Laboratory Study of Hypervelocity Impact-Driven Chemical Reactions and Surface Evolution of Icy Targets

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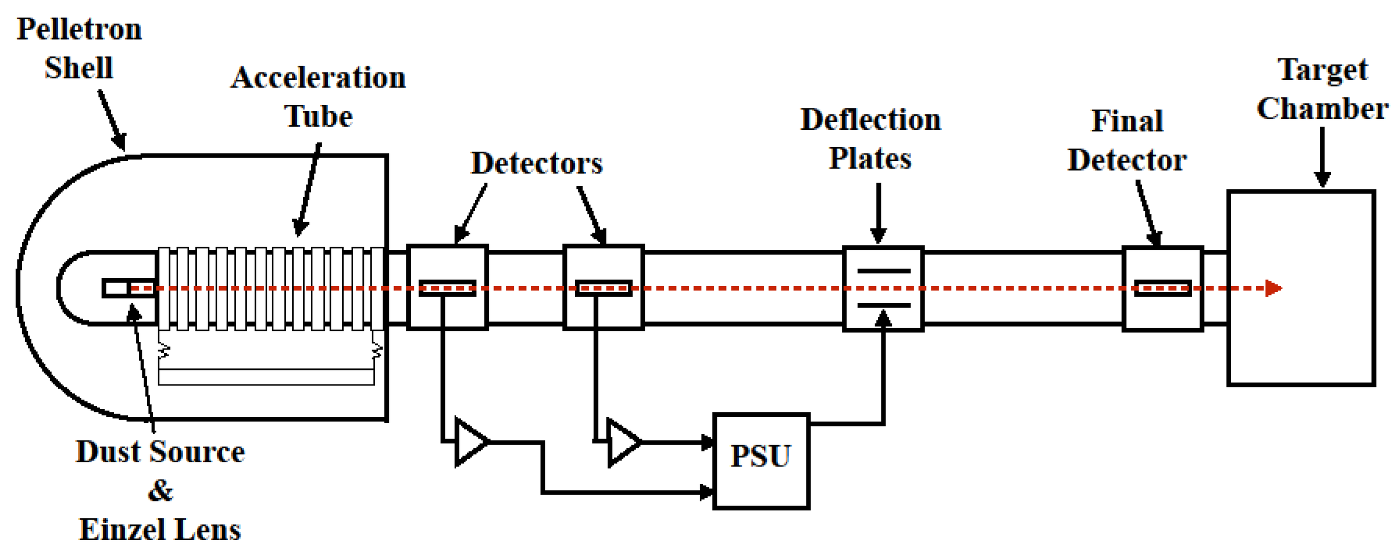
Project Overview

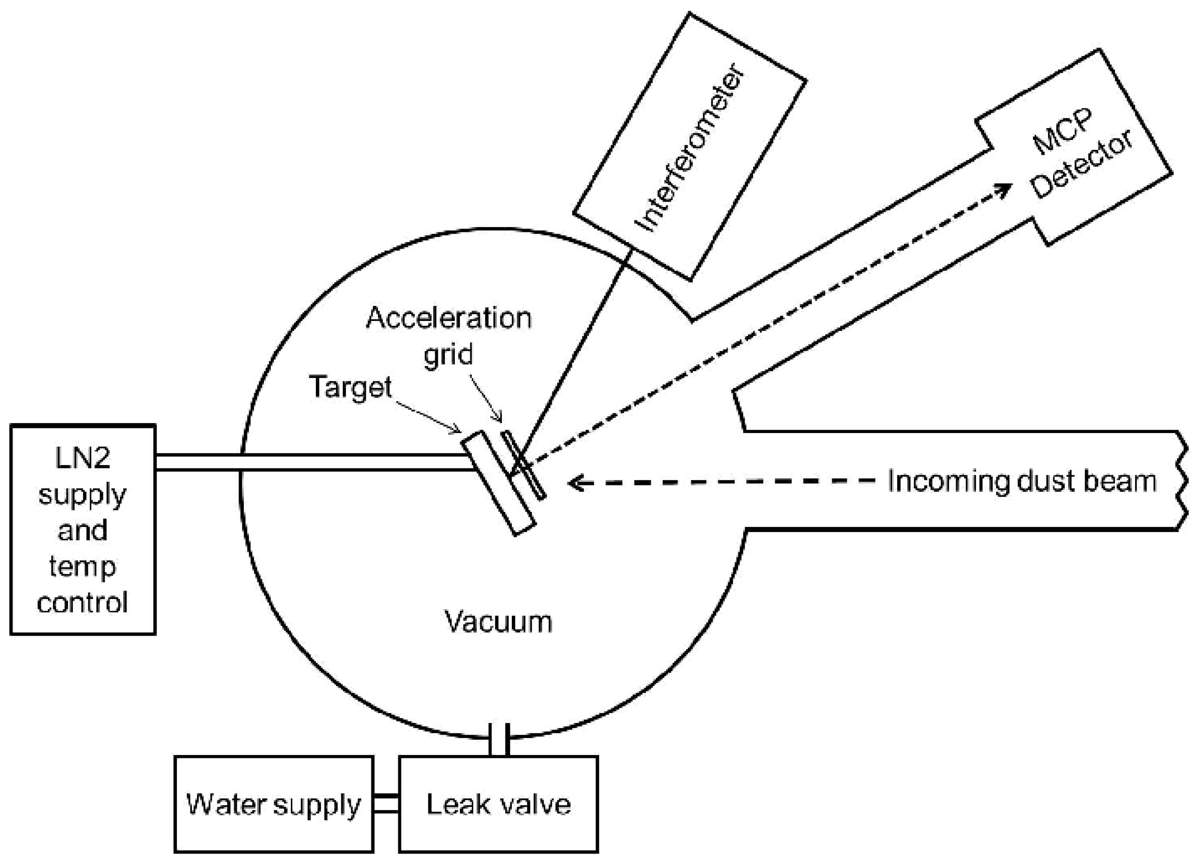
Interplanetary dust particle (IDP) impacts may be an important mechanism for creating complex organic molecules on airless icy bodies (e.g. icy moons of Jupiter and Saturn), but there is little experimental evidence about how dust impacts alter local chemistry. Further, several fly-by missions of Europa and other icy worlds have been proposed, which include studies of organic chemistry in ice dust picked up by impact-ionization time of flight instruments on fly-by spacecraft. However, it is not well understood if such chemistry can survive impact at typical fly-by velocities. While there have been numerous simulations of amino acid survivability for such fly-by missions to Europa or Enceladus, none have been performed with actual dust impact. With the creation of a cryogenically cooled ice target at the NASA SSERV Institute for Modeling Plasma, Atmospheres, and Cosmic Dust (IMPACT), it is now possible to study micrometeoroid bombardment in a controlled environment and at energies typically encountered in nature. Highly valuable data concerning the evolution of icy bodies under hypervelocity bombardment and the genesis of complex organic chemistry can be gathered in unique and tightly controlled experiments.

IMPACT Accelerator



- Dust velocity <100 km/s
- User-specified mass, velocity, size

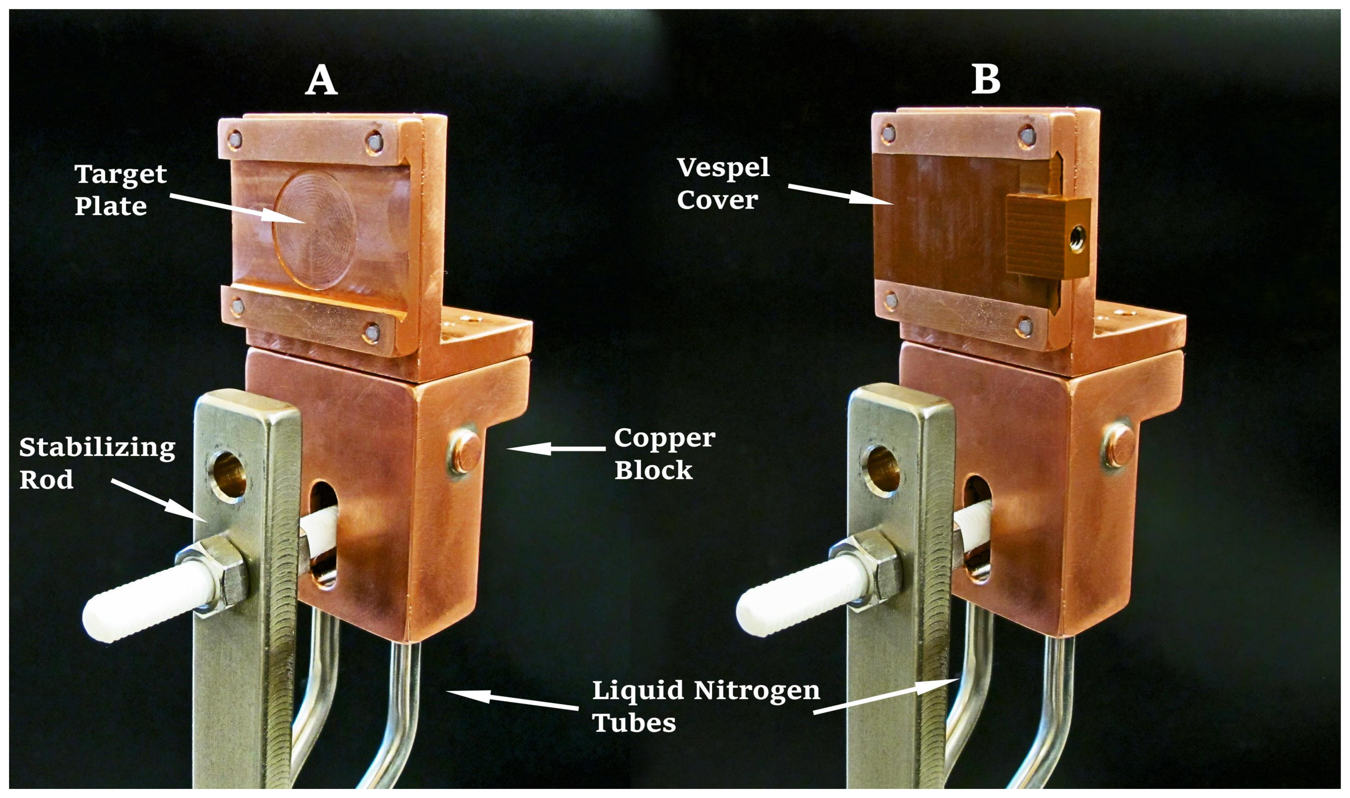
Cryogenic Ice Target



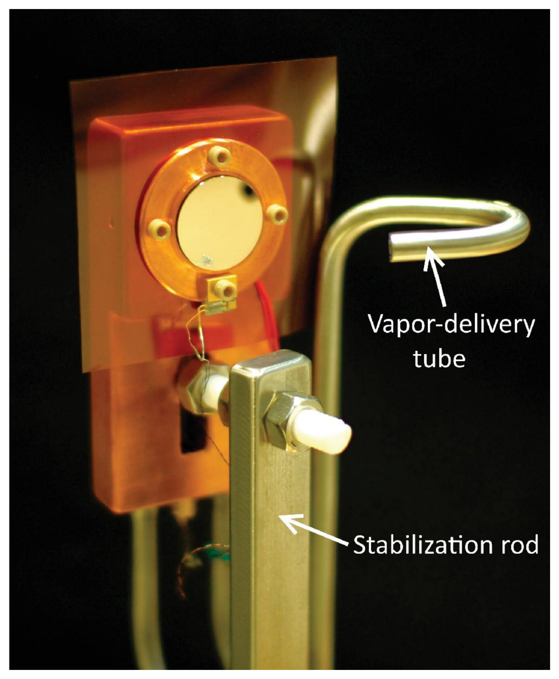
Dust particles strike ice surfaces prepared by vapor deposition or flash-freezing. Upon impact, ejecta plumes of ionized plasma are created. A high voltage grid accelerates these ions into a time of flight mass spectrometer to analyze plume composition.

Ice Production

Flash-Freezing and Vapor Deposition



To preserve homogeneity in salty ice mixtures, a flash-freezing setup has been created. Liquid mixtures are placed on the target plate, and a Vespel cover is slid into place. The upper assembly is then dropped into liquid nitrogen, freezing the mixture before salts can diffuse. The assembly is then quickly placed into the vacuum chamber, where the Vespel cover is removed after pumping down to high vacuum to prevent contamination from atmospheric moisture.

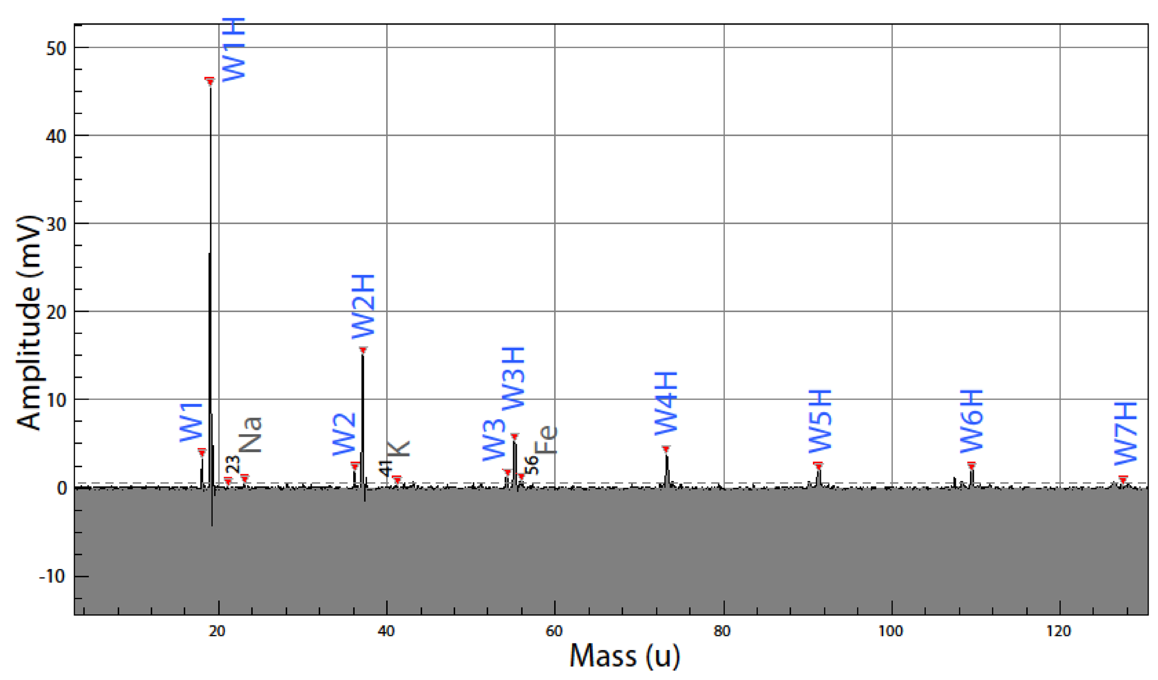


Simple mixtures such as pure water or methanol can be vapor deposited onto a gold-coated sapphire substrate. This allows for highly controlled growth at user-specified temperatures, as different temperatures yield different ice structures. Ice thickness can also be measured by Fabry-Perot interferometry using a laser reflected off the gold substrate.

Ongoing Experiments

Pure Water Spectra

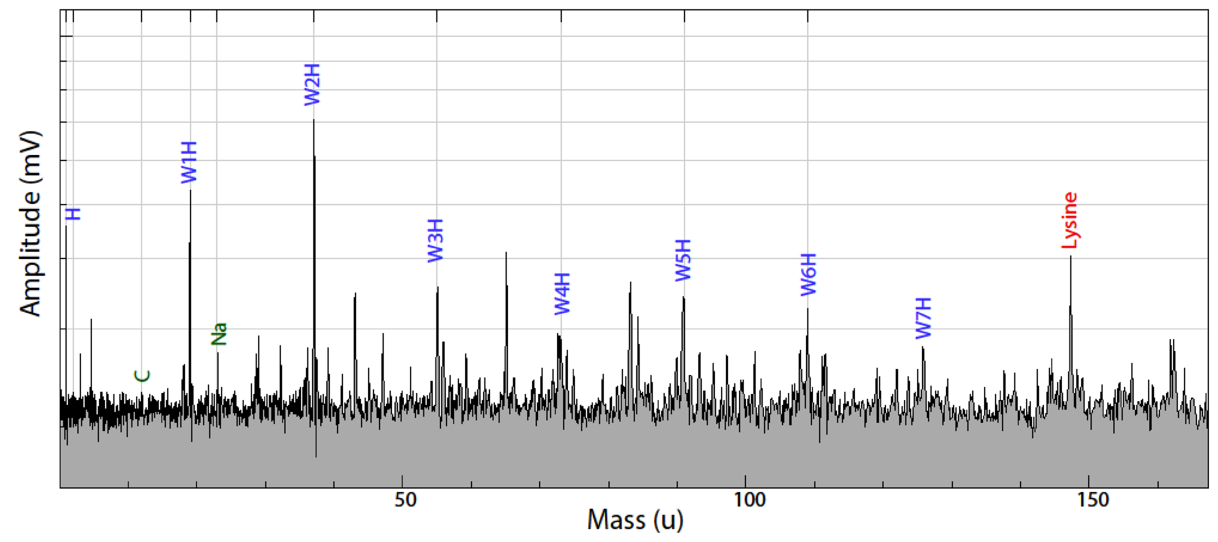
Iron dust particles are impacted into pure water ice prepared by cold (80 K) and warm (~150K) vapor deposition or by flash freezing. These experiments will **compare true dust impacts to laser or light-gas gun simulations**.



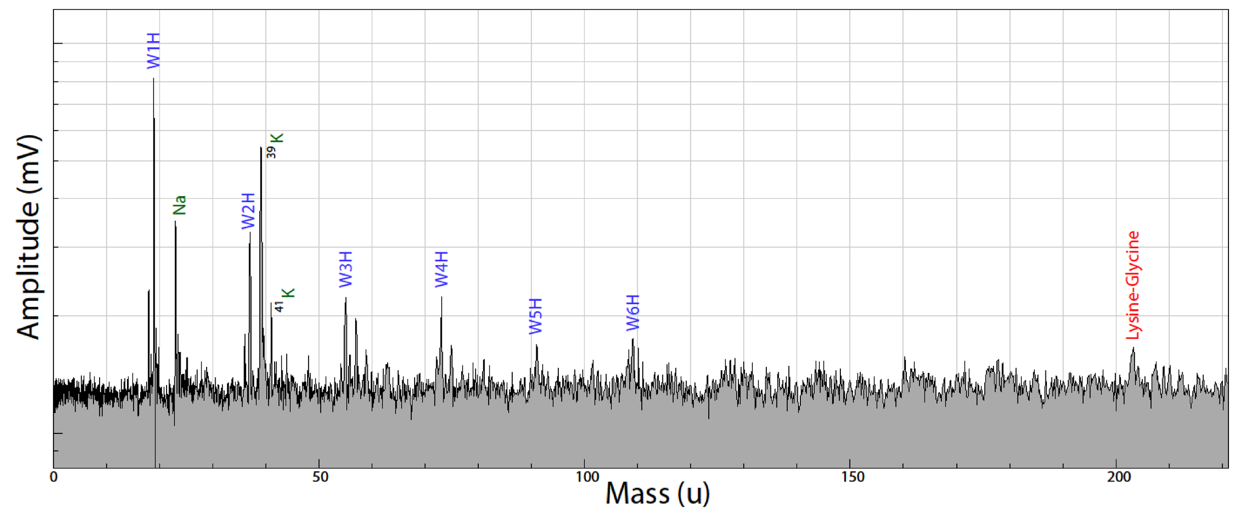
A spectrum produced by an 11 km/s iron particle impacting pure water ice.

Survivability of Organic Chemistry

Water is doped with amino acids or peptides (amino acid chains) and bombarded with dust to gain a clearer picture of the **survivability of complex organic chemistry and its dependence on velocity or other impact characteristics** in impact-ionization time of flight instruments. Early results show that some of this chemistry survives even high velocity impacts.



Spectrum produced by an 18 km/s impact into 1 molar **lysine-water ice**.



Summed spectra from a water solution containing a **lysine-glycine di-peptide amino acid chain**. Summed spectra can be used to improve the signal-to-noise ratio and to increase the visibility of low-amplitude mass lines.

Upcoming Experiments

The ion yield of actual dust impacts is not well understood, and this is important for the gardening effect of micro-meteoroid bombardment of atmosphere-less surfaces. We will **determine the ion production of typical dust impacts into ice surfaces.** We will also introduce salt to the ice to **study how ion yields change with salt concentration.**

While CO_2 has been observed in icy Saturnian moons, the mechanism for its creation is not well understood. A pilot study will **determine the instrument sensitivity to CO_2 frozen into the ice.** We will then impact **carbonaceous dust, such as graphite, into water ice and iron particles into carbon bearing ice, such as methanol**. This will determine if hypervelocity dust impacts can explain these observations.

Laser ablation and light-gas gun experiments have been successful in **creating simple organic chemistry from base components**, and this suggests that IDPs may be a mechanism for creating complex organic chemistry and amino acid precursors. We will determine if IDPs can create this chemistry and what **velocity ranges and critical chemical precursors are most effective for amino acid production**.