THE ASTROPHYSICAL JOURNAL, 193:L5–L6, 1974 October 1

CHANCE COINCIDENCES IN THE ABSORPTION-LINE SPECTRUM OF 4C 05.34

Y. P. VARSHNI
Department of Physics, University of Ottawa, Ottawa, Canada
Received 1974 June 12; revised 1974 July 11

ABSTRACT

It is shown that the distribution of absorption-line redshifts for the quasar 4C 05.34 is consistent with the hypothesis that the proposed systems arise because of chance coincidences between the wavelengths of search lines (at appropriate values of z) and the wavelengths of observed absorption lines.

Subject headings: quasi-stellar sources or objects — redshifts

Several quasi-stellar objects are now known to show many absorption lines in their spectra. These QSOs are as follows: 3C 191, PHL 938, PKS 0119−04, PKS 0237−23, TON 1530, B194, 4C 05.34, PHL 957, Markarian 132, and 1331+170. Quasars OH 471 and OQ 172 have also been reported to have a rich absorption spectrum, though the results have not yet been published.

The interpretation of these spectra on the redshift hypothesis is in a very unsatisfactory state (Lynds 1968; Burbidge, Lynds, and Stockton 1968; Cohen 1972). Bahcall (1970) and others have emphasized that one must prove that any proposed set of identifications is physically and statistically significant.

Here we examine the question of whether the distribution of absorption-line redshifts is significantly different from what would be expected from chance coincidences. The classic work on the question of chance coincidences is that of Russell and Bowen (1929), and we shall adapt here their approach. Bahcall and Goldsmith (1971) have analyzed the absorption spectrum of 4C 05.34 by well-defined rules and have proposed eight systems, at $z = 2.8751$, 2.8106, 2.7703, 2.5925, 2.4743, 2.1819, 1.8593, and 1.7758, respectively. We shall consider here, as a test case, the same QSO.

Bahcall and Goldsmith (1971) used a list of 36 search lines. In order to be acceptable, a candidate redshift (z) was required to satisfy the following four rules: (1) Lyman-alpha must be present and of strength greater than or equal to 2 if it is in the accessible wavelength range. (2) Lyman-beta must appear if it is in the accessible wavelength range. (3) There must be at least two identified lines of strength greater than or equal to 2. (4) A minimum of four lines must be identified in a way that is consistent with atomic physics and a reasonable ionization equilibrium. Lines of strength zero were not counted among the four required lines.

The maximum permissible wavelength discrepancy was set at 2 Å in the observed frame. The searches were carried out on a computer.

The absorption lines in 4C 05.34 lie between 3497 and 6006 Å (Lynds 1971). Bahcall and Goldsmith (1971) varied z from 0 to 3.0 in steps of 4×10^{-4}. At each of these values of z, a certain number of lines in the search list will fall in the wavelength region 3497–6006 Å. This number will change slowly as we vary z. It turns out that to a good degree of approximation, we can assume that the number of search lines remains the same over an interval of 0.2 in z. In table 1 we show the number of search lines available in various intervals. (Search lines were taken from Bahcall 1968, and Bahcall and Goldsmith 1971). The number was counted at the midpoint of the interval. For any given z we can then calculate the number of chance coincidences from an expression derived by Russell and Bowen (1929):

$$C = pN \, , \tag{1}$$

where

$$p = \left[1 - \left(1 - \frac{2x}{X}\right)^{M}\right] .$$

Here N is the total number of lines to be identified (78 in the present case, excluding strength 0 lines), x is the wavelength coincidence tolerance (2 Å, following Bahcall and Goldsmith), X is the wavelength interval, and M is the number of search lines. Also, the standard deviation is given by

$$\sigma^2 = Np(1 - p) \, . \tag{2}$$

The calculated values of C and σ for different intervals are shown in table 1.

In each of these intervals, there are 500 values of z.

TABLE 1

NUMBER OF SEARCH LINES, C, AND σ FOR VARIOUS REDSHIFT INTERVALS FOR 4C 05.34

z Interval	Number of Search Lines	C	σ
3.0–2.8	22	2.6904	1.6117
2.8–2.6	22	2.6904	1.6117
2.6–2.4	19	2.3291	1.5032
2.4–2.2	16	1.9660	1.3844
2.2–2.0	16	1.9660	1.3844
2.0–1.8	14	1.7230	1.2981
1.8–1.6	9	1.1121	1.0470
1.6–1.4	10	1.2346	1.1023
1.4–1.2	11	1.3570	1.1547
1.2–1.0	10	1.2346	1.1023
1.0–0.8	9	1.1121	1.0470
0.8–0.6	8	0.9893	0.9883
0.6–0.4	9	1.1121	1.0470
0.4–0.2	4	0.4962	0.7022
0.2–0	2	0.2485	0.4977

The distribution of redshift systems arising from chance coincidences with L lines will be given by a normal distribution,

$$F = \frac{500}{\sigma(2\pi)^{1/2}} \exp\left[-\frac{1}{2}\left(\frac{L-C}{\sigma}\right)^2\right] . \quad (3)$$

It may be noted that not all of these systems are independent; only about 25 percent of these are really independent systems (because for independent systems, the redshifts should differ by at least 0.0015; otherwise too many lines are common).

Bahcall and Goldsmith (1971) have concerned themselves only with those absorption systems which have a minimum of four lines of strength greater than 0. The total number of such systems on the chance coincidence hypothesis will be given by

$$S = \int_{3.5}^{\infty} \frac{500}{\sigma(2\pi)^{1/2}} \exp\left[-\frac{1}{2}\left(\frac{L-C}{\sigma}\right)^2\right] dL . \quad (4)$$

The values of this function as a function of z are compared with the distribution of the eight systems of Bahcall and Goldsmith in fig. 1. The total number of chance coincidence redshift systems between $z = 0$ and $z = 3.0$ is 640. Among the 78 lines under consideration, 46 (i.e., 59% of the total) are of strength greater than or equal to 2. Here we are looking at redshift systems which have four lines or more. It is readily seen that a vast majority of these systems will have a minimum of two lines of strength greater than or equal to 2. That is, rule 3 will be satisfied for about 600 systems or so. If we allow for the fact that the difference between two redshifts should be ≥ 0.0015, we are left with about 150 systems. Then we must consider the following remaining factors which will limit the number of "acceptable" systems: (a) Rules 1 and 2. (b) The identified lines should be consistent with atomic physics and a reasonable ionization equilibrium. As far as the latter condition is concerned, it is satisfied by an extremely high percentage of combinations of lines in Bahcall's search list. An examination of the absorption redshift systems proposed for 4C 05.34 and for other quasars shows that the condition regarding consistency with atomic physics, which refers to the completeness of multiplets, relative intensities of lines, and certain other factors, depends to a considerable degree on individual tastes and preferences.

To allow for both of these factors, another reduction factor will come into play; it appears to be about 19. For $z < 1.876$, Lα goes out of the observing window, and rule 1 of Bahcall will not be operative in this region. However, the number of chance coincidence systems in this region is as such quite small, and only a small enhancement due to the absence of rule 1 can be expected.

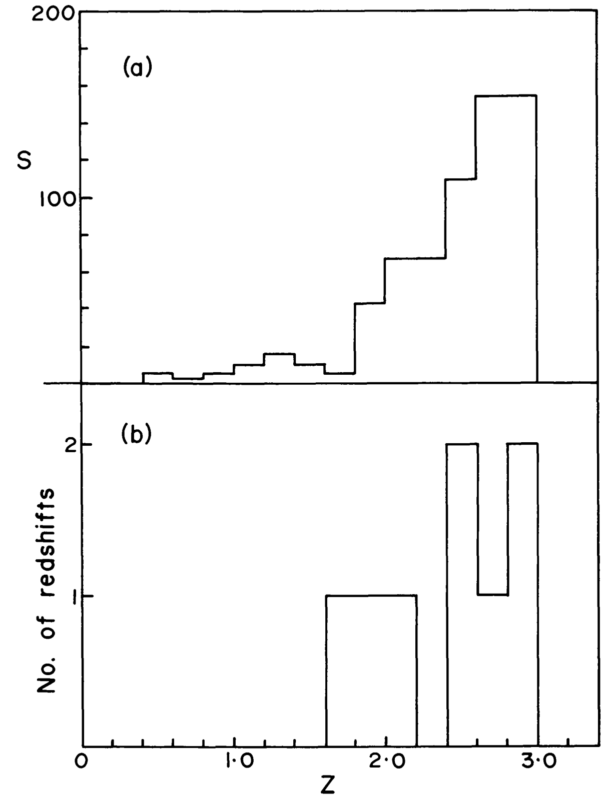

FIG. 1.—Distribution of absorption-line redshifts of 4C 05.34: (*a*) Chance coincidence hypothesis, (*b*) eight systems of Bahcall and Goldsmith (1971).

Allowing for the small sample size (only eight systems), the chance-coincidence redshift distribution is seen to be very similar to that of the systems proposed by Bahcall and Goldsmith. We are led to the inescapable conclusion that the proposed systems are consistent with the hypothesis that the coincidences between the wavelengths of search lines for certain arbitrary values of z and the wavelengths of observed absorption lines in 4C 05.34 are fortuitous. Consequently, we fear that no physical significance can be attached to these absorption systems and their z values. It may also be noted here that the eight redshift systems of Bahcall and Goldsmith (1971) "identify" only 47 lines out of the 93 observed. We thus find that the redshift hypothesis is of no help in understanding the absorption-line spectrum of 4C 05.34.

We may note here that recently we have shown (Varshni 1973*a*, *b*, 1974) that there is no need of assuming redshifts for the emission lines in QSOs.

REFERENCES

Bahcall, J. N. 1968, *Ap. J.*, **153**, 679.
———. 1970, *Comments Ap. and Space Phys.*, **2**, 221.
Bahcall, J. N., and Goldsmith, S. 1971, *Ap. J.*, **170**, 17.
Burbidge, E. M., Lynds, C. R., and Stockton, A. 1968, *Ap. J.*, **152**, 1077.
Cohen, J. G. 1972, *Nature*, **237**, 273.
Lynds, C. R. 1968, in *Beam-Foil Spectroscopy*, ed. S. Bashkin (New York: Gordon & Breach), Vol. **2**, p. 539.
Lynds, R. 1971, *Ap. J.* (*Letters*), **164**, L73.
Russell, H. N., and Bowen, I. S. 1929, *Ap. J.*, **69**, 196.
Varshni, Y. P. 1973*a*, *Bull. APS*, **18**, 1384.
———. 1973*b*, submitted for publication.
———. 1974, *Bull. AAS*, **6**, 213, 308.

Y. P. VARSHNI: Department of Physics, University of Ottawa, Ottawa, Ontario K1N 6N5, Canada