A Rosetta/OSIRIS View on the Jigsaw Puzzle of Modern Cometary Science

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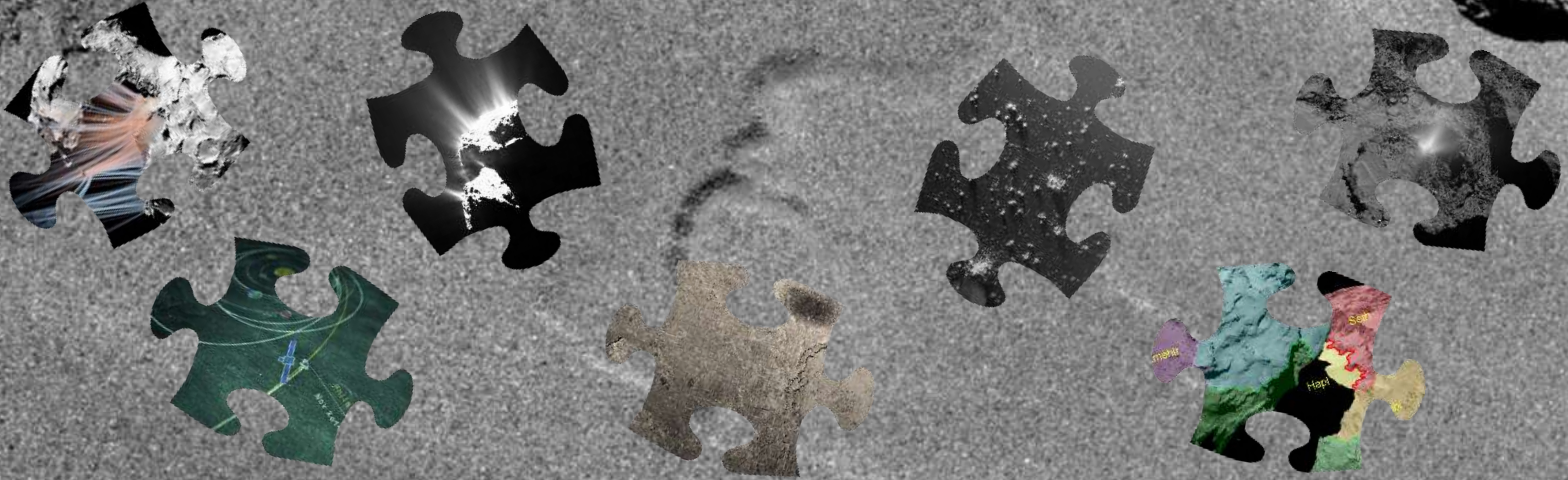
1. What is really known?

2. What is relevant for the bigger picture?
(formation and evolution)



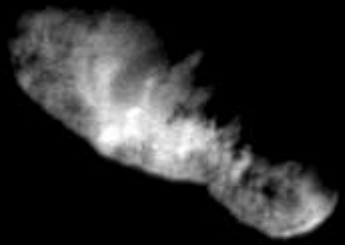
Fact sheet

Mass: 9.982×10^{12} kg
Volume: 18.7 km^3
Density: 0.53 g/cm^3
Ice: 14 – 33 wt%
Porosity: ~ 71 %
Rotation period*: 12 hours
Albedo: 5.9 %

* in 2016

The <u>shape</u> poses challenges in modelling (but it shouldn’t be much of a surprise).

1P/Halley - 1986

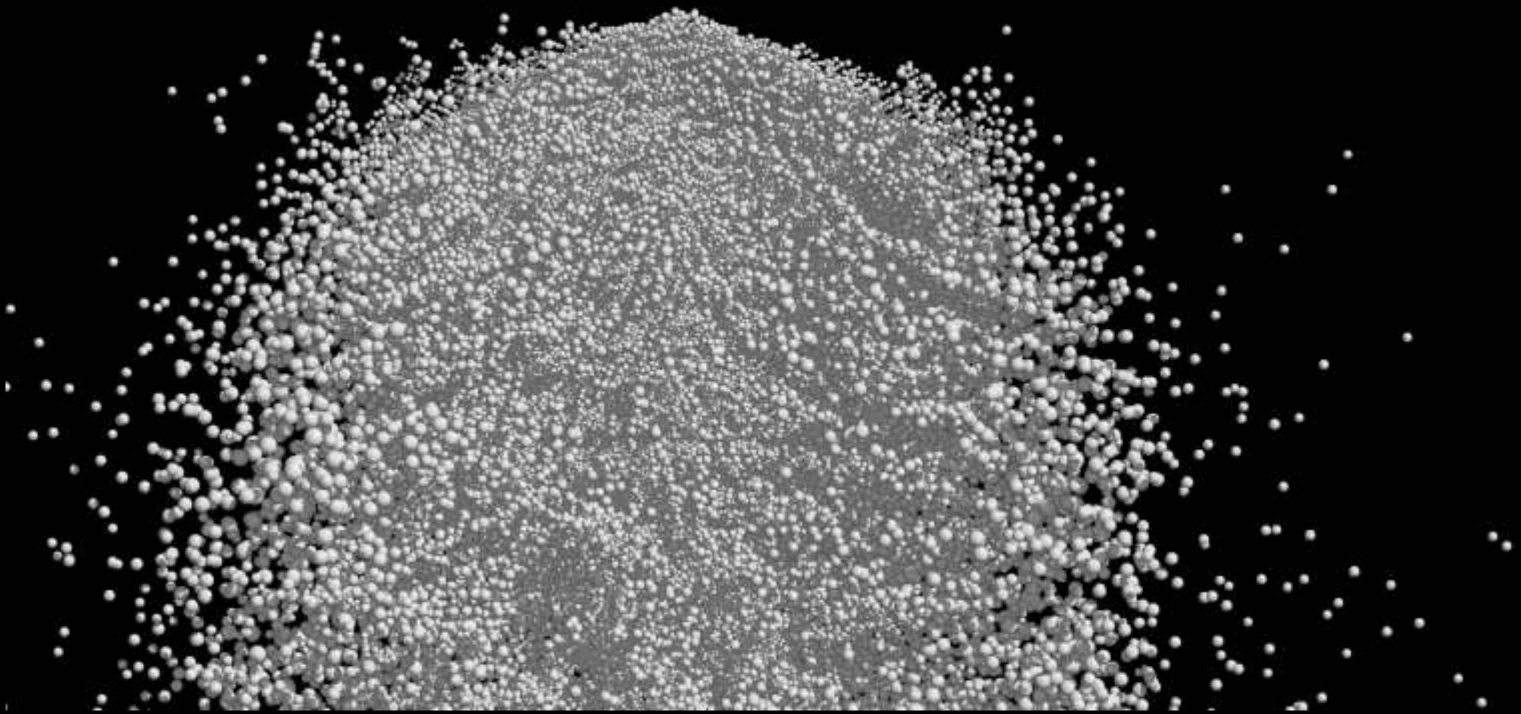


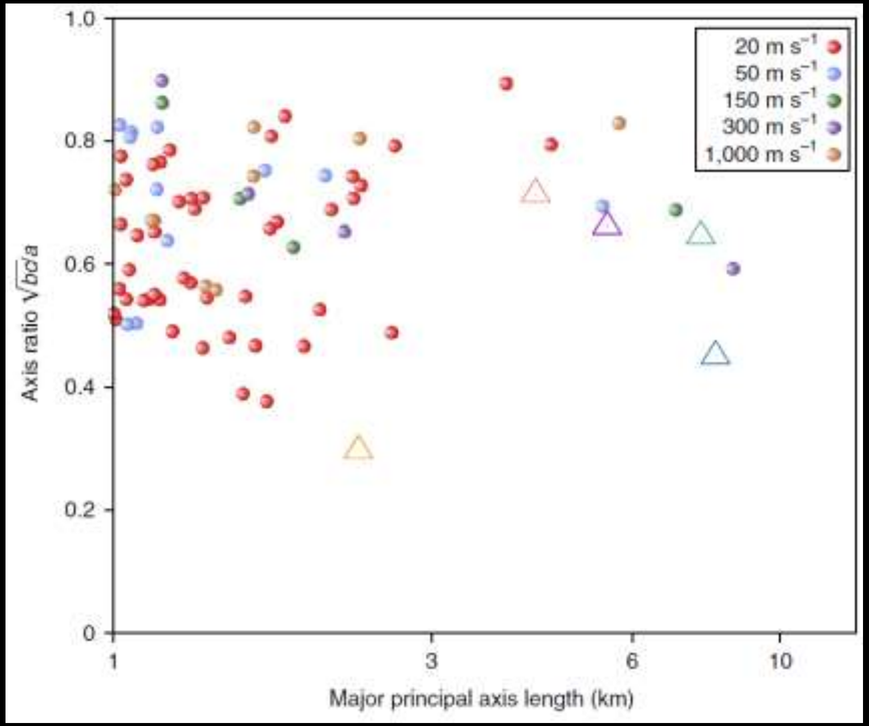
19P/Borelly - 2001

103P/Hartley 2 - 2010

25143 Itokawa

Formation of bi-lobal shapes is omnipresent.





left: 150 m/s impact
general: no significant temperature or porosity increase

Schwartz et al., 2018

Bulk density as low and porosity as high as expected.

SPC (v1.7) shape model

1. Volume Measurement:

- OSIRIS shape models
- $V = 18.56 \pm 0.02$ km^3 (Preusker et al., 2017)

2. Mass Determination:

- Rosetta Radio Science Instrument (RSI)
- Measure mass (grav. pull) from Doppler shift
- $M = (9{,}982 \pm 3) \times 10^9$ kg (Pätzold et al., 2016)

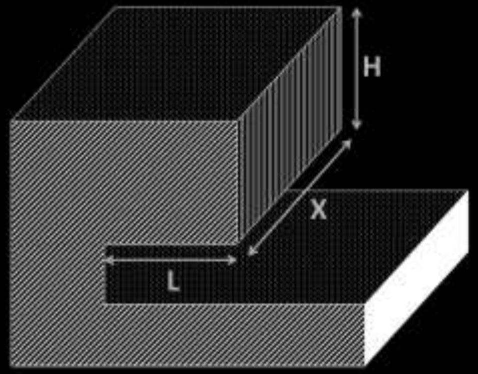
3. Density & Porosity

- $\rho = M/V = 537.8 \pm 0.7$ kg/m^3
- $14\% \leq f_{ice} \leq 33\%$ (Rotundi et al., 2015)
- 25% metal/sulfides, 42% rock/organics, and 32% ice (mass), thus $\rho = 1820$ kg/m^3 (Davidsson et al., 2016)
- $\psi = (71 \pm 2)\%$

Strength in the expected range, no proof for “consolidated terrain”.

Applied data:

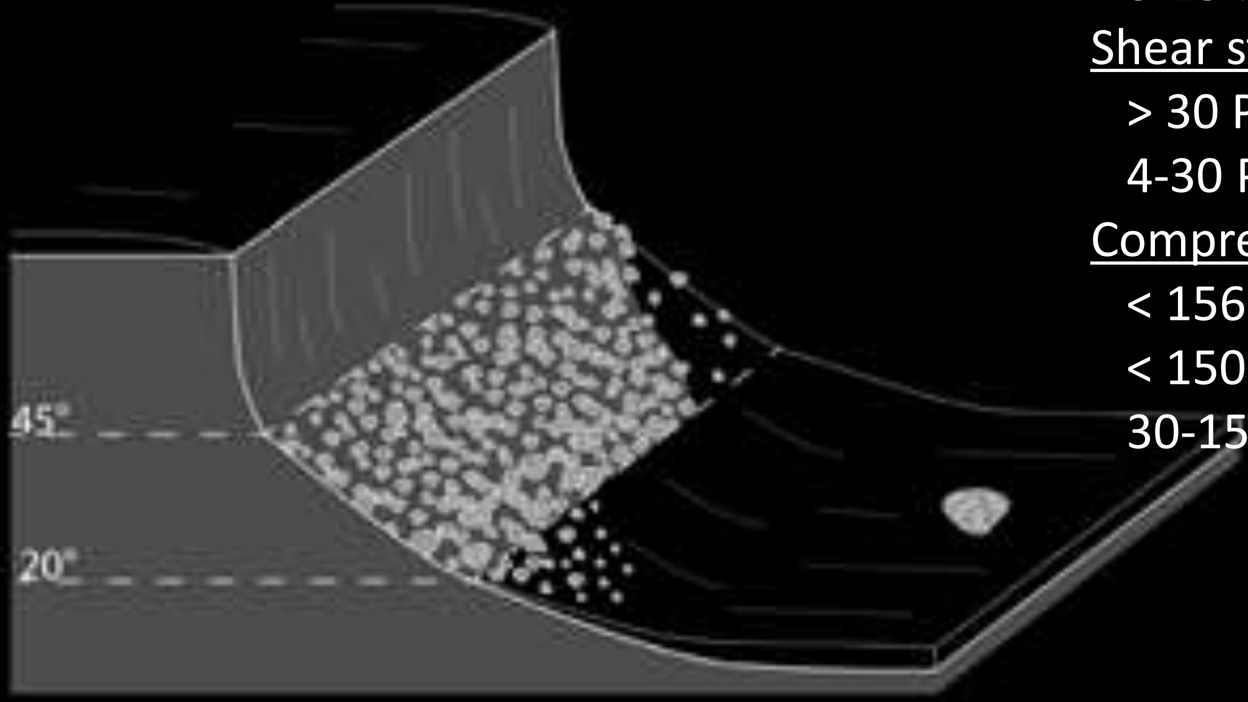
- Overhangs, collapsed structures, boulders, cliffs, and Philae’s footprint
- Images and shape models



Tensile strength σ_T:
< 150 Pa (collapsed structures)
3-15 Pa (overhangs)

Shear strength σ_S:
> 30 Pa (Hathor cliffs)
4-30 Pa (fine surface materials and boulders)

Compressive strength σ_C:
< 15600 Pa (fine surface materials)
< 1500 Pa (collapsed structures)
30-150 Pa (overhangs)



Groussin et al., 2015

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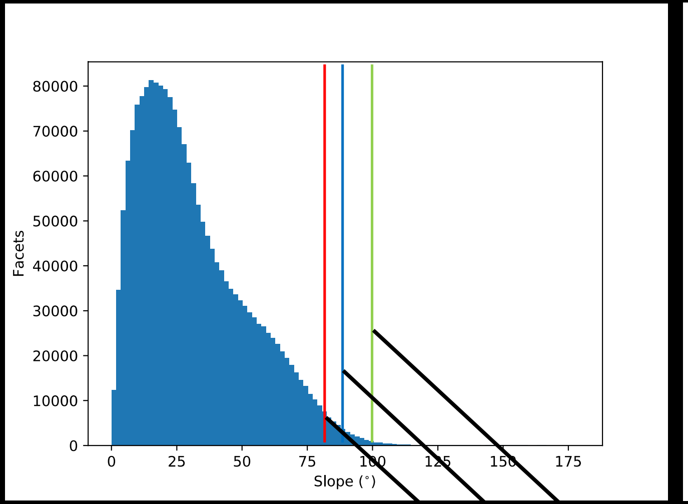
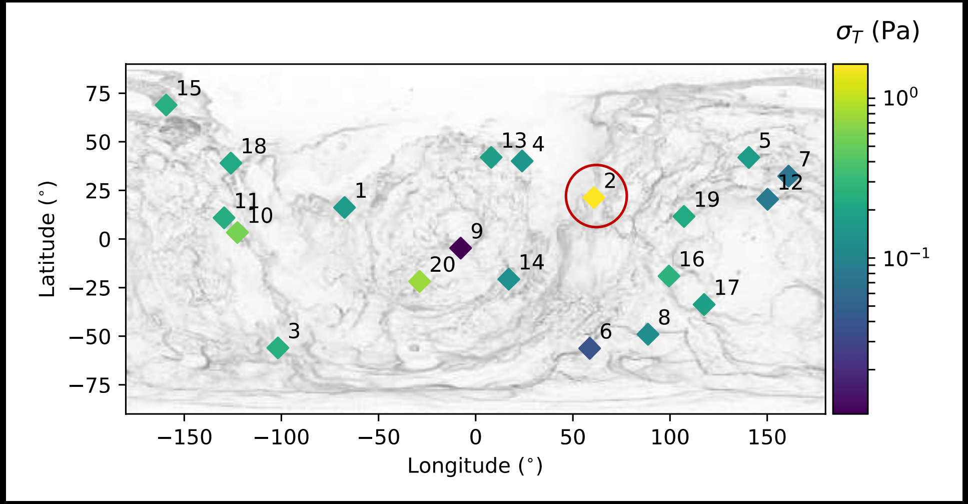
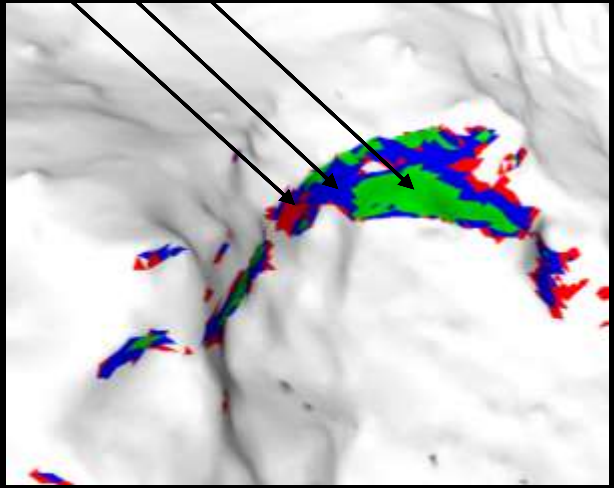
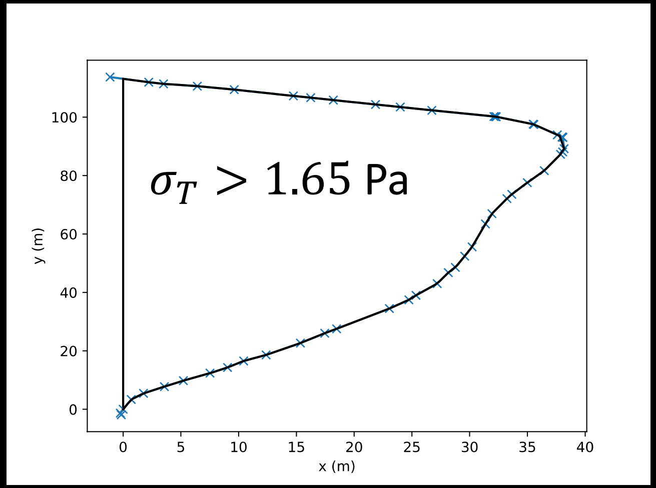


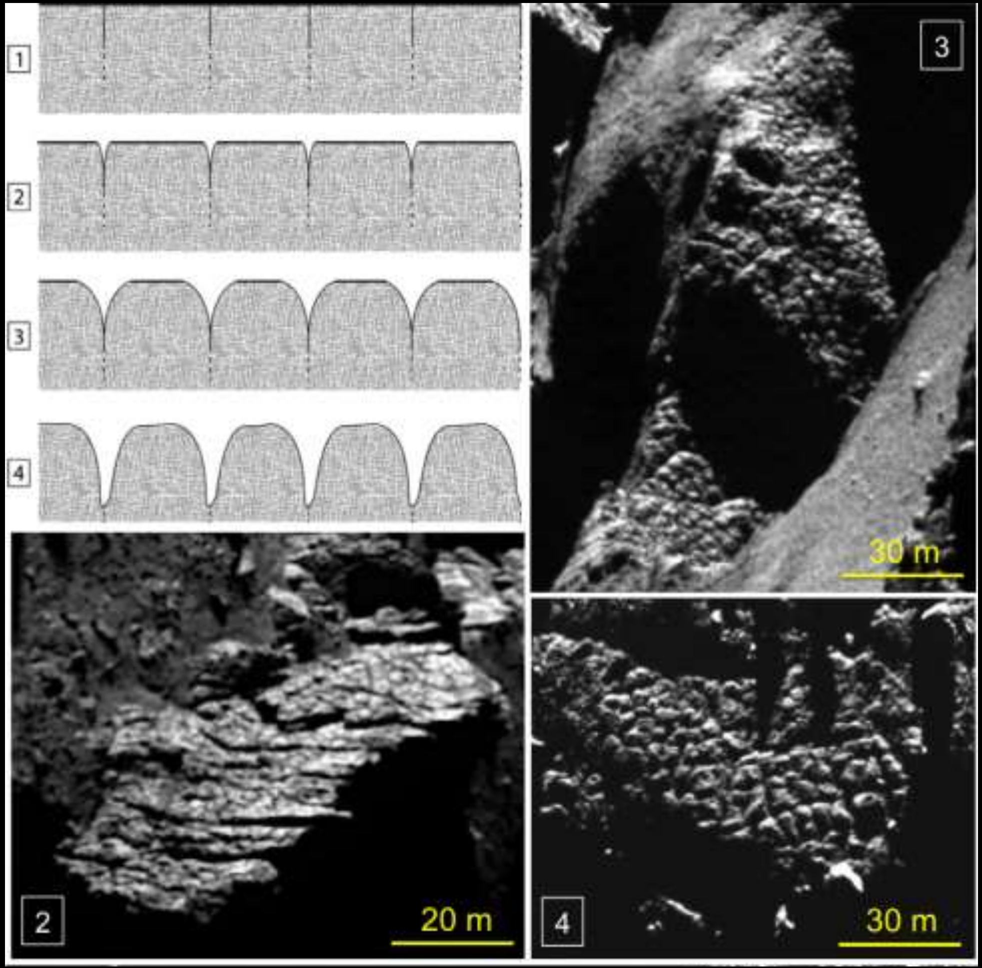




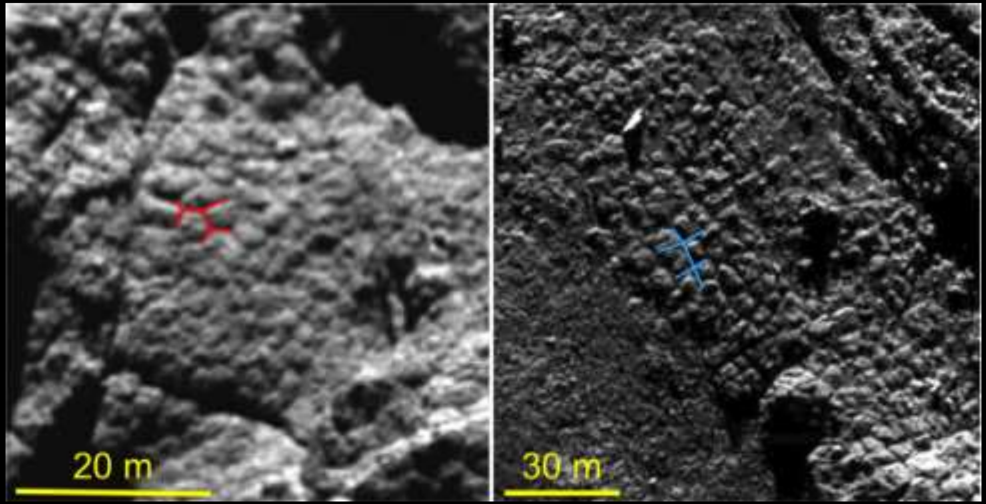


Attree et al., 2017

Formation and evolution of <u>cracks</u> debated.



Auger et al., 2018



"Their formation is consistent with the diurnal or seasonal temperature variations in a hard (MPa) and consolidated sintered layer of water ice, located a few centimeters below the surface. "

What is the required material strength to propagate cracks on the meter scale?

Activity has many faces:
diffuse (?), jet-like, transient, outbursts, sunset.

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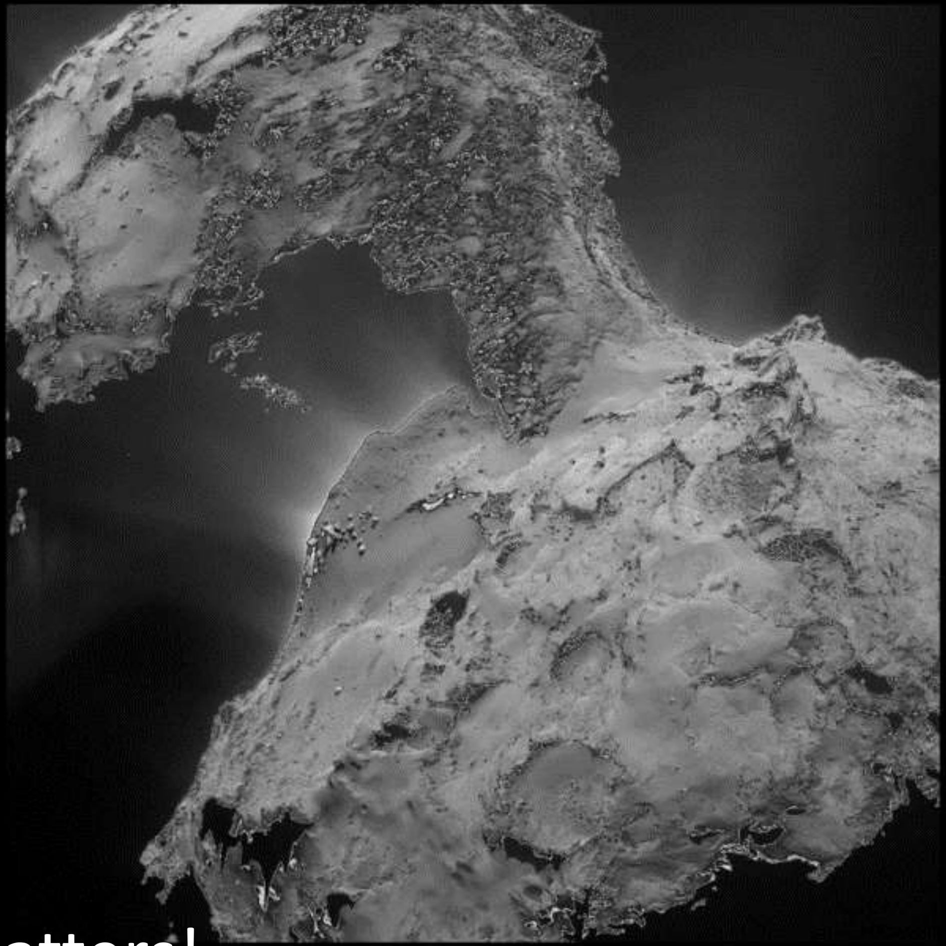
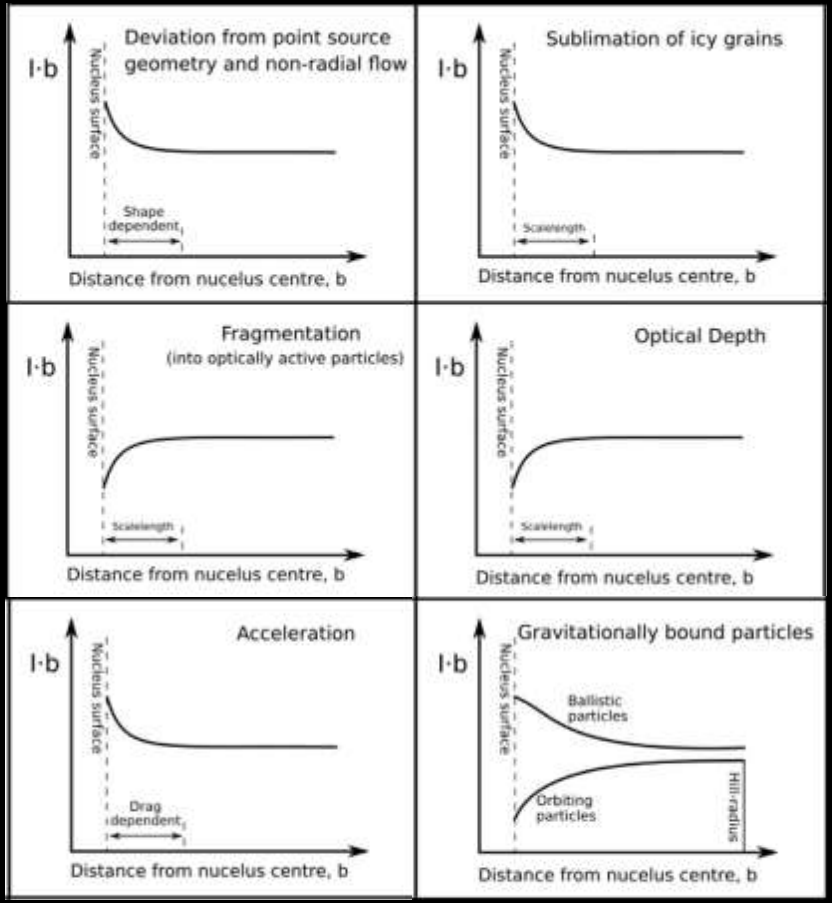


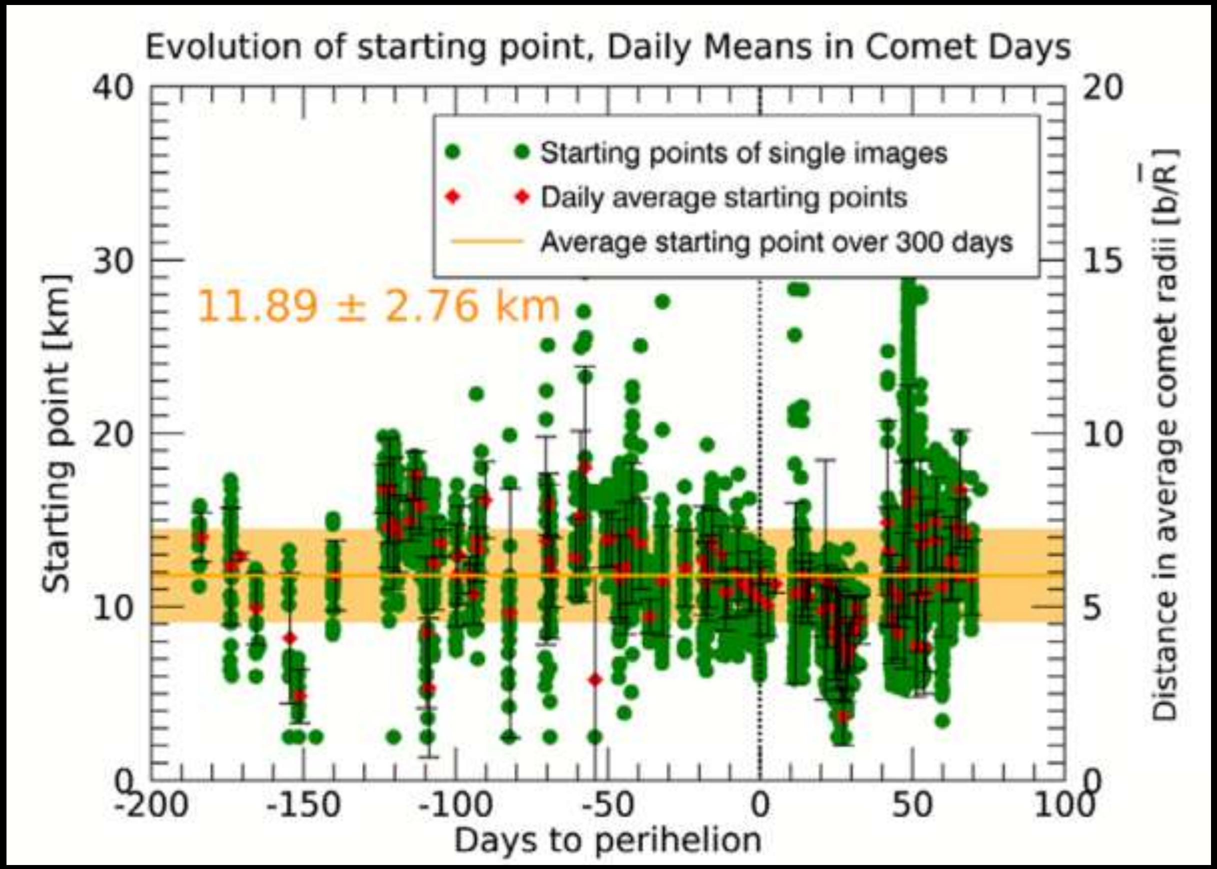
Observation geometry matters!

Shi et al., 2018

Processes of <u>inner dust-coma</u> (below 12 km) complex, thus poorly understood.



$$f(b; u, v, w, z) = u/b^v + wb + z$$

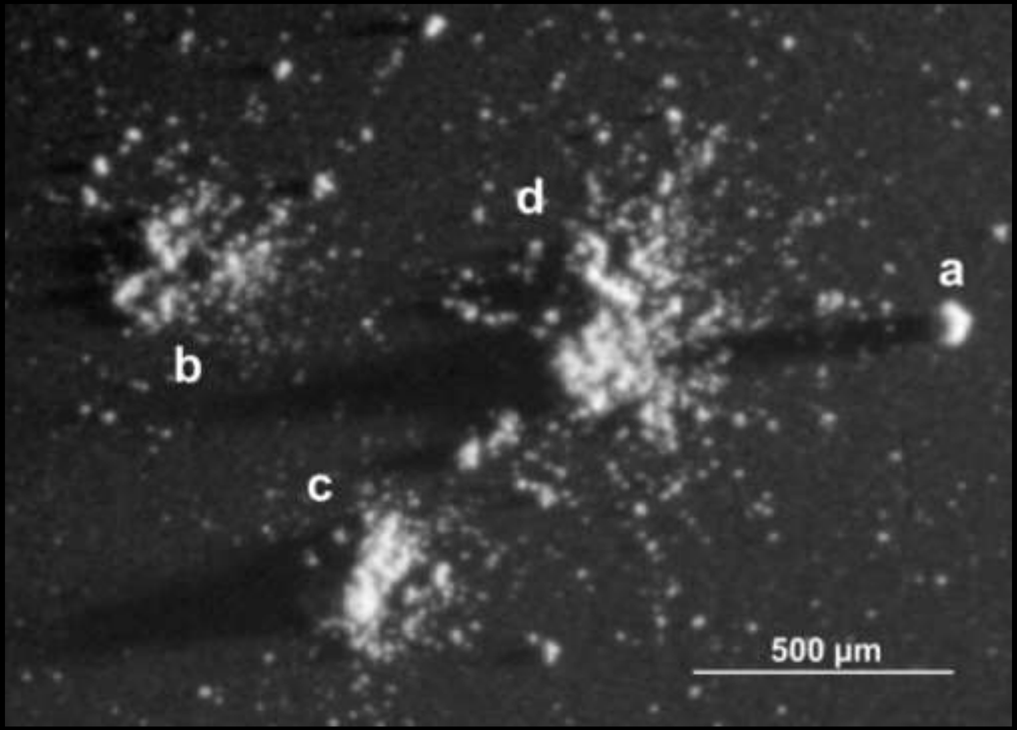


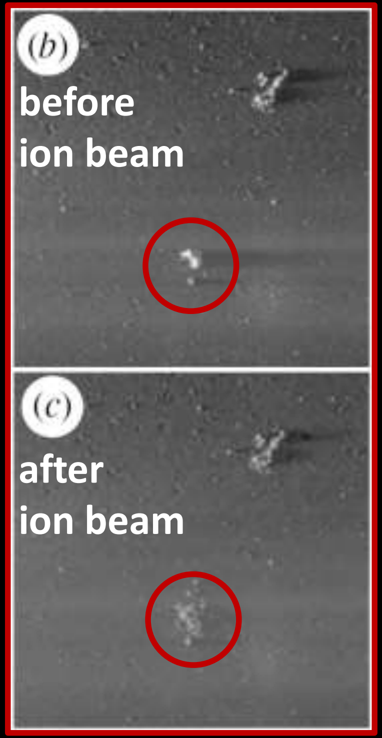
Gerig et al., 2018

The brightness ("dust density") as a function of impact parameter ("projected radius") follows a <u>"1/r" profile above 11.89 km</u>.

Dust properties are consistent with agglomeration.

Langevin et al., 2016





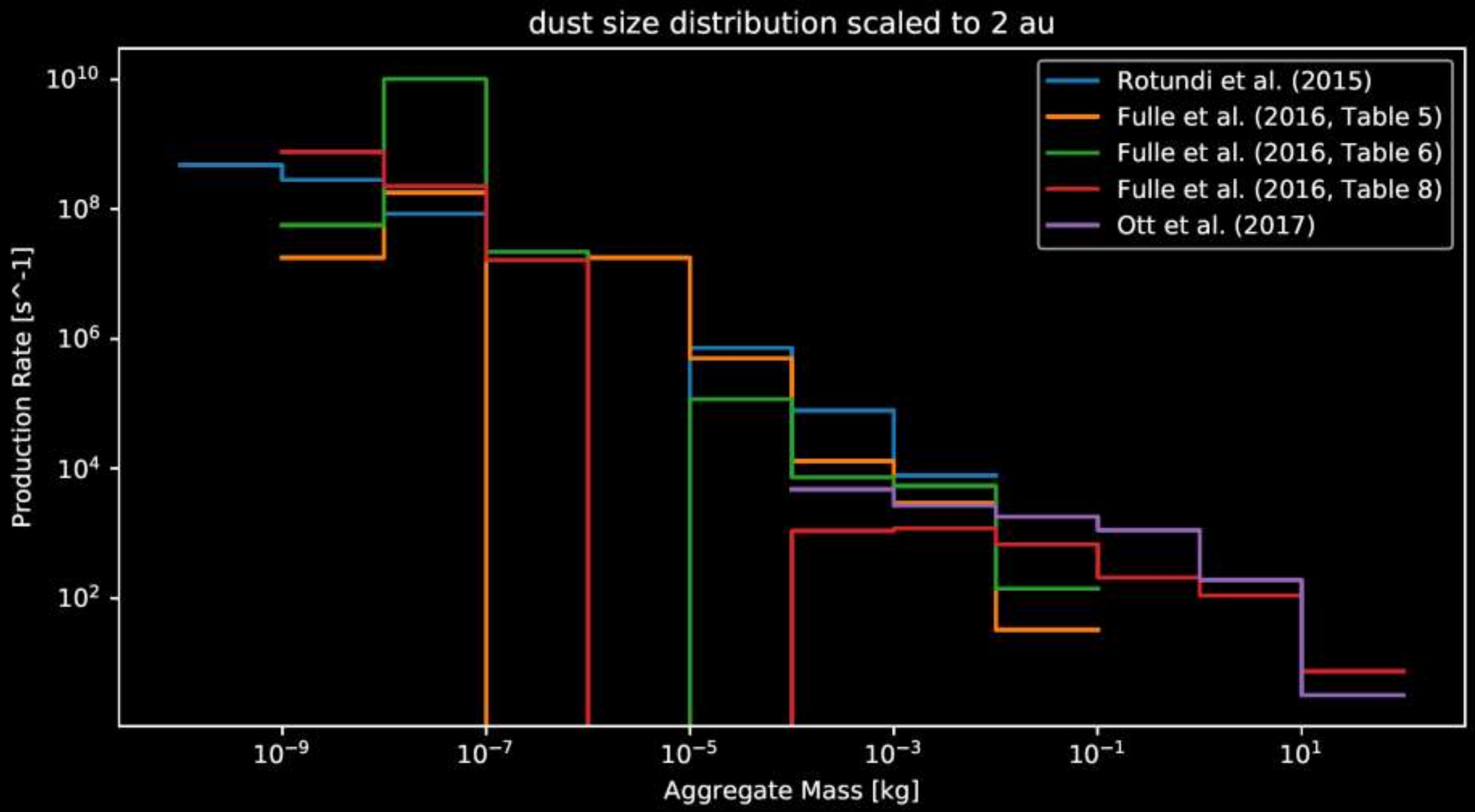
Hilchenbach et al., 2017

Mannel et al., in prep.

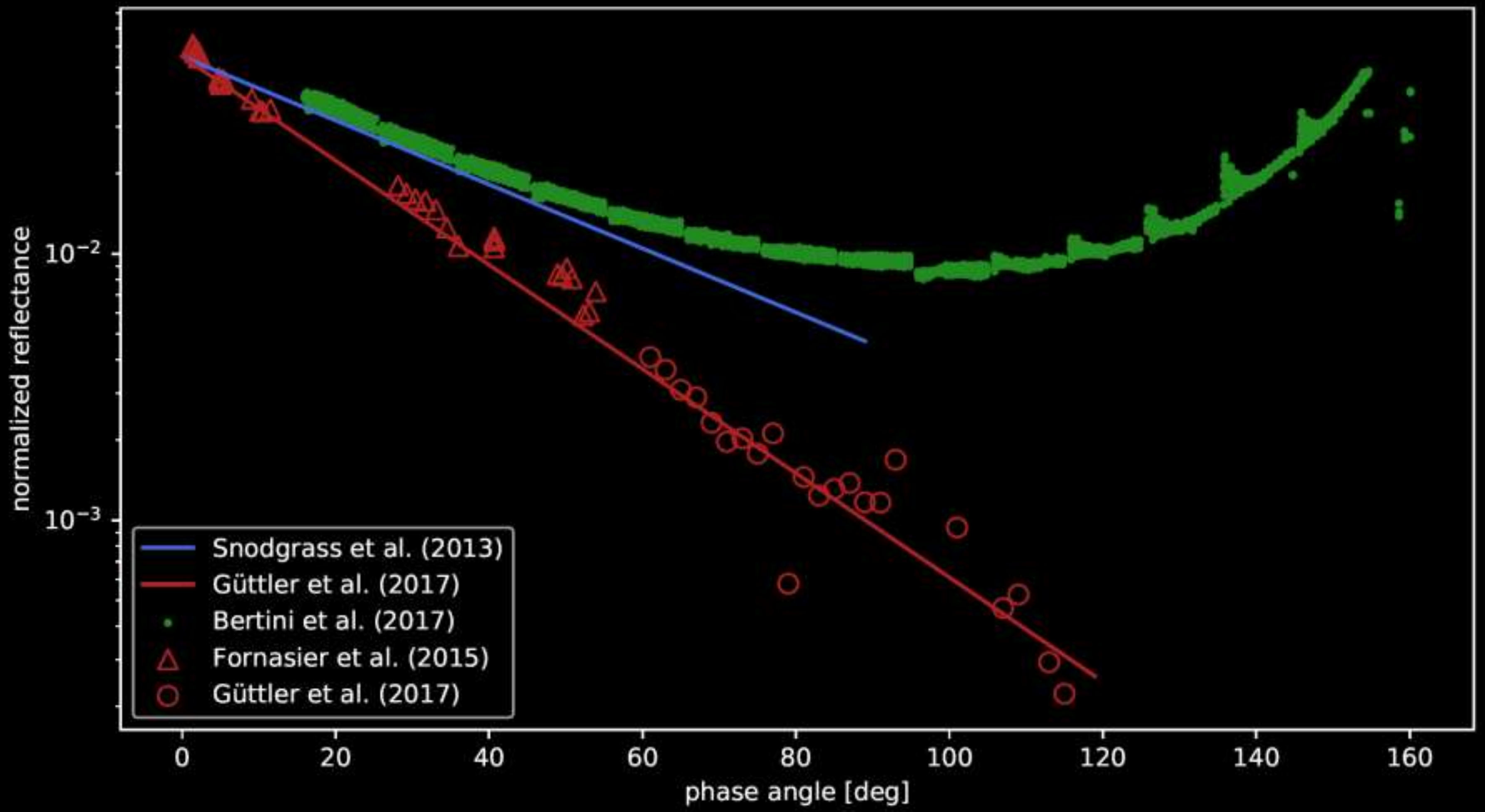
COSIMA: Loose structures, can be broken up by electrostatic charging (using SIMS ion beam).

MIDAS: Smallest observed structures in the 0.1 µm range. Consistent with several model approaches (VIRTIS, MIRO, etc.)

The dust size distribution is variable and not fully understood.

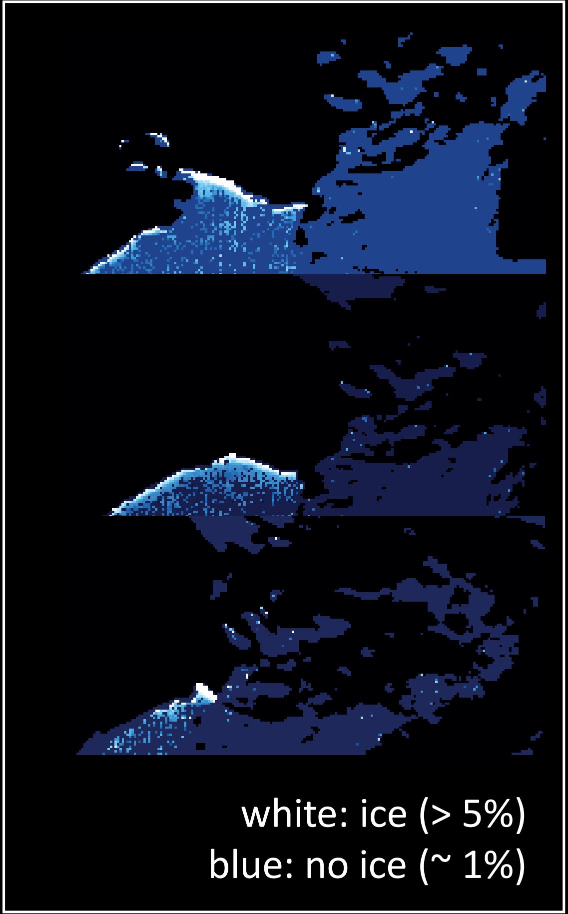


The dust phase function affects most size measurements.

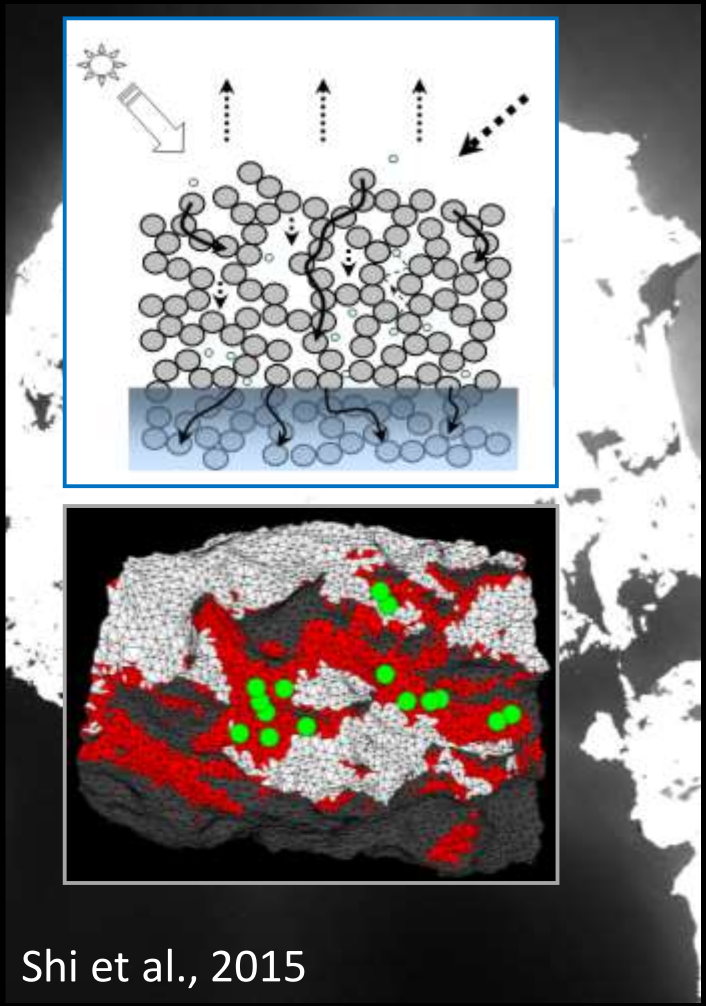


Many <u>sub-surface processes</u> are understood but model dependent.

Fornasier et al., submitted

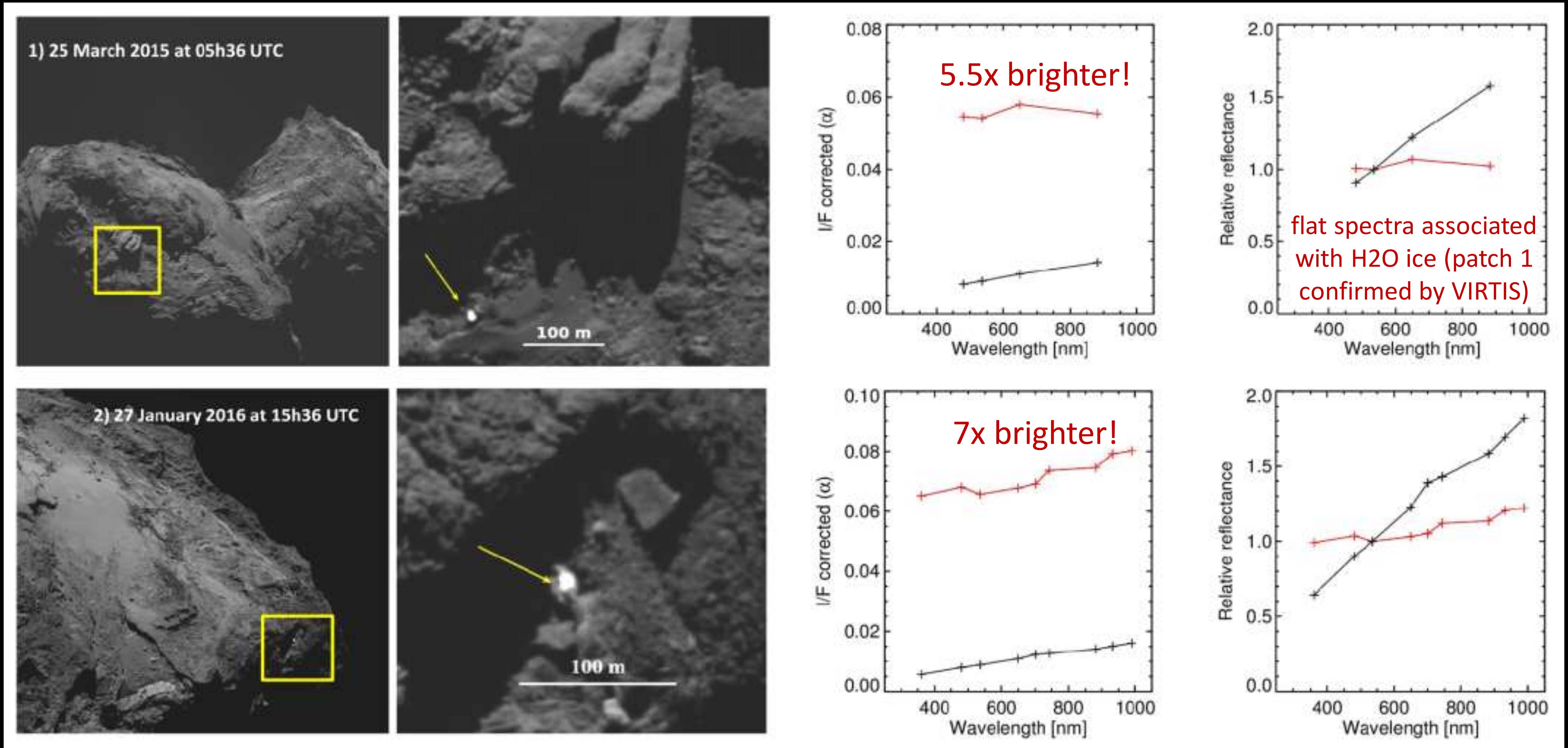


De Sanctis et al., 2015



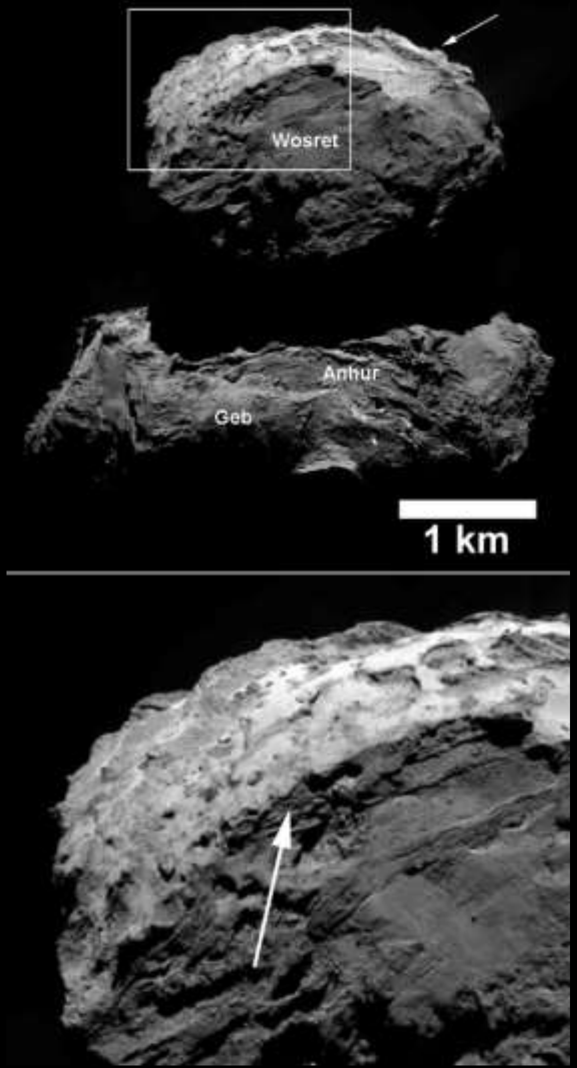
Shi et al., 2015

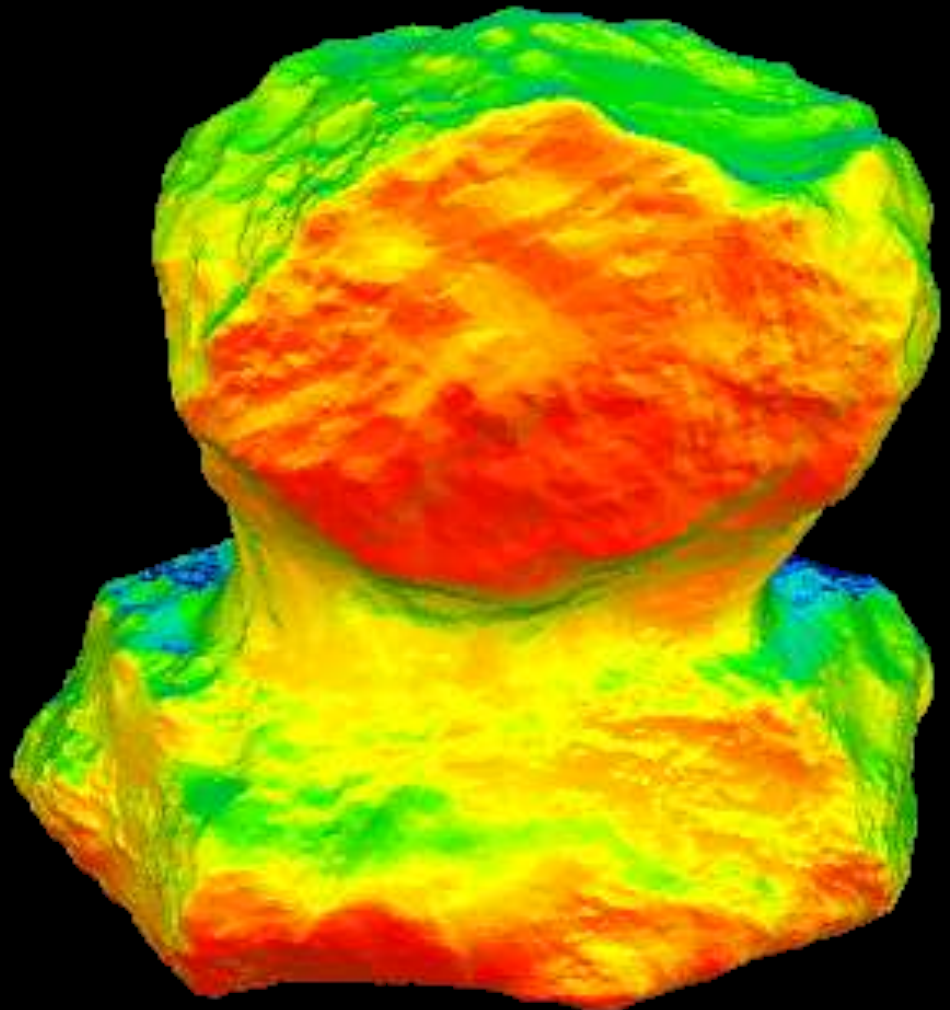
Bright patches indicating inhomogeneity?



Deshapriya et al., 2016

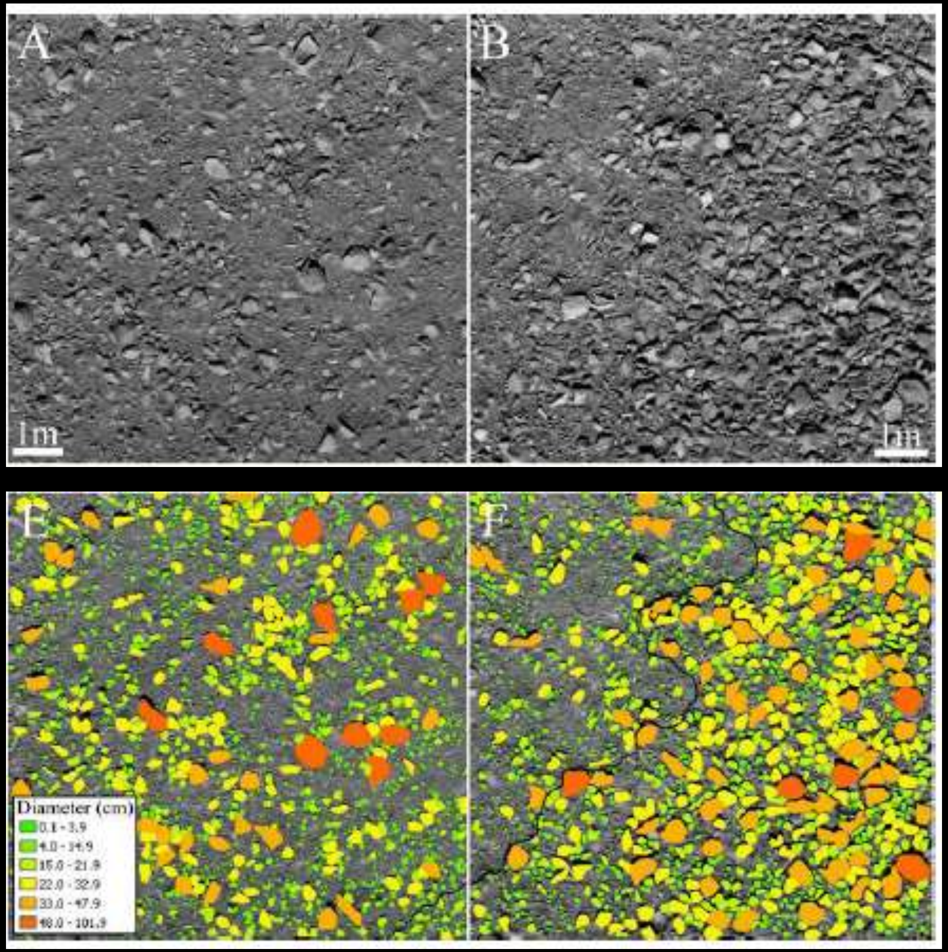
<u>Back fall</u> is much more important than previously acknowledged.

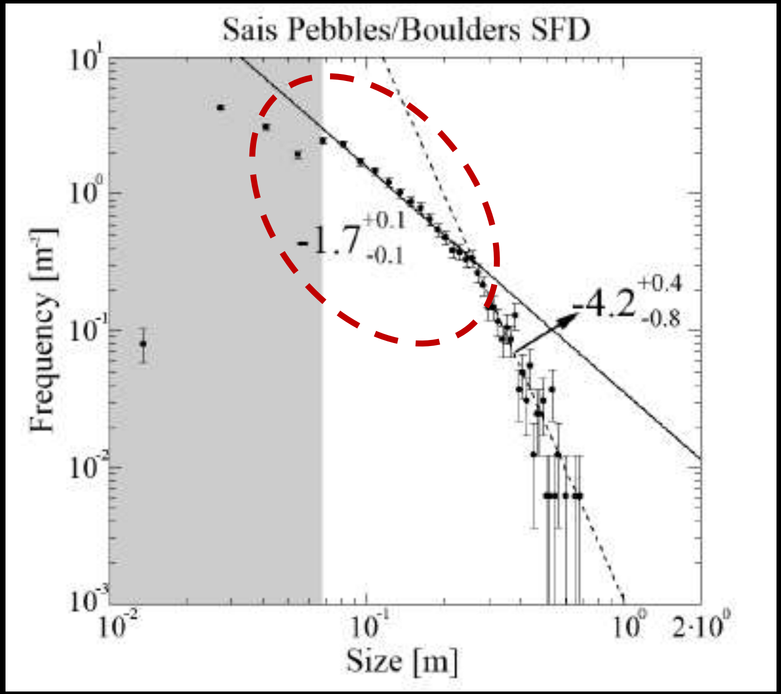




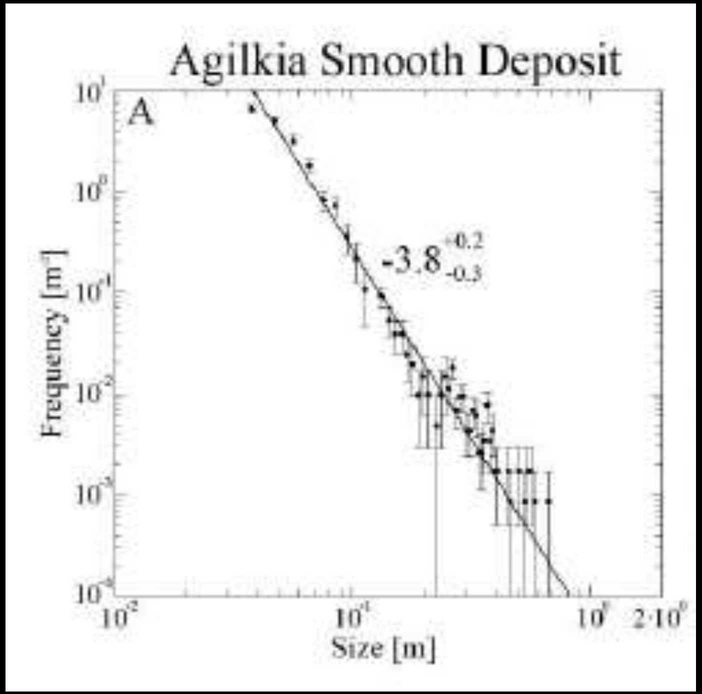
Keller et al., 2017

Which material is falling back?
Size segregation?





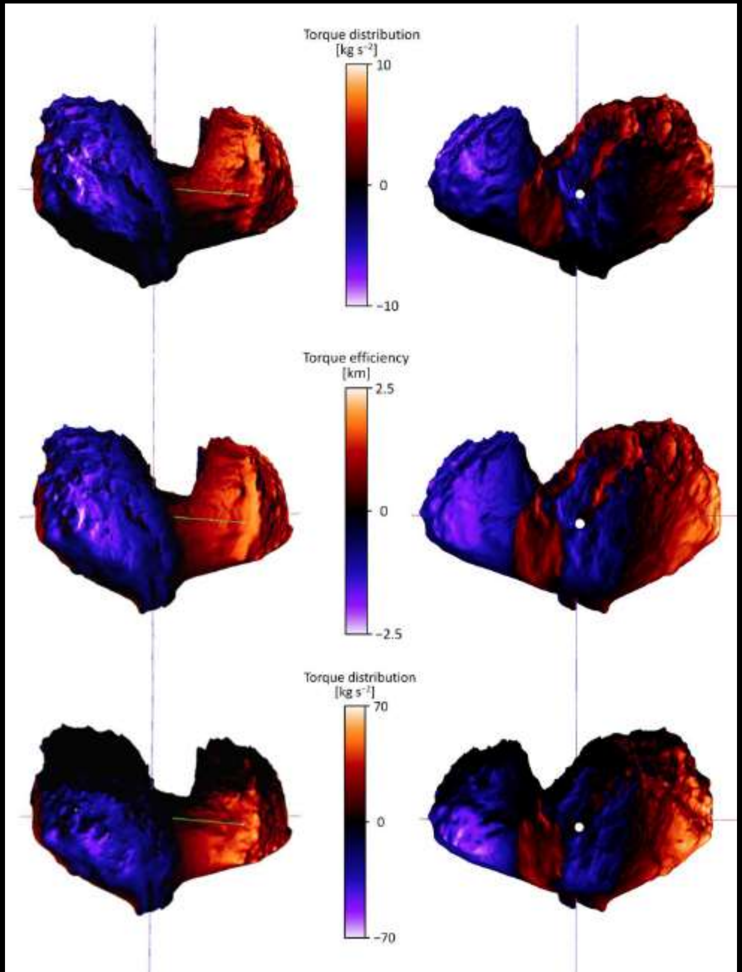
Rosetta landing site Sais

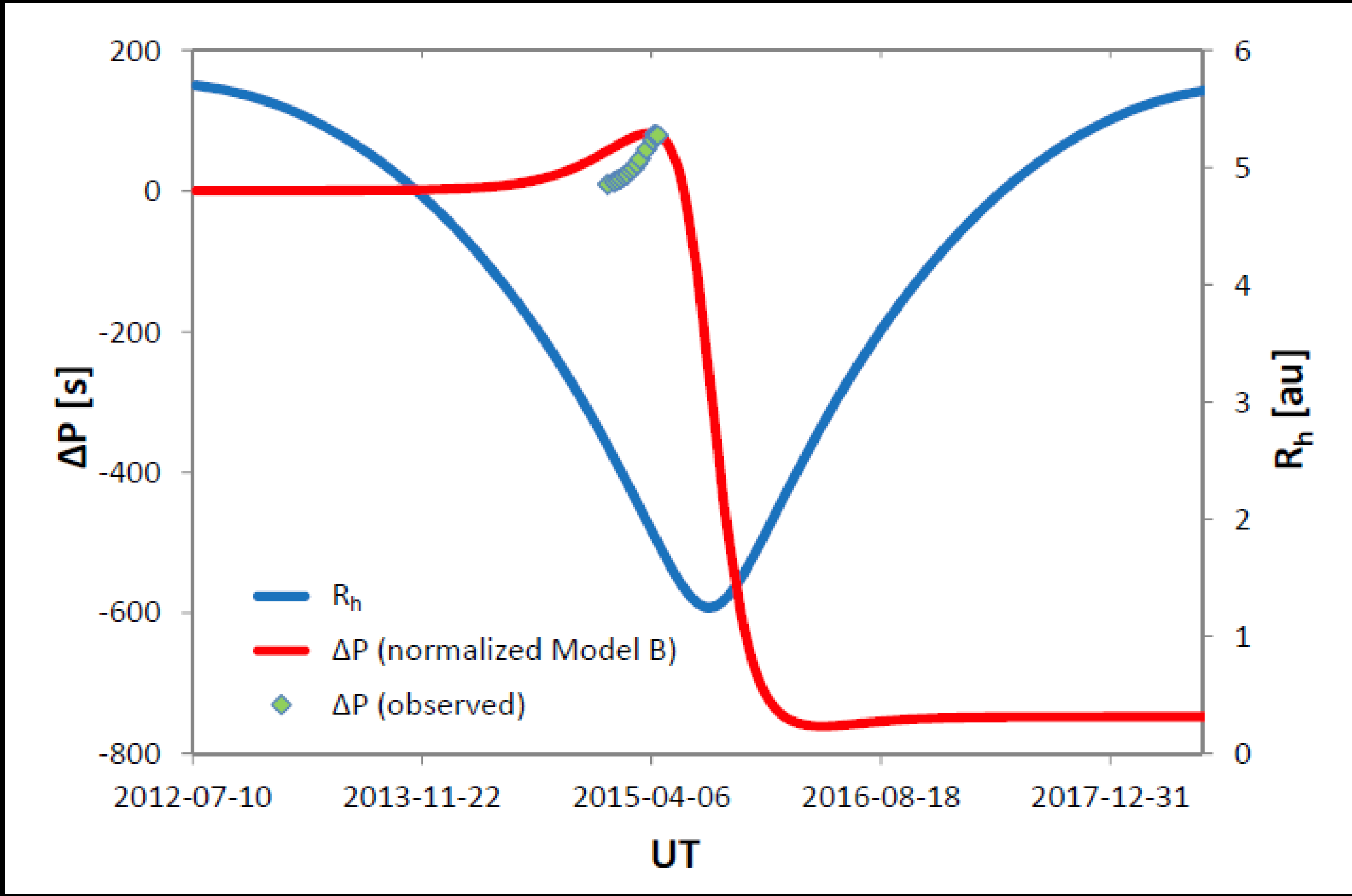


Philae touchdown site Agilkia

Pajola et al., 2017

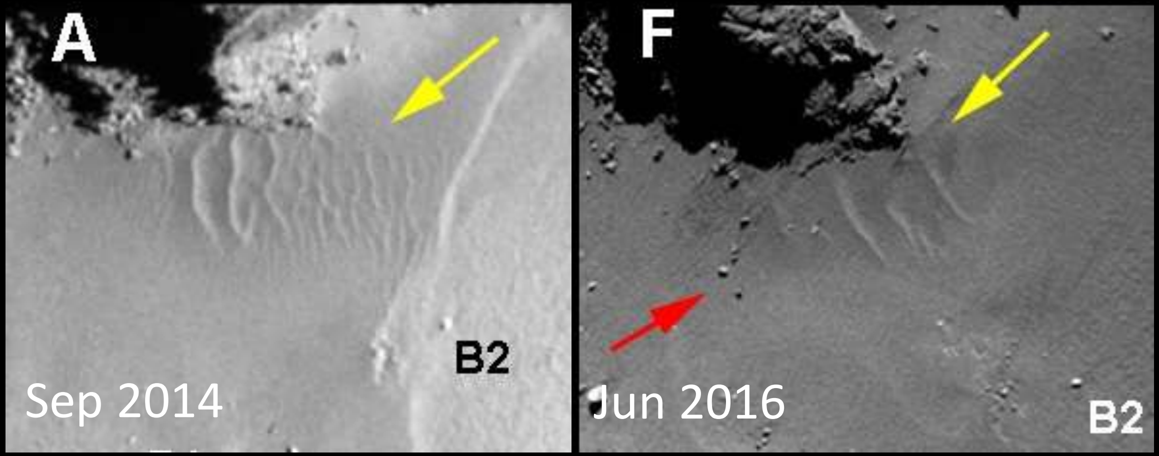
Non-gravitational forces were studied in greater detail than ever before.

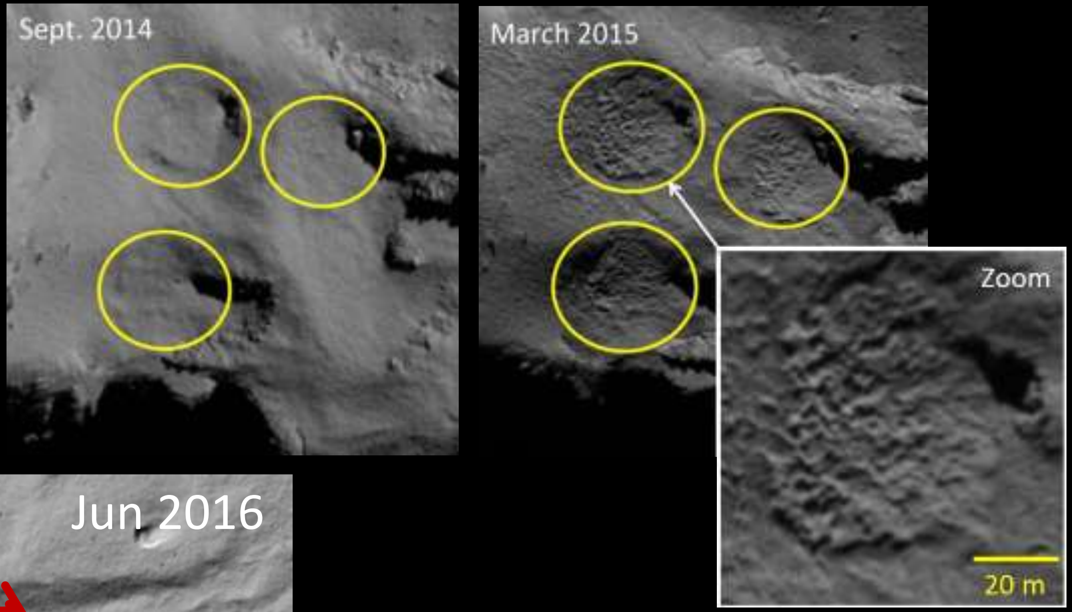


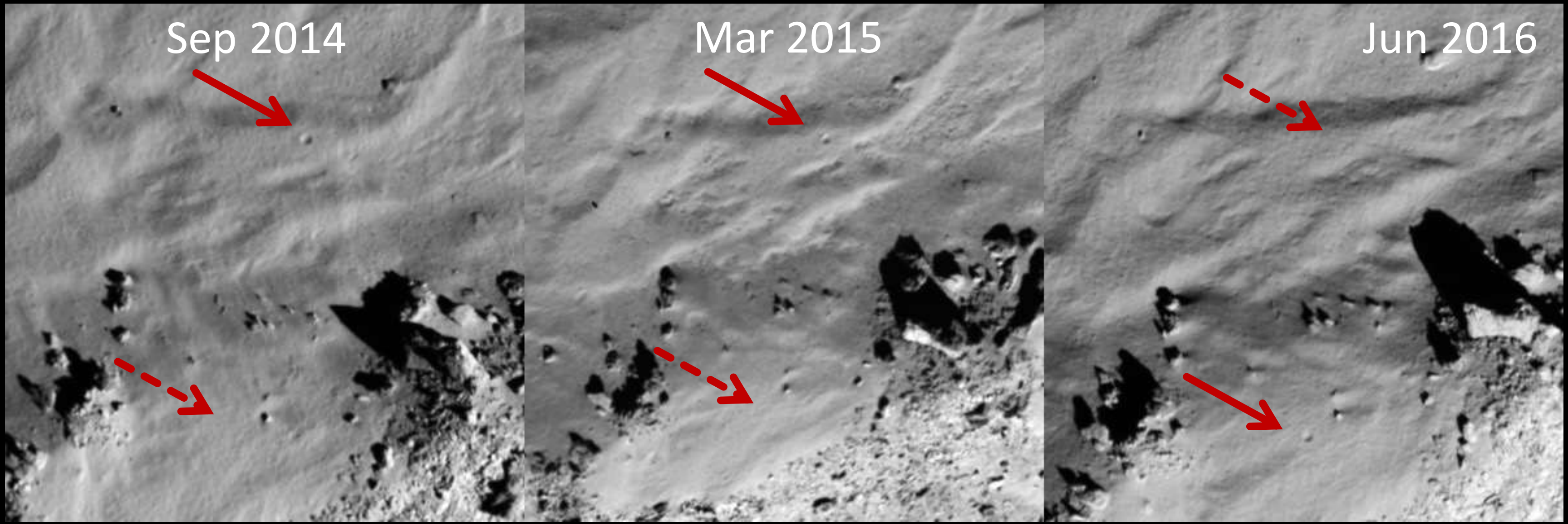


Keller et al., 2015

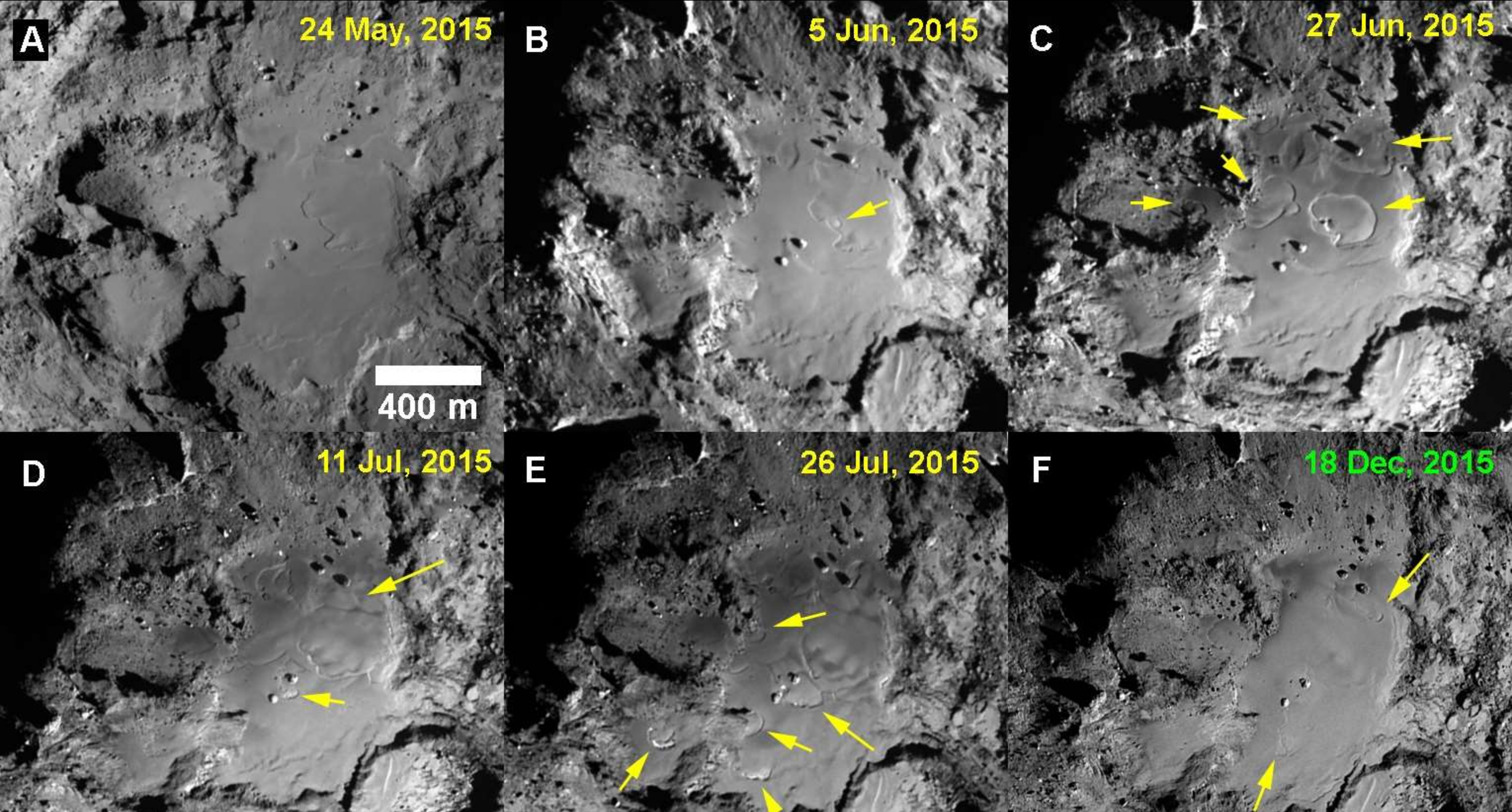
Surface changes are mostly localized and as obscure as activity itself.





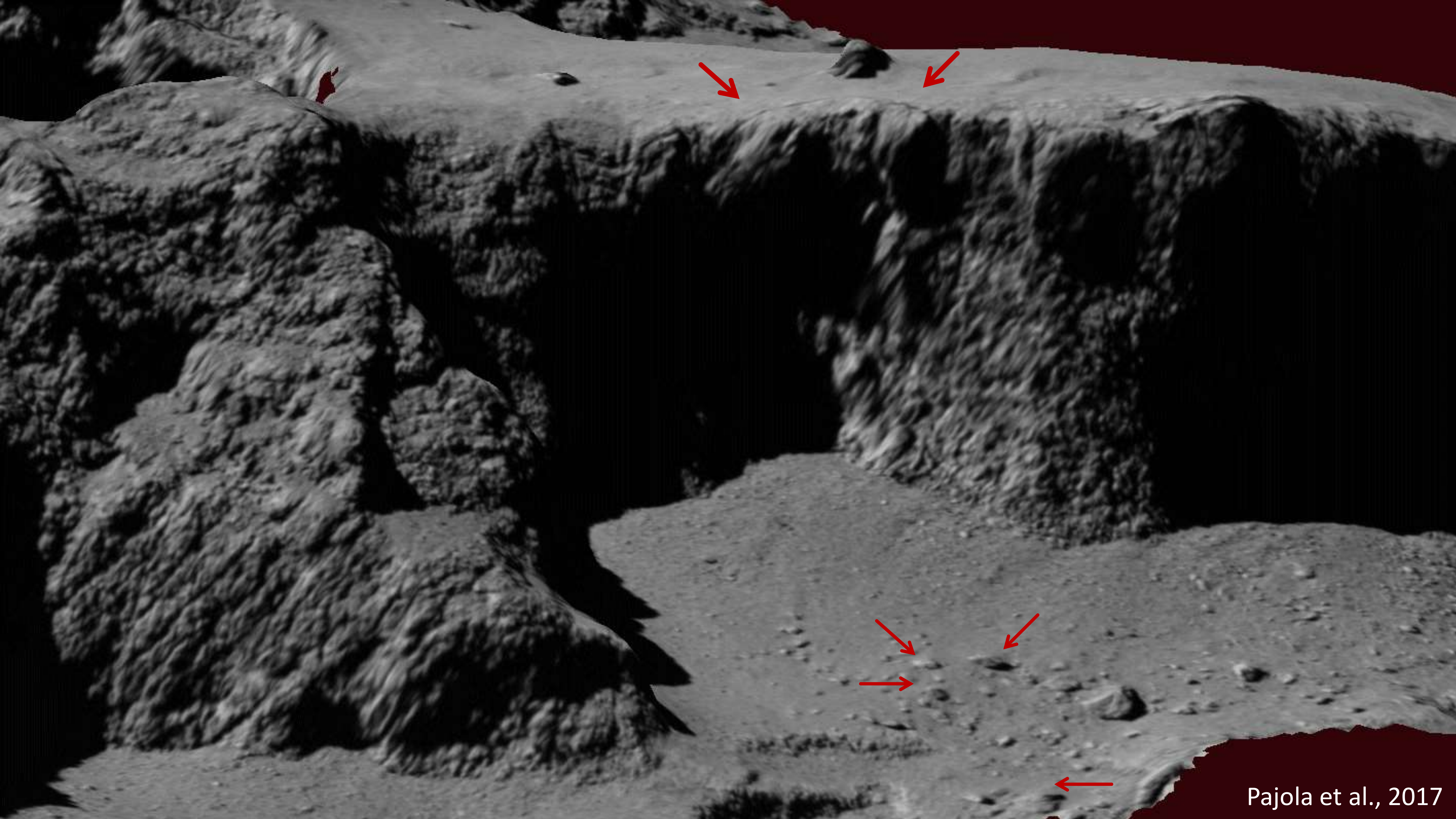


El-Maarry et al., 2017
Hu et al., 2017

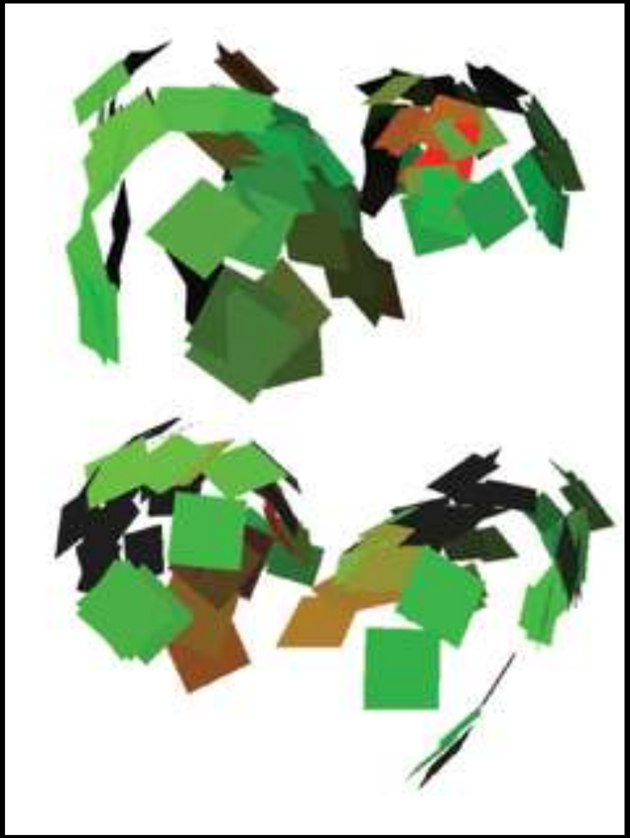


20-30 cm/h, >60.000 m^3 collapsed

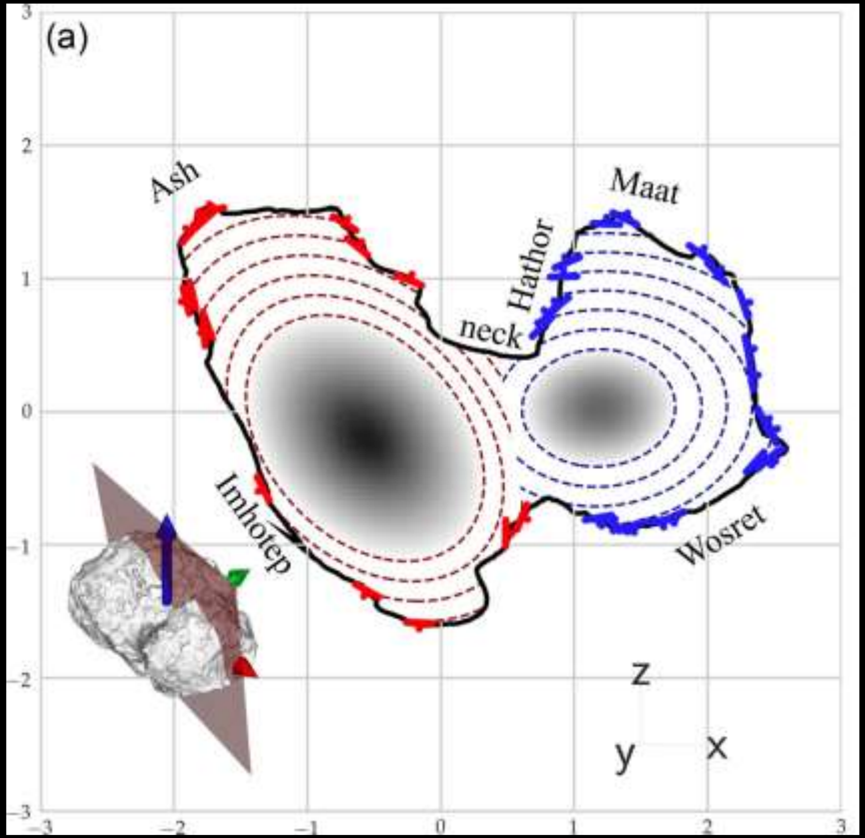
Groussin et al., 2015


Pajola et al., 2017

Layering is a mystery – several ideas and possible implications.



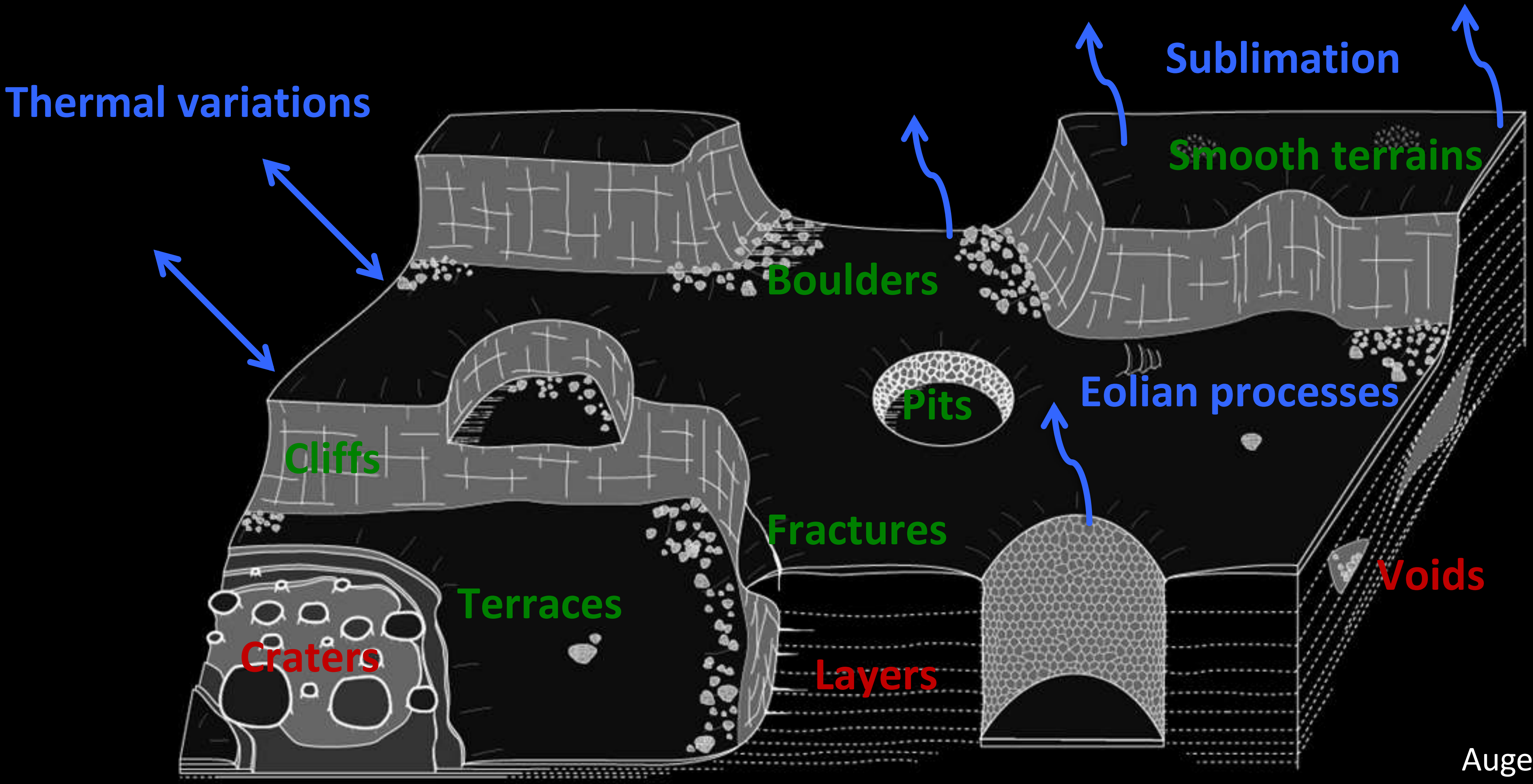
Massironi et al., 2015



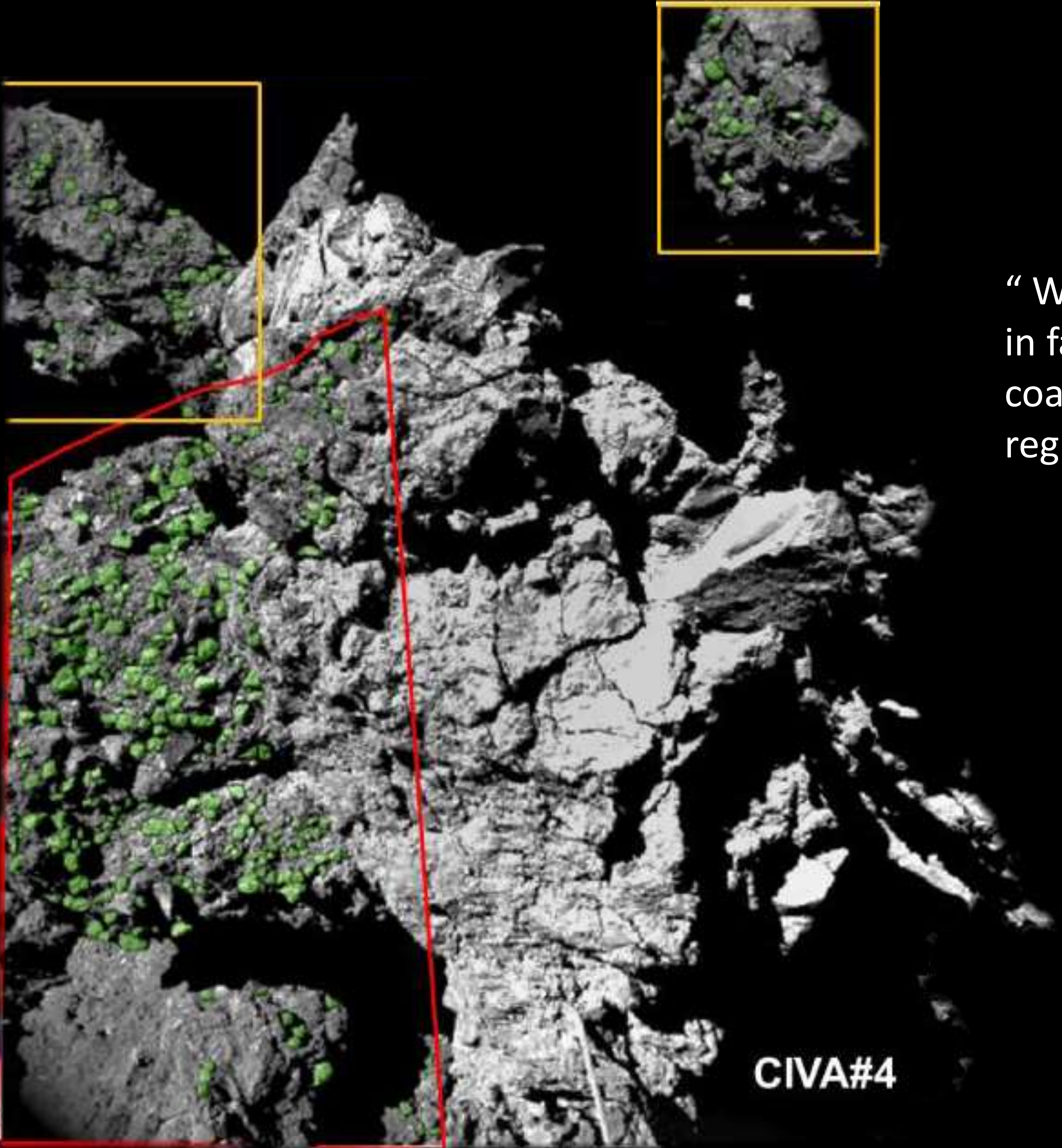
Penasa et al., 2017

Franceschi et al., in prep.

Surface processes and features are manifold in appearance and nature.



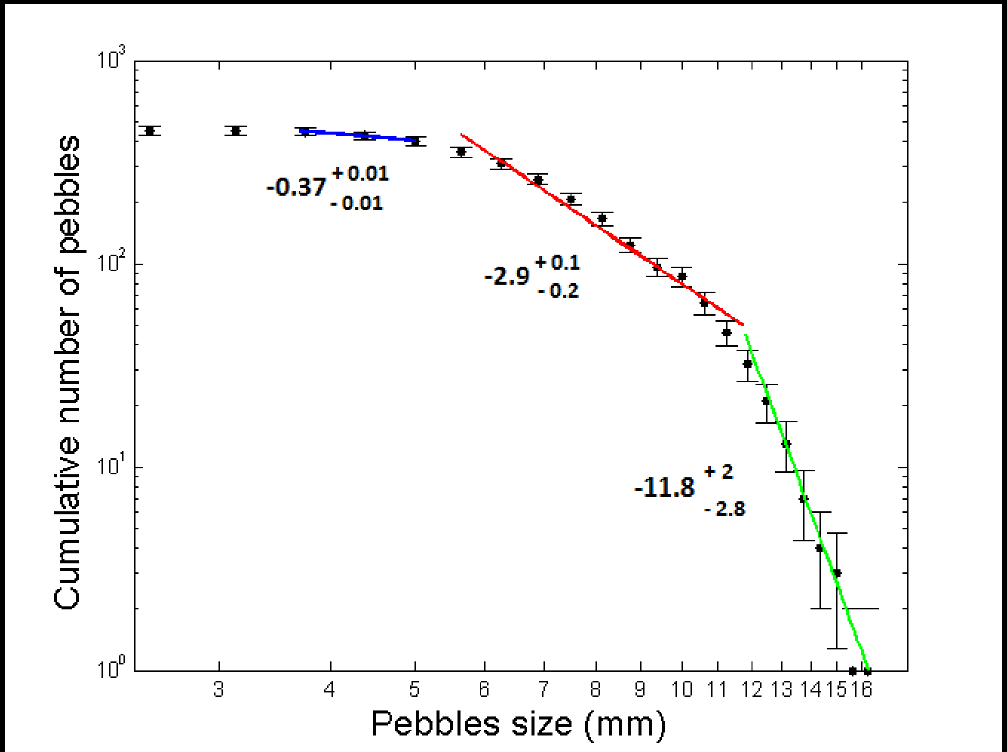
Auger, PhD thesis



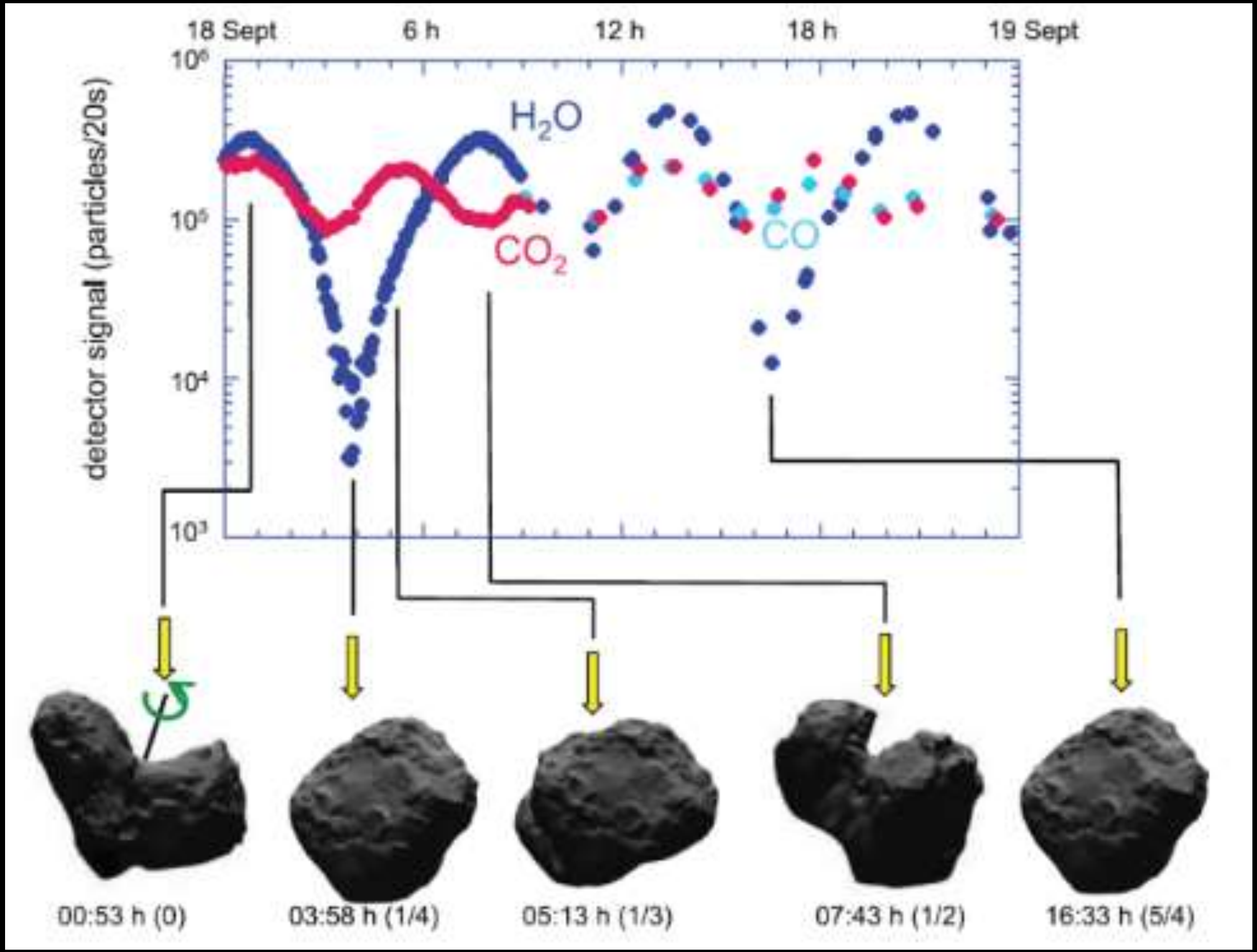
Small-scale structures

“ We thus speculate that the Abydos landscape could be in favour of <u>pebble accretion model</u> instead of runaway coagulation model with a formation location in the outer region of the Solar System. “

Poulet et al., 2016



Core temperature is low, exact value not clear.

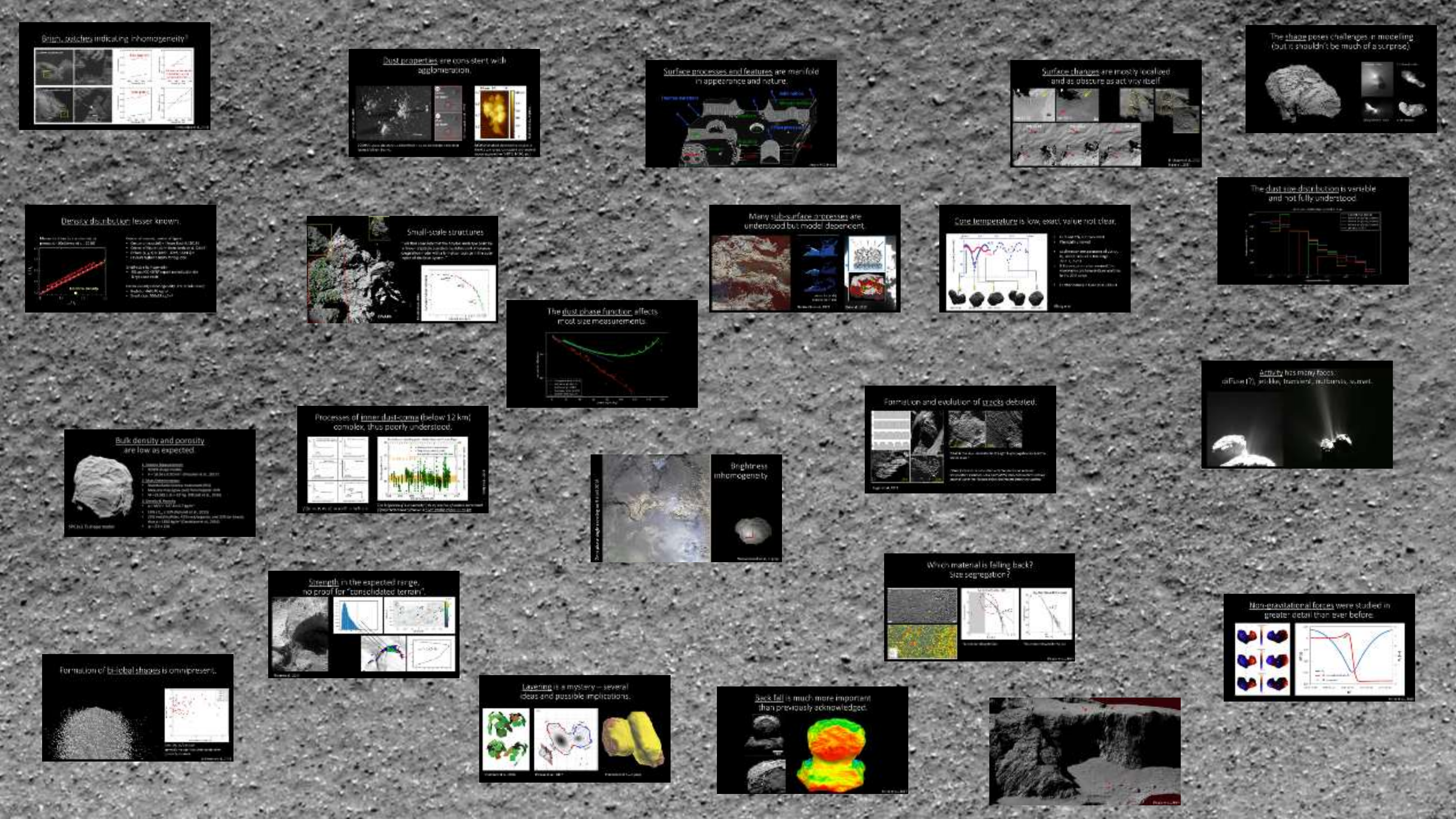


- H_2O and CO_2 not correlated
- Physically unmixed

- Sublimation temperatures of CO, O_2, N_2, and Ar ices all in the range $22 < T_s < 25$K
- If these ices are also unmixed, the maximum core temperature could be in the 25 K range

- Further details in Gasc et al. (2017)

Hässig et al.



Bright patches indicating inhomogeneity?
Dust properties are consistent with agglomeration.
Surface processes and features are manifold in appearance and nature.
Surface changes are mostly localized and as obscure as activity itself.
The shape poses challenges in modelling (but it shouldn't be much of a surprise)
Density distribution lesser known.
Small-scale structures
Many sub-surface processes are understood but model dependent.
Core temperature is low, exact value not clear.
The dust size distribution is variable and not fully understood.
The dust phase function affects most size measurements.
Activity has many faces: diffuse (?), jet-like, transient, outbursts, sunset.
Formation and evolution of cracks debated.
Processes of inner dust-coma (below 12 km) complex, thus poorly understood.
Bulk density and porosity are low as expected.
Brightness inhomogeneity
Which material is falling back? Size segregation?
Strength in the expected range, no proof for "consolidated terrain".
Non-gravitational forces were studied in greater detail than ever before.
Formation of bi-lobal shapes is omnipresent.
Layering is a mystery – several ideas and possible implications.
Back fall is much more important than previously acknowledged.