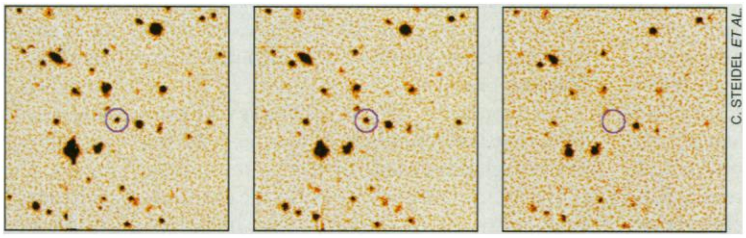
ASTRONOMY

Ancient Galaxy Walls Go Up; Will Theories Tumble Down?

IRVINE, CALIFORNIA—Few things are stranger than traveling far from home and finding yourself in familiar surroundings. Yet, that's just what astronomers are experiencing as they probe some of the farthest—and, hence, earliest—reaches of the universe. Speaking at a National Academy of Sciences colloquium here 2 weeks ago, Charles Steidel of the California Institute of Technology (Caltech) described new evidence suggesting that giant walls of galaxies, hundreds of millions of light-years long, may have crisscrossed the universe when it was just 15% of its present age. These structures, says Steidel, "are indistinguishable from what you see at any other distance."



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Shrinking in the violet. A distant galaxy, visible through red and green filters, vanishes in the ultraviolet.

So far, Steidel's group has found just one definite wall and two strong candidates. But if the finding is confirmed—and other observers have less direct evidence pointing to similar structures in the early universe—it will push the evidence for giant groupings of galaxies back in time by billions of years. It may even indicate that the universe's largest features were there from the beginning. "It's a fantastic result," says Neta Bahcall of Princeton University.

It is also troubling for some theorists. "The more you push this back in time, the harder pressed the theorists become," says Judith Cohen of Caltech, who has seen similar structures at more modest distances (*Science*, 18 October 1996, p. 343). If the early universe looks so similar to the modern one on large scales, then gravity hasn't resculpted it over time, which implies that it may have far less mass than theorists prefer. That's in line with evidence of a scarcity of mass in the nearby universe but at odds with one measurement of how fast the cosmic expansion rate is changing, which hints at a much higher density of matter (see next page).

Steidel and his colleagues—Kurt Adelberger and Melinda Kellogg at Caltech, Mark Dickinson at Johns Hopkins University, Mauro Giavalisco from the Carnegie Observatories, and Max Pettini from the Royal Greenwich Observatories—found these structures by exploiting a shortcut for picking out galaxies at huge distances. They take pictures of the sky through filters of different colors and compare them. Light coming from the most distant galaxies has to traverse so much interstellar space that the sparse hydrogen there is enough to blot out part of their ultraviolet spectrum. As a result, the galaxies are visible in red and green images but disappear in ultraviolet. The observers then aim the giant 10-meter Keck telescope in Hawaii at each object that meets this color criterion, to measure how much of its light has been redshifted—displaced toward the long-wavelength end of the spectrum—by the expansion of the universe. The redshift indicates the galaxy's distance and thus its age.

As of last month, the team had cataloged 168 galaxies at redshifts of between 2.8 and 3.5, which translates to perhaps 2 billion years after the big bang—early days in a universe that is now at least 12 billion years old. Earlier efforts had identified just a handful of galaxies and hundreds of strange, brilliant objects called quasars in this early epoch. But now, with a whole population of what Steidel calls "normal galaxies, garden-variety things" in hand, he and his colleagues have a sample big enough to study.

They quickly noticed that the numbers of these galaxies varied widely in different "fields" scattered around the sky. The reason became clear when the astronomers arranged the 70 galaxies in the densest field by redshift. They found that many of the galaxies were clustered at a redshift of 3.1, creating a density spike and pushing up the overall galaxy numbers in that field. Two other spikes seem to be emerging in the same field, and there are hints of them in other fields as well, says Steidel: "It looks as though they are actually quite common."

The spikes, says Margaret Geller of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Massachusetts, probably mark places where the Keck's line of sight is piercing great sheets of galaxies. Steidel hasn't measured their dimensions. But Geller suspects that they resemble her own Great Wall, a collection of galaxies within a few hundred million light-years of Earth that forms a sheet some 100 megaparsecs long—more than 300 million light-years—which she and her CfA colleague John Huchra mapped during the 1980s. Caltech's Cohen also has a sense of déjà vu, having traced similar structures at redshifts of about 1.0, billions of light-years away. Steidel's finding, she says, "extends in a quantum leap our earlier work."

The finding also matches clues from studies of quasars. As their light passes through clouds of gas on its way to Earth, it picks up shadows—dark spectral lines. This spectral bar code indicates that the clouds contain elements forged in stars, implying that galaxies are nearby, and it also reveals the clouds' distances. They, too, seem to fall into large clumps at redshifts as high as 3.0, says Jean Quashnock of the University of Chicago, one of the researchers doing the work.

All of this evidence for an early large-scale structure could support a scenario that Alex Szalay of Johns Hopkins has been exploring with Richard Bond of the Canadian Institute for Theoretical Astrophysics in Toronto. They argue that this cosmic clumpiness originated a few hundred thousand years after the big bang, long before any galaxies formed and while the universe was still a sea of hot, ionized gas. Theorists believe this hot soup of matter pulsed with oscillations, or "sound waves," that would have created density peaks. Then, as the universe cooled, "this pattern gets frozen in," Szalay says.

The sound waves would have been about the right size to gather primordial matter into clumps measuring 100 megaparsecs or so. And if the soup had the right ingredients, the clumps could have turned into the great walls of galaxies persisting all the way up to the present. "Every survey that is deep enough detects [structure] on 100-megaparsec scales," says Szalay, who detected traces of this pattern in the nearer universe during the late 1980s. "It starts to make perfect sense."

A modern-looking early universe is not what many other theorists expected, however. The matter-rich universe they have pictured should evolve rapidly over time, spurred by gravitational forces, so that its early architecture should look nothing like today's. "Any time the early universe starts looking more like today's, it favors a low [density]," says Princeton's Bahcall.

One thing is clear: Observers will have to explore still greater distances and earlier times to see whether the eerie familiarity of the early universe really does go back all the way to the beginning.

–Tim Appenzeller