Residual Fringe Subtraction to Mitigate Direction Dependent Errors

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Overview

- Introduction
- Direction- and time-dependent errors
- Fringes in the residual visibility plane
- Fringe subtraction
- Conclusion

RFI Mitigation

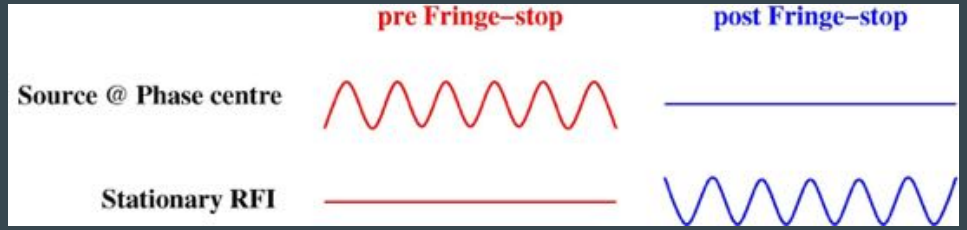
- Persistent, strong, broad band RFI at GMRT 150 MHz.
- Used RfiX (RFI Excision; Athreya, 2009) to get rid of most RFI

... while salvaging the observed visibilities.

- Improved image noise from ~2.5 mJy to ~0.7 mJy

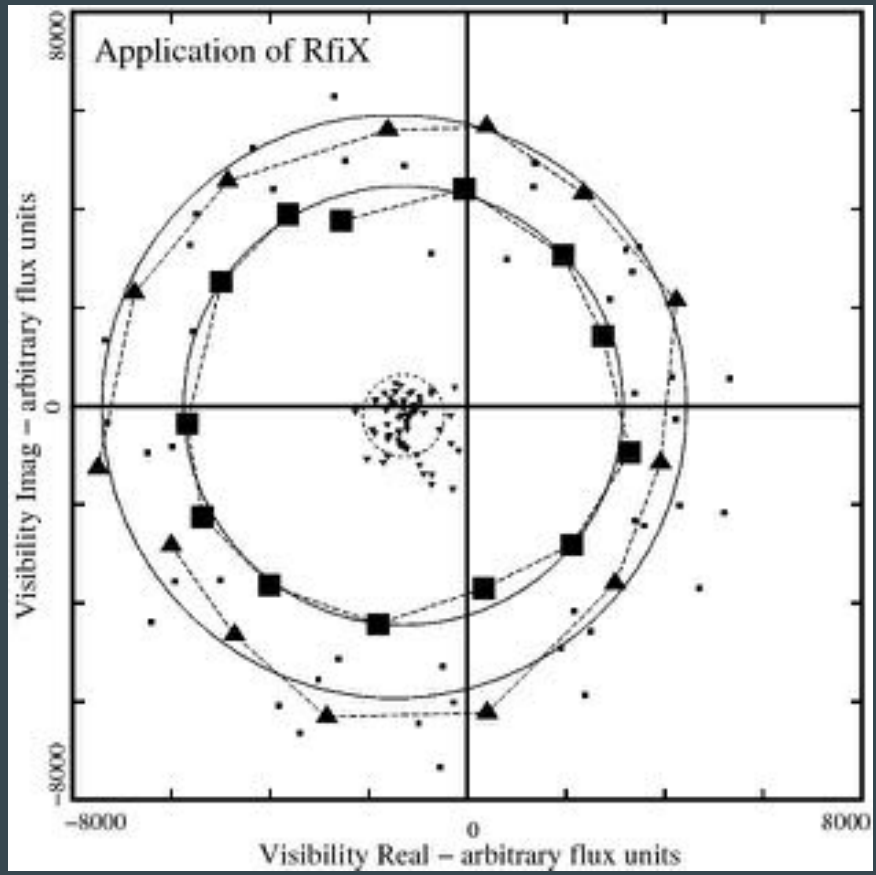
... routinely and with relative ease

RFI Mitigation - RfiX (2009)



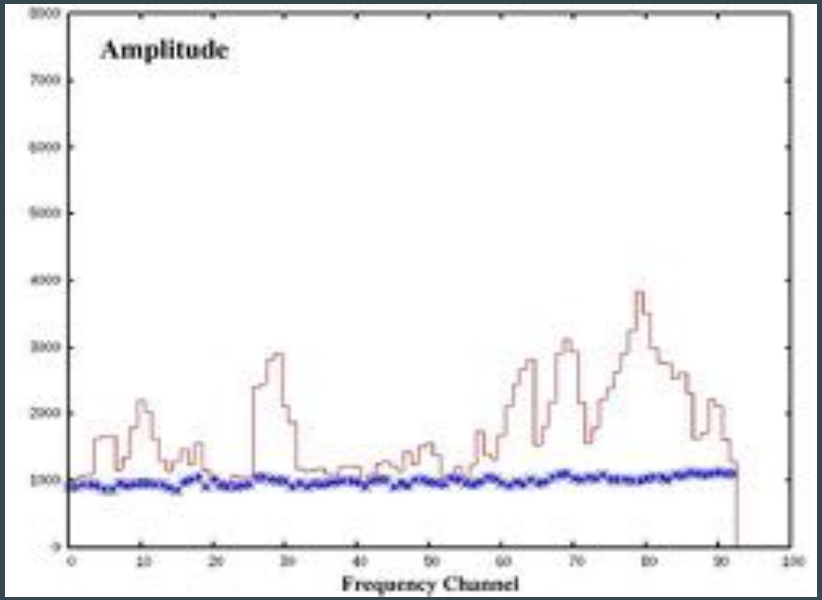
RFI causes the visibility vector to describe a circle as a function of time on the complex visibility plane.

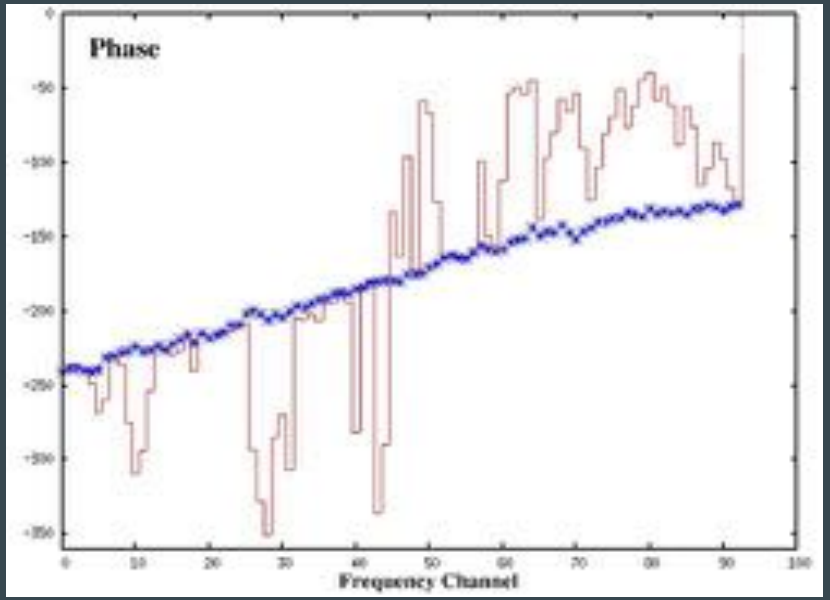
Circle centre ⇛ True visibilities



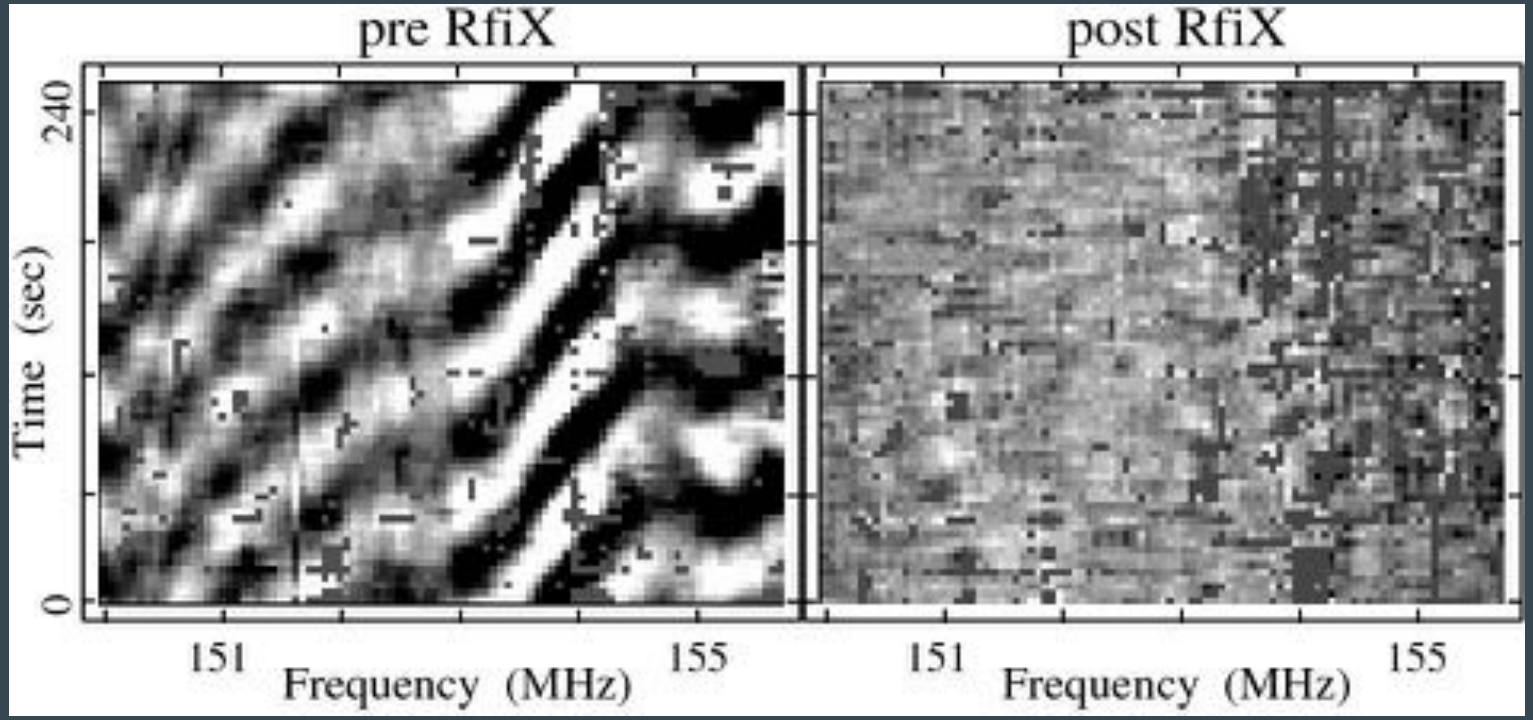
RFI Mitigation - RfiX (2009)

RfiX recovers true visibilities (blue)
even in the presence of very strong, broad and narrow band RFI (red)





RFI Mitigation - RfiX (2009)



RFI Mitigation

After mitigating most of the RFI

We reduced image noise from ~2.5 mJy to ~0.7 mJy

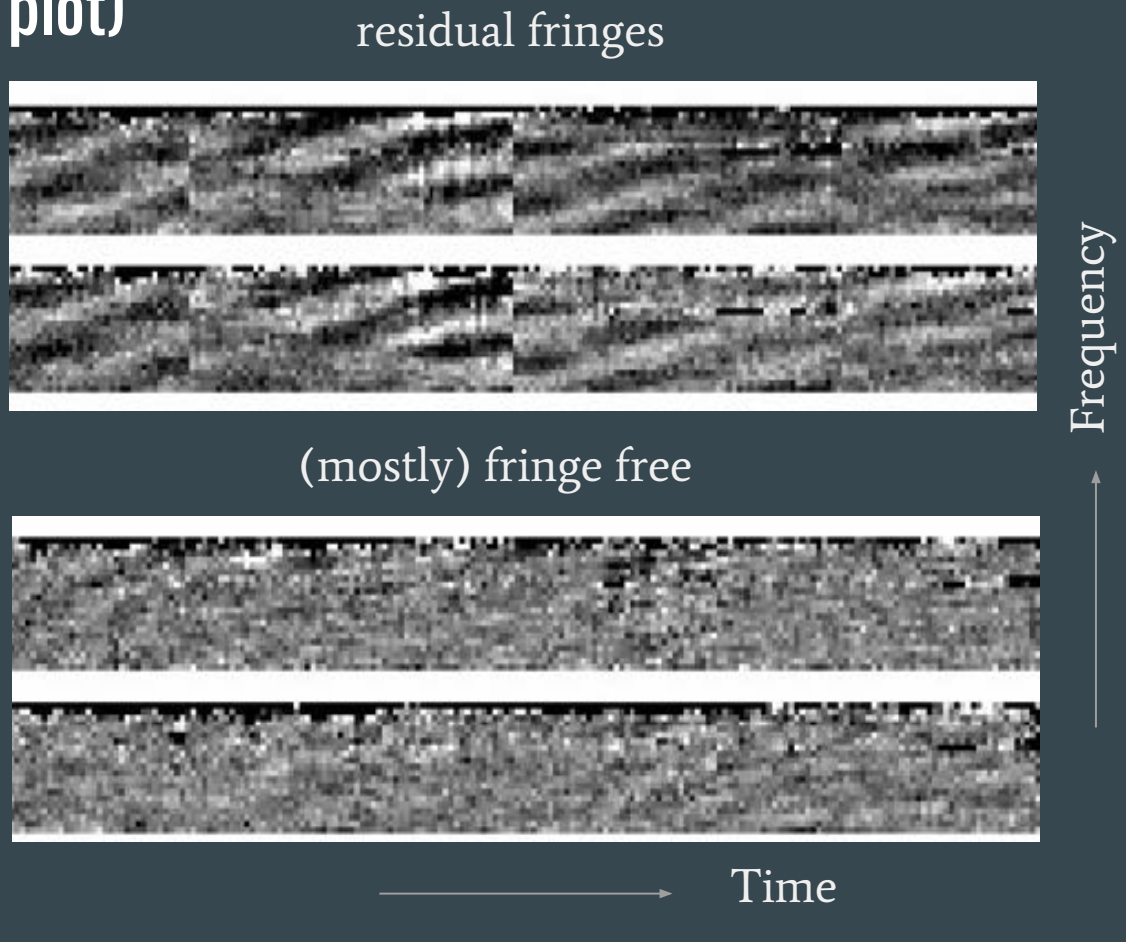
But could not go below 0.7 mJy

(confusion limit ~ 0.2 mJy for GMRT 150 MHz)

Residual UV (time-channel plot)

Post CLEAN :
Residual UV
time-channel plane
showed RFI-like
structure.

However, turned out
to be not RFI.

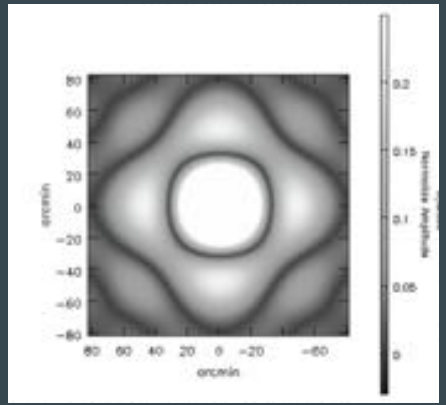


Baseline errors - direction and time dependent

Cannot be decomposed into antenna gains - no self-cal correction

Several causes :

- Primary beam effect
  - azimuthal asymmetry
  - pointing jitter
- Non-isoplanatic ionosphere
- Baseline dependent gain fluctuations
- Selfcal spreads baseline-based errors of a few into many others



(from Bhatnagar et al., 2008)

Residual Fringes

- CLEAN subtracts a time-invariant source during deconvolution.
- The time- and direction-dependent source errors introduce time-variable and baseline-dependent fringes in the residual visibilities.
- These fringes are essentially the under-subtracted or over-subtracted flux from the strongest sources in the field.

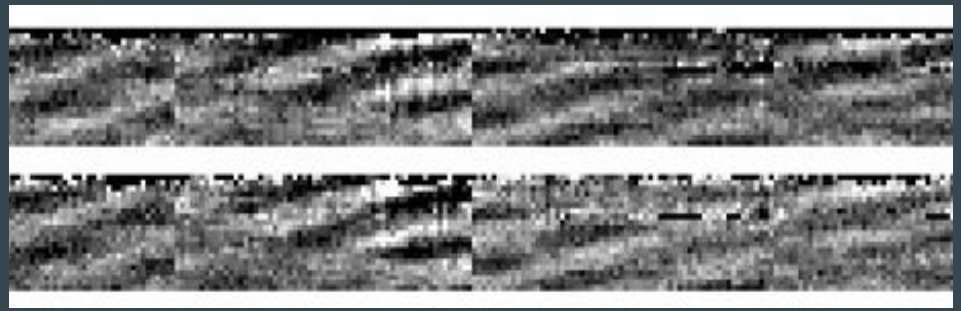
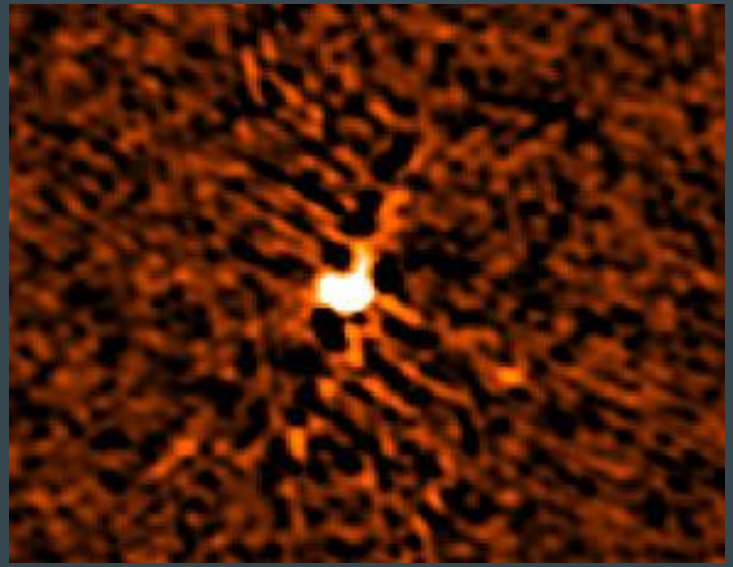


Image Plane

- Distorted structure - most obvious in strong sources
- Many spurious peaks around strong sources
- Large noise systematics throughout the image



Reduces the detectability of faint sources

Fringe Subtraction - Prescription

- Subtract such fringes baseline-by-baseline, channel-by-channel
- Constrain the subtraction model to the
  - calculated value from a few of the strongest sources
  - amplitudes much higher than the strongest unCLEANed sources
- This will avoid subtracting genuine faint sources in the visibilities

Fringe Subtraction

Note:

- Not error-correction through calibration!
- (Strong) source structures dynamic range may not improve

Reduction of noise floor for detection of faint sources

Fringe Subtraction

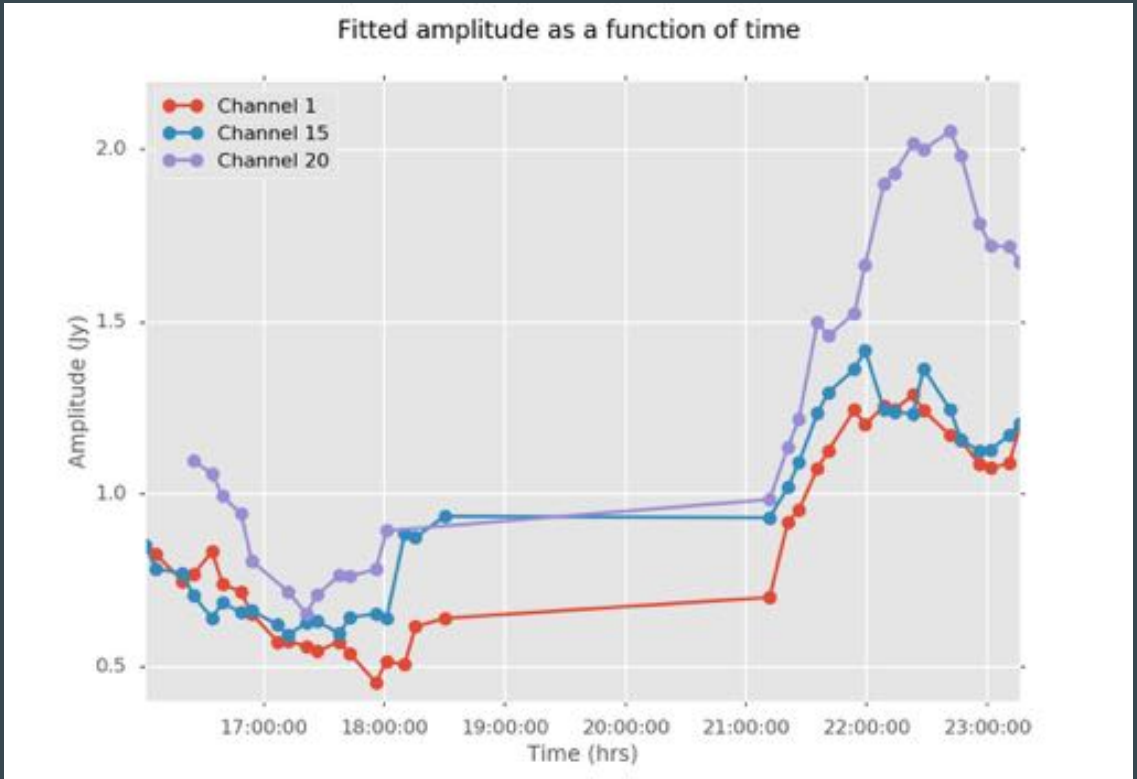
Before defringing

After defringing

Frequency

Time

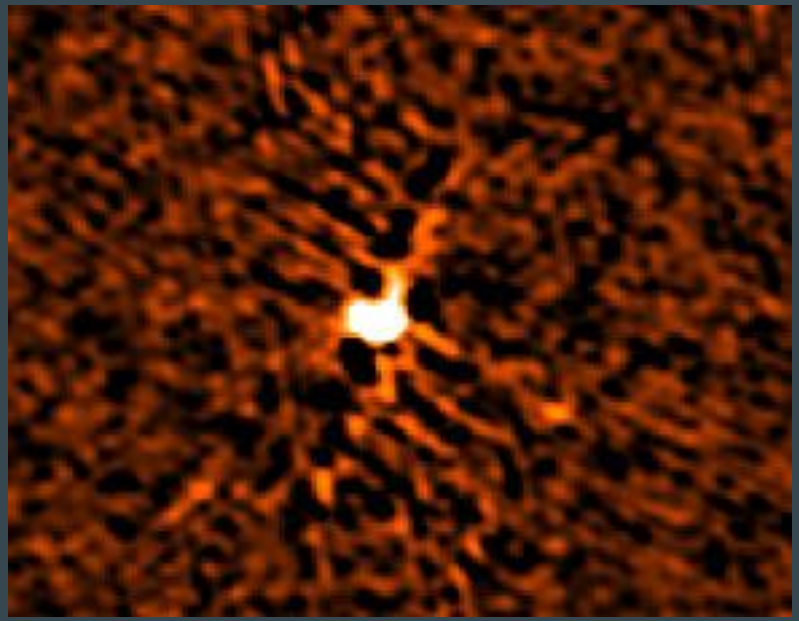
Fringe Subtraction - Amplitude vs. Time



Single source single baseline (similar pattern in 3 different channels)

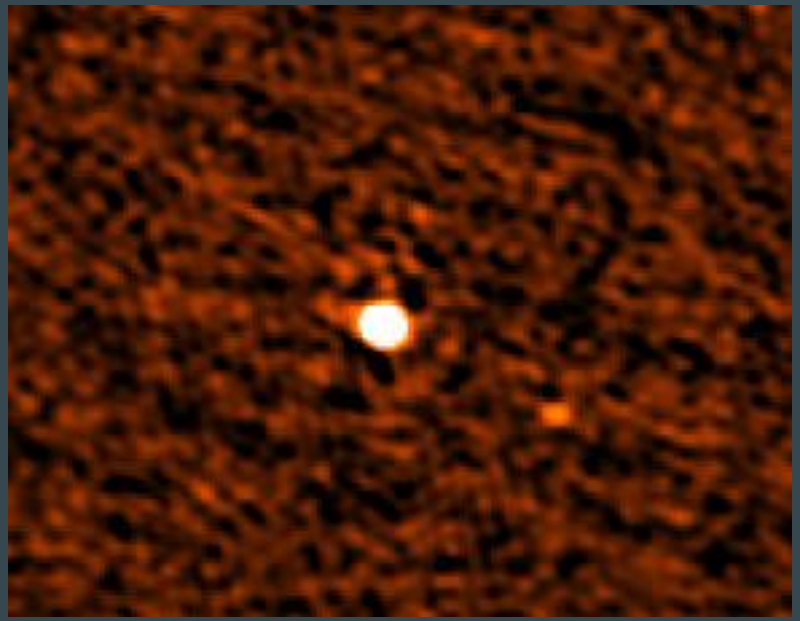
We fit only one source model at a time.

Fringe Subtraction



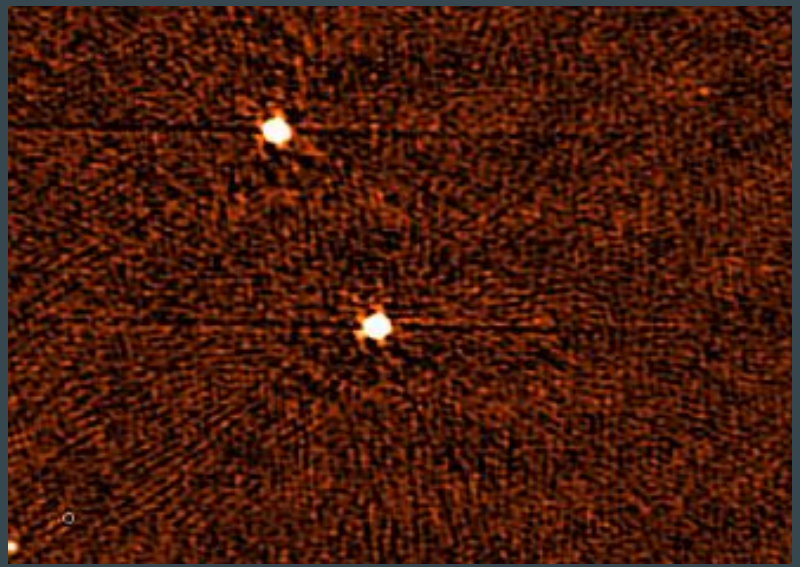
S = 0.246 Jy
σ = 1.65 mJy

~ 30 % improvement



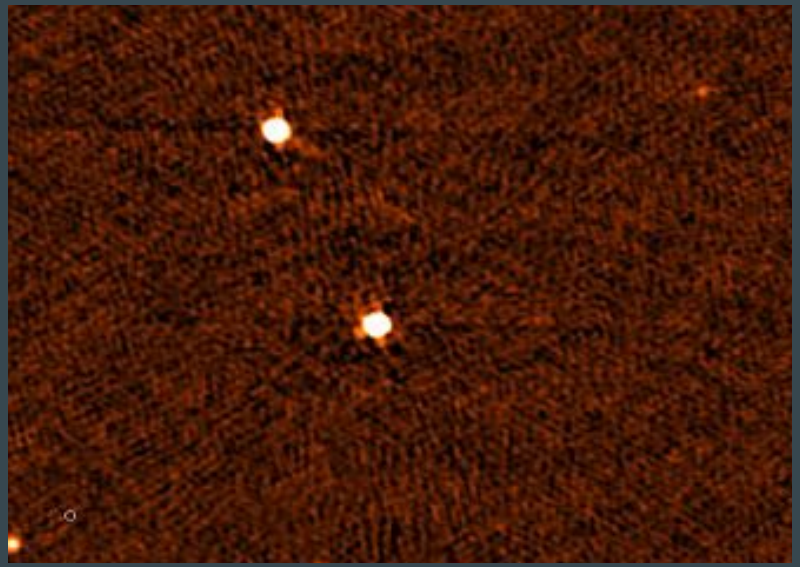
S = 0.250 Jy
σ = 1.13 mJy

Fringe Subtraction

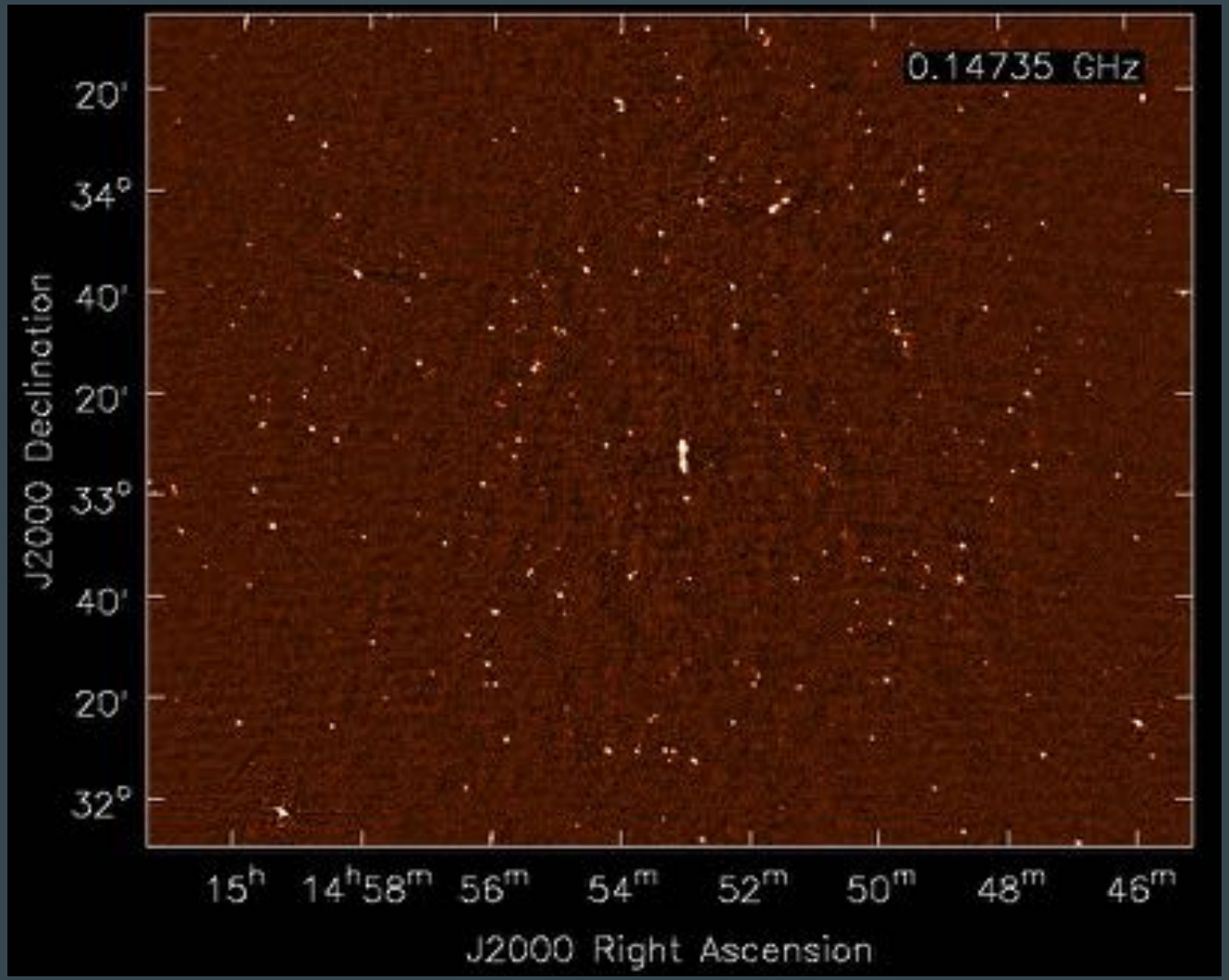


S_1 = 0.420 Jy; S_2= 0.502 Jy
σ = 0.70 mJy

~ 40 % improvement



S_1 = 0.424 Jy; S_2= 0.507 Jy
σ = 0.40 mJy



Before:
σ = 0.70 mJy
(not shown)

~ 35 % improvement

After:
σ = 0.45 mJy
(shown on left)

Summary

- Residual fringes in the visibilities due to apparent source variability.
- Subtracting these fringes reduces the noise floor in the image
- However, source structure source doesn't improve - improves detectability of faint emission
- Computationally, conceptually simple
    - Beam/ionosphere/sky model not required
    - Only (strong) source positions
- Results in a 30 - 40 % improvement in rms noise and systematics.

Thank You

I would like to thank the organizers for partial support to attend this meeting.