OXYGEN ISOTOPE STUDY OF INTERPLANTARY DUST PARTICLES: INSIGHT INTO THE OXYGEN RESERVOIRS OF THE COMET FORMING REGION. N. A. Starkey[1], I. A. Franchi[1] and J. Davidson[2]. [1]Planetary and Space Sciences, The Open University, Milton Keynes, MK7 6AA. UK. Email: n.starkey@open.ac.uk. [2]Lunar & Planetary Laboratory, University of Arizona, Tucson, AZ 85721-0092, USA.

Introduction: Recent work on Wild2 cometary samples shows evidence for sampling of high-T grains that have strong similarities to components in carbonaceous chondrites. Such grains in cometary samples have been used as evidence for large-scale radial mixing in the early Solar System [1,2]. However, Wild2 samples are biased towards relatively coarse-grained material, with finer-grained components being either too small or dispersed along aerogel track walls [3] to be analysed with sufficient isotopic precision.

Stratospheric IDPs preserve fine-grained and OH-bearing phases largely unmodified during atmospheric entry and capture. This fine-grained material is arguably the most primitive Solar System material available for analysis, some of which most likely originates from comets. As such, IDPs offer the opportunity to analyse O-isotopes in Solar System materials that represent the outer Solar nebula. The majority of in-situ O-isotope analyses on cometary materials by SIMS technique have been performed on large ferromagnesian minerals from Stardust [2] and a few IDPs [4]. 'Bulk' O-isotope analyses of a few fine-grained IDPs have been performed by SIMS [5] providing some initial insight into O-isotope systematics of outer Solar System reservoirs.

In this study we use a NanoSIMS 50L to analyse O-isotopes in a set of IDPs. The NanoSIMS offers a small beam size thereby allowing more controlled and even sputtering of small, thin, pressed samples. These measurements are at a level of precision that allows for their comparison to analyses of samples from inner Solar System bodies. Of particular importance is understanding the relationship between the fine- and coarse-grained phases that accreted in the outer Solar System and whether fine-grained material experienced recycling through the inner Solar System. If fine-grained IDPs represent unproccessed dust from the outer Solar nebula then they have the potential to test models for self-shielding and, in particular, the location and nature of the self-shielding environment.

Methods: The IDPs analysed in this study were from large cluster particles. Three of the particles were from the Grigg-Skjellerup collection (L2055 Cluster 5 (Drake), L2055 Cluster 11 (Frobisher) and L2054 Cluster 4 (Hawkins)) and 3 were from non-specific collectors (L2005 Cluster 31 (Cortes and Pizarro) and L2006 Cluster 14 (Midford)). The particles were pressed into high-purity gold foil and characterised by FEG-SEM EDX prior to NanoSIMS analysis. O-isotope analyses were performed with a Cs^+ probe with a current of ~50pA that was rastered over the samples in spot mode (5x5 µm raster). ^{16}O was measured on a faraday cup and ^{17}O, ^{18}O (and $^{24}Mg^{16}O$) were measured on electron multipliers. Charge compensation was applied using the electron gun. The mass resolution was set to >10,000 (Cameca definition) for all analyses primarily to resolve the interference of ^{16}OH on ^{17}O. Isotope ratios were normalised to SMOW using San Carlos olivine that bracketed the analyses. IDP Hawkins was corrected to Al_2O_3 for matrix effect. The IDPs were also analysed in NanoSIMS imaging mode for H, C and N abundance and isotopic compositions [6].

Results: All particles display chondritic EDX spectra. Based on particle texture and C/H ratio (an indicator for the relative hydrous/anhydrous nature of the particles [7]), the IDPs can be broadly separated into three groups. 1) Anhydrous particles: Drake, Pizarro, Cortes and Midford. These show the finest-grained porous texture with relatively high C/H ratios (>1). Midford has a very high C/H (>2) and δD ~5000‰, similar to OM3 discussed in [7]. 2) Hydrous particle: Frobisher shows a predominantly platy texture resulting in a more compact, less porous, structure with a C/H ratio of <0.5. 3) Refractory grain (hydrous): Hawkins consists of a large (~8x4 µm) angular grain of Al-oxide (corundum) attached to three small fine-grained porous particles (<2 µm diameter). These fine-grained particles are carbon poor but variable (C/H 0-0.3).

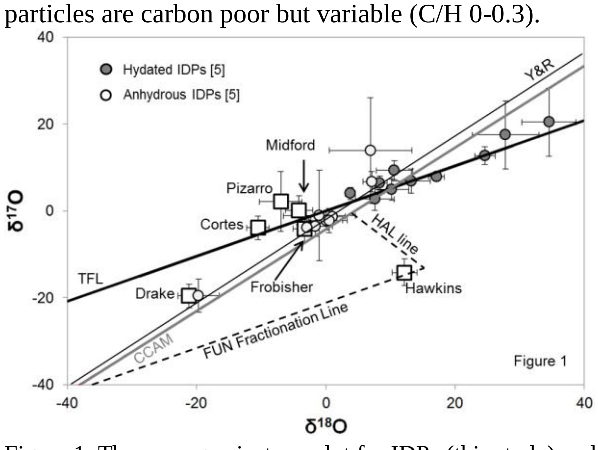

Figure 1. Three oxygen isotope plot for IDPs (this study) and anhydrous and hydrated IDPs [5]. TFL, CCAM and Y&R lines shown for reference.

Oxygen isotope results: See Figure 1. The hydrated IDP Frobisher has a bulk composition of $\delta^{18}O$ = -3.3‰ and $\delta^{17}O$ = -4.1‰ placing it close to, but slightly above, the CCAM [8] and Y&R lines [9]. The bulk compositions of the anhydrous IDPs extend from $\delta^{18}O$ = -21.2‰ to -3.3‰ and $\delta^{17}O$ = -19.6‰ to 2.2‰. These values are strongly influenced by Drake which is much more ^{16}O-rich compared to the other IDPs. All the anhydrous IDPs plot slightly above the CCAM and Y&R lines (Drake plots within error of the Y&R line). IDP Hawkins has a very unusual isotopic composition, with $\Delta^{17}O$ = -21‰ ($\delta^{18}O$ = 12.2‰ and $\delta^{17}O$ = -14.2‰) placing it well below the CCAM and Y&R lines. These values suggest Hawkins is non-terrestrial. The angular shape of Hawkins (and its possible platy fracture planes apparent after NanoSIMS sputtering) is distinct from 'aluminium oxide spheres' reported in IDP collections, thought to be terrestrial [10]. However, this is the first Al-oxide grain with such a distinctive O-isotope composition to be reported in an IDP collection and, as such, further analyses are planned to verify the measurement and origin of the grain.

Interpretation: The O-isotope composition of some of the anhydrous IDPs (Cortes, Pizarro and Midford) are within error of each other but are distinct from the more ^{16}O-enriched anhydrous IDP Drake. The O-isotope compositions of Cortes, Pizarro and Midford overlap with the more ^{16}O-rich end of the range of anhydrous IDPs measured by [5]. The anhydrous IDPs of this study have O-isotope compositions distinct from all known meteorite classes. However, if they are part of the same IDP trend as defined by the samples in [5], then it could be concluded that the vast majority of anhydrous IDPs have an O-isotope composition that is similar to that of bulk carbonaceous chondrites. These anhydrous IDPs also overlap the O-isotope composition of anhydrous phases measured in AMM's (e.g. [11,12]). The relatively ^{16}O-rich anhydrous IDP Drake is lighter than any known whole-rock meteorite composition and lighter than all other IDPs measured to date apart from one (GM4-2 [5]) which has an almost identical composition. These two relatively ^{16}O-enriched IDPs have such a distinctive isotopic composition that they may form a separate grouping of IDPs that may suggest that they sample a distinct Solar System reservoir. It is possible that these two particles represent a continuum of compositions extending up to the relatively ^{16}O-poor IDPs, however, this seems unlikely as there are no samples in the IDP collection, or indeed in the wider meteorite or AMM collections, that bridge the gap between these IDPs and the relatively ^{16}O-depleted grouping. Inevitably, more samples will be required to assess the apparent grouping in the anhydrous IDP collection (to date n=8) and, in turn, the potential O-isotope reservoir(s) that these IDPs sample. Until this is possible it can only be concluded that the groups must have originated from O-isotope reservoirs that have exchanged by varying amounts with a heavier O-isotope reservoir or with heavy reservoirs of different compositions in a different time or location.

IDP Hawkins is distinct from all other IDPs measured in this or any other IDP study to date. The O-isotope composition of Hawkins is very similar to HAL, a hibonite-FUN inclusion from Allende that is extremeley mass fractionated [Fig.1; 13]. While corundum grains are very rare in FUN inclusions, small grains have been observed [14]. The fact Hawkins is attached to fine-grained hydrated particles may suggest that it has an asteroidal origin, but a cometary origin cannot be ruled out. If Hawkins originates from an asteroid then it is directly comparable to meteoritic FUN inclusions. However, a cometary origin would potentially add FUN inclusions to the range of materials observed across inner and outer Solar System materials. ^{16}O-rich refractory grains have been observed in the Stardust collection and are thought to represent CAI fragments (e.g. Inti [15]). The presence of such grains in Wild2 has been used to argue for radial drift of refractory material from the inner to outer Solar System [15], in the same way as for chondrule-like Stardust fragments [2]. This mechanism could explain the presence of high-T processed components at a distance of >30Au where high-T's are not expected in traditional models of Solar System formation. Alternatively, it may be possible to achieve high-T dense regions in the outer Solar System [16]. If this is the case then the presence of high-T refractory material in outer Solar System bodies could be accounted for without the need for transport of material from the inner Solar System.

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