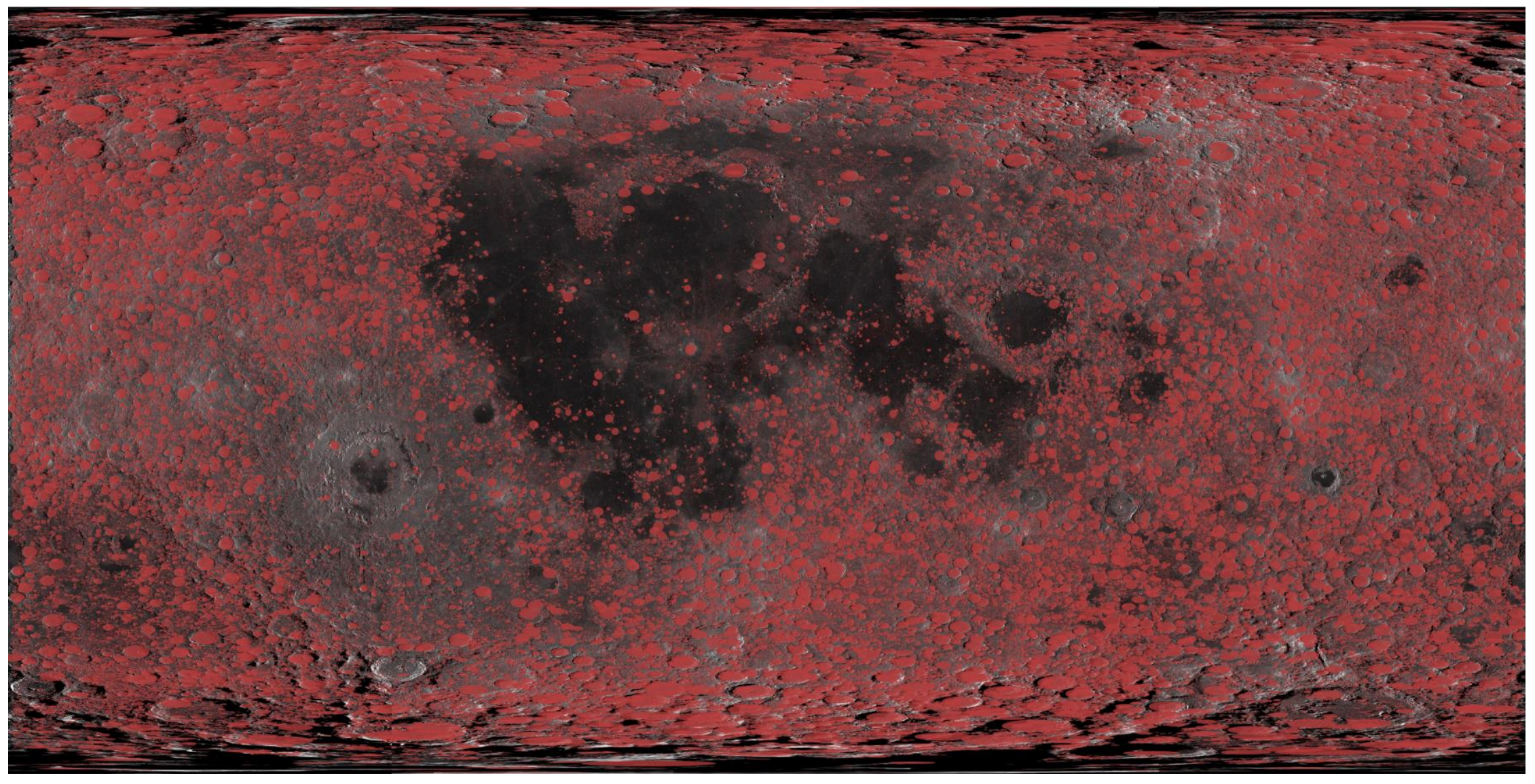


its impact geometry (angle) and velocity could be inferred from the orbit of the meteoroid population

Large & Slow ≠ Small & Fast

Project 2: (Automatic) Global crater database on the Moon derived using YOLO deep learning model

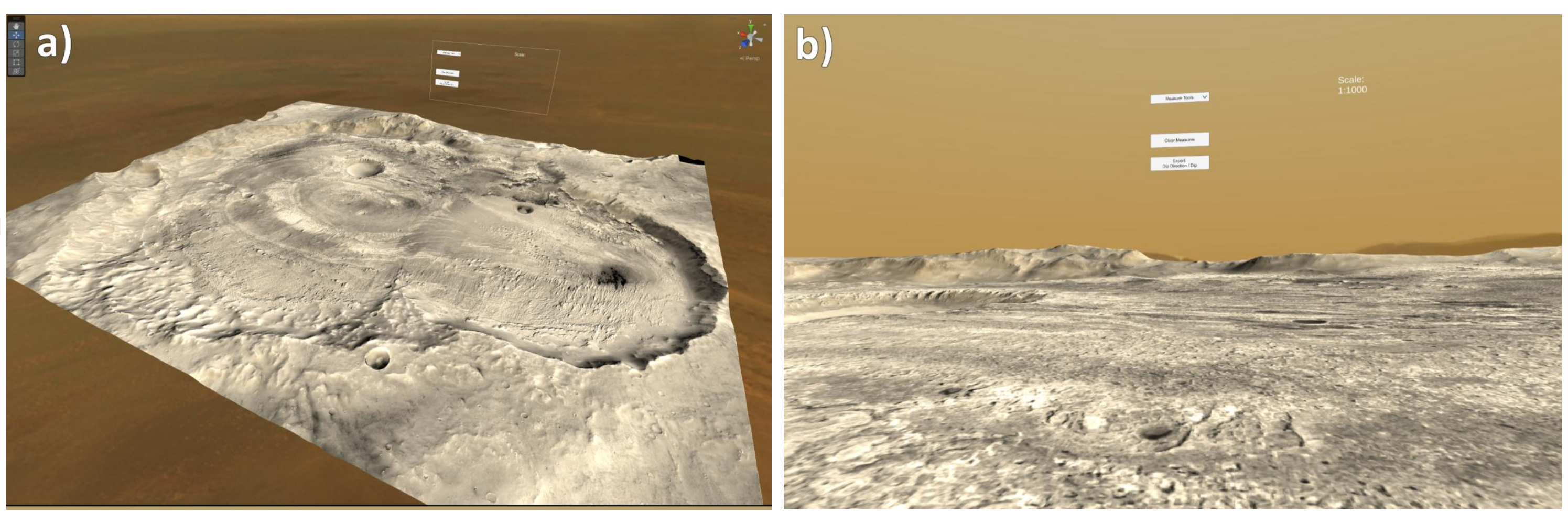




Overview of the global catalog LU5M812TGT of ≥0.4 km lunar craters (red circles) overlaid on the LROC WAC Global Mosaic.

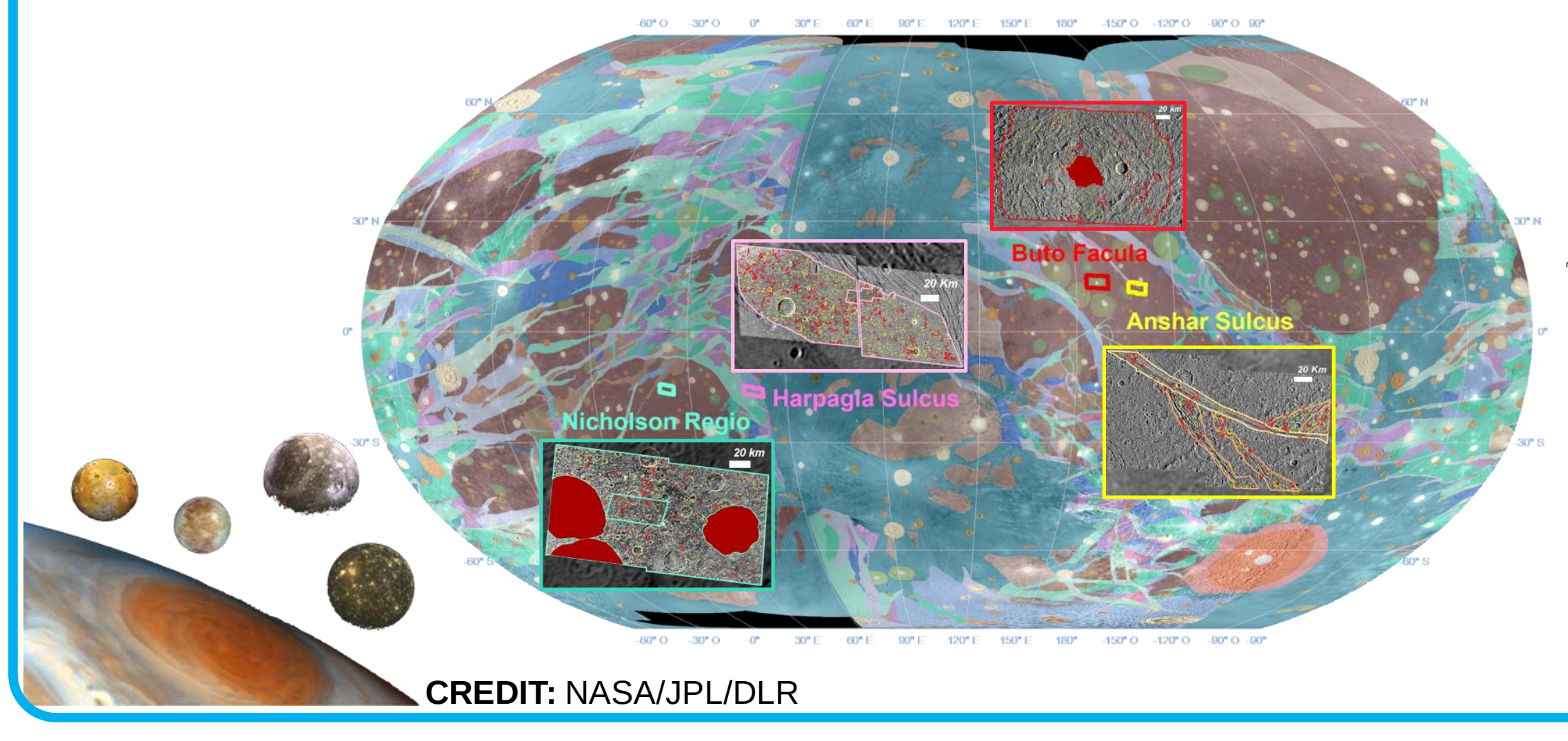
Project: Stereo reconstruction of crater morphology on Mars

CREDIT:
ESA/DLR/FU Berlin/G. Michael

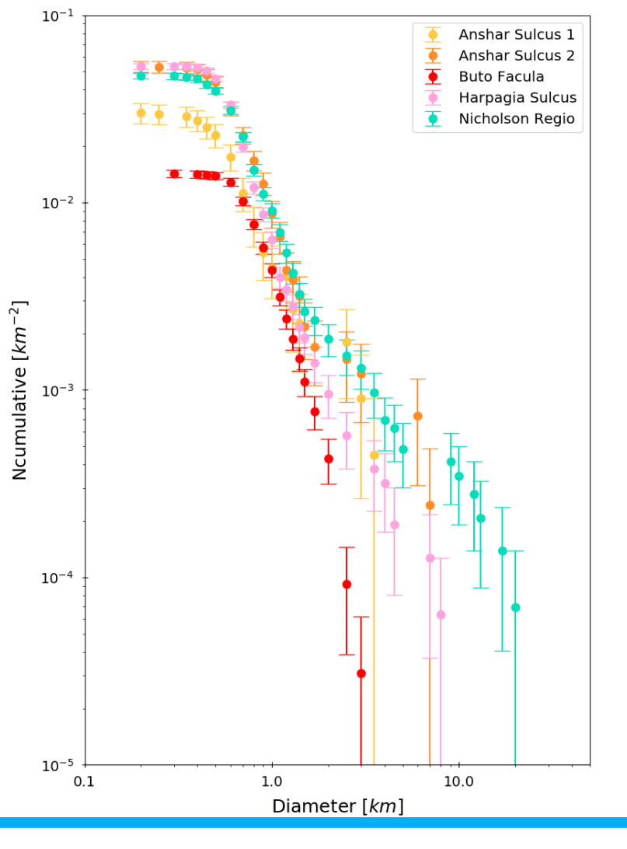


a) The craters Yelapa (smaller) and Izamal (D~150 km) in Meridiani region of Mars.
b) The two craters have been reconstructed in 3D through stereogrammetry on ExoMars TGO CaSSIS and MRO CTX images, then mosaicked and optimized for use in a VR environment.

Project 1: (Manual) Global crater database on Ganymede



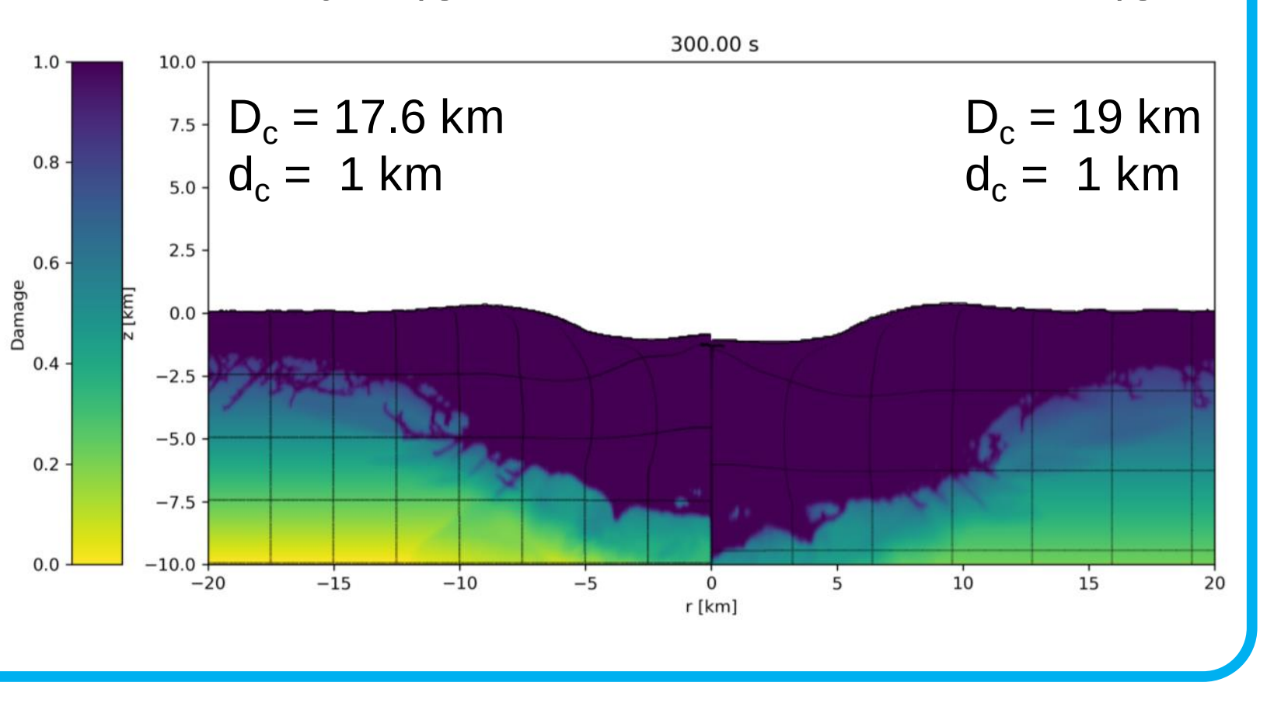
CREDIT: NASA/JPL/DLR



Project 2: Scaling Law

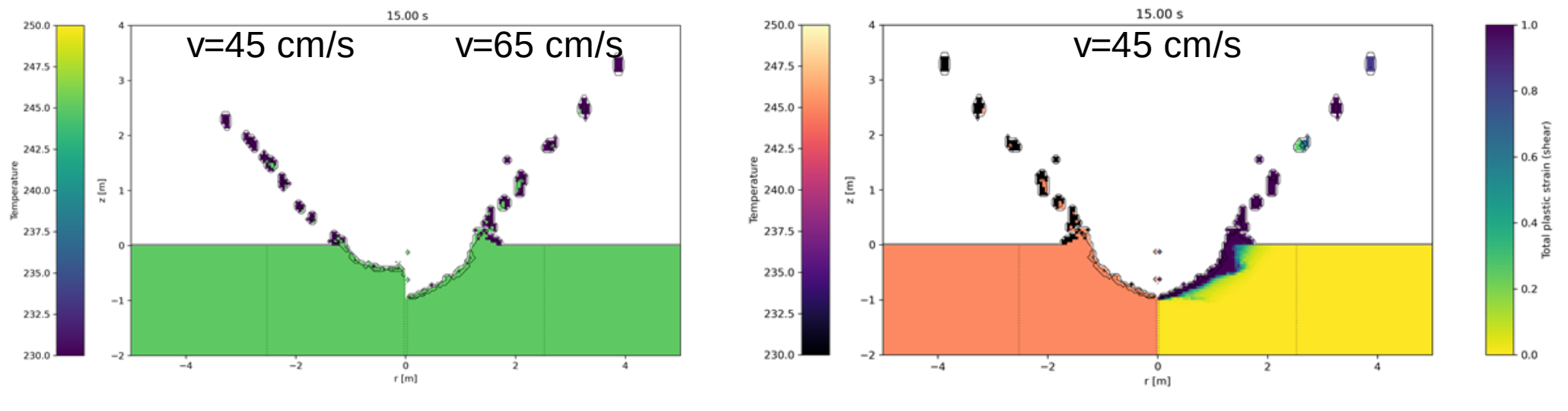
L = 1 km
v = 10 km/s

L = 1.27 km
v = 7 km/s

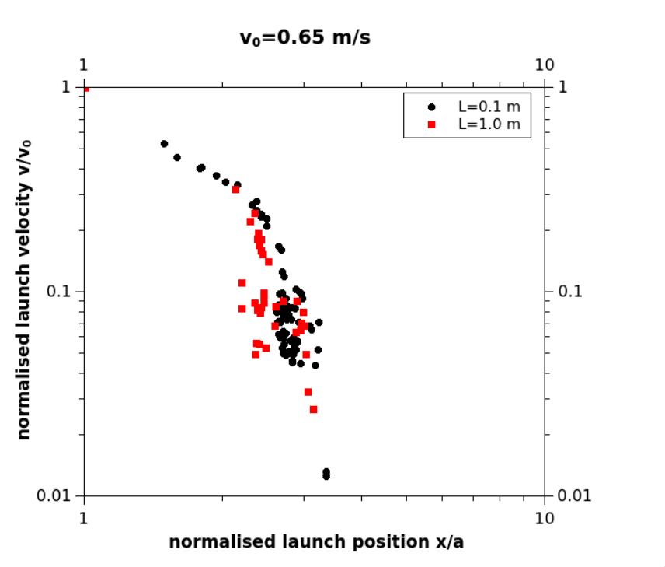


Project: Long term dynamics of boulders around the Didymos-Dimorphos binary

Projectile: L=1.0 m



CREDIT: ESA



CREDIT: Dr. R. Luther (MfN)

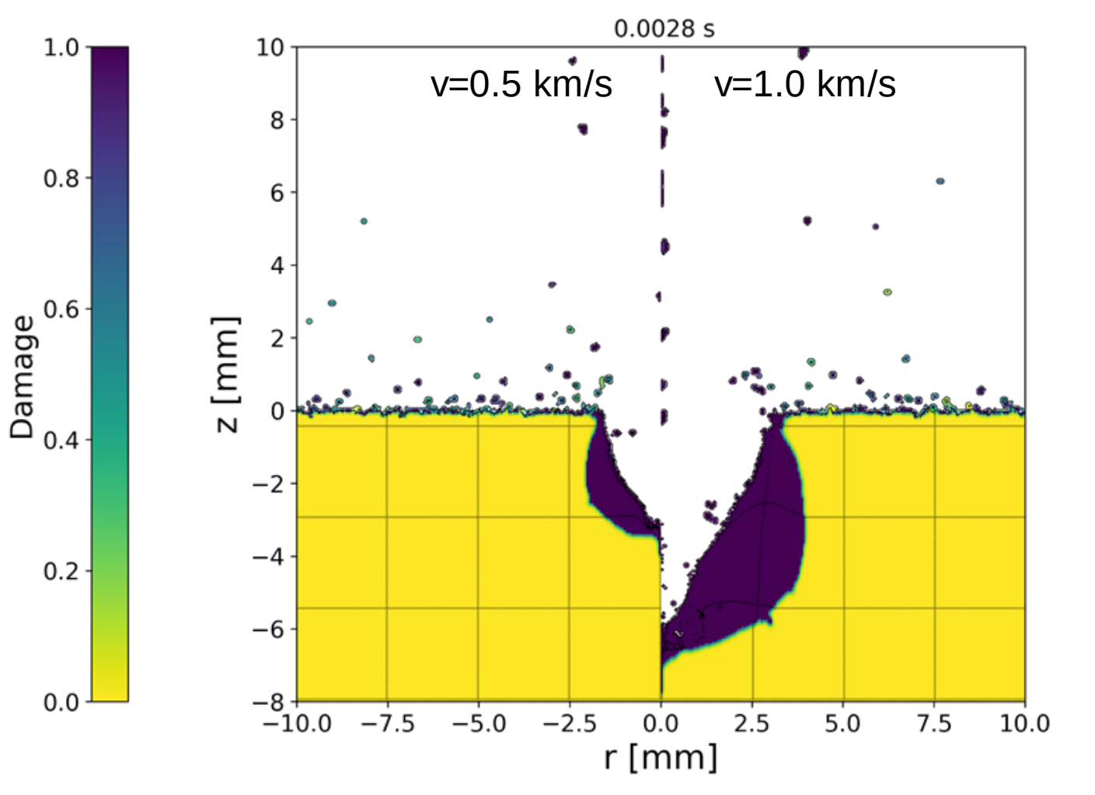
Project: Layers as building blocks of comets *to be carried out as ESA CI IDS*

CREDIT: Geraint Jones,
UCL Mullard Space Science Laboratory

GOALS:

I. classify the geological units on the comet in a relative chronostratigraphy, to finally assess the surface evolution;
II. characterize the shape and inner structure of the cometary nuclei;
III. determine the outcome of a collision with the cometary nucleus, and the initial impact conditions (object size, velocity, composition, strength, and density) under which such a collision can led to accretion rather than disruption;
IV. test the “Talp” model.

Projectile: L=1.0 mm



CREDIT: ESA