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Reproducing impact ionization mass spectra of icy analogue materials at different impact speeds

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In situ mass spectrometers analyzing the composition of icy grains in space like the Cosmic Dust Analyzer (CDA) on Cassini, the Surface Dust Analyser (SUDA) onboard the future Europa Clipper Mission, or the Enceladus Icy Jet Analyzer (ENIJA) on a future Enceladus mission employ the impact ionization mechanism to ionize substantial parts of the ice grains by the kinetic energy of the impact. As the impact speed of the grains can vary greatly in space, the resulting cation or anion mass spectra can have very different appearances. On Earth μm and sub-μm sized ice grains, as encountered typically in space, cannot be accelerated to speeds above about 2 km/s and therefore the impact ionization process can currently not be reproduced in the laboratory.

However, a laser based analogue experiment where a μm sized liquid water beam is intersected by a pulsed infrared laser at suitable energies and wavelengths has been demonstrated to be a good analogue to the impact ionization of ice grains. The cationic and anionic products are monitored by a high performance time of flight mass spectrometer. In this way, CDA's cationic mass spectra from ice grains emitted by Saturn's cryo-volcanically active moon Enceladus could be accurately reproduced. The quantitative reproduction of the CDA mass spectra with a specific salty solution in the analogue experiment gave invaluable insights into the composition of Enceladus' subsurface ocean (Postberg et al. 2009, 2011).

In this work, we demonstrate the capability of our improved laser experiment in Heidelberg to quantitatively reproduce CDA spectra recorded at a wide variety of impact speeds. CDA spectra of E ring ice grains recorded at different impact speeds varying from 4 – 16 km/s are grouped into different speed regimes. We accurately reproduce the drastically varying spectral appearances by tuning the laser parameters and the delay time of the system in front of the mass spectrometer. We compare CDA spectra of different composition (Type 1, 2, and 3 from Postberg et al., 2008, 2009) recorded at the different speed regimes with our analogue spectra and prove the capability of the Heidelberg analogue experiment to reproduce them. The next step will be a comprehensive data base of cation and anion mass spectra from icy analogue materials used by current and future space missions.