Detection of Organic Molecules and D-H Ratios in Laboratory Mass-Spectra of Hypervelocity Dust Impacts into Ice

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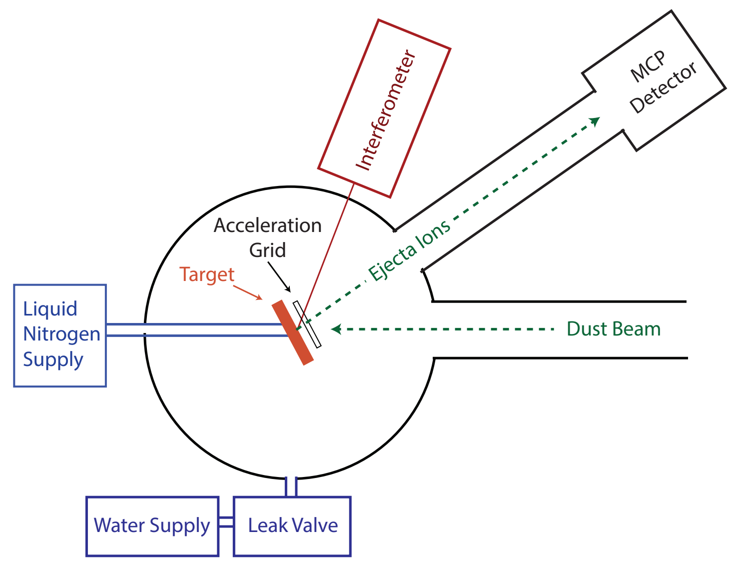
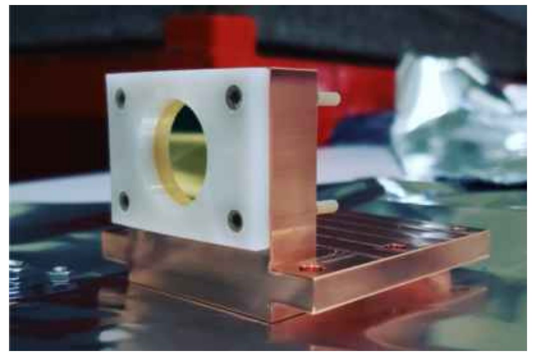
Project Overview

Using the cryogenic impact ionization target at the University of Colorado dust accelerator, ices with complex organics or specified isotopic ratios can be created. These ices are then bombarded with hypervelocity dust and the ejecta plume is sampled with time-of-flight (TOF) mass spectrometry. Such analysis can be used to determine what types of chemistry can be measured by impact ionization TOF instruments on flyby spacecraft and what effects dust bombardment has on long-term chemical evolution of icy surfaces.

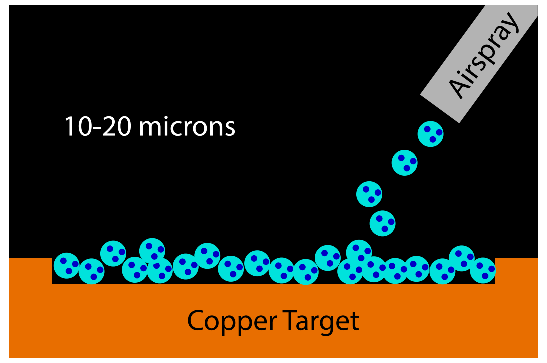


Ice Production

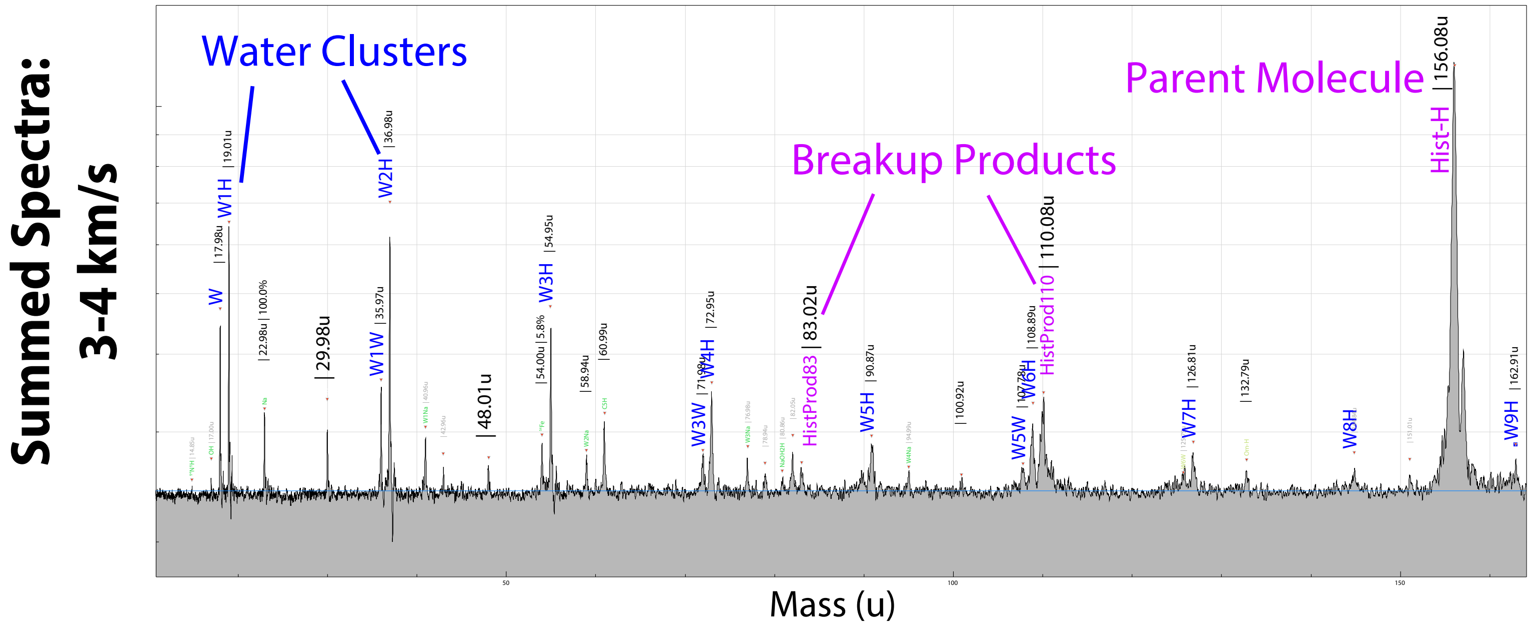


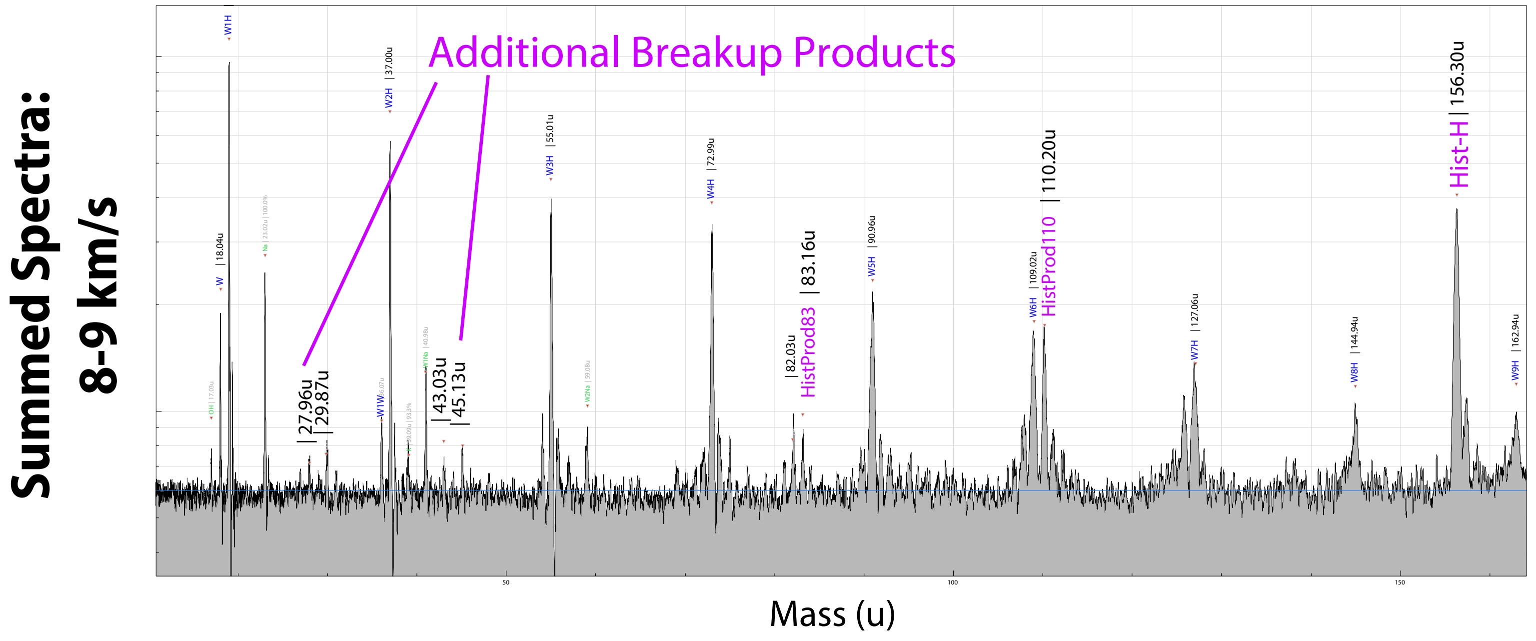
Vapor deposition is used for simple ice mixtures, and ice thickness can be measured by Fabry-Perot interferometry.

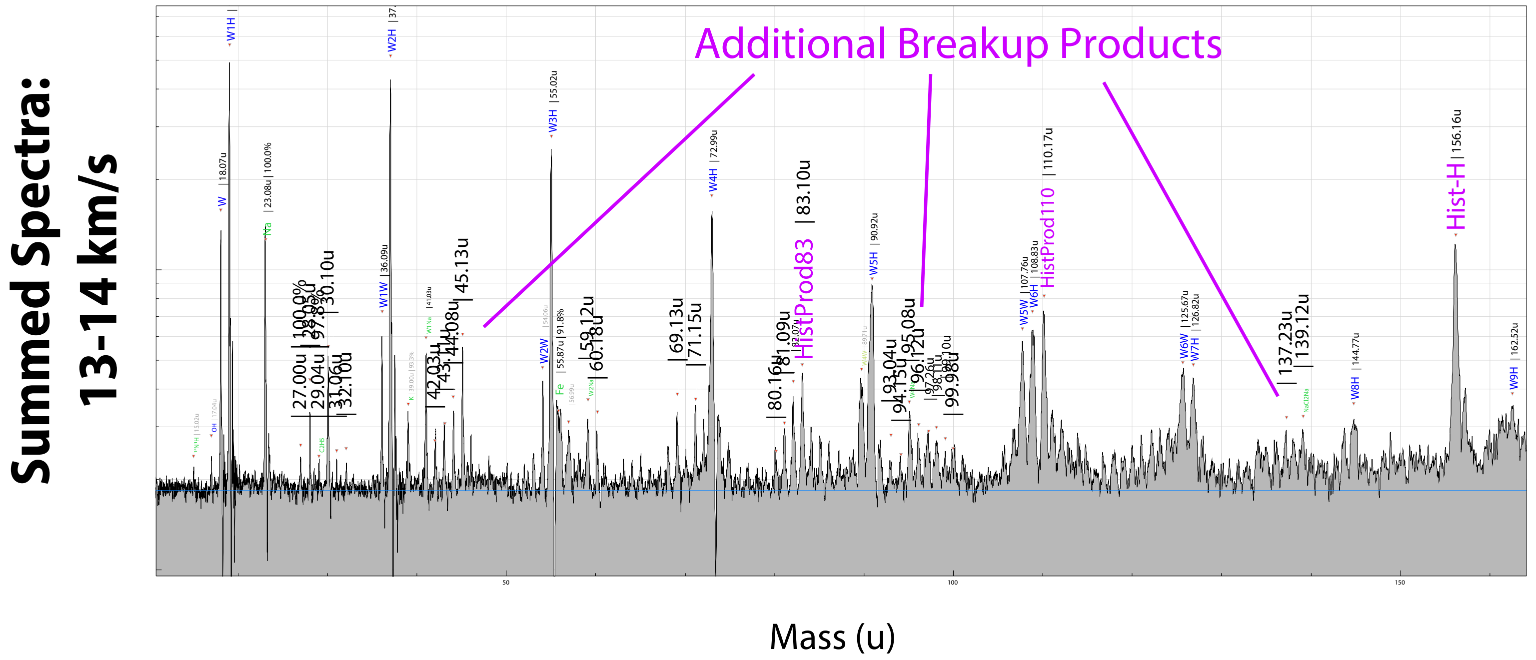
A novel airbrushing system is used for complex mixtures, such as water ice doped with amino acids. Sometimes vapor deposition is used on top of these airbrushed surfaces.



Mass Spectra of Airbrushed Histidine and Water Ice







Detection of Histidine

A solution of histidine monohydrochloride was airbrushed onto a target plate and then freeze-dried in a nitrogen environment. This target plate was then installed into the cryogenic ice target and cooled down to 77 Kelvin. Vapor deposition was then used to grow a thin later of water ice on the surface, and the system was bombarded with hypervelocity dust.

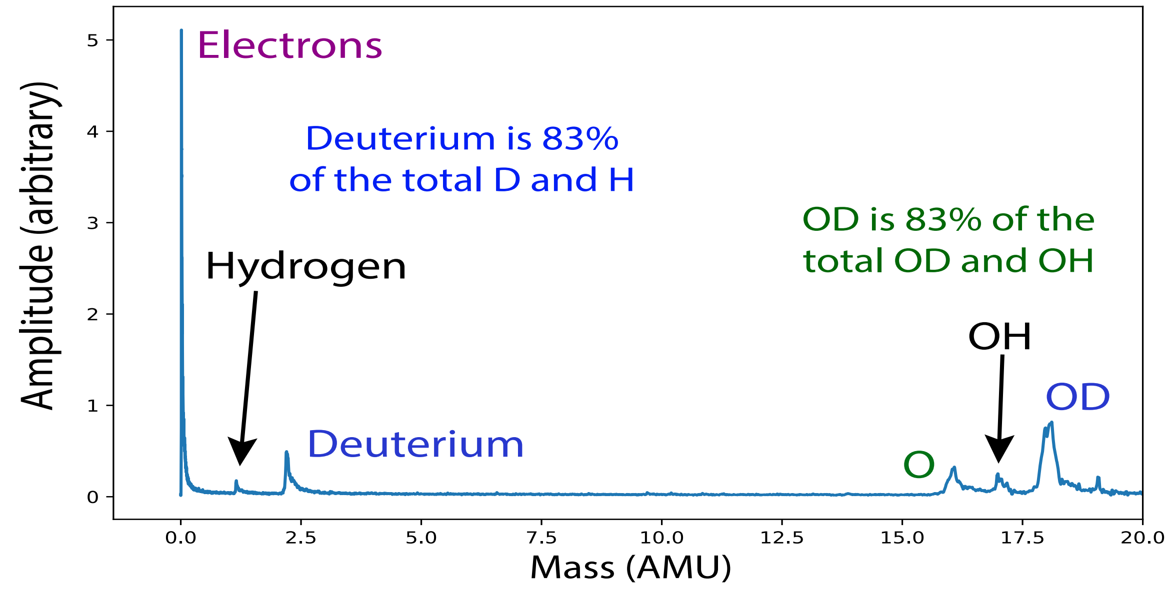
At low velocity (<5 km/s), breakup products at mass 110 and 83 are observed, indicating that these products are readily produced in the impact process. The parent histidine molecule is also observed with a very strong signal.

As velocity increases, more breakup products are observed, especially after about 12-13 km/s. Importantly, these breakup products are similar but not identical to those found in the NIST Webbook, where histidine was intentionally shattered using electron ionization. This indicates that even in the event of breakup, the amino acid species can be recovered from the TOF data.

Ongoing work is determining if relative ratios of amino acids can be correctly measured, as this may enable impact ionization TOF instruments to detect biotics in icy dust grains above ocean worlds, and further analysis is determining the critical velocities for histidine's breakup products.

Detection of D-H Ratio

Coadded Negative Ion Spectra from a 80-84% Deuterium Mixture



Coadded negative ion spectra from aluminum dust impacts into water ice containing 80% deuterium ions (relative to hydrogen ions). The D-H ratio is important in formation models for icy moons throughout the solar system. Our TOF was able to correctly identify the ratio of deuterium to hydrogen in a water ice sample by coadding spectra. This means that impact ionization TOF instruments on fly-by spacecraft may be able to measure the D-H ratio of icy moons and help constrain their formation models.