Rosetta - ESA’s comet lander mission

Conference or Workshop Item

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Rosetta

ESA’s Comet Lander Mission

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Open University

3 May 2012
Keck Institute for Space Studies
Pasadena
Rosetta mission

1993  ESA approve Rosetta mission as a cornerstone mission for its long term science programme. Target comet 46P Wirtanen.
2002  Jan 2003 launch postponed
2003  Feb 2004 launch planned. New target 67P Churyumov-Gerasimenko
2004  March 2\textsuperscript{nd} Launch

Objectives:
Rendezvous with a comet and study the nucleus for more than one year as it passes through perihelion. Investigate the origin of comets, the relationship between cometary and interstellar material and its implication with regard to the origin of the solar system
67P/Churyumov-Gerasimenko

Discovered September 1969 by Klim Churyumov and Svetana Gerasimenko

Perihelion  1.28 AU
Aphelion  5.74 AU
Orbital Period  6.57 years

Most recent perihelion,
2008 magnitude 12

Chosen as new Rosetta target, March 2003

Estimated size of nucleus  3 x 5 km
Rotation period  ~12 hours

Gas production rate  220kg s⁻¹

History:
Before 1840, Perihelion  4.0 AU
1840 Close encounter with Jupiter, perihelion 3.0 AU
1959 Close encounter with Jupiter, perihelion 1.29 AU
2007 Encounter with Jupiter, perihelion 1.25AU
Rosetta Power

Rosetta: 2x14m solar panels 64m²
8700 W at 1 AU  920 W at 3 AU
Hibernation until 10:00 GMT 20 Jan 2014

Philae:  Solar panels 10 W
Primary batteries 1000 Wh
Secondary batteries 100 Wh
Philae Lander
Separation Descent & Landing

Distance 2.7 AU
Height 2 km
Duration 30 min

- Try and get measurement if Lander is passing over an interesting area
- Mean free path at $10^{-7}$ mBar $\sim$ 100m
  - Ion molecule reactions

Comet activity at 3.5AU (ICES model) $6 \times 10^{24} - 6 \times 10^{26} - 6 \times 10^{28}$ s$^{-1}$
Composition 90% H$_2$O, 9% CO$_2$, 1% organics
Partial pressure H$_2$O 1 km from surface $\sim 10^{-9} - 10^{-7} - 10^{-5}$ mbar
Rosetta Lander on the comet

Weight on comet ~10 g
Attached by harpoon & ice screws
Lander Payload....

- 11 Instruments
- Rosetta Bible
CIVA Comet Infrared and Visible Analyser

Panoramic Cameras

- Total 7 cameras
- 5 single, 1 stereoscopic pair
- FOV 60°
- Resolution ~1mm @1m
  ~2m at horizon
- Topography
- Albedo
- Surface features, vents, jets
- Surface changes

Bibring et al. 2007
CIVA-P  Panoramic camera

Rosetta solar panels

CIVA at Mars
ROLIS ROsetta Lander Imaging System

Downward looking camera
Operation during SDL
Resolution 0.3mm/pixel @30cm
Can image drill bore hole and APXS site

Multispectral imaging
LEDs 470, 530, 640 and 870 nm
APXS Alpha Particle X-ray Spectrometer

- Predecessor of MER APXS
- Curium 244 alpha source
- Elemental composition $z \geq 23$
- Alpha spectrum carbon and oxygen

Klingelhöfer et al. 2007
CONSERT
Comet Nucleus Sounding Experiment by Radio-wave Transmission

- Internal structure of comet
- Change in velocity and amplitude of radio signal during comet orbit

Kofman et al. 2007
ROMAP
ROsetta MAgnnetmoeter and Plasma monitor

- Magnetic properties of comet
- Interaction with solar wind
- Pirani sensor $10^{-3}$ – 10 mbar
- Penning sensor $10^{-8}$ – $10^{-3}$ mbar
- Magnetometer
  - Range $\pm 2000$ nT
  - Resolution 10 pT
- Plasma monitor

Auster et al. 2007
SESAME
Surface Electric Sounding and Acoustic Monitoring Experiment

- **CASSE** Comet Acoustic Surface Sounding Experiment
  - Frequency from ~3 Hz to 3.3 kHz
  - Vertical structure

- **PP** Permitivity Probe
  - Water ice content

- **DIM** Dust Impact Monitor
  - Mechanical properties
  - Properties on impacting dust grains

Seidensticker et al. 2007
MUPUS MUlti PUrpose Sensor package

- Physical Properties of surface layers, depth ~30cm
  - Density
  - Porosity
  - Cohesion
  - Thermal diffusivity
  - Thermal conductivity
  - Temperature
- Anchor
  - Temperature
  - Accelerometer
- MUPUS Penetrator
- Thermal Mapper

Spohn et al. 2007
SD2 Sampler, drill & distribution system

Drill to ~ 30 cm depth
Collect sample
Deliver to oven on carousel

Finzi et al. 2007
SD2 - Sample drilling and distribution system

Collects surface and comet subsurface samples

Drilling depth up to 30cm

Sample size $20\text{mm}^3 \sim 3\text{mg}$

Sample placed in one of 26 ovens on a carousel

16 Medium Temperature Ovens (max $180^\circ\text{C}$) for CIVA microscope, COSAC and Ptolemy

10 High Temperature Ovens (max $800^\circ\text{C}$) for COSAC and Ptolemy
CIVA Comet Infrared and Visible Analyser

Microscope Cameras Medium Temperature Ovens with window

- CIVA M/V - Visible
  - FOV 3mm
  - Resolution 7µm
  - Illumination 3 LEDs
    - 525nm, 640nm and 880nm
  - + daylight illumination

- CIVA M/I - Infrared
  - FOV 3mm
  - Resolution 40µm
  - Spectral range 1-4µm
  - 3nm steps
  - Detection of UCAMMs?

In flight calibration

Bibring et al. 2007
COSAC
COmet Sampling And Composition experiment

- GC-MS
- Pyrolysis >600°C
- Chemical processing
- 8 GC columns
  - 5 chemical composition
  - 3 Chiral
- Thermal conductivity detector
- Time Of Flight MS
  - Mass range 2-350 amu
  - Mass resolution 350

Goesmann et al. 2007
Ptolemy

Chemical processing
Hydrogen gas and control
Mass Spectrometer box
Sample Inlet
Helium control
3 GC Columns
Electronics/computer

QM Post Vibration Test: E-Box Panels Removed to Reveal PCBs

2002/1/3
Surface and sub-surface sample from comet delivered by SD2
5 Medium temperature ovens (180°C Max)
4 High temperature ovens (800°C Max)
1 of which contains coma trapping material
Field effect electron source - nanotips

Ceramic spiral electron multiplier (H Lauche MPAe)

Mass range 10 to 150 amu
Resolving Power better than unit
Volume 10 x 9 x 9 cm
Electrode mass 50g
Overall mass < 500g
Power ~ 1W

RF electronics

Ion counting electronics

Ceramic spiral electron multiplier (H Lauche MPAe)

Drive electronics

Compact mass spectrometer
No permanent magnets
Operate at $10^{-3}$ mbar

Field effect electron source - nanotips

Mass range 10 to 150 amu
Resolving Power better than unit

Volume 10 x 9 x 9 cm
Electrode mass 50g
Overall mass < 500g
Power ~ 1W

Ptolemy Mass Spectrometer - Ion Trap
Measurement of $^{13}\text{C}$ isotope ratios

Comparison of a sample gas 8.8 per mil heavier than a reference gas

Delta = 8.80
Mean = 7.23
GC Columns

GC1 separates CO, CO₂

GC2 separates CO, N₂ and H₂

GC3 separation of organic volatiles

Direct Channel

ReO

glass

Pt C

Mass Spectrometer
Zero Enrichment analysis of CO$_2$

Sample size 20 nmol
Analysis time 5 minutes per sample

$\delta^{45}$
1 $\sigma$ error 17‰
average 5.0‰

$\delta^{46}$
1 $\sigma$ error 25‰
average 4.0‰
## Payload Summary

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Investigations</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• CIVA</td>
<td>Cameras, microscope</td>
<td>3.4</td>
</tr>
<tr>
<td>• ROLIS</td>
<td>Descent camera</td>
<td>1.4</td>
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<tr>
<td>• APXS</td>
<td>Elemental Composition</td>
<td>1.3</td>
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<tr>
<td>• CONsert</td>
<td>Internal Structure</td>
<td>1.8</td>
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<tr>
<td>• ROMAP</td>
<td>Magnetic and Plasma</td>
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<td>• SESAME</td>
<td>Structure, dust impact</td>
<td>1.8</td>
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<td>• MUPUS</td>
<td>Physical properties</td>
<td>2.2</td>
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<tr>
<td>• SD2</td>
<td>Sample acquisition, structure</td>
<td>4.7</td>
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<tr>
<td>• COSAC</td>
<td>Molecular composition</td>
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<tr>
<td>• Ptolemy</td>
<td>Isotopic composition</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**Total**                            26.7

*Science before SDL*
Additional Slides
Mass Spectrometer

Advantages:
- Compact design
- No magnets
- Operate at $10^{-3}$ mbar

$$V_{ej} = \frac{m r_0^2 \Omega^2}{4e}$$

Scan function:

$R_0 = 8\text{mm}$
Frequency $\sim 0.55\text{MHz}$
1.8 V/amu
Mass Spectrometer – Open University
Ptolemy Lutetia Operations

Insolation, Solar distance 2.73 AU

Distance from Lutetia centre (km)

- Sub-solar point 15000 km
- Close Approach (CA) 3162 km
- COSAC
- Ptolemy
- In situ instruments
- HTO+ DFMS COPS
- ROSINA
- RPC-MAG & ROMAP
- Remote sensing instruments
- Alice
- MIRO

CA-2h50 153,000 km
CA-1h 54,000 km
CA-15 mins 15,500 km
CA +1hr 54,000 km
CA +2hr 108,000 km
Lutetia – Rosetta flyby 2010

132x101x76 km
Ptolemy Mass Spectra

Average background

Close approach