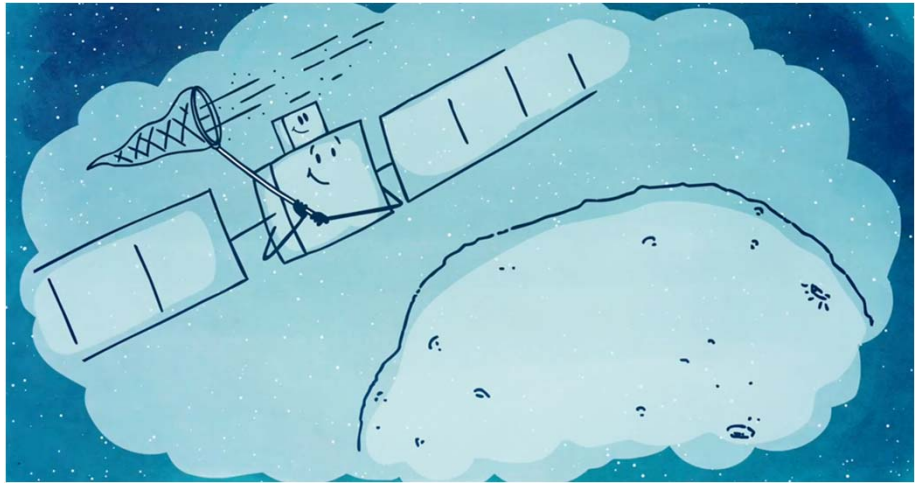
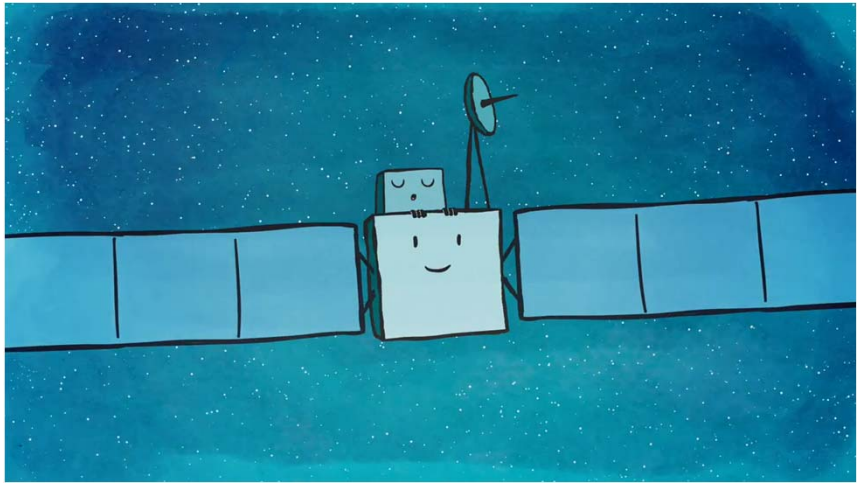




Quelques nouvelles de la mission ROSETTA

Hervé Cottin

UPEC Connaissance - Action | UNIVERSITÉ PARIS-EST CRÉTEIL VAL DE MARNE

lisa

SFE Société Française d'Exobiologie

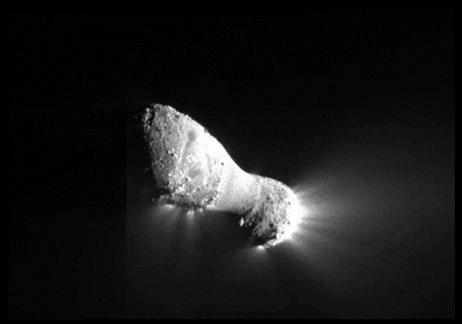
Les comètes : Généralités

Noyau ≈ Glaces + Minéraux + Organiques Réfractaires

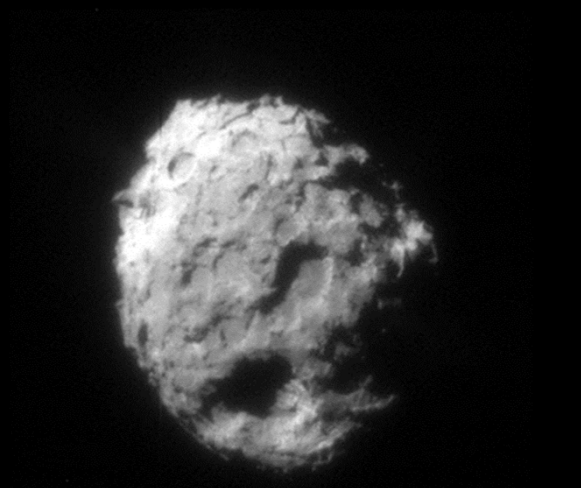
Environnement ≈ Gaz + Poussières

Noyau de 9P/Tempel 1 (2005)

Comète C/1995 O1 (Hale-Bopp)
en Mars 1997



Noyau de 103P/Hartley
(2010)

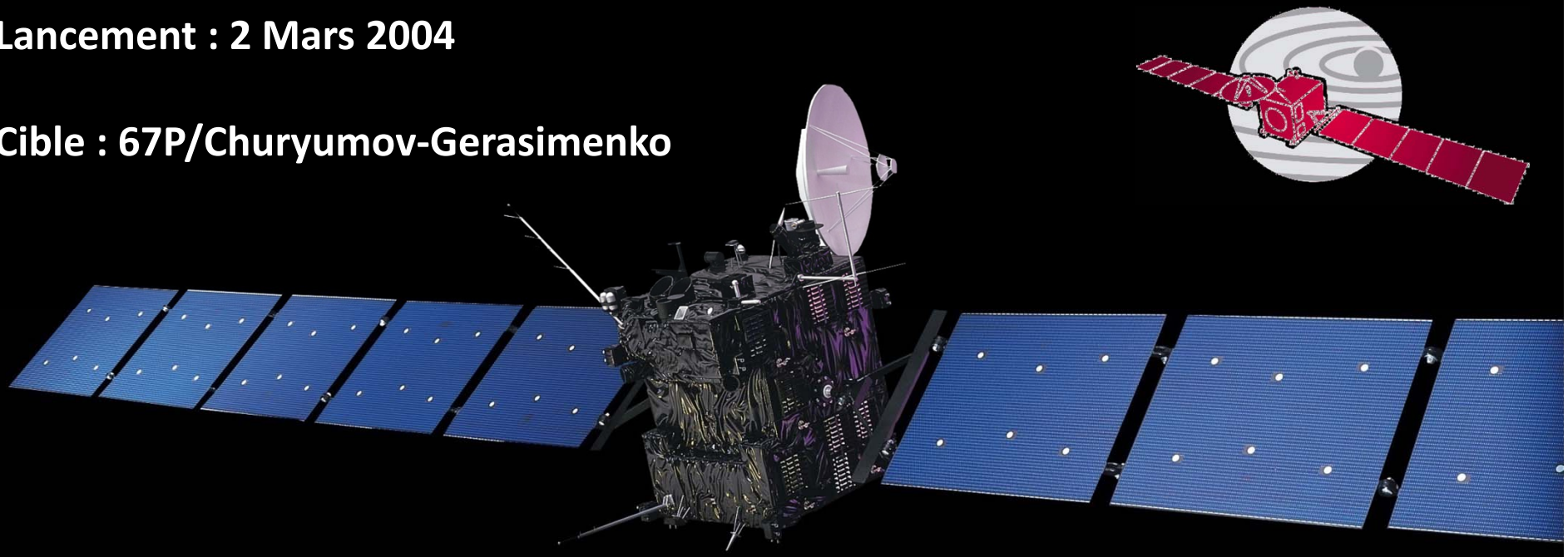


Noyau de 81P/Wild 1 (2004)

Rosetta : Généralités

Lancement : 2 Mars 2004

Cible : 67P/Churyumov-Gerasimenko



- ✓ **1ére mise en orbite autour d'un noyau cométaire**
- ✓ **1ére analyse in-situ d'une comète à plus de 2 UA**
- ✓ **1er atterrissage sur un noyau cométaire**

⇨ **Une mission extrêmement ambitieuse**

Rosetta : Généralités

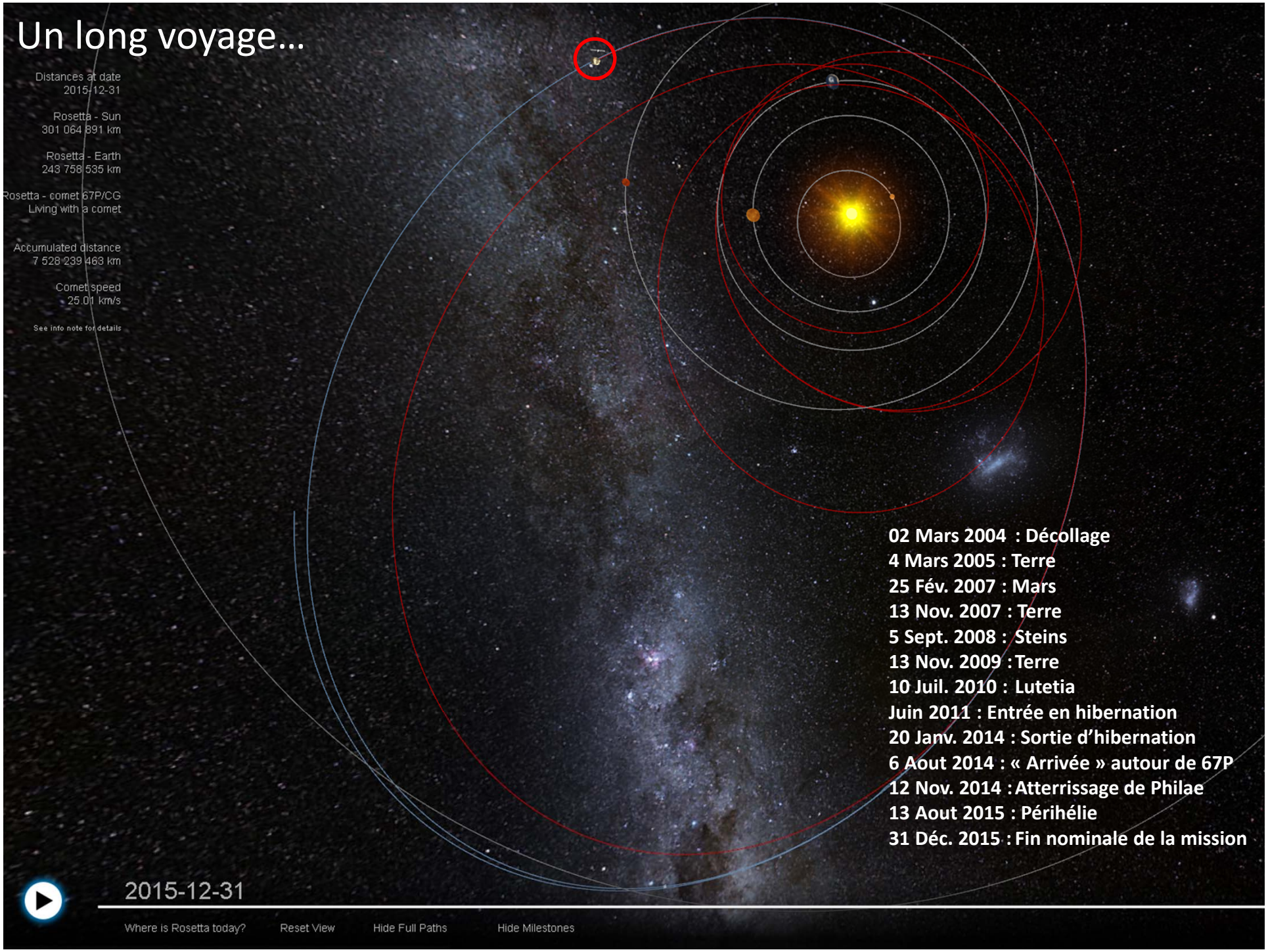
Lancement : 2 Mars 2004

Cible : 67P/Churyumov-Gerasimenko

- ✓ **<u>1 orbiteur « Rosetta »:</u>**
  - ✓ **2.8 x 2.1 x 2 mètres + 2 panneaux solaires de 15 m (64 m^2)**
  - ✓ **2 970 kg (1 300 kg sans le carburant)**
  - ✓ **11 instruments (165 kg)**

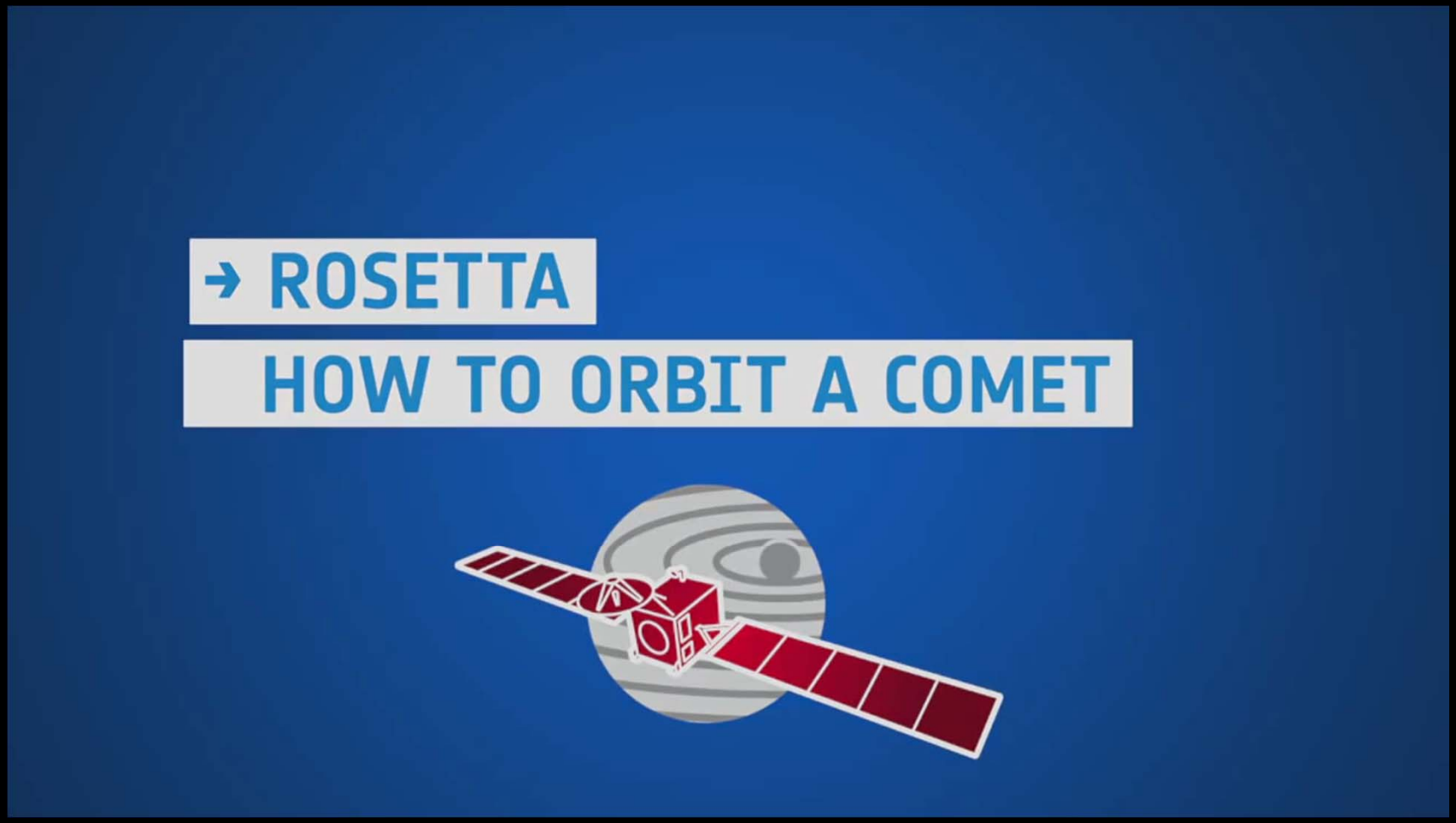
- ✓ **<u>1 lander « Philae »:</u>**
  - ✓ **1 mètre de coté x 0.8 m de haut**
  - ✓ **100 kg**
  - ✓ **10 instruments (21 kg)**

Un long voyage…

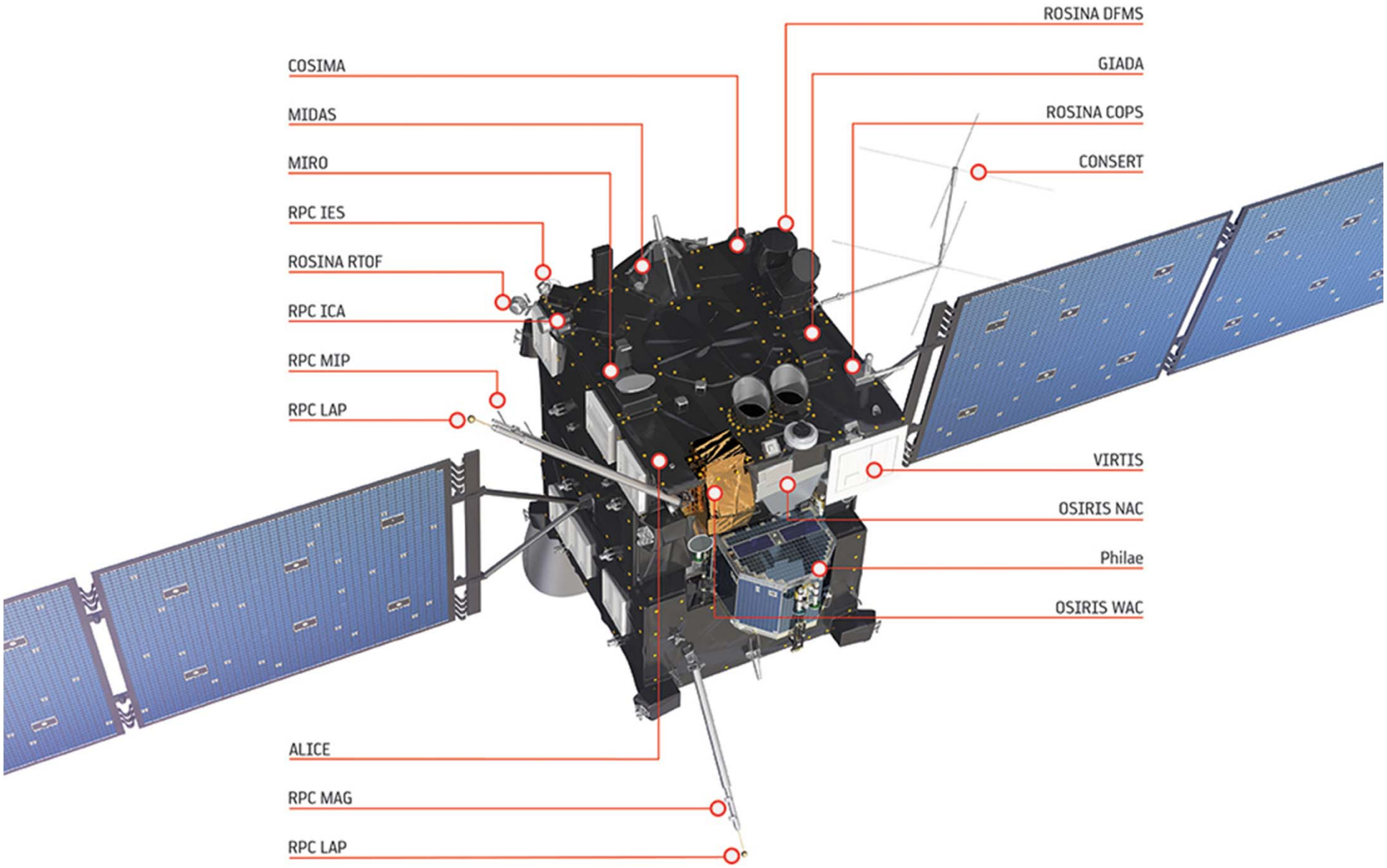


02 Mars 2004 : Décollage
4 Mars 2005 : Terre
25 Fév. 2007 : Mars
13 Nov. 2007 : Terre
5 Sept. 2008 : Steins
13 Nov. 2009 : Terre
10 Juil. 2010 : Lutetia
Juin 2011 : Entrée en hibernation
20 Janv. 2014 : Sortie d'hibernation
6 Aout 2014 : « Arrivée » autour de 67P
12 Nov. 2014 : Atterrissage de Philae
13 Aout 2015 : Périhélie
31 Déc. 2015 : Fin nominale de la mission

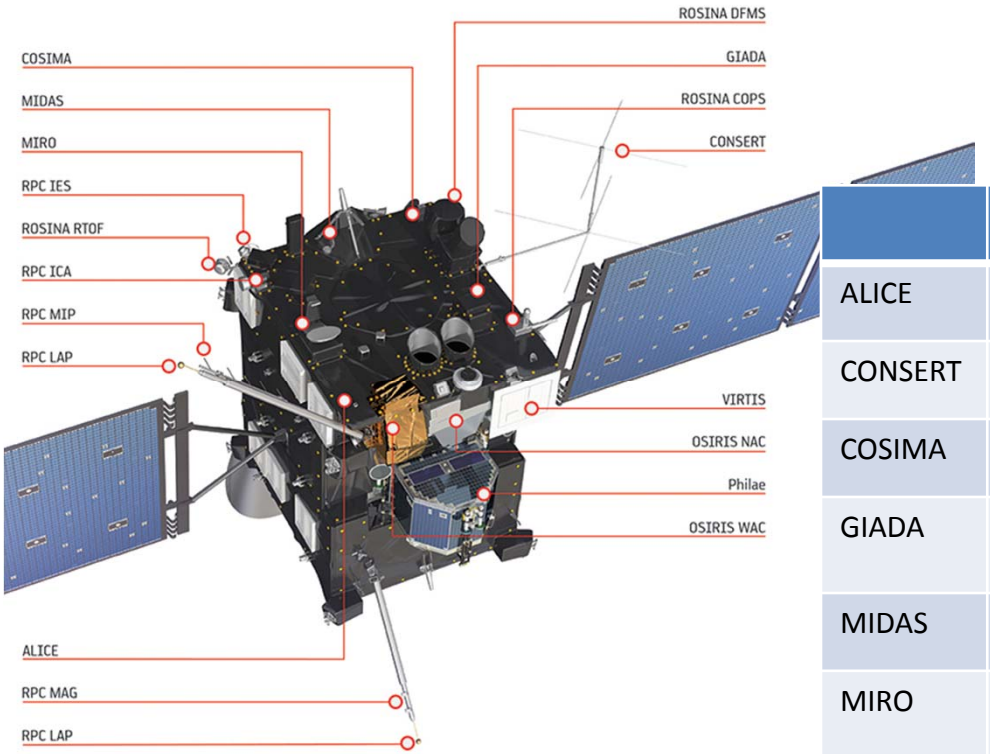
La trajectoire de Rosetta



Les instruments à bord de l'orbiteur « Rosetta »

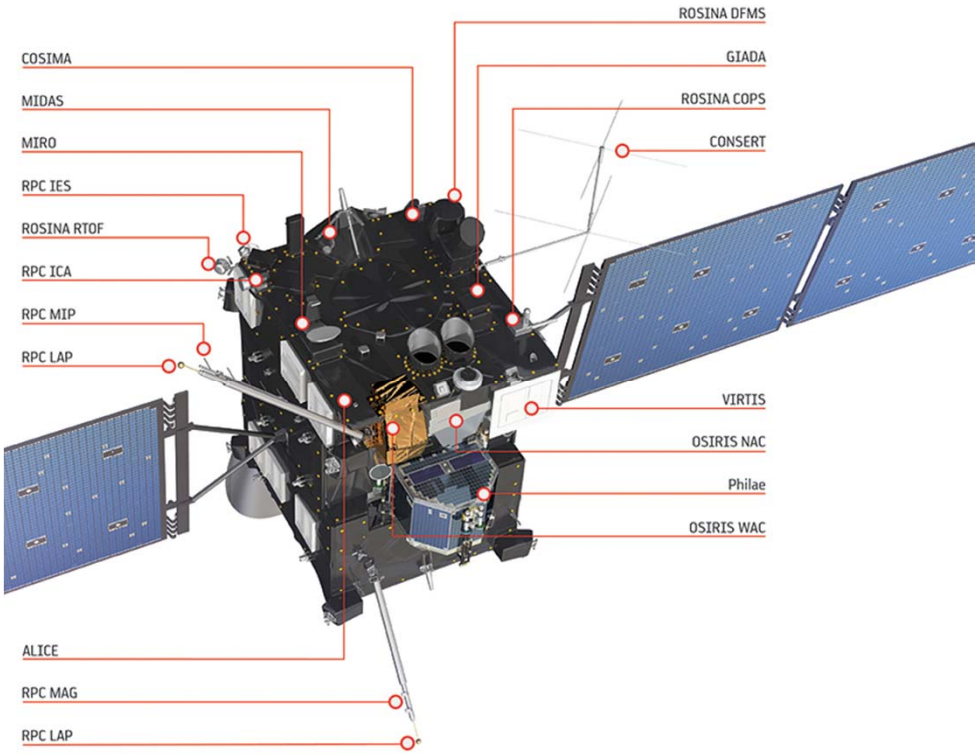


Les instruments à bord de l'orbiteur « Rosetta »



ALICE	**Ultraviolet Imaging Spectrometer** (characterising the composition of the comet nucleus and coma)
CONSERT	**Comet Nucleus Sounding Experiment by Radio wave Transmission** (studying the internal structure of the comet with lander Philae)
COSIMA	**Cometary Secondary Ion Mass Analyser** (studying the composition of the dust in the comet's coma)
GIADA	**Grain Impact Analyser and Dust Accumulator** (measuring the number, mass, momentum and velocity distribution of dust grains in the near-comet environment)
MIDAS	**Micro-Imaging Dust Analysis System** (studying the dust environment of the comet)
MIRO	**Microwave Instrument for the Rosetta Orbiter** (investigating the nature of the cometary nucleus, outgassing from the nucleus and development of the coma)
OSIRIS	**Optical, Spectroscopic, and Infrared Remote Imaging System Camera** (a dual camera imaging system consisting of a narrow angle (NAC) and wide angle camera (WAC) and operating in the visible, near infrared and near ultraviolet wavelength range)
ROSINA	**Rosetta Orbiter Spectrometer for Ion and Neutral Analysis** (determining the composition of the comet's atmosphere and ionosphere, and measuring the temperature, velocity and density of the gas flow, comprising: DFMS (Double-focusing mass spectrometer), RTOF (Reflectron Time-Of-Flight mass spectrometer) and COPS (Comet Pressure Sensor))
RPC	**Rosetta Plasma Consortium** (studying the plasma environment of the comet, comprising: ICA (Ion Composition Analyser), IES (Ion and Electron Sensor), LAP (Langmuir Probe), MAG (Fluxgate Magnetometer), MIP (Mutual Impedance Probe), PIU (Plasma Interface Unit))
RSI	**Radio Science Investigation** (tracking the motion of the spacecraft to infer details of the comet environment and nucleus)
VIRTIS	**Visible and Infrared Thermal Imaging Spectrometer** (studying the nature of the comet nucleus and the gases in the coma)

Les instruments à bord de l'orbiteur « Rosetta »



Spectroscopie

✓ Ultraviolet : ALICE
-- 70-205 nm

✓ Visible : OSIRIS
-- NAC – 250 – 1000 nm (12 filtres)
-- WAC – 240-720 nm (14 filtres)

✓ Infrarouge : VIRTIS
-- plusieurs canaux 0.25 – 5 µm

✓ Mm & sub-mm : MIRO
-- 188 Ghz (1.6 mm) (continuum data only)
-- 562 Ghz (0.5 mm) (continuum & high resolution)

Virtis main characteristics and requirements

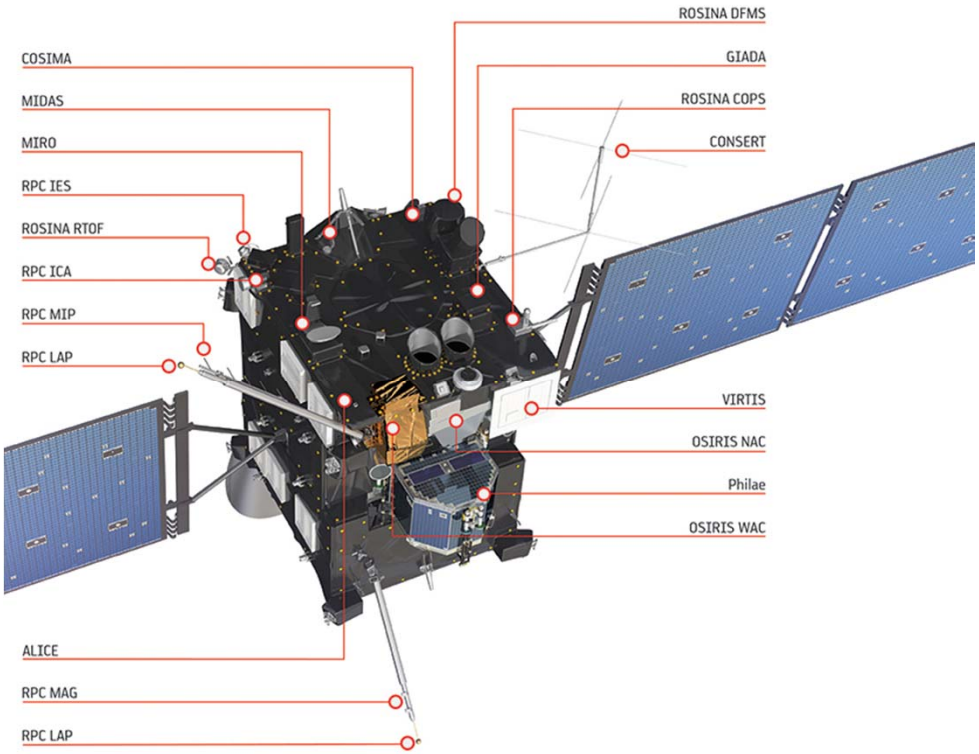
	VIRTIS-M Visible	VIRTIS-M InfraRed	VIRTIS-H
Spectral Range (nm)	220.1–1046.0	952.8–5059.2	*Order* 0 4.05–5.03 *Order* 1 3.47–4.32 *Order* 2 3.04–3.78 *Order* 3 2.70–3.37 *Order* 4 2.43–3.03 *Order* 5 2.21–2.76 *Order* 6 2.03–2.53 *Order* 7 1.88–2.33
Spectral Resolution $\lambda/\Delta\lambda\lambda$	100–380	70–360	1300–3000
Spectral Sampling (nm) (1)	1.89	9.44	0.6
Field of View (mrad × mrad)	63.6 (slit) × 64.2 (scan)	63.6 (slit) × 64.2 (scan)	0.49 × 1.47
Max Spatial Resolution (μrad)	248.6 (slit) × 250.8 (scan)		

TABLE I

Rosetta-ALICE characteristics, spacecraft resource requirements, and measured performance summary (Ground cal and Flight results)

Parameter	Proposed/Specified performance	Measured performance
Passband:	700–2050 Å	680–2060 Å (Flight)
Spectral	4–8 Å (point source)	4–8 Å (Ground Cal); 4–9 Å (Flight)
Resolution:	10–12 Å (extended source)	8–12 Å (Ground Cal and Flight)
Spatial resolution:	0.05° × 0.6° (Nyquist sampled)	0.05° × 0.6° (Nyquist sampled)
Active FOV:	0.1° × 6.0° (Proposed FOV)	0.05° × 2.0° + 0.1° × 2.0° + 0.1° × 1.5° (final design)

Les instruments à bord de l'orbiteur « Rosetta »



Imagerie & Résolution spatiale

✓ OSIRIS :
WAC 5 m.pixel^{-1} à 100 km
NAC 1.86 m.pixel^{-1} à 100 km

✓ COSIMA :
14 µm.pixel^{-1}

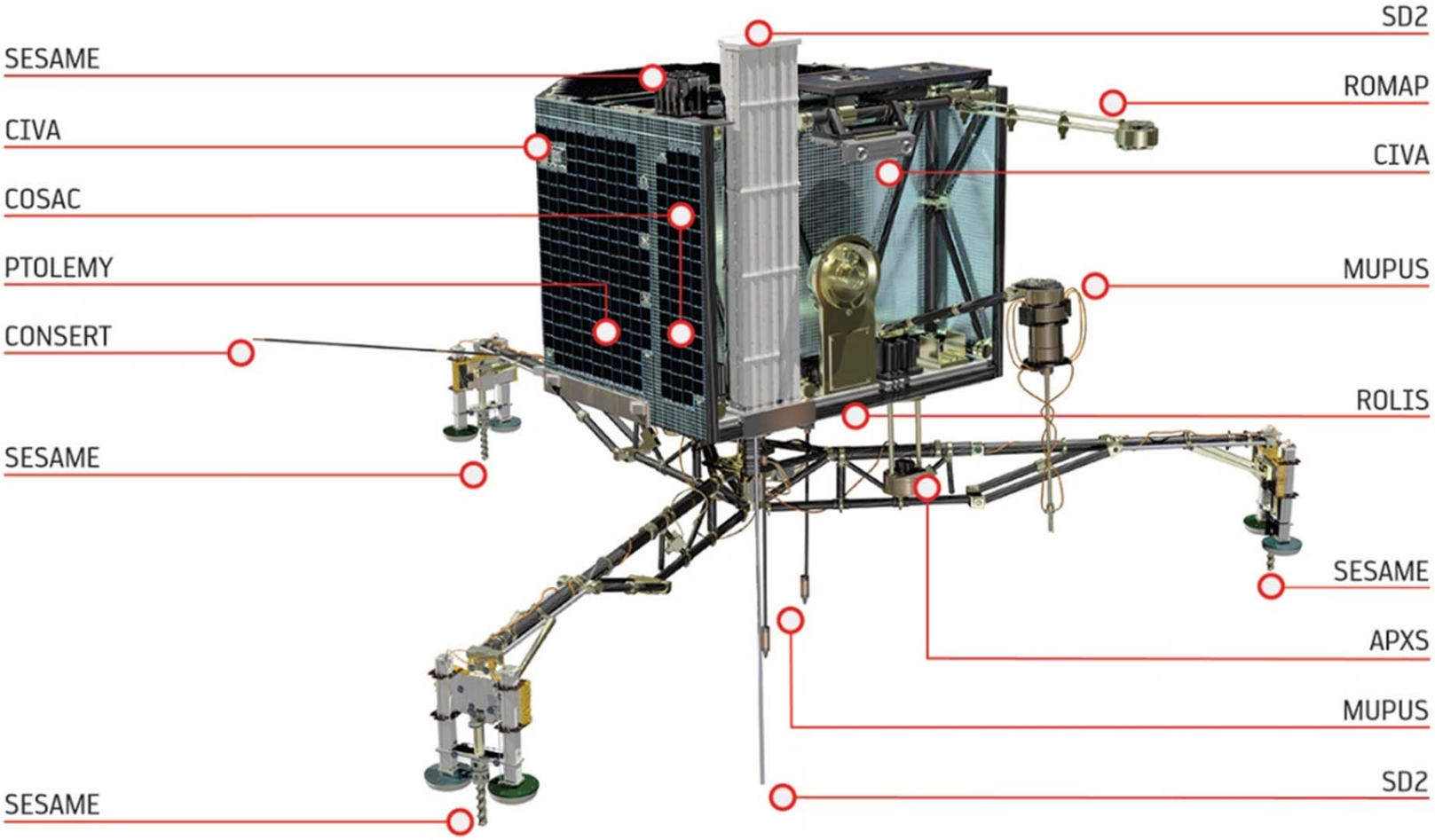
✓ MIDAS :
4 nm.pixel^{-1}

Spectrométrie de masse

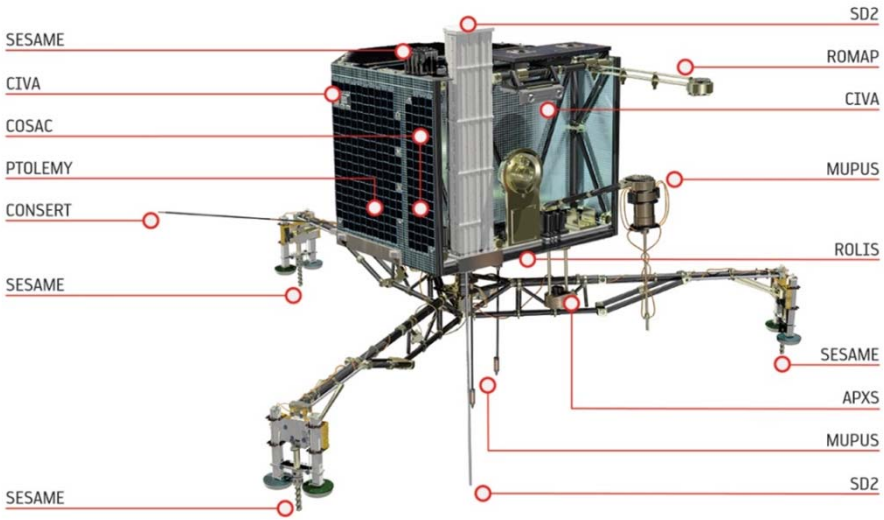
✓ DFMS (ROSINA):
m / Δm = 3000 at 1% peak height

✓ COSIMA :
m / Δm = 1400 at 50% peak height

Les instruments à bord de l'atterrisseur « Philae »



Les instruments à bord de l'atterrisseur « Philae »



SDL : Separation, Descent, Landing
Nov 12th, 7h (largué à 22,5 km)

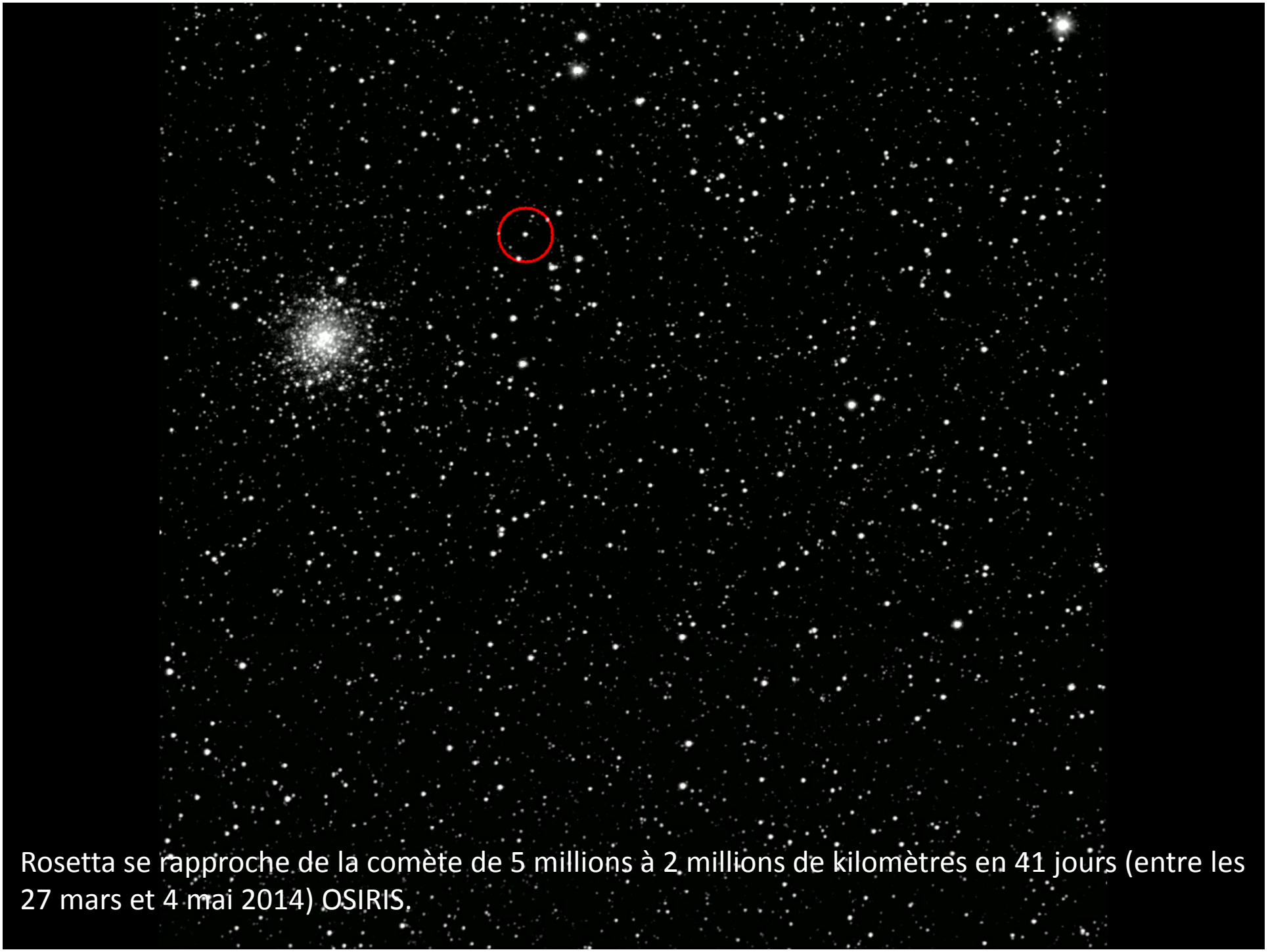
FSS : First Science Sequence : 2,25 days (50 to 56h)

LTS : Long Term Sequence : mid Nov 2014- March 2015

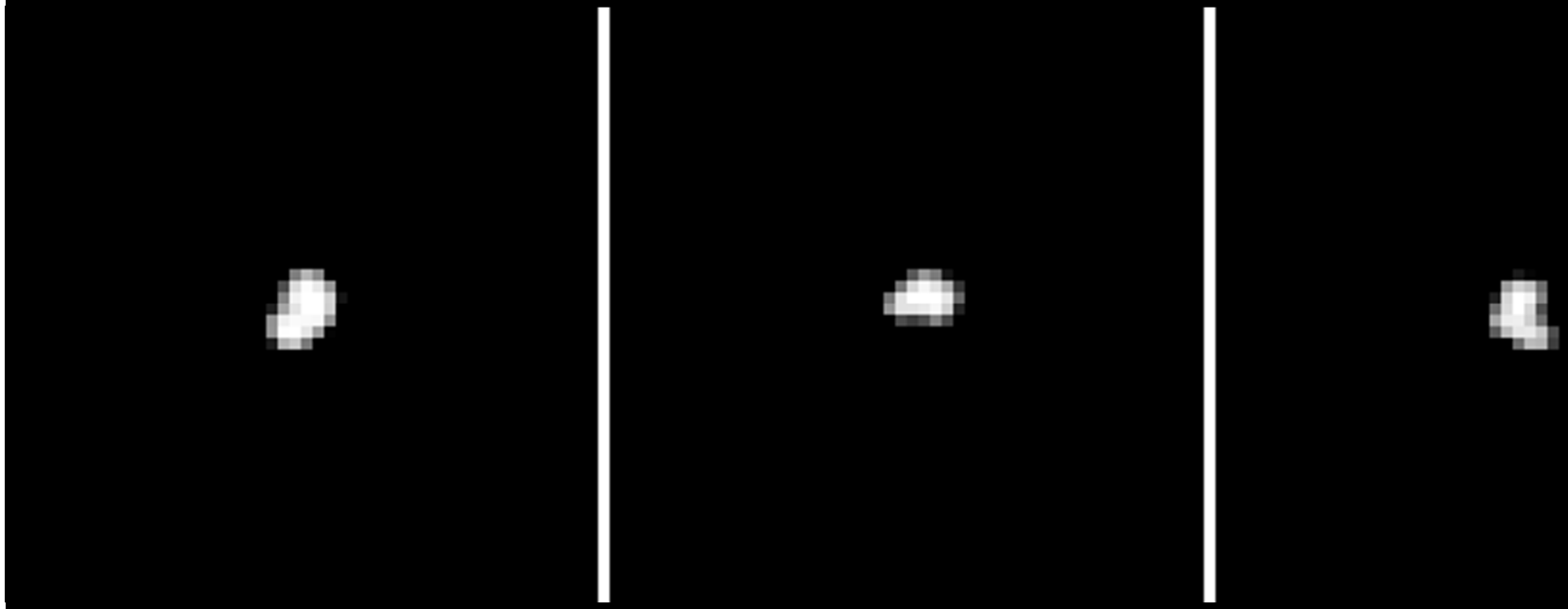
APXS	**Alpha Proton X-ray Spectrometer** (studying the chemical composition of the landing site and its potential alteration during the comet's approach to the Sun)
CIVA	**Comet Nucleus Infrared and Visible Analyser** (six cameras to take panoramic pictures of the comet surface)
CONSERT	**COmet Nucleus Sounding Experiment by Radiowave Transmission** (studying the internal structure of the comet nucleus with Rosetta orbiter)
COSAC	**The COmetary SAmpling and Composition** (detecting and identifying complex organic molecules)
PTOLEMY	**Using MODULUS protocol (Methods Of Determining and Understanding Light elements from Unequivocal Stable isotope compositions)** to understand the geochemistry of light elements, such as hydrogen, carbon, nitrogen and oxygen.
MUPUS	**MUlti-PUrpose Sensors for Surface and Sub-Surface Science** (studying the properties of the comet surface and immediate sub-surface)
ROLIS	**Rosetta Lander Imaging System** (providing the first close-up images of the landing site)
ROMAP	**Rosetta Lander Magnetometer and Plasma Monitor** (studying the magnetic field and plasma environment of the comet)
SD2	**Sampling, drilling and distribution subsystem** (drilling up to 23 cm depth and delivering material to onboard instruments for analysis)
SESAME	**Surface Electric Sounding and Acoustic Monitoring Experiment** (probing the mechanical and electrical parameters of the comet)

67P/Churyumov-Gerasimenko

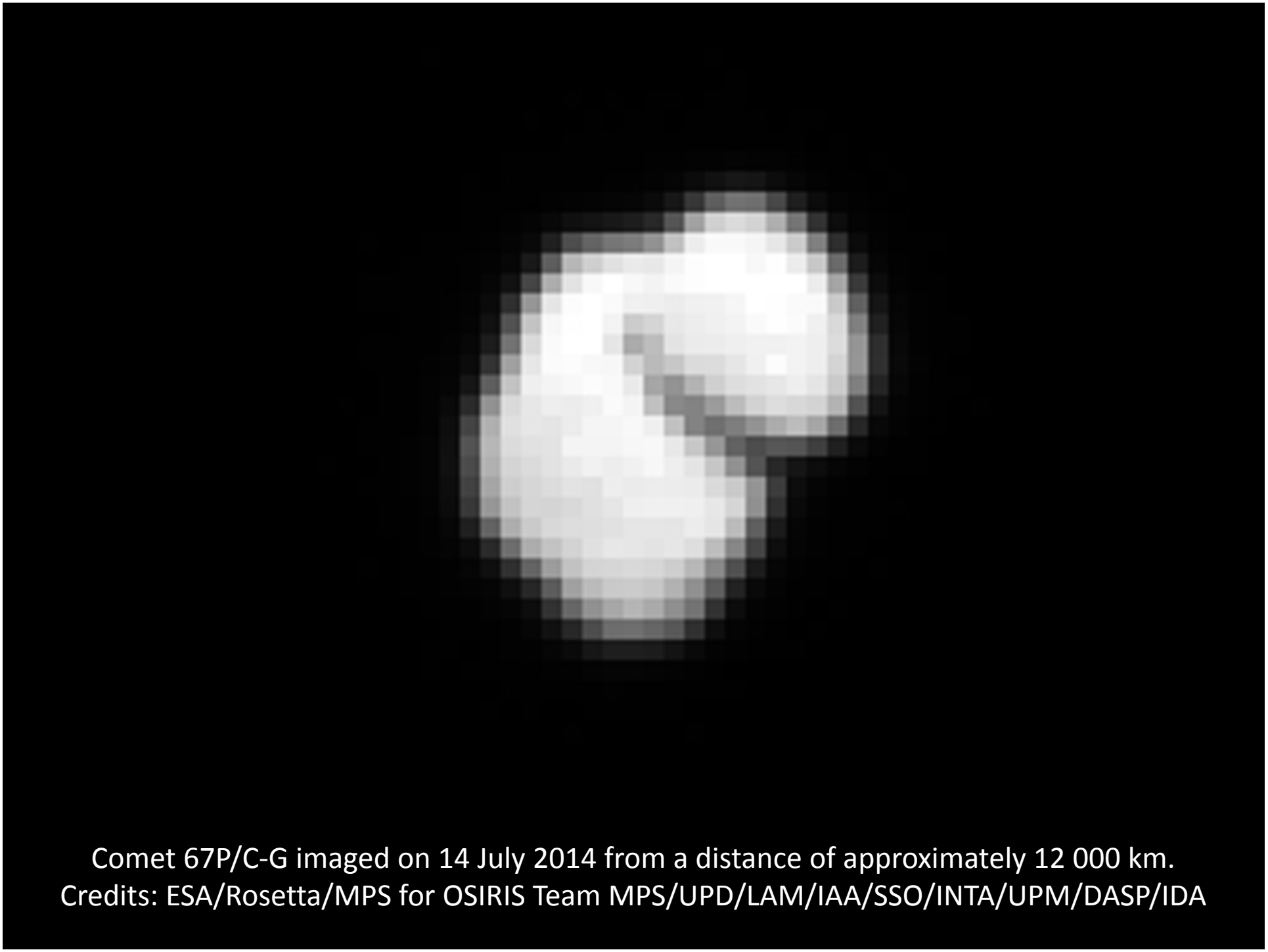
période orbitale	6,6 ans
excentricité	0,632
périhélie	1,29 ua
aphélie	5,74 ua



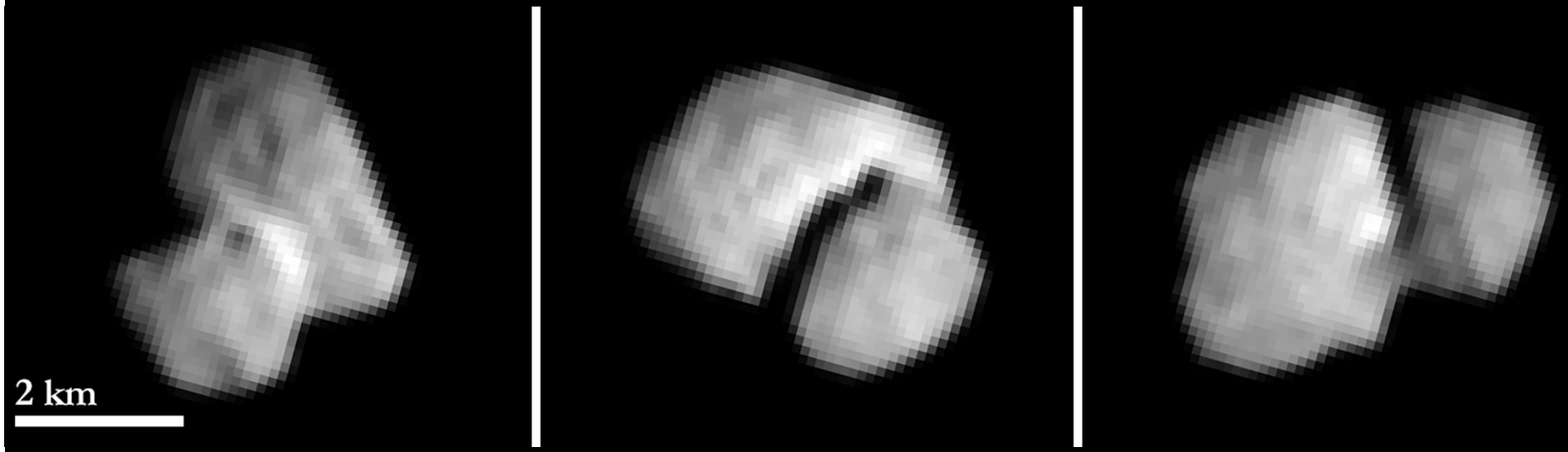
Rosetta se rapproche de la comète de 5 millions à 2 millions de kilomètres en 41 jours (entre les 27 mars et 4 mai 2014) OSIRIS.



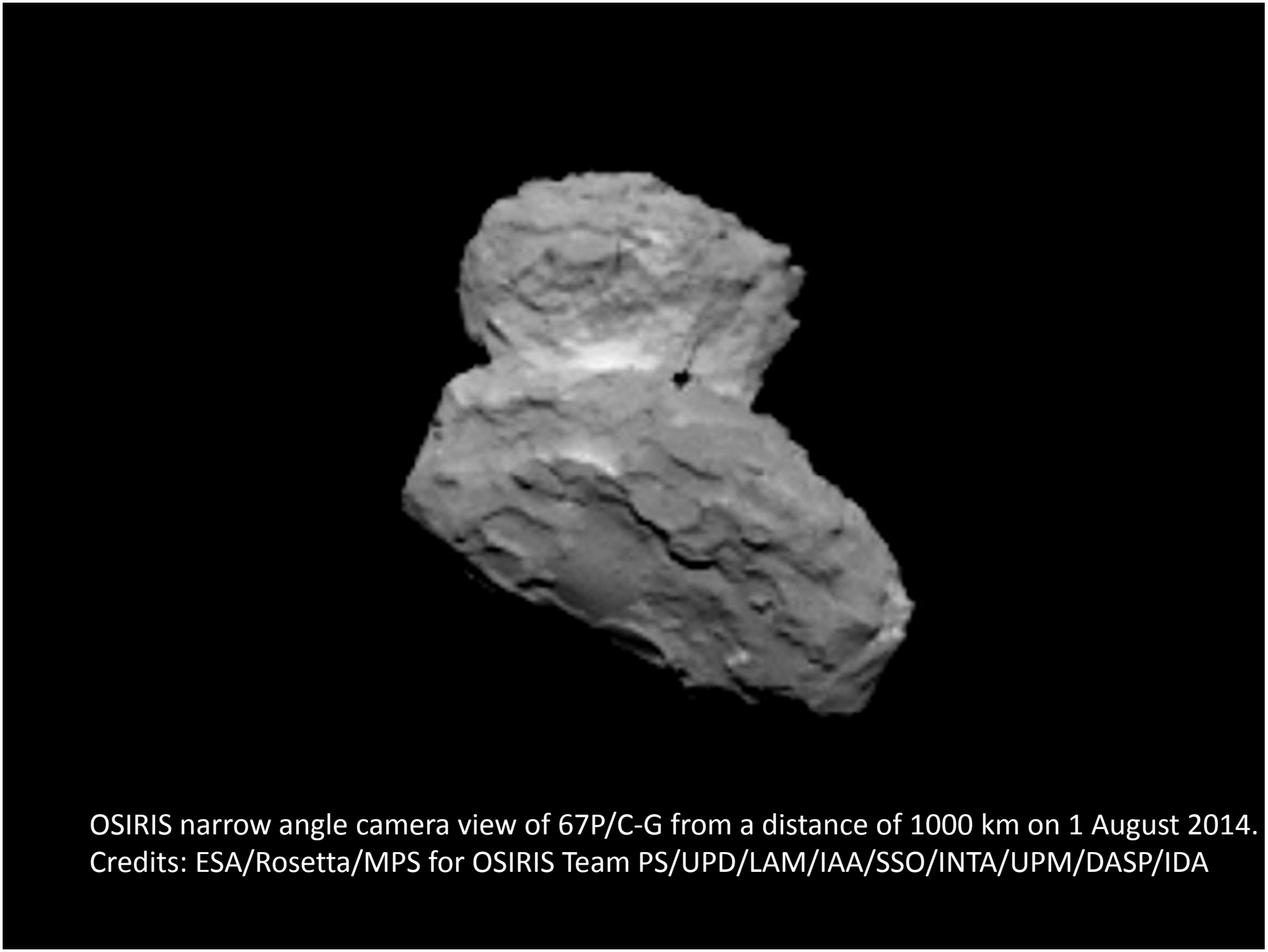
This sequence of three images are separated by 4 hours, and were taken on 4 July by the narrow angle camera of Rosetta's scientific imaging system, OSIRIS. At this time, 37 000 km lay between the spacecraft and the comet, similar to the altitude at which geostationary satellites orbit Earth.



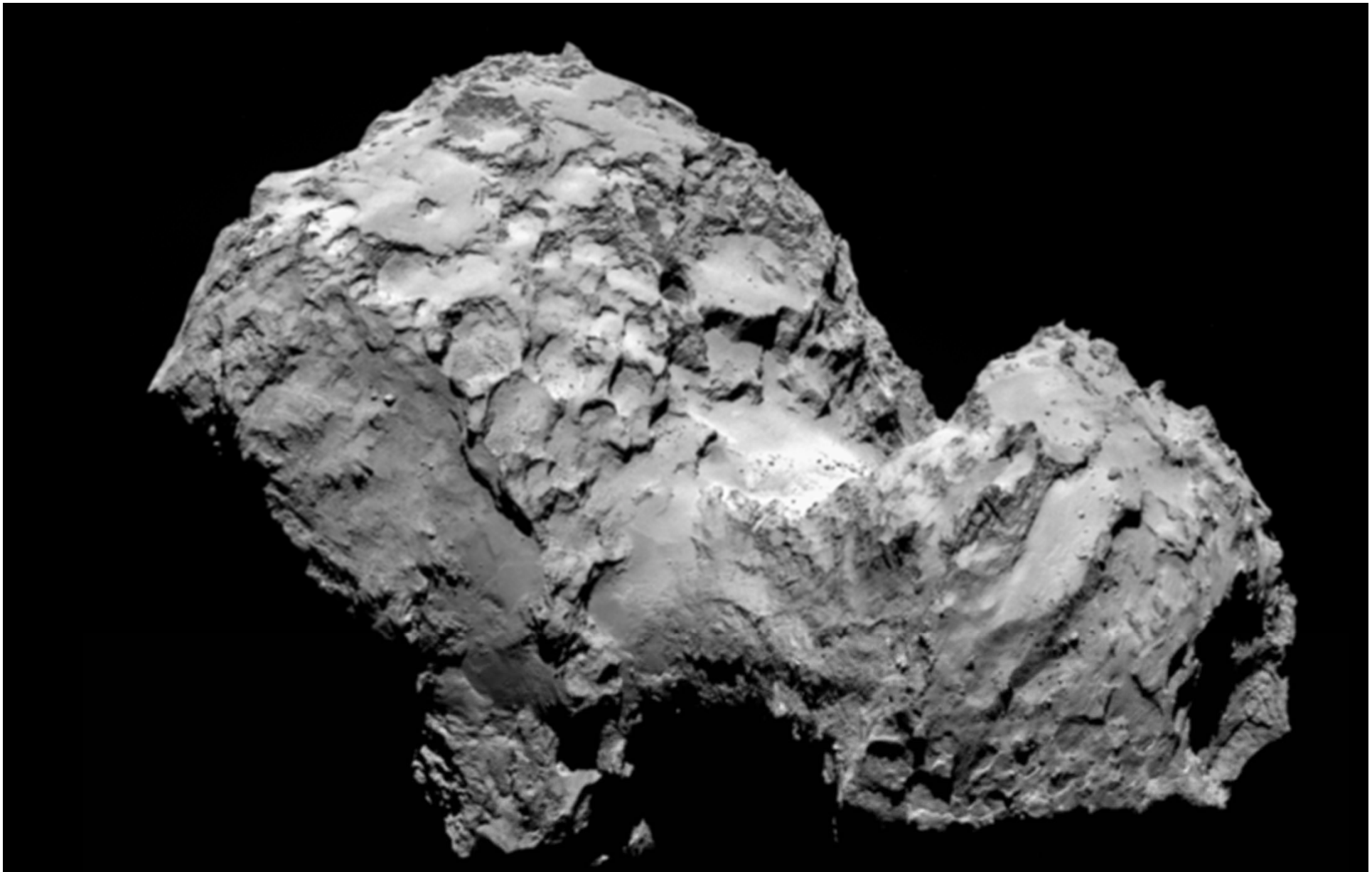
Comet 67P/C-G imaged on 14 July 2014 from a distance of approximately 12 000 km.
Credits: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA



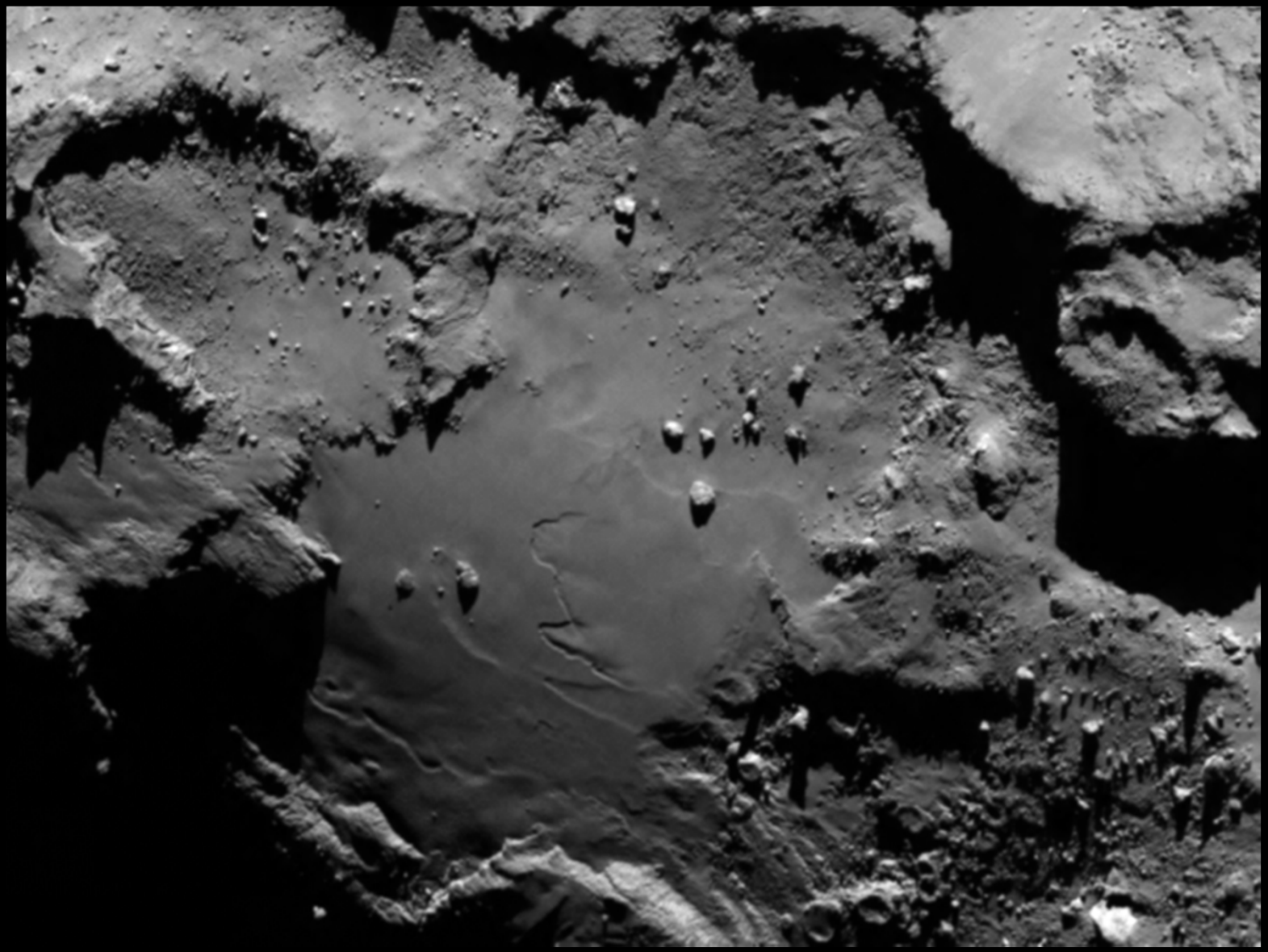
July 20th from a distance of 5,500 km, comet 67P/Churyumov-Gerasimenko's largest features are beginning to stand out in the OSIRIS narrow angle camera view.



OSIRIS narrow angle camera view of 67P/C-G from a distance of 1000 km on 1 August 2014.
Credits: ESA/Rosetta/MPS for OSIRIS Team PS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

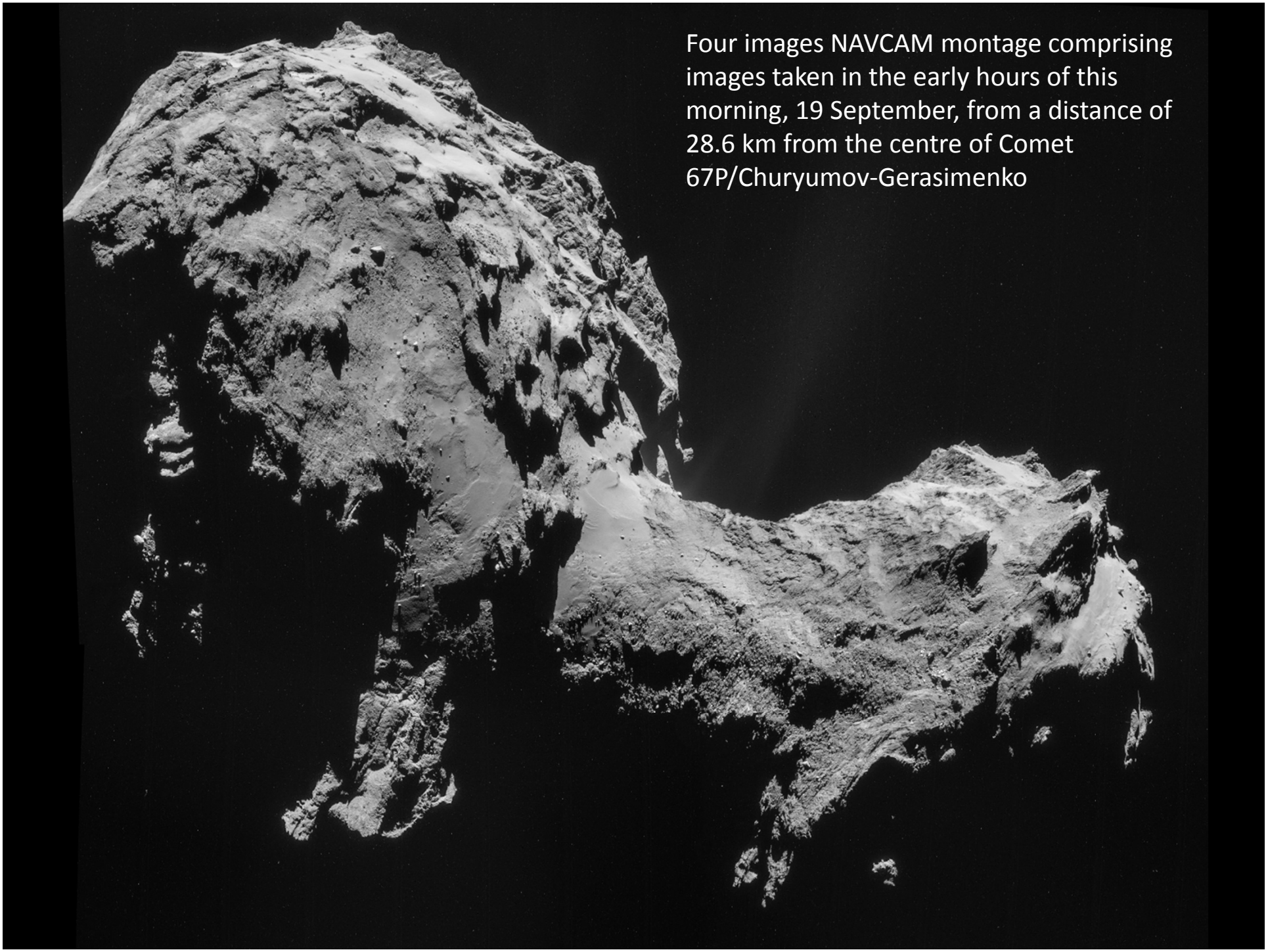


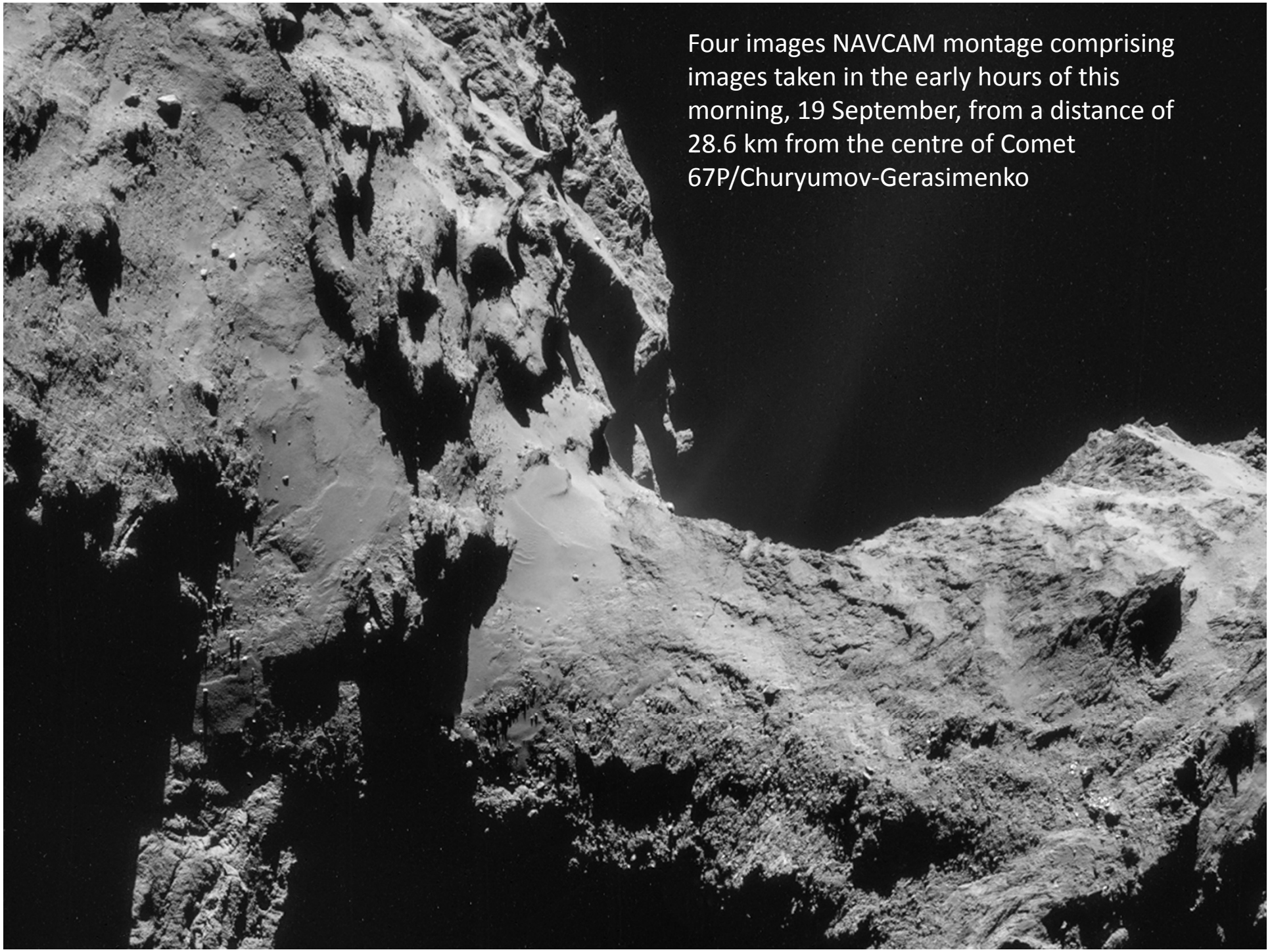
The image shows Comet 67P/Churyumov-Gerasimenko by Rosetta's OSIRIS narrow-angle camera on 3 August from a distance of 285 km. The image resolution is 5.3 metres/pixel. The image was exposed for 1.6 seconds. It is unprocessed, just brightness scaled.



This image, focusing on a smooth region on the ‘base’ of the ‘body’ section of comet 67P/C-G, was taken by Rosetta’s OSIRIS narrow-angle camera, 6 August 2014. The image clearly shows a range of features, including boulders, craters and steep cliffs. It was taken from a distance of 130 km and the image resolution is 2.4 meters per pixel

Rosetta navigation camera (NAVCAM) image taken on 21 August 2014 at a distance of about 69 km from comet 67P/C-G. Credits: ESA/Rosetta/NAVCAM.


Four images NAVCAM montage comprising images taken in the early hours of this morning, 19 September, from a distance of 28.6 km from the centre of Comet 67P/Churyumov-Gerasimenko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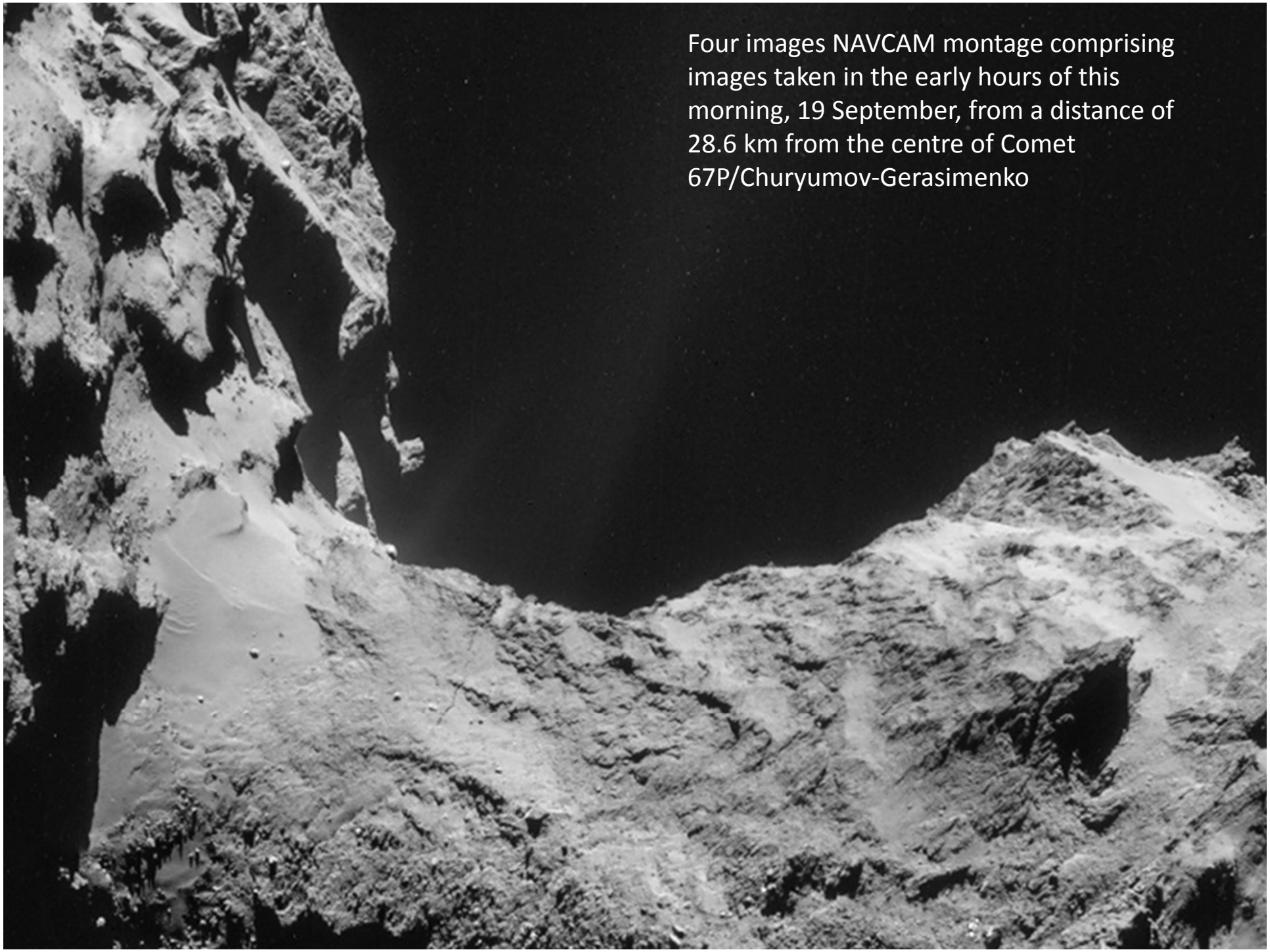
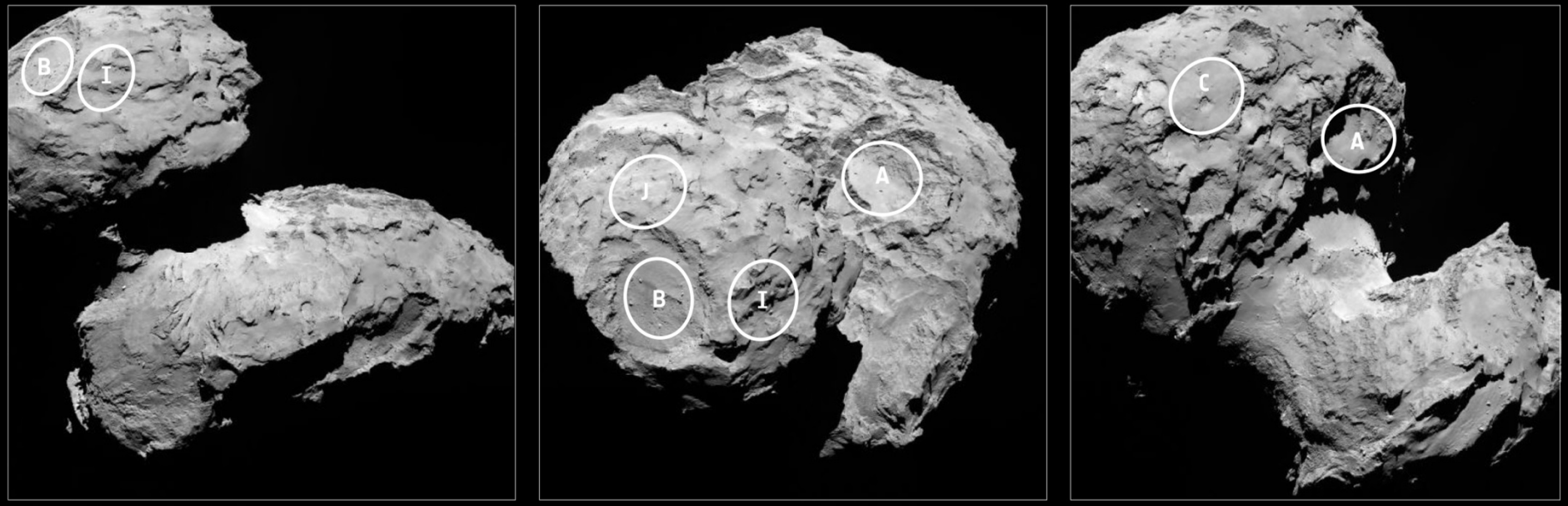
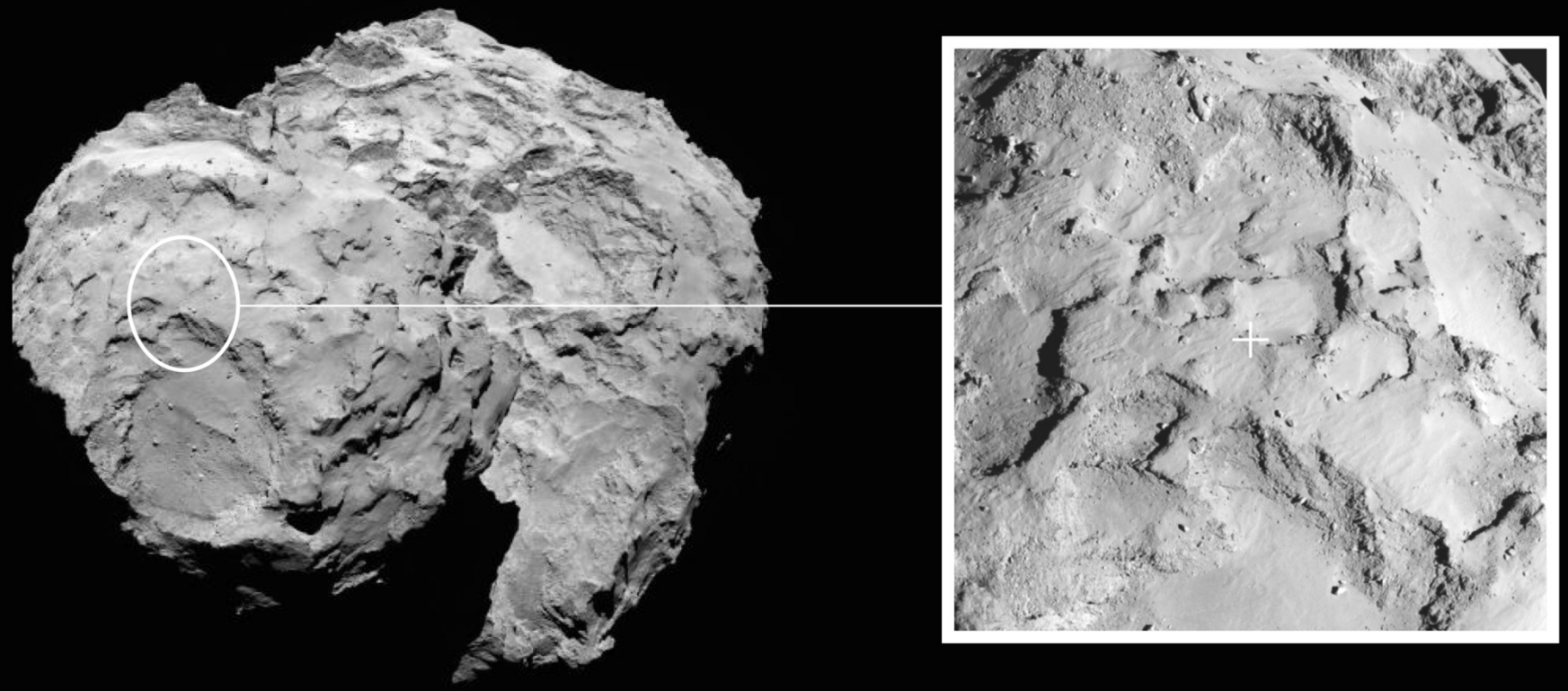

Four images NAVCAM montage comprising images taken in the early hours of this morning, 19 September, from a distance of 28.6 km from the centre of Comet 67P/Churyumov-Gerasimenko

Sélection du site d’atterrissage



Five candidate sites were identified on Comet 67P/Churyumov-Gerasimenko during the Landing Site Selection Group meeting held 23–24 August 2014. The approximate locations of the five regions are marked on these OSIRIS narrow-angle camera images taken on 16 August from a distance of about 100 km. The comet nucleus is about 4 km across. The sites were assigned a letter from an original pre-selection of 10 possible sites identified A through J. The lettering scheme does not signify any ranking. Three sites (B, I and J) are located on the smaller of the two lobes of the comet and two sites (A and C) are located on the larger lobe.
Credits: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

→ PHILAE'S LANDING SITE



Atterrissage le 12 Novembre 2014

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

Close-up of Philae's primary landing site J, which is located on the 'head' of Comet 67P/Churyumov–Gerasimenko. The image was taken by Rosetta's OSIRIS narrow-angle camera on 20 August 2014 from a distance of about 67 km. The image scale is 1.2 metres/pixel.

Site J offers the minimum risk to the lander in comparison to the other candidate sites, and is also scientifically interesting, with signs of activity nearby. At Site J, the majority of slopes are less than 30º relative to the local vertical, reducing the chances of Philae toppling over during touchdown. Site J also appears to have relatively few boulders and receives sufficient daily illumination to recharge Philae and continue science operations on the surface beyond the initial battery-powered phase.

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

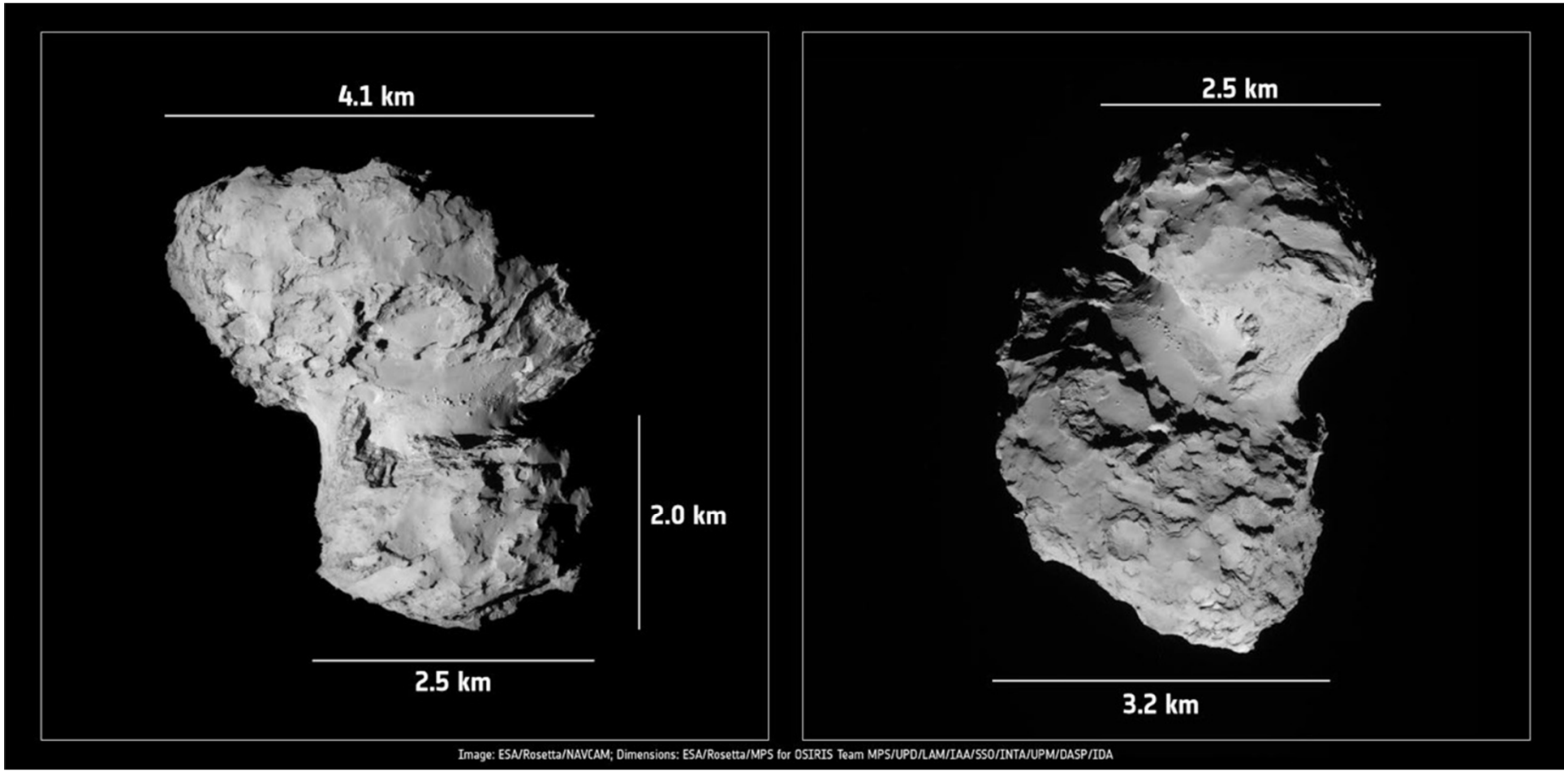
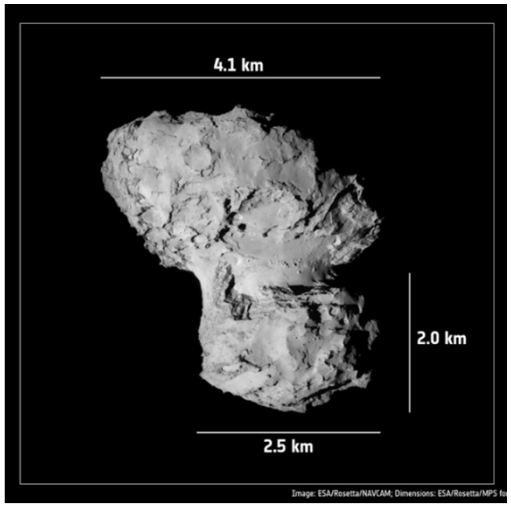
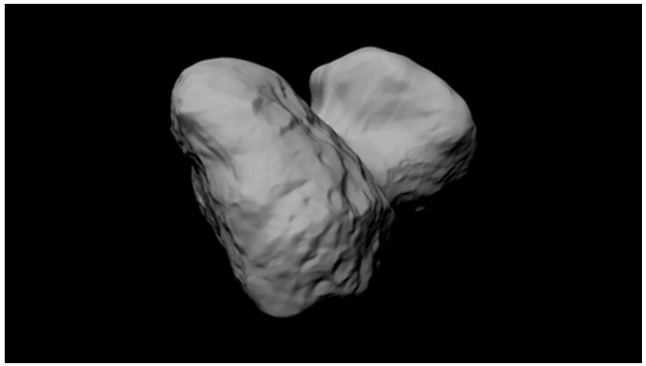


Image: ESA/Rosetta/NAVCAM; Dimensions: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA





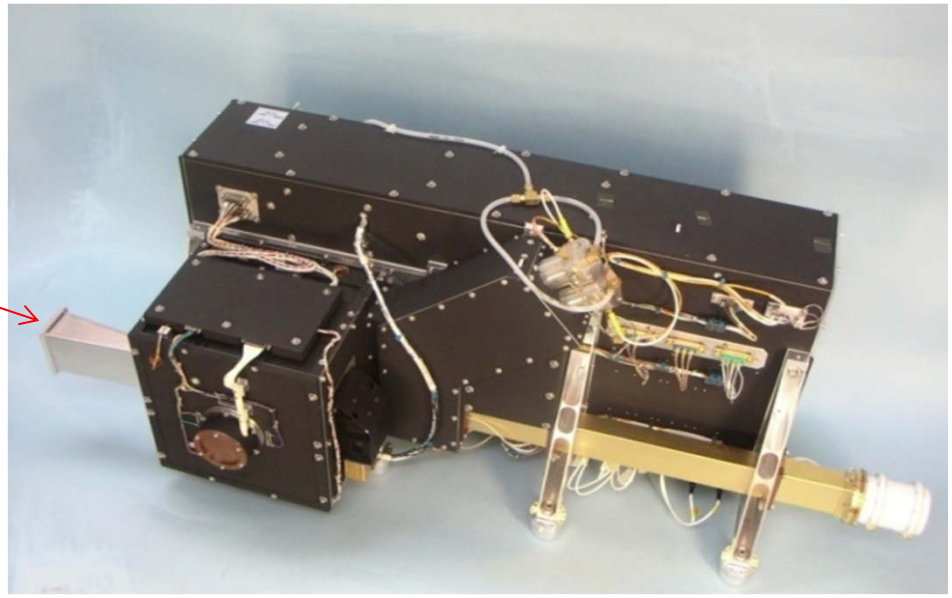
Dimensions (small lobe)	2.5 x 2.5 x 2.0 km	OSIRIS
Dimensions (large lobe)	4.1 x 3.2 x 1.3 km	OSIRIS
Rotation	12.4043 hours	OSIRIS
Spin axis	Right ascension: 69 degrees; Declination: 64 degrees	OSIRIS
Mass	10^13 kg	RSI
Volume	25 km^3	OSIRIS
Density	0.4 g/cm^3	RSI / OSIRIS
Water vapour production rate	300 ml/sec (Jun 2014); 1–5 l/sec (Jul-Aug 2014)	MIRO
Surface temperature	205–230K (Jul-Aug 2014)	VIRTIS
Subsurface temperature	30–160K (Aug 2014)	MIRO
Gases detected	Water, carbon monoxide, carbon dioxide, ammonia, methane, methanol	ROSINA
Dust grains	A few tens of microns to a few hundreds of microns	COSIMA (detections also by GIADA)

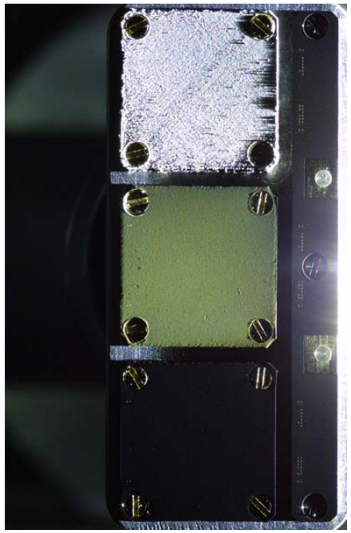
COSIMA (COmetary Secondary Ion Mass Analyzer)

Instrument équipé d'un **TOF-SIMS** = Time Of Flight- Secondary Ion Mass Spectrometer

Son but est d'identifier la composition moléculaire, élémentaire et isotopique des grains cométaires collectés.

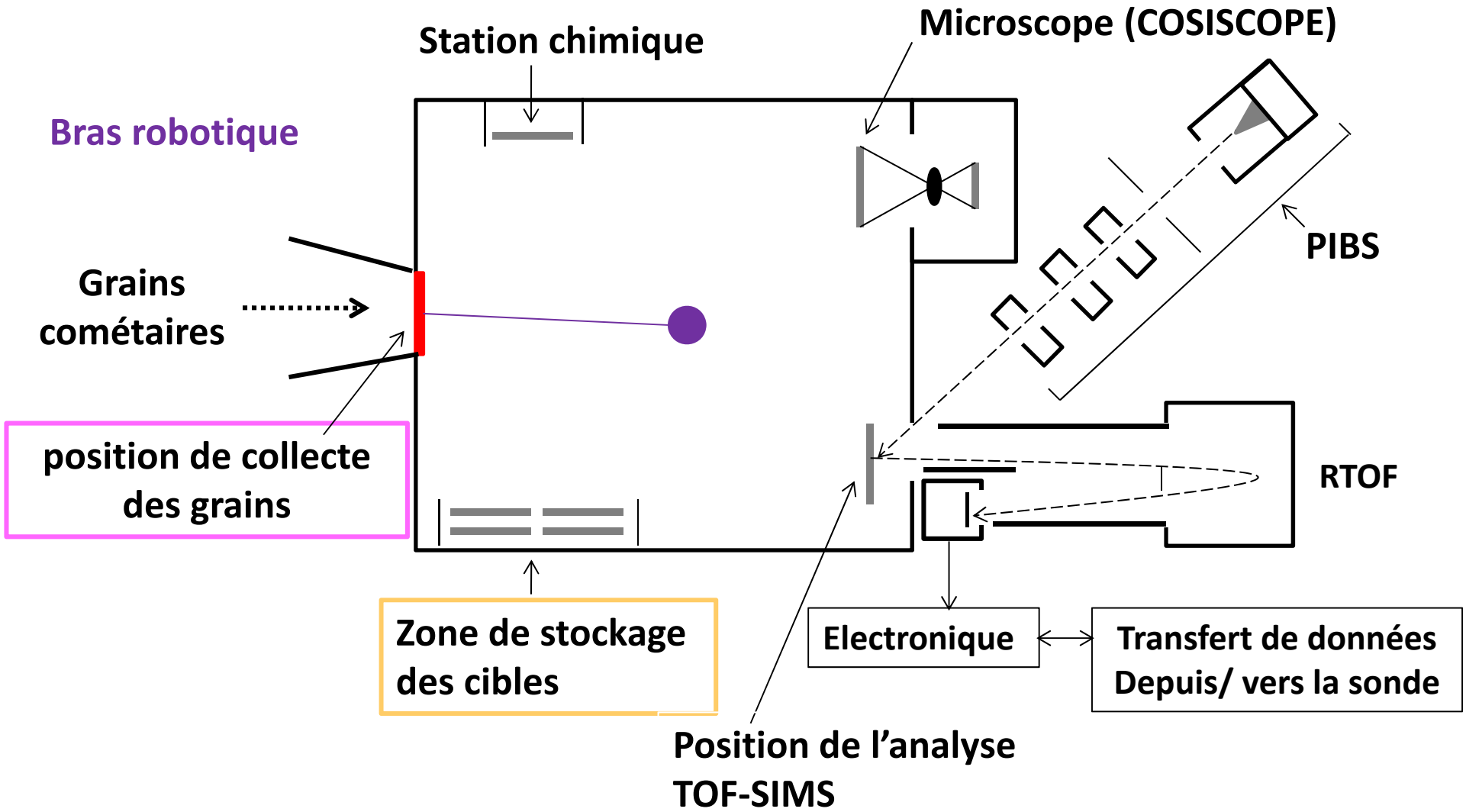
Entrée des grains cométaires





Il va collecter les grains cométaires sur différents types de cibles métalliques (Or, argent, platine, palladium...)

Schéma de principe de COSIMA



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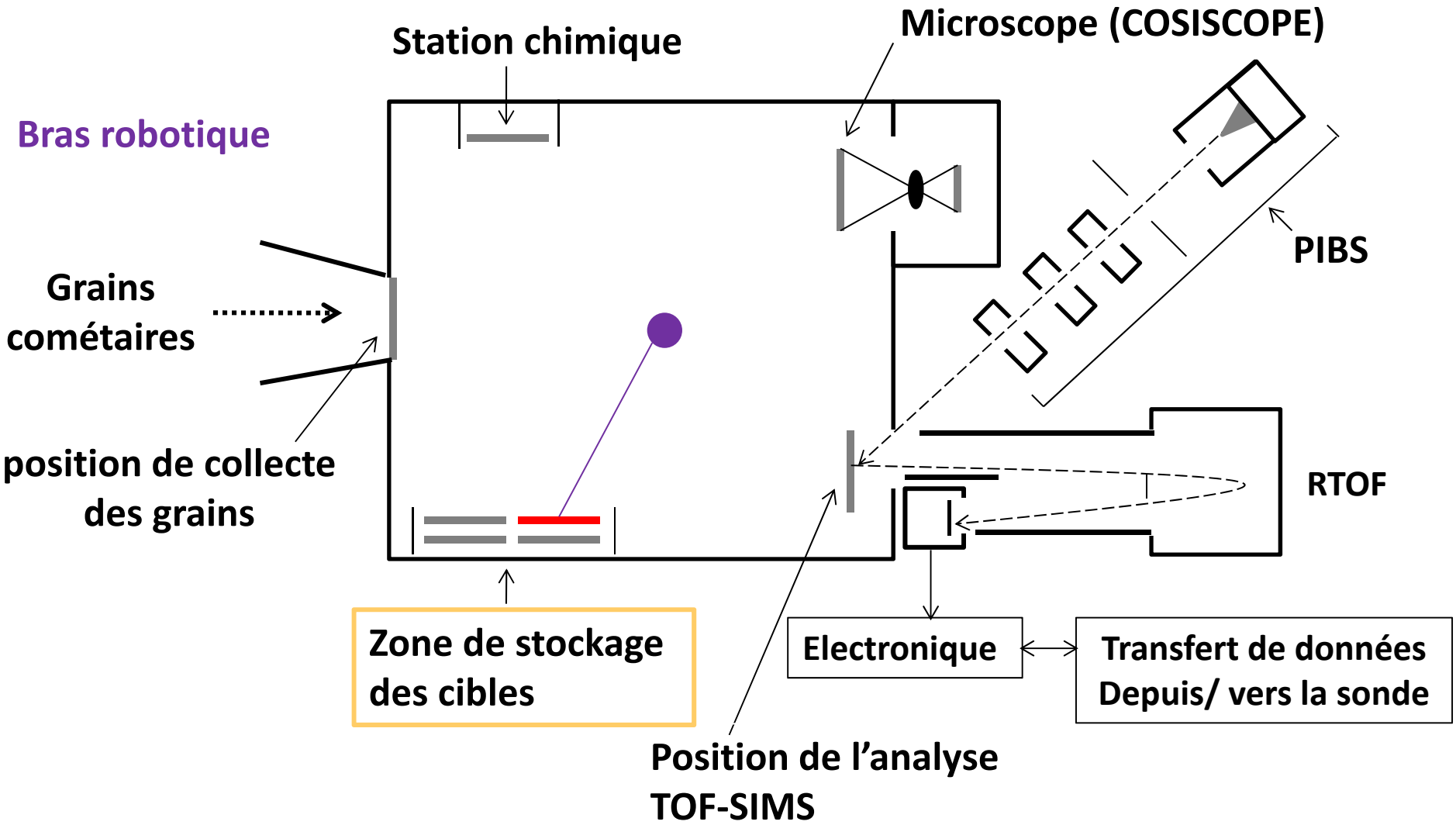

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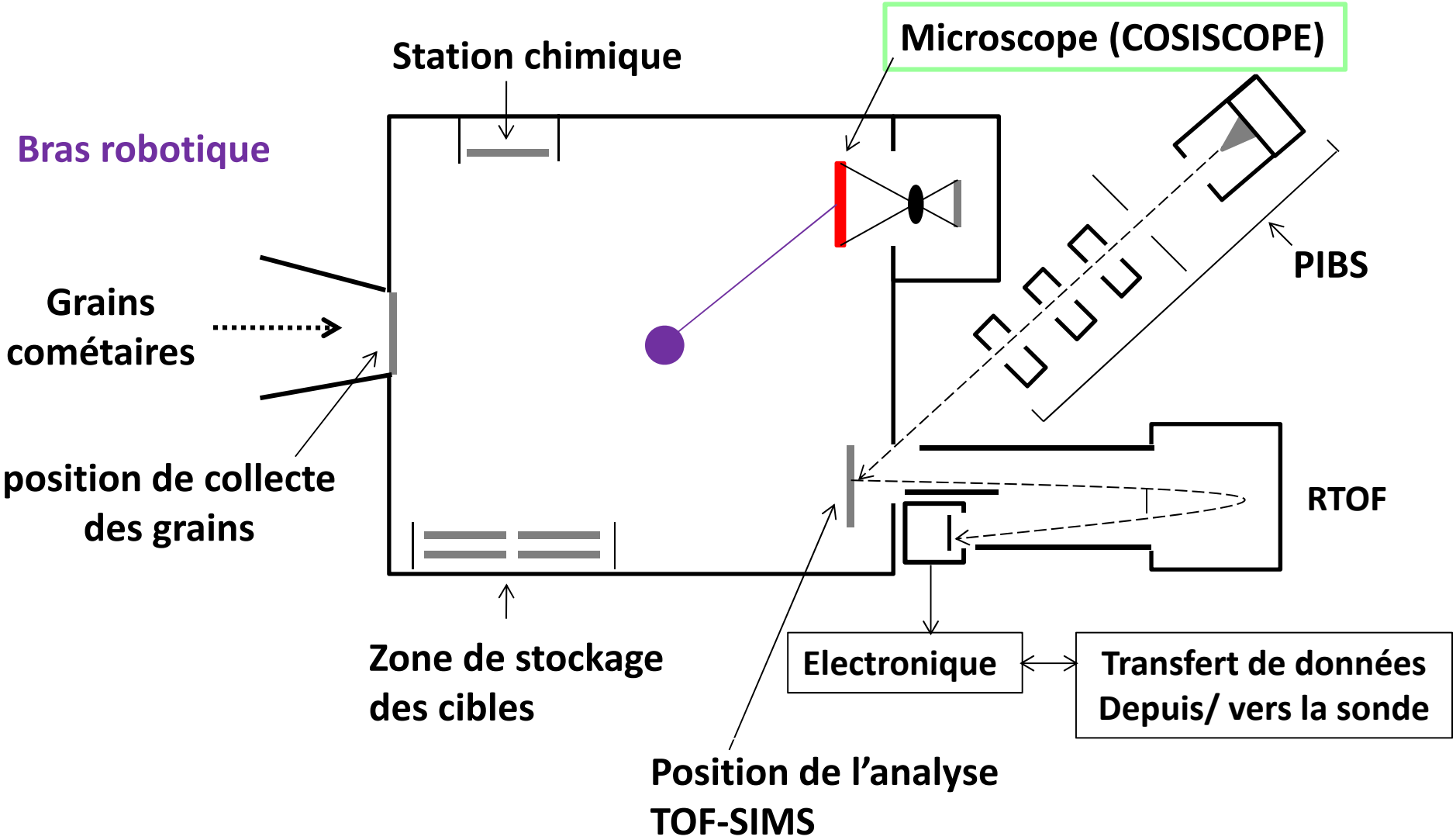


Schéma de principe de COSIMA

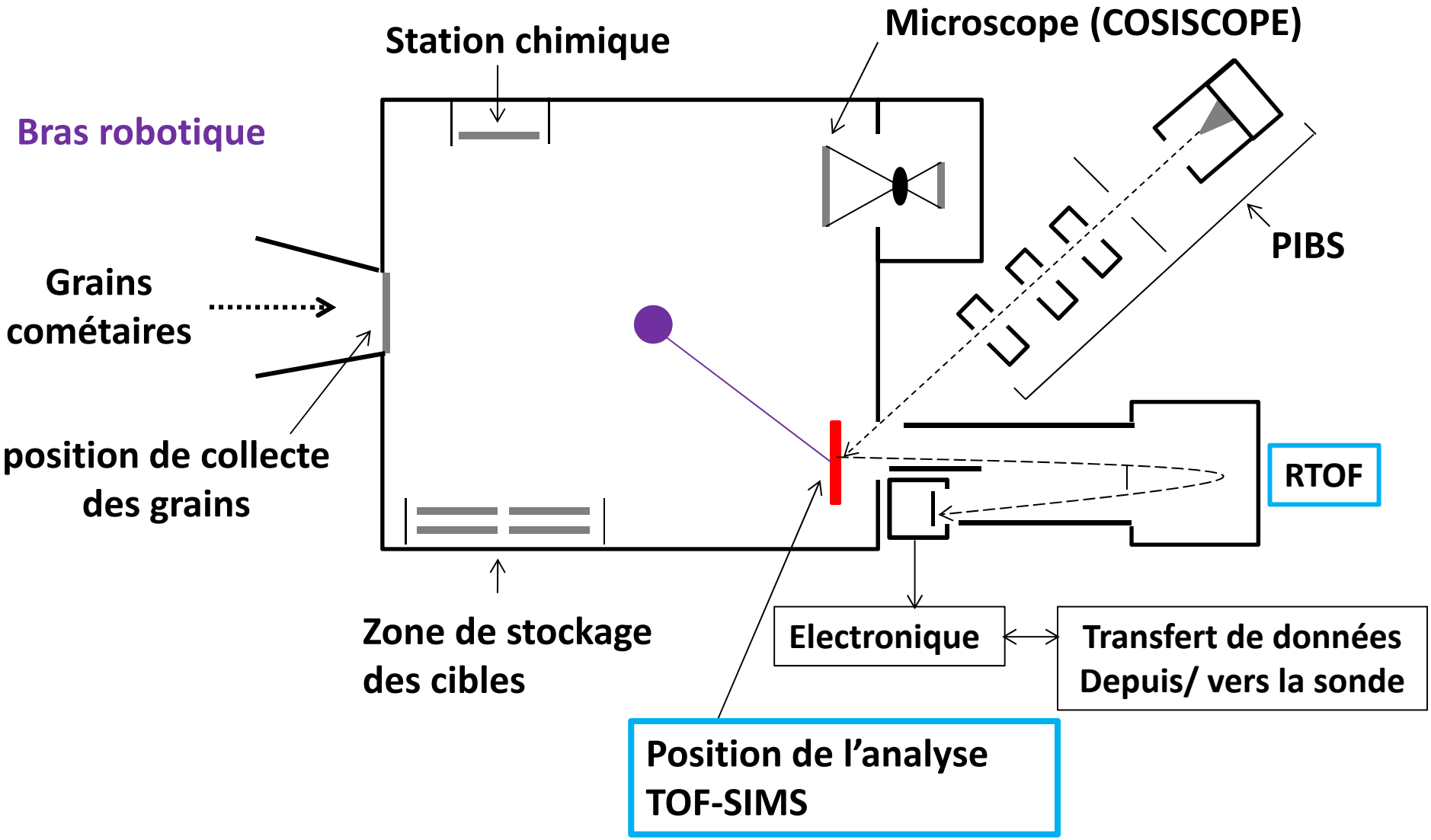
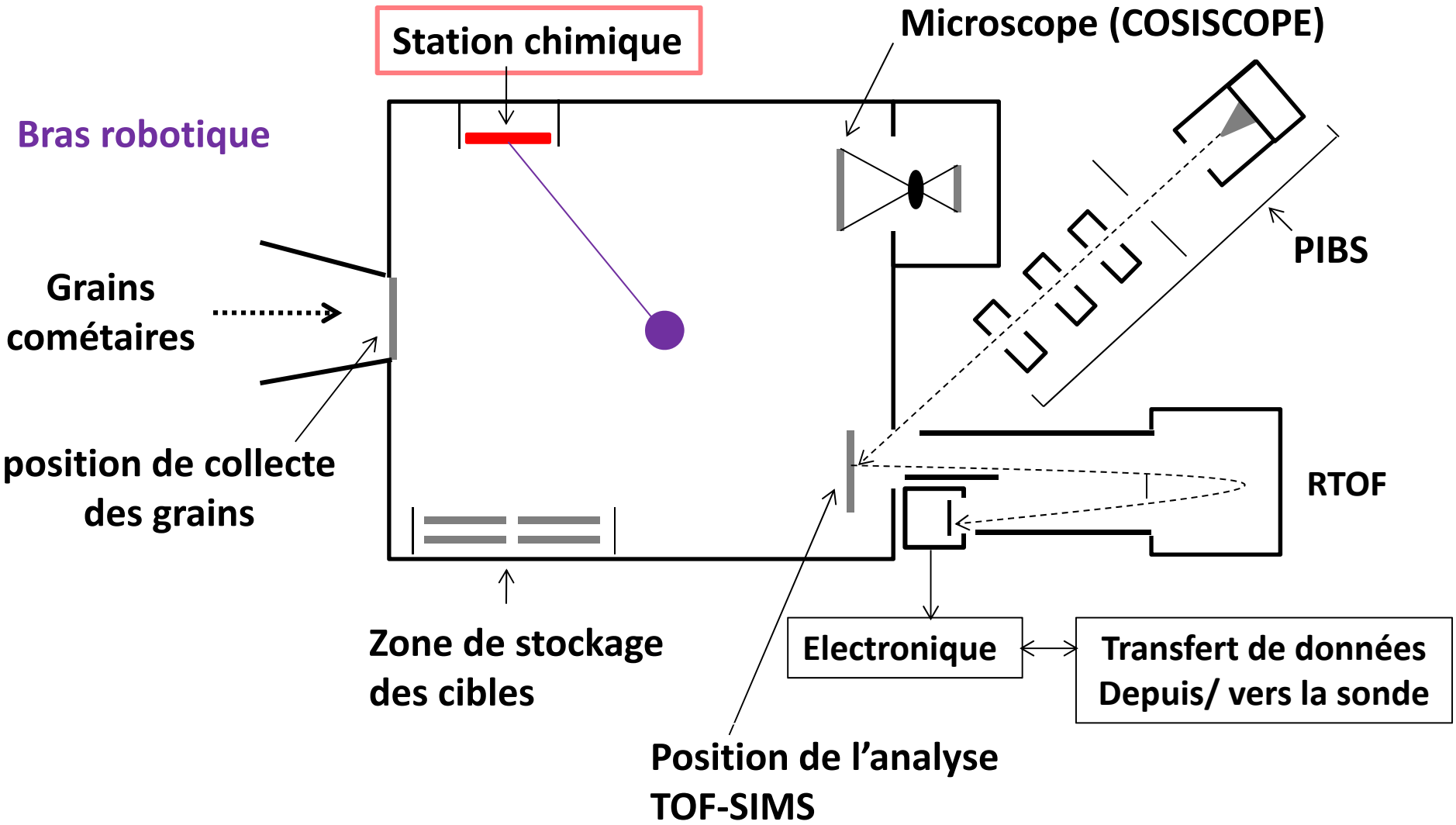
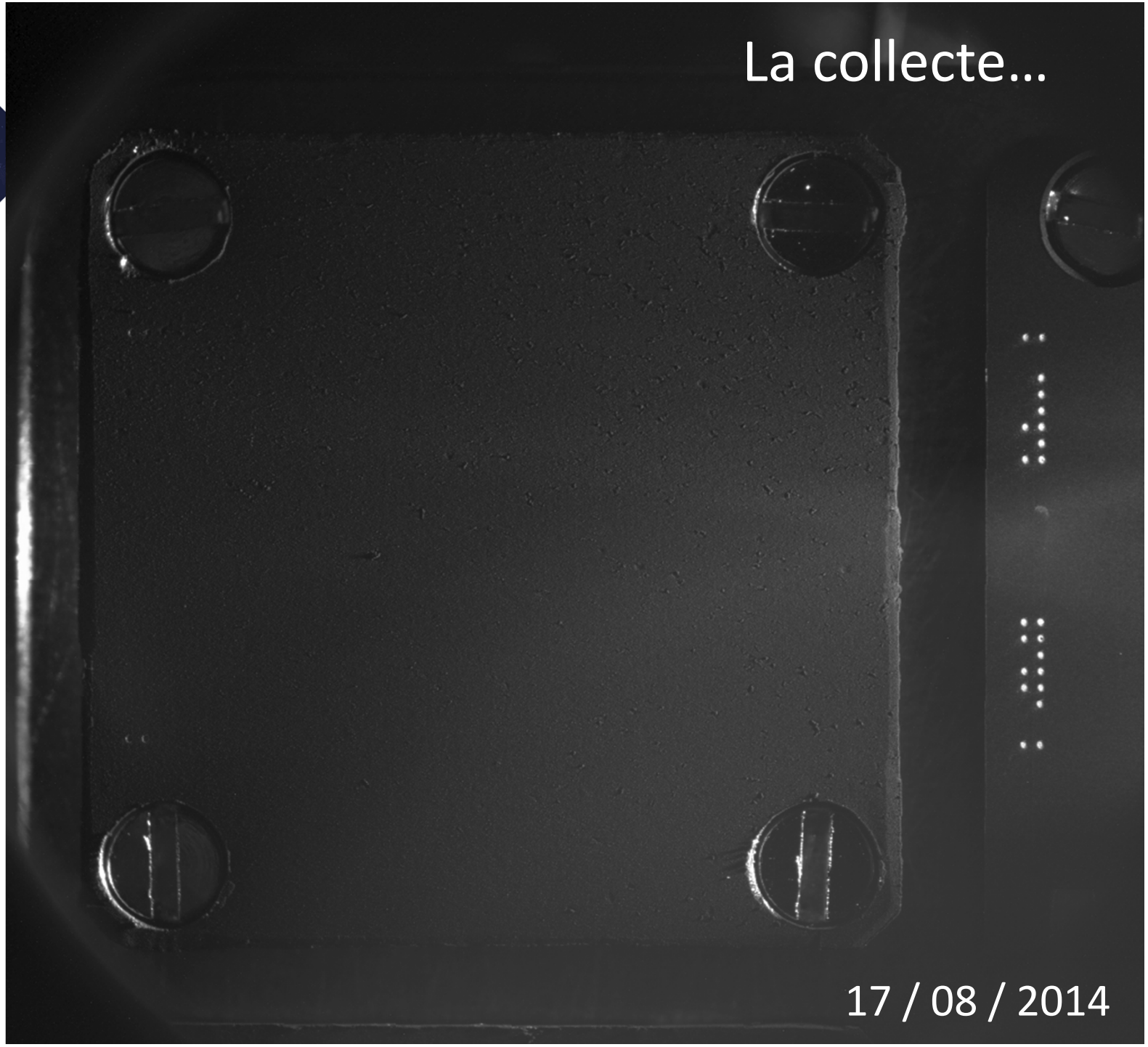
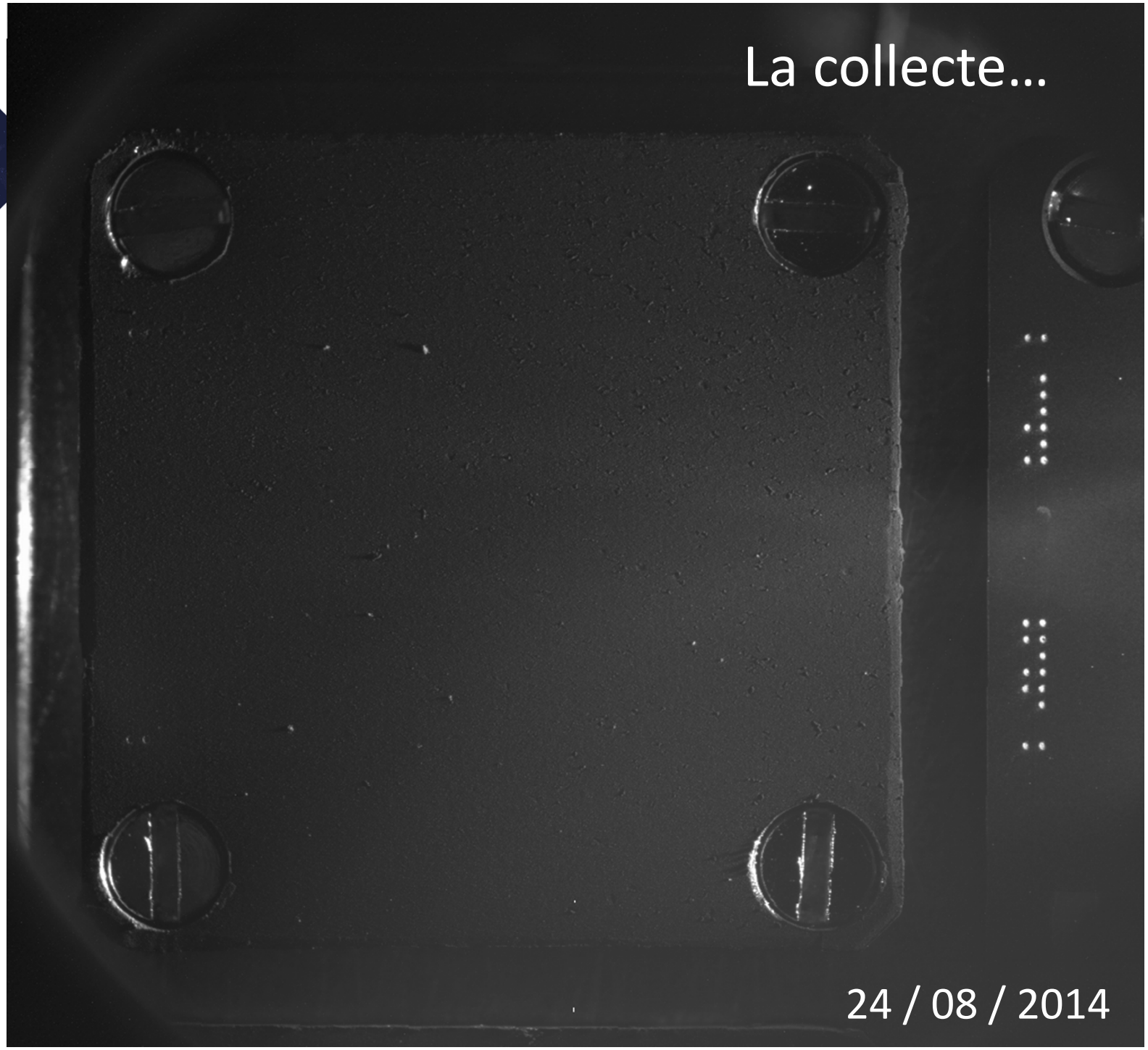


Schéma de principe de COSIMA




La collecte…
17 / 08 / 2014


La collecte…
24 / 08 / 2014

Conclusions

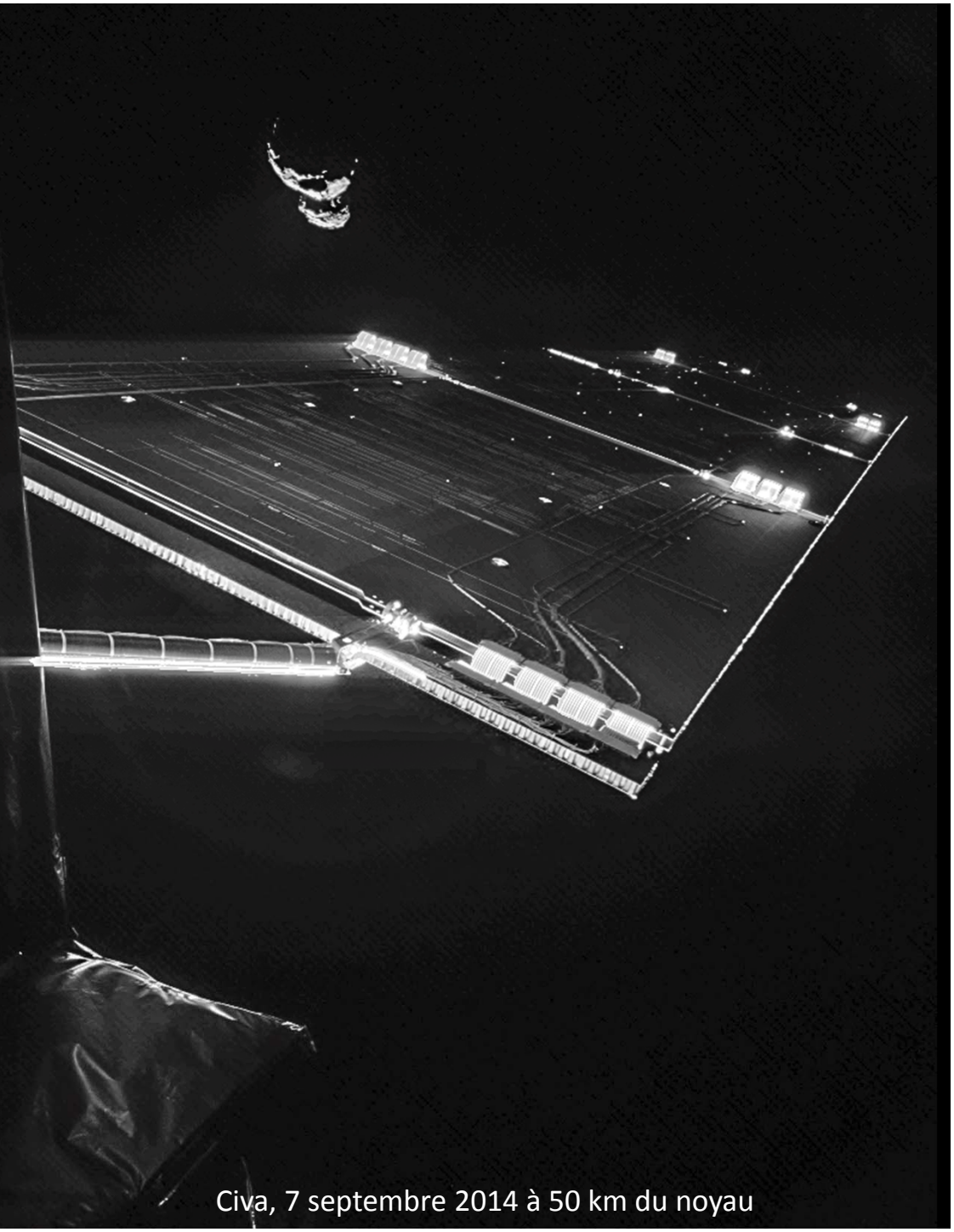
- ✓ 12 Novembre 2014 : Atterrissage de Philae sur le noyau

- ✓ Rosetta va suivre la comète au moins jusqu'à décembre 2015…

Les observations scientifiques ne font que commencer…

- ✓ Premières publications dans Science début Novembre…

- ✓ Toutes les nouvelles sont publiées ici : http://blogs.esa.int/rosetta/



Civa, 7 septembre 2014 à 50 km du noyau

ROSETTA n'est pas la première sonde spatiale cométaire

- ✓ **Véga 1 & Véga 2 :**
  - ✓ Survol de 1P/Halley à 8900 et 8000 km de distance, les 6 et 9 mars 1986

- ✓ **Giotto :**
  - ✓ Survol à 600 km de 1P/Halley le 14 mars 1986 (RH = 0.91 AU)

- ✓ **Deep Space 1 :**
  - ✓ Survol de 19P/Borelly le 22 septembre 2001 (RH = 1.6 AU)

- ✓ **Stardust :**
  - ✓ Survol à 236 km de 81P/Wild 2 le 2 Janvier 2004 (RH = 1.86 AU)
  - ✓ Retour d'échantillon, le 15 Janvier 2006

- ✓ **Deep Impact :**
  - ✓ Survol à 3000 km (+ impact) de 9P/Tempel 1 le 4 Juillet 2005 (RH = 1.54 AU)

- ✓ **Deep Impact a été rebaptisée Epoxi :**
  - ✓ Survol à 700 km de 103P/Hartley 2 le 4 novembre 2010 (RH = 1.06 AU)

- ✓ **Stardust a été rebaptisée Stardust-Next :**
  - ✓ Survol à 200 km de 9P/Tempel 1 le 14 février 2011