HINTS FOR NEUTRINO-PROCESS BORON RECORDED IN STARDUST FROM SUPERNOVAE. W. Fujiya[1], P. Hoppe[2] and U. Ott[2], Earth and Planetary Science, the Univ. of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan (fujiya@eps.s.u-tokyo.ac.jp), [2]Max Planck Institute for Chemistry, J.-J.-Becher-Weg 27, 55128 Mainz, Germany.

Introduction: Lithium, Be and B have very low abundances in the universe compared to other light elements [1]. Much of the Li, Be and B production relies on high-energy (>100 MeV) galactic cosmic ray (GCR) induced spallation reactions. The predicted isotopic ratios (^{7}Li/^{6}Li = 1.4 and ^{11}B/^{10}B = 2.5 [2]) are much lower than the solar values (^{7}Li/^{6}Li = 12.06 [3] and ^{11}B/^{10}B = 4.03 [4]). Other potential sources of Li and B are spallation reactions between low energy (MeV range) C and O nuclei and interstellar H in star forming regions [5]. In this case, ~2x lower ^{7}Li/^{6}Li and ~1.5x higher ^{11}B/^{10}B than the solar values are predicted. In type II supernovae (SNeII), while Li and B are largely destroyed before the explosion, significant amounts of ^{7}Li and ^{11}B are predicted to be synthesized by neutrino-nucleus reactions (ν-process) and/or α-process when they explode [e.g., 6]. The predicted isotopic ratios in the overall ejecta of 15 $M_{\odot}$ SNeII are much higher (^{7}Li/^{6}Li ~ 3000 and ^{11}B/^{10}B ~ 300 [6]) than the solar values. Lithium and B in the solar system obviously consist of at least two of the components mentioned above.

In this study, we searched for records of ν-process (i.e. high ^{7}Li/^{6}Li and ^{11}B/^{10}B ratios) in presolar SiC X grains. Lithium- and B-isotopic compositions have been measured in presolar SiC grains from AGB stars and SNeII [7-10]. No B isotope anomalies have been reported from this work. In contrast, Gyngard et al. [10] reported low ^{7}Li/^{6}Li ratios in large SiC grains from AGB stars, which are attributable to cosmic ray irradiation while the grains were in the interstellar medium. Here we report on Li- and B-isotopic measurements on SiC X grains, believed to come from SNeII, with the NanoSIMS 50 ion probe, taking advantage of its high spatial resolution and high detection efficiency.

Experimental: By NanoSIMS ion imaging (Cs^{+} primary ion beam, ~100 nm beam size, ~1 pA) [11] we measured the C- and Si-isotopic compositions of ~1100 SiC grains, separated from the Murchison meteorite at MPI for Chemistry [12]. We detected thirteen X grains based on their characteristic light Si. This search was conducted together with a search for anomalous SiC grains with heavy Si [13]. Following ion imaging all X grains were relocated in the SEM. Except for one grain, all were analyzed for Li- and B-isotopic compositions. $^{6,7}Li^{+}$, $^{10,11}B^{+}$, and $^{28}Si^{+}$ were measured with the O^{-} primary ion beam (~300-500 nm beam size, ~1-5 pA) which was rastered over the grains. The relative sensitivity factors (RSF) of Li/Si and B/Si, and the instrumental mass fractionations of Li and B isotope measurements were corrected using SRM611 glass grains dispersed on a clean Au foil.

Results and Discussion: Based on the SEM and ion images, seven X grains (0.6 to 1.5 µm in size) turned out to be single grains and, therefore, we concentrate on the results of these. Their ^{12}C/^{13}C ratios range from 38 to 345, with six of the grains having isotopically light C, δ^{29}Si ranges from -178 to -556‰, and δ^{30}Si from -245 to -432‰ (Fig. 1).

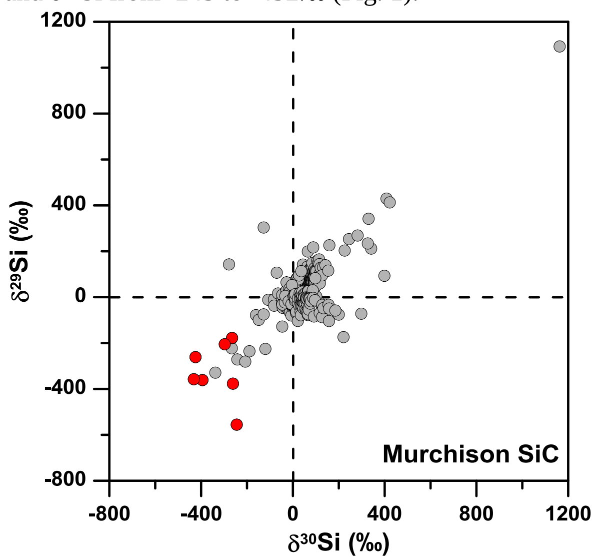

Figure 1: Si-isotopic compositions of presolar SiC grains measured by NanoSIMS ion imaging. Seven single X grains analyzed for Li and B are shown in red.

All ^{7}Li/^{6}Li and ^{11}B/^{10}B ratios of single X grains are solar within 1.2σ and 1.8σ, respectively (Fig. 2). When we consider averages of the seven X grains then we obtain the solar ^{7}Li/^{6}Li ratio as well; for B, however, there is a small ^{11}B excess of 161 ± 77‰, i.e., an anomaly at the 2σ level is found. For the single X grains Li/Si ratios are 0.3-4.5x solar (median: 1.9x) and B/Si ratios are 0.6-10x solar (median: 1.7x).

Like Mg and Ca, Li is not expected to condense efficiently into SiC based on their chemical similarity [8]. Hence, the approximately solar Li/Si in the X grains is likely derived from laboratory or meteoritic contamination, i.e., SN Li represents only a tiny fraction of the observed Li. Spallation reactions would result in strong enrichments in ^{6}Li (Fig. 2), which is not observed. Gyngard et al. [10] reported large ^{6}Li enrichments in

SiC grains from AGB stars attributable to GCR spallation reactions. However, Li/Si ratios are about two to three orders of magnitude lower in the grains studied by [10] than those in this study. In a simple two-component mixing calculation, considering spallogenic Li with $^7Li/^6Li$ = 5 (low-energy GCR) and Li contamination with $^7Li/^6Li$ = 12.06, the contribution of spallogenic Li is limited to only ~4%, given the observed 2σ lower limit for the average $^7Li/^6Li$ ratio of 11.46 in our X grains. Note that here we included also the five X grains that are not single grains because AGB stars grains would contribute only negligibly to the overall Li [10]. In this scenario Li_{spal}/Si is ~10^{-6}, about three orders of magnitude higher than what would be expected from standard GCR irradiation if spallogenic Li retention is taken into account. We consider this as unrealistic even if we assume an extremely violent irradiation around the SN parent stars.

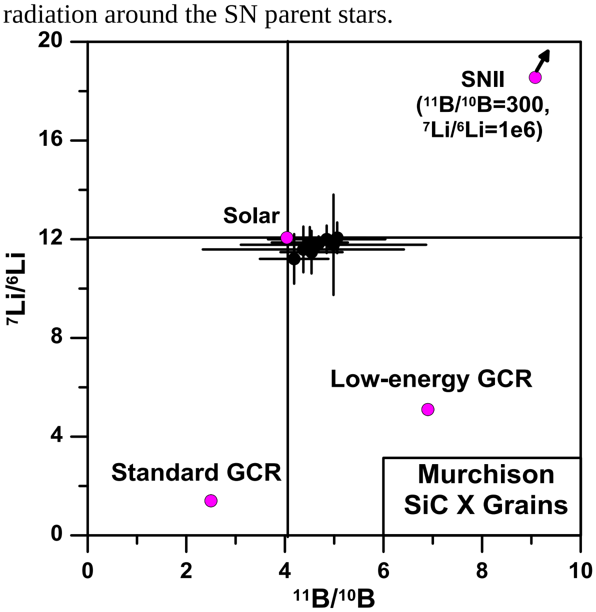

Figure 2: Li-and B-isotopic ratios in seven SiC X grains. Predictions for spallogenic Li and B by GCR and for a 15M$_\odot$ SNII [6] in a typical mixing scenario are shown for comparison.

Like for Li, a contribution of spallogenic B to the overall B in X grains is likely to be negligible, since production rates are similar for Li and B by spallation reactions. On the other hand, Hoppe et al. [8] argued that B abundances in X grains should roughly reflect B abundances at the condensation site in SNII ejecta (under equilibrium condensation conditions with C/O > 1). In Fig. 3 we show profiles of ^{7}Li, ^{10,11}B, ^{12}C, and ^{28}Si in the interior of a 15 M$_\odot$ SNII [6]. Mixing scenarios involving matter from the different SNII zones [14], which can reproduce the C, N, and Si isotopic ratios of typical X grains [e.g., 15], lead to B/Si ratios on the order of 10^{-4}, about one order of magnitude higher than observed in this study. Boron from SNeII is expected to be heavily enriched in ^{11}B; typical mixing scenarios have $^{11}B/^{10}B$ of ~300, significantly higher than observed in our X grains. Hence we conclude that much of the observed B is contamination. A mixture of 11% SNII B and the remainder B contamination can reproduce the observed $^{11}B/^{10}B$ values in our X grains. In this case, the fraction of B with SN origins has B/Si ~10^{-6}, two orders of magnitude lower than predicted for typical SN mixtures. This implies that the B condensation is not as efficient as predicted or that the B production in SNeII via ν-process is much lower than thought. In any case, the small ^{11}B enrichments in our X grains give a first observational hint that SNeII are in fact sources of ^{11}B.

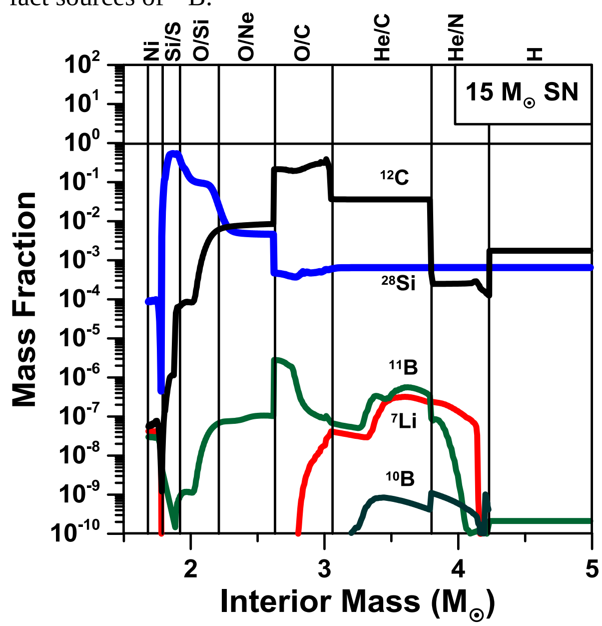

Figure 3: Selected isotopes in a 15 M$_\odot$ SNII [6].

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