

Laboratory calibration of Rosetta/COSIMA

Preparation for comet 67P/Churyumov-Gerasimenkov

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Abstract

The Rosetta spacecraft – launched in 2004 – carries the **CO**metary **S**econdary Ion **M**ass **A**nalyser (COSIMA) on board. COSIMA is a high-resolution ($m/\Delta m \approx 2000$ at $m = 100$ amu; from FWHM) time-of-flight mass spectrometer dedicated to the insitu analysis of (10 μm and bigger) dust grains in the coma of comet 67P/Churyumov-Gerasimenkov beginning in 2014.

Grains collected on metal black substrates are identified with an optical camera. An indium ion beam is used to sputter material from the grain surface, and the released secondary ions are accelerated in an electric field to form secondary ion time-of-flight mass spectra.

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

We prepared cometary dust analogue samples from well-defined natural and synthetic minerals (pyroxene, olivine, hydrous silicates, sulfides, etc.), which – except for hydrous minerals – have been unambiguously identified in cometary matter. Spectra of these samples were obtained with the COSIMA RM 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'Environnement at Orléans/France.

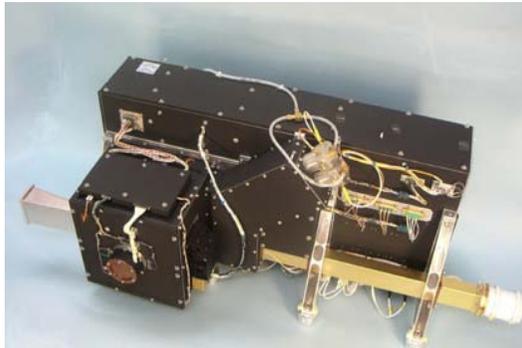
We present results from measurements on mineral samples (powder with grain sizes $> 10 \mu\text{m}$) prepared on different substrate materials (gold, silver, gold black). Usually, spectra of sample and substrate are very similar due to the high sensitivity of TOF-SIMS for surface contaminants, implying that very careful sample preparation is necessary. Signals from repeated measurements at the same sample (or substrate) location are fairly stable due to good internal stability of the COSIMA instrument. On the other hand, measurements obtained at different sample locations on the same natural mineral vary from one location to the next which may be due to sample inhomogeneities.

Science Objectives

- Analysis of the elemental composition (and isotopic composition of some key elements) of cometary dust particles
- Mineralic and petrographic characterisation of the inorganic phases – all related to solar system chemistry
- Chemical characterisation of the main organic components, homologous and functional groups
- Cosmochemical and cosmophysical processes during the evolutionary history of the comet

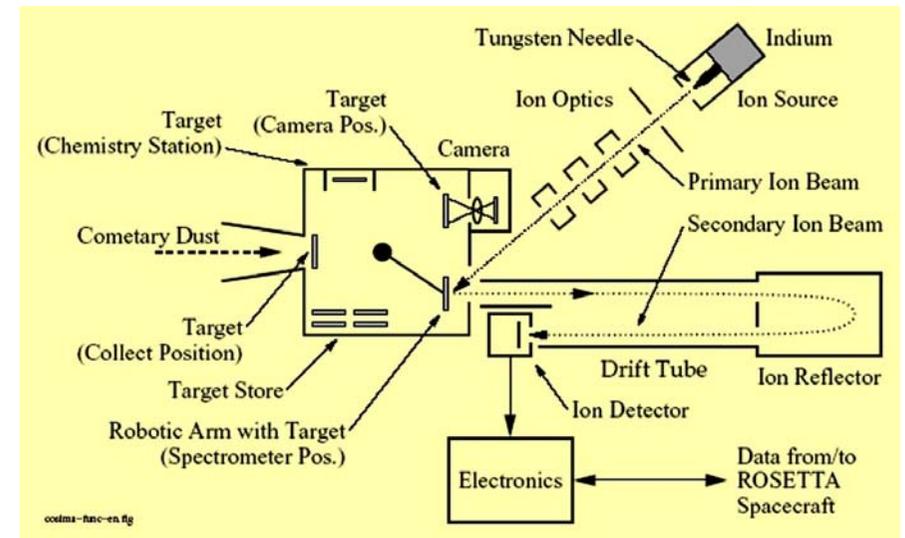


Rosetta spacecraft and lander Philae (graphics ESA)



COSIMA instrument in-flight configuration

Functional Principle



- (1) Dust is collected on metal black targets which are stored in Target Manipulation Unit
- (2) Dust grains are identified 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

Samples and Methods

- Minerals (except for hydrous minerals) identified in cometary matter (e.g. Stardust, Deep Impact, comet obs., IDPs; Tab. 1).
- Obtain well-analysed terrestrial samples of these minerals.
- Deposit mineral grains on COSIMA target (Fig. 1).
- Get COSIMA reference spectra of these samples (Fig. 2).
- If necessary, get higher resolution spectra with TOF-SIMS instruments in Münster/Germany and Orléans/France.
- Chemometric (multivariate) analysis to distinguish minerals [2].
- Absolute calibration with reference standards [3].

Table 1: List of selected reference minerals.

Anhydrous Silicates	Hydrated Silicates	Other Minerals
Clinopyroxene	Serpentine	FeS (e.g. pyrrhotite)
Orthopyroxene	Smectite	Spinel
Olivine		Dolomite
Anorthite		SiC, Graphite
		Quartz

Measurements (1)

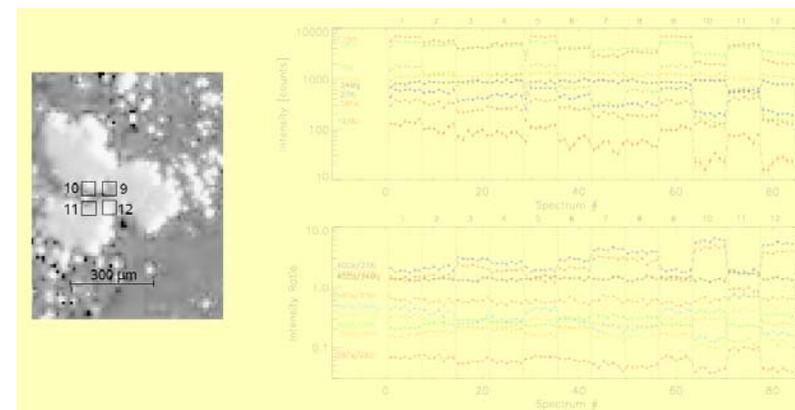


Figure 1: *Left*: Image of clinopyroxene prepared on COSIMA blank gold target (see Fig. 2 for a spectrum). Spectra were measured on three 2 x 2 rasters with step sizes of 20 µm (position 1 to 4), 40 µm (position 5 to 8), and 80 µm (position 9 to 12). Raster 3 with 80 µm step size is indicated. Raster positions 1, 5 and 9 are identical. *Right*: Line intensities (*top*) and intensity ratios (*bottom*) for selected lines. Numbers of raster positions are given at the top. Seven spectra were measured at each raster position.

Measurements (2)

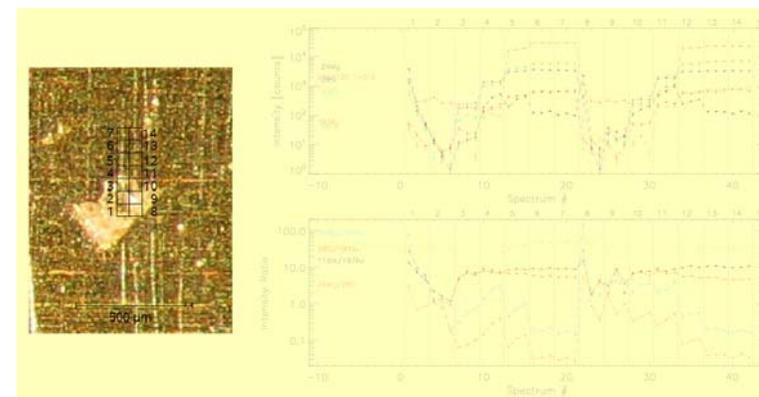


Figure 3: *Left*: Image of synthetic forsterite ($Mg_2 SiO_4$) grain prepared on COSIMA blank gold target. A 7 x 2 raster is indicated where spectra were obtained. Raster positions are labelled 1 ... 14; *Right*: Line intensities (*top*) and intensity ratios (*bottom*) of selected lines. Numbers of raster positions are given at the top. Three spectra were measured at each raster position. Intensities and intensity ratios measured on the target are fairly stable while larger variations are observed on the sample.

Laboratory Spectrum

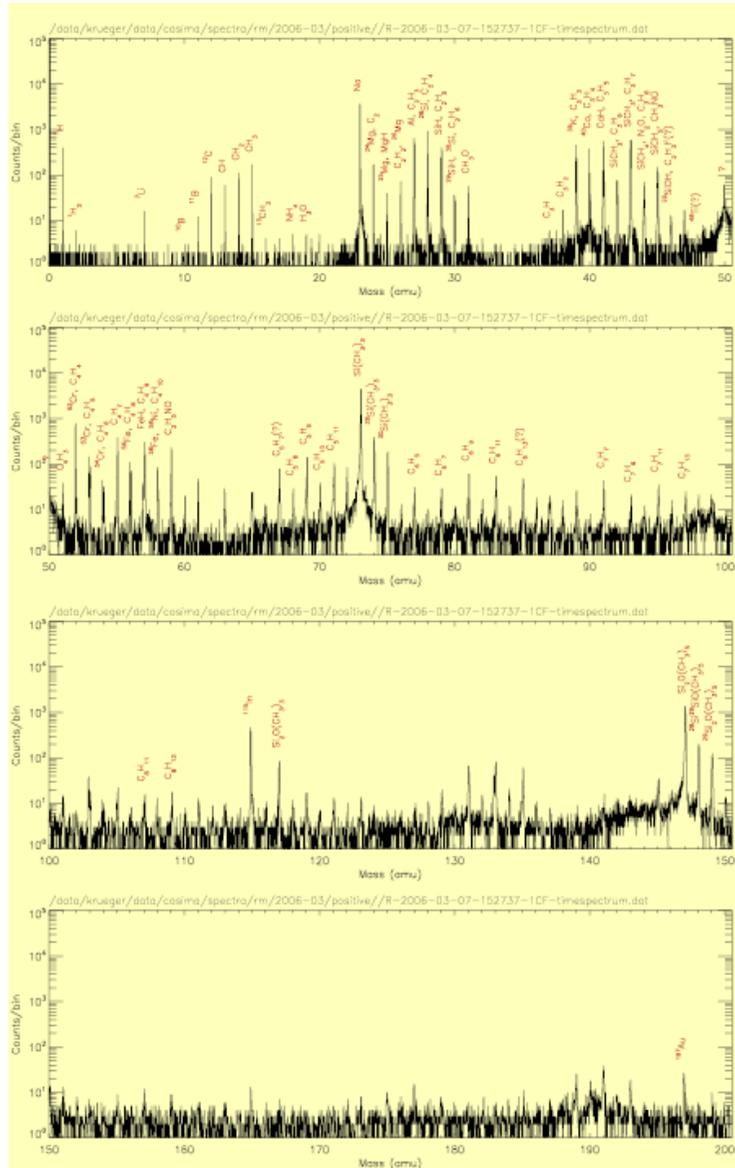


Figure 2: COSIMA laboratory spectrum of clinopyroxene (Ca (Mg, Fe) Si₂ O₆) measured in positive ion mode. The sample was prepared on a blank gold target (Fig. 1). Several identified lines are labelled. Due to the high mass resolution of COSIMA, inorganic and organic peaks are usually resolved. Peaks at mass 73 and 147 are due to silicone oil contamination. Indium (mass 115) is the peak of the primary ions.

Conclusions

- Line intensities from repeated measurements at the same sample (or target) location are fairly stable due to good stability of the COSIMA instrument (Fig. 1 and 3).
- Surface charging on the sample leads to strong intensity drop on the sample (Fig. 3).
- Spectra from sample and target locations can be distinguished from intensity ratios of specific lines (e.g. Mg/Si; Fig. 3).
- Intensity ratios measured at different sample locations on the same mineral vary from one location to the next (Fig. 1). May be due to geometry effects and/or sample inhomogeneities. Primary ion sputtering may lead to improvement.
- Organic peaks are mostly due to hydrocarbons, while oxygen and nitrogen compounds are rare (Fig. 2).

References

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