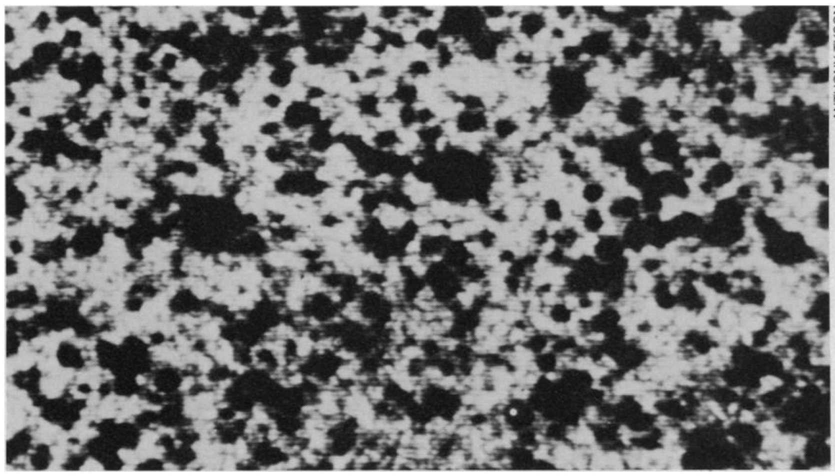
Giving the Galaxies a History

Aided by powerful telescopes, astronomers are looking back at galaxies as they appeared billions of years ago. What they see is a dynamic, evolving universe



ANTHONY TYSON

Dinosaurs of the cosmos. *Some of these faint galaxies date from the first half of the universe's history and look quite different from present-day galaxies.*

THESE DAYS, AN OUTSIDER listening to some astronomers discussing their subject might mistake them for biologists discussing an ecosystem. Their conversation is full of references to populations that are emerging, evolving, and even going extinct. But instead of living things, they are talking about galaxies.

The terminology reflects researchers' new awareness that whole groups of galaxies have evolved together like living species, causing the universe to undergo dramatic changes over its roughly 15-billion-year history. Take, for example, the discovery that as recently as 2 billion years ago, the skies were dominated by a population of small galaxies known as "blue dwarfs"—a now-vanished breed. Scientists think these dwarfs either merged to form the larger galaxies that predominate today, or somehow blinked out. Either way, the change was dramatic, says astronomer Lennox Cowie of the University of Hawaii, the leader of the team that first pinned down the age of a group of these strange little galaxies.

Together with more recent work that has hinted at still other vanished species of galaxies, the discovery highlights a marked departure from the previous view, held for years, of a more static universe. "People used to think there was a certain time in the early universe when it [galaxy formation] all happened," says Oxford University astronomer George Eftathiou. But instead, "galaxies have been forming throughout the history of the universe."

That view first got a jolt in the 1970s, when observers noticed a handful of nearby galaxies lighting up with bursts of star formation—hardly an appropriate behavior for supposedly mature galaxies. But at the time astronomers lacked the technology to look further back into cosmic history to see what other phases of evolution galaxies might have passed through. In the telescopes of the day, really distant, and therefore primitive, galaxies showed up as nothing more than faint, featureless spots.

The desire to study those dim objects was one of the major rationales for building the Hubble Space Telescope, although it was cruelly thwarted by the discovery of the telescope's flawed mirror. Meanwhile, however, astronomers had improved the sensitivity of the light detectors for their earth-bound telescopes. And in the past few years they have succeeded at gazing into the past and catching their first glimpses of galactic evolution.

What they've found so far is that the make-up of the universe has changed in surprising ways. First, researchers discovered that the number of galaxies in earlier epochs was much greater than today. In 1983, for example, Anthony Tyson, an astronomer at AT&T Bell Laboratories, and his colleagues started counting the very faintest galaxies visible—a rough approximation of the galaxies that lie at the greatest removes of space and time. They found that the early universe had two to 30 times more galaxies than it has today.

But the technology of the time, though improved, didn't allow Tyson's group to measure the galaxies' red shifts, the key to their ages and distances. As a result, the researchers couldn't tell for certain whether they were looking at things that were inherently bright but very distant, or just close and dim.

Enter Cowie and his colleagues. Late last year, they announced that they had captured red shifts for at least some of the brighter of these faint objects with the aid of new and improved infrared detectors (*Nature*, 12 December 1991). The result: The objects Tyson had spotted are both dim and relatively distant. They make up a population of little blue galaxies, just one one-hundredth the size of our own Milky Way and unlike anything seen today, that seem to have ruled the universe 2 billion years ago.

The puzzling implication was that within 2 billion years—not so long on the scale of cosmic history—the blue dwarfs vanished, giving way to the current population of full-sized galaxies. "They have to have gone somewhere," says Oxford astronomer Cedric Lacey. "The question is what they've turned into." One possibility is that existing galaxies grew from mergers of these dwarfs. We might be looking at the building blocks of the current universe, says Cowie.

Other astronomers, including S. George Djorgovski of the California Institute of Technology, are skeptical of the merger hypothesis, however. The problem, he says, is that most present galaxies are thin spirals, which would have been disrupted by mergers. "If a dwarf galaxy fell into the Milky Way," he says, "it would have puffed up the thickness by a factor of two."

Lacey suggests an alternative fate: These blue blazers may have dimmed into a population of low luminosity galaxies that still exist but are too faint to have been spotted yet. That may have happened, says Princeton astronomer James Gunn, when the small galaxies used up all their star-forming gas. Eftathiou also thinks that the blue dwarfs may have burned out—but with a final pop. "These little galaxies can be relatively fragile," he says. Supernovas—the explosions of dying stars—might have blown all the star-forming gas out of the small galaxies. "What's left of them could contribute to background radiation, but each individual one would be difficult to see."

But if blue dwarfs simply faded or blew away instead of merging into modern galaxies like the Milky Way, then some other galaxies, presumably co-existing with the blue dwarfs, must have been the precursors of the modern galaxies. So before he can draw any conclusion about the blue dwarfs' place in history, Cowie says, a critical question will have to be answered: Did larger galaxies exist in the same number then as now or were they deficient in the past?

Although Cowie didn't see any larger galaxies in his survey, he says that may be because his technique was biased against them. He took measurements using detectors sensitive to a range of wavelengths, including optical and infrared, but he selected his sample using just blue light, which favors the dwarf galaxies. That's because the prolific star-production in these galaxies tends to emit blue light. Next time he plans to collect his sample using infrared wavelengths. That technique, he says, should "reflect the bulk of star population."

Still, it may be hard to pick out other species amid so many blue dwarfs. "The sky is badly polluted with these small fry," laments Berkeley astronomer Hyron Spinrad. Finding early normal galaxies, he says, is like searching for a needle in a haystack.

And there's no guarantee that spotting new galaxy types will simplify the picture of galactic evolution. Astronomers may soon find themselves in the position of taxonomists faced with heaps of seemingly unrelated fossils. In work that's still unpublished, but which he described at the American Astronomical Society's annual meeting last month in Atlanta, AT&T's Tyson found that before the era of the blue dwarfs the universe was populated by still other kinds of galaxies. He got this evidence by observing objects hundreds of times fainter than Cowie's, although he's the first to admit that he knows much less about these dim specimens than Cowie knows about his sample. Tyson couldn't, for example, measure red shifts for his galaxies. He had to resort to other, less direct techniques to learn about these faint denizens of an earlier universe.

Tyson got an approximation of their sizes by essentially "de-blurring" them and reconstructing them as they would appear under ideal viewing conditions. He says he did that by looking at relatively nearby stars and measuring exactly how much the image was blurred by the atmosphere and the imperfection of the telescope. He then worked backwards to subtract that blurring and come up with a clear reconstruction of the diameter of his faint galaxies. What that technique revealed was a past universe full of galaxies that were larger and more spread out than today's. "At that point gravity hadn't had enough time to pull things in," he says. The galaxies have been collapsing ever since then, he says, like individual sparks shrinking down as the fireworks of the Big Bang exploded outward.

The faintness of Tyson's bloated galaxies showed that they had to be distant. But further evidence came from a phenomenon called gravitational lensing, in which light from distant objects is distorted by intervening matter. The more lensing, the farther away the objects must be. From the amount of distortion he saw in his faint galaxies, Tyson inferred that many of them actually date from the first half of the universe's history.

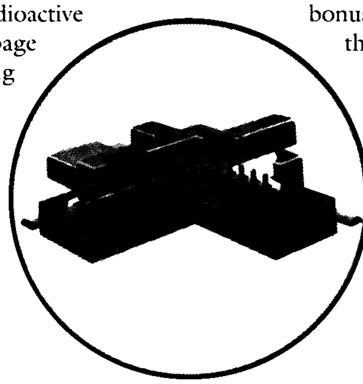
But red shift remains the distance and age indicator of choice. When the 10-meter Keck Telescope—equipped with the largest mirror ever—starts making these observations later this year from the top of Hawaii's Mauna Kea, it will allow astronomers to go another factor of 10 fainter than Cowie's sample and still measure red shift. "That's when things will start getting interesting," Tyson says. "Then you can really start to look at distant galaxy populations."

Tyson compares the current understanding of galactic evolution to the emerging understanding of stellar evolution in the 1940s. "Before that, people just thought there were stars—big ones, small ones, red ones and blue ones," he says. Then they realized that different groups, or populations, of stars arose at different times, the first springing up big and bright and later ones—emerging from a more chemically complex universe—coming out smaller and redder.

By the same token, Tyson says, the changing density, temperature, and pressure in the universe as a whole probably gave rise to different populations of galaxies over the course of cosmic history. After all, galaxies started forming just a billion years after the Big Bang, he says, and, "it's been a long time since then." ■ **FAYE FLAM**

LIGO Gets a Site

Last week, the citizens of Hanford, Washington, received good news from the federal government—for a change. The National Science Foundation (NSF) announced that the area, in which the government is now cleaning up high-level radioactive waste (see "Briefings," page 1073 of this issue), along with Livingston, Louisiana, were the two sites selected for a $210 million project aimed at directly observing—for the first time—the gravitational waves predicted by Einstein's theory of general relativity. Construction of the Laser Interferometer Gravitational Wave Observatory, better known as LIGO, may start at one of the two sites by the end of the year, predicts the project director, Caltech physicist Rochus Vogt. Construction at the other site is planned to begin a year later.



Catch a wave. *Artist's rendition of one LIGO detector—soon to begin construction at Hanford, Washington.*

The site selection process, which lasted almost a year and involved a Caltech analysis of all 19 proposals, an outside committee review led by former NSF director John Slaughter, and consideration by the NSF itself, eliminated 17 other sites before settling on Hanford and Livingston. Among the factors considered in site selection were flatness, seismic stability, access to major research universities, and distance from other proposed sites. The LIGO effort demands two widely separated sites since laser fluctuations, microearthquakes, and acoustic noise at one facility may affect its extremely sensitive measurements, producing a false gravitational wave signal. The Hanford site, which has the added bonus of already being owned by the Department of Energy, is separated by more than 3000 kilometers from the Livingston site, a privately owned forest about 30 miles east of Baton Rouge.

Last year, LIGO almost stalled in Congress when the House axed its construction money from the budget. But intensive lobbying in the Senate by the NSF, Caltech, and MIT, another sponsor of the project, revived LIGO and President Bush ultimately authorized $23.5 million for the project in 1992. In its 1993 budget request, the NSF asked for more than $48 million, but no battle is expected in the House, as long as NSF's overall budget is not sliced dramatically. The selection of Hanford and Livingston should give new momentum to international LIGO-type efforts, says Vogt. Ultimately, he says, at least one more facility in Europe will be needed to triangulate the source of any gravitational waves detected. France, Germany, and Italy are considering participating, Vogt says, and a decision on a third site may come within 6 months. ■ **JOHN TRAVIS**