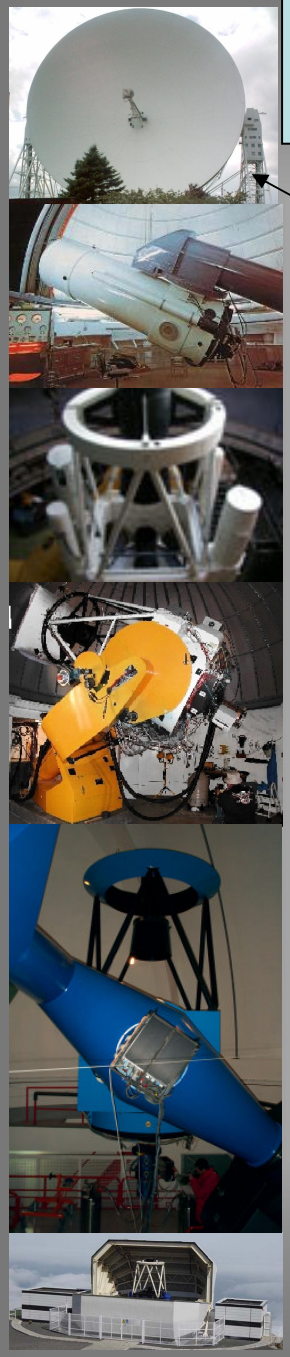
25 YEARS AFTER THE DISCOVERY: SOME CURRENT TOPICS ON LENSED QSOs

Santander (Spain), 15th-17th December 2004



The University of Manchester
Jodrell Bank Observatory

MANCHESTER 1824

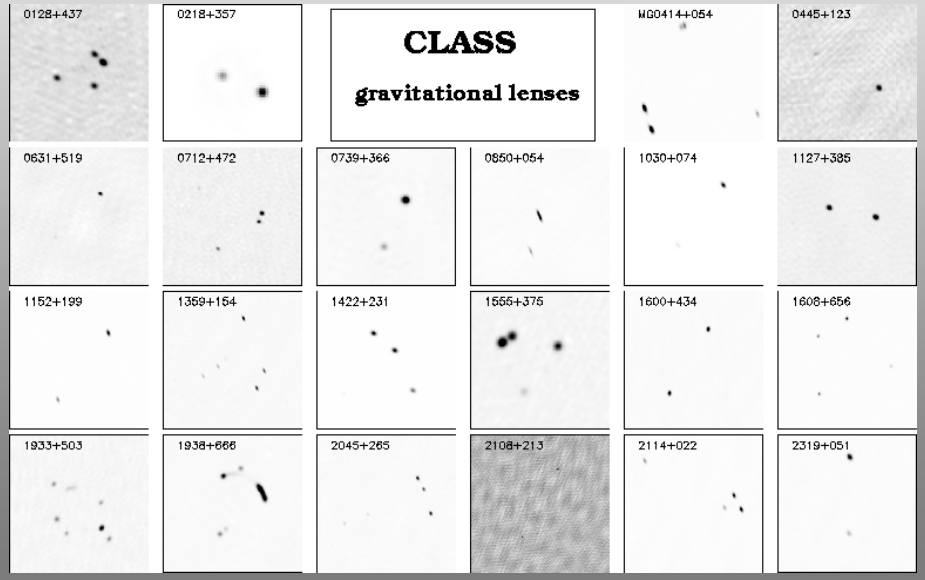
CLASS B0218+357 and the Hubble Constant

Tom York
Neal Jackson
Ian Browne
Olaf Wucknitz (Potsdam)
Jess Skelton

York et al, astro-ph/0405115

JVAS/CLASS survey

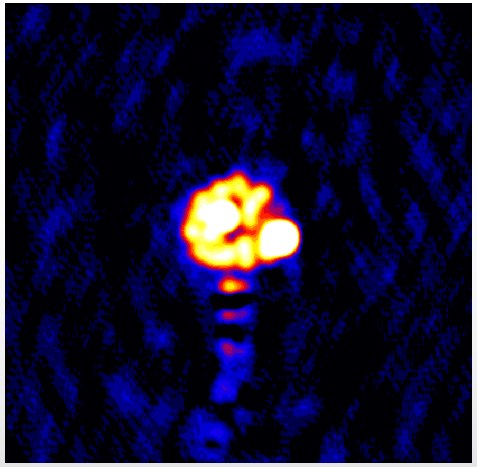
- VLA 8.4GHz snapshots
- Resolved sources followed up with Merlin
- 22 lenses from 1990-1999

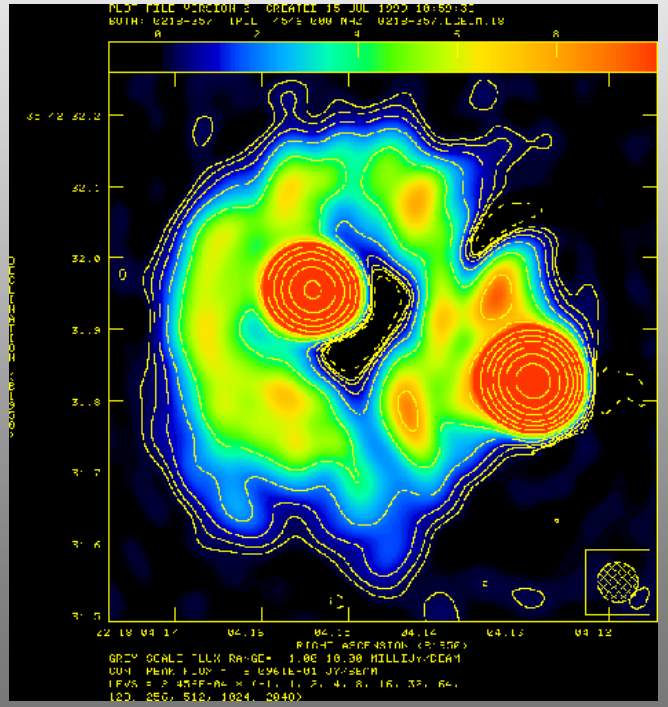


Myers et al. 2003
Browne et al. 2003

Radio properties of 0218

- Double source, separation 334mas
- 830, 340 mJy at 8.4GHz; variable
- Einstein ring
- Flat-spectrum core of larger overall source

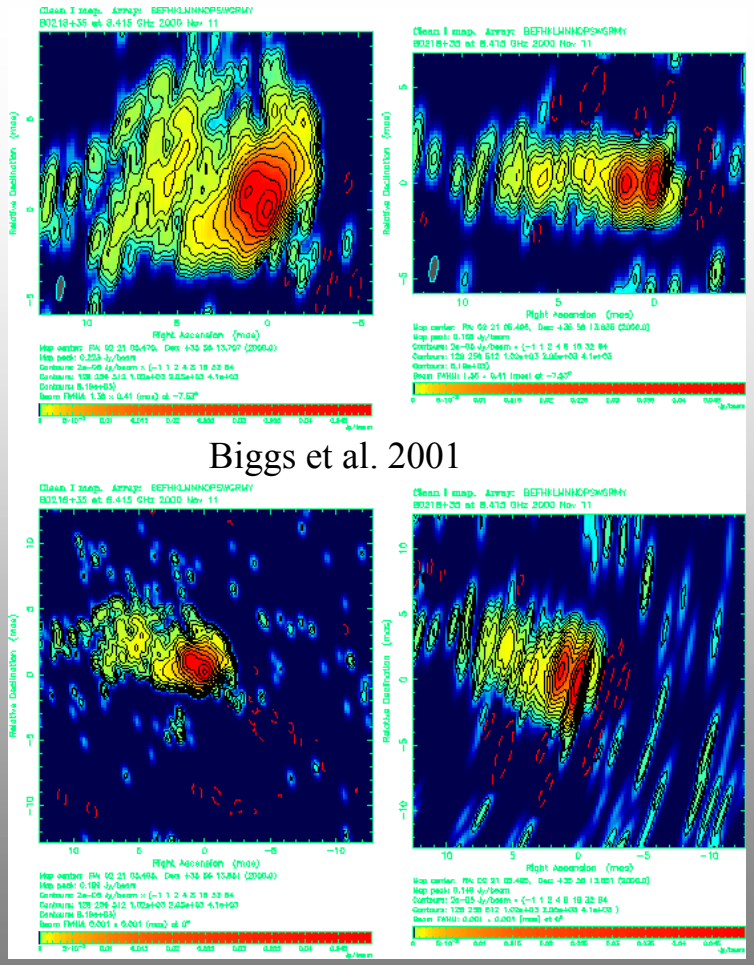




Patnaik et al. 1992

Radio properties of 0218 (ctd)

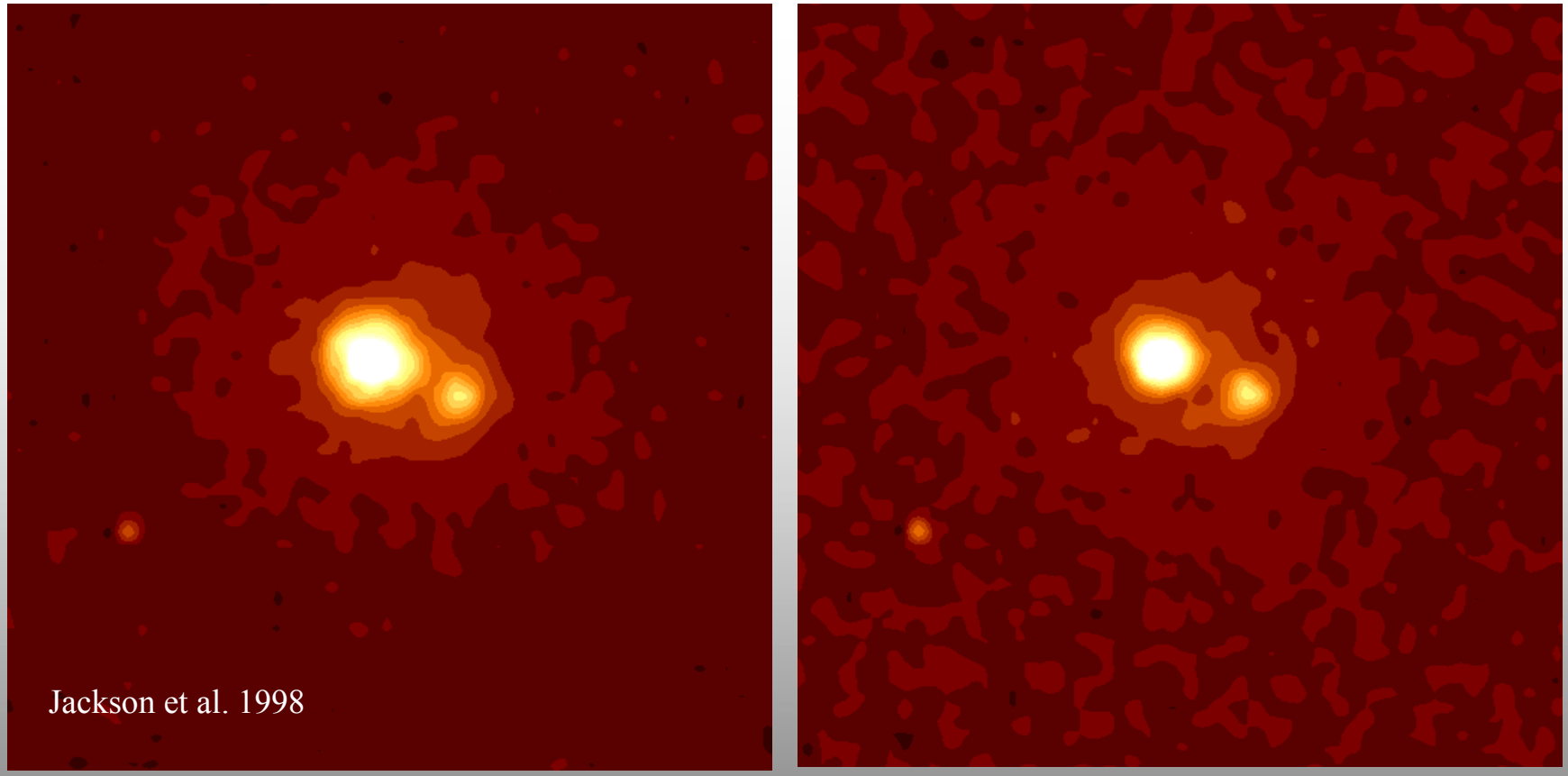
- Also has VLBI structure in both components!
- Complex and knotty jet in both A and B



Biggs et al. 2001

Redshifts of lens and source are 0.6847 and 0.944 (Browne et al. 1993, Carilli et al. 1993, Cohen et al. 2003)

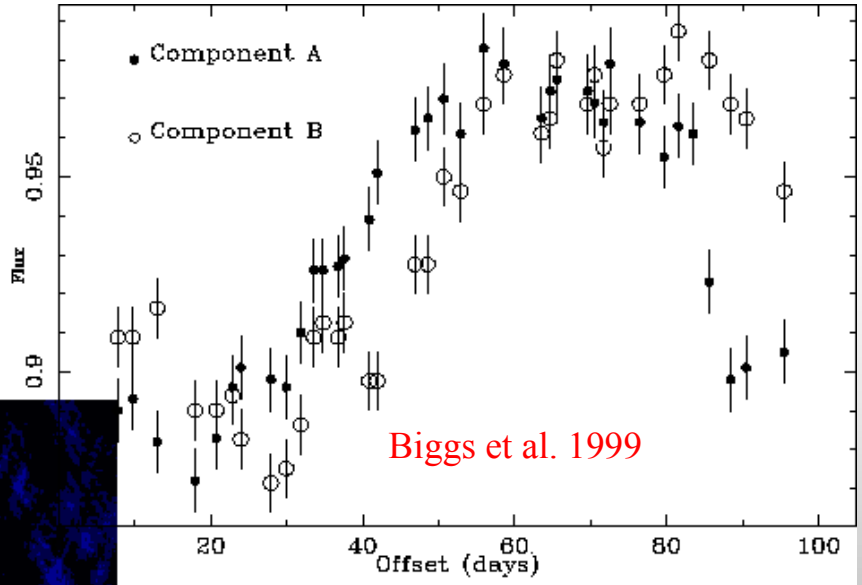
Optical properties of 0218



HST/WFPC2 I (left) and V (right). Flux ratio is different – GMC towards A? (Wiklind & Combes 1995, Menten & Reid 1996).

Measurement of time delay

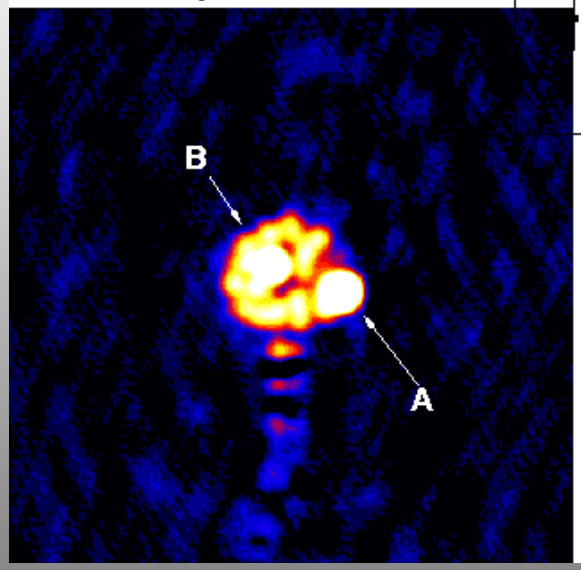
The gravitational lens JVAS0218+357



Biggs et al. 1999

Radio light curves

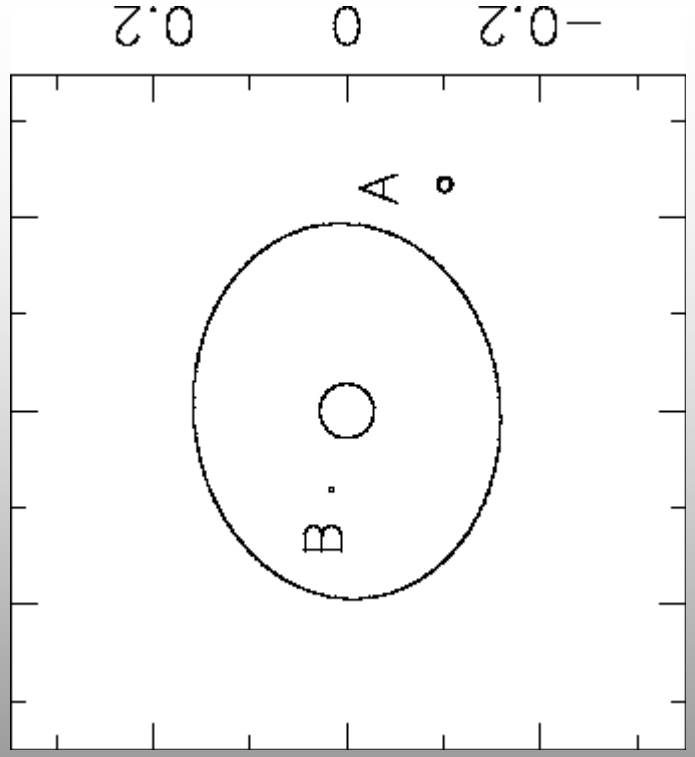
Radio map



Time delay = 10.5+/-0.4 days
Hubble constant estimate:
69 km/s/Mpc (+13/-19, 95%)

Mass models

- Usual problem with 2 images: constraints
- But in this case have Einstein ring *and* VLBI structure

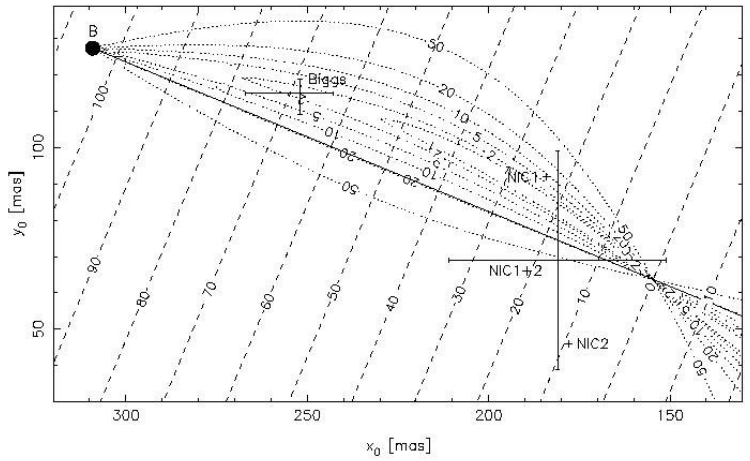


LensCLEAN models

- Kochanek & Narayan 1992
- Developed by Ellithorpe et al. 1996, Wucknitz 2004
- Analogous to radio CLEAN but with lens inversion inbuilt – construct source structure by iteration

Lens centre is crucial

- Lens centre gives both Ho and M:R index
- Without it, get neither
- LensCLEAN gives it but better to measure directly as well
- Wucknitz et al. 2004: 78+/-4 km/s/Mpc



Lehar et al. 2000; Wucknitz et al. 2004

Fun with PSFs…

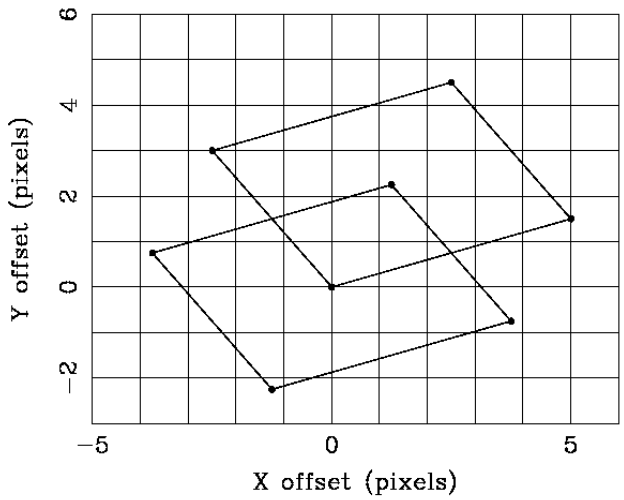
- 80mas PSF vs ~50mas B-G separation
- B is about 20x brighter peak than G
- PSF is not perfect – variable with time

Would you like to win a game you don't know how to play?
Just use your lack of knowledge in a systematic way.

(as far as I know, Cambridge Maximum Entropy group)

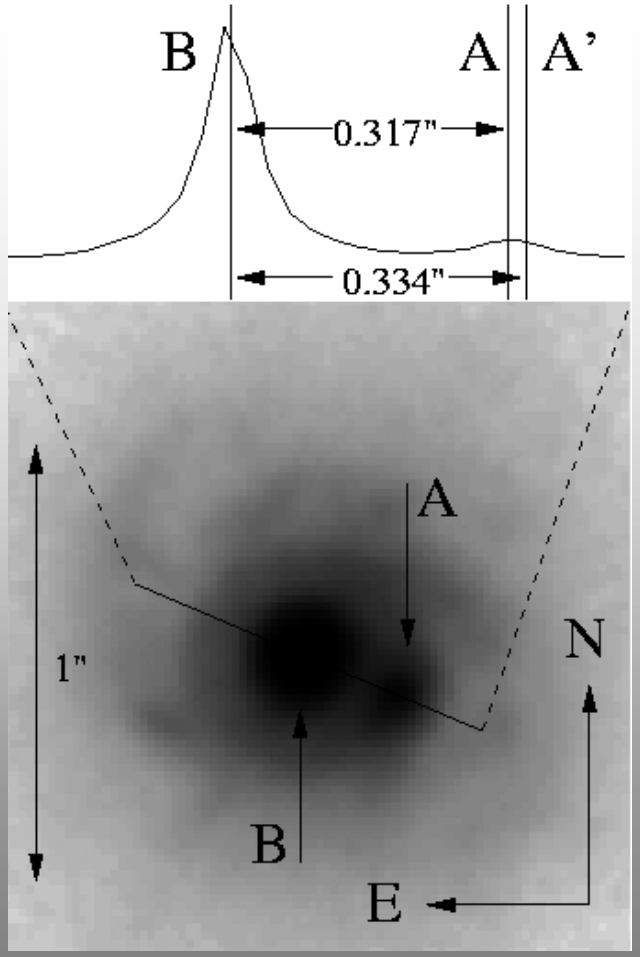
HST/ACS observations

- 36 orbits, 32 on source
- I band (F814W)
- WFC used to avoid scattered light problem
- 8-point dither to recover the 80-mas resolution

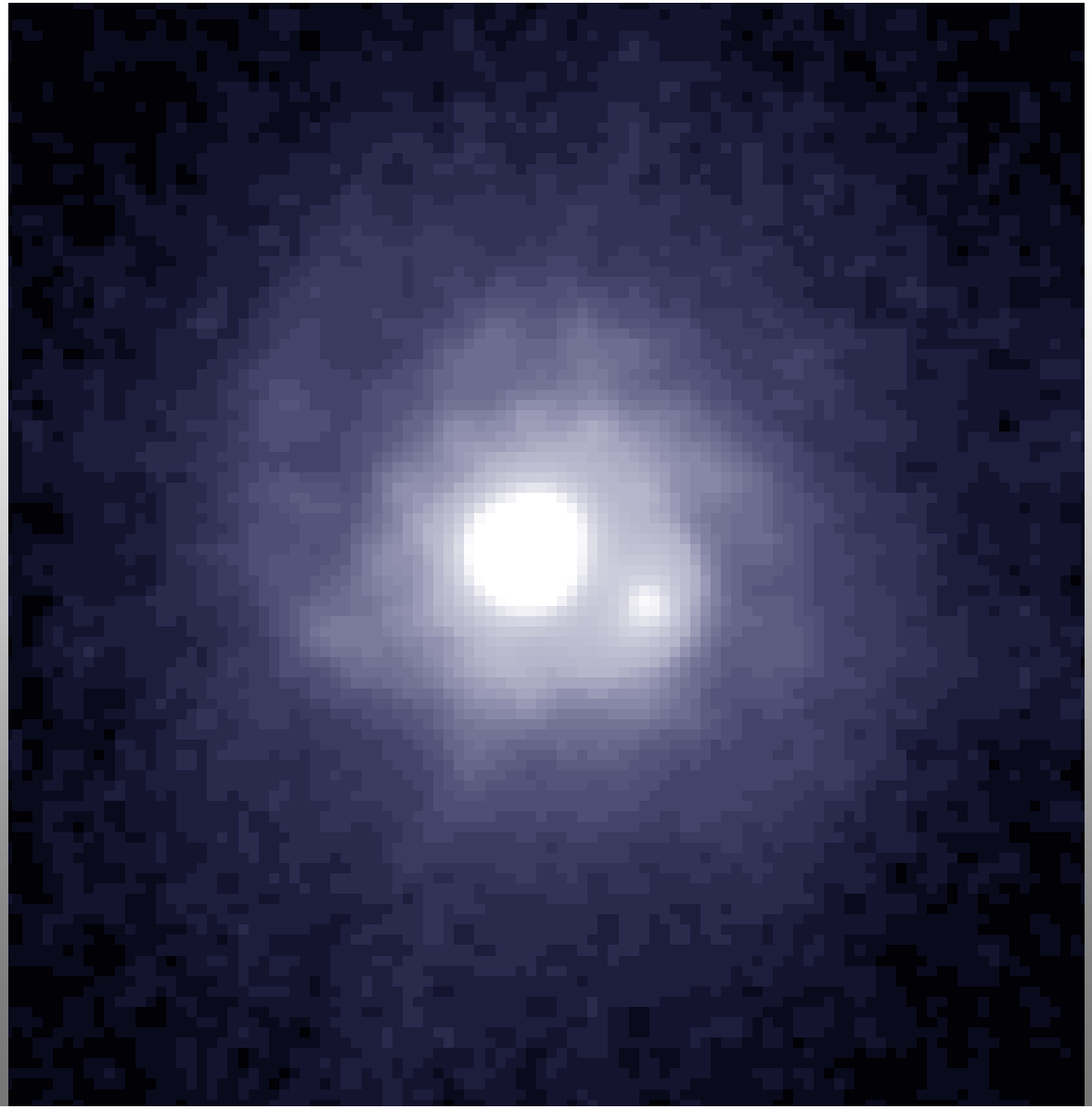


HST/ACS observations

- 5 epochs obtained
- PSF different in each!
- A and B appear closer than 334mas
- Galaxy has clear spiral arms
- Close to face-on
- Irritating star-forming regions

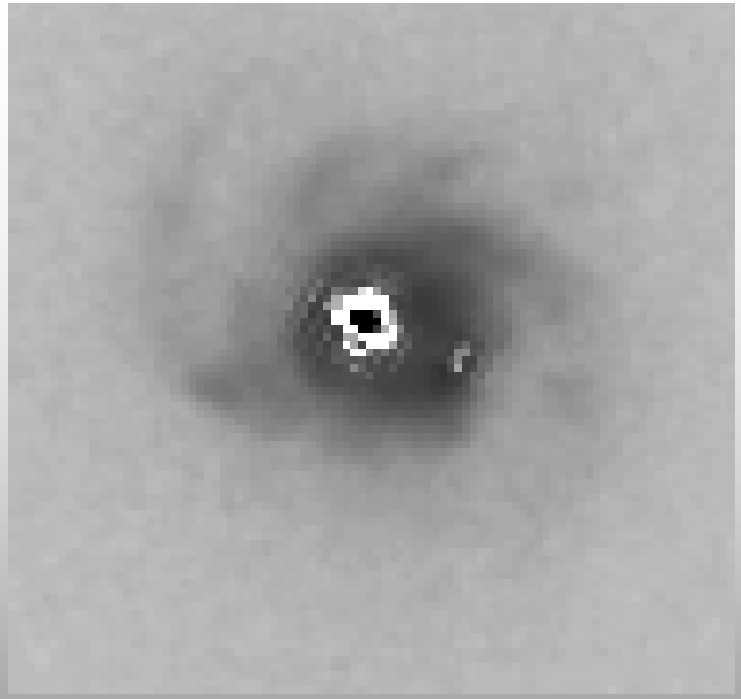


The same picture, in colour



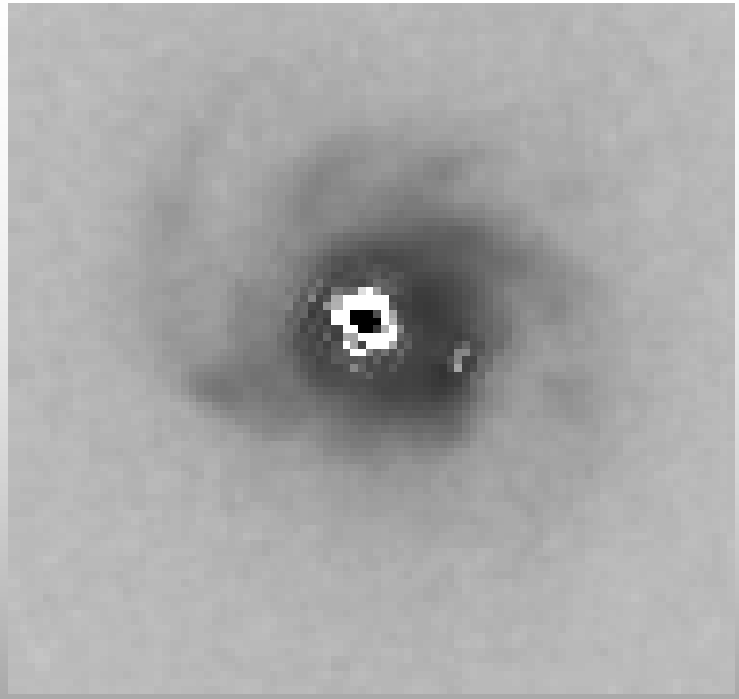
Deconvolution method

- Make and test several PSFs (separate star, field stars)
- Use to deconvolve A, B by measurement and subtraction of peaks
- Leaves residual

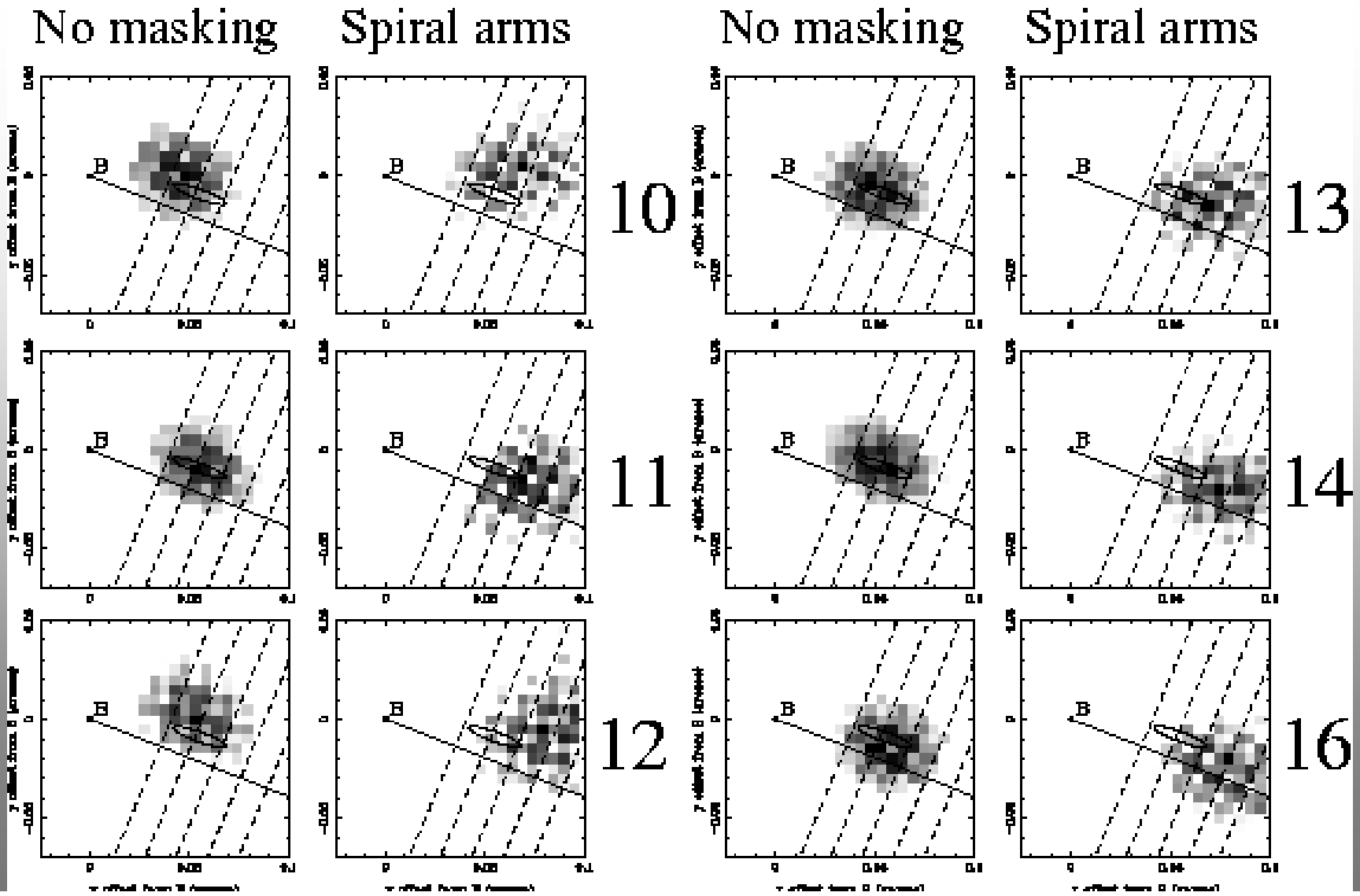


Deconvolution method

- Choose possible galaxy position
- Calculate symmetry parameter corrected for photon and PSF errors
- Gives a χ^2 surface, best galaxy position
- Can do with or without blanking spiral arms



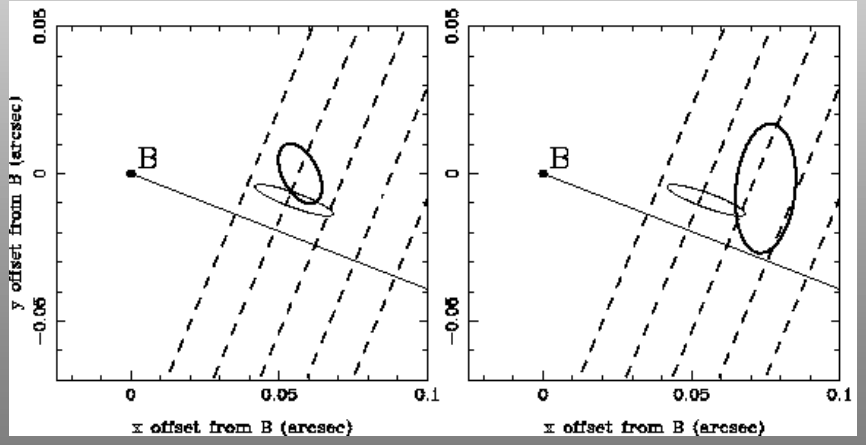
Results


No masking
Spiral arms
No masking
Spiral arms
10
13
11
14
12
16

Value of Hubble constant

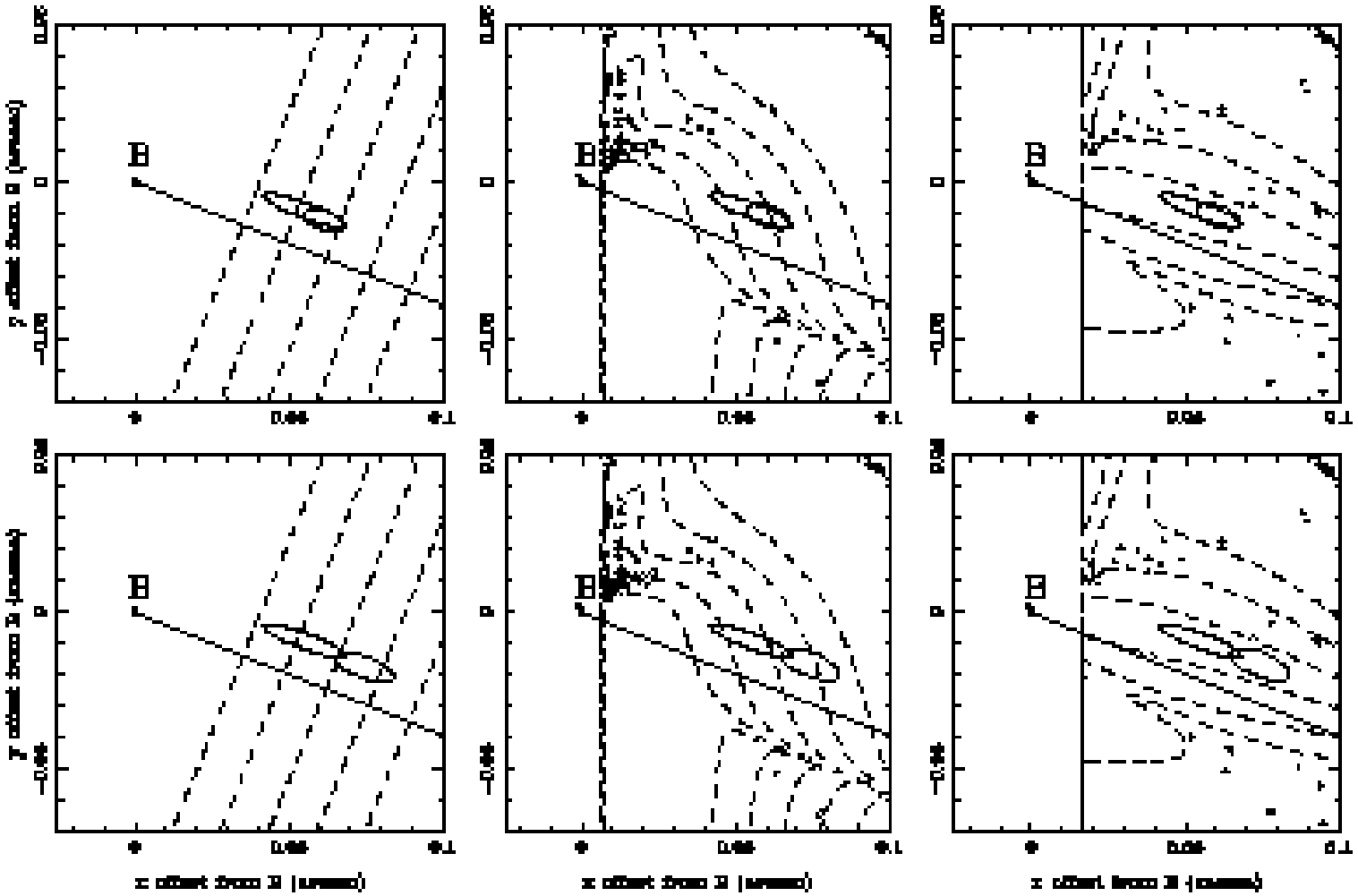
Data used	Masking	Position (RA, δ from B)	H0 (isothermal)	H0 (free index)	M:R index
optical	none	+57, +0	79+/-7	68+/-6	1.13+/-0.08
optical	arms	+75, -5	66+/-9	56+/-14	1.16+/-0.19
VLBI+optical	none	+60,-12	74+/-6	70+/-5	1/05+/-0.03
VLBI+optical	arms	+74,-18	64+/-8	61+/-7	1.05+/-0.04

York et al. 2004 (optical only) in bold; Wucknitz et al. 2004 (VLBI only) in fainter type, for the isothermal case.



Value of Hubble constant

ISOTHERMAL FREE-INDEX MASS-RADIUS INDEX



Ellipses represent VLBI-only and a combination of optical+VLBI constraints.

Other implications

- Very close to isothermal
- Central position still crucial
- Likely to dominate error until new observations (HST/JWST)…
- …at which point, time delay needs refining
- No point in doing either to <3%

The error budget

- galaxy position (ignore arms): ~6%
- time delay: 4%
- line-of-sight matter: ~2%
- shear by nearby galaxies: 1-2%
- uncertainty in Ω, Λ: 1-2%

All errors are 2-sigma. They ignore the effect of the spiral arms, which is the biggest systematic in the measurement.