COMPARISON OF THE ORGANIC COMPOSITION OF COMETARY SAMPLES WITH RESIDUES FORMED FROM THE UV IRRADIATION OF ASTROPHYSICAL ICE ANALOGS. S. N. Milam[1,2,3], M. Nuevo[1], S. A. Sandford[1], G. D. Cody[4], A. L. D. Kilcoyne[5], R. M. Stroud[6], and B. T. De Gregorio[6], [1]NASA Ames Research Center, MS 245-6, Moffett Field, CA 94035, USA (e-mail: Stefanie.n.milam@nasa.gov), [2]SETI Institute, 515 N Whisman Rd, Mountain View, CA 94043, USA, [3]current address: NASA Goddard Space Flight Center, Code 691, Greenbelt, MD 20771, USA, [4]Geophysical Laboratory, Carnegie Institution of Washington, 1530 P St NW, Washington, DC 20005, USA, [5]Advanced Light Source, Lawrence Berkeley National Laboratory, 1 Cyclotron Rd, Berkeley, CA 94720, USA, [6]Naval Research Laboratory, Washington, DC 20375, USA.

Introduction: The NASA Stardust mission successfully collected material from Comet 81P/Wild 2 [1], including authentic cometary grains [2]. X-ray absorption near-edge structure (XANES) spectroscopy analysis of these samples indicates the presence of oxygen-rich and nitrogen-rich organic materials, which contain a broad variety of functional groups (carbonyls, C=C bonds, aliphatic chains, amines, amides, etc.) [3]. One component of these organics appears to contain very little aromatic carbon and bears some similarity to the organic residues produced by the irradiation of ices of interstellar/cometary composition. Stardust samples were also recently shown to contain glycine, the smallest biological amino acid [4]. Organic residues produced from the UV irradiation of astrophysical ice analogs are already known to contain a large suite of organic molecules including amino acids [5–7], amphiphilic compounds (fatty acids) [8], and other complex species. This work presents a comparison between XANES spectra measured from organic residues formed in the laboratory with similar data of cometary samples collected by the Stardust mission.

Experimental: Organic residues were produced experimentally from the UV irradiation of mixtures of astrophysical ices containing H_2O, CH_3OH, CO, and NH_3 in relative proportions 100:50:1:1 at low temperature (~7 K), see Fig. 1. Other residues were also produced from the irradiation of mixtures with no NH_3, and mixtures containing alkanes (C_3H_6), **e** in Fig. 1, and/or naphthalene ($C_{10}H_8$), **f** in Fig. 1. Such experiments aim at simulating processes believed to occur in dense molecular clouds and in cold icy bodies of the Solar System, in particular comets. Some residues were also exposed to further UV radiation (~50-80 hrs) at room temperature for a comparison with warm, high flux regions such as a protostellar disk. We measured C-, N-, and O-XANES spectra of these residues with the scanning-transmission X-ray microscope (STXM) at beamline 5.3.2 at the Advance Light Source (ALS). XANES analyses allowed us to assess the organic functional group chemistry and overall atomic composition of these residues.

Results and discussion: The combination of C-, N-, and O-XANES spectra of the residues indicate the presence of a number of chemical bonds and functions among which carbonyls, C=C bonds, alcohols, amides, amines, and nitrile groups. We will present comparisons of the chemical functionality and C/N/O ratios measured in residues produced from different starting ice mixtures with the organics seen in the Stardust samples from Comet 81P/Wild 2 (see Fig. 2).

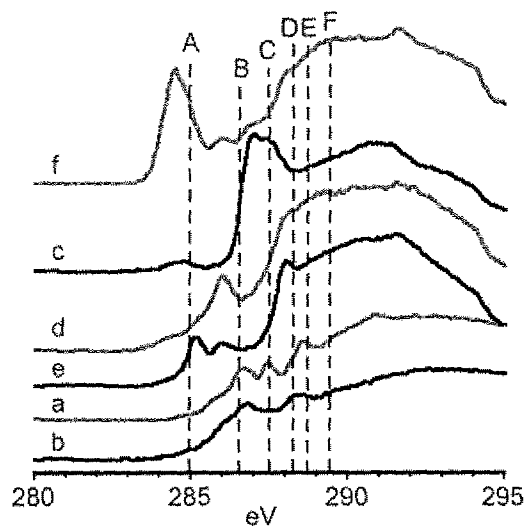

Figure 1. C-XANES spectra from laboratory residues obtained by warmed interstellar/cometary ice analogs exposed to UV radiation. Samples are labeled **a–f**, where the mixtures are **a** $H_2O:CH_3OH:NH_3:CO$ ~ 100:50:1:1; **b** $H_2O:CH_3OH:NH_3:CO$ ~ 100:50:1:1 with post-irradiation at room temperature; **c** $H_2O:CH_3OH:CO$ ~ 100:50:1; **d** $H_2O:CH_3OH:CO$ ~ 100:50:1 with post-irradiation at room temperature; **e** $H_2O:CH_3OH:C_3H_8:NH_3:CO$ ~ 100:50:10:1:1; and **f** $H_2O:CH_3OH:NH_3:CO:C_{10}H_8$ ~ 100:50:1:1:1. Peaks for specific functional groups are labeled **A–F**; where **A** (~285 eV) corresponds to aromatic or olefinic carbon; **B** (~286.5 eV) to oxygen substituted double-bonded carbon; **C** (~287.5 eV) to methyl groups; **D** (~288.2 eV) to carbonyl carbon in amide moieties; E (~288.7 eV) to carbonyl carbon in carboxyl moieties; and F (~289.4 eV) to alcohol/ether moieties.

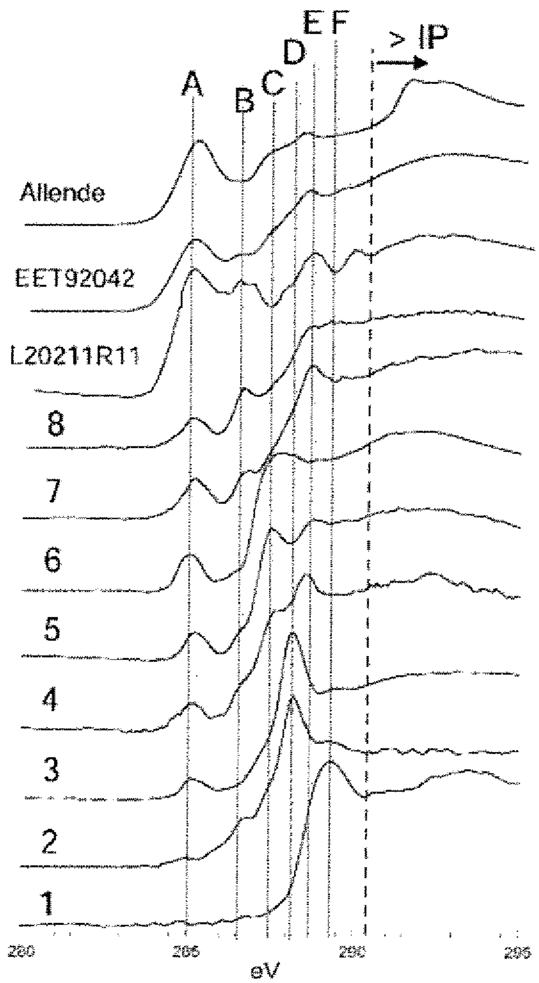

Figure 2. Figure from Cody et al. [3]. C-XANES spectra obtained for organics associated with particles from the Stardust aerogel collector (samples numbers **1**–**8**), the anhydrous IDP (L2011R11), CR2 meteorite (EET 92042), and a CV3 meteorite (Allende). **A**–**F** are the same as in Figure 1. The carbon 1s threshold is labeled by IP.

References: [1] Brownlee D. E. et al. (2006) *Science*, *314*, 1711–1716. [2] Sandford S. A. et al. (2006) *Science*, *314*, 1720–1724. [3] Cody G. D. et al. (2008) *Meteoritics & Planet. Sci.*, *43*, 353–365. [4] Elsila J. E. et al. (2009) *Meteoritics & Planet. Sci.*, *44*, 1323–1330. [5] Bernstein M. P. et al. (2002) *Nature*, *416*, 401–403. [6] Muñoz Caro G. M. et al. (2002) *Nature*, *416*, 403–406. [7] Nuevo M. et al. (2008) *Orig. Life Evol. Biosph.*, *38*, 37–56. [8] Dworkin J. P. et al. (2001) *Proc. Natl. Acad. Sci.*, *98*, 815–819.