DISC: DEEP-SPACE INTERSTELLAR DUST COLLECTOR. A. J. Westphal[1], A. L. Butterworth[1], C. E. Jilly-Rehak[1], Z. Gainsforth[1], S. R. Messenger[2], R. Ogliore[3], R. M. Stroud[4], [1]Space Sciences Laboratory, U. C. Berkeley, Berkeley CA 94720-7450 (westphal@ssl.berkeley.edu), [2]ARES, NASA/JSC, Houston, TX 72110, [3]Materials Science Physics Department, Washington University, 1 Brookings Dr, St. Louis, MO 63130, [4]Materials Science and Technology Division, Naval Research Laboratory, Code 6366, 4555 Overlook Avenue SW, Washington, DC 20375

Introduction: Interstellar dust and gas are the fundamental building blocks of the Solar System. **Deep Space Gateway presents an unprecedented opportunity to carry out an interstellar dust sample return mission with a collecting power sufficient to collect and return hundreds of particles to terrestrial laboratories**. The Deep-space Interstellar Dust Collector (DISC) would have a collecting power more than an order of magnitude greater than that of the pioneering Interstellar Dust Collector onboard the Stardust spacecraft. DISC would require no power or telemetry. It would be modular and lightweight, but, somewhat reminiscent of photographic film, would require recovery to carry out the scientific objectives.

Samples of the galaxy: The Solar System is moving at ~26 km/sec with respect to the local interstellar medium. This motion results in a continuous stream of interstellar gas and dust that, from our perspective, appears to originate approximately from the constellation Ophiuchus [1]. Dust from this stream can be captured by appropriate passive collectors, and returned to terrestrial laboratories for analysis.

Stardust heritage: Stardust, the fourth in NASA's Discovery line of planetary science missions, was launched in 1999. Before its encounter with comet 81P/Wild 2 in 2004, it exposed a dedicated ~0.1m^2 aerogel and Al foil collector to the interstellar dust stream for ~200 days. In 2014, the analysis team announced the discovery of seven particles of probable interstellar origin identified in the Stardust collector [2]. These particles exhibited surprising diversity. The measured interstellar dust flux was smaller than anticipated, and no more than ~12 particles greater than 1 pg (10^{-12} g) in mass were captured by the collector. Laboratory confirmation of interstellar origin of these candidates through measurement of oxygen isotopic composition is underway, but it is clear that the compositional and mineralogical diversity observed in the Stardust collection requires a statistical sample at least an order of magnitude larger than that collected by Stardust to make measurements that can be used to understand the bulk properties of interstellar dust, and to compare with bulk astronomical observations.

DISC Science Objectives: Collection of >100 large interstellar dust particles will require a collecting power (the product of area and exposure time) more than an order of magnitude larger than that of the Stardust Interstellar Dust Collector. This objective would be fulfilled using a ≥1 m^2 collector exposed to the interstellar dust stream for at least six months.

Sample return enables analyses using state-of-the-art instruments in terrestrial laboratories. Some instruments are far too large ever to fly in space. Stardust interstellar dust candidates, for example, were analyzed using x-ray and infrared microprobes at synchrotrons – these are facilities the size of shopping malls. Samples returned by Apollo, Genesis, Stardust, and other sample return missions are now being studied using instruments that did not exist at launch of these missions. These analyses include x-ray (Fig. 1) and infrared absorption spectroscopy, x-ray fluorescence mapping, x-ray diffraction, isotopic analysis using ion microprobes, and others.

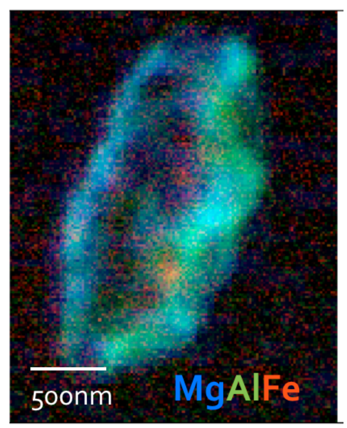

Fig. 1. Scanning transmission x-ray composition map of the interstellar dust candidate Orion, extracted from the Stardust interstellar dust collector[2,7]. (Beamline 11.0.2, Advanced Light Source, Lawrence Berkeley National Laboratory).

Lessons from Stardust: The community learned two important lessons from the Preliminary Examination of the Stardust interstellar dust collector [1].

The first lesson was that a variety of collecting media broadens the science that can be done. The Stardust collector was composed of aerogel [3,4] and Al foils [5] (85% and 15% by area, respectively). The foils were used as an engineering feature, but turned out to be important as a serendipitious capture medium [5]. Here we envision three capture media: aerogel tiles, polished high-purity Al plates, and high-purity, semiconductor-grade Ge wafers, similar to those used on the Genesis mission [6], overlaid with ~10 nm-thick silicon nitride membranes for trajectory reconstruction. This would enable high-precision elemental and isotopic composition measurements of interstellar dust particles. Other capture media (e.g., carbon-based aerogel, isotopically-doped silica aerogel, graphite planchets) could be accommodated as they are developed.

The second lesson was that any part of the spacecraft in the field of view of the collector is a potential source of secondary ejecta due to impacts of micrometeoroids on the spacecraft. Impacts of secondary ejecta in the collectors can lead to a substantial background. While these particles can usually be identified through various means [5,7], this is labor intensive and each analytical step adds risk to the samples. It is highly preferable to accommodate the collector in such a way that no part of the spacecraft is in the field of view of the collector.

DISC Payload: An interstellar dust collection mission with large collecting power would be enabled by the Deep Space Gateway. Several key characteristics of DISC facilitate accommodation in the DSG architecture:

- No power is required
- No telemetry is required
- No thermal control is required
- Modular design
- Lightweight (< 30 kg)
- Compact stowed envelope for launch and recovery
- Deployable and recoverable with robotic arm
- Deployment and recovery timing are not critical, because of the near constancy of the interstellar dust stream flux

Requirements:

- The collector shall be recovered to complete science objectives
- The collector shall be mounted externally on the DSG with an unrestricted view to space
- The integrated interstellar dust stream exposure time shall be >180 days for a 1m^2 collector
- The collector shall be deployed to maximize the exposure to the interstellar dust stream
- The orientation of the collector during exposure shall be recorded

Interstellar dust radiant tracking:

The Stardust interstellar dust collector was mounted on an articulated arm, which enabled alignment of the normal vector of the collector with the interstellar dust stream. Because of effects of light pressure during interstellar dust transport in the heliosphere, the interstellar dust radiant direction is not unique, but depends on β, the ratio of the light pressure force to gravitational force [8]. For Stardust, the collector was aligned during the exposures to the β=1 interstellar dust radiant. DISC would track on the β=0 radiant, corresponding to larger and more compact particles. This alignment maximizes the collecting power of the collector for capture of large interstellar dust particles, and, for capture media such as aerogel that record trajectories, allows for rejection of interplanetary dust particles, which also constitute a background. In principle, DISC would also be aligned as much as possible to the ISD radiant during exposure. A passively articulated mount might be periodically re-oriented using the DSG arm. Multiple external mount points to which the collector could be moved during the course of a one-year exposure could also optimize the collecting power and minimize backgrounds. A detailed model of the expected orientation history of the DSG would be required to determine the relative distributions of trajectories of interstellar dust and interplanetary dust impacts. Interstellar dust capture speed for DISC would be comparable to or lower than that of Stardust during times when Earth's motion is generally aligned with the interstellar dust stream.

References

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