Structure of Radio Galaxies and Quasars
– Synthesis Observations

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STRUCTURE OF RADIO GALAXIES AND QUASARS – SYNTHESIS OBSERVATIONS

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The last three years have seen exciting new synthesis observations from the VLA, MERLIN, Cambridge, Westerbork, Fleurs, Culgoora and Molonglo. The implications of recent synthesis data for source physics generally have been reviewed by Begelman *et al.* (84 Rev.Mod.Phys. 56, 255) and for radio jets in particular by Bridle and Perley (84 *Ann.Rev.AA* 22, 319). Many observations relating to energy transport in extragalactic sources are discussed in the Turin Workshop on "Astrophysical Jets" (Reidel 82, ed. A.Ferrari and A.G.Pacholczyk), though much new work has appeared since this volume.

The traditional distinction (maintained in this triennial report) between compact and extended sources is vanishing, as many high dynamic range maps have found extended emission around "compact" sources (*e.g.*, Browne *et al.* (82 *MNRAS* 198, 673; Browne *et al.* 82 *Nature* 299, 788; Perley *et al.* 82 *ApJLett* 255, L93; Ulvestad *et al.* 83 *ApJ* 266, 18; Schilizzi and de Bruyn 83 *Nature* 303, 26; Ulvestad and Johnston 84 *AJ* 89, 189; De Pater and Perley 84 *ApJ* 273, 64; Antonucci and Ulvestad 84 *Nature* 308, 617). A large fraction of strong extragalactic sources has both compact cores and some kiloparsec-scale or larger structure. The prominence of the cores relative to the larger structures varies by more than 10,000:1 from source to source. The success of relativistic flow models for the compact core-jets has encouraged "unified" models wherein this variation is attributed to differing inclinations of different sources to the line of sight.

1. SOURCE SAMPLES

Jets – Jets are detected in many weak radio galaxies, where they are normally fairly symmetric, i.e. "two-sided" (Bridle and Perley 84), and in a high proportion of sources in well-observed complete samples of extended QSRs, where they are always very asymmetric, i.e. "one-sided" (Owen and Puschell 84 *AJ* 89, 932; Neff and Brown 84 *AJ* 89, 195; Burns *et al.* 84 *ApJ* 283, 515). They are however relatively hard to detect in strong, edge-brightened radio galaxies (Bridle and Perley 84) though some clear examples are now known (*e.g.*, Linfield and Perley 84 *ApJ* 279, 60; Perley *et al.* 84 *ApJ* 285, L35). Among powerful extended sources, the relative prominence of jets increases with that of their radio cores (*e.g.*, Burns *et al.* 84 *ApJ* 283, 515; Saikia 84 *MNRAS* 208, 231). The intensity asymmetries, dominant magnetic field configurations and collimation (spreading rates) of detected jets all correlate with both core and total powers (Bridle 84 *AJ* 89, 979).

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Galaxies and Clusters – Jenkins (82 *MNRAS* 200, 705) used the Cambridge 5-km array to study a complete sample of 34 bright E and S0 galaxies, showing that weak sources are confined within the optical galaxies while more powerful ones can attain sizes of several hundred kiloparsecs. Ulrich and Meier (84 *AJ* 89, 203) mapped 18 B2 radio galaxies at 5 GHz to isolate their radio cores, and found that the core luminosity correlated with the stellar optical luminosity. Burns and Gregory (82 *AJ* 87, 1245) studied a complete sample of 20 4C radio galaxies in poor clusters with the VLA at 1.4 and 5 GHz. They found a high rate of detection of radio jets in weak radio galaxies (*cf.* above), and found several examples of tailed structures, indicating that this morphology is not restricted to rich cluster environments. They found no clear correlation between the radio morphologies and (low-resolution) X-ray imaging of the clusters. Hanisch (84 *AA* 133, 192) surveyed 37 poor clusters at 1.4 GHz with the WSRT, but found no further examples of head-tail structure. A study of radio galaxies in 65 rich clusters using the WSRT at 1.4 GHz was begun by Fanti *et al.* (83 *AA* 105, 200; *AASupp*, 51, 179; *AASupp*, 52, 411).

Quasars – Several samples of extended QSRs were mapped with the VLA. Owen and Puschell (84 *AJ* 89, 932) studied 26 QSRs from the Jodrell Bank 966 MHz survey. Hintzen *et al.* (83 *AJ* 88, 709) mapped 117 QSRs (mainly at $z < 1.5$). Neff and Brown (84 *AJ* 89, 195) studied 60 QSRs with known VLBI cores. Feigelson *et al.* (84 *AJ*, 89, 1464) mapped 15 QSRs from X-ray samples. Swarup *et al.* (84 *MNRAS* 208, 813) studied 31 of the largest QSRs. Significant numbers of distorted structures suggesting interactions with ambient IGM have been found in these samples, as well as the one-sided jets mentioned above.

Survey Samples – Peacock and Wall (82 *MNRAS* 198, 843) completed a structural survey of a sample of 168 sources with 2.7-GHz flux densities >1.5 Jy, and showed that 44% of unresolved (mostly $<5''$) sources have spectral indices >0.5. The VLA was used to map 237 sources from the GB2 survey with 1.4 GHz flux densities >0.55 Jy (Machalski *et al.* 82 *AJ*, 87, 1150; Machalski and Condon 83 *AJ*, 88, 143) and 126 with 1.4 GHz flux densities between 0.20 and 0.55 Jy (Machalski and Condon 83 *AJ*, 88, 1591). Lawrence *et al.* (84 *ApJ* 278, L95) reported statistics of radio structure types and optical identifications from VLA snapshots of 602 MIT-Green Bank survey sources with 5 GHz flux densities >0.05 Jy.

2. INDIVIDUAL SOURCES

The most detailed information on individual sources comes from high resolution studies of the biggest, brightest and nearest objects, so I highlight such work here.

Jets – Multifrequency studies of the jet in the radio galaxy NGC6251 by Saunders *et al.* (82 *MNRAS* 197, 253) and Perley *et al.* (84 *ApJSupp* 54, 292) showed variations in its spreading rate (implying that it is not free everywhere), lateral oscillations, and knot structure indicating local particle acceleration. Perley *et al.* also showed that the 3-D magnetic field in this jet is not axisymmetric, and found rotation measure gradients indicating a magnetoionic medium outside the jet but within the optical galaxy.

VLA observations of the jet in M87 at 0.1$''$ resolution (Biretta *et al.* 83 *ApJ* 274, L27) discovered a sharp inner edge to Knot A and an overpressure relative to the surrounding X-ray gas over much of the jet, though the variable spreading rate of the jet argues that it is not free. The knot structures suggest that they are shocks in the outflow from M87. There is also evidence for absorption of the knot emission below 408 MHz (Charlesworth and Spencer 82 *MNRAS* 200, 933).

Multifrequency VLA mapping of the jet in Cen A by Burns *et al.* 83 *ApJ* 273, 128) showed that it could be thermally confined by surrounding X-ray gas, and revealed strong similarities between its radio and X-ray intensity distributions. This makes severe demands of particle acceleration mechanisms in the jet if its X-ray emission is interpreted as synchrotron emission. Culgoora and Molonglo maps of Cen A by Slee *et al.* (83 *Proc.ASA* 5, 247) showed that the lobes have a 327 to 843 MHz spectral index of 0.7 while the jet region has a spectral index of 0.93 – this goes against the general trend for jets to have flatter spectra than the lobes they enter, and also questions the synchrotron interpretation of the X-ray jet (though higher resolution observations below 1 GHz are desirable).

Hot Spots – Resolutions better than 0.5$''$ are needed to characterize the hot spot properties of distant powerful sources, *e.g.*, Schilizzi *et al.* (82 *J. Astrophys. Astron.* 3, 173). Two main classes of hot spots have been recognised in well resolved powerful sources – compact flat-spectrum hot spots and more diffuse steep-spectrum spots. These may have similar total fluxes in the same source, but very the compact spots have much higher energy densities and much lower total energies (*e.g.*, Lonsdale and Morison 83 *MNRAS* 203, 833). One-sided radio jets, where these are visible, tend to point toward the most compact hot spot (Lonsdale and Morison 83 *MNRAS* 203, 833; Burns *et al.* 84 *ApJ* 283, 515), though exceptions are known. Magnetic fields in hot spots generally lie parallel to the ridge lines of the hot spot emission (*e.g.*, Swarup *et al.* 84 *MNRAS* 208, 813).

Some compact hot spots in QSR lobes have internal pressures that are too great to be directly ram confined assuming normal IGM densities and subrelativistic advance velocities (*e.g.*, Lonsdale and Barthel 84 *AA* 135, 46). If such spots are supplied by jets that flow into them and stagnate, very high jet velocities and conversion efficiencies would be required for energy and momentum balance. The morphologies and spectra of these spots and of their lobes (which often contain larger, secondary hot spots) suggest that they may be emission from oblique shocks at which jet outflows are deflected rather than stopped (see also Lonsdale 84 *MNRAS* 208, 545), possibly alleviating these difficulties. Lonsdale and Barthel 84 also discuss how plasmoid models may provide acceptable alternatives.

Lobes and Trails – As with jets, the biggest and the brightest continue to reveal new details. Qualitatively new classes of non-relaxed structure have been found in radio lobes using the VLA – polarized filaments (Cyg A – Perley *et al.* 84 *ApJ* 285, L35), and highly polarized rings or shells (Her A – Dreher and Feigelson 84 *Nature*, 308, 43; 3C310 – van Breugel and Fomalont 84 *ApJ* 282, L35). The origins of these structures are unclear, but the rings suggest episodic events or instabilities in the plasma outflow from the nucleus to the lobes. The projected magnetic fields run parallel to the ridges of most of the filaments and rings. The prominence of the jets and lack of strong hot spots in the powerful source Her A is unusual, given the general power-morphology trends for extragalactic sources.

Van Breugel (82 *AA* 110, 225) mapped the spectral index distributions and magnetic field configurations in the jets and outer regions of the radio galaxies 3C31, 3C66B and 3C129 with the WSRT (see also van Breugel and Jaegers 82 *AASupp* 49, 529). He found a peculiar Faraday depolarization and rotation at the base of the jet in 3C66B which may be due to foreground magnetoionic material in the parent galaxy (*cf.* NGC6251 above). Strom *et al.* (83 *AA* 122, 305) also used the WSRT to study the depolarization dichotomy between the North and South lobes of 3C31, suggesting large differences in the thermal densities on the two sides of the active nucleus. They found that the magnetic field, which is predominantly perpendicular to the inner jets, turns through 90 deg to run parallel to the long axis of the outer lobes. Alexander *et al.* (84 *MNRAS* 209, 851) derived the spectral index distribution over the lobes of Cyg A from multifrequency mapping and concluded that if some aspects of this are attributed to synchrotron ageing of material flowing away from the hot spots, their velocity of advance should be about 0.05c.

WSRT studies of the largest known rich cluster source (1919+479) by Robertson (84 *AA*, 138, 41) were consistent with buoyant shaping of its large scale "wide angle tail" (WAT) structure, but neither buoyancy, gravitational bending nor dynamic pressure could account for the bent structure observed in 3C465 with the VLA by Eilek *et al.* (84 *ApJ* 278, 37) and at Cambridge by Leahy (84 *MNRAS* 208, 323). There is disagreement over whether motions of the parent galaxies through their clusters are large enough to explain the detailed shapes of 3C465 and other WATs. Galaxy velocities of order 500 km/s are required to produce the observed WATs by moving a twin jet away from static trail emission deposited in an earlier stage of its evolution, but it is unclear whether these are consistent with other constraints on the galactic velocities and with the ages of the radio trails estimated from observed spectral steepening (*cf.* Eilek *et al.* 84 and Leahy 84).

Symmetries and orientations – New examples of sources with bends or S symmetry suggesting precessional or rotational motion of the primary collimator have been found, mainly in QSRs (Gower and Hutchings 82 *ApJLett* 253, L1; Hunstead *et al.* 84 *MNRAS* 207, 55; Gower and Hutchings 84 *PASP* 96, 19; Muxlow *et al.* 84 IAU Symp. 110, 141) but also in one radio galaxy (Condon and Mitchell 84 *ApJ* 276, 472). Specific precessional models fitted to these sources are generally complex and their parameters are not yet obligatory. Lonsdale 84 found morphological and spectral symmetries in 3C196 that are consistent with physical rotation of its primary collimator followed by outflow of material from the most compact hot spots. The total intensity symmetries of the lobes of powerful doubles are often broken at high resolution but it is not clear whether this favors alternating-ejection models for all such sources (Rudnick and Edgar 84 *ApJ* 279, 74; Ensman and Ulvestad 84 *AJ*, 89, 1275).

Observations of 3C218 (Hyd A) at Fleurs by Simkin and Ekers (83 *ApJ* 265, 85) showed an edge darkened radio structure (unusual for a source of its relatively high power) elongated along the optical rotation axis of the galaxy, confirming a trend shown by other powerful radio galaxies. Kapahi and Saikia (82 *J. Astrophys. Astron.* 3, 161) discuss a possibly related alignment between the radio elongations and the optical minor axes in radio galaxies with prominent nuclear cores. Jaegers (83 *AA* 125, 172) documented three parallel edge-darkened sources in the field of 3C130, all possibly identified with galaxies; he suggested that this parallelism may reflect alignments among the three galaxies resulting from common membership in a cluster.

Steep Spectrum Cores (SSCs) – MERLIN and VLA maps of 3C380, a powerful edge-darkened source (also violating the general power-morphology trend) has been shown to have a complex extended structure (Wilkinson *et al.* 84 *Nature*, 308, 619). van Breugel *et al.* (84 *AJ* 89, 5) give VLA maps of 23 SSC sources; they find low degrees of polarization and misalignments between the core components and more distant lobes. These results suggest that SSCs manifest strong interactions between radio emitting plasma and dense ISM on a sub-galactic scale, analogous to those seen in radio Seyfert galaxies (*e.g.*, NGC1068 – Wilson and Ulvestad 83 *ApJ* 275, 8) and studied in detail in some nearby radio galaxies with extranuclear line emission and small distorted radio sources (Heckman *et al.* 82 *ApJ* 262, 529; van Breugel *et al.* 84 *ApJ* 276, 79 and *ApJ* 277, 82).

More of Commission 40 report.

i) Extended Sources

With the addition of the VLA and MTRLI to the complement of image-forming radio telescopes and the development of procedures for high-dynamic-range mapping with the Bonn 100-m antenna, the literature of structure measurements has become very extensive. Only a few aspects are mentioned explicitly here. The four major parts of typical extended sources are (1) small-diameter "cores" in the optical objects, (2) "jets" linking these to (3) diffuse "lobes" which in low-luminosity sources are relaxed in structure and limb-darkened but in higher-luminosity sources may contain (4) compact "hot spots" and are limb-brightened. Jets form the topic of Section (iii) below. For recent reviews of extended source structures see Miley (1980) and Fomalont (1980).

Sources which are distorted from the basic linear shape (I structure) of extragalactic sources may have either "inversion" or "mirror" symmetries (S or C structures). Ekers 1981, Ekers et al. 1981 and Shaver et al. 1981 examine the incidence of these distortions in complete samples of radio galaxies. They conclude that (a) the amount of distortion increases with decreasing radio luminosity, (b) S symmetry is most likely to occur in isolated multiple-galaxy systems and (c) rich cluster environments convert all morphologies to C symmetry.

Total and polarized intensity distributions over many of the brighter and larger sources have been determined at several frequencies with resolutions of a few arc seconds or tens of arc seconds (e.g., Burch 1979a,b,c, De Young et al. 1979, Fanti et al. 1981, Gioia and Gregorini 1979, Högbom 1979, Laing 1981a,b, Strom and Willis 1980, van Breugel 1980a,b,c,d, van Breugel and Willis 1981, Willis et al. 1981, Wright 1979). High frequency mapping with single dishes has provided similar data at arc-minute resolution for some sources of large angular size (e.g. Klein and Wielebinski 1979, Strom et al. 1980, Wall and Schilizzi 1979). These studies provide maps of spectral index, of Faraday rotation and depolarization and hence of projected magnetic fields, over the nearer and larger sources. These in turn constrain models of the energy flow through, and evolution of, the major parts of the extended sources.

The 3C source list is still the most intensively studied. New maps of 3C sources at one or more frequencies (in addition to those referred to above) have been given by Andernach et al. 1979, Birkinshaw et al. 1981, Bridle and Fomalont 1979, Bridle and Vallée 1981, Bridle et al. 1981a,b, Burns and Christiansen 1980, Dreher 1981, Downes 1980, Fomalont et al. 1979,1980a,b, Haschick et al. 1980, Jones et al. 1981, Kotanyi 1980b, Kronberg et al. 1980, Laing 1980, Lonsdale and Morison 1980, Owen et al. 1980, Perley and Johnston 1979, Perley et al. 1979,1980a,b, Reich et al. 1980b, Rudnick et al. 1981, Spangler and Cook 1980, Wilkinson 1981 and Willis and Schilizzi 1979.

The structure of the radio galaxy Cygnus A has been studied over an exceptionally wide range of frequencies, from 150 MHz (Winter et al. 1980) to 22 GHz (Berlin et al. 1980, Dreher 1979,1981) and 150 GHz (Kafatos et al. 1980). There is no evidence for spectral steepening of the lobes from 1 GHz to 150 GHz, but a bridge of emission between the lobes is much stronger at 150 MHz than at 2.7 GHz. Four large-diameter sources were mapped at 43 and/or 74 MHz by Perley and Erickson 1979.

Further examples of "giant" radio galaxies 1 Mpc or more in extent have been documented (Hine 1979, Masson 1979, Mayer 1979, Ulrich et al. 1980). Possible far-outlying components of 3C sources are reported by Reich et al. 1980a, Salter and

Haslam 1980, and Stute et al. 1980.

The distinction between "compact" and "extended" sources made comonly in the literature, and for convenience in this report, has been shown to be artificial by the detection of low-level extended emission associated with luminous compact sources (Kapahi 1979, Kus et al. 1981, Moore et al. 1981, Perley and Johnston 1979, Perley et al. 1980b, Wardle et al. 1981 and Wilkinson 1981).

Mapping surveys of clusters of galaxies have been made by Andernach et al. 1980,1981, Burns and Owen 1979, Burns and Ulmer 1980, Burns et al. 1981, Gavazzi 1979, Gavazzi and Perola 1980, Kotanyi 1980a, Harris et al. 1980a,b,c, Perola and Valentijn 1979, Perola et al. 1980, Schallwich and Wielebinski 1979, Valentijn 1980 and Waldthausen et al. 1979.. Singal et al. 1980 report lunar occultation studies of clusters.

Detailed maps of "tailed" (C-shaped) sources in cluster environments have been made by Bridle et al. 1979, Bridle and Vallée 1981, Burns 1981, Burns and Owen 1980, Burns et al. 1979, Downes 1980, Fanti et al. 1981, Harris et al. 1980a, McHardy 1979, Owen et al. 1979, Robertson 1980,1981, Simkin and Ekers 1979, Simon 1979, Valentijn 1979a,b,1981, Vallée et al. 1979,1981, and van Breugel 1980b.

The reality of very extended cluster "haloes" has continued to be controversial. That in the Perseus cluster has been shown to be an artifact of earlier low-resolution data (Birkinshaw 1980, Gisler and Miley 1979) whereas some others have been confirmed (Ballarati et al. 1981, Hanisch 1980, Hanisch and Erickson 1980, Hanisch et al. 1979). Jaffe and Rudnick (1979) searched for new haloes.

Structures of complete samples of quasars have been examined by Fanti et al. 1979, Potash and Wardle 1979, and Wills 1979. The "double quasar" 0957+561A,B has been studied intensively in search of constraints on gravitational-lens models (Greenfield et al. 1980a,b, Noble and Walsh 1980, Pooley et al. 1979, Roberts et al. 1979).

Structural information for samples of sources studied by the method of lunar occultations have been reported by Subrahmanya and Gopal-Krishna 1979, Singal et al. 1979, Venkatakrishna and Swarup 1979 and Joshi and Singal 1980. Sources from these samples have been studied interferometrically by Menon 1980.

Structures of sources identified with bright galaxies have been determined by Beck et al. 1979,1980, Condon 1980, de Bruyn and Hummel 1979, Feretti and Giovaninni 1980, Gioia and Gregorini 1980, Grave et al. 1981, Hummel 1980a,b, Klein and Emerson 1981, Kotanyi 1979,1981, Kronberg and Biermann 1981, Pfleiderer et al. 1980, Van Albada 1980, van der Hulst et al. 1981, and Viallefond et al. 1980. Structures of sources in disturbed galaxies have been determined by Fosbury and Wall 1979, Ghigo 1980, and Kronberg et al. 1979,1981.

Structures of sources in Seyfert galaxies have been measured by Meurs and Wilson 1981, Ulvestad et al. 1981b, Ward et al. 1980, Willis 1979, Wilson 1981a,b, Wilson and Willis 1980, and Wilson et al. 1980. Extended structures associated with BL Lac objecta are reported by Danziger et al. 1979 and Weiler and Johnston 1980.

Other structure studies not referenced above include that of B2 radio galaxies by Grueff et al. 1981, of S4 survey sources by Kapahi 1981, of 4C sources by Rudnick and Adams 1979, of 4C sources with steep spectra by Tielens et al. 1979, and of strong sources at 5 GHz by Ulvestad et al. 1981a.

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(iii) Radio Jets

About seventy extragalactic radio sources are now known to contain bright, well-collimated radio features extending from unresolved cores at the centers of their parent optical objects towards their more extended radio emission. Such features are usually called "jets" (although there is no direct evidence for flow of matter along them). They have been detected in sources spanning the full range of radio luminosity from weak nearby galaxies to powerful quasars. The jets are commonly presumed to be due to radiative losses in or around "energy pipelines" linking the cores of active galaxies and quasars to their extended emission, as envisioned in continuous-beam source models (Blandford and Rees 1974, 1978).

Recent observations of the structures of large-scale (arcsec to several arcmin) jets in extragalactic sources have been reported by Birkinshaw et al. 1981, Bridle 1981, Bridle et al. 1979, 1980, 1981, Browne and Orr 1981, Burch 1979a,b, Burns 1981, Burns and Christiansen 1980, Burns and Owen 1980, Davies et al. 1981, Ekers et al. 1981, Fanti and Parma 1981, Feigelson 1981, Fomalont 1980, Fomalont et al. 1980, Högbom 1979, Jones et al. 1981, Laing 1980, Masson 1979, Neff 1981, Owen et al. 1980, Perley 1981, Perley et al. 1979, 1980, Potash and Wardle 1980, Rudnick and Burns 1981, Saunders et al. 1981, Schreier et al. 1981, Vallée et al. 1981, van Breugel 1980a,b, van Breugel and Willis 1980, and Willis et al. 1981. Properties of the large-scale jets are reviewed by Miley (1980), Willis (1981) and Bridle (1981).

VLBI observations of asymmetric small-scale (sub-arcsec) jetlike structures near the radio cores of galaxies and quasars have been reported by Cohen and Readhead 1979, Cohen et al. 1981, Cotton et al. 1981, Kellermann et al. 1981, Linfield 1981, Pauliny-Toth et al. 1981, Pearson and Readhead 1981, Pearson et al. 1980, Preuss et al. 1980, Readhead 1980, Readhead and Wilkinson 1980, and Simon et al. 1980.

Large-scale jets occur in 70% to 80% of sources in complete samples of nearby radio galaxies from the B2 and 3CR radio surveys, but the detection rate in more powerful sources is lower (Ekers et al. 1981, Fanti and Parma 1981, Bridle 1981). Jets may therefore make up a smaller fraction of the total luminosity in the more powerful radio sources.

Observations of the internal structures of well-resolved jets show that they expand laterally at variable rates (Bridle et al. 1979,1980, Bridle 1981, Fanti and Parma 1981, Feigelson 1981, Perley et al. 1979, Willis et al. 1981). This presumably means that they are subject to some form of lateral confinement.

Observations of linear polarization in large-scale jets are reported by Birkinshaw et al. 1981, Bridle et al. 1979,1981, Burns 1981, Burns and Christiansen 1980, Burns and Owen 1980, Fanti and Parma 1981, Fomalont et al. 1980, Laing 1980, Owen et al. 1980, Perley et al. 1979,1980, Potash and Wardle 1980, Saunders et al.

1981, Vallée et al. 1981, van Breugel 1980a,b, van Breugel and Willis 1981 and Willis et al. 1981. In well-resolved jets, degrees of polarization from 30% to 40% are common at wavelengths shorter than 21cm, and polarizations as high as 65% have been detected (Willis et al. 1981). Such high polarizations imply well-ordered magnetic structures in the jets. This is confirmed by direct mapping of the projected magnetic field structures in well-resolved jets (Bridle 1981, Burch 1979b, Fanti and Parma 1981, Fomalont et al. 1980, Willis et al. 1981). The projected fields are generally either perpendicular to, or parallel to, the axes of extension of the jets; perpendicular fields dominate in jets produced by low-luminosity cores, while parallel fields dominate in jets produced by high-luminosity cores (Bridle 1981).

Elongated structures resembling abbreviated jets have been reported in two Seyfert galaxies (Booler et al. 1981, Johnston et al. 1981, Wilson 1981).

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