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Analog Mass Spectra of Astrobiologically Relevant Organic Material for Spaceborne Mass Spectrometers and their Future Implications

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Abstract

Characterizing the abundances of various amino acids, peptides and fatty acids is fundamental in the search for extraterrestrial life. For future space mission these investigations are possible with in situ space detectors [1] [5] that assess the abundances of these key species in ice grains potentially emerging from ocean bearing moons like Europa and Enceladus [3] [4]. Distinguishing biotic and abiotic fingerprints of these organic substances is crucial to further enhance the possibilities in interpreting mass spectra of ice grains in space.

With our worldwide unique experimental setup we are able to reproduce mass spectra of amino acids, peptides and fatty acids in ice grains. We simulate the impact ionization mechanism in space by an infrared laser intersecting an ultrathin water beam. The resulting spectra have been demonstrated to be highly comparable to those of ice grains detected by impact ionization space detectors like the Cosmic Dust Analyzer (CDA) on board the recently ended Cassini mission and the Surface Dust Analyser (SUDA) on board the future Europa Clipper mission [2]. The experimental setup (IR-FL-MALDI-ToF-MS) consists of a vacuum chamber ($\approx 5 \times 10^{-5}$ mbar) in which a water beam (radius of 7 – 9 µm) with dissolved chemicals therein is inserted. Mixtures of other solvents like methanol and acetonitrile with water can also be used and, therefore, all water soluble and many water insoluble substances can be analyzed. A pulsed infrared laser (λ = 2840 nm) hits the beam of the aqueous solution. In this way cations, anions, electrons and neutral molecules of the solvent and the dissolved substances therein are created. The cations as well as the anions can be analyzed in a commercial ToF-MS. The setup will be upgraded in future with an additional ultraviolet laser to subsequently ionize the neutral molecules that can then be analyzed in the same ToF unit.

Our laboratory results show a high sensitivity on the tested substances. The detection limits of salts and organics are in the ppm or even ppb range. Different amounts of the analytes lead to different intensities of the related peaks in the mass spectra. We are able to easily differentiate between biotic and abiotic signatures of amino acids and fatty acids in the analog spectra. Peptides can also be reliably characterized. By comparing the laboratory results with spacecraft data we have the ability to recognize and distinguish such signatures in ice grains from icy moons with a subsurface ocean. We are currently developing a comprehensive spectral reference library for in situ space detectors from a wide variety of organic analog materials in icy grains.

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