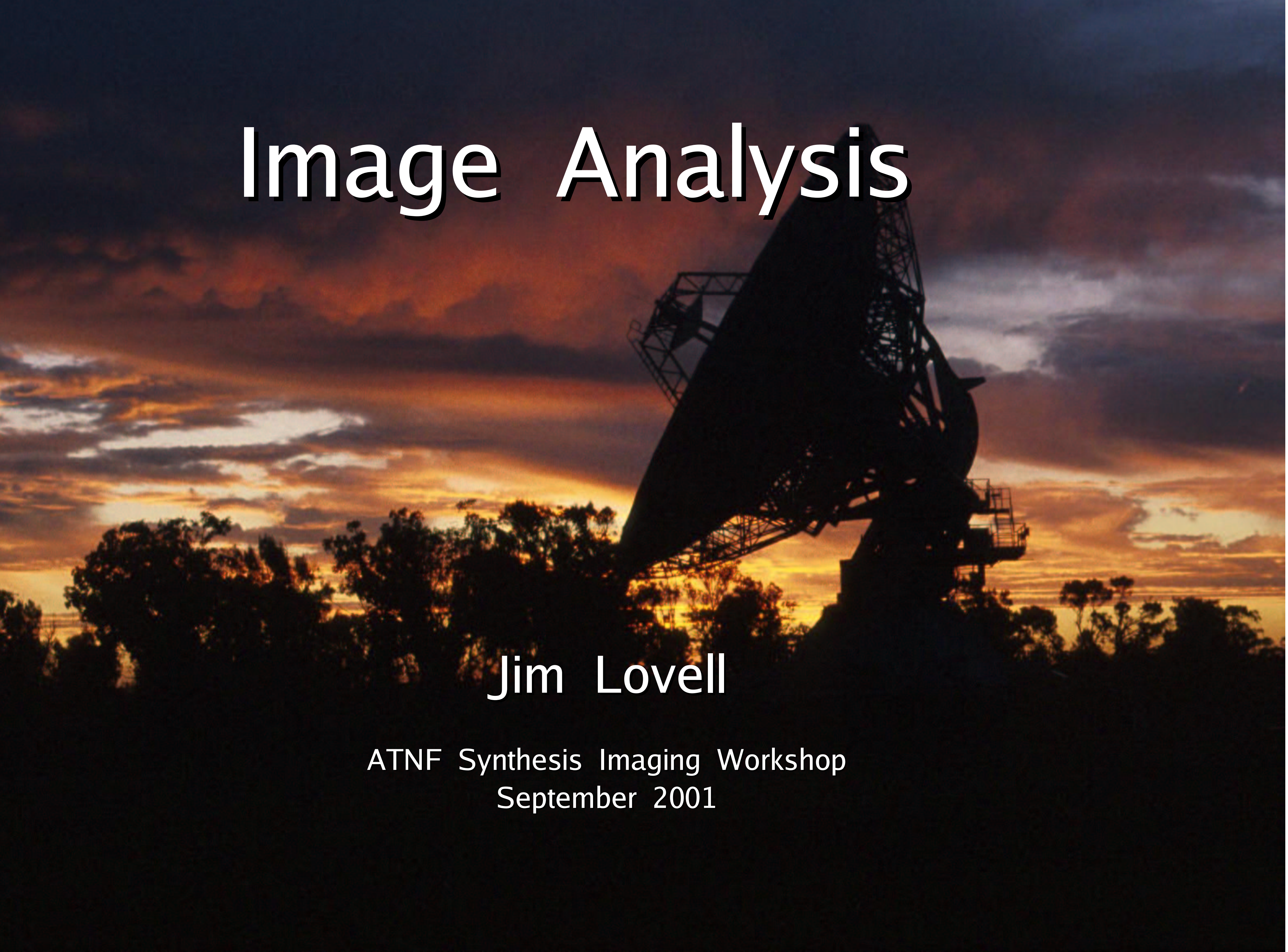

Image Analysis

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ATNF Synthesis Imaging Workshop
September 2001

What Do You Want to Measure?
(What you want to do and how to do it.)

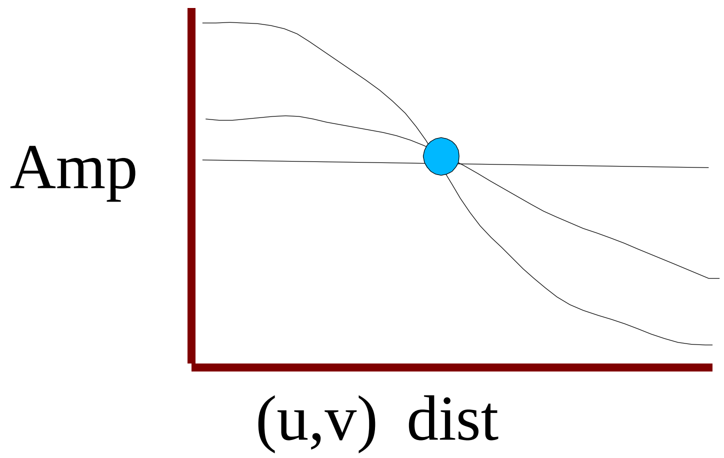
- Flux density of components
- Absolute positions
- Relative positions and motions
- Flux density variability
- Spectral index, rotation measure etc (image combination).
- Overlay with other wavelength images

Personal Bias/Ignorance

- Aips++ has excelent image analysis capabilities. Can do almost everything that Miriad, AIPS and Difmap can plus more.
- Paths of least resistance (i.e hassle):
- ATCA data:
  - Calibrate in Miriad
  - Imaging or model fitting in Difmap. If mosaicing or bandwidth smearing effects are important use Miriad.
- VLBI/SVLBI data:
  - Calibration and fringe-fitting in AIPS
  - Imaging/model fitting in Difmap. Wide-field imaging with IMAGR in AIPS.
- Detailed image analysis in Miriad or AIPS

Errors

- Errors given by fitting software should be treated with skepticism
  - Generally assumed errors are stochastic
  - No accounting for on-source errors etc
  - Components are not necessarily independent. e.g. Usually a strong correlation between intensity and diameter. Extreme example is one (u,v) point:

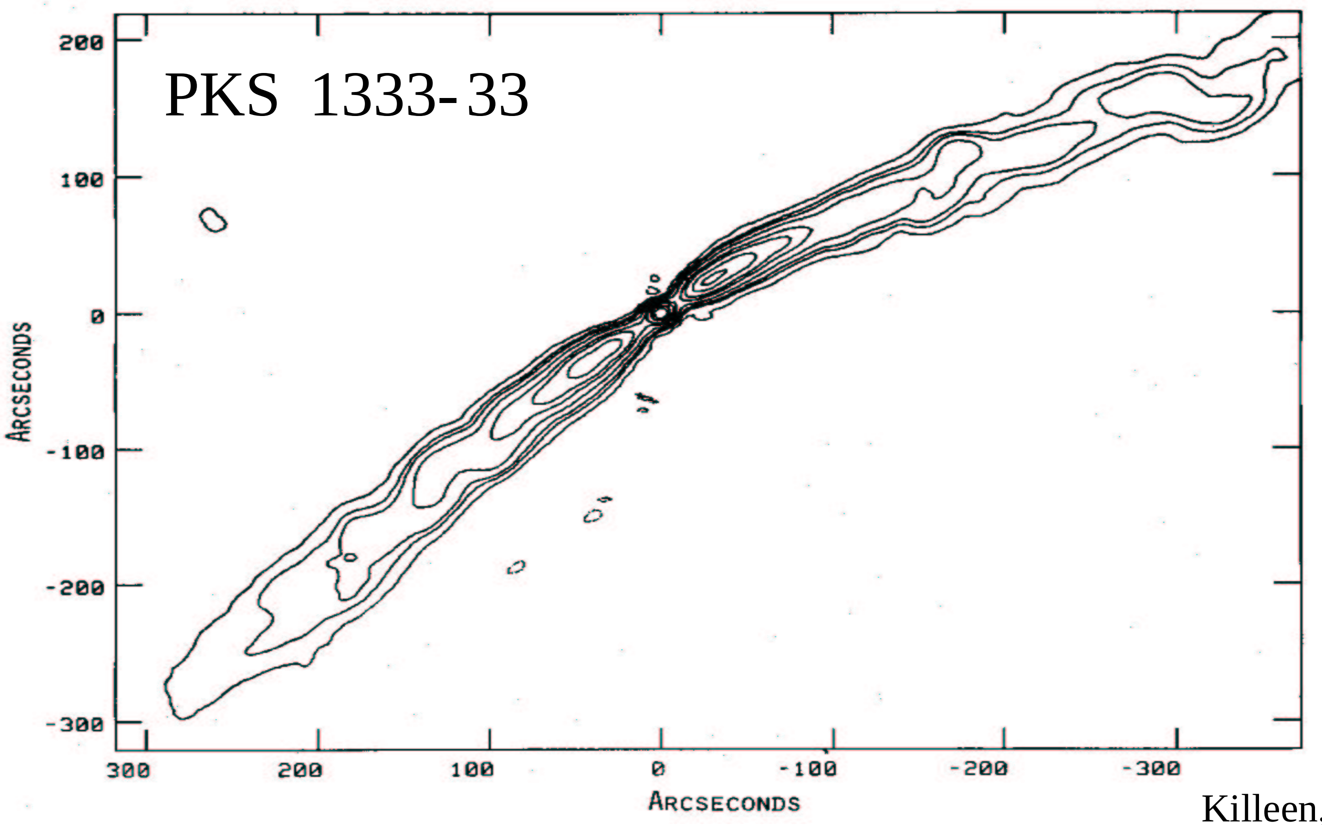


Component Fluxes

1. Discrete Components: Model Fitting
   - Model fitting is suitable for relatively discrete, isolated features.
   - Usually not a unique solution, so choose the simplest possible model (fewest components, simplest shapes)
     - Point source -> circular Gaussian -> elliptical Gaussian.
   - Model components tend to be too simple for more complex structures.

Component Fluxes cont.

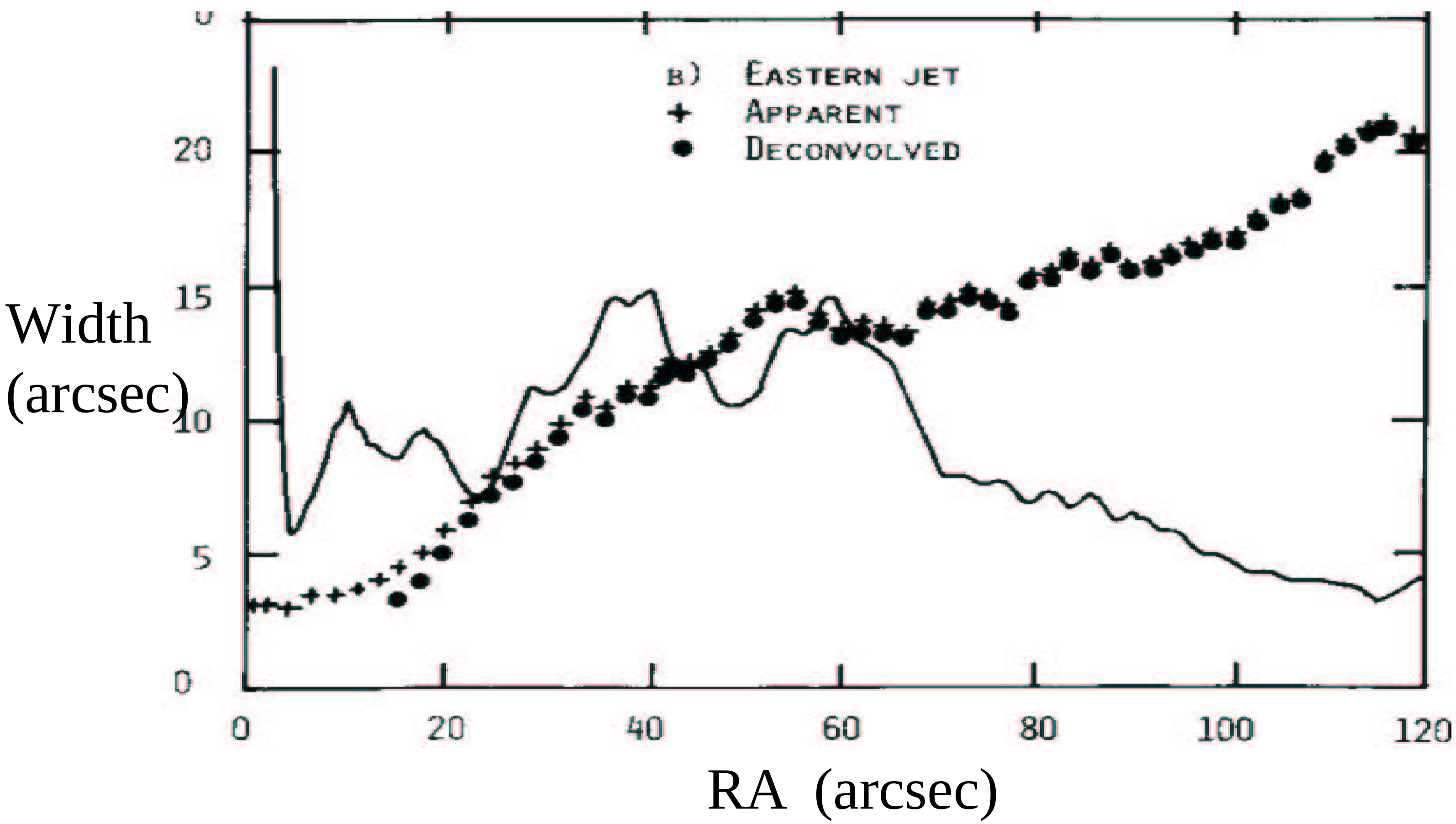
- Extended Sources
  - Reducing the dimensionality can help.



Killeen, Bicknell & Ekers 1986

Reducing the dimensionality

- Fit to jet width vs distance



Component Fluxes cont.

- Extended Sources
  - Reducing the dimensionality can help.
  - Integrated intensity.
    - Sum the intensity within a given region
    - Sum the clean components making up the region of interest.

Absolute Positions

- Depends on the quality of calibration:
  - Precision of the position of the phase-cal
  - Separation of source from phase-cal (closer the better)
  - Weather, phase stability
  - Signal to noise

Relative positions and motions

- Limited by signal-to-noise

Flux Density Variability

- Between epochs: easy.
- Within epochs: difficult.

NOTE: Check your secondary cal isn't an Intra-Day Variable!

- Imaging algorithms assume the source stays constant during the observation

1) Split data into N segments and image each one separately
2) Measure S(t) of variable component(s)
3) Subtract variable component from the visibility data.
4) Image whole dataset

- A similar procedure may be required before combining data from different arrays or array configs.

Image Combination

- Often desirable to combine images to
  - Measure polarisation,
  - Measure spectral index,
  - Measure rotation measure,
  - Look for differences,
  - Compare with optical, X-ray etc.
- When combining radio images, restore all images with the same beam first.

Polarisation

- Alignment should not be a problem as any self-cal solutions from imaging I can be passed directly to Q and U.
- Polarised intensity:

$$I_P = \sqrt{I_Q^2 + I_U^2}$$

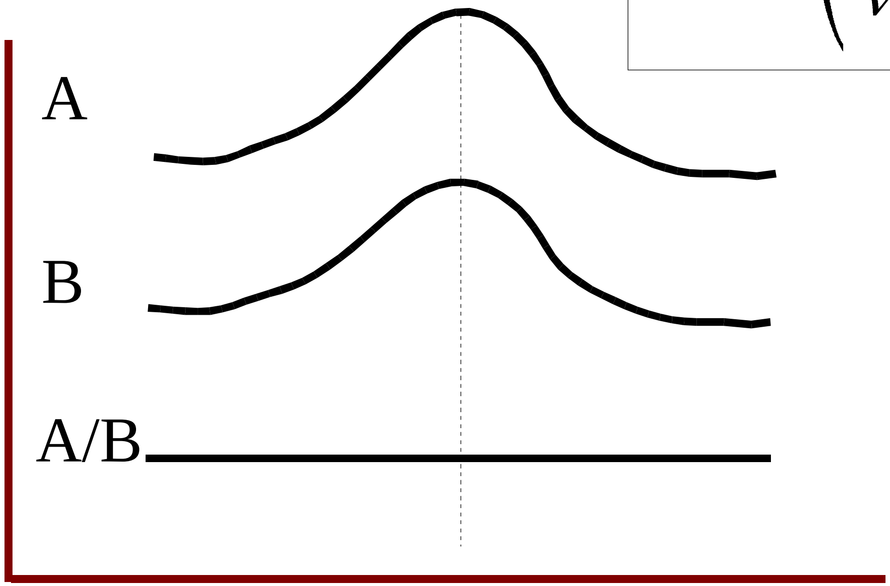
- Linear polarisation position angle:

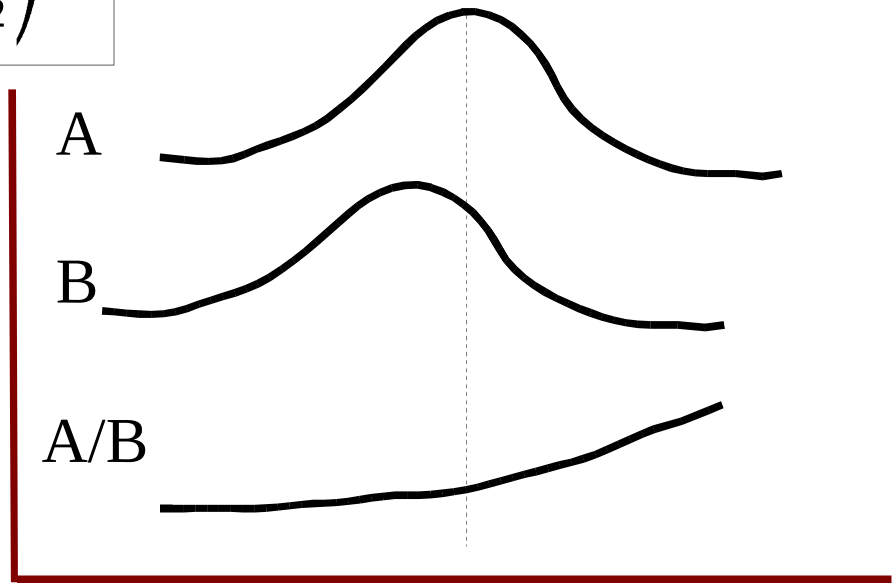
$$\psi = 0.5 \arctan\left(I_U / I_Q \right)$$

Low S/N, Misalignment

- Beware of edge effects due to low S/N or image misalignment.
  - In spectral index mesurements you can end up with a fake gradient.

$$\frac{S_1}{S_2} = \left(\frac{\nu_1}{\nu_2} \right)^{\alpha}$$

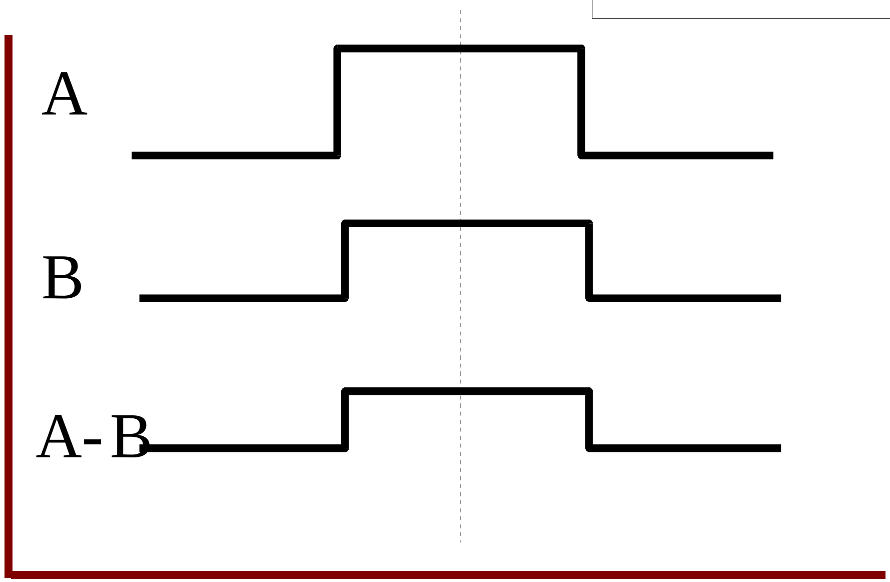




Low S/N, Misalignment

- Beware of edge effects due to low S/N or image misalignment.
  - Extreme rotation measures are possible

$$RM = \frac{\psi(\nu_1) - \psi(\nu_2)}{\lambda_1^2 - \lambda_2^2}$$



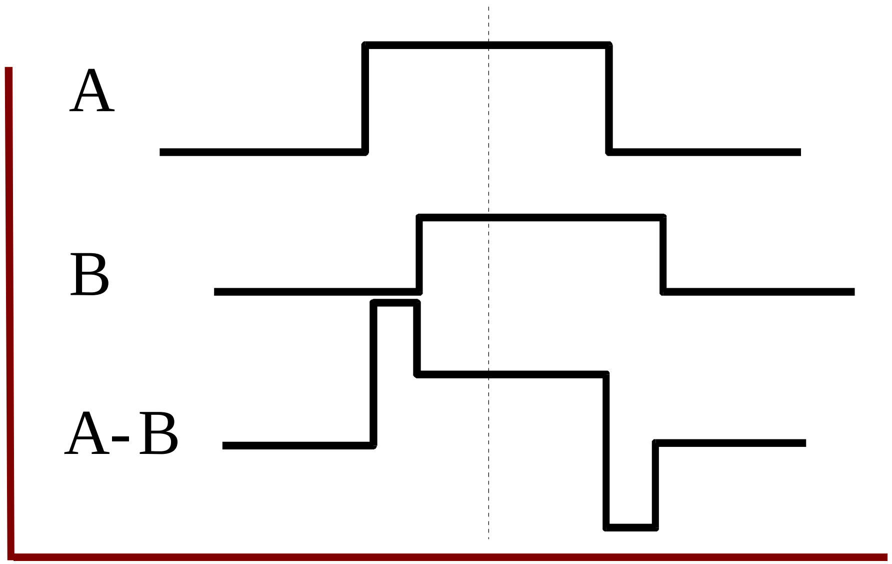


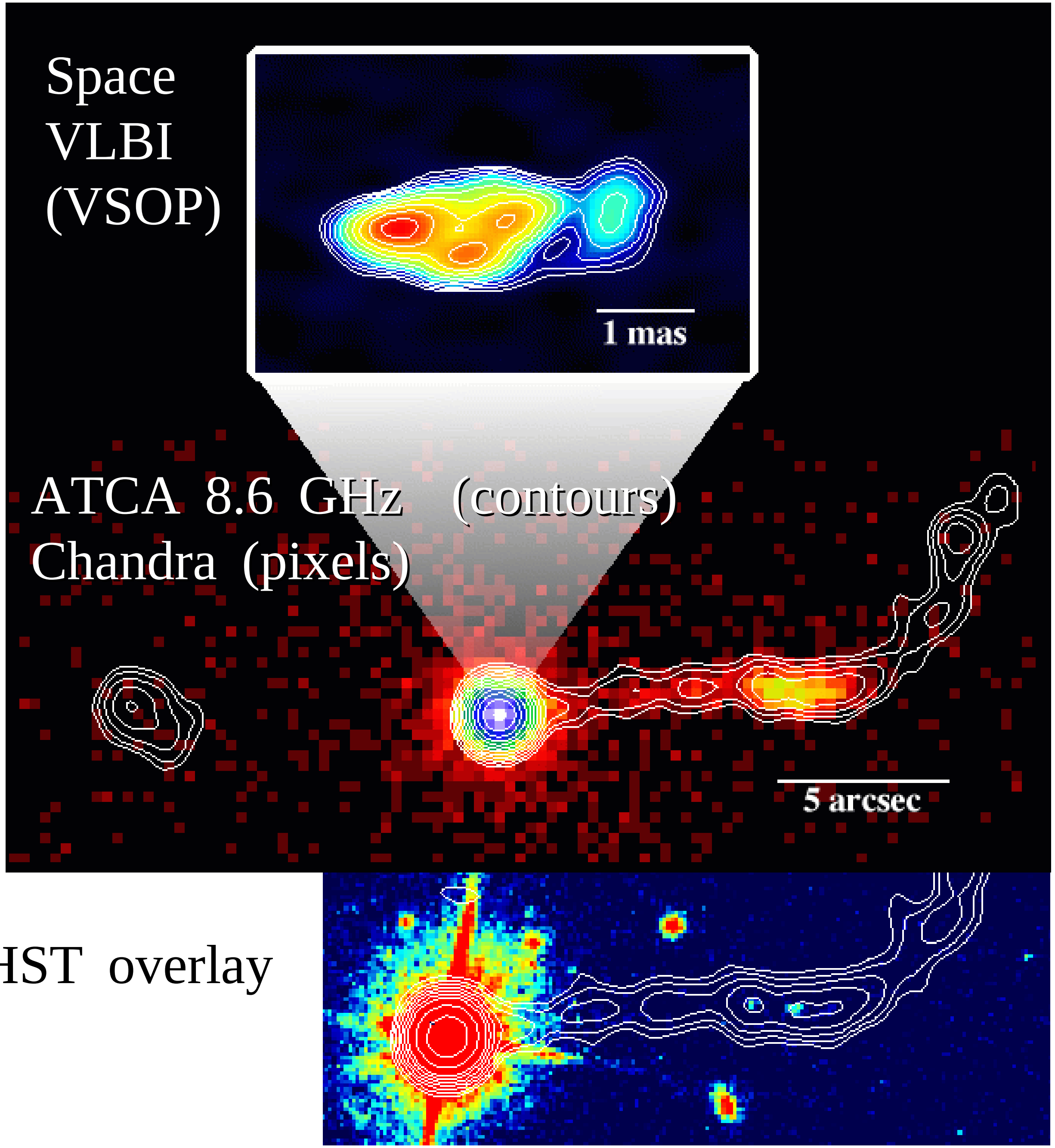
Image Overlays

- Can be tricky if X-ray/optical/radio have different astrometric precision.
- Two approaches:
  1) Accept the uncertainties
  2) If there are multiple components in each image, look for an alignment with the best correlation.

Example: PKS 0637–752

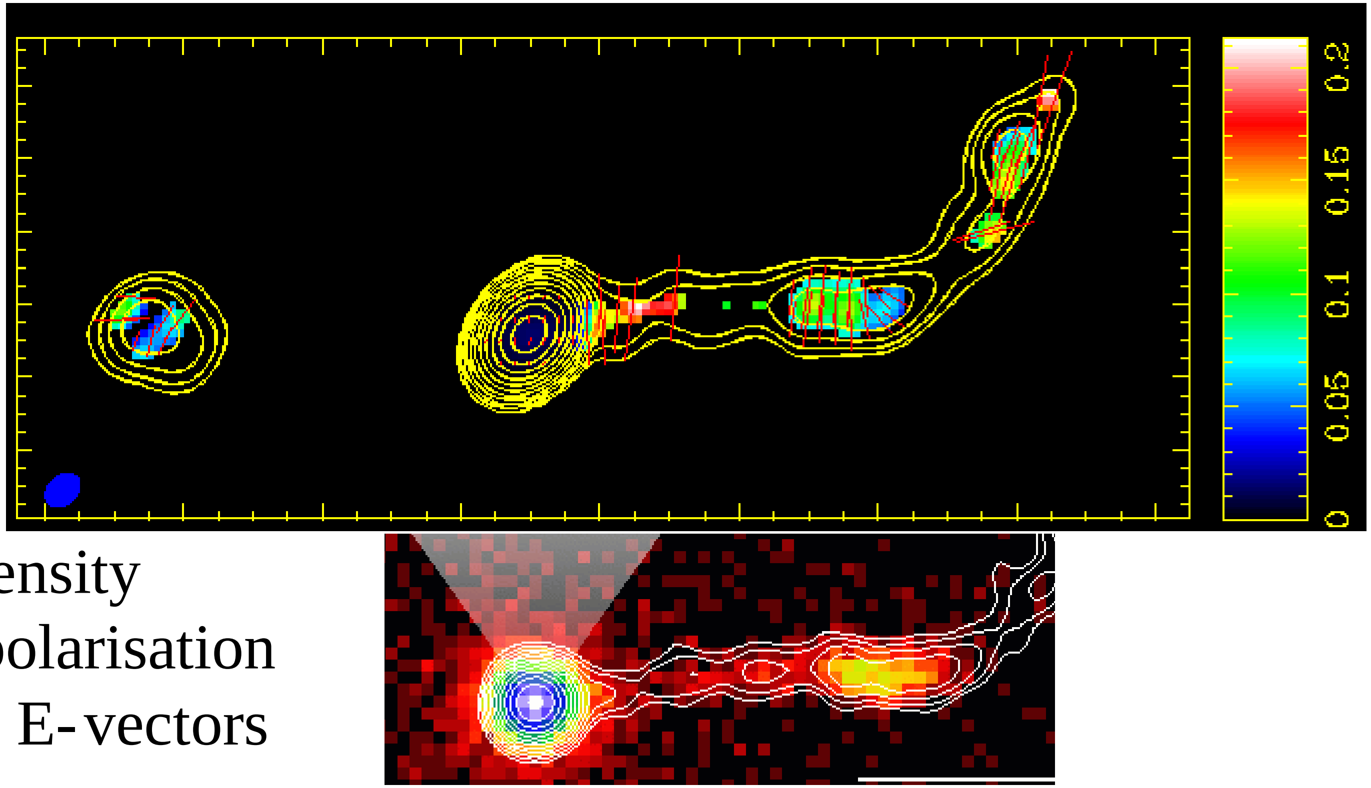
Quasar, z=0.651

(Montage from Difmap image and overlays in Miriad)



ATCA/HST overlay

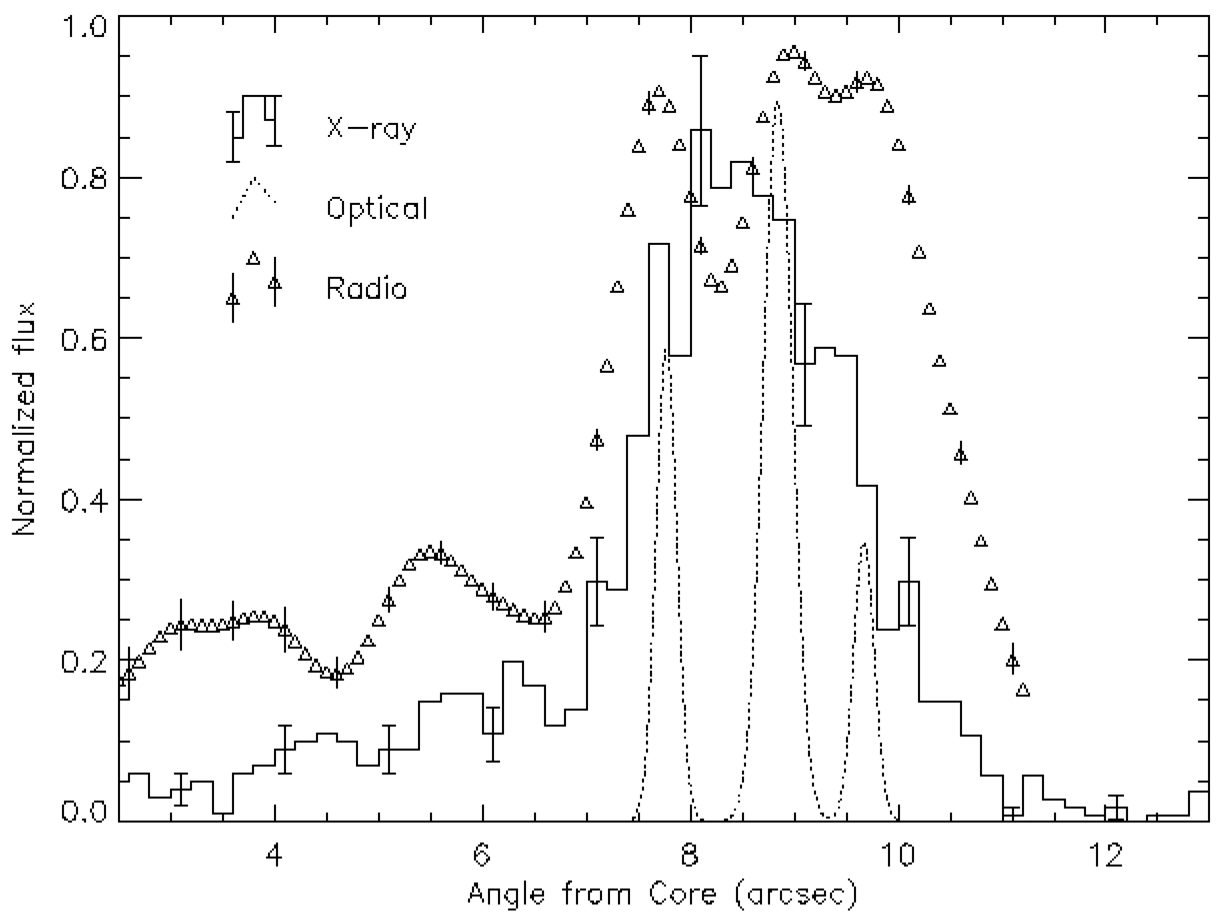
PKS 0637–752 cont.



ATCA 8.6 Ghz
Contours: total intensity
Pixels: fractional polarisation
Lines: polarisation E-vectors

(Imaged in Difmap, polarisation and overlays in Miriad)

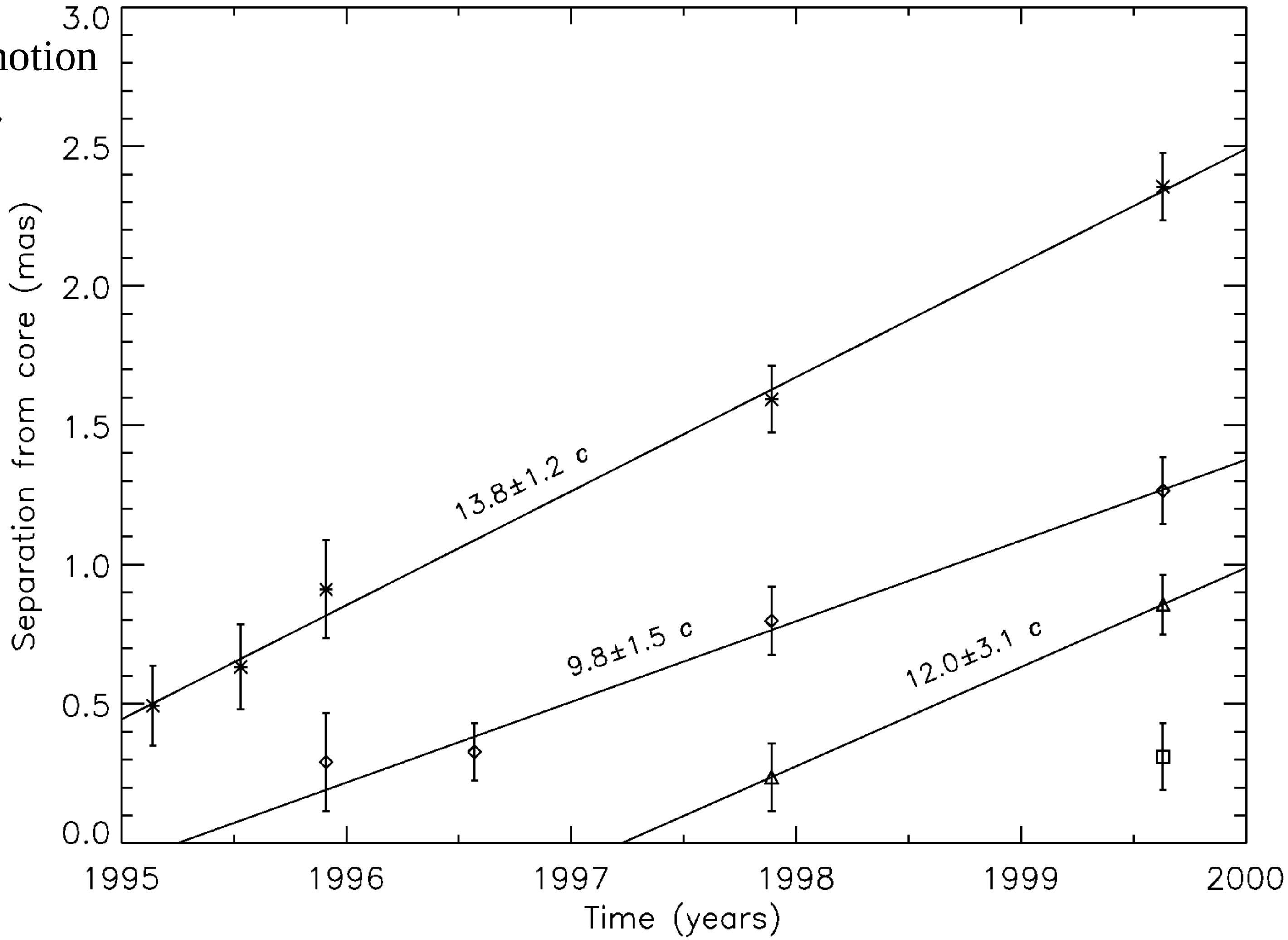
PKS 0637–752 cont.



(Slice along radio jet in AIPS)

PKS 0637–752 cont.

VLBI Component motion (separation vs time).



(Model fit to VSOP and ground-only VLBI data in Difmap)

Tasks, commands

	Miriad task	Difmap command	AIPS task	Aips++ function
Visibility plane model fitting	Uvfit, uvmodel	Modelfit	Uvfit, (slime)	-
Image plane model fitting	Maxfit, imfit	-	Maxfit, jmfit, imfit, sad	image.fitsky, imagefitter (spatial), image.maxfit, image.fitprofile, imageprofiler
Image plane integrated flux	Imstat	Imstat, “S” in mapplot	Imean, imstat, tvstat, blsum	image.statistics
Slices	Ellint	-	Slfit, xgaus	image.getchunk, image.getregion, image.putchunk, image.putregion
Component or continuum subtraction	Uvsub, imlin, uvlin, uvmodel	Setcont	Uvmod, uvsub	image.modify
Forming polarisation images	Impol	multi_model true; polvec; mapl pcln	Comb	image.various
Rotation measure	Imrm	-	Comb	imagepol.rotationmeasure, image.fourierrotationmeasure
Spectral Index	Maths	-	Comb	image.calc
Other image combinations	Maths	-	Comb, sumim	image.calc
Maths operations on a single image	Maths	-	Maths	image.calc
Re-grid, transformations	Regrid	-	Lgeom, ohgeo, hgeom	image.regrid
Overlays	Kview, Cgdisp	-	Kntr, pcntr, tvblink	viewer/skycatalog

Resources

- Follow the links from the *ATNF Software And Tools* page:
  www.atnf.csiro.au/computing/software
- Aips++: see the *Getting Results* documentation for an overview of image analysis.
- Miriad: see Chapter 18 of the *Users Guide*
- Difmap: see the *Difmap Cookbook*
- AIPS: see chapter 7 of the *AIPS Cookbook*