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Experiments for the detection of microbial biosignatures in ice grains from Europa and Enceladus

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Detecting and identifying biosignatures is key to the search for life on extraterrestrial ocean worlds. Saturn’s moon Enceladus emits a plume of gas and water ice grains, formed from its subsurface ocean, into space. A similar phenomenon is suspected to occur on Jupiter’s moon Europa. Impact Ionization mass spectrometers, such as the Cosmic Dust Analyzer (CDA) onboard the past Cassini mission or the Surface Dust Analyzer (SUDA) on board the upcoming Europa Clipper mission, can sample the emitted ice grains, rendering the ocean accessible for compositional analysis by spacecraft flybys. The CDA data collected in the Saturnian system showed that Enceladus’ ocean is salty [1] and contains a variety of organic material, such as complex macromolecules [2] and low mass volatile compounds, the latter of which potentially act as amino acid precursors and are capable of interacting within or near Enceladus’ hydrothermal vent system [4], or Enceladus’ porous rocky core [5]. Although these findings enhance Enceladus’ relevance as a potential habitable environment, biosignatures have so far not been identified.

Interpreting the space-based icy grain data requires on-ground calibration via analogue experiments. The Laser Induced Liquid Beam Ion Desorption (LILBID) technique is capable of accurately reproducing the mass spectra of ice grains recorded in space [6]. Previous LILBID experiments have shown that bioessential molecules, namely amino acids, fatty acids, and peptides can be detected in the ice grains [7], and that abiotic and biotic formation processes of these molecules can be distinguished from each other [8]. The next steps are to investigate whether building blocks of bacteria, such as membrane lipids – indicators for earthlike microbial life - can also be detected in ice grains and characterized using future impact ionization mass spectrometers. To predict their spectral appearance in impact ionization mass spectra, high sensitivity LILBID experiments on extracts from Escherichia Coli and Sphingopyxis alaskensis were performed. Spectra of lipids, and the corresponding aqueous phases produced during their extraction, potentially containing polar molecules, were produced using increasingly NaCl-rich matrices, designed to mimic the salty ocean of Enceladus or Europa.

In the mass spectra, we identify fragments characteristic for the building blocks of bacteria, such as fatty acids deriving from the bacteria's membrane lipids. Sensitivity to lipid fragments and polar molecules decreases with rising salt concentration. These spectra, as well as those of other biosignatures, have been incorporated into a comprehensive database, to provide comparable analogue data of a wide range of compounds applicable to future impact ionization mass spectrometers.

References

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