

**Fe-XANES MEASUREMENT OF AN ANHYDROUS CLUSTER IDP.** G. J. Flynn<sup>1</sup>, A. Lanzirotti<sup>2</sup>, and S. R. Sutton<sup>2,3</sup>. <sup>1</sup>Dept. of Physics, SUNY-Plattsburgh, 101 Broad St., Plattsburgh NY 12901 (george.flynn@plattsburgh.edu), <sup>2</sup>CARS, Univ. of Chicago, Chicago IL 60637, <sup>3</sup>Dept of Geophysical Sciences, Univ. of Chicago, Chicago IL 60637.

**Introduction:** Chondritic porous interplanetary dust particles (CP IDPs) are, most likely, not a complete or representative sample of their parent body. A typical  $\sim 10 \mu\text{m}$  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 [1]. Cluster IDPs, which are typically  $\sim 100$  times the mass of  $10 \mu\text{m}$  CP IDPs contain large mono-mineralic grains, sampling the parent body at a much larger size scale than  $10 \mu\text{m}$  CP IDPs.

We have previously reported synchrotron x-ray fluorescence (XRF) elemental and x-ray diffraction (XRD) mineralogical characterization of several large cluster IDPs [1]. Five of the eight cluster IDPs we examined 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  $\text{Zn/Fe} > 0.3 \times \text{CI}$ , criteria previously identified as correlating with a low degree of thermal alteration [1].

Although the 5 to  $15 \mu\text{m}$  CP IDPs are enriched relative to CI in many moderately volatile elements, with a mean enrichment of  $\sim 4 \times \text{CI}$  for Cu, Zn, Ga, Ge, and Se [2], 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).

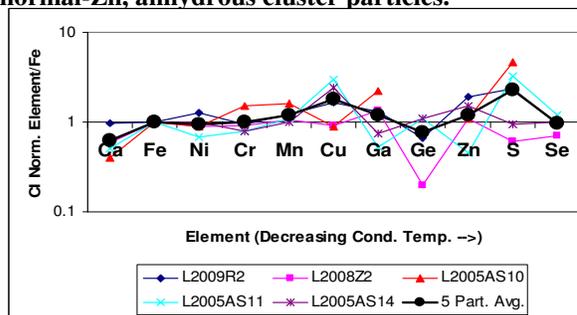
Of the elements enriched over CI in the  $\sim 10 \mu\text{m}$  CP IDPs, Zn is present in the highest amount and is most accurately determined in our XRF analysis. While Zn in the  $\sim 10 \mu\text{m}$  CP IDPs is  $\sim 4 \times \text{CI}$ , the mean Zn content of the five cluster IDPs is only  $1.2 \times \text{CI}$  [1]. 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 [3], although the volume fraction of the large mineral grains would be 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. This result suggests that the CP IDPs are not a representative sample of their parent body.

**Fe-XANES:** Fe is a major element ( $\sim 18.5\%$ ) in chondritic meteorites, and the Fe-oxidation state correlates with the mineralogy of meteorites. Urey and Craig [4] showed that meteorite groups can be distinguished from one another by their Fe-oxidation states. We have begun a project to systematically determine the Fe oxidation states of these cluster IDPs by Fe X-ray Absorption Near-Edge Structure (XANES) spectroscopy.

Ogliore et al. [5] have compared the oxidation state of Fe in 194 fragments, totaling  $\sim 300$  ng, of the Comet 81P/Wild 2 particles collected by the Stardust spacecraft with that of 15 CP IDPs and concluded that the Wild 2 particles contain much more Fe-metal than the CP IDPs, indicating they did not originate from similar parent bodies. But the Wild 2 particles include large mineral grains, some  $>10 \mu\text{m}$  in size, not included in the CP IDPs [3]. Thus, our Fe-XANES measurement of anhydrous cluster IDPs that incorporate larger grains from the CP IDP parent body, comparable in size to some of the larger Wild 2 particles collected by Stardust, provides a further test of Ogliore et al.'s [5] result.

**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.**



**Samples and Analytical Techniques:** We have, thus far, performed Fe-XANES on only a single large cluster IDP – L2009R2, shown in Figure 2. The particle was mounted on an  $\sim 7 \mu\text{m}$  thick Kapton film for the previous XRF and XRD analyses, and the Fe-XANES analysis was performed on the same mount. Fe-XANES was measured in fluorescence mode, raster scanning an  $\sim 8 \mu\text{m}$  monochromatic x-ray beam over the the sample, and measuring the fluorescence emission. The monochromator was then stepped by 0.2 eV, and another fluorescence emission image was obtained. A total of 200 images were acquired over the energy range from 7100 eV to 7140 eV, the region surrounding the Fe K-edge. The XANES spectrum at each pixel was derived from this image stack.

**Results:** The area covered by the fragments of L2009R2 is significantly larger than a  $10 \mu\text{m}$  particle, as shown in Figure 2, indicating that this cluster is significantly more massive than the individual CP IDPs.

We summed the Fe-XANES spectra over the entire area of L2009R2 and compared this average spectrum to the spectra of three standards -- Fe-metal, fayalite ( $\text{Fe}^{2+}$ ), and hematite ( $\text{Fe}^{3+}$ ), as shown in Figure 3. The summed Fe-XANES spectrum of L2009R2 is closer to the spectrum of fayalite than to either the Fe-metal or the  $\text{Fe}^{3+}$  standard, indicating that this cluster is dominated by  $\text{Fe}^{2+}$  minerals.

To investigate variation in the Fe-bonding in this cluster, we grouped the data into nine separate areas, each corresponding to one of the distinct Fe-concentrations identified in Figure 2. Differences between these spectra, shown in Figure 4, suggest that this anhydrous cluster IDP contains at least two different Fe-bearing phases.

Fe-metal can be easily distinguished from other Fe-bearing phases by its Fe-XANES spectrum (see Figure 3). None of the nine areas of L2009R2 has an Fe-XANES spectrum similar to Fe-metal, indicating that Fe-metal is not the dominant Fe-bearing phase in any of the nine areas. Detailed, pixel-by-pixel analysis will be required to determine if any individual pixel is dominated by Fe-metal, but our preliminary analysis suggests that this anhydrous cluster IDP does not contain a large amount of Fe-metal.

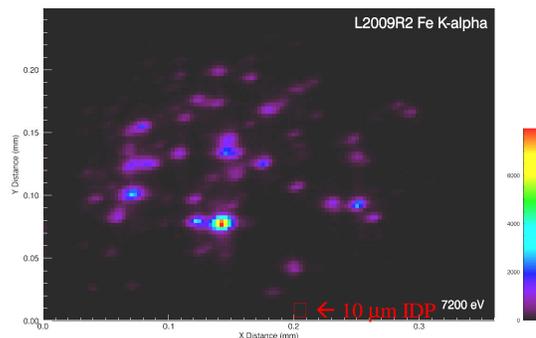
**Conclusions:** L2009R2 appears to be dominated by Fe with a valance near  $\text{Fe}^{2+}$ . The absence of large amounts of Fe-metal in L2009R2 suggests that even at the size scale of the cluster IDPs the anhydrous IDP parent body is different from the Wild 2 particles analyzed by Olgioire et al. [5].

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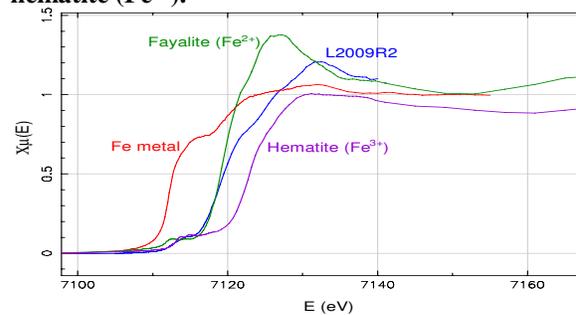
tron Light Source (NSLS). Use of the NSLS, Brookhaven National Laboratory, was supported by the U.S. Department of Energy, Office of Basic Energy Sciences, Contract No. DE-AC02-98CH10886.

**References:** [1] Flynn, G. J. et al. *Lunar & Planet. Sci XXXIX*, Abs. #1391 (2008). [2] Flynn, G. J. et al., *Meteoritics*, 28, 349 (1993). [3] Flynn, G. et al. *Lunar & Planet. Sci. XL*, Abs. #1166 (2009). [4] Urey, H. C. and Craig, H., *Geochim. Cosmochim. Acta*, 4, 36-82 (1953). [5] Olgioire, R. et al. *EPSL*, 296, 278-286 (2010).

**Figure 2: Fe-image of anhydrous cluster IDP L2009R2. (Image 360  $\mu\text{m}$  wide. Red box is 10  $\mu\text{m}$ .)**



**Figure 3: Fe-XANES spectrum summed over the entire map of L2009R2 compared to the spectra of these standards -- Fe-metal, fayalite ( $\text{Fe}^{2+}$ ), and hematite ( $\text{Fe}^{3+}$ ).**



**Figure 4: Fe-XANES spectra of the nine individual areas of L2009R2 (indicated by colored boxes).**

