ASTRONOMY

The Space Telescope Spies on Ancient Galaxy Menageries

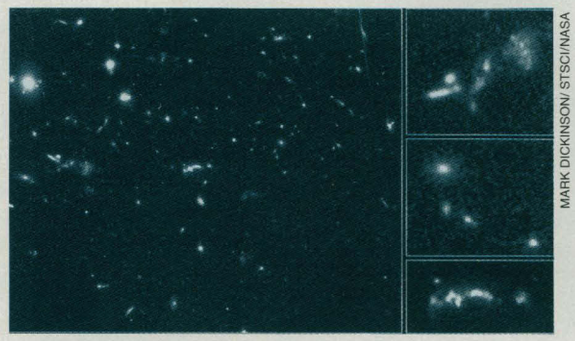
A year after its vision was sharpened with corrective lenses, the Hubble Space Telescope is astonishing astronomers with its insights. The latest: a view of the universe billions of light-years away—the equivalent of looking back in time toward the big bang. And like the fossil record from the primitive Earth, these snapshots of the early universe reveal some inhabitants that haven't changed much over the eons, as well as some strange denizens that have long since evolved into different forms or gone extinct.

"We see a tremendous menagerie of starry objects which have no counterpart in the present-day universe," says project scientist Mark Dickinson of the Space Telescope Science Institute in Baltimore, who announced the discoveries with other Space Telescope scientists last week. But the differences between the early galaxies and those of today may be less unsettling than the similarities. Among the Space Telescope findings was a galaxy that looked startlingly modern at a time when the universe was just a tenth of its present age—a cosmic anachronism that has some researchers reconsidering ideas about how the universe evolved.

Until now, astronomers studying these distant (and therefore early) celestial objects knew only the celebrities among them: quasars and radio galaxies, objects thousands of times brighter than galaxies are today. Run-of-the-mill objects such as the precursors of ordinary galaxies were at best faint smudges, with no indication of shape or redshift—a measure of distance. But with the repaired Hubble, astronomers have been able to measure redshifts and dimly discern the shapes of galaxies most of the way back to the big bang.

When the images are arranged in a timeline, says project scientist Alan Dressler of the Carnegie Institution in Pasadena, California, they offer "clear evidence that the universe is changing." Step back some 9 billion years—two thirds of the way back to the big bang—in an image made by Dickinson, and the universe is aswarm with what look like torn fragments of present-day galaxies. These objects, says Dressler, may be the precursors of the spiral galaxies seen today. Over time, the force of gravity might have merged them into the pinwheel forms of spiral galaxies like our own Milky Way.

The ragged appearance of these fragments probably reflects their high gas content, says Robert Brown of the National Radio Astronomy Observatory in Charlottesville, Virginia. The gas, which hadn't had a chance to coalesce into stars, made these early galaxies more delicate than their starrier modern counterparts. They could easily have been distorted by close encounters with neighboring galaxies, which would have been common in the crowded early universe.



MARK DICKINSON/ STSCI/NASA

Windows in time. Space Telescope images reveal young spiral galaxies 5 billion years ago *(left)* and what may be their precursors 9 billion years ago *(above)*.

Move closer to the present era, in Dressler's images showing a cluster of galaxies some 5 billion years old, and the spiral galaxies familiar today come into view, though Dressler notes that they are "more ragged looking" than modern counterparts. But whatever they lacked in symmetry, they made up in abundance; confirming earlier suspicions, the Hubble images show that the spiral shape was far more common among these youthful galaxies than in galaxies closer to us in space and time. One possibility, says Dressler, is that collisions between these early spirals sheared away their pinwheel arms, forming some of the shapeless elliptical galaxies that abound in the universe today.

If so, a few of today's ellipticals could have formed recently. But others, the Hubble images suggest, could be living fossils. Along with the ancestral spirals in Dickinson's image, for example, were ellipticals that look surprisingly like modern elliptical galaxies. Some give off the red light characteristic of old stars—a sign that they had formed even farther back in time. Elliptical galaxies must have been among the first to appear, which is surprising, because many astronomers had postulated that ellipticals would form more slowly than spirals. And they must have done so earlier than astronomers expected galaxies of any kind to form.

That possibility is underscored by the most distant images of all, which open a window on a time 12 billion years ago, nine tenths of the way back to the big bang, and show a fully formed elliptical galaxy. The first hints of that galaxy had come from ground-based observations, made in Chile by Duccio Macchetto of the Space Telescope Science Institute, that revealed a specific pattern of absorption in the light of a quasar 12 billion light-years away (*Science*, 24 December 1993, p. 1969).

The absorption spectrum suggested that something rich in hydrogen gas—presumably a galaxy—lay just in front of the quasar. When Macchetto aimed the Space Telescope at the same point in the sky, he saw the unmistakable image of an elliptical object. Astronomers assume that it takes at least a billion years for an elliptical galaxy to collapse from gas and dust. And yet this one was fully formed just 1 or 2 billion years after the big bang. "It's a big puzzle," says Macchetto.

The presence of a full-fledged elliptical so soon after the universe is supposed to have formed doesn't cast doubt on the reality of the big bang, says Princeton University cosmologist Jeremiah Ostriker, but it does raise questions about the nature of the beginning. One favored variant of big-bang theory assumes the event spawned a universe containing a density of matter high enough to eventually halt its expansion. But that model also predicts that matter in the primordial universe was distributed so evenly that galaxy formation was delayed, says Ostriker. As a result, Macchetto's finding may push cosmologists toward a picture of a less dense, ever-expanding "open" universe, in which galaxies could take shape earlier.

As Hubble's search for distant galaxies continues, they may be pushed even more decisively in that direction. Macchetto says his ground-based search has identified a few other possible galaxies at extreme distances, and he is looking forward to studying them through the Space Telescope. Some, however, particularly those that are extremely red, may remain out of reach. That's because the expansion of the universe, which shifts starlight toward longer wavelengths, can push the light of a distant red object right out of the visible range and into the infrared. But once the Hubble is fitted with a new infrared camera, due to be installed during the next servicing mission, astronomers should be able to see galaxies about as far back as there are galaxies to be seen.

–Faye Flam

ALAN DRESSLER / CARNEGIE INSTITUTION/NASA