



**Enregistrement et référencement des données de
l'imageur haute définition OSIRIS,
embarqué sur la mission Rosetta/ESA**

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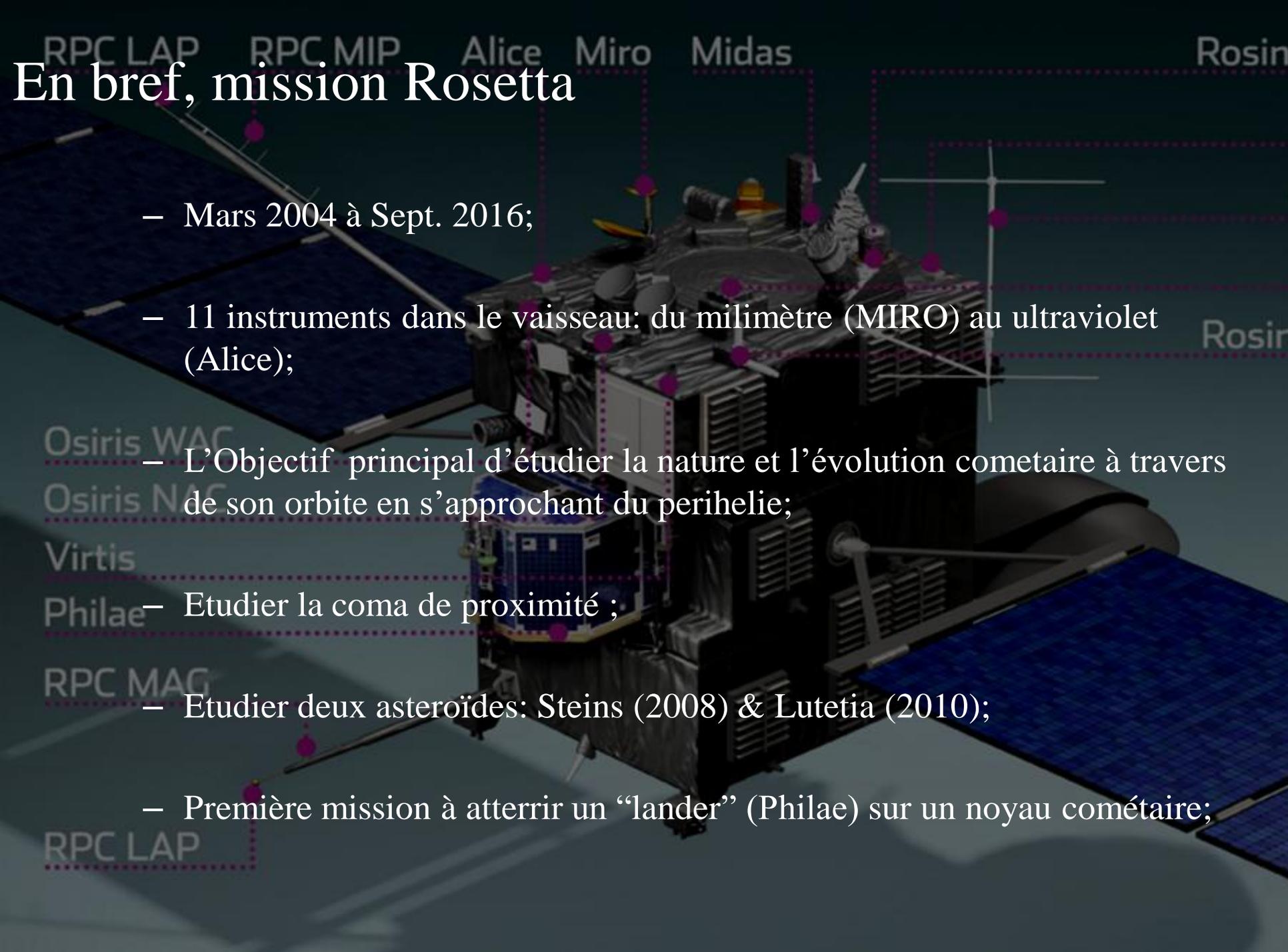
Deshapriya, J. D. P.

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En bref, mission Rosetta

- Mars 2004 à Sept. 2016;
- 11 instruments dans le vaisseau: du millimètre (MIRO) au ultraviolet (Alice);
- L'Objectif principal d'étudier la nature et l'évolution cométaire à travers de son orbite en s'approchant du perihelie;
- Etudier la coma de proximité ;
- Etudier deux astéroïdes: Steins (2008) & Lutetia (2010);
- Première mission à atterrir un "lander" (Philae) sur un noyau cométaire;



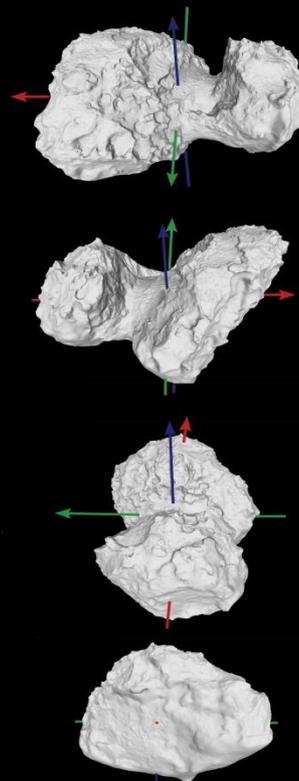
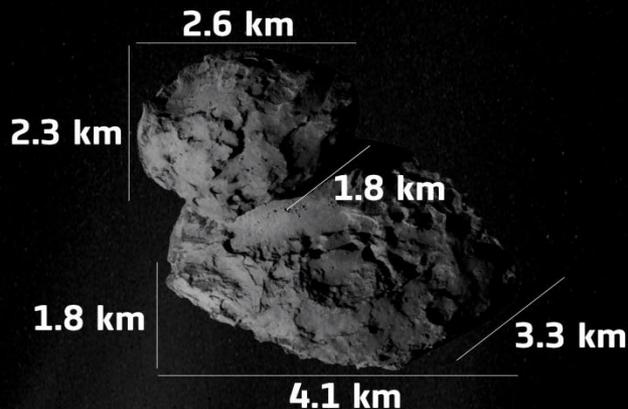
→ COMET 67P/CHURYUMOV–GERASIMENKO'S VITAL STATISTICS

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

OSIRIS, les yeux du vaisseau



→ ROSETTA'S OSIRIS INSTRUMENT IN NUMBERS

- **Système de deux camera d'haute définition:**
 - NAC (Champs Réduit) à 18.6 mrad/px
 - WAC (Champs vaste) à 101 mrad/px
 - Error < 2% (UV ~10%)
 - 98 mil images obtenues (76 mil de la comète)
 - PI: Holger Sierks (MPS-MPI-Allemagne)

– **Objectif principal:**

- » phénomènes transitoires,
- » modèle de forme,
- » morphologie,
- » inhomogénéités spectrales

- > 98 219 images taken during entire mission
- > 76 308 images taken at comet
- > 150 225 shutter activations
- > 23 486 door operations
- > 129 000 filter/hand pass changes
- > 115 497 telecommands sent
- > 22 176 hours of operation

OSIRIS¹ WAC²

OSIRIS NAC³

– **Prob.:** jusqu'à 1000 images

→ Eff.

Majorité des séquences prises en raison de la résolution de 0.25 à 1 m
14 filtres de 0.25 à 0.72 µm
Majorité des séquences prises en raison de la résolution de 0.25 à 1 m

¹ Optical, Spectroscopic, and Infrared Remote Imaging System

² Wide-Angle Camera

³ Narrow-Angle Camera

OSIRIS, les yeux du vaisseau



→ ROSETTA'S OSIRIS

- Système de deux camera d haute def
- NAC (Champs Réduit) à 18.

MISSION: To image the comet's nucleus and its gas and dust coma

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– Spectro-photometrie NUV-VIS-NIR:

- NAC: 22 combinaisons de filtres de 0.25 à 1 μm
- WAC: 14 filtres de 0.24 à 0.720 μm
- Majorité des sequences prises à 3 / 5 / 7 / 11 filtres

– Prob.: jusq

→ Eff

OSIRIS¹ WAC²

OSIRIS NAC³

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OSIRIS, les yeux du vaisseau



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OSIRIS¹ WAC²

OSIRIS NAC³

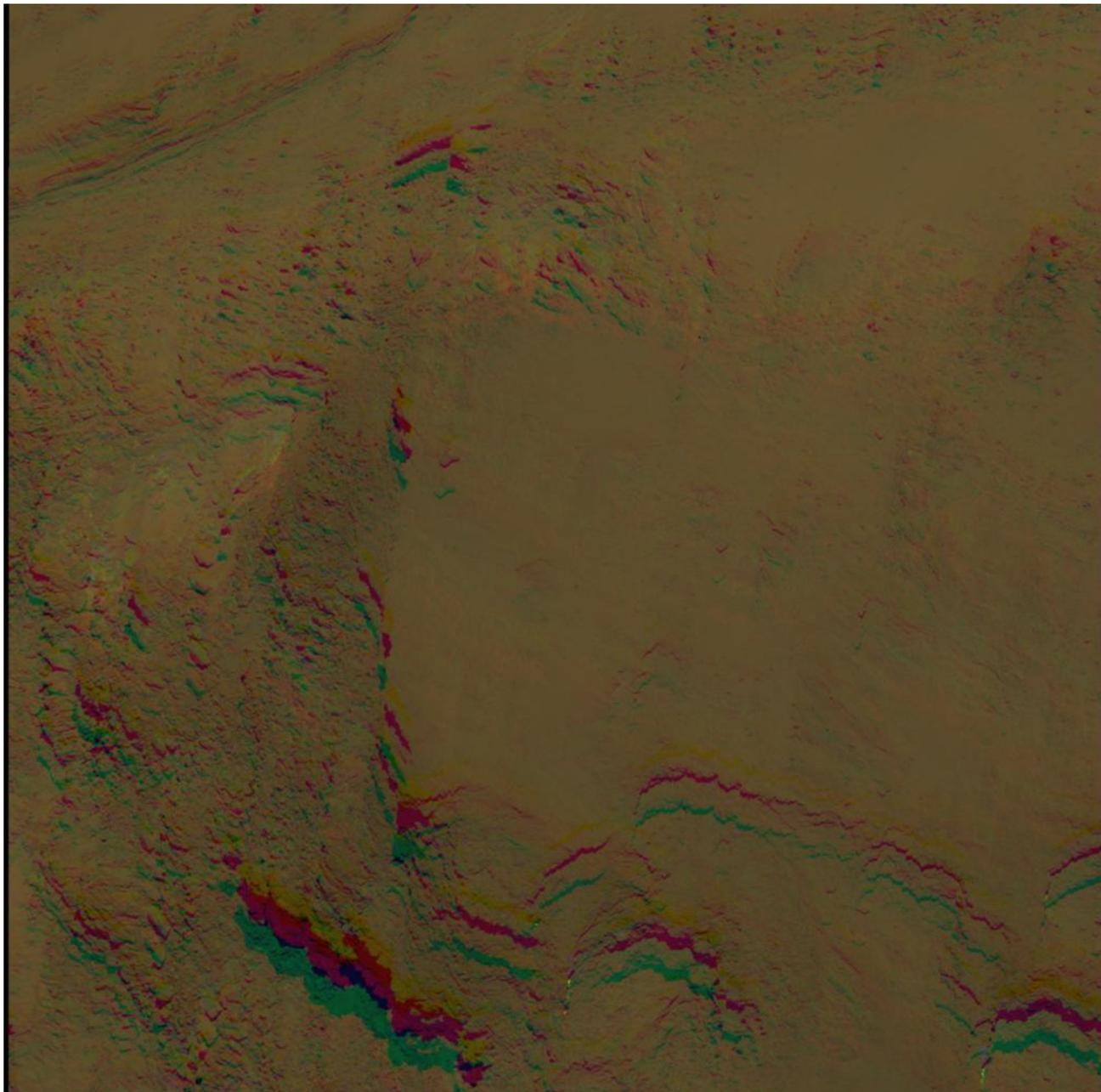
14 filtres de 0.25 à 1.0 micromètres
Majorité des sequences en 5 / 7

- **Prob.:** jusqu'à ~2.5 minutes pour obtenir toute la séquence
→ Effets de projection et mouvement!

¹ Optical, Spectroscopic, and Infrared Remote Imaging System
² Wide-Angle Camera
³ Narrow-Angle Camera



**ENREGISTREMENT DES
IMAGES**



STP103_FLYBY_001

NAC

2016-04T09T21.48

27 km altitude

0.5 m/px

$V = 1 \text{ m/s}$

11 filtres en 2m24s

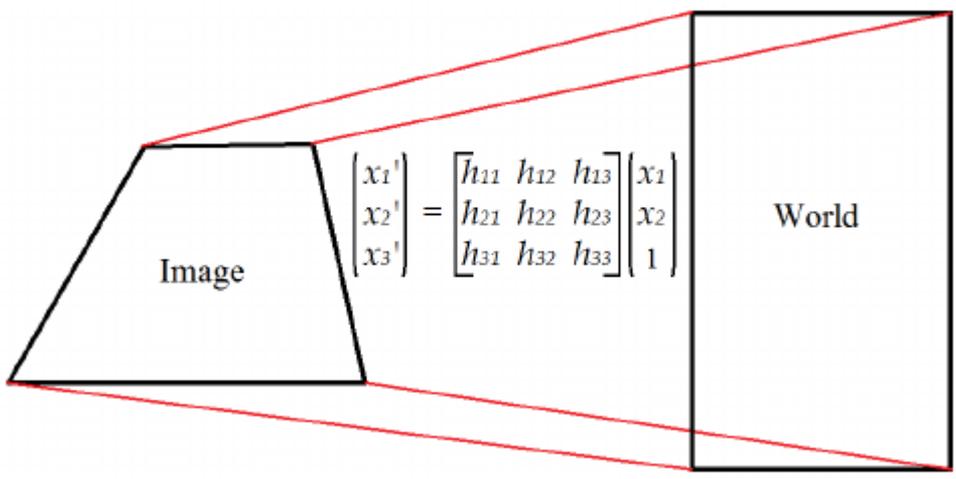
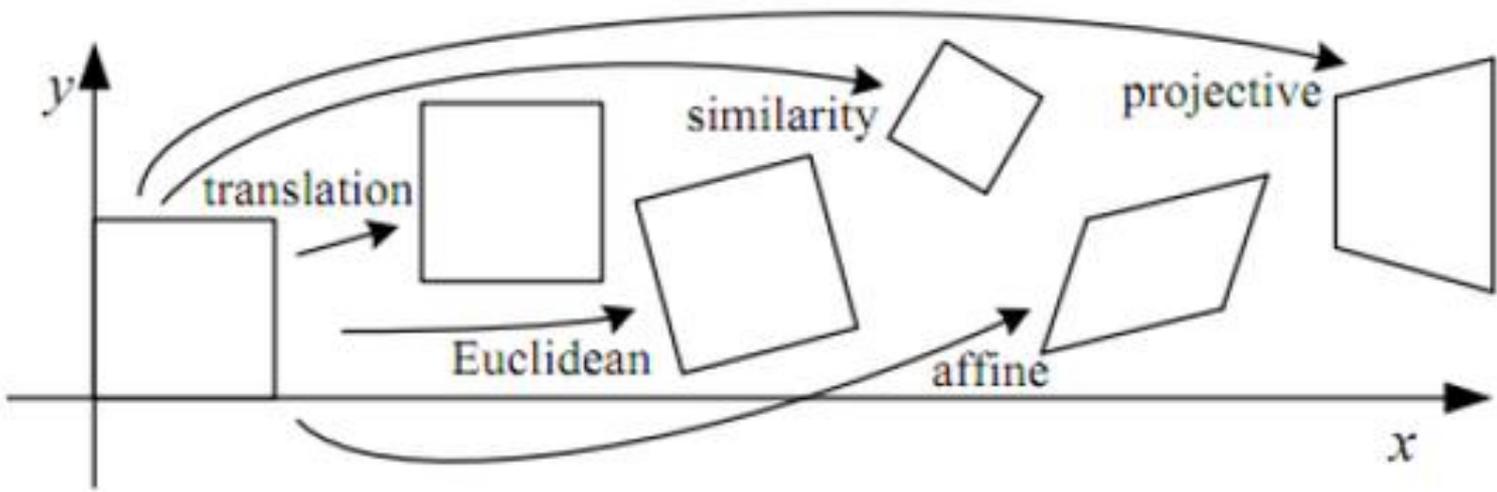
Defasage $\sim 180 \text{ m}$

Apis Wall.

Khonsu

Imhotep

Transformations homographiques

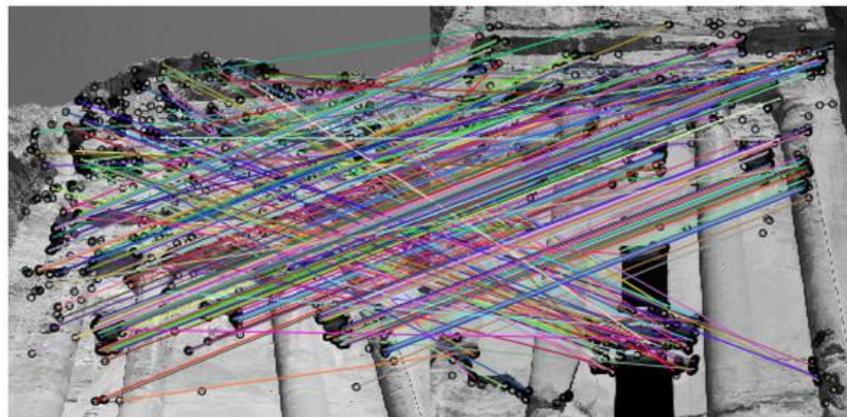




(a) Petra images



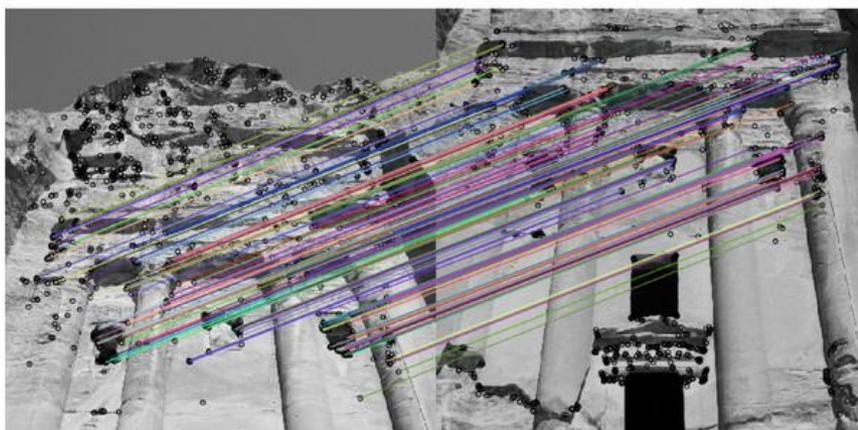
(d) Warped & positioned



(b) ORB binary features

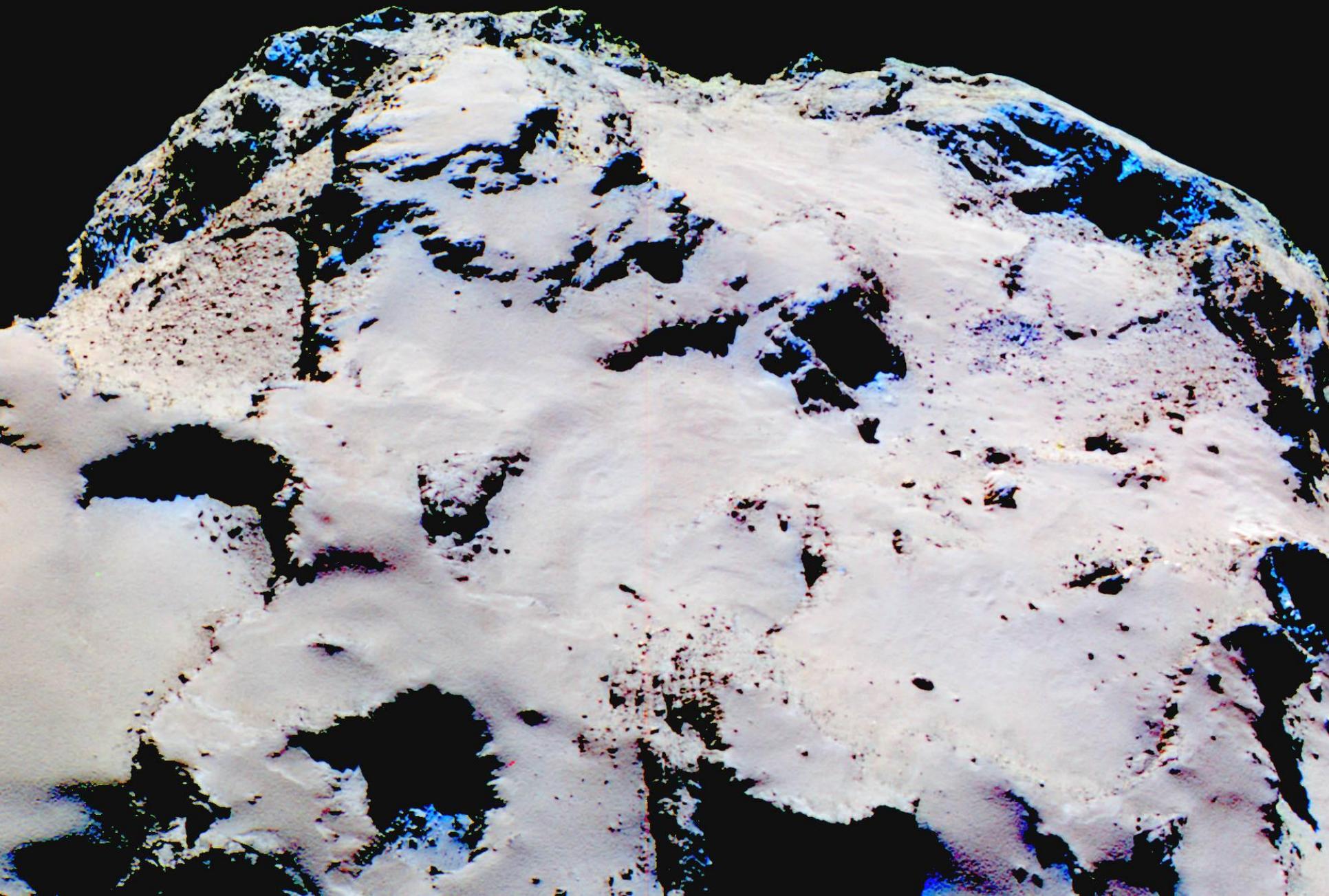


(e) Final result, combined with Enblend



(c) RANSAC-filtered features

Pour la plupart, ça fonctionne très bien (deplac. < 2 px)...

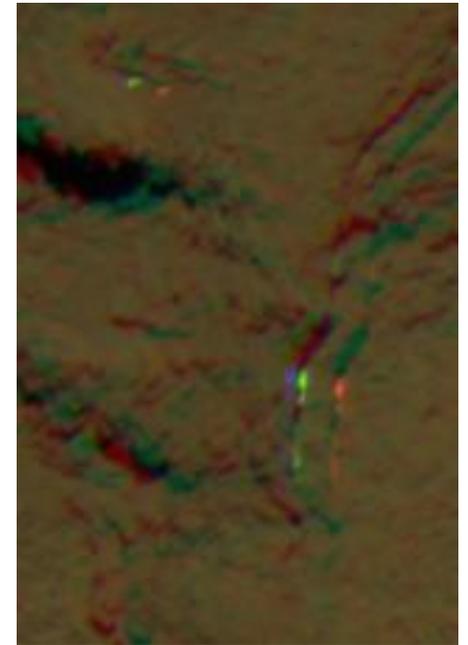


Transf. Projective ~2000 points



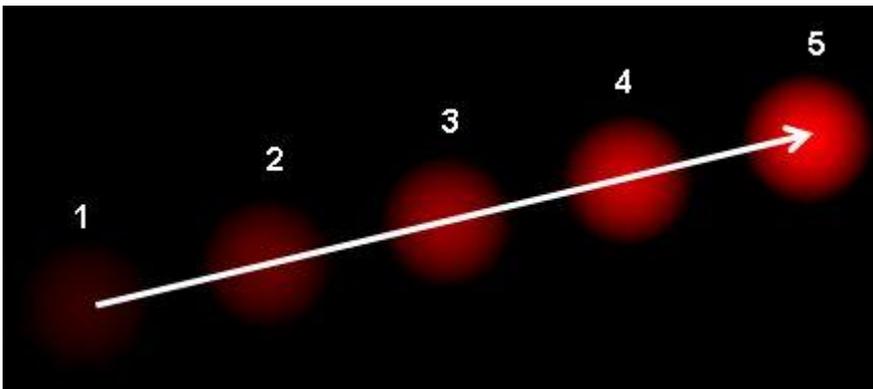
Information
perdu à cause
des obliquités et
déplacement.

RGB → Composé par
la première, milieu
et dernière image de
la séquence.

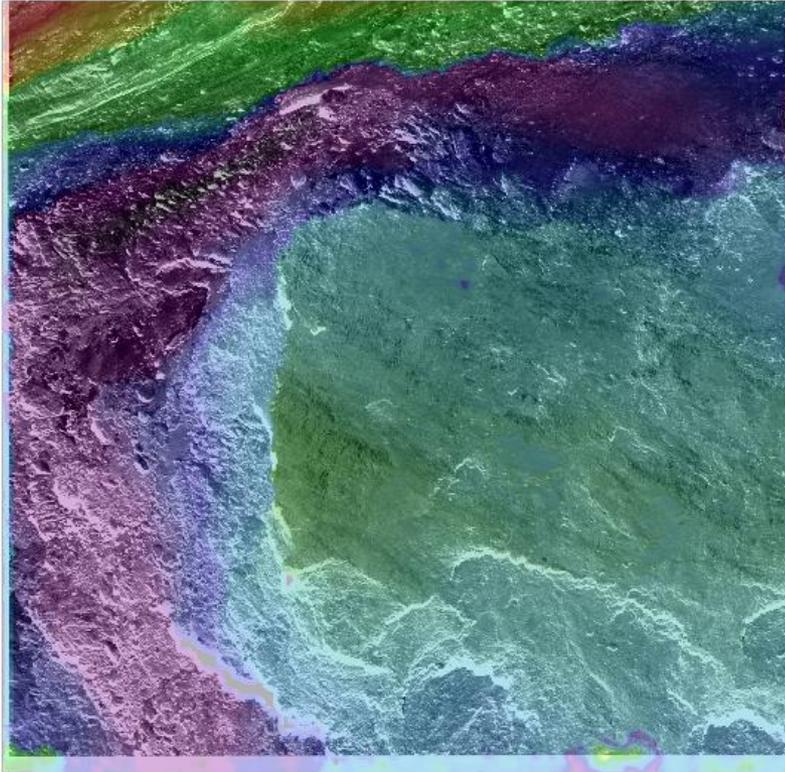


Enregistrement par flux optique

- En developpement/par demande
- Farnerback , G. (2003) → Flux dense
- Segmentation et enregistrement en morceaux individuellement
- Transf. de Similairité pour l'instant
- Hasselmann et al. (in prep.)
- Github (in prep.)



Magnitude



Shift

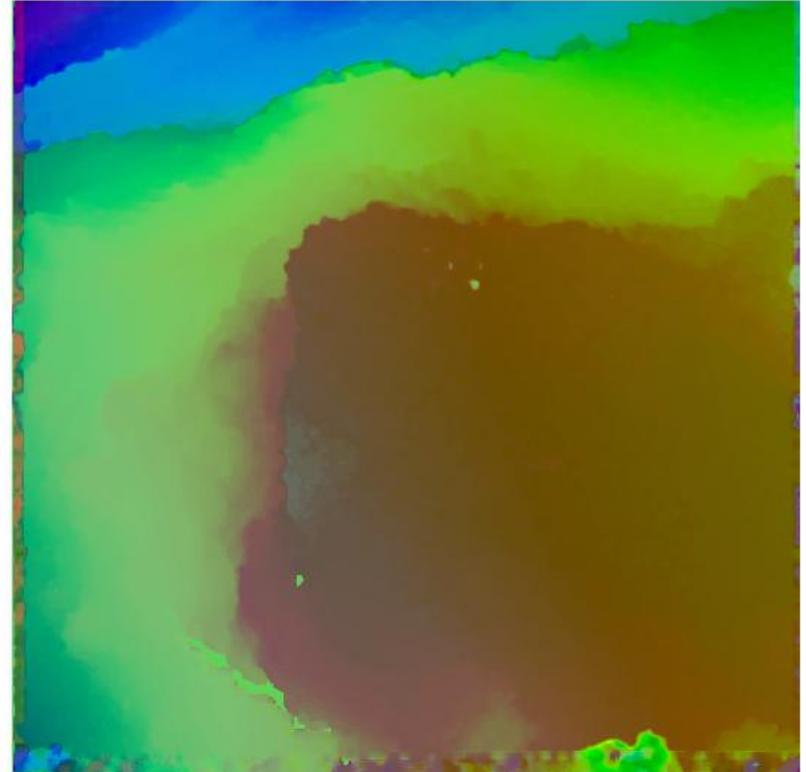
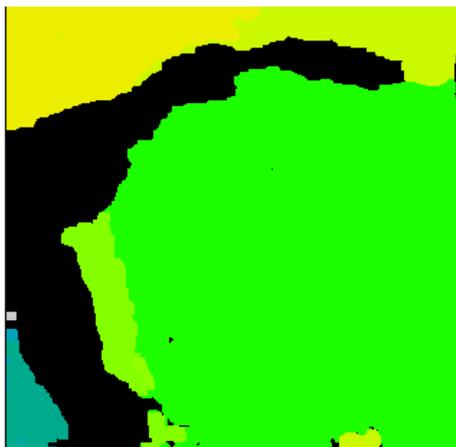
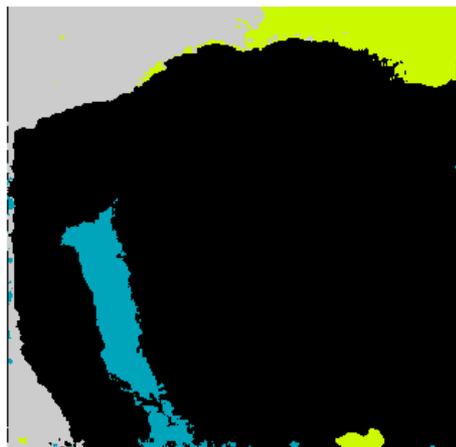


Image Référence \leftrightarrow Dernière image

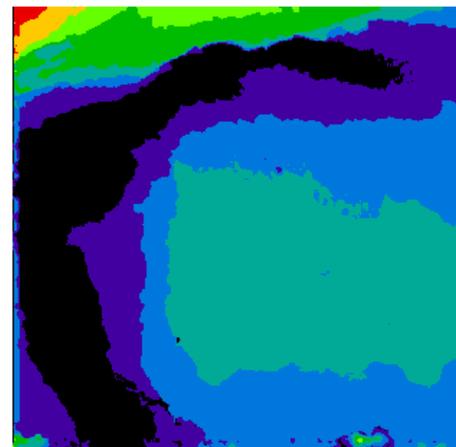
Labels

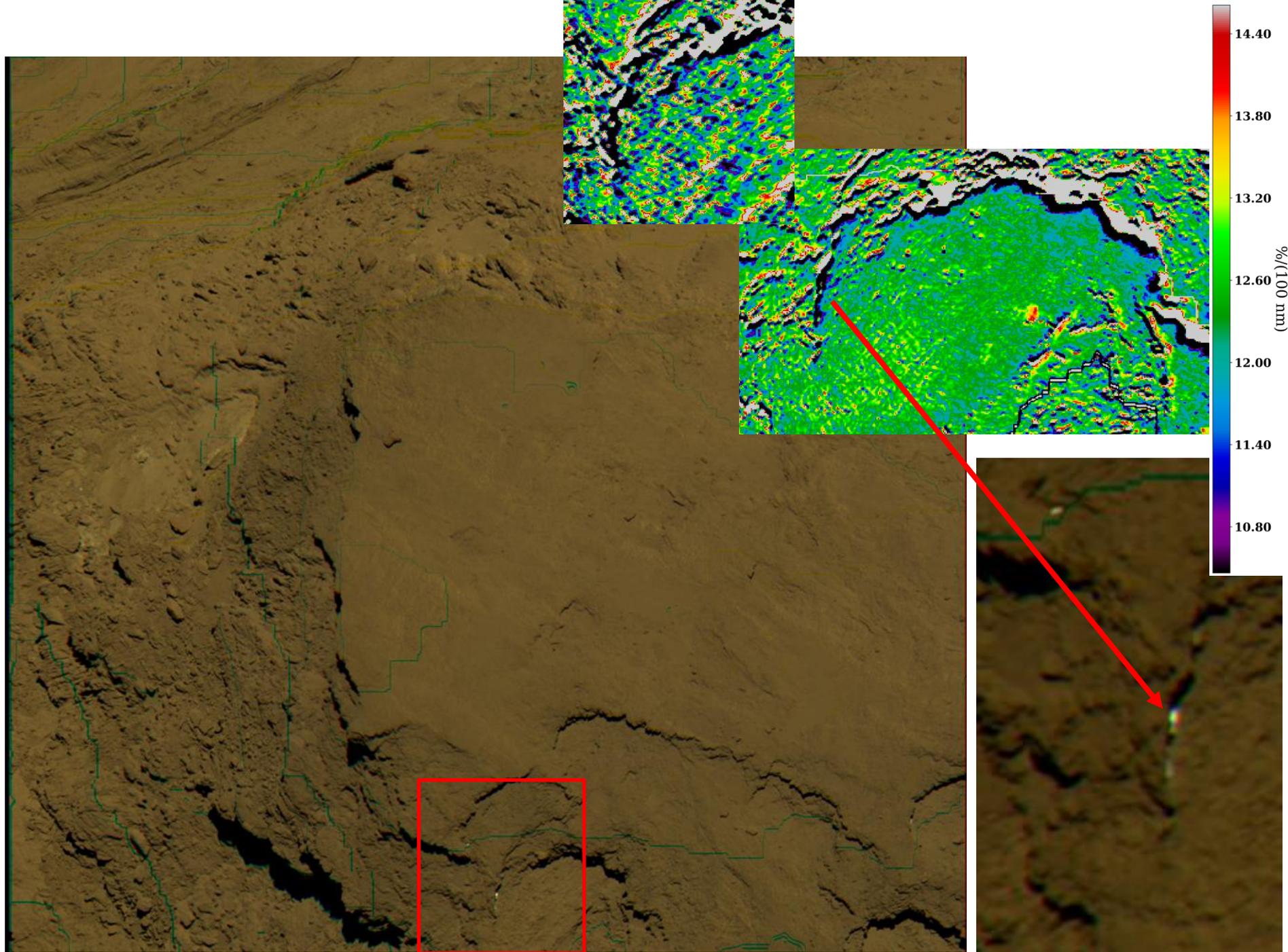


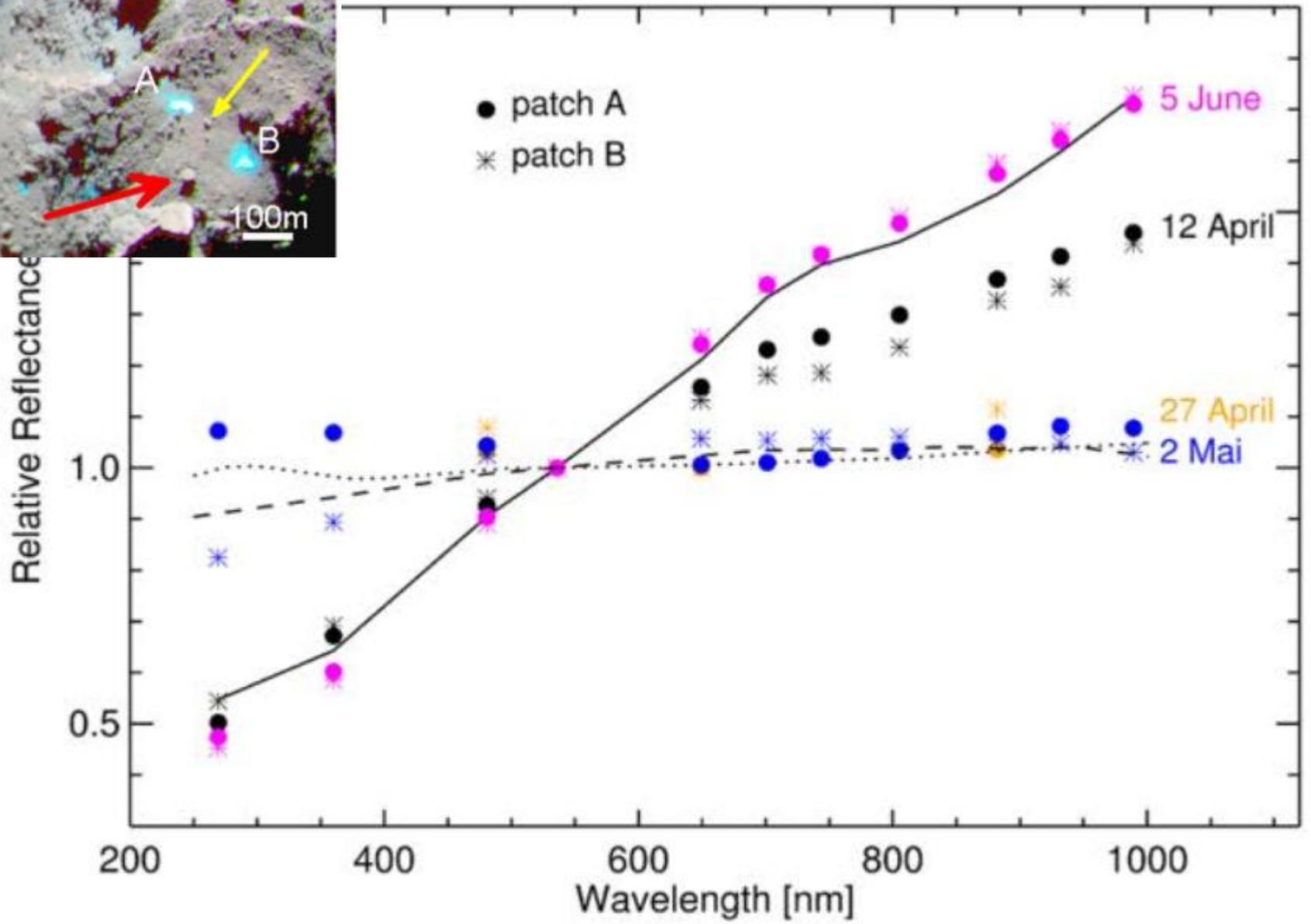
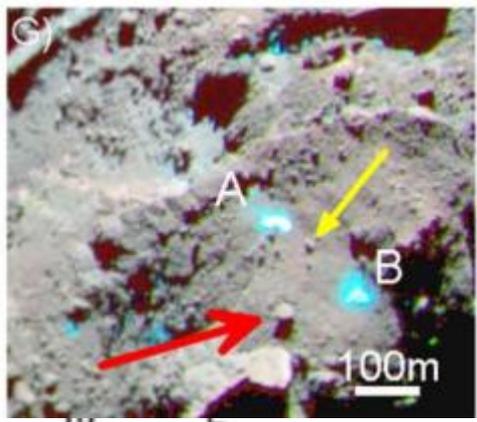
Sign labels



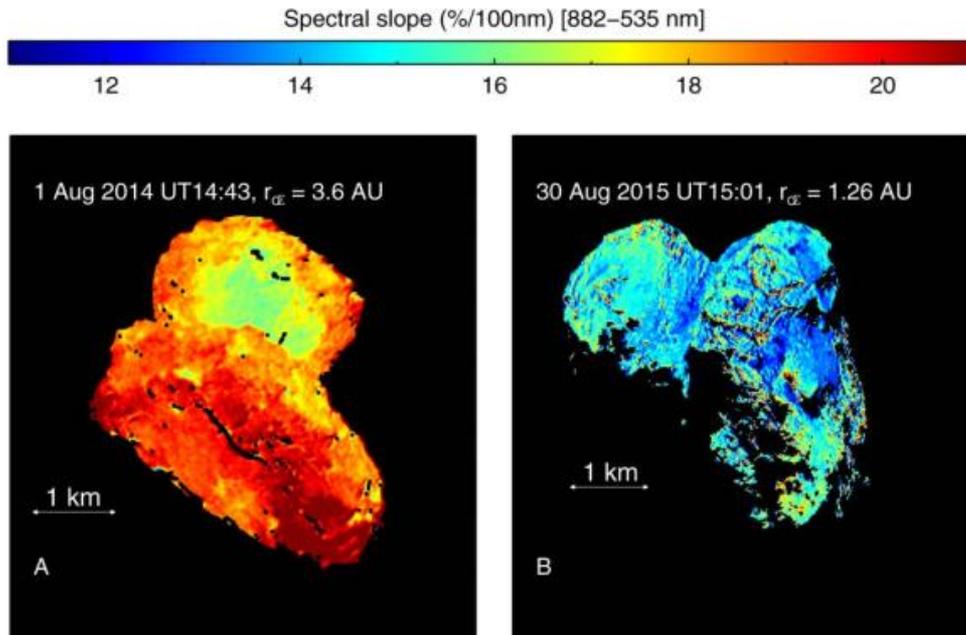
Magnitude labels





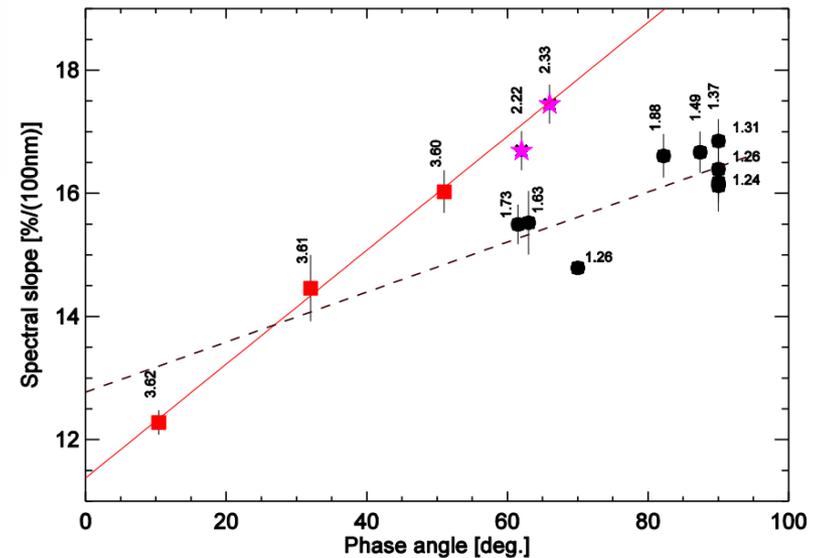


Résultats spectrophotométriques



Fornasier et al. (2016, Science)

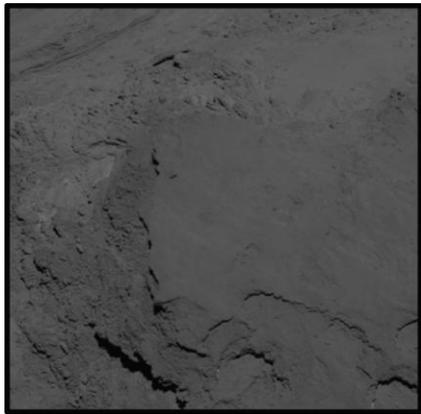
Fornasier, Hasselmann, Barucci et al. (A&A, 2015)



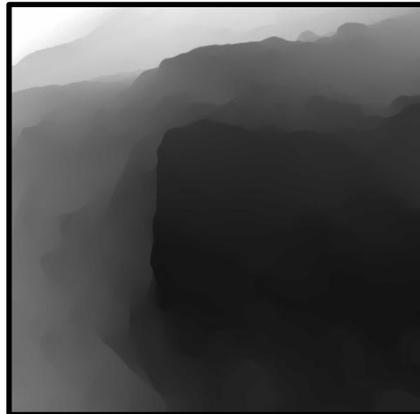


COMETO-RÉFÉRENCEMENT

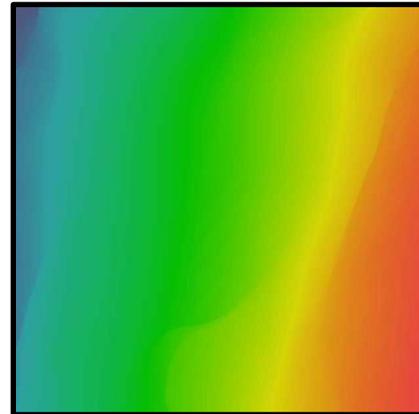
Cometo-Référencement



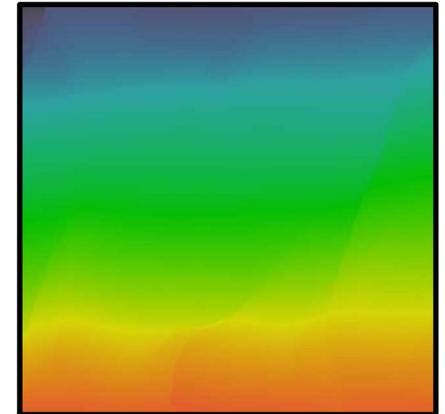
650 nm



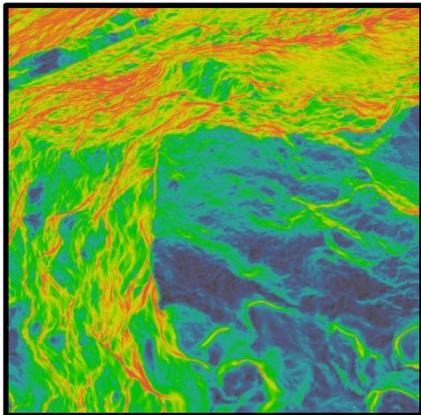
Altitude



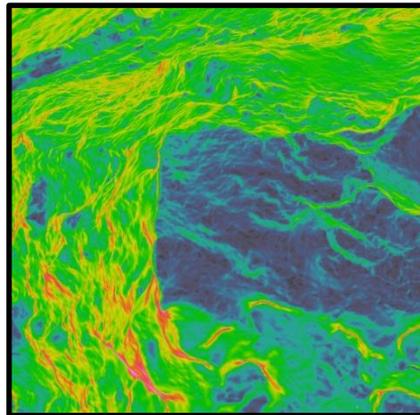
Latitude



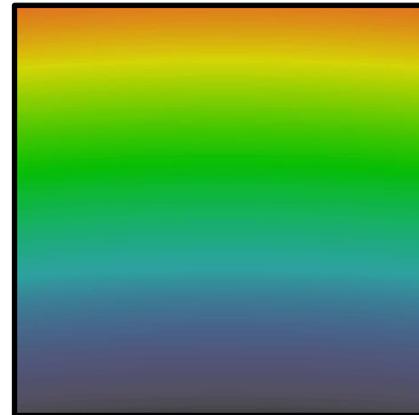
Longitude



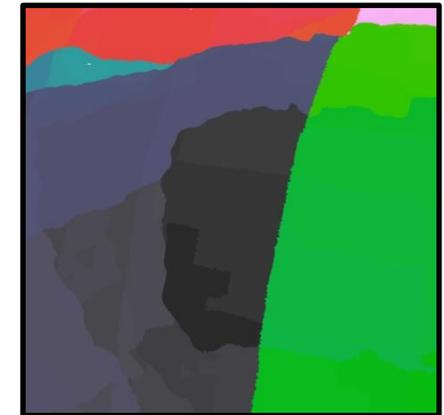
Angle d'emergence



Angle d'incidence



Angle de phase

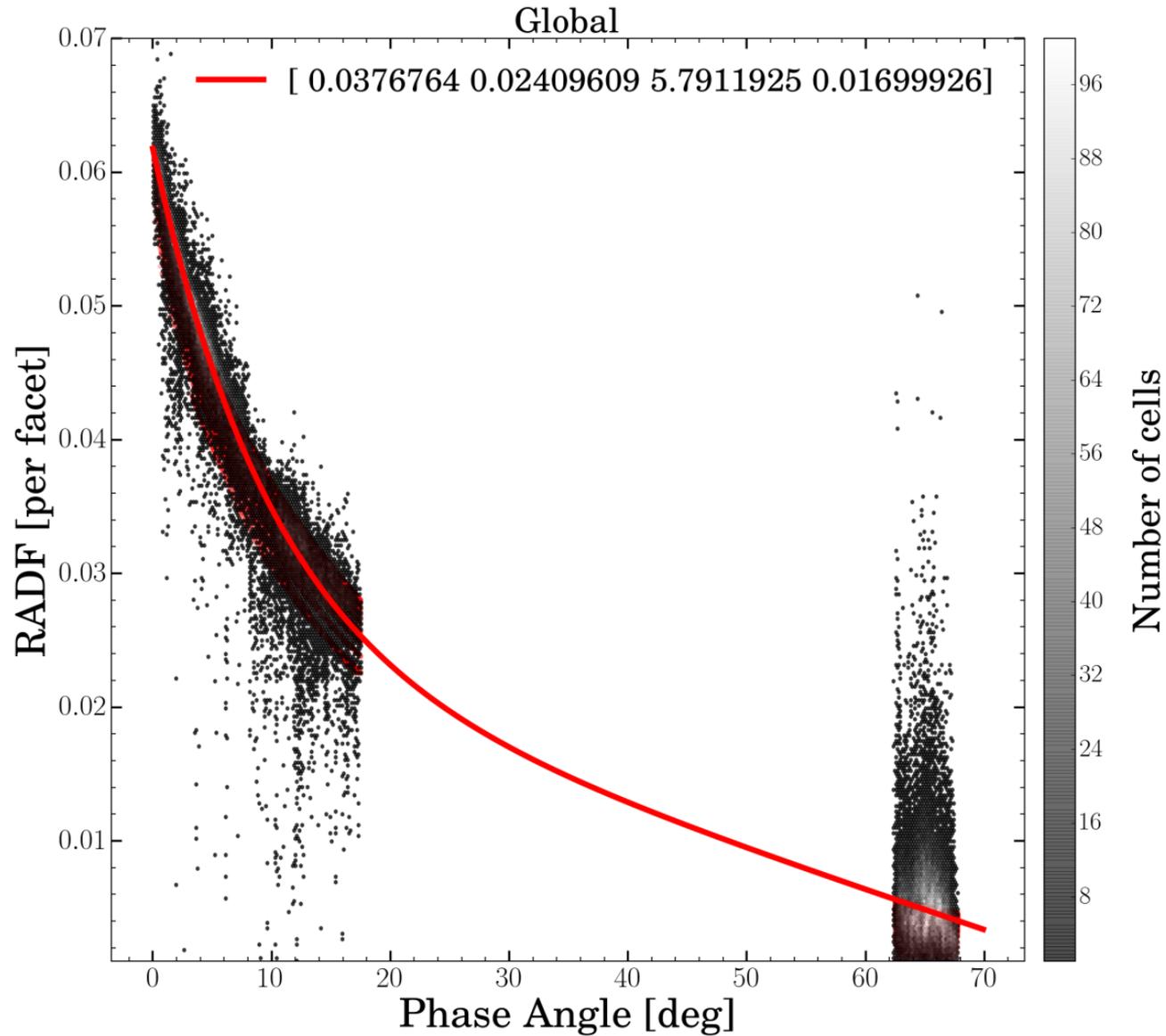


facet (cube)

- SHAP7 5M SPG (~1.5 metre res., Preusker et al. 2017)
- NAIF SPICE & ESA Kernels
- OASIS – FORTRAN (Jorda et al., 2010, SPIE)
- Python 2.7 API (Hasselmann, P.H.)

Courbe de Diffusion

Hasselmann et al. (2017, MNRAS)



Modélisation avec Hapke IMSA (2012)

$$r_{\text{Hapke}(\alpha, \mu_0, \mu, \lambda)} = K_{(h_s)} \frac{w_\lambda}{4} \left(\frac{\mu_{0e}}{\mu_e + \mu_{0e}} \right) [(1 + B_{\text{SH}(\alpha)}) P(\alpha) + (H_{(\mu_0/K, w_\lambda)} H_{(\mu/K, w_\lambda)} - 1)] S_{(\mu_0, \mu, \alpha)}$$

Diagram illustrating the components of the Hapke model equation:

- Factor de porosité (Porosity factor) points to $K_{(h_s)}$
- Diffusion Simple (Simple Diffusion) points to $\left(\frac{\mu_{0e}}{\mu_e + \mu_{0e}} \right)$
- Effet d'Opp. (Opposition effect) points to $B_{\text{SH}(\alpha)}$
- Fonction de phase de la particule (Particle phase function) points to $P(\alpha)$
- Diffusion multiple (Multiple Diffusion) points to $(H_{(\mu_0/K, w_\lambda)} H_{(\mu/K, w_\lambda)} - 1)$
- Fonction d'ombrage (Shading function) points to $S_{(\mu_0, \mu, \alpha)}$

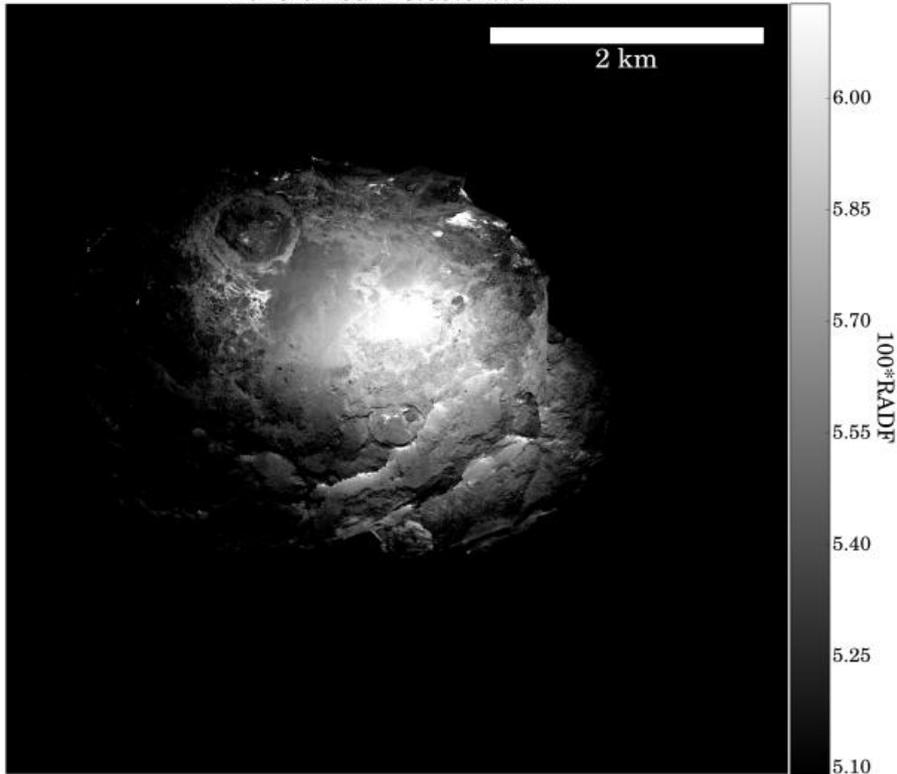
Hasselmann et al. (2016, Icarus, 2017, MNRAS)

w	± 0.001	0.027
B_0	± 0.3	2.42
h_s	± 0.005	0.081
g_{sca}	± 0.02	-0.424
$\bar{\theta}$ (°)	$\pm 3^\circ$	26
$\rho_{v, \text{Hapke}}$ (per cent)	± 0.05	6.14
K	± 0.005	1.245
$1 - \phi^c$ (per cent)	± 2 per cent	82
HWHM_{SH} (°)	$\pm 0.3^\circ$	9.28

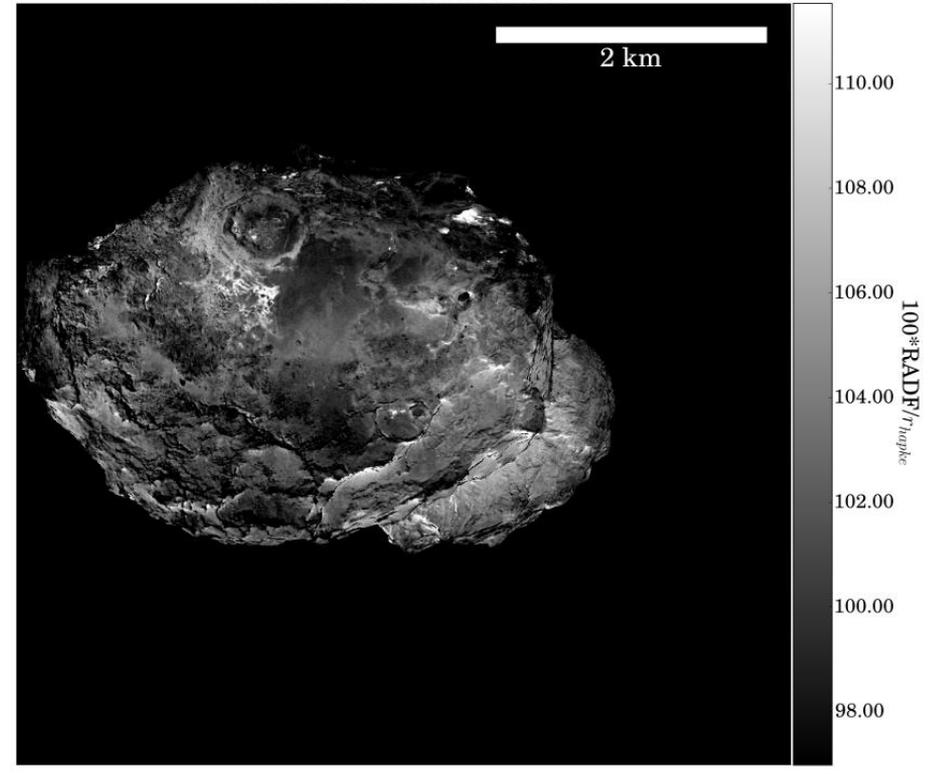
- Paramètres liés à la propriété granulaire de la surface.
- Hapke (2012, Cambridge Edition)
- Inversion : BFGS (Byrd et al., 2005) (Scipy Package)
- Inversion global à 10.000 conditions initiales
- Inversion facet-par-facet depuis le model de forme;
- Correction Photométrie → “Vrai Albedo”

“Vrai” Albedo \rightarrow Albedo phase=0 deg. à 630 nm
Seulement 6.2% (Organiques+Charbonneux, confirmé par COSIMA)

2016-04-09T23.59.32.754Z

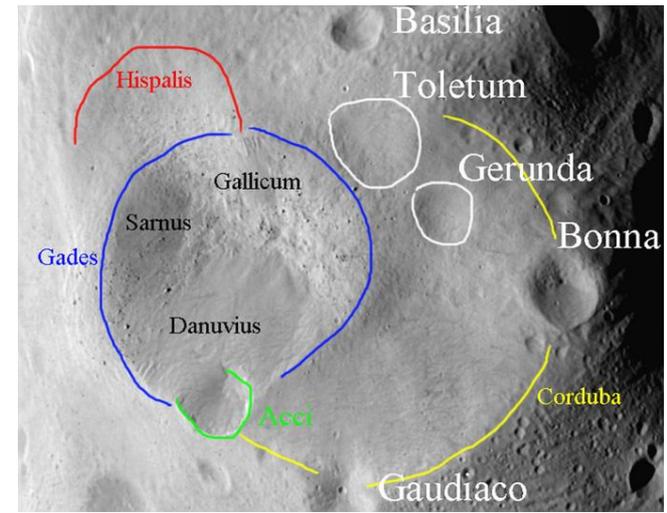
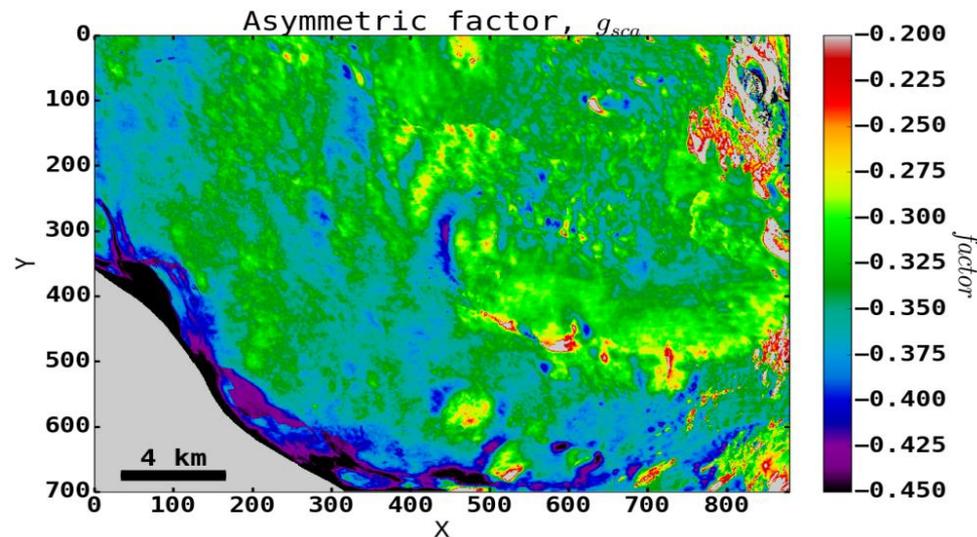
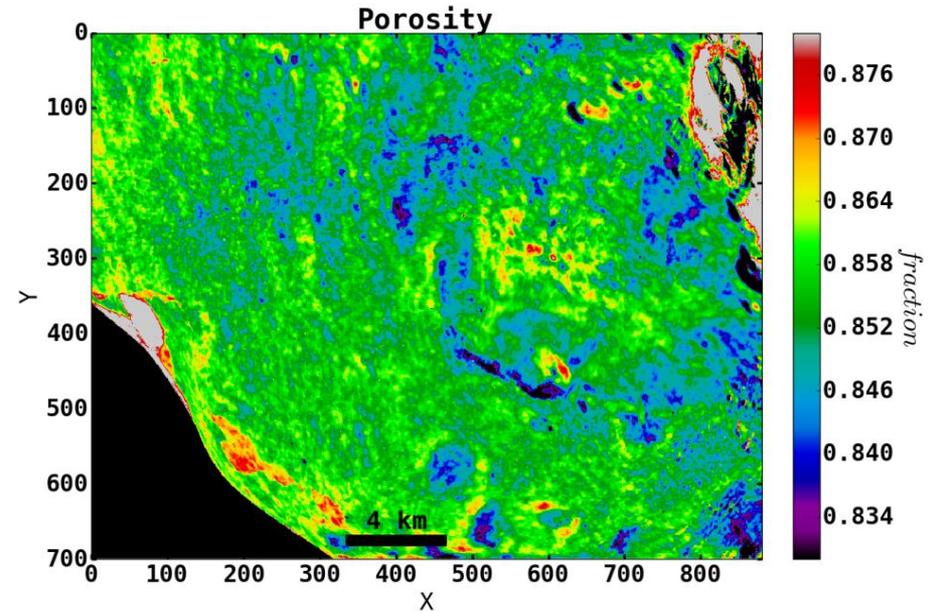
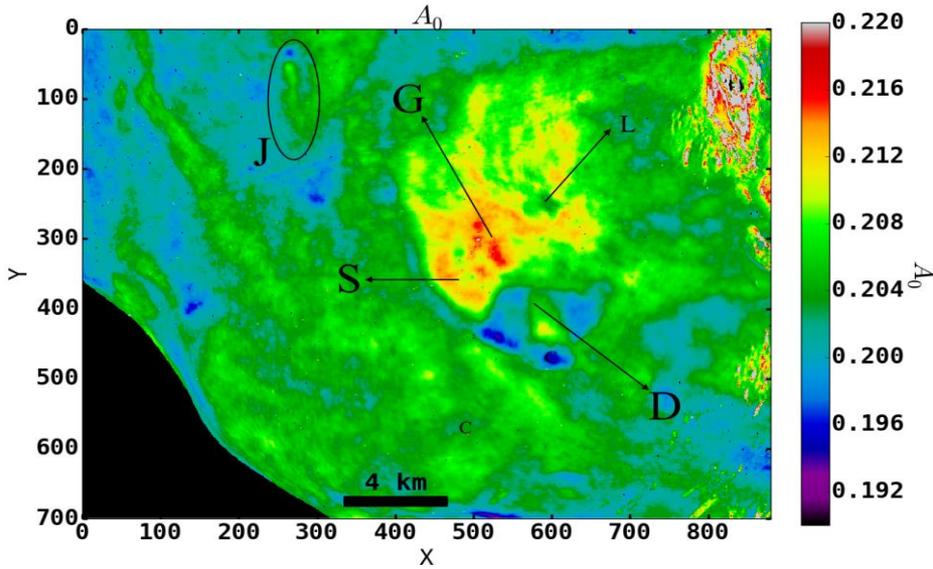


2016-04-09T23.59.32.754Z

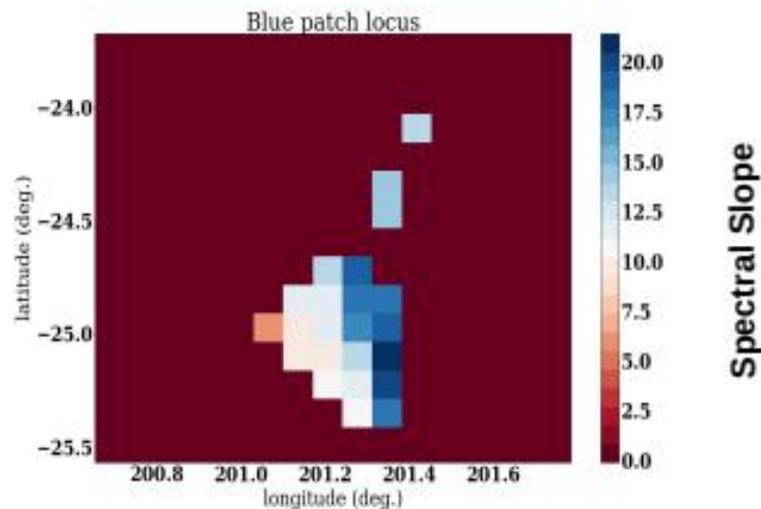
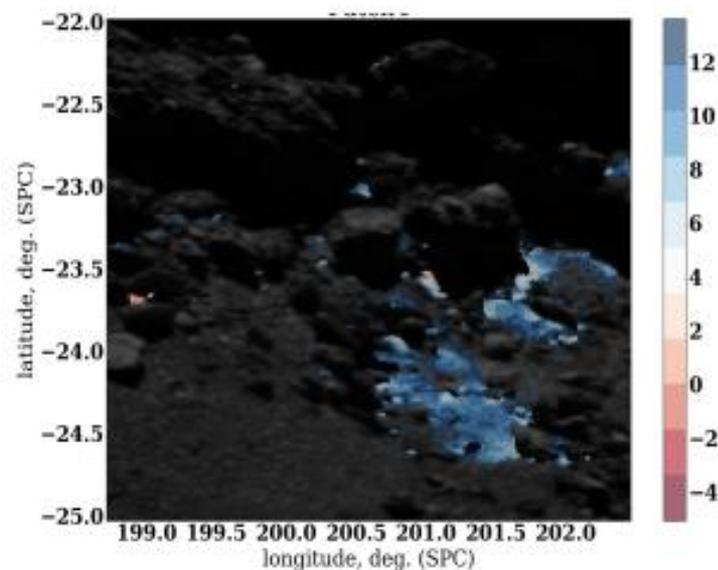


Hasselmann et al. (2016, Icarus) → Cratère Baética à (21) Lutetia

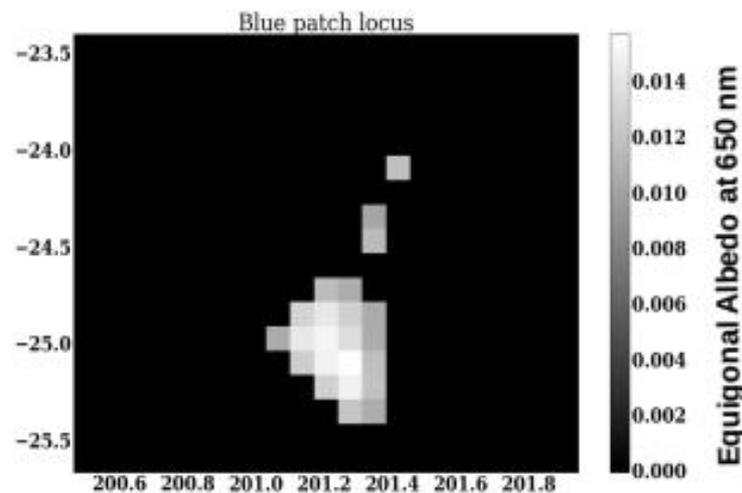
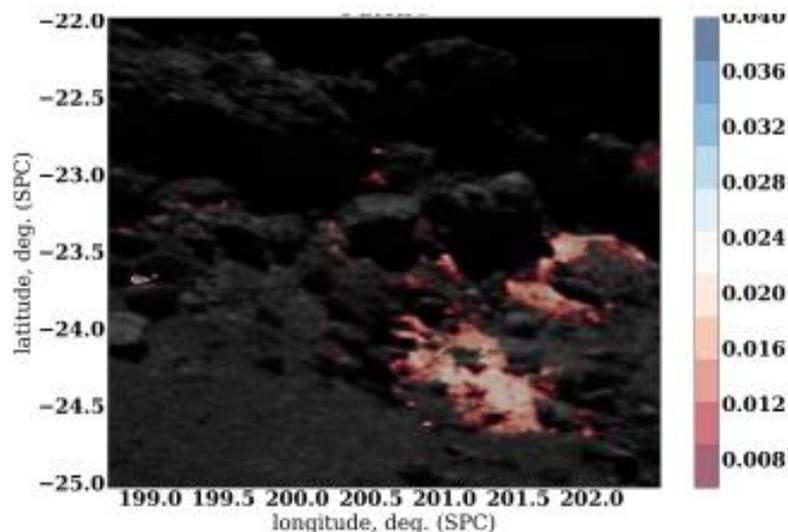
Cartes des paramètres de Hapke



Taches de glace: OSIRIS \leftrightarrow VIRTIS-M-VIS (0.4-0.9 μm , 250 μrad) (en developpement)



Lat(OSIRIS) - Lat(VIRTIS) = 1 deg.



Références

Hapke, B. Theory of Reflectance and Emittance Spectroscopy. *Cambridge University Press*, **2012**

Fornasier, S.; Hasselmann, P. H.; Barucci, M. A.; Feller, C.; Besse, S.; Leyrat, C.; et al. *Astronomy and Astrophysics*, **2015**, 583, A30 .

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Hasselmann, P. H.; Barucci, M. A.; Fornasier, S.; Feller, C.; Deshapriya, J. D. P.; Fulchignoni, M.; Jost, B.; Sierks, H.; et al. *Monthly Notes of Royal Astronomical Society*, **2017**, 469, S550-S567 .

Repository:

<https://github.com/pedrohasselmann>

Website:

<https://sites.google.com/view/pedrohasselmann/home>



Merci!

