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 In work that's still unpublished, but which he described at the American Astronomical Society's annual meeting last month in Atlanta, AT&T's Tyson found that before the era of the blue dwarfs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.

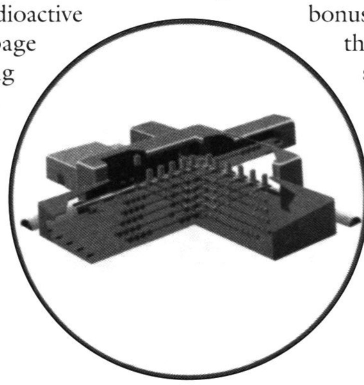
But red shift remains the distance and age indicator of choice. When the 10-meter Keck Telescope—equipped with the largest mirror ever—starts making these observations later this year from the top of Hawaii's Mauna Kea, it will allow astronomers to go another factor of 10 fainter than Cowie's sample 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