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Flux density and linear polarization measurements of variable radio sources at λ 9.00 mm (33.5 GHz)

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Summary. Measurements of the flux densities of 12 extragalactic sources at λ 9 mm throughout 1980 June to 1982 March are presented. This period includes the decay of the 1980 outburst of BL Lac. Measurements of the integrated linear polarization of the stronger sources are also given and compared with those of other observers.

1 Introduction

The flux density measurements reported in this paper are a continuation of those presented earlier by the same authors (Flett & Henderson 1981) and derive from a further seven observing periods at the SERC's Chilbolton Observatory between 1980 June and 1982 March. The latter date ends the series of observations; thereafter the Chilbolton dish was no longer available for this type of radio astronomical measurement.

Details of the apparatus and experimental procedure, given in the original paper, are not repeated here.

2 Results

2.1 FLUX DENSITY MEASUREMENTS

Monitoring of the 12 sources 3C 84, NRAO 150, 3C 111, 3C 120, OJ 287, 3C 273, 3C 274, 3C 279, 3C 345, BL Lac, 3C 446 and 3C 454.3, together with the primary flux density standard DR 21 has continued. The new data are presented in Table 1. Those for BL Lac are also shown as a graph (Fig. 1) because of the particular interest of its outburst during 1980.

2.2 POLARIZATION MEASUREMENTS

Measurements of the linear polarization of the stronger sources have been made as described by Flett & Henderson (1979) and are given in Table 2. Several (N) independent measurements were combined to give one tabulated result P_M per cent. Each P_M per cent was then corrected in the manner described by Wardle & Kronberg (1974, p. 254) to give an unbiased value P per cent. The weighted mean values of Table 2 were similarly corrected.

Table 1. Variations of flux density at λ9 mm.

Jy (error) Date:	1980.69	1980.94	1981.21	1981.41	1981.76	1981.96	1982.24
3C 84	52.1 (0.3)	50.6 (0.3)	50.8 (1.6)	46.9 (2.9)	55.6 (0.9)	60.5 (2.5)	52.9 (0.5)
NRAO 150	8.4 (1.0)	8.3 (0.3)	7.8 (0.4)	7.3 (0.5)	7.0 (0.5)	7.8 (0.3)	7.1 (0.2)
3C 111	2.5 (0.3)	2.8 (0.9)	1.9 (0.2)			2.9 (0.9)	2.2 (0.2)
3C 120	3.3 (0.1)	2.2 (0.2)	2.5 (0.2)	3.7 (2.2)		2.8 (0.2)	3.7 (0.7)
OJ 287	3.9 (0.6)	3.9 (0.1)	4.1 (0.5)	6.2 (0.2)	6.4 (0.2)	7.9 (0.4)	3.6 (1.0)
3C 273	24.7 (0.1)	28.2 (0.3)	30.5 (0.9)	30.0 (0.9)	34.4 (0.2)	30.9 (0.2)	31.3 (0.4)
3C 274	17.2 (0.7)	13.9 (0.3)	14.5 (0.9)	15.4 (0.7)	14.2 (0.3)	14.3 (0.2)	13.7 (0.3)
3C 279	10.5 (0.6)	8.7 (0.6)	9.8 (0.4)	10.1 (0.7)		11.3 (0.3)	9.3 (1.7)
3C 345	14.4 (0.6)	12.8 (0.2)	14.8 (0.4)	15.9 (0.9)	16.4 (0.6)	17.9 (0.9)	16.6 (0.9)
BL LAC	11.6 (0.6)	7.3 (0.4)	6.4 (0.3)	5.1 (0.4)	6.7 (0.7)	5.4 (0.5)	3.8 (0.1)
3C 446	5.6 (0.4)	5.4 (0.6)	5.8 (0.4)	5.8 (1.0)	7.1 (0.8)	6.8 (1.0)	5.4 (0.1)
3C 454.3	11.0 (0.8)	8.0 (0.3)	9.7 (2.1)	12.1 (1.1)	14.4 (0.6)	12.7 (0.7)	10.6 (0.7)

Note: the errors quoted in all tables are standard errors.

3 Discussion

The results are compared in Table 3 with others at wavelengths between 20 and 3 mm where available. For further information, reference may be made to the compilation by Tabara & Inoue (1980) of all the data on linear polarization of radio sources at wavelengths down to 3 mm published prior to 1978 December. In addition, a review of the optical and infrared polarization of active extragalactic objects (blazars) by Angel & Stockman (1980) contains measurements of some 60 sources including 3C 279, 3C 345, BL Lac and 3C 454.3, while a study of the infrared polarization of 18 BL Lac objects by Impey *et al.* (1982) includes data

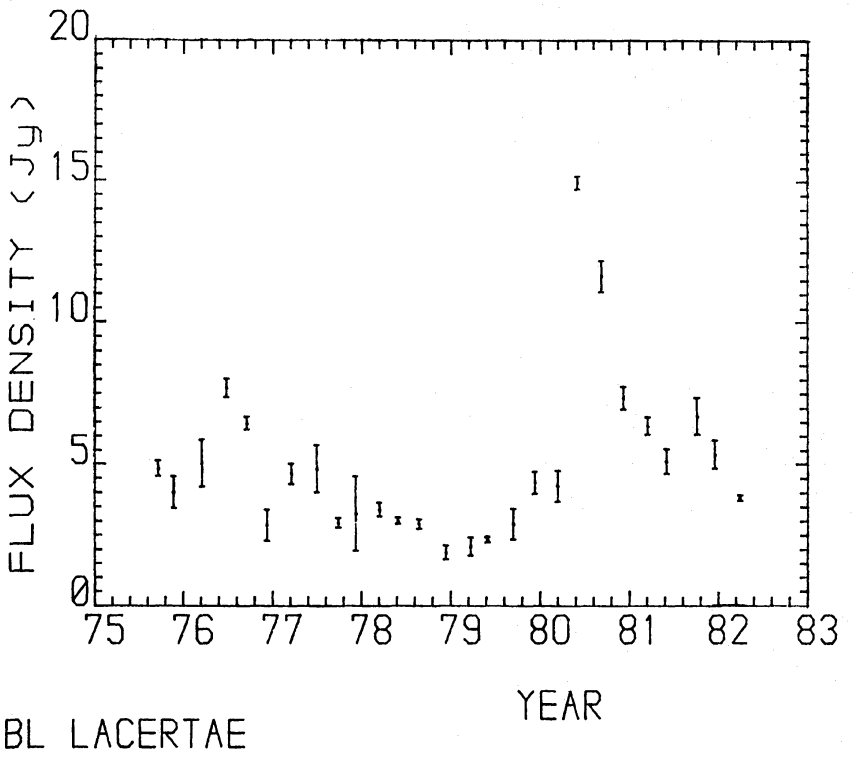

Figure 1. Variation of the flux density of BL Lac at λ 9 mm.

Table 2. Polarization measurements at λ 9 mm.

Date	P_M per cent	Error (±)	P per cent	PA (°)	Error (±)	Intensity (Jy)	Error (±)	N
NRAO 150								
1979.95	3.6	1.4	3.3	102	11	8.3	0.6	14
1980.69	3.0	2.6	1.5	164	23	8.4	1.0	11
Weighted mean P per cent = 2.2 ± 1.2						Weighted mean PA = 108°.5 ± 13.2		
3C 273								
1979.65	3.7	1.4	3.4	138	11	17.1	1.0	8
1980.69	3.9	1.2	3.7	138	9	24.7	0.1	5
1980.94	3.7	1.1	3.5	119	9	28.2	0.4	5
1981.21	6.1	0.9	6.0	137	4	30.5	0.1	4
1981.43	4.4	1.1	4.3	170	7	30.0	0.9	5
Weighted mean P per cent = 4.0 ± 0.5						Weighted mean PA = 140°.0 ± 3.6		
3C 274								
1979.70	4.0	0.8	3.9	63	6	14.6	0.4	7
1980.69	7.0	1.9	6.7	46	8	17.2	0.7	6
1980.94	11.2	1.9	11.0	42	5	13.9	0.3	6
1981.21	4.9	1.5	4.7	31	9	14.5	0.9	11
1981.43	3.2	2.2	2.3	56	19	15.4	0.7	5
Weighted mean P per cent = 4.7 ± 0.6						Weighted mean PA = 50°.9 ± 3.7		
On omission of result dated 1980.94:						Weighted mean PA = 53°.7 ± 4.5		
Weighted mean P per cent = 4.0 ± 0.6								
3C 279								
1979.70	4.2	2.3	3.5	55	15	8.1	0.3	6
1979.95	10.1	3.8	9.4	81	11	8.4	0.5	5
1981.21	2.7	3.6	0	25	34	9.8	0.4	3
Weighted mean P per cent = 3.7 ± 1.7						Weighted mean PA = 62°.8 ± 11.3		
3C 345								
1979.95	6.6	2.8	6.0	5	12	9.4	0.5	5
1980.69	3.3	1.8	2.8	5	15	14.4	0.6	9
1981.21	3.3	2.7	1.9	161	22	14.8	0.4	5
Weighted mean P per cent = 3.6 ± 1.3						Weighted mean PA = 0°.6 ± 9.5		
BL LAC								
1980.42	8.0	2.1	7.7	121	8	15.0	0.3	6
1980.69	4.4	1.4	4.2	30	9	11.6	0.6	8
3C 454.3								
1979.70	6.8	1.5	6.6	31	6	6.1	0.4	11
1979.95	3.8	4.2	0	14	29	5.8	0.6	6
1980.41	4.2	2.7	3.2	180	18	7.5	0.7	4
1980.69	4.6	2.2	4.0	47	13	11.0	0.8	7
1981.21	8.7	2.7	8.3	167	9	9.7	2.1	4
Weighted mean P per cent = 4.5 ± 1.0						Weighted mean PA = 22°.5 ± 6.2		

on 3C 345 at 2.2 μm. Inoue (1977) proposes a simple model to explain polarization measurements of these variable sources and also derives rotation measures and intrinsic position angles.

With the exception of 3C 274 the sources are known to show variations with time that are in some cases large and rapid. The new polarization data, which must be viewed in this context, are for a wavelength where too few measurements are currently available. We now consider the results for individual sources.

Table 3. Polarization measurements for six sources at mm wavelengths.

NRAO 150 mm	*P* per cent	±	PA	±	Epoch	Reference
9.0	2.2	1.2	108	13	1980.3	This paper
3C 273						
19.4	1.2	0.2	131	3	1966 Apr	Allen, Barrett & Crowther (1968)
15.5	1.6	0.6	147	11	1967–68	McCullough & Waak (1969)
9.55	2.1	1.6	142	49	1967.4	Hobbs (1968)
9.55	2.3	0.7	144	8	1969.5	Hobbs & Waak (1972)
9.5	1.8	0.6	140	16	1970 Dec	Wardle (1971)
9.0	4.0	0.5	140	4	1980.7	This paper
3.03	2.3	0.5	125	6	1977 Feb	Hobbs, Maran & Brown (1978)
3C 274						
19.7	2.5	0.7	55	5	1965–66	Allen *et al.* (1968)
19.0	4.4	0.7	41	10	1965–66	Allen *et al.* (1968)
9.55	3.6	2.2	26	15	1969.5	Hobbs & Waak (1972)
9.5	4.4	0.7	51	8	1970 Dec	Wardle (1971)
9.0	4.7	0.6	51	4	1980.7	This paper
	(4.0	0.6)	(54	5)	1980.7	This paper
3.03	2.4	2.1	38	16	1977 Feb	Hobbs *et al.* (1978)
3C 279						
19.4	0.9	1.1	97	20	1966 Apr	Allen *et al.* (1968)
15.5	3.8	0.8	103	6	1967–68	McCullouch & Waak (1969)
9.55	4.1	4.0	8	22	1969.5	Hobbs & Waak (1972)
9.0	3.7	1.7	63	11	1980.5	This paper
3C 345						
9.55	6.5	2.7	118	15	1969.5	Hobbs & Waak (1972)
9.0	3.6	1.3	1	10	1980.6	This paper
3.03	6.0	3.1	40	14	1977 Feb	Hobbs *et al.* (1978)
3C 454.3						
15.5	0.8	0.7	11	25	1967–68	McCullough & Waak (1969)
9.5	2.9	2.2	118	32	1969.5	Hobbs & Waak (1972)
9.0	4.5	1.0	23	6	1980.5	This paper

3C 273

The position angle appears to be well measured and remarkably constant for wavelengths near 1 cm. Our value of *P* per cent is higher than that obtained by other workers.

3C 274 (VIRGO A)

If 3C 274 is regarded as a constant source then the weighted mean value of *P* per cent is 4.5 ± 0.5 and of PA is 50° ± 3 at approx. 9.3 mm. They are obtained from vector addition of data at λ9.55, 9.5 and 9.0 mm. If our one inexplicably large result of 1980.94 is omitted then revised values are shown in brackets and change the above *P* per cent and PA to 4.1 ± 0.5 and 52° ± 3 respectively.

BL LAC

The new data on intensity show the 1980 outburst decaying to a more normal quiescent level and supplement those of Mutel, Aller & Phillips (1981) at 6.3, 3.8 and 2.1 cm and of

Ennis (1982) at 1 mm. The position angle of the polarized component changed by about 90° (with 180° ambiguity) between epoch 1980.42 when the outburst had just reached its peak and 1980.69 when the outburst was just subsiding. Aller, Aller & Hodge (1981) give measurements of the flux density and linear polarization of this source at 6.3, 3.8 and 2.1 cm for the period 1977 April to 1980 June. The paper by Phillips & Mutel (1982) which describes remarkable changes in the structure of BL Lac between 1980.93 and 1981.44 is also of relevance.

4 Conclusion

There remains a need for simultaneous measurements over the widest range of wavelengths attainable of intensity and polarization for each of the sources listed and a greater accuracy at the mm and low cm wavelengths. In our case the magnitude of errors severely limits the separation of true variability from statistical fluctuations in many cases.

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References

Allen, R. J., Barrett, A. H. & Crowther, P. P., 1968. *Astrophys. J.*, **151,** 43.
Aller, H. D., Aller, M. F. & Hodge, P. E., 1981. *Astr. J.*, **86,** 325.
Angel, J. R. P. & Stockman, H. S., 1980. *A. Rev. Astr. Astrophys.*, **18,** 321.
Ennis, D. J., 1982. *PhD thesis,* California Institute of Technology.
Flett, A. M. & Henderson, C., 1979. *Mon. Not. R. astr. Soc.*, **189,** 867.
Flett, A. M. & Henderson, C., 1981. *Mon. Not. R. astr. Soc.*, **194,** 961.
Hobbs, R. W., 1968. *Astrophys. J.*, **153,** 1001.
Hobbs, R. W. & Maran, S. P. & Brown, L. W., 1978. *Astrophys. J.*, **223,** 373.
Hobbs, R. W. & Waak, J. A., 1972. *Astr. J.*, **77,** 342.
Impey, C. D., Brand, P. W. J. L., Wolstencroft, R. D. & Williams, P. M., 1982. *Mon. Not. R. astr. Soc.*, **200,** 19.
Inoue, M., 1977. *Pub. Astr. Soc. Japan,* **29,** 593.
McCullough, T. P. & Waak, J. A., 1969. *Astrophys. J.*, **158,** 849.
Mutel, R. L., Aller, H. D. & Phillips, R. B., 1981. *Nature,* **294,** 236.
Phillips, R. B. & Mutel, R. L., 1982. *Astrophys. J.*, **257,** L19.
Tabara, H. & Inoue, M., 1980. *Astr. Astrophys. Suppl. Ser.*, **39,** 379.
Wardle, J. F. C., 1971. *Astrophys. Lett.*, **8,** 183.
Wardle, J. F. C. & Kronberg, P. P., 1974. *Astrophys. J.*, **194,** 249.