

NEW BLAZARS DISCOVERED BY POLARIMETRY

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ABSTRACT

We have discovered 31 blazars and confirmed five others as part of a program of optical polarimetry of a complete sample of radio sources. This increases the number of known polarized radio sources by 40%. Twenty-five blazars were measured more than once, and strong variability in flux density is seen in 10 objects. The level of interstellar polarization was checked with observations of several faint stars near the position of each radio source. Some of the new blazars have large redshifts and are optically faint. There are equal numbers of objects with strong and weak emission lines, and the weak-lined objects have the largest ratios of optical to radio power. We present tentative evidence for an unprecedented pair of polarized objects, only one of which is a radio source. In a complete radio sample selected at 5 GHz, 40% of the optical counterparts with stellar images are highly polarized. This fraction increases with increasing dominance of a compact radio component.

Subject headings: BL Lacertae objects — polarization — radio sources: galaxies

I. INTRODUCTION

The small set of radio sources classified as blazars is of particular relevance to the study of active galactic nuclei. Following Angel and Stockman (1980), we define blazars as active galactic nuclei (AGN) showing strong radio emission, rapid variability, and high linear polarization. This definition includes highly polarized quasars (Moore and Stockman 1981), as well as the classical BL Lac objects. The property that appears to be fundamental to blazars is compact radio emission, because searches for radio-quiet examples have generally been unsuccessful (Impey and Brand 1982; Borra and Corribeau 1984). Even X-ray selected blazars can be detected, albeit weakly, at radio wavelengths (Stoeckel *et al.* 1985). What unites blazars is the strong evidence for nonthermal radiation across the entire electromagnetic spectrum. A single synchrotron component can often account for the spectrum from millimeter to ultraviolet wavelengths. In objects at low redshift, such as most of the BL Lac objects, the nonthermal AGN can be masked by dust and starlight in the surrounding galaxy. The variable polarization seen in blazars is a signature of the incoherent synchrotron process. There is also indirect evidence that relativistic motion is boosting the observed continuum of many blazars. Indications of relativistic motion include the lack of Compton-scattered X-rays (Marscher *et al.* 1979), the enormous infrared luminosities and short variability time scales (Impey *et al.* 1982), and the large fraction of blazars that are superluminal radio sources (Cohen 1986).

The number of blazars has increased slowly but steadily over the last 10 years. Stein, O'Dell, and Strittmatter (1976) listed 32 lineless BL Lac objects in their review article. This had increased to 60 in Weiler and Johnston (1980), 73 in Véron-Cetty and Véron (1985), 84 in Véron-Cetty and Véron (1987), and 87 in the recent compilation of Burbidge and Hewitt (1987). We note that a number of sources in the last four references do not have published polarimetry. Ledden and O'Dell (1985) presented a list of 75 BL Lac objects and highly polarized quasars with confirming polarimetry. High linear polarization is an important characteristic of blazars, because it directly indicates optically thin synchrotron emission in an

ordered magnetic field. A striking alignment of polarization position angle with the radio VLBI structure axis has also been noted (Rusk and Seaquist 1985; Impey 1987). High polarization is almost always associated with large amplitude optical variability, in contrast to most quasars which are unpolarized and quiescent (Bonoli *et al.* 1979; Stockman, Moore, and Angel 1984; Moore and Stockman 1984). Therefore, we use linear polarization as a primary confirming attribute of blazars. As yet, no complete sample exists. In this paper, we discuss blazars discovered in a polarization survey of a complete radio sample. All radio sources stronger than 2 Jy at 5 GHz and identified with stellar objects were included in the sample. In particular, no selection was made according to optical brightness or emission-line strength.

II. OBSERVATIONS

The observations were made using the MINIPOL polarimeter at Las Campanas Observatory in Chile. All observations were obtained on the Du Pont 100 inch (2.5 m) telescope during the period 1984 March 29 to 1986 June 4. Conditions were photometric, and seeing was in the range of 1" to 1.5" throughout. There are few published measures of optical polarization for southern radio sources; our project was an attempt to achieve completeness for an all-sky 2 Jy radio sample. We present 70 observations of 36 polarized radio sources. Only eight of these are at northern declinations. Twenty-five sources were observed twice and six were observed three or more times. Six sources (0138–097, 0414+009, 1034–293, 1144–379, 1309–216, 1415+259) from Table 1 are listed in Burbidge and Hewitt (1987) and four others (0454–234, 0458–020, 0537–441, 1424+240) are listed in Ledden and O'Dell (1985). However, only 1415+256 has published polarimetry. All are radio-selected, except for 1100–230 and 1415+256 which are X-ray selected (Halpern *et al.* 1986). These new observations increase the number of known blazars by 40%.

The MINIPOL polarimeter of the University of Arizona is an accurate and efficient instrument (Dolan and Tapia 1986). The instrumental polarization is less than 0.01%, and observa-

TABLE 1
NEW BLAZARS

Object	z	RA (h m s)	Dec (° ' ")	Date (U.T.)	p ± σ(p) (%)	θ ± σ(θ) (°)	P _{max} /P _{min} (95% Conf.)	V	S _{5GHz} (Jy)	α _{ro}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
0118-272	...	01 18 09.5	-27 17 07	2-01-85	17.38 .25	151 4	17.88/16.88	15.67	1.2	.55
				2-06-85	17.05 .32	150 1	17.69/16.41	15.61		
0138-097	...	01 38 56.9	-09 43 51	1-29-85	3.64 1.54	168 12	6.52/ 0.00	17.01	1.2	.66
				2-01-85	13.92 2.87	138 6	19.37/ 7.89	18.16		
				2-09-85	13.38 .32	141 1	14.02/12.74	16.64		
0208-512	1.003	02 08 56.9	-51 15 08	1-30-85	11.52 .43	88 1	12.38/10.66	16.93	3.3	.74
0301-243	...	03 01 16.3	-24 22 00	2-09-85	10.57 .20	52 1	10.97/10.17	15.50	0.4	.45
0332-403	1.455	03 32 25.3	-40 18 24	1-29-85	14.71 1.77	113 3	18.17/11.00	18.30	2.9	.84
0414+009	...	04 14 17.6	+00 58 03	2-09-85	2.76 .29	131 3	3.21/ 1.15	16.39	...	...
0438-436	2.852	04 38 43.2	-43 19 10	4-02-84	4.63 1.01	27 6	6.55/ 2.44	18.45	7.2	.93
0454-234	0.890	04 54 57.3	-23 29 29	3-30-84	7.16 .94	109 4	8.99/ 5.18	19.84	2.1	.94
				4-11-85	27.28 .35	74 1	27.98/26.58	16.58		
0458-020	2.286	04 58 41.3	-02 03 34	4-13-85	9.75 3.98	127 12	17.24/ 0.00	19.23	1.8	.87
				4-14-85	16.49 5.06	146 9	26.48/ 5.71	19.09		
0537-441	0.894	05 37 21.1	-44 06 45	3-29-84	10.47 .19	133 1	10.85/10.09	15.79	4.0	.72
				2-02-85	18.76 .37	98 1	19.50/18.02	16.40		
0605-085	0.870	06 05 36.0	-08 34 19	3-29-84	2.06 .35	138 5	2.73/ 1.39	16.67	3.5	.73
				4-02-84	2.12 1.48	124 20	4.03/ 0.00	18.53		
				1-29-85	9.94 1.37	127 4	12.71/ 7.06	18.57		
0823+033	...	08 23 13.6	+03 19 16	1-25-85	13.94 .35	162 1	14.64/13.24	16.80	1.4	.64
				2-09-85	22.98 .37	3 1	23.72/22.24	16.61		
0823-223	...	08 23 50.7	-22 20 44	4-02-84	3.98 .14	100 1	4.26/ 3.70	15.48	1.2	.67
				2-03-85	9.06 .87	61 3	10.75/ 7.27	17.09		
1034-293	...	10 34 55.9	-29 18 27	4-02-84	7.28 .36	13 1	8.00/ 6.56	16.74	1.5	.66
				2-06-85	6.85 .42	34 2	7.69/ 6.01	15.63		
1055+018	0.888	10 55 55.3	+01 50 04	3-29-84	4.92 .53	146 3	5.96/ 3.88	16.67	3.5	.73
1100-230	...	...	...	2-04-85	2.68 .23	52 2	3.13/ 2.21	16.02	...	...
				4-10-85	3.26 .36	81 3	3.96/ 2.54	16.48		
				4-12-85	2.45 .17	79 2	2.79/ 2.11	16.20		
1144-379	...	11 44 30.9	-37 55 31	3-29-84	5.02 .27	95 2	5.56/ 4.48	17.86	2.3	.79
				2-02-85	1.06 1.88	...	4.01/ 0.00	18.64		
				4-11-85	8.51 .43	49 2	9.37/ 7.65	16.72		
1244-255	0.638	12 44 06.7	-25 31 26	1-26-85	8.41 .17	110 1	8.75/ 8.07	15.95	1.4	.63
				2-02-85	11.16 .39	56 1	11.94/10.38	16.42		
1309-216	1.491	13 09 49.6	-21 40 30	4-13-85	12.26 .90	160 2	14.01/10.41	18.25	1.2	.76
1335-127	0.541	13 35 00.0	-12 42 10	4-01-84	10.60 .46	8 1	11.52/ 9.68	16.16	2.2	.65
				2-02-85	3.76 5.03	...	12.05/ 0.00	19.57		
				4-11-85	7.69 .28	83 1	8.25/ 7.13	16.09		
1349-439	...	13 49 51.4	-43 57 49	4-02-84	21.50 .43	2 1	22.36/20.64	16.27	0.8	.57
				2-03-85	18.70 .51	156 1	19.72/17.68	17.73		
				4-13-85	18.62 .46	149 1	19.54/17.70	16.81		
				4-14-85	11.59 .82	150 2	13.23/ 9.95	17.19		
				4-15-85	11.74 .29	150 1	12.32/11.16	18.12		
				4-16-85	10.01 .22	142 1	10.45/ 9.57	16.11		
1415+256	0.237	14 15 41.3	+25 57 15	4-12-85	2.90 .11	163 1	3.96/ 1.69	17.44	...	...
1424+240	...	14 24 45.1	+24 00 54	4-02-84	4.72 .28	14 2	5.28/ 4.16	15.10	0.3	.39
				4-14-85	4.52 .35	178 2	5.04/ 3.97	18.39		
1424-418	...	14 24 46.5	-41 52 52	4-01-84	6.60 .33	80 1	7.26/ 5.94	17.02	3.0	.74
				4-11-85	9.43 .61	40 2	10.65/ 8.21	17.26		
1502+106	1.839	15 02 00.2	+10 41 17	4-02-84	2.90 .56	160 5	3.96/ 1.69	17.94	2.3	.79
				4-14-85	10.57 1.39	162 4	13.28/ 7.65	17.85		
1504-167	0.876	15 04 16.4	-16 40 58	1-30-85	5.23 .70	52 4	6.67/ 2.24	17.69	2.0	.76
1519-273	...	15 19 37.2	-27 19 30	4-01-84	11.40 .57	65 1	12.54/10.26	17.28	2.4	.74
				4-11-85	5.92 .73	70 4	7.34/ 4.38	17.90		
1532+017	1.420	15 32 20.5	+01 40 48	4-12-85	3.50 .23	131 2	3.96/ 3.04	16.67	1.3	.64
				4-15-85	5.00 .28	88 2	5.56/ 4.44	16.46		

TABLE 1—Continued

Object	z	RA (h m s)	Dec (° ' ")	Date (U.T.)	p ± σ(p) (%)	θ ± σ(θ) (°)	p _{max} /p _{min} (95% Conf.)	V	S _{5GHz} (Jy)	α _{ro}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1548+056	...	15 48 06.9	+05 36 12	4-02-84	4.58 1.10	14 7	6.67/ 2.24	18.58	2.3	.84
				4-15-85	2.85 1.27	162 13	5.21/ 0.00	18.79		
1610-771	1.710	16 10 51.6	-77 09 52	4-11-85	3.77 .74	78 6	5.17/ 2.21	17.83	3.6	.82
				4-16-85	2.30 1.13	77 14	4.67/ 0.00	17.95		
1954-388	0.626	19 54 39.0	-38 53 13	4-02-84	10.89 .26	179 1	11.41/10.37	16.68	2.1	.69
				4-12-85	10.18 .83	140 2	11.79/ 8.47	16.86		
2206-260	...	22 06 10.0	-26 03 10	4-13-85	20.05 .80	128 1	21.65/18.45	17.74	0.3	.59
2240-260	...	22 40 41.8	-26 00 15	6-04-86	15.14 .47	140 1	16.08/14.20	17.88	1.0	.72
2243-123	0.630	22 43 39.8	-12 22 41	6-01-86	3.30 .37	153 3	4.02/ 2.52	15.82	2.5	.63
				6-02-86	3.39 .22	135 2	3.83/ 2.95	16.24		
2254-204	...	22 54 00.0	-20 27 43	4-15-85	9.29 1.45	64 4	12.04/ 6.24	17.85	0.4	.64
				6-04-86	14.31 .63	25 1	15.57/13.05	16.60		
2355-534	1.006	23 55 18.2	-53 27 56	6-03-86	3.62 .64	15 5	4.84/ 2.37	17.78	1.7	.75
				6-04-86	1.49 .45	30 9	2.38/ 0.54	17.57		

tions of faint sources are limited by photon statistics. Use of a Wollaston prism and two GaAs tubes gives high throughput; the observations described here were mostly made without a filter. The polarization efficiency was checked every night using a Glan prism. Polarized and unpolarized standard stars were observed each night. Table 1 lists the polarization, position angle, and magnitude of 36 radio sources. Object names, redshifts, and positions for epoch 1950 are given in columns (1), (2), (3), and (4). We note that redshifts are based on the typical spectra of emission-line quasars, with the exception of 1415+259 which has a surrounding galaxy redshift and 1309-216 which has an absorption redshift. The redshift of 0454-234 is disputed and must be considered uncertain. The UT date of the observation is in column (5). Columns (6) and (7) have the polarization and position angle with errors, and column (8) lists the 95% confidence interval of the polarization measurement. The confidence interval was determined using the Rice distribution for low signal-to-noise ratios, and the unbiased polarization was computed according to the method described by Simmons and Stewart (1985). The V magnitude through a 2"7 aperture is listed in column (9), and the mean 5 GHz flux density is listed in column (10). Column (11) has the radio to optical spectral index, calculated assuming $\alpha = -d \ln S_\nu / d \ln \nu$. The polarization error is derived from the counting statistics of the modulated signal arriving at the phototubes. The repeatability and internal consistency of many of the position angle measurements is a small fraction of a degree; however the absolute determination of position angles on the sky is only accurate to 1°.

The photometric zero point was determined each night with an accuracy of 2-3% using standard stars. However, the use of a small fixed aperture limits the absolute accuracy of the magnitudes. The seeing throughout these observations was generally stable and in the range 1" to 1".5, therefore most of the zero points agree to less than 10%. Unfiltered fluxes were converted to V magnitudes using a correction which incorporates the telescope reflections and instrument optics, convolved with the spectral response of the GaAs tubes and the energy distribu-

tion of the blazar. Unfortunately, many of the radio sources do not have multicolor optical photometry published. Therefore, we have applied a correction based on the mean optical spectral index for 91 blazars (Impey and Neugebauer 1988). The mean is $\alpha_{\text{opt}} = 1.41$ ($\alpha = -d \log S_\nu / d \log \nu$), with 30% in the range $1.6 < \alpha < 1.2$, 60% in the range $2.0 < \alpha < 1.0$, and 90% in the range $2.5 < \alpha < 0.6$. The mean color correction with 1 σ errors is $\Delta = V - m(\text{unfiltered}) = 2.309^{+0.028}_{-0.012}$.

The criterion for classification as a blazar was a polarization greater than 2.5%. Detection of low values of nonthermal polarization depends on demonstrating that the interstellar polarization is small in the direction of the radio source. Therefore, we observed 104 faint ($12 < V < 16$) field stars near the 36 radio sources. The field stars are faint enough to lie on average beyond the local volume ($\sim 10^8 \text{ pc}^3$), where most interstellar polarization is imprinted (Verschuur 1970). Figure 1a shows the distribution of interstellar polarization with galactic latitude. Less than 10% of the field stars have $p > 1\%$, and they are all at the lower galactic latitudes, $|b^{\text{II}}| < 45^\circ$. The dotted line in Figure 1a is the envelope that includes the largest values of interstellar polarization. Figure 1b shows the blazar data added, and there is no overlap between the ranges of interstellar and nonthermal polarization. For the few radio sources with $p < 4\%$, or when the lower bound on the 95% confidence interval is zero, the local interstellar polarization is less than 2%. Some of the low values were for sources where repeated measurement showed flux or polarization variability, providing confirmation of the synchrotron process. Therefore, we are confident that interstellar polarization is a minor component of any of the measurements in Table 1.

III. DISCUSSION

a) Properties of the Polarized Radio Sources

These new sources show all the familiar properties of blazars: high polarization, and variations in three Stokes parameters (I , Q , U) on time scales of days to years. Four blazars have linear polarization exceeding 20%, and 19 have

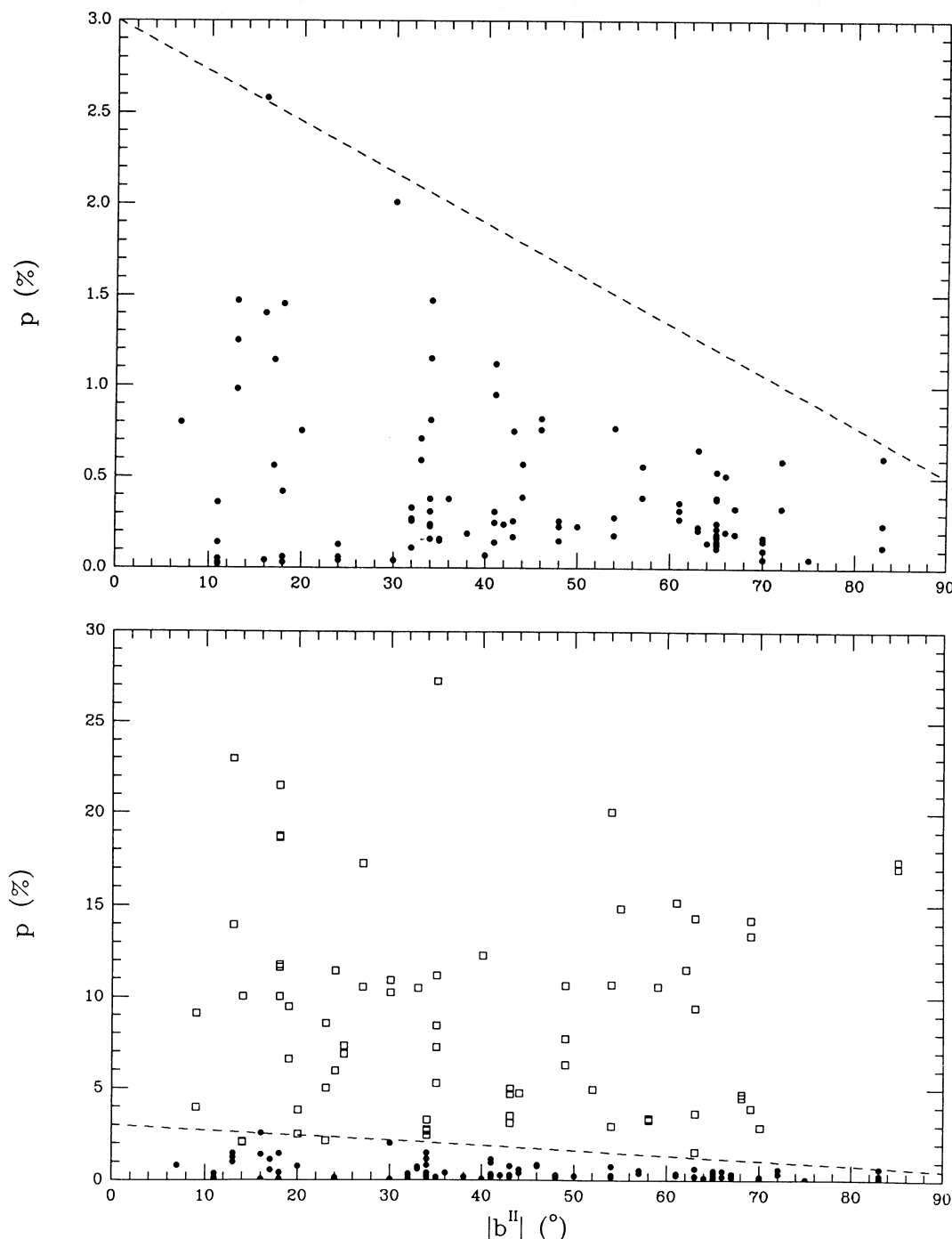


FIG. 1.—(a) Linear polarization plotted against galactic latitude $|b^{\text{II}}|$ for 104 field stars in the vicinity of strong radio sources. (b) As above, but with 69 observations of 36 radio sources plotted as open boxes. The dotted line marks the upper envelope of interstellar polarization.

polarization of over 10%. The characteristics of intensity variations are unclear with such limited monitoring, but three blazars had intensity variations of more than 2.5 mag, 10 had variations of more than a magnitude, and nine had variations of less than 20%. We note that the source 1349–439 was extraordinarily active during 1985 April. Half of the new blazars have redshifts based on strong emission lines, and so may be described as high-polarization quasars (HPQs). The other half have lines too weak to measure a redshift and fit the description of BL Lac objects. The spectra of a number of

these weak lined objects are plotted in the catalog of Wilkes *et al.* (1983).

Many of the new blazars are optically faint ($V > 18$), and have large (steep) values of α_{ro} . Eight have redshifts greater than one, and one is the highest redshift polarized source known, 0438–436 with $z = 2.852$. It is interesting that sources with strong emission lines (HPQs) have steeper values of α_{ro} than sources with weak emission lines (BL Lacs). The solid line histograms in Figures 2a and 2b show the distribution of α_{ro} for strong and weak lined objects respectively. The difference is

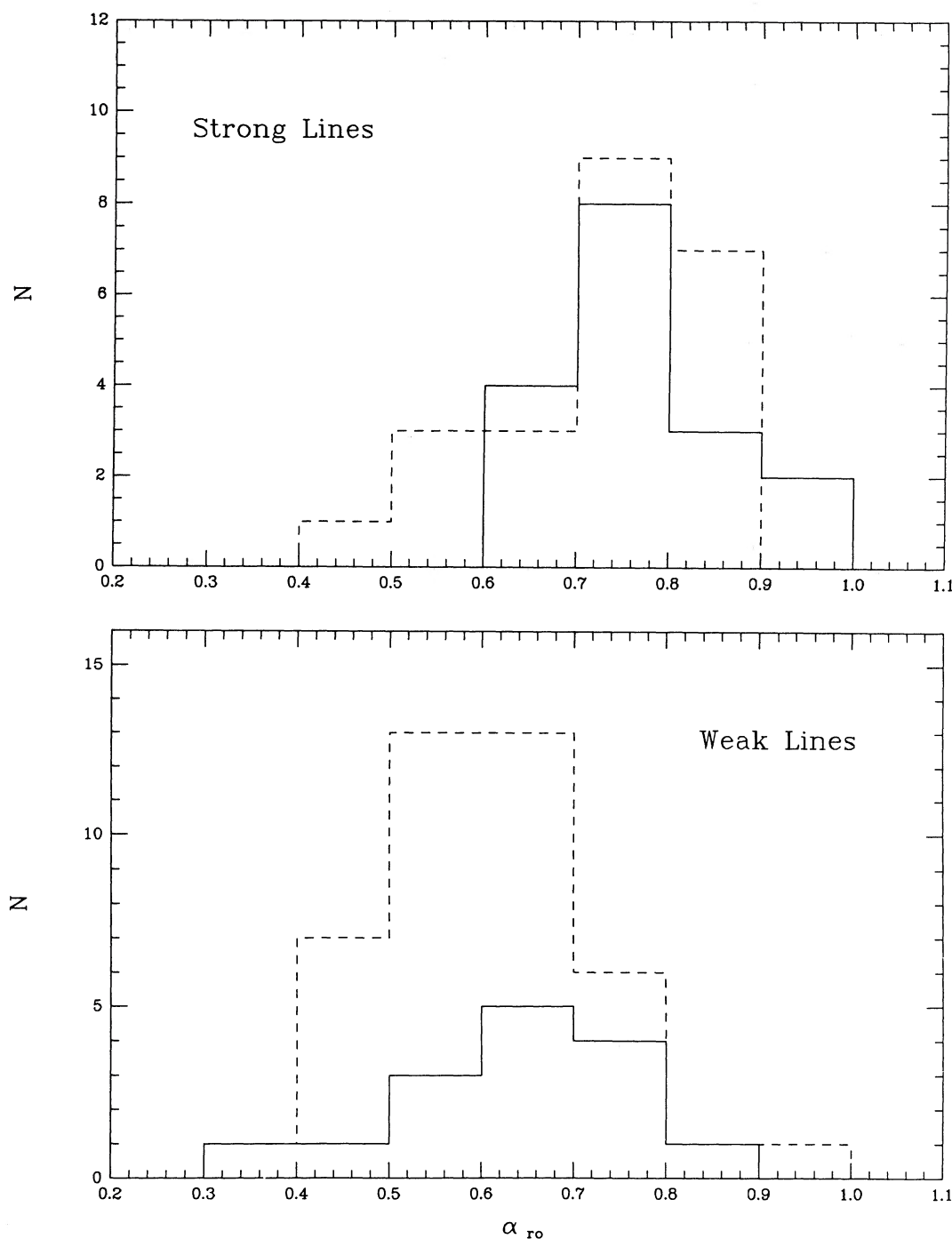


FIG. 2.—(a) Histogram of radio to optical spectral index, α_{ro} , for polarized radio sources with strong emission lines. New blazars from this paper shown as solid line, blazars from the compilation of Ledden and O'Dell (1985) shown as dotted line. (b) As above, but histogram of α_{ro} is plotted for polarized radio sources with weak emission lines.

significant at the 99.7% level, using the nonparametric Mann-Whitney test. Mean spectral slopes are $(\alpha_{ro})_{HPQ} = 0.757 \pm 0.092$, and $(\alpha_{ro})_{BL Lac} = 0.643 \pm 0.121$. Interestingly, a similar effect can be seen in the compilation of Ledden and O'Dell (1985), shown as the dotted lines in Figures 2a and 2b. Ledden and O'Dell found almost identical mean slopes of $(\alpha_{ro})_{HPQ} = 0.735 \pm 0.104$, and $(\alpha_{ro})_{BL Lac} = 0.636 \pm 0.120$, a difference in the distributions significant at the 99.9% level. Presumably, they lumped the two classes together and did not

comment on the difference because of the inhomogeneity of their sample. In a complete radio sample, however, such an effect is significant. The difference in spectral slopes means that weak lined blazars have on average a factor of 4 times stronger optical continuum emission relative to their radio emission, than strong lined blazars.

It has been claimed that an unusually large number of lineless polarized objects (the classical BL Lac objects) have low redshifts. Twelve out of 19 of the BL Lacs in Ledden and

O'Dell (1985) with redshifts have $z < 0.2$. This is so different from the redshift distribution of radio quasars that several authors have argued that the properties of many BL Lacs can best be explained by gravitational microlensing (Ostriker and Vietri 1985; Schneider and Weib 1988). However, Table 1 contains 18 polarized sources with weak emission lines, and the lack of an extended image on deep UK Schmidt plates indicates that the redshifts are $z > 0.2$. The absence of high-redshift BL Lac objects must be at least partly due to the fact that optically faint radio sources have been neglected in polarization studies.

b) 1349–439: A Double Blazar?

The confirming polarimetry of the Parkes source 1349–439 included observations of four nearby field stars. The large number of interstellar calibrators was due to the relatively low galactic latitude of the radio source ($b^{\text{II}} = 18^\circ$). Nearby star D showed a surprising level of polarization, $p = 7.2 \pm 1.3\%$. Data obtained over the next three nights and 14 months later showed that stars A and B had constant and low polarization, while the polarization of star D varied in the range 2%–7%. The observation of 1349–439 and its stellar companions are listed in Table 2, ordered by date of observation. We note that the photometric zero point on 1985 April 16 was unusually high due to extraordinary and stable seeing of FWHM 0".7. The positions of the four companions to 1349–439 measured at epoch 1985.5 accurate to 2" are A: $13^{\text{h}}52^{\text{m}}07^{\text{s}}.3$, $-44^\circ09'00''$; B: $13^{\text{h}}52^{\text{m}}06^{\text{s}}.2$, $-44^\circ09'08''$; C: $13^{\text{h}}52^{\text{m}}05^{\text{s}}.3$, $-43^\circ09'15''$; D: $13^{\text{h}}52^{\text{m}}08^{\text{s}}.4$, $-43^\circ09'04''$. The distance between 1349–439 and star D is 65". The polarization variability of star D indicates that the origin of the polarization is intrinsic. Only at its low level does the polarization of star D approach the interstellar value. Is this an example of a serendipitous detection of a radio-quiet blazar? Or does the low galactic latitude and lack of strong flux variability imply the detection of a new type of polarized star? Spectroscopy and further polarimetry and photometry of star D are needed to be certain.

c) Blazars in a Complete Radio Sample

The properties of individual blazars have received much attention, often in the form of simultaneous multifrequency

observations over the entire electromagnetic spectrum. Some of the blazars presented here will find their way into these observing programs. Our overall aim is different: to develop a statistical basis for the blazar phenomenon. The focus of this study is on a radio-selected sample because of the evidence that compact radio emission is fundamental to the nonthermal radiation that dominates the energy budget of blazars. It has been known for a long time that the optical counterparts of strong radio sources selected at a high radio frequency have a median magnitude of $V \sim 18$ (Bolton 1977). Only a small percentage of a radio complete sample remains unidentified, and almost all the optical counterparts are bright enough for spectroscopy, photometry, and polarimetry on large telescopes. Optical selection effects are relatively unimportant. A full discussion of the polarization properties of strong radio sources will be presented in a future paper.

The large haul of new blazars demonstrates that the study of high-frequency radio samples is a fruitful way to proceed. About 40% of the sources in a complete 5 GHz radio sample are polarized blazars. The true fraction may be even higher, since some variable objects can lie below the polarization threshold at the time of observation. The likelihood of detecting a blazar at optical wavelengths depends on the radio structure; most flat spectrum ($\alpha_{\text{rad}} > 0.5$) or compact sources are blazars, but steep spectrum ($\alpha_{\text{rad}} < 0.5$) sources are rarely blazars. There is no substantial difference in the luminosity functions of polarized and unpolarized radio sources, a fact of some relevance to models which represent blazars as relativistically beamed radio sources.

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TABLE 2
1349–439 AND COMPANIONS

Object (1)	Data (2)	1985 Apr 13 (3)	1985 Apr 14 (4)	1985 Apr 15 (5)	1985 Apr 16 (6)	1986 Jun 3 (7)
1349–439	$p \pm \sigma(p)$	18.62 0.46	11.59 0.82	11.74 0.29	10.01 0.22	...
	$\theta \pm \sigma(\theta)$	149 1	150 2	150 1	142 1	...
	(V)	(16.81)	(17.19)	(18.12)	(16.11)	...
Star A	$p \pm \sigma(p)$	0.56 0.26	...	...	0.64 0.11	0.42 0.18
	$\theta \pm \sigma(\theta)$	98 10	...	...	99 5	104 12
	(V)	(15.45)	...	...	(14.95)	(15.63)
Star B	$p \pm \sigma(p)$	1.14 0.56	...	...	0.78 0.38	...
	$\theta \pm \sigma(\theta)$	89 14	...	...	128 13	...
	(V)	(17.31)	...	...	(16.89)	...
Star C	$p \pm \sigma(p)$	0.57 1.46	...	...	...	...
	$\theta \pm \sigma(\theta)$	~143	...	...	...	...
	(V)	(17.66)	...	...	...	...
Star D	$p \pm \sigma(p)$	7.20 1.25	1.47 1.00	1.48 1.23	7.45 1.07	2.43 0.75
	$\theta \pm \sigma(\theta)$	124 5	120 19	119 23	132 4	174 9
	(V)	(18.87)	(18.74)	(18.70)	(18.65)	(18.76)

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