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OPTICAL POLARIMETRY OF BROAD-LINE RADIO GALAXIES

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ABSTRACT

We have observed the linear polarization of 13 broad-line radio galaxies drawn from the list of Grandi and Osterbrock. Two of the objects, 3C 109 and 3C 234, are strongly polarized ($p > 7\%$ in unfiltered light). As a class, these active galaxies display larger polarizations than both Seyfert 1 galaxies and quasars. We attribute the polarizations primarily to extinction and scattering by dust, though nonthermal components may contribute at a secondary level. This conclusion is based on (1) the constancy of the polarization position angles found from multiple observations of 10 of the galaxies, (2) the increase in polarization toward shorter wavelengths observed in 3C 445, (3) a polarization in the strong Hα emission of 3C 390.3 similar to that of the surrounding continuum, and (4) a correlation found between the polarization and the decrement of the broad components of the Balmer lines. In addition, the polarizing dust appears to be concentrated in or around the broad-line region since the polarization correlates with the [O III]/Hβ (broad) value. The existence of dust affords a partial explanation for two of the spectral signatures of broad-line radio galaxies: steep Balmer decrements and strong forbidden lines relative to the permitted lines.

Subject headings: galaxies: nuclei — galaxies: Seyfert — interstellar: matter — polarization — radio sources: galaxies

I. INTRODUCTION

Of the three classes of active extragalactic objects which display broad emission lines, extensive polarimetric surveys have been completed for both the Seyfert 1 galaxies (Maza 1979) and the QSOs (Stockman 1978; Moore and Stockman 1981, 1983; Stockman, Moore, and Angel 1983). It is only recently that initial observations have been reported for the third class, the broad-line radio galaxies (BLRGs) (Antonucci 1982).

Though similar in appearance and luminosity to Seyfert 1 galaxies, the broad-line radio galaxies are distinguished optically by weaker Fe II emission, steeper Balmer decrements, and larger [O III] (5007 Å)/Hβ values (Osterbrock, Koski, and Phillips 1976; Grandi and Osterbrock 1978; Osterbrock 1978; Yee and Oke 1978). This, along with their strong radio emission, identifies the broad-line radio galaxies as a separate class, distinct from the Seyfert 1 galaxies and the QSOs.

Antonucci (1982) dealt principally with the relationship between the polarization position angle and the orientation of the extended radio structure. However, from polarimetry of the emission lines he concluded that the polarizations in a number of the galaxies were due to scattering by free electrons or dust grains, or transmission by aligned dust grains. Because the BLRGs display steep Balmer decrements and red continua, this seems a plausible explanation. However, confirmation of the existence of dust in active extragalactic objects, particularly within the broad-line region, is important since dust can dominate the infrared emission (Rieke and Lebofsky 1979; Soifer and Neugebauer 1981; Rudy *et al.* 1982; Rudy and Puetter 1982), affect the derived abundances of refractory elements (Gaskell, Shields, and Wampler 1981), and modify the transfer of radiation through the region (Baldwin and Netzer 1978; Rudy and Puetter 1982).

In this paper we report the results of a polarimetric survey of broad-line radio galaxies. With the exception of Mrk 668, all galaxies are drawn from the list of Grandi and Osterbrock (1978). We observed all but two of the 14 BLRGs discussed by them. One of these, PKS 0353+021, is at a redshift of 0.6, while the other, 3C 287.1, has been measured by Antonucci (1982). Our primary intent is to identify the origin of the polarization by searching for variability, by multicolor observations, and from correlations with other observed properties.

II. OBSERVATIONS

The polarimetric observations of the 13 broad-line radio galaxies were obtained during a period extending from 1979 March to 1982 November. The observations were made on three telescopes: the 1.5 m reflector operated by the University of Minnesota and the University of California, San Diego, located on Mount

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Lemmon, the 2.3 m telescope of Steward Observatory, and the 4 m Mayall reflector on Kitt Peak.

Two different polarimeters were used to acquire the data, one incorporating a Pockels cell and the other a rotating half-wave plate. The Pockels cell instrument is the same as that used by Maza (1979), Stockman (1978), and Moore and Stockman (1981) and is similar to that described by Angel and Landstreet (1970). The other polarimeter, designated the "Two-Holer" polarimeter/photometer, was constructed by G. D. S. at the University of Minnesota. It incorporates a rotating, achromatic half-wave plate and is optimized for measurements of linear polarization.

Table 1 provides both an observing log and a summary of the observations. The data from 1982 May, August, September, and November were obtained with the rotating wave plate polarimeter and the remainder with the Pockels cell instrument. Most of the data are in unfiltered light using GaAs photomultipliers. The sensitivity range of these tubes is from the atmospheric cutoff at 3200 Å to ~8600 Å, where the quantum efficiency drops sharply. For the majority of the galaxies the effective wavelength in unfiltered light is approximately 5800 Å with this value shifting further to the red for the steep-spectrum objects ($\alpha > 2$) such as 3C 109, 3C 234, and 3C 445.

In addition to measurements in unfiltered light, we have measured four of the galaxies through broad-band filters: 3C 234, 3C 445, PKS 2349−014, and 4C 29.06. The filter designated C-500 is a Hoya blue filter which transmits from 3200 Å to 6400 Å. The Hoya R-62 and R-68 and the Corning 2-63 are red filters which provide bands that turn on at 6200 Å, 6800 Å, and 6300 Å, respectively, and extend to the red limit of the phototube.

We also observed the polarization of the Hα line and surrounding continuum in the BLRG 3C 390.3. These observations are presented in Table 2 along with the effective wavelengths and bandpasses of the filters. From a spectral scan of the region around Hα (obtained at the same epoch by B. Margon), we estimate that the broad component of Hα accounts for 60% of the flux in the bandpass designated 1018 in Table 2. The bulk of the remainder of the flux is due to continuum emission, with minor contributions from the narrow component of Hα and from [N II] and [S II].

The data of Tables 1 and 2 may be contaminated by interstellar polarization from the Galaxy. To assess this we have first computed the galactic reddening for each object from the H I column density and the dust-to-gas ratio via the prescription of Burstein and Heiles (1978). A crude estimate of the magnitude of an interstellar component to the polarization can then be

TABLE 1

POLARIMETRIC OBSERVATIONS OF BROAD-LINE RADIO GALAXIES

Object	Date (UT)	Filter	Telescope	Aperture	$p(\%)$	θ
3C 109	1982 Sep 21	none	2.3 m	2″9	7.84 ± 1.50	172° ± 6°
	1982 Nov 21	none	2.3 m	2″9	9.31 ± 2.58	171° ± 9°
3C 120	1981 Oct 24	none	2.3 m	2″5	1.12 ± 0.12	105° ± 3°
3C 227	1979 Apr 1	none	2.3 m	4″0	1.66 ± 0.39	25° ± 7°
	1979 Apr 29	none	2.3 m	4″0	1.16 ± 0.41	35° ± 10°
	1980 Jan 13	none	2.3 m	4″0	2.54 ± 0.65	26° ± 7°
	1981 Oct 24	none	2.3 m	2″5	2.56 ± 0.41	32° ± 6°
3C 234	1982 Apr 30	none	2.3 m	2″5	9.67 ± 1.00	160° ± 3°
	1982 Apr 30	2-63	2.3 m	2″5	8.80 ± 1.20	160° ± 4°
	1982 May 15	none	1.5 m	4″0	7.45 ± 1.14	161° ± 4°
	1982 May 15	C-500	1.5 m	4″0	7.77 ± 1.96	165° ± 7°
3C 332	1982 Apr 30	none	2.3 m	2″5	2.09 ± 1.00	100° ± 20°
3C 381	1981 Oct 23	none	2.3 m	2″5	1.78 ± 1.13	27° ± 25°
	1982 Sep 21	none	2.3 m	2″9	1.76 ± 0.55	50° ± 10°
3C 382	1979 Apr 2	none	2.3 m	4″0	1.19 ± 0.16	51° ± 4°
	1979 Apr 30	none	2.3 m	4″0	1.28 ± 0.16	50° ± 4°
	1979 May 22	none	2.3 m	4″0	1.12 ± 0.21	47° ± 6°
	1980 Jun 9	none	2.3 m	4″0	0.94 ± 0.19	41° ± 6°
	1980 Jun 20	none	2.3 m	4″0	0.90 ± 0.18	43° ± 6°
	1981 Oct 24	none	2.3 m	2″5	0.93 ± 0.18	50° ± 6°
3C 390.3	1979 Sep 18	4-96	2.3 m	4″0	2.06 ± 0.39	165° ± 5°
	1980 Jan 17	none	4.0 m	6″0	0.88 ± 0.18	159° ± 6°
	1980 Apr 11	mone	2.3 m	4″0	1.05 ± 0.25	155° ± 7°
3C 445	1981 Oct 22	none	2.3 m	2″5	1.65 ± 0.29	147° ± 5°
	1982 Aug 18	none	2.3 m	2″9	1.32 ± 0.35	146° ± 6°
	1982 Aug 18	C-500	2.3 m	2″9	1.78 ± 0.29	134° ± 5°
	1982 Aug 18	R-68	2.3 m	2″9	1.02 ± 0.23	146° ± 6°
4C 29.06	1982 Sep 21	none	2.3 m	2″9	1.12 ± 0.18	114° ± 5°
	1982 Sep 21	C-500	2.3 m	2″9	0.89 ± 0.21	121° ± 7°
4C 35.37	1982 Apr 30	none	2.3 m	2″5	2.00 ± 1.37	11° ± 2°
Mrk 668	1982 Apr 30	none	2.3 m	2″5	0.35 ± 0.25	156° ± 30°
PKS 2349−014	1981 Oct 22	none	2.3 m	2″5	0.96 ± 0.20	160° ± 6°
	1982 Aug 20	C-500	2.3 m	2″9	1.29 ± 0.16	158° ± 3°
	1982 Aug 20	R-62	2.3 m	2″9	1.00 ± 0.25	157° ± 6°

TABLE 2

MULTICOLOR POLARIMETRIC OBSERVATIONS OF 3C 390.3 OBTAINED ON 1980 JANUARY 16 AND 17

Filter	Bandpass	λ_{eff}	$p(\%)$	θ
4-96	1800 Å	4700 Å	1.83 ± 0.22	$148° \pm 4°$
056+6000	900 Å	6000 Å	1.40 ± 0.20	$151° \pm 5°$
1018 (Hα)	264 Å	7023 Å	1.15 ± 0.20	$161° \pm 6°$
RG 780	800 Å	8200 Å	0.83 ± 0.23	$150° \pm 8°$

obtained using a formula similar to that suggested by Maza (1979) and based on the work of Hiltner (1956) and Serkowski, Mathewson, and Ford (1975):

$$p(\%) = 3.0E(B-V) . \tag{1}$$

Note that this relation is very approximate since there is a great deal of scatter in the polarization-versus-reddening relationship for galactic stars that was used to determine equation (1) (Serkowski, Mathewson, and Ford 1975). We expect that there is significant reddening toward only three of the galaxies we have observed: 3C 109, $E(B-V) = 0.26$; 3C 120, 0.13; and 3C 382, 0.09. The polarizations derived from equation (1) are 0.78%. 0.39%, and 0.27%, respectively. For the most heavily reddened galaxy, 3C 109, we measured the polarization of two stars within 3′ of the galaxy. Their polarizations are 0.7% and 0.9% in unfiltered light, with similar position angles that are nearly perpendicular to that of 3C 109. For this object alone the tabulated polarization is corrected for the interstellar component; we do not believe that the interstellar polarization contributed significantly to the observed values for the remainder of the objects.

III. DISCUSSION

The most significant feature of Table 1 is the magnitude of the observed polarizations. To estimate a mean polarization for the sample as a whole, we first correct each measurement for a bias due to its observational error (Stockman and Angel 1978):

$$p'^2 = Q^2 - \sigma Q^2 + U^2 - \sigma U^2 , \tag{2}$$

where Q and U are the normalized Stokes parameters of linear polarization. Our 13 observations together with Antonucci's measurement of 3C 287.1 (3.10% ± 1.55%), the only BLRG in his sample for which we do not have observations, yield a mean polarization of $p = 2.2\%$. Even without the strongly polarized objects 3C 109 and 3C 234, the mean polarization is 1.2%. This may be compared with the value 0.6% derived for the QSOs by Stockman (1978) (including both radio-quiet and radio-loud objects but exclusive of the highly polarized, optically violent variable QSOs) and the value of 0.8% found for the Seyfert 1 galaxies by Maza (1979).

The polarized emission from the broad-line radio galaxies is likely to arise from either of two distinct processes: synchrotron emission, which may be intrinsically polarized, or scattering, which can process and polarize radiation that is initially unpolarized. The scattering agents can be either free electrons or grains of dust. If the latter, polarization can originate either from the dichroic extinction by grains which are aligned by magnetic fields and positioned on line between the source and the observer (this is the manner in which the interstellar polarization is produced) or from scattering at angles other than 180°. Since the latter does not require the existence of a magnetic field, it is of interest to distinguish between the two cases.

There are a number of methods we may employ to ascertain the nature of the polarization in our sample of BLRGs. The most straightforward is a search for variability. While the absence of variability on short time scales (periods of several months or less) is inconclusive, rapid variability, particularly in the polarization position angle, indicates the polarization is nonthermal (synchrotron) in origin. Such polarizations are typical of the so-called blazars: BL Lacertae objects and optically violent variable QSOs (Angel and Stockman 1980).

Our data set includes multiple observations of eight objects: 3C 109, 3C 227, 3C 234, 3C 381, 3C 382, 3C 390.3, 3C 445, and PKS 2349−014. In addition, Maza's thesis (1979) contains observations of 3C 120 and 3C 390.3, while Antonucci (1982) presents measurements of 3C 227, 3C 234, 3C 382, and 4C 29.06. In the entire data set only two objects, 4C 29.06 and 3C 227, show evidence of possible variability. Antonucci measured a polarization of 1.92% ± 0.27% at 128° ± 4° for 4C 29.06. The position angle differs only marginally from our values, but the magnitude is nearly a factor of 2 larger. Although the observations were acquired with different apertures and very different effective wavelengths, additional polarimetry of this galaxy seems warranted. 3C 227 shows variations in the magnitude of the polarization but little or no changes in the position angle. Such variations do not necessarily indicate a polarization which is nonthermal in origin. The nuclear emission may be variable and intrinsically unpolarized and may be scattered, or transmitted through a region of polarizing dust. When this variable nuclear flux of constant fractional polarization is measured together with the constant, unpolarized starlight, variations in the magnitude of the polarization of the total emission are observed, but no changes in the position angle of the polarization are seen.

The galaxies which might be expected to show the largest variations are 3C 109 and 3C 234, since in active extragalactic objects, strong polarization is nearly always accompanied by rapid variability (Angel and Stockman 1980). From only two nights of data on 3C 109 no strong statement concerning variability can be made; further monitoring is necessary. For 3C 234, however, the polarization is constant between Antonucci's measurements and our own, and in fact, Antonucci attributes the polarization to electron scattering, or scattering or transmission by dust on the basis of spectropolarimetric observations.

Comparing the polarization of an emission line to that of the surrounding continuum is another possible method for distinguishing between a dust-scattering and a nonthermal origin for the polarized emission (Angel *et al.* 1976; Schmidt and Miller 1980; Thompson *et al.* 1980; Martin *et al.* 1982). Since the line emission is expected to be intrinsically unpolarized, detection of similar polarization in both line and continuum indicates scattering or extinction of both emissions by dust. (Some component due to electron scattering is also possible though an extremely large amount of material would be necessary to produce a substantial polarization of the broad lines [see the discussion by Stockman 1978].) Antonucci's conclusion that the polarization in 3C 234 is due to electron scattering or scattering or transmission by dust is based on the polarizations of identical strength and position angle found for Hα and the adjacent continuum. Likewise, for 3C 390.3 we observe no discontinuity in the polarization through the strong Hα feature (see Table 2). This does not contradict the results of Babadzhanyants and Hagen-Thorn (1975), who found that polarization increased but did not change position angle when the brightness of the nucleus increased. They explained the polarization in terms of a constant, unpolarized stellar contribution and a nuclear component that was variable in brightness with constant fractional polarization. (This is the model we discussed previously for 3C 227.) The nuclear component is exactly what would result if the emission from that region were variable and unpolarized and passed through, or scattered from, a region of polarizing dust.

Less definitive than variability or spectropolarimetry in identifying the origin of the polarization are multicolor observations. If the polarization is due to dust scattering or transmission, we expect it to display a wavelength dependence. Transmission through aligned dust in the Galaxy produces a polarization that typically peaks in the range 4500–5500 Å, with a steep decline to the blue and more gradual decrease to the red (Serkowski, Mathewson, and Ford 1975). Rayleigh scattering by dust may produce a polarized component whose intensity varies as λ^{-4} and extends well into the ultraviolet. Taken together with an unpolarized stellar component, a wavelength-dependent polarization will result. Similarly, a wavelength-dependent polarization will be observed from a nonthermal source of constant polarization if this object resides in a host galaxy. Maza, Martin, and Angel (1978) have considered this problem in detail. They find that the galaxy is generally redder than the nonthermal source, producing a polarization which, like dust scattering and transmission, decreases to the red. For 3C 445, the only BLRG in addition to 3C 390.3 for which we observe a polarization that decreases with wavelength, the wavelength dependence is not due to dilution by starlight. The power-law-like, nuclear component is redder ($\alpha = 2.4$, Yee and Oke 1978) than a typical galaxy and completely dominates the optical energy output of the system (Miller 1981). The fact that the polarization in the blue filter (effective wavelength in the rest frame of 3C 445 is $\sim$4900 Å) is stronger than in unfiltered light ($\sim$5900 Å) suggests that we have not seen the turnover that would identify a polarization from transmission by aligned grains. An additional measurement further to the blue would be necessary to distinguish between a dust transmission or dust-scattering origin for the polarization in 3C 445.

Beyond these methods we can correlate the observed polarizations with other properties indicative of a nonthermal, a dust-scattering, or a dust transmission origin. Suggestive of the last would be a correlation between the polarization and the broad-line Balmer decrement since the extinction produced by the dust would increase the Hα/Hβ value. Maza (1979) found that the more strongly polarized Seyfert galaxies displayed steeper decrements. Accordingly, we plot the broad-line Balmer decrement versus polarization for 13 BLRGs in Figure 1. The Hα/Hβ values are from Grandi and Osterbrock (1978) and papers referenced therein, plus measures for 3C 109 (Yee and Oke 1978) and Mrk 668 (Osterbrock and Cohen 1979; R. Cohen, private communication). Five of the objects, 3C 109, 3C 234, 3C 287.1, 3C 332, and 3C 381, have no published values for the broad Hβ component. For these galaxies the total flux of Hβ was used to calculate the Balmer decrement. These are distinguished by arrows in the direction of increasing Balmer decrement. For 3C 234 we have two additional estimates of the broad Hβ component. One is provided by R. Cohen (private communication), who estimated an upper limit of $\sim$one-fourth the narrow Hβ

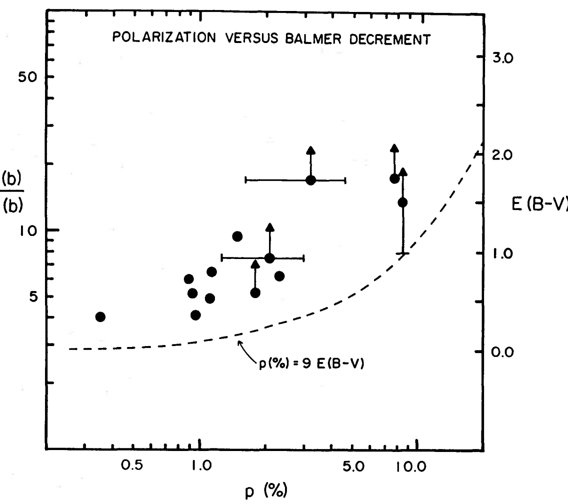

FIG. 1.—The ratio of the broad components of Hα and Hβ plotted against the linear polarization in unfiltered light for 13 broad-line radio galaxies. No point is plotted for 4C 35.37 because Hα has not been observed. The polarization of 3C 287.1 ($p = 3.10$%) is from Antonucci (1982). The points with arrows extending upward are galaxies with no published value for the broad component of Hβ. For these objects the total Hβ flux (the sum of the broad and narrow components) was used to determine Hα/Hβ. The value of $E(B-V)$ corresponding to a given decrement is computed assuming an intrinsic decrement of 2.85 and a Savage and Mathis (1979) reddening law. The dashed line represents a rough upper limit to the polarization possible for a given amount of reddening assuming the mechanism responsible for the polarization is dichroic extinction by aligned grains. Galaxies falling beneath this line would necessarily have some other mechanism such as scattering or synchrotron emission producing the polarization.

component. The point which represents 3C 234 in Figure 1 uses this value. In addition, S. Willner (private communication) has measured the broad component of Paschen-α. Using the case B value of $P\alpha/H\alpha = 0.12$, we have derived a reddening value and used it to compute an $H\beta$ strength. This value is shown as the lower bar on 3C 234 in Figure 1.

A least squares fit to the data of Figure 1 yields a slope of 0.45 with a linear correlation coefficient of 0.83. Both the linear correlation coefficient and the Kendall rank correlation coefficient indicate that the probability of a random occurrence of such a fit is less than 0.003. If the Balmer decrements are increased 50% for the five galaxies for which we have used the lower limits (a reasonable value considering the measurement uncertainties in the broad $H\beta$ fluxes), both the linear and Kendall rank correlation coefficients increase.

Although large polarizations and extinctions are concomitant in Figure 1, we cannot say that the polarizations are due to dichroic absorption by aligned grains alone. Since dust in front of the source may well be accompanied by dust to the side, scattering at angles other than 180° may also be important. In an attempt to distinguish between a dust transmission or dust-scattering origin, we have, in Figure 1, plotted a line corresponding to $p(\%) = 9E(B-V)$. This is an empirical upper limit to a dust transmission polarization for a given amount of reddening that was found to hold for stars in the Galaxy by Serkowski, Mathewson, and Ford (1975). Since polarization from scattering can occur with little or no reddening, objects falling below the dashed line in Figure 1 would most likely produce their polarizations in this manner. Since all the galaxies in our sample lie above this line, the origins of the polarizations are consistent with either dust transmission or dust scattering accompanied by some extinction.

One of the observational features which serves to distinguish BLRGs from Seyfert 1 galaxies and QSOs is the strength of the forbidden lines relative to the permitted lines (Grandi and Osterbrock 1978; Miller 1981). In Figure 2 we have plotted the ratio of [O III] (5007 Å) to the broad component of $H\beta$ versus the polarization. The least squares line has a slope of 1.1 and a linear correlation coefficient of 0.69. The probability of chance occurrence associated with the linear correlation coefficient is less than 0.008, while that associated with the Kendall rank correlation coefficient is less than 0.002. (As with the previous correlation, both the correlation coefficients improve with a 50% decrease in the broad $H\beta$ fluxes for the five galaxies in which this value is uncertain.) This relationship between the polarization and the [O III]/$H\beta$ value suggests that the polarizing dust is concentrated in or around the broad-line region, preferentially extinguishing the flux from this region. If this is the case, the forbidden lines of BLRGs should generally display weaker polarizations than the permitted lines.

Finally, Antonucci (1982) has reported evidence for a sample of radio galaxies that the optical polarization tends to align along or perpendicular to the extended

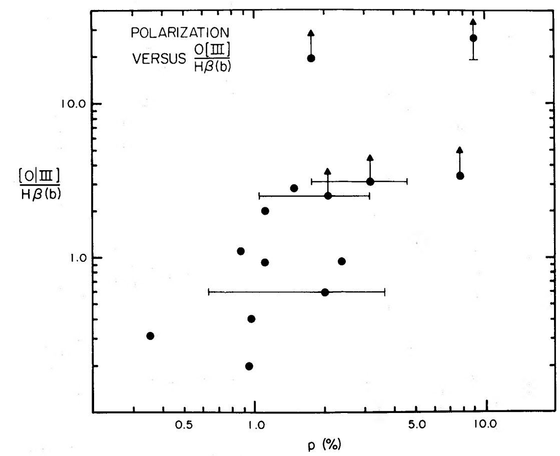

FIG. 2.—The ratio of the flux in the [O III] line at 5007 Å to that of the broad component of $H\beta$ plotted against the polarization in unfiltered light for 14 broad-line radio galaxies. The straight line which best fits the data has a slope of 1.1. The explanation for the arrows on five of the data points is as in Fig. 1.

radio structure. We have presented data on an additional nine galaxies. Of these, four have no radio maps (Mrk 668, 3C 445, 4C 35.37, and PKS 2349−014). Extended maps are given for 3C 109, 3C 332, and 3C 381 by Riley and Pooley (1975) and for 3C 390.3 by Hargrave and McEllin (1975). Both extended and VLBI maps have been published recently for 3C 120 (Balick, Heckman, and Crane 1982; Walker *et al.* 1982). The angular differences between the radio structure and the optical polarizations for these galaxies are 3C 109, 39°; 3C 120, 33°; 3C 332, 64° ± 25°; 3C 381, 47°; and 3C 390.3, 10°. The angle for 3C 120 is uncertain because of contamination from interstellar polarization within the Galaxy, while the error associated with that for 3C 332 is too large to draw any accurate conclusions. The optical polarization of 3C 390.3 is aligned along the radio structure, while those of 3C 109 and 3C 381 are oriented neither parallel nor perpendicular to the radio structure. Thus our data neither contradict nor strongly support Antonucci's result.

IV. SUMMARY AND CONCLUSIONS

We have presented polarimetric observations of 13 broad-line radio galaxies. These objects, as a class, are more strongly polarized than either QSOs or Seyfert 1 galaxies. From the observed absence of variability in the polarization position angles, from multicolor observations, and from a correlation between the polarization strengths and the Balmer decrements, we conclude the polarizations are due principally to scattering or extinction by dust grains, though we cannot rule out some contributions from intrinsically polarized synchrotron emission. An additional correlation between the polarization and the ratio of the [O III] (5007 Å) line and broad $H\beta$ component suggests that the polarizing dust lies within or near the broad-line region, preferentially absorbing the emission from this region.

The polarizing dust contributes, via extinction, to some of the observational signatures of BLRGs, namely, the steep Balmer decrements and the enhancement of the forbidden lines relative to the permitted lines. Despite its importance, there remain certain observed properties of the broad-line radio galaxies that dust extinction cannot explain. Osterbrock, Koski, and Phillips (1976) found that in none of the four BLRGs they observed could the Balmer lines be modeled by case B recombination values and any known reddening law. The optical depth effects which exist in the broad-line regions of quasars and Seyfert 1 galaxies (Puetter *et al.* 1981; Soifer *et al.* 1981; Lacy *et al.* 1982; Kwan and Krolik 1981; and Canfield and Puetter 1981 are a few of the references) and in 3C 390.3 (Ferland *et al.* 1980; Netzer 1982) are almost certainly present in many of the other BLRGs. Also, the differences between continuum shapes representative of BLRGs and quasars (Miller 1981) cannot be reconciled by dust absorption alone. The spectrum of 3C 234 (Grandi and Osterbrock 1978; Grandi and Phillips 1979) if de-reddened by $E(B-V) = 1$–2 mag would display the turnup in the ultraviolet typical of quasars. However, the BLRG Mrk 668, with small polarization and Balmer decrement and little additional evidence for reddening, does not show such spectral behavior (Osterbrock and Cohen 1979).

A progression of the three classes of broad-line emitting objects by decreasing dust content (in or around the BLR) as determined from their polarizations is: broad-line radio galaxy, Seyfert 1 galaxy, and quasar. The red optical continua and steep Balmer decrements of the BLRGs are additional arguments that the BLRGs are the dustiest of the broad-line objects. Such a progression is not due solely to a simple luminosity dependence in which the dust content decreases with increasing luminosity. Although such a relationship seems to hold for the Seyfert 1 galaxies and the quasars, the BLRGs certainly compete favorably with the Seyfert 1 galaxies in terms of total luminosity. It appears that factors in addition to the luminosity determine the amount of dust present in the broad-line region.

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Note added in proof.—Van Breugel (private communication) has mapped 3C 445 at 20 cm; the difference between the directions of the optical polarizations and the extended radio structure is 27°.

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