Seeking the places where the elements are made

Supernovas may manufacture heavy chemical elements. Astronomers are now seeking gamma-ray evidence to tell whether they do or not

By Dietrick E. Thomsen

The universe contains 92 natural chemical elements, from hydrogen with one proton to uranium with 92. Each element comes in several isotopes, since different numbers of neutrons can associate with each number of protons.

One of the outstanding questions in astrophysics is whether all these assorted nuclei have been present from the beginning of the universe, or are being manufactured as the universe goes along. The physics of constructing nuclei requires a cataclysmic event to do the job. If the nuclear manufacture was not accomplished in some big bang that originated the universe, then it must take place in smaller cataclysms occurring from time to time in the history of the universe.

A good candidate for the position of element factory is an exploding star or supernova. A study of conditions in supernovas has led Drs. Donald Clayton of Rice University, Sterling A. Colgate of New Mexico Institute of Mining and Technology, Gerald J. Fishman of Rice University and Joseph Silk of Cambridge University to conclude that supernovas do in fact so serve (SN: 5/6/68, p. 330). In addition, they believe, this can be checked observationally, and there is a way in which the data could be used to determine whether the rate of nuclear synthesis has changed during the history of the universe.

Their research began with a computer model of the things that occur when a star explodes. This was used to simulate a supernova and look at abundances of elements in the debris from the explosion. The results were encouraging from the outset.

"We get a remarkable agreement with abundances in nature," says Dr. Clayton. The coincidence has convinced the scientists that supernovas are where elements are manufactured. That is, most of the elements.

"Exploding stars, which produce everything else," says Dr. Clayton, "produce no iron 56."

But rather than being a source of trouble, this could be a key to the rate of synthesis.

Iron 56 is an abundant element in the chemistry of the universe. But instead of producing it, the supernova model produces nickel 56 in the abundance proper to iron. Nickel 56 is a radioactive isotope that decays into iron 56. Dr. Clayton and his associates suggest that this is what happens in the universe: Supernovas produce nickel 56, which then changes itself to the isotope of iron.

While the change is going on, gamma rays are given off, and these gamma rays have characteristic frequencies, one of the strongest of which is at 847 kilo-electron-volts. Searching for these characteristic frequencies, they suggest, could prove the hypothesis.

Furthermore, if nuclear synthesis has been going on throughout the history of the universe, gamma rays from past activity should still be around. But these past records should be shifted toward lower energies and frequencies.

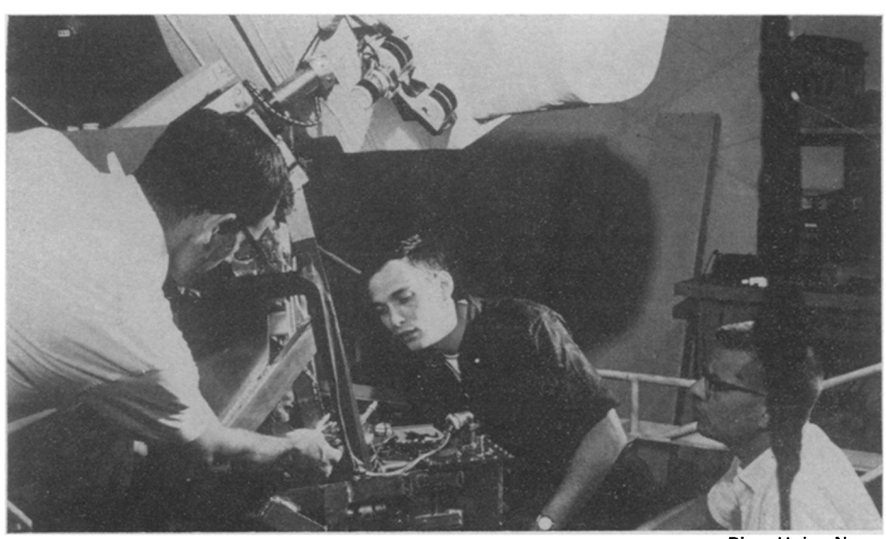
This would be the case because the expansion of the universe has carried away from earth the regions where past nuclear synthesis happened, and the motion lowers the frequency of radiation emitted from those regions.

According to Drs. Clayton and Silk, detection of the shifted frequencies would provide "a wholly new astronomical datum." The brightness of each shifted frequency would tell the rate at which nuclear synthesis was proceeding when that particular radiation was emitted, and so a history of nuclear synthesis for as far back into the history of the universe as can be seen could be built up.

"I believe that this radioactivity has even been observed," says Dr. Clayton. "Workers at the University of California at San Diego," he says, "find an anomaly in the gamma-ray spectrum, but they can't prove it is my (spectographic) line."

More conclusive evidence is being sought. Dr. Clayton's colleague in the Rice University Space Science Department, Dr. Robert C. Haymes, is in Argentina flying balloons to record gamma rays. One of the things he is looking for is the 847 kilo-electron-volt line.

Dr. Haymes's data may show that one or a few supernovas are producing nickel that turns into iron. A gamma-ray detector continuously watching from a satellite will be needed, Dr. Clayton thinks, to confirm the more general and historical parts of the hypothesis. □



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Dr. Haymes (right) and co-workers adjust balloon-borne gamma-ray detector.