ALUMINIUM FOILS OF THE STARDUST INTERSTELLAR COLLECTOR; THE CHALLENGE OF RECOGNISING MICROMETER-SIZED IMPACT CRATERS MADE BY INTERSTELLAR GRAINS.

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Introduction: Preliminary Examination (PE) of the Stardust cometary collector [1] revealed material embedded in aerogel and on aluminium (Al) foil. Large numbers of sub-micrometer impact craters gave size, structural and compositional information [2,3]. With experience of finding and analyzing the picogram to nanogram mass remains of cometary particles, are we now ready for PE of the Interstellar (IS) collector? Possible interstellar particle (ISP) tracks in the aerogel are being identified by the stardust@home team [4]. We are now assessing challenges facing PE of Al foils from the interstellar collector.

Interstellar particle collections: The IS collector was deployed to intercept the stream of ISP for a total of 195 days during two periods in 2000 and 2002, at a heliocentric distance between 2 and 2.6 AU. The flux of ISP is likely to have been ca. 7×10^{-5} m^{-2} s^{-1} [5], implying a total fluence of ca. 1200 particles > 80nm per square meter, impacting with a relative velocity of up to 26 kms^{-1}. Galileo and Ulysses dust analyser data [6] suggest a peak in abundance at a particle size of ca. 300nm, and probably a minimum size of 50nm.

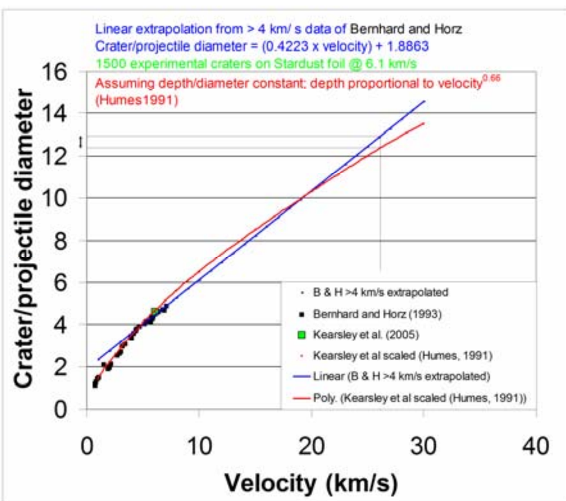

Figure 1. Extrapolation of existing crater size calibration data. Experimental data is still needed for 10-30 kms^{-1} range to bracket Stardust ISP collection velocity. Raw data plotted is extracted from [7], and Stardust foil craters [8] scaled by relationship described in [9].

What might have been collected: There is currently no extensive direct experimental crater size calibration of sub-µm impact features at an appropriate velocity for the IS collector. Existing calibrations are mainly based upon larger particles at lower velocity [7,8]. Scaling of these older data [9] yields an approximate relationship (Figure 1), with impact feature diameter ≈ 12.5 impactor diameter. Given total exposed area of foil, ca. 132 mm^2, fluence estimates suggest a total of perhaps only 15 features > 10 µm diameter from ISP impacts. The majority of ISP craters are likely to be below 5 µm diameter.

What could be determined: Optical microscopy may only find the very largest ISP impacts (e.g. > 5 µm). Finding sparse micrometer-scale impact craters on 'large' areas of foil will be time-consuming, needing automated, high-resolution scanning electron microscopy in instruments of high cleanliness for efficient determination of particle fluence and grain size distribution. Interpretation of scanned images may be difficult if the foils show extensive surface roughness (from handling during mounting of the aerogels), as was seen on the cometary side of the collector.

Micrometeoroid impacts on spacecraft in low Earth orbit (LEO) can yield detectable Mg silicate residues [10], suggesting such materials may be found under the similar velocity regime of the Stardust IS collection. Positive identification of ISP impacts will be a major objective during foil PE, although detailed compositional analysis is reserved for later research. Analogue impact experiments will be needed to assess alteration of particle composition during impact under appropriate conditions.

Distinguishing spacecraft secondary ejecta: The Stardust@home distributed search has identified likely spacecraft-derived secondary impacts in interstellar collector aerogel tiles. 15 oblique tracks have been found so far, apparently due to projectiles with low entry speed, some parallel and consistent in trajectory with > 1 µm secondary ejecta from impacts on the aft solar panels (Fig. 2). Hundreds of extremely small, parallel tracks (submicron grains?) are heterogeneously distributed and may come from one impact.

Our volumetric measurements of LEO solar cell impacts show ejecta can exceed 200 x impactor mass, with perhaps 15% ejected in a conical sheet of glass fragments > 100nm, at ca. 60 degrees from the cell surface [11]. Although most ejecta tracks should be distinguishable by oblique orientation, during collector maximum inclination (Fig. 2) ejecta from a small area on each panel may approach perpendicular to the collector. Unfortunately, Al foil craters from secondary ejecta may not be easy to distinguish by shape.

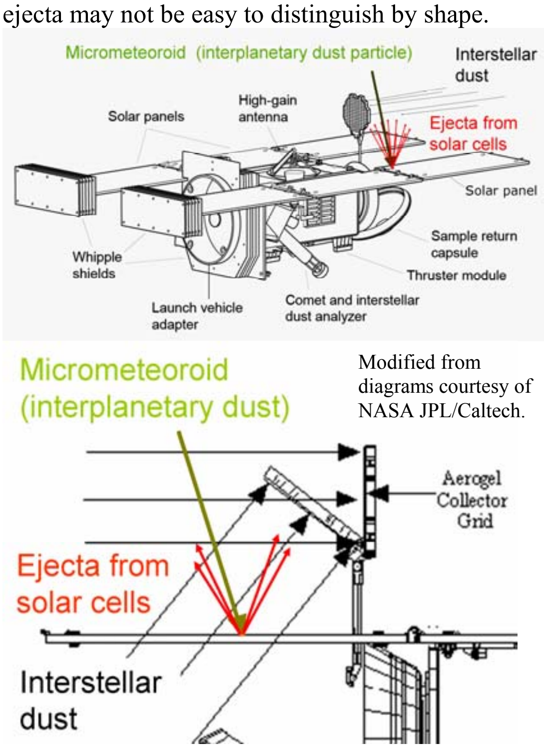

Figure 2. Possible impacts on the aft solar panels.

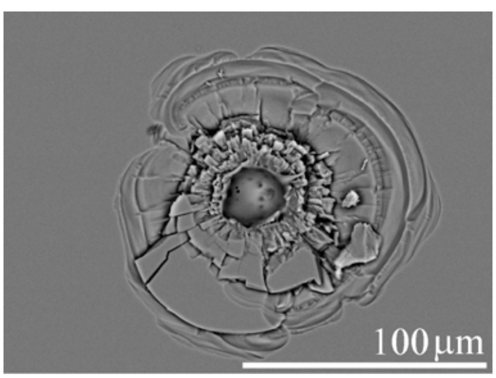

Figure 3. Backscattered electron image (BEI) of LEO micrometeoroid impact on Hubble Space Telescope (HST) solar cell, with inner melt pit (source of jets), surrounding shatter zone (source of fragmental ejecta cone) and broad conchoidal spallation zone.

Fortunately, Stardust solar cells were of a widely used type [12] and it is likely that ejecta can be recognized from distinctive refractory composition (Figure 4), especially if the cover glass is Mg and F coated radiation-resistant Ce-rich borosilicate. Microanalysis of crater and track contents by non-destructive and non-contaminating methods will be required during PE to screen out secondary ejecta impacts from potential ISP samples, before selection for post-PE detailed analysis.

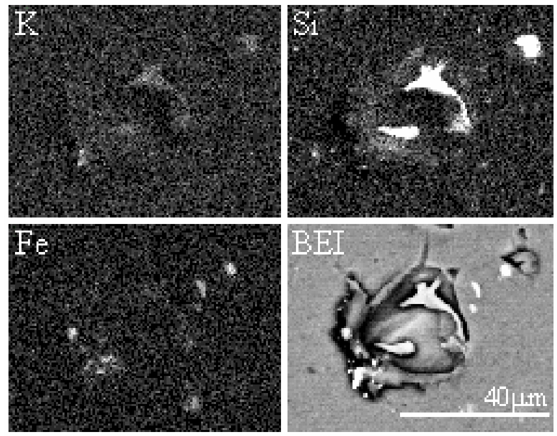

Figure 4. X-ray maps and BEI show mixed secondary ejecta residue of solar cell glass (K and Si rich) and projectile (FeNi metal) in an impact feature on Al plate held above the site of a primary hypervelocity light gas gun impact on a HST solar cell.

Conclusions: Preliminary Examination of the aluminium foils on the interstellar particle collector will require exhaustive high resolution imaging, with emphasis on identification and rejection of impacts by secondary spacecraft ejecta. PE should provide both ISP fluence/grain-size distribution data and the precise locations of craters for subsequent detailed elemental and isotopic analysis.

References: [1] Brownlee D.E. et al. (2006) *Science, 314,* 1711-1716. [2] Hörz F. et al. (2006) *Science, 314,* 1716-1719. [3] Kearsley A. T. et al. *MAPS* in press. [4] Westphal A.J. et al. (2007) *LPSC* abstract #1457. [5] Altobelli N. et al. (2005) *Workshop on Dust in Planetary Systems* abstract #4027. [6] Landgraf M. et al. (1999) *Planet. Space Sci., 47,* 1029-1050. [7] Bernhard R. P. and Hörz F. (1995) *Int. J. Impact Eng. 17,* 69-80. [8] Kearsley A. T. et al. (2006) *MAPS, 41.2*, 167-180. [9] Humes D. (1991) in Levine A. (ed.) NASA Conf. publication *3134,* S399-418. [10] Kearsley A. T. et al. (2007) *Adv. Space Res. 39,* 590-604. [11] Mandeville J.-C. and Bariteau M. (2004) *Adv. Space Res., 34,* 944-950. [12] Gasner S. et al. (2003) NASA Tech. Report Server, document 20060046258.

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