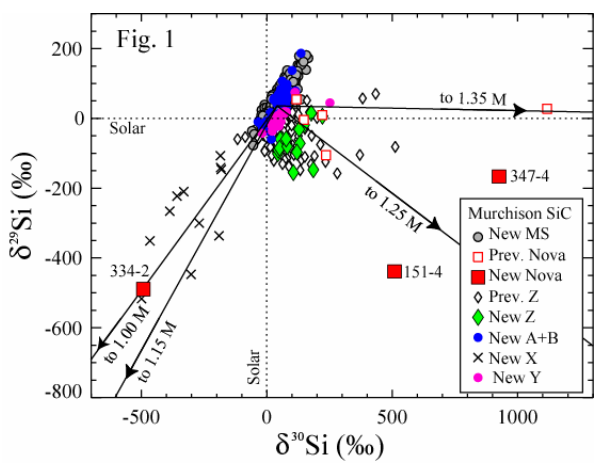
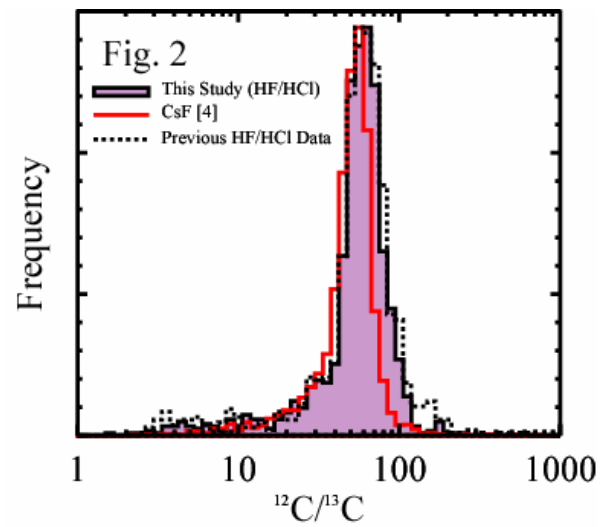
NEW PRESOLAR SILICON CARBIDE GRAINS WITH NOVA ISOTOPE SIGNATURES. L. R. Nittler[1] and P. Hoppe[2]. [1]Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Rd NW, Washington DC, 20015, (lrn@dtm.ciw.edu), [2]Max-Planck-Institute for Chemistry, Cosmochemistry Department, P.O. Box 3060, D-55020 Mainz, Germany.

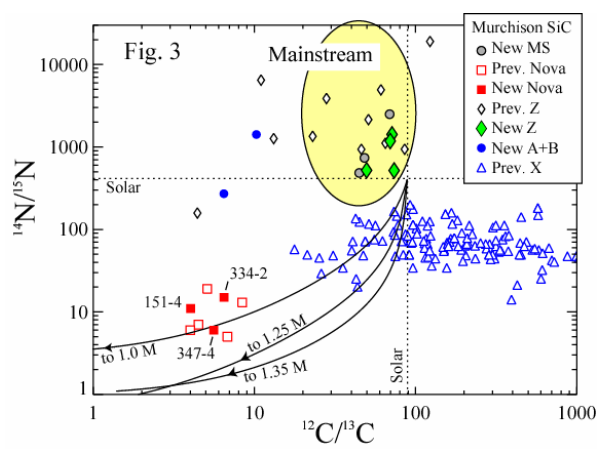
Introduction: The vast majority of presolar silicon carbide grains found in meteorites originated in asymptotic giant branch (AGB) stars and supernova explosions [1]. In contrast, out of several thousand analyzed SiC grains, only a very few with isotopic signatures strongly suggesting an origin in nova explosions have previously been identified [2]. We report the identification of three new SiC grains from the Murchison meteorite with C, Si, and N isotopic ratios indicative of nova nucleosynthesis.

Methods and Results: SiC grains from a Murchison residue prepared using the standard methods [3] were deposited on a gold foil and automatically analyzed for their Si- and C-isotopic ratios with the Carnegie ims-6f ion microprobe [4]. Of 1300 measured Si-rich grains, 1150 had Si/C ratios consistent with SiC and reasonably small error bars. Following the automated analyses, 12 selected grains were manually analyzed for $^{14}N/^{15}N$ ratios as well.



The isotopic data are shown in Figs. 1-3. All but two of the grains have isotopic compositions within the ranges of previous results. The sub-classes A, B, X, Y and Z are present at levels consistent with previous results [4, 5]. The median $^{12}C/^{13}C$ ratio of the grains is 55, significantly higher than the median value of 50 found for ~3,000 grains extracted from Murchison using a chemistry based on CsF [4]. In fact, as shown in Fig. 2, the distribution of the new grains is quite similar to previous measurements of SiC extracted using the usual HF/HCl technique, but distinct from the CsF data of [4]. This result strongly indicates that there are populations of presolar SiC grains with subtly distinct isotope compositions that are destroyed by at least one of the methods used to isolate the grains from host meteorites.





Two grains, 151-4 and 347-4, have Si isotope compositions outside previously observed ranges; these grains were also found to have very low $^{12}C/^{13}C$ and $^{14}N/^{15}N$ ratios. Grain 334-2 has Si-isotopic ratios in the range of the supernova-derived X grains, but its $^{12}C/^{13}C$ and $^{14}N/^{15}N$ ratios are much lower than observed in X grains. A few previously reported X grains have $^{14}N/^{15}N<20$, but these all have $^{12}C/^{13}C>$ solar (Fig. 3). The $^{14}N/^{15}N$ ratios of the 4 measured Z grains are within the range of the few Z grains previously analyzed for N [6].

Discussion: The C- and N-isotopic ratios of grains 151-4, 334-2, and 347-4 are closely similar to those of a few grains previously suggested to originate in classical novae [2], although their Si-isotopic compositions are different. Novae are thermonuclear explosions occurring when H-rich matter accretes onto a white dwarf star from a stellar companion. The high temperature nuclear processing that follows (primarily proton capture) leads to very low $^{12}C/^{13}C$ ratios as well as significant modifications of the isotope compositions of other light elements (~up to S) and the synthesis of some important radioactivities, including ^{26}Al [7]. The precise nucleosynthesis that occurs in a nova depends on the nature of the progenitor white dwarf, namely whether it is composed of C and O (CO novae) or of O and Ne (ONe novae). ONe novae occur on more massive white dwarfs ($M>\sim 1M_{\odot}$) than do CO novae, but the exact minimum mass for an ONe nova is unknown. Amari et al. [2] compared the data for a few nova grain candidates with the results of many nova nucleosynthesis calculations. They showed that the Si isotopic ratios of the grains required an origin in ONe novae, since only these can produce the observed enrichments in ^{30}Si.

Shown in Figs. 1 and 3 are mixing lines between close-to-solar compositions (average mainstream composition for Si, solar for C and N) and the bulk ejecta of ONe novae of different white dwarf masses [7]. The compositions of the new grains can be qualitatively explained by the nova models at least as well as the previous grains could. Like the previous grains, the ^{30}Si enrichments in grains 151-4 and 347-4 seemingly require an origin in relatively massive novae ($>\sim 1.25M_{\odot}$). In contrast, the ^{28}Si-rich composition of grain 334-2 requires that it formed in a less massive nova. However, it still apparently requires an ONe parent, since CO nova models do not predict large ^{30}Si depletions [7].

Despite the qualitative agreement with nova models, several problems identified by [2] persist. First, based on the mixing calculations, the grains only contain a small amount (<5%) of pure nova ejecta; most of the grains' atoms must have come from the companion star. Second, there is an inconsistency between the C-N data and the Si data: most of the grains lie above the mixing lines for the massive novae indicated by the Si isotopes. However, there is qualitative consistency in the sense that the mass sequence suggested by Si of (light to heavy) 334-2, 151-4 and 347-4 is consistent with the C-N data. Third, astronomical observations indicate that CO novae produce more dust than ONe novae, but all of the identified nova SiC grains seem to originate in ONe novae. Fourth, the bulk ejecta of ONe novae are O-rich, making it difficult to produce C-rich dust like SiC.

Some of these problems may be alleviated if the grains did not in fact form in the nova ejecta itself, but in AGB winds from the companion stars. This would require that the surface composition of the companions is modified by re-accretion of some of the ejecta from recurrent nova outbursts [8]. Since more massive white dwarfs experience more frequent recurrent nova outbursts than less massive ones [9], it is perhaps more likely that a significant amount of material could be transferred onto the companion stars of ONe rather than of CO novae. As in single AGB stars, dredge-up of nuclear processed material would increase the C/O ratio to greater than 1 so that SiC could form. Also, cool-bottom processing (CBP) could increase the surface $^{14}N/^{15}N$ ratios [10], relative to the pure mixing of nova ejecta into the solar composition (Fig. 3). Note that, because of its short lifetime, ^{26}Al potentially can be used as a test of the proposed scenario. If the nova outbursts occur significantly prior to the companion star's AGB phase and consequent SiC formation, relatively low $^{26}Al/^{27}Al$ ratios are expected. On the other hand, high $^{26}Al/^{27}Al$ ratios (>0.1), in the range of nova models, would indicate that the grains formed soon after the nova events, either indicating a formation within the ejecta itself or that the companion star was in the AGB phase while the nova outbursts occurred. Of two grains previously analyzed for Al-Mg [2], one had an inferred $^{26}Al/^{27}Al$ ratio in the range expected for nova ejecta, but the other was lower, within the range expected for CBP [10]. Planned NanoSIMS measurements of Al-Mg and Ti isotopes in the new nova grains should help better constrain their origins.

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