Struggle to escape distant galaxies creates giant halos of scattered photons

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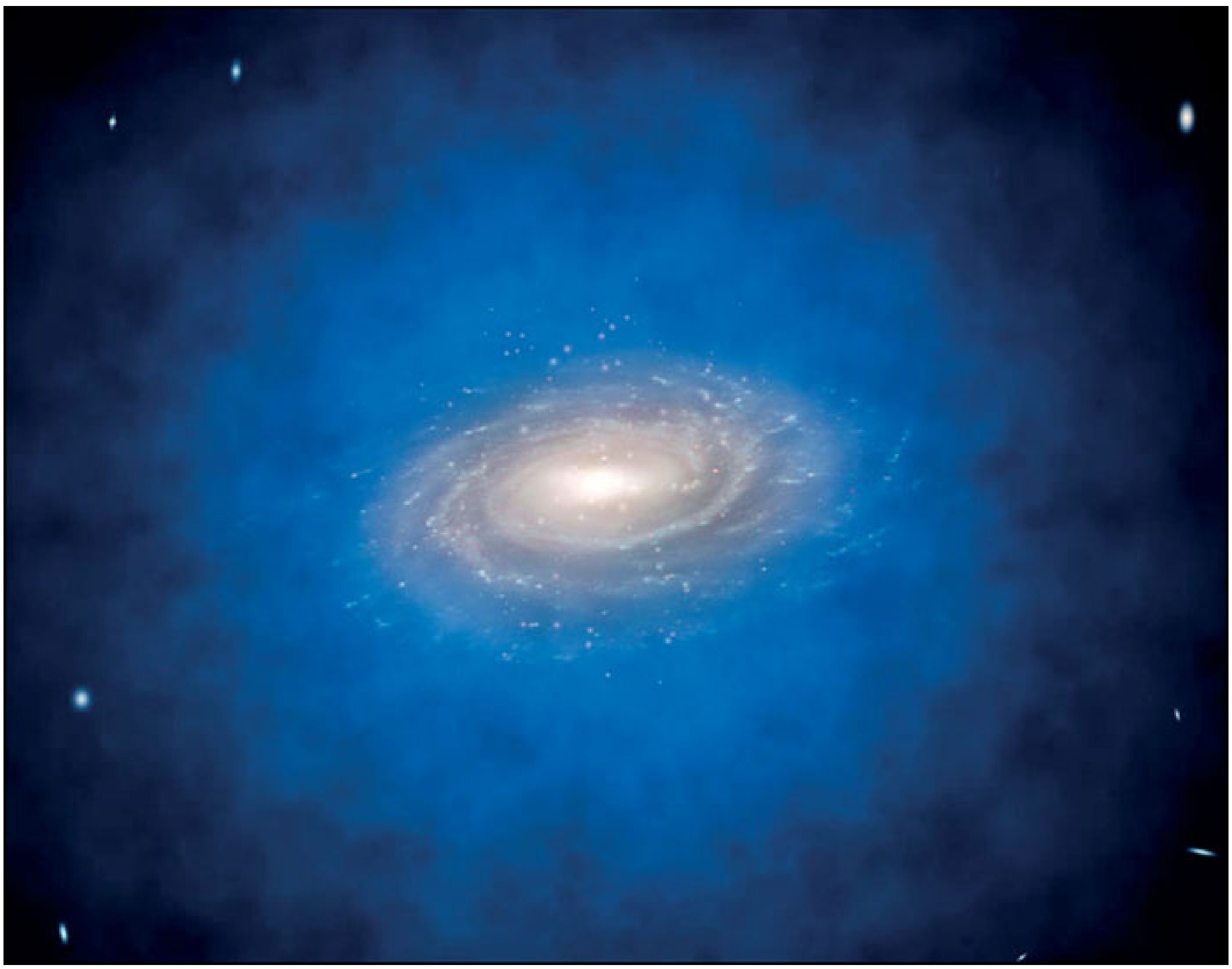


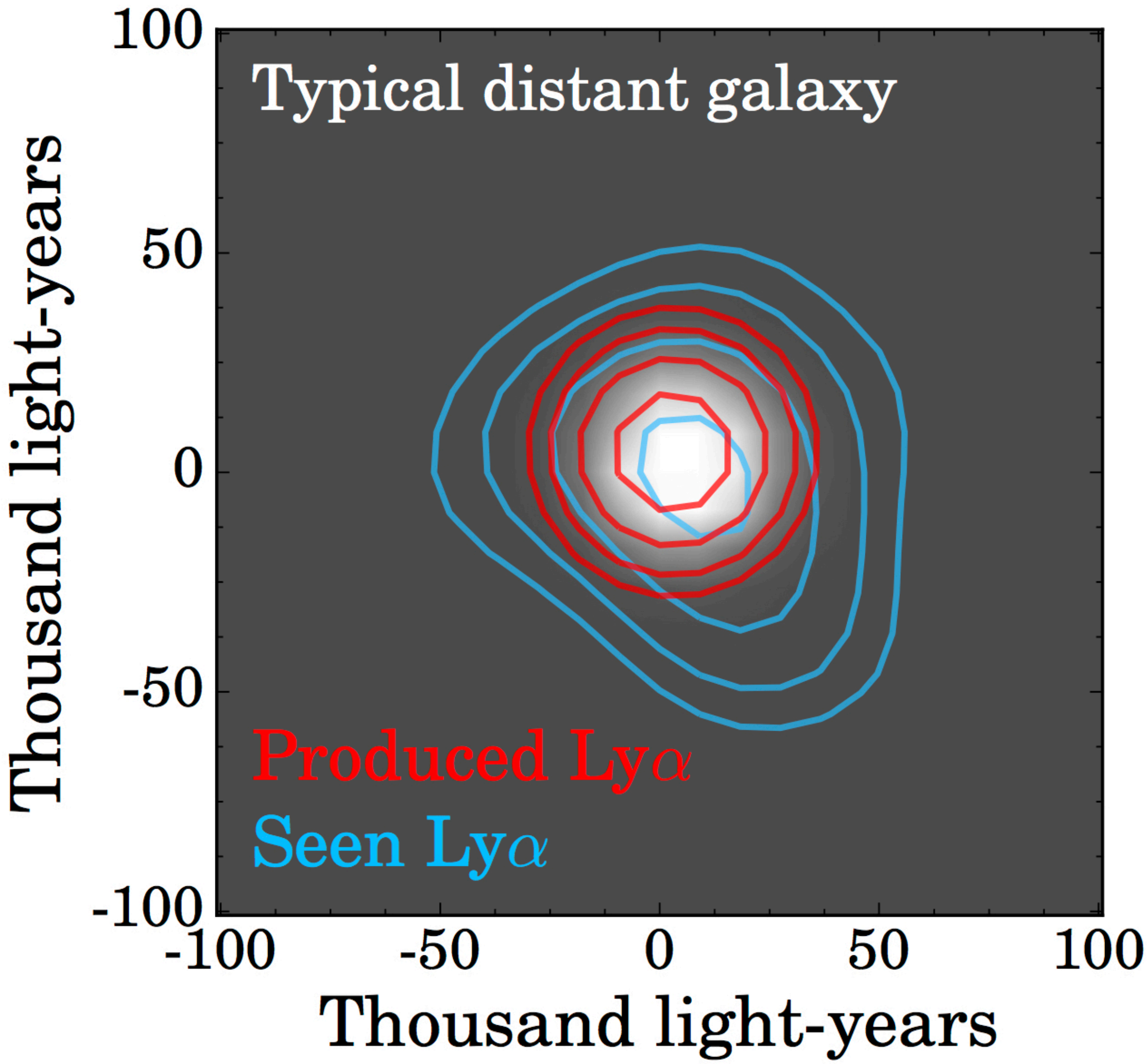
This artist's impression shows a Milky Way type galaxy in the local Universe, surrounded by a much larger halo of blue, faint light, made of Lyman-alpha photons. While these photons were produced around hot, young stars in much more central regions, they struggle to escape the galaxies, suffering many absorptions and re-emissions as they try to escape, and creating these giant haloes. For typical distant galaxies, only a few per cent actually make it out at all. This is what astronomers have now been able to see for similar galaxies that existed 11 billion years ago, in a very young, active Universe. This has important implications for studying the young Universe, where these photons are remarkably important, but are usually measured over only the very central component of each galaxy. Credit: ESO/L. Calçada

Astronomers led by David Sobral and Jorryt Matthee, of the Universities of Lancaster in the UK and Leiden in the Netherlands have discovered giant halos around early Milky Way type galaxies, made of photons (elementary particles of light) that have struggled to escape them. The team reports its findings in the journal *Monthly Notices of the Royal Astronomical Society*.

In order to understand how our own Milky Way galaxy formed and evolved, astronomers rely on observing distant galaxies. As their light takes billions of years to reach us, telescopes can be used as time machines, as long as we have a clear indicator to pinpoint the distance to the objects being observed. As with closer galaxies, stars and planets, astronomers use the technique of spectroscopy to analyse their light, dispersing it into a spectrum.

Scientists then look for characteristic features (spectral lines) that tell them about properties including the composition, temperature and movement of the object. With the most distant galaxies, only one spectral feature typically stands out, the so-called Lyman-alpha line associated with hydrogen gas.

Jorryt Matthee comments: "Newly born stars in very distant galaxies are hot enough to break apart hydrogen in surrounding clouds of gas, which then shines brightly in Lyman-alpha light, in theory the strongest such features observable in a distant galaxy. Yet in practice, Lyman-alpha photons struggle to escape galaxies as gas and dust block and diverge their travel paths, making it a complex process to understand."



The figure shows some observations conducted with the Isaac Newton Telescope in La Palma and with the UKIRT telescope in Hawaii of one of the (almost 1000) young Milky Way type galaxies in the very early Universe. The results allowed astronomers to measure where, and how many, photons were produced (indicated by the red contour lines), and then compare with those that have actually escaped (blue contour lines) these distant galaxies. The results reveal large haloes of Lyman-alpha photons that struggled to escape, while the vast majority of these photons never make it out at all. Credit: J. Matthee/D. Sobral

Using the Isaac Newton Telescope (INT) on La Palma in the Canary Islands, astronomers developed a unique experiment to study almost 1000 distant galaxies. They surveyed the sky using the Wide Field Camera and custom-made filters, in order to measure where the Lyman-alpha is produced, how much of it there is, and where it comes out of galaxies.

David Sobral says: "We have used dozens of dedicated nights on the INT to understand how Lyman-alpha photons escape, and from which galaxies. We looked back in time 11 billion years, essentially the limit of where we can identify distant galaxies and study them in detail. Most importantly, we were able to predict accurately how many Lyman-alpha photons were effectively produced in each galaxy and where this happened. Then we compared them with the ones that actually reach the INT."

The results show that only 1-2% of those photons escape from the centres of galaxies like the Milky Way. Even if we account for all the photons at a large distance from the centre, fewer than 10% escape.

"Galaxies forming stars in the distant Universe seem to be surrounded by an impressively large, faint halo of Lyman-alpha photons that had to travel for hundreds of thousands of light years in an almost endless series of absorption and re-emission events, until they were finally free. We now need to understand exactly how and why that happens", adds Sobral.

When the James Webb Space Telescope begins operation in 2018, astronomers expect to be able to look even further back in time, opening up a new window on the first galaxies and stars. Studying how the escape fraction evolves over time can tell us about the kind of stars producing these photons, and the properties of interstellar and intergalactic gas.

More information: The new work appears in two papers in *Monthly Notices of the Royal Astronomical Society*:

"The CALYMHA survey: Lyman-alpha; escape fraction and its dependence on galaxy properties at z = 2.23", Jorryt Matthee, David Sobral, Iván Oteo, Philip Best, Ian Smail, Huub Röttgering and Ana Paulino-Afonso, *Monthly Notices of the Royal Astronomical Society*, 458, 449, 2016. A copy of the paper is available from doi.org/10.1093/mnras/stw322

"The CALYMHA survey: Lyman-alpha luminosity function and global escape fraction of Lyman-alpha; photons at z=2.23", David Sobral, Jorryt Matthee, Philip Best, Andra Stroe, Huub Röttgering, Iván Oteo, Ian Smail, Leah Morabito, Ana Paulino-Afonso, 2016, *Monthly Notices of the Royal Astronomical Society*, in press. After the embargo expires, the paper will be available at mnras.oxfordjournals.org/conte … /11/30/mnras.stw3090

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