INTERPLANETARY DUST: A NEW SOURCE OF EXTRATERRESTRIAL MATERIAL FOR LABORATORY STUDIES; D.E. Brownlee, D.A. Tomandl, E. Olszewski, Dept. of Astronomy, Univ. of Wash., Seattle, WA 98195.

Interplanetary dust grains are transient solar system bodies with typical lifetimes less than 10$^5$ years. In spite of short particle lifetimes, the population of dust in the inner solar system is maintained in quasi-equilibrium by injection of fresh material from interstellar medium and debris produced by disintegration of asteroids and comets. A considerable amount of evidence indicates that most of the particles at 1 AU are dust grains recently released from short period comets. Interplanetary dust can be collected for laboratory analysis and it provides a source of material distinctly different from established sources of extraterrestrial material—meteorites and the moon.

Over the past three years we have collected nearly 300 extraterrestrial particles from the stratosphere using NASA U-2 aircraft. The particles range in size from 2μm to 60μm with the typical particle being ~10μm. Some of the particles are spheroidal and appear to have melted during atmospheric entry but most particles show no outward signs of thermal alteration. More than half of the unmelted particles contain implanted solar wind He and are believed to be rather pristine samples of interplanetary dust. The following observations are considered very strong evidence that the collected particles are extraterrestrial; 1) the most common particle type matches cosmic elemental abundances for eleven of the most abundant elements in chondrites, 2) many of the particles contain $^4$He at concentrations as high as 0.25 cm$^3$(STP) g$^{-1}$, 3) a few particles have been found which contain the meta-stable minerals wüstitte and clinoenstatite.

Of the hundreds of interplanetary dust particles analyzed, most appear to have been produced by gentle disintegration (probably in space) of a common type of parent material. The parent material is a black aggregate of grains which range in size from ~10A to microns but have typical sizes of ~1000A. Occasional grains of Ni bearing pyrrhotite and Fe poor olivine and pyroxene are found in the aggregates as particles ranging in size from <1000A to several microns. The major mineral phase in the aggregate material is very fine grained and is tentatively identified as a poorly crystallized hydrated silicate. The elemental compositions of most of the recovered interplanetary dust particles are close to chondritic abundances (Fig.1).

In many ways the analyzed dust particles show strong similarities to Cl and C2 meteorites. Like the meteorites, interplanetary dust particles are unequilibrated fine grained aggregates of minerals with widely differing condensation temperatures. The following properties of interplanetary dust imply a close similarity to Cl and C2 meteorites and distinction from most other meteorite classes; 1) very fine grained (~1000A), 2) carbon and sulfur contents >4%, 3) contain Fe$_{1-x}$$^5$ with >1% Ni, 4) contain iron poor olivine and pyroxene, 5) contain magnetite, 6) contain hydrated silicates (tentative identification). The carbon and sulfur contents of many of the collected particles indicate closest similarity to Cl meteorites (Fig. 1).

Although interplanetary dust shows strong similarities to carbonaceous chondrites, it differs in ways which suggest that it is a unique material unlike known meteorites. In figure 1 the composition of seven interplanetary
dust particles are compared with C2 averages. The particle analyses appear to have systematic differences from the C2 norm but the important point is that the analyses of these ~10μm size particles agree with cosmic abundances better than do analyses of similar volumes of fine grained material from C1 and C2 meteorites. A conspicuous difference is that S and Ca abundances in the particles are relatively normal while the fine grained material in C1 meteorites is depleted by nearly an order of magnitude relative to C1 averages (Richardson and McSween 1976). The process (leaching?) which redistributed S and Ca in C1 meteorites apparently did not occur on the interplanetary dust parent bodies.

A major difference between C1 and C2 meteorites and interplanetary dust is the detailed nature of their microstructure as revealed in high resolution SEM and TEM observations. The fine grained materials in the meteorites are typically rather compact masses of platelets, crumpled foils and fibers. In comparison the dust particles examined are more porous, finer grained, more complex and generally they do not contain the fibrous platey textures commonly seen in C1 and C2 meteorites. Figure 2 illustrates the complex microstructure seen in many of the dust particles examined. In the TEM many of the ~1000A grains seen in Figure 2 are revealed to be aggregates of grains in the 10A to 500A size range. The complex, porous, fragile structure of many interplanetary dust particles may be incompatible with a prior history of residence in a regolith environment. Short period comets which are major dust producers cannot have regoliths because of the high loss rate of surface material due to the ablation of ices.

Although detailed analysis has just begun, the available data suggests that interplanetary dust is very primitive solar system material, at least as primitive as the most primitive known meteorites. Some of the properties of interplanetary dust tentatively support the hypothesis that meteorites are fragments of asteroid regolith and that interplanetary dust is material released from comets. If the dust particles are from comets then there is a distinct possibility that they contain pre-solar interstellar grains.

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Figure 1 - Elemental composition of 6 U-2 particles (diameters 3μm to 12μm) and meteoroid residue found inside a 110μm crater from Skylab 4. The data is normalized to the bulk composition of the Murchison C2 chondrite.

Figure 2 - SEM photo of part of a 13μm interplanetary dust particle collected with the U-2. The particle has a chondritic composition and a very porous, highly three dimensional structure which can only partially be appreciated in this two dimensional view. Scale bar = 1μm.