

Wide Field Instrumental Polarization and its Correction

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- Outline:

- Instrumental polarization
 - Beam measurements on EVLA antennas
 - Full field polarization correction
 - Limitations of correction
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Instrumental polarization

- Reflections of radio signals are generally polarizing
 - Antenna design minimizes polarization using symmetries to cancel net polarization
 - Cancellation only possible one location in beam
 - Feed and electronics introduce additional instrumental polarization.
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Instrumental polarization, cont'd

- Instrumental polarization adds spurious polarization to source response.
 - Accurate removal of instrumental polarization critical to determine intrinsic source polarization and rotation measure.
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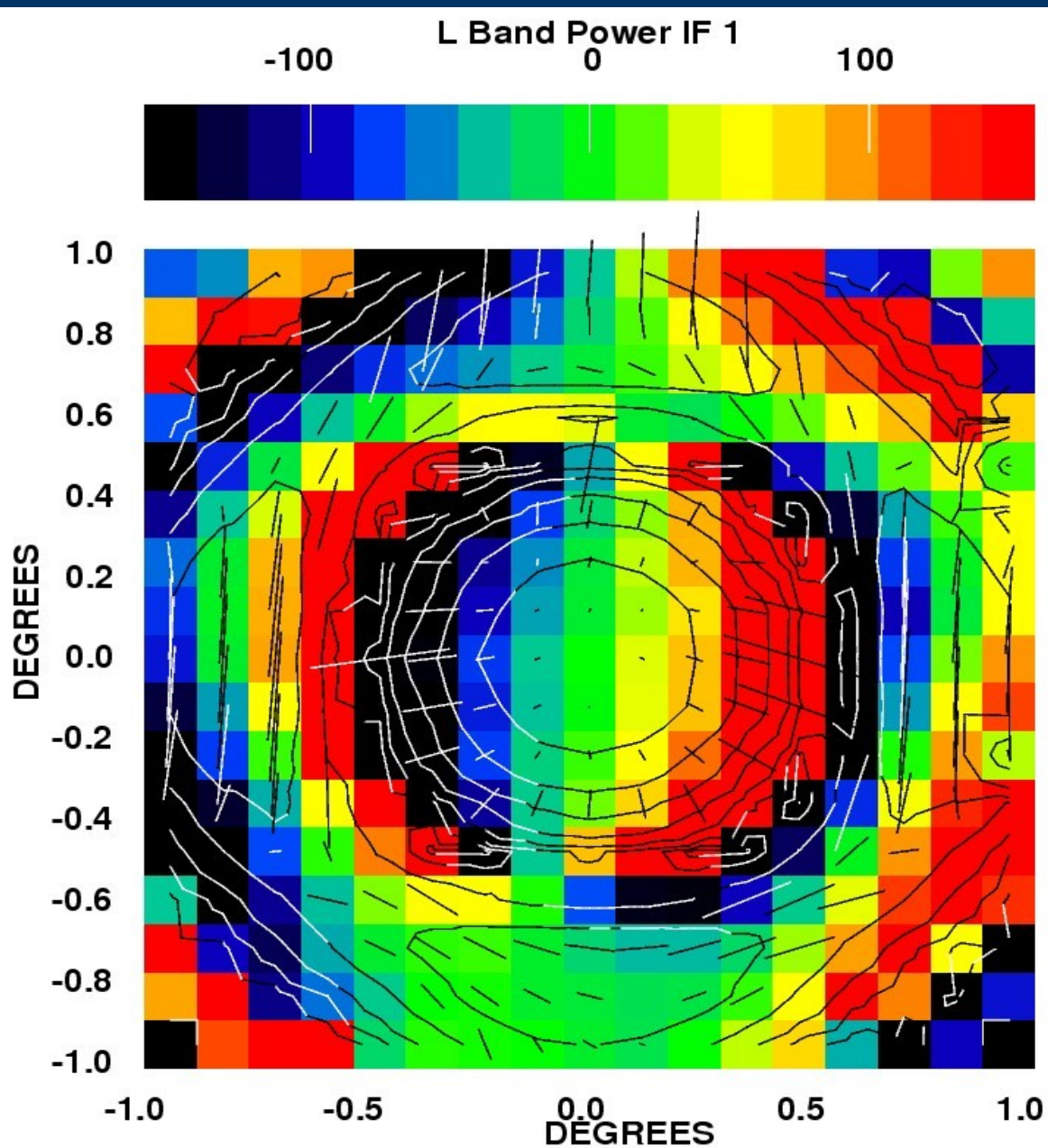
Instrumental polarization, cont'd

- Traditional calibration corrects on-axis instrumental polarization.
 - Off-axis instrumental polarization tends to cancel with varying parallactic angle and has been ignored.
 - Deep, wide area surveys of RM will need off-axis corrections.
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EVLA Beam Measurements

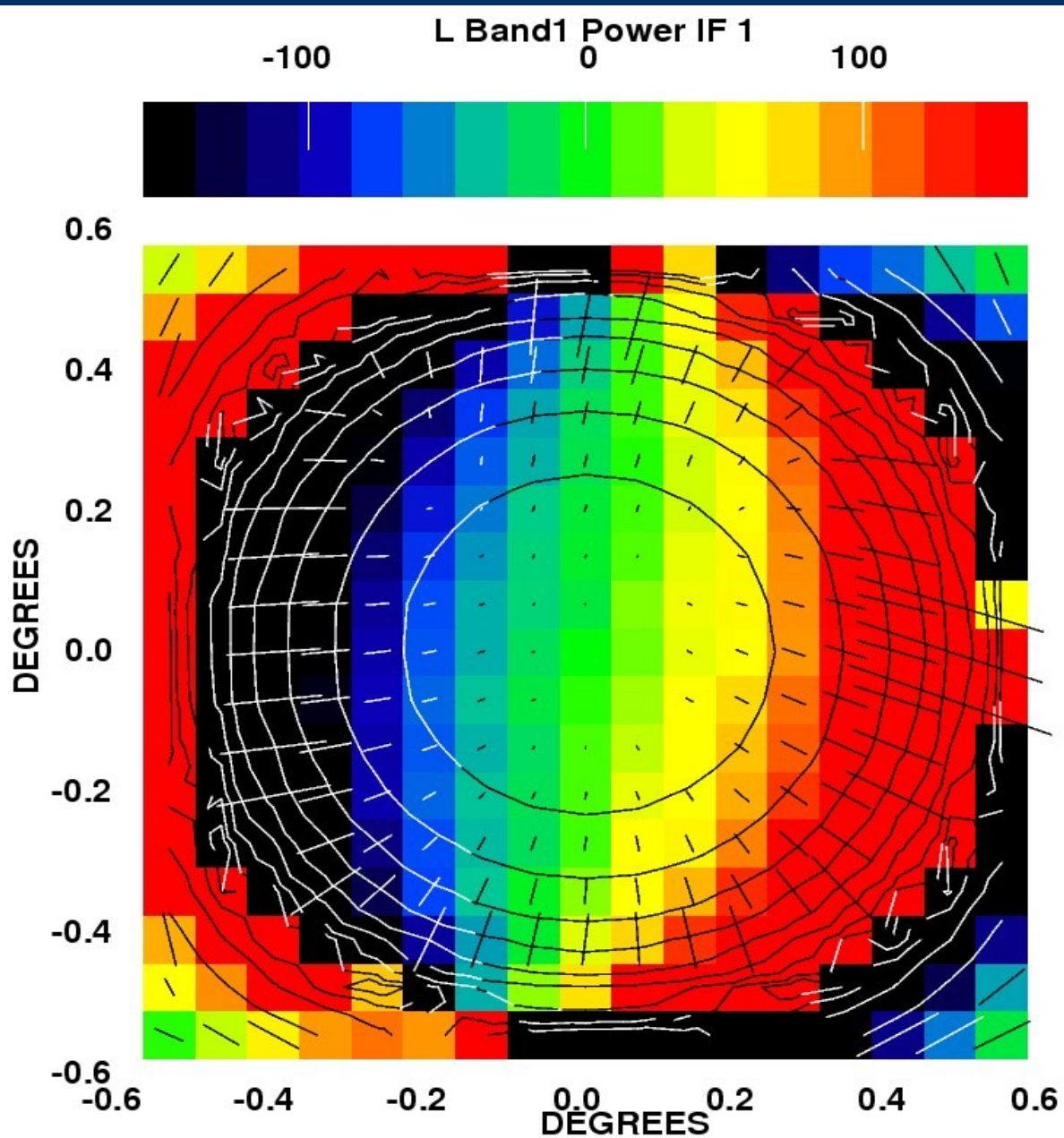
- As part of EVLA commissioning the beam patterns were measured in Stokes I, Q, U, V at a range of frequencies.
- Used VLA (narrow band) correlator

EVLA Beam at 20 cm



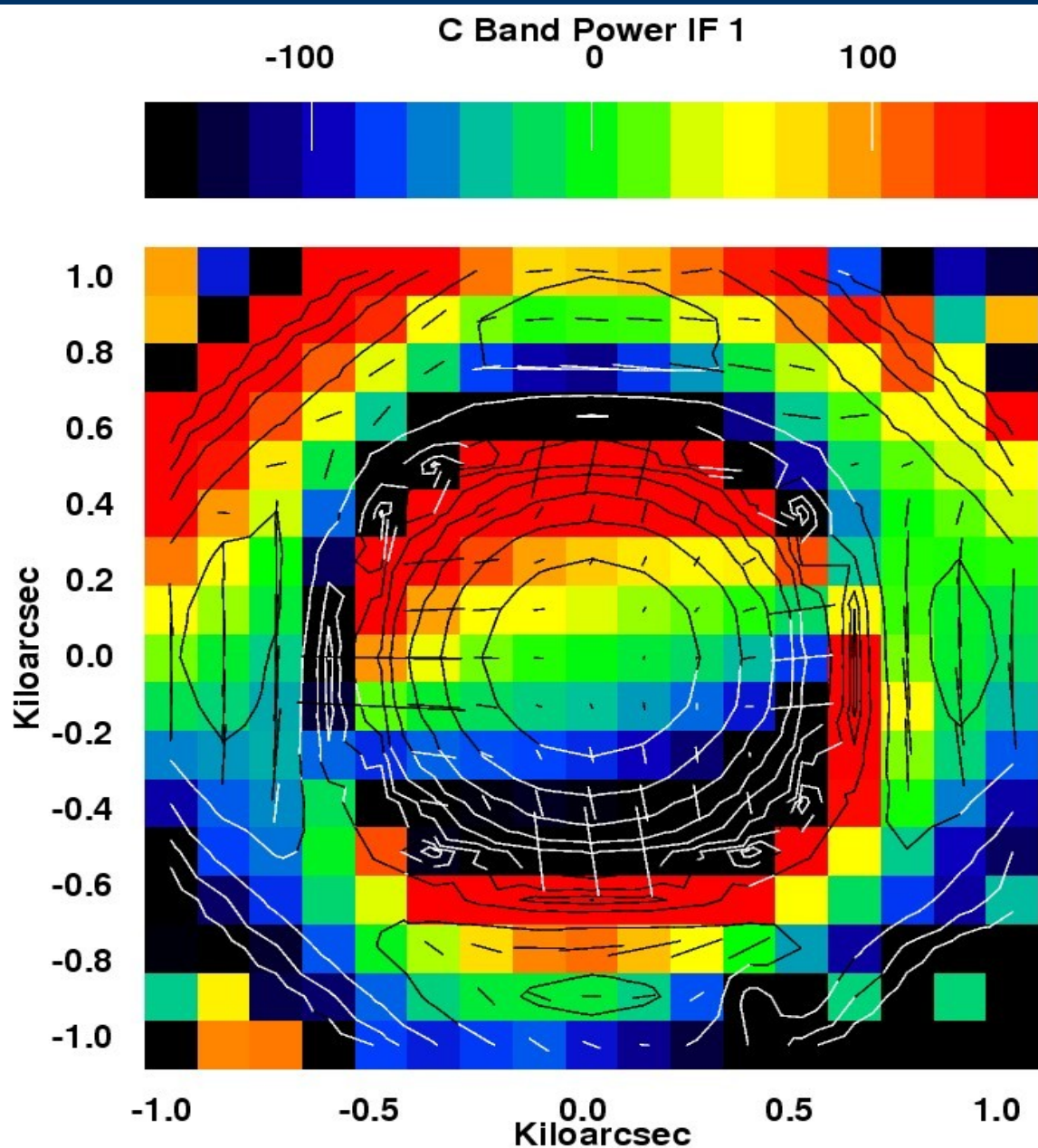
Contours Stokes I
Colors Stokes V
Vectors Stokes $Q+iU$

EVLA Beam at 20 cm, higher resolution



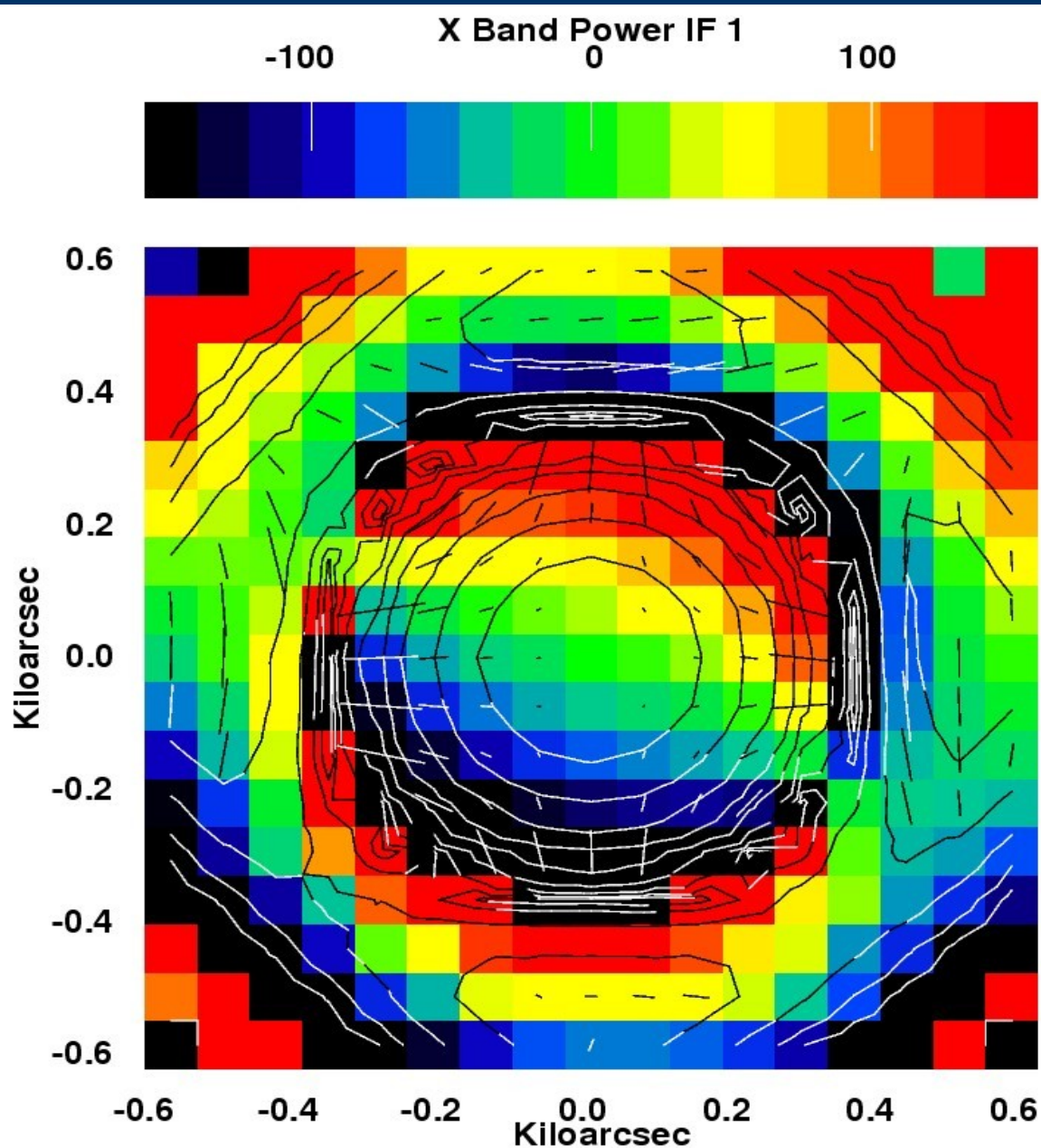
Contours Stokes I
Colors Stokes V
Vectors Stokes Q+iU

EVLA Beam at 6 cm



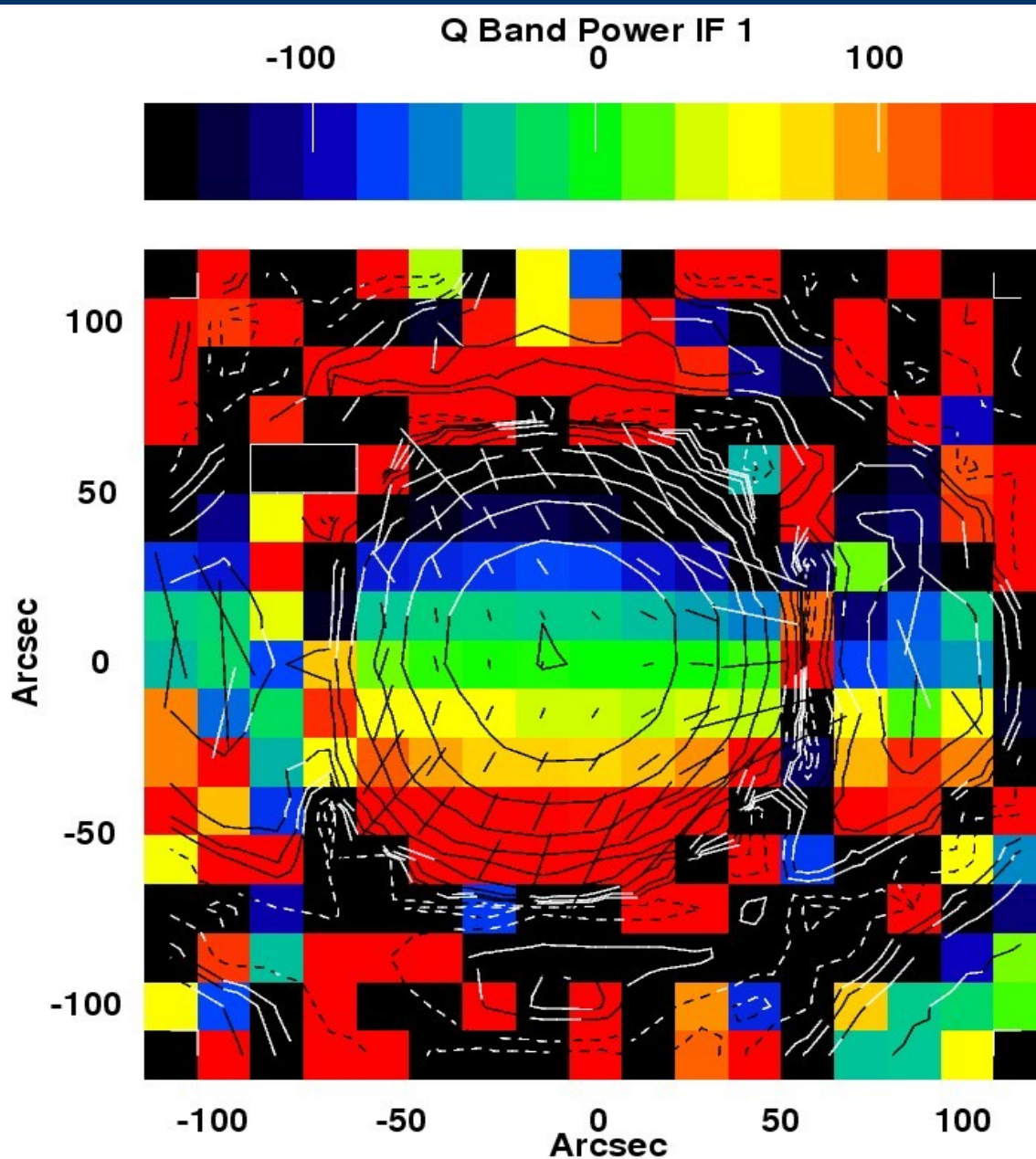
Contours Stokes I
Colors Stokes V
Vectors Stokes Q+iU

EVLA Beam at 3.6 cm



Contours Stokes I
Colors Stokes V
Vectors Stokes $Q+iU$

EVLA Beam at 7 mm



Contours Stokes I
Colors Stokes V
Vectors Stokes Q+iU

Correction of off-axis instrumental polarization

- Instrumental polarization is the polarized response to a non polarized source
- Can compute instrumental response to Stokes I based on knowledge of instrumental polarization beam.



Correction of off-axis instrumental polarization, cont'd

- Instrumental polarized response to sky model is:

$$Q = \sum_{i=1}^n G_{Q_i} S_i e^{j2\pi(ux_i + vy_i + wz_i)},$$

$$U = \sum_{i=1}^n G_{U_i} S_i e^{j2\pi(ux_i + vy_i + wz_i)}.$$

Where G_{Q_i} and G_{U_i} are the Q and U beams in the direction of sky model component i , S_i is the flux density and x_i , y_i and z_i the position of component i

Correction of off-axis instrumental polarization, cont'd

- Correcting for the rotation by the parallactic angle χ

$$Q' + jU' = (Q + jU) * \exp(-2j\chi)$$

- Interferometric response is

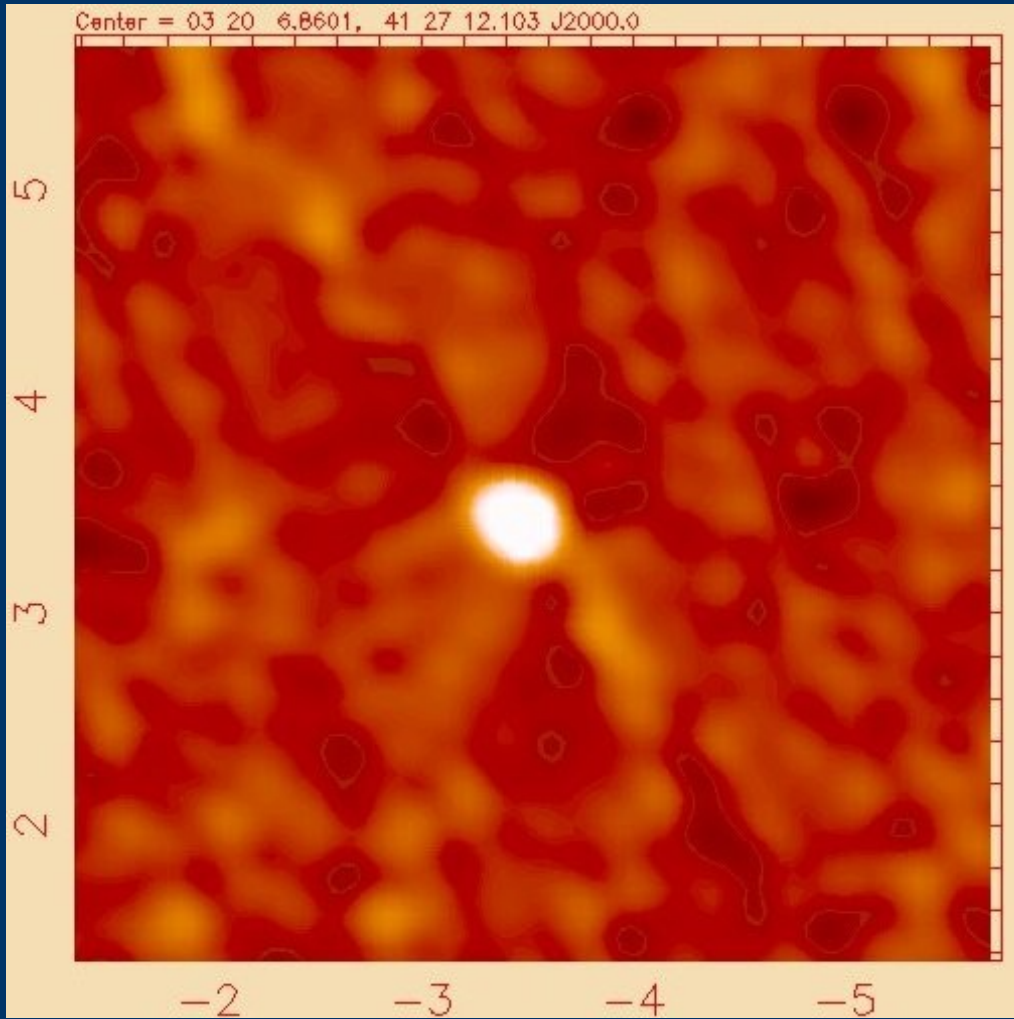
$$\begin{aligned} RL &= Q' + jU', \\ LR &= Q' - jU'. \end{aligned}$$

- Can subtract interferometer response from data to correct.
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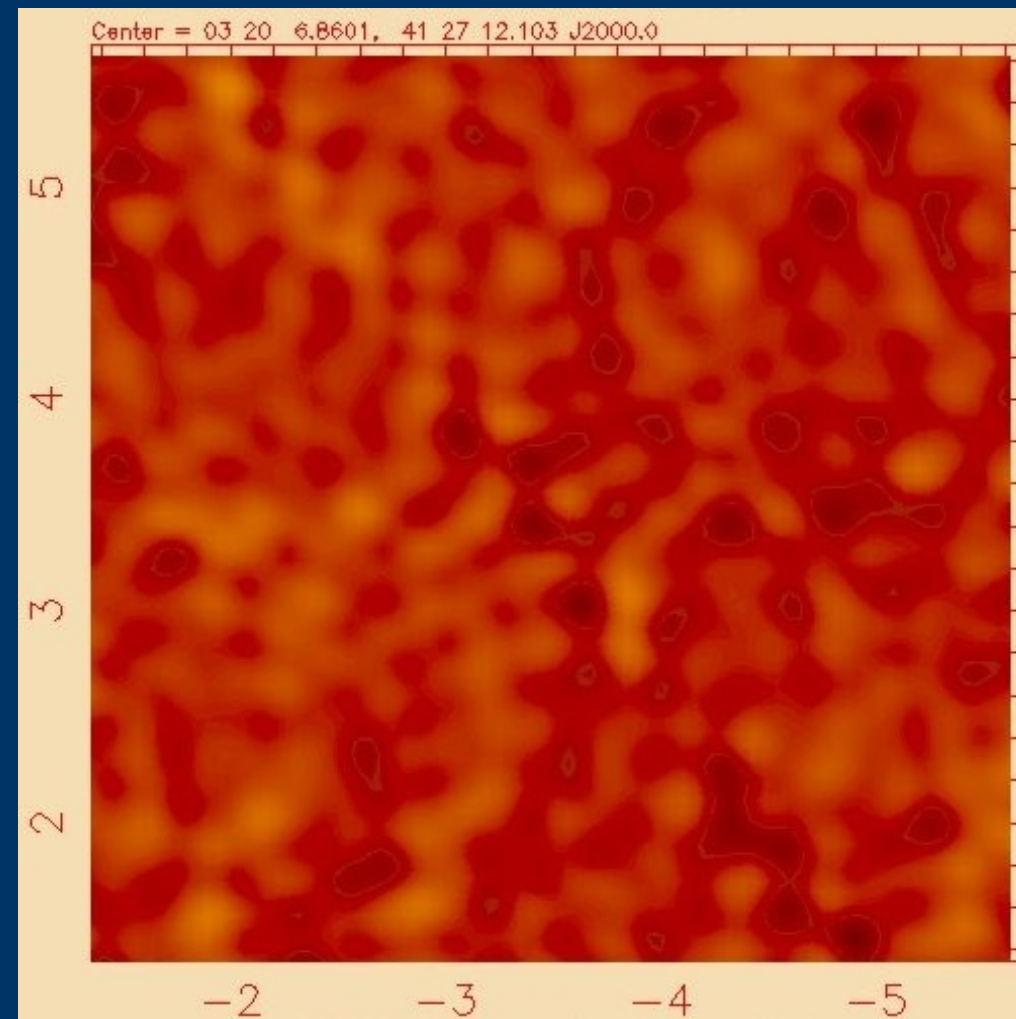
Example Polarization Correction

- Made pointed observations of calibrator at the half power at a number of orientations
 - Used beam images from holography to correct Stokes V, Q, U from Stokes I sky model (CLEAN image)
 - 3C84 at 6 cm (5.6 Jy)
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Stokes V correction

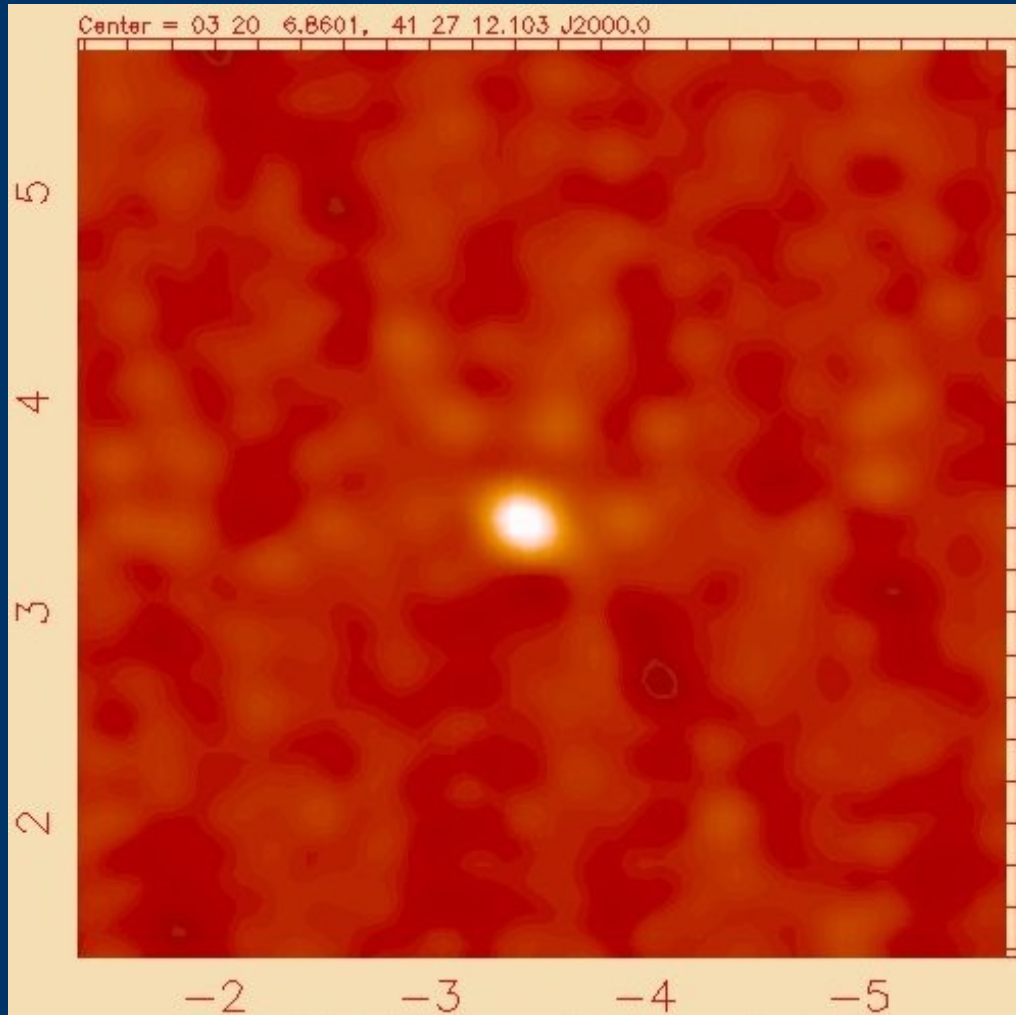


**3C84 without correction,
peak 300 mJy**

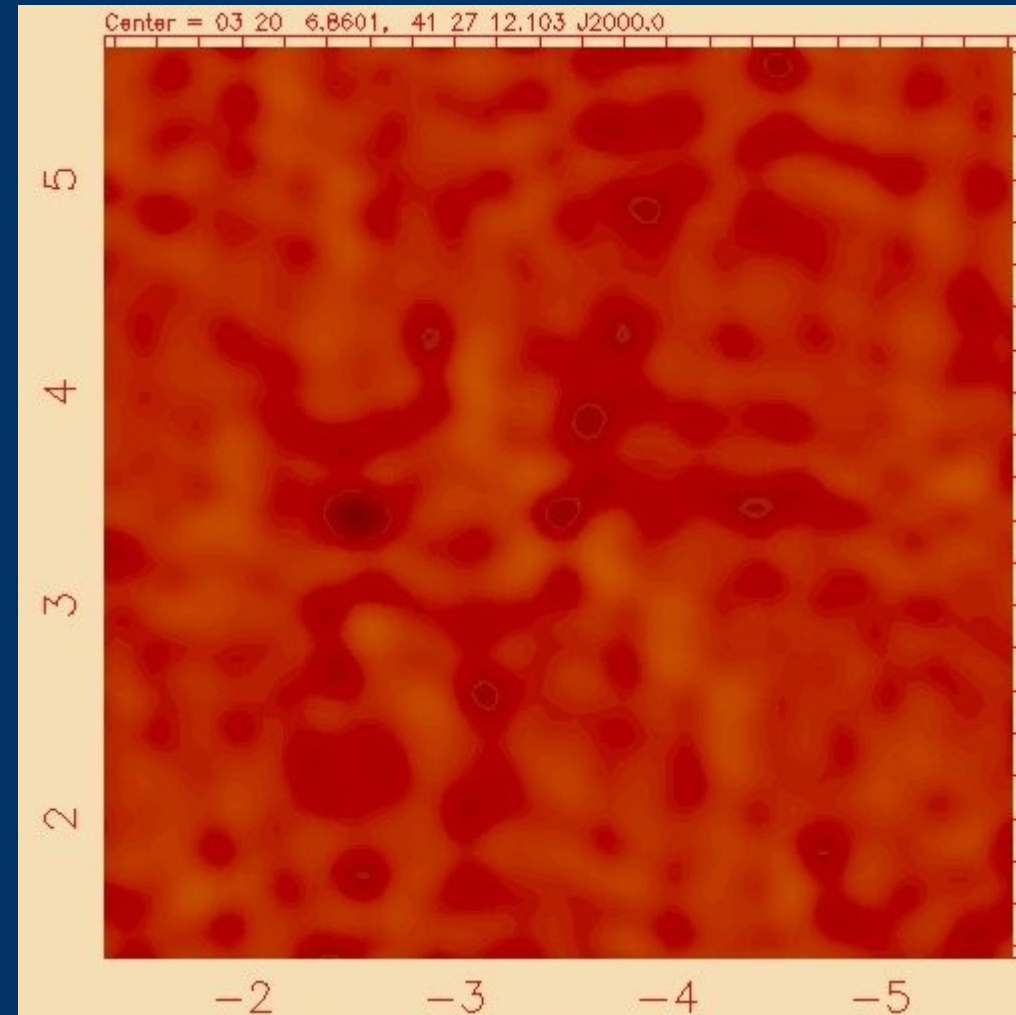


3C84 with correction

Stokes Q correction

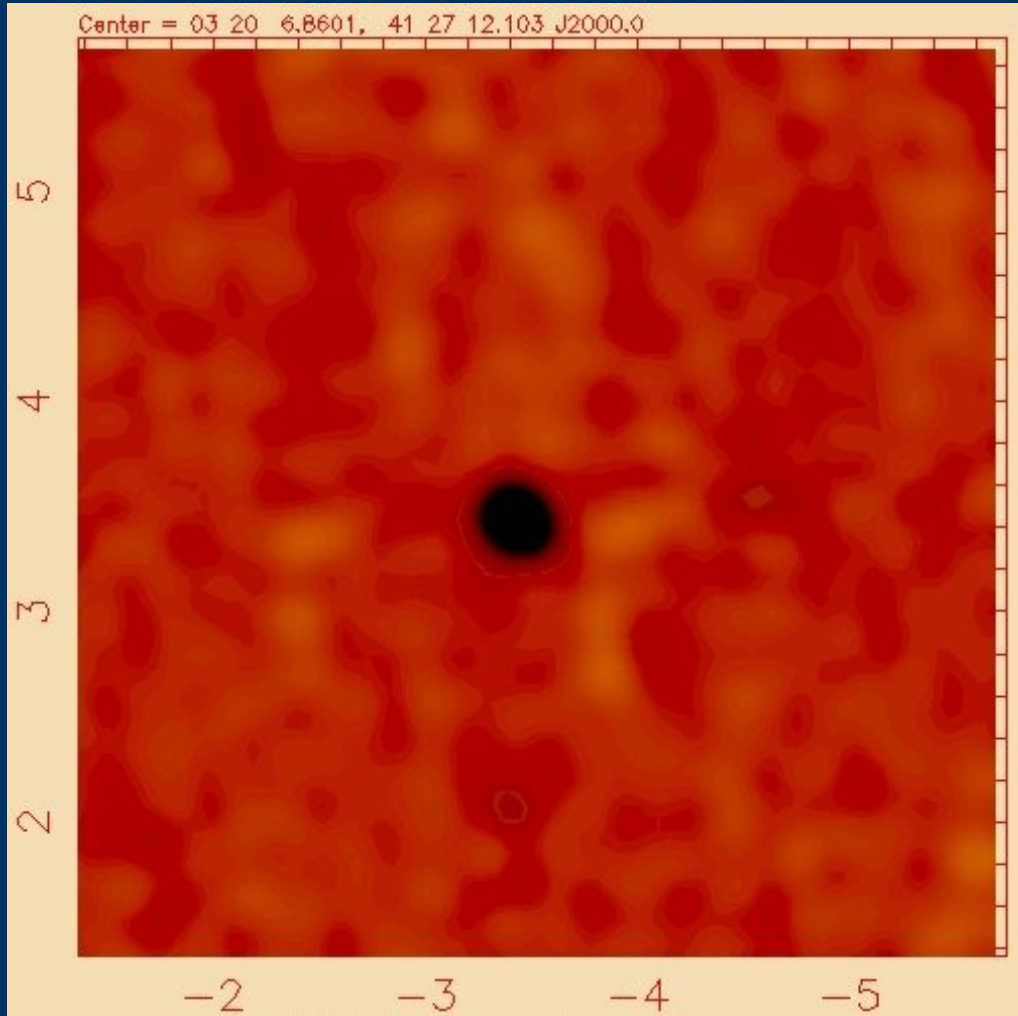


**3C84 without correction,
peak 77 mJy**

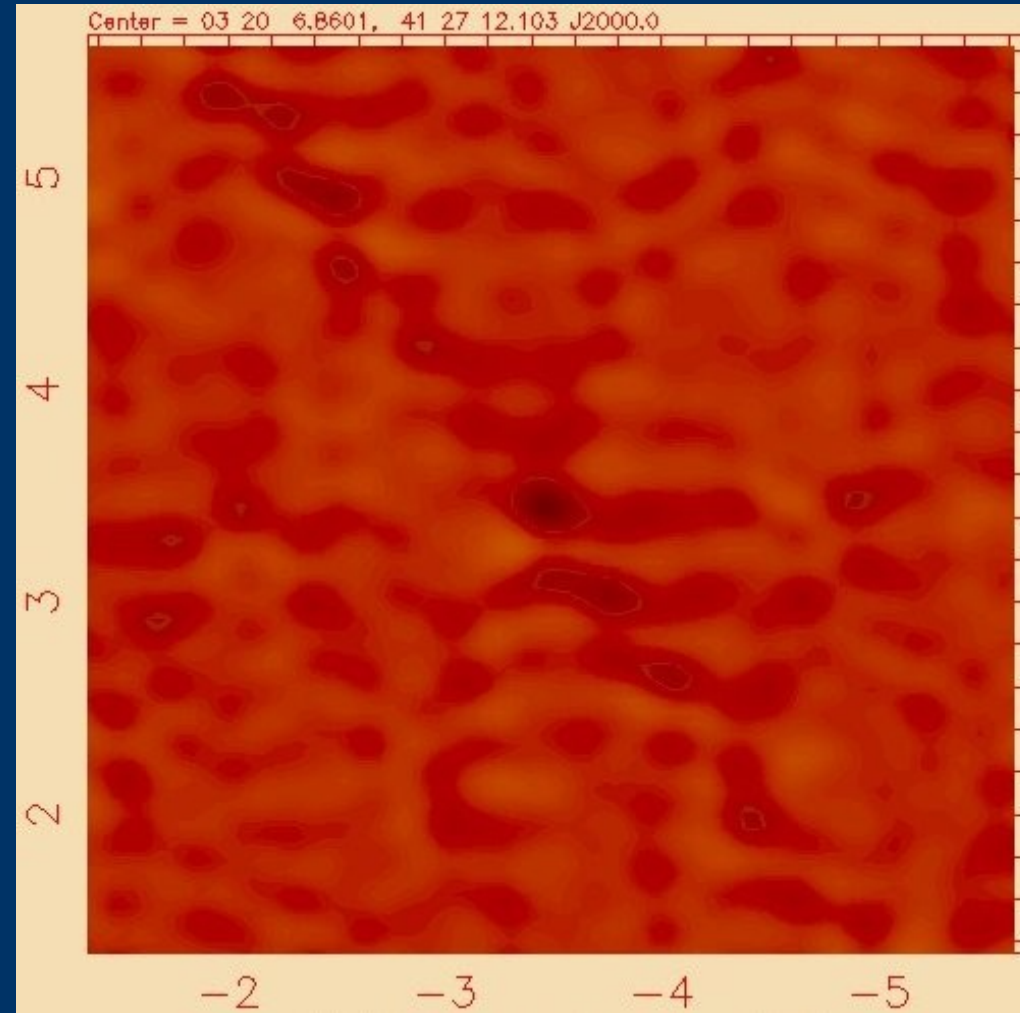


3C84 with correction

Stokes U correction



**3C84 without correction,
peak -122 mJy**



3C84 with correction

Example correction, cont'd

- Mostly OK, some residual left in U
 - General result; correction good to a factor of 5
 - Why no better?
 - Test data same as holography:
 - Same source
 - Same correlator setting
 - Same frequency
 - Same calibration
 - Close in time
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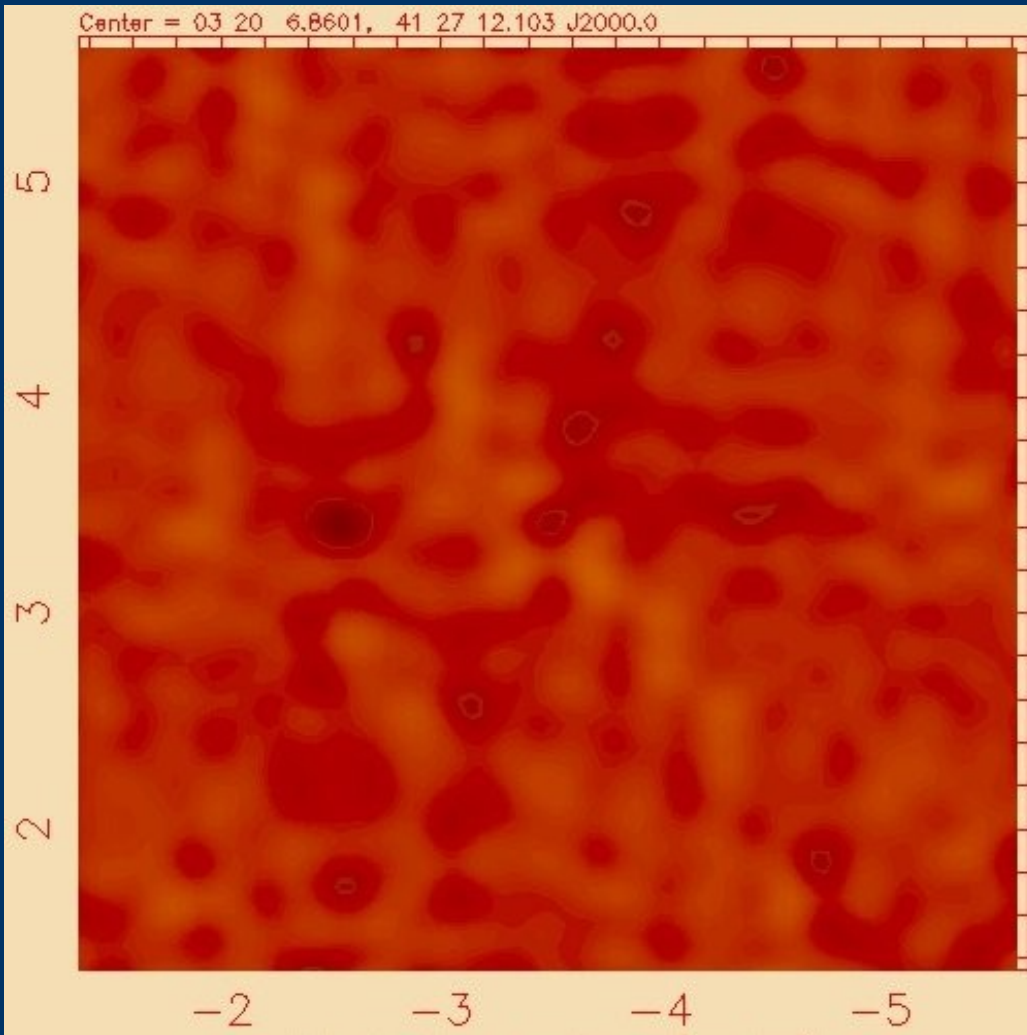
Reasons for limited correction

- Possible reasons
 - Ignoring phase of beam image
 - Limited resolution of beam pattern
 - Different observing geometry
 - Variation among antennas
- Test possibilities

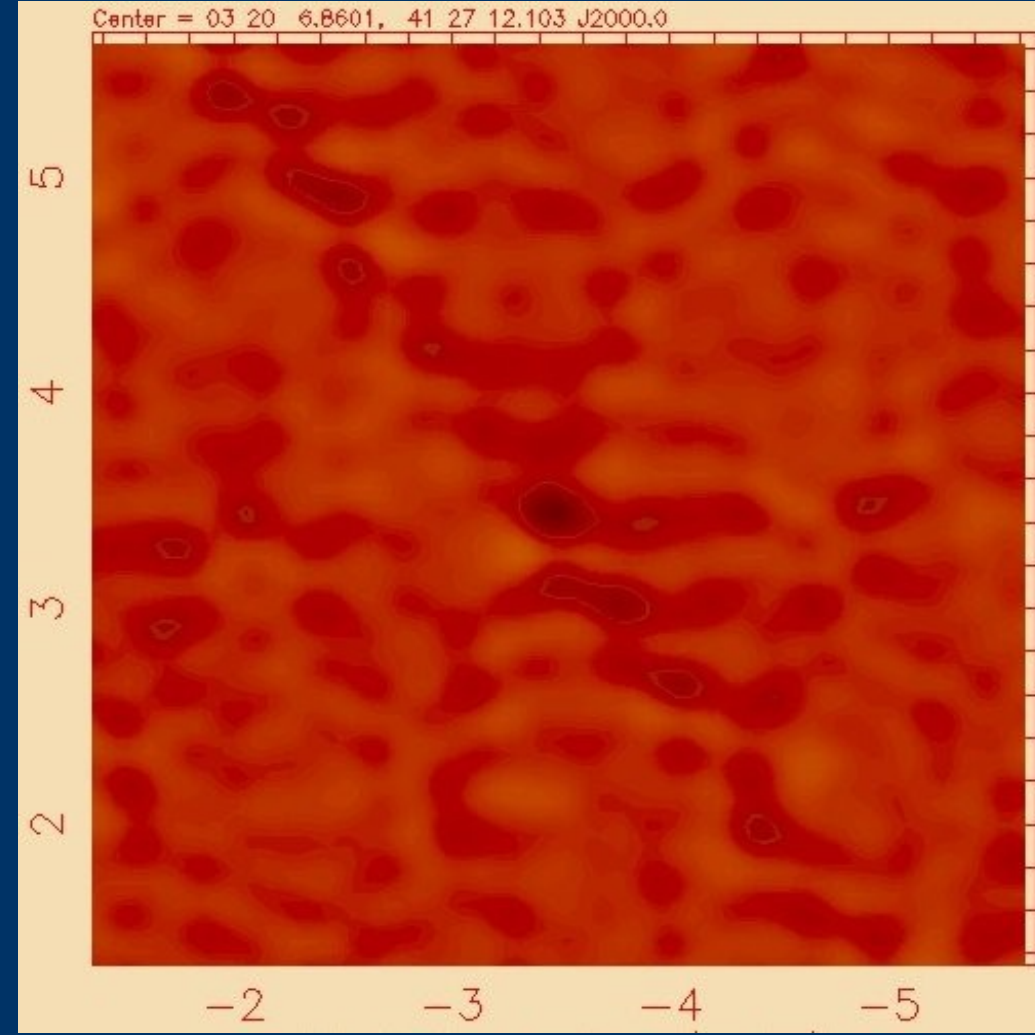
Effect of phase

- Determined complex average polarization beam
- Correction using complex beam
- No significant change
- Beam phases are close to zero

Effect of phase



Q with correction



U with correction

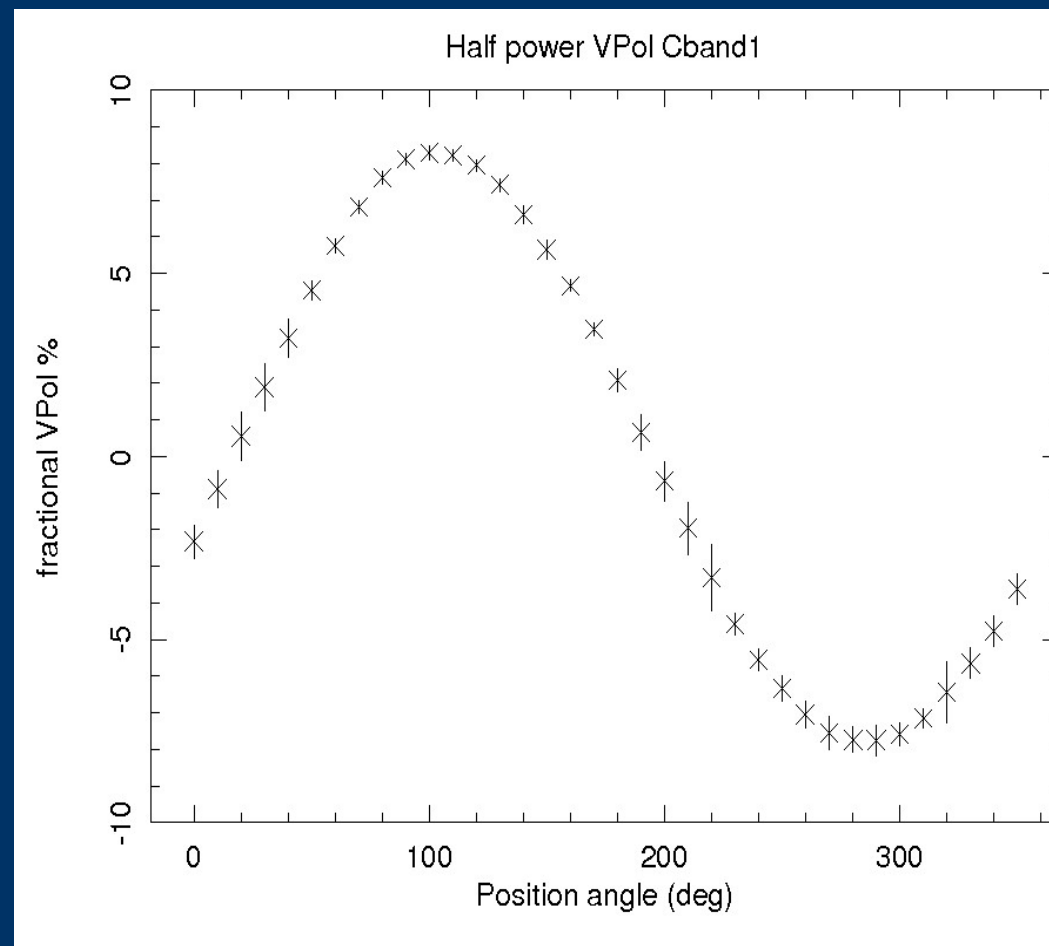
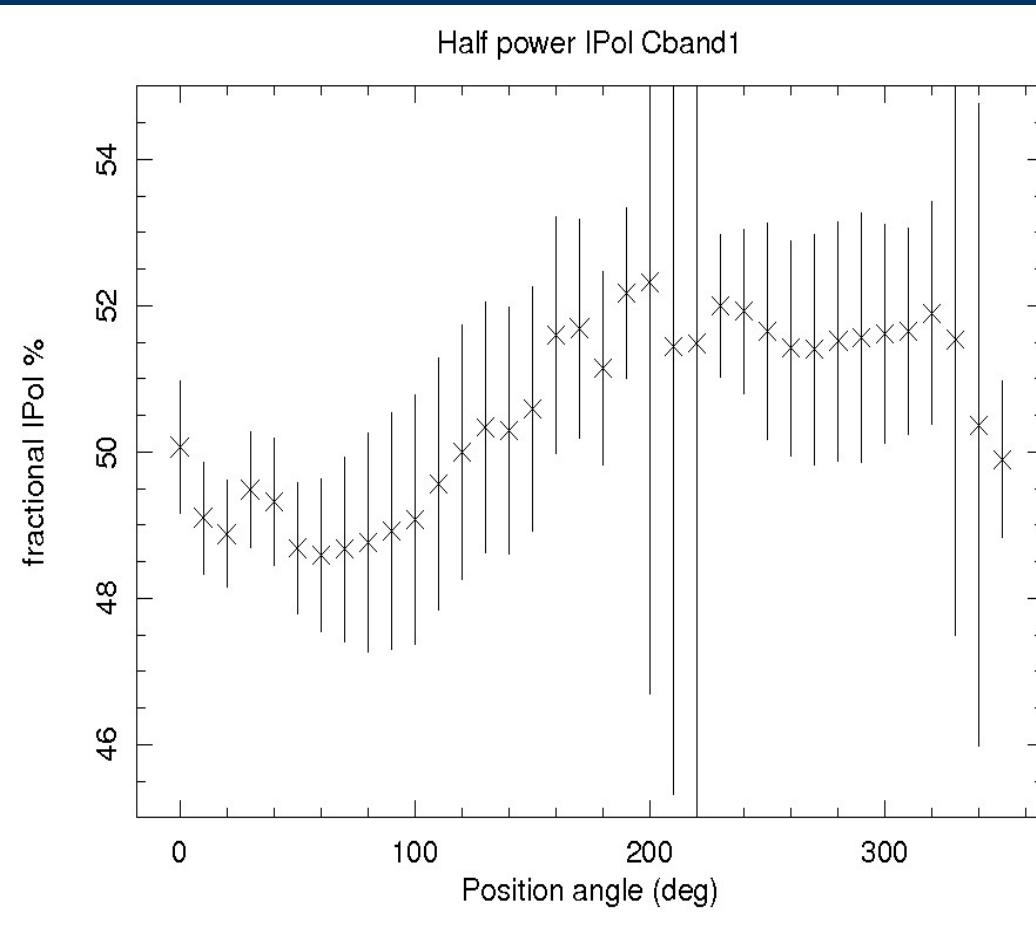
Effect of Beam resolution

- Made beam images with higher resolution holography
 - Correction using high resolution beam
 - No significant change
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Variation Among Antennas

- Correction using a single beam pattern for all antennas will have limited accuracy if there is variation
 - Weighting other than “natural” in imaging gives different antennas different weights
 - Determine individual antenna patterns and compare
 - Determine values around \sim half power circle.
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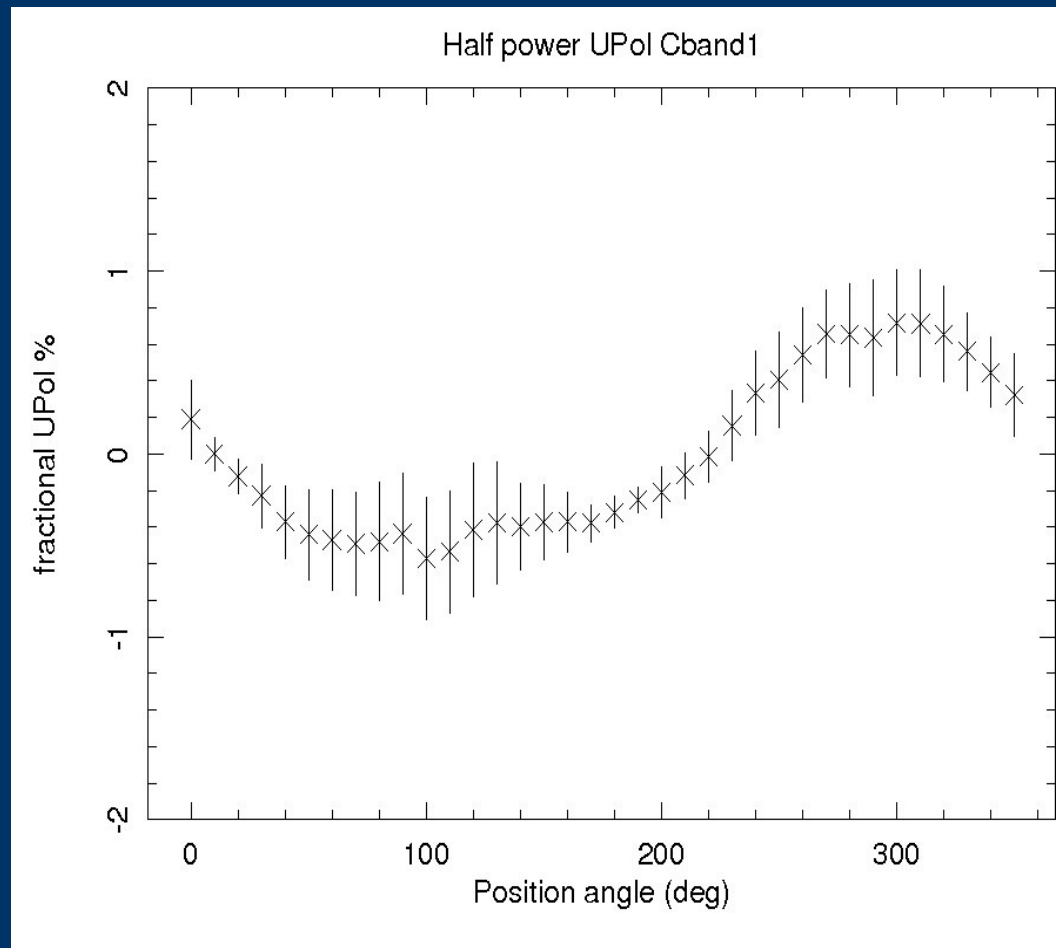
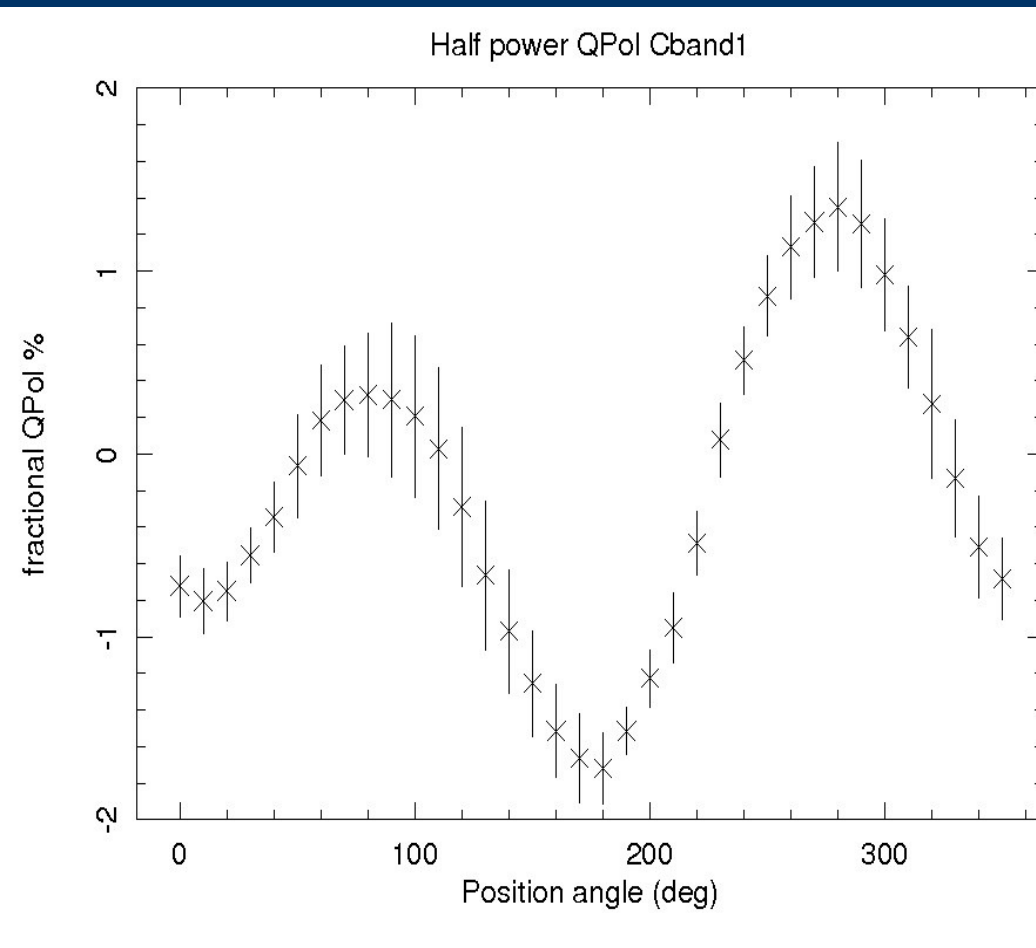
Varying EVLA Beam Asymmetries I, V



**Average and RMS of
Stokes I around ~half
power circle, 6 cm**

Stokes V

Varying EVLA Beam Asymmetries Q , U



Stokes Q

Stokes U

Variation among antennas, cont'd

- There is enough variation in off-axis instrumental linear polarization to limit accuracy of correction
- Even for EVLA the highest precision correction requires individual antenna corrections

Conclusions

- Off-axis instrumental polarization is significant
 - Beam polarization images can be used to correct
 - For EVLA the beam polarization does not change rapidly with frequency
 - Ultimate correction may require individual antenna beams.
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