

UNDERSTANDING THE EFFECTS OF COLLISIONAL EVOLUTION AND SPACECRAFT IMPACT EXPERIMENTS ON COMETS AND ASTEROIDS

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Introduction: Comets and asteroids have endured impacts from other solar system bodies that result in outcomes ranging from catastrophic collisions to regolith evolution due to micrometeoroid bombardment of the surface ices and refractory components. Experiments designed to better understand these relics of solar system formation have been conducted on Earth in a laboratory setting, as well as in space through, e.g., the Deep Impact mission to Comet Tempel 1 [1]. Deep Impact fired a high-speed impactor into the roughly 6 km nucleus of the comet. The ejecta plume generated by the impact was studied by both spacecraft instrumentation and groundbased telescopes.

A future impact mission called AIDA, or Asteroid Impact and Deflection Assessment, is now being designed collaboratively between ESA, NASA, the Observatoire de la Côte d'Azur (OCA), and the the Johns Hopkins Applied Physics Lab (JHU/APL) [2]. This mission would combine the Asteroid Impact Mission (AIM, led by ESA) with the Double Asteroid Redirect Test (DART) Mission (led by JHU/APL and NASA). These spacecraft would impact both asteroids in the 65803 Didymos system, including the 800m primary asteroid by AIM and its 150-m Didymoon companion by DART. The goal of the mission is to better understand potentially hazardous asteroids through investigating the effects of a kinetic impact on a small asteroid. To that end, AIM will carry a host of scientific instruments onboard to characterize the ejecta material within the plume due to the impact by DART.

Experiments: Inspired by the Deep Impact mission, a suite of laboratory based impact experiments have been conducted in the Experimental Impact Laboratory at the NASA Johnson Space Center. These experiments are designed to better understand collisions occurring both amongst solar system bodies throughout

their lives, as well as the results of the spacecraft generated impacts. Utilizing the vertical gun, minerals commonly detected in the dust of comets and on the surfaces of asteroids have been targeted for impacts at 2 – 2.8 km s⁻¹. This includes both solid and granular magnesium rich forsterite and orthoenstatite, diopside, magnesite, and siderite minerals. With the ability to cool targets by use of a cold jacket, fed by liquid nitrogen into the vacuum chamber, targets can be cooled down to roughly -100C, and their temperature monitored by thermocouples attached to the target container. The minerals were emplaced in grains of laboratory grade KBr to allow the shock front to pass through the target material, much like the refractory components on the surfaces of asteroids or comets.

Analysis: To determine the effects of both collisional evolution and spacecraft induced impacts, the materials were analyzed using a Fourier Transform Infrared Spectrometer (FTIR), Scanning Electron Microscope (STEM) and Transmission Electron Microscope (TEM). Evidence of shock imparted by the impacts can be seen in both shifting of the peaks of the infrared spectra, as well as planar dislocations in the TEM images. Comparison of effects with respect to target temperature, impact speed, and peak pressure will be presented.

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References:

- [1] https://www.nasa.gov/mission_pages/deepimpact/mission/
- [2] <https://www.nasa.gov/planetarydefense/aida>