RADIATION INDUCED VOID IN THE SPECTRUM OF TOL 1038-2712

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ABSTRACT

Detection of a large void (∼7 Mpc) is reported between the redshifts 2.16286 and 2.20748 in the Ly α forest of TOL 1038-2712. This void is centered near a foreground QSO TOL 1037-2704 which is at a distance ∼4.4 Mpc away from the void. The estimated probability for the void to occure by chance in front of the foreground QSO is few times 10^{-3}. Various implications of the void being produced by excess ionization due to foreground QSO are discussed.

Subject headings: QSO:general-QSO:absorption lines-IGM-intergalactic medium.

1. INTRODUCTION

Ly α lines seen in the spectra of QSOs are believed to be produced by neutral hydrogen clouds in the intergalactic medium (IGM). Being the most abundant objects at higher redshifts Ly α clouds can provide valuable information regarding the IGM over a wide span of look back time. Bajtlik et al. (1998, here after BDO) have shown that the deficit of lines seen in the Ly α forest close to the QSOs, known as proximity effect, can be used to estimate the intensity of the ionizing UV background radiation.

Properties of Ly α clouds in addition to be useful in understanding the IGM can be used to infer various physical properties of QSOs. Srianand & Khare (1996) have shown Lyα clouds with $\mathrm{z_{abs}} > \mathrm{z_{em}}$ can be used to get bounds on the relative velocity shifts between broad emission lines, peculiar velocity of the QSOs and their evolution with redshift.

In this work we study the effect of foreground QSO TOL 1037-2704 on the Ly α forest of the background QSO TOL 1038-2712. We have used Ly α line list from the sample of Dinshaw & Impey (1996) which is originally compiled to study the extent of large scale structure of the intervening metal line absorbers. We have identified a void exactly at the position of the foreground QSO and estimated its significance using the numerical simulations. The implications of void on the estimates of background radiation and the QSO models are discussed in the following sections. For all our calculations we use $\mathrm{H_o} = 100\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$ and $\mathrm{q_o} = 0.5$.

2. VOID IN THE Ly α FOREST

The distribution of Ly α clouds and QSOs in the field of TOLOLO group of QSOs are shown in Figure 1. One can clearly see an apparent lack of Ly α absorption lines along the line of sight to Tol 1038-2712 (between redshifts 2.1652 and 2.2075) close to the foreground QSO Tol 1037-2704 ($\mathrm{z_{em}} = 2.195$). The angular seperation between the two QSOs is 17'.9. This corresponds to a proper separation of $4.4\mathrm{h}^{-1}$ Mpc at z = 2.195. The redshift difference 0.0422 at z = 2.195 gives a proper length of $\sim 7\mathrm{h}^{-1}$ Mpc for the void.

We have estimated the number of Ly α clouds per unit redshift, N(z), for the Ly α lines along 4 QSO sight lines, which are 3 Mpc away from the QSOs, using maximum likelihood method. The results for limiting rest equivalent width $0.1\AA$ together with redshift distribution calculated based on the high resolution sample compiled by Srianand & Khare (1994, sk94) are given in Table 1. Also given in the table are the total number of lines used in the analysis, total redshift path and average redshift of the samples. We performed numerical simulations to estimate the significance for the occurence of a gap near the foreground QSO to establish a connection between the void and the foreground QSO.

In our numerical simulations we assume no evolution in the number density of Ly α clouds as this is true for small redshift intervals. The distribution of number of Ly α clouds along the line of sight is assumed to be Poissonian with mean given in Table 1. We generated a random line list for the QSO Tol 1038-2712 considering the observed redshift window. We repeated the simulations for over 50000 times for different values of the number of Ly α clouds per unit redshift (as given in Table 1). The estimated probability of occurence of voids, with size greater than the observed one (and number of lines along the line of sight same as the observed number) anywhere along the line of sight and close to the foreground QSO are given in Table 2 (P1 and P2 respectively). The probability of finding a gap similar or greater than the observed void by chance is few times 10^{-3}. Thus it is clear the void is real and not due to any random fluctuations in the interline spacing of Ly α clouds. In what follows we discuss various implications of the presence of this void.

3. IMPLICATIONS OF THE VOID

3.1. Background Radiation field

The presence of foreground QSO close the centre of the void naturally favours the void being produced by the proximity effect. If this is true one can get a bound on the intensity of ionizing UV background radiation, J_ν. We have assumed the QSO radiation to be emitted isotropically and has not varied much over a long time scale. We have calculated the continuum flux at the Lyman limit for each QSO in the field from its V-magnitude assuming the spectral energy distribution of the QSOs to be a powerlaw, $f_\nu \propto \nu^{-\alpha}$, (with spectral index $\alpha = 0.636 \pm 0.303$ estimated from Tytler & Fan 1992). We have not introduced any correction to the magnitude due to emission line flux as estimated contribution in the redshift window 2.0 to 2.5 is very low (between 0.005 to 0.025).

We have plotted, in Figure 2, the total Lyman limit flux seen by each Ly α clouds due to all the know QSOs in the field against the absorption redshift. We have not taken the absorption along the line of sight into account in the calculations as the redshift path lengths are small. The quoted error bars are errors in flux due to 1σ uncertainty in the mean spectral index. Also plotted in the figure are the background radiation values quoted by various authors in the literature.

The Lyman limit flux at the center of the void is $\log(\mathrm{f}/4\pi) = -21.60^{+0.04}_{-0.03}$ ergs s^{-1} cm^{-2} Hz^{-1} Sr^{-1}. Thus the implied upper limit of the background radiation field at z$\sim$2.19 is,

$$\log(\mathrm{J}_\nu) \leq -21.60^{+0.04}_{-0.03}, \quad (1)$$

in ergs s^{-1} cm^{-2} Hz^{-1} Sr^{-1}. This value is consistent with the lower limit, -21.80 ergs s^{-1} cm^{-2} Hz^{-1} Sr^{-1}, quoted by Fernandez-Soto et al (1995) based on the proximity effect on the Ly α forest due to foreground QSOs. It is clear from the figure 2 that the quoted upper limit is much lower than most of the values available in the literature based on the proximity effect.

We have performed the standard proximity effect calculations prescribed by BDO using the available Ly α data along the 4 QSO sight lines in the field. We have calculated the expected number of lines in different relative velocity bins with respect to QSOs for column density distribution index, $\beta = 1.5$, and rest equivalent width cutoff $0.1\mathring{A}$. In these calculations we have assumed no evolution for the number density of Ly α clouds and used the mean number densities given in Table 1. The ratio of expected number, $\mathrm{N}_{\mathrm{exp}}$, to observed number, $\mathrm{N}_{\mathrm{obs}}$, of Ly α clouds in different relative velocity bins with respect to the QSOs are given in Figure 3 for three different values of the background intensity. The errorbars are calculated considering the distribution of number of lines along the line of sight to be Poissonian.

I-model underpredicts the number of Ly α clouds near the QSO by more than 2σ when we consider the background intensity value equal to the obtained upper limit (top pannel in Figure 3). The predicted distribution is however consistent with the background value estimated by BDO and Bechtold (1994)(bottom pannel in Figure 3). The disagreement between the value of background intensity calculated using two different method can be accounted for if either our assumption of isotropic emission is wrong or the QSO luminosity has varied within the light travel time between QSO and void. In the following sections we discuss the implications of these possiblities in detail.

3.2. Long term fading of QSOs

In this section we assume the emisson from the QSO to be isotropic and try to put constraints on different QSO evolution models based on the background radiation values estimated from the void and from general proximity effect calculations. One can estimate lower limit on the life time of the QSO from its distance from the void. The separation 4.4 Mpc corresponds to a light travel time of 2×10^7 Yrs. Thus the life time of the foreground QSO 1037-270 is

$$t_{\mathrm{qso}} \geq 2 \times 10^7 \text{ Yrs}. \quad (2)$$

The observed luminosity evolution of QSOs can be interpreted as (a) the evolution of a single long lived ($t_{\mathrm{qso}} = 10^{10}$ Yrs) population of QSOs or (b) the evolution of successive geneation of short lived QSOs ($t_{\mathrm{qso}} = 10^8$ Yrs). Our estimated lower limit is consistent with both the models for QSOs. Boyle et al.(1991) have shown that the luminosity evolution of QSOs can be parameterized by

$$L(z) \propto (1+z)^k \quad (3)$$

with best fitted value of $k = 3.45 \pm 0.10$. Thus in the case of long lived population the luminosity of QSOs will not change within the light travel time between TOL 1037-270 and void. Both the models are consistent if the background intensity is less than the upper limit quoted based on the presence of void in the previous section. However if the actual background value is higher than the upper limit quoted here, as suggested by the general proximity effect estimates, one will need a reduction in the luminosity of TOL 1037-270 by a factor $> 2-16$ within 2×10^7 Yrs. Dobrzycki & Bechtold (1991) identified a void in the spectra of Q0302-003 close to a foreground QSO Q0301-005. Unlike the present case the void is displaced from the foreground QSO towards lower wavelength side. The distance between the centre of the void and Q0301-005 is 4.25 Mpc. The corresponding light travel time is 1.34 $\times10^7$ Yrs. The estimated Lyman limit flux from the QSO at the center of the void is $10^{-21.8}$ ergs s^{-1} cm^{-2} Hz^{-1} Sr^{-1}. Thus for different background value estimated in the literature Q0301-005 (like TOL 1037-270) also needs a reduction in the luminosity by a factor $> 3-40$ within 2×10^7 Yrs. Fadding of QSOs within such a short time scale can not be explained by the long lived QSO models. Thus if the intensity of background radiation is high and if QSOs radiate isotropically, observation of voids due to foreground QSOs favour models in which the luminosity evolution is realized as the superposition of activities in successive generation of short lived QSOs (Hachnelt & Rees 1993).

It is known that long lived interpretation has problems with observations. It predicts larger remnant black holes ($\sim 10^9 M_\odot$) and smaller Eddington ratios (~ 0.001) in low redshift AGNs than are corrently inferred from emission line and continuum studies (Padovani 1989). Our analysis gives an independent observational proof against the long lived QSO interpretation.

3.3. Anisotropic Emission in QSOs

Crotts (1989) has suggested an anisotropic emission from QSOs to explain the nondetection of proximity effect due to foreground QSOs. If TOL 1037-2704 is not an isotropic emitter and not varied, then we require an excess collimated beam (with radiation roughly an order of magnitude more compared to that along our line of sight) within a cone of angle 76^o perpendicular to the line of sight.

Dorbrzycki & Bechtold (1991), in order to explain the displaced void, proposed an opening angle of 140^o assuming the radiation towards void is same as that received along our line of sight. If their assumption is true one should see a void in the spectrum of Q0301-005 close to the emission redshift along our line of sight. We are not finding any such deficit in the intermediate resolution spectra of Q0301-005 observed by Steidel (1990) and simple assumption of Dorbrzycki & Bechtold (1991) may not be correct. The distribution of lines near this QSO is consistent with high values of background radiation. The void can be explained if the excess collimated beem is within a cone angle of $< 70^o$. Thus the foreground void in both the cases favour a narrow collimated beam inexcess to a isotropic emission than a wide angle cone of emission caused by shadowing of a portion of the emission. However more observations are needed to get a clear picture about the beaming models.

4. CONCLUSIONS

We have reported detection of a void ($\sim$ 7Mpc) in the spectrum of QSO TOL 1038-2712 close to the foreground QSO TOL 1037-2704. Using numerical simulations we have shown the chance probability of occurence of void close to the foreground QSO is $\sim 10^{-3}$.

We have estimated the upper limit on intensity of background radiation field to be $-21.6^{+0.04}_{-0.03}$ ergs s^{-1} cm^{-2} Hz^{-1} Sr^{-1} assuming the void is produced by the proximity effect of the foreground QSO. Based on the I-model and Ly α lines along four QSO sightlines we have shown the actual background intensity is higher than the estimated upper limit. We discuss two possiblities inorder to account for this difference.

If QSOs emit isotropically the presence of void will give another observational proof against long lived population models of QSOs. If QSO does not vary within few times 10^7 Yrs, our result suggest a narrow collimated cone emission toward the void (with flux a order or magnitude higher) in addition to the isotropic emission to be a possible source of the void.

Most of the available observations of pairs of QSO spectra till date (Crotts 1990; Fernendez-Soto et al. 1996) fail to detect voids near foreground QSOs. Even in the only two cases where voids are detected one is found at the redshift of the foreground QSO and the other at redshift less than that of the foreground QSO. If beaming picture is correct one would like to see displaced voids towards higher wavelenght side also. Thus case with displace void towards higher wavelength side will give a proof for the beaming arguments.

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Table 1: Results of Maximum Likelihood Analysis

Sample	Number	z-path	$< z >$	N(z)
Whole	79	0.60	2.30	132.22±11.50
SK94	374	2.24	2.73	152.31±12.31

Table 2: Results of Numerical Simulations

N(z)	P1(10^{-3})	P2(10^{-3})
152.31	2.7	1.1
141.99	3.3	1.5
132.22	5.0	2.0

Figure Caption

Fig 1. Distribution of QSOs and Ly α clouds in the field of Tololo group of QSOs. Ly α clouds are represented by open squares and the void under consideration is marked as ”V”.

Fig 2. Total UV ionizing flux, due to all know QSOs in the field, received by Ly α absorbing clouds along four lines of sights. Error bars are due to error in average spectral index. Horizondal lines are available background radiation estimates in the literature.

Fig 3. Ratio of expected number, $N_{\rm exp}$, to the observed number, $N_{\rm exp}$, of Ly α clouds in different relative velocity bins with respect to QSOs (calculated for N(z)=152.31). The values of J_ν are given in ergs s^{-1} cm^{-2} Hz^{-1} Sr^{-1}.

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