POLARIZATION PROPERTIES OF RADIO CORES

D. J. SAIKIA
TIFR, GMRT Project, Poona University Campus,
Ganeshkhind, Pune 411007, India and
University of Manchester, NRAL, Jodrell Bank,
Macclesfield, Cheshire SK11 9DL, England

1. Introduction : radio structures and unification schemes

Extragalactic radio sources associated with elliptical galaxies and quasars exhibit a rich variety of structures on scales ranging from < few parsecs to over a Mpc. The sources with extended (> tens of kpc) structure are often classified into the low-luminosity FRI sources which usually have diffuse outer lobes, and the high luminosity FRII sources which tend to have bright hotspots at the outer edges. (Miley 1980; Bridle & Perley 1984). The FRI and II types differ in a number of other aspects as well such as the structure and magnetic field orientation in the radio jets, morphology of the parent optical galaxies and their environments (Bridle & Perley 1984; Lilly & Prestage 1987; Owen and Laing 1989). It therefore seems unlikely that the two FR classes either represent different phases in an evolutionary sequence or are caused by differences in orientation or the supply of energy to the outer lobes.

Radio sources can also be classified into the lobe- or core-dominated ones depending on the prominence of the subarcsecond nuclear component, also called the radio core. The cores usually have a flat spectrum ($\alpha < 0.5$ where $S \propto \nu^{-\alpha}$). Steep-spectrum cores or SSCs are also found, but are relatively rare (Saikia, Kulkarni & Porcas 1986). Considerable evidence now suggests that the bulk of the core-dominated sources are the normal lobe-dominated sources seen end-on. Early work on the unification of lobe and core-dominated FRII quasars (Orr & Browne 1982; Kapahi & Saikia 1981, 1982) has been extended to include radio galaxies as well (Owen 1986; Scheuer 1987; Barthel 1989). On the other hand there have been a number of suggestions that the BL Lacs may be the relativistically beamed counterparts of the FRI sources (Browne 1983; Antonucci & Ulvestad 1985; Ulrich 1989). This idea has been extended to include the flat spectrum radio galaxies as well which possibly manifest themselves as BL lacs in the more extreme cases (Saikia et al. 1989, 1990, in preparation).

Another group of sources often discussed are the compact steep-spectrum sources or CSSs which are defined to be $\lesssim 10$ kpc and include the well known VLBI doubles (Phillips & Mutel 1982). Many of the CSSs are believed to be confined to small dimensions by a dense interstellar

R. Beck et al. (eds.), Galactic and Intergalactic Magnetic Fields, 385–393.

medium (cf. Saikia 1988 for a review). In this review we concentrate on the polarization properties of the cores in extended sources, and the CSSs. For lack of space we do not discuss their variability characteristics as well as measurements of circular polarization, but refer the reader to the review by Saikia & Salter (1988).

2. Integrated polarization of cores at radio wavelengths

These studies are important in order to investigate the physical conditions in the nuclear regions, clarify any differences between different kinds of objects, and help understand the importance of orientation and relativistic motion in active nuclei. Strong cores and core-dominated sources have been studied by a number of authors but weak cores in extended sources have received very little attention largely because of observing difficulties. One of the most extensive multifrequency polarization studies of compact flat-spectrum sources showed that the median value of polarization is ~2.5% between 1.4 and 90 GHz independent of frequency (Jones et al. 1985; Rudnick et al. 1985). High resolution observations of a large sample of compact radio sources with the VLA A-array (Perley 1982) show that the median polarization for flat-spectrum cores in quasars is ~2% at both 1.4 and 5 GHz. (Saikia et al. 1985, 1987). Similar results have been reported by Rusk (1989). These studies do not imply frequency independence for the individual sources, but only for the median values. Although some sources show systematic trends with frequency (Rudnick et al. 1978), the frequency dependence is largely random. Polarization observations of variable quasars at 408 MHz (Conway et al. 1972) also suggest a median value of ~2%. At these wavelengths, however, contamination by extended emission could be important, and it would be useful to investigate this aspect with high-resolution polarization mapping.

Thus, there is no depolarization at radio and millimetre wavelengths that could be attributed to internal Faraday depolarization (Jones & O'Dell 1977c), decreased dominance of relatively unpolarized opaque regions (Jones & O'Dell 1977 a,b; Jones & Hardee 1979) or greater magnetic field ordering on smaller scales dominating the shorter wavelength emissions (Jones et al. 1985). The general observed polarization characteristics can be described by magnetic fields that are largely random but have a slight anisotropy (Jones et al. 1985). Numerical simulations of nearly steady, isothermal, constant-velocity jets that carry along magnetic fields with a Kolmogorov turbulence spectrum are capable of reproducing qualitatively many of the observed features (Jones 1986).

Rudnick & Jones (1982) made multifrequency VLA observations of 40 sources with $\alpha < 0.5$ and noted that the source properties were related to their spectral shapes. The ones with complex spectra, which form the bulk of their sample, are highly variable, are ~2% polarized, and have no evidence of depolarization. The simple-convex spectrum sources vary slightly, and are ~1% polarized with no frequency dependence. The straight-spectrum sources are not variable and exhibit significant depolarization, reminescent of the CSSs which also show some evidence of depolarization (Saikia et al. 1985, 1987; van Breugel et al. 1984).

Saikia et al. (1985, 1987) found that the cores in quasars tend to be more strongly polarized at both 6 and 20 cm than those in galaxies or empty fields. This appears to be true for both FSCs and CSSs. Rusk (1989) has suggested this to be consistent with Rudnick & Jones' (1982) results since the spectral shape appears to be correlated with optical identification. Rudnick et al. (1986) reported a positive correlation between core radio luminosity and degree of polarization, and they suggested that this might be a possible explanation for the observed differences between galaxies and quasars. Saikia et al. (1987) found no evidence of such a correlation when the galaxies and quasars are considered separately, and for the small fraction whose core luminosities are similar, they again found a similar difference in core polarization between galaxies and quasars. High-resolution observations of cores in galaxies and quasars with similar redshift distributions and spectral shapes will help to clarify the situation further.

3. Rotation Measures

Rotation measure (RM) studies of compact cores could provide useful information on physical conditions in the vicinity of the active nucleus. However, such studies are complicated by the effects of opacity and variability. Some have tried to find long-term average position angle (PA) differences in variable sources (Wardle 1977), whereas Rudnick & Jones (1983) have tried to circumvent the problem by observing at sufficiently close wavelengths so that the radiation received is from the same electron population. These multifrequency observations have shown that the RMs of compact flat-spectrum sources are similar to other sources in their vicinity, with any intrinsic contribution being < 30 rad m^{-2}. (Rudnick and Jones 1983; Rudnick et al. 1986; Saikia et al. 1985). Gillian Holmes and I have been studying the RMs of a sample of cores from observations at 20, 18, 6 and 2 cm. The 20, 18 and 6 cm data are usually consistent with a small valve of RM, although measurements between 18 and 6 cm would be useful for confirming this. The predicted value at 2 cm using this value of RM is often different from the observed value by more than the measurement errors. It is interesting that using higher frequency data, Wrobel (1987) and O'Dea (1989) have found a number of cores to have RMs of hundreds of rad m^{-2}, the median value being < 200 rad m^{-2} (O'Dea 1989). These values of RM all suggest that there is no uniform dense medium in the vicinity of the nucleus capable of confining the broad-line clouds (Rudnick & Jones 1983; O'Dea 1989). They are consistent with magnetic confinement of emission-line clouds only if the field is very disordered and/or the electron density and path length overestimated in the intercloud region (O'Dea 1989). Saikia et al (1987) suggested that the low RM may be due to the small angle of inclination to the line of sight so that the radio emission from the nuclear jets or cores in these core-dominated sources do not pass through the emission-line regions. If so, one might expect larger RMs for the cores in lobe-dominated sources believed to be at large angles to the line of sight. Although RMs for very weak-cored sources have not yet been determined, the tendency for the core polarization E-vector at 6 cm to be perpendicular to the radio source axes of quasars (Section 6) suggests that their core RM is small.

In the case of CSSs, Flatters (1987) found no evidence of a high RM in 3C380, while Saikia et al. (1985) noted a weak trend for a small sample of CSSs to have a higher RM than extended galaxies and quasars. More recently, Kato et al. (1987) and Aizu et al. (1990) have found a number of sources to have RMs > 1000 rad m^{-2}. They appear to be either CSSs or radio sources in cooling-flow clusters.

4. VLBI polarimetry

Besides the early observations of 3C454.3 by Cotton et al. (1984), most of the published results are from Roberts & Wardle. They have so far reported their results for 3C345, 3C120, 0735+178, BL Lac and OJ287 (Wardle & Roberts 1986; Roberts et al. 1987; Wardle et al. 1986; Gabuzda et al. 1989). The cores are usually < 5% polarized, while the jets can approach values as high as 60%. It is interesting to note that Inoue (1977) arrived at somewhat similar results using multifrequency polarization data and total-intensity VLBI structural information. Changes in orientation of the E-vector along the VLBI jet are sometimes seen. Besides optical depth effects, this could also be due to different RMs for the different knots, changing relativistic aberration, twisted fields (Konigl & Choudhuri 1985) or evolution of the magnetic field. In the galaxy 3C84, which has an unpolarized subarcsec core (Perley 1982), no polarization has been detected from either component even on VLBI scales (Strom, private communication).

5. Optical polarization characteristics

At optical wavelengths, the polarization survey of bright quasars by Stockman et al. (1984) showed that the vast majority of these are < 2% polarized, with an average value of 0.6%, while ~1% of the entire sample, and ~15% of the radio-selected quasars, are >3% polarized. The low-polarization quasars (LPQs) are at most mildly variable and appear to have similar distributions of the degree of polarization irrespective of whether they are radio or optically selected. In contrast, the high-polarization quasars (HPQs) often exhibit strong, rapid variability and resemble Lacertids in many of their characteristics.

In a recent optical polarization survey of a complete sample of radio sources selected at 5 GHz, Impey & Tapia (1988) find that at least 40% of the sources are > 3% polarized. In a similar survey by Fugmann & Meisenheimer (1988), about 60% of the flat-spectrum objects are > 5% polarized while none of the 28 steep-spectrum objects are strongly polarized. Similar results have also been found by Wills et al. Since blazars have quiescent phases of low polarization, the fraction of blazars is bound to increase as repeat measurements are made. Besides accurate polarimetry, the high blazar success rate compared with the Stockman et al. survey is due to the large proportion of sources dominated by flat-spectrum cores (FSCs) in a sample selected at high radio frequency. This is also borne out by the fact that the sources with high polarization are those with the flattest spectra. Also, high-accuracy polarimetry by Impey et al. of the superluminal

https://doi.org/10.1017/S0074180900190606 Published online by Cambridge University Press

quasar 3C273, which has always shown <0.5% polarization, has revealed a miniblazar containing <5% of the total optical flux. The close relationship between blazar activity and superluminal motion suggested by earlier work (Moore & Stockman 1981, 1984) has now become more apparent through improved optical and VLBI data. Impey .(1987) notes that atleast 70% of the superluminal sources are blazars.

Meisenheimer (1990, in preparation) has shown for his sample of flat spectrum quasars that the highest degree of polarization is seen for the fainter rather than the brightest quasars. This would be consistent with the behaviour of some sources such as OJ287 (Hagen-Thorn 1980) which exhibit the highest polarizations when the object is optically faint. The decrease in polarization by either unpolarized features in the continuum spectra or different orientations of the field in the newly ejected components needs to be investigated. Photometric and polarimetric monitoring of a sample of objects would also be useful.

Although there is a close relationship between high polarization, variability, and radio emission, a number of radio sources appear to exhibit high, but nearly constant, optical polarization. Nevertheless, they are usually included in list of blazars. Possible examples are 3C66A, 3C68.1, 0521-365, 0752+258, and 1400+162. They tend to have weaker radio cores than do the strongly variable blazars (Saikia et al. 1987). Among nearby galaxies, Bailey et al. (1986) find the nucleus of Cen A to be 9% polarized in the near-infrared and to exhibit blazar characteristics with the possible exception of violent variability. Other possible examples of low-luminosity blazar activity are IC5063 (Axon et al. 1982; Hough et al. 1987) and NGC1052 (Rieke et al. 1982).

The observed characteristics of blazars, especially their strong, rapid variability, are generally accepted as indicators that at both radio and optical/near infrared wavelengths, the radiation is synchrotron emission. On the other hand, the cause for the polarization of LPQs is not so clear. The optical polarization of Seyfert and radio galaxies is possibly largely due to scattering and is not discussed here. Among Seyferts, only NGC1275 (3C84) exhibits blazar-like characteristics but this object is not a typical Seyfert.

Although there is no significant depolarization at radio wavelengths, it appears that the radio polarization of FSCs is much less than the observed optical polarization of blazars. For example, the median optical polarization from Angel & Stockman (1980) is close to 10%, compared with 2% at radio wavelengths. Also the highest polarization found in the radio compendium of Aller et al. (1985) is 15%, while blazar polarization often rises well above 30% in the optical/near infrared.

6. Alignment of core polarization with radio structure

One of the early results to emerge in the study of alignments was the discovery by Stockman et al. (1979) that the PAs of optical polarization in LPQs tend to be aligned with the extended radio structures. Hence, $\Delta\phi_{opt}$, the acute angle formed by the optical polarization and radio axis, is $\sim 0^\circ$. Moore & Stockman (1984) updated this correlation and hinted that there may be a bimodal distribution. For blazars, or more generally the FSCs, the polarization characteristics may be strongly variable, but a majority of them exhibit a preferred PA over successive outbursts. For such sources, $\Delta\phi_{opt}$ is again $\sim 0^0$ (Wardle et al. 1984).

At radio wavelengths, Saikia & Shastri (1984) found the core polarization PA at 6 cm to be orthogonal to the large-scale radio axis ($\Delta\phi_{rad} \sim 90^0$) in a sample of lobe-dominated quasars that lie outside regions of large RM in the sky. A similar trend was also noticed in a small sample of galaxies (Antonucci 1984). Assuming that the effects of Faraday rotation are small, this implies that the magnetic field in the core, which is possibly associated with the VLBI-scale jets, is along the large-scale radio axis. However, for the core-dominated quasars which have smaller projected linear sizes than the lobe-dominated sources, they found no preferred value of $\Delta\phi_{rad}$ and suggested that this may be due to their small angle of inclination to the line of sight.

Further, several authors have noticed that the radio polarization PA is orthogonal to the VLBI structural elongation, i.e. $\Delta\phi_{rad-VLBI} \sim 90^0$. Rusk & Seaquist (1985) and Rusk (1989) have confirmed this for a large sample. The distribution of $\Delta\phi_{rad-VLBI}$ could be bimodal, with a few sources having values close to $0°$ (Aller et al. 1983; Jones et al. 1985). This could be due to either the influence of synchrotron self-absorption or shock compression of the magnetic field in the VLBI-scale jets. Rusk (1989) has found a greater likelihood for Lacertids to have $\Delta\phi_{rad-VLBI} \sim 0^0$. Unlike the radio polarization, the optical polarization PA in LPQs and blazars tends to be aligned with the VLBI-scale structure (e.g. Rusk & Seaquist 1985; Rusk 1989; Impey 1987), but no such trend was seen for a small sample of 10 radio galaxies (Impey 1987).

7. BL Lacs and HPQs

Although the resemblance of some of the properties of BL lacs and HPQs has led to the general use of the term "blazars" for these two groups, there are a number of differences which suggest that they are possibly different kinds of objects. The well-known differences are the redshift distributions, consistent with that idea that the BL Lacs may be the beamed counterparts of the nearby FRI sources, and also their emission-line strengths, in spite of a few cases of strong emission lines in HPQs being swamped by the continuum. Rusk (1989) has highlighted the difference in the orientation of the core polarization vector relative to the VLBI axis. Worral (1988) has pointed out differences in their X-ray ``excess´´. There has been evidence of differences in their radio variability (Ghosh and Gopal-Krishna 1989), Doppler factors estimated using synchrotron self-Compton models for their X-ray emission (Madau et al. 1987), and perhaps in their optical variability as well (Smith et al. 1988). We find that the distributions of their optical polarization (Angel & Stockman 1980; Fugmann & Meisenheimer 1988 and Impey & Tapia 1988) are also significantly different with the BL Lacs exhibiting much higher polarization. The median values of the distributions are about 7 and 10% for the HPQs and BL Lacs respectively. A more detailed discussion of the differences between BL Lacs & HPQs including their polarization properties will be presented elsewhere.

Acknowledgements
It is a pleasure to thank a large number of colleagues and friends, particularly Chris Salter, Ian Browne, Robin Conway, Simon Garrington, Gillian Holmes, Vijay Kapahi, Chris O´Dea, Ashok Singal and Govind Swarup for several useful discussions on cores and their polarization characteristics. I also thank Klaus Meisenheimer and Richard Strom for communicating their results prior to publication, and Vasant Kulkarni and Ashok Singal for a critical reading of the manuscript.

References

Aizu, K., Inoue, M., Tabara, H. Kato, T. 1990. This volume.
Aller, H.D., Aller, M.F., Latimer, G.E., Hodge, P.E. 1985. Ap.J. Suppl. 59:513
Aller, H.D., Hodge, P.E., Aller, M.F. 1983. Ap. J. Lett., 274:L19.
Angel, J.R.P., Stockman, H.S. 1980, Ann. Rev. Astron. Astrophys. 18:321
Antonucci, R.R.J. 1984. Ap. J. 278:499.
Antonucci, R.R.J., Ulvestad, J.S. 1985. Ap.J. 294:158
Axon, D.J., Bailey, J., Hough, J.H. 1982. Nature 299: 234
Bailey, J., Sparks, W.B., Hough, J.H., Axon, D.J. 1986, Nature 322: 150
Barthel, P.D. 1989. Ap.J. 336:606.
Bridle, A.H., Perley, R.A. 1984. Ann. Rev. Astron. Astrophys. 22: 319
Browne, I.W.A. 1983. MNRAS 204, 23P
Conway, R.G., Gilbert, J.A., Kronberg, P.P., Strom, R.G. 1972, MNRAS 157: 443
Cotton, W.D., Geldzahler, B.J., Marcaide, J.M., Shapiro, I.I., Sanroma, M., et al. 1984. Ap. J. 286: 503
Flatters, C. 1987, Nature 326: 683
Fugmann, W., Meisenheimer, K. 1988. Astron. Astrophys. Suppl. 76: 145
Gabuzda, D.C., Wardle, J.F.C., Roberts, D.H. 1989. Ap. J., 338: 743
Ghosh, T., Gopal-Krishna 1989. Astron. Astrophys. in press
Hagen-Thorn, V.A. 1980. Astrophys. Space Sci. 73:263
Hough, J.H., Brindle, C., Axon, D.J., Bailey, J., Sparks, W.B. 1987, MNRAS 224: 1013
Impey, C. 1987. In Superluminal Radio Sources. ed. J.A. Zensus, T.J. Pearson, Cambridge University Press
Impey, C.D., Tapia, S. 1988. Ap. J. 333:666
Inoue, M. 1977. Publ. Astron. Soc. Jpn. 29: 593
Jones, T.W. 1986. Can. J. Phys. 64: 463
Jones, T.W., Hardee, P.E. 1979. Ap. J. 228: 268
Jones, T.W., O´Dell, S.L. 1977a. Ap. J. 214: 522
Jones, T.W., O´Dell, S.L. 1977b. Ap. J. 215: 236
Jones, T.W., O´Dell, S.L. 1977c. Astron. Astrophys. 61: 291
Jones, T.W., Rudnick, L., Aller, H.D., Aller, M.F., Hodge, P.E., et al. 1985. Ap. J. 290: 627
Kapahi, V.K., Saikia, D.J. 1981. Bull. astr. Soc. India, 9: 77
Kapahi, V.K., Saikia, D.J. 1982. J. Astrophys. Astr. 3, 465.
Kato, T., Tabara, H., Inoue, M., Aizu, K. 1987. Nature 329: 223
Konigl, A., Choudhuri, A.R. 1985. Ap. J. 289: 188
Lilly, S.J., Prestage, R.M. 1987. MNRAS 225: 531
Madau, P., Ghisellini, G., Persic, M. 1987. MNRAS 224: 257

Miley, G.K. 1980. Ann. Rev. Astron. Astrophys. 18: 165
Moore, R.L., Stockman, H.S. 1981. Ap. J. 243: 60
Moore, R.L., Stockman, H.S. 1984. Ap. J. 279: 465
O´Dea, C.P. 1989. Astron. Astrophys. 210: 35
Orr, M.J.L., Browne, I.W.A. 1982, MNRAS 200: 1067
Owen, F.N. 1986. IAU Symp. 119: Quasars eds. Swarup, G., Kapahi, V.K., Dordrecht
Owen, F.N., Laing, R.A. 1989. MNRAS 238: 357
Perley, R.A. 1982. Astron. J. 87: 859
Phillips, R.B., Mutel, R.L. 1982. Astron. Astrophys. 106: 21
Rieke, G.H., Lebofsky, M.J., Kemp. J.C. 1982. Ap. J. Lett. 252: L53
Roberts, D.H., Gabuzda, D.C., Wardle, J.F.C. 1987. Ap. J. 323: 536
Rudnick, L., Jones, T.W. 1982. Ap. J. 255: 39
Rudnick, L., Jones, T.W. 1983. Astron. J. 88: 518
Rudnick, L., Jones, T.W., Aller, H.D., Aller, M.F., Hodge, P.E., et al. 1985, Ap. J. Suppl. 57: 693
Rudnick, L., Jones, T.W., Fiedler, R. 1986. Astron. J. 91: 1011
Rudnick, L., Owen, F.N., Jones, T.W., Puschell, J.J., Stein, W.A. 1978. Ap. J. Lett. 225: L5
Rusk, R.E. 1989. Ph. D. Thesis, University of Toronto
Rusk, R., Seaquist, E.R. 1985. Astron. J. 90: 30
Saikia, D.J. 1988. In Active Galactic Nuclei, eds. Miller, H.R. & Wiita, P.J., Springer-Verlag
Saikia, D.J., Junor, W., Cornwell, T.J., Muxlow, T.W.B., Shastri, P. 1989. MNRAS, in press
Saikia, D.J., Kulkarni, V.K., Porcas, R.W. 1986. MNRAS 219: 719
Saikia, D.J., Salter, C.J. 1988. Ann. Rev. Astron. Astrphys. 26:93
Saikia, D.J., Salter, C.J., Neff, S.G., Gower, A.C., Sinha, R.P., et al. 1987. MNRAS 228: 203
Saikia, D.J., Singal, A.K., Cornwell, T.J. 1987. MNRAS 224: 379
Saikia, D.J., Shastri, P. 1984. MNRAS 211: 47
Saikia, D.J., Swarup, G., Kodali, P.D. 1985. MNRAS 216: 385
Scheuer, P.A.G. 1987. In Superluminal Radio Sources, eds, Zensus, A.J., Pearson, T.J., Cambridge University Press
Smith, A.G., Leacock, R.J., Webb, J.R. 1988. In Active Galactic Nuclei, eds. Miller, H.R., Wiita, D.J., Springer-Verlag
Stockman, H.S., Angel, J.R.P., Miley, G.K. 1979. Ap. J. Lett. 227: L55
Stockman, H.S., Moore, R.L., Angel, J.R.P. 1984. Ap. J. 279: 485
Ulrich, M.-H. 1989. In BL Lac objects:10 years after, ed. Maraschi, L.
van Bruegel, W., Miley, G., Heckman, T. 1984. Astron. J. 89: 5
Wardle, J.F.C. 1977. Nature 269: 563
Wardle, J.F.C., Moore, R.L., Angel, J.R.P. 1984. Ap. J. 279:93
Wardle, J.F.C., Roberts, D.H. 1986. In Continuum emission in Active Galactic Nuclei, ed. Sitko, M.L., NOAO
Wardle, J.F.C., Roberts, D.H., Potash, R.I., Rogers, A.E.E. 1986. Ap. J. Lett. 304: L1
Worral, D.M. 1988. In Active Galactic Nuclei, eds. Miller, H.R. & Wiita, P.J., Springer-Verlag
Wrobel, J. 1987. In Superluminal Radio Sources, eds. Zensus, A.J., Pearson, T.J., Cambridge University Press.

CAMENZIND: Statistical analysis of unified schemes are usually based on much too simple models of relativistic jets. More realistic models show that there is a distribution in magnetic fields, Lorentz factors, opening angles and the properties of the ambient medium (on pc and kpc scale). Is it possible e.g. to test P. Barthel's unified scheme for quasars and FR II radio galaxies (1989, Ap.J. **336**, 606)?

SAIKIA: I agree. Taking into account the distributions in the various parameters while comparing model predictions with observations when more and better quality data become available would obviously be the next step. There are a number of possible tests for the unified scheme such as spectropolarimetric observations of galaxies to look for the quasar nuclei, studies of narrow emission line properties, host galaxies, radio size distributions, core strengths and distortions in radio structures. I believe the scheme to be true at some level. Peter Barthel has discussed some of the tests in his paper. I would also refer you to the discussion by Ian Browne and Peter Scheuer in the proceedings of the Big Bear workshop on Superluminal Radio Sources after Peter Scheuer introduced the idea.

BIERMANN: Most quasars are radio-weak and so it seems difficult to build a unified scheme based on radio-strong objects only. Some very early papers tried to combine the two extremes of radio-strong and radio-weak quasars. Several recent papers on optically selected quasars (Chini et al., 1989, Astron. Astrophys. **219**, 87; Sanders et al., 1989, preprint) shed some light on the properties of these objects. How do you fit the radio-weak quasars into a unified scheme?

SAIKIA: Unification of radio-loud and radio-weak quasars in terms of merely geometrical effects is not going to be easy. I have sometimes wondered whether the radio-weak quasars have very 'weak' jets compared to the radio-strong ones, somewhat reminiscent of the difference between jets seen in edge-on spirals and the powerful elliptical galaxies. The radio structures of radio-weak quasars observed with high angular resolution and studies of the host galaxies in radio- loud and radio-weak quasars would be very useful (e.g. Hutchings, Janson and Neff, 1989, Ap.J. **342**, 660). It is also interesting that radio-weak quasars do not tend to exhibit blazar activity, consistent with the idea of 'weak' jets.

PERLEY: Joan Wrobel has recently measured the RM in the compact core dominated radio source 3C 371. She finds the RM of the kpc-scale jet is less than 10 rad/m^2, but that of the core exceeds 300 rad/m^2.

SAIKIA: Chris O'Dea and Joan Wrobel's work, amongst others, have shown a number of sources to have RMs of a few hundred rad/m^2 using observations at wavelengths smaller than about 6 cm. The smaller values of core RM reported in the literature are usually from longer wavelength data. It is possible that different frequencies pick up different components which are at different locations along a VLBI-scale jet. We need a lot more high resolution observations to try and understand these possible variations in core RM. This is also important for understanding the correlation of lobe depolarization with jet sidedness discovered by Robert Laing (1988, Nature **331**, 149) and Simon Garrington et al. (1988, Nature **331**, 147).