ISOTOPICALLY PRIMITIVE INTERPLANETARY DUST PARTICLES OF COMETARY ORIGIN: EVIDENCE FROM NITROGEN ISOTOPIC COMPOSITIONS.

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Introduction: The presence of large and variable H and N isotopic anomalies in interplanetary dust particles (IDPs) is well-established [*e.g.*, 1] and attests to the primitive nature of the material present in IDPs. Last year we reported on the C, N and O isotopic systematics of two unusual IDPs [2]. Both contain grains with highly anomalous O isotopic compositions, indicative of a presolar origin, and exhibit N isotopic anomalies, in the form of ^{15}N-enriched bulk compositions as well as more localized enrichments in ^{15}N (up to +1270 ‰). Moreover, a ^{15}N-rich hotspot in one IDP contains the first C isotopic anomaly reported in IDPs [2, 3]. With the extension of our isotopic imaging survey to additional IDPs, we confirm the existence of a sub-group of IDPs with primitive isotopic characteristics.

Experimental Procedures: We are using the Washington University NanoSIMS to measure the C, N and O isotopic compositions of IDPs from collectors L2009, L2011 and L2036. Measurements are made in raster imaging mode, in which a Cs^+ is rastered over the sample surface and secondary ions are collected simultaneously at high mass resolution. The procedures are similar to those outlined in our previous work [2–4] and consist of one set of measurements for C and N ($^{12}C^-$, $^{13}C^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$, $^{28}Si^-$) and another for O ($^{16}O^-$, $^{17}O^-$, $^{18}O^-$, $^{28}Si^-$, $^{24}Mg^{16}O^-$). Carbon and N isotopes have been measured in 39 IDPs and O isotopes have been measured in a subset of 21 of these.

Presolar Grains in IDPs: We have identified nine presolar grains in six different IDPs, based on their anomalous O isotopic compositions (Fig. 1). Six of the grains (B1, D1, G2, G3, H1, K1) have elevated $^{17}O/^{16}O$ ratios and solar to moderately depleted $^{18}O/^{16}O$ ratios, similar to Group 1 presolar oxide grains [5], which are thought to originate in red giant or asymptotic giant branch stars. The three remaining grains (E1, G1, H2) exhibit ^{18}O-enrichments, two of them with slightly elevated $^{17}O/^{16}O$ ratios. Metal-rich stars and type II supernovae have been suggested as possible sources for such grains [5, 6].

Most of the grains range in size from about 250 nm to 400 nm, but one grain from Eliot (E1) is quite large, 550 x 700 nm^2. We took high magnification photos with a field emission SEM and obtained EDS spectra of seven of the grains using 5 keV accelerating voltage to minimize contributions from underlying or surrounding material. Four grains (G1, G2, G3, H1) are identified as pyroxene; two are Mg-rich (G1, G3), and two are Fe-rich (G2, H1). The remaining three grains (D1, E1, H2) have (Fe+Mg)/Si ratios lower than those of either olivine or pyroxene (2 and 1, respectively). None of the grains appear to be olivine, although presolar olivine has been observed in another IDP [7] and in the primitive carbonaceous chondrite Acfer 094 [8]. Amorphous silicates observed in the dust shells around evolved stars are dominated by olivine with only a minor (< 10 %) pyroxene component [9]. However, among crystalline silicates, pyroxene is more abundant than olivine [10].

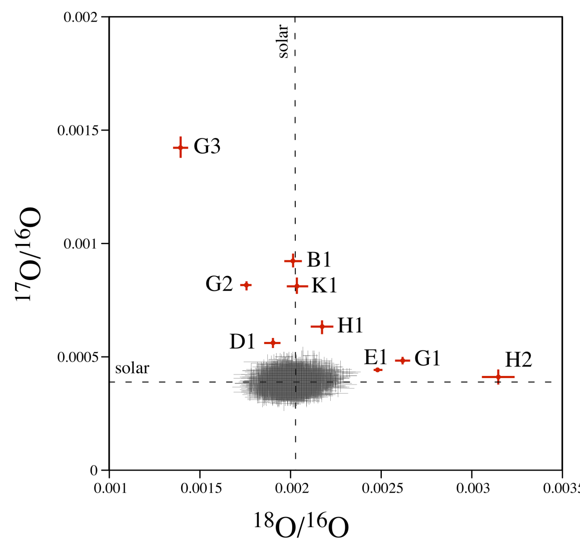

Figure 1. Oxygen isotopic compositions (1σ errors) of presolar grains compared with isotopically normal sub-regions of the same IDPs (in black). Letters refer to the IDPs in which each grain is found: B: Benavente; D: du Gard, E: Eliot; G: Galsworthy; H: Hesse; K: Kipling.

We calculated the abundance of presolar grains in our IDPs by dividing the area of the grains by the total area of all 21 IDPs imaged and arrive at an abundance of 135 ppm.

C and N Isotopic Systematics: Last year we noted that the two IDPs, Kipling and Benavente, in which we observed presolar grains also exhibit bulk enrichments of ^{15}N and contain hotspots with the largest ^{15}N enrichments seen to date; one of these ^{15}N hotspots is also depleted in ^{13}C, the first C isotopic anomaly observed in an IDP [2, 3]. TEM observations indicate that the anomalies are associated with hetero-atomic organic matter [3]. Of the four additional IDPs containing presolar grains reported here, three of them (Galsworthy, du Gard and Hesse) also have bulk ^{15}N enrichments and large ^{15}N-rich hotspots (Table 1). The ^{15}N-rich hotspot in Hesse also exhibits a C isotopic anomaly (Fig. 2). In contrast to the ^{13}C depletion observed in Benavente [2, 3], this hotspot is enriched in ^{13}C by +125 ‰. The remaining IDP, Eliot, shows a modest bulk depletion of ^{15}N and contains no anomalous N hotspots.

Of the 33 other IDPs whose C and N isotopic compositions we have measured, several contain ^{15}N-rich hotspots of varying magnitude, but only four show bulk ^{15}N enrichments as well as ^{15}N-rich hotspots. Two of these are different fragments of the same cluster particles from which du Gard (L2009-c13) and Hesse and Galsworthy (L2036-c18) come. The two remaining IDPs come from a different cluster particle on collector L2036 and have not yet been measured for O isotopic compositions.

Discussion: The data presented above show the existence of a discrete sub-group of IDPs characterized by anomalous bulk N compositions. These IDPs are isotopically primitive compared to other IDPs, with larger ^{15}N-rich hotspots, occasional C isotopic anomalies and abundant presolar silicate grains. Recent N isotopic measurements of the CN spectra of comets Hale-Bopp and LINEAR give low $^{14}N/^{15}N$ ratios of 140 ± 35 and 140 ± 30, respectively [11], values similar to those observed in many of the N hotspots in these IDPs (Table 1). On the other hand, higher than terrestrial $^{14}N/^{15}N$ ratios, similar to what we see in Eliot, have also been reported [12, 13]. These similarities imply a cometary origin for this sub-group of N-anomalous IDPs and suggest that bulk N isotopic compositions can be used to identify isotopically primitive IDPs. Variations in bulk N compositions probably reflect mixing of different phases (*e.g.*, [11]) and variable degrees of secondary processing. If we assume that these IDPs do indeed represent a distinct population, we can calculate an abundance of presolar grains in this sub-group of IDPs of 450 ppm, 3 times higher than the abundance in all our IDPs. This value is an order of magnitude lower than an initial estimate of ~5500 ppm for presolar silicates in IDPs [7], but is still significantly higher than recent estimates of 20–25 ppm for the abundance of presolar silicates in primitive meteorites [8, 14], emphasizing the primitive nature of interplanetary dust particles relative to other solar system materials.

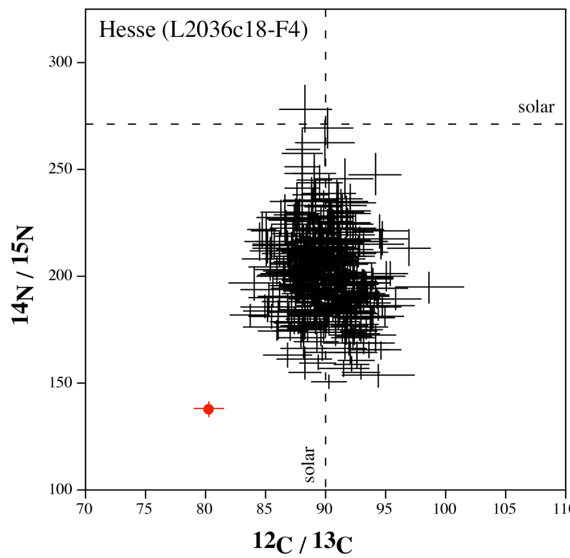

Figure 2. Isotopic composition of hotspot compared to similar-sized regions of Hesse. Errors are 1σ. Note the spread to sub-solar N isotopic compositions in the bulk of the IDP.

References: [1] Messenger S. *et al.* (2003) *Space Sci. Rev.* **106**, 155-172. [2] Floss C. and Stadermann F. J. (2003) *LPS XXXIV*, #1238. [3] Floss C. *et al.* (2004) *Science*, submitted. [4] Floss C. and Stadermann F. J. (2002) *LPS XXXIII*, #1350. [5] Nittler L. R. *et al.* (1997) *Astrophys. J.* **483**, 475-495. [6] Choi, B.-G. *et al.* (1998) *Science* **282**, 1284-1289. [7] Messenger S. *et al.* (2003) *Science* **300**, 105-108. [8] Nguyen A. and Zinner E. (2004) *Science*, submitted. [9] Demyk K. *et al.* (2000) *Astron. Astrophys.* **364**, 170-178. [10] Molster F. J. *et al.* (2002) *Astron. Astrophys.* **382**, 241-255. [11] Arpigny C. *et al.* (2003) *Science* **301**, 1522-1524. [12] Jewitt, D. C. *et al.* (1997) *Science* **278**, 90-93. [13] Ziurys, L. M. *et al.* (1999) *Astrophys. J.* **527**, L67-L71. [14] Mostefaoui S. *et al.* (2003) *MAPS* **38**, A99.

Table 1. C and N Isotopic Compositions of Presolar Grain Bearing IDPs

	Bulk C $^{12}C/^{13}C$ ($\delta^{13}C$ ‰)	**C hotspots** $^{12}C/^{13}C$ ($\delta^{13}C$ ‰)	**Bulk N** $^{14}N/^{15}N$ ($\delta^{15}N$ ‰)	**N hotspots** $^{14}N/^{15}N$ ($\delta^{15}N$ ‰)
Kipling (L2011-R12)	normal	none	180 (+510)	130; 121 (+1090; +1250)
Benavente (L2036-G16)	normal	97 (-70)	224 (+215)	120 (+1270)
du Gard (L2009-c13-I4	normal	none	251 (+85)	146; 134 (+860; +1030)
Galsworthy (L2036-c18-F2)	normal	none	230 (+185)	139; 139 (+960; +960)
Hesse (L2036-c18-F4)	normal	80 (+125)	203 (+340)	135 (+1015)
Eliot (L2036-c24-I3)	normal	none	304 (-105)	none

Normal “solar” values are $^{12}C/^{13}C$ = 90 and $^{14}N/^{15}N$ = 272; the C hotspots are each associated with the N hotspot listed.