COMMON LINES IN THE REST-FRAME ABSORPTION-LINE SPECTRA OF QSOs?

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Abstract. Libby *et al.* (1984) have studied the absorption-line data for 13 QSOs in the rest-frames of the QSOs. It is shown that the number of groups in which 5 lines or more lie within a wavelength interval of 1.0 Å found by these authors is insignificantly different from that that would be expected from chance coincidences. Consequently, there is no evidence that the rest-frame wavelengths at which these groups occur have any special significance.

1. Introduction

In a recent paper, Libby *et al.* (1984) (hereafter referred to as LRL) have compared the absorption-line spectra of 13 QSOs. Assuming the redshift hypothesis, for each QSO, these authors converted the observed wavelengths to the rest-frame of the QSO by blueshifting them by the emission redshift. A comparison of these rest-frame wavelengths showed that 55 lines each occur in five or more QSOs within a wavelength interval of 1.0 Å or less. To estimate the probability that this agreement is chance, LRL generated random number spectra (nonsense spectra) for each QSO as follows: suppose in any QSO spectrum in the rest-frame, there are N_1 absorption lines shortward of Lα in a wavelength interval $\Delta\lambda_1$ and there are N_2 lines longward of Lα in a wavelength interval $\Delta\lambda_2$, then in the random number spectra the same number of lines were generated in the same wavelength intervals on the two sides of Lα. Using several sets of nonsense spectra, LRL found an average of 13 ± 2 random groups with 5 or more lines within a wavelength interval of 1.0 Å. Taken at face value, these results indicate that the number of coincidences found in the observed rest-frame spectra is significant. This implies the following: (1) the redshifts have physical significance; (2) if one assumes the cosmological interpretation of redshifts, then a substantial number of absorption lines are not random, that is they are not principally caused by absorption in clouds randomly distributed between each QSO and the Earth but instead are caused by substances intrinsic in each QSO.

One of us has questioned the existence of redshifts in the spectra of QSOs and has proposed an alternative explanation (Varshni, 1973, 1974a, 1975a, 1977a, b, 1978, 1979, 1982; Varshni and Lam, 1976). It is obvious that if the results of LRL are correct, these provide evidence against Varshni's theory. Also, if one assumes the cosmological redshift hypothesis, the results of LRL, if correct, clearly point to the intrinsic origin for the absorption lines of QSOs. Thus it was of considerable interest to closely examine the results of LRL.

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2. The Coincidences Found by LRL

We shall use the same data as those used by LRL (Roberts *et al.*, 1978; Sargent *et al.*, 1979; Young *et al.*, 1979, 1982; Sargent *et al.*, 1982), and shall assume the redshift hypothesis. The following analysis is all on the wavelengths in the rest-frames of QSOs.

LRL state that there are 55 groups in which 5 lines or more lie within a wavelength interval of 1.0 Å and they have listed these groups in their Table I. A close examination of these groups, however, shows that five of these have a width greater than 1.0 Å. These five groups are (1139.5, 1139.0, 1138.3, 1138.7, 1138.9), (1180.66, 1181.45, 1181.59, 1181.74, 1181.19), (1243.0, 1243.2, 1243.4, 1244.2, 1243.9), (1255.9, 1254.9, 1255.4, 1254.3, 1255.0), and (1287.1, 1287.4, 1286.4, 1287.4, 1287.8). Clearly these should be eliminated. That leaves us with 50 groups. An analysis of the data for the 13 QSOs shows that there are a total of 171 groups which have 5 lines or more within 1 Å. These groups are not all independent. Many of them have common lines with neighbouring groups. LRL have selected 50 out of these 171 but they have not given the rules that they used in selecting these 50. We have used the following rules which appear to be logical and reasonable.

(1) Groups with n lines are more important than those with $(n - 1)$ lines. Thus, one selects groups with 10, 9, 8, 7, ... lines (in this order). A corollary of this rule is that it is better to have one group of 6 lines than to have two with 5 lines each. Suppose there is a sequence of lines $\lambda_1 \ldots \lambda_{10}$ such that λ_1 to λ_6 lie within 1 Å and λ_6 to λ_{10} also lie within 1 Å. The problem is how to apportion the lines. Should one form one group of λ_1 to λ_6 or two groups of λ_1 to λ_5 and λ_6 to λ_{10}? To be consistent with rule 1, the former possibility was followed.

(2) If a line falls within the 1 Å width of a group, and if this group is selected, then the line in question cannot be included in another group.

Using these rules we find 45 groups with 5 lines or more within a wavelength interval of 1.0 Å. Thus we were able to reproduce LRL result except for a difference of 5. This difference arises because LRL have included groups in their list which are excluded by the corollary to rule 1 above. However, this difference of 5 is not important. So long as one follows the same set of rules in analysing the real spectra and nonsense spectra, the significance of groups found in the real spectra can be assessed.

3. Repetition of the Work of LRL

We have generated 10 nonsense spectra using the same procedure as that used by LRL. Further, to simulate the resolution of the real spectra it was constrained that $\Delta\lambda_{\min}^{N} \geq \Delta\lambda_{\min}$, where $\Delta\lambda_{\min}^{N}$ and $\Delta\lambda_{\min}$ are the minimum line spacings in the nonsense and actual spectra, respectively. On analysing these spectra by rules given in Section 2, the numbers of groups having 5 or more lines within a wavelength interval of 1.0 Å were found to be 35, 39, 40, 40, 42, 41, 33, 36, 38, and 41. Thus the average is 38.5 ± 2.8, which is much higher than 13 ± 2, the value reported by LRL. It is possible that there was a serious error in the computer program of LRL.

4. Line Densities

There is another factor that LRL have not considered carefully; namely, the density distribution of lines, in generating their nonsense spectra. The density of lines plays a very important role in determining chance coincidences (Russell and Bowen, 1929; Russell *et al.*, 1944; Varshni, 1974b, c, 1975b, 1981, 1983). In Figure 1(a)–(c) we show

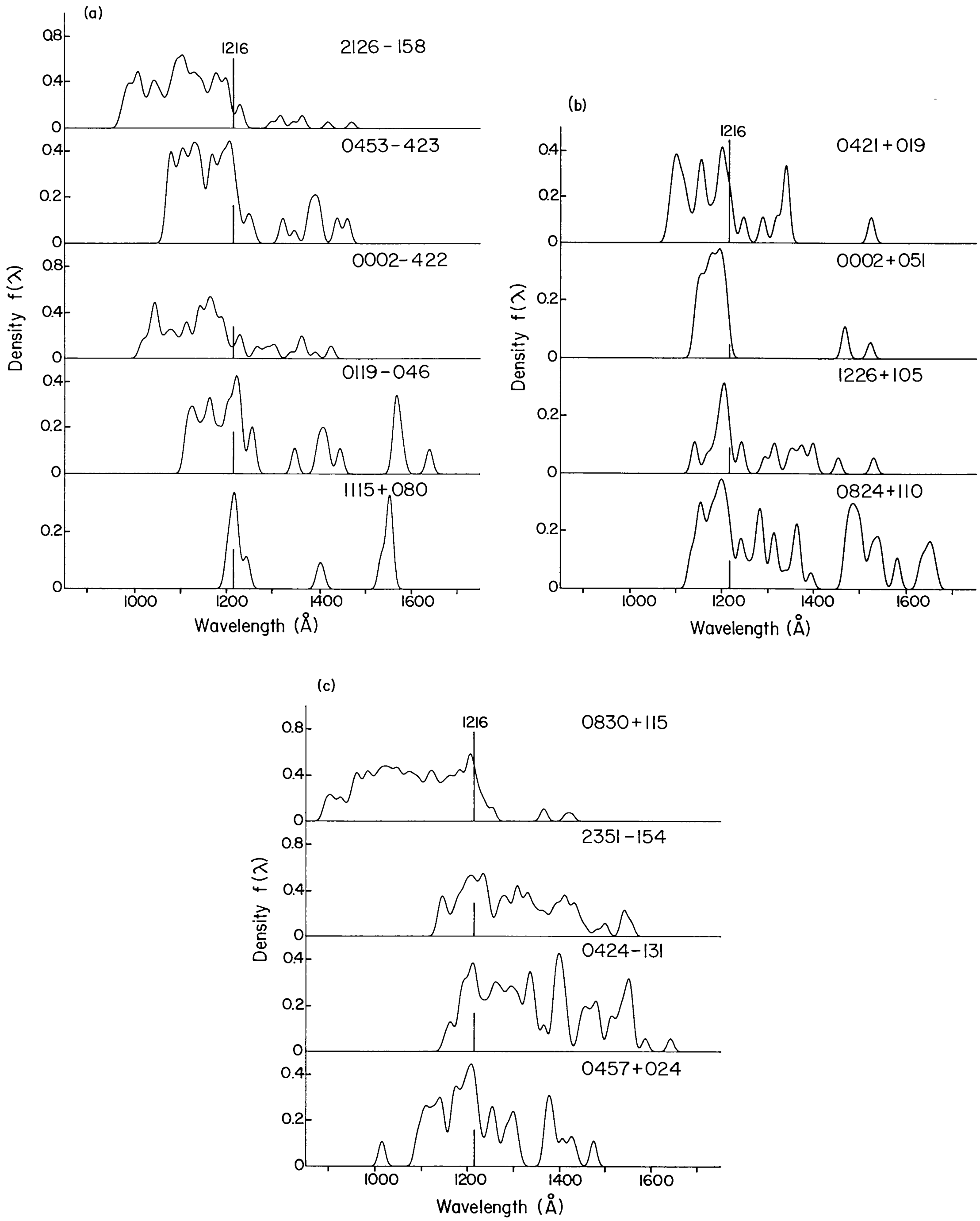

Fig. 1(a)–(c). Line density distribution, $f(\lambda)$, as a function of the wavelength for the 13 QSOs. The position of $L\alpha$ is indicated.

the line-density function for the spectra of 13 QSOs under consideration. These were obtained by convoluting the actual line distribution with gaussians of half-width $w = 10$ Å: i.e.,

$$f(\lambda) = \frac{1}{N\omega\sqrt{\pi}} \sum_{n=1}^{N} e^{-(\lambda-\lambda_n)^2/w^2} .$$

Here, λ_n are the wavelengths of the N lines in the spectrum of the QSO being considered. This procedure destroys information about the line positions on a scale $\delta\lambda < 2w$ while retaining the distribution on scales larger than $2w$.

It will be noticed in Figure 1(a)–(c) that the density of lines varies considerably over the length of the spectrum for most of the QSOs. The assumption by LRL that each spectrum can be divided in two parts (at 1216 Å) with flat distributions on either side can only be considered a first approximation and is not fully satisfactory.

5. Ghost Spectra and Results

We have generated ghost spectra for 10 sets of these 13 QSOs using a random number generator on a computer. A ghost spectrum is defined as a nonsense spectrum which simulates the real spectrum of an object in all its statistical characteristic features, but can be clearly distinguished from it (cf. Varshni, 1975b). For each QSO the ghost spectra were generated using its line density function shown in Figure 1(a)–(c) and it was constrained that $\Delta\lambda^G_{\min} \geqslant \Delta\lambda_{\min}$, where $\Delta\lambda^G_{\min}$ is the minimum line spacing in the ghost spectrum.

These ghost spectra were analysed using the rules given in Section 2. It was found that the number of groups having 5 or more lines within a wavelength interval of 1.0 Å in the ten cases are 40, 38, 41, 46, 37, 42, 43, 39, 40, and 43. Thus the average is 40.9 ± 2.5 as compared to 45 for the real spectra. The improvement over the previous result is small and it is readily understandable. Most of the coincidences ($\sim 90\%$) occur at $\lambda < 1216$ Å and in this region the flat spectrum approximation is a reasonable one.

The present investigation clearly shows that the number of groups found by LRL is insignificantly different from that that would be expected from chance coincidences. Thus, there is no evidence to suggest that the coincidences in rest-frame absorption-line wavelengths found by LRL have any physical significance. It further follows that there is no evidence to support the two consequences resulting from LRL's work, referred to in the Section 1.

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