A Method to Discriminate between Abiotic and Biotic Processes on Cryovolcanically Active Ocean Worlds

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Discriminating between abiotic and biotic signatures of amino acids and fatty acids on extraterrestrial ocean worlds is key to the search for life and its emergence on these bodies. Cryovolcanically active ocean worlds, such as Enceladus and potentially Europa, eject water ice grains formed from subsurface water into space. The ejected ice grains can be sampled by impact ionization mass spectrometers onboard spacecraft – such as Cassini's Cosmic Dust Analyzer (CDA) – thereby exploring the habitability of the subsurface oceans. Complex organic macromolecules [1], as well as nitrogen- and oxygen-bearing organics that could act as amino acid precursors [2], were recently detected by the CDA in Enceladean ice grains. The next step is to determine whether potential biosignatures, such as amino acids and fatty acids, may also be detected using impact ionization mass spectrometry and whether abiotic and biotic signatures can be distinguished after a hypervelocity ice grain impact.

Previous experiments with an analogue Laser Induced Liquid Beam Ion Desorption (LILBID) spectrometer, proven to accurately reproduce the mass spectra of water ice grains at different impact speeds in space [3], have shown that most amino acids, fatty acids and peptides in pure water ice grains can be detected at nanomolar concentrations [4]. Here, we investigate the mass spectral appearance and detection limits of amino acids and fatty acids, in proportions representative of either biotic or abiotic formation processes, in a more realistic, Enceladus-like scenario. The analytes are mixed with over twenty additional organic (e.g., carboxylic acids) and inorganic background components (e.g., salts) suitable for ice grains formed from Enceladean ocean water which has interacted with the moon's rocky core.

We find it is possible to distinguish and identify abiotic and biotic mass spectral fingerprints of potential biosignatures from the background even under these difficult conditions. In contrast to our previous work, we here find that amino acids and fatty acids form characteristic sodium-complexed molecular cations in a salty matrix. Detection limits of the organic biosignatures
depend strongly on their Pkₐ values and the salinity of the ice grains. Amino acid and fatty acid concentrations realistic for abiotic and biotic processes in the Enceladus ocean can be detected and characteristic abiotic and biotic mass spectral signatures can be clearly distinguished from each other [5]. We infer from our experiments that ice grain encounter velocities of 3 – 6 km/s are most appropriate for the detection of the distinctive signatures of the biomolecules. In this work, we established a standard methodology to detect and discriminate between abiotic and biotic processes in ice grains from extraterrestrial water environments.

References:
