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To prove their case, Steidel and his collaborators needed to measure the actual distances to the dropout galaxies.

Last October, the astronomers got their chance. Atop an extinct volcano in Hawaii, they pointed the world's largest optical telescope—the W.M. Keck Telescope on Mauna Kea—at some of their candidates. The spectra revealed that 17 of these galaxies have redshifts between 3 and 3.4, indicating that the bodies reside about 13 billion light-years from Earth.

"There was a lot of relief and a lot of excitement," Steidel recalls. "This was really the leg we needed to stand on to push this technique further along."

In applying the multicolor search method, he adds, "we are trying to get a global picture. We're not interested in finding an unusual object in order to say that we've found the most distant galaxy known. Instead, we want to know what the typical galaxy population is like, how far galaxy formation has come along at a certain snapshot [in time.] And we're finding [these galaxies] in a systematic way, rather than by pure luck."

Last month, Steidel and his colleagues headed back to Hawaii, just days after two of his collaborators, Dickinson and Giavalisco, helped unveil the Hubble Deep Field image at a meeting of the American Astronomical Society in San Antonio. The team zeroed in on six galaxies, imaged in the Deep Field and another Hubble picture, that vanished in the ultraviolet. Using Keck to measure redshifts, the team found that all six galaxies are indeed distant, Steidel told SCIENCE NEWS.

Like the other 17 objects observed in October, these galaxies have a bluish tinge compared with older galaxies, indicating that they are still forming their first generation of stars. So far, says Steidel, use of this color criterion has proved a winning strategy: 90 percent of the galaxies that vanish in the ultraviolet reside at large distances.

Because his team has spied so many galaxies at this remote epoch, Steidel concludes that galaxy formation was already well under way 13 billion years ago. Evidence of even earlier galaxy formation also comes from the existence of the powerful light beacons called quasars, with redshifts as great as 5. The atypical galaxies that house quasars must have formed even before the more ordinary galaxies that Steidel's team has found.

But when did the average, run-of-the-mill galaxy assemble? That's the question astronomers are now poised to answer, says Alan Dressler of the Carnegie Observatories. Armed with the new findings on primeval galaxies, "we're ready to bust into the early universe and find out how galaxies formed," he notes.

Steidel and his colleagues have already taken the first step. In a cursory examination of the Hubble Deep Field, he and Dickinson independently applied the same ultraviolet dropout technique. This time, however, they sought galaxies from even greater distances and more remote reaches of cosmic time. Such objects, which would reside farther than 13.5 billion light-years from Earth, would have a redshift greater than 4.

The astronomers saw few galaxies that fill the bill.

"Basically, you should be able to see the same kind of [distant galaxies], were they to exist, at a redshift greater than 4," Steidel comments. "The fact is that we don't."

Dickinson cautions that the color criterion for finding distant galaxies is harder to apply at higher redshifts but admits that the preliminary findings suggest a startling possibility. If the galaxies aren't visible, perhaps they hadn't yet come into being.

"I think that means it's very likely that the galaxies we've been seeing had formed somewhere between redshift 4 and redshift 3.5," Steidel says.

Astronomers may finally have peered far enough back in time to come face to face with a blank slate—the point at which most galaxies had yet to assemble. □

Astronomy

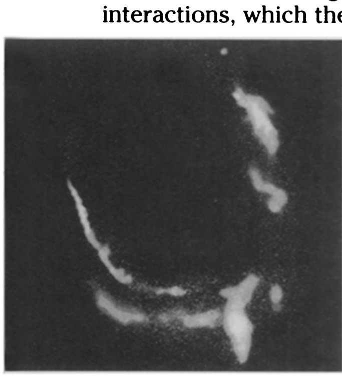
Galactic harassment

As astronomers have peered deeper into space and further back in time, they've noticed a curious trend. Clusters of galaxies that date to several billion years ago contain a high percentage of spiral galaxies with lots of blue, young stars. In contrast, clusters today mainly harbor the football-shaped galaxies known as ellipticals and contain redder, older stars.

To explain this phenomenon, some researchers have suggested that galaxies in clusters collide like bumper cars, triggering starbirth and ultimately transforming spiral galaxies into ellipticals. Others have suggested that the gravitational tug exerted when one galaxy slowly passes another may account for the structural changes.

New computer simulations suggest a third explanation. A rarer interaction, in which galaxies remain far apart and pass each other at high speed, may best explain the changes in clusters, assert Ben Moore of the University of Washington in Seattle and his colleagues in the Feb. 15 NATURE. Although such interactions, which the team calls "galactic harassment," may occur only once every billion years, simulations indicate that the cumulative effect can indeed trigger star formation and transform a small spiral galaxy into an authentic elliptical.

Robert D. Joseph of the University of Hawaii in Honolulu challenges the simulations, which treat the harassing galaxies as points instead of extended objects. He says that at present, the model is too simplistic to explain convincingly the observed changes in clusters.



University of Washington

Simulation of a spiral galaxy as it orbits through a dense galactic cluster. Other galaxies in the cluster have stripped material from the spiral, creating the two long tails.

Narrowing the gap between cosmic ages

Everyone knows you can't be older than your mother. Yet that's the paradox facing cosmologists as they try to determine the age of the universe. On the one hand, astronomers have estimated that globular clusters, the oldest groupings of stars in the universe, have a minimum age of 14 billion years. On the other hand, several determinations of the Hubble constant, which measures the cosmic rate of expansion, indicate that the universe is only 8 to 12 billion years old.

A new analysis of the ages of the 17 oldest clusters in our galaxy lessens the discrepancy. Brian Chaboyer of the Canadian Institute for Theoretical Astrophysics in Toronto and his colleagues fed recent observational data and predictions into more than 4 million computer models of stellar evolution. The team tested how uncertainties in the estimated composition of stars and the rate at which they burn hydrogen would affect the calculated age of clusters.

In the Feb. 16 SCIENCE, Chaboyer's team reports that globular clusters have a minimum age of 12 billion years. The new lower limit, at least 2 billion years younger than previous estimates, overlaps—just barely—with some Hubble Space Telescope measurements of the age of the universe. "We're at a point now that a few billion years [less] does start to make a difference," notes Chaboyer. He adds, however, that a discrepancy remains because "the odds are 20 to 1 that globular clusters are older than 12 billion years."