The Origin of Elements

There were two attacks on the problem of understanding the origin of chemical elements in the universe, both in the 1940s. George Gamow and his younger colleagues Ralph Alpher and Robert Herman explored the avenue provided by big bang cosmology. According to this model, during the period of around 1 - 200 seconds, the universe passed through a density - temperature phase when conditions were suitable for thermonuclear fusion. Gamow believed that this process would generate most atomic nuclei found in the universe.

A paper written by Alpher, Hans Bethe and Gamow in the Physical Review in 1948 described this approach and because of the names of the authors, the theory became known as the α-β-γ theory.

In the end, it turned out that the process worked only for light nuclei, up to essentially helium, with every small quantities of Li, Be and B. The gap between atomic mass range 5 - 8, caused by the lack of stable nuclei made the nucleosynthesis process impossible beyond this range.

In 1946, in a paper in the Monthly Notices of the Royal Astronomical Society, Fred Hoyle proposed the alternative route of stellar nucleosynthesis. As main sequence stellar models had demonstrated, stars like the Sun are making helium in a slow but steady way by synthesizing hydrogen nuclei. Why not pursue this process further in future evolutionary stages?

Again, the gap in the mass range 5-8 became an obstacle. Although Ed Salpeter had proposed 'jumping' across this gap to make carbon from three helium nuclei, a three-body collision being rare, would not work. In 1954, Hoyle came up with the ingenious solution that the reaction to carbon is a resonant reaction. His calculations suggested that this reaction should produce an excited state of carbon which would subsequently decay to normal state. The question was, did such an excited state of carbon exist?

The question was soon settled when Ward Whaling and Willy Fowler at Caltech found it by experiment! And so, not only was the crucial gap bridged, but a way was found to understand the evolution of stars beyond the main sequence. The next important landmark in stellar nucleosynthesis was the comprehensive work of Geoffrey and Margaret Burbidge, Willy Fowler and Fred Hoyle in 1957. Popularly known as the B³FH theory, it explained how most nuclei are formed in stars.

Did this supplant the primordial nucleosynthesis theory of Gamow, et al? Not quite! That theory was to make a comeback, as we shall see in the next Parsecstone.