Looking inside Comet 67P/C-G

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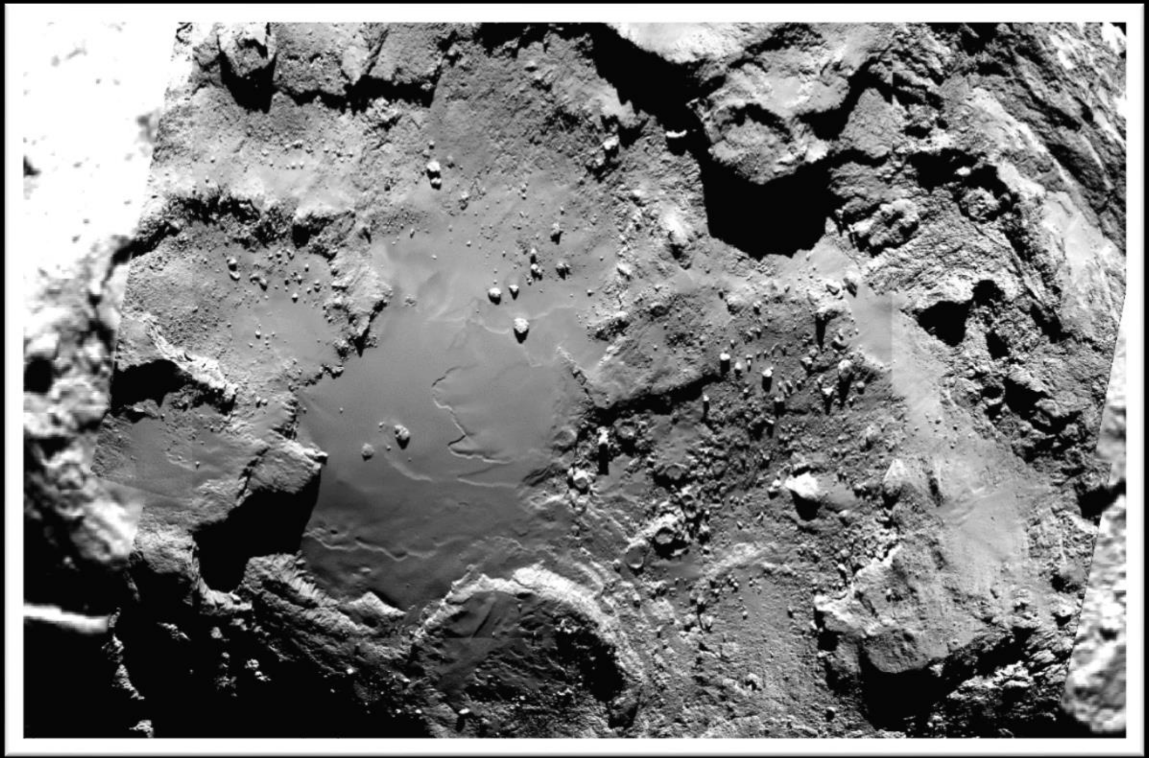
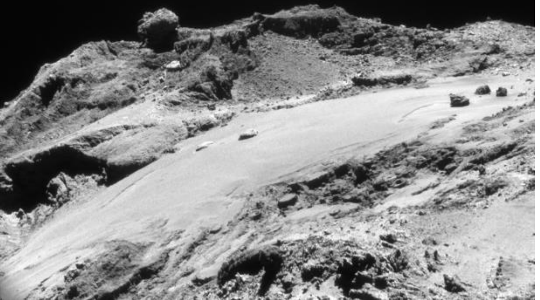


Image credit : ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Jet Propulsion Laboratory
California Institute of Technology

I. The Rosetta mission & comet 67P/C-G



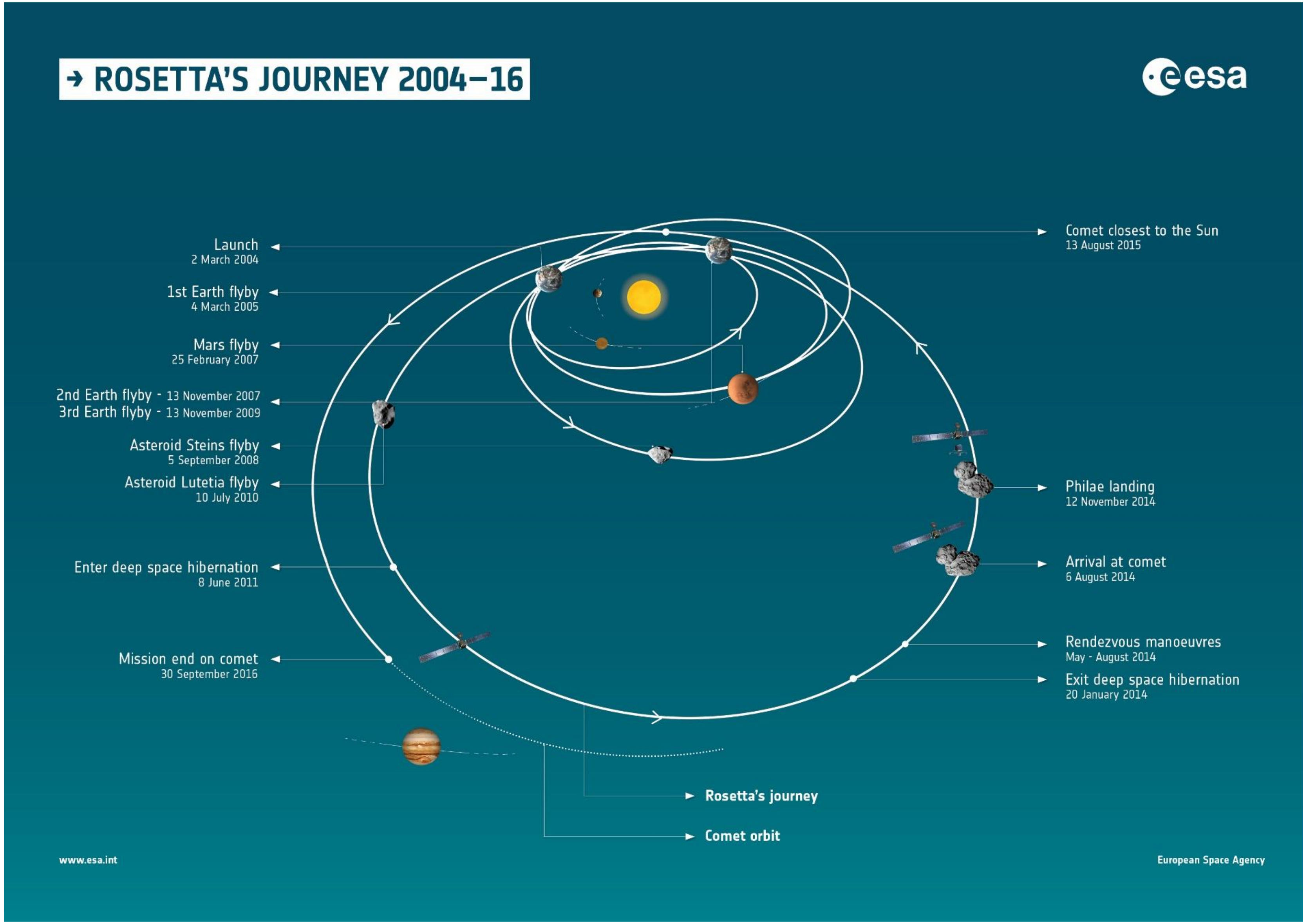


Image credit : ESA/Rosetta

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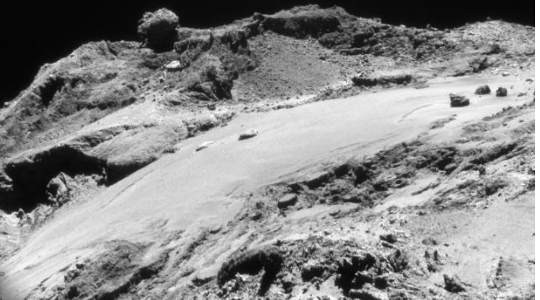

Images credit : ESA/Rosetta

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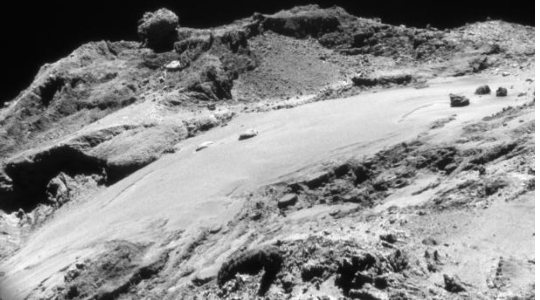
The Orbiter:

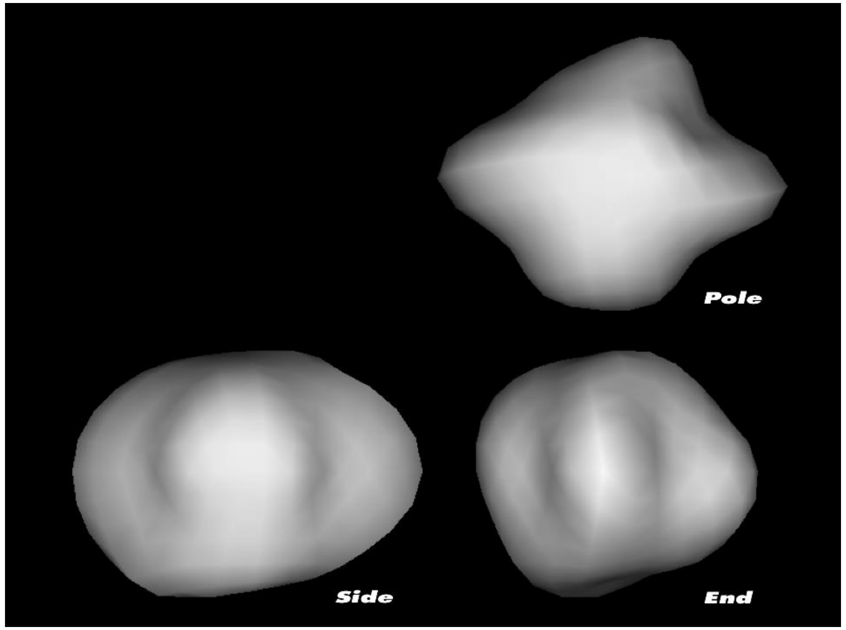
- Remote and *in-situ* observations of the coma and nucleus
- 11 instruments
- 2 with strong NASA participation

The Lander:

- *In-situ* measurements at the surface of the nucleus
- Power for 3 days of operation
- 10 instruments

I. The Rosetta mission & comet 67P/C-G





NASA, European Space Agency and Philippe Lamy

2003

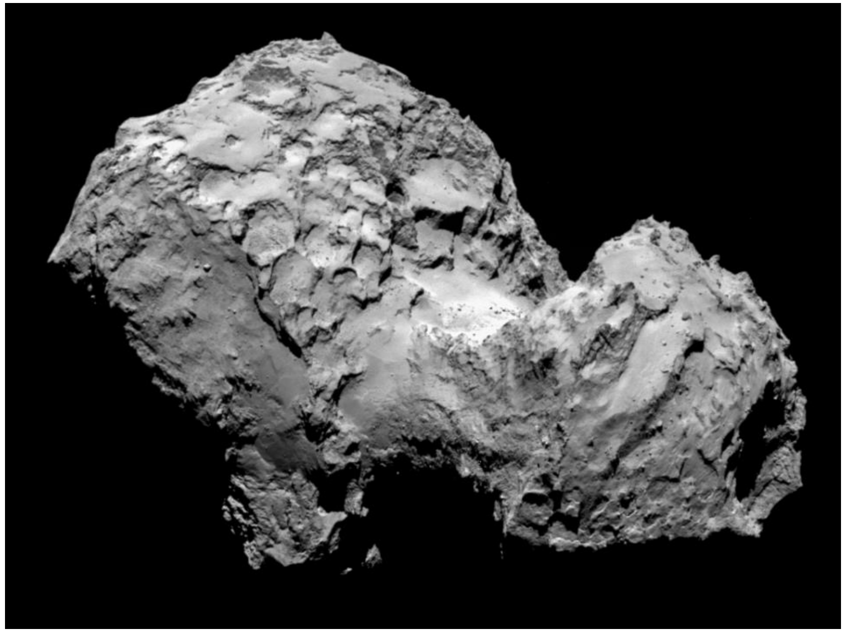
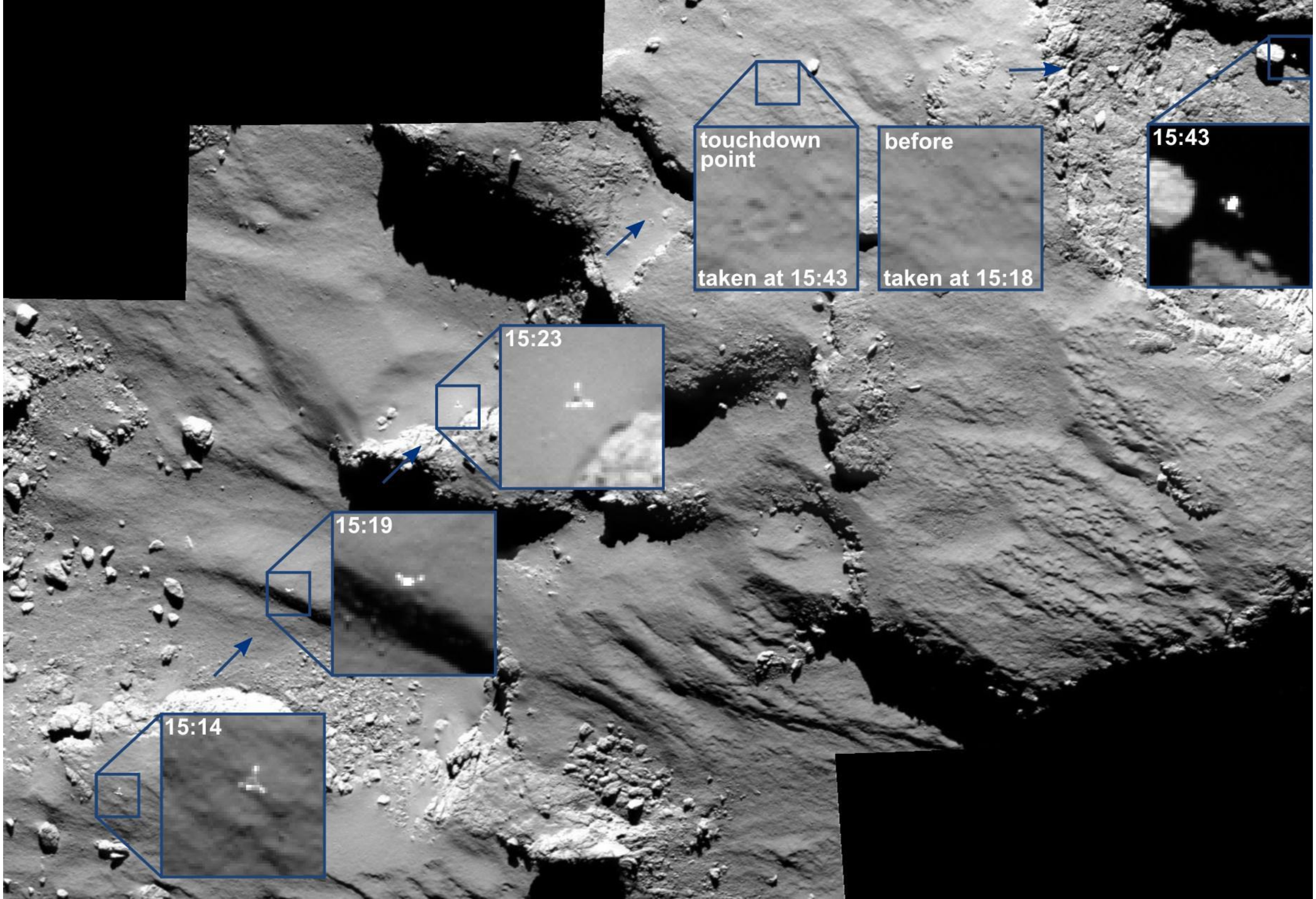


Image credit : ESA/Rosetta

2014



ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

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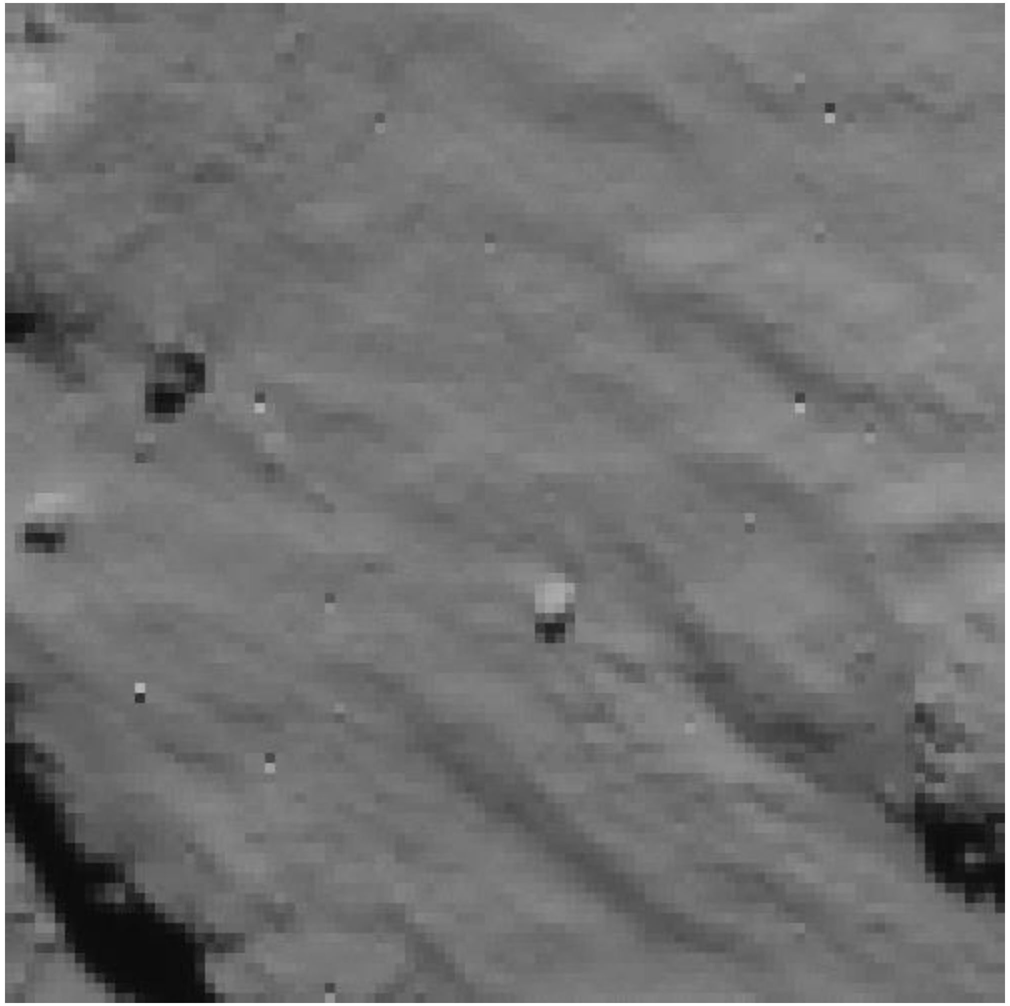

Image credit : ESA/Rosetta

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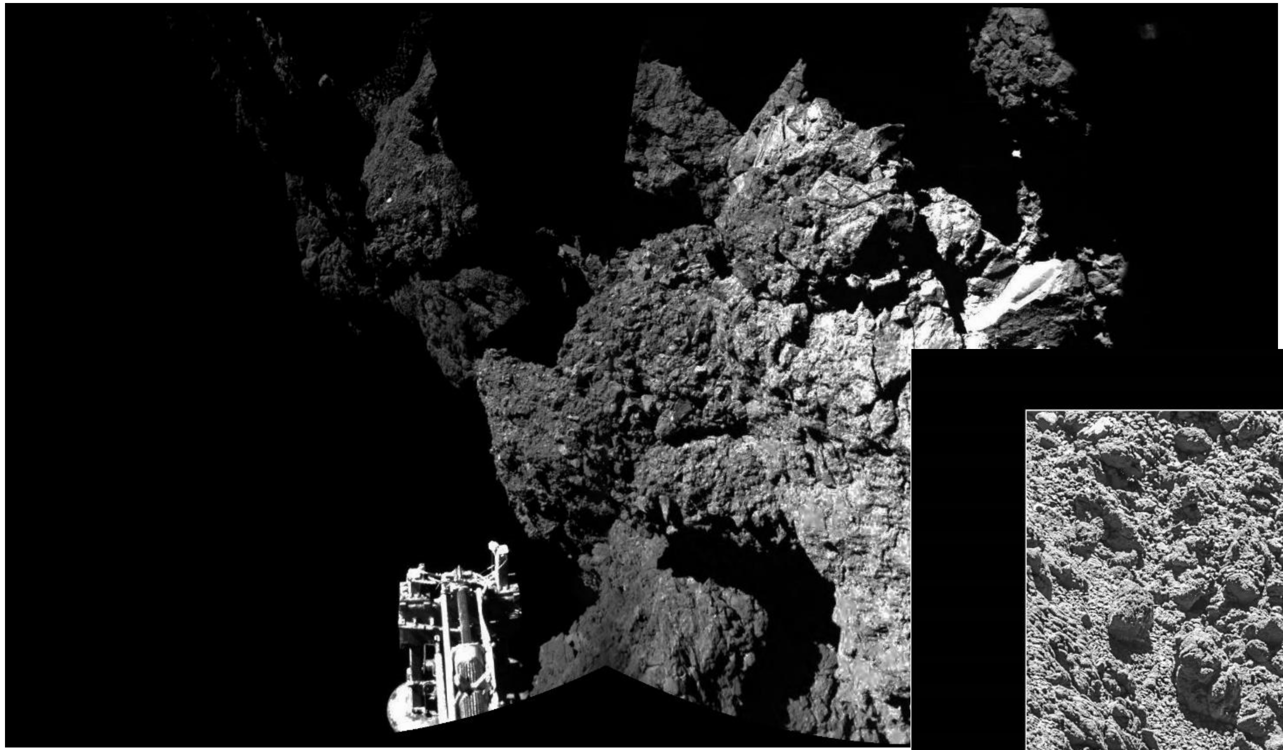
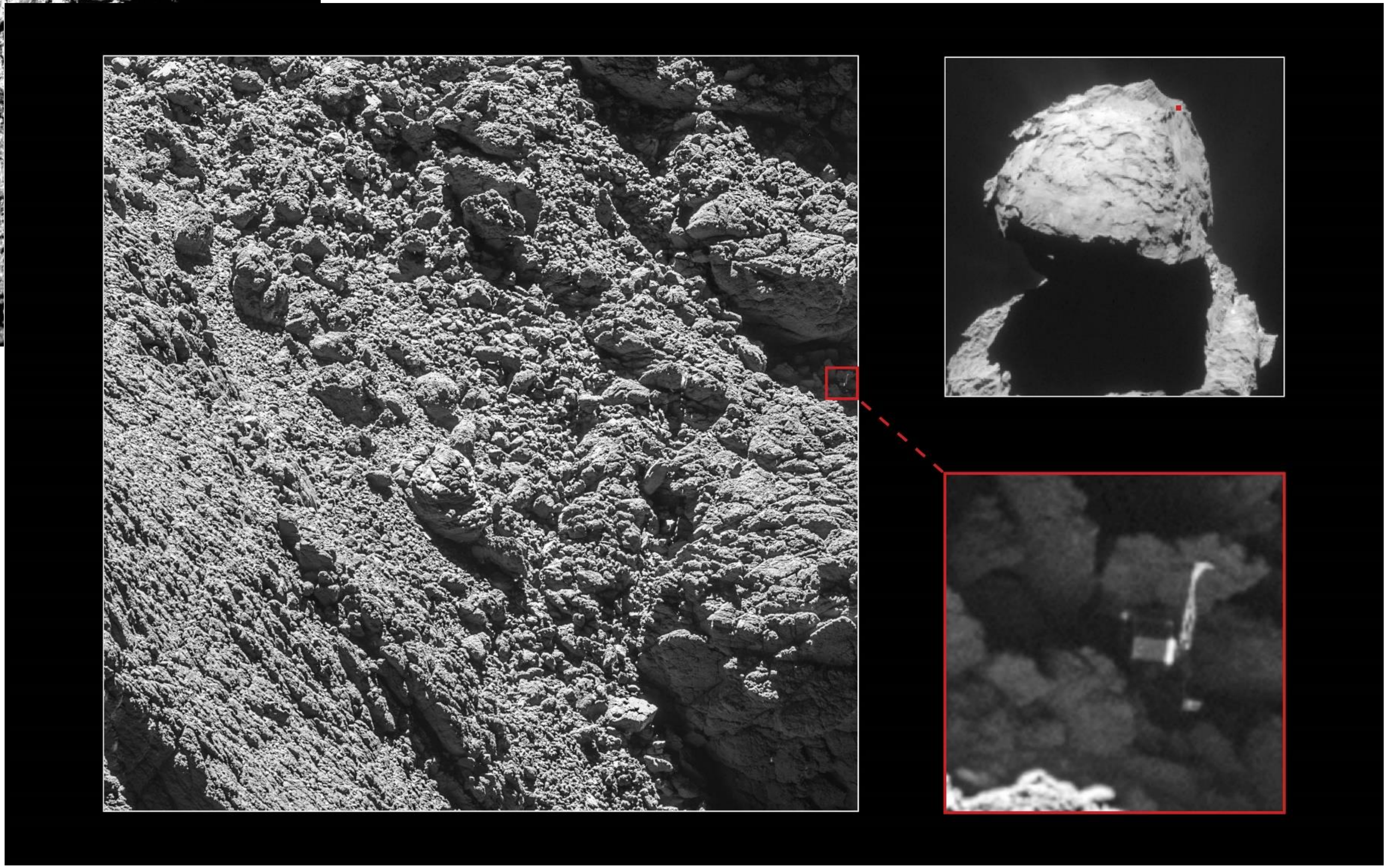
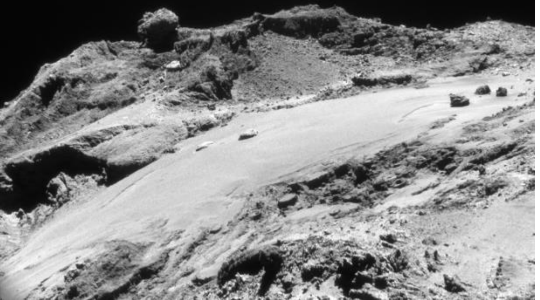


ESA/Rosetta/Philae/CIVA



ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA; context: ESA/Rosetta/NavCam



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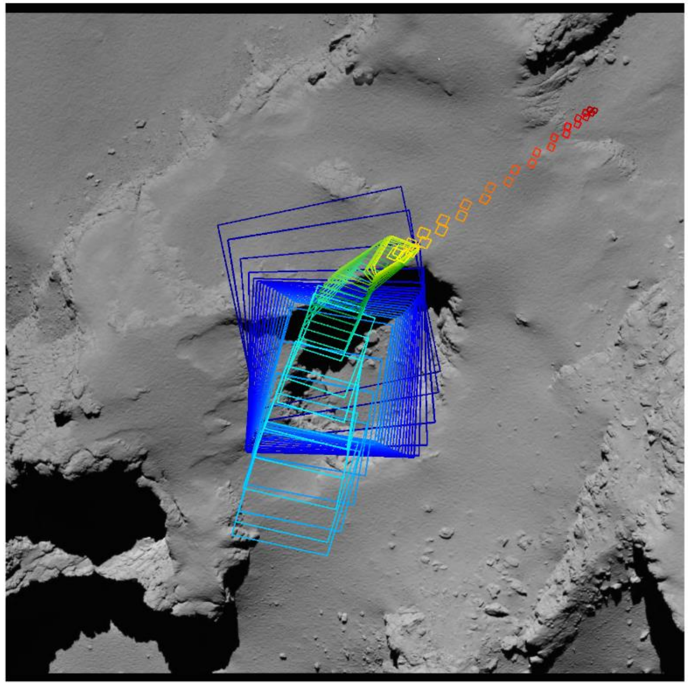

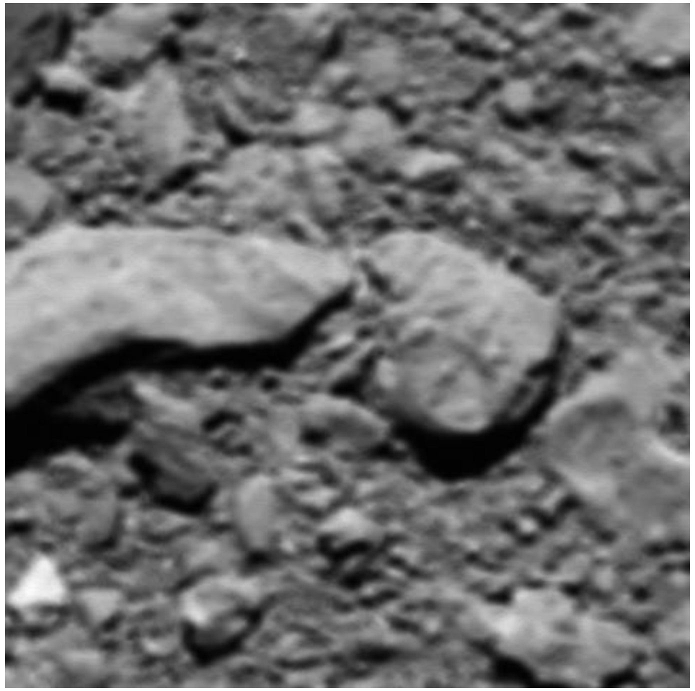

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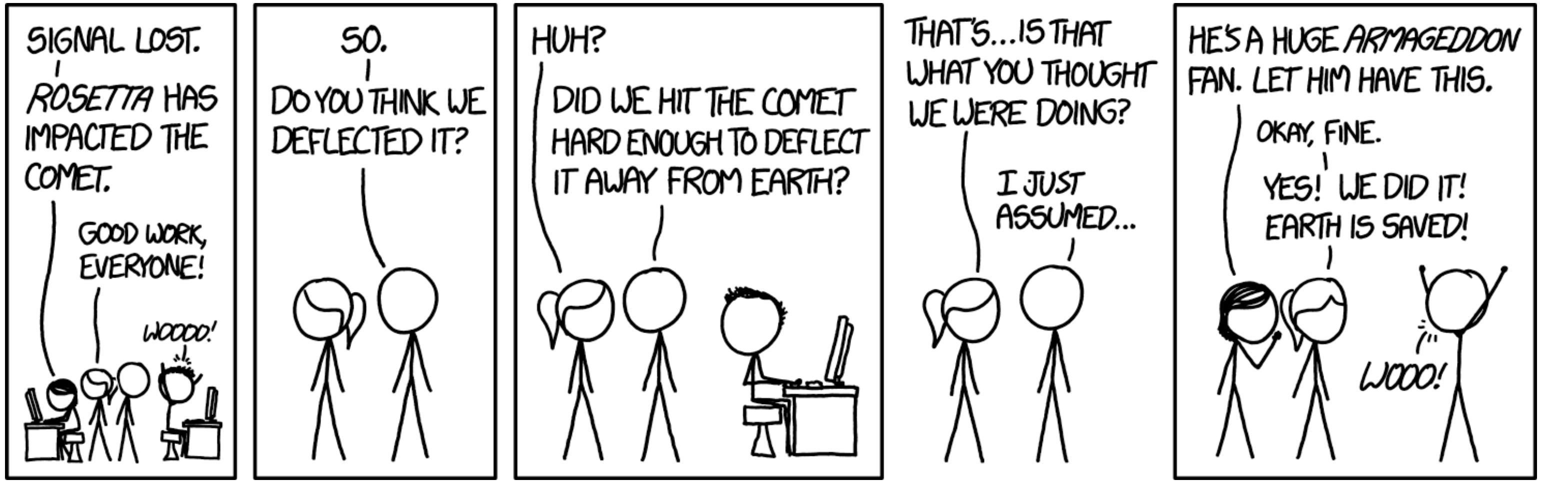
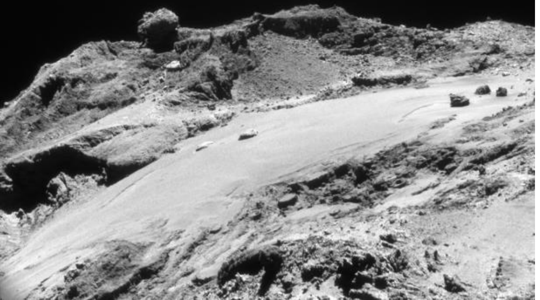
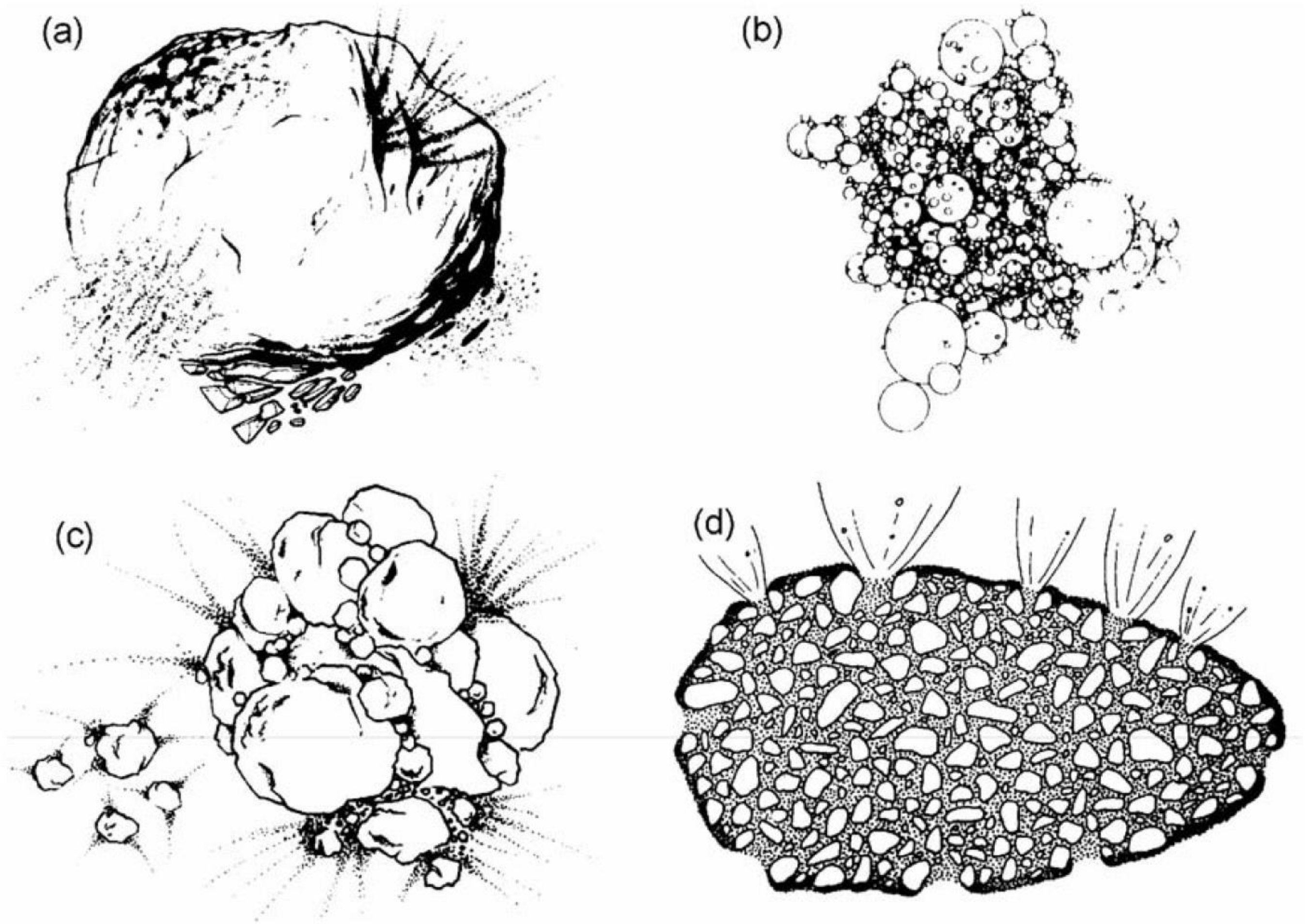


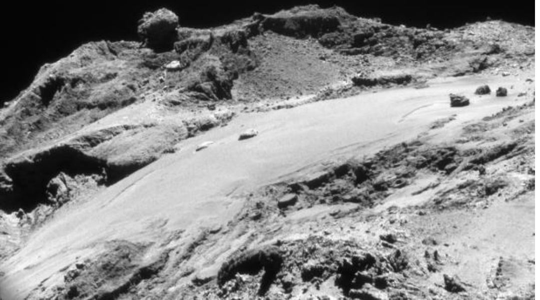
Credit: xkcd

II. The internal structures of comets





See Weissman and Lowry, Structure and density of cometary nuclei, 2007



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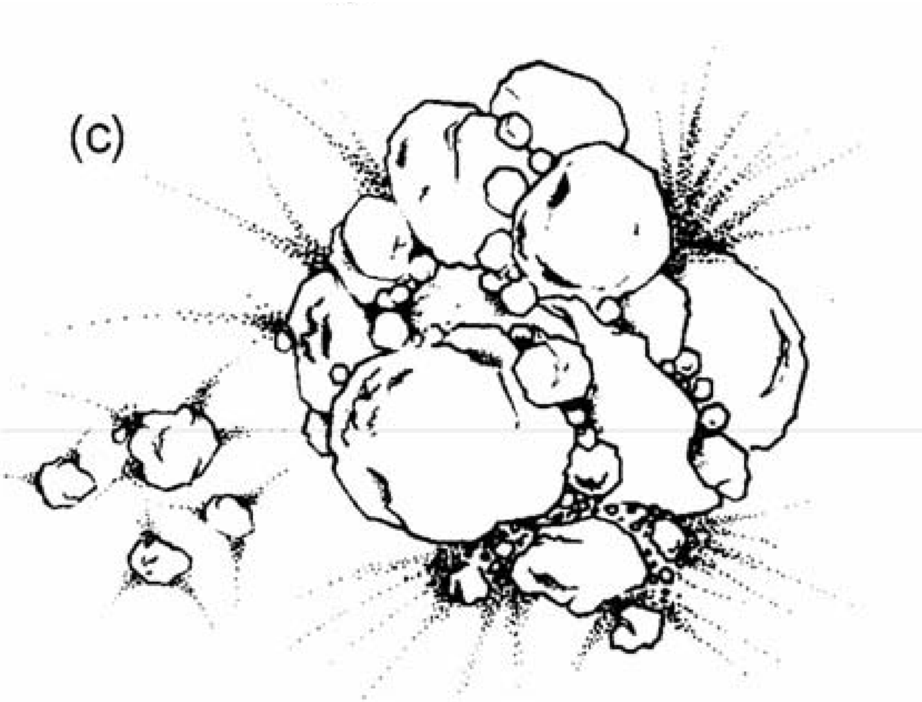
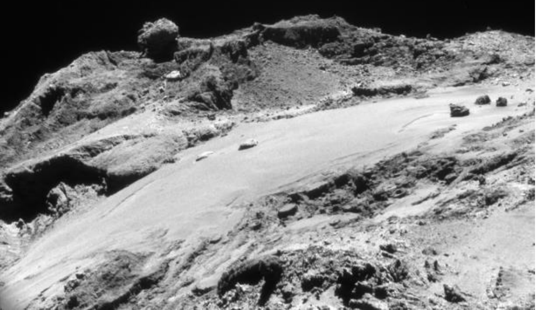
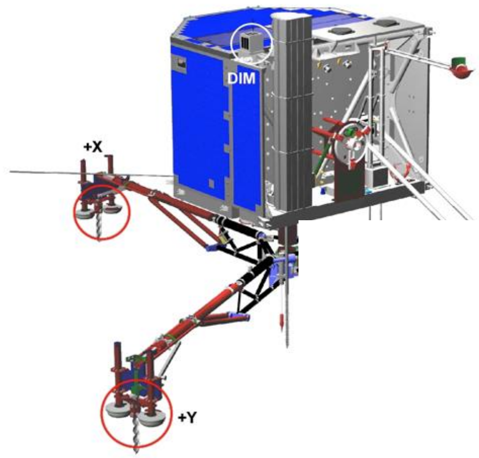


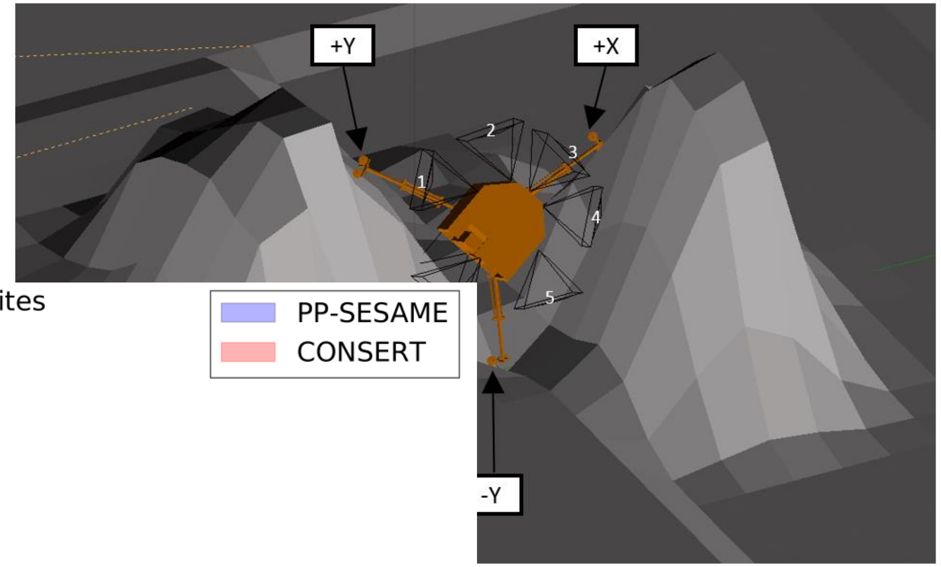
- C-G's nucleus seems to be primordial rubble pile
- Not formed from pieces of larger parent bodies
- Cycles of sublimation and recondensation forms an "eggshell" on surface
- Ejection and deposition of dust on the surface

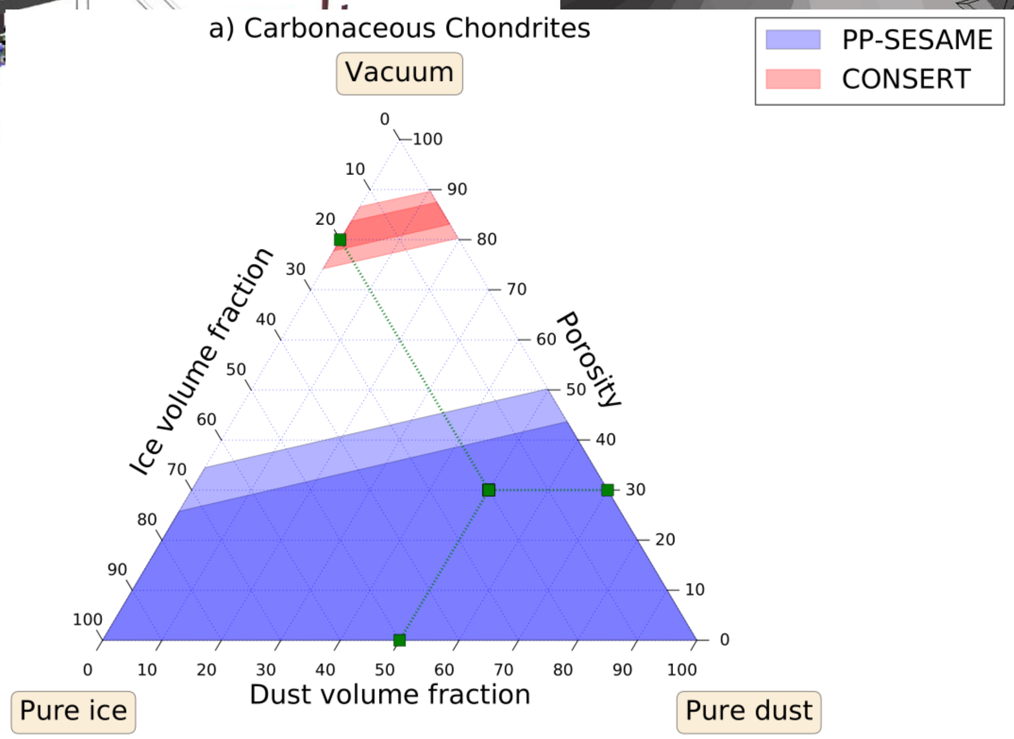


II. The internal structures of comets

My PhD: What does SESAME-PP tells us about the internal structure of comets (Lethuillier et al. 2016) ?







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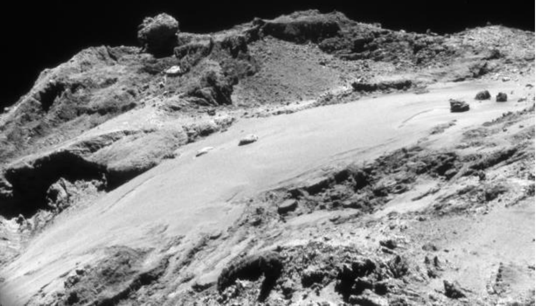
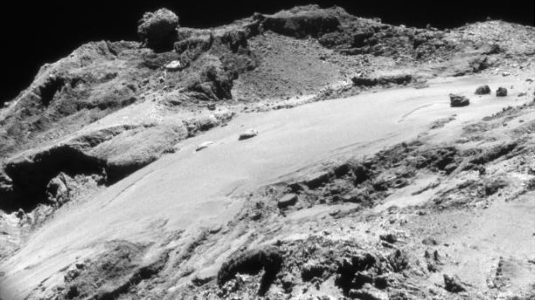
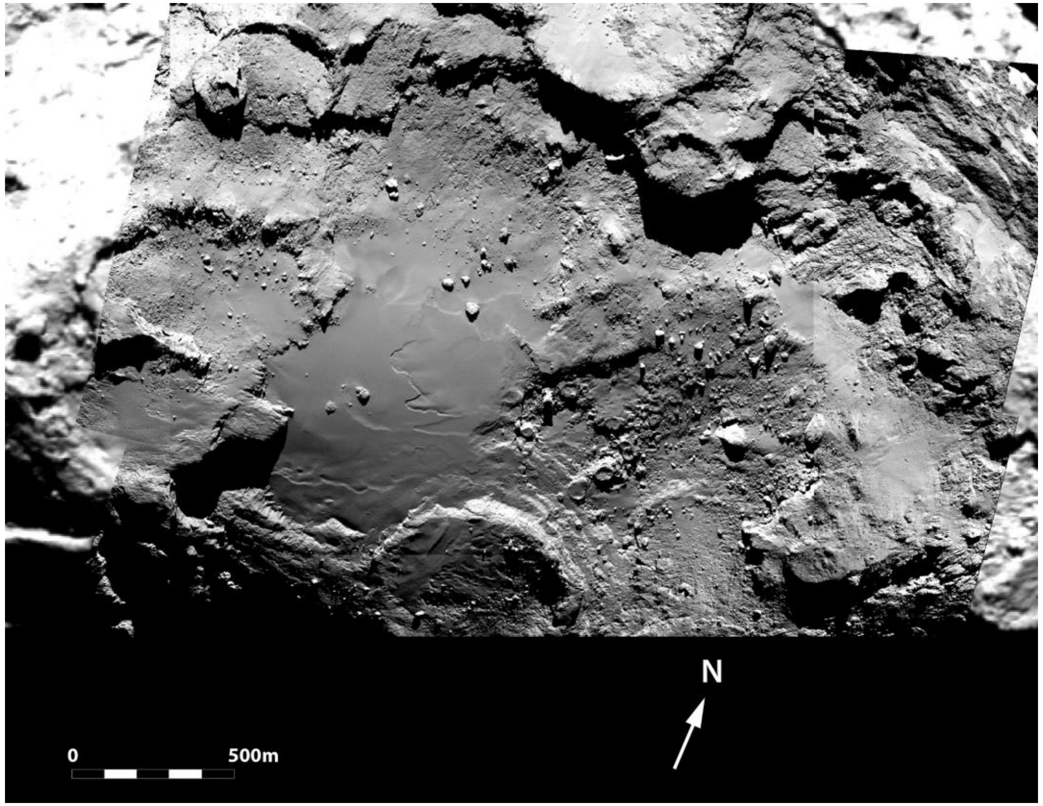


How can the MIRO instrument help understand the internal structure and evolution of cometary nuclei ?

- MIRO is a passive microwave radiometer
- Located on the Rosetta orbiter
- Combined with spectrometer to analyze the coma
- Works at two frequencies (190 GHz, 1.6 mm and 562 GHz, 0.5 mm)
- Can help constrain the top layer of the cometary nucleus (down to 10 cm)



III. The Imhotep region



ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

- Located on the main lobe of the nucleus
- Was observed twice by MIRO at very high spatial resolution (20/40 m).
- Overserved at 3 AU from the sun before (2014) and after (2016) perihelion

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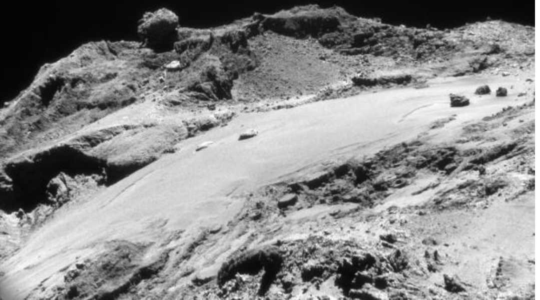

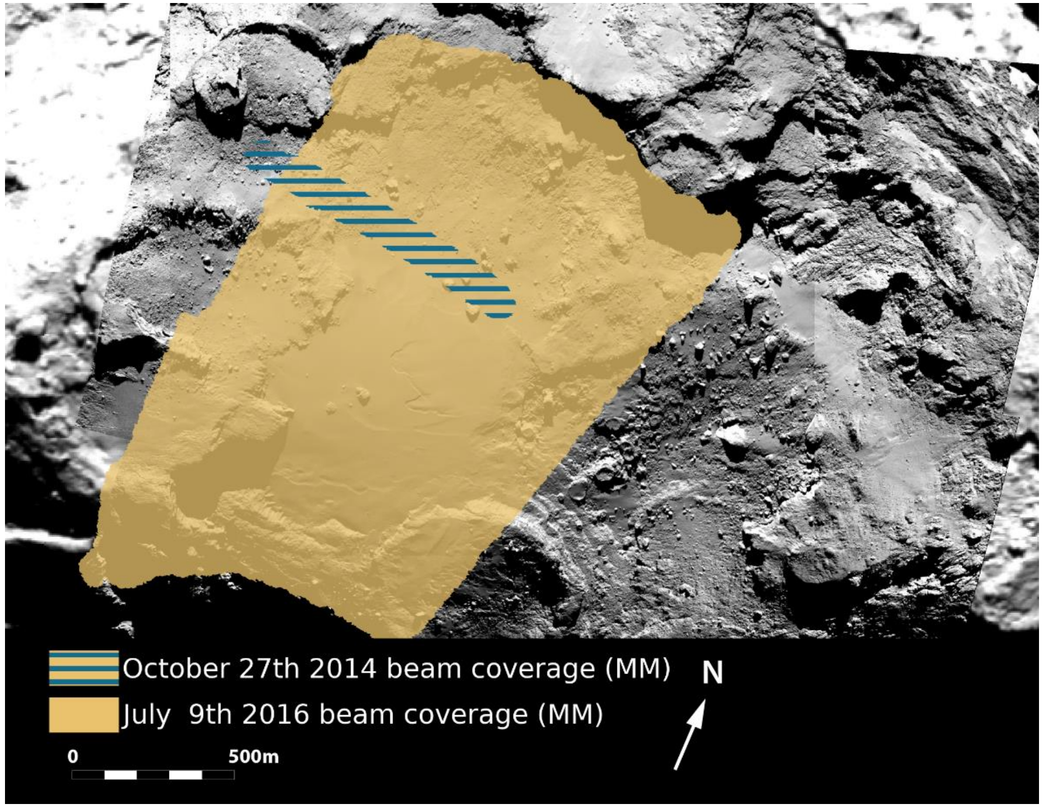

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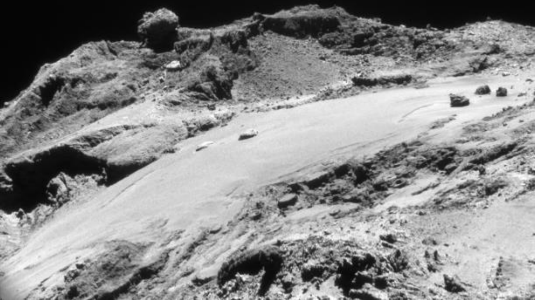
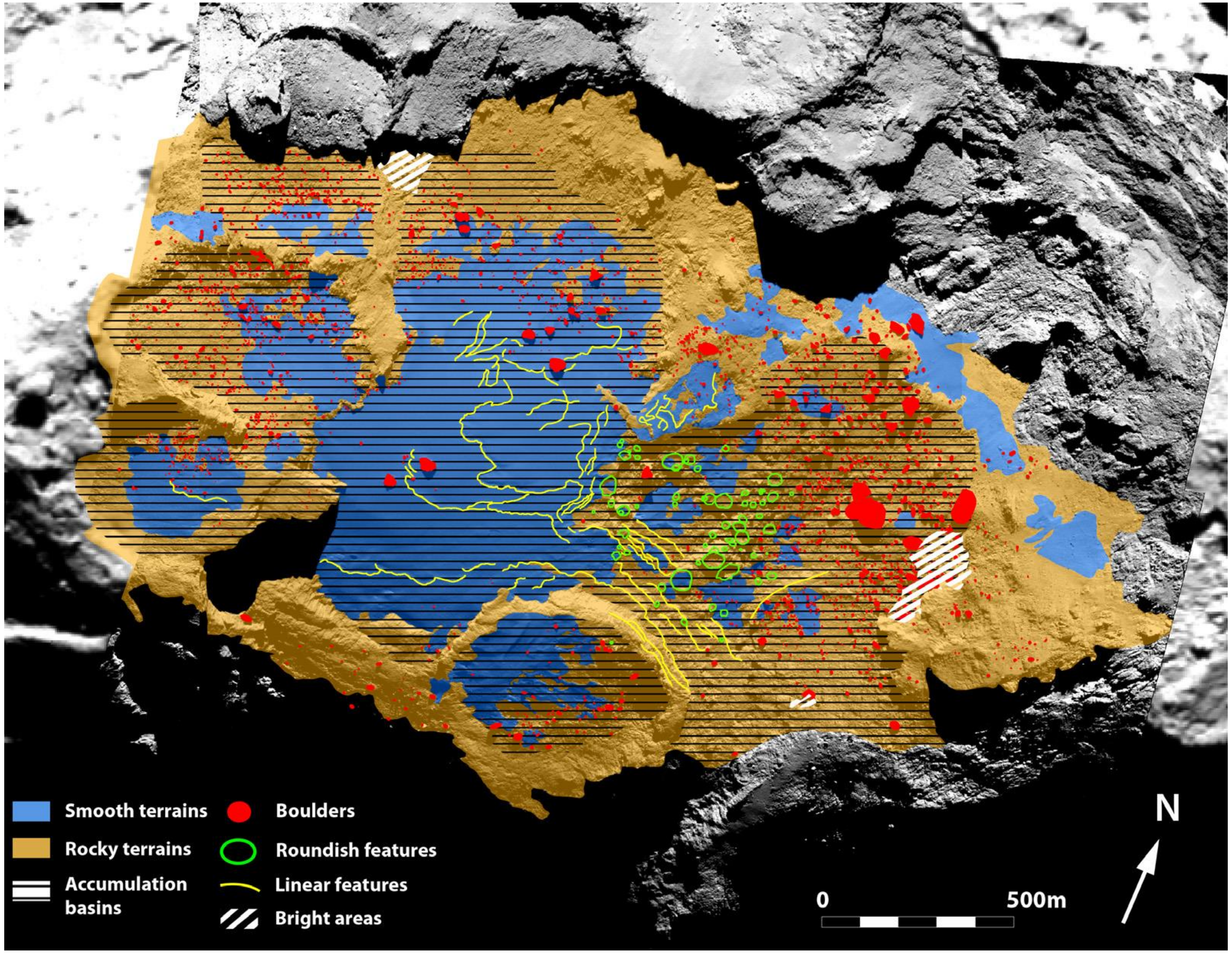
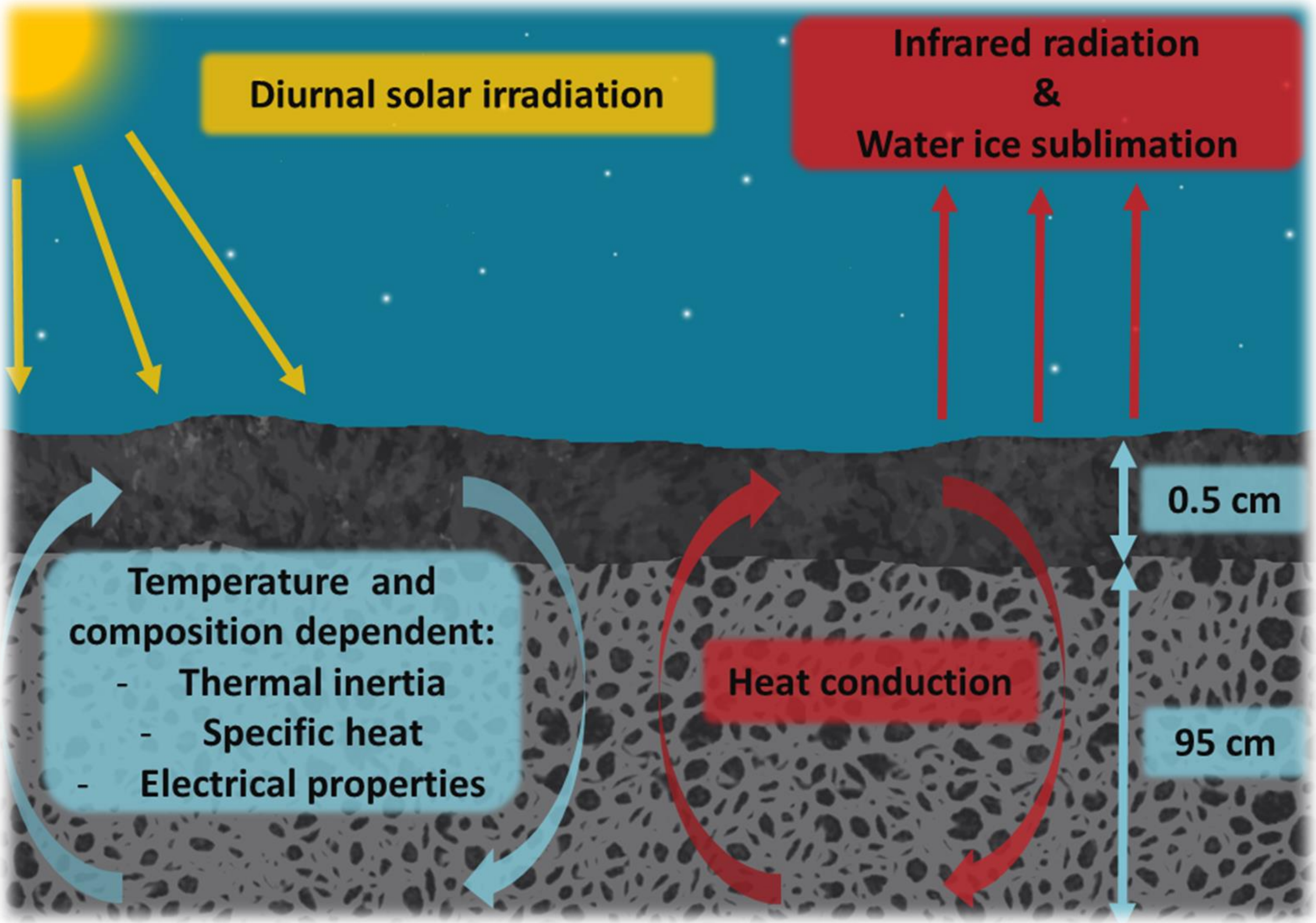




Geomorphology of the Imhotep region on comet 67P/Churyumov-Gerasimenko from OSIRIS observations, Auger et al. 2015.

IV. Thermal model & method



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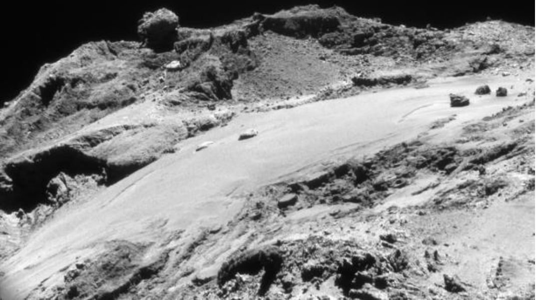
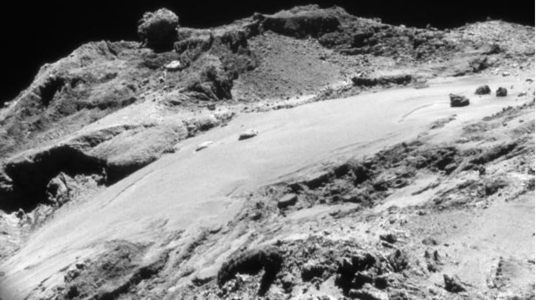


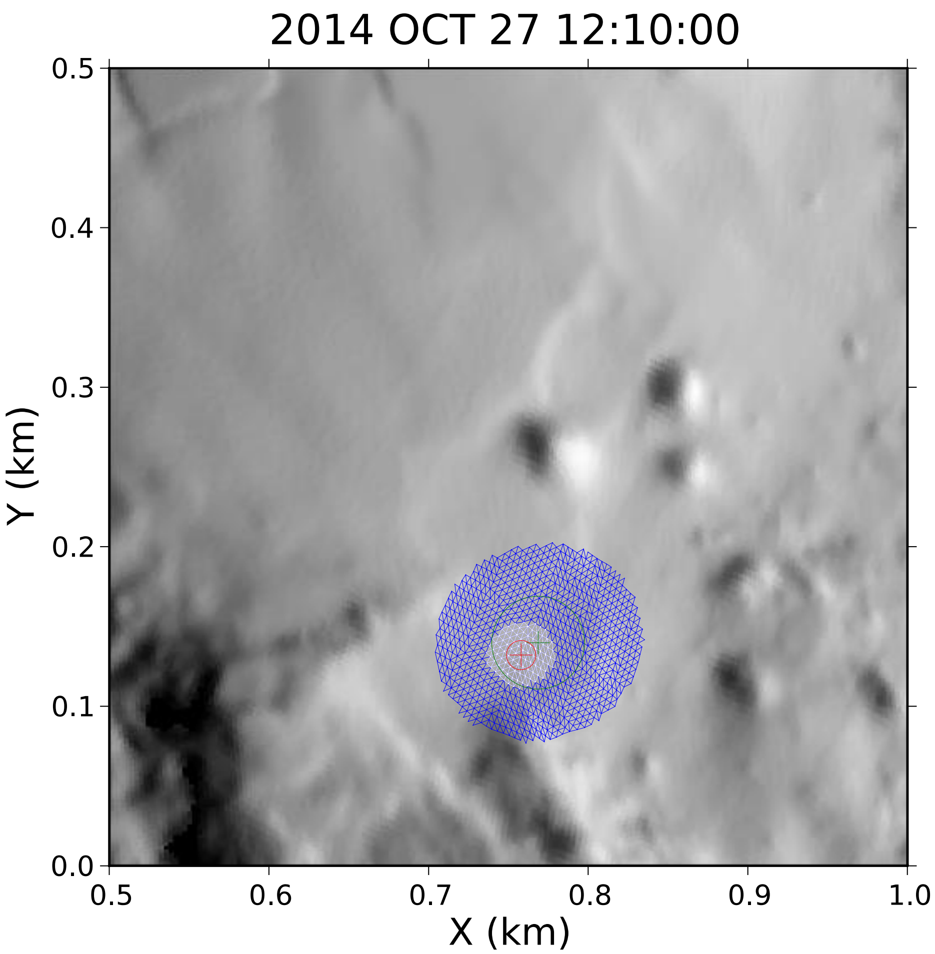
What assumptions are made ?

- The ice is crystalline water ice
- The dust is chondritic in nature
- No significant horizontal changes in the areas observed

IV. Thermal model & method



In order to calculate the illumination we use a 12 million facet shape model of the nucleus and SPICE kernels.



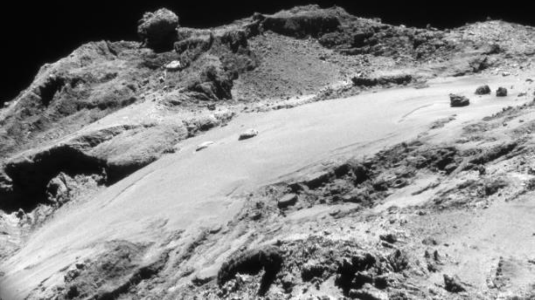
"Full" calculation

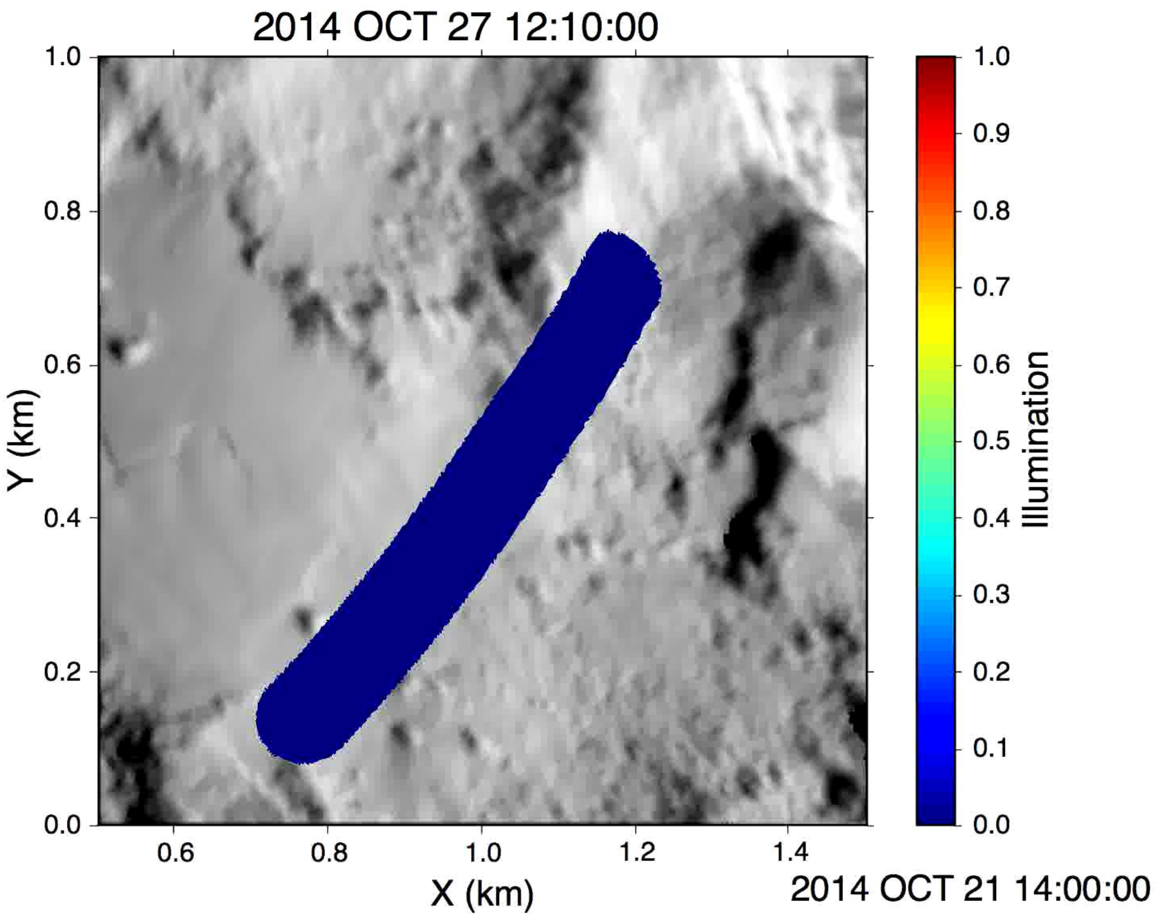
- Compute insolation for each tile in the footprint
- Compute temperature profile for each tile in the footprint
- Compute antenna temperature from weighted average

Approximate calculation

- Compute insolation for each tile in the footprint
- Compute beam averaged insolation
- Compute average temperature profile from average insolation

IV. Thermal model & method





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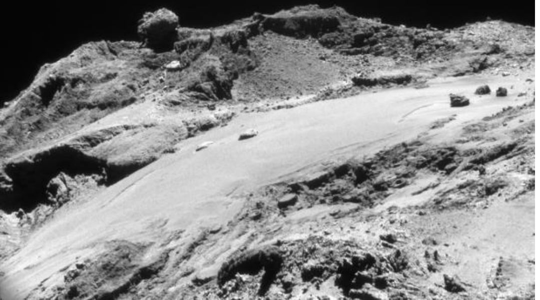

Icarus 219 (2012) 618–629

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Outgassing of icy bodies in the Solar System – II: Heat transport in dry, porous surface dust layers

Bastian Gundlach *, Jürgen Blum

Institut für Geophysik und extraterrestrische Physik, Technische Universität Braunschweig, Mendelssohnstr. 3, D-38106 Braunschweig, (

Icarus 221 (2012) 925–939

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Radar properties of comets: Parametric dielectric modeling of Comet 67P/Churyumov–Gerasimenko

Essam Heggy [a,*], Elizabeth M. Palmer [b], Wlodek Kofman [c,d], Stephen M. Clifford [e], Kevin Righter [f], Alain Hérique [c]

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…t de Planétologie et d'Astrophysique de Grenoble (IPAG) UMR 5274, Grenoble F-38041, France
…h Academy of Sciences, ul. Bartycka 18A, Warsaw, Poland
…0 Bay Area Boulevard, Houston, TX 77058, USA
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Note

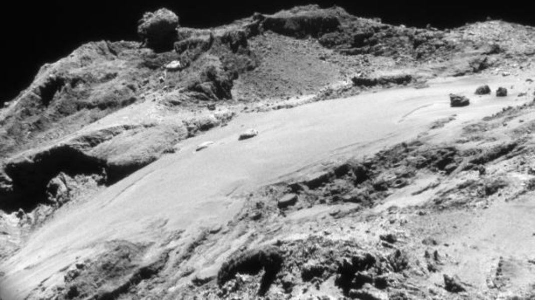
Dielectric measurements and radar attenuation estimation of ice/basalt sand mixtures as martian Polar Caps analogues

CrossMark

E. Mattei [a,*], S.E. Lauro [b], G. Vannaroni [b], B. Cosciotti [b], F. Bella [b], E. Pettinelli [b]

[a] *Dipartimento DEIM-DEB, Università degli Studi della Tuscia, Largo dell'Università snc, 01100 Viterbo, Italy*
[b] *Dipartimento di Matematica e Fisica, Università di Roma TRE, Via della Vasca Navale 84, 00146 Rome, Italy*

IV. Thermal model & method

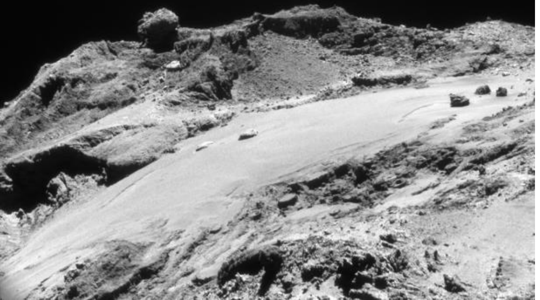


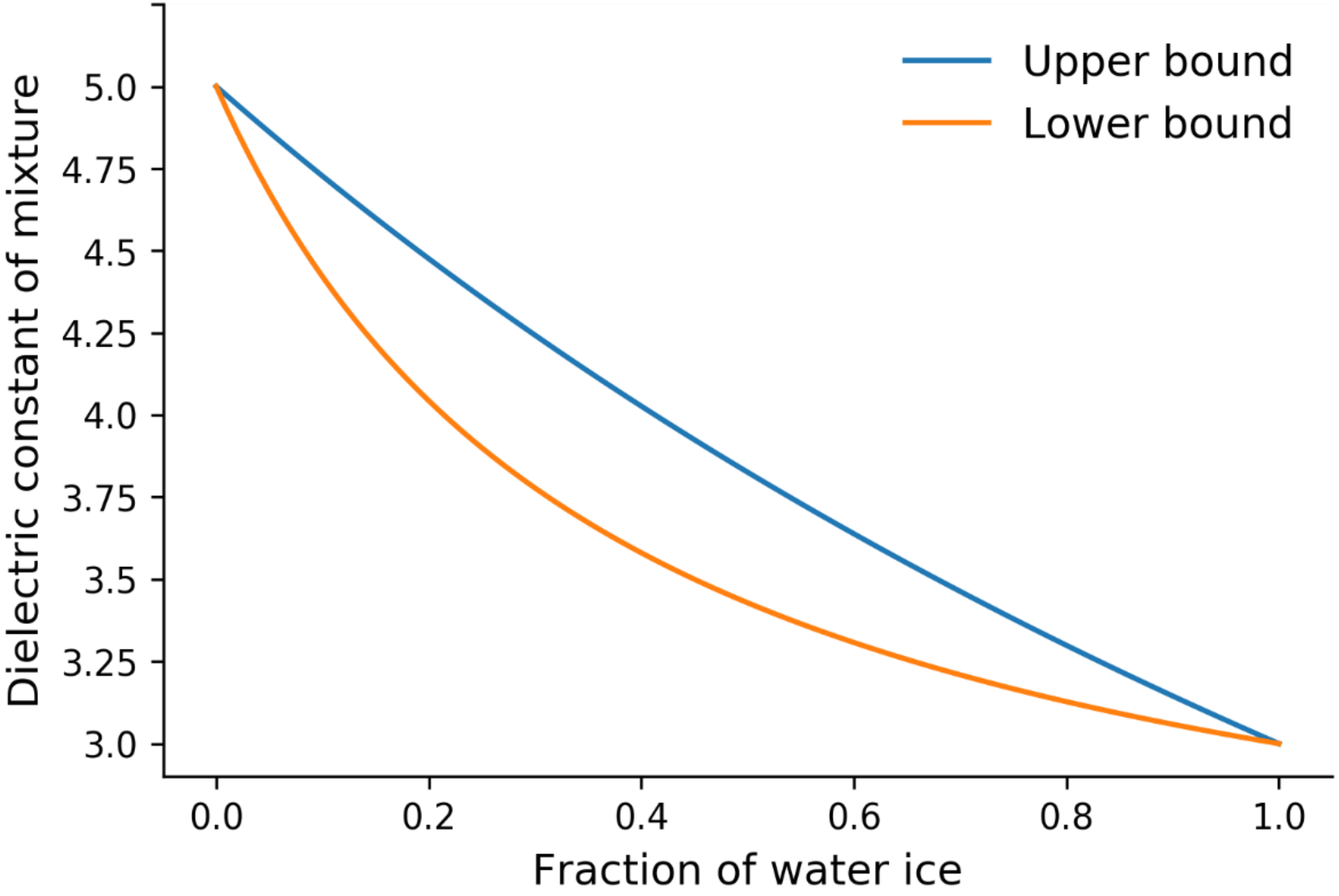
- The electrical properties of the water ice/dust/vacuum mixture is unknown.

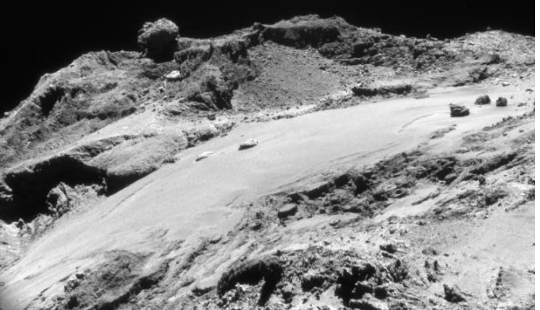
- To calculate it we can use mixing laws but each mixing law only applies to certain situation.

- To overcome this problem we use the Hashin & Shtrikman bounds (1962).

IV. Thermal model & method







IV. Thermal model & method

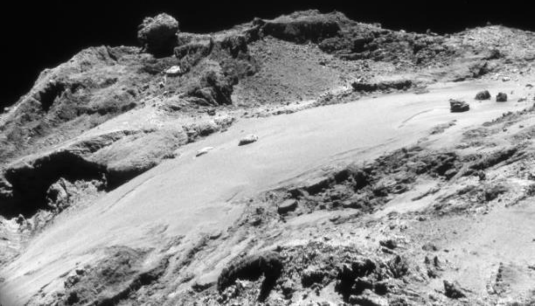
Input parameters:

- Dust/Ice/Vacuum fraction of the top layer
- Dust/Ice/Vacuum fraction of the bottom layer

Run model for several comet days and nights until it converges to a stable diurnal cycle

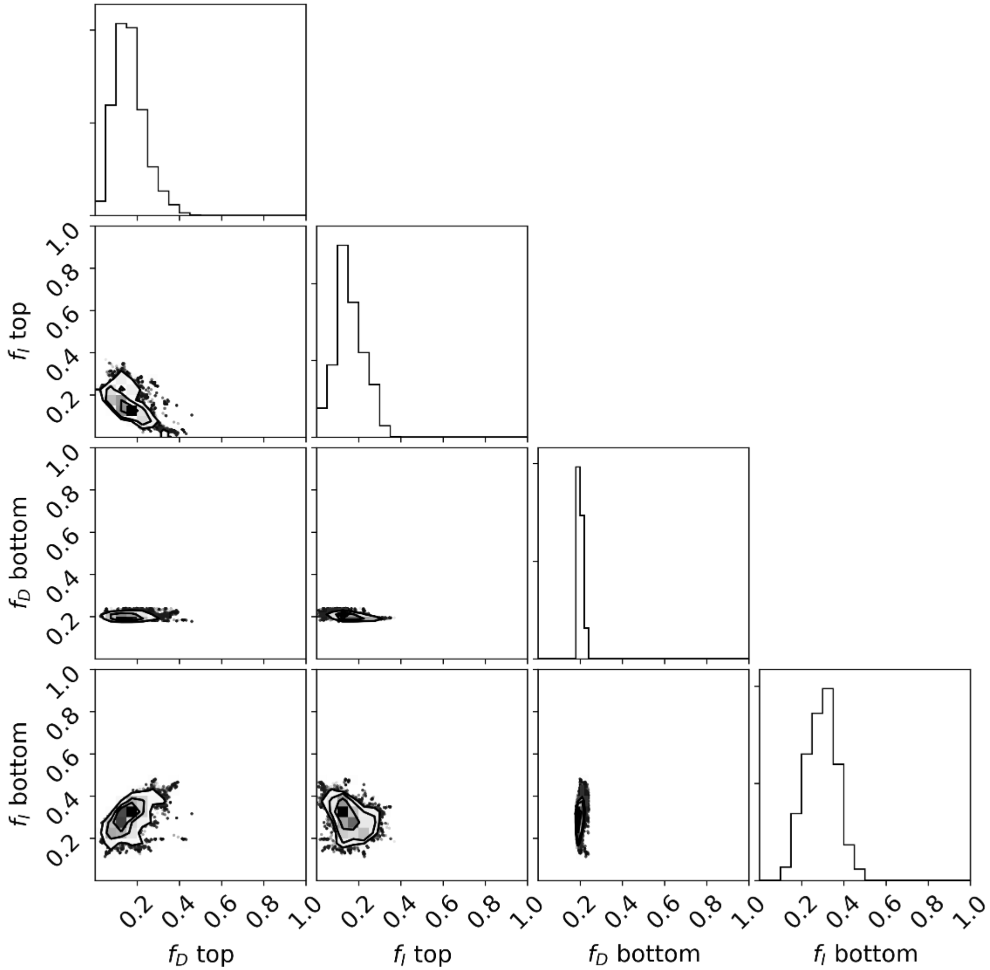
Calculate the root mean square difference between the modeled and observed brightness temperatures

Explore parameter space until a global minimum for the root mean square is found.

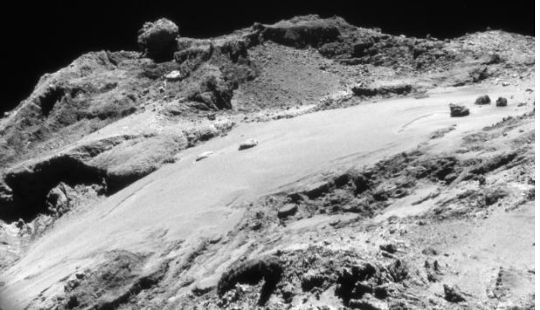


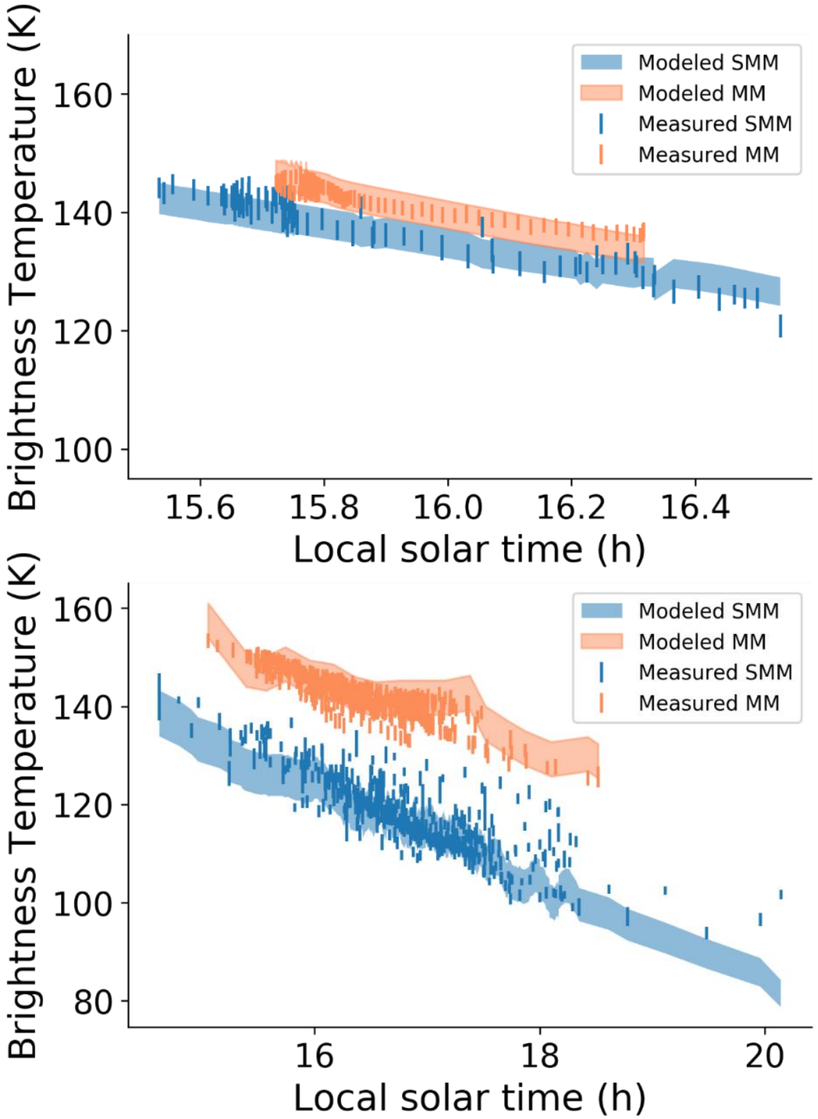
IV. Thermal model & method

Using a Python ensemble sampling toolkit for affine-invariant MCMC (emcee: The MCMC Hammer. Foreman-Mackey et al. 2013):



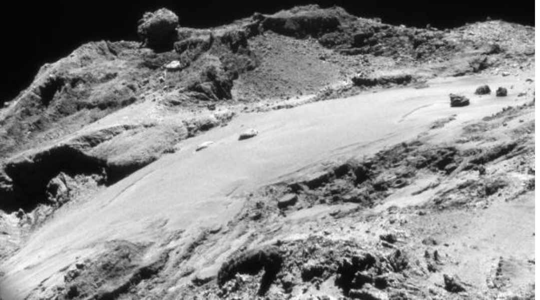
IV. Results and interpretation

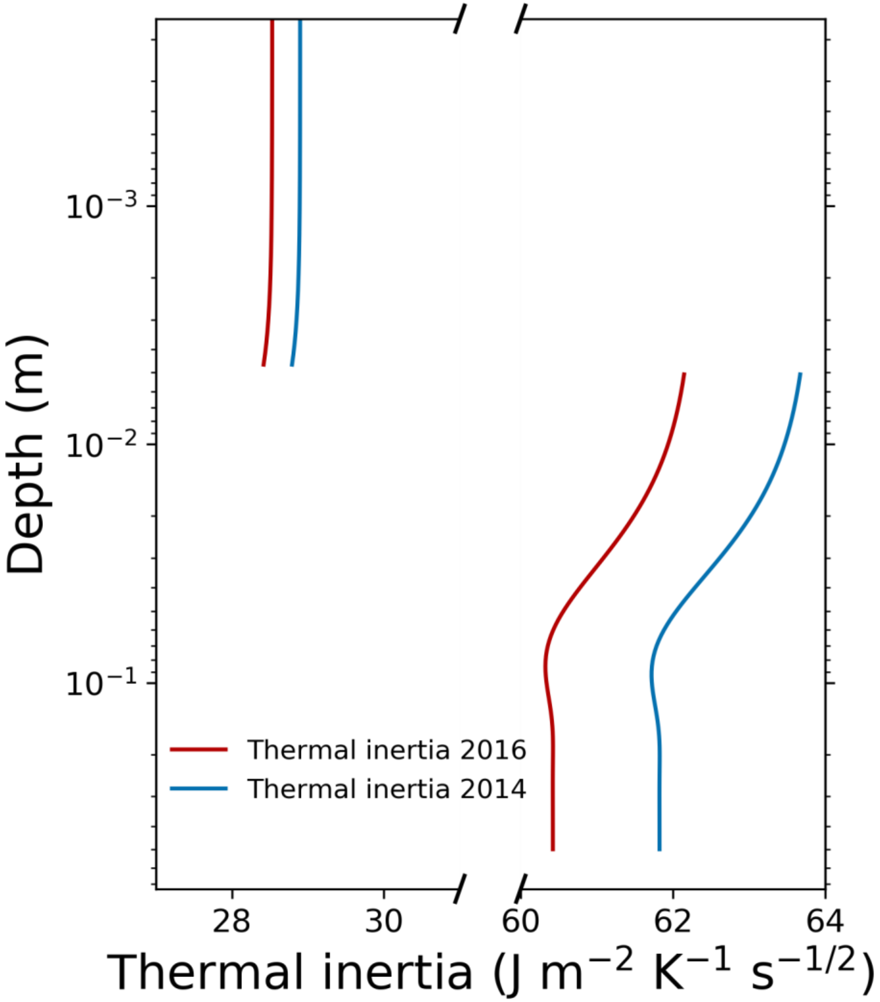




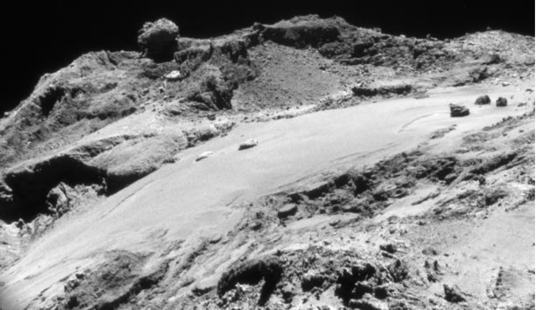
- For the first time we obtained a good fit in both the SMM/MM channels for both observations of the Imhotep region.
- Error bar in the model due to uncertainties in the electrical and thermal properties.
- The 2016 fit can be improved by being more selective with the observed areas.

IV. Results and interpretation



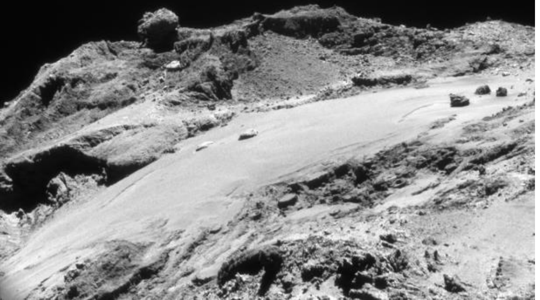


- Big difference between both layers
- We have a thermally insulating layer on the top.
- The thermal inertia decreased between 2014 and 2016.



IV. Results and interpretation

Instrument	Region observed	Thermal inertia ($J/m^2/K/S^{1/2}$)
MIRO	All nucleus (2014)	10-50
MIRO	Imhotep and Ash (September 2014)	10-30
MUPUS	Abydos (November 2014)	50 – 120
MIRO	Seth, Ash and Aten (September 2014)	<80
VIRTIS	Seth, Ash and Aten (September 2014)	40-160
MIRO	Imhotep (October 2014 & July 2016)	60-64



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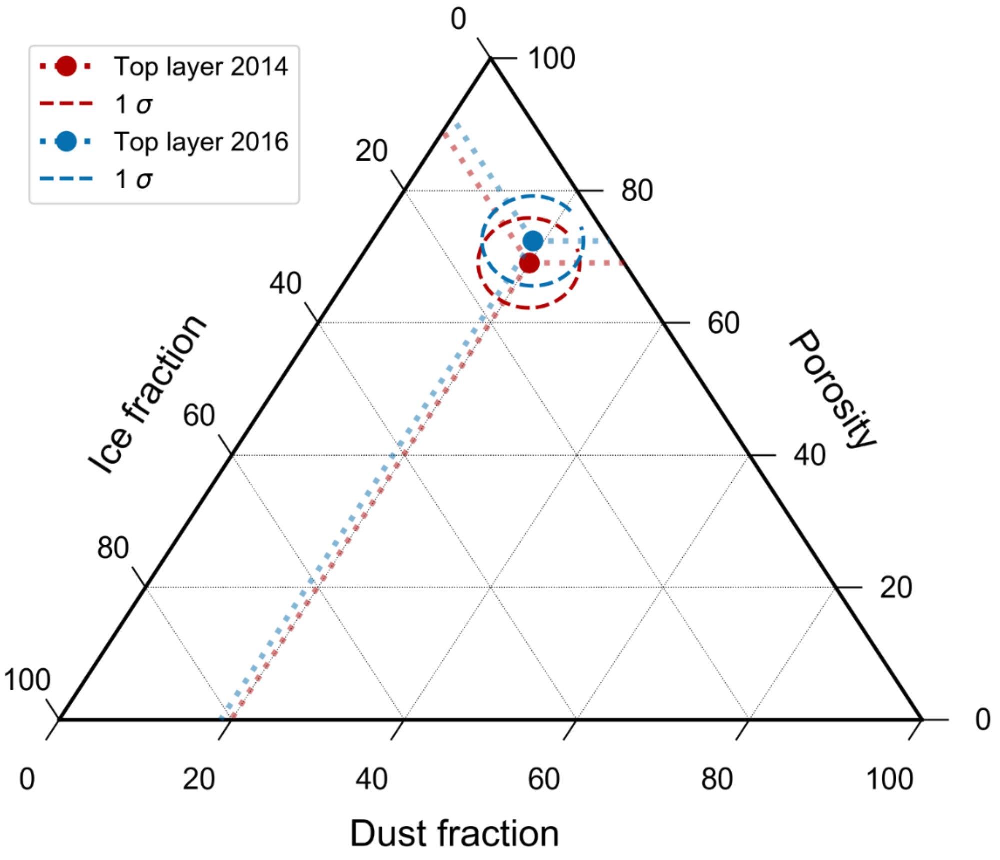
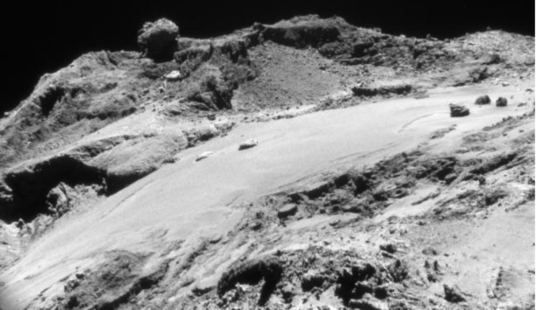


- At both dates we are in presence of top layer composed primarily of porous dust (P > 70 %).
- Between both observations there is small change in the properties.
- The change is not significant when compared to the error bar.



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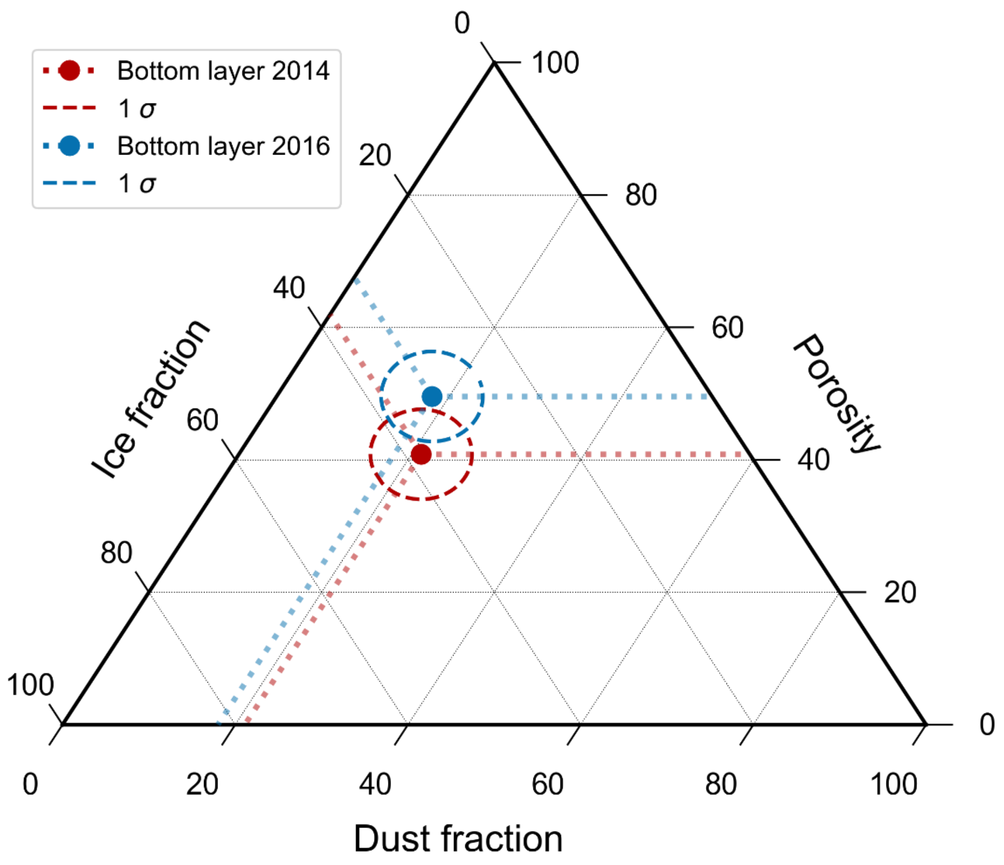
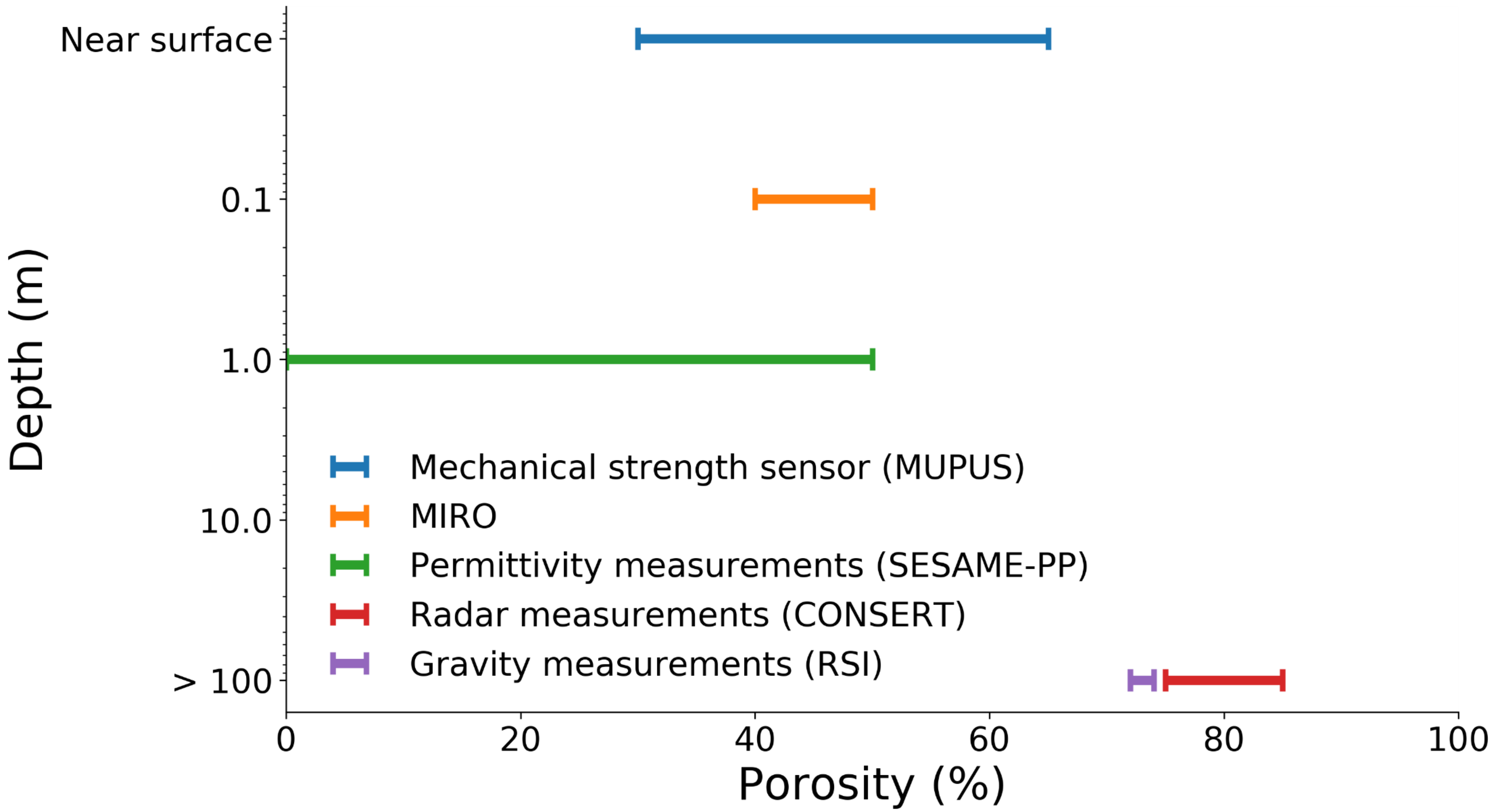
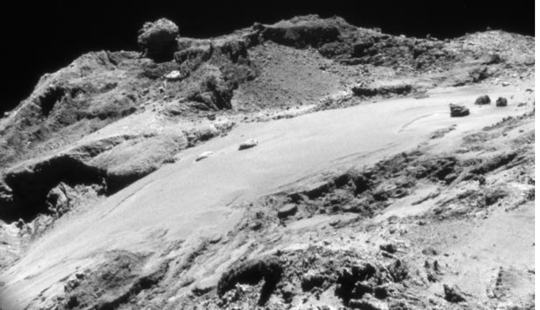


- At both dates we are in presence of more compact bottom layer (P < 50 %).
- The water ice volume in the bottom layer is higher than the dust volume (15-20 % more).
- The models seem to imply that there is less water ice and more porosity in 2016 than in 2014.

IV. Results and interpretation

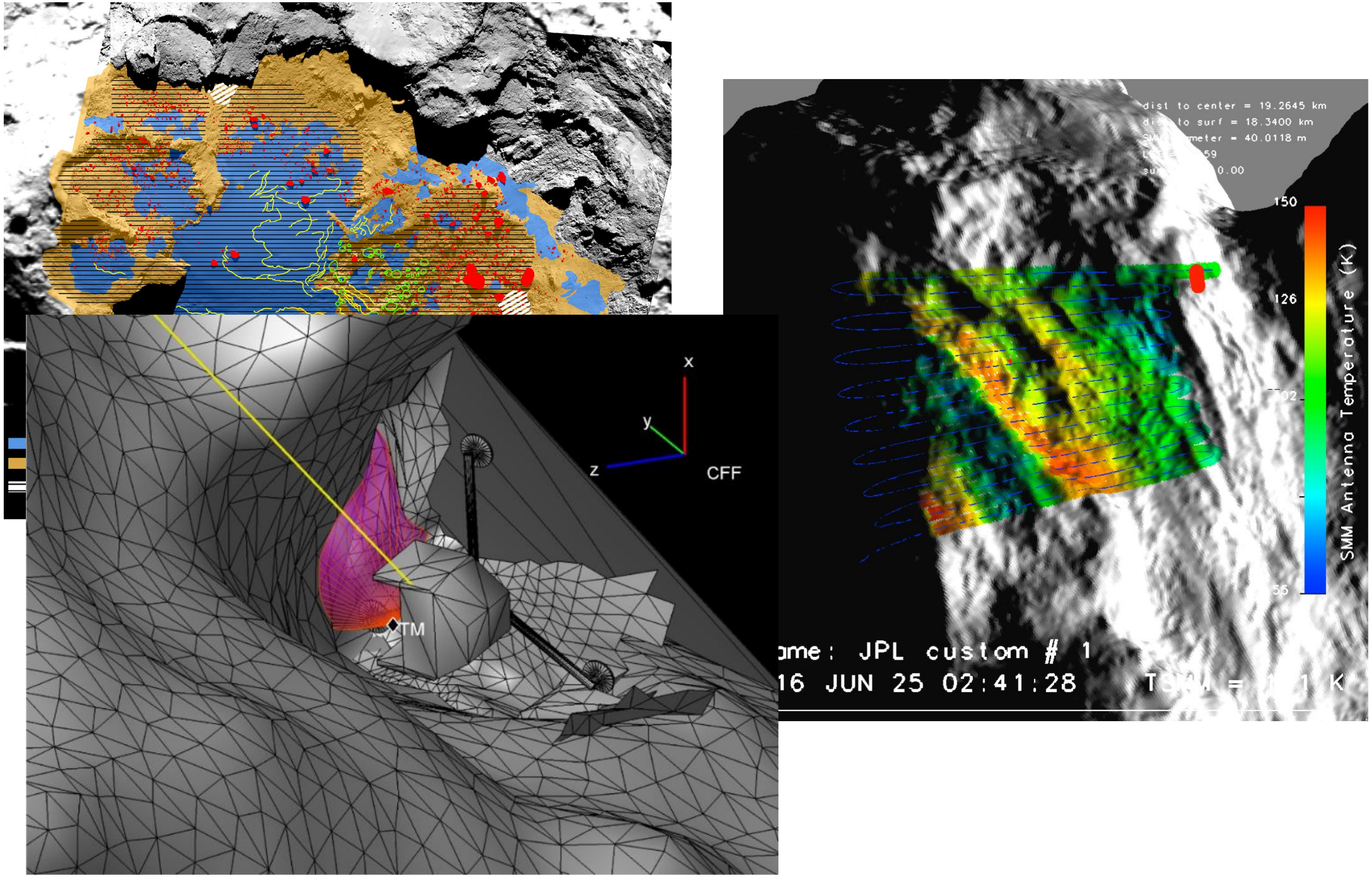




Conclusion

- We obtained for the first time a good fitting model to the high resolution measurements made by MIRO of the Imhotep region.
- We observe a decrease in water ice content and an increase in porosity consistent with a sublimation of water ice in the subsurface as the comet went by perihelion.
- To obtain a good fit, conservative assumptions were made, resulting in error bars on the composition that are as big as the changes observed.
- Explore additional assumptions on the subsurface.
- Explore different geomorphological regions

What's next ?



x
y
z
CFF
TM
dist to center = 19.2645 km
dist to surf = 18.3400 km
150
126
SMM Antenna Temperature (K)
JPL custom # 1
16 JUN 25 02:41:28