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The ongoing quest for detection of 21-cm signal in the Reionization Era : uGMRT Observation Band-2 in ELAIS-N1 deep field

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Half a century has passed since the first observation of Cosmic Microwave Background (CMB) radiation. Over the decades, many have attempted to study the first emissions from luminous sources, such as the Cosmic Dawn (CD) and Epoch of Reionization (EoR), through ground-based radio observations using both single-dish antennas (e.g., EDGES, SARAS3) and interferometers (e.g., uGMRT, LOFAR, MWA, PAPER, HERA, NenuFAR). Radio observations provide an unobstructed view of the universe, penetrating dust clouds and revealing hidden regions. One promising probe, the 21-cm signal from the spin-flip transition of neutral hydrogen, has the potential to unveil the physics behind the epochs of the early universe. Recently, the H1 21-cm signal was detected from star-forming galaxy (SFG) using the upgraded Giant Metrewave Radio Telescope (uGMRT) interferometer at a redshift of $z \sim 1.3$ [2], within the post-reionization era ($z < 6$). However, the detection of 21-cm signals from the reionization era remains elusive. This era is crucial, as the emission of ultraviolet radiation carved out ionized regions around luminous sources, forming the galaxies and Active Galactic Nuclei (AGN) observed in the current universe.

Current-generation low-frequency radio telescopes, such as LOFAR and HERA, have endeavored to establish upper limits for the 21-cm signal. LOFAR, for instance, has accumulated data over 10 nights at redshift $z \sim 9.1$ [4], while HERA has gathered data over 18 nights at redshifts $z = 7.9$ and 10.4. Despite these extensive efforts, clear detection of the 21-cm signal has not yet been achieved. Future-generation ground-based radio telescopes, including SKA-low and SKA-mid, are expected to directly image large-scale structures from the early universe. Additionally, several upcoming space-based radio telescopes, such as LEDA and DARE, aim to probe the early universe.

From the uGMRT we have studied the ELAIS-N1 deep field of the Northern Sky and constraints on the parameters for the 21-cm signal in Band-3 (300-500 MHz) with direction-independent calibration [1, 3]. For the first time, we are pursuing the reionization era with the uGMRT in Band-2 (120-250 MHz). We collected three nights of data and calibrated it using a direction-dependent approach, considering ionospheric delay corrections. The final image achieved an RMS noise level of 236 μJy/beam with a resolution of 11.45 arcsec. Our catalog of the image contains 1029 sources at a central frequency of 183 MHz with flux densities $\geq 5\sigma$. We characterized the dominant foreground galactic diffuse synchrotron emission with visibility and image based estimation and constrained it in terms of a power-law. Using foreground removal technique, we further eliminated the foregrounds from the residuals after removing the point sources. We are presenting our initial results for the upper limit at high redshift using the uGMRT.

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2. Chakraborty & Roy, "Detection of HI 21 cm emission from a strongly lensed galaxy at $z \sim 1.3$," *MNRAS,* **519**, pp.4074-4081, doi:10.1093/mnras/stac3696.

3. A. Chakraborty, "First Multi-redshift Limits on Post-Epoch of Reionization 21 cm Signal from $z = 1.96$-3.58 Using uGMRT", *The Astrophysical Journal*, **925**, 27 pp., doi:10.3847/1538-4357/ac1c78.

4. F. G. Mertens, "Improved upper limits on the 21-cm signal power spectrum of neutral hydrogen at $z \approx 9.1$ from LOFAR," *MNRAS*, **493**, pp.1662-1685, doi:10.1093/mnras/staa327.