FOUR INTERSTELLAR DUST CANDIDATES FROM THE STARDUST INTERSTELLAR DUST COLLECTOR.

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Introduction: In January 2006, the Stardust sample return capsule returned to Earth bearing the first solid samples from a primitive solar system body, Comet 81P/Wild2, and a collector dedicated to the capture and return of contemporary interstellar dust. Both collectors were $\sim$0.1 m^2 in area and were composed of aerogel tiles (85% of the collecting area) and aluminum foils. The Stardust Interstellar Dust Collector (SIDC) was exposed to the interstellar dust stream for a total exposure factor of 20 m^2·day [1]. The Stardust Interstellar Preliminary Examination (ISPE) is a consortium-based project to characterize the collection using non-destructive techniques. The goals and restrictions of the ISPE are described in [2,3]. A summary of analytical techniques is described in [4].

Tracks We have so far identified 54 particle tracks in the aerogel collector. The distribution of azimuth angles is shown in Fig. 1.

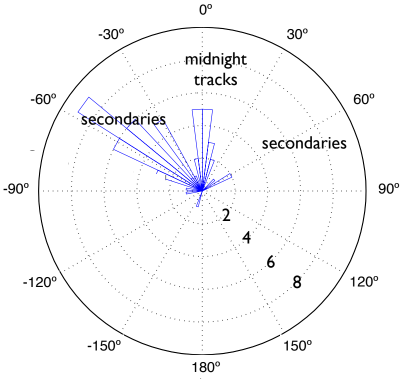

Fig. 1: Rose diagram of trajectories of 54 off-normal tracks. For details, see Westphal *et al.* [5]

"Midnight" tracks: A population of 16 tracks with $\sim -20^\circ < \phi < +20^\circ$ (so-called "midnight" tracks) are consistent in their trajectories with an origin in the interstellar dust stream (for particles with $\beta \sim 0$), or with secondaries from an impact or impacts on the lid of the sample return capsule (SRC). The ambiguity is due to the articulation of the collector during exposure [5]. To determine the origin of these particles, we extracted four of them in keystones and picokeystones [6], mounted them in silicon nitride sandwiches [4], and analyzed them on the X-ray fluorescence microprobe ID13 at the European Synchrotron Radiation Facility (ESRF), on the X-ray fluorescence microprobe 2-ID-D at the Advanced Photon Source (APS), and on the scanning transmission X-ray microprobe 11.0.2 at the Advanced Light Source (ALS).

A track is considered to be a candidate for an impact by an interstellar dust particle if it has a trajectory consistent with an origin in the interstellar dust stream *and* it has a composition or chemistry consistent in a broad sense with extraterrestrial material. Based on these criteria, we have rejected as candidates most of the tracks that we have discovered. Examples of tracks rejected as candidates are particles containing Ce or Al metal. We have reported previously on two promising candidates that pass our criteria, track 30 (Orion/Sirius) and track 34 (Hylabrook)[5]. Here we report the discovery of two new candidates.

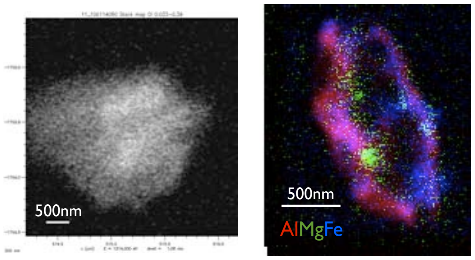

Fig. 2: (left) STXM Mg map of Sirius. (right) Al, Mg, Fe tricolor STXM map of Orion.

	Orion	Sirius
Mg	50 fg	230 fg
Al	840 fg	< 28 fg
Fe	5 fg	5 fg

Table 1: Composition of Orion and Sirius measured by STXM.

I1043,1,30: Orion/Sirius: The elemental composition of track 30 measured by a combination of XRF and STXM was reported last year [5,6]. STXM analysis of this track showed that the original projectile consisted of two particles that separated during capture and which have distinct compositions. The terminal particle, Orion, is Al-rich and XRD analysis shows a good fit to a spinel structure plus an additional, unidentified component. Al K-edge XANES shows that most of the Al is in an amorphous phase. The second particle, Sirius, is $\sim 3\mu$m upstream of Orion and is It is Mg-rich and shows no evidence of crystallinity. Neither of these particle compositions is expected from secondary ejecta from impacts on the SRC lid. The first XRF/XRD analysis, done at ID13 at ESRF, was done before the second particle was recognized, and was done in a geometry in which the two particles overlapped. A second XRF/XRD analysis was done at ID22 at ESRF in a modified geometry in order to resolve the two particles from each other. This analysis resulted in partial physical dispersion of Sirius, but had no observable effect on Orion. We give a detailed discussion of this unexpected effect in a companion abstract [7].

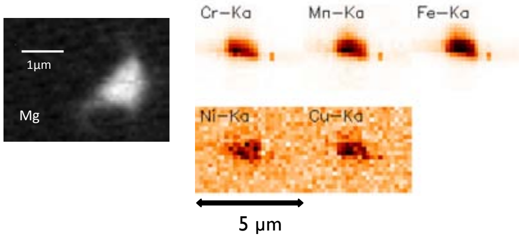

Fig. 3: (left) STXM Mg map of Hylabrook. (right) Cr, Mn and Fe XRF maps of Hylabrook taken at ID13.

I1047,1,34: Hylabrook: Hylabrook was first analyzed on the STXM beamline 11.0.2 at the ALS, then analyzed on the XRF/XRD beamline ID13, then returned to Berkeley for further analysis on 11.0.2. Hylabrook is a Mg-rich particle with Mg mineralogy distinct from Sirius [6]. This composition is unexpected from secondary ejecta from impacts on the SRC lid. In the 2.1 μm^2 terminal particle, the major element is 1.8 pg Mg (S:N >20). Minor Al was also detected (18 fg Al, S:N $\sim$1.2). The aerogel was too dense for either Fe or O measurement. Useful diffraction data were obtained at ID13, but we have not yet been successful in finding a unique fit to these data. Preliminary analysis indicates that Hylabrook consists of multiple crystals. The diffraction pattern shows an asterism of about 5 degrees. During the XRF/XRD analysis, fluence limits were inadvertently exceeded by approximately $\sim$ 160, which resulted in partial physical dispersion of Hylabrook. The core of the particle appears to be intact and the Mg XANES spectrum is somewhat modified. We give a detailed discussion of this unexpected effect in a companion abstract [7]. After Hylabrook was affected by hard x-ray irradiation, the Al was found in the surrounding halo, but not in the remaining core, and Mg was in both the halo and the core. This suggests Hylabrook comprises at least two different Mg phases; the bulk is Mg without Al, plus a small fraction Mg-Al.

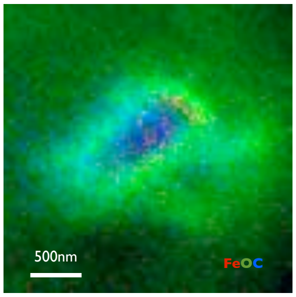

Fig. 4: STXM Fe,C,O map of Merlin.

I1047,1,37: Merlin: Merlin is a C-rich particle with minor Fe and trace Ti. Mg, Al and Si are below detection limits. Unlike Orion/Sirius or Hylabrook, track 37 has a composition that could originate as secondary material from an impact on the phenolic heatshield of the SRC lid, although the presence of Fe is unexpected. Samples of the heat shield will be required to make a comparison. We were not able to do C XANES on this particle because of the large optical depth of the picokeystone near the C edge. STXM analyses found Track 37 terminal particle is 1.7 μm^2 containing 51 fg C and 2.6 fg Fe (Atomic C/Fe $\sim$90). The signal-to-noise from aerogel background for both measurements was approximately 2. The O map shows 253 fg O in a 2.3 μm^2 aerogel shell. We placed an upper limit of 4 fg on Mg.

I1003,1,40: Track 40 was discovered during preparation for automated scanning. Track 40 is unique among the candidates in having a morphology that appears to be consistent with very high speed ($>$ 15 km sec^{-1}) capture. Organic materials were below detection limits in an FTIR analysis. STXM analysis showed Mg, Al below detection limits. Si and C were detected in the track walls, but it is not clear whether this is simply compressed aerogel (with indigenous C) or is residue from the projectile. We identified two terminal particles. One tentatively showed 0.2 fg Fe in 0.07 μm^2; since we did not do an energy stack, errors are factor of $\sim$2. This particle also tentatively indicated 0.4 fg (6 fg μm^{-2}) of C, but the aerogel background was $\sim$10$\times$ higher than this, $\sim$ 60 fg/$^{\mu}$m^2. STXM is particularly sensitive for C and Fe, so Mg or Al present in these quantities ($<$1 fg) would be below detection thresholds.

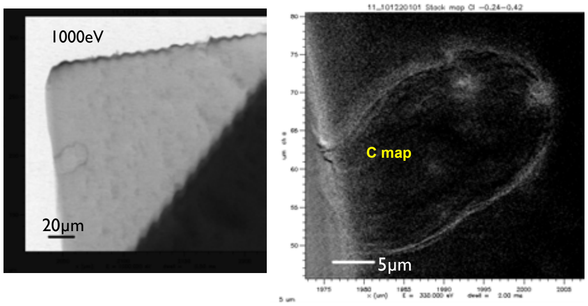

Fig. 5: (left) Track 40 image in its picokeystone at 1000 eV. (right) STXM C map of Track 40.

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References: [1] Tsou, P., *et al.* (2003) JGR *108*, E10. [2] Westphal A. J. *et al.* (2008) 39th LPSC, 1855. [3] Westphal A. J. *et al.* (2009) 40th LPSC, 1786. [4] Westphal A. J. *et al.* (2009) 20th Int. Conf. on X-ray Optics and Microanalysis, in press. [5] Westphal A. J. *et al.* (2010) 41st LPSC, 2050. [6] Westphal A. J. *et al.* (2010) MAPS Suppl *73*, 5302. [7] Simionovici, A. *et al.* (2011) these proceedings.