Chapter 3

THE RADIO IMAGES AND RADIO SPECTRA

The radio images obtained from the VLA using the procedures described in the previous chapter are presented in this chapter. For each observed object, the integrated radio spectrum for the whole source and the component spectra over as wide a radio frequency range as possible have been compiled, which are also presented. A description of each source, incorporating not only data obtained from the images presented herein but also extensive data from the literature, is given.

3.1 The VLA radio images

The images are presented in Figs. 3.1 to 3.38. The contours represent loci of constant surface brightness, on which are superposed the polarization data. The length of the superposed line segments at each pixel represents the polarized flux density in the case of the C-array images and the degree of fractional polarization in the case of the B- and A-array images unless stated otherwise. The orientation of the line segments represents the orientation of the polarization E-vectors. The Gaussian beams used in the deconvolution are plotted as hatched ellipses. In those cases where the present observations detect only an unresolved component, no image is presented. The position of the associated optical object is marked by a cross in each case.

The radio data obtained from the VLA measurements on individual objects are presented in **Table 3.1**, which is arranged as follows :

Column 1:	source name.
Column 2:	VLA configuration used (A, B or C), and radio wavelength band (cm).
Columns 3-5:	Half Power Beam Width of the synthesized beam: major and minor axes, and position angle respectively.
Columns 6,7:	r.m.s. noise levels of the total power and polarization images respectively.
Column 8:	designation of the radio component (Opt for the optical object; N for north, NE for northeast, etc.).
Columns 9-14:	positions of the components. Radio positions are from the present VLA measurements. Optical positions are taken from the literature in a majority of the cases, and measured directly from POSS prints for the rest.
Columns 15,16:	peak surface brightness and radio flux density for each component.
Column 17:	largest angular size (LAS) of the source
Columns 18,19:	fractional polarization and position angle of the E-vector at the position of the peak of surface brightness.
Column 20:	code indicating reference to the optical position measurement.

3.2 The radio spectra

The overall radio spectra between ~10 MHz and ~90 GHz are presented in Fig. 3.39. Where possible, the spectra of the individual components are also shown. The total flux densities have been compiled mostly from the flux density catalogues

Table 3.1 The radio sources observed with the VLA.

Source [1]	VLA Array & Waveband (cm) [2]	synthesised beam (HPBW) major (") [3]	minor (") [4]	PA (°) [5]	r.m.s. noise total (mJy/beam) [6]	polarized (mJy/beam) [7]	[8]	Radio position(1950) of Peak Right Ascension h [9]	m [10]	s [11]	Declination (°) [12]	(') [13]	(") [14]	Peak Surface Brightness (mJy/beam) [15]	Flux density (mJy) [16]	LAS (") [17]	Polarization % [18]	PA (°) [19]	Ref. [20]
0003-002	B, 2	0.49	0.40	163	1.05		Opt	00	03	48.86	-00	21	06.4			4.8			D86
							N			48.86			05.5	361	460				
							C			48.85			06.3	94	95				
							S			48.76			10.0	15	105				
0051+291	B, 6	0.66	0.47	67	1.5		Opt	00	51	02.08	29	08	51.1			2.8			PW
							NE			02.25			52.3	29	65				
							C			02.06			51.2	138	140				
0115+027	B, 6	1.35	1.32	138	0.22	0.11	Opt	01	15	43.61	02	42	19.7			13.1			C83
							W1			43.30			17.9	50			17	7	
							W1+W2			43.47			18.2	55	225				
							C			43.64			19.6	140			2.5	165	
							E1			43.89			21.5	25			7	176	
							E1+E2			44.13			21.9	57	200				
0232-042	C, 6	5.24	3.94	171	2.3	0.3	Opt	02	32	36.55	-04	15	10.2			13.2			C83
							W^g			35.97			09.4	184	184		10.8	30	
							C+E			36.65			09.7	226	285		≤ 0.13		
	C, 2	1.77	1.42	19	1.7	3.4	W^g			35.92			09.7	33	75		≤ 11.2		
							C^g+E			36.59			10.1	120	159		≤ 2.9		
							E			36.80			09.4	12			≤ 23.1		
0241+622	B, 2	0.63	0.41	61	1.34	0.68	Opt	02	41	00.62	62	15	27.2			3.9			TSMB
							C			00.68			27.6	894	957		0.7	90	
	A, 20	3.35	1.43	61	0.32		C			00.68			27.4	183	192		≤ 1		
							SE			01.19			25.9	43	49		≤ 2		
	A, 6	0.99	0.43	63	0.19		C			00.67			27.4	322	322		0.1	55	
							SE			01.15			25.9	6	8				
	A, 2	0.31	0.13	64	0.39		C			00.69			27.52	188	200		0.3	95	

Table 3.1 (Contd.)

Source	VLA Array & Waveband	synthesised beam (HPBW)			r.m.s. noise			Radio position(1950) of Peak						Peak Surface Brightness	Flux density	LAS	Polarization		Ref.
		major	minor	PA	total	polarized		Right Ascension			Declination						%	PA	
	(cm)	(")	(")	(°)	(mJy/beam)			h	m	s	(°)	(')	(")	(mJy/beam)	(mJy)	(")		(°)	
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
0309+411	C, 6	4.96	3.88	72	1	0.2	Opt	03	09	44.81	41	08	47.9			26.8			pr
							C^g			44.82			48.9	337	337		2.2	30	
	C, 2	1.65	1.27	71	2.3	2.2	C^g			44.78			48.8	465	465		2.1	39	
	B, 20	5.94	3.84	94	0.72		NW			43.00		09	06.0	7					
							C^g			44.78		08	49.2	289	304				
0409+229	A, 20	1.55	1.40	69	0.36	0.25	Opt	04	09	44.70	22		27.8			4.5			PW
							NW			44.52			29.1	410	504		6.8	94	
							C			44.67			27.6	198	249		6.9	133	
							NE			44.82			29.4	75	97		1.2	91	
0615+578	A, 20	1.33	1.16	152	0.3	0.16	unidentified									8.0			
							NW	06	15	51.54	57	53	19.4	237	582		0.1	172	
							C?			51.99			15.5	20			0.4	29	
							SE			52.26			14.6	24	87		4.5	48	
	A, 6	0.38	0.32	152	0.12	0.16	NW			51.54			19.6	37	43		7.5	129	
							C?			52.02			15.2	1.6					
							SE			52.22			14.7	1.3	8				
0717+170	C, 6	5.36	4.28	55	0.4	0.6	unidentified									105.7			
							W^g	07	17	34.24	17	04	07.3	99	197		17	45	
							C?^{g}			36.87			22.1	4	9		≤ 16.6		
							E^g			40.98			50.1	15	30		10.2	140	
	C, 2	1.68	1.51	70	1.7	2.4	W			34.24			07.5	12	158		≤ 20.9		
0740+380	C, 6	5.00	3.96	95	0.9	0.2	Opt	07	40	56.82	38	00	31.0			100.4			C83
							C^g			56.8			30.8	213	229		0.6	24	
							E1^g		41	00.03	37	59	05.4	8					
							E1+E2^g		41	00.39	37	58	59.8	28	39		≤ 0.8		
	C, 2	1.7	1.33	92	1.2	2.4	C^g		40	56.78	38	00	31.0	30	78		≤ 8.5		
							E2		41	00.42	37	58	59.9	≤ 3.5					

Table 3.1 (Contd.)

Source	VLA Array & Waveband	synthesised beam (HPBW)			r.m.s. noise			Radio position(1950) of Peak						Peak Surface Brightness	Flux density		Polarization		Ref.
	(cm)	major (")	minor (")	PA (°)	total (mJy/beam)	polarized (mJy/beam)		Right Ascension h	m	s	Declination (°)	(')	(")	(mJy/beam)	(mJy)	LAS (")	%	PA (°)	
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
0742+376	C, 6	5.21	3.98	95	0.8	0.2	Opt	07	42	22.63	37	38	33.6			62.3			pr
							W1			18.69		39	14.7	44			10.6	75	
							W1+W2			18.98		39	11.2	78	126		3.9	143	
							C^g			22.60		38	33.2	60	60		4.6	175	
	C, 2	1.77	1.36	95	1.4	2.1	W1			18.46		39	15.8	8	103		≤ 38.2		
							W2			19.00		39	11.0	10			≤ 27.6		
							C			22.60		38	33.2	49	52		≤ 6.4		
0814+201	A, 20	1.36	1.26	175	0.13	0.13	Opt?	08	14	12.35	20	08	04.4			unresolved			S79
							C			11.51			01.9	281	283		4	124	
	A, 6	0.39	0.36	170	0.17	0.22	C			11.51			01.9	180			1.4	100	
0821+394	C, 6	4.59	4.32	82	6.4	0.4	Opt	08	21	37.26	39	26	28.0			24.0^k			PW
							C^g			37.34			28.1	1036	1247		1.4	120	
	C, 2	1.96	1.4	100	8.1	2.5	C^g			37.31			28.2	992	1270		0.6	116	
0836+195	C, 6	4.72	4.37	98	0.3	0.2	Opt	08	36	15.00	19	32	24.4			31.2			MH
							SW^g			14.75			07.1	3	7		≤ 5.0		
							C^g			14.98			24.9	74	77		3.6	109	
							NE^g			15.31			37.3	68	88		7.7	95	
	C, 2	1.53	1.48	75	1.1	1.6	C^g			14.97			25.0	28	38		≤ 5.7		
							NE^g			15.30			37.8	11	18		≤ 21.9		

Table 3.1 (Contd.)

Source	VLA Array & Waveband (cm)	synthesised beam (HPBW) major (")	minor (")	PA (°)	r.m.s. noise total (mJy/beam)	polarized (mJy/beam)		Radio position(1950) of Peak Right Ascension h	m	s	Declination (°)	(')	(")	Peak Surface Brightness (mJy/beam)	Flux density (mJy)	LAS (")	Polarization %	PA (°)	Ref.
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
0919+218	A, 20	1.38	1.24	179	0.12	0.12	Opt	09	19	53.07	21	49	33.5			11.2			SN
							SW			52.74			30.6	9			≤ 3		
							C+NE1+SW			53.04			34.0	63	231		2.6	8	
							NE2			53.32			38.4	157	278		5.9	66	
	A, 6	0.41	0.4	11	0.10	0.12	SW			52.95			33.2	1.4	30				
							C			53.03			33.6	19	23		≤ 3		
							NE1			53.06			34.6	15	30		21	138	
							NE2			53.34			38.5	38	45		25	42	
0932+022	C, 6	6.15	4.75	116	0.6	0.2	Opt	09	32	42.93	02	17	39.6			44.8			MH
							W^g			40.95			16.1	51	137		15.4	159	
							C^g+E			43.00			41.2	82	143		1.1	125	
							E			43.26			44.6	45			5.7	115	
	C, 2	1.65	1.34	30	1.2	2.6	C^g			42.94			41.1	76	93		< 3.9		
							E			43.30			44.8	11	25		< 22.2		
1007+417	C, 6	4.84	3.95	104	0.9	0.2	Opt	10	07	26.13	41	47	24.4			32.0			C77
							SW^g			25.91			05.6	302	454		8.8	160	
							C^g			26.10			25.3	149	189		3.2	108	
							NE^g			26.33			36.6	21	38		4.2	106	
	C, 2	1.57	1.29	85	1.4	2.3	SW^g			26.00			05.2	52	183		≤ 9.9		
							C^g			26.11			25.3	70	111		≤ 4.8		
							NE^g			26.28			37.0	7	20				
1012+232	A, 20	1.34	1.28	174	0.44	0.24	Opt	10	12	00.50	23	16	12.3			18.0			W76
							N			00.50			18.1	15	40		≤ 4		
							C			00.50			12.1	659	719		3.2	73	
							S			00.57			00.7	62	300		13.8	33	
	A, 6	0.41	0.39	177	0.4	0.15	C			00.50			12.1	1083	1220		0.6	179	
							S			00.58			00.6	9	35		7.9	164	

Table 3.1 (Contd.)

Source [1]	VLA Array & Waveband (cm) [2]	synthesised beam (HPBW) major (") [3]	minor (") [4]	PA (°) [5]	r.m.s. noise total (mJy/beam) [6]	polarized [7]	[8]	Radio position(1950) of Peak Right Ascension h [9]	m [10]	s [11]	Declination (°) [12]	(') [13]	(") [14]	Peak Surface Brightness (mJy/beam) [15]	Flux density (mJy) [16]	LAS (") [17]	Polarization % [18]	PA (°) [19]	Ref. [20]
1040+123	A, 20	1.43	1.32	171	0.54	0.19	Opt	10	40	06.02	12	19	15.1			7.4			W76
							W1			05.67			15.5	470	653		13.2	108	
							C+W2			05.99			15.1	1710	2045		9	86	
							E			06.18			14.7	170	413		4	100	
	A, 6	0.41	0.39	85	0.36	0.13	W1			05.67			15.4	130	177		15.6	90	
							W2			05.90			15.4	20			22.2	15	
							C			06.00			15.1	1150	1205		10.4	24	
							E			06.20			15.1	7	17		≤ 10		
1047+096	C, 6	4.67	4.14	175	0.3	0.3	Opt	10	47	48.95	09	41	47.7						MH
							W^g			45.11		42	12.3	11	21		3.8	157	
							NW^g			48.59		42	01.6	5	13		9	48	
							C			49.02		41	44.7	29			7.3	1	
							C+SE^g			49.14		41	42.1	56	117		4.4	85	
	C, 2	1.53	1.37	17	1.1	1.9	C^g+SE			48.92		41	47.0	16	112		≤ 27.5		
							SE^g			49.15		41	41.1	7			≤ 22.4		
1055+201	C, 6	4.37	4.01	16	3.1	0.3	Opt	10	55	37.59	20	07	55.3			21.2			MH
							NW^g			37.12		08	15.3	510	690		3.2	125	
							C^g			37.55		07	54.9	846	959		0.1	93	
	C, 2	1.48	1.31	176	6.6	2.5	NW^g			37.16		08	15.7	103	277		≤ 2.8		
							C^g			37.56		07	55.3	832	889		5.4	175	
1055+018	A, 6	0.46	0.41	168	0.62		Opt	10	55	55.33	01	50	03.4			unresolved			W76
							C			55.32			03.5	2670	2680		4.1	109	
	A, 2	0.16	0.13	167	1.2		C			55.316			03.45	4120	4135		4.3	134	

Table 3.1 (Contd.)

Source	VLA Array & Waveband (cm)	synthesised beam (HPBW) major (")	synthesised beam (HPBW) minor (")	synthesised beam (HPBW) PA (°)	r.m.s. noise total (mJy/beam)	r.m.s. noise polarized (mJy/beam)		Radio position(1950) of Peak Right Ascension h	m	s	Declination (°)	(')	(")	Peak Surface Brightness (mJy/beam)	Flux density (mJy)	LAS (")	Polarization %	Polarization PA (°)	Ref.
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
1132+303	A, 20	1.30	1.22	24	0.31	0.13	Opt	11	32	16.25	30	22	02.3			15.5			PW
							NW			16.00		22	07.9	22	218		4.4	23	
							C+SE1			16.22		22	02.2	227	316		5.6	75	
							SE2			16.72		21	56.4	92	562		1.5	78	
	A, 6	0.42	0.42	46	0.17	0.11	NW			15.95		22	07.7	1.1	67				
							C+SE1			16.23		22	02.5	72.4	138		6.1	88	
							SE1			16.26		22	01.4	21.8			3.8	46	
							SE2			16.73		21	55.9	5.6	130		≤ 1		
1136-135	B, 6	4.93	4.24	152	3.83		Opt	11	36	38.51	-13	34	05.9			16.0			MH
							NW			37.74			00.9	332	490		8	30	
							C+SE			38.39			06.7	521	1055				
	A, 20	1.84	1.25	17	1.6	0.39	NW			37.92			01.1	730	1541		10.1	177	
							C			38.52			06.0	570	570		1.6	140	
							SE1+S			38.74			10.8	250	1478		5.6	34	
	A, 6	0.56	0.38	10	0.24	0.14	NW			37.90			01.1	129	522		7.8	31	
							C			38.52			06.0	444	462		1.8	13	
							SE1			38.75			10.8	13			12	46	
							SE1+SE2			38.80			07.8	22	606		22.2	101	
1203+109	A, 20	1.43	1.31	171	0.24	0.1	Opt	12	03	22.62	10	59	35.4			5.6			WWD
							NW			22.48			38.0	17	31		5.9	115	
							N			22.63			36.9						
							C			22.61			35.8	98	206		6.4	95	
							S			22.66			33.5	47	94		3.5	57	
	A, 6	0.45	0.41	175	0.1	0.1	NW			22.47			38.2	2	8				
							N			22.63			37.1	17	39		9.1	75	
							C			22.59			35.6	54	60		0.9	130	
							S			22.65			33.5	6	20		8	87	

Table 3.1 (Contd.)

Source	VLA Array & Waveband (cm)	synthesised beam (HPBW)			r.m.s. noise			Radio position(1950) of Peak						Peak Surface Brightness (mJy/beam)	Flux density (mJy)	LAS (")	Polarization		Ref.
		major (")	minor (")	PA (°)	total (mJy/beam)	polarized		Right Ascension h	m	s	Declination (°)	(')	(")				%	PA (°)	
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
1222+216	B, 6	3.30	2.02	58	1.44		Opt	12	22	23.44	21	39	23.5			15.0			H84
							S			23.40			16.0	30					
							C^g			23.50			24.0	875	949		2	90	
							E			24.23			26.3	75	148				
	A, 20	1.32	1.41	5	1.8		S			23.31			13.9	12					
							C			23.43			22.6	704					
							E			24.17			25.2	66					
1320+299	C, 6	4.74	4.09	58	1.2	0.2	Opt	13	20	40.47	29	57	23.2						F79a
							A^g			40.52		57	23.8	277	298		4.7	135	
							B^g			42.21		57	12.3	195	229		9.5	126	
							C^g			43.77		56	54.3	69	78		9.6	9	
	C, 2	1.54	1.34	51	1.7	1.9	A^g			40.51		57	23.6	159	159		4.3	149	
							B^g			42.17		57	12.0	39	49		16.9	133	
							C^g			43.75		56	54.1	14	29		$\leq$ 24.7		
	B, 20	3.31	2.95	9	0.3		A			40.51		57	23.6	379	427		2.6	138	
							Bw+Be			42.17		57	12.0	511	669		1.5	167	
							Be										3.5	61	
							C			43.75		56	54.1	213	247		9.5	21	
	B, 6	1.2	1.15	129	0.22		Ac+Ae			40.50		57	23.4	260	270		4.1	120	
							Ae			40.78		57	22.6	5					
							Bw+Be			42.15		57	11.9	120	229		12.5	111	
							Be										6.2	20	
							C			43.75		56	54.0	49	73		9.5	8	
	A, 20	1.24	1.22	42	0.27		Ac+Ae			40.50		57	23.5	330	385		5	130	
							Ae			40.79		57	22.8	12					
							Bw+Be			42.16		57	11.8	330	645		1	141	
							Be										13	70	
							C			43.75		56	54.1	140	225		9.5	21	

Table 3.1 (Contd.)

Source [1]	VLA Array & Waveband (cm) [2]	synthesised beam (HPBW) major (") [3]	minor (") [4]	PA (°) [5]	r.m.s. noise total (mJy/beam) [6]	polarized (mJy/beam) [7]	[8]	Radio position(1950) of Peak Right Ascension h [9]	m [10]	s [11]	Declination (°) [12]	(') [13]	(") [14]	Peak Surface Brightness (mJy/beam) [15]	Flux density (mJy) [16]	LAS (") [17]	Polarization % [18]	PA (°) [19]	Ref. [20]
1320+299	A, 6	0.37	0.36	35	0.25		Ac+Ae			40.50		57	23.54	210	260		5.5	132	
(contd.)							Ae			40.81		57	22.80	3					
							Bw+Be			42.15		57	11.76	75	250		18.5	105	
							Be							6					
							C			43.77		56	53.74	24	80		9.5	4	
	A, 2	0.12	0.11	34	0.39		Ac							140	160		5.5	125	
1347+539	C, 6	4.88	3.84	106	1.8	0.2	Opt	13	47	42.66	53	56	08.0			5.3$^{\varphi}$			C77
							C^g			42.61			08.5	836	891		1.8	13	
	C, 2	1.66	1.27	125	2.6	3.9	C^g			42.58			08.4	611	666		4.5	50	
1354+195	C, 6	4.40	4.24	175	2.7	0.6	Opt	13	54	42.09	19	33	43.9			43.7			C83
							NW^g			41.73			59.2	60			3.4	178	
							C^g+NW+SE			42.10			44.1	1292	1761		4.8	70	
							SE^g			42.43			16.6	73			14.3	50	
	C, 2	1.56	1.41	2	4.5	3.7	C^g			42.07			43.9	944	1048		3.4	55	
1415+463	A, 20	1.54	1.42	56	1.1	0.23	Opt	14	15	13.47	46	20	55.5			13.2			C77
							SW1			12.23			52.1	82	252		7.1	115	
							SW2			12.3			54.1	91			8.7	142	
							C			13.43			55.6	567	567		1.5	9	
	A, 6	0.44	0.42	49	0.28	0.15	SW1			12.24			52.0	6					
							SW1+SW2			12.30			54.1	23	81		10.4	123	
							C			13.43			55.6	647	647		0.4	132	
1419+315	C, 6	4.42	3.91	63	0.8	0.2	Opt	14	19	19.39	31	32	43.7						F79a
							W^g			18.82		32	38.8	17			10.9	157	
							C^g			19.36		32	43.5	54	140		1.6	13	
							E			19.84		32	37.8	28			11.6	108	
							SE^g			23.37		30	38.1	54	54		≤ 0.9		
	C, 2	1.51	1.35	50	1.1	1.9	W			18.86		32	38.8	4					
							C^g			19.33		32	43.4	38	89		≤ 7.4		
							E^g			19.83		32	37.1	9					

Table 3.1 (Contd.)

Source	VLA Array & Waveband (cm)	synthesised beam (HPBW) major (")	minor (")	PA (°)	r.m.s. noise total (mJy/beam)	polarized		Radio position(1950) of Peak Right Ascension h	m	s	Declination (°)	(')	(")	Peak Surface Brightness (mJy/beam)	Flux density (mJy)	LAS (")	Polarization %	PA (°)	Ref.
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
1433+177	B, 6	2.02	1.93	48	0.29	0.2	Opt	14	33	36.12	17	42	36.5			10.0			WWD
							N			36.09			42.0	18	27		10	21	
							C			36.08			36.8	302			5	61	
							SE			36.19			32.5	192	246		4	89	
	A, 6	0.41	0.41	139	0.22	0.21	N			36.09			42.2	11	25		10.2	12	
							C+jet			36.09			36.7	228	250		3.3	58	
							SE			36.20			32.2	92	231		1.7	124	
1509+158	B, 6	2.22	2.11	47	0.38		Opt	15	09	52.47	15	51	39.2			9.0			pr
							W			51.95			36.3	128	184		17	73	
							C+E			52.45			39.0	117	203		4	0	
	A, 20	1.44	1.39	148	0.24	0.15	W1			51.95			36.4	298	343		17.5	87	
							W2			52.00			39.9	34	116		10.3	177	
							C+W3			52.45			39.3	99	155		6.1	165	
							E			52.57			39.0	72	214		≤ 0.8		
	A, 6	0.42	0.41	138	0.23	0.22	W1			51.94			36.6	99	130		18	74	
							W3			52.38			39.0	5.2	30		15.2	172	
							C			52.43			39.3	80	90		2.2	165	
							E			52.56			38.4	8	85		≤ 8		
1547+309	B, 6	1.6	1.1	104	0.14	0.16	unidentified									15.3			
							NW	15	47	11.92	30	56	22.2	64	235				
							C?			12.57			17.9	9					
							SE			12.97			14.9	37	85				
1636+473	C, 6	4.32	3.77	97	0.8	0.2	Opt	16	36	19.17	47	23	28.7			20.0			pr
							C^{g}			19.17			28.8	500	500		1.6	53	
							NE1+NE2			19.45			46.0	48	150		1.5	164	
							NE2			19.99			47.0				11.8	179	
	C, 2	1.61	1.22	70	2.9	1.6	C^{g}			19.15			28.5	914			1.3	53	
							NE1^{g}			19.34			45.6	13	991				
							NE2^{g}			19.39			46.4	13					

Table 3.1 (Contd.)

Source	VLA Array & Waveband (cm)	synthesised beam (HPBW) major (")	minor (")	PA (°)	r.m.s. noise total (mJy/beam)	polarized		Radio position(1950) of Peak Right Ascension h	m	s	Declination (°)	(')	(")	Peak Surface Brightness (mJy/beam)	Flux density (mJy)	LAS (")	Polarization %	PA (°)	Ref.
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
1637+574	B, 6	1.54	1.36	121	0.74	0.13	Opt	16	37	17.33	57	26	16.2			4.0			C77
							C^g+W			17.43			15.9	1604	1678		3.4	111	
1729+501	C, 6	4.44	3.87	71	1	0.6	Opt	17	29	49.26	50	09	44.3			20.4			C77
							C^g			49.27			44.2	39	43		5.5	50	
							E^g			50.71			29.3	352	414		18.2	48	
	C, 2	1.43	1.23	68	1.3	1.8	C^g			49.28			44.1	18	23		$\leq$ 10.7		
							E^g			50.74			29.3	93	142		10.2	43	
1741+279	A, 6	0.38	0.41	102	0.25	0.22	Opt	17	41	57.97	27	54	04.8			10.1			H84
							N			57.91			10.4	17	84		6.5	147	
							C			57.89			04.8	178	194		6.4	71	
							S			58.02			01.0	3	28				
1842+681	A, 20	2.49	1.21	99	0.28	0.22	Opt	18	42	43.36	68	06	19.2			4.0			C77
							C			43.50			19.7	636			1.7	92	
							C+NW							636	726				
	A, 6	0.75	0.37	100	0.29	0.21	C			43.49			19.6	1320	1321		1.4	37	
2041-149	B, 20	5.67	3.91	178	0.69		Opt?	20	41	29.17	-14	56	32.8			30.5			S79
							W			29.08			33.6	186	280				
							E			31.08			43.0	125	205				
	B, 6	1.56	1.23	159	0.13	0.1	W			29.09			33.7	47	76		1.5		
							E			31.09			43.1	21	61		18	18	

Table 3.1 (Contd.)

Source [1]	VLA Array & Waveband (cm) [2]	synthesised beam (HPBW) major (") [3]	synthesised beam (HPBW) minor (") [4]	synthesised beam (HPBW) PA (°) [5]	r.m.s. noise total (mJy/beam) [6]	r.m.s. noise polarized (mJy/beam) [7]	[8]	Radio position(1950) of Peak Right Ascension h [9]	m [10]	s [11]	Declination (°) [12]	(') [13]	(") [14]	Peak Surface Brightness (mJy/beam) [15]	Flux density (mJy) [16]	LAS (") [17]	Polarization % [18]	Polarization PA (°) [19]	Ref. [20]
2251+134	B, 6	1.30	1.25	172	0.46	0.5	Opt	22	51	51.93	13	25	49.1			6.6			W79
							SW			51.69			46.0	80	170		4	68	
							C			51.88			48.9	397			2	90	
							NE			51.98			50.9	110	180		1.5		
2325+269	B, 6	1.29	1.21	35	0.25	0.2	Opt	23	25	28.60	26	59	23.0			7.4			MH
							NW			28.41			24.8	198	331				
							C			28.54			21.4	53					
							SE			28.68			18.3	22	85				

Legend: g: the position is derived from a Gaussian fit to the image. k: LAS is from the image of Kapahi (1981b); op: LAS is from Owen & Pucshell (1984).

References to the optical position: C77: Cohen et al. (1977); C83:Clements (1983); D86:Downes et al. (1986); F79a:Fanti et al. (1979a); H84: Hintzen (1984); MH:Miley & Hartsuijker (1978); PW:Potash & Wardle (1979); pr:present work; S79:Singal et al. (1979); SN:Stannard & Neal (1977); TSMB:Tzanetakis et al. (1978); W76:Wills (1976); WWD:Wills et al. (1973); W79:Wills (1979).

listed in Kühr *et al.* (1979) and Kühr *et al.* (1981). Other references used and not listed by Kühr are given in Table 3.2. Estimates of the flux densities from aperture synthesis instruments have sometimes been included to provide information where none is available from single-dish measurements. All the flux densities have been converted to the scale of Baars *et al.* (1977). A linear ($a + b \log \nu$) or parabolic ($a + b \log \nu + c \log^2\nu$) least-squares fit to the spectra (that includes weighting by errors) has been overlaid on the plots. In the case of the components, an error in the flux densities of 10 percent is assumed unless the quoted errors are higher. The fits should not, however, be taken too literally, especially beyond the frequency range where good measurements are unavailable.

3.3 Description of the individual sources

A description of each of the objects for which VLA images were obtained is given below. An extensive survey of the literature was made for information on the objects at radio wavelengths, and the descriptions here include the data thus compiled, with focus on multifrequency morphology, spectral characteristics, radio variability and polarization characteristics. Whenever a spectral index has been quoted, it has been obtained by a linear least-squares fit to the flux density measurements. Whenever Faraday rotation measures (RMs) are given, they are obtained from linear-least-square fits to the measurements, taking into account the errors.

The source 1320+299 was studied in somewhat greater detail than the rest of the objects. The apparently very large angular size of the source was an embarrassment to the relativistic beaming scenario. Moreover, the source

Table 3.2 Sources of radio flux density measurements.

Reference	Frequency
Abraham _et al_. (1984)	22, 44 GHz
Amirkhanyan (1981)	8.7, 14.4 GHz
Artyukh _et al_. (1969)	86 MHz
Artyukh & Vetukhnovskaya (1981)	102 MHz
Barthel (1984)	5 GHz
Binette _et al_. (1981)	5 GHz
Braude _et al_. (1978)	14.7,16.7,20,25 MHz
Braude _et al_. (1979)	14.7,16.7,20,25 MHz
Braude _et al_. (1981)	14.7,16.7,20,25 MHz
Bridle & Purton (1968)	10 MHz
Condon _et al_. (1982)	1.41 GHz
Dixon & Kraus (1968)	1415 MHz
Ehman _et al_. (1974)	1415 MHz
Fitch _et al_. (1969)	1415 MHz
Gear _et al_. (1984)	150, 300, 350 GHz
Gregorini _et al_. (1984)	408 MHz
Hoglund (1967)	750 MHz
Large _et al_. (1981)	408 MHz
Lawrence _et al_. (1983)	4.76 GHz
Rinsland _et al_. (1974)	1415 MHz
Roger _et al_. (1986)	22 MHz
Salonen _et al_. (1983)	37 GHz
Scheer & Kraus (1967)	1415 MHz
Seilstad _et al_. (1983)	10.8 GHz
Simard-Normandin _et al_. (1980)	1.59,1.721 GHz
Simard-Normandin _et al_. (1981b)	1.6,14.8 GHz
Simard-Normandin _et al_. (1981c)	2.7,8.1 GHz
Simard-Normandin _et al_. (1982)	10.5 GHz
Singal _et al_. (1979)	327 MHz
Spangler & Cotton (1981)	0.43, 1.4 GHz
Sutton _et al_. (1974)	408 MHz
Willson _et al_. (1972)	408,1407 MHz
Windram & Kenderdine (1969)	408 MHz
Wright _et al_. (1982)	2.7, 5 GHz

characteristics, especially those of the polarized emission, were interesting in themselves. It was therefore imaged very extensively with the VLA, and a discussion of the results is given.

0003−002 : Lyne (1972) pointed out that this source was one-sided. The lunar occultation observations with the Ooty Radio Telescope at 327 MHz (Joshi, 1981) showed the 'core-component' to consist of two compact components. But, due to the uncertainties in their positions, it was not clear as to which of these was associated with the QSO. The VLA image at $\lambda 2$ cm presented in Fig. 3.1 confirms the radio structure inferred from the Ooty observations. Now that a good optical position is available (Downes *et al.*, 1986), it is clear that the southern component is the core, and the source is two-sided with a very asymmetric separation ratio. The optical position is also plotted in the figure.

The source is a triple with a steep overall spectrum ($\alpha \sim -0.77 \pm .004$). The projected linear size of the source is ~41 kpc. It is thus a Compact Steep Spectrum (CSS) quasar. (Saikia *et al.* (1987a) discuss it in detail.)

0051+291 : This source was classified as one-sided from the observations of Potash & Wardle (1979). In the VLA B-array image (Fig. 3.2), it still appears one-sided. However, its integrated spectrum (Fig. 3.39) is steep ($\alpha \sim -0.56 \pm .03$), and its projected linear size is ~ 23 kpc; it is thus a CSS source. Swarup *et al.* (1986) discuss further details.

0115+027 : A two-sided source, though with a somewhat asymmetric separation ratio of 1.4:1 (Fig. 3.3). (Earlier Westerbork observations of Miley & Hartsuijker (1978) did not resolve the western component from the core, and it appeared one-sided. In the VLA image here, there are suggestions of a curving jet towards the eastern component, and the polarization E-vectors appear to be systematically aligned perpendicular to the jet and following the bends in it.

The overall spectrum of the source is steep ($\alpha \sim -0.9 \pm .01$). Using the peak flux densities from this map and the $\lambda 20$ cm map of Hintzen *et al.* (1983), the spectral index of the nuclear component is ~ −0.08. The VLB Interferometric position measured at 2.29 GHz by Morabito *et al.* (1982) agrees within errors with the photometric position determined by Clements (1983). Wehrle *et al.* (1984) measure a VLBI correlated flux density of 60 ± 10 mJy for the core at 2.3 GHz .

The spectral indices of the western (W1 + W2) and eastern (E1 + E2) components are ~ −1 and −0.8 respectively. The integrated RM of the quasar has been reported to be 9.8 ± 2.4 rad m^{-2} with the intrinsic polarization position angle, ψ, of 8 ± 6 (Tabara & Inoue 1980) and 9 ± 11 rad m^{-2} with ψ of 6 ± 5 (Simard-Normandin *et al.*, 1981a).

0232−042 : This is an asymmetric source where the $\lambda 2$ cm surface brightness ratio of the outer components is 2.8 and the separation ratio is 3.3 (Fig. 3.4c). The total intensity and polarization maps at $\lambda 6$ cm are presented in Figs. 3.4a and b respectively. Miley & Hartsuijker (1978) did not separate the eastern component from the core. No evidence is found here or in the $\lambda 20$ cm VLA map of Hintzen *et al.* (1983) for the component Miley & Hartsuijker (1978) suggested 28 arcsec to the west. Hintzen *et al.* (1983) have found a bridge of emission connecting the western component to the core.

The overall spectrum of the source is straight below ~ 2 GHz ($\alpha = -0.83 \pm 0.06$); it appears to flatten at higher frequencies. The nuclear component has an α of -0.38 ± 0.06. The VLBI position of Morabito *et al.* (1983) agrees within errors with the optical position of Clements (1983). The QSO is optically variable (e.g., Tritton & Selmes, 1971).

For the extended components, $\alpha_{west} \sim -1.05 \pm 0.08$ and $\alpha_{east} \sim -1.0 \pm 0.1$. The RM of the quasar has been reported to be 4.6 ± 1.2 rad m^{-2} with ψ of $34 \pm 3°$ by Tabara & Inoue (1980) and 5 ± 1 rad m^{-2} at $32 \pm 3°$ by Simard-Normandin *et al.* (1981a). The polarization at 5 GHz integrated over the source gives a PA consistent with the above values, although the PAs for the eastern and western components differ by ~ 40°. The central component is unpolarized.

0241+622 : The radio image of Tzanetakis *et al.* (1978) showed that this nearby x-ray quasar, which is in the Galactic plane (b = 2°.4), has radio emission only on one side of its nucleus. Hutchings *et al.* (1982) confirmed this with better VLA observations at $\lambda 6$ and 20 cm. The A-array maps at $\lambda 20$ and 6cm (Figs. 3.5a and b) (though made with a very elongated u-v coverage) confirm the structure reported by Hutchings *et al.* (1982). The B-array observations detect only the nuclear component. Both the overall and the nuclear spectra are flat with $\alpha \sim 0.3 \pm 0.1$. The source has been reported to be a variable at 10.7 GHz (Feldman 1979; Feldman *et al.* 1981). The large range in the flux densities seen wherever multiple measurements at a single frequency are available also suggests that the quasar is variable. From VLBI observations at 10.7 GHz, Geldzahler & Shaffer (1979) find that ~ 70 per cent of the flux density is from a core of size 0.55 ± 0.1 mas, while the remaining 30 per cent is from a more extended structure of size $\gtrsim$ 26 mas. They remark that interstellar scattering may be affecting the observed angular structure.

The spectral index of the outer component using the measurements below ~ 3 GHz is ~ −0.7 ± 0.2. The 5 GHz flux density of Hutchings *et al.* (1982) and of the present VLA observations appear to have been underestimated.

It must be pointed out that this object is of relatively low radio luminosity, and is detectable at radio wavelengths only because it is nearby. At a higher redshift where quasars usually are, it would have been classified as belonging to the 'radio-quiet' category. Indeed, from spectroscopy and V, B and R band imaging, Romanishin *et al.* (1984) infer that the elliptical nebulosity underlying the QSO is probably a spiral galaxy. (Radio-loud quasars are now believed to reside mostly in elliptical galaxies; e.g., Malkan, 1984; Fried, 1986).

0309+411 : The observations of Kapahi (1979) with the WSRT had shown this source to have a one-sided north-westerly extension to the compact component that was identified with a faint galaxy. Gisler & Miley (1979), from their results at 610 MHz which showed similar structure, suggested that it could be a head-tail source, though unlikely to be associated with the Perseus cluster in whose direction it lies.

While the VLA data with the C-configuration do not show any extension to the compact source, the B-array observations here barely detect the extension to the north-west at a peak surface brightness level of ~ 7 mJy/beam. O'dea & Owen (1985a) also detected it with the VLA A-array at λ20cm. The position of their peak surface brightness for this component is closer to the core than that of Kapahi (1979), as is that of the B-array image presented here (Fig. 3.6). But this is not necessarily inconsistent since it is clear that this component has a very diffuse structure. Indeed, WSRT observations at 327 MHz by de Bruyn (1985) with very high dynamic range have shown that the radio source is in fact two-sided, with an angular extent of ~ 9 arcminutes.

The overall spectrum of the source is presented in Fig. 3.39. The spectrum is flat/inverted at frequencies $\gtrsim$ 2 GHz and appears to steepen at lower frequencies. This is clearly consistent with the existence of the diffuse extension to the north-west, which is expected to have a very steep spectrum. The spread in the multiple measurements of flux density and also flux density monitoring at 10.8 GHz (Seilstad *et al.* 1983) clearly suggest that the source is variable.

The degree of polarization is similar at λ6 and 2 cm and the measured PAs imply an RM of about −50± 25 rad m^{-2}. The PAs derived by the measurements presented here are not compatible with the value of 83° ± 8° of Simard-Normandin *et al.* (1982) at 10.5 GHz, although the degree of polarization is in agreement. Earlier, Simard-Normandin *et al.* (1981b) had reported a fractional polarization of 6.55 ± 0.6 percent at a PA of 13 ± 2° at 1660 MHz. It seems very likely that the source is also a polarization variable.

The position of the compact radio component measured by VLBI at 2.29 GHz (Morabito *et al.* 1982) coincides with the position of the identified optical object within the errors. Van Breugel *et al.* (1981) measure a correlated flux density of ~ 400 mJy at 5 GHz for the compact component.

0309+411 appears to be associated with a galaxy of apparent magnitude 18^{m} (and unknown redshift) in the direction of the Perseus cluster (redshift = 0.018). It is not clear if the optical object is physically located in the Perseus cluster or is a background galaxy. It has a structure somewhat suggestive of ’head-tail’ morphology. But curiously, most of the flux density is concentrated in the component with flat radio spectrum, which is fairly highly polarized (~ 2 percent at λ6 cm) and is variable, probably in both total radio flux density and polarization.

0409+229 : From the displacement inferred between the radio centroids at 2.7 and 8.1 GHz, Potash & Wardle (1979) conjectured that this quasar was one-sided. The VLA A-array images presented here (Fig. 3.7) show that it is a triple source with very misaligned extended components. Perley (1982) also found it to be a strongly bent triple.

The overall spectrum is steep up to ~ 1 GHz, and flattens at higher frequencies (Fig. 3.39). The core component spectrum is inverted. With VLBI at 2.29 GHz, Wehrle *et al.* (1984) measured a correlated flux density of 0.21 ± 0.04 Jy for the core component. The associated QSO is extremely red ($\alpha_{optical} \sim -3 \pm 0.5$; Smith & Spinrad 1980). The fractional polarization and its orientation determined here are consistent with the data of Perley (1982) at λ20 cm. Simard-Normandin *et al.*

(1981a) report an overall RM of −4 ± 4 rad m^{-2} with ψ of 80° ± 4°. Using the same data but assuming a rotation of ~ 180° between the PAs at λ6 and λ21 cm (which gives a better correlation), Tabara & Inoue (1980) derive an RM of 80 ± 10 rad m^{-2} and a ψ of 36° ± 14°. The direction of the source is not one of high RM in the sky (Simard-Normandin & Kronberg, 1980). Observations at closely spaced wavelengths and of similar resolution are required to clarify the ambiguity.

0615+578 : Based on data from Owen *et al.* (1978), this source was tentatively classified by Kapahi (1981a) as of the one-sided type; the radio component coincident with the QSO proposed as the identification had a steep radio spectrum between 2.7 and 8.1 GHz. Subsequently, this and another proposed optical identification (Cohen *et al.*, 1977 and Wills, 1976) have both been found to be stars (Wills & Wills, 1976 and Walsh *et al.*, 1979).

The present image at λ20 cm (Fig. 3.8a) clearly shows that the object is a triple source. There is a hint of a jet from the nuclear component to the north-western lobe, visible more clearly in the λ6 cm image (Fig. 3.8b). The jet is polarized at λ6 cm, and the polarization orientation indicates that the projected magnetic field is aligned along the jet, and then changes into a circumferential configuration at the terminal hot spot. The integrated spectrum of the source is straight with $\alpha \cong -0.87 \pm 0.09$, and the northwest component has an α of -1.2 ± 0.1. It is quite likely that this object is a quasar, though only a deep search for the associated optical object can confirm this.

0717+170 : This source was found to be one-sided by Joshi (1981), and it was included here to confirm or otherwise his tentative suggestion that it is a head-tail source in a cluster. From lunar occultation scans at 327 MHz with the Ooty Radio Telescope, Joshi (1981) concluded that the object has a 'head' (containing ~ 75 percent of the total flux density) and a 'tail' with a weak secondary component at the end. He found a red galaxy close to the 'head' of the source and suggested it as possible identification.

The present data at $\lambda 6$ cm confirm the radio structure of Joshi (1981). But the morphology (Figs. 3.9a and b) is strongly reminiscent of FR Type II objects (Fanaroff & Riley, 1974). The polarization data also suggest that the two outer components represent the lobes of a typical triple radio source. Moreover, the western component has an extremely relaxed structure at $\lambda 2$ cm (Fig. 3.9c) with no evidence of any compact component coincident with the galaxy of 18^{m} (which is marked in the figure). It must be noted that the signal–to–noise was insufficient to permit self-calibration of the image at $\lambda 2$ cm.

A search near the central component revealed no new candidate for the optical identification above the limit of the Palomar Observatory Sky Survey (POSS) prints. The other galaxies in the field are marked in Fig. 3.9a. It seems likely from the above arguments that the proposed identification of Joshi (1981) is a chance superposition. The source is presently classed as unidentified.

The overall radio spectrum of the source is straight between 80 MHz and 5 GHz (spectral index $\alpha = -0.81 \pm 0.04$). The two-point spectral index for the western component is -0.85 ± 0.05 between 327 and 4885 MHz. Since the south-west component is very faint at λ2 cm, the flux density as determined from the aperture synthesis image is uncertain. Therefore, the derived flux density excess seen relative to the spectrum between 327 and 4885 MHz is unlikely to be significant.

0740+380 : Data at 5 GHz from the Cambridge 5-km telescope (Riley & Pooley, 1975) showed that this quasar had a single outer component, though ~ 100 arcsec away to the south-east. The VLA C-array image at λ6 cm shows a similar picture (Fig. 3.10). Wilkinson *et al.* (1974) and Schilizzi *et al.* (1982) showed that the northwestern source was a double at position angle 132°. The map of Cawthorne *et al.* (1986) delineates the nuclear component between the double, which is coincident with the optical QSO. While the double structure *is* oriented towards the southeastern component implying a possible relation between the two, there is no evidence of any emission bridging the two sources in any of the data, nor even in the observations of Conway *et al.* (1983) at 962 MHz with the Jodrell Bank interferometer. It is therefore possible that the two sources are physically distinct objects; indeed, Conway *et al.* (1983) arrived at the same conclusion. A search therefore was made on the POSS prints for a separate optical identification for the southeastern component, but none was found. The accurate QSO position is coincident within errors with the position of the peak at λ2 cm (inset, Fig. 3.10).

The spectrum of the "whole" source is straight above 100 MHz with $\alpha = -1.24 \pm 0.02$, but appears to turn over at lower frequencies. The spectrum of the northern triple (the plot is in a separate figure) is also steep

($\alpha = -1.21 \pm 0.02$). With a VLB Interferometer between Westerbork and Effelsburg, Kapahi & Schilizzi (1979) measured a correlated flux density of 291 mJy at 1417 MHz from the northeastern source, which is ~ 22 percent of its total flux density. But because there is no evidence for the presence of a flat spectrum component in the spectrum of the northeastern source, they concluded that the correlated flux density that they measure is unlikely to come from a nuclear component with flat radio spectrum. If the northeastern source is a separate object, then it would be of projected linear size 14 kpc. This, together with the steep radio spectrum, would imply that it is a CSS source.

Measurements $> 2\sigma$ among those quoted by Tabara & Inoue (1980) and the VLA data presented here obtain an RM of ~ 30 rad m^{-2} and a ψ of ~ 15°.

0742+376 : This source appears to be one-sided with an angular size of ~ 62 arcsec (Figs. 3.11a, b and c), consistent with the structure reported by Katgert-Merkelijn *et al.* (1980) and Machalski *et al.* (1982). The integrated spectrum is straight ($\alpha = -1.0 \pm 0.02$). The index for the core is ~ 0.1 ± 0.1 between 5 and 15 GHz. The 15 GHz flux density of the western component ($\alpha_{1.4}^{5GHz} = -1.2 \pm 0.1$) is unreliable due to its low brightness. It is interesting that the PA of the $\lambda 6$ cm polarization changes by ~ 70° between components W1 and W2.

Although the northwestern double is aligned with the southwestern component, there is no evidence for any emission connecting them in either the images presented here or the VLA data at 1465 MHz of Machalski *et al.* (1982). However, no optical object was found on the POSS prints at the position of the northwestern component. It is not clear whether the two components are related.

0814+201 : From lunar occultation data obtained using the Ooty Radio Telescope at 327 MHz, and the Optimum Deconvolution (ODM) algorithm for the deconvolution (Subrahmanya, 1979), Subrahmanya & Gopal-Krishna (1979) inferred that this object, which is in the direction of the Cancer cluster, has a double structure. Although the present VLA observations at $\lambda 20$ and $\lambda 6$ cm detect only an unresolved single component, its position is well within the error window of the *western component* of Subrahmanya & Gopal-Krishna (1979). No images are presented for this object. No radio emission is detected from the region of the eastern component of Subrahmanya & Gopal-Krishna, down to a peak surface brightness of 0.13 mJy/beam and 0.53 mJy/beam at $\lambda 20$ and $\lambda 6$ cm respectively. It is this latter component that was found by them to be identified with a 20^{m} red object. The unresolved compact source thus remains unidentified (unless it is taken to be related to the weaker object; but the source would then consist of a nuclear component of very steep radio spectrum and an outer component of flat spectrum which is unlikely). Imaging at a low frequency is required to determine the nature of the connection between the two components detected by Subrahmanya & Gopal-Krishna (1979).

The source has an α of ~ -0.35 ± 0.06 (including the fluxes measured by the VLA).

0821+394 : Kapahi (1981b) detected a single secondary component to the south-west of the nuclear component of this object (Westerbork observations at 5 GHz) and thus classified it as one-sided. Stannard & Neal (1977) had also reported a one-sided structure for this object, though the position of their outer component is ~ 16 arcsec away from that of Kapahi (1981b). They, however, cautioned against possible uncertainties due to the proximity of 0822+394, which is 6.2 arcminutes distant at 60° (Bridle *et al.*, 1972). Potash & Wardle (1979) did not detect the secondary component at either 2.7 or 8.1 GHz. There is no evidence for the presence of the secondary component in the C-array data presented here. At both λ6 and 2 cm, the object appears unresolved. (No image is presented.)

However, the integrated spectrum of the source (Fig. 3.39: only those flux density measurements that are believed to be unaffected by confusion due to 0822+394 are plotted) speaks for there being significant extended emission: there is definite indication of steepening at lower frequencies. Imaging that is sensitive to diffuse radio structure is required to determine the nature of this object. Note that the spread in the flux density measurements at the higher frequencies implies that the source is probably a variable at these frequencies. The VLBI position measured by Morabito *et al.* (1982) coincides within errors with the position of the QSO.

The RM is 14 ± 5 rad m^{-2} with a ψ of 119° ± 7° (Simard-Normandin *et al.*, 1981a). The PAs derived from the present measurements, viz., 116° and 120° at λ2 and 6 cm respectively, are similar to the intrinsic value.

0836+195 : This quasar was believed to be of the one-sided kind from several previous observations (Jenkins *et al.*, 1977; Miley & Hartsuijker, 1978; Subrahmanya & Gopal-Krishna, 1979). It is a triple source (Fig. 3.12a and b) with a prominent core component and a large surface-brightness ratio for the outer components (23:1 at $\lambda 6$ cm). The flux density of the south-west component of 7 mJy is consistent with the upper limit of 10 mJy of Miley & Hartsuijker (1978), and is lower than the noise level of Jenkins *et al.* (1977). This component has been missed in the VLA (A-array, $\lambda 6$ cm) image obtained by Barthel *et al.* (1988) as well. It has possibly been detected by Douglas *et al.* (1980) at 365 MHz; they deduced that the angular size of the source was 28 ± 1 arcsec along a PA of 9° ± 3°, which is in broad agreement with the value of 31 arcsec along a PA of ~ 15° derived from the present measurements.

The overall spectrum of the source is straight ($\alpha = -0.94 \pm 0.02$). The spectral index of the north eastern component appears to be rather steep (~ -1.4) but more accurate flux densities are required to ascertain this. For the nuclear component, $\alpha = -0.58 \pm 0.07$ between 2.7 and 15 GHz.

The RM of the source is 10 ± 1 rad m^{-2}, with a ψ of 98° ± 4° (Simard-Normandin *et al.*, 1981a), which is consistent with the measurements here at $\lambda 6$ cm. Transatlantic VLBI at 5 GHz (Barthel *et al.*, 1984) detected a faint nucleus with a correlated flux density of $55 \lesssim S_{\mathrm{correlated}} \lesssim 70$ mJy.

0919+218 : This quasar has a triple structure (Figs. 3.13a and b), but with a very asymmetric surface brightness ratio for the outer components. For this reason, it appeared one-sided in the data of Potash & Wardle (1979). Even Hintzen *et al.* (1983), from their $\lambda 20$ cm VLA image, only tentatively classify it as a triple source. The $\lambda 6$ cm image clearly shows a jet from the nucleus towards the north eastern component, with the E-vectors aligned perpendicular to the jet and turning circumferential in the terminal hot spot.

The overall spectrum of the object is steep (α = −0.88 ± 0.02). The nuclear component is weak, and does not flatten the spectrum at higher frequencies. The spectrum of the northeastern component is also steep (α = −0.90 ± 0.08).

0932+022 : The outer components are very asymmetrically located (separation ratio ~ 0.2 (Figs. 3.14a and b). The eastern component was not resolved from the core by Miley & Hartsuijker (1978). On the western side of the nucleus, there is weak component (~ 3.5 arcsec from the core, with $\alpha \sim -1$ and $S_{1413} \sim 9$ mJy) in addition to the normal edge-brightened lobe at ~ 40 arcsec from the core (Hintzen *et al.* (1983); Swarup *et al.*, 1984), which has not been detected in the λ2 cm image.

The spectral index of the entire source is −0.78 ± 0.02; the indices for the western and eastern lobes and the core between 1.4 and 15 GHz are −0.99 ± 0.05, -0.76 ± 0.03, and −0.11 ± 0.09 respectively. From long-baseline interferometric observations at Jodrell Bank, Bentley *et al.* (1976) detected a flux density of 150 ± 50 mJy at 1666 MHz from a component of size < 0.1 arcsec. Since both the outer hot spots appear to be resolved by the VLA with a 0.5 arcsec beam at λ6 cm (Swarup *et al.*, 1984), this component is possibly the core. Within the quoted errors, its flux density at 1666 MHz is consistent with the core spectrum.

From VLBI observations, Preston *et al.* (1983) quote an upper limit to the correlated flux density of 110 mJy at 2.3 GHz. Barthel *et al.* (1984) measure a correlated flux density of 90 mJy at 5 GHz from a component of $\lesssim$ 1 mas size.

1007+417 : Though absent from the list of Kapahi (1981a), this source was included here because of the high ratio of the flux densities of the outer components reported by Owen *et al.* (1978). The images are presented in Figs. 3.15a, b and c. Kapahi (1981b) did not detect the component to the north.

The source has a straight spectrum ($\alpha = -0.68 \pm 0.01$). The spectral indices of the northern and southern lobes and the core are -0.51 ± 0.1, -0.72 ± 0.04, and -0.44 ± 0.13 respectively. The presence of the jet (imaged by Owen & Puschell, 1984 and by Saikia *et al.*, 1986) appears to steepen the core's spectrum.

1012+232 : This was classified as one-sided from the observations of Potash & Wardle (1979). Later observations of Hintzen *et al.* (1983) with the VLA at λ20 cm also did not detect the northern outer component of low surface brightness that is seen in the image here at λ20 cm (Fig. 3.16a).

The peak surface brightness of the northern component is comparable to the noise level of the image of Hintzen *et al.* (1983) (10 mJy/beam), while the noise level in the present map is 0.4 mJy/beam. The two data sets are therefore not inconsistent. The source is thus a triple, very asymmetric, with a separation ratio of ~ 2, and surface brightness ratio of ~ 4 at λ20 cm. The northern component remains undetected in the λ6 cm data (Fig. 3.16b).

There are suggestions of the beginnings of a curving jet-like feature that starts out at a position angle of ~ 138° (cf. Fig. 3.16b) and then bends southwards (cf.

Fig. 3.16a). The polarization E-vectors at $\lambda 6$ cm align perpendicular to the jet structure. The overall spectrum of the quasar is steep at low frequencies ($\lesssim 1$ GHz) and then flattens towards higher frequencies. The spread in the multiple measurements of flux density that are available at some frequencies suggests that the source is a variable at $\gtrsim 1$ GHz, and especially at 11 GHz. The nuclear component ($\alpha = 0.23 \pm 0.05$) has been reported to vary at 8 GHz by Potash & Wardle (1979).

The southern component has a steep spectrum ($\alpha = -0.35 \pm 0.3$). The derived flux density of the southern component by both Potash & Wardle (1979) (8 GHz) and the present $\lambda 6$ cm data appear to be underestimates.

Simard-Normandin *et al.* (1981a) report a very negative integrated RM for the source (-308 ± 32 rad m^{-2}), with ψ of $81° \pm 21°$. There are no other sources in their list that are local to that region of the sky for which they derive such a large negative RM.

1040+123 : This a very well studied 3CR object (3CR245). It appeared one-sided in the Cambridge 5-km map of Jenkins *et al.* (1977). However, from lunar occultation observations at 240, 408 and 1420 MHz, Lyne (1972) found that there are extended components on both sides of the nuclear component, though very asymmetric in their separation from it (see also Kapahi, 1981a). Indeed, the re-analysis of the data of Jenkins *et al.* (1977) data using the brighter component as the phase reference (Laing, 1981) shows the three components of the source.

The present VLA images at $\lambda 20$ and 6 cm (VLA A-array: Figs. 3.17a and b) show the triple source very clearly. The $\lambda 6$ cm image and shows the jet from the nucleus towards the western component (also clearly seen in the MERLIN image by Foley and Davis at 1666 MHz; cited in Hough, 1986). The polarization E-vectors align in the familiar "perpendicular" configuration. The images are consistent with previously published maps of the object (including Davis *et al.*, 1983; Hintzen *et al.*, 1983).

The overall spectrum of the source is steep up to ~ 5 GHz, and flattens out at higher frequencies. Below 5 GHz, α is -0.67 ± 0.002. The western and eastern components have a steep spectrum ($\alpha = -0.95 \pm 0.06$ and -1.2 ± 0.4 respectively). It appears that the 5 GHz flux density determined by the present VLA observations is a gross underestimate.

The multiple flux density measurements available at the same frequency indicate that the nuclear component is variable at frequencies $\gtrsim$ 5 GHz. While Bennett *et al.* (1984) do not classify the object as strongly variable from their monitoring at 5 GHz, Seilstad *et al.* (1983) find a significant variation in 1982 at 10.7 GHz; Wehrle *et al.* (1984) report a change in the correlated flux density measured by VLBI at 2.29 GHz between 1980 and 1982. The variability at 10.8 GHz is associated with structural changes on milliarcsecond scales (Hough 1986). Hough (1986) also cites variability detected at 8 GHz and 15 GHz.

Barthel *et al.* (1984) measured a correlated VLBI flux density of ~ 400 mJy for the milliarcsecond-scale nuclear component, and also detected structure on a scale of ~ 10 mas. The latter was confirmed by the VLBI observations of Hough (1986). From multi-epoch VLBI observations, Hough & Readhead (1988) derive a superluminal expansion velocity in the nucleus of ~ 3c.

The integrated RM of the object is ~ 30 ± 2 rad m^{-2} with ψ of 22° ± 1°.

1047+096 : This source was suspected to be one-sided from the observations of Miley & Hartsuijker (1978). They suggested (on the basis of evidence they found for a bridge of emission) that the extreme western component, ~ 60 arcsec from the central component was related to it. The present VLA observations clearly indicate that the central component of Miley & Hartsuijker (1978) is itself a triple source with largest angular size of ~ 21 arcsec. Hintzen *et al.* (1983) did not detect the northern lobe of this triple. The flux density of the northern component (Fig. 3.18) measured here is ~ 13 mJy at λ6 cm (with a size of 4.9 ± 3.6 arcsec along a PA of 1°), consistent with its non-detection at 1413 MHz to a limit of ~ 4 mJy/beam by Hintzen *et al.* (1983). The triple in the image of Hintzen *et al.* (1983) shows a curved structure, which is also reflected in the polarization structure imaged here.

There appears to be no evidence for any connecting jet linking the two extreme radio sources in any of the data. In fact, the extreme northwestern component itself appears as a double source (Hintzen *et al.*, 1983). A possible optical identification for this was looked for, but none was found above the limit of the POSS prints. Presently it is suggested that the northwestern source is unrelated to the QSO.

The spectrum of the entire complex appears straight between ~ 16 MHz and 5 GHz (α ~ −0.98 ± 0.03). It presently appears that the flux density of Wardle & Miley (1974) at 8GHz may be an underestimate. A single dish measurement at

15 GHz would be useful to determine if the spectrum flattens at frequencies > 5 GHz. The spectral index of the western (possibly unrelated) source is −0.6 ± 0.1 between 1.4 and 8 GHz, while that of the triple associated with the quasar is −1.02 ± 0.07 between ~ 0.6 and 8 GHz. The flux density of the western source at 610 MHz appears to be overestimated and has not been used in evaluating the spectral index. Barthel *et al.* (1984) report a marginal detection by VLBI, with a correlated flux density of ~ 25 mJy at 5 GHz.

Reliable measurements of the integrated polarization are not available to determine the RM.

1055+201 : This source appears one-sided in the present images (Figs.3.19), and also in the maps of Hintzen *et al.* (1983). There is a suggestion of extended structure on the opposite side of the core from the observations of Douglas *et al.* (1980) at 365 MHz, who find the source to be an asymmetric double with a flux density ratio of ~ 8.5 and largest angular size of ~ 50 arcsec. But the PA of −78° ± 2° for their model fit is not consistent with the data presented here. That the source is two-sided has now been confirmed (e.g., Hooimeyer *et al.* 1987).

The integrated spectrum of the source is straight below ~ 1 GHz ($\alpha = -0.69 \pm 0.02$) but flattens at higher frequencies. The spectral index of the extended component is −0.76 ± 0.04 between 1.4 and 15 GHz. The core has an inverted spectrum ($\alpha = 0.52 \pm 0.12$) between 1.4 and 15 GHz. The present VLA measurement of the flux density of the core is higher that that of Miley & Hartsuijker (1978) at the same frequency by ~ 60 per cent, suggesting that the core may be variable. The position of the milliarcsecond-scale nuclear component at 2.29 GHz determined by Morabito *et al.* (1982) is consistent with the position of the QSO within errors. Barthel et al. (1984) measure a correlated flux density of 950 mJy at 5 GHz with VLBI. Hooimeyer *et al.* (1987) infer the structure of the nuclear component on milliarcsecond scales to be one-sided, pointing towards the larger structure.

The source has an RM of -22.8 ± 2.2 rad m^{-2} and ψ of $123° \pm 5°$ (Tabara & Inoue, 1980). The PA derived here at $\lambda 6$ cm is consistent with this value.

1055+018 : Lunar occultation observations with the Ooty Radio Telescope at 327 MHz (Singal *et al.*, 1979) implied a double structure for this source, with a separation of ~ 1.5 arcsec and flux density ratio of 1:3 and with the QSO proposed as identified with the brighter component. (It may be worth noting that the object is in the direction of the Abell cluster 1139 (Owen *et al.*, 1982). Perley (1982) detected an outer component at $\lambda 20$ cm, but this is 4 arcsec away from the nucleus. The present observations do not detect any extended structure to the quasar, either at $\lambda 6$ or at $\lambda 2$ cm. However, Wardle *et al.* (1981) find evidence for a "halo"-like structure of size ~ 11 arcsec around the compact object at 2.7 GHz, and VLA imaging by Browne & Perley (1986) at $\lambda 6/20$ cm shows that the object has emission on *both* sides of the nucleus, with a largest angular size of 29 arcsec and surface brightness ratio of ~ 2. The object is an inter-planetary scintillator at 327 MHz (Banhatti *et al.*, 1983)

The overall spectrum of the object (Fig. 3.39) is flat. A linear fit to the quasi-simultaneous flux density measurements of Owen *et al.* (1980) which are marked by open circles in the figure, gives an α of -0.17 ± 0.01. The variability of the object is well established at both high frequencies (Medd *et al.*, 1972; Dent *et al.*, 1974; Bennett *et al.*, 1984) and low frequencies (Fanti *et al.*, 1981; Spangler & Cotton, 1981). The correlated VLBI flux has also been found to vary (Wehrle *et al.* 1984). Further, Slee (1984) observed an extremely strong outburst at 80 and 160 MHz, which is poorly understood. Gopal-Krishna *et al.* (1984) argue that it is very unlikely that slow interstellar scintillations are causing this outburst, and that if it is due to relativistic beaming, singularly large Doppler factors are implied. VLBI imaging at 1.667 GHz has shown milliarcsecond-scale extensions to the north west and north east (Romney *et al.* 1984). Two-epoch VLBI observations have led Padrielli *et al.* (1986) to conclude that, while marginally significant size variations occur on milliarcsecond scales, the expansion rate predicted by the relativistic beaming model for the low frequency variability is too low to be measured with their resolutions.

The polarization of the nuclear component measured here at λ6 and 2 cm is consistent with the measurements of Rudnick *et al.* (1985). The fractional polarization at λ6 cm is twice that measured by Perley (1982). The latter values are, however, consistent with those of de Pater & Weiler (1982). The integrated RM of Simard-Normandin *et al.* (1981a) is -45 ± 1 rad m^{-2} with ψ of $124° \pm 1°$.

1132+303 : This is a triple source but with a very asymmetric surface brightness ratio (Figs 3.20a and b). Potash & Wardle (1979) missed the fainter northwestern component, and the source was therefore designated as one-sided. A jet extends out from the central component towards the brighter southwestern lobe. The overall spectrum of the quasar is steep ($\alpha = -0.94 \pm 0.01$). The northwestern and southeastern components also have steep spectral indices of -0.99 ± 0.1 and -1.2 ± 0.1 respectively.

1136−135 : The two-sidedness of this quasar was masked by the low resolution of the earlier data of Miley & Hartsuijker (1978). This is almost so even in the B-array image presented here (Fig. 3.21a). But the A-array images at λ20 and 6cm (Fig. 3.21b and c) clearly show both the outer components with a separation ratio of 1.7:1. In the northwestern component, the polarization data suggest a highly ordered magnetic field along its elongation. The largest angular size measured here (~ 17 arcsec) is significantly lower than that of ~ 25 arcsec obtained by Fomalont & Moffet (1971) at λ21cm, by MacDonald & Miley (1971) or by Wilkinson *et al.* (1974) at λ11cm.

The position of the VLBI component detected by Morabito *et al.* (1982) agrees with that of the QSO. The integrated spectrum of the source is straight ($\alpha = -0.7 \pm 0.03$). The spread in the total flux density values at 10 GHz suggests that the source may be variable at this frequency. The total flux density at λ6 cm measured here (~ 1500 mJy) differs significantly from the values listed by Kühr *et al.* (1981) suggesting that the source might be variable at 5 GHz as well. The RM has been found to be ~ -25.6 ± 2.1 rad m^{-2} with ψ of 49° ± 5° by Tabara & Inoue (1980) and -26 ± 1 rad m^{-2} with ψ of 51° ± 2° by Simard-Normandin *et al.* (1981a).

1203+109 : Miley & Hartsuijker (1978) found an outer component of 8 mJy and a core component of 149 mJy at 5 GHz (the latter being associated with the QSO). It appears from the present observations (Figs 3.22a and b) and also the image of Hintzen *et al.* (1983) at λ20cm that this 'core' component is a triple source of rather complex structure. No component appears at the position of the outer component of Miley & Hartsuijker (1978) either in the image of Hintzen *et al.* (1983) or in the present observations. The polarization E-vectors in the jet are aligned perpendicular to it and bend with it.

Barthel *et al.* (1984) detect a correlated flux density of 50 mJy at GHz with European VLBI, possibly from a milliarcsecond-scale core. The overall spectrum of the source is steep ($\alpha = -0.77 \pm 0.02$). The southern component has an α of $\sim -1.3 \pm 0.1$. The resolution of the image at λ20cm here or in Hintzen *et al.* (1983) is insufficient to delineate the other component, so no spectrum has been determined.

1222+216 : The early observations of MacDonald & Miley (1971), Miley & Hartsuijker (1978) and Potash & Wardle (1979) did not detect the second outer component of low surface brightness. This component is severely misaligned with respect to the jet that extends to the eastern outer component (Figs. 3.23a and b). Note that the southern outer component in the B-array image is ~ 17 times the noise level in the image. The A-array image shows the curved jet with the aligned polarization E-vectors also curving.

Multiple flux density measurements at 5 GHz suggest that the source is variable. VLBI on the core at 5 GHz (Barthel *et al.*, 1984) shows a component of size < 1 mas with a flux density of ~ 600 mJy. Hooimeyer *et al.* (1987) report a one-sided milliarcsecond scale structure that is extended in the direction of the outer lobe. The total spectrum of the source is straight ($\alpha = -0.55 \pm 0.02$). α is -0.94 ± 0.11 for the southern component and -0.5 ± 0.2 for the eastern component.

1320+299 : This radio source is associated with a quasar of 20th magnitude. It was first mapped at radio wavelengths using the Westerbork Synthesis Radio Telescope (Fanti *et al.* 1977, Fanti *et al.*, 1979a) at λ20 and 6cm. The object showed a very peculiar one-sided structure: two components (B and C) on the same side of the component coincident with the quasar (A) and at separations ~ 25 and 50 arcsec respectively from A. It was one of the most extended among the then known one-sided sources (Kapahi, 1981a).

Feretti *et al.* (1982) confirmed the one-sidedness using the WSRT, and showed steepening of the radio spectral index outwards from component A. The orientation of the magnetic field (as inferred from the polarization orientation—the deduced value of the external RM was low) was found to differ significantly from one component to another. Applying the model of Burn (1966), they inferred from the fractional polarization values that the magnetic field in all the three components was rather irregular. Further, from a comparison of its optical images on the POSS print and a Palomar plate taken by Bracessi in 1967, they inferred that the nuclear component was variable in the optical. The source did seem a typical one-sided quasar in that it had a very prominent nuclear component and optical variability.

But given its inferred size (largest angular size = 50 arcsec), Feretti *et al.* (1982) concluded that relativistic effects were unlikely to be the cause of the asymmetry.

The VLA radio images made here are presented in Figs. 3.24a to g. There is no emission connecting the three well separated components. Component A has a one-sided radio structure with a prominent core. The spectral index is -0.42 ± 0.05. Clearly, there is very little depolarization for component A. The RM is also low (~ 5 rad m^{-2}). Component B has an interesting asymmetric structure, with a high brightness 'head', and a 'tail' bending towards the north-east and extending to ~ 3 arcsec. The polarization at $\lambda 6$ cm appears to be perpendicular to the elongation and follows the bend in the structure. There appears to be considerable depolarization between $\lambda 6$ and 20 cm. Component C shows a slight extension towards the north-west. No significant depolarization is indicated. The RM inferred from the $\lambda 20$cm (A-array) and $\lambda 6$ cm (B-array) data is ~ 5 rad m^{-2}.

The spectra of components A, B, and C are shown in Fig.3.39. The spectral indices of the components have been evaluated using the lowest resolution VLA images at $\lambda 20$, 6 and 2cm. Component A has a flat spectrum while B and C have steep spectra.

A CCD image of the field of 1320+299 (3.2 arcmin x 1.9arcmin) was obtained at the f/15 Cassegrain focus of the 1.0m Jacobus Kapteyn Telescope, La Palma on August 3, 1986 (Fig. 3.24h). A 1500 second exposure was taken through an R band interference filter. The seeing was ~ 1 arcsec, and the zenith extinction coefficient 0.11 mag. R magnitude of the QSO is 19.95. Any other object that might be coincident with or be in between radio components B and C has an R magnitude fainter than 21.5 mag (which is five times the r.m.s. of the image).

Are the three components A, B and C physically related and part of the same object? The probability of three unrelated sources so aligned by chance is extremely low, but there is no evidence from the radio data alone of any physical association. Component A has a radio structure that is typical of core-dominated radio quasars mapped with limited dynamic range, and its QSO might even be a variable. Although component B is reminiscent of low radio luminosity 'head-tail' sources usually found in clusters of galaxies, since any associated galaxy is fainter than 21.5 mag and hence would certainly be further than redshift ~ 0.5, the implied radio luminosity is very high for a head-tail source (cf. O'dea & Owen 1985b). On the other hand, B and C could be the outer components of a single radio source.

1347+539 : Owen *et al.* (1978) detected a marginally resolved component with a flux density of 50 ± 18 mJy at 2695 MHz at a distance of ~ 31 arcsec from the core of this quasar, which suggested a possible one-sided structure. The present observations do not detect this component to a limit of ~ 1.8mJy/beam with a beam of ~ 4.9 x 3.8 arcsec. Recent VLA observations with the A-array at $\lambda 6$ cm (Perley, 1982); Owen & Puschell, 1984) show one-sided emission extending up to ~ 5 arcsec to the north west of the core. They do not detect any component at the position of the outer component of Owen *et al.* (1978).

The overall spectrum of the quasar is flat at high frequencies and shows signs of steepening at low frequencies. The source appears to vary at 10.8 GHz (Seilstad *et al.*, 1983). The position of the nuclear component detected by VLBI at 2.29 GHz agrees well with that of the QSO.

1354+195 : This is a core dominated triple source (Figs. 3.25a and b). The jet towards the southern component that is suggested in the figures is seen clearly in the λ18cm image of Rusk & Rusk (1986). The outer components are asymmetrically located (separation ratio = 1.8). The southeastern component was not detected by Miley & Hartsuijker (1978) and MacDonald & Miley (1971), and the quasar was thereby was included in the list of Kapahi (1981a). The A-array observations of Perley (1982) also missed the southern component.

The quasar has long been known to be radio variable (Medd *et al.*, 1972; Altschuler & Wardle, 1976). Kesteven *et al.* (1976) and Wardle *et al.* (1981) found it to variable at 2.7 GHz, while monitoring by Bennett *et al.*, 1984 showed mild variability at 5 GHz. The optical QSO is also known to be mildly variable (Pica *et al.*, 1980). VLBI observations at 10.7 GHz (Marscher & Broderick, 1983) indicate extensions of up to ~ 7 mas. The most compact structure is an equal double (separation ~ 0.75 mas) along a PA of 151°, close to the axis of the entire source.

From transatlantic VLBI at 5 GHz, Zensus *et al.* (1984) find 53 percent of the total flux density in a compact component of size ~ 0.5 mas. U.S. VLBI at 5 GHz by Rusk & Rusk (1986) shows a milliarcsecond secondary component ~ 8 arcsec southeast of the brighter compact component.

The radio spectrum is steep below 2 GHz ($\alpha = -0.65 \pm 0.04$) but flattens above it. If the weaker component detected by Wilkinson *et al.* (1974) is assumed to be the core, then the core spectrum turns over around 1-2 GHz. The spectral index of the north-west component is −1.04 ± 0.05.

The reported RMs of this source are 4.2 ± 0.8 rad m^{-2} with ψ of 72° ± 1° (Tabara & Inoue, 1980) and 5 ± 1 rad m^{-2} with ψ 69° ± 2° (Simard-Normandin *et al.*, 1981a). The polarization orientations obtained here are consistent with these values.

1415+463 : Kapahi (1981b) found this to be one-sided. The model fit of Owen *et al.*(1978) had indicated that the nuclear component was a double at 2.7 GHz. The present data (Figs 3.26a and b) do not corroborate this, nor do subsequent published data (Perley, 1982); Perley *et al.*, 1982; Owen & Puschell, 1984); the quasar still appears one-sided. Imaging with better sensitivity is needed to detect any jet from the core component towards the western double. There is mild suggestion of it in the λ20cm image here and also in the polarization data of Owen & Puschell (1984).

The nuclear component appears to be mildly variable at frequencies $\gtrsim$ 1 GHz. Monitoring at 10.8 GHz does indicate variability (Seilstad *et al.*, 1983). The overall spectrum is flat with signs of steepening at frequencies lower than ~ 2 GHz. The spectrum of the nuclear component appears to turn over at ~ 3 GHz. The spectrum of the western double is steep with an index of −0.88 ± 0.08. With VLBI at 2.29 GHz, Morabito *et al.* (1982) detect a milliarcsecond component which agrees well in position with that of the QSO.

1419+315 : Fanti *et al.* (1977) and Fanti *et al.* (1979a) first suggested that this quasar was one-sided. While the core component appeared resolved in their observations, the outer component located ~ 130 arcsec to the south-east appeared unresolved. In the present observations (VLA C-array: Fig. 3.27a, b and c), the S-E component still appears unresolved, but the core component is resolved into three components misaligned by about 80°. The quasar is coincident with the central one of the three, which is also the most weakly polarized and has a flat spectrum ($\alpha \sim -0.31 \pm 0.11$). The polarization E-vectors appear to follow the bends in the overall structure.

The spectral index of the northern triple is -0.6 ± 0.1 between 1.4 and 15 GHz. The spectrum of the entire complex appears straight between 178 and 5000 MHz with $\alpha \sim -0.69 \pm 0.04$. The monitoring of Seilstad *et al.* (1983) did not show any variability of the quasar at 10.8 GHz between 1979 and 1982. (See Saikia *et al.*, 1987b for a detailed study.)

There is no evidence in any of the data for any emission linking the northern triple with the southern component, and an examination of the POSS prints showed no possible identification. It is presently suggested that the two are unrelated objects. It has a steep radio spectrum ($\alpha = -0.8 \pm 0.1$ between 1.4 and 5 GHz) and is probably a CSS object.

1433+177 : This quasar is a slightly misaligned triple source (misalignment angle of ~ 20°) with a highly asymmetric surface brightness ratio of ~ 8:1 (Figs. 3.28a and b). The weak and fairly diffuse northern component that also appears in the map of Hintzen *et al.* (1983) was not detected by the earlier observations of Wills (1979), and therefore the source was categorized as of the one-sided kind. Hintzen *et al.* (1983) also detected possible further emission trails to the north.

The presence of a jet that is suggested by the polarization in the B-array image is clearly manifest in the A-array $\lambda6$ cm image (Fig. 3.28b). This image also reveals a highly polarized extension to the compact core which is unresolved by the B-array map.

The source has a steep overall spectrum with index $\alpha \sim -0.7 \pm 0.01$ below ~ 1 GHz but flattens at higher frequencies. The spectrum of the core component appears to turn over at ~ 2 GHz. The core flux density plotted at 2.7 GHz (Wills, 1979) is probably dominated by emission from the extension to the core referred to above. The northern and southern components have steep spectra ($\alpha = -0.7 \pm 0.1$ and -0.8 ± 0.1 respectively).

1509+158 : This quasar appeared one-sided in the observations of Wills (1979), but this has turned out to be due to the very asymmetric separation ratio of its outer components. The eastern component that is coincident with the QSO appears to have extensions in both the image (Figs. 3.29a, b and c), and the two-sided nature of the source is explicit in the A-array image at $\lambda6$ cm.; it reveals a compact component coincident with the QSO, well separated from the eastern lobe.

The westward extension to the eastern component in the lower resolution images and in the orientation pattern of the polarization suggests the presence of a jet connecting the two components. This is manifest in the A-array image, though at a low surface brightness level.

The source has a steep overall spectrum ($\alpha = -0.83 \pm 0.05$). The eastern and western components have more or less steep spectra above ~ 1 GHz

(α = −0.6 ± 0.1 and ~ −0.8 ± 0.1 respectively).

1547+309 : The map of Rudnick & Adams (1979) at 8 GHz showed this object to be a connected double source with a galaxy coincident with the northwestern component. Katgert-Merkelijn *et al.* (1980) also found a similar structure with the WSRT at 5 GHz. The object was therefore classified as one-sided.

The source has a steep spectrum (α = −0.97 ± 0.01). The VLA B-array image from the present observations (Fig. 3.30) clearly shows a typical edge-brightened triple morphology. It is therefore presently suggested that the optical identification is a chance association. (See Saikia *et al.* (1986) for details.)

1636+473 : The observations of Kapahi (1981b) first showed this source to be one-sided. The lobe to the north of the core component (Figs. 3.31a, b and c) is quite odd; it is elongated along an axis that is at ~ 70° to the line joining the core and the lobe's eastern peak. An image with MERLIN at better resolution is presented by Browne *et al.* (1982a) and Wilkinson (1982). The data of Perley (1982) and Perley *et al.* (1982) are consistent with all of the above. A map at 2.7 GHz with the Cambridge 5-km telescope by Pooley has also been quoted as having the same general features (Browne *et al.* 1982a).

The northern lobe appears somewhat similar to a normal double/triple radio source. An optical identification for it was therefore looked for on the POSS prints, but no likely candidates were found. It is interesting that from VLBI observations Porcas (personal communication) finds the core to be extended by ~ 0.5 mas in the north-south direction.

The position of the milliarcsecond core component detected by Morabito *et al.* (1982) with VLBI at 2.29 GHz agrees well with that of the QSO. The overall spectrum of the source flattens at high frequencies and possibly rises above ~ 10 GHz. Although the 90 GHz datum has large errors it shows that the spectrum must steepen again between 10 and 90 GHz. While the spectrum of the core appears to be curved, that of the extended emission is straight between 408 MHz and 15 GHz ($\alpha = -0.72 \pm 0.03$). The source is a variable at 10.8 GHz (Seilstad *et al.*, 1983). The PAs in the core are similar at $\lambda 6$ and 2cm. Assuming Faraday rotation to be small at $\lambda 6$ cm, the projected magnetic field of the extended component would be along its axis.

1637+574 : Observations with the NRAO interferometer at $\lambda 11$cm showed that this quasar consists of a core and a secondary component at a separation of ~ 9 arcsec towards the south-west (Owen *et al.*, 1978). This secondary component is not found in the present observations (Figs. 3.32). However, there is evidence for weak extended emission towards the north and north-west. This structure is consistent with the observations of Perley (1982) and Rudnick & Jones (1983).

The quasar has a complex spectrum. There is a large spread in the flux density values where multiple measurements are available, indicating that the source is definitely variable. (Seilstad *et al.* (1983) have detected variability at 10.8 GHz.) From VLBI observations at 5 GHz, Pearson & Readhead (1981) find the core flux density to be ~ 810 mJy. Morabito *et al.* (1982) measured a VLBI position for the milliarcsecond component that agrees well with that of the QSO. The spectral index derived from a straight fit to the quasi-simultaneous flux density measurements of

Landau *et al.* (1986) is 0.03 ± 0.004.

From their VLA observations at λ18 and 20cm, Rudnick & Jones (1983) find the RM of the compact component to be 22 ± 42 rad m^{-2}. Using their VLA measurements at λ6 and 2cm as well, the RM is 13 ± 5 rad m^{-2}.

1729+501 : This object was first shown to be one-sided by Owen *et al.*(1978). No second outer component has been detected in the images given here (Figs. 3.33a, b and c). The quasar has a relatively weak core component contributing only ~ 10 percent of the total flux density at λ6 cm. Hintzen *et al.* (1983) and Owen & Puschell (1984) also find the source to be one-sided from VLA observations at λ20 and 6cm respectively.

The core spectrum appears to flatten below ~ 5 GHz. The integrated spectrum appears straight between 26 MHz and 15 GHz ($\alpha = -0.73 \pm 0.03$). The 26 MHz flux density has been estimated by subtracting the extrapolated flux density of the confusing source, 1729+491 (4C 49.29). For the extended component to the east, α is -0.73 ± 0.03 between 1.4 and 15 GHz.

1741+279 : The southern outer component of low surface brightness was missed in the earlier observations of Potash & Wardle (1979), and the source was therefore included in the list of Kapahi (1981a). The present A-array image at λ6 cm (Fig. 3.34) shows the two (slightly non-collinear) outer components to the north and south of the nucleus. The surface brightness ratio is ~ 6:1 at λ6 cm. The image here also shows a jet extending from the nucleus to the outer component.

The source has a steep overall spectrum (α = −0.63 ± 0.02). Spangler & Cotton (1981) tentatively suggest that it may be a low frequency variable, though they remark that it is singular in having a steep overall radio spectrum to boot.

Using data from Hintzen *et al.* (1983), the spectral indices of the northern and southern components are −0.69 ± 0.11 and −0.81 ± 0.11 respectively. The nucleus is not delineated well enough there to permit determination of its spectrum.

1842+681 : This quasar appears to have a faint one-sided extension to the north-west at λ20cm (Fig. 3.35). Only the nuclear component is detected at λ6 cm. No image is therefore presented. Owen *et al.*(1978) had found a secondary component to north of the core at λ11cm.

The overall spectrum of the quasar is complex. A straight fit gives an index of 0.08 ± 0.01. The spread in the flux density values suggests that the source is variable. Kapahi (1981b) measured a change of ~ 30 percent in the flux density at 5 GHz over ~ 3 months. It is also variable at 10.8 GHz (Seilstad *et al.*, 1983).

The spectrum of the nuclear component as derived from the peak surface brightness values of the present VLA images is inverted (α = 0.45 ± 0.08). The position of the compact component detected by Morabito *et al.* (1982) with VLBI at 2.29 GHz agrees with that of the QSO.

2041−149 : The lunar occultation observations of Singal *et al.* (1979) detected two components at 327 MHz, one of which was coincident with a red object on the POSS plates. The structure obtained by the present maps at λ6 and 20cm (Figs 3.36a and b), broadly confirm this. However, the more detailed morphology (particularly at λ20cm) is strongly reminiscent of a double radio source with a weak, undetected core. Both the components have steep spectra (α is −0.94 ± 0.1 and −0.98 ± 0.003 for the western and eastern components respectively) and the λ20cm image shows a bridge of emission between them. The source as a whole has an α of −0.94 ± 0.02. It is possible that the coincidence between the western component and the red object is by chance. The POSS plates were searched for an object in between the two radio components, but none was found.

A deep optical observation, as also more sensitive radio observations at high frequencies that might reveal a possible core, would be of interest. In any case, the source cannot really be classed as "one-sided" since the component coincident with the supposed optical identification is not of flat spectrum.

2251+134 : Perley (1982) has shown this to be a triple source. The maps presented in Fig. 3.37 confirm this. Wills (1979) had detected two components for this source, one coincident with the QSO and the other to the north west at a position angle of ~ 40°. This had led to its inclusion in the list of Kapahi (1981a). But the northwestern component has not been detected in the maps presented here, nor by Perley (1982).

The source has a separation ratio of ~ 1.6:1. Both the total intensity distribution and the polarization pattern at λ6 cm suggest a curved jet bridging the core and the southern component.

Morabito *et al.* (1982) measured a position for a milliarcsecond-scale component with VLBI AT 2.29 GHz that agrees with that of the QSO. Hooimeyer