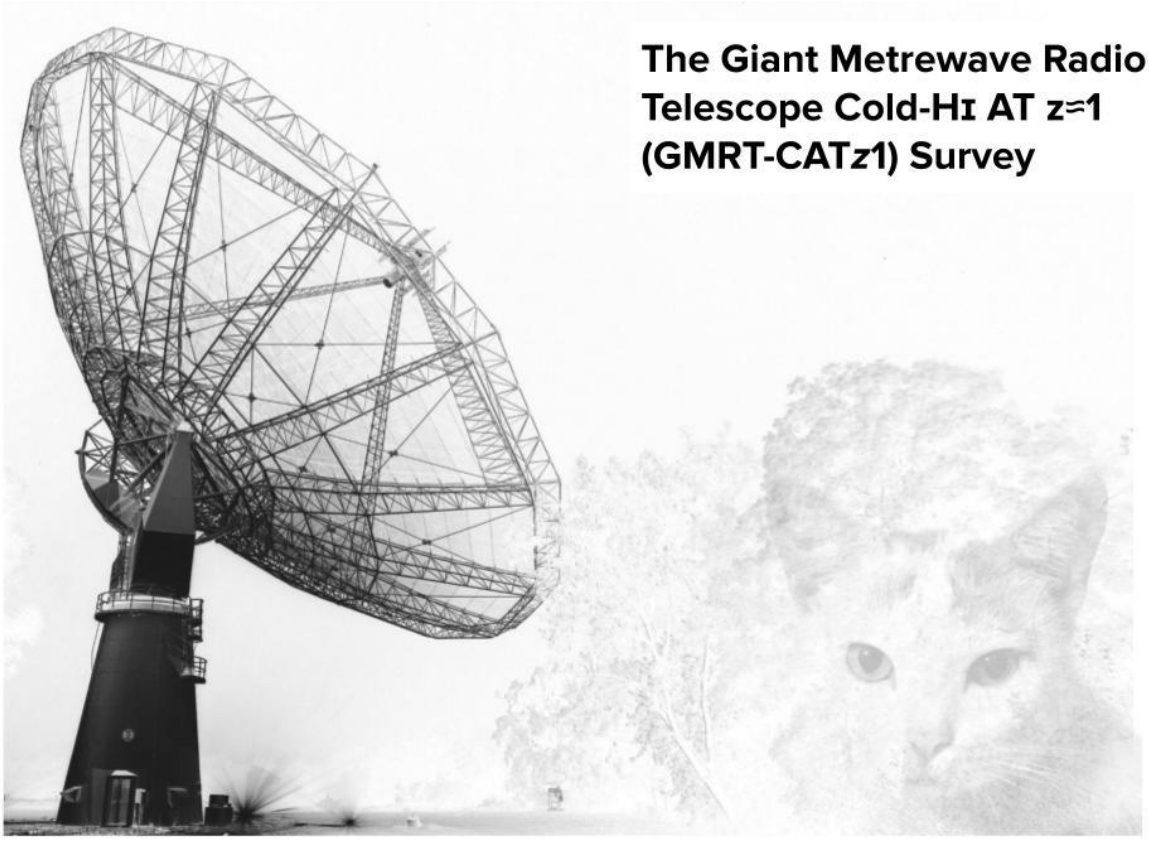
National Centre for Radio Astrophysics (NCRA) – Press Note English – 20/09/2022



A team of astronomers from the National Centre for Radio Astrophysics (NCRA-TIFR) in Pune has used the Giant Metrewave Radio Telescope (GMRT) to measure the relative amounts of hydrogen gas and stars in galaxies in the early Universe. Their results show that star-forming galaxies nine billion years ago were primarily made up of neutral hydrogen gas. This is very unlike galaxies today which have most of their mass in stars. The research has been published in the August 10 issue of The Astrophysical Journal Letters.

The ordinary ("baryonic") matter in galaxies is mostly in the form of atomic or molecular hydrogen and stars. Over the lifetime of a galaxy, atomic hydrogen cools and gets converted to molecular hydrogen, which further collapses to form stars. The relative amounts of atomic, molecular and stellar material in a galaxy are hence indicative of its evolutionary stage. For example, a galaxy that is highly evolved (i.e. has been forming stars for a long time) is likely to have consumed most of its gas, and to have much more mass in stars than in gas.

"If we consider a typical galaxy today, we know that nearly two-thirds of its total baryonic matter is in the stars, with one-third in atomic gas, and only about 6% in molecular form. Most of the ordinary matter in nearby galaxies is thus in stars. But the situation in the early galaxies has been a mystery, despite many efforts to address this question." said Aditya Chowdhury, a Ph.D. student at NCRA-TIFR and the lead author of the new study.

“Recent observations of molecular gas in the early galaxies have shown that the molecular gas is comparable to the stars in mass, providing the first hints that these galaxies are very different from galaxies today”, said Nissim Kanekar, an astronomer at NCRA-TIFR and a co-author of the study. “However, until now, the critical missing piece of the puzzle has been the atomic gas mass in these galaxies, which is very hard to measure with today’s telescopes.”

For nearby galaxies, a spectral line in the hydrogen atom, at a wavelength of roughly 21 cm, is routinely used to measure the atomic gas mass. However, this 21 cm line is very weak, and it is extremely difficult to directly detect the line from the distant galaxies in the early Universe. The team at NCRA-TIFR carried out deep GMRT observations of selected regions of the sky in the “GMRT Cold-HI AT $z \approx 1$” (GMRT−CATz1) survey, and combined the 21 cm signals of thousands of galaxies in the early Universe to detect their average 21 cm line emission.

“The GMRT detection of the average 21 cm line signal allowed us to directly measure the average atomic gas mass of the target galaxies, and to compare this average atomic gas mass to their average molecular gas mass and average stellar mass. We found that galaxies in the early Universe, 9 billion years ago, had a dramatically different composition from galaxies today! Most of the mass of the early galaxies, about 70%, is in the form of atomic gas, with only around 16% of the mass in the stars!” said Chowdhury.

“The current study settles a long-standing debate about the early galaxies, providing a complete picture of what these galaxies were made up of. We now know that galaxies in the early Universe were mostly made up of neutral gas. Over the past nine billion years, this large reservoir of gas in galaxies was converted into stars, producing galaxies like our Milky Way whose mass is dominated by stars.” said Jayaram Chengalur, another co-author of the study, and also an astronomer at NCRA-TIFR.

The results have been published in the August 10 issue of The Astrophysical Journal Letters (https://iopscience.iop.org/article/10.3847/2041-8213/ac8150). The research was carried out by Aditya Chowdhury, Nissim Kanekar, and Jayaram Chengalur of NCRA-TIFR, using data from the 510-hour GMRT−CATz1 survey. 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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