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THE SPECTRUM OF THE QUASAR B2 1225+31

M. S. WILKERSON, G. COLEMAN, G. GILBERT, P. A. STRITTMATTER, AND R. E. WILLIAMS
Steward Observatory, University of Arizona
J. A. BALDWIN AND R. F. CARSWELL
Institute for Astronomy, Cambridge
AND
S. A. GRANDI
Lick Observatory, University of California, Santa Cruz
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ABSTRACT

The spectrum of the intrinsically bright QSO B2 1225+31 ($z_{em} \sim 2.2$) has been analyzed in the range 3140 Å < λ < 8000 Å, using image-tube scanner and echelette data. The emission lines are abnormally weak and broad, although their relative intensities are comparable to those of other QSOs. The absorption-line spectrum is exceedingly rich shortward of emission Lα. One absorption system ($z_A \sim 1.7941$) is very well established, with 25 resonance-line identifications. Several other systems are suggested but the evidence is in no case compelling. No strong evidence for line locking or abnormal abundances was found in this object.

Subject heading: quasars

I. INTRODUCTION

The 15.8 mag QSO B2 1225+31 was identified by Bergamini *et al.* (1973). Subsequent studies of the radio and optical properties have been made by Crovisier *et al.* (1974); by Fanti *et al.* (1975), who also provided a finding chart; and by Ulrich (1976), who determined the emission-line redshift $z_{em} \sim 2.2$. Ulrich also noted the presence of several strong absorption lines in the spectrum and identified one clear-cut absorption system at a redshift $z_{abs} = 1.793$. B2 1225+31 is the brightest high-redshift QSO so far known. As such, it was included in our program of intermediate resolution (~2 Å) spectroscopy of QSO absorption lines and emission-line profiles.

II. THE OBSERVATIONS

Observations of B2 1225+31 have been carried out both at Lick Observatory and at Steward Observatory between 1974 and 1976. The Lick data were obtained with the Cassegrain image-tube scanner (ITS; Robinson and Wampler 1972) on the 3 m telescope on the nights of 1974 May 27 and 28, and 1976 March 4 and 29. Three different gratings were used, giving values of approximately 20 Å, 10 Å, and 3 Å, respectively, for the full width of an unblended line at half-maximum intensity. The scans cover the wavelength range 3500–8600 Å. A composite low-resolution spectrum is shown in Figure 1. The Steward data consist of four spectrograms (SI 1401, 1402, 1567, 1601) obtained with the RCA 33063 image tube and the Cassegrain echelette spectrograph (Carswell *et al.* 1975) attached to the 2.3 m telescope. The spectrograms were recorded on baked Kodak IIa-O emulsion and cover the wavelength range 3100–6300 Å at a resolution $\Delta\lambda/\lambda \sim 5 \times 10^{-4}$. The plates were measured with the PDS microdensitometer at Kitt Peak National Observatory by using an entrance aperture of 16 μm and steps of 8 μm. The data were reduced on the CDC 6400 computers at Kitt Peak and the University of Arizona. The reduced data are shown in Figure 2, after conversion to intensity and addition of individual spectra. Some further single-order observations in the red region of the spectrum were made with the Steward Observatory digital TV system (Gilbert, Angel, and Grandi 1976).

III. THE EMISSION SPECTRUM

The continuum energy distribution can be roughly fitted by a power law of the form $f_\nu \propto \nu^{-0.62}$, although there are considerable deviations from such a fit. There is a broad emission hump in the region near the Mg II absorption lines near 7800 Å. This feature appears in two independent scans. As in many QSOs, the continuum appears depressed shortward of the Lα emission line, probably due to Lα absorption. Measurements with a polarization analyzer attached to the ITS (Nordsieck 1974) on the night of 1974 May 28 give an upper limit of about 1% for the linear polarization averaged over the 4900–7300 Å wavelength range.

The emission lines are very broad, weak, and asymmetrical. The redshift is therefore rather uncertain. Redshifts determined from the first moment of the flux in each line are given in Table 1, together with full widths at half-intensity, equivalent widths (W), and relative intensities. The positions of the Lα, C IV, and

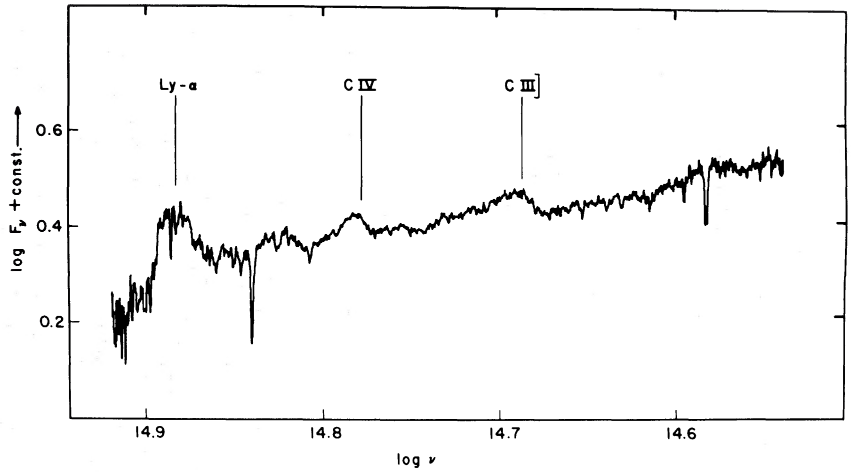

FIG. 1.—Composite low-resolution spectrum of B2 1225+31 obtained with the Lick Observatory image-tube scanner system.

C III] lines for a redshift $z = 2.230$ (the redshift of Lα) are marked on Figure 1. The broad emission hump between Lα and C IV is due to Si IV and O IV] λ1400.

The emission profiles of Lα, C IV, and C III] obtained with the ITS are shown in Figure 3 reduced to the redshift of the C IV line. It is clear that both C IV and C III] have extended blueward wings, the effect apparently being stronger in C III]. This result, however, is very sensitive to the assumed continuum level and must accordingly be treated with caution. There is no doubt that the C IV line cuts off earlier to the red than C III]. The Lα line is clearly strongly affected by Lα absorption, especially toward the blue where the observed radiation falls below the continuum level extrapolated from higher wavelengths. This is a common feature of high-z QSO spectra. The Lα feature also extends farther to the red than either C IV or C III], indicating probable blending with a N V λ1240 emission line.

The profiles of C IV and C III] are similar to those seen in PHL 957 (Coleman *et al.* 1976) and are consistent with those expected from an expanding cloud of gas the far side of which is obscured. The origin of this obscuration is unknown but in C III], at least, cannot be due to self-absorption. Although dust cannot be excluded as an absorption mechanism, there is little evidence in QSO spectra for the presence of "normal" grains in the emission-line region of QSOs. In view of the densities and dimensions normally assigned to the line-emitting regions of QSOs (see Strittmatter and Williams 1976, and references therein), electron scattering seems to be the most natural explanation. The generally sharper profile of C IV could then be ascribed to additional self-absorption or simply to velocity differences between regions where C^{+++} and C^{++} ions predominate.

The equivalent widths and relative emission-line strengths listed in Table 1 are of rather low accuracy because of uncertainties in the continuum level. The equivalent widths are, however, quite small by QSO standards. When compared with the corresponding rest wavelength values in a sample of QSOs observed by Baldwin *et al.* (1973), the equivalent widths in B2 1225+31 are between 4 and 5 times smaller. They are also approximately 3 times smaller than those found in PHL 957 (Coleman *et al.* 1976). However, the ratio of the Lα to C IV line strengths is about 3 to 1, which is in the range normally found for QSOs (Oke, Neugebauer, and Becklin 1970; Davidson 1972). The C III] line is apparently as strong as or stronger than C IV λ1550, which is unusual in QSO spectra, although there are a few other such cases (PHL 957 and 1331+17, for example). The weakness of the C IV line relative to the C III] line might in principle be caused by a high-energy cutoff in the ionizing spectrum (as was noted by Davidson [1973] with reference to PHL 957). It is, however, difficult to see how the normal Lα to C IV line ratio or the apparently significant contribution from N V could be reconciled with this hypothesis.

IV. THE ABSORPTION LINES

Absorption lines are evident in B2 1225+31 even at relatively low spectral resolution. The echelette data, however, revealed a very dense distribution of absorption lines, especially in the region shortward of Lα. In order to establish the reality or otherwise of the weaker features, we proceeded as follows. Each spectral order on each spectrogram was analyzed independently and the wavelength and strength (on a scale of 1–5) of each possible feature were noted. Those lines of strength greater than 2 which appeared with internally consistent strengths in all spectrograms and orders where they should have been observable are listed in Table 2 as definite lines. Approximate equivalent widths are also given for these features. In addition, there were several lines of strength 1 or 2 which appeared on all plates but whose strengths were not consistent from plate to plate or order to order, or which could still conceivably be due to noise. These

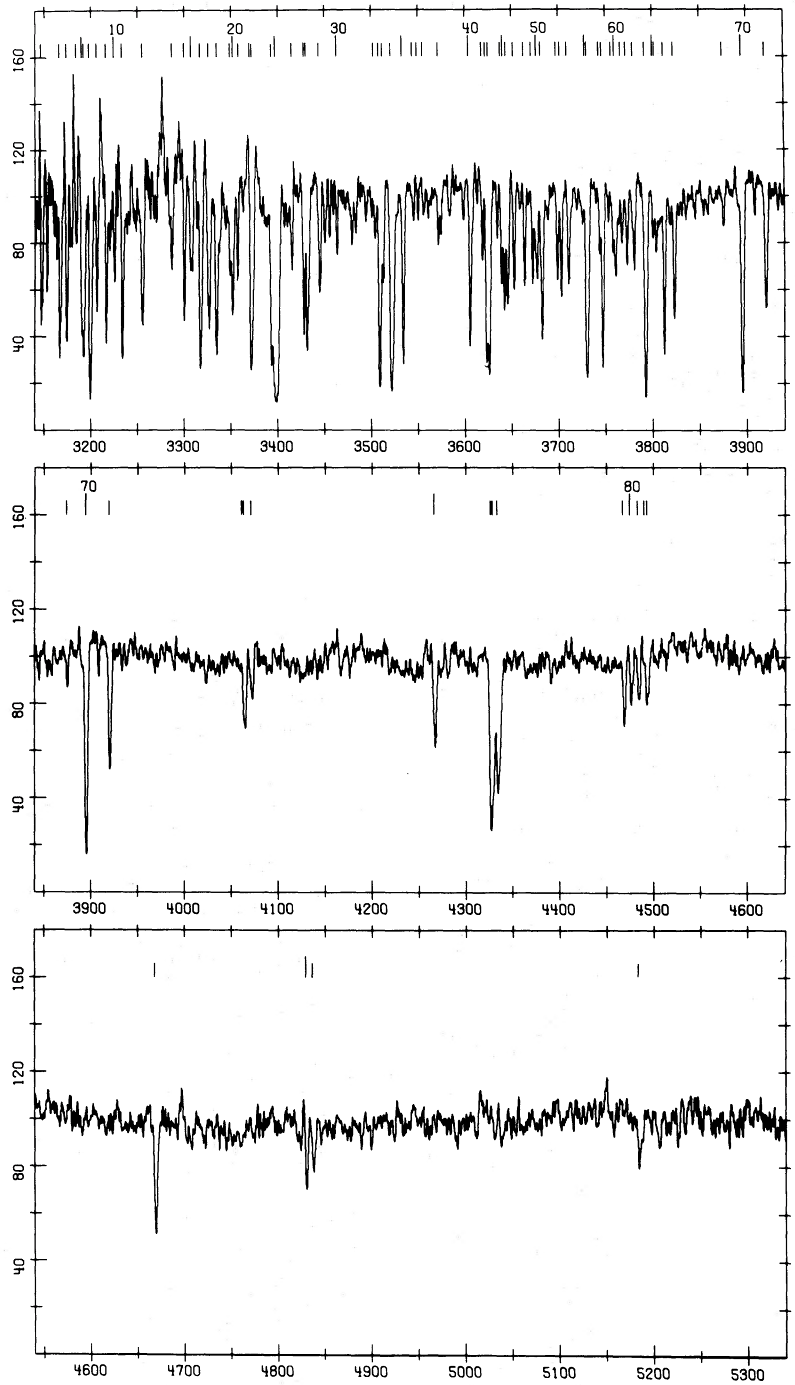

FIG. 2.—Composite echelette spectrum of B2 1225+31 reduced to relative intensity and normalized over the observed spectral range. Definite lines are indicated above the spectrum. Two close vertical bars indicate absorption lines which could be caused by two different redshift systems.

features are listed in Table 3 as possible lines. The probability of discovery for the weaker lines clearly depends on both the signal-to-noise ratio and position in spectral orders (because of the confirmation procedure). The list is thus not complete for lines of strength less than ~3. The coverage in the 5000–6000 Å range is also less complete than elsewhere for instrumental reasons. All the features noted by Ulrich (1976) were confirmed.

The line lists were then analyzed for absorption systems, using a computer program developed by Coleman (1978). Each potential system is assigned a

TABLE 1

EMISSION-LINE DATA

Line	Observed λ (1st moment)	z	FWHM (Å)	Observed W (Å)	Relative Intensity
Lα λ1216 (+N v λ1241)	3927.54	2.230	170	44	10
Si IV λ1400	4477.37	2.198	170	10	2
C IV λ1549	4918.19	2.173	185	22	4
C III] λ1909	5953.03	2.118	400	50	7

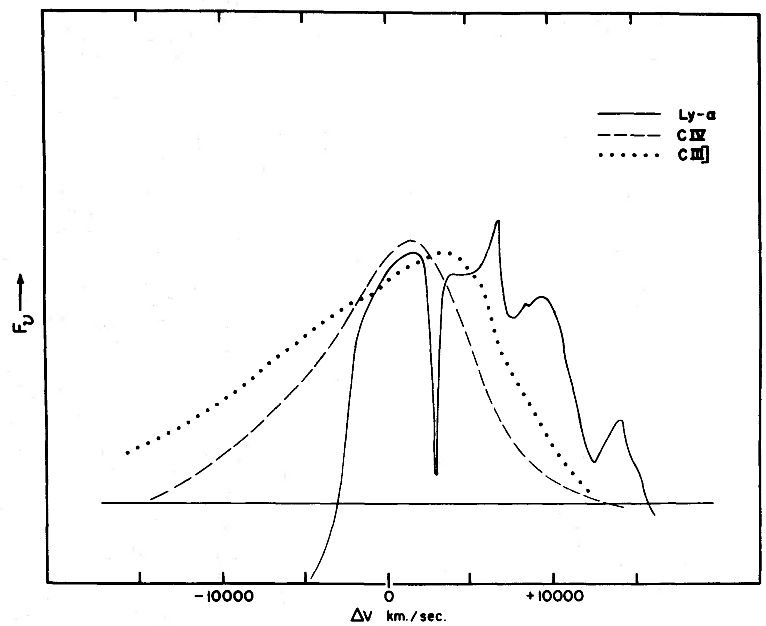

FIG. 3.—Comparison of Lα, C IV, and C III] emission-line profiles obtained with the Lick Observatory image-tube scanner. The velocity scale is appropriate for the rest frame of the QSO, and the zero of the velocity scale is defined by the redshift of the C IV line.

probability of occurring by chance in a locally random distribution of lines having the same general density distribution (Coleman *et al.* 1976). Only one clear-cut redshift system was found; the corresponding features are listed in Table 4. Several other physically self-consistent systems listed in Table 5 may be real but have a nonnegligible probability of arising by chance. These systems are discussed individually below.

a) *Individual Redshift Systems*

i) *System A* ($z_A = 1.7941$)

This system, which was discovered by Ulrich (1976), is exceedingly well defined and is rather similar in ionization structure to system *A* ($z = 1.7755$) in 1331+17 (Carswell *et al.* 1975) and to system *K* ($z = 1.7969$) in PHL 957 (Coleman *et al.* 1976). The H I region spectrum is well developed, although some of the weaker Fe II transitions and Si II λ1808 are not observed. There is marginal evidence for N v λ1238.8 absorption, but the wavelength agreement is poor and the λ1242.8 transition was not observed. A search was made for lines arising from excited fine-structure levels of the ground state but the results, which are listed in the lower section of Table 4, were inconclusive. There is some evidence from the Si II lines that the fine-structure levels are populated. The population of the excited fine-structure level of C II should, however, be relatively greater than in Si II (Bahcall and Wolf 1968). The resultant C II λ1335.4 line is not clearly discernible in our data, although it might be blended with the very strong C II λ1334.5 feature at 3729–3731 Å. A similar situation arises in 3C 191 (Williams *et al.* 1975), where the line density is much lower than in 1225+31 and the identification of Si II fine-structure level lines is more secure. We note that, unlike 3C 191, the Si II λ1304 line is clearly present in B2 1225+31 at a strength comparable to Si II λ1526. The results may permit a resolution of the problems associated with relative Si II resonance-line oscillator strengths (Williams *et al.* 1975; Nussbaumer 1977). The large number of lines present may also permit abundance studies, although preliminary analysis suggests that these are approximately solar.

TABLE 2

DEFINITE LINES

λ	W (Å)	λ	W (Å)	λ	W (Å)	λ	W (Å)
3147.4......	1.3	3415.0......	0.6	3671.9......	0.6	4072.2......	0.6
3167.2......	1.8	3428.0......	1.4	3676.2......	1.2	4266.8......	1.4
3174.4......	1.6	3431.8......	2.0	3682.1......	1.7	4327.4......	4.2
3184.6......	0.4	3444.8......	1.2	3698.4......	0.7	4334.7......	2.9
3191.9......	3.5	3463.1......	0.5	3702.5......	0.8	4468.6......	0.9
3199.7......	3.3	3503.7......	0.3	3710.4......	0.9	4476.0......	0.6
3206.6......	1.1	3509.0......	2.8	3730.1......	3.2	4484.3......	0.6
3216.7......	1.2	3512.6......	0.7	3743.5......	0.4	4493.2......	0.9
3225.4......	0.7	3521.9......	4.3	3746.7......	1.9	4669.5......	1.8
3234.1......	1.9	3534.0......	1.9	3757.4......	0.5	4830.3......	0.8
3255.5......	2.1	3544.8......	0.4	3760.3......	1.0	4837.7......	0.7
3286.5......	1.5	3549.8......	0.3	3767.1......	0.4	5184.7......	0.7
3300.3......	1.3	3555.9......	0.3	3772.5......	0.5	5206.1......	0.5
3307.7......	1.5	3571.4......	0.5	3780.0......	0.6	6549.7......	0.8
3317.8......	2.6	3605.3......	1.5	3792.5......	3.1	6657.5......	1.7
3326.6......	2.1	3618.4......	0.4	3800.2......	0.3	7228.5......	0.5
3334.8......	2.3	3623.1......	2.2	3803.6......	0.5	7265.1......	1.4
3349.0......	0.6	3626.1......	1.9	3812.2......	1.6	7814.0......	5.5
3351.9......	1.4	3638.8......	0.7	3822.9......	1.4	7833.7......	4.5
3357.2......	0.6	3641.9......	1.1	3875.1......	0.3	7969.3......	1.1
3372.3......	2.9	3645.3......	1.3	3895.3......	3.2		
3393.2......	1.1	3652.2......	0.8	3920.5......	1.8		
3397.7......	6.3	3663.4......	0.7	4064.5......	1.2		

ii) *System B* ($z_B = 1.6241$)

This system is based on eight lines, including most of those that appear prominently in QSO spectra. The wavelength agreement is reasonably good, although the relative strengths of the Si IV components suggests that there is an additional contribution to the λ3681 line. Both Lα and Si II λ1260.4 are also identified with lines in other, though less plausible, redshift systems.

iii) *System C* ($z_C = 1.8855$)

This system is based primarily on Lα and the C IV doublet. The λ3444 line is clearly too strong to be Si II λ1193.3, since the λ1190.4 feature is absent.

iv) *System D* ($z_D = 1.8958$)

This higher-ionization system contains, in addition to Lα, lines identified as N V, Si IV, and C IV. The

TABLE 3

POSSIBLE LINES

λ	S	λ	S	λ	S	λ	S
3123..........	2	3456..........	1	4023..........	1	4721..........	1
3139..........	2	3459..........	1	4036..........	2	4752..........	1
3153..........	2	3479..........	1	4042..........	1	4761..........	1
3161..........	1	3482..........	1	4070..........	2	4820..........	1
3164..........	1	3501..........	1	4091..........	1	4900..........	1
3171..........	1	3561..........	1	4107..........	1	4918..........	1
3179..........	1	3575..........	1	4159..........	1	4922..........	1
3209..........	1	3589..........	2	4167..........	2	4956..........	1
3214..........	2	3600..........	1	4177..........	1	4988..........	2
3220..........	1	3604..........	1	4182..........	1	4991..........	1
3228..........	2	3635..........	1	4276..........	1	5005..........	2
3247..........	1	3658..........	2	4287..........	1	5021..........	2
3252..........	1	3719..........	1	4318..........	1	5156..........	2
3268..........	2	3753..........	1	4340..........	1	5251..........	1
3270..........	1	3801..........	1	4342..........	1	5340..........	1
3277..........	2	3807..........	1	4353..........	1	5360..........	1
3297..........	1	3819..........	1	4391..........	1	5527..........	1
3315..........	1	3845..........	2	4428..........	1	5618..........	1
3339..........	1	3853..........	1	4536..........	1	5887..........	1
3346..........	1	3868..........	1	4549..........	1	6635..........	1
3401..........	1	3909..........	2	4579..........	1	6956..........	1
3407..........	1	3934..........	1	4618..........	1	7551..........	1
3421..........	1	3988..........	1	4703..........	1		
3451..........	2	3998..........	1	4708..........	1		

TABLE 4

REDSHIFT SYSTEM A ($z_A = 1.7945$)

Line	EW(Å) or S	Identification	Redshift	Δλ	Comments
3171	(1)	NI λ 1134.6	1.7948	+0.3	
3326.6	2.1	SiII λ 1190.4	1.7945	0.0	
3334.8	2.3	SiII λ 1193.3	1.7946	+0.1	
3351.9	1.4	NI λ 1199.9	1.7935	-1.2	
3372.3	2.9	SiIII λ 1206.5	1.7951	+0.7	Also NII 1084.0 in System E
3397.7	6.2 vb	Lα λ 1215.7	1.7948	+0.4	
3463.1	0.5	NV λ 1238.8	1.7955	+1.2	
3521.9	4.3	SiII λ 1260.4	1.7943	-0.2	
3638.8	0.7	OI λ 1302.2	1.7943	-0.2	Also SiII 1260.4 in System C
3645.3	1.3	SiII λ 1304.4	1.7946	+0.1	
3729(-31)	3.2 vb	CII λ 1334.5	1.7943	-0.3	
3895.3	3.2 vb	SiIV λ 1393.8	1.7947	+0.3	
3920.5	1.8	SiIV λ 1402.8	1.7948	+0.4	
4266.8	1.4	SiII λ 1526.7	1.7948	+0.5	
4327.4	4.2 b	CIV λ 1548.2	1.7951	+0.9	
4334.7	2.9	CIV λ 1550.8	1.7951	+0.9	Also SiIV 1393.8 in System E
4493.2	0.9	FeII λ 1608.4	1.7936	-1.4	
4669.5	1.8	AlII λ 1670.8	1.7948	+0.5	
5184.7	0.7	AlIII λ 1854.7	1.7954	+1.5	
5206.1	0.5	AlIII λ 1862.8	1.7948	+0.5	
6549.7	0.8	FeII λ 2344.2	1.7940	-1.1	
6635	(1)	FeII λ 2374.4	1.7944	-0.3	
6657.5	1.7	FeII λ 2382.7	1.7941	-0.9	
7228.5	0.5	FeII λ 2586.7	1.7945	0.0	
7265.1	1.4	FeII λ 2600.3	1.7939	-1.5	
7814.0	5.5	MgII λ 2796.3	1.7944	-0.3	
7833.7	4.5	MgII λ 2803.5	1.7943	-0.6	
7969.3	1.1	MgI λ 2852.7	1.7936	-2.5	
Line	**Strength**	**Identification**	**Redshift**	**Δλ**	**Comments**
3338	(1)	SiII λ 1194.5	1.7945	0.0	
3345	(1)	SiII λ 1197.4	1.7936	-1.0	
3534.0	1.9	SiII λ 1264.3	1.7952	+0.8	
3658	(2)	SiII λ 1309.3	1.7939	-0.8	Also SiII 1393.8 in System B and CIV 1550.8 in System F
3731:	3.2 b	CII λ 1334.5	1.7933	-1.5:	Blend with CII 1334.5
4286	(1)	SiII λ 1533.4	1.7950	+0.8	

main problems are a rather poor wavelength fit and the weakness of the λ4035 line identified with Si IV λ1393.8. The λ4061 feature identified with Si IV λ1402.8 must therefore be primarily due to absorption at another redshift.

v) *System E* ($z_E = 2.1093$)

Neither the wavelength agreement nor the line-strength consistency is particularly satisfactory for this system. Clearly, Lβ, N II λ1084.0, and Si IV λ1393.8 are too strong to be the sole contributors to the observed features. Lα seems also rather weak. Perhaps the most serious objection to the system is the absence of N V and C IV lines if the S IV and O VI identifications are accepted.

vi) *System F* ($z_F = 1.3582$)

System *F* suffers mainly from the absence of the Mg II doublet which should appear at 6594 and 6611 Å. Our data show weak possible features in this region, as well as possible identifications for the Fe II λ2587 and λ2600 transitions. None of these features were, however, considered sufficiently clear to include in Table 3. Further observations are planned to settle this question. In the meantime, we consider the evidence for system *F* to be marginal in view of the relatively poor wavelength agreement.

vii) *System G* ($z_G = 2.1197$)

This system is based on Lβ, Lα, and the C IV doublet. There is no indication in our data that C II, Si II, Si III, Si IV, or N V is present, and in the absence of other features of similar ionization, the identifications of lines of N I and O VI are doubtful.

In summary, system *A* is well established; systems *B* through *G* appear marginal but can be tested with higher-resolution data. We note that essentially all

TABLE 5

POSSIBLE REDSHIFT SYSTEMS

Line	Strength	Identification	z	Δλ	Comments
		System B (z = 1.6251)			
3167.2	1.8	SiIII λ 1206.5	1.6251	-0.1	
3191.9	3.5	Lα λ 1215.7	1.6256	+0.2	Also Lβ in System E
3307.7	1.5	SiII λ 1260.4	1.6243	-1.1	Also SiIV λ1402.8 in System F
3503.7	0.3	CII λ 1334.5	1.6254	+0.3	
3658	(2)	SiIV λ 1393.8	1.6245	-0.9	Also CIV λ1550.8 in System F
3682.1	1.7	SiIV λ 1402.8	1.6248	-0.5	Too strong
4064.5	1.2	CIV λ 1548.2	1.6253	+0.2	
4072.2	0,6	CIV λ 1550.8	1.6258	+0.8	
		System C (z = 1.8865)			
3444.8	1.2	SiII λ 1193.3	1.8868	+0.3	Too strong
3463.1	0.5	NI λ 1199.9	1.8861	-0.5	
3483.0	(1)	SiIII λ 1206.5	1.8868	+0.3	
3509.0	2.8	Lα λ 1215.7	1.8864	-0.1	
3638.8	0.7	SiII λ 1260.4	1.8870	+0.6	Also OI λ1302.2 in System A
4468.6	0.9	CIV λ 1548.2	1.8863	-0.3	
4476.0	0.6	CIV λ 1550.8	1.8863	-0.3	
		System D (z = 1.8963)			
3521.9	4.3	Lα λ 1215.7	1.8970	+0.8	Also SiII λ1260.4 in System A
3589	(2)	NV λ 1238.8	1.8971	+1.0	
3599.5	(2)	NV λ 1242.8	1.8963	0.0	
3866	(1)	CII λ 1334.5	1.8969	+0.8	
4036	(2)	SiIV λ 1393.8	1.8956	-1.0	
4062	1.2b	SiIV λ 1402.8	1.8956	-1.0	
4484.3	0.6	CIV λ 1548.2	1.8964	+0.2	
4491.0	0.9	CIV λ 1550.8	1.8959	-0.6	Blended with FeII λ1608.4 in System A
		System E (z = 2.1103)			
(3191.9	3.5	Lβ λ 1025.7	2.1118	+1.5)	Too strong. Also Lα in System B
3209	(1)	OVI λ 1031.9	2.1097	-0.6	
3228	(2)	OVI λ 1037.6	2.1106	+0.3	
3372.3	2.9	NII λ 1084.0	2.1109	+0.6	Also SiIII λ1206.5 in System A
3702.5	0.8	SiII λ 1190.4	2.1103	0.0	
3710.4	0.9	SiII λ 1193.3	2.1094	-1.1	
3753	(1)	SiIII λ 1206.5	2.1107	+0.5	
3780	0.6	Lα λ 1215.7	2.1093	-1.2	Too weak
4334.7	2.9	SiIV λ 1393.8	2.1100	-0.4	Too strong. Also CIV λ1550.8 in System A
4362	(1)	SiIV λ 1402.8	2.1102	-0.1	
		System F (z = 1.3582)			
3147.4	1.3	CII λ 1334.5	1.3584	+0.3	Too strong?
3286.5	1.5	SiIV λ 1393.8	1.3579	-0.4	
3307.7	1.5	SiIV λ 1402.8	1.3579	-0.4	Also SiII λ1260.4 in System B
3599.5	(1)	SiII λ 1526.7	1.3577	-0.8	
3652.2	0.8	CIV λ 1548.2	1.3589	+0.9	
3658	(2)	CIV λ 1550.8	1.3588	+0.8	Also SiIV λ1393.8 in System B
3792.2	3.1	FeII λ 1608.4	1.3579	-0.5	Too strong
5527	(1)	FeII λ 2344.2	1.3577	-1.2	
5618	(1)	FeII λ 2382.7	1.3578	-1.0	
		System G (z = 2.1197)			
3199.7	3.3	Lβ λ 1025.7	2.1195	-0.2	
3220	(1)	OVI λ 1031.9	2.1205	+0.8	
3743.5	0.4	NI λ 1199.9	2.1198	+0.2	
3792.5	3.1	Lα λ 1215.7	2.1196	-0.1	
4830.3	0.8	CIV λ 1548.2	2.1199	+0.4	
4837.7	0.7	CIV λ 1550.8	2.1195	-0.3	

strong lines longward of the Lα and N v emission line have been identified in the above systems, most of them in system *A*.

b) Lα/Lβ *Pairs*

In most high-*z* QSOs the number density of lines shortward of Lα is usually many times higher than at longer wavelengths. This statement applies to B2 1225+31 also. Lynds (1971) suggested that these lines were due mainly to Lα absorption and it therefore follows that correspondingly large numbers of Lα/Lβ pairs should also be found when the redshift is sufficiently high to permit observations of Lβ. In the present case, the wavelength interval corresponds to $3700 \leqslant \lambda_{L\alpha} \leqslant 3900$ in which there are eight definite lines of equivalent width exceeding 0.5 Å which are not well identified in system *A*. Our analysis indicated the presence, within a Lβ wavelength tolerance of ±1 Å, of five possible Lα/Lβ pairs in this region compared with an expected number ~1–2 due to chance. It therefore appears that three or four of these pairs should be real. Only one of the six redshifts associated with the possible Lα/Lβ systems is, however, supported by other identifications. The exception is system *G* at $z = 2.1197$, for which there are supporting C IV identifications (λ4829 and λ4836).

c) C IV *Doublets*

A similar analysis was conducted for possible C IV doublets. Again, all lines associated with system *A* were first removed from the list and the acceptance tolerance was set at ±1 Å. For candidate C IV λ1548 lines of equivalent width exceeding 0.5 Å, the number of C IV doublets in the range 3140–5000 Å was found to be 11, of which about six would be expected by chance, mainly in the region shortward of Lα. Five systems may thus be real. Of course, three belong to the apparent C IV line-locking quartet at 4468.6, 4476.0, 4484.3, and 4491.0 Å, respectively. The two outer doublets are already identified in systems *C* and *D*, while the inner pair might be associated with Lα at 3512.6 Å, although the wavelength agreement is not very good. Two others are associated with systems *B* and *G*.

There is no evidence for any excess of C IV doublets over that expected by chance in the region shortward of Lα, at least for C IV λ1548 lines of equivalent width exceeding 0.5 Å.

d) *Special Wavelength Ratios*

Special ratios of redshift factors are of interest as possible evidence for ejection of material from QSOs. Although the emission redshift is somewhat uncertain, it seems that no absorption redshift system appears at the ratio $R = (1 + z_{\rm em})/(1 + z_{\rm abs}) = 1.11$ as in, for example, PHL 957 and 1331+17. System *A*, which is in many respects similar to the "line-locked" systems in these two QSOs, is close in that it has a ratio $1.115 < R < 1.156$, depending on the emission line used to determine the redshift. Among absorption systems, the possibility of triple line locking in C IV has been noted above. In addition, there is evidence for possible locking between systems *A* and *F* for which $R = (1 + z_A)/(1 + z_F) \sim 1.1858$ compared with values of $R = 1.183$ between systems *A* and *K* in PHL 957 and $R = 1.193$ between systems *A* and *C* in 1331+17. This ratio corresponds approximately to the Lα/Lβ wavelength ratios (1.185) and, in PHL 957 and 1331+17, the respective systems appear to be locked, with absorption Lα and Lβ respectively at the Lyman limit in the emission system. In view of the uncertainty in system *F*, however, the evidence for line locking in B2 1225+31 is very weak.

V. SUMMARY AND CONCLUSIONS

Our results on B2 1225+31 may be summarized as follows:

1. The emission lines are unusually weak, broad, and asymmetric.
2. The emission-line profiles differ strongly from line to line, resulting in considerable uncertainty in the emission-line redshift. The relative line strengths are, however, comparable to those seen in certain other QSOs.
3. The absorption-line spectrum is very rich, especially in the region shortward of the Lα emission line. This is almost certainly due to a large number of low-column-density clouds in the line of sight producing only Lyman-line absorption.
4. One clear-cut absorption system (*A*) with $z_A = 1.7941$ was identified. Its ionization state indicates the presence of an extensive H I region together with zones of moderate (up to C IV) ionization. The line strengths are consistent with an approximately solar composition.
5. No strong evidence for line locking was found, although some tentative indications require further examination.

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J. A. Baldwin and R. F. Carswell: Institute of Astronomy, Madingley Road, Cambridge, England

G. Coleman: Dyer Observatory, Vanderbilt University, Nashville, TN 37235

G. Gilbert: Steward Observatory, University of Arizona, Tucson, AZ 85721

S. A. Grandi: Lick Observatory, UCSC, Santa Cruz, CA 95064

P. A. Strittmatter, M. S. Wilkerson, and R. E. Williams: Steward Observatory, University of Arizona, Tucson, AZ 85721