UCSD scientists answer fundamental question about makeup of the universe

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For centuries, scientists have attempted to determine the total amount of baryonic matter in the universe -- ordinary matter such as protons, neutrons and electrons which make up all of the elements.

Now researchers at the University of California, San Diego report that they have accurately measured the amount of deuterium, an extremely sensitive measure of baryonic density, in a nearly primordial gas cloud at the far reaches of the universe.

"The density of baryons in the universe is one of the few cosmological constants -- it's a really basic number like knowing the size or mass of the Earth," said David Tytler, a UCSD professor of physics who headed the study. "It's used extensively in cosmology and has a big effect on such things as how galaxies form."

The finding, reported in the May 15 issue of the journal Nature, however, also raises a new issue: apparently about 90 percent of the universe's ordinary matter is missing.

"Added together, all the matter in galaxies and gas clouds accounts for only about a tenth of what we estimate," said Tytler, a member of UCSD's Center for Astrophysics and Space Sciences. "The most likely scenario is that the rest is located in the halos of galaxies in objects similar to low mass stars, or in the hot gas between galaxies."

Together with UCSD colleagues Xiao-Ming Fan and Scott Buries, Tytler conducted a four-year search -- first with the Lick Observatory in San Jose, Calif., then the Keck telescope in Hawaii -- to find a quasar whose light passed through a suitably cool and primordial gas cloud on its way to Earth.

They then used the Keck telescope's high-resolution spectrograph in Hawaii to measure the ratio of deuterium to hydrogen (D/H) in the gas cloud by analyzing how it absorbed light from a distant quasar.

A small amount of deuterium, a rare form of hydrogen with an extra neutron, is believed to have been created in the universe at the time of the Big Bang. Because the amount of deuterium created is inversely related to the density of baryonic matter in the universe, scientists have long sought to accurately measure it as a means of determining the total mass of ordinary matter in the universe.

The problem they faced, however, is that deuterium has steadily been destroyed since the Big Bang, mainly by being converted into helium in the interior of stars. Thus, measurements of deuterium taken within our galaxy, for example, would have been inaccurate.

The primordial gas cloud studied by the UCSD scientists, however, formed about 1 billion years after the Big Bang and contained very little carbon and silicon, indicating that it was nearly pristine and most had not been cycled through stars where these elements are made.

As expected, the amount of deuterium detected -- 1 deuterium for every 50,000 hydrogen atoms -- indicated that the mass of baryons in the universe is far too small to stop the expansion of the universe.

Tytler's results conflict with those of another group of astronomers who carried out similar D/H measurements on a different gas cloud in 1994 and concluded that the baryonic mass of the universe was about five times less than what the UCSD team found. Their results were consistent with the amount of presently observed luminous matter comprising all the baryons in the universe. That would suggest that the massive halos of invisible material surrounding ordinary galaxies must be made up of non-baryonic material.

The new UCSD data give a robust measurement, which shows that the "probable detection" reported by the other group was incorrect and caused by hydrogen rather than deuterium.

In fact, the shear abundance of hydrogen in the universe has been the major stumbling block to achieving an accurate measurement of primordial deuterium.

"Hydrogen and deuterium absorb light at slightly different wavelengths, but most gas clouds are too complex and the weak signal from deuterium is swamped by the much larger hydrogen signal," Tytler said.

The ramifications of Tytler's results could be far-ranging. Scientists, for example, must now re-examine current estimates of the amount of helium and lithium in the universe.

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