

Data model extensions:

Polarimetry Interferometry

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with thanks to Paddy Leahy & Robert Laing



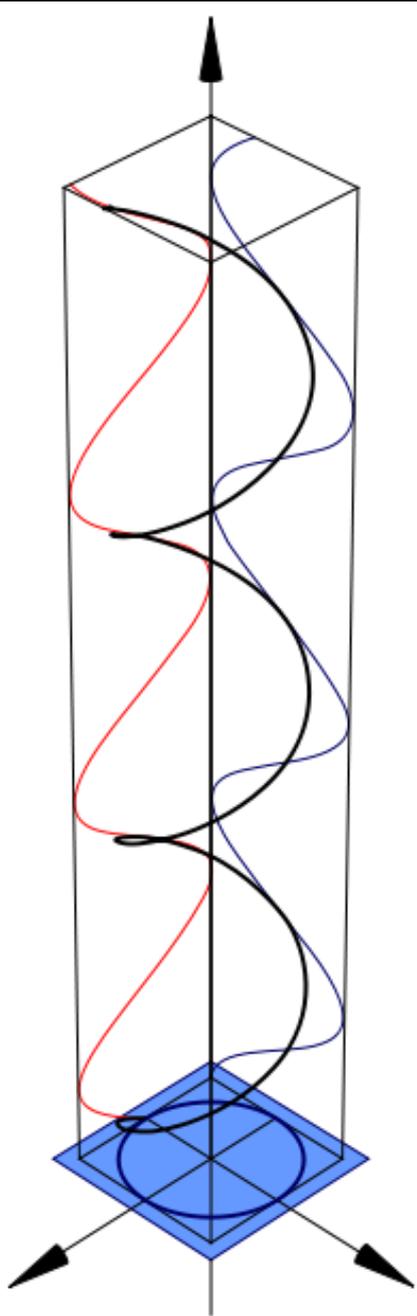
The University of Manchester
Jodrell Bank
Observatory



MANCHESTER
1824



Some polarization jargon



CIRCULAR

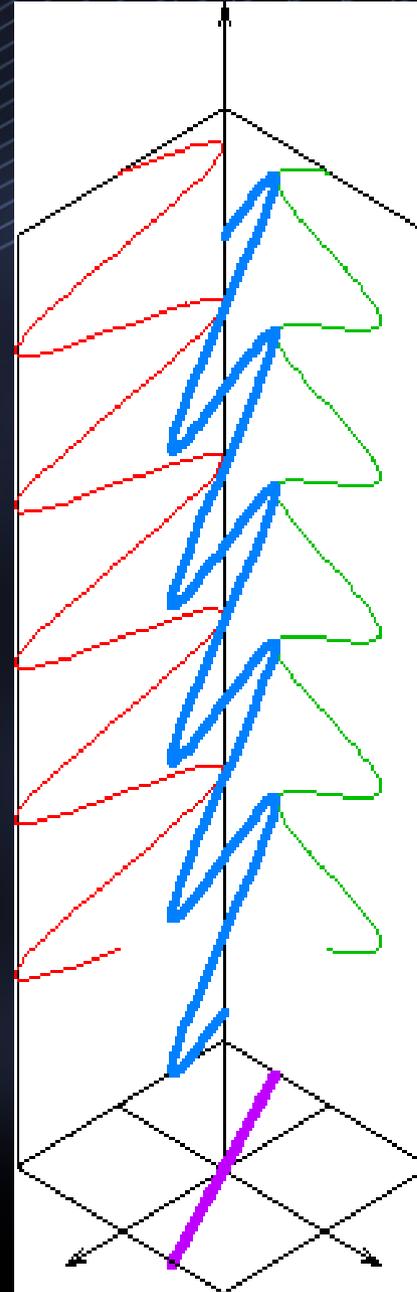
Left-hand
LHC, L, LL
etc.

Right-hand
RHC, R, RR
etc.

Cross hands
LR RL
make linear

Stokes V =
 $(RR-LL)/2$

Fractional
 V/I , $|V|/I$, %
etc.



LINEAR

Stokes Q =
 $(RL + LR)/2$

Stokes U =
 $(RL - LR)/2i$

Polarized intensity
 $P = \sqrt{(Q^2 + U^2 + V^2)}$

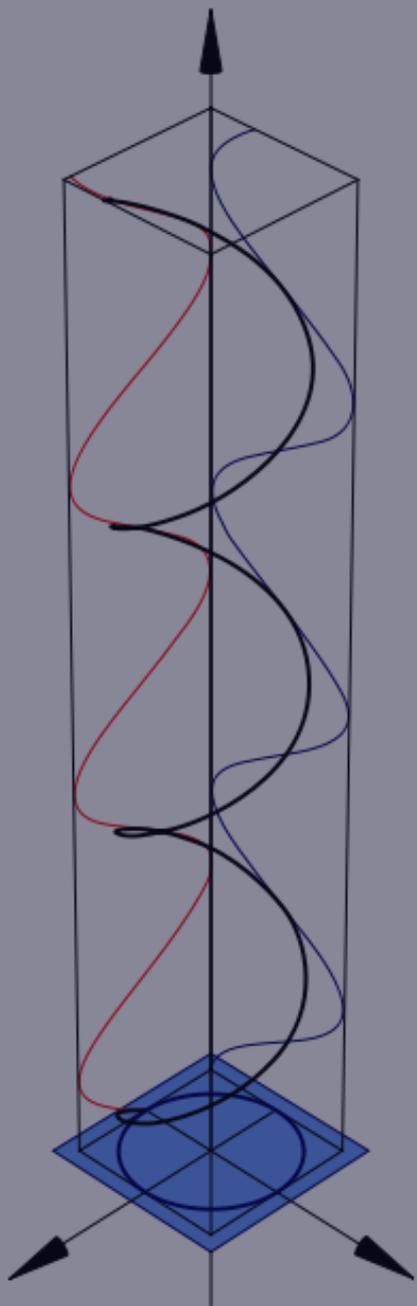
Polarization angle
 $\chi = \frac{1}{2} \text{atan2}(U/Q)$

Linear feeds
X, XX, Y, YY

Cross hands XY YX

Diagrams thanks to
Wikipedia

Some polarization jargon



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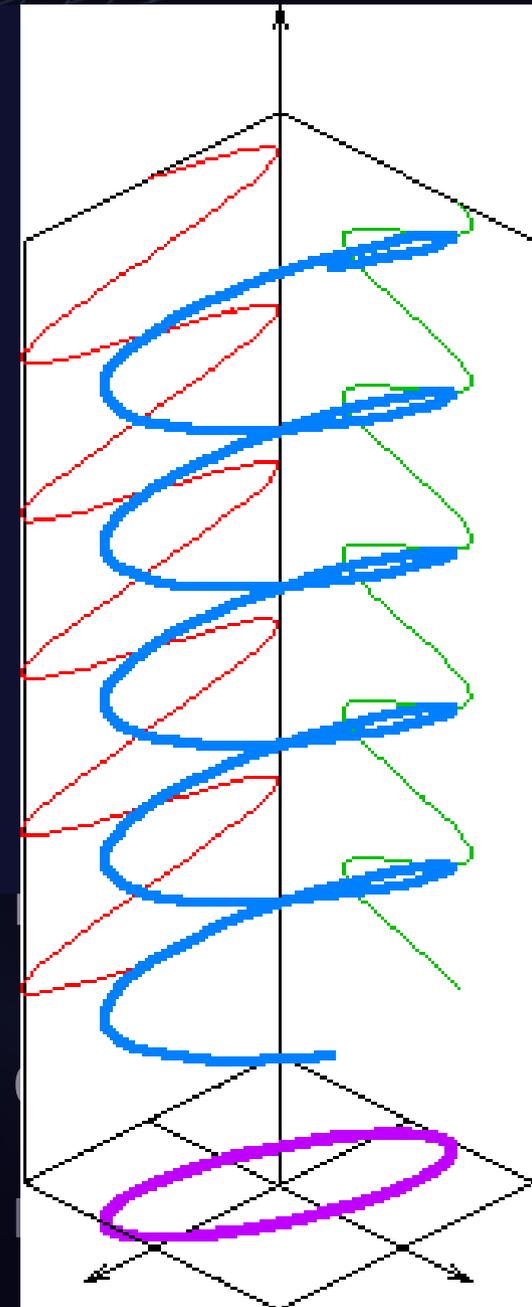
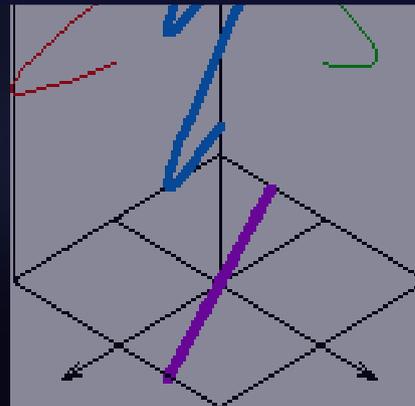
ELLIPTICAL

Combination of
linear and circular

TOTAL INTENSITY
Stokes I

OPTICAL/IR
rotated prisms
give O, E

End products are
the same



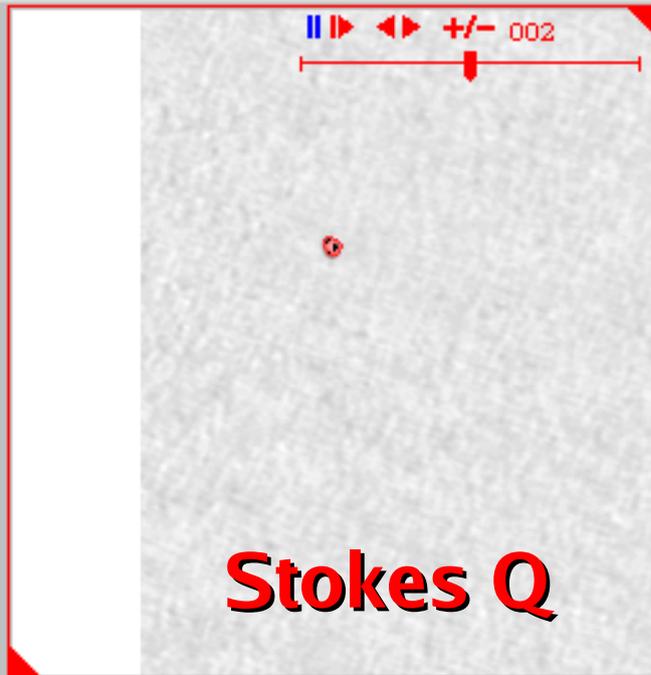
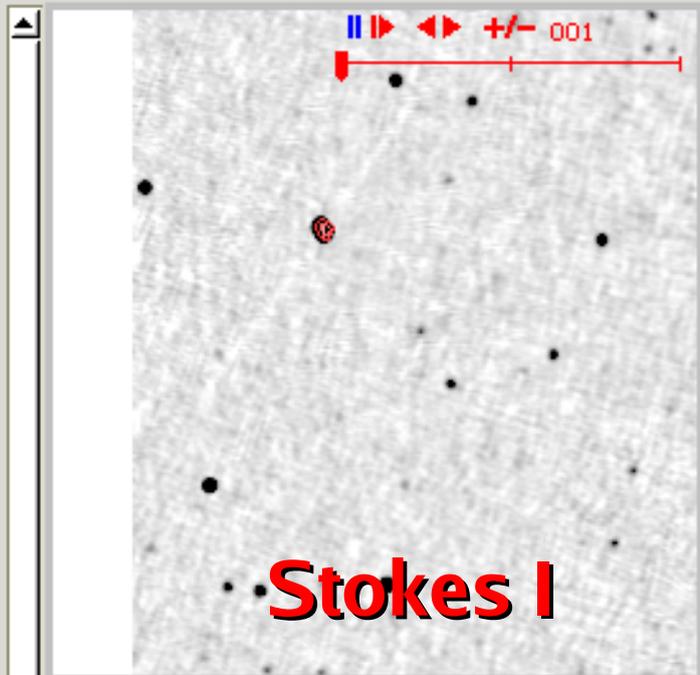


Location **22:46:00.61 +81:56:54.2**

ICRS

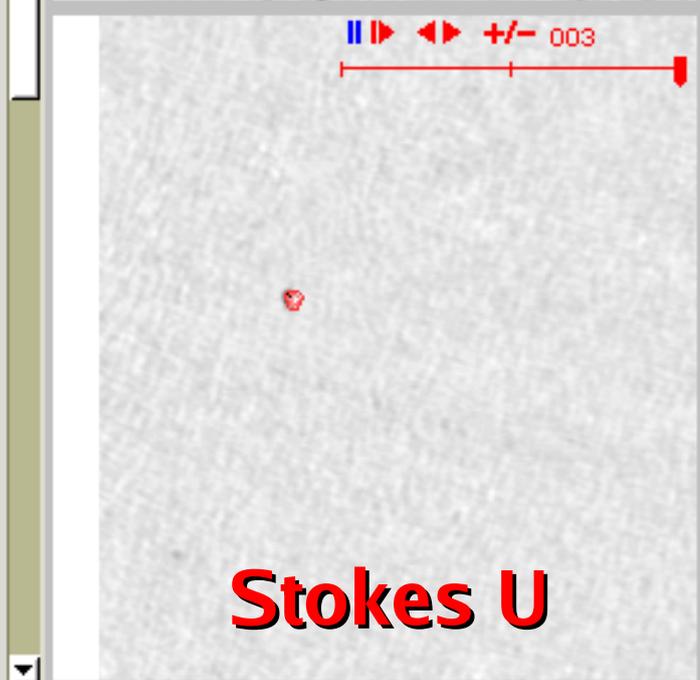
Pixel **unknown**

full



select
pan
zoom
dist
draw
tag
text
filter

Eye icon
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10



NVSS I Q U cube
Q, U typically few % I
U can be negative
Different dynamic ranges needed

Contours
NVSS_C22301
AIPS VL
NVSS_C22301

Zoom 1/32x

Astronomical polarization

- Observable
 - Forms of flux density but with additional derived properties
 - No specified polarization (usually) implies total intensity
- Polarization axis
 - A single data set can have one or more polarizations
 - If the polarization axis is present, must specify
 - number of polarizations present
 - ordered list of labels e.g.
 - NVSS image 'cube' I Q U or single images P, χ
 - Visibility data LL RR LR RL (**ORDER CAN DIFFER**)
 - Spectrum LHC or LCP or L
 - **CONVENTIONS DIFFER**
- Need agreed vocabulary and definitions
 - Software should recognise multiple labels in common use

Polarization axis

- Often only one polarization state per image (etc.)
- Each plane of multiple polarization axis inherits first plane properties, but can replace them
 - Spatial and spectral location, bounds usually the same
 - Sensitivity, dynamic range etc. can differ
 - First plane may not be total intensity
 - Some properties may not make sense for pol. angle
- Metadata extraction tools should recognise FITS codes (not all possibilities are official)

1	2	3	4	-1	-2	-3	-4	-5	-6	-7	-8
I	Q	U	V	RR	LL	RL	LR	XX	YY	XY	YX

Use case 1.

Finding suitable (semi-)raw data

- Search e.g. VLA, MERLIN archive by position etc.
 - Want data with e.g. RR LL RL LR
 - Targets, calibrators in same config, close in time
 - Possible extra information such as
 - Primary beam leakage, sensitivity maps
 - External ionospheric data (GPS, electron counts..)
 - Models for standard calibration sources
 - *Just need pointer to these, not full description*
- Enable a typical interferometry archive pipeline to produce images in various polarization products
- Assume that pipeline knows observatory-specific heuristics (e.g. 2003 delay error in cross-hands).

Use case 2.

Analysing 'science ready' polarization images

- Want data at a certain location with Stokes I Q U
 - Need usual total intensity information
 - Model must indicate polarization calibration status
 - Has leakage been corrected?
 - Ideally, typical residual/extra systematic QU errors
 - Or could be pointer to map
 - Similarly, has pol. angle been rotated to conventional origin?
 - Noise statistics/error maps desirable but deducable
 - Pointer to processing history (if only for humans)
- Pipeline to advanced products, e.g. rotation measure, pol. angle, fractional polarization
 - Human might have to calculate errors

Polarization summary

- Registry-level description (not mutually exclusive):
 - Linear? Circular? Other polarization products?
- Draw up agreed vocabulary (allow unambiguous alternatives e.g. LHC, LCP, with code to interpret)
- Polarization axis must be explicitly ordered
- Facility to describe calibration status e.g.
 - Leakage
 - Pol. angle
 - Systematic as well as statistical errors in both
- Pointers to external/supporting data, history
- User/observatory provides processing pipelines

Interferometry data 1

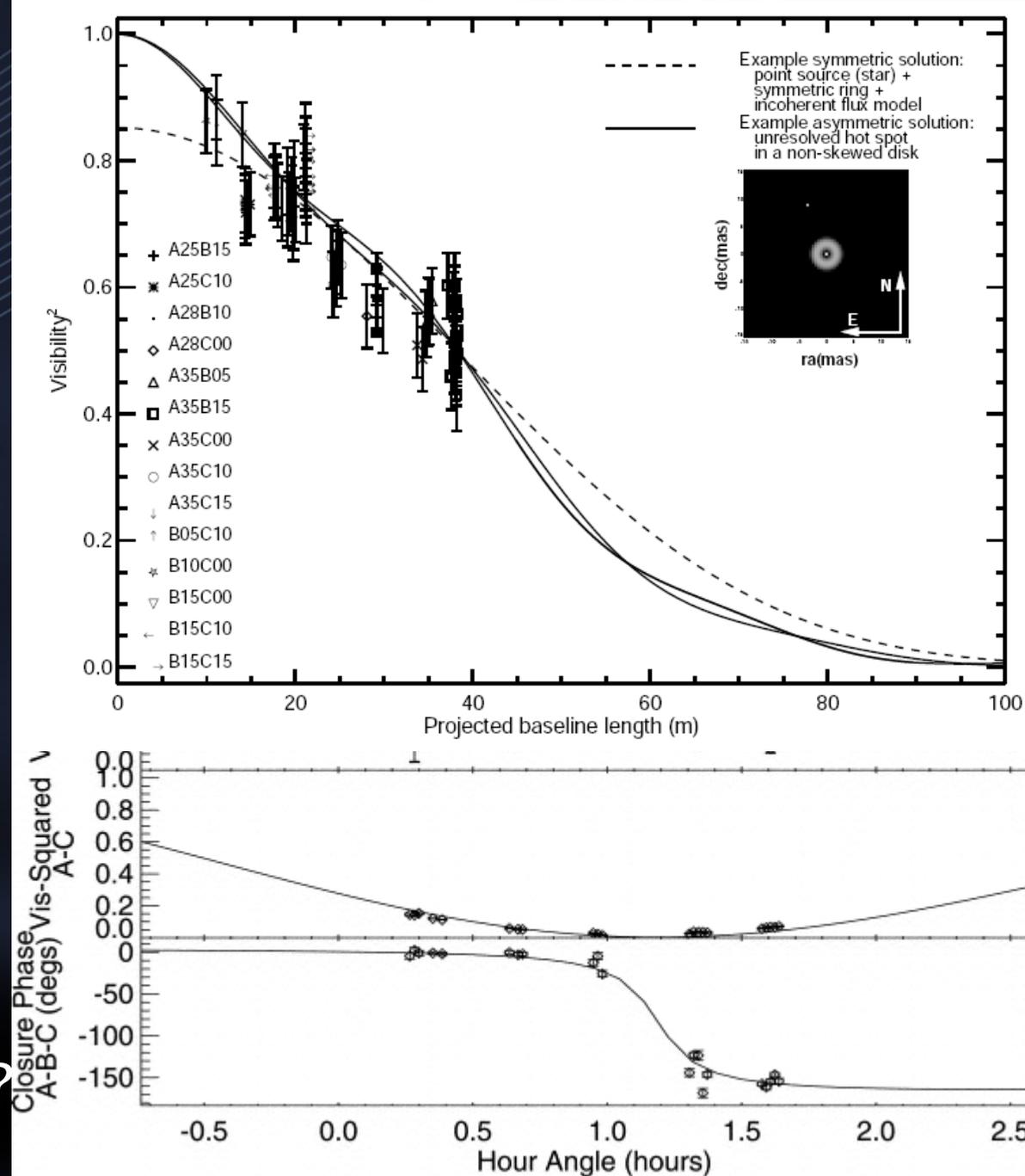
- Calibrated, multi-antenna mm/m-wave visibility data
 - Spatial, spectral etc. axes as usual
 - Description of products e.g. image resolution range
 - Spatial frequency axis
 - Coverage - missing spacings etc. - excellent quality indicator
 - Also useful for images etc.!
 - Ready to image, extract 'light' curves etc.
 - Most information packaged with data e.g. bandpass table
 - Cal. status may differ on spectral, polarization etc. axes
 - Might need to extract calibration sources
 - e.g. to align multi-epoch flux scale
- Pointers to external/supporting data, history
- User/observatory provides processing pipelines

Interferometry data 2

- Raw-ish, multi-antenna mm/m-wave visibility data
 - Ideally as per calibrated data (more complicated pipelines)
 - All information not always available
 - e.g. position, frequency/config, pols, integration time
 - Baseline lengths as on Earth surface
 - Can calculate effective resolution, field of view etc.
 - Should this be observatory's responsibility?
 - Sometimes easiest to find by processing data!
 - Places with public archives most likely to provide good information anyway...
 - Some information belongs in provenance

Optical/IR interferometry

- 1-few movable baselines
- Typical products:
 - Visibility amplitude
 - Closure phase
- As a function of:
 - Time
 - Hour Angle
 - Projected baseline or spatial frequency
- Archive (VLTI)
 - Investigate potential demand by non-PIs?
 - Are all results published?



Interferometry priorities

- Adding a spatial frequency axis would help select appropriate quality calibrated data
- Main demand for VO development is for polarization!
- Characterise most present data in terms of products
- Encourage use of data provider pipelines
 - Relatively few observatories, much information often packaged with data
 - Use switches/pointers to confirm existence of supporting info
 - MERLINImager 'proof of concept'
 - Essential for massive data sets
 - (E)VLA development; EVN provide user-side version
- Future: ALMA and VLTI, MRO etc requirements; SKA