# MODELING THE EVOLUTION OF THE LYMAN-ALPHA FOREST

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We study the time evolution of the number density of Ly$\alpha$ clouds in a CDM model using numerical simulations. We demonstrate that two Ly$\alpha$ cloud populations may be distinguished: a 'void' component and a component associated with dense structures.

We have performed simulations described in detail by Mücket et al. (1996) modeling the cloud distribution along a line of sight up to a fictitious QSO at redshift $z = 5$. In particular, the UV flux has been obtained consistently by the same simulation. We have assumed that the flux generated at given redshift $z$ is proportional to the rate at which the baryonic material cools below $T_4 = 0.5$ ($T = 10^4 T_4$) in the simulation. Besides heating due to the photoionizing UV flux we have considered in rough approximation heating due to star formation processes. In Fig. 1 the obtained time dependent flux intensity is shown. The simulations used $128^3$ particles on a $256^3$ grid and a box size of 12.8 Mpc corresponding to a co-moving cell size of 50 kpc ( $h = 0.5$, $\Omega_b$ = 0.05). During the simulation we distinguished between two different populations of clouds: (1) Clouds being involved in shell-crossing processes (shocks) and therefore associated with structures of enhanced density like filaments and sheets. (2) Gas clouds being located in the surroundings of the structures and in underdense regions (voids) of the matter distribution. Results are shown in Fig. 2. The square symbols give the data points one has to compare with (Lu et al. (1991); Petitjean et al. (1993); Bahcall et al. (1993)). The left hand figure presents the time-dependence of $dn/dz$ for all clouds ($\gamma \approx 2.6$ for $1.5 < z < 5.$ and

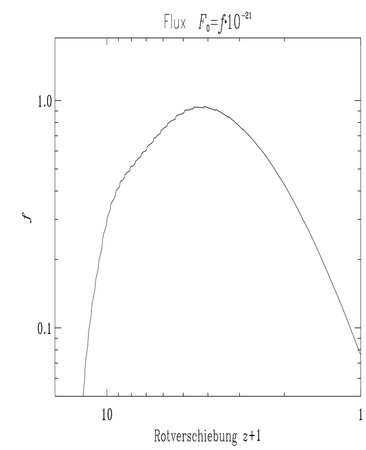


Figure 1: The computed flux as a function of the redshift $1 + z$

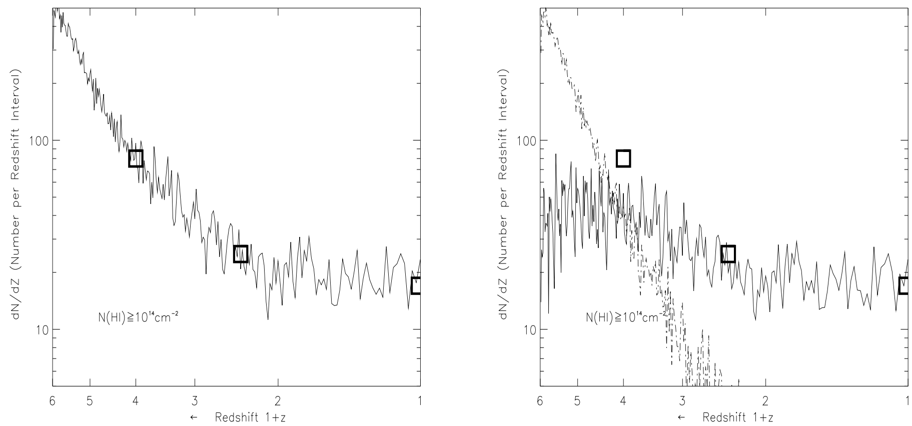


Figure 2: The evolution of the number density per redshift for $N_{\rm HI} \geq 10^{14}$: total contribution (left) and separate contributions of the two Ly$\alpha$ cloud populations

$\gamma \approx 0.6$ for $0 < z < 1.5$, where a power law $dn/dz \propto (1+z)^{\gamma}$ is assumed); cp. also with observations presented by Januzzi (this volume). The right hand figure shows the contribution of the two populations separately. The dashed curve gives the time evolution of the "void" population showing a very strong evolution ($\gamma \geq 5$) of the number density according to $N_{HI} \propto (1+z)^5$ if the optically thin clouds are co-expanding. The curve for the time dependence of the "filament" population leads to $\gamma \approx 2.5$ till $z \approx 1.5$ and shows then a clear flattening ($\gamma \approx 0.6$ for $z < 1.5$ ). That would lead to the conclusion that Ly$\alpha$ clouds with $N_{HI} > 10^{14}$ cm$^{-2}$ observed at low redshifts are all associated with dense structures. At high redshifts the main contribution to the number density comes from the "void" population. The investigations show that a considerable part of clouds with lower column densities ($N_{HI} \leq 10^{13}$ cm$^{-2}$ survives till $z = 0$ (cp. with observation of Stocke et al. (1995)). The obtained HI distribution has been used to generate complete spectra along the l.o.s. and to determine the $N_{HI}$ and Doppler parameter distribution. Taking in mind the general assumptions of our model the results lead to the conclusion that the Ly$\alpha$ absorption line observations can provide direct information about the distribution of the dark matter structures in the universe.

## References

1. J.P. Mücket, P. Petitjean, R. Kates, R. Riediger, A&A, 308, 17, 1996.