Late Formation of Silicon Carbide in Type II Supernovae

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The origin of dust in the universe is a contentious topic. It remains unclear whether dust can be efficiently produced in the violent deaths of type II supernovae (SNII) [1,2]. Due to the rarity of SNII occurrences and observational difficulties arising from the presence of preexisting interstellar dust surrounding SNII remnants, long-term astronomical observations of dust formation are extremely limited [3]. Presolar X SiC grains extracted from primitive meteorites, on the other hand, are characterized by large ^{28}Si excesses and the initial presence of short-lived ^{44}Ti ($\tau_{1/2}$ = 60 *yr*), both of which clearly link X grains to an SNII origin [4]. Thus, we can use an alternative method, laboratory isotopic analysis of X grains, to infer the timing of dust production in SNII.

X grains incorporated materials from at least the inner Si/S zone that produces pure ^{28}Si and the outer C-rich He/C zone of an SNII [4]. Since the short-lived ($\tau_{1/2}$ = 330 *day*) ^{49}V, which decays to ^{49}Ti, is abundantly made in the inner Si/S zone, the ^{49}V-^{49}Ti systematics of X grains provides a potential chronometer for grain formation in SNII. We therefore analyzed the V-Ti isotopic compositions of 16 X grains extracted from Murchison using the NanoSIMS 50L instrument at Carnegie Institution [5]. Our isotopic data reveal a positive correlation between ^{49}Ti and ^{28}Si excesses, which is attributed to the radioactive decay of ^{49}V to ^{49}Ti in the inner highly ^{28}Si-rich Si/S zone. In addition, ^{50}Ti is only made in the outer He/C zone together with ^{49}Ti by a neutron-capture process. We thus used ^{50}Ti as a proxy to correct for the amount of ^{49}Ti incorporated into each X grain from the outer He/C zone. After the correction, a tighter correlation is observed between the ^{28}Si and corrected ^{49}Ti excesses, which implies that these supernova SiC grains formed >2 years after their parent stars exploded, in good agreement with recent dust condensation calculations [6]. The astronomical observation of continuous buildup of dust in supernovae over several years can, therefore, be interpreted as a growing addition of C-rich dust to the dust reservoir in supernovae.

[1] Dunne et al. (2003) *Nature*, **424**, 285–287. [2] Krause et al. (2004) *Nature*, **432**, 596–598. [3] Gall et al. (2014) *Nature*, **511**, 326–329. [4] Nittler et al. (1996) *ApJ*, **462**, L31–L34. [5] Liu et al. (2018) *Sci. Adv.*, **4**, eaao1054. [6] Sarangi et al. (2015) *A&A*, **575**, A95.