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Anisotropic [OIII] emission in radio loud AGN *

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Abstract. We present the results of spectropolarimetry of a sample of 7 powerful radio galaxies and 2 quasars with $0.07 < z < 0.35$ obtained to detect possible anisotropies in the [OIII] line emission, which could explain the higher [OIII] luminosity of quasars than that of radio galaxies within the framework of the Unified Model of radio-loud AGN. We detect polarized [OIII] in 4 radio galaxies, consistent with the possibility that a considerable fraction ($\sim 20\%$) of the observed [OIII] emission is scattered in a similar way to the hidden nuclear continuum. However, small but detectable rotation between the polarization direction of the line and of the continuum in two radio galaxies shows that the geometry of the emitting regions can be different.

Key words: Line: formation, Scattering, Techniques: polarimetric, Galaxies: active, Radio continuum: galaxies

1. Introduction

Jackson & Browne (1990, hereafter JB90) have found that the [OIII] 5007Å line luminosity of a sample of powerful radio galaxies (RG) from the 3CRR catalogue with $0.15 < z < 0.85$ is lower by factors of 5–10 than that of a corresponding sample of quasars (RQ), matched in redshift and extended radio power. Lawrence (1991) also finds that, at a given radio power quasars and broad line radio galaxies have stronger [OIII] emission than narrow line radio galaxies in a sample of FRII 3CRR sources with $z < 0.5$. Similarly, Seyfert 1 galaxies have higher [OIII] luminosity than Seyfert 2, for a given radio luminosity (Lawrence 1987). However Keel et al. (1994) found no significant difference in the [OIII] luminosity between type 1 and type 2 objects for a sample of IRAS Seyfert galaxies selected for their warm far infrared colours. This difference in [OIII] luminosity between RQ and RG has been regarded as a failure of the Unified Model for radio–loud AGN, since it was thought that this forbidden line would be emitted only from regions at a large enough distance from the nucleus to be unobscured by the material causing the anisotropy in the featureless nuclear continuum and in the permitted broad lines, and that therefore its luminosity should be the same for RQ and RG, if they are parent populations, as discussed in Antonucci (1993). More recently, however, Hes et al. (1993, hereafter HBF93) have found that the [OII] 3727Å line luminosity is the same for matched samples of RG and RQ in a redshift range similar to that of JB90 ($0.2 < z < 0.8$), consistent with the prediction of the Unified Model.

These findings are confirmed by an analysis of the [OIII] and [OII] line luminosities of the complete sample of 2Jy southern radio sources observed by Tadhunter et al. (1993). Also in this case the average [OIII] luminosity of the RQ with $0.15 < z < 0.7$ exceeds that of the RG in the same redshift range by a factor of about 6, while the average [OII] luminosities are about equal (see Fig. 1).

HBF93 suggest that the partial failure of the [OIII] test might be due to the fact that this line, which has a higher critical density than [OII], might have a significant component from the nuclear region, and thus be subject to pronounced anisotropic obscuration. If this were the case, the [OIII]5007 line would be partially polarized in RG, since its obscured component would be scattered as we know happens for the broad permitted lines (Antonucci 1984, di Serego Alighieri et al. 1994). Therefore we have performed a spectropolarimetric study of a sample of 7 RG to search for polarized [OIII] line emission. We have also examined the polarization of [OII] to see if it behaves differently from [OIII]. Finally we have observed 2 RQ, in which there should be a much smaller scattered fraction.

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* Based on observations obtained at the European Southern Observatory, La Silla, Chile, and at the Isaac Newton Group of Telescopes, La Palma, Canary Islands, Spain

Table 1. The sample and the observations

Object	Type	z	Radio P.A. (deg.)	Opt. P.A. (deg.)	Slit P.A. (deg.)	Slit length (arcsec)	Exp. Time (min.)
3C 227	BLRG	0.0861	84	119	90	15.2	4×15 + 4×15
3C 327	RG	0.1039	100	98	127	9.1	4×10
0806−10	RG	0.110	19	40	30	7.5	4×20 + 4×20
1549−79	RG	0.150	68	169	169	14.0	4×20 + 4×20
3C 273	RQ	0.158	42	42	42	14.0	4×3 + 4×3
3C 196.1	RG	0.198	42	52	54	13.4	4×20 + 4×20
3C 180	RG	0.220	171	28	34	14.0	4×15 + 4×12
1151−34	BLRG	0.258	70	round	90	12.8	4×15
1355−41	RQ	0.313	124	unresolved	90	12.8	4×10 + 4×10

Fig. 1. Histograms of the [OIII] and [OII] line luminosities for radio galaxies (thin line) and quasars (thick line) with $0.15 < z < 0.7$ in the complete sample of southern 2Jy radio sources of Tadhunter et al. (1993).

2. Observations and analysis

The sample of RG and RQ was selected with the following criteria: 1. the redshift should be between 0.07 and 0.35, so that the emission lines of [OIII] at 4959 and 5007Å and of [OII] at 3727Å fall in the range where EFOSC1, the instrument used, has good efficiency; 2. the coordinates should be in the range $6^h \leq R.A. \leq 16^h$ and $Dec. \leq 10°$, to be observable from La Silla in the allocated period; 3. the radio source should be in the 3CR (Spinrad et al. 1985) or in the 2Jy catalogue (Wall & Peacock 1985), which are the most completely identified catalogues of powerful radio sources covering most of the sky.

We have observed 9 of the 13 radio sources, which fulfill the above criteria. Of the remaining 4 sources, 3C 287.1 (an N galaxy at z=0.2159) has been observed spectropolarimetrically by Antonucci (1984), and the others (3C 198, a RG at z=0.0815, 0736+01, a RQ at z=0.191, and 0859−25, a RG at z=0.305) were not observed for lack of time. However the 9 objects observed were not selected out of the sample of 13 for any specific reason. Therefore our observations should give an unbiased view of the problem of [OIII] anisotropy in radio loud AGN.

The object 1151−34 was classified as a quasar by Wall & Peacock (1985). However it has large equivalent width narrow lines and its absolute magnitude is below the limit for quasars used by Véron–Cetty & Véron (1996). It has a broad component at Hα, possibly double peaked (Eracleous & Halpern 1994), present also at Hβ. We therefore list it as a broad line radio galaxy.

Table 1 lists the observed objects and the parameters for the observations, which were performed with EFOSC1 on the ESO 3.6m telescope in La Silla in March 1995 for all objects except for 3C 327 and 0806-10 (also named 3C 195, but not a 3CR object). 3C 327 was observed with EFOSC1 in June 1994. 0806-10 was observed with ISIS on the William Herschel Telescope on La Palma (Tinbergen & Rutten 1992) in March 1994. Details of the spectropolarimetric mode of EFOSC1 and of the observing procedure and data reduction are given by di Serego Alighieri & Walsh (1995). The spectrograph slit width was 2 arcsec in all cases and was aligned with the optical elongation of the object, when this is clearly asymmetric. EFOSC1 and ISIS use a beamsplitting polarization analyzer to separate the ortogonal polarization states and a half–wave plate to rotate the polarization direction. For each object we obtained one or two sets of 4 spectral frames taken with the half–wave plate in position angle $0°$, $22.5°$, $45°$ and $67.5°$. Each frame has two spectra of the object with perpendicular polarization and several sky spectra. After bias subtraction and flat–fielding, the object and sky spectra were extracted from the frames and wavelength calibrated, followed by sky subtraction and flux calibration, using observations of spectrophotometric standard stars (Stone & Baldwin 1983, Oke 1990). The portion of the slit used for object extraction was selected to include all line emission and its length is listed in Table 1. The polarization was analyzed with a set of procedures developed in collaboration with J. Walsh (see also Walsh 1992). In order to achieve a significant S/N ratio, the object spectra were summed over wavelength bins selected to separate the main emission lines and line–free continuum sections, and to avoid sky lines. We note that it is crucial to perform this rebinning *before* the computation of the U and Q Stokes parameters, in order to avoid a bias error due to the non normal error distribution of the Stokes parameters (di Serego Alighieri 1997). Statistical errors were derived by propagating the poissonian photon noise in the object and sky spectra along the procedure used to obtain the polarization parameters. The zero point offset in the polarization position angle was obtained by observations of polarization standard stars (Turnshek et al. 1990, Schmidt et al. 1992).

3. Results

Of the results of our spectropolarimetry we present and discuss here only those that are relevant for the anisotropy in the [OIII] emission. The polarization of the continuum will be discussed in a separate paper. An effective way to detect polarized line emission is to look for the line in the polarized flux spectrum. This method provides a visual impression of the line polarization and of its reliability, although it does not yield the most usefull measurement. Figure 2 gives both the total flux spectra and the polarized flux spectra for our sample of radio sources. The [OIII]4959,5007 lines are clearly detected in the polarized spectra of the RG 0806–10 and 1549–79; they are seen with some significance in the RG 3C 327, 3C 180 and in the BLRG 3C 227; they are not present in the RQ 3C 273, 1355–41 and in the BLRG 1151–34. We remark that there is no sign of [OII]3727 in the polarized flux spectra, except possibly in 1549–79.

In order to give a quantitative measure of the line polarization we have obtained the emission line fluxes for [OIII]4959,5007 and for [OII]3727 from the object spectra extracted from the original 2–dimensional spectra, using a simple continuum subtraction and line integration. Then the polarization parameters are computed from the individual line fluxes. We have performed the continuum subtraction in an automatic way for all the individual spectra of each object after the selection of the continuum sampling regions, to avoid as much as possible the effects of a subjective continuum subtraction on the polarization. The errors were estimated taking into account all sources of poissonian noise, including the line flux, and the subtracted continuum and sky. These were propagated using a Monte Carlo simulation, similar to that described by Fosbury et al. (1993). Table 2 lists the line polarization which we have obtained for the sum of the two [OIII] lines at 4959 and 5007 Å, together with the polarization of the continuum around 5000 Å in the rest frame. The degree of polarization has been corrected for the bias expected for a definite positive quantity at low S/N (e.g. Wardle & Kronberg 1974). We also give the flux and the equivalent width for the two [OIII] lines.

The results of the line polarization analysis are consistent with the visual impression gathered from the plots of the polarized flux in Fig. 2: [OIII] polarization is measured with good accuracy (P/$\sigma_P > 5$) for the RG 0806–10 and 1549–79, with marginal accuracy (P/$\sigma_P \sim 2.5$) for the RG 3C 227 and 3C 180, while P/σ_P is smaller than 2 for the other objects and we can only give upper limits to the polarization, corresponding to a 95.5% degree of confidence. No measurable polarization of [OII]3727 is detected, although given the low S/N in the blue part of the spectrum this result is not of high significance. It is interesting to notice that the continuum around 5000 Å is polarized at a significant level in all objects except 1151–34.

Regarding the orientation of the polarization we first remark that there is a significant difference in the orientation of the [OIII] and continuum polarization in 3C 227 and in 0806–10, while the two polarizations are parallel in the other 2 RG with clearly detected [OIII] polarization, namely 1549–79 and 3C 180. The position angle in the optical listed in Table 1 refers to the major axis of the innermost structures in broad band images (de Koff et al. 1996, Cimatti & di Serego Alighieri 1995), with the exception of 3C 227 for which we list the orientation of the bright [OIII] bar, since the broad band continuum structure is round (Prieto et al. 1993). The direction of the [OIII] polarization is perpendicular to the [OIII] bar in 3C 227, to the elongation of the innermost isophote of the Hα image by Cimatti & di Serego Alighieri (1995) in 0806–10 (i.e. 3C 195), and to the inner opposite–cones structure in 3C 180 (de Koff et al. 1996). On the other hand the direction of the [OIII] polarization does not bear any special relation with the outer elliptical isophotes, nor with the inner radio jet (Murphy et al. 1993) in 1549–79. However for this RG we do not have an emission line image nor a high resolution image showing the inner structure. The continuum polarization around 5000Å is perpendicular to the optical broad band major axis for all RG, except for the BLRG 3C 227 and for 1549–79.

4. Discussion

Since the detected line polarization is of the order of a few percent only, we cannot exclude *a priori* that it could be due to trasmission through aligned dust grains. We have first examined the influence of interstellar polarization in our Galaxy and exclude that it is the dominant contributor to the detected line polarization for the following reasons: a) galactic interstellar polarization would affect in the same way the line and the continuum while we observe a different degree and orientation in 3C 227 and in 0806–10; b) the detected line and continuum polarization are perpendicular to well defined structures in the environment of the AGN itself, while such a systematic trend is not expected for galactic polarization; c) the maximum galactic interstellar polarization expected from the galactic extinction, according to the empirical relation ($P_{max}(\%) \leq 9E_{B-V}$), is much smaller than the observed polarization in 3C 227

Table 2. The results of spectropolarimetry

Object	$P_{[OIII]}$ (%)	$\theta_{[OIII]}$ (deg.)	$P_{cont.}$ (%)	$\theta_{cont.}$ (deg.)	$f_{[OIII]}$ $(10^{-16} ergs^{-1} cm^{-2})$	E.W. (Å)	E^a_{B-V}
3C 227	1.27±0.52	15±7	1.90±0.12	50±3	586	96	0.006
3C 327	< 1.0		0.63±0.33	3±15	891	208	0.105
0806−10	1.65±0.31	147±4	3.92±0.35	130±3	1207	362	0.099
1549−79	3.54±0.70	50±4	2.92±0.27	49±3	252	238	0.128
3C 273[b]	< 2.3		0.23±0.03	82±3	2828	12	0.001
3C 196.1	< 7.2		0.83±0.21	130±10	38	23	0.055
3C 180	1.11±0.49	109±8	0.59±0.37	113±15	396	317	
1151−34	< 3.2		< 1.4		147	110	0.091
1355−41	< 3.6		1.22±0.17	108±3	267	18	0.063

[a] Galactic extinction from Burstein & Heiles (1982)
[b] For 3C 273 all [OIII] measurements refer to the 5007Å line only

and 1549–79 (Table 2 lists the galactic extinction E_{B-V} from Burstein & Heiles 1982); d) the observed polarization rises in the blue for all RG and is therefore inconsistent with the Serkowski curve peaking around 5500Å, expected for interstellar polarization (Serkowski et al. 1975).

It is more difficult to rule out a contribution from the interstellar polarization in the AGN host galaxy, since in this case we cannot exclude that the lines of sight to the continuum and to the line emission go through a different local ISM and are polarized differently, and that the dust grains are aligned with local structures. Indeed the polarization of the broad line RG 3C 109 at $z = 0.307$, where [OIII] is polarized at a much lower level than the continuum and broad lines, has been interpreted as due to transmission through aligned dust grains within the host galaxy (Goodrich & Cohen 1992). However in this case the polarization of the continuum follows well a Serkowski curve with a maximum around 5000Å in the rest frame, and its direction is not related to the structure of the source: it is at 60° from the inner optical axis of the HST image (de Koff et al. 1996) and at 42° from the VLBI axis. For our sample, the perpendicularity of the polarization with structures in the host galaxy and the inconsistency of the observed polarization with a Serkowski curve make it very unlikely that transmission through local dust is the main polarizing mechanism.

The only other possible mechanism for producing net [OIII] line polarization also in integrated light is anisotropic scattering, which occurs when a substantial fraction of the [OIII] emission is hidden from direct view but can escape in other directions along which it is scattered toward us, or when the scattering material is distributed anisotropically around most of the [OIII] emitting region, even if this is not obscured. The anisotropic obscuration and scattering mechanism has been used to explain the presence of a polarized type 1 spectrum in Seyfert 2 and radio galaxies in the framework of the AGN unification (Antonucci, 1993). In particular in distant powerful radio galaxies the polarization has been found to be perpendicular to the elongated optical structure, which is aligned with the radio axis (e.g. Cimatti et al. 1993). The idea is that powerful RG harbour a quasar, whose strong continuum and broad lines are hidden by obscuration. The obscuring material is distributed (e.g. in a torus) such that the quasar radiation can escape only along two opposite directions (or cones) aligned with the radio axis, and then it is scattered in our direction with a net polarization even in integrated light. If the structure of the obscuring material and of the [OIII] emitting region are such that the latter is at least partially hidden from direct view, then [OIII] would be polarized in a direction approximately perpendicular to the optical and radio axis. The exact correspondence of the direction of polarization of [OIII] and of the continuum is not required, since the two emitting regions can have a different location behind the obscuring material and therefore a slightly different mean scattering direction. The [OIII] polarization results on our sample are all consistent with anisotropic scattering. Of the two possible mechanisms for producing the anisotropy in the scattering we favour anisotropic obscuration over an anisotropic distribution of the scattering material for similarity with the mechanism producing the anisotropic scattering of the continuum and broad lines, which must be obscured. However, contrary to what happens to the nuclear continuum and broad lines, which are only visible through scattering in many RG, a fraction of the [OIII] emission in our RG must be seen directly, since the line polarization is generally lower than that of the continuum, particularly if the latter is corrected for dilution by stellar light.

In order to evaluate the fraction $f_{[OIII]_s}$ of the observed [OIII] emission which is scattered, we assume that the intrinsic polarization of the scattered [OIII] is equal to that of the scattered continuum. This assumption is reasonable if the scattering material is the same for the line and for the continuum and if the scattering geometries are not too different. Then

$$f_{[OIII]_s} = f_{cont._s} \frac{P_{[OIII]}}{P_{cont.}}$$

where $P_{[OIII]}$ and $P_{cont.}$ are the observed polarization for the [OIII] lines and for the surrounding continuum respectively,

Fig. 2. The total flux spectra (top) and the polarized flux spectra (bottom) of the observed AGN. The latter ones have been rebinned to 15Å to decrease noise. Spurious features due to cosmic rays and to imperfect sky line subtraction are marked with asterisks.

and $f_{cont._s}$ is the fraction of the continum which is scattered. The latter can be estimated from the stellar fraction f_*, in the assumption that the only dilution of the polarization at 5000Å is from stars ($f_{cont._s} = 1 - f_*$). We have estimated $f_{[OIII]_s}$ only for 0806-10 and for 1549-79, where line and continuum polarization are measured with a good accuracy. The stellar fraction at 5000Å, estimated from a fit of the stellar features (i.e. the CaII H and K lines and the G band), with a synthetic stellar spectrum are 0.55 and 0.85 respectively for the 2 RG. Then $f_{[OIII]_s} = 0.22, 0.18$ for 0806-10, 1549-79. Although the parameters are uncertain and there are several simplifying assumptions, if a fifth of the observed [OIII] emission is scattered and if the scattering efficiency is 2-3% (see Fig. 7 of Manzini & di Serego Alighieri 1996), then the total [OIII] emission, if viewed directly, would be about 6 to 10 times larger than the observed one, consistent with the ratio of [OIII] luminosity of quasars and radio galaxies as given by JB90 and by our analysis of the southern 2Jy RG. Therefore our results bring the [OIII] test of JB90 back in the realm of the schemes unifying quasars and radio galaxies.

They also help in refining the unification picture. If a large fraction of [OIII] around a radio loud AGN is emitted anisotropically and the anisotropy is caused by obscuration, then the conditions for [OIII] emission must exist also in regions within the obscuring material (e.g. inside the torus). In particular the density must be lower than the [OIII]5007 critical density (7.9×10^5 cm^{-3}). Although data with a higher UV sensitivity than ours are necessary to exclude [OII]3727 polarization, the results of HBF93 suggest that this line is emitted isotropically. Then regions with a density below the [OII]3727 critical density (3.0×10^3 cm^{-3}) are not found within the obscuring material.

If the [OIII]5007 line is radiated by material at or below the critical density for collisional de-excitation, the observed luminosity allows a lower limit to be placed on the size of the emitting region. Where O^{2+} is the dominant ionization state and the electron temperature is close to 10^4 K, the radius of a spherical emitting region in units of 10pc is given by

$$r_{10} \sim 0.9 L_{42}^{1/3} f_{-5}^{-1/3} n_c^{-2/3} \zeta^{-1/3}$$

where L_{42} is the line luminosity in units of 10^{42} erg s^{-1}, f_{-5} is the volume filling factor in units of 10^{-5} (van Breugel 1988), n_c is the electron density in units of the [OIII] critical density and ζ is the oxygen abundance in units of the solar value.

Although such a calculation presupposes some knowledge of the filling factor of the gas, the indicated sizes are typically somewhat smaller than the small-scale nuclear disks seen in HST images of some nearby radio galaxies, eg. 3C 270 with $r < 100pc$ (Jaffee et al. 1993). The [OII] line however, because of its much lower critical density, must be radiated by gas occupying a considerably larger volume only an insignificant fraction of which would be obscured by such nuclear structures.

The idea of a partial line obscuration for [OIII] but not for [OII] is also consistent with the results of Baker (1997) on a complete sample of quasars: she finds that the negative correlation between emission line equivalent width and radio core dominance is much stronger for [OIII] than for [OII].

5. Conclusions

We have looked for anisotropies of the [OIII] emission in radio loud AGN by examining the [OIII] line polarization in a sample of 7 powerful radio galaxies and 2 quasars in the redshift range $0.07 \leq z \leq 0.35$. We find that the [OIII]5007,4959 lines are significantly polarized in 4 of the radio galaxies. In at least 3 of them the direction of [OIII] polarization is perpendicular to the axis of the extended line emission. Although some contribution from polarization by interstellar dust in the host galaxy cannot be excluded, our results strongly suggest that a fraction of the [OIII] line emission is not seen directly in radio galaxies, but is scattered toward us after anisotropic obscuration by the same material which hides the quasars postulated by the Unified Model. For the 2 radio galaxies where line polarization is observed with the highest accuracy, we estimate that the [OIII] line radiation which is emitted behind the obscuring material can be about 6 to 10 times larger that the directly observed one, thereby explaining within the framework of the Unified Model the higher [OIII] luminosity of quasars with respect to radio galaxies. Spectropolarimetric data with higher sensitivity and spectral resolution are necessary first to check whether anisotropic scattering is less important for [OII], as expected from the equivalent [OII] luminosity of quasars and radio galaxies. Secondly, important information can be obtained on the kinematics of the line emitting gas and of the scattering material by a comparison of the line profiles in the total flux spectra and in the polarized flux spectra, in analogy to what has been done for planetary nebulae (e.g. Walsh & Clegg 1994). Finally, differences in the geometric distribution of the obscured regions emitting the continuum, the broad lines and the narrow [OIII] lines can be examined in more detail. Such differences are seen in planetary nebulae and in the AGN Cygnus A (Ogle et al. 1997).

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References

Antonucci R. R. J., 1984, ApJ, 278, 499
Antonucci R., 1993, ARA&A, 31, 473
Baker J.C., 1997, MNRAS, 286, 23
Burstein D., Heiles C., 1982, AJ, 87, 1167
Cimatti A., di Serego Alighieri S., 1995, MNRAS, 273, L7
Cimatti A., di Serego Alighieri S., Fosbury R. A. E., Salvati M., Taylor D., 1993, MNRAS, 264, 421
de Koff S., Baum S. A., Sparks W. B., Biretta J., Golombek D., Macchetto F., McCarthy P., Miley G. K., 1996, ApJS, 107, 621
di Serego Alighieri S., Cimatti A., Fosbury R. A. E., 1994, ApJ, 431, 123
di Serego Alighieri S., Walsh J. R., 1995, Spectropolarimetry with EFOSC1. In: Benvenuti P. (ed.) Calibrating and understanding HST and ESO instruments", ESO Conf. and Workshop Proc. No. 53, Garching bei München, p. 71
di Serego Alighieri S., 1997, Polarimetry with large telescopes. In: Rodriguez de Espinosa J. M. et al. (eds.) Instrumentation for large telescopes, Cambridge University Press, Cambridge (in press)
Eracleous M., Halpern J. P., 1994, ApJS, 90, 1
Fosbury R. A. E., Cimatti A., di Serego Alighieri S. 1993, The Messenger, 74, 11
Goodrich R. W., Cohen M. H., 1992, ApJ, 391, 623
Hes R., Barthel P. H., Fosbury R. A. E., 1993, Nature, 326, 362
Jackson N., Browne I. W. A., 1990, Nature, 343, 43
Jaffee W., Ford H. C., Ferrarese L., van den Bosch F., O'Connel R. W., 1993, Nature, 364, 213
Keel W.C., de Grijp M.H.K., Miley G.K., Zheng W., 1994, A& A, 283, 791
Lawrence A., 1987, PASP, 99, 309
Lawrence A., 1991, MNRAS, 252, 586
Manzini A., di Serego Alighieri S., 1996, A& A, 311, 79
Murphy D.W. and the SHEVE Team, 1993, 2.3 GHz VLBI images of southern hemisphere radio galaxies and quasars. In: Davis R. J. & Booth R. S. (eds.) Cambridge University Press, Cambridge, p. 243
Ogle P. M., Cohen M. H., Miller J. S., Tran H. D., Fosbury R. A. E., Goodrich R. W., 1997, ApJ (in press)
Oke J. B., 1990, AJ, 99, 1621
Prieto M. A., Walsh J. R., Fosbury R. A. E., di Serego Alighieri S., 1993, MNRAS, 263, 10
Schmidt G. D., Elston R., Lupie O. L., 1992, AJ, 104, 1563
Serkowski K., Mathewson D. S., Ford V. L., 1975, ApJ, 196, 261
Spinrad H., Djorgovski S., Marr J., Aguilar L., 1985, PASP, 97, 932

Stone R. P. S., Baldwin J. A., 1983, MNRAS, 204, 347
Tadhunter C. N., Morganti R., di Serego Alighieri S., Fosbury R. A. E., Danziger I. J., 1993, MNRAS, 263, 999
Tinbergen J., Rutten R., 1992, A User Guide to WHT Spectropolarimetry, User Manual No. XXI, Isaac Newton Group, La Palma
Turnshek D. A., Bohlin R. C., Williamson II R. L., Lupie O. L., Koornneef J., Morgan D. H., 1990, AJ, 99, 1243
van Breugel W. J. M., 1988, Extended optical line emission in radio galaxies. In: Meisenheimer K. & Röser H.–J. (eds.) Hot spots in extragalactic radio sources, Springer, Berlin, p. 121
Véron–Cetty M.P., Véron P., 1996, A catalogue of quasars and active nuclei (7th Edition), ESO Scientific Report No. 17, Garching bei München
Wall J. V., Peacock J. A., 1985, MNRAS, 216, 173
Walsh J. R., 1992, The reduction of spectropolarimetry data. In: Grosbøl P. J. & de Ruijsscher R. C. E. (eds.) 4^{th} ESO/ST–ECF Data Analysis Workshop, ESO Conf. and Workshop Proc. No. 41, Garching bei München, p. 53
Walsh, J. R., & Clegg, R., 1994, MNRAS, 268, L41
Wardle J. F. C., Kronberg P. P., 1974, ApJ, 194, 249

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