The Chase is On

U.S. ROSETTA MISSION

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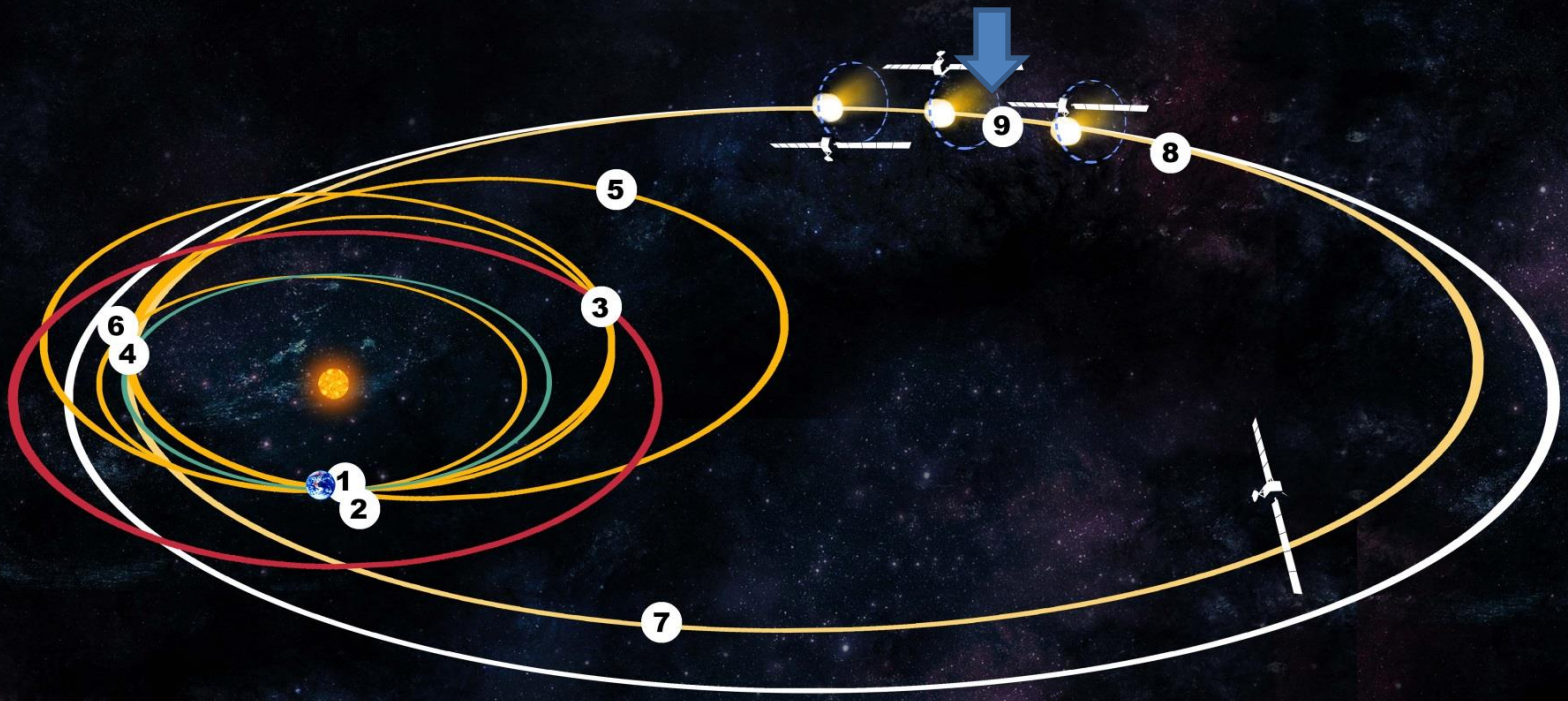
US Project Manager — US Project Scientist

October 9, 2014

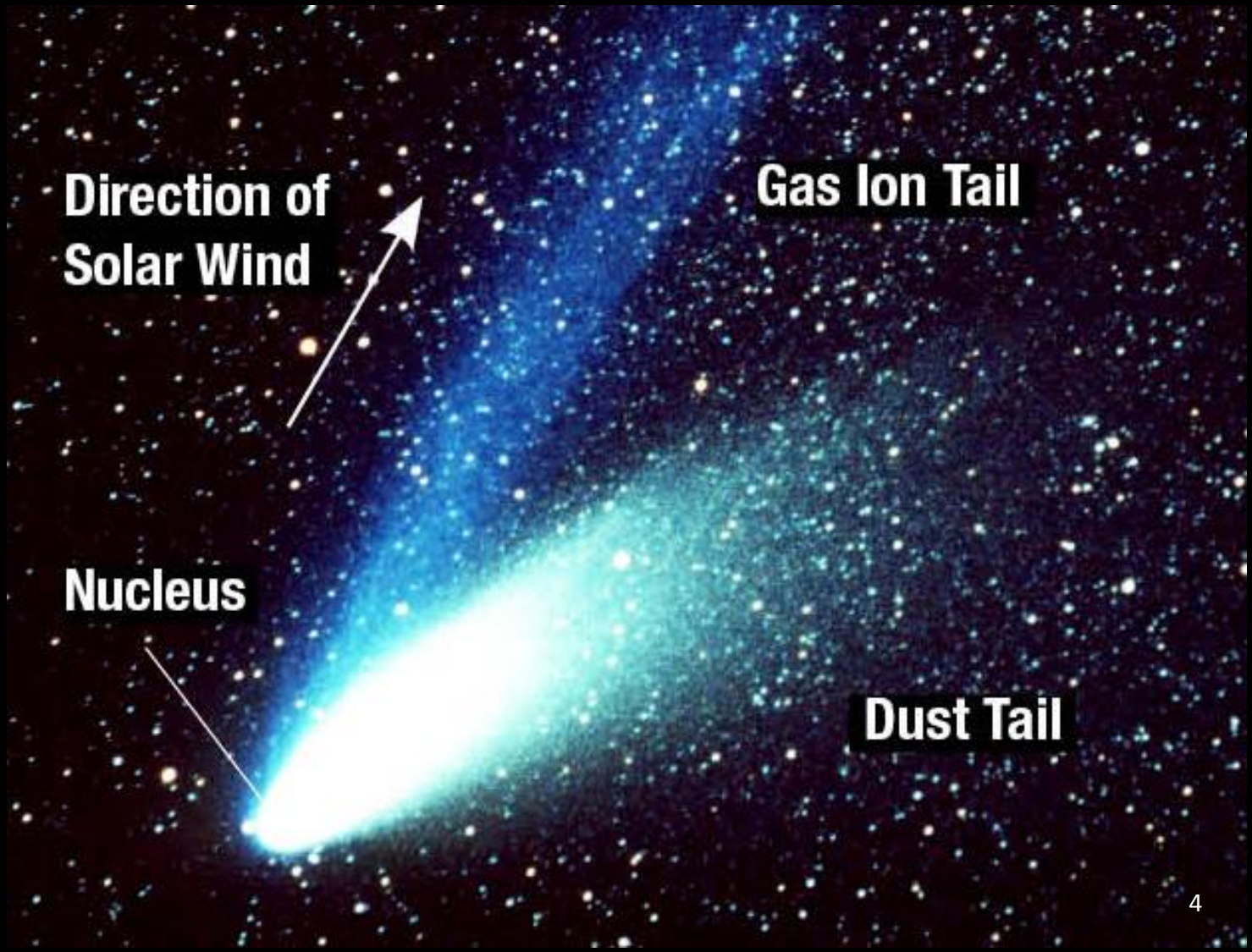
rosetta's trajectory



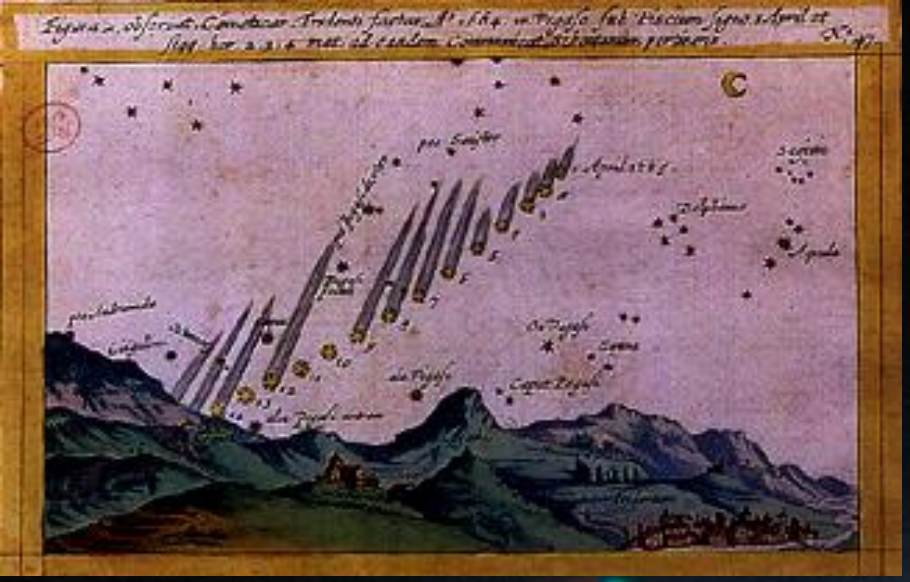
1. Launch, March 2nd 2004
2. First Earth swingby, March 3rd 2005
3. Mars swingby, February 26th 2007
4. Second Earth swingby, Novmber 14th 2007
5. Asteroid Steins flyby
6. Third Earth Flyby, November 11 2009
7. Asteroid Lutetia flyby
8. Arriving at the comet in 2014
9. Rosetta observes comet 67P/Churyumov- Gerasimenko

Mars Orbit Earth's Orbit Rosetta's Orbit Comet Orbit

Credit: NASA/JPL Caltech



Comet Hale-Bopp NASA



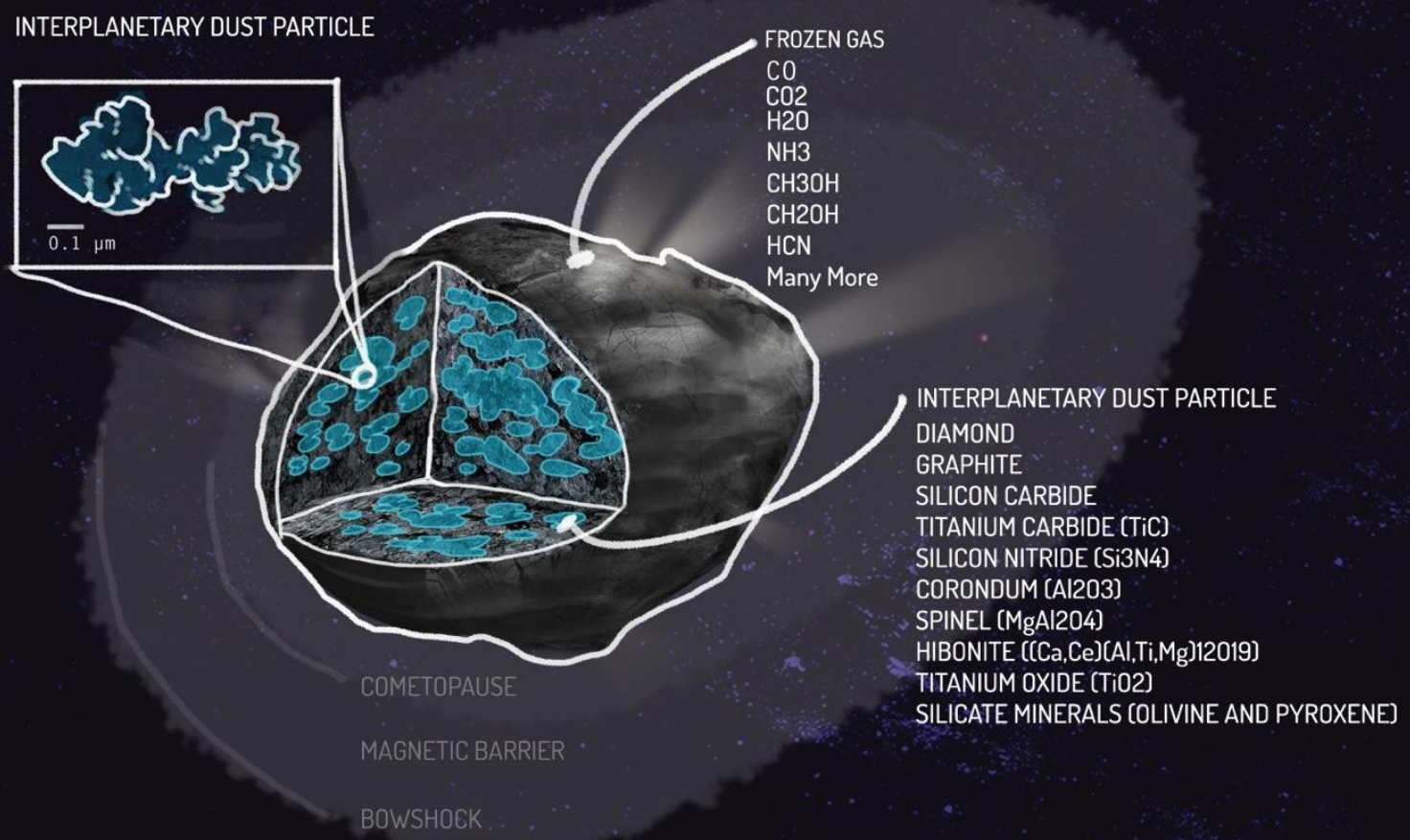
ISON Composite Photo Nov 15, 2013; credit European Southern Observatory

Members of the horizon 2000 committee meeting in Venice, 1984

- European objectives, going back to 1980s, for Rosetta include obtaining original material

National Aeronautics and Space Administration

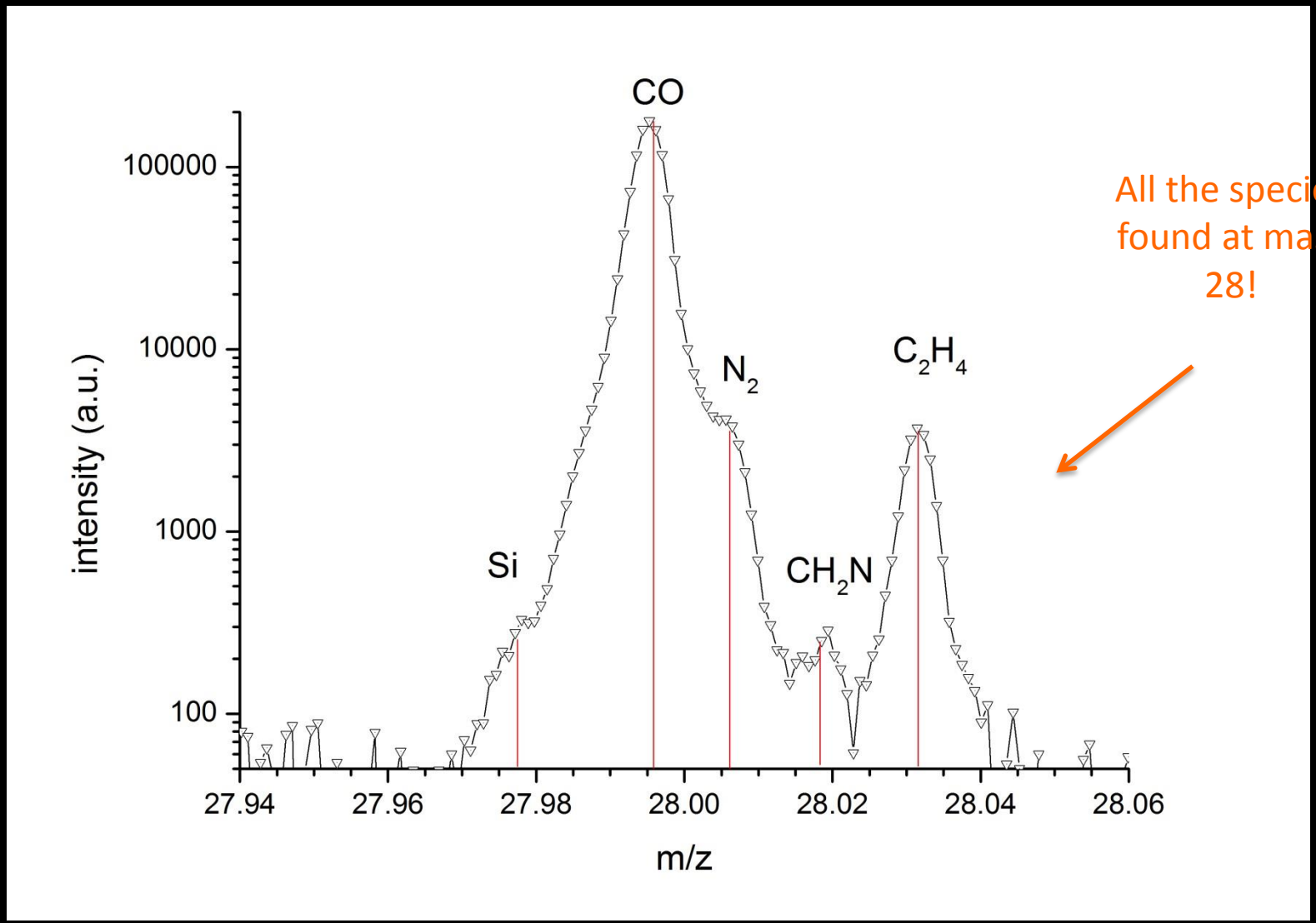
WHAT IS A COMET MADE OF?



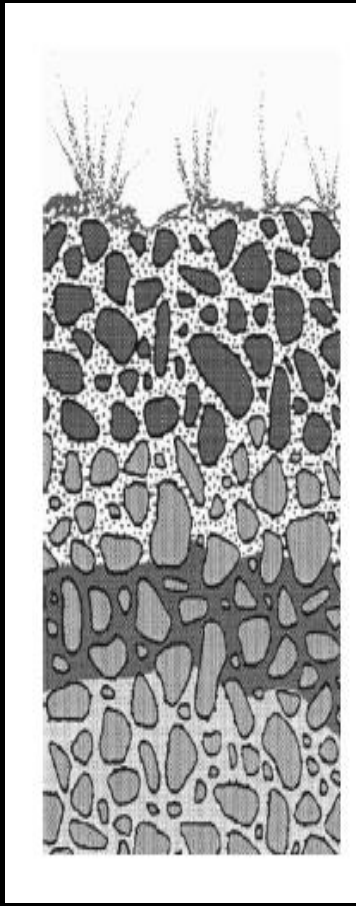
Credit: NASA/JPL Caltech

High resolution neutral mass spectrum of mass 28!

ROSINA was designed to differentiate between CO & N_2, all at mass 28.
We can finally get accurate assessment of amount of N_2 in primitive materials!



Nucleus thermal properties:
A team effort of 7 instruments



Surface Temperature controlled by roughness:
Osiris (dm, m scale), CIVA-P, ROLIS (mm, cm scale)

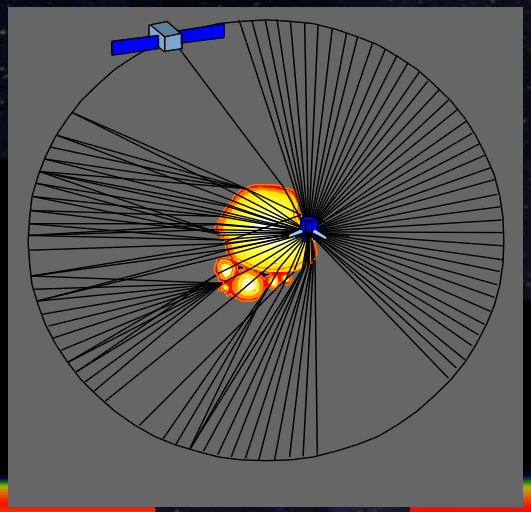
Measure Temperature in the top few µm:
VIRTIS, MUPUS

Heat transport determined by thermal conductivity, porosity, density: MUPUS, SESAME

Measure T down to 10s cm: MIRO, MUPUS

CONSERT Instrument

Orbiter receives radio waves

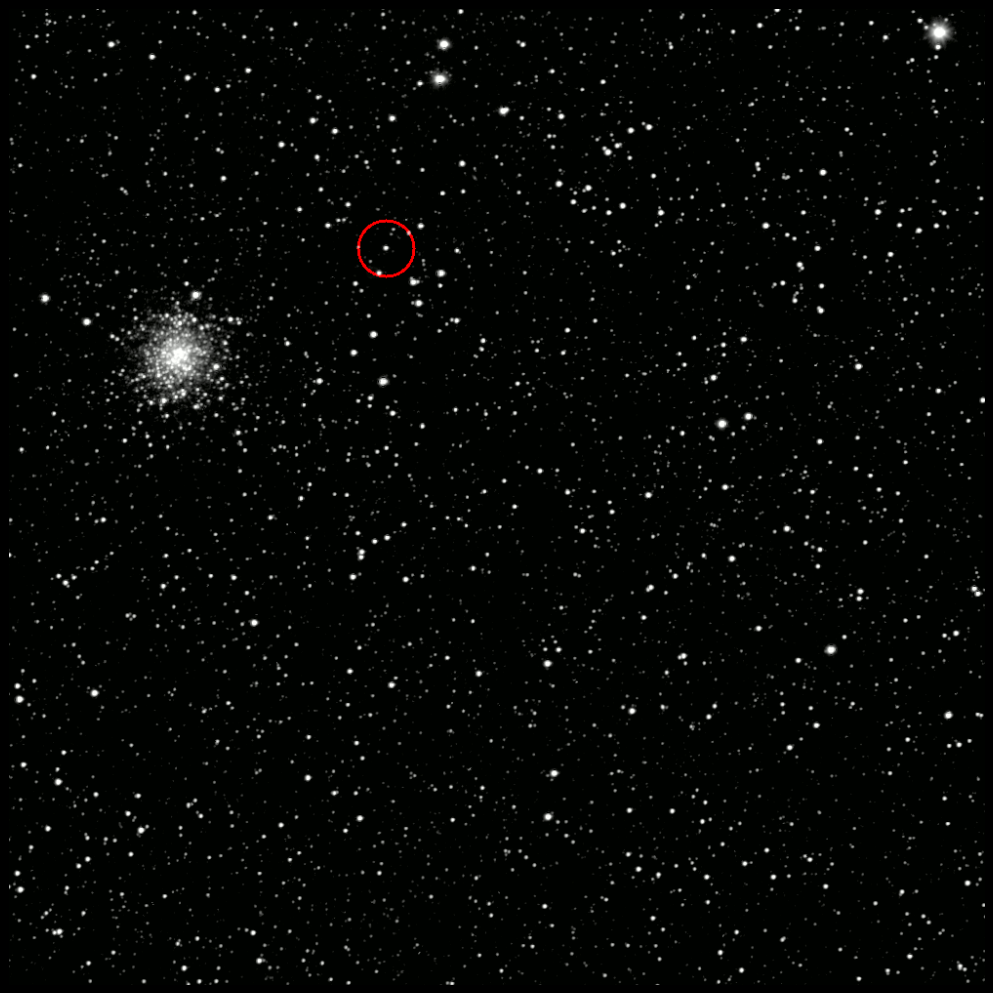


Lander sends radio waves

Nucleus material (different dielectric properties

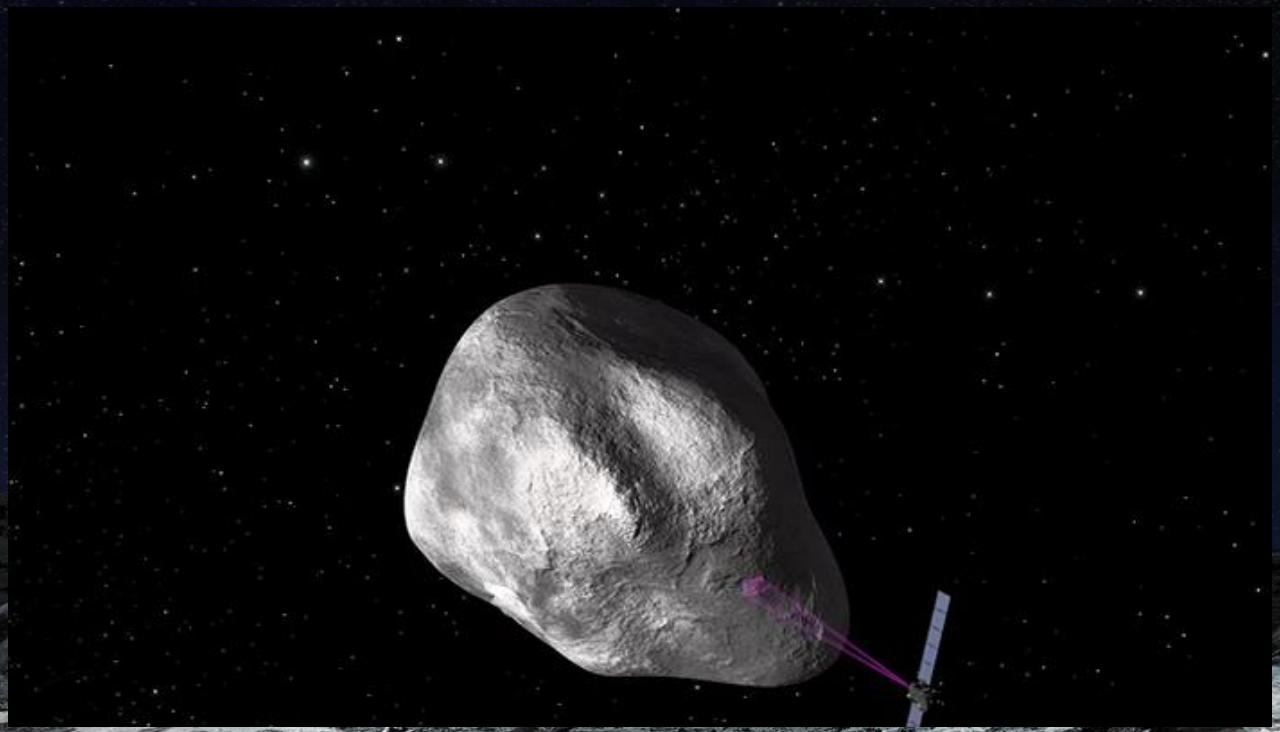
Credit: ESA/CNES

Comet Outburst



Credit: ESA/Rosetta/NAVCAM

We expected comet 67P to be round!

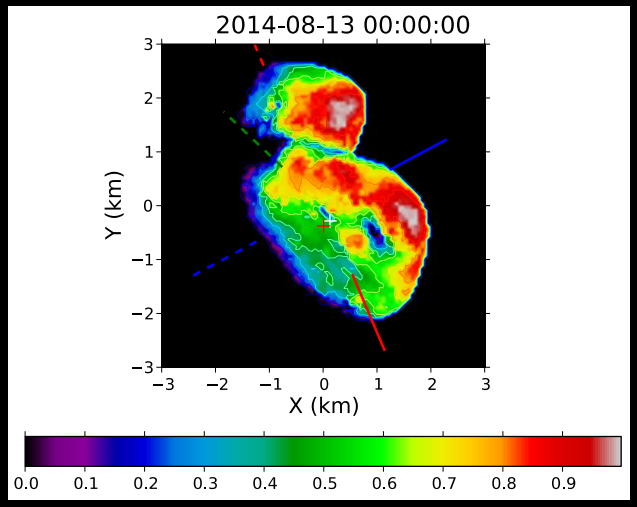


Credit: ESA/Rosetta/OSIRIS

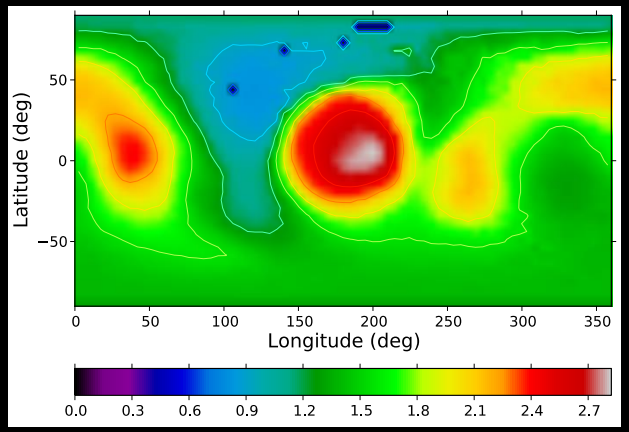
Credit: ESA/Rosetta/OSIRIS

Temperature map on 3D model

OSIRIS SHAP1



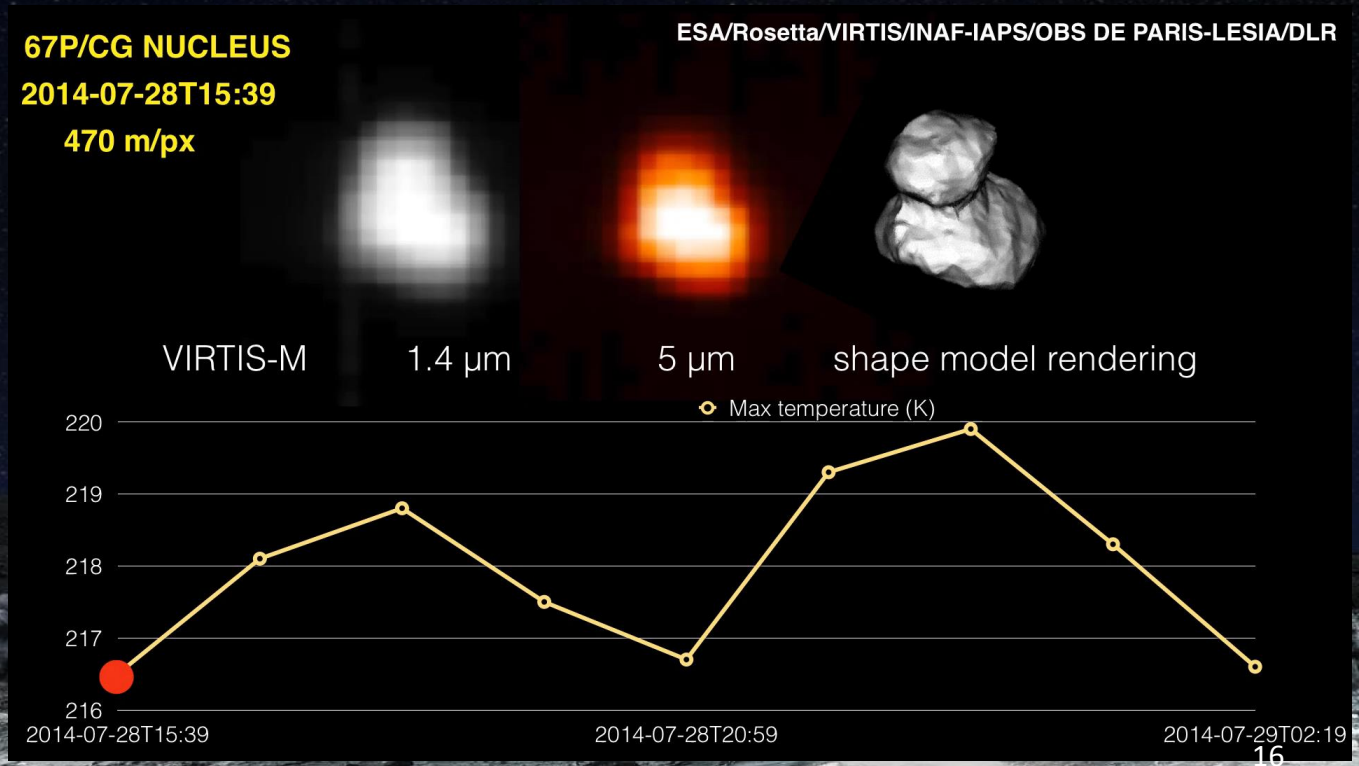
About 5000 facets

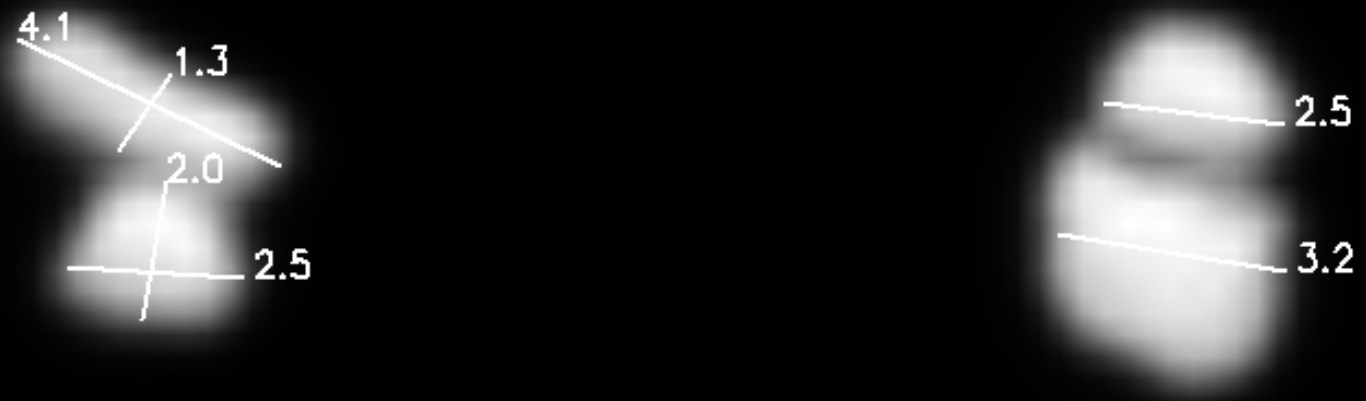


ESA/NASA/JPL-Caltech

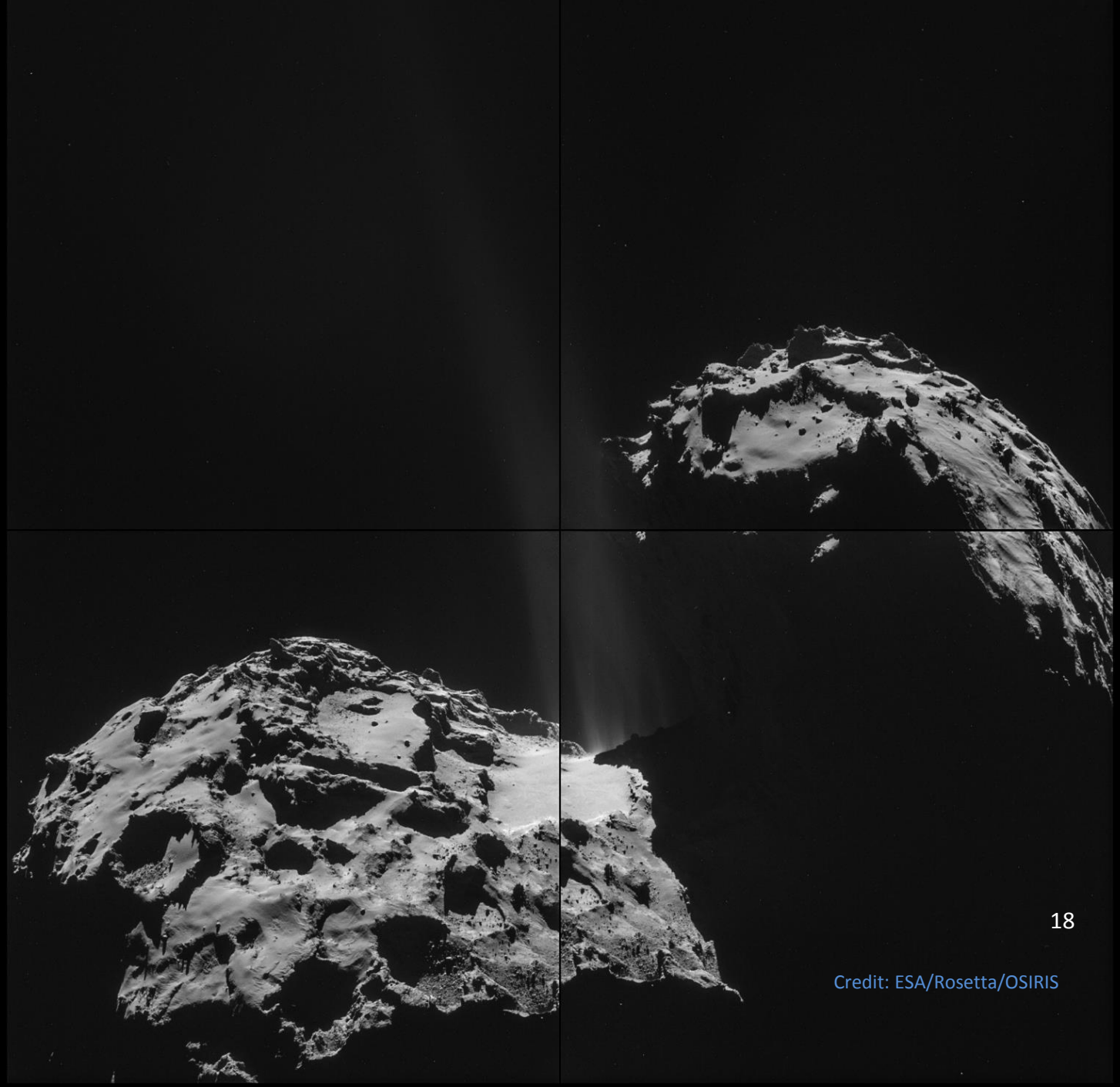
Infrared Instrument

VIRTIS

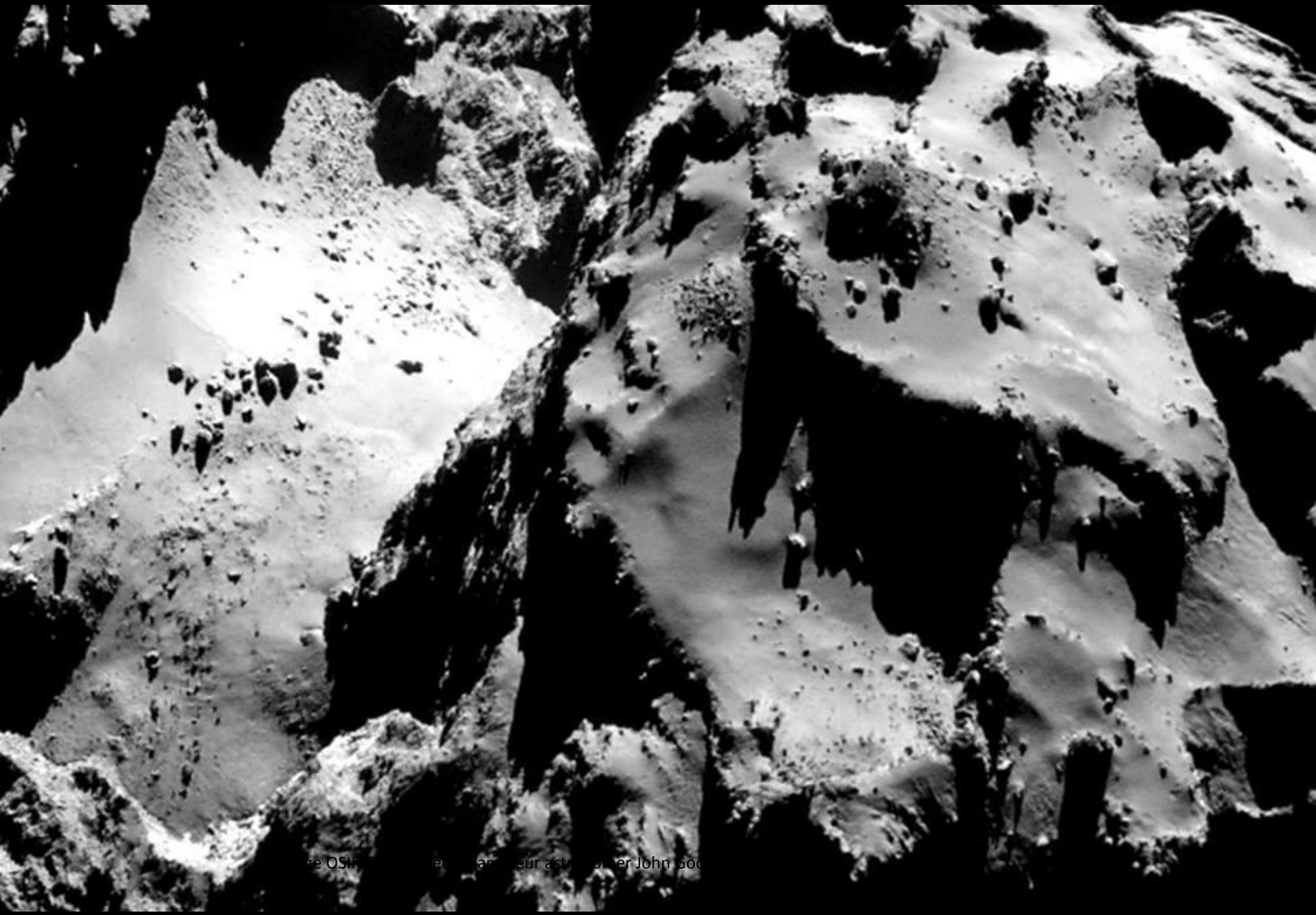




Credit: ESA/Rosetta/OSIRIS

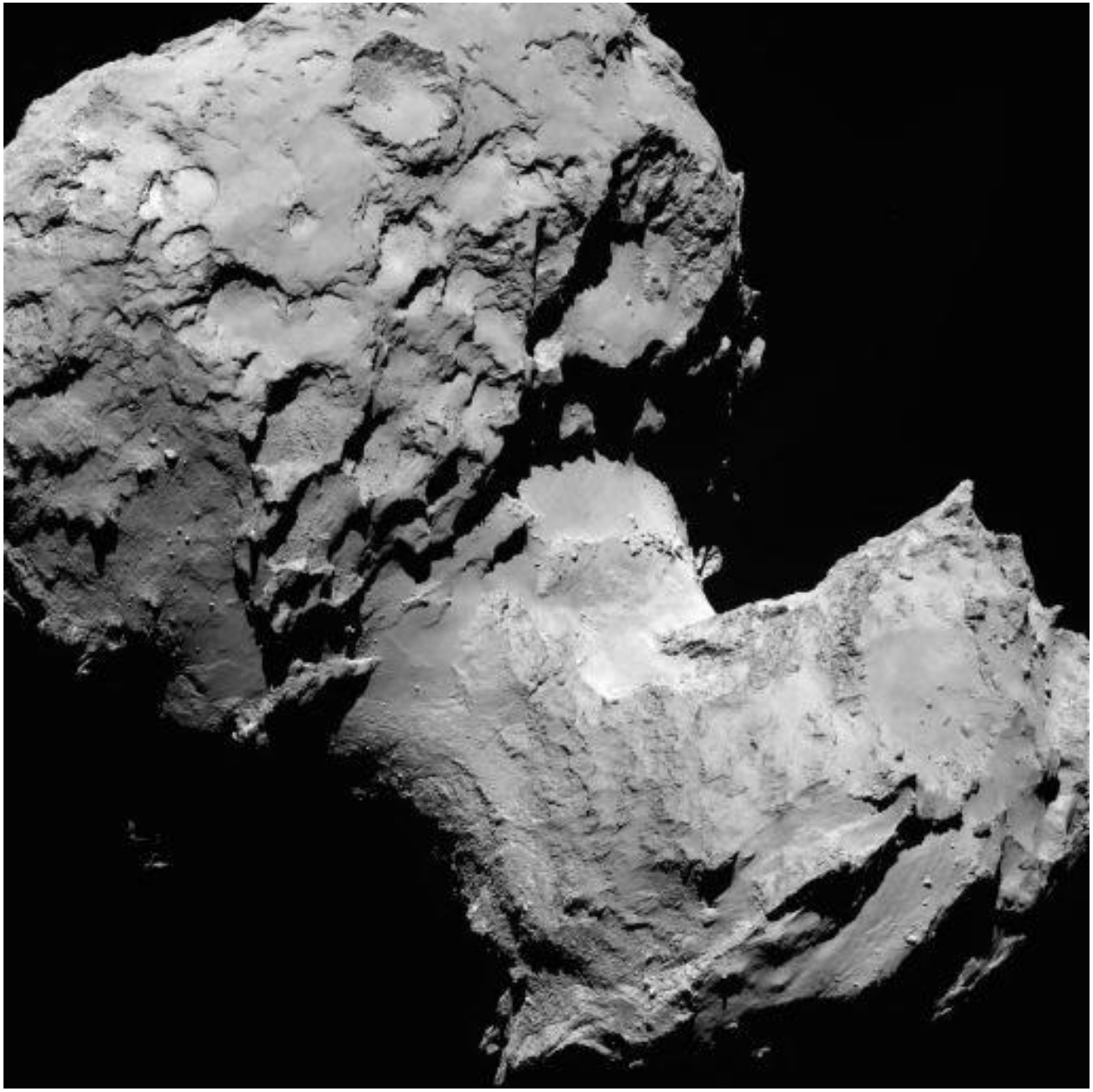


Credit: ESA/Rosetta/OSIRIS



How to Land on a Comet?

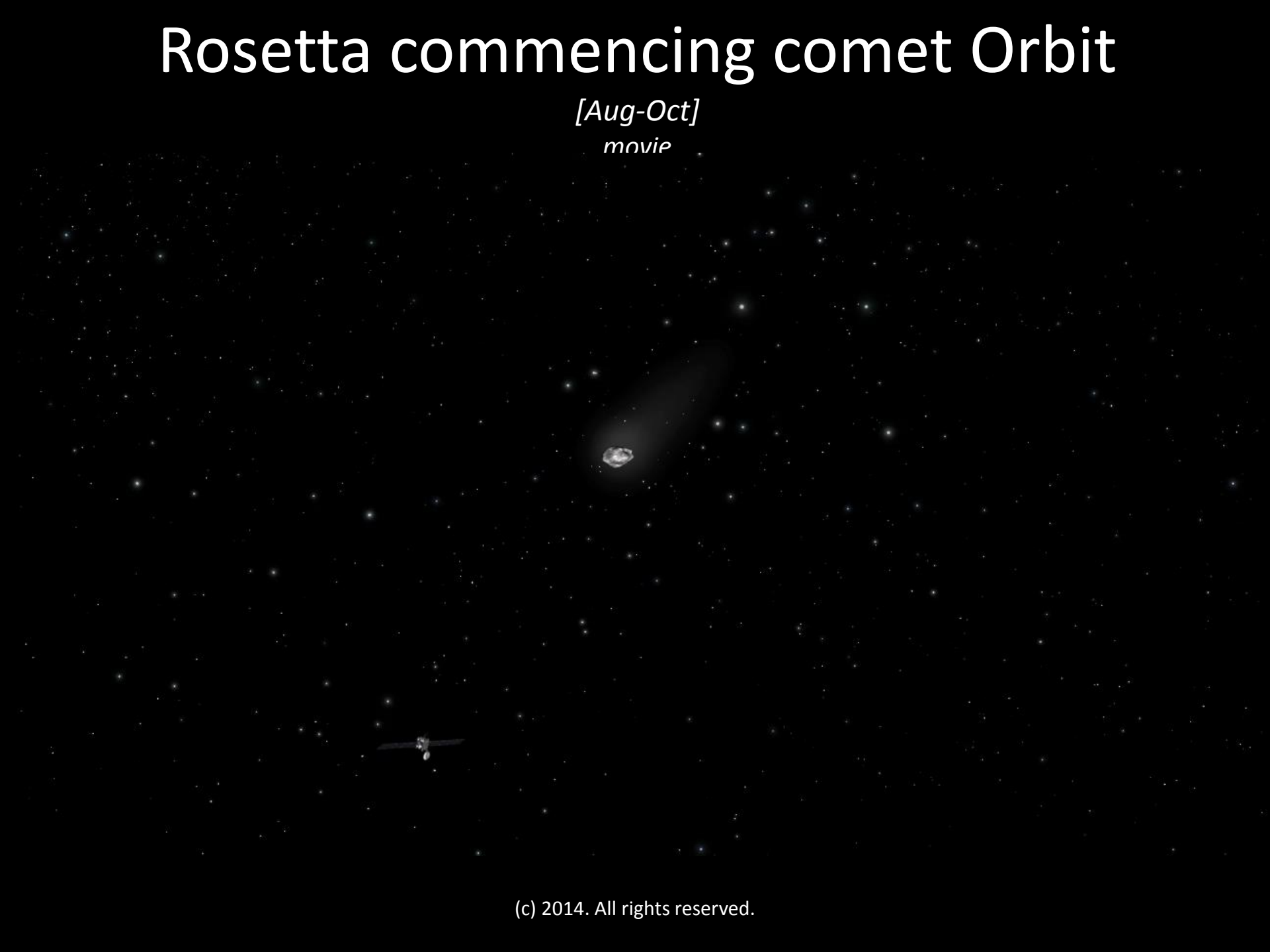
Credit: NASA/JPL Caltech



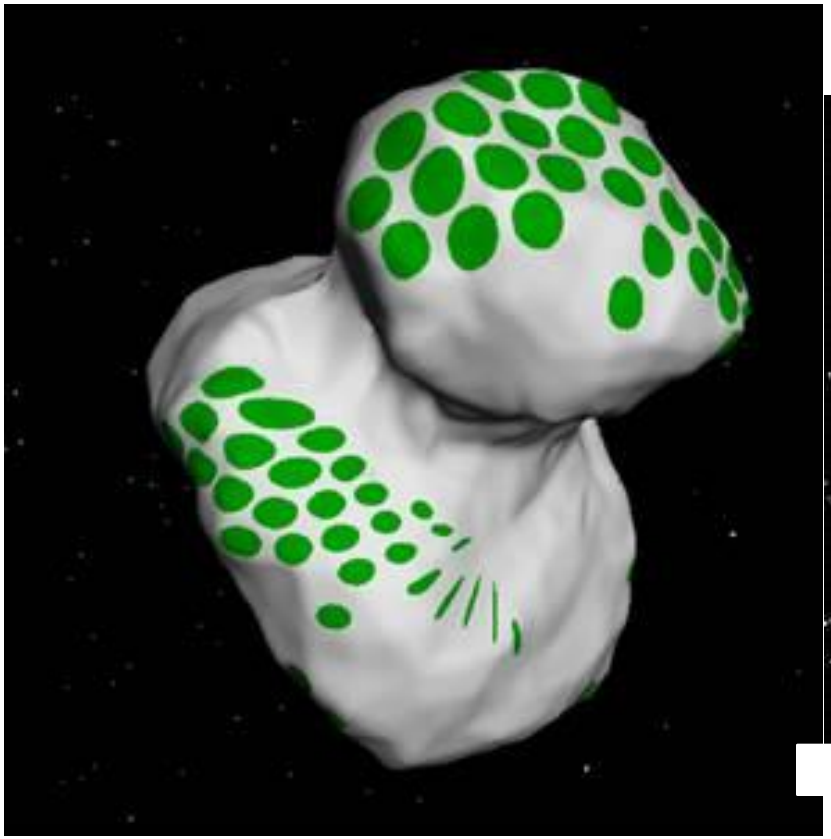
Rosetta commencing comet Orbit

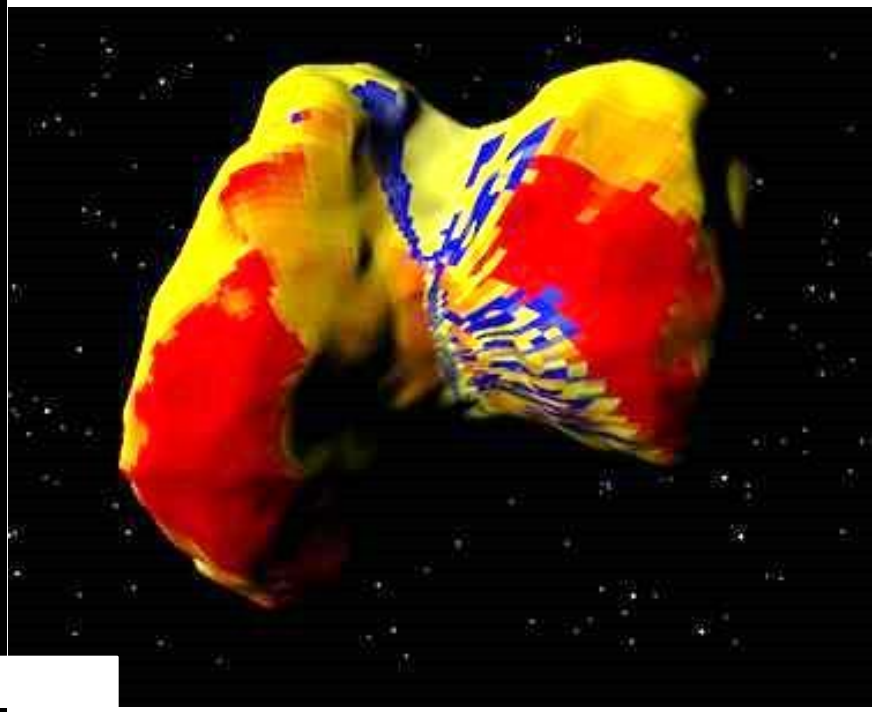
[Aug-Oct]

movie



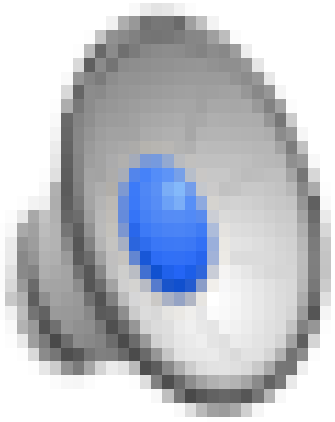
Possible Landing Areas





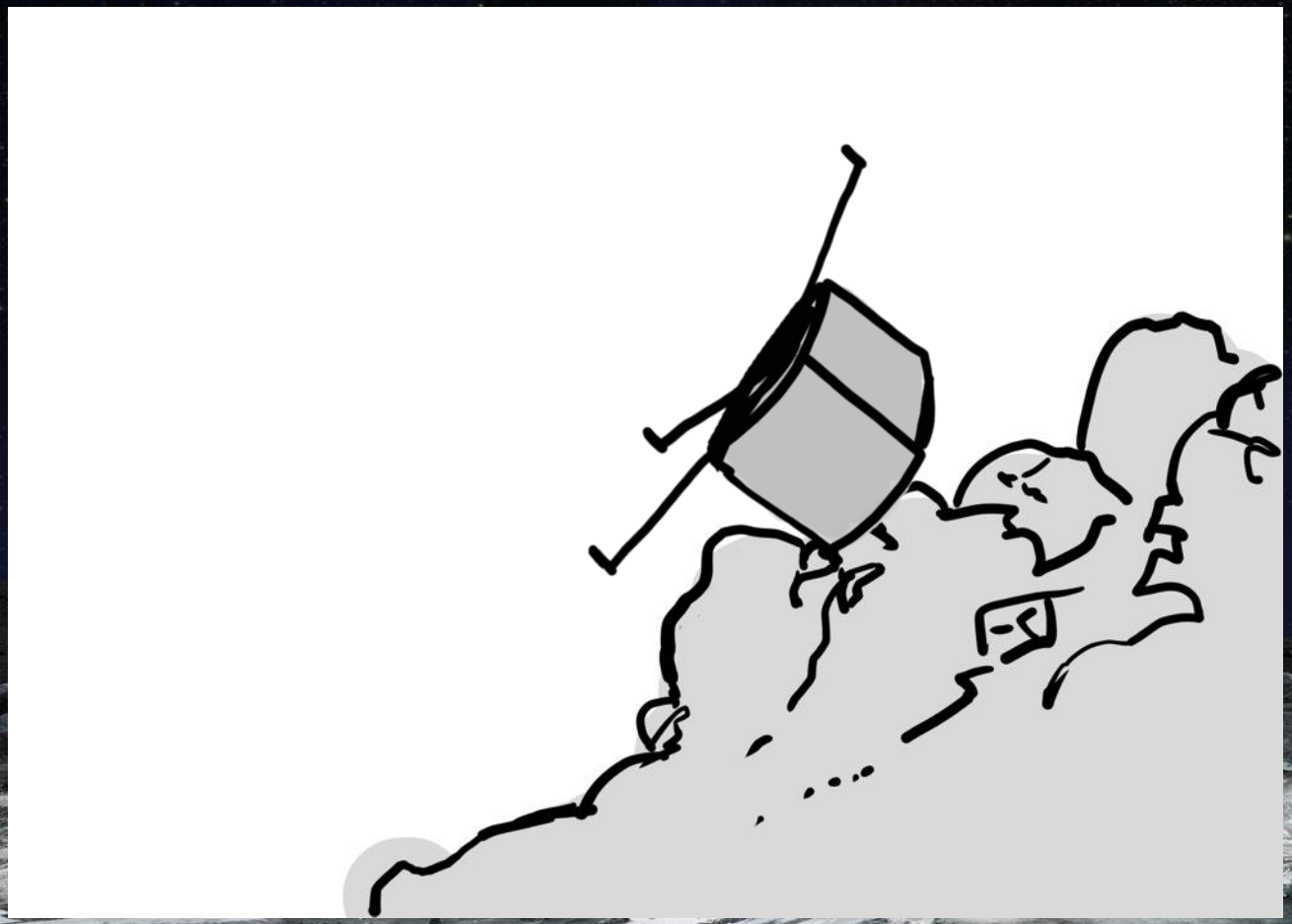
Lander Deployment [video]

Philae Landing Site



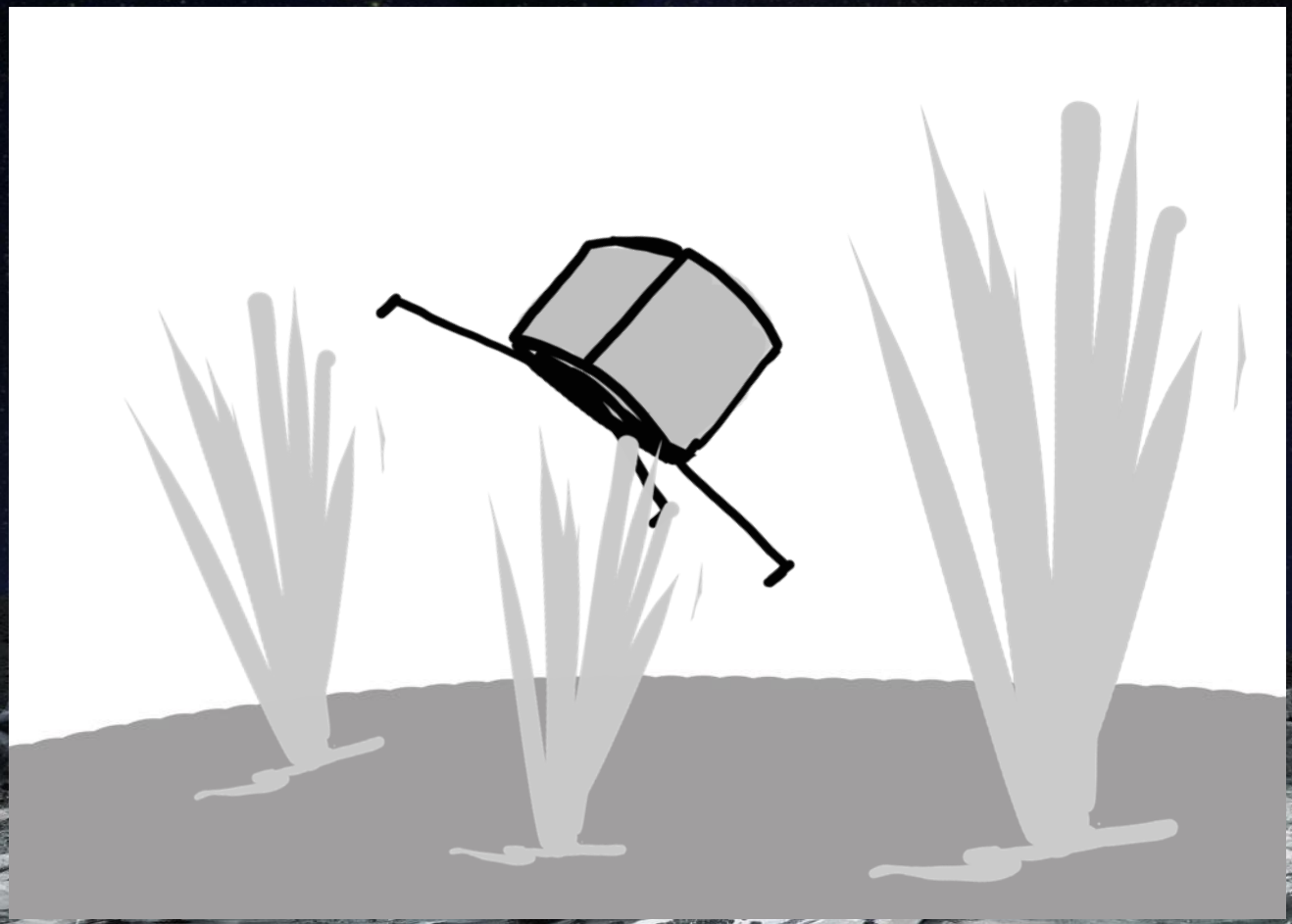
Credit: S.F. Hviid/ESA/OSIRIS

Don’t crash into boulders!



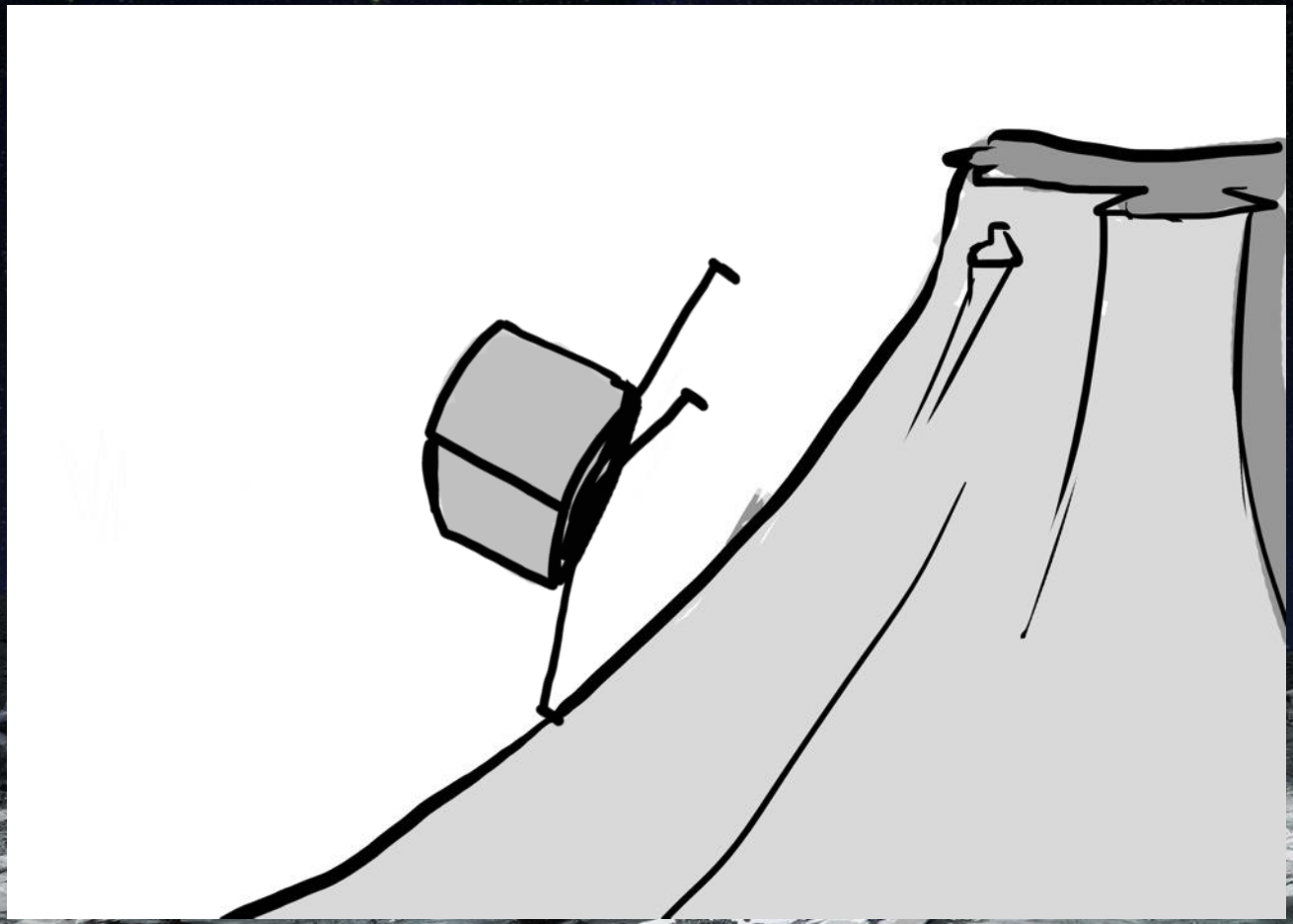
Credit: NASA/JPL Caltech

Stay away from jets!



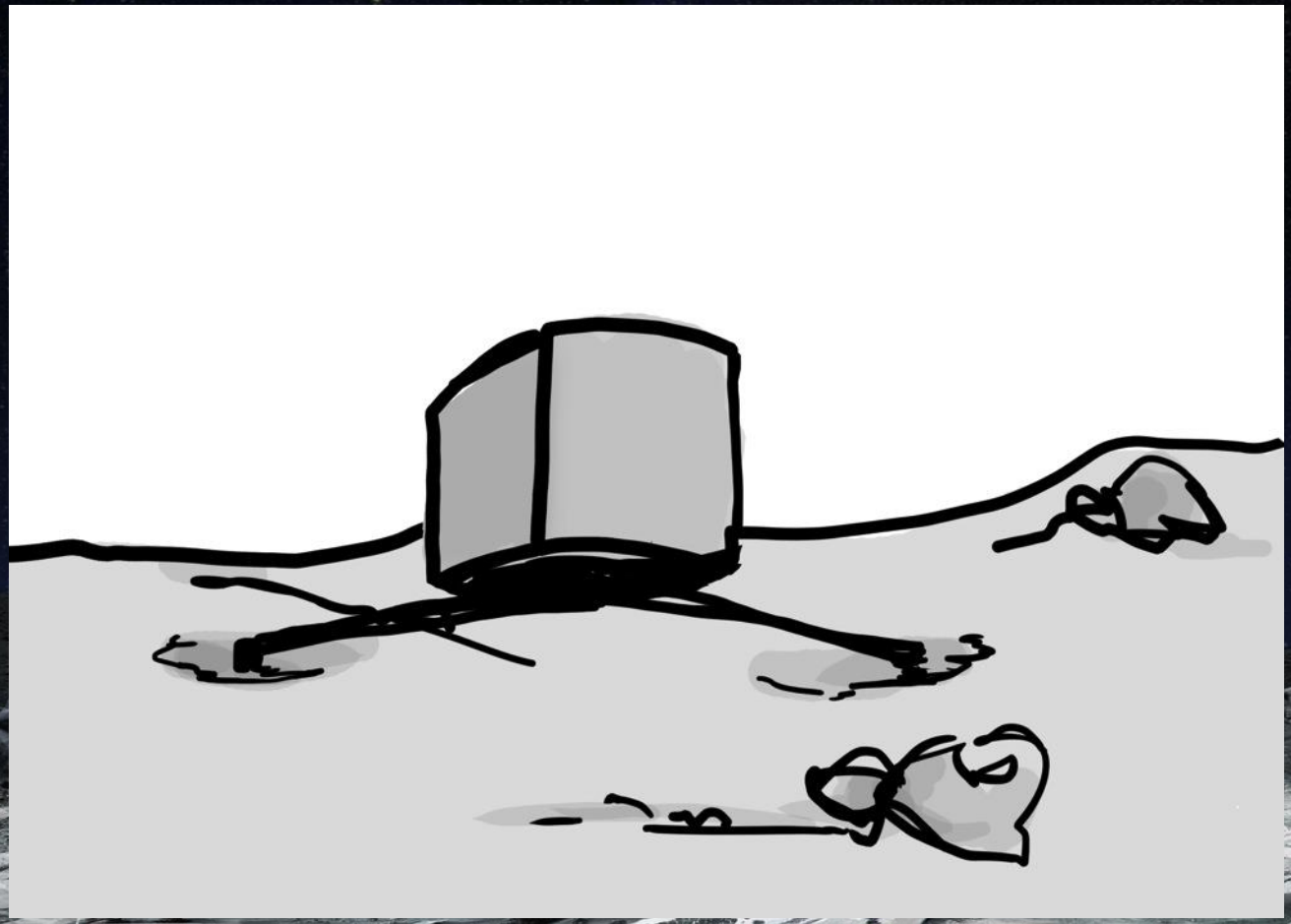
Credit: NASA/JPL Caltech

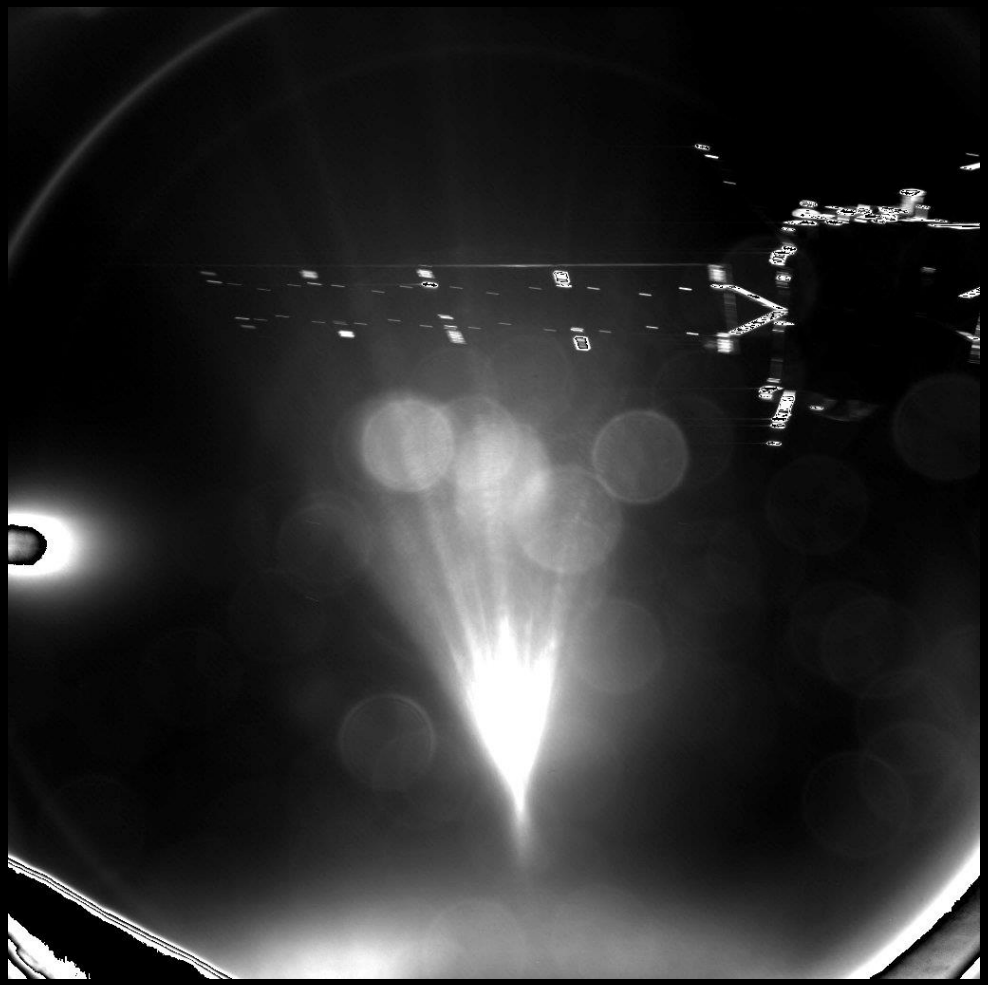
Don't tip over on a steep slope!



Credit: NASA/JPL Caltech

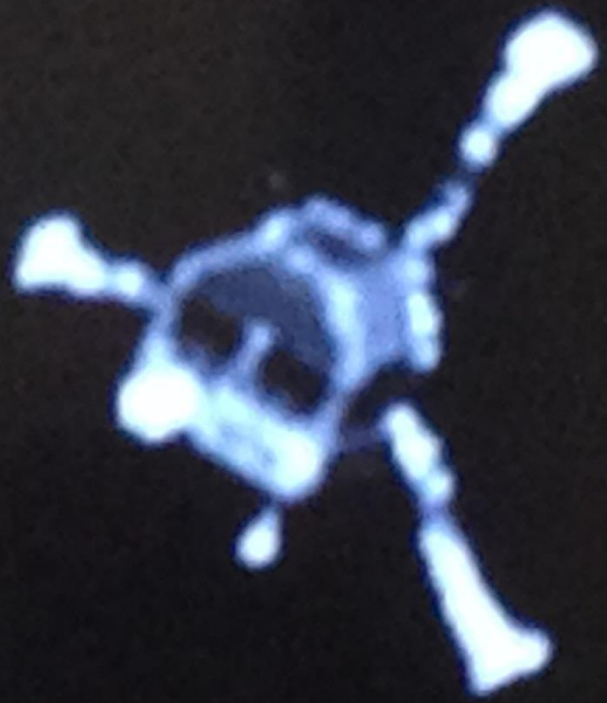
Don't sink in the dust!





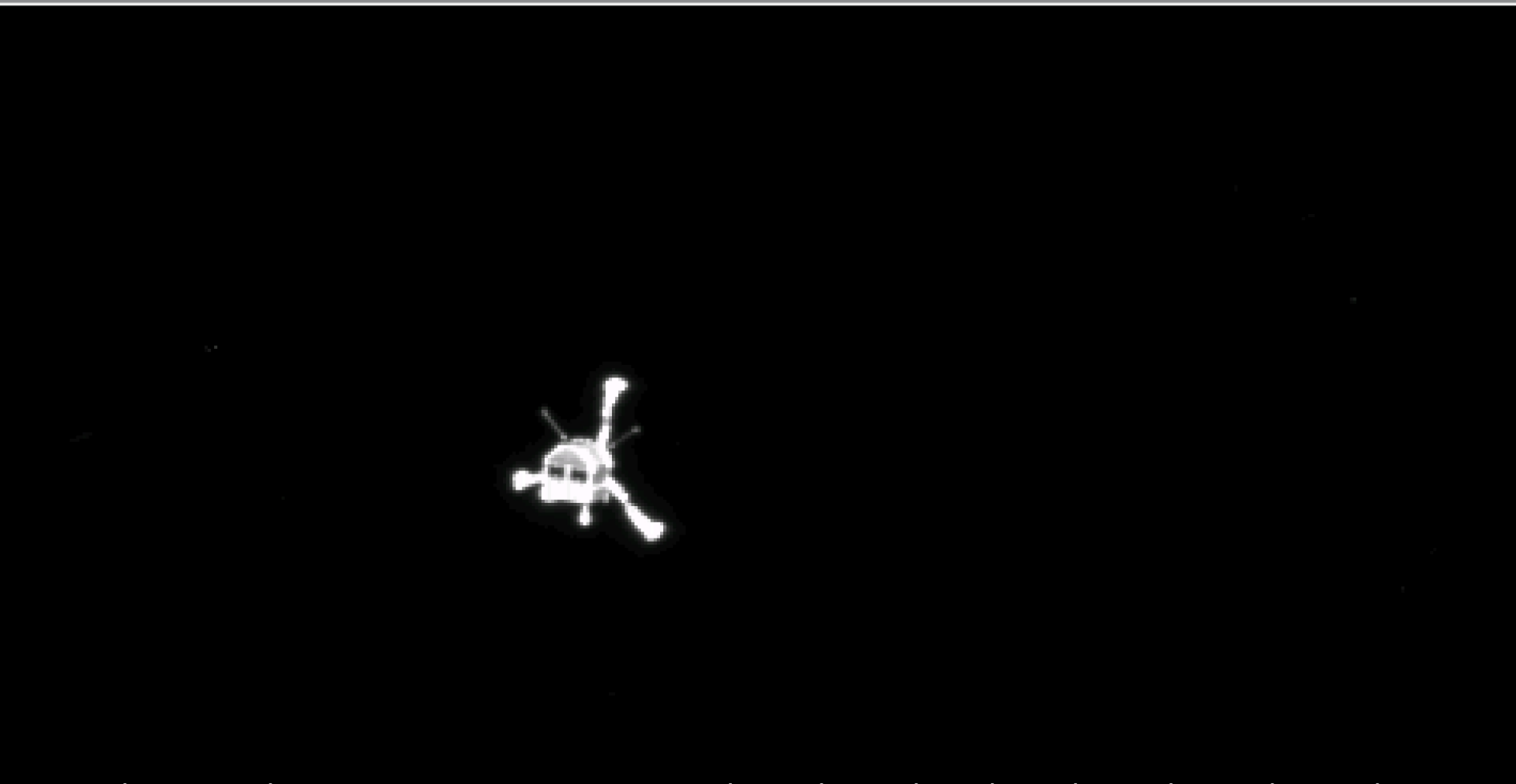
ESA/Rosetta/Philae/CIVA

Philae in flight from Osiris on the Orbiter



Close up of Philae in flight from the science camera OSIRIS. Navigators took a sight of relief seeing this picture because it showed that the lander attitude is correct, the Rolis camera is pointed down, the legs are deployed.

Credit: ESA



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

Credit: ESA

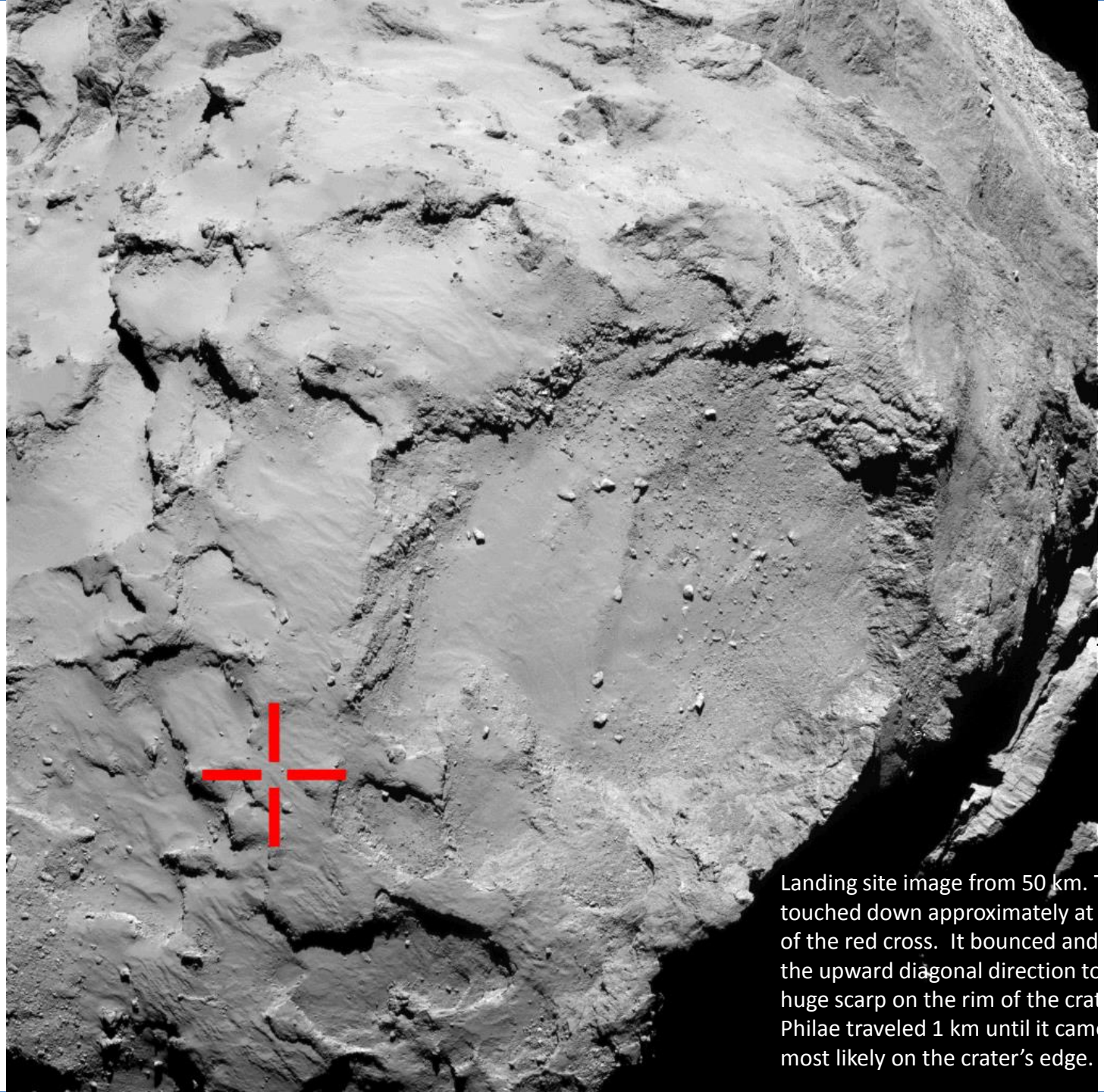
Philae approaching the comet 1:15 h before the touchdown. The descent duration was 7 hours with the comet rotation of approximately 12 h. These parameters made for an interesting trajectory. There was no ability to control the lander after its release. An onboard gyro kept the legs pointed down.

Credit: DLR/Rolis

First image of landing site from camera mounted under the lander.

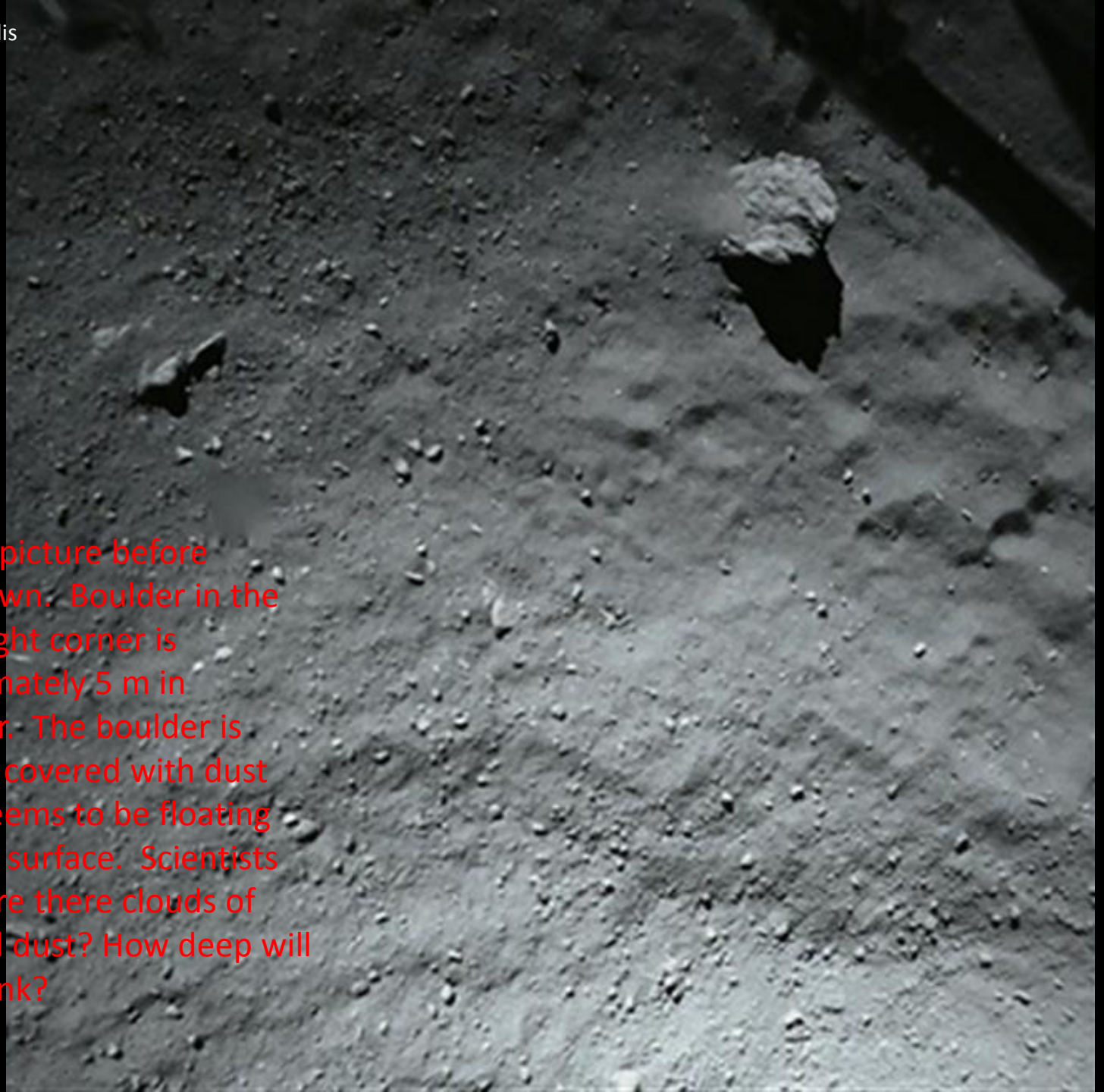
One of the lander legs ivisible in the upper corner.

Resolution 3m/pixel.

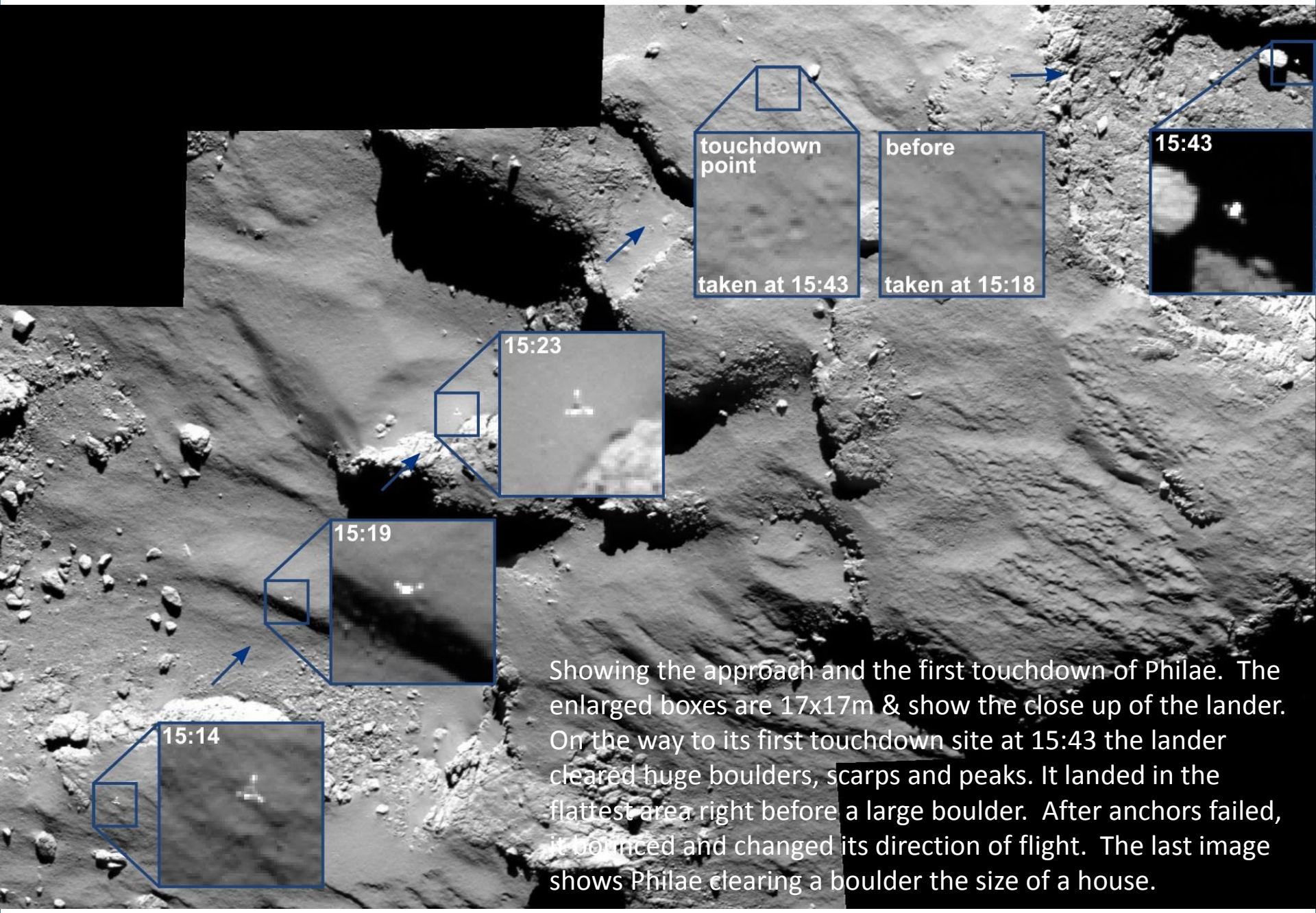


Landing site image from 50 km. T
touched down approximately at
of the red cross. It bounced and
the upward diagonal direction to
huge scarp on the rim of the crat
Philae traveled 1 km until it came
most likely on the crater's edge.

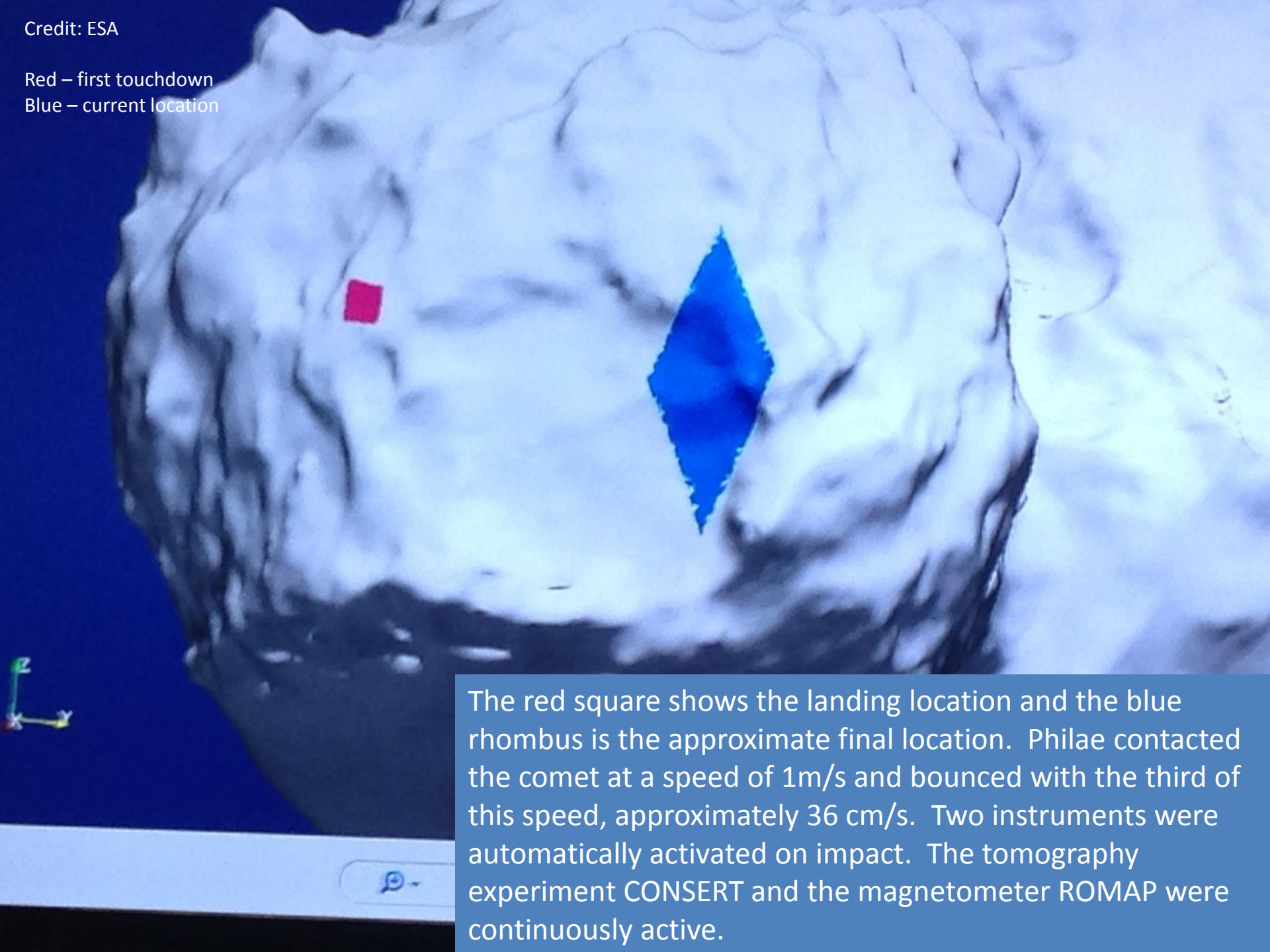
Credit: DLR/Rolis



The last picture before touchdown. Boulder in the upper right corner is approximately 5 m in diameter. The boulder is partially covered with dust which seems to be floating over the surface. Scientists asked: are there clouds of levitated dust? How deep will Philae sink?

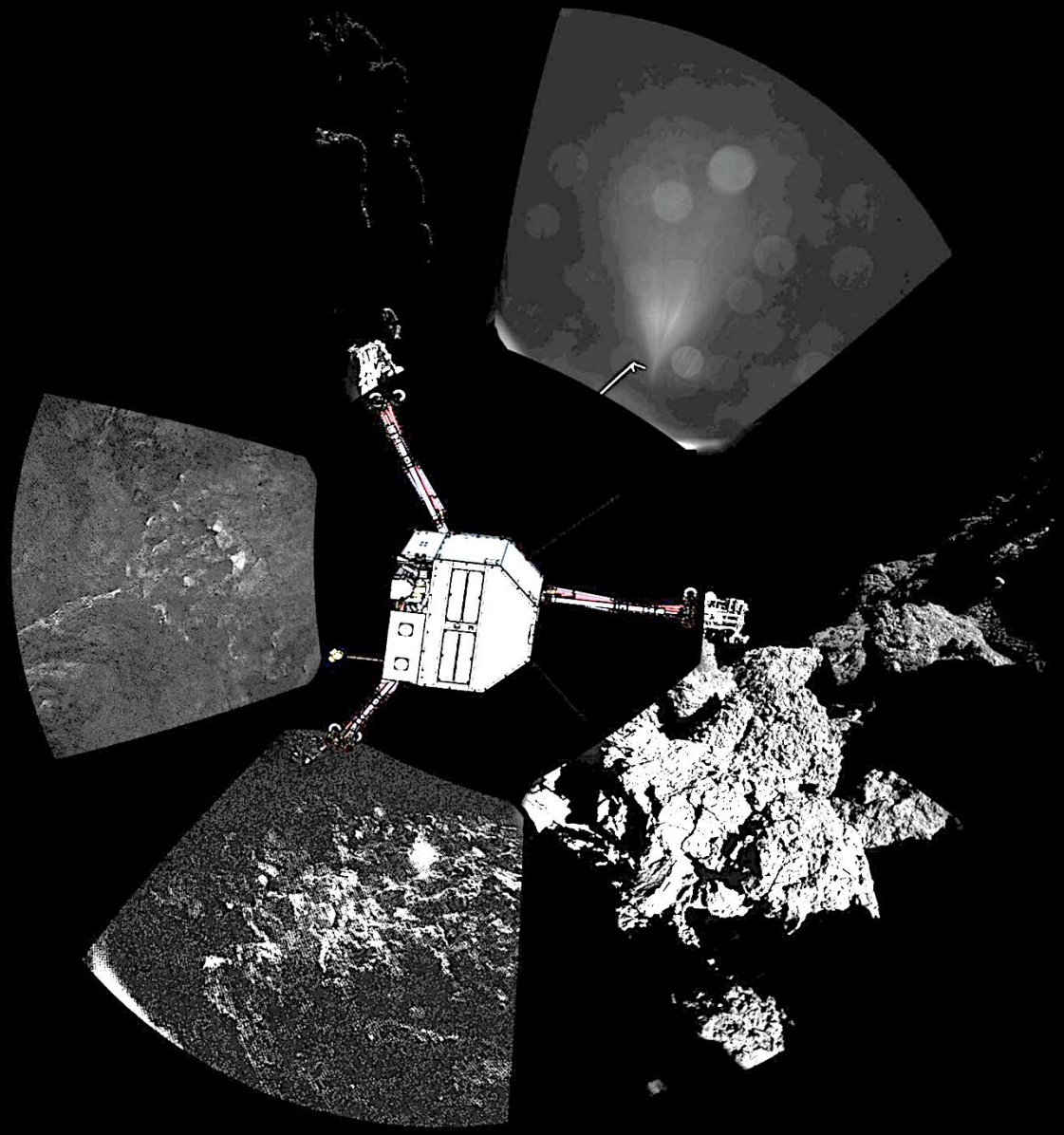


Showing the approach and the first touchdown of Philae. The enlarged boxes are 17x17m & show the close up of the lander. On the way to its first touchdown site at 15:43 the lander cleared huge boulders, scarps and peaks. It landed in the flattest area right before a large boulder. After anchors failed, it bounced and changed its direction of flight. The last image shows Philae clearing a boulder the size of a house.

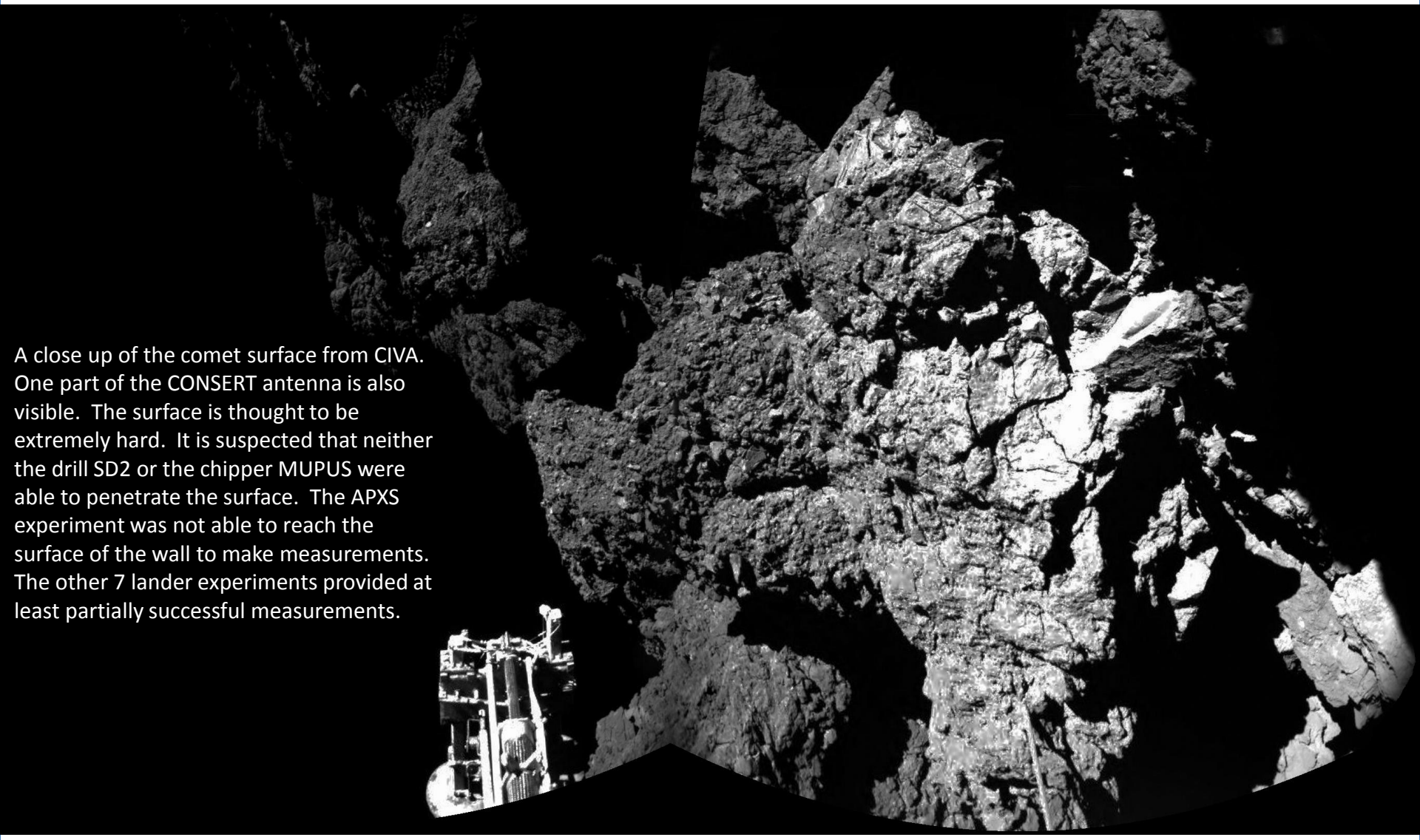


The red square shows the landing location and the blue rhombus is the approximate final location. Philae contacted the comet at a speed of 1m/s and bounced with the third of this speed, approximately 36 cm/s. Two instruments were automatically activated on impact. The tomography experiment CONSERT and the magnetometer ROMAP were continuously active.

Credit: ESA/CIVA/CNES



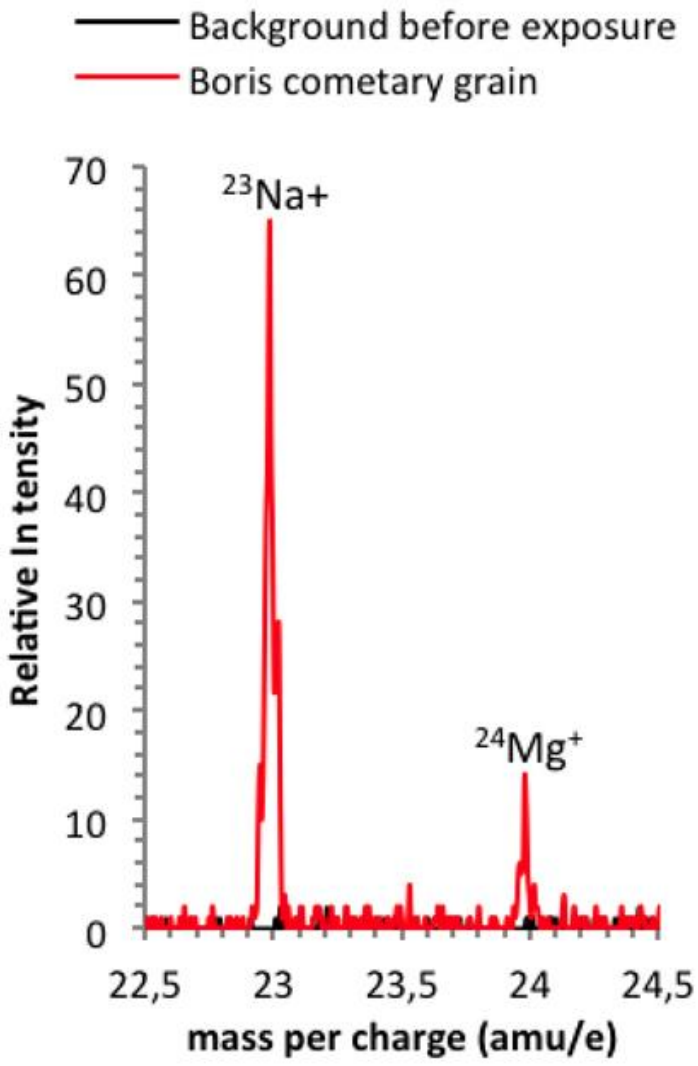
Panoramic view of final resting spot. The black pentagon in the middle shows the body of the Philae lander. Cameras mounted around the body. show reflections from all 3 legs. One of them points at the dark sky & is not resting on ice.

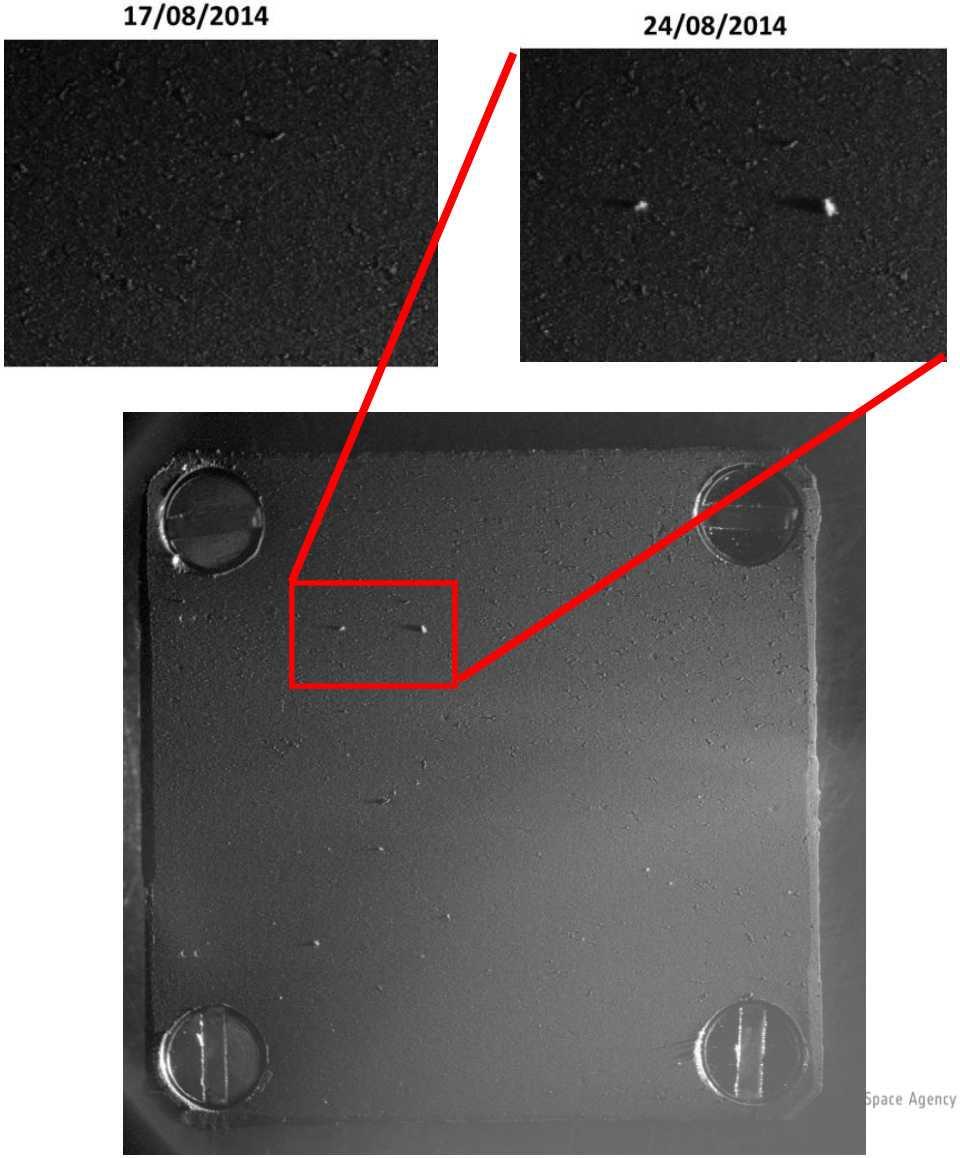


A close up of the comet surface from CIVA. One part of the CONSERT antenna is also visible. The surface is thought to be extremely hard. It is suspected that neither the drill SD2 or the chipper MUPUS were able to penetrate the surface. The APXS experiment was not able to reach the surface of the wall to make measurements. The other 7 lander experiments provided at least partially successful measurements.


An activist uses science to fight animal research p. 366
A battle of principles in the e-cigarettes debate p. 375
Counting molecular garbage chutes in intact neurons p. 439
Science
$10
23 JANUARY 2015
sciencemag.org
AAAS
Catching a comet
Rosetta follows a relic of the early solar system toward the Sun
pp. 358 & 387

Comet coma and activity - dust

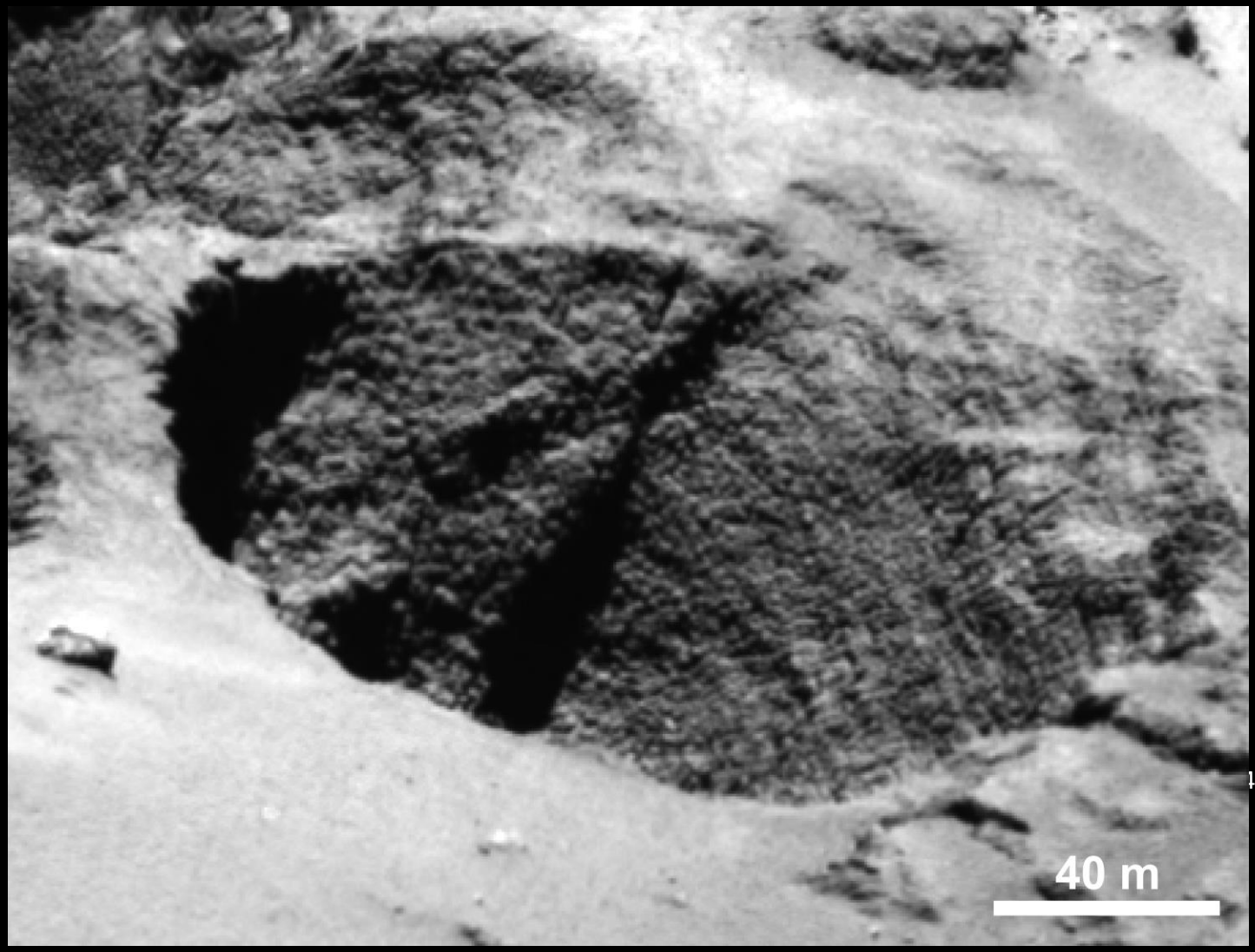




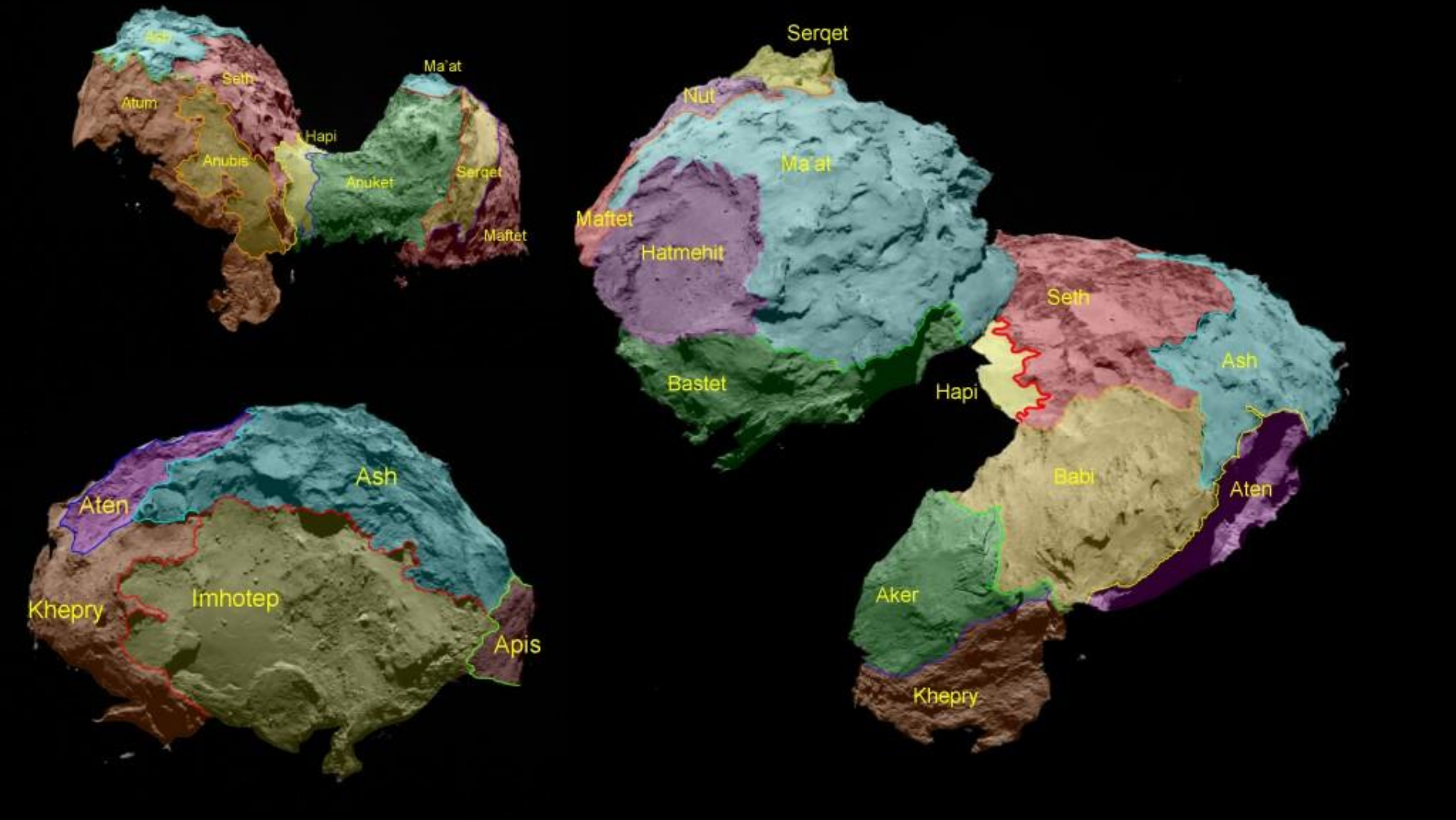
PTOLEMY

- 1 sniff observation 9 minutes after first landing
  - Water
  - Organics
- 6 sniff observations at 3rd landing site
  - Water
  - Less organics
  - Changes over time. Changing ratio

Dragon Eggs



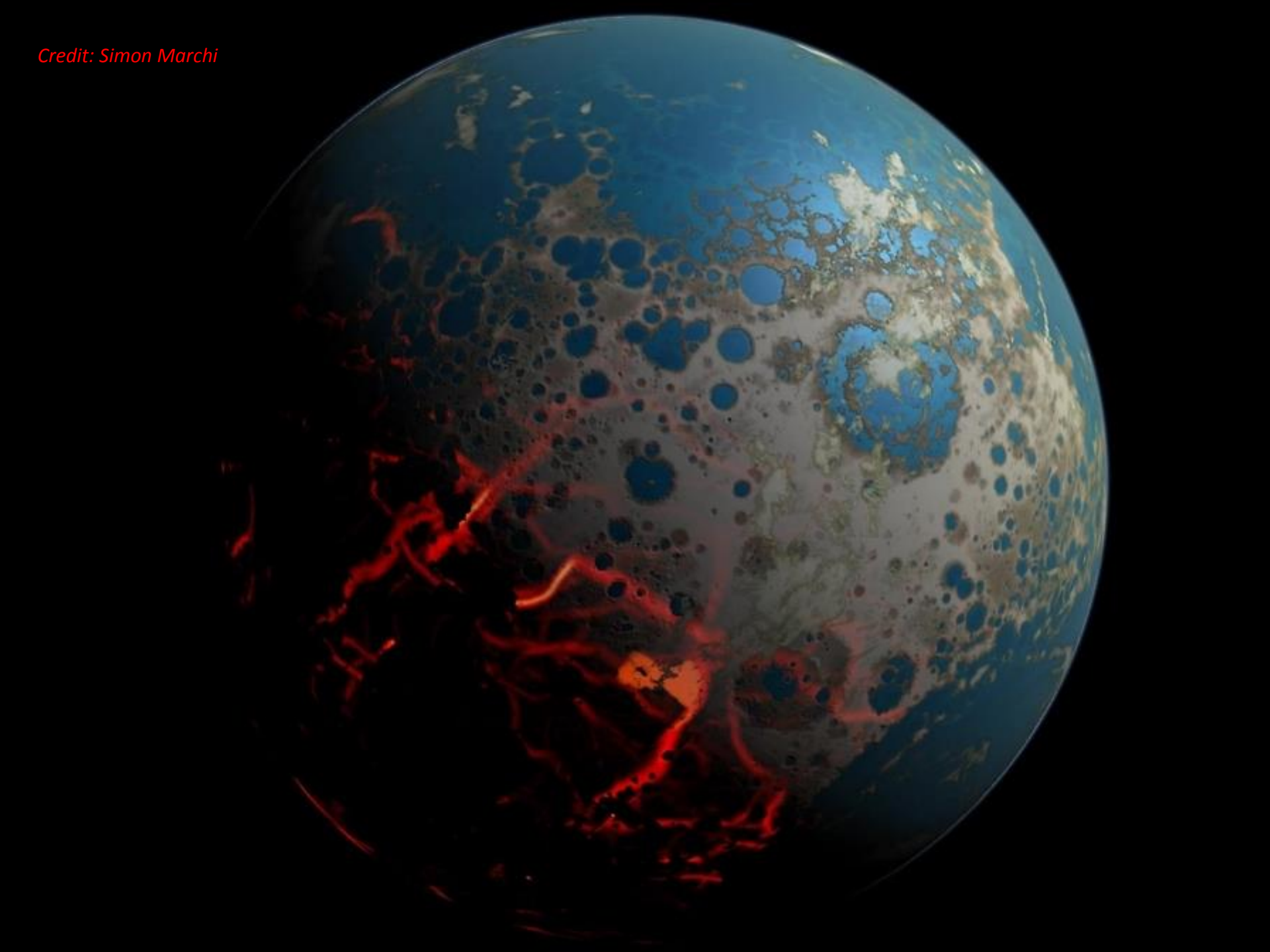
Place Names


Ash
Seth
Ma'at
Atum
Hapi
Anubis
Anuket
Serqet
Maftet
Serqet
Nut
Ma'at
Maftet
Hatmehit
Seth
Ash
Bastet
Hapi
Babi
Aten
Aker
Khepry
Ash
Aten
Imhotep
Khepry
Apis

Ice on the comet?

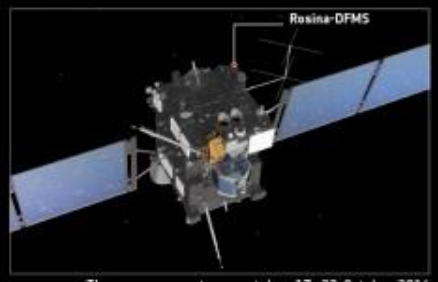
Nice Model [video]

Credit: NASA/JPL Caltech


Credit: Simon Marchi

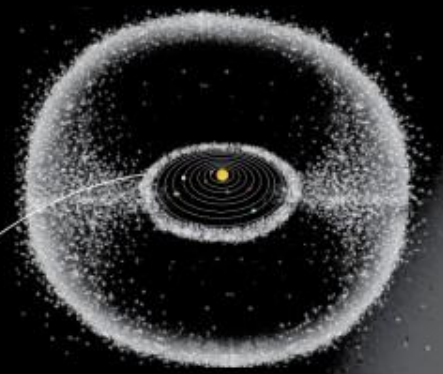
N_2

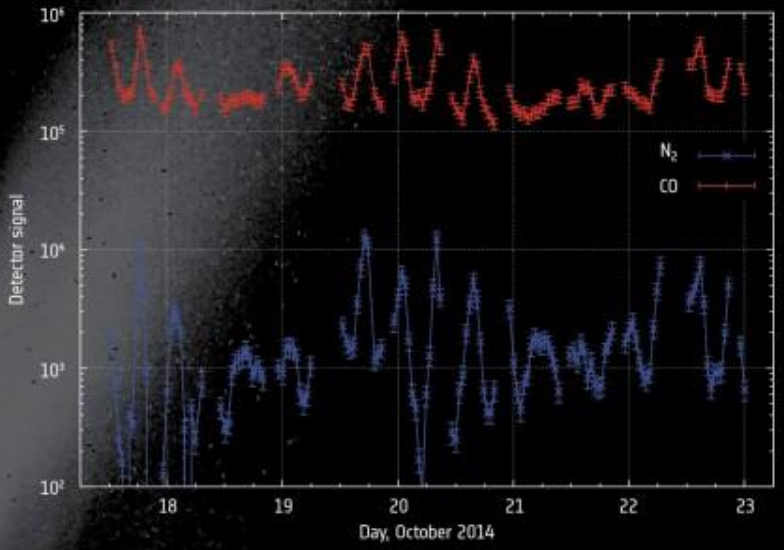
Rosetta has made the first detection of molecular nitrogen at a comet



The measurements were taken 17–23 October 2014

By comparing the ratio of N_2 to CO at the comet with that of the protosolar nebula, it was discovered the comet must have formed at low temperatures, consistent with the Kuiper Belt.





ROSINA recorded variations in the amount of molecular nitrogen (N_2) and carbon monoxide (CO) detected as a function of time, comet rotation and position of the spacecraft above the comet. An average ratio of N_2/CO of $(5.70 \pm 0.66) \times 10^{-3}$ was determined, with minimum and maximum values of 1.7×10^{-3} and 1.6×10^{-2}, respectively.

The detector signal is integrated over 20 seconds. A correction factor accounting for the instrument sensitivity is applied in order to derive the ratio.

78%
of Earth's atmosphere is molecular nitrogen, N_2

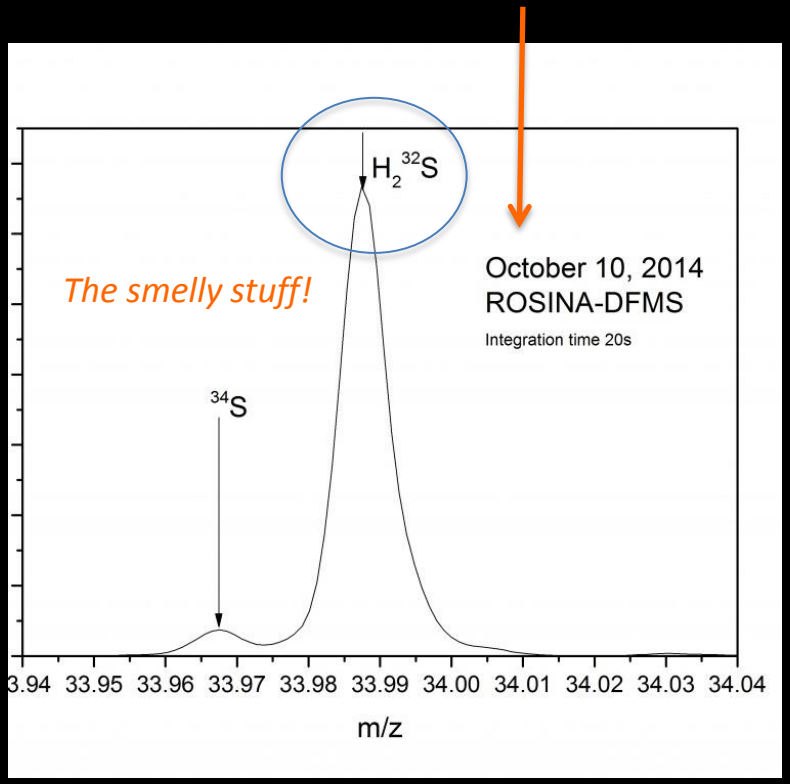
Although comets could have delivered some nitrogen to Earth, the new study suggest that Jupiter-family comets like 67P/C-G are not the major source.

Rosetta Nugget: Rosetta's Rotten Perfume!

National Aeronautics and Space Administration

NASA

The ROSINA instrument was specially designed to sort out many different molecules that have the same mass. Here are multiple species at mass 34!



ESA/ ROSINA/ University of Bern.

Among species detected in the coma:

Sulfur species!

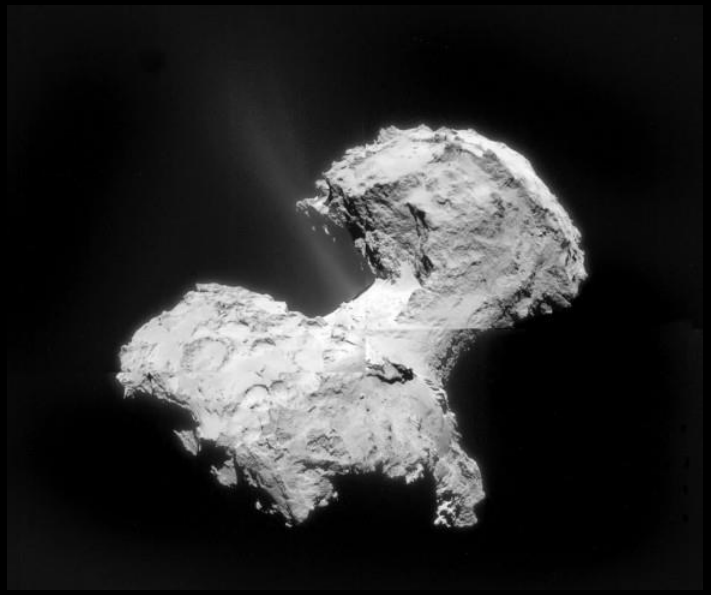
The comet smells of rotten eggs

Ammonia in the coma!

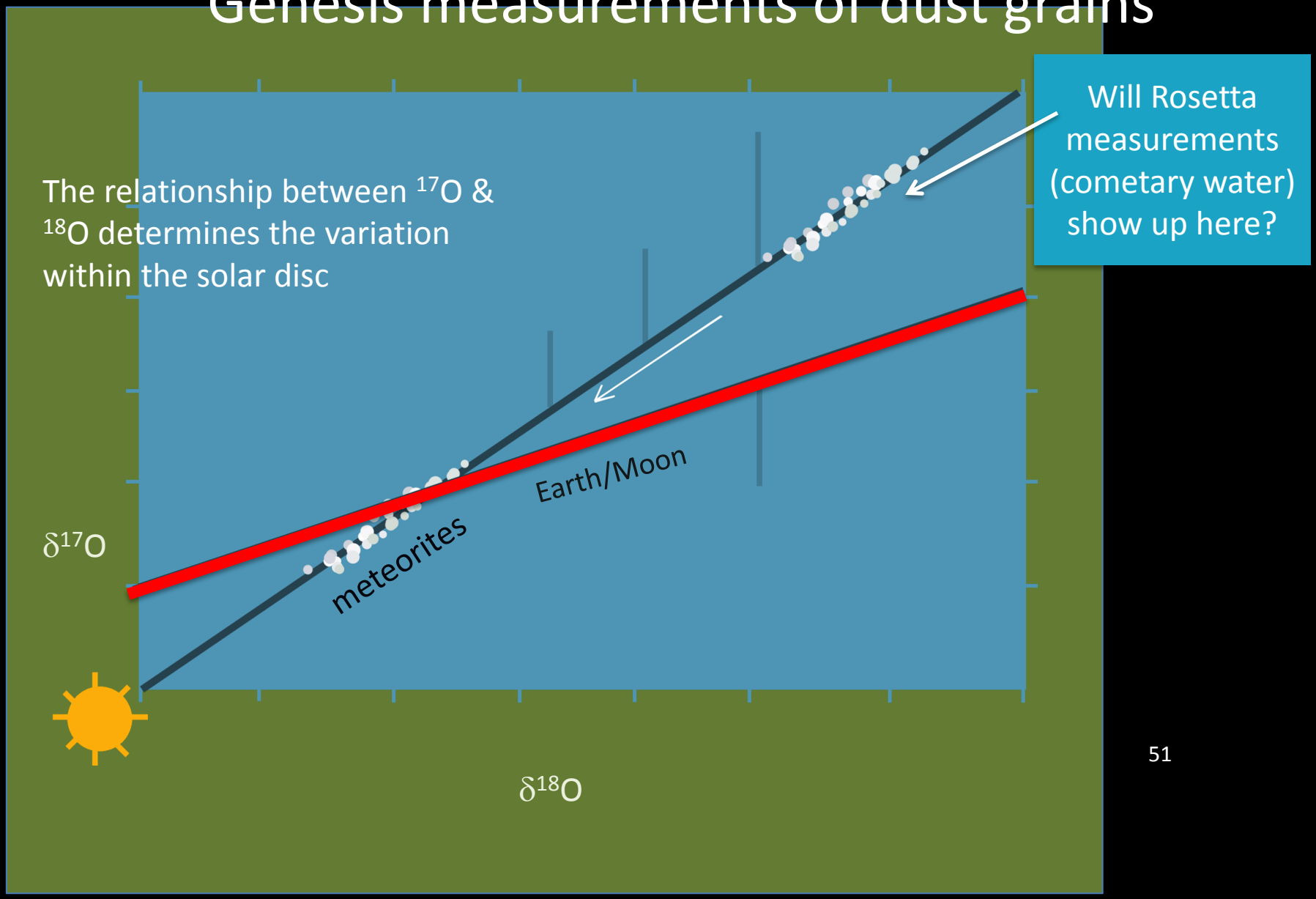
The comet smells like horse droppings

Lots of acids, alcohols, hydrocarbons!

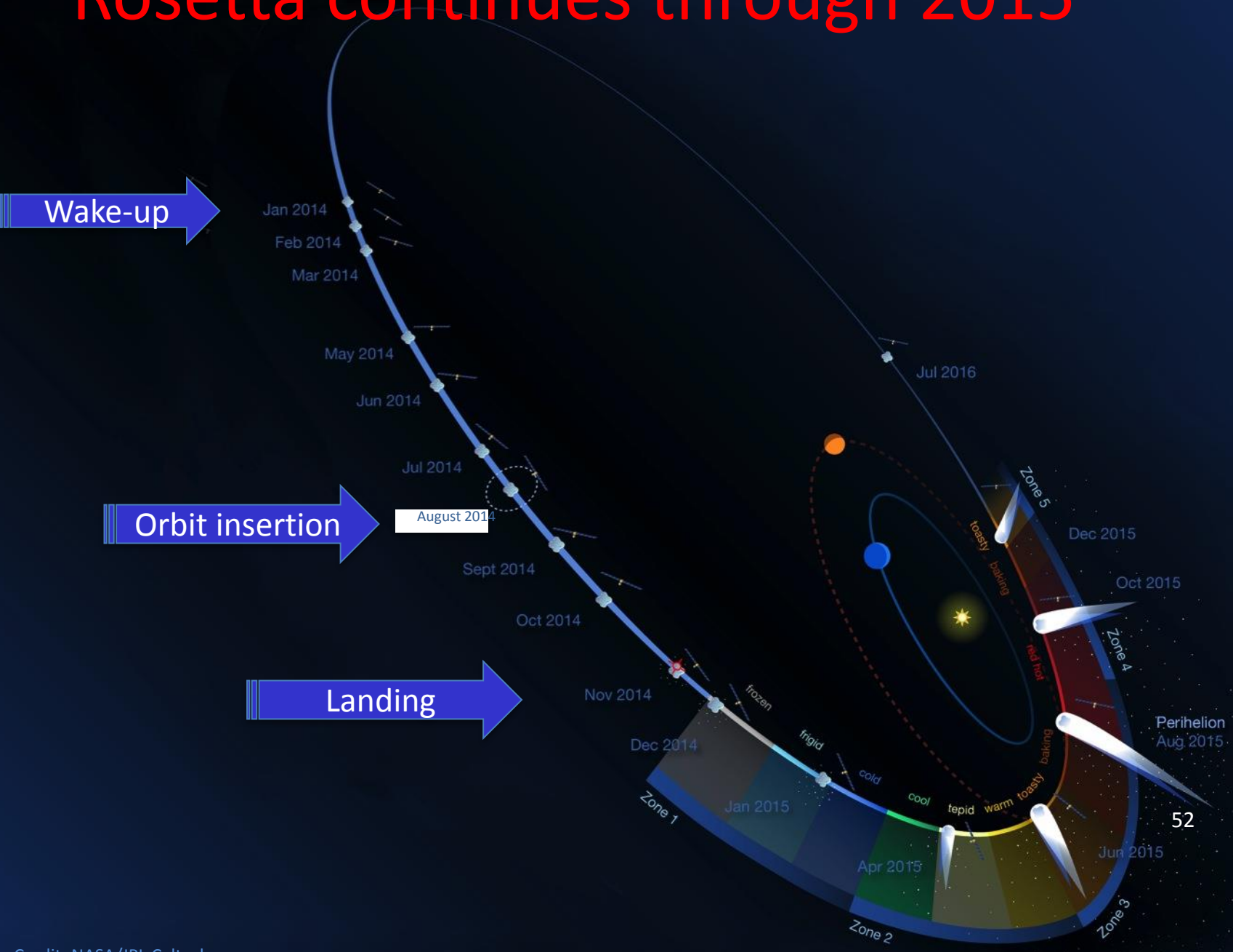
Comet smells like a drunk



Geochemical ‘order’ of the solar system before Genesis measurements of dust grains



Rosetta continues through 2015



Credit: NASA/JPL Caltech

Future of the Lander?

- The lander has run out of the primary battery power after completing its experiment campaign which lasted approximately 2 days.
- Some excellent science data was obtained by CONSERT (tomography), ROMAP (magnetization), ROLIS (spectral camera). Other experiments' success is still evaluated.
- All experiment data was uploaded to the orbiter and downloaded to the ground.
- The body of the lander was rotated to increase solar illumination which may possibly allow recharging of the secondary battery.
- It is hoped that the lander may be able to warm up and at least partially recharge its battery allowing another science sequence.
- The orbiter mission will now continue with the comet escort. Scientists are excited by the opportunity of witnessing the comet change on its way to perihelion.

Rosetta is an ESA mission with contributions from its member states and NASA.
Rosetta's Philae lander is provided by a consortium led by DLR, MPS, CNES and ASI.

Find more:
@ESA_Rosetta
http://blogs.esa.int/rosetta

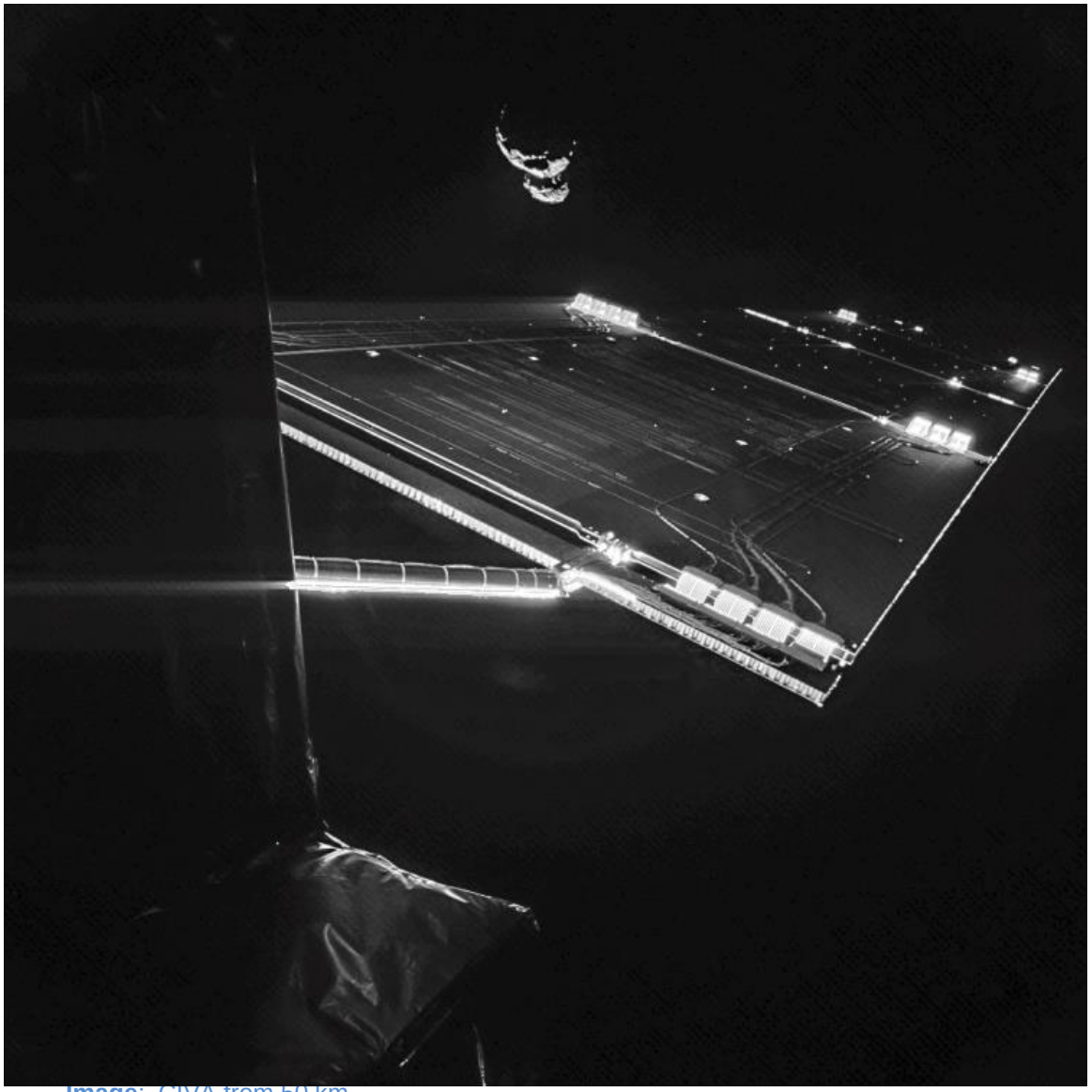


Image: CIVA from 50 km