INTENSITY CORRELATION OF IONIZING BACKGROUND AT HIGH REDSHIFTS

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Lin Zuo[1,2]
[1]Astronomy Department, Caltech, Pasadena, USA
[2]CITA, University of Toronto, Toronto, Canada

1. THE INTENSITY CORRELATION FUNCTION ξ_J

Suppose that in a Euclidean space there are uniformly (randomly) distributed discrete ionizing sources and absorbers.* In this case the effective optical depth is $\tau_{eff}(r) = r/r_0$, where r_0 is the absorption length scale at which $\tau_{eff} = 1$. Given two positions $\vec{r} = 0$ and $\vec{r}_1$ we have derived the joint probability $W(J_0, J_1)dJ_0dJ_1$ that the mean Lyman limit frequency intensity at $\vec{r} = 0$ is between $J_0 \to J_0 + dJ_0$ and at the same time the mean Lyman limit frequency intensity at $\vec{r}_1$ is between $J_1 \to J_1 + dJ_1$ (see Zuo 1992). In our derivation we have assumed that the total optical depths along two different lines of sight are not correlated. This is a good approximation if the sizes of the absorbers are small and if the space density of the ionizing sources is low. From $W(J_0, J_1)$ we can show that the Lyman limit frequency intensity correlation function $\xi_J(r_1)$ is given by (Zuo 1992)

$$\xi_J(r_1) \equiv \frac{\langle J_0 J_1 \rangle}{\langle J \rangle^2} - 1 = \frac{1}{8\pi r_0^3} \frac{1}{n} \frac{\langle L^2 \rangle}{\langle L \rangle^2} \frac{1}{u_1} I_J(u_1), \tag{1}$$

where $u_1 = r_1/r_0$ and

$$I_J(u_1) = 2\int_0^\infty \frac{v}{\mathrm{sh}v} e^{-u_1 \frac{1+e^{-v}}{1-e^{-v}}} dv. \tag{2}$$

We assume that QSOs were the dominating ionizing sources at early epochs. We adopt $q_0 = 0.5$, $H_0 = 50\mathrm{km\ sec^{-1}Mpc^{-1}}$ and use the model B QSO luminosity function of Boyle, Shanks and Peterson (1988) for $z \leq 2.2$. At $z \geq 2.2$ we assume that quasars have a constant comoving space density and there was no luminosity evolution for individual sources. For the quasar spectrum we adopt $L_\nu \propto \nu^{-0.5}$ for $\lambda > 1216\mathring{A}$ and $L_\nu \propto \nu^{-1}$ for $\lambda < 1216\mathring{A}$. We then get, for $z \geq 2.2$, $\langle L^2 \rangle / (n\langle L \rangle^2) \simeq 0.3 \times 10^6 (1+z)^{-3}\mathrm{Mpc}^3$. We have calculated τ_{eff} and r_0 by using Miralda-Escudé and Ostriker (1990) Model A2 absorption.

The resulting intensity correlation ξ_J is large at small separations and at high redshifts. This is because the absorption by QSO absorption line systems reduces the total number of dominating ionizing sources involved in producing J and therefore enhances the fluctuations significantly.

2. ABSORPTION LINE EQUIVALENT WIDTH CORRELATION $\xi_{1/W}$

According to standard models the Lyα forest lines observed in quasar absorption spectra are produced by intervening clouds which are highly ionized by the ionizing background. Therefore these clouds may serve as intensity indicators and help us to constrain the

* Since the ionizing field at the Lyman limit frequency is a local phenomenon (see Zuo 1991), the Euclidean space approximation is good enough at high redshifts.

intensity correlation function and the space density of the dominating ionizing sources at high z. If the majority of Lyα forest lines are on the linear part of the curve of growth and the rest equivalent width W of an absorption line is proportional to J, we then have $W = A/J$, where A depends only on the intrinsic properties of an absorbing cloud, i.e., $A \propto \int \alpha_H n_H^2 dl$ for ionized clouds with α_H denoting the hydrogen recombination coefficient and n_H the total hydrogen number density. This suggests that we should study $1/W$ correlation of the Lyα forest lines.

For eight selected QSOs we have carried out the $\xi_{1/W}$ measurements (see Zuo 1992 for details). In four cases, i.e., Q0000–263, Q2000–330, Q0055–269 and Q1247+267, we have detected a positive correlation signal in the smallest separation bins, which seems to have been produced mainly by the lines near the QSO emission redshifts.

One explanation for the detected correlations is that the spectral signal-to-noise ratio (S/N) systematically declines towards the blue end because the detector quantum efficiency decreases at shorter wavelengths. Also when absorption lines are close enough to the quasar redshift to be superposed on the blue wing of the Lyα emission line, the S/N ratio is boosted significantly. Thus more weak lines near z_{em} may be included in the line list and this leads to the observed $1/W$ correlation. This explanation can be tested by measuring the simulated spectra with inhomogeneous continuum S/N. Another possibility is that the observed correlation signals may be produced by the enhanced ionizing field near the QSOs. If this is true then from the affected wavelength range and the estimated Lyman limit luminosity $L \approx 7 \times 10^{31}$ergs sec^{-1}Hz^{-1} of Q0000–263, we conclude $J_{-21} \lesssim 0.1$ at $z \simeq 4$, where $J = 10^{-21} J_{-21}$ergs s^{-1}cm^{-2}Hz^{-1}sr^{-1}.

How the measured $\xi_{1/W}$ results compare with our theoretical ξ_J? A straightforward comparison is difficult because of the equivalent width cut-off effect, i.e., observationally only those lines with an equivalent width larger than a certain threshold value can be positively detected. This effect depends on the intrinsic $f(A)$ distribution of the absorbing clouds and usually makes $\xi_{1/W}$ smaller than ξ_J (see Zuo 1992). If the observed $1/W$ correlation is produced by the proximity effect, then we know that the intrinsic $f(A)$ distribution is favorable enough for us to detect the general (not near a known QSO) J correlation. The sample 6 of Q0000–263, which excludes the lines within a distance 20Mpc from the QSO, does show a significant $\xi_{1/W}$ signal at the smallest separation. To check whether the magnitude is also consistent with our ξ_J calculation we need to know the exact shape of the $f(A)$ distribution. On the other hand if galaxies dominated J at high z then we don't expect to see any J correlation, except near a known powerful QSO (the proximity effect). The detected $1/W$ correlation may have to be explained by the non-uniform S/N ratio effect.

REFERENCES

Boyle, B. J., Shanks, T. & Peterson, B. A., 1988. *Mon. Not. R. astr. Soc.*, **235**, 935.
Miralda-Escudé, J. & Ostriker, J. P., 1990. *Astrophys. J.*, **350**, 1.
Zuo, L., 1991. *Ph.D. Thesis*, Ch. 2, California Institute of Technology.
Zuo, L., 1992. *Mon. Not. R. astr. Soc.*, in press.