

Mystery behind decline of star formation rate after its peak 8-10 billion years ago uncovered

For long, scientists have been intrigued by the decrease in the rate at which stars were formed in galaxies after it peaked about 8-10 billion years ago. They have now deciphered the mystery behind this decline in star formation activity by measuring the atomic hydrogen of the galaxies.

Galaxies are made up mostly of gas and stars. Gas converts to stars with time. Understanding this conversion requires measurement of the atomic hydrogen gas, the primary fuel for star formation in galaxies in early times. Astronomers have long known that galaxies formed stars at a higher rate when the universe was young than they do today. But the cause of this decline is unknown, mostly because there was no information about the amount of atomic hydrogen gas at that time.

A team of astronomers from the National Centre for Radio Astrophysics (NCRA-TIFR), Pune, and the Raman Research Institute (RRI), Bangalore, an autonomous institute of the Department of Science & Technology (DST), Government of India has used the upgraded Giant Metrewave Radio Telescope (GMRT), operated by NCRA-TIFR, to measure the atomic hydrogen content of galaxies seen as they were 8 billion years ago. The research carried out by Aditya Chowdhury, Nissim Kanekar, and Jayaram Chengalur of NCRA-TIFR, and Shiv Sethi, and K. S. Dwarkanath of RRI and published in the journal *Nature* records the earliest epoch in the universe for which atomic gas content of galaxies has been measured.

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“Given the intense star formation in these early galaxies, their atomic gas would be consumed by star formation in just one or two billion years. And, if the galaxies could not acquire more gas, their star formation activity would decline, and finally cease”, said Aditya Chowdhury, a Ph.D. student at NCRA-TIFR and the lead author of the study. “The observed decline in star formation activity can thus be explained by the exhaustion of the atomic hydrogen,” he added.

The measurement of the atomic hydrogen mass of distant galaxies was done by using the upgraded GMRT to search for a spectral line in atomic hydrogen.

K. S. Dwarkanath of RRI, a co-author of the study, mentioned, “We had used the GMRT in 2016, before its upgrade, to carry out a similar study. However, the narrow bandwidth before the GMRT upgrade meant that we could cover only around 850 galaxies in our analysis, and hence were not sensitive enough to detect the signal.”

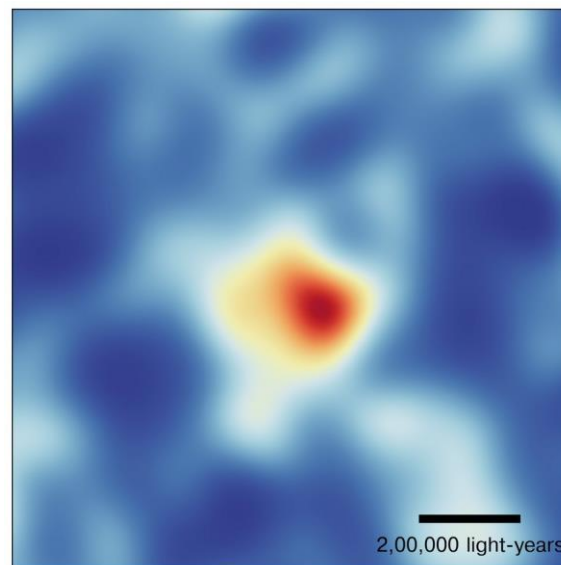
“The big jump in our sensitivity is due to the upgrade of the GMRT in 2017”, said Jayaram Chengalur, of NCRA-TIFR, a co-author of the paper. “The new wideband receivers and electronics allowed us to use 10 times more galaxies in the stacking analysis, giving sufficient sensitivity to detect the weak average 21 cm signal.”

Detecting the 21 cm signal from the most distant galaxies in the universe was the main science goal of the GMRT when it was designed and built by a team led by Govind Swarup in the 1980s

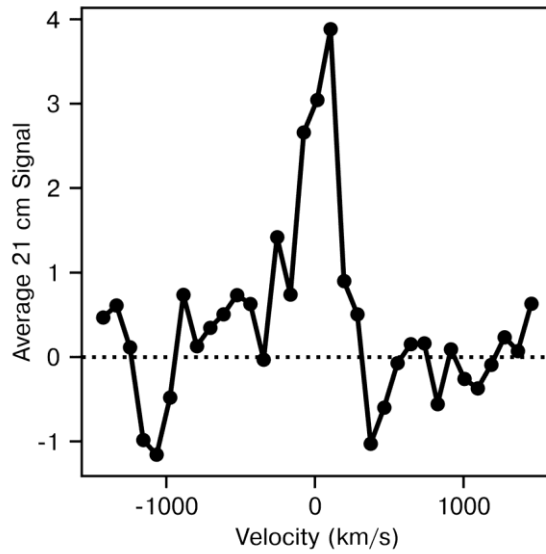
and 1990s. “Govind Swarup was very interested in this work and was following it keenly. Sadly, he passed away shortly before it was published. This work would not have been possible without him and the wonderful team that he put together to first build and then upgrade the GMRT”, said Nissim Kanekar of NCRA- TIFR, a Swarna Jayanti Fellow of DST and co-author of the study.

Technical explanation of GMRT upgradation

Unlike stars, which emit light strongly at optical wavelengths, the atomic hydrogen signal lies in the radio wavelengths, at a wavelength of 21 cm, and can only be detected with radio telescopes. Unfortunately, this 21 cm signal is very weak and difficult to detect from distant individual galaxies even with powerful telescopes like the upgraded GMRT. To overcome this limitation, the team used a technique called “stacking” to combine the 21 cm signals of nearly 8,000 galaxies that had earlier been identified with optical telescopes. This method measures the average gas content of these galaxies.



Caption: An image of the stacked 21 cm signal detected with the upgraded GMRT, arising from atomic hydrogen gas in galaxies 22 billion light-years away.



Caption: The spectrum of the stacked 21 cm signal detected with the upgraded GMRT, arising from atomic hydrogen gas in galaxies 22 billion light-years away. The width of the signal gives an indication of the average rotation of galaxies 8 billion years ago.



Caption: A GMRT antenna at night. Picture by Rakesh Rao.

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