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ON THE ABSORPTION-LINE SPECTRUM OF 4C 05.34

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ABSTRACT

Eight acceptable absorption redshifts are found in the spectrum of 4C 05.34 reported by Lynds. The absorption redshifts range from $z = 2.875$ to $z = 1\ 776$. An average nonsense spectrum has 1.4 acceptable redshifts. The absence of absorption from excited fine-structure states implies that the absorbing region has an electron density $\lesssim 10^2$ cm^{-3} and is at a distance $\gtrsim 1$ kpc from the continuum source of the QSO.

I. INTRODUCTION

The QSO 4C 05.34 has the largest emission-line redshift ($z_{\rm em} = 2.877$, Lynds and Wills 1970) and the most absorption lines, 93 (Lynds 1971) thus far reported. The analysis of the absorption spectrum of 4C 05.34 is therefore unusually interesting. It is also unusually difficult because of the large number of lines and the possibility of blending. Many unknown parameters are involved in the analysis, including the number of redshift systems, their actual values, and the choice of standard (unredshifted) lines. In principle, more than 10^4 independent redshift systems must be examined, from $z = 4.5000$ to $z = 0.0000$. It therefore seemed useful to apply to 4C 05.34 the systematic method for identifying absorption lines in QSOs with rich spectra developed by Bahcall (1968, hereafter called Paper I). This method has the advantage that it provides a quasi-statistical measure of the significance of the identifications. Lynds (1970*a*) generously provided us with a list of the observed absorption lines and several beautiful photographs of the spectrum prior to the publication of his paper on the absorption-line spectrum of 4C 05.34 (Lynds 1971). As a mutual check on the significance of the identifications, as well as the dependence of reported redshifts on identification method, we agreed with Lynds that we would complete our analysis before reading his paper. Sections II and III of the present paper, which discuss our analysis of the observed spectrum and ten nonsense spectra that have the same characteristic features as the spectrum of 4C 05.34, were therefore completed before we read the paper of Lynds (1971). Section IV contains a comparison of our results with his. The reader is referred to the excellent paper of Lynds (1971) for a detailed discussion of the observational results.

Our principal conclusions are listed below. First, there are eight "acceptable" absorption redshifts in the observed spectrum: $z = 2.8751$, 2.8106, 2.7703, 2.5925, 2.4743, 2.1819, 1.8593, and 1.7758 (four of these were found by Lynds 1971: $z = 2.88$, 2.81, 2.77, and 2.47). Second, the eight acceptable redshifts identify 81 percent of all of the strong lines (i.e., 22 out of the 27 lines of strength ≥ 3) but only 34 percent of the weaker lines (strength ≤ 2). Third, the eight accepted redshift systems lead to the prediction of a number of reasonably strong absorption lines in the ultraviolet (3200–3500 Å) and the near-infrared (6000–7000 Å), as well as many fainter lines in the visual that are possibly observable at high dispersion. Fourth, an average nonsense spectrum has 1.4 acceptable absorption redshifts (with, on the average, only 1.7 out of 27 or 6 percent of the strong lines identified). Fifth, the absence of absorption lines originating on excited fine-struc-

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ture states of C, N, Si, and Fe ions implies that the absorbing region must have an electron density $\lesssim 10^{+2}$ cm^{-3} and be at a distance $\gtrsim 1$ kpc from the continuum source of the QSO (1 kpc $\gg$ conventionally estimated dimensions of the emission-line regions of QSOs).

In agreement with Lynds, we find no absorption redshifts with $z = 1.95$. This result does not support the suggestion by Burbidge (1967) that the absorption redshift $z = 1.95$ occurs unusually often.

It is interesting that the previously proposed formula for the expected number N of absorption redshifts in a QSO with emission redshift $z_{\rm em}$, i.e., $N = 2[(1 + z_{\rm em})^{3/2} - (1.2)^{3/2}]$ (Bahcall and Spitzer 1969) predicts nine absorption redshifts for 4C 05.34.

Lynds (1970*b*, 1971) has suggested that most of the absorption lines observed shortward of the Lα emission line in QSOs such as 4C 05.34 are due to Lα absorptions unaccompanied by other transitions. Another explanation for the distribution of observed absorption lines is obtained by noting (cf. Paper I) that $z_{\rm abs}$ is often substantially less than $z_{\rm em}$ and that many of the standard unredshifted lines have $\lambda_{\rm standard} \approx 1000$–1300 Å. Therefore, $(1 + z_{\rm abs})\lambda_{\rm standard}$ is naturally less than $(1 + z_{\rm em})1215.7$ Å for most of the lines. If we take account of this interpretation for the crowding of absorption lines shortward of Lα, the unidentified lines (which are primarily weak lines) may be: (1) weaker transitions associated with the identified redshifts; (2) independent redshift systems that are difficult to identify because the wavelength accuracy and even the existence of weaker lines is less certain than for strong lines; or (3) mostly Lα lines as suggested by Lynds. It seems to us likely that all three of these possibilities have some role to play in the explanation of the unidentified lines. The fact that we identify 20 out of the 25 strong lines shortward of the Lα emission line in 4C 05.34 in absorption systems containing between 4 and 11 lines suggests that explanations (1) and (2) do play some role.

The most important question regarding the observed absorption lines is whether or not some of the lines originate at cosmological distances from the QSO in whose spectrum they appear (for a review of the evidence on this question, cf. Bahcall 1971). Large-redshift QSOs such as 4C 05.34 offer a unique opportunity to study this question. On the basis of the "cosmological" explanation for the absorption lines (i.e., they occur at large distances from the QSO), one expects that the number of relatively small absorption redshifts ($z_{\rm abs} \sim 1.7$ to 2) will not depend very strongly on $z_{\rm em}$ for $z_{\rm em} \gtrsim 2$. The "local" hypothesis for all the absorption lines (i.e., that they originate in or near the QSO) suggests that as $z_{\rm em}$ becomes larger the number of observed absorption redshifts in the range 1.7–2 should decrease. Our identification of the absorption systems $z = 2.1819$, 1.8593, and 1.7758 supports the cosmological hypothesis for the origin of the absorption lines.

II. IDENTIFICATIONS

a) *Method*

We have used the systematic method for identifying absorption lines in QSSs with rich spectra that is described in Paper I. The standard lines used in our searches were essentially the same as those given in Table 1 of Paper I except that we added the short-wavelength line N II λ915.6 and the average of the C IV doublet $\lambda_{\rm av}$1549.06 and omitted, on the basis of previous experience (cf. Bahcall, Greenstein, and Sargent 1968; Burbidge, Lynds, and Stockton 1968; Bahcall, Osmer, and Schmidt 1969; Lynds 1970*b*), all lines from excited fine-structure states. The total number of standard lines was 36. In order to be acceptable, a candidate redshift was required to satisfy the following four rules (cf. Paper I and Bahcall *et al.* 1969):

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.

Of the above rules, only rule 2 regarding Lβ is new; we have also investigated the effect of dropping rule 2 (cf. § III*c*). The maximum permissible wavelength discrepancy was set at 2 Å in the observed frame. In searching for identifications within the matrix formed by the observed and standard lines, we used a tolerance $\epsilon = \pm 1.25 \times 10^{-3}$ in z at $z = 2$ and a step size $\delta = 4 \times 10^{-4}$ in z from a maximum z of 3.0 to a minimum z of 0.0. A redshift was considered a candidate for further study if the computer found a minimum of five matches between observed and standard lines in the tolerance range ϵ described above.

b) Identifications

Our identifications for the spectrum of 4C 05.34 (Lynds 1970*a*, 1971) are given in Table 1. Eight redshifts are acceptable according to the above rules; they are: z = 2.8751, 2.8106, 2.7703, 2.5925, 2.4743, 2.1819, 1.8593, and 1.7758. These eight redshifts definitely identify 22 out of the 27 very strong lines (strength ≥ 3), i.e., 81 percent of the very strong lines. The fraction of the weaker lines that are definitely identified is much smaller, namely, 10 out of the 19 strength-2 lines for a 53 percent identification success and only 16 out of the 47 strength-0 and strength-1 lines for a 34 percent identification success. The ratio of strong to weak lines identified is $22/(9 + 16) = 0.88$. We shall see in § III that the corresponding ratio for the nonsense spectra is only 0.30. The high percentage of strong lines identified in the spectrum of 4C 05.34 may reflect the fact that the wavelength measurements, strengths, and even the existence of the weaker lines is less certain than for the strong lines (cf. Lynds 1971). The rms wavelength discrepancy σ_λ in the observed frame averages to about 1 Å for the eight acceptable systems.

c) Questionable Identifications and Other Searches

In addition to the accepted identifications shown in Table 1, we also show several questionable identifications that are indicated by brackets enclosing the doubtful standard line. These questionable identifications were not used as evidence supporting the acceptance of any redshift, nor were they included among the lines successfully identified in the percentages given in the preceding paragraph. Most of the additional identifications are questionable because of poor wavelength agreement, although the identification with Fe II λ1144.95 in the z = 2.8751 system was judged doubtful because the lines in this absorption system are predominantly from more highly ionized atoms. The identification of λ_{obs} = 4529.91 Å with Si II λ1260.4 in the z = 2.5925 system was judged highly unlikely because of the absence of an expected line at λ_{obs} = 4286.8 Å due to Si II (strength 2) λ1193.3. It would be interesting to make a more thorough search for a possible line near λ_{obs} = 4286.8 Å.

We examined several special redshifts that might identify the few unidentified lines. The only interesting redshift found in this way was z = 1.4311 which identified four observed lines (strengths in parentheses)—λλ4529.9 (5), 4507.97 (3), 4061.5 (1), and 3766.3 (3)—with the following standard lines (in order): Al III (1) λ1862.8, Al III (2) λ1854.7, Al II λ1670.8, and C IV λ_{av} = 1549.5. This redshift was not accepted because the weaker of the Al III pair was identified with the stronger observed line. Nevertheless, it would be interesting to reexamine the observed lines λλ = 4529.9 and 4507.97 Å at higher dispersion to see if blending may have affected the relative line strengths. It might also be useful to search for the Fe II lines that could appear at λ_{obs} = 5699.0, 5772.7, and 5792.9 Å due to Fe II λλ2344.2, 2374.5, and 2382.8 if the 1.4311 redshift is real.

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TABLE 1

IDENTIFICATIONS FOR THE ABSORPTION SPECTRUM OF 4C 05.34 REPORTED BY LYNDS (1971)

Wavelength (Å)	Strength	Indentification
	$z=2.8751$	
3974.34	1	Lβ λ1025.7 (+0.4)
3997.07	5	O VI λ1031.95 (+1.8)
4019.67	3	O VI λ1037.6 (+1.2)
4436.74	3	[Fe II λ1144.95 (0.0)]
4676.18	1	Si III λ1206.5 (−0.9)
4710.81	4	Lα λ1215.7 (0.0)
4800.96	2	N V λ1238.8 (−0.5)
4816.94	2	N V λ1242.8 (−1.0)
5402.04	0	Si IV λ1393.8 (−1.1)
6005.61	1LD	C IV, A V λ1549.5 (−1.2)
	$z=2.8106$	
3706.10	3D	Lγ λ972.5 (−0.2)
3908.29	1D	Lβ λ1025.7 (+0.3)
4549.09	2	Si II λ1193.3 (−2.0)
4631.03	4	Lα λ1215.7 (+1.4)
4800.96	2	Si II λ1260.4 (+2.0)
4972.03	1	[Si II λ1304.4 (−1.6)]
5903.80	1LD	C IV, A V λ1549.5 (+0.5)
	$z=2.7703$	
3535.98	2	Lε λ937.8 (−0.2)
3582.46	3	Lδ λ949.7 (−1.7)
3668.39	2	Lγ λ972.5 (−1.7)
3683.54	3	C III λ977.0 (+0.1)
3867.06	3D	Lβ λ1025.7 (+0.2)
4084.42	1D	[N II λ1084.0 (+2.6)]
4233.72	0	Fe III λ1122.5 (−1.5)
4317.20	0D	Fe II λ1144.95 (−0.4)
4549.09	2	Si III λ1206.5 (−0.2)
4582.94	5	Lα λ1215.7 (+0.5)
5032.97	0	C II λ1334.5 (−1.5)
5839.00	0LD	C IV λ1548.2 (−1.9)
	$z=2.5925$	
3683.54	3	Lβ λ1025.7 (+1.3)
3706.10	3D	O VI λ1031.95 (+1.2)
3727.17	4B	O VI λ1037.6 (+0.5)
3894.82	2	N II λ1084.0 (−0.6)
4366.50	5B	Lα λ1215.7 (+0.8)
4451.95	0	N V λ1238.8 (−1.6)
4529.91	5	[Si II λ1260.4 (−1.9)]
5008.10	1	Si IV λ1393.8 (−1.1)
	$z=2.4743$	
3565.61	3D	Lβ λ1025.7 (−1.9)
3582.46	3	[O VI λ1031.95 (+2.9)]
3603.32	3	[O VI λ1037.63 (+1.8)]
3766.27	3	N II λ1084.0 (−0.1)
4223.59	4	Lα λ1215.7 (+0.1)
4304.62	1	N V λ1238.8 (−0.6)
4317.20	0D	N V λ1242.8 (+0.7)
4380.43	2	Si II λ1260.4 (−1.3)
4639.10	1	[C II λ1334.5 (−2.6)]
4842.29	1	Si IV λ1393.8 (+0.1)
5377.37	3	C IV λ1548.2 (+1.6)
5386.67	3	C IV λ1550.8 (+1.2)

NOTE.—Numbers in parentheses to the right of the standard lines are wavelength discrepancies (predicted minus observed wavelength) in the observed frame. The identifications in brackets are questionable and were not considered as evidence supporting other identifications. Letters following the line strengths stand for low dispersion (LD), diffuse (D), and broad (B) (see Lynds 1971).

TABLE 1—*Continued*

Wavelength (Å)	Strength	Identification
	$z=2.1819$	
3641.86	3	Fe II λ1144.95 (+1.3)
3867.06	3D	Lα λ1215.7 (+1.1)
4010.48	1	Si II λ1260.4 (−0.1)
4246.98	3	C II λ1334.5 (−0.7)
4436.74	3	Si IV λ1393.8 (−1.9)
4465.08	4D	Si IV λ1402.8 (−1.5)
	$z=1.8593$	
3603.32	3	Si II λ1260.4 (+0.6)
3816.09	2D	C II λ1334.5 (−0.4)
3985.83	2	Si IV λ1393.8 (−0.7)
4010.48	1	Si IV λ1402.8 (+0.4)
	$z=1.7758$	
3497.85	2	Si II λ1260.4 (+0.9)
3706.10	3D	C II λ1334.5 (−1.8)
3867.06	3D	Si IV λ1393.8 (+1.8)
3894.82	2	Si IV λ1402.8 (−1.0)
4296.49	3	C IV λ1548.2 (+1.0)
4304.62	1	C IV λ1550.8 (0.0)
4639.10	1	Al II λ1670.8 (−1.2)

We also made a number of unsuccessful specialized searches to try to identify additional lines. For example, we examined cadidates with redshifts in the range 4.5 to 3 and also candidates that did not satisfy rule 2, i.e., in which Lβ could appear but was not identified in the observed spectrum. No acceptable new redshifts were found in this way. We then reduced to four the number of matches required in the observed–standard matrix for a redshift to be a candidate for detailed study. In this search we added the requirement that one of the following lines: Si II λ1260.4, C IV (2) λ1548.2, or C IV λ_{av}1549.5 be identified and be of strength ≥ 3. No new identifications were found in any of the above searches.

We searched for additional line identifications in the eight accepted redshifts using the lines from Table 2 of Paper I. The lines from that table are expected to be less strong and include lines from excited fine-structure states, from neutral atoms, and from atoms that are relatively less abundant (at least in the Galaxy) such as Ar, S, Ge, etc. We also included lines arising from metastable states using Table 1 of Bahcall and Feldman (1970). The total number of such added standards was 92. No obviously acceptable pattern of identifications was found, although the chance coincidences with such a large class of standard lines are so large that a statistically significant set of identifications is probably impossible.

d) Other Expected Absorption Lines

A number of other absorption lines are either possible or predicted on the basis of the eight accepted redshift systems shown in Table 1. Some of the most important of these lines are (redshifts in which they are expected are in parentheses): C III λ977 (z = 2.875, 2.8106, 2.4743, 2.5925), Si III λ1206.5 (z = 2.8106, 2.4743), C IV λλ1548.2, 1550.8 (z = 2.5925, 1.8593), Al II λ1670.8 (z = 2.4743, 2.1819), and Fe II λλ2344.2, 2374.5, 2382.8 (z = 1.8593, 1.7758). For the two smallest redshift systems (z = 1.8593 and

1.7758), the Lα lines are predicted to be at accessible wavelengths. The test of whether or not they appear is critical for the two systems $z = 1.8593$, 1.7758. It is particularly important to determine if the Lα line actually appears in the $z = 1.8593$ system since this is the only one of our eight redshifts that is based on only four lines and hence is most likely to be accidental (cf. Table 2 of § III).

e) Limits on the Physical Conditions

Transitions from the ground fine-structure states of C II, N II, Si II, Fe II, and Fe III are among the identified lines in the eight accepted redshift systems. No lines from excited fine-structure states are definitely identified. The absence of lines from the excited fine-structure states allows one to place limits on the average electron density N_e in the absorbing medium and on the minimum distance D between the absorbing medium and 4C 05.34 (cf. Bahcall and Wolf 1968, especially Table 1 and § VI*g*). We find:

$$N_e \lesssim 10^2\ \mathrm{cm}^{-3} \quad \text{and} \quad D \gtrsim 1\ \mathrm{kpc}\,. \tag{1}$$

III. NONSENSE SPECTRA

In order to determine how many of our eight accepted redshift systems might be due to chance coincidences between standard and observed lines, we have analyzed 10 nonsense spectra with the same rules that were applied to the observed spectrum. The nonsense spectra were constructed by a random-number program (cf. Paper I) that ensured that each spectrum had the same characteristic features as the observed spectrum. In particular, the nonsense spectra all had 93 lines in the region 3500–6000 Å with a minimum separation between two wavelengths of 6 Å. Each of the random-number spectra had the same number of lines of strengths 5, 4, 3, etc., as in the observed spectrum.

Our results for the 10 nonsense spectra are summarized in Table 2. We found a total of 14 acceptable redshift systems among the 10 nonsense spectra, for an average of 1.4 accidental redshift systems per random-number spectrum. A total of 70 lines were identified in the 10 spectra investigated. One nonsense spectrum had three independent acceptable redshift systems for a total of 15 lines identified. Two other spectra each had

TABLE 2

ACCEPTED REDSHIFTS IN TEN NONSENSE SPECTRA

z	Lα Strength	Total Number of Lines	σ_λ (Å)	Strength-5 Lines	Strength-4 Lines	Strength-3 Lines	Strength-2 Lines	Strength-1 Lines	Strength-0 Lines
2.7994...	3	5	0.9	1	...	1	1	1	1
2.6866...	3	5	0.9	...	...	2	...	3	...
2.3663...	2	4	...	...	...	2	1	1	...
2.3595...	2	5	1.0	...	...	...	4	...	1
2.2815...	2	6	1.2	...	...	1	2	3	...
2.2798...	2	7	1.1	...	1	...	4	2	...
2.2398...	4	5	1.2	...	1	1	1	2	...
2.2356...	4	4	1.0	...	1	...	...	3	...
2.1011...	3	4	1.2	...	...	1	1	2	...
2.0672...	2	7	1.1	...	...	1	2	2	2
1.9930...	5	5	1.2	1	...	...	2	1	1
1.9900...	2	4	1.0	...	...	1	2	1	...
1.9390...	3	4	1.0	...	...	1	1	2	...
1.5920...	...	5	1.0	...	...	1	2	1	1

NOTE.—The redshifts given here were identified in the 10 random-number spectra according to the same rules used in studying the spectrum of 4C 05.34. An average of 7.0 lines per nonsense spectrum were identified, of which 1.7 were, on the average, of strength ≥ 3. The quantity σ_λ is the rms wavelength discrepancy as computed in the observed frame.

two acceptable redshift systems for a total of 10 and 11 lines identified, respectively. As can be seen from Table 1, seven of the 14 redshift systems occur in the narrow bands $z = 2.24$ to 2.28 and $z = 1.94$ to 1.99.

We note that only 25 percent of the lines identified in the nonsense spectra are of strength ≥ 3. In the observed spectrum, 46 percent of the lines that are identified are of strength ≥ 3. A more detailed comparison of the identifications in the observed and nonsense spectra is given in Table 3.

IV. COMPARISON WITH LYNDS

The previous discussion is based on work that was completed by prior agreement before we read the paper of Lynds (1971). We now compare our results with his.

Lynds lists five redshifts for which he gives a qualitative impression of the relative credibility ranging from certain ($z = 2.8754$ and 2.4739), to probable ($z = 2.8098$ and 2.7701), to possible (2.7262). The four probable and certain redshifts are also in our Table 1; each of these four redshifts corresponds to a prominent system of lines with a Lα line of strength 4 or 5. The one redshift listed as "possible" by Lynds, $z = 2.7262$, was initially rejected by us because it has a Lα line of strength 5 but no Lβ line. In addition, Lynds also identified in this system a single C I resonance line and a line from a metastable state, C III λ1175.6. We find both of these identifications somewhat unsatisfactory for reasons given below.

The agreement between the two sets of identifications for the four redshift systems in common is satisfactory, although not complete, if we confine ourselves to lines that appear in our primary search list of standard lines (Table 1 of Paper I). The interested reader may wish to compare in detail the identifications in Table 1 of the present paper with those in Table 2 of Lynds (1971) in order to see what the specific differences are.

Lynds has suggested tentatively that there may be transitions involving neutral atoms other than hydrogen (C I and O I) and absorption from a metastable state, e.g., C III λ1175.7. If these suggestions are correct, they tell us a great deal concerning the nature of the medium that produces the absorption lines. However, we believe these tentative identifications are probably not correct because (among other reasons) they are not consistent with other identifications in the same systems (at least on the basis of the material already published by Lynds 1971). The O I line λ1302.2 was identified in the system $z = 2.8754$, but the stronger O I line λ988.8 is not present (at $\lambda_{obs} = 3832$ Å). Also, the potentially strong N I lines $\lambda\lambda$1134.6 and 1199.9 are not present. The C I line λ1277.3 was identified in the system $z = 2.7262$, but the other strong lines of C I $\lambda\lambda$1560.3, 1328.8, and 945.2 are absent in the same system. Finally C III λ1175.7 was identified by Lynds in the system $z = 2.8106$ in which we have suggested the more conventional lines Si II $\lambda\lambda$1260.4 and 1193.4. Since the Si II lines show no evidence of components from excited fine-structure states, it appears unlikely on physical grounds (cf.

TABLE 3

COMPARISON OF IDENTIFICATIONS IN OBSERVED AND NONSENSE SPECTRA

Spectrum	Number of Acceptable Redshifts	Total Number of Lines Identified	Percentage Strong Lines Identified	Percentage Weak Lines Identified	σ_λ (Å) (average)
Observed spectrum	8	47	81	34	1.1
"Average" nonsense spectrum	1.4	7.0	6	8	1.1

NOTE.—The numbers for an "average" nonsense spectrum were obtained by adding together all the identifications for the 10 random-number spectra and then dividing by 10. Strong lines are defined as lines of strength ≥ 3 and weak lines as ones with strengths ≤ 2. The quantity σ_λ is the root mean square wavelength discrepancy as computed in the observed frame.

Bahcall 1967) that they coexist with a significant population of metastable C III ions. Similar remarks can be made about the system $z = 2.4743$ in which Lynds also tentatively suggested the presence of C III λ1175.7, and we propose the ground-state transitions of N II λ1084.0, Si II λ1260.4, and possibly C II λ1334.5.

Lynds (1971) has stressed, in connection with the problem of uncertain identifications, that a statistical solution may be possible even though individual cases are still uncertain. We note that the density of observed lines in the spectrum of 4C 05.34 is about one line per 27 Å and a permissible wavelength error is $\sim\pm 2$ Å. Thus the probability is ~1 in 7 that a line with a randomly chosen wavelength between ~1000 and 1500 Å could be "identified" in a given redshift system with $z \sim 2$ or 3. If one were to add only *one* such nonsense line to our original list of standard lines, the probability is greater than 70 percent that the nonsense line would be identified in one or more of our eight redshift systems. This calculation provides some indication of the difficulty of making statistically significant individual identifications in a spectrum as rich as that of 4C 05.34.

We are grateful to Dr. R. Lynds for generously supplying us prior to publication with the list of observed lines in 4C 05.34 and with several beautiful photographs of the spectrum. One of us (S. G.) would like to thank the California Institute of Technology and the National Science Foundation for making possible his work on this problem.

REFERENCES

Bahcall, J. N. 1967, *Ap. J.* (*Letters*), **149**, L7.
———. 1968, *Ap. J.*, **153**, 679 (Paper I).
———. 1971, *A.J.*, **76**, 283.
Bahcall, J. N., and Feldman, U. 1970, *Ap. J.*, **161**, 389.
Bahcall, J. N., Greenstein, J. L., and Sargent, W. L. W. 1968, *Ap. J.*, **153**, 689.
Bahcall, J. N., Osmer, P. S., and Schmidt, M. 1969, *Ap. J.* (*Letters*), **156**, L1.
Bahcall, J. N., and Spitzer, L., Jr. 1969, *Ap. J.* (*Letters*), **156**, L63.
Bahcall, J. N., and Wolf, Richard A. 1968, *Ap. J.*, **152**, 701.
Burbidge, G. R. 1967, *Ap. J.*, **147**, 851.
Burbidge, G. R., Lynds, C. R., and Stockton, A. N. 1968, *Ap. J.*, **152**, 1077.
Lynds, R. 1970*a*, private communication.
———. 1970*b*, *I.A.U. Symposium No. 44, External Galaxies and Quasi-stellar Objects* (in press).
———. 1971, *Ap. J.* (*Letters*), **164**, L73.
Lynds, R., and Wills, D. 1970, *Nature*, **226**, 532.