PRESOLAR SiC GRAINS IN METEORITES FROM CARBON-OXYGEN NOVA OUTBURSTS. M. Bose[1] and S. Starrfield[1], [1]School of Earth and Space Exploration, 550 E. Tyler Mall Building PSF, Room 686 Tempe, AZ 85287 (Maitrayee.Bose@asu.edu).

Introduction: Laboratory measurements of presolar SiC grains and comparisons to observations of dust in stars and models of stellar evolution have taught us immensely about nucleosynthesis and complex processes in the interiors of stars. For example, chemical compositions of 30 Galactic carbon stars show $^{12}C/^{13}C$ compositions comparable to those of the mainstream SiC grains [1]. Large scale mixing in Type II supernovae has been used to explain several isotopic ratios of a large inventory of carbonaceous grains, and to deduce that a large contribution from the He/N layer in the SN is required [2], although deficiencies in supernova models have also been raised [e.g., 3]. The origin of SiC grains that exhibit low $^{12}C/^{13}C$ ratios (< 10), low $^{14}N/^{15}N$ ratios in the range ~5–20, large ^{30}Si excesses and high $^{26}Al/^{27}Al$ ratios has been under intense debate. These grains have been argued to have formed in ONe novae [4], primarily based on predictions from ONe nova models [5, 6]. The grain compositions require mixing of Solar material (> 90 % contribution) with that synthesized in nova outbursts with white dwarf (WD) masses 1.15 and 1.25 $M_\odot$ [4].

More recently, Iliadis et al. predicted nova dust signatures using a Monte Carlo approach, where values for the peak temperature, density, reaction rates in a Carbon Oxygen (CO) WD were chosen, and then an exponential decrease in those values as a function of time was assumed, for a given WD mass, luminosity, mass accretion rate and 50–50 mix between the accreted and WD composition [5]. Comparisons to oxygen- and carbon-rich nova candidate grains found reasonable agreement with several grains.

We have performed a full evolutionary simulation of classical nova explosions by following the evolution of thermonuclear runaways (TNRs) on CO WDs. The output of these new multi-dimensional studies of TNRs in WDs (henceforth, referred to as MDTNR) are compared to the observations of ^{7}Li in V5668 Sgr [6]. The same abundance predictions are being compared to the compositions measured in SiC grains that are thought to condense in nova explosions. Because the new simulations attempt to match the peak luminosities and ejection velocities observed in nova explosions, they are more diagnostic of actual nova environments. Details of this work can be found in [7].

Method: NOVA is a one-dimensional, fully implicit, Lagrangian hydrodynamic computer code described in [8 & references therein]. The simulations that produced the isotopic abundances used in this study were done with 150 mass zones. It includes convective mixing and we have varied both the mass of the WD (from 0.6 $M_\odot$ to 1.35 $M_\odot$) and the composition of the accreted material. In our studies of TNRs in WDs, Solar matter is accreted and mixing with the core material occurs after the TNR (temperatures > 7×10^7 K) is well underway, reaching levels in agreement with observations of the ejecta abundances. The Solar composition is switched to a mixed composition: either 25 % core material and 75 % Solar or 50 % core material and 50 % Solar. We then followed the TNR through the peak and tabulated the amount of ejected gases, their velocities, abundances, and bolometric light curves.

Results and Discussion: We plotted the results of the simulations in a $^{12}C/^{13}C$ and $^{14}N/^{15}N$ isotope plot (Fig. 1), and attempted to explain the compositions of thirty SiC nova candidate grains from the literature, which includes highly probable grains from [5].

Mixing lines between the terrestrial ratios and simulated values from the new CO nova models were drawn. Proportions of nova ejecta vs. solar system contribution were calculated, which showed that 17 out of 27 grains show a good fit for both carbon and nitrogen isotope compositions (Fig. 1). Three grains have no nitrogen data available, and no fits were found for the remaining SiC grains. The proportion of nova ejecta to be mixed with Solar material are listed (in percentage) for the MDTNR 25-75 simulation with 1.15 $M_\odot$ WD mass because it can explain a large number of nova candidate compositions (Fig. 1). Several grains that lie on this 1.15 $M_\odot$ mixing line require > 90 % material from the nova ejecta. The highly plausible grain M11-151-4 (M11 in Fig. 1) that also plot on the MDTNR 25-75 1.15 $M_\odot$ mixing line require ~95 % of material from the nova ejecta.

Next we attempted to fit the isotopes of silicon ($^{28}Si/^{30}Si$ and $^{29}Si/^{28}Si$), sulfur ($^{34}S/^{32}S$ and $^{33}S/^{32}S$), and aluminum ($^{26}Al/^{27}Al$) simultaneously. Qualitatively, the silicon isotopes fit the presolar grain data well (Fig. 2). Several simulations have silicon isotope ratios very close to terrestrial ratios that perfectly matched the SiC grain data with no solar system contribution. In addition, the MDTNR 50-50 1.35 $M_\odot$ simulation is able to explain a large number of the SiC grains that lie on the mixing line (Fig. 2). Furthermore, 8 out of 17 SiC grains with $^{26}Al/^{27}Al$ ratios can be explained quantitatively by high-mass models, e.g., 1.35 $M_\odot$ WD MDTNR model require ~85–95 % nova material to be mixed with Solar material, which agrees well with observations in other isotopes. However, we required that the same simulation fit at least three isotope ratios of a given presolar grain, and posing this constraint, only eight grains can be reproduced by the identical simulation. 50 % of these grains have multiple solutions, e.g., grain M2-A1-G410, as listed in Table 1, can be accurately quantified by both 25-75 0.8 $M_\odot$ and 1 $M_\odot$ models. Hence, we placed additional constraints. We defined a grain to be of nova origin, if the proportion of nova contribution from the mixing calculations is similar (within 25 %) for any three isotope ratios. Based on this criteria, four grains are nova grains (Table 1). These grains require > 75 % contribution from the nova ejecta to fit the grain compositions.

The uncertainties in the models are unknown at present but can be as large as 50 % and so grains with proportions of nova contribution that differ by 50 % are considered to be in the *maybe* category. Only one grain G1342 falls in this category.

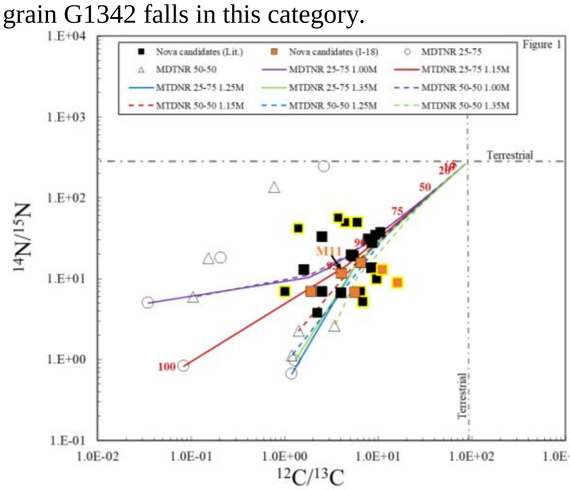

***Fig. 1**: The $^{12}C/^{13}C$ and $^{14}N/^{15}N$ ratios of nova candidate grains from the literature are plotted in black. The SiC grains with a higher probability of being products of CO nova based on [5] are shown in orange (I-18). Black and orange grains with yellow outlines don't fit these carbon and nitrogen simulations. For the MDTNR model with WD mass of 1.15 $M_\odot$, the proportion of nova ejecta is written next to the mixing line.*

Conclusions: The comparisons of the new CO simulations to the SiC grain compositions show 2 major outcomes: First, the 0.8–1.35 $M_\odot$ CO MDTNR 25-75 models, where mixing between the core and accreted material in the binary star system occurs after TNR is initiated, can explain the isotope compositions of four presolar SiC grains. One grain possibly of nova origin requires MDTNR 50-50 simulation with 1.35 $M_\odot$ WD. Nova dust associated with such a large WD have been observed for the first time. Second, the grain compositions require < 25 % of Solar material to reproduce the grains' compositions, which confirm that nova dust grains, albeit present in low abundance, are a component of the presolar grain inventory.

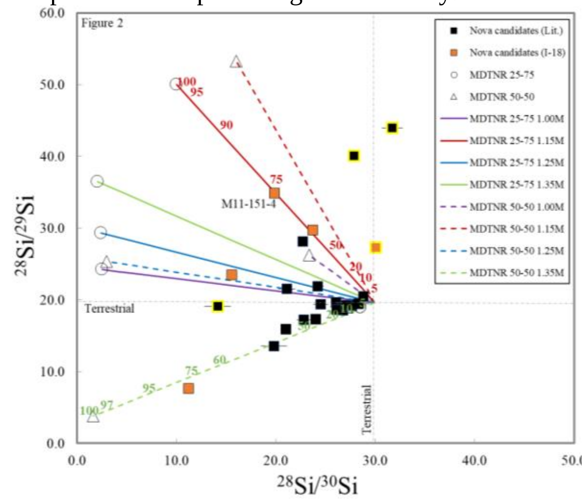

***Fig. 2**: The $^{28}Si/^{29}Si$ and $^{28}Si/^{30}Si$ ratios of nova candidate grains from the literature are plotted in black. The SiC grains with a higher probability of being products of CO nova based on [5] are shown in orange (I-18). Black and orange grains with yellow outlines don't fit the simulations. For the MDTNR model with WD mass of 1.15 $M_\odot$ and 1.35 $M_\odot$, the proportion of nova ejecta is written next to the mixing lines.*

Table 1: Nova grains in meteorites

Grain name [ref]	Best fit simulation	Isotopes that fit
M11-151-4	25-75 1.15 $M_\odot$	C,N,Si,Al
M2-A1-G410	25-75 0.8 $M_\odot$	C,N,Si,Al
G1342(maybe)	50-50 1.35 $M_\odot$	C,N,Si
G283	25-75 1.35 $M_\odot$	C,N,Al
GAB	25-75 & 50-50 1.00 $M_\odot$	C,N,S

In classical novae, nucleosynthesis occurs via proton capture at higher temperatures than predicted before [6], and carbon-rich dust grains can be produced in the oxygen-rich environment of the WDs. Thus, we speculate that SiC grains can form in the winds of novae, where the criterion C > O may not be locally imposed, and thus nova winds can be chemically inhomogeneous.

References: [1] Lambert D. L. et al. (1986) ApJSS 62, 373-425. [2] Yoshida T. and Hashimodo M. (2004) ApJ 606, 592-604. [3] Lin Y. et al. (2010) ApJ 709, 1157-1173. [4] Amari S. et al. (2001) ApJ 551, 1065-1072. [5] Iliadis C. et al. (2018) ApJ 855, 76-90. [6] Starrfield S. et al. (2019) In prep for ApJ. [7] Bose M. and Starrfield S. (2018) arXiv: 1812.11432. [8] Starrfield S. et al. (2009) ApJ 692, 1532-1542.