NEW REACTION RATES AND IMPLICATIONS FOR NOVA NUCLEOSYNTHESIS AND PRESOLAR GRAINS. F. Gyngard[1], L. R. Nittler[1], E. Zinner[2], J. Jose[3], S. Cristallo[4], [1] Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road NW, Washington, DC 20015, USA, fgyngard@dtm.ciw.edu, [2]Laboratory for Space Sciences and Department of Physics, Washington University, St. Louis, MO 63130, USA, [3]Dept. Fisica i Enginyeria Nuclear, Universitat Politecnica de Catalunya & Institut d'Estudis Espacials de Catalunya, Barcelona, Spain, [4]Dept. de Fisica Teorica y del Cosmos, Universidad de Granada, Granada, Spain.

Introduction: Presolar grains ("stardust") found in the matrices of primitive meteorites have become accepted as relic dust from asymptotic and red giant branch (AGB and RGB) stars of various masses and metallicities, supernovae (SNe), and novae [1]. However, accurate determinations of the stellar origins for presolar grains rely on detailed comparison of the grains' isotopic compositions with the predicted compositions from models of their purported progenitor astrophysical environments. In this regard, nuclear cross-sections (at temperatures appropriate for a given stellar setting), and, in turn, nuclear reaction rates, have fundamental importance to the predicted nucleosynthetic yields.

Novae, in which accretion of material from typically a main sequence star (K-M dwarf) onto a white dwarf (WD) companion causes a thermonuclear runaway, are a unique laboratory for nuclear astrophysics [2]. In particular, the nuclear processing that occurs in ONe novae during the runaway is predicted to produce copious enrichments in the yields of ^{13}C, ^{15}N, ^{17}O, ^{25}Mg, ^{26}Al and ^{30}Si [3]. As novae are prodigious at dust production [4], it is not surprising that both carbonaceous and O-rich presolar grains with these isotopic signatures, indicative of condensation in nova outflows have been found [5-7]. While some of the grains may have an ambiguous origin and could have originated from SNe [8, 9], several SiC grains with extremely low ^{12}C/^{13}C and ^{14}N/^{15}N ratios and oxides with very high ^{17}O/^{16}O ratios are likely nova grains. Here we report the O-isotopic composition of 4 new presolar oxides (2 alumina and 2 spinel) of possible nova origin, and the Mg-Al isotopic compositions of the 2 spinel grains, then compare these compositions to the predicted isotopic yields from both models of first dredge-up (FDU) and nova nucleosynthesis, calculated with the latest available reaction rates.

Experimental Methods: Grains from the CG residue [10] of the Murray CM2 chondrite were automatically analyzed for ^{16,17,18}O$^-$ and ^{24}Mg^{16}O$^-$ and ^{27}Al^{16}O$^-$ in the Carnegie NanoSIMS 50L with the system described in [11]. Two of the grains were not identified by the automated system, but were observed as ^{17}O hotspots in large clumps of grains. For anomalous grains that were near normal ones, the surrounding solar system (SS) grains were sputtered away, and the O isotopes were remeasured. In a separate session, ^{24,25,26}Mg$^+$, ^{27}Al$^+$, ^{40,44}Ca$^+$, and ^{48}Ti$^+$ were measured in multicollection with an ~10 pA, 0.5 – 1.0 µm O$^-$ primary beam.

Results and Discussion: The predicted maximum ^{17}O/^{16}O ratio that can be reached in low- and intermediate-mass AGB and RGB stars (of close-to-solar metallicity) has been taken to be 0.004 [12]; grains having ^{17}O/^{16}O ratios much greater than this limit are likely of nova origin. However, FDU calculations incorporating the new estimate of the solar metallicity [13] and updated reaction rates important for the CNO cycle – especially ^{14}N(p,γ)^{15}O and ^{15}N(p,γ)^{16}O (both reduced by ~2x) [14] – lead to higher ^{17}O/^{16}O ratios [15], in particular around the 2M$_\odot$ star (Fig. 1). A re-evaluation of the so-called "AGB cutoff" may reduce the number of candidate nova grains. The effect on calculated ^{18}O/^{16}O ratios is smaller, with at most a reduction of ~7% compared to the previous models [12].

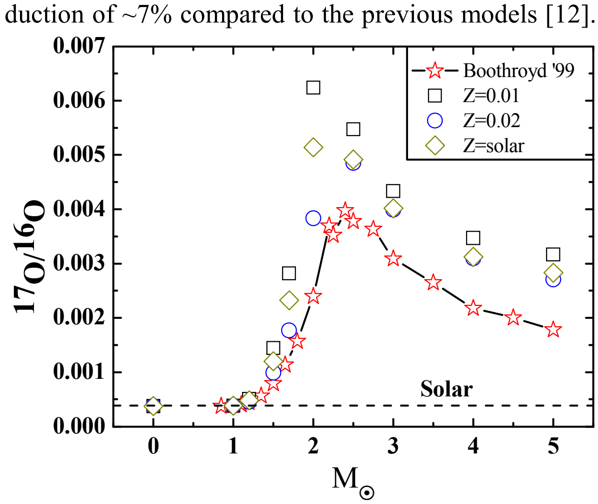

Figure 1. Theoretical ^{17}O/^{16}O ratios as a function of stellar mass calculated for several metallicities and compared to [12].

Regardless, the ^{17}O/^{16}O ratios of the newly discovered grains, as well as those of several grains in the literature [8, 11, 16, 17] (Fig. 2), are above the cutoff and indicate nova grains. Also shown are the O-isotopic compositions predicted for novae with either a CO or ONe WD core (depending on whether they're more massive than ~1.1M$_\odot$ or not) for various stellar masses and degrees of mixture between the WD and the material accreted from the companion star (hence multiple compositions for the same stellar mass). Previous model results [5] matched the grain data without the need for ad-hoc mixing with SS composition material [11]; however, with the new $^{17}O(p,\gamma)^{18}F$ [18] and $^{18}F(p,\gamma)^{19}Ne$ [19] reaction rates, ^{18}O is much more efficiently destroyed and the predictions completely miss the grain data. Mixing with solar matter is now required to match the data (red line in Fig. 2), analogous to the situation for purported SiC nova grains [6], where the model compositions are much more extreme than what was actually measured in the grains.

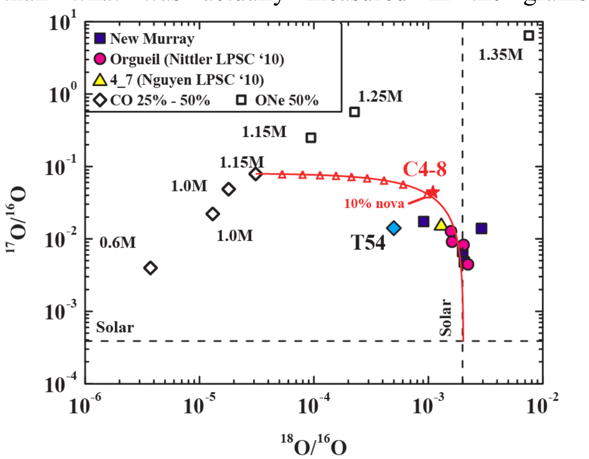

Figure 2. O-3 isotope plot of potential nova grains compared to new model predictions.

The Mg isotopic compositions of the grains and the updated model predictions are shown in Fig. 3. Two grains have large enrichments in ^{25}Mg and ^{26}Mg (δ^{25}Mg-values of 388 ± 10‰ and 241 ± 7, δ^{26}Mg-values of 318 ± 10‰ and 307 ± 7‰, respectively). Two of the new nova candidate grains could not be successfully analyzed for Mg-Al; one had been completely sputtered away before, while the measurement of the other grain was compromised by redeposited Mg after sputter removal of nearby grains. Unlike the case for the O isotopes, the calculated Mg-Al compositions from the models are not greatly affected by the updated reaction rates. As with the case for O, the predicted Mg isotopic ratios are much more extreme than the grain data and mixing between nova ejecta and material of solar composition is again required to explain the grains composition (red lines in Fig. 3). Why the grains contain such large ^{17}O isotopic enrichments but Mg isotopic ratios orders of magnitude smaller than the model predictions is an outstanding question, though, it has been hypothesized that isotopic exchange either in the interstellar medium or on the meteorite parent body may have reduced the grains' Mg anomalies [20]. Discovery of an extremely ^{17}O-rich grain with Mg isotopic ratios more closely matching the model predictions could provide unequivocal certainty of a nova origin for these grains. Unfortunately, trace elements are not easily incorporated into alumina and spinel, making future comparisons between model predictions and grain data for other elemental systems difficult. However, the nova models predict extraordinarily large enrichments of ^{39}K and ^{40}Ca relative to the minor isotopes of K and Ca, respectively, strongly dependent on the mass of the WD. The discovery of presolar hibonite ($CaAl_{12}O_{19}$) grains with large ^{17}O excesses indicative of a nova origin could provide an opportunity of testing these predictions.

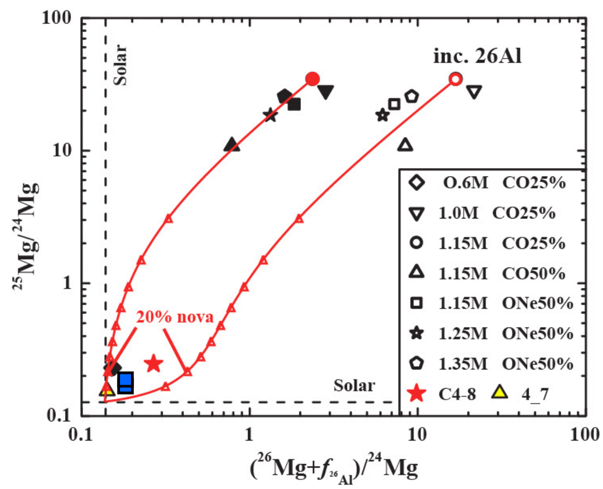

Figure 3. Plot of the Mg isotopic compositions of the grains compared to model data. The parameter "*f*" reflefts the preferential condensation of Al into spinel grains. It is model sensitive and varies depending on the Mg and Al isotopic abundances of the computed nova ejecta.

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