REMARKABLY HIGH ABUNDANCE OF PRESOLAR GRAINS IN INTERPLANETARY DUST PARTICLES COLLECTED FROM THE COMET GRIGG-SKJELLERUP DUST STREAM.

A. N. Nguyen[1], H. Busemann[1,2] and L. R. Nittler[1], [1]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road NW, Washington DC 20015, USA (nguyen@dtm.ciw.edu), [2]Planetary & Space Science Research Institute, The Open University, Milton Keynes, MK7 6AA, UK.

Introduction: Interplanetary dust particles (IDPs) have been shown to preserve isotopic anomalies, particularly in nitrogen and hydrogen associated with molecular cloud organic material [1-3]. Furthermore, with the heightened capabilities of the NanoSIMS ion microprobe, submicrometer-sized presolar silicate grains have been identified in IDPs [3-6]. Recently, four IDPs collected during the 2003 Earth passage through the comet Grigg-Skjellerup dust stream were analyzed by isotopic and micro-Raman imaging [7]. All of the samples display heterogeneous distributions and anomalous "hotspots" in both D/H and $^{15}N/^{14}N$ ratios (Fig. 1). Raman spectra for these samples indicate disordered C similar to the most primitive interstellar organic material in meteorites [8]. These data support the possibility that the IDPs studied by [7] did indeed originate from comet Grigg-Skjellerup. Of the four samples, L2054 E1, a fragment from a cluster IDP, and individual IDP L2054 G4 have the highest D-enrichments, with δD up to 16,000 ‰. We thus focus on these two samples to conduct further isotopic studies.

Experimental: The IDPs L2054 E1, L2054 F1 (a fragment from the same cluster IDP as E1), L2054 G2, L2054 G3, and L2054 G4, all of which had been pressed into Au foils, were analyzed by raster ion imaging with the Carnegie NanoSIMS 50L ion microprobe. A focused (~100 nm) Cs^+ primary ion beam was rastered over the IDPs, and negative secondary ions of the three O isotopes, ^{12}C, ^{28}Si, and $^{12}C^{14}N$ were measured simultaneously along with secondary electrons. Integrated ion images were produced and from these, O isotopic ratio images were also calculated. Regions of interest were defined and their O isotopic ratios were normalized to the average ratio of the IDP. Grains having O isotopic compositions distinct from the isotopically normal sub-regions of the sample could thus be identified. The mineral species (i.e., oxide or silicate) was estimated from the $^{28}Si^-$ signal. For L2054 E1 and G4, the three Si isotopes and $^{24}Mg^{16}O$ were analyzed in a second set of measurements. In addition, ^{16}O and ^{17}O were measured again to ensure that any grains previously identified as having anomalous $^{17}O/^{16}O$ ratios could easily be located and their Si isotopic ratios deduced. The Si isotopic ratios and the $^{17}O/^{16}O$ ratio were normalized to those of the average IDP.

Results: *L2054 E1 and F1:* No anomalous grains

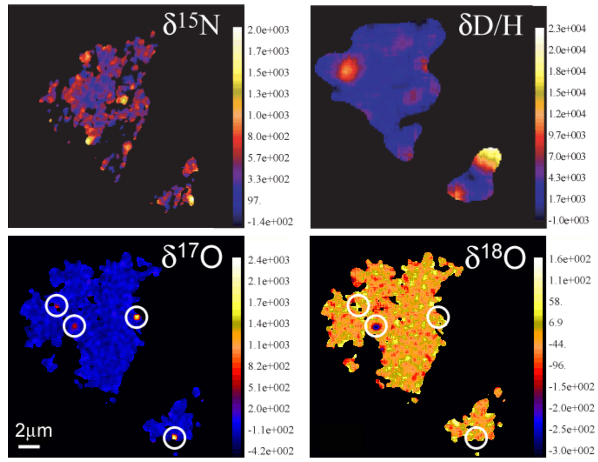

Figure 1. Isotopic ratio images of L2054 E1. The N (NanoSIMS) and D (IMS-6f) measurements were performed previously by [7]. Grains having anomalous compositions appear distinct from the rest of the IDP. Presolar silicate grains are circled in the O ratio images.

were identified in F1 (~15 μm^2). However, four grains having anomalous O isotopic compositions were identified in L2054 E1 (~140 μm^2, Fig. 1). All four grains have $^{28}Si^-/^{16}O^-$ ratios similar to the average ratio of the IDP fragment, which is composed mostly of silicate minerals. In addition, all grains display $^{24}Mg^{16}O^-$, making it likely that these grains are Mg-rich circumstellar silicates. One of these grains is enriched in ^{29}Si and ^{30}Si ($\delta^{29}Si$ = 149 ± 25 ‰; $\delta^{30}Si$ = 133 ± 30 ‰). *L2054 G4:* This ~40 μm^2 IDP was found to contain 7 grains with anomalous O isotopic compositions. Six of these grains were unambiguously identified during the second set of measurements (though also visible in the first) and thus the $^{18}O/^{16}O$ ratios were not well determined. All of the grains appear to be silicates with some Mg. The Si isotopic compositions for these grains fall in the range observed for mainstream SiC grains and for other presolar silicate grains [9, 10]. In addition, one grain has depletions in ^{29}Si and ^{30}Si ($\delta^{29}Si$ = -159 ± 25 ‰, $\delta^{30}Si$ = -74 ± 39 ‰) similar to those seen in SiC X grains that originate from Type II supernova. The $^{28}Si^-/^{16}O^-$ ratio for this grain is greater than the average for this IDP. An attempt to obtain the C isotopic composition for this grain was not successful as the grain had been sputtered away. *L2054 G2 and G3:* No anomalous grains were found in these two large (total analyzed area ~1800 μm^2) individual IDPs, which also show less extreme H and N isotopic variability than the other samples.

Discussion: Fig. 2 shows the O isotopic ratios of the presolar silicates from L2054 E1 and G4. The 5 grains for which we have $^{18}O/^{16}O$ data fall into the presolar oxide Group 1 believed to originate from low-mass red giant and asymptotic giant branch stars [11]. The Si isotopic ratios for all grains are plotted in Fig. 3 along with the SiC mainstream correlation line. This correlation line mainly reflects the initial composition of the parent stars.

The inferred abundance of presolar silicate grains in the cluster IDP of which E1 and F1 are fragments is 0.35 %. The abundance in IDP L2054 G4 is 1.5 %. In contrast, the estimated average abundance of presolar silicates in isotopically primitive IDPs is ~375 ppm [3]. Clearly L2054 E1 and G4 are some of the most primitive extraterrestrial materials studied. This is exemplified not only by the exceptionally high abundances of presolar grains, but also by the large D and ^{15}N anomalies and extremely disordered Raman signatures seen previously [7].

That two of four studied IDPs from the L2054 April 2003 collection, one cluster particle and one individual one, are so strikingly different from almost all previously studied IDPs is statistically unlikely. This strengthens the possibility of a link to comet Grigg-Skjellerup. Unusual noble gases reported for some IDPs from the same collection might also support such a link [12]. However, it is interesting to note that the IDPs studied here show much higher abundances of presolar organic matter and presolar grains than has been found in samples from comet Wild-2 [13, 14]. If the IDPs are indeed from Grigg-Skjellerup, then this difference might reflect heterogeneity within or between comets or biases introduced by the different sampling methods.

References: [1] Aléon J. et al. (2001) *Geochim. Cosmochim. Acta, 67*, 3773-3787. [2] Busemann H. et al. (2006) *Science, 312*, 727-730. [3] Floss C. et al. (2006) *Geochim. Cosmochim. Acta, 70*, 2371-2399. [4] Messenger S. et al. (2003) *Science, 300*, 105-108. [5] Floss C. and Stadermann F. J. (2004) *LPS XXXV*, Abstract #1281. [6] Messenger S. et al. (2005) *Science, 309*, 737-741. [7] Nittler L. R. et al. (2006) *LPS XXXVII*, Abstract #2301. [8] Busemann et al. (2007) *Meteoritics & Planet. Sci., submitted.* [9] Mostefaoui S. and Hoppe P. (2004) *ApJ, 613*, L149-L152. [10] Nguyen A. N. et al. (2007) *ApJ, submitted.* [11] Nittler L. R. et al. (1997) *ApJ, 483*, 475-495. [12] Palma R. L. et al. (2005) *Meteoritics & Planet. Sci. (Supp.), 40*, Abstract #5012. [13] Sandford S. A. et al. (2006) *Science, 314*, 1720-1724. [14] McKeegan K. D. (2006) *Science, 314*, 1724-1728.

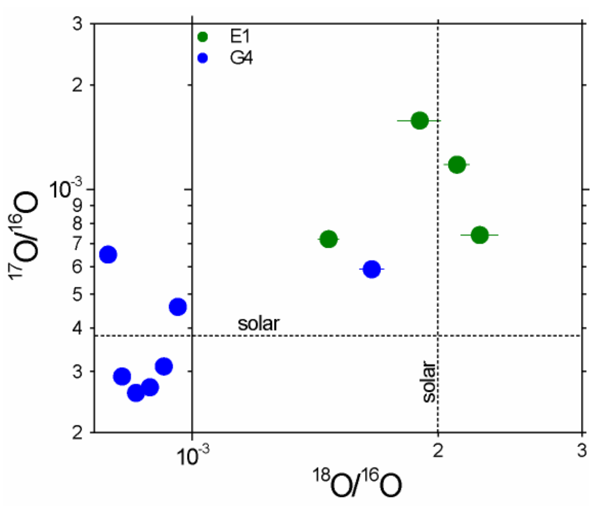

Figure 2. Oxygen isotopic ratios for presolar silicates from IDPs L2054 E1 and G4. The data points on the left represent the silicates from G4 for which $^{18}O^{-}$ was not directly measured. Error bars are 1σ.

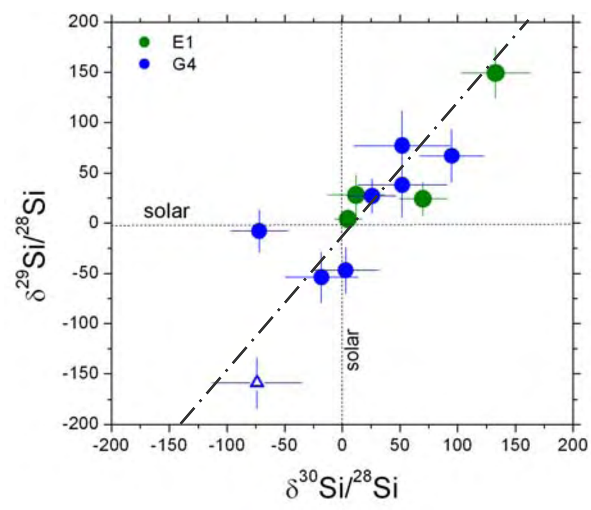

Figure 3. Silicon isotopic ratios for presolar silicates from IDPs L2054 E1 and G4. The triangular data point is a possible SiC X grain from G4. Error bars are 1σ. Also shown is the SiC mainstream correlation line (dash-dotted line).