EVOLUTION OF CORRELATION FUNCTIONS IN MODELLED LYMANα FOREST SPECTRA

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Abstract

We study the evolution with redshift of the Lymanα forest with a PM-code including photo-ionization and cooling of the baryonic matter component [4, 6, 7]. Since the code reproduces the statistics of $\mathrm{d}n/\mathrm{d}b$, $\mathrm{d}n/\mathrm{d}N_{\mathrm{HI}}$ and $\mathrm{d}n/\mathrm{d}z$ very well, now we consider the clustering properties of the Lymanα forest clouds in more detail. We have computed the two-point correlation functions along random lines of sight at different redshift intervals. The resulting signal at $\Delta v < 300\,\mathrm{km\,s^{-1}}$ for $z \approx 3$ is in good agreement with recent observations [2]. We discuss the origin and the behavior of the correlation signal evolution depending on redshift and column density.

1 Introduction

Using the two population description of the Lymanα forest clouds from our simulation, we are

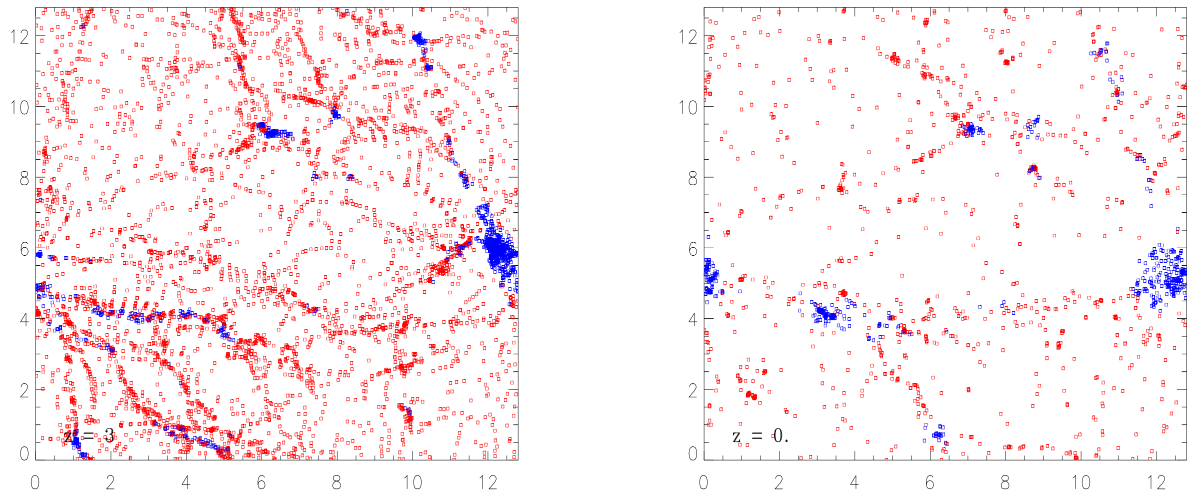

Figure 1: void (open squares) and filamentary (shaded squares) population clouds in a slice of 50 kpc thickness of a $(12.8\,\mathrm{Mpc})^3$ simulation box at redshift $z = 3$ (left) and $z = 0$ (right).

able to discern the gas which is involved in shock processes and mostly located in dense filaments or clumps ("filamentary" population) and the primordial gas still not influenced by any shock heating ("void" population) [7] (s. Figure 1). The evolution of this two gas components has shown to be quite different: at high redshift, the void component is dominant and the number of absorbers are strongly declining with redshift. At medium redshift $z \approx 2$, the number density of the void component drops below the nearly constant level of the filamentary component. At low redshift, the gas in filaments dominates the number density distribution with an almost flat power law (s. Figure 2).

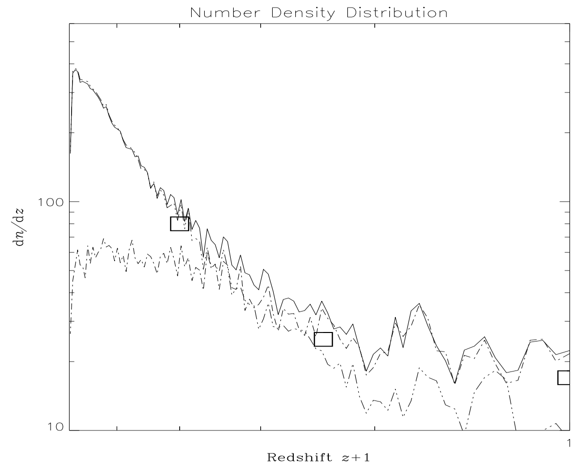

Figure 2: Number density distribution for absorption lines with $N_{\rm HI} > 10^{14}$ cm^{-2} of the filamentary (dash-dotted line) and void (dash-threedotted line) gas component, resulting in an overall distribution (solid line) which is in good agreement with the observations [1, 3, 5] (data points).

2 Correlation Functions

On the basis of the simulated spectra we have derived the two-point correlation functions for the cloud distributions along the lines of sight in order to determine the clustering properties of the IGM in dependence of the column densities of the clouds and of the redshift evolution. We were able to reproduce the signal reported by Cristiani et al. [2] for $\log N_{\rm HI} > 13$ at redshift $z = 3$ which decreases with increasing redshift (cp. Figure 3 and Figure 4, left panels).

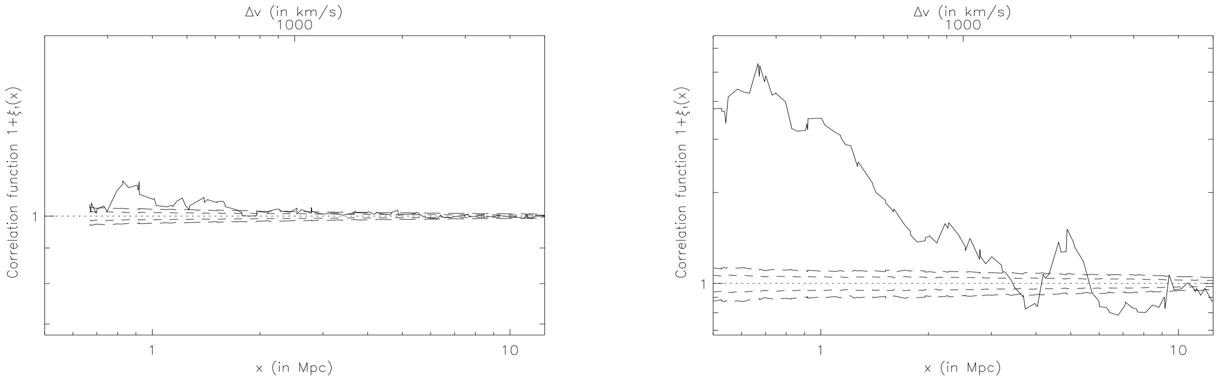

Figure 3: Correlation Functions of Lymanα forest clouds at redshift $z = 3$ with column densities $\log N_{\rm HI} > 13$ for both populations (left) and the filamentary population only (right). The dashed lines give the 1σ and 2σ level of a possonion distribution respectively.

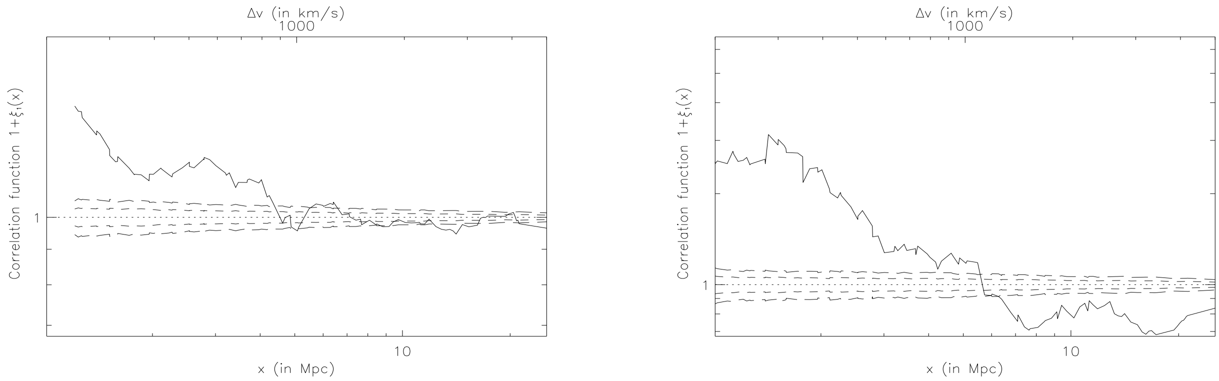

Figure 4: Correlation Functions of Lymanα forest clouds at redshift $z = 1.5$ with column densities $\log N_{\rm HI} > 13$ for both populations (left) and the filamentary population only (right). The dashed lines give the 1σ and 2σ level of a possonion distribution respectively.

However, taking into account the filamentary population only, both the amplitude and the correlation radius increase drastically (cp. Figure 3 and Figure 4, right panels). In this case the shape and the strength of the signal do almost not change with redshift and column density. Contrary the correlation function including both components is very sensitive to the column density thresholds and is strongly evolving with redshift. Considering clouds at higher column densities increases the signal significantly. It is not possible however to discriminate the two populations by column density cuts only.

3 Redshift Evolution

Fitting a power law $\xi[r] = \left(\frac{r}{r_0}\right)^{-\gamma}$ to the correlation functions, we found $\gamma \approx 1.6$ more or less constant over the whole redshift range. We therefore plotted the evolution of the remaining parameter r_0 for both populations over the whole redshift range (s. Figure 5).

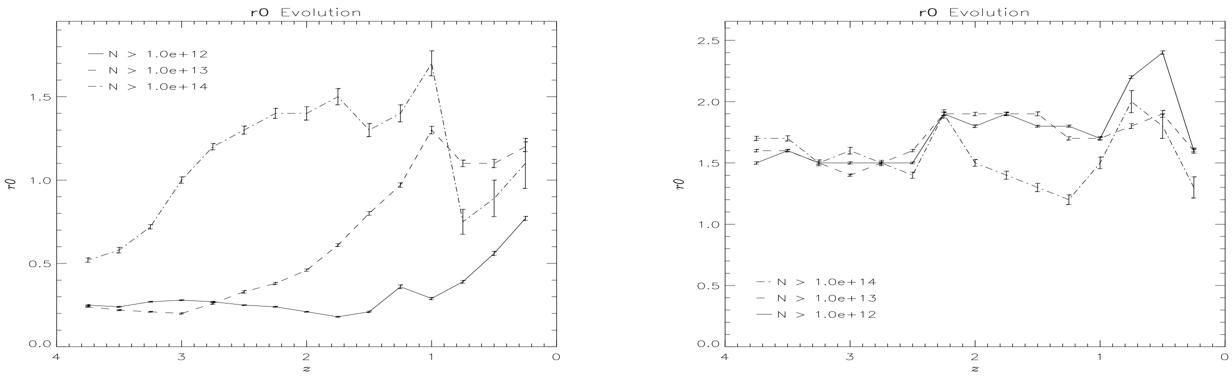

Figure 5: Redshift evolution of r_0 for fitted correlation functions $\xi[r] = \left(\frac{r}{r_0}\right)^{-\gamma}$ with fixed $\gamma = 1.6$ for both populations (left) and the filamentary population only (right). Error bars result form fitting the correlation functions with least χ^2.

Figure 5 (left panel) indicates on a transition from small scale clustering (≈ 0.3 Mpc comoving) to clustering scale of about 1.5 Mpc. Small scale clustering appears at epochs and column density thresholds when the contribution of the void population is dominant. At low redshifts and/or high column densities the contribution by filaments and halos leads to an increasing correlation radius which is at $z \sim 0$ in agreement with the the almost constant correlation radius due to the contribution from the filamentary population only. We conclude that the intergalactic gas is clustered on typical scales of ~ 0.3 Mpc probably related to the typical cloud size of the diffuse gas. In course of evolution the HI density of those clouds will be deluted by cosmic expansion and the UV-flux. A fraction of these clouds will accrete onto the dense structures like filaments and galactic halos. This eventually results in a characteristic separation between the gas clouds given by the structure of the filamentary distribution.

4 Conclusions

In our simulation we are able to distinguish between two populations of absorbing HI clouds:

- the filamentary population mostly located in big halos and elongated filamentary structures which produces a strong clustering signal at scales ≈ 1.5 Mpc comoving.
- the void population consisting probably of mainly primordial gas surrounding the filamentary structures and filling the voids delineated by the filaments. This population is weakly clustered on smaller scales of ≈ 0.3 Mpc comoving.

According to which population is dominant a transition between the two scales can be noticed at each given column density threshold. Since the filamentary structures contain the dense matter configurations where most probably star formation occured the havy element absorption lines (e.g. CIV) are expected to be good tracers for these structures [8].

References

[1] J.H. Bahcall, J. Bergeron, A. Boksenberg, G.F. Hartig, B.T. Jannuzi, S. Kirhakos, W.L.W. Sargent, B.D. Savage, D.P. Schneider, D.A. Turnshek, R.J. Weymann, A.M. Wolfe, 1993, *Astrophys. J., Suppl. Ser.* **87**, 1

[2] S. Cristiani, S. D'Odorico, V. D'Odorico, A. Fontana, E. Giallongo, S. Savaglio, 1997, *Mon. Not. R. Astron. Soc.* **285**, 209

[3] L. Lu, A.M. Wolfe, D.A. Turnshek, 1991, *Astrophys. J.* **367**, 19

[4] J.P. Mücket, P. Petitjean, R.E. Kates, R. Riediger, 1996, *Astron. Astrophys.* **308**, 17

[5] P. Petitjean, J.K. Webb, M. Rauch, R.F. Carswell, K. Lanzetta, 1993, *Mon. Not. R. Astron. Soc.* **262**, 499

[6] P. Petitjean, J.P. Mücket, R.E. Kates, 1995, *Astron. Astrophys.* **295**, L9

[7] R. Riediger, P. Petitjean, J.P. Mücket, 1998, *Astron. Astrophys.* **329**, 30

[8] W.L.W. Sargent, 1998, in *Galaxy Evolution: Connecting the Distant Universe with the Local Fossil Record*, 39