Keck finding: Did stars predate galaxies?

In astronomy, one maxim has always seemed to hold true: Stars reside in galaxies.

But new observations with the world's largest optical telescope suggest that the first generation of stars formed more than a billion years before galaxies.

Antoinette Songaila and her colleagues base this tentative conclusion on a study of heavy elements — atoms heavier than helium — in gas clouds that fill the space between galaxies several billion light-years from Earth. The team, from the University of Hawaii in Honolulu, finds that the clouds aren't pristine reservoirs of hydrogen and helium, the main elements forged in the Big Bang.

Instead, the clouds, observed as they appeared when the cosmos was less than one-third its current age, are contaminated with highly ionized carbon, an element that could only have been created inside stars.

The clouds appear too wispy to be fledgling galaxies. Unlike denser hydrogen clouds, which rank as prime candidates for galaxies in the making, these clouds do not seem to cluster together. In addition, most of the clouds the group studied had roughly the same abundance of carbon, regardless of their inferred density. This argues that the carbon represents a pollutant from some outside source.

These lines of evidence suggest, but do not prove, that the carbon came from a generation of stars that predated the clouds and the formation of galaxies, Songaila says.

"Scientists have long suspected that there might have been an early generation of stars that formed prior to the period of galaxy formation," says Lennox L. Cowie, who collaborated with Songaila. "Our observations could be the first evidence for this population."

Songaila, Cowie, Tae-Sun Kim, and Esther M. Hu report their work in the April Astronomical Journal.

The team used the 10-meter Keck Telescope atop Hawaii's Mauna Kea to measure the abundance of carbon in vast, low-density clouds of hydrogen. Like foreground trees silhouetted by a distant searchlight, these clouds make their presence known by absorbing light from a bright background quasar, forming a thicket of absorption lines known as the Lyman-alpha forest.

The team found that in the clouds, up to one atom in a million was ionized carbon. This carbon abundance, about one-hundredth the amount in the sun's vicinity, matches a prediction of cosmologist Jeremiah P. Ostriker of Princeton University and his colleagues.

How could stars have predated galaxies? Ostriker explains that some 300,000 years after the Big Bang, the universe had cooled enough for ions and electrons to recombine into atoms, allowing matter and radiation to go their separate ways. This enabled gases to begin clumping together. Because there were many more small clumps than large ones, star-size objects — rather than galaxy-size bodies — could have been the first to form.

When the massive members of this early generation of stars exploded as supernovas, they would have littered the cosmos with carbon and other heavy elements. By heating their surroundings, these stars would have prevented other, similarly small collections of matter from condensing. However, larger clusters of gas and dust would have had enough gravity to overcome this thermal pressure and eventually condense into galaxies.

"These stars may have modified the intergalactic gas to help create the conditions necessary for galaxy formation," says Cowie.

Ostriker likens the early groupings of stars to the clusters of stars in the Milky Way's Orion nebula. Excited about the Keck findings, he notes that the observations "are not direct evidence that stars predate galaxies, because we don't know when the first galaxies formed, but they certainly make it more likely."

However, Kenneth M. Lanzetta of the State University of New York at Stony Brook cites a caveat. He and his colleagues report in the April 1 Astrophysical Journal that some Lyman-alpha clouds, rather than residing between galaxies, actually constitute vast halos around galaxies.

The clouds examined by Lanzetta's team lie nearer the Milky Way than those in the Keck study and are observed as they appeared when the cosmos was about half its current age. But if more distant clouds also form the outer parts of galaxies, the carbon detected by Songaila's team may simply reflect galactic activity rather than a generation of stars without galaxies, he says.

— R. Cowen

Does the Milky Way hide its black hole?

A new way of modeling black holes may quell doubts about whether one of the cosmic beasts lurks at the center of our galaxy.

Astronomers have long suspected that an unseen object with 1 million times the mass of the sun is pulling on stars and gas clouds at the Milky Way's heart (SN: 10/31/92, p.296). Gases swallowed by this black hole should give off telltale emissions. But scientists believe that Sagittarius A*, an intense radio source at the galactic center, emits far too little radiation — especially gamma rays and X rays — to be a black hole.

Now Ramesh Narayan, Insu Yi, and Rohan Mahadevan of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., have developed a model that explains how Sagittarius A* could gobble gas, yet remain faint.

The scientists argue that gas enters the black hole before it can emit much radiation. In their model, which they call an advection-dominated accretion solution, the gas gets hotter than in previous models but flows more quickly. The model also treats angular momentum more completely. They calculate that a black hole somewhat less than a million times the sun's mass sucks in more than 99.9 percent of the gas' energy, leaving less than 0.1 percent to be radiated.

"The key point is that while there's gas falling in and it gets heated up, the heat doesn't get radiated immediately," explains Narayan, whose group reports the model in the April 13 Nature. "Instead, it just stays inside the gas and then disappears into the black hole. So what you see is not all the heat that was generated but only the little fraction that happened to be radiated."

The group's predictions agree closely with observations of gamma rays, X rays, and radio and infrared emissions from Sagittarius A*. "With only a couple of free parameters to twiddle, they predict a spectrum which matches that of [Sagittarius A*] remarkably well," Gerry K. Skinner of the University of Birmingham in England writes in a commentary accompanying the report.

"People who have noticed that there's surprisingly little high-energy radiation have tended to think there can't be a black hole there, whereas people who simply studied the dynamics of the stars concluded there must be," Skinner says. "This paper seems to reconcile those two views by pointing out that in some circumstances, a large black hole can be swallowing quite a large amount of matter, and yet very little high-energy radiation can be produced."

"This is certainly a very reasonable hypothesis," comments astrophysicist Roger Blandford of the California Institute of Technology in Pasadena. "I don't think it can persuade a skeptic, but it addresses one of the more serious objections" to a Milky Way black hole.

Skinner notes that as Earth- and space-based telescopes uncover evidence of black holes in other galaxies, "there may be ample opportunity for testing the idea in a range of circumstances." Narayan's group expects to publish results for two black holes outside our galaxy soon.

— J. Kaiser