

## COMBINED CARBON, NITROGEN, AND OXYGEN XANES SPECTROSCOPY ON HYDRATED AND ANHYDROUS INTERPLANETARY DUST PARTICLES.

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**Introduction:** Interplanetary dust particles (IDPs) collected from the Earth's stratosphere generally contain percent-level concentrations of organic matter [1]. This organic matter in IDPs is important for several reasons:

- 1) some IDPs contain interstellar organic matter, identified by high D/H or <sup>15</sup>N, providing the opportunity to characterize this interstellar material,
- 2) comparison of the organic matter in anhydrous IDPs to that in hydrated IDPs can help establish the effects of parent body aqueous alteration, and,
- 3) IDPs are believed to have delivered to the surface of the early Earth pre-biotic organic matter important for the origin of life [2].

X-Ray Absorption Near-Edge Structure (XANES) spectroscopy provides information on the functional groups present in a sample, and XANES can be performed on the nano-scale, comparable to the size of some of the sub-units of the IDPs. The energies of the XANES transitions are diagnostic of the type of bonding of the C, N, and O, allowing identification of the functional groups present in the sample.

As part of our ongoing effort to characterize the organic matter in the IDPs, we have performed carbon- and oxygen- and the first nitrogen-XANES spectroscopy on two IDPs and acid-insoluble residue from the CM2 meteorite Murchison.

**Samples and Techniques:** We performed C-, N-, and O- XANES analysis, using two Scanning Transmission X-ray Microscopes (STXMs) on beamline X1A of the National Synchrotron Light Source (Brookhaven National Laboratory). We analyzed one anhydrous IDP, L2011R11, and one hydrated IDP, L2008U13, as well as a sample of Murchison acid residue. Slices, ~100 nm thick, were prepared by ultramicrotomy, and deposited on SiO substrates. This thickness is suitable for transmission measurements at x-ray energies from 250 to 600 eV, the energy range covering the K-shell binding energies of C, N, and O. Each sample was rastered through a monochromatic x-ray beam in the STXM. X-rays were detected behind the sample, producing an absorption image of the sample at the energy of the x-rays.

A sequence of absorption images was taken over energies near the C, N, and O K-edges, including the pre-edge energy range where x-rays induce transitions

to unoccupied bonding orbitals at energies just below the binding energy. These images were then aligned, allowing absorption spectra to be derived at individual pixels, over selected areas, or over the whole particle, as described by Jacobsen et al. [3]. In this preliminary effort, we derived spectra integrated over the entire area of the particle. The resulting C-, N-, and O-XANES spectra are shown in Figures 1, 2, and 3.

**Results:** These measurements differ from our prior measurements on IDPs in that we averaged over the whole section, including all phases, rather than obtaining spectra of the organic rich areas. As a result the carbon analyses could include carbon-bearing phases such as carbonate, while the oxygen analyses are likely to be dominated by the silicate minerals and oxides. Nitrogen, however, is likely to be present mostly in organic matter, thus whole-section analyses are likely to characterize any organic N host(s).

*C-XANES.* The C-XANES spectra of the two IDPs and the Murchison residue each show the three strong absorption features, near 285, 286.5 and 288.5 eV, that we have previously reported for almost all IDPs analyzed to date [1]. The feature near 285 eV is diagnostic of the C-ring functional group, while the feature near 288.5 eV is diagnostic of carbonyl (C=O). The hydrated IDP, L2008U13, has an additional absorption at 290.3 eV, consistent with carbonate (which is observed in this IDP by TEM). The anhydrous IDP, L2011R11, and the Murchison residue both show an absorption near 290.8 eV, which we have not yet associated with a particular functional group.

*O-XANES.* The O-XANES spectra of the two IDPs and Murchison residue each show a strong pre-edge absorption near 531 eV, consistent with carbonyl. We have previously reported the carbonyl absorption in the organic-rich area of another IDP and shown that the silicate in that IDP gave no pre-edge absorption [4].

*N-XANES.* Each of the N-XANES spectra is weaker and noisier than the C-, or O-XANES spectra as a result of the low N content of IDPs and Murchison residue. However, the N K-edge is seen in all three spectra confirming the presence of percent-level N in all three samples, consistent with previous EELS measurements on IDPs [5]. Two weak, broad pre-edge features are seen in all three samples, near 400 and 402 eV. N-XANES pre-edge absorptions near 400 and 402 eV have been reported in the literature for several N-bearing functional groups [6], but these first N-

XANES spectra are too noisy to reliably determine the center positions of the N absorption features and, thus, to infer the N functional groups.

**Conclusions:** We have obtained the first N-XANES spectra of IDPs, and found percent-level N in both particles. However, these two IDPs were selected for this initial study because each has a high carbon content. More IDPs must be analyzed to determine an average N content. If the N is not uniformly distributed, but is concentrated in one phase (e.g., organic matter), then we will obtain N-XANES spectra with improved signal/noise, allowing identification of N functional groups, by focusing on these N-rich regions as we have previously done for C analysis.

**References:** [1] Flynn, G. J., L. P. Keller, S. Wirick and C. Jacobsen (2000) in *A New Era in Bioastronomy*, ASP Conf. Series, V. 213, 191-194. [2] Anders, E. (1989) *Nature*, 342, 255-257. [3] Jacobsen, C., et al. (2000) *Journal of Microscopy*, 197, 173-184. [4] G. J. Flynn, M. Feser, L. P. Keller, C. Jacobsen, S. Wirick, and S. Avakians (2001) *Lunar and Planetary Science XXX, LPI Houston, Abstract #1603*. [5] Keller, L. P. et al. (1995) *Meteoritics*, 30, 526. [6] Franke, R., S. Bender, and J. Hormes (1995) *Physica B*, 208 & 209, 293-294. [6]

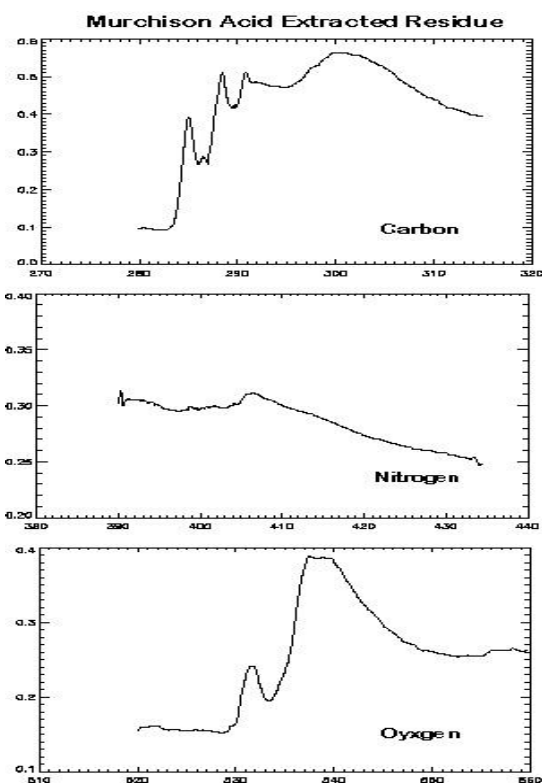


Figure 1: Carbon, nitrogen, and oxygen XANES spectra of Murchison acid residue.

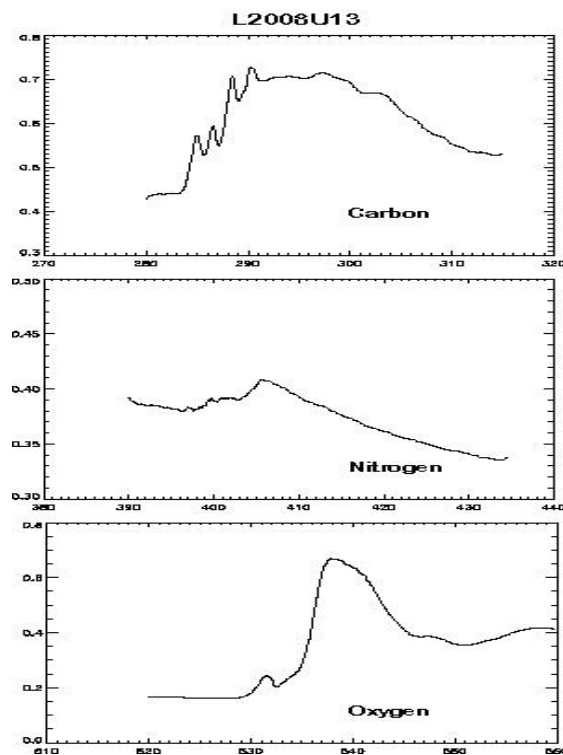


Figure 2: Carbon, nitrogen, and oxygen XANES spectra of the hydrated IDP L2008U13.

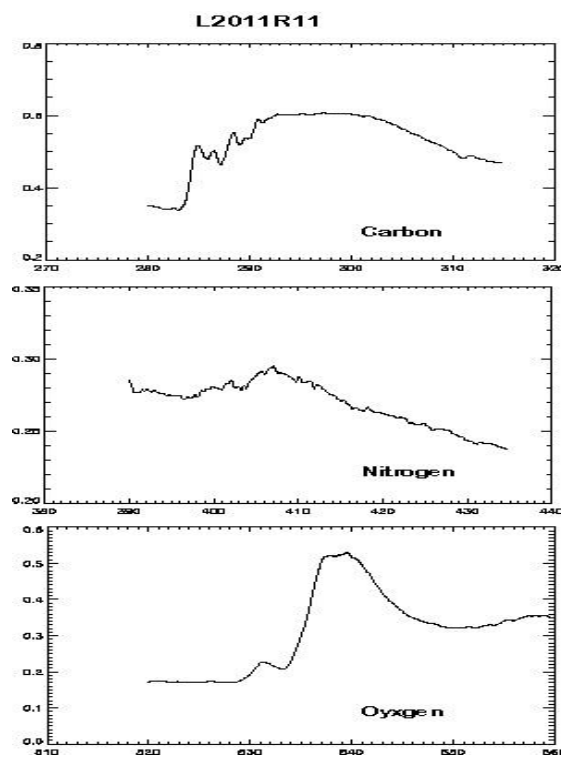


Figure 3: Carbon, nitrogen, and oxygen XANES spectra of the anhydrous IDP L2011R11.