CHARACTERIZATION OF 81P/WILD 2 PARTICLES C2103,1,98,1,0, C2103,1,98,2,0, and C2065,1,97,1,0.

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Introduction: Analyses of cometary materials provide information about the inventories of carbon, nitrogen, and other elements in the regions where comets formed [1-3]. We report studies of three Stardust fragments made using nuclear reaction analysis (NRA) to measure C, N, O, and Si; FTIR to characterize organic matter; synchrotron-induced x-ray fluorescence (SXRF) to determine Fe and certain element/Fe ratios; and SEM/EDAX to image sample morphology. We also had three technical goals. 1) Previously we made blank corrections to C and N based on analyses of aerogel samples *not* flown on Stardust [4]. For this work, we obtained particle-free, Stardust aerogel from a portion of the cell that contained cometary particles studied by [4]. 2) To assess the compositional variability of possibly comet-like extraterrestrial material, we examined several grains taken from the CI chondrites Orgueil and Alais. 3) We undertook a study of grains of Illinois coal fired at high velocity into aerogel as possible analogs for captured Stardust grains.

Samples: L. Keller and K. Messenger extracted particles C2103,1,98,1,0 (C2103,1), C2103,1,98,2,0 (C2103,2) and C2065,1,97,1,0 (C2065). After FTIR analyses, the grains were pressed into high-purity indium foils. Fred Hörz furnished samples of newly made and thoroughly baked aerogel for bombardment with Illinois coal. The bombardment was done using a two stage light gas gun at the University of Kent. B. Zanda supplied samples of Alais and Orgueil. The instrumental methods used are described in [4].

Results: *Aerogel blanks* - Table 1 shows elemental concentrations of aerogel measured by NRA. Signals were stable over time, ruling out significant deposition of C and N during irradiation. The O/Si atom ratios exceed the expected value of 2.0 by ~25% as a result of unavoidable cross section and data processing uncertainties. The average concentration of C measured for a large scanned area (0.1 mm^2) of C2054 is 5 wt%, 10× and 3× the values of 0.5 wt% from [5] and 1.4 wt% from [4], respectively. The newly made aerogel supplied by F. Hörz contains ~3.5 wt% C. Concentrations of N were below the detection limit, ~1×10^9 atom N/μm^2 for an irradiation of 1 μC.

Table 1. Atom fractions

	Si	O	C	N
Aerogel				
New	0.27	0.67	0.055	<0.005
C2054BL1	0.27	0.68	0.081	<0.005
C2054BL2	0.27	0.68	0.081	<0.005
C2054BL3	0.27	0.68	0.081	<0.005
Stardust				
C2103,1	0.27	0.67	0.057	<0.005
C2103,2	0.28	0.45	0.31	~0.005
C2065	0.20	0.49	0.30	<0.005

Stardust fragments - Figure 1 shows SEM/EDAX images of three Stardust fragments taken without C coating. Each fragment is ~10 μm across. No peaks from Fe or Ni were evident in the EDAX x-ray spectra. Only the EDAX x-ray spectrum of C2103,2 had a Mg K-α peak. Evidently, the samples are rich in aerogel.

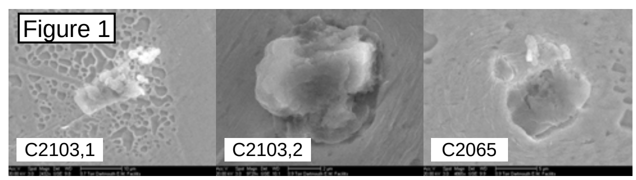

Figure 1

Characteristic infrared absorptions resulting from CH and C=O stretches were observed in the FTIR spectra of all three Stardust fragments. The spectrum of C2065 shows the highest C-H/Si-O peak ratio. As the Si-O content is high, we infer that this fragment contains abundant organics. The spectrum of C2103,1 exhibits a comparable ratio. In comparison, C2103,2 has far weaker but readily detectable organic features.

Figure 2 shows carbon maps for the Stardust fragments. Like C21 [4], fragments 2103,2 and 2065 both contain large concentrations of elemental carbon, ~20 wt%; The C concentration of fragment 2103,1, 3.6 wt%, is below the C2054 blank level, 5 wt%. All fragments contained less than 0.5 wt% N.

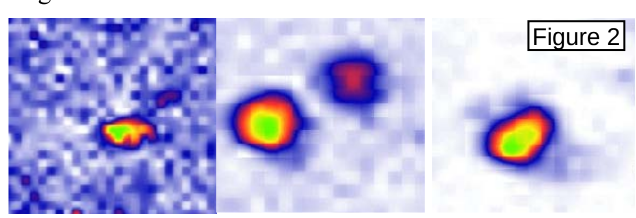
Figure 2

Figure 3 shows CI-normalized elemental ratios from SXRF. For comparison, means and 1-σ confidence limits are plotted for several whole tracks [6,7]; the ranges of the many individual analyses taken along these tracks are larger than the 1-σ limits.

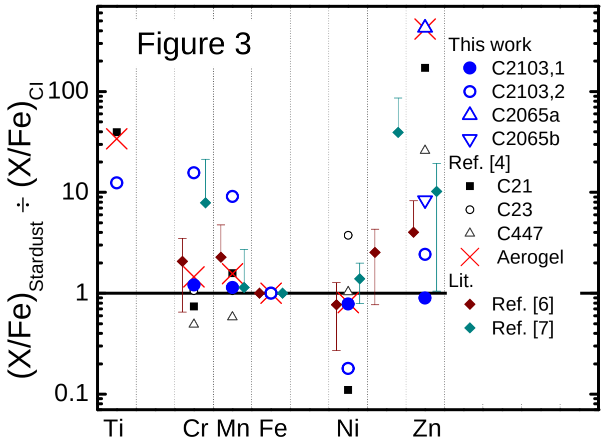

Figure 3

Illinois coal - A high-velocity shot of Illinois coal into aerogel produced the track shown in Figure 4. Scans with NRA, SEM/EDAX, and SXRF yielded no signal above background levels. The coal may have vaporized or ablated while decelerating in aerogel. Recent work shows that during capture significant mass loss (equivalent to ~10 μm of projectile material) accompanied by grain surface temperatures from ≥1500 ºC [8] to 2050 ºC [9] can occur. Significant mass loss and/or processing of organic rich impactors can thus reasonably be expected.

Alais and Orgueil - We analyzed spots in the CI chondrites Alais and Orgueil in order to assess the likely range of C and N variation in small, random samples of material heterogeneous on the micron scale. NRA of ~30×30 μm^2 areas in two separate fragments of each stone of gave the following average atom fractions: Orgueil, C=0.08, N=0.004; Alais, C=0.15, N=0.004, which may be compared to bulk CI values of C=0.06 and N=0.005.

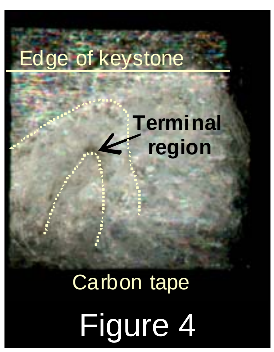

Figure 4

Figure 5 shows the results of 27 SXRF spot analyses of 5 grains from the Orgueil CI chondrite. Relative instrumental sensitivities were calculated as in [6]. The means for three independently measured quantities, the CI normalized ratios Cr/Fe=0.83±0.21, Mn/Fe=0.62±0.21, and Zn/Fe=0.70±0.26, although consistently low, match the expected value of 1.0 to within 2-σ. The CI-normalized Ni/Fe ratio of 0.55±0.17 is more than 2-σ lower than expected. Although matrix effects may account for these generally lower concentrations, sampling bias seems a more likely explanation. Any systematic error is smaller than the range of variation in elemental concentrations observed in both the CI samples and Stardust fragments.

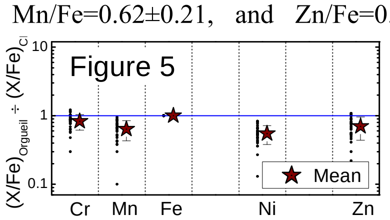

Figure 5

Discussion: The 3 Stardust fragments analyzed contain compressed or partially melted aerogel and must be associated with the capture of Wild 2 material. The Ni concentrations of 2103,1 and ,2 show the presence of cometary material. Remarkably, none of the new fragments contains detectable nitrogen. Although C concentrations in ultra thin sections of Stardust fragments vary widely sub micron scale [10], C/N atom ratios for 8 organic-rich samples occupy a narrow range, from 4 to 14 [11]. The new, high C/N ratios of Stardust fragments implied in Table 1 may be artifacts of the aerogel capture process, resulting perhaps from the processing of organic carbon present in the aerogel.

Conclusions: Some particle-free aerogel used to capture Stardust particles contains 5 wt% C, about 10× times the expected value [5]. Either carbon concentrations in the flight aerogel varied from place to place or the aerogel picked up additional carbon over time. Stardust fragments C2103,2 and C2065 contain high concentrations of C, but no detectable N. Such high concentrations of C are uncommon in microtomed sections. Detailed petrography of a carbon-rich Stardust fragment would be desirable. A shot of Illinois coal fired into high-purity aerogel produced a track with no detectable terminal particles. The coal may have disaggregated to submicron, carbon-rich grains and/or vaporized during deceleration. Vaporization would be consistent with observations of labile organics in the Stardust samples [12]. Analyses of random grains of CI chondrites agree well enough with accepted CI abundances to suggest that 15-20 random analyses of C and N in 'bulk' Stardust grains will give representative results.

References: **[1]** Brownlee D.E. et al. (2006) *Science*, *314*, 1711-1716. **[2]** Flynn G.J. et al. (2006) *Science*, *314*, 1731-1735. **[3]** Keller L.P. et al. (2006) *Science*, *314*, 1728-1731. **[4]** Gallien et al. (2008) *M&PS*, *43*, 335-351. **[5]** Tsou P. et al. (2003) *JGR*, doi:10.1029/2003JE002109. **[6]** Lanzirotti A. et al. (2008) *M&PS*, *43*, 187-213. **[7]** Ishii H. et al. (2008) *M&PS*, *43*, 215-231. **[8]** Burchell M.J. et al. (2009) *PSS*, in press. **[9]** Hörz F. et al. (2009) *M&PS*, in press. **[10]** Matrajt G. et al. (2008) *M&PS*, *43*, 315-334. **[11]** Cody G. et al. (2008) *M&PS*, *43*, 353-365. **[12]** Sandford S. et al. (2006) *Science*, *314*, 1720-1724.