FAINT EXTENDED RADIO SOURCES SURROUNDING ACTIVE GALAXY NUCLEI +

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INTRODUCTION

As is clear from many papers in this volume, the phenomenology of radio sources associated with active galaxy nuclei (AGNs) is very diverse. It is attractive nevertheless to try and retain the belief that complex effects may have simple causes. In this case the great variety of structures seen in broad band radio surface photometry over a tremendous range of angular resolution is preferably thought of as the result of one basic process in which plasmas are ejected in an intrinsically symmetric manner at bulk velocities which (at least initially) are relativistic. The complexity is then attributable to many circumstances, e.g.:

- the engine's time dependent output
- the engine's directionality which may
  - a) be very steady
  - b) precess
  - c) jump eratically
- the plasma's opacity at radio wavelengths
- the geometry of the source-observer configuration
- the relativistic kinematic effects which so strongly depend on that geometry
- the circumnuclear environment of the engine, i.e. the gas and dust content of the AGN
- the circumgalactic environment of the parent galaxy
- the nearest neighbours of the parent galaxy
- the selection effects of our samples.

We report here some early results of a programme which searches for faint radio emission and its morphology in the immediate vicinity of very radio bright AGNs. This programme utilises a newly developped capacity of the Synthesis Radio Telescope at Westerbork, based on the

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many redundant spacings inherent in the uniformity of this East-West array (Noordam and De Bruyn, 1982). The method, its principles and power are described by De Bruyn in this volume.

THE SAMPLE

From the catalogue of radio sources compiled by Kühr et al. (1981) we culled the list of galaxies and BL Lacs satisfying the conditions: (i) $S_{6\ cm} > 1$ Jy, (ii) $\delta > 25^o$, (iii) $z < 0.10$. The latter two conditions in order to have a beam no larger than 3.5 x 8 arc s FWHM and a linear resolution of order 10 kpc or better ($H_o = 50$). From this list of 21 sources the four objects were selected which have the strongest core flux and flat or inverted spectra. To these four we added, for the purpose of this exploratory programme, the radio galaxy 3C 111, not in the Kühr catalogue because of its low galactic latitude ($b = -9^o$) but otherwise meeting our criteria. Table 1 summarizes some pertinent facts about this five source sample.

These sources were observed at a frequency of 4874 MHz with the Westerbork SRT, in the configuration which yields 91 interferometers with 38 different spacings from 72 to 2732 m in 72 m increments.

Taking advantage of the array's redundancy in the manner described by De Bruyn (this volume), high dynamic range cleaned maps were obtained from which, in the uv plane, 99 to 99.9% of the core source's peak flux has been removed.

RESULTS

In *all cases* faint extended emission is detected surrounding the ultracompact (more or less opaque) core source in the AGN.

For the three 'point sources' BL Lac, OQ 208 and 4C 39.49 the extended emission is very weak but clearly visible as diffuse emission enveloping the central source. Table 2 describes these sources.

The structure of the two remaining sources, 3C 371 and 3C 111, is more complex. In addition to its core component 3C 371 has several other features: A, a component unresolved in this observation, $\sim$ 3 arc s from the core in p.a. $\sim -115^o$, known also from VLA (Perley et al., 1980) and MERLIN (Browne et al., 1982) maps; B, an extended structure enveloping the core *and* feature A, emanating from the core, elongated $\sim$ 12 arc s, 18 kpc in p.a. $\sim + 150^o$ and $\sim$ 20 arc s, 30 kpc in p.a. $\sim - 30^o$ at the 1% of peak flux contour level; finally feature C, an outer lobe of diffuse emission about 25 arc s, 38 kpc from the central source along p.a. $\sim - 100^o$, a direction also present on the VLBI scale as a one-sided milliarcsecond jet according to Pearson and Readhead, 1981. Hence there are three very different directions manifest in this source at this level of brightness and dynamic range. It is particularly

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TABLE 1

Source	Other Names	Radio position of the core $\alpha(1950)$	$\delta(1950)$	Approximate flux of central component at 6 cm (Jy)	z	Distance (Mpc) $H_0=50$ kms^{-1} Mpc^{-1}
0415+37	3C111	$04^h15^m00^s.60$	$37^o54'19.5$	3.3 (variable)	0.0485	295
1404+28	0Q208, MK668	14 04 45.62	28 41 29.2	2.9	0.077	470
1652+39	4C39.49, MK501	16 52 11.75	39 50 24.6	1.4	0.033	200
1807+69	3C371	18 07 18.54	69 48 56.9	1.7	0.051	310
2200+42	BL Lac, OY401	22 00 39.36	42 02 08.5	4.8 (variable)	0.070	425

Source	Beam size (FWHM) angular size (arcs)	Beam size (FWHM) linear size kpc	Comments	
0415+37	3.5x5.7	5x8	Classical triple radio galaxy VLBI: one sided jet Inverted core spectrum	Laing, 1981 Linfield, 1981
1404+28	3.5x7.3	8x17	Markarian galaxy VLA unresolved Inverted spectrum	Ulvestad et al. 1981
1652+39	3.5x5.5	3x5	Markarian galaxy VLA unresolved Flat spectrum	Ulvestad et al. 1981
1807+69	3.5x3.7	5x6	N-galaxy Core + secondary component at ∿ 3 arc sec distance One side VLBI jet, misaligned with secondary comp. Complex flat spectrum	} Browne et al. 1982 } Perley et al. 1980 Pearson, Readhead, 1981
2200+42	3.5x5.2	7x11	VLA unresolved VLBI: two components Complex flat spectrum	Ulvestad et al. 1981 Philips, Mutel, 1982; Pearson, Readhead, 1981

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Table 2

	Estimate of extended emission (% of total source flux)	WHz^{-1}	Approximate Dimensions of extended component (NS x EW)
BL Lac	0.7	7.2×10^{23}	24 x 8 arc s 48 x 16 kpc
OQ 208	0.3	2.3×10^{23}	10 x 15 arc s 23 x 35 kpc
4 C 39.49	1.6	1.1×10^{23}	20 x 10 arc s 18 x 9 kpc

interesting that current activity, visible as VLBI structure in the form of a one sided jet, points towards the diffuse, relatively distant and presumably relatively old component C, not to the much brighter feature A, which looks like a one sided jet at VLA and MERLIN resolutions and is presumably rather younger than component C. The engine in 3C 371 could be a multiple one, each turned on part of the time, with the current one repeating a performance of $\sim 10^{7\pm1}$ years ago when the now diffuse component C was formed.

The triple radio galaxy 3C 111, fifth source in our sample, did not yield a reliable map of the active nucleus' immediate vicinity, due to grating ring interference from the bright outer lobes. The map is very interesting nevertheless, for it shows at very faint levels, remarkable structure of the bridge connecting the bright active core to the outer lobes. On the south side this bridge $\sim$ 300 kpc in length, is normal, i.e. sharply bounded. On the northern side the bridge has a faint but remarkable veil extending up to 80 kpc away from the bridge at the 0.15 % of peak flux brightness level. There are other examples of such faint extensions, e.g. that of 3C 430 (Riley and Pooley, 1975) but none of such great dimensions, either relative or absolute, are known to us. We intend to pursue this phenomenon at other wavelengths.

CONCLUSIONS

This exploratory study of a small heterogeneous sample can only lead to provisional conclusions.

- AGNs are not naked radio sources, they are at least enveloped by faint very extended radio sources.
- The extended radio sources are often amorphous, showing no particular structural features or symmetries.
- The extended radio sources have sizes and powers, intermediate between those of radio galaxies and normal galaxies (Hummel, 1980), not unlike the radio properties of some Seyfert galaxies (Meurs, 1982; Meurs and Wilson, 1983).

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- In 3C 371 the extended radio source has features which in relation to the milliarcsecond and subarcsecond structure suggest the presence of more than one basic direction which persist over long time scales.
- The radio galaxy 3C 111 has a radio bridge apparently eroded by an intergalactic wind or onesided diffusion.

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