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THE MEAN ABSORPTION DUE TO THE LYα FOREST IN THE SPECTRA OF HIGH REDSHIFT HIGHLY LUMINOUS QUASARS

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Abstract. The Lyα forest is an absorption phenomenon seen in the spectra of high redshift quasars (QSOs). It is the only direct observational evidence of the existence of a pervasive intergalactic medium (IGM), which is believed to contain, at high redshift, most of the baryonic matter of the universe. In this paper, we first present our new observations of high redshift highly luminous QSOs (m $\leq$ 16.70 and 2.62 $\leq z_{em} \leq$ 3.91) in the Northern Hemisphere, obtained with the CARELEC spectrograph at the OHP. We then use these observations to determine the redshift evolution of the mean absorption in the Lyα forest.

1 Introduction

The numerous absorption lines seen in the spectra of distant quasars, the so-called Lyα forest, reveal the intergalactic medium (IGM) from the local universe up to redshifts larger than 6. It is believed that more than 90% of the cosmic baryonic matter is in the photo-ionized inter-galactic medium, at least from z$\sim$2 to z$\sim$3. Numerical simulations have shown that the gas follows well the potential of the underlying dark-matter.

The standard method to analyze the observed Lyα forest is to fit the spectra as a superposition of Voigt profiles (e.g. Carswell et al. 1987). The IGM is therefore described as a juxtaposition of discrete clouds rather than a continuous field. New methods have been implemented recently to recover the real space density distribution of the IGM by inversion of the Lyα forest (Nusser & Haehnelt, 2000; Pichon et al. 2001). Using these new methods, it is possible to derive the statistical characteristics of the density field and therefore to determine the power spectrum of the initial perturbations which is a fundamental prediction of different cosmological theories.

To calibrate the simulations and therefore these new methods, it is crucial to know what is the actual mean H I optical depth of the IGM. In this project, we use medium spectral resolution of luminous high-redshift QSOs to constrain better this quantity.

2 Observations and data reduction

We have observed twelve bright and high redshift QSOs (m $\leq$ 16.70 and 2.62 $\leq z_{em} \leq$ 3.91, see Table 1) with the CARELEC spectrograph at the Observatoire de Haute-Provence (OHP) from April 24 to May 2, 2006. The 300 lines/mm grating was used with 133 Å/mm cross dispersion grating and a FWHM resolution $\sim$ 5.5 Å with the f/15.5 Cassegrain focus bonnette. The height of the slit was 5.5 arc-min with a width of 3 arc-second. The detector was an EEV chip with 2048$\times$1024 pixels of 13.5 μ each. The central wavelength was λ5500 Å and the useful wavelength range $\lambda\lambda$3800 to 7300 Å. The reduction was performed using routines from the LONG MIDAS context. The cosmic rays were flagged using a median filter. Wavelength calibration was done using the He and Th lamps. Air-vacuum wavelength conversion and heliocentric correction were applied. The flux

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calibration was performed by observing two standard stars, Feige 34 and BD +26 2606, with the same instrumental configuration and they were reduced in exactly the same way as the QSOs.

Table 1. *Observed QSOs*

QSO	z_{em}	m_v
APM 08279+5255	3.911	15.20
B 1422+231	3.620	16.50
HS 0741+4741	3.210	16.20
S4 0636+68	3.177	16.60
SBS 1425+606	3.164	16.57
HS 1946+7658	3.051	16.20
S5 1759+75	3.050	16.50
HS 1248+7102	2.990	16.70
CSO 1107	2.830	17.10
HS 1700+6416	2.736	16.20
CSO 1061	2.669	16.20
CSO 38	2.620	16.40

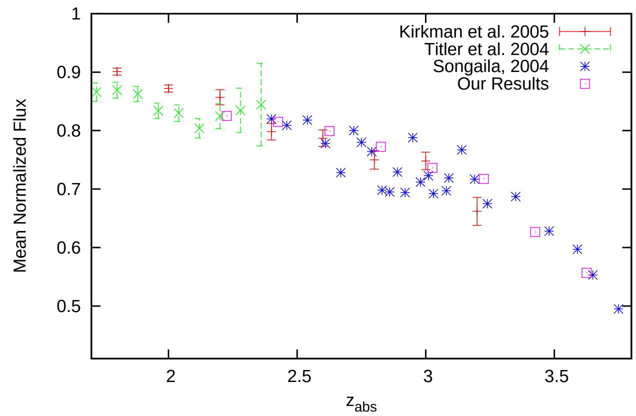

Fig. 1. *Mean normalized flux as a function of redshift.*

3 Mean absorption and results

Even if baryons in the intergalactic medium, from the local universe up to z $\sim$ 6, are highly ionized, the small residual fraction of neutral hydrogen is large enough to induce a detectable absorption because of the large cross-section for the Lyα transition. The mean absorption due to the Lyα forest is therefore the most basic observable of the baryonic matter in the universe. Following Oke & Korycansky (1982), the mean flux decrement is: $D_A = \langle 1 - \frac{f_{\rm obs}}{f_{\rm cont}} \rangle = \langle 1 - e^{\tau} \rangle = 1 - e^{\tau_{\rm eff}}$
where $f_{\rm obs}$ is the observed (residual) flux, $f_{\rm cont}$ is the estimated flux of the unabsorbed continuum, τ is the resonance line optical depth, and $\tau_{\rm eff}$ is the effective value of it. The final aim of our work is to discuss the uncertainties in the continuum determination but in this particular paper we will just use the local continuum for QSOs with $z_{\rm em} < 3.5$ and the smooth continuum for QSOs with $z_{\rm em} > 3.5$. Note that we did not use the spectruum of CSO 1107 in our calculations because of the low S/N ratio obtained for this QSO (S/N $<$ 35). We used the wavelength range from $\lambda_{Ly\beta}(1 + 3000({\rm km/s})/c)$ to $\lambda_{Ly\alpha}(1 - 5000({\rm km/s})/c)$ to avoid the proximity effect close to the QSO and also to avoid confusion owing to an overlap of intervening Lyα and Lyβ absorptions. Figure 1 shows the mean normalized flux ($\langle \frac{f_{\rm obs}}{f_{\rm cont}} \rangle$) as a function of redshift for $\Delta z = 0.2$. Our results not only show, as expected, a smooth evolution of the mean absorption with redshift, but are also in good agreement with the partial results of Kirkman et al. (2005), Tytler et al. (2004), and Songaila (2004) with less dispersion.

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