Soft X-ray Photoionizing Organic Matter from Comet Wild 2; Evidence for the Production of Organic Matter by Impact Processes . S. Wirick[1], G. J. Flynn[2], C. Jacobsen[3], K. Nakamura-Messenger[4], M. Zolensky[4], and S. Sandford.[5] [1]Focused Beam Enterprises, Westhampton, NY, (swirick@bnl.gov), [2]Depart. Of Physics, SUNY Plattsburgh, NY 12901,[3] Argonne Nat. Lab.,Argonne, IL 60439, [4] NASA Johnson Space Center, Houston, TX 77058, [5] Ames, Moffett Field, CA., 94035

Introduction: The Stardust mission collected both mineral and organic matter from Comet Wild 2 [1,2,3,4]. The organic matter discovered in Comet Wild 2 ranges from aromatic hydrocarbons to simple aliphatic chains and is as diverse and complex as organic matter found in carbonaceous chondrites and interplanetary dust particles.[3,5,6,7,8,9]. Compared to insoluble organic matter from carbonaceous chondrites the organic matter in Comet Wild 2 more closely resembles organic matter found in the chondritic IDPS.

Common processes for the formation of organic matter in space include: Fischer-Tropsch, included with this aqueous large body and moderate heating alterations; UV irradiation of ices; and; plasma formation and collisions. The Fischer-Tropsch could only occur on large bodies processes, and the production of organic matter by UV radiation is limited by the penetration depth of UV photons, on the order of a few microns or less for most organic matter, so once organic matter coats the ices it is formed from, the organic production process would stop. Also, the organic matter formed by UV irradiation would, by the nature of the process, be insensitive to photodissocation from UV light. The energy of soft X-rays, 280-300 eV occur within the range of extreme ultraviolet photons.

During the preliminary examination period we found a particle that nearly completely photoionized when exposed to photons in the energy range 280-310eV. This particle experienced a long exposure time to the soft x-ray beam which caused almost complete mass loss so little chemical information was obtain. During the analysis of our second allocation we have discovered another particle that photoionized at these energies but the exposure time was limited and more chemical information was obtained.

Analytical Techniques: Using the scanning transmission X-ray microscope (STXM) at The X1A beamline, National Synchrotron Light Source [10] STACK absorption images were collected on Comet Wild 2 particle numbers, FC3,0,2,4,4 and C2054,0,35,100,5. These data sets consist of a series of images collected at different energies covering the range between 280-310 eV. The images are aligned in the X and Y dimensions so one can obtain spectra from single pixels. The pixel size used in this data set was 40nm and the energy increments were 0.3 eV from 280-283.4 eV, 0.1 eV from 283.5-292 eV and 0.3 from 292-310eV. The 2 particles analyzed were embedded in sulfur and ultramicrotomed at JSC and microtomed sections were placed onto silicon monoxide backed, copper TEM grids.

Results: Morphologically, both particles are similar. They are approximately the same size. Both particles appear to be made of small globules associated with some long, stringy matter. FC3,0,2,4,4 experienced more than an order of magnitude more radiation dose than C2054,0,35,100,5 (3.2×10^8 gray versus 1.4×10^7 gray), resulting in more mass loss which can be seen by observing the difference between the image at 280.0 eV and 300.0 eV. C2054,0,35,100,5 also lost mass as can be seen by comparing the images at 288.2 eV and 300 eV. Neither particles are pure carbon (images at 280 eV, an energy below the carbon K-edge where elements heavy than carbon absorb), though there are areas in C2054,0,35,100,5 that are carbon rich.

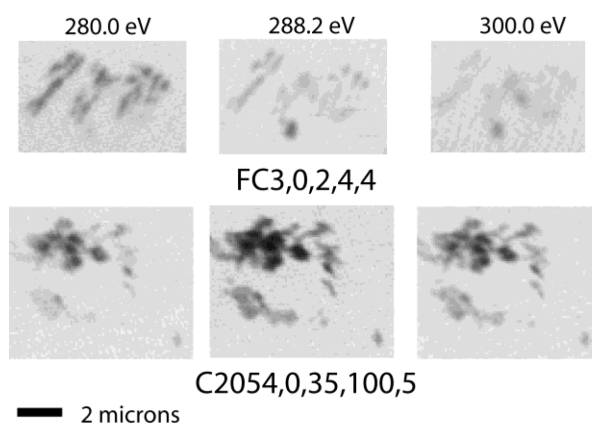

Figure 1. X-ray absorption images of Comet Wild 2 particles.

Figure 2 shows 2 spectra obtained from FC3,0,2,4,4 from 2 small globules that survived exposure to the X-ray beam. Spectrum A was collected from the initial data set. Another data set was collected 2 months later (spectrum B.) and clearly shows the alteration of this organic matter continued after the particle was no longer exposed to the soft X-ray beam. Figure 3 shows 10, single pixel spectra from the first data set collected on C2054,0,35,100,5. On this scale we see significant variability in the carbon spectra. Peak positions in the region of 285 eV vary from 283.6 to 285.2 eV. Two of the spectra have small absorption peaks at 286.2 eV and the region around 288 eV peak energies vary from 288.0 eV to 289.3 eV.

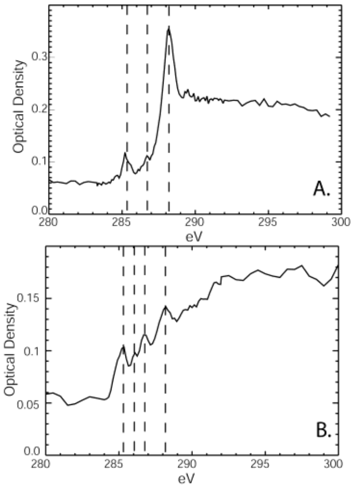

Figure 2 Carbon absorption spectra from FC3,0,2,4,4. Spectrum A. was obtained from 2 small globules that survived exposure to the X-ray beam. Spectrum B. was obtained from the same area 2 months later.

In general, the spectra shown in Figure 3 are representative of saturated hydrocarbons though the presence of absorption in the 285 eV region suggests crosslinking of these carbon chains.

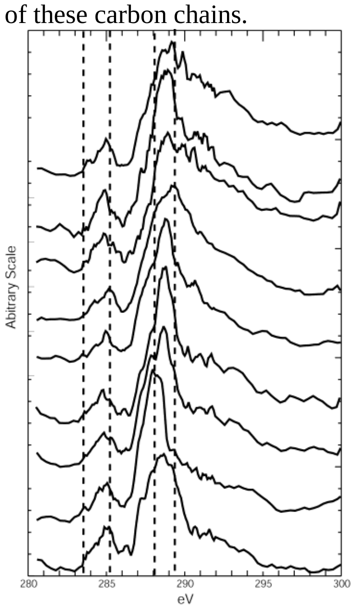

Figure3. Carbon absorption spectra from initial data set collected from C2054,0,100,5. Spectra were collected from 40nm spots and were boxcar smoothed by 2.

Figure 4 shows 40 nm, single pixel carbon absorption spectra collected from C2054,0,35,100,5 after 4 months. Both particles were stored in a dark, nitrogen purged box when not being analyzed. There is only small variability in the spectra. A large absorption peak is centered at 284.8 eV, with a small peak at 286.7 occurring in some areas of the sample. There is another strong absorption at 288.4 eV with small energy shifts occurring around this energy in some of the spectra.

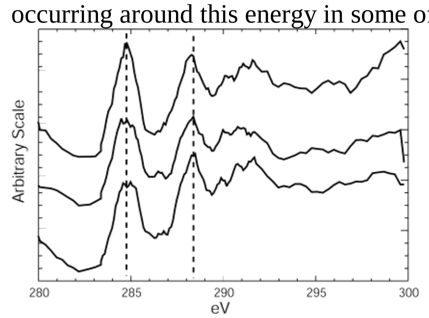

Figure 4 Carbon absorption spectra from C2054,0,35,100,5, taken 4 months after the first exposure to soft X-rays.

Discussion: Though morphologically similar, FC3,0,2,4,4 and C2054,0,35,100,5 are chemically different. Neither the initial or later spectra are similar. C2054,0,35,100,5 is similar to carbon absorption spectra collected from indigenous carbon found in carbonaceous chondrites though the absorption peaks near 285 eV are broader than peaks observed in carbonaceous chondrites. The variability seen in the initially data set for C2054,0,100,35,5 suggests a heterogeneous mixture of carbon compounds that alter at different rates and times. For FC3,0,2,4,4 there were pieces of the particle that lost mass at different times in the STACK, also suggesting a heterogeneous mixture.

Conclusions: Two particles from Comet Wild 2 photoionize when exposed to soft X-rays. The process believed to produce organic matter on comets is UV photoionizing of ices. These particles could not have formed from this process and they would not survive for any length of time on or near the surface of Wild 2 where they would be exposed to photons in the 280-300 eV range. They were either produced by the capture event, likely from the formation of a plasma or by the shock wave effect. The particles could have also come from the interior of the comet and may have been formed by a collision event or some unknown process that forms organic matter in the subsurface area of Comet Wild 2.

References: [1] Zolensky, M. E. et al,(2006), Science,314,1735,[2] Brownlee, D., et al,(2006), Science,314,1711, [3] Keller, L.P. et al, (2006), Science,314,1728,[4]Sandford,S.,et al,(2006), Science, 314,1720,[5]Clemett, S., et al, (2010), MAPS, 45, 701-722, [6] Wirick, S., et al, (2009), MAPS, 44, 1611-1626, [7] deGregorio, B., et al, (2009), LPSC XL, id 2260, [8] Glavin, D.P., et al, (2008), MAPS, 43, 399,-413, [9] Cody, G., et al, (2008), MAPS 43, 353-365 [10] Jacobsen, C. et al (2000) J. of Microscopy, 197, 173-184.