PRESOLAR GRAINS IN MICROMETEORITES: EVIDENCE FOR THE INJECTION OF SUPERNOVA DUST INTO THE SOLAR NEBULA. P. Haenecour[1,2], C. Floss[1,2], R. Ogliore[1,2], A. Wang[1,3], and T. Yada[4]. [1]McDonnell Center for the Space Sciences, [2]Laboratory for Space Sciences and Physics Dept., [3]Dept. of Earth and Planetary Sciences, Washington University in St. Louis, 1 Brookings Drive, St. Louis, MO 63130, USA. [4]Inst. Space Astronaut. Science, Japan Aerospace Explor. Agency, 3-1-1 Yoshinodai, Chuo, Sagamihara, Kanagawa, Japan. (pierre@lpl.arizona.edu)

Introduction: Micrometeorites (MMs) are small extraterrestrial particles collected on the Earth's surface that are intermediate in size (~50-2000 µm) between interplanetary dust particles (IDPs) and meteorites. Previous studies have suggested that, while at least a small fraction of the MM population might have originated from comets [1], most MMs have isotopic and elemental compositions similar to chondrites and, thus, are consistent with asteroidal origins [2].

While presolar grains (e.g. silicate, oxide, and SiC grains) have been reported in fine-grained MMs in abundances similar to the ones observed in primitive chondrites, initial observations also suggested a higher relative abundance of supernova (SN) silicate and oxide grains in MMs and IDPs than in carbonaceous chondrites [3], possibly indicating a spatial/temporal heterogeneity in the distribution of SN grains in extraterrestrial materials. However, this observation was not statistically conclusive, as it is based on only 19 O-anomalous grains. Here we report on the identification of 66 O-anomalous and 25 C-anomalous presolar in seven fine-grained Antarctic MMs (T98NF2, T98H3, T98H5, T98G6, T98G8 and T00Iba030). These additional data provide better statistics, thus allowing us to revisit this question.

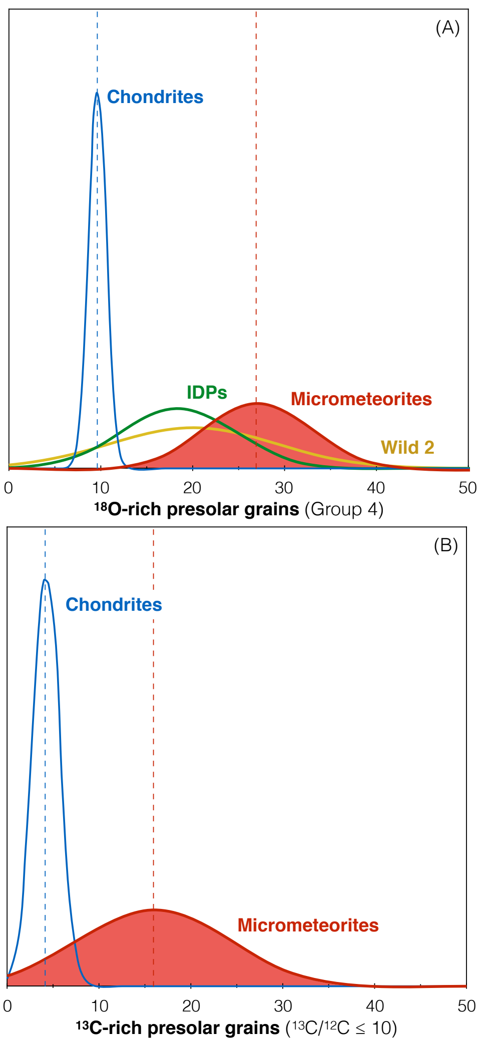

Figure 1. Probability density distributions for the overall abundance of O- (A) and C-rich (B) SN grains in the different solar system materials.

Experimental Methods: Isotopically anomalous presolar grains were located using NanoSIMS 50 raster ion imaging of carbon ($^{12,13}C^-$) and oxygen ($^{16,17,18}O^-$) isotopes in the seven MMs following routine analytical conditions [4]. We mapped a total area of 39,900 µm^2 in these MMs.

O-anomalous Grains: Considering both the 66 newly identified O-anomalous grains and the 19 grains reported by [3], we calculate a relative proportion of SN grains (^{18}O-rich Group 4) in MMs of 27 ± 6% (1σ), which is significantly higher than the one in carbonaceous chondrites (overall = 9.6 ± 1.0%, Fig. 1A). Comet 81P/Wild 2 and IDPs have a distribution of SN grains (~20%) more similar to the one in MMs than in meteorites, but the significance of this observation is limited because it is based on only 5 and 49 O-anomalous grains identified in the NASA Stardust cometary samples and IDPs, respectively. We also observe significant variations between individual MMs (between 18 – 58%), but the relative abundance of SN grains in each MM is at least two times higher than the meteorite abundance. A high proportion of SN grains (43%) was also recently observed in an ultracarbonaceous MM [5]. Similar variations in the proportion of SN grains are not observed between individual fine-grained areas in meteorites, suggesting that they are not simply related to poor statistics or clumpiness in the data but likely reflect different formation histories or distinct parent bodies for some of these MMs. Therefore, our new results, based on a larger number of grains, confirm the initial observations by [3] and provide clear evidence for a spatial/temporal heterogeneity in the distribution of SN grains in the solar protoplanetary disk.

C-anomalous Grains: Interestingly, the proportion of extremely ^{13}C-rich SiC grains ($^{12}C/^{13}C \leq 10$) in the

MMs (16 ± 8%) is also significantly higher than in chondrites (4.2 ± 1.5%, Fig. 1B). Recent studies have shown that at least some (if not most) of these grains originated from SN [6,7]. Therefore, like O-rich grains, the relative abundance of C-rich SN grains is about 3-4 times higher in MMs than in chondrites, thus providing further evidence of a heterogeneous distribution of SN grains in the protoplanetary disk.

Possible Origin(s) of the Heterogeneous Distribution of SN Grains: One could envisage that the low abundance of SN grains in meteorites compared to MMs reflects the preferential destruction of SN grains in meteorites by alteration processes (e.g., aqueous alteration). This would require that meteorites experienced significantly more alteration than MMs, and that SN grains are more susceptible to alteration than other presolar grains. However, it is hard to envision an alteration process that would preferentially destroy both O- and C-rich SN grains without affecting presolar grains from other stellar sources. Moreover, meteorites of different petrologic types (e.g., CR2-3, CO3) have similar proportions of SN grains within uncertainties despite experiencing significantly different alteration histories.

A more likely scenario is that the heterogeneous distribution of SN grains in astromaterials reflects the injection of SN material into the solar protoplanetary disk. This theory has been previously invoked to account for the presence of short-lived radionuclides and nucleosynthetic anomalies in early solar system materials [8,9], as well as for the identification of extremely ^{54}Cr-rich (> 11 × solar) spinel grains in the Orgueil meteorite [10]. Some studies have also suggested that a nearby SN could have triggered the collapse of the molecular cloud, leading to the formation of the solar system [11].

However, other studies have argued that the observation of short-lived radionuclides in early solar system objects could simply reflect galactic background inherited from the injection of material by previous generations of star formation into dense regions of the ISM [12], and/or reflect spallation production by intense activity of the proto-sun [13]. Calculations have also suggested that the probability of direct injection of SN material into the protoplanetary disk is very low, on the order of less than one in a thousand [14]. However, the recent confirmed identification of SN-produced ^{60}Fe in galactic cosmic rays [15], deep-sea terrestrial deposits [16] and Apollo 12, 15 and 16 lunar samples [17] provides definitive evidence that at least one SN exploded in the vicinity of the solar system, as recently as the lower Pleistocene (~1.5-2 Myr ago), seeding it with newly-synthesized SN material.

Depending on the timing of parent body formation, the higher proportion of supernova grains in MMs than chondrites could reflect either a spatial or temporal heterogeneity. This conclusion thus suggests two possible formation scenarios: (1) if the parent bodies accreted at the same time during solar system formation, the heterogeneous distribution of supernova grains reflects their formation in different places in the solar nebula, sampling distinct presolar grain populations, or, (2) if there is a significant time gap between accretion, the difference in the relative abundance of supernova grains would reflect a temporal heterogeneity, with the accretion of chondrite parent bodies before the injection of newly formed SN material, followed by formation of the MM parent bodies. This second hypothesis implies that the MMs accreted the solar nebula average of presolar grains (initial presolar grain abundance) plus the presolar grain contribution from a SN. To test this second scenario, we searched for any significant difference in the abundances of O-anomalous and C-anomalous grains between primitive chondrites and MMs. However, the addition of 15–20% supernova grains to the MM parent bodies would correspond to only small variations, on the order of 10 and 20 ppm, respectively for C-anomalous and O-anomalous grain abundances, which would not be discernible within current 2σ errors.

Conclusions: Our study demonstrates that SN grains (including both ^{18}O-rich and extremely ^{13}C-rich grains) are at least about 2-3 times more abundant in MMs than in chondrites and, thus, confirms the heterogeneous distribution of supernova grains in the solar nebula. This implies that chondrites and MMs originated from distinct parent bodies and provides further evidence for the injection of newly formed material from a nearby SN explosion into the solar protoplanetary disk.

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