SEARCH FOR CONTEMPORARY INTERSTELLAR DUST IN THE STARDUST COLLECTOR. Andrew J. Westphal1, Ronald K. Bastien2, Anna L. Butterworth3, Josh Von Korff2, David Anderson3, Bryan Mendez1, Rastika Prasad1, Nicole Kelley1, David Frank1, Robert Lettieri1, Zack Gainsforth1, Christopher J. Snead1, Jack L. Warren3, Michael E. Zolensky2, 20064 Stardust@home “dusters”3, 3 Space Sciences Laboratory, University of California at Berkeley, Berkeley CA 94720, USA 2 KT NASA Johnson Space Center, Houston, TX 77058, USA 3 Stardust@home volunteers located world-wide.

Introduction

In January 2006, the Stardust return capsule returned to earth bearing the first samples of contemporary interstellar dust. Several dozen interstellar dust particles near 1 µm in diameter are estimated [1] to have been captured in the ~ 1000 cm² aerogel collector. Before they can be analyzed, these particles must be identified. Here we describe the effort to find these interstellar particles (ISP). This project consists of two distinct parts: the collection of high-magnification digital images of the collector, and a massive distributed web-based search for the ISP tracks in the aerogel collectors called Stardust@home.

Digital high-magnification imaging of the S IDC

The Stardust Interstellar Dust Collector (S IDC) consists of 132 aerogel tiles and 240 aluminum foils. The S IDC is under curation in the Cosmic Dust Laboratory at Johnson Space Center. We modified an automated scanning microscope to accommodate the S IDC. This microscope was developed several years ago at Berkeley for experimental nuclear astrophysics work. The automated microscope consists of a Leitz metallographic microscope with computer-controlled stage and focus. Imaging is done with a 1024×768 CCD camera with Firewire interface. A Mac mini computer controls the stage and acquires images from the CCD using Astro IIDC software (Aupperle Services and Contracting). We scan one aerogel tile at a time using a 10× objective, which results in a 480µm × 340µm field of view in the digital images. First, we measure altitudes of the surface of the tile on a coarse grid. We then generate a unix script using MATLAB that implements automated scanning of the tile. The MATLAB code interpolates between points on the coarse “focus map” to determine surface heights. In each field of view, we collect a stack of 43 images spanning ~ 200µm in focus depth, descending from just above the aerogel surface. Because of surface roughness, especially near the edges of the tiles, this interpolation fails approximately 20% of the time. The movies are collected at full resolution as ~25MB QuickTime movies. These movies are archived under JSC curation. Movies are then shipped to Berkeley for the next steps in the search. First, the movies are automatically separated into individual frames and compressed. They are then uploaded to Amazon Storage, which has generously donated extensive storage space and web access for this project.

Stardust@home implementation

Here we enlist the help of thousands of amateur collaborators in the search for the tracks of interstellar dust. To implement the Stardust@home project, we wrote a “Virtual Microscope” (VM) in html and javascript that emulates a real microscope. The VM runs on most web browsers and does not require the download of any software. URLs for the stack of images in a single field of view are delivered to the VM by a server at Berkeley. These point to images stored in the distributed Amazon Storage server. The user moves the computer mouse along a slider to focus up and down – behind the scenes, this causes the VM to rapidly slew through the stack of 43 images. The granularity of focussing mechanism is typically imperceptible.

If the user identifies a feature of interest, the user clicks on it. The VM records the position of the click, and asks for confirmation. If no feature is found, the user clicks a “no track” button. If the focus range is inadequate for searching, the user clicks a “bad focus” button. The VM reports the user action and coordinates within the field of view to the server, which records the event in a mysql database.

Each volunteer must go through an online tutorial and pass a test before registering and participating in Stardust@home. As of 12 December 2006, 20064 people had collectively performed more than 30 million searches. Through an online forum hosted on the Stardust@home website, participants have extensive discussions, and have named themselves “dusters.” We adopt this terminology here.

Stardust@home detector calibration

Large particle physics and particle astrophysics projects often employ large multichannel instruments. Examples are STAR at RHIC[3], AMANDA at the South Pole[5], and the SuperKamiokande in Japan[4]. In some detectors, particularly those employing photomultiplier tubes, noise rates for individual detectors may be up to 100 kilohertz, but by employing multiple coincidence techniques, the noise rate of the entire instrument is negligible.

Figure 1: Average individual duster sensitivity as a function of track diameter.

The ensemble of dusters may be thought of as a single,
large multichannel instrument. We individually calibrate each
detector (duster) using calibration images, which consist of
one-fifth of the images in the datastream. The presence of
calibration images is known generally to the dusters, but they
do not know whether any particular image is a calibration
image. These calibration images are either known blanks, or
are images in which the image of a single track has been dubbed
into the field of view. We used a single image of a submicron
carbonyl iron grain that was fired into an aerogel collector
using the Heidelberg tandem Van der Graaf dust accelerator
at $\sim 20 \text{ km sec}^{-1}$. We rotated the image randomly through
$2\pi$, and applied a magnification factor between 0.2 to 1.5
in diameter and, independently, in depth to the track image.
This enables us to measure sensitivity (efficiency in detecting
tracks) as a function of track diameter over a range of 2.5$\mu$m
to 14$\mu$m. These track diameters correspond to particles sizes
of $\sim 0.3 - 1.5\mu$m, using the track-to-particle diameter value
($\sim 9$) reported by Burchell et al.[2]. (This ratio is likely to be
larger for the SIDC since the aerogel densities are lower and the
velocities are higher than in the Burchell et al. experiments.
This will result in even lower particle size thresholds.) Using
the blank images, we can also measure the specificity, that is,
the efficiency at correctly identifying empty fields. In Figs. 1
and 2, we show the average measured sensitivity as a function
of track diameter for the entire ensemble of Stardust@home
detectors, and the integral distribution of specificity. These
remarkably high efficiencies may be partially due to the testing
requirement before participation in the project.

We emphasize that these are *not* efficiencies for the inte-
grated instrument. The reason is that we use multiple coinci-
dence for triggering. With at least six searches per field-of-
view (multiplicity = 6) and a requirement of two-fold coinci-
dence, the efficiency of the instrument will be nearly unity over
the entire range of track diameters in the calibration dataset.
In practice, the multiplicity up to now is $\gg 100$.

**Stardust@home candidates**

After promising fields of view have been identified through
multiple coincidence, four of us review them at Berkeley. We
will then collect images in transmitted light of these candidates,
using much higher magnification objectives 25$\times$ and 50$\times$.
This scanning requires unfolding aluminum foils behind the
tiles. Testing is currently underway to determine whether
foil unfolding compromises the integrity or orientation of the
aerogel tiles.

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**References**

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