Abstract

Observations of the neutral hydrogen (HI) 21-cm signal hold the potential of allowing us to map out the cosmological large-scale structures (LSS) across the entire post-reionization era ($z < 6$). Several 21-cm intensity mapping experiments are planned to map the LSS over a large range of redshifts and angular scales, many of these targeting the Baryon Acoustic Oscillations. It is, therefore, important to model the HI distribution in order to correctly predict the expected signal, and more so to correctly interpret the results after the signal is detected. In this thesis, our main objective is to model the 21-cm intensity mapping signal and study its evolution across the different redshifts in the post-reionization era.

We have carried out semi-numerical simulations to model the HI distribution and study the HI power spectrum $P_{\rm HI}(k, z)$ across the redshift range $1 \leq z \leq 6$. We have modelled the HI bias as a complex quantity $\tilde{b}(k, z)$ whose modulus squared $b^2(k, z)$ relates $P_{\rm HI}(k, z)$ to the matter power spectrum $P(k, z)$, and whose real part $b_r(k, z)$ quantifies the cross-correlation between the HI and the matter distribution. We study the z and k dependence of the bias.

The 21-cm intensity mapping signal experiences redshift-space distortion due to the peculiar motion of the HI . We extend the previous simulations to incorporate redshift-space distortion and predict the expected redshift space HI 21-cm power spectrum $P^s_{\rm HI}(k_\perp, k_\parallel)$ using two different prescriptions for the HI distributions and peculiar velocities. We model $P^s_{\rm HI}(k_\perp, k_\parallel)$ assuming that it is the product of $P_{\rm HI}(k) = b^2 P(k)$ with a Kaiser enhancement term and a Finger of God (FoG) damping which has σ_p the pair velocity dispersion as a free parameter. Considering several possibilities for the bias and the damping profile, we find that the models with a scale dependent bias and a Lorentzian damping profile best fit the simulated $P^s_{\rm HI}(k_\perp, k_\parallel)$ over the entire range $1 \leq z \leq 6$.

In a subsequent work, we refine our simulations to properly incorporate the HI motions within the galaxies which are associated with haloes. This is achieved through a line profile which accounts for both the rotational and random (thermal and turbulent) motions of the HI within galaxies. The functional form of the double horned line profiles used here is motivated by observations of $z = 0$ spiral galaxies. Analyzing the simulated 21-cm power spectrum over the redshift range $1 \leq z \leq 6$ we find that the HI motions within galaxies makes a significant contribution that is manifested as an enhancement in the FoG effect. The results indicate that, at $z > 3$ FoG is mainly dominated by the internal motions and a measurement here could provide a handle on the line profiles of high redshift galaxies.

Observation of the fluctuations in the 21-cm background is perceived to be an important probe of non-Gaussianity. The bispectrum, the three point correlation function in Fourier space, is the lowest order statistic sensitive to the non-Gaussian features. This motivates us to explore the 21-cm bispectrum in the post-reionization era. We have estimated the 21-cm bispectrum in the z range $1 \leq z \leq 6$ using semi-numerical simulations of the HI distribution. The simulations start from Gaussian initial conditions and the bispectrum emerges from the non-linear gravitational clustering and the non-linear bias of the HI distribution. We determine the k and z range where the 21-cm bispectrum can be adequately modelled using the predictions of second order perturbation theory, and we use this to predict the redshift evolution of the linear and quadratic HI bias parameters b_1 and b_2 respectively.

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