Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2014/04/jls.htm
2014 Vol. 4 (S4), pp. 1343-1349/Kiamehr
Research Article

PREDICTING QSOs CONTINUA FROM THE SDSS AT z~3, m_g< 18 AND S/N > 20

***Zeinab Kiamehr**
Department of Marines Sciences, Basic Sciences group, Chabahar Maritime University, Chabahar, Iran
**Author for Correspondence*

ABSTRACT
Quasar (QUASAR or QUASi-stellAR or QSO) is one of over a thousand known extragalactic objects, star like in appearance and having spectra with characteristically large red shifts, that are thought to be the most distant and most luminous objects in the universe. In the spectrum of distant QSOs and in a region with wavelengths shorter than the Lyα emission radiation, a lot of absorption lines are being seen which relate to neutral hydrogen in the intergalactic medium. Absorption lines imprinted on the spectra of bright background QSOs are one of the main sources of information about the physical and chemical properties of intervening systems. It is well known that information about their temperature, density, chemical abundances, and kinematics can be extracted from the analysis of these absorption lines. In order to measure this absorption, must first determined the QSO continuum. This is not obvious especially at low spectral resolution and high red shifts where there is little unabsorbed continuum remaining in the spectrum. Therefore a mathematical technique to predict the QSO continuum of the bright SDSS-DR7 QSO at z~3 has been applied and measures the amount of absorption, known as the flux decrement, *DA*. The end our measured flux decrement with the other works to check the accuracy of this method has been compared.

Keywords: *Observational Cosmology, QSO Continuum, Intergalactic Medium (IGM), Principal Component Analysis (PCA)*

INTRODUCTION
The numerous absorption lines seen in the spectra of distant QSOs blue wards of the Lyα emission line from the QSO, the so-called the Lyα forest, reveal the intergalactic medium(IGM) up to redshift larger than 6. The Lyα forest was predicted and first detected by Gunn and Peterson (1996). It provides information on the overall matter distribution on scales smaller than those accessible with other observables as the Cosmic Microwave Background (CMB) (Croft *et al.*, 1998a; Pichon *et al.*, 2001a; McDonald *et al.*, 2005a). The physical understanding of the intergalactic medium comes from the detailed comparison between the results of N-body numerical simulations of the growth of structures in the universe and observations of the Lyα absorption lines (Petitjean and Ledoux, 1999a; Theuns, 2005b).
The absorption lines seen in the spectra of distant QSOs reveal the intergalactic medium, environment of QSO, halo and disk of galaxies up to redshifts larger than 6, i.e. about 13 milliard light years (Rauch *et al.*, 1998b). Understanding the chemical abundances in these distant is a major goal of QSO research. The first spectroscopic studies shown simply that QSOs contain metals elements (such as: C, N, O and heavier) produced by stellar nucleus synthesis. In order to measure this absorption, must first determine the QSO continuum.
For this purpose, the intrinsic QSO continuum has to be determined over the Lyαforest. In spite of the many measurements (Schneider *et al.*, 1991; Becker *et al.*, 2001b; Kim *et al.*, 2007a; Bernardi, 2003a; Seljak and Cen, 2003b; White *et al.*, 2003c; Aracil *et al.*, 2004a; Songaila, 2004b; Tytler *et al.*, 2004b; Kirkman *et al.*, 2005c; DallAglio *et al.*, 2009) no consensus has been reached yet on what is the best method to determine the continuum. Although the broad picture describing the IGM might be correct, the measurement of the power spectrum is limited by uncertainties in the determination of the QSO continuum for scales larger than ~$12h^{-1}$Mpc (Nicolson, 1999b; Efstathiou *et al.*, 2002b; Nusser and Haehnelt, 2000; Songaila and Cowie, 1996; Whitney *et al.*, 1983; Strauss, 2002a). Francis *et al.*, (1992), applied PCA to the Large Bright QSO Survey optical spectra of QSOs to give an objective classification

scheme, and showed that any normalized QSO spectrum$q_i(\lambda)$, is well represented by a reconstructed spectrum$r_{i,m}(\lambda)$, is a weighted sum of *m* principal components:

$$q_i(\lambda) \cong r_{i,m}(\lambda) = \mu(\lambda) + \sum_{i=1}^{m} c_{ij}\varepsilon_j(\lambda) \quad (1)$$

$\mu(\lambda)$is the mean of many QSO spectra,$\varepsilon_j(\lambda)$ is the *j*th principal component, and $c_{ij}$is its weight. May be able to predict the unabsorbed flux in the Lyα forest if it is correlated with the unabsorbed flux at other wavelengths. Correlations have been applied in a set of QSO spectra that cover both 1020Å≤λ≤1215Å and 1216Å≤λ≤1600Å. The red-side has been used spectra of individual QSOs to make predictions of their blue sides. In this study, PCA method applied to derive the continuum of QSO spectra in the Lyα forest and to discuss their influence on the determination of the mean HI absorption of the IGM and its evolution with redshift (Aghaee *et al.*, 2006; Suzuki *et al.*, 2005b; Hewett *et al.*, 2001c).

PCA of QSO Spectra

PCA is a popular technique for identifying the moments that describe the variance in data without relying on having measured those moments in their natural coordinate frame (Francis *et al.*, 1992). More recently, Suzuki *et al.*, (2005d) used PCA to find correlations between the red ($\lambda > 1200$Å) and blue ($\lambda < 1200$Å) parts of the spectra in order to derive the continuum in the Lyα forest from the red continuum. The calculation of correlation matrix related to different wavelengths by using the average continuum (Suzuki *et al.*, 2005d).

$$\mathrm{R}(\lambda_m, \lambda_n) = \frac{1}{N-1}\sum_{i=1}^{N}\frac{[q_i(\lambda_m) - \mu(\lambda_m)][q_i(\lambda_n) - \mu(\lambda_n)]}{\delta(\lambda_m) - \delta(\lambda_n)} \quad (2)$$

Where$\mathrm{R}(\lambda_m, \lambda_n)$is the correlation between λ_m and λ_n, $q_i(\lambda)$ is the continuum-fitted and normalized spectrum for the *i*th QSO, ***N*** is the total number of QSO spectra, and $\delta(\lambda_m), \delta(\lambda_n)$ are the standard deviations of the flux in the *m*th and *n*th wavelength bins λ_m and λ_n, respectively and λ_m and λ_n are of wavelengths *m* and *n*. The wavelengths correlation of red and blue part of spectrum of about 0.2–0.6 and for emission lines, this correlation is about 0.8 (Suzuki *et al.*, 2005), so it seems that only by the red part of spectrum able to predict blue part. The covariance matrix ***V*** has been calculated for 50 QSOs (Eq.3), by analyzing the covariance matrix ***V*** and making the matrix ***P***, principal components have been obtained. So covariance matrix consists of the diagonal matrix***Λ***beside special vectors and has eigenvalues of ***V***.

$$\mathrm{V}(\lambda_m, \lambda_n) = \frac{1}{N-1}\sum_{i=1}^{N}[q_i(\lambda_m) - \mu(\lambda_m)][q_i(\lambda_n) - \mu(\lambda_n)] \quad (3)$$

$$V = P^{-1}\Lambda P \quad (4)$$

The considered eigenvalues are called principal components that are connected with columns of the matrix ***P***. The first, second and third PCS account for 63:4; 14:5 and 6:2% of the variance respectively, and the first seven PCS take 96:1% of the total variance. The first PCS carries Lyα, Lyβ and high ionization emission line features (OVI, NV, SiIV and CIV) that are sharp and strong. The second PCS has low ionization emission line features (FeII, FeIII, SiII and CII) that are broad but not sharp. Weights c_{ij}, related with the *j* principal component of an *i* QSO spectrum is calculated (Eq.5), these weights are dependent on the whole spectrum. If the first *m* principal component has been used, the rebuilt spectrum with $r_{i,m}(\lambda)$ has been gotten the$\xi_j(\lambda)$ look similar to QSO spectra but with more structure at the wavelengths of the emission lines (Aghaee *et al.*, 2010b).

$$c_{ij} = \int_{1020\text{Å}}^{1600\text{Å}}[q_i(\lambda) - \mu(\lambda)]\varepsilon_j(\lambda)d\lambda \quad (5)$$

The goal is the predict continuum in the Lyα forest by using wavelengths spectrum longer than emission line of QSO Lyα. For determining the connection between red and blue parts of QSOs spectrum, the first *m* principal component $\xi_j(\lambda)$ with weights c_{ij} must be found. All wavelengths related to both red and blue parts of spectrum (1020Åto 1600Å) have been used. Then repeating the first phase of course only by using the red part of spectrum (1216Åto 1600Å). The obtained principal component in this phase is

showed by $\varepsilon_j(\lambda)$ and the related weights are showed by d_{ij}. The weights is written in matrix (N × m) for C = c_{ij} and similarly for D = d_{ij}. Finally finding matrix (m × m) projection matrix X = x_{ij} , which translates the weights found on the red side to the weights for the whole spectrum (Eq.6), where *N* is number of QSOs, and *m* is the first ten principal component spectra (PCS). The first ten PCS were used, because have the greatest amount of variance (greater than 96.1%) and the other PCSs involve little variance, which are almost negligible.

C=D.X (6)

Making a Prediction

In the PCA method, the continuum of individual QSOs is predicted using the red side of its spectrum. The covariance matrix ***V*** can be calculated for the training set as (Eq.3). The PCS can be found by decomposing the covariance matrix ***V*** into the product of the orthonormal matrix ***P*** which is composed of eigenvectors, and the diagonal matrix $\boldsymbol{\Lambda}$ containing the eigenvalues (Eq.4). The weight c_{ij} of the jth principal component for QSO spectrum $q_i(\lambda)$ can be found by (Eq.5). The weights b_{ij}, a_{ij} and $P_{i,m}(\lambda)$ can be made by the red side of its spectrum:

$$b_{ij} = \int_{1216Å}^{1600Å} [q_i(\lambda) - \mu(\lambda)]\xi_j(\lambda)d\lambda \quad (7)$$

$$a_{ij} = \sum_{k=1}^{m} b_{ik}\, x_{kj} \quad (8)$$

$$P_{i,m}(\lambda) = \mu(\lambda) + \sum_{j=1}^{m} a_{ij}\xi_j(\lambda) \quad (9)$$

Table 1: List QSOs with redshift z ~3, m_g< 18 and S/N > 20

QSO	z	S/N	m_g
J123549.46+591027.0	2.82	28.9	17.053
J020950.71-000506.4	2.841	29.1	17.026
J103249.88+054118.3	2.845	28.4	17.374
J084948.98+275638.7	2.848	21.4	17.964
J012156.03+144823.9	2.869	31.1	17.422
J160843.90+071508.6	2.8775	35.3	17.803
J105236.34+253956.1	2.878	23.6	17.853
J093207.46+365745.5	2.893	27	17.696
J135044.66+571642.9	2.896	27.3	17.445
J003311.34-171041.5	2.905	20.6	17.973
J152119.68-004818.7	2.9339	25.5	17.932
J075326.11+403038.6	2.929	20.9	17.917
J160441.47+164538.3	2.932	38	16.908
J111038.63+483115.6	2.953	33	16.792
J130337.21+194926.7	2.953	22.5	17.844
J134811.76+281801.8	2.9655	39.4	17.566
J090423.37+130920.7	2.968	30.6	17.596
J120331.29+152254.7	2.9763	32.7	17.933
J132255.66+391207.9	2.978	25.4	17.752
J120006.25+312630.8	2.984	34	17.619
J143912.34+295448.0	2.9923	24.1	17.654

The spectrum of $P_{i,m}(\lambda)$ is different from the rebuilt spectrum in $r_{i,m}(\lambda)$, because therebuilt spectrum of weights resulted from red and blue parts of the obtained spectrum, while in these assumptions, have been used only weights of the red part of spectrum (Suzuki *et al.*, 2005d).

Data and Main Results

We made a code and then applied it to allSDSS-DR7 (Sloan Digital Sky Survey-Data Release7) spectral data of high luminous QSOs (g magnitude <18) at z~3 which have an S/N ratio of more than 20 (Table 1). The QSOcontinuum for all QSOs in this sample has been predicted, which recovered the rest-wavelength range between 1020Å, the Lyβ+OIV emission-line blended, and 1600Å, the CIV emission line. The results were shown of this method for 4 QSOs (Figure 1).The means of all predicted continuum spectra for each one of 21 QSOs and the resulted spectrum has been taken and the mean continuum was compared with the mean continuum of 50 QSOs (z≤1) in the article (Suzuki *et al.*, 2005d) (Figure 2).

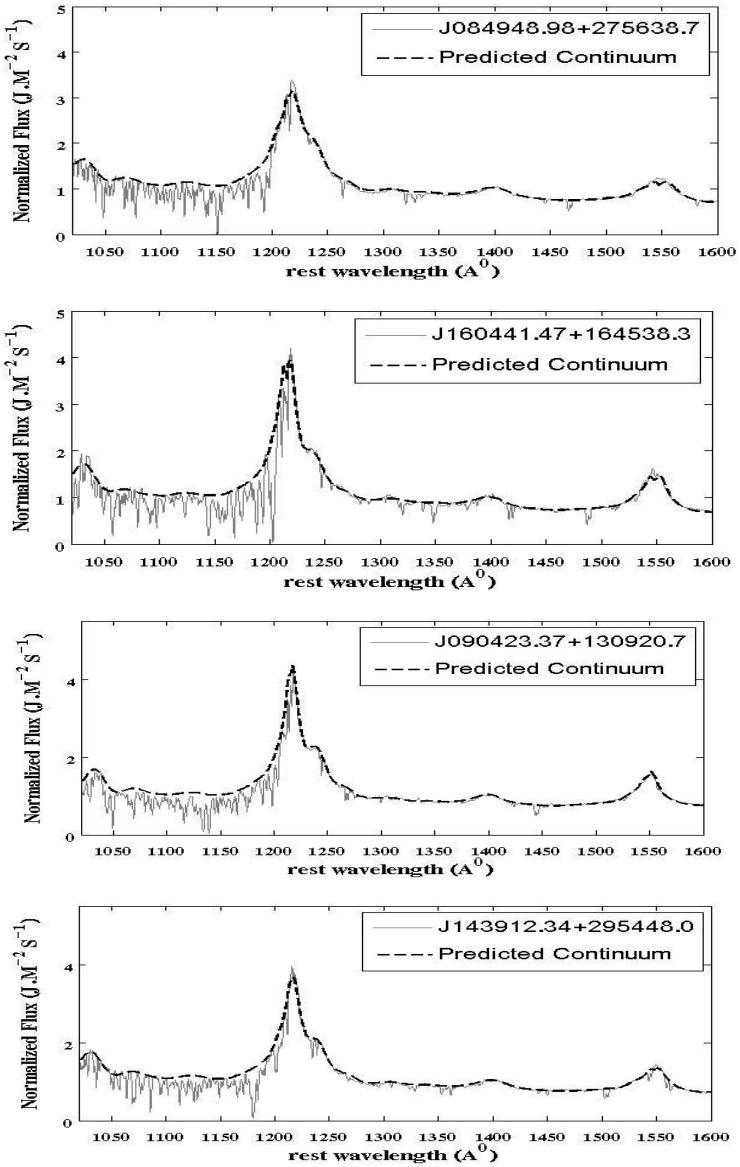

Figure 1: Example of a continuum predicted for 4 QSOs, SDSS-DR7 J084948.98+275638.7, J160441.47+164538.3, J090423.37+130920.7 and J143912.34+295448.0. Observational spectrum and the predicted continuum for these QSOs derived from applying the PCA method described in the text

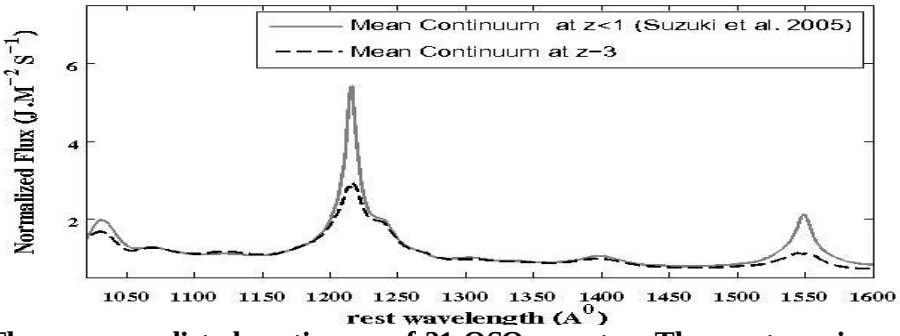

Figure 2: The mean predicted continuum of 21 QSOs spectra: The spectrum is normalized near 1280Å

Determining the Quantity of Neutral Hydrogen Absorption

After determining continuum for all QSOs and for the purpose of determining the average quantity of neutral hydrogen absorption by the intergalactic medium (Aghaee *et al.*, 2010b), the *DA* parameter has been calculated, which is defined according to the following equation in the region of the Lyα forest.

$$DA = \frac{1}{(\lambda_2 - \lambda_1)} \int_{\lambda_1}^{\lambda_2} \frac{(F_{cont} - F_{obs})}{F_{cont}} d\lambda \quad (10)$$

$F_{obs}$is the observed flux, F_{cont} is the flux in the continuum derived from PCA method. The optional wavelength confines for calculating *DA* between (Eq.11) and (Eq.12) was considered, whereas c is the light velocity and the step of transition to red was defined Δz = 0:1. Errors are taken as the standard deviation of the points in the bin divided by the square root of the number of points. At the end, the average quantity of neutral hydrogen absorption in transition to different redshifts was measured. Our results are compared with other works (Table 2 and Figure 3).

$$\lambda_{Ly\beta}(1 + 3000(km/s)/c) \quad (11)$$

$$\lambda_{Ly\alpha}(1 - 5000(km/s)/c \quad (12)$$

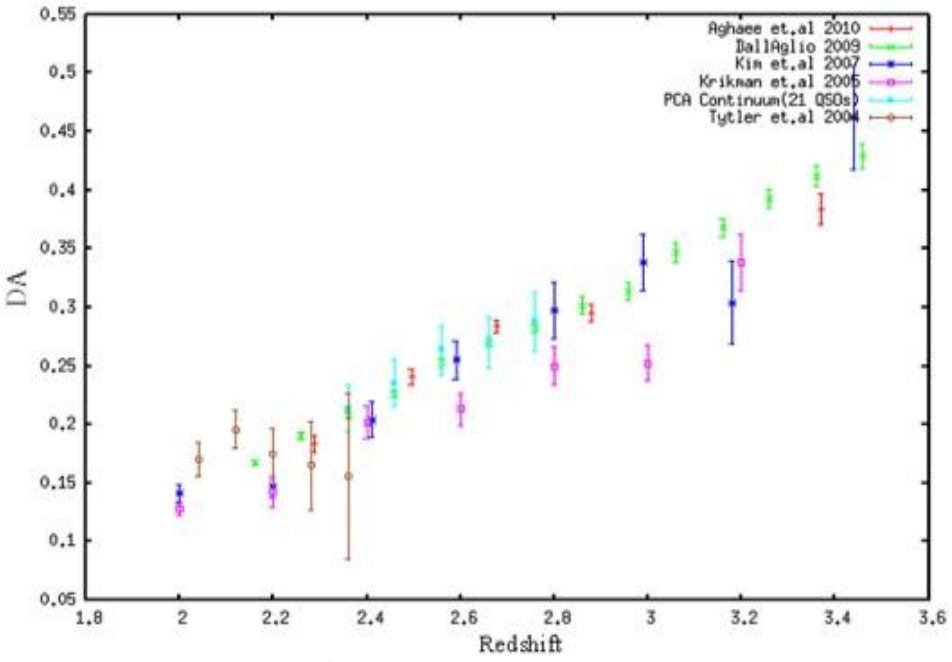

Figure 2: *DA* versus redshift For our results, each point corresponds to the mean

Table 2: *DA* versus redshift for our results, each point corresponds to the mean *DA* in bins of Δz= 0.1 calculated using all QSOs with more than14 lines of sight per bin. Previous measurements by Tytler *et al.*, (2004b); Kirkman *et al.*, (2005c); Kim *et al.*, (2007a); DallAglio *et al.*, (2009) and Aghaee *et al.*, (2010b) are overplotted

z	*DA*	Error
2.36	0.2137	0.01993
2.46	0.2356	0.01940
2.56	0.2634	0.02058
2.66	0.2701	0.02158
2.76	0.2876	0.02503

CONCLUSION

In this paper the PCA method has been discussed, to derive the continuum of QSOs in the Lyα forest. The continuum is used in particular to determine the mean absorption of the IGM. The PCA method was applied to a sample of 21 QSOs (z ~3, m_g<18 and S/N >20). The mean absorption in the IGM, *DA*hasbeen measured, after estimating the continuum with the PCA method applied to the all data. As can be seen in (Figure 2), our results are consistent with the other works which can represent the accuracy of the method. For future researches may be used from other three continuum fitting methods (PL, IE, SL), to predict the continuum for these QSOs. We do think, however, that the best approach is probably to use a combination of these methods.

It should be noted that this paper with Paris *et al.*, (2011) has notable similarities and differences, both of these redshift range of 3 is considered that the existing 78 QSO at z~3, S/N ratio and mg are different (see table 1 Paris *et al.*, 2011). In this paper we examine a subset of the 78 QSO; we made a code and then applied it to all SDSS spectral data of high luminous QSOs at z~3. In fact we've ignored of QSOs with low signal to noise ratios, because if more noise is made more errors, so using QSOs with high signal to noise ratio, we will less error and more accurately. However, in Paris *et al.*, (2011) range wavelength from 1020 to 2000Å considered, but we in this paper for improving the accuracy of our results, wavelength range to predicted continuum in the Lyman-alpha forest limit have selected. On the other hand, the numbers of QSOs in the wavelength range of 1020 to 1600Å which is greater than the number of QSOs that have a range of wavelengths from 1020 to 2000Å. Then we focused on the wavelength range from 1020 to 1600Å.

REFERENCES

Aghaee A, Petitjean P, Stalin S, Guimaraes R and Aracil B (2006). *Proceedings of the Annual Meeting of the French Society of Astronomy and Astrophysics, Proceedings of the Annual meeting of the French Society of Astronomy and Astrophysics* 315.

Aghaee A, Petitjean P, Srianand R, Stalin S and Guimarães R (2010b). Determination of the Mean HI Absorption of the Intergalactic Medium, *Journal of Astrophysics and Astronomy* **31** 59-79.

Aracil B, Petitjean P, Pichon C and Bergeron J (20014a). Metals in the intergalactic medium, *Astronomy and Astrophysics* **419** 811-819.

Becker RH *et al.*, (122). Evidence for Reionization at z~6: Detection of a Gunn-Peterson Trough in a z=6.28 Quasar, *The Astronomical Journal* **122**(6) 2850-2857.

Bernardi M *et al.*, (2003a). A Feature at z~3.2 in the Evolution of the Ly α Forest Optical Depth, *The Astronomical Journal* **125**(1) 32-52.

Croft Rupert AC, Weinberg David H, Katz Neal and Hernquist Lars (1998a). Recovery of the Power Spectrum of Mass Fluctuations from Observations of the Ly alpha Forest, *Astrophysical Journal* **495** 44.

Dall'Aglio A, Wisotzki L and Worseck G (2009). The UV background photoionization rate at 2.3 < z < 4.6 as measured from the Sloan Digital Sky Survey, *Submitted to the Astrophysical Journal, astroph/0906* **1484** 1-14.

Efstathiou A, Rowan-Robinson M and Verma A (2002b). Submillimetre observations of hyperluminous infrared galaxies, *Monthly Notice of the Royal Astronomical Society* **335**(4) 1163-1175.
Francis PJ, Hewett PC, Foltz CB and Chaffee FH (1992). An objective classification scheme for QSO spectra, *Astrophysical Journal, Part 1 (ISSN 0004-637X)* **398**(2) 476-490.
Hewett PC, Foltz CB and Chaffee FH (2001c). The Large Bright Quasar Survey. VII. The LBQS and FIRST Surveys, *The Astronomical Journal* **122**(2) 518-535.
Kiamehr Z and Aghaee A (2012). Determination of the quasar continuum using the principal components of spectrum, *Msc. Thesis, University of Sistan and Baluchestan, Zahedan*.
Kim S, Bolton J, Viel M, Haehnelt G and Carswell R (2007a). An improved measurement of the flux distribution of the Lyα forest in QSO absorption spectra: the effect of continuum fitting, metal contamination and noise properties, *Monthly Notices of the Royal Astronomical Society* **382** 1657-1674.
Kirkman D, Tytler D, Suzuki N, Melis C, Hollywood S, James K, Geoffrey L, Jena T, Paschos P and Norman M (2005c). The HI opacity of the intergalactic medium at redshifts 1.6 < z < 3.2, *Monthly Notices of the Royal Astronomical Society* **360** 1373-1380.
McDonald P *et al.*, (2005a). The Linear Theory Power Spectrum from the Ly α Forest in the Sloan Digital Sky Survey, *The Astrophysical Journal* **635**(2) 761-783.
Nicolson I (1999b). *Unfolding our Universe* (Cambridge University Press) **294**.
Nusser A and Haehnelt M (2000). The amplitude of mass density fluctuations at z~3.25 from the Lyα forest of Q1422+231, *Monthly Notices of the Royal Astronomical Society* **313**(2) 364-376.
Petitjean P and Ledoux C (1999a). Damped Lyman- α Systems, *Astrophysics and Space Science* **265**(1/4) 483-486.
Pichon C, Vergely JL, Rollinde E, Colombi S and Petitjean P (2001a). Inversion of the Lyman α forest: three-dimensional investigation of the intergalactic medium, *Monthly Notices of the Royal Astronomical Society* **326**(2) 597-620.
Rauch M, Sargent Wallace LW and Barlow Thomas A (1998b). Glimpses of the Interstellar Medium at Redshift 3.5, *eprintarXiv: astro-ph/9812027*.
Schneider DP, Schmidt M and Gunn JE (1991). PC 1247 + 3406 - an optically selected quasar with a redshift of 4.897, *Astronomical Journal (ISSN 0004-6256)* **102** 837-840.
Seljak U and Cen R (2003b). Precision cosmology from the Lyman α forest: power spectrum and bispectrum, *Monthly Notices of the Royal Astronomical Society* **344**(3) 776-788.
Songaila A and Cowie L (1996). Metal enrichment and Ionization Balance in the Lyman Alpha Forest at Z = 3, *Astronomical Journal* **112** 335.
Strauss MA (2002a). Science Breakthroughs with the Sloan Digital Sky Survey: Results and Opportunities, *Survey and Other Telescope Technologies and Discoveries. Edited by Tyson, J. Anthony; Wolff, Sidney. Proceedings of the SPIE* **4836** 1-9.
Suzuki N, Tytler D, Kirkman O, John M and Lubin D (2005d). Predicting QSO Continua in the lyα Forest, *Astrophysical Journal* **618** 592-600.
Theuns Tom (2005b). Numerical simulations of quasar absorbers, Probing Galaxies through Quasar Absorption Lines, *IAU Colloquium Proceedings of the International Astronomical Union 199, held March 14-18 2005, Shanghai, People's Republic of China*, edited by Peter R Williams, Cheng-Gang Shu and Brice Menard (Cambridge University Press) Cambridge 185-204.
Tytler D, Kirkman D, O'Meara M, Suzuki N, Orin A and Lubin D (2004c). Mean amount of Absorption from the Intergalactic Medium, *American Astronomical Society Meeting 205, #129.06; Bulletin of the American Astronomical Society* **36** 1557.
White RL, Helfand DJ, Becker RH, Gregg MD, Postman M, Lauer TR and Oegerle W (2003c). An I-Band-selected Sample of Radio-emitting Quasars: Evidence for a Large Population of Red Quasars, *The Astronomical Journal* **126**(2) 706-722.
Whitney AR, Porcas RW and Preston RA (1983). Detection of a compact radio source near the center of a gravitational lens - Quasar image or galactic core, *Science* **219** 54-56.