On the genesis and detectability of organic chemistry in hypervelocity impact ice spectra. Zach Ulibarri[1] (zachary.ulibarri@colorado.edu), Tobin Munsat[1], Bernd Abel[2], Richard Dee[1], David James[1], Sascha Kempf [1], Zoltan Kupihar[3], Zoltan Sternovsky[1], [1]IMPACT, University of Colorado, Boulder, Colorado, United States, [2]Leibniz Institute of Surface Engineering, Leipzig, Germany, [3]University of Colorado, Dept. of Chemistry and Biochemistry, Boulder, Colorado, United States.

Introduction: Water ice is prevalent in the solar system, and there have been numerous studies of the effects of radiation and charged particle bombardment of water ice in laboratory settings. However, many questions yet remain concerning the effects of interplanetary dust particle (IDP) bombardment on icy surfaces and bodies. This is despite the fact that IDP impacts are expected to be at least as important as radiation and charged particle bombardment.

Since liquid water is regarded as a prerequisite for life, icy ocean worlds such as Europa and Enceladus are the focus of several planned NASA and ESA fly-by missions. Water plumes erupting from Enceladus's surface have been observed, and analysis from the Cassini spacecraft's impact ionization time of flight (TOF) mass spectrometer indicates that the environment around Enceladus is rich with dust from both the ice surface and the subsurface ocean.

While some laboratory work has been performed to match CDA flight spectra, these studies have laser ablated flowing liquid sources rather than impacting actual dust into ice surfaces. However, the University of Colorado dust accelerator at the Institute for Modeling Plasma, Atmospheres, and Cosmic Dust (IMPACT, *impact.colorado.edu*), paired with a cryogenic target capable of creating H_2O ice mixtures, allows for unique and tightly controlled experiments to study hypervelocity dust impacts into ice, providing results more closely aligned with actual spacecraft data than laser ablation. Such experiments will answer significant questions about the chemical evolution of icy bodies under dust bombardment as well as the survivability and detectability of complex organic chemistry in icy dust grains studied by impact ionization TOF instruments on flyby spacecraft.

Experimental Results: Water ice was doped with various amino acids and bombarded with dust. TOF chemical analysis of the impact plume shows that amino acids and even the more fragile di-peptide dual amino acid chain lysine-glycine survive the impact process and can be measured directly. Furthermore, spectra from impacts into water ice doped with the amino acid histidine show that fragmentation products are related but not identical to those found in the NIST electron impact ionization mass spectra of histidine. This indicates that even in the event of breakup, it may be possible to use the breakup products as a means to identify the parent molecule. Fig. 1 shows such a spectrum, produced by a 3.2 km/s iron dust impact, with the parent histidine molecule highlighted in green and the breakup products highlighted in red.

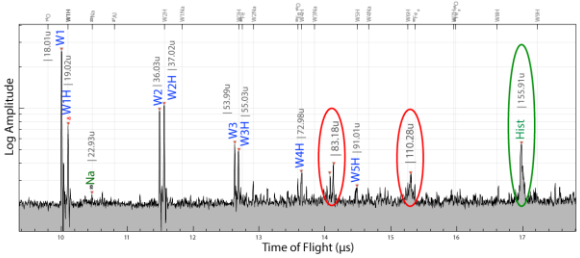

Figure 1. Spectrum produced by a 3.2 km/s iron dust impactor into water ice doped with histidine. In addition to direct detection of the parent molecule (highlighted in green), breakup products related to the NIST electron impact ionization breakup products are observed (highlighted in red).

In experimental investigations into the long term chemical evolution of icy bodies under dust bombardment, gaseous CO_2 was doped into water ice and bombarded by iron dust. CO_2 was detected at velocities >3 km/s. At high velocity (>15km/s), CO at mass 30 AMU was produced, and a strong line at mass 32 AMU was occasionally observed. While mass 32 could be O_2 molecules, O_2 would be expected to charge negative and thus would not be measured in this positive ion spectrum. More importantly, such strong lines at mass 32 are not observed in high velocity dust impacts into pure H_2O ice, and thus far they have only been detected in spectra produced by impacts into these CO_2 and H_2O ice mixtures.

Another explanation for the lines at mass 32 is methanol, CH_3OH. If this is the case, then these results may indicate that simple inorganic carbon chemistry is being converted by dust impact into simple organic chemistry. Ongoing experiments are using isotopic carbon-13 CO_2 in an otherwise similar experiment to definitively break the ambiguity between O_2 and CH_3OH. If the line at mass 32 is in fact methanol, the carbon-13 will shift the line to 33 AMU.

Future experiments will probe the creation of organic chemistry from inorganic sources. Other experiments will determine if relative concentrations of amino acids can be inferred from impact ionization TOF spectra.