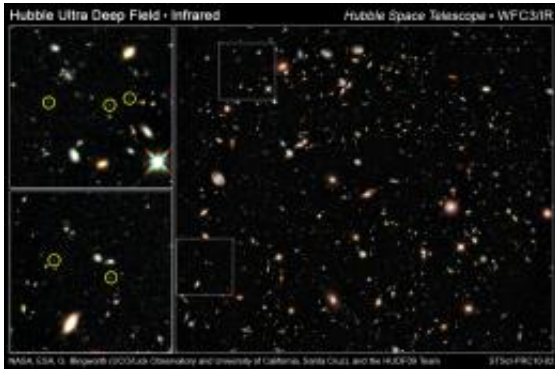


# Hubble Reaches the 'Undiscovered Country' of Primeval Galaxies

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This is the deepest image of the universe ever taken in near-infrared light by NASA's Hubble Space Telescope. The faintest and reddest objects (left inset) in the image are galaxies that correspond to "look-back times" of approximately 12.9 billion years to 13.1 billion years ago. No galaxies have been seen before at such early epochs. These galaxies are much smaller than the Milky Way galaxy and have populations of stars that are intrinsically very blue. This may indicate the galaxies are so primordial that they are deficient in heavier elements, and as a result, are quite free of the dust that reddens light through scattering. Credit: NASA, ESA, G. Illingworth (UCO/Lick Observatory and University of California, Santa Cruz), and the HUDF09 Team

(PhysOrg.com) -- NASA's Hubble Space Telescope has broken the distance limit for galaxies and uncovered a primordial population of compact and ultra-blue galaxies that have never been seen before.

The deeper Hubble looks into space, the farther back in time it looks, because light takes billions of years to cross the observable Universe. This makes Hubble a powerful "time machine" that allows astronomers to see galaxies as they were 13 billion years ago, just 600 million to 800 million years after the Big Bang.

"With the rejuvenated Hubble and its new instruments, we are now entering uncharted

territory that is ripe for new discoveries," says Garth Illingworth of the University of California, Santa Cruz, leader of the survey team that was awarded the time to take the new WFC3 infrared data on the Hubble Ultra Deep Field (imaged in visible light by the Advanced Camera for Surveys in 2004). "The deepest-ever near-infrared view of the Universe — the HUDF09 image — has now been combined with the deepest-ever optical image — the original HUDF (taken in 2004) — to push back the frontiers of the searches for the first galaxies and to explore their nature," Illingworth says.

Ross McLure of the Institute for Astronomy at Edinburgh University and his team detected 29 galaxy candidates, of which twelve lie beyond redshift 6.3 and four lie beyond redshift 7 (where the redshifts correspond to 890 million years and 780 million years after the Big Bang respectively). He notes that "the unique infrared sensitivity of [Wide Field Camera 3](#) means that these are the best images yet for providing detailed information about the first galaxies as they formed in the early Universe".



Early Galaxies in HUDF WFC3/IR Closeup. Credit:

NASA, ESA, G. Illingworth (UCO/Lick Observatory and University of California, Santa Cruz), and the HUDF09 Team

James Dunlop of the University of Edinburgh agrees. "These galaxies could have roots stretching into an earlier population of stars. There must be a substantial component of galaxies beyond Hubble's detection limit."

Three teams worked hard to find these new galaxies, announced in a burst of papers immediately after the data were released in September, and were soon joined by a fourth team, and later a fifth. A total of 15 papers have been submitted to date by astronomers worldwide. The existence of these newly found galaxies pushes back the time when galaxies began to form to before 500-600 million years after the Big Bang. This is good news for astronomers building the much more powerful James Webb Space Telescope (JWST; planned for launch in 2014), which will allow astronomers to study the detailed nature of primordial galaxies and discover many more even farther away. There should be plenty for JWST to hunt for.

The deep observations also demonstrate the progressive buildup of galaxies and provide further support for the hierarchical model of galaxy assembly where small objects accrete mass, or merge, to form bigger objects over a smooth and steady, but still dramatic, process of collision and agglomeration, as these small building blocks fuse into the larger galaxies known today.

"These ancient galaxies are only one twentieth of the Milky Way's diameter," reports HUDF09 team member Pascal Oesch of the Swiss Federal Institute of Technology in Zurich. "Yet they must be the seeds from which the great galaxies of today were formed," adds HUDF09 team member Marcella Carollo of the Swiss Federal Institute of Technology.

These newly found objects are crucial to understanding the evolutionary link between the birth of the first stars, the formation of the first

galaxies and the sequence of evolutionary events that resulted in the assembly of our Milky Way and the other "mature" elliptical and majestic spiral galaxies in today's Universe.

The HUDF09 team also combined the new Hubble data with observations from NASA's Spitzer Space Telescope to estimate the ages and masses of these primordial galaxies. "The masses are just 1 percent of those of the Milky Way," explains team member Ivo Labbe of the Carnegie Institute of Washington, lead author of two papers on the data from the combined NASA Great Observatories. He further noted that "to our surprise, the results show that these galaxies at 700 million years after the Big Bang must have started forming stars hundreds of millions of years earlier, pushing back the time of the earliest star formation in the Universe."

The results are gleaned from the HUDF09 observations, which are deep enough at near-infrared wavelengths to reveal galaxies at redshifts from 7 to beyond redshift 8.[1] The clear detection of galaxies between redshifts 7 and 8.5 corresponds to lookback times of approximately 12.9 billion years to 13.1 billion years.

"This is about as far as we can go to do detailed science with the new HUDF09 image. It shows just how much the James Webb Space Telescope is needed to unearth the secrets of the first galaxies," says Illingworth. The challenge is that spectroscopy is needed to provide definitive redshift values, but the objects are too faint for spectroscopic observations (until JWST is launched), and the redshifts have to be inferred from the apparent colours of the galaxies.

The teams are finding that the number of galaxies per unit of volume of space drops off smoothly with increasing distance, and the HUDF09 team has also found that the galaxies become surprisingly blue intrinsically. The ultra-blue galaxies are extreme examples of objects that appear so blue because they may be deficient in the heavier elements, and as a result, are quite free of the dust that reddens light through scattering.

A longstanding problem with these findings is that it still appears that these early galaxies did not emit

enough radiation to "reionise" the [early Universe](#) by stripping electrons from the neutral hydrogen that cooled after the Big Bang. This "reionisation" event occurred between about 400 million and 900 million years after the Big Bang, but astronomers still don't know which light sources caused it to happen. These newly discovered galaxies date from this important epoch in the evolution of the Universe.

Provided by ESA/Hubble Information Centre

Perhaps the density of very faint galaxies below the current detection limit is so high that there may be enough of them to support reionisation. Or there was an earlier wave of galaxy formation that decayed and then was "rebooted" by a second wave of galaxy formation. Or, possibly the early galaxies were extraordinarily efficient at reionising the Universe.

Due to these uncertainties it is not clear which type of object or evolutionary process did the "heavy lifting" by ionising the young Universe. The calculations are inconclusive, and so galaxies may do more than currently expected, or astronomers may need to invoke other phenomena such as mini-quasars (active supermassive black holes in the cores of galaxies) — current estimates suggest that quasars are even less likely than galaxies to be the cause of reionisation. This is an enigma that still challenges astronomers and the very best telescopes.

"We know the gas between galaxies in the Universe was ionised early in history, but the total light from these new galaxies may not be sufficient to achieve this." said Andrew Bunker of the University of Oxford, a researcher on one of the European teams.

Hubble's WFC3 infrared camera was able to make deep exposures to uncover new [galaxies](#) at roughly 40 times greater efficiency than its earlier infrared camera that was installed in 1997. The WFC3 brought new infrared technology to Hubble and accomplished in four days of observing what would have previously taken almost half a year for Hubble to complete.

**More information:** [1] The redshift value is a measure of the stretching of the wavelength or "reddening" of starlight due to the expansion of

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