Small, but plentiful: How the faintest galaxies illuminated the early universe

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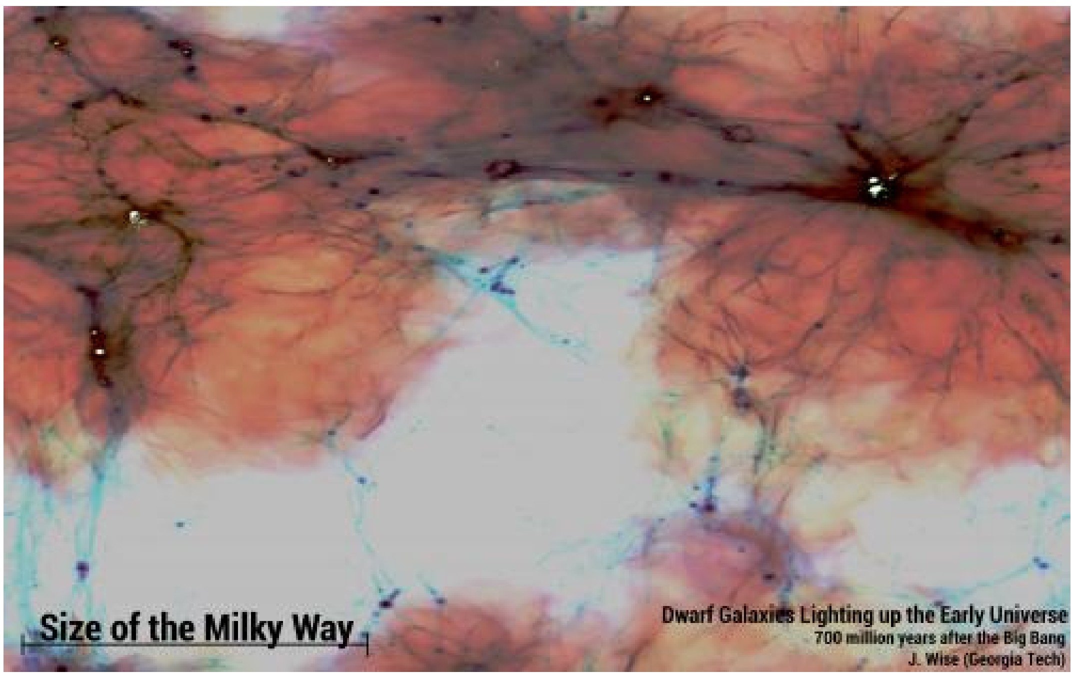

A view of the entire simulation volume showing the large scale structure of the gas, which is distributed in filaments and clumps. The red regions are heated by UV light coming from the galaxies, highlighted in white. These galaxies are over 1000 times less massive than the Milky Way and contributed nearly one-third of the UV light during re-ionisation. The field of view of this image is 400,000 light years across, when the universe was only 700 million years old. Credit: John Wise

(Phys.org) —Astronomers investigating behaviour of the universe shortly after the Big Bang have made a surprising discovery: the properties of the early universe are determined by the smallest galaxies. The team report their findings in a paper published today in the journal *Monthly Notices of the Royal Astronomical Society*.

Shortly after the Big Bang, the universe was ionised: ordinary matter consisted of hydrogen with its positively charged protons stripped of their negatively charged electrons. Eventually, the universe cooled enough for electrons and protons to combine and form neutral hydrogen. This cool gas will eventually form the first stars in the universe but for millions of years, there are no stars. Astronomers therefore aren't able to see how the cosmos evolved during these 'dark ages' using conventional telescopes. The light returned when newly forming stars and galaxies re-ionised the universe during the 'epoch of re-ionisation'.

Astronomers agree that the universe became fully re-ionised roughly one billion years after the Big Bang. About 200 million years after the birth of the cosmos, ultraviolet (UV) radiation from stars began to split neutral hydrogen into electrons and protons. It took another 800 million years to complete the process everywhere. This epoch of re-ionisation marked the last major change to gas in the universe, and it remains ionised today, over 12 billion years later.

However, astronomers aren't in agreement on which type of galaxies played the most important role in this process. Most have focused on large galaxies. The new study by researchers at the Georgia Institute of Technology and the San Diego Supercomputer Center indicates scientists should also focus on the smallest ones.

The researchers used computer simulations to demonstrate the faintest and smallest galaxies in the early universe were essential. These tiny galaxies – despite being 1000 times smaller in mass and 30 times smaller in size than our own Milky Way galaxy – contributed nearly 30 percent of the UV light during this process.

Other studies often ignore these small 'dwarf' galaxies as they weren't thought to form stars, because the UV light from nearby larger galaxies was too strong and suppressed these tiny neighbours.

"It turns out these dwarf galaxies did form stars, usually in one burst, around 500 million years after the Big Bang," said Prof. John Wise, of the Georgia Institute of Technology, who led the study. "The galaxies were small, but so plentiful that they contributed a significant fraction of UV light in the re-ionisation process."

The team's simulations modelled the flow of UV stellar light through the gas within galaxies as they formed. They found that the fraction of ionizing photons escaping into intergalactic space was 50 percent in small galaxies (more than 10 million solar masses). It was only 5 percent in larger galaxies (300 million solar masses). This elevated fraction, combined with their high abundance, is exactly the reason why the faintest galaxies play an integral role during re-ionisation.

"It's very hard for UV light to escape galaxies because of the dense gas that fills them," said Wise. "In small galaxies, there's less gas between stars, making it easier for UV light to escape because it isn't absorbed as quickly. Plus, supernova explosions can open up channels more easily in these tiny galaxies in which UV light can escape."

A zoomed-in view of the most massive dwarf galaxy in the simulation, seen when the universe was only 700 million years old. This galaxy only has 3 million solar masses of stars, compared to 60 billion solar masses in our Milky Way. The yellow points represent the older and cooler stars in the galaxy, and the blue points show the young and massive stars forming just before this snapshot of the simulation. The haze around the stars show the gas distribution in the galaxy with blue and red representing hot and cold temperatures, respectively. Credit: John Wise

The team's simulation results provide a gradual timeline that tracks the progress of re-ionisation over hundreds of millions of years. About 300 million years after the Big Bang, the universe was 20 per cent ionised. It was 50 per cent at 550 million years. The simulated universe was fully ionised at 860 million years after its creation.

"That such small galaxies could contribute so much to re-ionisation is a real surprise," said Prof. Michael Norman, of the University of California San Diego and one of the co-authors of the paper. "Once again, the supercomputer is teaching us something new and unexpected; something that will need to be factored into future studies of re-ionisation."

The research team expects to learn more about these faint galaxies when the next generation of telescopes is operational. For example, NASA's James Webb Space Telescope, scheduled to launch in 2018, will be able to see them.

More information: his research has been published in Wise J. el al., "The Birth of a Galaxy - III. Propelling reionisation with the faintest galaxies", *Monthly Notices of the Royal Astronomical Society*, in press, published by Oxford University Press. A preprint of the paper is available.

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