NEW INSIGHTS INTO SUPERNOVA NUCLEOSYNTHESIS FROM A PRESOLAR SIC GRAIN WITH UNIQUE CARBON ISOTOPIC COMPOSITION. P. Hoppe[1], M. Pignatari[2,3,4], J. Kodolányi[1], and E. Gröner[1], [1]Max Planck Institute for Chemistry, 55128 Mainz, Germany (peter.hoppe@mpic.de), [2]Konkoly Observatory, Budapest, Hungary, [3]E. A. Milne Centre for Astrophysics, University of Hull, UK, [4]NuGrid Collaboration.

Introduction: Primitive Solar System materials contain small quantities of presolar grains that formed in the winds of evolved stars and in the ejecta of stellar explosions [1]. A rare but important subgroup of presolar grains are SiC grains from supernovae (SN), the Type C and X grains, which constitute about 1-2 % of all presolar SiC grains. Also, some of the SiC grains classified as nova grains might actually have a SN origin [2]. Important characteristics of SiC SN grains are enhanced abundances of ^{12}C (most grains) and ^{15}N, and of ^{28}Si (X grains) or ^{29,30}Si (C grains). Furthermore, SiC SN grains incorporated significant amounts of radioactive ^{26}Al, ^{32}Si (mostly in C grains), and ^{44}Ti. First attempts to explain these signatures in the context of Type II SN (SNII) models considered selective, large-scale mixing of matter from the inner Si- and S-rich zone with matter from the outer C-rich zones. More recently, Pignatari et al. [3] presented an alternative scenario in which a C- and Si-rich (C/Si) zone forms by explosive He burning at the bottom of the He shell, an attractive site for SiC condensation, making the need for selective, large-scale mixing redundant.

Here, we present comprehensive isotope data (C, N, Si, S, Mg-Al, Ca-Ti) of three selected SiC grains (one C grain, two putative nova grains) which were identified by an automated C and Si ion imaging survey of presolar SiC grains, primarily conducted to search for SN grains to be studied afterwards by FIB/TEM for structure [4] and by CHILI for heavy element isotope compositions [5]. The isotope data of the C grain and the two putative nova grains are compared with predictions from one SN model of [6].

Experimental: SiC grains from Murchison separate KJD (median size: 0.81 μm) [7] were screened for SN and putative nova grains by C and Si ion imaging with the NanoSIMS at MPI for Chemistry [8]. For this purpose a focused Cs^+ ion beam (~1 pA, 100 nm) was rastered over 143 30 x 30 μm^2-sized fields and negative secondary ion images of ^{12}C, ^{13}C, ^{28}Si, ^{29}Si, and ^{30}Si were recorded in multi-collection. Subsequently, three selected grains were measured for N, S, Mg-Al, and Ca-Ti isotopic compositions. We recorded in multi-collection negative secondary ions of ^{12}C, ^{13}C, ^{12}C^{14}N, ^{12}C^{15}N, and ^{28}Si (session 1) and of ^{28}Si, ^{32}S, ^{33}S, ^{34}S, and ^{36}S (session 2), employing a Cs^+ primary ion beam (~1 pA, 100 nm), and positive secondary ions of ^{24}Mg, ^{25}Mg, ^{26}Mg, ^{27}Al, and ^{28}Si (session 3) and of ^{28}Si, ^{40}Ca, ^{42}Ca, ^{44}Ca, and ^{48}Ti (session 4), employing a focused O^- primary ion beam (~5 pA, 400 nm).

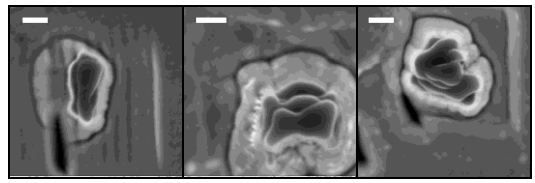

Figure 1. SEM pictures of C grain KJD-6-24-3 (left), and of putative nova grains KJD-1-11-5 (middle) and KJD-3-23-5 (right). Scale bars: 200 nm.

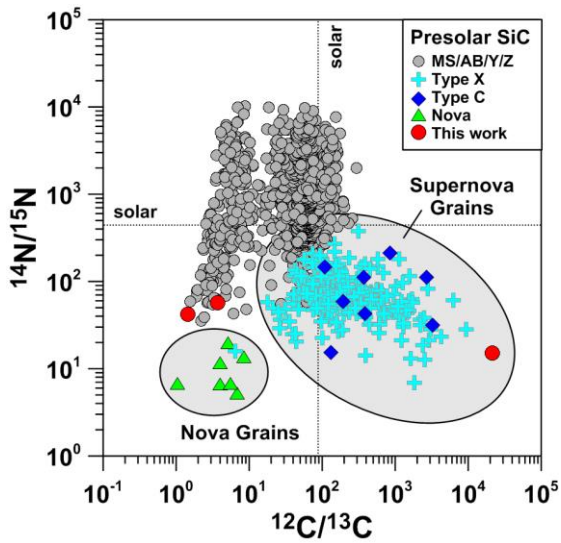

Figure 2. Carbon- and N-isotopic compositions of presolar SiC grains. Data sources: [4, 9] and this work.

Results and Discussion: Among the 640 SiC grains identified by ion imaging are 9 X grains, 2 C grains, 1 Si_3N_4 X grain, and 2 putative nova grains. C grain KJD-6-24-3 and the putative nova grains KJD-1-11-5 and KJD-3-23-5 (Fig. 1) were selected for follow-up isotope studies by NanoSIMS.

Grain KJD-6-24-3 (600 x 250 nm^2) has ^{12}C/^{13}C = 21400 ± 3500, ^{14}N/^{15}N = 15.0 ± 0.3, δ^{29}Si = 380 ± 15 ‰, and δ^{30}Si = 835 ± 22 ‰ (Figs. 2 and 3), the signature of C grains. The ^{32}S excess of ~20% corresponds to ^{32}Si/^{28}Si = 5.6 ± 2.0 x 10^{-4}. Magnesium, Al, Ca, and Ti concentrations are low and no evidence for significant amounts of ^{26}Al and ^{44}Ti was found. The ^{12}C/^{13}C ratio of KJD-6-24-3 is the highest ^{12}C/^{13}C ratio ever found for presolar grains and suggests incorporation of

larger amounts of He shell matter during SiC condensation than for other SN grains. All isotopic ratios are well reproduced within a factor of 1.5 by SN model 25T-H10 of [6] if matter from the outer C/Si zone is mixed with matter from the inner O/Nova zone (Fig. 4). This model considers ingestion of 0.1 % H into the He shell of a 25 $M_\odot$ SNII before the explosion and artificially increased temperature and density at the bottom of the He shell during explosion. The selected mixture extends over 0.06 $M_\odot$ and has C/O > 1. Our finding confirms the predicted high ^{15}N and low ^{26}Al abundances of He shell matter and gives further support for the validity of the Pignatari et al. models.

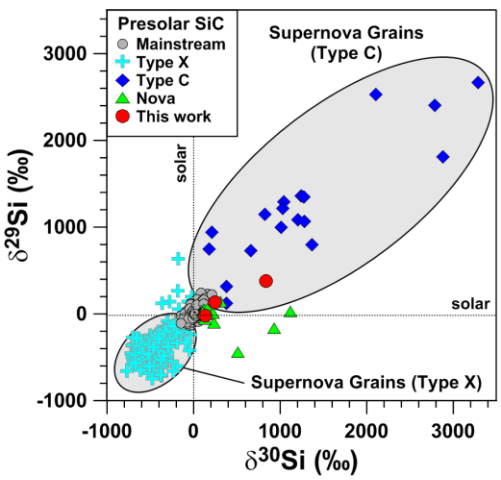

Figure 2. Silicon-isotopic compositions of presolar SiC grains. Data sources: [4, 9] and this work.

Grain KJD-1-11-5 (500 x 360 nm^2) has $^{12}C/^{13}C$ = 3.7 ± 0.1, $^{14}N/^{15}N$ = 57.4 ± 1.3, $\delta^{29}Si$ = -23 ± 9 ‰, and $\delta^{30}Si$ = 136 ± 11 ‰ (Figs. 2 and 3). The C- and Si-isotopic compositions are compatible with previously found nova grains while its $^{14}N/^{15}N$ ratio is higher by about a factor of 5. Magnesium is monoisotopic ^{26}Mg with $^{26}Al/^{27}Al$ = 0.205 ± 0.012. Grain KJD-1-11-5 exhibits a small, but significant ^{32}S excess from which $^{32}Si/^{28}Si$ = 8.1 ± 2.9 x 10^{-4} can be inferred. No evidence for ^{44}Ti was found, albeit large uncertainties exist. The lower than solar $^{33}S/^{32}S$ ($\delta^{33}S$ = -303 ± 110 ‰) is incompatible with nova model predictions [10] and the $^{26}Al/^{27}Al$ is clearly higher than that of other putative nova grains, except of one SiC grain for which the nova origin, however, was questioned [2]. We, therefore, favor a SN origin also for KJD-1-11-5. In the context of SN model 25T-H10, a fairly good fit can be obtained for the major elements C and Si and for $^{26}Al/^{27}Al$ if the full C/Si zone is mixed with an extended O/Nova zone (Fig. 4). However, this mixture has $^{14}N/^{15}N$ and $^{32}Si/^{28}Si$ ratios that are too low by almost an order of magnitude. The presence of both explosive H burning and neutron capture (^{32}Si) signatures in grain KJD-1-11-5 points towards presence of strong asymmetries in the He shell following the H-ingestion event [11] and are an important constraint for multi-dimensional H-ingestion simulations in massive stars.

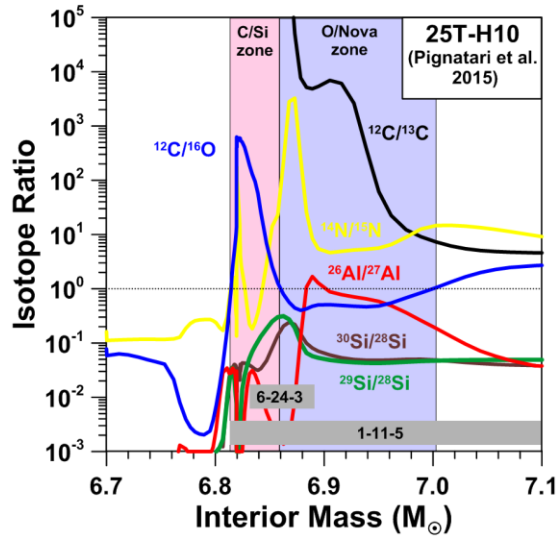

Figure 4. Profiles of selected isotope ratios in the interior of a 25 $M_\odot$ SNII (model 25T-H10 of [6]). The grey-shaded bands indicate the mixing range to account for the isotopic signatues of grains KJD-6-24-3 and KJD-1-11-5.

Grain KJD-3-23-5 (520 x 360 nm^2) has $^{12}C/^{13}C$ = 1.4 ± 0.1, $^{14}N/^{15}N$ = 42.3 ± 0.5, $\delta^{29}Si$ = 132 ± 15 ‰, and $\delta^{30}Si$ = 248 ± 20 ‰ (Figs. 2 and 3). Magnesium is essentially monoisotopic ^{26}Mg with $^{26}Al/^{27}Al$ = 0.018 ± 0.02, which is at the lower end of SiC SN grains. No evidence for ^{32}Si and ^{44}Ti was found. A nova origin seems most likely for this grain.

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