Subaru telescope discovers a Rosetta Stone cluster of galaxies

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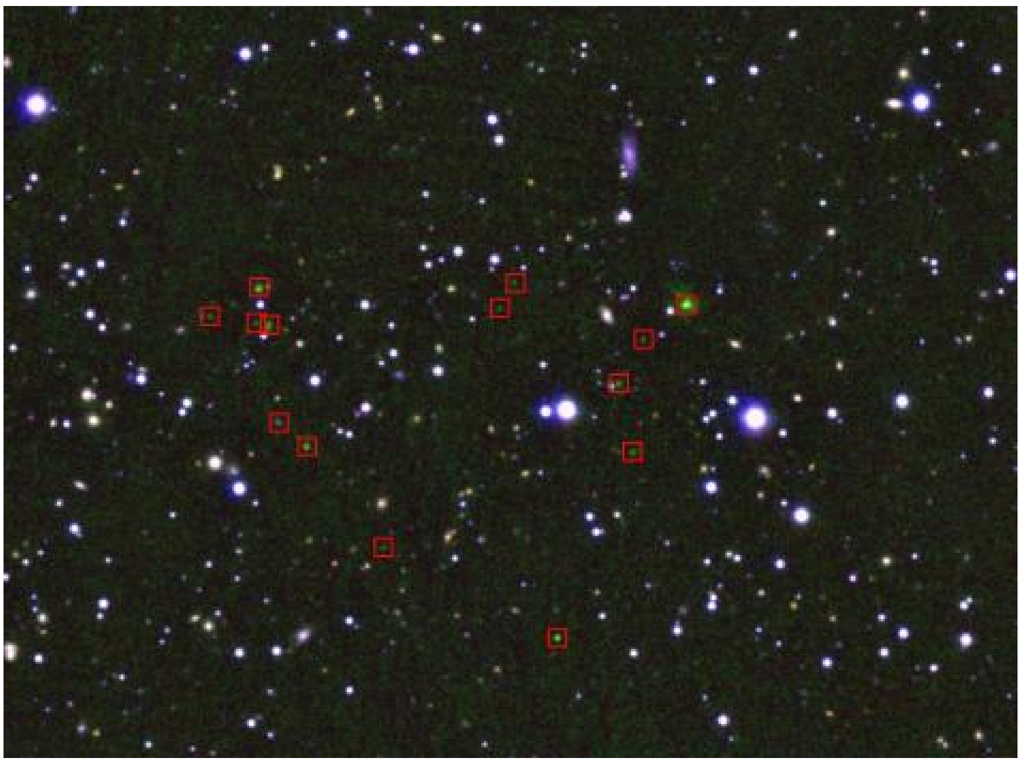

Figure 1: The 4C 23.56 protocluster area. The red squares show objects (color-coded in green) that emit H-alpha emission lines. The field of view is 3.0 arcminutes by 3.7 arcminutes. Parameters of this observation: Telescope: Subaru Telescope (effective aperture 8.2 m) Focus: Cassegrain Instrument: MOIRCS (Multi-Object Infrared Camera and Spectrograph) Filters: J band (1.26 micron), narrow band NB2288 (2.29 micron), Ks band (2.15 micron) Dates in UT: June �, 2007; August 23, 2008; September 19, 2008, and October 15, 2010 Exposure time: 45 minutes in J band, 46 minutes in Ks band, 2.3 hours in NB2288 band. Orientation of the picture: north is up, and east is left. Coordinates: Right Ascension (J2000.0) = 21 h 7.3 m, Declination (J2000.0) = +23 d 29.8 m (toward the constellation Vulpecula)

An international team of researchers led by Ichi Tanaka from the National Astronomical Observatory of Japan (NAOJ) has discovered an aggregate of galaxies undergoing a burst of star formation that may hold the key to understanding how galaxies formed in the early universe.

The aggregate is located toward the Constellation Vulpecula and is 11 billion light years away (redshift z = 2.5), 2.7 billion years after the birth of the universe, when it was still in its infancy. These baby-booming galaxies may be a proto-cluster, an ancestor of present-day clusters of galaxies; they still seem to be growing into full-size galaxies. The discovery is the product of observations in 2007 with the Multi-Object Infrared Camera and Spectrograph (MOIRCS) on the Subaru Telescope and later observations with the Spitzer Telescope. By analyzing near-infrared emission data from the Subaru Telescope with mid-infrared emission data from the Spitzer Telescope, the current research team was able to identify the bright objects in the infrared as members of a primordial cluster. This accomplishment shows how the feedback between archived data, technology, and collaboration can produce continuing breakthroughs in our knowledge of the universe.

The Quest to Understand How the Earliest Galaxies Formed

Astronomers interested in understanding how galaxies evolved after the Big Bang, 13.7 billion years ago, search for that place in time when the transition from chaos to structure occurred—a celestial "Rosetta Stone" era that can clarify how early galaxies developed. They speculate that the transition to galactic structures probably occurred between ten and eleven billion years ago. Images of galaxies during this period can provide a basis for understanding the formation of galaxies. However, observation of such distant objects is difficult.

Measurements of Star Formation Rates as Clues for Finding Ancient Galaxies

Although current telescopes may capture faint images of ancient galaxies, scientists need more evidence to confirm and identify the nature of the objects in these images. The star formation rate (SFR) is one of the fundamental criteria that astronomers seek to establish in their search for ancient galaxies, because the SFR was likely to be quite high during galaxy formation.

Spectroscopic analysis of the signatures of an object's light can provide an estimate of SFR. H-alpha emission lines are one of the most popular signature lines that astronomers use to approximate SFR; they measure ionized hydrogen in the visible (optical) part of the spectrum.

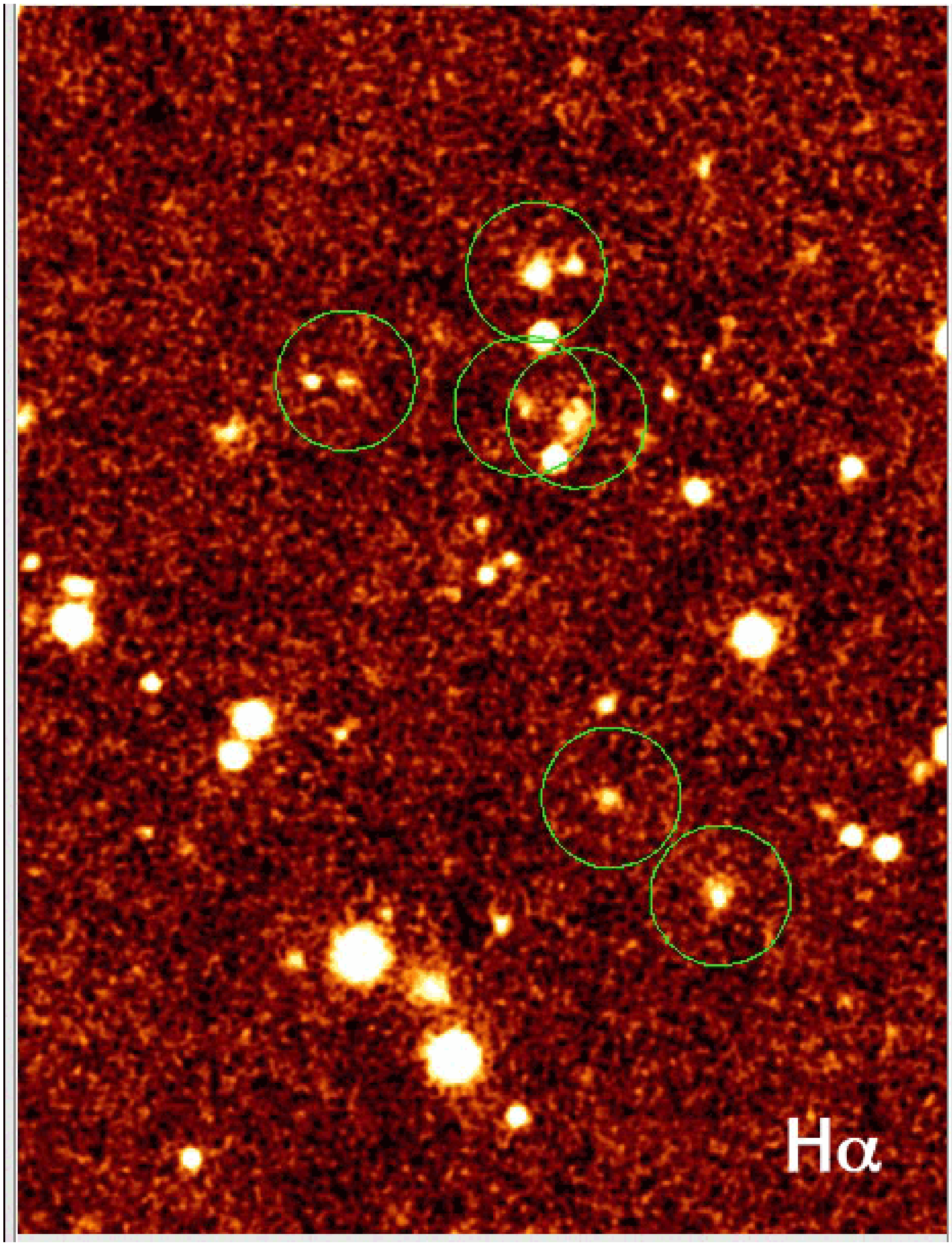

Figure 2: Close-up of a group of H-alpha-emitting galaxies located at the top left of Figure 1. The animation shows H-alpha emitting galaxies, alternating between the Ks (continuum) and H-alpha emissions. The circled objects are brighter in the line emissions.

However, atmospheric emissions begin to restrict measurements with H-alpha lines to a redshift of 2.7 (z = 2.7), a distance of about 11.2 billion light years away. The further the target galaxy is, the longer the wavelength of the spectral lines becomes; this is called the "redshift effect." A ground-based telescope cannot overcome this z = 2.7 boundary.

The Path to Discovery

Nevertheless, the current team was able to identify a primordial galaxy about 11 billion light years away. They overcame limitations in measuring features of far-distant objects by analyzing emission data from observations of the same area with two different telescopes at two different times.

In 2007, Subaru astronomer Ichi Tanaka used the Subaru Telescope to direct observations toward the area 4C 23.56, one of the more promising areas for proto-cluster candidates. The Subaru Telescope was mounted with MOIRCS and used a narrow band (NB) filter for detecting H-alpha lines at specific distances. The observations yielded data about the area that would become one piece of the solution to identifying the objects in the observations.

The tipping point for completing the discovery of the primordial galaxy came in the summer of 2010, when Tanaka was a resident at the European Southern Observatory (ESO) Some of Tanaka's colleagues were studying distant galaxies and analyzing archived data from the Spitzer Space Telescope when they noticed the presence of objects with faint mid-infrared emissions around 4C 23.56. Subsequent discussions with the European astronomers highlighted the meaning and significance of the connection between the near-infrared H-alpha emission lines obtained from the ground-based Subaru Telescope with the mid-infrared emissions from the Spitzer Space Telescope.

Analysis of the two data sets from the ground-based Subaru Telescope and the Spitzer Space Telescope produced a powerful set of findings.

The Subaru observations with MOIRCS and a narrow band filter yielded a significant array of near-infrared emission-line objects around 4C 23.56. Although Subaru's H-alpha data alone was not sufficient to establish a high star formation rate, its link with Spitzer's mid-infrared data was. In addition, comparison of the star-formation rates in this area with those in another or in the general field show a clear difference in their star-forming activities. The area around 4C 23.56 at a redshift of z = 2.48 indicates that the team discovered a cluster of galaxies during an epoch of major star formation.

The discovery even surprised the researchers. Tanaka enthusiastically reflected about the breakthrough: "These primordial galaxies show a very high star formation rate, corresponding to the creation of about several hundreds of Suns per year. Such high star formation rates do not occur in any nearby galaxies, including the Milky Way. In addition, the number of mid-infrared sources apparently exceeds the amount that can be attributed to the objects visible in H-alpha emission. This indicates that there could be more dust-enshrouded galaxies with active star formation, invisible as H-alpha emissions but detectable in the mid-infrared."

Although clusters of galaxies in the universe form large and complicated networks, there are only a handful proto-clusters known to belong "Rosetta Stone" era. The cluster of galaxies discovered in the current observation is at z = 2.5. This is the furthest known primordial cluster of galaxies that comes within the H-alpha observable range with a ground-based telescope.

The current research team hopes to expand their efforts to locate and decode more Rosetta Stone galaxies by using the Subaru Telescope and the Atacama Large Millimeter Array (ALMA), a sub-millimeter interferometer to be commissioned soon.

Provided by Subaru Telescope