Polarization with the GMRT: a case study of MACS J0025.4–1222

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www.csiro.au

with J.S. Farnes

Talk layout

▶ Magnetic fields in the Universe

▶ Polarization with the GMRT at 610 MHz:

   ▶ In theory
   ▶ In practice

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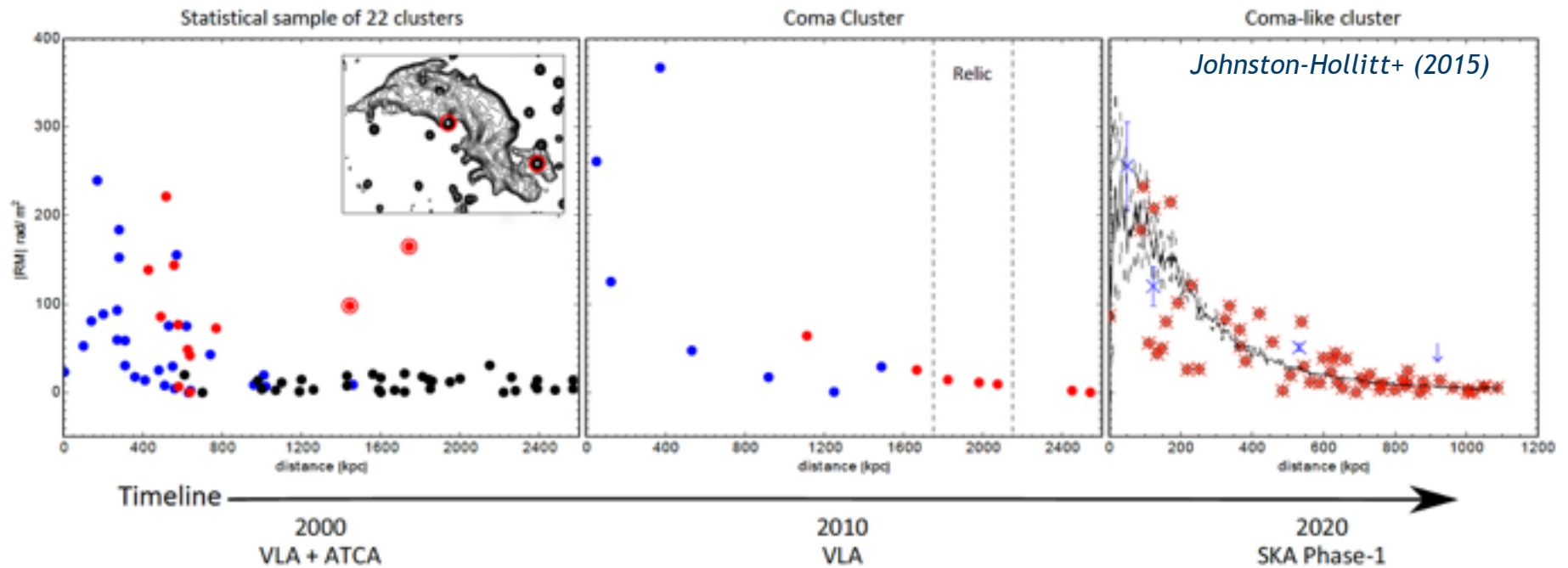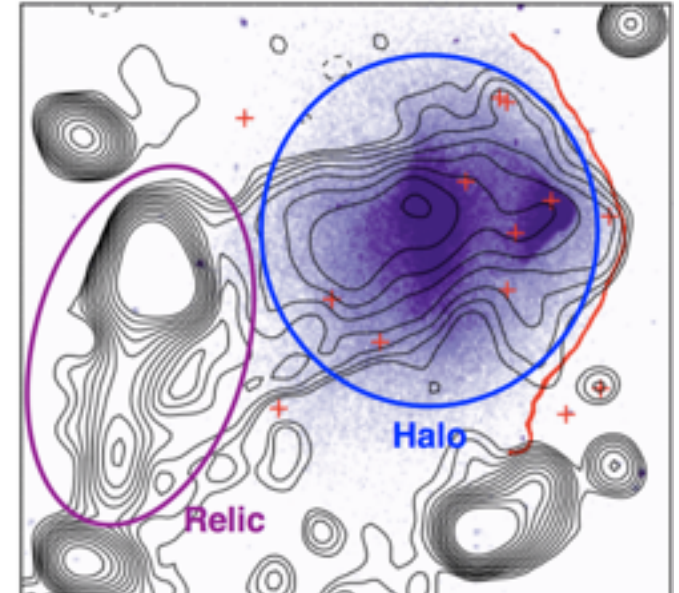# Magnetic Fields in the Universe

The origins of cosmic magnetism

- Big science driver for the SKA
    - Primordial or late-stage?

- Two main methods of probing magnetic fields:
    - Direct detection of synchrotron emission
    - Rotation measures (e.g. *Brentjens & de Bruyn 2005*)
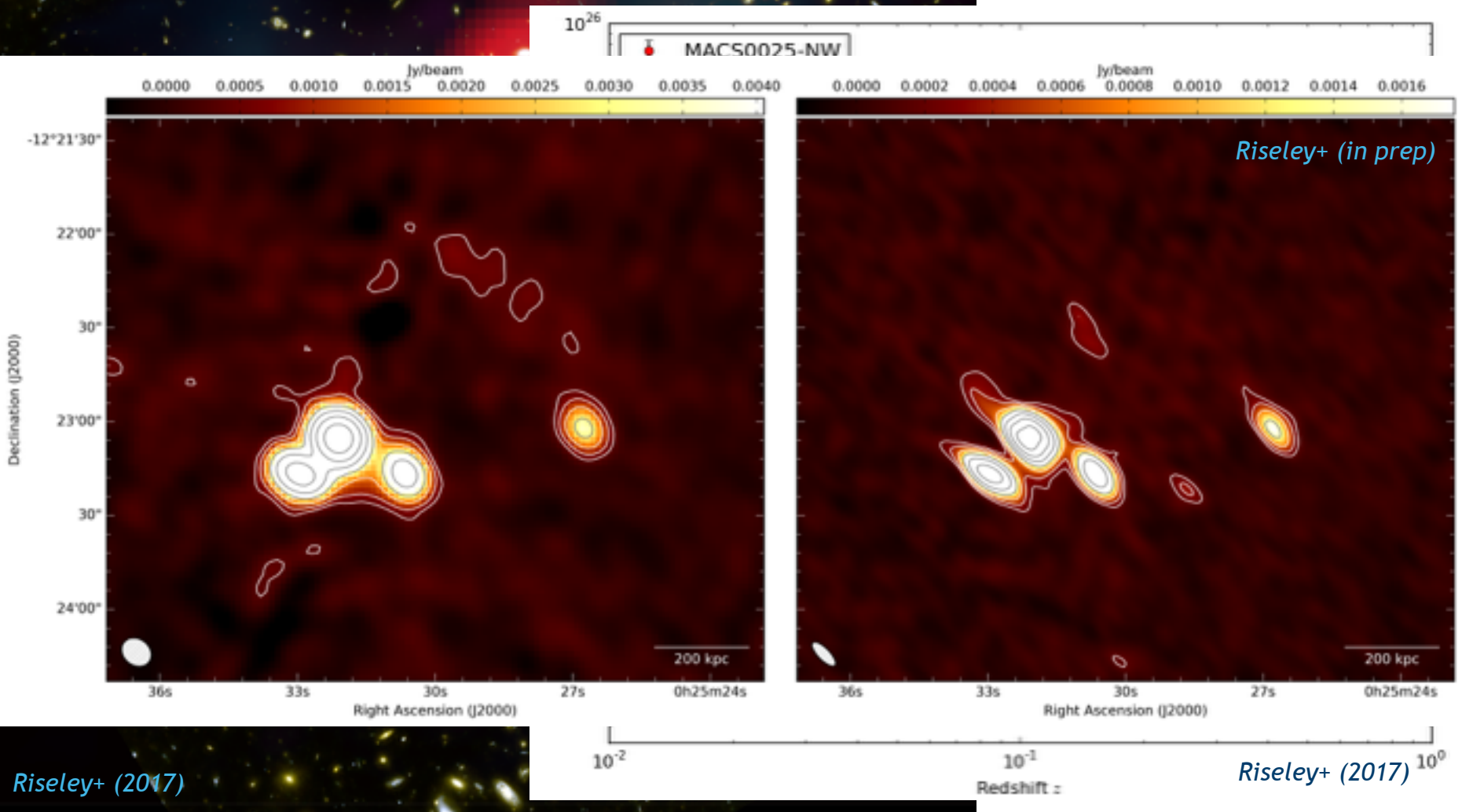
- Radio emission => magnetic fields

Johnston-Hollitt+ (2015)

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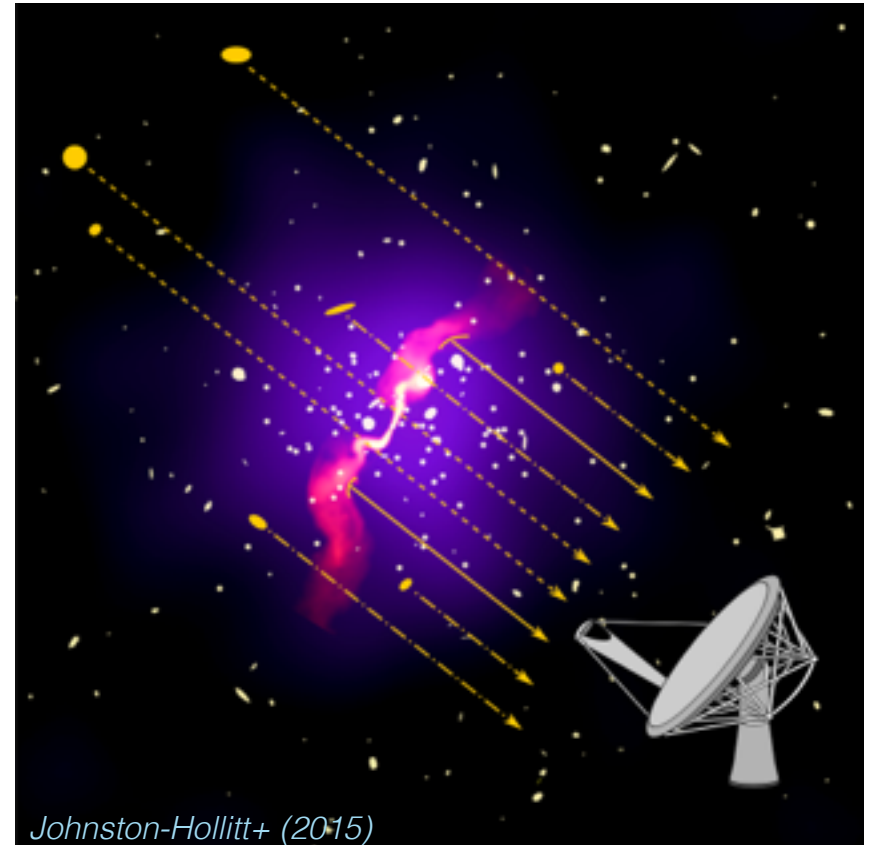
Why clusters?

- Haloes:
  - Unpolarized, wide variety of morphologies, typically Mpc-scale, associated with turbulence
  - *Disordered magnetic fields*
- Relics:

Johnston-Hollitt+ (2015)

Statistical sample of 22 clusters | Coma Cluster | Coma-like cluster

Timeline ⟶

2000
VLA + ATCA

2010
VLA

2020
SKA Phase-1

MACS J0025.4–1222

Riseley+ (in prep)

Riseley+ (2017)

Riseley+ (2017)

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Polarization with the GMRT?

It *is po

NGC7552

NGC7582

Spectropola
at 610 MHz

J. S. Farnes,[1]

[1] Cavendish Laboratory;
[2] Sydney Institute for As
[3] National Centre for Ra
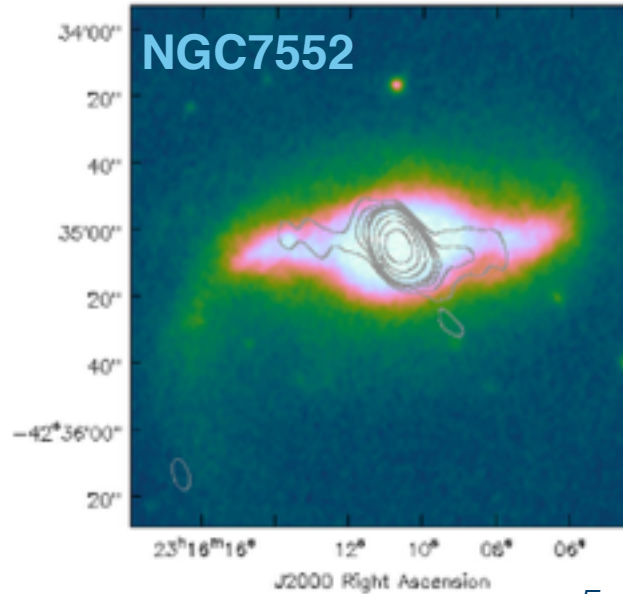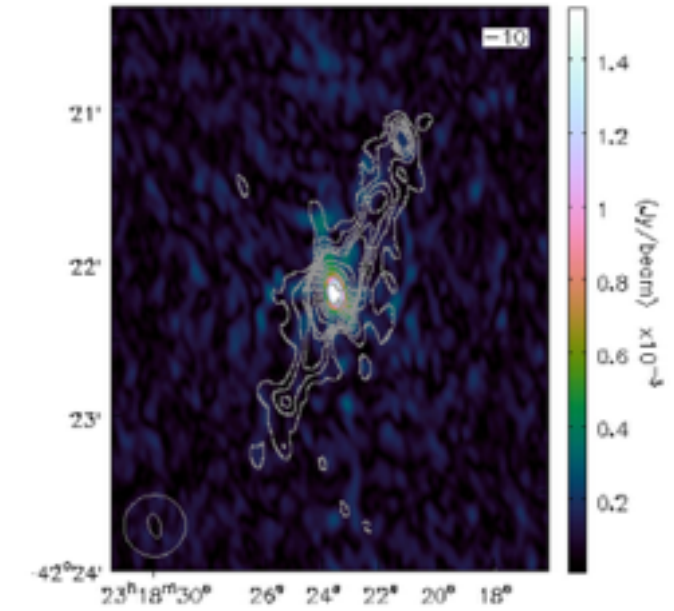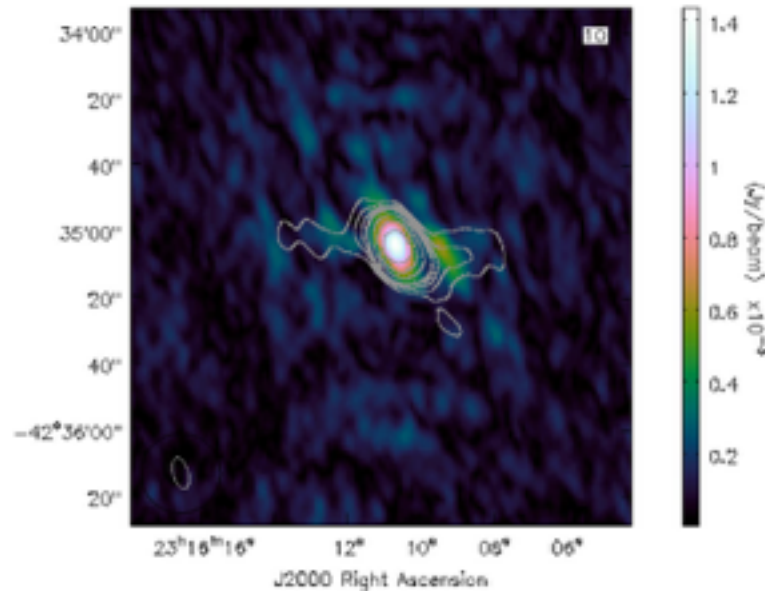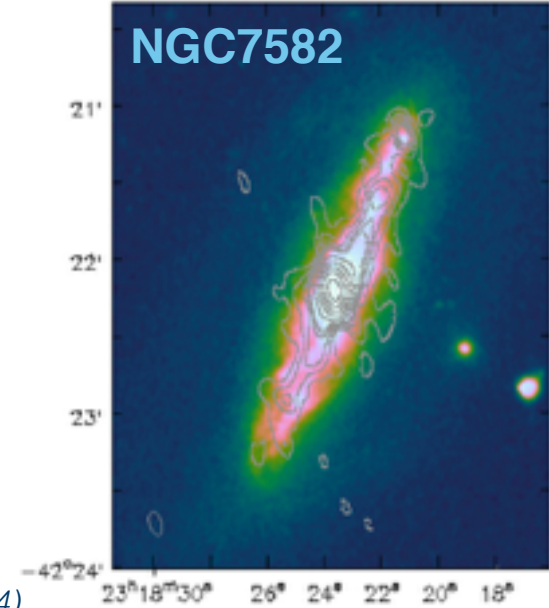
Farnes+ (2014)

Methodology

- ▶ If you're up for a challenge:
  - ▶ Iterative calibration & flagging process in CASA
  - ▶ Import into AIPS & run POL_PROC pipeline (*Farnes+ 2014, Riseley+ in prep*)
  - ▶ Ionospheric correction (JPL model)
  - ▶ Leakage calibration
  - ▶ Absolute phase between R and L is left unconstrained => "instrumental RM" of ~ few x100 rad/m^2
  - ▶ Calibrate EVPA using known polarization properties of 3C138.
  - ▶ Facet imaging on per-channel basis

R Amplitude Leakage

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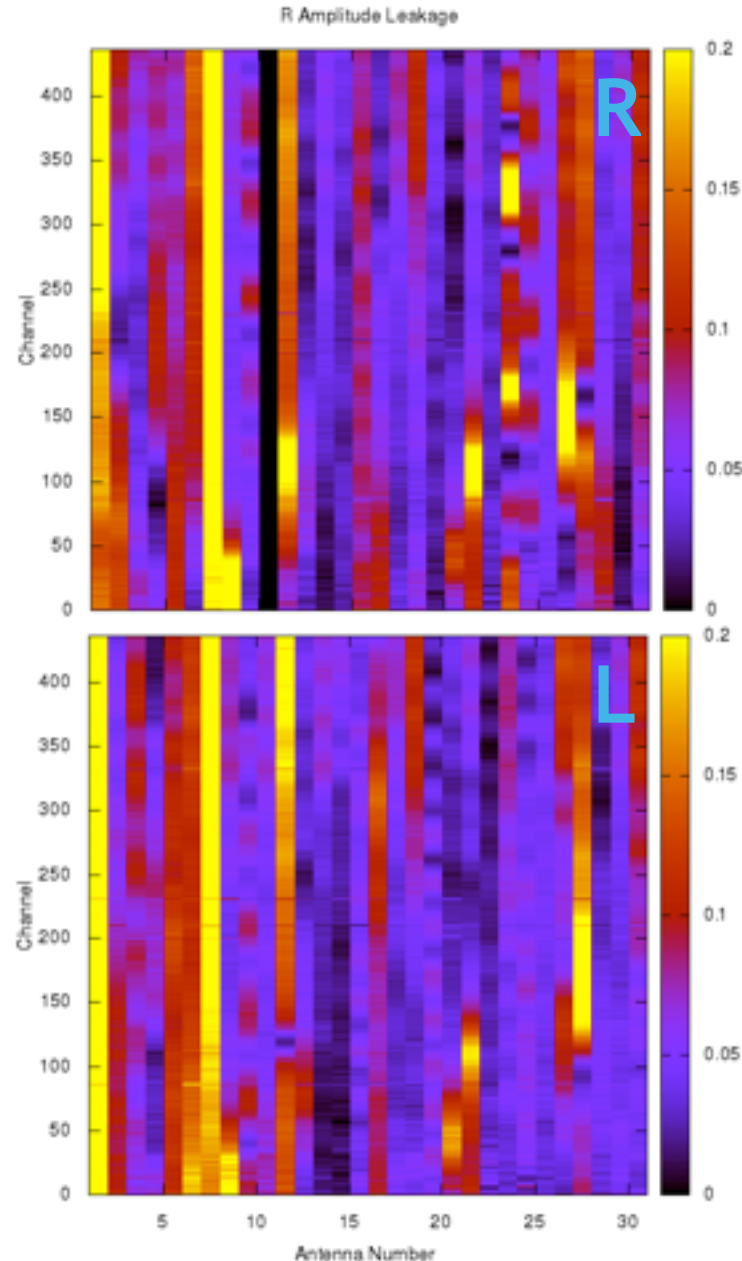
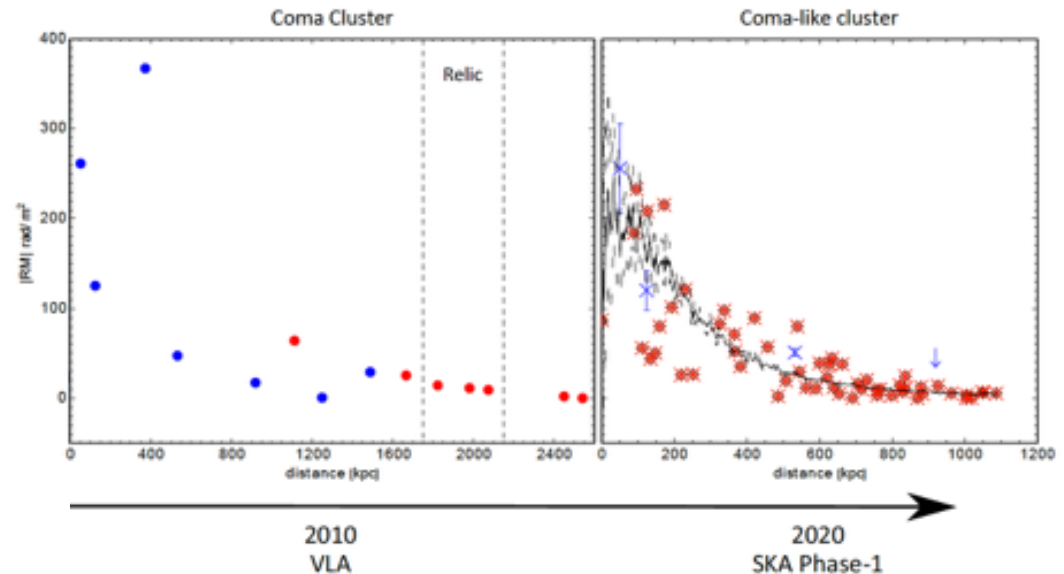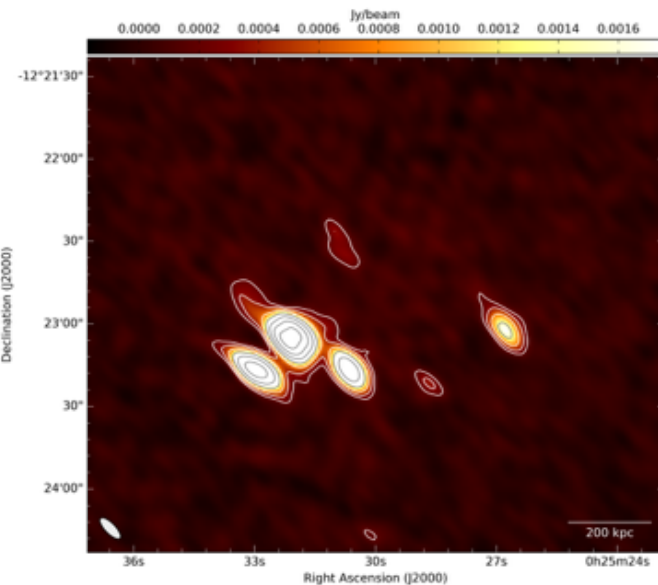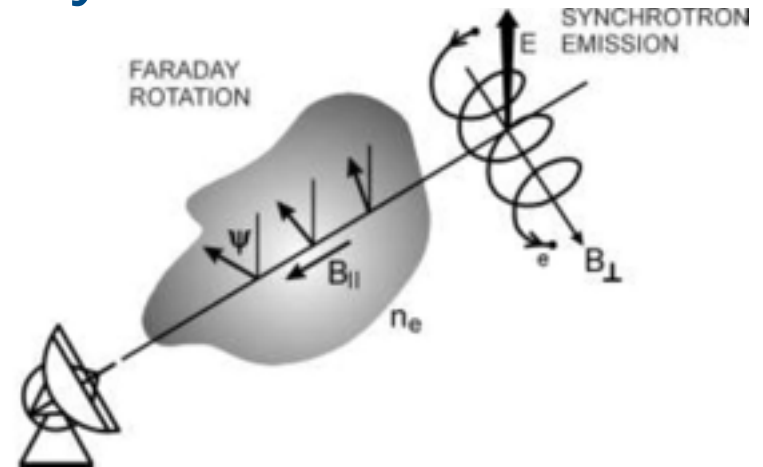# Rotation Measure (RM) synthesis

▶ Faraday rotation of polarized emission by magnetized plasma along LOS

  ▶ *Brentjens & de Bruyn (2005)*

▶ In general: $\quad \mathrm{RM} = \dfrac{\mathrm{d}\chi(\lambda^2)}{\mathrm{d}\lambda^2}$

▶ Then: $\quad \mathrm{RM} = 0.812 \displaystyle\int_{\mathrm{LOS}} n_e \, \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{l}$
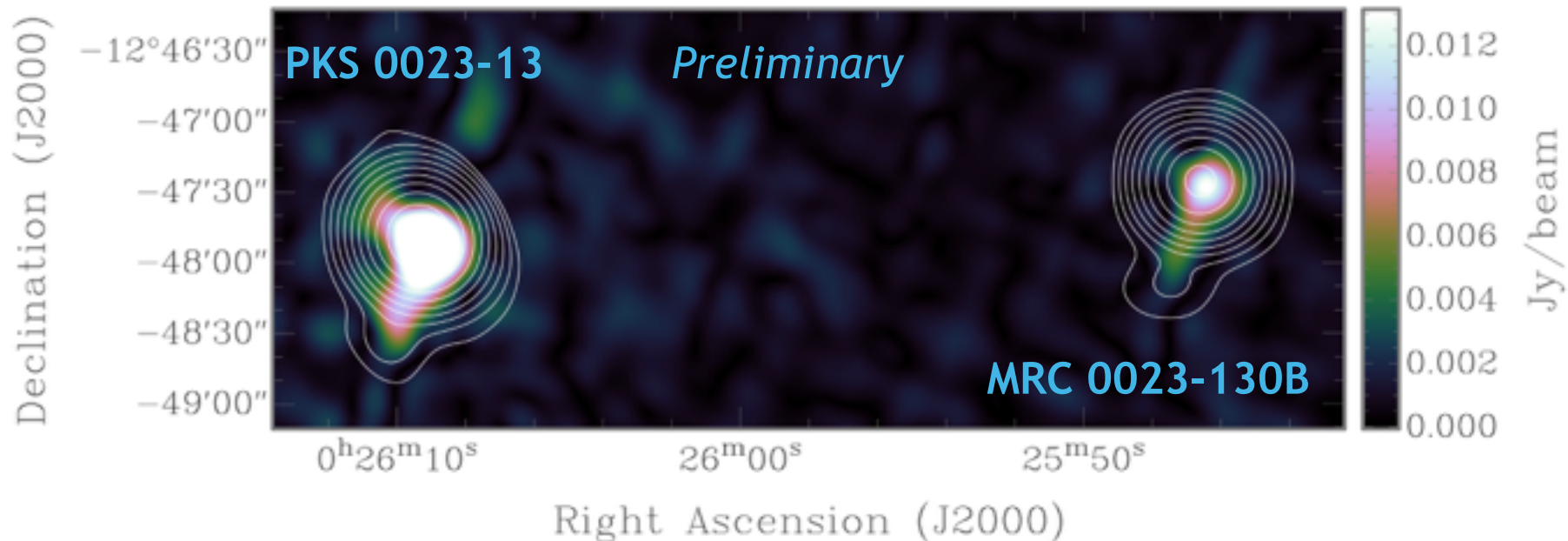
Polarization with the GMRT!

Widefield polarization
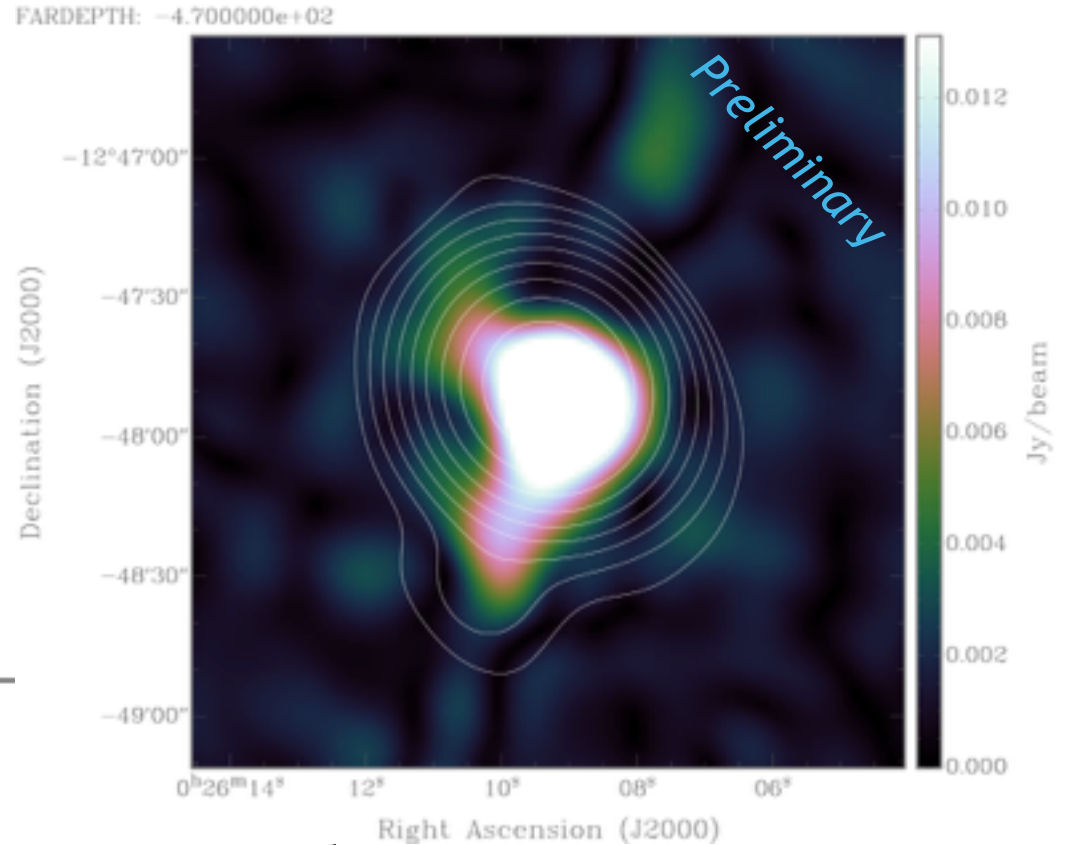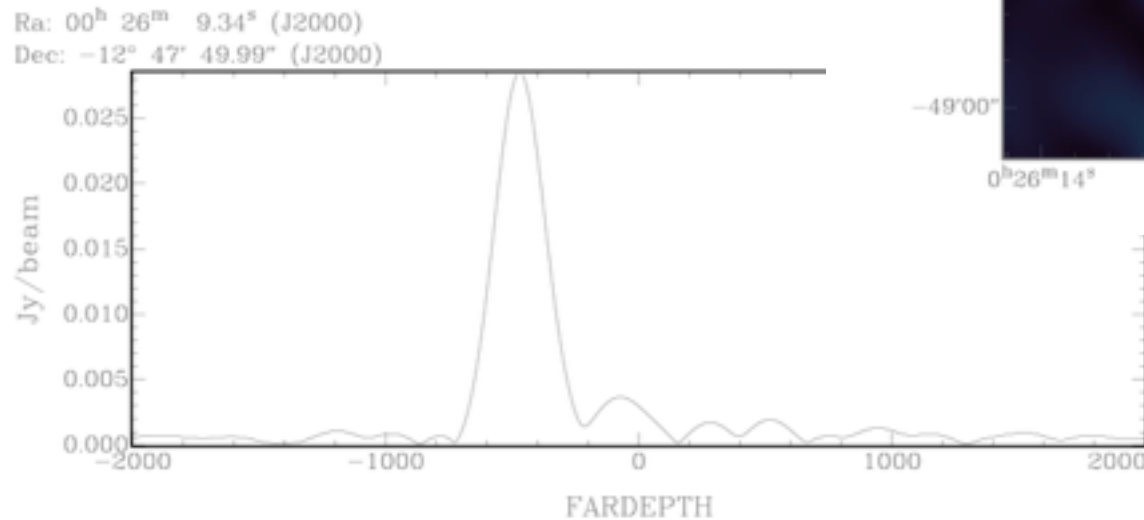
▶ RM synthesis performed using Python-based code

    ▶ RM-clean employed (*Heald+ 2009*)

    ▶ 1σ threshold approx. 200 µJy/beam/RMSF

   ▶ Cleaned spectrum convolved with FWHM equal to RMSF

PKS 0023–13

- Present in RM catalogue of *Taylor+ (2009)*
  - RM= +64.8 rad/m^2
  - P/I= 1.62%
- Our results:
  - RM ~ -470 rad/m^2
  - P/I ~5.1%

What causes this enhanced polarization fraction?

- On-axis leakage effects largely corrected for.
  - High-leakage (>15%) antennas flagged.
  - Remainder typically low leakage (<5%)
- Off-axis leakage?
  - Unexplored for new feeds
  - Holography for old feeds suggests <few% for source positions
  - Large χ track averages response significantly
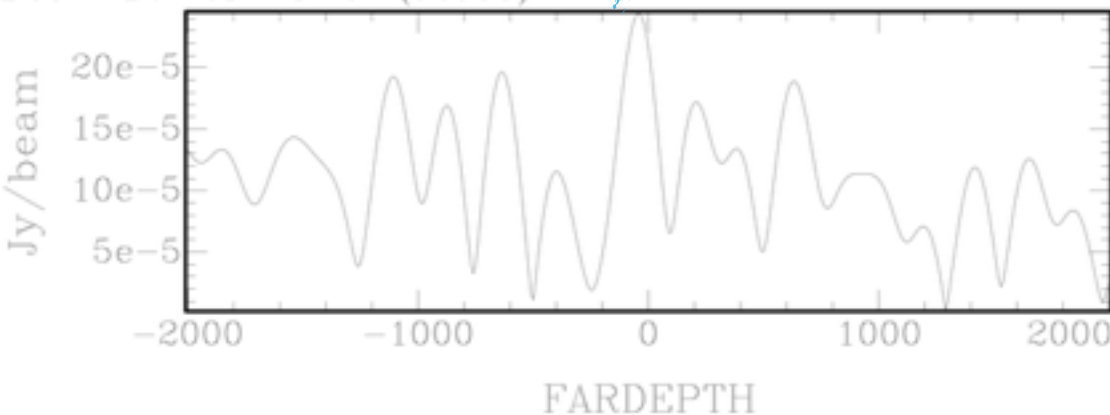- Other (non-exhaustive) potential causes:
  - Calibration? RFI?

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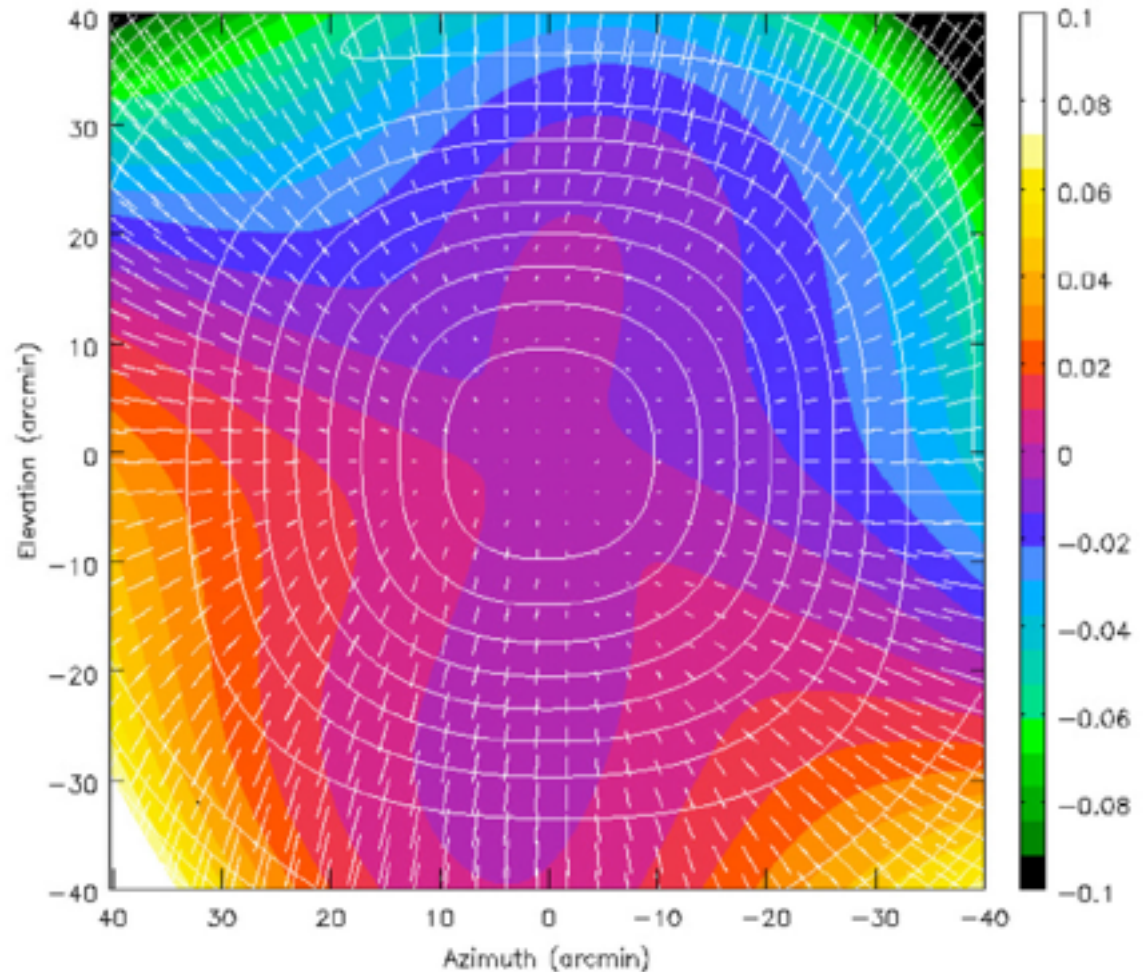
What about MACS0025?

▶ **Hints of emission? Poorly-sampled foreground?**

  ▶ Noise too high at present *BUT* only 1/6th of the data

  ▶ Still some calibration systematics to figure out

  ▶ More RFI to excise…
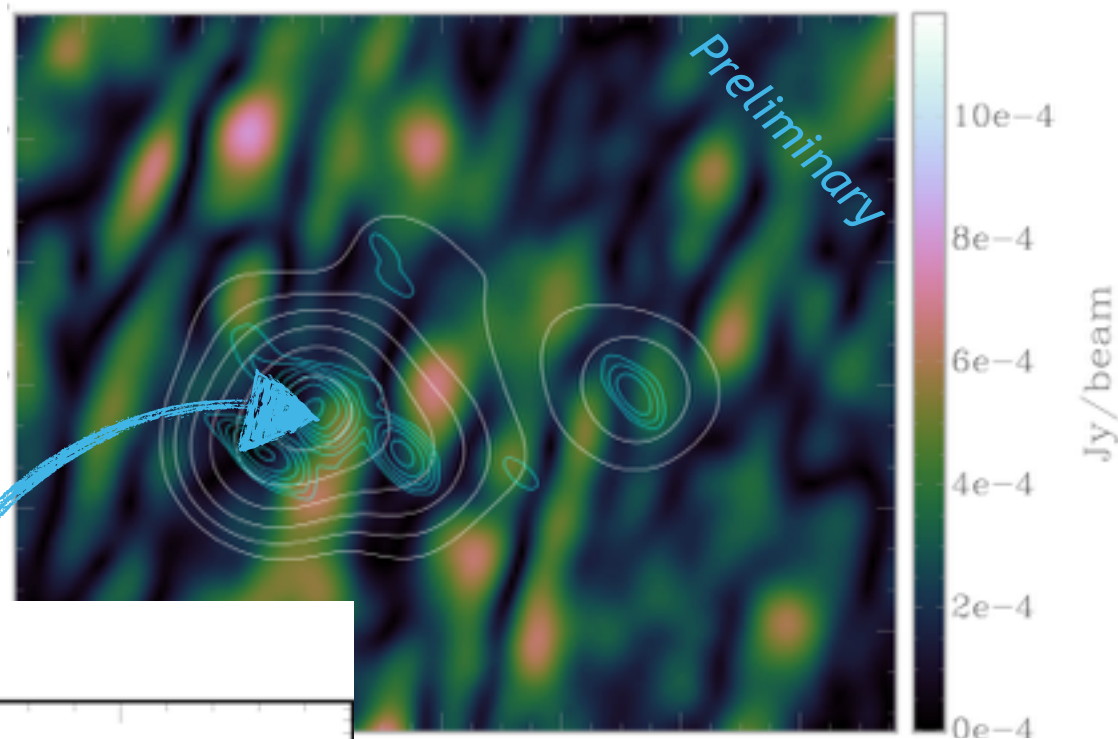
Preliminary

Ra: 00^h 25^m 32.17^s (J2000)
Dec: −12° 23' 5.76" (J2000)

Conclusions

- Polarization with the GMRT *is possible*
  - RFI is always a problem. In polarization, doubly so

- Still a few issues to work out, but preliminary results are promising
  - First polarimetry work with new feeds

- The uGMRT should deliver transformational polarization science:
  - Faraday-space resolution almost as good as LOFAR / MWA
  - Retains sensitivity to Faraday-thick emission

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Thank you for listening

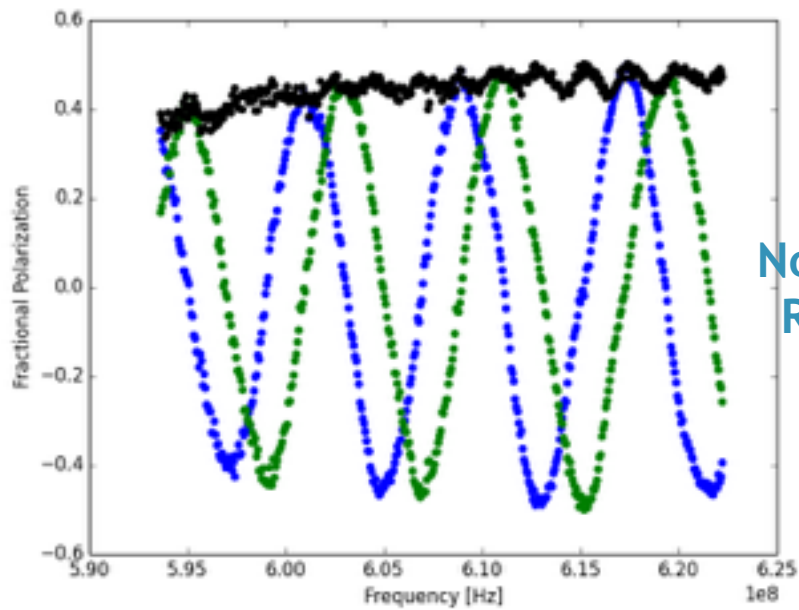**CASS/Perth**
C. J. Riseley
OCE Postdoctoral Fellow
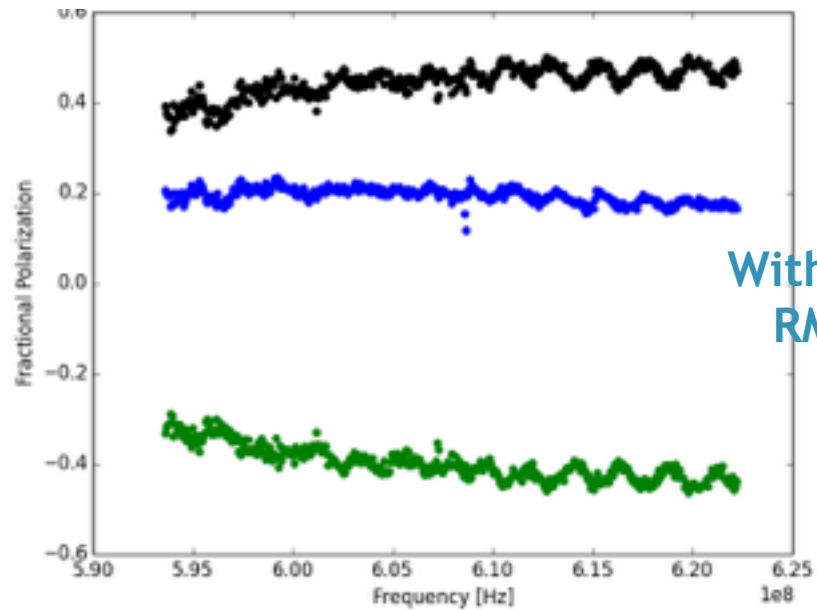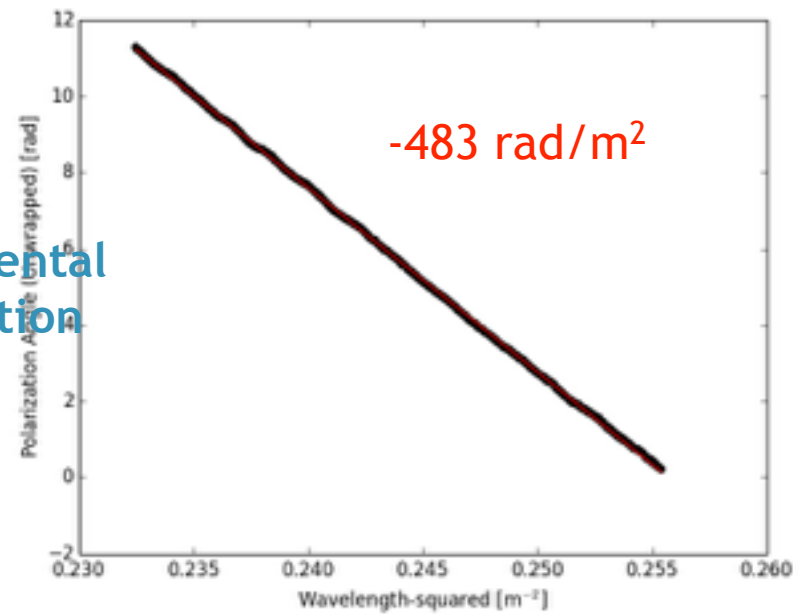*t*   +61 8 6438 8602
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No instrumental
RM correction

-483 rad/m^2

With instrumental
RM correction

+3.76 rad/m^2

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