A very old galaxy that may be very young

Back toward the beginning of time lies presumably the epoch when the basic structural elements of the universe began to form. Looking far out into the universe, and therefore far back in time, astronomers hope to see galaxies as they looked when they were just beginning to form. This week in Pasadena, Calif., at the meeting of the American Astronomical Society, a group reported the finding of a galaxy two-thirds of the way back to time zero that has the appearance of a galaxy that is just beginning to form.

Astronomers know of a few other galaxies just as far back or slightly farther back that look much more mature than this one. So if this one, known as 3C326.1, is truly a protogalaxy — a galaxy at its very beginning — it may change some astronomers' minds about how and when galaxies formed.

The object 3C326.1 is one of the 300 bright radio sources listed in the Third Cambridge Catalogue. For quite a few years Hyron Spinrad, an astronomy professor at the University of California at Berkeley, and a group of associates and students have been surveying the items in this catalog looking for optical counterparts, hoping to find examples of galaxies at an early stage of their development. This one appears to be the most primitive and is certainly quite different from others of the same age and distance. Associated in the discovery are Patrick McCarthy, Michael Strauss and Wil Van Breugel of Berkeley; S. George Djorgovski of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., and James Liebert of the University of Arizona in Tucson.

They think 3C326.1 is a protogalaxy because it contains a large amount of ionized hydrogen and comparatively few stars. As McCarthy observes, a mature galaxy exhibits a great deal of starlight and very little gas. The light from 3C326.1 is mostly the emission of ionized hydrogen called Lyman alpha. At rest in the laboratory, Lyman alpha appears in the ultraviolet at 1,216 angstroms. Here, it is redshifted to the edge of the visible violet (3,400 angstroms). On that basis the object has a redshift of 1.825, placing it two-thirds of the way back to the Big Bang. To put it another way, we are seeing it as it looked 12 billion years ago.

Lots of gas and few stars are what astronomers would expect a protogalaxy to have. The object fulfills another protogalaxy criterion in that it appears to be forming new stars at a very high rate, between 1,000 and 5,000 per year (about 1,000 times the rate for a mature galaxy such as our own). It is about 100 kiloparsecs, or 300,000 light-years, across and has a mass equal to about 100 billion suns. It is very luminous — 100 billion times the sun's luminosity.

If 3C326.1 is a protogalaxy, it poses theoretical questions of galaxy formation. As Djorgovski points out, astronomers have tended to believe that most of the galaxies formed in a fairly short period, about 100 million years or so, somewhere near the beginning of the universe. That 3C326.1 could be so primitive in comparison with other known galaxies at the same epoch would mean that the period during which galaxies could have formed is much longer than theorists had thought, perhaps even a few billion years long.

The current work began in the spring of 1986 with high-resolution maps of the radio source made with the Very Large Array of radiotelescopes near Socorro, N.M. This shows a double source, two close centers of radio emission. In June 1986 an optical image of the same part of the sky made with the 120-inch telescope at the Lick Observatory on Mt. Hamilton, Calif., using a special ultraviolet sensor, showed that the radio source lies within the area where the ionized hydrogen is concentrated. McCarthy says the optical work could not have been done two years ago; an ultraviolet sensor of the requisite sensitivity did not exist. Djorgovski compares the observation of this 24th-magnitude object to seeing a 100-watt light bulb 100 million kilometers away. It took a 4 1/2-hour exposure to build up the image with the 120-inch telescope; Spinrad estimates it would take 100 hours with the Space Telescope.

Although doubts have been expressed, 3C326.1 seems in most respects to look as a protogalaxy should. The radio source is the prime exception; theorists would not have expected it in a protogalaxy. But Spinrad says the observers are willing to let natural objects be what they are: "We are not disposed to believe everything we are told." — *D.E. Thomsen*

New heights in superconductivity

For years, but with very little success, researchers have been trying to find materials that become superconductors at higher temperatures. Until recently, the best they could do were certain metal alloys that abruptly lose their electrical resistance at temperatures below 24°K, barely above absolute zero and well below the boiling point of liquid nitrogen.

That situation has changed suddenly with the surprising discovery of a new class of materials that show onset of superconductivity at temperatures greater than 40°K. Raising the transition temperature means that less costly refrigeration techniques can be used to cool these materials enough to turn them into superconductors, thereby increasing the number of potential applications.

The new approach was suggested last year when researchers at the IBM research center in Zurich, Switzerland, found that lanthanum copper oxide, with barium randomly replacing some of the lanthanum atoms in the compound, becomes partially superconducting at 30°K. Now, researchers at the University of Houston and at AT&T Bell Laboratories in Murray Hill, N.J., in separate efforts, have tinkered with the material in various ways to push the superconducting transition temperature to an unprecedented 40°K.

Whereas most known superconductors are metal alloys such as mixtures of niobium and tin, the new materials are conducting oxides, which in some ways are more like ceramics than metals. "This is quite surprising to us," says Robert C. Dynes, physics and chemistry research director at Murray Hill. "For reasons that are not yet at all obvious to us, conducting oxides have properties that result in quite enhanced superconducting characteristics," he says. "You have to throw away preconceived notions that metals are superconductors, and you have to start again."

Houston's Paul C.W. Chu obtained increased transition temperatures by putting the oxide under high pressure to reduce the distance between atoms in the compound. More recently, he has achieved the same result by substituting strontium for barium. Researchers at Bell Labs have modified the conducting oxide's composition to produce a sharp transition to superconductivity that is less than 2° wide. Their material is completely superconducting at 36°K. Reports from Houston and Bell Labs are to be published in PHYSICAL REVIEW LETTERS, probably later this month.

Researchers have lots of room to search for ways of further increasing the superconducting transition temperature. "You can change the composition; you can change the elements; you can apply pressure," says Chu. "With all this flexibility, I don't see a limit in the near future."

Thin films of the new material have a "potentially excellent future" in detectors and electronic devices, says Stanford University's Theodore H. Geballe. "One can always find difficulties in working with this material," he says, "but compared with the problems that were overcome in working with [niobium-tin alloys], for example, these are no greater, and the stakes are higher." Japanese researchers already have a great deal of experience working with another superconducting oxide, barium bismuth lead oxide.

"I think it's very exciting and open-ended right now," says Geballe. "Who knows how far it will go?" — *I. Peterson*