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Research Essay

It has been a long time since we observed signatures of the existence of dark matter by means of cosmological and astrophysical probes. A consistent and precise theory has been built about the quantity and general properties of dark matter. However, its fundamental nature is still one of the significant mysteries of modern physics which places a huge theoretical and observational challenge in our field of view. [1]

Besides efforts in the standard framework of astrophysics, other theoretical techniques ranging from effective field theory to machine learning and artificial intelligence have been used to address this issue[1]. Recently, there has been a growing interest in the potential of the 21cm emission/absorption signal of hydrogen to help uncover the solution to this mystery. The 21cm signal has proven to be one of the only available probes of large-scale structure in the most distant reaches of the universe[4]. Its lack of astrophysical contamination and ability to prob very small-scale structures over a large volume makes it a great candidate for seeking dark matter fingerprints[3].

Since the 21cm signal is sensitive to the thermal state of intergalactic hydrogen, it is capable of probing exotic processes during that era, like dark matter decay/annihilation and effects of primordial black holes[3]. The annihilation of dark matter is known to affect the thermal and ionizing history of the intergalactic medium (IGM) by heating it earlier and more uniformly compared to other astrophysical X-ray sources. The energy input from the decay or annihilation of dark matter will affect the hydrogen kinetic temperature, resulting in a shift in the ionization fraction. This shift will contribute to the $Ly\alpha$ background, thus leaving a detectable imprint on the 21cm signal[2][5].

Although this will be a considerably small contribution, if we overcome the ionospheric, interference, and foreground issues, the 21cm signal is capable of constraining proposed dark matter candidates. It has been shown that combined observations of the 21cm background and its gradient can put constraints, at least on decaying light dark matter candidates[5].

Therefore, we are optimistic that the data from Experiment to Detect the Global EoR Signature (EDGES) and future high-precision radio telescopes like the Square Kilometre Array (SKA) will help us in revealing the fundamental nature of dark matter[4].

References

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