Quasar Study Provides Insights into Composition of the Stars That Ended the 'Dark Ages'

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A team of astronomers has uncovered new evidence about the stars whose formation ended the cosmic "Dark Ages" a few hundred million years after the Big Bang.

In a presentation today at the annual winter meeting of the American Astronomical Society (AAS), California Institute of Technology graduate student George Becker is scheduled to discuss his team's investigation of several faraway quasars and the gas between the quasars and Earth. The paper on which his lecture is based will be published in the *Astrophysical Journal* in March.

One quasar in the study seems to reveal numerous patches of "neutral" gas, made up of atoms where the nucleus and electrons cling together, floating in space when the universe was only about 10 percent of its present age. This gas is thought to have existed in significant quantities only within a certain time-frame in the early universe. Prior to the Dark Ages, all material would have been too hot for atomic nuclei to combine with their electrons; after, the light from newly-formed stars would have reached the atoms and stripped off the electrons.

"There should have been a period when most of the atoms in the universe were neutral," Becker explains. "This would have continued until stars and galaxies began forming."

In other words, the universe went from a very hot, very dense state following the Big Bang where all atomic nuclei and electrons were too energetic to combine, to a less dense and cooler phase-albeit a dark one-where the nuclei and the electrons were cool enough to hold onto each other and form neutral atoms, to today's universe where the great majority of atoms are ionized by energetic particles of light.

Wallace Sargent, who coined the term Dark Ages in 1985 and who is Becker's supervising professor, adds that analyzing the quasars to learn about the early universe is akin to looking at a lighthouse in order to study the air between you and it. During the Dark Ages, neutral atoms filling the universe would have acted like a fog, blocking out the light from distant objects. To end the Dark Ages, enough stars and galaxies needed to form to burn this "cosmic fog" away.

"We may have detected the last wisps of the fog," explains Sargent, who is Bowen Professor of Astronomy at Caltech.

The uniqueness of the new study is the finding that the chemical elements of the cool, un-ionized gas seem to have come from relatively ordinary stars. The researchers think this is so because the elements they detect in the gas- oxygen, carbon, and silicon-are in proportions that suggest the materials came from Type II supernovae.

These particular explosions are caused when massive stars collapse and then rebound to form a gigantic explosion. The stars needed to create these explosions can be more than ten times the mass of the sun, yet they are common over almost the entire history of the universe.

However, astronomers believe that the very first stars in the universe would have been much more massive, up to hundreds of times the mass of the sun, and would have left behind a very different chemical signature.

"If the first stars in the universe were indeed very massive stars," Becker explains, "then their chemical signature was overwhelmed by smaller, more typical stars very soon after."

Becker and his colleagues believe they are seeing material from stars that was blown into space by the supernovae explosions and mixed with the pristine gas produced by the Big Bang. Specifically, they are looking at the spectra of the light from quasars as it is absorbed during its journey through the mixed-up gas.

The quasars in this particular study are from the Sloan Digital Sky Survey, an ongoing mapping project that seeks, in part, to determine the distances of 100,000 quasars. The researchers focused on nine of the most distant quasars known, with redshifts greater than 5, meaning that the light we see from these objects would have been emitted when the universe was at most 1.2 billion years old.

Of the nine, three are far enough away that they may have been at the edge of the dark period. Those three have redshifts greater than 6, meaning that the universe was less than 1 billion years old when they emitted the light we observe. By comparison, the present age of the universe is believed to be about 13.7 billion years.

Becker says that the study in part promises a new tool to investigate the nature of stars in the early universe. "Now that we've seen these systems, it's reasonable to ask if their composition reflects the output of those first very massive stars, or whether the mix of chemicals is what you would expect from more ordinary stars that ended in Type II supernovae.

"It turns out that the latter is the case," Becker says. "The chemical composition appears to be very ordinary."

Thus, the study provides a new window into possible transitions in the early universe, Sargent adds. "The relative abundance of these elements gives us in principle a way of finding out what the first stars were.

"This gives us insight into what kind of stars ended the Dark Ages."

Observations for this study were performed using the 10-meter (400-inch) Keck I Telescope on Mauna Kea, Hawaii. In addition to Becker and Sargent, the other authors are Michael Rauch of the Carnegie Observatories and Robert A. Simcoe of the MIT Center for Space Research.

Source: Caltech

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