Catching Pieces of a Comet

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In the early morning of January 15, 2006, a small spacecraft named Stardust completed its 7-year mission to a comet and returned to Earth, delivering a precious cargo of dust samples from the tail of Comet Wild-2. These were the first solid samples to be brought back to Earth by NASA since the 1960s Apollo missions to the Moon. Scientists from around the world eagerly awaited a chance to get a detailed glimpse of the dusty material that was a witness to the very birth of our solar system. Astromaterials Research and Exploration Science (ARES) scientists played key roles in the recovery of the spacecraft after its fiery descent onto a dry lake bed in Utah and in transporting the samples back to the Stardust Laboratory at the Johnson Space Center, where the collection canister was opened and we had our first look at the samples inside.

The comet particles were trapped in an exotic material called silica aerogel – an extremely low-density and transparent solid. The special properties of aerogel allowed the comet particles to be stopped and preserved even though they hit the aerogel with a velocity six times faster than a speeding bullet. To the surprise and delight of Stardust mission members, many large dust impacts were easily visible to the naked eye. In the Stardust Laboratory, Fred Hörz and ARES curation staff members Tom See, Ron Bastien, and Jack Warren photographed and documented the entire collection. Keiko Messenger took the lead in the "heavy lifting," deftly extracting and subdividing numerous microscopic comet particles from the aerogel, thus providing samples for dozens of scientists all over the world.

Fred Hörz, Lindsay Keller, Tom See, and Mission Principal Investigator Don Brownlee examine the Stardust collector.

A bulbous track (~11 mm total length) in aerogel from the Stardust mission.

In a first for a sample return mission, a large segment of the scientific community – which included nearly 200 scientists from around the world – was involved in the initial analyses. ARES laboratories were ready for the preliminary analysis of Stardust samples with an array of state-of-the-art instruments provided by Stardust mission grants won by ARES scientists Scott Messenger, Lindsay Keller, Simon Clemett, and Mike Zolensky. The transmission electron microscope installed by Keller was used to probe the mineralogy and chemistry of the Stardust samples at nearly the scale of individual atoms, while Messenger made critical isotopic measurements with a first-of-its-kind ion microprobe to determine the origin of grains 1,000 times smaller than the diameter of a human hair. Analyses of the molecular makeup of the organic matter in Stardust grains were obtained using a sophisticated mass spectrometer built by Clemett.

What have we learned from the Stardust samples? One of the most important discoveries thus far was the identification of minerals in some of the comet particles that could only have formed at extremely high temperatures very close to the early sun. How did mineral grains that formed so close to the sun end up in a comet that came together in the icy region beyond the orbit of Neptune? Earlier models predicted that turbulence within the disk of gas and dust that became the planets would mix together these hot and cold grains, while other models required that some grains formed close to the sun could be blown out and scattered onto the disk by stellar winds. The Stardust samples will allow us to test these models for the first time. They will also allow us to develop new models since the samples are on Earth and available for additional study now and in the future, when even more sophisticated analyses will be obtained by future generations of scientists.

Another major discovery from the analyses of the comet samples was the finding of particles rich in organic matter. Comets are believed to have brought water and organic matter to the early Earth. It is important to understand the nature of these materials because they are necessary ingredients for the origin of life. One of the first analyses obtained on the samples using the ARES infrared microscope showed abundant hydrocarbons in many of the particles. Subsequent analyses revealed that some of this organic matter formed in the cold cloud of dust and gas that was the precursor to the solar system.