COSMIC REIONIZATIONS AND 21CM OBSERVATIONS

The redshifted 21cm line of neutral hydrogen (HI) is an incisive probe of the high-redshift universe, allowing in principle for creation of full spatial 3D-maps of hydrogen as a function of cosmic time in the redshift range $z \sim 6 - 200$ (Furlanetto et al., 2006; Pritchard and Loeb, 2012). The HI line is redshifted to frequencies below 200MHz and can therefore be observed by radio telescopes (Tozzi et al., 2000). Beyond maps, this cosmic signature will test fundamental physics from the Dark Ages, the formation of the first compact radiation sources at Cosmic Dawn, and the reionization of neutral hydrogen with galaxy formation during the Epoch of reionization (Barkana, 2016).

First-generation radio telescopes have targeted two summary statistics of the 21cm line: the all-sky average brightness temperature (the "global" signal) from Cosmic Dawn as a function of redshift, and the power spectrum of spatial fluctuations as a function of Fourier wavemodes and redshift. As expected, different physics is probed at different redshifts: During the *Dark Ages*, between recombination and the formation of the first astrophysical objects, the baryonic perturbations remain linear and the physics is simple enough that the 21cm intensity directly can be traced back to cosmological parameters and for example break the degeneracy between the neutrino mass and the CMB optical depth (Pritchard and Pierpaoli, 2008), distinguish inflationary models (Masui and Pen, 2010), and test various physics beyond the standard model including neutrino decay (Chianese et al., 2019) and dark matter annihilation (Koopmans et al., 2021). The *Cosmic Dawn* era probes astrophysics like the star formation rate, X-ray SEDs, and the mass of star-forming halos (e.g. Barkana (2016) and Bye et al. (2022)). Finally, the Epoch of Reionization constrains the ionization history of hydrogen, the mean free path of ionizing photons in Stromgren spheres, the CMB optical depth, and X-ray heating (DeBoer et al., 2017).

Experiments targeting the global signal include the Experiment to Detect the Global EoR Signature (EDGES, Bowman and Rogers, 2010; Monsalve et al., 2017, 2018, 2019), SARAS (Shaped Antenna measurement of the background RAdio Spectrum, Singh et al., 2022), REACH (Radio Experiment for the Analysis of Cosmic Hydrogen, de Lera Acedo et al., 2022), PRIZM (Probing Radio Intensity at high-Z from Marion, Philip et al., 2019), MIST (Mapper of the IGM Spin Temperature, `http://www.physics.mcgill.ca/mist/`), and DAPPER (Dark Ages Polarimeter PathfindER, Burns et al., 2019). These experiments have only recently reached the necessary sensitivity to observe cosmological signals, but EDGES have put a lower limit on the length of the Epoch of Reionization (Bowman and Rogers, 2010) and has made a claimed detection of the global signal (Bowman et al., 2018). This claim has subsequently been countered by a claim of non-detection (Singh et al., 2022), but if truly of cosmic origin, the measured absorption profile can likely not be explained by standard physics as it suggests cooling of the hydrogen gas faster than what can be achieved with adiabatic cooling due to the expansion of the universe. So-called exotic models–which go beyond ΛCDM—have been proposed as explanations for the EDGES detection, including charged Dark Matter (Muñoz et al., 2018), dark matter-baryon interactions (Barkana et al., 2018; Barkana, 2018), and early Black Holes (Ewall-Wice et al., 2018).

For the power spectrum, upper limits are being placed (The HERA Collaboration et al., 2022; Abdurashidova et al., 2022), which constrain early heating of the IGM, but no claim of the same magnitude as EDGES have been made.

Future plans for the field include improved sensitivity of current telescopes, new earth-based telescopes like the Square Kilometer Array (Gupta, 2022), and pathfinders for space based missions (e.g LuSEE, Bale et al. (2020)).

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