Interpretation of Interferometric data

Christian A. Hummel (European Southern Observatory)

Acknowledgements: Michelson Summer School Authors

Courtesy of Tyler Nordgren

Overview

Interferometers as telescopes

Responses to simple models

Aperture plane visibility

Example interpretations

Polychromatic interferometry

Extended sources

Not enough data?

If all fails, suspect your calibrator!

Praxis of modelling

Interferometers as telescopes

Photometric field of view
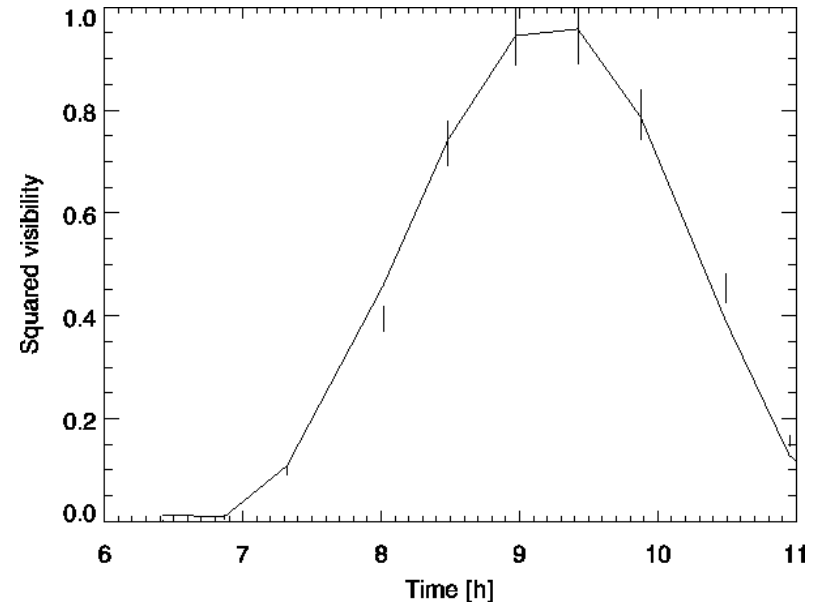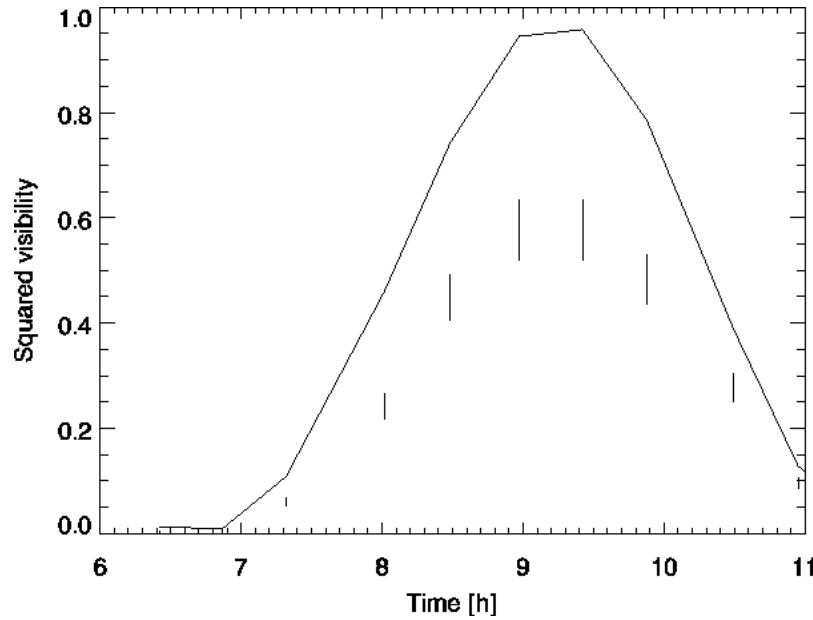
Interferometric field of view

Aperture synthesis

Sensitivity: it's the correlated flux!

WHERE D'YOU SUPPOSE THEY PUT THE EYEPIECE?

Courtesy of Tyler Nordgren

Mizar A (V=2.3)
with B (V=4.0) at 14"
(Mark III)

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

Interferometric field of view

PLot file version 1 created 22-JAN-1999 16:42:56
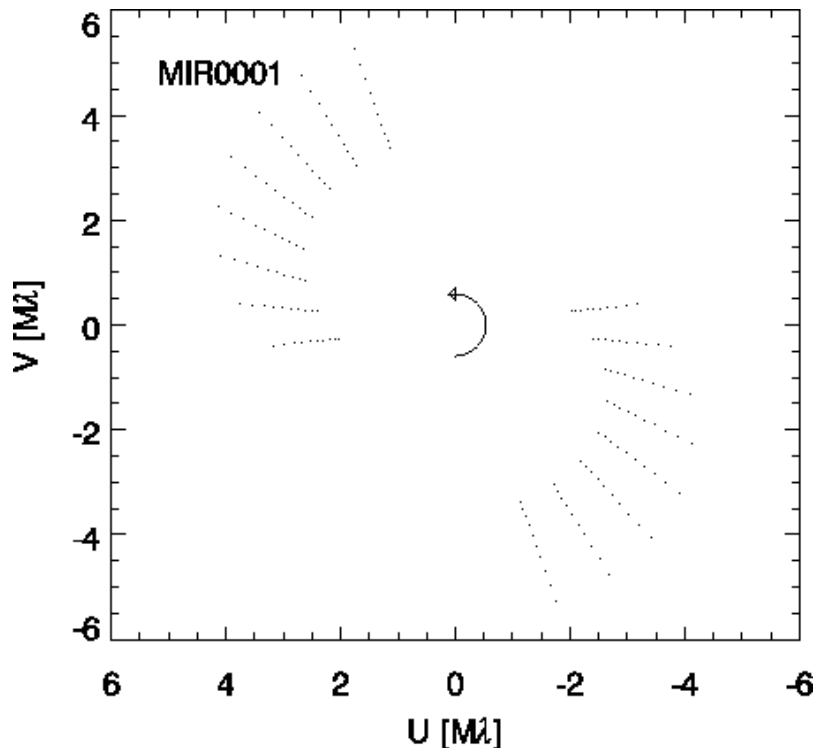FKV0572 IPOL 4.3750E+14 HZ FKV0572.ICLN.7

β CrB
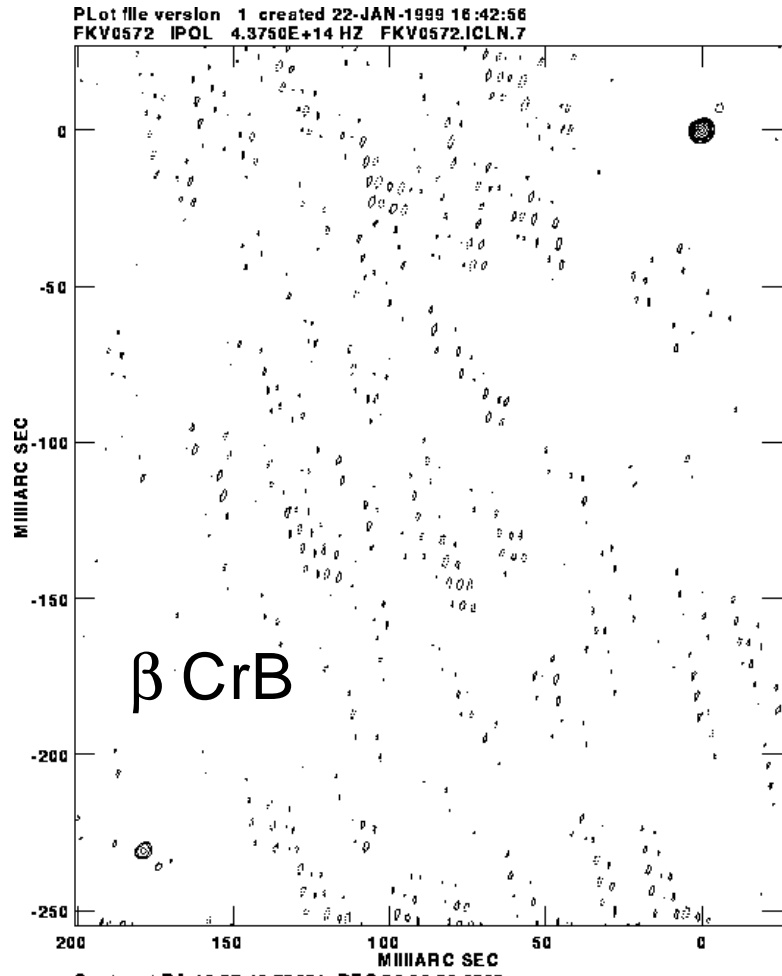
Center at RA 15 27 49.73081 DEC 29 06 20.5298
Peak flux = 8.9930E-01 JY/BEAM
Levs = 8.9930E-03 * (-1.00, 1.000, 2.000,
5.000, 10.00, 20.00, 50.00, 80.00)

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

FKv0572

1997-07-09
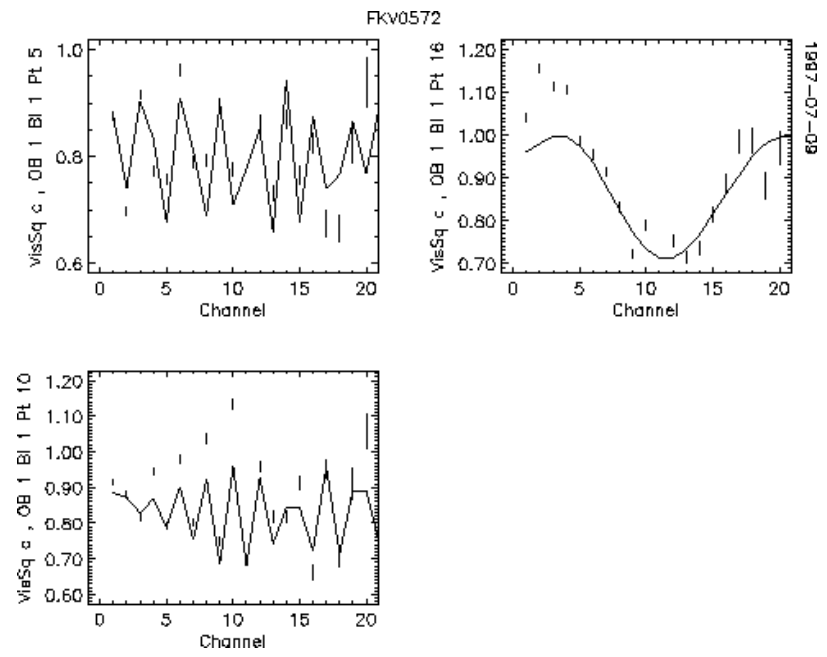
(NPOI)

Aperture synthesis


```
function mapvis,map,u,v
;
; Compute the visibility for a map at a single coordinate u and v[lambda].
; Map positions are in mas. map.x corresponds to RA and increases towards
; East, i.e. left.
;
RAD=180/!pi
MAS=1/3600000.d0
;
arg=2*!pi*(u*map.x+v*map.y)*MAS/RAD
;
return,total(map.i*complex(cos(arg),sin(arg)))
;
end
                                                    1,1          Top
```
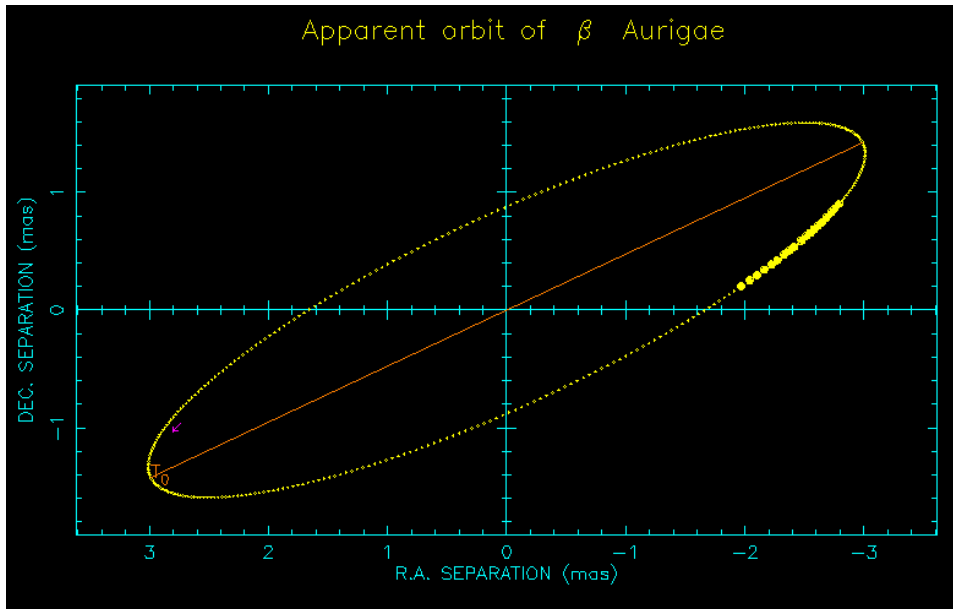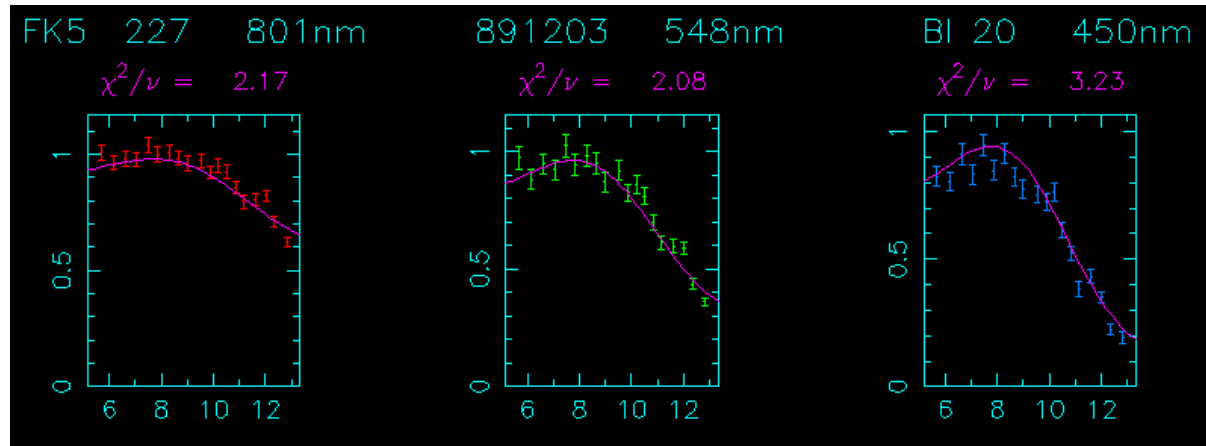
MIDI, UT2-UT3, $\delta = -61$

Aperture synthesis and orbital motion

β Aur
(Mark III)

P = 4 days

Responses to simple models

Point source ("unresolved")

Uniform disk

Elliptical disk

Limb darkened disk

Binary, mystery star
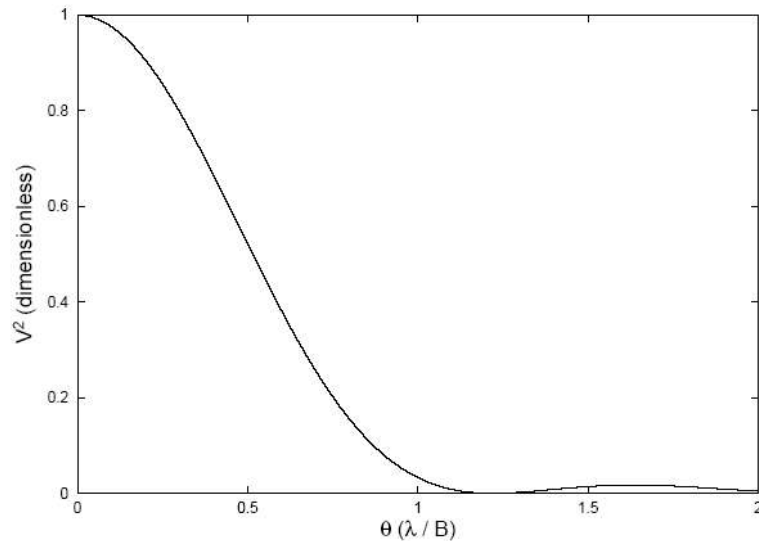
Gaussian

Ring

Uniform disk

Figure 2.6: Squared Normalized Visibility Amplitude for the Uniform Disk. The disk diameter θ is plotted in units of the interferometer fringe spacing $\lambda / B_\perp$.

Session Edit View Settings Help

```
IDL> mas_per_rad=180/!pi*3600*1000.
IDL> uvdist=1./(2.0/mas_per_rad)
IDL> print,uvdist
   1.03132e+08
IDL> ud=2.0
IDL> arg=!pi*ud/mas_per_rad*uvdist
IDL> print,(2*beselj(arg,1)/arg)^2
   0.0328304
IDL>
```

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.
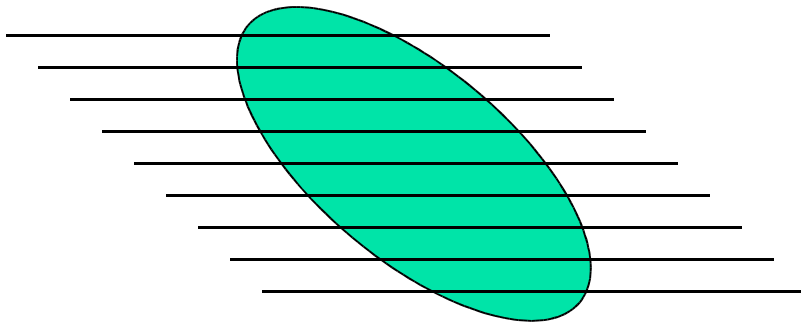
Fourier transform strip brightness distribution
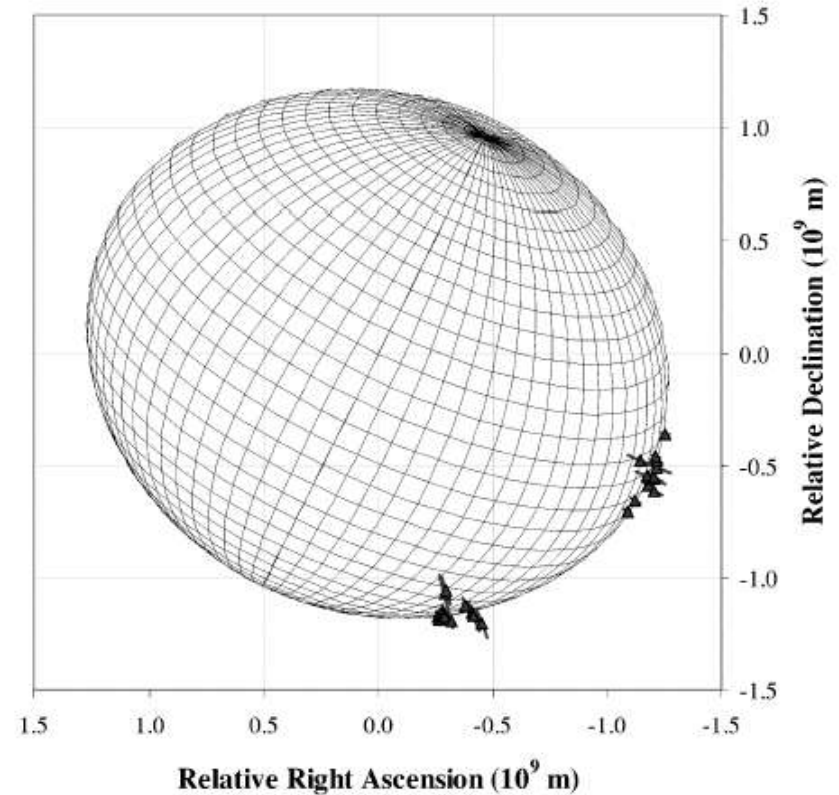
van Belle et al. (2001)

Limb darkened disk
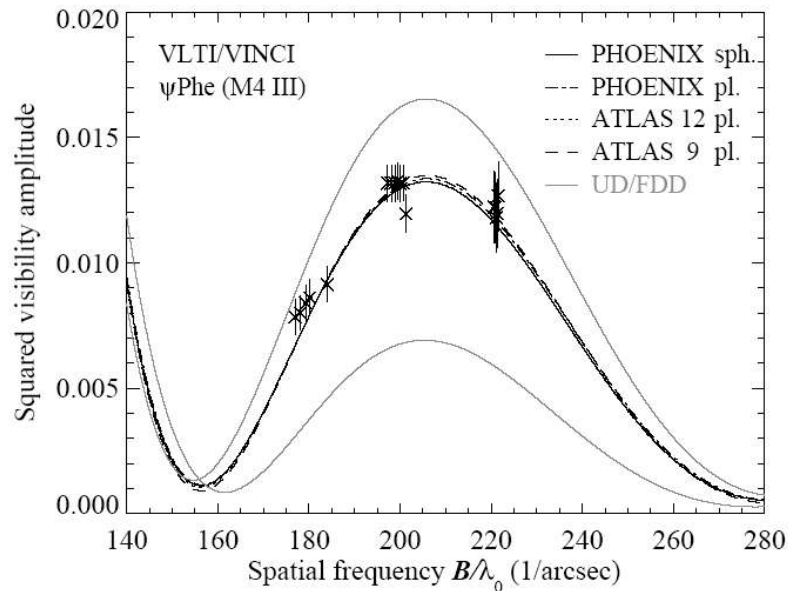
$$D_\lambda(\mu) = I_\lambda(\mu)/I_\lambda(1) = 1 - x_\lambda(1-\mu).$$

```
alpha=1-ld_coeffs
beeta=ld_coeffs
arg=!pi*model.diameter*mas2rad*sqrt(u^2+v^2)
visamp=(alpha*beselj(arg,1)/arg+beeta*sqrt(!pi/2)* $
        sqrt(2/(!pi*arg))*(sin(arg)/arg-cos(arg))/ $
        sqrt(arg*arg*arg))/(alpha/2+beeta/3)
return,complex(visamp)*flux
```

Wittkowski et al. (2003)

Binary

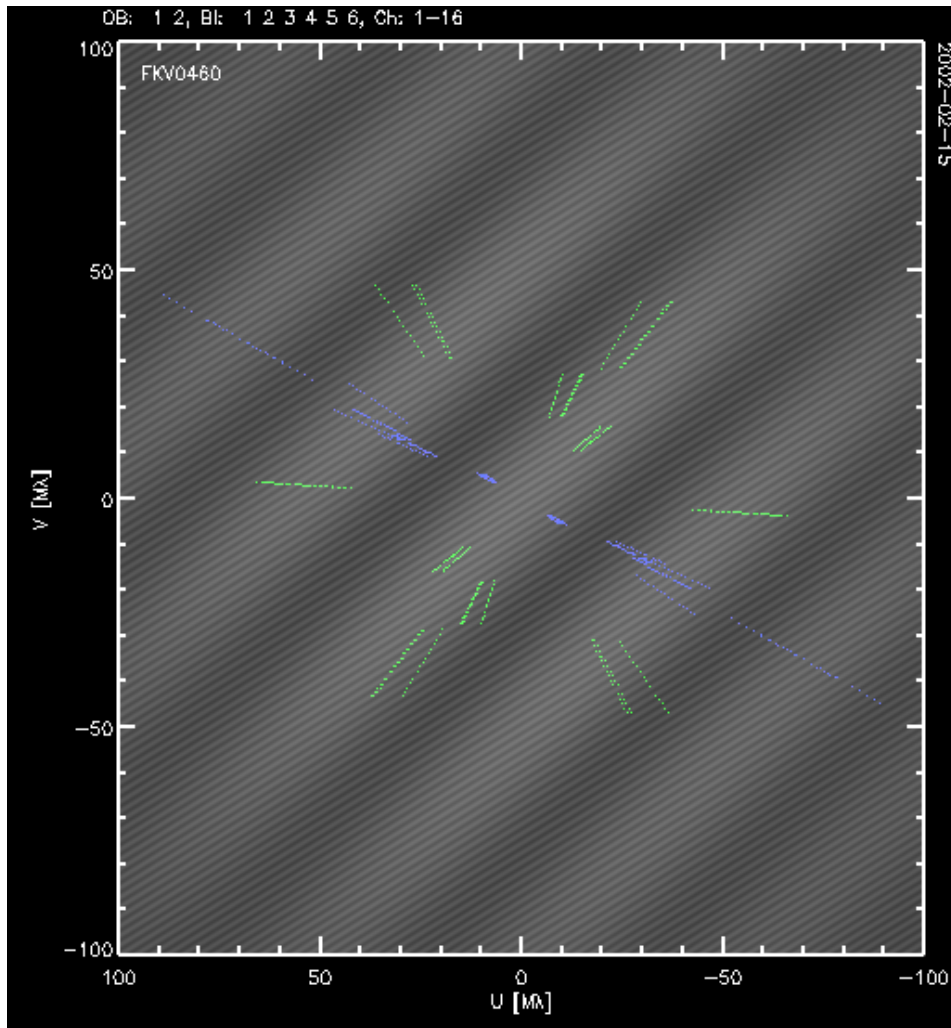FK5 193 801nm

$\chi^2/\nu = 11.21$
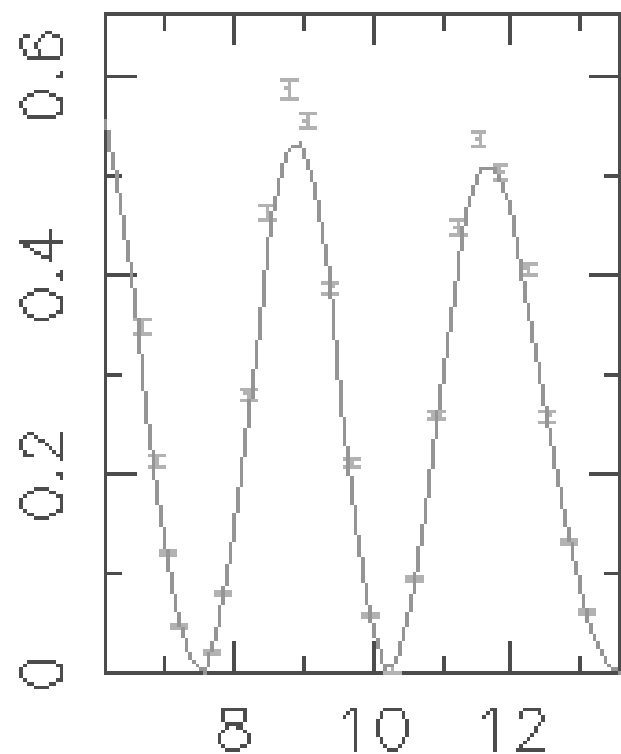
BI 1 501nm

$\chi^2/\nu = 6.10$
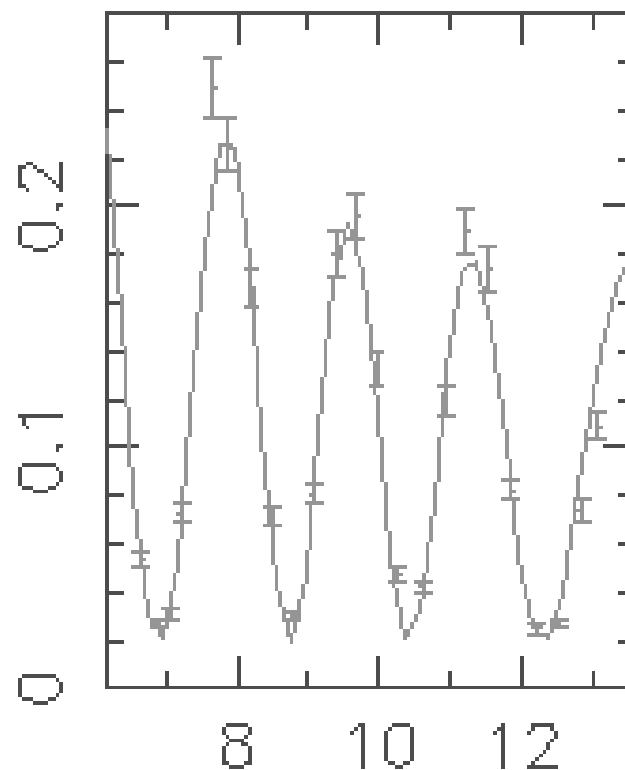
Mark III

Mystery star
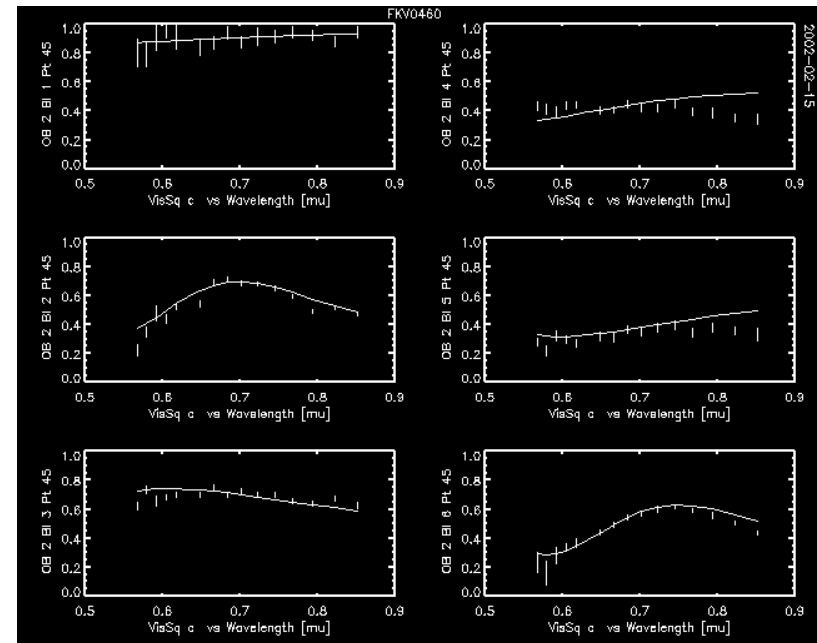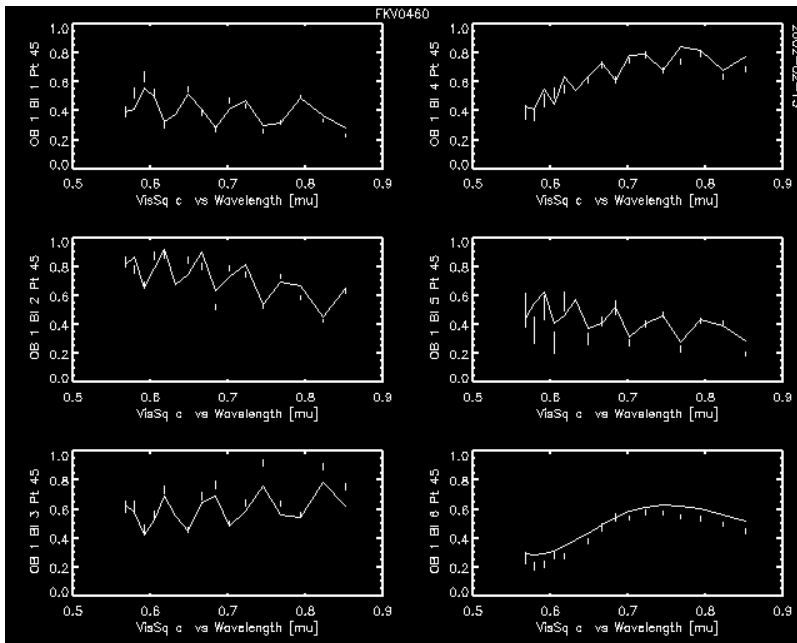
All baseline PAs

2nd spectr., One PA

Triple star
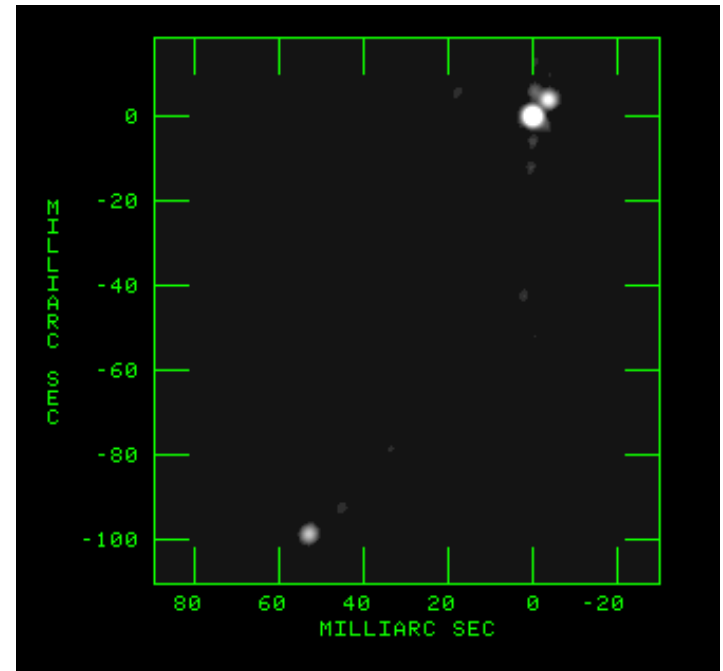
η Vir (Hummel et al. 2004)

Aperture plane visibility

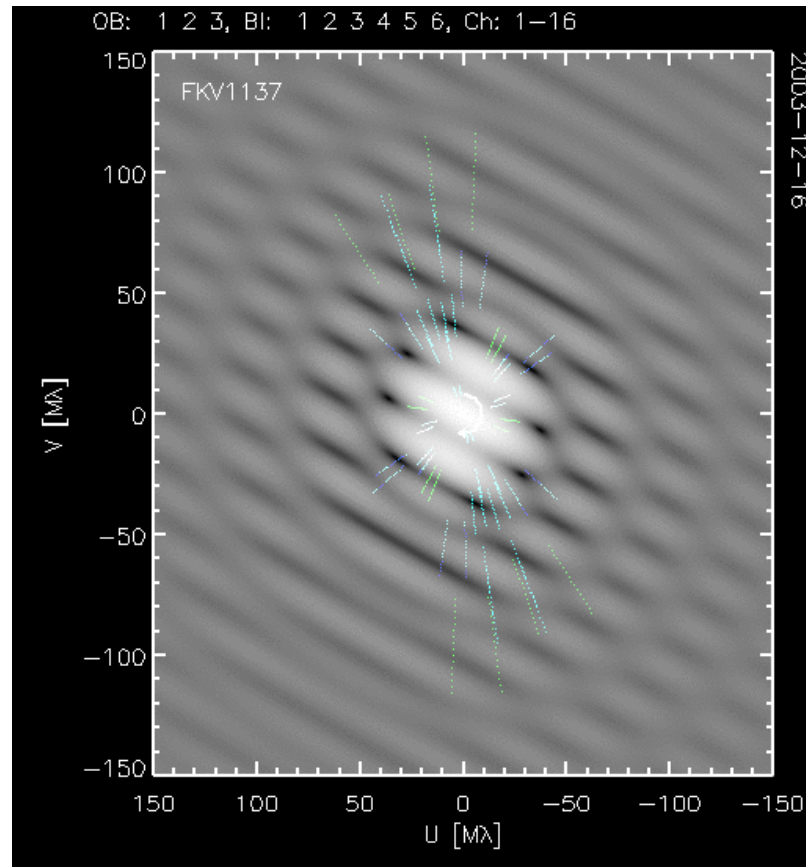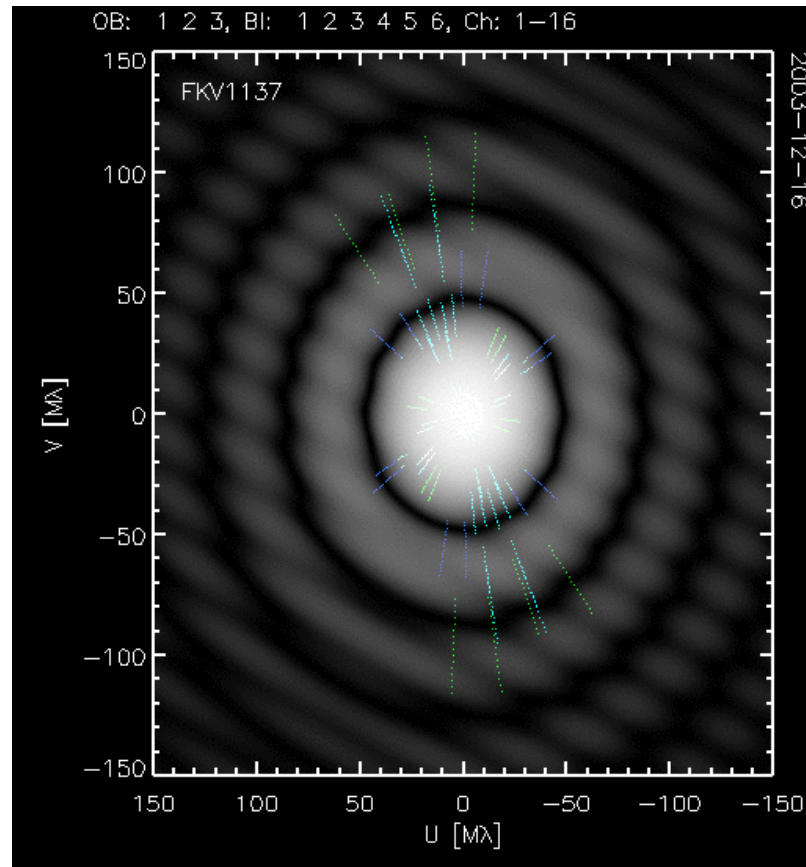Equal magnitude binary

Resolved component in binary

Faint secondary vs resolved primary

Archimedes spiral

Equal magnitude binary
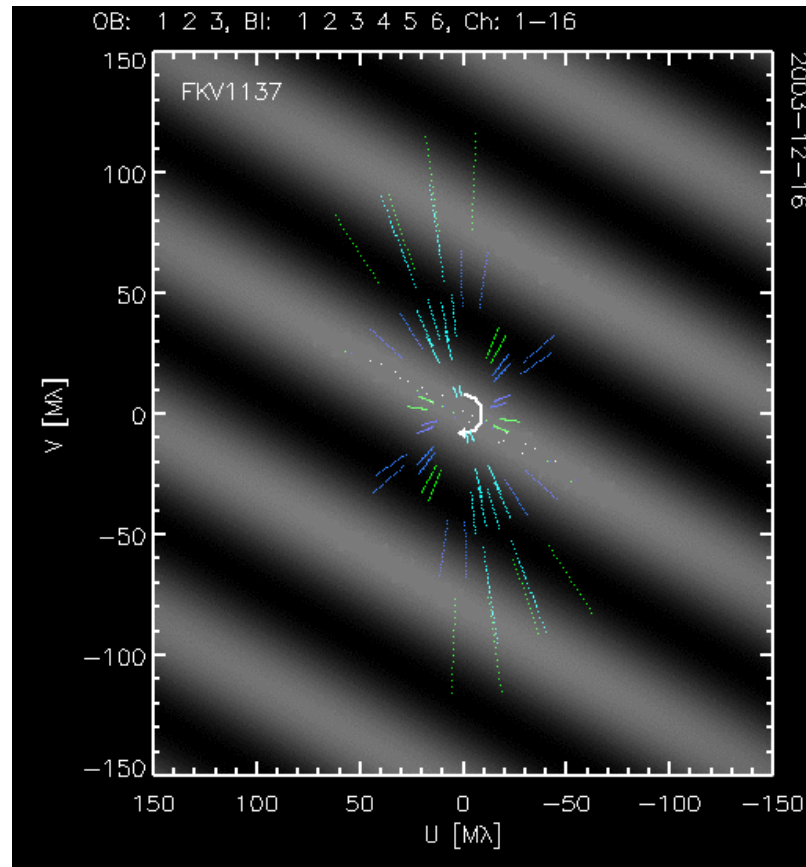
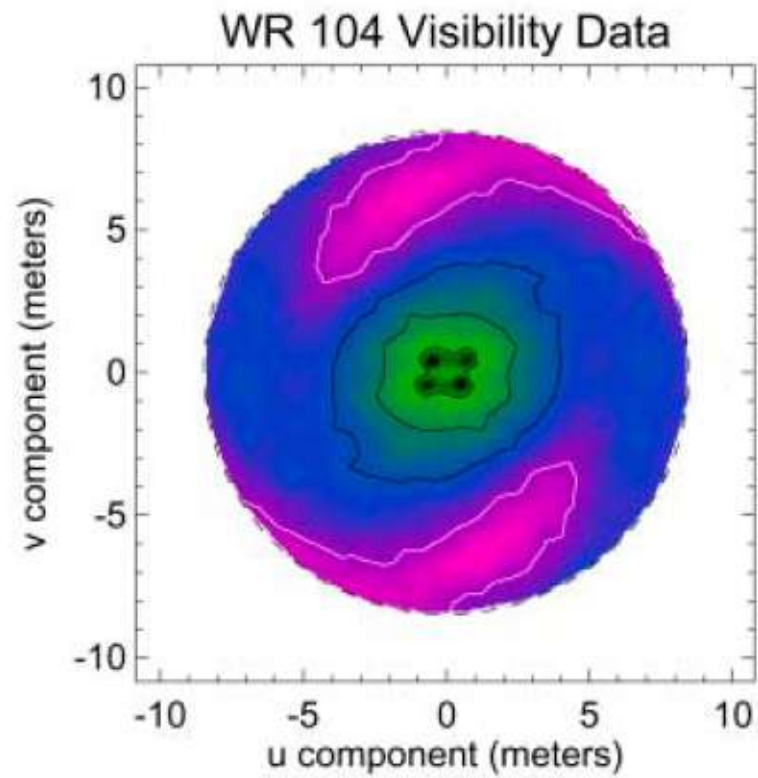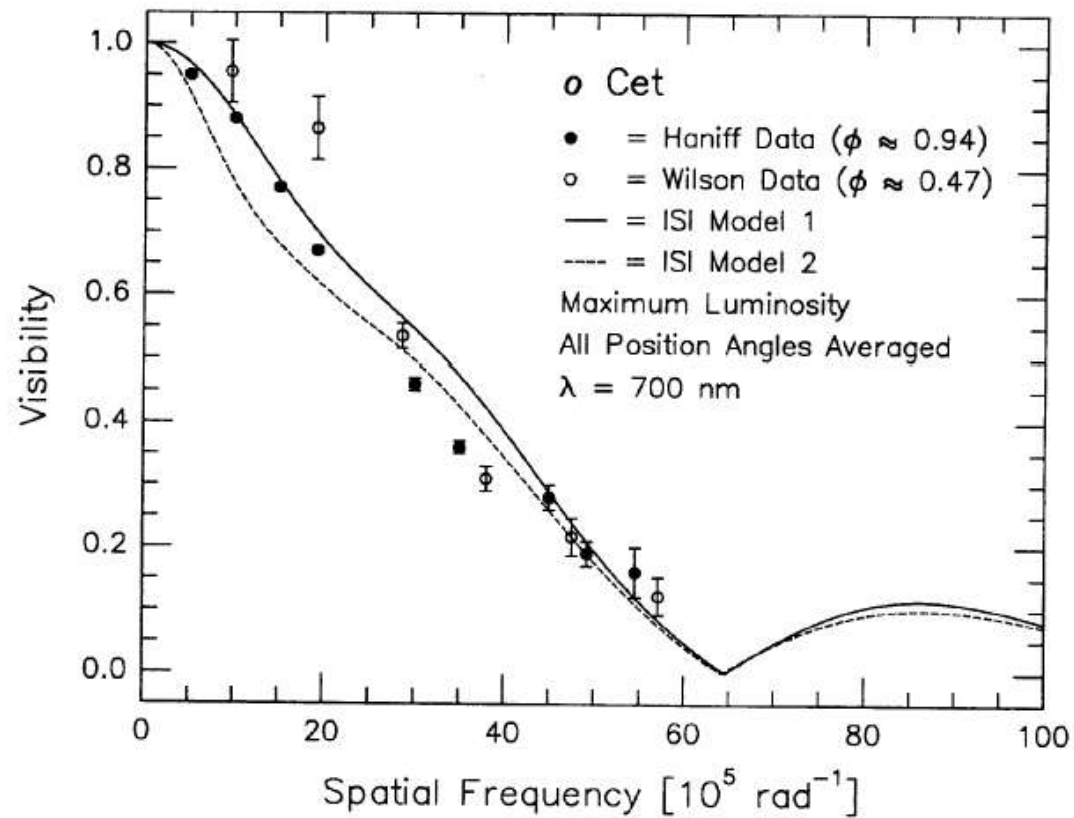# Resolved component in binary

Faint secondary vs resolved primary

Archimedes spiral

WR 104 Visibility Data

Monnier et al. 1999

Example interpretations (1)

Danchi et al. 1994

Example interpretations (2)

Danchi et al. 1994

Example interpretations (3)

(a)

Danchi et al. 1994

Example interpretations (4)

WR 104 at 2.2 μm (Apr 1998)
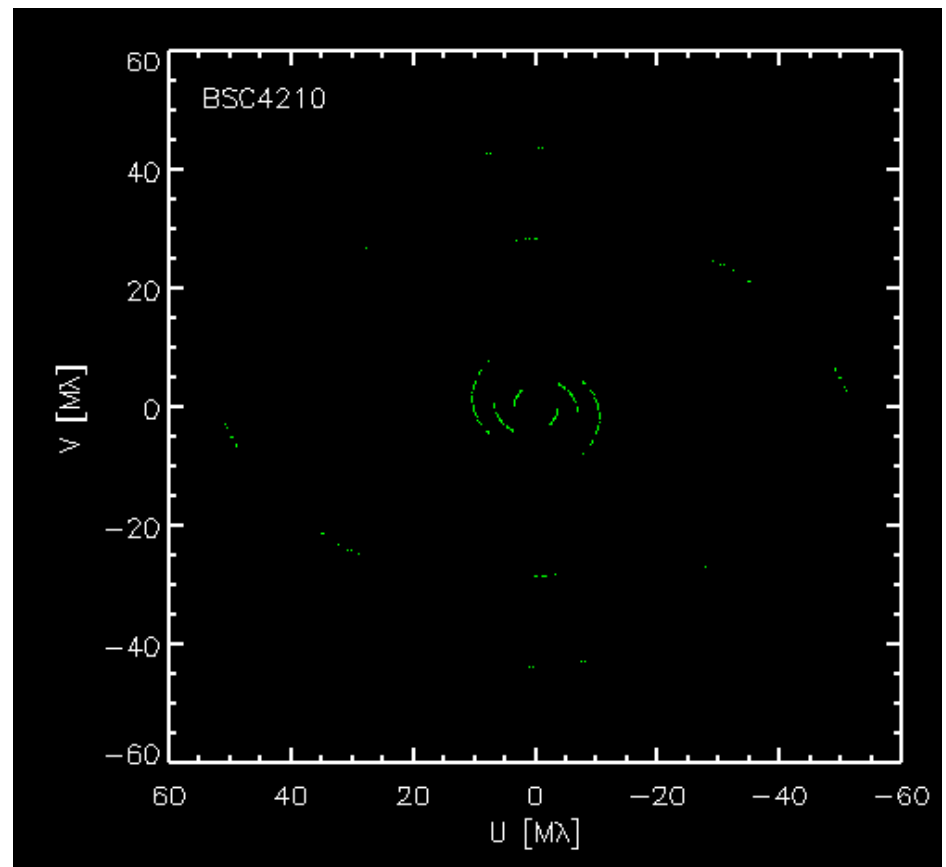
Monnier et al. 1999
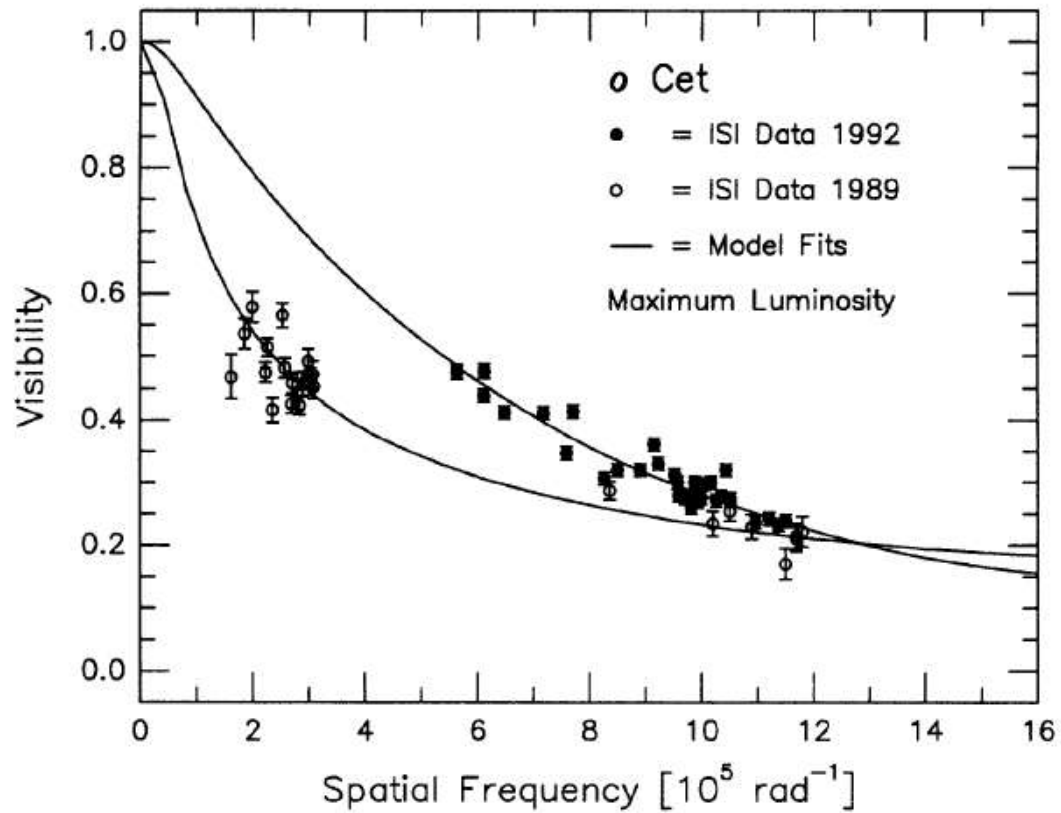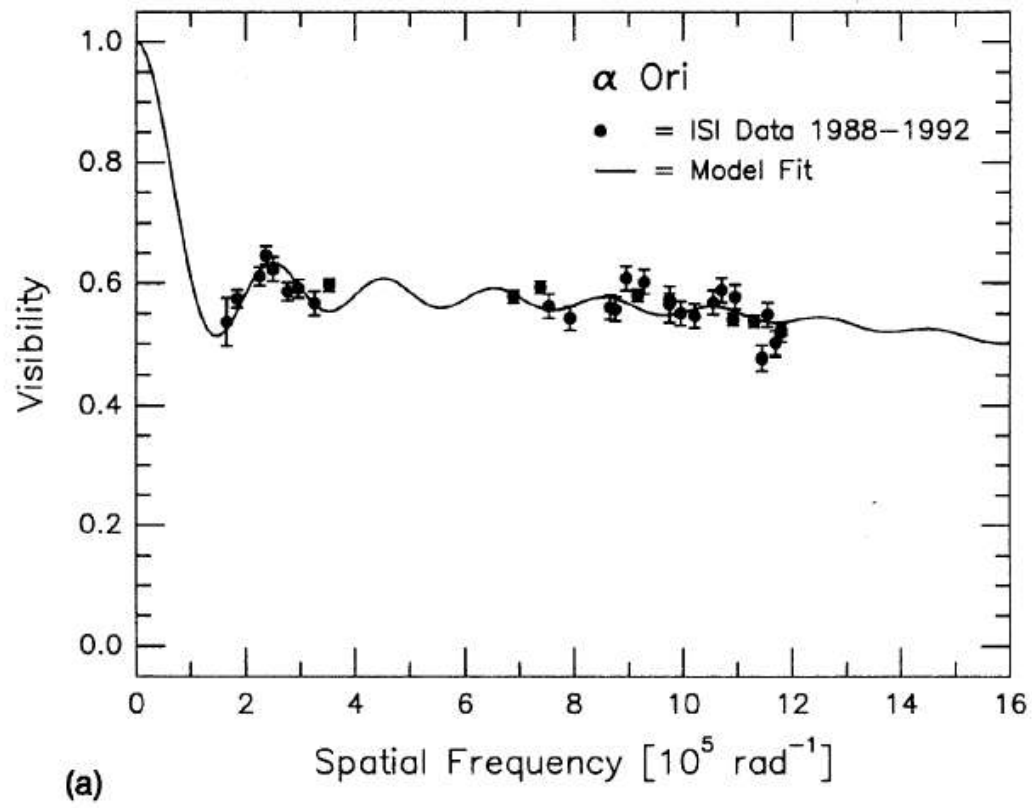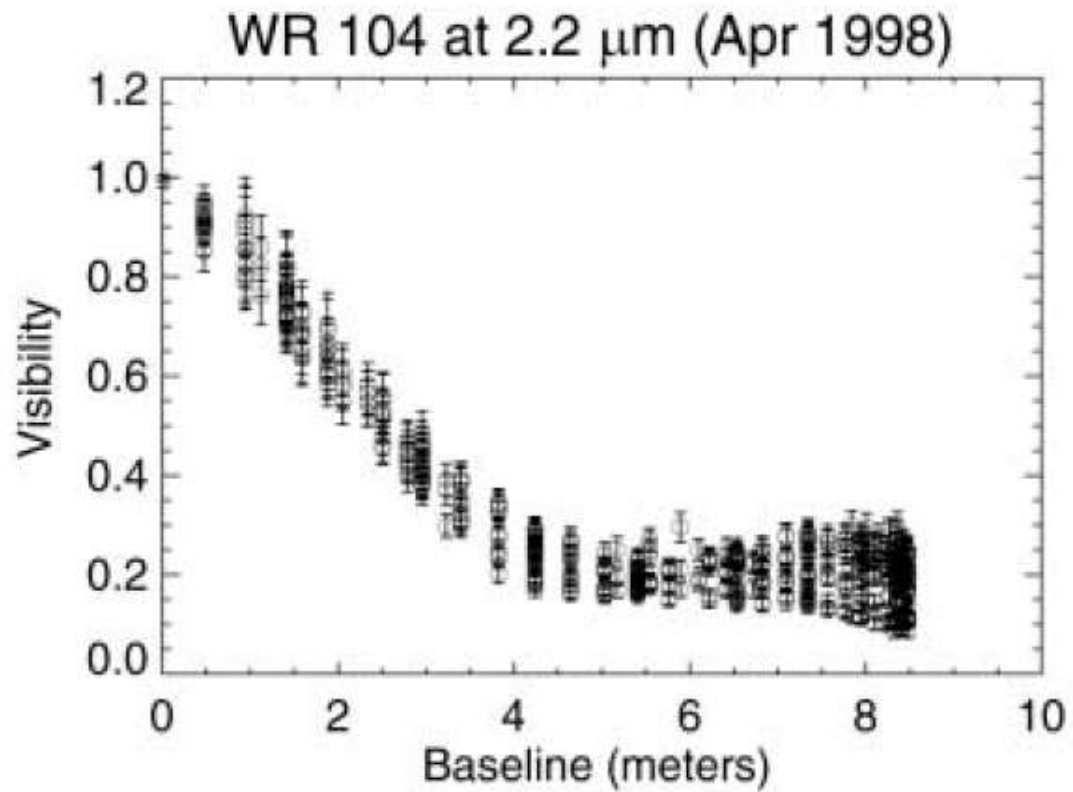
Example interpretations (5a)
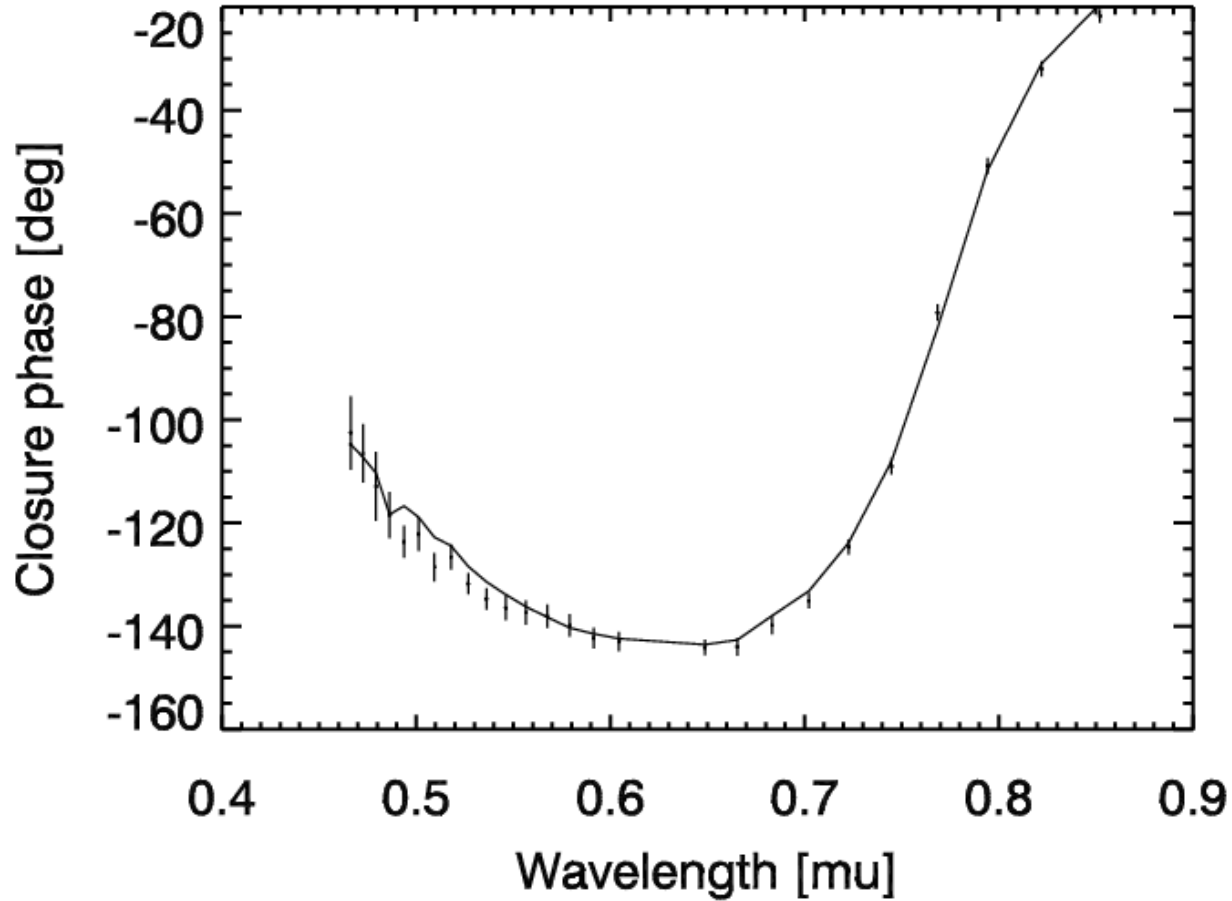

VLTI/VINCI
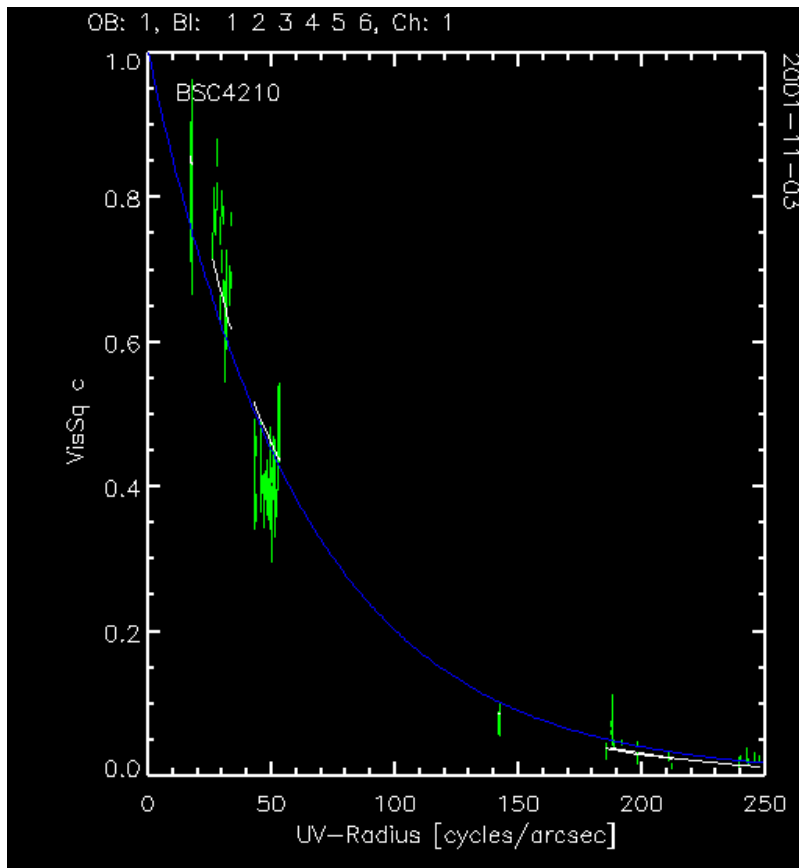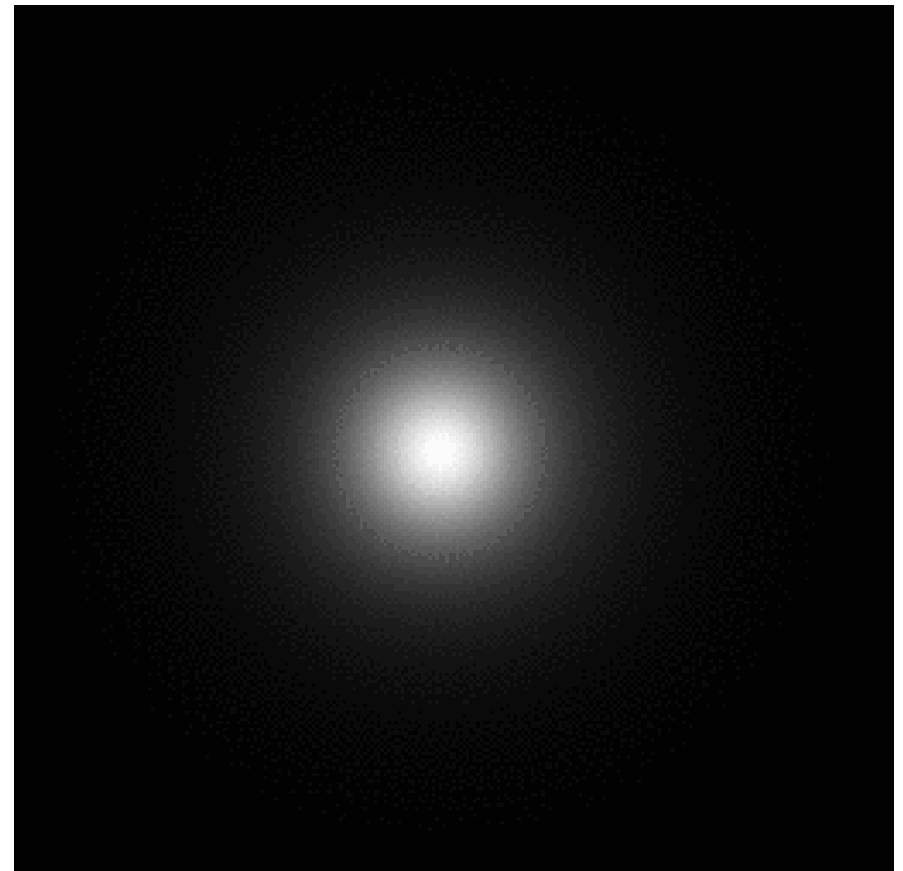
η Car

Example interpretations (5b)

VLTI/VINCI

Altair

(NPOI)

Peterson et al. 2005
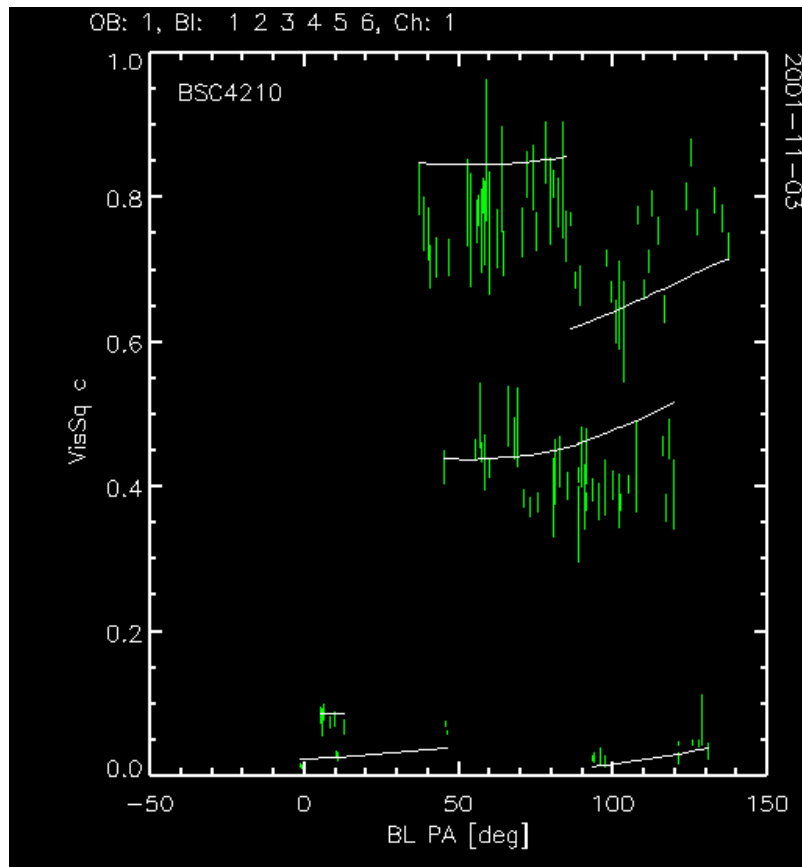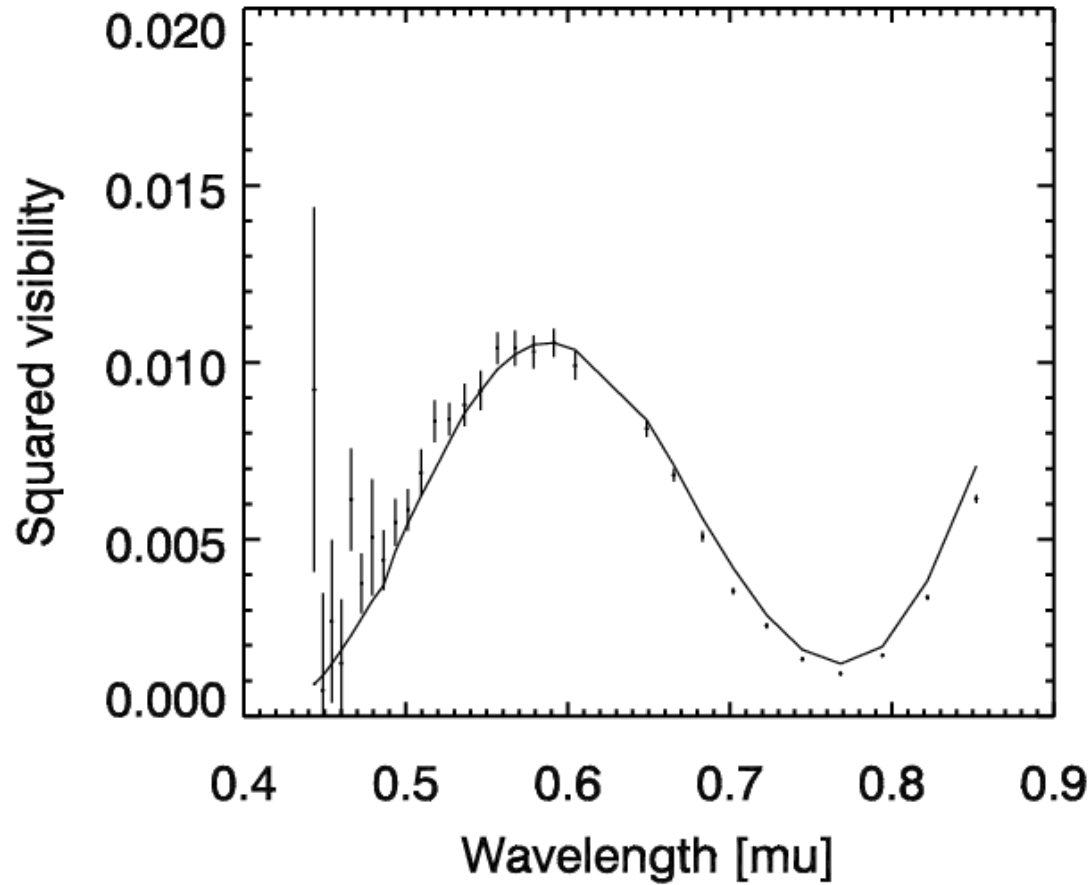
Example interpretations (6b)

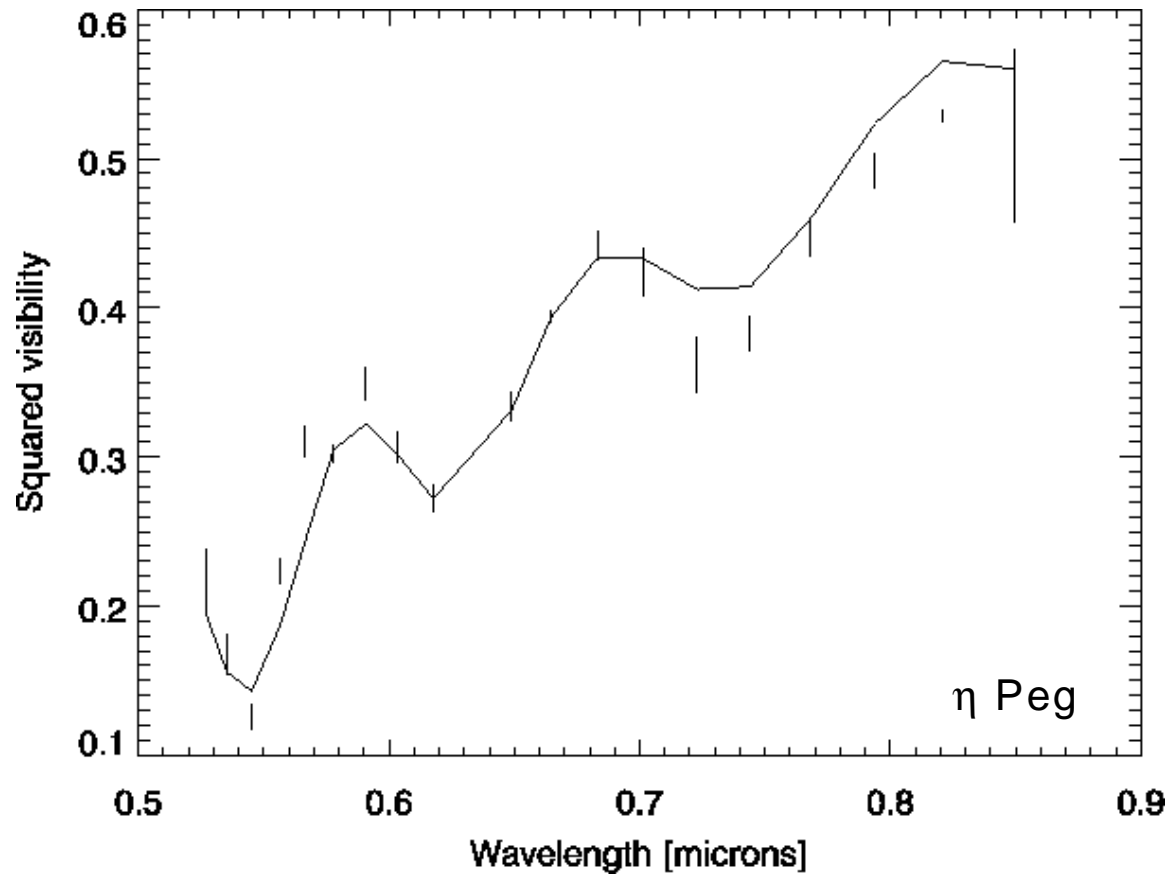Altair
(NPOI)

Peterson et al. 2005

Polychromatic interferometry

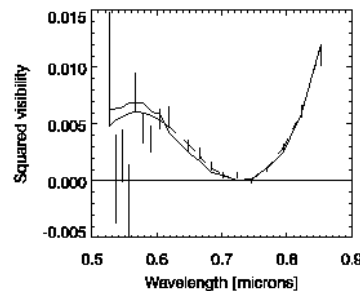Disperse the light!
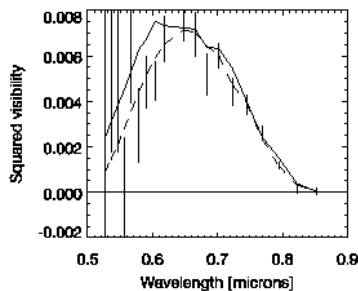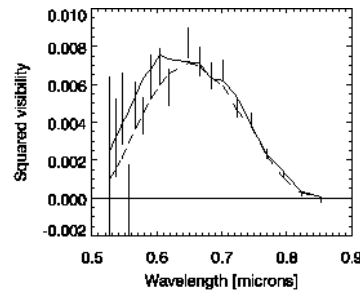
Broad band aperture synthesis

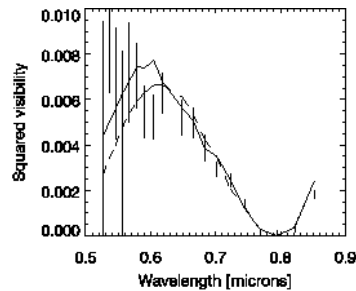Source structure dependent on wavelength

Composite spectrum binary

η Peg
(NPOI)

Stellar atmospheres

$$V_{\mathrm{LD}}(\lambda) = \int_0^1 S_\lambda \, I_\lambda^\mu \, J_0[\pi \, \theta_{\mathrm{LD}} \, (B/\lambda) \, (1 - \mu^2)^{1/2}] \, \mu \, d\mu$$

```
f1=(mu*profile)/profile(n_elements(mu)-1)
f2=beselj(arg*sqrt(1-mu^2),0)*f1
;
return,int_tabulated(mu,f2)/int_tabulated(mu,f1)
```

γ Sge

MIDI visibility spectra of disks

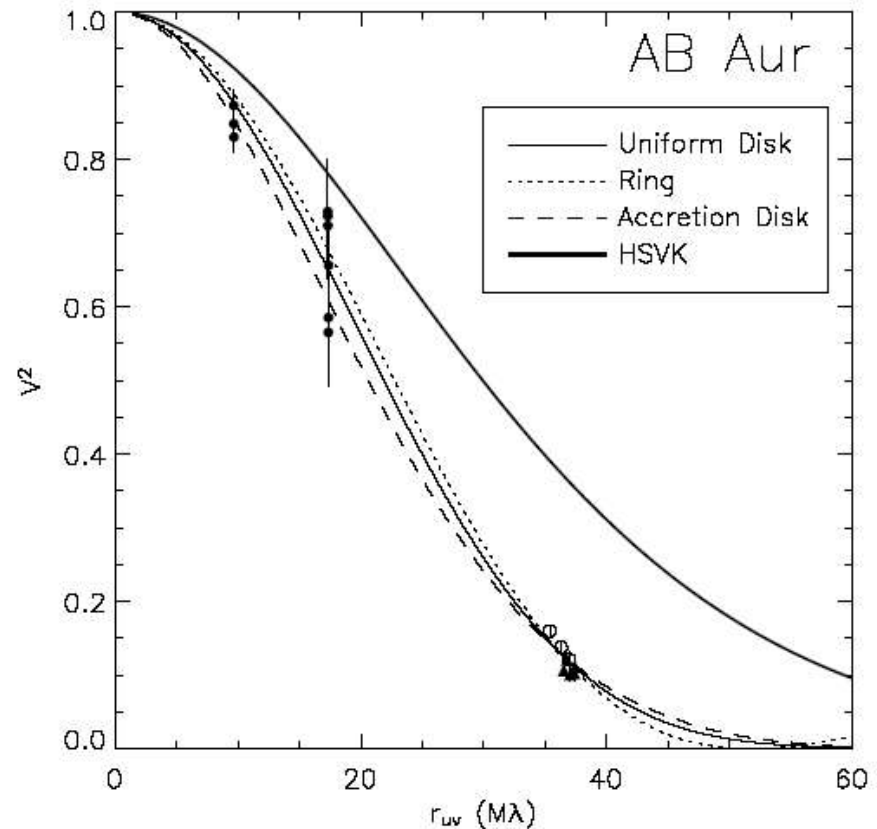

Leinert et al. 2004
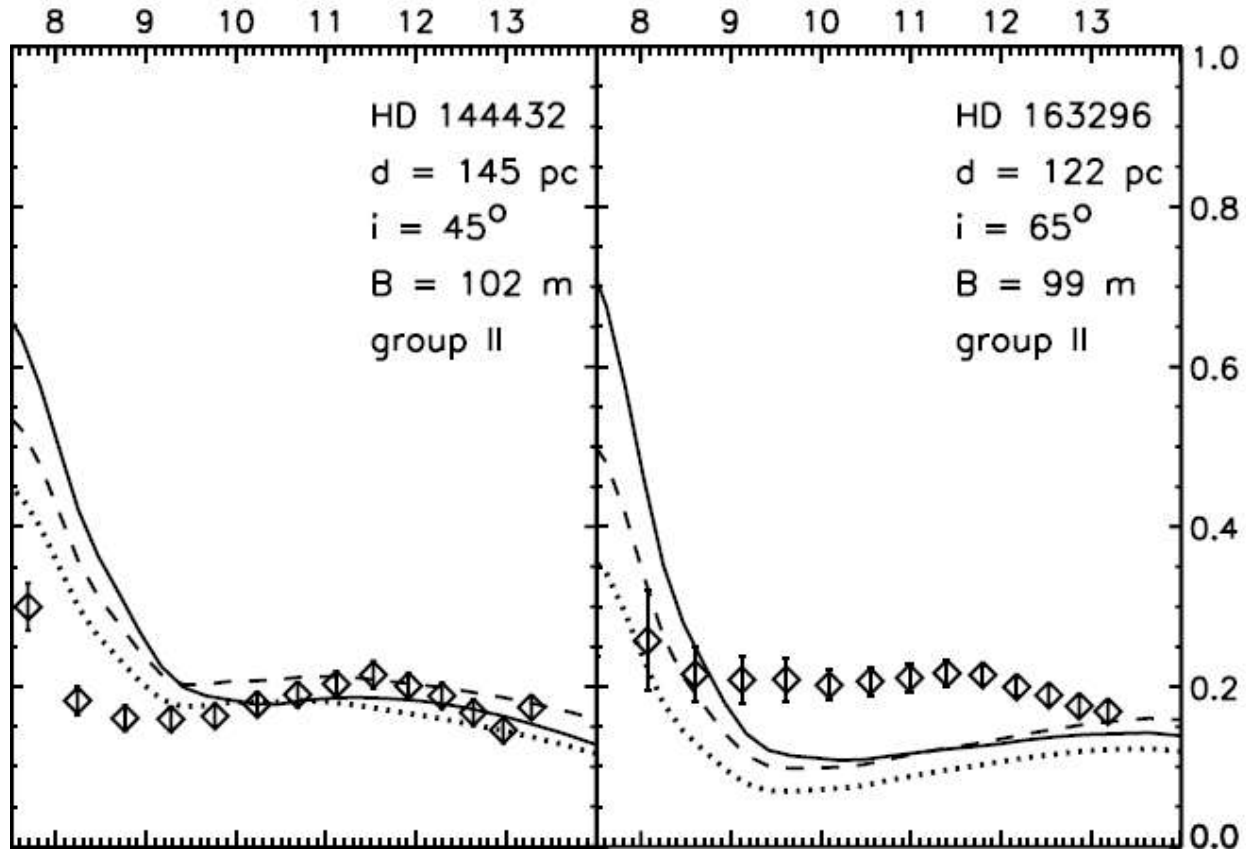
Extended sources

Zero spacing flux

Incoherent flux correction

Bandwidth smearing

Not enough data?

Other sources of info:

- Spectro-astrometry
- NACO
- SED
- Other?

Eisner et al. 2003

If all fails, suspect your calibrator

Is it too resolved?

Is it a binary?

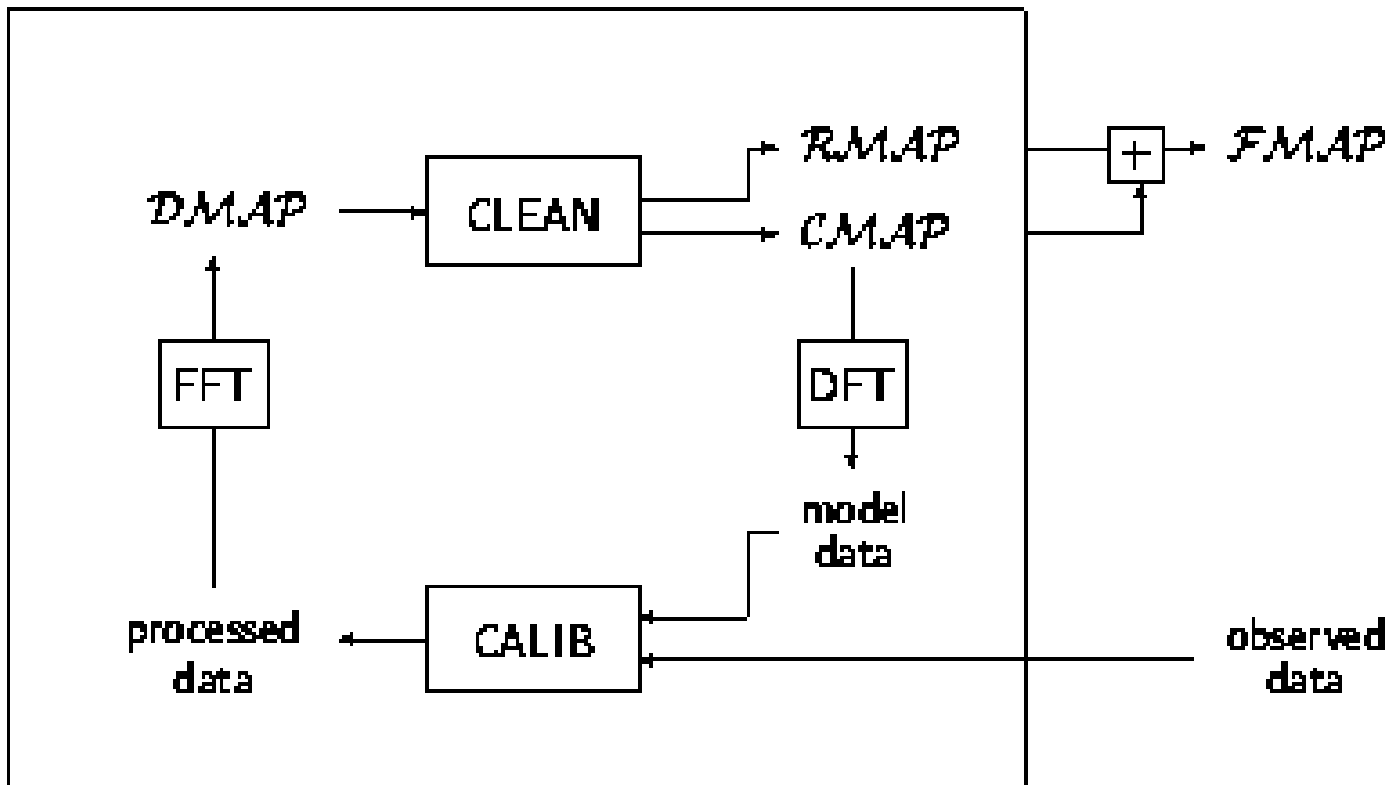# The praxis of modelling

Assembling a hierarchical model

Levenberg-Marquardt NL LSQ

Use squared visibility, not visibility

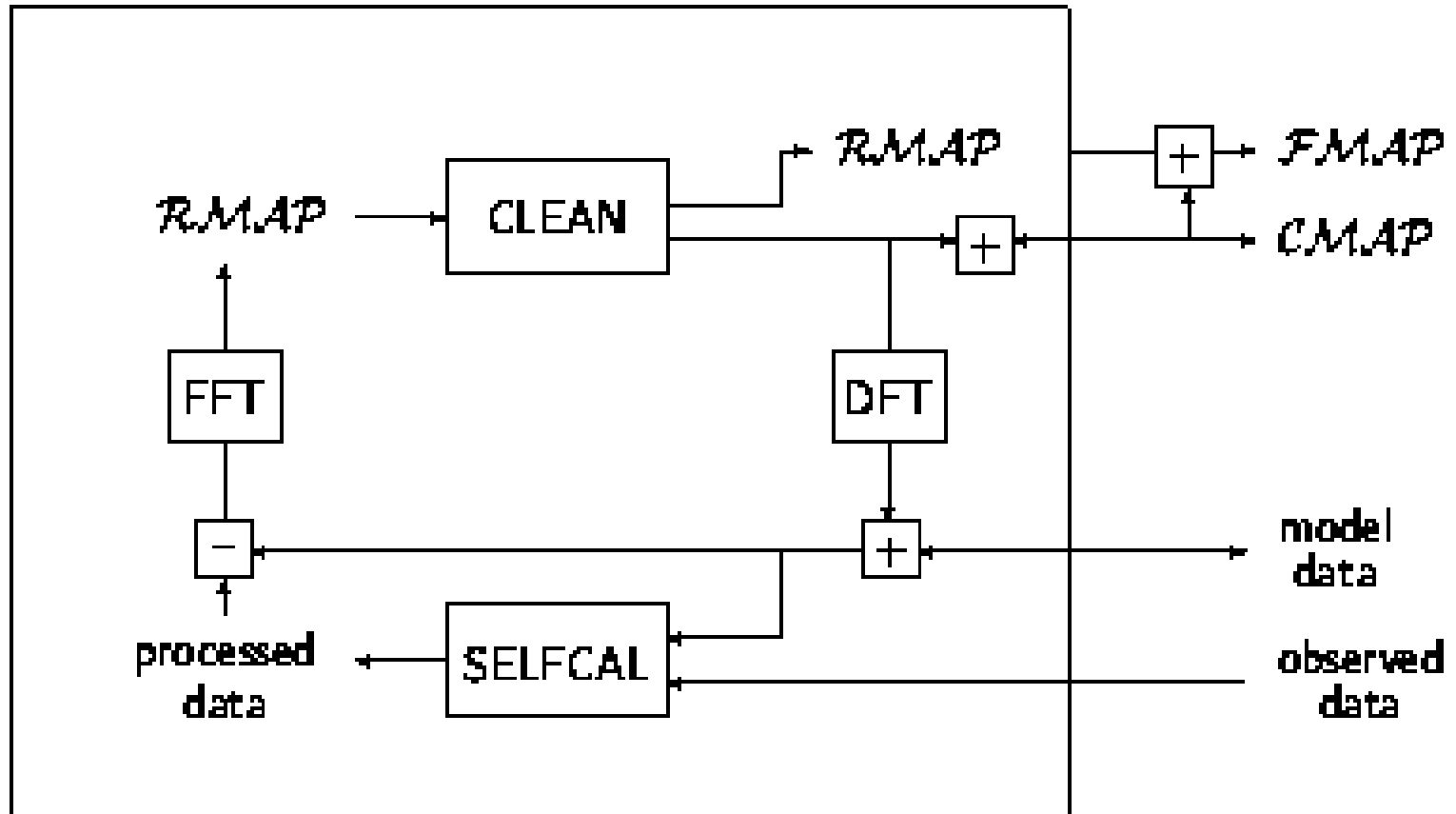Make sure band pass integration uses same units as the transmission function

Interferometric imaging
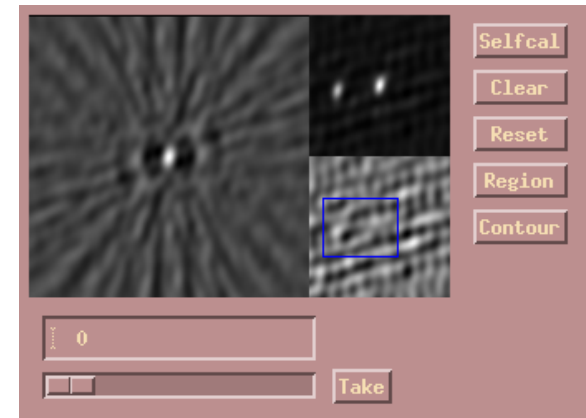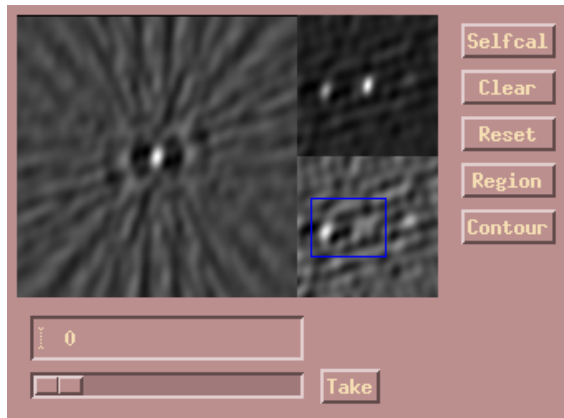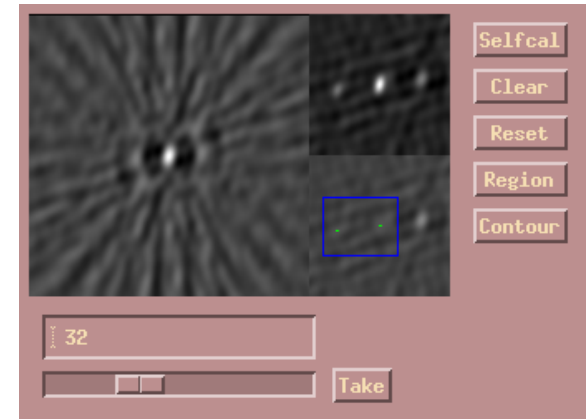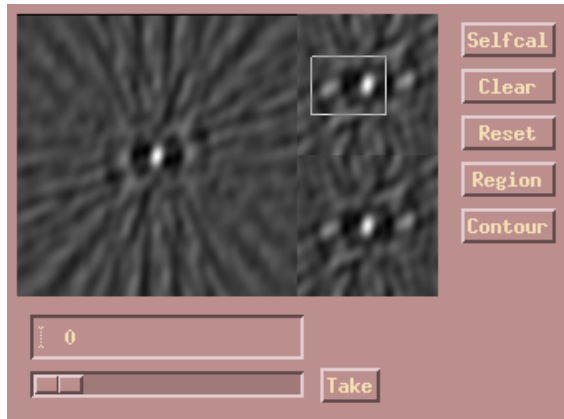

(Conventional) Hybrid mapping

Difference mapping

Difference mapping

Pearl (OYSTER)

Imaging composite spectrum binaries

(Pearl/OYSTER)