ASTROPHYSICS

Galaxy connections

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A combined millimetre- and visible-light view of a forming cluster of galaxies in the young Universe adds yet another piece to the puzzle of how today's Universe of galaxies formed and evolved.

What is the evolutionary pathway of a galaxy? And how do different galaxy populations relate to one another? On page 61 of this issue, Tamura and colleagues[1] get closer to answering these questions by showing that two apparently very dissimilar types of star-forming galaxy develop synchronously within a young cluster of galaxies seen 2 billion years after the Big Bang.

It is now 30 years since the advent of charge-coupled device (CCD) cameras on large optical telescopes facilitated the first meaningful searches for 'primeval' galaxies in the young Universe[2]. These first surveys were motivated by the natural expectation that young, rapidly star-forming galaxies would be bright at ultraviolet wavelengths owing to the presence of large numbers of very hot, short-lived massive stars. In particular, it was anticipated that these galaxies would exhibit strong ultraviolet emission lines owing to the ionization and subsequent recombination of hydrogen atoms. Because of the expansion of the Universe, the strongest such line, Lyman-α, would be redshifted from its original ultraviolet wavelength of 121.5 nanometres into the observable optical window at redshifts $z > 2.5$.

In the past decade, with the additional light grasp offered by 8-metre-class optical telescopes, this technique of finding galaxies through their Lyman-α emission has really come of age, and substantial numbers of young galaxies have been discovered out to redshifts $z > 5$. The current record holder for the most distant known object is a Lyman-α emitter (LAE) uncovered at $z = 6.96$, when the Universe was less than 1 billion years old[3].

There is no doubt that LAEs fit the bill as young, star-forming galaxies. However, individually they are generally rather unspectacular objects, with low masses and typical star-formation rates of only a few solar masses per year. They certainly fall a long way short of the extreme bursts of star formation apparently required at high redshift to produce the massive, old stellar populations found in present-day elliptical galaxies[4]. But such super-starbursts in the young Universe have now been found, as a result of a second technological revolution in the mid-1990s — the advent of the first submillimetre- and millimetre-wave cameras[5].

It turns out that in these extreme starburst galaxies, which form several hundred solar masses of stars per year, most of the ultraviolet light from the young stars is absorbed by interstellar dust grains, re-emitted in the far-infrared, and redshifted to (sub)millimetre wavelengths. These submillimetre galaxies (SMGs) seem to be very different from even the most extreme LAEs, and understanding the origin of this difference, and the nature of any connection between these two populations, has become an important goal in current galaxy-formation research. In their study, Tamura *et al.*[1] shed some interesting new light on this issue, presenting the results of the first large-scale millimetre-wave survey of a known proto-cluster of LAEs at $z = 3.1$ (ref. 6).

Even in this sort of targeted study, establishing the relationship between SMGs and LAEs is a tricky business. Optical astronomy is still far ahead of millimetre-wave astronomy in terms of image quality and information content. By nature of their selection, LAEs are discovered at a well-defined redshift, whereas the millimetre-wave image of a given patch of sky detects all very luminous dust-enshrouded galaxies along the line of sight out to extreme redshifts of $z \sim 8$.

This 'complete' view of the Universe offered by millimetre-wave astronomy is in fact one of its greatest strengths, and is a key driver for the forthcoming Atacama Large Millimeter/Submillimeter Array (ALMA) facility in Chile. But the image obtained by Tamura *et al.*[1] at a wavelength of 1.1 mm, using the AzTEC camera[7] mounted on the 12-metre-diameter ASTE (Atacama Submillimeter Telescope Experiment) telescope, essentially consists of 15 blobs with unknown redshifts, and rather poorly determined positions. Nevertheless, the strength of the AzTEC map is that it is 20 times bigger than previous (sub)millimetre maps of this field of the sky, and Tamura *et al.* have extracted maximum information from this new image. In particular, they present a compelling case that at least some of the SMGs lie within the $z = 3.1$ filamentary proto-cluster traced out by the LAEs.

The evidence is quantified in terms of a statistically significant cross-correlation between the positions of the LAEs and SMGs on the sky. However, perhaps the most convincing result is the visually obvious fact that the brightest SMG uncovered in the AzTEC image lies right in the heart of the proto-cluster. At the same time, Tamura *et al.* reaffirm the distinction between LAEs and SMGs. None of the LAEs is detected in the AzTEC map; the authors were unable to achieve even a marginal detection at 1.1 mm when attempting to add the millimetre-wave fluxes extracted from the AzTEC map at the positions of all 166 LAEs. This non-detection confirms that typical LAEs contain less than

NATURE

50 & 100 YEARS AGO

50 YEARS AGO

According to the present model, the solar corona consists of a gas of electrons and protons with a small mixture of heavy elements which is isothermal at a temperature of approximately a million degrees and which is in hydrostatic equilibrium in the gravitational field of the Sun. The alternative model which we propose is that the solar corona consists of trapped charged particles moving in the magnetic field of the Sun, very like the charged-particle cloud surrounding the Earth which has been recently discovered by Van Allen and his collaborators.

In order to check the hypothesis suggested above, precise measurements of the polarization over a wide spectral range, as well as of the spectral composition of the light, will be important. We are now planning to carry out such measurements during the eclipse of October 2, 1959.

From *Nature* 9 May 1959

100 YEARS AGO

Statements have been made in the medical and general Press that the electric waves used in wireless telegraphy are injurious to the operators and produce various diseases, such as conjunctivitis, corneal ulceration, and leukoma. Mr. Marconi writes to the *Times* to deny these suggestions, for which, he says, there is no evidence whatever. He adds:— "During the twelve years or so of our operations we have had to deal with no single case of compensation for any injury of this origin, nor, so far as I can ascertain, has any such injury been suffered. Speaking for myself, I may remark that my own good health has never been better than during the often extended periods when I have been exposed for many hours daily to the conditions now challenged, and in the constant neighbourhood of electrical discharges at our Transatlantic stations, which I believe are the most powerful in the world."

From *Nature* 6 May 1909