A-to-Z Solver : Modeling the antenna aperture illumination function

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Outline

(1) What is the problem?

- Antenna primary beams are frequency dependent and rotationally asymmetric

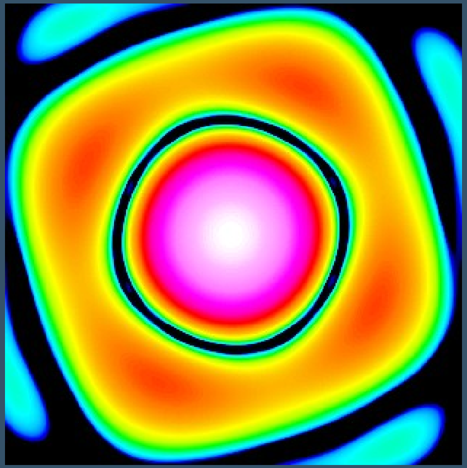
(2) How have we solved it?

- Model the antenna aperture illumination pattern
- Implement in existing AW projection algorithm

Antenna primary beams

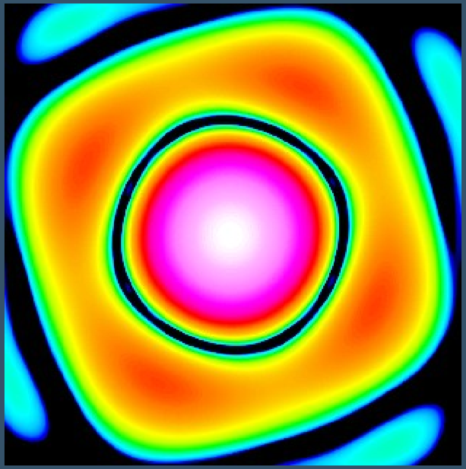
- Determines the gain as a function of frequency, polarization and direction in the sky
- In optics terms : The far field diffraction pattern
- Fourier transform of the aperture illumination pattern (AIP)

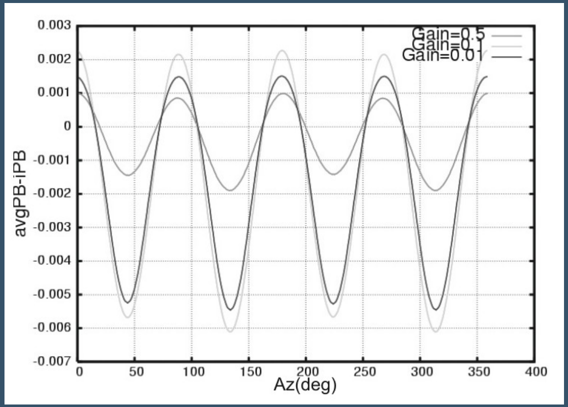
Right: EVLA S Band Stokes I PB at ~ 3 GHz



The problem

- The antenna primary beam is rotationally asymmetric (typically)
- Therefore off-axis sources will show time-dependent behaviour



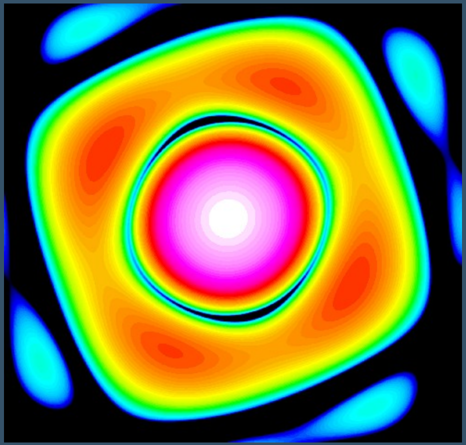


Bhatnagar et al., 2008

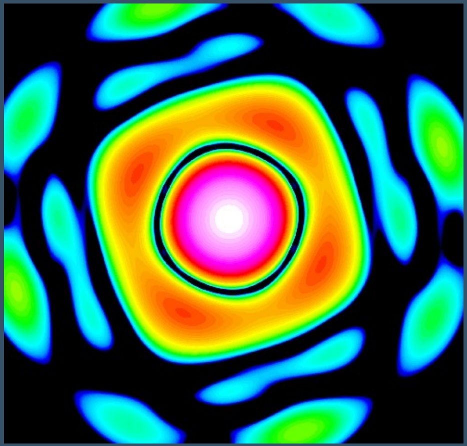
The problem

- Antenna primary beam also frequency dependent
  - A source in the main lobe at 2 GHz could end up in the first sidelobe at 4 GHz. Fractional bandwidth is 100% (2 GHz – 4 GHz)

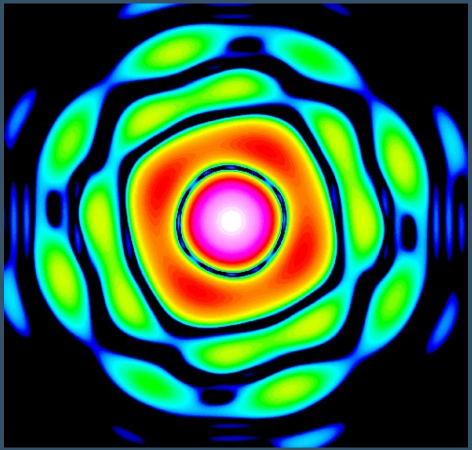
2 GHz



3 GHz



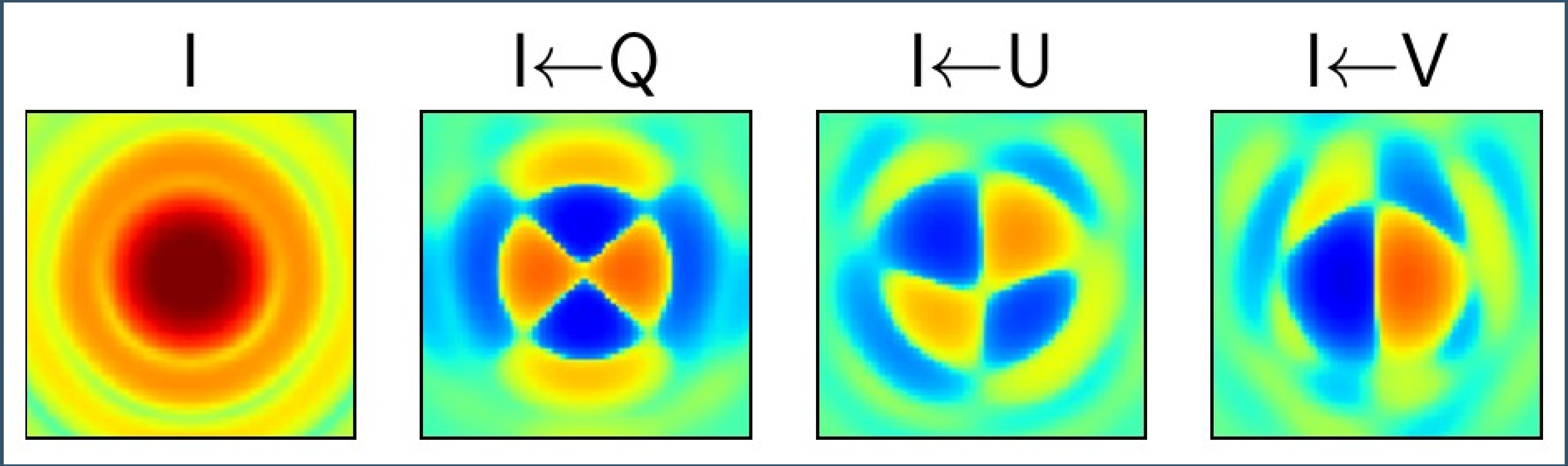
4 GHz



The problem

- Widefield polarization requires modeling leakages

MeerKAT Stokes leakage beams



AW Projection

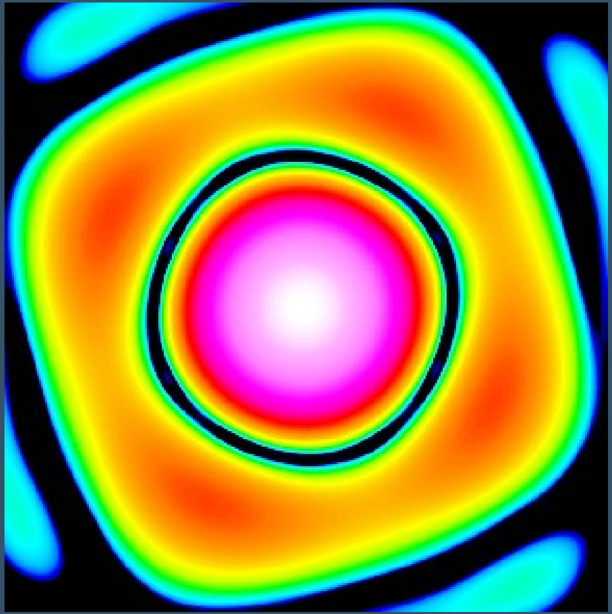
- During imaging, use a gridding kernel that “knows” about the antenna aperture (A term) and widefield effects (W term) (Bhatnagar et al., 2008; Bhatnagar et al., 2013)
- In principle, this can correct for rotational asymmetries, frequency dependence in all Stokes (full Mueller)

AW Projection

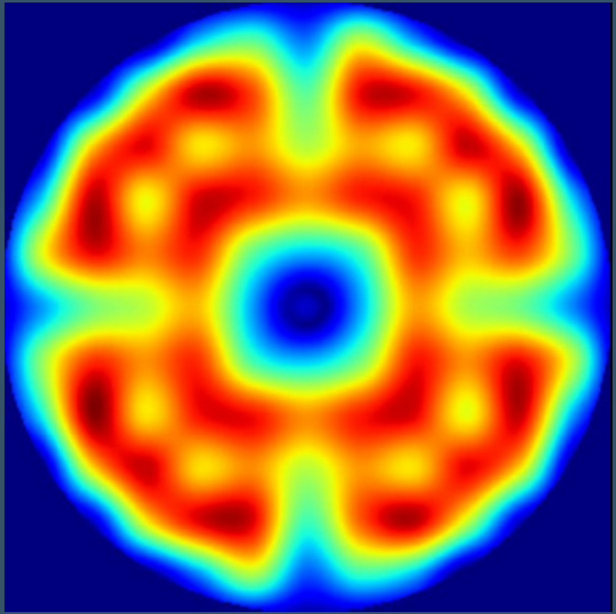
… requires an accurate aperture model

Current implementation : ray traced model (Jagannathan et al., 2017)

Aperture Illumination Patterns



FT



A-to-Z Solver

- Use Zernike polynomials to model the complex aperture
- Why aperture? -
  - Natural domain to model optical effects that cause PB weirdness
  - Aperture size is fixed – specified by the geometry of the antenna.
- Telescope agnostic – only requires antenna holography

Zernike Polynomials

- Orthogonal on a unit circle
- Developed to model optical apertures
- Does not require tuning to model full Stokes features

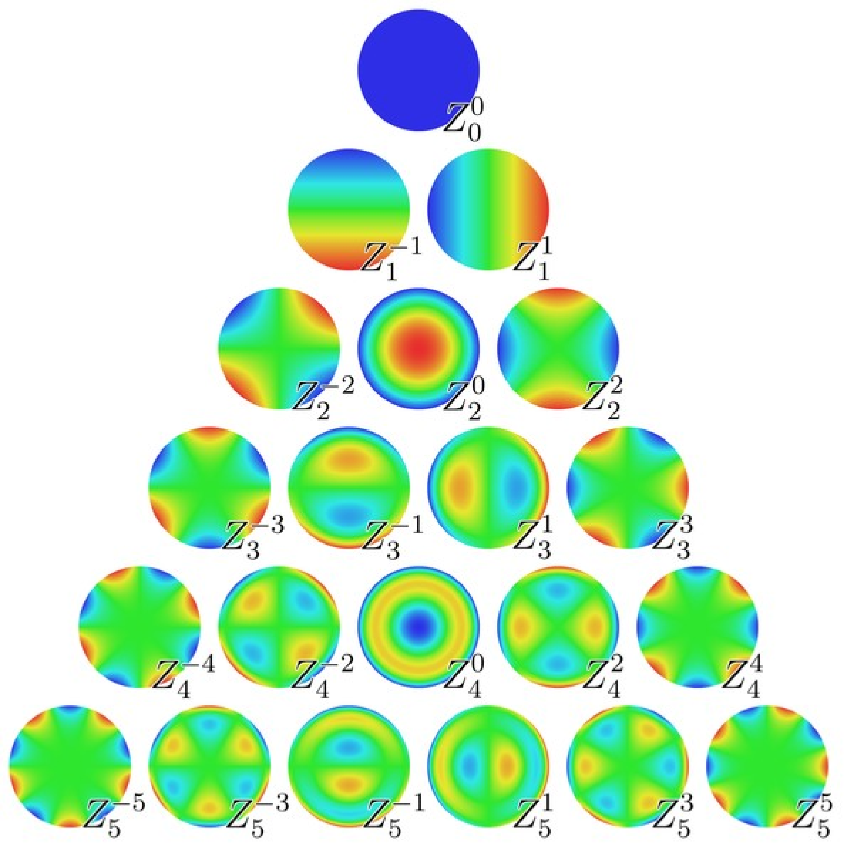
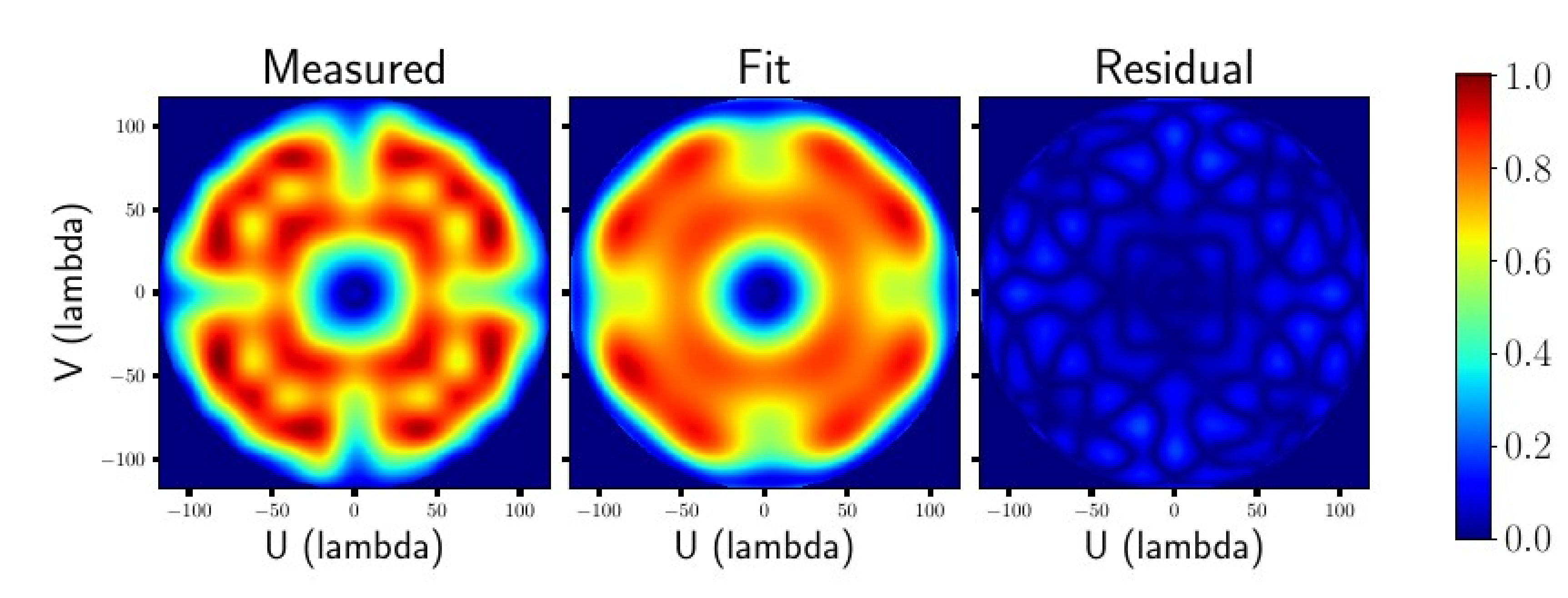


Image courtesy Wikimedia Commons

A-to-Z Solver

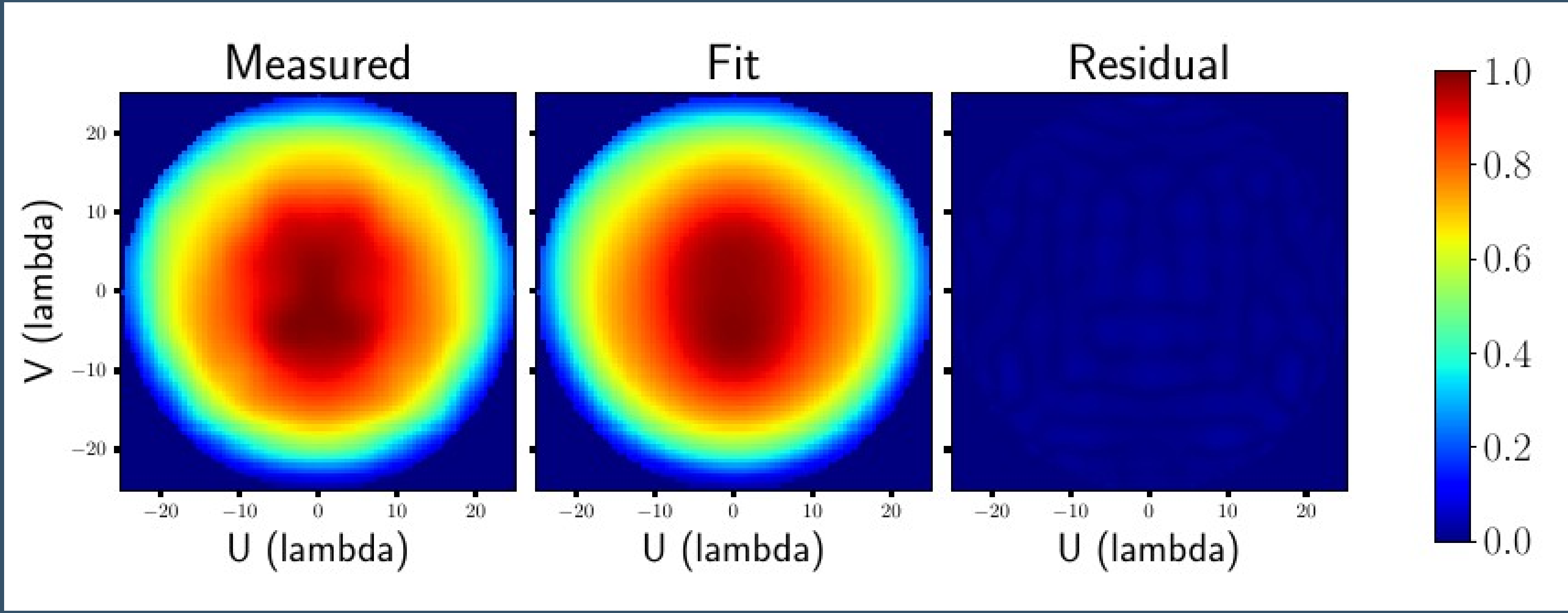
- Successfully modeled PBs for EVLA, MeerKAT, ALMA
- Implemented in AW project framework
- Currently evaluating imaging performance

EVLA



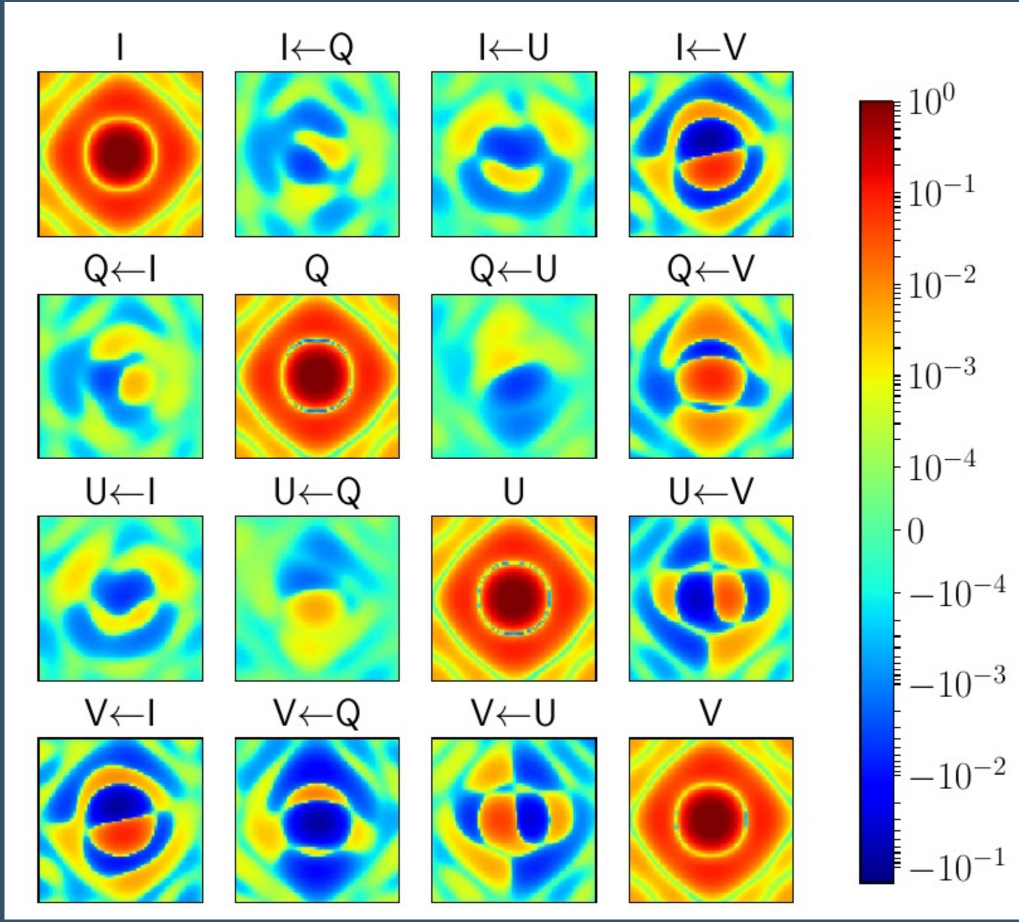
Measured
Fit
Residual
V (lambda)
U (lambda)
U (lambda)
U (lambda)
100
50
0
−50
−100
−100
−50
0
50
100
1.0
0.8
0.6
0.4
0.2
0.0

MeerKAT

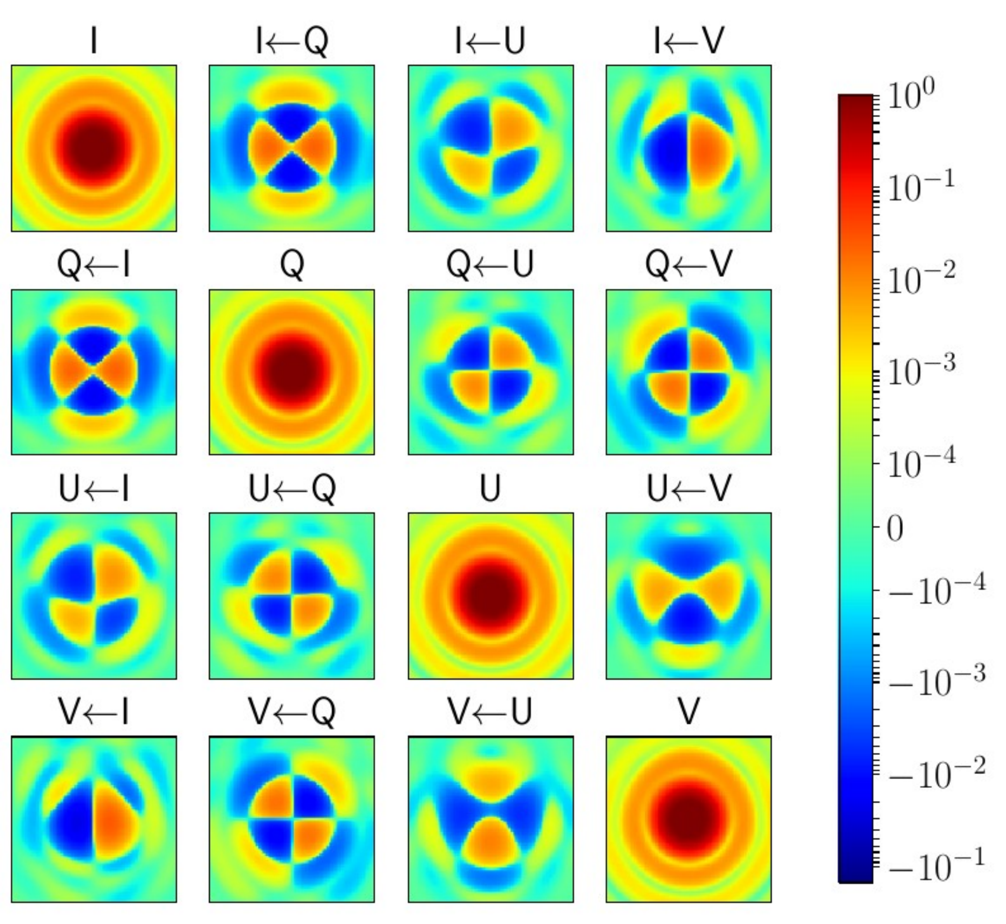


Measured
Fit
Residual
V (lambda)
U (lambda)
U (lambda)
U (lambda)
20
10
0
−10
−20
−20
−10
0
10
20
1.0
0.8
0.6
0.4
0.2
0.0

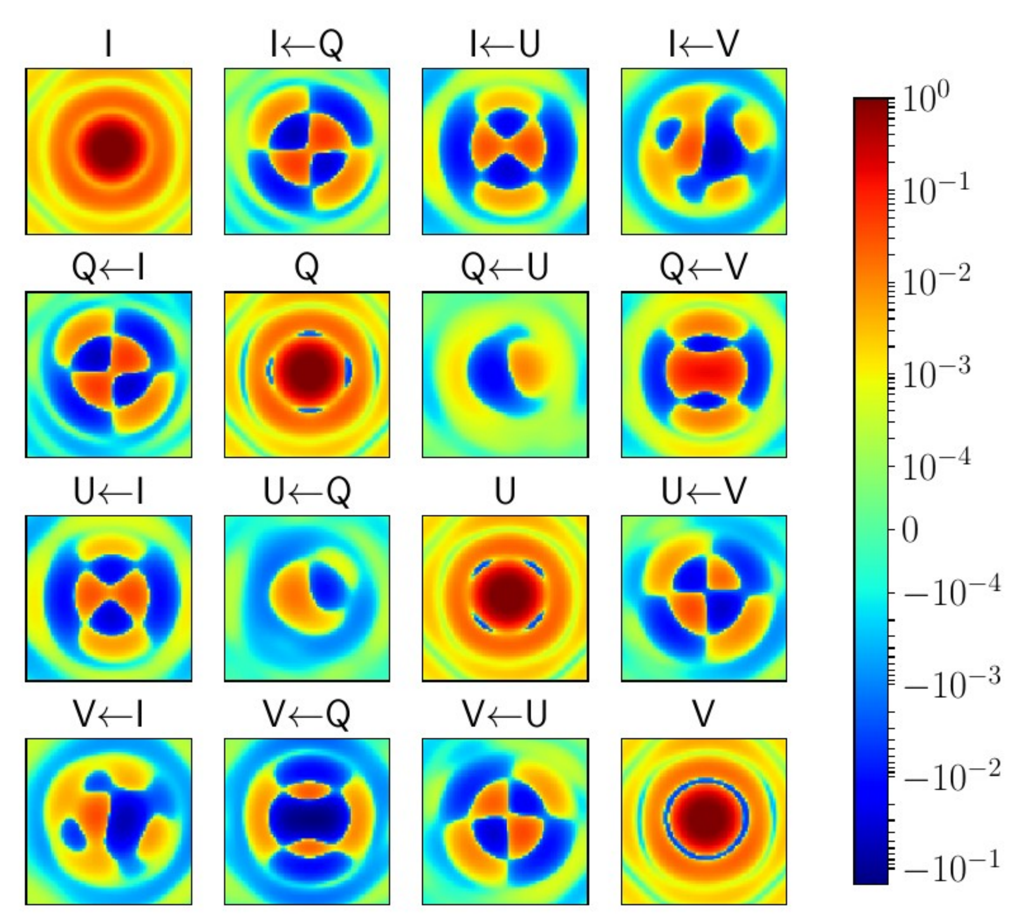
EVLA – Full Mueller model



MeerKAT – Full Mueller model



ALMA DV – Full Mueller Model



Summary

- New algorithm to model the aperture illumination pattern → full Stokes PB
- Works well for different telescopes, frequency bands
- Currently in R&D, will be in CASA in the future.