CHEMICAL COMPOSITIONS OF LARGE CLUSTER IDPs. 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: We previously determined that ~10 µm interplanetary dust particles (IDPs) collected from the Earth's stratosphere are enriched in many moderately volatile elements by a factor of ~3 over the CI meteorites [1]. However, these IDP measurements provide no direct constraint on the bulk chemical composition of the parent body (or parent bodies) of the IDPs.

Collisions are believed to be the major mechanism for dust production by the asteroids, producing dust by surface erosion, cratering and catastrophic disruption. Hypervelocity impact experiments at ~5 km/sec, which is the mean collision velocity in the main belt [2], performed by Flynn and Durda [3] on ordinary chondrite meteorites and the carbonaceous chondrite meteorite Allende show that the 10 µm debris is dominated by matrix material while the debris larger than ~25 µm is dominated by chondrule fragments. Thus, if the IDP parent body is similar in structure to the chondritic meteorites, it is likely that the ~10 µm IDPs oversample the fine-grained component of the parent body.

We have examined the matrix material from the few meteorites that are sufficiently fine-grained to be samples of potential IDP parent bodies. This search has, thus far, not produced a compositional and mineralogical match to either the hydrous or anhydrous IDPs. This result, coupled with our recent mapping of the element distributions, which indicates the enrichment of moderately volatile elements is not due to contamination on their surfaces [4], suggests the IDPs represent a new type of extraterrestrial material.

Nonetheless, the meteorite fragmentation results suggest that compositional measurements on 10 µm IDPs only provide a direct constraint on the bulk chemical composition of the IDP parent body if the size-scale of the grains in the parent body is <<10 µm. The stratospheric collections include many non-chondritic, mono-mineralic grains, collected along with the fine-grained chondritic IDPs. Some of these grains, which include volatile-poor olivine and pyroxene as well as calcophile-rich sulfides, have fine-grained, chondritic material (i.e., small bits of typical 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 fine-grained IDPs. Thus, the bulk composition of the IDP parent body can only be reconstructed by adding to the fine-grained, chondritic IDPs the *correct amount* of this non-chondritic material.

Qualitatively, the addition of olivines and pyroxenes will reduce the mean content of many moderately-volatile elements while the addition of sulfides will increase the content of some of these elements. However, the quantitative task of adding these mono-mineralic grains to the fine-grained IDPs cannot be accomplished by simply adding the non-chondritic material in proportion to its occurrence on the stratospheric collectors because:

1) it is not clear that all of the olivines, pyroxenes, sulfides or other mineral grains found on the stratospheric collectors are extraterrestrial,

2) the settling rate of a particle depends on its density and shape, thus the concentration factor for these high-density, mono-mineralic grains is lower at the collection altitude than it is for the lower-density, fine-grained aggregate IDPs, and,

3) the atmospheric entry survival of a particle is a function of density, so higher density grains (e.g., sulfides) are more likely to vaporize on entry, even if they enter with the same velocity as fine-grained, lower-density aggregates.

The collection of "cluster IDPs," which enter the atmosphere as large particles, some larger than 50 µm in diameter, containing both fine-grained aggregate material and mono-mineralic grains 10 µm in size and sometimes even larger, provides an opportunity to characterize the bulk chemistry and the mineralogy of the IDPs and their parent body at a significantly larger scale than we have done previously.

A 10 µm, porous IDP weighs only a few nanograms, while a 50 µm IDP weighs about 125 times that much and frequently includes mono-mineralic grains up to at least ~10 µm in size. By completely characterizing the composition and mineralogy of a single cluster IDP we characterize the IDP parent body at a mass scale more than two orders-of-magnitude larger than has been done by analyzing 10 µm IDPs.

Although most ~10 µm IDPs are not significantly altered by atmospheric deceleration, modeling indicates only ~10% of 50 µm IDPs with a density of 1 g/cc are not heated above 1000 K on entry [5]. We cannot determine *a priori* that a particular cluster has been altered by entry heating. Thus, we expect to analyze clusters exhibiting varying degrees of heating in an effort to identify a few "pristine" cluster IDPs that preserve their pre-entry chemical abundances.

Samples and Analysis Techniques: Recent modifications, funded by a NASA SRLIDAP Grant [NAG5-11904], to the X26A beamline at the National Synchrotron Light Source (Brookhaven National Laboratory) allow us to perform x-ray fluorescence (XRF) and x-ray diffraction (XRD) mapping on all of the material from an entire cluster particle. We obtain the bulk composition by adding the point spectra and we obtain bulk mineralogy by adding the x-ray diffraction patterns acquired by raster scanning the entire cluster.

We expect to find both hydrous and anhydrous cluster particles. Anhydrous clusters are likely to be more interesting than hydrous clusters, since anhydrous 10 µm IDPs are enriched in the moderately volatile elements by ~3 to 4 times the CI contents [6] while the hydrous 10 µm IDPs have ~CI contents of these elements [7]. The XRD data will allow us to classify the particles as dominated by hydrous or by anhydrous silicate, while the XRF data will allow us to infer the degree of heating using Zn and Ge contents. Heated particles can be recognized by depletions of Zn and Ge, which correlate well with other indicators of entry heating, including solar wind He content [8] and the development of magnetite rims [9]. The most interesting clusters will be those that have not experienced significant entry heating, and thus preserve their original, pre-atmospheric composition. In addition to characterizing the most unaltered clusters, we will be able to determine the effects of thermal alteration, since some will certainly be heated, and, aqueous alteration, since some will certainly be hydrous.

We were allocated five essentially complete cluster particles – L2008Z1 (CLU#17), L2008Z2 (CLU#16), L2009R1 (CLU#14), L2009R2 (CLU#13), and L2021S1 (CLU#6) -- each having a large total mass. Each cluster was transferred in a drop of silicone oil to a 7 µm thick Kapton film. We previously established that silicone oil is sufficiently clean for the elements we analyze, providing only a minimal background at Fe and Br, and silicone oil does not interfere with XRD.

The particles were analyzed by raster scanning the ~8x10 µm x-ray beam, in 5 µm steps, over the area of the Kapton that is covered by the sample. Thus far we have completed the chemical analysis of all of the material from the L2021S1 cluster, scanning a 42x27 pixel grid in 5 µm steps with a dwell time of 40 seconds per pixel. The total XRF accumulation was 12.6 hours, with about one-third of that time on particle fragments and the remainder on Kapton between the fragments. Thus, the element detection limits are comparable to our normal 3-hour analysis of individual IDPs (i.e., ~3 ppm for elements from Ni to Br). The second particle was more spread out on the Kapton, requiring a larger scanning area. Thus far we have completed raster scans of two areas of the L2008Z1 cluster, with a 45 sec dwell time per pixel. One scan covered a 32x29 pixel grid and a second covered a 20x27 pixel grid. Together we estimate that these two scans sampled ~60% of the mass of the cluster particle.

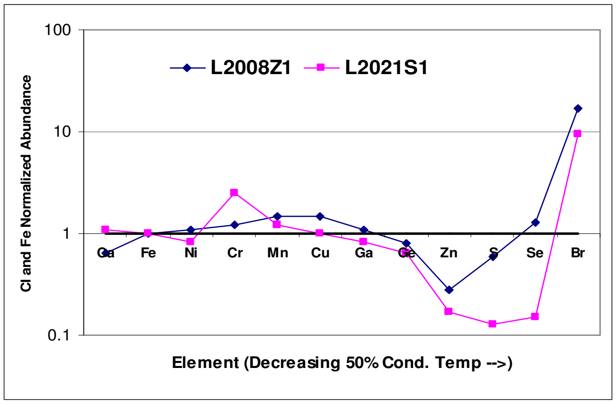

Figure 1: CI and Fe normalized element abundances for two large cluster IDPs – L2008Z1 and L2021S1. S and Se were not detected in L2021S1, so values shown for S and Se are detection limits.

Results: The CI and Fe normalized bulk compositions of the two cluster IDPs are shown in Figure 1. Both of the particles show significant Zn depletions, with Zn/Fe = 0.28xCI in L2008Z1 and Zn/Fe = 0.17xCI in L2021S1. We have previously determined that particles with Zn/Fe ratios <0.33xCI show other indicators of significant atmospheric entry heating. Thus, both of these cluster IDPs are likely to have experienced alteration during atmospheric deceleration. Bromine is enriched to ~10xCI in both of these cluster IDPs, comparable to the mean Br enrichment of other entry-heated IDPs. The remaining elements are all within a factor of 2 of CI in both particles, except Cr (Cr/Fe = 2.5xCI), S and Se (which are both below detection limits) in L2021S1

Since the low Zn content of each of these cluster IDPs indicates it was heated severely enough to alter its chemical composition, we are unable, from these two particles, to determine if sampling the IDP parent body at a larger size results in a CI-like elemental abundance pattern. However, the analysis of the remaining three cluster IDPs may aid in this determination.

References: [1] Flynn, G. J. et al. (1996) in *Physics; Chemistry; and Dynamics of Interplanetary Dust,* ASP Conf. Series; **104**, 291-297 [2] Bottke, W. F. et al. (1994) *Icarus*, **107**, 255-268. [3] Flynn, G. J. and D. D. Durda (2004) *Planet. and Space Sci.*, **52**, 1129-1140. [4] Flynn et al. (2004) *Lunar and Planet. Sci. XXXV*, Abst. #1334. [5] Flynn, G. J. (2001) in *Accretion of Extraterrestrial Matter Throughout Earth's History*, Kulwer Academic Publishers, 107-127. [6] Flynn, G. J. et al (1993) *Meteoritics*, **28**, 349. [7] Flynn, G. J. et al. (1994) *Lunar & Planet. Sci. XXV*, 381-382. [8] Kehm, K. et al. (2002) *Meteoritics & Planet. Sci.*, **37,** 1323-1335. [9] Flynn, G. J. et al. (1992) *Lunar & Planet. Sci. XXIII*, 375-376.