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Organic compounds from Enceladus' sub-surface ocean as seen by CDA

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Abstract

The ice and dust particles ejected into Saturn's E-ring provide direct insight into the composition of Enceladus' sub-surface ocean. This ocean is in contact with the rocky-core and there is evidence for hydrothermal activity [1][2]. Chemical species in the liquid are transported through vents and ejected out of Enceladus in the form of gas and ice particles. The volatile organic components found in the gas phase have already been thoroughly investigated [3]. Here we perform a compositional analysis of mass spectra from organic-rich ice grains and infer the composition of the refractory organic component of the plume. As expected, we find more complex organic molecules than in the gas. Among others we identify fingerprints of different aromatic compounds and amines.

1. Introduction

Enceladus is emitting a plume of gas and ice particles from its fractured South Polar Terrain (SPT), the so-called "Tiger Stripes". The source of Enceladus plume and of the E-ring is the moon's sub-surface ocean. The chemical species ascending from the liquid reservoir, transported through vents and ejected into space include organic molecules [3][4][5].

Three compositional types of ice grains have already been identified by the Cosmic Dust Analyzer (CDA) onboard Cassini spacecraft; Type-1—almost pure water, Type-2—organic rich and Type-3—salt rich [4][5].

In contrast to Type-1 and Type-3 spectra, which have already been well characterized, organic rich Type-2 spectra have not yet been investigated in detail. Type-2 spectra display great diversity indicating varying contribution of different organic species. A multitude of organic species has already been identified in the plume of gas [3]. By analyzing organic rich Type-2 grains we can access refractory organic compounds from Enceladus' sub-surface ocean. The composition of Type-2 spectra is inferred using a laboratory experiment that provides analogues for spectra from ice particle impacts. The simulation of a variety of organic compounds in a water matrix allows us to identify characteristic families among Type-2 spectra and attribute them to certain class of organic compounds.

2. Experimental setup

We simulate CDA Type-2 spectra with an experimental setup in our Heidelberg laboratory: Infrared Matrix Assisted Laser Desorption Ionisation Time of Flight Mass Spectrometer (IR-MALDI-TOF-MS). An aqueous solution of organic compounds is vertically injected in the form of a liquid microbeam of about 10 µm in diameter. The liquid beam is shot and ionized by a pulsed infrared laser with a wavelength of 2850 nm. The adjustable setup successfully simulates different impact energies of impinging ice grains onto the CDA metal target at different impact velocities. The generated cations are accelerated towards a reflectron-type Time-of-Flight mass spectrometer.

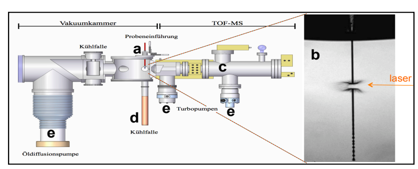

Fig. 1: Shown is the experimental setup to simulate CDA organic rich Type-2 spectra at different impact velocities. (a) beam site. (b) beam irradiated by laser. (c) mass spectrometer. (d) cryotrap. (e) pumps. [6]

3. Results

Among other compounds we have identified characteristic fragments patterns of two classes of organics: (i) aromatics (ii) amines. Typically fragment cations of aromatic compounds are stable at velocities up to 15 km/s and of amines up to velocities of 8 km/s.

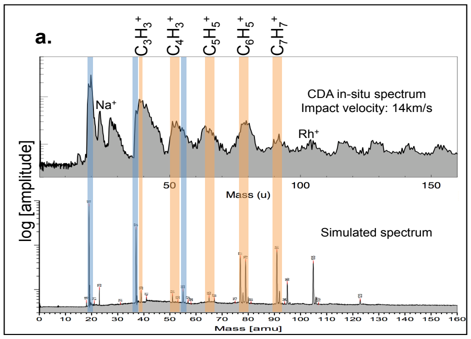

Fig. 2a: Characteristic fragments of aromatic compounds | An aqueous solution of benzoic acid (C_6H_5-COOH, 0.15% mol/kg) with benzyl alcohol (C_7H_7-OH, 2.5% mol/kg) is used to simulate the CDA in-situ spectrum of aromatic compounds. Orange stripes show characteristic fragments pattern ($C_nH_{\leq n}^+$) of aromatic compounds at mass lines 39, 51, 65, 77 and 91(u) (u = unified atomic mass unit), whereas blue stripes show pure water cluster species $H^+(H_2O)_{n=1-3}$. Generally Tropylium cations ($C_7H_7^+$: 91u) form from a benzyl group (C_7H_7-R) whereas Phenyl cations ($C_6H_5^+$: 77u) form from oxygen bearing aromatic compounds (C_6H_5-COR). Fragments from other organic species are also present but not labelled.

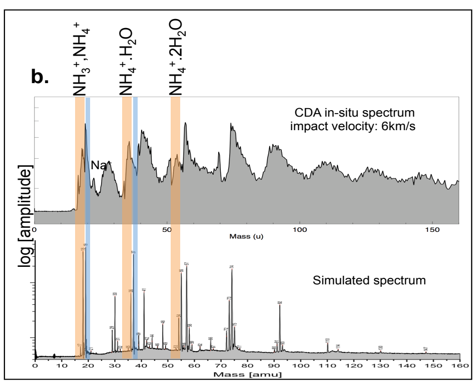

Fig. 2b: Characteristic mass lines of amines | An aqueous solution of butyl-amine (C_4H_9-NH_2, 5% mol/kg) is used to characterize amines in the CDA ice grain spectrum. Orange stripes show the characteristic pattern of amine compounds in a water matrix at mass lines 17, 18, 36 and 54 (u), whereas blue stripes shows pure water cluster species $H^+(H_2O)_{n=1,3}$. The major characteristic fragment of amines is the mass line at 18u (NH_4^+). The ammonium cation (NH_4^+) forms cluster species with water at mass lines 36u and 54u of the form $NH_4^+.(H_2O)_{n=1,2}$. Fragments from other organic species are also present but not labelled.

4. Summary and Conclusions

Our experimental setup in Heidelberg (IR-MALDI-TOF-MS) provides a better understanding of organic-rich CDA-TOF spectra of ice particles from Enceladus over a wide range of impact velocities. Among others two organic families, aromatics and amines could be identified in the ice matrix. Type-2 spectra show contributions from other, yet unspecified, organic species. This demonstrates that the analysis of Type 2 grains is a key element in understanding of Enceladus subsurface processes. Currently work is in progress to verify other organic families in the dataset. In future work we will quantify concentrations of organic compounds in the ice grains emitted from Enceladus.

Acknowledgements

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References

[1] Hsu, H.W. et.al.: Nature, Vol. 519, 207-210, 2015.

[2] Iess, L. et.al.: Science, Vol. 344, 78-80, 2014.

[3] Waite Jr., J. H. et.al.: Nature, Vol. 460, 487-490, 2009.

[4] Postberg, F. et.al.: Nature, Vol. 459, 1098-1101, 2009.

[5] Postberg, F. et.al.: Icarus, Vol. 193, 438-454, 2008.

[6] Beinsen, A.: Dissertation 2011, Georg-August-Universität Göttingen.