THE CLASS LENS J1934+504

D.R.MARLOW, C.M.SYKES, S.NAIR, N.J.JACKSON, I.W.BROWNE AND P.N.WILKINSON
NRAL, Jodrell Bank, University of Manchester, U.K.

A.G. DE BRUYN
NFRA, Dwingeloo

S.T. MYERS
University of Pennsylvania

AND

C.D. FASSNACHT
California Institute of Technology

Abstract.

The lens J1934+504 was found during the course of the CLASS survey and MERLIN and VLA radio maps show up to 10 components. Four of these 10 components are flat spectrum and are compact; the rest have steep spectra and are more extended. A lens model using an elliptical mass distribution gives a good fit to the observed image configuration and component flux densities. The underlying source has been modelled to be a flat spectrum core flanked by two compact components lying symmetrically relative to the core. One of the lobes is quadruply imaged whilst the other is doubly imaged. The core is also quadruply imaged.

1. Introduction

The CLASS survey of flat spectrum radio sources has the primary aim of discovering new, radio loud gravitational lens systems. A survey of 10,000 radio sources is being made with the VLA at 8.4 GHz. Those sources which are found to possess multiple components or complex structure are followed-up at increased resolution with MERLIN and the VLBA. Improved resolution allows one to separate genuine lens systems consisting of multiple images with flat spectra from systems with a flat spectrum core and steep spectrum extended radio emission. Three new lenses, 1600+434, 1608+656 and 0712+472 (Jackson *et al.*, 1995; Myers *et al.*, 1995; Jackson *et al.*, 1997a) have already been anounced. In this paper we discuss the dis-

TABLE 1. Observations of J1934+504

Telescope	Obs. date	Exp. time	Frequency or λ
VLA	1994 Mar 2	30 s	8.4 GHz
MERLIN	1995 Jun 23	1 hr	5 GHz
VLA	1995 Jul 6	30 min	15 GHz
VLA	1995 Jul 6	30 min	8.4 GHz
VLA	1995 Aug 28	1 hr	15 GHz
VLA	1995 Sept 2	5 min	15 GHz
MERLIN	1995 Oct 27	18 hr	1.7 GHz
Keck	1995 Sept 29	50 min	407 to 911nm
HST	1995 Nov 11	800s	540 nm
HST	1995 Nov 11	1000s	814 nm
VLBA	1995 Nov 12	40 min	5 GHz
VLBA	1996 Jun 25	16 hr	1.6 GHz

covery of the most complex arcsec-scale radio lens system yet known, J1934+504 (Sykes *et al.*, 1997; Nair *et al.*, 1997).

2. Observations

A log of the observations made of J1934+504 is given in Table 1; the MERLIN 1.7 GHz and 5 GHz maps are shown in Figure 1. The individual components are labelled 1 to 8; in addition there is a weak component (1a) close to 1 visible in the MERLIN 1.7 GHz map. Component 2 is extended and its morphology implies that it consists of two merging components (see below). A comparison of the two maps clearly shows the components have different spectral characteristics. Note, in particular, components 4 and 5 alternate at being the brightest components between the 1.7 GHz and 5 GHz maps, the later dominating at higher frequencies. In Figure 4 we have combined the information from all the different maps to obtain radio spectra for all the components. One can see that components 1,3,4 and 6 all have flat spectra while the rest appear steep. Indeed, the flat spectrum components are the most compact. Components 1,3 and 4 are clearly detected with the VLBA at 5 GHz and appear to have angular sizes of $\leq$3 mas (Figure 2). However, with the VLBA at 1.7 GHz (Figure 3), components 3 and 6 are not detected which may be tentative evidence for variability considering their strength in the MERLIN 1.7 GHz map. Components 5 and 7 are clearly resolved which will be useful in further constraining the mass model.

Optically, J1934+504 does not have an identification on the POSS, however recent HST observations made with WFPC 2 at 540 nm and 810 nm reveal a

Figure 1. MERLIN radio images of the J1934+504 system. Top: 1.7-GHz image. Bottom: 5-GHz image.

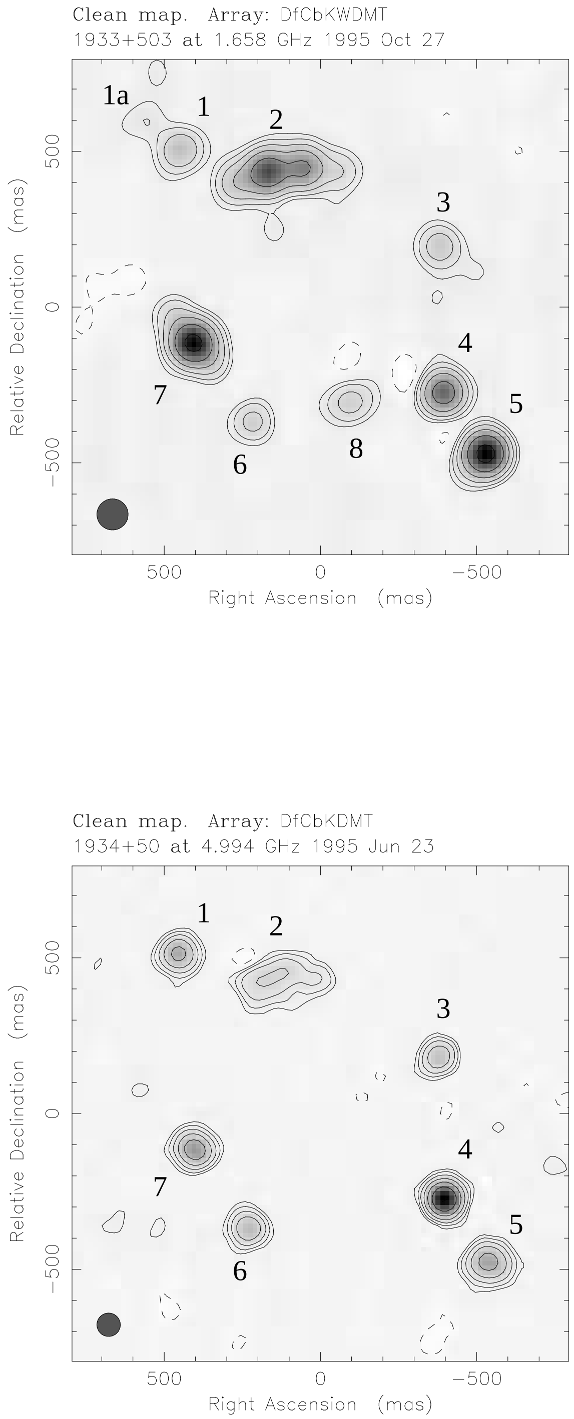
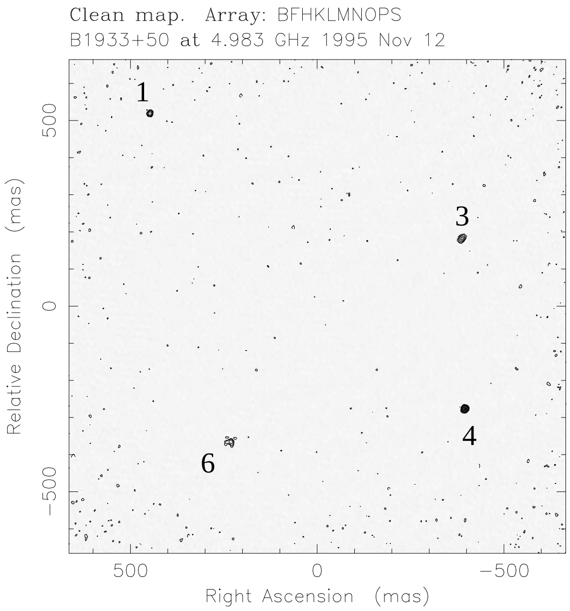


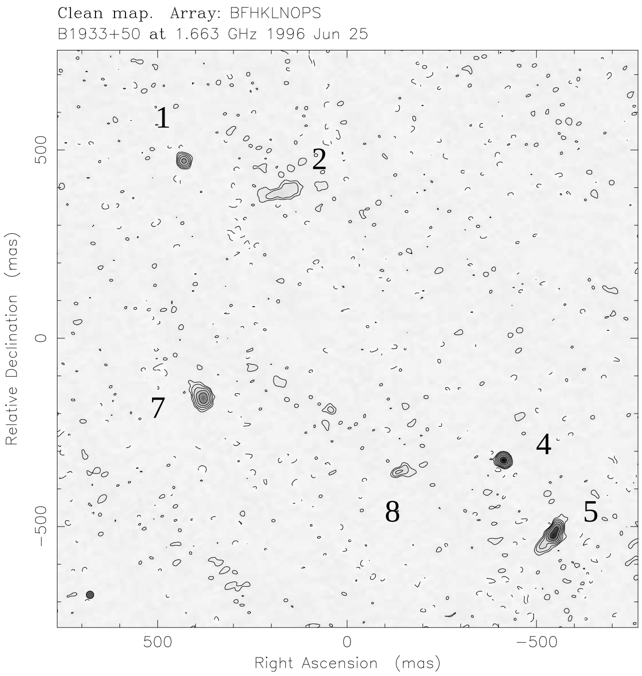
Figure 2. VLBA 5 GHz image of the J1934+504 system.



Cpt	Positions (mas)		Flux Density (mJy)			
	RA	DEC	1.7GHz	5GHz	8.4GHz	15GHz
1	828	800	3.26	5.61	4.27	4.05
2	540	717	23.04	8.04	4.40	3.54
3	16	460	3.06	4.78	3.35	2.45
4	0	0	9.18	19.38	15.68	15.48
5	-132	-196	16.89	7.25	4.45	3.90
6	615	-76	2.16	5.64	3.62	3.16
7	803	156	19.82	8.26	5.20	4.37

TABLE 2. Flux densities of components at various frequencies and their positions measured relative to component 4 (Position (J2000) RA 19 34 30.899, DEC 50 25 23.22).

Figure 3. VLBA 1.7 GHz image of the J1934+504 system.

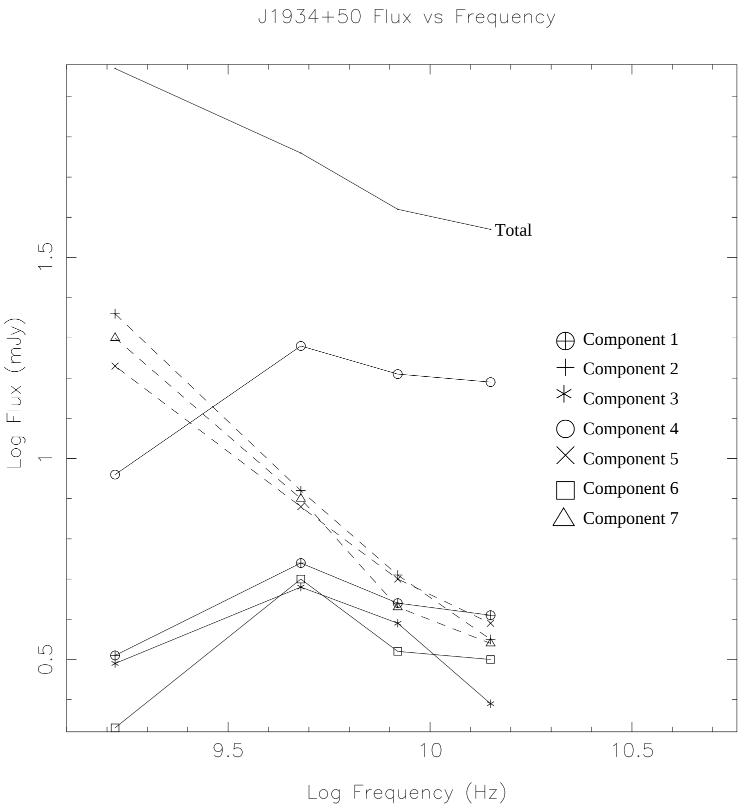


flattened galaxy at the radio position (Jackson *et al.*, 1997b) which we believe to be the lens. The direction of the galaxy orientation is at P.A. -40±5°. No sign of optical emission is seen from the lensed object.

3. A Lens Model

The large number of components observed in J1934+504 indicates that a multiple component source is being lensed, with more than one component undergoing multiple imaging. Based on the assumption that the lensing galaxy is a standard elliptical, we would expect to see either a quadruply or doubly-imaged configuration for a given source component. The MERLIN 1.7 GHz map would appear to be composed of two quad configurations; features 2,5 and 7 (with component 2 a pair merging tangentially) form one quad and 1,3,4 and 6 form a flat spectrum

Figure 4. Radio spectra for the seven strongest components of J1934+504. The overall spectral index of the source when all components are added over frequency is $\alpha = -0.5$, within the limit for CLASS.



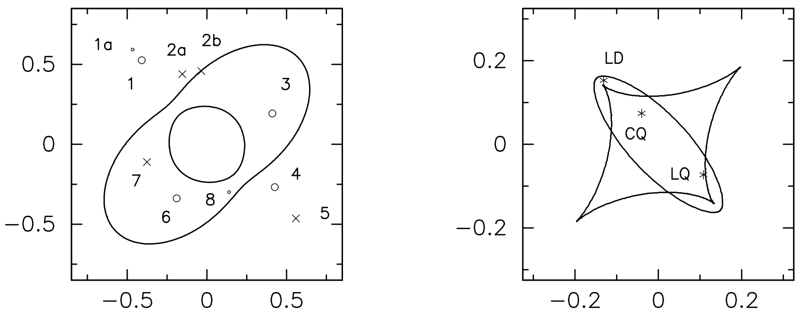
quad. Components 8 has a counterpart, 1a, to the NE of component 1 (see Figure 5). More detailed discussions of the lens model for J1934+504 are given in Nair *et al.* (1997).

The source, were it not lensed, would consist of a compact central flat-spectrum radio core, which have the spectral properties of images 1,3,4 and 6. This radio core is joined by two steep spectrum radio features, the three components found (by modelling) to lie in almost a straight line, on the scale of a few hundred mas.

4. Discussion

The lens system J1934+504 is interesting because it has three source components lensed by the same galaxy. Thus this system will provide a strong test of underlying assumptions made when modelling gravitational lenses. The simple lens model disscussed above, if correct, will give assurance that similar models can be adopted

Figure 5. A lens model for J1934+504. *(a):* Image plane critical curves for the lens model, on which observed image positions have been superposed. The lens is centred at (0,0). Images landing very near a critical curve suffer very high magnifications, tending to merge with nearby images across such curves (2a with 2b, for example). Image positions marked with large open circles form the quad arising from lensing of the source's core, crosses mark one lobe's quad images, and the small open circles denote the other lobe's double image. *(b):* Source plane caustics for this model. The positions of the three source components are marked with asterisks. 'LQ','CQ' and 'LD' denote the sources of the lobe quad, core quad and lobe double.



with confidence, generally. The large number of well defined constraints in the system provide a good test of the different types of lensing mass distributions/ potentials.

Also, this should be a good system for determination of Hubble's constant through time delays in variability, particularly as it has both compact variable and non-variable components. More detailed modelling is revealing J1934+504 to be, in all probability, an isolated lens and certainly more simple than 0957+561 say.

Finally, with an established lens model, it would be interesting to investigate the source for the possibility of super-luminal motion, and if it is present, how it manifests itself in the lensed images.

5. Acknowledgements

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