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Simulations of cosmic reionization: comparison between different techniques

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Abstract. We compare a set of semi-numerical simulations with a radiative transfer simulation of the epoch of reionization (EoR) in their ability to predict the redshifted 21-cm signal from the neutral hydrogen (H I) in this epoch. Specifically we compare how well they can mimic various redshift space observables of the 21-cm signal from this epoch.

1. Introduction

Many of the first generation radio interferometric surveys (*e.g.* GMRT, LOFAR, MWA, 21CMA etc.) of the epoch of reionization (EoR) have already started accumulating data. Simulations are essential to interpret these observations by estimating a large number of mostly unknown parameters from this epoch. The radiative transfer simulations of EoR very accurately predicts the redshifted H I 21-cm signal from this epoch. However, they are extremely expensive interms of computational time ($\sim$ million of core hr and few terabyte of memory). On the other hand sem-numerical simulations are computationally cheap (need $\sim 10^5$ times less computational time and a few gigabyte of RAM) but include more approximate physics in them. It is thus worthwile to check whether these semi-numerical simulations can reproduce the reionization history, morphology and the redshift space 21-cm signal from this epoch up to a certain acceptable accuracy. We compare all our simulations by estimating the

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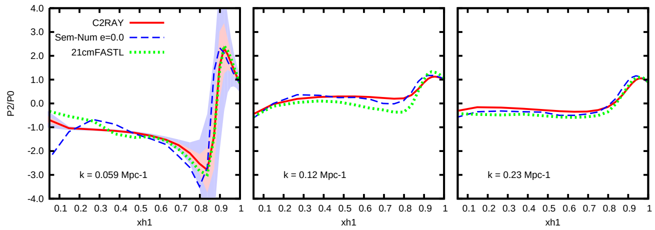

Figure 1. This shows the evolution of the ratio P_2^s/P_0^s with $\bar{x}_{\rm H\,I}$ at three representative k values. The shaded region in pink and blue shows uncertainty due to the system noise in 5000 and 2000 hr of observation of LOFAR.

angular multipole moments (P_0 and P_2) of the power spectra of redshifted 21-cm signal while taking into account the effect of redshift space distortions. These quantities are capable of quantifying the redshift space distortions present in the signal as well the nature of reionization (Majumdar et al. 2013).

2. Simulations

All our simulations are based on a single N-body run, carried out using the CubeP^{3}M code. From this, halos were identified using a spherical over-density method, which are treated as the host for reionization sources. Radiative transfer simulation used by us is C^2-ray (see Mellema et al. 2006 for further details). One semi-numerical simulation (Sem-Num, based on Choudhury et al. 2009) in our analysis considers the same halos as its sources and generates the ionization map by excursion-set formalism. The other semi-numerical simulation (CPS+GS, based on Zahn et al. 2011; Mesinger et al. 2011) uses a conditional Press-Schechter technique to identify ionized regions using just a Gaussian smoothed version of the N-body density field. The redshift space distortion is incorporated following Jensen et al. (2013).

3. Observables of the redshifted 21-cm signal

We observe that the angular multipole moments of the 21-cm signal estimated from Sem-Num and CPS+GS are in well agreement with C^2-ray (with $\sim$ 85% accuracy) and this error is well within the noise uncertainties for LOFAR (Figure 1). However, the history and morphology of reionization is better represented by Sem-Num compared to CPS+GS owing to a better source model (see Majumdar et al. 2014 for further details).

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