Combining Rosetta observations and numerical models to explore the nucleus and coma of Comet 67P/Churyumov-Gerasimenko

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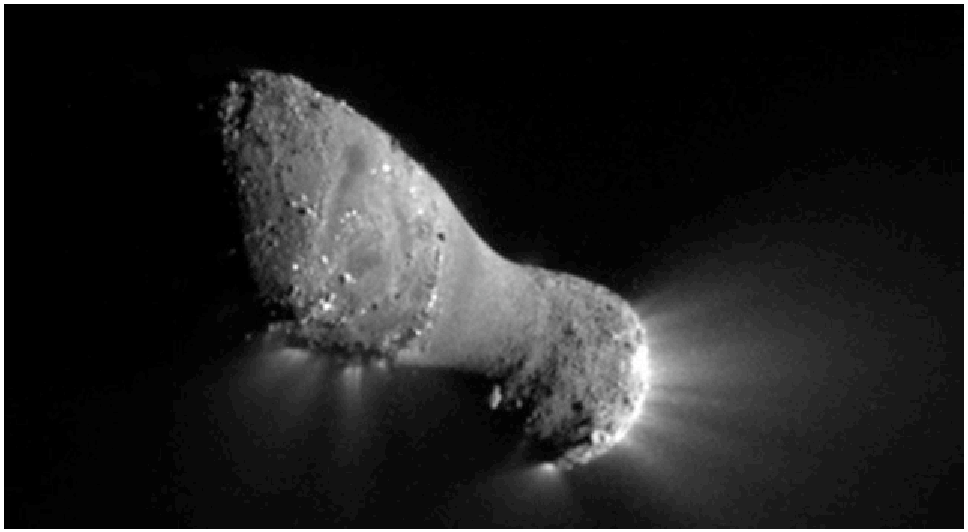
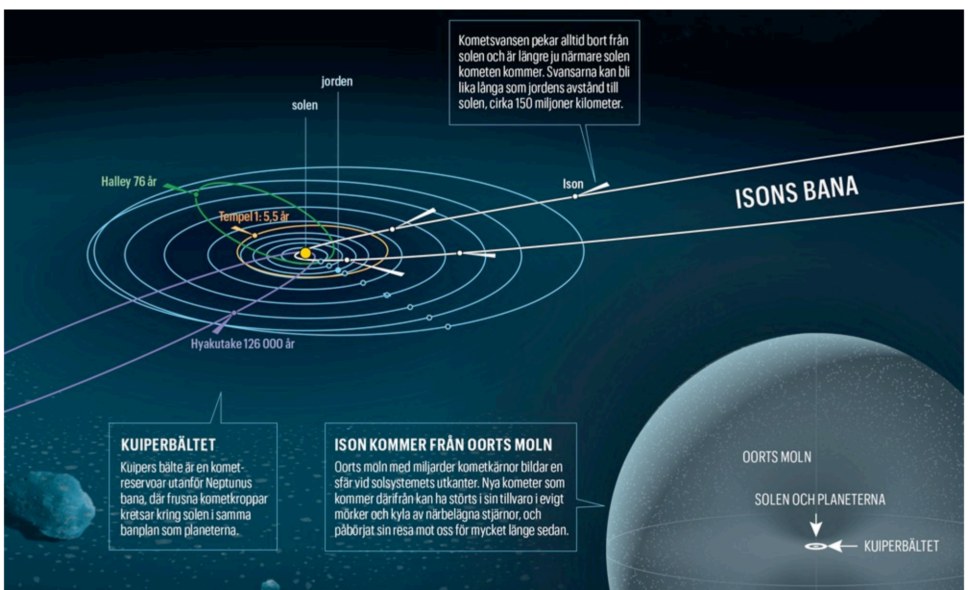
Planetary Science (incl. Rosetta) blog:

www.solsystemetshistoria.wordpress.com

www.thehistoryofthesolarsystem.wordpress.com

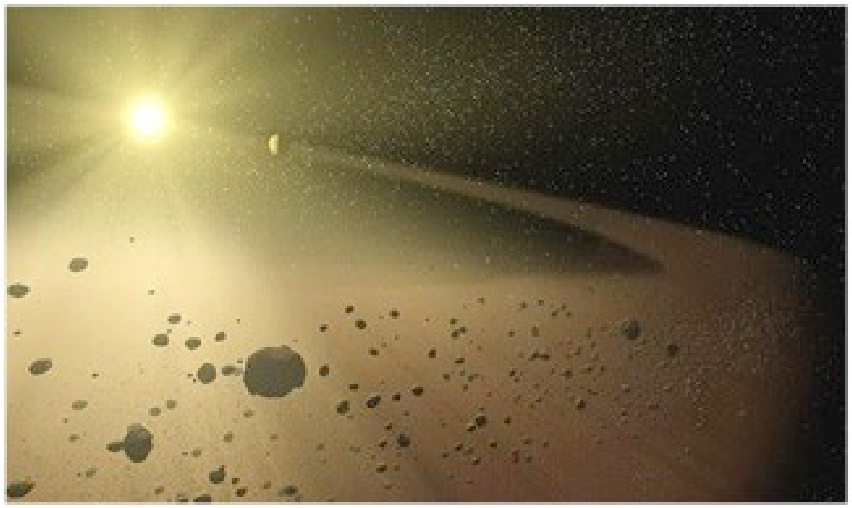
What is a comet?



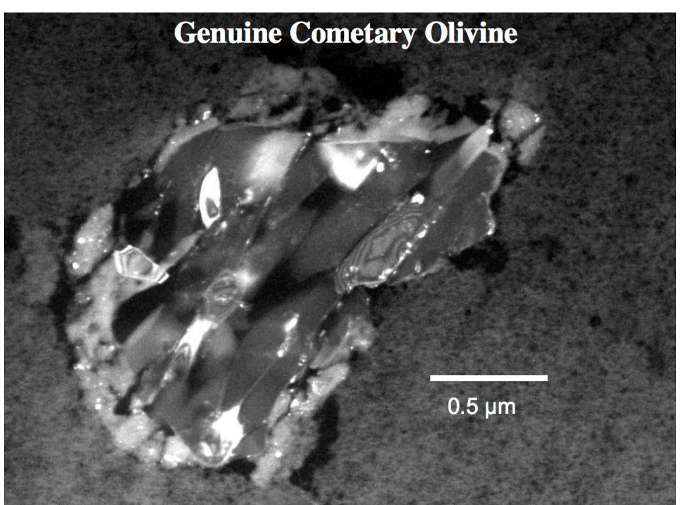


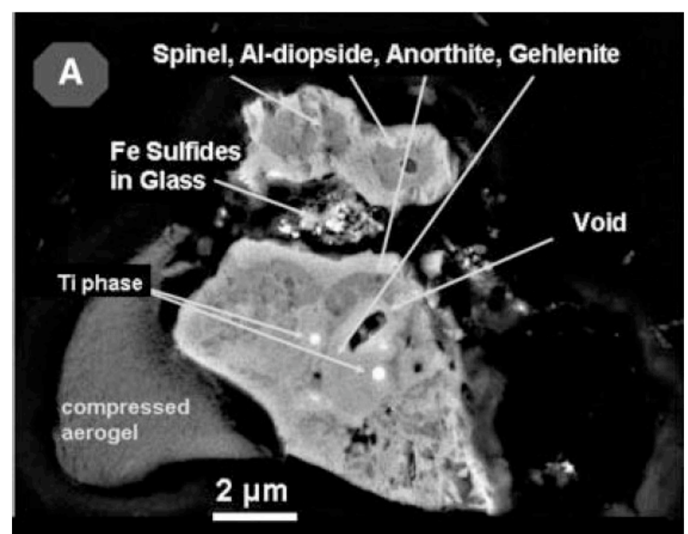
Davidsson, Forskning & Framsteg 9/2013

Why study comets?

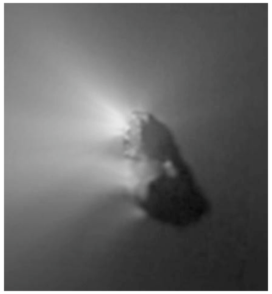


- Icy planetesimals from beyond snowline
- Chemical composition of Solar Nebula (SN)
- SN physical properties (e.g. radial mixing)
- Physics of planetesimal formation
- Organics/water to Earth



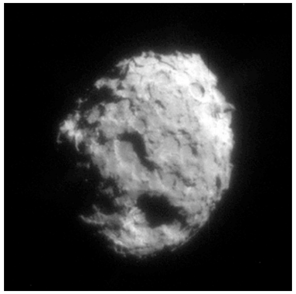


What makes Rosetta unique?

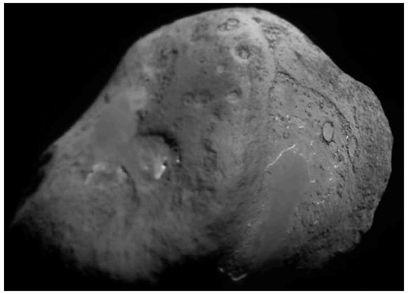


1P/Halley
Giotto etc
1986

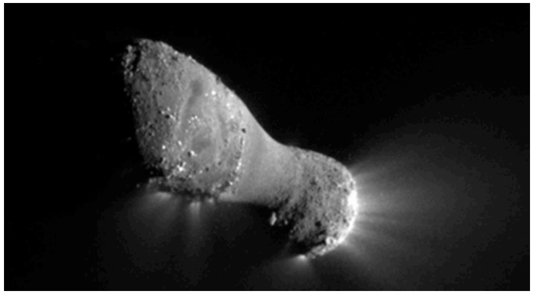
19P/Borrelly
Deep Space 1
2001



81P/Wild 2
Stardust
2002



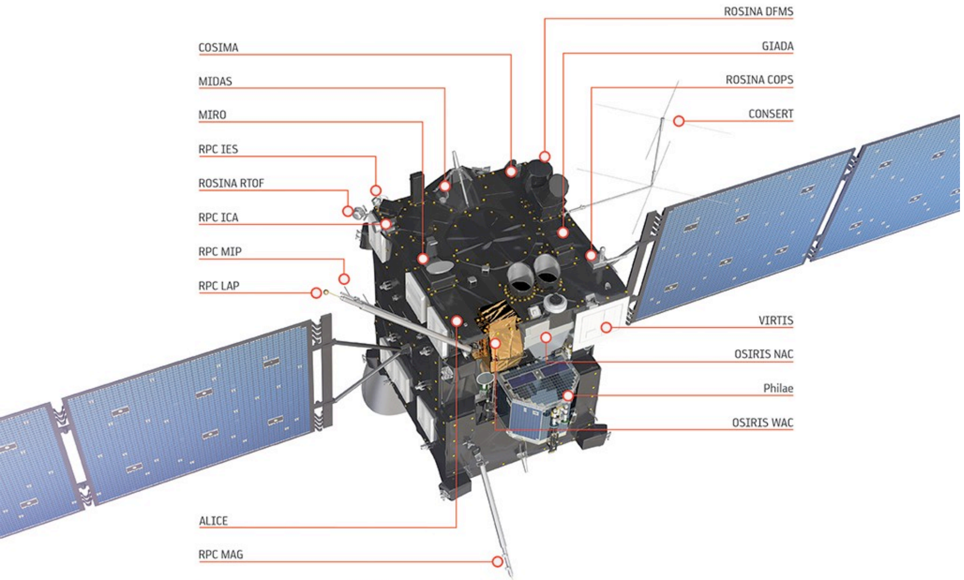
9P/Tempel 1
Deep Impact
2004
Stardust-NExT
2011

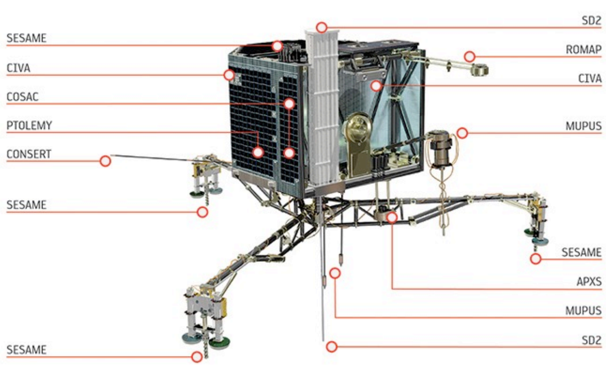


103P/Hartley 2
EPOXI
2010

- All large-distance (100's of km), short-duration (~1h) flybys
- All comets are very different!
- Rosetta: first orbiting spacecraft around a comet nucleus
- Rosetta: first landing on a comet nucleus (Philae)
- Rosetta: first short-distance (few km), long-duration (~1.5 year) mission
- Instrument suite unprecedented

Rosetta payload





- Rosetta's main objectives
  - *Physical and chemical properties of nucleus and coma?*
  - *How does comet activity work?*

- Nucleus interior (CONSERT)
- Elemental abundance (APXS)
- Isotope ratios (ROSINA, MIRO)
- Gas composition (ROSINA, VIRTIS, ALICE, MIRO)
- Dust properties (GIADA, MIDAS)
- Plasma environment (LAP, ICA)

OSIRIS

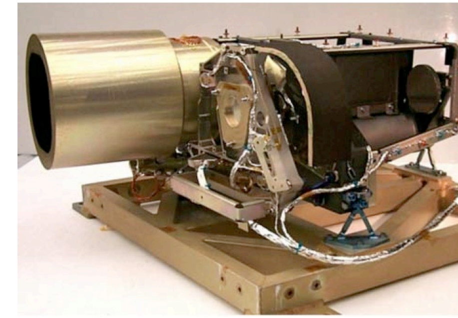


TABLE V
Filters of the narrow angle camera.

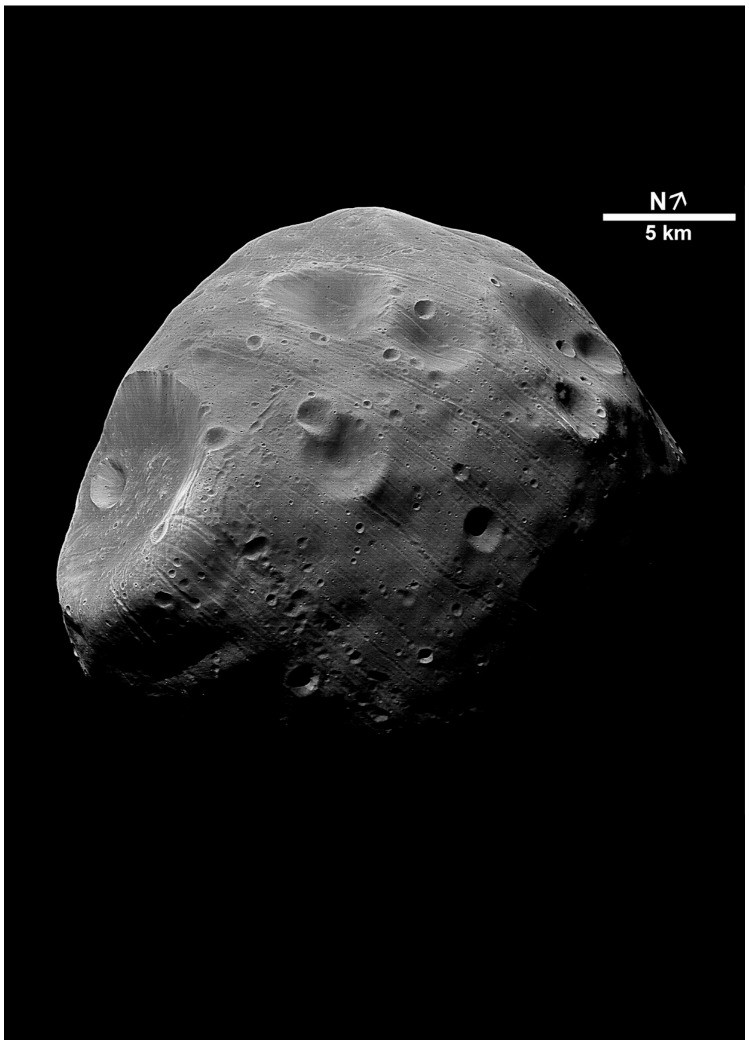
Name	Wavelength (nm)	Bandwidth (nm)	Peak Trans. (%)	Objective
FFP-UV	250–850		>99	UV focusing plate for use of filters in wheel 2
FFP-Vis	250–1000		>95	Vis focusing plate for use of filters in wheel 2
FFP-IR	300–1000		>99	IR focusing plate for use of filters in wheel 1
NFP-Vis	300–1000		>98	Vis focusing plate for near-nucleus imaging
Far-UV	269.3	53.6	37.8	Surface spectral reflectance
Near-UV	360.0	51.1	78.2	Surface spectral reflectance
Blue	480.7	74.9	74.6	Surface spectral reflectance
Green	535.7	62.4	75.8	Surface spectral reflectance
Neutral	640.0	520.0	5.0	Neutral density filter
Orange	649.2	84.5	92.4	surface spectral reflectance HMC orange filter
Hydra	701.2	22.1	87.4	Water of hydration band
Red	743.7	64.1	96.0	Surface spectral reflectance
Ortho	805.3	40.5	69.8	Orthopyroxene
Near-IR	882.1	65.9	78.4	Surface spectral reflectance
Fe_2O_3	931.9	34.9	81.6	Iron-bearing minerals
IR	989.3	38.2	78.1	IR Surface reflectance

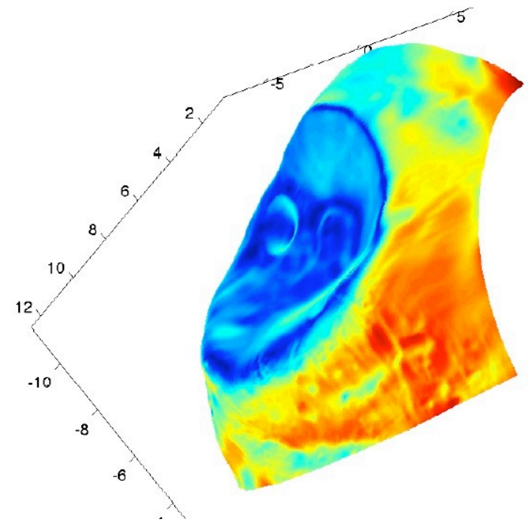
TABLE VI
Filters of the Wide Angle Camera.

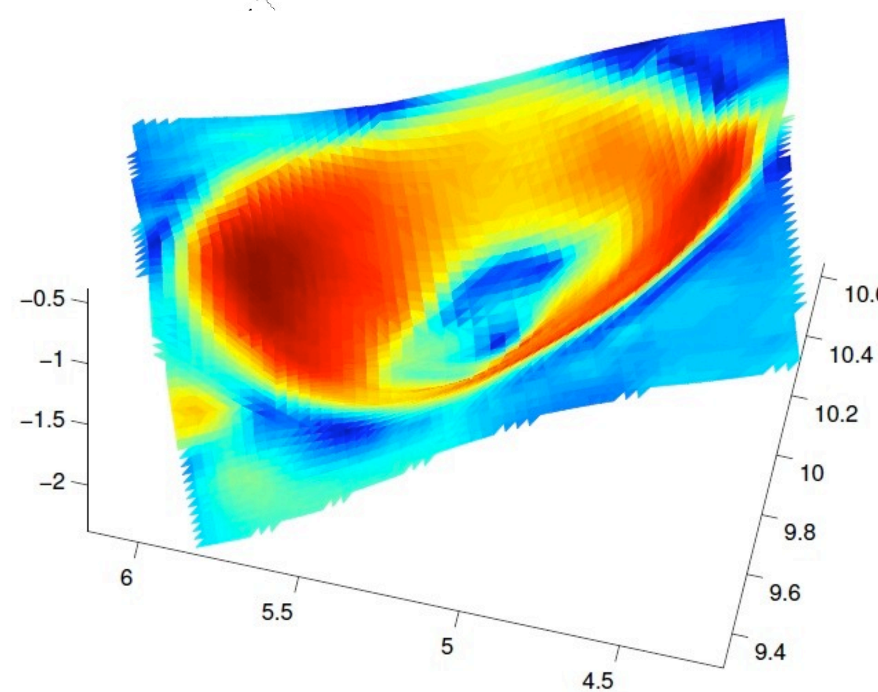
Name	Wavelength (nm)	Bandwidth (nm)	Peak Trans. (%)	Objective
Empty				Empty position to allow the use of filter wheel 2
Empty				Empty position to allow the use of filter wheel 1
UV245	246.2	14.1	31.8	Continuum surface spectral reflectance
CS	259.0	5.6	29.8	CS gas emission
UV295	295.9	10.9	30.4	Continuum for OH
OH-WAC	309.7	4.1	26.0	OH emission from the vicinity of the nucleus
UV325	325.8	10.7	31.6	Continuum for OH surface spectral reflectance
NH	335.9	4.1	23.6	NH gas emission
UV375	375.6	9.8	57.3	Continuum for CN surface spectral reflectance
CN	388.4	5.2	37.4	CN gas emission
Green	537.2	63.2	76.8	Dust continuum cross-correlation with NAC
NH_2	572.1	11.5	60.9	NH_2 gas emission
Na	590.7	4.7	59.0	Sodium gas emission
VIS610	612.6	9.8	83.4	Continuum for OI surface spectral reflectance
OI	631.6	4.0	52.4	O (^{1}D) gas emission for dissociation of H_2O
R	629.8	156.8	95.7	Broadband filter for nucleus and asteroid detection (NAC redundancy)

- NAC (nucleus), WAC (coma). PI: Holger Sierks (Max-Planck, Göttingen)
- Filters (Spectrogon; Swedish hardware contribution). Rickman “Lead scientist”, Davidsson “co-investigator”
- Photometric colors (nucleus composition, albedo, surface texture)
- Map dust/gas distributions in coma (dust/gas production versus time and location)
- Nucleus geology
- Digital Terrain Model

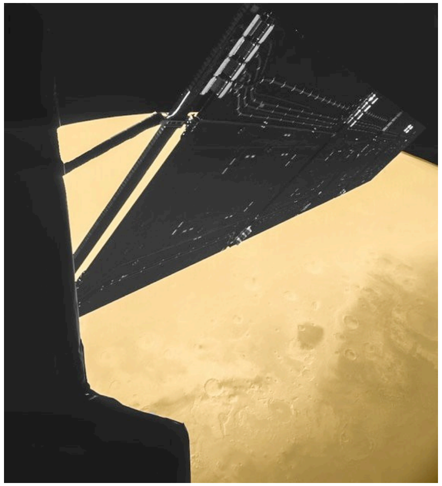
Digital Terrain Model

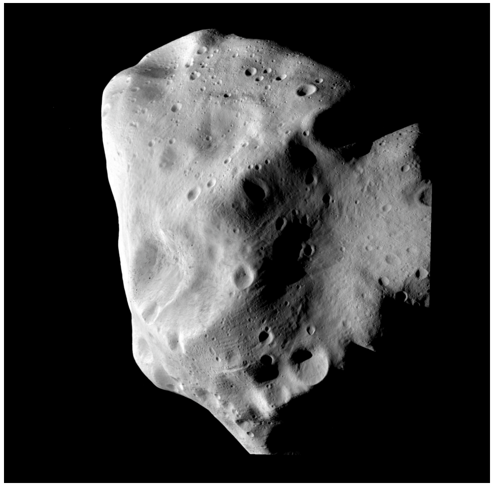




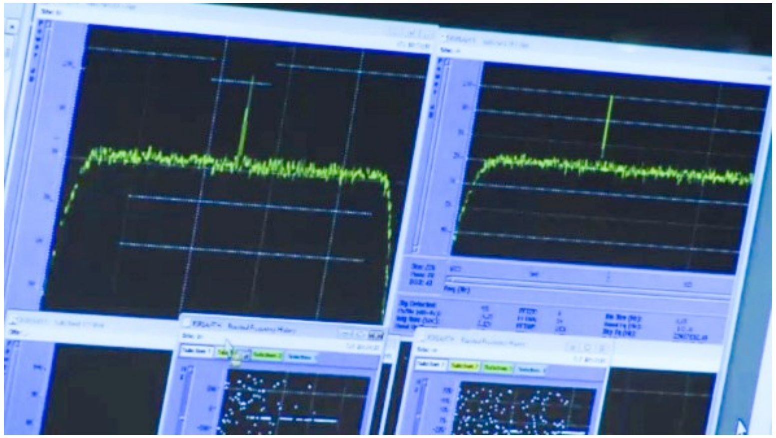


Rosetta mission so far

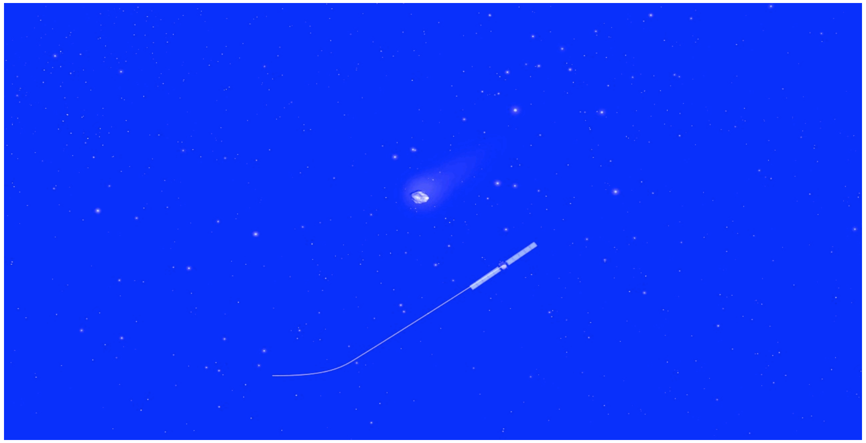



- Launch on March 2, 2004
- Earth swing-by (March 4, 2005; Nov 13, 2007; Nov 13, 2009)
- Mars swing-by (Feb 25, 2007)
- Steins flyby (Sep 5, 2008)
- Lutetia flyby (July 10, 2010)
- Enter hibernation (June 8, 2011)
- Exit hibernation (Jan 20, 2014)



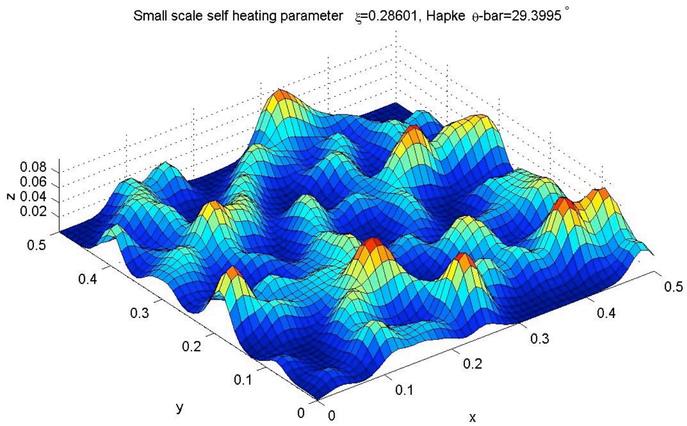
Rosetta mission

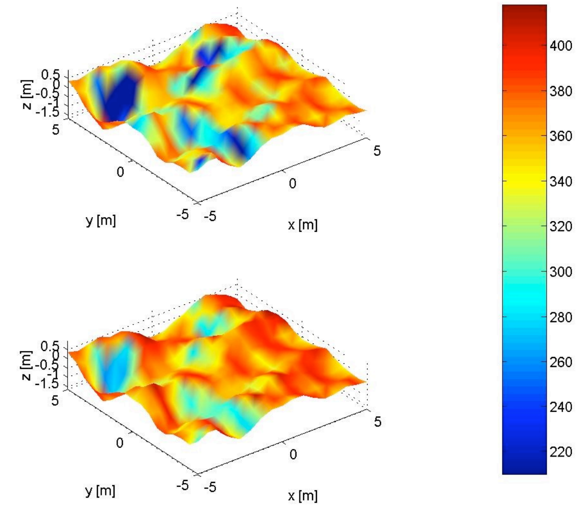


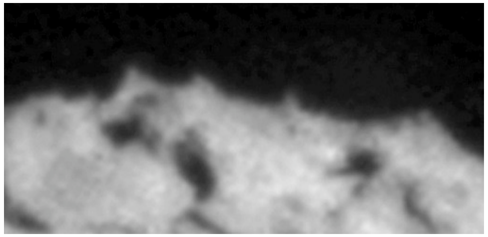
- Rendezvous manoeuvre: May 2014
- Comet arrival: Aug 2014 (3.6 AU)
- Philae landing: Nov 11, 2014 (3.0 AU)
- Main mission phase - “parking” at 100 km, excursions to ~1000km, 10 flybys to 10-30 km
- Perihelion: Aug 13, 2015

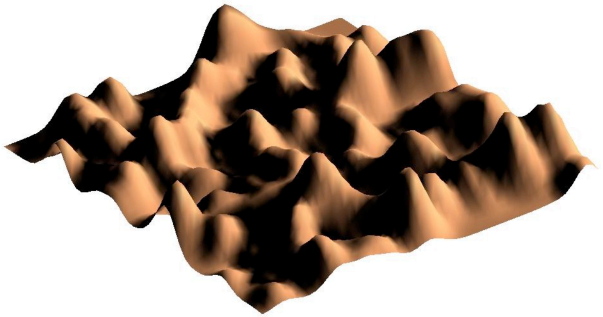
  (1.24 AU)
- End of mission: Dec 31, 2015 (2.0 AU)

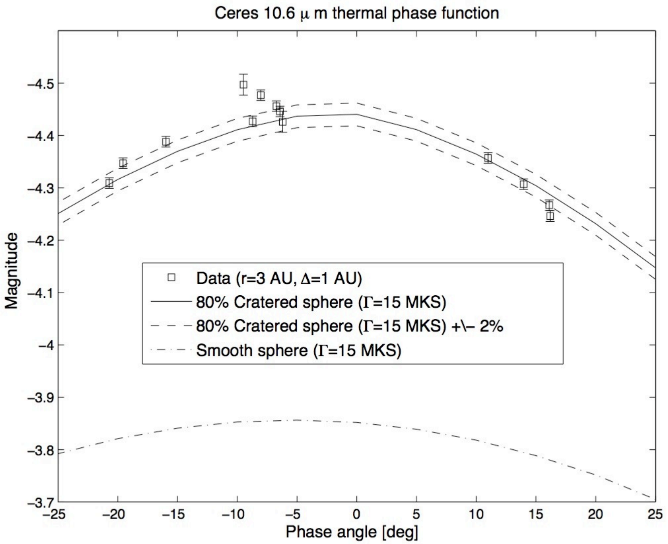
Thermophysical modeling of rough terrain





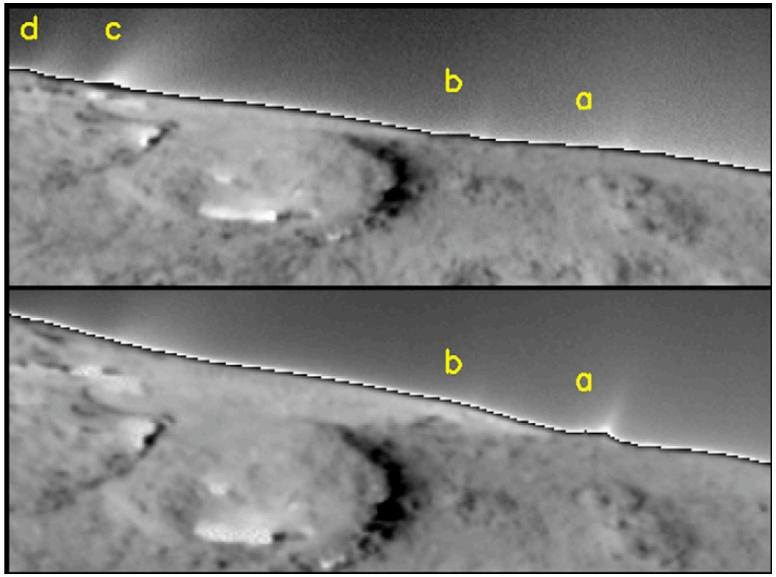


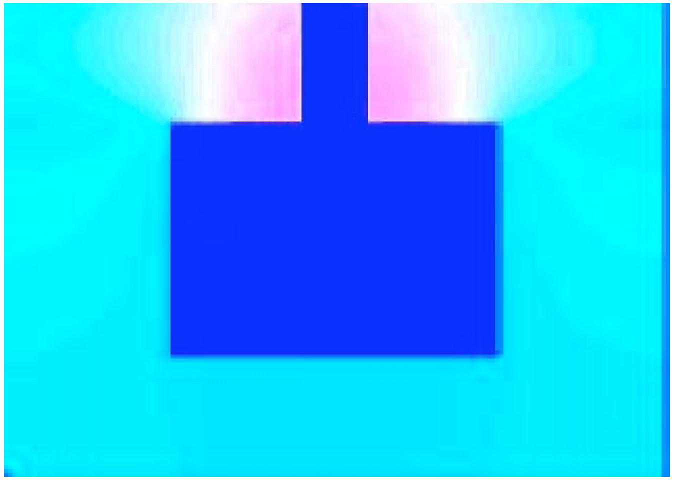




Determine thermal inertia, surface roughness – Model validation with Philae ground truth

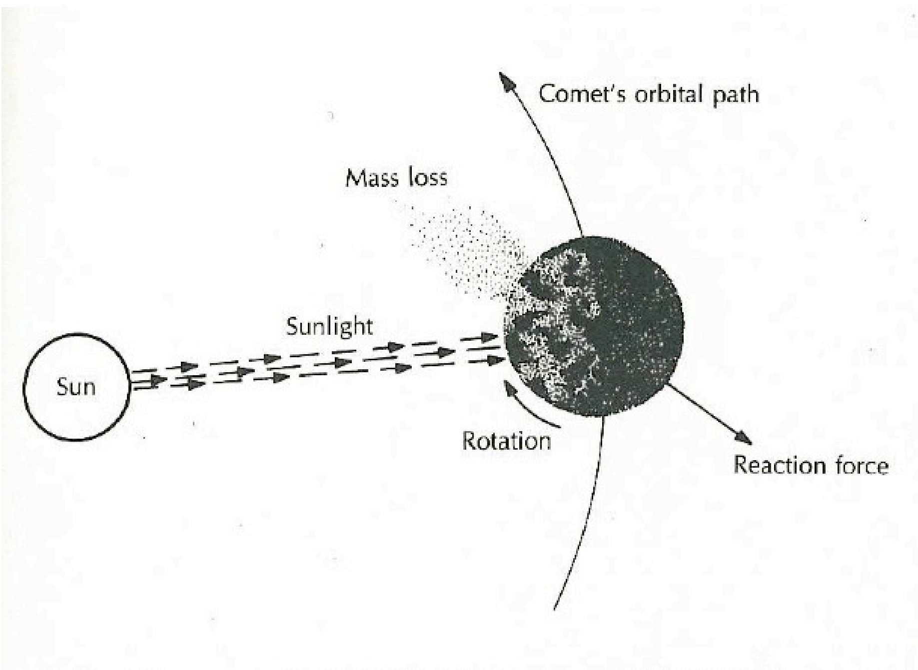
Thermophysical modeling of outgassing

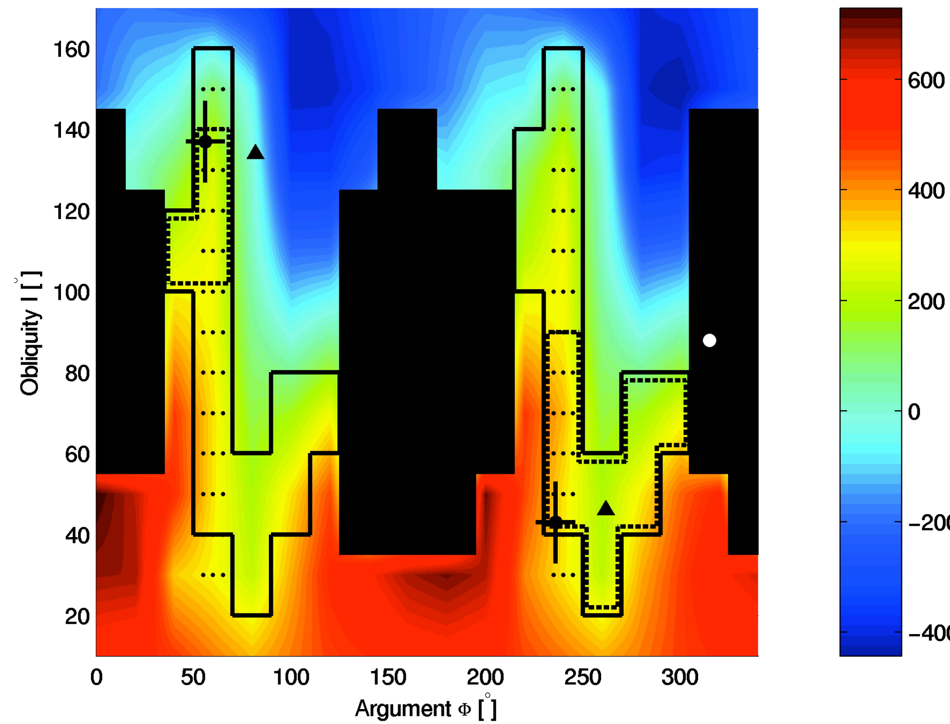




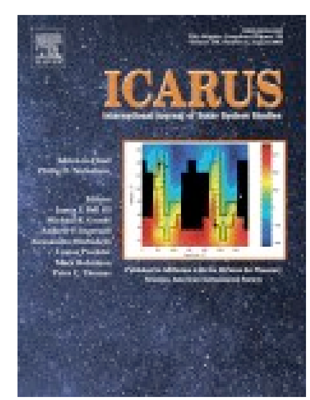
- A major Rosetta goal is to understand comet activity
- Sophisticated models in Uppsala
  - Gradual absorption of radiation in surface layer
  - Heat conduction
  - Sublimation/condensation
  - Gas diffusion
  - Nucleus/coma interaction
- Sublimation under dust mantle
- Venting from sub-surface cavity
- Correlation between nucleus/coma H_2O, CO, CO_2 abundances
- Cosmogonic implications

Non-gravitational forces



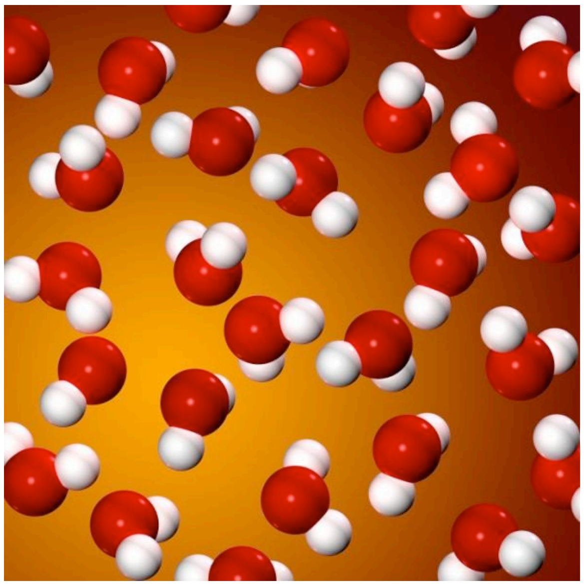


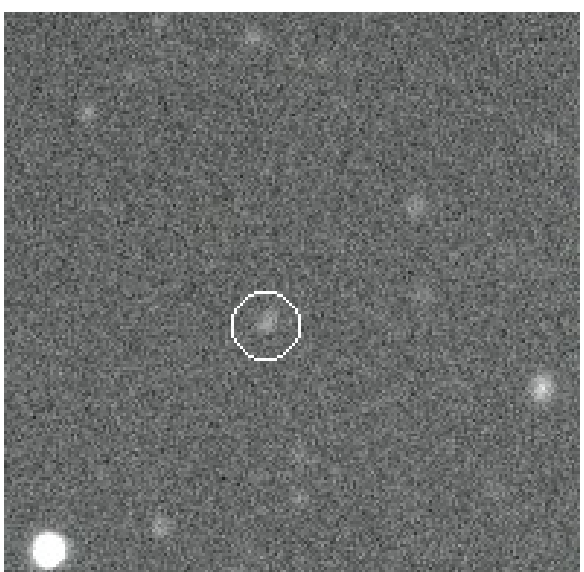
Davidsson & Gutierrez (2005). *Icarus* **176**,453



- Spin axis (α,δ)=(30°,90°)
- Bulk density ρ=100-370 kg m^{-3}
- 2-11% of surface active

Dust dynamics in the Knudsen layer





- Near-nucleus coma modeled kinetically on molecular level (Direct Simulation Monte Carlo – DSMC)
- Grain dynamics from gas drag calculations
- Identify and measure dynamics of individual grains in OSIRIS image sequences
- Understand dust mass loss

Summary

- Comets are key to understand Solar System formation and early evolution
- Rosetta mission is a unique comet exploration mission in human history

- Thanks to the SNSB, Swedish scientists can be part of this unique encounter with a comet and contribute to the analysis of Rosetta data