Coordinated Microanalyses of Seven Particles of Probable Interstellar Origin from the Stardust Mission.

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Stardust, a NASA Discovery-class mission, was the first sample-return mission to return solid samples from beyond the Moon. Stardust was effectively two missions in one spacecraft: it returned the first materials from a known primitive solar system body, the Jupiter-family comet Wild 2; Stardust also returned a collector that was exposed to the contemporary interstellar dust stream for 200 days during the interplanetary cruise. Both collections present severe technical challenges in sample preparation and in analysis. By far the largest collection is the cometary one: approximately 300 µg of material was returned from Wild 2, mostly consisting of ~1 ng particles embedded in aerogel or captured as residues in craters on aluminum foils. Because of their relatively large size, identification of the impacts of cometary particles in the collection media is straightforward. Reliable techniques have been developed for the extraction of these particles from aerogel. Coordinated analyses are also relatively straightforward, often beginning with synchrotron-based x-ray fluorescence (S-XRF), X-ray Absorption Near-Edge Spectoscopy (XANES) and x-ray diffraction (S-XRD) analyses of particles while still embedded in small extracted wedges of aerogel called ``keystones'', followed by ultramicrotomy and TEM, Scanning Transmission X-ray Microscopy (STXM) and ion microprobe analyses (e.g., Ogliore et al., 2010). Impacts in foils can be readily analyzed by SEM-EDX, and TEM analysis after FIB liftout sample preparation.

In contrast, the interstellar dust collection is vastly more challenging. The sample size is approximately six orders of magnitude smaller in total mass. The largest particles are only a few pg in mass, of which there may be only ~10 in the entire collection. The technical challenges, however, are matched by the scientific importance of the collection. We formed a consortium carry out the Stardust Interstellar Preliminary Examination (ISPE) to carry out an assessment of this collection, partly in order to characterize the collection in sufficient detail so that future investigators could make well-informed sample requests. The ISPE is the sixth PE on extraterrestrial collections carried out with NASA support. Some of the basic questions that we asked were: how many impacts are there in the collector, and what fraction of them have characteristics consistent with extraterrestrial materials? What is the elemental composition of the rock-forming elements? Is there crystalline material? Are there organics?

Here we present coordinated microanalyses of particles captured in aerogel, using S-FTIR[5], S-XRF[7-9], STXM[6], S-XRD[10]; and coordinated microanalyses of residues in aluminum foil[13], using SEM-EDX, Auger spectroscopy, STEM, and ion microprobe. We discuss a novel approach that we employed for identification of tracks in aerogel[3], and new sample preparation techniques developed during the ISPE[4]. We have identified seven particles – three in aerogel and four in foils – that are most consistent with an interstellar origin. The seven particles exhibit a large diversity in elemental composition[2]. Dynamical evidence, supported by l~~L~~aboratory simulations of interstellar dust impacts in aerogel and foils[11], and numerical modeling of interstellar dust propagation in the heliosphere[12], suggests that at least some of the particles have high optical cross-section, perhaps due to an aggregate structure. However, the observations are most consistent with a variety of morphologies.

References:
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