Twenty years after space shuttle astronauts deployed the Hubble Space Telescope, the orbiting observatory continues to reach new heights. Now, astronomers have used Hubble’s Wide Field Camera 3 (WFC3) to scale a fresh peak — by plumbing uncharted depths. The newly installed camera peered deeper into the universe than Hubble ever had before and revealed galaxies more than 13 billion light-years from Earth.

These galaxies also give us a look far back in time. The most distant galaxies in the new images existed just 600 million years after the Big Bang. These objects are much smaller than the Milky Way and other big galaxies that dominate the universe today. In effect, they give researchers a look at the baby galaxies that ultimately grew into the mature objects surrounding us.

The latest results come from two sets of Hubble observations. The first targeted a pencil-thin slice of sky in the northeastern corner of the southern constellation Fornax. Astronomer Garth Illingworth of the University of California, Santa Cruz, led the team that pointed WFC3 at the spot for 48 hours. The camera took images through three filters that isolate different wavelengths in the near-infrared part of the spectrum.

This region coincides with the original Hubble Ultra Deep Field (HUDF), taken in visible light by the Advanced Camera for Surveys (ACS) in late 2003 and early 2004. Many of the discoveries from the new HUDF09 come through comparing it with the original Ultra Deep Field.

A second team, led by Roger Windhorst of Arizona State University, observed a slightly larger area just north of the HUDF09. For this panoramic photo, the team combined WFC3 observations at three near-infrared wavelengths and three ultraviolet wavelengths with earlier ACS images through four visible-light filters. The resulting 10-color mosaic provides an unprecedented view of thousands of galaxies.

Both fields lie within a wider region targeted by the Great Observatories Origins Deep Survey (GOODS), an extragalactic laboratory for studying cosmic evolution. Astronomers have viewed this area with Hubble, the infrared-sensitive Spitzer Space Telescope, the Chandra X-ray Observatory, and large ground-based telescopes. The region appears nearly empty without a big telescope — the brightest star glows at 14th magnitude, some 1,000 times dimmer than the faintest naked-eye star.
Hunting the cosmic edge

Within weeks of Hubble’s observations, astronomers discovered a slew of distant galaxies in the fields. Finding these far-flung objects isn’t as easy as you might expect. For brighter and nearer galaxies, the task is pretty simple: Take a spectrum of the object through a large scope, and determine its redshift. The redshift measures how much the universe’s expansion has shifted the light to longer (redder) wavelengths. Not only are the new galaxies exceedingly faint, but they also lie so far away that their light has been shifted out of the visible spectrum. No telescope on Earth or in space can capture a spectrum of the farthest galaxies. Instead, astronomers determine their redshifts, and thus distances, from how bright they appear through different near-infrared filters. (See “How to find a galaxy’s distance” on page 61.) That’s where WFC3 comes in. Only it has the capability to see the faint light from these remote galaxies. Illingworth’s team, one of six exploring the new data, discovered 16 galaxies at redshifts of around 7 and five more at redshifts of 8. The farthest one has a redshift of about 8.5, which corresponds to an era just 600 million years after the Big Bang. (See “Age vs. redshift” on page 59 for the relationship between the two.) And this comes just 6 years after Hubble’s ACS set the previous record by uncovering galaxies at redshifts slightly greater than 6, some 900 million years after the Big Bang. Illingworth even claims evidence for three galaxies at redshifts of about 10, which pushes their ages back to within 500 million years of cosmic genesis. These galaxies show up through only the longest-wavelength WFC3 filter, however, so the team isn’t quite as confident in these detections.

Small and blue

The newfound galaxies don’t bear much resemblance to the majestic spirals and great ellipticals prominent in the nearby universe. They have diameters only about 5 percent that of the Milky Way and masses less than 1 percent that of our galaxy. Still, Hubble reveals them as more than mere dots. Several appear ragged and distorted, no doubt through encounters with their neighbors. These baby galaxies are the seeds that grow through mergers into large galaxies like ours. These distant objects also are much bluer than galaxies today. (Don’t get confused by this color reference; they still appear red to our telescopes. But when scientists factor out the redshift caused by universal expansion, they realize these galaxies emit light at the blue end of the spectrum.)
Two apparently interacting galaxies dominate the left side of this close-up from Hubble’s panoramic deep field (at the bottom center of the image on pages 56 and 57). These two have redshifts of 0.08, which means they lie just 1 billion light-years from Earth. The pretty face-on spiral galaxy at top left has a redshift of 0.68, which places it more than 6 billion light-years away. The faintest galaxies here are more than 10 billion light-years distant.

Astronomers interpret this blueness to mean that the galaxies contain significantly less dust than closer galaxies and few heavy elements. Heavy elements build up in stars over time. Supernova explosions then disperse those elements, which form dust, and the dust scatters and reddens starlight.

Eventually, sometime between 400 and 900 million years after the Big Bang, the young universe generated enough radiation to reionize the hydrogen. But nobody knows for sure what objects contributed to it. Most astronomers think young galaxies did much of the heavy lifting. However, galaxy counts of the youthful cosmos show that they may not have produced the radiation alone. Other scientists suspect mini-quasars fueled by supermassive black holes could have done the trick, or at least helped.

Astronomers hope to glean further clues from additional observations in the GOODS region. The HUDF09 data used to date covers only about one-third of the area researchers plan to observe. Hubble went back and viewed more in February and will wrap up the imaging later in 2010. But it likely will take the James Webb Space Telescope to make real headway. This 6.5-meter telescope, due to launch in 2014, is optimized to observe infrared radiation and take spectra of faint objects.

James Webb Space Telescope to make real headway. This 6.5-meter telescope, due to launch in 2014, is optimized to observe infrared radiation and take spectra of faint objects. This is about as far as we can go to do detailed science with the new HUDF09 image,” says Illingworth. “This shows just how much the Webb Telescope is needed to unearth the secrets of the first galaxies.”

To learn about the Hubble Space Telescope’s earlier deep fields, visit www.Astronomy.com/toc.