FURTHER ANALYSIS OF THE MOLECULAR STRUCTURE OF COMETARY ORGANIC MATERIAL.
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Introduction: The organic material in comets is of special interest because of its contribution to the organic budget of the Earth during its early history where it might have contributed to the beginning of life [1]. The Stardust mission collected material from comet Wild 2 for comprehensive analysis in the laboratory [2].

Organic material in the Stardust samples has been successfully analyzed with different methods like IR-spectroscopy, L^2MS and XANES [3-5]. The results from these measurements indicate high O/C and N/C ratios as well as an elevated CH_2/CH_3 ratio and low abundances of aromatic molecules. This composition is quite different from meteoritic material and IDPs [3] and most likely originates from a dense cloud and/or protosolar nebula rather than the diffuse ISM or stellar source and is consistent with radiation processing of astrophysical ices [3]. A drawback of these analytical methods is that generally only functional groups can be determined [4,5].

The aim of our study is to determine the molecular structure of organic molecules from Wild 2 using time-of-flight secondary ion mass spectrometry (TOFSIMS) because it records complete mass spectra. Our TOFSIMS instrument is equipped with a primary ion gun using C_{60} ions which break up upon impact spreading the kinetic energy over the 60 carbon atoms. This leads to relatively low energy sputtering and the excavation of nano-craters. Organic molecules around the crater are lifted gently and a have low fragmentation rate making it possible to detect complete molecules in the mass spectrum [6,7]. Fractionation patterns can be used to recognize certain molecules [8] or determine functional groups of unknown molecules. Additionally, depth profiling of organic material is possible because the material underneath the sputtering craters mostly survives unaltered [7].

We have previously analyzed a longitudinally cut track (C2012,15,134,0,0) and reported several polycyclic aromatic hydrocarbons (PAHs) around the track [9]. These PAHs were at constant levels in the aerogel and no enrichment towards the track was found making it unlikely that these were of cometary origin. This does fit with expectations as the track was a short and 'carrot-shaped', such tracks are not associated with organic-rich impactors from the comet.

Samples: Two aerogel track sections were allocated for this second part of the study. They are of type B which are bulbous tracks associated with organic-rich impactors. These tracks were cut open longitudinally and into narrow sections roughly 100µm long and as wide as the tracks themselves. The first section, data from which is reported here is C2063,5,154,0,0. The second, still to be measured, is C2061,9,113,0,0.

Results: So far only preliminary results are available for track C2063,5,154,0,0 whilst the analysis is still ongoing. The geometry of the sample makes analysis very complicated because parts of the sample are at different heights leading to different flights times and overlapping peaks. These cannot be deconvoluted for secondary ion images but mass spectra from separate regions-of-interest help to quantify results.

No mineral forming elements (like Mg, Al, K, Ca, Cr, Mn, Fe, Cu) were detected in the track area as can be seen in figure 1 indicating the absence of inorganic material in the track section. Intensities in the top left corner of the images stem from the Cu-grid holding the aerogel sample down. The area at the bottom of the images is an Al-block to hold the aerogel in place.

As the aerogel is a spun glass, the aerogel is defined by O and Si images in figure 1. Different organic molecules can be seen in the aerogel and especially the track area. Preliminary examination shows short-chain aliphatic hydrocarbons like C_2H_5 and C_3H_5, amongst several others, in the track area. These are very common and can be found on many sample surfaces once samples have been handled in air and are most likely contamination.

Naphthalene ($C_{10}H_8$) is a polycyclic aromatic hydrocarbon (PAH) which can be found in the track area as well as in the aerogel parts to the right and left of the track. This is similar to our previous results [9] where several PAHs (Naphthalene, Phenanthrene, Pyrene) were found around the track with no enrichment towards the track.

One very interesting organic molecule is C_3ONH_7 which could be a fragment of Alanine ($C_3O_2NH_7$) if one of the oxygen atoms is lost by fragmentation during the ion bombardment. The distribution of this secondary ion shows an enhancement in the track area but less so in the surrounding aerogel. This would associate this organic material with the track and therefore the impacting cometary material. Because we have not yet measured an Alanine standard or similar molecules to check their fragmentation patterns, the identification of the parent molecule of the $C_3O_2NH_7$ molecule in the track is still pending.

Outlook: The results are very interesting and encouraging although the interpretation of the data is made very complicated by the geometry of the sample. More work is needed analyzing the data as well as the analysis of further standards to determine fragmentation patterns for the identification of specific organic molecules. This will be reported at the conference.

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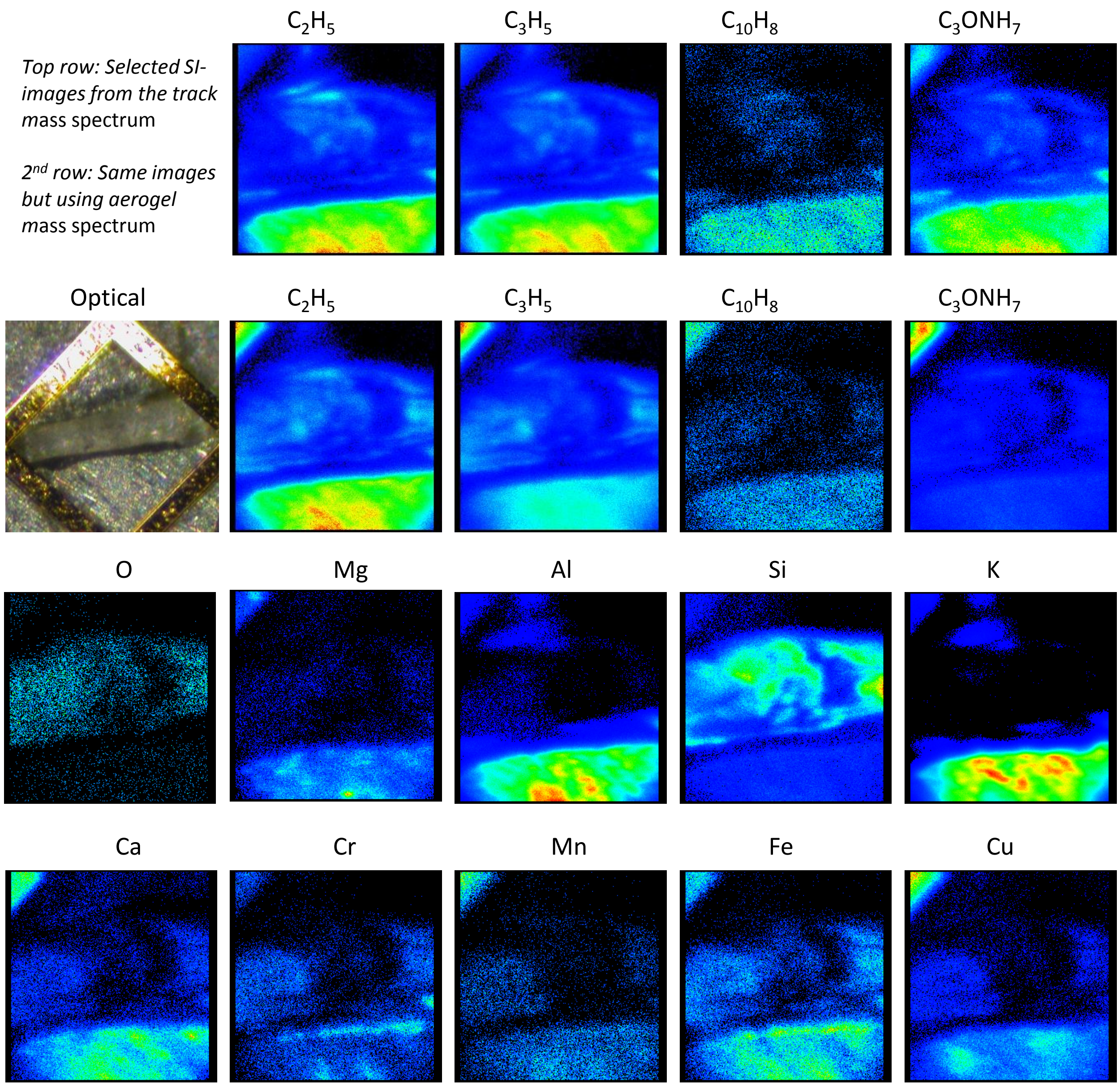

Figure 1: Optical and secondary ion images of track 154 with a field-of-view of 250µm for the secondary ion images and around 500µm for the optical image. There is part of the Cu-grid visible in the top left corner of the SI-images and part of the Al holding block in the bottom of the images. The Si-image defines the aerogel area with the track best visible in the $C_{10}H_8$-image.