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Calibration of the CDA with silicate dust analogues

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Abstract

The Cosmic Dust Analyser onboard the Cassini spacecraft is able to determine the elemental composition of interstellar dust particles via its time-of-flight impact mass spectrometer. For the analysis of the data obtained, the laboratory calibration of the CDA flight spare instrument is neccessary. Submicron- to micron sized natural dust analogues with known composition were prepared and finally accelerated at the Heidelberg dust accelerator facility onto the CDA flight spare unit and a high resolution impact mass spectrometer, the Large Area Mass Analyser. The resulting spectra from these hypervelocity impacts were investigated with respect to their elemental features.

1. Introduction

Interstellar dust (ISD) has recently become a highly interesting topic of astrophysical research. ISD plays a key role in the Interstellar Medium (ISM) that occupies the space between the stars in the galaxy and contributes the raw material for planet formation processes (for a review see [4]).

In situ analysis of cosmic dust enables the dust composition to be linked to the dynamical properties of the particle and hence to its source. ISD grains were first identified in the data set from the Ulysses dust detector [5] and further observed by in situ dust detectors onboard Galileo and Cassini ([3], [1], [2]).

The dust composition is obtained via the process of impact ionization time-of-flight (*TOF*) mass spectrometry. In situ dust detectors need terrestrial laboratory calibration. Particles of known composition are accelerated due to an electrostatic field to velocities up to $100\,\mathrm{km\,s^{-1}}$, which is achieved by using a Van-de-Graaff accelerator.

2. Experimental setup

An essential amount of the ISD population are silicates with ferromagnesian composition alike pyroxene and olivine. Therefore, we obtained orthopyroxene as a natural dust analogue resembling the composition of ISD.

After reducing the rock sample to grains with sizes ranging from about $0.05\,\mu\mathrm{m}$ to about $4\,\mu\mathrm{m}$, the sample was coated with a conductive layer with a thickness between 5 and $15\,\mathrm{nm}$ prior to acceleration, since the particles need to hold charge. Here, the metal coating method developed by Hillier [6] was employed. We used a 2MV Van-de-Graaff accelerator at the Heidelberg dust accelerator facility [7], to shoot the pyroxene particles with speeds between $1\,\mathrm{km\,s^{-1}}$ and $35\,\mathrm{km\,s^{-1}}$ onto the Large Area Mass Analyser (LAMA) and onto the Cosmic Dust Analyser (CDA) flight spare instrument, with the latter being an exact copy of the instrument onboard the Cassini spacecraft. The integrated linear *TOF* mass spectrometer achieves a mass resolution between $\frac{m}{\Delta m} \sim 20$ to $\frac{m}{\Delta m} \sim 40$ [8]. For ensuring the correct association of the structures visible in the CDA spectra, impact experiments with a high resolution impact mass spectrometer, LAMA, with a mass resolution of $\frac{m}{\Delta m} \sim 300$ and a so-called reflectron design [9], were conducted as well. Finally, the data of both instruments were processed by a software package developed for analysing impact mass spectra.

3. Results

LAMA and CDA spectra show a range of species to be distinguished according to their different possible sources. Thus, we have to discriminate the contamination from the actual composition of the dust analogues, for there are target contaminants and impurities (e.g. $\mathrm{H^-}$, $\mathrm{Na^-}$, $\mathrm{K^-}$ and $\mathrm{C^-}$, among others).

LAMA spectra show well defined mass lines (upper panel of Fig.1). Very well visible are major constituents of the sample material, which are $\mathrm{Mg^+}$, $\mathrm{Al^+}$ and $\mathrm{Si^+}$. As well, $\mathrm{Fe^+}$, $\mathrm{Mn^+}$ and $\mathrm{Cr^+}$ and their isotopes can be identified. The target material $\mathrm{Ag^+}$ shows as a distinct double and forms target-projectile cluster (e.g. AgMg). Very characteristic is the formation of carbon-and hydrocarbon cluster throughout the spec-

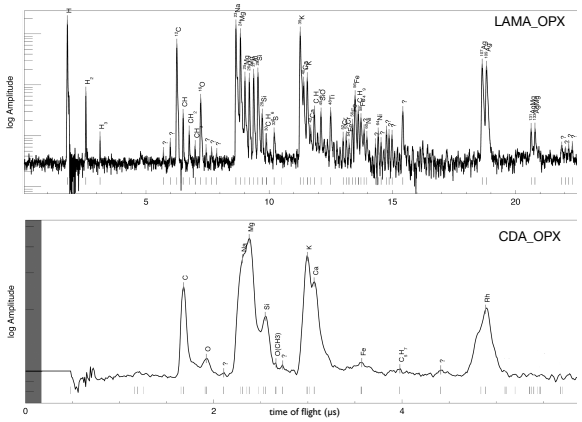

Figure 1: Zoomed-in-view of a sum spectrum of 134 LAMA spectra in comparison with the sum spectrum of 51 CDA spectra illustrating the occurrence of the main features within the spectra. The question marks above mass lines show not yet identified features. The y-axis shows the amplitude in V on a logarithmic scale.

tra (e.g. C, CH, C_2, C_2H, etc.).

The identification of features within the CDA (lower panel of Fig.1) is more difficult. Peaks are broad and not well defined. Masses close to each other can barely be distinguished and often only be assumed due to a ”bulge” in the broad adjoining mass line. However, one of the most abundant species of the sample material, Mg^+, can be very well identified, as can Si^+ and Ca^+. Fe^+ and other minor constituents, can not be identified from the background noise. The target material of the CDA, Rh^+, shows as a distinct peak here. Target-projectile cluster are rare and not visible here.

4. Summary

Here presented are the first results of the calibration experiments with siliceous dust analogues shot onto the CDA flight spare instrument. The sample used as dust analogue material was accurately analysed beforehand. We are able to identify the main element species of the dust sample within the CDA spectra. Using a high resolution mass spectrometer, such as LAMA, as a "control unit", supports the verification of results.

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