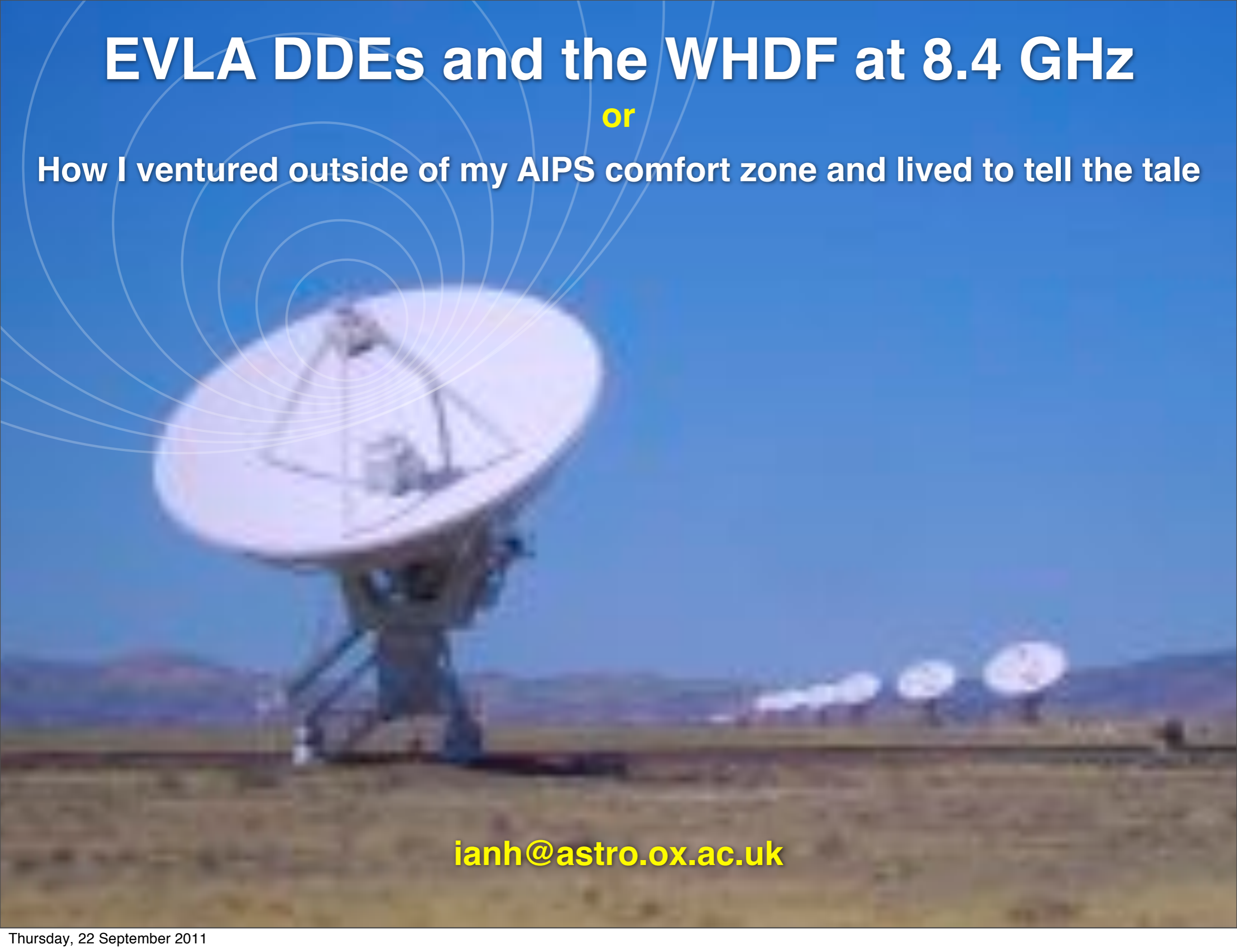


# EVLA DDEs and the WHDF at 8.4 GHz

or

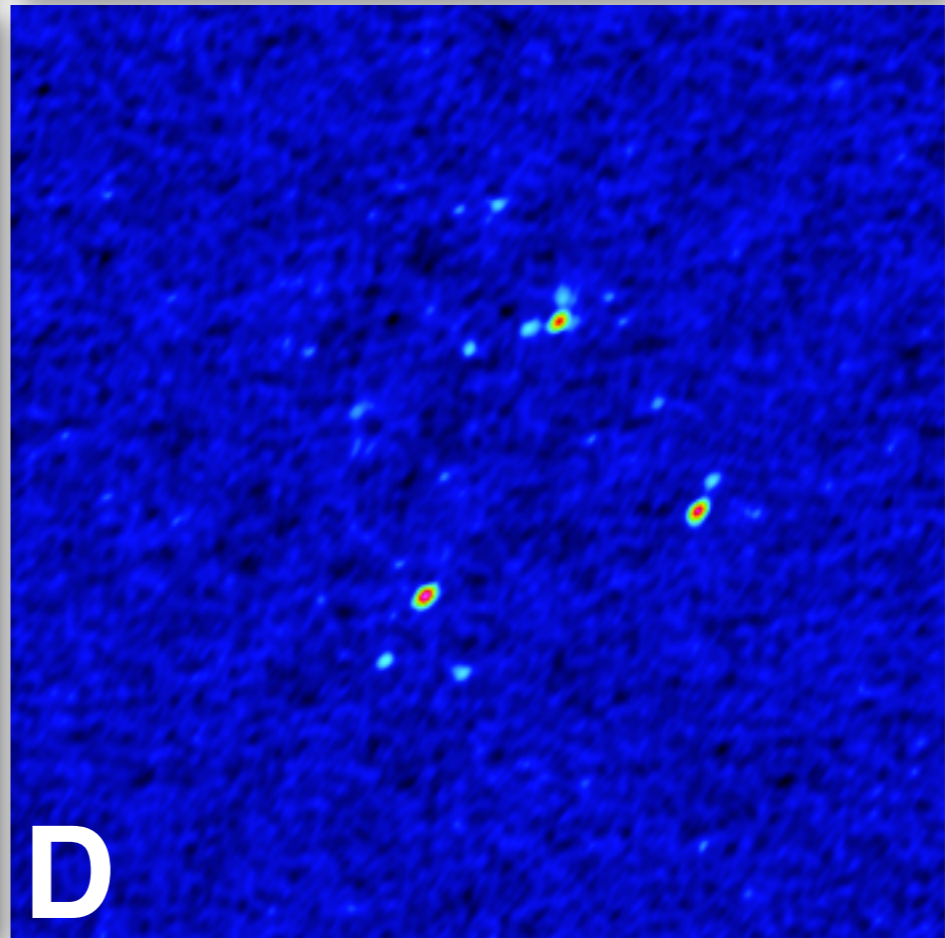
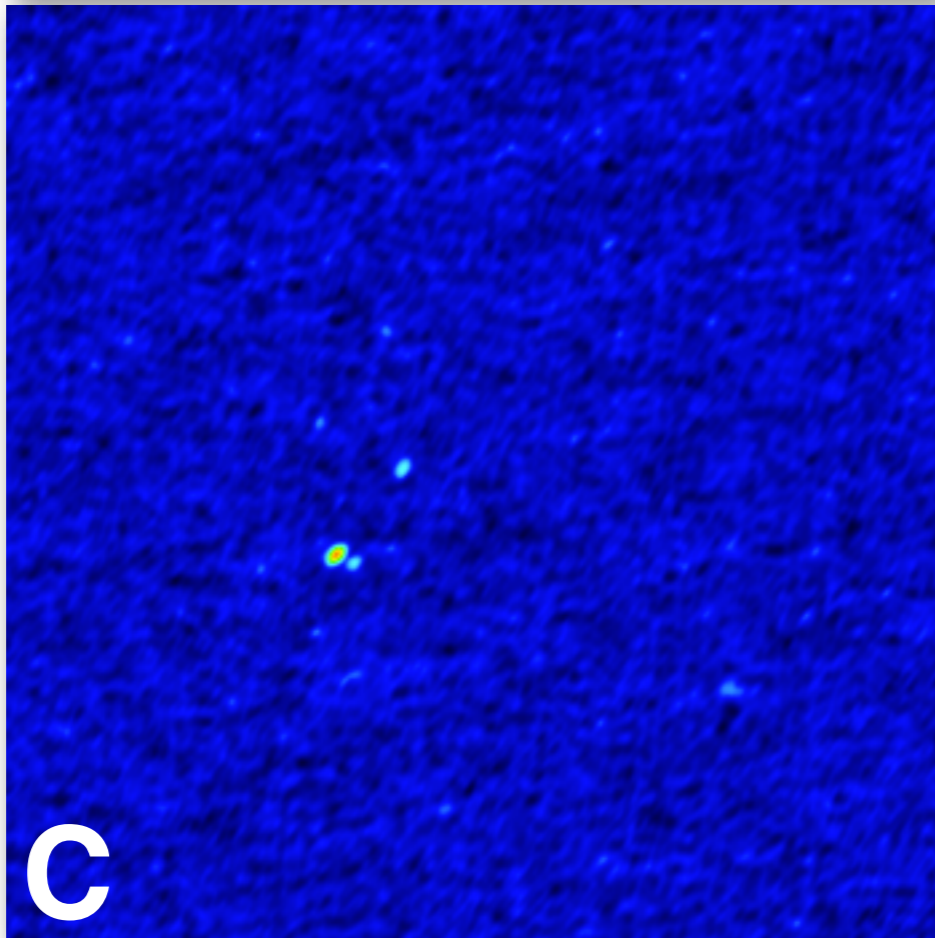
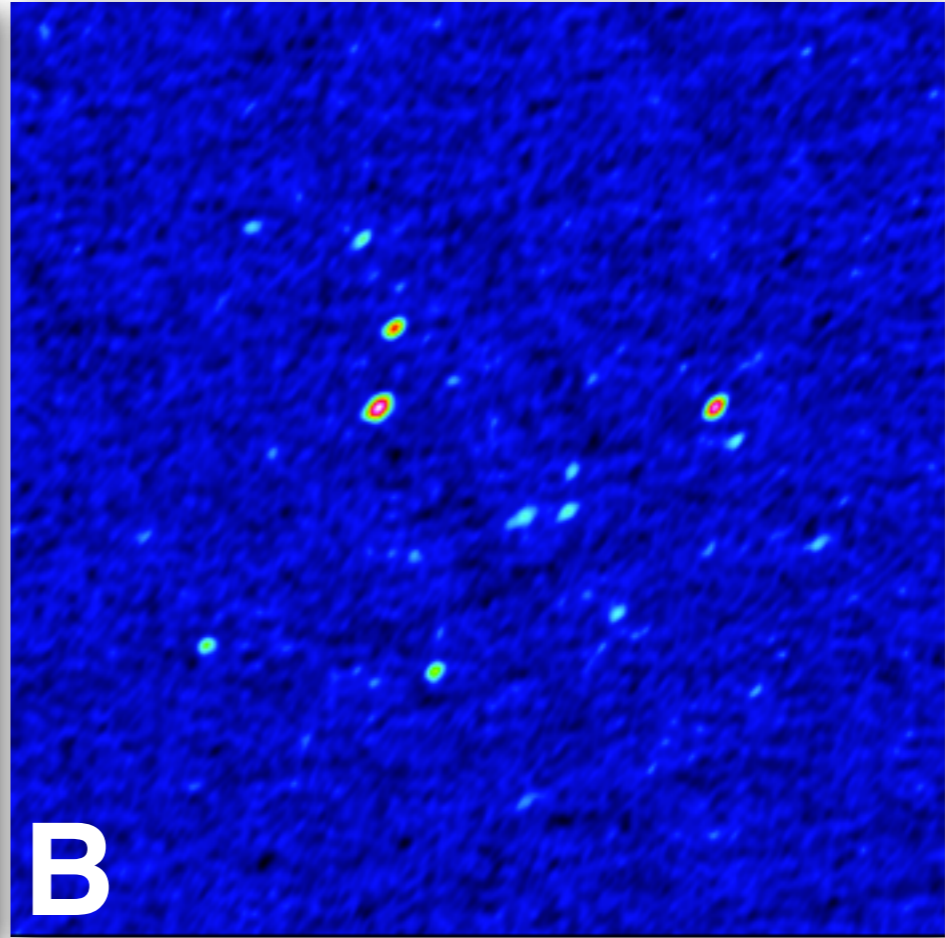
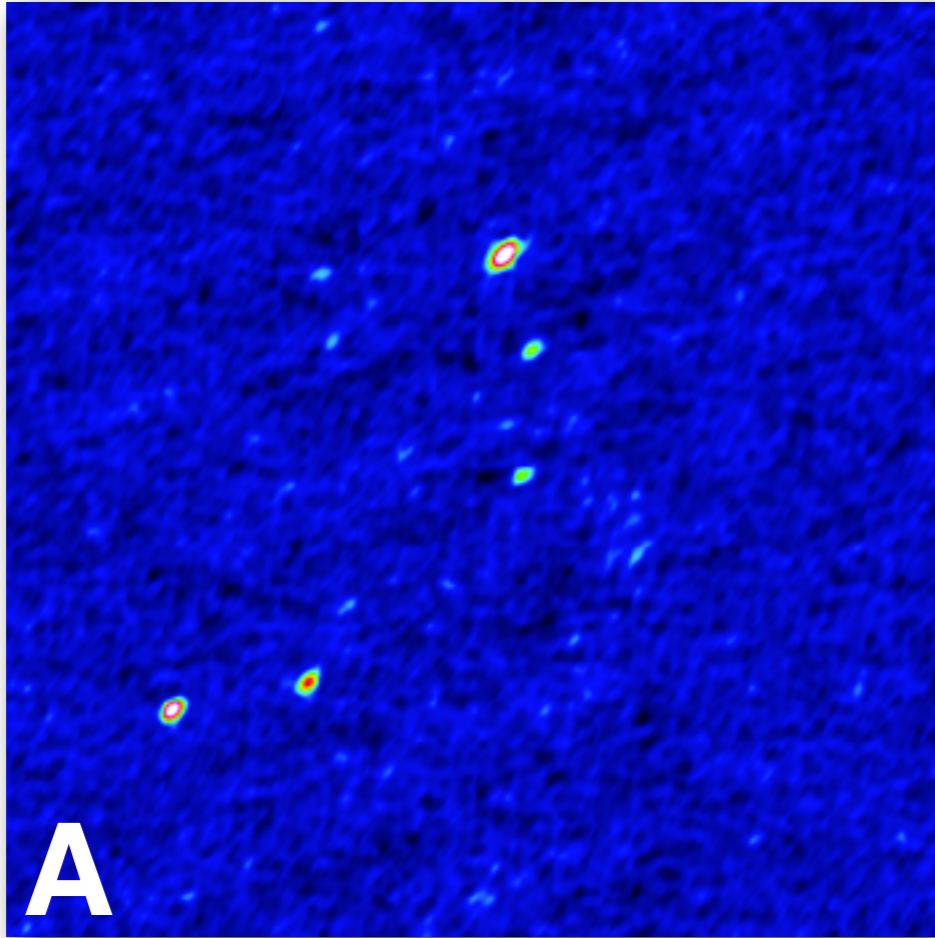
How I ventured outside of my ALPS comfort zone and lived to tell the tale



[ianh@astro.ox.ac.uk](mailto:ianh@astro.ox.ac.uk)

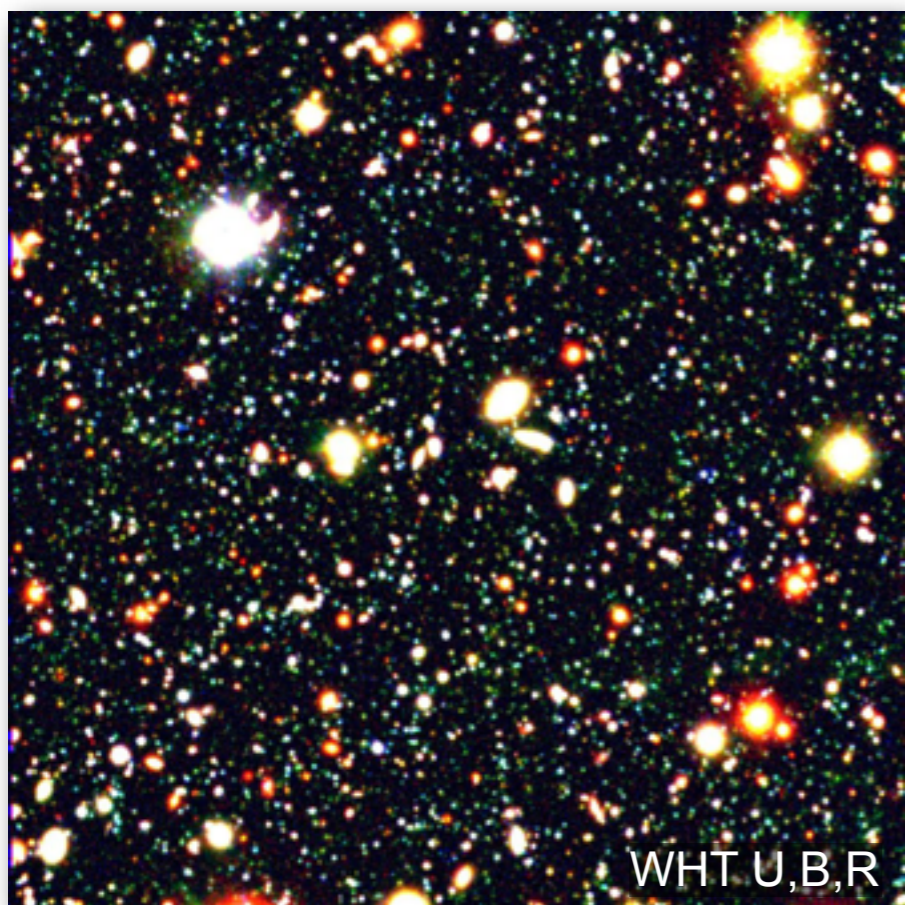


Yeah, I know what a fugazi is.

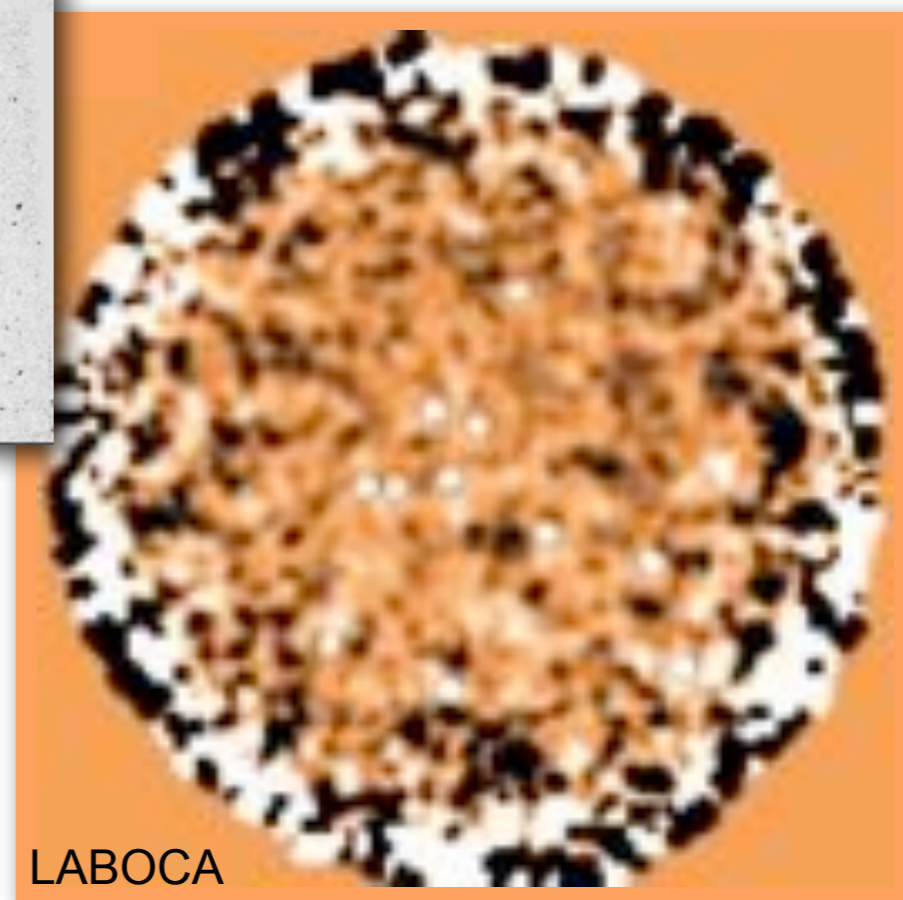
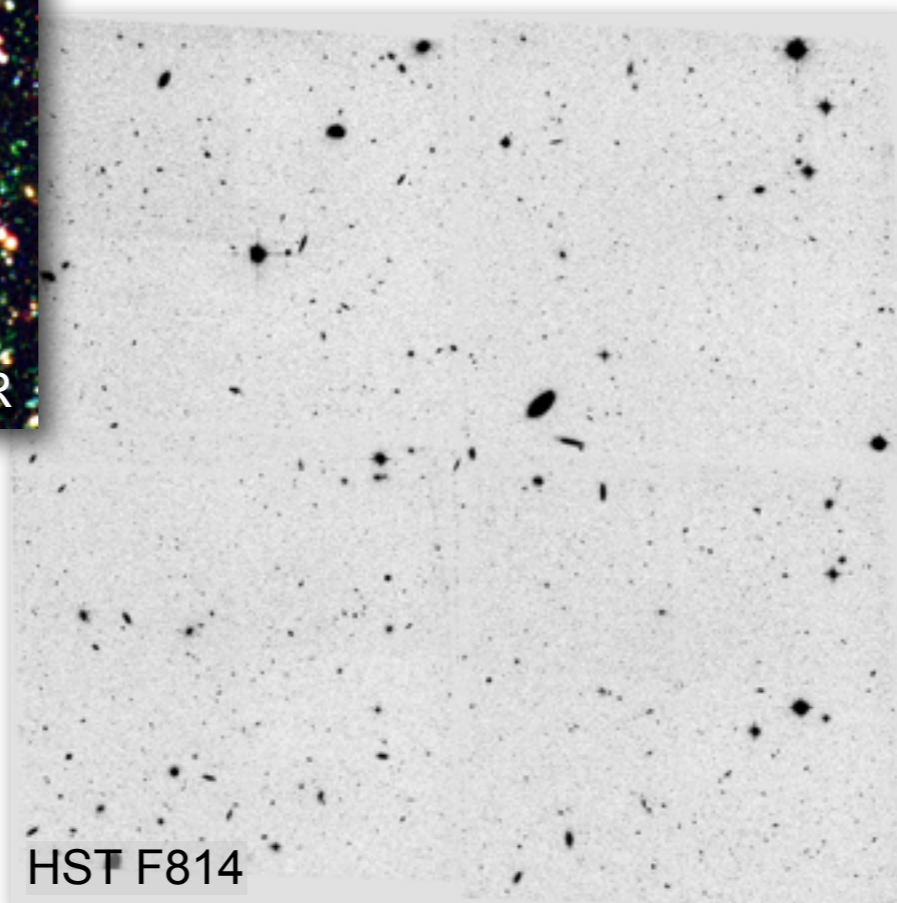




# Context: sub-mm galaxies and QSOs in the William Herschel Deep Field



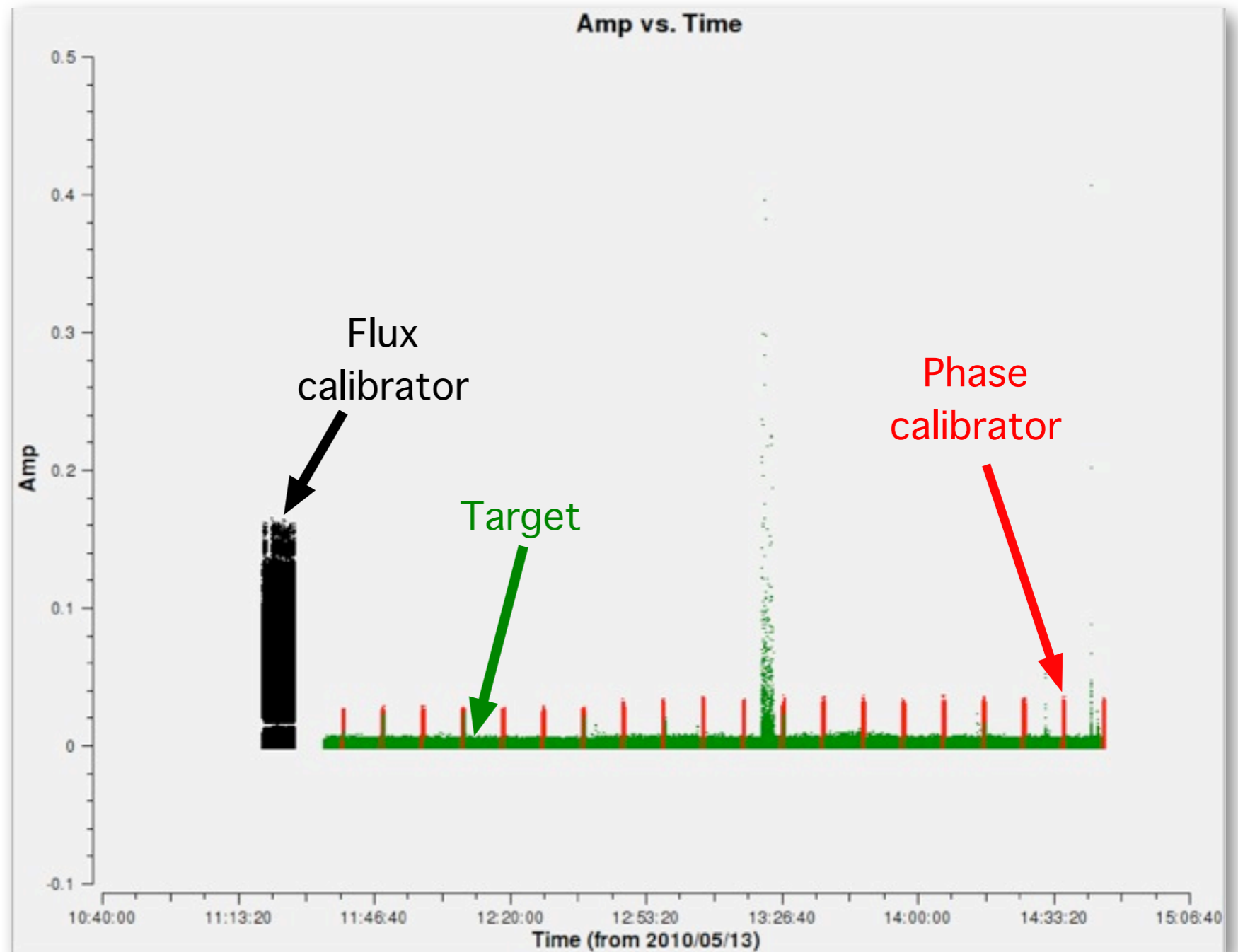
**WHT** *U B R I Z* imaging ( $B < 27.9$  mag)  
**UKIRT** *H K* imaging  
**HST ACS** High-resolution *I* band imaging



**Chandra** X-ray  $10^{-15}$  erg s<sup>-1</sup> cm<sup>-2</sup> (70 ks)  
**LABOCA** 870  $\mu$ m sub-mm survey (21 h)  
**EVLA** Deep 8.4 GHz radio (35 h)

# EVLA observations of the WHDF

AS1008\_sb1094913\_1\_000.55349.39414662037  
AS1008\_sb1094913\_1.55326.477696724534  
**AS1008\_sb1094913\_1.55329.46954527778**  
AS1008\_sb1094913\_1.55344.4072031713  
AS1008\_sb1094913\_1.55353.44451736111  
AS1008\_sb1094913\_2.55355.37769755787  
AS1008\_sb1166741\_1.55333.45861159722  
AS1008\_sb1166741\_1.55343.43126916667  
AS1008\_sb1166809\_1\_000.55327.47497940972  
AS1008\_sb1166809\_1\_001.55328.451462557874  
AS1008\_sb1166809\_1.55283.82364069445  
AS1008\_sb1166809\_1.55311.49789672454  
AS1008\_sb1166809\_1.55320.473294317126  
AS1008\_sb1166809\_1.55324.69096299769  
AS1008\_sb1349024\_1\_000.55332.46100375  
AS1008\_sb1349024\_1\_000.55337.5100403588  
AS1008\_sb1349024\_1\_000.55350.41217465278  
AS1008\_sb1349024\_1\_001.55335.45317630787  
AS1008\_sb1349024\_1.55331.464087141205  
AS1008\_sb1349024\_1.55336.5127268287  
AS1008\_sb1349024\_1.55351.47178395833  
AS1008\_sb1349024\_6\_000.55358.53580408565  
AS1008\_sb1349024\_6.55357.372279421295  
AS1008\_sb1349024\_8.55362.35865112269  
AS1008\_sb1349024a\_6\_000.55357.448393287035




Post-flagging, post-averaging gain calibration performed with CASA  
flux scale → bandpass → complex gain



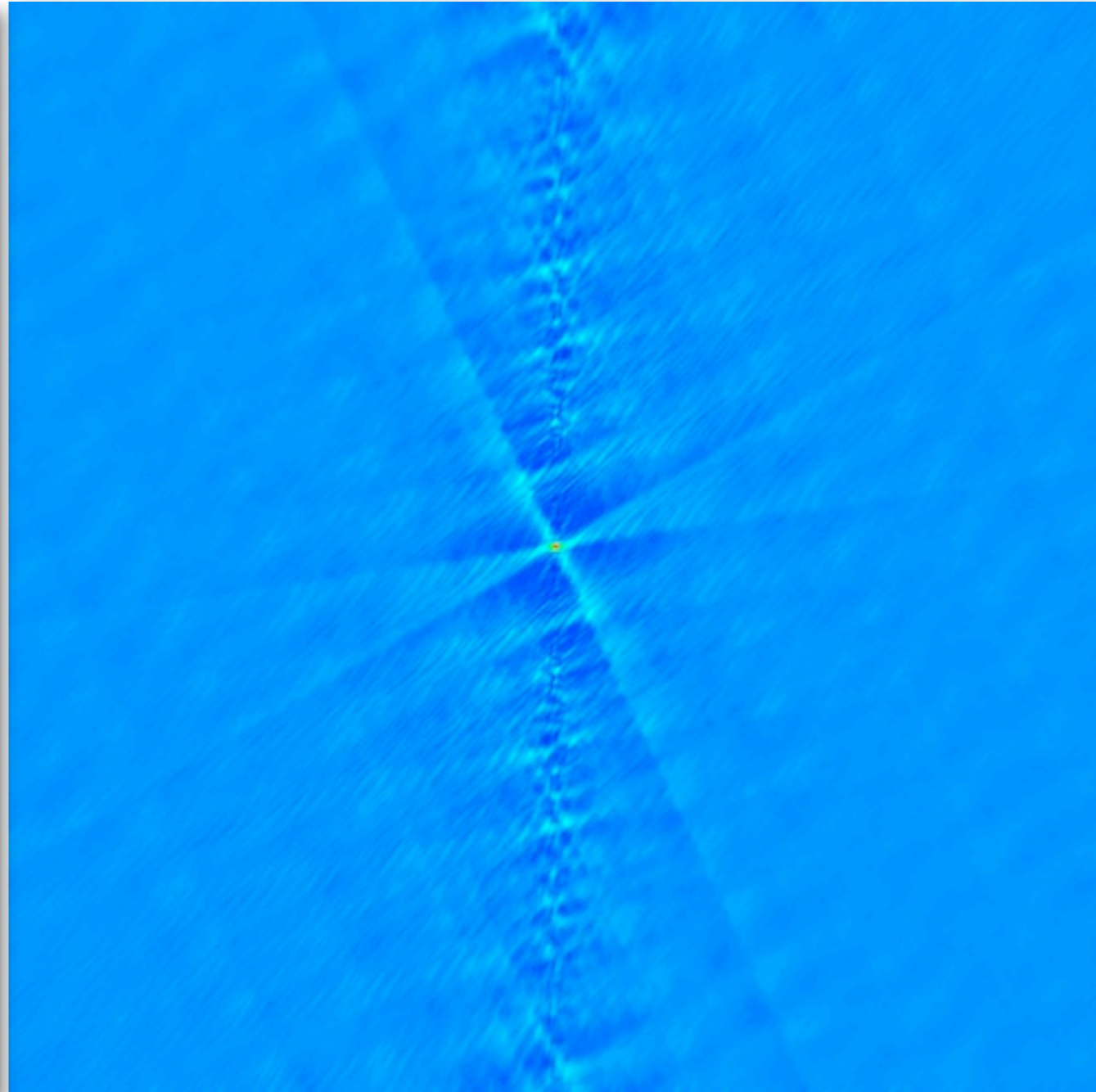
# Two features of this target field that an estate agent would describe as 'quirky'

The phase calibrator

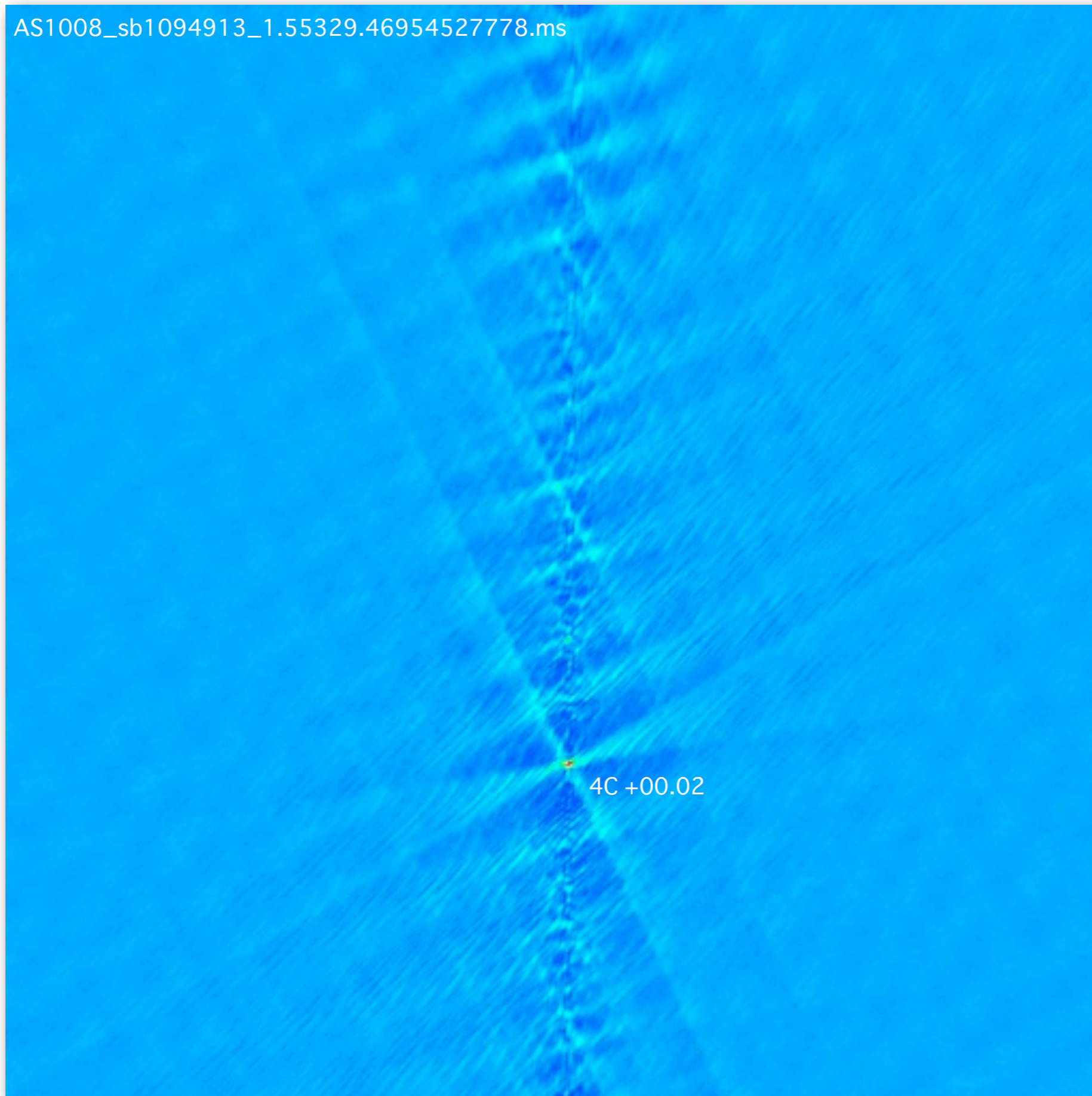


4C +00.02  
0.6 Jy

The point-spread function



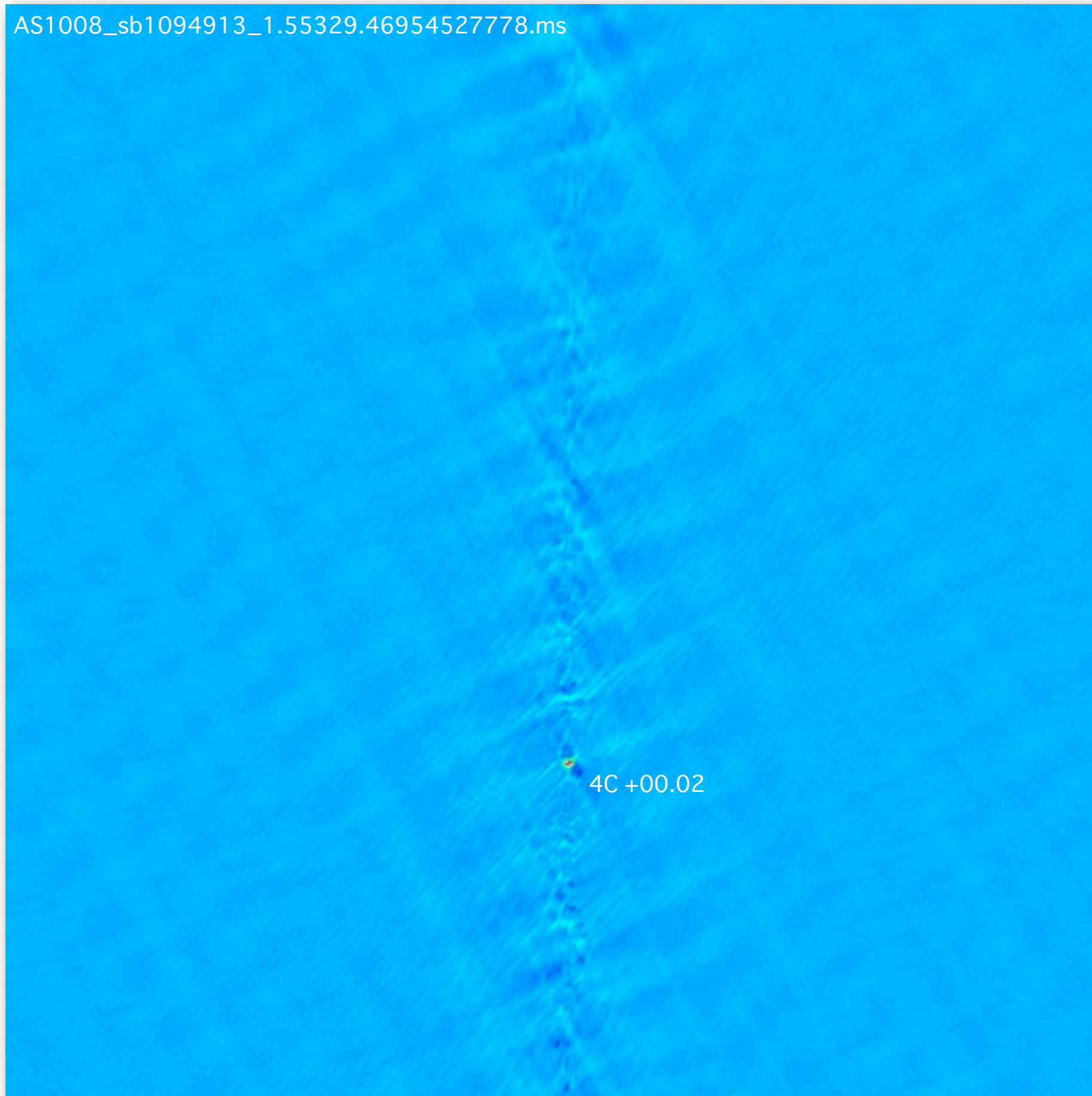
# Wide-field dirty image of target



0.5 deg

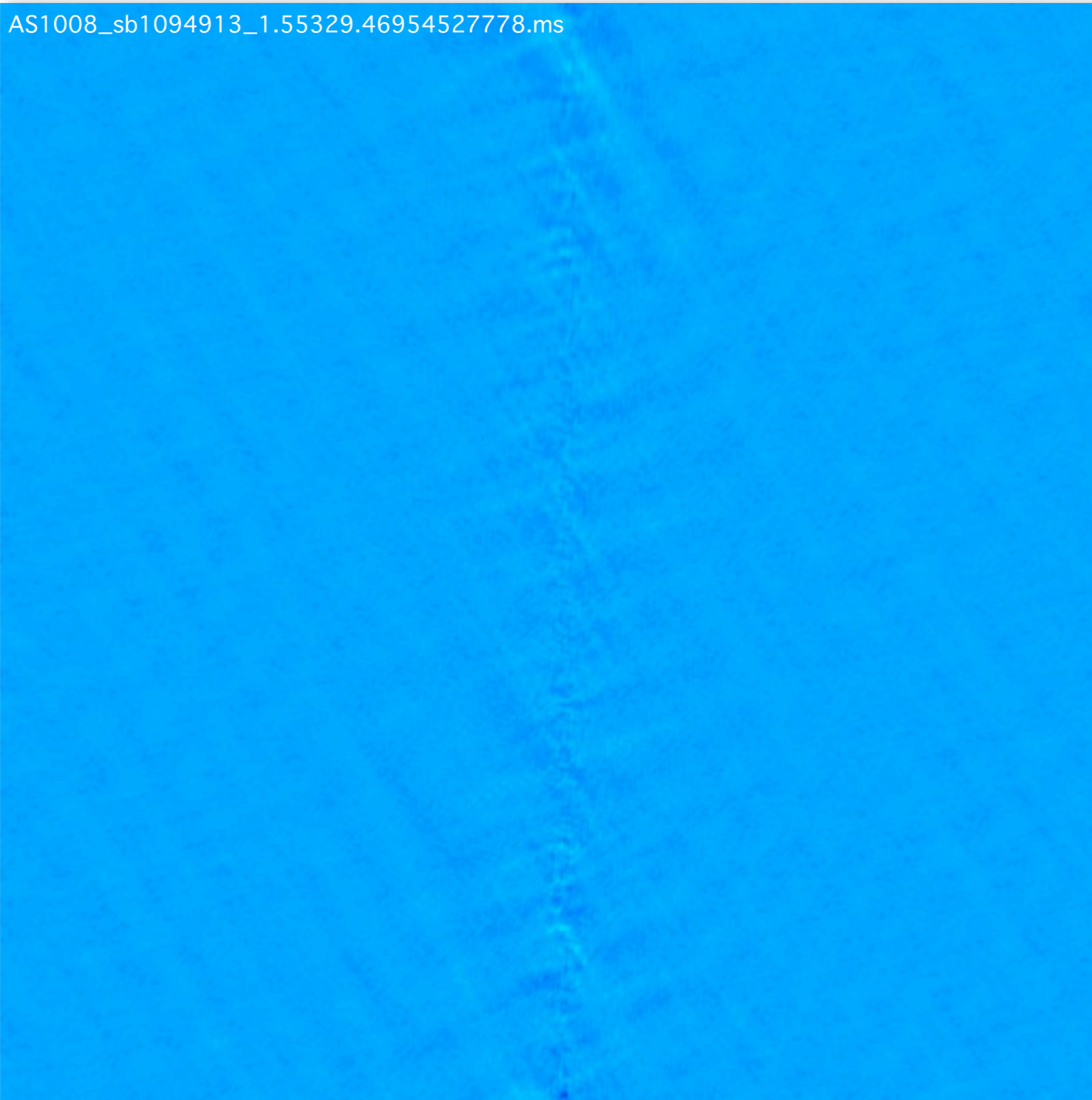


# Deconvolved image



0.5 deg

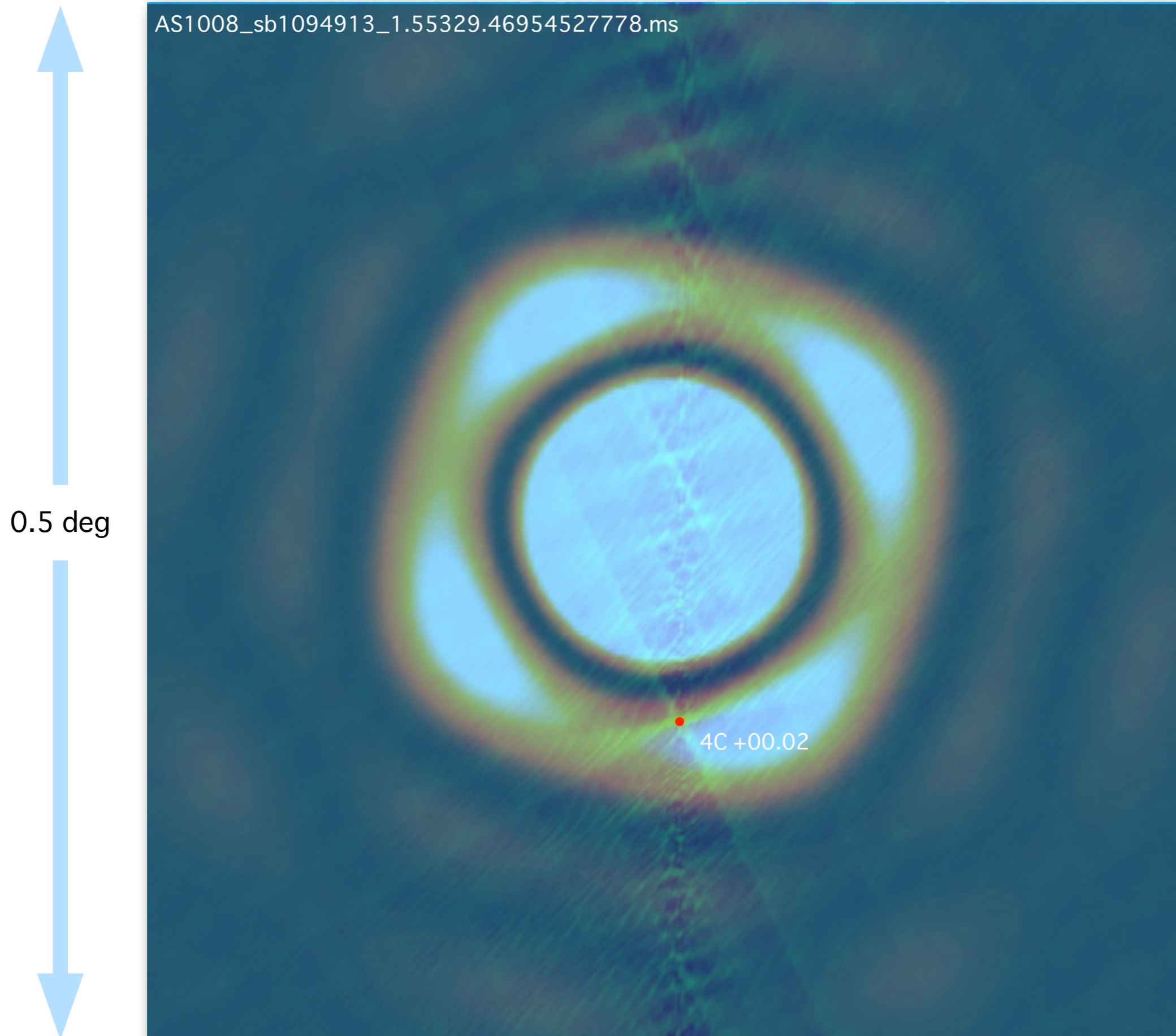
# Subtract MODEL\_DATA column and image residuals



0.5 deg



# The EVLA primary beam: NOT a luxury problem!

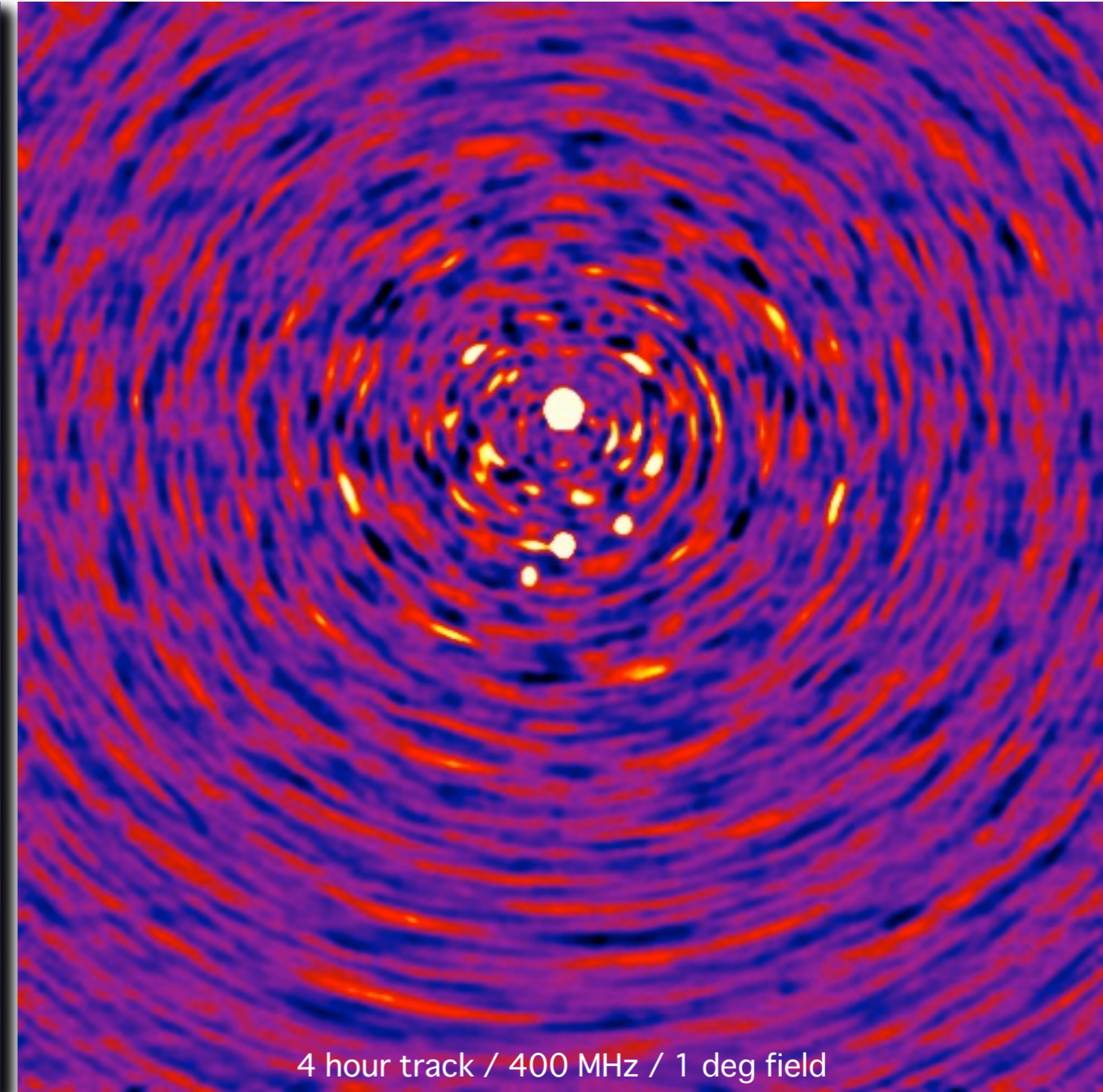
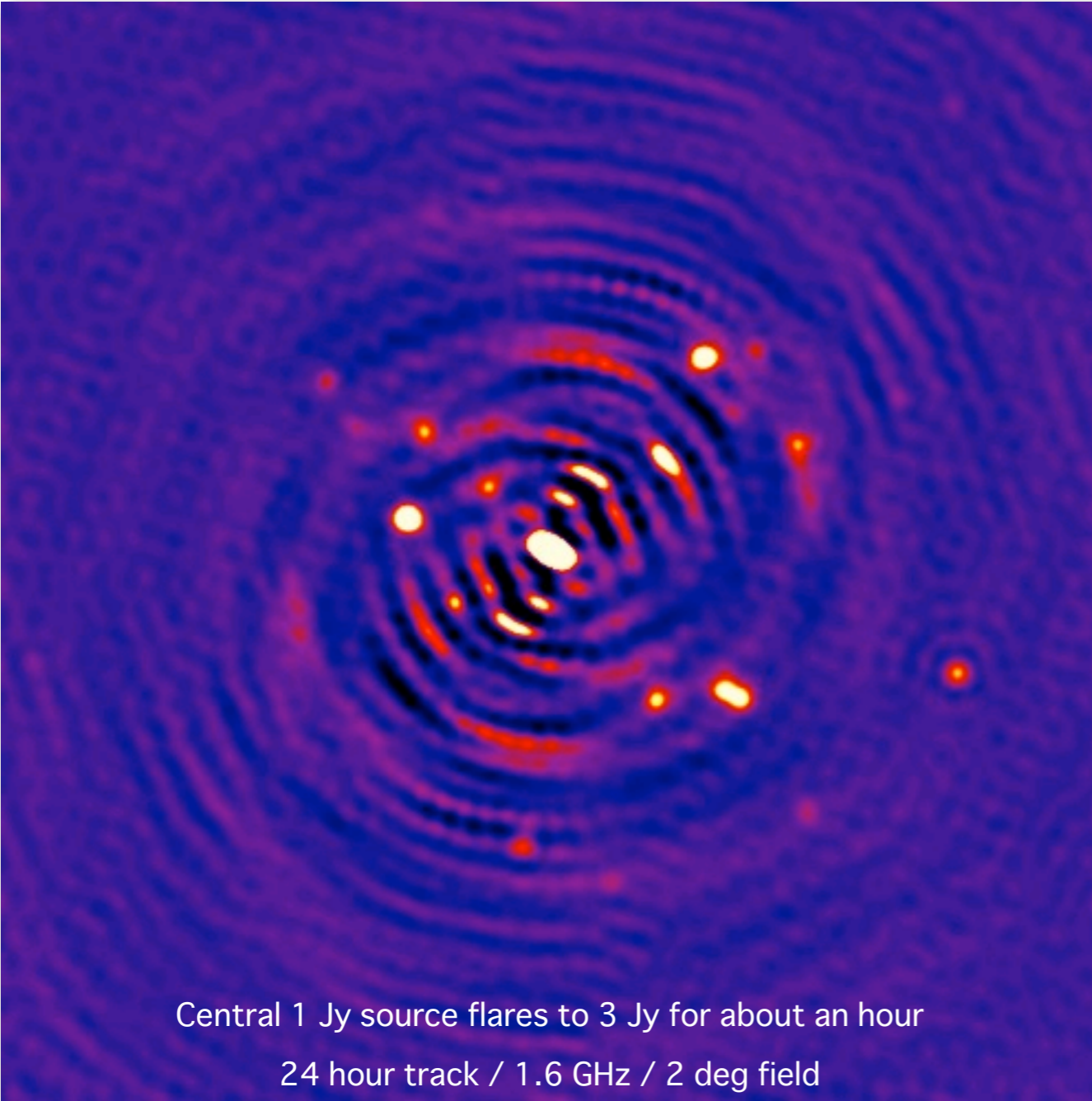




# Intrinsic or apparent transients? Either way your continuum map is a mess

MeqTrees KAT-7 simulation

OSKAR simulation (Dulwich, Mort, Salvini)



Deconvolved image, Briggs weighting

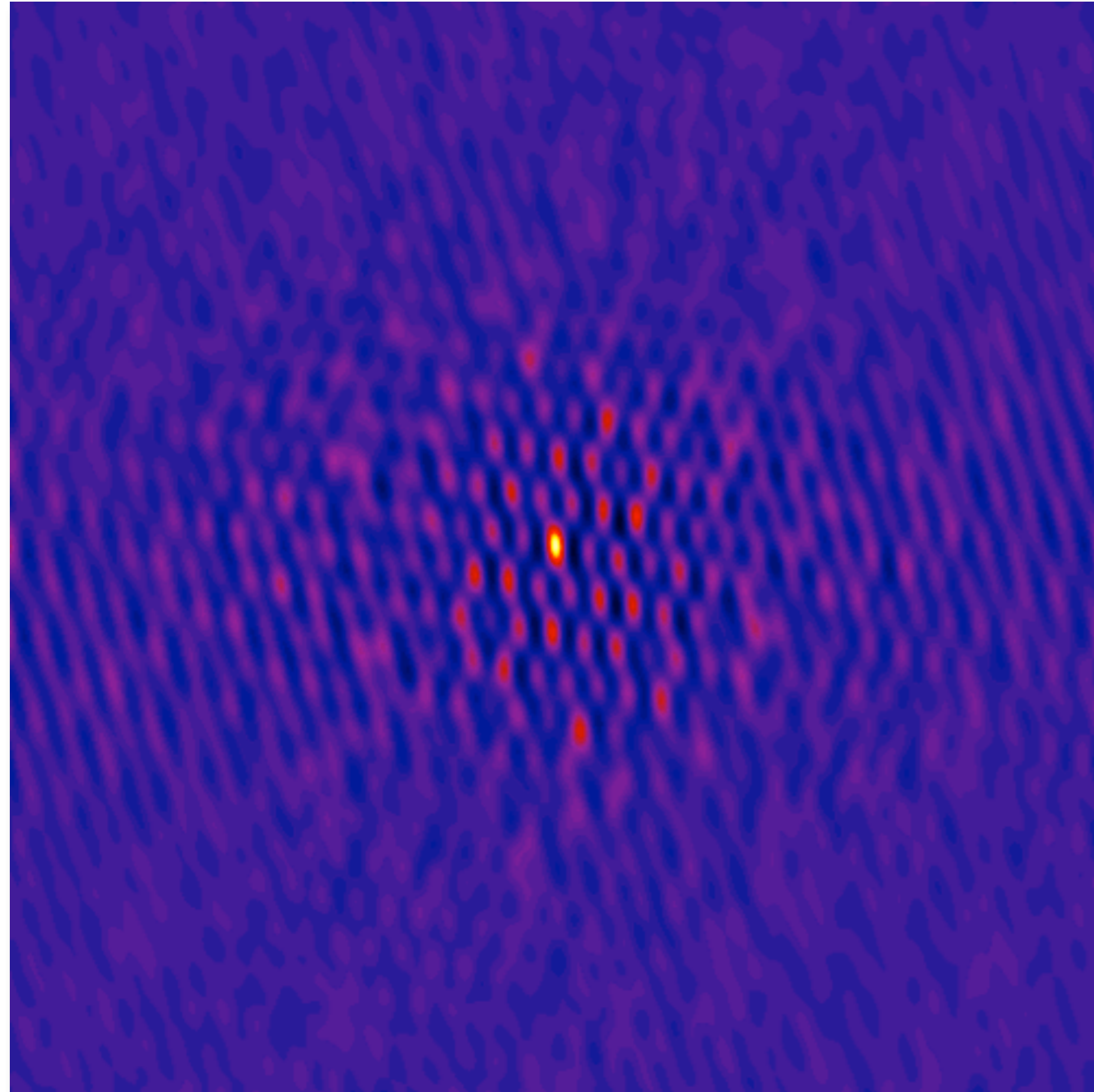
Deconvolved image, natural weighting



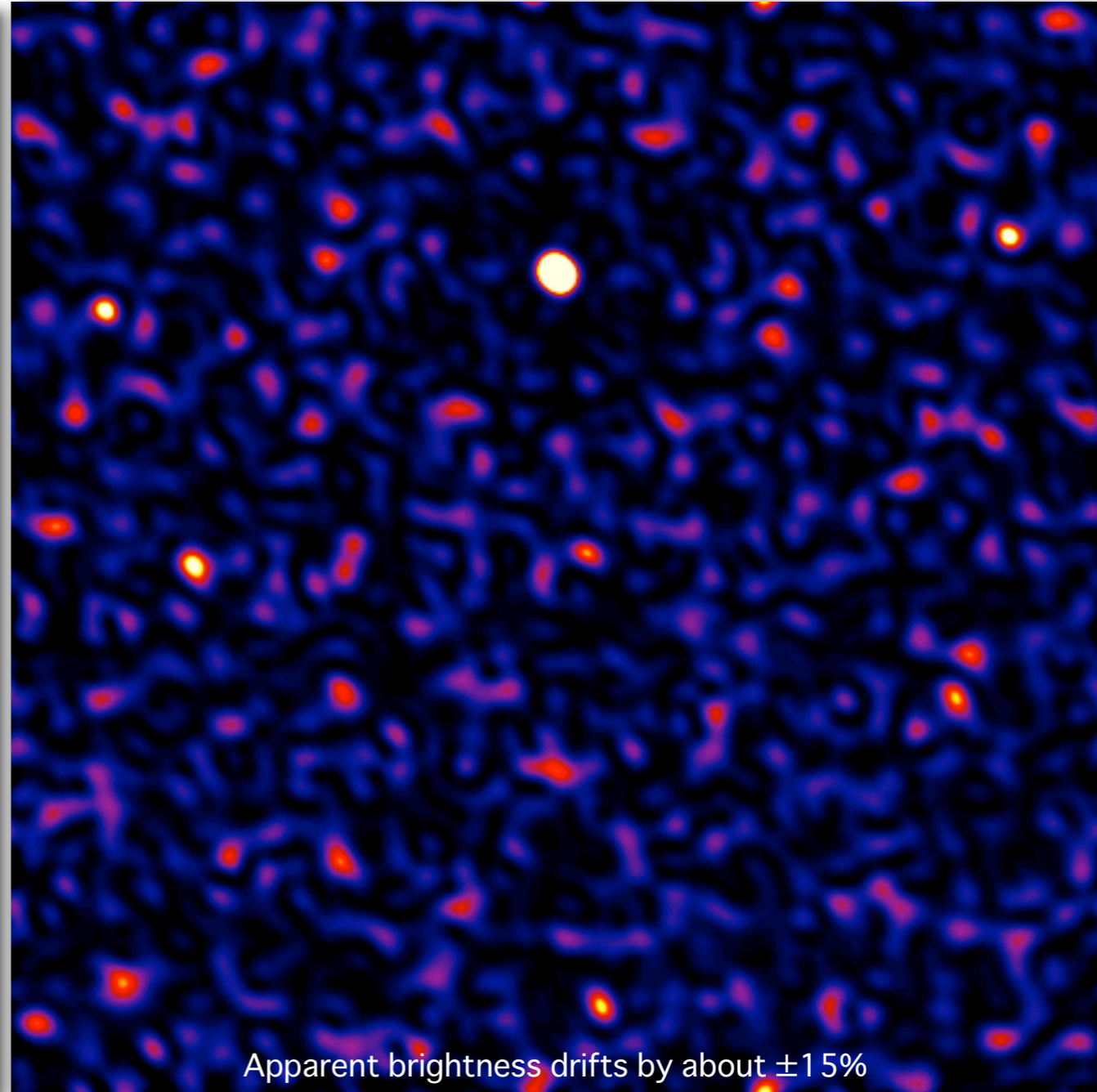
# Intrinsic or apparent transients? Either way your continuum map is a mess

MeqTrees KAT-7 simulation

OSKAR simulation (Dulwich, Mort, Salvini)



48 × 30-minute snapshot dirty images



Apparent brightness drifts by about  $\pm 15\%$

48 × 5-minute snapshot dirty images

# Direction-dependent calibration to the rescue



# Peeling





# AIPS HELP file for PEELR in 31DEC11



As of Mon Jul 25 5:08:21 2011

**PEELR:** RUN PEELR for proc to calibrate interfering sources


## INPUTS

<a href="#">INNAME</a>			Input UV file name (name)
<a href="#">INCLASS</a>			Input UV file name (class)
<a href="#">INSEQ</a>	0.0	9999.0	Input UV file name (seq. #)
<a href="#">INDISK</a>	0.0	9.0	Input UV file disk unit #
<a href="#">IN2NAME</a>			Input image name (name)
<a href="#">IN2CLASS</a>			Input image name (class)
<a href="#">IN2SEQ</a>	0.0	9999.0	Input image name (seq. #)
<a href="#">IN2DISK</a>	0.0	9.0	Input image disk unit #
<a href="#">OUTNAME</a>			Output UV file name (name)
<a href="#">OUTCLASS</a>			Output UV file name (class)
<a href="#">OUTSEQ</a>	-1.0	9999.0	Output UV file name (seq. #)
<a href="#">OUTDISK</a>	0.0	9.0	Output UV file disk unit #.
<a href="#">NFIELD</a>	1.0	4096.0	Number facets in IN2NAME
<a href="#">NGAUSS</a>	1.0	10.0	Number resolutions in IN2NAME
<a href="#">PPARM</a>	0.0		List of <= 100 facets to peel
<a href="#">BCHAN</a>	0.0	16384.0	Lowest channel number 0=>all
<a href="#">ECHAN</a>	0.0	16384.0	Highest channel number
<a href="#">SOLINT</a>			CALIB solution interval (min)
<a href="#">SOLTYPE</a>			Soln type, ' ', 'L1', 'GCON', 'R', 'L1R', 'GCOR'
<a href="#">SOLMODE</a>			'P' phase only, else 'A&P'
<a href="#">WEIGHTIT</a>	0.0	3.0	Modify data weights function
<a href="#">APARM</a>			General CALIB parameters 1=min. no. antennas 2 > 0 => data divided 3 > 0 => avg. RR,LL



AIPS HELP file (version 31DEC) peel

← → ↻ casa.nrao.edu/docs/taskref/peel-task.html ☆ 🔒 🔧

 National Radio Astronomy Observatory  Search NRAO

Monday, July 25, 2011

[NRAO Home](#) > [CASA](#) > TaskRef  Search

[\[next\]](#) [\[prev\]](#) [\[prev-tail\]](#) [\[tail\]](#) [\[up\]](#)

### 0.1.57 peel

Requires:

Synopsis Do direction dependent selfcal(s) and optionally remove annoying sources. **Description**

#### Arguments

Inputs	
vis	Name of the input visibility set. allowed: string Default:
dirs	List of directions to peel. allowed: any Default: variant ""
remove	Subtract the selfcalibrated source(s) from the data. allowed: bool Default: True
calmode	Type of selfcal to do. (p: Phase only, a: Ampl only. ap: both allowed: string Default: p

#### Example

## Peeling

$$\mathbf{D}_{pq}^{(1)} = \mathbf{D}_{pq} - \tilde{\mathbf{G}}_p \mathbf{X}_{s_0 pq} \tilde{\mathbf{G}}_q^H$$



Solve for differential gains

$$\mathbf{V}_{pq} = \mathbf{G}_p \left( \sum_s \Delta \mathbf{E}_{sp} \mathbf{X}_{spq} \Delta \mathbf{E}_{sq}^H \right) \mathbf{G}_q^H$$

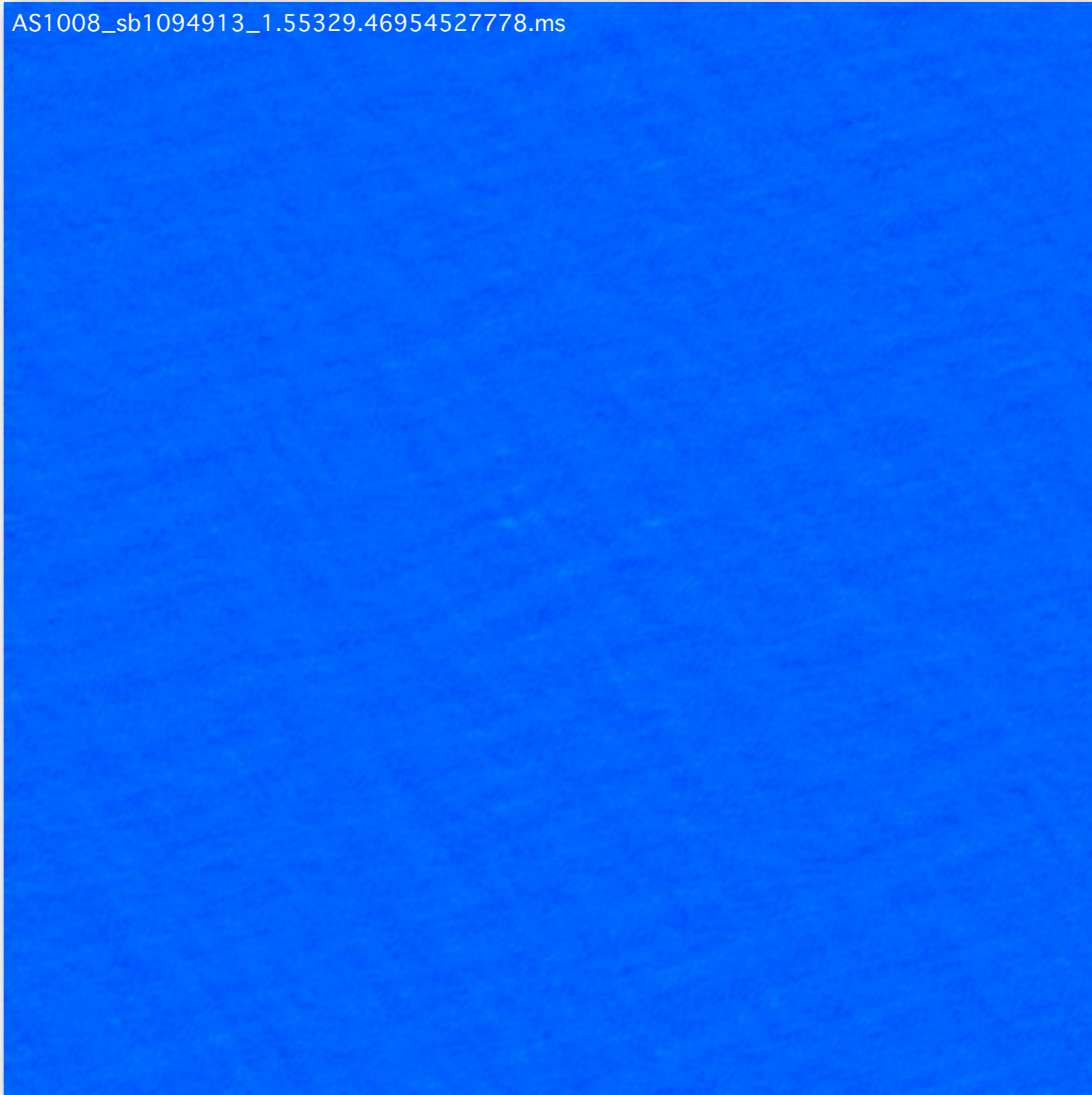
Best 'traditional-cal' residual image, 21  $\mu$ Jy RMS



0.5 deg



# Solve for differential gains with MeqTrees and subtract model, $1.2 \mu\text{Jy}$ RMS

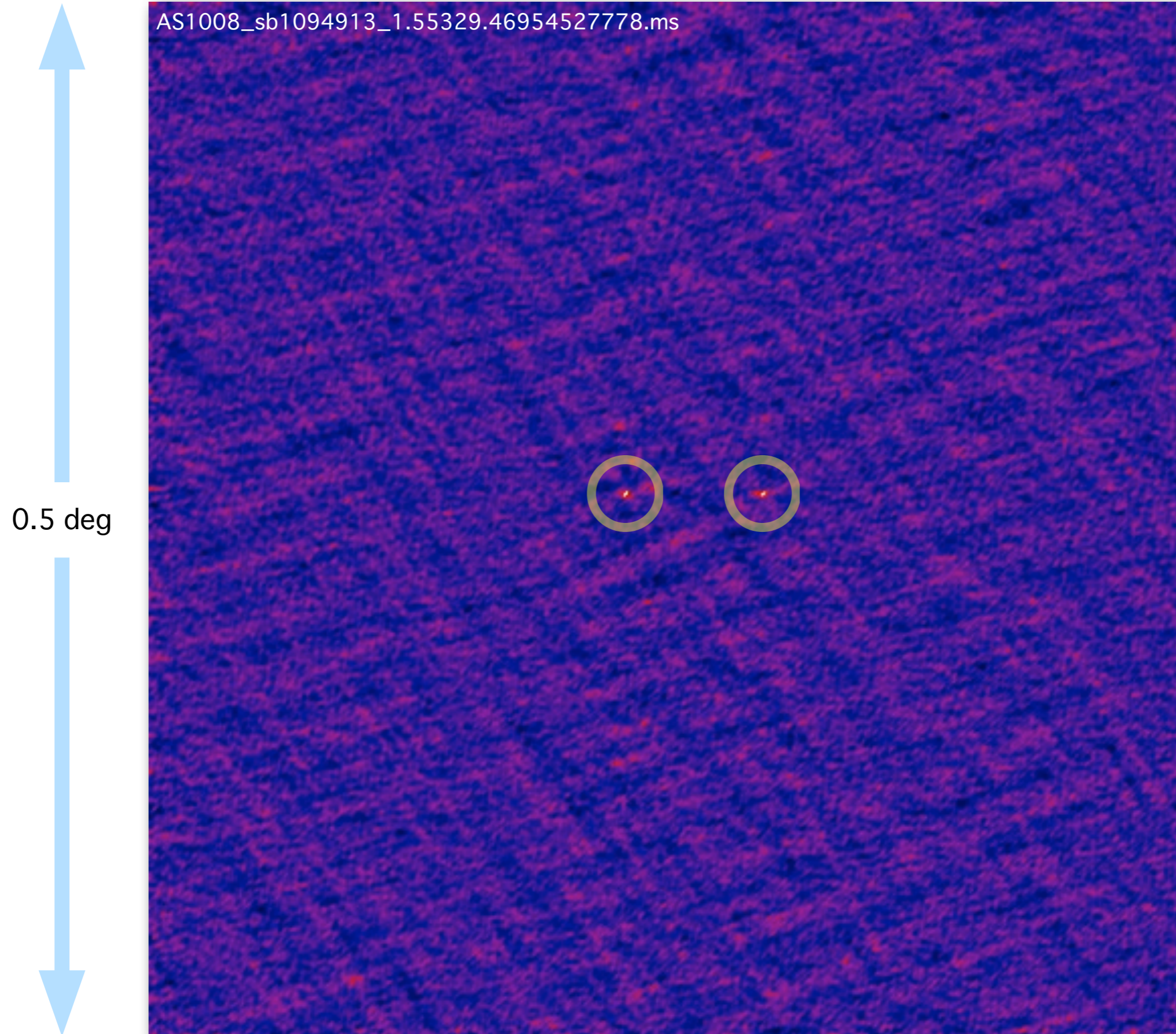


0.5 deg

Smirnov, A&A, 572, 107, 2011  
Noordam & Smirnov, ApJ, 524, 61, 2011



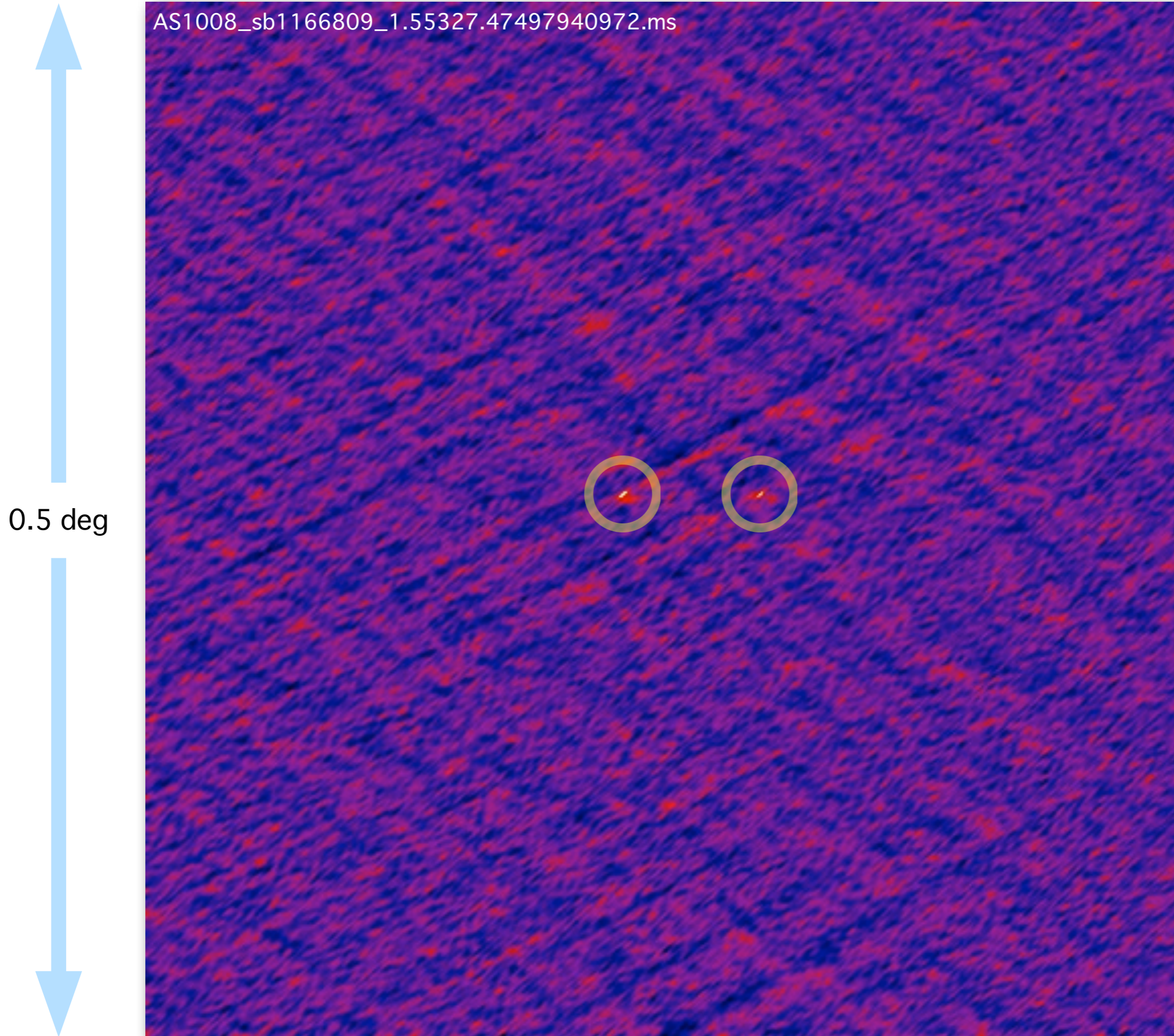
# Solve for differential gains with MeqTrees and subtract model, $1.2\ \mu\text{Jy}$ RMS



Smirnov, A&A, 572, 107, 2011  
Noordam & Smirnov, ApJ, 524, 61, 2011



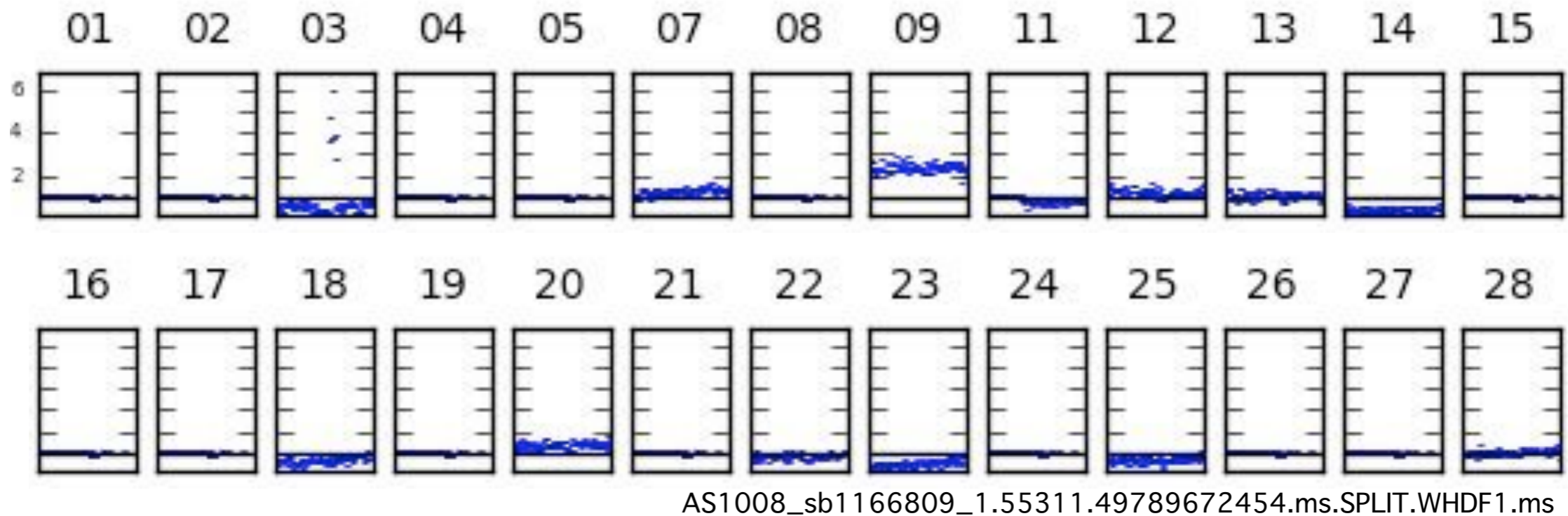
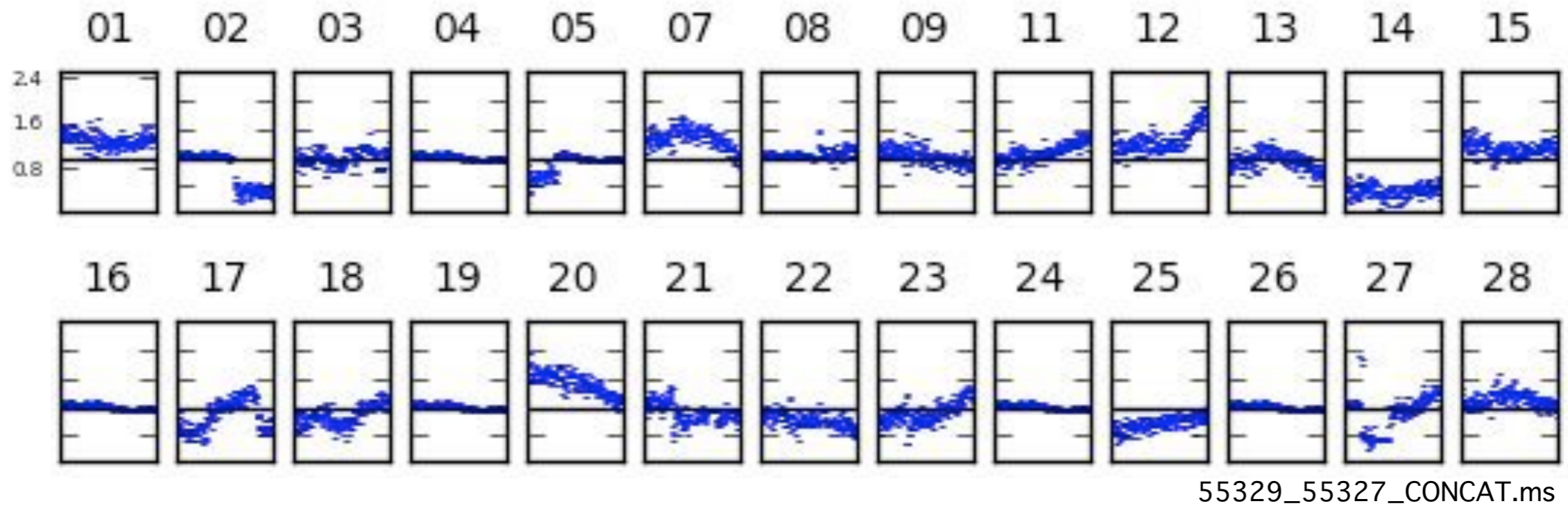
# Solve for differential gains with MeqTrees and subtract model, $1.2\ \mu\text{Jy}$ RMS



Smirnov, A&A, 572, 107, 2011  
Noordam & Smirnov, ApJ, 524, 61, 2011



# dE solutions per antenna for two Measurement Sets





# Solving for the 'variable' sources in our simulations

The image shows a screenshot of the Tigger software interface. On the left, a table lists astronomical sources with columns for name, RA, Dec, r, and type. Below the table is a plot showing a simulated field of view with a blue background and yellow stars. A dashed blue box highlights a region labeled 'no flare.fits'. On the right, the 'TDL Compile-time Options' dialog box is open, showing various settings for the simulation. The 'MS selection' section shows 'MS: KAT7.MS', 'Interferometers to use: all', and 'Correlations to use: 2x2, diagonal terms only'. The 'Processing options' section includes 'Start Purr on this MS' (checked), 'Read additional uv-model visibilities from MS' (unchecked), and 'Calibrate (fit corrupted model to data)' (checked). The 'Image-plane components' section includes 'Sky model' (expanded) with 'Use TiggerSkyModel module' (checked), 'Tigger LSM file: sumsslsm.lsm.html', and 'Source subset: =TRANSIENT' (highlighted in a green box). Other options include 'Make solvable source parameters' (unchecked), 'Use Calico.OMS.central\_point\_source module' (unchecked), 'Use Siamese.OMS.fitsimage\_sky module' (unchecked), 'Use Siamese.OMS.gridded\_sky module' (unchecked), 'Export sky model as kvis annotations' (unchecked), 'Use E Jones (primary beam)' (unchecked), 'Use dE Jones (differential gains)' (checked), 'Use DiagReallmag module' (checked), 'Matrix type: complex', 'Initial value, diagonal: 1', 'Initial value, off-diagonal: 0', 'Solve for each source independently' (unchecked), 'Use FullReallmag module' (unchecked), and 'Use DiagAmplPhase module' (unchecked). The dialog box has 'Compile', 'Load', 'Save', and 'Cancel' buttons at the bottom.

name	RA	Dec	r	type
22	J1930M72	19h05m26.21s -73°50'02.40"	0.0'	Gau
43	J1930M76	19h15m54.44s -74°39'36.90"	65.4'	Gau
21	J1930M76	19h04m34.79s -74°51'56.50"	62.0'	Gau
52	J1930M76	19h19m50.42s -74°35'58.50"	74.6'	Gau
12	J1845M76	19h00m20.34s -74°10'48.00"	29.6'	Gau
64	J1930M76	19h31m55.52s -74°34'17.40"	116.8'	Gau
13	J1845M76	19h01m04.48s -74°29'25.10"	43.2'	Gau

**TDL Compile-time Options**

**MS selection**

MS: KAT7.MS  
Interferometers to use: all  
Correlations to use: 2x2, diagonal terms only

Start Purr on this MS

**Processing options**

Read additional uv-model visibilities from MS  
 Calibrate (fit corrupted model to data)  
Calibrate on:  
...using interferometers:  
Output visibilities:  
 Flag output visibilities

**Image-plane components**

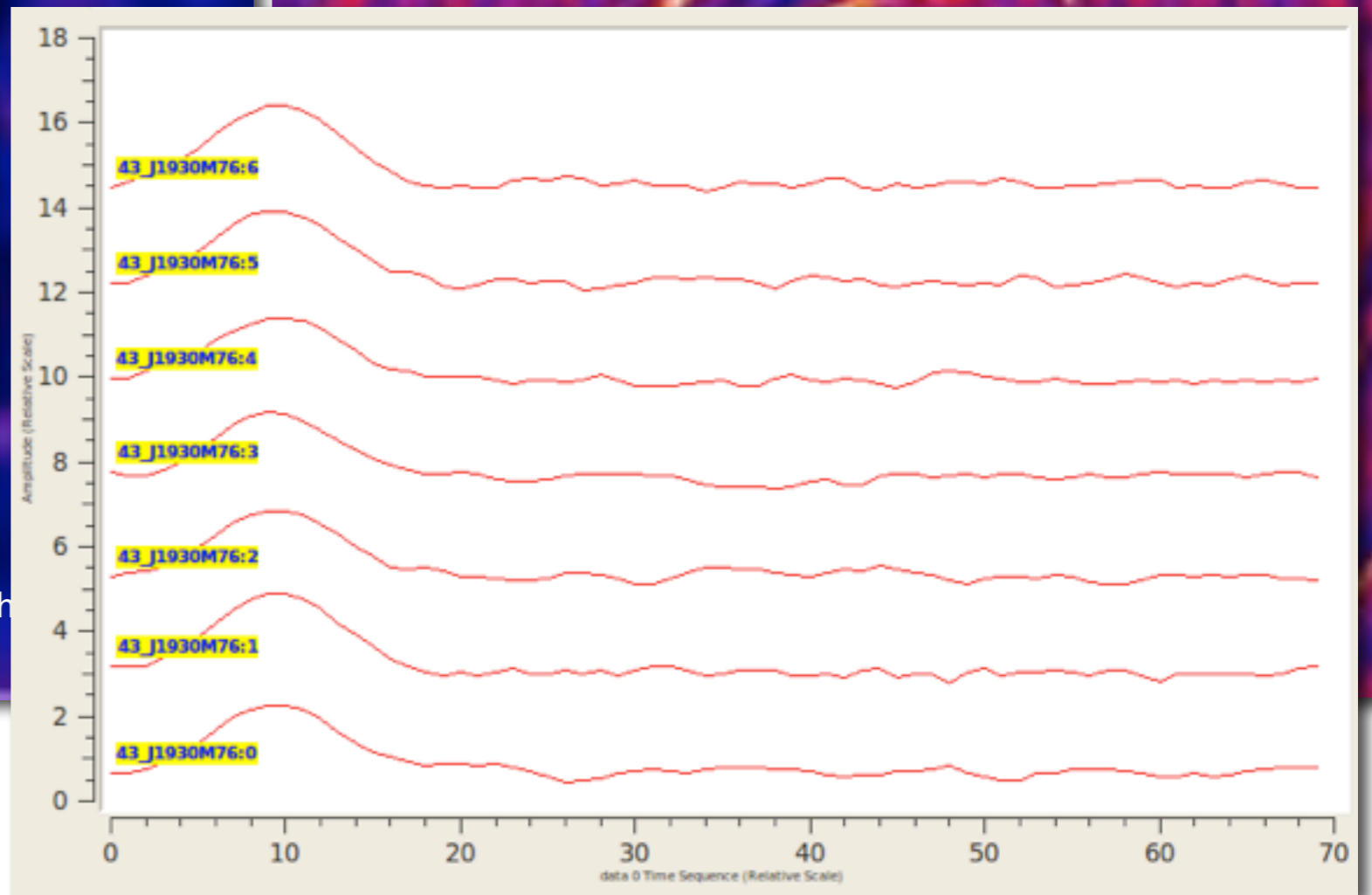
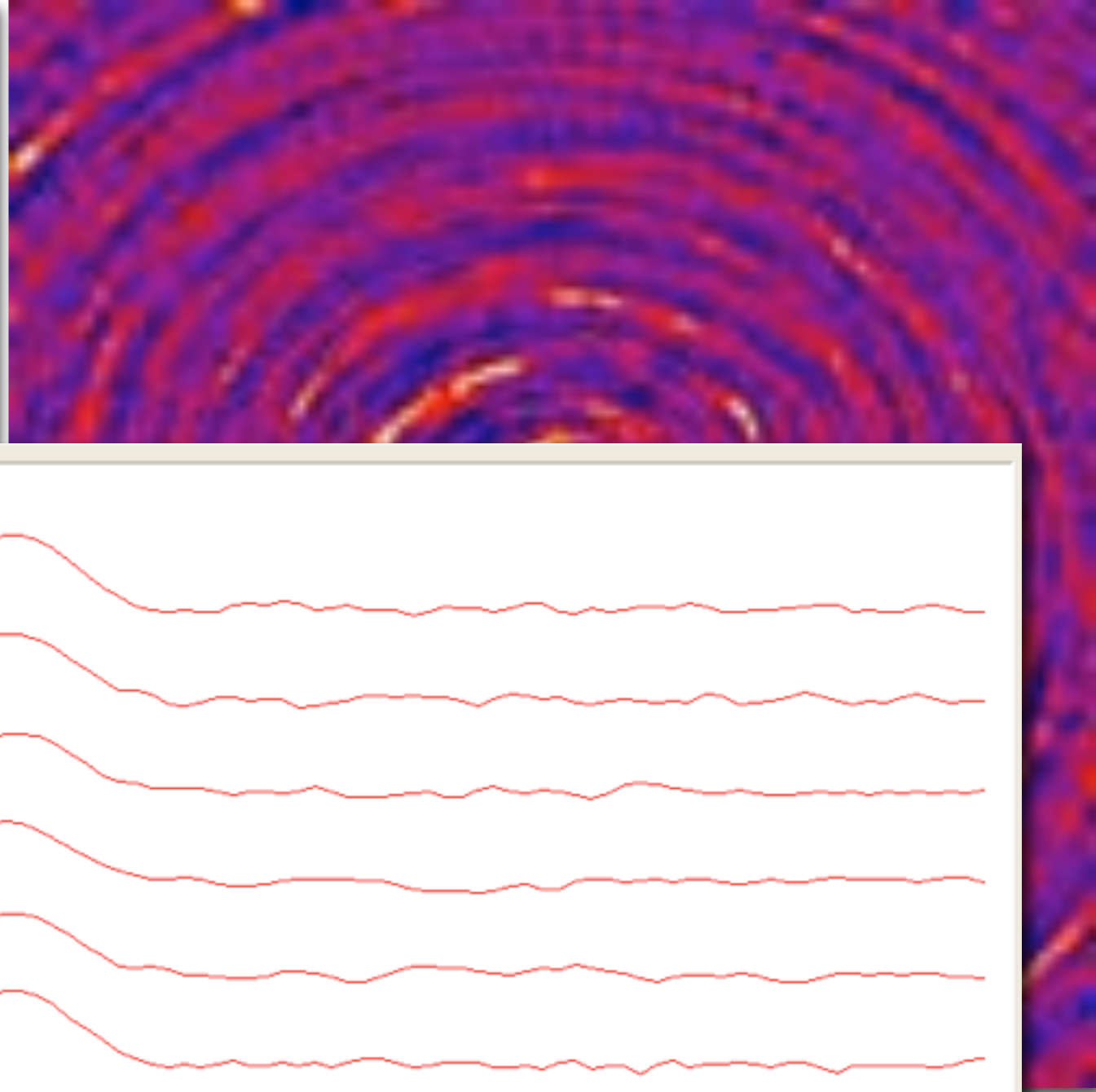
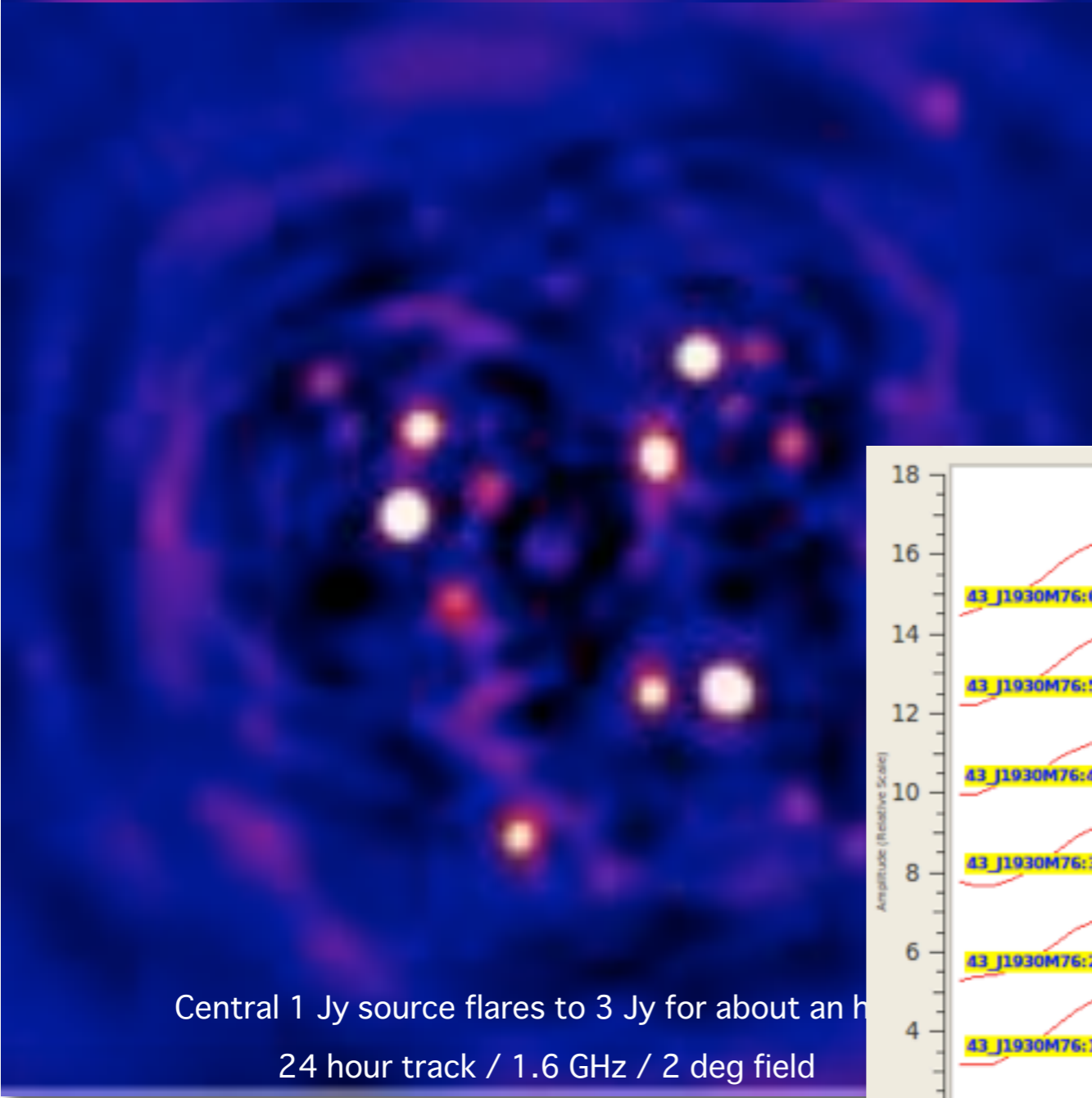
Use 'TiggerSkyModel' module  
Tigger LSM file: sumsslsm.lsm.html  
Source subset: =TRANSIENT  
 Make solvable source parameters  
 Use 'Calico.OMS.central\_point\_source' module  
 Use 'Siamese.OMS.fitsimage\_sky' module  
 Use 'Siamese.OMS.gridded\_sky' module  
 Export sky model as kvis annotations  
 Use E Jones (primary beam)  
 Use dE Jones (differential gains)  
 Use 'DiagReallmag' module  
Matrix type: complex  
Initial value, diagonal: 1  
Initial value, off-diagonal: 0  
 Solve for each source independently  
 Use 'FullReallmag' module  
 Use 'DiagAmplPhase' module

Compile Load Save Cancel

# Solving for the 'variable' sources in our simulations

MeqTrees KAT-7 simulation

OSKAR simulation (Dulwich, Mort, Salvini)





# Automating everything

# Flagging full spectral resolution data

The image is a composite of two scenes. On the left, a computer terminal window displays a configuration file for an interactive flagger. A dialog box titled "Progress" is overlaid on the terminal, showing a progress bar at 99% and the text "Drawing item 'Amp vs. Time'". The terminal text includes:

```
er/interactive flagger for visibility data.  
= 'AS1008_sb1094913_1.55326.477696724534.REMERGED.ms' # input visibility data  
" # plot x-axis (blank for default/current)  
" # plot y-axis (blank for default/current)  
True # data selection parameters  
" # field names or field index numbers (blank for all)  
" # spectral windows:channels (blank for all)  
" # time range (blank for all)  
" # uv range (blank for all)  
" # antenna/baselines (blank for all)  
" # scan numbers (blank for all)  
" # correlations (blank for all)  
" # (sub)array numbers (blank for all)  
" # MS selection (blank for all)  
  
True # data averaging parameters  
" # average over channel? (blank = False, otherwi  
" # average over time? (blank = False, other value  
False # only valid if time averaging is turned on. aver.
```

On the right, a smartphone displays a stopwatch application. The time shown is 57:25.8. The interface includes a "Stop" button, a "Lap" button, and a "Stopwatch" icon in the dock at the bottom.



# Automatic flagging of full-resolution data with rficonsole

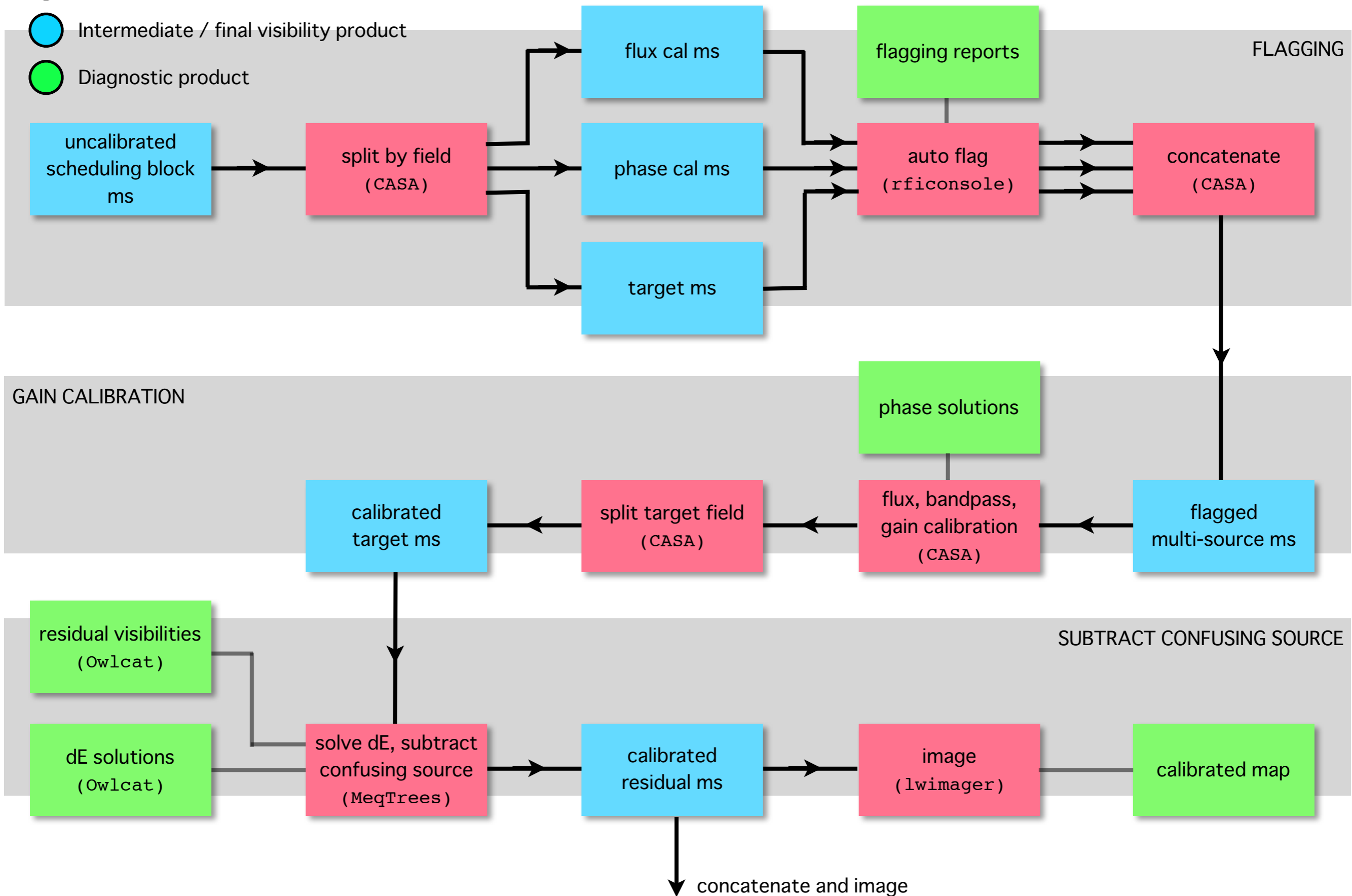


# Automated calibration scheme / software inventory

● Software

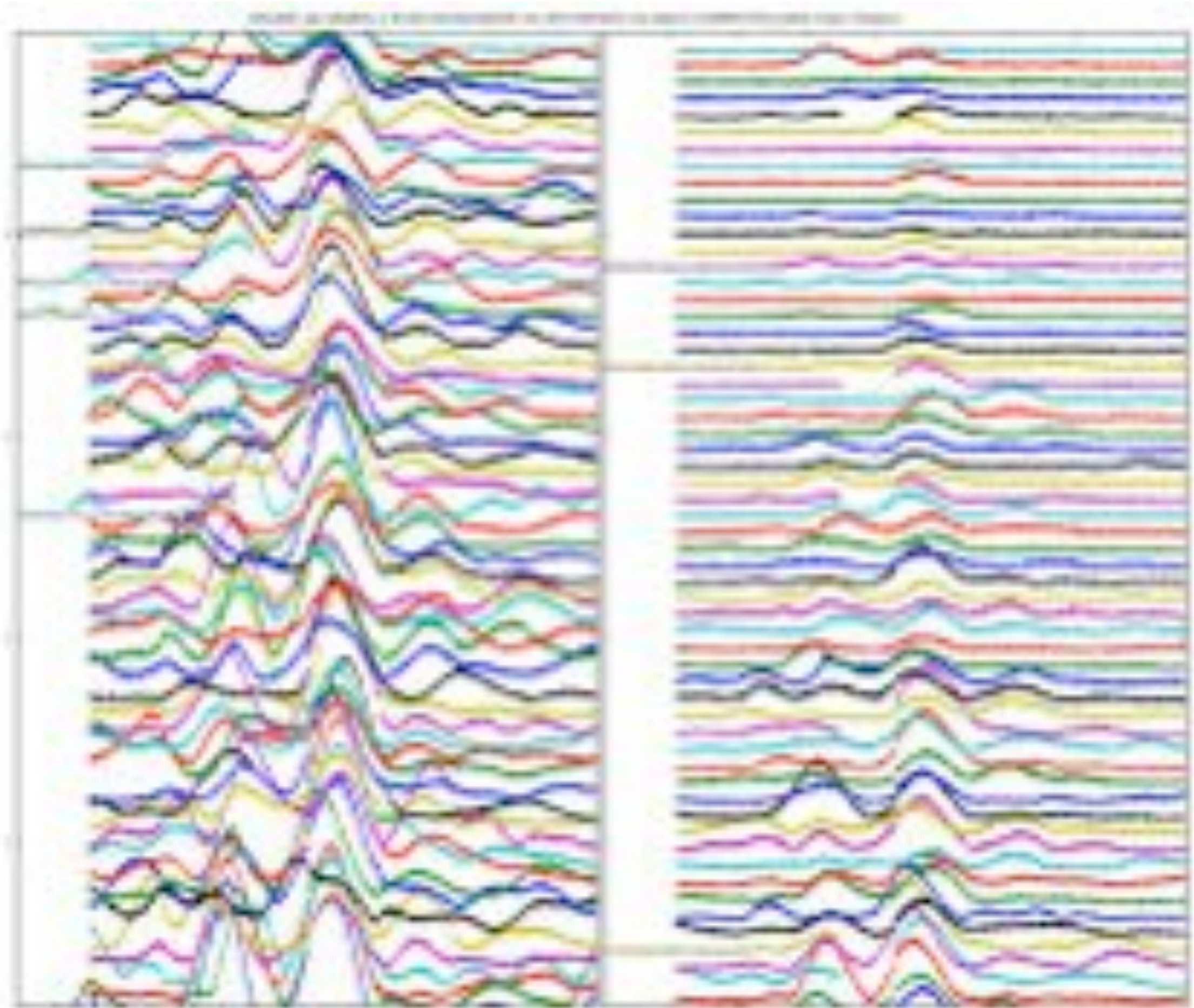
● Intermediate / final visibility product

● Diagnostic product



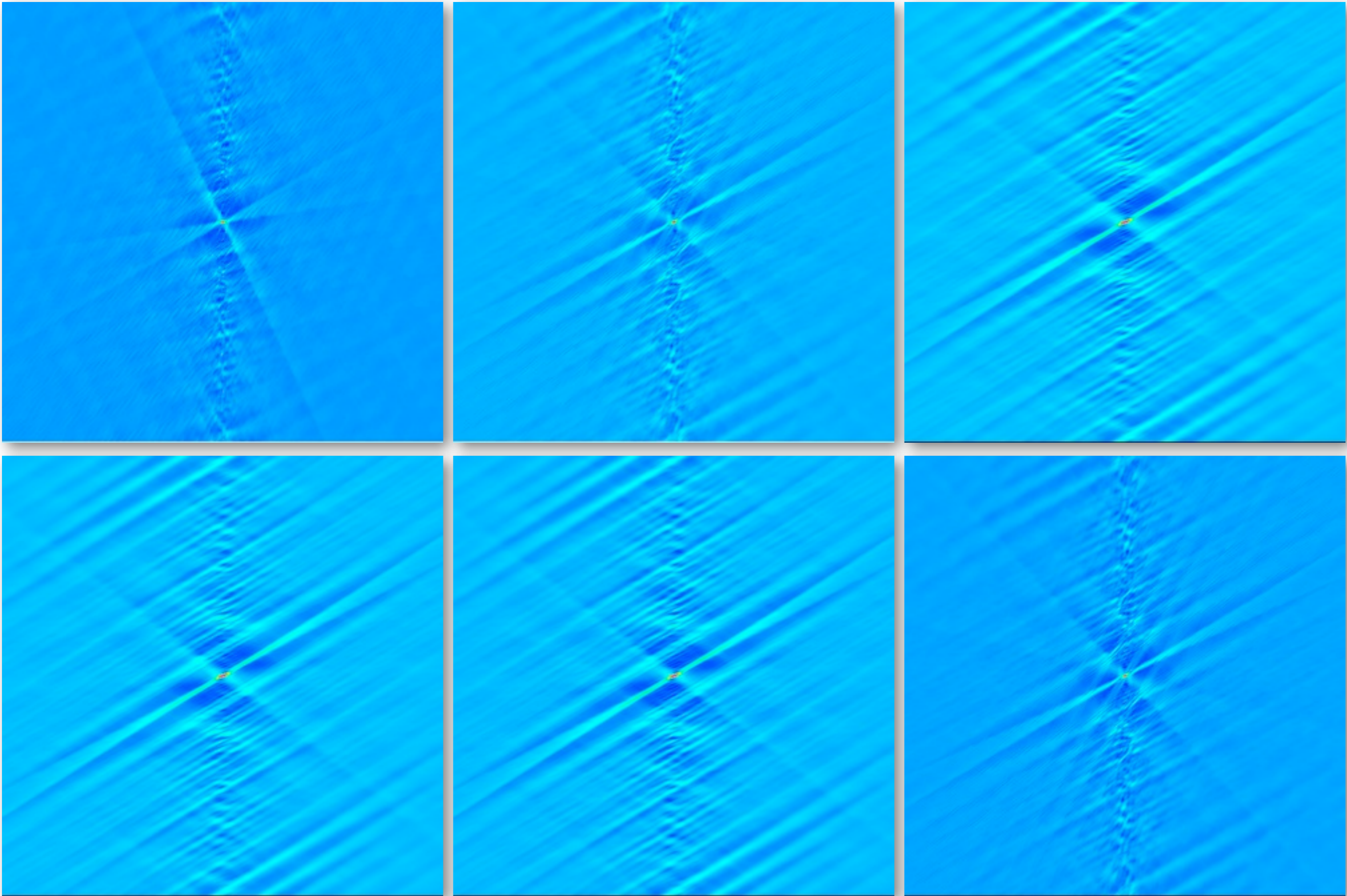


# The importance of diagnostic data products: UFOs over New Mexico?



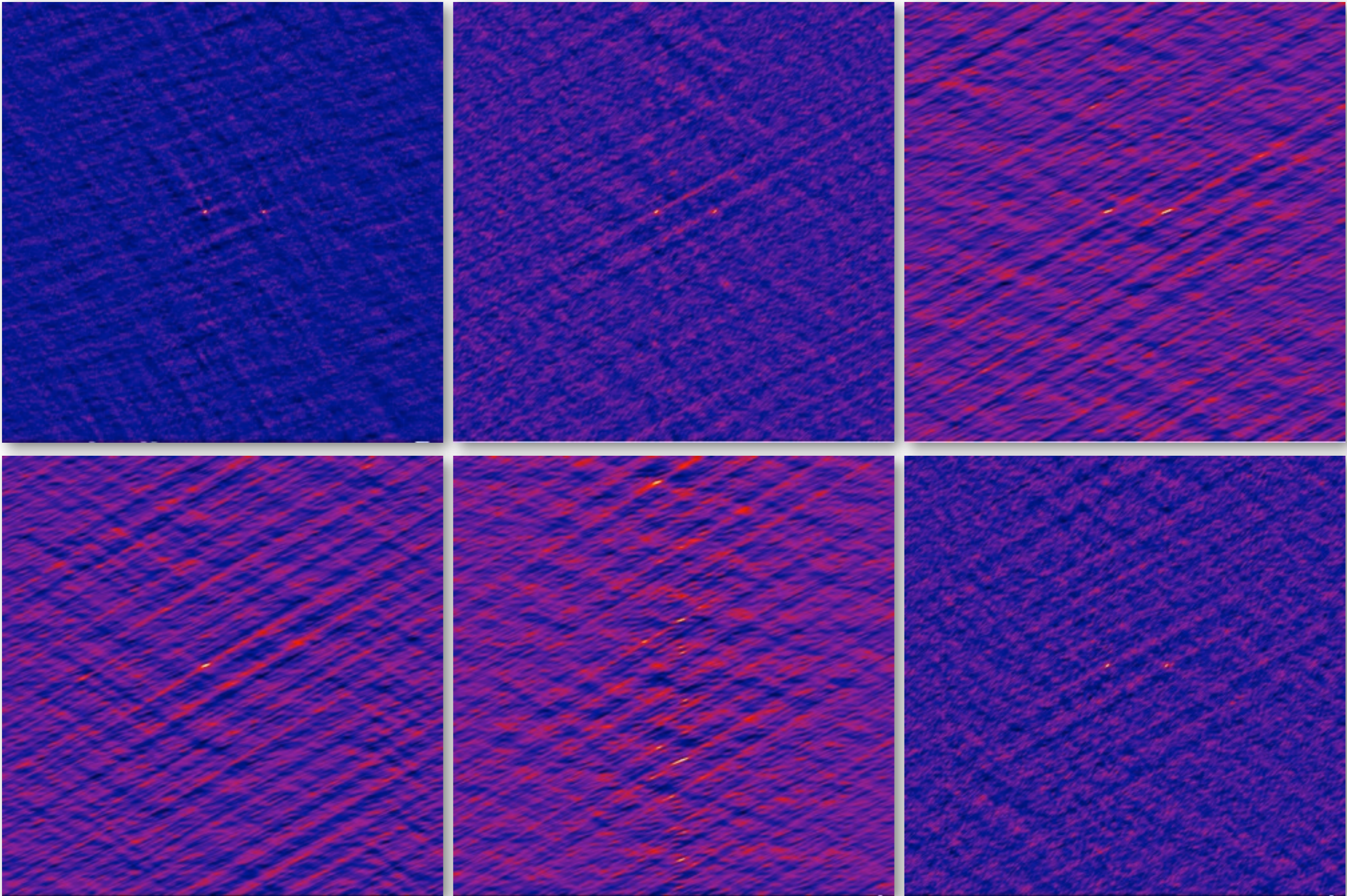


# Automatically generate PSF images



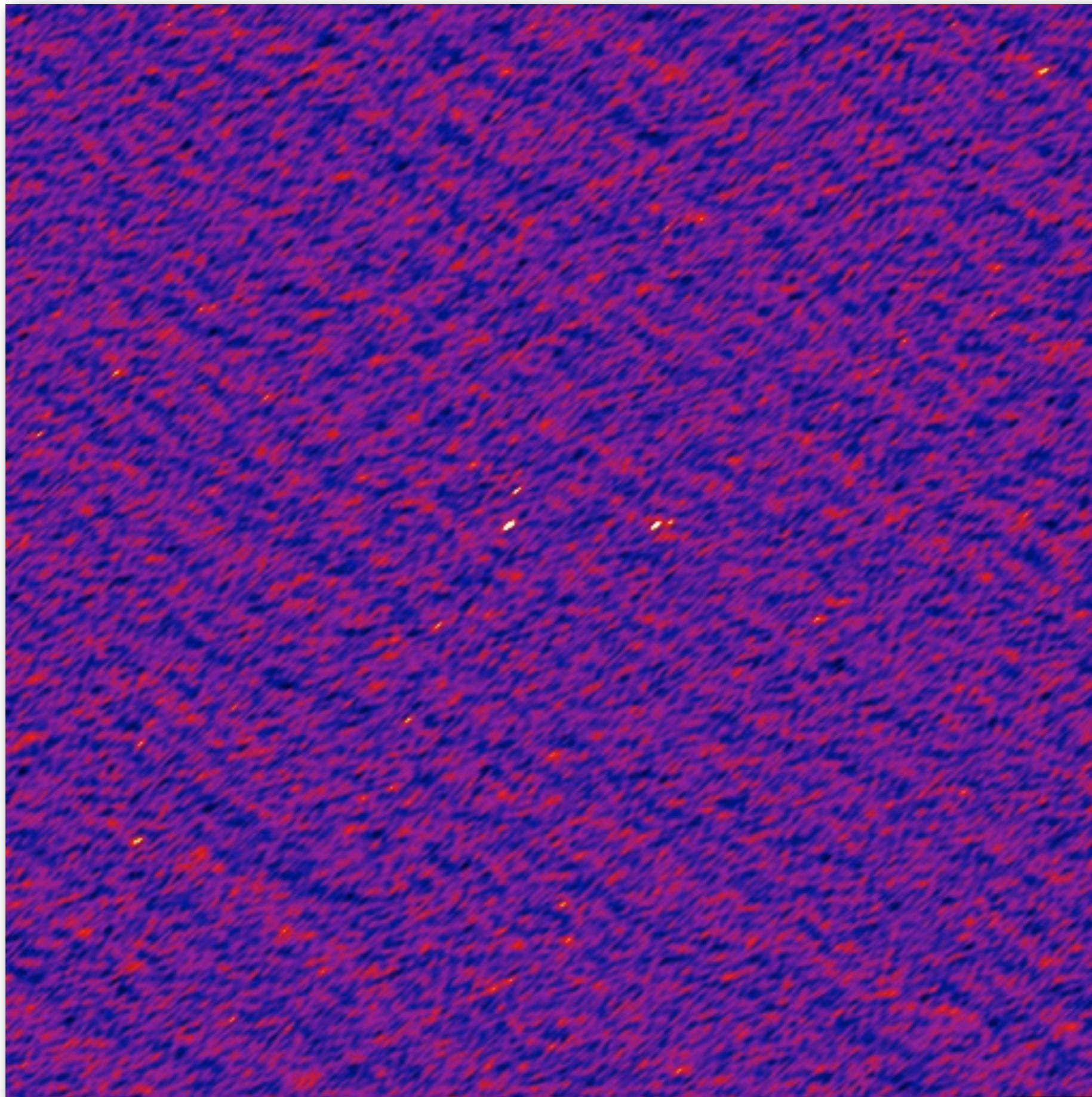


# Automatically generate dirty maps





Map from 6 MS  $\times$  2 SPW, 13  $\mu$ Jy RMS

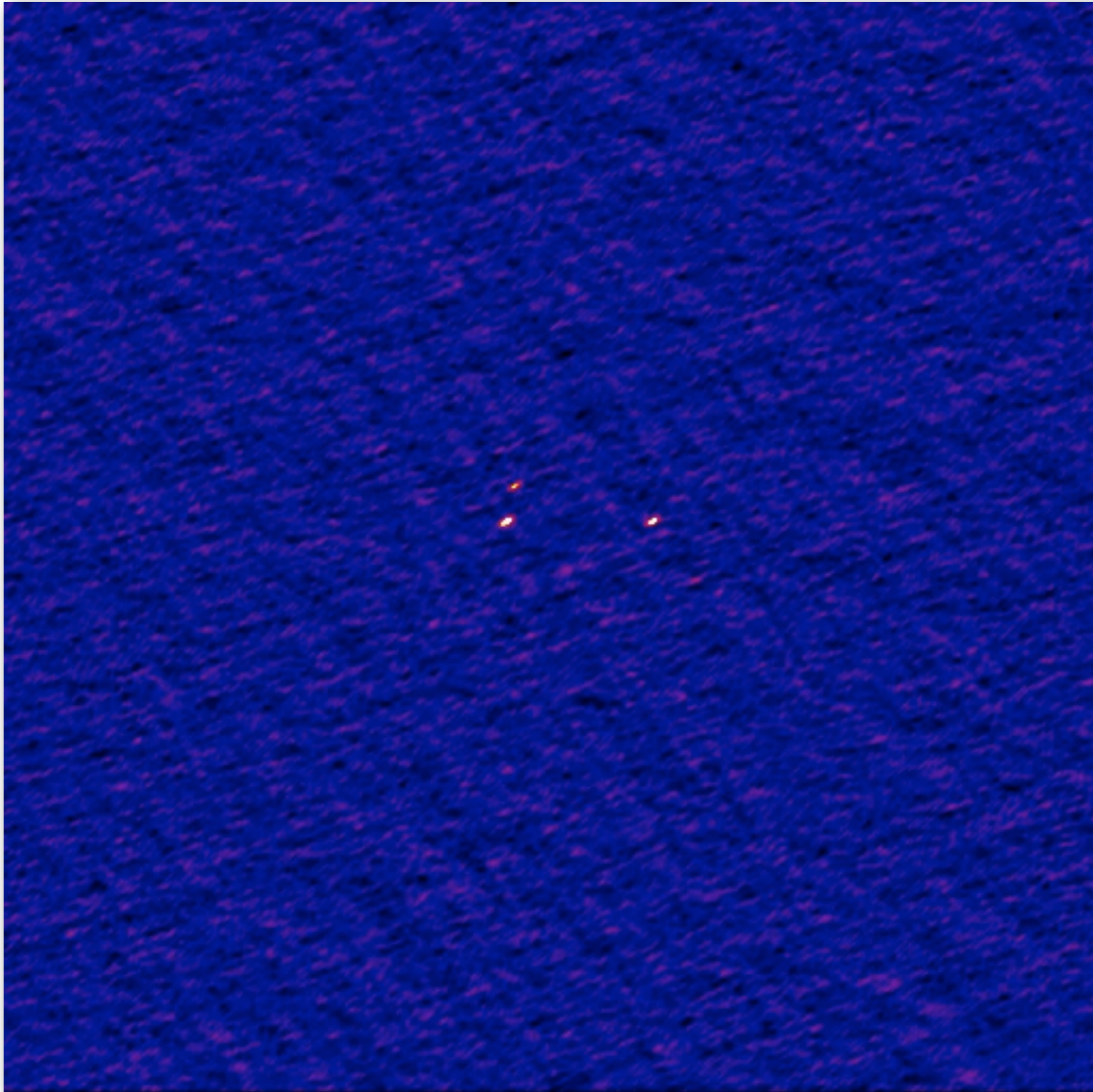




Less is more: 5 MS  $\times$  2 SPW, 6  $\mu$ Jy RMS

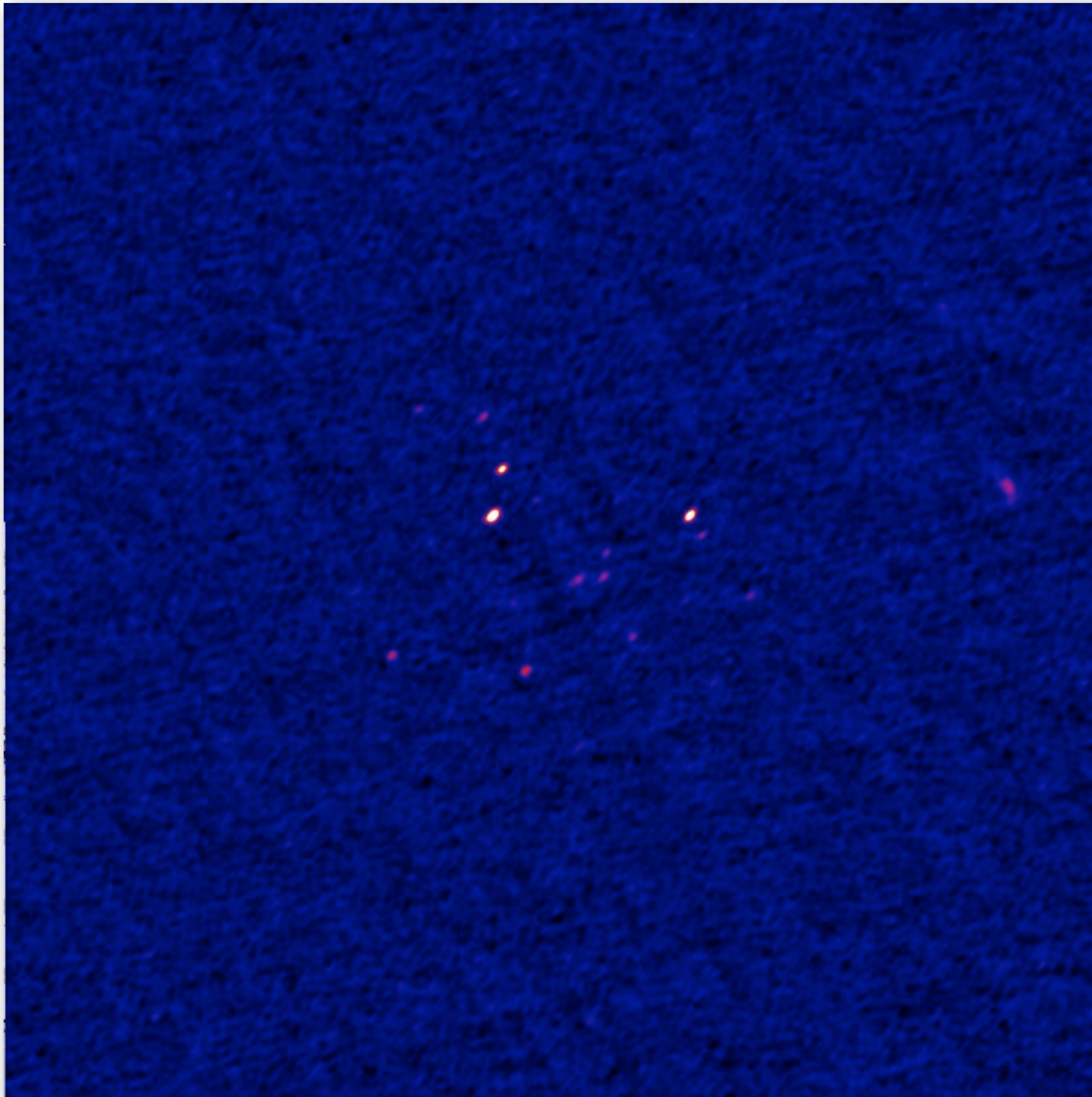


0.5 deg





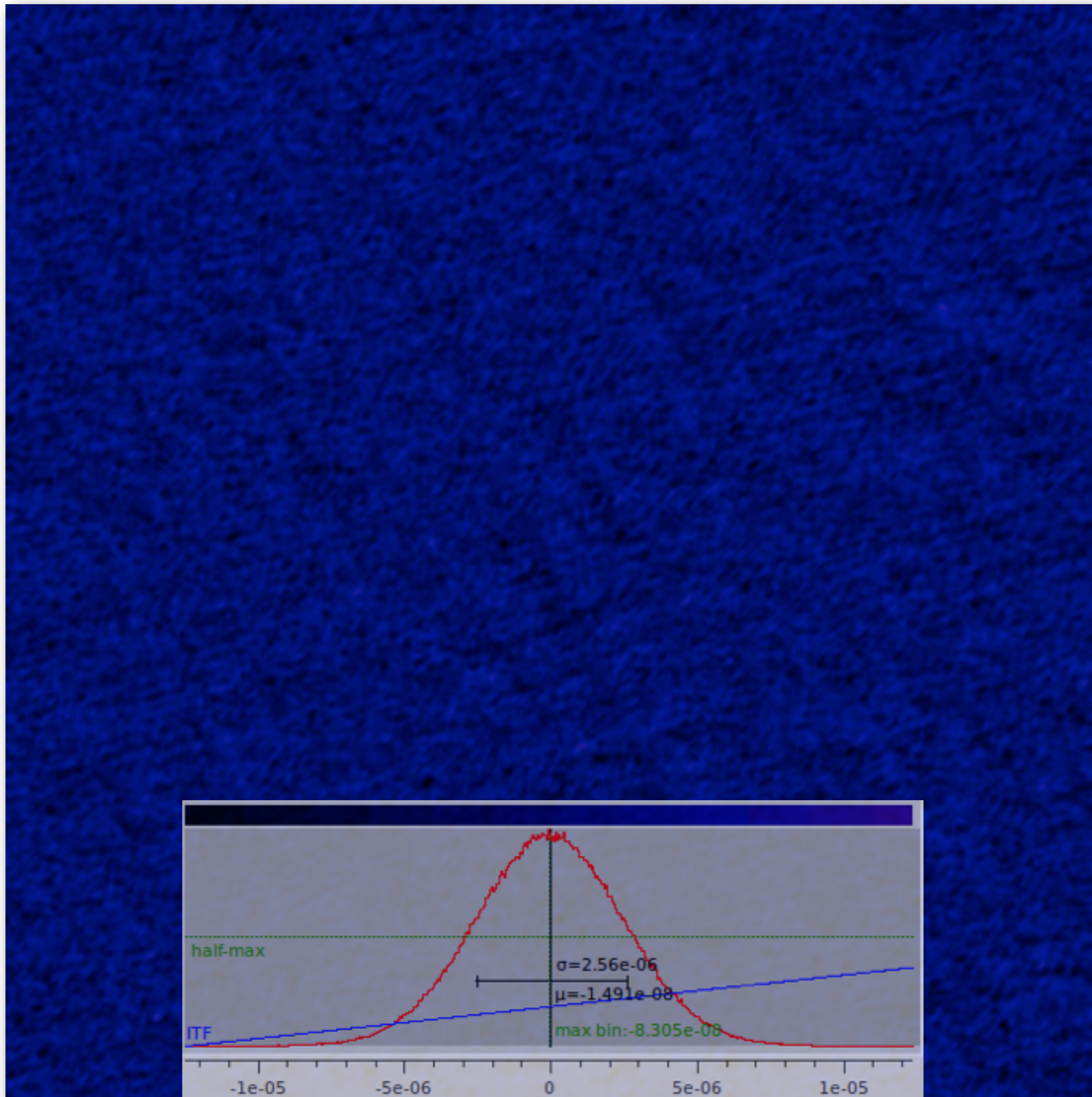
Final map:  $2.5\mu\text{Jy RMS}$



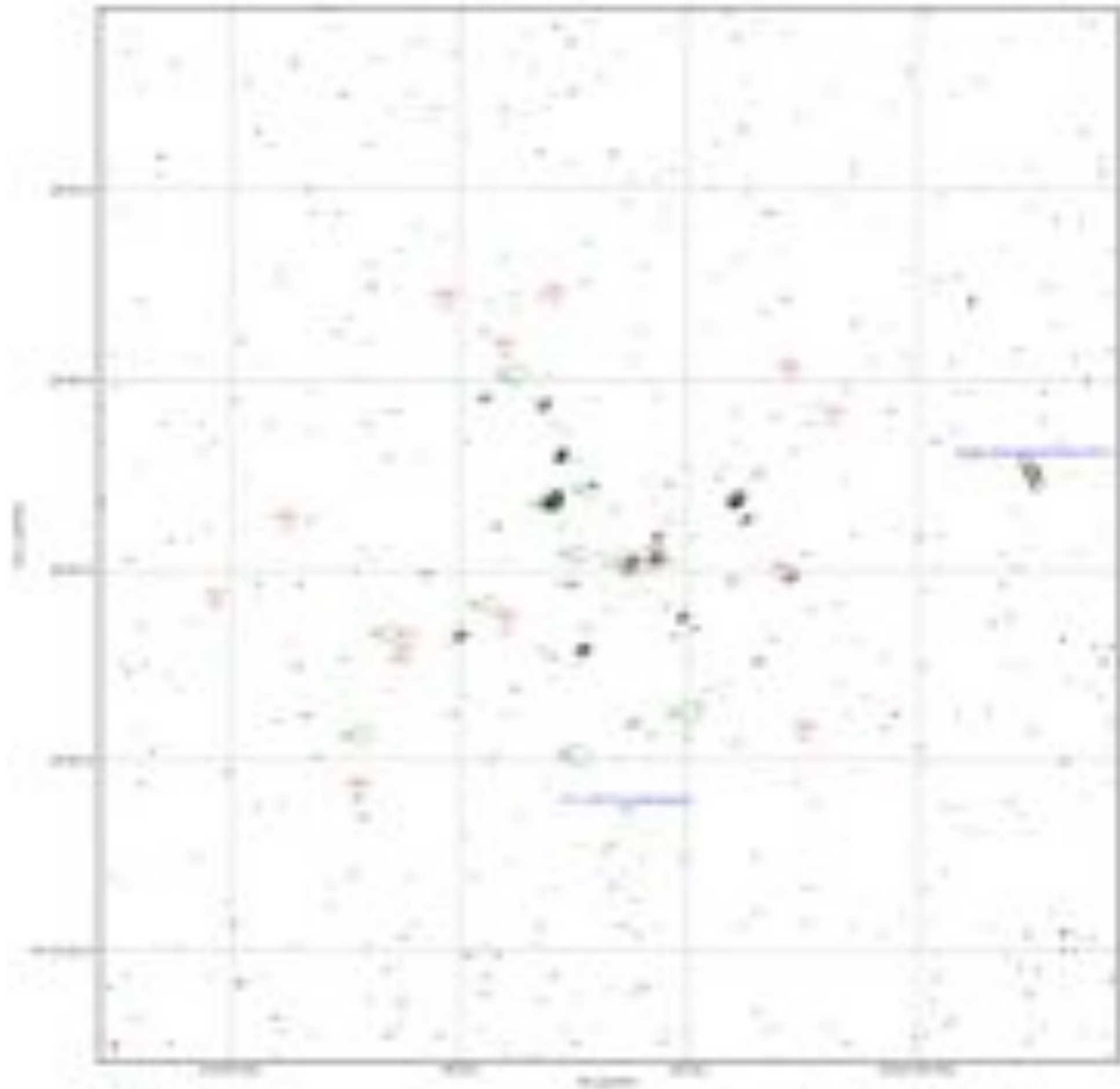


# Subtraction of 17 sources $> 5\sigma$

0.37 deg

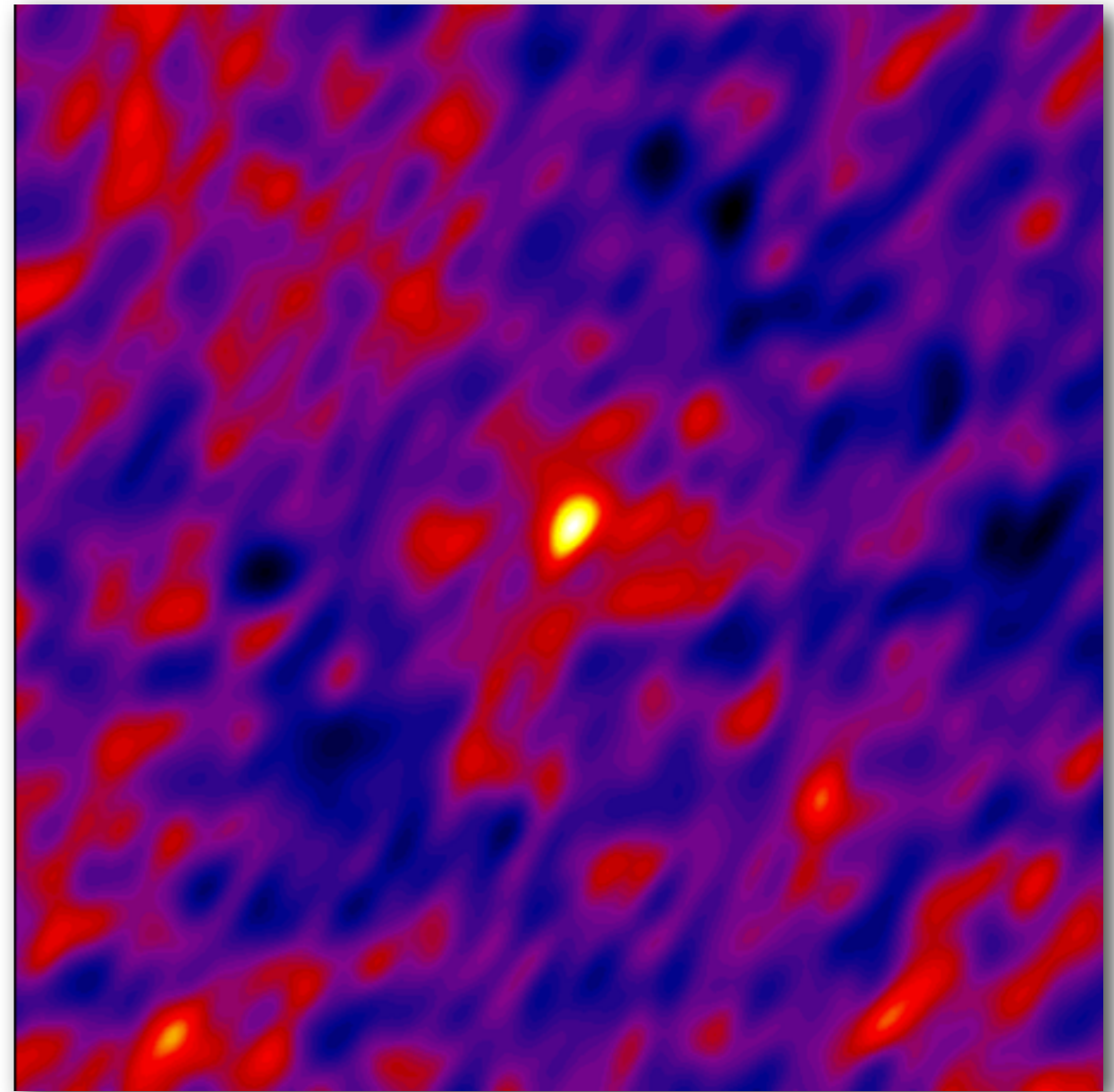
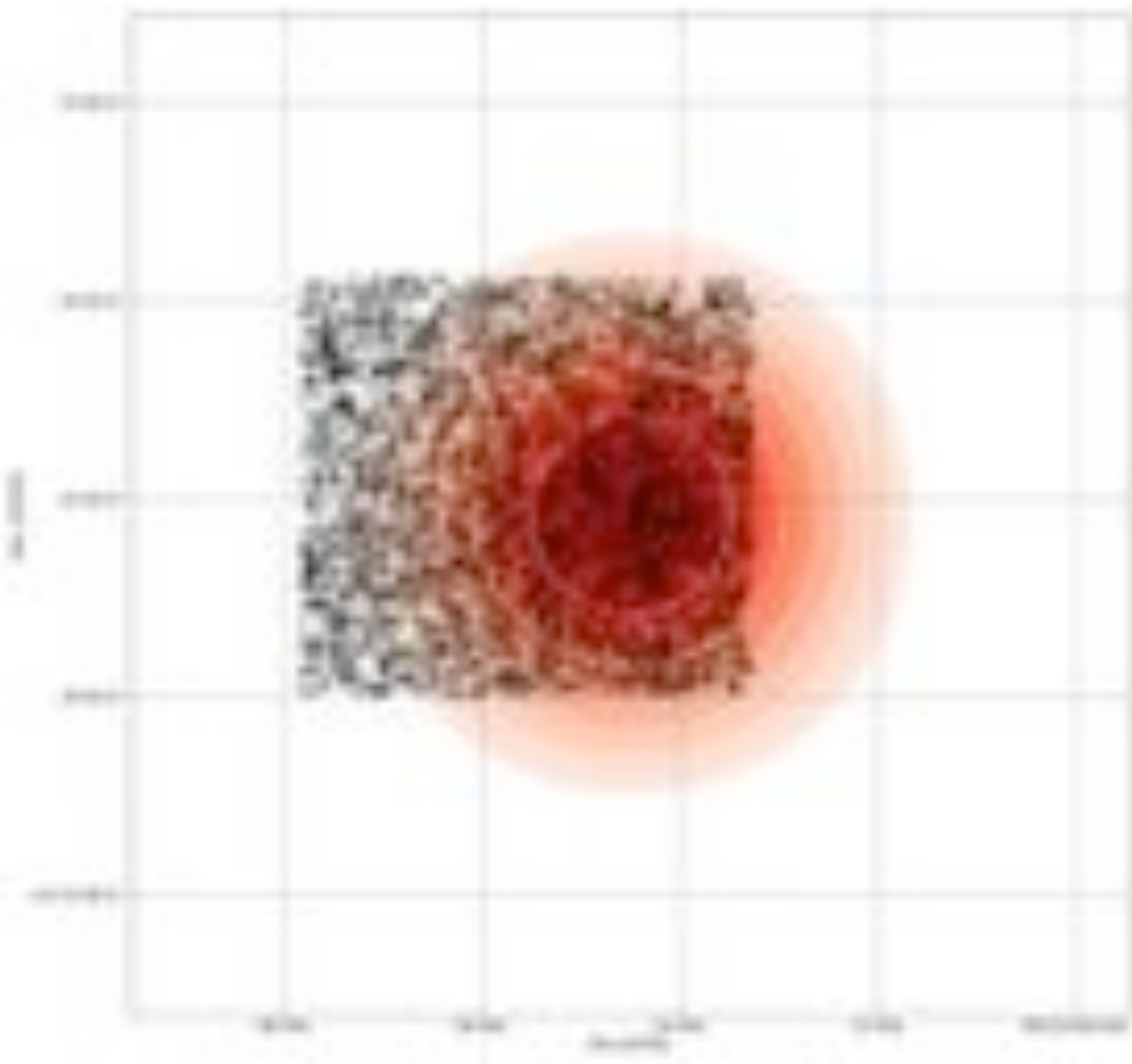


Quasars, sub-mm sources and radio contours (lowest contour =  $3\sigma$ )





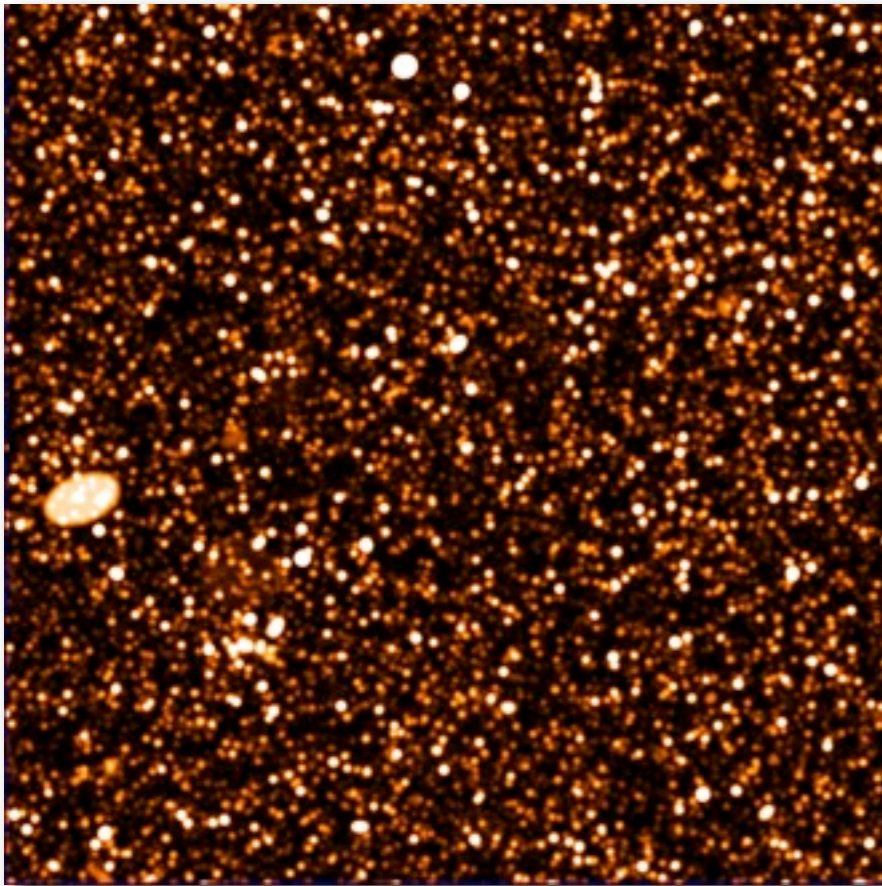
# Stacked $3\sigma$ continuum detection from 2673 optical positions



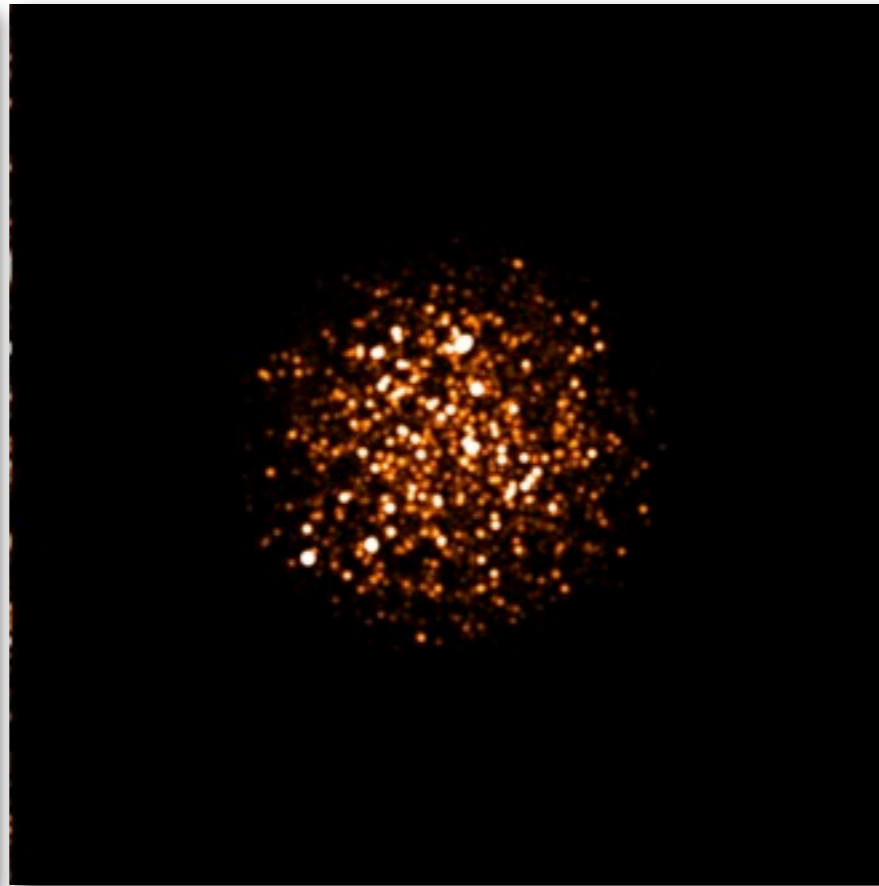
Effective RMS noise in stacked map = 95 nJy

# Simulating benchmark maps with MeqTrees and S<sup>3</sup>

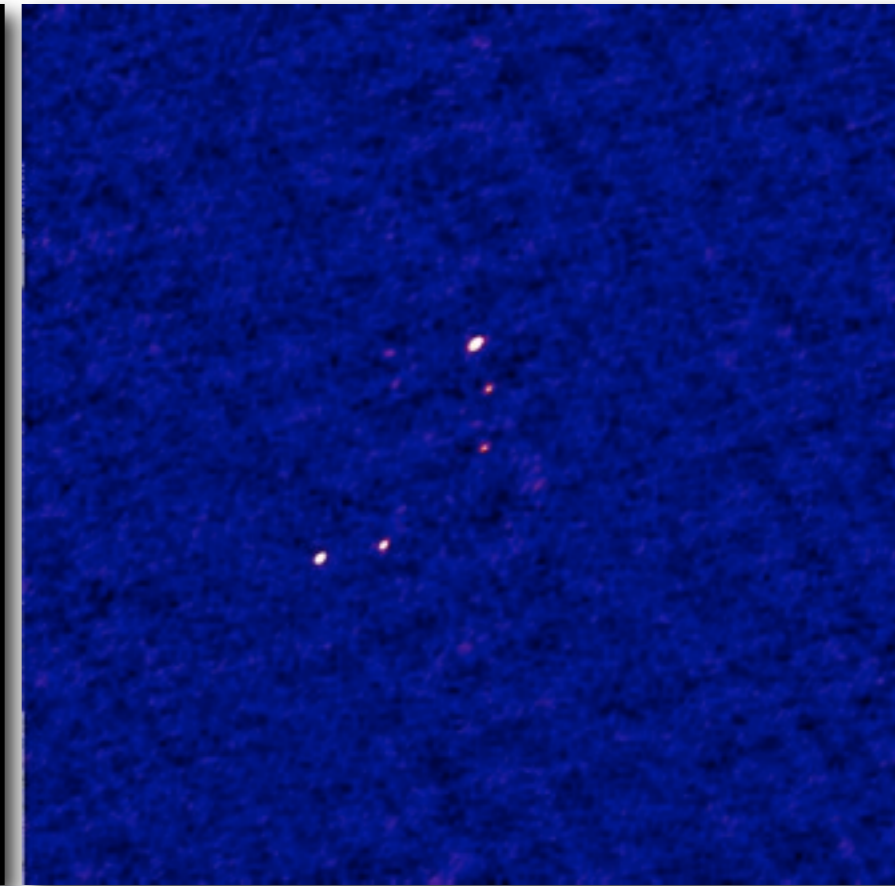
Ideal simulated sky at 8.4 GHz



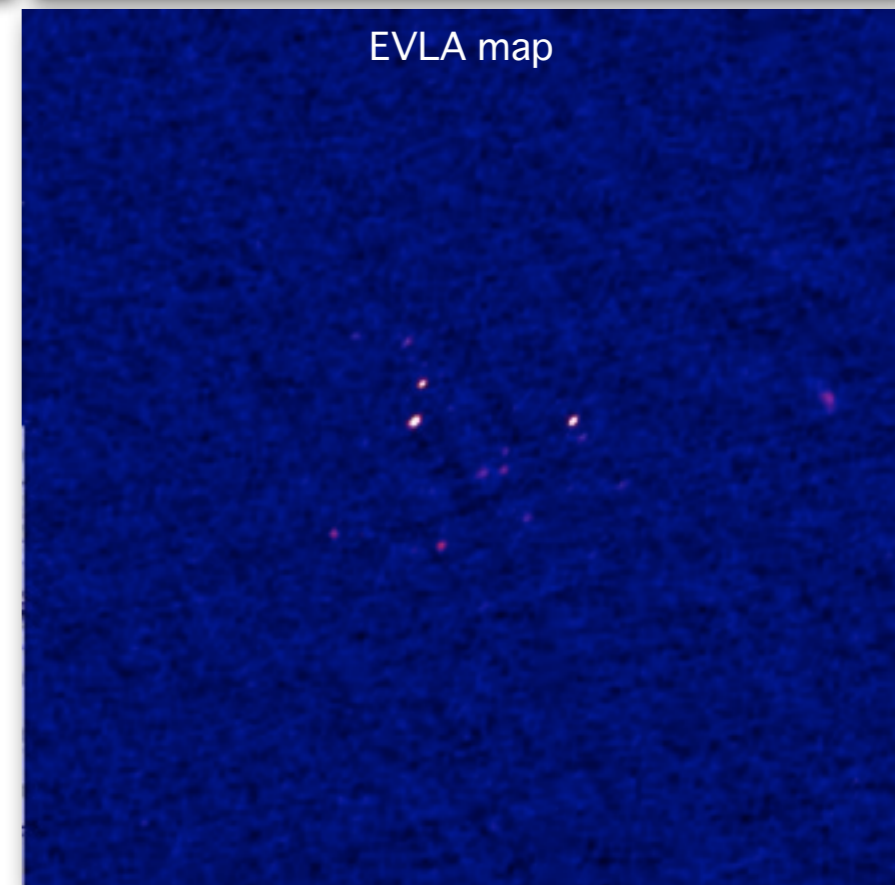
Applied primary beam attenuation



Generate perturbed visibilities and image



EVLA map



$$\sigma = \frac{\sqrt{2} k T_s}{A \eta_Q} \sqrt{\Delta \nu_{IF} \tau_a}$$



# The two-step programme to being a contented radio astronomer



1. Observe at X-band
2. Do not spatially resolve anything