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A comprehensive study of the EoR 21-cm signal bispectrum

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1 Extended Abstract

Understanding the evolutionary history of our Universe is one of the major goals of modern cosmology. Precise measurements of the Cosmic Microwave Background Radiation (CMBR) and accurate maps of the galaxies in the nearby universe have revolutionized our understanding of this history. Together they provide a somewhat detailed picture of the very early phase of the Universe and of its present state. However, our knowledge of how the universe has evolved between these two extreme ends is actually very limited.

One of the most important missing pictures in this history is the phase that includes the Cosmic Dawn (CD) and the Epoch of Reionization (EoR), the period during which the very first sources of light were formed. The UV and X-ray radiation emitted by these and by the subsequent population of sources gradually heated and "re"-ionized the cold inter-galactic medium (IGM), consisting of mostly neutral hydrogen (HI). Radio interferometric observations of the redshifted 21-cm signal, originating from spin flip transitions in HI atoms from this era, promise to resolve many of the fundamental puzzles associated with this period.

The present time is particularly exciting for this rapidly growing field, as several radio telescopes, such as the Giant Metrewave Radio Telescope (GMRT) in India, the LOw-Frequency ARray (LOFAR) in Europe, the Murchison Widefield Array (MWA) in Australia, the Precision Array for Probing the Epoch of Reionization (PAPER) and the Hydrogen Epoch of Reionization Array (HERA) in South Africa etc., are currently in a race to detect this signal. Very recently, scientists may have gotten the first glimpses of this signal through the Experiment to Detect the Global EoR Signature (EDGES). The upcoming enormous Square Kilometre Array (SKA) is expected to be able to image the HI distribution using this signal at different cosmic times, which is not possible by the presently.

The EoR 21-cm signal is expected to be highly non-Gaussian in nature and this non-Gaussianity is also expected to evolve with the progressing state of reionization. Therefore the signal will be correlated between different Fourier modes (k). Most of the ongoing efforts to detect the EoR 21-cm signal using radio interferometers focus on measuring the signal through power spectrum. The power spectrum will not be able to capture the signal correlation between different Fourier modes. We use a higher-order estimator – the bispectrum – to quantify this evolving non-Gaussianity. We study the bispectrum using an ensemble of simulated 21-cm signal and with all possible unique k triangles in the Fourier space. Different unique triangles are expected to capture different features of the non-Gaussianity. We develop and apply an improved and faster algorithm to compute bispectrum for all unique k triangles within a reasonable computing time. We include the line-of-sight (LoS) anisotropies arising due to the matter peculiar velocities in our simulated signal. We further demonstrate how this LoS anisotropy named redshift space distortions, which will be the inherent part of any observation of the signal, affects the amplitude and the sign of the signal bispectrum compared to the scenario when we do not include it in our simulated signal. Finally, we identify among all of the unique k triangle configurations which ones would be detectable, taking into consideration mock observations with LOFAR and the SKA1-LOW.