National Centre for Radio Astrophysics (NCRA), Pune
Press Note – 4th June 2021

GMRT measures the atomic hydrogen gas mass in galaxies 9 billion years ago.

A team of astronomers from the National Centre for Radio Astrophysics (NCRA-TIFR) in Pune, and the Raman Research Institute (RRI), in Bangalore, has used the Giant Metrewave Radio Telescope (GMRT) to measure the atomic hydrogen gas content of galaxies 9 billion years ago, in the young universe. This is the earliest epoch in the universe for which there is a measurement of the atomic hydrogen content of galaxies. The new result is a crucial confirmation of the group's earlier result, where they had measured the atomic hydrogen content of galaxies 8 billion years ago, and pushes our understanding of galaxies to even earlier in the universe. The new research has been published in the 2 June 2021 issue of *The Astrophysical Journal Letters*.

Galaxies consist of mostly gas and stars, with new stars forming from the existing gas during the life of a galaxy. Stars formed much more frequently when the universe was young than they do today. Astronomers have known for more than two decades that the star formation activity in galaxies was at its highest about 8-10 billion years ago, and has declined steadily thereafter. Until recently, the cause of this decline was unknown, mostly because we have had no information about the amount of atomic hydrogen gas, the main fuel for star formation, in galaxies at these early times. This changed last year when a team of astronomers from NCRA and RRI, including some of the authors from the present study, used the upgraded GMRT to obtain the first measurement of the atomic hydrogen gas content of galaxies about 8 billion years ago, when the star-formation activity of the Universe began to decline. They found that the likely cause for the decline in star formation in galaxies is that galaxies were running out of fuel.

Aditya Chowdhury, a Ph.D. student at NCRA-TIFR, and the lead author of both the new study and the 2020 one, said, "Our new results are for galaxies at even earlier times, but still towards the end of the epoch of maximum star-formation activity. We find that galaxies 9 billion years ago were rich in atomic gas, with nearly three times as much mass in atomic gas as in stars! This is very different from galaxies today like the Milky Way, where the gas mass is nearly ten times smaller than the mass in stars."

The measurement of the atomic hydrogen gas mass was done by using the GMRT to search for a spectral line in atomic hydrogen, which can only be detected with radio telescopes. Unfortunately, this "21 cm" signal is very weak, and hence nearly impossible to detect from individual galaxies at such large distances, around 30 billion light years from us, even with powerful telescopes like the GMRT. The team hence used a technique called "stacking" to improve the sensitivity: this allowed them to measure the average gas content of nearly 3,000 galaxies, by combining their 21 cm signals.

"The observations of our study were carried out around 5 years ago, before the GMRT was upgraded in 2018. We used the original receivers and electronics chain of the GMRT before its upgrade, which had a narrow bandwidth. We could hence cover only a limited number of galaxies; this is why our current study covers 3000 galaxies, compared to the 8,000 galaxies of our 2020 study with the wider bandwidth of the upgraded GMRT.", said Nissim Kanekar of NCRA-TIFR, a co-author of the study.

Barnali Das, another Ph.D. student of NCRA-TIFR, added, "Although we had fewer galaxies, we increased our sensitivity by observing for longer, with nearly 400 hours of observations. The large volume of data meant that the analysis took a long time!".

"The star formation in these early galaxies is so intense that they would consume their atomic gas in just two billion years. And, if the galaxies could not acquire more gas, their star formation activity would decline, and finally cease.", said Chowdhury. "It thus appears likely that the cause of the declining star-formation in the Universe is simply that galaxies were not able to replenish their gas reservoirs after some epoch, probably because there wasn't enough gas available in their environments."

"Reproducibility is foundational to science! Last year, we reported the first measurement of the atomic gas content in such distant galaxies. With the present result, using a completely different set of receivers and electronics, we now have two independent measurements of the atomic gas mass in these early galaxies. This would have been hard to believe, even a few years ago!", said Kanekar.

K. S. Dwarakanath of RRI, a co-author of the study, mentioned "Detecting the 21 cm signal from distant galaxies was the main original goal of the GMRT, and continues to be a key science driver for building even more powerful telescopes like the Square Kilometre Array. These results are extremely important for our understanding of galaxy evolution.".

The results have been published in the 2 June issue of The Astrophysical Journal Letters (https://iopscience.iop.org/article/10.3847/2041-8213/abfcc7).

The research was carried out by Aditya Chowdhury, Nissim Kanekar, and Barnali Das of NCRA-TIFR, and Shiv Sethi, and K. S. Dwarakanath of RRI. The Giant Metrewave Radio Telescope was built and is operated by NCRA-TIFR. The research was funded by the Department of Atomic Energy, India, and the Department of Science and Technology, India.

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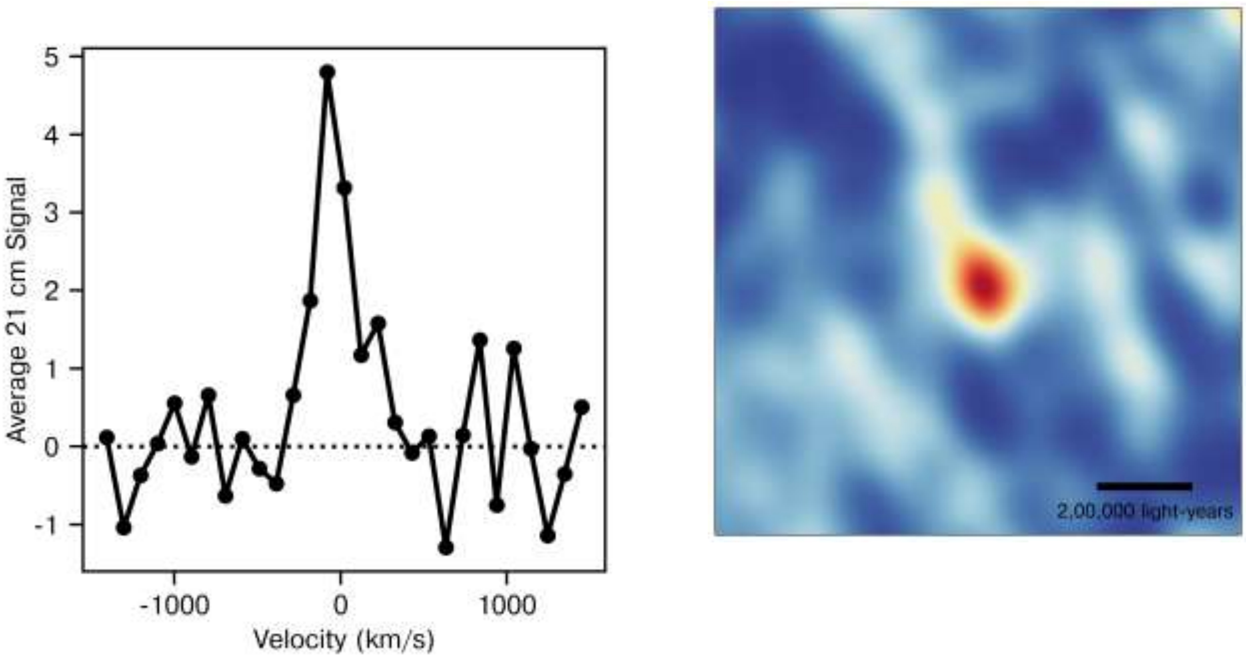
Caption: The two panels show the detected GMRT 21cm signal, as a spectrum (left panel) and an image (right panel).



Caption: A GMRT antenna at night (Picture credit: Rakesh Rao)