



Rosetta - An example for a modern planetary mission

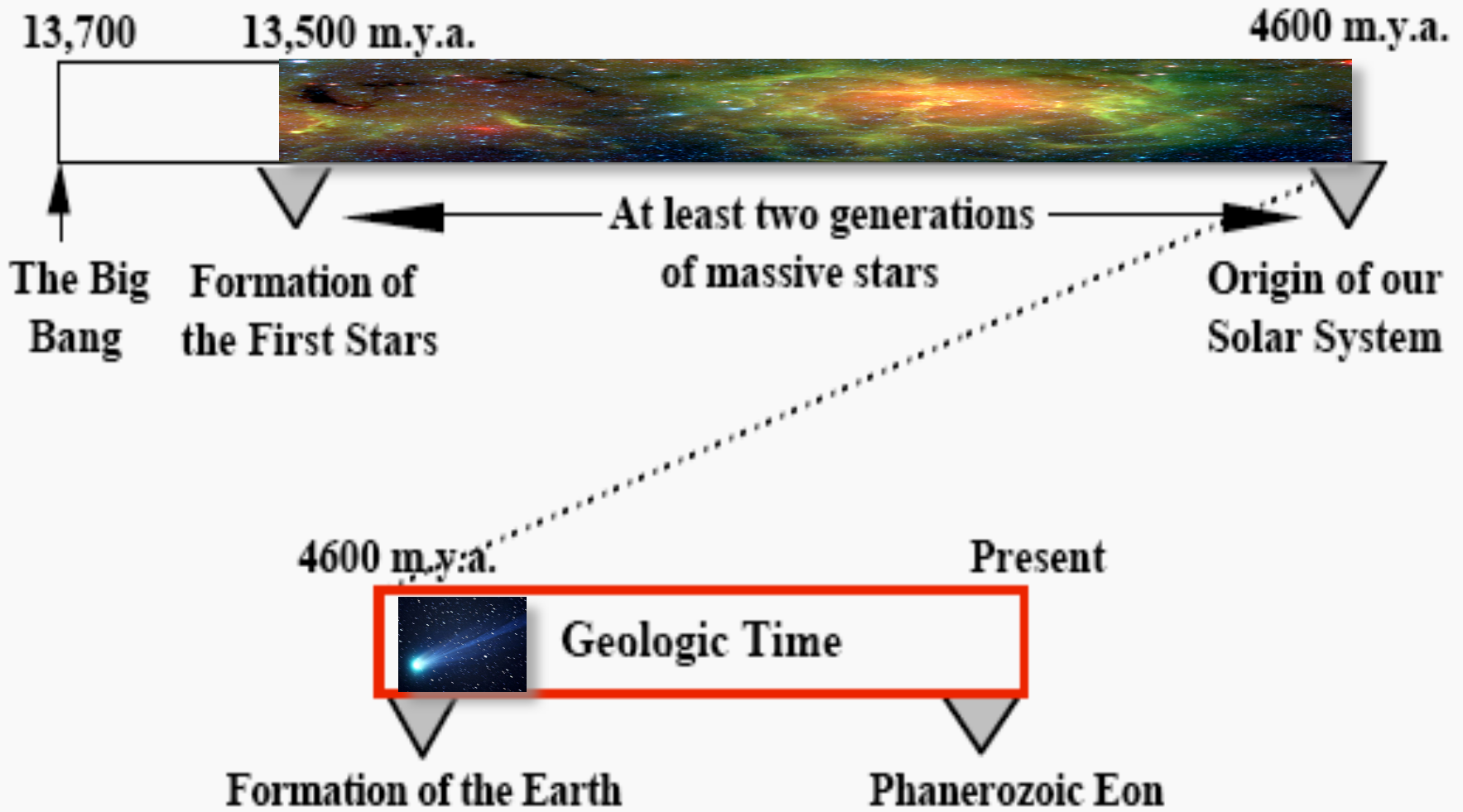


M. Hilchenbach

Outline

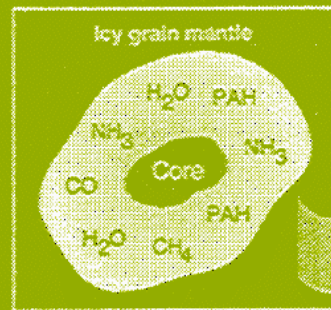
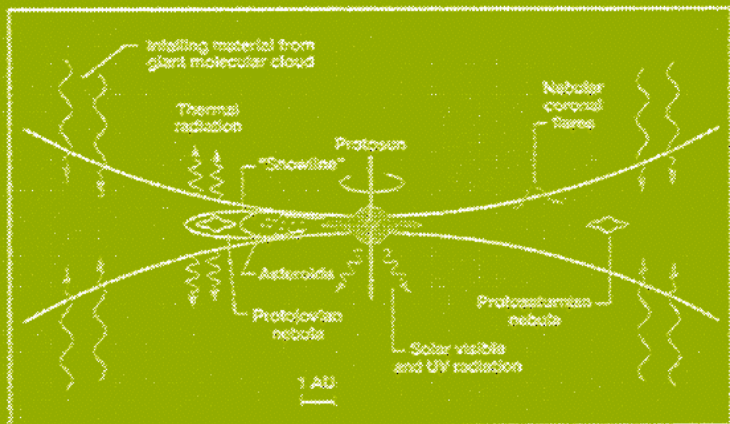
- **timeline, matter and comets**
- schedule and management approach for new missions
- Rosetta mission and payload
- Rosetta mission highlights up to 2010

Cosmological Timeline

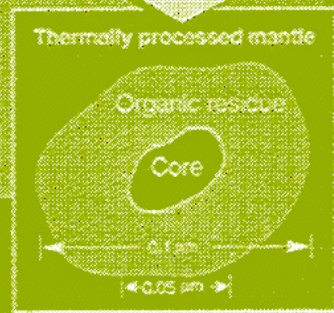
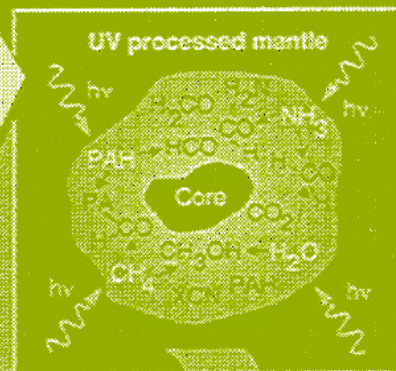


All dates are in millions of years ago (m.y.a.).

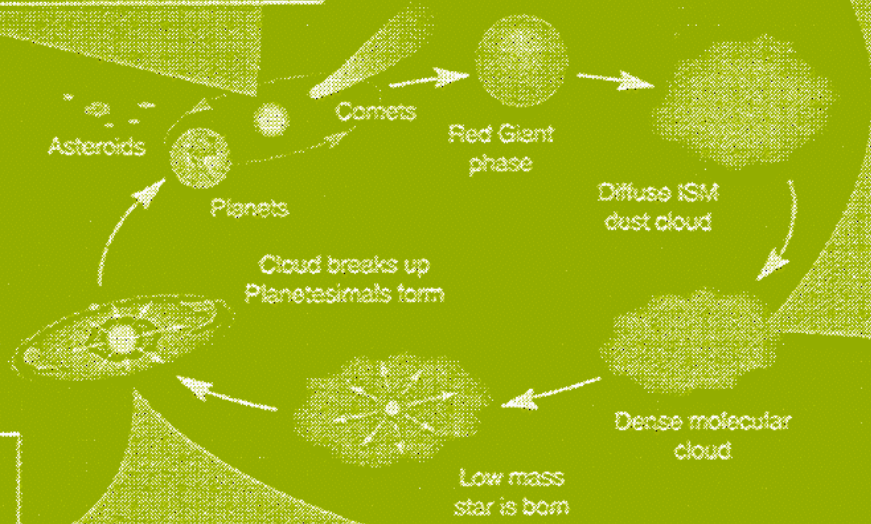
Nebular chemical & physical processes



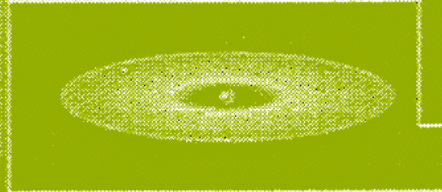
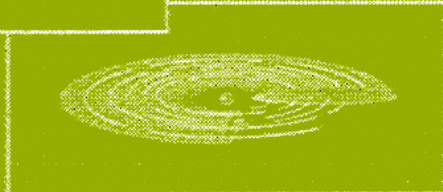
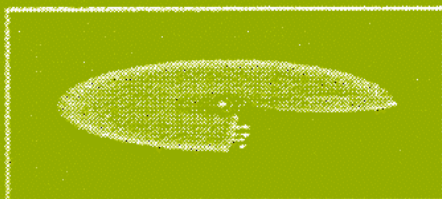
Energetic processing in molecular clouds



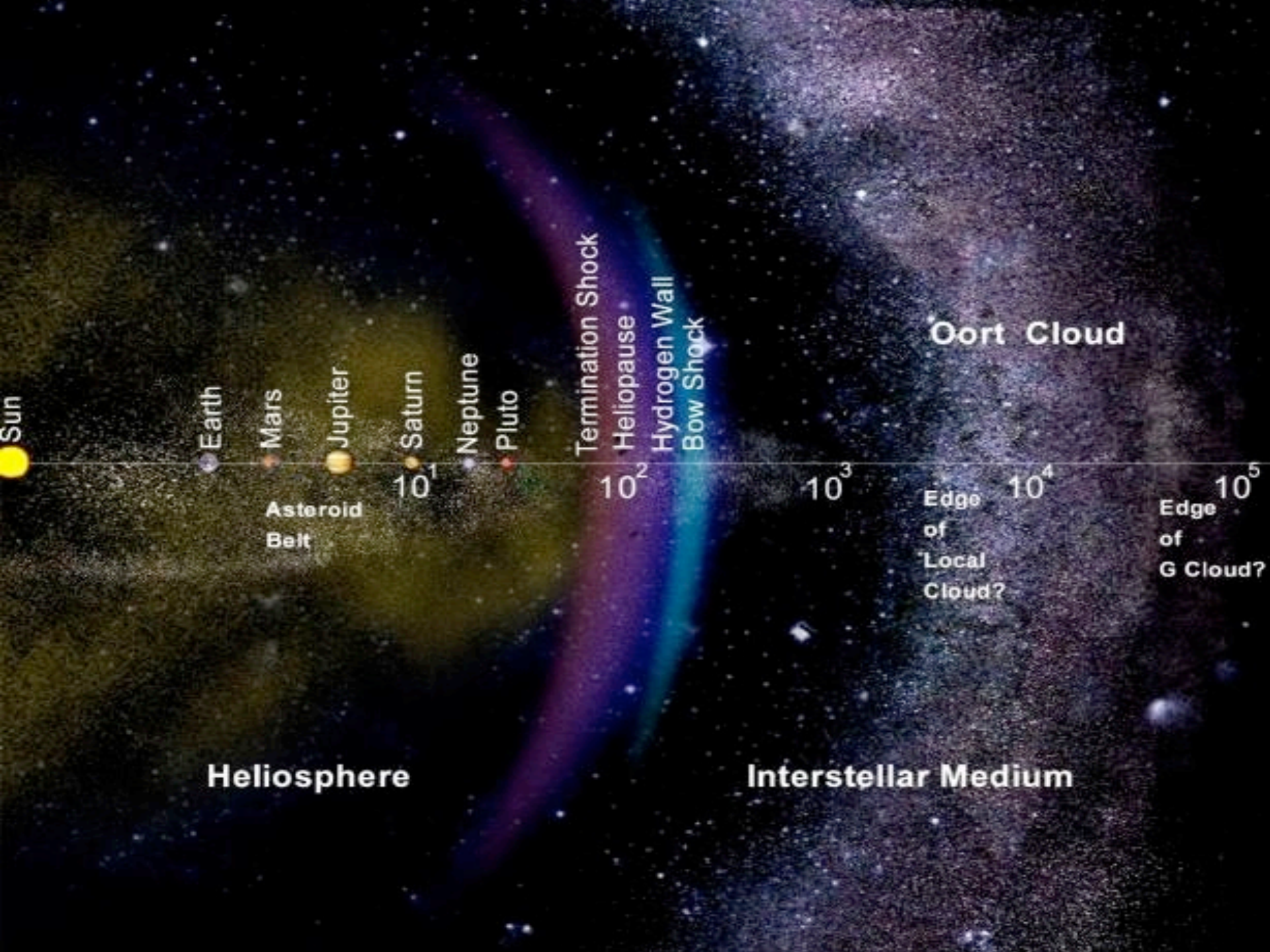
Life cycle of a low mass star



Origin & Evolution of the Solar System



Outer Solar System nebular evolution



Sun

Earth

Mars

Jupiter

Asteroid Belt

10^1

Saturn

Neptune

Pluto

Termination Shock

Heliopause

Hydrogen Wall

Bow Shock

10^2

10^3

Oort Cloud

10^4

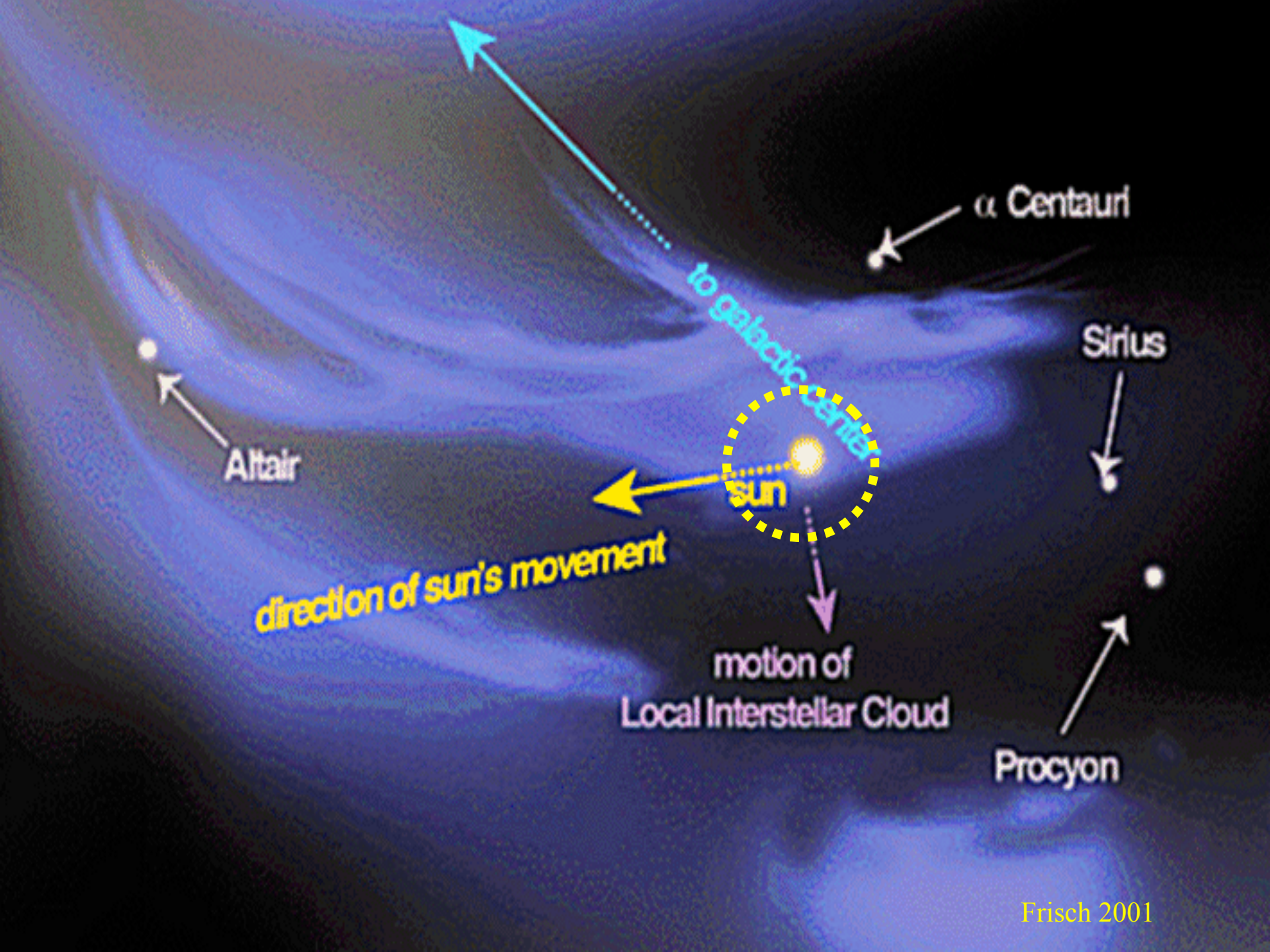
Edge of Local Cloud?

10^5

Edge of G Cloud?

Heliosphere

Interstellar Medium



Altair

α Centauri

Sirius

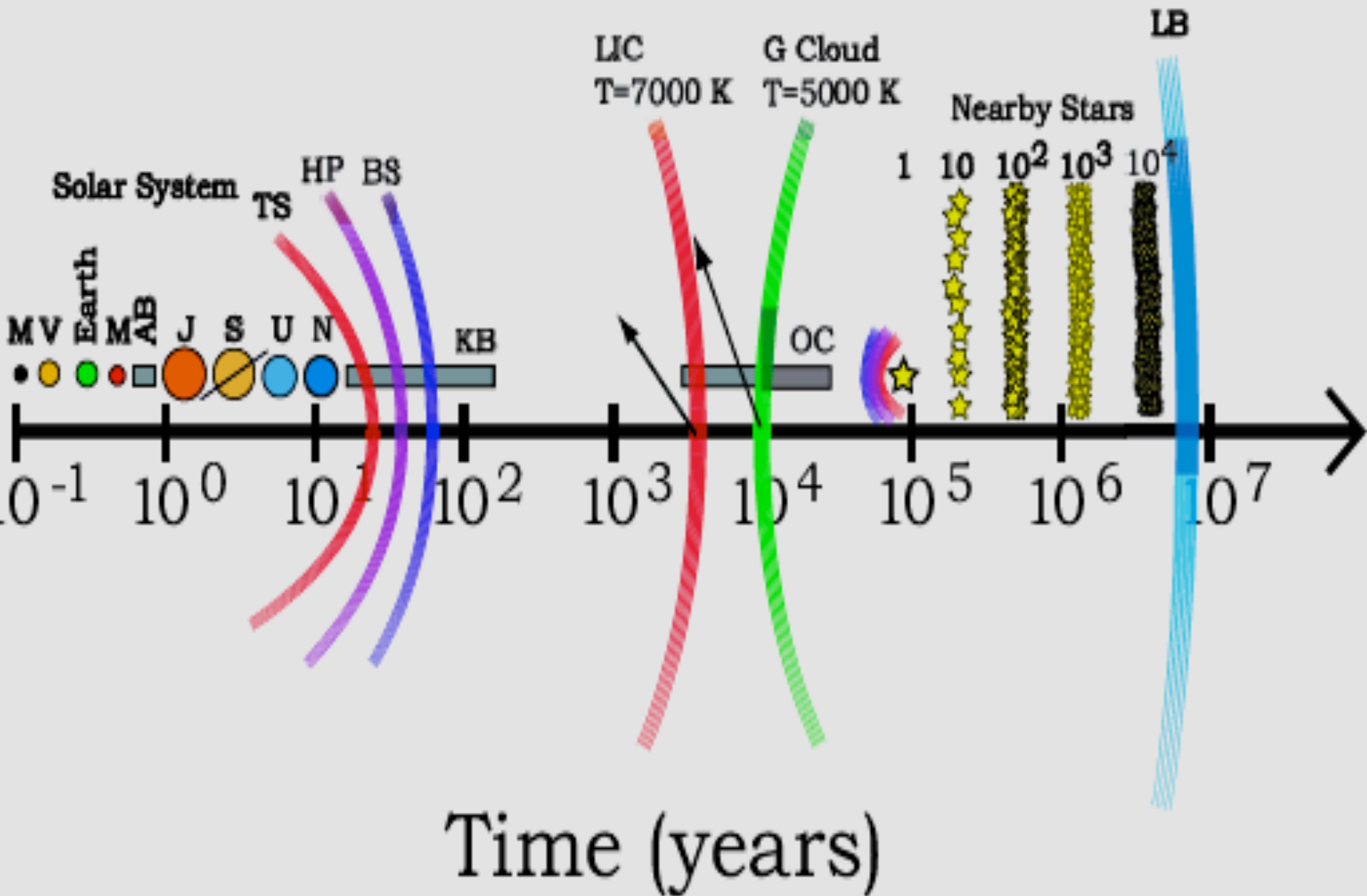
sun

direction of sun's movement

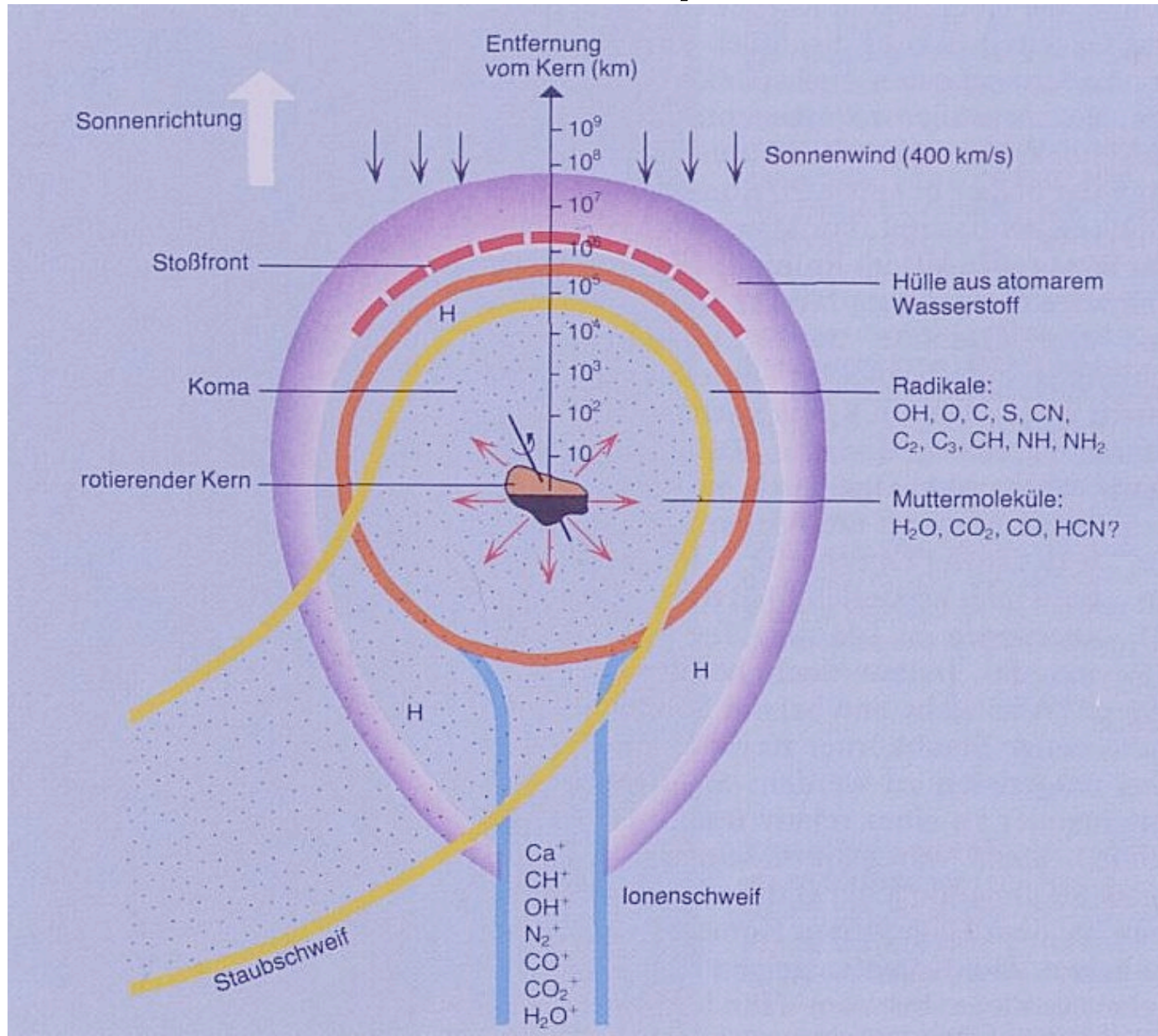
motion of
Local Interstellar Cloud

Procyon

to galactic center



Comets – greatest and tiniest cheaters in the solar system

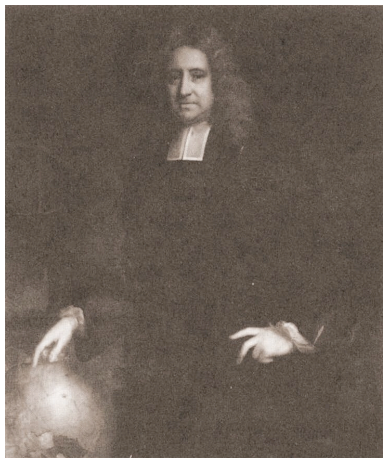
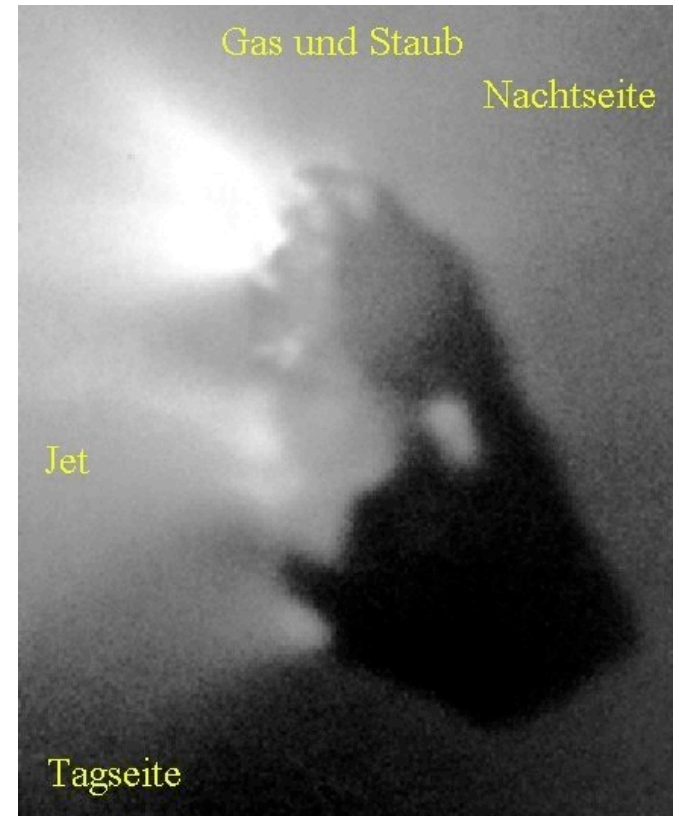




Comet Halley (March 13, 1986)

Famous comet: Halley

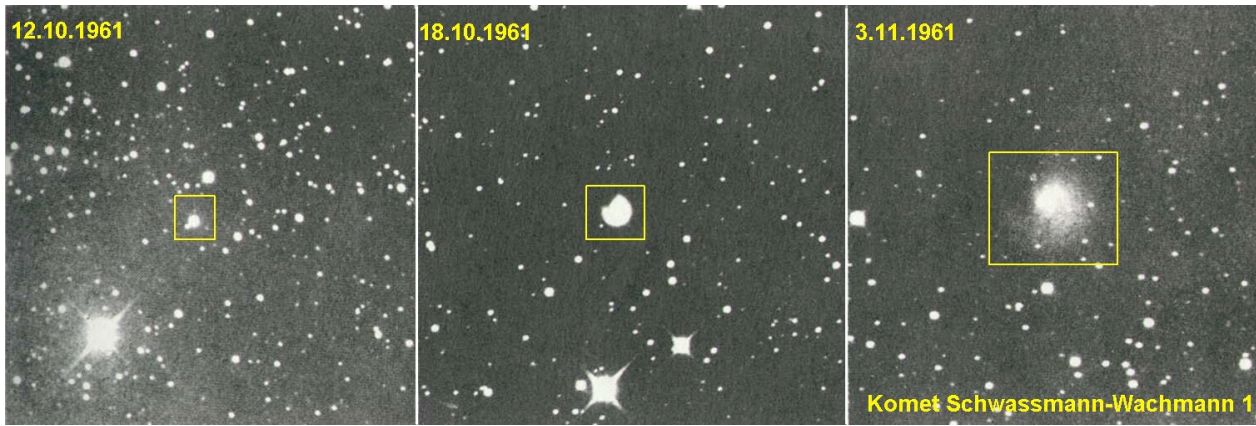
nucleus, gas and dust 1986



Edmond Halley, painted
by Thomas Murray

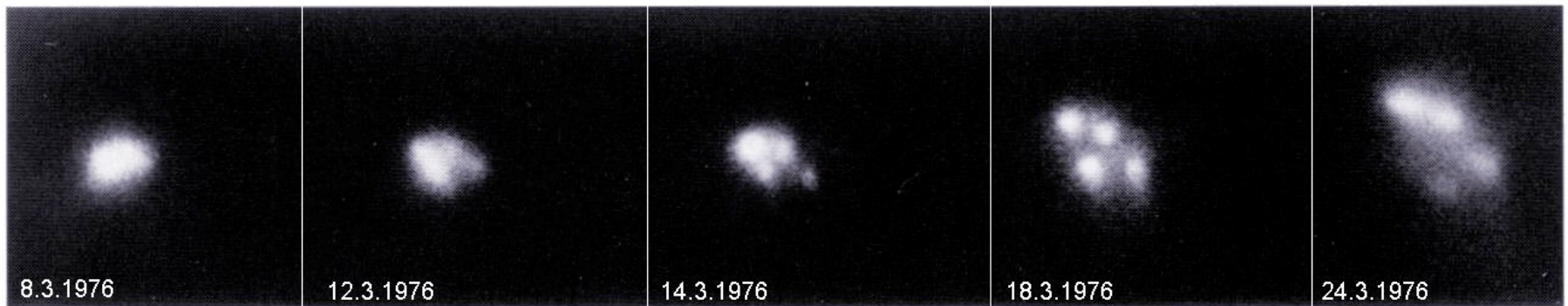
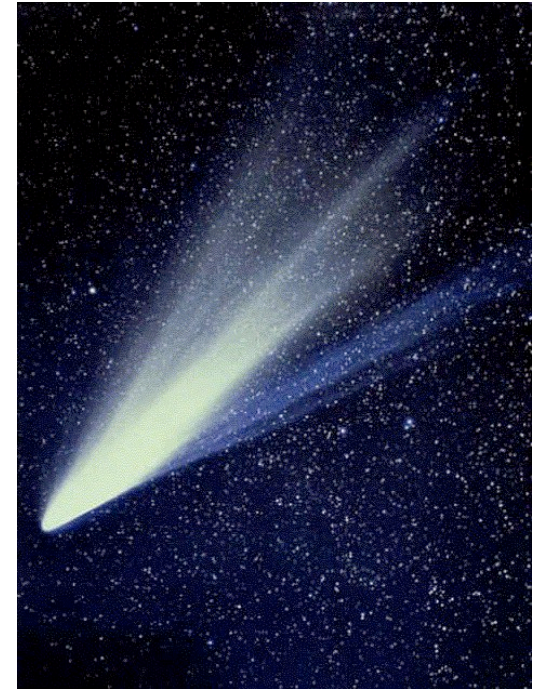
„dirty snowbal“ ?

Comets

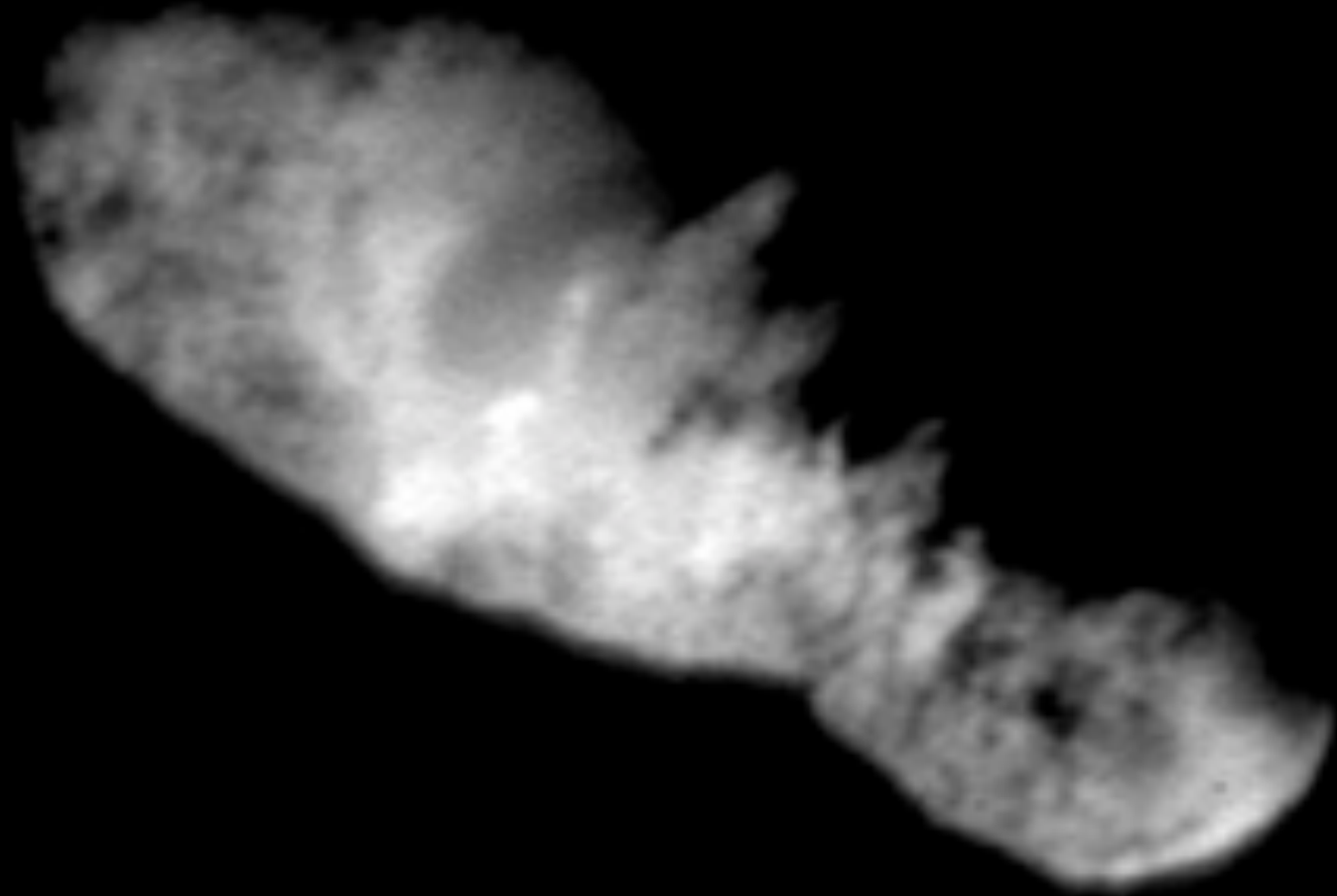


Schwassmann-Wachmann I,
outburst beyond Jupiter's orbit

Comet West, 1976



Cometary nucleus 19 P/Borelly



Deep space I
2001

Cometary nucleus 81 P/Wild-2

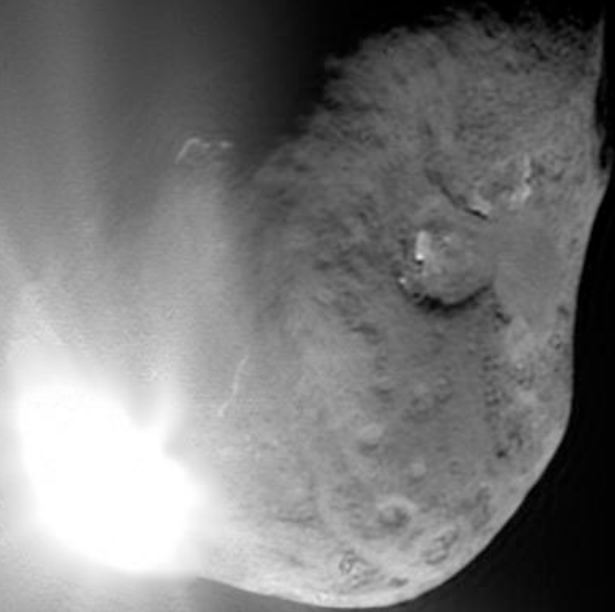


Stardust
2004



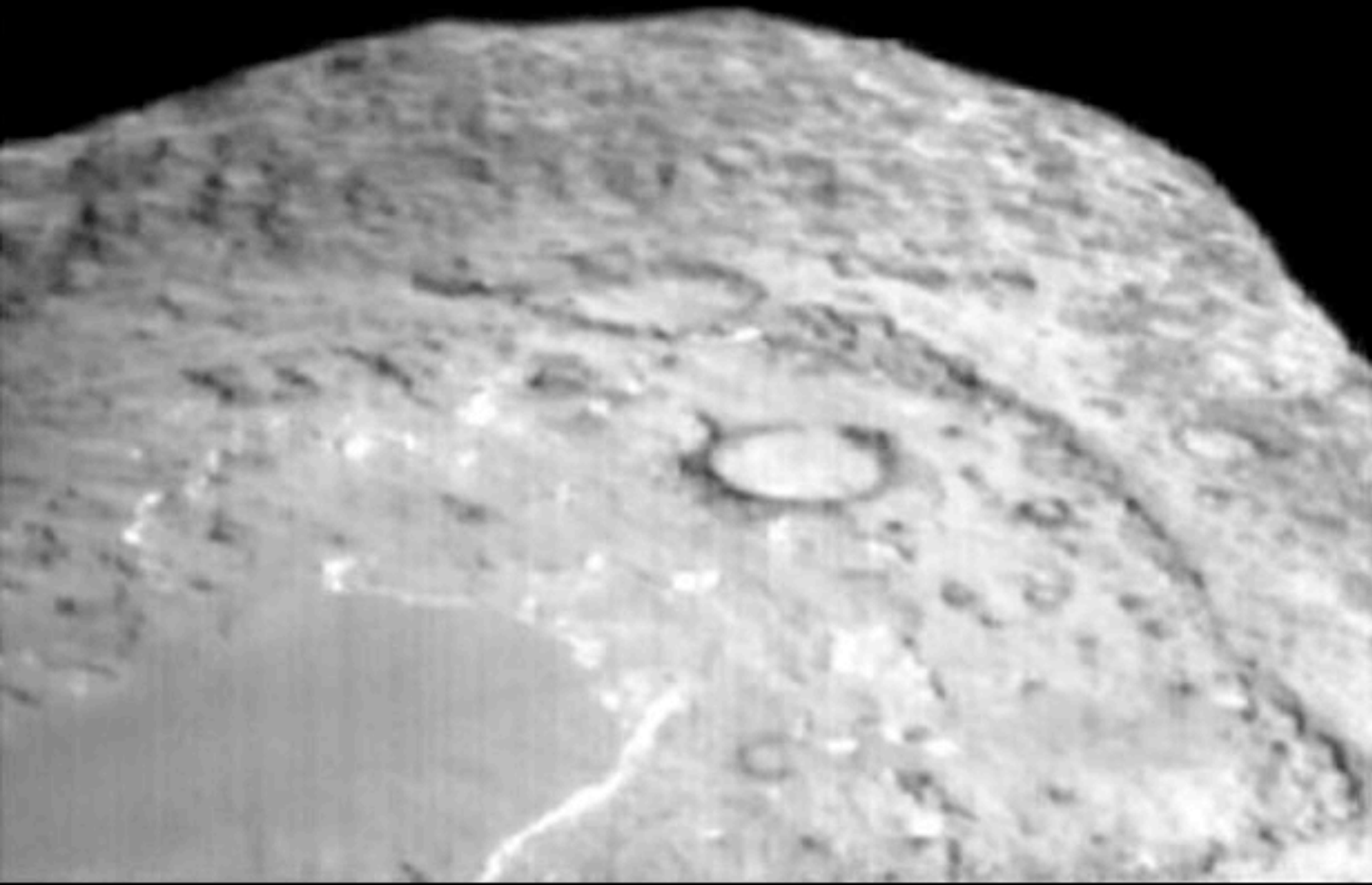
~ 5 km

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



Deep Impact
2005

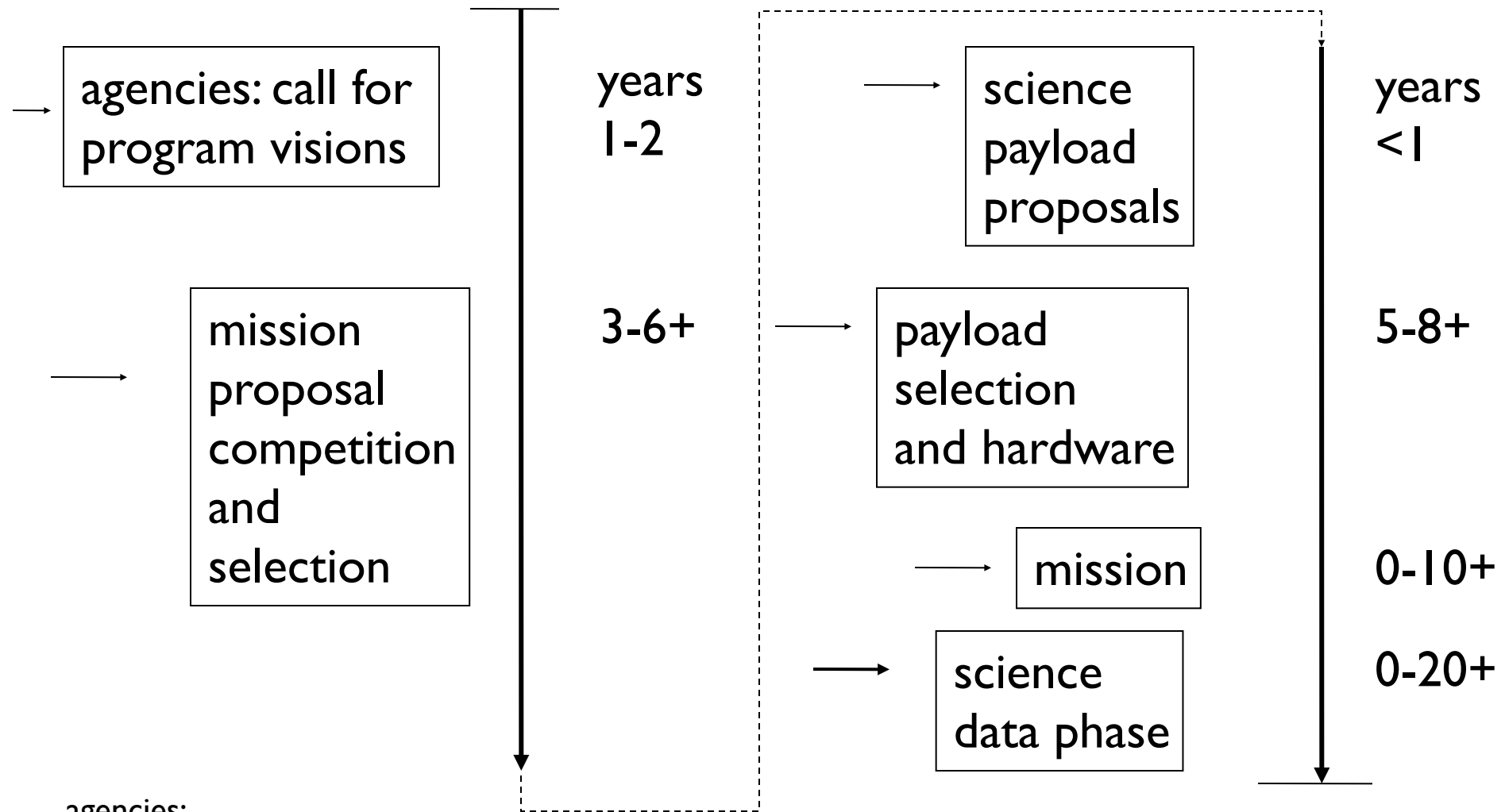
Tempel I - close-up



Outline

- timeline, matter and comets
- **schedule and management approach for new missions**
- Rosetta mission and payload
- Rosetta mission highlights up to 2010

Timeline for new space missions



agencies:

ESA, NASA, DLR, CNES etc.

Children's Books Online:
the Rosetta Project, Inc.
www.childrensbooksonline.org



The largest collection of illustrated antique children's books on the World Wide Web. Maine-based, volunteer-driven, not-for-profit, giving books away for free since 1997.

Space missions: General management approach



payload:
scientific institutes
and/ or industry

satellite:
agency contracted to industry

mission operation:
agency



mission science return:
scientific institutes

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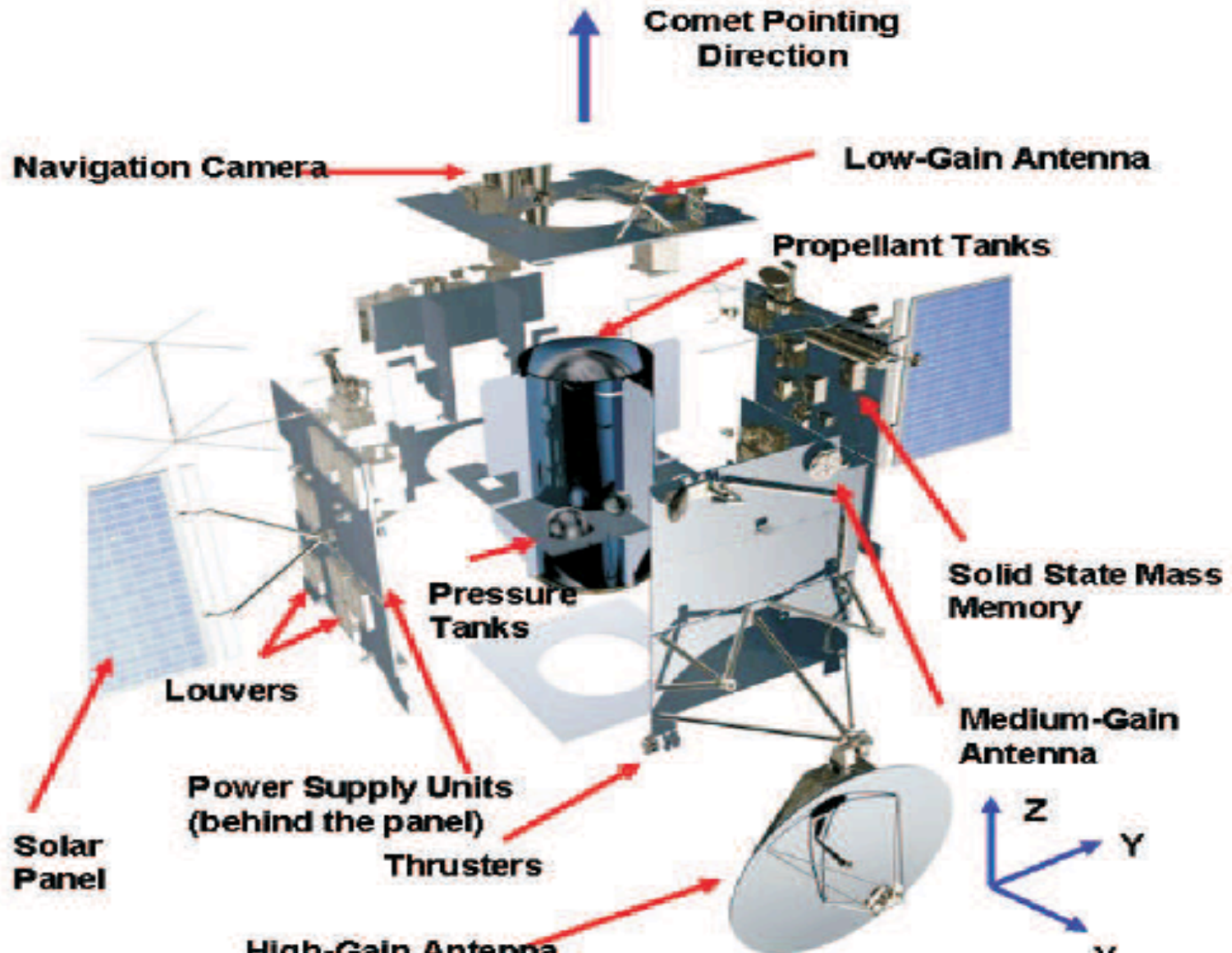
Science goals of Rosetta mission

- 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.

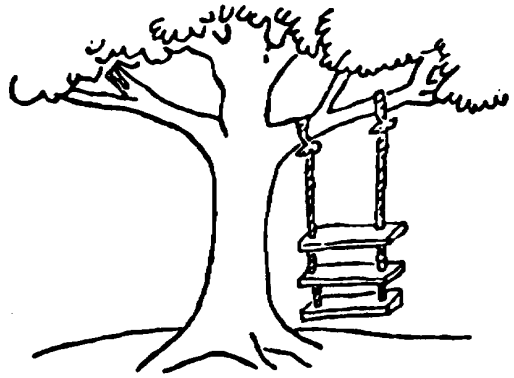


**Mission Rosetta :
orbiter and lander**

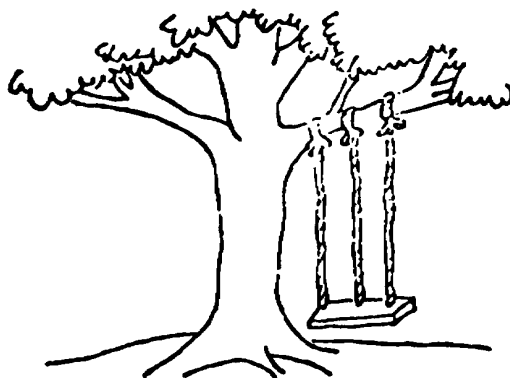
Rosetta



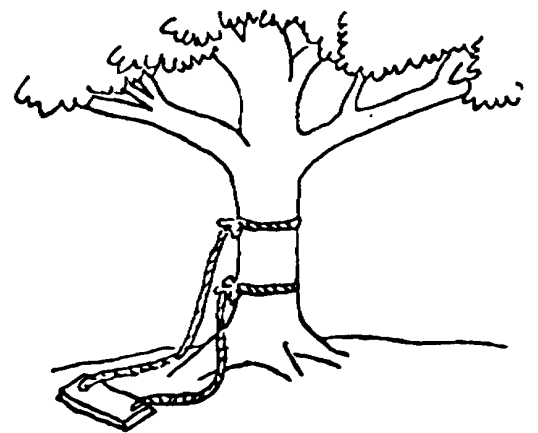
Design Depends on Individual Who Defines Problem



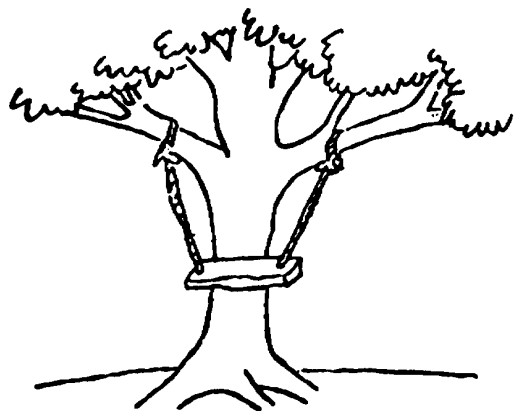
As proposed by the project sponsor



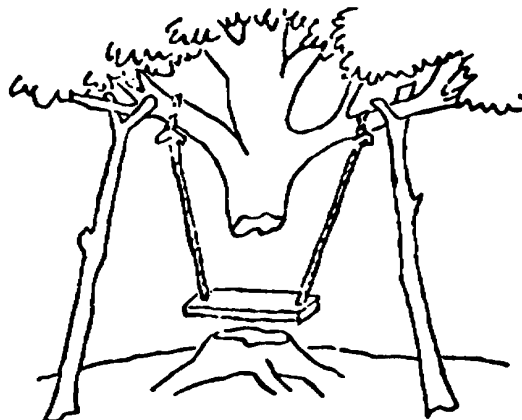
As specified in the project request



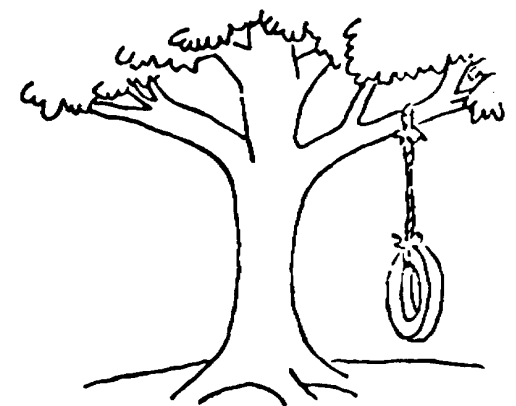
As designed by the senior designer



As produced by manufacturing



As installed at the user's site



What the user wanted

FIGURE 1.4

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

update of landing gear
Oct 2003



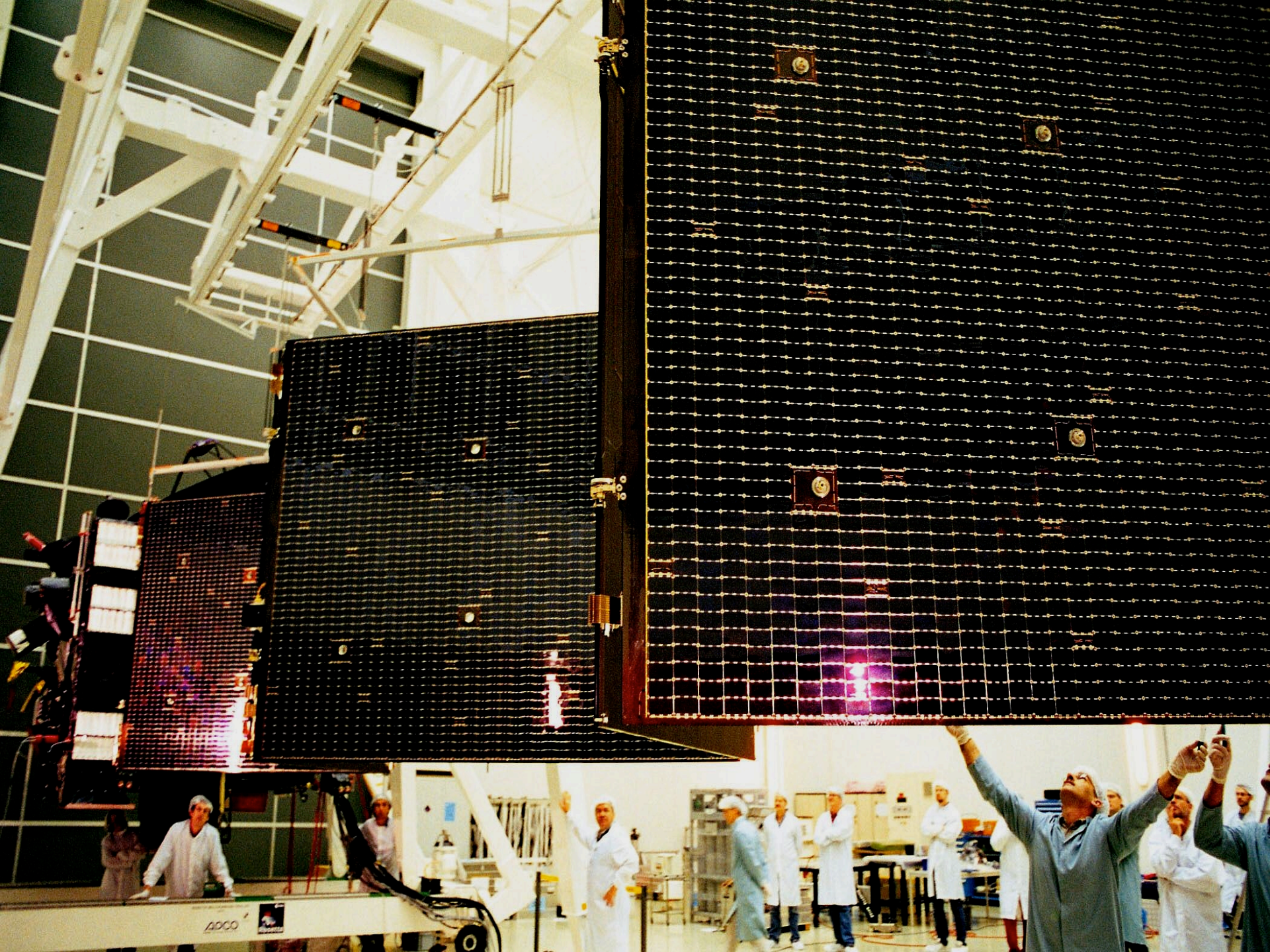
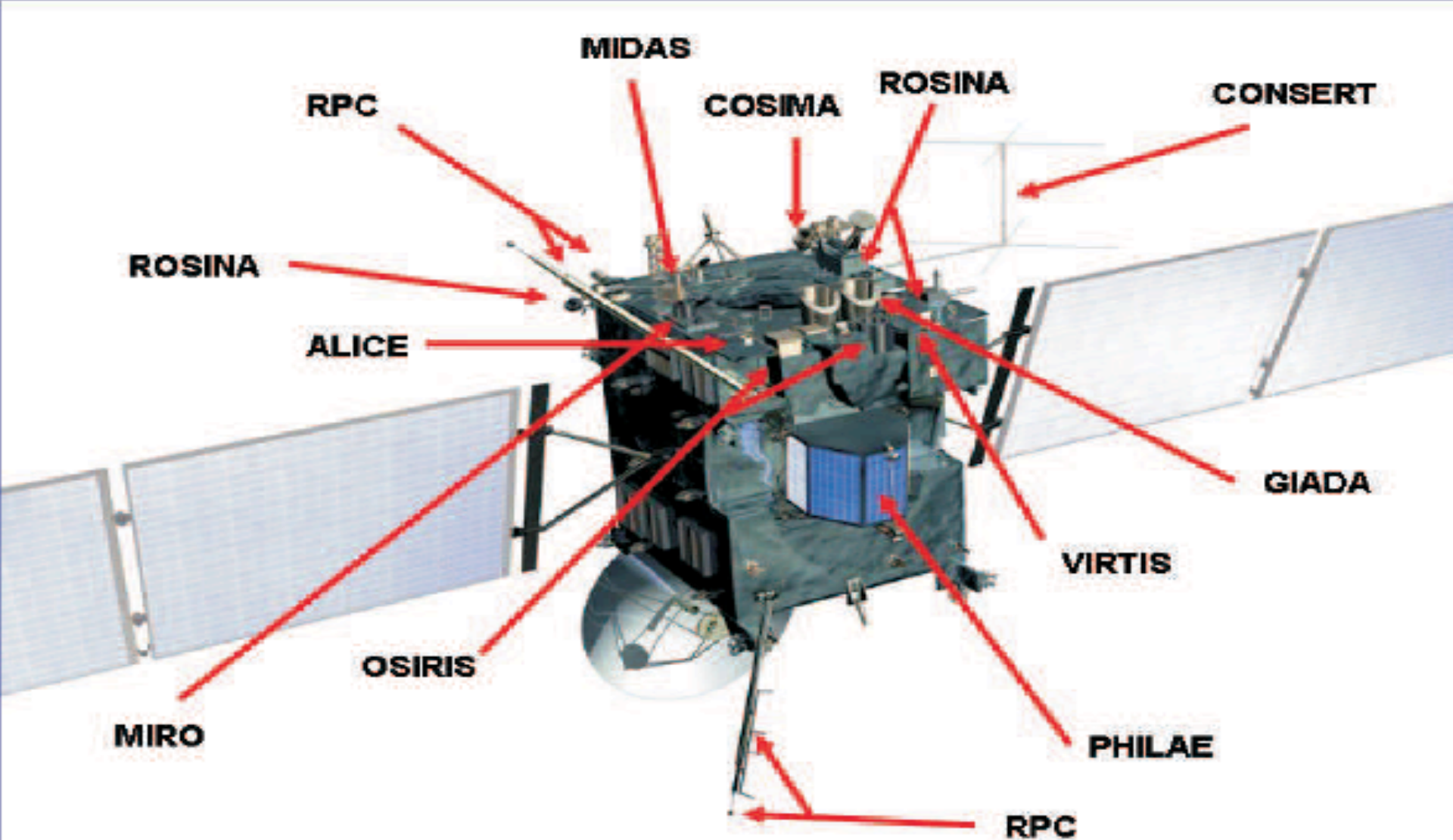


Table 2 Spacecraft Properties

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 Orbiter Experiments and Philae



Plasma- and neutral particle measurements onboard ROSETTA

RPC: Plasma- and magnet field

ROSETTA ORBITER CONSORTIUM (RPC)
 (S)ensors & joint instrument control, space-craft interface, power management unit (PIU)

- Physical properties of the nucleus
- Inner coma structure, dynamics, seronomy
- Development of cometary activity
- Solar-wind interaction
- Formation and evolution of plasma tail
- Solar-wind asteroid interaction

Fluxgate Magnetometer (MAG)
 PI: K.-H. Glassmeier (FRG)

Langmuir Probe (LAP)
 PI: R. Boström (S)

Mutual Impedance Probe (MIP)
 PI: J.-G. Toulignon (F)

Ion Electron Sensor (IES)
 PI: J.L. Burch (USA)

Ion Composition Analyser (ICA)
 PI: R. Lundin (S)

Co-Investigators: France, Sweden, UK, USA, Hungary, Germany

ROSINA: abundance and velocity of gas and ions

ROSINA
 PI: H. Balsiger (Univ. Bern/Switzerland)

Rosetta Orbiter Spectrometer for Ion and Neutral Analysis

Two sensors:
 DFMS: double focusing magnetic mass spectrometer
 FTOF: reflection type time of flight mass spectrometer

- Elemental, isotopic, molecular composition of cometary atmosphere and ionosphere
- Bulk velocities of neutral and ionized components
- Homogeneous and inhomogeneous reactions of neutrals and ions in dusty cometary atmosphere and ionosphere
- Investigate possible asteroid outgassing

Co-Investigators: Switzerland, France, Belgium, USA, Germany



MIDAS: Dustmicroscope

MIDAS
MICRO-IMAGING DUST ANALYSIS SYSTEM
P.I.: W. Riederer (WLF, Graz, Austria)

- Imaging and statistical analysis of impact craters caused by interplanetary dust particles
- Characterization of dust environment of the asteroids
- Spatial and temporal variations of particle flux
- Shape, volume, topographic structure to a few μm
- Size distribution from $\sim 4 \mu\text{m}$ to a few μm
- Statistical evaluations on sizes, volumes and shapes
- Images of single particles (spatial resolution $4 \mu\text{m}$)

Co-Investigators:
Austria
France
Germany
Norway
The Netherlands
UK
ESA

Dust measurements onboard ROSETTA

GIADA: Dust flux measurements

GIADA
GRAIN IMPACT ANALYSER AND DUST ACCUMULATOR
P.I.: E. Bussoletti (Ist. Univ. Navale, I)

- In-situ dust flux measurements of grains coming from the nucleus and from other directions (Reflected by solar radiation pressure)
- Dust momentum and velocity distribution
- Single grains mass determination
- Spatial and temporal variations of dust flux

Co-Investigators:
Italy
Spain
UK
France
Germany
USA

COSIMA: Element abundancies

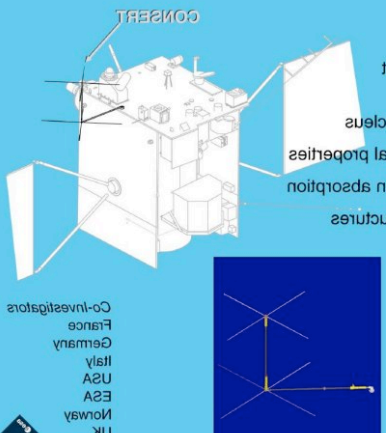
COSIMA
Cometary Secondary Ion Mass Analyser
P.I.: J. Kissel (MPE, FRG)

- Variations between individual particles
- Variations with the chemical states
- Molecular, elemental, isotopic composition
- Inorganic and organic phase
- Analysis of emitted dust grains

Co-Investigators:
Germany
France
Finland
Italy
Austria
Switzerland
USA




CONCERT: radiowavetransmission („tomography“)



CONCERT
Pr: W. Kofman (Cephad'GA, France)
Comet Nucleus Sounding Experiment
by Radiowave Transmission

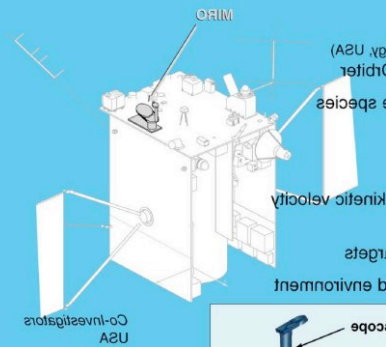
- Probing the interior of the comet nucleus
- Mean permittivity to identify electrical properties
- Class of nucleus material from mean absorption
- Search for irregularities or small structures
- Identification of internal interfaces
- Size of possible cometsimals

Co-Investigators
France
Germany
Italy
USA
ESA
Norway
UK




Elektromagnetic waves onboard ROSETTA (I)


MIRO: microwavemeasurements




MIRO
Pr: S. Gulikis (JPL, California Institute of Technology, USA)
Microwave Instrument for the Rosetta Orbiter

- Absolute abundances of major volatile species
- Fundamental isotope ratios
- Surface outgassing rate
- Nucleus subsurface temperature and kinetic velocity close to nucleus surface
- Subsurface temperature of asteroid targets
- Search for low levels of gas in asteroid environment

Co-Investigators
USA
France
Germany




RSI: mass and density




RSI
Pr: M. Pätzold (IGM, Germany)
Radio Science

EXPERIMENT USES THE ROSETTA SPACECRAFT RADIO SUBSYSTEM FOR ITS MEASUREMENTS

- Solar corona sounding
- Asteroid (Siv) mass and bulk density
- Dust grain distribution and plasma content of the inner coma
- Gas & dust jet interactions with the spacecraft
- Cometary orbit
- Mass, bulk density and gravity coefficients of the nucleus

Co-Investigators
Germany
Norway
USA
France
Sweden
UK




OSIRIS: The ROSETTA cameras

OSIRIS
 PI: H.U. Keller (MPE, Germany)
 Scientific Imaging System

Two cameras:
 WAC: Wide Angle Camera
 NAC: Narrow Angle Camera

- Volume, shape, bulk density and surface properties of cometary nucleus
- Angular momentum vector and rotational properties
- Activity and overall mass loss along the orbit
- Sources of dust and gas emission on the nucleus
- 3-D spatial distribution of near-nucleus dust and gas
- Size, volumes, rotational and surface properties of asteroid targets

Co-Investigators:
 USA, UK, ESA, Sweden, Spain, Italy, France, Germany

ESA

Elektromagnetic waves onboard ROSETTA (II)

ALICE: UV spectrometer

ALICE
 PI: A. Stern (SWRI, USA)
 UV-Spectrometer

- Determine volatiles and rare gas content of nucleus — information on the formation temperature and thermal history
- Production rates and spatial distribution of H_2O , CO , CO_2
- Atomic budget measurements of C , H , O , N , S — elemental composition of volatiles on nucleus
- Study onset of activity
- Spectral mapping of nucleus
- Photometric properties and ice/rock ratio of small grains
- Time variability of O^+ , N^+ , S^+ , C^+ emissions in coma and ion tail

Co-Investigators:
 USA, France

ESA

VIRTIS: Infrared spectrometer

VIRTIS
 PI: A. Coradini (Ist. Astron. Spaziale, Roma, I)
 VISIBLE AND INFRARED THERMAL IMAGING SPECTROMETER

- Study of cometary nucleus and its environment
- Nature of solids on the surface
- Identification of gaseous species
- Physical conditions of the coma
- Characterization of asteroids

Co-Investigators:
 USA, Poland, France, Germany, Italy

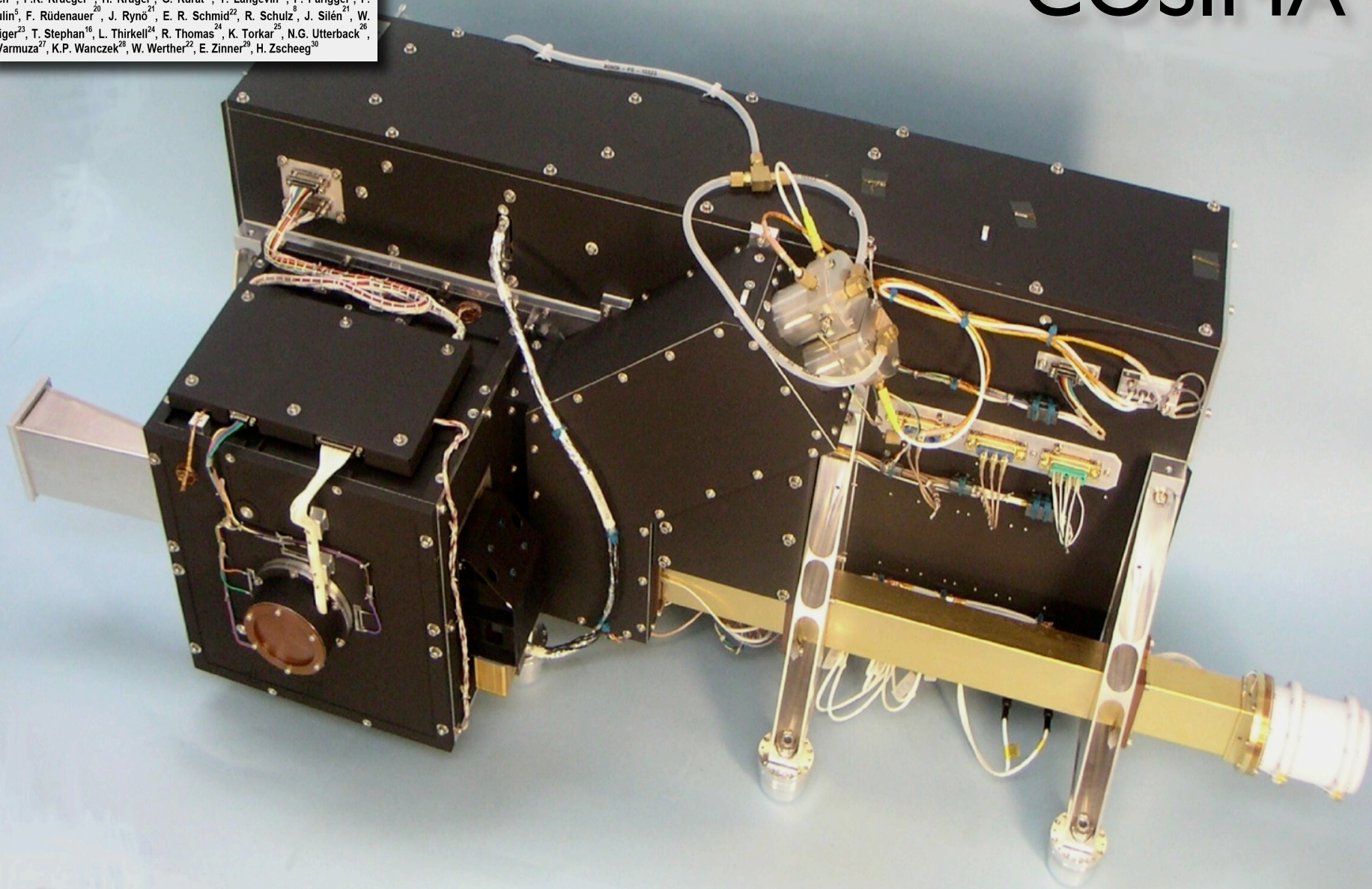
ESA



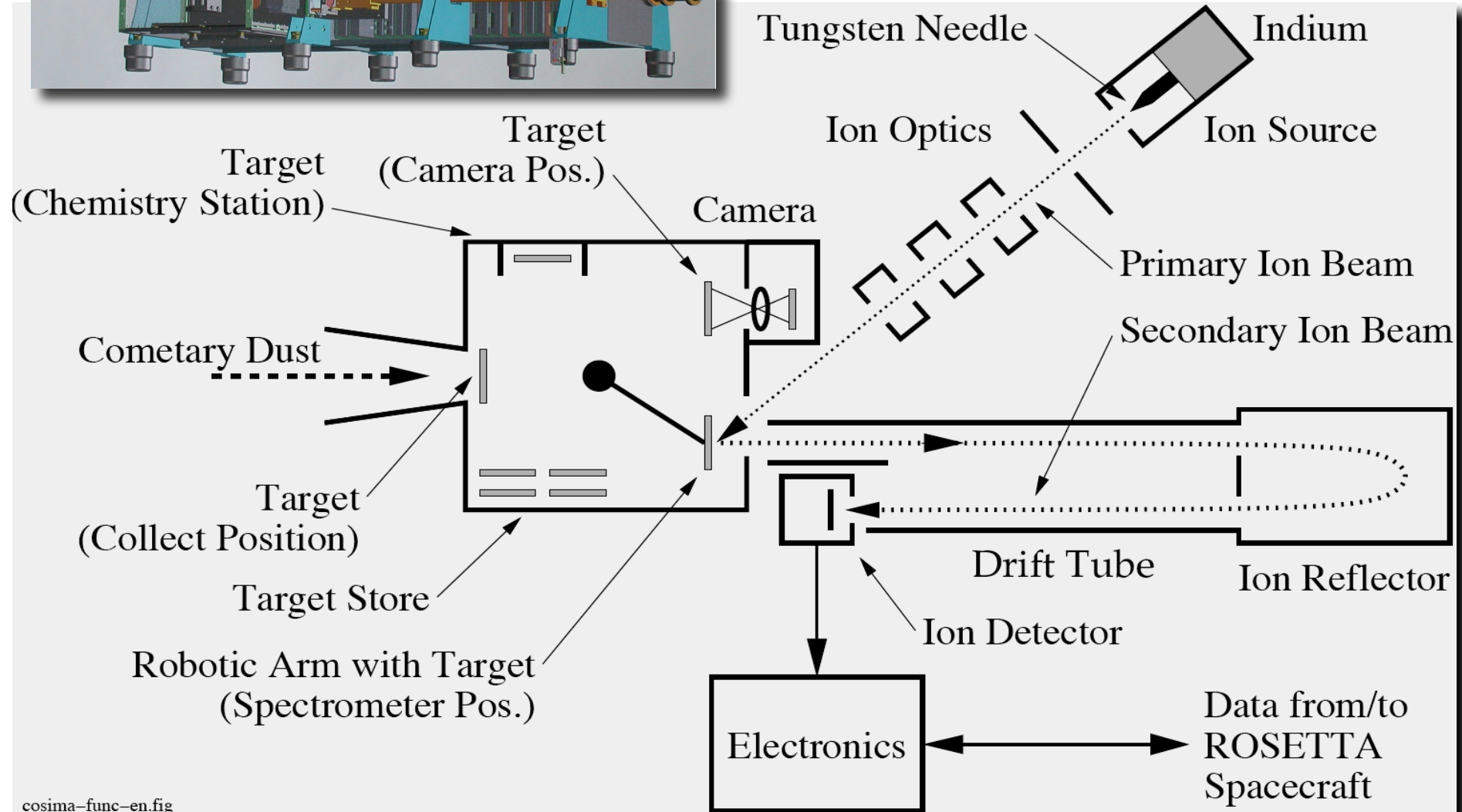
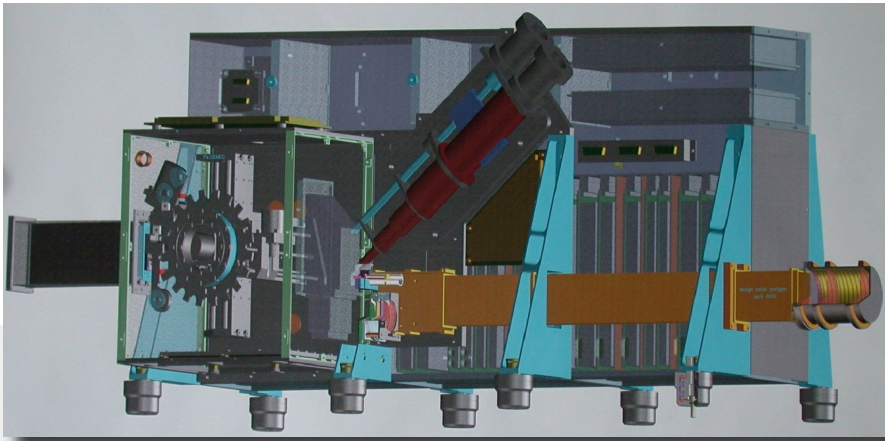
COSIMA, a High Resolution Time-of-Flight Secondary Ion Mass Spectrometer for the Analysis of Cometary Dust Particles

J. Kisse¹, K. Altwegg², B.C. Clark³, L. Colangeli⁴, H. Cottin⁵, S. Czempel⁶, J. Eibl⁶, C. Engrand⁷, H.M. Fehring⁸, B. Feuerbacher⁹, M. Fomenkova¹⁰, A. Glasmachers¹¹, J. M. Greenberg¹², E. Grün¹³, G. Haerendel⁶, H. Henkel¹⁴, M. Hilchenbach¹, H. von Hoerner¹⁴, H. Höfner⁶, K. Hornung¹⁵, E.K. Jessberger¹⁶, A. Koch¹⁴, F.R. Krueger¹⁷, H. Krüger¹, G. Kurat¹⁸, Y. Langevin¹⁹, P. Parigger⁶, F. Raulin⁵, F. Rüdener²⁰, J. Ryno²¹, E. R. Schmid²², R. Schulz⁸, J. Silén²¹, W. Steiger²³, T. Stephan¹⁶, L. Thirkell²⁴, R. Thomas²⁴, K. Torkar²⁵, N.G. Utterback²⁶, K. Varmuza²⁷, K.P. Wanczek²⁸, W. Werther²², E. Zinner²⁹, H. Zscheeg³⁰

Rosetta COSIMA



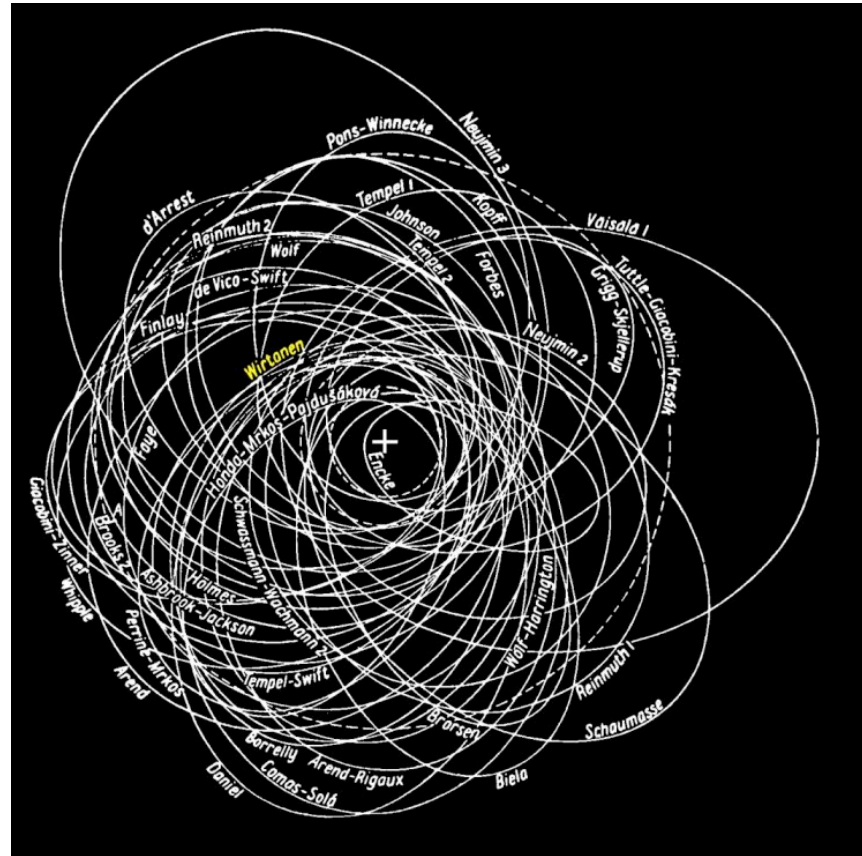
COSIMA- functional diagram



Selection of target comet for the Rosetta mission - I



Selection of target comet for the Rosetta mission - II



2003

conditions:

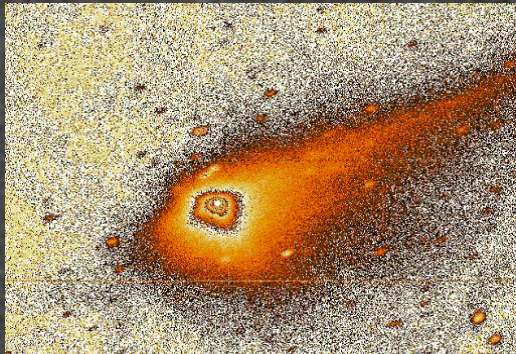
periodic comet, „new“ in the inner solar system and target comet should not fall apart*, and rocket should be ready for launch in time....

*unpredictable...

Target comet for Rosetta in 2003 :

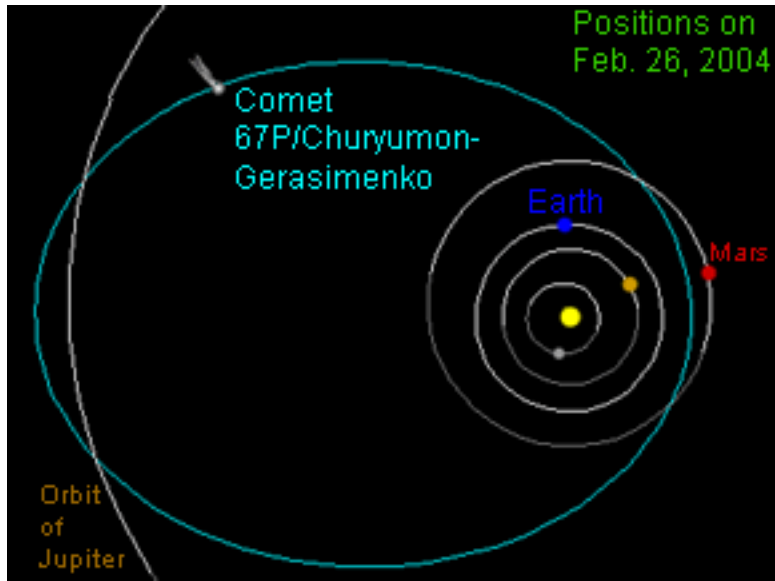
67P/Churyumov-Gerasimenko

size	=	<u>3 x 5 km</u>
perihelion	=	1.292 AU
aphelion	=	5.730 AU



67P/Churyumov-Gerasimenko
February 1st 2003

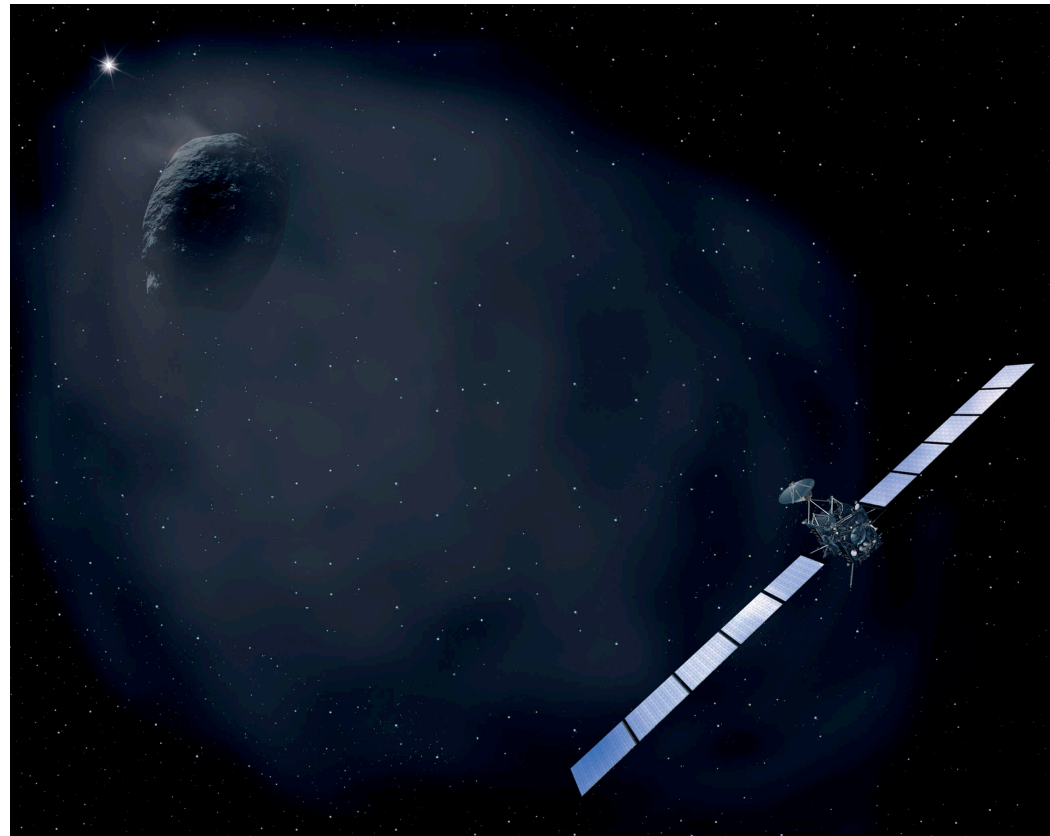
Approaching comet 67P/Churyumov-Gerasimenko



Journey to comet (2004-2014)



Launch of
Ariane V
2004



Science at comet
(2014/2015: 12 month)

ROSETTA Flugbahn

journey: ~ 10 years

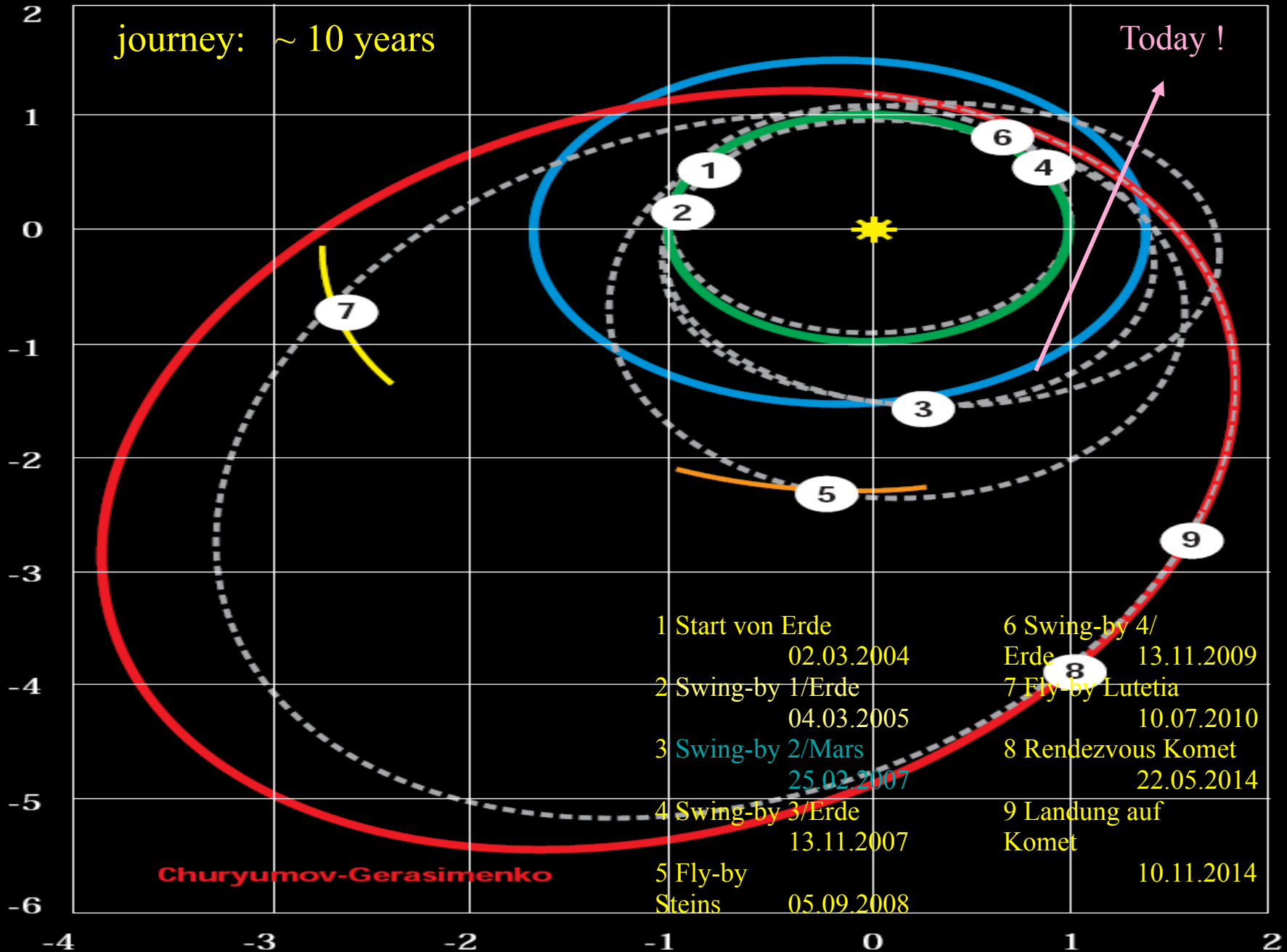
Today !

Y Koordinate (AU)

X Koordinate (AU)

Churyumov-Gerasimenko

- | | | | |
|--------------------|------------|------------------------|------------|
| 1 Start von Erde | 02.03.2004 | 6 Swing-by 4/
Erde | 13.11.2009 |
| 2 Swing-by 1/Erde | 04.03.2005 | 7 Fly-by Lutetia | 10.07.2010 |
| 3 Swing-by 2/Mars | 25.02.2007 | 8 Rendezvous Komet | 22.05.2014 |
| 4 Swing-by 3/Erde | 13.11.2007 | 9 Landung auf
Komet | 10.11.2014 |
| 5 Fly-by
Steins | 05.09.2008 | | |





...and in Nov 2014

Outline

- timeline, matter and comets
- schedule and management approach for new missions
- Rosetta mission and payload
- **Rosetta mission highlights up to 2010**

Mission operation

- **Mission Operations Centre:** European Space Operations Centre (ESOC), Darmstadt, Germany
- **Prime Ground Station:** New Norcia, near Perth, Australia
- **Science Operations Centre:** Space Astronomy Centre (ESAC), Madrid, Spain
- **Lander Control Centre:** DLR, Cologne, Germany
- **Lander Science Centre:** CNES, Toulouse, France
- Planned operational duration: 12 years

Outlook and milestones towards comet 67P/Churyumov-Gerasimenko

Table 1 Milestones of the ROSETTA Mission

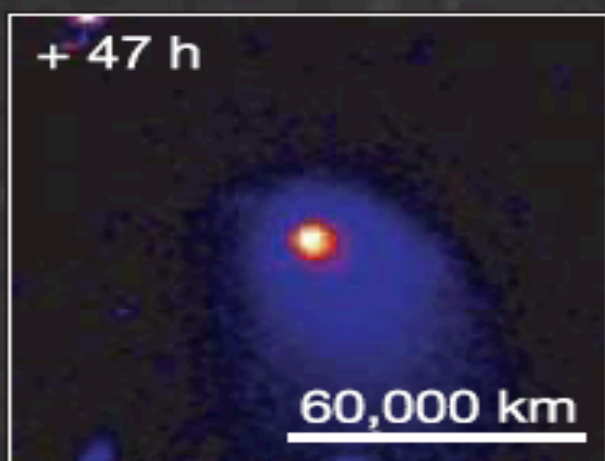
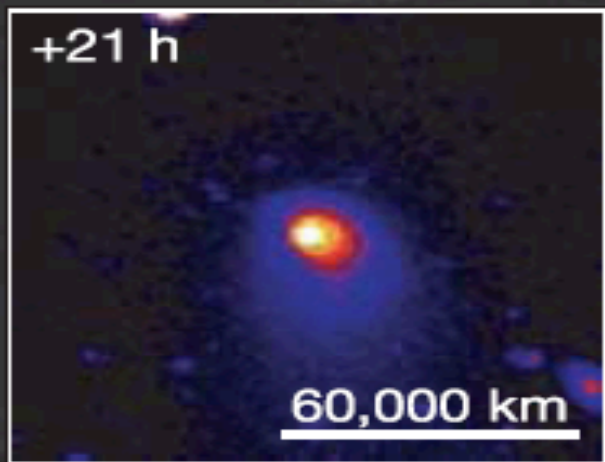
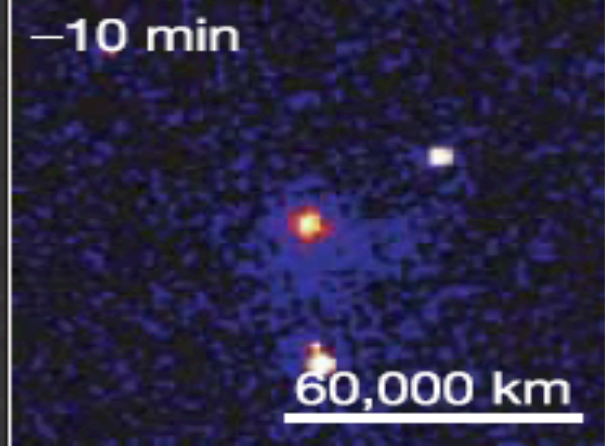
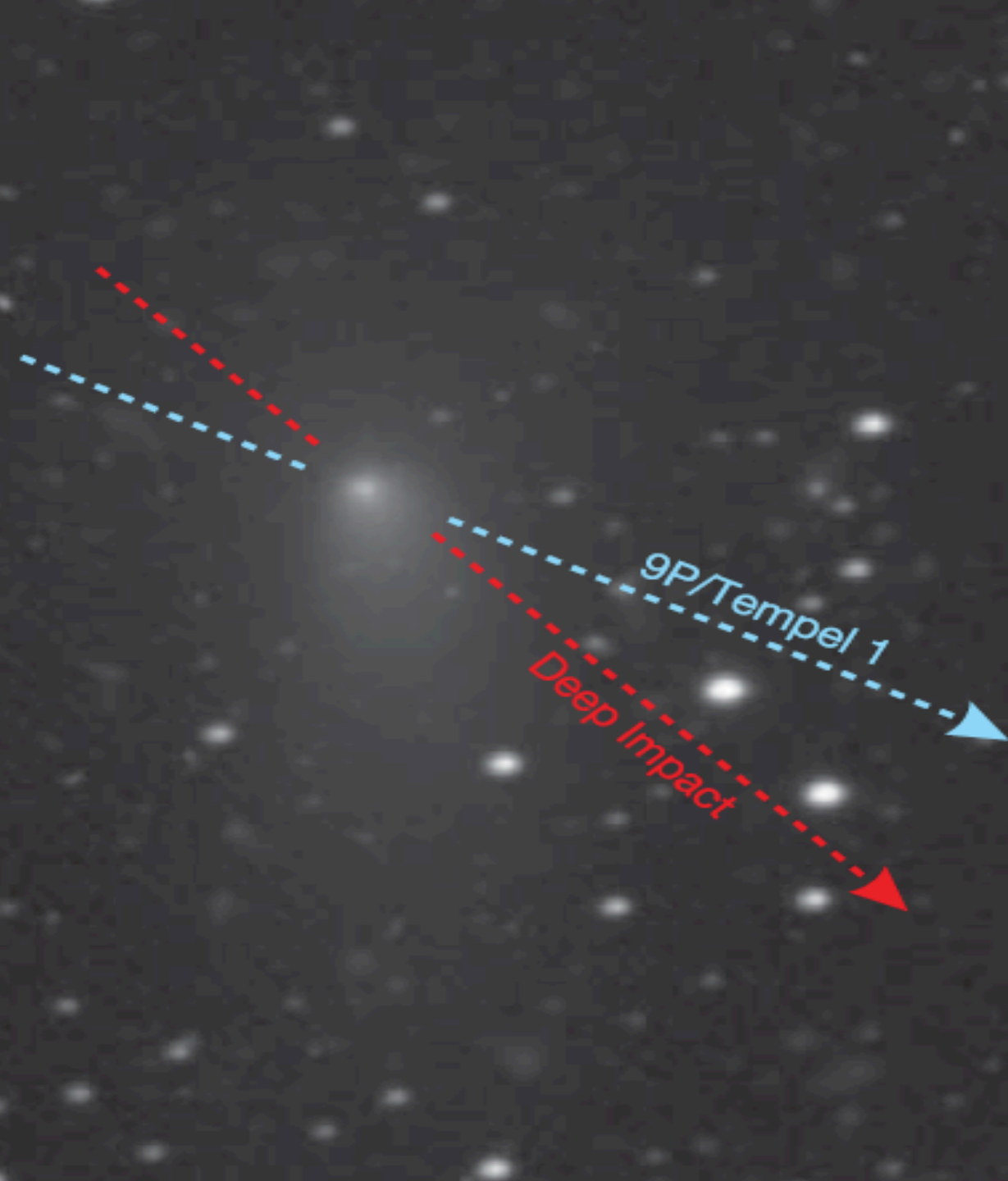
Mission Event	Nominal Date
Launch	March 2, 2004
First Earth Gravity Assist	March 4, 2005
Mars Gravity Assist	February 25, 2007
Second Earth Gravity Assist	November 13, 2007
2867 Steins Flyby	September 5, 2008
Third Earth Gravity Assist	November 13, 2009
21 Lutetia Flyby	July 10, 2010
Rendezvous Manoeuvre 1 and Start of Hibernation	January 23, 2011
Exit Hibernation	January, 2014
Comet Rendezvous	Spring, 2014
Maneuver Between 4.5 and 4.0 AU	
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

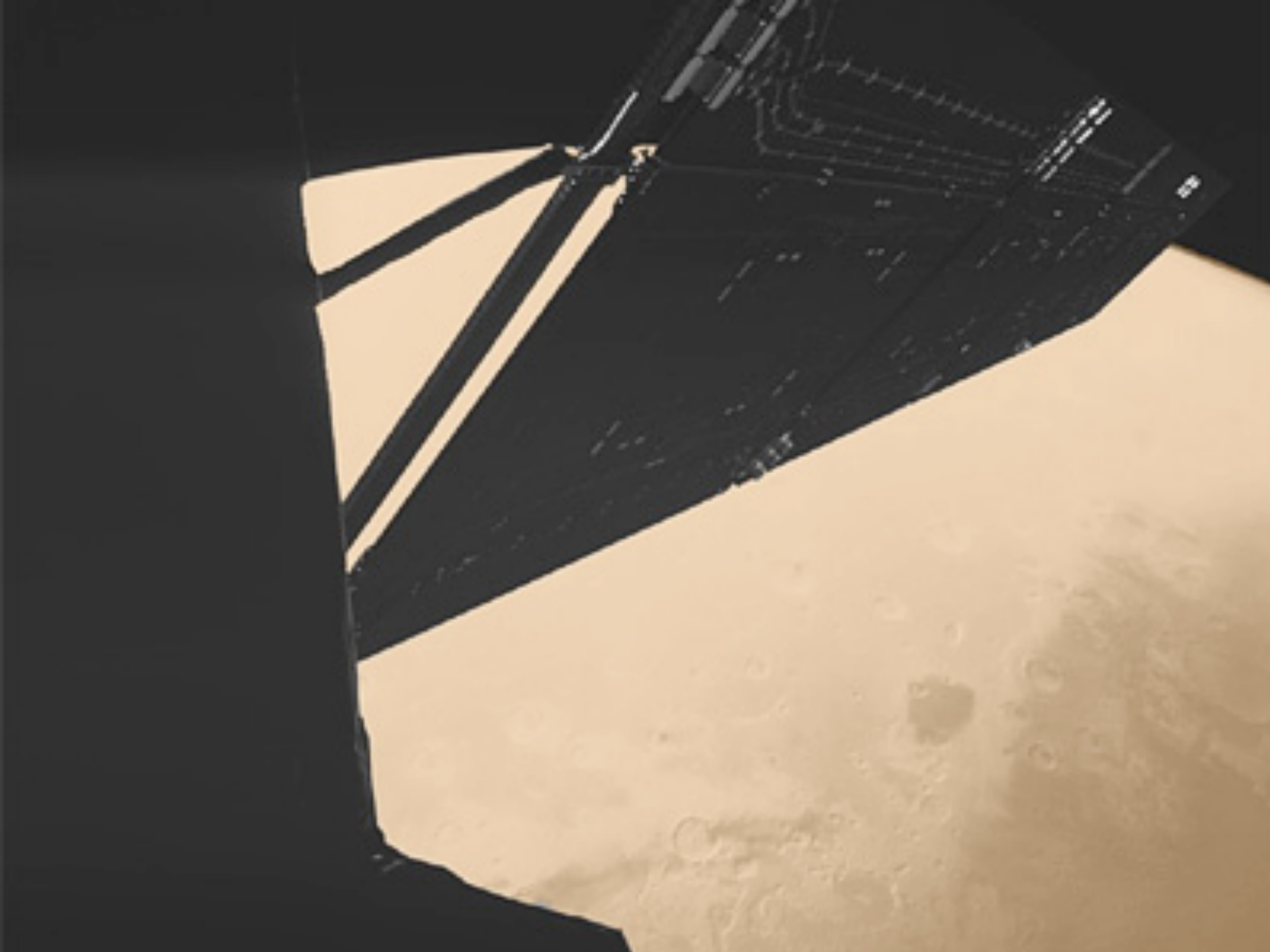




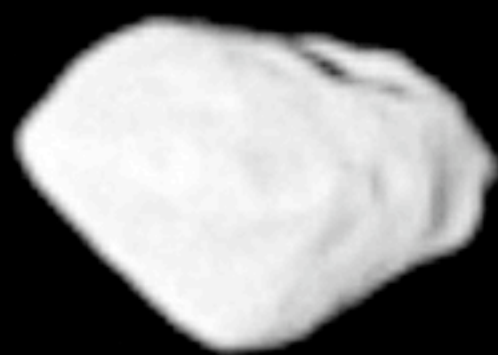
M42 Orion Nebula - Osiris NAC Color Composite

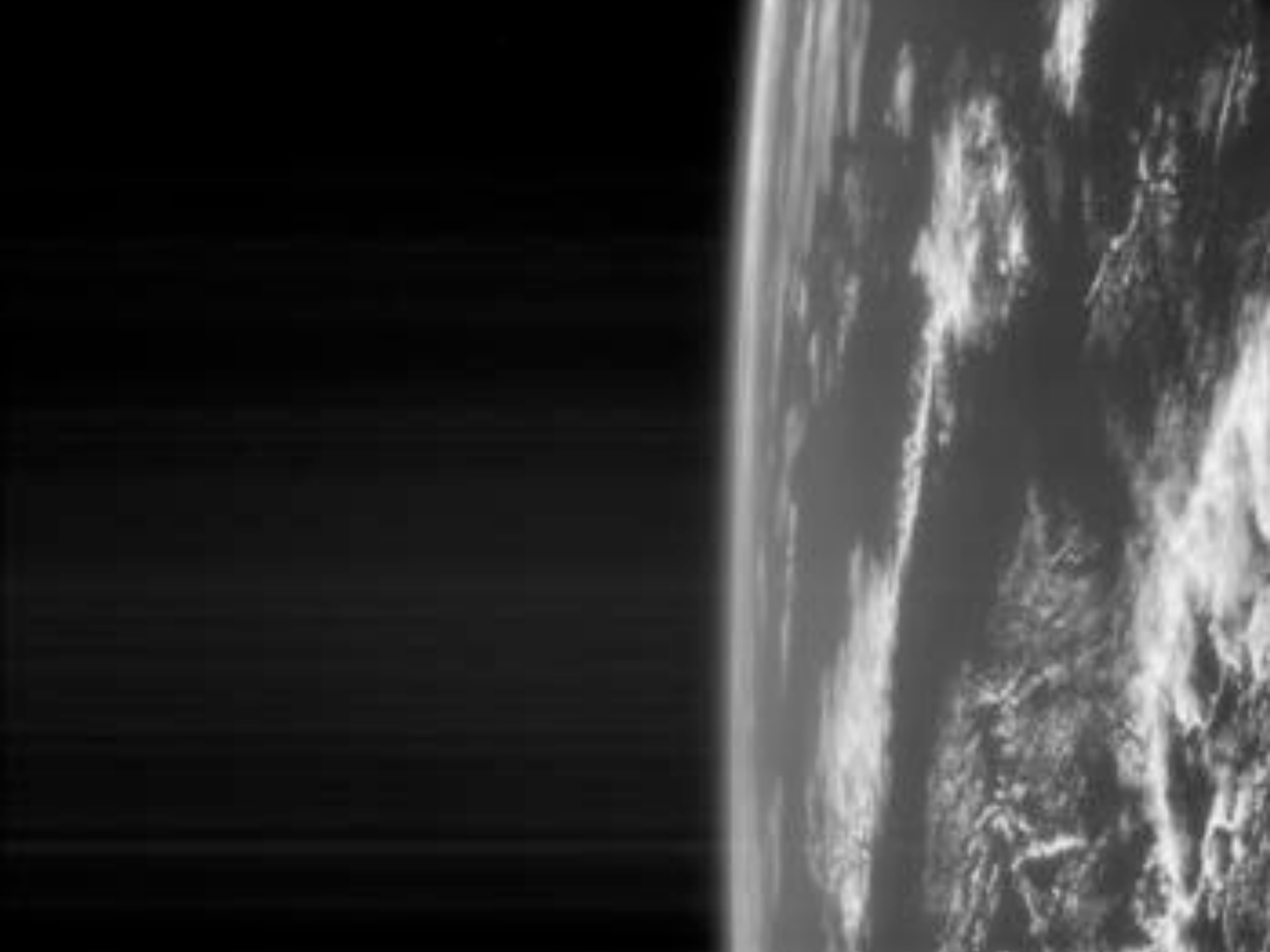




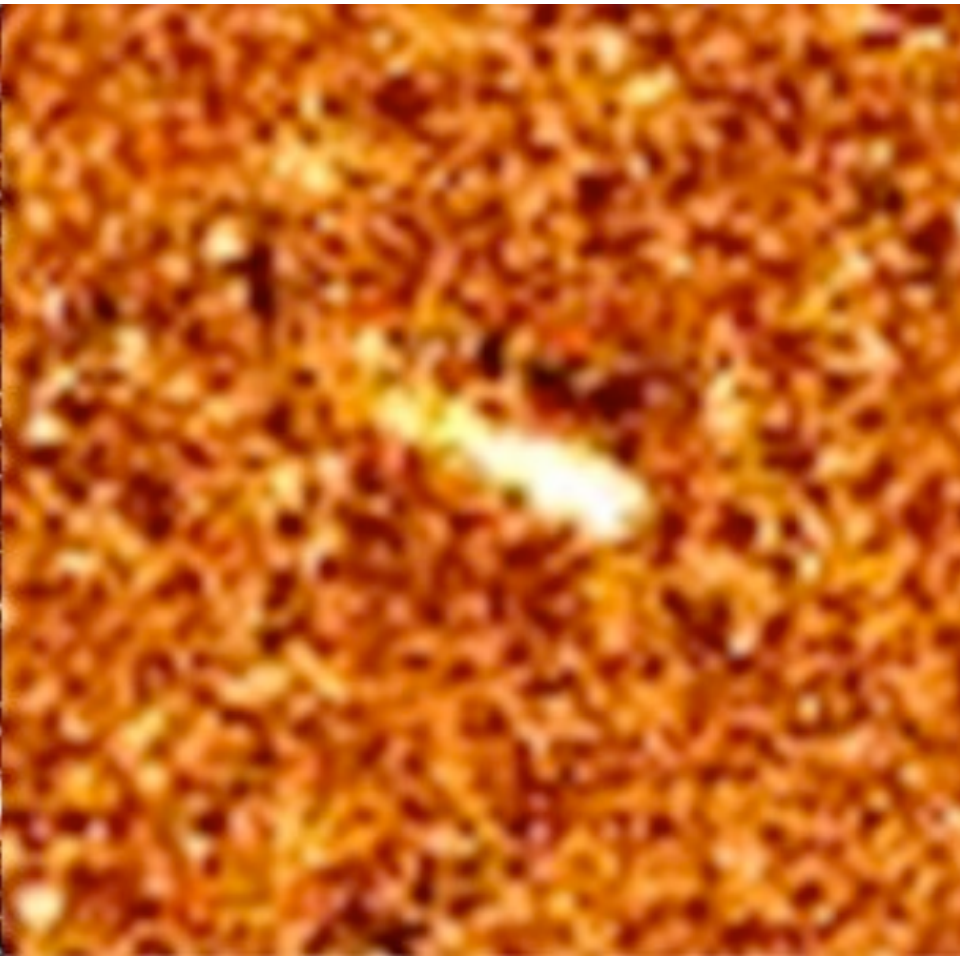
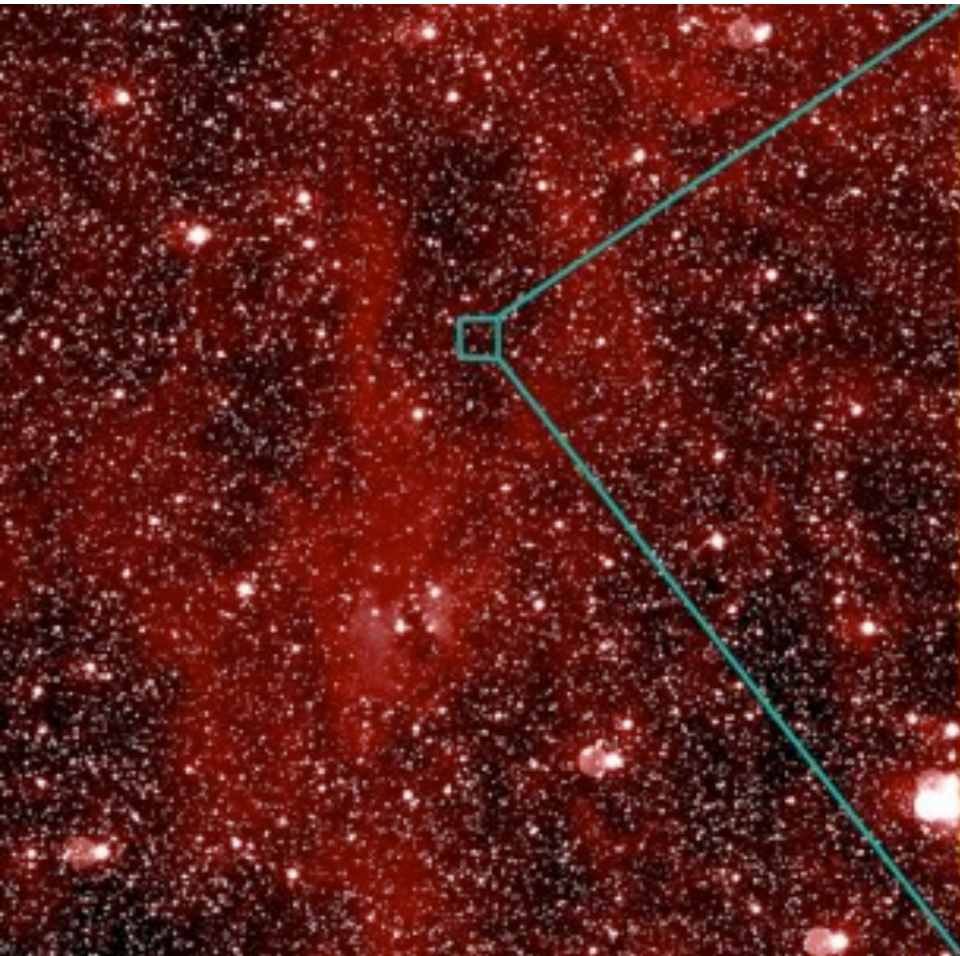














Outlook and milestones towards comet 67P/Churyumov-Gerasimenko

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
Rendezvous Manoeuvre 1 and Start of Hibernation	January 23, 2011
Exit Hibernation	January, 2014
Comet Rendezvous	Spring, 2014
Maneuver Between 4.5 and 4.0 AU	
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



