Rosetta/COSIMA: High Resolution In-Situ Dust Analysis at Comet 67P/Churyumov-Gerasimenkov

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Abstract

The COmetary Secondary Ion Mass Analyser (COSIMA) instrument on board ESA's Rosetta spacecraft is a high-resolution time-of-flight mass spectrometer dedicated to the in-situ analysis of cometary dust. Rosetta was launched in 2004 and will reach comet 67P/Churyumov-Gerasimenkov in 2014.

The COSIMA instrument will collect cometary dust on metal targets and identify grains with sizes 10 µm and bigger with an optical camera. Material from the grain surface is sputtered with an indium ion beam and the generated secondary ions are accelerated in an electric field. Time-of-flight secondary ion mass spectra are obtained with a mass resolution of $m/\Delta m \approx 2000$ at m = 100amu.

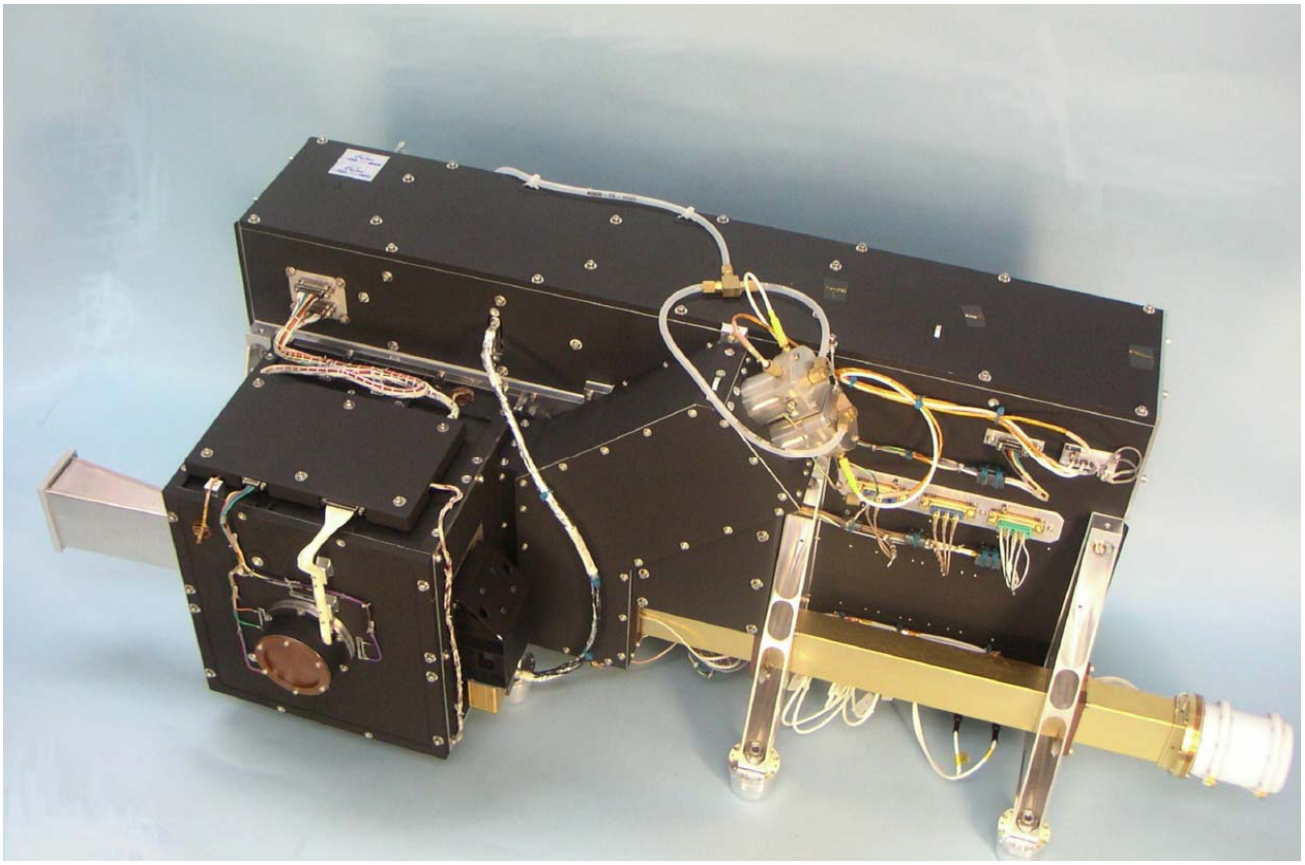
The goal of the COSIMA investigation is the in-situ characterisation of the elemental, molecular, mineralogic, and isotopic composition of dust in the coma of comet 67P/C-G. To reach this goal, we perform an extensive laboratory measurement program with a COSIMA reference instrument (RM), a twin of the flight instrument, located at Max-Planck-Institut für Sonnensystemforschung (MPS).

Cometary dust analogues are prepared from natural and synthetic minerals (pyroxene, olivine, hydrous silicates, sulfides, etc.) with known composition and, which are believed to exist in comets. Reference spectra of these samples are obtained with the COSIMA RM instrument and with laboratory time-of-flight secondary ion mass spectrometer (TOF-SIMS) instruments located at the University of Münster/Germany and the Laboratoire de Physique & Chimie de L'Environment in Orléans/France.

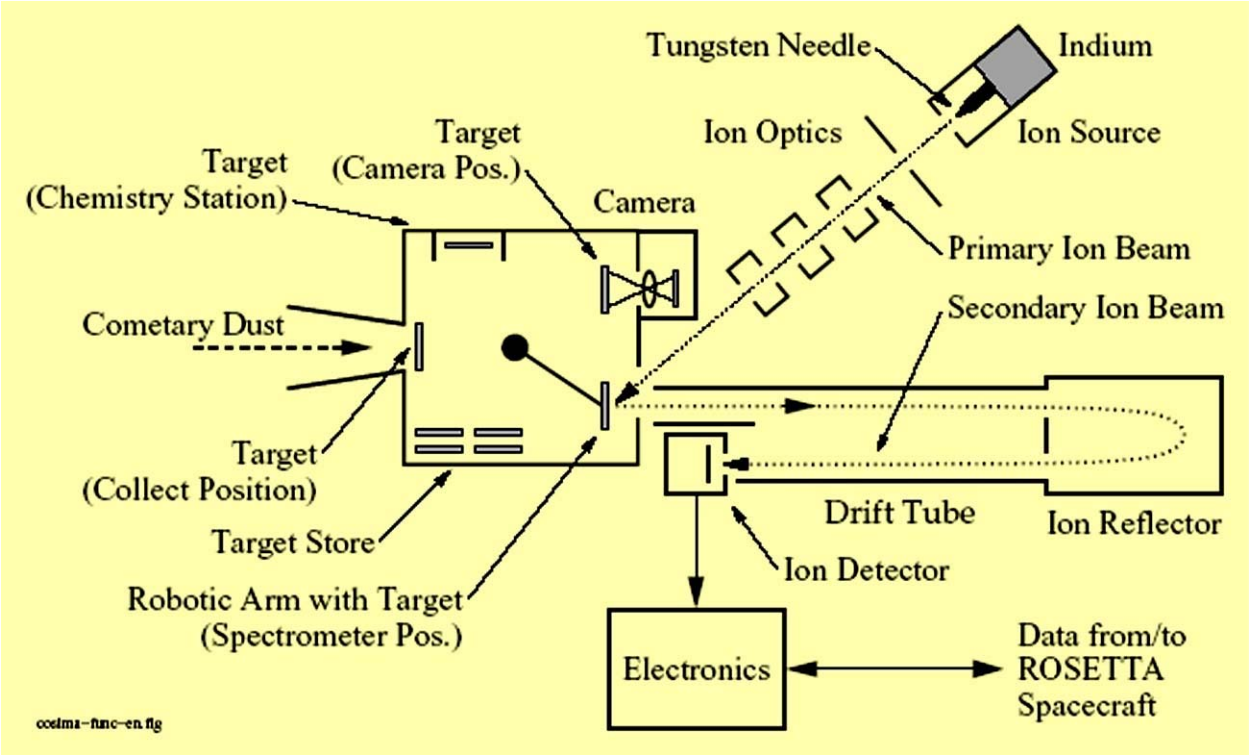
We present first results on the calibration of the COSIMA RM instrument and the identification of the elemental and mineralogic composition of reference samples.

Science Objectives

- Analysis of the elemental composition (and isotopic composition of some key elements) of cometary dust particles
- Mineralogical and petrographic characterisation of the inorganic phases
- Chemical characterisation of the main organic components, homologuous and functional groups
- Cosmochemical and cosmophysical processes during the evolutionary history of the comet



Functional Principle



(1) Dust is collected on metal black targets which are stored in Target Manipulation Unit
(2) Dust grains are located by microscopic camera COSISCOPE
(3) A pulsed Indium ion beam partially ionizes the dust grains
(4) Secondary ions are accelerated by an electric field and travel through a drift tube with ion reflector
(5) Ions are detected by ion detector; flight times are recorded by T/D converter
(6) Mass spectra are calculated from the time-of-flight spectra

COSIMA Specifications

• Atomic mass range	1 . . . 4000 Da
• Mass resolution m/Δm at m = 100amu	≈ 2000 amu
• Mass	19.8 kg
• Indium ion pulse duration	≈ 5 ns
• Indium ion energy	8 keV
• Power consumption from 28 V DC	20.4 W

Target Image

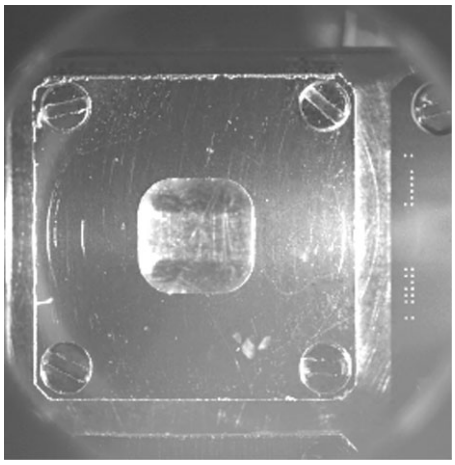


Figure 1: COSISCOPE image of blank gold COSIMA target prepared with clinopyroxene powder (typical grain size ≈20 µm). The target size is 1 cm^2.

Library Of Spectra From Reference Minerals

- Literature survey to define set of minerals detected or expected in cometary material (Stardust, Deep Impact, comet observations, IDPs, etc.).
- Get well-analysed terrestrial samples of these minerals.
- Grind these minerals to ≈20µm grain size and deposit them on COSIMA targets.
- Obtain COSIMA reference spectra of these samples (Fig. 3).
- If necessary, get higher resolution spectra with TOF-SIMS instruments in Münster/Germany and Orléans/France.
- Perform chemometric (multivariate) evaluation to distinguish different minerals [1, Fig. 2].
- Perform absolute calibration with reference standards [3] to obtain elemental (and isotopic) abundances.

Chemometric Evaluation

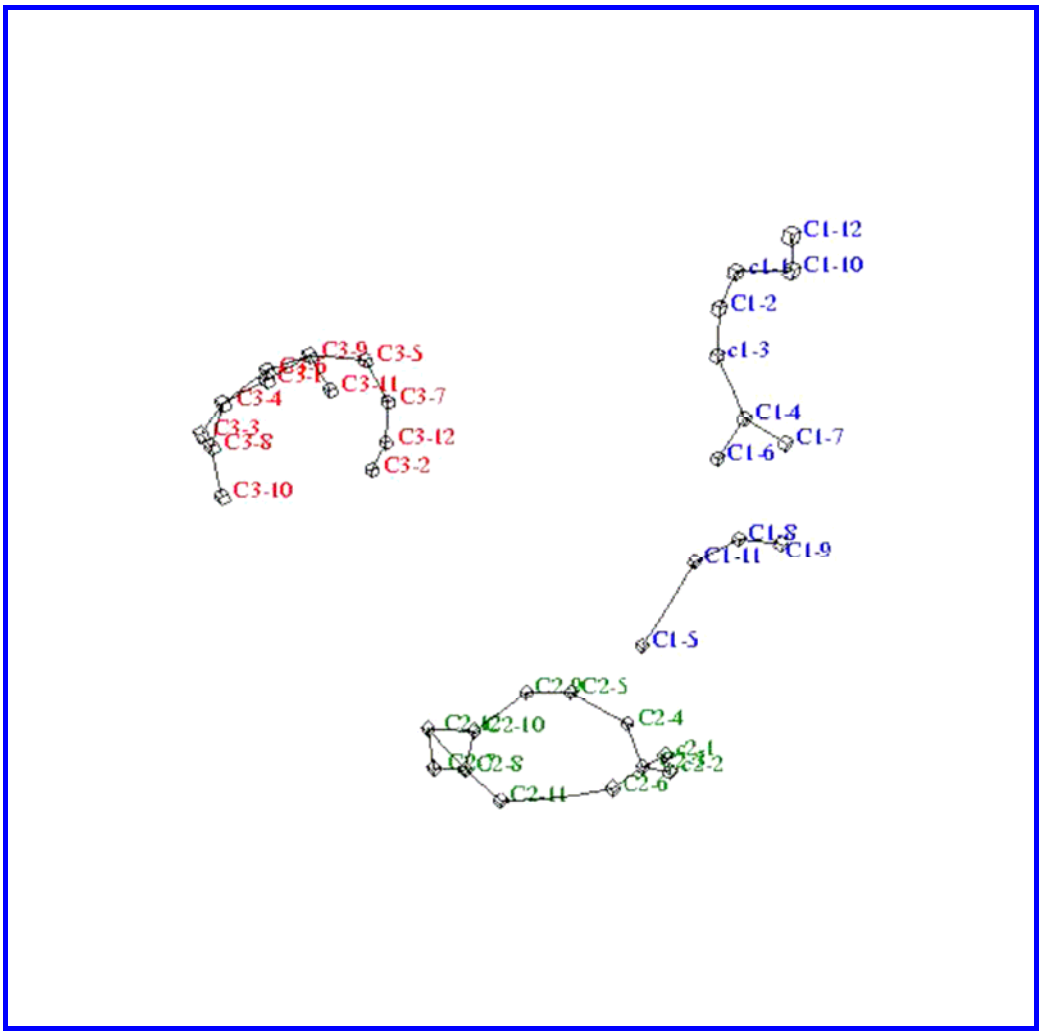


Figure 2: Results from a multivariate (Corico) analysis of COSIMA spectra obtained from three minerals (clinopyroxene (C1), orthopyroxene (C2), olivine(C3)), corrected for target contribution. 12 spectra were used for each mineral. The spectra form well separated clusters corresponding to the three mineral classes; spectra from clinopyroxene are split into two groups. Application of multivariate data analysis methods requires the representation of each mass spectrum by a vector. Vector elements are the intensities of selected peaks. A set of spectra defines a matrix X with a row for each spectrum (sample, object) and a column (variable, feature) for each selected mass. Corico is a nonlinear mapping of the feature space onto a sphere [2]; the algorithm is based on correlation coefficients calculated from vector pairs and on partial correlation coefficients. The correlation coefficient is used as a measure of spectra similarity. The method can be used for cluster analysis and for classification. Corico visualises multivariate data in the form of scatter plots, with dots representing similar vectors being close to each other. Remarkable correlations are indicated by connected dots. Groups of similar vectors (spectra) form clusters and are represented as a network of links.

Mass Spectrum

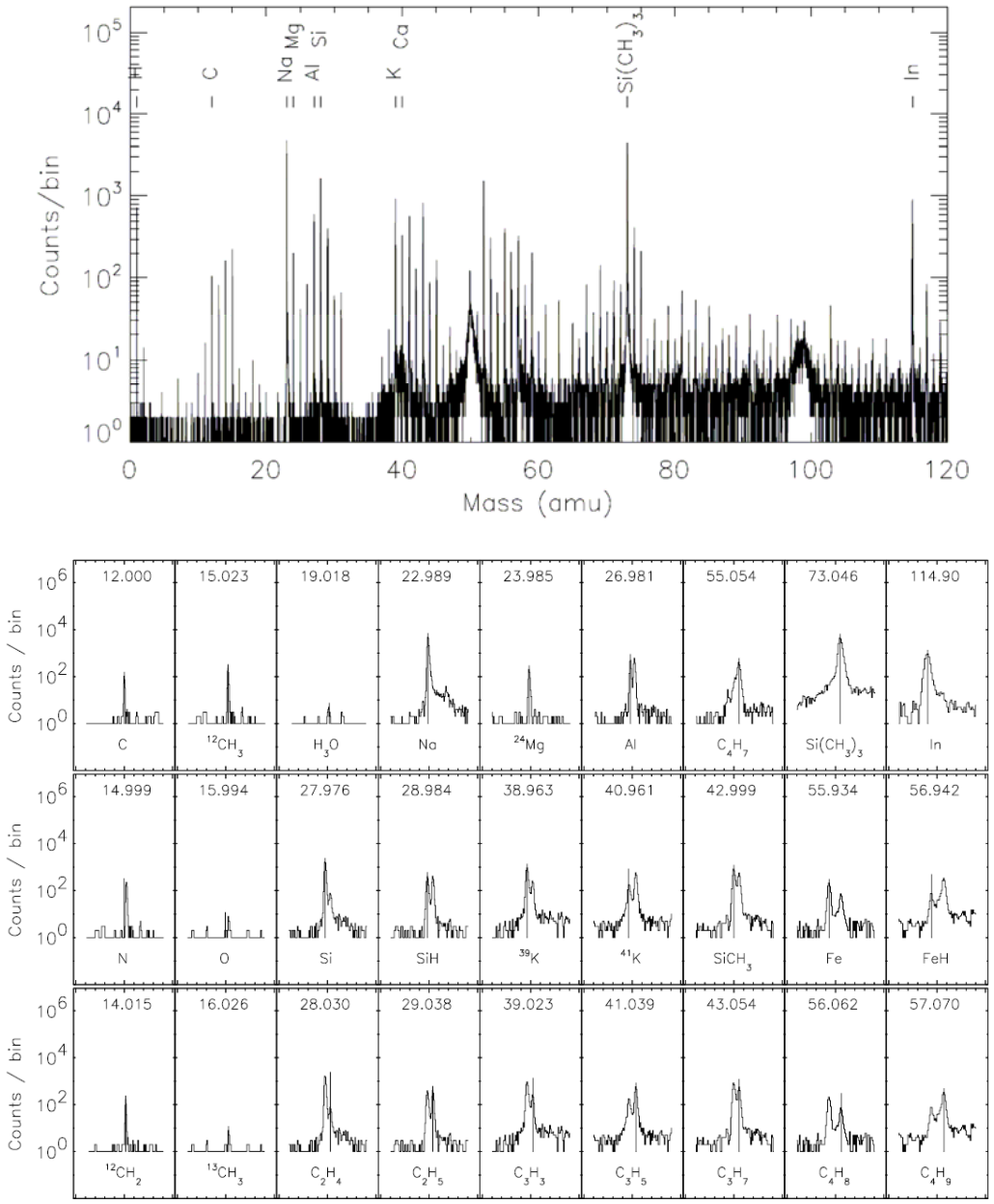


Figure 3: *Top:* COSIMA spectrum of clinopyroxene on gold target (positive ion mode). *Bottom:* Selected lines in higher resolution. The mass range is ±0.5amu. The potential identification of atoms or molecules and their mass are labeled in each window, the position of the mass is indicated by a vertical line. For the same integer mass number, organic molecule peaks are at the right, while inorganic ion peaks are at the left of the integer mass number. The top panel shows mass peaks with a unique atom or molecule identification. The center panel shows mass peaks with potentially both organic and inorganic atoms or molecules within the same mass range of ±0.5amu. The bottom panel shows organic molecules, mainly hydrocarbons. Comparison of the center and bottom panels reveals the mass resolution of COSIMA, which is sufficient to resolve e.g. Si and C_2H_4.

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