National Centre for Radio Astrophysics (NCRA)
Tata Institute of Fundamental Research (TIFR)
Press Note – 28th June 2022

The uGMRT confirms sharp reduction of atomic hydrogen in early universe

A team of astronomers from the National Centre for Radio Astrophysics (NCRA-TIFR) in Pune has used the upgraded Giant Metrewave Radio Telescope (GMRT) to find evidence for a sharp reduction in the amount of atomic hydrogen gas in galaxies over a 1-billion-year interval, from 9 billion years ago to 8 billion years ago. This detection of a rapid change in the atomic gas mass of galaxies in the early Universe helps to solve a long-standing open problem regarding the evolution of star-formation activity in the Universe. The research has been published in the June 1 issue of The Astrophysical Journal Letters.

Gas and stars are the two key components of galaxies: the gas is the fuel for star formation. The life cycle of a galaxy essentially involves acquiring gas from its surroundings, and then converting its gas into stars. Once the gas supply of the galaxy is exhausted, it would stop forming stars. It has been known for more than two decades that galaxies in the Universe 8-11 billion years ago formed stars at a rate 10 times higher than the rate in galaxies like our own Milky Way today. Why galaxies stopped forming stars at this high rate has hitherto been a mystery. Astronomers at NCRA-TIFR have been trying to address this open question by directly measuring the atomic hydrogen gas content of the early galaxies, a very challenging problem.

“In 2020, we had used the upgraded GMRT to report the first direct measurement of the atomic gas mass of galaxies in the early Universe, roughly 8 billion years ago. This measurement, made possible due to the powerful new capabilities of the upgraded GMRT, gave tantalizing hints into the causes of the decline in the star-formation activity in galaxies 8 billion years ago.”, said Aditya Chowdhury, a Ph.D. student at NCRA-TIFR and the lead author of the new study.

Atomic gas in galaxies can be studied by observing a spectral line in the hydrogen atom, at a wavelength of approximately 21 cm. Unfortunately, this so-called 21 cm line is weak and hence very difficult to detect in distant galaxies. Chowdhury and the team have been using a technique called “stacking” to combine the 21 cm signals from thousands of known galaxies. This allows them to measure the average atomic gas properties of the galaxies, despite not detecting any galaxy individually.

“The 2020 results showed that the early galaxies consume their gas in star formation on a short timescale, roughly one billion years, far quicker than similar galaxies today. However, in principle, galaxies can replenish their gas reservoir by acquiring gas from their surroundings. If this were to actually be taking place, the early galaxies could continue to form stars at a high rate.”, said Nissim

Kanekar, an astronomer at NCRA-TIFR and a co-author of the study.

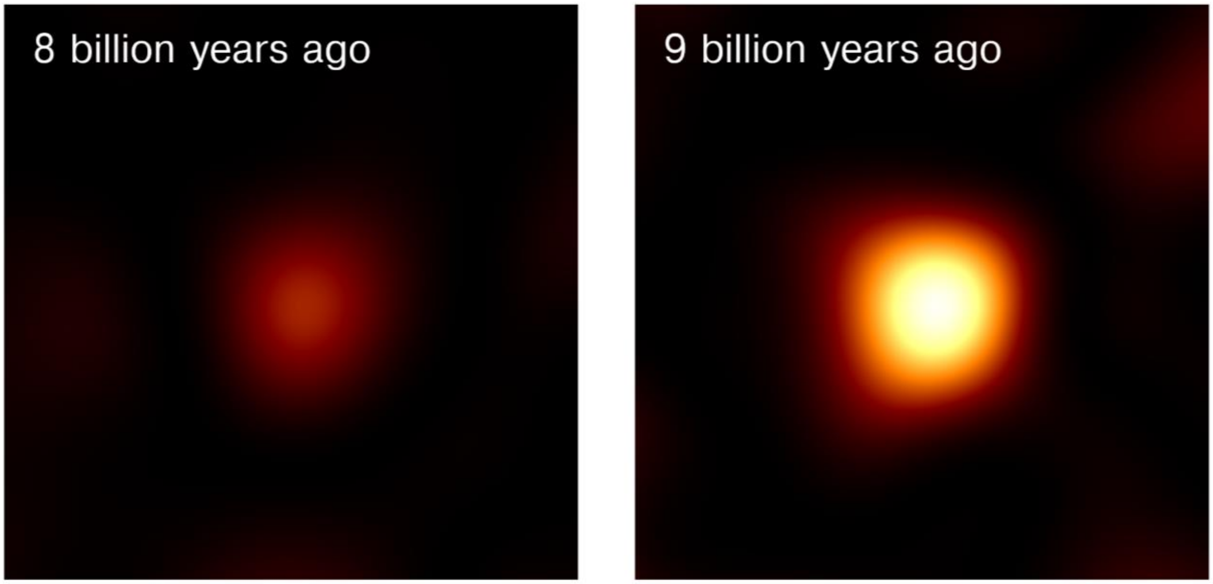
"The only way to directly test whether the gas reservoir is consumed or replenished is to measure the atomic gas mass of these galaxies at two different periods in the Universe's history, separated by around one billion years. The new *GMRT-CATz1* survey was designed to have enough sensitivity to do exactly this.", said Jayaram Chengalur, another co-author of the study, and also at NCRA-TIFR.

The new GMRT data allowed the team to directly measure the average atomic gas mass of galaxies at the two epochs, 8 and 9 billion years ago. "Remarkably, we found that the average gas mass indeed declines steeply, over roughly a billion years: Galaxies eight billion years ago contain roughly three times less atomic gas than galaxies with the same stellar mass nine billion years ago!", said Kanekar. "This clearly indicates that the galaxies have been unable to replace the gas consumed in star formation. This is why the star-formation activity drops at later times: there's just not enough gas to fuel a high rate of star-formation! And this is especially true for the biggest galaxies, which have the highest star-formation activity.", added Chowdhury.

The results from the GMRT-CATz1 survey have filled a critical gap in our understanding of how the early galaxies evolved towards their present state. The team of astronomers at NCRA-TIFR now plan to push their GMRT study of the atomic gas content of galaxies to even earlier epochs in the Universe.

The results have been published in the June 1 issue of The Astrophysical Journal Letters (https://iopscience.iop.org/article/10.3847/2041-8213/ac6de7). The research was carried out by Aditya Chowdhury, Nissim Kanekar, and Jayaram Chengalur of NCRA-TIFR, using data from the 510-hour "GMRT Cold-HI AT $z\approx1$" (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.

Contacts:
Aditya Chowdhury (chowdhury@ncra.tifr.res.in ; 97651 15719),
Nissim Kanekar (nkanekar@ncra.tifr.res.in; 80071 89477),
Jayaram Chengalur (chengalu@ncra.tifr.res.in ; 94223 22923),
Yashwant Gupta (ygupta@ncra.tifr.res.in) ; Phone: 020-25719242
CH. Ishwara-Chandra (ishwar@ncra.tifr.res.in); Mobile: 9403136630
J. K. Solanki (solanki@ncra.tifr.res.in); Mobile: 9890447888
Anil Raut: (anil@gmrt.ncra.tifr.res.in); Mobile: 8605525945



Caption: Images of the average 21 cm signal detected with the upgraded GMRT, arising from atomic hydrogen gas in galaxies 8 billion years ago (left) and 9 billion years ago (right). The 21 cm signal from galaxies 9 billion years ago is found to be approximately three times brighter than the signal from galaxies 8 billion years ago. This implies that galaxies nine billion years ago contained about 3 times more atomic gas than their counterparts eight billion years ago.