MORE INTERSTELLAR EXPOSURE AGES OF LARGE PRESOLAR SIC GRAINS FROM THE MURCHISON METEORITE. F. Gyngard[1], J. N. Ávila[2,3], T. R. Ireland[2,3], and E. Zinner[1], [1]Laboratory for Space Sciences and Department of Physics, fgyngard@wustl.edu, Washington University, St. Louis, MO 63130, USA, [2]Research School of Earth Sciences, The Australian National University, Canberra ACT 0200, Australia, [3]Planetary Science Institute, The Australian National University, Canberra ACT 0200, Australia.

Introduction: While the formation age of the Solar System (SS) is well known to be 4.57 Gyr, as derived from Pb-Pb dating of Ca-Al inclusions from primitive meteorites, the lifetimes of presolar grains ("stardust") found in the matrices of many similarly primitive meteorites are unknown or uncertain. These grains have isotopic thumbprints diagnostic of their astrophysical origins: red and asymptotic giant branch (RGB and AGB) stars of different metallicities and masses, Type II supernovae (SNe), and possibly novae [1]. As evidenced by their extreme isotopic compositions compared to SS materials, presolar grains have largely escaped the isotopic homogenization and equilibration of the early SS, and thus provide a record of the interstellar medium (ISM) before the formation of the SS. Accurate determination of the lifetimes of these grains would have important implications for the survivability of dust in the ISM, provide constraints on timescales for the evolution of the proto-solar nebula and incorporation of dust into the proto-planetary disk, and perhaps reveal distinct stellar, temporal events that may have triggered the formation of the SS (e.g., from nearby AGB or SN).

Unfortunately, both theoretical and experimental considerations limit the practicability of absolute age dating of individual presolar grains: low abundances of the elements typically used in long-lived chronometer systems such as U-Th-Pb or Rb-Sr; small grain sizes, predominantly less than a few microns; fundamental uncertainty of the initial parent and daughter nuclide abundances in the grains before isotopic closure; and, unknown preferential elemental fractionation during grain condensation [2].

Alternatively, ISM ages can be calculated from measurements of isotopes of spallogenic origin (e.g., ^{3}He, ^{6}Li, and ^{21}Ne), expected to be produced by bombardment from galactic cosmic rays (GCRs) during the grains' residence in the ISM. Such analyses have yielded a range of exposure ages from less than 50 Myr to ~1 Gyr for presolar SiC grains [3-5]. In addition to their relatively large sizes, in some rare cases, trace-elements are better incorporated into the SiC crystal lattice structure than into other presolar minerals such as oxides and silicates, making SiC well-suited for multi-element isotopic analyses of low abundance systems. Similar to the situation for determining absolute ages, there are inherent difficulties both experimentally and in knowing the GCR flux over 4.5 Gyr in the past, as well as performing the appropriate recoil loss correction required for grains of this size, in which a significant fraction of spallogenic components may be lost [6].

Here we report Li isotopic measurements in 19 LS+LU SiC grains that have been previously analyzed for several heavy elements (e.g., Ba, Eu, Pb, U, and Th) [2,7,8]. Ten of the grains have large enrichments in ^{6}Li, greater than 2σ, indicative of production by GCR irradiation.

Experimental Methods: Grains from the LS+LU residues [9] were picked with a micromanipulator from glass slides, pressed into Au foil with a quartz disk, and compositionally identified as SiC by SEM-EDX. Carbon and Si isotopes were then measured in multi-detection with the Washington University NanoSIMS by a ~1 pA, ~100 nm Cs^{+} primary beam. Grains having diameters ≳5 µm were subsequently analyzed for their isotopic compositions of several heavy elements by SHRIMP II and SHRIMP-RG at The Australian National University, using the methods described in [10].

Following heavy element analyses, positive ions of ^{6,7}Li, ^{10,11}B, and ^{30}Si produced by an O^{-} primary ion beam were simultaneously measured with the Washington University NanoSIMS. A NIST 610 glass standard with nominal Li and B abundances of 354 and 351 ppm, respectively, was used for normalization of the Li and B isotopic and elemental compositions.

Results and Discussion: Eighteen out of 19 grains show enrichments in ^{6}Li (Fig. 1) up to ~230 ‰; however, only 10 are anomalous at the 2σ level (with 5 grains plotting more than 3σ away from solar). These 10 ^{6}Li enriched anomalous grains consist of 9 mainstream grains and 1 Y grain (Fig. 2). Interestingly, four of the grains have C, Si, and Li isotopic compositions comparable within 1σ, as well as similar anhedral (blocky and smooth) morphological features. This is suggestive that not only may they have formed in the same star, but may be fragments of a single, larger grain. However, their U/Pb ratios are different.

Cosmogenic exposures ages derived for the 10 grains with ^{6}Li enrichments 2σ greater than solar, calculated in the same manner as [3] except without correction for recoil loss, cover a large range. Two grains have ages of around 2 Gyr, and 1 grain has an exposure time of ~4 Gyr; the remaining 7 grains have exposure ages of 80 to 700 Myr, which are generally consistent with determinations from previous Li measurements. Errors are nominally estimated at

~50%; however, determining the uncertainties both in the irradiation models and the measured elemental abundances is difficult. Theoretical calculations predict that SiC grains will be destroyed by grain-grain collisions and/or SN shockwaves in the ISM in at most 1.5 Gyr [11]. Exposure ages considerably longer than this are difficult to explain both astrophysically and experimentally. While the ages reported here are not recoil-loss corrected (due to uncertainties in the grains' sizes), any correction applied will only make the ages longer.

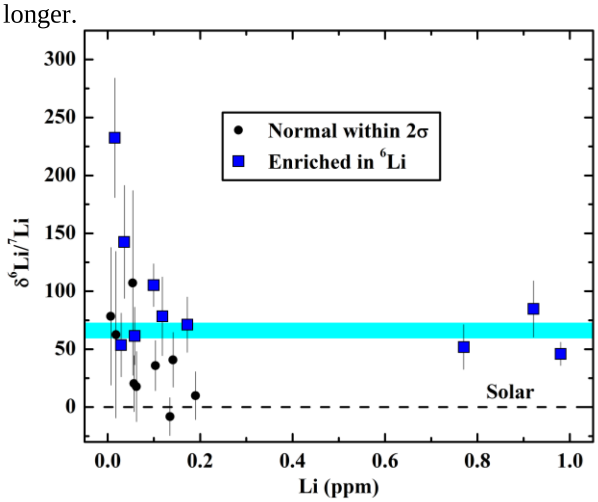

Figure 1. Plot of the Li isotopic compositions of the 19 grains measured in this study, expressed as δ-values with 1σ error bars, as a function of their Li elemental abundance in ppm by weight. The horizontal band is an error-weighted mean of the 10 anomalous grains corresponding to $\delta^6Li/^7Li = 66 \pm 7$.

It seems physically implausible that grains could have been floating in the ISM for billions of years prior to incorporation into the proto-planetary disk – more work is needed to determine if these long ages could be the result of some experimental artifact. One possibility is a fundamental inaccuracy in the determination of the Li elemental abundances, which are necessary for calculation of the exposure ages. While the Li isotopic *ratios* cannot easily be seen to result from instrumental complications (i.e., there are no realistic mass interferences at mass 6 that were not resolved, and no QSA effects given the low Li abundances both for the grains and standards), no matrix-matched standards exist. Thus, measured elemental abundances possibly have large uncertainties. In fact, the four grains with very similar C, Si, and Li isotopic compositions have different calculated exposure ages due to variations in Li elemental abundances, possibly from differences in relative contributions of indigenous spallogenic Li and Li from contamination.

Assuming that SiC grains can survive for 100s of Myr in the ISM and that CR exposure ages have been correctly determined, it may be that these very old grains are not representative of the local galactic environment from which the SS formed. Proto-planetary disks typically condense from dust and gas on timescales of at most 10s of Myr [12] and galaxies are not static but grow from the inside out [13]. Dust grains with ages on the order of a galactic year (~230 Myr) or greater may have radially migrated from inner regions of the Milky Way and subsequently been swept up during the rotation of the local ISM from which the SS formed around the galactic center. As metallicity decreases with increasing galactic radius, grain migration over long timescales might explain why many presolar grains have higher metallicities than the SS, contrary to expectations from Galactic Chemical Evolution if they had formed only from stars in the local ISM.

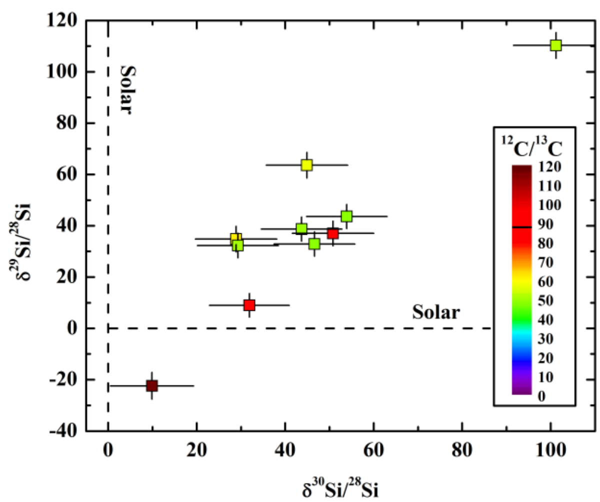

Figure 2. Plot of the Si isotopic compositions of the 10 Li-anomalous grains, expressed as δ-values with 1σ error bars. Symbols are color coded to indicate their respective $^{12}C/^{13}C$ ratios (solar = 89).

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