ASTRONOMY

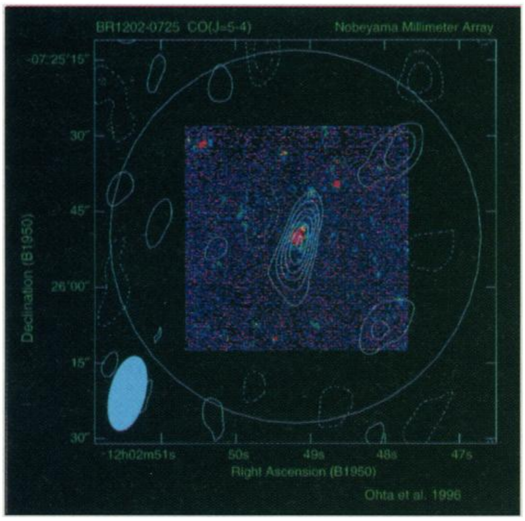
CO in the Early Universe Clouds Cosmologists' Views

Like the old sea chest in *Treasure Island*, which contained a treasure map at its very bottom, the universe often hides its most valuable secrets in its greatest depths—the farthest distances and earliest times that telescopic observers can probe. These observers are searching not for the glitter of gold, but for the gleam of early galaxies, whose time of formation yields a test of cosmological theories. They have found more than they bargained for: A spate of such detections has shown so much activity early in cosmic history, says Rogier Windhorst of Arizona State University, that "the standard cosmology is in trouble." And the most recent observation, which suggests that the universe contained a region of massive star formation when it was just a billion years old, has intensified the warning signs.

Reporting in this week's issue of *Nature*, two groups, one led by Kouji Ohta of Kyoto University in Japan and the other by Alain Omont of the Institut d'Astrophysique de Paris, announced that they have detected the glow of a giant cloud of carbon monoxide (CO) in the universe at that early age. These heavy elements are generated only in the nuclear furnaces of stars, which can then explode and spew the material back into space. So, Ohta says, "such a huge amount of molecular gas indicates the presence of a starburst," or stellar nursery, in which the most massive and shortest lived stars have already died and exploded. And that could conflict with the most widely accepted cosmological models, which predict that widespread galaxy formation didn't get under way until much later.

Astronomers had been wondering about the nature of the gas cloud studied by the two groups since it was identified earlier this year near a distant beacon called a quasar, whose light as seen from Earth is stretched to longer wavelengths by a "redshift" of 4.7. That large redshift indicates that the quasar and the cloud existed when the expanding universe was less than 10% of its present age. The possibility was intriguing because the cloud seemed to be emitting more ultraviolet light than could be explained by reradiation of the quasar's light (*Science*, 5 April, p. 37). Some astronomers thought a starburst might be the cause, but the evidence was indirect. So the groups went looking for more conclusive evidence: the infrared "fingerprints" of CO, which emits telltale spectral lines when jostled by collisions with other molecules.

The large redshift means that the light from the cloud arrives at Earth stretched out to radio wavelengths. To detect it, Omont and a multinational team of collaborators went to the big dishes of the Institut de Radio Astronomie Millimétrique on the Plateau de Bure in the French Alps. The team also searched for the broadband glow of warm dust—another signature of starbursting. The search paid off, says team member Philip Solomon of the State University of New York (SUNY), Stony Brook. The researchers detected "huge quantities" of both: roughly 100 million solar masses of dust and 10 billion solar masses in the total amount of gas as estimated from the CO luminosity.



KOUJI OHTA

Stellar nursery. Carbon monoxide emission (contour map) from a quasar, superimposed on optical image.

The Japanese group, using the Nobeyama Millimeter Array, detected similarly massive amounts of CO. The presence of so much CO suggests that just a billion or so years after the big bang, "you already have a second and probably a third generation of star formation going on," says Solomon. And the detections, says Patrick Thaddeus of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, could open the way to probing early galaxies even more closely using other molecular and atomic emissions. "It is quite lovely to see molecules at that great a distance," he says.

Cosmologists do not yet know whether the cloud is a rare oddball or a common event. But the recent discovery of early galaxies elsewhere suggests that star formation was taking place on a broad scale in the infant universe. Just 2 weeks ago in *Nature*, Esther Hu of the University of Hawaii and Richard McMahon of the University of Cambridge in the United Kingdom announced the detection of two forming galaxies that were nearly as distant as the CO-emitting object, but far from any quasar.

If such gas clouds do turn out to litter the early universe, says Marc Davis, a cosmologist at the University of California, Berkeley, the consequences would be "pretty dramatic" for cosmological theory. Many theorists favor a relatively dense cosmos—containing just enough matter to keep the universe poised between infinite expansion and recollapse. But if they are right, and the early universe already contained many collapsed gas clouds, the cosmic "lumps" of background gas from which they must have emerged should have been quickly amplified by gravity, resulting, Davis says, in "much more massive galaxies, much more massive clusters of galaxies—much more massive everything than we see today."

The difficulties with dense universes grow with a finding made by James Dunlop of the University of Edinburgh in the United Kingdom, Arizona State's Windhorst, and their colleagues. In June, they announced that they had used the 10-meter Keck telescope at Mauna Kea, Hawaii, to find a galaxy at a redshift of 1.55 containing stars at least 3.5 billion years old—substantially older than the age of the universe itself at that redshift, according to the standard picture. Although this "age problem" had been noticed for very old stars in local globular clusters, the distant measure gives an "independent answer," says Windhorst. Because of its own gravitational pull, a dense universe would have expanded faster in the past than today, reaching its present size at a younger age. One possible way out of the problem, Windhorst notes, is the so-called cosmological constant, a large-scale repulsion first postulated by Einstein.

Still, Davis cautions, the skirmish over the accuracy of the standard model is far from one-sided. At a Princeton cosmology conference in June, for example, Amos Yahil of SUNY Stony Brook announced that approximate distance estimates of hundreds of faint galaxies observed by the orbiting Hubble Space Telescope show a rapid falloff in their statistical frequency at about a redshift of 2, a result consistent with the standard picture. The analysis was conducted by Yahil together with his SUNY colleague Kenneth Lanzetta and Spanish researchers Alberto Fernández-Soto of the University of Cantabria and Ana Campos of the Astrophysical Institute of Andalusia. Says Yahil, "Something's got to give." Whether that means the standard view will eventually find smooth sailing or be riddled with broadsides is anyone's guess.

–**James Glanz**