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International Centre for Radio Astronomy Research

Low-frequency pulsar polarimetry across the MWA Band

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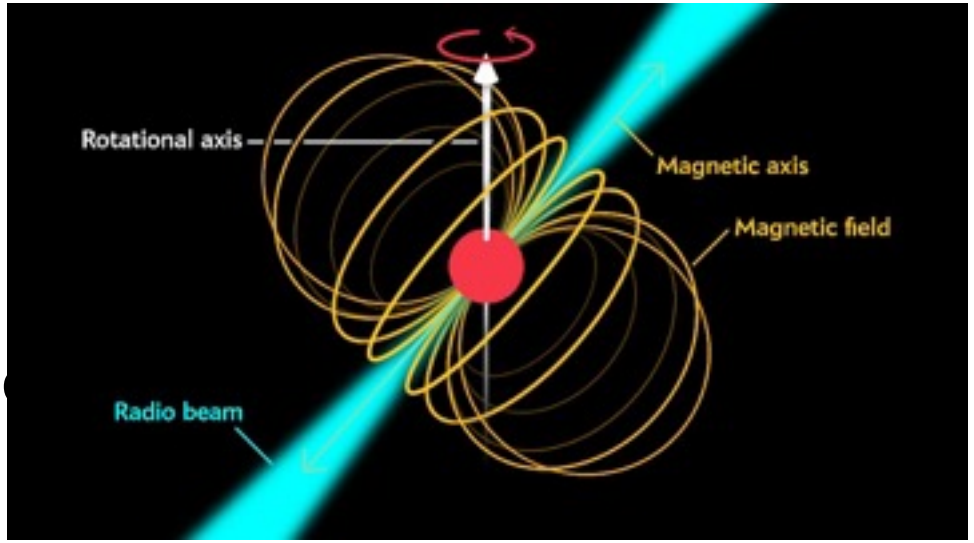
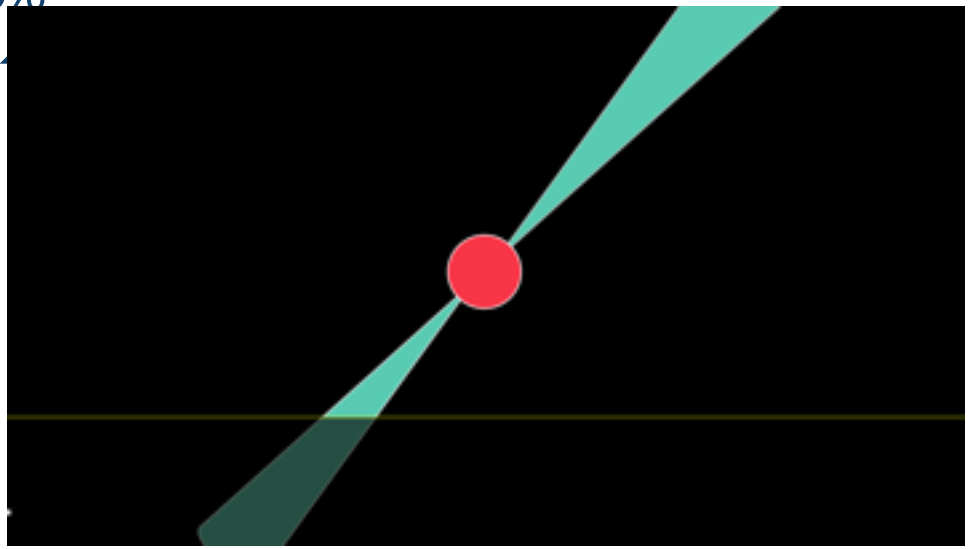
Pulsars and their polarisation properties

- Highly magnetised
  - (~10^8 - 10^{14} G)

- Highly polarised radio emissi
  - Linear:
    - Average ~20%, highest ~100%
    - Tends to ↓ with frequency
  - Circular :
    - Average ~10%

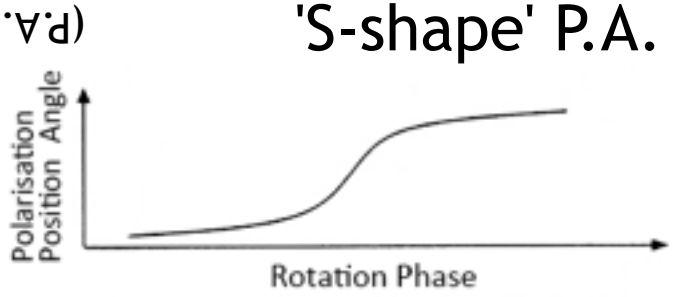


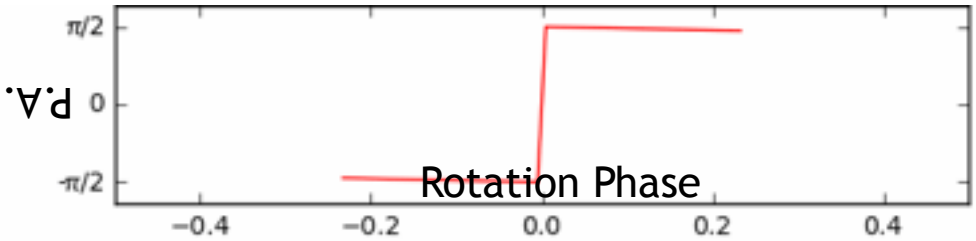


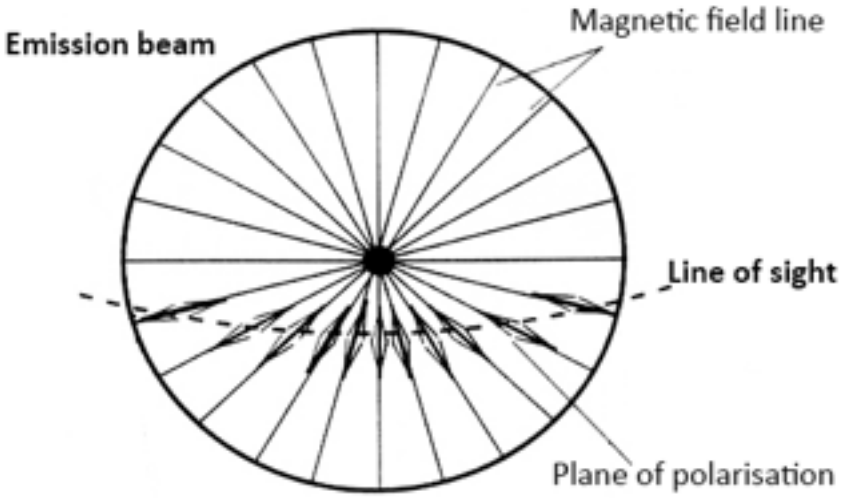
Credit: Jen Christiansen

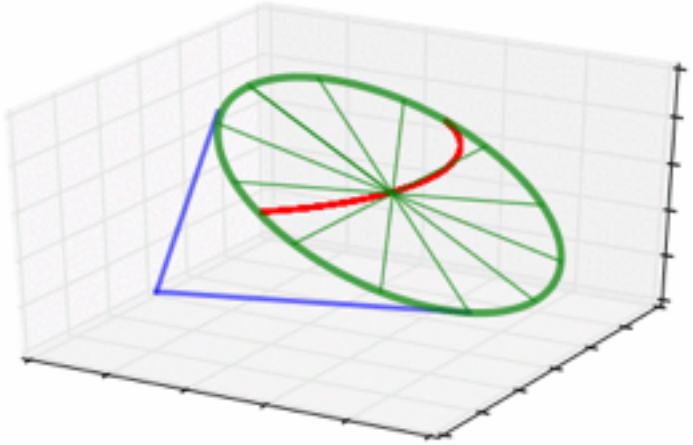
The Rotating Vector Model (RVM)

'S-shape' P.A. curve





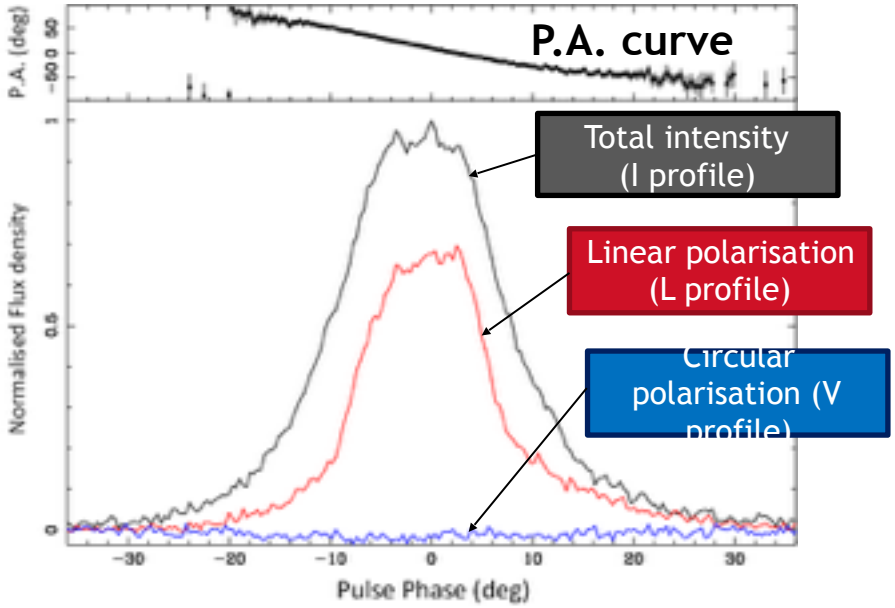




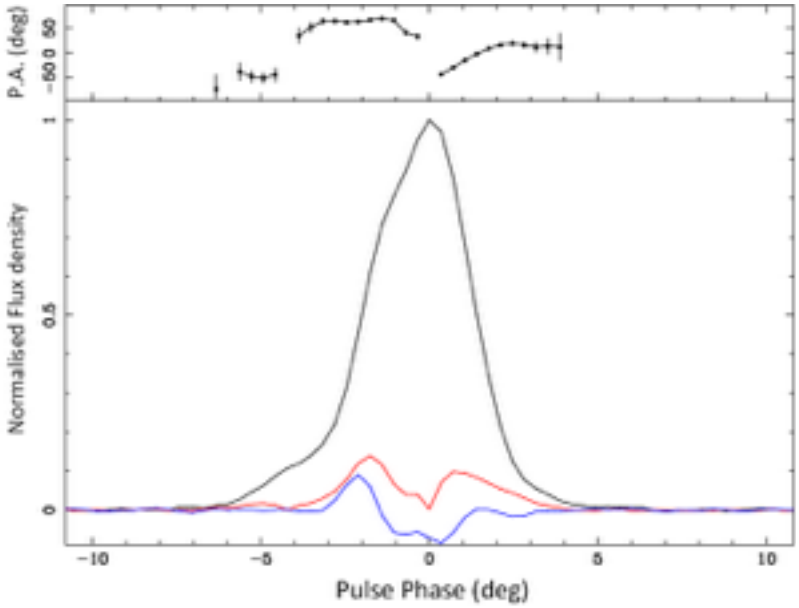
Radhakrishnan and Cooke (1969)

Polarisation profiles of pulsars from observations

J0630-2834 at 690 MHz



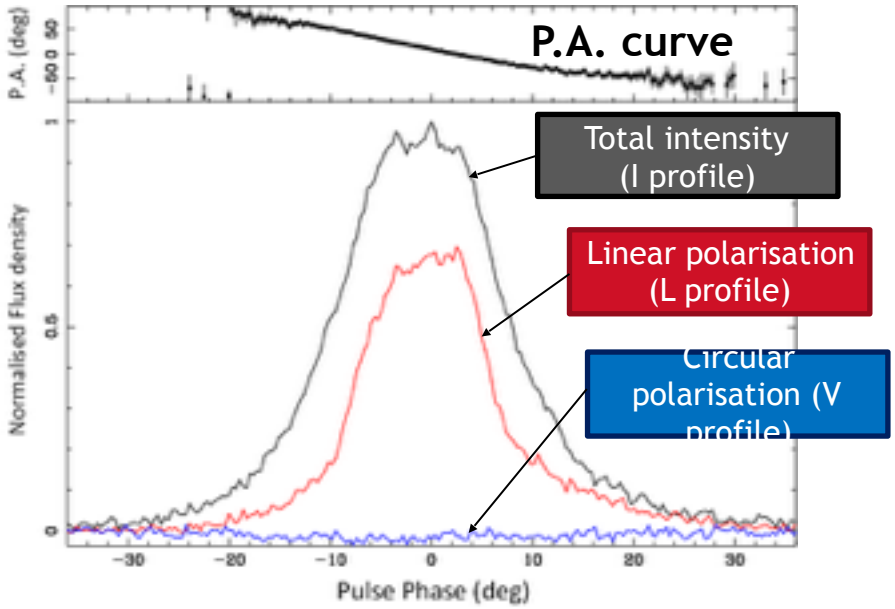
J1913-0440 at 690 MHz



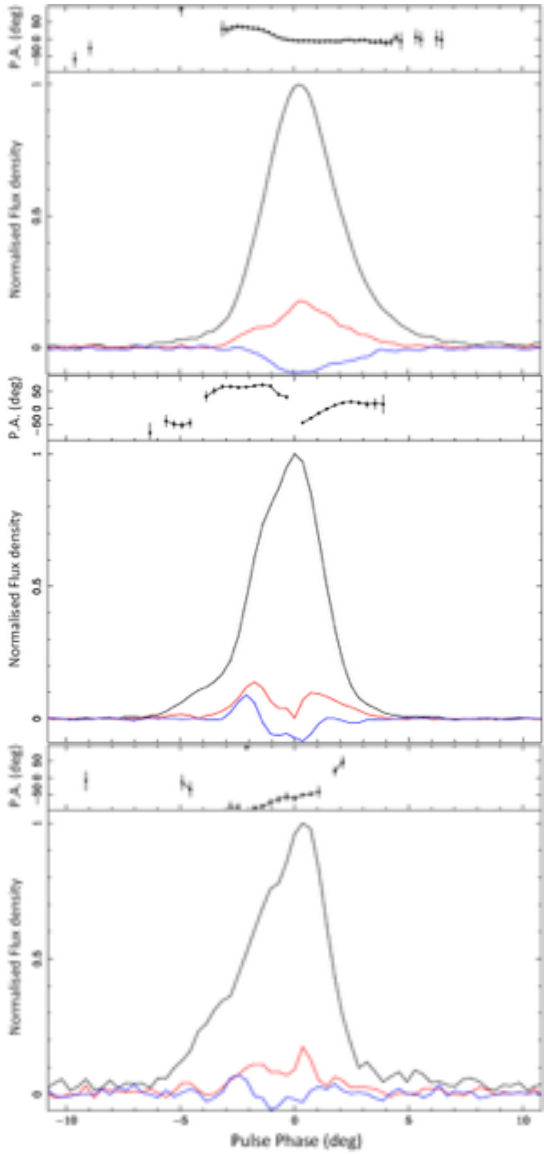
Johnston et al. (2008)

Polarisation profiles of pulsars from observations

J0630-2834 at 690 MHz



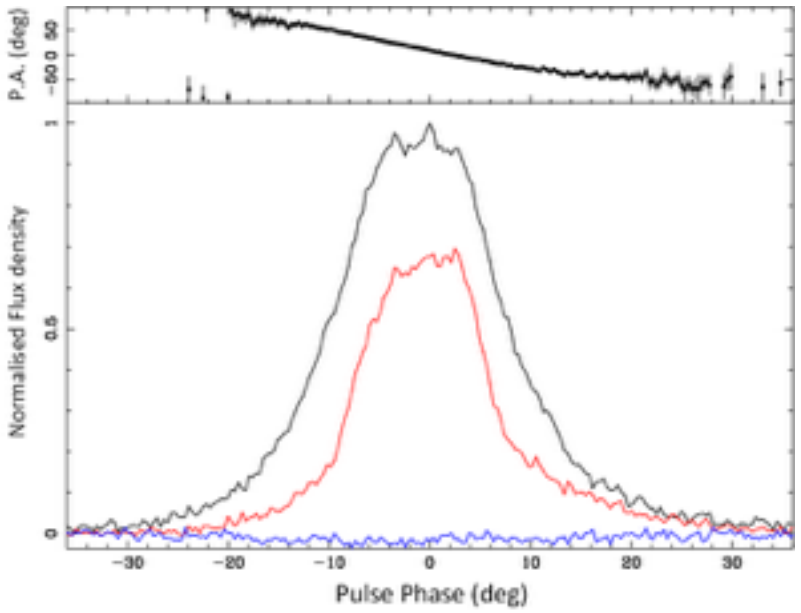
J1913-0440



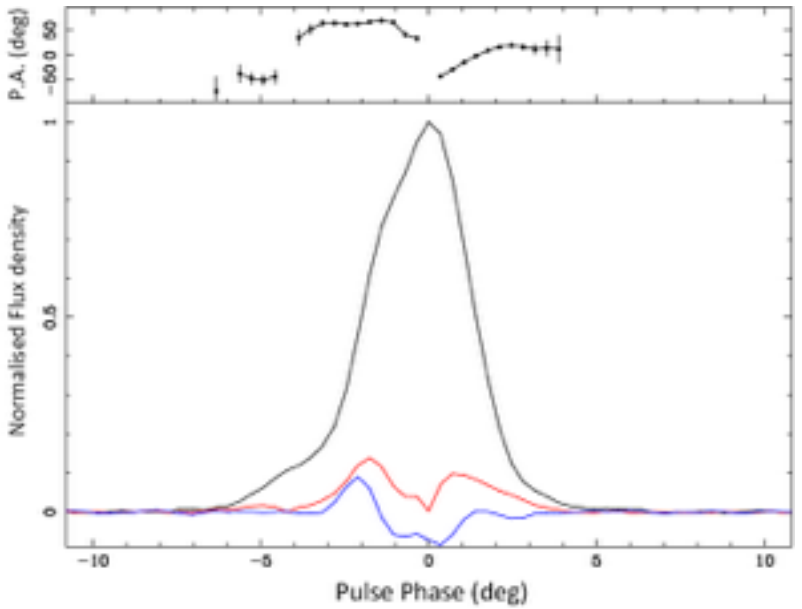
Johnston et al. (2008)

Polarisation profiles of pulsars from observations

J0630-2834 at 690 MHz



J1913-0440 at 690 MHz

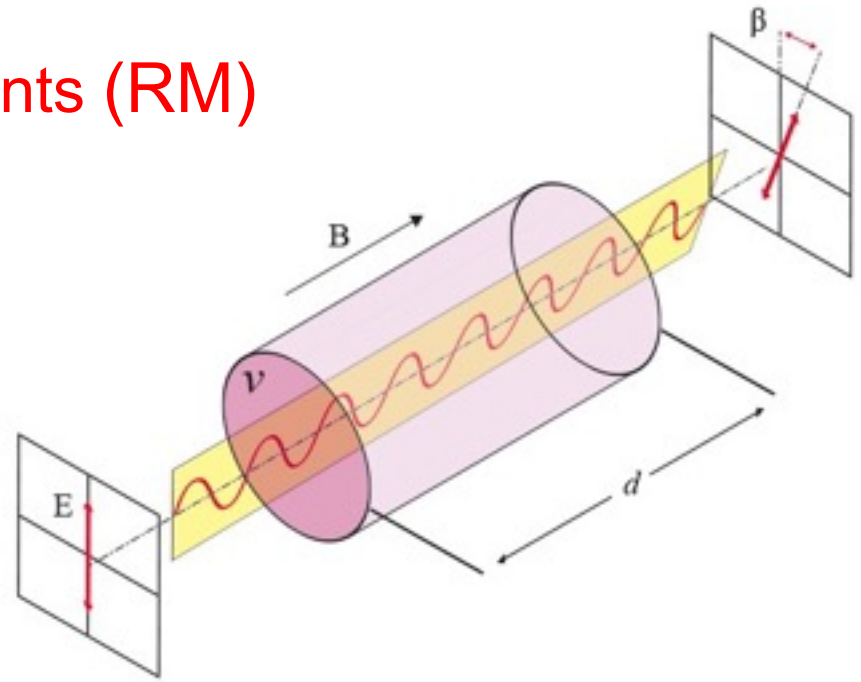


Johnston et al. (2008)

- Polarisation observation of pulsars can provide information of:
  - Beam geometry (e.g. RVM fits of the P.A. curve)
  - Emission mechanism (e.g. why linear polarisation ↓ when frequency ↑?)
  - Interstellar medium properties
  - Galactic magnetic field

Observable effects due to ISM

Faraday Rotation Measurements (RM)



Credit : wikipedia.org

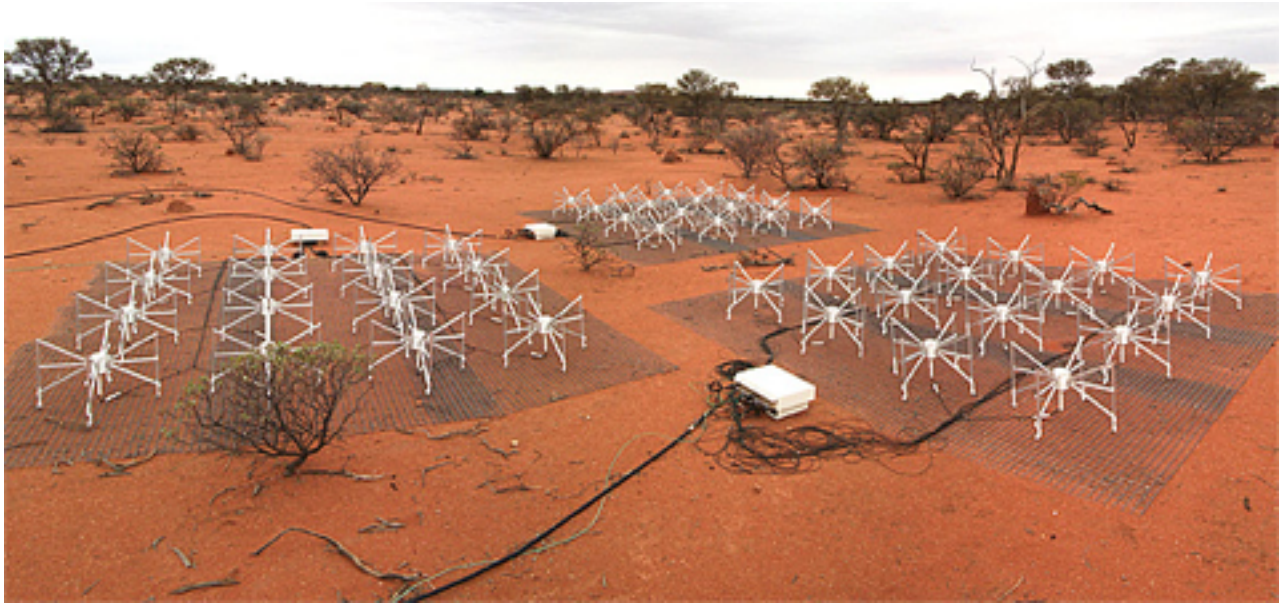
$$\Delta\Psi_{\mathrm{PPA}} \equiv \lambda^2 \times \mathrm{RM}$$

$$\mathrm{RM} = \frac{e^3}{2\pi m_{\mathrm{e}}^2 c^4} \int_0^d n_{\mathrm{e}} B_{||}\, \mathrm{d}l$$

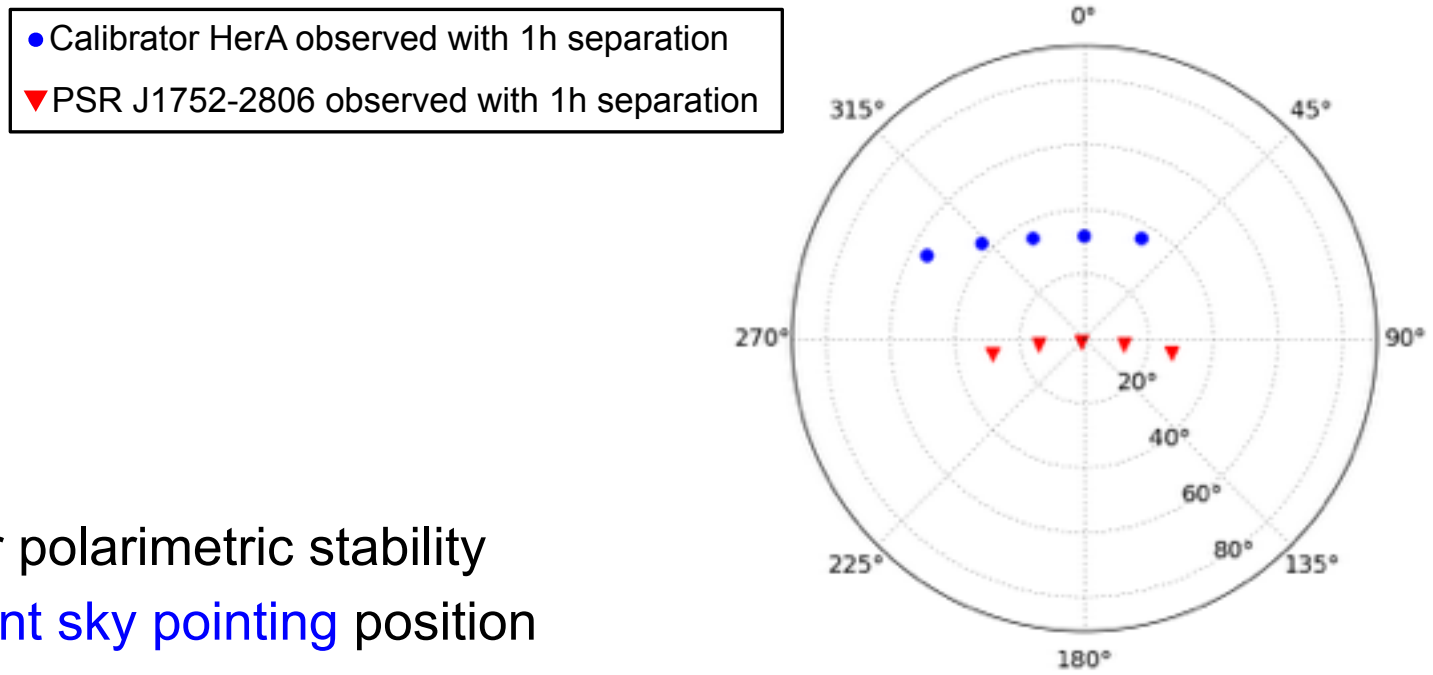
$$\langle B_{||} \rangle \equiv \frac{\int_0^d n_{\mathrm{e}} B_{||}\, \mathrm{d}l}{\int_0^d n_{\mathrm{e}}\, \mathrm{d}l} = 1.23\,\mu\mathrm{G} \left(\frac{\mathrm{RM}}{\mathrm{rad\,m^{-2}}}\right) \left(\frac{\mathrm{DM}}{\mathrm{cm^{-3}\,pc}}\right)^{-1}$$

MWA polarimetric calibration and beamforming

- Aperture array: direction-dependent beam model (polarimetric response in different pointing directions)
- Calibration process (e.g. RTS): get the direction independent Jones Matrix
- Form a coherent beam with Jones Matrix solution (Ord et al. in prep)

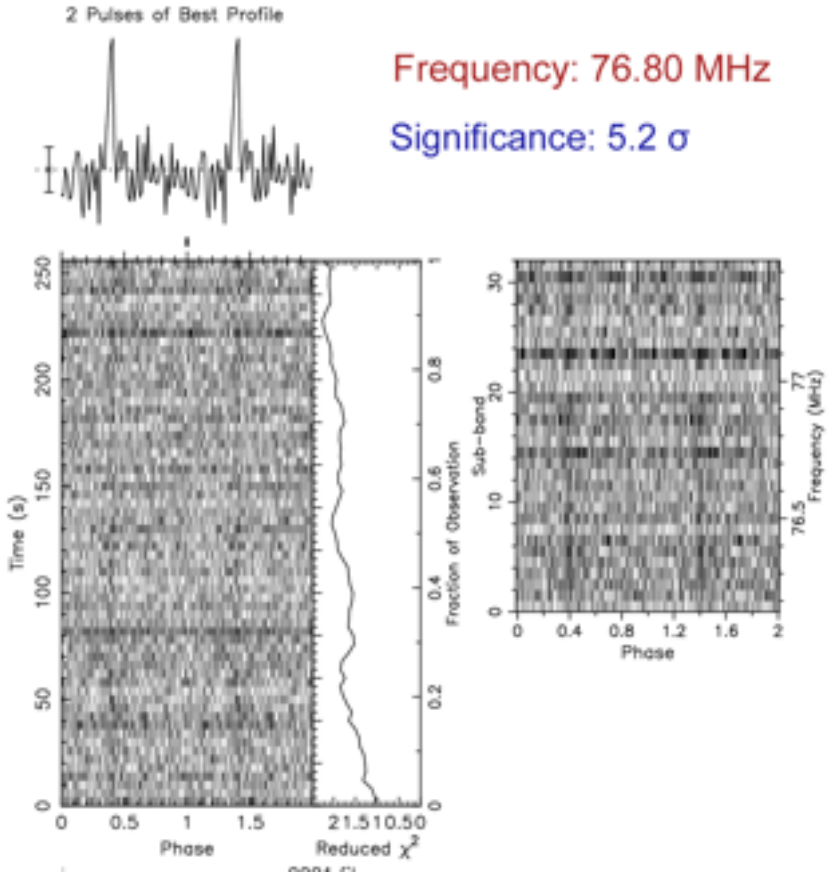


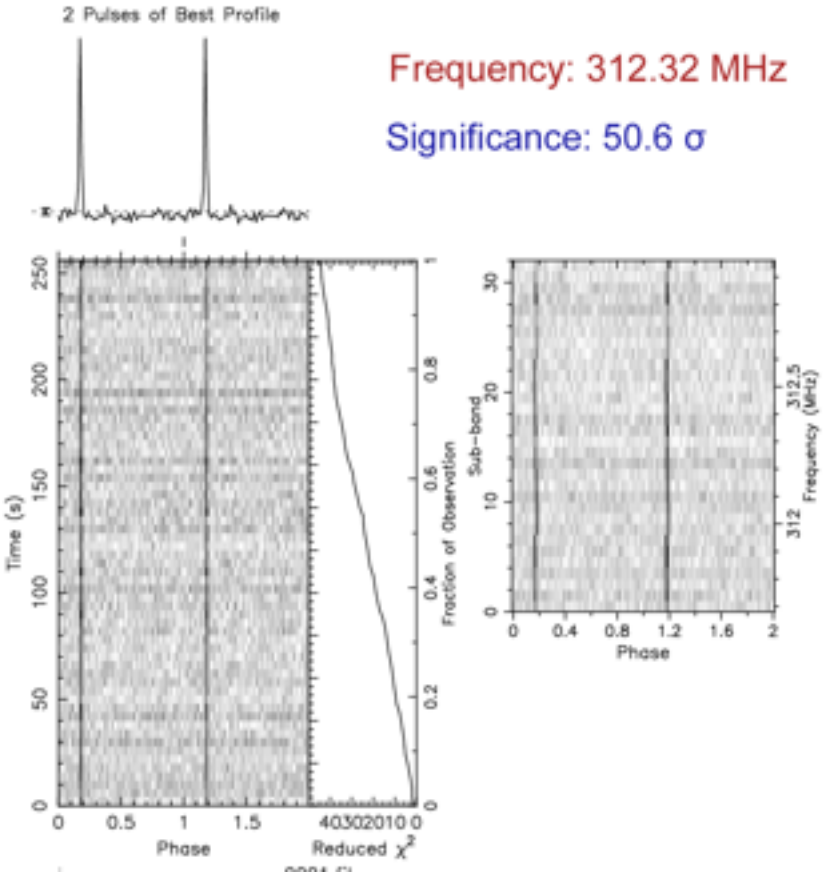
Testing polarimetric capability



- Checking our polarimetric stability
  - With different sky pointing position
  - In a spread frequency range: 76.80 – 312.32 MHz
    (24 × 1.28MHz separate channels simultaneously)
- Cross check with other instruments
  - With German LOFAR stations (Tremblay et al. in prep)

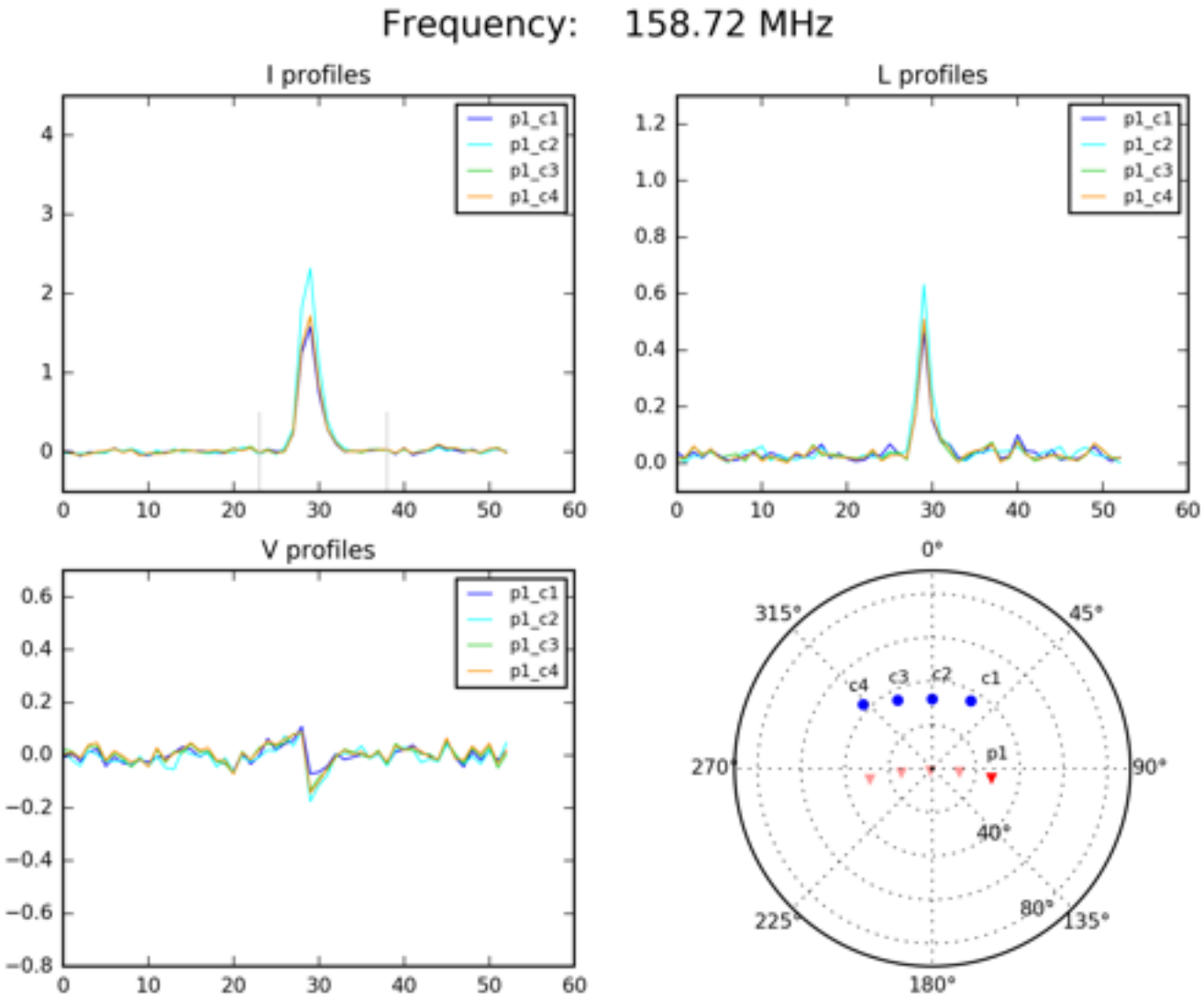
Detections of J1752-2806





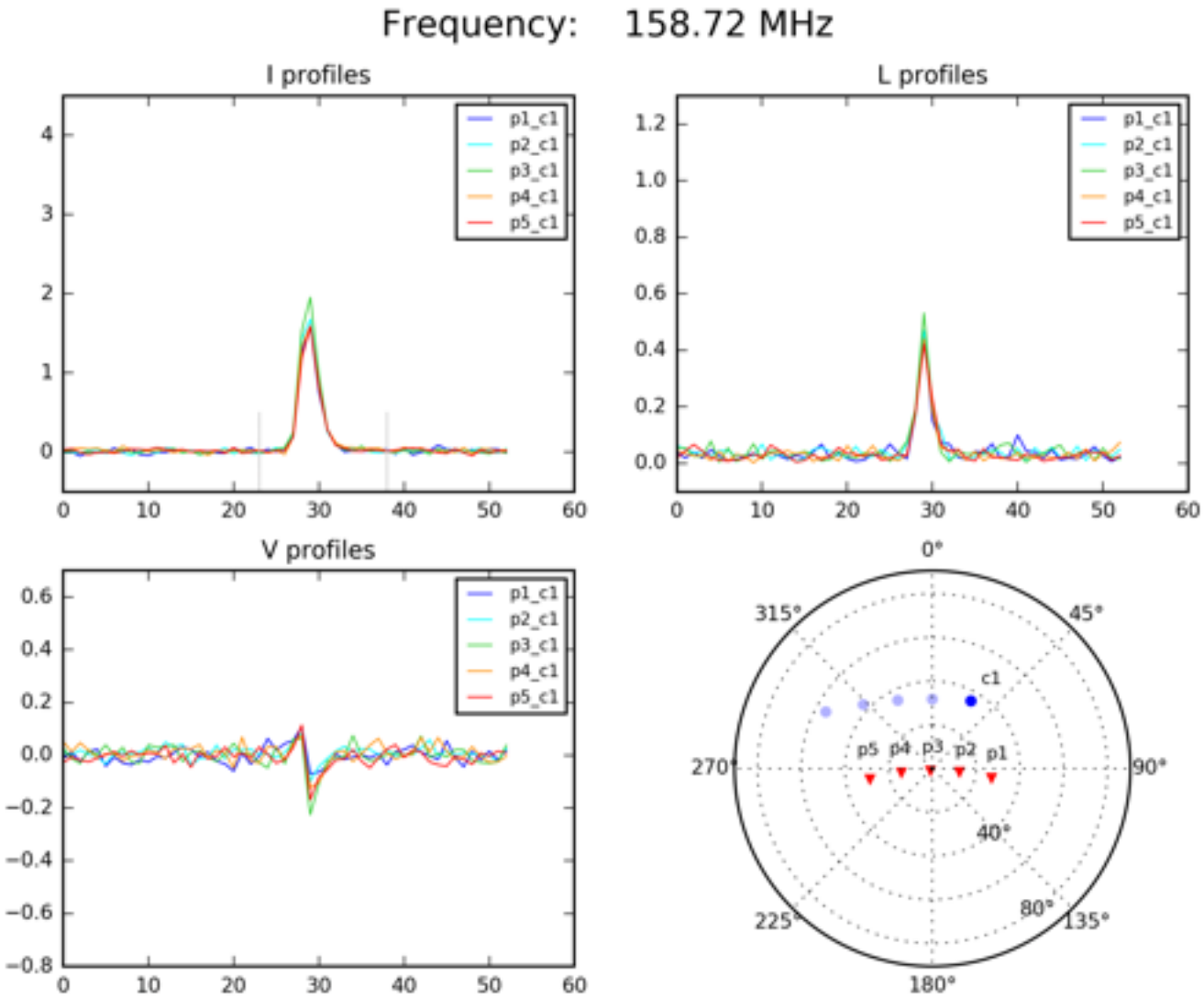
These are the lowest and highest frequency pulsar profiles with the MWA

Stability with calibrator position



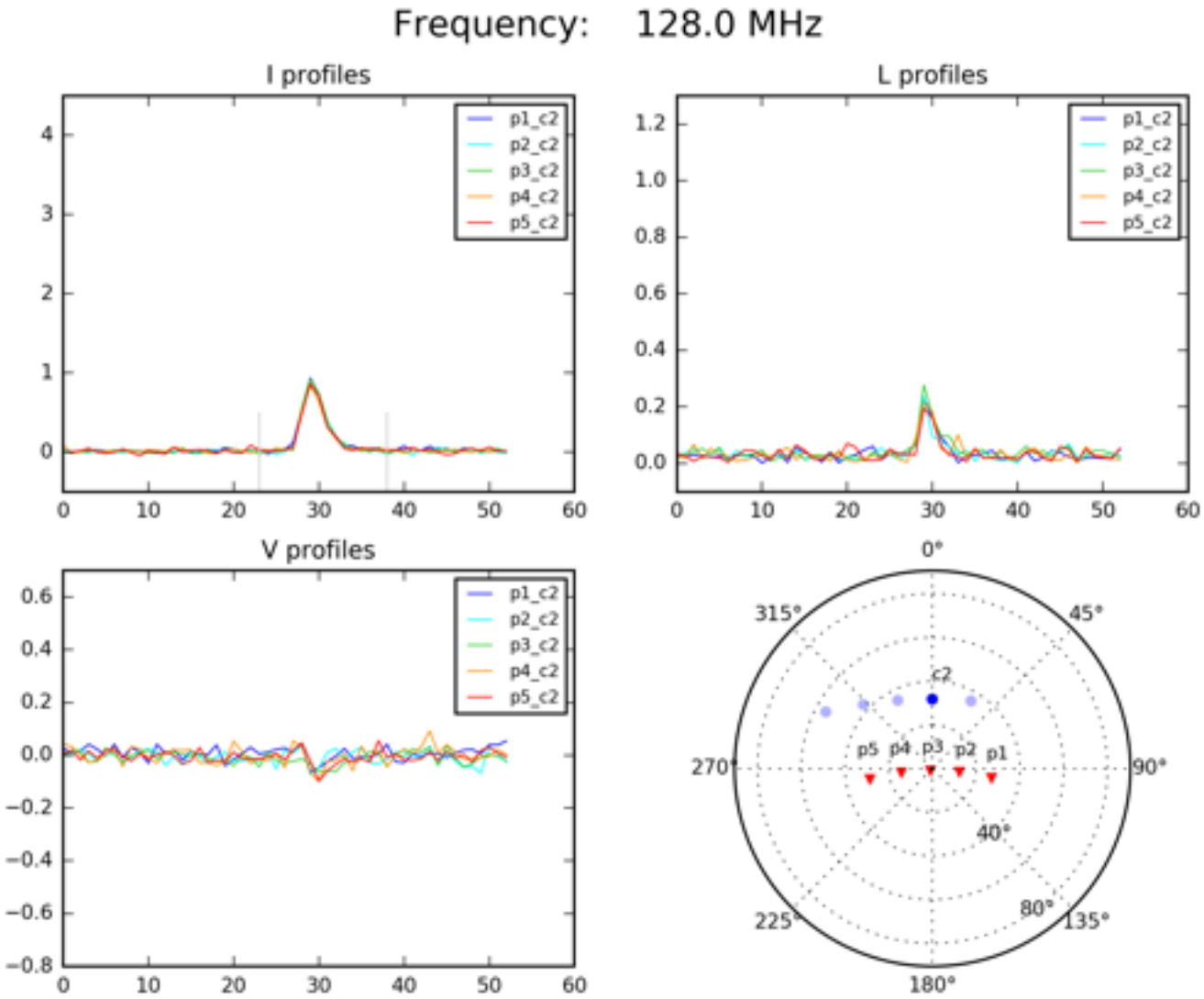
Comparing polarimetry profiles of the pulsar using different calibrator observation

Stability with target position



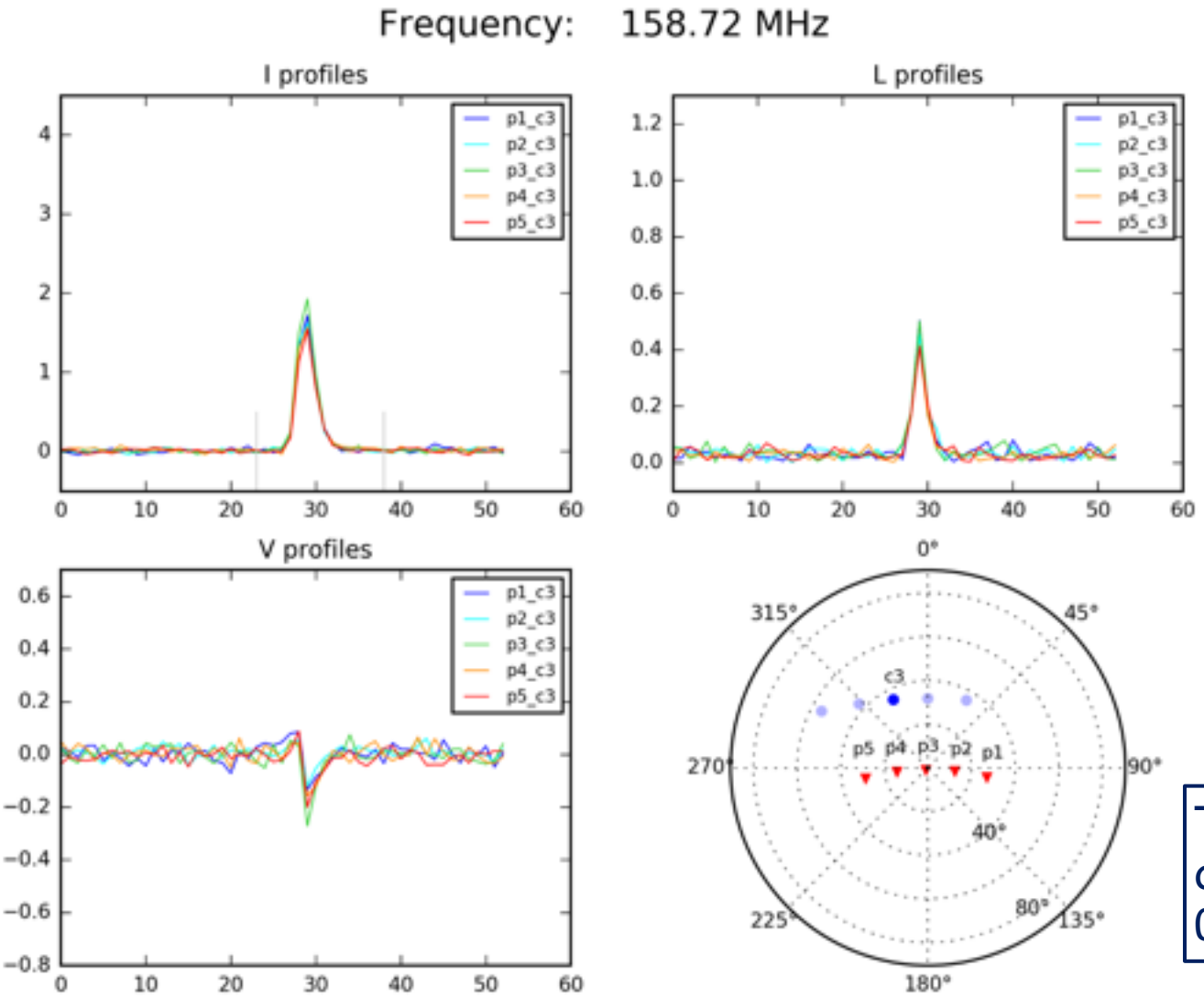
Comparing polarimetry profiles among different pointing of the pulsar

Stability among frequencies



Comparing polarimetry profiles among different pointing of the pulsar

Linear polarisation degree stability



p1_c3:

L/I= 18.4 ± 5.5 (

p2_c3:

L/I= 16.7 ± 6.1 (

p3_c3:

L/I= 15.5 ± 6.5 (

p5_c3:

L/I= 14.5 ± 7.1 (

p5_c3:

L/I= 16.5 ± 6.5 (

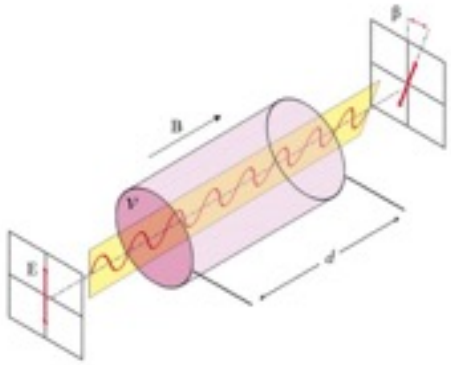
The linear polarisation degree is stable (ZA: 0~30°)

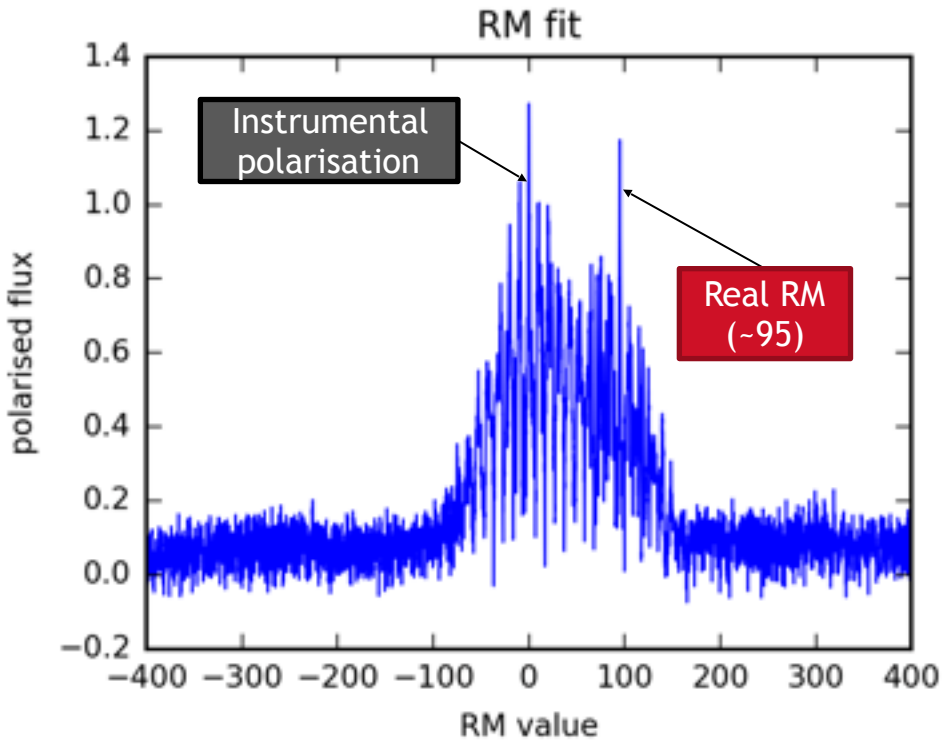
Examples: different pointing of the pulsar with the 3rd calibrator observation

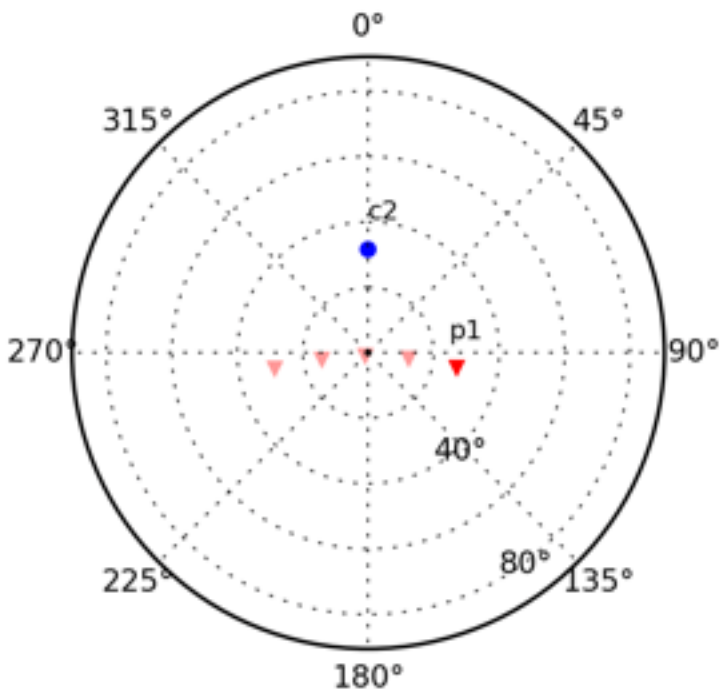
RM fit results for different pointing

Faraday Rotation Measurements (RM)

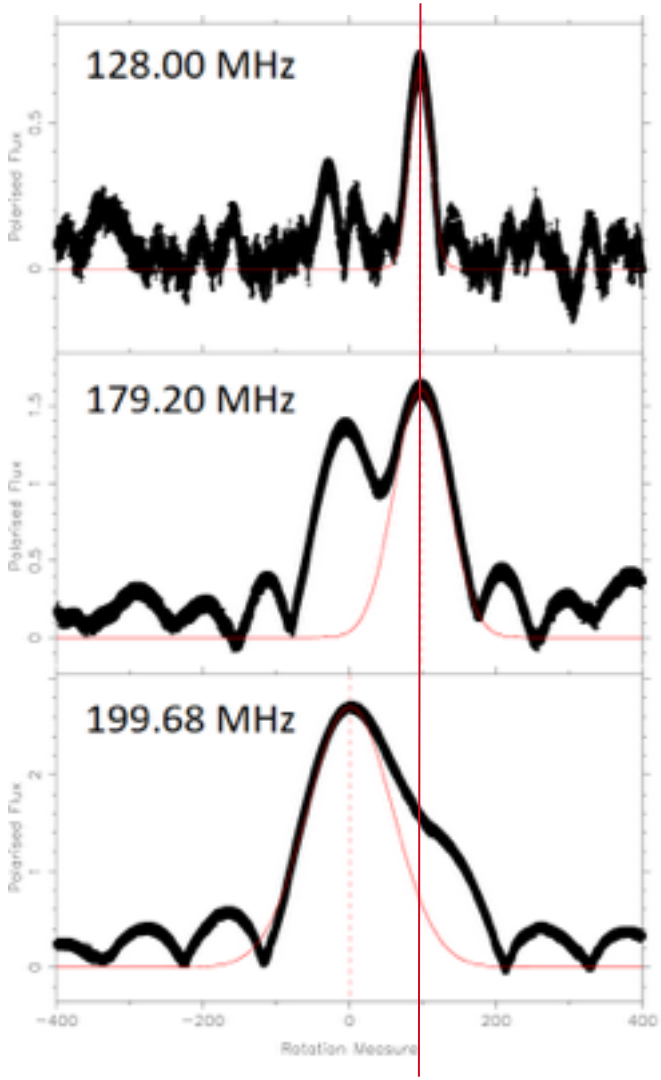
$$\Delta\Psi_{\mathrm{PPA}} \equiv \lambda^2 \times \mathrm{RM}$$







Frequency dependent RM fit results



Zero peak caused by instrumental polarisation tend to ↑ with higher freqency

Real RM (~95)

Cross check with other instruments

- Compare the same pulsars at the same frequencies with two independent instruments.
- Collaborate with German LOFAR stations

The German Long Wavelength Consortium

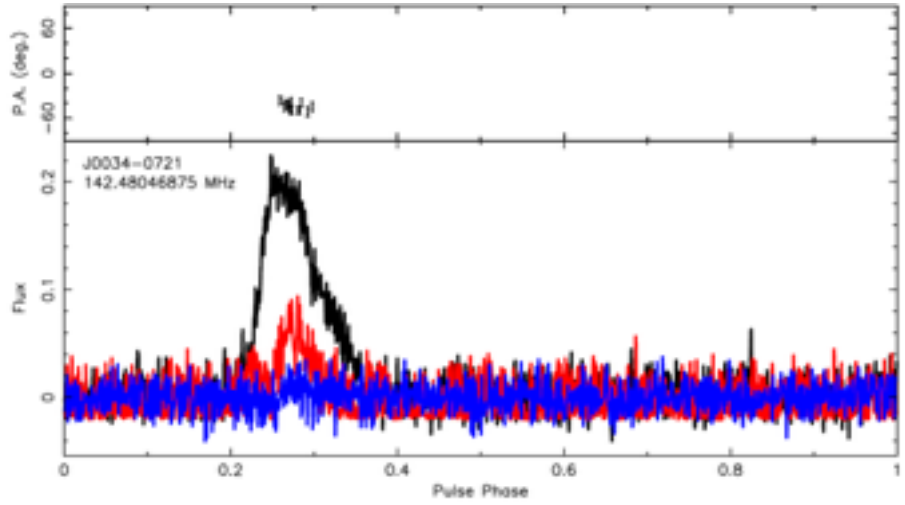
DAAD
Deutscher Akademischer Austausch Dienst
German Academic Exchange Service

We are comparing a subset (~8) of commonly visible pulsars

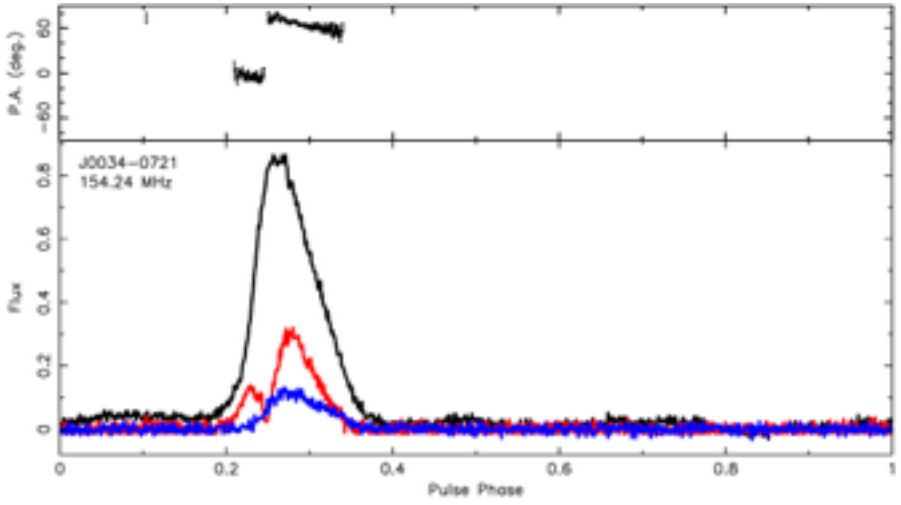
(Tremblay et al. in prep)

MWA Polarimetry vs GLOW

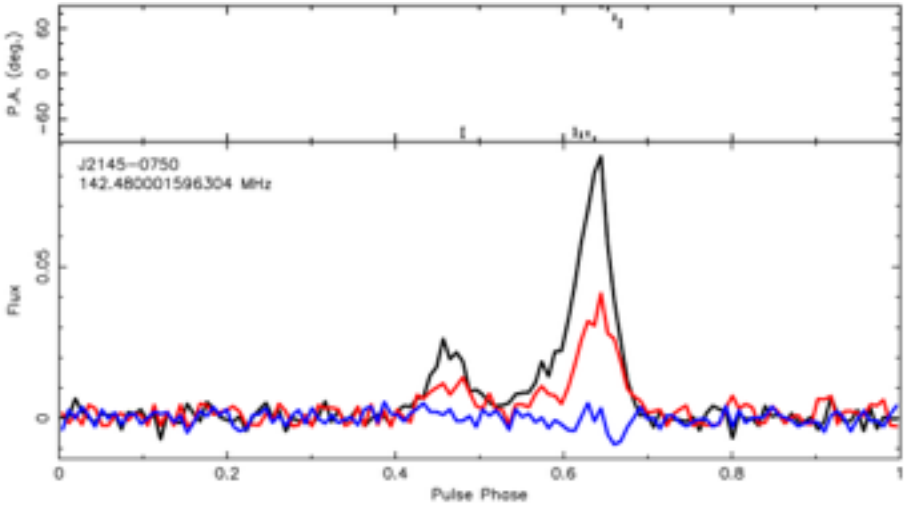
J0034-0721 140-145 MHz MWA



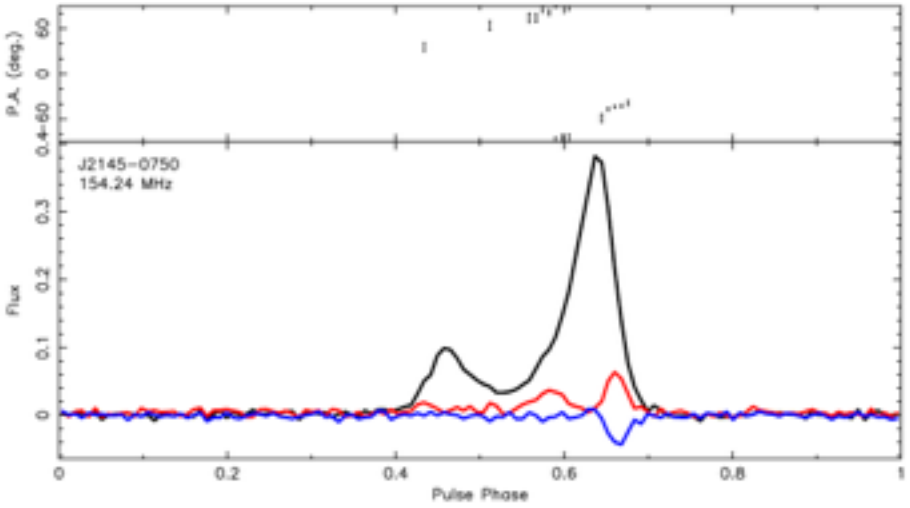
J0034-0721 140-145 MHz GLOW



J2145-0750 140-145 MHz MWA



J2145-0750 140-145 MHz GLOW



Tremblay et al. in prep

Conclusions and Future work

- The current MWA polarimetric calibration stability is generally good; the variation of linear polarisation degree for PSR J1752 is less than ~20% (across all different combination of pulsar and calibrator pointing we tested)
- Cross check with GLOW
- Plan to compare with the instrumental polarisation from image data and testing with other beam models
- Aim to get polarisation profiles for a large sample of southern pulsars -> pulsar emission physics (e.g. the degree of polarisation with frequency) and beam geometries (e.g. RVM fits of the P.A. curve)

Thanks