A VLBI study of the gravitational lens JVAS B0218+357

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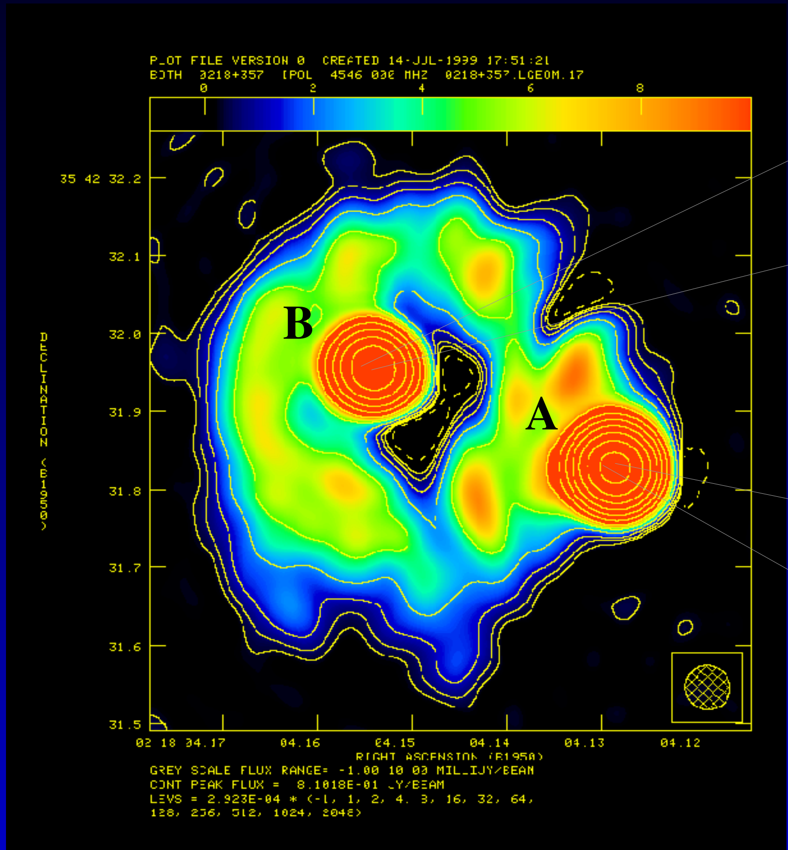
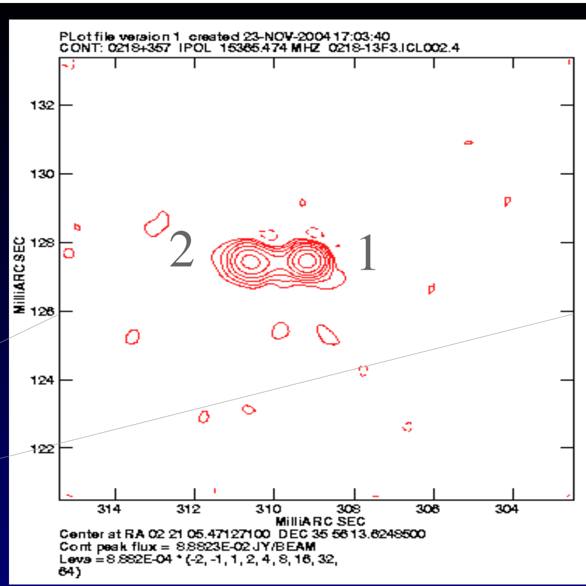
B0218+357

- Double image lens system
- Image separation ~ 334 mas
- Einstein ring of a similar diameter
- $z_l \sim 0.68$, $z_s \sim 0.94$
- Time delay ~ 10 days



MERLIN-VLA 5 GHz
Biggs et al., 2001

B



A

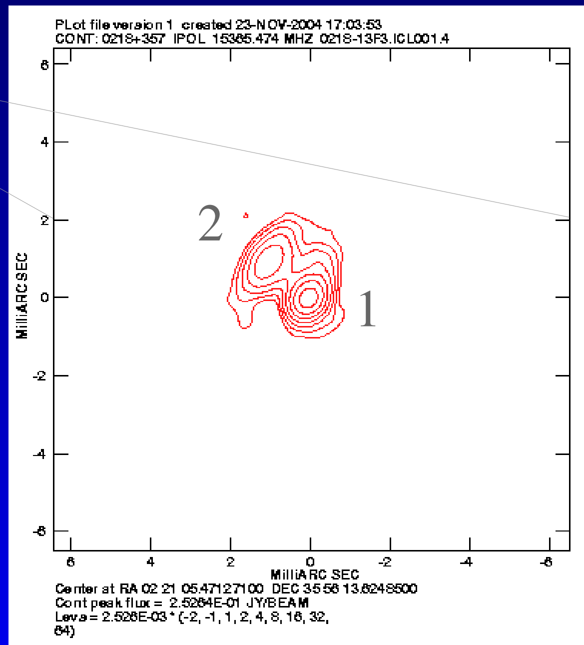
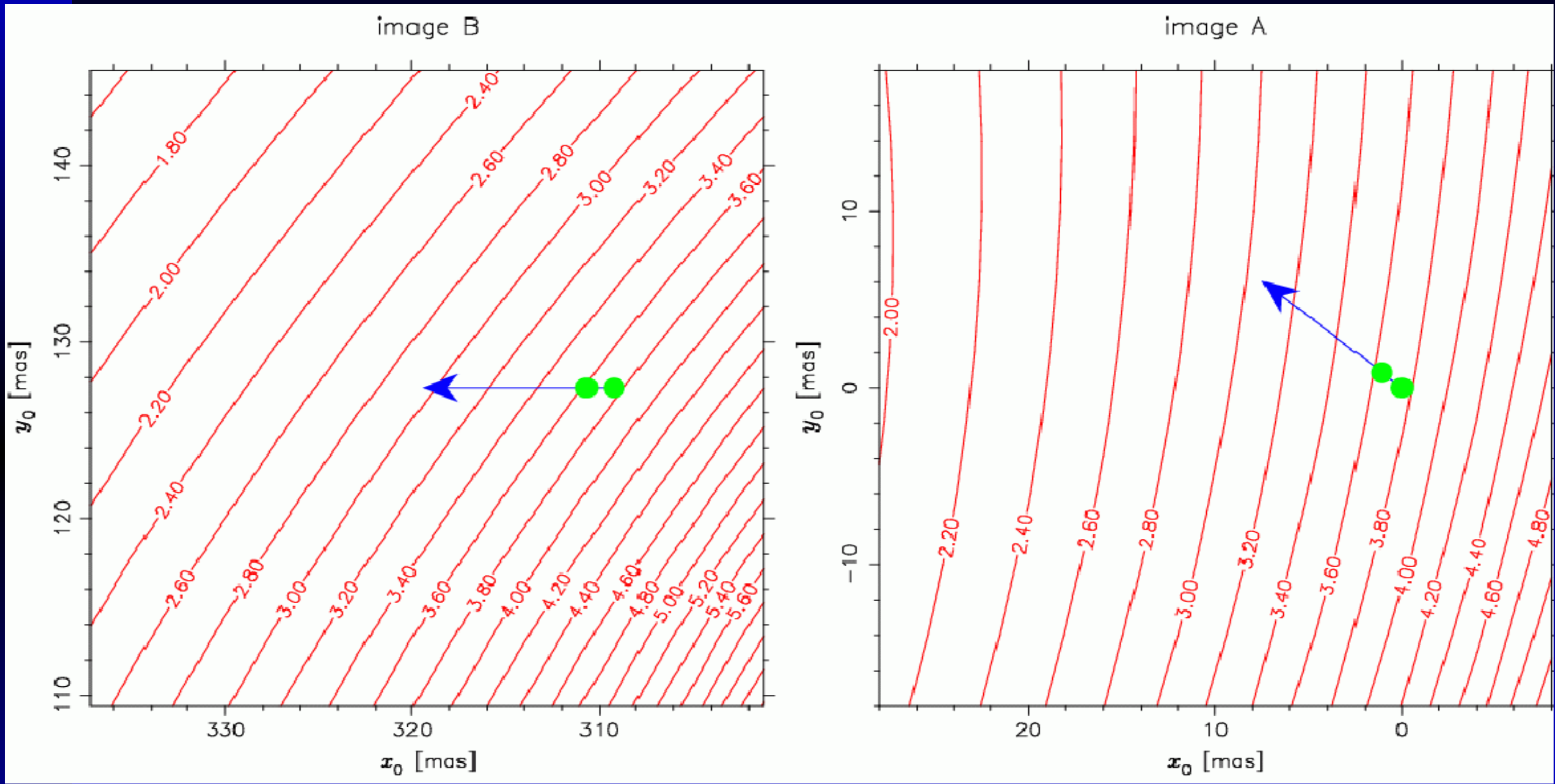


Image flux ratios

ν (GHz)	Interferometer	Resolution (mas)	Flux Density: F^A (mJy)	Flux Density: F^B (mJy)	F^A/F^B
1.7	VLBI	5	445	170	2.62
5	MERLIN	50	728	245	2.97
5	EVN	5	660	210	3.14
5	VLBI	1	515	196	2.63
8.4	VLA	200	767	236	3.25
8.4	VLBI	1.3	777 $\pm$ 30	230.9 $\pm$8	3.37$\pm$0.17
8.4	VLBI	1	690	202	3.41
15	VLA	120	698	189	3.69
15.3	VLBA	0.5	1000 $\pm$12	276$\pm$6	3.62$\pm$0.09

The image flux density A/B drops from ~ 3.6 at 15 GHz to ~ 2.6 at 1.65 GHz

Relative magnification gradient across the image plane



Wucknitz (LensClean), 2002

Sources of contamination

I. Changing image positions with frequency

II. An extended background source structure

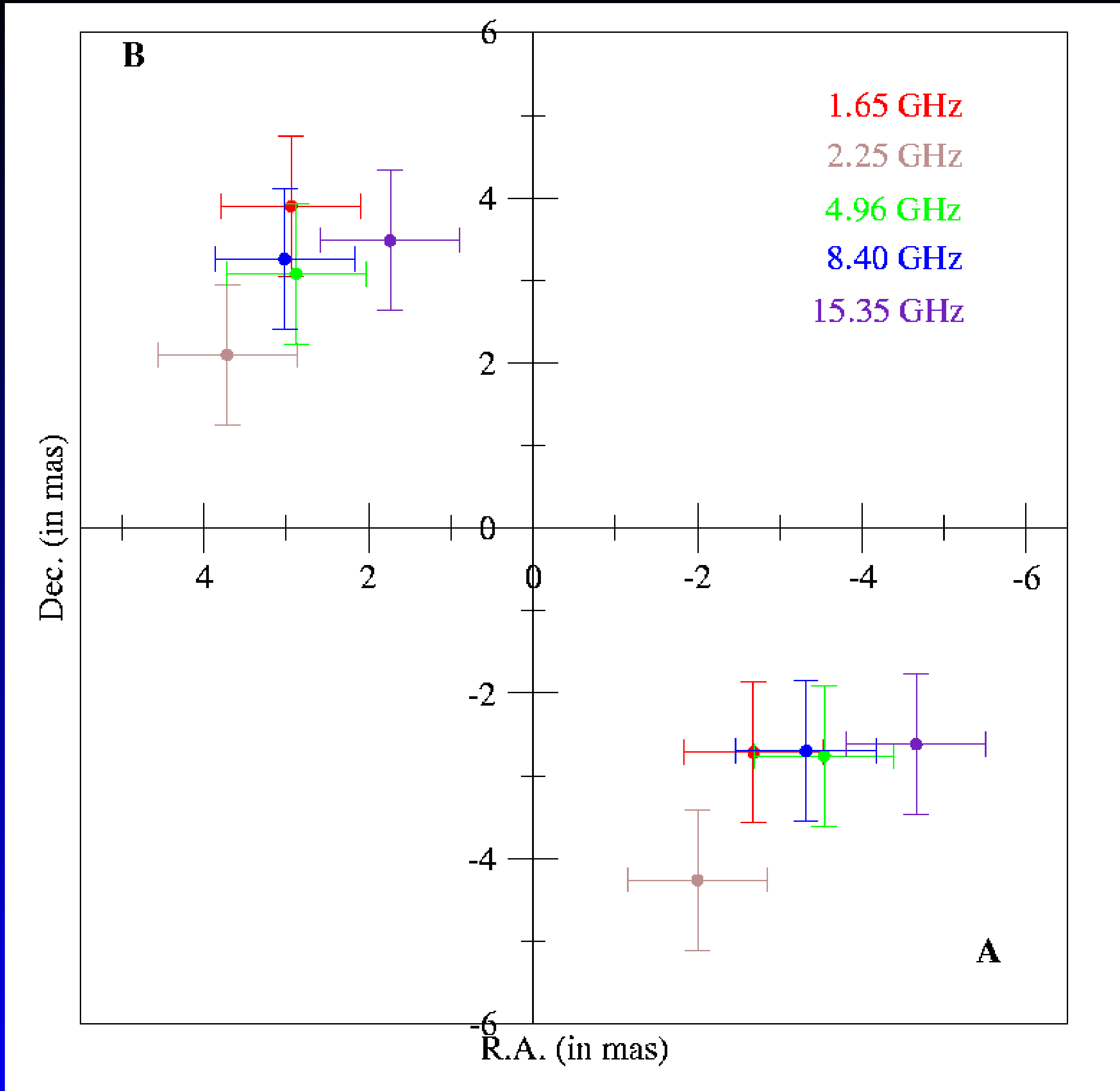
III. Absorption/Scattering

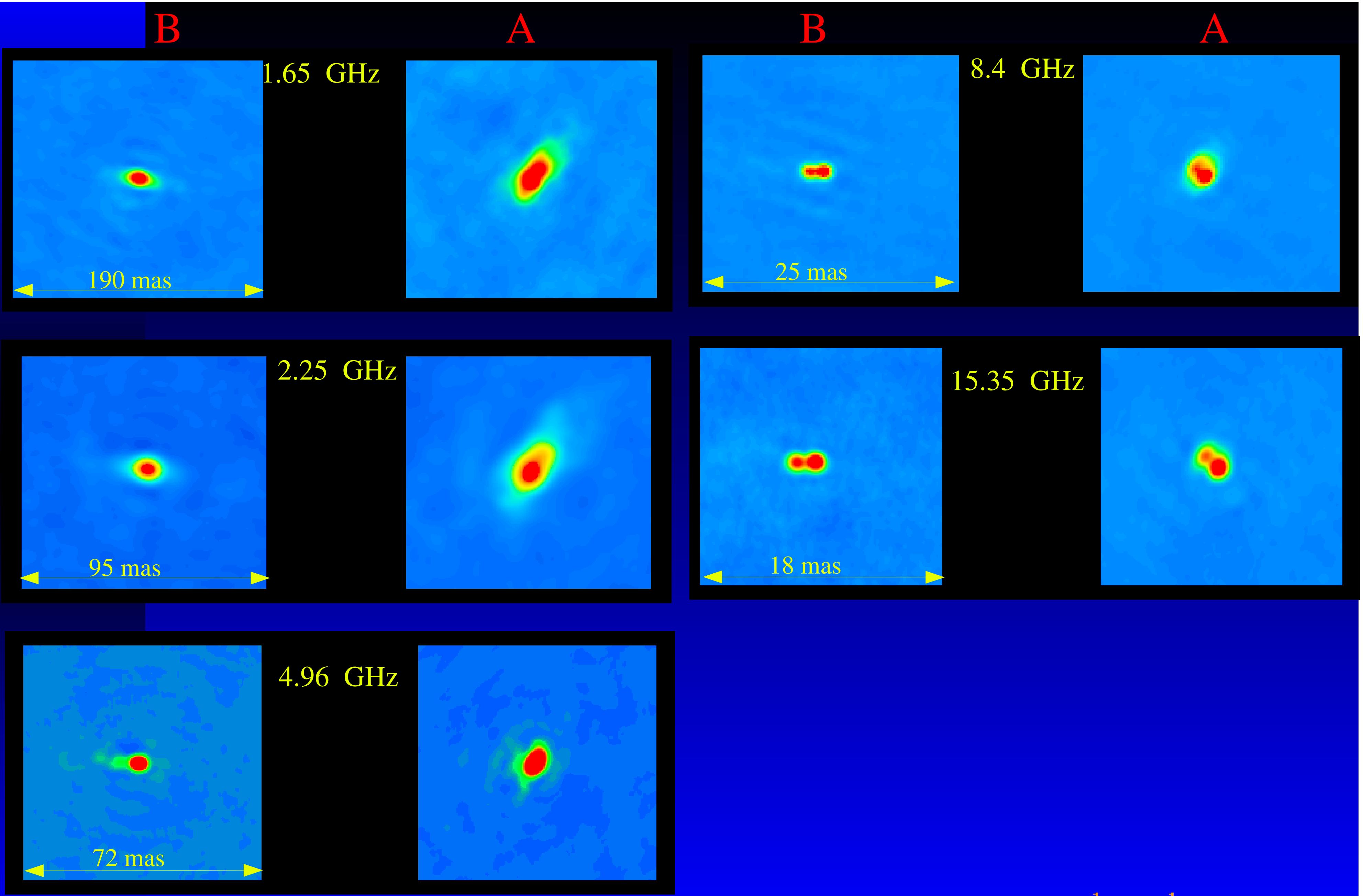
IV. Substructure

V. Instrumental shortcomings

Phase-referenced observations : 2002 Jan – 13th/14th/15th
(VLBA + EB)

- 15.3, 8.4, 4.9, 2.3 and 1.7 GHz (2 cm, 3.6 cm, 6 cm, 13 cm, 18 cm)
- Phase references selected on the criteria of having flat spectrum indices and point like structure
- Lens ~ 1Jy → inversion of "target" and "phase calibrators" labels.
- Data reduction using AIPS software, manual ionospheric phase calibrations.

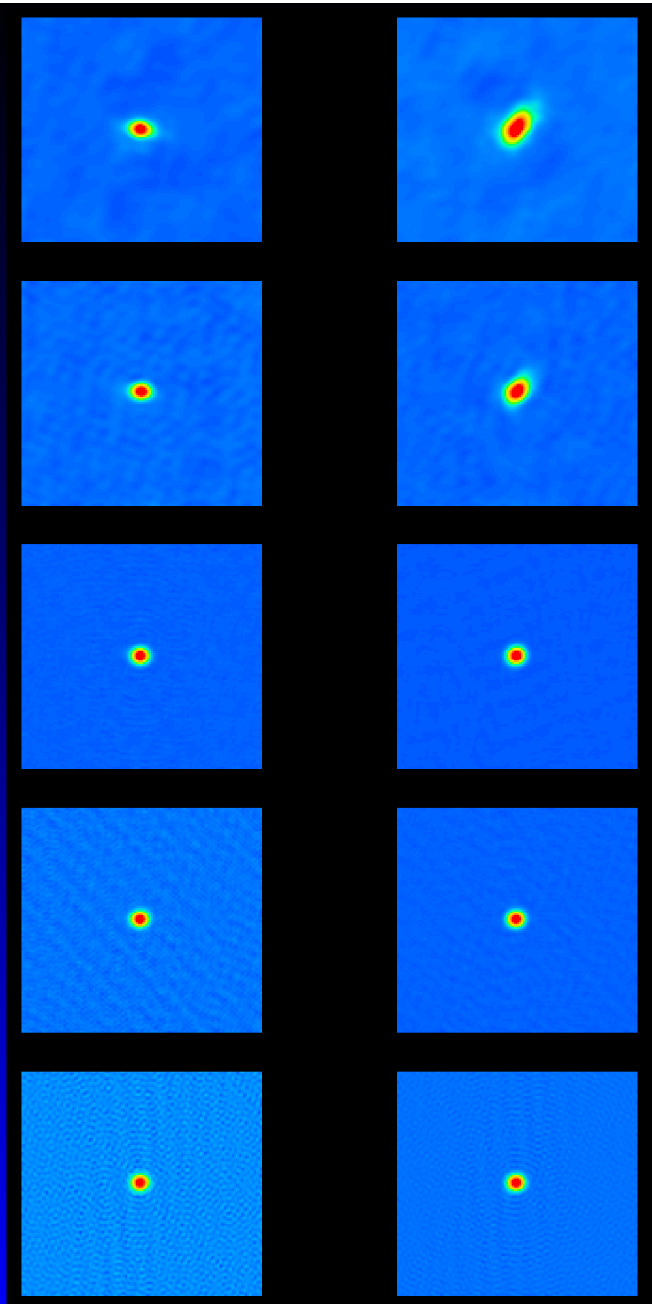

B
A
1.65 GHz
2.25 GHz
4.96 GHz
8.40 GHz
15.35 GHz
6
4
2
0
-2
-4
-6
Dec. (in mas)
R.A. (in mas)


B
A
B
A
1.65 GHz
190 mas
8.4 GHz
25 mas
2.25 GHz
95 mas
15.35 GHz
18 mas
4.96 GHz
72 mas

256 by 256 mas

beam size : 12 mas

Decreasing ν



B

A

ν (GHz)	Pixel size (mas)	Flux Density: F^A (mJy)	Flux Density: F^B (mJy)	F^A/F^B
1.65	5	549 ± 5	266 ± 5	2.06 ± 0.04
2.25	3	695 ± 10	255 ± 15	2.73 ± 0.17
4.96	2	652 ± 5	220 ± 5	2.96 ± 0.07
8.40	1	690 ± 5	205 ± 5	3.37 ± 0.10
15.35	0.5	695 ± 10	177 ± 10	3.93 ± 0.23

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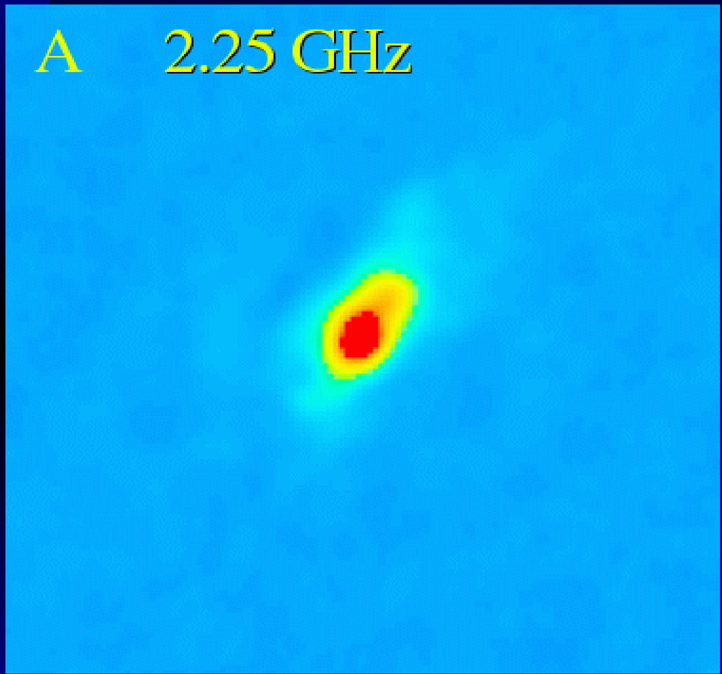
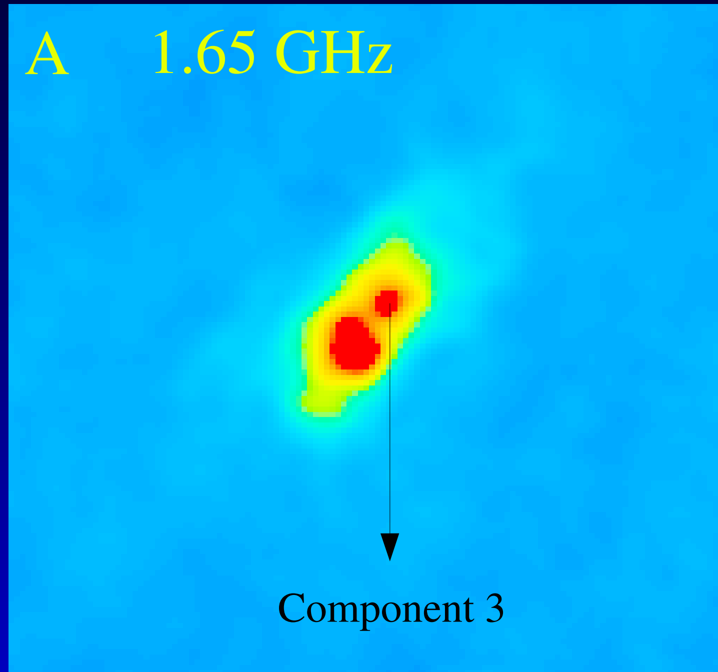
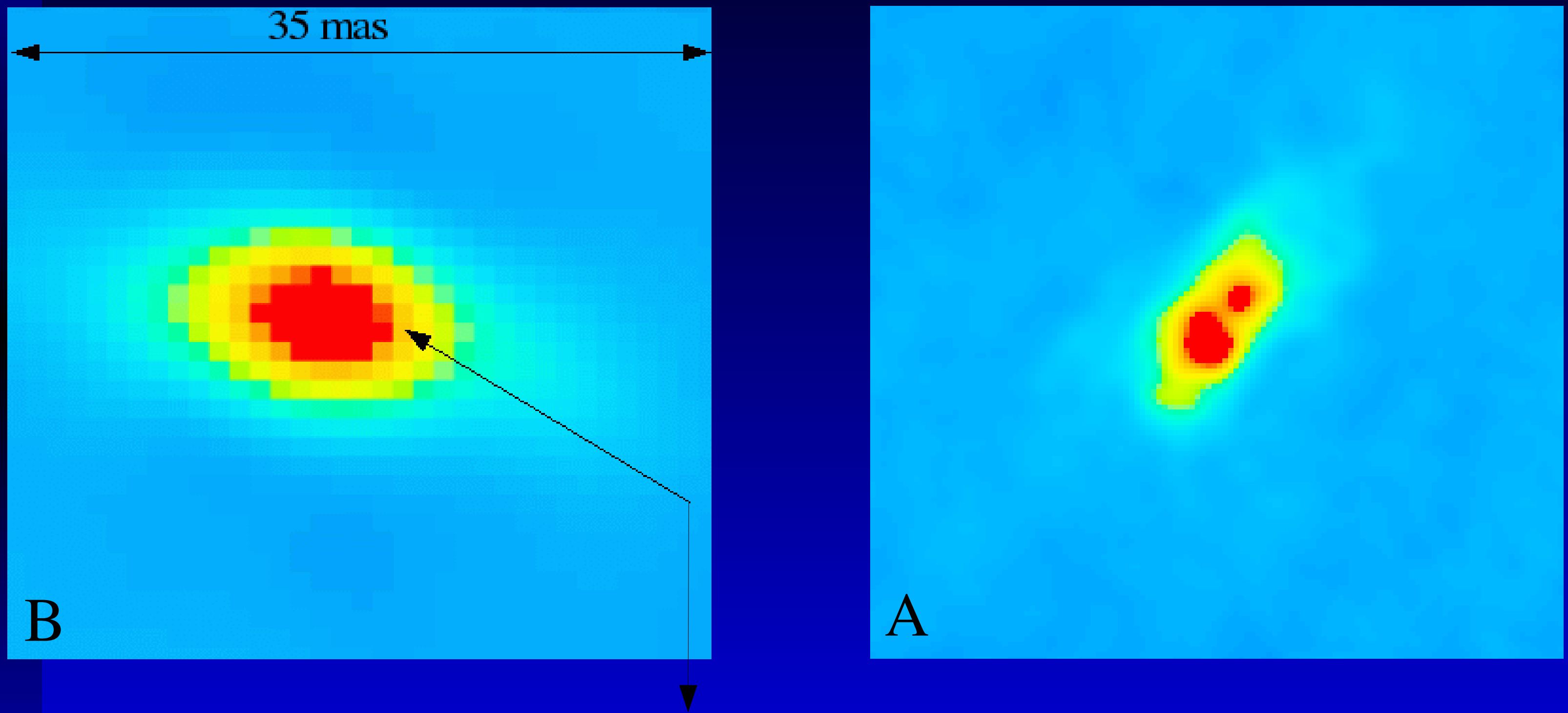
Another component detected in image A





128 mas



Predicted position of component 3 in image B from model derived by LensClean

The ratios are determined by dividing the total flux density of image A by that of image B...under what conditions is that valid?

ν (GHz)	Pixel size (mas)	Flux Density: F^A (mJy)	Flux Density: F^B (mJy)	F^A/F^B
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Relative Magnification

$$RM = \frac{\mu_A}{\mu_B} = \frac{F_A}{F_B}$$ $\longleftarrow$ for a point source

$$\mu = \frac{d\Omega_{img}}{d\Omega_{sou}}$$

where Ω is the image or the source area (solid angle) in the sky. For a source of finite size with varying surface brightness the above expression for the image flux ratio modifies to,

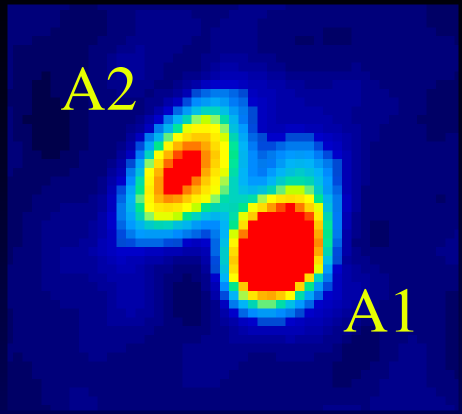
$$\frac{F_A}{F_B} = \frac{\iint_{\Omega_A} \mu_A I_s \, \mathrm{d}\Omega_A}{\iint_{\Omega_B} \mu_B I_s \, \mathrm{d}\Omega_B}$$ $\longleftarrow$ for an extended source

$$S = \sum_{i,j} \frac{f_{ij}}{\mu_{ij}}$$

Observations (2 cm)

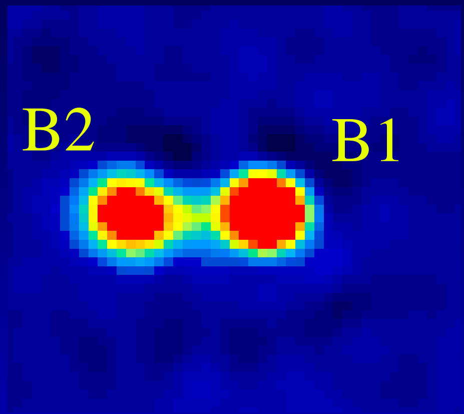
A1 - A2 = (0.98, -0.92) ± 0.07

B1 - B2 = (1.40, 0.03) ± 0.07



Model

B1 - B2 = (1. 17, 0.19)



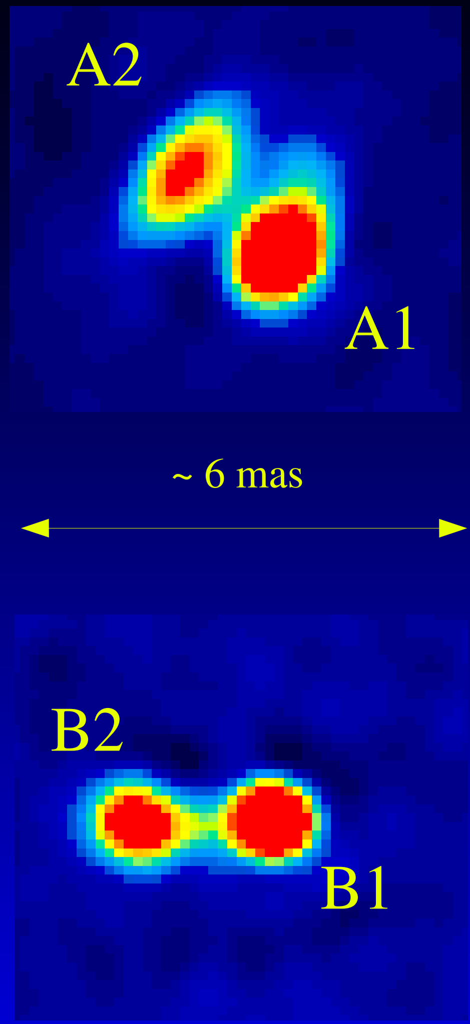
The component separation B1-B2 is off by ~ 3σ in RA

2 cm ... (Observations)

A1/B1 = 3.88 ± 0.06

A2/B2 = 3.44 ± 0.10

The optimal lens model predicts a change in the relative magnification by not more than ~ 0.1 for a shift in position of the order of a mas.



Summary

- Frequency dependant core-shift very small in the context of anomalous flux ratios.
- The simple SIEP model does not comply with the VLBI constraints obtained from the sub-component separation in the individual images making determination of averaged relative magnification difficult.
- Image A flux density remains constant to within ± 25 mJy at 15.35, 8.4, 4.96 and 2.25 GHz and drops by ~ 150 mJy at 1.65 GHz. At the same frequency a third component is detected.
- The issue of varying flux ratios still not solved, the other plausible reasons like absorption or scattering in the lens galaxy or the effect of sub-structure lensing have still to be investigated.

Sources of contamination, so far...
(summary of the summary)

I. Changing image positions ✔

II. Magnification gradient across the image plane ?

III. Absorption/Scattering.....still to be quantified

IV. Substructure.....still to be quantified