Interpreting multi-wavelength observations of the Epoch of Reionization from next generation telescopes

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The Epoch of Reionization (EoR) is one of the least understood periods in the history of the universe. In this project, our goal was to explore the potential of future multi-wavelength observations in understanding this epoch. We first explore the possibility of using the redshifted 158 μm line from singly ionized carbon (CII) atoms for this purpose. The $158\mu m$ CII line is an extremely viable, alternate probe of the Epoch of Reionization. It directly complements the purpose served by the 21cm line. Where 21cm line traces the distribution of the neutral hydrogen gas, and thus the state of reionization, the CII line serves as a tracer of the star formation rate (SFR).A direct relation between CII luminosity and SFR can be established as follows:

$$log_{SFR} = \alpha(logM_{halo} - 10) + \gamma log(\frac{1+z}{6}) + \delta \tag{1}$$

([1]) To further establish an upper and a lower bound on the values of L_{CII}, the L_{CII} and SFR relation can be parameterized as:

$$\log_{10}(L_{CII}[L_\odot]) = a_{L_{CII}} \times \log_{10}(\frac{SFR}{M_\odot yr^{-1}}) + b_{L_{CII}} \tag{2}$$

[2] Hence, we have attempted to constrain the minimum dark matter halo mass, that hosts the early photon sources, using the CII power spectrum from the EoR using an Artificial Neural Networking (ANN) based signal emulator and Bayesian Inference via a Markov Chain Monte Carlo (MCMC) framework. We discovered that since the CII power spectrum is very featureless (the only feature it has is variation of its amplitude with the minimum host halo mass of the sources), one requires a very large training data set to train the emulator for it to be able to predict the signal power spectrum with an appreciable degree of accuracy. In addition, it was found that despite using a large training set, the emulator seems to have a tendency to produce degenerate data at certain points, especially towards the boundaries of our parameter space. This anomaly was discovered by using the MCMC algorithm in tandem with the *emulator* and comparing the obtained estimates of the minimum host halo mass with the same obtained from MCMC runs in tandem with the *simulator*. We have further shown that the CII $\otimes$ 21cm cross-power spectrum has more features compared to the auto-power spectra of CII and thus would require a smaller training set to emulate the same. In addition, since this cross-power spectrum is dominated by the fluctuations in the HI 21cm field, this can potentially be used as a more robust statistic for constraining all three of the necessary EoR parameters. We are presently in the process of exploring this second approach in detail and are expecting definitive results in the coming months.

References

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