IDENTIFICATION OF IMPACT CRATERS IN ALUMINUM FOIL FROM THE STARDUST INTERSTELLAR DUST COLLECTOR: AN UPDATE. C. Floss. Laboratory for Space Sciences and Physics Department, Washington University, St. Louis, MO, USA. (Email: floss@wustl.edu)

Introduction: In addition to the first unambiguous cometary samples, from comet 81P/Wild 2 [1], NASA's Stardust mission was designed to collect the first samples of contemporary interstellar dust. The Stardust interstellar dust collector collected particles for 229 days during two exposures prior to the spacecraft encounter with Wild 2 and tracked the interstellar dust stream for all but 34 days of that time. The Al foils make up ~15% of the total collection surface and about 12-15 particles, with 2/3 of those less than ~1 µm in size, were expected to have impacted the available Al foil area.

The initial investigation of these samples took place under the auspices of the CAPTEM-approved Stardust Interstellar Preliminary Examination (ISPE). The ISPE proposed to carry out non-destructive, non-invasive searches for, and analyses of, interstellar dust candidates in the Stardust interstellar tray and focused on two parallel investigations: extraction and analysis of tracks in aerogel identified through Stardust@home, and search for and characterization of impact craters in the aluminum foils [2].

The work of the ISPE team resulted in the discovery and characterization of seven probable interstellar dust particles [3], four of which were identified from impact craters in the Al foil [4]. At the formal conclusion of the ISPE two years ago, only ~5% of the available Al foil area had been measured. We have continued the work of scanning Al foils from the Stardust interstellar tray in order to identify additional interstellar dust candidates. Here we report the results of our work to date.

Experimental: Foil scanning is done in automated mode using the JEOL 840a SEM at Washington University. By combining our instrument control software with custom written software, we are able to automatically map an entire foil in a single (long) run. Foils are divided into multiple grids of about 0.25 mm^2. Manual z-axis focusing is done in the center of each region, after which the grids are further divided into individual images 106 x 80 µm in size. The z-axis positions are interpolated from one grid center to the next to ensure good focus for all individual images in a grid and the x, y, and z coordinates are individually stored. The images are mapped at 15 kV, 5 nA for 10 sec per frame, providing a resolution of ~50 nm/pixel with a dwell time of 0.001 sec/µm^2. The entire array is imaged automatically in sequence, and each image is saved with a unique label identifying its position on the foil.

Images from the foils (~5000 for short foils and ~10,000 for long foils) are manually examined independently by at least two undergraduate students, and the candidate craters identified are subsequently ranked. The most likely candidates are then imaged at higher resolution to ascertain which are actual impact craters.

Results: We have scanned a total of four long (N) foils and two short (W) foils: 1010N, 1031N, 1032W, 1047N, 1061N and 1063W. Image examination is still in progress on foil 1010N, but we have identified a feature on this foil that appears to be an unusually large impact crater (Fig. 1). However, additional analysis (e.g., Auger spectroscopy and/or FIB/TEM) will be needed to confirm the identification. A similar feature found on foil 1047N during the ISPE ultimately turned out to be a hole created during the foil flattening process [4].

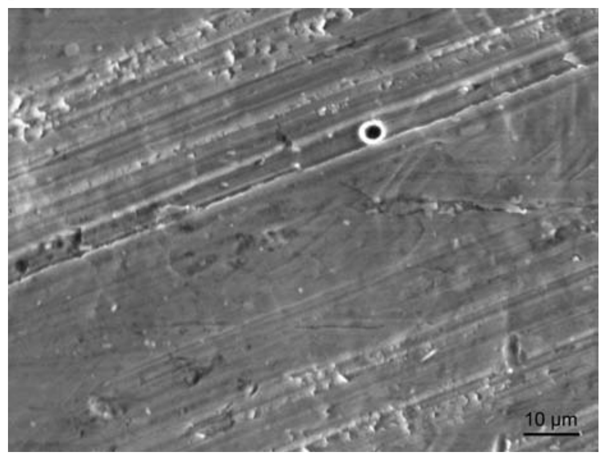

Figure 1. Secondary electron image 314@43 from interstellar foil 1010N,1. The impact feature is approximately 4 µm in diameter.

Approximately 2700 candidate craters were identified from the other foils, of which 1125 were selected for higher resolution imaging. Table 1 shows the resulting 19 likely impact craters. Eleven of these were investigated as part of the ISPE [4]; the remaining eight are shown in Fig. 2. While some are clear impact craters, others are more ambiguous and, like 314@43 mentioned above, will require additional analysis for confirmation.

Outlook: The number of impact craters identified on individual foils is clearly highly variable and the foils examined by our laboratory as part of the ISPE fortuitously contained a relatively high proportion of craters. Moreover, many of the potential new impact features shown in Fig. 2 are unconventional compared to 'traditional craters' and it remains to be seen whether compositional analyses can confirm an extraterrestrial or even secondary impact origin for these features. Despite these obstacles, the results of the ISPE demonstrate that continued scanning and examination of the Al foils on the interstellar collector has the potential to provide important new information about contemporary interstellar dust.

References: [1] Brownlee D. E. et al. (2006) *Science* 314, 1711-1716. [2] Westphal A. J. et al. (2008) *LPSC XXXIX*, #1855. [3] Westphal A. J. et al. (2014) *Science* 345, 786-791. [4] Stroud R. M. et al. (2014) *MAPS* 49, 1698-1719.

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Foil	Crater*	Diameter (µm)	Comments
1031N,1	*037@02*	*0.24*	*secondary impact*
	158@35	*0.56*	*secondary impact*
	183@23	0.31	
	196@04	0.64	
	201@14	0.55	
	216@45	*0.65*	*Mg, Si; available for additional analysis*
	218@25	0.52	
	239@11	*0.61*	*Mg, Si; available for additional analysis*
1032W,1	041@32	0.79	
1047N,1	012@04	0.28	
	272@14	0.17	
1061N,1	*022@44*	*0.35*	*Mg, Si; available for additional analysis*
	036@33	***0.37***	***interstellar dust candidate***
	041@33	*0.29*	*secondary impact*
	069@22	***0.39***	***interstellar dust candidate***
	135@30	***0.46***	***interstellar dust candidate***
	188@24	*0.66*	*secondary impact*
	205@32	*0.63*	*secondary impact*
1063W1,	007@44	0.41	

*craters in italics were investigated during the ISPE; those in bold are probable interstellar dust [4].

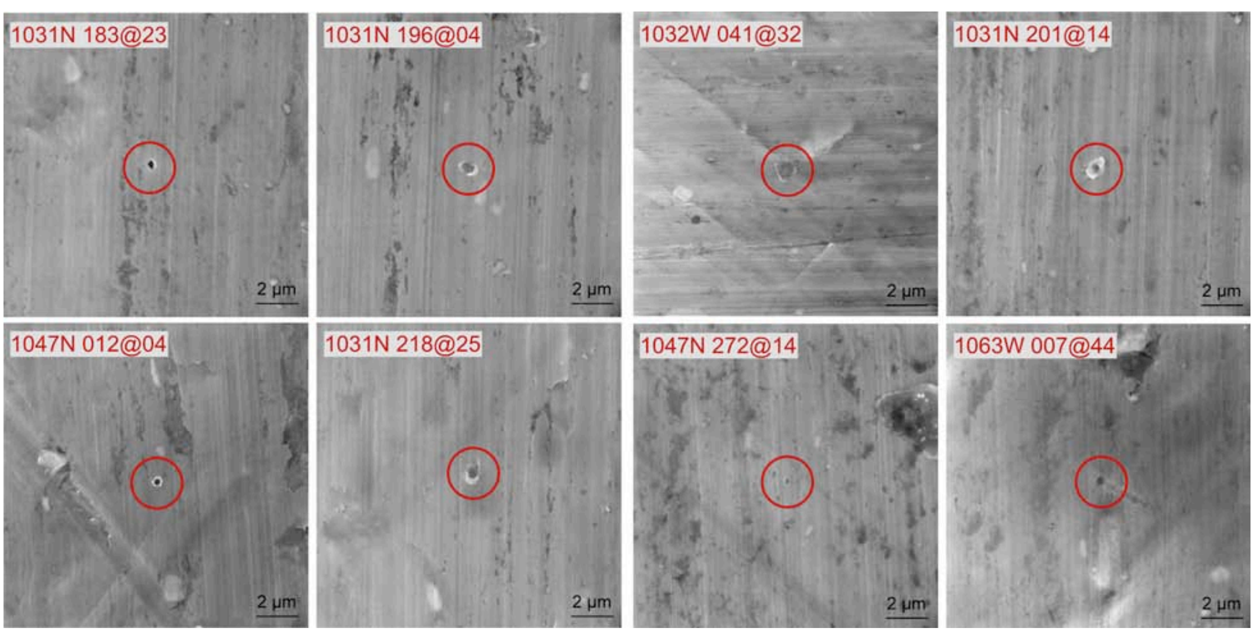

Figure 2. Secondary electron images of impact features from Stardust interstellar foils 1031N, 1; 1032W,1; 1047N,1; and 1063W,1.