



## Error Recognition aka how you know you have done something dumb

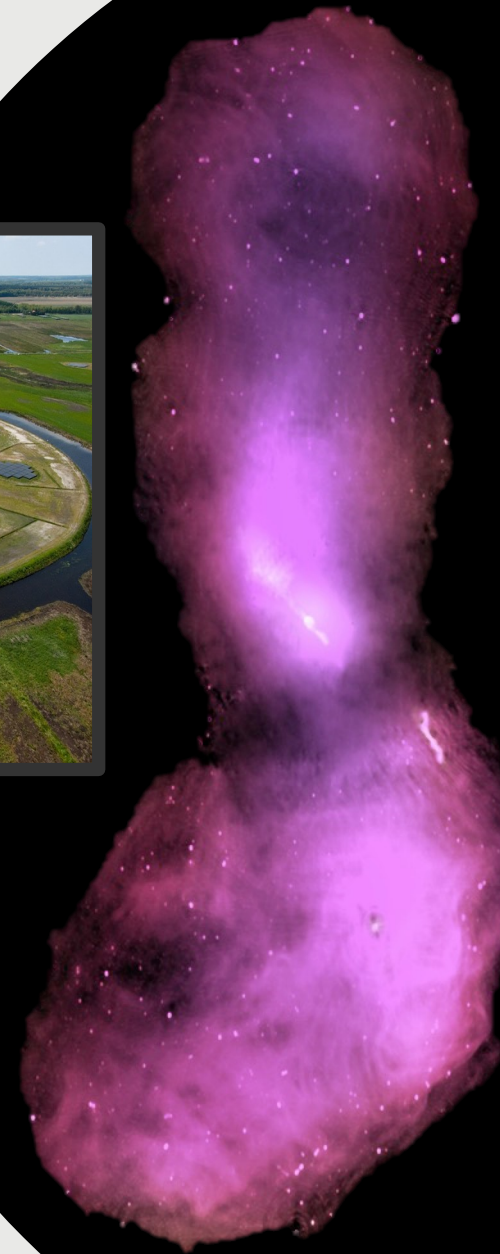
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*7<sup>th</sup> of June 2018*

*Thanks to Ron Ekers and Greg Taylor*



UNIVERSITY OF LEEDS

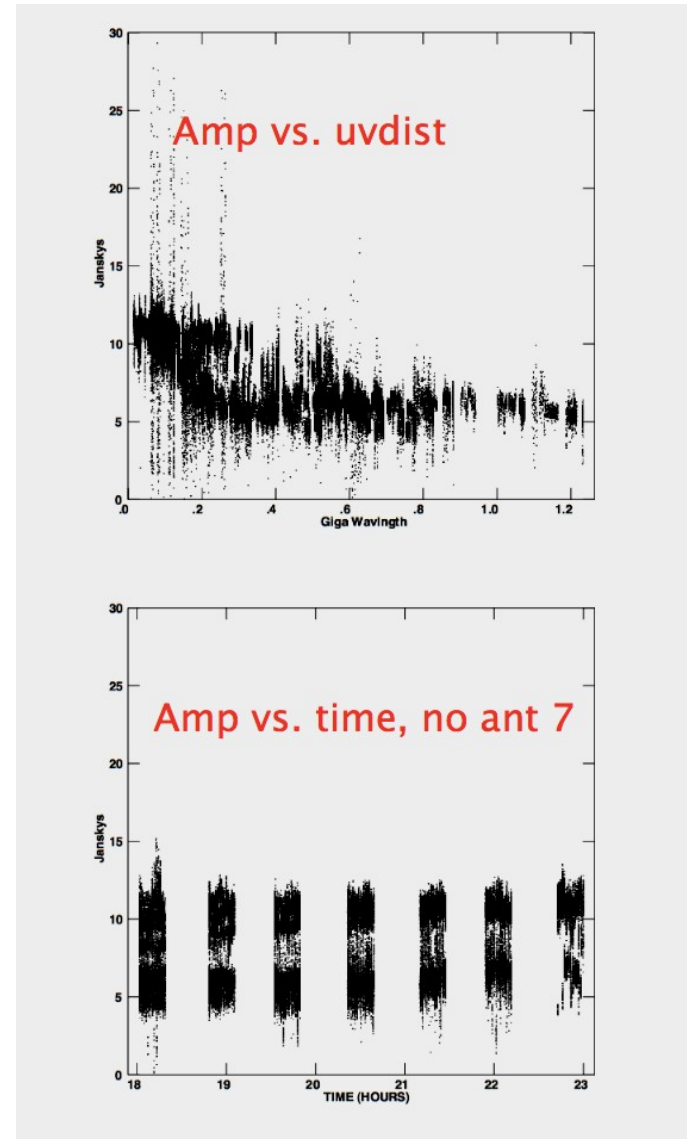
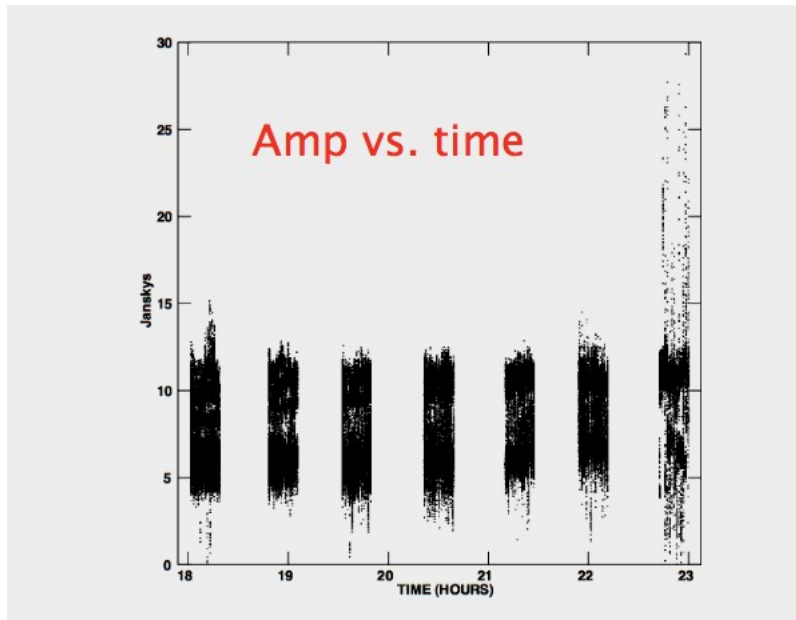
# What went wrong?

- › How do I know I have bad calibration? What is the problem? RFI? Bad phase solution interval? Smearing from averaging?
- › How do I know what is making my image bad?
- › Note that most errors (besides CLEAN) occur in the aperture plane, not image plane



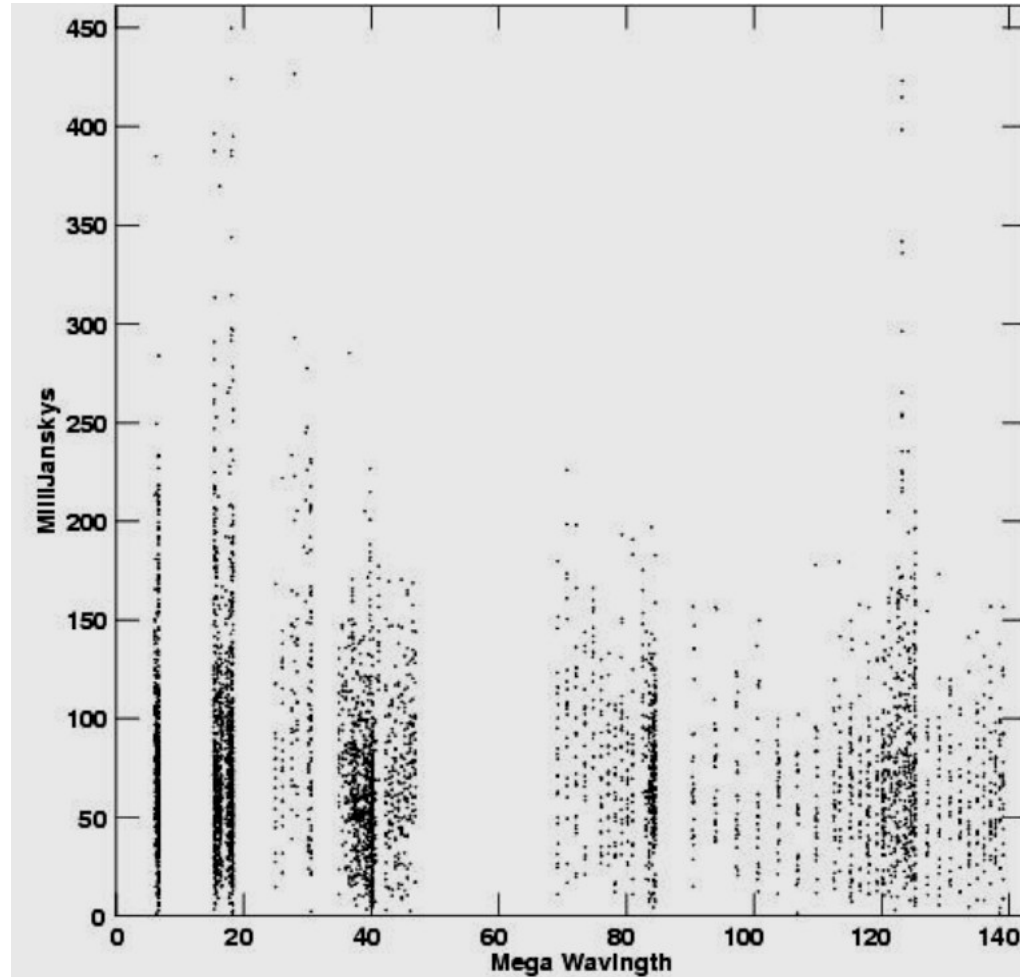
# General Wrongness - calibration

- › Wiggles or gradients in phase, gain versus frequency – INSPECT and look for outliers



# General Wrongness - calibration

- › If faint source, hard to identify outliers. All you can do is quack and remove 3 sigma outlier points



# General Wrongness - image

- › Look for odd structures – such as streaks, rings
- › Symmetric structures are usually a dead giveaway that something is wrong

- $\exp(i\varphi) = \cos\varphi + i\sin\varphi$ 
  - Real & Even  $\Leftrightarrow$  Real & Even
  - Real & Odd  $\Leftrightarrow$  Imag & Odd

**Symmetric image errors are often due to amplitude errors**

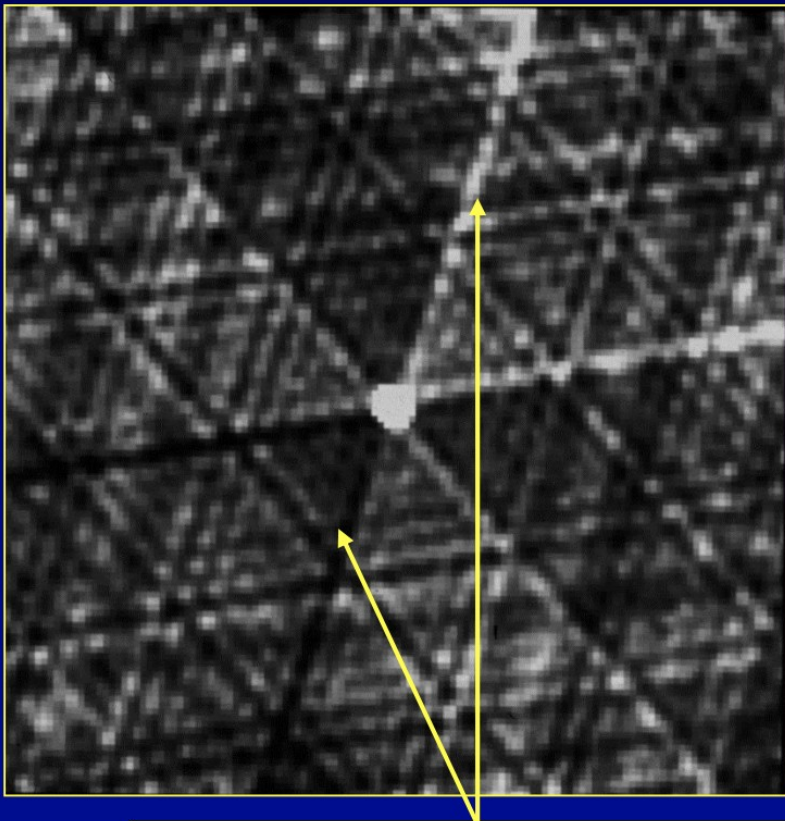
**image errors with odd symmetry or asymmetric often due to phase errors**



## Phase and amp error

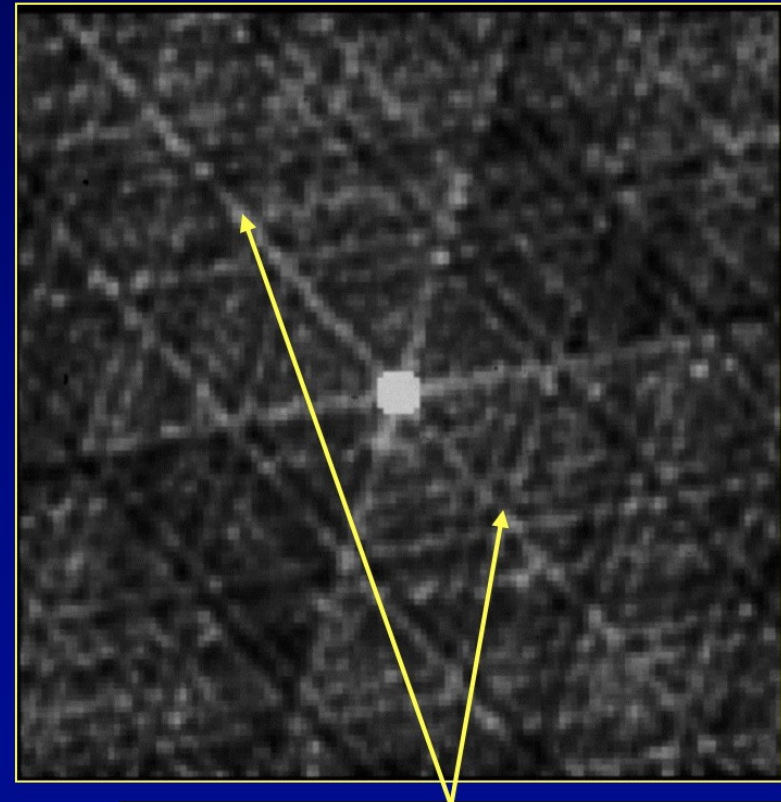
- › Can not get rid of beam pattern despite CLEANing deep enough (short burst of bad data – just a bad scan)

### 10 deg phase error



anti-symmetric ridges

### 20% amp error

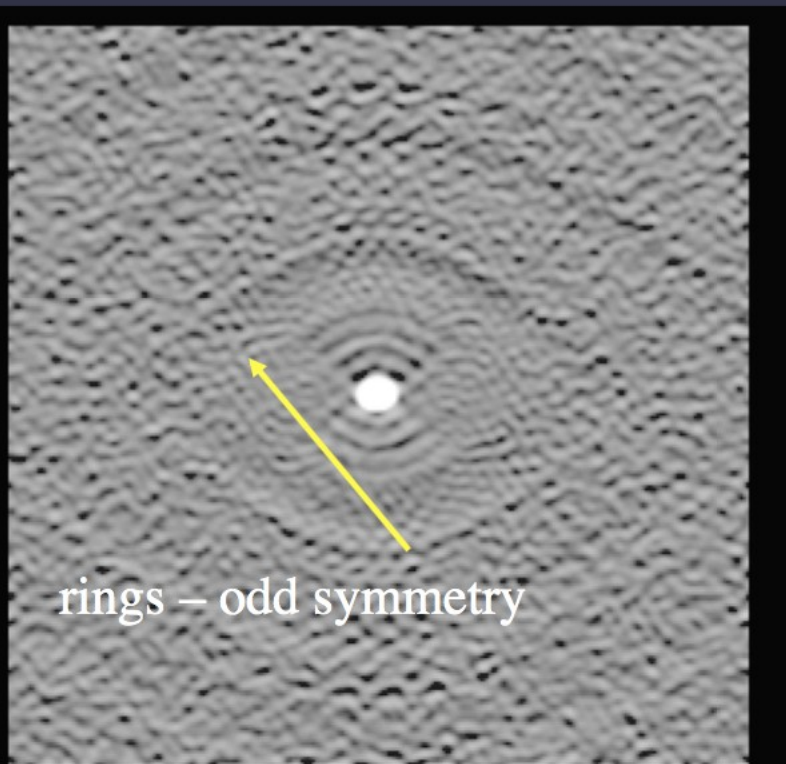


symmetric ridges

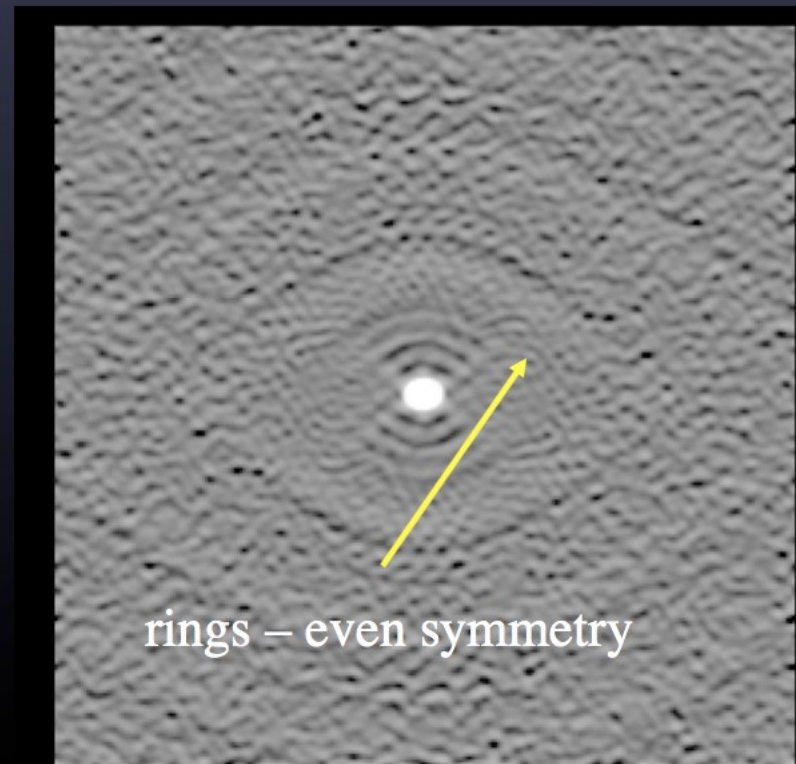
# Persistent errors over most of observations

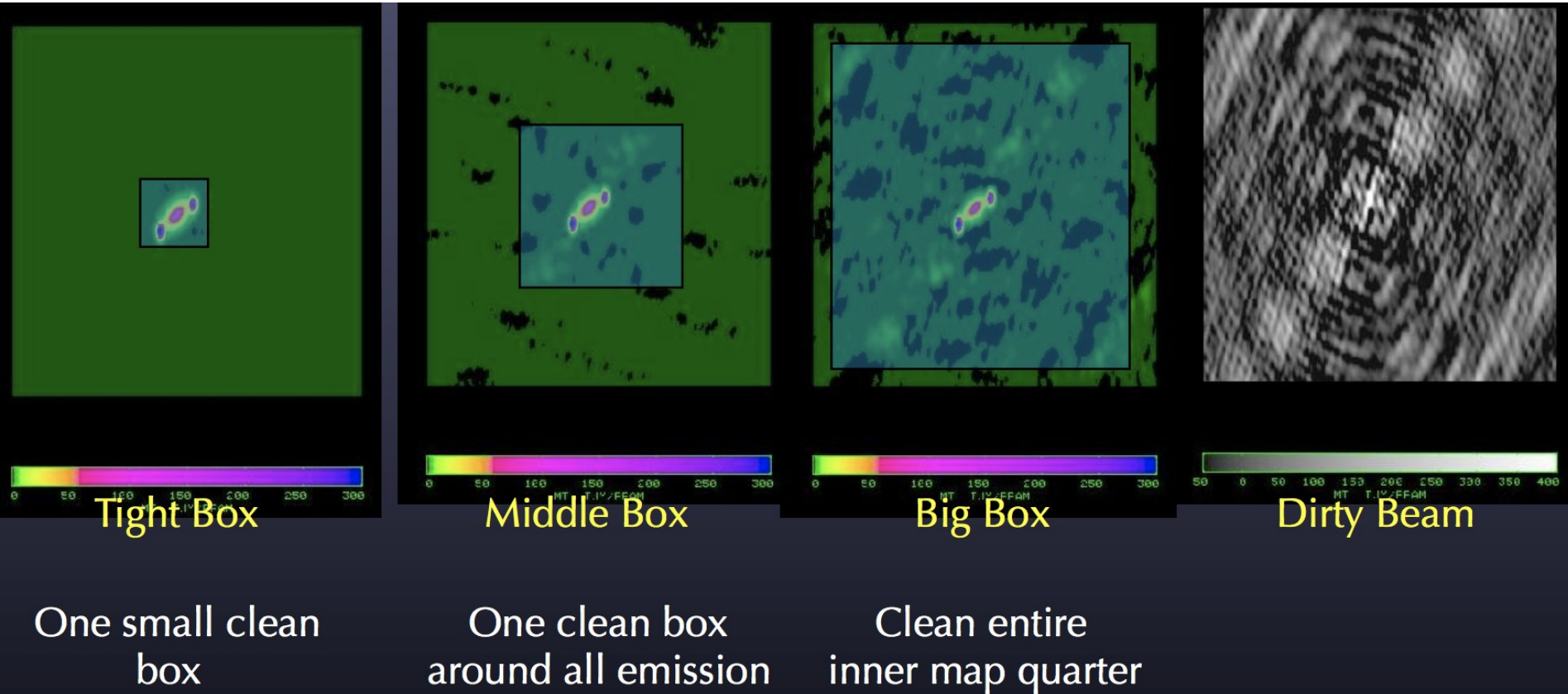
NOTE: 10 deg phase error to 20% amplitude error  
cause similar sized artifacts

10 deg phase error for  
one antenna all times  
rms 2.0 mJy



20% amp error for one  
antenna all times  
rms 2.3 mJy



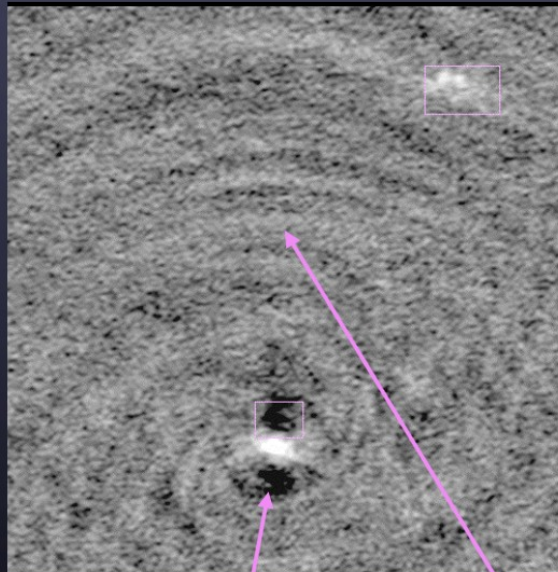


*Make box as small as possible to avoid cleaning noise interacting with sidelobes*



## Under/over cleaning

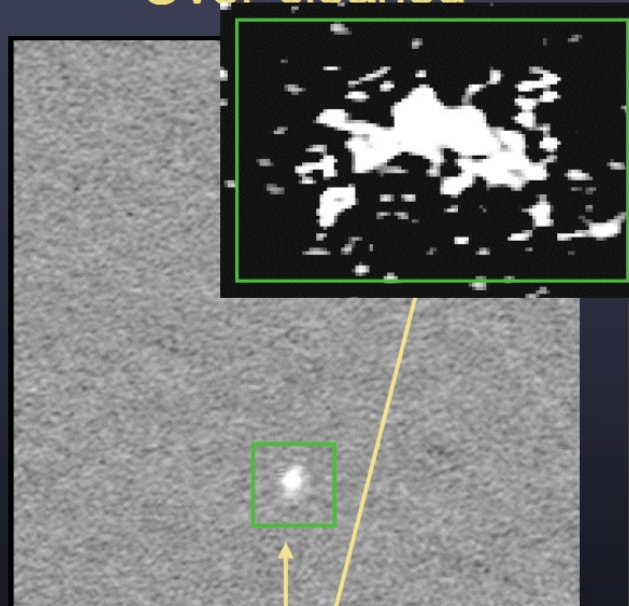
Under-cleaned



Residual sidelobes  
dominate the noise

Emission from  
second source sits  
atop a negative "bowl"

Over-cleaned



Regions within  
clean boxes  
appear "mottled"

Properly cleaned



Background is thermal  
noise-dominated;  
no "bowls" around  
sources.

# General Rule of Thumb

- › 5 sigma to believe structure and you should reach 3 to 5 times the theoretical predicted noise level

$$S_{rms} = \frac{2kT_{sys}}{A_{eff} \sqrt{N_A (N_A - 1) t_{int} \Delta \nu}}$$

- › Error artefacts can be additive or multiplicative

- some errors add to visibilities

$$V + \epsilon \Leftrightarrow I + \mathcal{F}\epsilon$$

- others *multiply* or *convolve* visibilities
  - multiplication  $\Leftrightarrow$  convolution in conjugate planes

$$V \epsilon \Leftrightarrow I * \mathcal{F}\epsilon$$

- convolution  $\Leftrightarrow$  multiplication in conjugate planes

$$V * \epsilon \Leftrightarrow I \mathcal{F}\epsilon$$

$$V + \epsilon \Leftrightarrow I + \mathcal{F}\epsilon$$

- adds to visibilities  $\Leftrightarrow$  adds to image
  - unconnected to real sources in the image
  - may make “fake” sources
- sources of additive errors:
  - noise
  - Interference (RFI, cross talk)
  - Sources outside beam (confusion, sun)
  - DC offsets



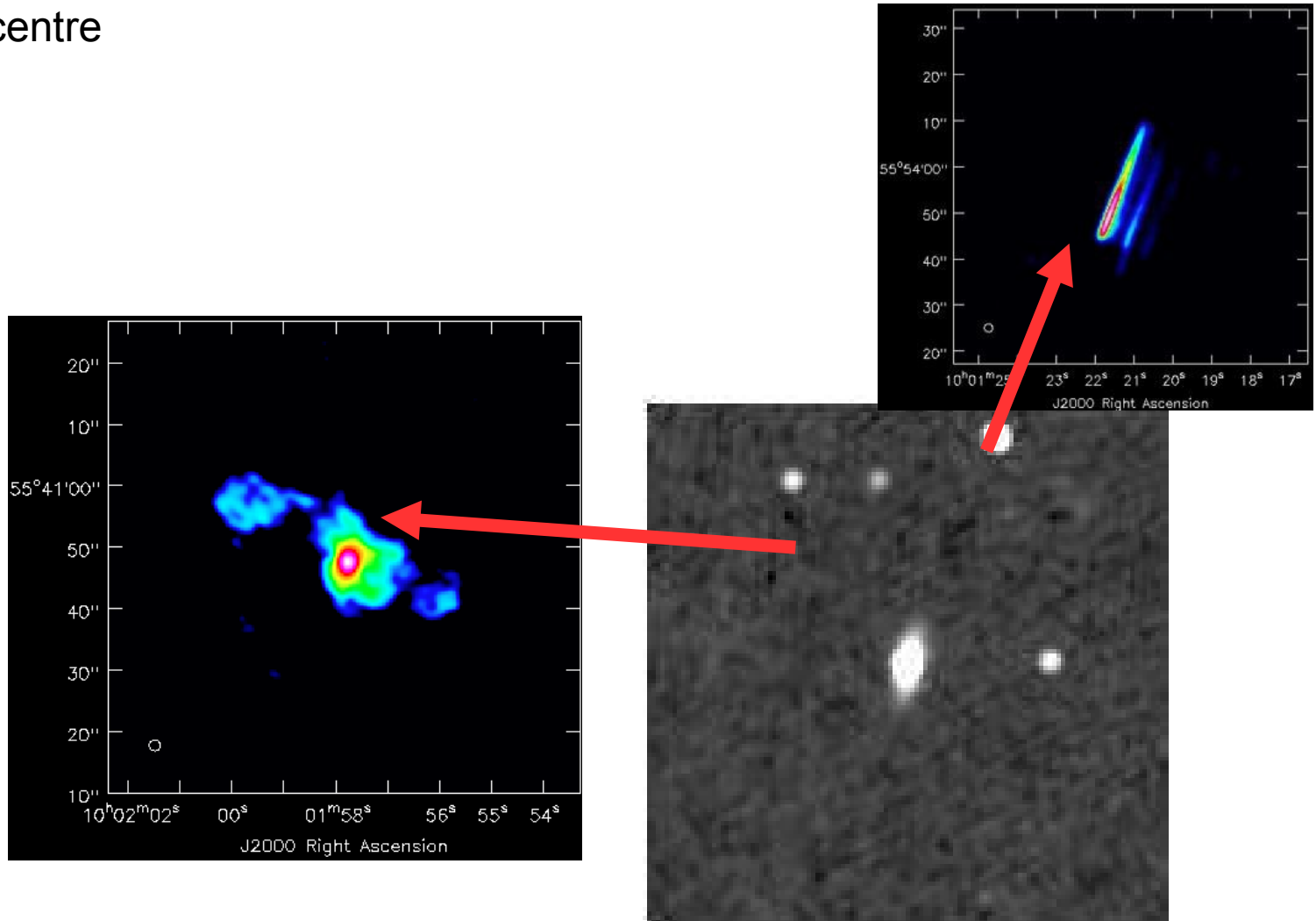
$$V \epsilon \Leftrightarrow I * \mathcal{F} \epsilon$$

$$V * \epsilon \Leftrightarrow I \mathcal{F} \epsilon$$

- others *multiply* or *convolve* visibilities
  - multiplication  $\Leftrightarrow$  convolution in conjugate planes
    - » examples - **multiplicative**: sampling, gain errors, atmosphere, missing spacings
    - » Examples - **convolution**: primary beam, gridding

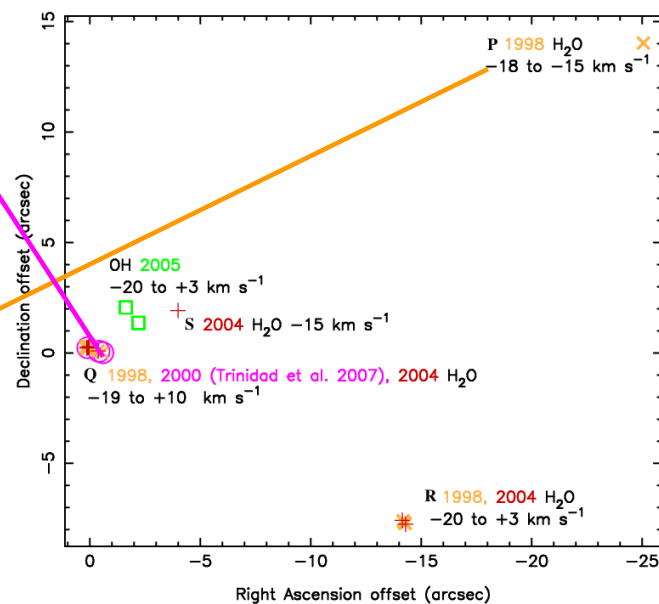
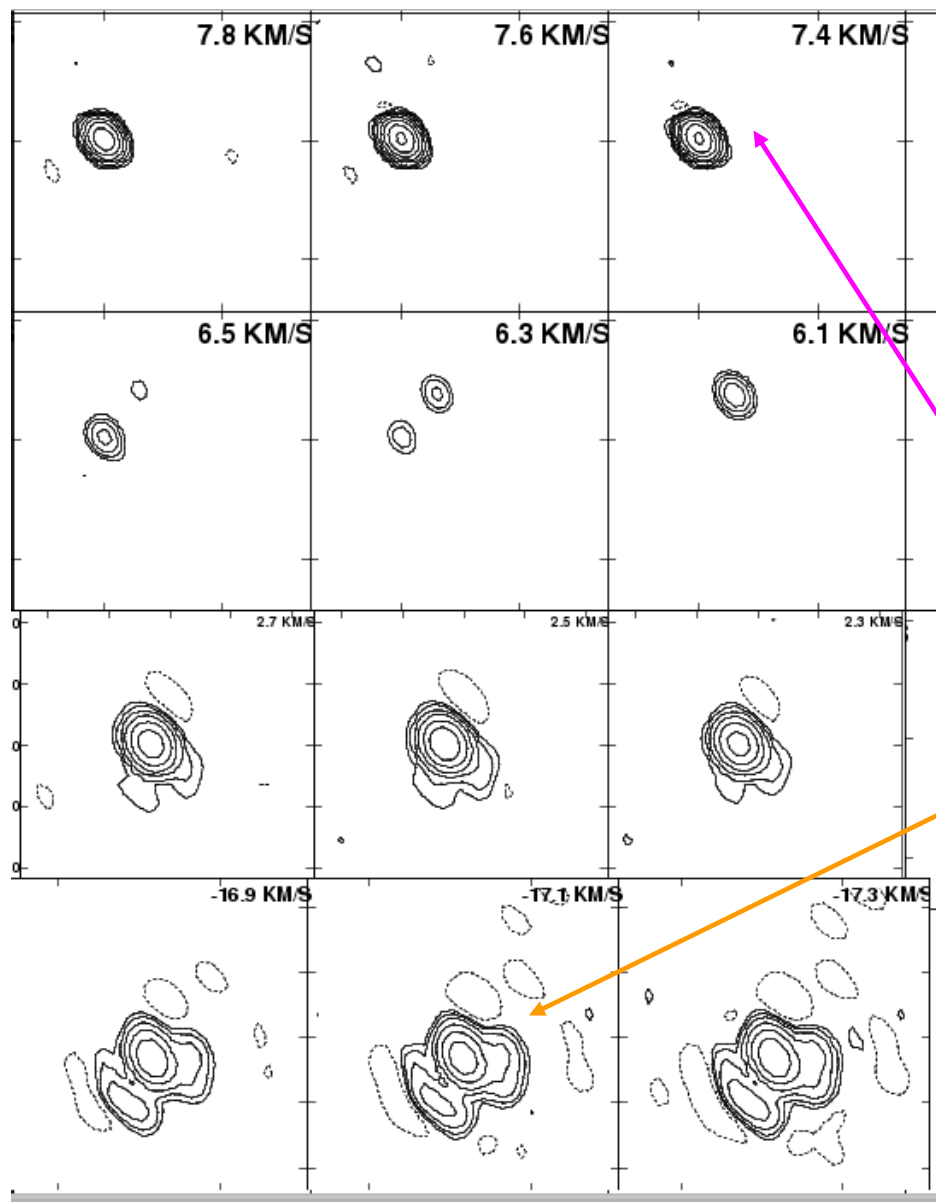
# Smearing

- › If you average in time or bandwidth too much, sources away from your pointing centre will be smeared, with it worse the more you average or further from the pointing centre



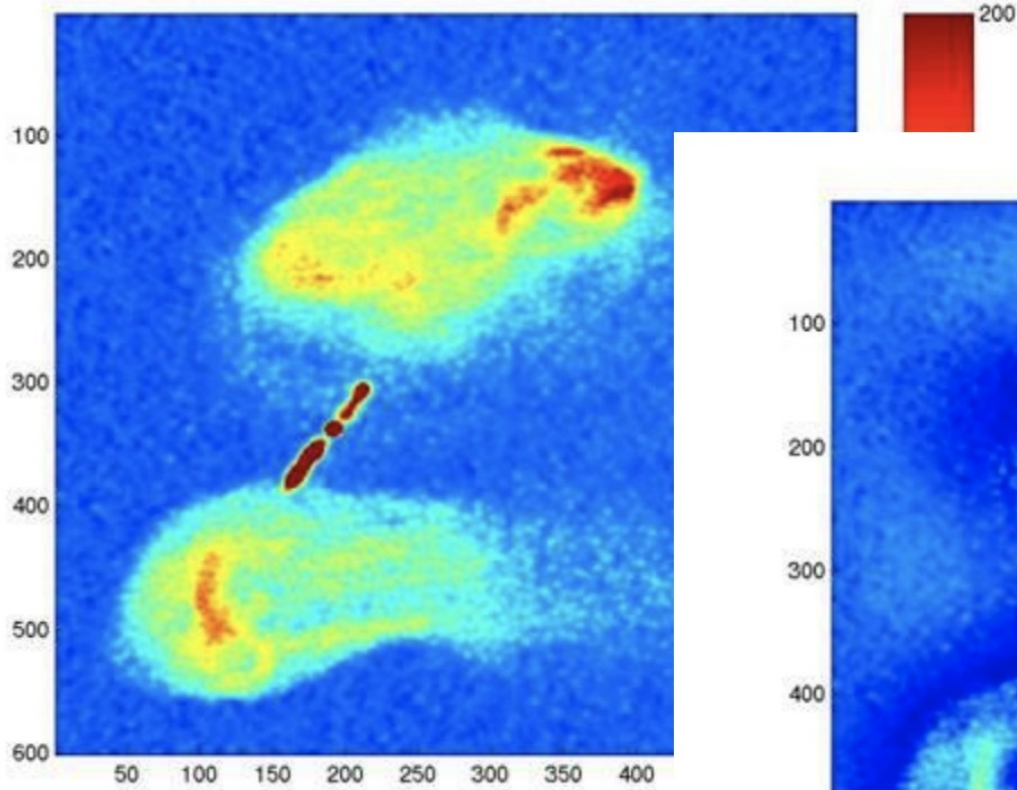
# Time Smearing

› Tangential

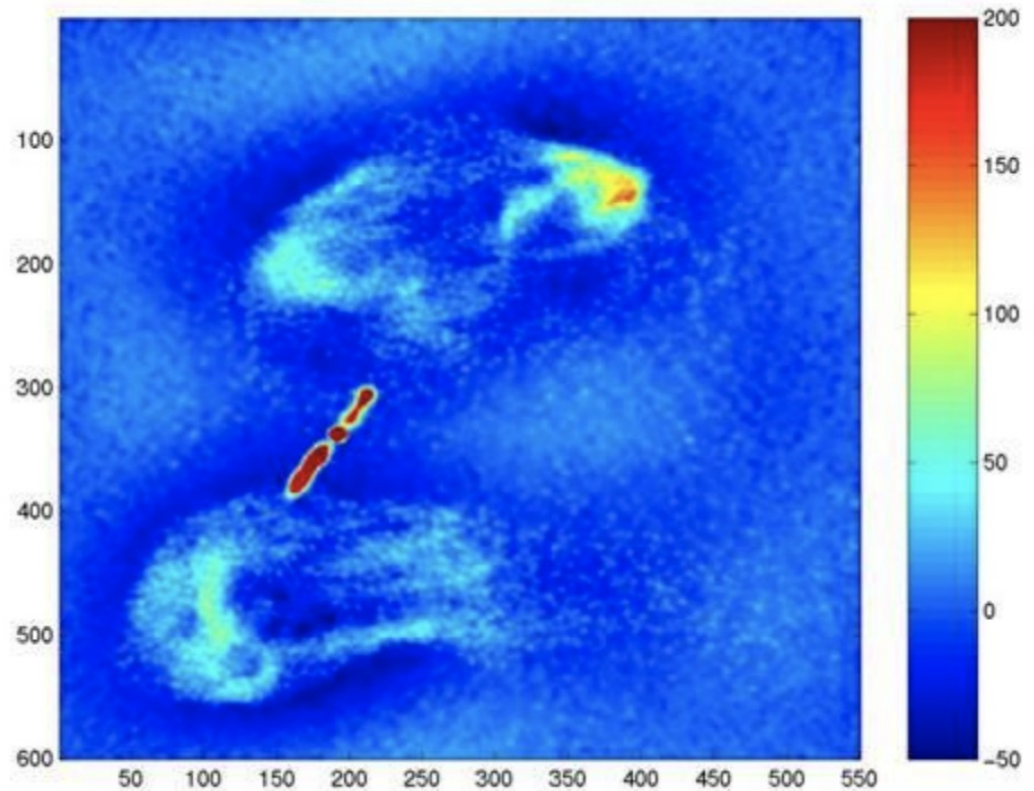


## Missing short baselines

# ASTRON



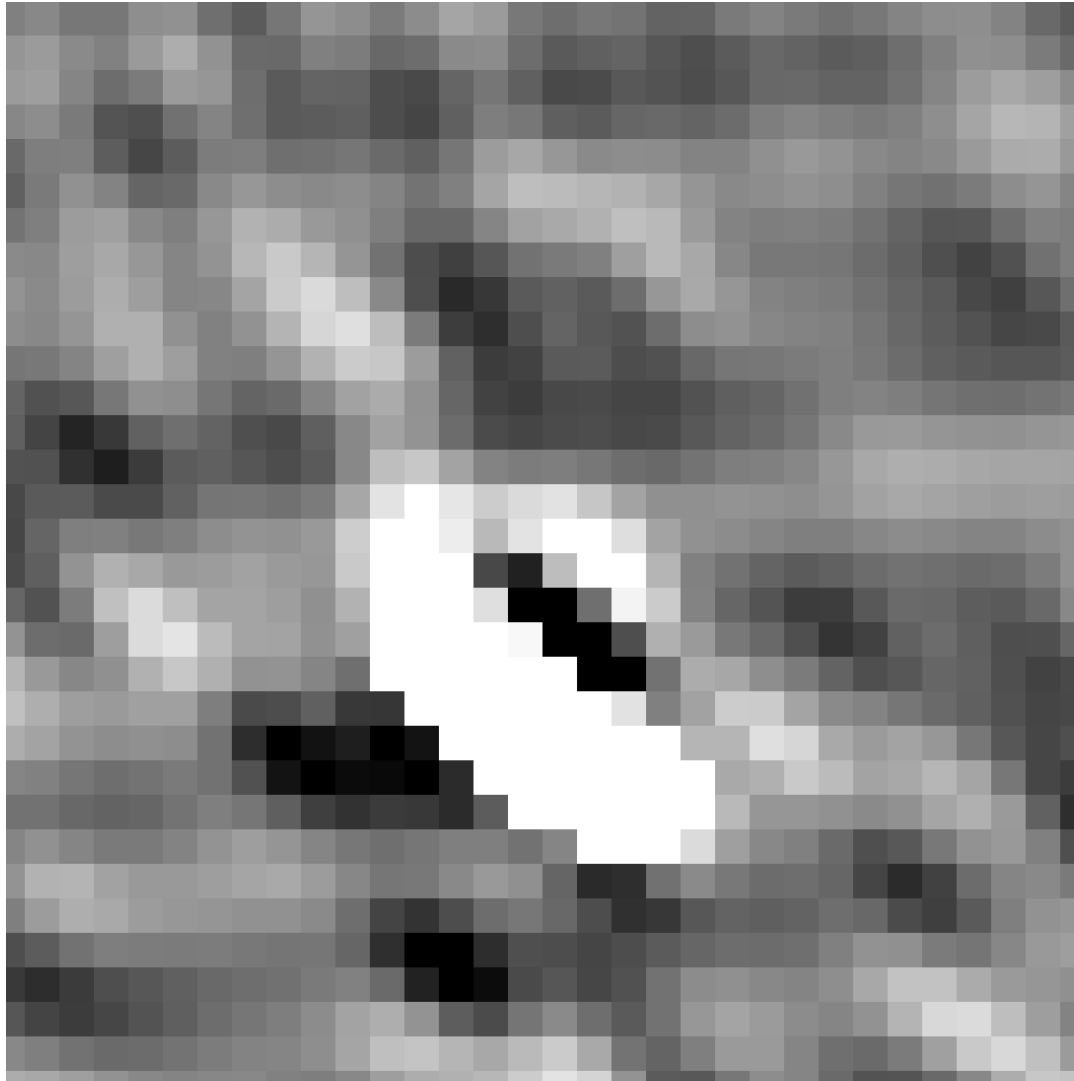
No short baselines →





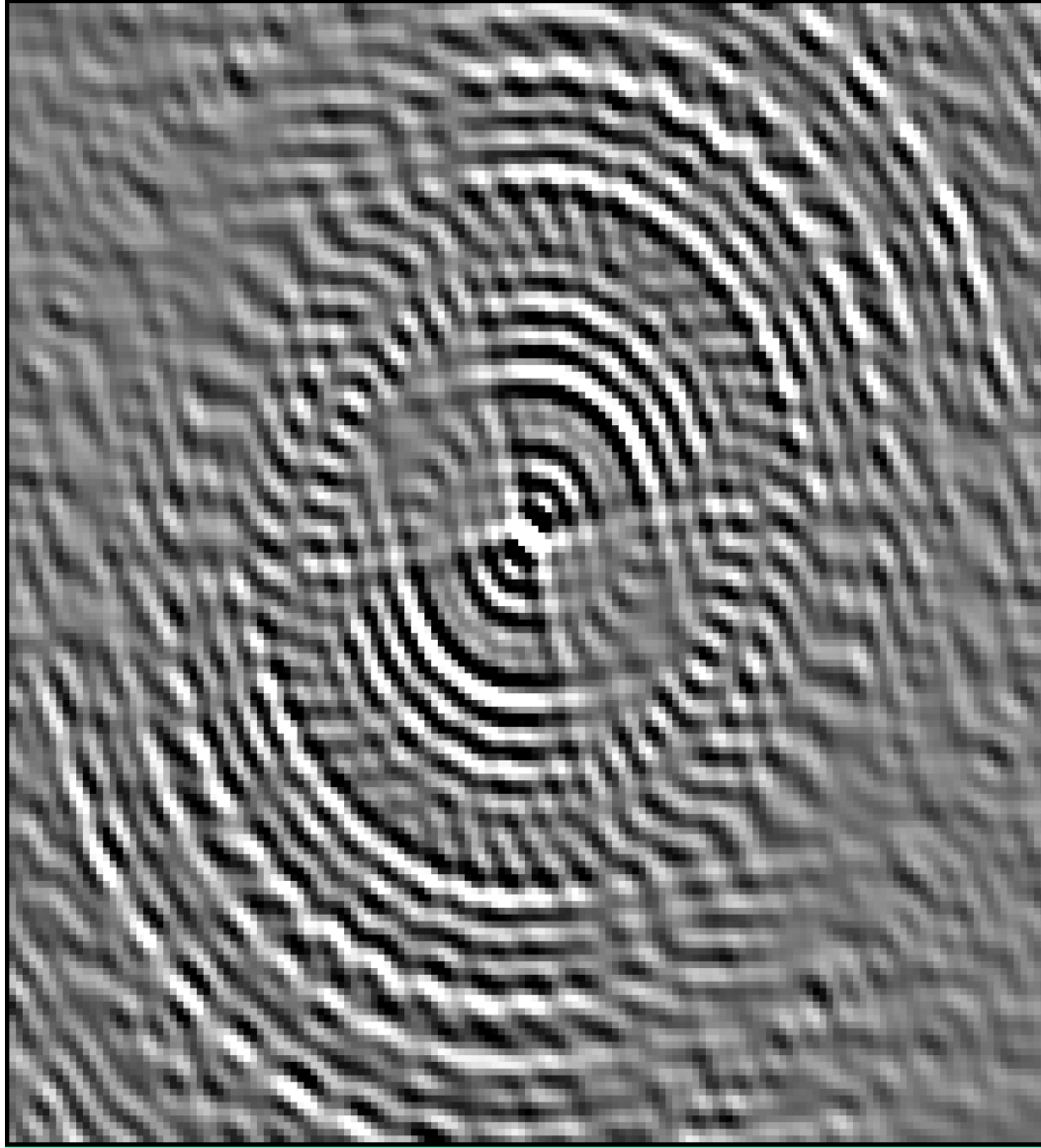
## Example of sleuthing

- › Source that could be being resolved but weird shape and negative feature:



## Example of sleuthing

› Beam



## Example of sleuthing

- › Worried could be overcleaning, clean box too large, or phase error.
- › Doing one iteration of phase self-cal, source disappears and main source straightens up



# Conclusions and tips

- › u-v plane
  - Look for outliers
  - Check gains and phases
  - Look for residuals (data – model)
- › Image plane
  - Do the defects look like the dirty beam?
  - Additive or multiplicative?
  - Symmetry properties?
  - Relate to possible data errors
  - Deconvolution problems

