Edited: unpublished material removed

Planetary Lander Cameras & Rosetta@67P

Stefan Schröder

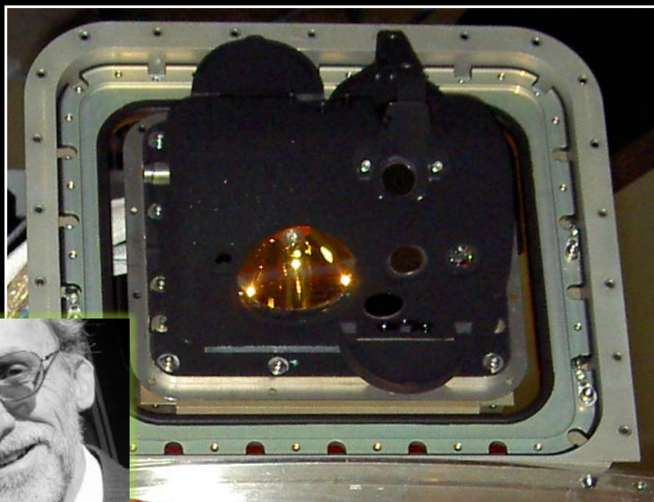
DLR

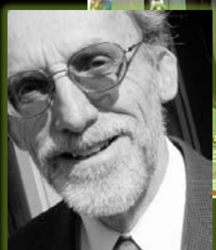
Takayama Summer School

25 Aug 2016

Planetary lander cameras

DISR on Huygens



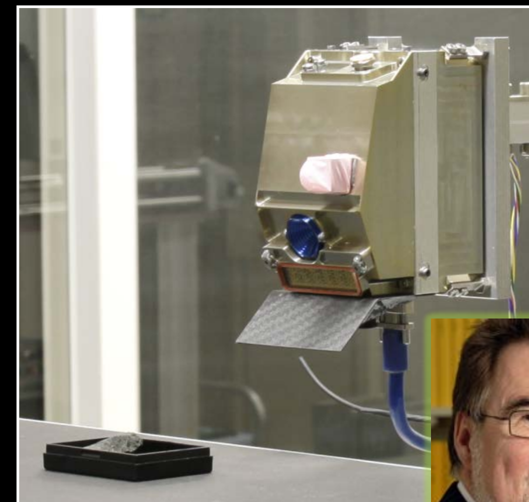


Martin Tomasko

ROLIS on Philae

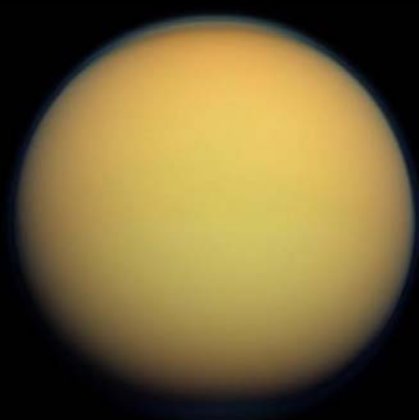
Stefano Mottola

Camera on MASCOT

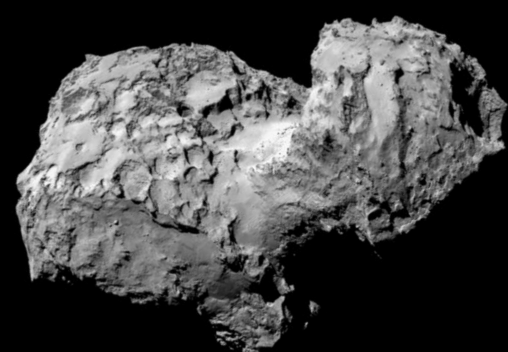


Ralf Jaumann

Landed on Saturn's moon Titan

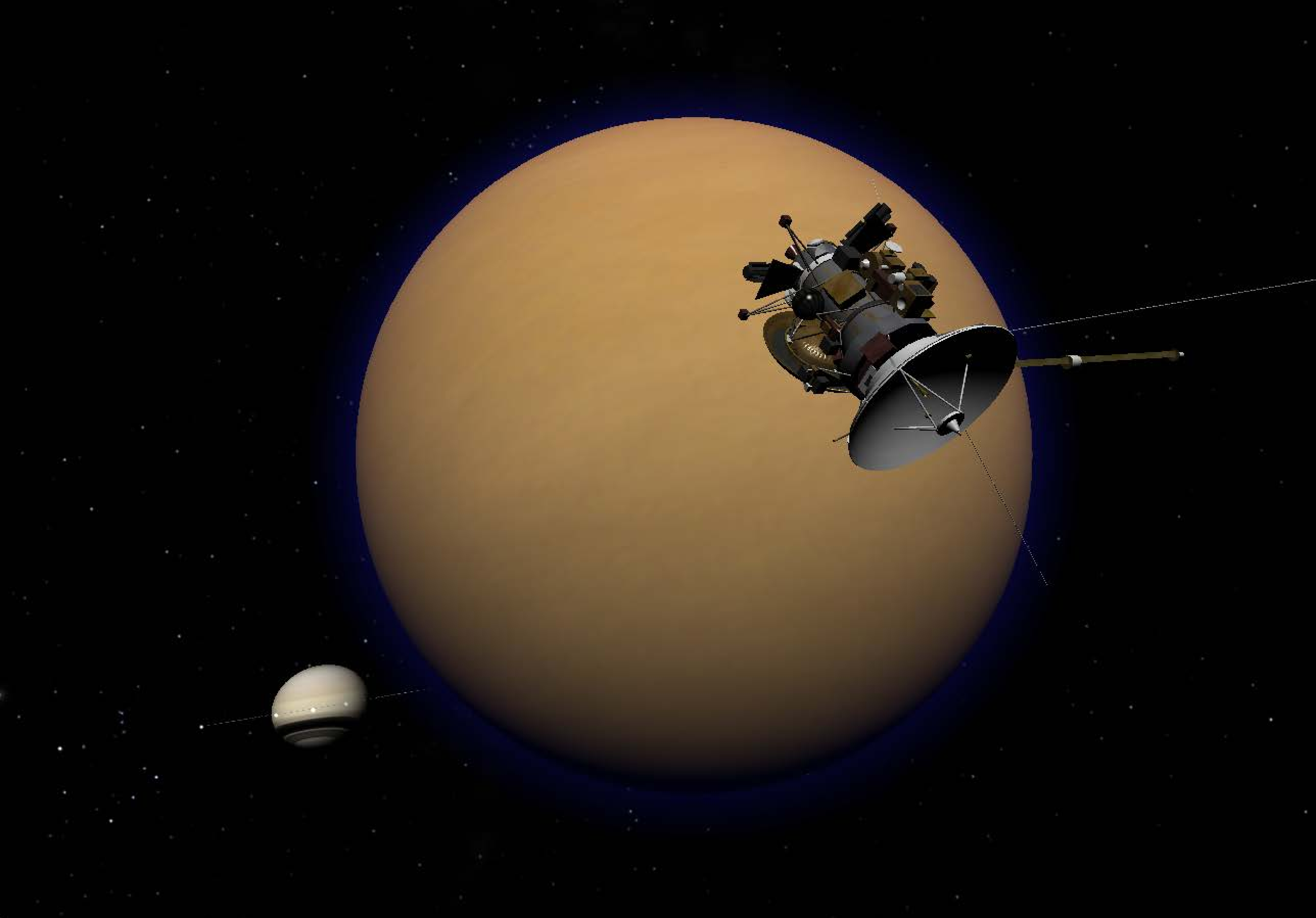


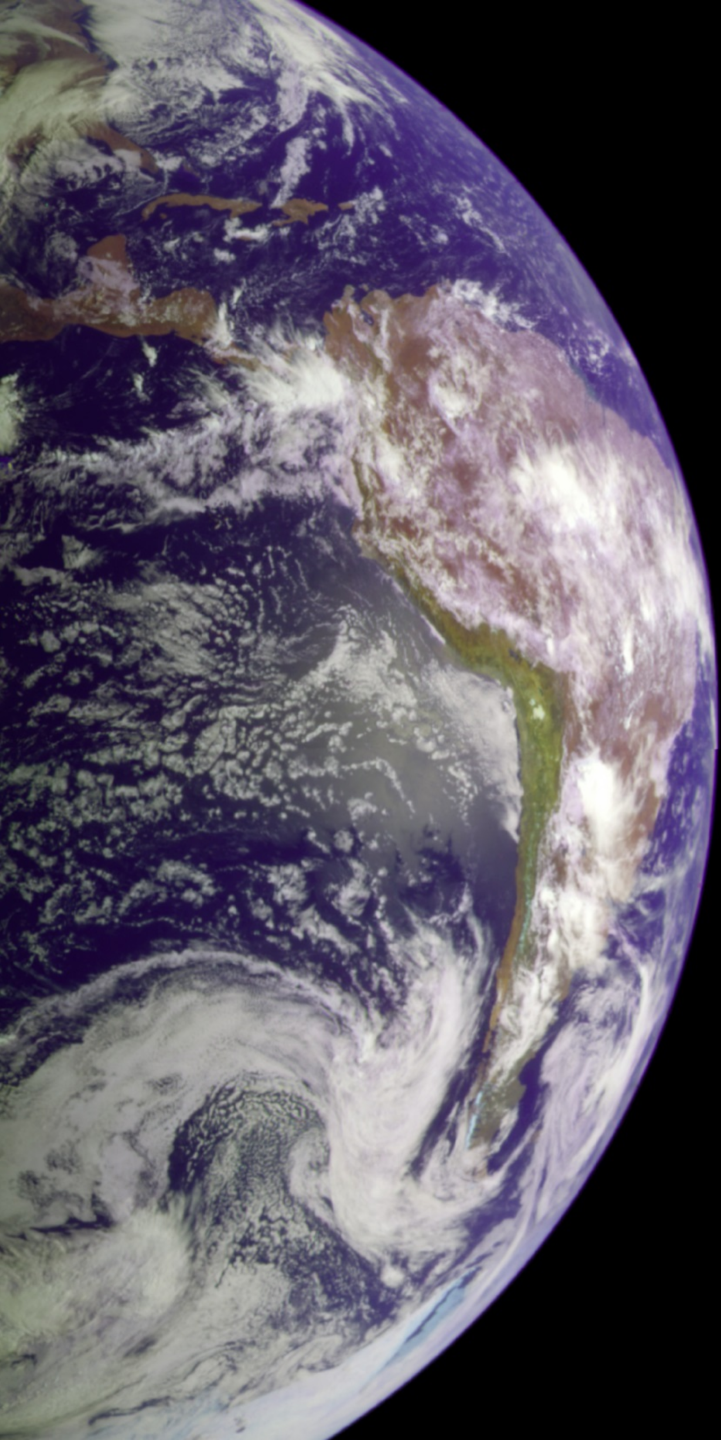
Landed on comet 67P



Will land on Ryugu!?

DISR: Cassini / Huygens





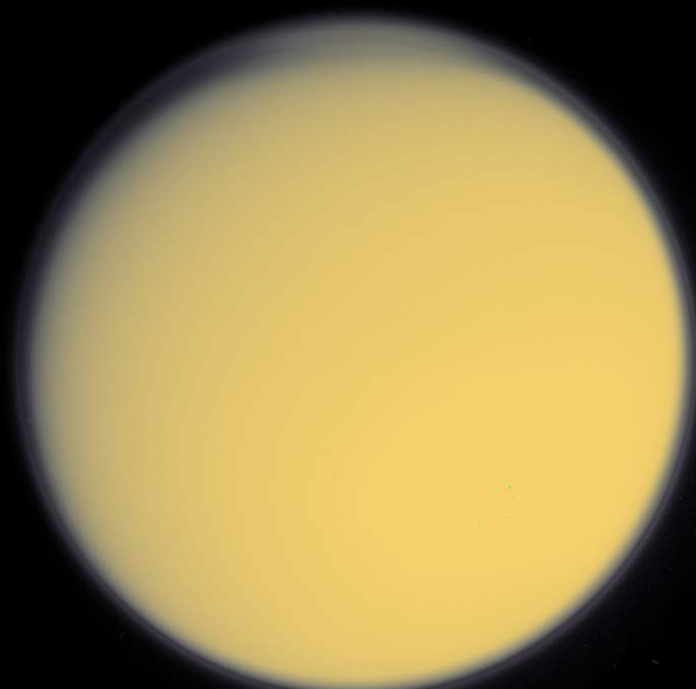
Saturn's largest moon Titan

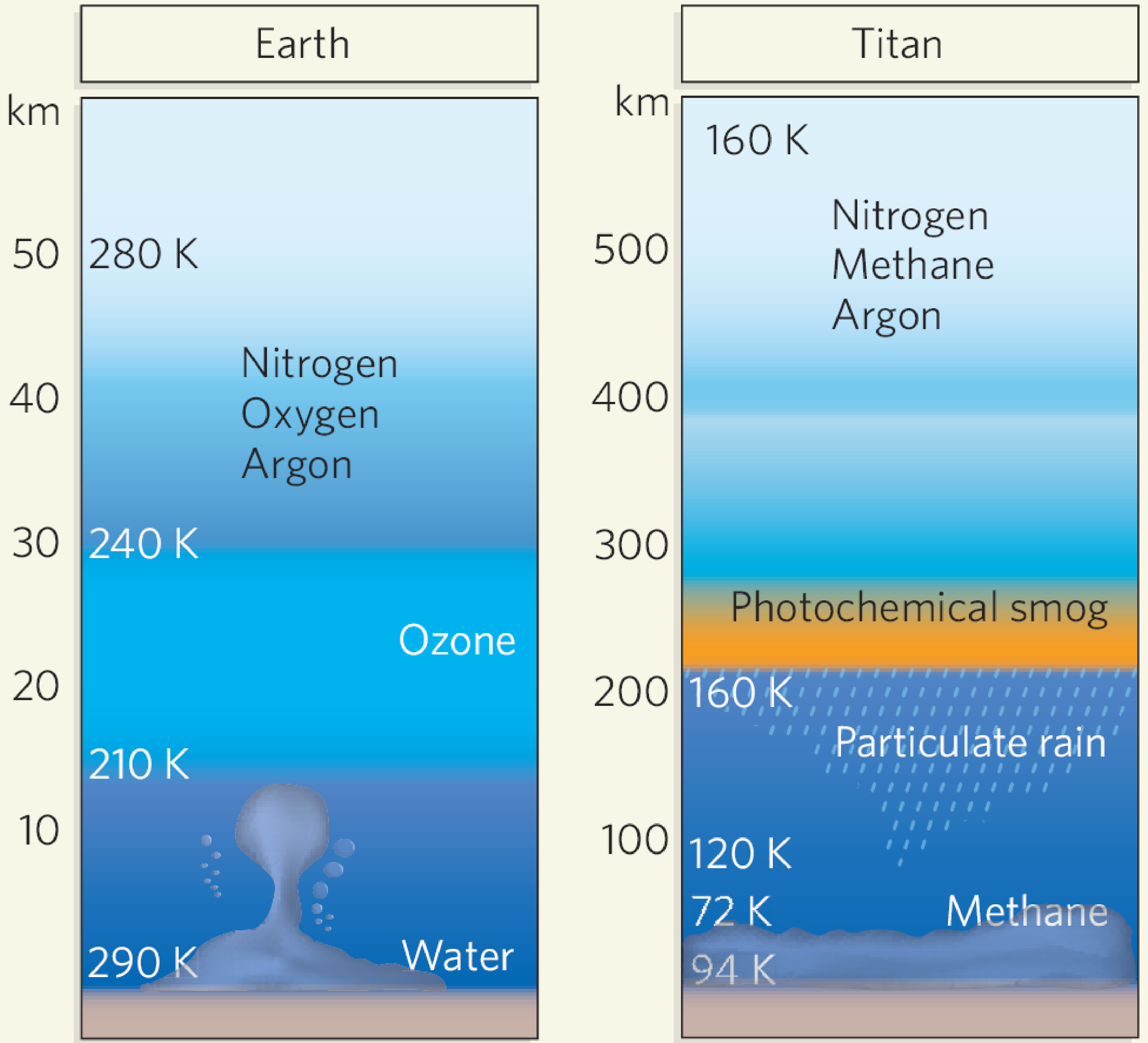
Radius: 2575 km

Density: 1.88 g cm^{-3}

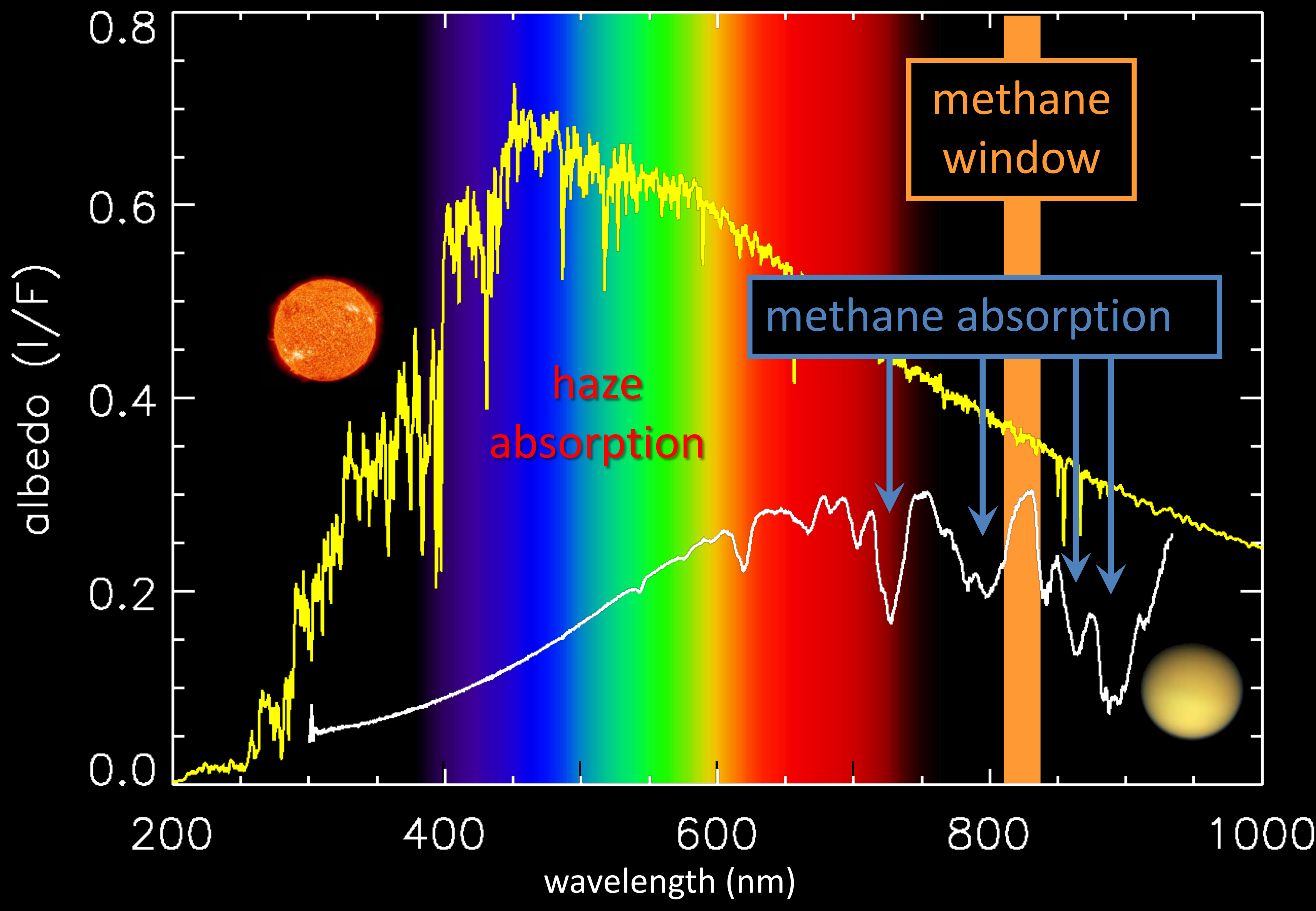
Surface temperature: 94 K

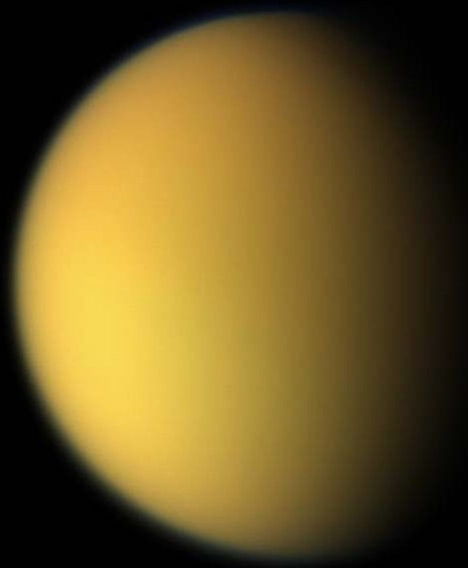
Atmosphere: 95% N_2, 5% CH_4, Ar, H_2, C_2H_6, C_2H_2, NH_3, ...



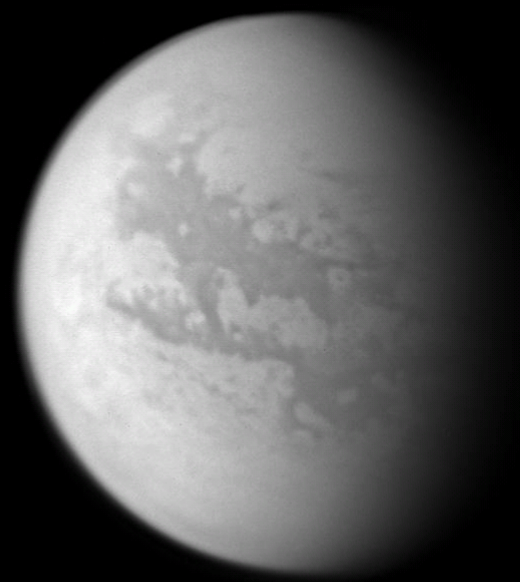

Earth
Titan
km
50
40
30
20
10
280 K
Nitrogen
Oxygen
Argon
240 K
Ozone
210 K
290 K
Water
km
500
400
300
200
100
160 K
Nitrogen
Methane
Argon
Photochemical smog
160 K
Particulate rain
120 K
72 K
Methane
94 K

Owen (2005)

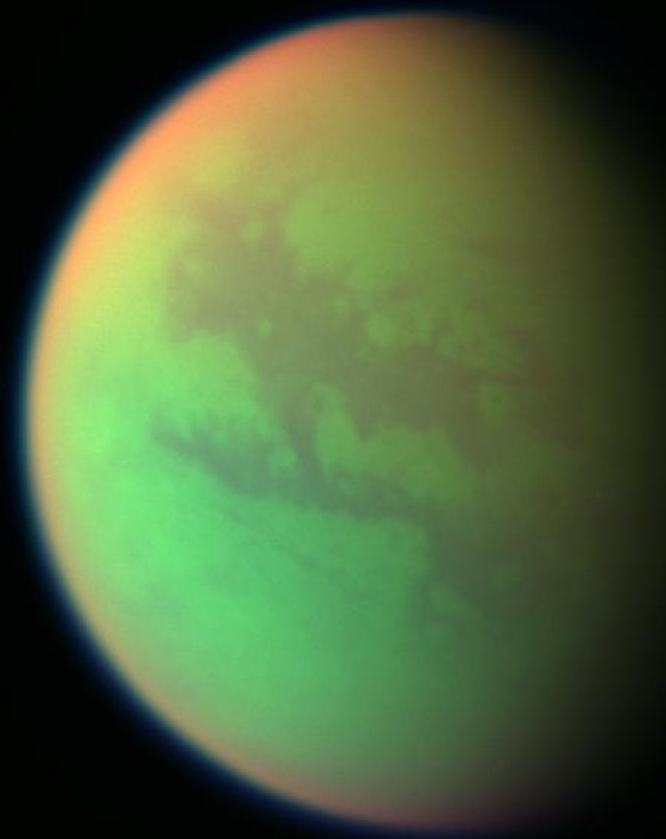

0.8
0.6
0.4
0.2
0.0
albedo (I/F)
methane window
methane absorption
haze absorption
200
400
600
800
1000
wavelength (nm)



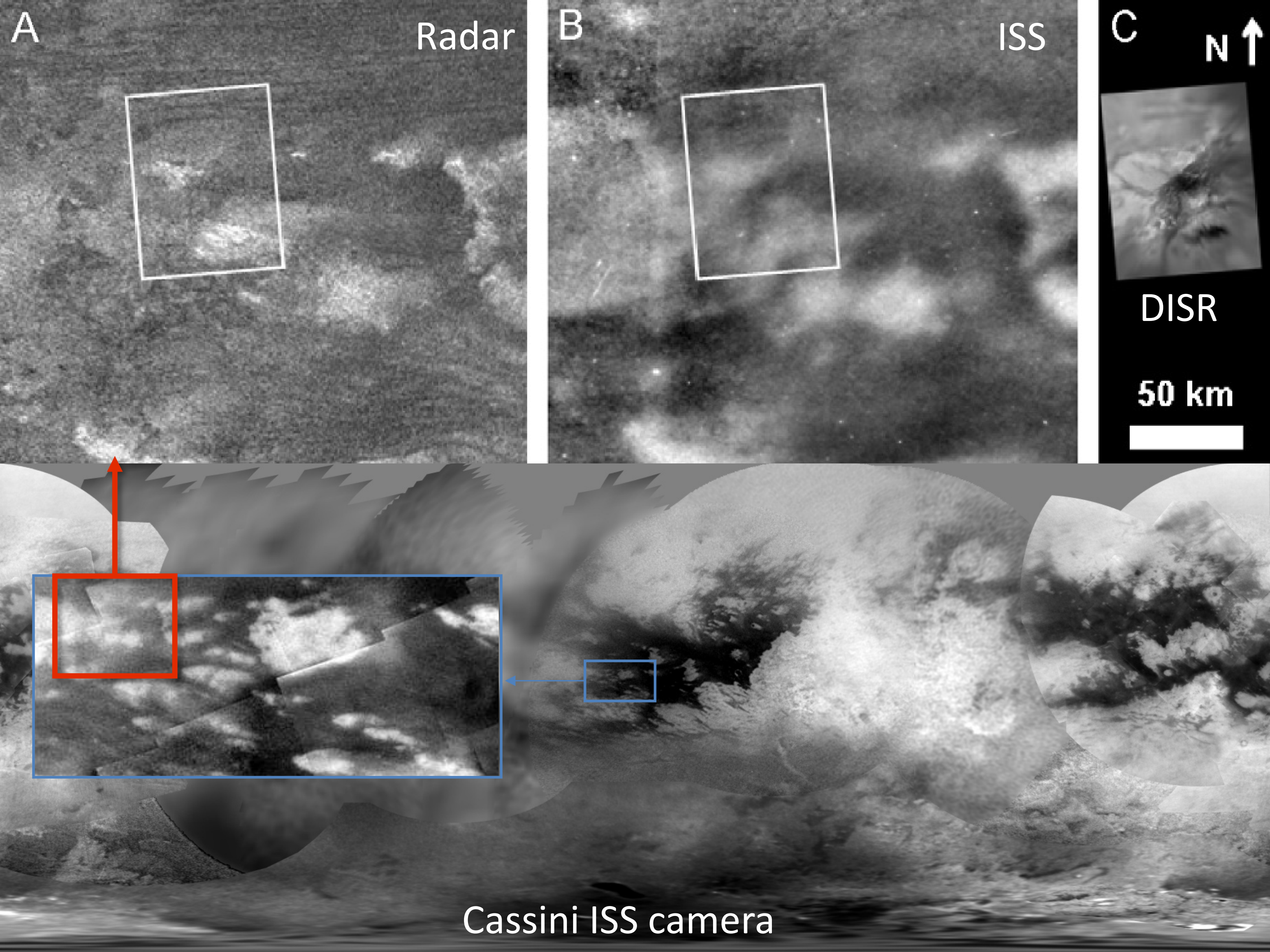
visible light
("true" color)

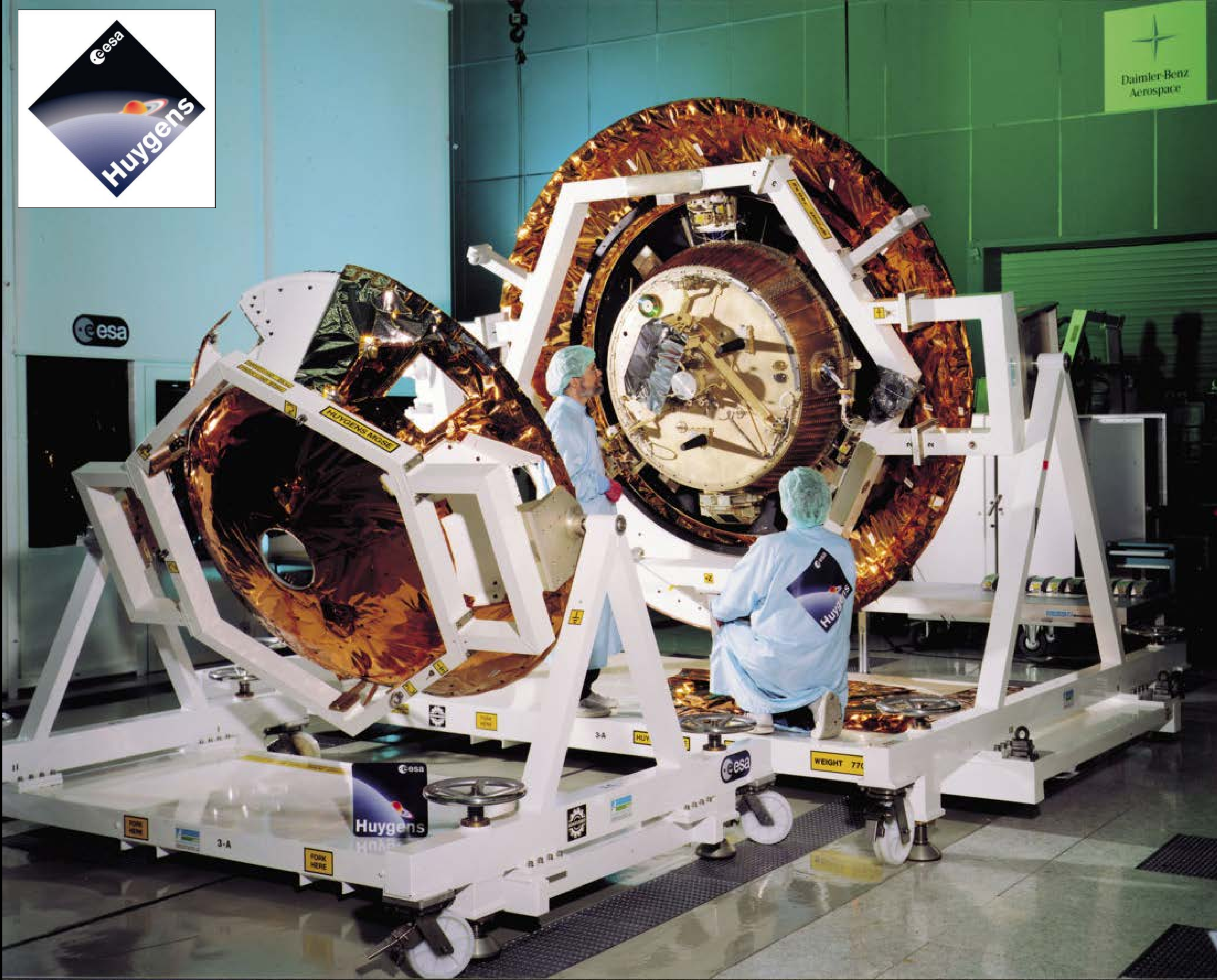


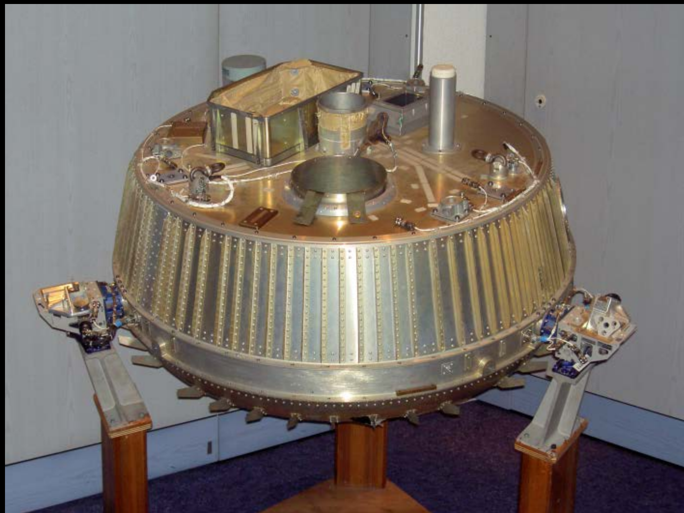
938 nm
(methane window)

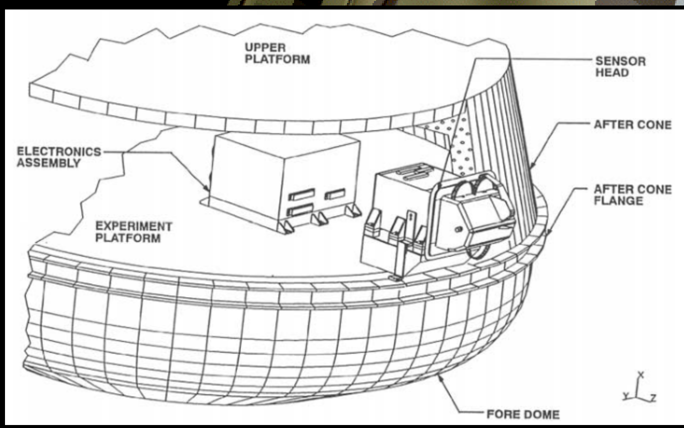


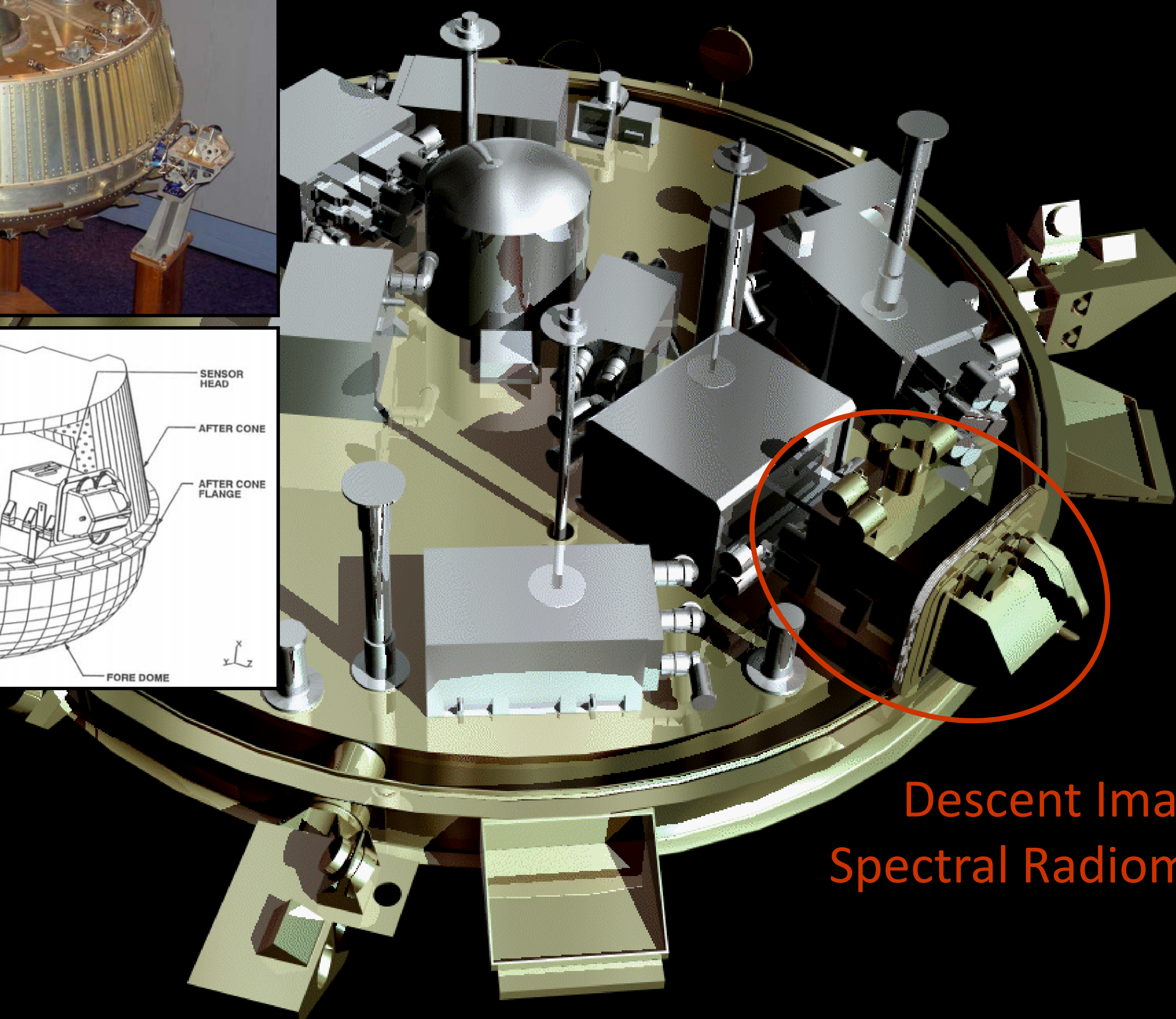
420, 889, 938 nm
(haze, methane band, methane window)


A
Radar
B
ISS
C
N
DISR
50 km
Cassini ISS camera

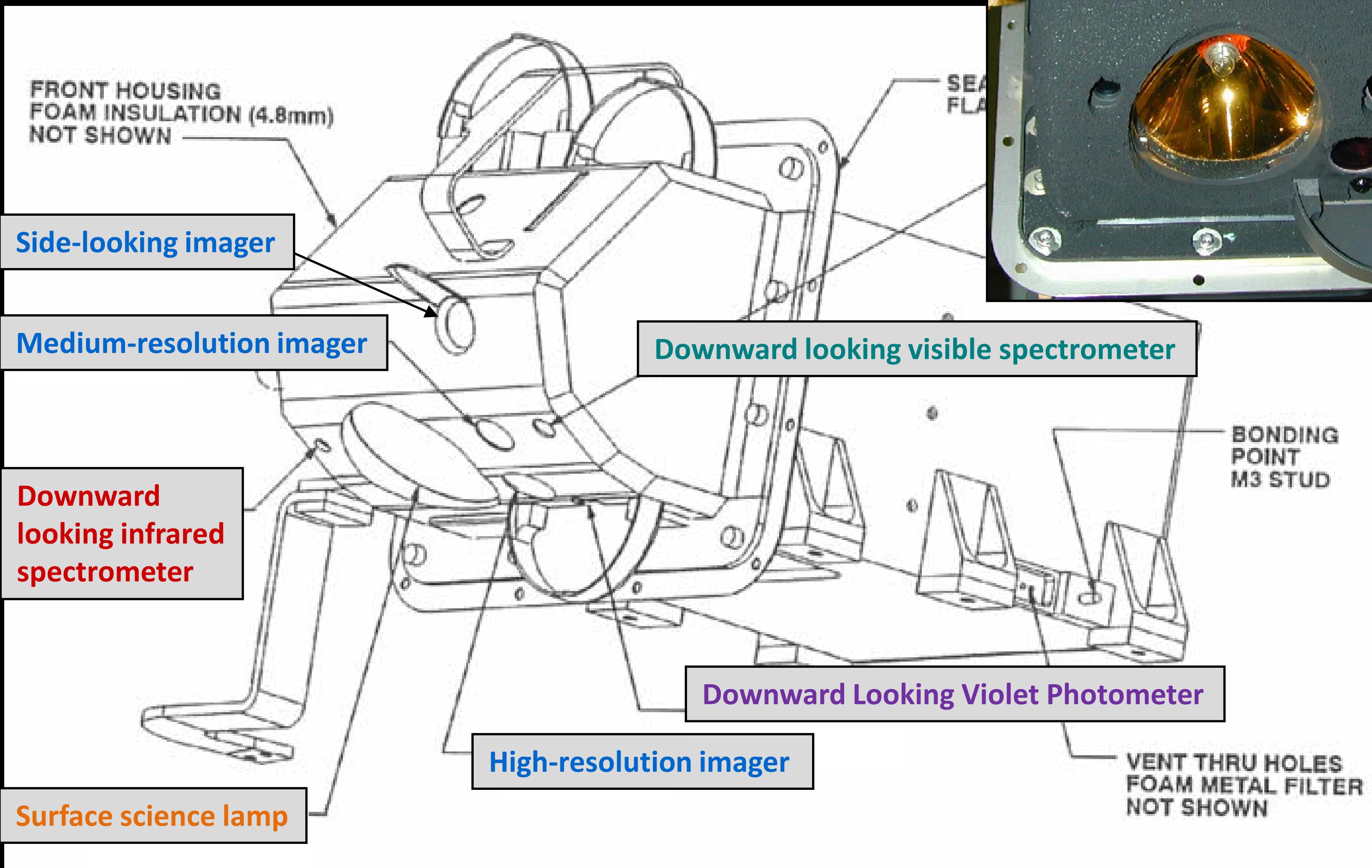

esa
Huygens
Daimler-Benz
Aerospace
esa
HUYGENS MGSE
FORK HERE
3-A
WEIGHT 77
esa
Huygens

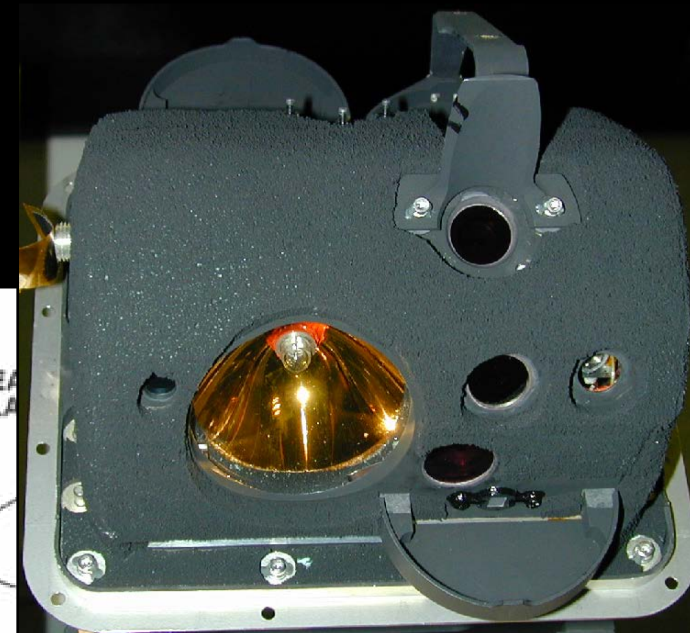



UPPER PLATFORM
SENSOR HEAD
AFTER CONE
ELECTRONICS ASSEMBLY
AFTER CONE FLANGE
EXPERIMENT PLATFORM
FORE DOME


Descent Imager / Spectral Radiometer

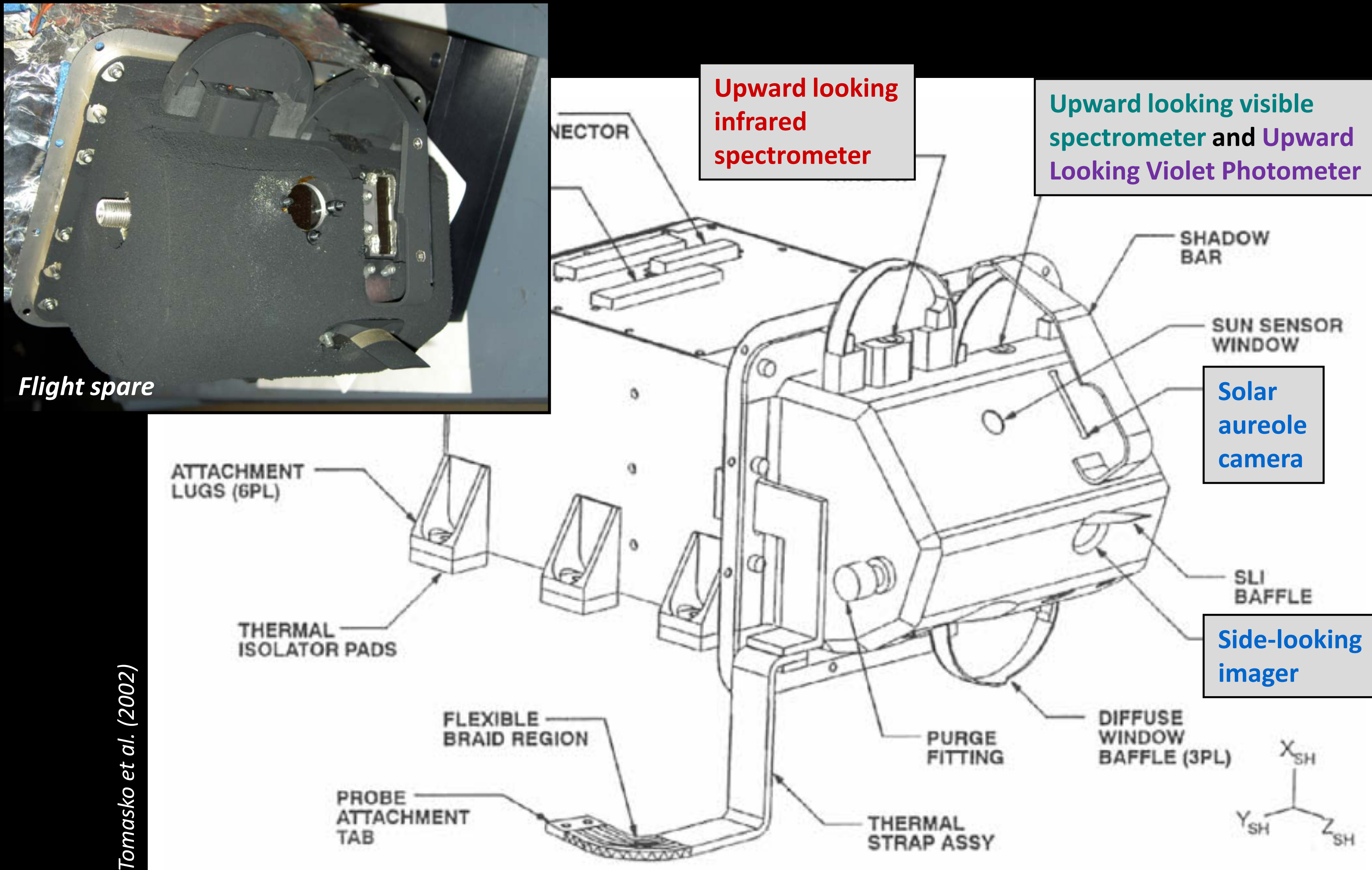
Descent Imager/Spectral Radiometer





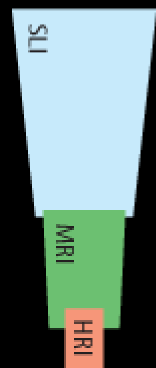
Tomasko et al. (2002)

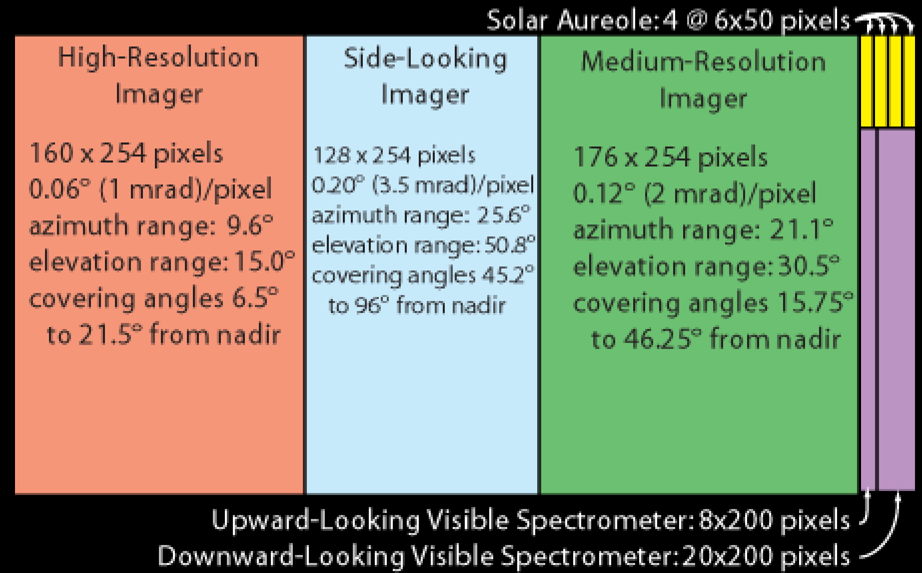
DISR top view

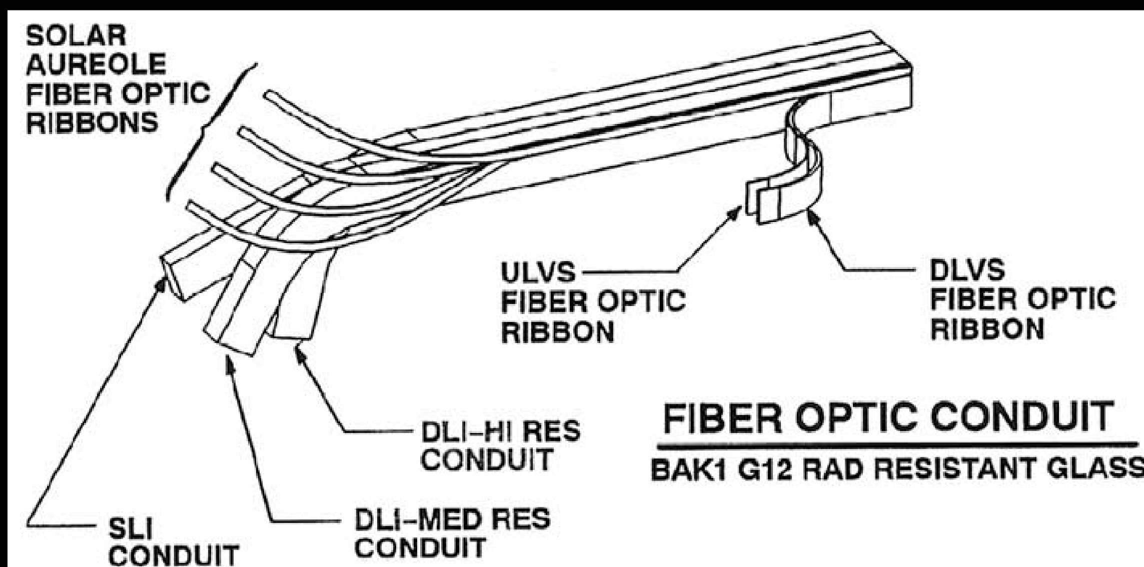


Tomasko et al. (2002)

DISR CCD


SLI
MRI
HRI

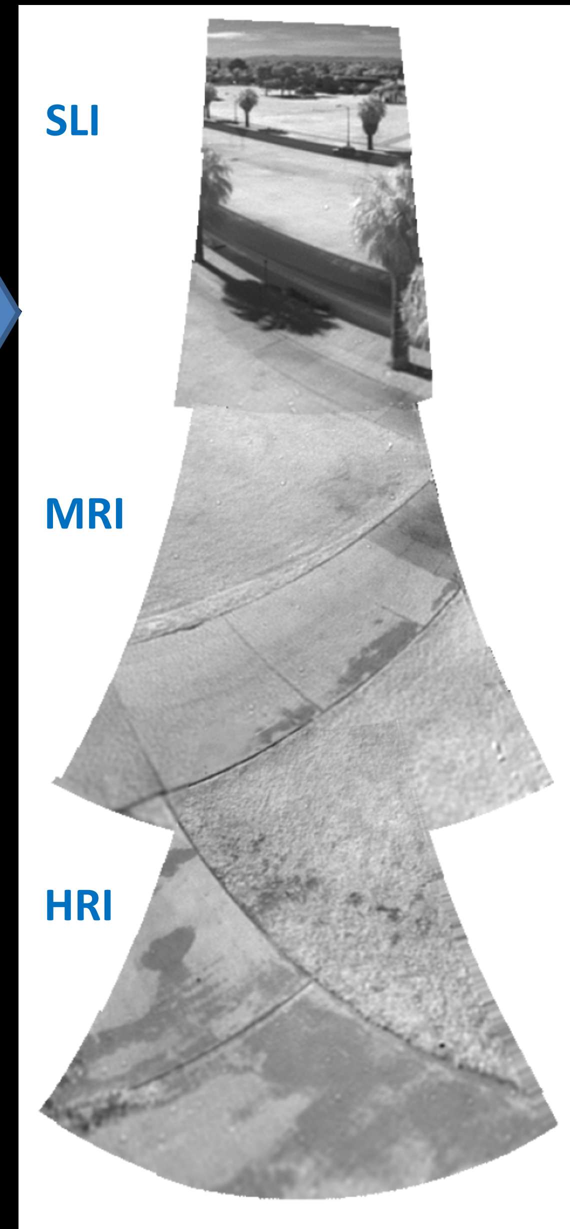

Solar Aureole: 4 @ 6x50 pixels
High-Resolution Imager
160 x 254 pixels
0.06° (1 mrad)/pixel
azimuth range: 9.6°
elevation range: 15.0°
covering angles 6.5° to 21.5° from nadir
Side-Looking Imager
128 x 254 pixels
0.20° (3.5 mrad)/pixel
azimuth range: 25.6°
elevation range: 50.8°
covering angles 45.2° to 96° from nadir
Medium-Resolution Imager
176 x 254 pixels
0.12° (2 mrad)/pixel
azimuth range: 21.1°
elevation range: 30.5°
covering angles 15.75° to 46.25° from nadir
Upward-Looking Visible Spectrometer: 8x200 pixels
Downward-Looking Visible Spectrometer: 20x200 pixels


SOLAR AUREOLE FIBER OPTIC RIBBONS
ULVS FIBER OPTIC RIBBON
DLVS FIBER OPTIC RIBBON
DLI–HI RES CONDUIT
DLI–MED RES CONDUIT
SLI CONDUIT
FIBER OPTIC CONDUIT
BAK1 G12 RAD RESISTANT GLASS

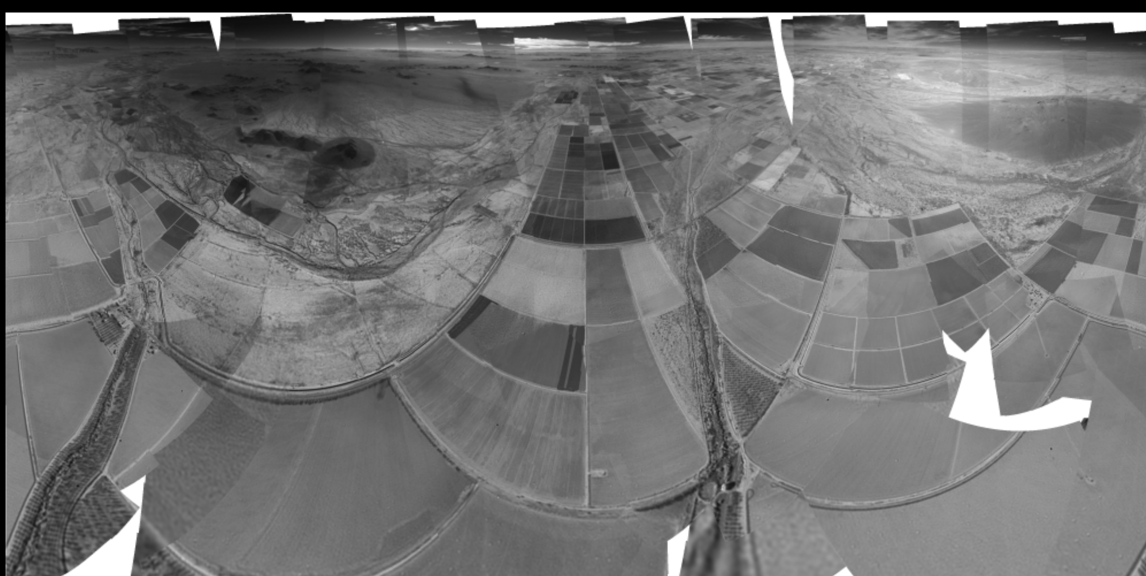
Pre-launch imaging tests

Rooftop test

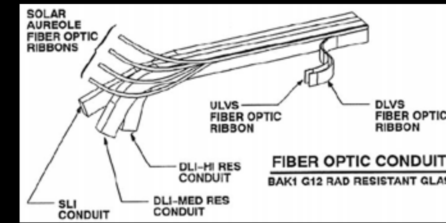
“Triplet” (Mercator projection)



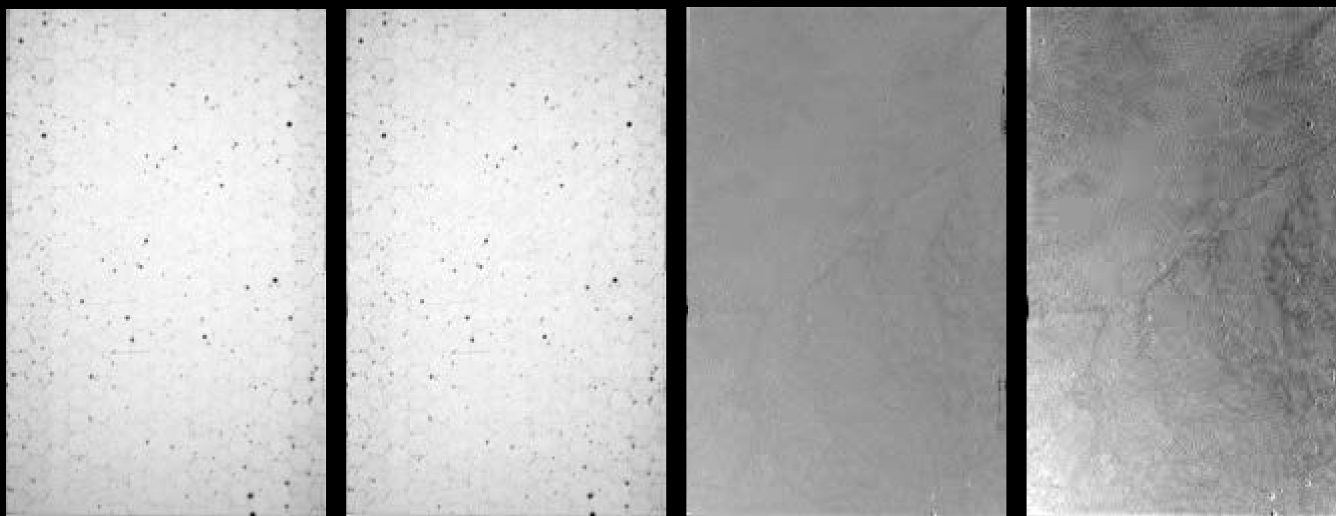
Helicopter test



Fiber optics / calibration

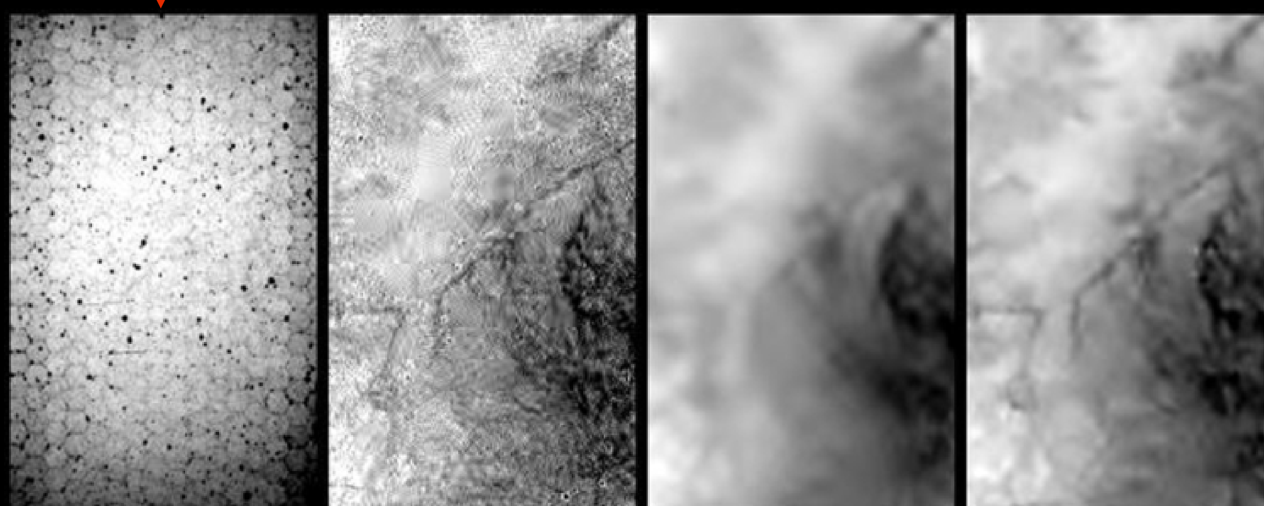


On board flat field | On board raw image | Divided by on board flat field & transmitted | Same, enhanced



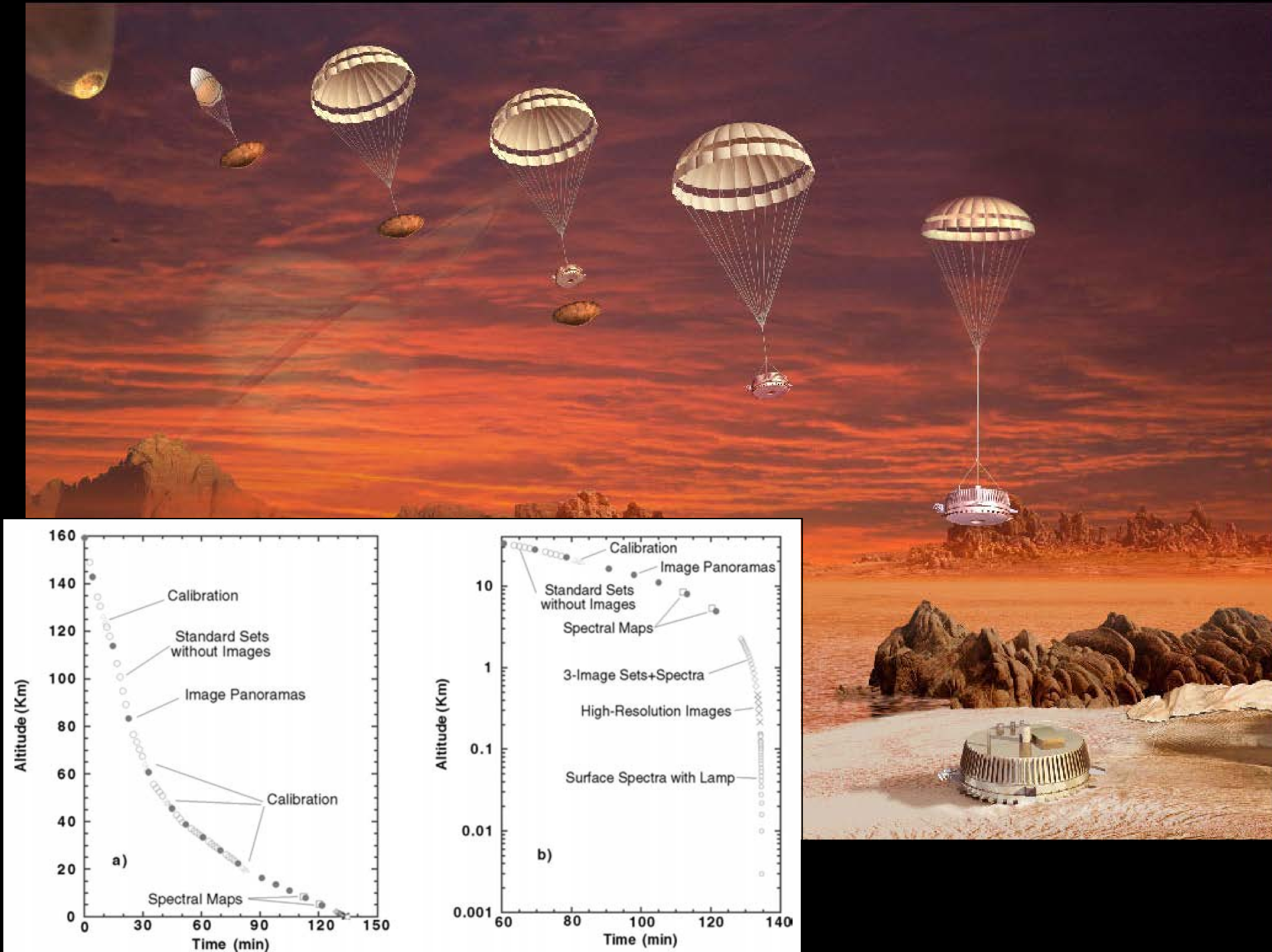
On board

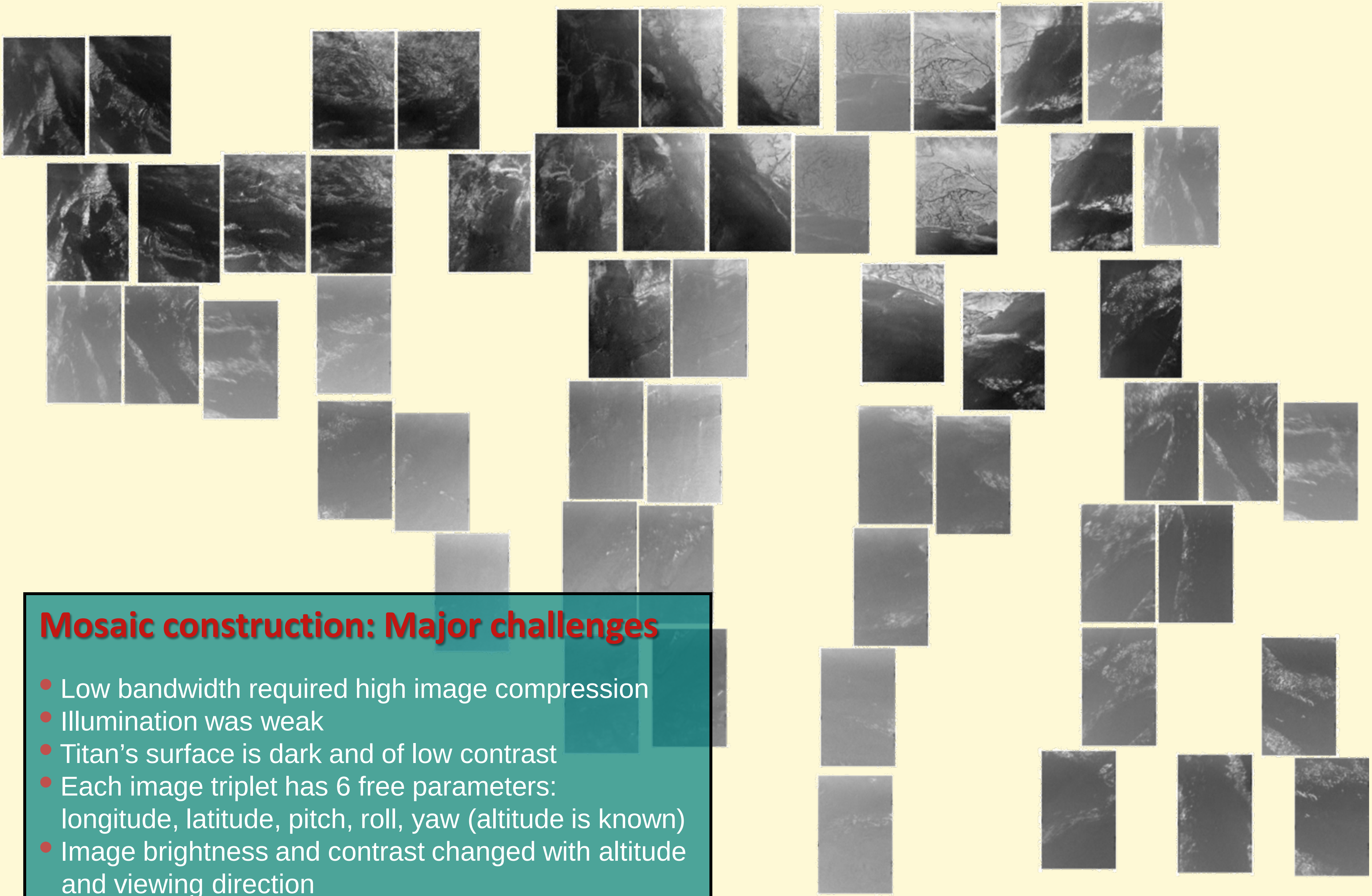
On ground



On board raw image (reconstructed) | Divided by corrected flat field | 2007 calibration | 2016 calibration

Karkoschka & Schröder (2016a)

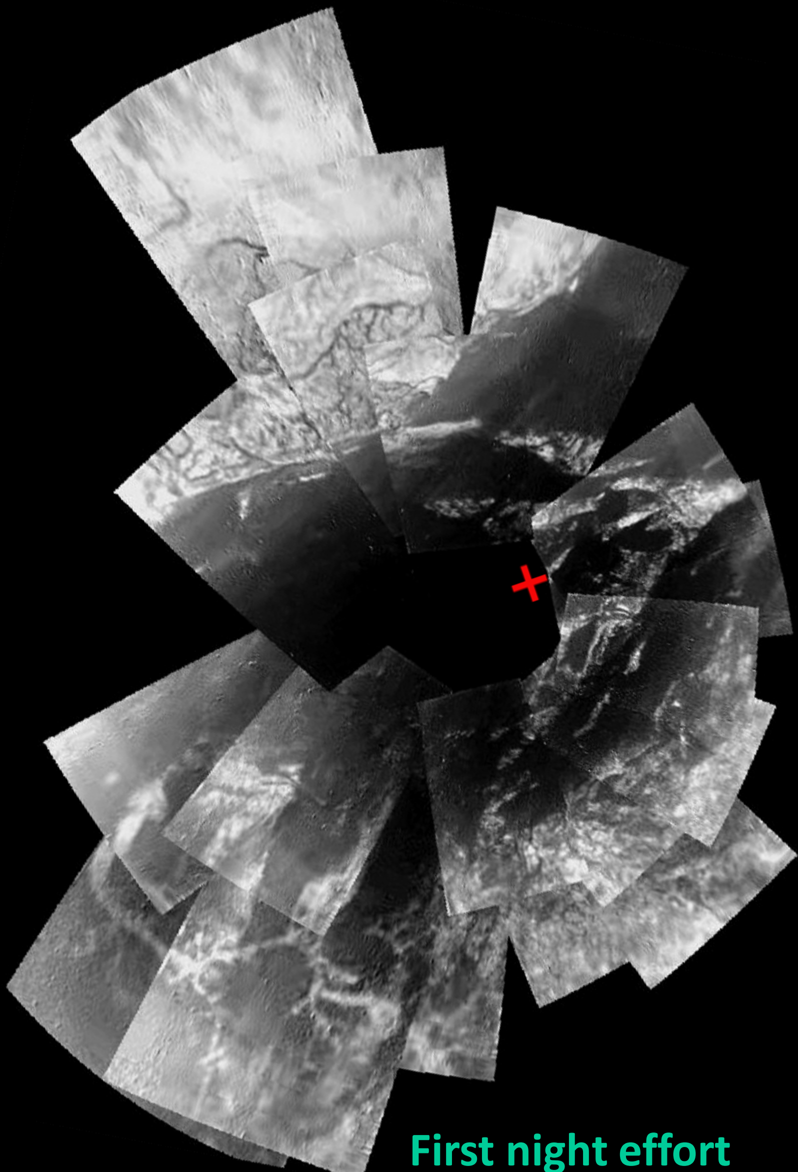

a)
Calibration
Standard Sets without Images
Image Panoramas
Calibration
Spectral Maps
Altitude (Km)
Time (min)
0
20
40
60
80
100
120
140
160
0
30
60
90
120
150
b)
Calibration
Image Panoramas
Standard Sets without Images
Spectral Maps
3-Image Sets+Spectra
High-Resolution Images
Surface Spectra with Lamp
Altitude (Km)
Time (min)
0.001
0.01
0.1
1
10
60
80
100
120
140



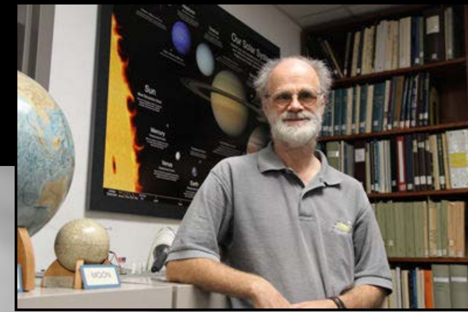
Mosaic construction: Major challenges

- Low bandwidth required high image compression
- Illumination was weak
- Titan's surface is dark and of low contrast
- Each image triplet has 6 free parameters: longitude, latitude, pitch, roll, yaw (altitude is known)
- Image brightness and contrast changed with altitude and viewing direction
- Half the images were lost (partial triplets)
- Rotation was reverse to that expected
- Sun sensor failed to lock most of the time

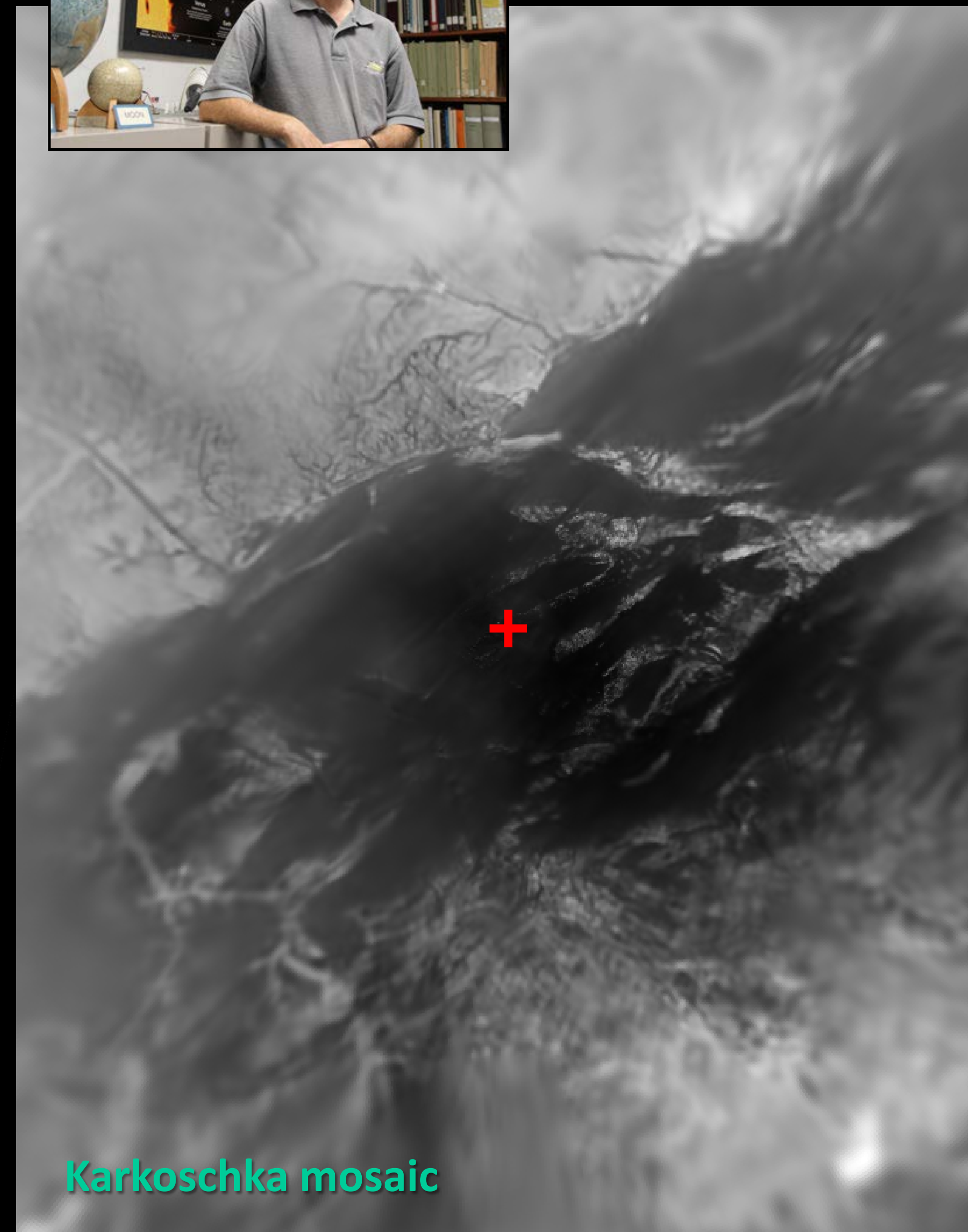
Reconstructions



First night effort

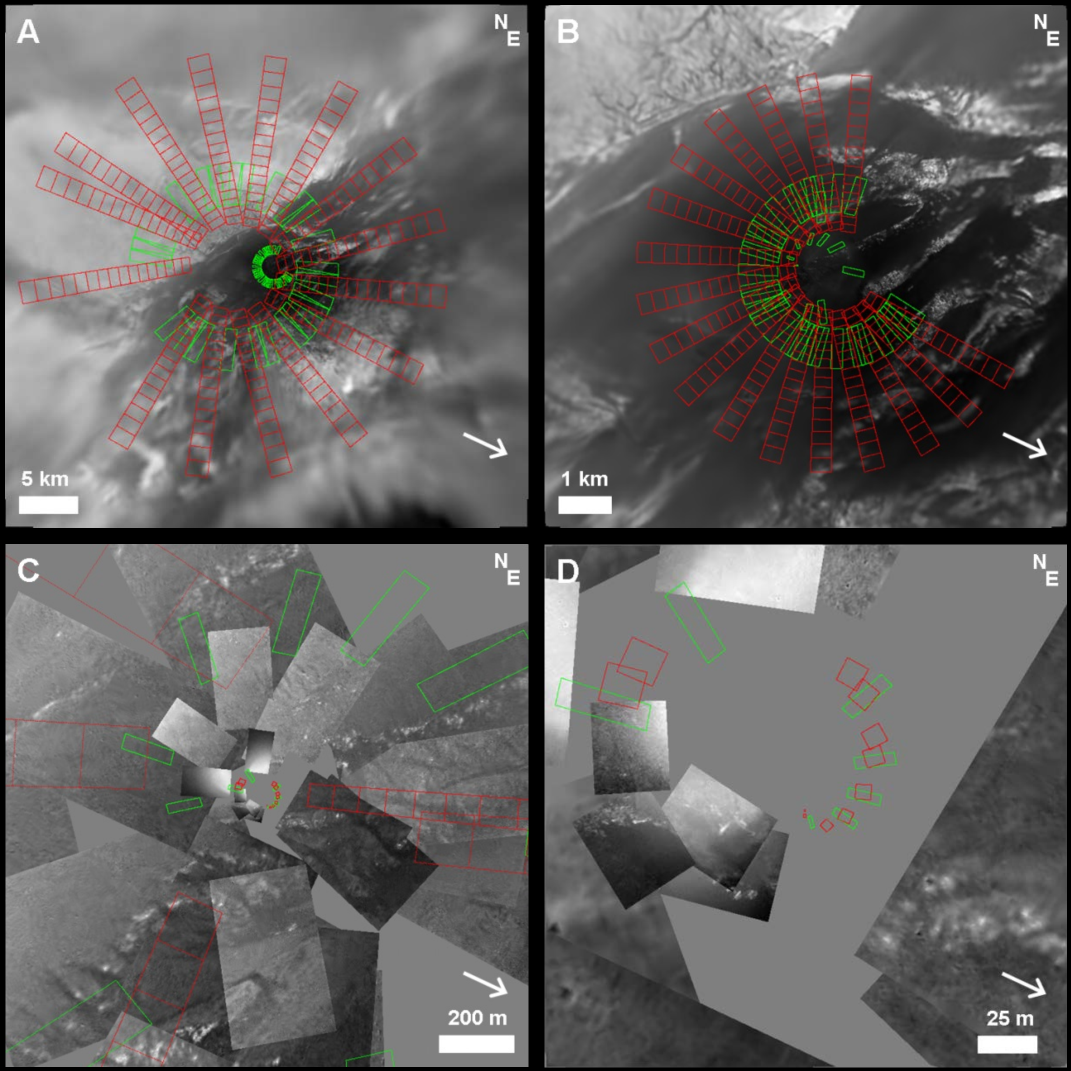


Erich Karkoschka, LPL

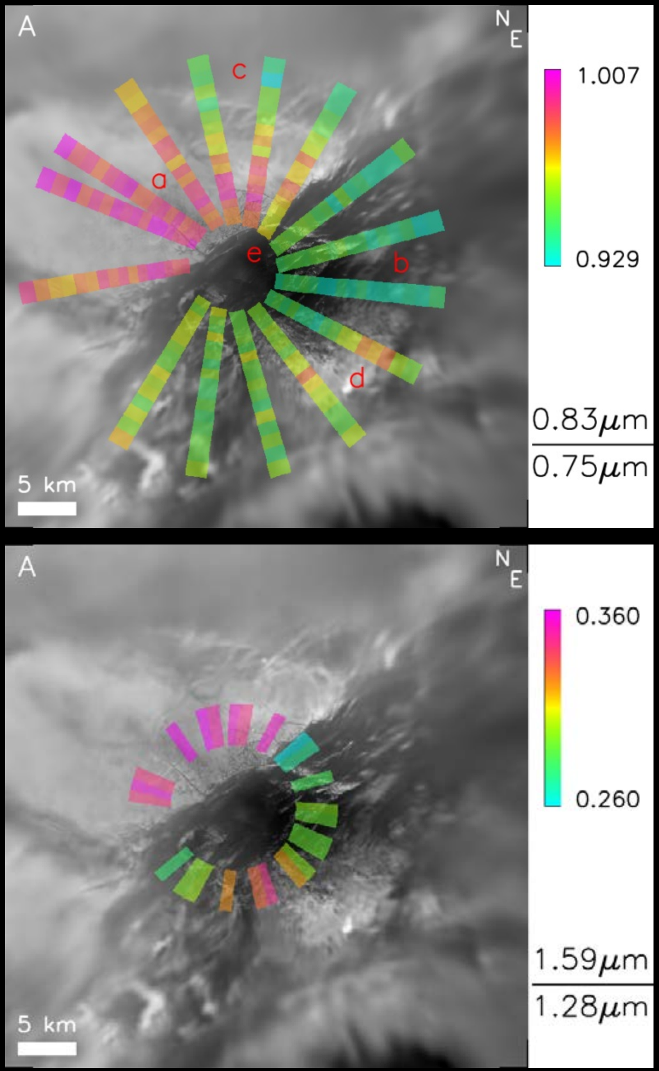


Karkoschka mosaic

DLVS/DLIS surface coverage



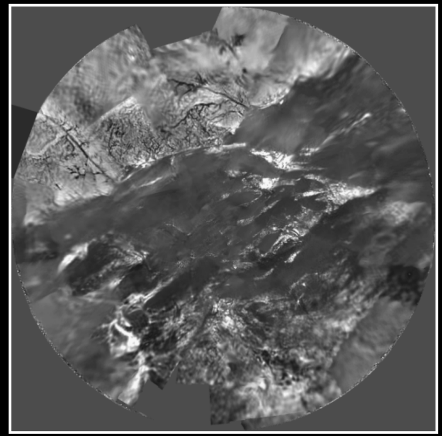
Schröder & Keller (2009)



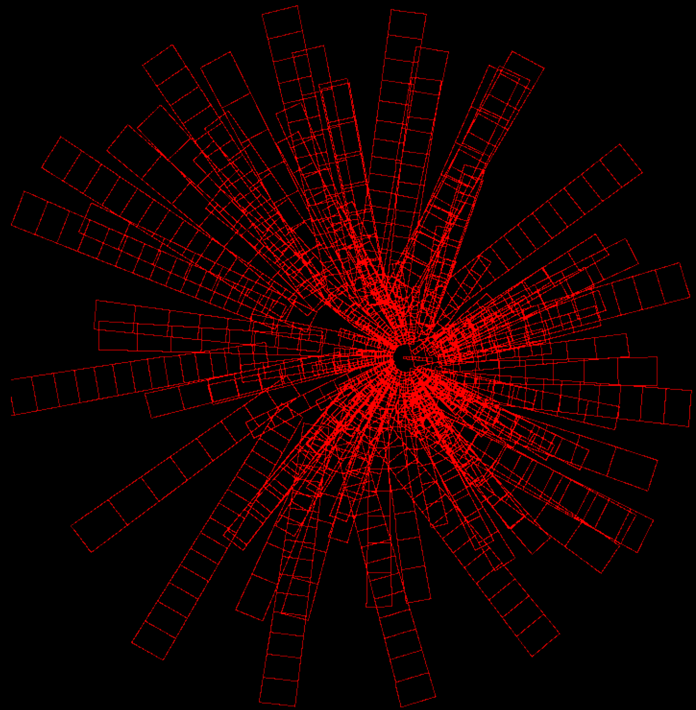
Keller et al. (2008)

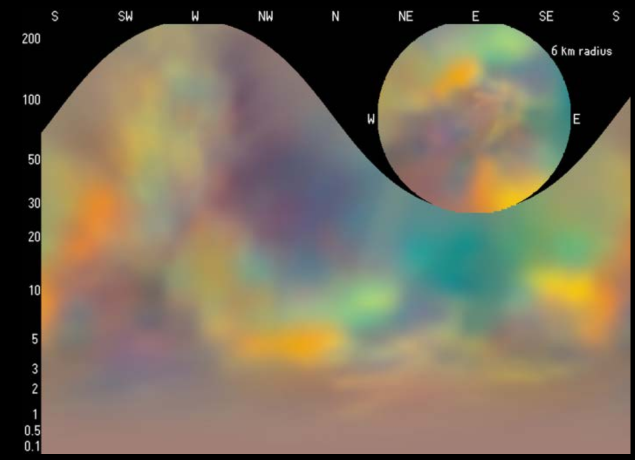
Color maps

Landing site

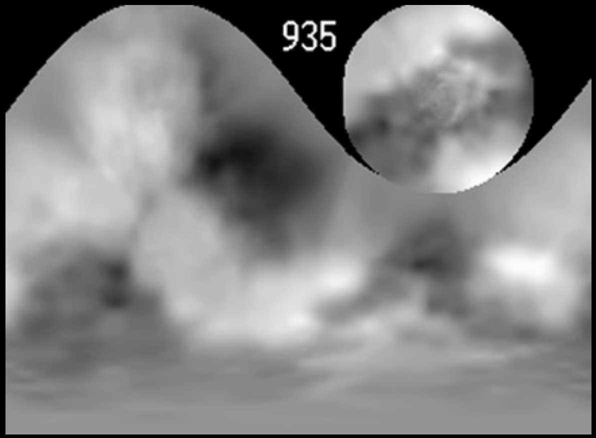


All Downward Looking Visible Spectrometer footprints (20-1 km altitude)





Enhanced color

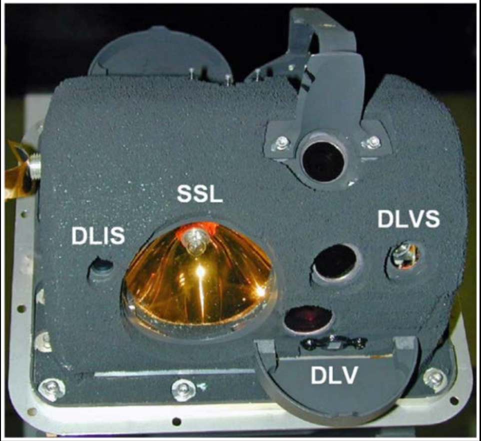


935 nm methane window

True color and contrast under Titan sky illumination

Karkoschka & Schröder (2016)

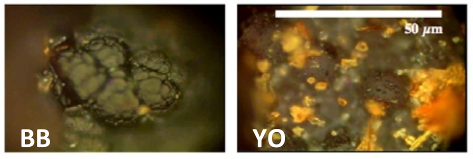
Surface reflectance spectrum

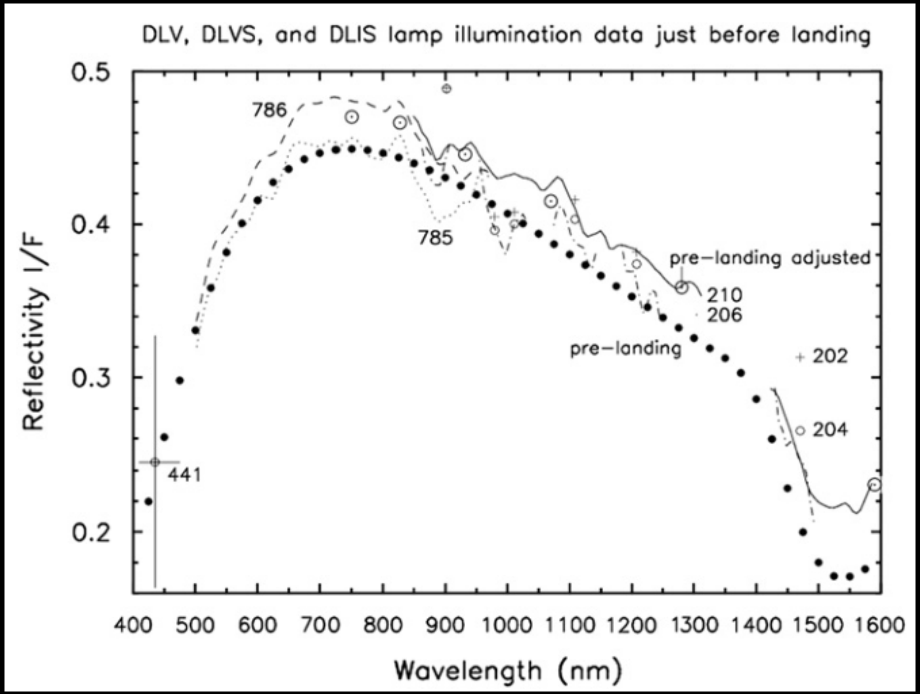


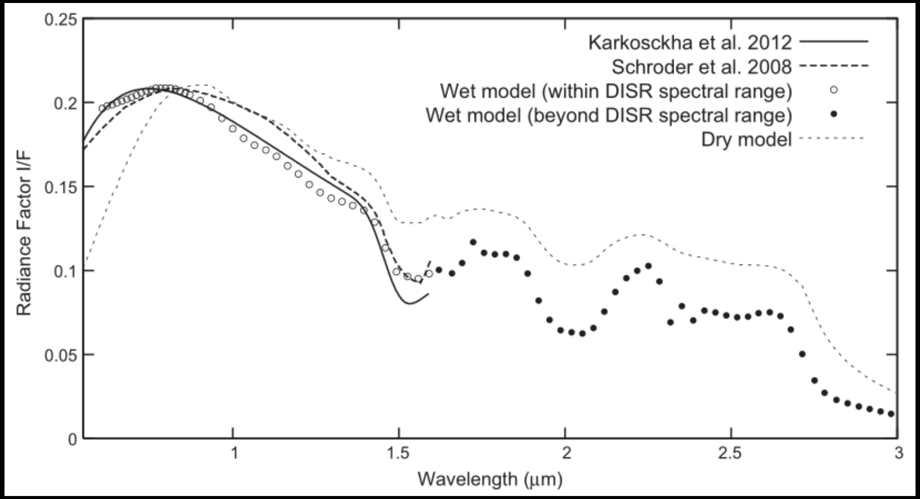
Titan surface reflectance spectrum reconstructed by *Tomasko et al. (2005)*, *Schröder & Keller (2008)* and *Karkoschka et al. (2012)*

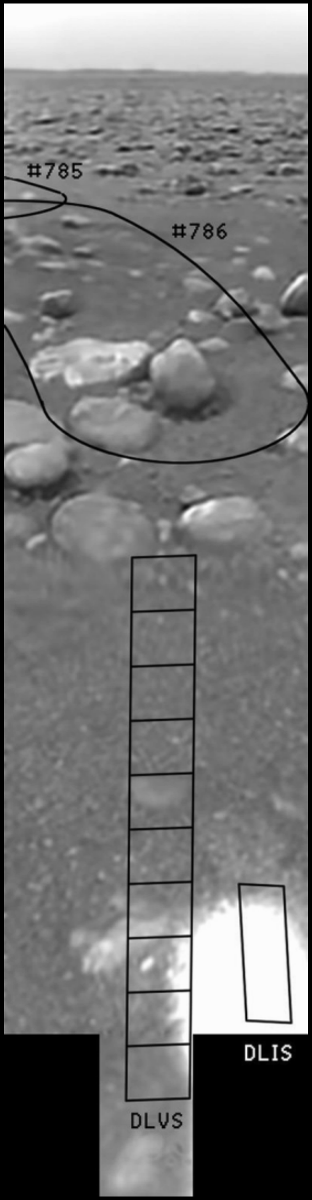
Spectrum is well modeled by a layer of water ice grains overlaid by a moist layer of weakly compacted photo-chemical aggregated aerosols (*Rannou et al. 2015*)

Tholins *(Bernard et al. 2006)*

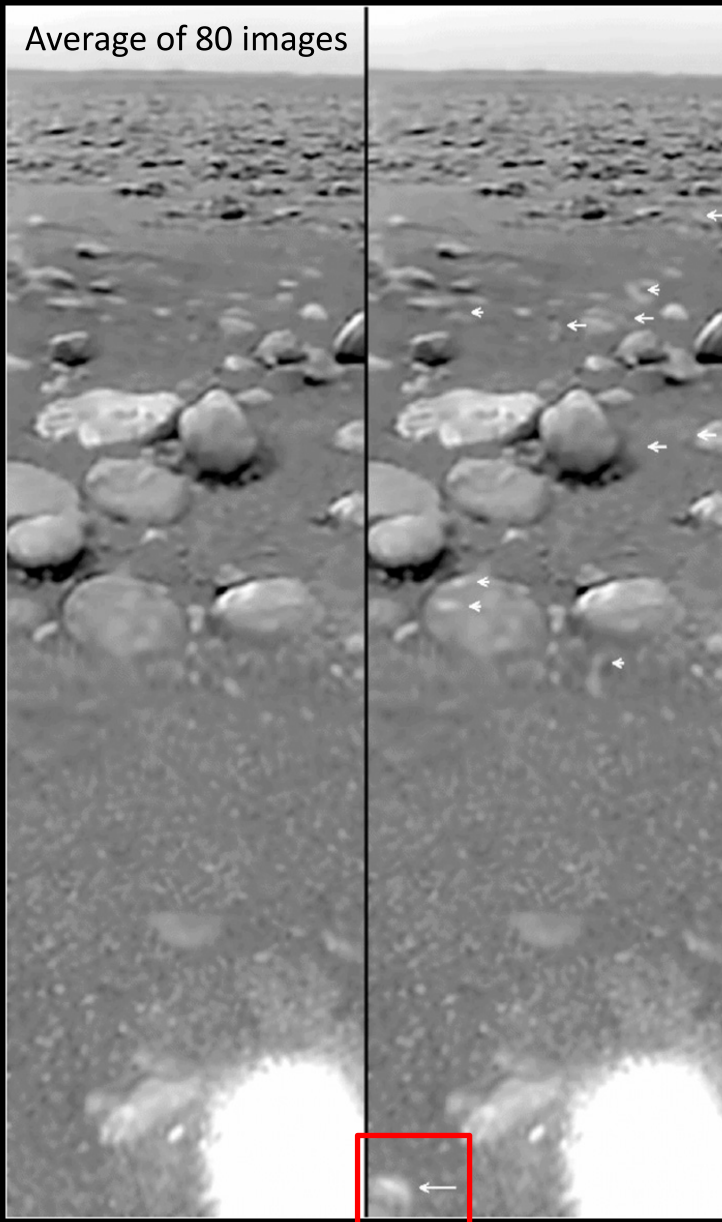


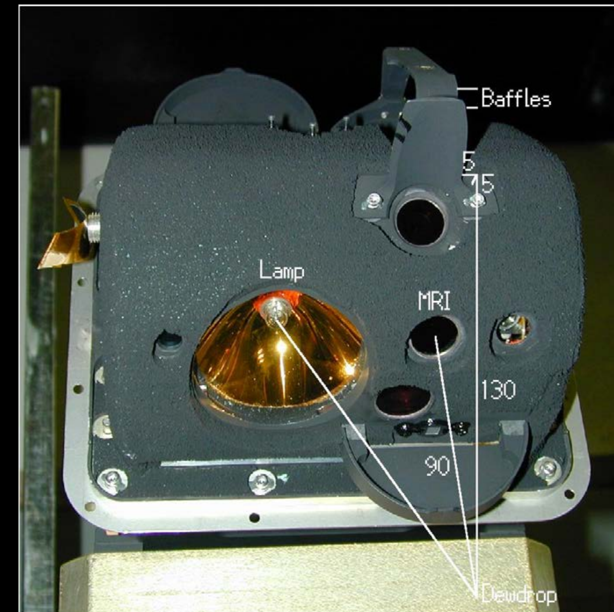


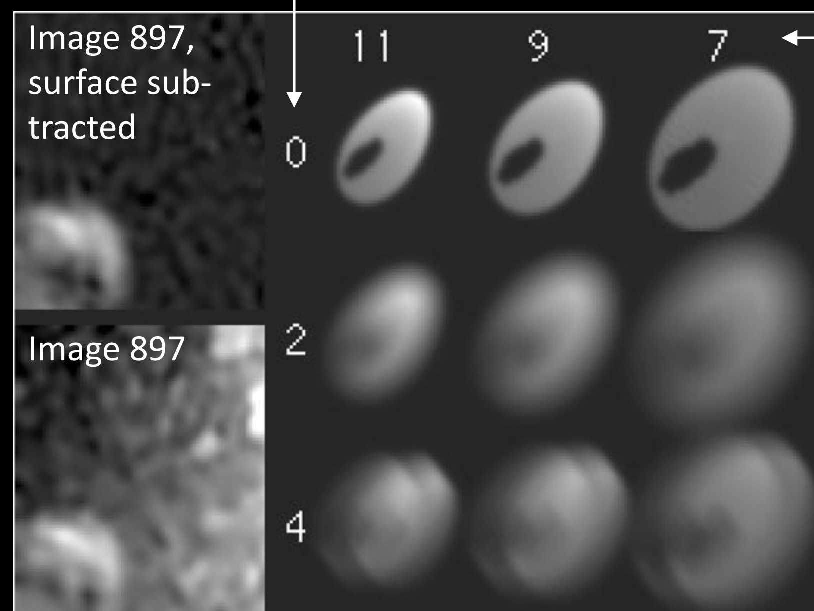




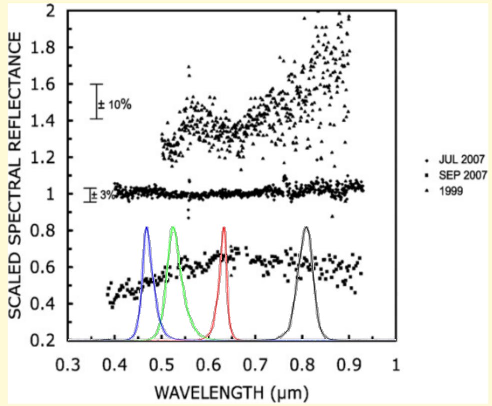
Surface images: Dew drop





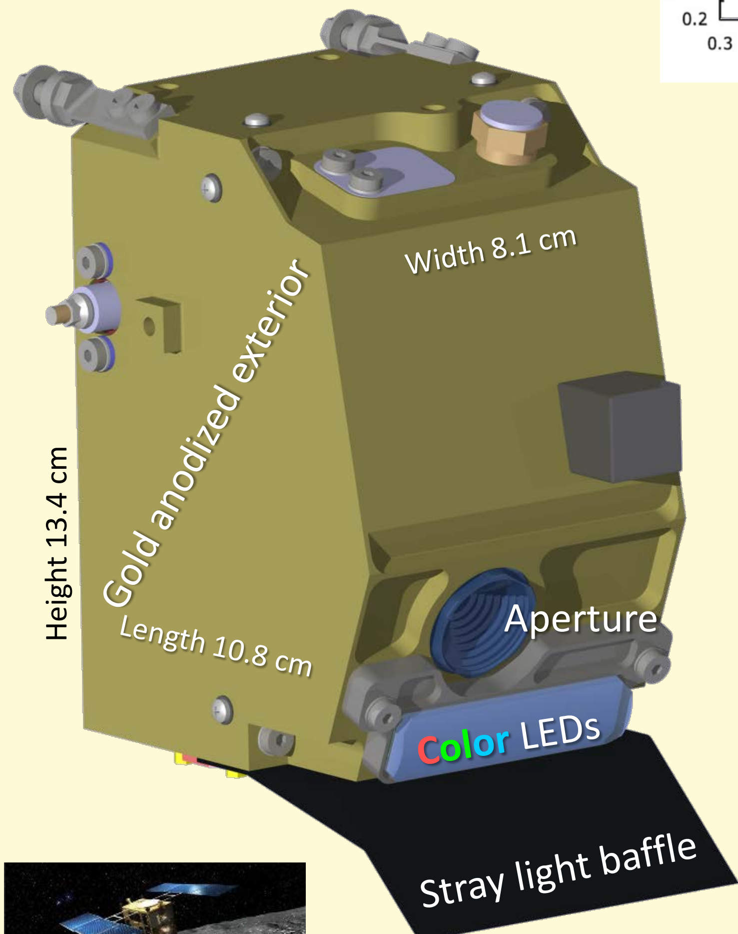


Karkoschka & Tomasko (2009)

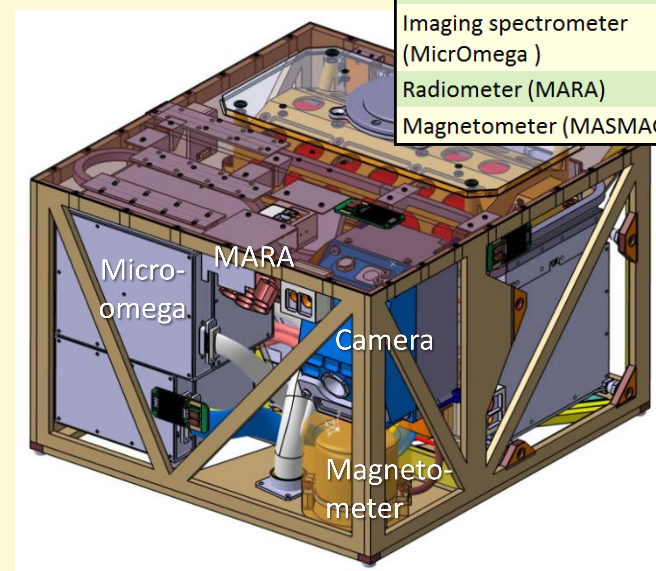


Ryugu shape model (Kawakami)

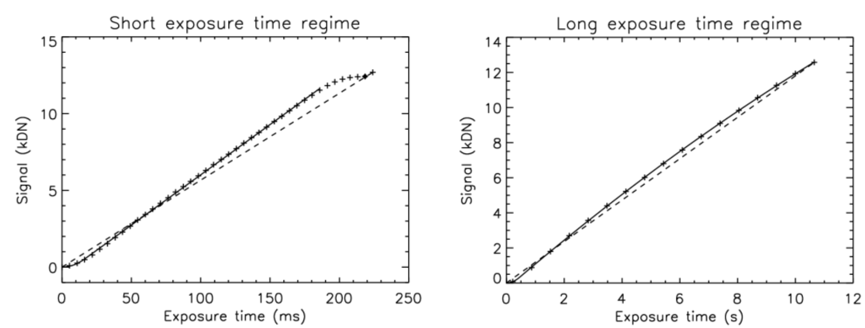
Camera (MASCAM)
Imaging spectrometer (MicrOmega)
Radiometer (MARA)
Magnetometer (MASMAG)



Sensor	Star1000 CMOS
Size	1024 × 1024 pixels
Square FOV	55°
Focal length	14.8 mm
F#	16
Pixel pitch	15 µm
Spectral range	panchromatic (0.4-1.0 µm)
LED (4 × 36)	Blue (470 nm) Green (530 nm) Red (640 nm) NIR (870 nm)

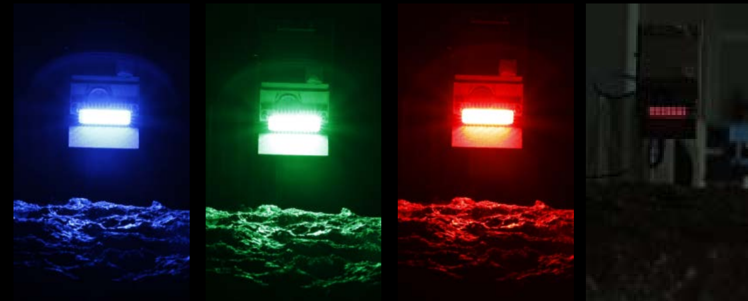


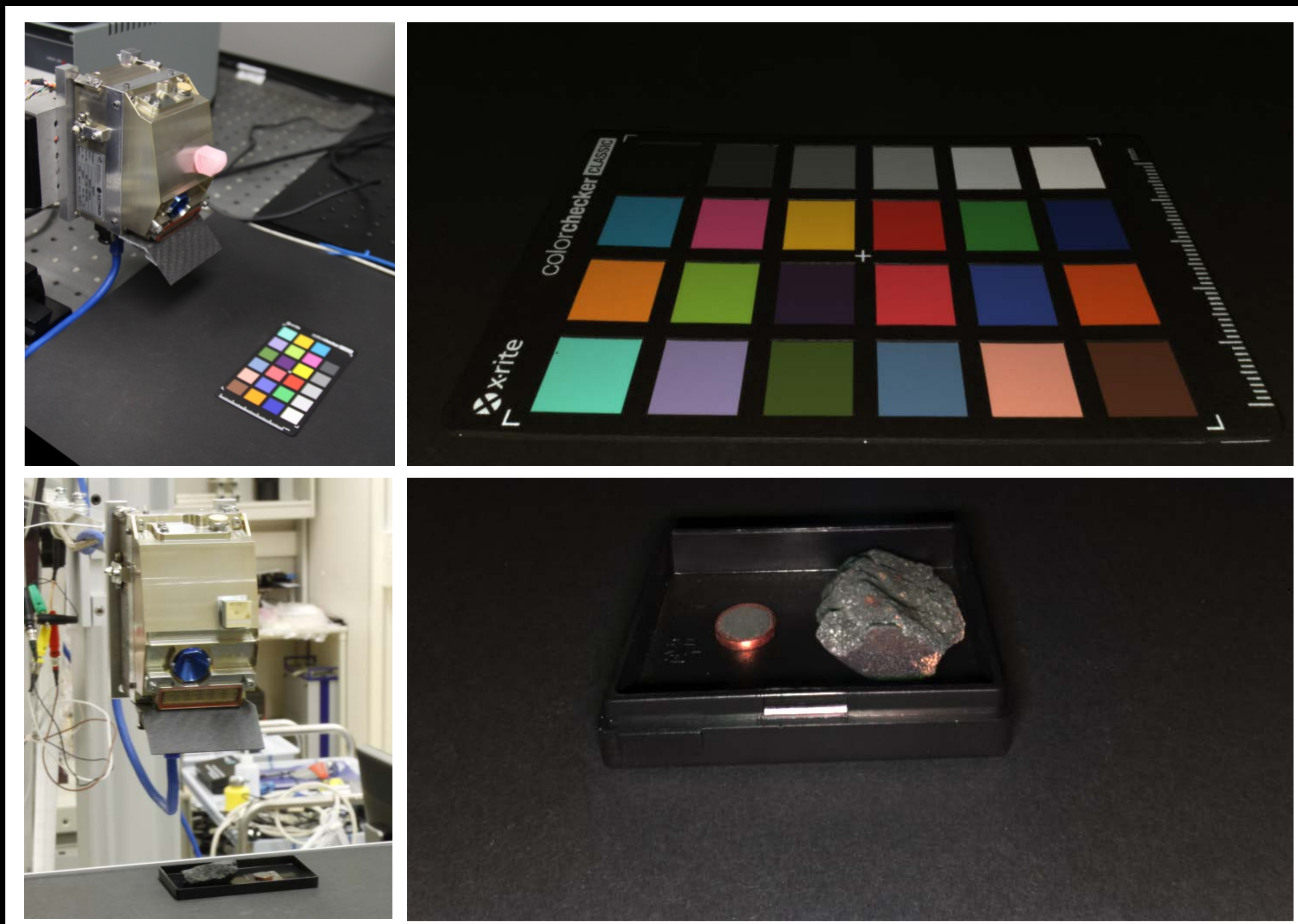
CMOS non-linearity



Jaumann et al. (2016)

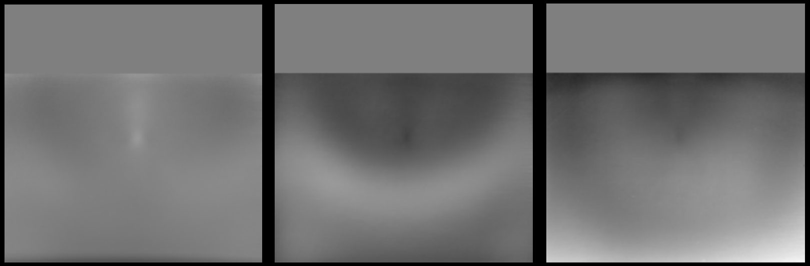
LED illumination



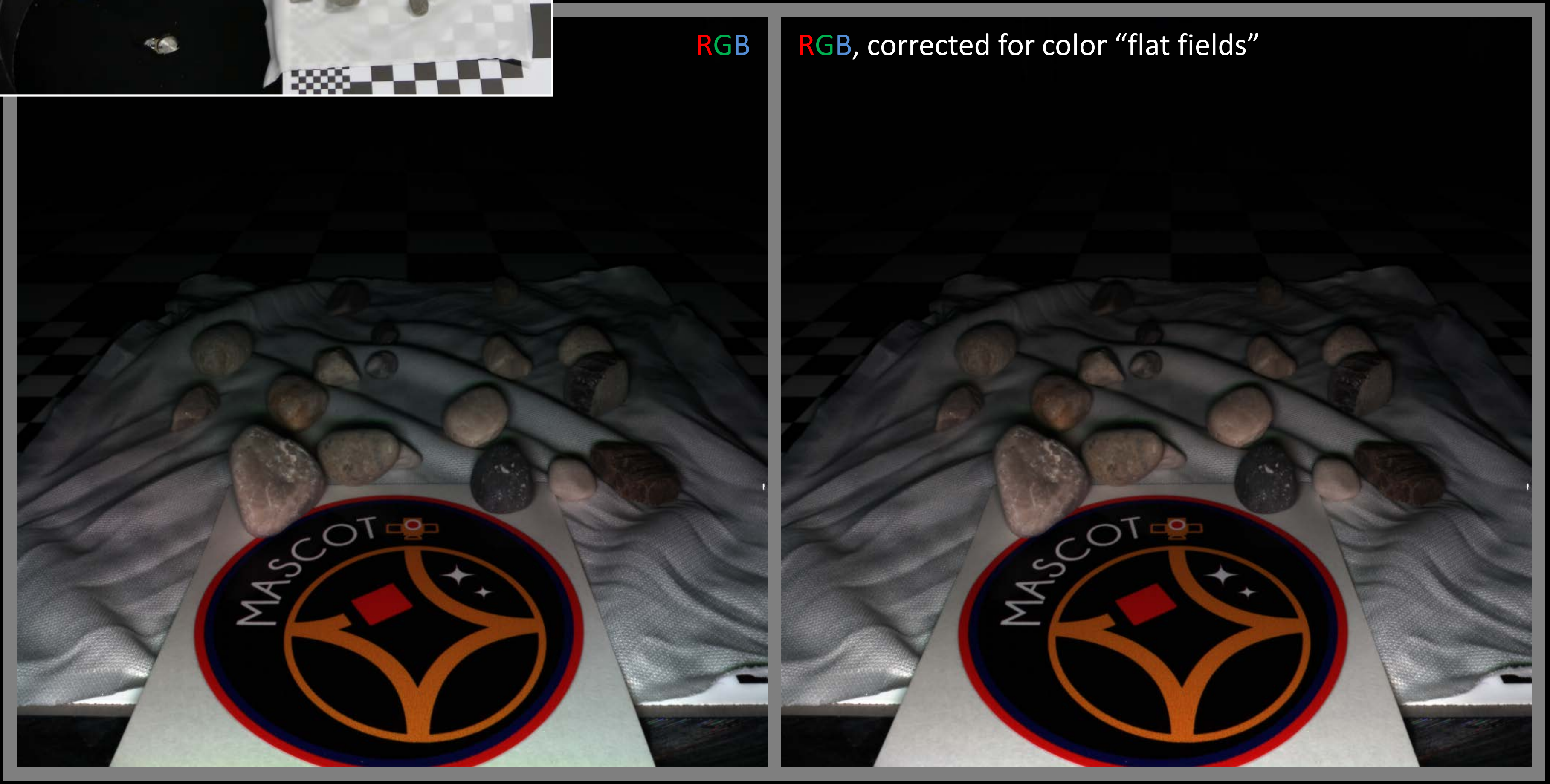


Jaumann et al. (2016)

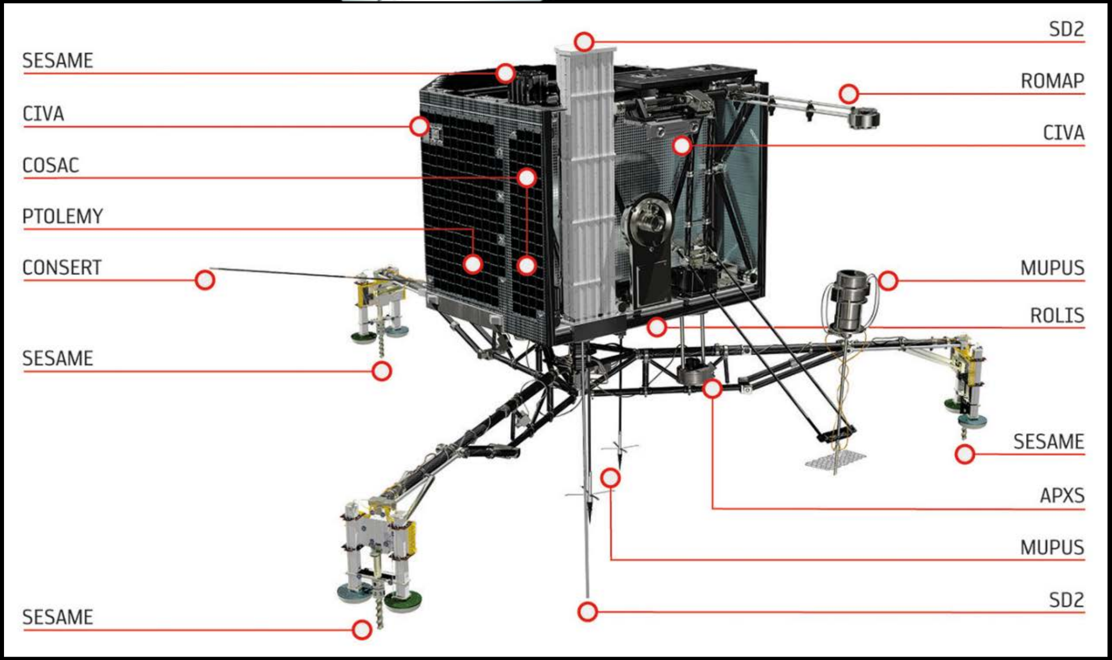
MASCOT LEDs



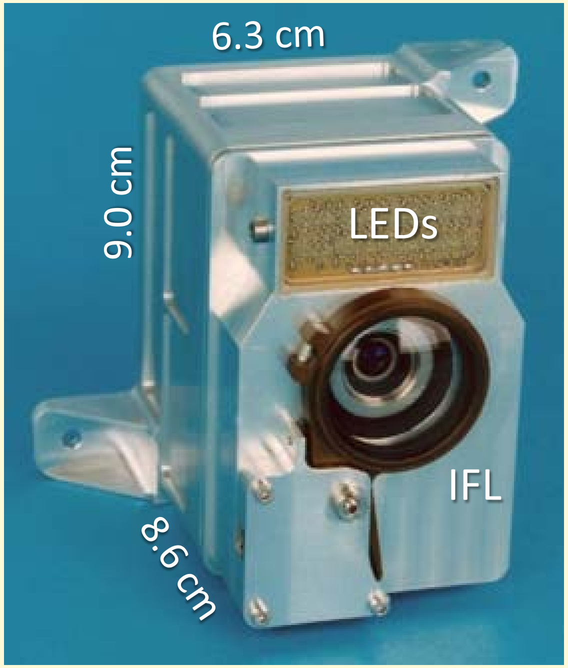
Jaumann et al. (2016)

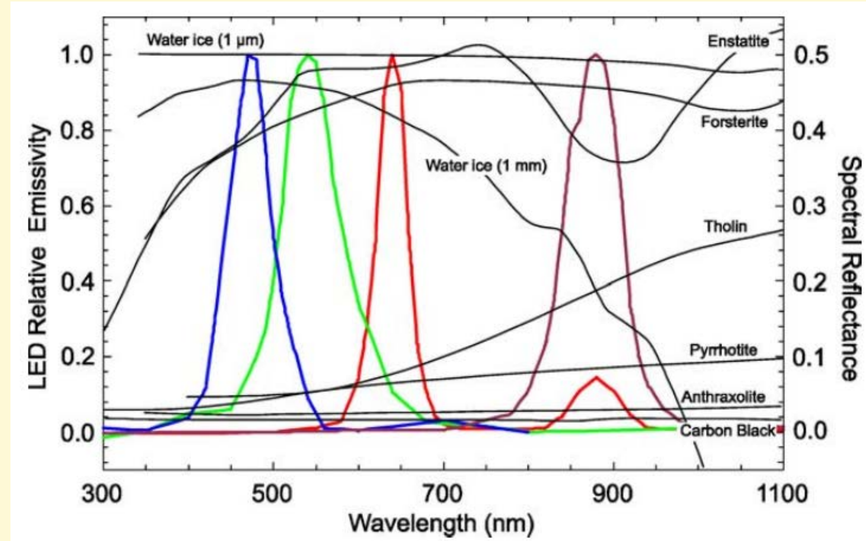


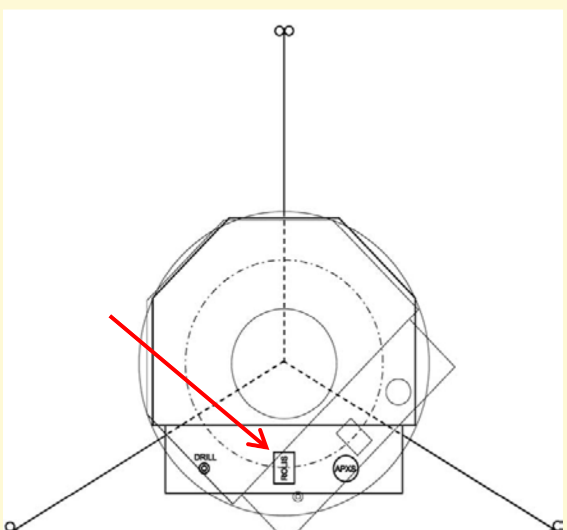
PHILAE


SESAME
CIVA
COSAC
PTOLEMY
CONSERT
SESAME
SESAME
SD2
ROMAP
CIVA
MUPUS
ROLIS
SESAME
APXS
MUPUS
SD2

ROLIS camera



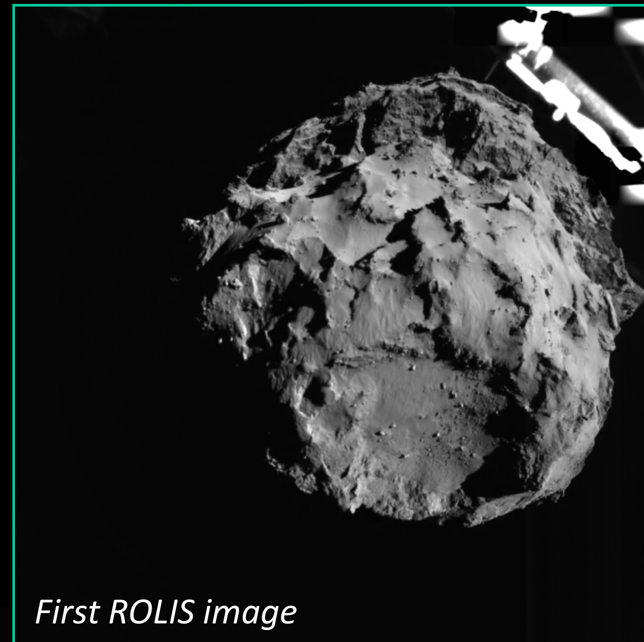




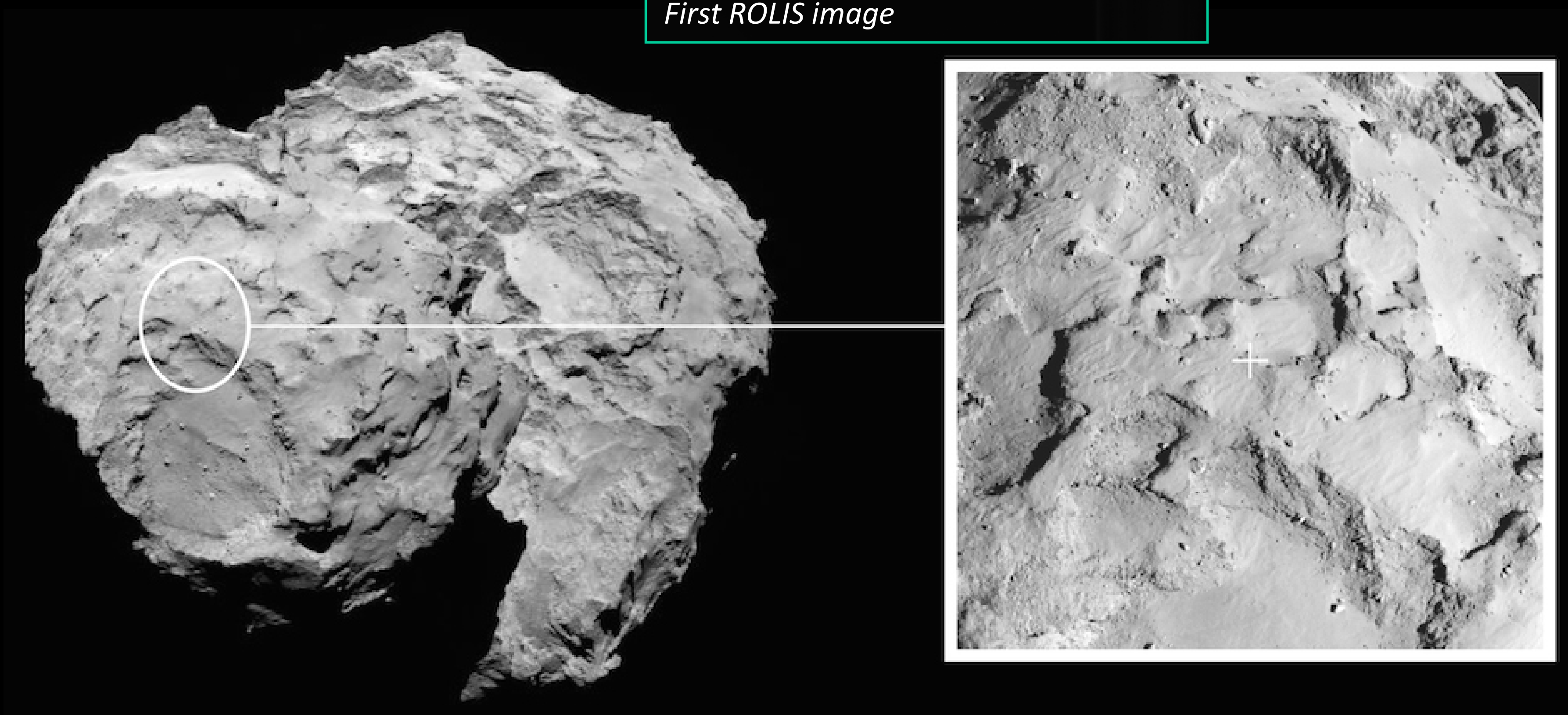
Sensor	Thomson (now Atmel) TH7888A CCD
Size	1024 × 1024 pixels
Square FOV	57.7°
Focal length (without IFL)	13.0 mm
F#	5
Pixel pitch	14 µm
Spectral range	panchromatic (0.4-1.0 µm)
LED (4 × 36)	Blue (470 nm) Green (530 nm) Red (640 nm) NIR (870 nm)

Mottola et al. (2006)

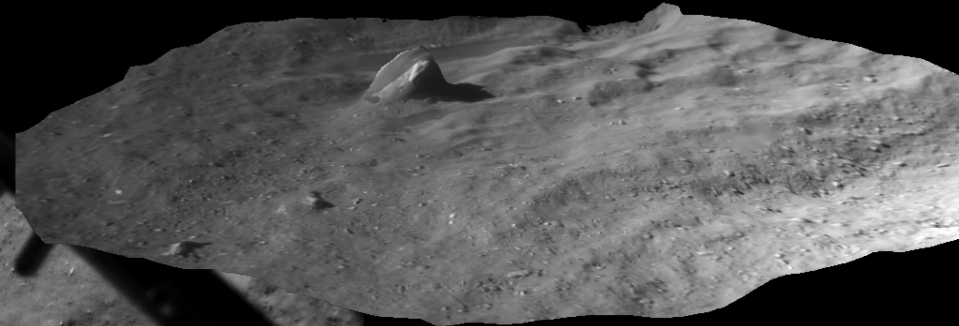
Philae's landing site



First ROLIS image

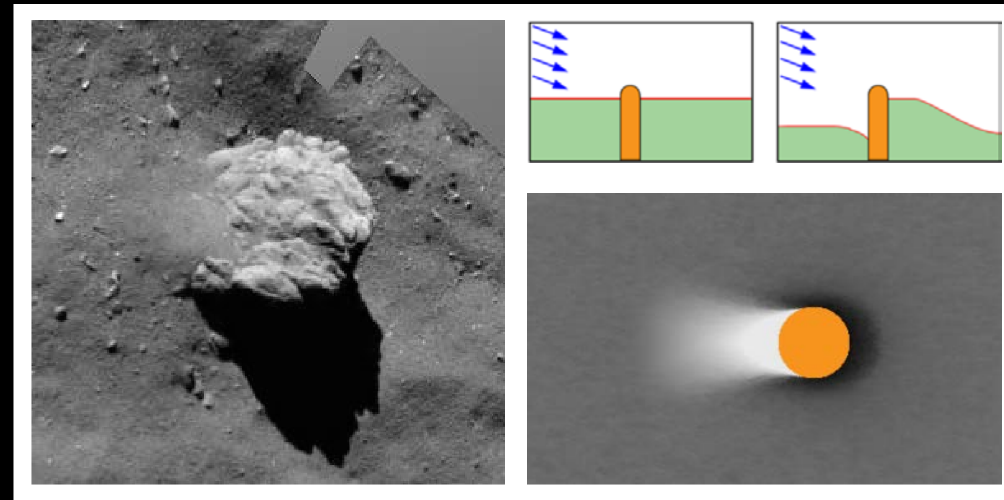


ROLIS descent image #1

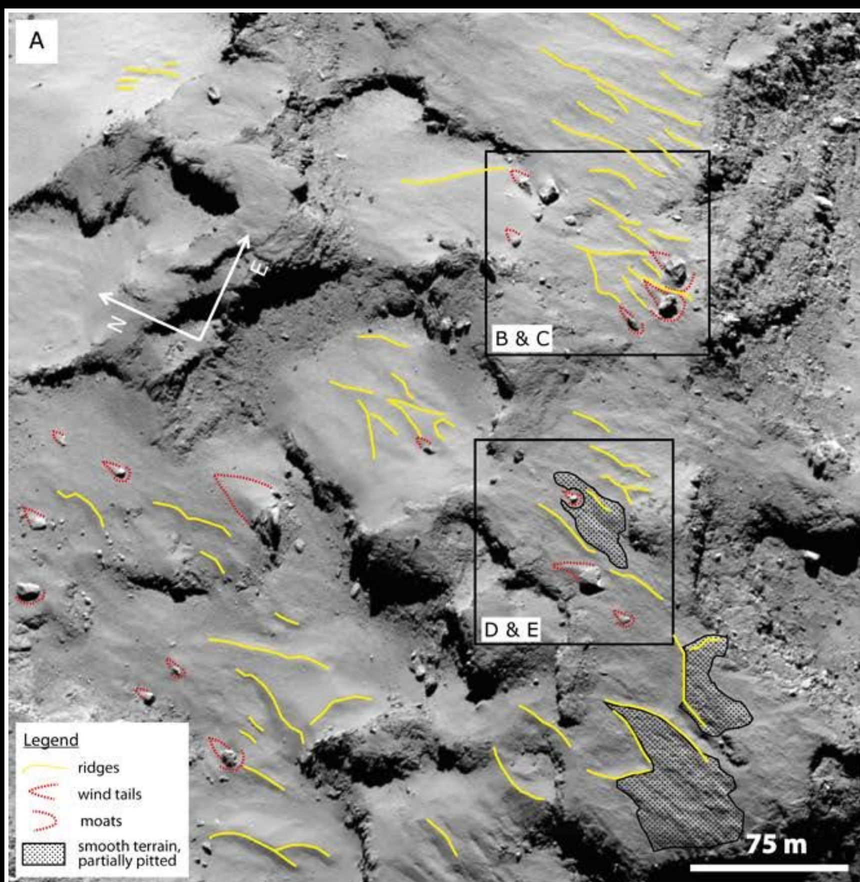


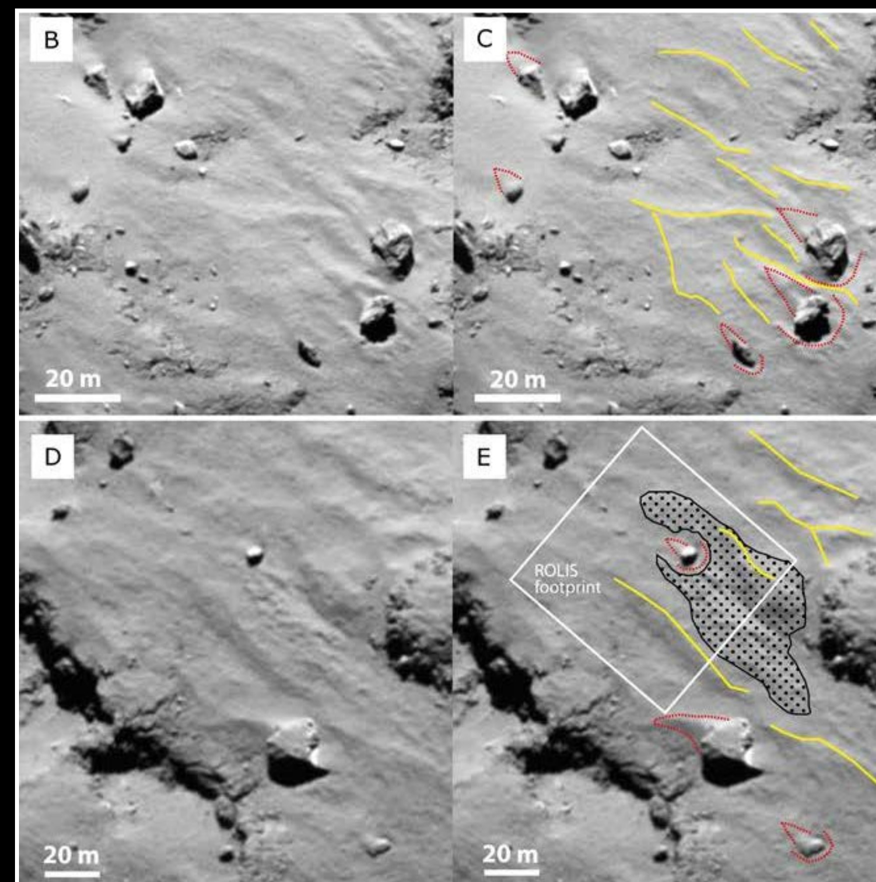
Mottola et al. (2015)

“Wind” tails



Mottola et al. (2015)

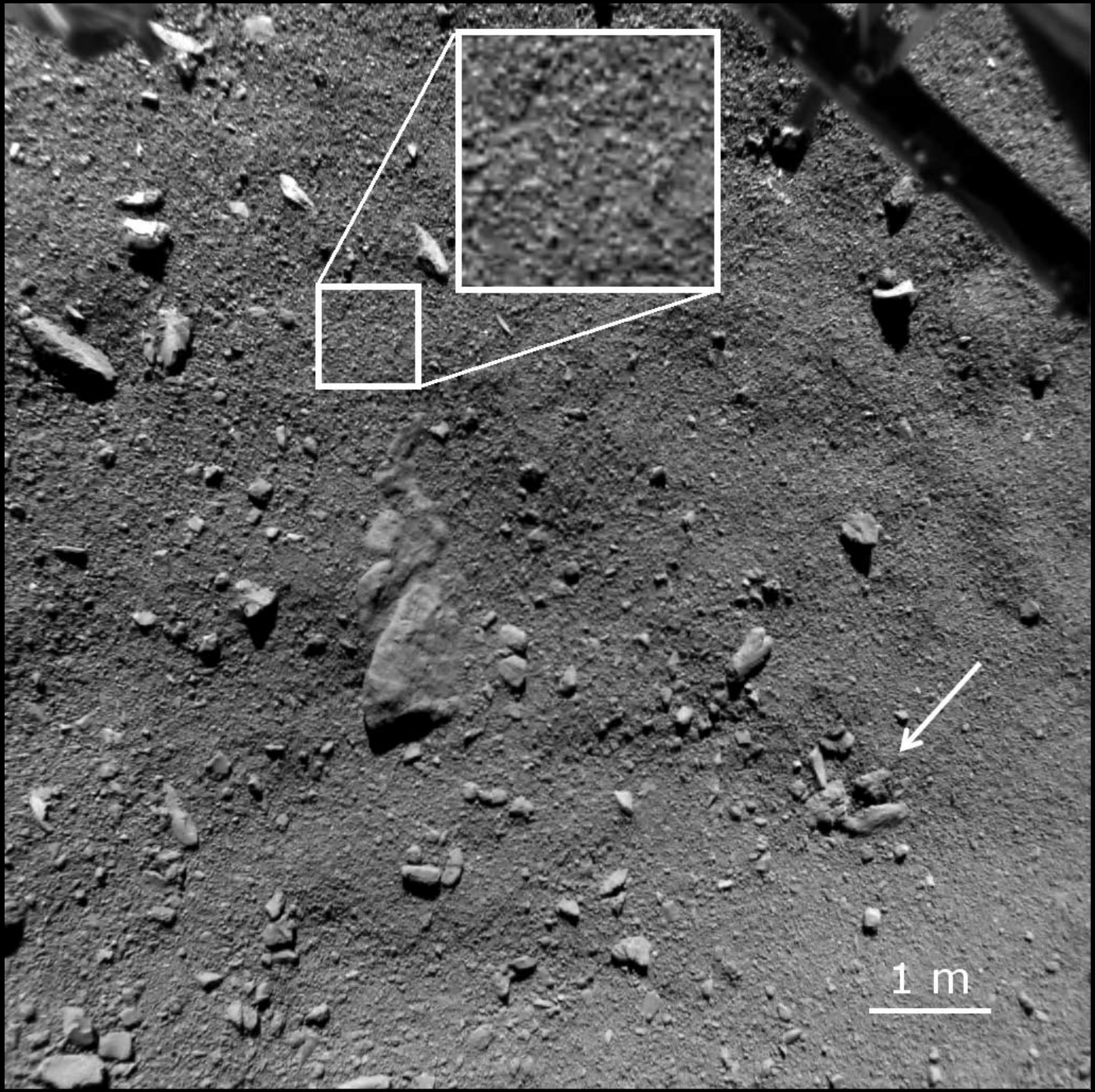




ROLIS descent image #7

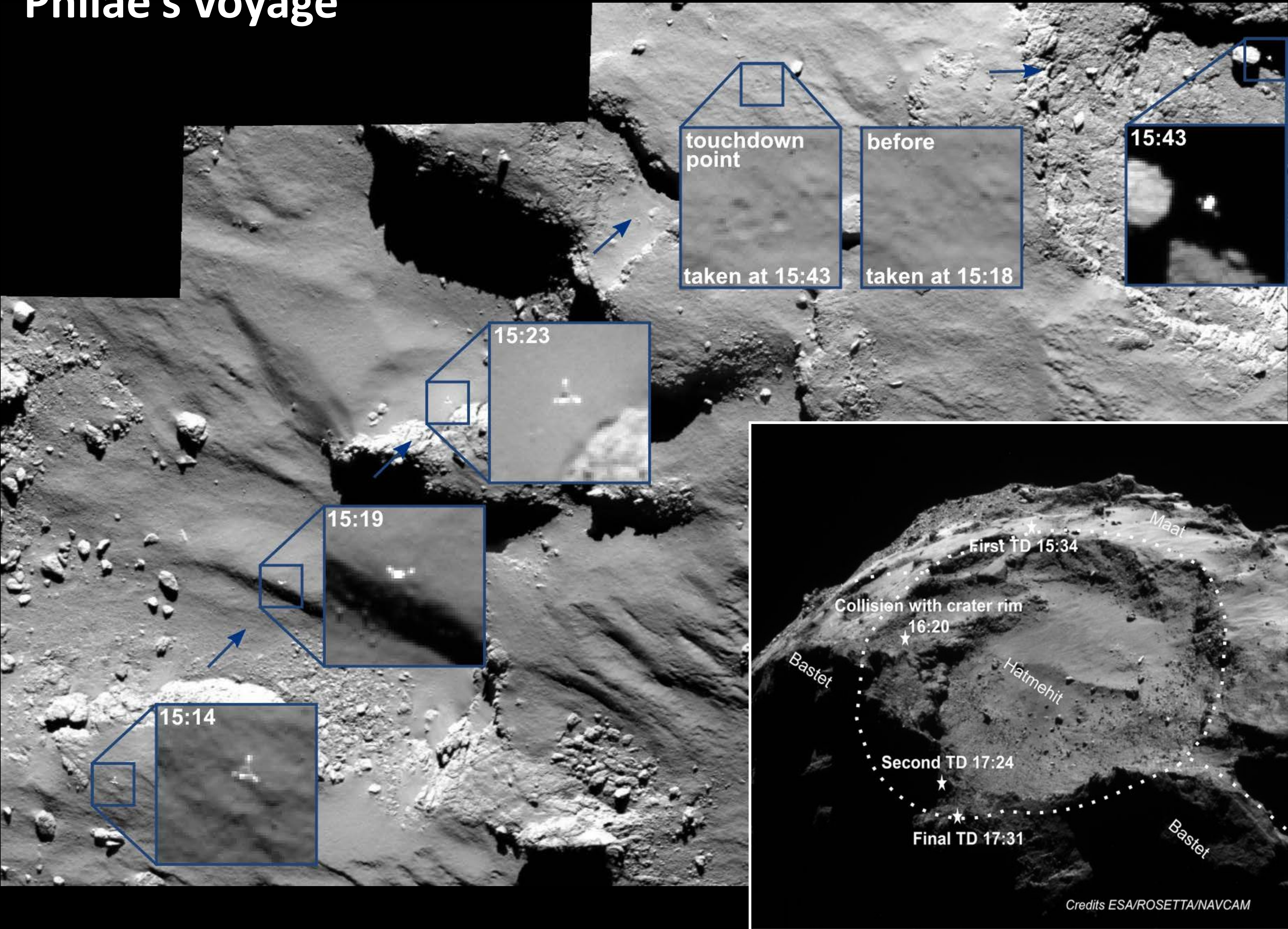
Probably "airfall" particles (*Thomas et al. 2015*)

Surface is granular at the resolution of 0.95 cm/pixel

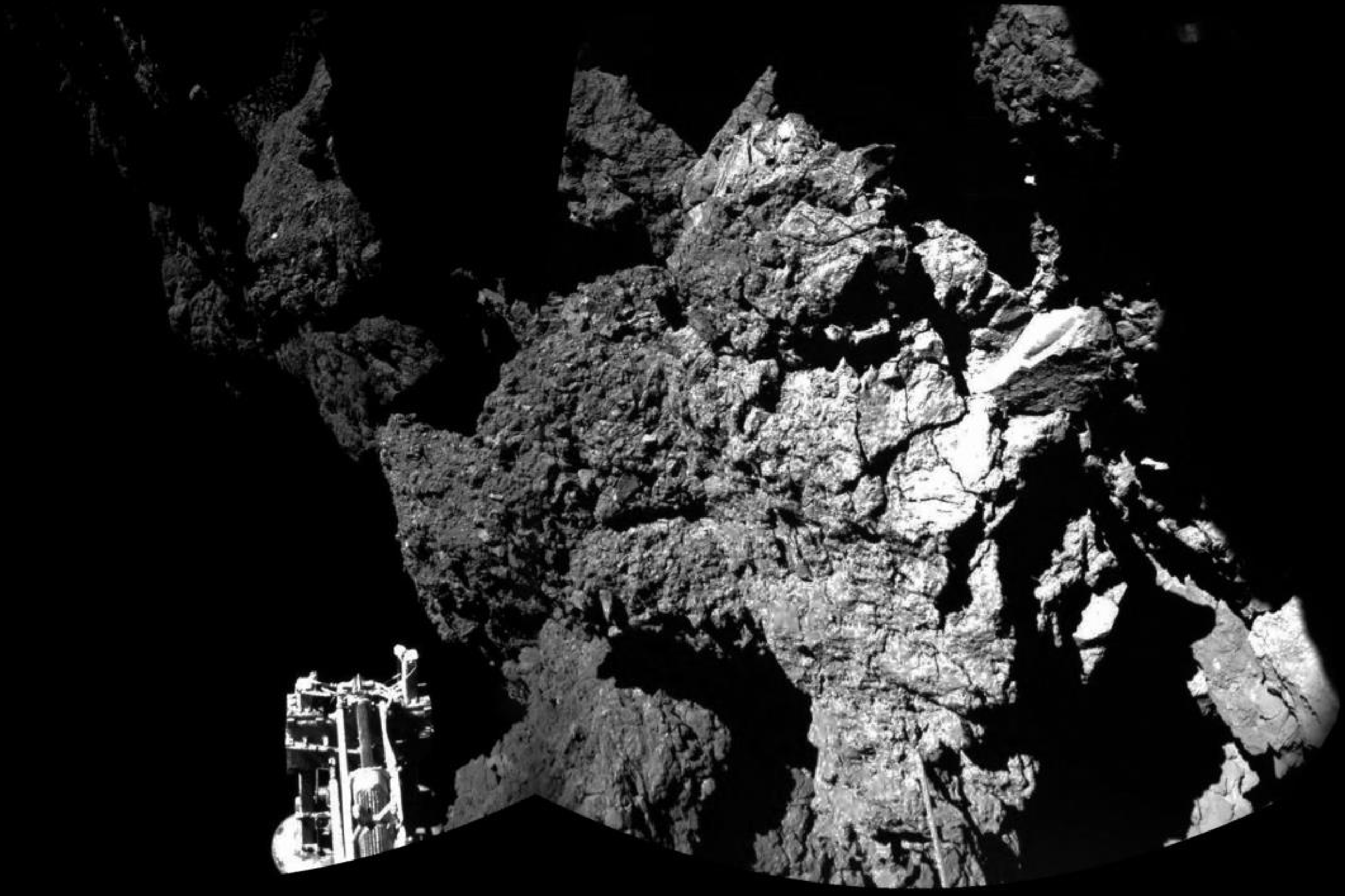


Mottola et al. (2015)

Philae's voyage

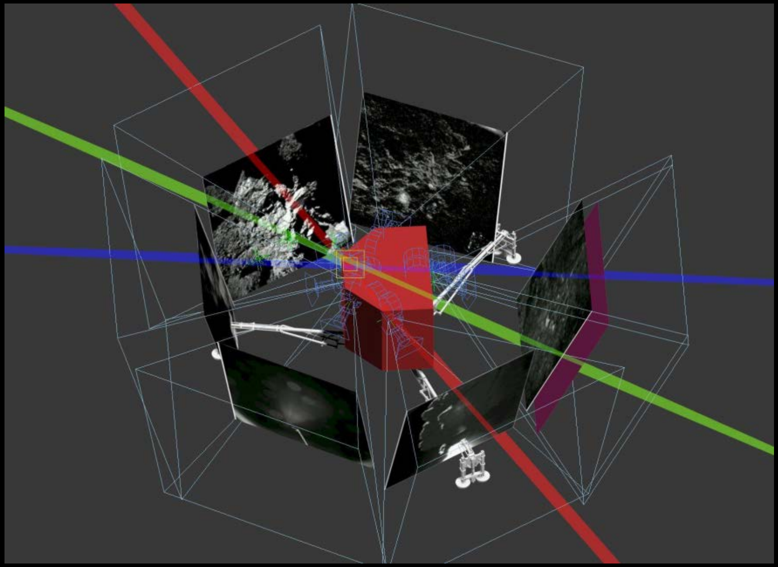


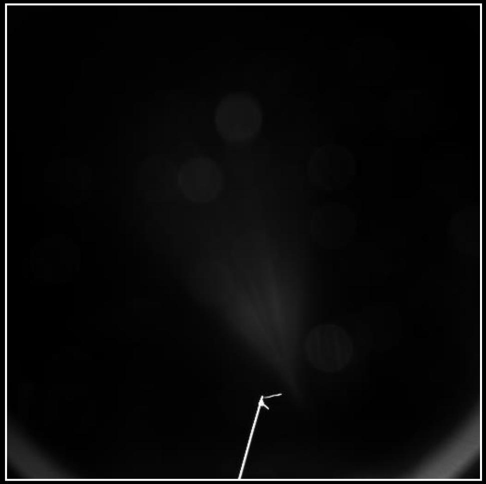
Surroundings (CIVA)

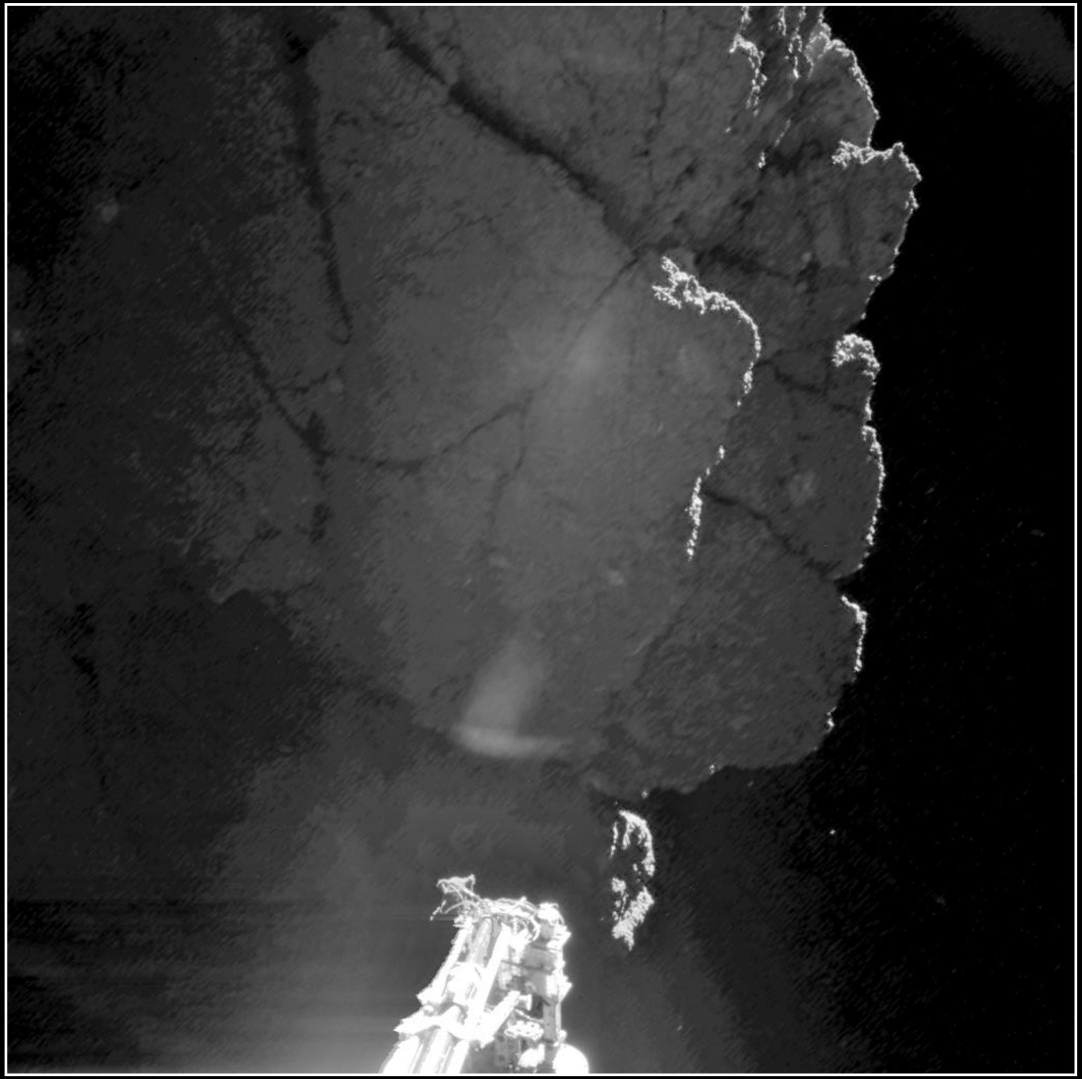


Bibring et al. (2015)

Surroundings (CIVA)



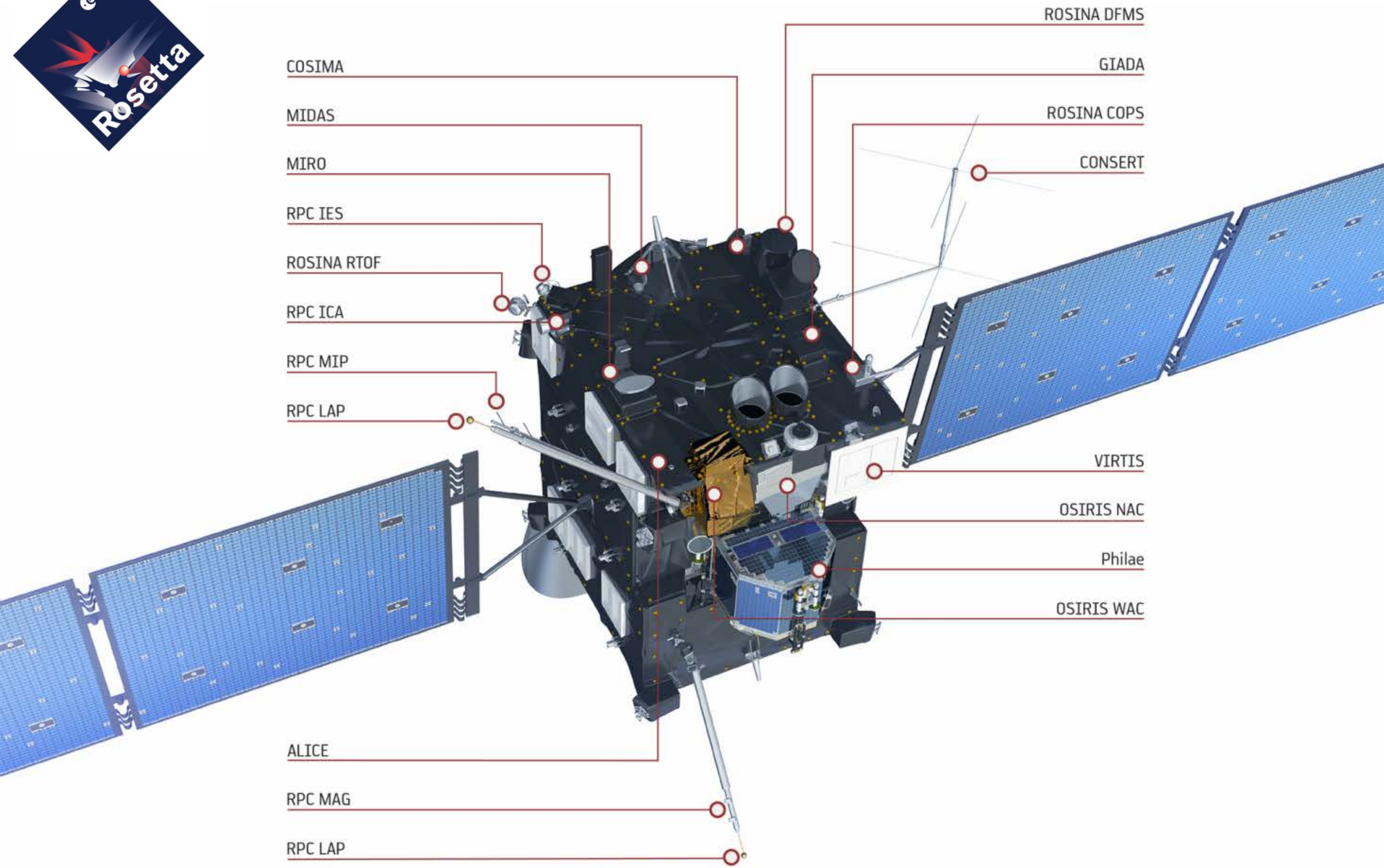




Bibring et al. (2015)

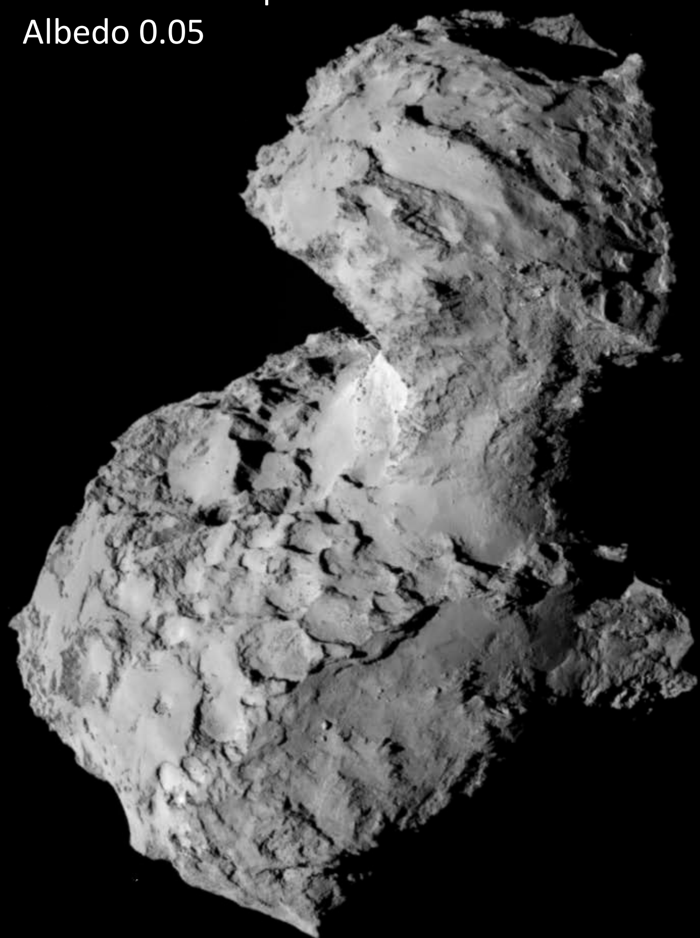
esa

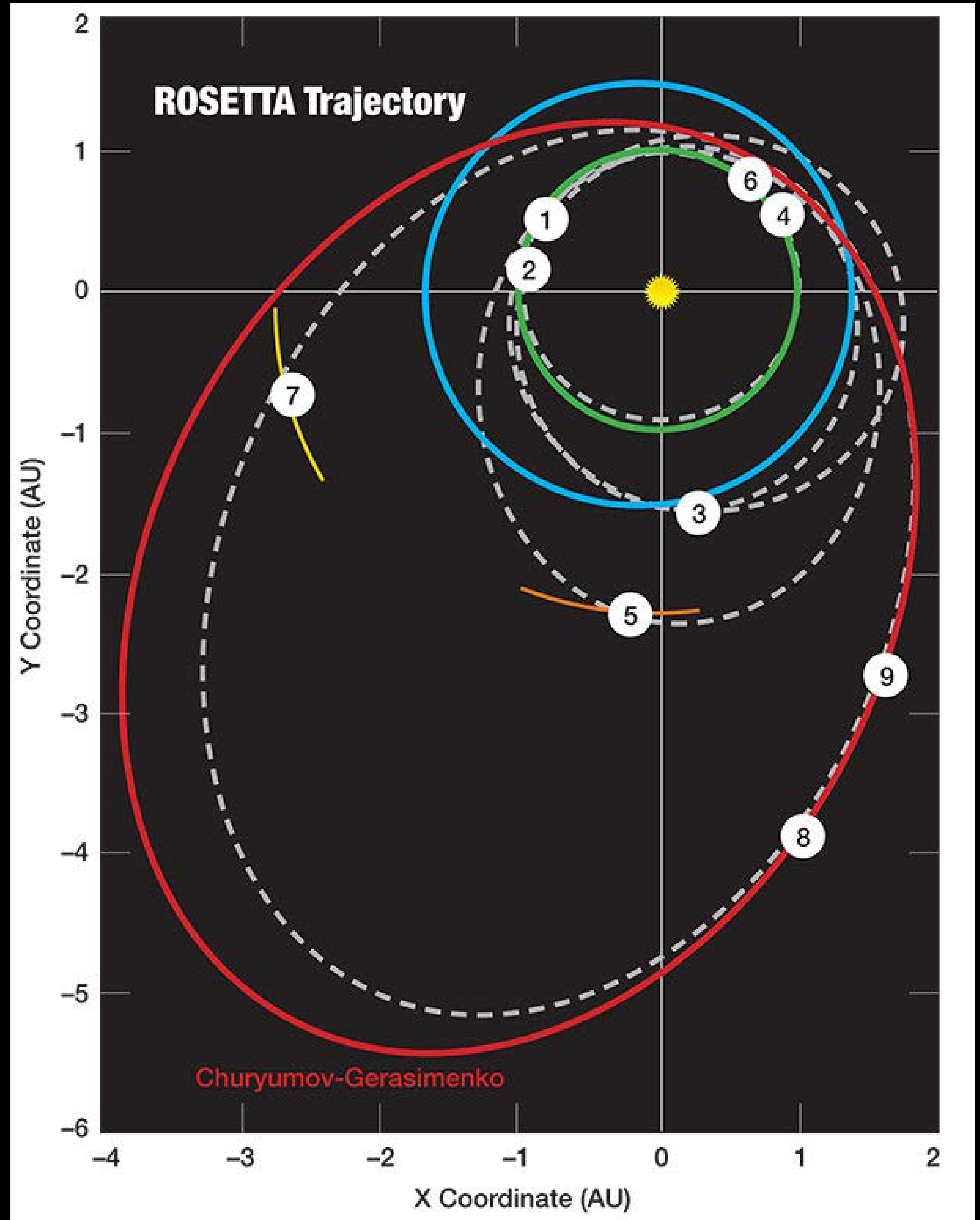
Rosetta



COSIMA
MIDAS
MIRO
RPC IES
ROSINA RTOF
RPC ICA
RPC MIP
RPC LAP
ALICE
RPC MAG
RPC LAP
ROSINA DFMS
GIADA
ROSINA COPS
CONSERT
VIRTIS
OSIRIS NAC
Philae
OSIRIS WAC

Northern hemisphere
Albedo 0.05

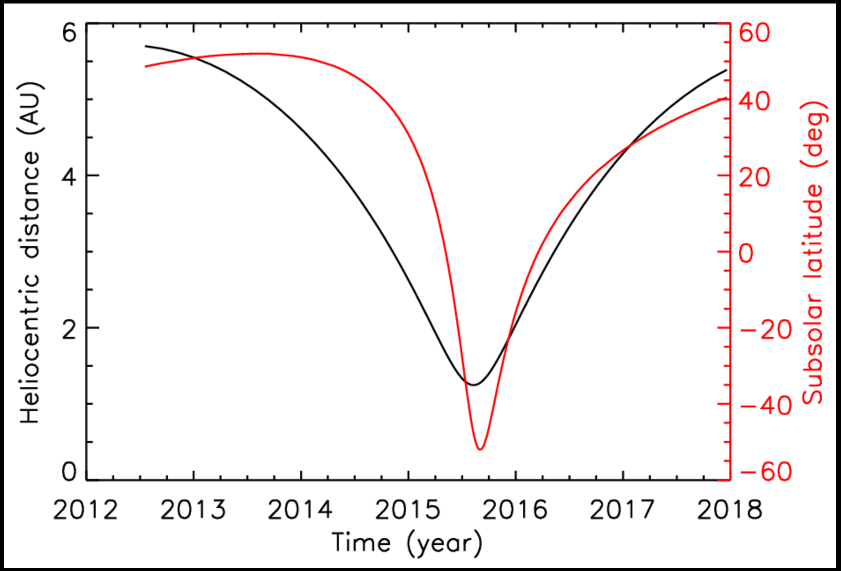


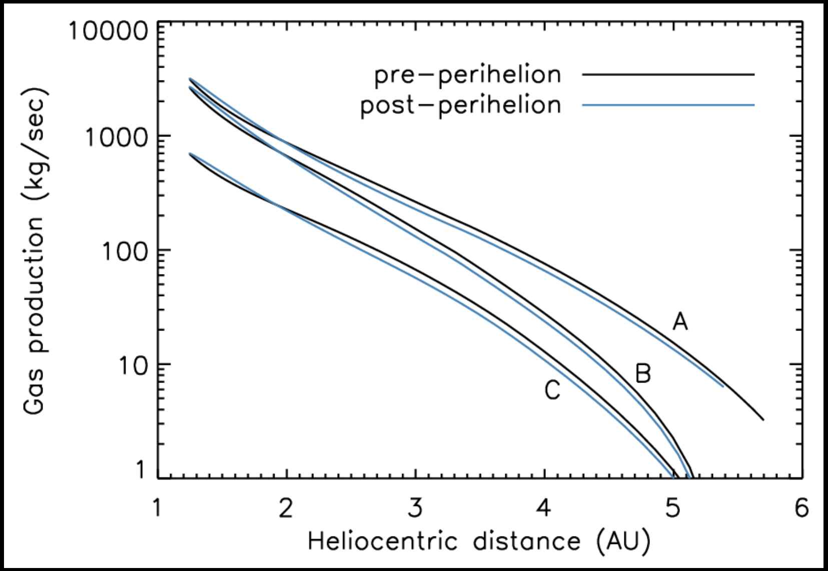


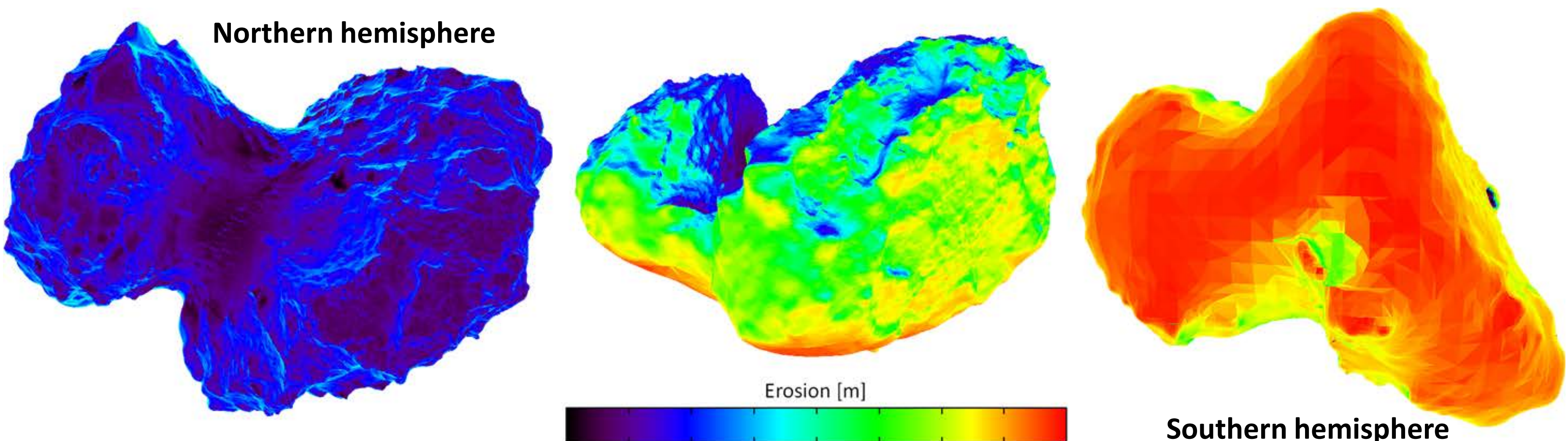
1 Start 3/2/2004
2 Gravity Assist 1/Earth 3/4/2005
3 Gravity Assist 2/Mars 2/25/2007
4 Gravity Assist 3/Earth 11/13/2007
5 Flyby Steins 9/5/2008
6 Gravity Assist 4/Earth 11/13/2009
7 Flyby Lutetia 7/10/2010
8 Rendezvous Churyumov-Gerasimenko 5/22/2014
9 Landing 11/10/2014

Earth — Mars — Asteroid Steins — Asteroid Lutetia

Seasons



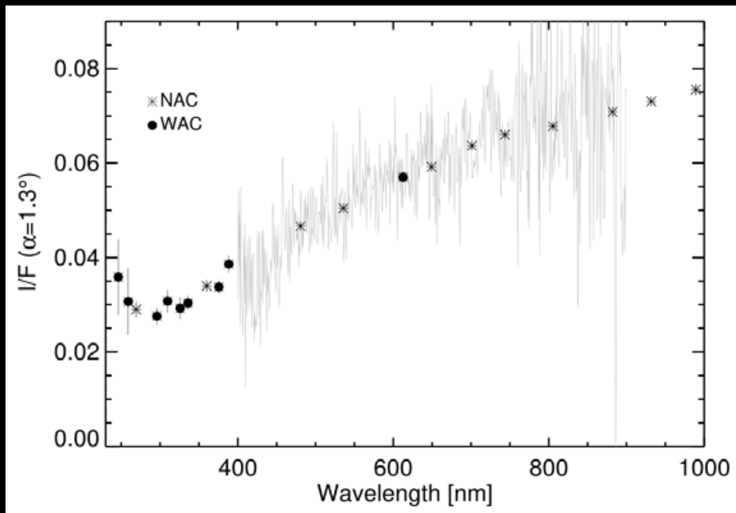


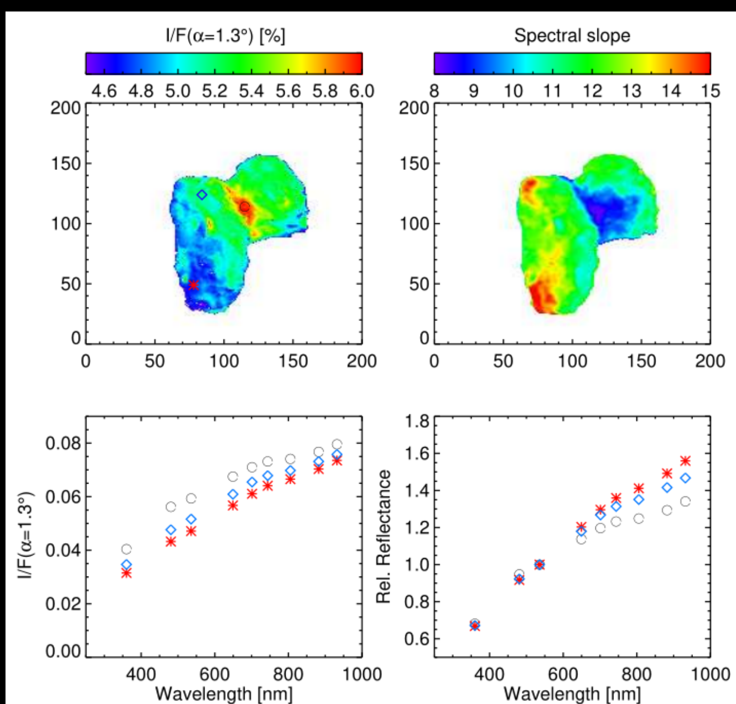


Keller et al. (2015)

Organic composition

OSIRIS camera (*Fornasier et al. 2015*)





VIRTIS spectrometer (*Capaccioni et al. 2015*)

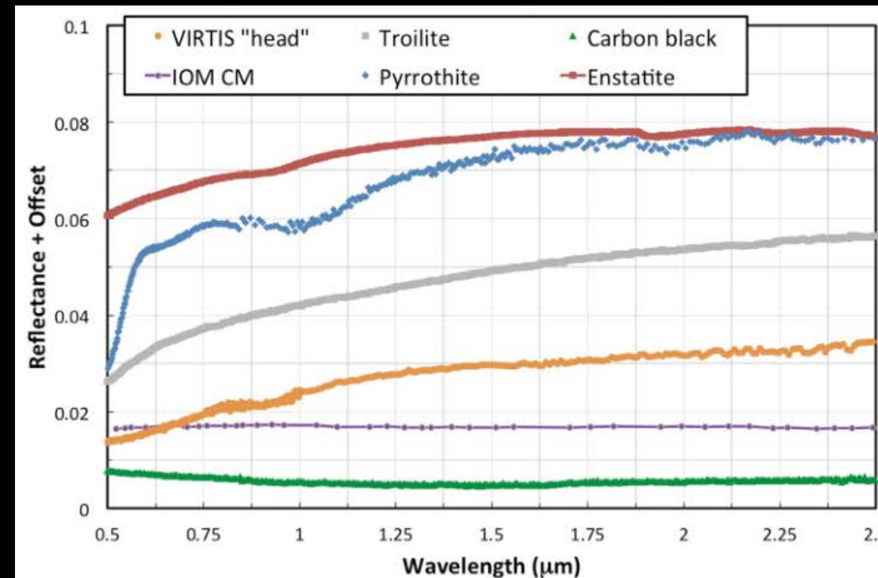
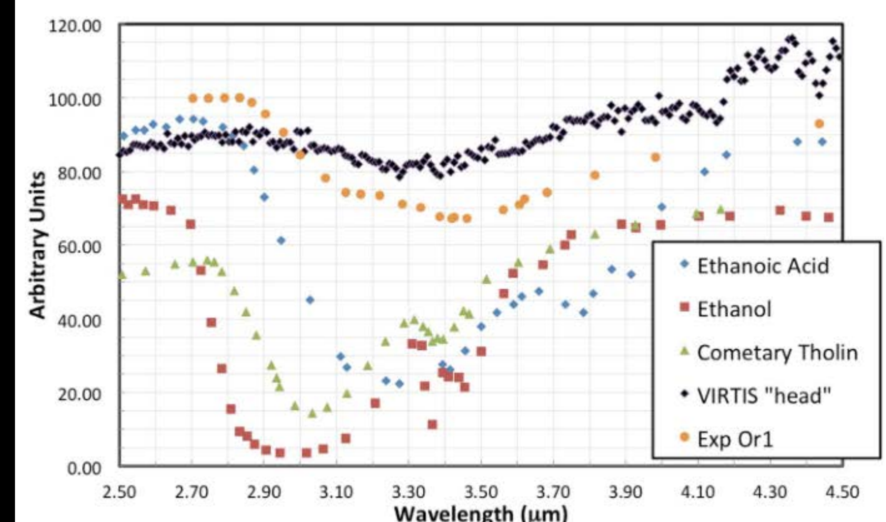
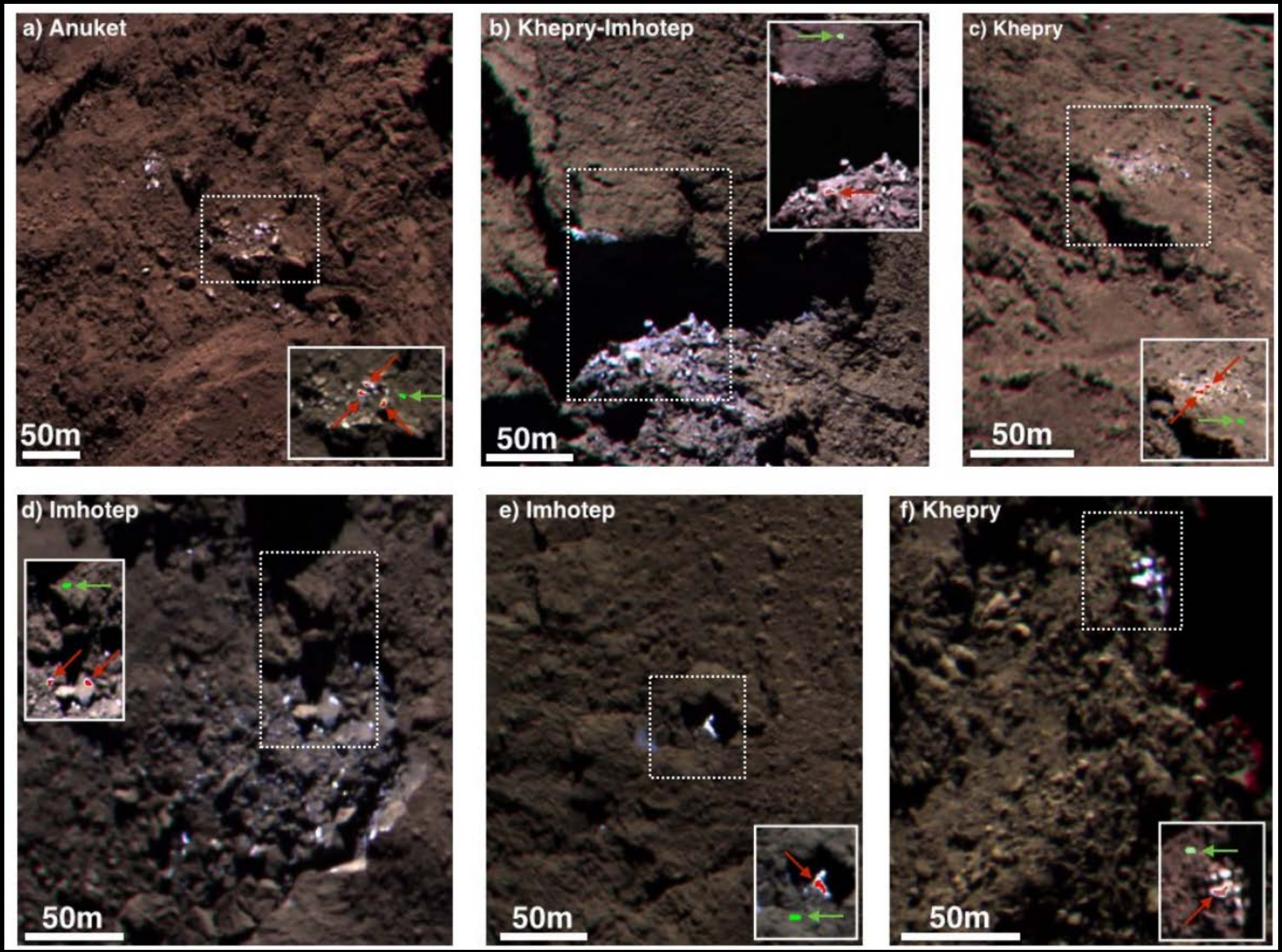


Fig. 3. The spectrum of the head shown in Fig. 1 is compared (in the spectral range 0.5 to 2.5 μm) to the spectra of several other compounds described in the text. Enstatite, pyrrothite, and troilite spectra are scaled down by 100, 75, and 50%, respectively. The Murchison IOM is from (*16*), enstatite spectrum from (*29*), troilite and carbon black spectra from (*30*), and pyrrothite spectrum from (*31*).



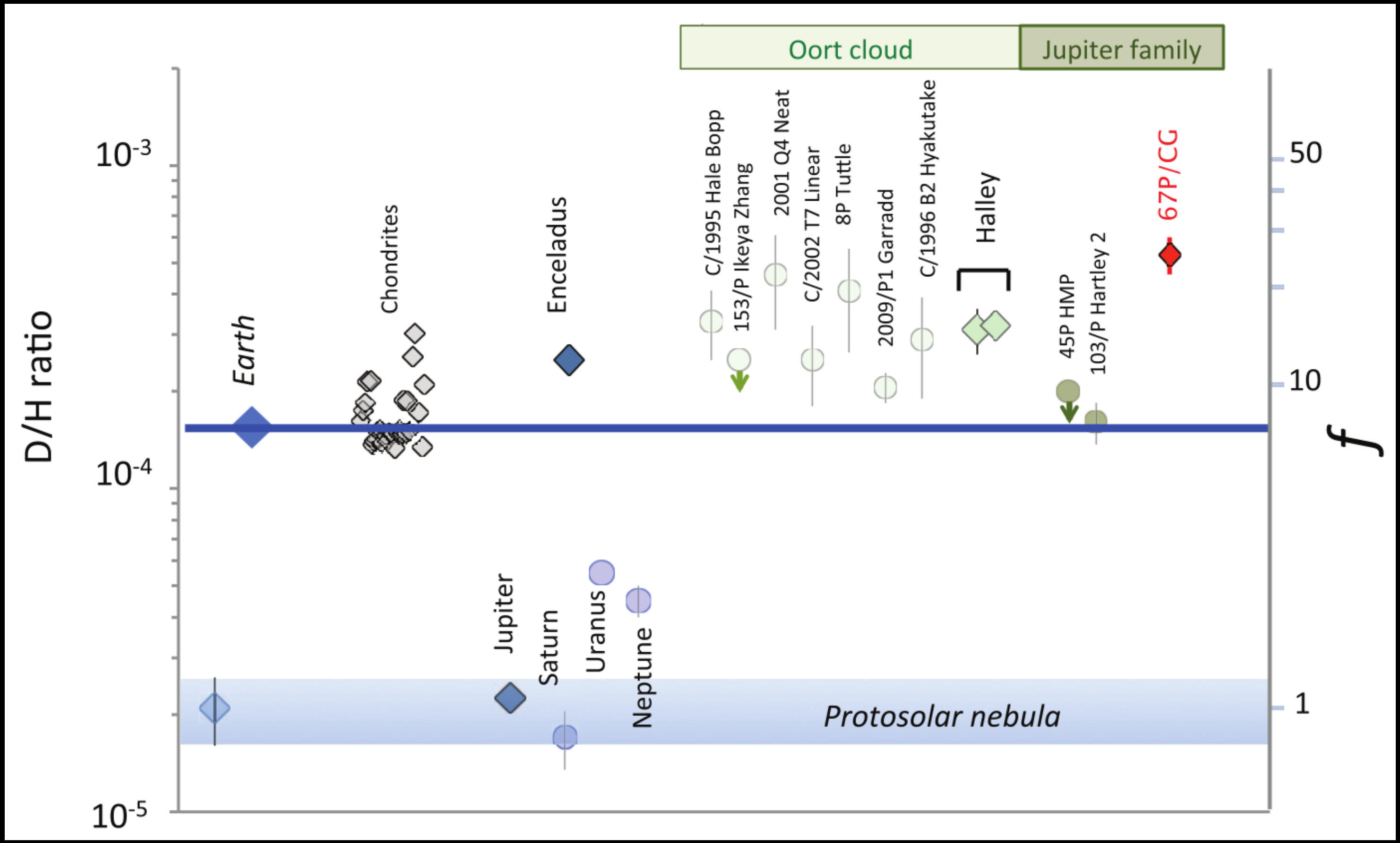
Water ice

High reflectivity of these bright patches indicates an areal mixture; intimate mixtures darken very rapidly (*Clark 1981*): evidence for heterogeneity



Pommerol et al. (2016)

Where does our water come from?



Diamonds represent data obtained by means of in situ mass spectrometry measurements, and circles refer to data obtained with astronomical methods. 67P value is from Rosetta's ROSINA mass spectrometer (*Altwegg et al. 2015*).

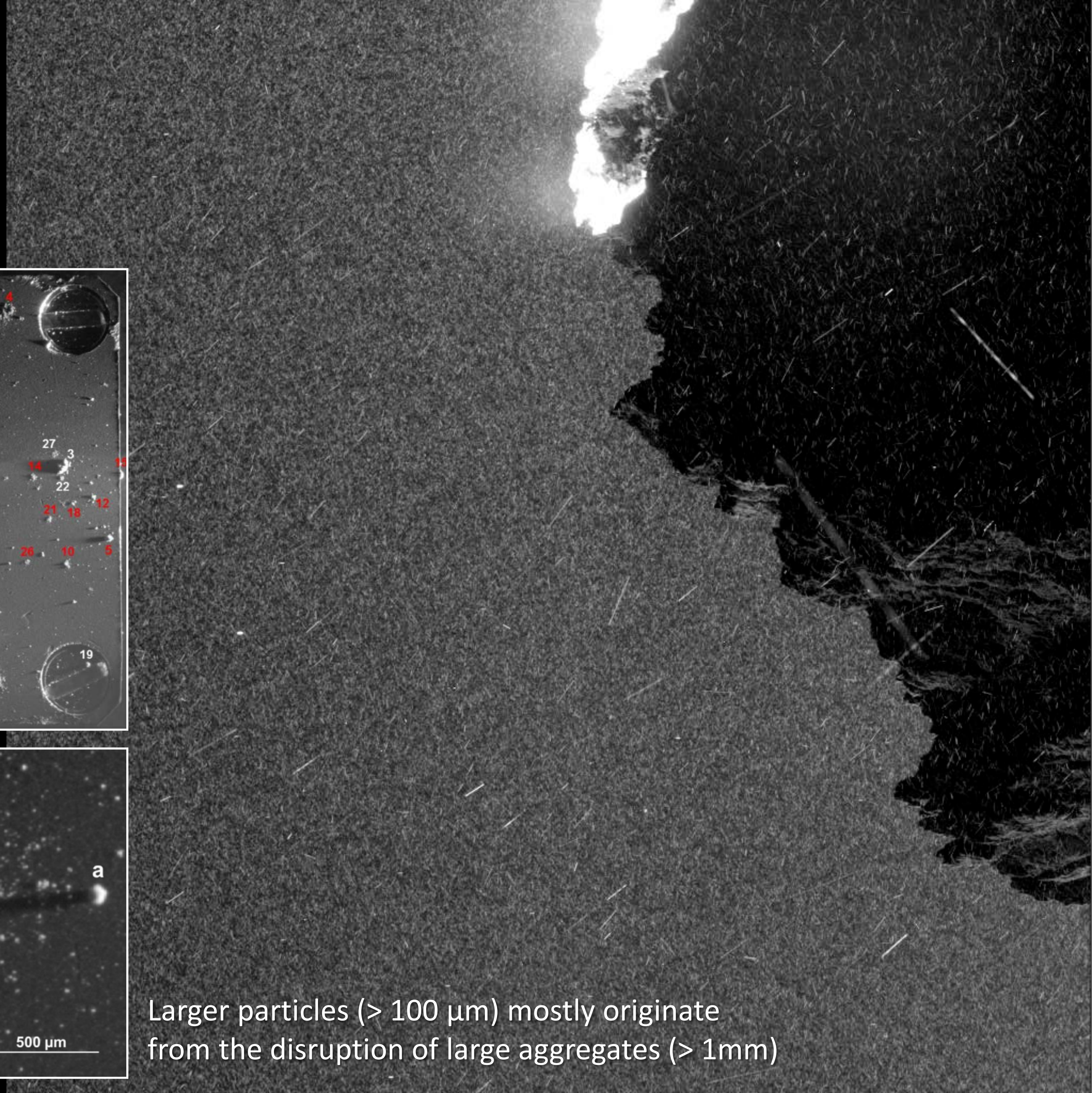
Activity & jets

At the beginning of the mission it was necessary to stretch the images to see the activity...

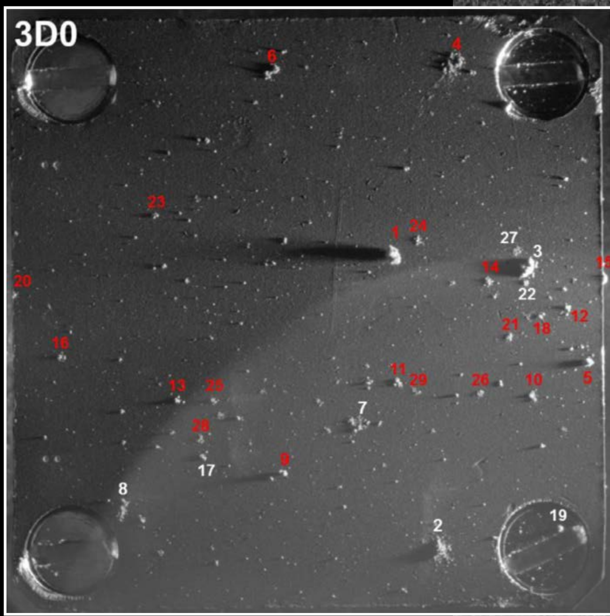
The entire comet surface is active (*Keller et al. 2015*)

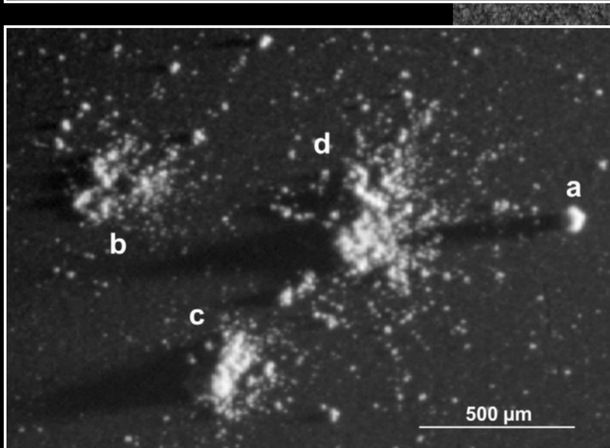
Particles

Fulle et al. (2015)



COSIMA (*Langevin et al. 2016*)





Larger particles (> 100 µm) mostly originate from the disruption of large aggregates (> 1mm)

The End

Rosetta landing: 30 September 2016