# Why it's important to always ask if your assumptions are correct, no matter how many decades they have been in place!

Melanie Johnston-Hollitt
Victoria University of Wellington

# Questioning Assumptions

- "Questioning assumptions is a crucial exercise for anyone looking to establish themselves as a revolutionary thinker and problem solver." – De Ranjit Voola – University of Sydney Business School
- It doesn't matter how long the assumption has been in place
- Examples
  - Good Complex CLEAN
  - Origin of Diffuse Emission in Clusters (cf Stefan Duchesne's talk)

# CLEANING Polarimetric Data

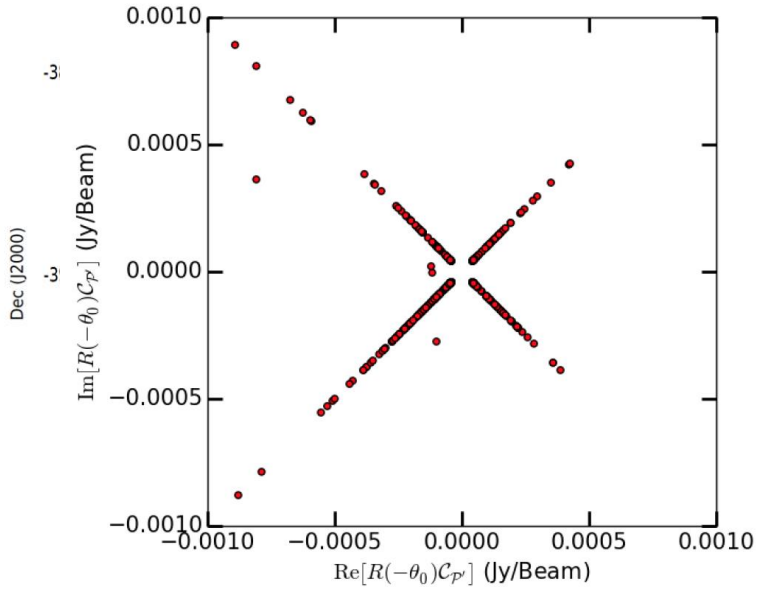
- Turns out the way we have been deconvolving polarimetric radio data has been wrong for the last 40 years!
- CLEANing is the process of deconvolving the telescope response (beam/psf) from the image. The approach is to looking for the highest peaks in an image and then remove the scaled beam/psf from that point and then repeat…
- Pioneered on Stokes I/Continuum Images (cf Hogbom, Steer, Ito & Dewdney, Clark etc…)

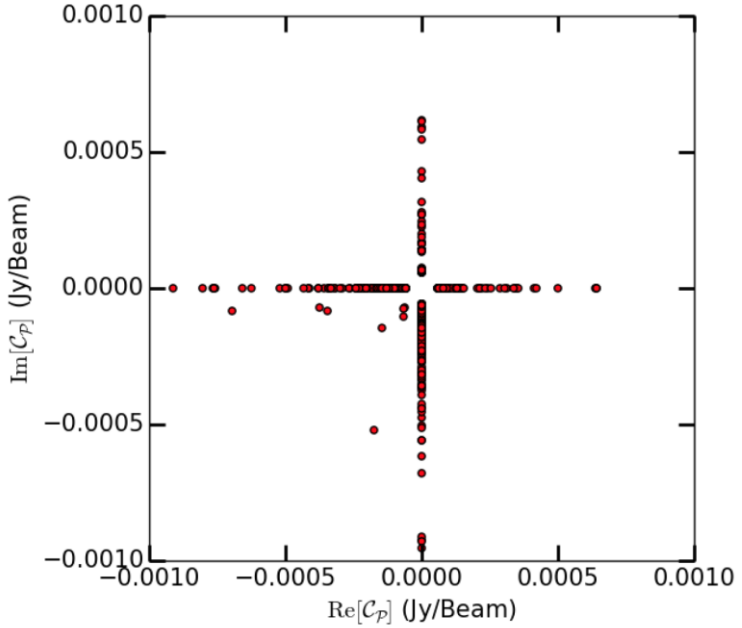
# CLEANing Polarisation Information

- Despite comments made in Hogbom's original paper, the process for CLEANing polarimetric data has been to repeat the continuum process on the two linear polarisation images (Stokes Q and U) separately.
- This ignores the complex vector nature of polarisation and produces CLEAN components which are biased by the deconvolution axis.

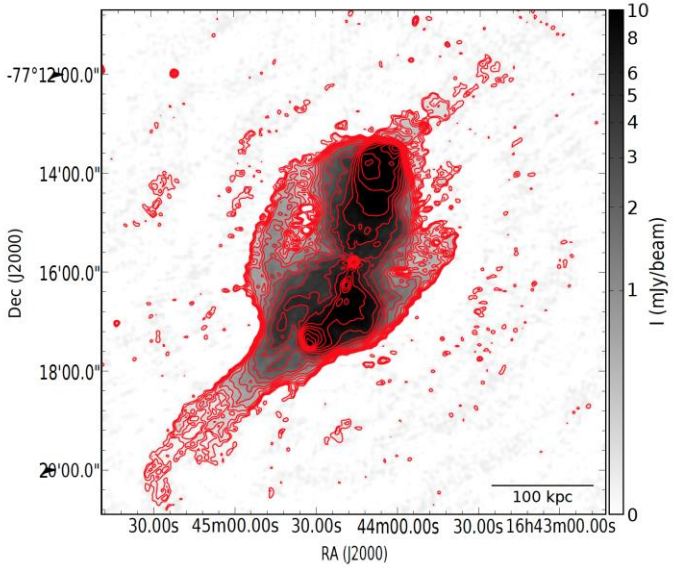
# Assumptions & Students

- I had always looked at polarisation residual maps and thought they looked a bit weird but assumed they were correct…
- Then I had a student who made a new plot…

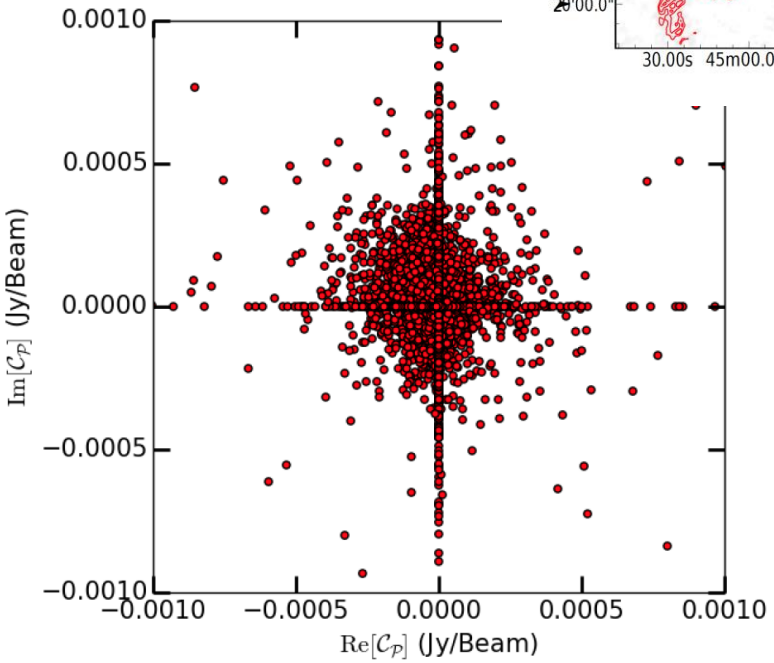


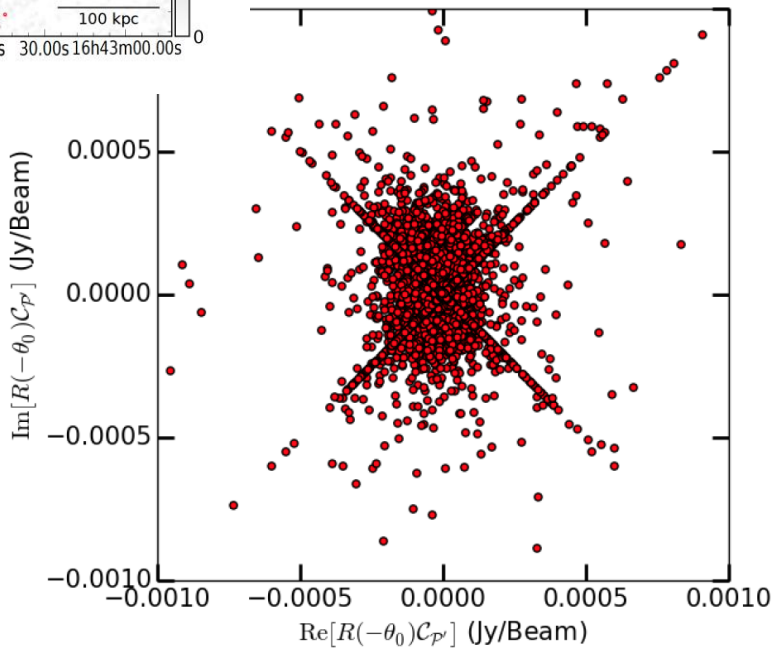



# Second Example

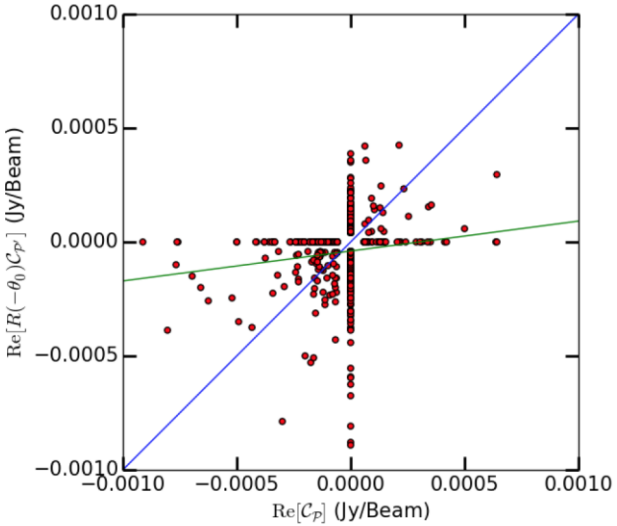


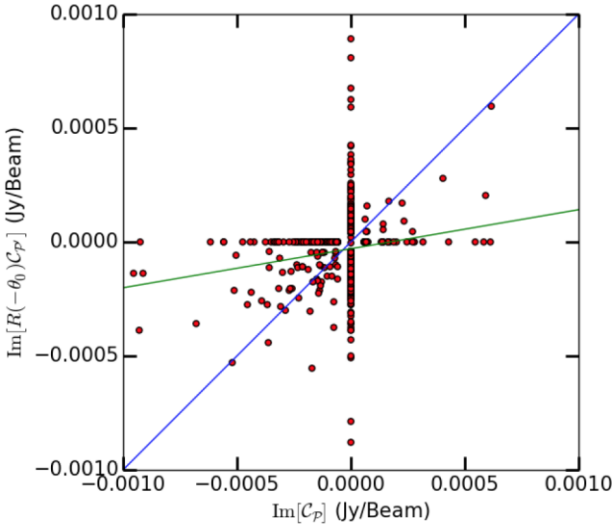

Current CLEAN methods were biased to generate components which were along the deconvolution axis – which is arbitrary and non-physical

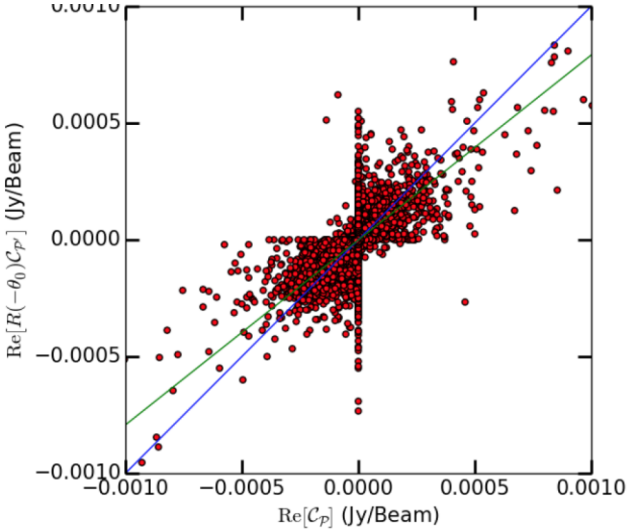


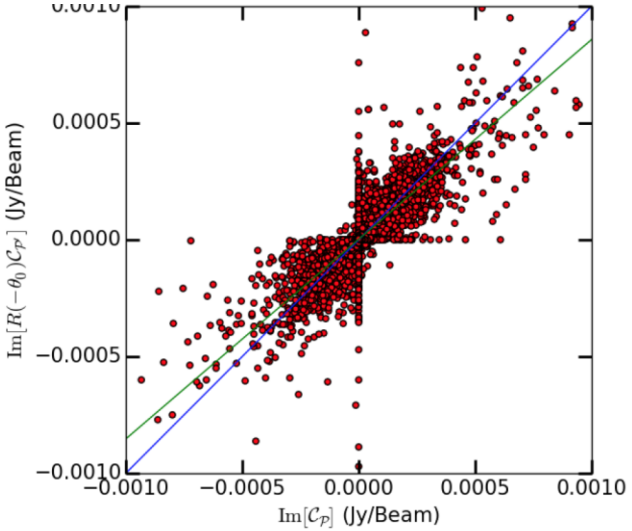



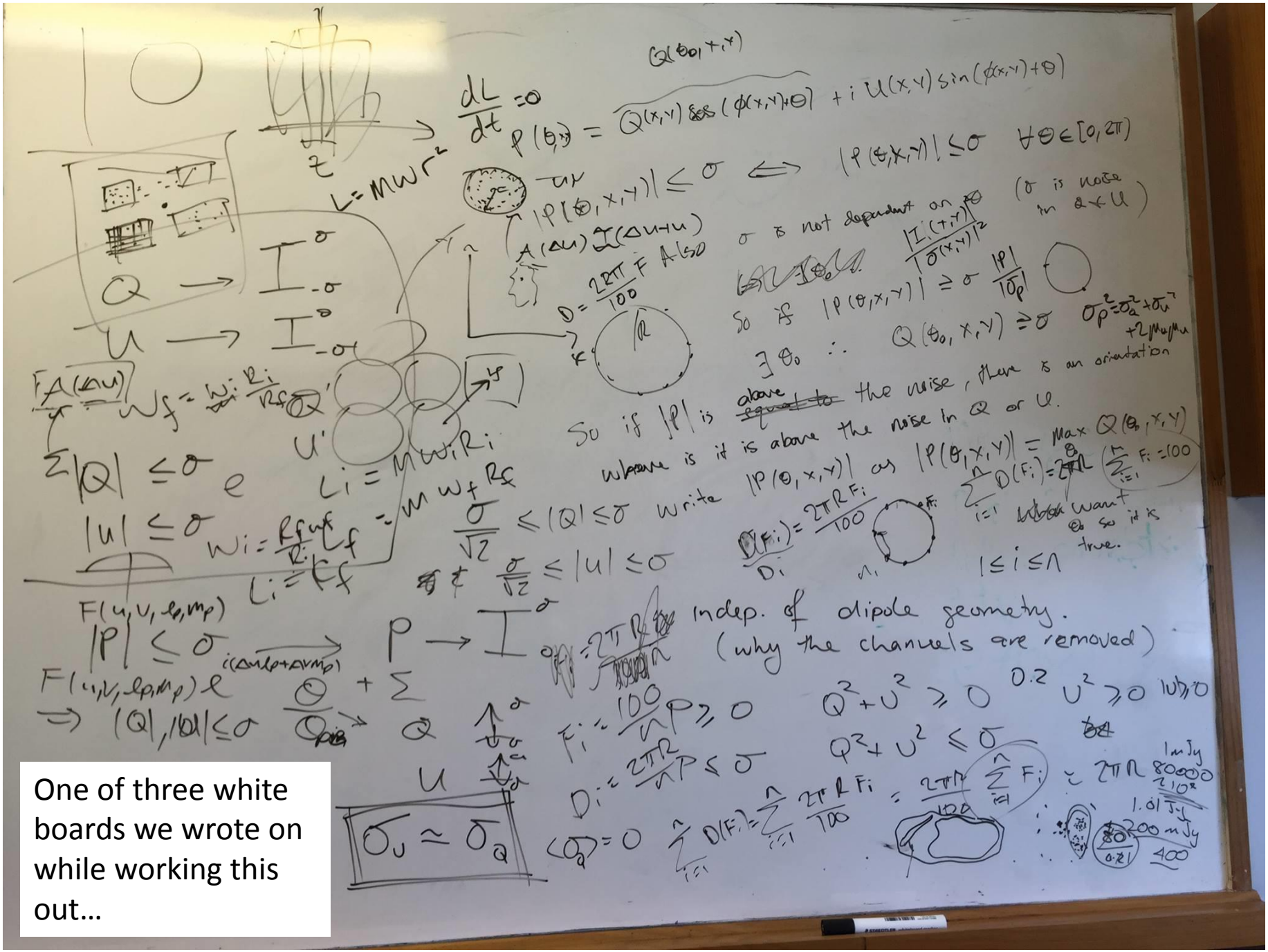
# Rotational Invariance





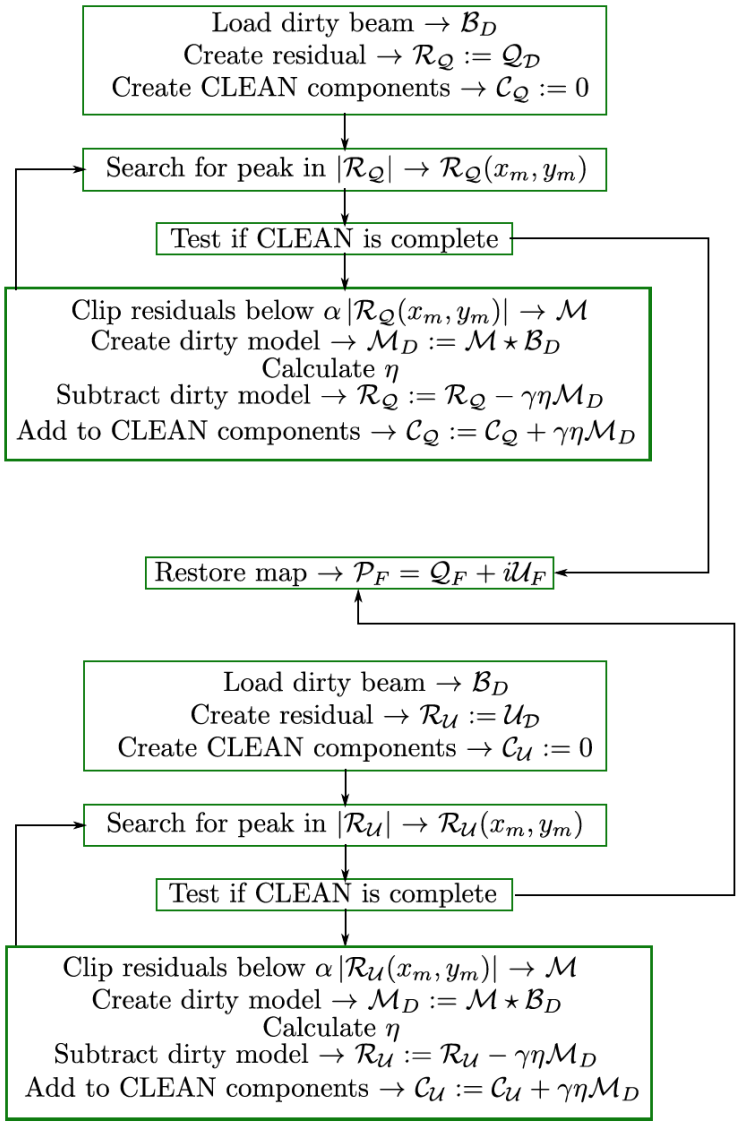
One of three white boards we wrote on while working this out…

# Solution

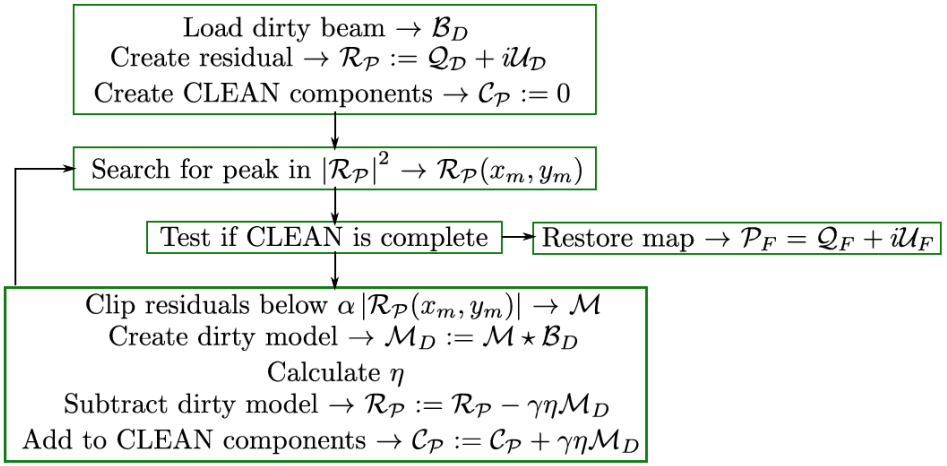
- The solution is simple – search for peaks in P not Stokes Q and U.
- This has a number of positive flow on effects:
  - Results are rotationally invariant eg physically more meaningful.
  - Code is less complex
  - Need less iterations
  - Can numerically see effects of rounding errors

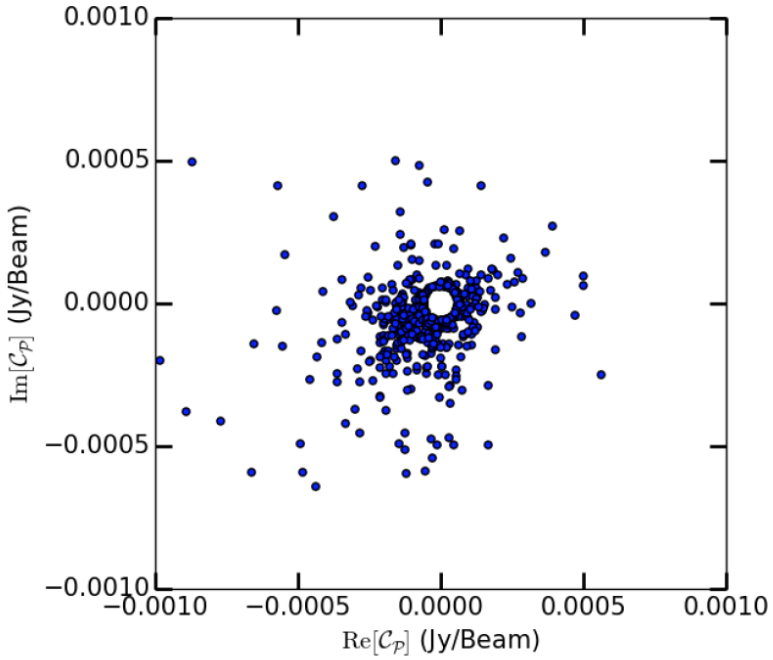
# Complex CLEAN

**Standard SDI CLEAN**




**Complex SDI CLEAN**




0.0010
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−0.0005
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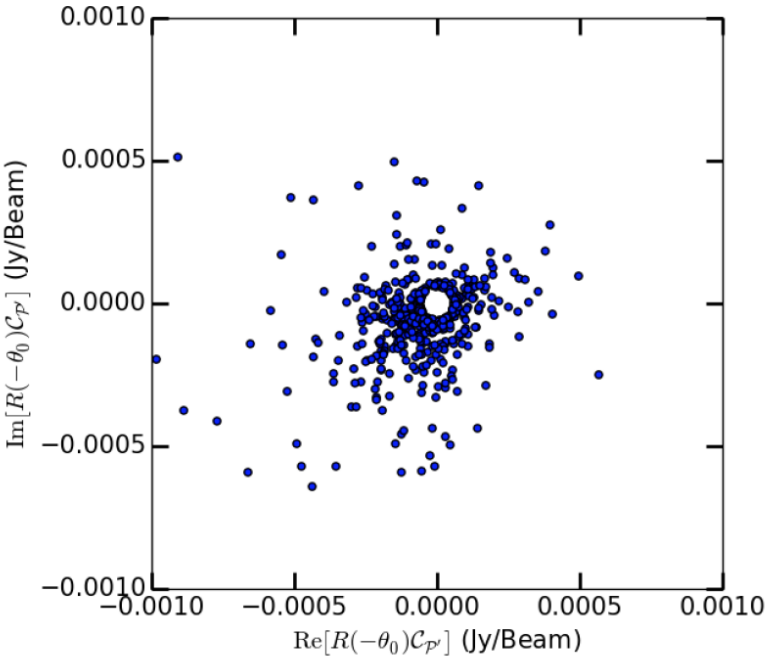
0.0010
$\mathrm{Im}[\mathcal{C}_{\mathcal{P}}]$ (Jy/Beam)
$\mathrm{Re}[\mathcal{C}_{\mathcal{P}}]$ (Jy/Beam)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−0.0005
−0.0010
−0.0010
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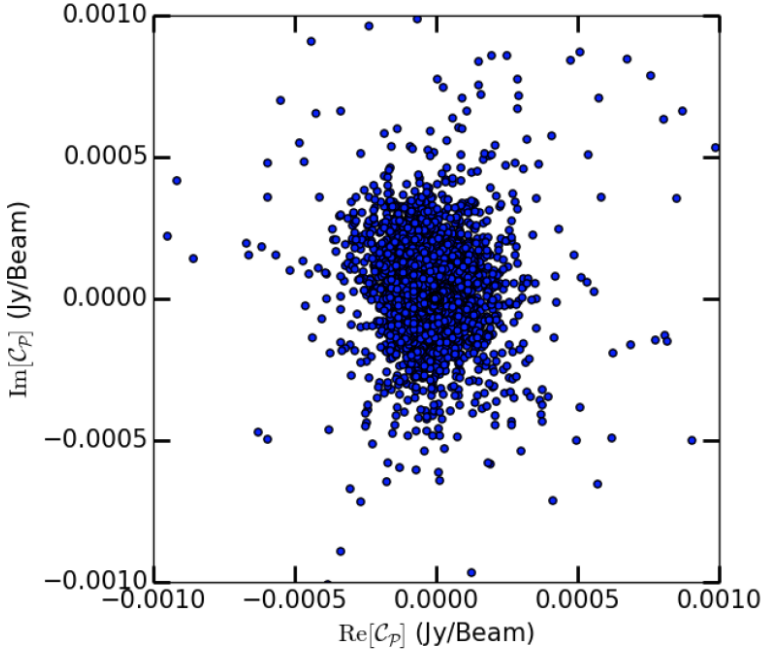
0.0000
0.0005
0.0010
$\mathrm{Im}[R(-\theta_0)\mathcal{C}_{\mathcal{P}'}]$ (Jy/Beam)
$\mathrm{Re}[R(-\theta_0)\mathcal{C}_{\mathcal{P}'}]$ (Jy/Beam)


0.0010
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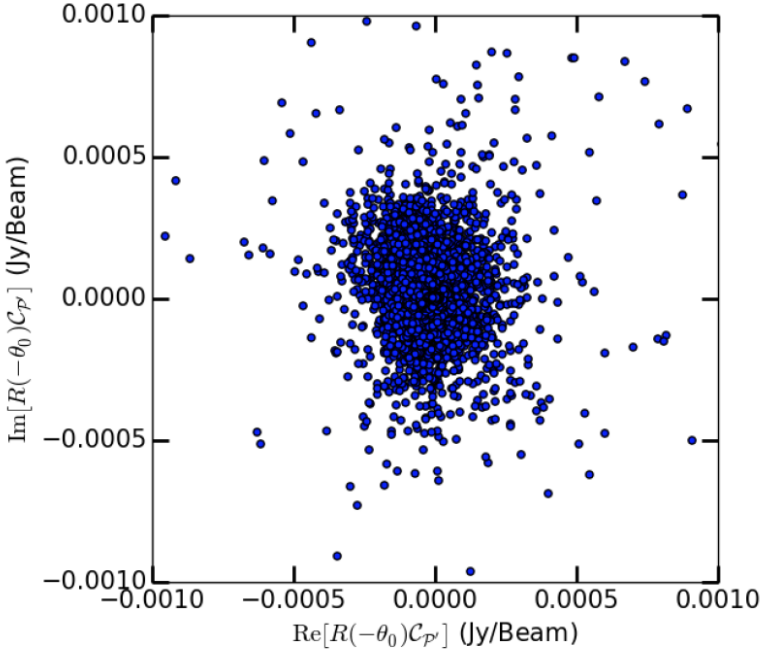
$\mathrm{Im}[\mathcal{C}_{\mathcal{P}}]$ (Jy/Beam)
$\mathrm{Re}[\mathcal{C}_{\mathcal{P}}]$ (Jy/Beam)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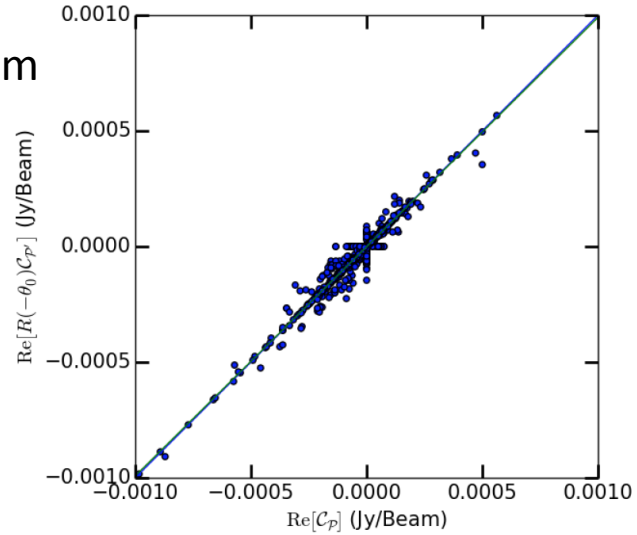
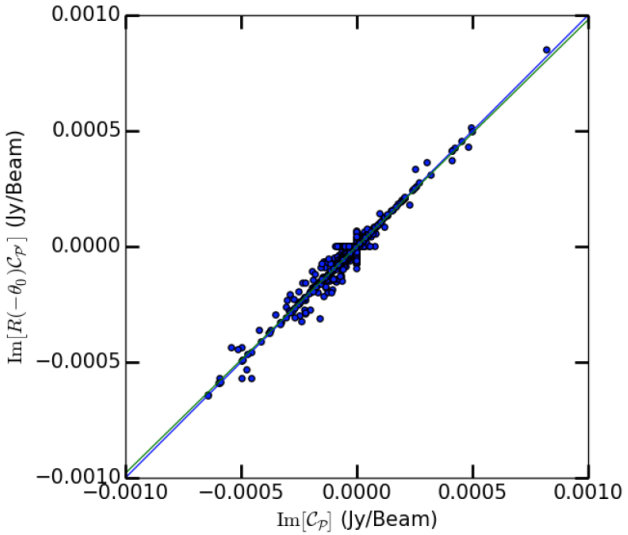
0.0010
$\mathrm{Im}[R(-\theta_0)\mathcal{C}_{\mathcal{P}'}]$ (Jy/Beam)
$\mathrm{Re}[R(-\theta_0)\mathcal{C}_{\mathcal{P}'}]$ (Jy/Beam)

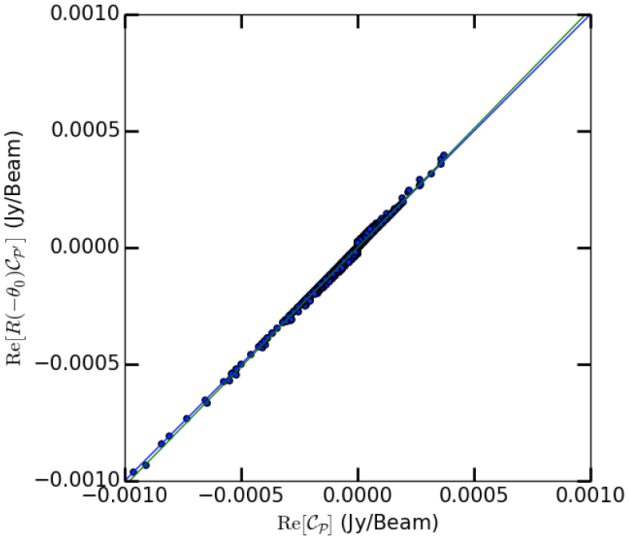
# Complex Hogbom vs SDI CLEAN

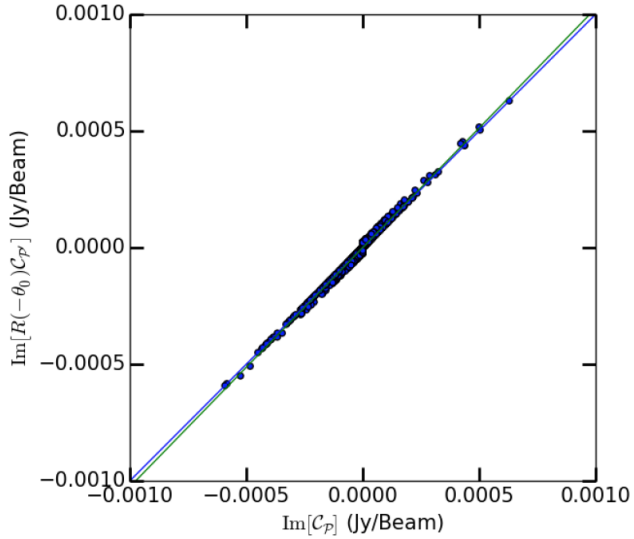
Complex Hogbom Components



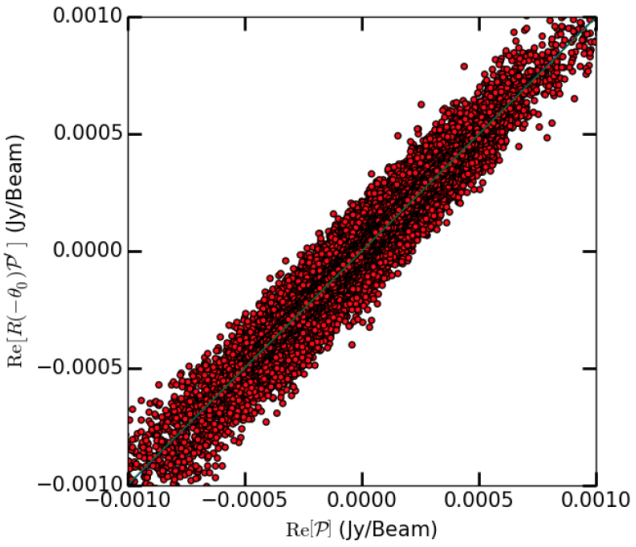

Complex SDI Components

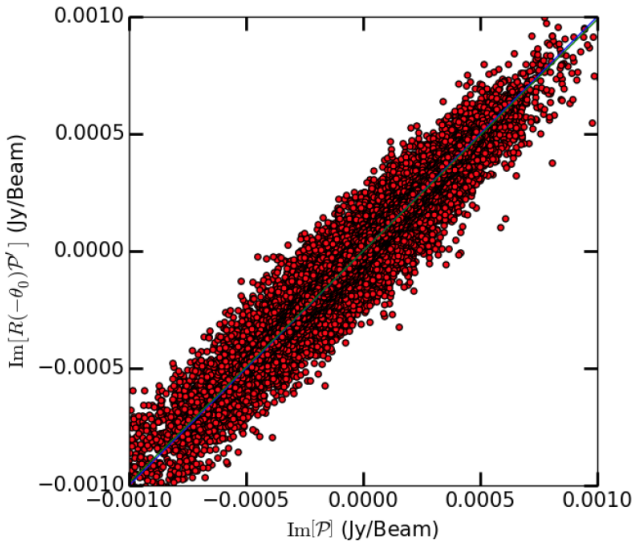


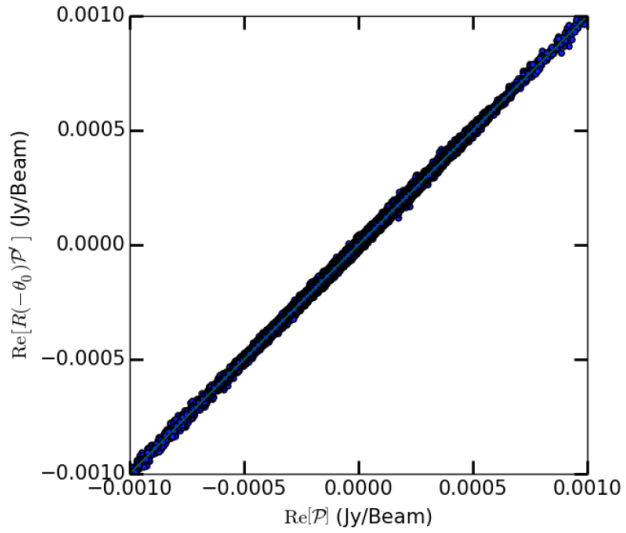
# Hogbom vs Complex Hogbom CLEAN

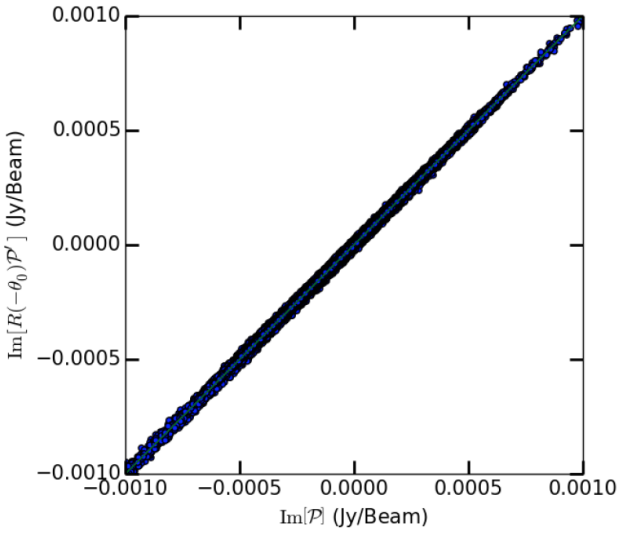
Hogbom
Image Values



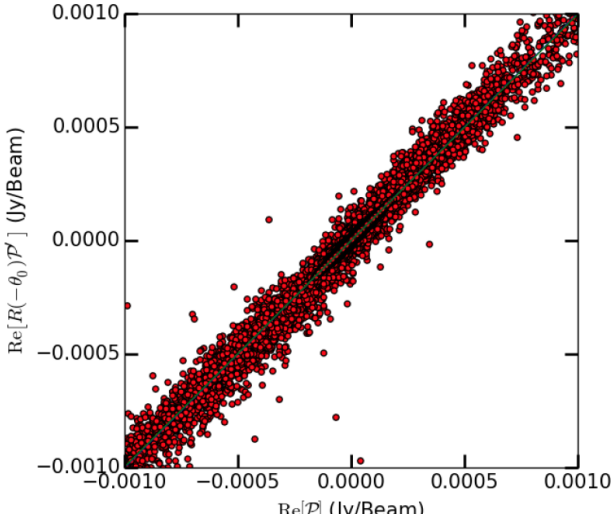

Complex Hogbom
Image Values

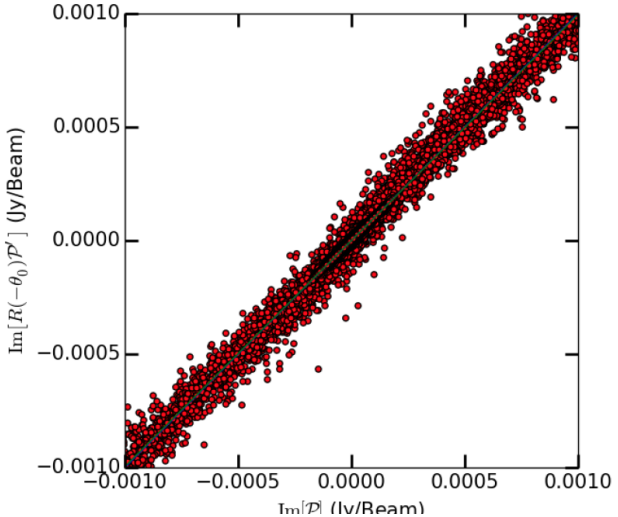


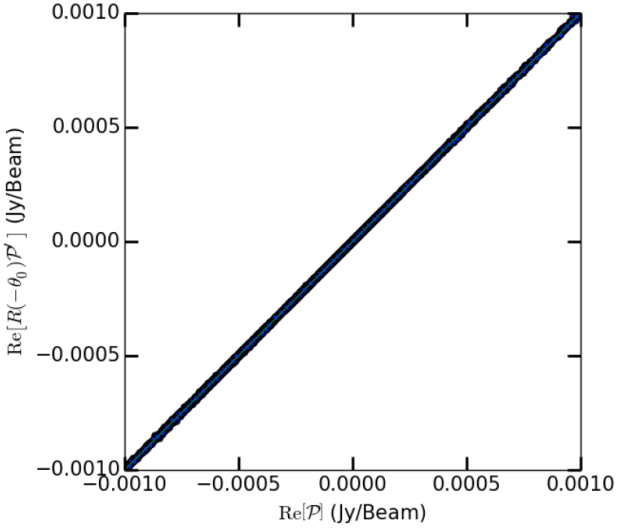
# SDI vs Complex SDI CLEAN

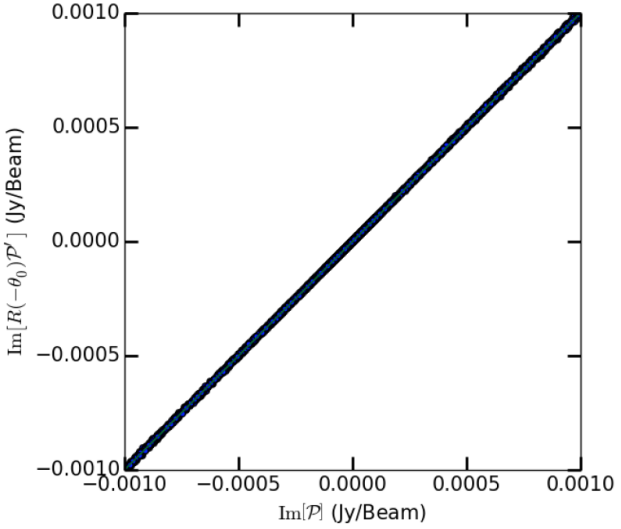
SDI
Image Values




SDI Hogbom
Image Values



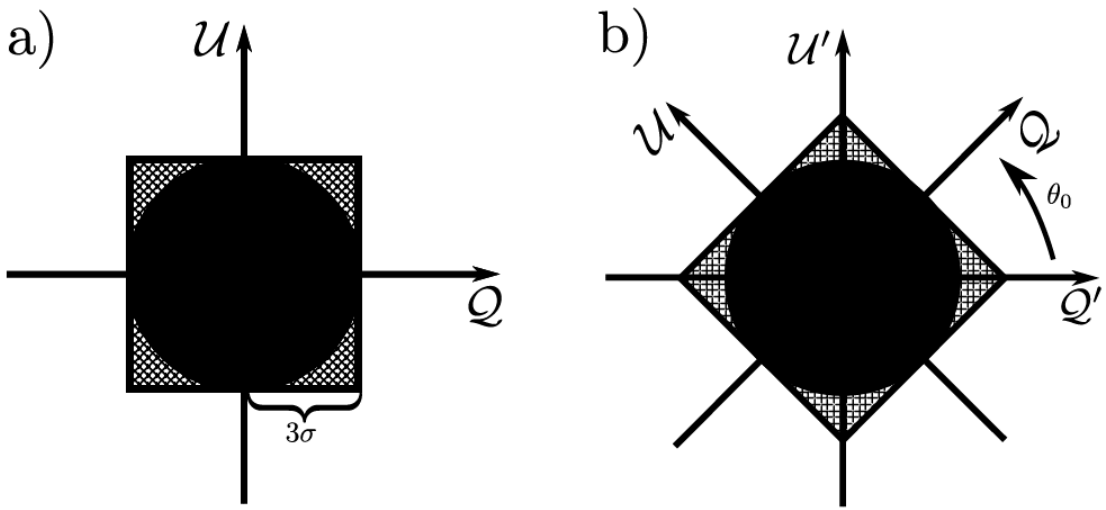



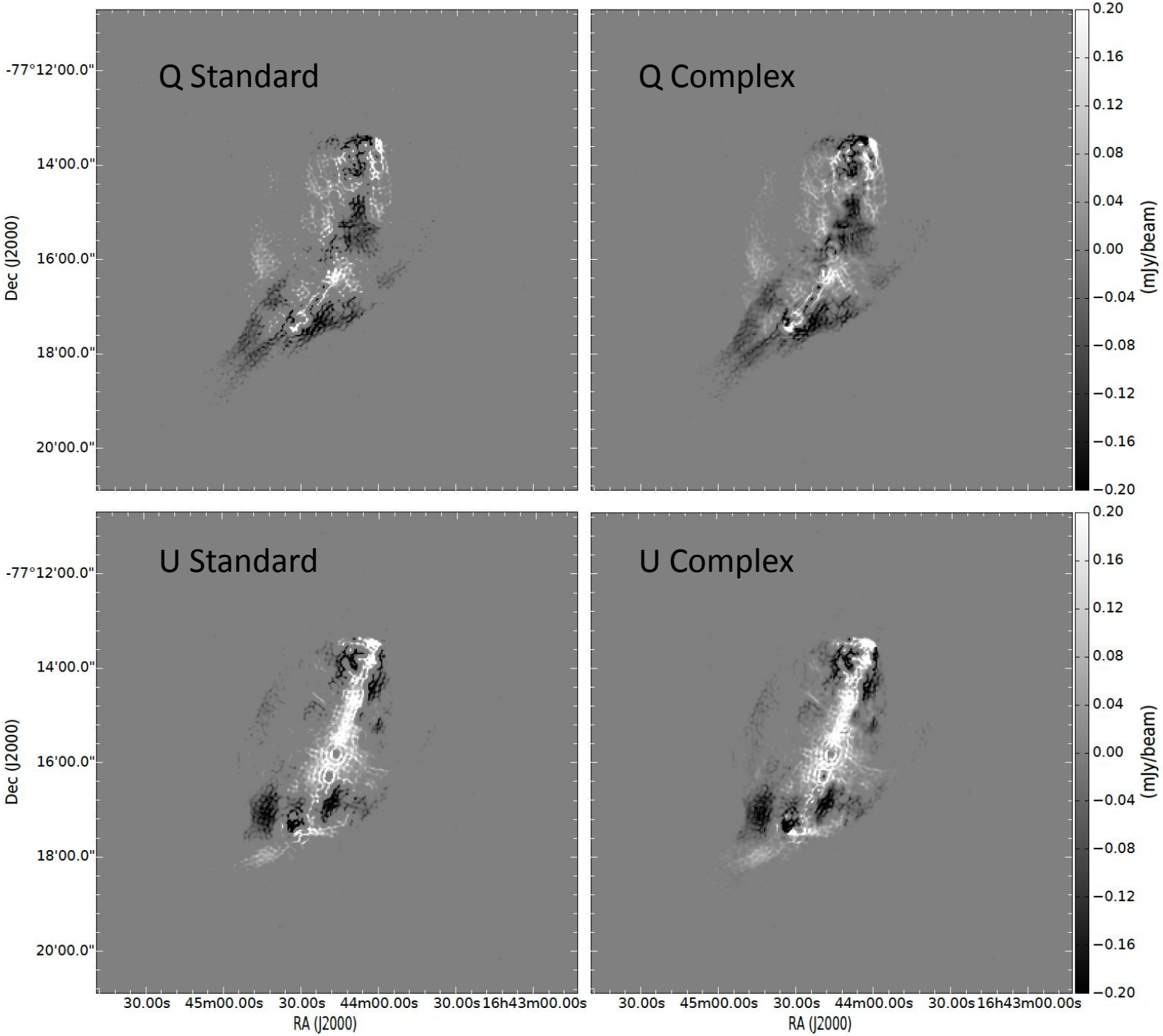
# Selecting Cutoffs

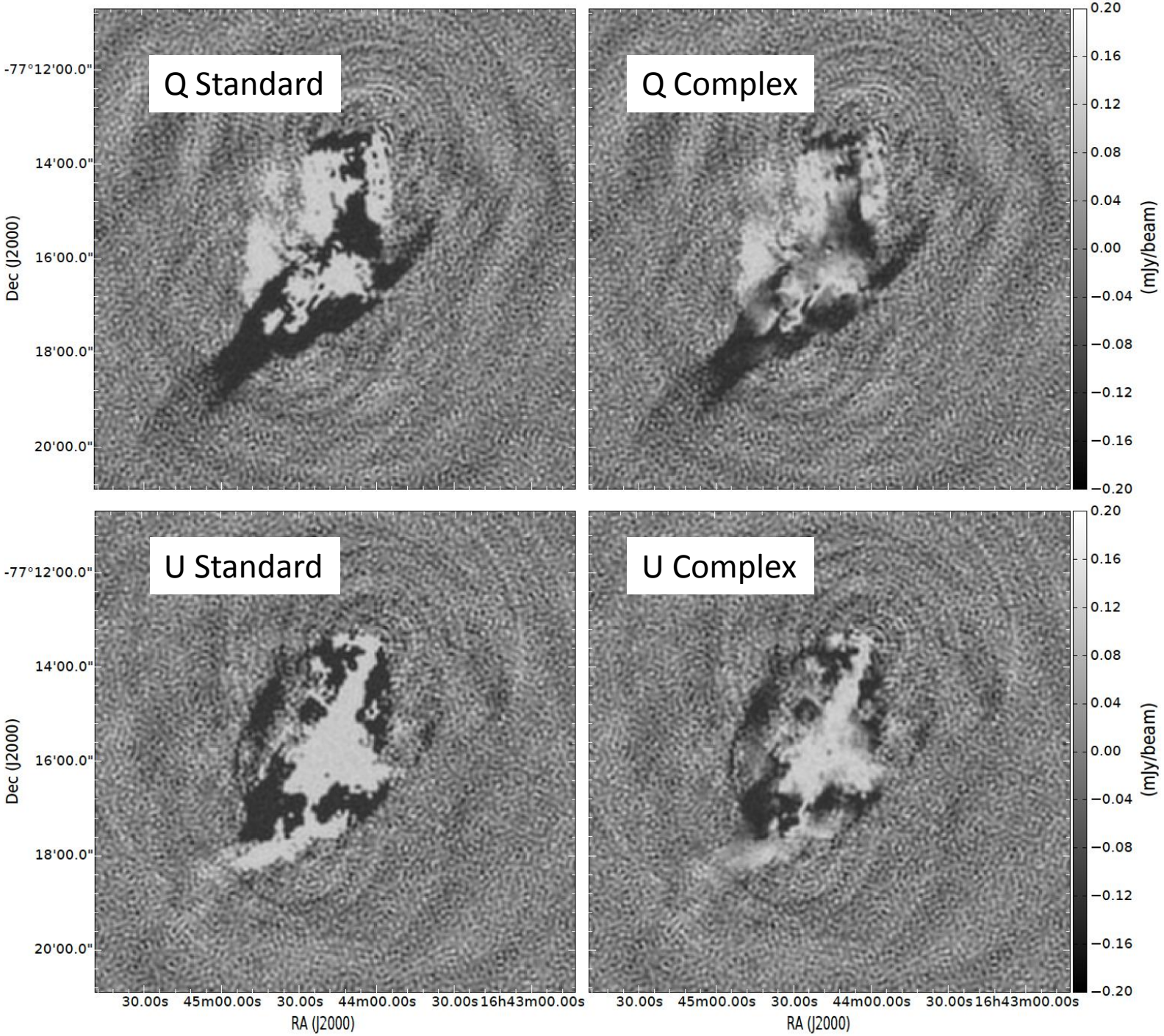
- Standard CLEAN will not select the same components due if the rotation axis is changed. It will not find components when

$$\frac{3}{\sqrt{2}}\sigma < |\mathcal{Q}| \leq 3\sigma \quad \text{and} \quad \frac{3}{\sqrt{2}}\sigma < |\mathcal{U}| \leq 3\sigma\,.$$

- Complex CLEAN will always finds components to the same level eg 3 sigma

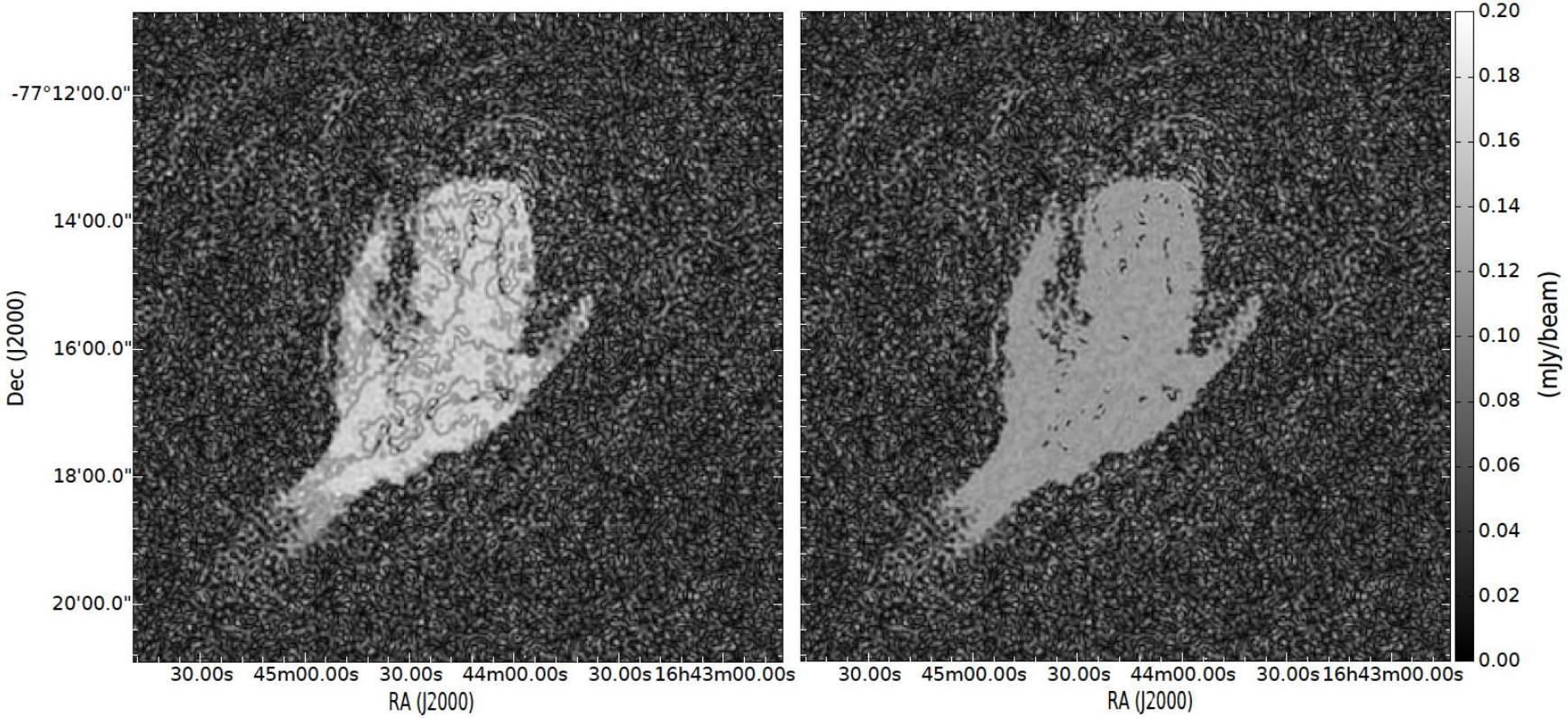



Q Standard
Q Complex
U Standard
U Complex
-77°12'00.0"
14'00.0"
16'00.0"
18'00.0"
20'00.0"
Dec (J2000)
30.00s
45m00.00s
30.00s
44m00.00s
30.00s
16h43m00.00s
RA (J2000)
0.20
0.16
0.12
0.08
0.04
0.00
−0.04
−0.08
−0.12
−0.16
−0.20
(mJy/beam)


Q Standard
Q Complex
U Standard
U Complex
-77°12'00.0"
14'00.0"
16'00.0"
18'00.0"
20'00.0"
Dec (J2000)
30.00s
45m00.00s
30.00s
44m00.00s
30.00s
16h43m00.00s
RA (J2000)
0.20
0.16
0.12
0.08
0.04
0.00
−0.04
−0.08
−0.12
−0.16
−0.20
(mJy/beam)

# Residuals

- Residuals in P go deeper, less spurious components, no canals!



# Conclusions: Polarisation CLEANing

- All current CLEANing algorithms don't deal with Stokes Q and U properly.
- WSClean by Offringa is sufficiently flexible to look for peaks in P (though it was not written to do this particularly, Andre is just a good Dutch generalist).
- SDI is considerably better than Hogbom CLEAN for complex, diffuse polarised sources.
- We have two new tasks in Miriad to do this now: csdi and moscsdi (for the mosaic case).
- See Pratley & Johnston-Hollitt (2016) for details.

# Conclusions: Assumptions & Finding Errors

- We should always challenge assumptions no matter how old
- Should always follow stuff up, and
- Make new types of plots!
- Please use Complex CLEAN for your polarimetry!
- Thanks Ron for making me spend three weeks finding a pointless error, because 20 years later it's still letting me find important ones!