SEARCH FOR STRUCTURAL CHANGES IN THE CORES OF "NEARBY" RADIO GALAXIES

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Recent VLBI observations of the central radio components in the lobe-dominated radio galaxies 3C111 (Götz et al. 1987) and 3C390.3 (Alef et al. 1987) show drastic changes in the structure of the compact emission regions. In 3C111 a jet-like feature with two knots and a flux density of 600 mJy which was visible in 1980.4 had disappeared in 1985.4. This implies "superluminal behaviour" with a characteristic speed of $\gtrsim 3c$. In 3C390.3, there is also evidence for superluminal motion: radio knots appear to be ejected from the core at a rate of about one every 4 years and move out with an apparent velocity of 4.1 c ($H_0 = 50$ km/s/Mpc throughout this paper) in the direction of the north-west extended lobe.

These observations are clearly relevant to the question: are radio galaxies energized by relativistic jets, and if so, is the apparent structure and temporal behaviour of their central radio components strongly influenced by relativistic beaming effects. The beaming hypothesis in its simplest form (Scheuer and Readhead 1979, Blandford and Königl 1979, Orr and Browne 1982) leads to "unifying schemes" which predict that in a sample of randomly oriented radio sources with similar intrinsic parameters, observable properties such as core prominence, asymmetry, and the occurrence of superluminal motion are mainly determined by the viewing angle of the observer. The best test of this hypothesis would be the VLBI observation of a statistically complete sample of radio galaxies without bias in orientation. This has so far been impossible due to sensitivity limits and the lack of dedicated VLBI networks. Only about a dozen of the central components of radio galaxies have been mapped with milliarcsec resolution.

The observation of strong structural variability in 3C111 and 3C390.3 prompted us to review the status of VLBI observations of a complete sample of "nearby" radio galaxies, which are strong at the 3C survey frequency of 178 MHz. We may ask whether the VLBI results available for this sample, collected in an unsystematic fashion by various observers bears some statistical significance with regard to the relativistic beaming hypothesis.

Table 1 lists 39 radio galaxies along with their milliarcsec core characteristics, if available, and other relevant parameters. These objects form a distance limited ($z < z$(3C273)=0.158) subset of the

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Table 1: Object (1)	P_{178} ($\frac{erg}{s.Hz}$) (2)	Radio type (3)	Size (kpc) (4)	$R_{5\ GHz}$ (5)	S_5(VLBI core) (Jy) (6)	$V_{app.}$ (7)	Refs. (VLBI) (8)
3C31	2.1E32	I	50	.06	<.12		1
3C33	8.6 33	II	380	.003			
3C35	2.1 33	II	980	<.02			
3C66B	5.0 32	I	150	.06	.12		2
3C76.1	5.6 32	I	40	<.01			
3C83.1B	7.6 32	I	140	.006			
3C84	7.9 32	I	180	.99	60. M	.4c	3
3C98	1.9 33	II	250	<.01	<.08		2
3C184.1	8.3 33	II	470	.005			
DA240	1.2 33	II	1960	.07	<.08		1, 2
3C192	3.4 33	II	300	<.004			
3C223	1.3 34	II	800	.007			
3C236	6.4 33	II	5860	.54	.32 M		4
3C264	4.9 32	I	30	.17			
3C272.1	8.1 30	I	11	.11	∿.13		2
3C274	8.4 32	I	6	.05	2.2 M	<.3c	5
3C285	2.2 33	II	230	<.01			
3C293	1.2 33	I	100	.80	<.08		2
3C296	3.2 32	I	180	.04			
3C303	1.0 34	II	60	.21	<.09		2
3C305	1.2 33	I	13	.09	<.08		2
3C310	7.1 33	I	360	.07			
3C314.1	6.9 33	I	520	<.03			
3C315	9.5 33	I	530	.13			
3C321	5.6 33	II	690	.03			
3C326	7.4 33	II	2630	.03			
N6109	4.1 32	I	690	.04			
3C338	1.2 32	I	34	.04	∿.09		2
N6251	2.5 32	I	2900	.58	.85 M	<.6c	6
3C382	3.0 33	II	280	.11	∿.08		2
3C386	3.0 32	I	120	.005			
3C388	9.2 33	II	70	.05	<.10		1
3C390.3	6.8 33	II	330	.09	.35 M	4.1c (?)	7
3C433	2.6 34	I	90	<.004			
3C442A	4.9 32	I	200	<.01			
3C449	1.5 32	I	150	.03			
3C452	1.6 34	II	730	.04	<.08		2
N7385	2.8 32	I	80	.09			
3C465	1.4 33	I	430	.10	.23		2

Meaning of Columns:

(2) Spectral power at 178 MHz; H_o = 50 km/s/Mpc and q_o = 0.5 throughout this table; e.g., 2.1E32 ≡ $2.1 \cdot 10^{32}$; Note: P_{178} (CYGNUS A) = 1.2E36 erg/(s.Hz)

(3) Classification of the overall radio structure of double sources

(Fanaroff and Riley 1974): the brightness distribution either peaks near the centre (type I) or at the ends of the radio lobes (type II).

(4) Projected overall size

(5) Fractional core flux density S(arcsec core)/S(total) at 5 GHz

(6) Flux density of milliarcsec core at 5 GHz, i.e. maximum correlated flux measured in VLBI pilot observation or flux contained in VLBI map marked by "M", if any. Note: the milliarcsec core fluxes of the remaining sources (without entry in column (6)) are all <.09 Jy (<.02 for most of them), the upper limit to their arcsec core fluxes.

(7) Apparent transverse velocity of any component motion

(8) References to VLBI observations. The numbers in columns (2), (4) and (5) are based on data from Laing et al. (1983), Kühr et al. (1979), Bridle and Perley (1984), and references therein.

References to Table 1:

[1]Graham et al. (1981)
[2]Preuss et al. (1977)
[3]Romney et al. (1984)
[4]Barthel et al. (1985)
[5]Schmitt and Reid (1986)
[6]Jones (1986)
[7]Alef et al. (1987)

catalogue by Laing, Riley and Longair (1983), which lists all radio sources with S(178 MHz) $\geq$ 10 Jy, $\delta \geq 10^o$ and $|b| \geq 10^o$. M82 has been omitted as it is both qualitatively and quantitatively very different from the other objects. The sample includes 16 classical double sources of type II. Note that some well known radio galaxies with relatively strong cores are not in this sample either because their galactic latitude is too low (Cyg A, 3C111) or because their 178 MHz fluxes are too weak (NGC315, 3C120). Of the 39 galaxies, 8 (2 of type II) have milliarcsec cores stronger than 0.1 Jy at 6 cm; of these, 5 have been mapped with milliarcsec resolution and for 4, there is some kinematic information available (Tab. 1). Note that 3C390.3 has the fourth strongest milliarcsec core in the sample, and the strongest in the subset of type II sources.

3C390.3 is the first lobe-dominated radio galaxy for which the evidence available so far suggests that superluminal motion is present. Its core contains only 9% of the total flux density at 6 cm and ranks only as number 12 in the whole sample. The observation of superluminal motion, the relative core strength, and overall size of 3C390.3 are not incompatible with the relativistic beaming hypothesis if one assumes, e.g., a Lorentz factor of 5 and an angle of 22^o between the source axis and our line of sight. However, if we interpret the observation in this way, only one or two more objects in the sample should show superluminal motion with $v \gtrsim 4$ c (e.g. Scheuer 1984). If the sample is restricted to the 23 powerful sources with spectral power > 10^{-3} times that of Cyg A

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at 178 MHz, statistically no further superluminal sources should be present. Furthermore, from the viewpoint of the relativistic beaming hypothesis, it is disturbing that the objects with the largest overall sizes in the sample (Tab. 1), the giant radio galaxies 3C236, NGC6251, 3C326 and DA240, for which one does not expect substantial Doppler boosting, have some of the most prominent cores. This has also been noted by Saripalli et al. (1986) as a general feature of giant radio galaxies.

We conclude that to the extent that apparent superluminal behaviour reflects relativistic bulk motion, the observations of 3C111 and 3C390.3 (independent of specific models or "unified schemes") support the idea that relativistic bulk motion is present in the central components of radio galaxies. However, the relativistic beaming hypothesis in its simplest form (as basis of a unified scheme) seems, even on the grounds of the limited evidence available so far, hardly applicable to the sample of nearby radio galaxies in Table 1.

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DISCUSSION

BIRKINSHAW: I'd like to comment on the importance of tracing the high-speed motions inferred from VLBI out to larger scales by high-precision astrometry (for example, using the VLA). I await the results of such studies (which I understand are presently in progress) with great interest.

PREUSS: Attempts to measure the core distance of brightness peaks in extended radio sources on larger scales (1" - 100") with high precision (<0."01) are underway. This is tried with VLBI by phase referencing methods.

LONGAIR: I was intrigued by the fact that, of the four extended radio galaxies studied with VLBI, only 3C 390.3 showed evidence of superluminal motion. In fact, it is the only one of your 4 sources which Julia Riley and I classified as "good" doubles in the sense that the extended structure of the double source contains hot spots (as edge-brightening) in both source components. Thus it may be that the probability of observing relativistic motion in "good" double sources is much higher than 1 in 4. The importance of extending the VLBI observations to a large sample of "good" doubles is very important.

I agree with Dr. Miley that the parent populations from which one can select superluminal sources seems to be becoming smaller and smaller and I believe this poses significant problems for the simplest forms of relativistic beaming models.

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