A MASSIVELY DISTRIBUTED SEARCH FOR IMPACTS IN ALUMINUM FOIL ON THE STARDUST INTERSTELLAR COLLECTOR A. J. Westphal[1], A. L. Butterworth[1], B. T. De Gregorio[2], R. Lettieri[1], W. Marchant[1], R. M. Stroud[2], D. Zevin[1], 90 stardust@home "dusters"[3], [1] Space Sciences Laboratory, University of California at Berkeley, Berkeley CA 94720, USA, [2] Nanoscale Materials Section, Naval Research Laboratory, 4555 Overlook Ave SW, Washington, DC 20375 USA, [3] Worldwide

Introduction: The Interstellar Dust Collector on the Stardust spacecraft was exposed to the interstellar dust stream for ∼200 days in two intervals prior to the encounter of the spacecraft with comet Wild 2. The ∼0.1 m^2 collector consisted of silica aerogel tiles (∼85% of the area), and Al foils (∼15% of the area). The collecting media are complementary: aerogel is superior in preserving impactor mineralogy and in preserving trajectory information, and foils are superior in ease of isotopic analysis, in being free of the major-rock forming element Si, and in allowing identification of smaller impactors.

A consortium organized to identify and characterize impacts on the Interstellar Collector, the Interstellar Preliminary Examination (ISPE)[1], developed techniques to identify and characterize impacts in aerogel and foil collectors. In the aerogel tiles, impacts could be identified through optical microscopy. We and our colleagues developed an automated optical microscope to collect optical imagery, and we developed an online "virtual microscope" to enable citizen scientists to search for tracks, in a project called Stardust@home[2]. More than 30,000 citizen scientists have collectively carried out more than 10^8 searches, and this ongoing project has resulted in the indentification of >200 impactors in the aerogel tiles. Both individual and ensemble-wide detection efficiency was measured using calibration images, which constituted approximately 20% of the images. (The volunteer "dusters" were aware of the calibration images, but the identify of specific calibration images was hidden. The use of calibration images also enabled the generation of a score for each user, which served as a motivator, and was publicly posted on the Stardust@home website.) Among 71 tracks identified during the ISPE, three had characteristics consistent with an interstellar origin[4]. In contrast with tracks in the aerogel tiles, impacts in the foils result in craters that are too small to resolve optically, so the ISPE developed automated scanning procedures for Scanning Electron Microscopy[5]. The images were searched by eye and using automated algorithms[3], and as a result 25 impacts were identified, four of which were consistent in their characteristics with an interstellar origin[4].

As a complementary approach to searching within research groups and to automated identification, we have developed a new and separate instantiation of Stardust@home for the identification of craters in SEM images of the Al foils.

Methods: The foils were removed from the Stardust collector using a double-bladed "pizza cutter", resulting in strips ∼2mm wide and 15 mm or 30 mm long, depending on whether the foil was adjacent to the short or long side of the aerogel block. We used mounts developed for the purpose during ISPE, which stretched the foils flat to minimize focusing problems. We followed contamination control protocols[5], to avoid excessive carbon deposition on the foils during scanning. The foils were scanned at NRL with a FEI Nova 600 FIB-SEM at 40nm/pixel. We scanned foils I1020W and I1126N, resulting in 24405 total images, which were split and compressed, and $219,555$ images were uploaded to the Amazon Storage for access to the foils search Virtual Microscope. Figure 1 shows a typical field of view.

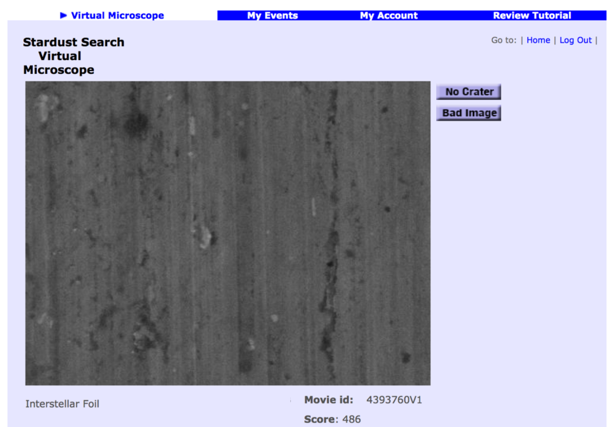

Fig. 1: A typical field of view on the foils search VM. The width of the field of view is 41μm.

Results: During the pilot phase of the foils search, ∼90 volunteers carried out ∼277,000 searches of ∼103,000 individual fields of view. As we do with Stardust@home, we measured detection efficiency using calibration images: based on responses to $11,965$ calibration images we measured a 96.4% ensemble-wide, single-volunteer detection efficiency. The scanning is still in progress, and the images were not distributed in a uniform manner. However, so far 17 features were identified as potential impactors at least four times, and 90 features were identified at least three times. As with the track search of Stardust@home, the goal of the foils search is not to definitively identify

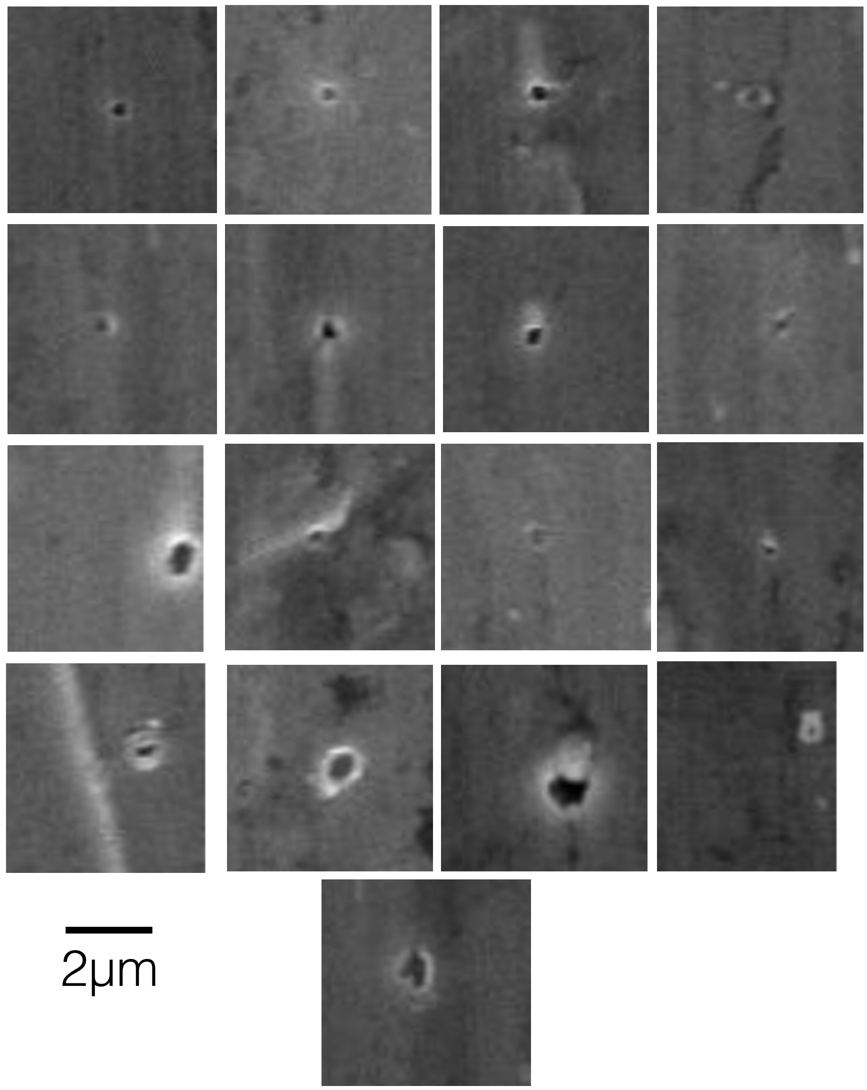

Fig. 2: Images of candidate impactors identified by Stardust@home foils search volunteers at least four times during the pilot phase of the foils search.

impacts, but to identify potential impacts with high confidence. Actual impacts are confirmed by subsequent high-resolution imaging, and EDX analysis to identify residues. We present the follow-up analyses on these candidates in an accompanying abstract in this conference proceeding[6].

In Fig. 2 we show images of the candidate impactors identified at least four times by Stardust@home foils search volunteers.

Discussion: The Stardust@home project has demonstrated that a massively distributed search with citizen scientists is an effective approach to identification of impact features in aerogel that are otherwise problematic to identify by automated means. Preliminary results from the Stardust@home foils search indicates that a similar approach may be effective for identification of impacts in aluminum foils.

References: [1] Westphal, A. J. et al. (2014) MAPS **49**, 1720. [2] Westphal, A. J. et al. (2014) MAPS **49**, 1509. [3] Westphal, A. J. et al. (2014) MAPS **47**, 729. [4] Westphal, A. J. et al. (2014) Science **345**, 786 [5] Stroud, R. M. et al. (2014) MAPS **49**, 1698. [6] Stroud, R. M. et al. (2016) this conference proceeding.