THE QUASAR PKS 0237 − 233: CHANCE COINCIDENCES AND THE ALLEGED CO REDSHIFT SYSTEMS

Y. P. VARSHNI

Department of Physics, University of Ottawa, Canada

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Abstract. It is shown that the number of redshifted CO absorption-line systems which are found in the spectrum of the quasar PKS 0237 − 233, using the rules of Varshalovich and Levshakov (1981), differ insignificantly from that that would be expected from chance coincidences. Consequently, the CO systems proposed by Varshalovich and Levshakov have no physical reality.

1. Introduction

In a recent paper Varshalovich and Levshakov (1981) (hereafter referred to as VL) have presented results obtained from their analysis of the absorption spectrum of the quasar PKS 0237 − 233 reported by Boroson *et al.* (1978). VL claim to have found 12 redshift systems containing CO lines, and they tabulate five of these. It was shown by the author in a previous paper (Varshni, 1981) that the number of C IV redshift systems proposed by Boroson *et al.* (1978) in the absorption spectrum of PKS 0237 − 233 differ, but insignificantly from that that would be expected from chance coincidences. The redshift z is an arbitrary parameter and it is important to determine whether or not the CO redshift systems proposed by VL are due to chance concidences. In the present paper we address ourselves to this question.

2. The 'Redshift' Systems of VL

VL employed a computer to search for CO absorption-line systems as follows: "The redshift interval $z = 1.62 - 1.90$ was scanned with a step $\Delta z = 0.001$, and at each z the lines were selected that satisfied the condition

$$|\lambda - \lambda_0(1 + z)| < \delta\lambda\,, \tag{1}$$

where $\delta\lambda = 0.3$–0.7 Å. As a result 12 systems were established, each containing at least three of the most intense CO lines whose equivalent widths were correlated with their oscillator strengths: $z_a = 1.590$, 1.601, 1.609, 1.640, 1.652, 1.657, 1.679, 1.683, 1.734, 1.786, 1.789, and 1.820."

However, an examination of Table II of VL shows that, at some stage of their investigation, VL diluted their requirements for an acceptable system in an arbitrary way. Their claimed system at $z = 1.6082$ does not have the CO(3, 0) line; similarly, in the $z = 1.6402$ system, the CO(1, 0) line is missing. Clearly, if one adheres to the conditions laid down by VL for an acceptable system, these two systems are unacceptable. For

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examining the question of chance coincidences, it is important that one must follow any set of rules consistently, and, therefore, we have adhered closely to the conditions laid down by VL.

To clarify the question of relative equivalent widths which were considered acceptable, VL's work was repeated, but with a finer step size, $\Delta z = 0.0002$. The three strongest lines in the CO $A^1\Pi \leftarrow X^1\Sigma^+$ system are those with (v', v'') equal to (1, 0), (2, 0), and (3, 0). The wavelengths of these three lines are 1509.8, 1477.6, and 1447.4 Å, respectively (Tilford and Simmons, 1972) and their oscillator strengths are 0.038, 0.043, and 0.036, respectively (Lassettre and Skerbele, 1971). The (2, 0) line is the strongest and thus the following conditions were used in the search

$$W_\lambda(2,0) \geq W_\lambda(1,0)\,, \qquad W_\lambda(2,0) \geq W_\lambda(3,0)\,.$$

In the spirit of Table II of VL, the z in condition (1) was identified with the mean z for the three CO lines.

It was found that the reported systems at z = 1.590, 1.601, 1.6082, 1.6402, 1.652, and 1.786 by VL could not be confirmed due to one or more of the following reasons: (a) all the three lines (1, 0), (2, 0), and (3, 0) were not present, (b) equivalent widths did not correlate with the oscillator strengths, (c) $\Delta\lambda$ was greater than 0.7 Å. On the other hand, seven new systems were found at z = 1.57123, 1.68731, 1.73604, 1.74865, 1.75048, 1.75629, and 1.79852. It seems that some of these systems were missed by VL because of the coarse Δz step used by them. Table I summarizes the equivalent widths of the identified lines in the 13 systems which satisfy VL's conditions. We may note here that the total number of systems which satisfy condition (1) alone in the spectrum of Boroson *et al.* (1978) is 71, but all of them are not completely independent of each other.

TABLE I

CO absorption-line systems which satisfy VL's rules in the spectrum of PKS 0237 − 233. The equivalent widths in colums 3 to 5 refer to identified lines

z (according to VL)	z (this paper)	$W_\lambda(1,0)$ Å	$W_\lambda(2,0)$ Å	$W_\lambda(3,0)$ Å
1.6567	1.65653	0.2	0.3	0.1
1.679	1.67818	0.1	0.1	0.1
1.6828	1.68248	0.1	0.2	0.1
1.734	1.73289	0.1	0.1	0.1
1.789	1.78957	0.2	0.2	0.1
1.820	1.81954	0.1	0.3	0.2
New systems	1.57123	0.1	0.3	0.3
	1.68731	0.1	0.1	0.1
	1.73604	0.1	0.1	0.1
	1.74865	0.1	0.1	0.1
	1.75048	0.1	0.1	0.1
	1.75629	0.1	0.1	0.1
	1.79852	0.1	0.3	0.1

3. Chance Coincidences

It is important to take into account the density distribution of lines for determining chance coincidence 'redshifts' (Varshni, 1974a, b, 1975). A detailed examination of the data of Boroson *et al.* (1978) and Figure 1 of Varshni (1981) shows that the absorption spectrum of PKS 0237 – 233 can be conveniently divided into 15 intervals, to allow for the varying density of lines, with 'walls' at 3715, 3740, 3760, 3810, 3860, 3880, 3900, 4080, 4110, 4120, 4150, 4170, 4205, 4270, 4285, and 4290 Å. In the previous paper (Varshni, 1981) ten ghost spectra were generated on a computer (IBM 360/65) and the same ghost spectra shall be used in the present investigation. The procedure used in the previous paper (Varshni, 1981) was as follows. The fifteen intervals were considered separately; inside an interval, the ghost wavelengths were generated in accordance with the formula

$$\lambda_i(\text{ghost}) = \lambda_{\text{min}} + R_i(\lambda_{\text{max}} - \lambda_{\text{min}}) , \quad (2)$$

where λ_{min} and λ_{max} represent the lower and upper limits, respectively, of the interval, and R_i is a uniformly distributed random number between zero and one (generated using the RANDU subroutine of IBM's Scientific Subroutine Package). The minimum separation between two lines in the spectrum reported by Boroson *et al.* (1978) is 0.4 Å; it was constrained that the minimum separation between two wavelengths in a ghost spectrum will be the same. The equivalent width of the ith observed line was assigned to λ_i(ghost). Thus, in any given interval, a ghost spectrum has the same number of lines of various equivalent widths as in the observed spectrum.

Each ghost spectrum was analysed for 'redshifted' CO absorption-line systems which satisfy VL's rules. The value of $\Delta\lambda$ in Equation (1) was taken to be 0.7 Å and the relative equivalent widths of the identified lines had to be similar to or identical to one of the

TABLE II

Number of CO systems in ghost spectra

Ghost spectrum number	Initiating number for RANDU	Total number of CO systems which satisfy VL's rules	Number of CO systems which satisfy VL's rules and which lie within $\Delta z = 0.001$ of a C IV system
1	28471	9	2
2	83123	12	2
3	26687	15	1
4	42003	10	1
5	62981	10	1
6	10737	15	1
7	78241	16	5
8	137	7	1
9	8873	11	1
10		12	2
Average		11.7 ± 2.8	1.7 ± 1.2

sets shown in Table I. The initiating number which was used (Varshni, 1981) for RANDU subroutine for generating the ghost spectrum and the total number of CO systems which satisfy VL's rules found in each of the ten cases are shown in Table II. The average number of acceptable CO absorption-line systems is 11.7 ± 2.8. It shows that the 13 CO systems found in the spectrum of PKS 0237 − 233 are consistent with the hypothesis that these are just chance-coincidences without any physical significance. It would appear that VL attach some importance to the fact that the z values of some of their CO systems lie very close to those of some of the C IV systems. In the spectrum of PKS 0237 − 233 there are three CO systems (Table I) which lie within $\Delta z = 0.001$ of a C IV system. For ghost spectra, in column 4 of Table II we show the number of CO systems which satisfy VL's rules and which lie within $\Delta z = 0.001$ of a C IV system. The average is 1.7 ± 1.2. The results make it obvious that the proximity of some CO systems to C IV systems as found by VL merely arises from chance coincidences and has no physical significance. The results presented here conclusively show that the number of CO redshift systems found in the absorption-line spectrum of PKS 0237 − 233 is insignificantly different from that that would be expected from chance coincidences. Consequently, these systems and their z values are devoid of any physical significance.

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References

Banerji, S. and Bhar, G. C.: 1978, *Astrophys. Space Sci.* **56**, 443.
Banerji, S. and Bhar, G. C.: 1979, *Astrophys. Space Sci.* **61**, 337.
Boroson, T., Sargent, W. L. W., Boksenberg, A., and Carswell, R. F.: 1978, *Astrophys. J.* **220**, 772.
Lassettre, E. N. and Skerbele, A.: 1971, *J. Chem. Phys.* **54**, 1597.
Tilford, S. G. and Simmons, J.: 1972, *J. Phys. Chem. Ref. Data* **1**, 147.
Varshalovich, D. A. and Leveshakov, S. A.: 1981, *Pis'ma Astron. Zh.* **7**, 204 [*Soviet Astron. Letters* **7**, 113 (1981)].
Varshni, Y. P.: 1974a, *Astrophys. J.* **193**, L5.
Varshni, Y. P.: 1974b, *Bull. Am. Astron. Soc.* **6**, 449.
Varshni, Y. P.: 1974c, *Bull. Am. Astron. Soc.* **6**, 213, 308.
Varshni, Y. P.: 1975a, *Astrophys. J.* **201**, 547.
Varshni, Y. P.: 1975b, *Astrophys. Space Sci.* **37**, L1.
Varshni, Y. P.: 1981, *Astrophys. Space Sci.* **74**, 3.