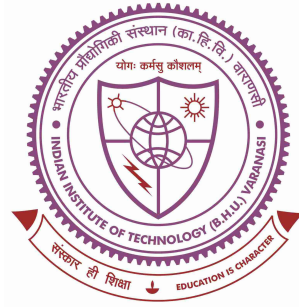


Using gravitational lensing to probe distribution of neutral hydrogen in the post-reionization Universe



THESIS SUBMITTED
FOR THE AWARD OF
DOCTOR OF PHILOSOPHY
in
PHYSICS
by
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DEPARTMENT OF PHYSICS
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ROLL NUMBER
17171001

YEAR OF SUBMISSION
2022

Chapter 5

Summary and conclusion

The main aim of this thesis has been to find the evolution of neutral hydrogen structure in the diffuse post-reionization era. Being a weak signal, the major problem in its observation is the Diffuse galactic Foreground signal and extragalactic point source emission.

To overcome this problem, here we propose to use strong gravitational lensing by nearby galaxy clusters. Previous studies (Cerny, 2018; Sharma et al., 2018) have shown that lensing can magnify the background signal keeping the DGSE unaltered. In this thesis, we investigated how it is feasible to observe the 21 cm signal with strong lensing phenomena. Our initial investigation demonstrated that the strong lensing does selectively enhance the 21 cm power spectra relative to the DGSE and hence this technique is promising. However, owing to the least covered region of strong magnification by the galaxy clusters, The estimates of lensed power spectra suffer high sample variance.

To overcome this issue we conceived an estimator of the lensed HI power spectra, the Combined Lens Estimator that uses the collective magnification along different cluster lens lines of sights assuming the spatial ergodicity of 21 cm fluctuations. Using known lens models from literature we show that with the bandwidth of 16 MHz, 5σ level of signal to noise detection of 21 cm power spectrum with an observation time of 400 hours for source at a redshift of 1.25 and 1.5 and 200 hours for source at a redshift of 3. Though the

selective enhancement of the 21 cm Power spectrum by lensing does not make it above the DGSE power spectrum, the relative decrement of the DGSE over 21 cm in this power spectrum is expected to overcome severe foreground mitigation challenges.

5.1 Limitations and Future Scope

This procedure has the advantage of observing the magnified background signal, In this thesis, we haven't evaluated the effect of error in the Lens models. Furthermore, we haven't also considered the effect of continuum emission from the galaxy cluster that also adds to the 21 cm signal. Though later is expected to be tamed by strategic uvsb procedure, the accurate lens models would be the key for the success of this method.

Apart from addressing the challenges of this technology discussed here, we would also like to access the effectiveness of detection of individual galaxy H I content and dynamical parameters by strong lensing. Blecher et al. (2019) have reported the first attempt to observe a strongly lensed galaxy at a redshift of 0.4. Ghara et al. (2018) discuss a matched filtering technique to use his observed visibilities to detect ionised bubbles in the reionization epoch. Since several optical observations (Cerny, 2018; Richard et al., 2010b, 2021) show detection of a large sample of lensed galaxies in post reionization era, we believe a parametric matched filter technique can be used to find H I content and dynamics of galaxies over a large range of post-reionization redshifts.

Here, we use gravitational lensing to improve on (a) the faint H I signal and (b) the ratio of H I signal to the foregrounds. The thesis presents a methodology, a lensing estimation of the redshifted 21-cms signal, which enhances the H I signal over the foregrounds including the diffuse foreground from the Galaxy. A method to further improve it would be to measure the radio foreground at multiple frequencies (other than the redshifted 21-cm frequency in question) in the direction of the galaxy cluster lenses and interpolate the signal at the observed frequency of the 21-cm signal. This method would also help with

the estimation of the continuum emission from the galaxy cluster itself. However, an estimation of the continuum signal effectively, to the required accuracy, is a challenge. Several methods including foreground subtraction (Trott, 2016) and foreground avoidance (Datta et al., 2010) have been proposed. We would like to investigate the effectiveness of these methods in the lensing estimator in a future study.

Fig 5.1 show a plot of the number of the lensed galaxies detected at different redshifts from (Richard et al., 2021). Such detections are then expected to shed light on the redshift dependence of Baryonic Tully fisher relation and relation of gas content and dynamics over a range of redshifts. We plan to pursue investigation in this direction in future.

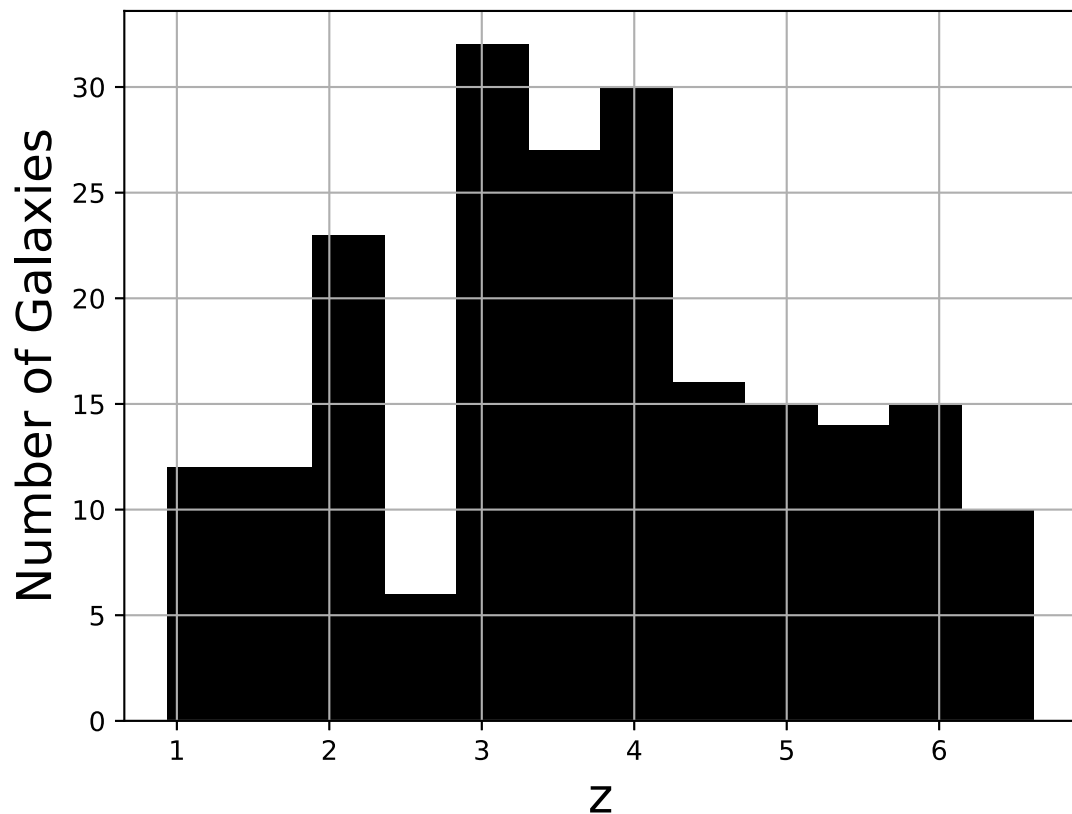


Figure 5.1: Histogram is between redshift and Number of galaxies with 12 number of bins, data is taken from Richard et al. (2021)