THE IMPRINT OF SUPERNOVA DUST IN THE SOLAR NEBULA.

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Introduction: Primitive Solar System materials contain small quantities of dust grains that formed in the winds of evolved stars and in the ejecta of stellar explosions. These grains are older than our Solar System and are known as presolar grains [1]. Presolar (stardust) minerals identified to date include silicon carbide (SiC), graphite, silicon nitride (Si$_3$N$_4$), oxides, and silicates. These grains are identified through large isotopic anomalies, the fingerprints of nucleosynthetic processes in the parent stars. Here, we will review the abundances of presolar supernova (SN) grains in primitive meteorites and discuss implications for the inventory of interstellar dust in the solar nebula.

Abundances of SN Grains: Primitive meteorites constitute the largest reservoir of primitive Solar System materials available for the study of presolar grains. The most abundant type of presolar (stardust) grains are silicates which are found with concentrations of up to ~100 ppm in primitive meteorites [2]. Silicon carbide has abundances of up to ~50 ppm (see compilation of abundance data in [3]), and graphite up to ~10 ppm [4]. Presolar oxides are about 20 times less abundant than presolar silicates, i.e., concentrations are up to ~10 ppm [2]. Silicon nitride grains are very rare, with concentrations of only ~20 ppb [5]. From this it follows that the presolar grain inventory is dominated by silicates, and to some extent by SiC. Presolar nanodiamonds are even more abundant than presolar silicates; however, it is unclear which fraction of them is real stardust and most of them might have formed by SN shockwave transformation of pre-formed organics in the interstellar medium (ISM) [6].

For a long time it was thought that the vast majority of presolar silicates, those from O isotope Group 1, formed in the winds of low-mass asymptotic giant branch (AGB) stars [7]. However, this view has changed due the recent finding of large $^{25}$Mg excesses along with only moderate $^{26}$Mg/$^{25}$Mg anomalies in a large number of O isotope Group 1 grains [8-10]. Stellar sources that can account for this Mg-isotopic signature are core-collapse SNe (CCSNe) and intermediate-mass AGB stars with super-solar metallicities [8]. Furthermore, $^{26}$Mg-poor and $^{25}$Mg-rich Group 1 silicates might originate from supergiants and/or SNe [10]. Traditionally, only O isotope 4 grains (~10%) and some of the rare Group 3 grains were considered to come from SNe; with consideration of Group 1 grains with specific Mg-isotopic signatures the fraction of potential SN grains increases to more than 30%.

Similarly, also the abundance of potential SN grains has increased among presolar SiC. Type X and C grains make up the classical SN grains; they account for about 1-2% of all SiC grains. More recently, also a significant fraction of Type AB grains have been considered to have a SN origin [11-12] which brings up the SN contribution to SiC to ~4%. If we combine presolar grain abundances with relative contributions of SNe it is found that the SN contribution is largely determined by the silicates. Hoppe et al. [13] estimated that the original stardust abundance in the solid matter entering the solar nebula was about a factor 100 higher than observed in the most primitive meteorites, i.e., in the lower percent range. With the inferred SN contribution of 30% it follows that the solar nebula must have contained about 1% of dust from SN explosions, much more than previously assumed.

Astronomical Observations and Models: Theoretical models predict CCSNe to be efficient dust producers, with dust masses of 0.1-1 M$_\odot$ [14]. High dust production efficiencies are confirmed by astronomical observations, e.g., for SN remnant Cassiopeia A [15]. Hydrodynamical simulations suggest that a significant fraction of newly formed dust survives the reverse shock in CCSNe; for silicates with typical sizes of presolar silicates this is about 10% [16]. Models of interstellar dust predict that most of the dust forms in interstellar clouds, while stardust makes up only a few % [17-18]. According to the dust model of [17] the dominant stellar silicate dust producers are CCSNe; even with consideration of dust destruction in SN reverse shocks their contribution to stardust in the ISM is still several 10%.

Conclusions: The inferred high abundance of dust in the solar nebula is qualitatively in line with predictions from interstellar dust models and astronomical observations. More isoalte studies of presolar grains could help to better constrain the contribution of SN dust to the solar nebula and to provide input for dust models. 

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