Astronomy

In search of the oldest galaxies

Researchers have peered deep into regions of space that appear empty on the most sensitive photographic plates—and have found those areas to be littered with celestial objects that seem to be galaxies just forming out of the remnants of the Big Bang.

Led by J. Anthony Tyson of AT&T Bell Laboratories in Murray Hill, N.J., the team of U.S. and Canadian scientists began the survey in 1983 to take advantage of the extremely sensitive imaging technology called the charge-coupled device (CCD), a computer-chip-like wafer that nearly allows astronomers to detect individual photons. The "deep CCD survey," published in the July ASTRONOMICAL JOURNAL, found 10 times as many objects as the researchers expected to see, according to Richard Wenk of Bell Laboratories.

Furthermore, the scientists believe these objects are young galaxies just forming. If so, their blue color would be the visible result of a Doppler shift of the ultraviolet light produced by early star formation in the galaxies. According to Wenk, such a redshift would place the galaxies about 12 billion light-years away, which is near most quasars and getting close to the theoretical beginning of the universe 15 billion years ago.

The objects are thought to be the first galaxies to form because the CCDs are theoretically able to see much farther back in the history of the universe than 12 billion years, and there seems to be nothing there in the optical wavelengths. "The implication is that there is nothing to see beyond [these galaxies] that is putting out photons," Wenk says.

Critics say the galaxies the Tyson team is seeing may just be relatively nearby dwarf galaxies, small galaxies that are difficult to see outside of the "local group" that surrounds our own Milky Way. Tyson will be able to prove them wrong only by getting spectra of many of the extremely dim objects and showing that they are in fact very redshifted. This large Doppler redshift could be caused only by light coming from the quickly expanding, young universe.

However, because the very faint light has to be split up to record a spectrum, it is much more difficult to record the spectrum of a dim object than to record the presence of the object itself. Tyson has measured the spectrum of some of the brighter objects and found them to have a fairly large redshift. The implication is that all the objects are the same distance away or farther.

Additional evidence that these objects are actually very distant galaxies lies in the distribution of light within the objects and the wavelength of light that is recorded, says Wenk. "The frequency [of light] is not what you would expect for a dwarf galaxy — the galaxies we are seeing seem to have an excess of blue, which should only happen when ultraviolet photons are shifted to blue," he says.

Even if the objects are galaxies, there are still not enough of them to account for all the "dark matter" — the missing mass that astronomers cannot see but think must still exist—in the universe, says Wenk. Proving the objects are galaxies would, however, give theoreticians a good idea of when galaxies began to form. Tyson's results would put the formation of the first galaxies at about 1 billion years after the Big Bang, and thereafter galaxies would continue to form until about 5 billion years later.

If he is truly seeing galaxies, Tyson can also show that the formation of stars didn't begin all at once, as some theoreticians have speculated. Such a "burst" model would result in a dramatic peak in the number of galaxies at a given age (and therefore redshift). Tyson does not see such a peak.

Wenk says Tyson and his colleagues are now looking at clouds of gas in the same area that may be protogalaxies forming even closer to the beginning of the universe.

Behavior

Bruce Bower reports from San Diego at the IEEE International Conference on Neural Networks

High society in the brain

Computer scientist Marvin Minsky of the Massachusetts Institute of Technology readily acknowledges that many researchers working on neural networks — computer models designed to simulate the behavior of small groups of neurons involved in functions such as seeing, smelling and even speaking — consider him "the devil." In 1969, Minsky and a colleague demonstrated that elementary neural networks popular at the time could not identify certain simple patterns. Shortly thereafter, work in this field slowed to a trickle.

Thanks to more sophisticated computer approaches, neural network research has revived in the last few years. And despite his reputation, Minsky says biological neural networks, or assemblies of brain cells responsible for various simple activities, are an integral part of his theory of mind.

"The mind uses all sorts of neural networks together, and each one is good at certain things," he maintains. In Minsky's view, millions of distinct networks work together, enabling people to think and behave. A special class of cell groups records what other networks do, activates memories and allows higher-level networks to call on the services of lower-order cell assemblies. This teeming "society" of networks is responsible for producing goal-directed behavior, Minsky argues.

But computer models of brain function still do not provide a clear picture of Minsky's "society of mind." Artificial neural networks can learn to recognize visual patterns or understand everyday speech, he says, "but sometimes you have a devil of a time figuring out how they did it. We still don't have a good way of characterizing the proper questions for neural networks."

Backing up 'back prop'

In the early 1970s, a neural network training procedure known as back propagation was developed by three independent sets of researchers. Since then, back propagation has become the predominant neural network approach to studying brain function.

Critics argue the system is biologically implausible and a poor model of how circuits of brain cells handle information. But one of the originators of back propagation, computer scientist Paul J. Werbos of the National Science Foundation in Washington, D.C., says there is a future for the system as a model of how humans learn.

Back propagation networks contain a layer of input units, a layer of output units and an intermediate or "hidden" layer of units. With repeated trials, the hidden layer takes on response properties that best accomplish the computational task being learned. During training, error signals are sent back through the network to adjust the strength of connections between all processing units in order to push the system toward a predetermined output. A recent experiment produced hidden-unit responses to visual input that closely matched electrical responses of monkey brain cells critically involved in vision (SN: 3/5/88, p.149).

Conventional wisdom, Werbos says, holds that information flows forward from cell to cell in the mammalian brain, but does not retrace its steps in the back propagation manner. "But I believe there is a biological basis to all this work in neural networks," he says. There are indications, for instance, of a backward flow of electrical processing among glia, poorly understood cells in the brain that serve as a kind of glue holding neurons in place. Glia may provide a biological basis for back propagation, says Werbos.

The challenge for computer modelers, he says, is to design back propagation learning rules that work faster than the relatively slow systems now in use, and to develop networks that learn about the environment without the external guidance of error signals.