Self-Calibration

Group1

Special thanks to

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Bang, Taehyeon

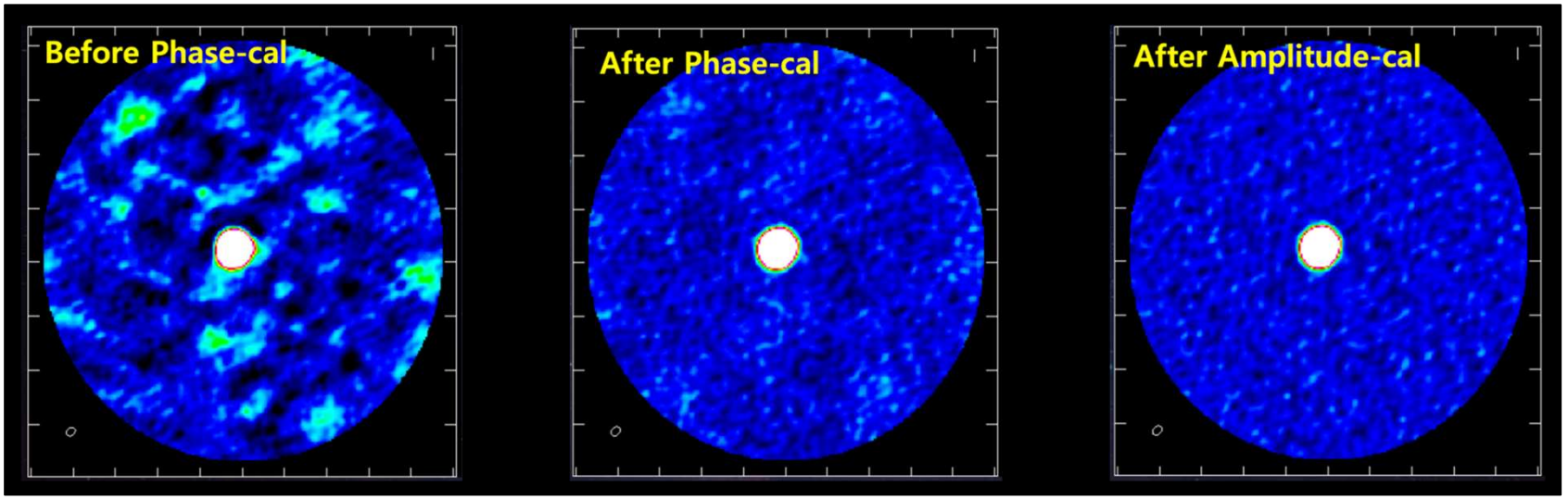
Why do we need calibrations?

Phase errors:

- Emission is smeared and astrometry is degraded.
- Flux is reduced and weak emission undetected
- Anti-sysmmetric artefacts in image

Amplitude errors:

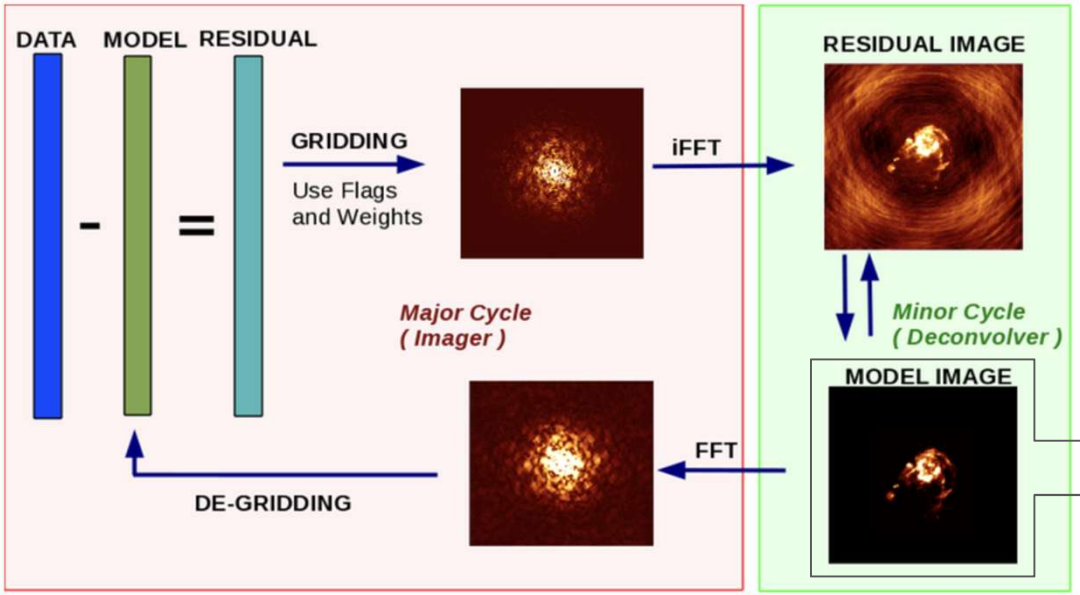
- Spotty or stripy emission
- Flux reduced and/or Noise increased
- Symmetric artefacts in image



Our Target - TW Hya

Atmospheric difference of position and time
between Phase-calibrator and targets (< a few degrees and times)

What is self-calibration?

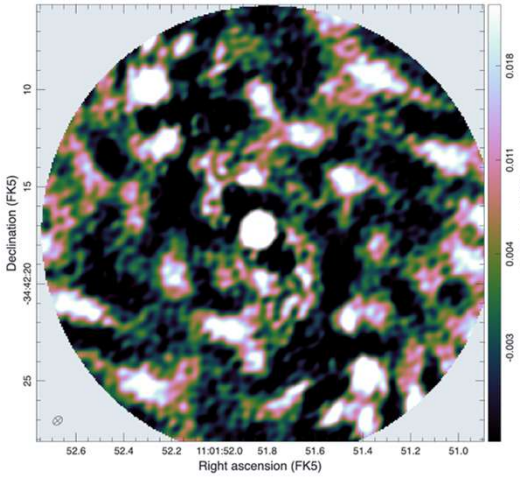


We could utilize a better **calibrator**

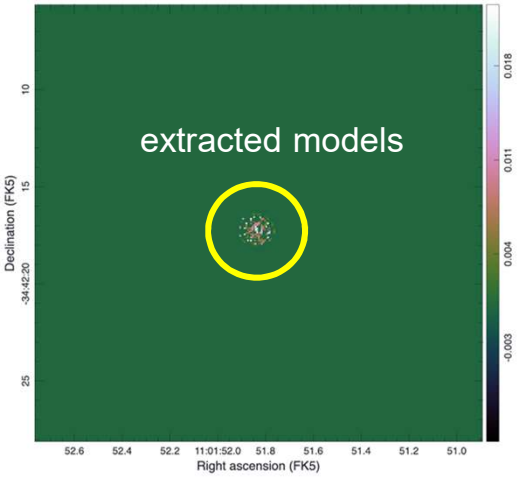
→ which is **the target!**

What is self-calibration?

Dirty Map



Model Map



$$V_{ij}^{obs} = \mathcal{G} V_{ij}^{true}$$

$$\left| V_{ij}^{obs} - \mathcal{G}_{ij}(t) V^{model} \right|^2$$

minimize!

➜ ***gaincal***

$$\frac{V_{ij}^{obs}}{\mathcal{G}} \approx V_{ij}^{true}$$

➜ ***applycal***

postulate the cleaned result as an **analog** of the phase calibrator at the source position!

What is self-calibration?

Sanity Check

inspection of sufficient S/N ratio must be preceded

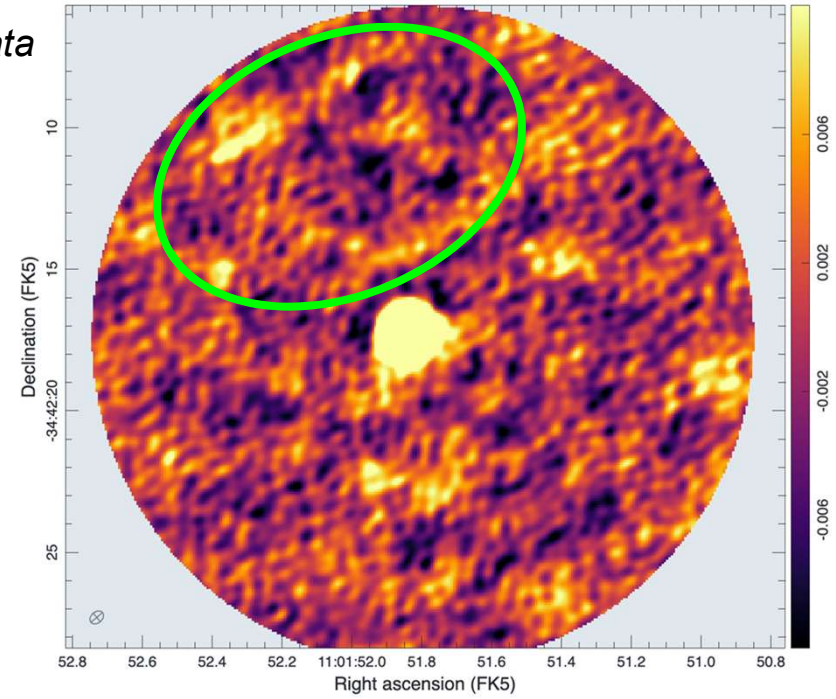
e.g., S/N >20 for ~25 antennas

- strong outlier included in the model
- severe variability of the data
- over-calibrated image

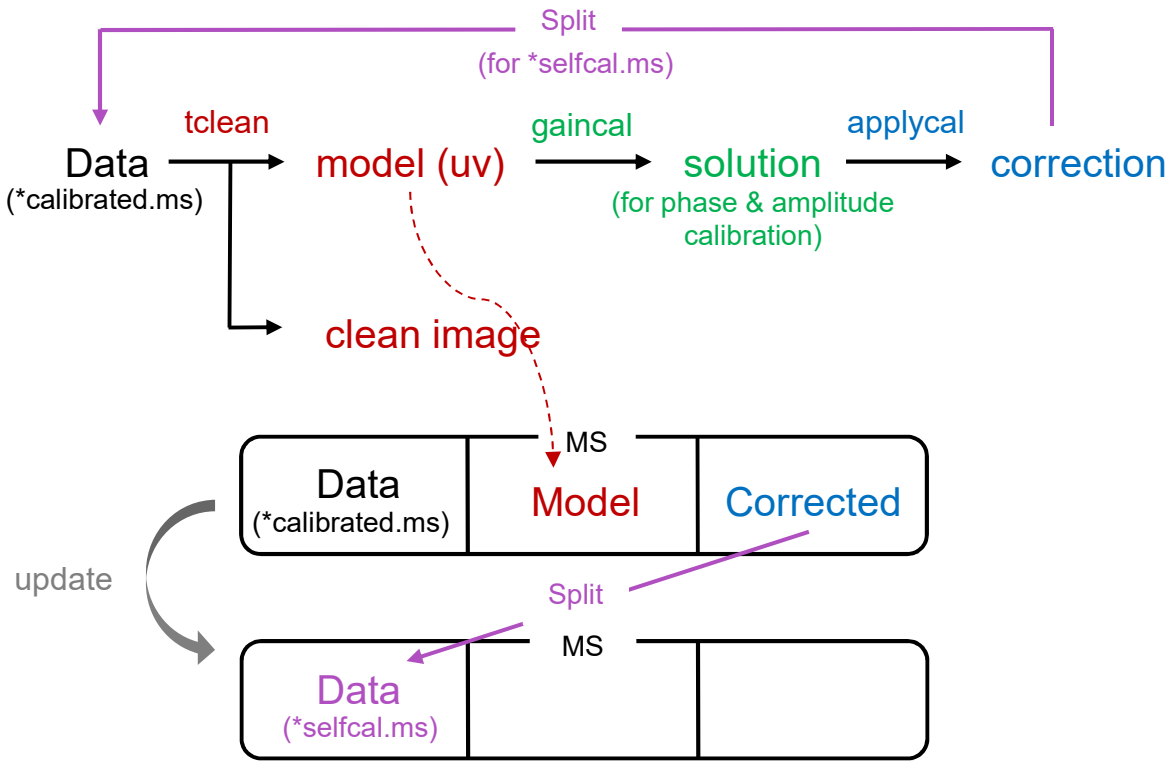
What is self-calibration?

significant residuals still exist after phase calibration (with J1037-265)

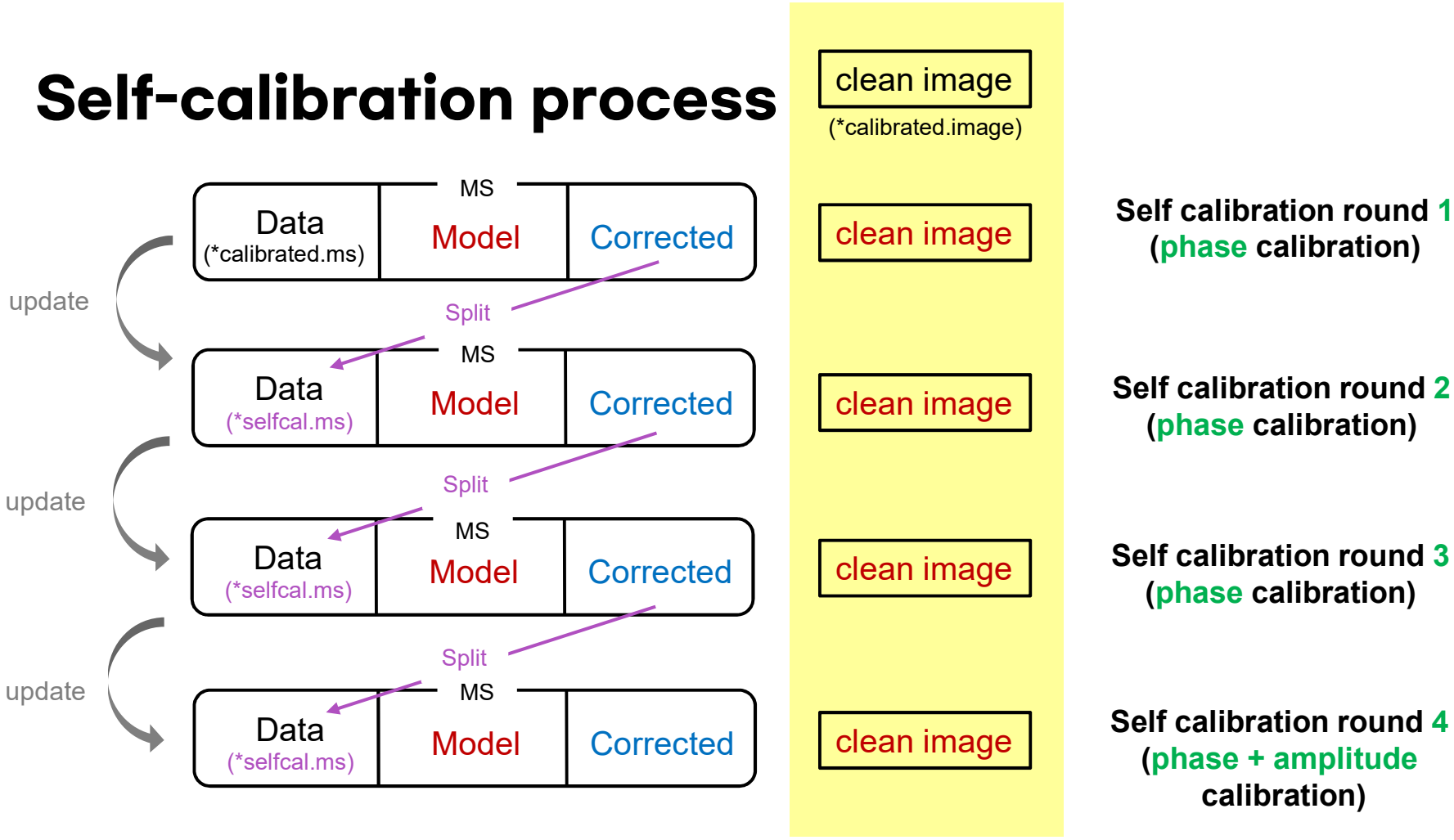
after cleaning the TW_Hya data



Self-calibration process



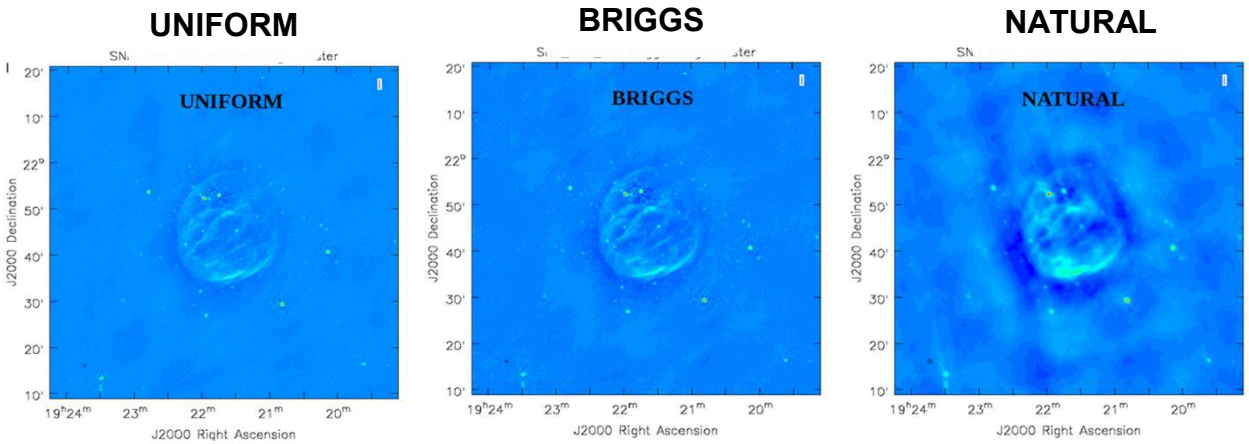
Self-calibration process



Adjusting parameter

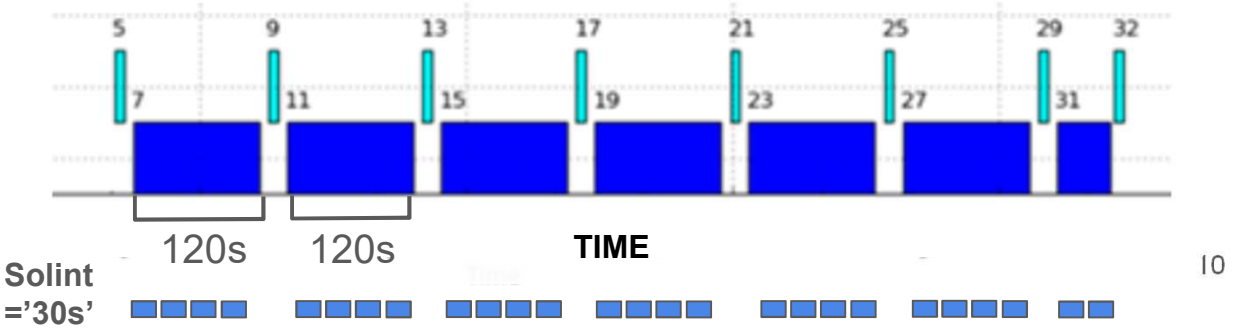
[Adjusting weighting]

- case 1(briggs)
- case 2(uniform)
- case 3(natural)



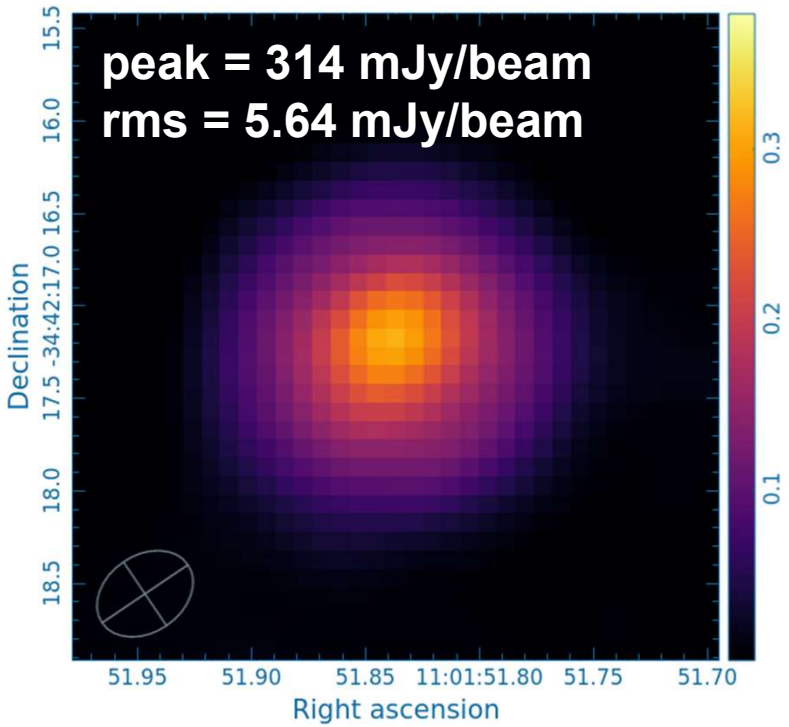
[Adjusting solint]

- what is solint
- solint result

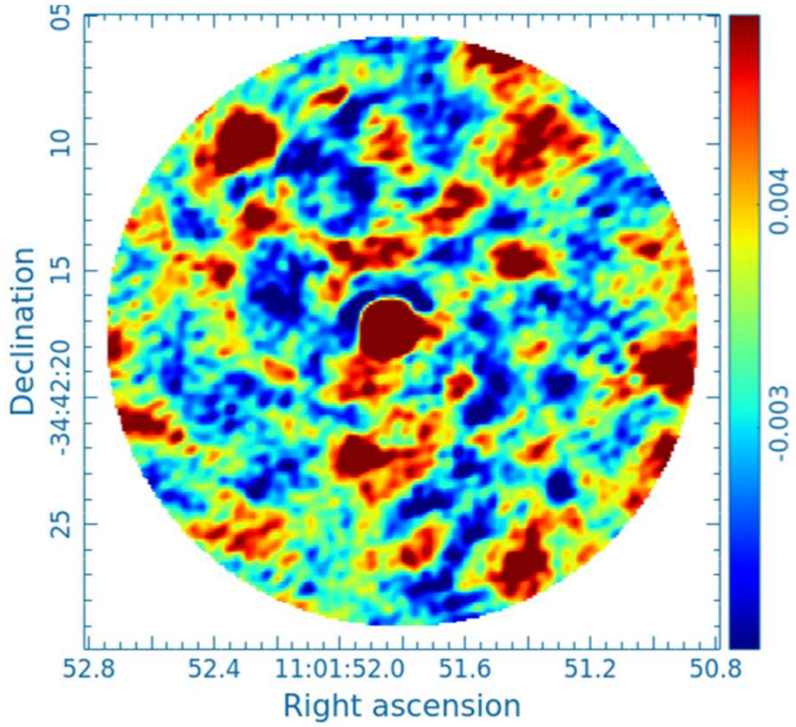


Case 1: weighting “briggs” (robust = 0.5)

Image



Residual



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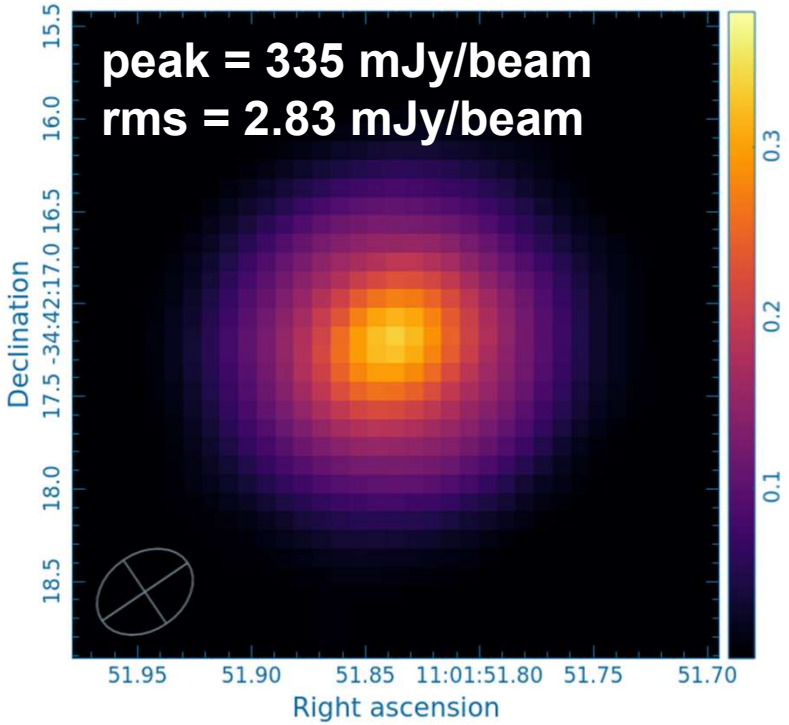
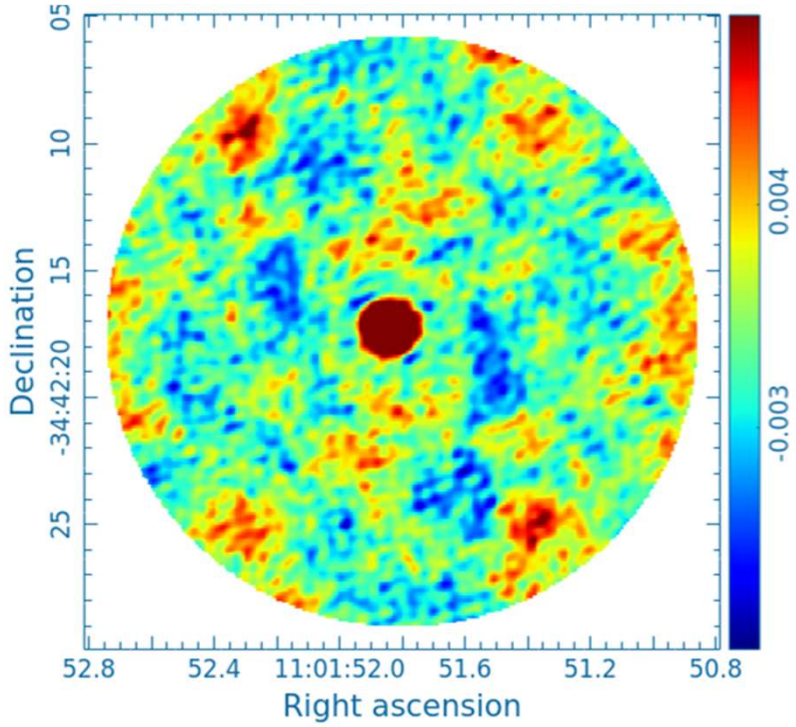


Residual



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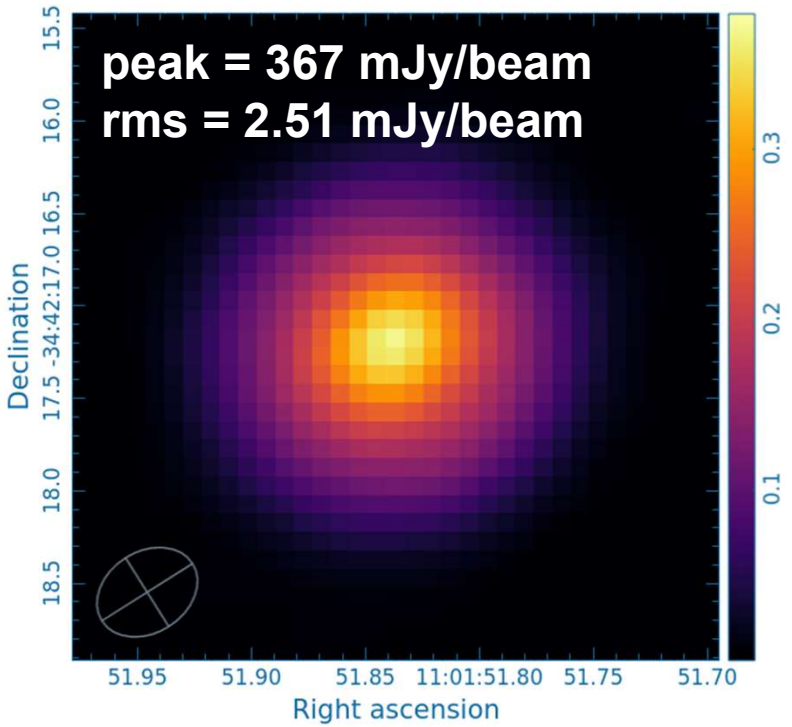
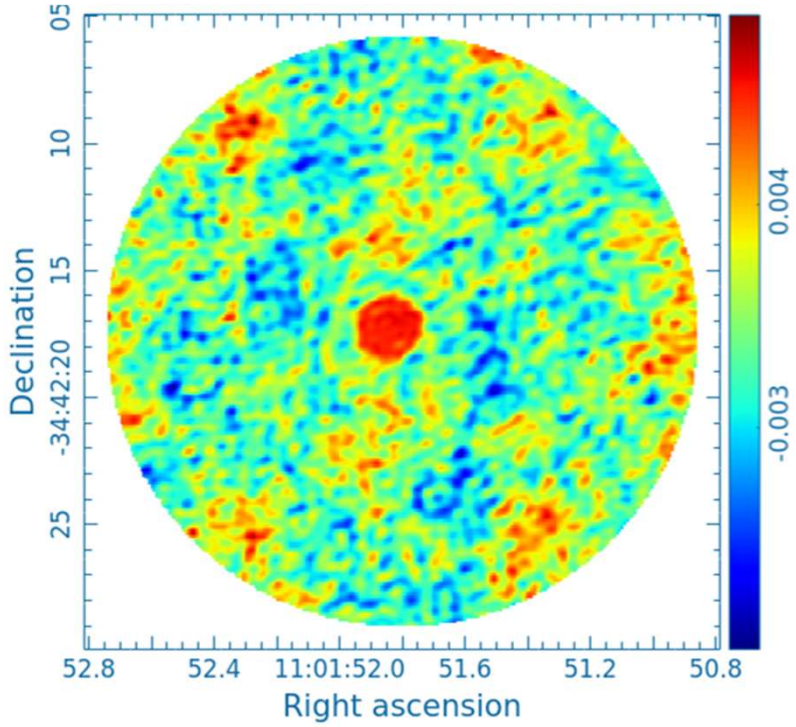


Residual



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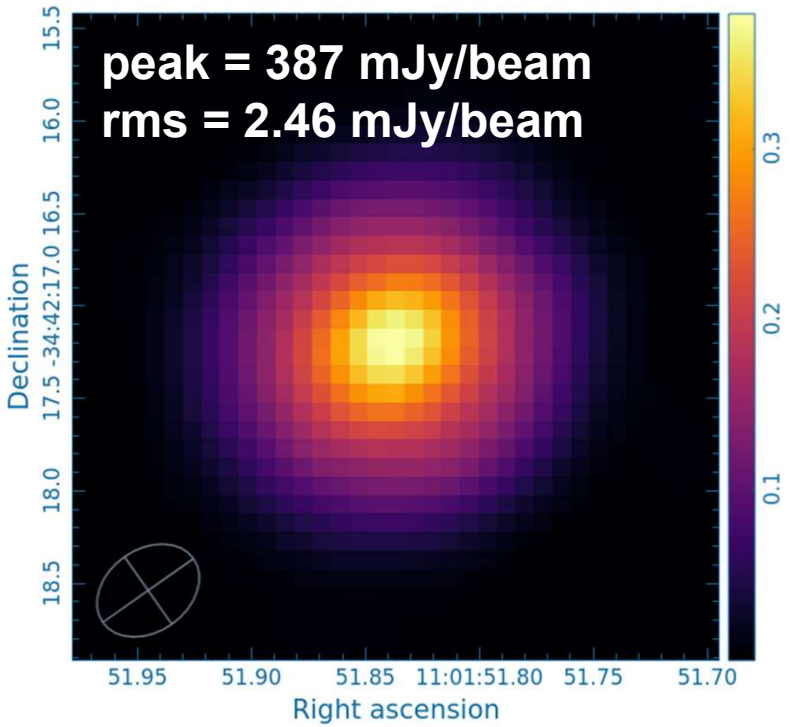

Residual

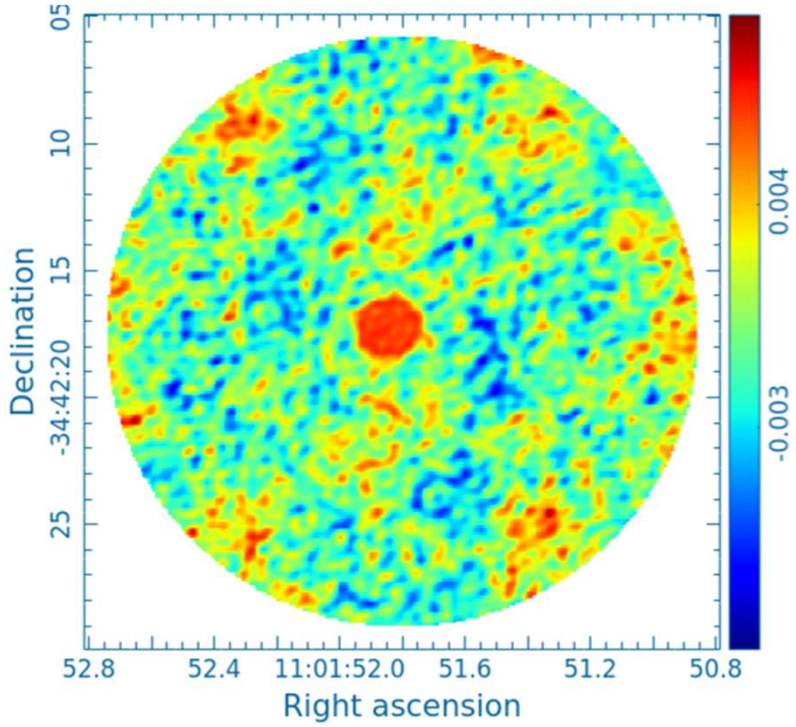

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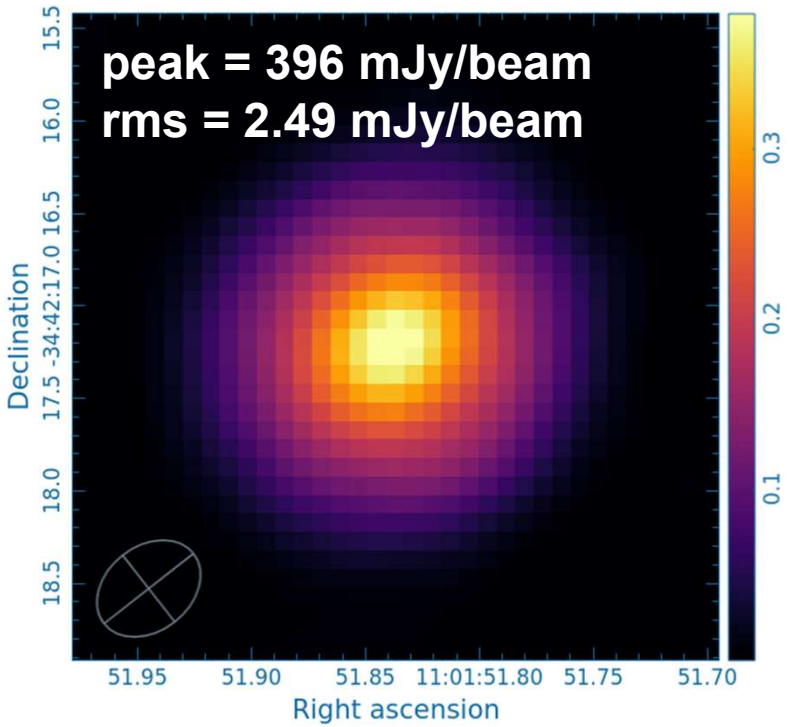
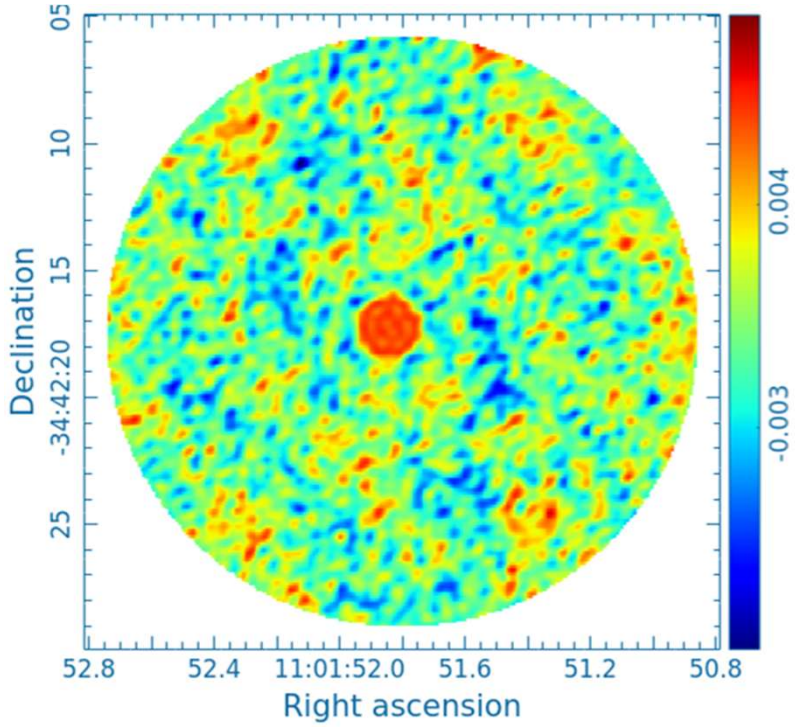
Image

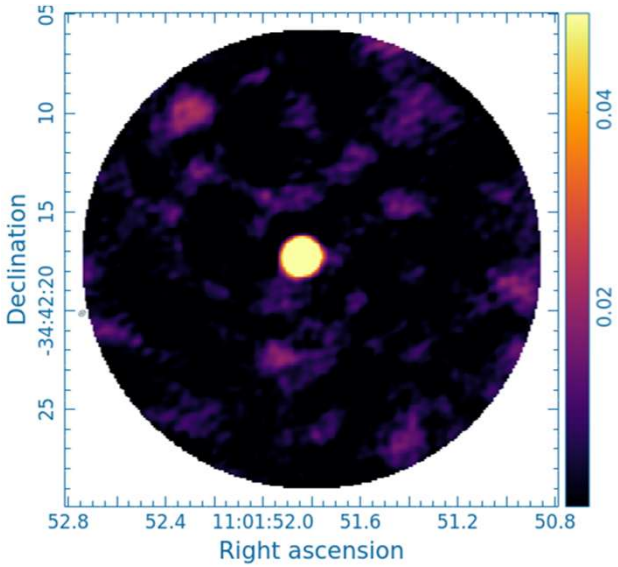


Residual



Case 1: weighting “briggs” (robust = 0.5)

Before

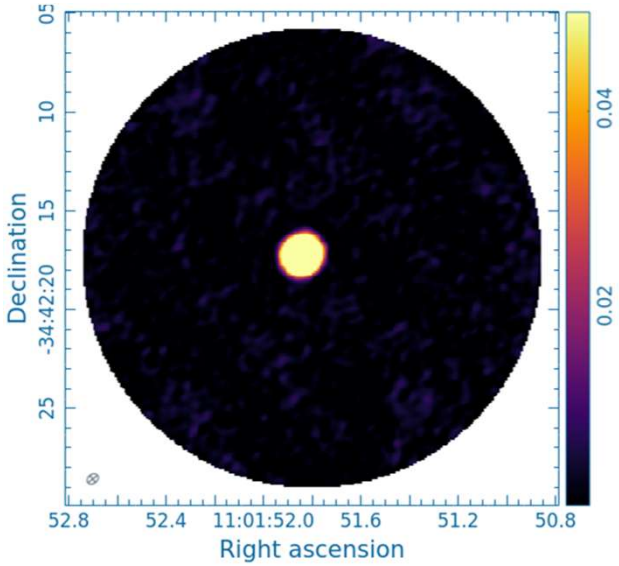


SNR	56
beam	0.560” * 0.416”

+184%

+9.64%

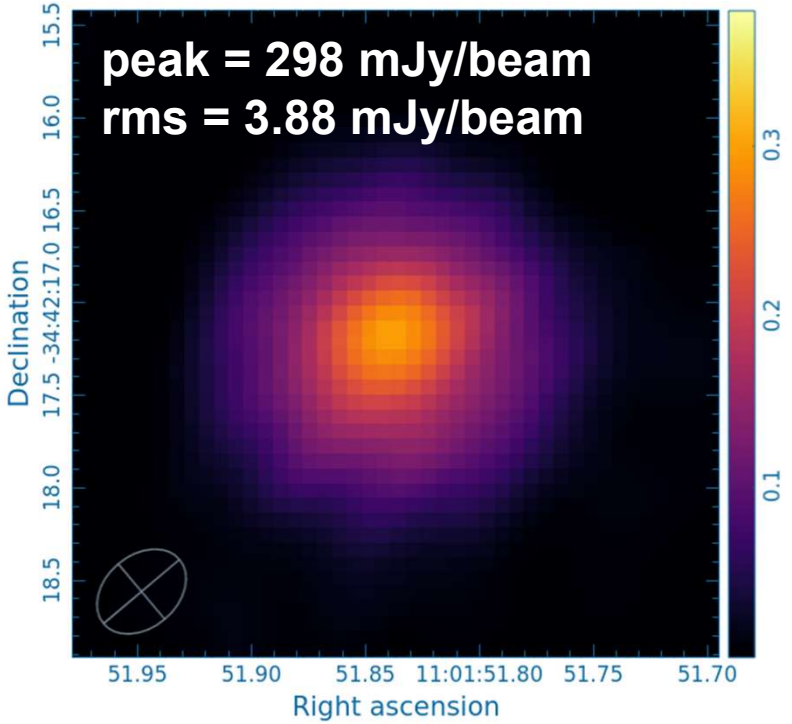
After



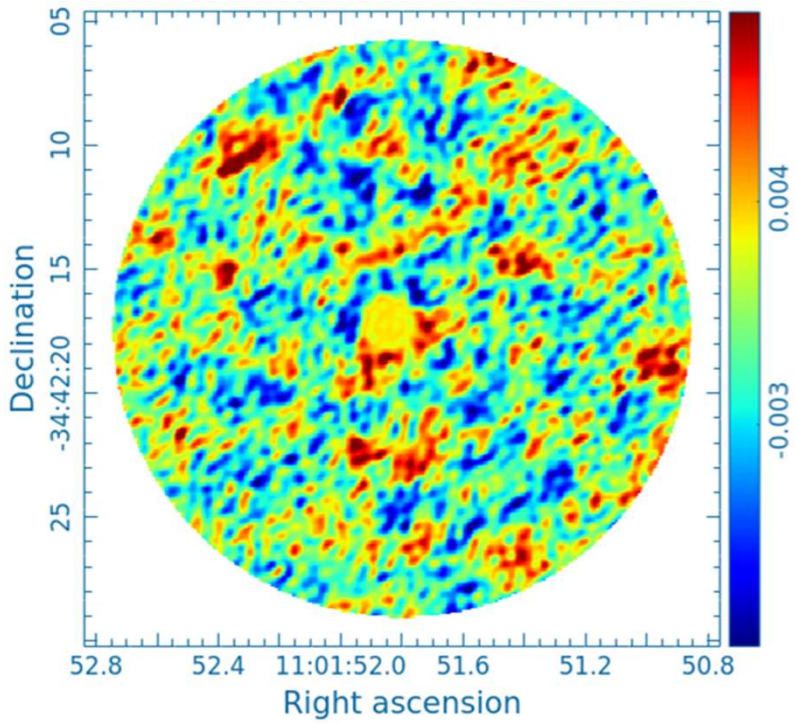
SNR	159
beam	0.614” * 0.457”

Case 2: weighting “uniform”

Image

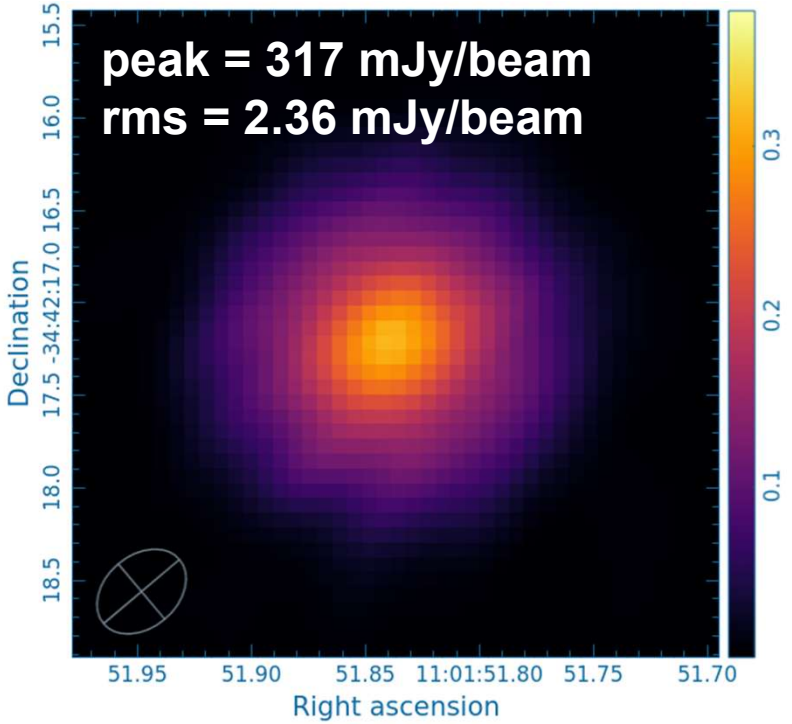


Residual

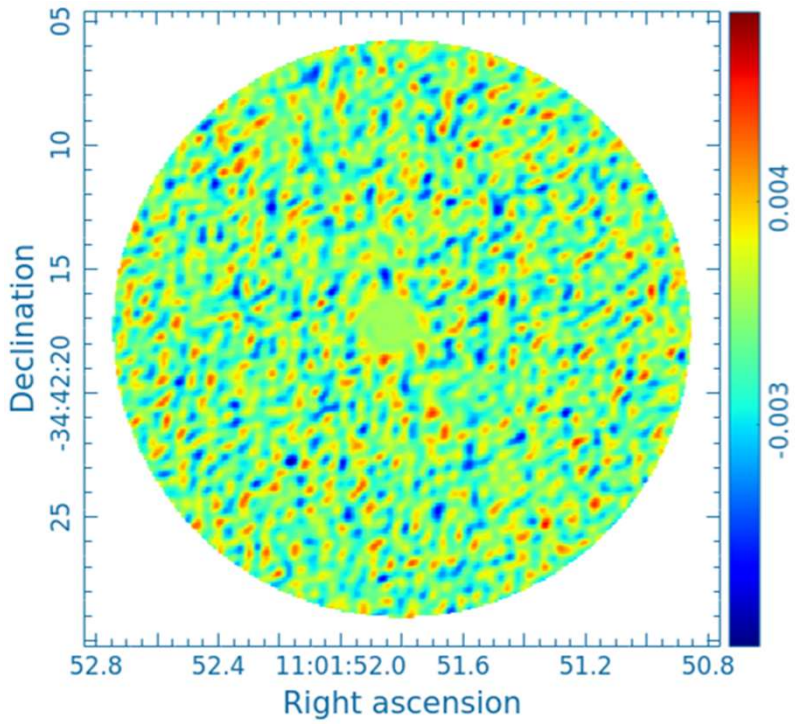


Case 2: weighting “uniform”

Image



Residual



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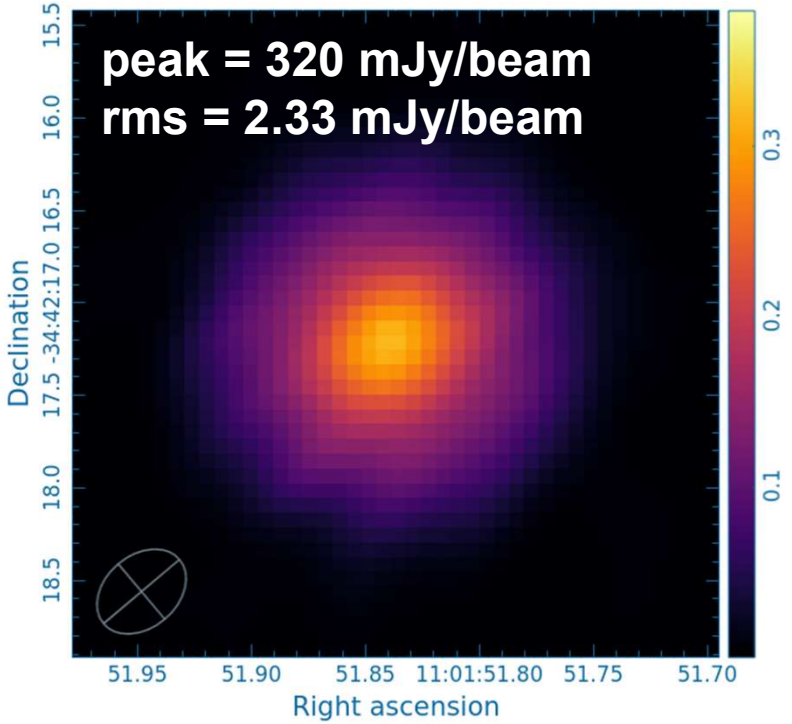
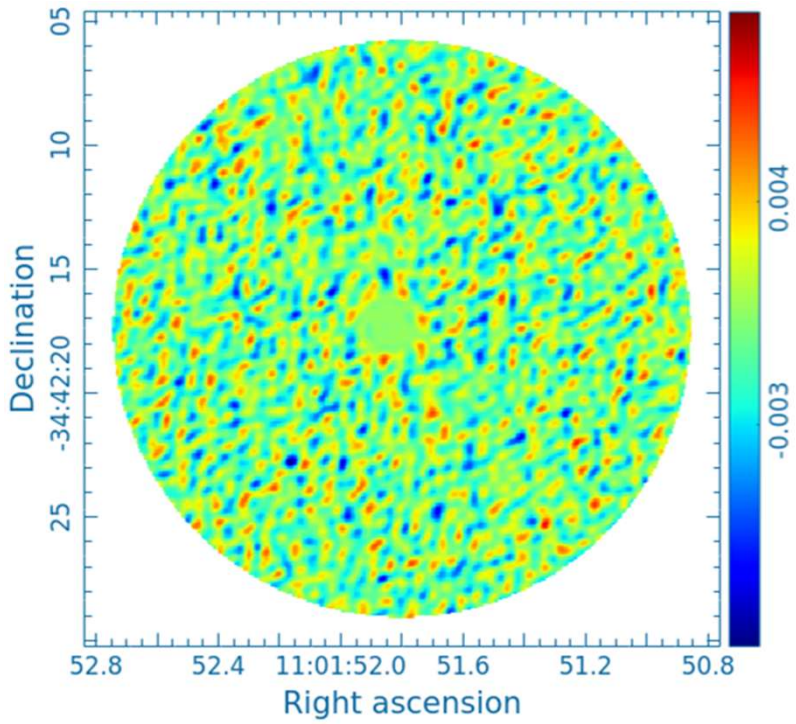


Residual



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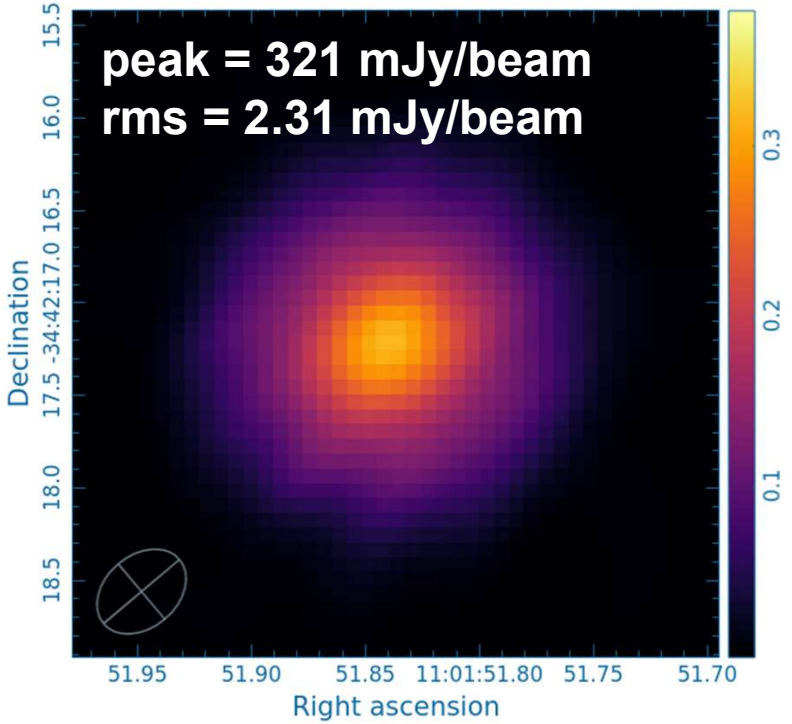
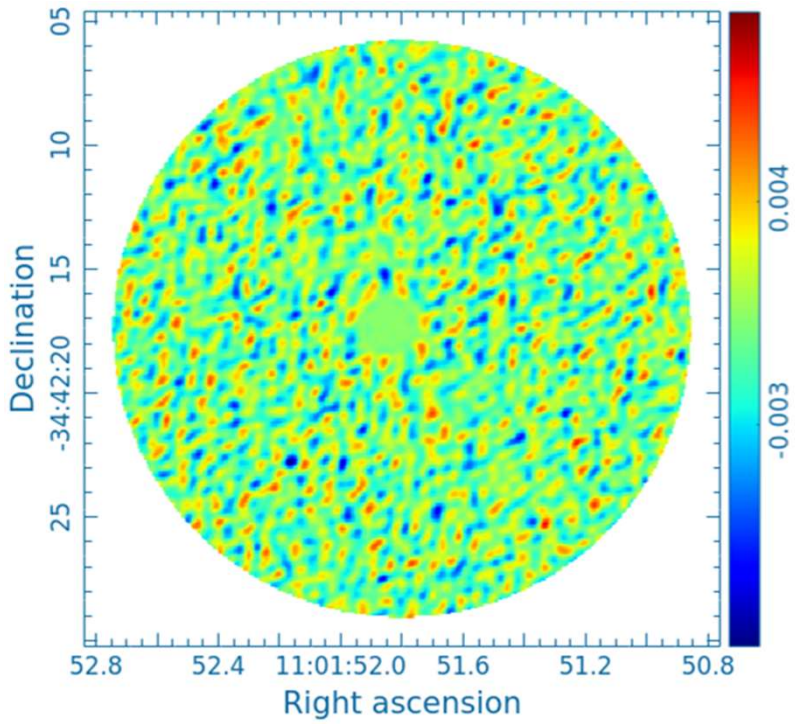


Residual



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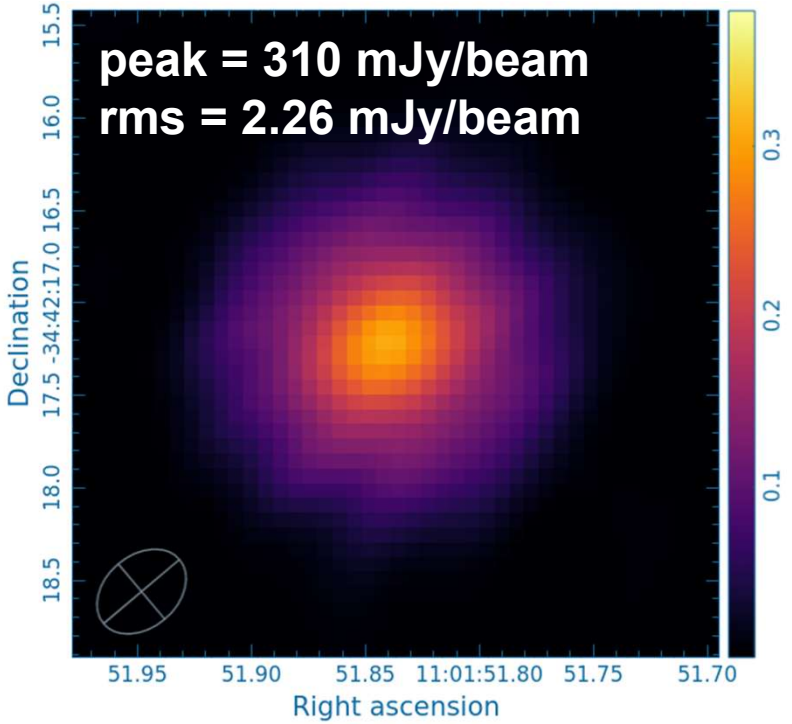
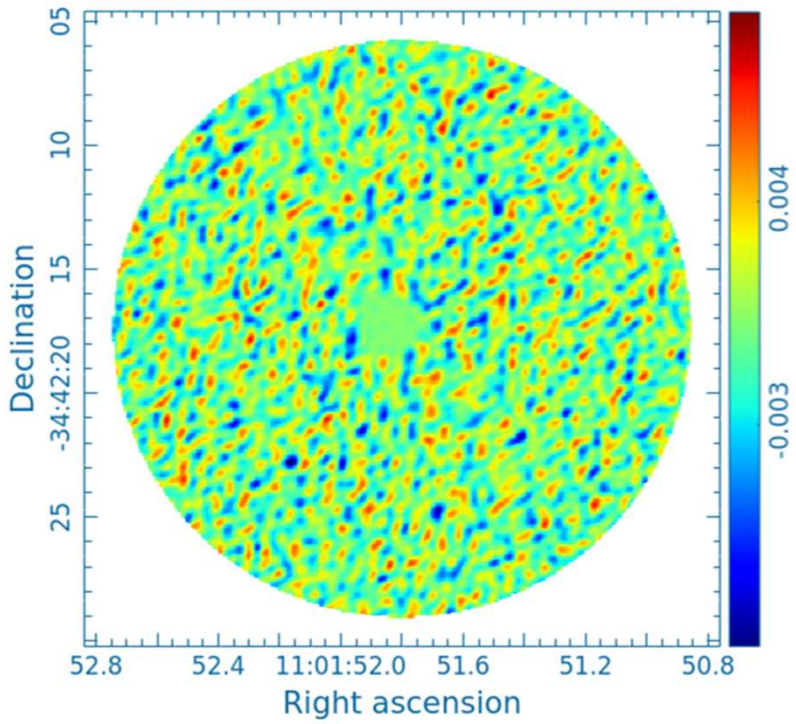
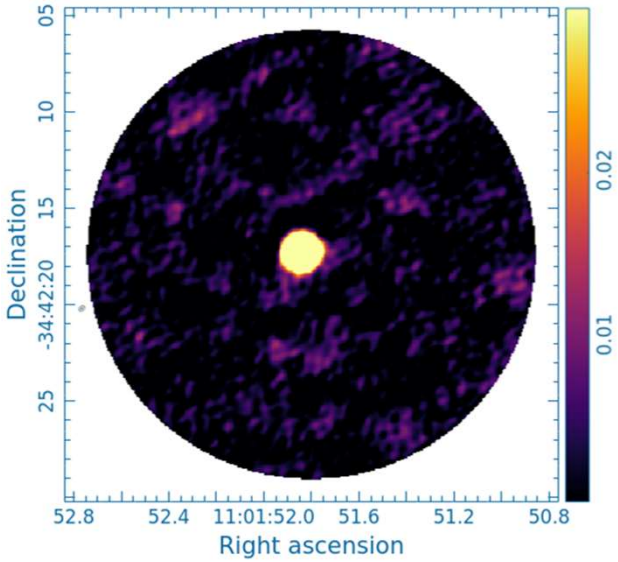


Residual



Case 2: weighting “uniform”

Before

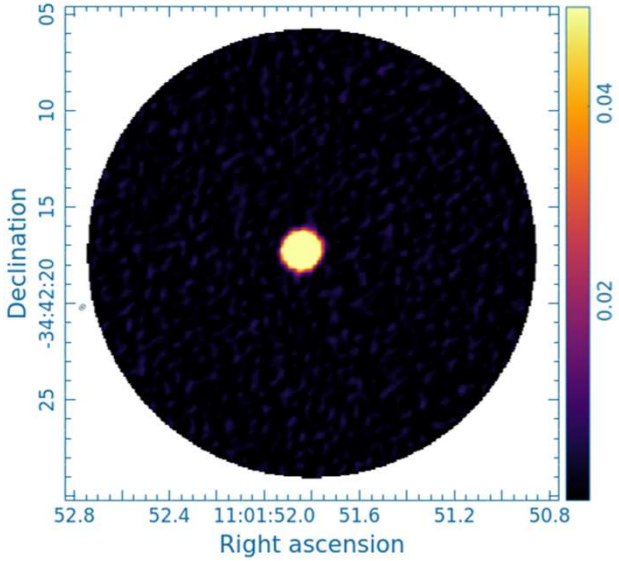


SNR	77
beam	0.537” * 0.390”

+77.9%

0%

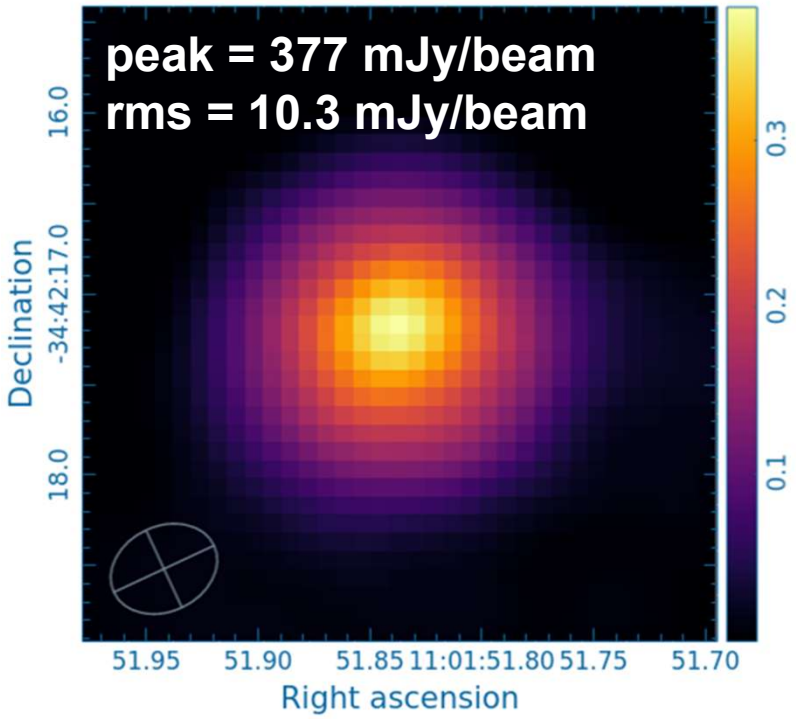
After



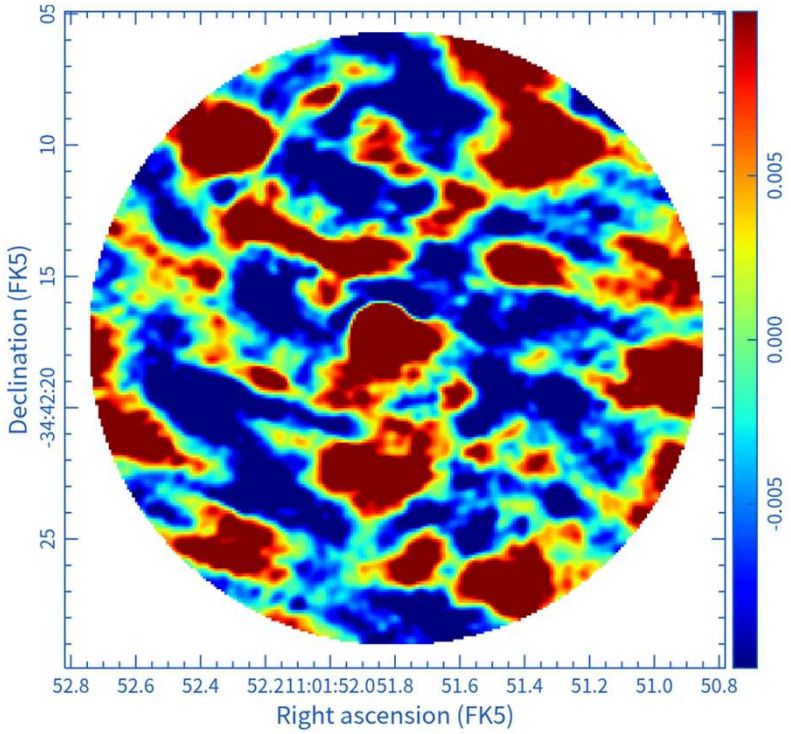
SNR	137
beam	0.537” * 0.390”

Case 3: weighting “natural”

Image

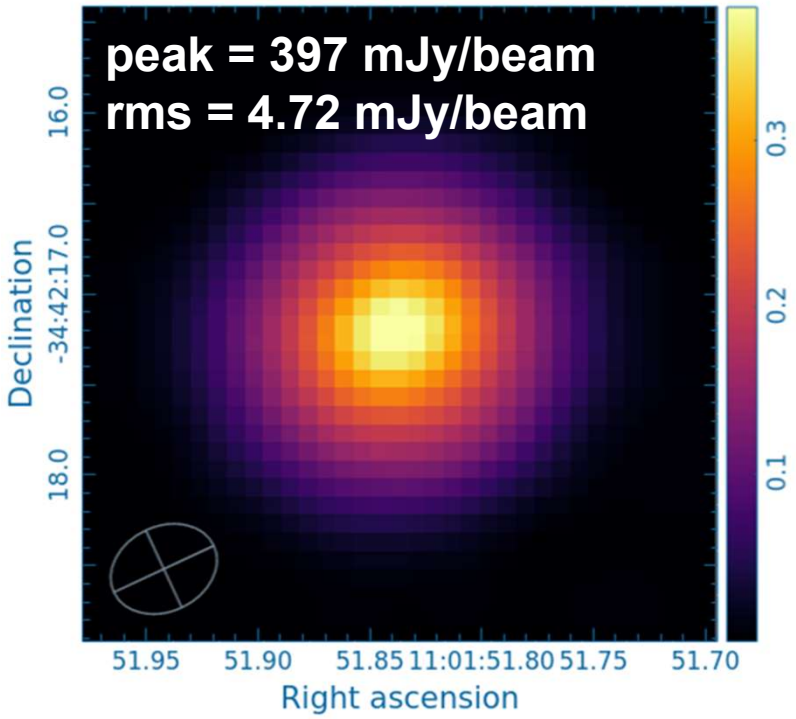


Residual

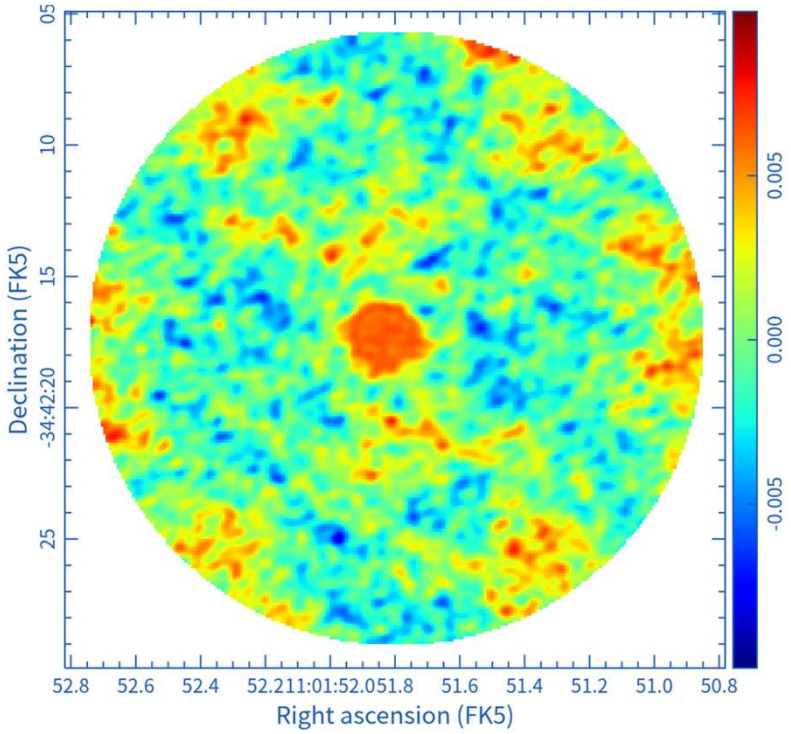


Case 3: weighting “natural”

Image

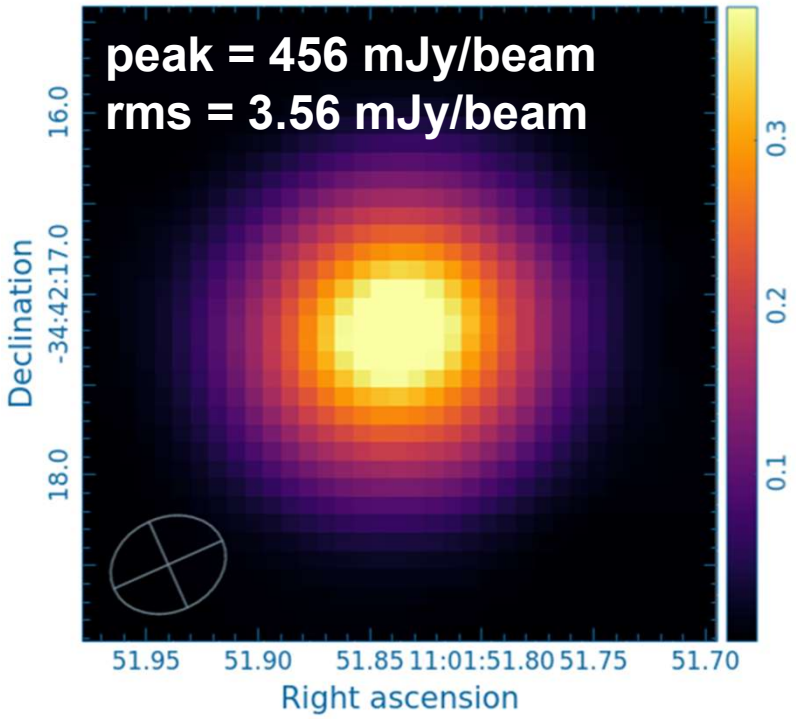


Residual



Case 3: weighting “natural”

Image



Residual

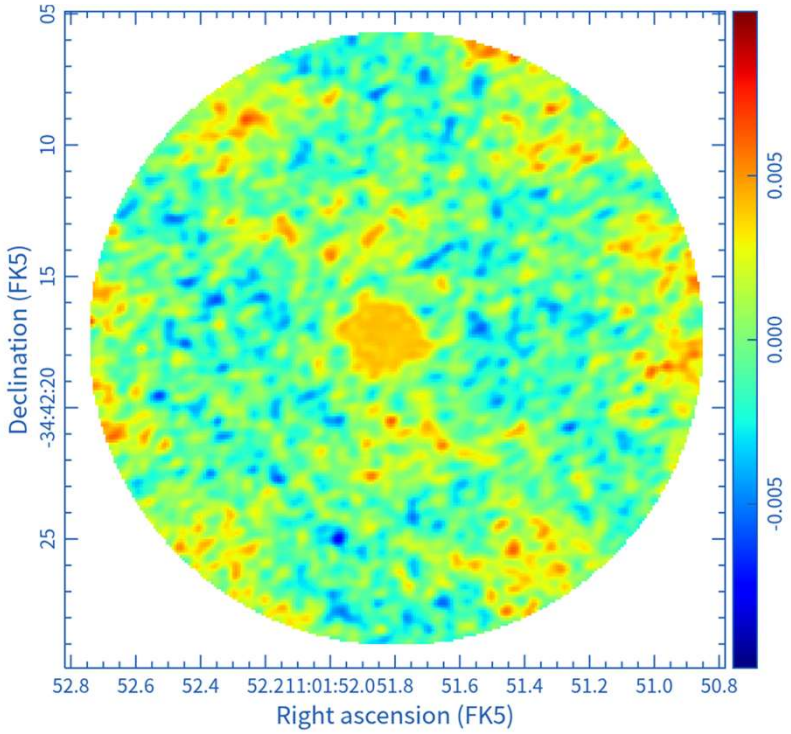


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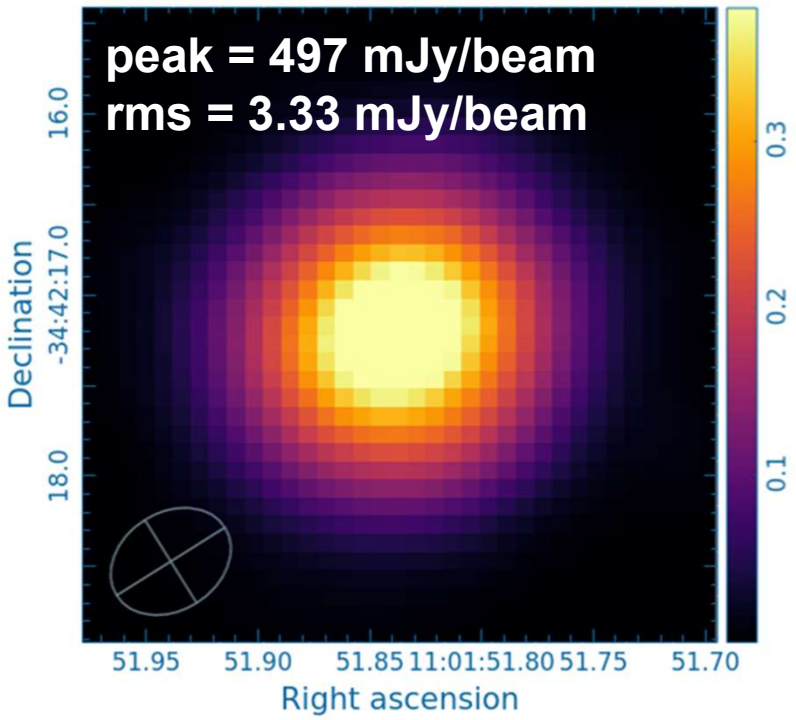
Image



Residual

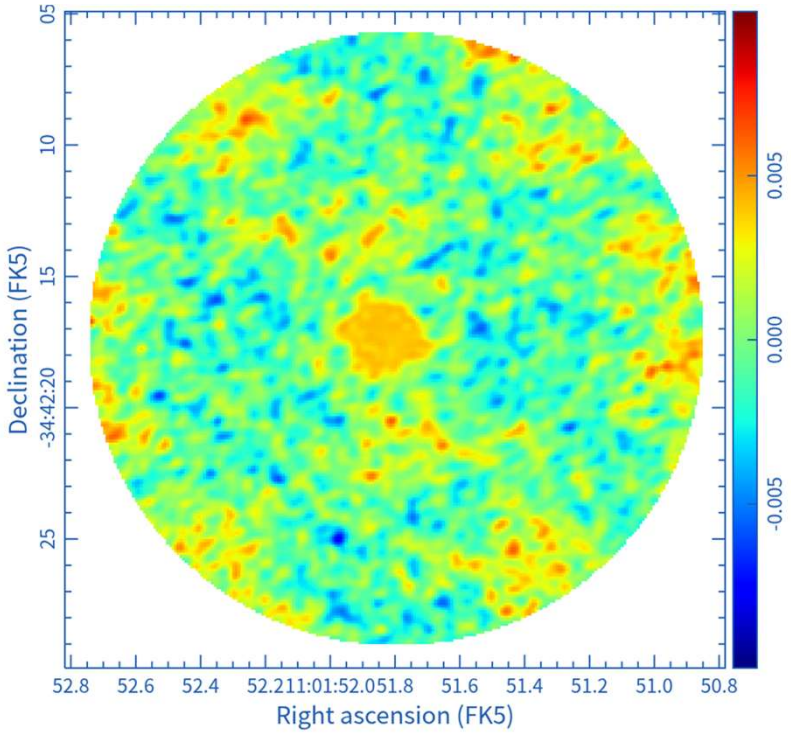


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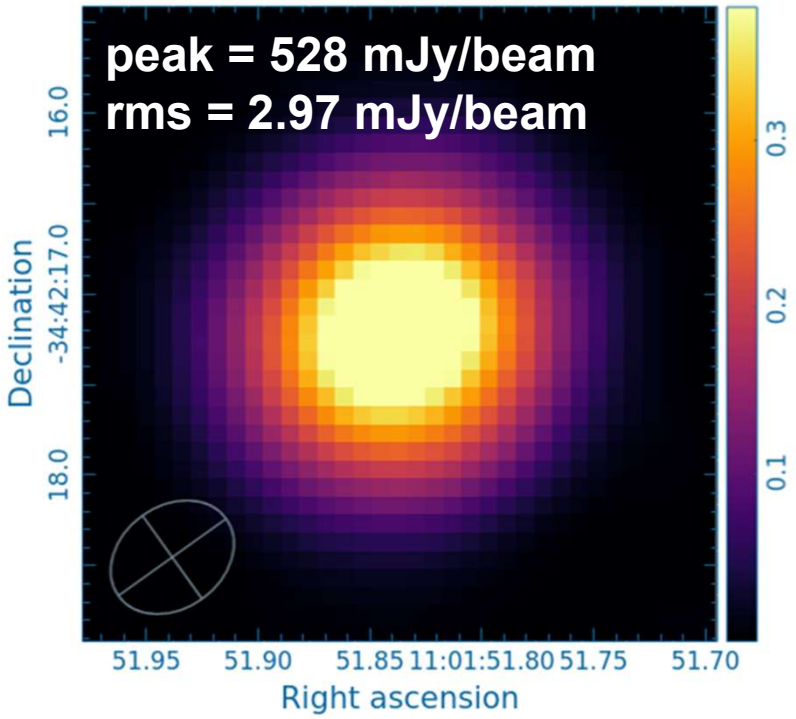
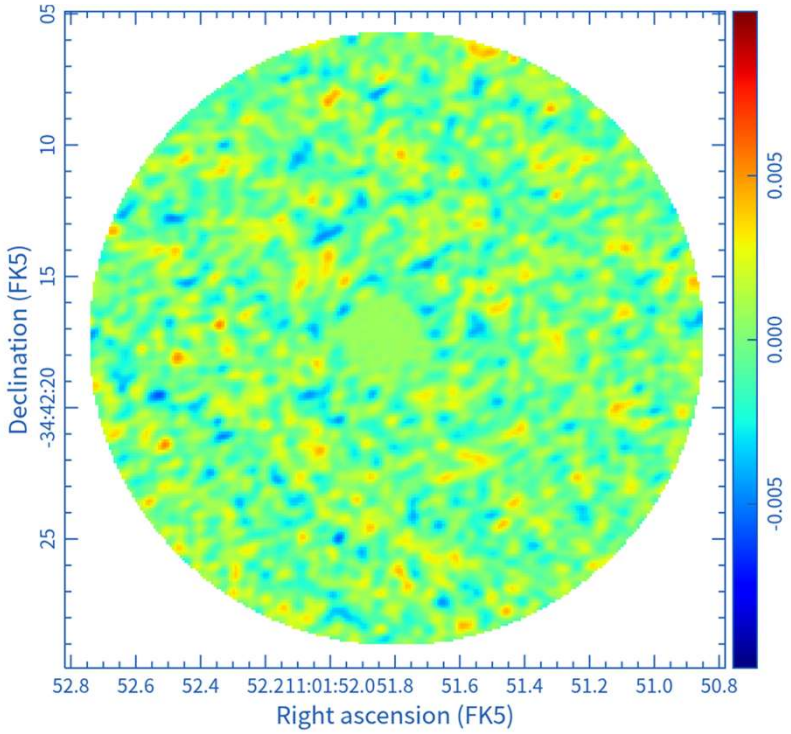
Image

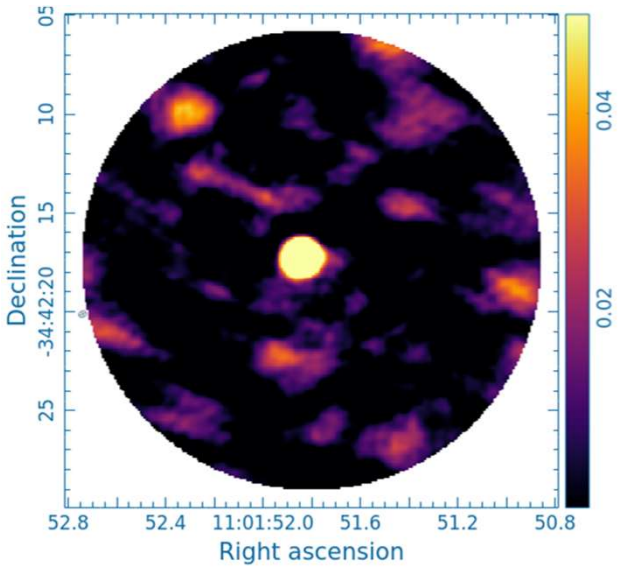


Residual



Case 3: weighting “natural”

Before

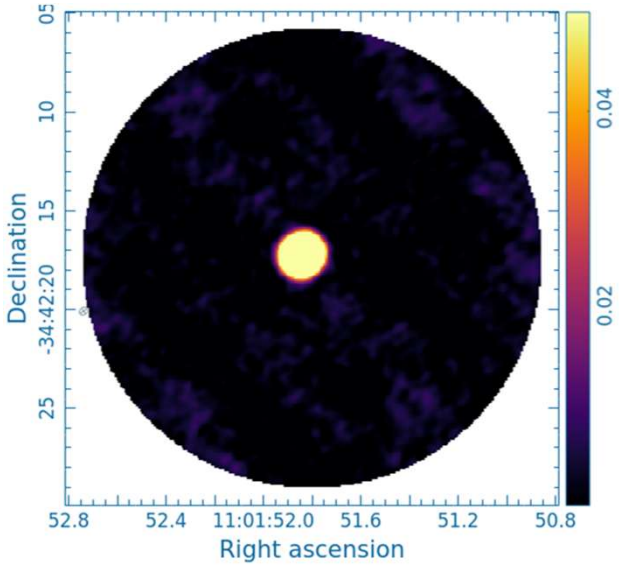


SNR	36.6
beam	0.609”

+659%

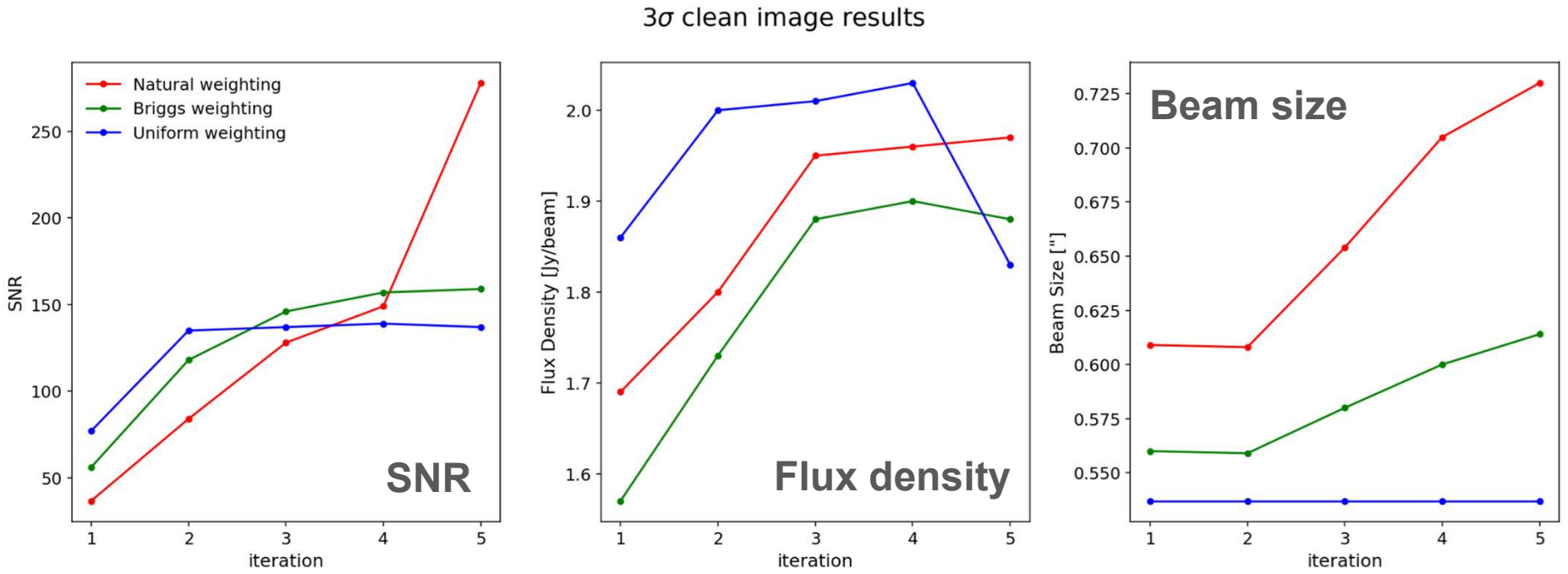
+19.9%

After



SNR	278
beam	0.730”

Comparison of three cases



Adjusting Solution Interval

gaincal

gaincal(*vis, caltable='', field='', spw='', intent='', selectdata=True, timerange='', uvrange='', antenna='', scan='', observation='', msselect='', solint='inf', combine='', preavg=-1.0, refant='', refantmode='flex', minblperant=4, minsnr=3.0, solnorm=False, normtype='mean', gaintype='G', smodel='', calmode='ap', solmode='', rmsthresh='', corrdepflags=False, append=False, splinetime=3600.0, npointaver=3, phasewrap=180.0, docallib=False, callib='', gaintable='', gainfield='', interp='', spwmap='', parang=False*) [source]

vis, caltable, field, spw, intent, selectdata, solint, combine, preavg, refant, refantmode, minblperant antenna, minsnr, solnorm, gaintype …

Adjusting Solution Interval

gaincal

gaincal(*vis, caltable='', field='', spw='', intent='', selectdata=True, timerange='', uvrange='', antenna='', scan='', observation='', msselect='', solint='inf', combine='', preavg=-1.0, refant='', refantmode='flex', minblperant=4, minsnr=3.0, solnorm=False, normtype='mean', gaintype='G', smodel='', calmode='ap', solmode='', rmsthresh='', corrdepflags=False, append=False, splinetime=3600.0, npointaver=3, phasewrap=180.0, docallib=False, callib='', gaintable='', gainfield='', interp='', spwmap='', parang=False*) [source]

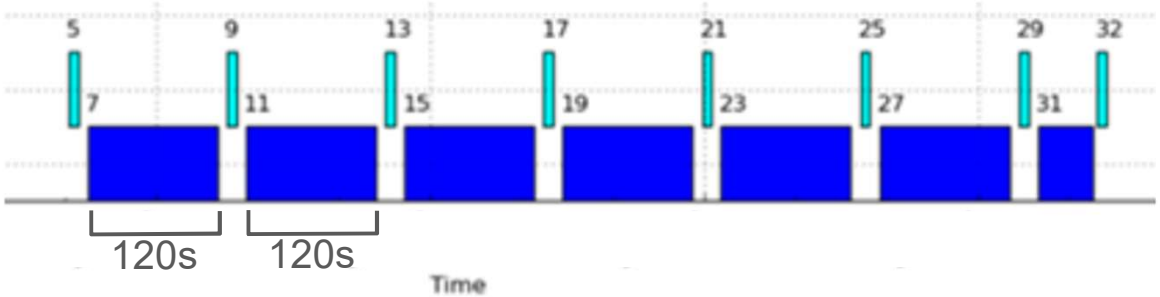
vis, caltable, field, spw, intent, selectdata, solint, combine, preavg, refant, refantmode, minblperant antenna, minsnr, solnorm, gaintype …

Adjusting Solution Interval

On-source

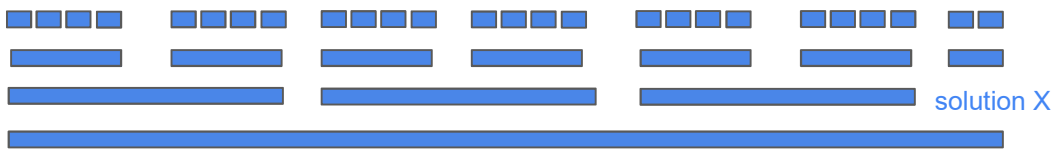
`solint` defines **how frequently** gain solutions (phase or amplitude) are calculated in time.

`combine` controls **which axes of the data are grouped together** when calculating solutions.



e.g.

Combine	Solint
=''	='30s'
=''	='inf'
='scan'	='240s''
='scan'	='inf''



Adjusting Solution Interval

`solint` defines **how frequently** gain solutions (phase or amplitude) are calculated in time.

`combine` controls **which axes of the data are grouped together** when calculating solutions.

Solution Interval Trade-off

- **Short solint** → Enables precise tracking of temporal variations but reduces SNR, potentially leading to unstable solutions

- **Long solint** → Improves SNR but may fail to capture temporal variations accurately

Goal!

To understand how self-calibration performance

depends on solution time interval

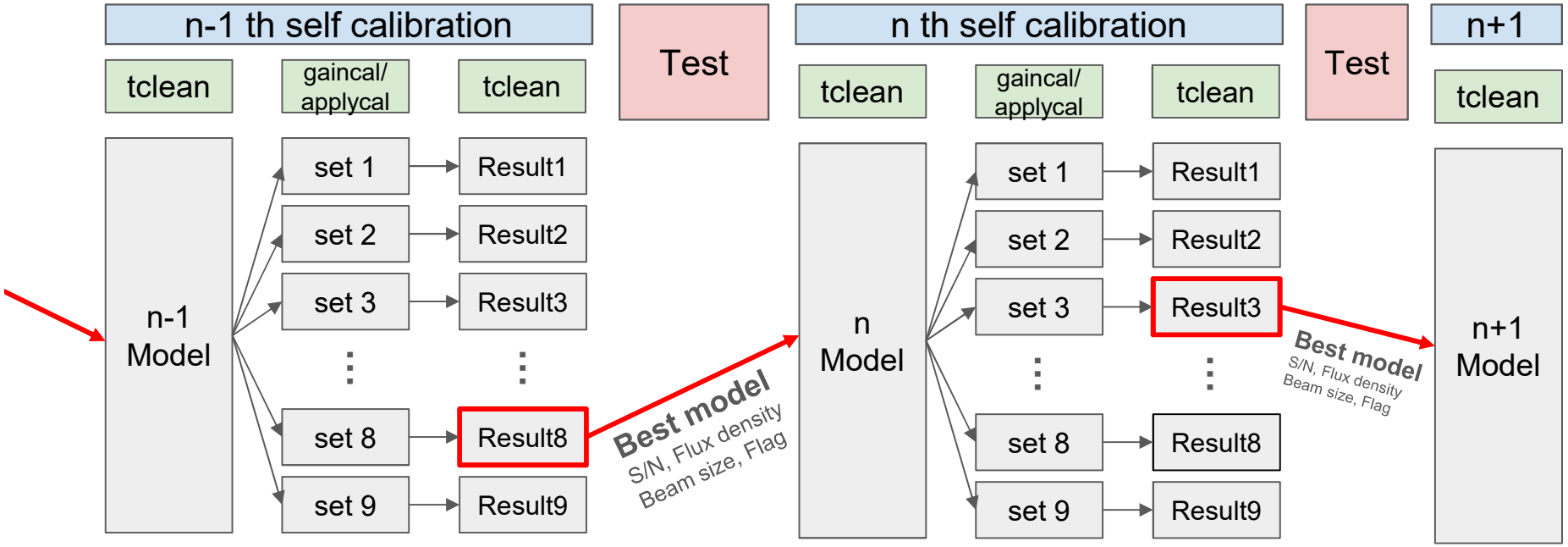
Strategy

obs = 5 scan

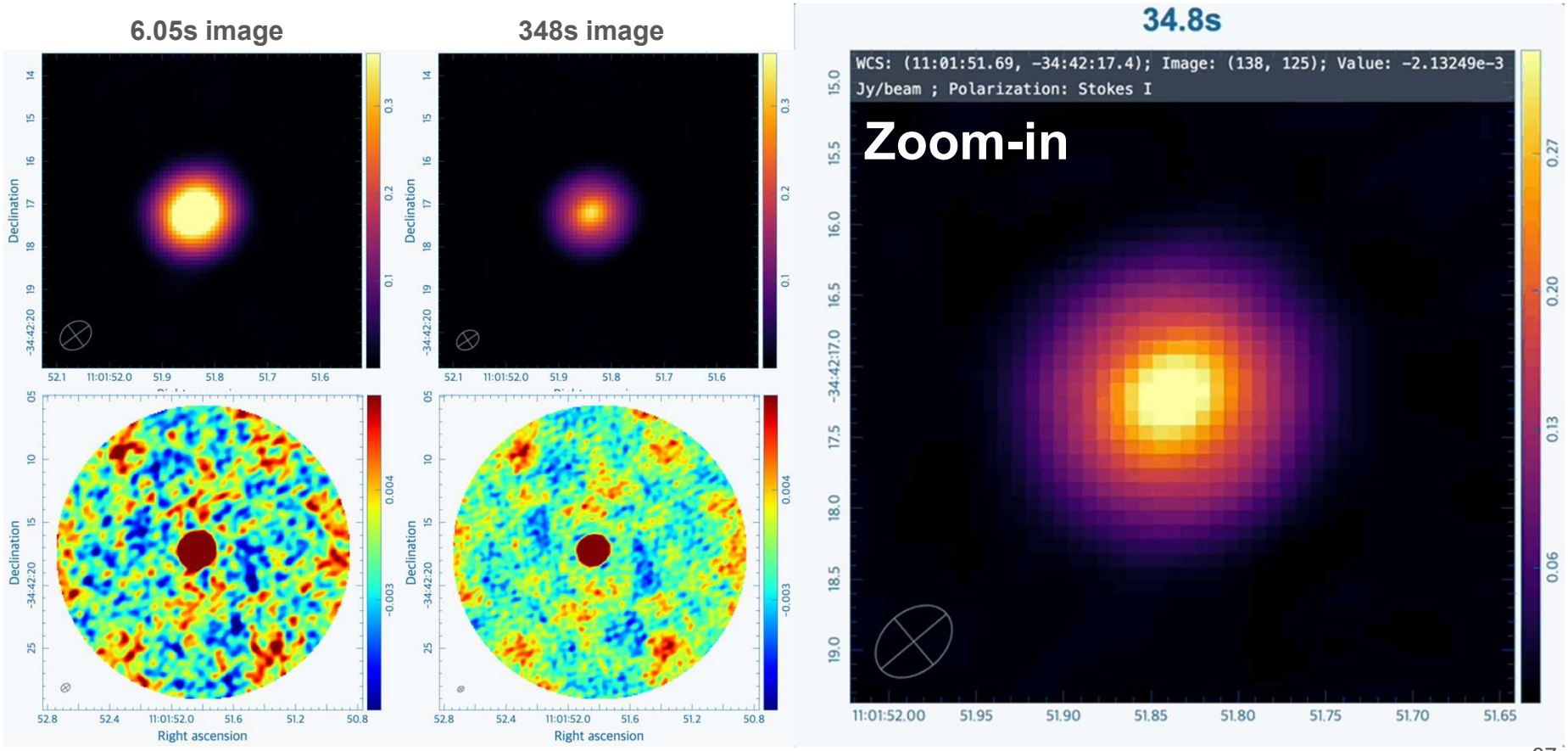
Combine	Solint	Combine	Solint	Combine	Solint
-	int (6.05s)	-	34.8s (0.1 scan)	-	87s (¼ scan)
-	116s (⅓ scan)	-	174s (½ scan)	-	inf (1 scan)
scan	509s (⅓ obs)	scan	763.5s (½ obs)	scan	inf (1 obs)

3 Phase self-cal + 1 Amplitude self-cal = 4 * 9 = **36 test sets**

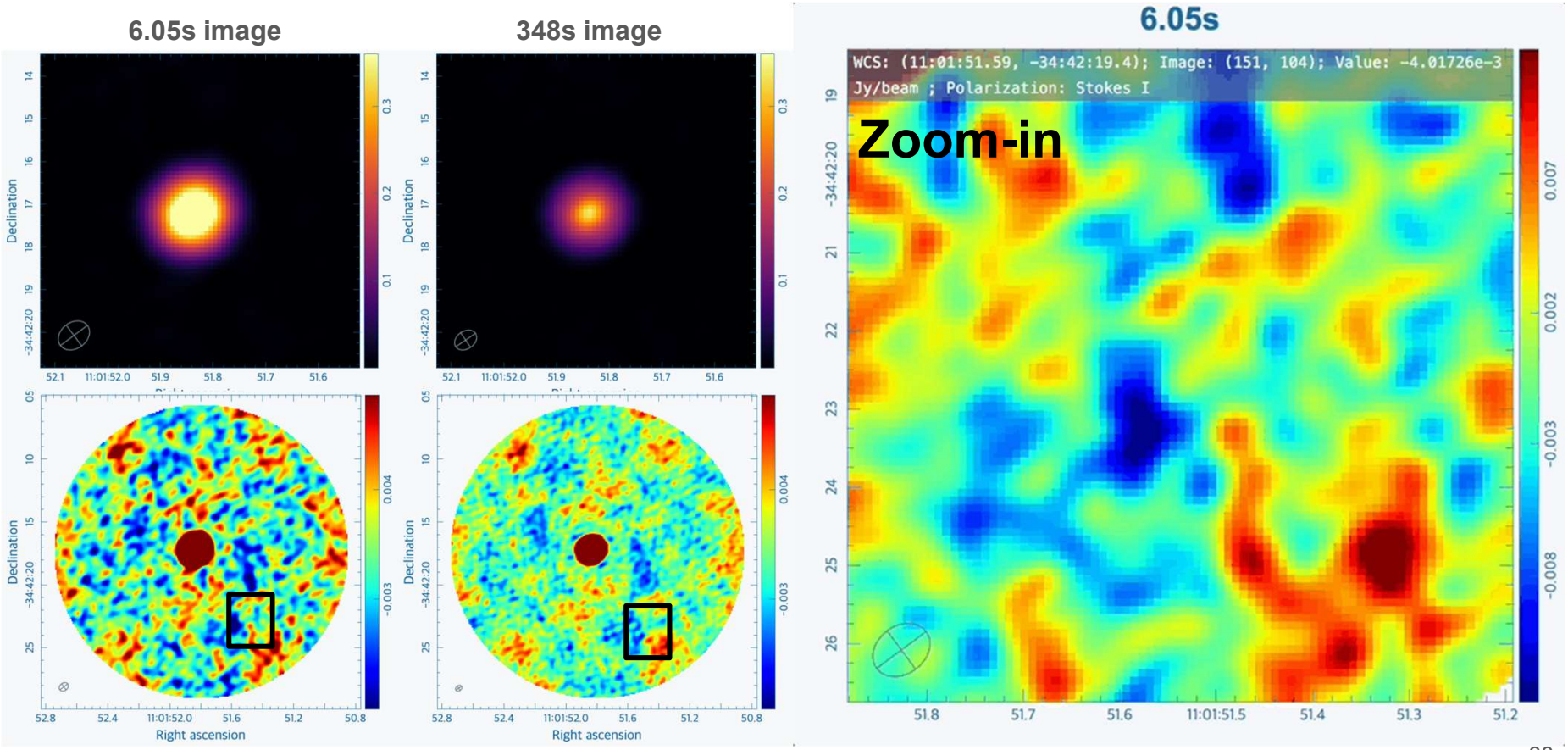
Method


n-1 th self calibration
tclean
gaincal/
applycal
tclean
Test
n th self calibration
tclean
gaincal/
applycal
tclean
Test
n+1
tclean
n-1
Model
set 1
set 2
set 3
set 8
set 9
Result1
Result2
Result3
Result8
Result9
Best model
S/N, Flux density
Beam size, Flag
n
Model
set 1
set 2
set 3
set 8
set 9
Result1
Result2
Result3
Result8
Result9
Best model
S/N, Flux density
Beam size, Flag
n+1
Model

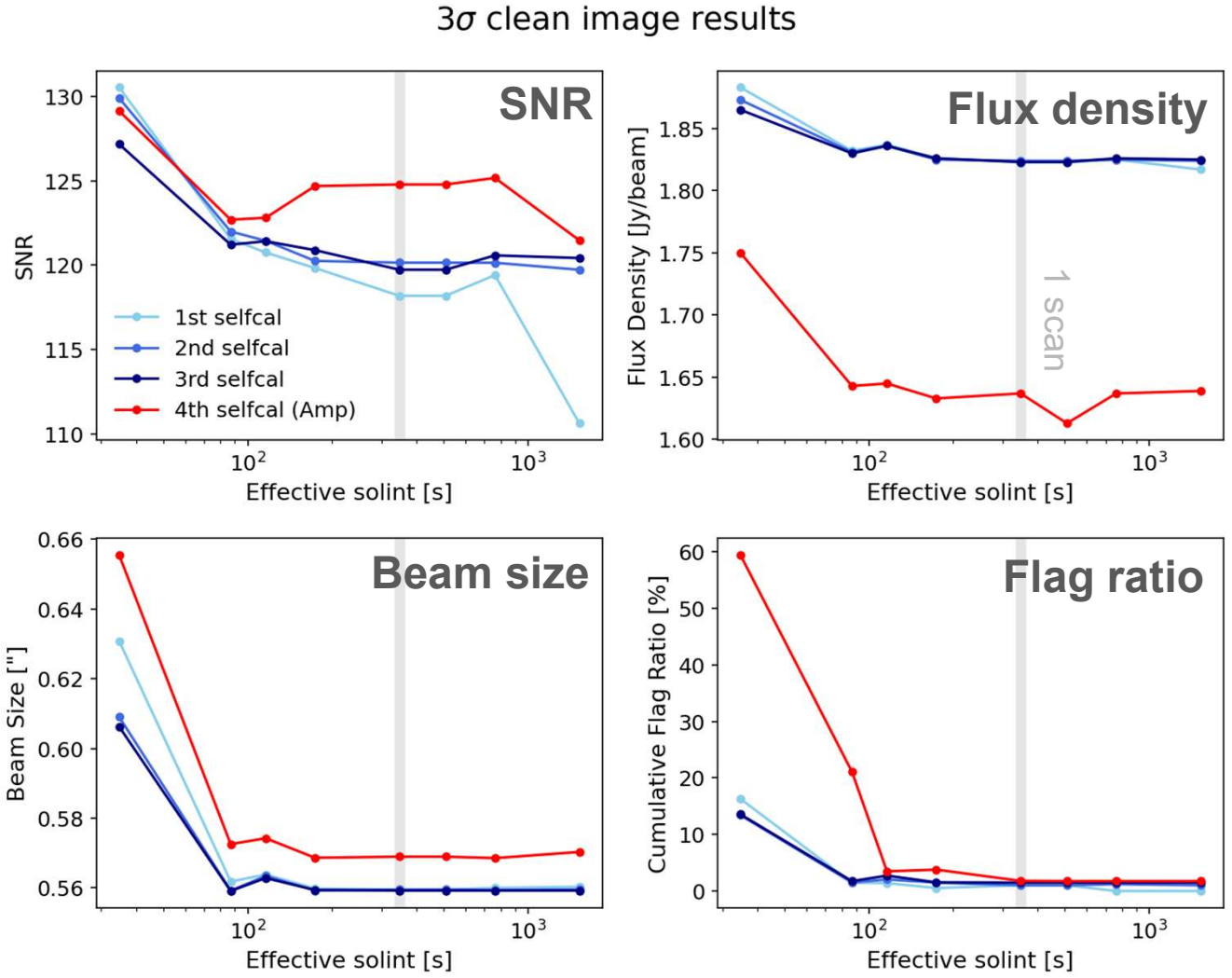
3rd Phase calibration image



3rd Phase calibration image



Result


3σ clean image results
SNR
SNR
130
125
120
115
110
1st selfcal
2nd selfcal
3rd selfcal
4th selfcal (Amp)
10^2
10^3
Effective solint [s]
Flux density
Flux Density [Jy/beam]
1.85
1.80
1.75
1.70
1.65
1.60
1 scan
10^2
10^3
Effective solint [s]
Beam size
Beam Size ["]
0.66
0.64
0.62
0.60
0.58
0.56
10^2
10^3
Effective solint [s]
Flag ratio
Cumulative Flag Ratio [%]
60
50
40
30
20
10
0
10^2
10^3
Effective solint [s]

Result P = Phase self-cal / A = Amplitude self-cal

Flagging limit (<15%) → Failed solution

P: 87s (¼ scan); **A: 116s (⅓ scan)**

Optimal solint

P: 1st → ½ obs; 2nd, 3rd → ½ scan

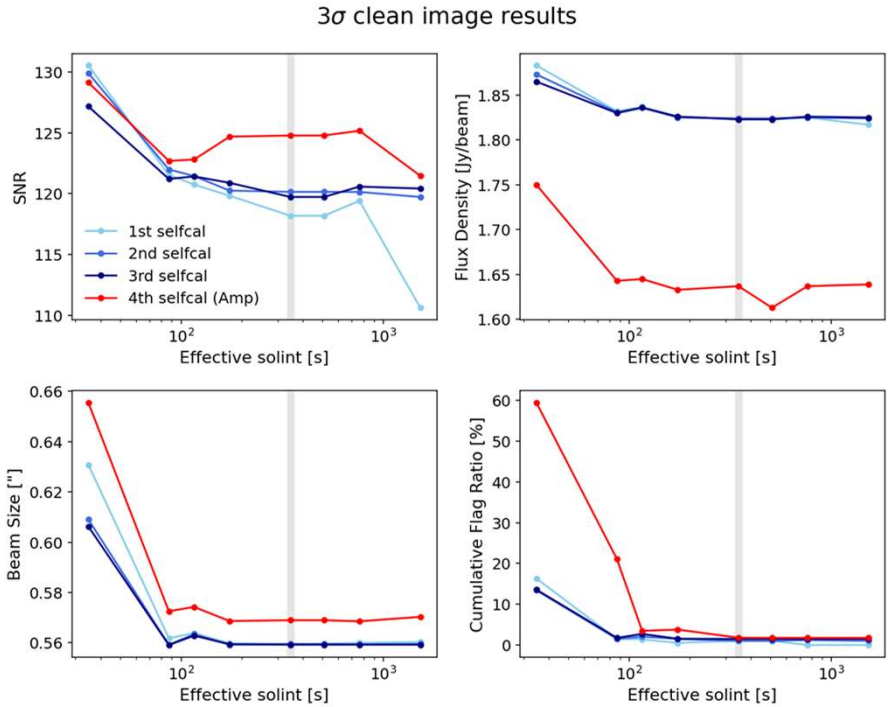
Iteration increase → More refined solutions at finer solint.

A: ½ obs, More accurate solutions at longer solint

∵ Require higher SNR data

Solint='inf' + combine='scan'?

SNR degradation in self-cal solutions significantly varying between scans?



Thank You

Case 1: weighting “briggs” (robust = 0.5)

clean image	1st image	2nd image	3rd image	4th image	final image
peak intensity (mJy/beam)	314	335	367	387	396
rms (mJy/beam)	5.64	2.83	2.51	2.46	2.49
SNR	56	118	146	157	159
flux (Jy)	1.57	1.73	1.88	1.90	1.88
beam size (arcsec)	0.560 * 0.416	0.559 * 0.415	0.580 * 0.439	0.600 * 0.445	0.614 * 0.457

Case 2: weighting “uniform”

clean image	1st image	2nd image	3rd image	4th image	final image
peak intensity (mJy/beam)	298	319	320	321	310
rms (mJy/beam)	3.88	2.36	2.33	2.31	2.26
SNR	77	135	137	139	137
flux (Jy)	1.86	2.00	2.01	2.03	1.83
beam size (arcsec)	0.537*0.390	0.537*0.390	0.537*0.390	0.537*0.390	0.537*0.390

Case 3: weighting “natural”

clean image	1st image	2nd image	3rd image	4th image	final image
peak intensity (mJy/beam)	377	397	456	497	528
rms (mJy/beam)	10.3	4.72	3.56	3.33	2.97
SNR	36.6	84	128	149	278
flux (Jy)	1.69	1.8	1.95	1.96	1.97
beam size (arcsec)	0.609 * 0.470	0.608 * 0.470	0.654 * 0.519	0.705 * 0.539	0.730 * 0.565