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Experiments for the Detection of Biosignatures in Irradiated Ice Grains with Europa Clipper's SUDA Mass Spectrometer

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Ocean worlds, such as Jupiter's icy moon Europa, are key targets in the search for extraterrestrial life. One powerful approach involves searching for biochemical signatures at the molecular level - both specific biosignature molecules and their distribution patterns. These include amino acids and fatty acids, the latter being considered as universal biomarkers of extraterrestrial life [1], while amino acids are some of the simplest molecules that could be a biosignature.

NASA's upcoming Europa Clipper mission [2] will evaluate Europa's habitability. The SUrface Dust Analyzer (SUDA [3]) is the onboard impact ionization mass spectrometer, which will provide compositional analyses of water ice grains, potentially rich in organic material derived from the subsurface ocean. SUDA has the capability to detect and distinguish between abiotic organic molecules [4,5] and (microbial) biosignatures [6,7,8] in Europa's ice grains. However, if such signatures are indeed present in Europa's surface ice, they are exposed to Jupiter's harsh magnetospheric radiation and may thus be destroyed and/or modified by high-energy particles, mainly electrons [9]. It is therefore crucial to evaluate the impact of Europa's radiation environment on the preservation of biosignatures in its surface ice and on their detectability with spaceborne instruments.

Here, we assess the effects of electron irradiation on the mass spectral signatures of molecular biosignatures embedded in ice, as detectable by SUDA-type mass spectrometers. We irradiated amino acids and fatty acids in water ice with high-energy (10 MeV) electrons and recorded analogue mass spectra using Laser Induced Liquid Beam Ion Desorption (LILBID), a technique that accurately simulates SUDA-type mass spectra [10]. Samples were irradiated with doses from about 300 Gy to 3.5 MGy, i.e., exposure on the timescale of minutes up to a year on Europa's surface at 0.1mm depth [11]. The irradiation experiments were conducted at conditions similar to those experienced by Europa's surface ice (i.e., high vacuum and surface temperatures between 80 and 130 K). Samples consisted of (i) 4 amino acids (alanine, aspartic acid, glycine, lysine) at a concentration of 0.01 wt% for each amino acid, (ii) fatty acids at simulated abiotic concentrations (all fatty acids at the same concentration) and (iii) fatty acids at simulated biotic concentrations (increased abundances for even carbon number fatty acids, especially C16 and C18, as compared to odd carbon number fatty acids).

Preliminary results show characteristic signals can be identified from both amino acids and fatty acids even at the highest tested dose, indicating that these biosignatures can persist under Europan surface conditions over long periods of time and be still easily detectable by SUDA. The intensities of peaks corresponding to high molecular mass amino acids was found to decrease with increasing radiation dose, indicating that these compounds undergo destruction due to the radiation, but they decreased with a lower degree than expected. Results will be further discussed in the context of surface location and depth on Europa, drawing implications for the detection of organic biosignatures with space missions such as Europa Clipper and other future icy moon missions [12].

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