ELEMENTAL AND MINERALOGICAL COMPOSITIONS OF CLUSTER IDPS: A POSSIBLE ANALOG TO THE WILD 2 PARTICLES COLLECTED BY STARDUST. G. J. Flynn[1], A. Lanzirotti[2], and S. R. Sutton[2,3]. [1]Dept. of Physics, SUNY-Plattsburgh, 101 Broad St., Plattsburgh NY 12901 (george.flynn@plattsburgh.edu), [2]CARS, Univ. of Chicago, Chicago IL 60637, [3]Dept of Geophysical Sciences, Univ. of Chicago, Chicago IL 60637.

Introduction: NASA's Stardust spacecraft collected the first particles clearly identified a originating on a specific comet, 81P/Wild 2, and delivered them to Earth for examination. Prior to the Stardust collection it had been suggested that some chondritic porous interplanetary dust particles (CP IDPs) collected from the Earth's stratosphere were from comets, based on the degree of heating experienced during atmospheric deceleration. In general, cometary particles, which are collected from elliptical orbits, are heated to higher temperatures on deceleration than are particles from main-belt asteroids [1]. Flynn [1] and Sandford and Bradley [2] indicated that olivine-dominated CP IDPs had experienced atmospheric entry heating, inferred from the apparent annealing of solar flare tracks, that suggested they were cometary. Brownlee et al. [3] concluded that CP IDPs were cometary based on the degree of heating inferred from He-release temperature profiles. But the Preliminary Examination of the Wild 2 particles suggested they were quite different from the CP IDPs [4]. Ishii et al. [5] reported that the low abundance of carbon and presolar grains and the absence of certain silicates, such as enstatite whiskers, distinguish the Wild 2 particles from CP IDPs. One similarity is that both the ~10 μm CP IDPs and the Wild 2 particles are significantly enriched in moderately-volatile elements compared to CI.

However, we have previously noted that the CP IDPs are, most likely, not a complete or representative sample of their parent body. A typical ~10 μm size CP IDP is an aggregate of $>10^4$ submicron grains having diverse mineralogies. The stratospheric collections include many non-chondritic, mono-mineralic grains, collected along with the fine-grained CP IDPs. Some of these mono-mineralic grains, which include volatile-poor olivine and pyroxene as well as chalcophile-rich sulfides, have fine-grained, chondritic material (i.e., small bits of CP IDPs) adhering to their surfaces. This indicates that at least some of the non-chondritic grains found on the stratospheric collectors are fragments from the same parent as the CP IDPs. Thus, the bulk elemental and mineralogical composition of the CP IDP parent body can only be reconstructed by adding to the fine-grained, chondritic IDPs the correct amount of this non-chondritic material. Cluster IDPs, which are typically ~100 times the mass of 10 μm CP IDPs contain large mono-mineralic grains, sampling the parent body at a significantly larger size scale than 10 μm CP IDPs.

We have begun elemental and mineralogical characterization of large cluster IDPs. Our preliminary results suggest the anhydrous chondritic cluster IDPs are similar to the Wild 2 particles collected by Stardust.

Samples and Analytical Techniques: We were allocated 8 large cluster IDPs from the L2005, L2008, and L2009 collectors. Each particle was transferred to an ~7 μm thick Kapton film. We performed x-ray fluorescence (XRF) elemental analyses and x-ray diffraction (XRD) mineralogical analyses by raster scanning an ~8 μm monochromatic x-ray beam over the the sample, adding the XRF spectra and adding the XRD patterns over the entire particle to provide bulk analyses [described in 6].

Cluster IDP Results: Five of the eight cluster IDPs were anhydrous, as demonstrated by the absence of d-spacings characteristic of clays in the XRD patterns, and showed minimal evidence of alteration during atmospheric deceleration, i.e., only a very minor amount of magnetite in XRD and Zn/Fe >0.3xCI, criteria previously identified as correlating with a low degree of thermal alteration [6].

Although the 5 to 15 μm CP IDPs are enriched relative to CI in many moderately volatile elements, with a mean enrichment of ~4xCI for Cu, Zn, Ga, Ge, and Se [7], the average composition of the five anhydrous cluster IDPs that show no evidence for element loss during atmospheric deceleration is generally consistent with a CI composition (see Figure 1).

Of the elements enriched over CI in the ~10 μm CP IDPs, Zn is present in the highest amount and is most accurately determined in our XRF analysis. While Zn in the ~10 μm CP IDPs is ~4xCI, the mean Zn content of the five cluster IDPs is only 1.2xCI. If these cluster IDPs consist of a mixture of fine-grained CP IDP material and large olivine, pyroxene, and sulfide, then more than 70% of the mass of the cluster particles must be in these larger mineral grains, although the volume fraction of the large mineral grains would smaller because of the density difference between the crystalline and the porous fine-grained material. The CP IDPs appear to sample the matrix of a parent body that is dominated by larger crystalline grains. This is consistent with the XRD results, which show these cluster IDPs are a mixture of pyrrhotite, fosterite and enstatite (see Figure 2).

Wild 2 Particles: The Wild 2 particles were significantly modified by the capture process. Although most grains larger than 1 µm in size appear to have survived capture intact, much of the fine-grained material in each particle was vaporized or mixed into aerogel on collection [4].

Comparison of Cluster IDPs with Wild 2 Particles: Capture alteration is sufficient to explain the scarcity of fine-grained material in the Wild 2 particles [4], and may also result in destruction of highly-elongated enstatite whiskers. The low abundance of isotopically anomalous grains and carbon in the Wild 2 particles can be explained by both the dilution of CP IDP-like fine-grained material, where isotopic anomalies and carbon are found, by larger mono-mineralic grains and by destruction of fine-grained material on capture.

A surprising feature of the Wild 2 particles was the large enrichment of moderately-volatile elements – Cu, Zn, and Ga – over CI element/Fe ratios. This is similar to the enrichment in moderately-volatile elements in CP IDPs. But, our results indicate this enrichment in CP IDPs does not reflect the composition of the parent body of the CP IDPs. The CP IDPs sample only the fine-grained component of the parent. Cluster IDPs, which incorporate larger mineral grains as well as CP IDP material, have a CI-like element pattern (Fig. 1).

If the Wild 2 particles are sililar to cluster IDPs, then our results on the cluster IDPs suggest that small (<15 µm) Wild 2 particles should show highly variable compositions, while the larger particles (>50 µm) should approach a CI-like composition. Only one of the 23 Wild 2 tracks whose element distributions were mapped during the Wild 2 Preliminary Examination is of comparable size to the cluster IDPs included in our study. This largest Wild 2 particle contains ~6.4 ng of Fe [8], which suggests a total mass of about 32 ng. It has an elemental composition consistent with CI (Figure 3), with no indication of a significant enrichment in moderately-volatile elements, the same pattern seen in cluster IDPs. The low S content of this Wild 2 particle may result from S vapoprization and redistribution outside of the analyzed volume [9].

Conclusions: Our results suggest that cluster IDPs may be a suitable analog for the Wild 2 particles collected by the Stardust spacecraft. These cluster IDPs appear to be aggregates of <30% fine-grained material, the traditional CP IDPs, combined with >70% larger crystalline olivine, pyroxene, and sulfide grains. If cluster IDPs are an analog to the Wild 2 particles, the results suggest that an insufficient number of large particles were analyzed during the Wild 2 Preliminary Examination to provide a representative elemental composition of the refractory component of Wild 2.

References: [1] Flynn, G.J. *Icarus,* **77**, 287-310 (1989). [2] Sandford, S.A. and J.P. Bradley, *Icarus*, **82**, 146-166 (1989). [3] Brownlee, D.E. et al., *Lunar & Planet. Sci. XXIV*, 205-206 (1993). [4] Brownlee, D.E. et al., *Science*, **314**, 1711-1716 (2006). [5] Ishii, H. et al., *Science,* **319**, 447-450 (2008). [6] Flynn, G.J. et al. *Lunar & Planet. Sci*., Abs. #1391 (2008). [7] Flynn, G.J. et al., Meteoritics, 28, 349 (1993). [8] Flynn, G.J. *Science*, **314**, 1731-1735 (2006). [9] Ishii, H. et al., *Science*, **319**, 447-450 (2008).

Figure 1: CI and Fe normalized element abundances for five large, normal-Zn cluster IDPs and the mean composition of the group of five large, normal-Zn, anhydrous cluster particles.

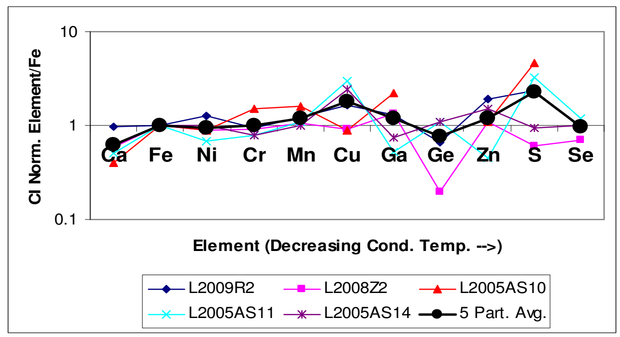

Figure 2: XRD pattern obtained on L2008Z2, dominated pyrrhotite, fosterite and enstatite.

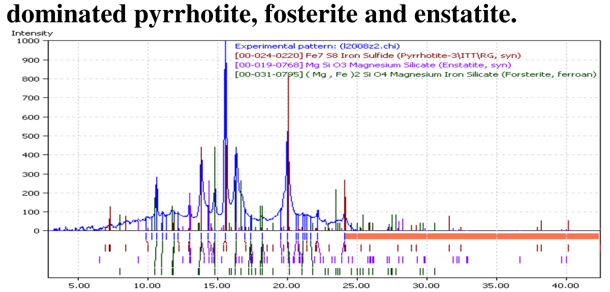

Figure 3: CI and Fe normalized element abundances in the largest of the 23 Wild 2 tracks examined during the Preliminary Examination [data from 8]