EXTRATERRESTRIAL DUST COLLECTION AT MAUNA LOA OBSERVATORY, HAWAI‘I.

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Introduction: An estimated 40,000 tons of extraterrestrial particles, produced primarily by small dust-producing bodies like comets and asteroids, arrive at the Earth's surface each year. Nearly all of this dust is rapidly obscured by the greater abundance of natural and anthropogenic terrestrial dust. Many methods have been applied to collect predominantly extraterrestrial (ET) dust. Historically, these have included magnetic sorting of metal-bearing particles from deep sea sediments [1,2] and dissolved salts [3]. Less altered and more complete collections are possible in locations where terrestrial dust flux is naturally low, and ongoing collections from polar ice, snow and well water [e.g. 4-7] and from the Earth's stratosphere by high altitude aircraft [e.g. 8] have provided the majority of samples of micrometeorites and cosmic dust in our collections to date. These collections suffer leaching from exposure to water and ice, contamination from silicone oil and loss of some organics from solvent removal of silicone oil [9].

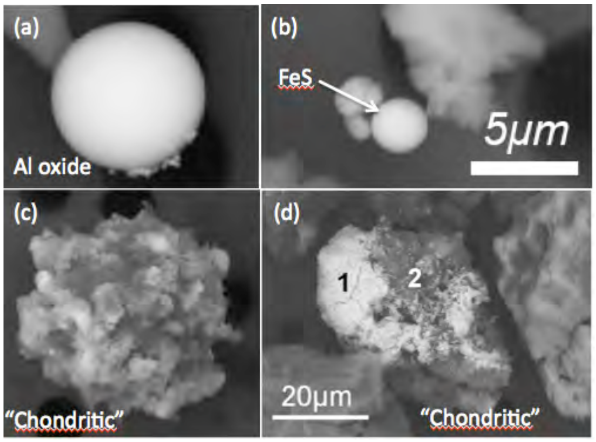

Figure 1: Particles collected from trade wind aerosol on Kwajalein atoll. (a) Aluminum oxide spherule. (b) FeS spherule. (c) & (d) Particles with chondritic compositions for Mg, Al, Si, S, Ca, Fe, Ni [10,11]. The Fe-rich surface labeled 1 in (d) may be a fusion crust.

High volume air samplers have recently been employed for ET dust collection in locations with limited terrestrial dust. In 2011, we installed a sampler on Kwajalein, a coral atoll in the Marshall Islands situated in the Pacific Ocean over 1000 miles from the nearest continent. In addition to abundant sea salt and coral, we identified particles of interest (Fig. 1) that include some with approximately chondritic composition as well as FeS and Al-oxide spherules [9-10]. Al-oxide spherules can be significant because they are consistent with rocket exhaust, the major anthropogenic particulate collected together with IDPs in the stratosphere [10]. We have also collected and are examining high-volume samples at the British Antarctic Research Survey's Halley VI Research Station station [11].

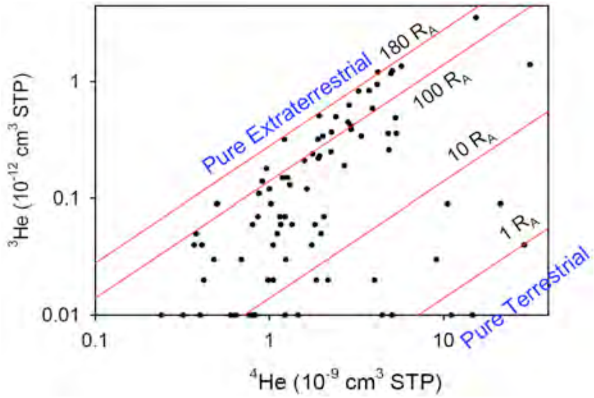

Figure 2: Helium isotope abundances in particulates measured in samples collected at MLO. (RA is the ^{3}He/^{4}He ratio normalized to the atmospheric value.)

We have recently initiated a new collection at the NOAA Mauna Loa Observatory (MLO) near the summit of Mauna Loa at an elevation of 11,141 feet above sea level. MLO has long been recognized as an ideal site for collection of tropospheric aerosols with down-mountain airflow at night accompanied by a reduced component of local natural and anthropogenic particulates. ET particulates previously collected at MLO recovered on a weekly schedule and analyzed for helium isotopes show elevated ^{3}He/^{4}He ratios that unambiguously confirm the presence of ET particles in almost every sample over a several year period, with dramatic variation in ET concentrations and ^{3}He/^{4}He ratios approaching pure extraterrestrial helium many samples (Fig. 2).

Methods: The MLO air sampler is shown in Figure 3. It is fitted with an anemometer and wind sector controller, and sampling occurs only when air flow is within ±45° of the down-mountain direction with wind speeds greater than 1 m/s. The first few filters were collected with a wind sector of ±90° and are likely to contain more terrestrial particles. Wind sector and threshold windspeed parameters may be further adjusted in future to optimize collection. The pump pulls 4.4 in. of water, as measured by a manometer, producing a nominal air flow of 1.4 m^3/min with a flapper valve to prevent backflow.

Figure 3: High-volume air sampler with anemometer at Mauna Loa Observatory.

Polycarbonate membrane filters with 5 µm diameter performation (Sterlitech Corporation, Kent, WA) were mounted on acrylic frames and placed in the filter cassette over the sampler head. Filters are exchanged approximately once per month or more frequently if a known meteor shower is being targeted for collection or if flow rates drop below ~75% of original flow.

For an initial examination, 3 filters were examined by optical microscopy. Particulates were transferred from the filters to spectroscopic-grade conductive carbon adhesive substrates which were then mounted on pin stubs and carbon-coated for scanning electron microscopy (SEM). SEM+EDX was performed in the newly-installed UH Helios 660 dual-beam FIB instrument with an Oxford Instruments Xmax N80 silicon drift detector. Energy dispersive x-ray spectroscopy (EDX) is useful as a first-pass assessment of ET origin: Near-chondritic compositions are an indication of the lack of differentiation expected for small primitive solar system bodies.

Findings and Future Plans: We have evaluated the loading of particulates on the filters as a function of exposure time and flow rates, and we are developing protocols for scanning the filters and identifying identifying ET particles. Optical microscopy shows that the individual particles are almost exclusively transparent. Since we are primarily interested in recovery of black and/or opaque carbon-rich IDPs and micrometeorites, the properties of the background aerosol particles are fortuitous. Following optical examination, sequential large fields of particulates are scanned using SEM-EDX to identify candidate ET particles (Fig. 4).

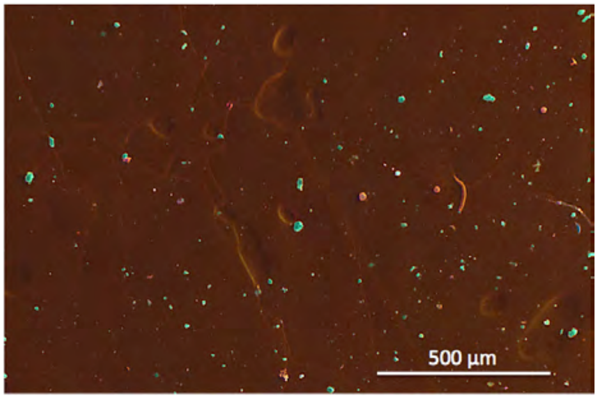

Figure 4: a) Secondary electron image with superimposed color coded element maps of particulates collected at MLO during the 2016 Perseid meteor shower.

During the next phase, we will optimize our sampling conditions. For example, because the loading of particles >1 µm is lower than expected (Fig. 4), we will evaluate higher flow rates and smaller filter areas. Modifications to the front end of sampling head will further optimize the sampler for recovery of ET particles.

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