Common Absorption Lines In Two Quasars

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Abstract.
We have found that in the absorption-line spectra of two quasars, 0237-233 and HE 1122-1648 there are a large number of common lines in the observed frame (earth frame). The number of common lines in the interval 3716-4116 Å is 64 while the expected number from the chance-coincidence theory is only 49.7 ± 5.7. An explanation is given.

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1. INTRODUCTION

The object PKS 0237-23 was identified as a quasar by Arp *et al.* [1]. There have been a number of investigations on the absorption-line spectrum of 0237-233 (z=2.22). We summarize these investigations here. Early observations were by Arp *et al.* [1] (33 absorption lines), Burbidge [2] (20 lines), Greenstein and Schmidt [3] (40 lines), Bahcall, Greenstein and Sargent [4] (49 lines) and by Burbidge *et al.* [5] (92 lines).

Boksenberg and Sargent [6] used the University College London image photon counting system (IPCS) at the Coude focus of the Palomar telescope to obtain the spectrum of 0237-233 at a resolution of 0.71 Å. They give a list of 75 absorption lines in the wavelength range 3737-4270 Å. Boroson *et al.* [7] (hereafter BSBC) carried out further observations on 0237-233 with the IPCS and these observations were combined with the older data of Boksenberg and Sargent [6]. These authors tabulated wavelengths and equivalent widths of 193 absorption lines in the spectral range 3716-4289 Å. Other observations are due to Sargent *et al.* [8], Petitjean and Bergeron [9] and by Aldcroft *et al.* [10].

Rollinde *et al.* [11] have obtained a high resolution and high S/N ratio spectrum of the quasar HE 1122-1628 (z=2.40) during Science Verification of the Ultra-violet and Visible Echelle Spectrograph at the European Southern Observatory on the 8.2 m KUEYEN telescope operated on Cerro Paranal, Chile. They list 187 absorption lines in the wavelength interval 3679-4116 Å.

2. COMPARISON

For 0237-233, for the interval 3679-4116 Å the best available data appears to be that of BSBC [7]. The common wavelength interval is however 3716-4116 Å. In this interval there are 175 lines in HE 1122-1628 and 140 lines in 0237-233. A comparison of the Rollinde *et al.* [11] data with the BSBC [7] data shows that if we allow the maximum difference between the two wavelengths, $\delta\lambda$ = 0.5 Å, there are 64 common lines. These lines are shown in Table 1.

Obviously the question arises of chance coincidences. Russell and Bowen [12] did pioneer work on this question. Using their formulas, we find that the expected number of chance coincidences in our case is 49.7, and the probable error is 5.7. This clearly shows that the 64 common lines are not due to chance coincidences, but have a physical reason that we shall discuss in the last section. In the next section we elaborate the details of our calculations.

3. METHOD

We define two spectral lines as coincident if they are separated by less than a given tolerance x. It is an elementary matter to calculate the probability of chance coincidences between spectral lines. Russel and Bowen [12] derive this probability from first principles :

TABLE 1. Common absorption lines in HE 1122-1648 and 0237-233.

id	HE 01122-1648 Å (air)	Intensity	0237-233 Å (air)	EW	Wavelength difference
1	3717.40	0.96	3716.9	0.6	-0.50
2	3723.25	2.03	3722.8	0.9	-0.45
3	3739.34	0.32	3739.4	0.6	0.06
4	3743.55	2.35	3743.3	0.5	-0.25
5	3747.70	0.46	3747.4	1.1	-0.30
6	3748.41	0.74	3748.8	0.2	0.39
7	3750.54	0.86	3750.3	0.2	-0.24
8	3758.09	0.24	3758.3	0.2	0.21
9	3761.46	0.40	3761.1	0.3	-0.36
10	3773.00	1.00	3773.3	0.5	0.30
11	3787.63	0.51	3788.0	0.5	0.37
12	3792.35	0.07	3792.3	0.5	-0.05
13	3805.04	0.37	3804.7	0.5	-0.34
14	3806.99	0.50	3807.4	0.1	0.41
15	3812.38	0.11	3811.9	0.1	-0.48
16	3821.67	2.12	3821.7	0.1	0.03
17	3827.39	0.06	3826.9	0.1	-0.49
18	3838.65	0.19	3838.5	1.2	-0.15
19	3840.16	2.27	3840.0	0.5	-0.16
20	3844.73	0.29	3845.2	0.1	0.47
21	3853.99	0.44	3854.4	0.3	0.41
22	3863.06	0.87	3862.6	0.8	-0.46
23	3869.43	0.21	3869.7	0.2	0.27
24	3876.69	0.29	3876.8	0.1	0.11
25	3878.98	0.02	3879.1	0.2	0.12
26	3882.02	0.04	3882.0	0.1	-0.02
27	3884.70	2.43	3884.3	0.2	-0.40
28	3886.98	0.18	3886.7	1.9	-0.28
29	3894.37	0.77	3894.1	0.4	-0.27
30	3900.96	0.26	3900.7	0.3	-0.26
31	3911.00	0.25	3910.8	0.2	-0.20
32	3924.47	0.05	3924.6	0.3	0.13
33	3925.10	0.09	3925.4	0.1	0.30
34	3930.86	0.17	3930.8	0.1	-0.06
35	3937.15	0.18	3937.2	0.1	0.05
36	3949.37	0.20	3949.5	0.7	0.13
37	3954.62	0.10	3954.9	0.1	0.28
38	3955.87	0.06	3955.7	0.1	-0.17
39	3956.62	0.17	3957.0	0.1	0.38
40	3959.42	0.08	3959.7	0.1	0.28
41	3963.54	2.29	3963.7	0.2	0.16
42	3979.04	0.24	3978.9	0.1	-0.14
43	3980.87	0.81	3981.3	0.1	0.43
44	3984.71	1.42	3984.7	0.1	-0.01
45	3987.04	0.35	3987.3	0.1	0.26
46	3988.91	2.33	3989.4	0.1	0.49
47	4010.39	0.57	4009.9	0.2	-0.49
48	4024.83	0.36	4025.1	1.2	0.27
49	4028.67	0.41	4029.0	0.1	0.33
50	4037.33	0.24	4037.6	0.1	0.27
51	4038.80	1.33	4038.4	0.1	-0.40
52	4041.29	2.17	4041.0	0.6	-0.29
53	4055.14	0.22	4054.8	0.1	-0.34
54	4056.06	0.23	4056.1	0.3	0.04
55	4057.36	0.30	4057.6	0.1	0.24
56	4063.35	0.21	4063.8	0.4	0.45
57	4078.79	1.61	4078.6	1.1	-0.19
58	4080.30	0.46	4080.4	0.3	0.10
59	4087.01	1.00	4087.2	0.2	0.19
60	4094.34	4.02	4094.5	0.1	0.16
61	4096.01	0.28	4095.7	0.2	-0.31
62	4098.14	0.06	4098.5	0.1	0.36
63	4100.79	0.02	4100.7	0.1	-0.09
64	4115.24	0.10	4115.2	0.4	-0.04

TABLE 2. Values used to calculate the number of chance coincidences

Symbol	Value	Description
	3716 Å to 4116 Å	Wavelength range under consideration
X	400 Å	Wavelength interval
x	0.50 Å	Tolerance ($\delta\lambda$)
n	175	Number of lines in HE 1122-1628 within range
N	140	Number of lines in 0237-233 within range
C	49.7	Expected number of chance coincidences using eq. (1) and (2)
σ	5.7	Standard deviation of C obtained from eq. (3)
A	64	Actual number of coincidences for tolerance x
$(A-C)/\sigma$	2.53	Significance of A in units of standard deviation

Given a spectrum containing n lines within an interval of X units of wavelength, the probability that a spectral line chosen at random within the interval X lies within x wavelength units of one or more of the spectral lines is $2x/X$. The probability that it will not coincide is $1-2x/X$. The probability that all n lines fail to coincide is $(1-2x/X)^n$ and the complementary probability that it will happen is

$$p = 1 - \left(1 - \frac{2x}{X}\right)^n \tag{1}$$

For small values of x, this gives approximately $p = 2nx/X$; but this value is too great, since it ignores the probable overlapping of the strips centered on different spectral lines. If we now start not with one, but with N arbitrarily chosen lines, the probability p will be the same for each. The expected number C of chance coincidences within the tolerance x will be given by

$$C = pN \tag{2}$$

It can easily be shown that the standard deviation of C is given by

$$\sigma^2 = Np(1-p) \tag{3}$$

Using HE 1122-1628 as the given spectra with $n = 175$ absorption lines we expect from eq.(1)(2) and (3) that out of $N = 140$ randomly distributed lines that 49.7 ± 5.7 coincidences will occur by chance (see Table 2).

The actual number of coincidences is 64 which is 2.53 standard deviations above the expected number of chance coincidences. The probability that a value deviates by this amount is proportional to area under the standard normal Gaussian distribution from 2.53 to infinity or approximately 6×10^{-3}. This very low probability confirms that the 64 common absorption lines are not due to chance coincidences.

4. DISCUSSION

The 64 common lines are readily understood on the basis of a theory of quasars proposed by us (Varshni, [13], [14], [15], [16], [17], [18], [19], Varshni and Lam [20], Varshni and Nasser [21]), which is based on sound physical principles, and does not need the assumption of redshifts. It provides satisfactory explanations of the various phenomena associated with quasars. In short, quasars are a special type of stars in which laser action is responsible for the strength of the broad emission lines. This theory is known as the plasma-laser star (PLAST) model of quasars. Most of the observational evidence on quasars either supports our theory or else is consistent with it.

If we consider two stars which belong to the same spectral class or to very neighboring spectral classes, for example two A2 type stars or one A2 type star and the other A3 type star, then they have very many common absorption lines. This arises because in the two cases the plasma where the absorption is occurring is very similar. In our theory of quasars the absorption is occurring in the extended atmosphere of a star, much like a shell star. The coincidences between the wavelength of absorption lines in HE 1122-1648 and 0237-233 is occurring because the shells of these two stars are quite similar.

Here it should be remembered that the observations on 0237-233 and HE 1122-1648 were carried out by different techniques. As noted by BSBC [7], some of the lines in their list are actually blends. It was found that some of the

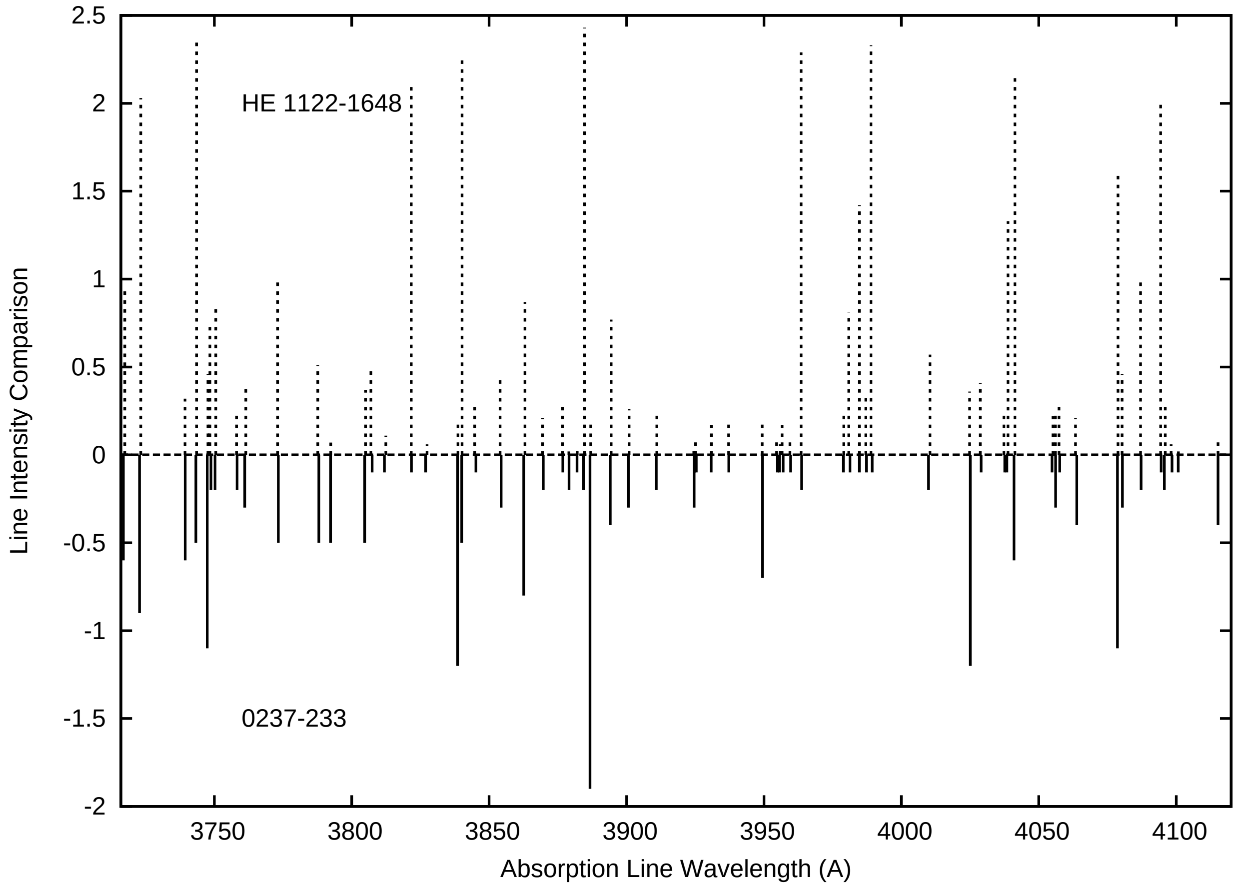

FIGURE 1. Intensity plot of the common absorption lines in HE 01122-1648 and 0237-233. The top half represents the HE 01122-1648 absorption line intensities. The negative values represent 0237-233 equivalent widths.

lines of 0237-233 have two lines of HE 1122-1628 within $\pm$ 0.5 Å; we have listed only one of the lines which was the nearest. It suggests that a higher resolution spectrum of 0237- 233 would likely show greater number of coincidences with HE 1122-1648 lines. The resolution obtained by BSBC [7] was only 0.7 Å (corresponds to 52 km/s). Now it is possible to obtain much better resolution in quasar spectra. If 0237-233 is studied with a resolution of 10 km/s, the accuracy would be much better and we expect the number density of lines to increase substantially. Such a data would provide a more accurate comparison with HE 1122-1648.

REFERENCES

1. H. C. Arp, J. G. Bolton, and T. D. Kinman. *ApJ*, **147**, pp. 840–845 (1967).
2. E. M. Burbidge. *ApJ*, **147**, pp. 845–848 (1967).
3. J. L. Greenstein, and M. Schmidt. *ApJ*, **148**, pp. L13–L15 (1967).
4. J. N. Bahcall, J. L. Greenstein, and W. L. W. Sargent. *ApJ*, **153**, pp. 689–698 (1968).
5. E. M. Burbidge, C. R. Lynds, and A. N. Stockton. *ApJ*, **152**, pp. 1077–1094 (1968).
6. A. Boksenberg, and W. L. W. Sargent. *ApJ*, **198**, pp. 31–44 (1975).
7. T. Boroson, W. L. W. Sargent, A. Boksenberg, and R. F. Carswell. *ApJ*, **220**, pp. 772–782 (1978).
8. W. L. W. Sargent, C. C. Steidel, and A. Boksenberg. *ApJS*, **68**, pp. 539–588 (1988).
9. P. Petitjean, and J. Bergeron. *A&A*, **283**, pp. 759–778 (1994).
10. T. L. Aldcroft, J. Bechtold, and M. Elvis. *ApJS*, **93**, pp. 1–46 (1994).
11. E. Rollinde, P. Petitjean and C. Pichon. *A&A*, **376**, pp. 28–42 (2001).
12. Russell, H. N. and I. S. Bowen. *ApJ*, **69**, pp. 196–208 (1929).
13. Y. P. Varshni. *Ap&SS*, **37**, pp. L1–L6 (1975).

14. Y. P. Varshni. *Ap&SS*, **46**, pp. 443–464 (1977).
15. Y. P. Varshni. in S.Fujita (ed.), *The Ta-You Wu Festschrift: Science of Matter*, Gordon and Breach, New York, 1978 pp. 285–305.
16. Y. P. Varshni. *Phys.Canada*, **35**, pp. 11–17 (1979).
17. Y. P. Varshni. *Ap&SS*, **117**, pp. 337–350 (1985).
18. Y. P. Varshni. *Ap&SS*, **149**, pp. 197–215 (1988).
19. Y. P. Varshni. *Ap&SS*, **153**, pp. 153–167 (1989).
20. Y. P. Varshni, and C. S. Lam. *Ap&SS*, **45**, pp. 87–97 (1976).
21. Y. P. Varshni, and R. M. Nasser. *Ap&SS* **125**, pp. 341–360 (1986).