ESA's Rosetta mission on the comet 67P/Churyumov-Gerasimenko

M. Fulchignoni

l'Observatoire de Paris | LESIA

1986

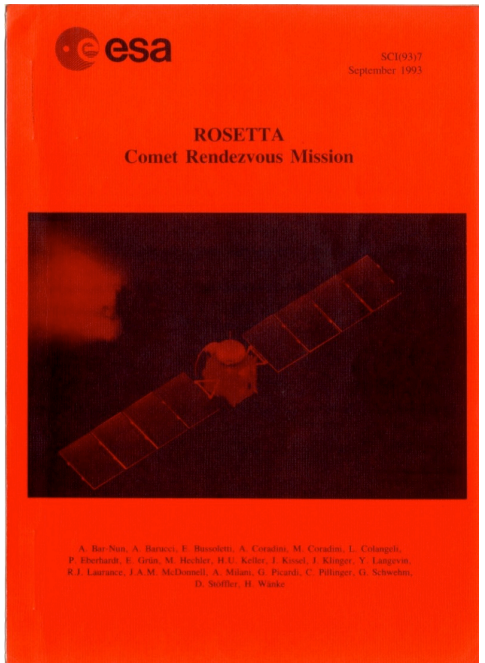
1987

1991

1988

1989

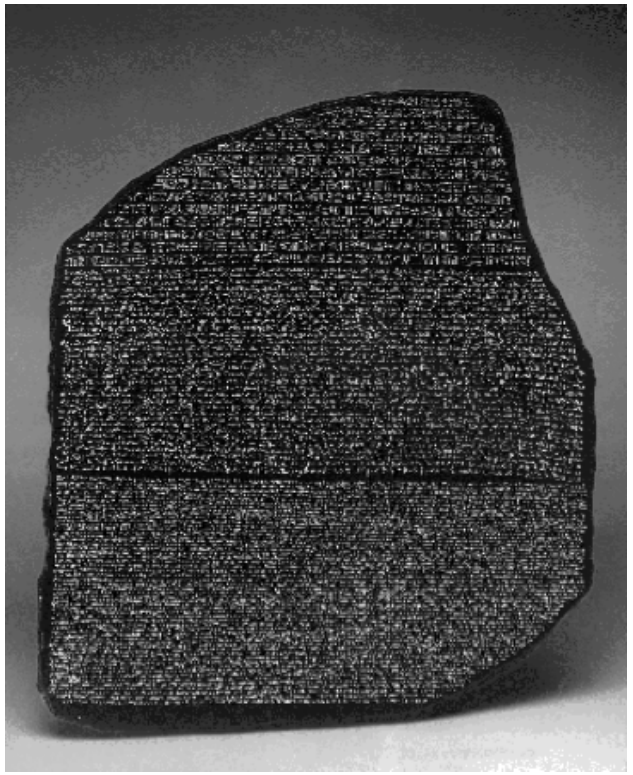
Selected in 1993




Rosetta
A comet rendezvous and two asteroid flybys mission

Flying through and landing on a comet

ESA Rosetta mission



- First rendezvous to a comet

Ambitious mission, ESA cornerstone aimed at the deciphering of our origins

- Scientific objectives

- Characterize the evolution of activity from aphelion to perihelion
- Determine the nucleus properties (structure, chemical & isotopic composition, physical & mineralogical properties), by orbiter payload & landing a modular laboratory on the still mysterious nucleus surface

Solar panels: 32m x1m

Flying through and landing on a comet

ESA Rosetta mission

- Constraints related to very low gravity field of comet nuclei

⇨ Relative velocity ≈ 0 at encounter

- Constraints on the trajectory

⇨ Trajectory parallel to that of the nucleus or around it for ≈ 1 yrs

⇨ Encounter near aphelion (smallest orbital velocity)

⇨ Near ecliptic trajectory with perihelion near 1 AU (less demanding)

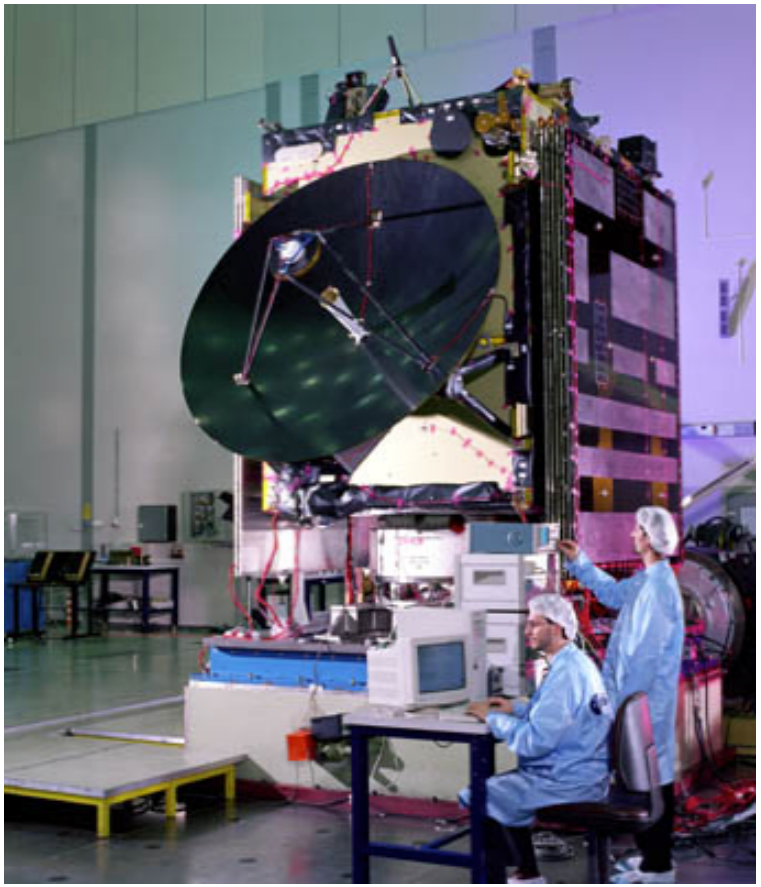
⇨ Aphelion not too far away (Jupiter family comet)

Building Rosetta

Massive and complex spacecraft

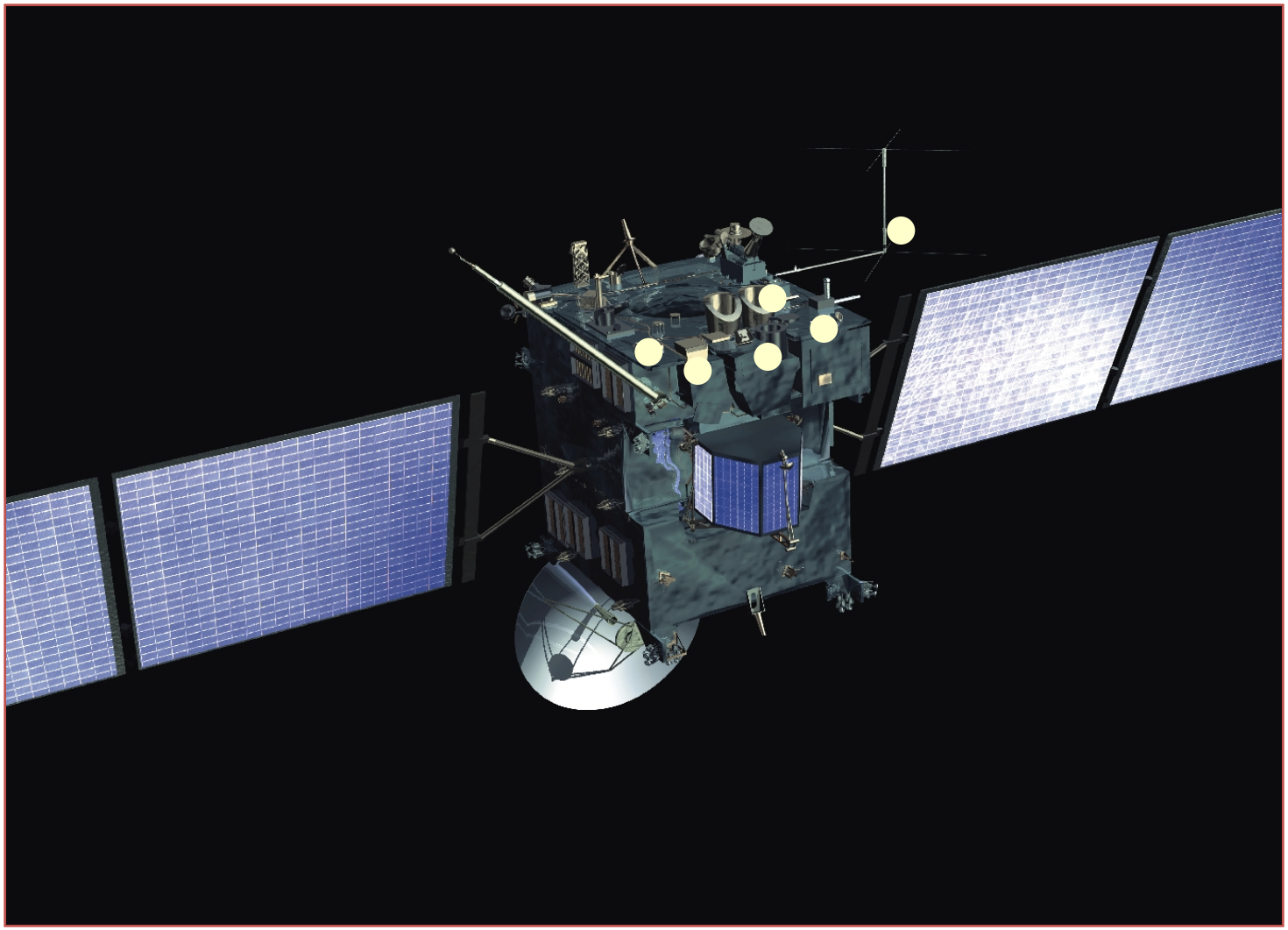
- Long duration mission
  - Long cruise phase (gravity assists and trajectory corrections)
  - Hibernation phase
  - Long rendezvous phase (2 years +)
- About 10 sophisticated experiments on the spacecraft, as well as on the “Philae” lander

⇨ About 3 m x 2 m x 2 m three axis stabilized spacecraft
⇨ 1.3 t (dry mass) + 1.6 t (fuel) (Philae = 110 kg)



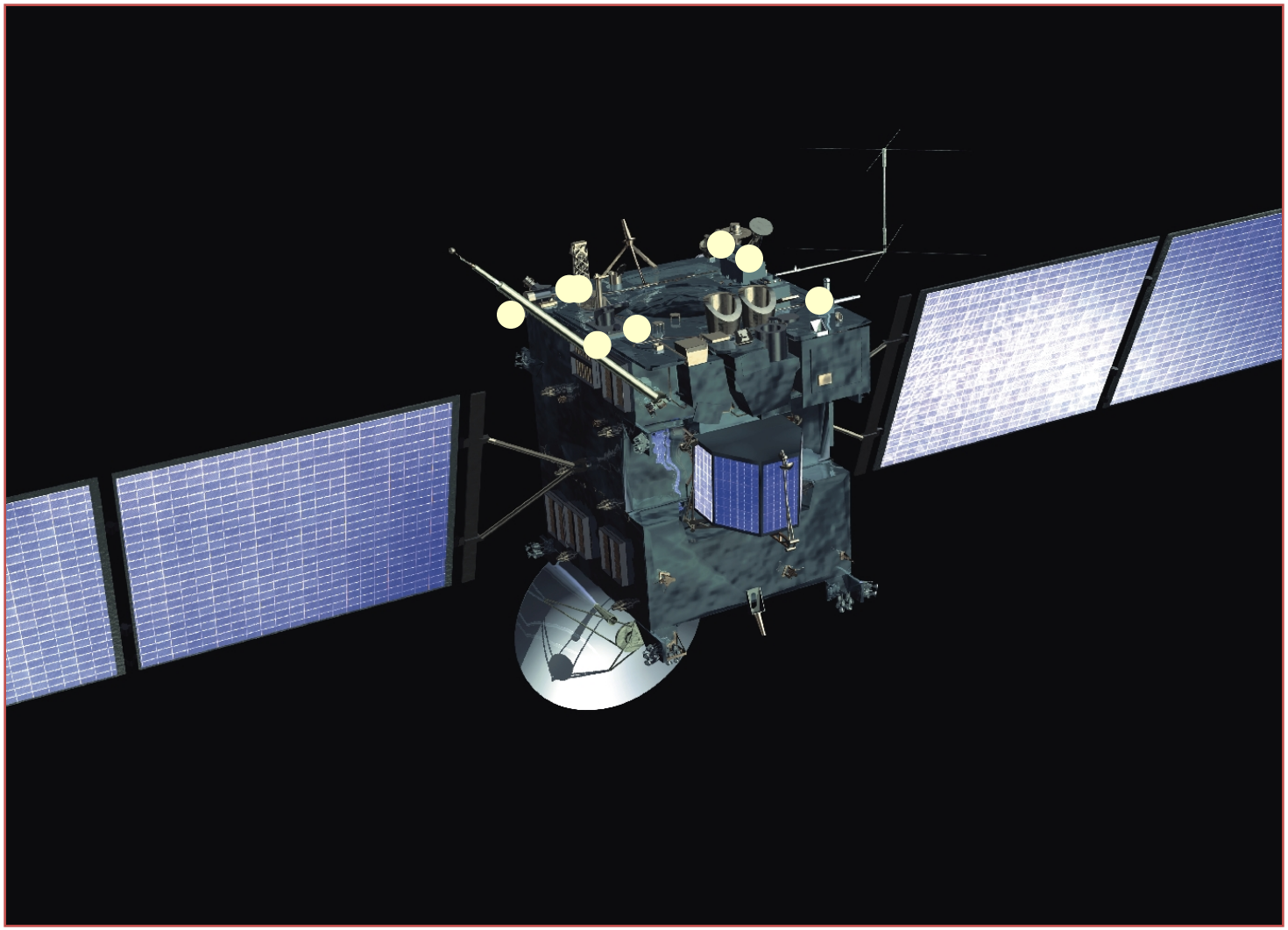
Integration the high gain antenna on a first model

Rosetta Spacecraft and Payload



- OSIRIS: [illegible] (Germany)

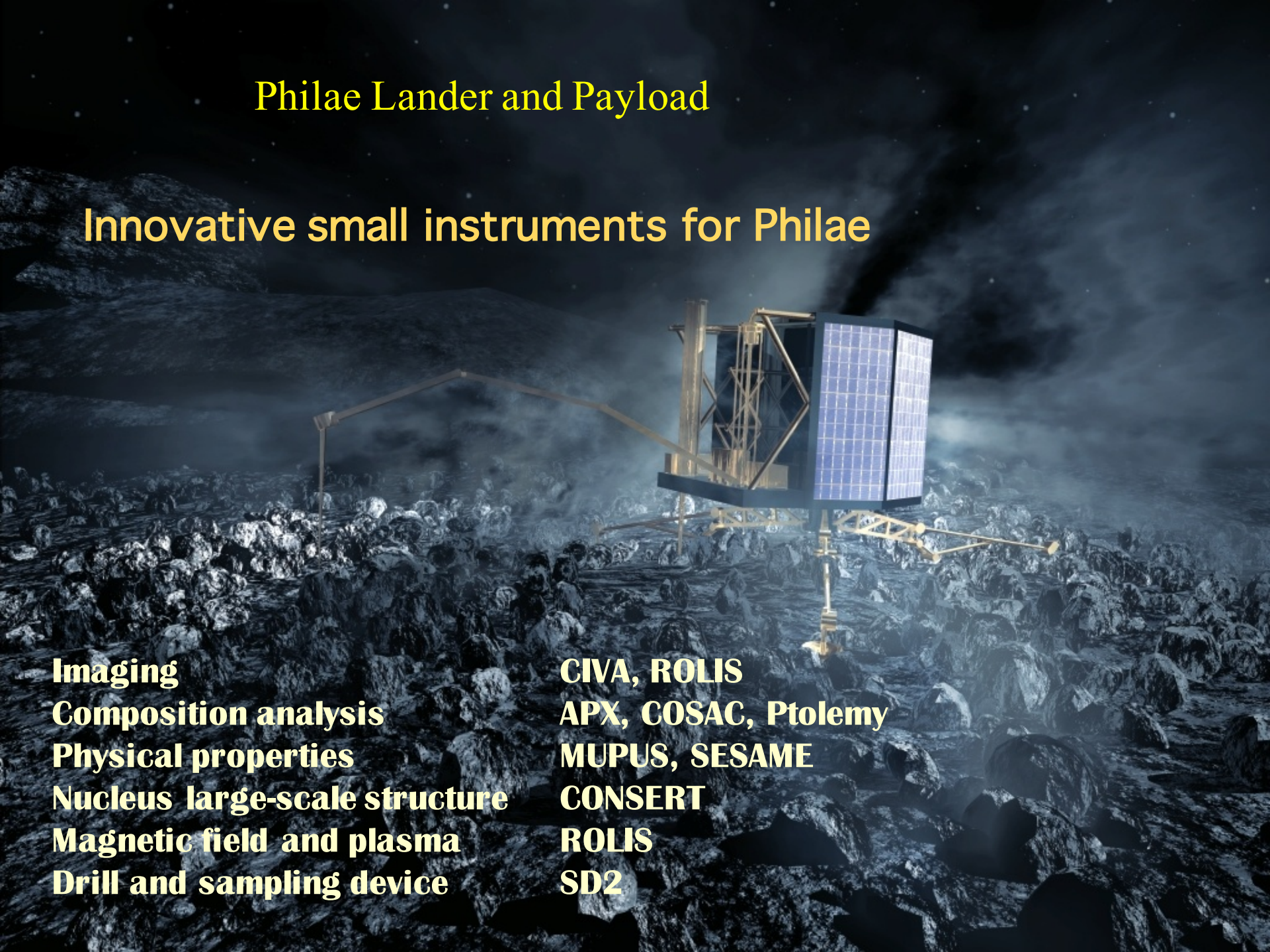
Rosetta Spacecraft and Payload



ROSINA (Univ. Bern, Switzerland)

Philae Lander and Payload

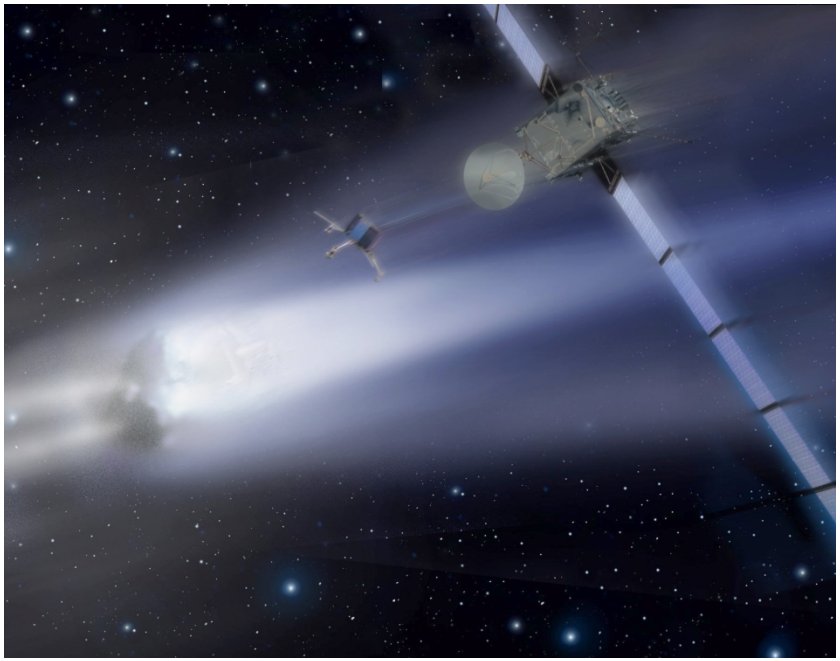
Innovative small instruments for Philae



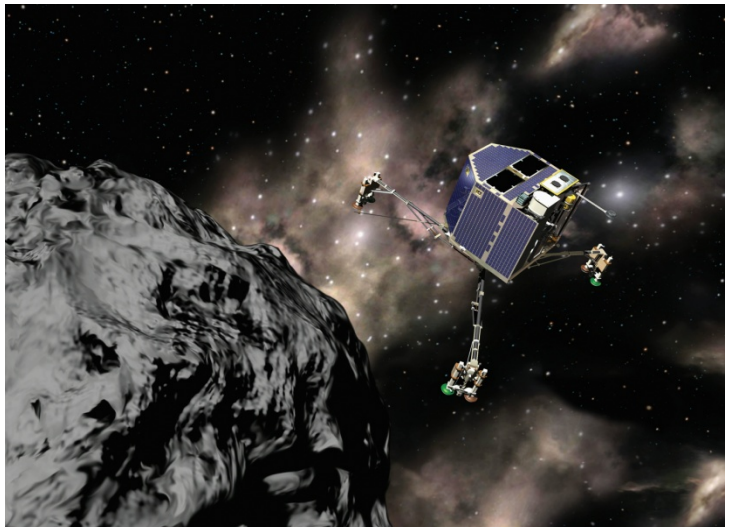
Imaging	**CIVA, ROLIS**
Composition analysis	**APX, COSAC, Ptolemy**
Physical properties	**MUPUS, SESAME**
Nucleus large-scale structure	**CONSERT**
Magnetic field and plasma	**ROLIS**
Drill and sampling device	**SD2**

The Rosetta challenges

- Rendezvous with a low gravity object
- Landing on a mysterious object (unknown porosity, variable activity)
  - Survey from 50 km (surface mapping) down to 1 km
  - Descent of the probe and deployment of the landing gear with tripod, anchors and harpoons



ESA artist views of the mission



Temperature and solar energy constraints

- Sophisticated solar panels

32 m long x 1m large , 25 % efficiency

Journey to Churyumov-Gerasimenko

2003-2004, expecting the launch…

- Spacecraft fully integrated, flown to Kourou in September 2003
- Report of the launch to comet Wirtanen (anticipated to take place in January 2003) after an Ariane 5 failure

Journey to Churyumov-Gerasimenko

The new target

- Churyumov-Gerasimenko

Orbital parameters

a = 3.507 UA i = 7.12° e = 0.632

$a^3/P^2 = 1\ UA^3\ year^{-2}$ ⇨ P = 6.57 years

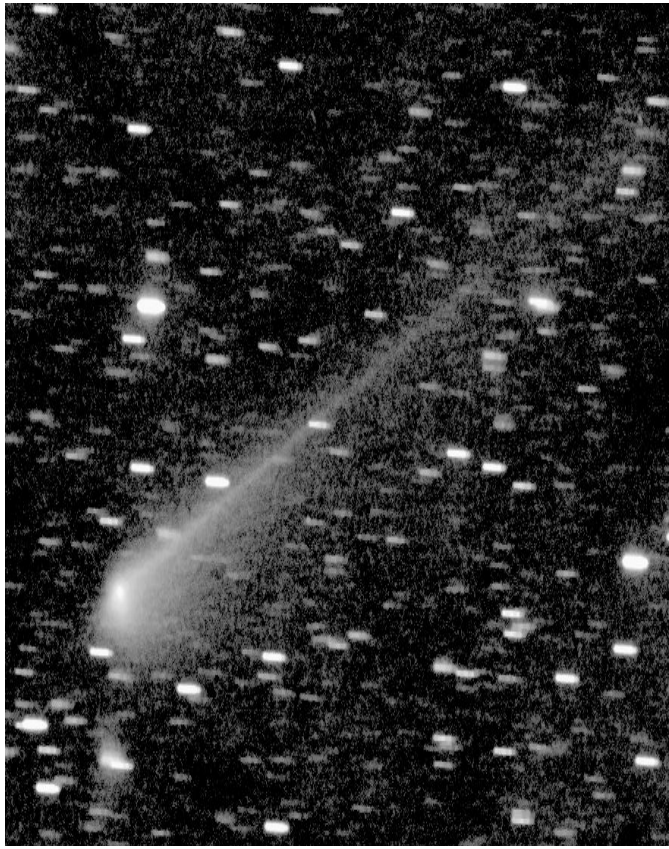
p = a(1-e) ⇨ p = 1.29 UA

p' = a(1+e) ⇨ p' = 5.74 UA

- Physical properties

(estimated from HST observations)

Nucleus about 3 km x 5 km



Journey to Churyumov-Gerasimenko

Launch by Ariane 5G+

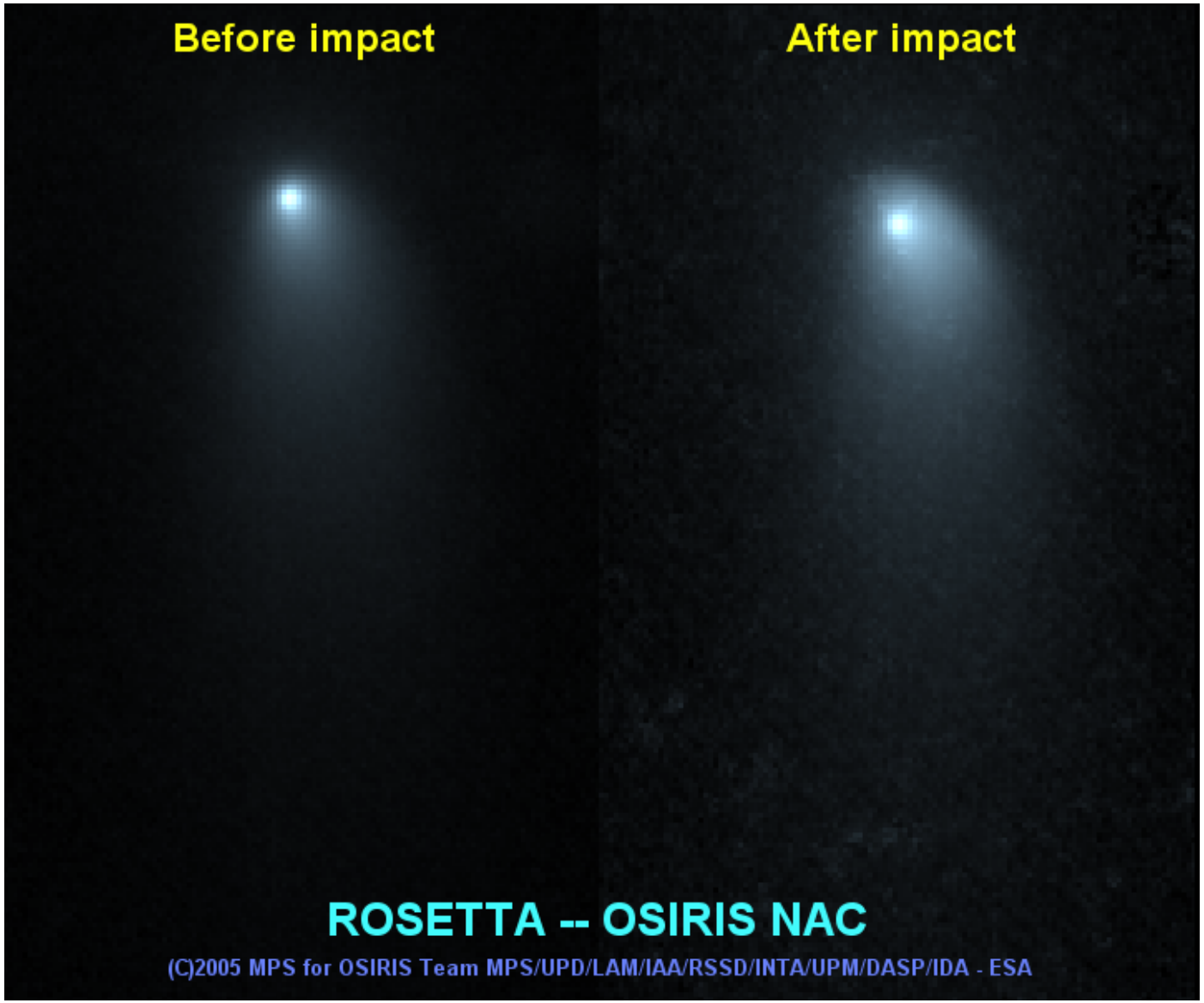
- One day report (meteorological and three more days report (insulation improvement)
- Successful launch, 2 March 2004
- After about 2 hours and 3 crossings of the radiation belts, successful upper stage ignition for interplanetary injection

Journey to Churyumov-Gerasimenko

- All commissioning satisfactory
- Images from Osiris Camera of comet C/2002 T7 LINEAR

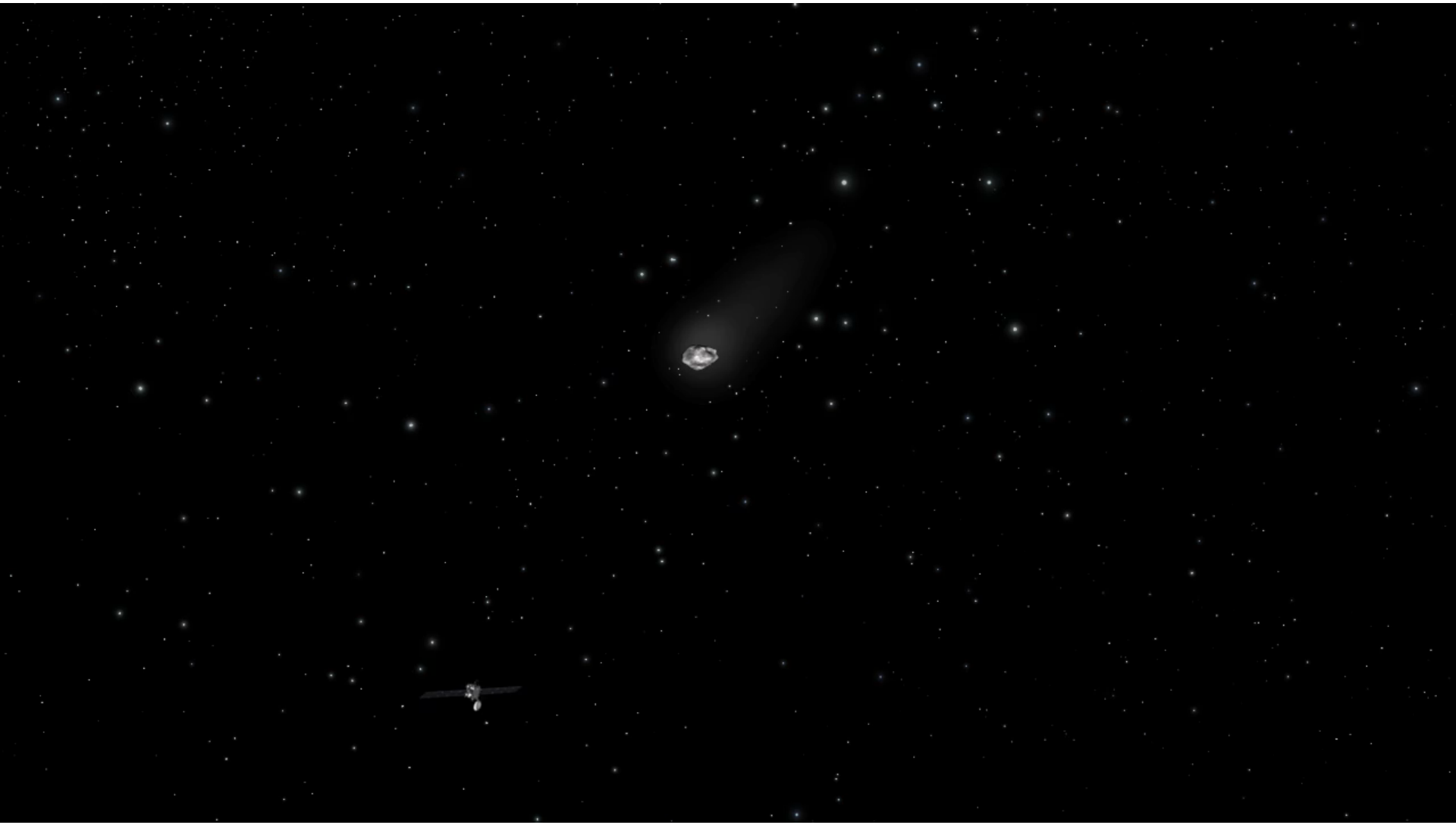
Rosetta was also seen from the Earth

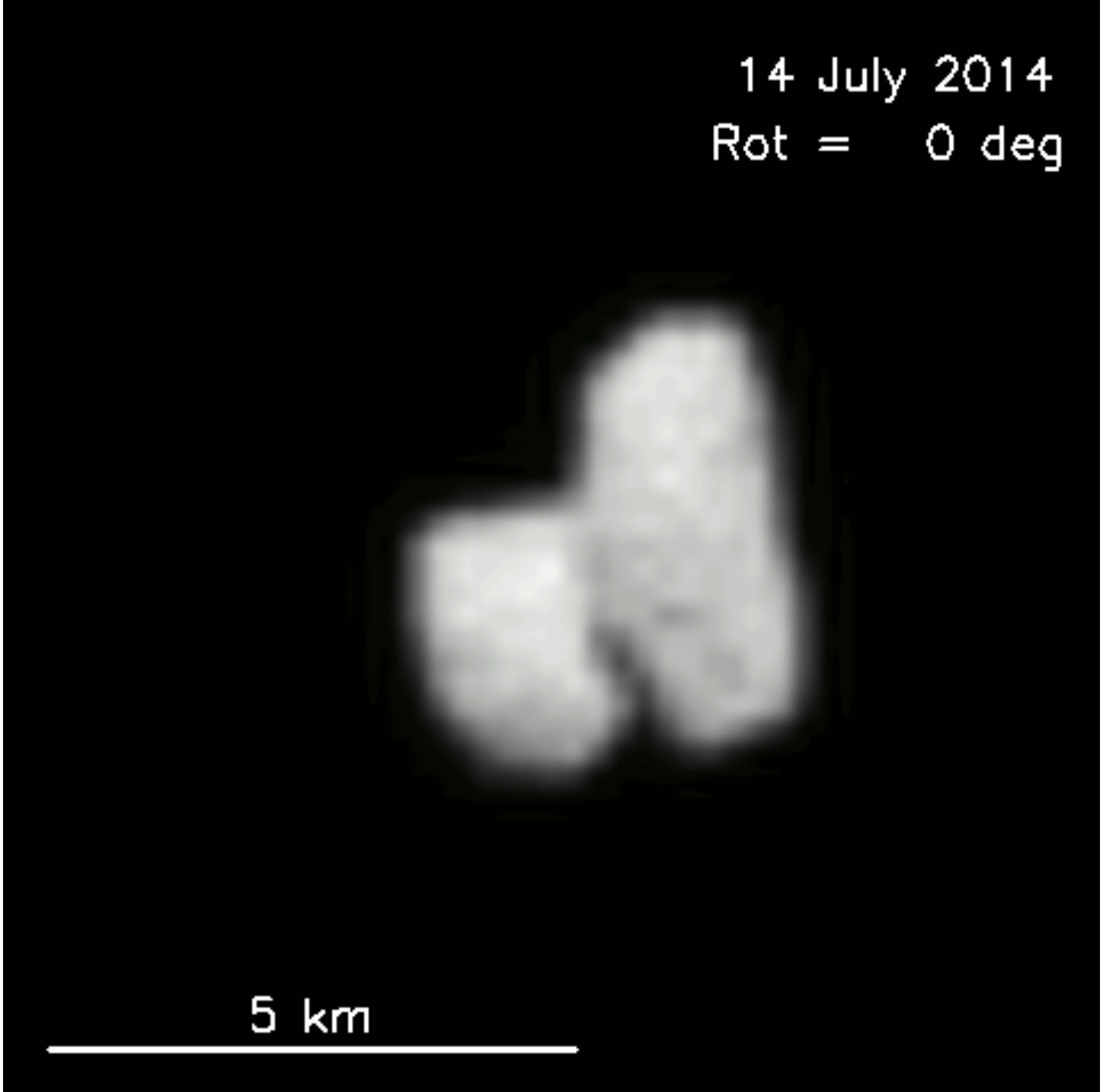
Deep impact observations in July 2005



Rosetta on its way to 67P/Churyumov-Gerasimenko is visiting Steins and Lutetia asteroids


January 2014
Exit deep space hibernation
May 2014
Major rendezvous manoeuvre
August 2014
Arrive at comet
November 2014
Lander delivery
August 2015
Closest approach to Sun




14 July 2014
Rot = 0 deg
5 km

→ COMET 67P/CHURYUMOV–GERASIMENKO'S VITAL STATISTICS

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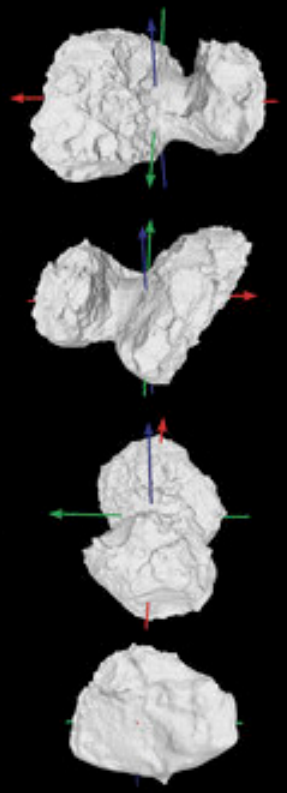
21.4 km³
Volume

1.0 × 10¹³ kg
Mass

470 kg/m³
Density

70–80%
Porosity



Rotation period
12.4043 hours

Spin axis:
69.3°
Right Ascension

64.1°
Declination

52°
Obliquity of the comet's rotational axis

X,Y Equatorial axes
Z Spin axis

4
Dust/gas ratio

5.3 × 10⁻⁴
D/H ratio

Average water vapour production
300 ml/s → June 2014
600 ml/s → July 2014
1200 ml/s → August 2014

−93°C to −43°C
Surface temperature

−243°C to −113°C
Subsurface temperature

6%
Average albedo

Rotation/shape model: OSIRIS; surface temperature: VIRTIS; subsurface temperature: MIRO; water production rate: MIRO; D/H: ROSINA; dust/gas: GIADA, MIRO, ROSINA; volume: OSIRIS; mass: RSI; density: RSI/OSIRIS; albedo: OSIRIS, VIRTIS; comet images: NavCam

Data based on values published in January 2015

www.esa.int

European Space Agency

→ PHILAE'S LANDING SITE

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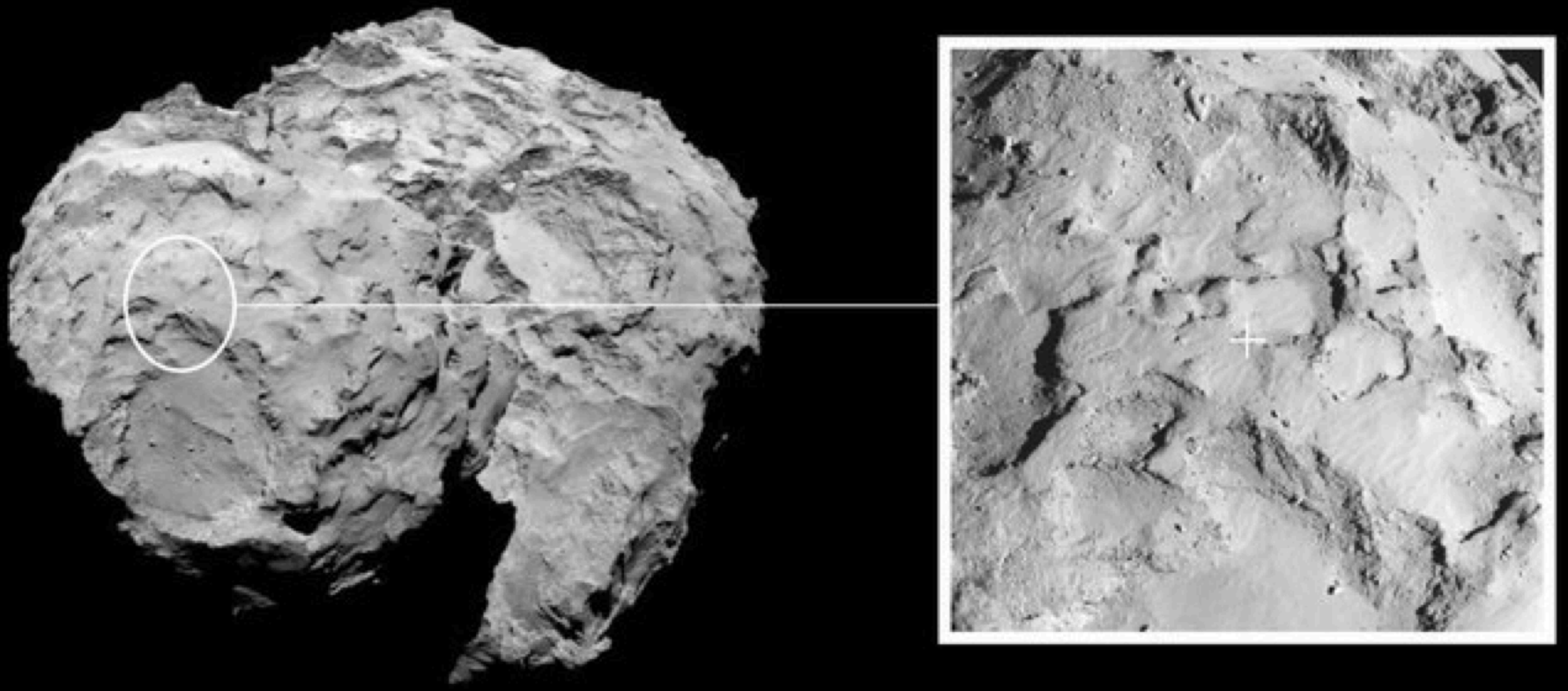
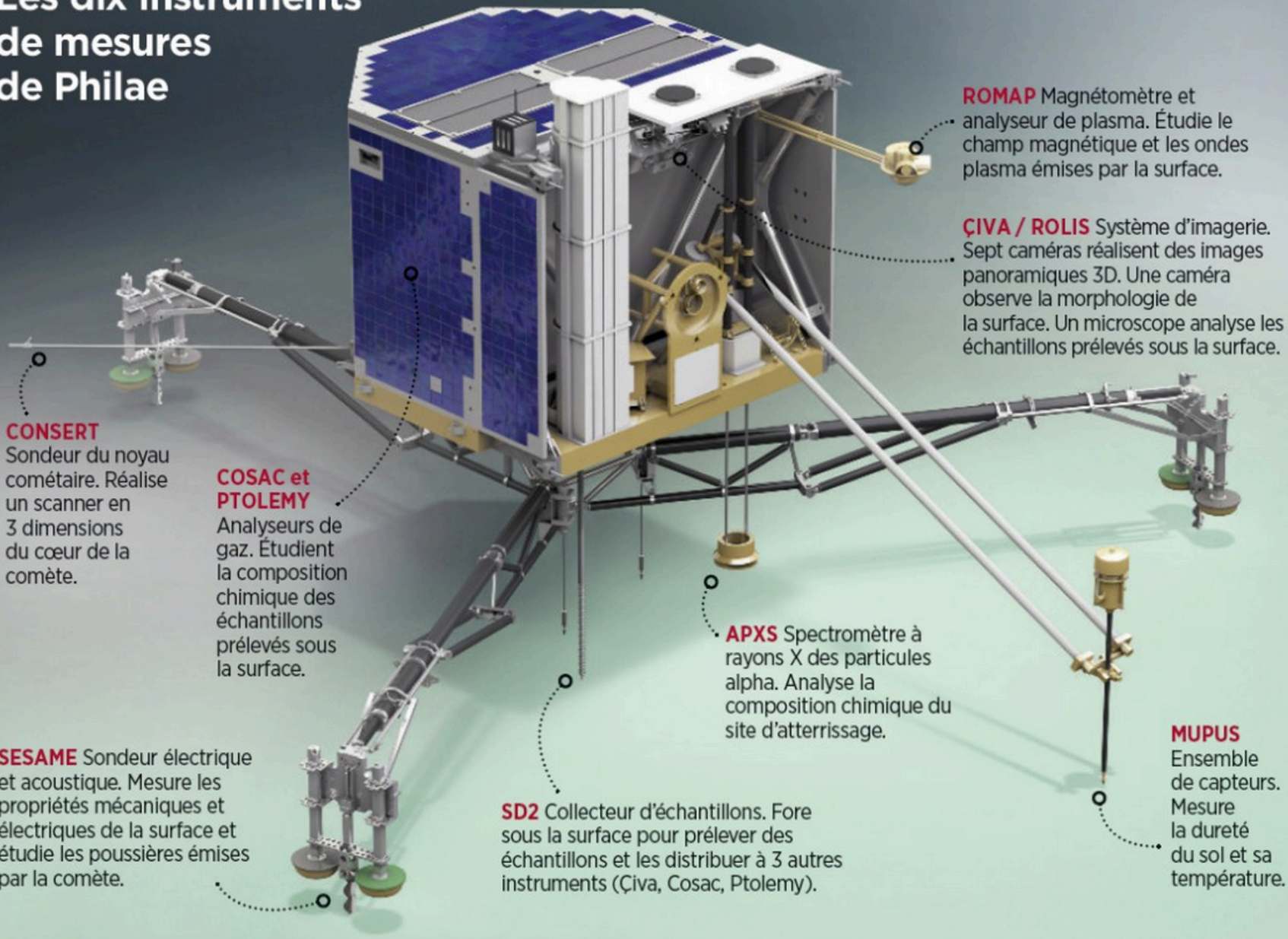


Agilkia region

Les dix instruments de mesures de Philae



ROMAP Magnétomètre et analyseur de plasma. Étudie le champ magnétique et les ondes plasma émises par la surface.

ÇIVA / ROLIS Système d'imagerie. Sept caméras réalisent des images panoramiques 3D. Une caméra observe la morphologie de la surface. Un microscope analyse les échantillons prélevés sous la surface.

CONSERT Sondeur du noyau cométaire. Réalise un scanner en 3 dimensions du cœur de la comète.

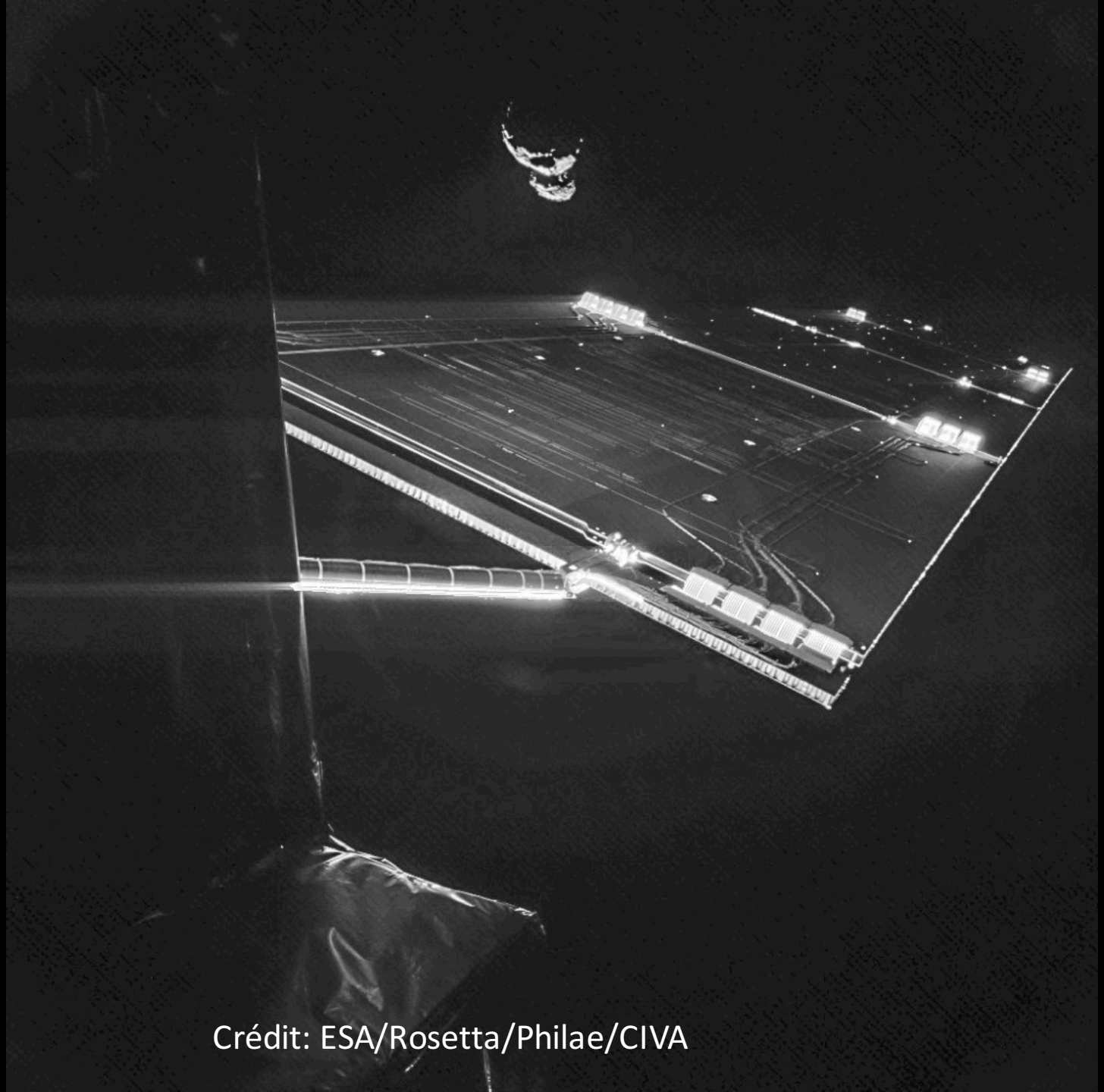
COSAC et PTOLEMY Analyseurs de gaz. Étudient la composition chimique des échantillons prélevés sous la surface.

APXS Spectromètre à rayons X des particules alpha. Analyse la composition chimique du site d'atterrissage.

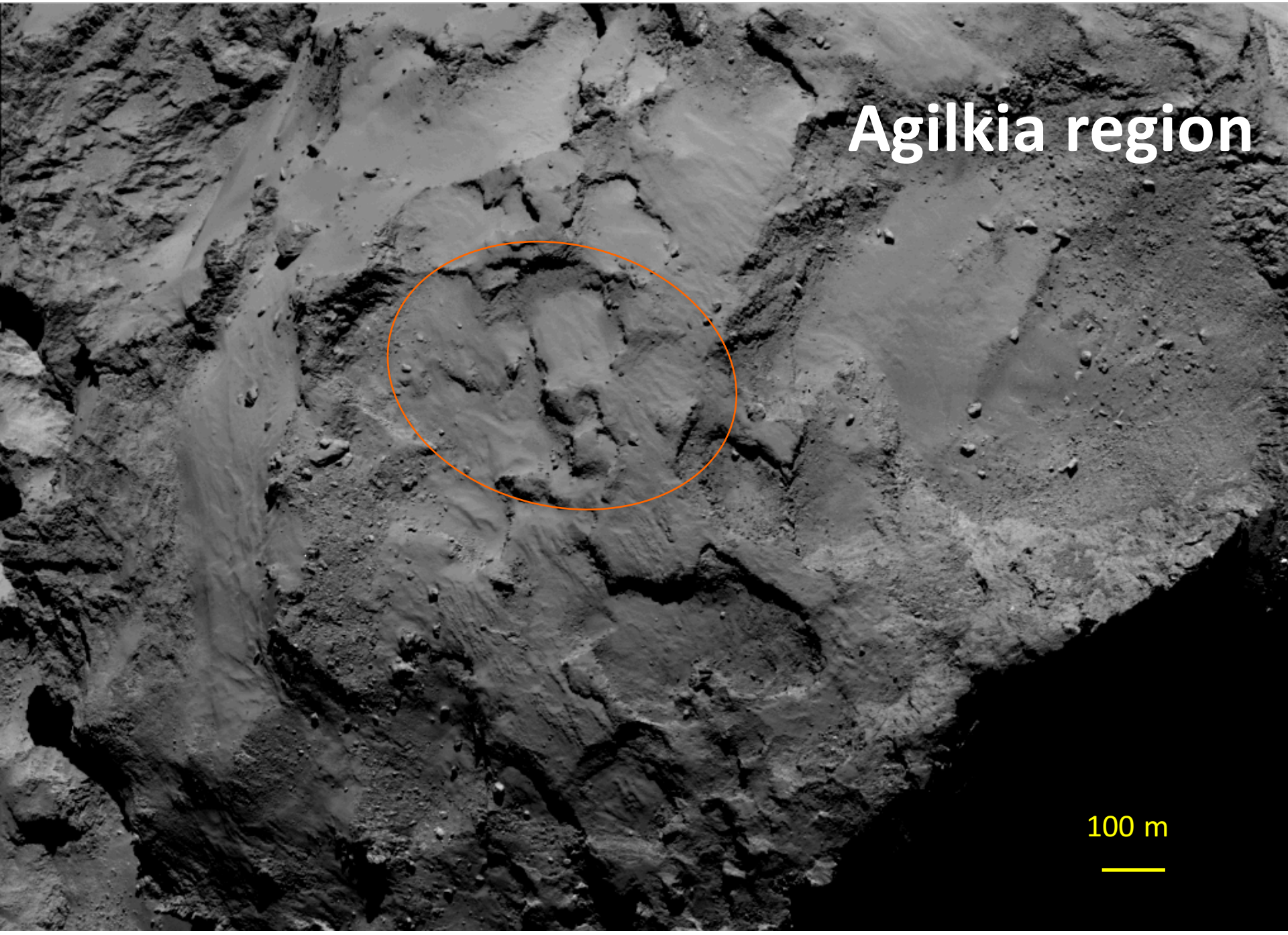
SESAME Sondeur électrique et acoustique. Mesure les propriétés mécaniques et électriques de la surface et étudie les poussières émises par la comète.

SD2 Collecteur d'échantillons. Fore sous la surface pour prélever des échantillons et les distribuer à 3 autres instruments (Çiva, Cosac, Ptolemy).

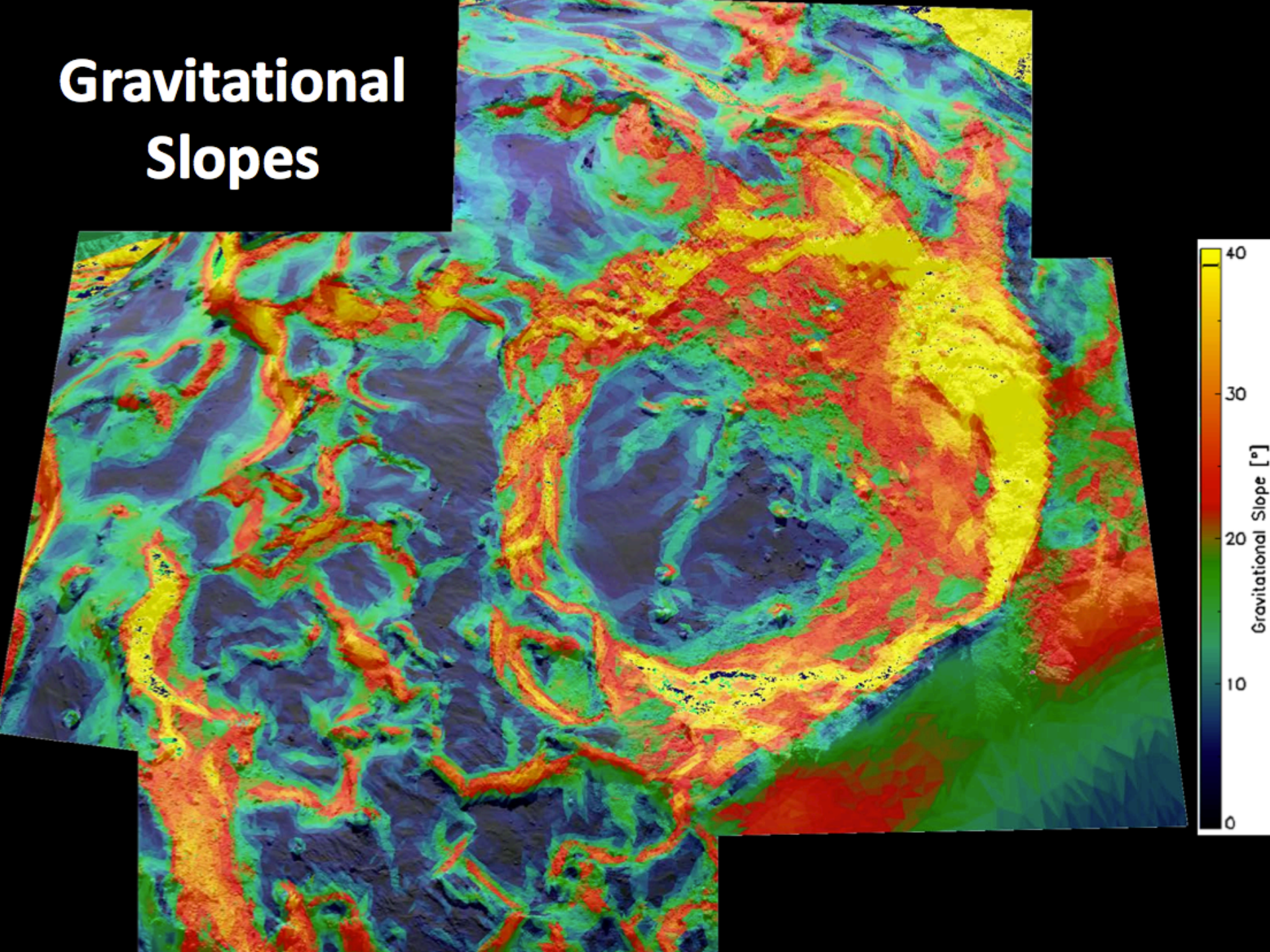
MUPUS Ensemble de capteurs. Mesure la dureté du sol et sa température.

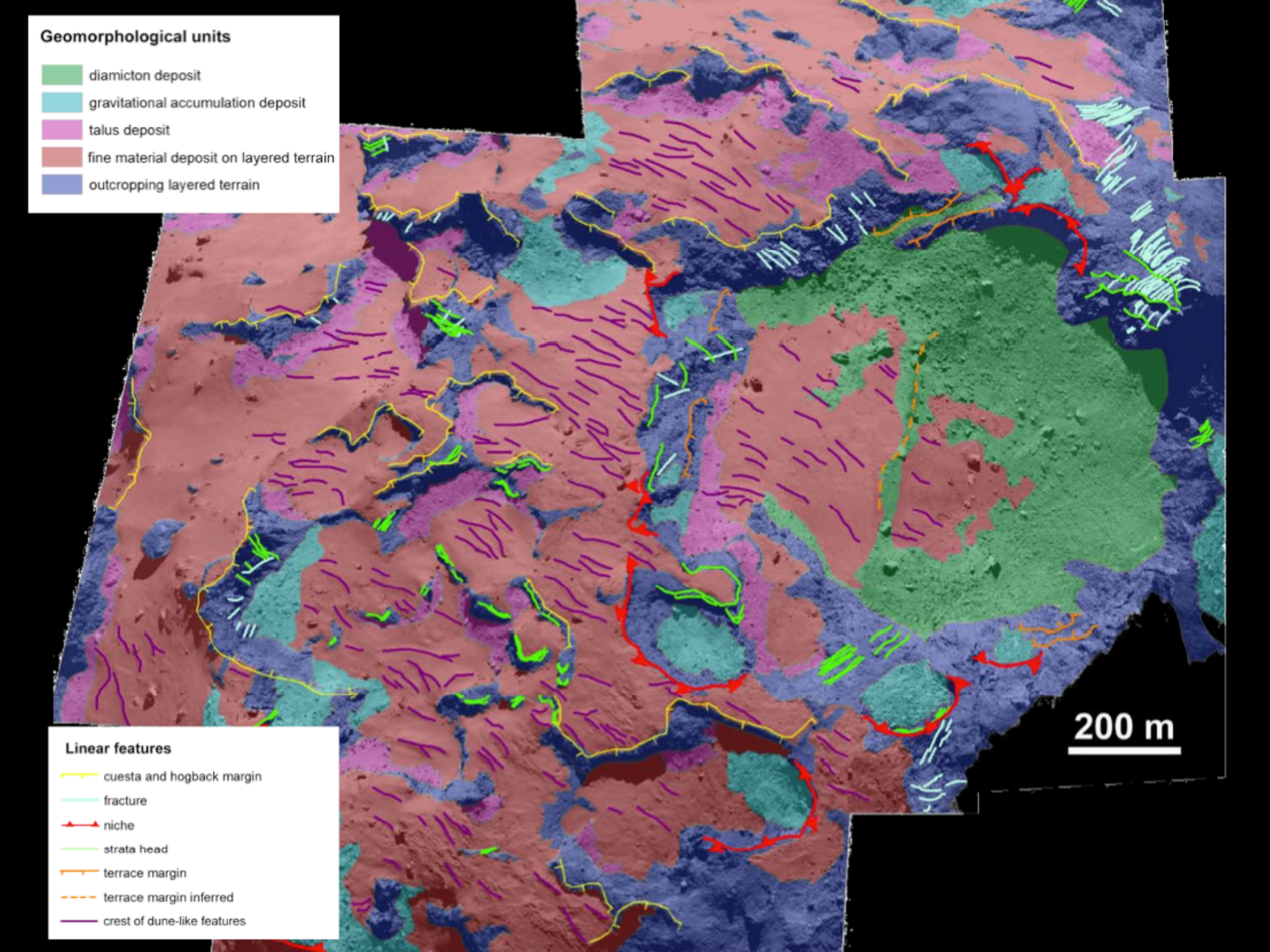


Crédit: ESA/Rosetta/Philae/CIVA


Agilkia region
100 m

Gravitational Slopes



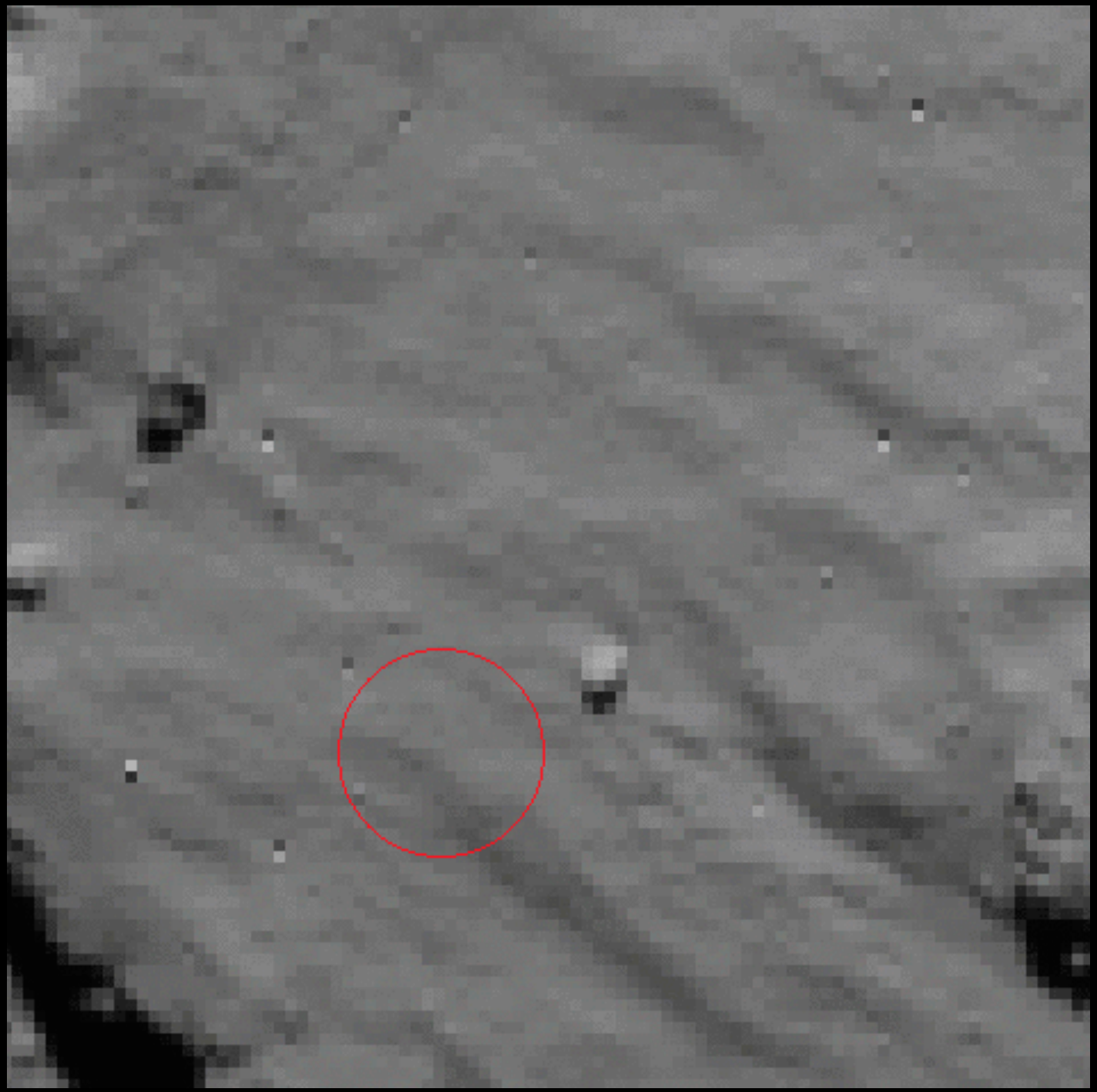

Geomorphological units
diamicton deposit
gravitational accumulation deposit
talus deposit
fine material deposit on layered terrain
outcropping layered terrain
Linear features
cuesta and hogback margin
fracture
niche
strata head
terrace margin
terrace margin inferred
crest of dune-like features
200 m

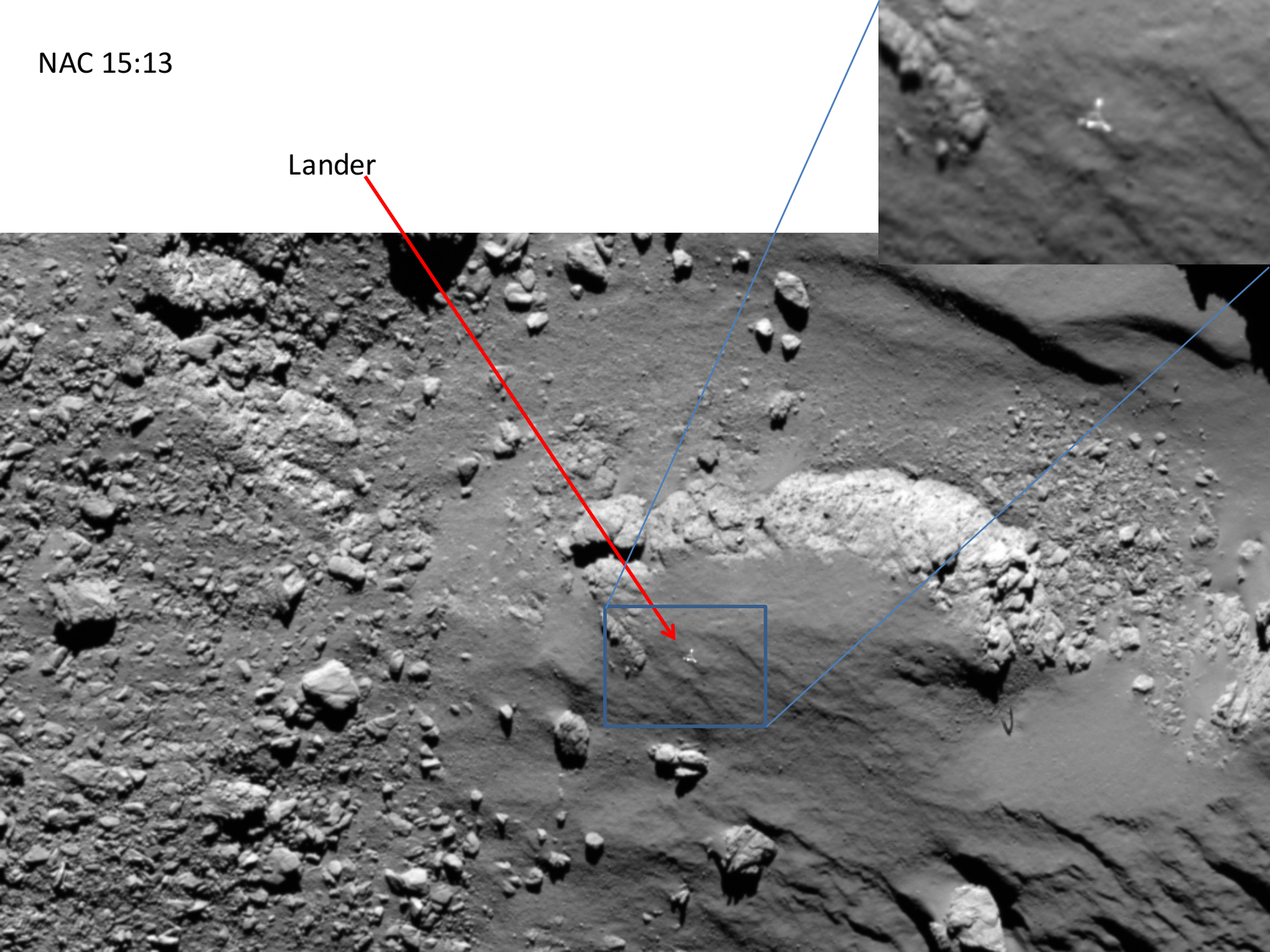
NAVCAM
15:30-15:34

1. 250m

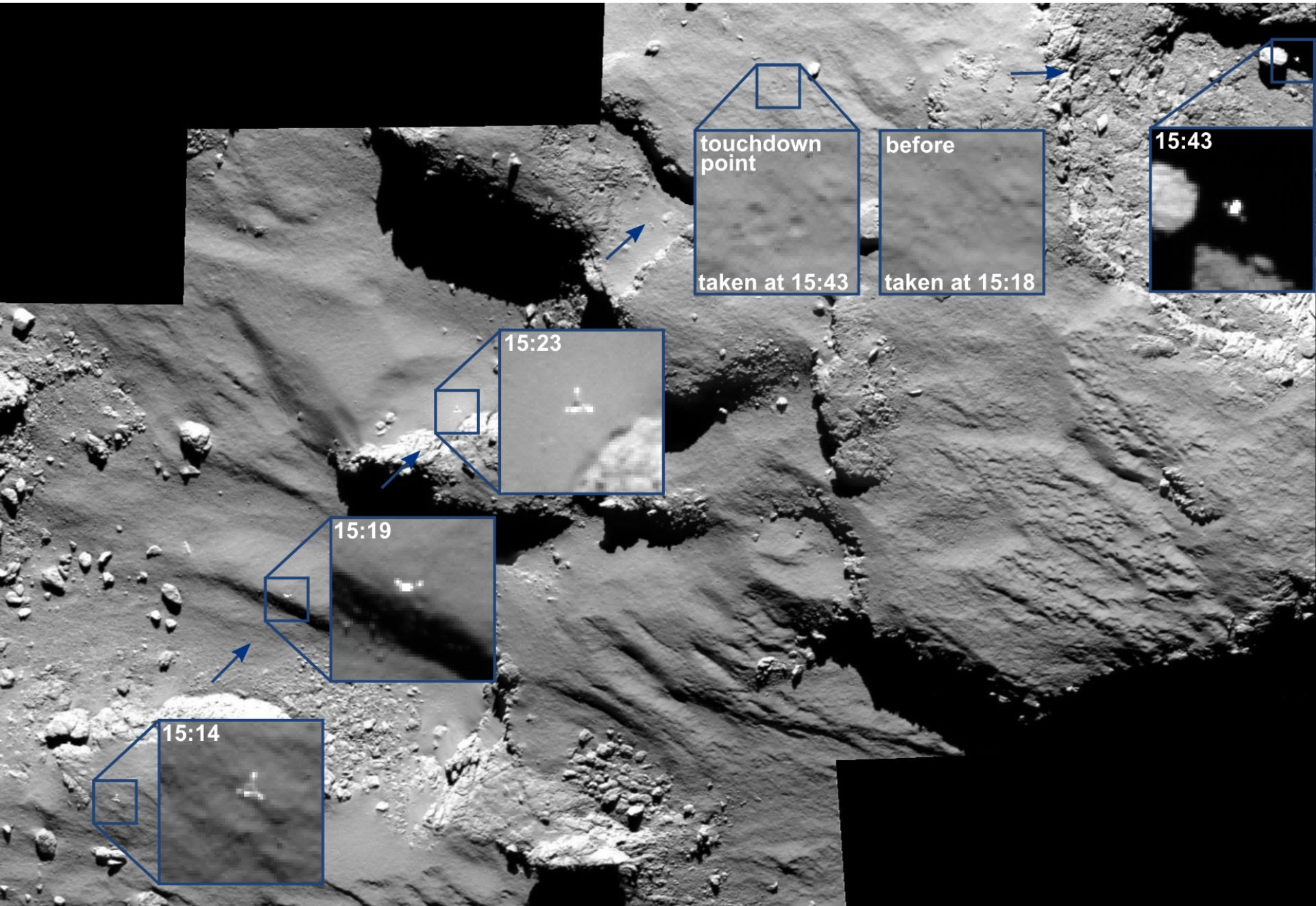
Rosetta @15km

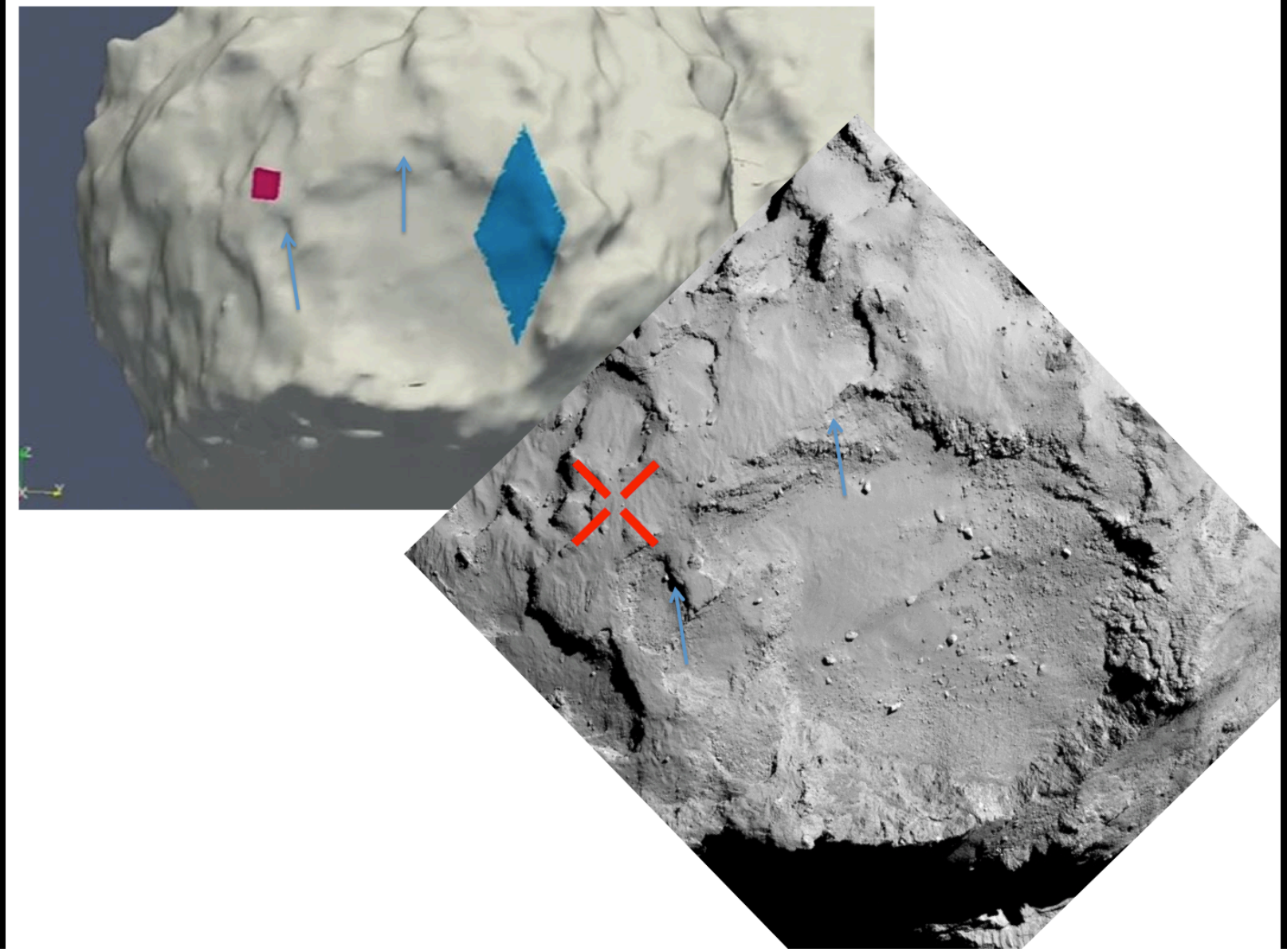
Res=1.5 m



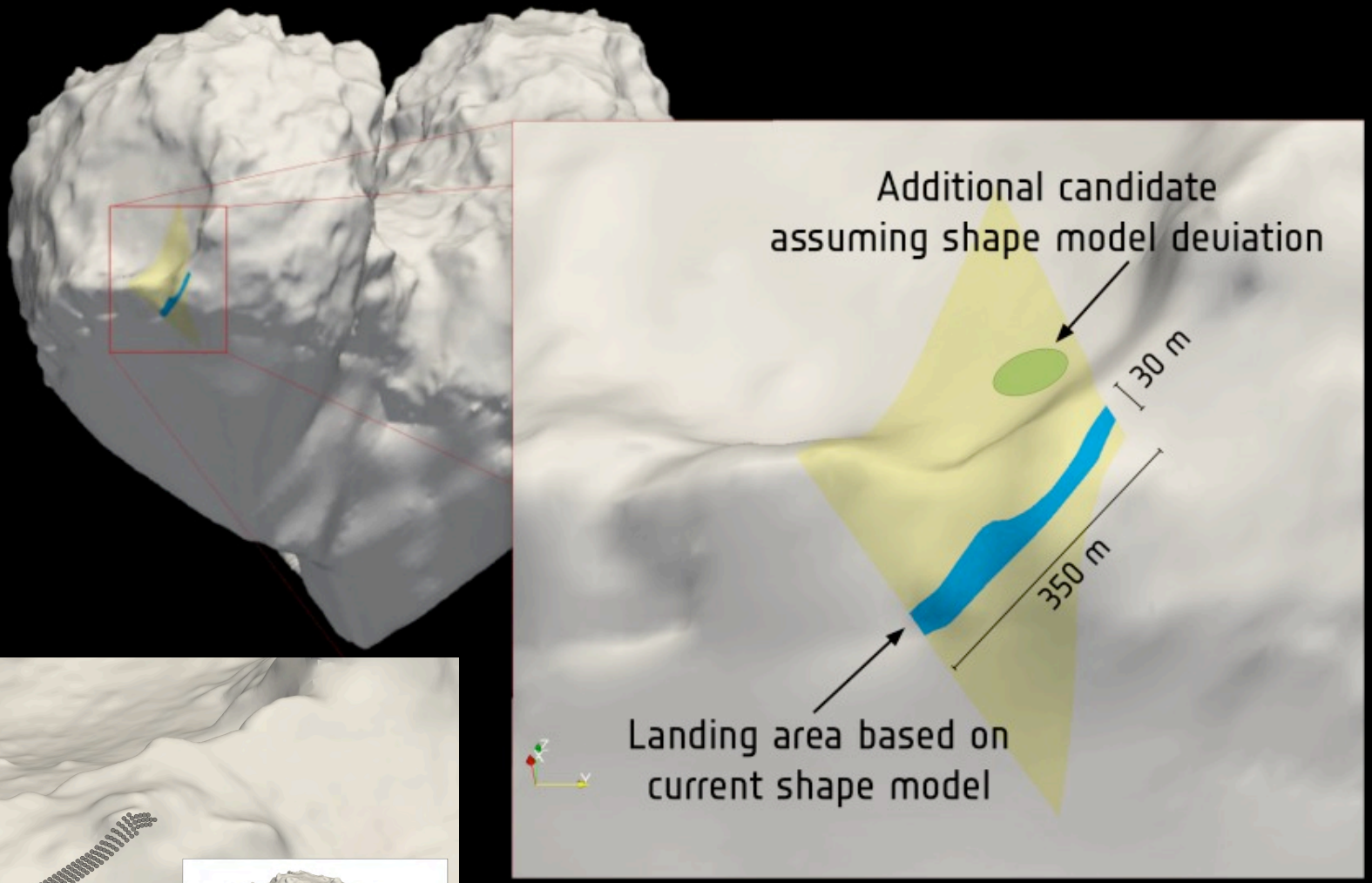

NAC 15:13
Lander

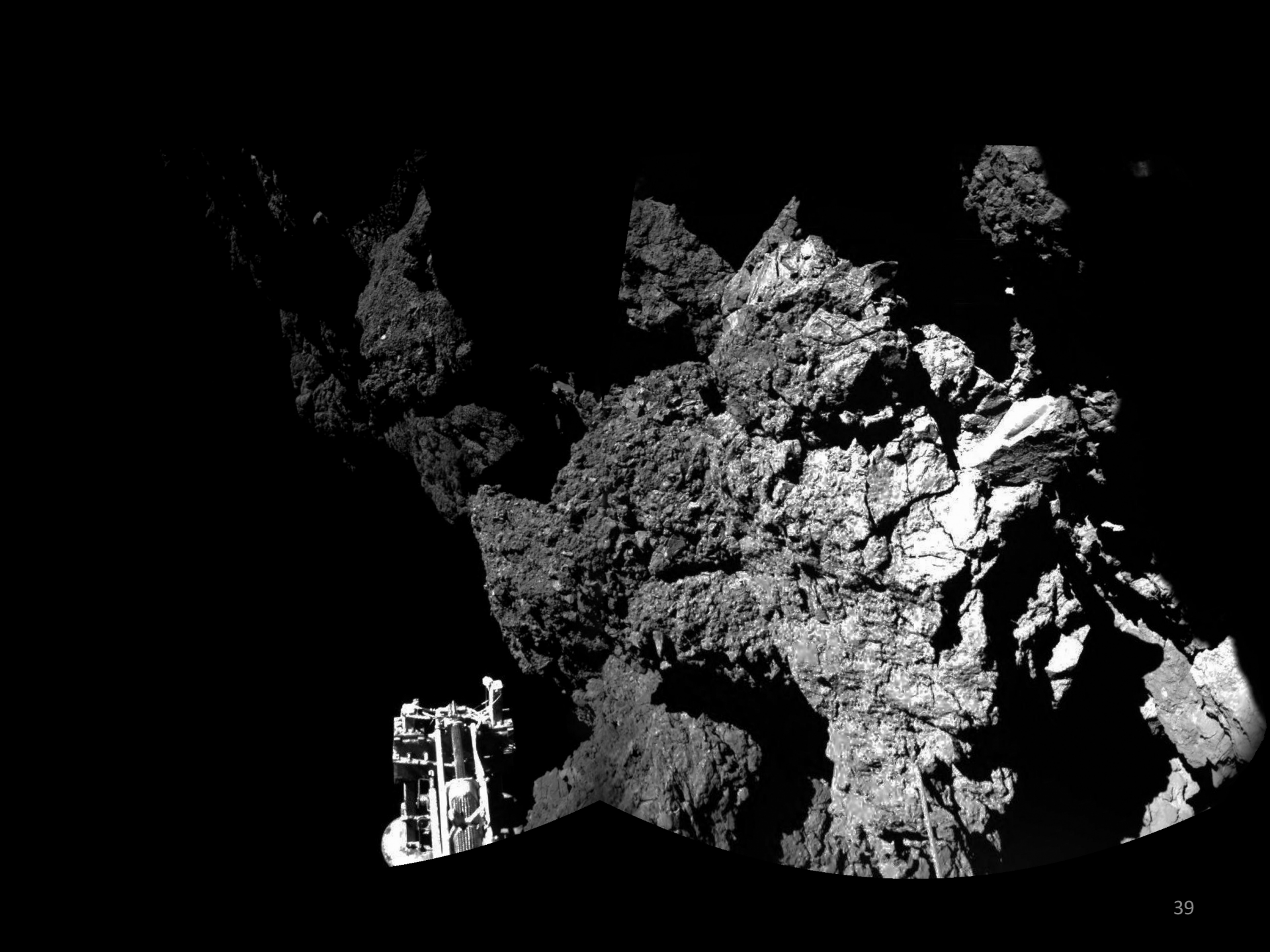
Touchdown 15:34

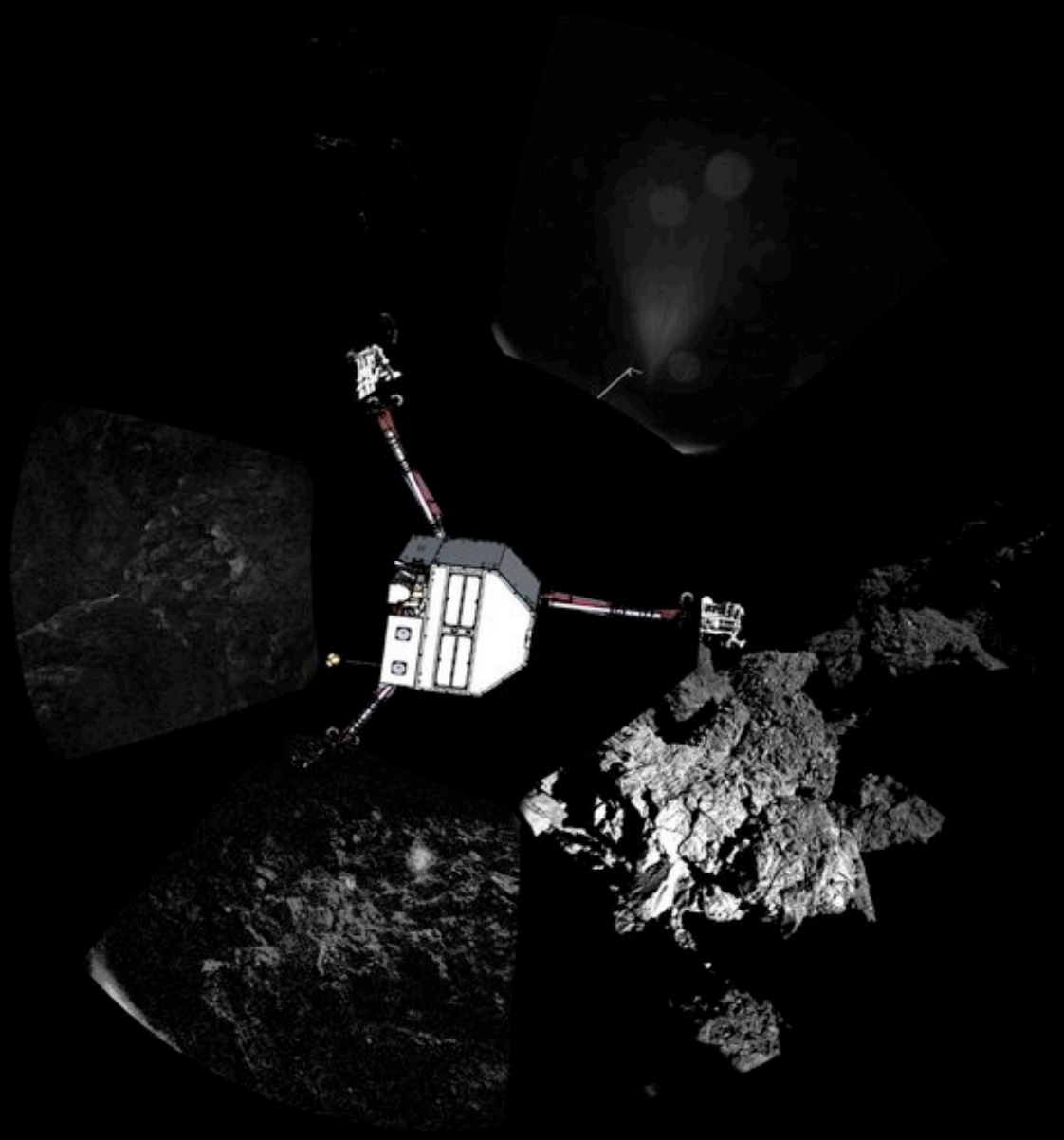




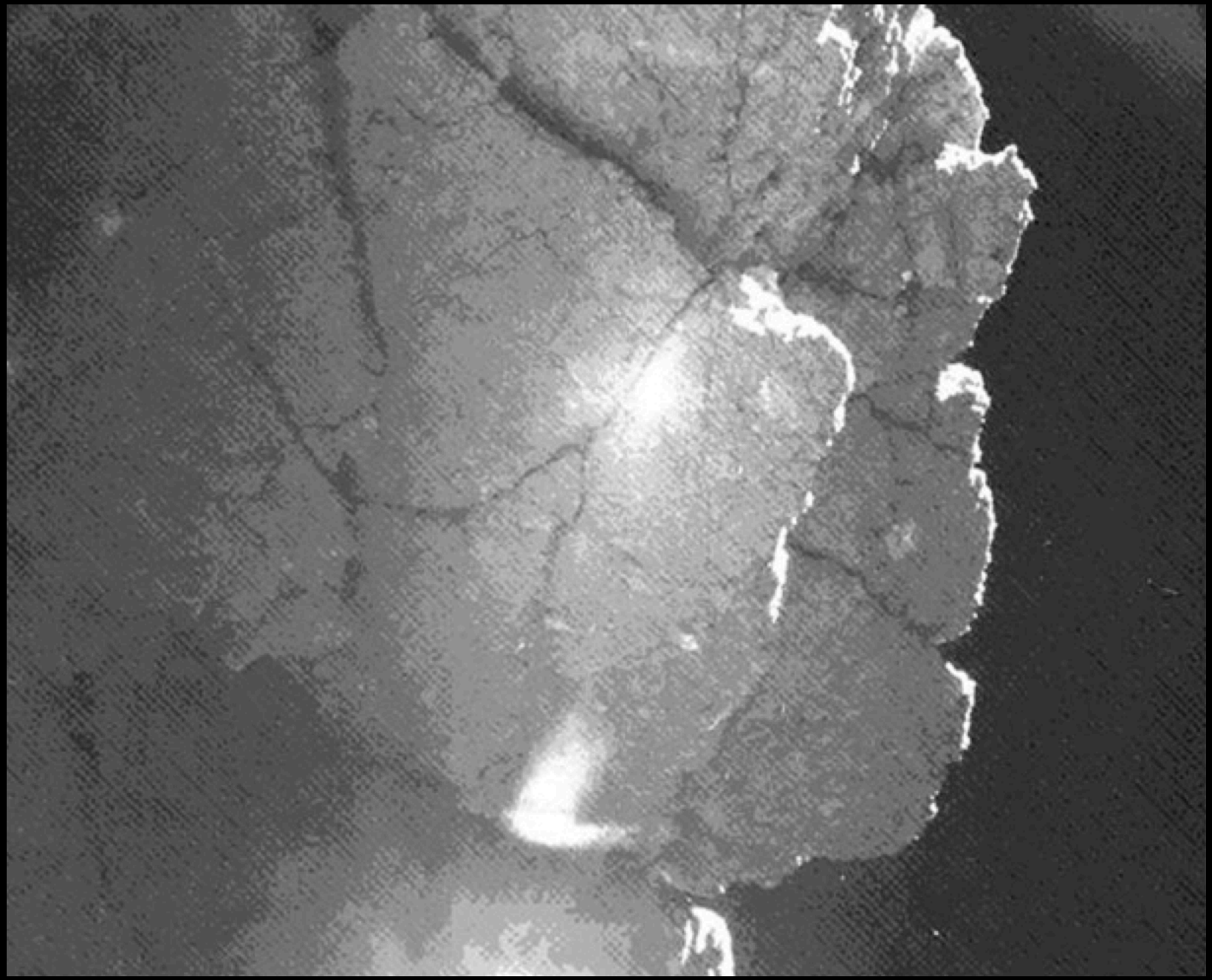
→ CONSERT estimation of landing area

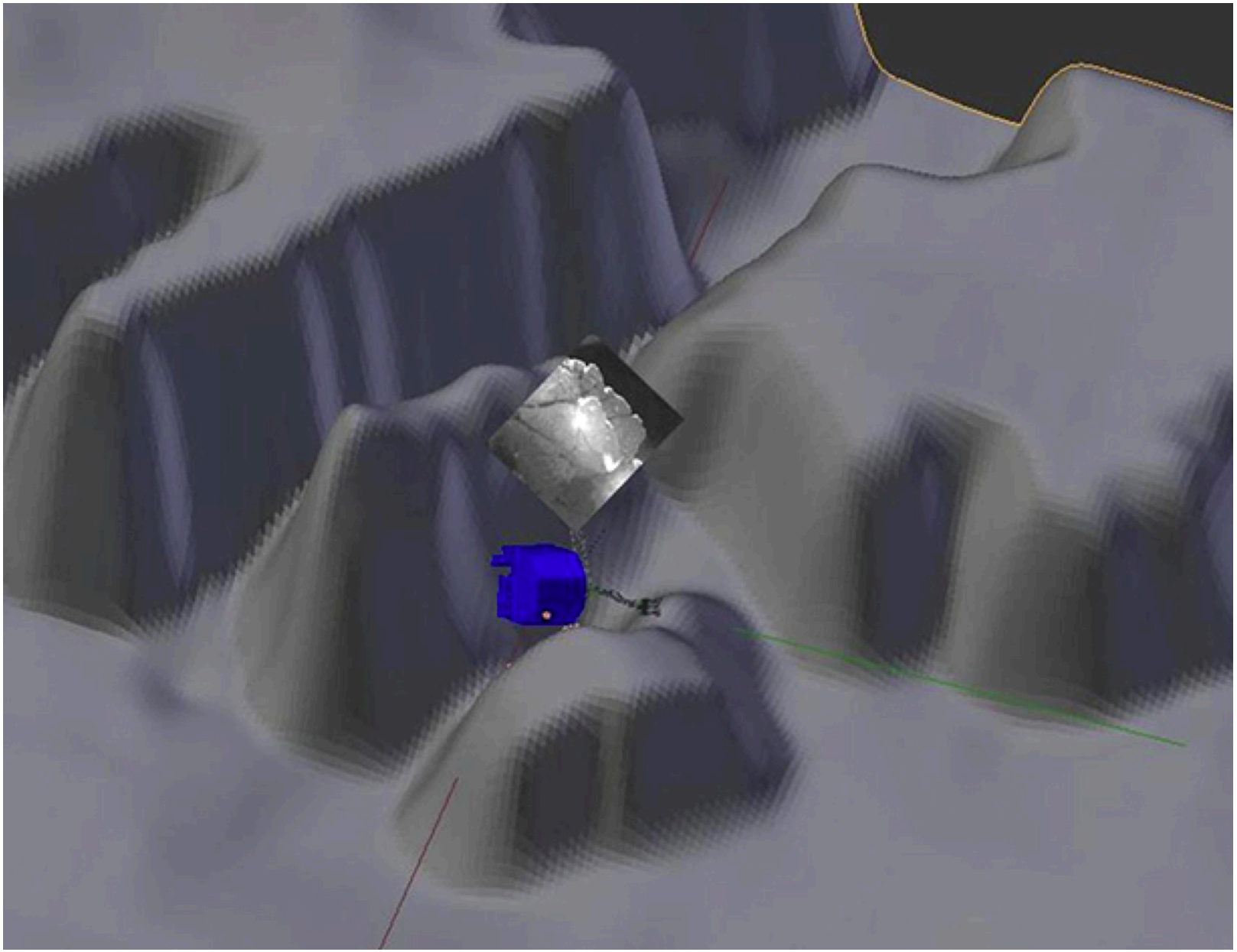




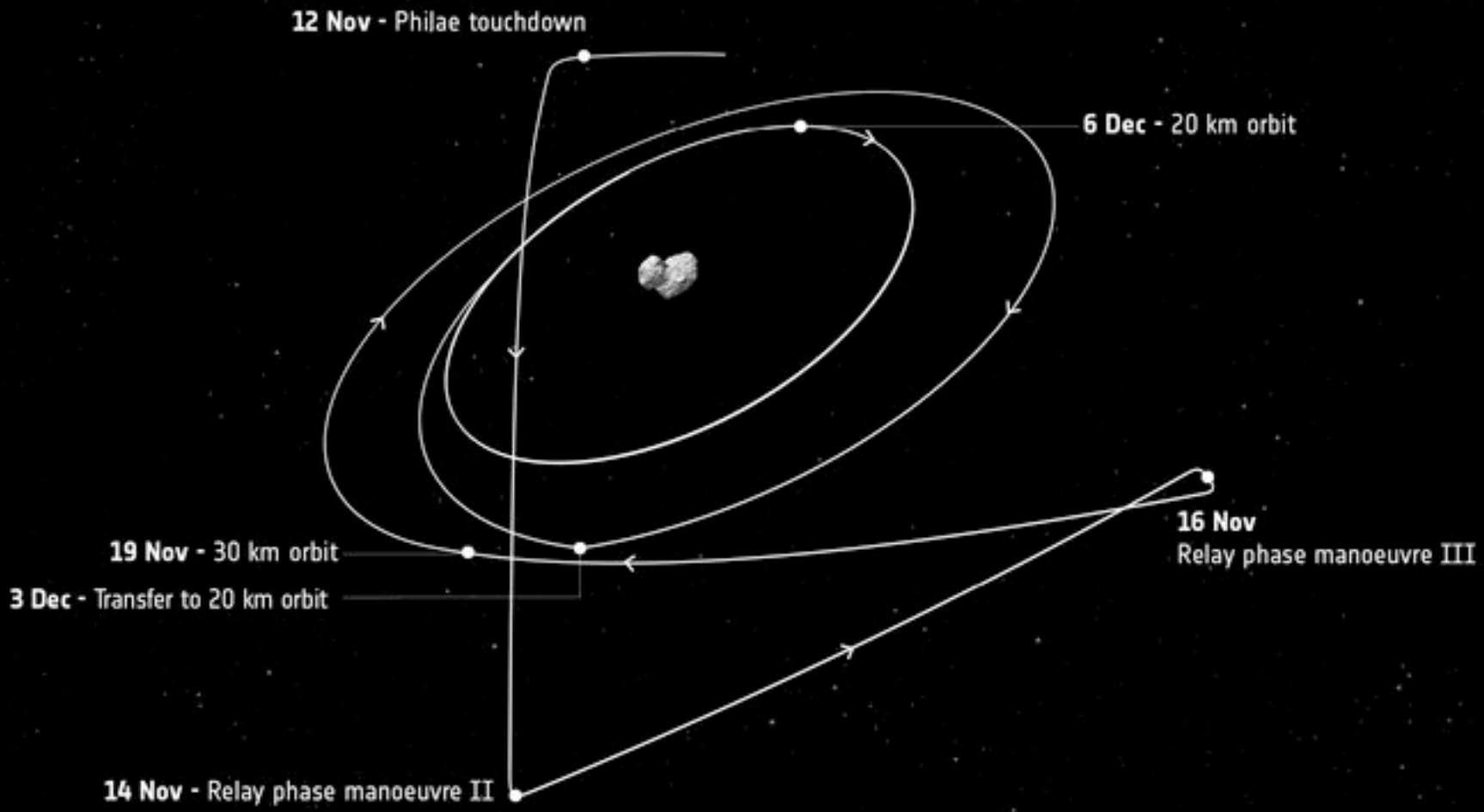


Superimposed on top of the image is a sketch of the Philae lander in the configuration the lander team currently believe it is in.





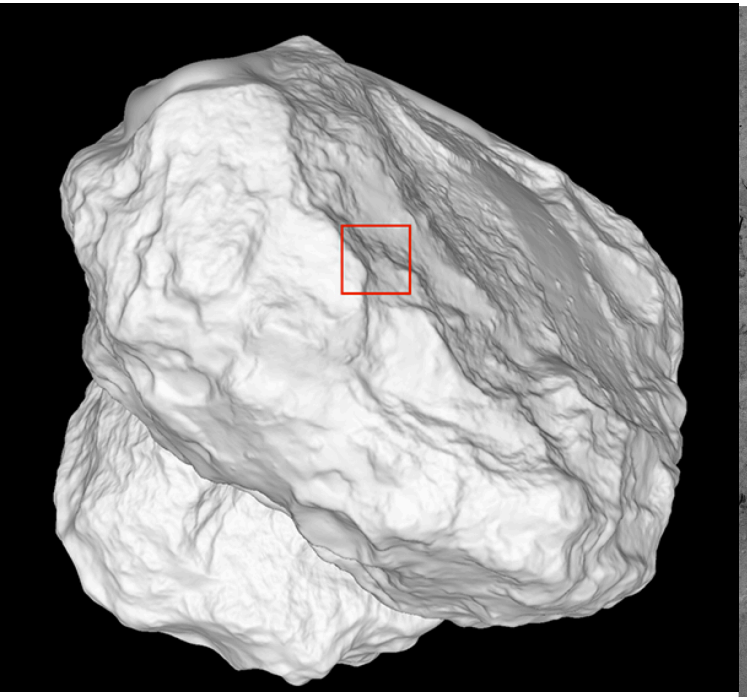
CNES reconstruction

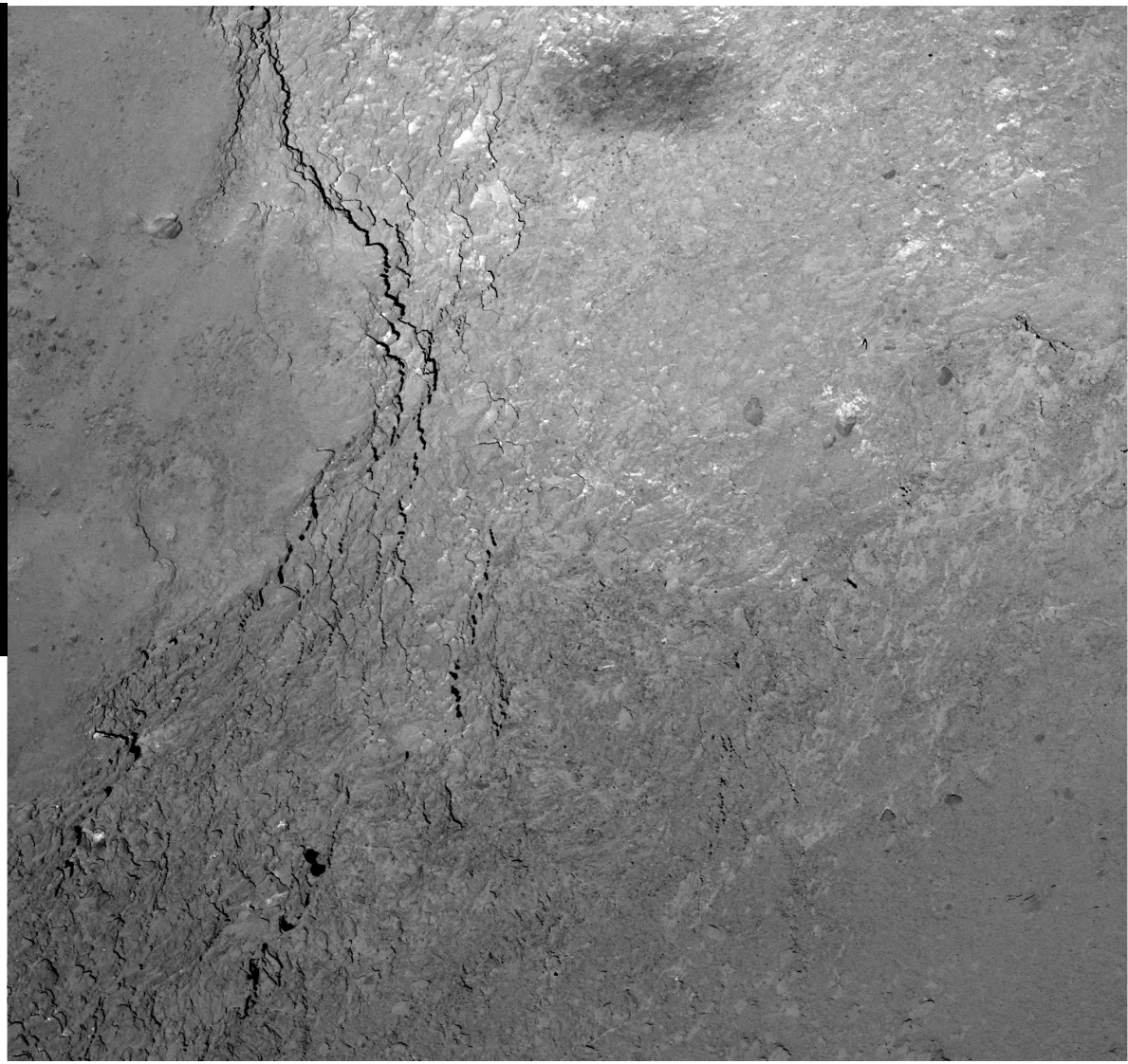

12 Nov - Philae touchdown
6 Dec - 20 km orbit
19 Nov - 30 km orbit
3 Dec - Transfer to 20 km orbit
16 Nov
Relay phase manoeuvre III
14 Nov - Relay phase manoeuvre II

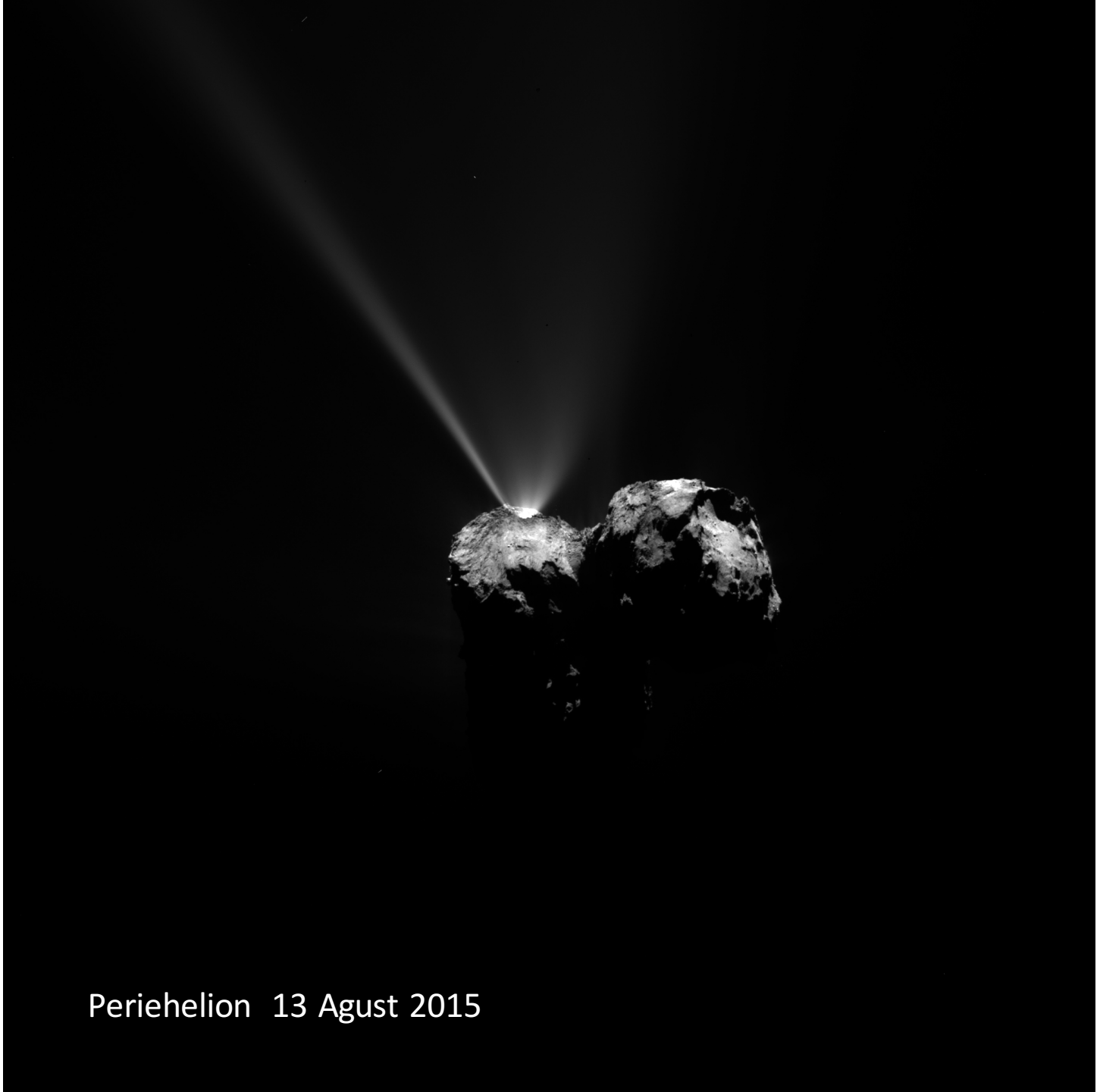
Close flyby

February 14, 2015 at 6 km

(Res.= 11 cm) Activity everywhere







Periehelion 13 Agust 2015