Bull. Astr. Soc. India (2003) 31, 451–452

Search for HI Reionization Epoch in the Early Universe

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Abstract. One of the most challenging problems in astronomy today is to search for reionization of the neutral hydrogen (HI), which is expected to occur somewhere between redshifts of about 6 to 20. The reionization is likely to result in spatial and spectral fluctuations in emission and absorption in the redshifted 21cm radiation of several milli-Kelvin (mK) in the frequency range of about 100 to 200 MHz. Also there is expected to occur a gradual step of few mK in the global 21cm radiation. Here we discuss various search strategies.

Keywords: GMRT, CMB, Reionization, RFI, HI, early universe.

1. Spatial and Spectral Features of HI

Absorption of CMB: Following the formation of first stars soon after the end of Dark ages, the resulting Ly-α flux will couple T_s of HI to its kinetic temperature T_k, which is initially $\ll T_{CMB}$. This will result in spatial/spectral fluctuations of the 21cm radiation in absorption against the CMB with estimated signal strength of ~40mK and a factor T_{CMB}/T_s larger than in emission. (Tozzi et al., 2000).

Emission features: With the growth of structures and formation of first quasars, the resulting soft x-rays and Ly-α will preheat the IGM so that $T_k \gg T_{CMB}$ and will couple spin temperature T_s to T_k. The expected fluctuations of the brightness temperature is several mK over several Mpc (few arcmins) at frequencies of about 150 to 230 MHz.

Global Signal: If the reionization occurred rather suddenly, the fraction of HI is likely to drop by a large factor in about a tenth of the Hubble time as predicated to occur at $z \sim 7$ to 15

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(e.g. Gnedin & Ostriker, 1997). Recent, WMAP observations of polarization of CMB indicate reionization at $z \sim 17$ *(Kogut, et al.,2003)*. This is likely to result in a Global signal across the sky and could be observed in principle with a single telescope of small size (Shaver et al. 1999).

2. Observational Strategies and Challenges

Although attempts are likely to be made for observing the Global signal using existing radio telescopes, challenges are formidable as there exist large nos of communication and commercial transmitters world wide in the frequency range < 230 MHz, giving rise to considerable radio frequence interference (RFI) to any sensitive radio astronomy observations. Further detection of the signature of the global signal in the presence of strong galactic and extragalactic background radiation (of ~100 to 400 K) poses problems. Size of the antennas is not important as sensitivity of a mK can be reached in an integration time, Δt, of only ~25,000 s (4 hr) for the bandwidth, Δf, of 1 MHz for a background temperature $T_{sys} \sim$ 150K, since $T_{min} \sim T_{sys}/(\Delta f \Delta t)^{1/2}$.

We propose searches for the Global signal by observing towards the North pole with a single parabolic dish of about 10 or 12 m diameter with low sidelobes, placed in a deep valley in the Himalayan region, say off Nainital, to avoid RFI. A receiver placed in a temperature controlled enclosure and also variation of path length between the antenna feed, the input calibration source and the receiver should minimize uncertainties due to the standing wave ratio in the system, allowing accurate calibration of the gain of the receiver as a function of the observing frequency. Observing towards North Pole may allow elimination of spurious response by distant radio sources in the sky, such as Cygnus A, Cas A, etc., as they would produce a daily variation which can be eliminated during data processing.

It is also planned to make observations for absorption features with GMRT in the frequency range of about 120-155 MHz. RFI is minimum particularly during periods when there are weekly electrical power shutdown by the Electricity Board in the surrounding areas of GMRT. Fluctuations of the 21-cm emission levels at ~150-200 MHz are expected to be only about ~2-10 mK (~5 mJy for angular resolution of ~3 to 10 arcmin). This is below the detection levels of GMRT. For investigating the process of galaxy formation in the early universe, one may construct a linear array of about 16 low cost parabolic dishes of about 18 m or 20 m diameter, placed in an RFI free location.

References

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