Progress report on GMRT AW-projection

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THE PROBLEM

- Antenna PBs can be rotationally asymmetric in the parallel hand correlations.
- Alt-Az mounted antennas rotate, and these rotations cause an apparent variation of source flux density.
- Polarisation leakage beams are inherently asymmetric, systematic errors in off axis polarisation.

PRIMARY BEAM EFFECTS

- For point sources, most of the times, things are fine.
- What if the source you are looking at is extended compared to the telescope beam?
  - The instrumental beam effects that can confuse the measurement of extended polarised signals, e.g.,
    - Squint
    - Squash

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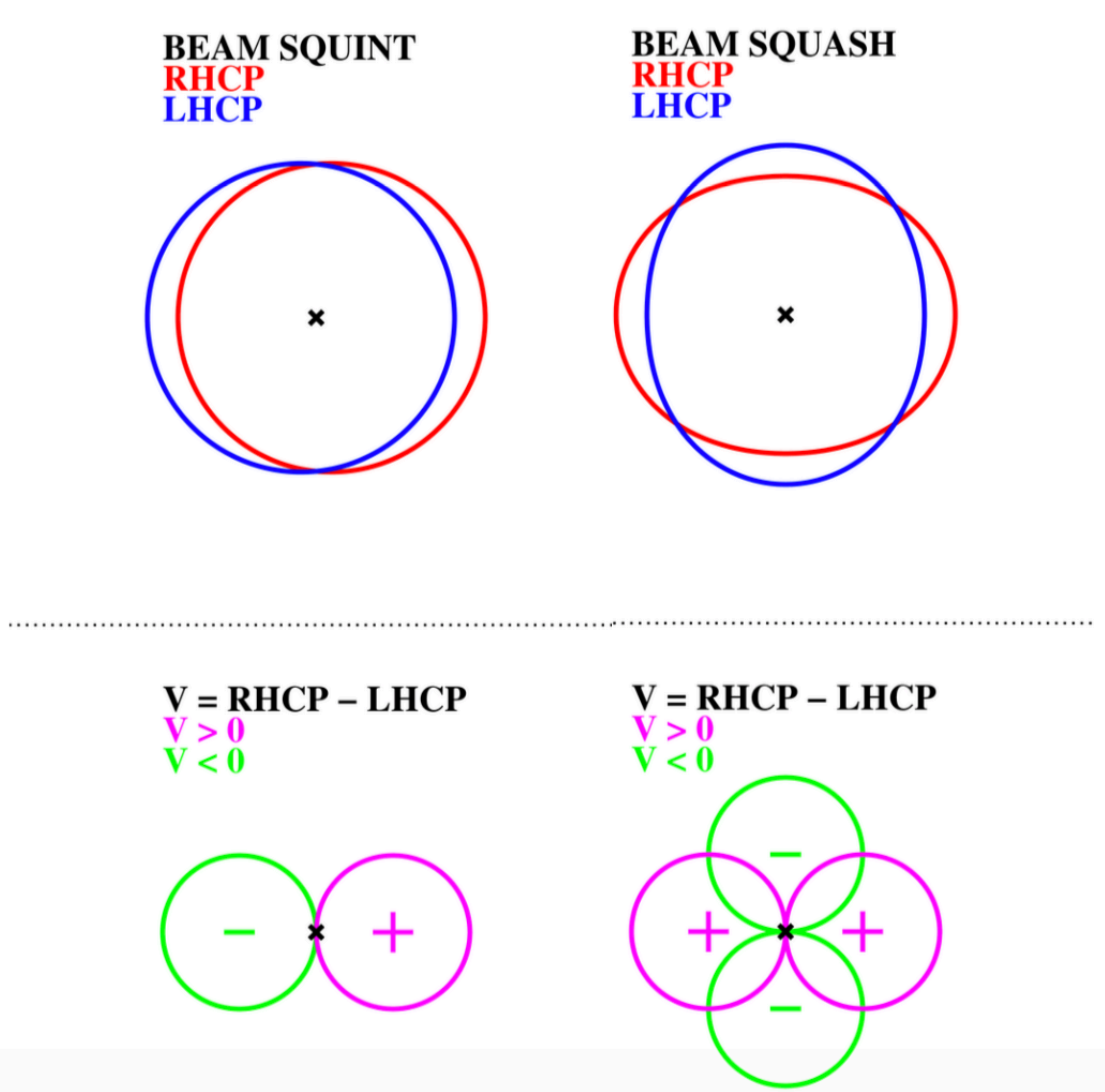

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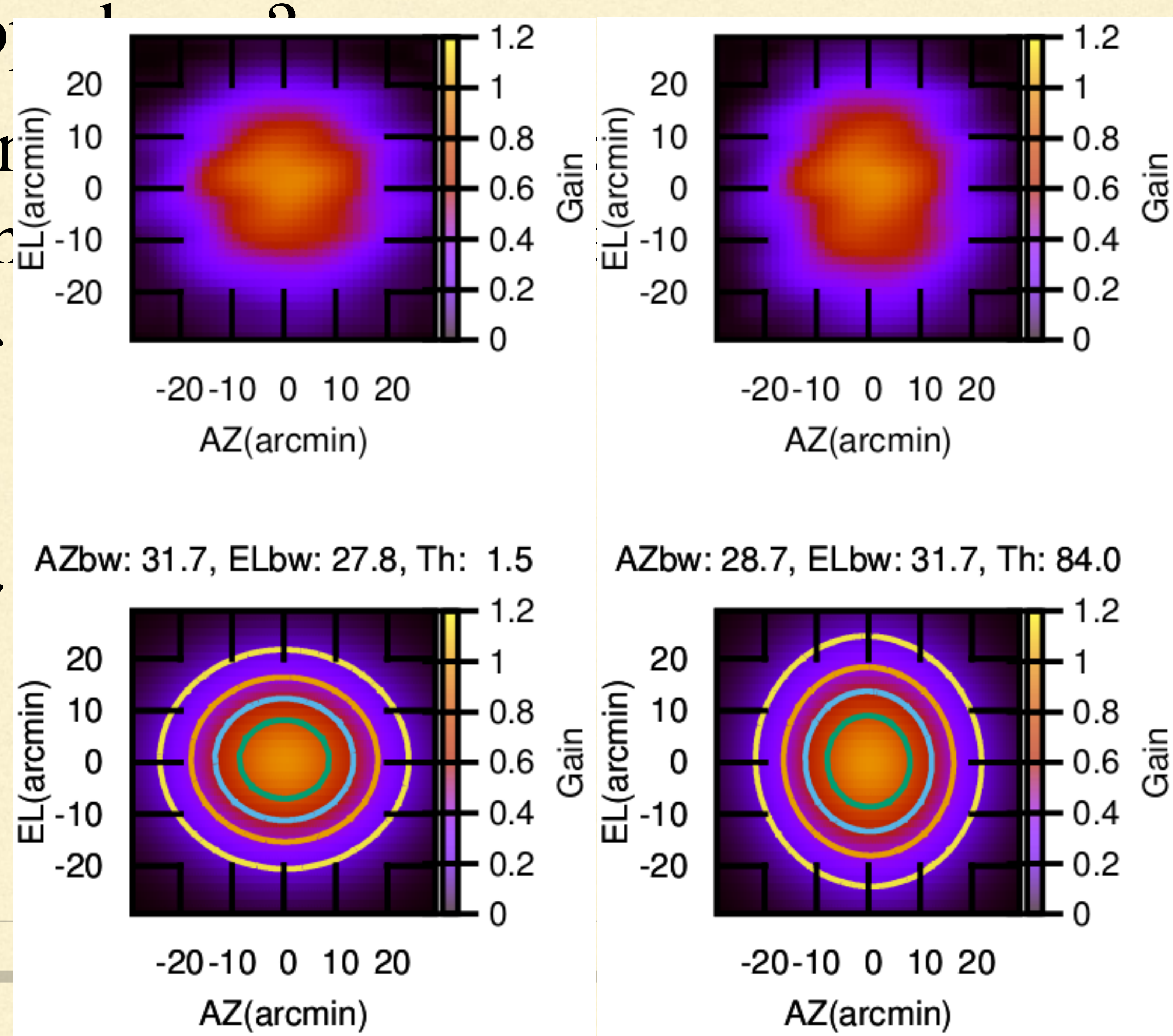


Credits: S.N. Katore (NCRA-TIFR)

STOKES PARAMETERS

- I – total intensity and sum of any two orthogonal polarisations
- Q & U – completely specify linear polarisation
- V – completely specifies circular polarisation
  - $RR = \mathscr{A}(RR)e^{i\psi RR} = I + V$
  - $LL = \mathscr{A}(LL)e^{i\psi LL} = I - V$
  - $RL = \mathscr{A}(RL)e^{i\psi RL} = Q + iU$
  - $LR = \mathscr{A}(LR)e^{i\psi LR} = Q - iU$

STOKES PARAMETERS

- I – total intensity and sum of any two orthogonal polarisations
- Q & U – completely specify linear polarisation
- V – completely specifies circular polarisation
- Stokes parameters (as percentages of I)
- Is it really that simple?
  - No, there are leakages…
    - The total intensity can leak into the polarised components (I into $\{Q,U,V\}$).

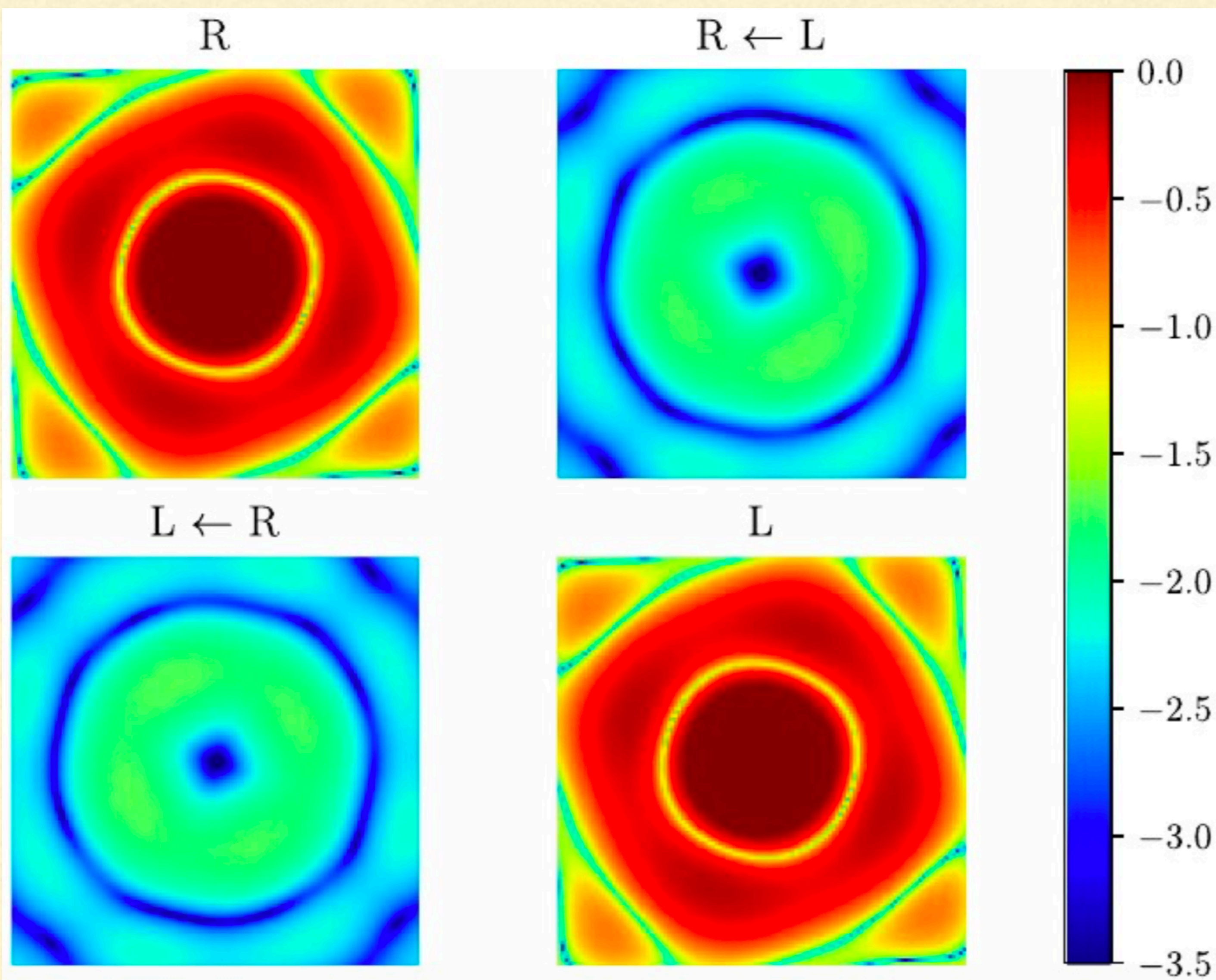
MUELLER MATRIX

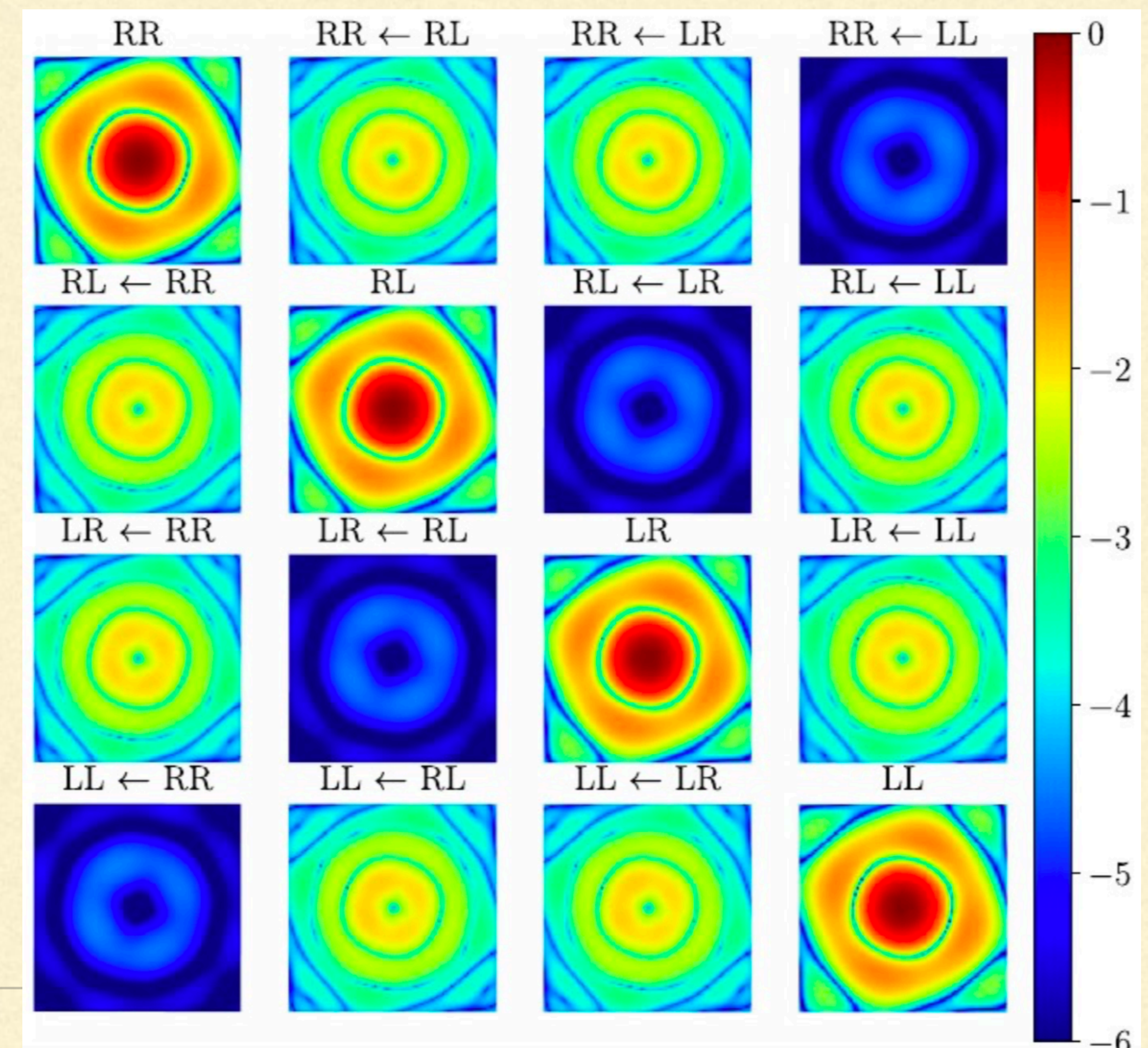
- The leakage of each polarisation into the other can be measured and quantified in a 4×4 matrix (Mueller 1943).
  - $$M = \begin{bmatrix} m_{II} & m_{IQ} & m_{IU} & m_{IV} \\ m_{QI} & m_{QQ} & m_{QU} & m_{QV} \\ m_{UI} & m_{UQ} & m_{UU} & m_{UV} \\ m_{VI} & m_{VQ} & m_{VU} & m_{VV} \end{bmatrix}$$
  - $$\begin{bmatrix} RR + LL \\ RL + LR \\ RL - LR \\ RR - LL \end{bmatrix} = \begin{bmatrix} m_{II} & m_{IQ} & m_{IU} & m_{IV} \\ m_{QI} & m_{QQ} & m_{QU} & m_{QV} \\ m_{UI} & m_{UQ} & m_{UU} & m_{UV} \\ m_{VI} & m_{VQ} & m_{VU} & m_{VV} \end{bmatrix} \cdot \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix}$$

MUELLER MATRIX

- VLA Mueller and Jones matrices
  - Obtained by Fourier Transforming the PB Holography measurements

Credits: Jagannathan et al. (2017)





MUELLER MATRIX

NCRA • TIFR

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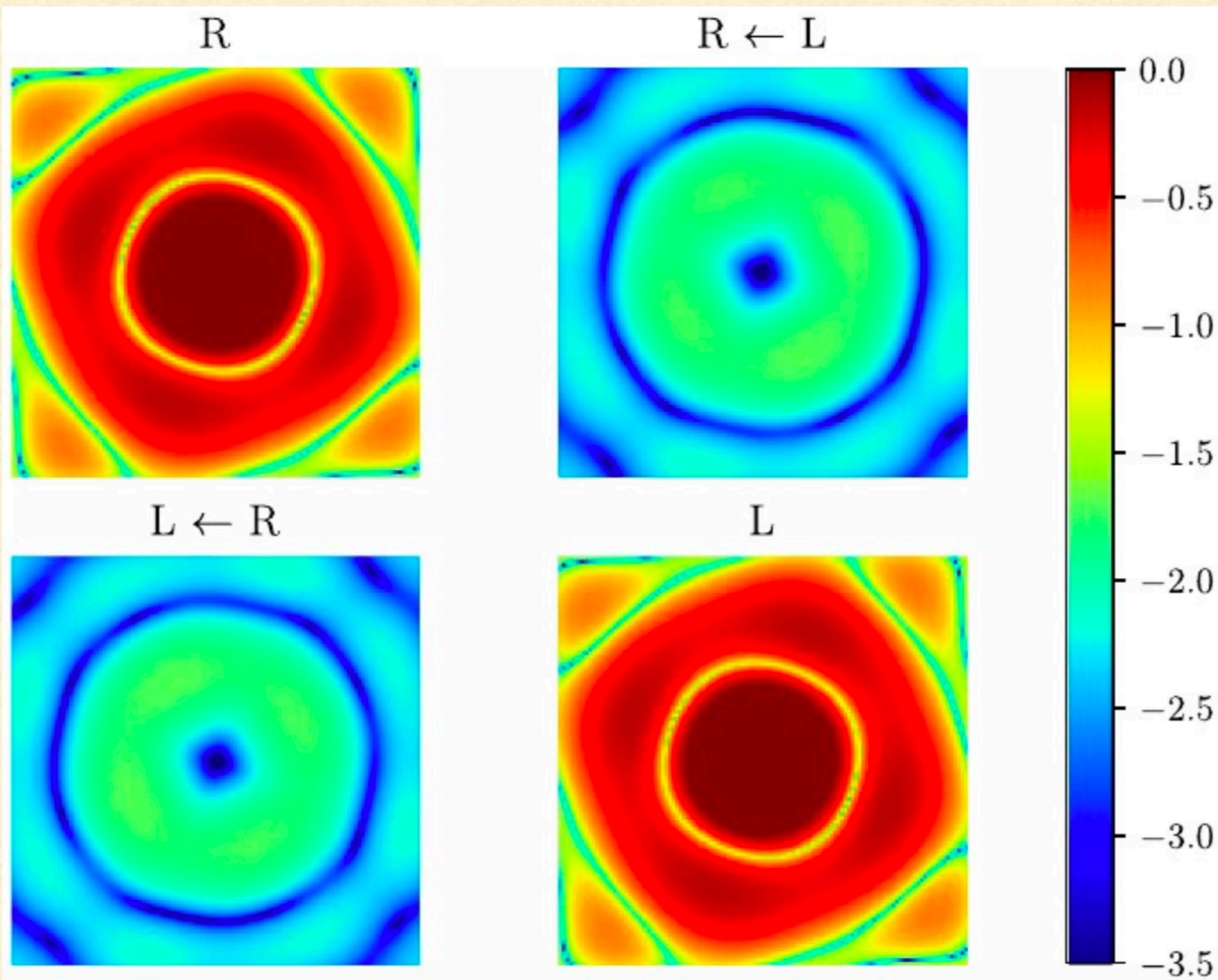
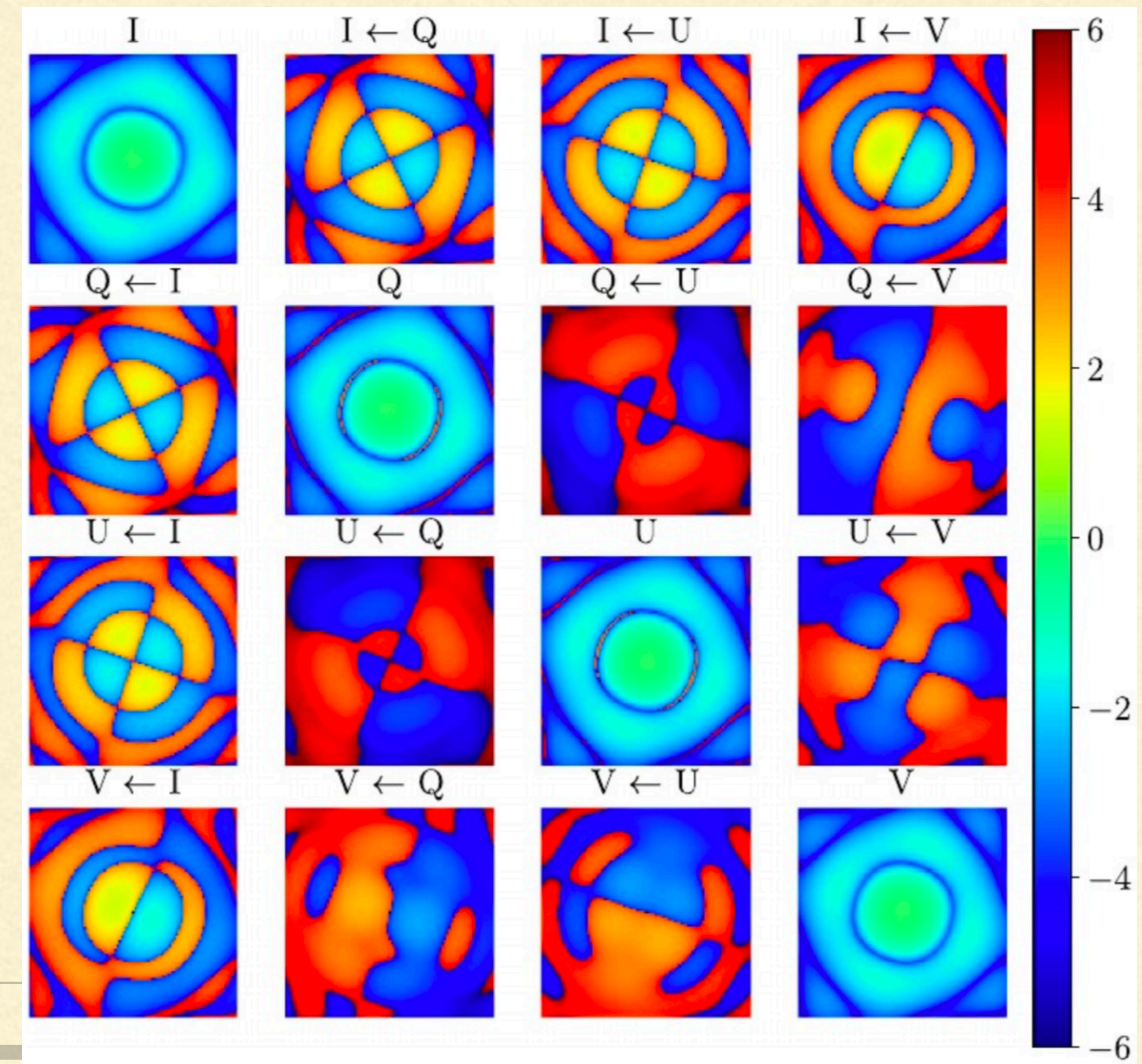
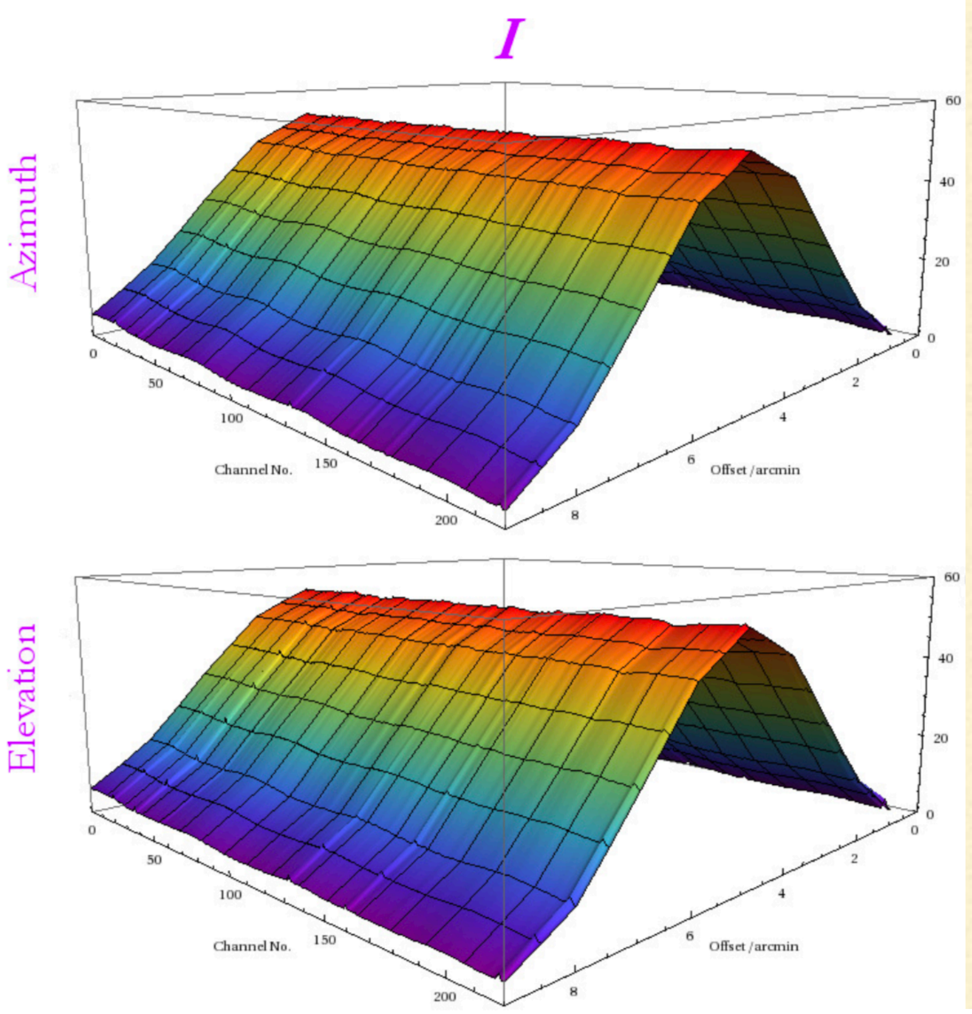




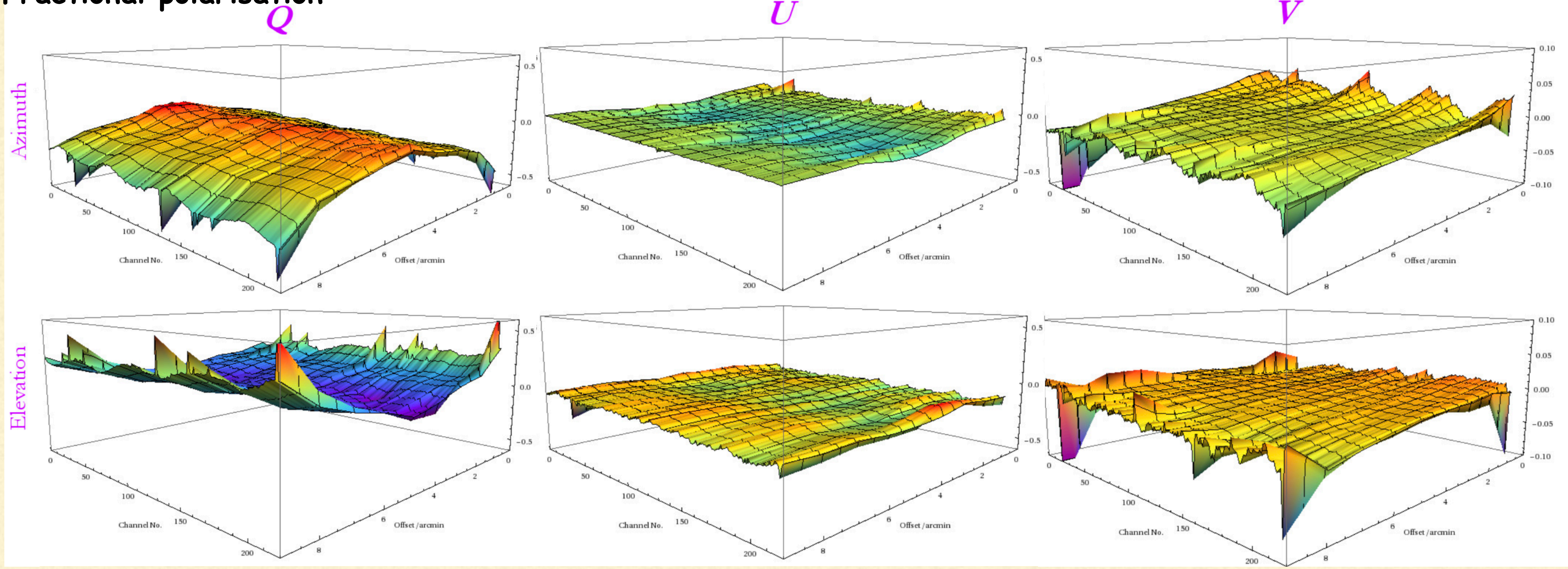
MUELLER MATRIX

- (GMRT) 325 MHz:
  - X-axis offset from phase-centre
  - Y-axis beam response
  - Z-axis channel/frequency



Farnes et al. (2012)

Fractional polarisation



MEASUREMENT EQUATION

$$\overrightarrow{V}_{ij}^{Obs}(\nu, t) = G_{ij}\ W_{ij}(\nu, t) \int P_{ij}\ M_{ij}(s, \nu, t)\ \vec{I}(s, \nu)\ e^{\imath \overrightarrow{b_{ij}}.\vec{s}}\ d\vec{s}$$

DATA
observed
visibility

DI gains

Weights

DD
&
Ionospheric
Corrections

Antenna PB
Bhatnagar+ 2008, 2013
Jagannathan+ 2019,…

MT-MFS
Rau+ 2011

non-coplanar
baselines
w-projection
Cornwell+ 2008

MEASUREMENT EQUATION

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- $= W_{ij}(\nu, t)\left[A_{ij} \star \overrightarrow{V}_{ij}\right]$

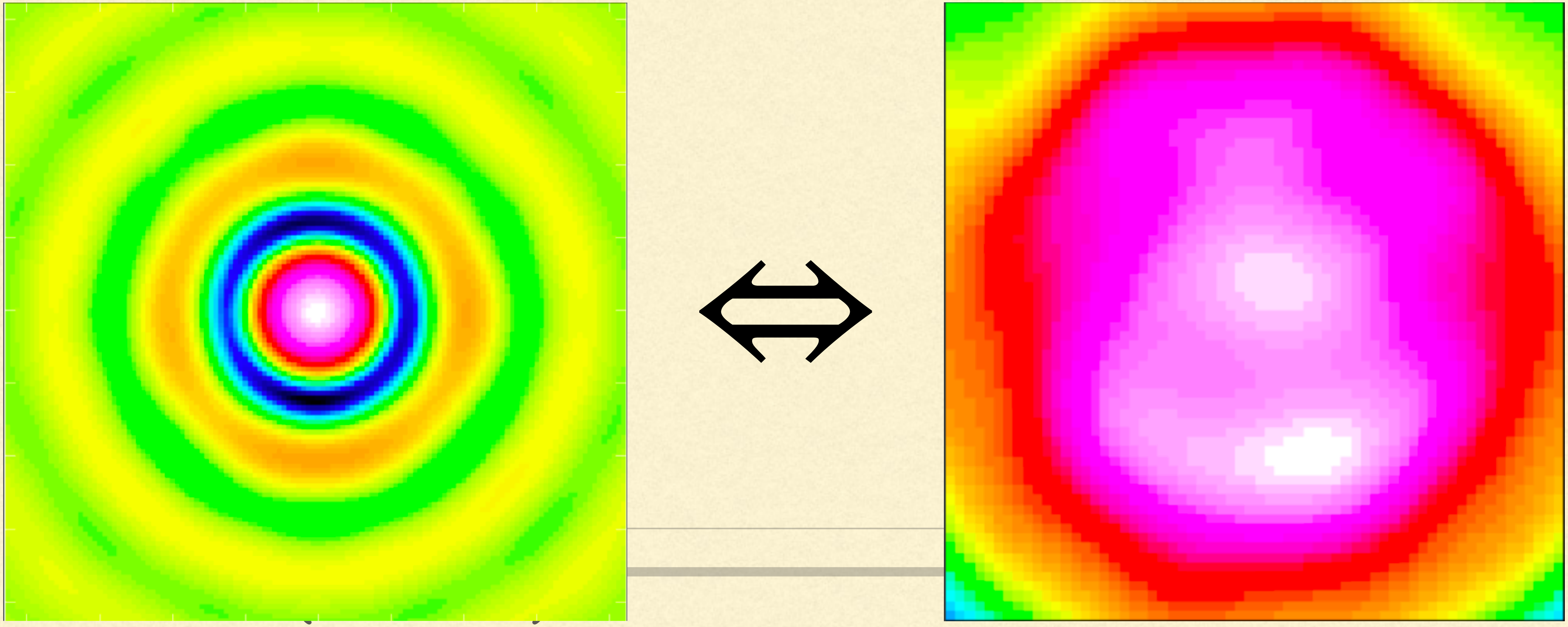
$$\text{where}, A_{ij} = A_i \otimes A_j^*$$

AIPs for two antenna

APERTURE ILLUMINATION PATTERN

- Holography data: MeerKAT
  - Obtained by Fourier Transforming the PB Holography measurements

S. Sekhar et al. (in preparation, UCT-IDIA)



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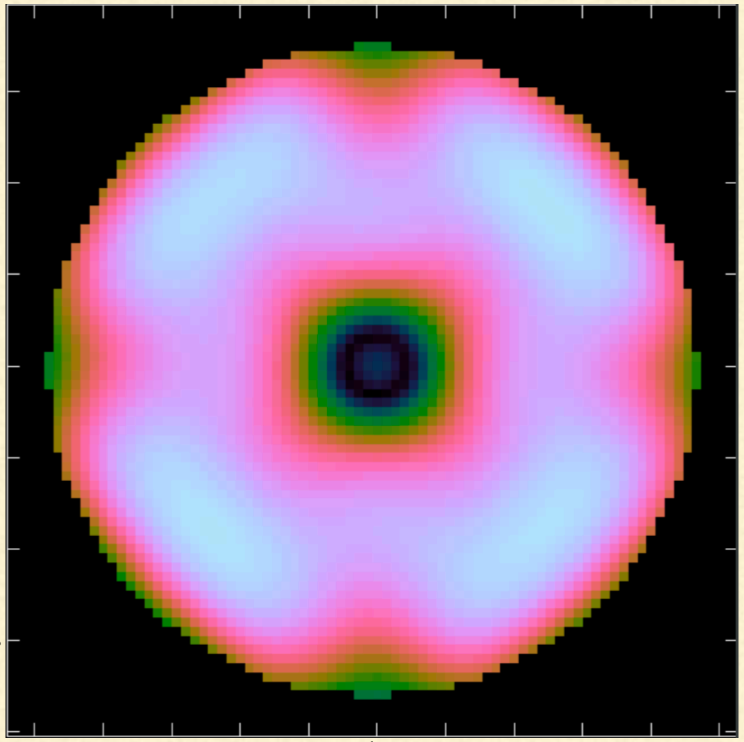
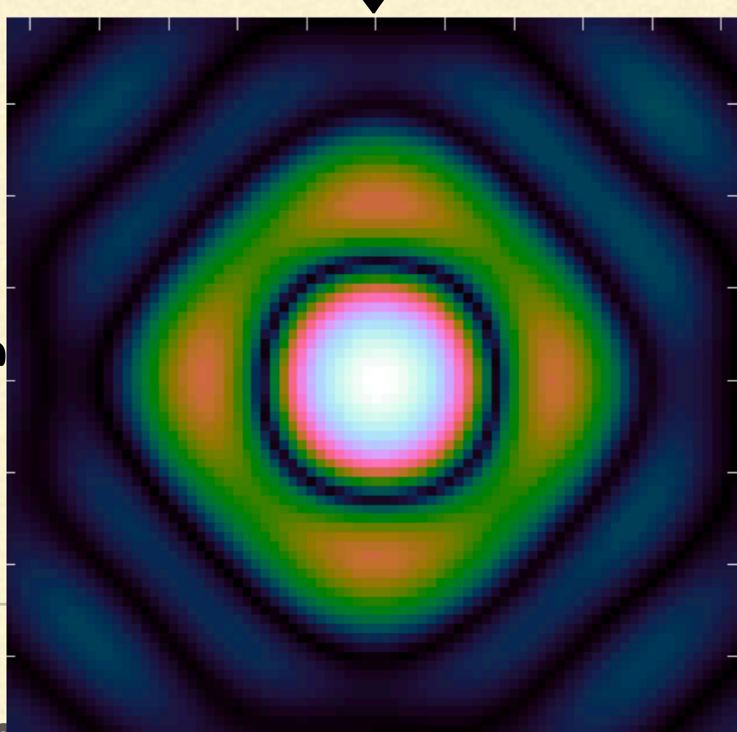
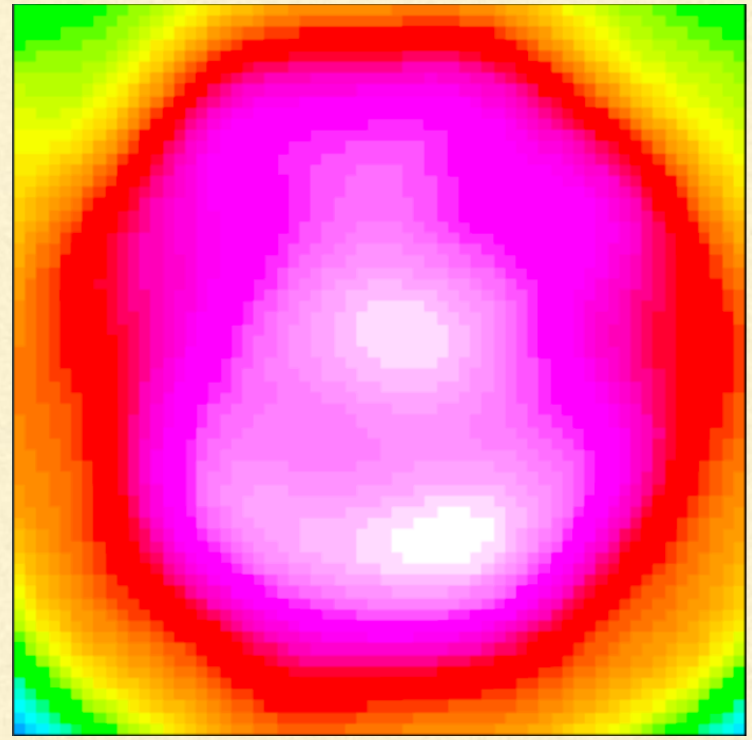
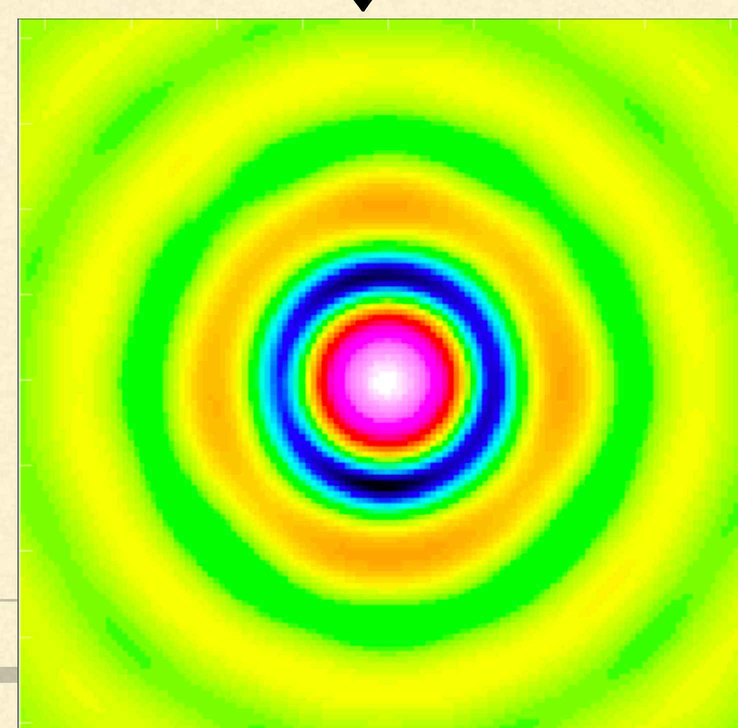




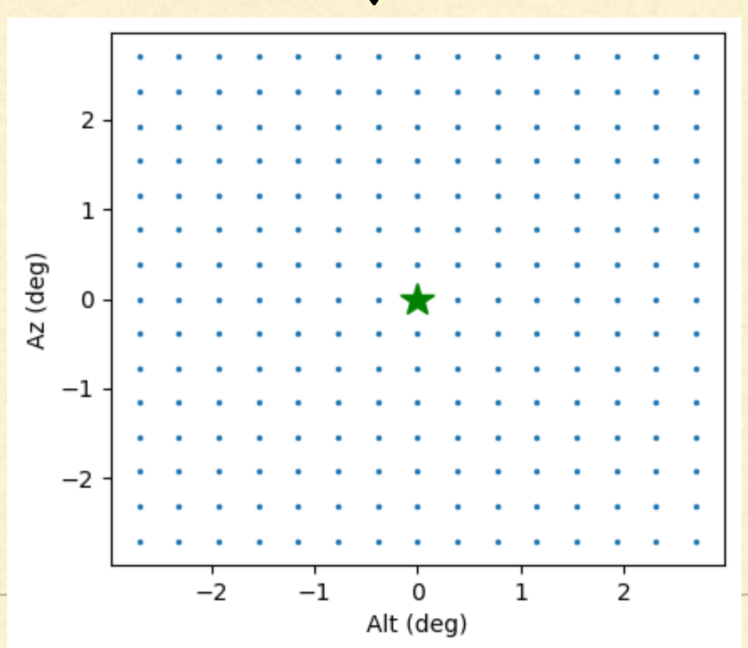
Credits: P. Jagannathan et al. (NRAO)





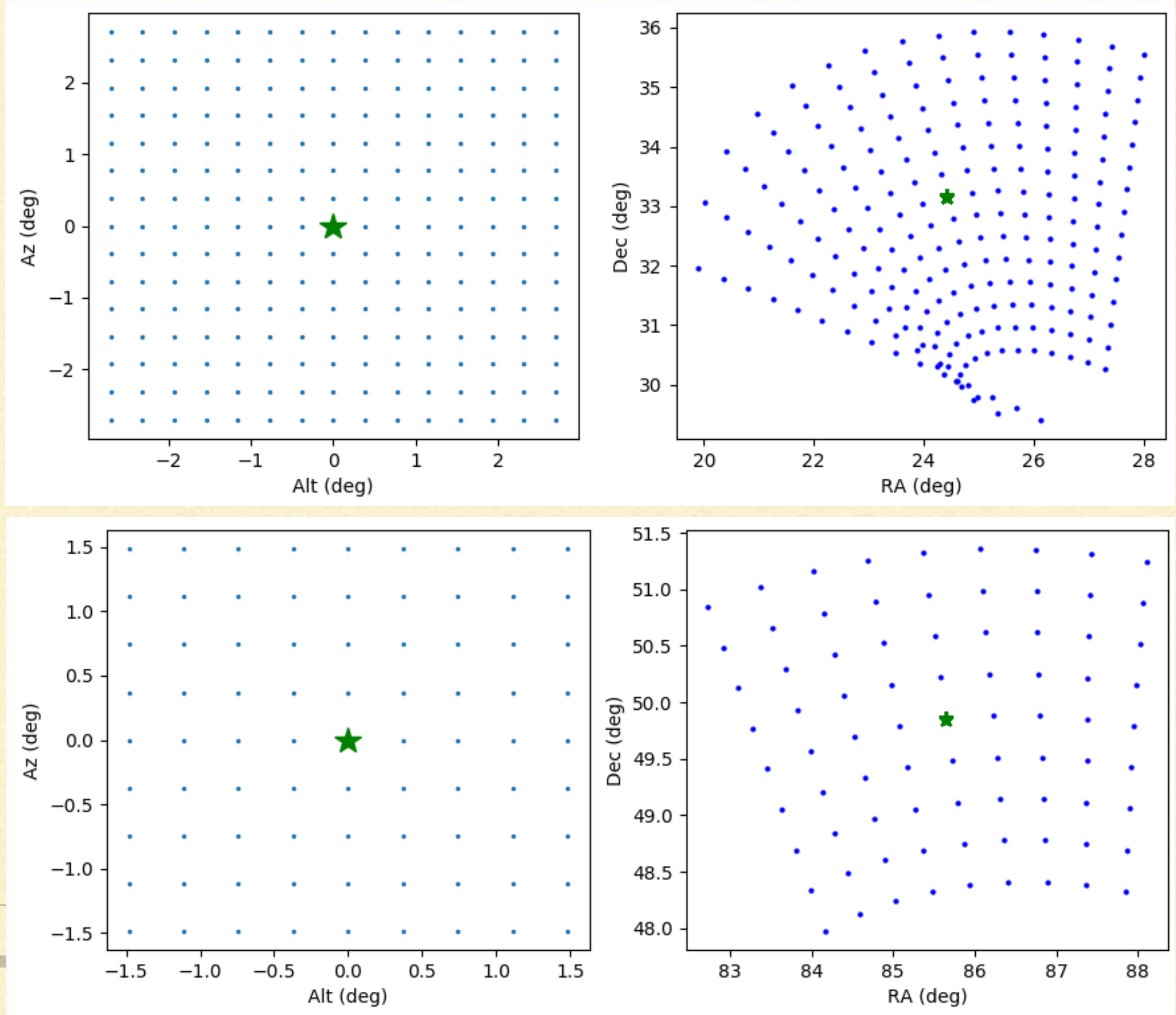
Credits: S. Sekhar et al. (UCT-IDIA)

determine



uGMRT DATA

- Holography data
  - scans/data as a function of time



UNDERSTANDING DATA

- Holography data
  - scans/data as a function of time
- construct (Stokes) image/beam
- Understanding the polarisation properties of the GMRT dish is fundamental …
- need for
  - “accurate aperture model”
  - casa implementation

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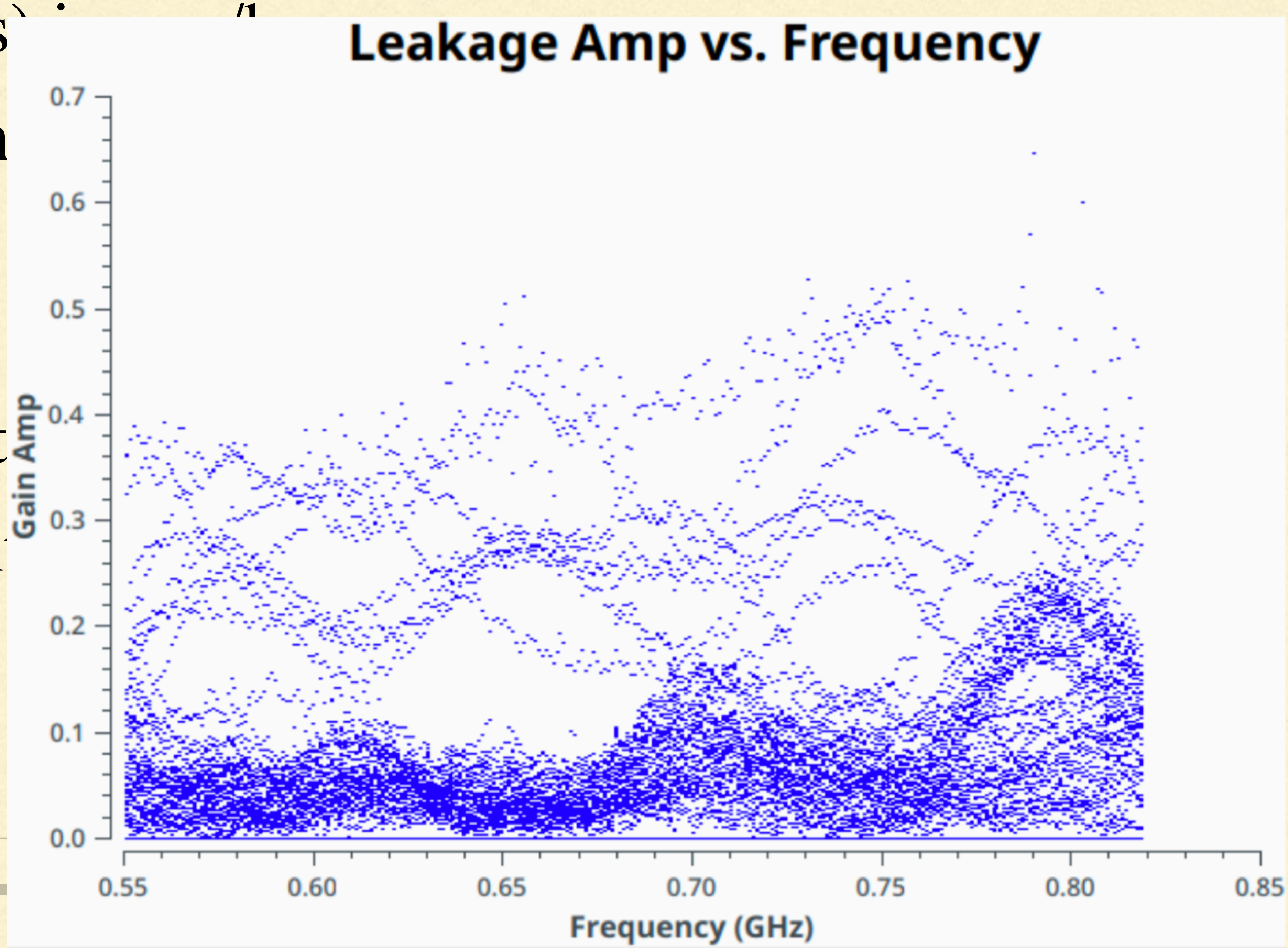

uGMRT DATA (BAND-4, 648 MHz)

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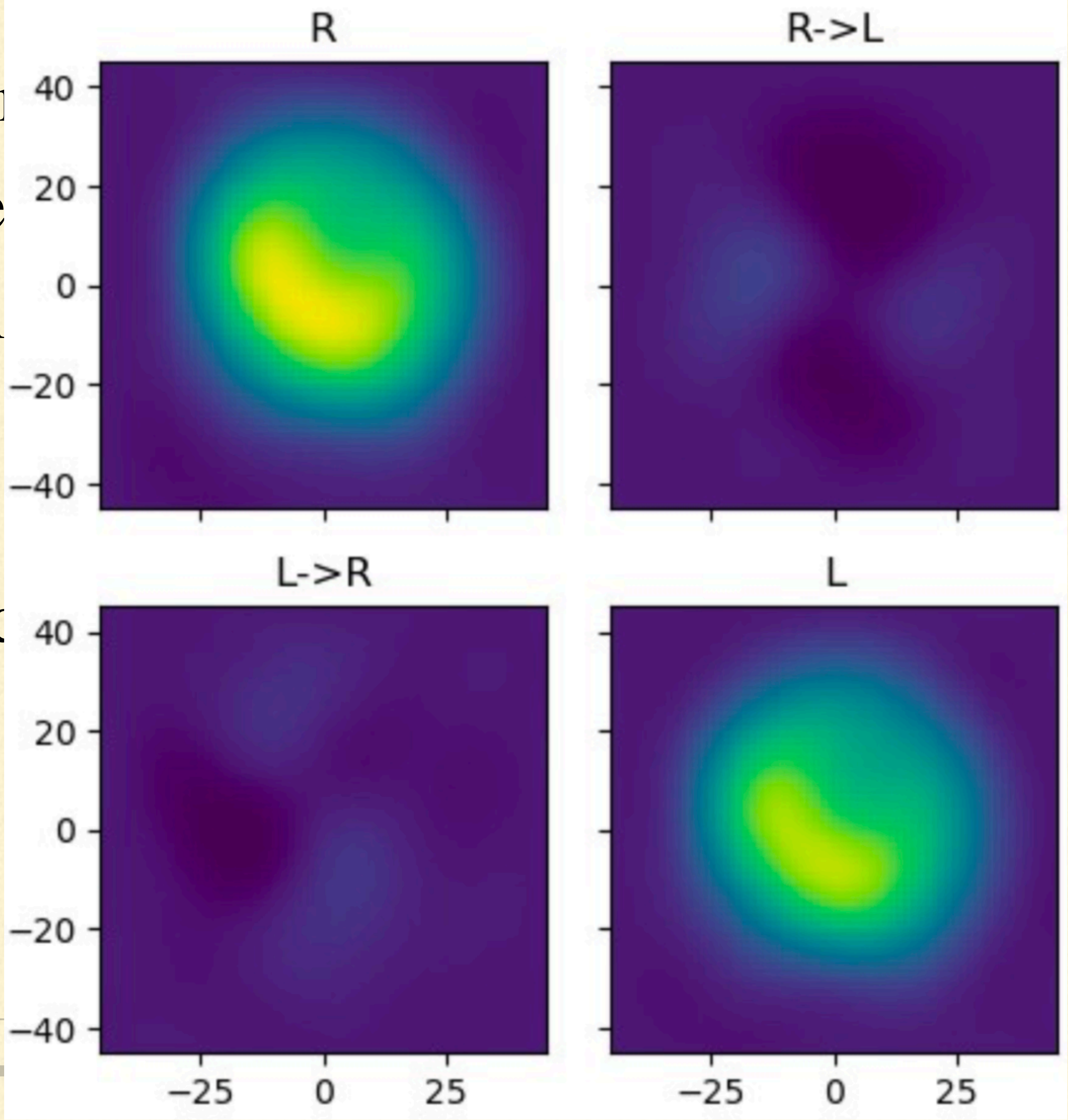
- construct (Stokes) image
- Understanding the polari is fundamental …
- need for
  - “accurate aperture moc
  - casa implementation
  - PB Jones matrices!



PUTTING THIS ALL TOGETHER

- In the end what we are trying to do is relate products from our correlator to the intrinsic polarised radiation from the source.
- So, we are correcting the raw correlator outputs for
  - imperfections in the receiver (leakages).
    - The orientation of the receiver with respect to the telescope structure.
    - The changing parallactic angle.
  - Any measured propagation related polarisation effects (e.g. Faraday rotation).