MULTI-EPOCH VLBI OBSERVATIONS OF BL LAC OBJECT 0716+714

W. W. Tian

National Astronomical Observatories, CAS, Beijing 100012, China. tww@ns.bao.ac.cn

ABSTRACT

Five epoch global VLBI and VLBA observations of the BL Lac object 0716+714 at 1.3 cm between 1993 and 1997 show its nuclear structures on sub-parsec to parsec scale with a strongly dominant core and several superluminally moving weak knots in the jet. The position angle of the core-jet structure varies in the range $4^0 - 26^0$. Three epoch VLBI observations at 3.6 cm between 1994 and 1996, and two epoch from 2 cm VLBA survey between 1996 and 1997, complement the source's nuclear structure.

INTRODUCTION

In radio band, 0716+714, is compact, core dominated BL Lac. VLBI studies since more than 20 years at 5GHz shows its core-dominated jet extending to the north with evolving structure. VLBI jet is inclined to the VLA jet (about 90^0). 0716+714 is observed by VLBI at 1.3, 2 and 3.6 cm between 1993 and 1996. All data are mapped by using the standard self-calibration algorithm in DIFMAP. Gaussian component models are then fitted to the calibrated visibilities by the CALTECH package.

RESULTS

Fig. 1 shows the morphology of 0716+714 at 1.3 cm with high resolution (0.2 – 0.4 mas). All pictures reveal its core-single side jet structures on a scale of 0.1 pc to 10 pc: strongly core dominated features, more than 4 weak knots in the jet. Among these observations, the one of Mar 21, 1994 has the most uniform UV-coverage and the longest observation time, therefore it has the highest dynamic range in image. The position angle of the core-jet structure varies in the range $4^0 - 26^0$. Basically the positional angles of knots gradually become smaller with increasing distance from the core. Thus the jet slightly tends to the north.

The first three plots in Fig. 2 show the nuclear structures of 0716+714 at 3.6 cm. Its morphology at 3.6 cm is very similar with its 1.3 cm counterpart: at least four resolved components and same extending direction for jet. For the first plot in Fig. 2, which is from full track observations with almost circular beam, the jet is continuous and very well constrained in narrow channel which is seen to slightly turn towards the north. This reveals that the energy outflow from the core is smoothly transferred into outer regions. This also suggests that the jet isn't seriously hampered by surrounding medium. The two images from the 2 cm VLBA survey are exhibited in the right of Fig. 2. Only the brightest jet components are seen at 2 cm. This should be related with the low dynamic range from the observations with totally intergrated time less than 1 hour for this source. Even though, the core-jet structure is still seen, the extension of the jet is in the same direction as in the other two band's.

The results of modelfits for all 10 datasets are summarized in Table 1. Modelfits confirm the detailed seen in the maps. In Table 1, columns 1 and 2 exhibit the observation epoch and frequency for each dataset, columns 3 to 8 give for each component its: label, total intensity, separation from the core r, error in r, structural position angle from the core θ, error in θ, and size (FWHM). According to our experience in model fitting, the solutions are not unique, there are usually a few sets of reasonable parameters of the model which can fit the calibrated data equally well. In general, the difference among corresponding parameters was small, so Table 1 shows the sets of parameters of the model, which was closest to the result from traditional imaging. Especially, if δ (error in r) is smaller than 1/5 beamsize, conservatively δr equal to 1/5 beamsize as standard error is used.

ACKNOWLEDGEMENTS

Author specially thanks Drs. T.P. Krichbaum, A. Witzel and A. Zensus for their providing data and helpful discussions.

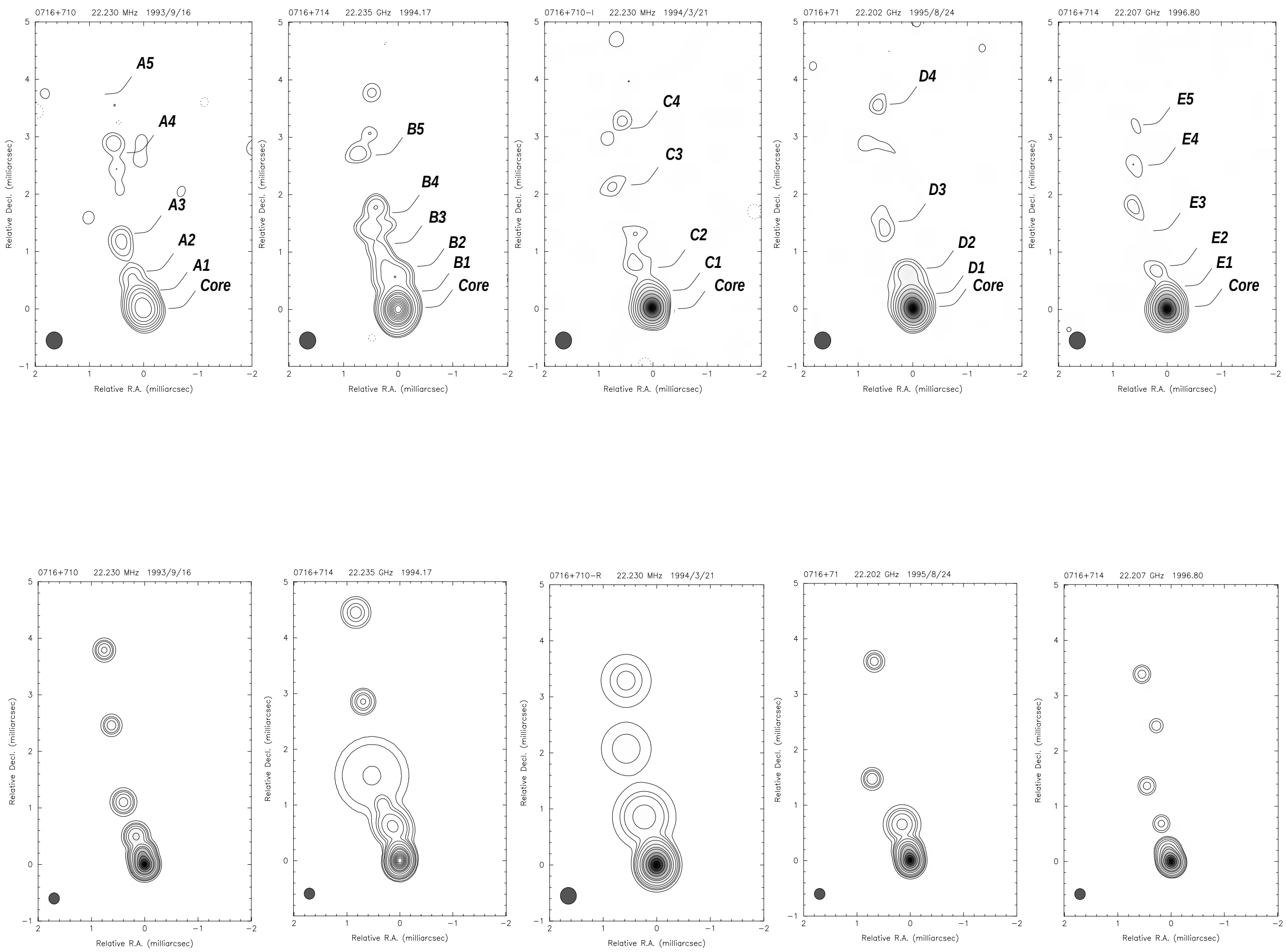

Figure 1: Upper: Core-jet structures of BL Lac 0716+714 at 1.3 cm (from left to right, a-e). Contour levels are: (a) -0.8, 0.8×2^n (n=0,...,6)% of the peak flux density of 0.259 Jy/beam; (b) -0.5, 0.3, 0.5, 1, 2, 5, 10, 15, 20, 30, 50, 70% of the peak flux density of 0.341 Jy/beam. (c), (d) and (e) have same contour levels (%): -0.7, 0.7×2^n (n=0,...,7); the corresponding peak flux density are 0.265, 0.251 and 0.180 Jy/beam. Each map has samely circlely restoring beams 0.3×0.3 mas, P.A.= 0^0 which is shown in the left corner of each map. Below: the model from model fitting with same contour levels: 0.1, 0.3, 0.5, 1, 2, 5, 10, 15, 30, 50, 70, 90 % of the corresponding maximum flux density of 0.250, 0.302, 0.268, 0.221 and 0.180 Jy/beam, respectively. The resolved beams is 0.2 mas except the third panel with resolved beams 0.3 mas.

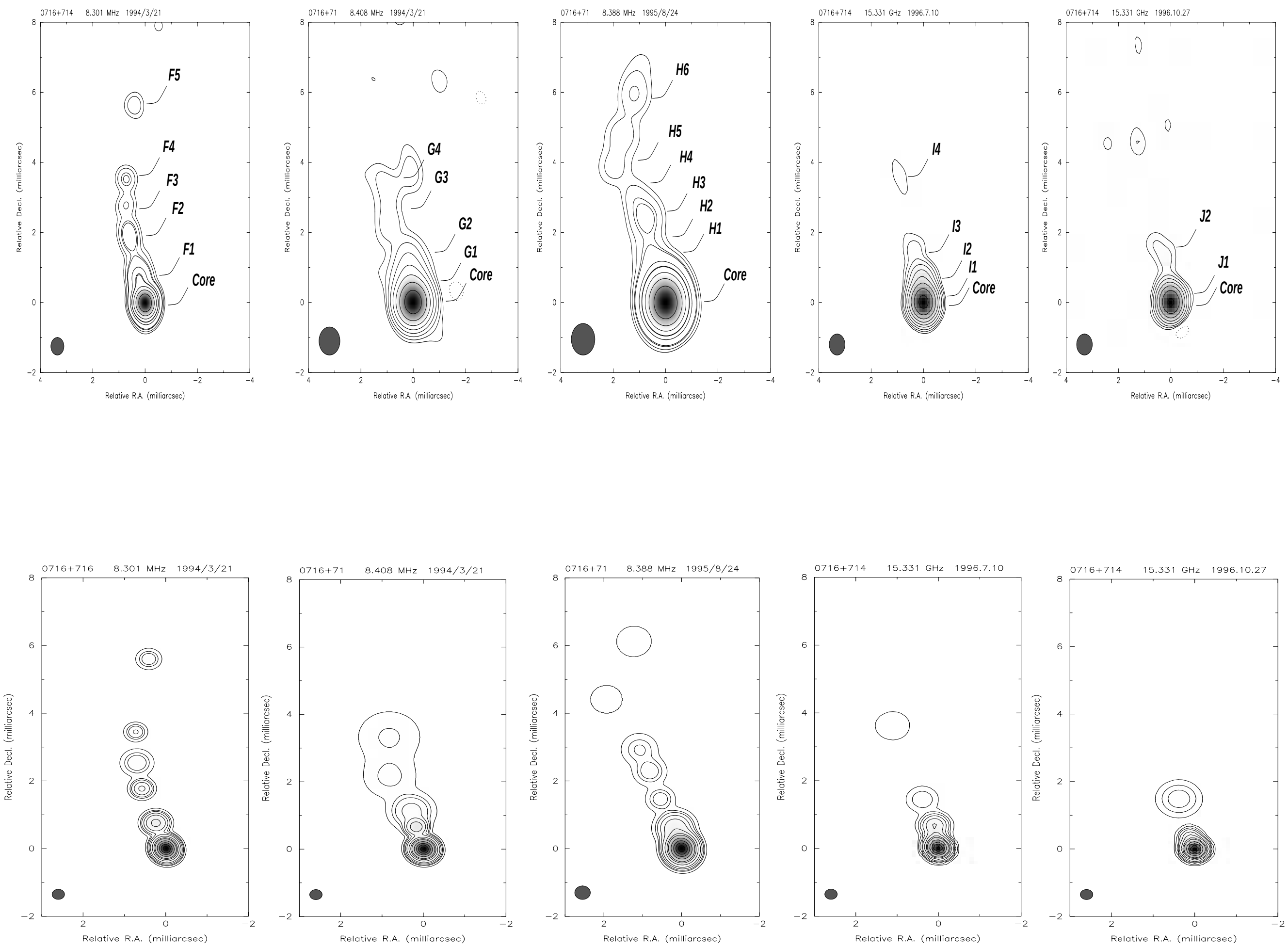

Figure 2: Upper: Core-jet structures of BL Lac 0716+714 at 2 cm and 3.6 cm (from left to right, f-j). Contour levels are : (f) -0.2, 0.2×2^n (n=0,...,8)% of the peak flux density 0.225Jy/beam; (g) -0.5, 0.5×2^n (n=0,...,7)% of the peak flux density 0.244Jy/beam; (h) same as (f), the peak flux density 0.255Jy/beam; (i) -0.3, 0.3×2^n (n=0,...,8)% of the peak flux density 0.228Jy/beam; (j) -0.7, 0.7×2^n (n=0,...,7)% of the peak flux density 0.247Jy/beam. The circlely restoring beams, which are followingly 0.5×0.5 mas, 0.8×0.8 mas, 0.9×0.9 mas, 0.6×0.6 mas and 0.6×0.6 mas, are shown in the left corners of each maps. Below: The model from model fitting with same contour levels: 0.1, 0.3, 0.5, 1, 2, 5, 10, 15, 30, 50, 70, 90% of the corresponding maximum flux density of 0.195, 0.192, 0.228, 0.203 and 0.229Jy/beam, respectively. The resolved beams are 0.3 mas except the third panel with resolved beams 0.4 mas.

Table 1: Parameters from models

Oberv. epoch year	Freq. GHz	Comp.	I (mJy)	r (mas)	δr (mas)	θ (deg)	$\delta\theta$ (deg)	FWHM (mas)
1993.71	22.23	Core	263.3	-	-	-	-	0.09x0.03
		a1	75.1	0.19	0.04	13	6	0.09
		a2	16.9	0.53	0.04	18	2	0.12
		a3	8.8	1.13	0.05	19	1	0.13
		a4	6.2	2.99	0.12	11	0	0.07
1994.17	22.24	Core	366.8	-	-	-	-	0.12x0.07
		b1	31.0	0.19	0.07	5	5	0.09
		b2	21.0	0.62	0.07	12	2	0.26
		b3	4.1	0.98	0.07	19	1	0.04
		b4	18.6	1.60	0.07	19	1	0.84
		b5	4.4	2.93	0.11	14	0	0.13
		b6	4.7	4.5	0.16	11	0	0.23
1994.22	22.23	Core	269.3			-	-	0.06x0.01
		c1	18.2	0.21	0.07	6	5	0.02
		c2	15.5	0.89	0.07	15	1	0.53
		c3	5.5	2.15	0.10	15	1	0.54
		c4	6.2	3.34	0.12	10	0	0.49
1995.64	22.23	Core	250.2	-	-	-	-	0.11x0.01
		d1	41.3	0.21	0.07	15	6	0.14x0.04
		d2	13.4	0.68	0.07	13	2	0.20
		d3	4.3	1.61	0.08	26	1	0.09
		d4	3.3	3.64	0.17	11	0	0.10
1996.80	22.21	Core	188.3	-	-	-	-	0.07x0.1
		e1	28.2	0.20	0.05	16	8	0.10
		e2	2.7	0.71	0.05	14	2	0.10
		e3	3.2	1.45	0.08	18	1	0.11
		e4	1.9	2.47	0.32	7	1	0.10
		e5	3.1	3.42	0.28	8	1	0.10
1994.21	8.30	Core	236.9	-	-	-	-	0.19x0.08
		f1	17.7	0.80	0.11	17	1	0.20
		f2	5.6	1.87	0.11	18	1	0.14
		f3	4.3	2.63	0.11	15	0	0.34
		f4	2.4	3.52	0.13	12	0	0.08
		f5	2.5	5.62	0.20	4	0	0.20
1994.22	8.41	Core	248.4	-	-	-	-	0.21x0.11
		g1	21.5	0.80	0.17	15	2	0.22
		g2	4.8	1.55	0.17	19	1	0.19
		g3	6.4	2.46	0.17	20	1	0.67
		g4	8.1	3.47	0.20	13	1	0.99
1995.64	8.39	Core	271.7	-	-	-	-	0.25x0.08
		h1	15.1	0.65	0.19	15	1	0.38
		h2	2.4	1.68	0.19	20	1	0.09
		h3	4.2	2.66	0.19	20	0	0.49
		h4	2.9	3.12	0.19	20	1	0.43
		h5	2.8	4.82	0.27	24	0	1.15
		h6	2.0	6.14	0.22	12	0	0.24
1996.52	15.33	Core	184.2	-	-	-	-	0.08x0.01
		i1	5l.4	0.16	0.13	18	0	0.20x0.02
		i2	17.7	0.69	0.13	8	0	0.23
		i3	3.2	1.50	0.13	15	1	0.38
		i4	3.6	3.79	0.13	17	1	0.94
1996.82	15.33	Core	233.5	-	-	-	-	0.05x0.01
		j1	19.5	0.30	0.13	18	1	0.19x0.02
		j2	9.8	1.53	0.13	17	0	0.54