

Astronomers miss 90% of distant galaxies

The rate of star formation in the early universe is mainly deduced based on a specific hydrogen-emission line observed in remote galaxies. It was already suspected that this Lyman- α line is strongly absorbed by dust but not to the extent now found by a careful study of the effect using the Very Large Telescope (VLT) of the European Southern Observatory (ESO). It turns out that on average only about 5% of the emitted radiation escapes the galaxies, which in turn means that almost 90% of remote star-forming galaxies cannot be detected by current methods.

The formation of the first galaxies and stars started in the first 100 million years after the Big Bang. Star-forming galaxies are characterized by the presence of short-lived, massive stars that emit predominantly ultraviolet light, which ionizes the gas in their neighbourhood. The recombination of ionized hydrogen results in a series of emission lines corresponding to the transition between different excitation levels of the atoms. The strongest lines are the Lyman- α emission at an ultraviolet wavelength of 121.6 nm and the Balmer H- α line visible in red at 656.3 nm. For a distant galaxy, these lines are observed at longer wavelengths because of the expansion of the universe. A galaxy at a redshift of $z=2$ will have the lines shifted towards longer wavelengths by a factor of $z+1=3$, making the Lyman- α line almost visible and moving the H- α line to the near infrared.

The Lyman- α line has an ideal wavelength to identify ionized hydrogen gas in high-redshift



Portion of the GOODS-South field of remote galaxies imaged by the FORS and HAWK-I instruments on two of the four 8.2-m telescopes of the VLT. (Courtesy ESO/M Hayes.)

galaxies with telescopes operating in visible light. It is furthermore typically 8.7 times brighter than the Balmer H- α line, which makes it the prime tracer of star formation at high redshift. Lyman- α is however also a resonant line and this means that its photons scatter on neutral hydrogen. This is a problem because it keeps the Lyman- α photons inside the galaxy for a long time, so giving them a big chance to be absorbed by dust before eventually escaping the galaxy.

The determination of the escape fraction of Lyman- α photons from the galaxy is difficult to assess. Model-dependent estimations based on galaxies observed at high-redshift ($z=2-3$) previously suggested an escape fraction between 30% and 60% on average. This is far above the measurement obtained now by an international group of astronomers lead

by Matthew Hayes from the Observatory of the University of Geneva. They have obtained an escape fraction of $5.3 \pm 3.8\%$ with a firm model-independent upper limit of $10.7 \pm 2.8\%$ at a redshift of $z=2.2$, which corresponds to galaxies whose light took 10 thousand million years to reach Earth (Hayes *et al.* 2010).

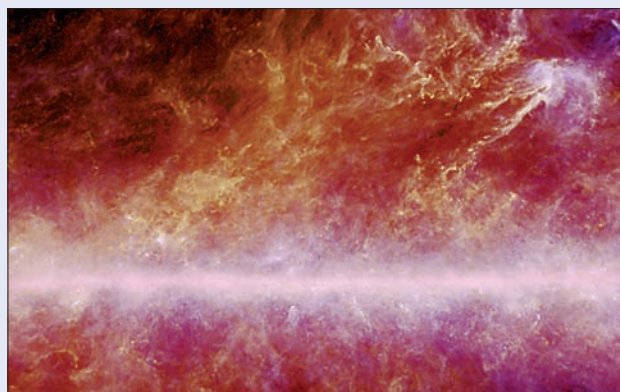
The result was obtained by looking at a field of galaxies with dedicated narrow-band filters to get the Lyman- α and H- α line emission at this particular redshift. The GOODS-South (Great Observatories Origins Deep Survey) field of view was chosen because it was observed previously by different instruments, which had already characterized the properties of its galaxies. A custom-built filter for Lyman- α was mounted on the FOCal Reducer and low-dispersion Spectrograph (FORS) camera on one of the four 8.2-m telescopes of the VLT, while the H- α line emission was recorded by the new High Acuity Wide field K-band Imaging (HAWK-I) camera attached to another VLT telescope.

The analysis of these unique observations shows that the Lyman- α line is undetectable in most star-forming galaxies. Indeed, 90% of the galaxies remain unnoticed, such that for every 10 galaxies detected, there should be 100. The determination of this huge proportion of missed galaxies will allow astronomers to obtain a far more accurate description of the history of star formation in the universe.

Further reading:

M Hayes *et al.* 2010 *Nature* **464** 562.

Picture of the month



This beautiful image of dust structures in the Milky Way is one of the first images by the Planck mission to be released by the European Space Agency (ESA). The image spans about 50° of the sky, showing giant filaments of cold dust in our galactic neighbourhood, within about 500 light-years from the Sun. It is a three-colour combination of data taken with Planck's High-Frequency Instrument (HFI), at wavelengths of 540 and $350\ \mu\text{m}$ (shown in red and yellow), and a $100\text{-}\mu\text{m}$ image (shown in white) taken in 1983 with the Infrared Astronomical Satellite (IRAS). White-pink tones show dust with a temperature of a few tens of kelvin, while the coolest dust at only about 12 K appears in red. The mapping of dust in our galaxy is bonus science for Planck which was launched in May 2009 primarily to study the cosmic microwave background, the relic light of the Big Bang. (Courtesy ESA and the HFI Consortium/IRAS.)