SUPERNOVA DUST INJECTION INTO OUR SOLAR SYSTEM: THEN AND NOW

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Introduction: Isotopic analyses of chondrules and sulfides in chondrites reveal that the early solar system contained live ^{60}Fe, at levels ^{60}Fe / ^{56}Fe ~ 3 x 10^{-7} [1]. The source of this short-lived radionuclide ($t_{1/2}$ = 2.6 Myr) is almost certainly one or more supernovae [1]. At question is whether there was a single supernova that injected material into a molecular cloud [2] or into a nearby protoplanetary disk [3,4], or whether multiple supernovae contaminated the Sun's molecular cloud long before it collapsed [5]. Simulations of the interaction of supernova ejecta with protoplanetary disks show that only ~ 1% of the gaseous ejecta intercepted by the disk are injected; if ^{60}Fe is to enter a nearby disk it must do so in the form of condensed dust. Further work shows these grains must exceed 0.1 μm in diameter to avoid being deflected around the disk or sputtered [4]. Whether injection of supernova material into a nearby disk can explain the meteoritic abundance of ^{60}Fe hinges sensitively on the efficiency η with which ^{60}Fe condenses into large grains.

It is difficult to constrain η, either theoretically or using astronomical observations. Estimates of the mass of dust in high-redshift galaxies imply that core-collapse supernova produce > 0.1 $M_{\odot}$ of dust each [6], but infrared fluxes from nearby supernovae generally cannot be used to argue directly for more than ~ 10^{-4} $M_{\odot}$ of dust [7]. In neither case are the *sizes* of supernova dust grains constrained observationally. Fortunately, the solar system acquired ^{60}Fe from a supernova at least one other time: ferromanganese crusts from the Pacific seafloor contain live ^{60}Fe, in layers 3 Myr old [8]. This has been corroborated by tentative detection of live ^{60}Fe in lunar drill cores [9]. The abundance of ^{60}Fe in these layers, combined with modeling, constrains η.

Results: The most likely source for the 3 Myr-old ^{60}Fe is a core-collapse supernova in the Scorpius-Centaurus OB association, at an approximate distance 100 pc [10]. Simulations show that gaseous supernova ejecta cannot penetrate the inner solar system for supernovae closer than 10 pc, due to the solar wind [11]. Supernova dust grains can reach the Earth, but only if they exceed roughly 0.1 μm in diameter [12]. Thus, ^{60}Fe must enter the Solar System 3 Myr ago in the same form required to enter a protoplanetary disk 4.56 Gyr ago. Using the (lower) lunar drill core ^{60}Fe abundance to calculate the fluence, assuming a distance of 100 pc, and a *maximum* ^{60}Fe mass per supernova of 2 x 10^{-4} $M_{\odot}$ [13], we estimate a lower limit on the efficiency with which ^{60}Fe condensed into large grains, $\eta > 0.04$. This high value implies that injection of ^{60}Fe into a protoplanetary disk may be consistent with meteoritic abundances.

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