Broad-band polarimetry with SKA1

Dominic Schnitzeler
Max Planck Institute for Radio Astronomy
schnitzeler@mpifr-bonn.mpg.de

Overview

Why broad-band polarimetry?

Individual sightlines

The resolution in RM / The maximum RM to which observations are sensitive / Tapering the edges of the window function / Stability of the bandpass and leakages over time, and the variation of leakages with frequency / The effect of spectral indices in pol. int. on RMclean

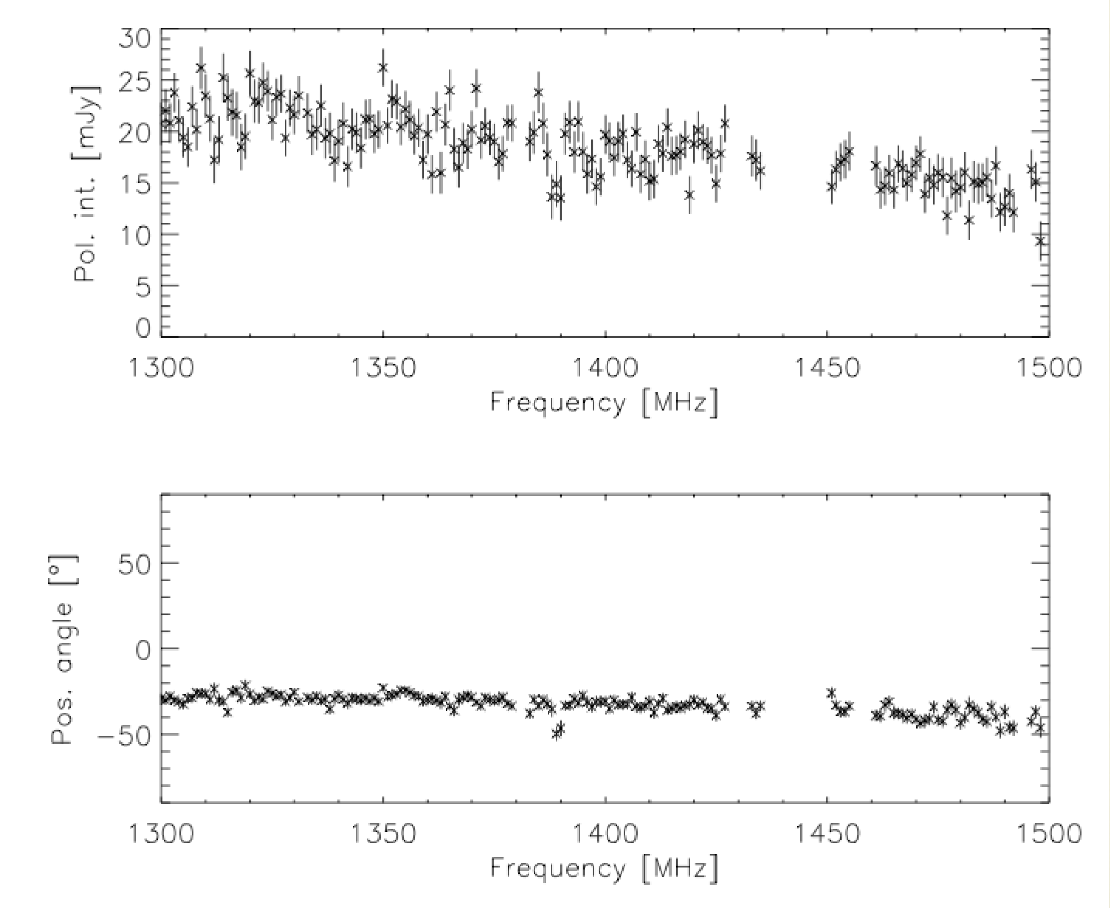
The whole field of view

The anatomy of the beam / Polarization purity across the field of view / Mosaicking and flagging

Discussion

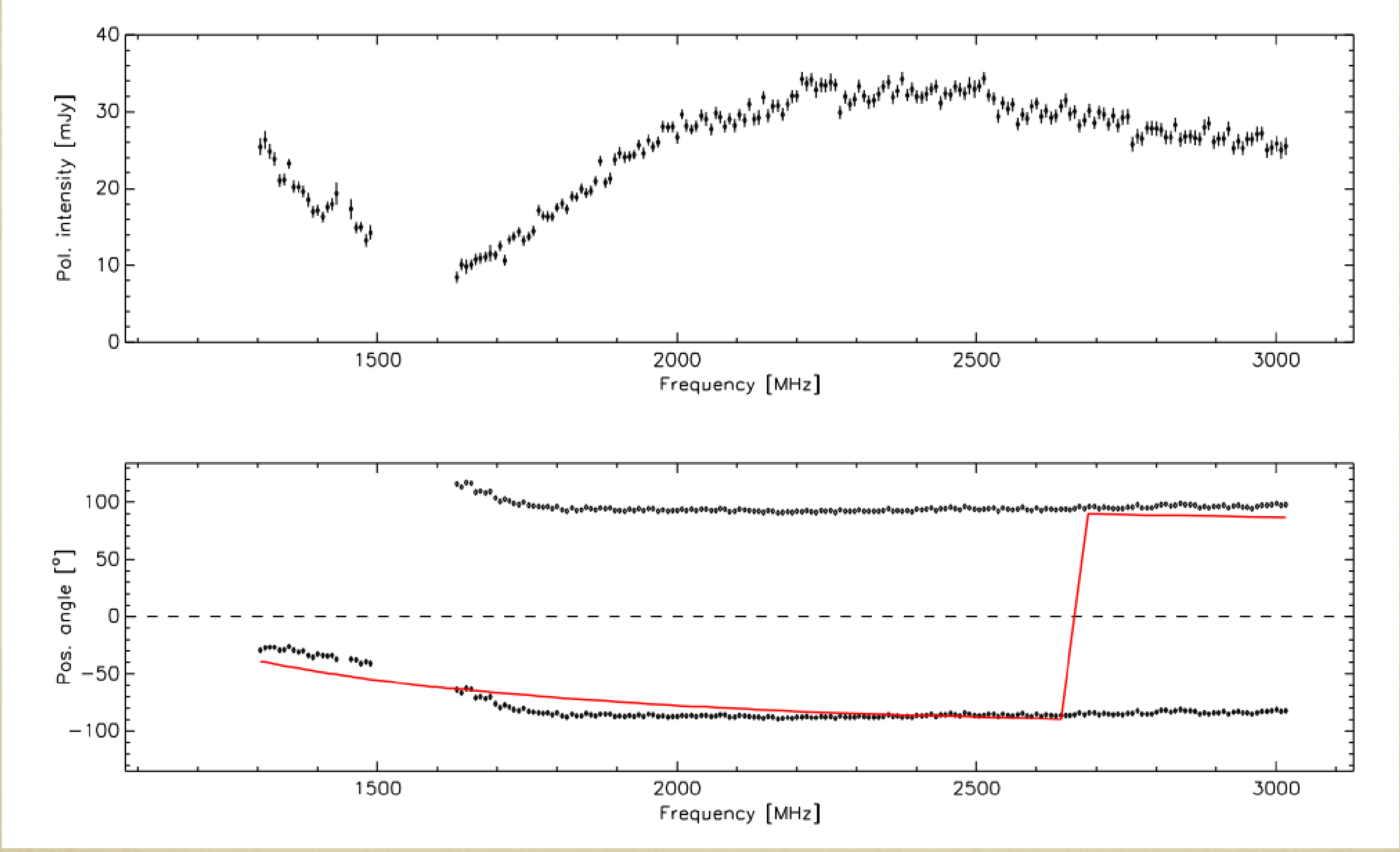
What can we learn from broad-band pol.?

Case study: a bright southern-hemisphere point source.



What can we learn from broad-band pol.?

The same source, now showing the full ATCA 1.3-3.1 GHz band:



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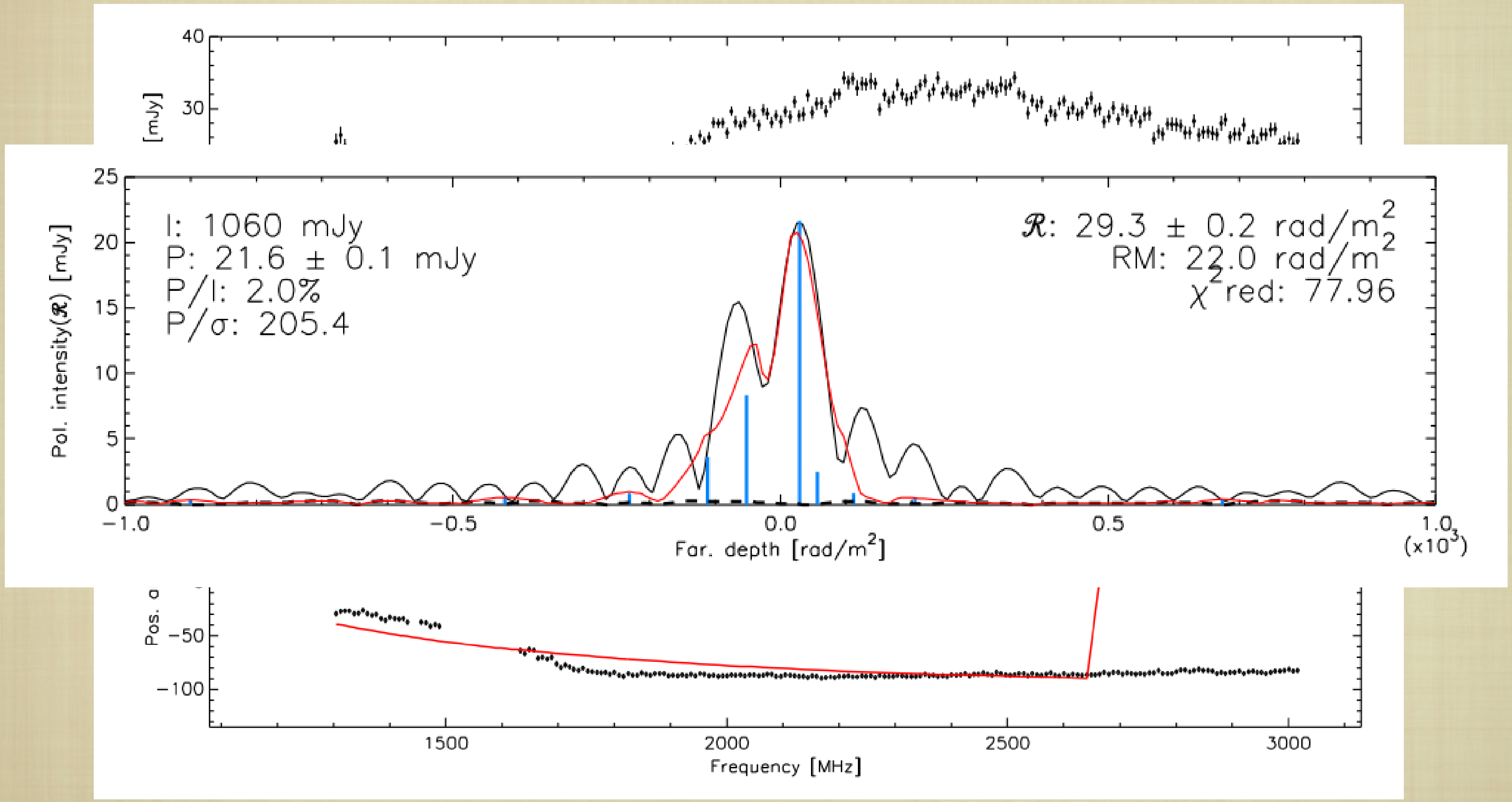


RM synthesis and SKA1

SKA1	Frequencies	FWHM	Resolution	RM_max	RM_wide
		rad/m^2	rad/m^2	rad/m^2	rad/m^2
low	50 – 350 MHz	0.1	0.1	84	4.3
mid	350 – 1050 MHz	5.8	4.8	3621	38.5
	950 – 1760 MHz	53.8	44.4	26260	108.1
survey	350 – 900 MHz	6.1	5.0	2577	28.3
	650 – 1670 MHz	21.0	17.4	16476	97.4

(assuming 1 MHz channels)

For these two columns:
see the next two slides

The resolution in RM

.. is not the same as the FWHM of the RM spread function

In optics, the Rayleigh criterion defines when two point source *of equal magnitude* can still be resolved: this happens when the companion lies at the first null of the PSF from the primary

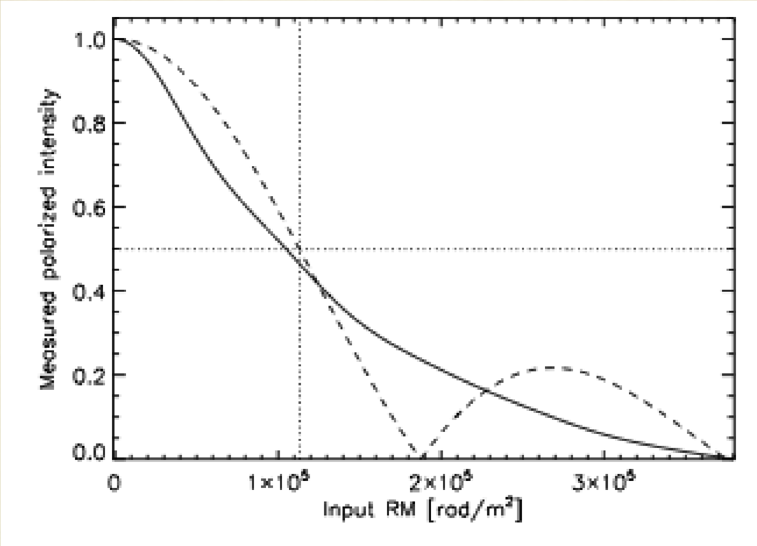
Translating this to RM synthesis: $RM_{res} = \pi/(\lambda^2_{max} - \lambda^2_{min})$ rad/m^2

Note 1: The uncertainty in RM still depends on the FWHM.

Note 2: Take care when analysing complex RM spectra.

The maximum RM that one can measure

In broad-band systems, channels in different parts of the band depolarize at different rates.



dashed line: B&dB (2005)

solid line: channel width is constant in frequency

Equation 35 from B&dB is a good estimate of the half-power point, but with sufficient S/N you can measure much larger RMs.

Example: ATCA, 1.3--3.1 GHz with 1 MHz channels, can measure RMs up to 350,000 rad/m^2

Sidelobe suppression of the RMSF

Sharp edges of the window function produce sidelobes out to infinity; this makes RMclean-ing more difficult.

Tapering the window function produces smoother edges, and the RMSF does not extend out to infinity anymore. The price you pay is a (slightly) reduced sensitivity.

RMclean assumes that the RM spectrum only contains delta functions convolved with the RMSF; when the RMSFs overlap, and you don't want to use parametric (forward) modelling, tapering can make your life easier.

Tapering has been used by Heald+ 09.

On-axis: outstanding issues

- For very large S/N ratios the uncertainty in RM (and the accuracy of the dirty-RM-beam) will be dominated by how well we understand and calibrate the instrument, and no longer by S/N.

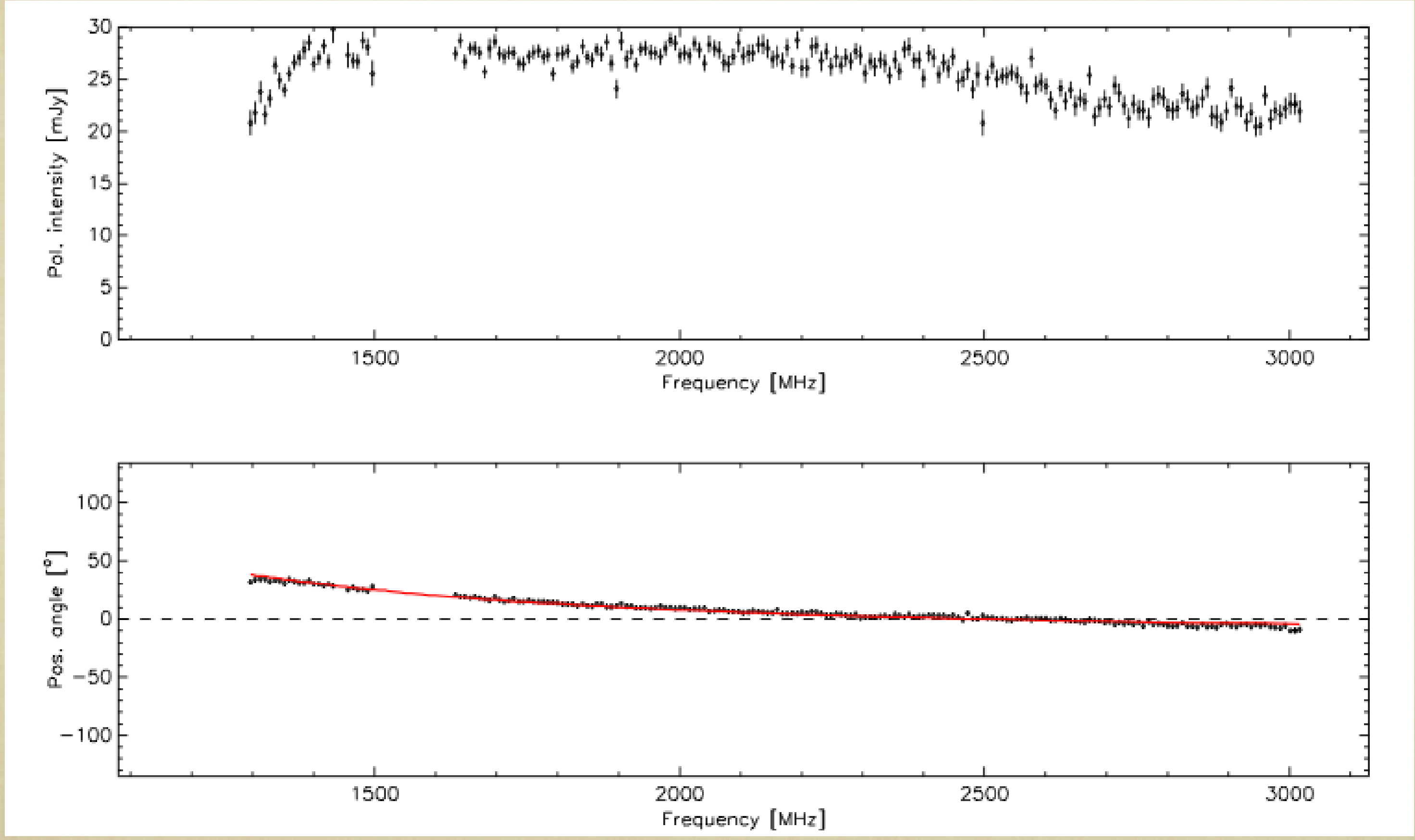
- How stable are the antenna bandpasses and leakages over time, and how do antenna leakages vary with frequency?

  ATCA: test observations of bright calibrators

- We are working on a method to infer the PI spectrum of emission at different RMs.

On-axis: spectral index effects

The wrong spectral index leads to the wrong RMSF that you remove in RM clean:



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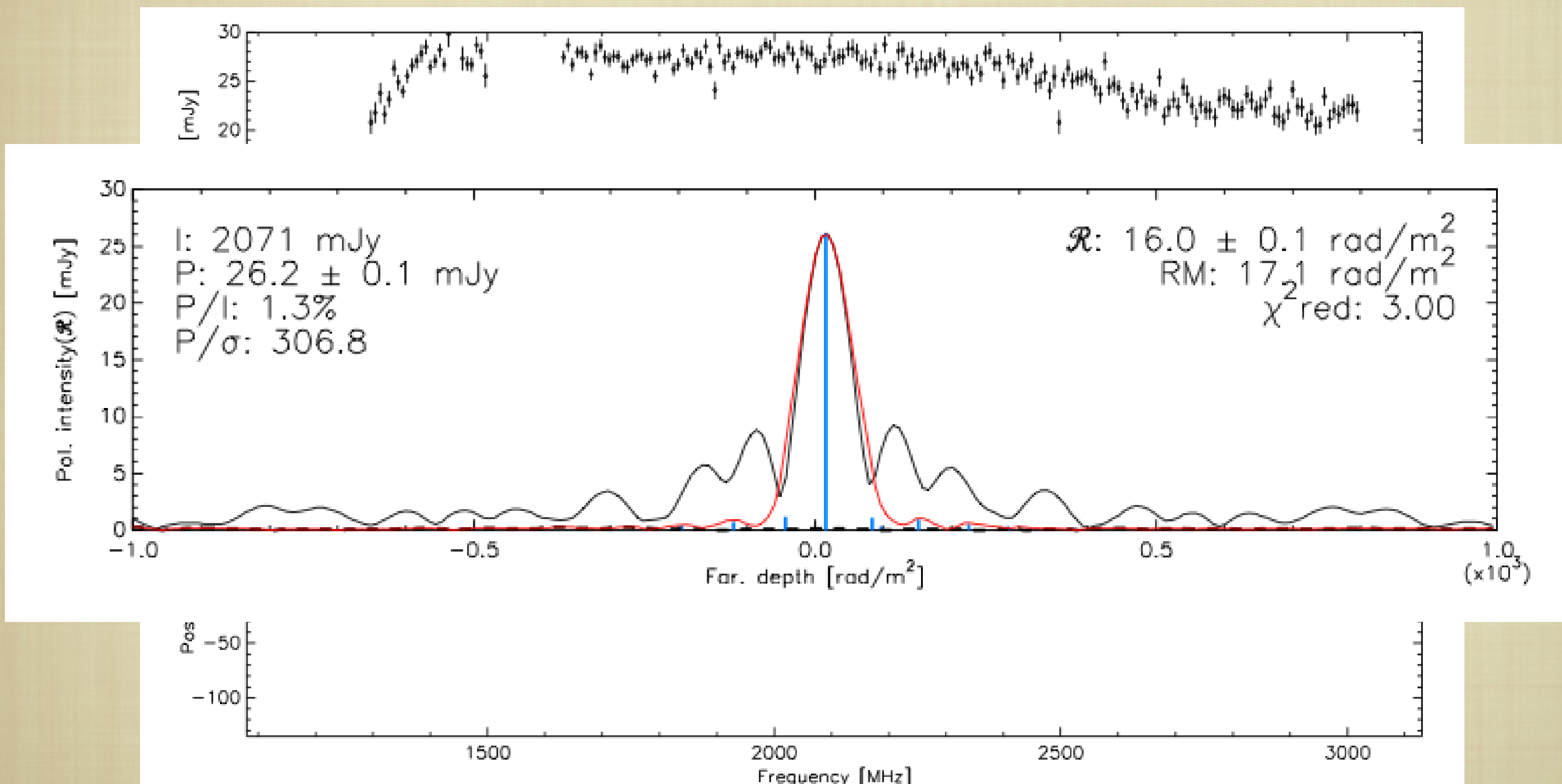

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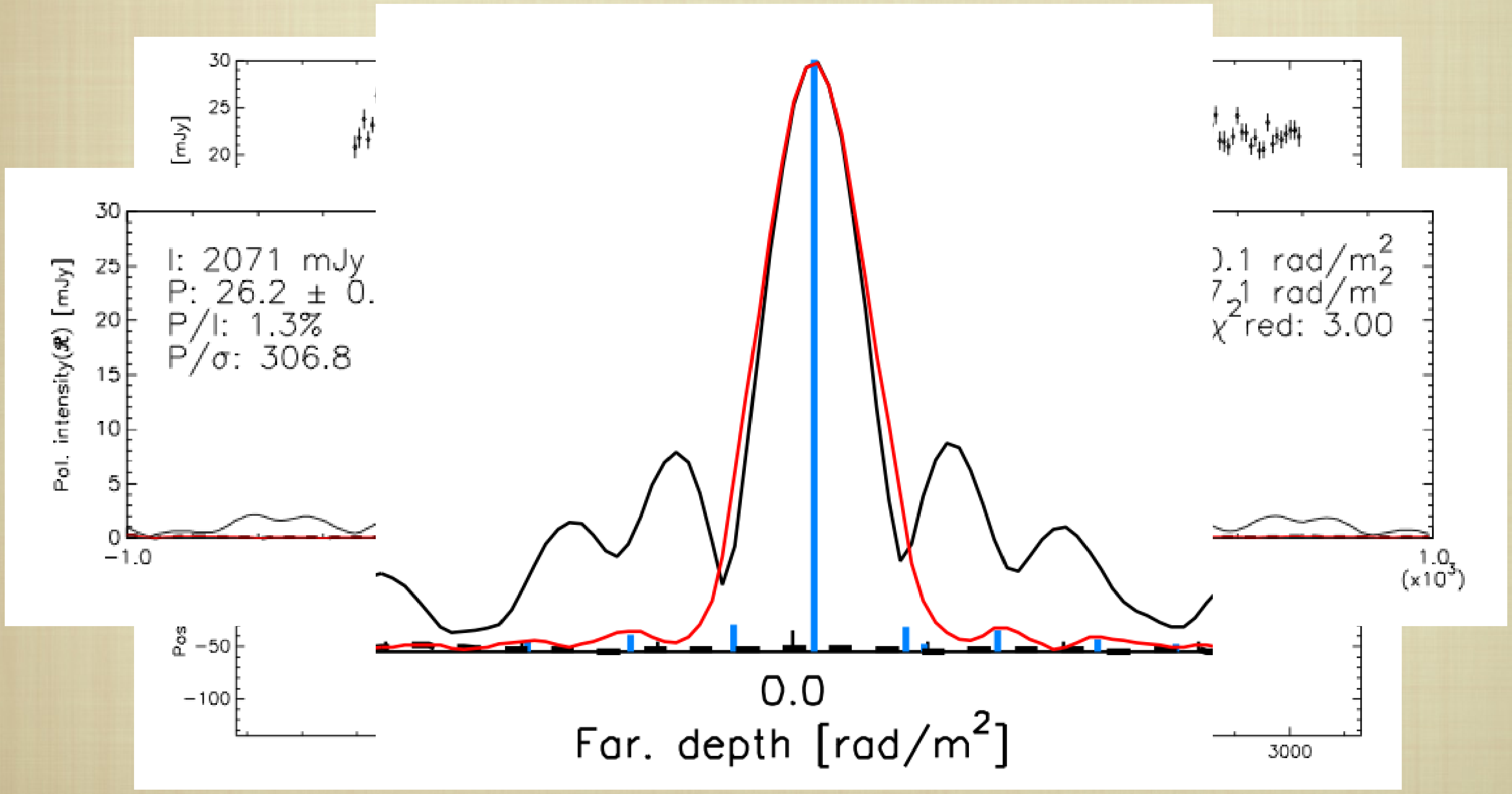
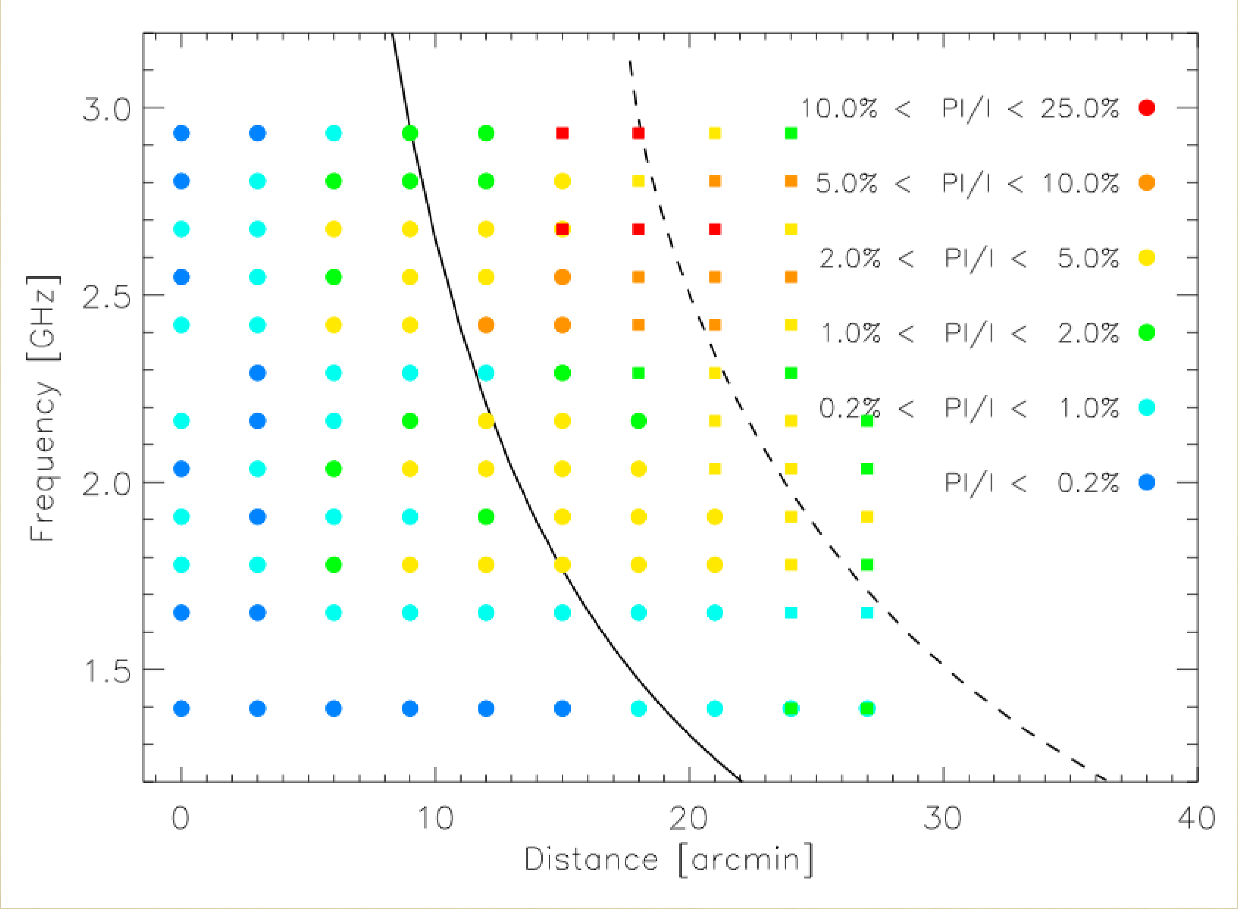


Off-axis: the anatomy of the beam

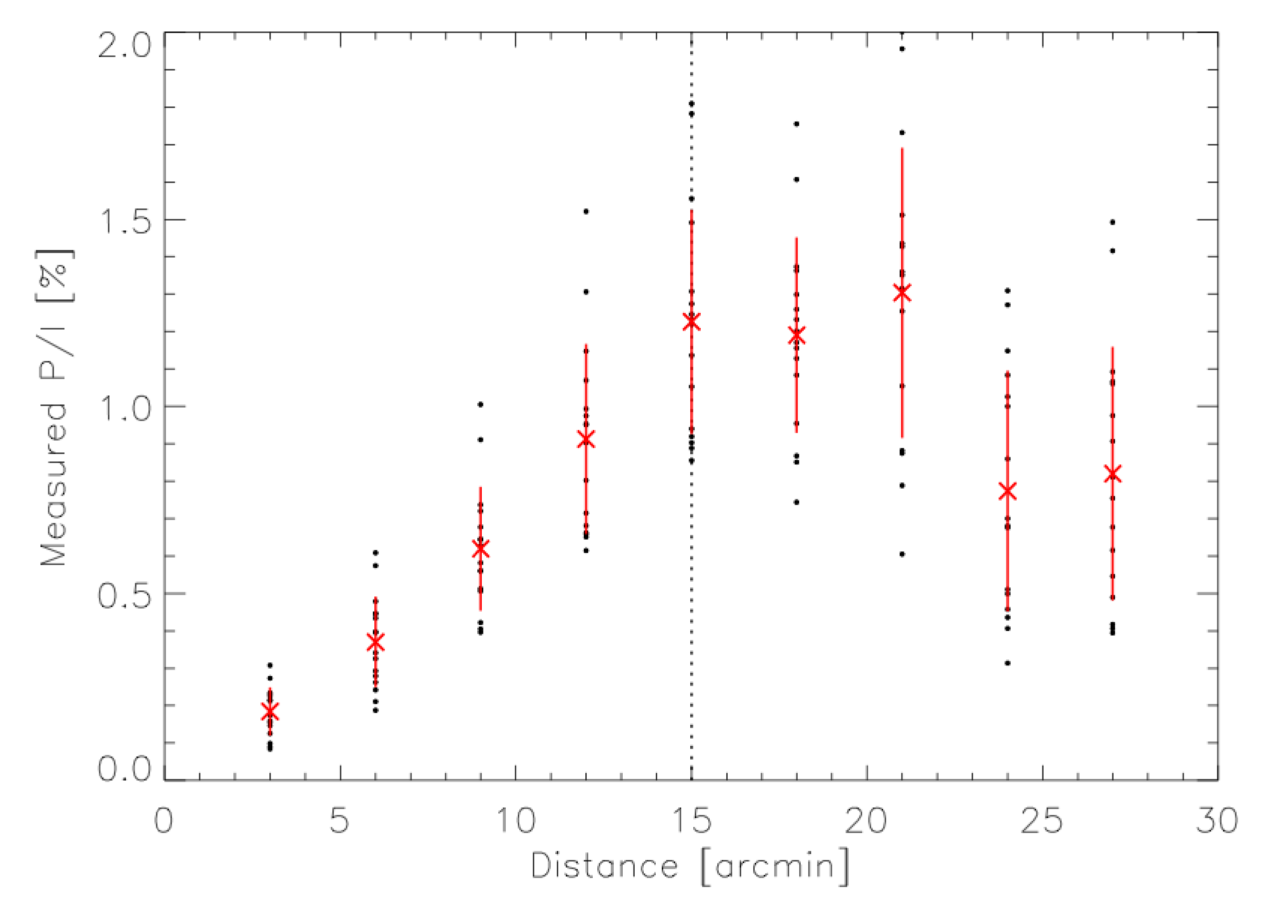
Example: the primary beam of the ATCA between 1.3--3.1 GHz



Solid/dashed lines: PB response has dropped to 50% and 5%, resp.

Off-axis: polarization purity across the FOV

Flagging the highest arminutes x GHz points:



With more time: accurate beam model (Reid+08 for DRAO ST)

Off-axis: a few more points

- Self-calibrating wide-band data

The spectral indices of your sources can vary: in the frequency range between 1 and 3 GHz many bright southern-hemisphere sources have positive spectral indices, and a small number show a maximum.

Don't use P/I as input for RM synthesis without checking Stokes I

Self-calibration in MIRIAD (the standard ATCA calibration package) can be done using multi-model, multi-frequency synthesis ('mmfs') where spectra are calculated over sub-bands, and the calibration solutions are interpolated across the sub-bands.

- Mosaicking

Flagging of individual pointings which are later combined into a single mosaic changes both the central frequency and the window function that is used in RM space.

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Real-time processing / data storage / decision tree for classifying RM spectra