Galactic Chemical Evolution of the Carriers of Heavy Elements

BRADLEY S. MEYER[1]

[1]Department of Physics and Astronomy, Clemson University, Clemson, SC 29634, USA, mbradle@clemson.edu

Nucleosynthesis in the early Universe created only hydrogen, helium, and trace amounts of lithium. After galaxies formed, stars coalesced from interstellar matter, lived quiescently for millions or billions of years, and died, typically in dramatic fashion. In their death throes, the stars ejected atoms of chemical elements heavier than helium back into the interstellar medium, thereby enriching it in those elements in time for the next cycle of star formation, life, and death. This cycling of matter that builds up the abundance of heavy elements in the life of a Galaxy is known as Galactic Chemical Evolution (GCE).

Much effort in the decades since the late 1940s and1950s, when nucleosynthesis theory was founded, has gone into the quantitative study of how stars create the chemical elements and how, over 8 billion years, GCE in our Galaxy led to the Solar System abundance pattern. These efforts have mostly been directed towards understanding the bulk solar abundances. More recently, studies of isotopic anomalies in meteorites have started to give clues as to how the carriers of isotopes into the early Solar System retained memory of their site of production. These effects may be direct, such as the presolar grains that are direct condensates from stars [1] or more subtle effects in which the carriers were not completely homogenized in the formation of early Solar System solids. The isotopes of Ca and Ti show large anomalies in calcium-aluminum-rich inclusions and primitive minerals [2]. This suggests those samples formed from variable amounts of the carriers of debris from low-entropy explosive stellar environments such as dense thermonuclear supernovae or, alternatively, electron-capture supernovae. Anomalies in other heavy elements such as Sr, Zr, Mo, Ru, W, and Os in bulk meteoritic samples indicate variable enrichments in the carriers of s-, r-, and p-process isotopes (e.g., [3,4,5]).

Quantitative GCE models are presented to help elucidate the chemical evolution of the carriers of the isotopes of key heavy elements. These models are computed with open-source, freely-available codes [6]. Interested readers may also find useful information in the author's blog [7].

[1] Clayton & Nittler (2004) *Ann. Rev. Astron. Astrophys.* **42,** 39-78. [2] Zinner *et al.* (1986) *ApJL* **311,** L103-L107. [3] Riesberg *et al.* (2010) *EPSL* **227,** 334-344. [4] Fischer-Gödde *et al.* (2015) *GCA* **168,** 151-171. [5] Yokoyama *et al.* (2015) *EPSL* **416,** 46-55. [6] http://sourceforge.net/p/nucnet-projects/wiki/Home/ [7] http://sourceforge.net/u/mbradle/blog/