NEW INSIGHTS INTO SUPERNOVA NUCLEOSYNTHESES FROM A PRESOLAR SiC GRAIN WITH UNIQUE CARBON ISOTOPIC COMPOSITION.  P. Hoppe1, M. Pignatari2,3,4, J. Kodolányi1, and E. Gröner5, 1Max Planck Institute for Chemistry, 55128 Mainz, Germany (peter.hoppe@mpic.de), 2Konkoly Observatory, Budapest, Hungary, 3E. A. Milne Centre for Astrophysics, University of Hull, UK, 4NuGrid 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 12C (most grains) and 15N, and of 28Si (X grains) or 28,30Si (C grains). Furthermore, SiC SN grains incorporated significant amounts of radioactive 26Al, 32Si (mostly in C grains), and 44Ti. 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, 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+ primary ion beam (~1 pA, 100 nm) was rastered over 143 30 x 30 μm²-sized fields and negative secondary ion images of 12C, 13C, 28Si, 29Si, and 30Si 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 12C, 13C, 12C14N, 12C15N, and 28Si (session 1) and of 28Si, 32S, 33S, 34S, and 35S (session 2), employing a Cs+ primary ion beam (~1 pA, 100 nm), and positive secondary ions of 24Mg, 25Mg, 26Mg, 27Al, and 28Si (session 3) and of 28Si, 40Ca, 42Ca, 44Ca, and 48Ti (session 4), employing a focused O+ primary ion beam (~5 pA, 400 nm).

Results and Discussion: Among the 640 SiC grains identified by ion imaging are 9 X grains, 2 C grains, 1 Si,N4 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 nm²) has 12C/13C = 21400 ± 3500, 14N/15N = 15.0 ± 0.3, δ28Si = 380 ± 15 ‰, and δ32Si = 835 ± 22 ‰ (Figs. 2 and 3), the signature of C grains. The 32S excess of ~20% corresponds to 32Si/34Si = 5.6 ± 2.0 x 10⁻⁴. Magnesium, Al, Ca, and Ti concentrations are low and no evidence for significant amounts of 26Al and 44Ti was found. The 12C/13C ratio of KJD-6-24-3 is the highest 12C/13C 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_☉ 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_☉ and has C/O > 1. Our finding confirms the predicted high ^15N and low ^26Al abundances of He shell matter and gives further support for the validity of the Pignatari et al. models.

Grain KJD-1-11-5 (500 x 360 nm^2) has ^12C/^13C = 3.7 ± 0.1, ^14N/^15N = 57.4 ± 1.3, δ^28Si = -23 ± 9 ‰, and δ^30Si = 136 ± 1 ‰ (Figs. 2 and 3). The C- and Si-isotopic compositions are compatible with previously found nova grains while its ^14N/^15N ratio is higher by about a factor of 5. Magnesium is monoisotopic ^26Mg with ^26Al/^27Al = 0.205 ± 0.012. Grain KJD-1-11-5 exhibits a small, but significant ^32S excess from which ^32Si/^28Si = 8.1 ± 2.9 x 10^-3 can be inferred. No evidence for ^44Ti was found, albeit large uncertainties exist. The lower than solar ^33Si/^32Si (δ^33Si = -303 ± 110 ‰) is incompatible with nova model predictions [10] and the ^26Al/^27Al 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 ^26Al/^27Al if the full C/Si zone is mixed with an extended O/Nova zone (Fig. 4). However, this mixture has ^14N/^15N and ^32Si/^28Si ratios that are too low by almost an order of magnitude. The presence of both explosive H burning and neutron capture (^28Si) 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 multidimensional H-ingestion simulations in massive stars.

Grain KJD-3-23-5 (520 x 360 nm^2) has ^12C/^13C = 1.4 ± 0.1, ^14N/^15N = 42.3 ± 0.5, δ^28Si = 132 ± 15 ‰, and δ^30Si = 248 ± 20 ‰ (Figs. 2 and 3). Magnesium is essentially monoisotopic ^26Mg with ^26Al/^27Al = 0.018 ± 0.02, which is at the lower end of SiC SN grains. No evidence for ^32Si and ^44Ti was found. A nova origin seems most likely for this grain.

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