CHEMICAL COMPOSITION OF WILD-2 SAMPLES RETURNED BY STARDUST. G. J. Flynn[1], P. Bleuet[2], J. Borg[3], F. Brenker[4], S. Brennan[5], E. Bullock[6], C. Daghlian[7], Z. Djouadi[3], T. Ferroir[7], Z. Gainsforth[8], J.-P. Gallien[9], Ph. Gillet[8], P. G. Grant[11], F. Grossemy[3], G. F. Herzog[12], H. A. Ishii[11], H. Khodja[10], A. Lanzirotti[13], J. Leitner[14], L. Lemelle[8], K. Luening[5], G. MacPherson[6], M. Marcus[15], G. Matrajt[16], T. Nakamura[17], T. Nakano[18], M. Newville[13], P. Pianetta[5], W. Rao[19], D. Rost[6], J. Sheffield-Parker[20], A. Simionovici[8], I. Sitnitsky[1], T. Stephan[14], S. R. Sutton[13], S. Taylor[21], A. Tsuchiyama[22], K. Uesugi[23], A. Westphal[9], E. Vicenzi[6], L. Vincze[24], [1]SUNY, Plattsburgh NY 12901 (george.flynn@plattsburgh.edu), [2]ESRF, Grenoble, France, [3]Institut d'Astrophysique Spatiale, Orsay, France, [4]JWG-University Frankfurt, Germany, [5]Stanford Linear Accelerator Center, Menlo Park CA, [6]Smithsonian Institution, Washington D.C., [7]Dartmouth College, Hanover NH, [8]École Normale Supérieure de Lyon, Lyon, France, [9]Univ. of California, Berkeley CA, [10]Lab. Pierre Süe, CEA/CNRS, Saclay, France. [11]Lawrence Livermore National Laboratory, Livermore CA, [12]Rutgers Univ., Piscataway NJ, [13]University of Chicago, Chicago IL, [14]Institut für Planetologie, Universität Münster, Germany, [15]Advanced Light Source, Berkeley, CA., [16]Univ. of Washingrton, Seattle WA, [17]Kyushu University, Hakozaki, Japan, [18]AIST/GSJ, Ibaragi, Japan, [19]University of Georgia, [20]XRT Limited, Port Melbourne, Australia, [21]ERDC-CRREL, Hanover, NH, [22]Osaka Univ., Japan, [23]JASRI/SPring 8, Hyougo, Japan, [24]Ghent Univ., Ghent, Belgium.

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On Jan. 2, 2004 NASA's Stardust spacecraft flew through the coma of comet Wild-2, capturing dust in low-density silica aerogel that was delivered to Earth on Jan. 15, 2006. A description of the capture cells is given in Tsou et al. [1]. Wild-2 is a short-period comet, believed to have originated in the Kuiper Belt. Thus, analysis of Wild-2 dust provides the first opportunity to probe conditions in the Kuiper Belt during dust formation and compare them with conditions in the asteroid belt, as inferred from primitive meteorites.

Aerogel capture results in a relatively gentle deceleration, so the capture of strong particles, such as crystalline grains, produces a conical track, typically having a length several hundred times the particle diameter, with a single terminal particle at the end. However, weak material, e.g., the Orgueil carbonaceous chondrite meteorite, shot into aerogel at ~6 km/s, comparable to the Stardust encounter with Wild-2, frequently leaves many fragments along the track. Many of the Wild-2 grains either broke up upon collection or deposited a significant fraction of their material along the walls of the track (as shown in Figure 1). In addition, the capture process results in accretion of a silica coating on the particle [1], suggesting the particle's surface contacted liquid silica, which could mobilize moderately volatile elements. Thus, silica aerogel is intimately mixed with many of the particles, making it impossible to determine the Si content of the Wild-2 material.

In order to determine the extent to which material was deposited along the tracks, "aerogel keystones," which are thin wedges of aerogel containing the intact track, were extracted from the capture cells using techniques developed by Westphal et al. [2]. The element distribution in each keystone was mapped by detecting the fluorescence x-rays produced by focused beams of x-rays or protons, using techniques described in REFERENCE 3.

Element maps of Track 19, which is typical of the Stardust trackstracks, shows that Fe is distributed along the track wall and in the terminal particle, while the Ni is concentrated in the track walls, with little Ni in the terminal particle. The Zn is distributed along only part of the track wall, while the Cr is concentrated in the terminal particle. A comparison of the chemical composition of the terminal particle with the chemical composition of all the material deposited along the entire track (Figure 3), including the terminal particle, indicates that terminal particles are not representative of the composition of the particle that impacted the aerogel. In particular, the Ni/Fe and Zn/Fe ratios are lower by more than an order-of-magnitude than the corresponding ratios averaged over the whole track. This indicates that the composition of the impacting particle can only be determined by summing elements over the entire track.

While measurement of the chemical compositions, even for many trace elements, of individual particles >0.5 µm in size is relatively straightforward using X-ray or Proton Microprobesthe measurement of elements distributed along the track is more complicated. These measurements must be performed while the material remains in a keystone of aerogel, and the impurities in the aerogel itself contribute to the fluorescence signal Tsou et al. [1] found 1800 ppb of Fe, XX ppb of Zn, etc. in a Stardust aerogel cell by ICP-MS. X-ray Microprobe measurements show the impurity content varies from spot to spot and from cell to cell, making background subtraction difficult. Thus, the number of elements that can be detected along the tracks is more limited than the number that can be detected in individual particles embedded in the same aerogel. DESCRIBE TECHNIQUE FOR SUMMING.

We have mapped the element distributions and determined the element abundances along six Stardust tracks, ranging from ~860 µm to ~3900 µm long. These compositions are given in Table 1. There is a high degree of variability in the fraction of the total Fe detected along the track that is contained in the terminal particle. This ranges from a low of about 10% of the total Fe in the terminal particle to a high of about 70% of the Fe in the terminal particle.

The individual tracks show significant variation in composition. We determined an average composition by adding the element contents of the 6 particles for all elements that were measured in all 6 particles. The average composition is within approximately a factor of 2 of the CI value for Cr, Mn, Ni, and Zn, but differs significantly for Ga (which averages 28xCI) due to the presence of two very high Ga particles in this set.

The terminal particles show significantly more variation in composition than the whole tracks, probably indicating that compositionally distinct mineral grains survive intact to the ends of the tracks. Figure 5 shows the compositions of the terminal particles from the same tracks that we have measured the whole track compositions.

The terminal particle in each of these 6 tracks was analyzed separately. These terminal particles have highly variable compositions, with order-of-magnitude or more variation in the Ca/Fe, Ni/Fe Cr/Fe, Mn/Fe Zn/Fe Rb/Fe, Se, Fe, and S/Fe ratios. Four of these six terminal particles are Cr-rich and Ga-rich compared to the CI element/Fe ratio, while Ge is <<CI in four of the 6 particles.

Conclusions: The terminal particles frequently contain significantly less than 50% of the total Fe deposited in the aerogel from the impact event, suggesting that the dust from comet Wild-2 is very weakly held together. Several of the terminal particles have very low Ni/Fe, which is consistent with XRD, FTIR, and TEM observations of olivine or pyroxene dominated terminal particles, but Ni-rich Fe-sulfide terminal particles are detected as well. The composition of terminal particles is generally not representative of the particle that struck the aerogel, but the composition of the original particle can be determined by mapping each element over the whole extent of the track. In particular, Ni and several moderately-volatile elements (e.g., Zn) are frequently found to be concentrated in the entry portion of the tracks.

The size-scale for compositional heterogeneity is at least 12 µm in Wild-2, which is a much larger size scale for hetrogenity than we see in the fine-grained, anhydrous interplanetary dust particles collected from the Earth's stratosphere [reference].

References: [1] Tsou, P. et al. (2003) *JGR*, **108**, E10, 3.1-3.21. [2] Westphal, A. et al. (2004) *Meteor. Planet. Sci.*, **39**, 1375-1386. [3] SXRF reference on track analysis.

Table 1:
Whole Track Element Abundances for 6 Stardust Particle

All Element Abundances in Femtograms

Track#	**S**	**Ca**	**Cr**	**Mn**	**Fe**	**Ni**	**Cu**	**Z**	**Ga**	**Fract. of Fe in TP**
19	**2200**	**70**	**373**	**92**	**12000**	**500**	**13**	**243**	**3**	
20			**116**	**123**	**1600**	**64**	**8**	**10**	**3**	
21			**740**	**646**	**25636**	**990**	**24**	**182**	**15**	
22			**4900**	**3960**	**179000**	**630**	**17**	**220**	**250**	

32	**1100**	**12000**	**0.26**	**0.29**	**1400**	**42**		**4**	**0.3**
68	**94000**	**12000**	**880**	**1200**	**67000**	**5400**		**330**	**140**

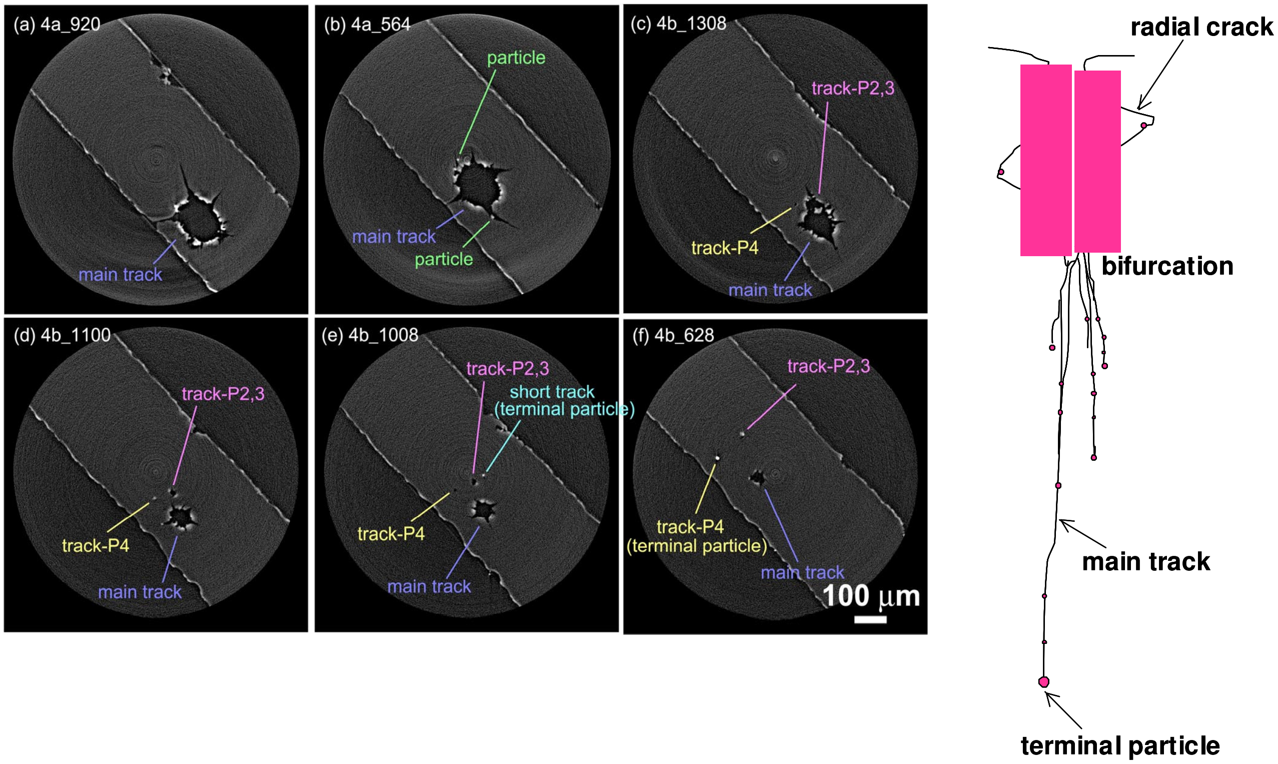

Figure 1: X-ray tomography, with a resolution of 0.5 μm/voxel, of a single event in the Stardust aerogel indicates that some tracks are quite complicated, showing radial cracks with embedded particles, bright track walls, suggesting a mixture of dust and condensed aerogel deposited along the wall, and birfucation with several individual particles at the end of tracks.

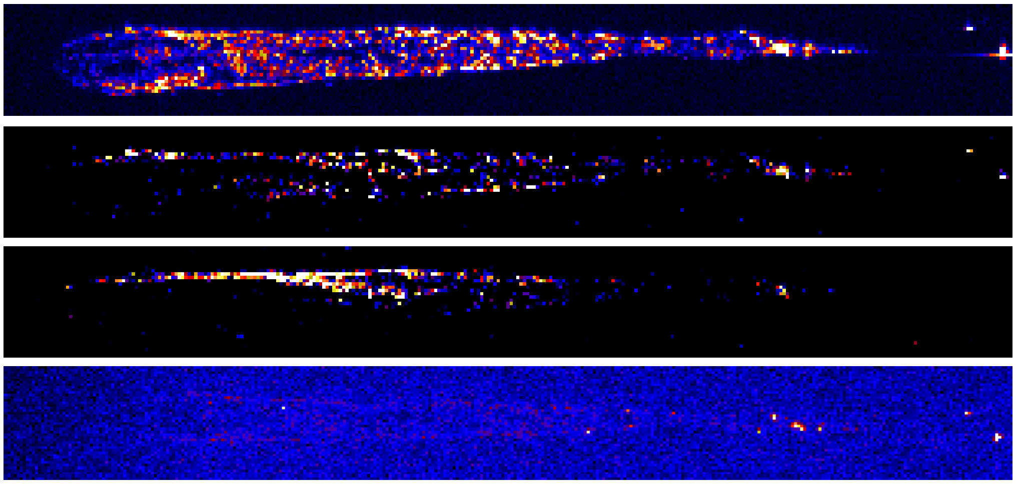

Figure 2: X-ray fluorescence maps of the distribution of Fe, Ni, Zn, and Cr along Stardust Track 19. While the Fe is distributed along the track walls and in the terminal particle, the Ni is concentrated in the track walls, with little Ni in the Terminal particle. Zn is distributed along only part of the wall and Cr is concentrated in the terminal particle.

Figure 3; Chemical composition of the Track 19 termi the whole track indicates that the terminal particle impacted the aerogel.

NOTE, we will show only the dark blue line (termi composition)

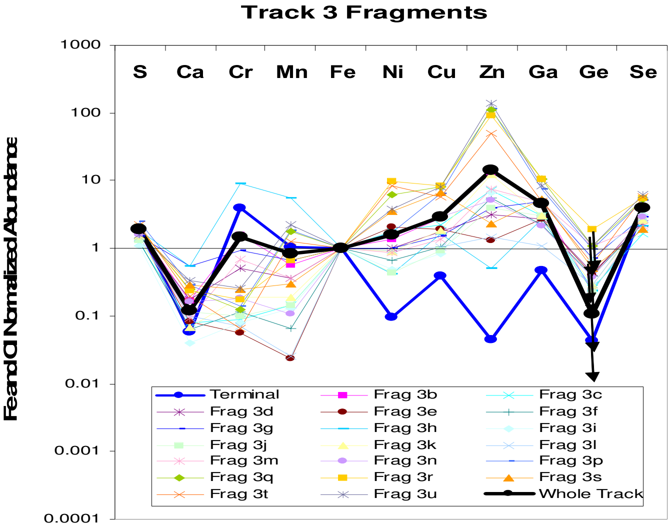

Figure 4: Element abundances in the 6 Stardust tracks and mass-weighted average composition of the 6 tracks (black line)

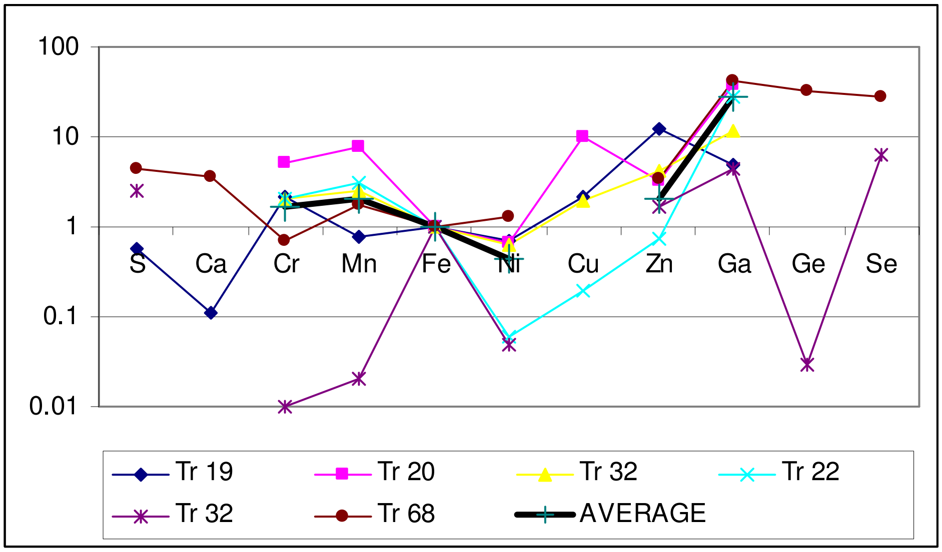

Figure 5: Compositions of the terminal particles in the 6 tracks for which whole track compositions are reported in Table 1. The terminal particles have highly variable compositions, with order-of-magnitude or more variation in the Ca/Fe, Ni/Fe Cr/Fe, Mn/Fe Zn/Fe Rb/Fe, Se/Fe, and S/Fe ratios.

NEED TO INCLUDE THE SPRING 8 DATA