Short-lived Extinct Radioactivities in the Solar Nebula

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In the last few years I have been studying the processes of nucleosynthesis in core-collapse supernovas and in the jets that will arise in accretion-extrusion disks surrounding the neutron star remnants [1,2]. These processes can produce general features in the solar system abundance distribution of the nuclides, in isotopic anomalies in primitive solar system materials, and in the radioactivities that will be formed in the explosion and carried with the shock from the supernova that compresses a molecular cloud core into collapse, forming the solar nebula. The expanding supernova envelope is heated by internal radioactivities and cooled by adiabatic expansion, so that after a month or two those radioactivities will become part of the condensed minerals within the solids that accompany the supernova gases injected into the solar nebula. When these radioactivities decay, their presence may often be deduced from anomalies in the isotopic composition of the resulting minerals. They may also show up in presolar grains produced by the supernova.

I have not yet engaged in a systematic survey of experimental measurements to find evidence of these radioactivities and other anomalies, but I have recently started keeping track of some cases that have come to my attention, and I mention these here.

The most obvious example is the entire class of calcium-aluminum inclusions (CAIs) and amoeboid olivine aggregates (AOAs). These objects have an approximate 5 percent enrichment of ^{16}O relative to the two heavier isotopes. It is known that mixing in the supernova is driven by anisotropies in the convective interior. ^{16}O is predominantly made in the late stages of helium burning, so silicate condensates made in the regions close to and including the regions of helium exhaustion are likely to have this anomaly. Further isotopic anomalies can by produced by energetic jet irradiation of the expanding supernova envelope from within, producing products such as ^{7}Be and ^{10}Be (half lives 53.3 days and 1.51×10^{6} years). The former is a short-lived radioactivity decaying on the expansion time scale of the supernova envelope and the latter is subject to solar nebula chemistry because the transit time from supernova to the nebula is of order 10^{5} years, and both are associated with CAIs.

Many short-lived extinct radioactivities probably have evidence for their existence sitting in the literature waiting to be identified. For example, I was checking on the discovery of the extinct radioactivity ^{135}Cs (2.3×10^{6} years), and noted that there was also an anomaly at mass 137. Thus ^{137}Cs (30.07 years) is a short-lived extinct radioactivity serendipitously discovered this way, but not identified as such by those responsible for the measurements because they lacked an intellectual framework within which to make the identification [3].

A somewhat similar case is that of the ^{53}Mn and ^{54}Mn anomalies found in carbonaceous chondrites [4]. These have half lives of 3.74×10^{6} years and 312 days, but the authors rejected the short-lived decay identification due to lack of the necessary intellectual framework.

In carbonaceous and some other chondrites there are ^{63}Cu anomalies correlated with the ^{16}O excesses, obviously due to the decay of ^{63}Ni (100.1 years), but falsely attributed to early solar system irradiation of refractory grains [5].

Some types of presolar grains are condensed in core-collapse supernova envelopes, particularly SiC grains. Here have been found extinct ^{44}Ti (49 years) [6] and extinct ^{49}V (330 days) [7].

I thank Katharina Lodders for useful conversations. Supported by the NASA Origins program.

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