

OXYGEN ISOTOPE COMPOSITIONS OF TWO STARDUST IMPACT CRATER RESIDUES. C. J. Snead<sup>1</sup>, K. D. McKeegan<sup>1</sup>, P. Boehnke<sup>1</sup>, <sup>1</sup>Dept. of Planetary, and Space Sciences, UCLA, Los Angeles, CA, 90095-1567, USA. [stardust2006@ucla.edu](mailto:stardust2006@ucla.edu).

**Introduction:** Samples from Comet 81P/Wild 2 collected and returned by NASA's Stardust mission have provided the first opportunity to measure the average (bulk) oxygen isotope composition of a known comet. An important motivation for collecting material from a Kuiper belt object was to constrain models for origin and evolution of oxygen isotope heterogeneities in the early solar nebula. Oxygen isotope measurements of samples from Comet 81P/Wild 2 collected by NASA's Stardust mission have revealed surprising similarities to minerals in carbonaceous chondrites which have been interpreted as evidence for large scale radial migration of dust components from the inner solar nebula to the accretion regions of Jupiter-family comets [1]. If this interpretation is correct, what the studies have so far not achieved is a measurement of the average oxygen isotope composition of material that formed and accreted in the distal cold regions of the nebula (well beyond the snow line).

Synchrotron X-ray analyses suggest that in at least some tracks, 65% to 90% of the collected grain mass resides in the upper bulbous portion of bulbous and carrot shaped aerogel tracks as submicron particles, while 10% to 35% of the mass resides in the larger (>1mm) terminal particles located at the end of the track [2]. These analyses have led to a model (e.g. see Fig 11 of [3]) of impacting Wild 2 dust as aggregates of loosely bound fine-grained material containing the occasional larger olivine, pyroxene, iron sulfide and iron oxide grains. This fine-grained component of impacting particles suffered from intimate mixing with oxygen-rich aerogel, making definitive oxygen isotope analysis extremely challenging. The aluminum foil substrates on the Stardust collector provide an opportunity for a low background alternative to the aerogel collectors for measuring the O-isotopic composition of both the coarse and the fine-grained components of impacting dust particles. Craters in the foils likely retain much of the impactor material in a well defined location (the crater) regardless of impactor grain size. In addition, examination of crater morphology can provide an opportunity to distinguish large, single grain impactors from fine-grained cluster impactors. However, the resulting projectile residues will have been shocked and heated from the impact. For the past two years, we have successfully developed techniques to measure crater residues from hypervelocity impacts, and have assessed fractionation effects resulting from the capture process by using simulated impacts of mineral standards into foil targets. Here we discuss the first

3-oxygen isotope measurements of two Stardust cometary foil craters.

**Experimental Techniques:** To assess potential fractionation effects of hypervelocity impact on our samples, we fired ground San Carlos olivine and Burma spinel powder into foil targets at ~6 km/sec using a light gas gun at the University of Kent. The resulting impact craters were cut from the targets, and mounted on specially prepared 1" Al rounds, each of which contained a crystal of the corresponding mineral. We observe a consistent, mass-dependent 4% shift in  $\delta^{18}\text{O}$ ; amongst mineral standards. These consistent results allow us to use the lab-produced impact craters as standards to correct for instrumental mass fractionation effects in our Stardust impact crater samples.

We were allocated five Stardust foil targets; of these, four foils contained impact craters of ~20-50 $\mu\text{m}$  diameter, and one was blank. Two of these craters (C2067N,3 and C2122W,4) had complex morphology which is suggestive of a fine-grained cluster projectile. After FE-SEM imaging and EDS analysis of each of the four craters, two craters with complex morphology (C2067 and C2122) were cut from the foils, flattened and mounted onto polished 1" aluminum rounds for ion probe analysis.

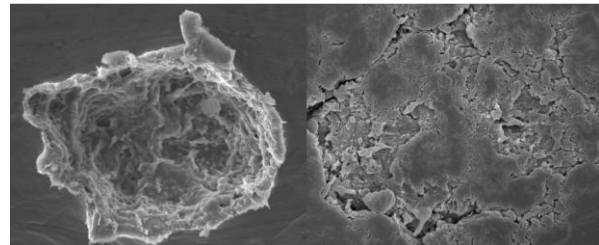


Figure 1: SEM images of a C2067,W,4 before and after the flattening process.

Oxygen isotopes were measured using a Cameca IMS-1270 ion probe with a 10KV, 0.5nA cesium primary beam of ~25 $\mu\text{m}$  diameter. The detection system was configured for 3-oxygen isotope multicollection, with  $^{16}\text{O}$  measured on a faraday cup, and  $^{17}\text{O}$  and  $^{18}\text{O}$  measured on electron multipliers. Individual crater analyses consisted of 100 count cycles of 5 seconds each. Because of the fragile nature of the crater residues, we chose not to employ an arbitrary presputter; instead, all of the sputtered ions were counted. After applying background, yield and deadtime corrections, we performed a change-point analysis on our data via

R [4,5] in order to determine when the sample attained sputtering equilibrium; data points collected prior to the change-point were excluded. Change-point analysis was also used to determine whether the residue had been completely sputtered; none of our analyses revealed a change-point that could be attributed to the complete sputter of a sample.

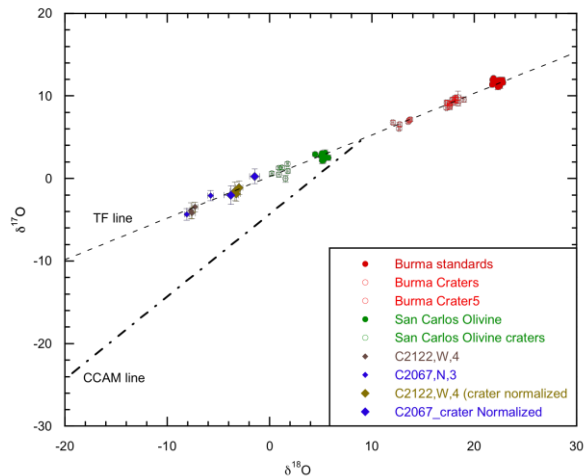


Figure 2: Measurements of craters C2122,W,4 and C2067,N,3 normalized to San Carlos olivine mineral standards and to simulated craters.

**Results and Discussion:** A summary of the results is plotted in figure 2. The two Stardust craters plot on the terrestrial fractionation line with an average value for C2122,W,4 of  $-7.53 \pm 0.6\text{‰}$  for  $\delta^{18}\text{O}$  and  $-3.82 \pm 1.3\text{‰}$ ; For C2067,N,3, the  $\delta^{18}\text{O}$  value is  $-6.9 \pm 0.4\text{‰}$  and the  $\delta^{17}\text{O}$  value is  $-3.2 \pm 0.9\text{‰}$ . Taking into account the second order correction by normalizing to the standard crater residues, the average value for C2122,W,4 is  $-3.21 \pm 0.6\text{‰}$  for  $\delta^{18}\text{O}$  and  $-1.49 \pm 1.3\text{‰}$  for  $\delta^{17}\text{O}$ . These values are consistent with measurements of crystalline aerogel track silicates in previous oxygen analysis studies [6-8]. We hope to measure the remaining two craters to get better comparison between the residue oxygen compositions and the track silicate compositions.

**References:** [1] McKeegan, K.D. et al. (2006) *Science*, 314, 1724-1728. [2] Flynn G. J. et al. (2006) *Science*, 314, 1731-1735. [3] Kearsley A.T. et al. (2009) *Meteoritics & Planet. Sci.*, 44 1489-1510. [4] R CoreW Team (2013) *R Foundation for Statistical Computing*, Vienna, Austria. [5] Killick, R. and Eckley, I (2013) *R package* [6] Messenger S. et al. (2008) *Meteoritics & Planet. Sci.*, 43(7) A97-A97. [7] Matrajt G. et al. (2008) *Geochimica Et Cosmochimica Acta*, 72, A603-A603. [8] Nakamura T. et al. (2008) *Science*, 321, 1664-1667.