Chapter 6

Concluding Remarks

The principle objectives of this thesis were to test the unified scheme for radio galaxies and quasars, and investigate the effects of environment and orientation on their observed properties using both total intensity and linear polarization observations. The sample for our study was selected from the MRC/1Jy complete sample (Kapahi et al. 1998a, b). It consists of all quasars and a representative sample of FRII radio galaxies, all with an angular size larger than about an arcmin. The lower cutoff on the angular size was adopted for future polarization observations of these sources at lower frequencies with the GMRT. The radio galaxies were chosen to have a similar redshift distribution to that of the quasars. The sample includes 15 quasars and 27 radio galaxies. The radio-continuum and linear-polarization observations of these sources were made at the Very Large Array (VLA) at two frequencies in the L-band (1.4 and 1.7 GHz), and two frequencies in the C-band (4.6 and 4.9 GHz). In addition, the sources were observed in total intensity in the X-band (8.4 GHz) and U-band (15 GHz) to study the cores and hotspots. The L-, C- and U-band observations were made with scaled arrays of the VLA so that the angular resolution of the observations are similar. The X-band observations to detect the cores were of higher angular resolution. In order to probe the environments of the galaxies we also carried out narrow- and broad-band optical observations of a subset of our sample of sources at Las Campanas Observatory, Chile using the 100-inch telescope.

Unified scheme and depolarization

We have investigated the effects of environment and orientation on the observed depolarization properties of the lobes in a matched sample of high-luminosity radio galaxies and quasars between λ 20 and 6 cm. We find that significant depolarization is usually seen in only those lobes which are within about 300 kpc of the parent galaxy. Among the 17 lobes in the entire sample which show significant depolarization with DP $<$ 0.9, 15 are within 300 kpc from the parent galaxy. Comparing the depolarization on opposite sides of the source, we find that the side which is closer to the parent galaxy shows significant depolarization. Of these 17 lobes where significant depolarization is seen, 13 lobes are closer to the parent galaxy compared to the lobe on the opposite side. The ratio of the depolarization parameter of the nearer lobe to the farther one is <1 for 28 of the 35 sources in the entire sample with reliable polarization information for both lobes, which again suggests that the nearer lobe is more depolarized than the farther lobe. The nearer component is also brighter in 26 of these 35 objects, suggesting that the nearer component is advancing outwards through a denser environment which is responsible for stronger depolarization and greater dissipation of energy. The depolarization asymmetry of the lobes on opposite sides for galaxies and quasars shows that the latter are marginally more asymmetric, consistent with the trend expected in the unified scheme. In our sample of sources the polarization properties of the lobes appear to be due to an asymmetric environment on opposite sides of the parent optical object, as well as possibly due to different orientations of the sources to the line of sight. The effects of the environment dominate the depolarization asymmetry in galaxies while the effects of orientation are seen in the quasars. Detailed information on the distribution of the depolarizing medium from optical and X-ray observations, as well as detection of radio jets in these objects to identify the approaching and receding components, should enable us the clarify further the relative importance of the effects of an asymmetric environment and orientation.

We have made optical narrow- and broad-band images of some of these sources for studying the environments around the radio galaxies and quasars and their effects on the polarization and other radio properties. The emission line data is available only for four galaxies and two quasars. However significant extended narrow-band emission is seen in only one galaxy and one quasar. The emission line gas is elongated within about 30° of the radio source axis in both cases, consistent with earlier studies on the orientation of optical and radio emission in high-redshift galaxies (McCarthy 1993). However, the radio lobes in both these sources do not show significant depolarization, and are well beyond this emission line gas. It would be useful to observe our sample of sources in detail to study the emission line gas distribution and also to study the possible cluster environments around them.

Relativistic beaming in radio galaxies and quasars

We have determined the relative core strength and the radio spectra of the cores and hotspots in our sample of radio galaxies and quasars from our multifrequency observations. The median value of the fraction of emission from the core at an emitted frequency of 8 GHz, f_c, is about 0.0015 and 0.09 for radio galaxies and quasars respectively, consistent with the unified scheme. We could determine the spectra of only two galaxies in our sample since most of them were not detected at a number of frequencies. However, the spectra of the cores have been determined for all the quasars. A comparison of the spectral indices of the cores in our sample of lobe-dominated quasars with a matched sample of core-dominated quasars shows that the high-frequency spectral index of these two classes are significantly different. The optically thin part of the synchrotron spectra is seen at a lower frequencies for lobe-dominated quasars compared to the core-dominated quasars, due to larger Doppler blueshift in the cores of latter. The difference can be understood in terms of Doppler effects and are consistent with the basic ideas of the unified scheme for radio galaxies and quasars. The difference in the spectral indices of the hotspots on opposite sides of the nucleus is larger for quasars compared to radio galaxies, the median values of the difference being about 0.12 and 0.06 for quasars and radio galaxies respectively. This difference could also be understood in terms of mild relativistic beaming of the hotspots. The hotspots have a curved radio spectrum steepening towards higher frequencies, possibly due to radiative losses. The difference is consistent with the unified scheme for radio galaxies and quasars and yields an estimate of hotspot speeds in the range of $\sim$ 0.2 to 0.5c. The information on the degree of spectral steepening close to hotspots is rather limited. Although the spectra of the hotspots in Cygnus A have been studied in some detail (Carilli et al. 1991), further high-resolution multi-frequency observations of our sources as well as of other sources would be valuable.

The well-known strong correlation between spectral index and redshift/luminosity is also seen in our sample when one considers the hotspot spectral indices. There is some evidence of a flattening of this relationship beyond z$\sim$1, consistent with earlier studies. Examining the low- and high-frequency spectral indices of the hotspots in our sample, the observed correlation does not appear to be due to the effects of K-correction alone. The difference in the low- and high-frequency spectral indices of the hotspots needs to be determined reliably for a larger number of high-redshift (z>1) objects to clarify our understanding of the observed $\alpha-$z relationship.

Giant radio sources

We have presented VLA observations of the giant quasars 0437$-$244 and 1025$-$229 from the Molonglo Complete Sample. The quasar 0437$-$244 is the highest redshift giant quasar known to date. These sources have well-defined FRII radio structure, possible one-sided jets, no significant depolarization between 1365 and 4935 MHz and low rotation measure ($|$ RM $|<$ 20 rad m^{-2}). We have compiled a sample of 53 known giant radio sources from the literature, and have compared some of their properties with a complete sample of 3CR radio sources with sizes between 50 kpc and 1 Mpc to investigate the evolution of giant sources, and test their consistency with the unified scheme for radio galaxies and quasars. The power-linear size or P-D diagram for the 3CR and giant sources shows a deficit of sources with radio luminosity greater than about 2×10^{27} W Hz^{-1} at 1.4 GHz and sizes over a Mpc. A similar trend was noted earlier by Kaiser et al. (1997), and appears to be true for this much larger sample of giant sources selected from samples covering a wide flux density range. The location of the giants in the P-D diagram suggests that they have evolved from the smaller sources. Suggestions that they might be of similar age to the smaller sources from spectral index studies should be treated with caution because of the large number of uncertainties and assumptions in these estimates. The equipartition magnetic field, B_{eq}, is smaller than the equivalent magnetic field of the microwave background radiation, B_{ic}, for the giant sources, while the reverse is true for the smaller sources. Thus inverse-Compton losses dominate for the giant radio sources, while synchrotron radiation losses are more important for the smaller sources. This is likely to severely limit the number of giant radio sources at large redshifts. We find an inverse correlation between the degree of core prominence and total radio luminosity, and show that the giant radio sources have similar core strengths to the smaller sources when sources of similar total luminosity are considered. Although many of the giants have stronger cores than the high-luminosity FRII radio sources (cf. Saikia & Kulkarni 1994), this is largely due to the inverse correlation between the degree of core prominence and total radio luminosity, and does not necessarily indicate a higher nuclear activity or more powerful central engine. The more prominent cores in the lower luminosity sources is possibly due to greater dissipation of energy by the radio jet close to the nucleus. The degree of collinearity for the giant radio sources is similar to that of the smaller sources, suggesting that the steadiness of the axis is not the determining factor for the formation of giant radio sources. The ratio of separation of the outer hotspots for the giant sources appears marginally larger than the smaller-sized sources. This is somewhat surprising and could be possibly due to interaction of the energy-carrying beams with cluster-sized density gradients far from the parent galaxy. For 6 sources with radio jets, the hotspot on the jet side is closer for 3 of the 4 galaxies and none of the two quasars. This suggests that the environment plays a stronger role for galaxies while in quasars the effects of orientation seem more significant. The giant quasars have more prominent cores, one of which 4C34.47 exhibits superluminal motion and the cores of both quasars with adequate data exhibit evidence of variability. Unlike the quasars, the radio cores of one of the galaxies, NGC6251, exhibits no evidence of significant variability, while the other NGC315 exhibits evidence of a flare around 1995 after maintaining a nearly constant flux density for about 20 yr including the observations of Ekers et al. (1981). Although the available data are very limited, these are consistent with the unified schemes for radio galaxies and quasars. Besides monitoring the cores, two other aspects of giant radio sources which seem interesting to pursue further are briefly discussed below.

Discovering new giant radio sources: We have seen a sharp cutoff in the number of giant radio sources above a linear size of 3 Mpc. Of the 53 giant radio sources in our sample, only one source namely 3C236 has linear size larger than 3 Mpc. The non detection of giants larger than 3 Mpc could be either due to selection effects or the evolution of radio sources on these scales. To distinguish between these scenarios, it is important to search for giant radio sources more than about 3 Mpc. Discovering more more giant sources associated with quasars would be useful to test the unified scheme for these large objects since only 5 such objects are presently known.

Giant Radio Sources and the IGM magnetic field: For probing the intergalactic medium (IGM), a significant aspect of the giant radio sources is that their radio lobes are well outside their parent galaxy environment and will be interacting directly with the IGM. By studying the rotation measure and the depolarization of the lobes of giant radio sources, it might be possible to get some estimate of the intergalactic magnetic field. However, the possibility that giant radio sources may also be evolving through environments with density gradients on these scales should be borne in mind.

References

Alexander P., Leahy J. P., 1987, MNRAS, 225, 1

Antonucci R., 1984, ApJ, 278, 499

Antonucci R., 1993, ARA&A, 31, 473

Antonucci R., Hurt T., Kinney A., 1994, Nature, 371, 313

Appl S., Camenzind M., 1993a, A&A, 270, 71

Appl S., Camenzind M., 1993b, A&A, 274, 699

Appl, S., 1996, in Hardee P.E., Bridle A.H., Zensus J.A., eds, *Energy Transport in Radio Galaxies and Quasars*, ASP Conference Series Vol 100, p 129

Athreya R. M., Kapahi V. K., McCarthy P. J., van Breugel W., 1997, MNRAS, 289, 525

Baade W., Minskowski R., 1954, ApJ, 119, 215

Baars J.W.M., Genzel R., Pauliny-Toth I.I.K., Witzel A., 1977, A&A, 61, 99

Baldwin J. E., 1982, in Heeschen D. S., Wade C. M., eds, *Extragalactic Radio Sources*, IAU symposium 97, Reidel, Dordrecht, p 21

Banhatti, D. G., 1980, A&A, 84, 112

Barthel P. D., 1987 in Zensus J. A., Pearson T. J., eds, *Superluminal Radio Sources*, Cambridge University Press, Cambridge, p 148

Barthel P. D., 1989, ApJ, 336, 606

Barthel P. D., Schilizzi R. T., Miley G. K., Jägers W. J., Strom R. G., 1985, A&A, 148, 243

Barthel P. D., Hooimeyer J. R., Schilizzi R. T., Miley G. K., Preuss E., 1989, ApJ, 336, 601

Baum S. A., Heckman T., 1989a, ApJ, 336, 681

Baum S. A., Heckman T., 1989b, ApJ, 336, 702

Baum S. A., Zirbel E. L., O'Dea C. P., 1995, ApJ, 451, 88

Best P. N., Longair M. S., Röttgering H. J. A., 1996, MNRAS, 280, 9P

Best P. N., Longair M. S., Röttgering H. J. A., 1997, MNRAS, 286, 785

Best P. N., Bailer D. M., Longair M. S., Riley J. M., 1995, MNRAS, 275, 1171

Bhatnagar S., Gopal-Krishna, Wisotzki L., 1998, MNRAS, 299, L25

Blandford R. D., 1990, in Courvoisier T. J. L., Mayor M., eds, *Active Galactic Nuclei (Saas-Fee Advanced Course 20)*, Spriger-verlag, Berlin

Blandford R. J., Rees M. J., 1974, MNRAS, 169, 395

Blandford R. D., Königl A., 1979, ApJ, 232, 34

Blundell K. M., Rawlings S., Willott C. J., 1999, AJ, 117, 677

Bridle A. H., Perley R. A., 1984, ARA&A, 22, 319.

Bridle A. H., Davis M. M., Fomalont E. B., Willis A. G., Strom R. G., 1979, ApJ, 228, L9

Bridle A. H., Davis M. M., Meloy D. A., Fomalont E. B., Strom R. G., Willis A. G., 1976, Nature, 262, 179

Browne I. W. A., 1983, MNRAS, 204, 23P

Burke B. F., Grahamsmith F., 1997, *An introduction to Radio Astronomy,* Cambridge University Press

Burn B. J., 1966, MNRAS, 133, 67

Carilli C. L., Perley R. A., Dreher J. W., Leahy J. P., 1991, ApJ, 383, 554

Chambers K. C., Miley G. K., van Breugel W. J. M., 1987, Nature, 329, 604

Chen F. F., 1984, Introduction to Plasma Physics and Controlled Fusion, Vol 1., Plenum Press , New York.

Chiu Y. T., 1975, Journ. Atmosph. Terr. Phys., 37, 1563

Cioffi D. F., Jones T. W., 1980, AJ, 85, 368

Clements D. L., Pérez-Fournon I., 1997 eds, *Quasar Hosts,* 1997, ESO Astrophysics Symposia

Cotter G., Rawlings S., Saunders R., 1996, MNRAS, 281, 1081

Cotton W. D., Feretti L., Giovannini G., Lara L., Venturi T., 1999, ApJ, in press (astro-ph/9902053)

Danziger I. J., Goss W. M., Frater R. H., 1978, 184, 341

Dennett-Thorpe, J., Bridle, A. H., Laing R. A., Scheuer, P. A. G., 1999, MNRAS, 304, 271

Dennett-Thorpe, J., Bridle, A. H., Scheuer, P. A. G., Laing, R. A., Leahy, J. P., 1997, MNRAS, 289, 753

di Serego Aligheiri., 1997, in Clements D. L., Pérez-Fournon I., eds, *Quasar Hosts,*, ESO Astrophysics Symposia, p 5

di Serego Alighieri, Cimatti, A., Fosbury, R. A. E., 1994, ApJ, 431, 123

Dreher J. W., Carilli C. L., Perley R. A., 1987, ApJ, 316, 611

Eilek J.A., Shore S.N. 1989, ApJ, 342, 187

Eilek J. A., Melrose D. B., Walker M. A., 1997, ApJ, 483, 282

Ekers R. D., Fanti R., Miley G. K., 1983, A&A, 120, 297

Ekers R. D., Fanti R., Lari C., Parma P., 1981, A&A, 101, 194

Fanaroff B. L., Riley J. M., 1974, MNRAS, 167, 31p

Feretti L., Giovannini G., Gregorini L., Parma P., Zamorani G., 1984, A&A, 139, 55

Fernini I., Burns J. O., Perley R. A., 1997, AJ, 114, 2292

Fernini I., Burns J. O., Bridle A. H., Perley R. A., 1993, AJ, 105, 1690

Fosbury R. A. E., 1997 in Clements D. L., Pérez-Fournon I., eds, *Quasar Hosts,*, ESO Astrophysics Symposia, p 1

Gardner F. F., Whiteoak J. B., 1966, ARA&A, 4, 245

Garrington S. T., Conway R. G., 1991, MNRAS, 250, 198

Garrington S. T., Conway R. G., Leahy J. P., 1991, MNRAS, 250, 171 (GCL91)

Garrington S. T. Leahy J. P., Conway R. G., Laing R. A., 1988, Nature, 331, 147

Ginzburg V. L., Syrovatskii S. I., 1969, ARA&A, 7, 375

Giovannini G., Feretti L., Gregorini L., Parma P., 1988, A&A, 199, 73

Gopal-Krishna, 1988, A&A, 192, 37

Gopal-Krishna 1996, in Ekers R., Fanti C., Padrielli L., eds, *Extragalactic radio sources*, IAU Symposium 175, p 373

Gopal-Krishna, Wiita P. J., 1990, A&A, 236, 305

Gopal-Krishna, Wiita P.J., 1991, ApJ, 373, 325

Gopal-Krishna, Wiita P.J., Saripalli L., 1989, MNRAS, 239, 173

Gregorini L., Padrielli L., Parma P., Gilmore G., 1988, A&AS, 74, 107

Hardcastle M. J., Alexander P., Pooley G. G., Riley J. M., 1997, MNRAS, 288, 859

Heckman T., van Breugel W. J. M., Miley G. K., 1984, ApJ, 286, 509

Hine R. G., 1979, MNRAS, 189, 527

Hine R. G., Longair M. S., 1979, MNRAS, 188, 111

Holmes G.F. 1991, PhD Thesis, University of Manchester

Hooimeyer J. R. A., Barthel P.D., Schilizzi R.T., Miley G.K., 1992, A&A, 261, 1

Hughes P. A., (ed), 1991, *Beams and Jets in Astrophysics*, Cambridge Astrophysics Series

Jägers W. J., 1986, PhD Thesis, University of Leiden

Jägers W. J., van Breugel W. J. M., Miley G. K., Schilizzi R. T., Conway R. G., 1982, A&A, 105, 278

Johnson H. L., 1963, in Strand K. A_A., ed, *Basic Astronomical Data*, University of Chicago Press

Johnson R. A., Leahy J. P., Garrington S. T., 1995, MNRAS, 273, 877

Jones P. A., McAdam W. B., 1992, ApJS, 80, 137

Kaiser C. R., Alexander P., 1997, MNRAS, 286, 215

Kaiser C. R., Dennett-Thorpe J., Alexander P., 1997, MNRAS, 292, 723

Kapahi V. K., Saikia D. J., 1982, JA&A, 3, 465

Kapahi V. K., Athreya R. M., Subrahmanya C. R., Baker J. C., Hunstead R. W., McCarthy P. J., van Breugel W., 1998a, ApJS, 118, 327 (K98)

Kapahi V. K., Athreya R. M., van Breugel W., McCarthy P. J., Subrahmanya C. R., 1998b, ApJS, 118, 275

Kawaguchi T., Mineshige S., 1999, in Terzian Y., Khachikian E., and Weedman D., eds, *Activity in galaxies and related phenomena*, IAU symposium 194, in press

Kellerman K. I., Sramek R., Schmidt M., Shaffer D. B., Green R., 1989, AJ, 98, 1195

Krolik J. H., Chen W., 1991, AJ, 102, 1659

Kronberg P. P., Wielebinski R., Graham D. A., 1986, A&A, 169, 63

Kukula M. J., Dunlop J. S., Huges D. H., Rawlings S., 1998, MNRAS, 297, 366

Lacy M., Hill G. J., Kaiser M.-E., Rawlings S., 1993, MNRAS, 263, 707

Lacy M., Rawlings, S., Saunders R., Warner P. J., 1993, MNRAS, 264, 721

Laing R. A., 1988, Nature, 331, 149

Laing R. A., 1984 in Bridle A. H., and Eilek J. A., eds, *Physics of energy transport in extragalactic radio sources*, proceedings of NRAO workshop no. 9, Green Bank.

Laing R.A., 1993, in Burgarella, D. Livio, M., O'Dea C., eds, *Astrophysical Jets*, Cambridge Univ. Press, p 95

Laing R. A., Peacock J. A., 1980, MNRAS, 190, 903

Laing R., Riley J. M., Longair M., 1983, MNRAS, 204, 151

Laing, R. A., Jenkins, C. R., Wall, J. V., Unger, S. W., 1994, in G.V. Bicknell, M.A. Dopita, and P.J. Quinn eds, *The First Stromlo Symposium: The Physics of Active Galaxies*, ASP Conference Series, Vol. 54

Large M. I., Mills B. Y., Little A. G., Crawford D. F., Sutton J. M., 1981, MNRAS, 194, 693

Leahy J. P., Williams A. G., 1984, MNRAS, 210, 929

Leahy J. P., Perley R. A., 1991, AJ, 102, 537

Leahy J. P., Muxlow T. W. B., Stephens, P. W., 1989, MNRAS, 239, 401

Liu R., Pooley G., 1990, MNRAS, 245, 17p

Liu R., Pooley G., 1991, MNRAS, 249, 343

Longair, M. S., 1994, *High Energy Astrophysics*, Cambridge University Press, Cambridge.

Longair M. S., Riley J. M., 1979, MNRAS, 188, 625

Lonsdale C. J., Barthel P. D., Miley G. K., 1993, ApJS, 87, 63

Machalski J., Condon J. J., 1985, AJ, 90, 5

Mack K.-H., Klein U., O'Dea C. P., Willis A. G., Saripalli L., 1998, A&A, 329, 431

Masson C. R., 1979, MNRAS, 187, 253

McCarthy P. J., 1993, ARA&A, 31, 639

McCarthy P. J., 1997, in Clements D. L., Pérez-Fournon I., eds, *Quasar Hosts,*, ESO Astrophysics Symposia, p 303

McCarthy P. J., van Breugel W., Kapahi V. K., 1991, ApJ, 371, 478

McCarthy P. J., van Breugel W. J. M., Spinrad H., Djorgovski S. G., 1987 ApJL, 321 L29

McCarthy P. J., Kapahi V. K., van Breugel W., Persson S. E., Athreya R. M., Subrahmanya C. R., 1996, ApJS, 107, 19 (M96)

McLure R. J., Dunlop J. S., Kukula M. J., Baum S. A., O'Dea C. P., Huges D. H., 1998, astro-ph/9809030

Melrose D. B., Macqart J.-P., 1998, ApJ, 505, 921

Miley G. K., 1980, ARA&A, 18, 165

Miller J. S., Antonucci R., 1983, ApJL, 271, L7

Moffet A. T., 1975, in Sandage A., Sandage M., and Kristian J., eds, *Galaxies and the Universe,* University of Chicago Press.

Myers S. T., Spangler S. R., 1985, ApJ, 291, 52

Nagar N. M., Wilson A. S., Mulchaey J. S., Gallimore J. F., 1999, ApJS, 120, 209

Neeser M. J., Eales S. A., Law-Green J. D., Leahy, J. P., Rawlings S., 1995, ApJ, 451, 76

O'Dea C. P., 1998, PASP, 110, 49

Orr M. J. L., Browne I. W. A., 1982, MNRAS, 200, 1067

Pacholczyk A. G., 1977, *Radio Galaxies*, Pregamon Press

Parma P., Morganti R., Capetti A., Fanti R., de-Ruiter H. R., 1993, A&A, 267, 31

Parma P., de Ruiter H. R., Mack K.-H., van Breugel W., Dey A., Fanti R., Klein U., 1996, A&A, 311, 49

Pearson T. J., Blundell K. M., Riley J. M., Warner P. J., 1992, MNRAS, 259, L13

Pedelty J. A., Rudnick L., McCarthy P. J., Spinrad H., 1989 AJ, 97, 647

Perley R. A., 1982, AJ, 87, 859

Perley R. A., 1996, VLA Calibrator Manual, NRAO.

Peterson B., 1997, *An introduction to active galactic nuclei*, Cambridge University Press.

Pogge R. W., 1989, ApJ, 345, 730

Prieto M. A., Walsh J. R., Fosbury R. A. E., di Serego Alighieri S., 1993, MNRAS, 263, 10

Rees M. J., 1989, MNRAS, 239, 1p

Rengelink R., Tang Y., de Bruyn A. G., Miley G. K., Bremer M. N., Röttgering H. J. A., Bremer, M. A. R., 1997, A&AS, 124, 259

Riley J. M., Warner P. J., 1990, MNRAS, 246, L1

Riley J. M., Warner P. J., Rawlings S., Saunders R., Pooley G. G., Eales S. A., 1989, MNRAS, 236, L13

Robson I., 1996, *Active galactic nuclei*, John Wiley & Sons Ltd

Röttgering H. J. A., Tang T., Bremer M. A. R., de Bruyn A. G., Miley G. K., Rengelink R. B., Bremer M. N. 1996, MNRAS, 282, 1033

Rudnick L., Jones T. W., Fiedler R., 1986, AJ, 91, 1011

Rush B., McCarthy P. J., Athreya R. M., Persson S. E., 1997, ApJ, 484, 163

Rybicki G. B., Lightman A. P., 1979, *Radiative processes in Astrophysics*, John Wiley, New York.

Ryle M., Longair M.S., 1967, MNRAS, 136, 123

Saikia D. J., 1981, MNRAS, 197, 11P

Saikia D. J., Salter C. J., 1988, ARA&A, 26, 93

Saikia D. J., Kulkarni V. K., 1994, MNRAS, 270, 897

Saikia D. J., Singal A. K., Wiita P. J., 1991, in Miller H. R., Wiita P. J., eds, *Variability of Active Galactic Nuclei*, Cambridge University Press, Cambridge, p 160

Saikia D.J., Garrington S.T., Holmes G.F. 1997 in Clements D.L., Pérez-Fournon I., eds, *Quasar Hosts*, ESO Astrophysics Symposia, Springer, p 13

Saikia D. J., Jeyakumar S., Wiita P. J., Hooda J. S., 1996, in Fanti C., Fanti R., O'Dea C. P., Schilizzi R. T., eds, *Proc. of the Dwingeloo Workshop on Compact Steep Spectrum and GHz Peaked Spectrum Radio Sources*, Istituto di Radioastronomia, Bologna, p 252

Saikia D. J., Junor, W., Cornwell, T. J., Muxlow T. W. B., Shastri P., 1990, MNRAS, 245, 408

Saikia D. J., Jeyakumar S., Wiita P. J., Sanghera H. S., Spencer R. E., 1995, MNRAS, 276, 1215

Saikia D. J., Holmes G. F., Kulkarni A. R., Salter C. J., Garrington S. T., 1998, MNRAS, 298, 877

Saripalli L., 1988, PhD Thesis, Indian Institute of Science, Bangalore, India

Saripalli L., Gopal-Krishna, Reich W., Kühr H., 1986, A&A, 170, 20

Saripalli L., Subrahmanyan R., Hunstead R. W., 1994, MNRAS, 269, 37

Saripalli L., Mack K.-H., Klein U., Strom R., Singal A. K., 1996, A&A, 306, 708

Saunders R., Baldwin J. E., Warner P. J., 1987, MNRAS, 225, 713

Scheuer P. A. G., 1974, MNRAS, 166, 513

Scheuer P. A. G., 1987, in Zensus, J. A., and Pearson T. J., eds, *Superluminal Radio Sources*, Cambridge University Press, Cambridge, p 104

Scheuer P. A. G., 1995, MNRAS, 277, 331

Schoenmakers A. P., Mack K.-H., Lara L., Röttgering H. J. A., de Bruyn A. G., van der Laan H., Giovannini G., 1998a, A&A, 336, 455

Schoenmakers A. P., de Bruyn A. G., Röttgering H. J. A., van der Laan H.,1998b, A&A, in press

Shklovskii I., 1963, SvA, 6, 465

Strom R. G., Willis A. G., 1980, A&A, 85, 36

Strom, R. G., Jägers, W. J., 1988, A&A, 194, 79

Strom R. G., Baker J. R., Willis A. G., 1981, A&A, 100, 220

Subrahmanya C. R., Hunstead R. W., 1986, A&A, 170, 27

Subrahmanyan R., Saripalli L., 1993, MNRAS, 260, 908

Subrahmanyan R., Saripalli L., Hunstead R. W., 1996, MNRAS, 279, 257

Swarup G., Banhatti D.G., 1981, MNRAS, 194, 1025

Thompson A. R., Clark B. G., Wade C. M., Napier P. J., 1980, ApJS, 44, 151

Thuan T. X., Gun J. E., 1979, PASP, 88, 543

Tran H. D., Cohen M. H., Ogle P. M., Goodrich R. W., di Serego S., 1998, ApJ, 500, 660

Tribble P. C., 1991, MNRAs, 250, 726

Trimble V., 1987, ARA&A, 25, 425

Ulrich, M.-H., Maraschi L., Urry, C. M., 1997, ARA&A, 35, 445

Urry C. M., Padovani P., 1995, PASP, 107, 803

Véron-Cetty M.-P., Woltjer L., 1990, A&A, 236, 69

Venturi T., Giovannini G., Feretti L., Comoretto G., Wehrle A. E., 1993, ApJ, 408, 81

Vigotti M., Grueff G., Perley R.A., Clark B. G., Bridle A. H., 1989, AJ, 98, 419

Wade R. A., Hoessel J. G., Elias J. H., Huchra J. P., 1979, PASP, 91, 35

Waggett P. C., Warner P. J., Baldwin J. E., 1977, MNRAS, 181, 465

Willis A. G., Strom R. G., 1978, A&A, 62, 375

Willis A. G., Strom R. G., Wilson A. S., 1974, Nature, 250, 625

Willis A. G., Strom R. G., Bridle A. H., Fomalont E. B., 1981, A&A, 95, 250

Willis A. G., Strom R. G., Perley R. A., Bridle A. H., 1982, in Heeschen D. S., Wade C. M., eds, *Extragalactic Radio Sources*, IAU symposium 97, Reidel, Dordrecht, p 141

Wilson A. S., Colbert, E. J. M., 1995, ApJ, 438, 62

Wright M. C. H., Chernin L. M., Forster J. R., 1997, ApJ, 483, 783

Zirbel E. L., Baum S. A., 1995, ApJ, 448, 521

de Bruyn A. G., 1989, A&A, 226, L13

de Bruyn A. G., Schoenmakers A. P., Röttgering H., van der Laan H., 1998, NFRA Newsletter No. 15, p 21

de Ruiter H. R., Parma P., Fanti C., Fanti R., 1990, A&A, 227, 351 van Breugel W., McCarthy P. J., 1989, in Meurs E. J. A. & Fosbury R. A. E., eds, *Extranuclear activity in galaxies*, ESO Conference and Workshop Proceedings No. 32, ESO, p 227

van Breugel W. J. M., Willis A. G., 1981, A&A, 96, 332

van Breugel W. J. M., Dey A., 1993, ApJ, 414, 563

van Breugel W., Heckman T., Miley G., 1984, ApJ, 276, 79

van Breugel W., Filippenko A. V., Heckman T., Miley G., 1985a, ApJ, 293, 83

van Breugel W., Miley G., Heckman T., Butcher H., Bridle A., 1985b, ApJ, 290, 496