Deuterium provides a cosmic numbers game

Seconds after its fiery birth, the universe forged the lightest elements in the cosmos: hydrogen and its rarer isotope, deuterium; two helium isotopes; and one lithium isotope. Of these, the amount of deuterium provides the most sensitive indicator of a key number in cosmology—the density of ordinary, or baryonic, matter, such as protons and neutrons. Baryon density profoundly influences the formation of galaxies.

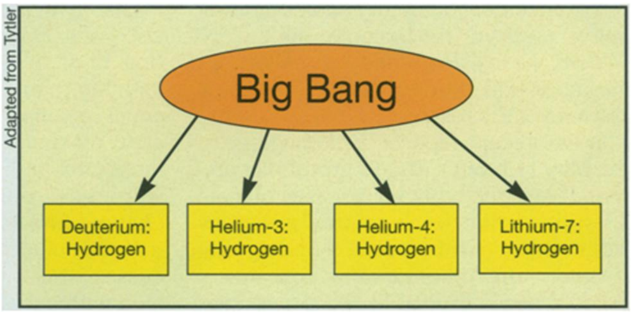
Stars burn deuterium, so its abundance has steadily declined. Thus, astronomers who seek the initial allotment of this isotope must look deep into space and far back in time.

In a new report, David Tytler, Xiao-Ming Fan, and Scott Burles of the University of California, San Diego measured deuterium abundance by observing light from the quasar QSO 1937-1009. The researchers detected the imprints of one or two gas clouds that the quasar light had passed through when the universe was only about 1 billion years old. They deduced an abundance of deuterium relative to hydrogen of 0.000023.

That value, reported in the May 16 NATURE, is about one-tenth of previously reported ratios estimated from other quasar observations. It indicates that the density of ordinary matter is about five times higher than previous estimates.

Even that density amounts to only 5 percent of the total density of matter needed to keep the universe poised between perpetual expansion and eventual collapse. To account for the formation of structure in the universe, theorists would still require that most matter in the cosmos consist of an exotic form of dark matter, hidden material that except for its gravity bears no resemblance to ordinary matter.

In a more recent, unpublished study, Tytler and Burles examined another quasar absorption system and deduced a similarly high value for the baryon density. The two findings, says Tytler, indicate that the universe contains too much ordinary matter to match the primordial abundances of two isotopes, helium-4 and lithium-7, calculated by other researchers. He suggests that the helium measurements contain systematic errors and that the stars in which lithium-7 have been measured are not accurate indicators of the primordial abundance. A less likely alternative, he says, is that the Big Bang model must be incomplete or wrong.



In addition to hydrogen, the Big Bang forged deuterium, helium-3, helium-4, and lithium-7.

Not everyone agrees with Tytler's measurements. Antoinette Songaila of the University of Hawaii in Honolulu, who has reported a lower baryon density (SN: 5/28/94, p. 349), says that Tytler may have incorrectly measured the amount of hydrogen in the gas clouds. Tytler, in turn, suggests that Songaila may have mistaken some hydrogen for deuterium in her team's study.

In their report, Songaila and her colleagues admitted that possibility. But in a new analysis described in the March 1 ASTROPHYSICAL JOURNAL LETTERS, two of her collaborators, Martin Rugers and Craig J. Hogan of the Universioty of Washington in Seattle, deem such an error extremely unlikely.

"The voting isn't in yet," notes cosmologist David N. Schramm of the University of Chicago. In a NATURE commentary, he and Chicago colleague Michael S. Turner suggest that recent measurements of helium-3 in the solar neighborhood may corroborate Tytler's low value for deuterium.

Because stars convert deuterium into helium-3, the abundance of helium-3 today may reflect the original deuterium abundance. Strengthening Tytler's finding of a low deuterium abundance, George Gloeckler of the University of Maryland at College Park and Johannes Geiss of the International Space Science Institute in Bern, Switzerland, report in the May 16 NATURE a low local abundance of helium-3.

"Ten years ago, we had no idea we could even do these [measurements]," says Songaila. "Now we're squabbling over the details. To me, that's a major advance." *— R. Cowen*

Blasting materials to magnetic extremes

Researchers in the laboratory don't often get a chance to glimpse the behavior of matter at the high pressures, temperatures, and magnetic fields attained in the interiors of stars and planets. As a step in that direction, an explosive series of experiments now under way at the Los Alamos (N.M.) National Laboratory is yielding data on the electric activity of various materials in extremely strong magnetic fields.

"Nobody has ever had magnetic fields this high," says Johndale C. Solem of the high-energy-density physics program at Los Alamos. "We're doing things that have never been tried before. Nothing in this experimental series is in any sense a small step from where we've been."

The current project involves researchers from Australia, Russia, Japan, and the United States, representing more than a dozen universities, laboratories, and research institutes. They apply compression technology originally developed at Los Alamos and in Russia for research on nuclear weapons.

To obtain magnetic fields in excess of 1,000 teslas, the scientists use explosive-driven generators designed and built in Russia. A household magnet typically produces a field of less than 0.01 tesla.

In the Russian device, a layer of high explosive surrounds a cylinder, a few centimeters across, made up of numerous fine, parallel wires embedded in epoxy. An initial electric pulse sends current through the wires, generating a magnetic field. When the explosive is detonated, the resulting shock wave penetrates the cylinder, shoving the wires together and turning them into an electricity-carrying cylinder, which greatly compresses the magnetic field. As the shock wave propagates inward, it compresses two additional wire-epoxy cylinders, further concentrating the accompanying magnetic field.

Consequently, samples of various materials packed into the center of this layered device experience very large magnetic fields, Solem says.

Using the Russian generator and a device designed at Los Alamos, researchers have investigated the electric behavior of superconductors, semiconductors, two-dimensional metals, and other materials.

Scientists know, for example, that strong magnetic fields cause conventional superconductors to lose their ability to conduct electric current without resistance. Theorists have predicted that when an applied magnetic field gets considerably stronger, the material can again become a superconductor. Tentative results using the explosive generator indicate that the electric resistance of the materials tested did decrease. "But the data need further analysis," Solem cautions.

In separate experiments in Russia at the once-secret weapons development site Arzamas 16, researchers are using a similar technique to compress argon gas into a purely metallic state (SN: 4/20/96, p. 250). Data obtained at a peak pressure of 7 million times atmospheric pressure indicate that this goal hasn't yet been reached. *— I. Peterson*