Comet particles provide glimpse of solar system's birth spasms

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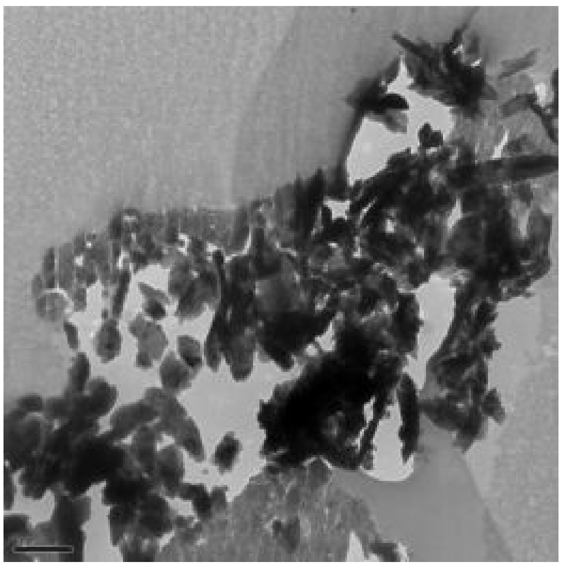

A transmission electron microscope image (magnified 5,000 times) of a slice of the Inti particle, which NASA's Stardust spacecraft collected in 2004 and returned to Earth two years later. Preparation of the sample caused some breakage. Scale bar is one micron, or one millionth of a meter. Image courtesy University of Chicago

Scientists are tracking the violent convulsions in the giant cloud of gas and dust that gave birth to the solar system 4.5 billion years ago via a few tiny particles from comet Wild 2.

These convulsions flung primordial material billions of miles from the hot, inner regions of the gas cloud that later collapsed to form the sun, out into the cold, nether regions of the solar system, where they became incorporated into an icy comet.

"If you take a gas of solar composition and let it cool down, the very first minerals to solidify are calcium and aluminum-rich," said Steven Simon, Senior Research Associate in Geophysical Sciences at the University of Chicago. And comet Wild 2 does contain these and other minerals formed at high temperatures. "That's an indication of transport from the inner solar system to the outer solar system, where comets are thought to have formed," he said.

Simon presents his data in the November 2008 issue (expected to be published early next year) of *Meteoritics and Planetary Science*. His 11 co-authors include Lawrence Grossman, Professor in Geophysical Sciences at the University of Chicago.

Either turbulence within the nebula, or a phenomenon called bipolar outflow from the early sun could account for the long-distance transport of cometary material, according to Simon and his Meteoritics co-authors.

Bipolar outflow results when the rotating disks that surround developing new stars jet gas from their polar regions, which astronomers have observed telescopically. "That's part of the so-called X-wind model, which is somewhat controversial," Simon said.

The controversial aspect of the X-wind model is the claim that the process would produce the kind of granules that Simon and his colleagues have now identified in comet Wild 2. Another less likely possibility: The cometary material in question may have formed around another star of composition similar to the sun, then drifted into the outer reaches of the solar system. There it became incorporated into comet Wild 2.

The extraterrestrial dust particles that Simon and his colleagues examined were among thousands that NASA's Stardust spacecraft collected from comet Wild 2 in January 2004. Two years later, Stardust became the first mission to return samples of a comet to Earth.

Simon, Grossman and collaborators identified all three particles described in the Meteoritics study as pieces of a shattered refractory inclusion, one of the most unusual and informative materials discovered in early analyses of the Wild 2 samples. Such inclusions, found in some meteorites, formed by condensation from the gas in the solar nebula at temperatures of more than 2,500 degrees Fahrenheit early in the history of the solar system.

The three particles were named Inti, Inti-B and Inti-C, after the Incan sun god. The original, unbroken particle would have measured no more than 30 microns across, much narrower than a human hair.

As Simon, Grossman and a team of colleagues reported in 2006, Inti contains a suite of minerals that likely were forged in fiery conditions found deep inside the cloud of gas and dust that formed the sun, Earth and the planets. And yet comets probably formed in the outer reaches of the solar system, far beyond Neptune.

Contributing to an array of scientific analyses in the Meteoritics article were co-authors David Joswiak, Donald Brownlee and Graciela Matrajt of the University of Washington; Hope Ishii, John Bradley, Miaofang Chi, Jerome Aléon, Stewart Fallon and Ian Hutcheon of Lawrence Livermore National Laboratory in California; and Kevin McKeegan of the University of California, Los Angeles.

Most of this team, including Simon and Grossman, were among the 75 co-authors who published the first analysis of the comet Wild 2 particles in the Dec. 15, 2006, issue of the journal Science. A striking aspect of the Science and Meteoritics studies is the similarity in chemical composition between the Wild 2 samples and particles from carbonaceous chondrite meteorites. These meteorites contain material that has been unaltered since the birth of the solar system 4.5 billion years ago.

Equally striking is the complete lack of any water-bearing minerals in the cometary grains. Carbonaceous chondrites are rich in hydrated silicates, clay-like minerals that emit water when heated, "but there's no hydrated silicate in the comet sample," Grossman said.

Scientists organized the Stardust mission with the expectation that Wild 2's samples would reveal a bonanza of exotic minerals, including debris from stars that had met their demise long before the birth of the sun. They may need to
rethink how comets formed, according to Grossman.

"Because they're loaded with ices we've always thought that these are outer solar system objects," he said. "But maybe cometary ices formed much closer in, after the inner part of the solar nebula cooled off, and incorporated the high-temperature stuff that formed earlier."

The Stardust mission was scientifically important because comets are usually out of reach, Grossman said. And yet aside from the sun, they may be the most abundant material in the solar system. "There may be more stuff in the comets than in all the planets put together," he said.

Source: University of Chicago

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