EXCESS ^{3}He IN CLUSTER INTERPLANETARY DUST PARTICLES (IDPs) FROM COLLECTORS L2009 AND L2011. R. O. Pepin[1], R. L. Palma[2], and D. J. Schlutter[1], [1]School of Physics & Astronomy, University of Minnesota, 116 Church St. S. E., Minneapolis, MN 55455, USA; e-mail: pepin001@tc.umn.edu, [2]Department of Physics, Sam Houston State University, Huntsville, TX 77341.

Extraordinarily high ^{3}He/^{4}He ratios, up to ~40 times the solar wind value, were measured by Nier and Schlutter [1] in cluster IDPs from stratospheric dust collectors L2005, L2006, and L2011. Those from L2011 have attracted particular attention because of the possibility that their anomalous ^{3}He/^{4}He ratios may be a signature of cometary debris, specifically from comet Schwassmann-Wachmann-3 [2,3]. However no comparably high ratios were found in subsequent analyses [3,4] of a suite of IDPs from collectors thought likely to have sampled S-W-3 material, which included 1 cluster particle from L2011 and 2 from collector L2009 (L2009 was flown at the same time and on the same aircraft as L2011, and should have sampled the same ambient population of stratospheric particles).

To expand the relevant data base, we have measured ^{4}He contents and ^{3}He/^{4}He ratios in one ~10 μm fragment from each of 13 cluster particles collected by L2009. Results from this study and from [1] are shown in Fig. 1. Again the

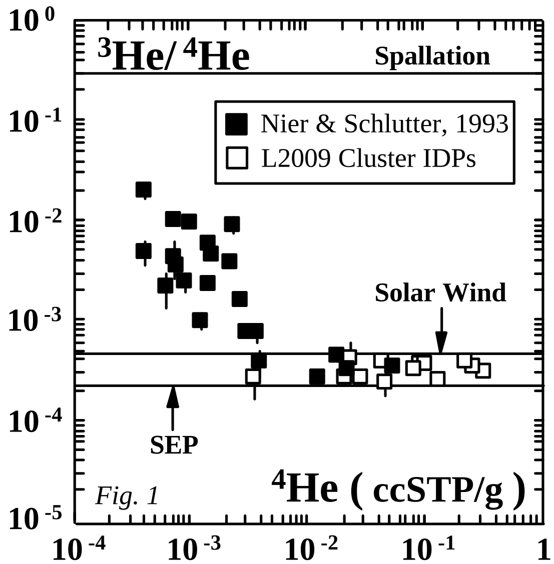

Fig. 1

high ratios reported by [1] are not replicated. All of the L2009 ^{3}He/^{4}He ratios fall between the solar wind (SW) and solar-energetic-particle (SEP) values, implying that ^{3}He excesses —i.e., above the levels expected for solar ion implantation— are absent. However the L2009 data plotted in Fig. 1 are for *total* He contents, which are mostly much higher in ^{4}He than those from [1]. Ten of the particles contained enough He to allow isotopic measurements on gas fractions sequentially evolved by stepwise degassing, and these thermal release profiles, two examples of which are shown in Fig. 2ab, lead to a quite different conclusion.

As seen in Fig. 2, first heating step(s) released most of the total sample He (% of total ^{4}He indicated in brackets) and are isotopically characterized by "base" ^{3}He/^{4}He ratios apparently reflecting a mixture of SW and SEP. Both of these surface-sited components are likely to be degassed in the first heating step. The elevated ^{3}He/^{4}He ratios appearing in the subsequent release fractions shown in Fig. 2ab point to the presence of an additional ^{3}He component.

Concentrations of excess ^{3}He (^{3}He*), calculated from $^3\text{He}^* = [^4\text{He}]_{meas}\,[(^3\text{He}/^4\text{He})_{meas} - (^3\text{He}/^4\text{He})_{base}]$ ccSTP/g where $(^3\text{He}/^4\text{He})_{base}$ is taken to be that in the first release and the ratio $(^3\text{He}/^4\text{He})_{base}/(^3\text{He}/^4\text{He})^*$ is assumed to be small, are plotted in Fig. 3a for the ten L2009 particles for which multi-step isotopic data were obtained. Also shown are ^{3}He* concentrations in Nier and Schlutter's [1] cluster IDPs, calculated assuming an SEP base composition. Measured ^{3}He/^{4}He ratios in most of these are so high that the alternative choice of a SW base makes little difference. This is particularly true for the L2011 particles measured by [1], which comprise 12 of the 22 particles in Figs. 1 and 3a and include the 5 highest in ^{3}He/^{4}He and ^{3}He*.

The notable feature of Fig. 3a is the near identity of both the distributions and the averages of the ^{3}He* concentrations in the two sample suites. It seems clear that the ^{3}He excesses responsible for the striking elevations of ^{3}He/^{4}He found by [1] and shown in Fig. 1 are also present at about the same levels in the L2009 cluster IDPs, but are masked in the Fig. 1 plot of total gas contents by their ≈50 to 100-fold higher concentrations of SW and/or SEP He.

Discussion. The most straightforward possibility is that the excess ^{3}He in these IDPs is a spallogenic record of exposure to galactic (GCR) and solar (SCR) cosmic rays. Exposure ages calculated from the Fig. 3a data and the ^{3}He GCR production rate appropriate for small bodies in space [5], shown at the bottom of Fig 3a, are plotted in Fig. 3b. Inclusion of production by SCR [5] would reduce these ages by ~33% for IDPs originating from an asteroidal source and evolving inward under Poynting-Robertson (P-R) drag, but for an outer solar-system dust source —e.g., the Kuiper belt— the SCR contribution is negligible.

The ≈100 Ma to >3 Ga exposure ages in Fig. 3b are ~1-2 orders of magnitude longer than the P-R lifetimes of IDPs with diameters of tens of μm [6], even those from a Kuiper belt source at ~40 AU [4]. Nominal P-R evolution times to 1 AU in the Ga range could be attained by millimeter-size meteoroids from the Kuiper belt; their disruption at high altitudes could conceivably have provided the cluster particles intercepted by the collectors. However erosion and eventual fragmentation of such large particles by collisions with hypervelocity interstellar grains [7] or interplanetary dust outward of 1 AU [8] may significantly reduce their space residence times, or destroy them entirely.

An alternative possibility might be that these particles acquired most of their spallogenic ^{3}He inventories not as small particle in space, but instead during a prolonged pre-irradiation by the GCR in a parent body regolith prior to ejection as IDPs. This scenario appears to require long-term upper regolith stability against overturn and ejection by impact. For burial depths of, say, •1 m, ^{3}He productions rates would be a factor •2 below that shown in Fig. 3a [9], and implied regolith residence times for accumulating the highest $^{3}He^{*}$ abundances in Fig. 3a would be comparable to or exceed the age of the solar system.

There are clearly difficulties in attributing all of the excess ^{3}He in these IDPs to GCR-induced spallation, in either space or regolith environments. The question is whether an additional and hitherto unrecognized source of ^{3}He is required, and if so what its identity is and where and when it might have contributed to IDP inventories.

References. [1] A. O. Nier & D. J. Schlutter (1993) *Meteoritics* **28**, 675. [2] S. Messenger & R. Walker (1998) *LPS* **XXIX**, #1906. [3] K. Kehm *et al.* (1999) *LPS* **XXX**, #1398. [4] R. O. Pepin *et al.* (2000) *Meteorit. Planet. Sci.* (in press). [5] R. C. Reedy (1987) *Proc. 17th LPSC*, E697. [6] J. A. Burns *et al*. (1979) *Icarus* **40,** 1. [7] J-C. Liou *et al*. (1996) *Icarus* **124,** 429. [8] E. Grün *et al*. (1985) *Icarus* **62,** 244. [9] R. C. Reedy (1985) *Proc. 15th LPSC*, C722.