STRONTIUM AND BARIUM ISOTOPES IN TYPE X PRESOLAR SILICON CARBIDE GRAINS ANALYZED WITH CHILI—TWO TYPES OF SUPERNOVA GRAINS.

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Introduction: We have measured strontium and barium isotopic ratios in ten SiC grains from Murchison separate KJG using the Chicago Instrument for Laser Ionization (CHILI), a resonance ionization mass spectrometry (RIMS) instrument designed for isotopic and chemical analysis at high spatial resolution and high sensitivity [1–3]. Seven of the grains showed isotopic ratios similar to ratios previously observed in mainstream SiC grains [4,5], consistent with formation in low-mass asymptotic giant branch (AGB) stars. Here, we focus on the three grains that are inconsistent with formation in AGB stars but might have formed in the ejecta of type II supernovae.

Samples and analytical procedures: After desorption from SiC grains with a 351 nm laser, strontium and barium atoms were ionized with tunable Ti:sapphire lasers using a two-photon, two color resonance ionization scheme for each element. Standards showed isotopic precision in the few ‰ range. Subsequently, grain residues were analyzed for carbon and silicon isotopes with a CAMECA NanoSIMS 50 at Washington University.

Results and discussion: Since the grains were almost entirely consumed during RIMS analysis and the sample mount showed signs of contamination, probably with hydrocarbons, the carbon analyses are not meaningful. However, all grain residues had sufficient silicon to perform isotopic analyses. The seven grains that showed mainstream strontium and barium isotopic signatures also showed silicon isotopic ratios consistent with mainstream grains. The other three grains are clearly of type X (Table 1), linking them to type II supernova ejecta. This was very fortunate, considering that X grains comprise only ~1 % of KJG grains [6]. Furthermore, two of the three X grains seem to belong to the less abundant X2 subtype, while one grain is a more common X1 grain. X0, X1, and X2 subtypes have been defined based on silicon isotopes [7]. Both types of X grains show distinct properties in strontium and barium isotopes (Table 1). Relative to the normalizing isotopes ^{86}Sr and ^{136}Ba, the X1 grain is depleted in ^{84}Sr, ^{87}Sr, ^{134}Ba, and ^{135}Ba, as well as enriched in ^{88}Sr, ^{137}Ba, and ^{138}Ba. The X2 grains are strongly depleted in ^{84}Sr, ^{87}Sr, and ^{88}Sr (or, equivalently, enriched in the normalizing isotope ^{86}Sr), and strongly enriched in ^{134}Ba. Depletions of the X2 grains in ^{135}Ba, ^{137}Ba, and ^{138}Ba are similar to those observed in mainstream grains [4,5].

Model calculations: In order to compare our results for the X grains with model calculations, we tried to reproduce observed isotope ratios with multizone mixing of ejecta from a type II supernova with 15 $M_\odot$ initial mass [8] (Table 1). Model 1 mixes the Si/S (3 %), O/Ne (26 %), He/C (45 %), and He/N (26 %) zones, reproducing, at least qualitatively, all isotope ratios observed for the X1 grain, except for ^{134}Ba/^{136}Ba (Table 1). The match improves if we consider incomplete decay of ^{134}Cs and ^{137}Cs with grain condensation within a few years after the supernova explosion and volatile cesium not incorporated into the grain. Also, branching at ^{85}Kr could play an important role in strontium isotope production. However, the C/O ratio of the mixture in model 1 is 0.14, which seems implausible for SiC condensation. Model 2, which is much simpler, mixes the Si/S (0.2 %), He/C (75 %), and He/N (25 %) zones, yielding an almost perfect match with X2-grain composition (Table 1). Here, the C/O ratio of the mixture is 7.9.

Conclusions and outlook: Strontium and barium isotopic analyses performed with CHILI showed clear differences between different types of presolar supernova grains. Future analysis of more X grains and improved supernova models should help to better constrain formation conditions for such grains within type II supernovae.

References: [1] Stephan T. et al. 2013. Abstract #2536. 44th Lunar & Planetary Science Conference. [2] Stephan T. et al. 2014. Abstract #2242. 45th Lunar & Planetary Science Conference. [3] Stephan T. et al. 2015. *Meteoritics & Planetary Science Supplement* 50:#5257. [4] Liu N. et al. 2014. *The Astrophysical Journal* 786:66. [5] Liu N. et al. 2015. *The Astrophysical Journal* 803:12. [6] Hoppe P. et al. 1994. *The Astrophysical Journal* 430:870–890. [7] Lin Y. et al. 2010. *The Astrophysical Journal* 709:1157–1173. [8] Rauscher T. et al. 2002. *The Astrophysical Journal* 576:323–348.

Table 1: Isotope data[a] of presolar SiC X grains analyzed with CHILI and NanoSIMS in comparison with model calculations.

Grain	Type	δ^{29}Si	δ^{30}Si	δ^{84}Sr	δ^{87}Sr	δ^{88}Sr	δ^{130}Ba	δ^{132}Ba	δ^{134}Ba	δ^{135}Ba	δ^{137}Ba	δ^{138}Ba
#14	X1	–220±23	–389±23	–518±37	–234±15	+702±20	+305±398	+545±391	–297±56	–589±26	+310±52	+1671±88
#6	X2	–415±18	–398±23	–282±610	–382±107	–474±47	–	–	+314±211	–649±67	–207±82	–99±71
#15	X2	–460±17	–434±23	–667±98	–424±27	–440±15	–	–	+645±219	–599±62	–331±73	–353±53
Model 1		–185	–464	–841	–412	+440	–	–	+412	–596	+565	+546
Model 2		–443	–448	–678	–388	–394	–	–	+796	–546	–297	–259

[a]Isotope data given as δ-values in ‰ relative to ^{28}Si, ^{86}Sr, and ^{136}Ba, respectively; uncertainties are 1σ from counting statistics.