COORDINATED EELS, EDX, AND FTIR ANALYSES OF ORGANIC MATTER IN A HYDRATED IDP.

L. P. Keller[1], I. Ohnishi[2]. G. J. Flynn[3], and S. Wirick[4]
[1]ARES, Code XI3, NASA-JSC, 2101 NASA Parkway, Houston, TX 77058, USA (Lindsay.P.Keller@nasa.gov), [2]JEOL Ltd., 3-1-2 Musashino, Akishima, Tokyo 196-8558, JAPAN, [3]SUNY-Plattsburgh, 101 Broad St., Plattsburgh, NY, 12901, and [4]Focused Beam Enterprises, 79 Baycrest Ave, Westhampton, NY 11977

Introduction: Hydrated interplanetary dust particles (IDPs) are widely believed to be derived from main belt asteroids that have undergone aqueous alteration. However, recent work on solar flare track densities in IDPs have identified a group of hydrated IDPs with high track densities that suggest an outer solar system source body (e.g. Edgeworth-Kuiper belt objects) [1]. Here we report our coordinated analyses of organic-rich materials in a hydrated IDP using a next-generation scanning and transmission electron microscope (STEM).

Methods: IDP U2153M1 was embedded in elemental sulfur and ultramicrotome thin sections ~50 nm thick were placed on amorphous carbon substrates for analyses by synchrotron FTIR, STEM EELS and EDX, and NanoSIMS. Synchrotron FTIR data were collected on Beamline 1.4 at the Advanced Light Source (Lawrence Berkeley National Laboratory). We used an aberration corrected JEOL JEM-ARM300F scanning and transmission electron microscope (STEM) equipped with a cold field emission gun operated at 200 and 60 kV and a Gatan Continuum GIF for electron energy-loss spectroscopy (EELS). The STEM is equipped with a newly developed ultrahigh sensitivity energy-dispersive X-ray (EDX) system composed of a wide gap objective lens pole-piece and two windowless silicon drift detectors whose individual active area is 158 mm^2 (each) for a total collection solid angle of ~2.2 sr [2]. The high collection efficiency of the EDX system enabled the simultaneous acquisition of EDX and EELS spectrum images. To minimize possible artifacts from beam damage, we collected both the EDX and EELS data at 60kV using a ~0.4 nm ~1 nA probe, with a dwell time of 0.1 s/pixel, with a zero loss FWHM of 0.3 eV.

Results and Discussion: The IDP U2153M1 contains abundant fine-grained Mg-rich saponite, FeNi sulfides, a large forsterite grain, and abundant carbonaceous material dispersed throughout matrix and as discrete nanoglobules (individuals and clusters as noted previously [3,4]). The presence of solar flare tracks in forsterite (~$3x10^{10}/cm^2$) and lack of magnetite on outer surfaces suggest that U2153M1 was not significantly heated during atmospheric entry. FTIR spectra from microtome thin sections show a strong 10 μm silicate complex, hydration features at 3 and 6 μm, a strong aliphatic C-H feature at 3.4 μm (Fig. 1d) and a broad carbonyl feature centered at ~5.8 μm.

We obtained preliminary EDX and EELS data from a cluster of nanoglobules and associated matrix in U2153M1. The EDX data show that the globule cluster contains major C, minor O and trace S, but N was not detected. The O is not homgeneously distributed but is concentrated in the outer margins of the cluster. The EELS data from the cluster show three distinct π* peaks (Fig 1a) that we assign to C=C and C=O (both carboxyl and ketone) functionality similar to previous work [e.g. 4]. The EELS data from nanoglobule cluster shows higher C=O in the rim where the highest O concentrations are observed by EDX. We hypothesize that the oxidized rim on the nanoglobule cluster resulted from parent body aqueous processing. We did not detect a N k-edge above background levels consistent with a lack of N detection by EDX. EELS data from the matrix immediately surrounding the nanoglobule cluster are distinct (Fig 1b). Compared to the nanoglobule cluster, the C-C π* peak in the matrix region is broad with a distinct shoulder at 286 eV, and another broad peak occurs between 287-288.5 eV. These broad features may result from greater aromatic and especially aliphatic diversity in matrix regions. The isotopic characteristics of the organic matter will be investigated by NanoSIMS to determine if they are isotopically anomalous in H and N.

References: [1] Keller, L. P. and Flynn, G. J. (2019) *LPSC 50,* #2002. [2] Ohnishi I. et al. (2016) *Microscopy & Microanalysis* 22:218. [3] Nakamura-Messenger, K. et al. (2006) *Science* 314, 1439. [4] DeGregorio, B. T. et al. (2013) *MAPS* 48, 904.

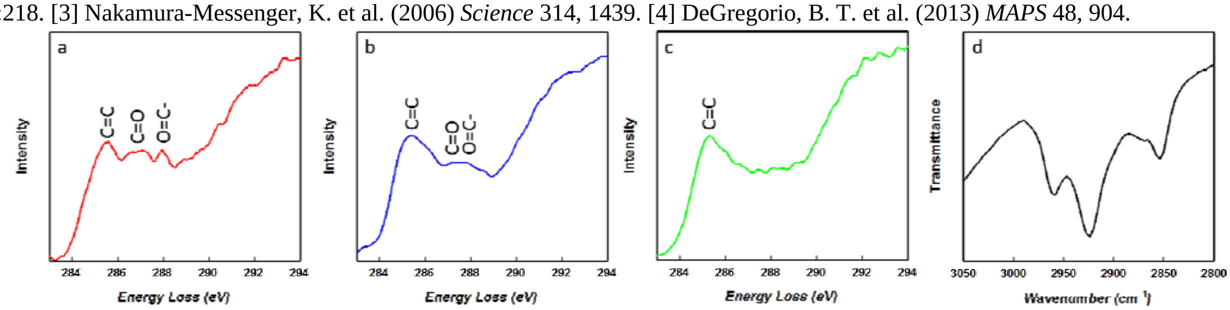

Figure 1. EELS spectra from the oxidized rim of the nanoglobule cluster (a) an area of adjacent matrix (b), and the carbon support substrate (c). Multiple π* peaks provide clues to the organic functionality in these regions. (d) FTIR spectrum from a microtome thin section of U2153M1 showing the C-H stretching region with well-resolved aliphatic CH_3 and CH_2 features.