The organic content of comets: how to get prepared for the COSIMA TOF-SIMS measurements onboard the ROSETTA spacecraft.

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The organic content of comets: how to get prepared for the COSIMA TOF-SIMS measurements onboard the ROSETTA spacecraft.

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Abstract

COSIMA is a time-of-flight secondary ion mass spectrometer (TOF-SIMS) onboard the ESA ROSETTA spacecraft. It is meant to collect and analyze dust grains ejected from the comet 67P/Churyumov–Gerasimenko. This instrument is devoted to the mineral and organic chemical analysis of dust grains. This presentation will focus on the extent to which the organic content of the comet can be characterized in situ with COSIMA. It will be based on the pre-calibration mass spectra that have been obtained with ground instruments on either pure organic compounds or extraterrestrial sample containing carbonaceous matter.

1. Introduction

The Rosetta mission launched by ESA in March 2004 will reach the comet 67P/Churyumov-Gerasimenko in August 2014 to perform the most exhaustive study ever achieved on comets so far [1]. A time-of-flight secondary ion mass spectrometer (TOF-SIMS), named COSIMA (COmetary Secondary Ion Mass Analyser), is onboard the orbiter Rosetta spacecraft [2] and has been built for the analysis of solid cometary grains collected in situ. COSIMA is one of the most promising instruments in the payload of Rosetta to identify the refractory organic molecules present on comets [3].

2. The COSIMA Instrument

The COSIMA instrument is a secondary ion mass spectrometer equipped with a dust collector, an optical microscope, a primary indium ion gun and a reflectron time-of-flight (TOF). Dust from the near comet environment will be collected on a target. The target can be moved in front of the microscope where the positions of the collected grains can be determined. The cometary grains will be bombarded with the indium ion gun. The resulting secondary ions will be accelerated and then extracted into the TOF mass analyzer and the secondary mass spectra will be recorded for science analysis (Figure 1). The mass resolution of COSIMA is about 1400 at 100 amu.

COSIMA is expected to measure the molecular, elemental and isotopic composition of the cometary grains in the framework of the solar system chemistry. It will assess the relevance of the cometary organic matter as potential precursor material for more complex organic matter in the frame of the study of the origin of life.

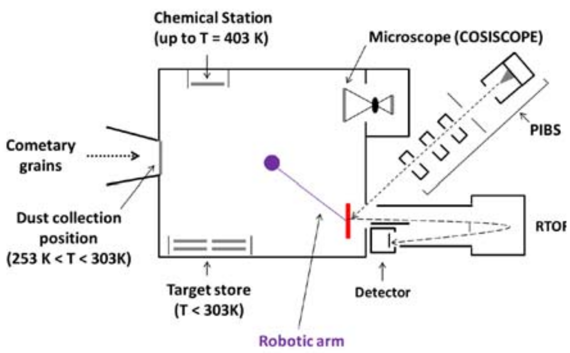

Figure 1: Schematics of the COSIMA instrument onboard the ROSETTA spacecraft. The main instrument features are the targets on which grains will be collected, the microscope (COSISCOPE) which allows to determine the grains locations, and the analysis position where grains will be bombarded with the Primary Ion Beam System (PIBS) and from which secondary ions will be accelerated and focused into the Reflectron Time Of Flight (RTOF) mass spectrometer. This figure is adapted from Kissel et al. (2007).

3. COSIMA and the study of the organic content of comets.

The main objective of COSIMA is to analyze the composition of cometary grains. Thanks to the resolving power of the instrument and mass defect properties, the organic matter can be discriminated from the mineral phases. However, the soluble organic component of the grains could contain several thousands (and probably more) of organic molecules [4] and cometary grains could also contain macromolecular and insoluble organic matter. Moreover, after ejection from the nucleus, grains will be subjected to both photon irradiation and heat in the coma, and to heat in the instrument [5]. These processes could lead to changes in the composition of organics in grains. Thus, the characterization of the solid organic components in cometary grains will be a challenging task for COSIMA.

The COSIMA team members are getting ready to decipher the organic content of cometary grains within the limits of analytical capabilities of the instrument. During the last few years, a library consisting of standard spectra of organic molecules (including hydrocarbons, nitrogenated bases, polycyclic aromatic hydrocarbons,…) has been constructed using ground instruments similar to the space COSIMA instrument. We also tested the analytical capabilities of COSIMA on laboratory analogs of cometary organic matter synthesized from heating and/or photolysis of icy mixtures, as well as on natural extraterrestrial samples such as carbonaceous chondrites.

We will present the calibration performed as well as the different methods that have been developed in order to facilitate the interpretation of the COSIMA mass spectra and more especially of their organic components. We will concentrate, among others subjects, to the aromatic structures search, the nitrogen to carbon elemental ratio or quasi-molecular ion peaks search.

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