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Probing the Epoch of Reionization through the cosmic 21-cm signal

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The advent of the first luminous sources in the Universe initiated the transformation of neutral intergalactic hydrogen into a highly ionized warm plasma. This transformation persists until the entire neutral intergalactic hydrogens are ionized, called the Epoch of Reionization (EoR). This phase is pivotal in unraveling the Universe's early structures. However, direct observation of these sources, even with space-based telescopes such as James Webb Space Telescope (JWST), remains challenging.

A promising avenue for the EoR is the redshifted 21-cm line emitted by neutral hydrogen. The 21-cm signal indirectly reveals the reionization signature in the intergalactic medium (IGM), providing insights into its ionization and thermal state. Notably, radio interferometry, such as Hydrogen Epoch of Reionization Array (HERA) and Square Kilometre Array (SKA), aims to detect the 21-cm signal. These observations involve mapping spatial fluctuations across the wide range of redshifts and eventually obtaining the 3D map of the first billion years of the Universe.

To glean information about these early sources, sophisticated methodologies like Bayesian statistics and machine learning are employed. A Bayesian framework, built upon the semi-numerical simulation 21cmFAST, emerges as a robust approach for inferring the astrophysical parameters during the EoR. This framework encompasses a galaxy model that differentiates star formation efficiency and escape fraction of ionizing photons, to include the rest-frame UV luminosity functions at high-redshift (z>6) in the Bayesian framework.[1] Furthermore, we introduce a new methodology of approximately correcting the number of ionizing photons to conserve the photon number, which is a limitation in semi-numerical simulation.[2] Our Bayesian framework yields an impressive outcome that, with the upcoming 21-cm signal and the rest-frame UV luminosity functions, the eight astrophysical parameters in our model are able to be constrained at the level of ~10 percent or better.[1,2,3]

Acknowledgments

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References

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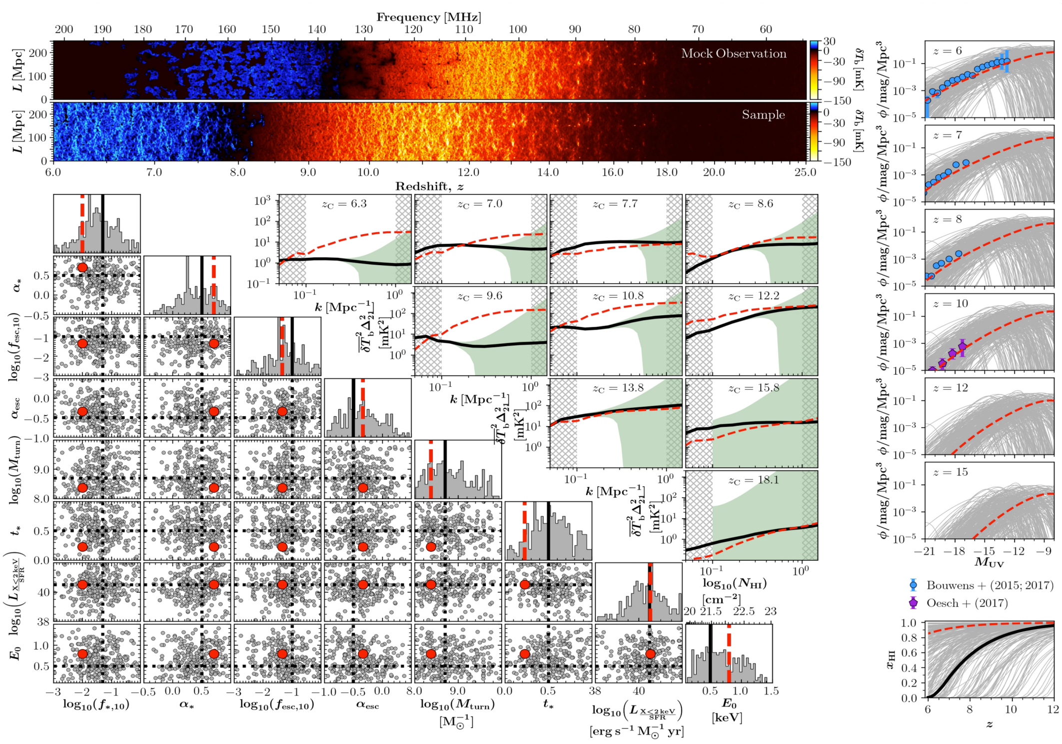

Figure 1. Schematic figure showing how our Bayesian framework works to constrain the astrophysical parameters using various observations, including the 21-cm power spectra