Organic compounds in ice grains from the subsurface ocean of Enceladus

N. Khawaja[1*]; F. Postberg[1], F. Klenner[1], L. Nölle[1], R. Reviol[1], R. Srama[2]

[1]Institutue of Earth Sciences, Heidelberg University, Germany
[2]IRS, University of Stuttgart, Germany

Cassini's on board mass spectrometers – the Ion and Neutral Mass Spectrometer (INMS) [1] and the Cosmic Dust Analyzer (CDA) [2] – have measured the plume of gas and ice grains ejected from Enceladus' south pole [3] that are linked directly to the moon's subsurface global ocean [4]. CDA provided evidences that the ocean is in contact with the rocky-core [5] and there is an on-going hydrothermal activity [6]. The detection of molecular hydrogen by INMS [7] not only confirmed water-mineral interaction but also indicates the geochemical process serpentinization to occur, similar to some of Earth's hydrothermal systems like Lost City [8]. The INMS has already detected multitudes of organic species in the gas phase [1] and CDA has indicated organic material in the ice grains [9]. In this work, we present a detailed compositional analysis of organic bearing ice grains and infer the composition of refractory organic components. Compared to the volatile organics detected by INMS, CDA detects larger and more complex organic compounds in the ice grains emitted from Enceladus' subsurface.

The Chemical Analyzer (CA) subsystem of CDA produces cationic time-of-flight (tof) mass spectra of hyper velocity grains impinging onto a rhodium metal target. From CDA mass spectra three compositional types of ice grains have already been identified [5,9]: Type 1 - almost pure water ice, Type 2 - organic enriched and Type 3 - salt rich. In contrast to Type 1 and Type 3, Type 2 spectra show a great diversity indicating varying contribution of different organic compounds. To infer the organic compounds we have used our analogue experiment in Heidelberg to reproduce different CDA spectra. A micron-sized water beam with dissolved substances is exposed to an infrared laser. As a result cations, anions and neutral species of water and the dissolved substances are produced that are very similar to those from the impact ionization process of ice grains observed with CDA [5]. Cation spectra are recorded by a commercial tof mass spectrometer and are used as analogue spectra for CDA ice impacts.

Aqueous solutions of a variety of organic compounds were tested to simulate different impact energies of impinging Type 2 grains onto the CDA metal target occurring at varying impact velocities. The simulation of organic compounds in a water matrix allows us to further classify CDA Type 2 spectra and attribute them to certain classes of organic compounds. Our results show that a substantial fraction of Type 2 grains contains at least three kinds of organic compounds: (i) amines (ii) carbonyls and (iii) aromatics. In ice grains spectra amines are identified by significant ammonium cations, carbonyl compounds are specified by characteristic acylium cations and aromatic species are identified by a series of aromatic fragment cations. In addition to the identified features Type 2 spectra often show contributions from other yet un-specified organic species that require more investigation in future. Our results show a strong indication of different organic compounds in ice grains emerging from the subsurface ocean. Like other inorganic products previously identified [6, 7], the observed organic species might be linked to hydrothermal sites [10] and be used to characterize their habitability.

References

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Short Summary

We are presenting a detailed compositional analysis of organic bearing ice grains emanating from the subsurface ocean of Enceladus. The results show that Cassini's onboard mass spectrometer, the Cosmic Dust Analyzer (CDA), has detected atleast three kinds of organic compounds.