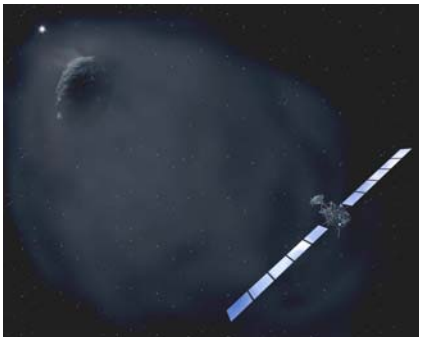
Rosetta - An example for a modern planetary mission

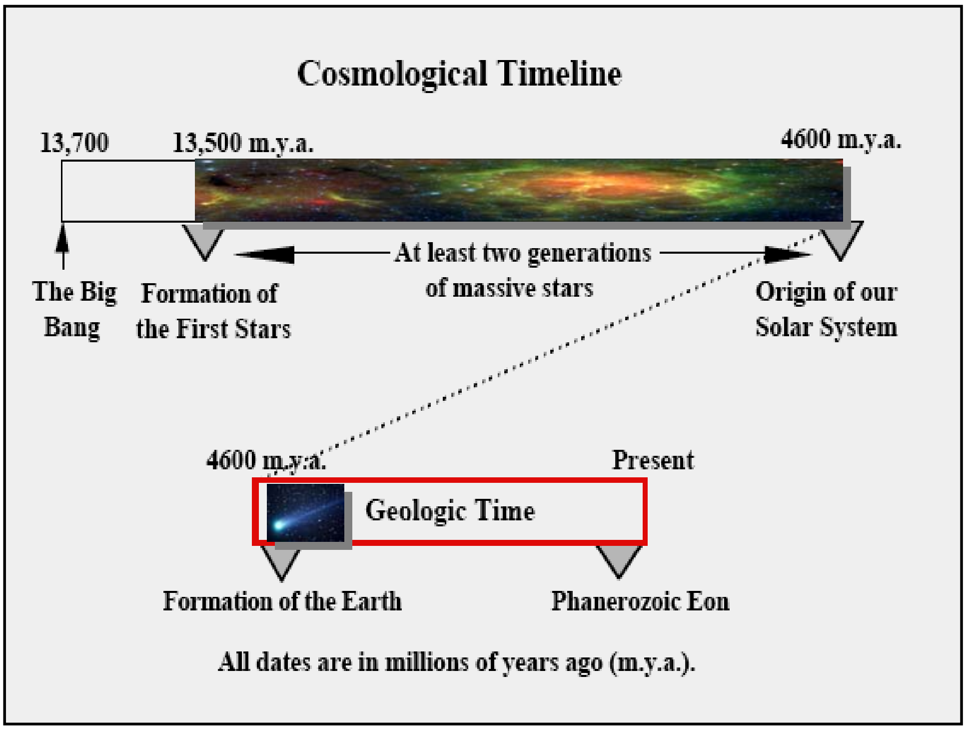
M. Hilchenbach

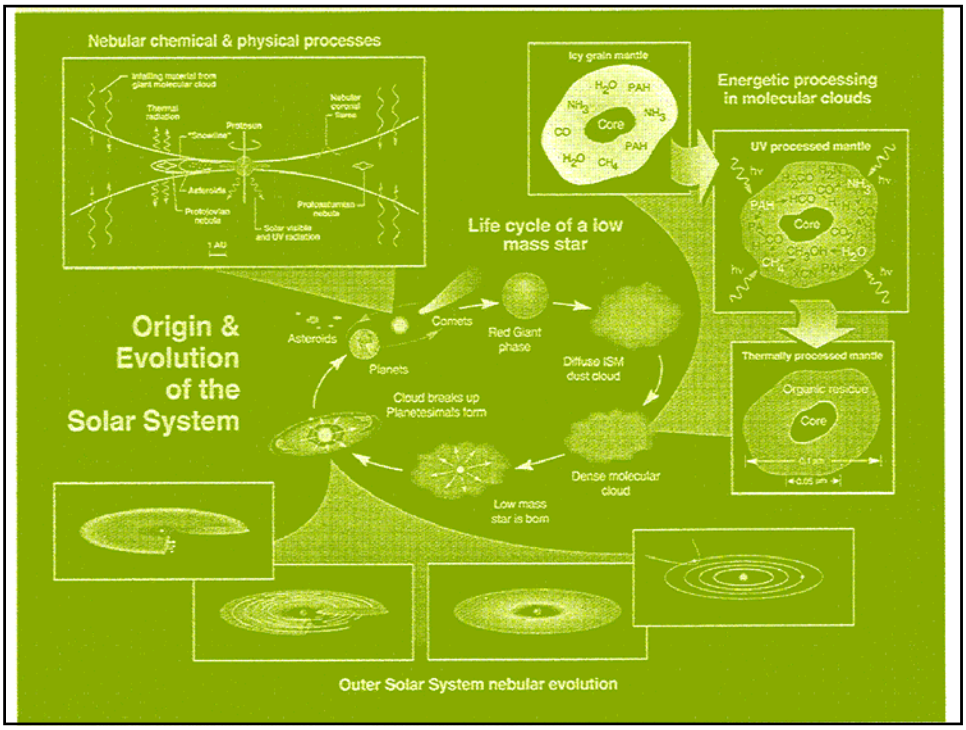
Max-Planck-Institut für Sonnensystemforschung
37191 Katlenburg-Lindau, Germany

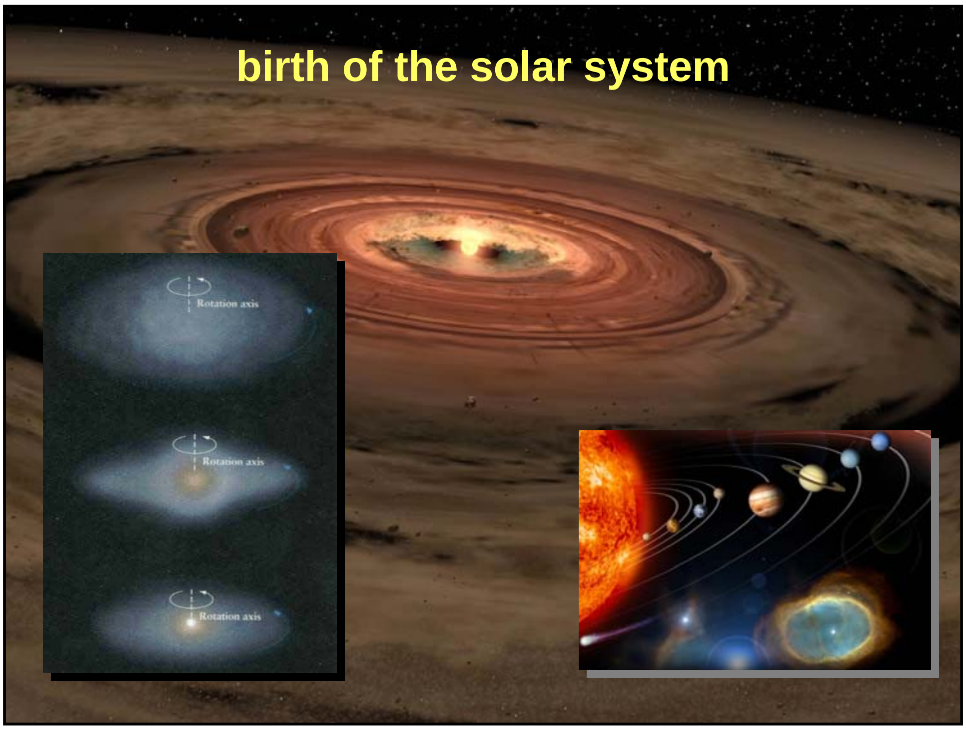


Outline

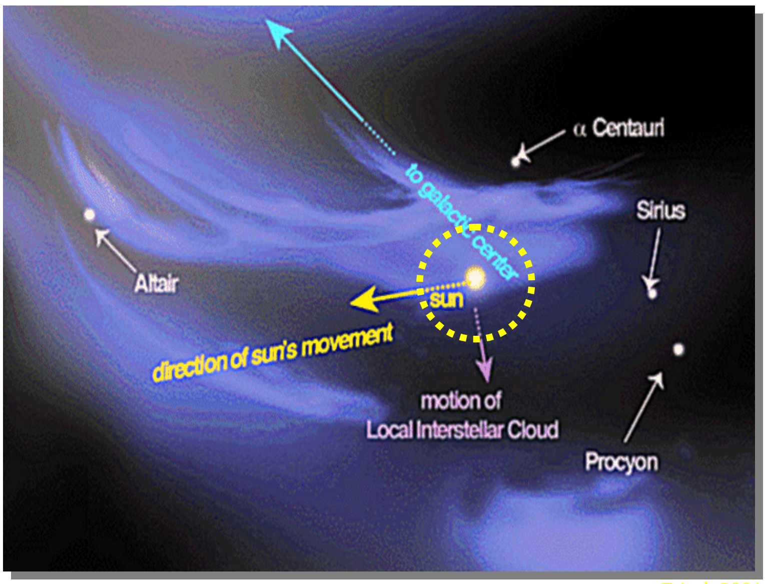
- <u>timeline, matter and comets</u>
- schedule and management approach for new missions
- Rosetta mission and payload
- first results from Rosetta science-phase


Cosmological Timeline
13,700
13,500 m.y.a.
4600 m.y.a.
At least two generations of massive stars
The Big Bang
Formation of the First Stars
Origin of our Solar System
4600 m.y.a.
Present
Geologic Time
Formation of the Earth
Phanerozoic Eon
All dates are in millions of years ago (m.y.a.).


Nebular chemical & physical processes
Energetic processing in molecular clouds
Icy grain mantle
UV processed mantle
Life cycle of a low mass star
Origin & Evolution of the Solar System
Comets
Red Giant phase
Asteroids
Planets
Diffuse ISM dust cloud
Cloud breaks up Planetesimals form
Thermally processed mantle
Organic residue
Dense molecular cloud
Low mass star is born
Outer Solar System nebular evolution

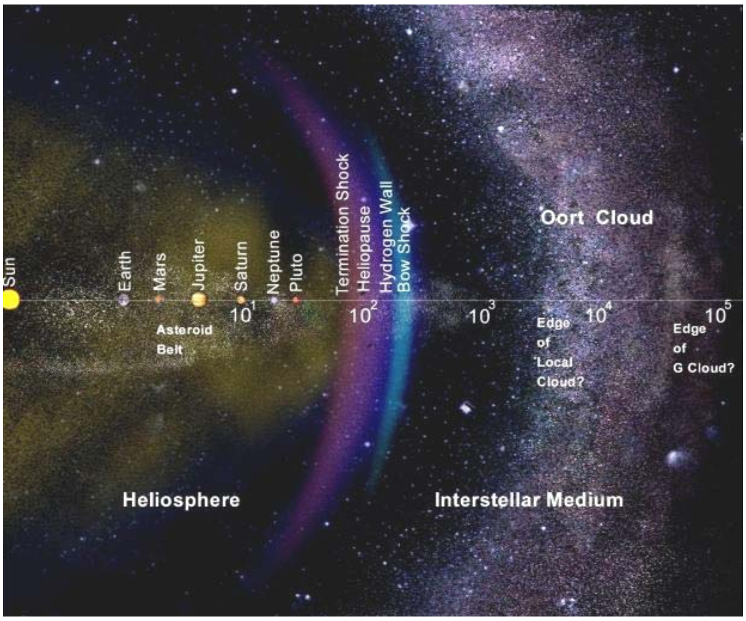


Local environment of our solar system

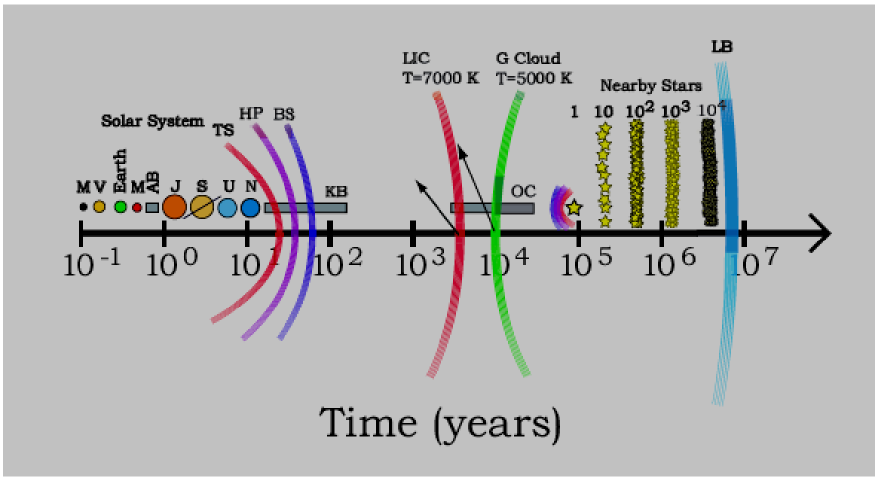


Frisch 2001

Local solar system regions



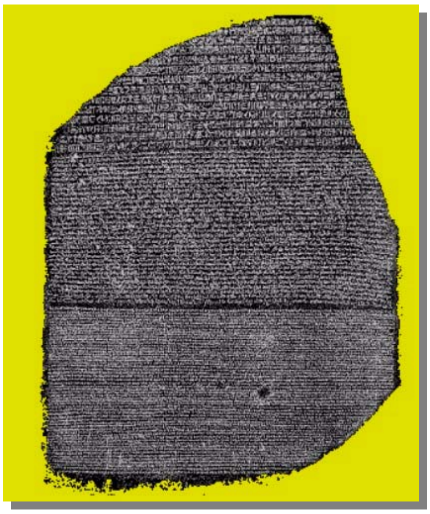
Local environment: future timeline



Redfill 1998

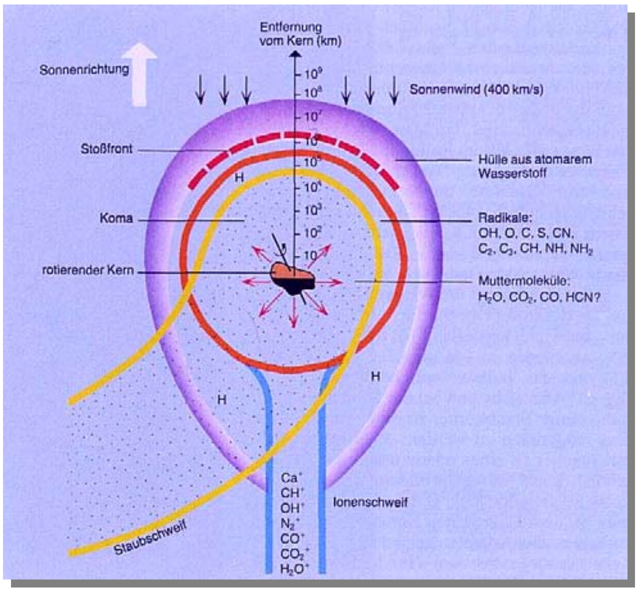
ROSETTA and PHILAE

ROSETTA stone



Island Philae, column and inscription

Comets – greatest and tiniest cheaters in the solar system



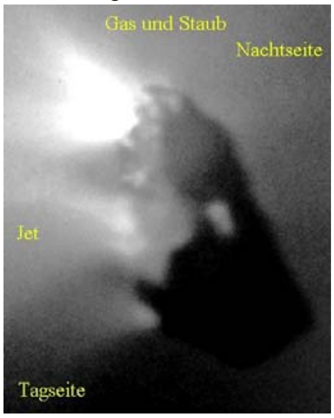
Famous comet: Halley

Comet Halley (March 13, 1986)

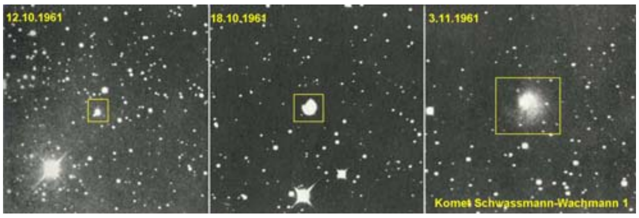
„dirty snowbal“ ?

Edmond Halley, painted byThomas Murray

nucleus, gas and dust 1986

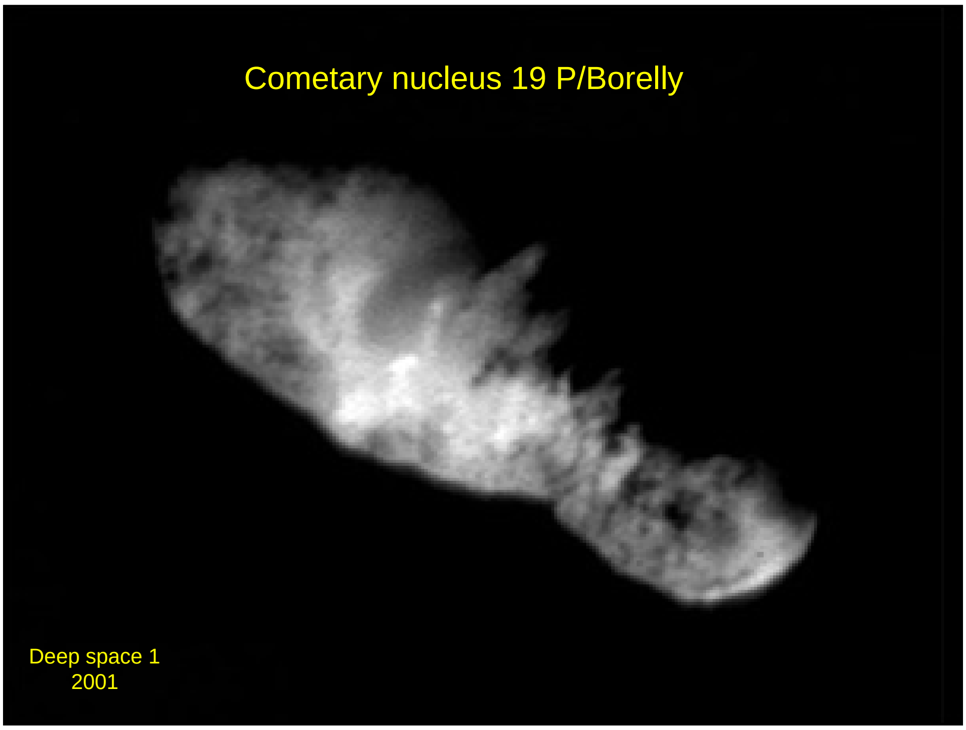


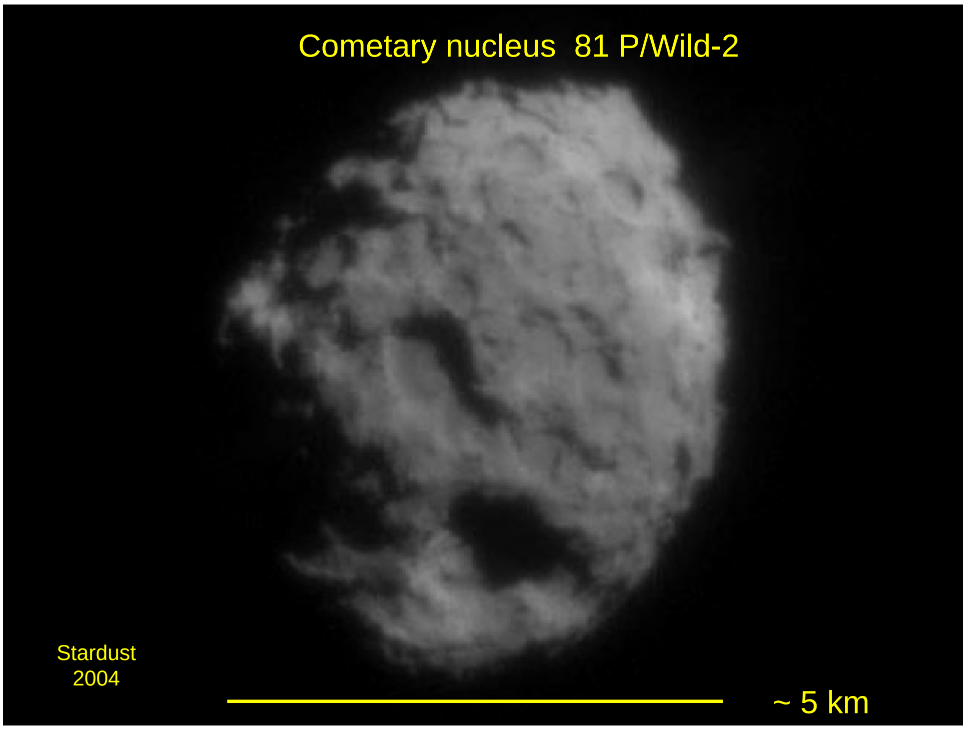
Comets

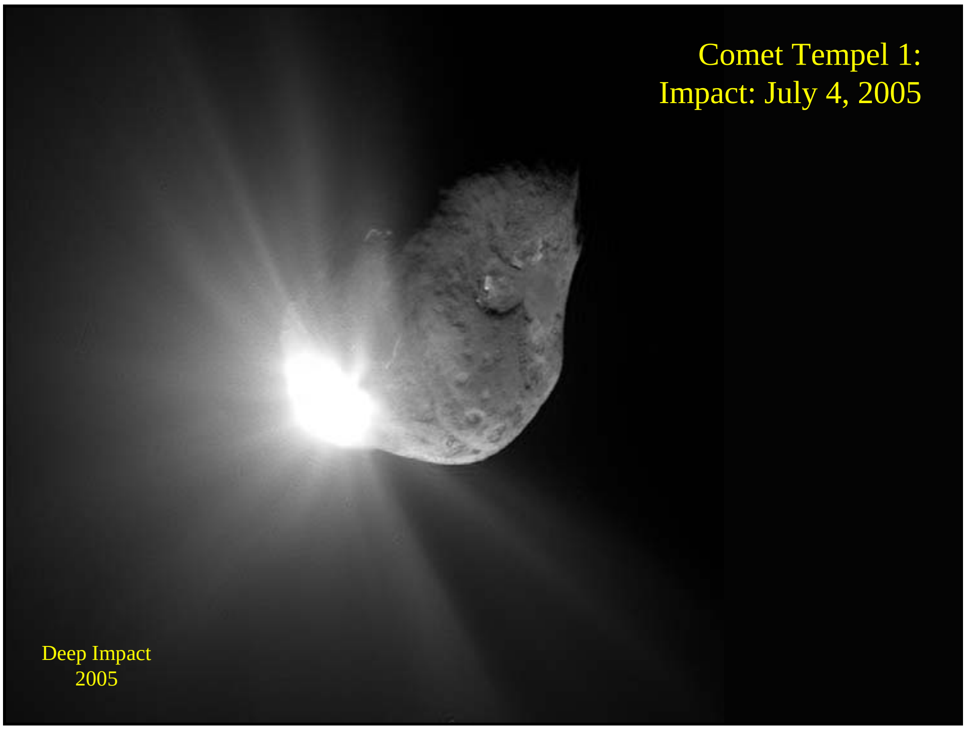


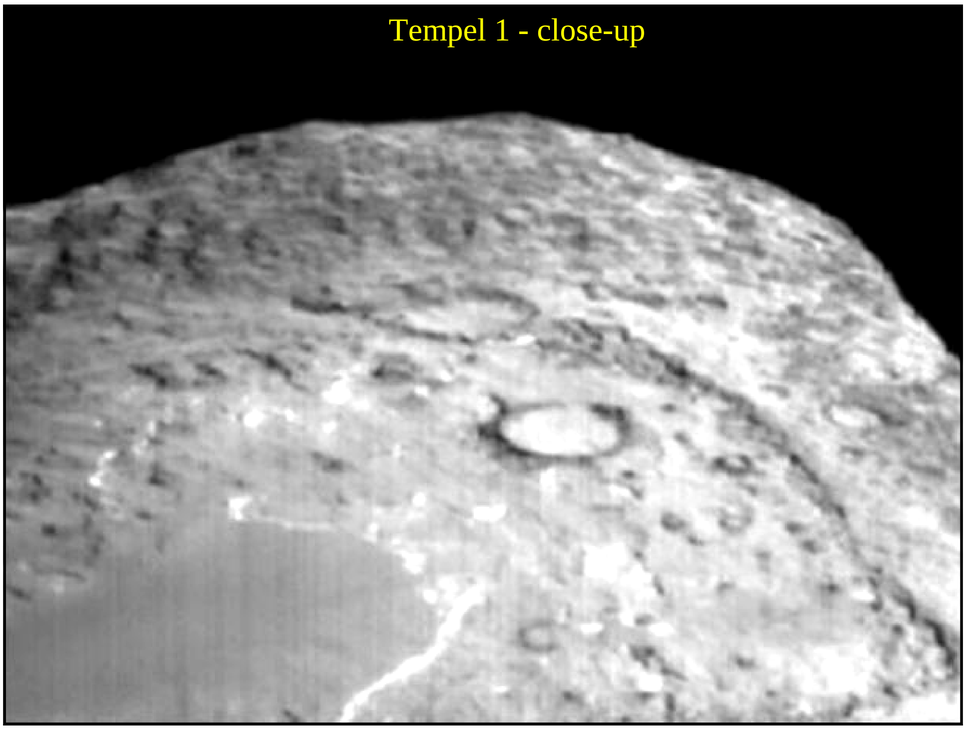
Schwassmann-Wachmann 1, outburst beyond Jupiter‘s orbit

Comet West, 1976


Cometary nucleus 19 P/Borelly
Deep space 1
2001


Cometary nucleus 81 P/Wild-2
Stardust
2004
~ 5 km


Comet Tempel 1:
Impact: July 4, 2005
Deep Impact
2005


Tempel 1 - close-up

Outline

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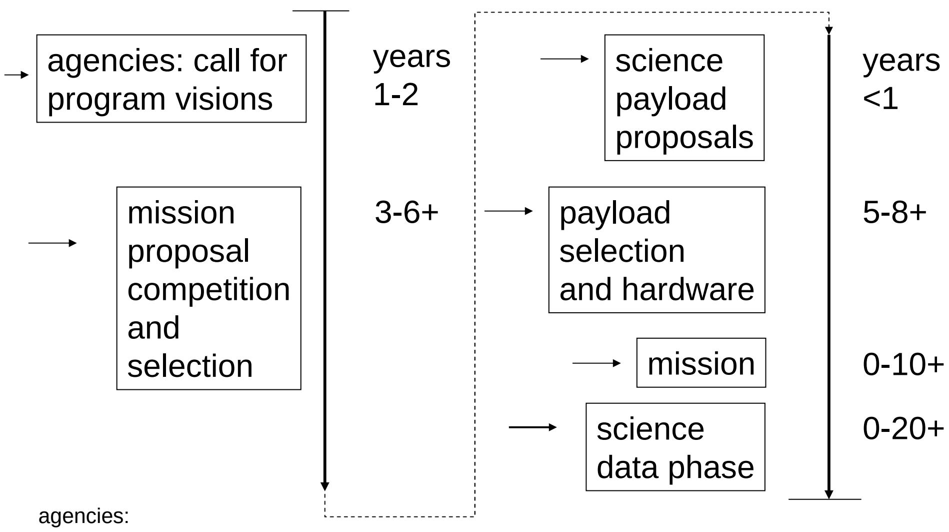
Timeline for new space missions



agencies:

ESA, NASA, DLR, CNES etc.

Space missions: General management approach

payload:
scientific institutes
and/ or industry

satellite:
agency with industry

mission operation:
agency

mission science return:
scientific institutes

Design Depends on Individual Who Defines Problem

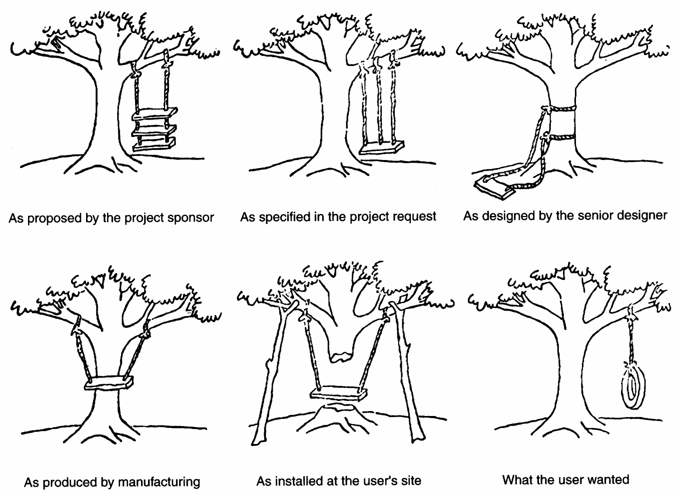


FIGURE 1.4
Note how the design depends on the viewpoint of the individual who defines the problem.

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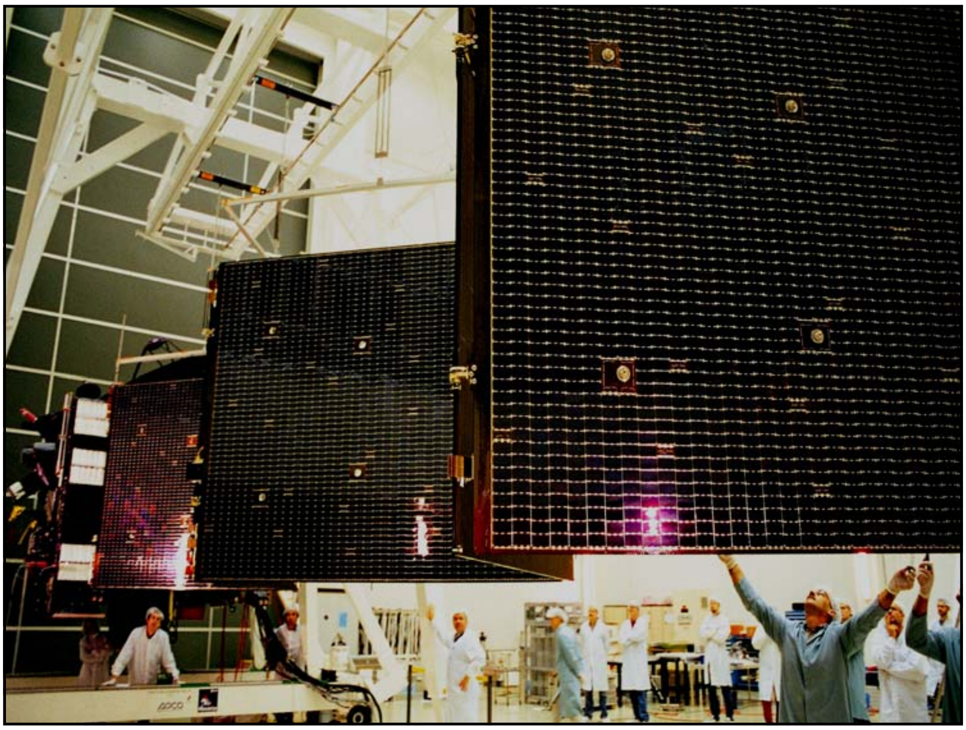
Science goals of Rosetta mission

- a global characterization of the nucleus,
- the determination of its dynamic properties,
- the surface morphology and composition,
- the determination of chemical, mineralogical and isotopic compositions of volatiles and refractories in the cometary nucleus,
- the determination of the physical properties and interrelation of volatiles and refractories in the cometary nucleus,
- studies of the development of cometary activity and the processes in the surface layer of the nucleus and inner coma, that is dust/gas interaction,
- studies of the evolution of the interaction region of the solar wind and the outgassing comet during perihelion approach.

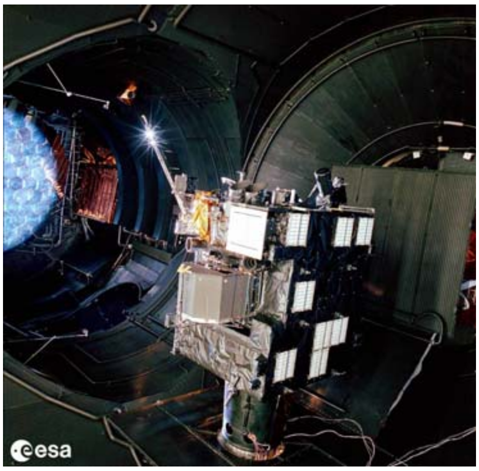
Mission Rosetta : orbiter and lander

Table 2 Spacecraft Properties

Size: main structure	2.8 x 2.1 x 2.0 m^3
Span of solar arrays	32 m
Launch mass: - total	2900 kg
- propellant	1720 kg
- science payload	165 kg
- lander PHILAE	100 kg
Solar array output	850 W at 3.40 AU 395 W at 5.25 AU
Propulsion subsystem	24 bipropellant 10 N thrusters
Operational life time	12 years
Prime contractor	Alenia Spazio, Italy



Rosetta and Rosetta Lander Philae

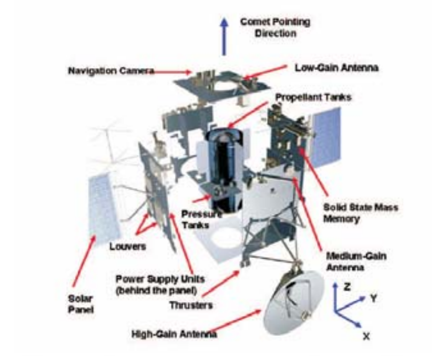


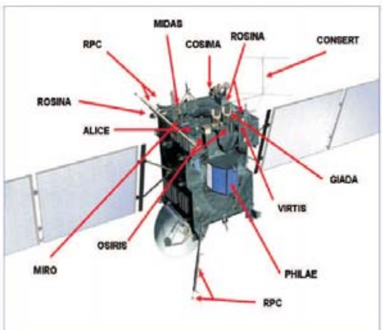
Rosetta (solar simulation test)

Rosetta Lander Philae attached to orbiter

Table 3 The Payload of the ROSETTA Mission

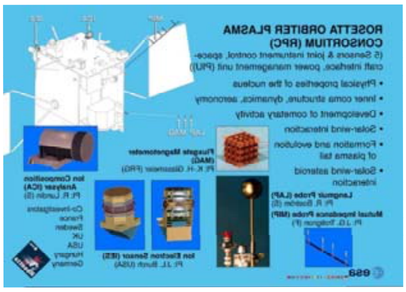
Instrument Name	Scientific Objectives	Principal Investigator
OSIRIS	Multi-Colour Imaging with a Narrow and a Wide Angle Camera	Horst-Uwe Keller MPS, Lindau Germany
ALICE	UV-Spectroscopy (70 nm - 205 nm)	Alan Stern SRI, Boulder, USA
VIRTIS	VIS and IR Mapping Spectroscopy ($0.25 - 5\ \mu m$)	Angioletta Coradini IAS-CNR, Rome, Italy
MIRO	Microwave Spectroscopy (1.3 mm and 0.5 mm)	Sam Gulkis JPL, Pasadena, USA
ROSINA	Neutral Gas and Ion Mass Spectroscopy DFMS: 12-200 AMU $M/\Delta M \approx 3000$ RTOF: 12-350 AMU $M/\Delta M > 1000$ incl. Gas Pressure Sensor	Hans Balsiger Universität Bern Switzerland
COSIMA	Dust Mass Spectrometer (SIMS, $m/\mu m \approx 2000$)	Martin Hilchenbach (formerly Jochen Kissel) MPS, Lindau Germany
MIDAS	Grain Morphology with an Atomic Force Microscope at nm Resolution	Willi Riedler IWF, Graz, Austria
CONSERT	Radio Sounding and Nucleus Tomography	Wlodek Kofman CEPHAH, Grenoble France
GIADA	Dust Velocity and Impact Momentum Measurement, Contamination Monitor	Luigi Colangelo INAF, Naples, Italy
RPC	Langmuir Probe (LAP)	Anders Eriksson (formerly Rolf Boström) IRF Uppsala, Sweden
	Ion and Electron Sensor (IES)	Jim Burch SRI, San Antonio, USA
	Flux Gate Magnetometer (MAG)	Karl-Heinz Glassmeier IGEP, TU Braunschweig Germany
	Ion Composition Analyser (ICA)	Rickard Lundin IRF, Kiruna, Sweden
	Mutual Impedance Probe (MIP)	Jean-Gabriele Trotignon LPCE/CNRS, Orleans France
	Plasma Interface Unit (PIU)	Chris Carr Imperial College, London England
RSI	Radio Science Experiment	Martin Pätzold Universität Köln Germany



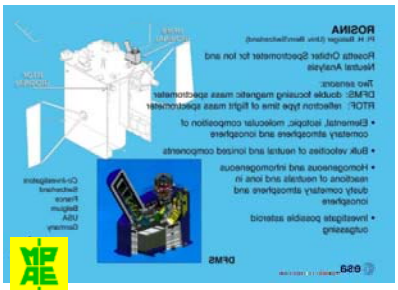


Plasma- and neutral particle measurements onboard ROSETTA

RPC: Plasma- and magnet field



ROSINA: abundance and velocity of gas and ions



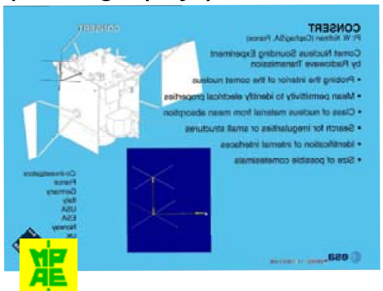
Dust measurements onboard ROSETTA

MIDAS: Dustmicroscope

COSIMA: Element abundancies

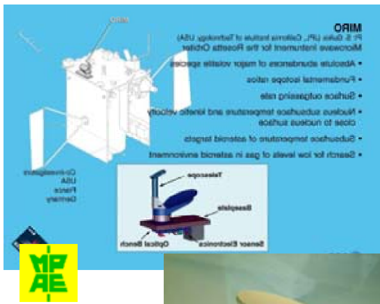
GIADA: Dust flux measurements

CONSERT: radiowavetransmission („tomography“)



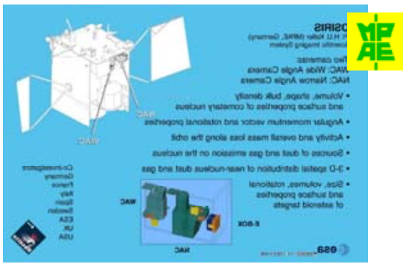
Elektromagnetic waves onboard ROSETTA (I)

MIRO: microwavemeasurements



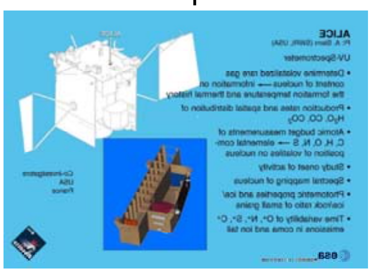
RSI: mass and density

OSIRIS: The ROSETTA cameras

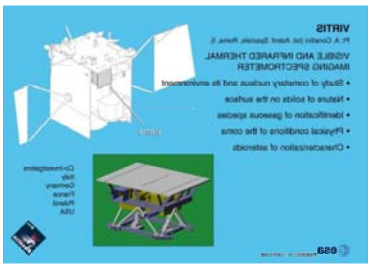


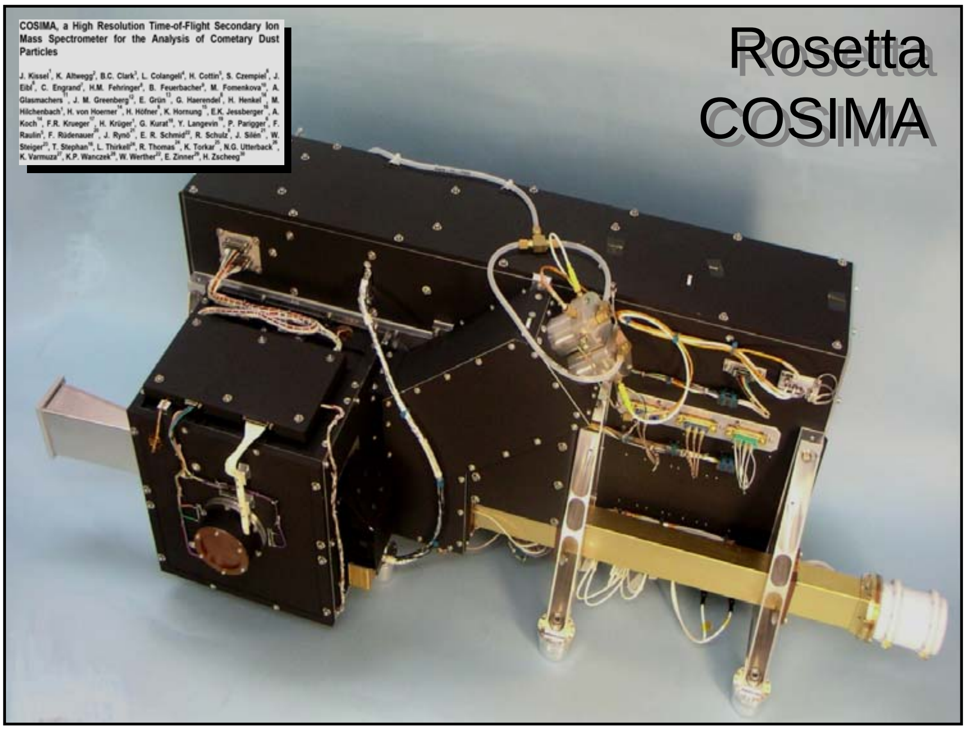
Elektromagnetic waves onboard ROSETTA (I)

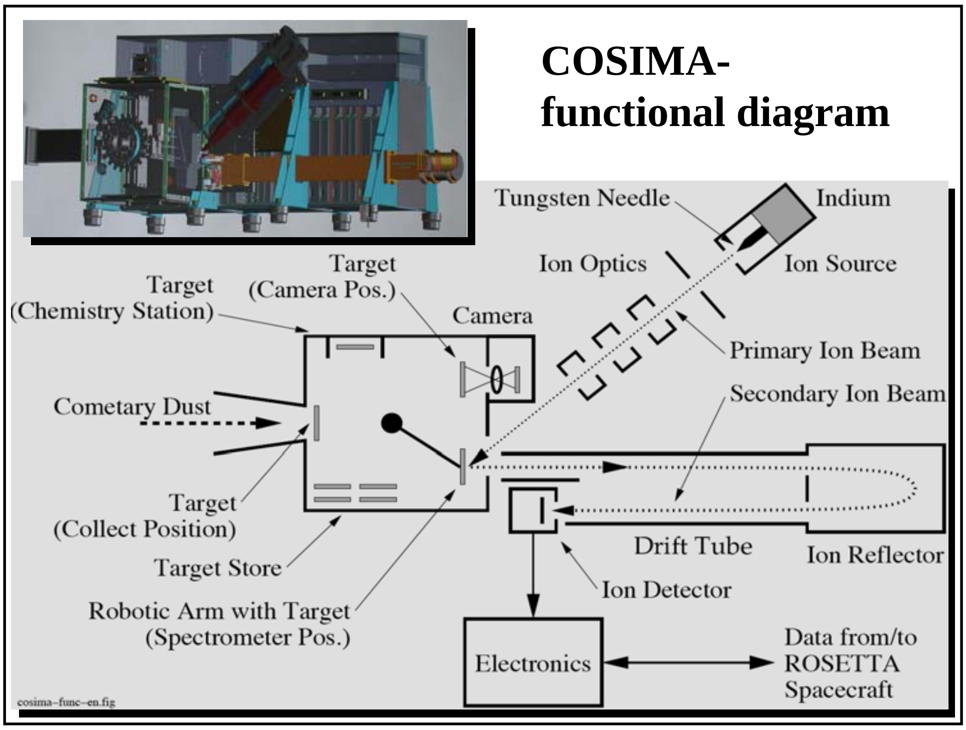
ALICE: UV spectrometer



VIRTIS: Infrared spectrometer




Rosetta
COSIMA
COSIMA, a High Resolution Time-of-Flight Secondary Ion Mass Spectrometer for the Analysis of Cometary Dust Particles
J. Kissel, K. Altwegg, B.C. Clark, L. Colangeli, H. Cottin, S. Czempiel, J. Eibl, C. Engrand, H.M. Fehringer, B. Feuerbacher, M. Fomenkova, A. Glasmachers, J. M. Greenberg, E. Grün, G. Haerendel, H. Henkel, M. Hilchenbach, H. von Hoerner, H. Höfner, K. Hornung, E.K. Jessberger, A. Koch, F.R. Krueger, H. Krüger, G. Kurat, Y. Langevin, P. Parigger, F. Raulin, F. Rüdenauer, J. Rynö, E. R. Schmid, R. Schulz, J. Silén, W. Steiger, T. Stephan, L. Thirkell, R. Thomas, K. Torkar, N.G. Utterback, K. Varmuza, K.P. Wanczek, W. Werther, E. Zinner, H. Zscheeg


COSIMA-
functional diagram
Tungsten Needle
Indium
Ion Optics
Ion Source
Target
(Camera Pos.)
Target
(Chemistry Station)
Camera
Primary Ion Beam
Cometary Dust
Secondary Ion Beam
Target
(Collect Position)
Drift Tube
Ion Reflector
Target Store
Ion Detector
Robotic Arm with Target
(Spectrometer Pos.)
Electronics
Data from/to
ROSETTA
Spacecraft
cosima-func-en.fig

Stardust (Comet 81P/Wild-2): In-situ and (future) laboratory measurements

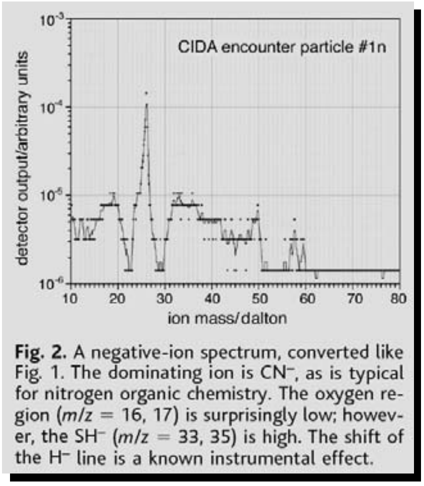
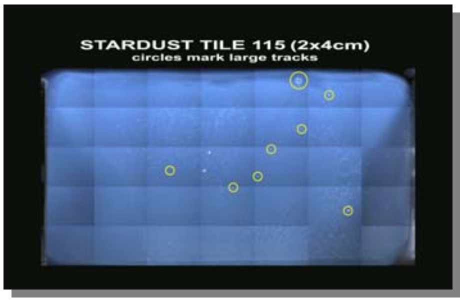


Fig. 2. A negative-ion spectrum, converted like Fig. 1. The dominating ion is CN^-, as is typical for nitrogen organic chemistry. The oxygen region (m/z = 16, 17) is surprisingly low; however, the SH^- (m/z = 33, 35) is high. The shift of the H^- line is a known instrumental effect.

Kissel et al 2004

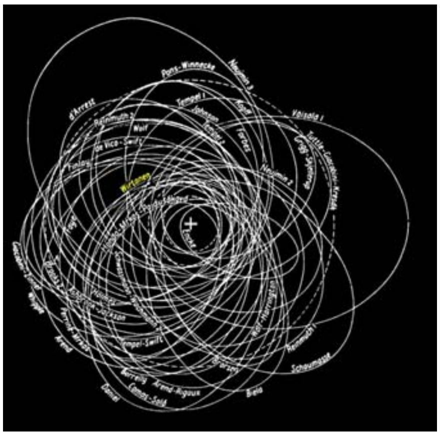
cometary dust, captured in aerogel, (sample return Jan 2006)



Tsou 2006

Selection of target comet for the Rosetta mission

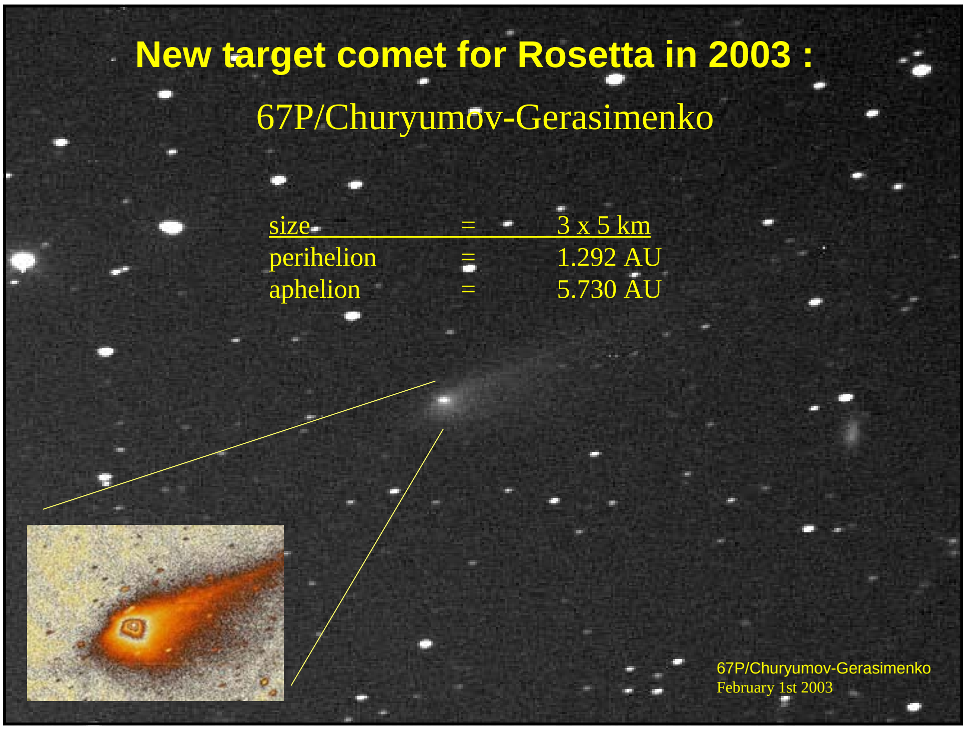
Selection of target comet for the Rosetta mission - II



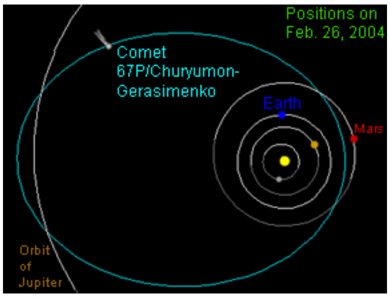
2003

conditions:
periodic comet, „new" in the inner solar system and target comet should not fall apart*, and rocket should be ready for launch in time....

*unpredictable...



Approaching comet 67P/Churyumov-Gerasimenko



Journey to comet (2004-2014)

Launch of
Ariane V
2004

Science at comet
(2014/2015: 12 month)

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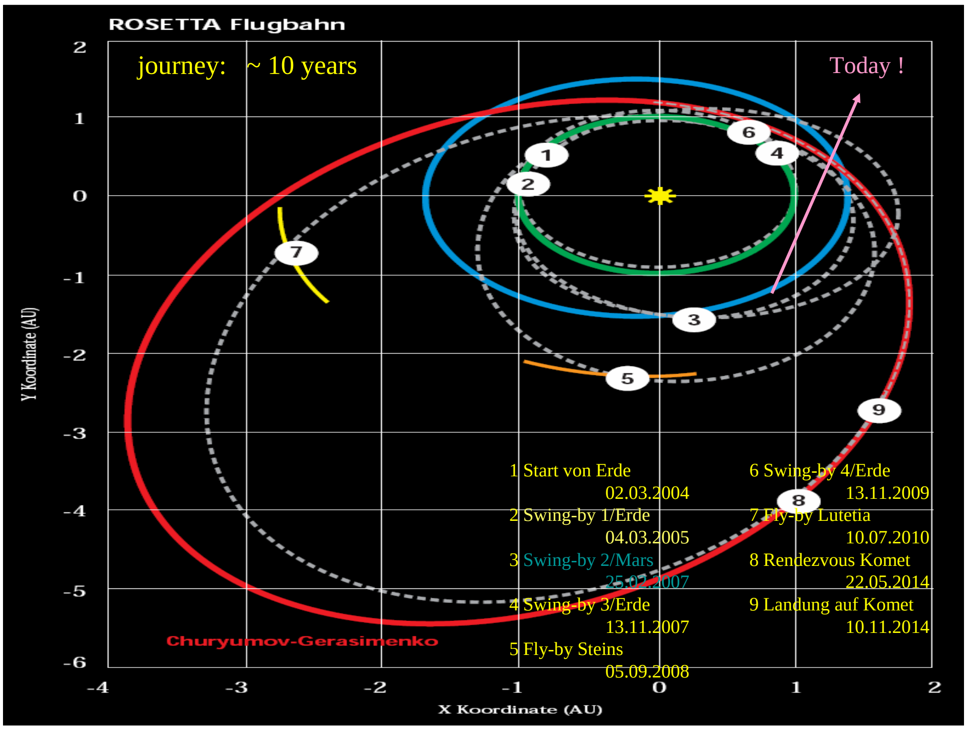


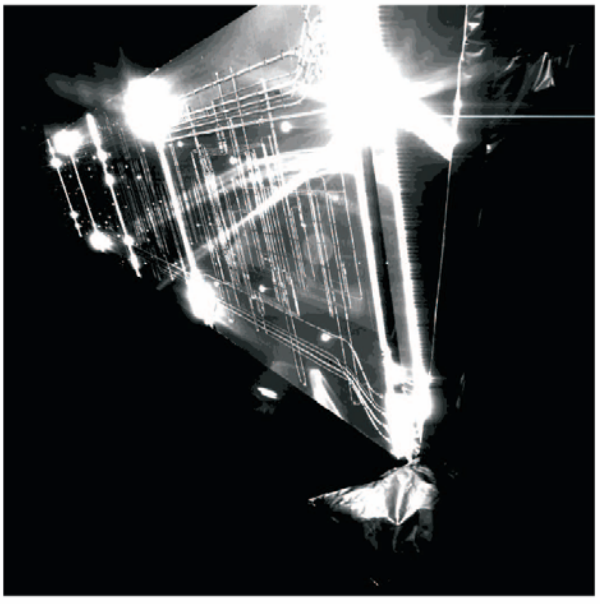


Fig. 4 One of ROSETTA's solar panels as seen in-flight from the PHILAE lander camera CIVA. For further details see Bibring et al. (2007b). Figure by courtesy of CIVA/PHILAE/ESA.

Rosetta
Osiris
observations
of Tempel 1
„Deep Impact“

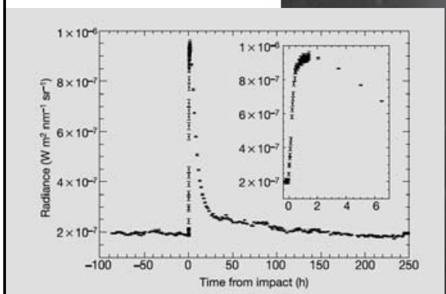
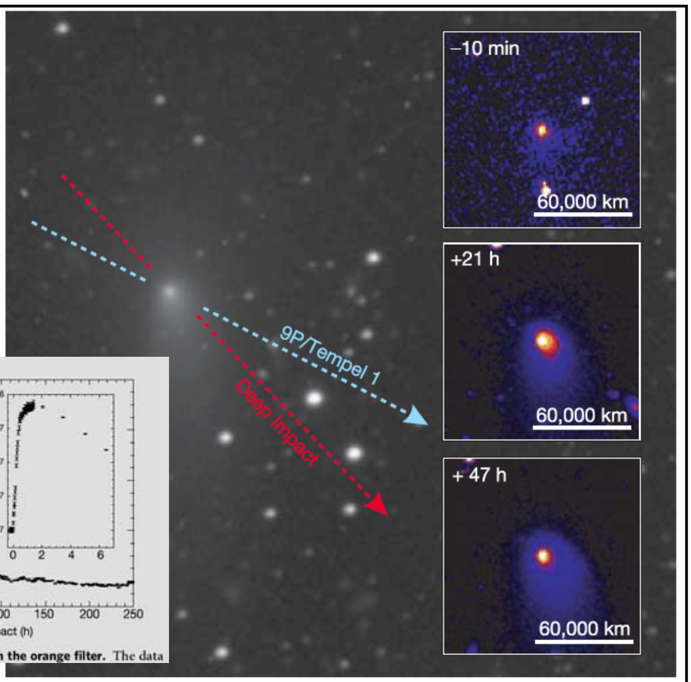


Figure 3 | Light curve of the cometary dust in the orange filter. The data



Küppers et al. 2006

Figure 1 | The Comet 9P/Tempel 1 as seen by the Osiris NAC. The NAC

Outlook and milestones towards comet 67P/Churyumov-Gerasimenko

Table 1 Milestones of the ROSETTA Mission

Mission Event	Nominal Date
Launch	March 2, 2004
First Earth Gravity Assist	March 4, 2005
Mars Gravity Assist	February 25, 2007
Second Earth Gravity Assist	November 13, 2007
2867 Steins Flyby	September 5, 2008
Third Earth Gravity Assist	November 13, 2009
21 Lutetia Flyby	July 10, 2010
Rendevous Manoeuvre 1 and Start of Hibernation	January 23, 2011
Exit Hibernation	January, 2014
Comet Rendezvous Maneuver Between 4.5 and 4.0 AU	Spring, 2014
Start of Near-Nucleus Operations at 3.25 AU	August 22, 2014
PHILAE Deployment	November, 2015
Perihelion Passage	August, 2015
End of Nominal Mission	December 31, 2015