# Modeling and imaging interferometric data

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# What it is not and disclaimers

- Not a tutorial
- Just to get you started
- Not comprehensive
- To include as many references as possible
- Eradicate some misconceptions…

# The future of optical interferometry…

- …depends on being able to image our sources
- …relies on images to develop models which are then fit to our data for the determination of their physical parameters
- …is based on experience gathered in the radio

# Resources!

- OLBIN software: http://olbin.jpl.nasa.gov/software/index.html
  - Good starting point of what's out there
- Bayesian model-fitting to OI-FITS-format data mfit: http://www.mrao.cam.ac.uk/~jsy1001/mfit/
- LITpro: a JMMC model fitting software: http://www.jmmc.fr/litpro
- OYSTER: advanced model fitting and experimental imaging: http://www.eso.org/~chummel/oyster/oyster.html
- BSMEM maximum entropy imaging: http://www.mrao.cam.ac.uk/research/OAS/bsmem.html
- MiRA – a Multi-aperture Image Reconstruction Algorithm: http://www-obs.univ-lyon1.fr/labo/perso/eric.thiebaut/mira.html
- MACIM: The Markov Chain Imager: http://www.physics.mq.edu.au/~mireland/MACIM/

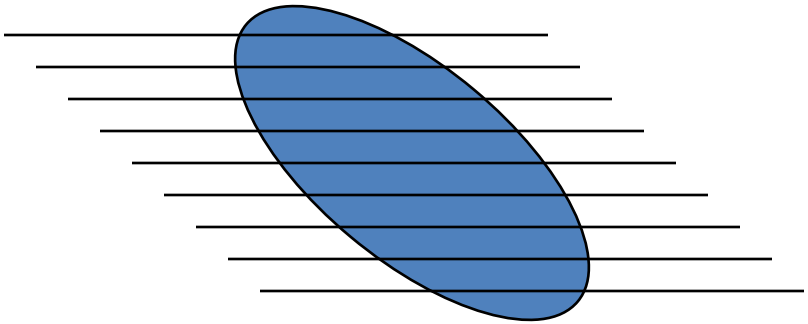
# From the treasure chest of advice

- Modeling includes a model of the data
- A single interferometric measurement observes the strip brightness distribution
- Conference quote: “The closure phase is insensitive to point-symmetric sources”
- Fit to squared visibility, not visibility (unless you used coherent integration)
- Make sure band pass integration uses same units as the transmission function

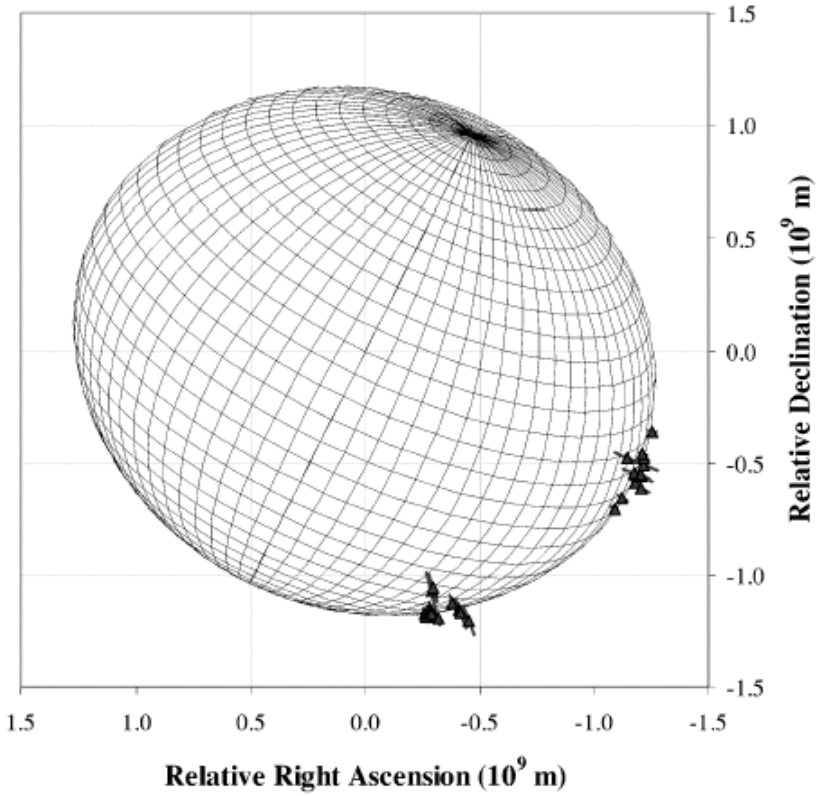
# Elliptical disk

```
u_r=          v*cos(disk.pa)+u*sin(disk.pa)
v_r=disk.ratio*(u*cos(disk.pa)-v*sin(disk.pa))
```

Transform (u,v) coord.

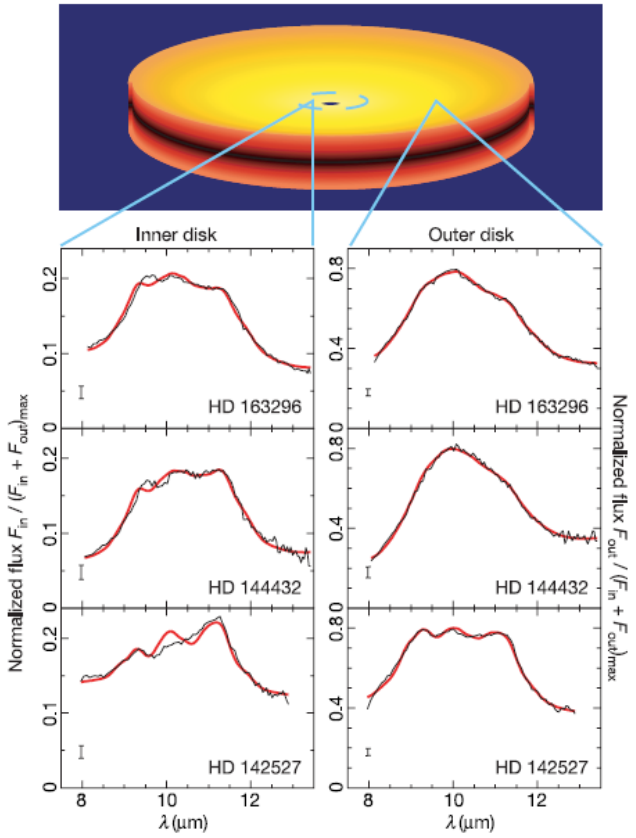


Fourier transform strip
brightness distribution




van Belle et al. (2001)

# Model-dependent interpretations

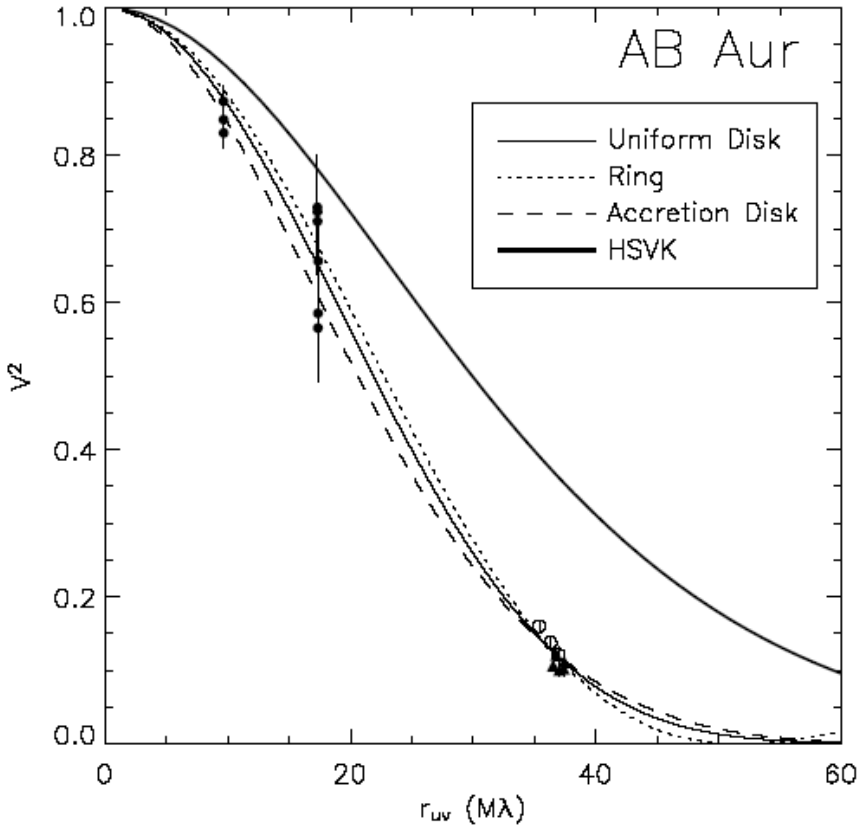



Van Boekel et al. 2004

# Not enough data?

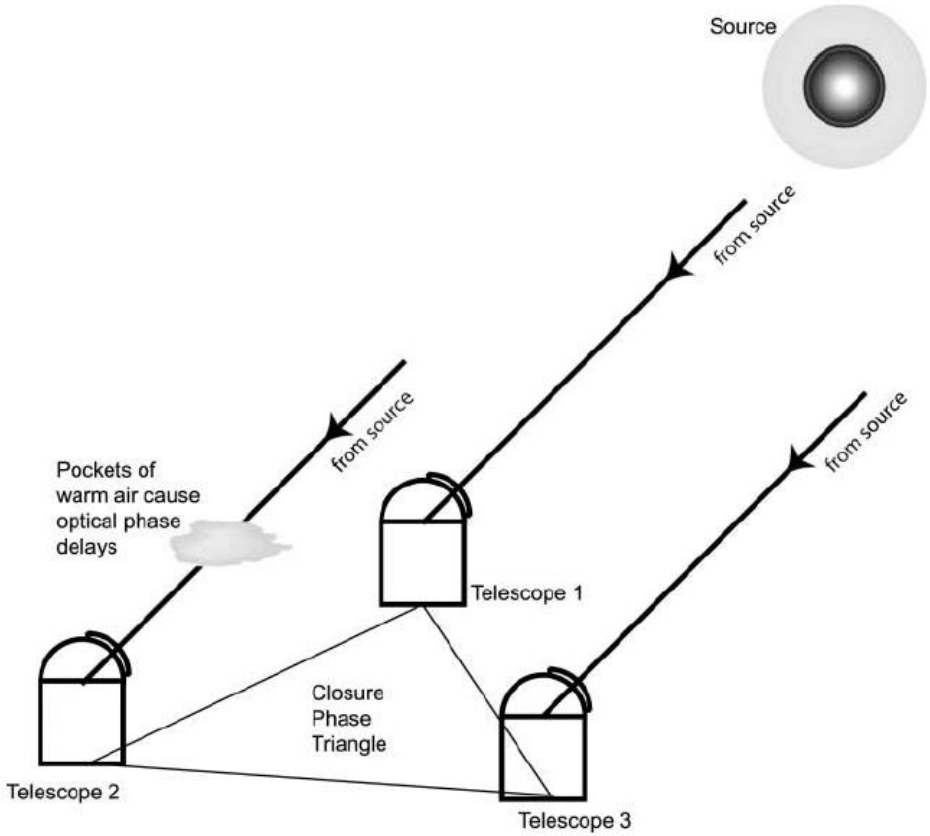
Other sources of info:

- SED
- Polarimetry
- AO imaging
- Spectro-astrometry
- Other?




Eisner et al. 2003

# Closure phases




Monnier et al. 2006

$$\Phi_{ijk}^{\mathrm{CP}} = \Phi_{ij}^{\mathrm{obs}} + \Phi_{jk}^{\mathrm{obs}} + \Phi_{ki}^{\mathrm{obs}}, \tag{3}$$

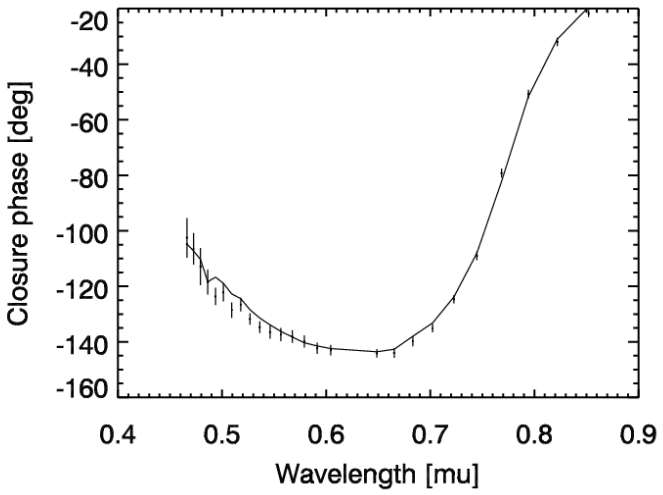
$$= \Phi_{ij} + (\phi_j - \phi_i) + \Phi_{jk} + (\phi_k - \phi_j) + \Phi_{ki} + (\phi_i - \phi_k), \tag{4}$$

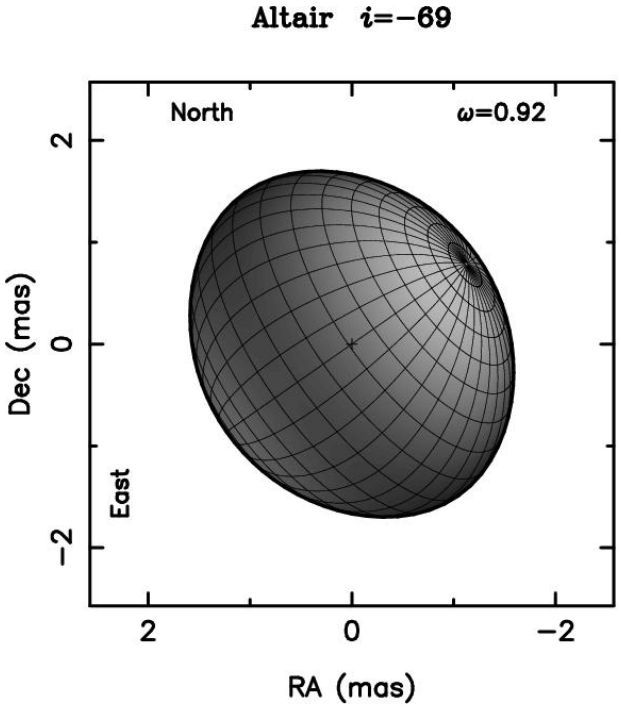
$$= \Phi_{ij} + \Phi_{jk} + \Phi_{ki}. \tag{5}$$

# What do closure phases tell us

- Lift 180˚ ambiguity on binary orientation
- Sensitive to small brightness differences between binary components
- Sensitive to asymmetric brightness on stellar surfaces

# Surface gravity darkening

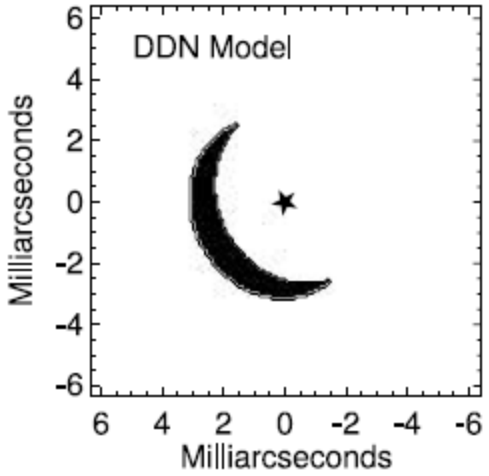


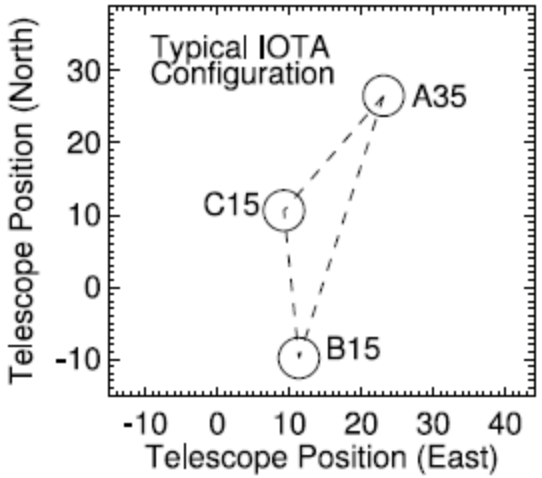



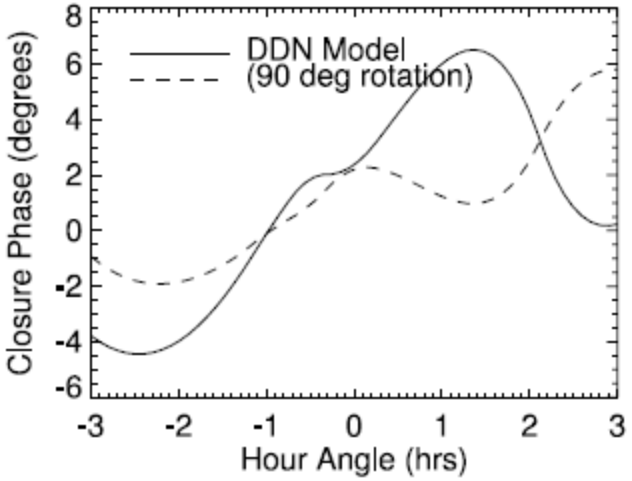

Peterson et al. 2004

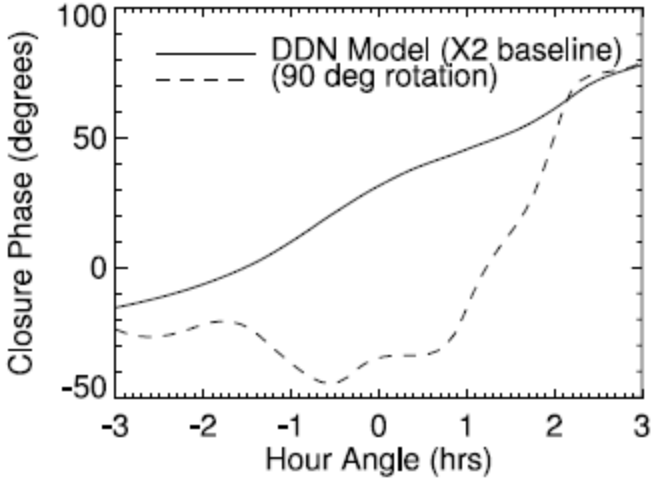
# Vertical inner rim

Monnier et al. 2006



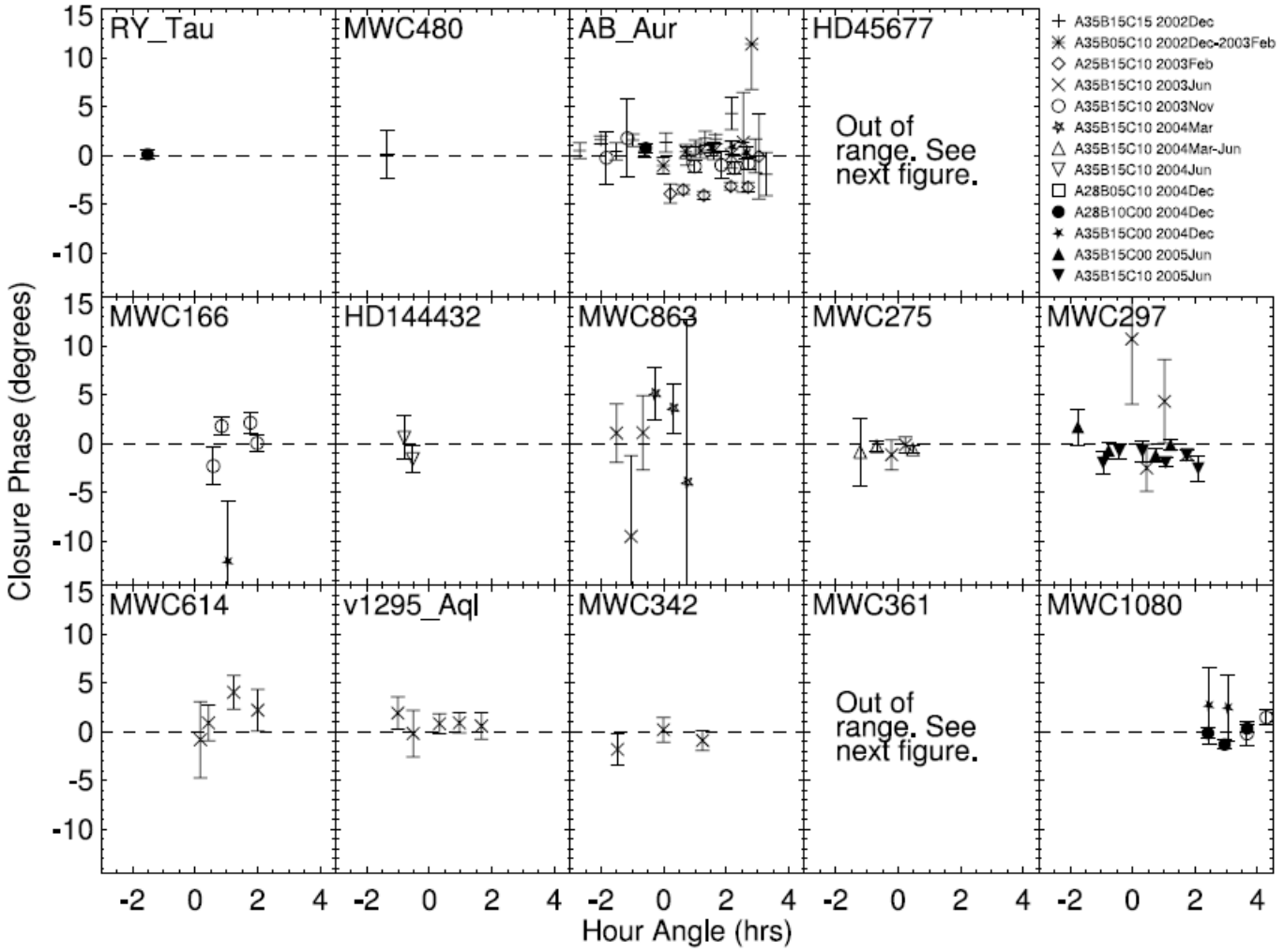



# Herbig Ae/Be NIR closure phases

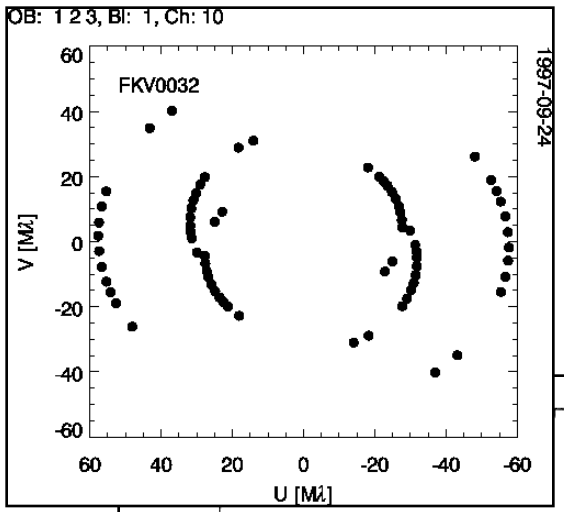
Monnier et al. 2006

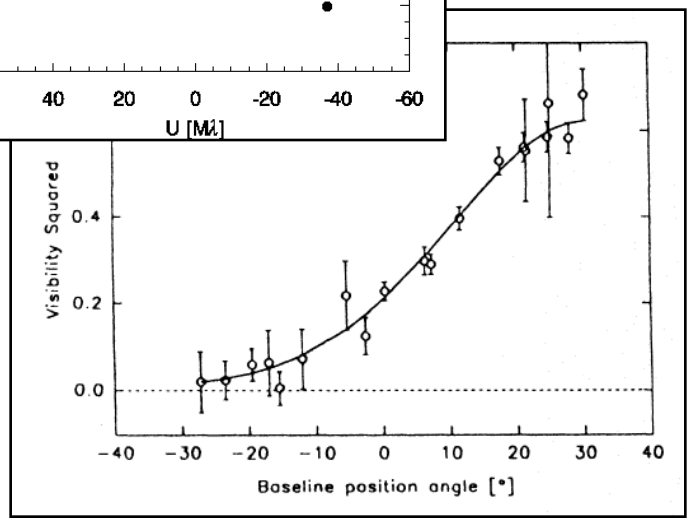


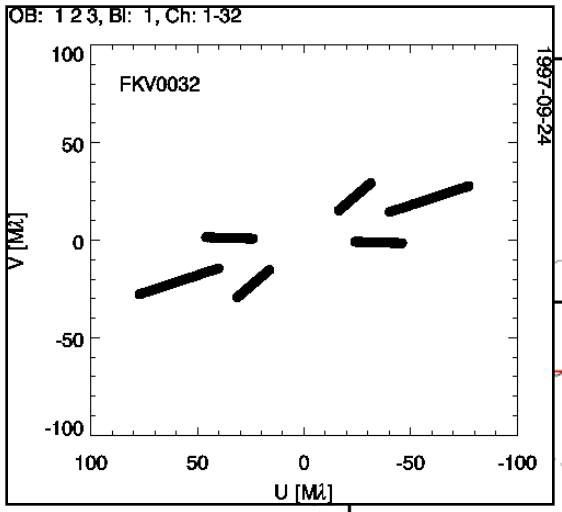
# Broadband aperture synthesis

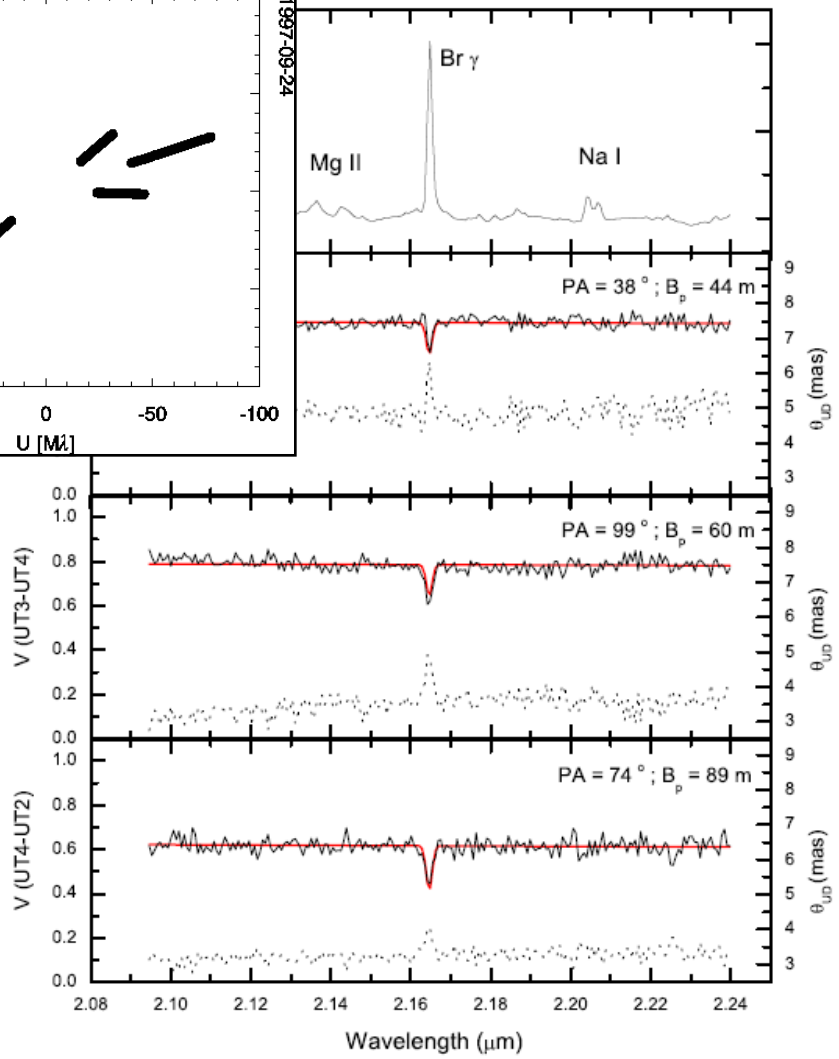
AMBER

Mark III



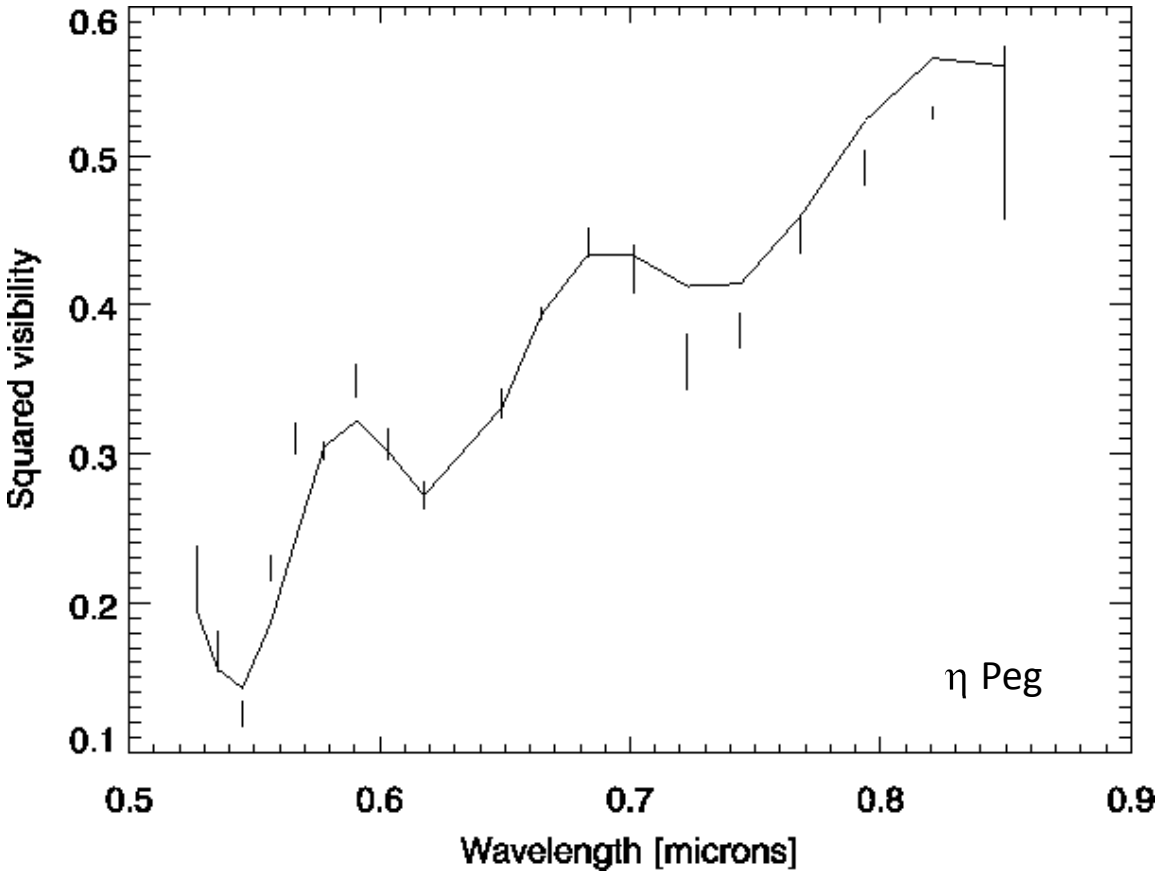



# Composite spectrum binary

η Peg = A+G
(NPOI)



# Interferometric imaging

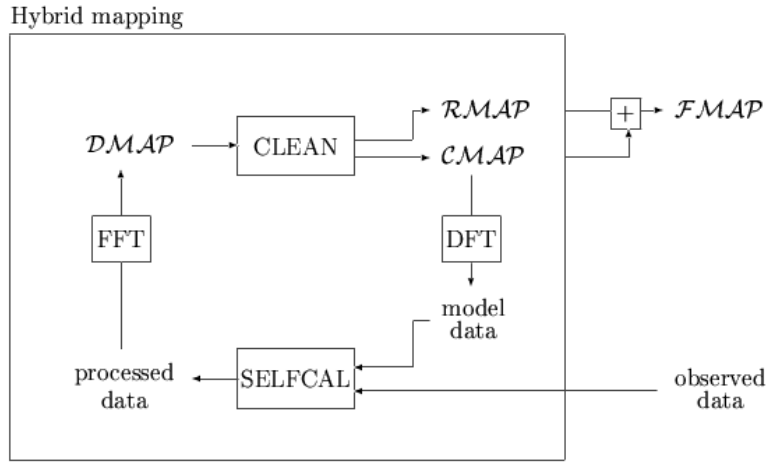
DMAP = dirty map
DMAP = FFT($V_{obs}$)

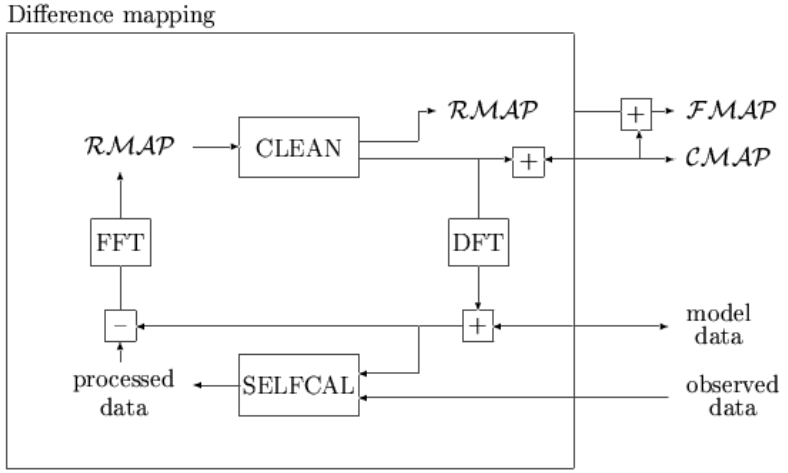
RMAP = residual map

CMAP = clean map
$V_{mod}$ = DFT(CMAP)

FMAP = final map
FMAP = RMAP + CMAP

DB = dirty beam



# CLEAN, by Högbom

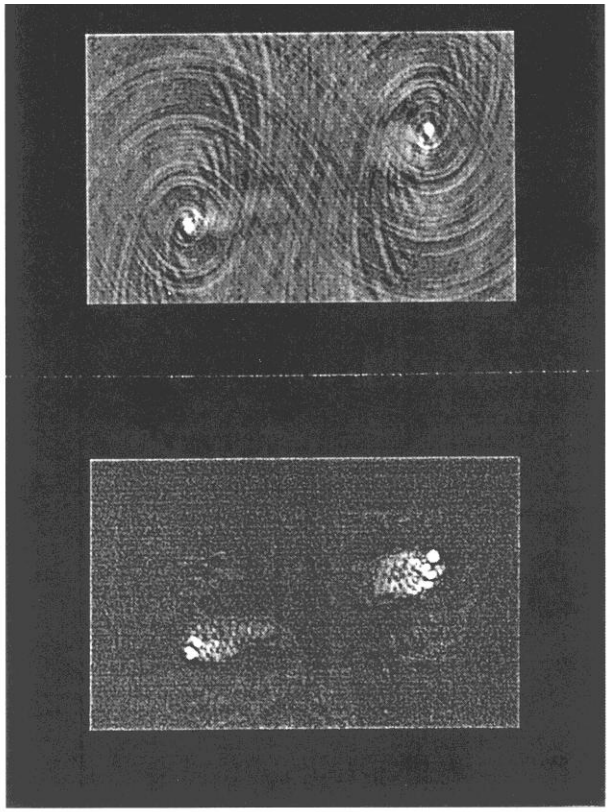
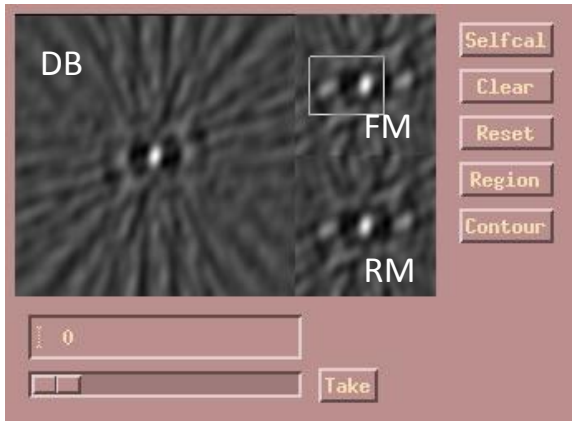


**Fig. 6.8.** The CLEAN process: maps of Cyg A made by MERLIN at 408 MHz (resol arcsec), before (a) and after (b) the process (courtesy T. B. Muxlow).

# An educational tool for imaging

(Pearl/OYSTER)

1

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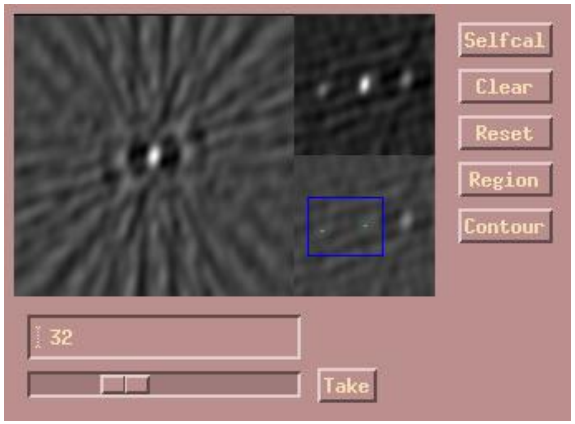


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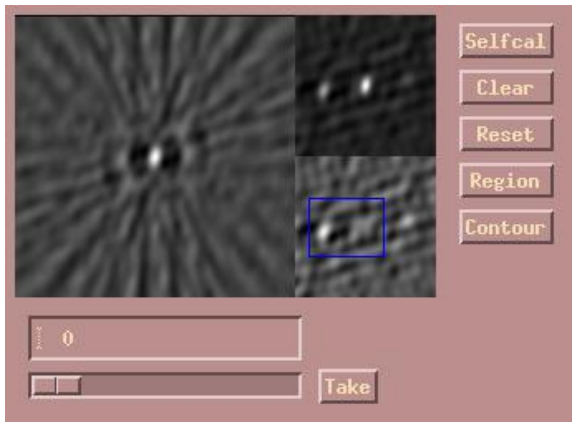
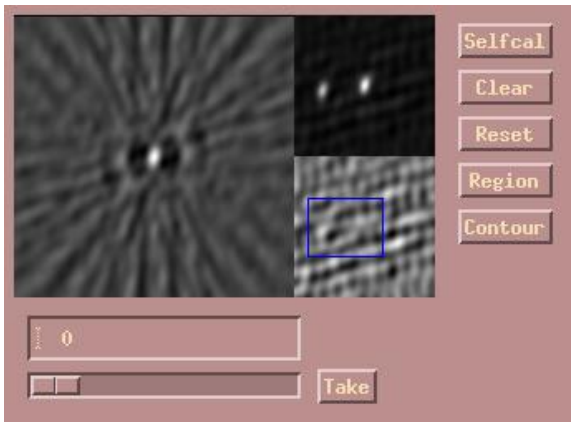


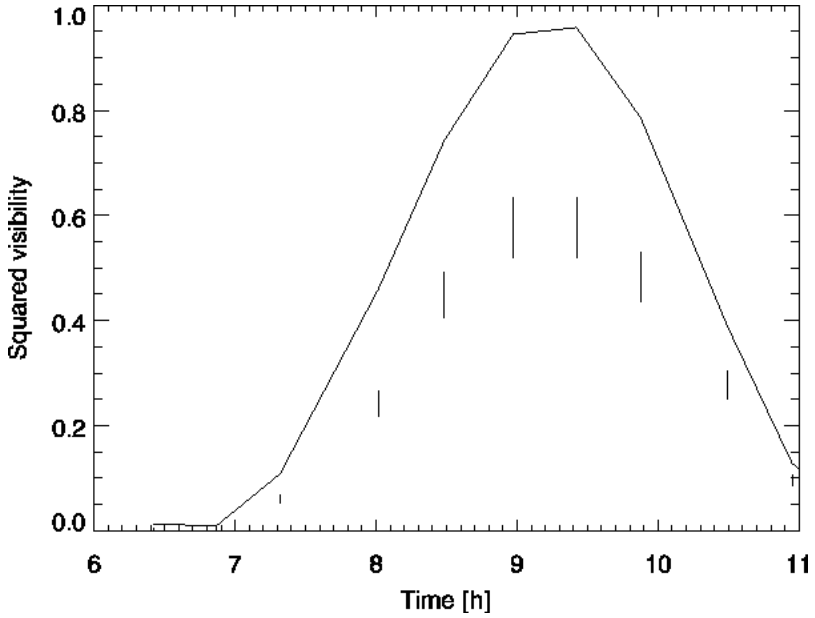

4

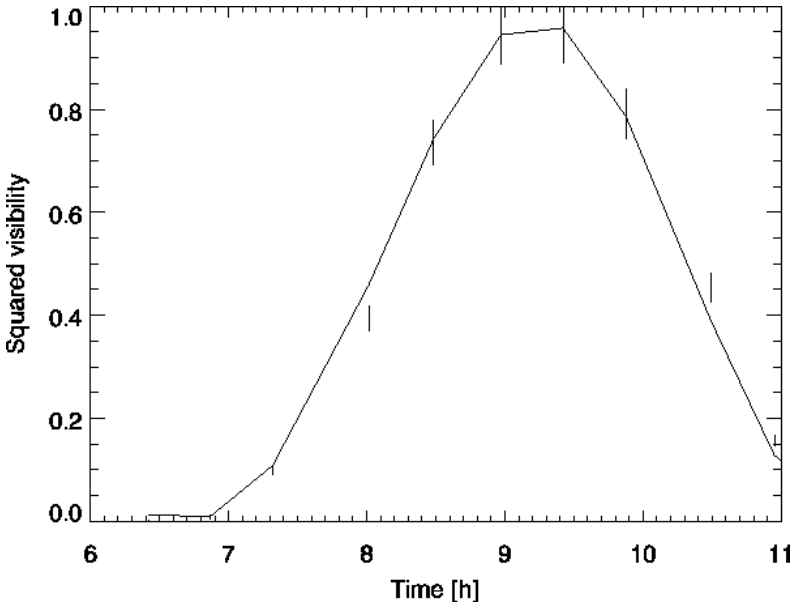


# Interferometers as telescopes

- Photometric field of view
- Interferometric field of view
- Aperture synthesis
- Sensitivity: it’s the correlated flux!

# Photometric field of view




Mizar A (V=2.3)
with B (V=4.0) at 14”
contributes uncorrelated flux

(Mark III)

Correction applied:

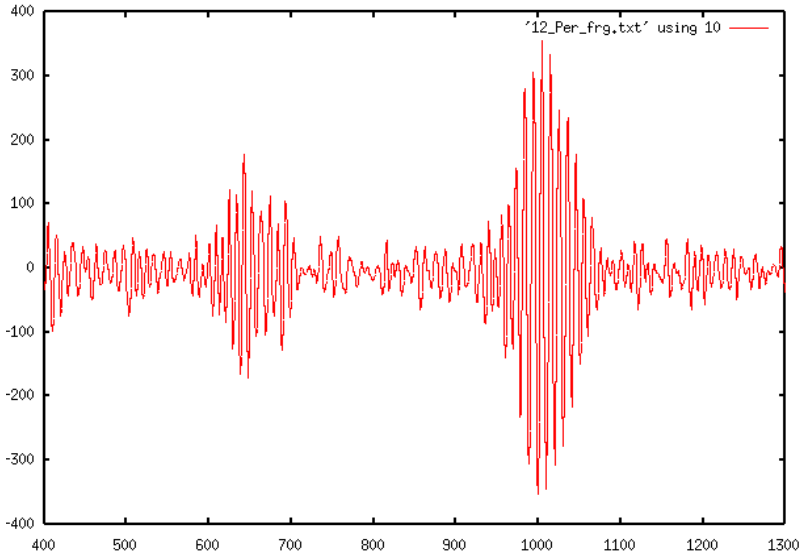
$$f = (1 + 10^{-\Delta m/2.5})^2$$

# Photometric field of view (VLTI)

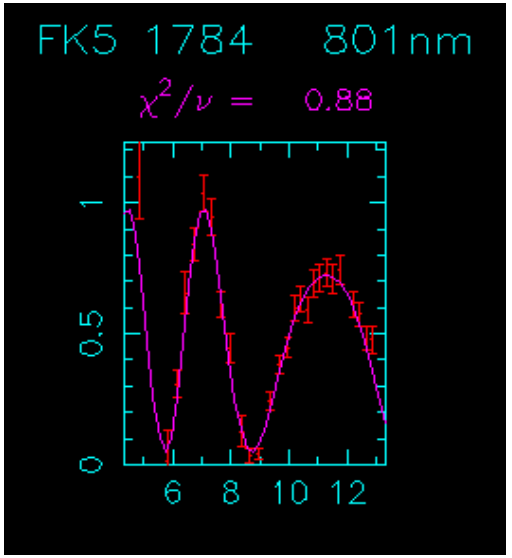
- MIDI: 2 arcseconds (bulk optics)
- AMBER: 65 mas with UTs, 280 mas with ATs (set by fibers)

# Interferometric field of view (I)

Width of fringe packet is inversely proportional to bandwidth

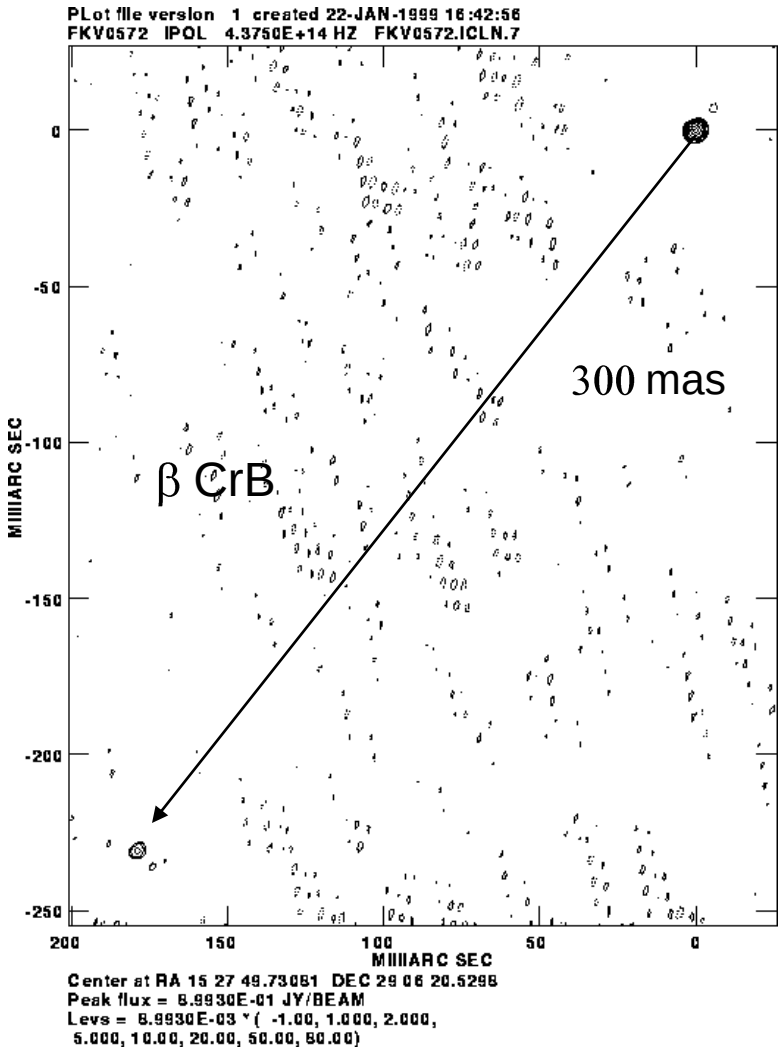



12 Persei observed on Oct 9, 2001 with the CHARA Array, K'-band, 330m baseline, separation 40 marcsec

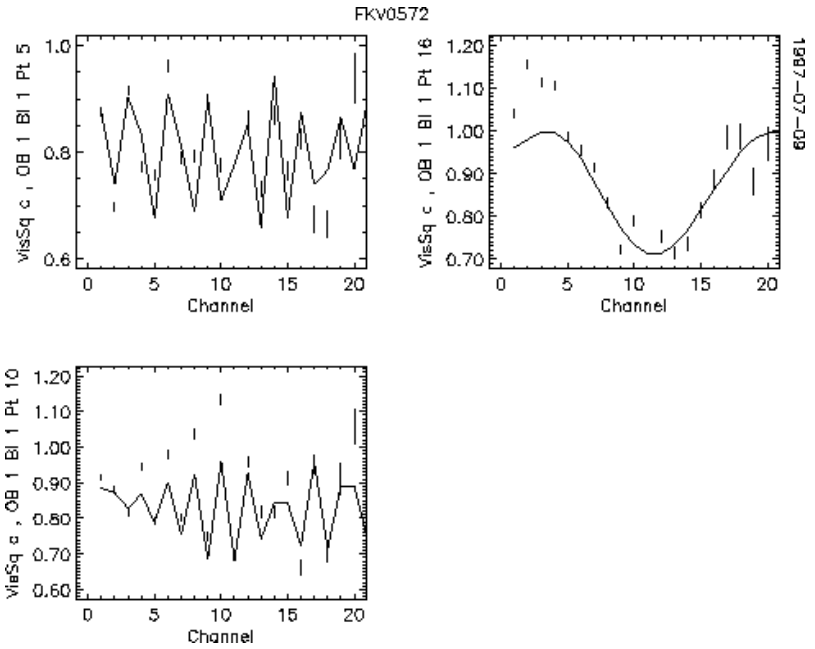



Mark 3 (Oct 8, 1992)

# Interferometric field of view (II)




$$\Delta\alpha = R\frac{\lambda}{B}$$




(NPOI)