Impact-Ionization Mass Spectrometry of Cosmic Dust

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Abstract

In situ characterization of cosmic dust grains typically involves impact-ionization time-of-flight mass spectrometry. Considering the performance and limitations of previous instruments, I designed and tested a novel, compact time-of-flight mass spectrometer for cosmic dust analysis. The instrument, Dustbuster, incorporates a large target area with a reflectron, simultaneously optimizing mass resolution, particle detection, and ion collection. Dust particles hit the 65-cm^2 target plate and are partially ionized by the impact. The resulting ions, with broad energy and angular distributions, are accelerated through the modified reflectron, focusing ions spatially and temporally to produce high-resolution spectra.

Initial performance tests of the Dustbuster used laser desorption ionization of embedded metal and mineral samples to simulate particle impacts. Mass resolution (mass/peakwidth) in these experiments ranged from 60 to 180, permitting resolution of isotopes. Subsequent experiments included hypervelocity microparticle impacts. Charged iron and copper microparticles, accelerated to 2-20 km/s in a 2 MV van de Graaff accelerator, impacted the Dustbuster. Mass resolution in these experiments ranged from 150 to 300 for iron and copper. Hydrogen, carbon, and oxygen ions appeared in many spectra. Field-induced emission of electrons immediately before

impact is a possible cause of ion formation from species with high ionization potentials. The implications of this ionization effect are discussed in relation to interpretation of mass spectra from other *in situ* dust analyzers.

Another time-of-flight instrument, originally designed as an energy analyzer, shows promise as a high-resolution mass spectrometer for high-flux cosmic dust environments.

Ice is an important component of particulates ejected from comets and other icy bodies in the solar system. Due to limited experimental data on ice particle impacts, I built an ice particle source based on a vibrating orifice aerosol generator connected directly to vacuum. Ice particles produced in this manner can be electrostatically accelerated for impact ionization studies.

Hypervelocity impact vaporization may have played a key role in the mass extinction that occurred at the Cretaceous-Tertiary (K-T) boundary. In order to study the speciation of gases that may have been produced in such an asteroid impact, I designed a specialized orthogonal extraction mass spectrometer for future laboratory impact experiments.