SEARCH FOR CONTEMPORARY INTERSTELLAR DUST IN THE STARDUST COLLECTOR. Andrew J. Westphal[1], Ronald K. Bastien[2], Anna L. Butterworth[1], Josh Von Korff[1], David Anderson[1], Bryan Mendez[1], Rastika Prasad[1], Nicole Kelley[1], David Frank[1], Robert Lettieri[1], Zack Gainsforth[1], Christopher J. Snead[1], Jack L. Warren[2], Michael E. Zolensky[2], 20064 Stardust@home "dusters"[3] , [1] *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 two extraordinary and unprecedented extraterrestrial samples. Stardust is the first spacecraft to return solid samples from beyond the moon. Though Stardust's main mission was to capture dust from the coma of comet Wild 2 - dust dating from the origins of the solar system some 4.5 billion years ago - it also captured a sprinkling of dust from distant stars, perhaps created in supernova explosions less than 10 million years ago.

"These will be the very first contemporary interstellar dust grains ever brought back to Earth for study," said Andrew Westphal, a UC Berkeley senior fellow and associate director of the campus's Space Sciences Laboratory who developed the technique NASA will use to digitally scan the aerogel in which the interstellar dust grains are embedded. "Stardust is not only the first mission to return samples from a comet, it is the first sample return mission from the galaxy."

Several dozen interstellar dust particles near 1 μm in diameter are expected to have been captured in the ~ 1000 cm^2 (about a square foot) 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 SIDC

We modified an automated scanning microscope to accommodate the SIDC. This microscope was developed several years ago at Berkeley for experimental nuclear astrophysics work. The images are collected at full resolution as $\sim$25MB QuickTime movies. 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

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.

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, 20,064 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."

Stardust@home detector calibration

Large particle physics and particle astrophysics projects often employ large multichannel instruments. Examples are STAR at RHIC, AMANDA at the South Pole, and the SuperKamiokande in Japan. 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.

The ensemble of >20,000 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 generally know whether any particular image is a calibration image. (Some extremely vigilant dusters have been able to identify subtle features in calibration images, and this may introduce a small overestimate in measurement of sensitivity described below.) 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 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 2.5μm to 14μm. These track diameters correspond to particles sizes of $\sim 0.3 - 1.5\mu$m, using the track-to-particle diameter value (~ 9) measured in laboratory experiments by Mark Burchell at the University of Kent. ing the blank images, we can also measure the specificity, that is, the efficiency at correctly identifying empty fields. The dusters are remarkably efficient at correctly identifying even the smallest tracks among the calibrations (2.5 μm), about 70%, and are better than 90% for tracks bigger than 4μm. 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 integrated instrument. The reason is that we use multiple coincidence for triggering. With at least six searches per field-of-view (multiplicity = 6) and a requirement of two-fold coincidence, 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× and 50×. 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. Several dozen candidates have been identified and are now under intense study to determine whether they are captured contemporary interstellar dust.