Rosetta - ESA’s comet lander mission

Conference 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: 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
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% $\text{H}_2\text{O}$, 9% $\text{CO}_2$, 1% organics
Partial pressure $\text{H}_2\text{O}$ 1 km from surface $\sim 10^{-9} - 10^{-7} - 10^{-5}$ mbar
Rosetta Lander on the comet

Weight on comet \( \sim 10 \) 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

panel thickness: 22 mm
(honeycomb structure)

seen in 10 px,
from ~ 2.2 m

CIVA sampling:
1 mrad,
as designed

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

Mottola et al. 2007
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 MAgnetsmoeter 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**  Permittivity 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

3 GC Columns

Helium control

Electronics/computer

QM Post Vibration Test: E-Box Panels Removed to Reveal PCBs
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
Ptolemy Mass Spectrometer - Ion Trap

- **RF electronics**
- **Ion counting electronics**
- **Ceramic spiral electron multiplier (H Lauche MPAe)**
- **Drive electronics**
- **Field effect electron source - nanotips**
- **Compact mass spectrometer**
- **No permanent magnets**
- **Operate at $10^{-3}$ mbar**

**Specifications:**
- 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
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

Mass Spectrometer

Direct Channel
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>
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<tr>
<th>Instrument</th>
<th>Investigations</th>
<th>Mass (kg)</th>
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<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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<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>
<td>4.9</td>
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<tr>
<td>Ptolemy</td>
<td>Isotopic composition</td>
<td>4.5</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>26.7</strong></td>
</tr>
</tbody>
</table>

Science before SDL  ✓
Additional Slides
Mass Spectrometer

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

Scan function:

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

Sample gas inlet

End cap electrode

Quartz spacers

Ring electrode

Lens

Gate

Electron multiplier

End cap electrode

Filament - electron source

$R_0 = 8\text{mm}$

Frequency $\sim 0.55\text{MHz}$

$1.8\text{ V/amu}$
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
- H10F-
- DFMS
- COPS
- ROSINA
- RPC-MAG &
- ROMAP
- Alice
- Remote sensing instruments
- 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

Philae
Rosetta orbiter body
Solar panel
Instrument orientation