LOW-REDSHIFT QUASARS AS THE ACTIVE NUCLEI OF COSMOLOGICALLY DISTANT INTERACTING GALAXIES: A SPECTROSCOPIC INVESTIGATION

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Received 7 March 1984; revised 5 April 1984

ABSTRACT

We present CCD spectra obtained with the 4-m telescope at Kitt Peak of 21 apparent companion galaxies to 15 low-redshift quasars. With one exception, each galaxy is located at an apparent projected distance of $\leqslant 50$ kpc from its quasar. We have determined redshifts of 19 of these galaxies (15 redshifts relying at least partially on stellar absorption lines). In 18 of the 19 total cases (95%), the galaxy and quasar radial velocities agree to $\leqslant 10^3$ km s^{-1} in the quasar rest frame. For absorption-line redshifts, the results are similar (14 of 15 at the quasar redshifts). We argue that our very high "success rate" relative to previous similar investigations stems primarily from our selection of close (in projection) apparent companions, which reduces contamination by foreground/background galaxies. Combining our data with similar data in the literature yields the following: 86% of the apparent close companions ($\leqslant 50$ kpc projected quasar/galaxy separation) share the quasar redshift, compared to only $\sim 40\%$ of the more distant (in projection) apparent companions. By virtue of its direct and general nature, we believe the present data represent the most convincing evidence yet for a cosmological origin of quasar redshifts. Our data also imply that imaging data alone are sufficient to test whether low-redshift quasars are preferentially associated with close companions (since the correction for unrelated line-of-sight galaxies will be small). This lends support to the hypothesis that galaxy interactions are an important means of triggering quasar activity. The low relative velocities of the quasars and companions (< 1000 km s^{-1}) are consistent with other evidence which indicates that low-z quasars are rarely found in rich relaxed clusters of galaxies. Finally, we point out that the close-companion galaxies in our sample do not themselves exhibit unusually strong nuclear activity and/or unusually high rates of star formation. This is consistent with data on nearby galaxy pairs, the great majority of which are apparently experiencing only modest nuclear stimulation.

I. INTRODUCTION

In recent years, considerable progress has been made toward answering two of the most crucial questions regarding quasars. First, are quasars the active nuclei of distant galaxies (i.e., are quasar redshifts "cosmological" in origin)? Second, by what mechanism is the quasar phenomenon stimulated?

Optical imaging surveys (e.g., Hutchings *et al.* 1984a; Wyckoff *et al.* 1981,1984) have demonstrated that low-redshift quasars are almost invariably imbedded in a region of resolved nebulosity ("fuzz") whose properties are consistent with those of a galaxy at the distance implied by the quasar redshift. However, only in a few cases has spectroscopy of this fuzz provided *direct* evidence that the fuzz is composed of stars sharing the quasar redshift (Stockton *et al.* 1979; Boroson and Oke 1982; Balick and Heckman 1983; Hunstead *et al.* 1984; MacKenty and Stockton 1984). In most cases, the spectroscopic properties of the fuzz are consistent with, but do not require, such an interpretation (Boroson *et al.* 1982; Boroson and Oke 1984).

Optical imaging surveys of quasars have provided another line of evidence which indirectly supports the cosmological hypothesis for quasar redshifts: Low-redshift quasars are seemingly located in regions of higher-than-average galaxy density and/or are unusually likely to be associated with an apparent companion galaxy (Yee and Green 1984; Hutchings and Campbell 1983; Gehren *et al.* 1984; Hintzen 1984). Galaxy interactions may therefore be implicated in the stimulation of quasar activity (e.g., Bothun *et al.* 1982a,b).

However, the association of low-redshift quasars with companion galaxies has not yet been firmly established on direct spectroscopic grounds. Many of the apparent companion galaxies may have redshifts which are substantially different from the quasar (either because they are close to the quasar only in projection, or because the quasar redshift is noncosmological). The most extensive spectroscopic study of galaxies near quasars was the seminal work by Stockton (1978a), who found that half the galaxies had very disparate redshifts relative to the quasars. In other cases, (e.g., Stock-

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 0004-6256/84/070958-08$00.90

ton 1982; Wampler *et al.* 1975), companion objects to quasars exhibit only emission lines and/or nonthermal continua. These objects may be either companion galaxies or quasar ejecta.

In conclusion, these various results leave somewhat open both the question of noncosmological redshifts in low-z quasars and the role played by galaxy interactions in spawning quasars.

Our purpose then in the present paper is to present spectroscopic observations of a large sample of apparent companion galaxies to low-redshift quasars. Unlike Stockton (1978a), we have concentrated almost exclusively on companions which are close ($\leqslant 50$ kpc, projected) to the quasar. This criterion was invoked to reduce the chance of contamination by foreground/background galaxies (see, for example, Yee and Green 1984) and to provide data having special relevance to tests of the putative link between galaxy interactions and quasars. Our data will also enable us to look for signs of unusual activity in the companion galaxies.

II. OBSERVATIONS AND DATA REDUCTION

We have selected our sample of apparent close companions to quasars from various imaging surveys (Hutchings *et al.* 1984b; Green *et al.* 1984; Hintzen 1984; Smith *et al.* 1984). These objects all have $m_v \lesssim 21.0$ or $m_r \lesssim 20.5$. With one exception, the galaxies all lie at apparent projected distances of $\leqslant 50$ kpc* from the quasar, at the (cosmological) distance of the quasar.

The observations were conducted in December of 1981, 1982, and 1983 using the Cryogenic Camera (CCD spectrograph) at the RC focus of the 4-m Mayall telescope of the Kitt Peak National Observatory (KPNO). The Cryogenic Camera was used in a long-slit mode, with the slit including both the quasar and the apparent companion galaxy.

Standard procedures at KPNO were followed to acquire, flat-field, distortion-correct, and sky-subtract the raw-data frames. The final processed frames cover the wavelength range from ~ 4550 to ~ 7980 Å with 15-20-Å spectral resolution, and cover the $\sim 4'$ slit length with 2–3″ spatial resolution (except in the redmost ~ 800 Å and bluemost ~ 400 Å, where the image is out of focus).

Quasar and galaxy spectra were both extracted from regions with a size of 2.5″ (the slit width) by 2.5″–4.2″ along the slit (depending on the angular size of the galaxy). The galaxy spectra are displayed in Fig. 1, and various spectral features of atmospheric and extragalactic origin are indicated.

The list of quasars and companion galaxies observed are listed in Table I. Column 1 gives the quasar designation. Column 2 gives the galaxy designation (additional information can be found in the Notes to the table). Column 3 contains our measured quasar redshift ($z_{\rm QSO}$). This was derived from the midpont of the [O III] λ 5007 lines at the 50% intensity level, and so (by analogy to Seyfert galaxies) may differ by 10^{-4}–10^{-3} from the true redshift of the putative underlying galaxy (e.g., Mirabel and Wilson 1984; Heckman *et al.* 1981). Our values for $z_{\rm QSO}$ agree to better than 10^{-3} with values in the literature (Hewitt and Burbidge 1980; Schmidt and Green 1983). Column 4 lists the velocity difference between the apparent companion galaxy and the quasar, in the rest frame of the quasar:

$$\Delta v \equiv c(z_{\rm Gal} - z_{\rm QSO})/(1 + z_{\rm QSO}).$$

The absorption and/or emission lines used to measure $z_{\rm Gal}$ are described in the Notes to the table. The quoted uncertainties are based on disagreements between $z_{\rm Gal}$ measured from the different spectral lines. Column 5 summarizes the way in which the galaxy redshift was determined (a, absorption lines only; e, emission lines only; a,e, both were used). Column 6 gives the projected linear separation between the quasar and galaxy at the cosmological distance of the quasar, and Column 7 the position angle of the galaxy relative to the quasar.

III. RESULTS

a) Redshift Differences

As summarized in Table I, we have observed 21 galaxies near 15 quasars. We have been able to determine redshifts for 19 of these galaxies, with 15 redshifts being based at least in part on stellar absorption lines.†

Our primary result is simple and compelling: *18 of the 19 apparent companion galaxies with measured redshifts have velocities within* $\sim 10^3$ *km s*$^{-1}$ *of the quasar*. If we restrict our attention to those objects exhibiting definitely measurable stellar absorption lines (i.e., to those objects which are unambiguously galaxies), the result is similar: 14 of the 15 galaxies share the quasar redshift.

These fractions of apparent companion galaxies sharing the quasar redshift are significantly higher than the value of 1/2 obtained by Stockton (1978a). We attribute this primarily to our concentration on very close ($\leqslant 50$-kpc projected separation) companion galaxies.

To further test this idea empirically, we have assembled spectroscopic data from the literature pertaining to the redshifts of apparent companion galaxies to quasars. We have limited this literature search to quasar redshifts (distances, by assumption) where true companion galaxies could be identified by conventional observational techniques ($z_{\rm QSO} \lesssim 0.6$). These data are summarized in Table II, which has a format similar to that of Table I. Combining the data in both tables, we find that 32 of the 37 (86%) apparent close companions (projected separations of $\leqslant 50$ kpc) share the quasar redshifts ($\Delta v \lesssim 10^3$ km s^{-1}), compared to only 15 of 46 (33%) of the more distant apparent companions.

Many of the quasar/galaxy pairs in Table II were discovered via a very different route from the one we have followed. That is, in some cases, searches for quasars in fields around bright (low-redshift) galaxies were conducted (e.g., Arp 1980a,b), rather than searches for faint galaxies in the vicinity of low-redshift quasars (as we have done). These different search procedures might well lead to artificially different distributions of quasar/galaxy separation and velocity differences. If we therefore restrict our attention to spectroscopic surveys of quasar/galaxy pairs which followed our procedure (e.g., Hintzen 1984; Stockton 1978a, 1982), we find (including our data) that 28 of the 32 (88%) close companions are at the quasar redshift, compared to only 11 of 25

*We use $H_0 = 100$ km s^{-1} Mpc^{-1} and $q_0 = 0$.

† It might be argued that emission lines could arise in gas expelled from the quasar seen only in projection on the putative companion. If so, the emission-line z would be unrelated to $z_{\rm Gal}$. For the eight companions in our sample with both absorption- and emission-line redshifts, $z_{\rm em} = z_{\rm abs}$ in all but possibly one case (0154 + 316 #1—see Notes to Table I).

(44%) of the distant companions (a difference which is significant at better than the 99.9% confidence level).

Yee and Green (1984) find from imaging data alone an enhancement of a factor of ~5 in the galaxy density within 10″ of quasars at $z < 0.45$ compared to the density in random fields (10″ corresponds to typically 30 kpc for their quasars). In the annulus from 10″ to 50″, the enhancement is only a factor of ~2. Thus, their imaging results are consistent with the spectroscopic results discussed above.

We conclude therefore that an overwhelming majority of galaxies with projected separations of ⩽50 kpc from low-redshift quasars share the quasar redshift, a property not shared by apparent quasar companion galaxies having greater projected separations.

b) The Nature of the Companion Galaxy Spectra

Hutchings *et al.* (1982a) and Stockton (1982) have speculated that an interaction between two galaxies can trigger not only the quasar itself but also a burst of star formation and/or nuclear activity in the companion. If this is the case, the companion galaxies might exhibit strong emission lines and a continuum contributed by young stars and/or nonthermal processes.

We can compare the strengths of the absorption and emission lines in the companion galaxies to the large body of data available on the nuclei of normal galaxies (Heckman *et al.* 1980; Keel 1983; Stauffer 1982) and on global emission from entire galaxies (Kennicutt and Kent 1983). Such a comparison can be only very rough since our projected aperture size (3–12 kpc) is intermediate between the aperture sizes in the nuclear and global surveys, and hence will suffer from very uncertain aperture corrections. For our close quasar companion galaxies, we find that the median Hα and/or [O III]λ 5007 emission-line equivalent width is ~5–6 Å. Comparing this to the data in Kennicutt and Kent (1983) and in Stauffer (1982), we conclude that unless the quasar companions are preferentially very early-type galaxies, the emission-line data provide no evidence for unusually large rates of star formation or nuclear activity.

Similarly, with the exception of the 3C48 companion (see also Balick and Heckman 1983) and the 0157 + 09 compan-

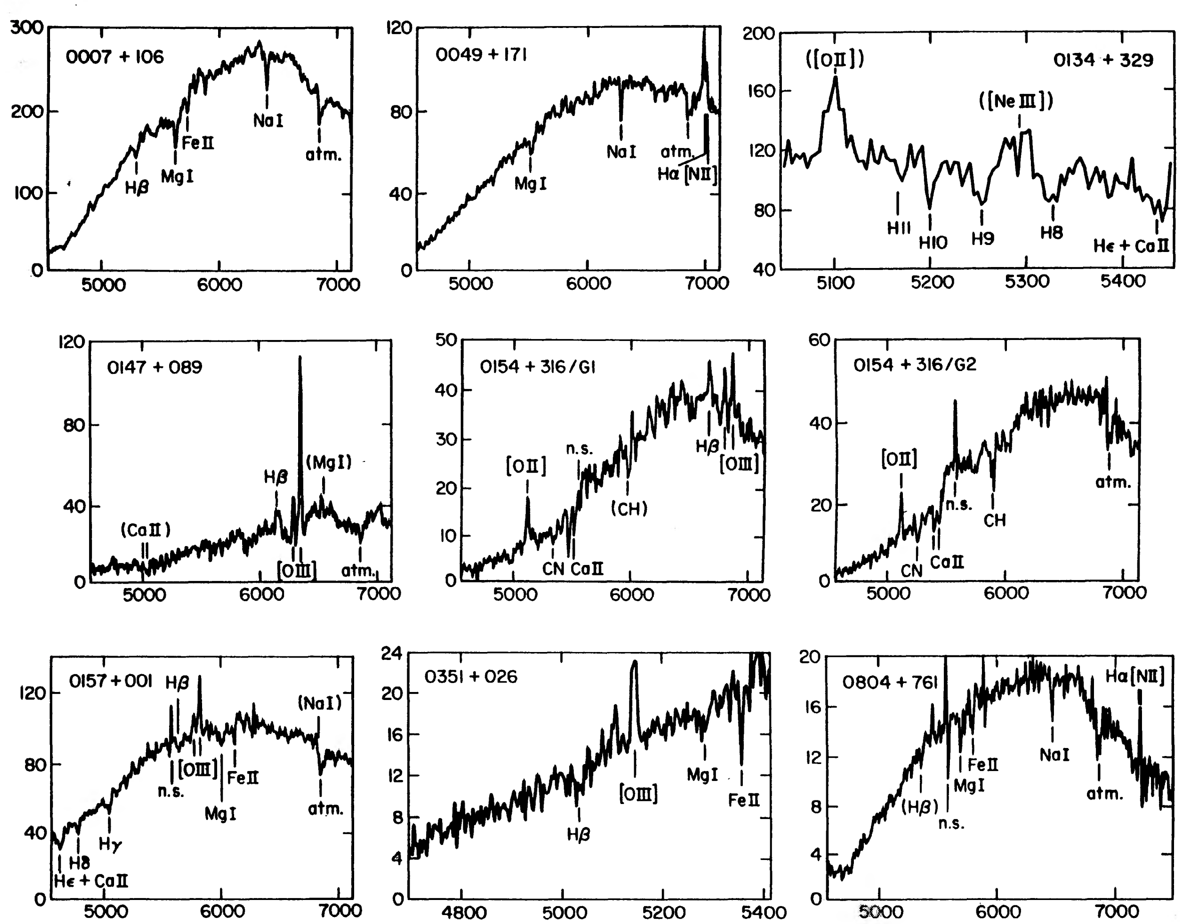

FIG. 1. Cryogenic Camera spectra of apparent quasar companion galaxies with measured redshifts. The spectra were typically extracted from regions 2.5″ by 4.2″ on the sky, and have spectral resolution of *f* 15–20 Å. The observed wavelength is plotted versus the detector signal (arbitrary units). Night-sky lines which could not be completely subtracted from the data are indicated by tick marks labeled with "n.s.," while atmospheric absorption features are labeled with "atm." Emission and absorption lines used to determine the galaxy redshifts listed in Table I are indicated by tick marks and identified as to line or species. Lines whose identifications are enclosed in parentheses were *not* used for redshift determination, and no general claim is made as to their detection. The data longward of *f* 7200 Å is noisy (bright sky), blighted by strong atmospheric absorption, and is out of focus (see the text). For these reasons, this spectral region is excluded from Fig. 1.

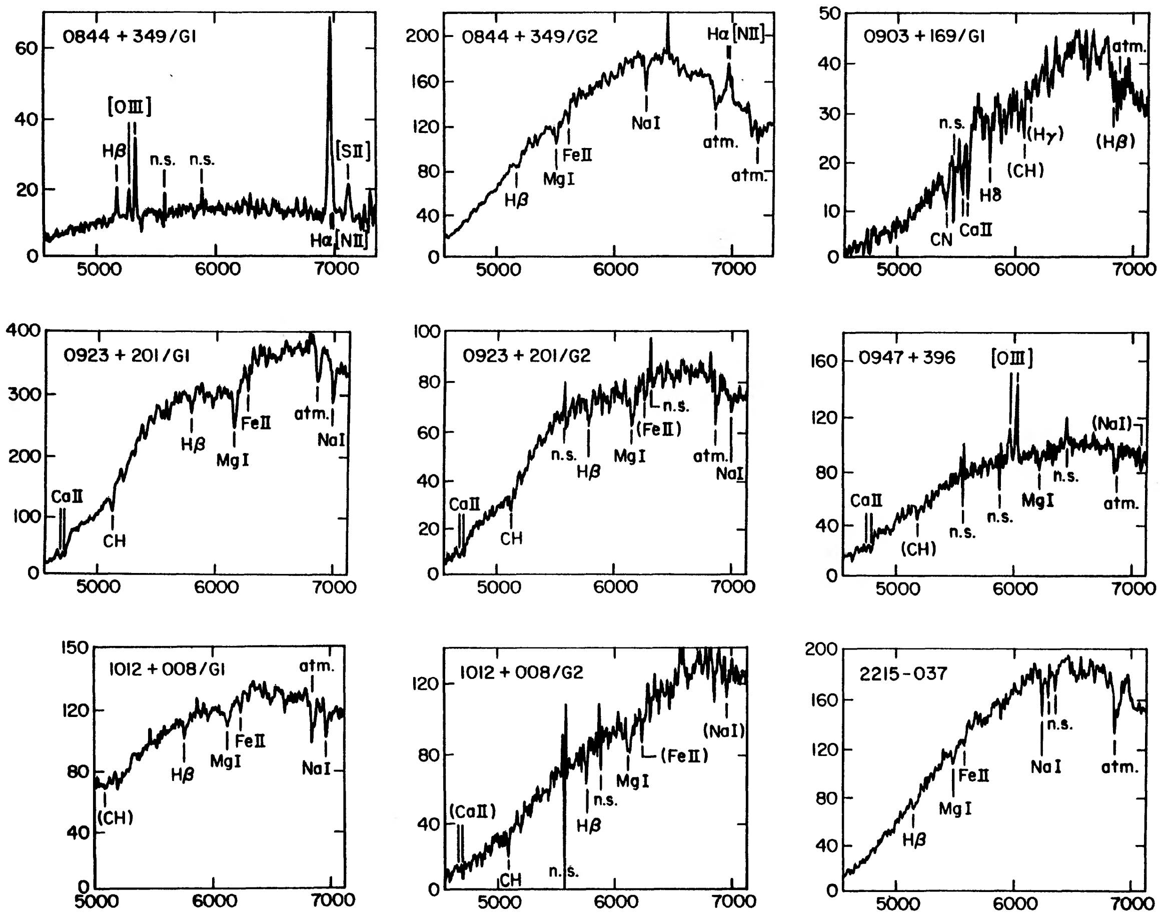

FIG. 1. (continued)

ion, the stellar absorption lines provide no compelling evidence for recent star formation. More specifically, for the 11 companions with the highest signal-to-noise data, the Mgb + MgH feature has a mean strength of 0.25 mag (see Mould 1978 for a definition of this parameter). Such a mean value is close to the mean found for a sample of the nuclei of normal galaxies covering all Hubble/de Vaucouleurs types, but is much higher than the values of 0.0–0.1 typifying nuclei with active star formation (Heckman *et al.* 1980).

We conclude that neither the emission lines nor the absorption lines provide any general evidence for strongly enhanced nuclear activity or star-formation rates in the close quasar companions. More and better data will be needed to quantify this statement.

IV. SUMMARY AND DISCUSSION

The present study extends and complements earlier imaging and spectroscopic investigations of the environments of low-redshift quasars, and has some important consequences for several of the major unresolved questions in quasar research.

In our view, the above results—because they are both direct and general—provide the most convincing demonstration to date that quasar redshifts are of cosmological origin. Previous related evidence has either been

(i) of a general nature, but only indirect (imaging of quasar fuzz; galaxy counts around quasars; arguments of continuity with type 1 Seyfert galaxies);

(ii) direct, but pertaining to only a few objects (spectroscopic detection of stellar absorption lines or λ 21-cm HI emission lines at the quasar redshift from the quasar fuzz);

(iii) direct, but with only a moderate rate of "success" (previous redshift determinations made for apparent quasar companion galaxies, many of which were located at rather large projected separations from the quasar).

In view of the direct and general nature of the evidence presented herein, apostles of the noncosmological interpretation of quasar redshifts must now either recant, or else maintain that the unknown laws of physics which fix the redshifts of the emitting material in quasars extend to apparently normal galaxies located at appreciable distances from the site of the quasar phenomenon itself.

Our data also have important implications for the hypothesis that galaxy interactions can trigger quasar activity. The above results imply that imaging data alone are sufficient to test whether an anomalously large fraction of low-redshift quasars have close-companion galaxies. That is, if "close companions" are defined to lie at projected separations of $\leqslant 50$ kpc from quasars, the correction for disparate redshift (line-of-sight) objects is likely to be very small ($\sim 15\%$). This is important on practical grounds, since imaging is far less

TABLE I. Observed properties of companions.

Quasar (1)	Galaxy (2)	z_{QSO} (3)	Δv (km s^{-1}) (4)	Lines (5)	Sep. (kpc) (6)	Pa (°) (7)
0007 + 106	1	0.0899	− 200 ± 100	a	40	188
0049 + 171	1	0.0640	+ 1000 ± 200	ae	45	178
0134 + 329	1	0.3670	+ 300 ± 200	a	16	184
0147 + 089	1	0.2688	0 ± 100	e	14	0
0154 + 316	1	0.3741	− 200/ + 3600?	e/a?	21	343
	2	—	− 700 ± 200	ae	76	163
0157 + 001	1	0.1624	+ 300 ± 200	ae	13	11
0351 + 026	1	0.0349	+ 100 ± 100	ae	7	186
0804 + 761	1	0.1000	0 ± 300	ae	35	106
0844 + 349	1	0.0637	+ 400 ± 100	e	9	196
	2	—	+ 400 ± 100	ae	22	200
0903 + 169	1	0.4106	0 ± 300	a	50	152
	2	—	?	None	32	145
0923 + 201	1	0.1922	− 500 ± 200	a	24	149
	2	—	− 600 ± 300	a	33	160
0947 + 396	1	0.2053	+ 100 ± 200	ae	24	225
1012 + 008	1	0.1865	+ 200 ± 100	a	6	102
	2	—	− 300 ± 200	a	16	322
1048 + 342	1	0.1676	+ 100 ± 100	e	6	290
	2	—	?	None	26	290
2215 − 037	1	0.2403	− 43 600 ± 200	a	37	6

Notes to Table I

0007+106=IIIZw2. Considered a quasar by Hewitt and Burbidge (1980, hereafter HB) and a quasar/Seyfert 1 by Schmidt and Green (1983, hereafter SG). Imaging data published by Hutchings *et al.* (1984b) and Green and Yee (1984, hereafter GY). Green *et al.* (1978) have published low-resolution spectroscopy of this object and another much more distant companion galaxy, both of which share the quasar redshift (See Table II). Our galaxy redshift (object 15 in GY and object B in Green *et al.* 1978) is derived entirely from absorption lines (Hβ, Mg I, Fe II, and Na I; see Fig. 1) indicative of an old stellar population.

0049+171=Mrk1148. Considered to be a quasar/Seyfert 1 by SG. Imaging data available from Smith *et al.* (1984, hereafter S84), Bothun *et al.* (1984), and GY. Redshift of companion galaxy based on Mg I and Na I absorption and Hα and [N II] emission.

0134+329=3C48. Classical radio-loud quasar (e.g., HB). Imaging data available from many sources (most recently, S84; GY; Gehren *et al.* 1984). The properties of the southern companion galaxy have been discussed by Balick and Heckman (1983), but we present the data here for the first time (Fig. 1). The galaxy redshift comes from the high-order Balmer absorption lines which are unusually strong in this object (Sec. III b), as they are in the host galaxy of 3C48 itself (Boroson and Oke 1982).

0147+089=PHL1186. Classical radio-quiet quasar (HB). Sources for imaging data are S84 and Hutchings *et al.* (1982b). Redshift comes entirely from emission lines ([O III]). Emission-line gas which is blueshifted by ~ 150 km s^{-1} relative to the quasar is also seen to the south of the quasar, opposite the companion. Thus, it is unclear whether the emission-line gas seen at the position of the companion belongs to the companion, or is part of an emission-line nebulosity associated with the quasar and only projected onto the companion. We regard this as an inconclusive case for this reason.

0154+316=4C31.06. Radio-loud quasar (HB), imaged by Gehren *et al.* (1984). Surrounded by six galaxies, of which two were covered by our slit (PA = 163°). Galaxy 1 is a curious case in that a firm emission-line redshift ([O II], Hβ, [O III]) and a tentative absorption-line redshift (Ca II, CN) disagree by 3800 km s^{-1} in the quasar rest frame (see Table I and Fig. 1)! The emission lines may arise in a nebulosity associated with the quasar which is projected onto the galaxy, or the tentative absorption-line redshift may be erroneous. Better data are needed, and we regard this as an inconclusive case. Galaxy 2 has a firm absorption (CN, Ca II, CH G band) and emission ([O II]) redshift, and is clearly dominated by an old stellar population.

0157+001=Mrk1014. Radio-quiet quasar from SG. Imaged by S84, GY, and MacKenty and Stockton (1984). The optical morphology of the fuzz is spectacular, consisting of a very extended ($\sim 30'' = 60$ kpc for $H_0 = 100$) oval envelope in which is imbedded a curving filament or jet projecting ~ 35 kpc to the N and then NE of the quasar. This filament has several knots, the brightest of which was covered by our slit. It is therefore not entirely clear whether this knot is a true companion galaxy. The redshift for this object was derived from the relatively strong Balmer absorption lines and from the Mg I and Fe II absorption lines. The spectroscopic and morphological evidence supports an interpretation of 0157 + 001 as a violent galaxy interaction and/or ongoing merger. Both the imaging and spectroscopic results reported in MacKenty and Stockton (1984) agree well with ours. They also conclude that a galaxy interaction is likely in Mrk1014.

0351+026. An x-ray selected quasar/active galaxy discussed in detail by Bothun *et al.* (1982a,b), Hutchings *et al.* (1982a), and Balick and Heckman (1983). We present here spectroscopic data on the companion superior to that published in Balick and Heckman. These new data allow us to determine an absorption-line redshift (Hβ, Mg, and Fe II), in addition to the emission-line redshift ([O III] and Hα) reported earlier.

0804+761. Quasar classification from SG and imaging data from GY. The companion-galaxy redshift is derived from both absorption (Hβ, Mg I, Fe II, Na I) and emission (blended Hα and [N II]λ 6583). Again, the stellar population appears predominantly old.

0844+349=Ton951. Quasar classification from SG and imaging data from GY. Galaxy 1 (object 2 in GY) exhibits strong emission lines (Hβ, [O III], Hα, [N II], [S II]) but no detectable absorption lines and so cannot be firmly regarded as a galaxy. Galaxy 2 (object 4 in GY) has a redshift derived from the Hβ, Mg I, Fe II, and Na I absorption lines and the Hα-plus-[N II]λ 6583 emission lines.

0903+169=3CR215. Classical radio-loud quasar (e.g., HB), imaged by Hintzen (1984). Our slit covered two galaxies (objects 4 and 25 in Hintzen), but we could only measure a redshift for the former. The galaxy redshift was derived purely from stellar absorption lines (CN, Ca II, Hδ).

0923+201=Ton1057. Quasar classification from SG and image from GY. We have observed two companion galaxies. Galaxy 1 (object 7 in GY) has many strong absorption lines expected from an old stellar population (redshift from Ca II, CH G band, Hβ, Mg I, Fe II, Na I). Galaxy 2 (object 8 in GY) is fainter, but otherwise spectroscopically similar.

0947+396. Quasar classification from SG and image from GY. The redshift of the companion galaxy (object 29 in GY) comes from the Ca II and Mg II absorption lines and the [O III] emission lines. Other lines seen in typical galaxy spectra are also present (CH G band and Na I).

1012+008. Quasar classification from SG and images from GY. Galaxy 1 (object 6 in GY) is so close ($\sim 3''$) to the quasar that its spectrum is badly contaminated by quasar light at the red and blue ends of the spectrum, where the Cryogenic Camera focus is poor (see Sec. II). The middle spectral region (5000–7200 Å) shows several strong absorption lines (redshift derived from the Hβ, Mg I, Fe II, and Na I lines). Galaxy 2 (object 18 in GY) is faint, but a redshift can be measured from the CH G band, Hβ, and Mg I lines. Other expected absorption lines are also probably present.

1048+342. Quasar classification from SG and image in GY. Our slit covered two galaxies. Galaxy 1 (object 5C in GY) is very close ($\sim 3''$) to the quasar, and its spectrum at $\lambda < 5000$ Å and $\lambda > 7000$ Å is badly contaminated by out-of-focus quasar light. The redshift is based solely on the [O III] and Hβ emission lines. Since these lines are also seen on the side of the quasar opposite the companion galaxy (blueshifted by ~ 250 km s^{-1} relative to the quasar), they may arise in an emission-line nebulosity not directly related to the apparent companion. Galaxy 2 (object 5B in GY) is faint, and no redshift was measured.

2215−037. An x-ray selected quasar imaged by Hutchings *et al.* (1984b) and S84. The bright apparent companion galaxy has a much lower redshift than the quasar, based on the Hβ, Mg I, Fe II, and Na I absorption lines. *If* the quasar and companion are physically connected, then the redshift of the quasar (and/or the companion) is noncosmological. Evidence for a physical connection between the quasar and companion should be sought.

TABLE II. Quasar companions from the literature.

Quasar (1)	Galaxy (2)	z_{QSO} (3)	Δv (km s^{-1}) (4)	Lines (5)	Sep. (kpc) (6)	Ref. (7)
0003 + 158	1	0.451	− 18 300	a	70	a
	2	—	0	ae	70	a
	3	—	− 35 000	e	104	a
0007 + 116	1	0.089	− 1 100	a	40	b
	2	—	+ 300	a	200	b
0015 + 162	1	0.554	− 2 000	?	900	c
0050 + 124	1	0.061	0	a	13	d
0121 + 108	1	0.510	− 91 000	?	171	e
0137 + 060	1	0.396	− 35 200	ae	125	f
0151 + 045	1	0.404	− 80 800	?	202	g
0210 + 860	1	0.184	− 1 000	a	26	h
	2	—	+ 1 000	a	182	h
	3	—	− 18 000	a	182	h
	4	—	+ 500	a	182	h
0214 + 108	1	0.408	− 500	a	122	a
0837 − 120	1	0.200	+ 700	a	26	i
0840 + 503/U7	1	0.303	− 67 200	a	7 726	j
0840 + 503/U10	1	0.305	− 67 600	a	3 399	j
0921 + 347/U1	1	0.230	− 54 900	?	156	k
0955 + 326	1	0.533	− 103 300	e	498	g,u
1004 + 130	1	0.240	+ 500	a	90	f
	2	—	0	ae	120	f
1045 + 128/U13	1	0.497	− 99 200	a	621	l,u
1045 + 128/U14	1	0.520	− 102 200	a	6 400	l,u
1048 − 090	1	0.344	− 50 900	e	87	f
1049 + 616	1	0.422	− 85 800	a	658	m,u
1103 − 006	1	0.426	− 89 200	ae	12 230	n,u
1128 + 315	1	0.289	+ 100	ae	21	f
	2	—	+ 200	ae	104	f
1150 + 497	1	0.334	− 9 600	a	70	f
1208 + 322	1	0.388	+ 14 500	ae	36	f
	2	—	− 53 500	e	122	f
1219 + 755	1	0.070	− 17 900	a	42	o
	2	—	+ 100	a	3	p
1223 + 252	1	0.268	− 43 800	e	98	f
1226 + 023	1	0.158	− 100	ae	146	q
1241 + 166	1	0.557	− 106 800	ae	1 050	g,u
	2	—	− 200	ae	30	a
	3	—	− 83 700	e	85	a
	4	—	− 17 800	a	147	a
	5	—	− 300	e	149	a
1302 − 102	1	0.286	− 33 300	e	102	f
	2	—	− 47 000	a	116	f
1510 − 089	1	0.361	− 23 000	a	87	f
1512 + 370	1	0.371	+ 300	a	39	f
1525 + 227	1	0.253	− 300	a	89	f
1545 + 210	1	0.264	+ 1 400	a	1 043	r
	2	—	+ 100	e	7	d
1548 + 114	1	0.436	− 400	ae	35	f
	2	—	− 600	a	47	f
1612 + 262	1	0.131	− 2 800	a	349	s
	2	—	+ 200	a	498	s
2135 − 147	1	0.201	− 200	a	14	f
	2	—	− 100	a	37	f
	3	—	+ 100	e	100	f
	4	—	0	e	4	d
2141 + 175	1	0.213	− 600	e	91	f
2251 + 113	1	0.323	0	ae	91	f
	2	—	+ 1 700	a	133	f
2252 + 129	1	0.543	− 99 200	?	106	n
2300 − 189	1	0.128	0	a	10	t
2305 + 187	1	0.313	− 15 600	e	22	f
	2	—	− 15 600	e	111	f
2308 + 098	1	0.432	− 56 000	a	35	f

References for Table II

[a] Hintzen (1984).
[b] Green *et al.* (1978).
[c] Margon *et al.* (1983).
[d] Stockton (1982).
[e] Mitton *et al.* (1977).
[f] Stockton (1978a).
[g] Burbidge *et al.* (1971).
[h] Miller *et al.* (1973).
[i] Wyckoff *et al.* (1980).
[j] Arp (1980a).
[k] Arp (1980b).
[l] Arp *et al.* (1979).
[m] Hewitt and Burbidge (1980).
[n] Burbidge *et al.* (1972).
[o] Arp (1971).
[p] Stockton *et al.* (1979).
[q] Stockton (1978b).
[r] Oemler *et al.* (1972).
[s] Gunn (1971).
[t] Hunstead *et al.* (1984).
[u] Gisler and Friel (1979).

time consuming than spectroscopy (and a much larger data base of imaging data already exists). It is also a result that is consistent with the careful analysis of imaging data conducted by Yee and Green (1984).

We note parenthetically that our spectroscopic data indicate that the companion galaxies are not experiencing strongly enhanced nuclear activity or star-formation rates. There are many possible explanations for this (e.g., the "starburst" or the nuclear activity in the companion dies out more quickly, the companion may not actually be interacting with the quasar host, the quasar host may have stripped gas from the companion and not reciprocated the favor). However, the above result is probably most simply interpreted as indicating that only a small fraction of galaxies in interacting systems are *strongly* "turned on" by the interaction. More data are needed to quantify this interpretation, but it is consistent with data on nearby interacting galaxies, which generally have only modestly increased rates of star formation and/or nuclear activity (e.g., Kennicutt and Keel 1984; Bothun and Schommer 1982).

We also wish to emphasize that the poor velocity resolution of the Cryogenic Camera (~ 700–1100 km s^{-1}) means that we cannot determine the precise relative velocities of the quasar host and companion galaxies. This is an important issue since the amount of dynamical damage done to the quasar host (which is presumably one important factor in determining the degree to which the nucleus is stimulated) will be a sensitive function of the relative velocity of the encounter. Our data can only establish that the quasar host and companion galaxies belong to the same group, but cannot prove that a significant interaction is occurring.

Finally, our data are consistent with the widely held belief that low-z quasars are rarely found in rich relaxed clusters of galaxies (see, most recently, Yee and Green 1984). With the possible exception of 0154 + 316/Galaxy 1, the velocity differences of the quasars and companions are small compared to velocity dispersion in such clusters. We concur with Yee and Green that compact groups or small clusters are the preferred environment for low-z quasars.

In the future, imaging and spectroscopic investigations with higher spatial/spectral resolution should be undertaken. Such work can study the quasar/galaxy interaction in detail and can extend the investigation to much higher quasar redshifts. The latter is important not only to demonstrate a cosmological origin for high quasar redshifts, but to test whether quasars in the early universe were stimulated by galaxy interactions or, instead, by internal processes related to galaxy formation.

We would like to thank the staff of the Kitt Peak National Observatory (and, in particular, Jeannette Barnes, Jim De Veny, Bill Ditzler, and Hal Halbedel) for their usual flawless assistance in obtaining and reducing the data presented here. T.M.H. thanks the Alfred P. Sloan Foundation for financial assistance. T.M.H. and E.P.S. acknowledge the support of Grant No. AST-82-16553 from the National Science Foundation and B.B. likewise acknowledges support under Grant No. AST-82-08041. We are also grateful to Richard Green and Howard Yee, Paul Hintzen, John Hutchings and collaborators, and Susan Wyckoff and collaborators, for their efforts to collect a large and excellent body of imaging data on low-redshift quasars. We thank the staff at CTIO for its help in our own quasar imaging program (the full results of which will be presented elsewhere). Finally, B.B. is grateful for the hospitality of Leiden Observatory, his "home away from home" during the final stages of this project.

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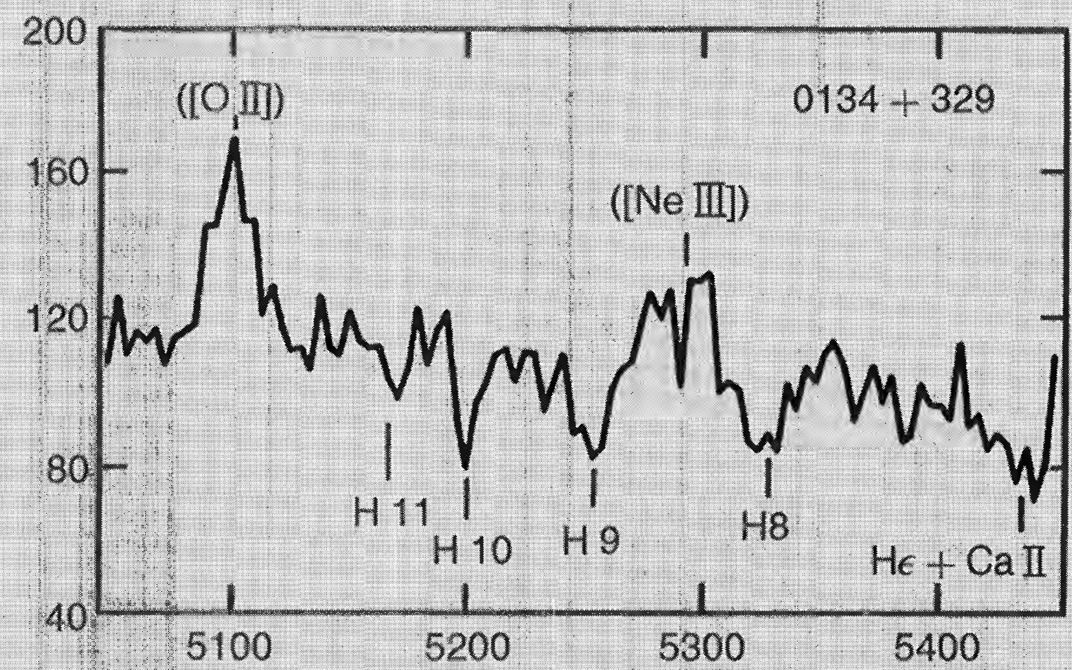

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