THE α-PROCESS IN SUPERNOVA PRESOLAR SiC GRAINS.

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Introduction The rare presolar SiC grains from supernovae (SNe), called SiC of type X, make up only $\sim 1\%$ of all presiolar SiC grains [1]. Identifying SNe as their source stars is based on enrichments in ^{12}C (for most grains), ^{15}N and ^{28}Si. In addition, a large fraction of the grains bears evidence for in-situ decay of the SN produced short-lived radioisotopes ^{26}Al ($t_{1/2} = 7.1 \times 10^5$ yr), ^{44}Ti ($t_{1/2} = 60$ yr) and ^{49}V ($t_{1/2} = 331$ d) [1].

Two recent studies measured the isotopic composition of heavy elements in SiC X grains: Pellin et al. [2] measured the isotopic composition of Fe, Sr, Zr, Mo, Ru, and Ba, and Marhas et al. [3] measured the isotopic composition of Ba. Surprisingly, none of the heavy elements measured showed the expected composition of the r-process. The Zr in 3 of the 4 measured grains was characterized by large enrichments in ^{96}Zr, while Mo in 6 of the 8 measured grains had a peculiar large enrichment in ^{95}Mo and ^{97}Mo. The neutron burst model of Meyer et al. [4] explained these Zr and Mo compositions very well qualitatively [2], and as was shown by Marhas et al. [3], mixing of neutron burst end member and solar composition could account for the compositions of most of the grains.

However, the Ba isotopic composition could not be explained by the neutron burst [3], as well as the Mo compsition of grain 153-8, which is solar within uncertainties for all isotopes, but depleted in ^{100}Mo. Here we present preliminary results of the new High Entropy Wind (HEW) model for the nucleosynthetic α-process that can explain the Mo isotopic compositions of most grains, including that of grain 153-8. This is an alternative mechanism to the neutron burst model.

The HEW model and the α-process The new HEW model is a parameterized description of the nucleosynthesis in a small spherical area, called the High Entropy Bubble (HEB), above the nascent proto-neutron star in core-collapse supernovae (SNe Type II) [5]. In the model, late neutrinos emitted by the proto-neutron star interact with matter in its outermost layers, leading to moderately neutron-rich and high entropy neutrino wind. The neutrino wind drives the nucleosynthesis in the HEB.

The conditions in the adiabatically expanding homogeneous HEB are described by three parameters: electron-fraction (Y_e), entropy (S, in units of k_b/baryon) and expansion velocity (V_{exp}, in units of km/sec). The dominant nucleosynthesis, α-process or r-process, is determined by the value of S. An important point to note is that after the reactions freezeout, the expanding and eventually ejected HEB mass zones have different initial entropies, so the overall ejected material is a superposition of different initial entropies.

The α-process is the build-up of increasingly heavier nuclei by primarily charged particle reactions, accompanied by n-capture reactions as well [5, 6]. It follows the SN driven photodisintegration of heavy nuclei in the progenitor star Fe core to protons, neutrons and α particles. While the "classical" α-rich freezeout terminates with nuclei of the Fe-peak, the α-process goes on to produce nuclei up to mass ~ 110. In addition, the α-process is a primary process. This means that it does not require any assumptions about the initial composition of the SN progenitor star, unlike the secondary s-process and neutron burst.

The HEW is the first model that incorporates both the α- and r-processes, so its results distinguish between the contribution of each process to the different nuclei. The results show that the light trans-Fe elements, Zn (Z=30) to Cd (Z=48), are produced in massive stars partially or primarily by the α-process. This is in good agreement with astronomical observations that show that the abundances of these elements are uncorrelated (Zn-Nb) or weakly correlated (Mo-Cd) with the abundances of r-process elements in ultra low metallicity (ULM) stars [5, 7]. It also means that isotopes of these elements that are thought to be produced by the p-, r- and s-processes are actually produced in massive stars by the α-process.

The α-process in SiC X grains Figure 1 is a three isotope plot of ^{100}Mo/^{97}Mo vs. ^{96}Mo/^{97}Mo. It shows the SiC X grains measured by Pellin et al. [2] (black diamonds), the latest neutron burst results of Brad Meyer and his colleagues [8] (in green), and HEW model results for the typical case of $Y_e = 0.476$ and $V_{exp} = 15,000$ km/sec (in red). The best match of the neutron burst and HEW models' results to the grain data is presented as mixing lines between their respective end members and solar composition. The names of two grains are listed as well. Grain 153-8 is the one mentioned above. Grain E2-10 (blue diamond) showed the largest ^{95,97}Mo enrichment. However, its C, N and Si isotopic composition was not measured, so it could not be classified [2].

The comparison in Fig. 1 shows that the HEW model

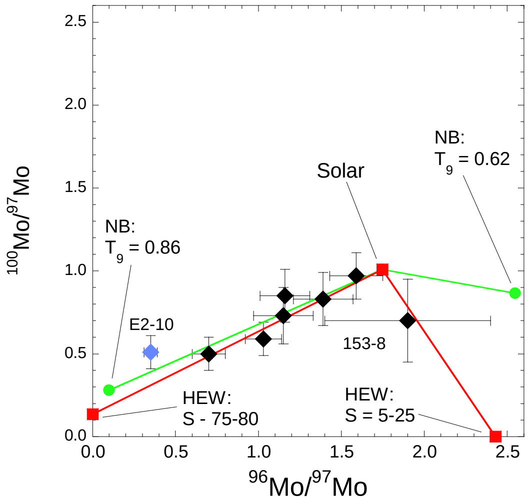

Figure 1: ^{100}Mo/^{97}Mo vs. ^{96}Mo/^{97}Mo, comparing SiC X grain data [2] (black diamonds) with results of the neutron beurst [8] (NB, in green, end members as dots, mixing lines with solar composition) and HEW (HEW, in red, end members as squares, mixing lines) models. Uncertainties are 2σ.

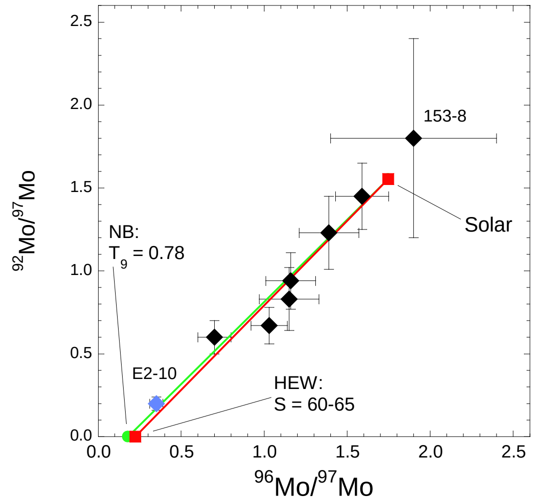

Figure 2: ^{92}Mo/^{97}Mo vs. ^{96}Mo/^{97}Mo, symbols as in Fig. 1

results for the superposition of initial S=75 and S=80 (S range of α-process with neutron-rich nuclei) is very similar to the neutron burst results for peak temperature of 0.86×10^9 ($T_9 = 0.86$) K. The mixing lines between the end members of both models and solar composition explain very well the compositions of all grains within the 2σ uncertainties, with the exception of grains 153-8 and E2-10 (the neutron burst mixing line is closer to the latter grain composition).

However, when comparing the models' results with the the composition of grain 153-8, one can see a difference. The grain's ^{100}Mo/^{97}Mo ratio, 0.7 ± 0.25, is lower than the solar ratio of 1.008 [9]. The mixing line of the new neutron burst result for $T_9 = 0.62$ K cannot account for the grain's ^{100}Mo/^{97}Mo ratio. On the other hand, the mixing line of the HEW model for the superposition of S in the range of 5-25 (range of α-process) agrees very well with the grain composition.

Another comparison of grain data with results of the neutron burst and HEW models is presented in Fig. 2. In this case, the ratio of ^{92}Mo/^{97}Mo is plotted vs. ^{96}Mo/^{97}Mo. The comparison here shows that the HEW and neutron burst models' results are practically identical, and both models can explain the compositions of almost all grains.

Conclusions The HEW model is an alternative to the neutron burst model. It predicts that Mo is produced in massive stars mainly by the primary α-process, in agreement with astronomical observations in ULM stars. The preliminary HEW model results presented here explain very well the compositions of most SiC X grains measured by [2], including the ^{100}Mo/^{97}Mo ratio of grain 153-8, which cannot be explained with the neutron burst model. In both cases shown, the HEW results explain the compositions of most grains as mixing between a narrow α-process S range and solar composition. However, the compositions of grain 153-8 indicate that they condensed from mixing with material that experienced different S ranges, but still in the α-process range.

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