Astronomy

Keck Telescope looks at the Big Bang

The largest single-mirror telescope in the world has revealed evidence that ordinary matter — such as protons and neutrons — makes up an even smaller fraction of the total mass of the universe than previously thought. Much more of the stuff that exerts a gravitational tug but that can't be seen may consist of exotic material rather than dim planets and burned-out stars.

Using the 10-meter W.M. Keck Telescope atop Hawaii's Mauna Kea, four astronomers have for the first time measured the abundance outside our galaxy of deuterium, a rare form of hydrogen with an extra neutron. Researchers trying to measure the extragalactic stores of this hydrogen isotope have failed in the past because smaller telescopes couldn't gather enough light. The Keck Telescope managed the feat in a single night.

Scientists seek to determine the abundance of deuterium because the isotope is believed to have been created only once — during the birth of the universe. Moreover, the amount of deuterium forged during the Big Bang is inversely proportional to the density of ordinary matter.

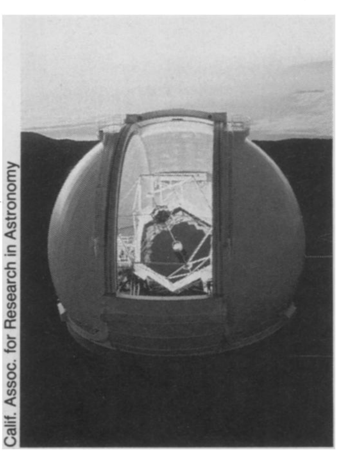
Later processes, such as the fusion of lighter nuclei into heavier ones inside stars, can deplete deuterium by converting it into helium. This explains why our galaxy's interstellar medium, created from the spilled contents of dead stars, has less deuterium than the early cosmos. Astronomers who measure deuterium in the Milky Way must estimate the rate of star birth in order to extrapolate back to the primordial amount. Such extrapolations can be fraught with uncertainty.

That's why astronomers have long sought to measure the amount of deuterium in a distant gas cloud far beyond our galaxy. A very distant cloud would look as it did when the universe was in its infancy, before waves of star formation had had a chance to whittle away at the deuterium.

Using light from a distant quasar, Antoinette Songaila of the University of Hawaii in Honolulu and her colleagues searched for the fingerprint of deuterium in a gas cloud observed when the cosmos was about one-quarter its current age. Deuterium in the cloud, which lies just in front of the quasar, absorbs specific wavelengths of the quasar light. The researchers measured the amount of the isotope using a spectrometer attached to the Keck Telescope. While the readings they obtained are consistent with the Big Bang model, the isotope's abundance — two deuterium atoms for every 10,000 hydrogen atoms — is higher than expected.

This may indicate that ordinary matter makes up only one-third as much of the density of the universe as thought, Songaila says. If so, much more of the cosmos, including the massive dark halos believed to surround galaxies, would have to be composed of exotic matter. She and her coworkers, Lennox L. Cowie of the University of Hawaii and Craig J. Hogan and Martin Rugers of the University of Washington in Seattle, report their work in the April 14 NATURE.

Songaila stresses that the finding must be confirmed by observations along the lines of sight of other quasars. The team notes that hydrogen in an errant cloud that might have floated past the quasar could have mimicked the deuterium spectrum. But they calculate that there's only about a 3 percent chance of being fooled in this way.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W.M. Keck Telescope.

Biochemistry

Tricks to make DNA beget DNA

For scientists interested in how life came about, the chicken-and-egg controversy boils down to a question of molecular replication. Modern DNA molecules — the stuff of genes — encode information about other molecules, including enzymes that enable DNA to replicate, mutate, and evolve as conditions change. But how did DNA — or perhaps RNA — replicate before there were enzymes?

Several research groups already have mimicked many of the necessary steps for molecular evolution (SN: 8/7/93, p.91) in their attempt to re-create conditions leading to the origin of life. But in their experiments they make new copies of these molecules artificially, with enzymes helping.

Now, two groups have tricked small pieces of DNA into making copies by themselves, without enzymatic assistance. Both teams report their results in the May 19 NATURE.

As a result of this work, "We are a step closer to understanding possible pathways to life," comments James Ferris of Rensselaer Polytechnic Institute in Troy, N.Y.

DNA and RNA are made up of long chains of nucleotides. In cells, each link in the chain readily pairs off with its complement: purines attach to pyrimidines and vice versa.

These connections give rise to DNA's typical structure — a double-stranded helix — which enzymes help split apart during cell division. The newly created single strands then act as templates. Each nucleotide seeks out a new partner, and these partners align to form a complementary strand, thereby creating two new double helices.

In test tubes, single purine nucleotides readily assemble on a pyrimidine template, but the reverse doesn't occur, so replication comes to a halt with mixed templates. Also, even when scientists could get molecules to replicate, those molecules could not make copies of their complements.

However, using DNA fragments with three nucleotides overcomes this obstacle, leading to the formation of complements on an ongoing basis, says Günther von Kiedrowski from Albert-Ludwigs University in Freiburg, Germany.

For their experiments, von Kiedrowski and a colleague put nucleotide threesomes into a solution that also contained a six-nucleotide strand. The matching threesomes then lined up to make a complementary six-nucleotide strand. This strand, too, began serving as a template for new strands.

Von Kiedrowski thinks that life's earliest molecules arose when small DNA fragments came together and served as templates for longer ones. Such fragments could have formed on clay substrates, adds Ferris.

Bigger nucleotide fragments also work, report Tianhu Li and Kyriacou C. Nicolaou, chemists at the Scripps Research Institute in La Jolla, Calif. They started with a palindromic sequence of 24 nucleotides: The order of purines and pyrimidines reads the same from either end of the strand.

In a slightly acidic solution, a double-stranded DNA fragment attracted two shorter, 12-nucleotide fragments, which assembled into a third 24-nucleotide strand upon the addition of a chemical reagent, the scientists report. Making the test-tube solution less acidic or adding more of the 12-nucleotide fragments causes that third strand to separate from the original double strand and to act as a template for a second strand complementary to itself, they add.

"We're not saying that we've created life," says Nicolaou, "but this is perhaps the first example that molecules can replicate themselves without the help of any enzymes."

Living systems expand exponentially: Two DNA strands beget four, which beget eight, then 16, then 32, and so on. Chemical systems increase incrementally, from one to two to three copies and so on. These new processes yield molecules at an in-between rate, say the scientists.