

Multi-configuration data combination

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Introduction.

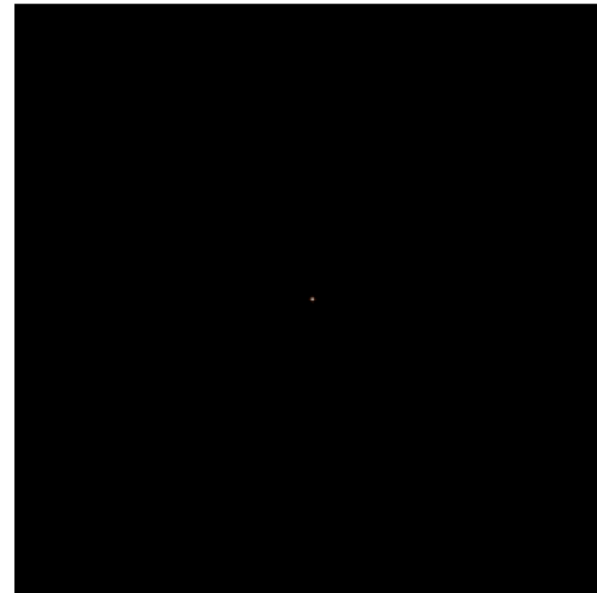
Why we need Multi-configuration combination?

Interferometric imaging

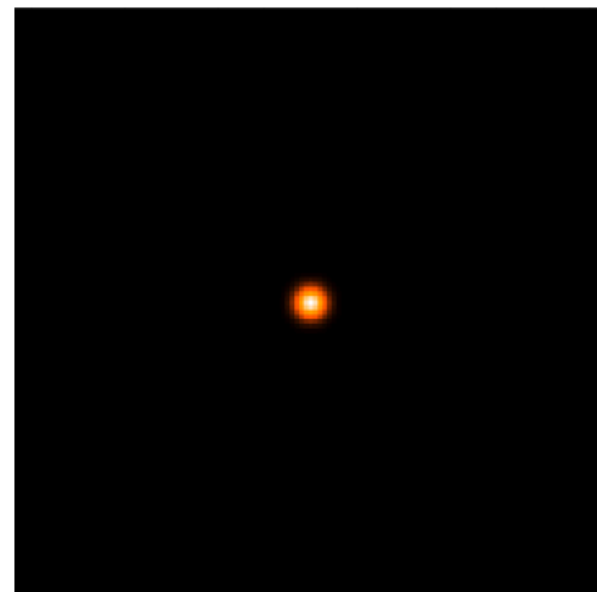
: Fourier Transform from visibility space to image space

[Credit: Andrea Isella] $T(x,y)$

δ Function



Gaussian

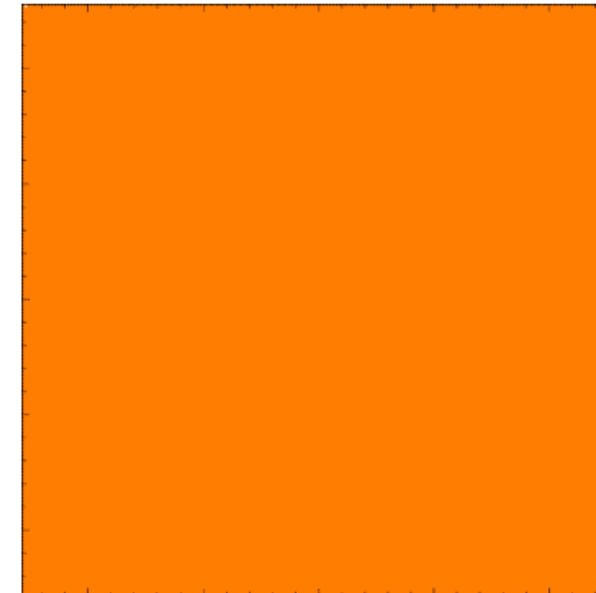


\longleftrightarrow

\longleftrightarrow

$|V(u,v)|$

Constant



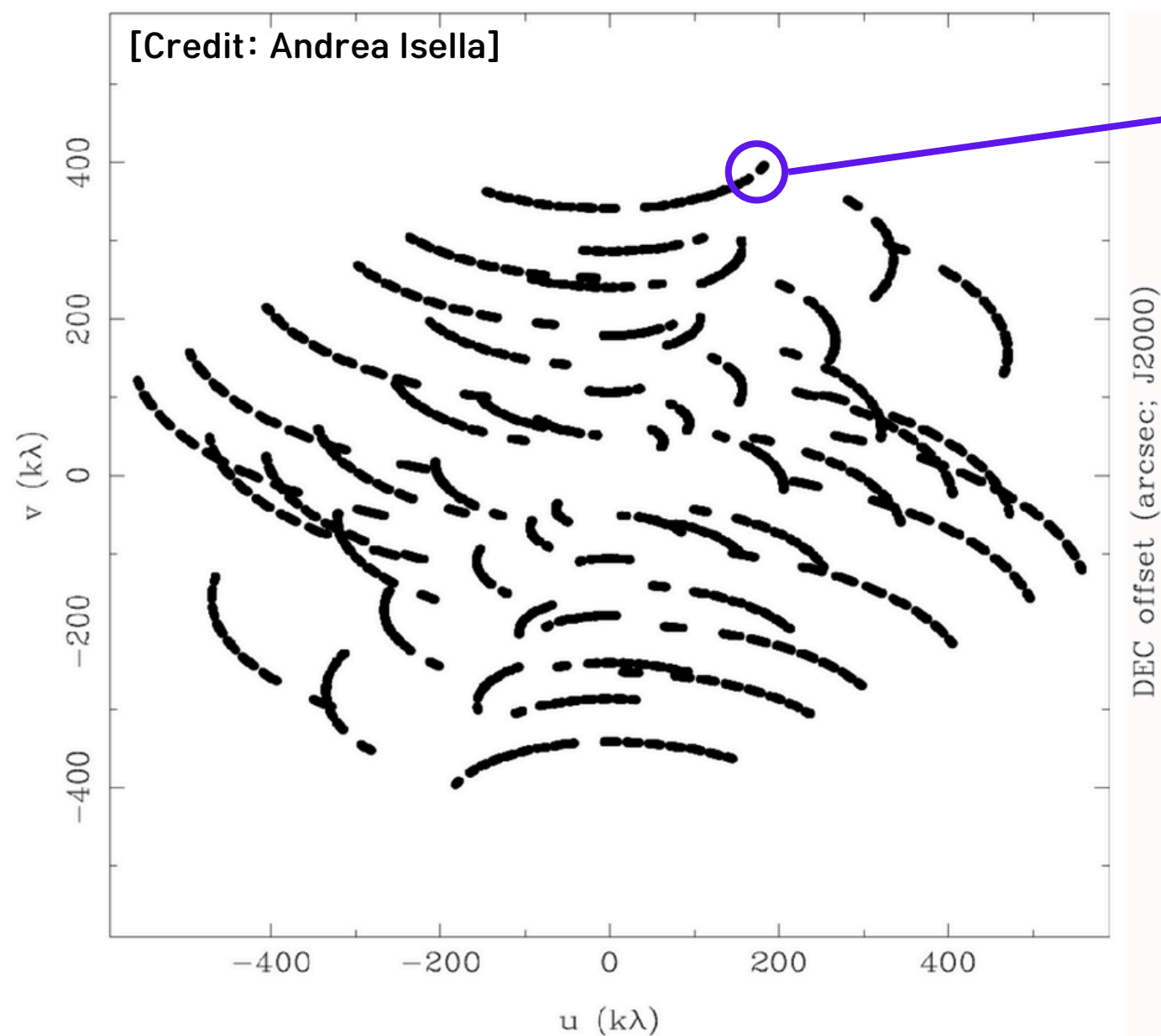
Gaussian



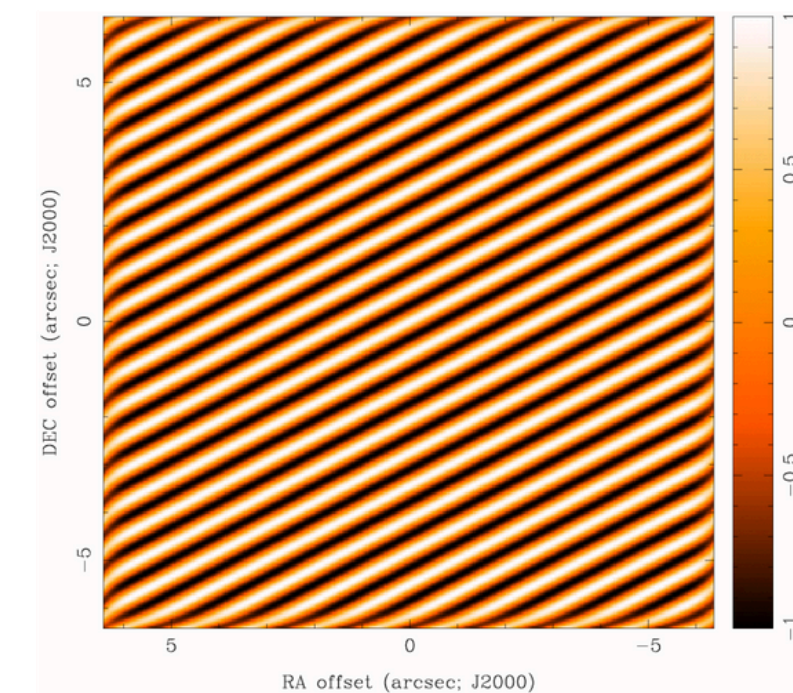
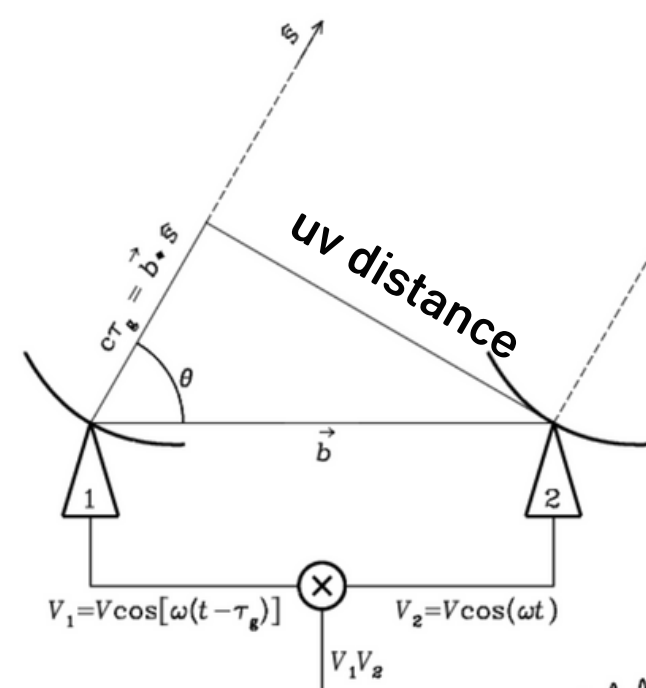
Why we need Multi-configuration combination?

Interferometric imaging

: Fourier Transform from visibility space to image space



Each data point is obtained from 'Antenna Pair'

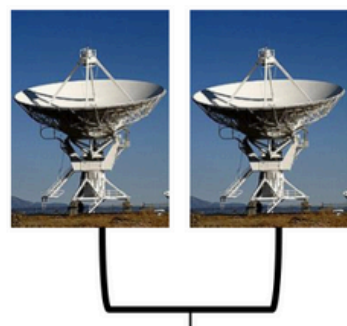
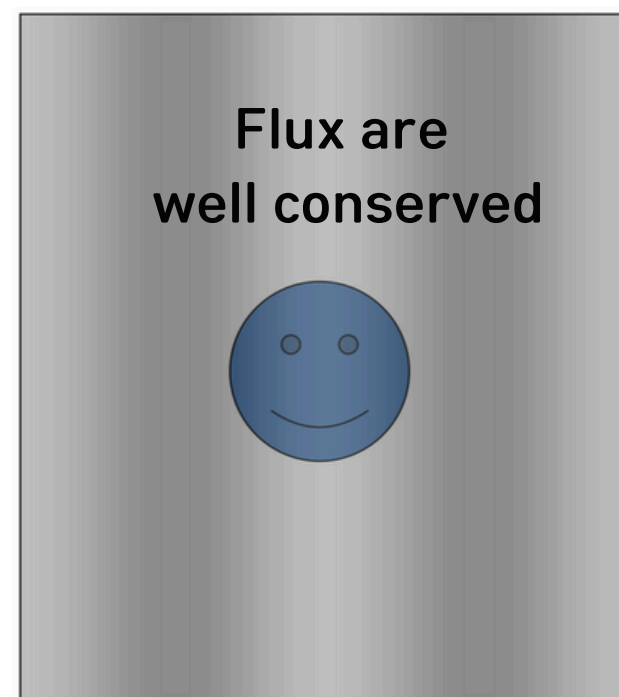


But the pair's response function is Sinusoidal
→ Response can be a negative value

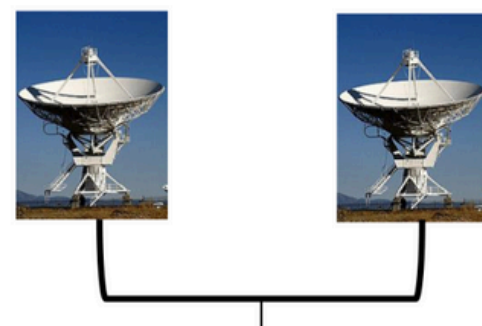
Why we need Multi-configuration combination?

Interferometric imaging

: Fourier Transform from visibility space to image space



Short Baseline (SB)



Long Baseline (LB)

Due to the Response function,
extended structures are
canceled out!

Long-Baseline only observation
can't capture extended structure.
Also, **flux can be underestimated.**

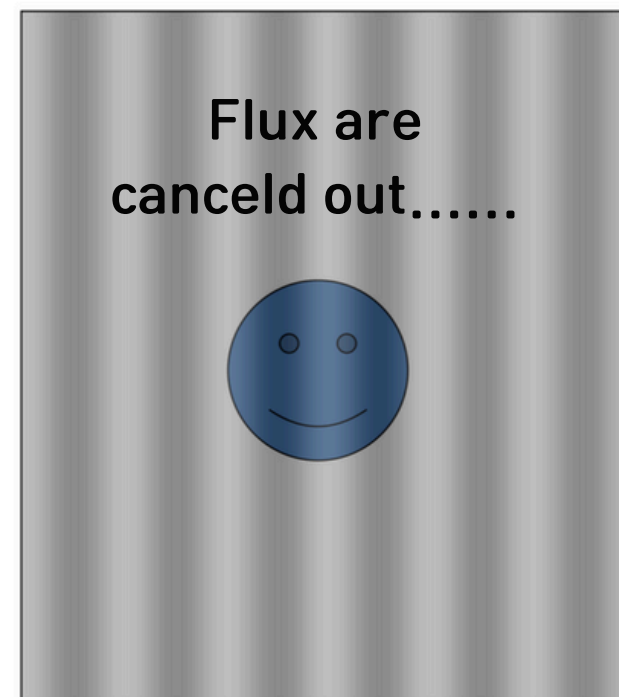
Why we need Multi-configuration combination?

Interferometric imaging

: Fourier Transform from visibility space to image space



Short Baseline (SB)



Long Baseline (LB)

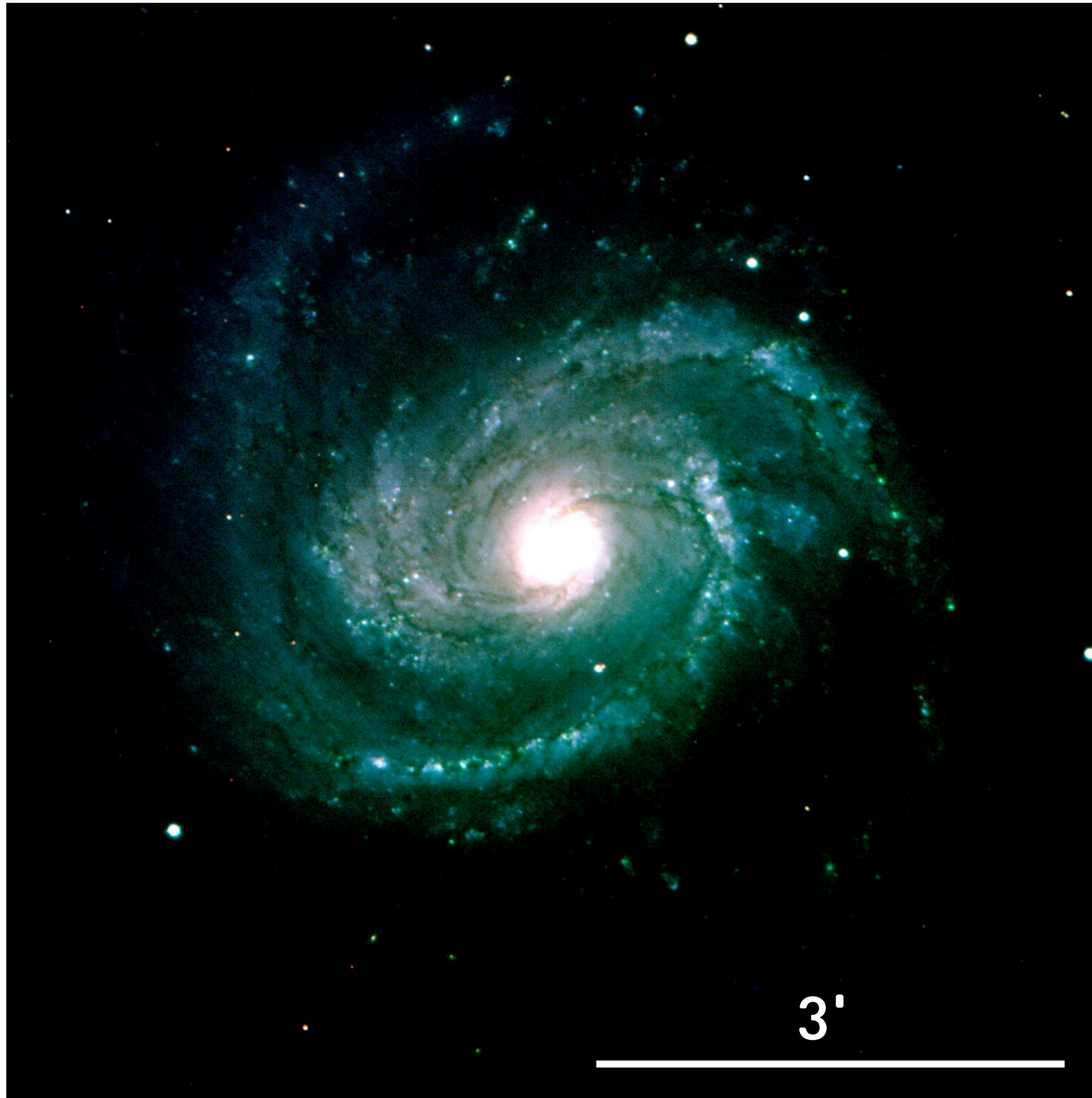
High resolution

Missing Flux

Long Baseline
+Short Baseline
+Single dish

Target: M100

[Credit: ESO]



Type: Spiral Galaxy

Location: (12h 22m 54.9s, +15d 49m 15s)

Distance: 16.9 Mpc ($v_{receding} = 1570 \text{ km/s}$)

Angular size: $\sim 3' \times 3'$

cf) 12m Single Dish primary beam size in Band 3: $45''$

→ Mosaic needed / Severe missing flux problem

Data: 12m, 7m, and TP

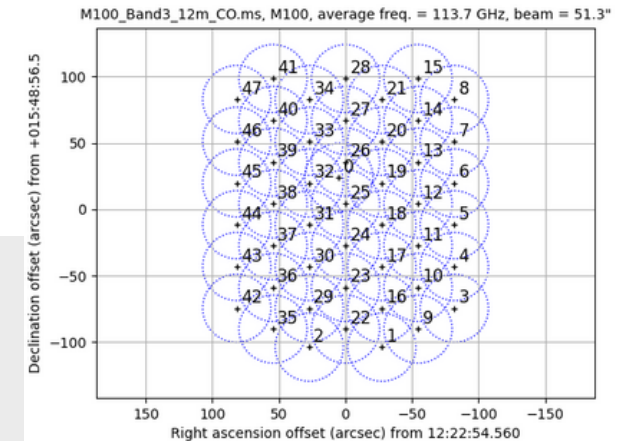
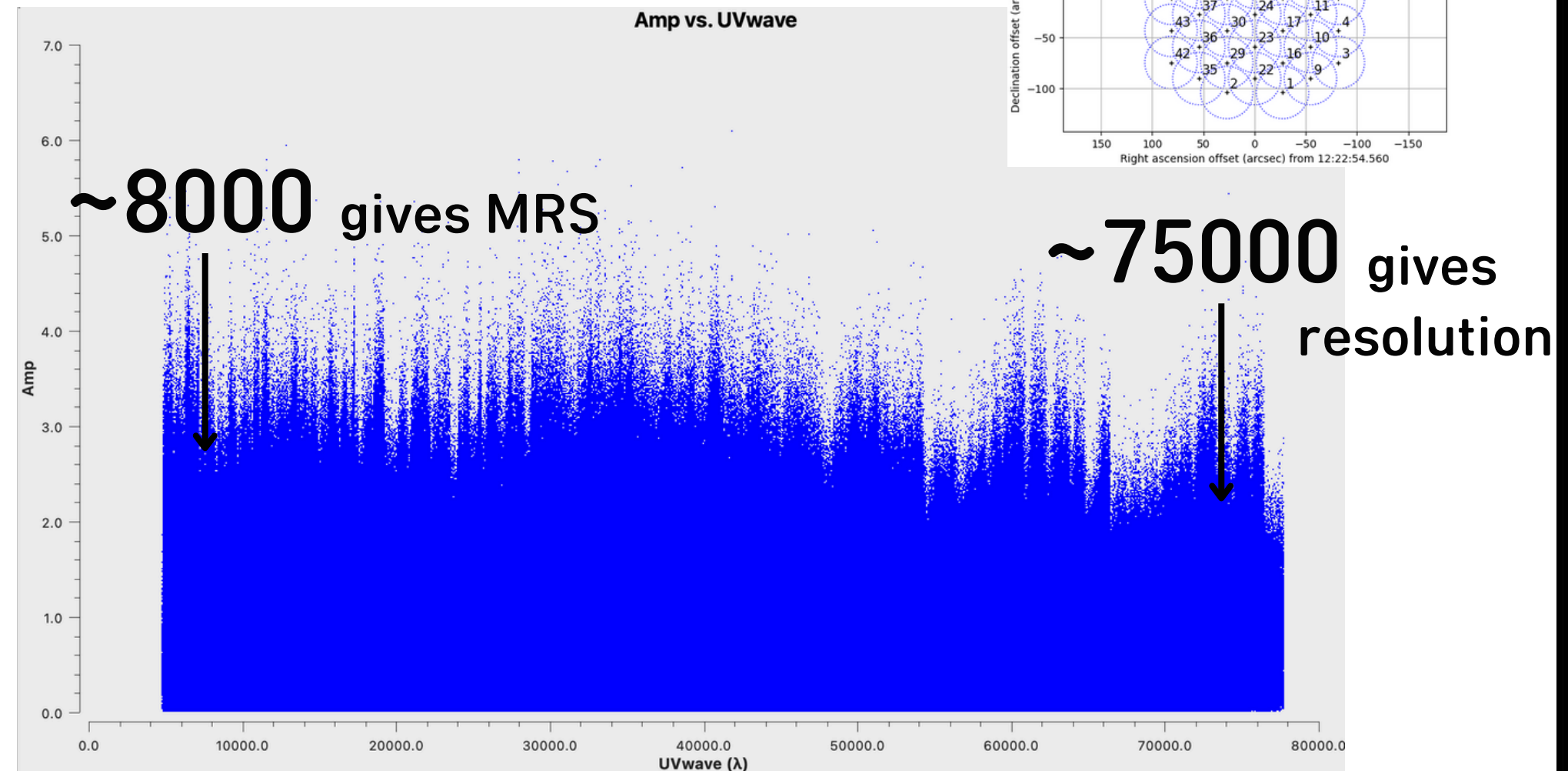
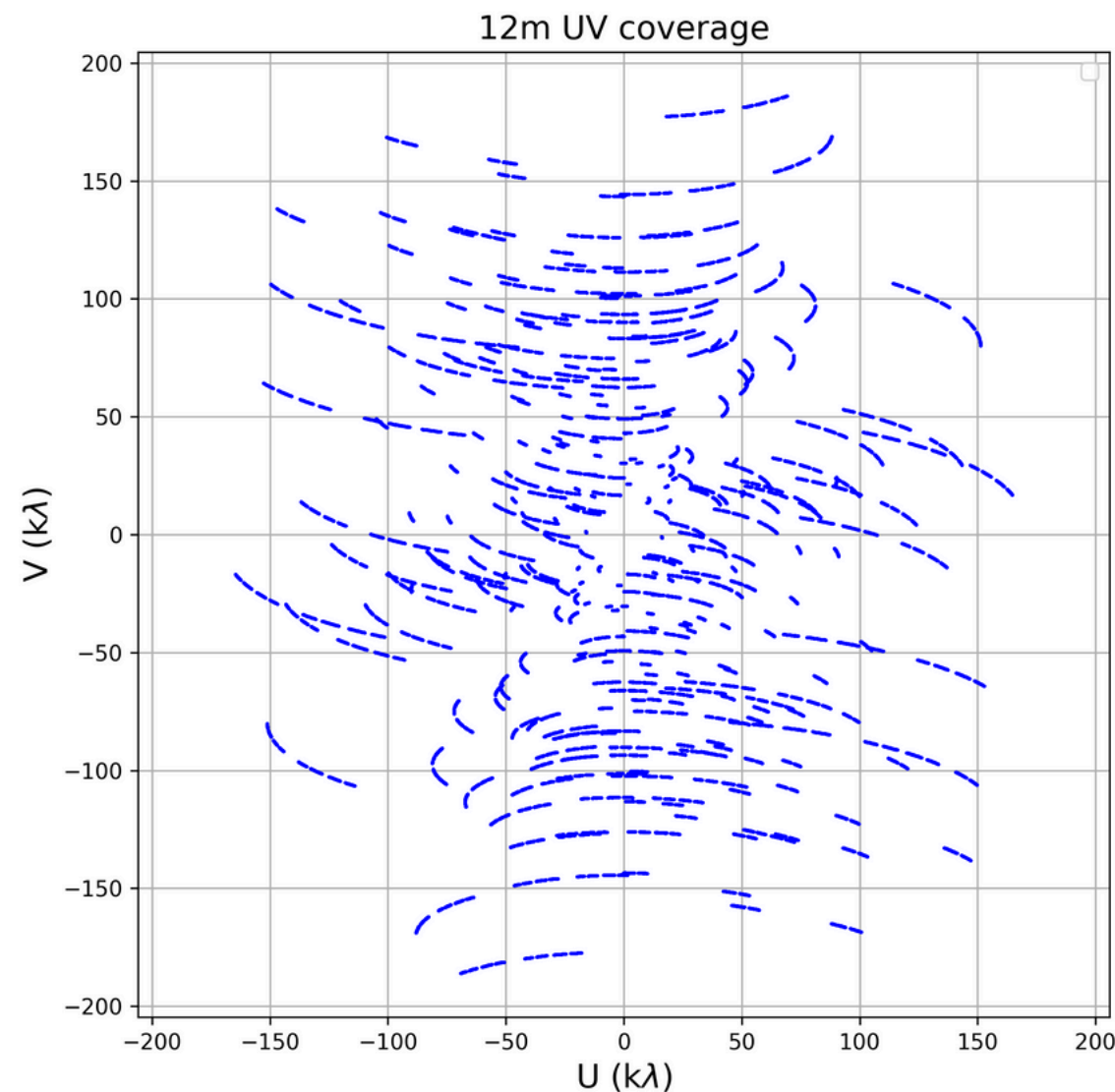
Target Line: CO (J=1–0) (Band 3)

Velocity resolution: $\sim 1.3 \text{ km/s}$

Data: CO (J=1-0) line (Band 3)

Observations: 12m array, 7m array, and TP

[12m array]: 22 Antennas, Mosaic observation



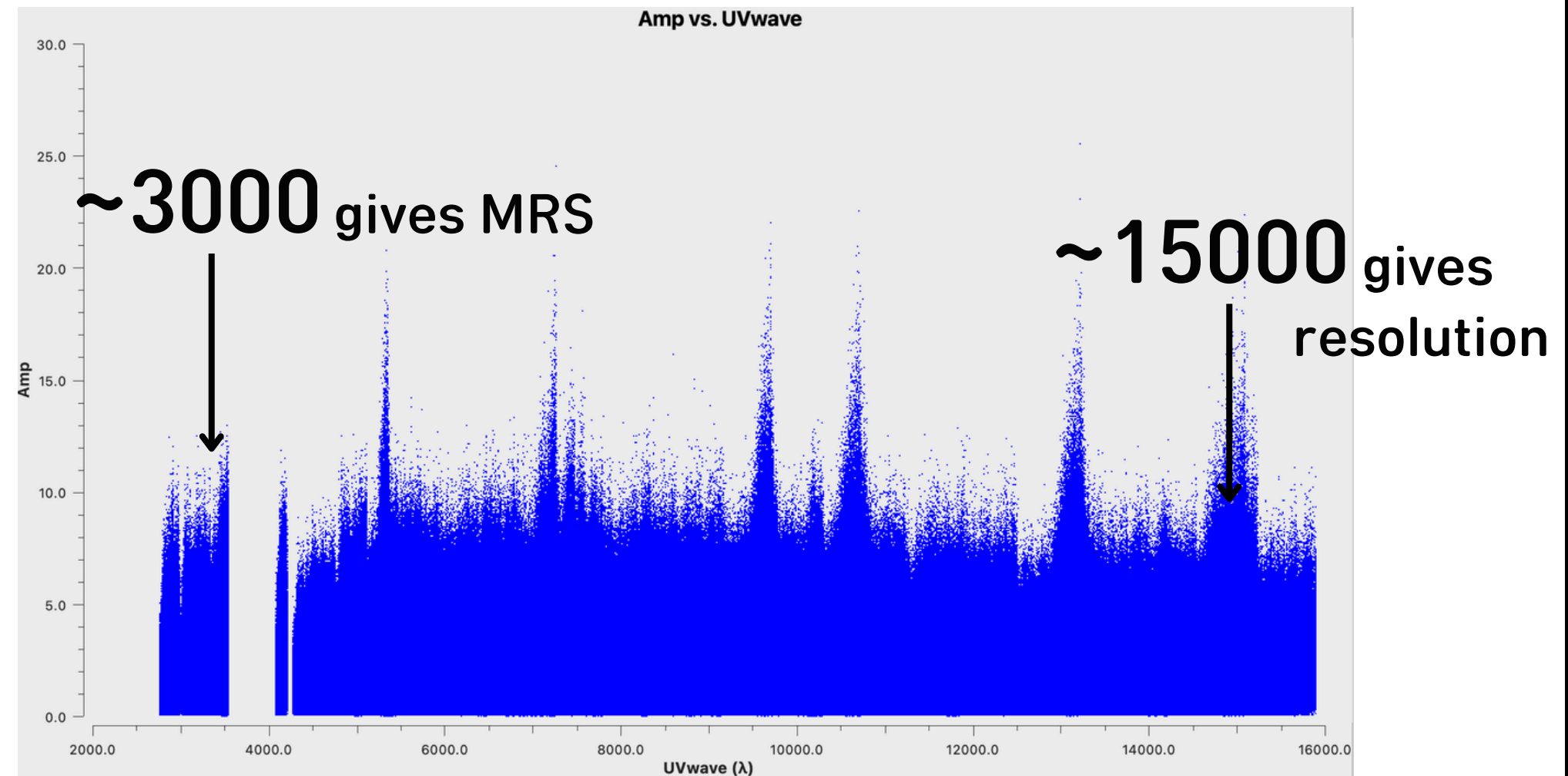
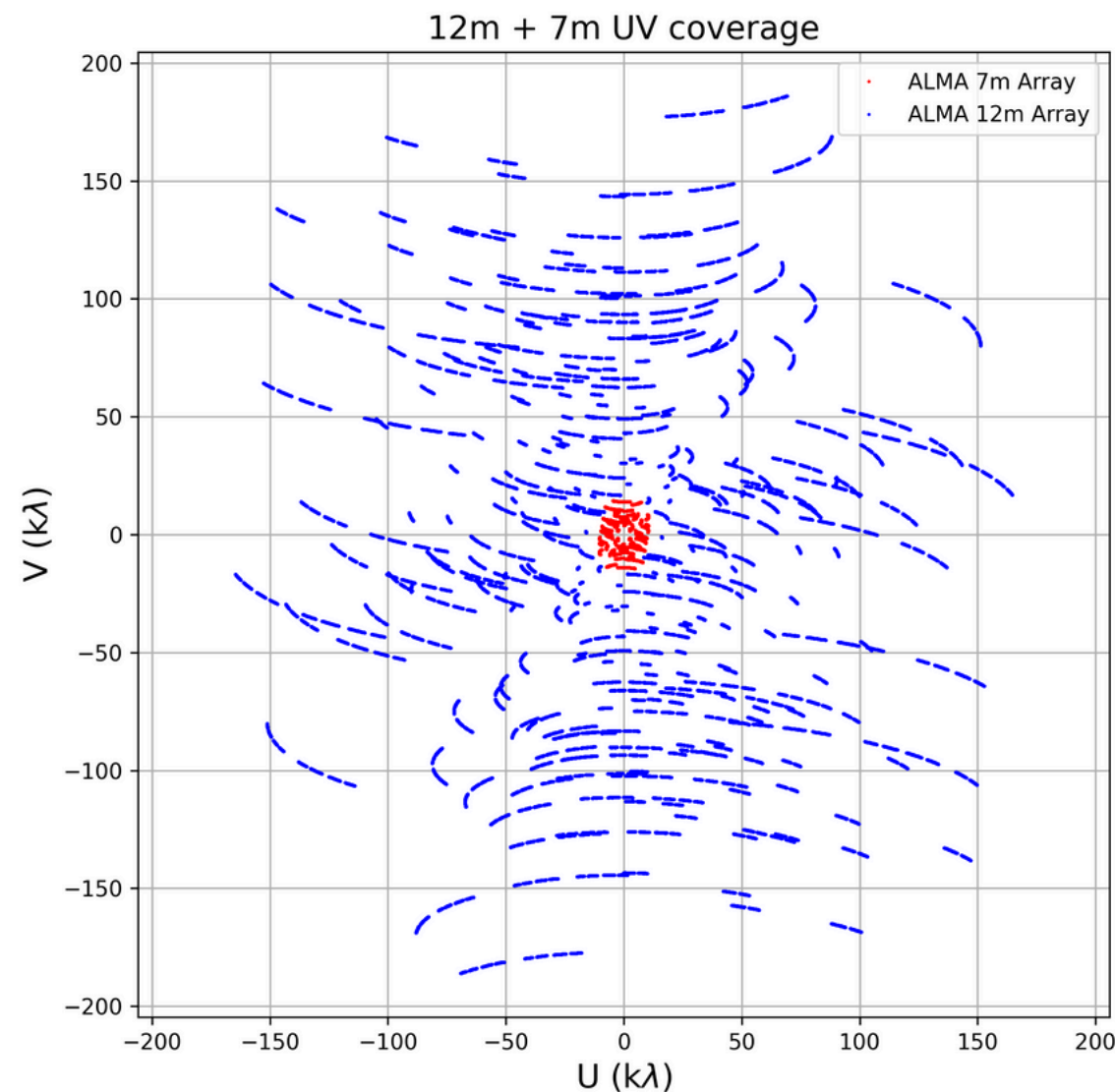
Angular resolution ~ 2.8", MRS ~ 25.8"

25.8": Much smaller than 3'

Data: CO (J=1-0) line (Band 3)

Observations: 12m array, **7m array**, and TP

[**7m array**]: 9 Antennas, Mosaic observation



Angular resolution ~ 13.8", MRS ~ 68.8"

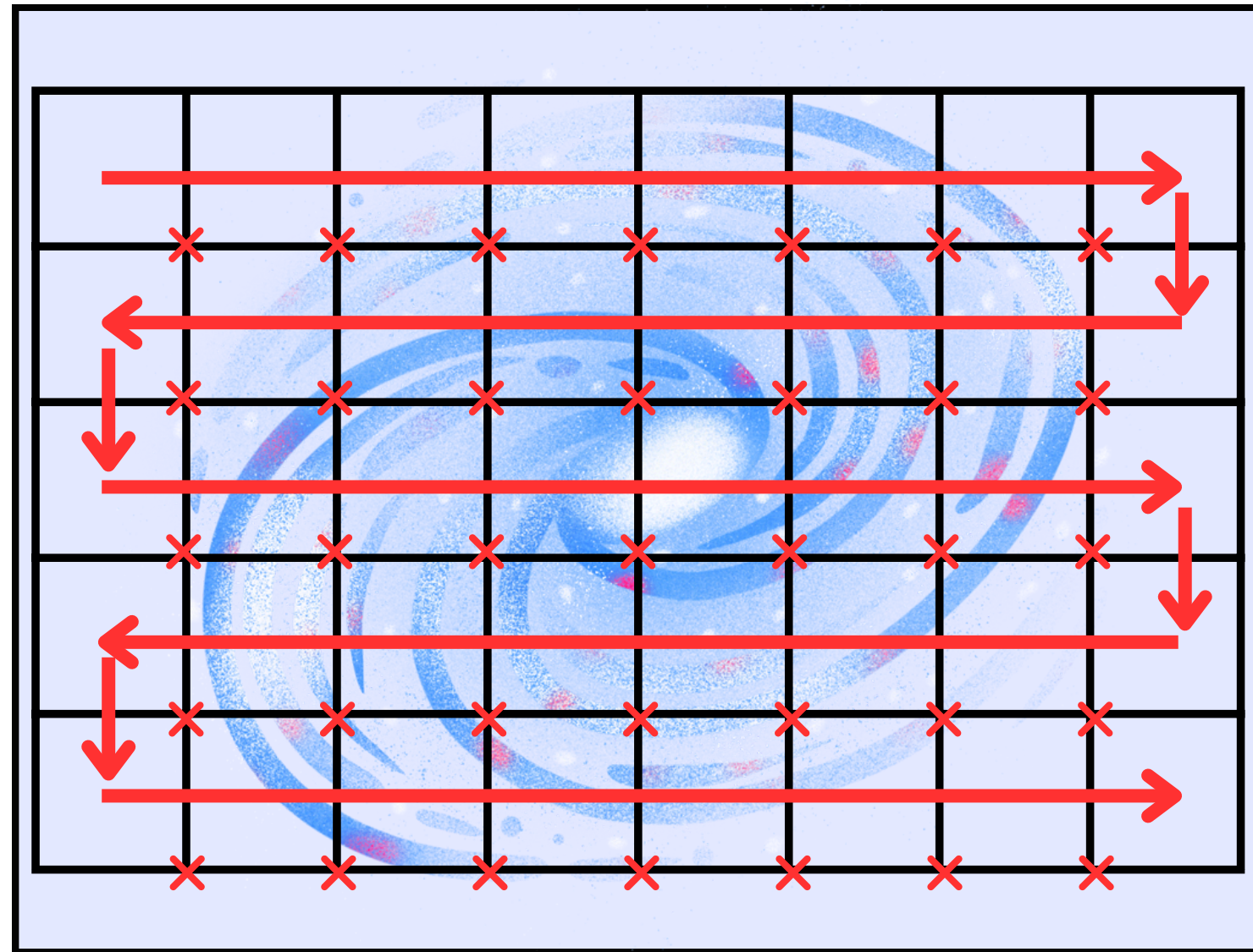
Lower resolution

68.8": Still smaller than 3'

Data: CO (J=1-0) line (Band 3)

Observations: 12m array, 7m array, and **TP**

[**Total Power**]: 2~3 Antennas per observation



Scan the whole target area
with scan pattern
(On-The-Fly scan pattern)

Observational Angular resolution
= $\sim 45''$

We obtain image! (not visibility)

Combining the 3 types of data

We will present...

Single Dish imaging
(TP imaging)

Combine 7m + 12m
(Combine in visibility space)

Combine
(7m + 12m) and TP image

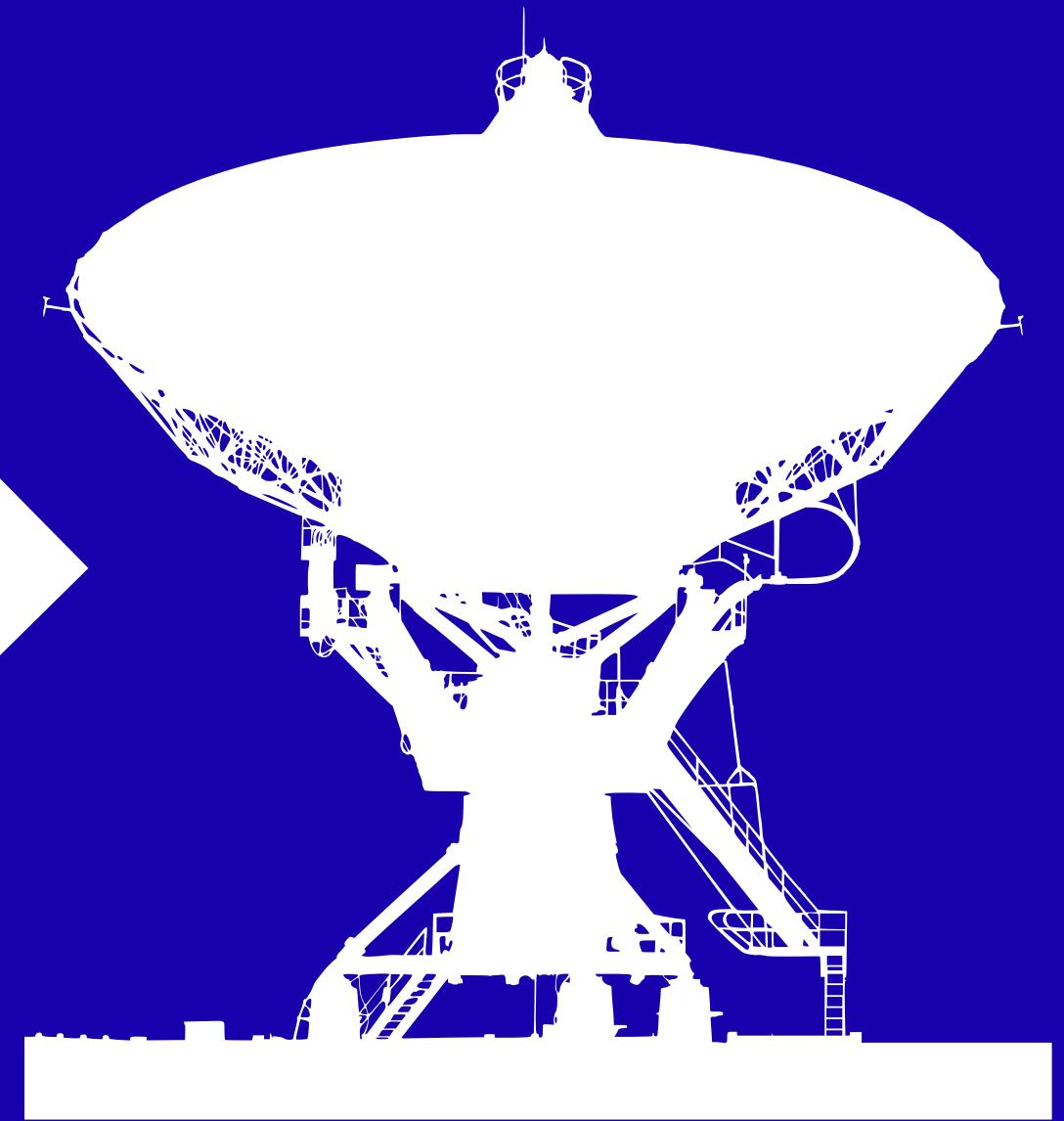
Feather

SDINT

TP2INT

Discussion about Results

Single Dish Imaging



SingleDish Data of M100

uid___A002_X85c183_X36f (DA61, PM03, PM04)

uid___A002_X85c183_X60b (DA61, PM03, PM04)

uid___A002_X8602fa_X2ab (PM02, PM03, PM04)

uid___A002_X8602fa_X577 (PM02, PM03, PM04)

uid___A002_X864236_X2d4 (PM03, PM04)

uid___A002_X864236_X693 (PM03, PM04)

uid___A002_X86fcfa_Xd9 (DV10, PM03, PM04)

uid___A002_X86fcfa_X664 (DV10, PM03, PM04)

uid___A002_X86fcfa_X96c (DV10, PM03, PM04)

SingleDish Data of M100

ALMA Band 3 (84–116 GHz)

Total–Power array (2 or 3 12m antennas)

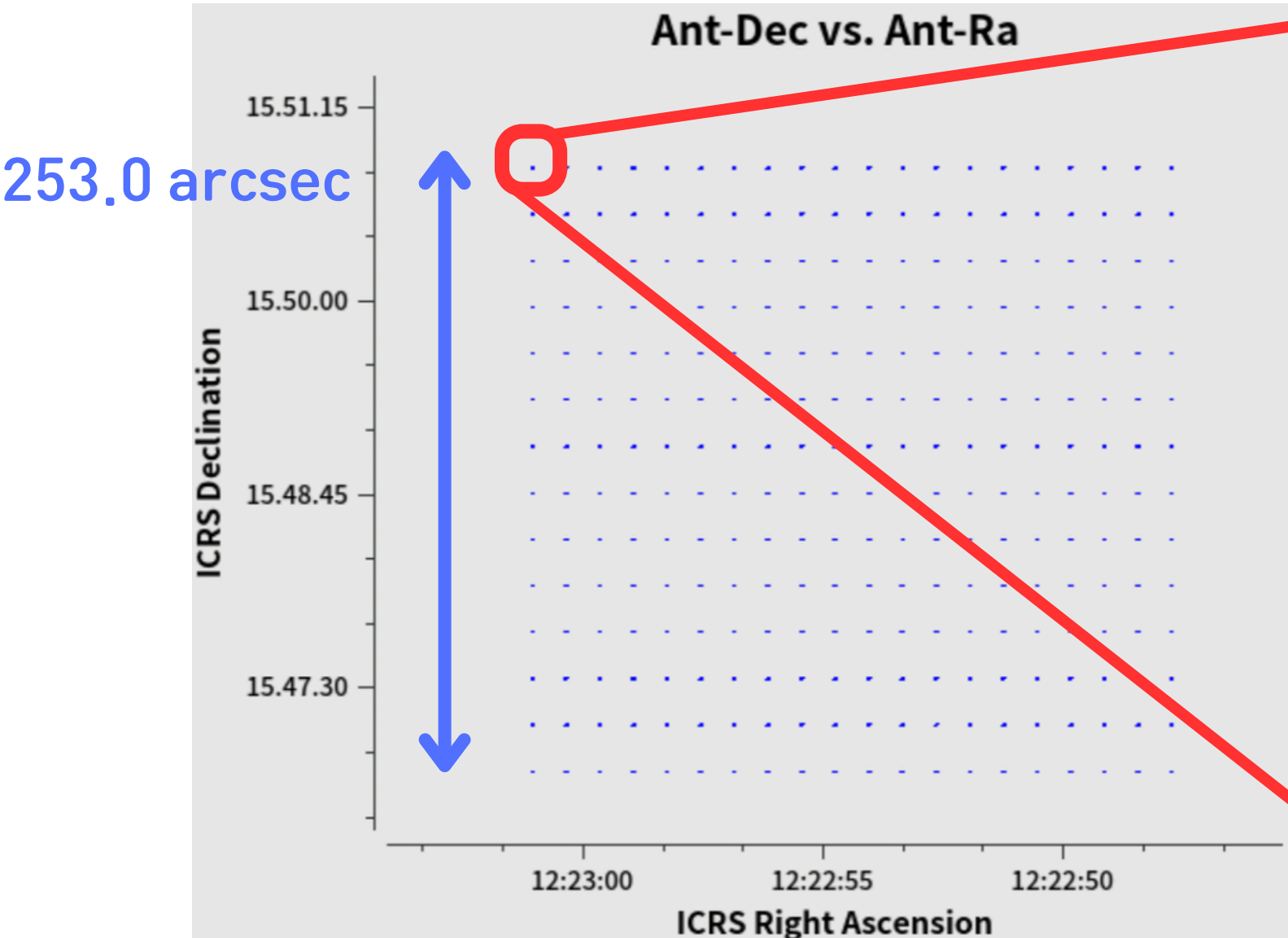
2–GHz–wide spectral windows are used, each having 4080 channels

Channel width: 488.281 kHz

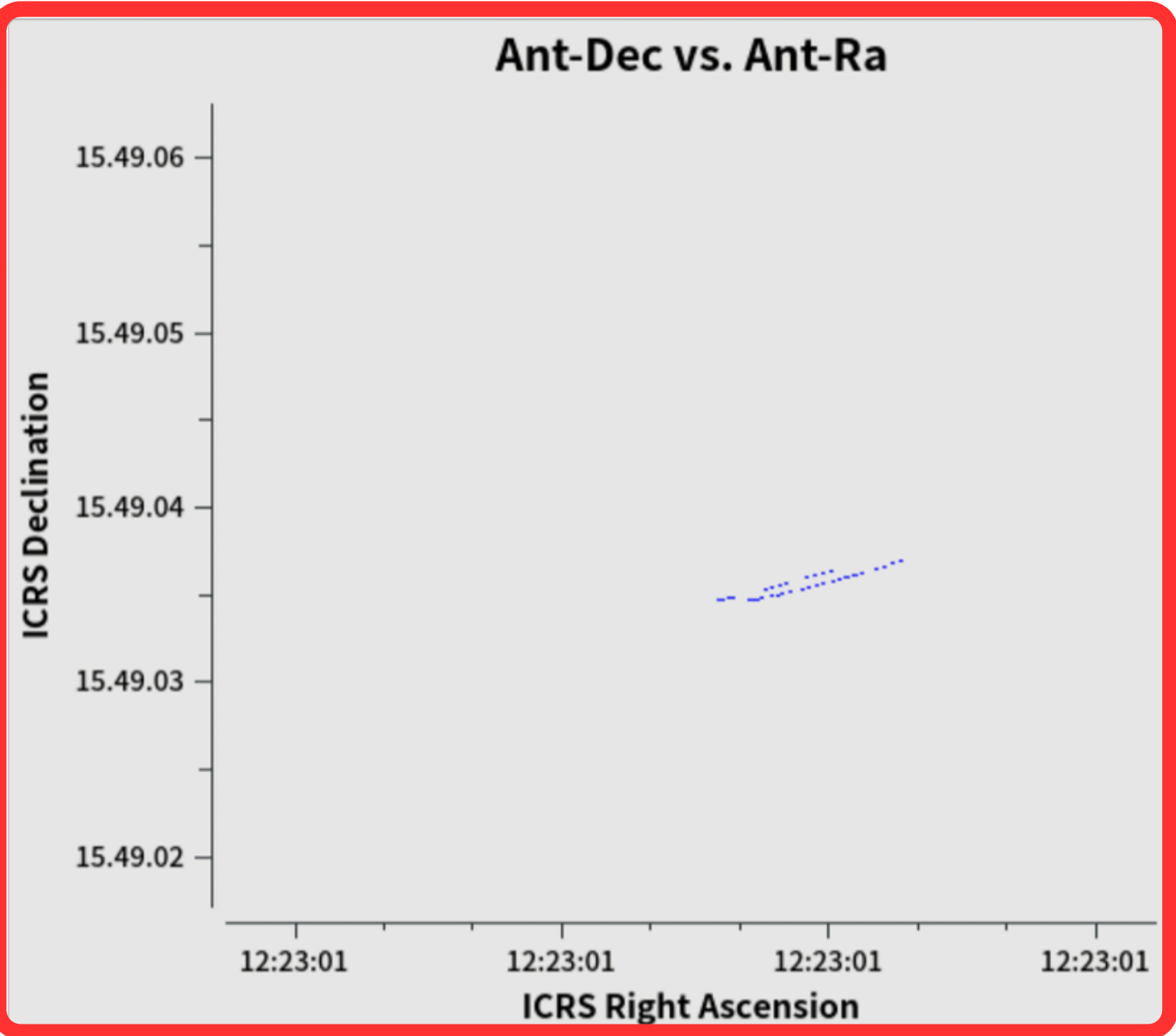
C0 (1–0) line with a rest frequency of 115.271 GHz

M100 Band3 SingleDish

Ant-Dec vs Ant-Ra

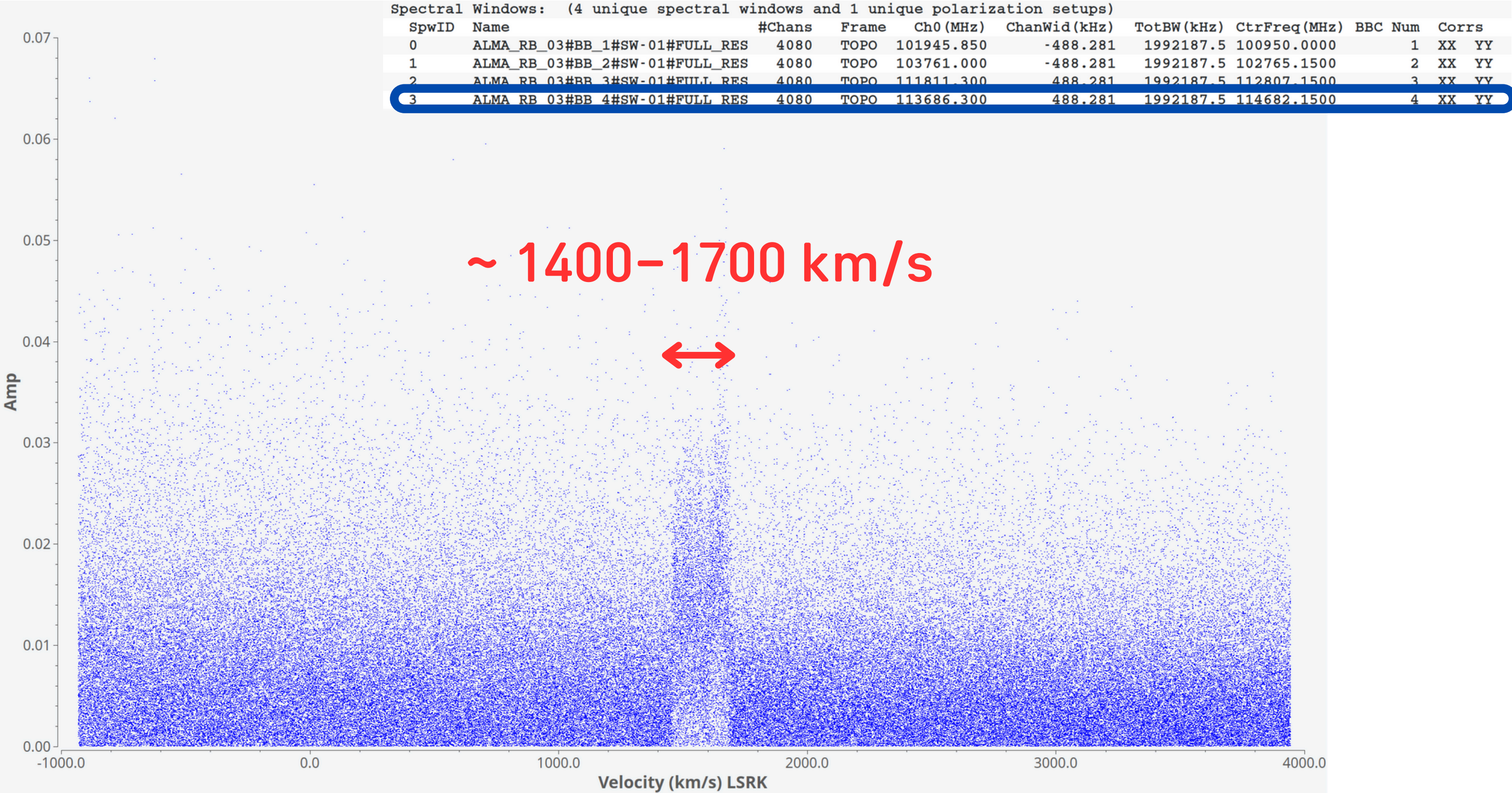


Ant-Dec vs Ant-Ra (zoomed)



Spectral Windows: (4 unique spectral windows and 1 unique polarization setups)											
SpwID	Name	#Chans	Frame	Ch0 (MHz)	ChanWid (kHz)	TotBW (kHz)	CtrFreq (MHz)	BBC	Num	Corrs	
0	ALMA_RB_03#BB_1#SW-01#FULL_RES	4080	TOPO	101945.850	-488.281	1992187.5	100950.0000		1	XX	YY
1	ALMA_RB_03#BB_2#SW-01#FULL_RES	4080	TOPO	103761.000	-488.281	1992187.5	102765.1500		2	XX	YY
2	ALMA_RB_03#BB_3#SW-01#FULL_RES	4080	TOPO	111811.300	488.281	1992187.5	112807.1500		3	XX	YY
3	ALMA_RB_03#BB_4#SW-01#FULL_RES	4080	TOPO	113686.300	488.281	1992187.5	114682.1500		4	XX	YY

M100 Band3 SingleDish



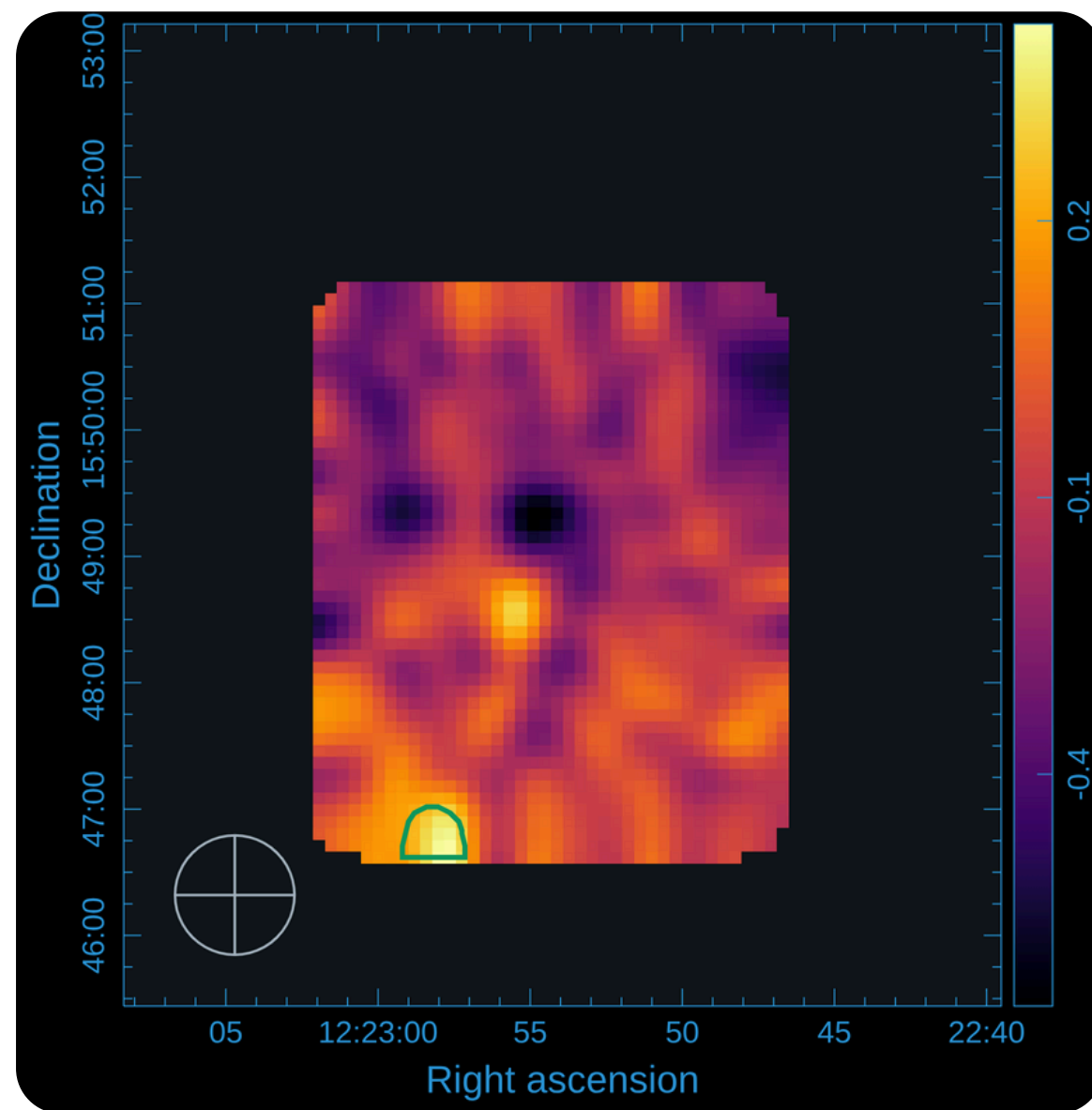
M100 Band3 SingleDish

Task: tsdimaging

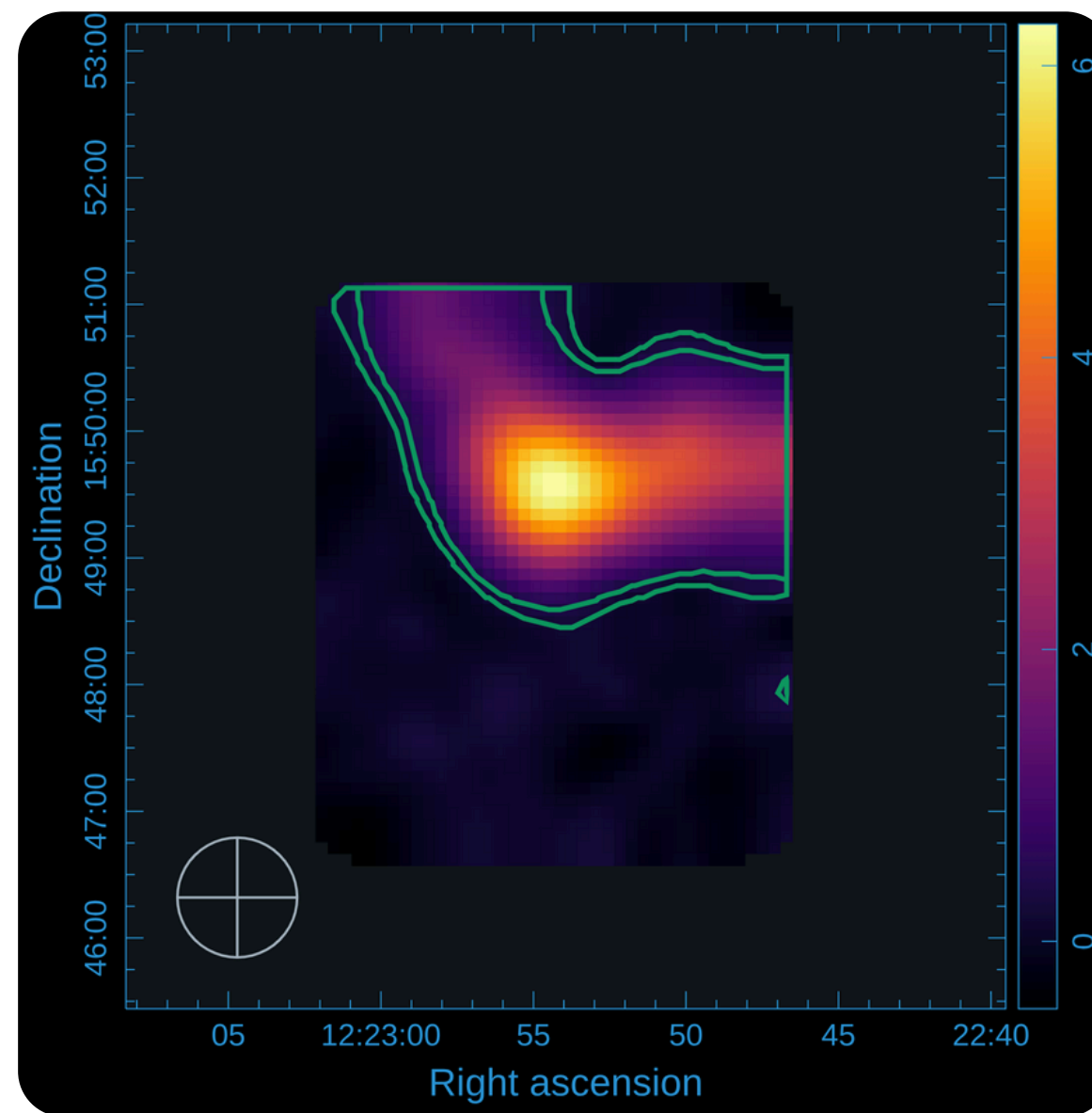
field	'M100'	veltype	'radio'	phasecenter	'J2000 12h22m54.9 + 15d49m15'
spw	3	outframe	'lsrk'	imsize	90
nchan	70	restfreq	'115.271204 GHz'	cell	'5.64 arcsec'
mode	'velocity'	gridfuntion	'SF'	brightnessunit	'Jy/beam'
start	'1400 km/s'	convsupport	6	overwrite	True
width	'5 km/s'	stokes	'I'		

M100 Band3 SingleDish

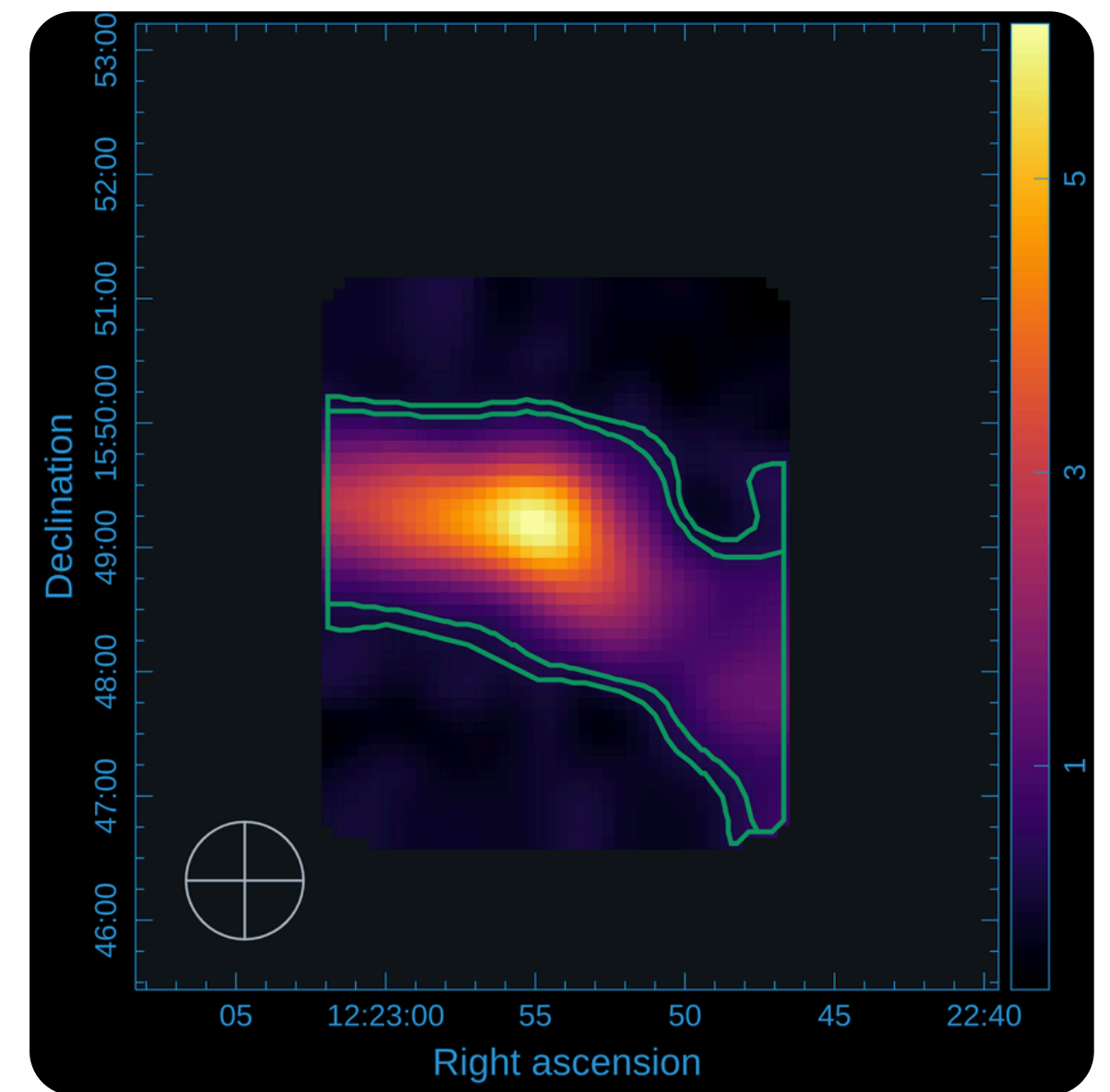
Ch1 image



Ch21 image

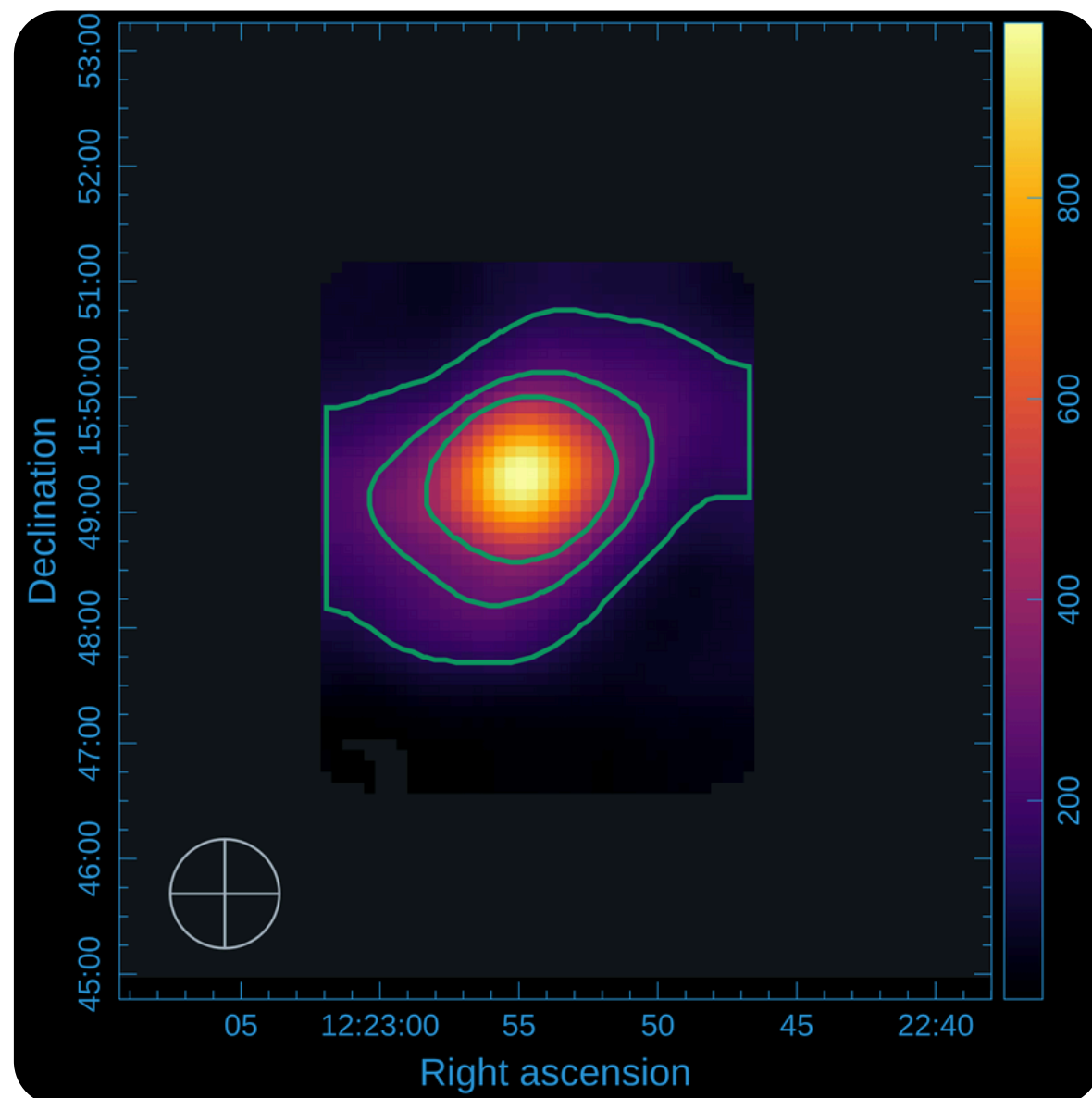


Ch41 image

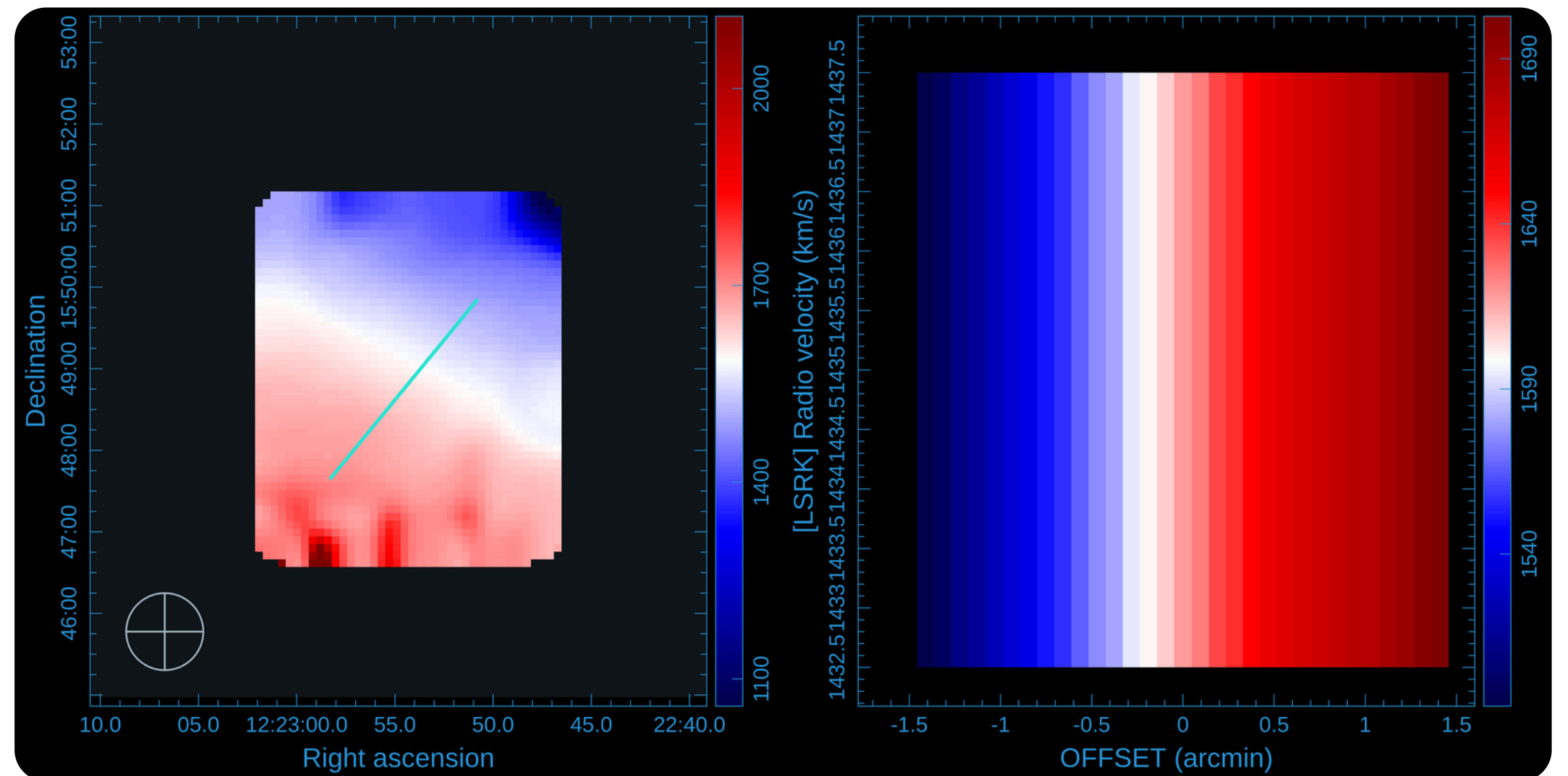


M100 Band3 SingleDish

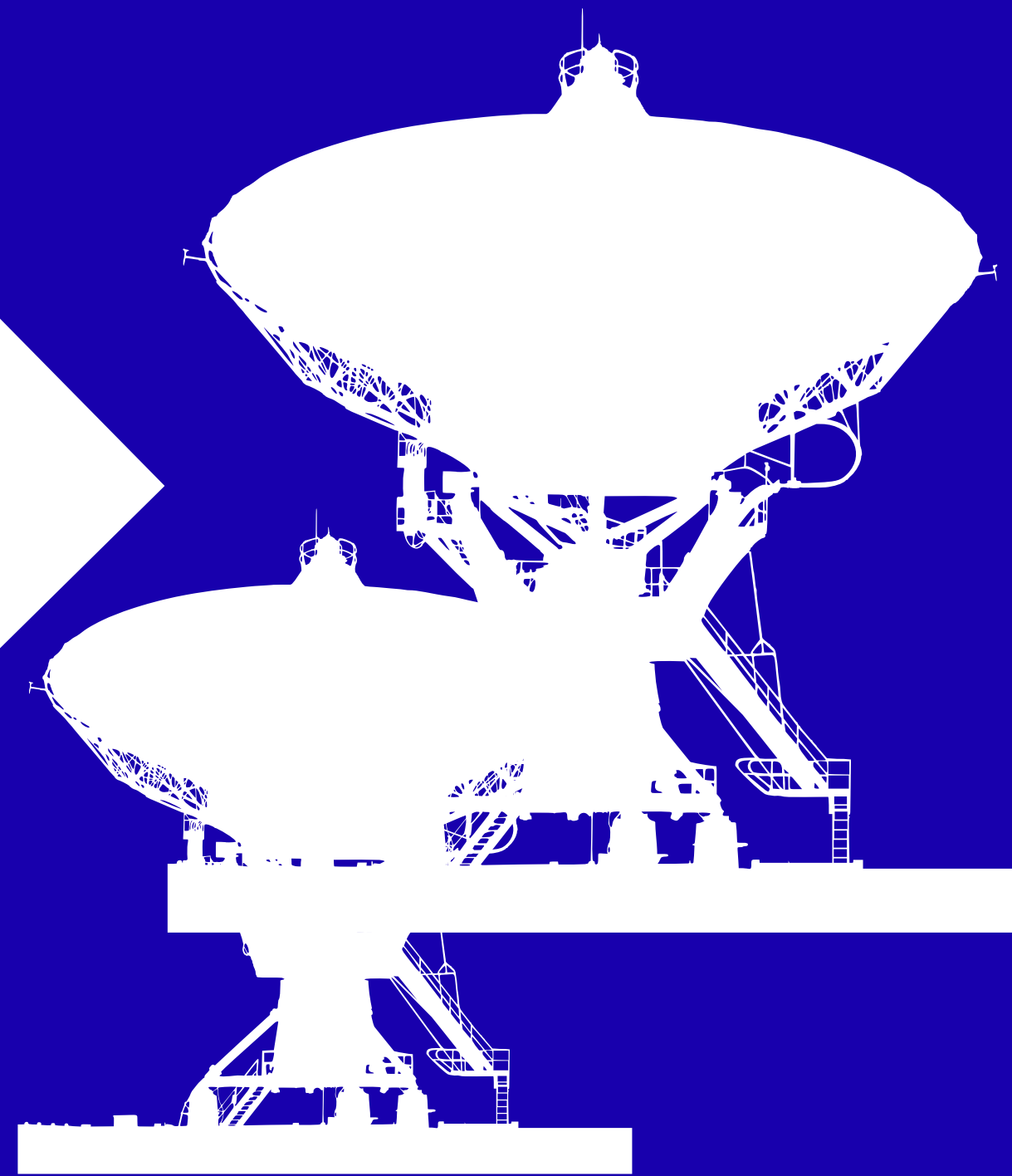
Moment 0 Map
(Integrated intensity)



Moment 1 Map
(Intensity weighted velocity distribution)



Combine 7m & 12m

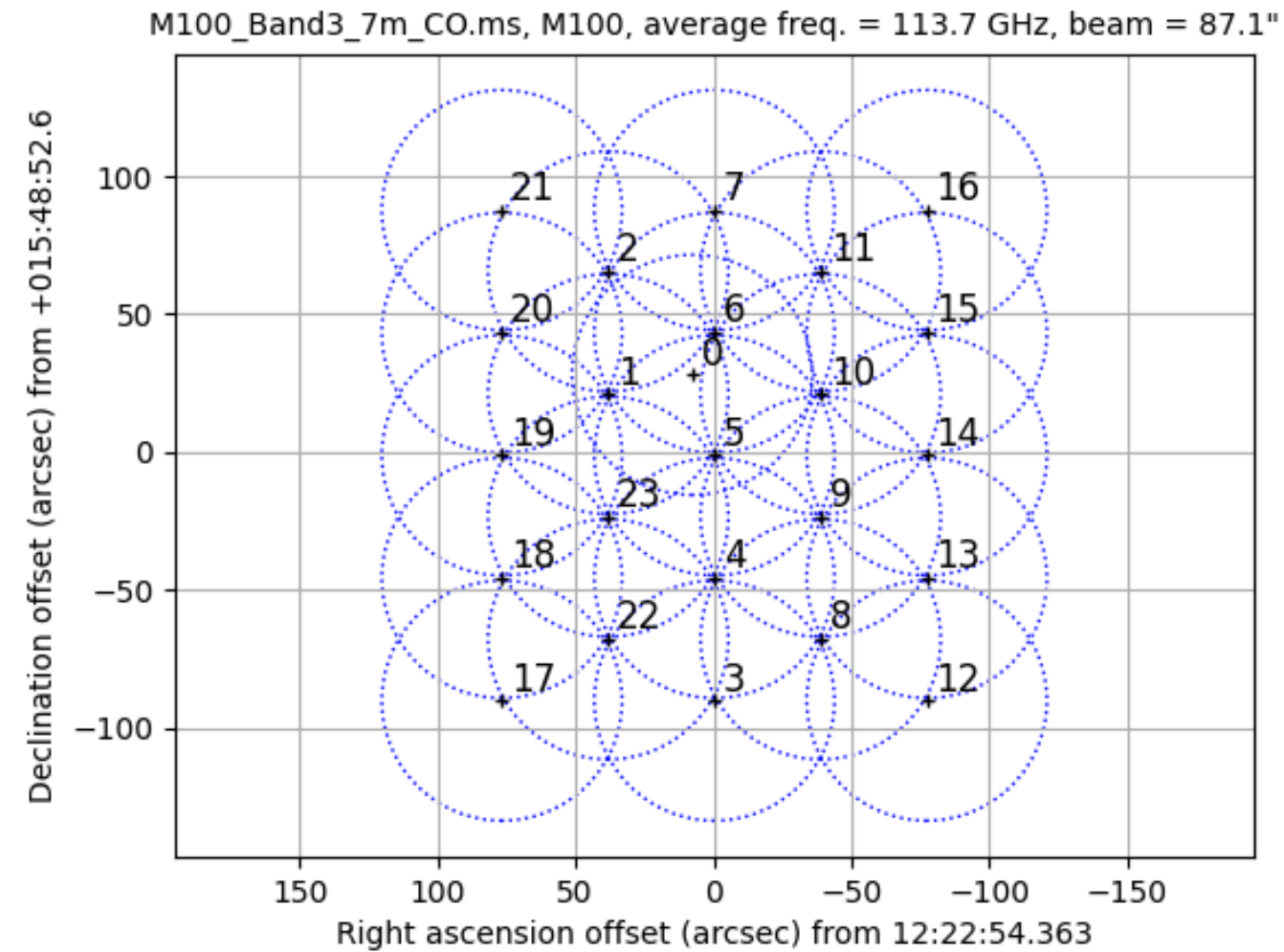


7m vs 12m

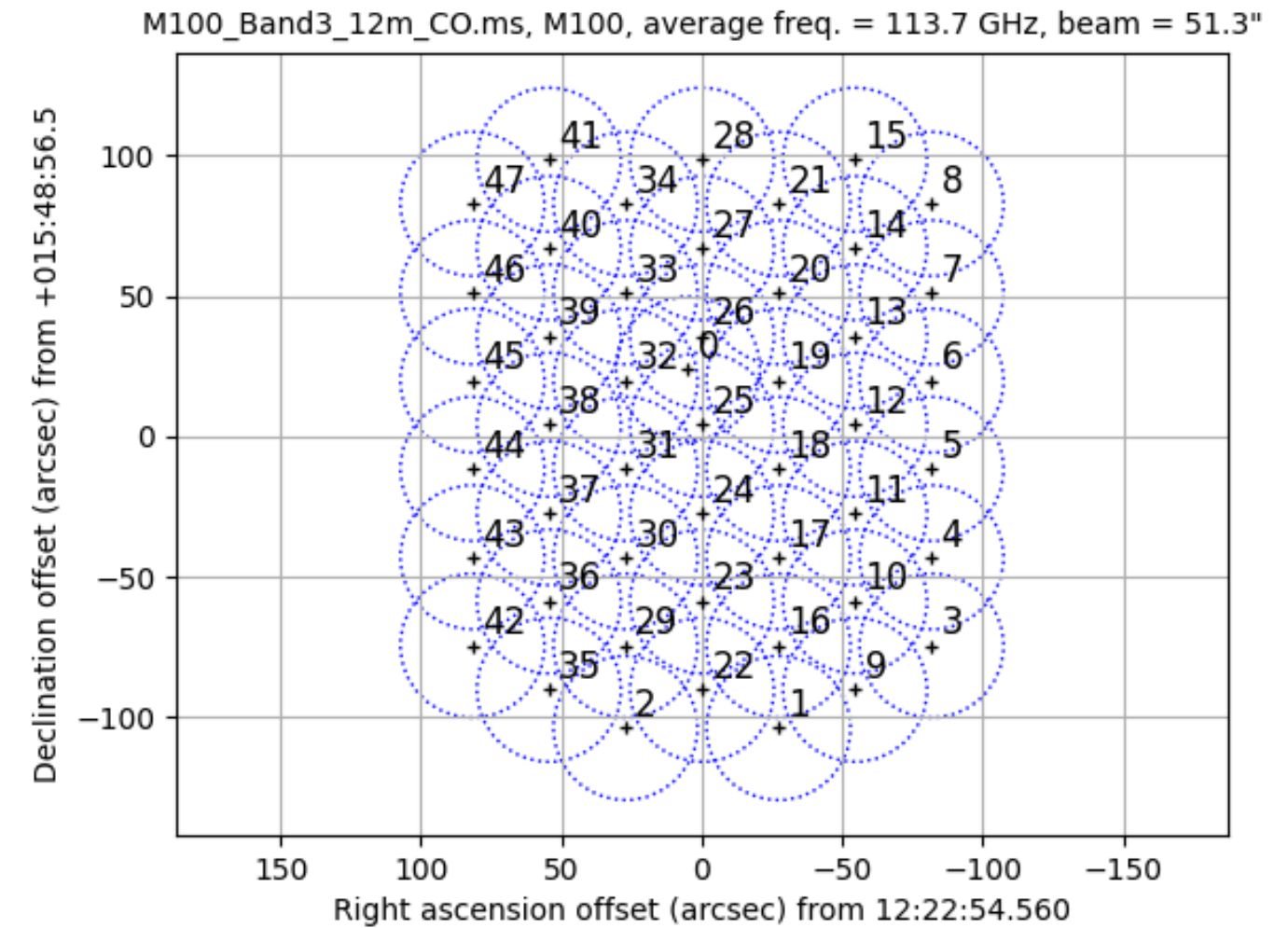
calibrate + split/concat done



M100_7m_CO.ms
M100_12m_CO.ms



7m Field: 23



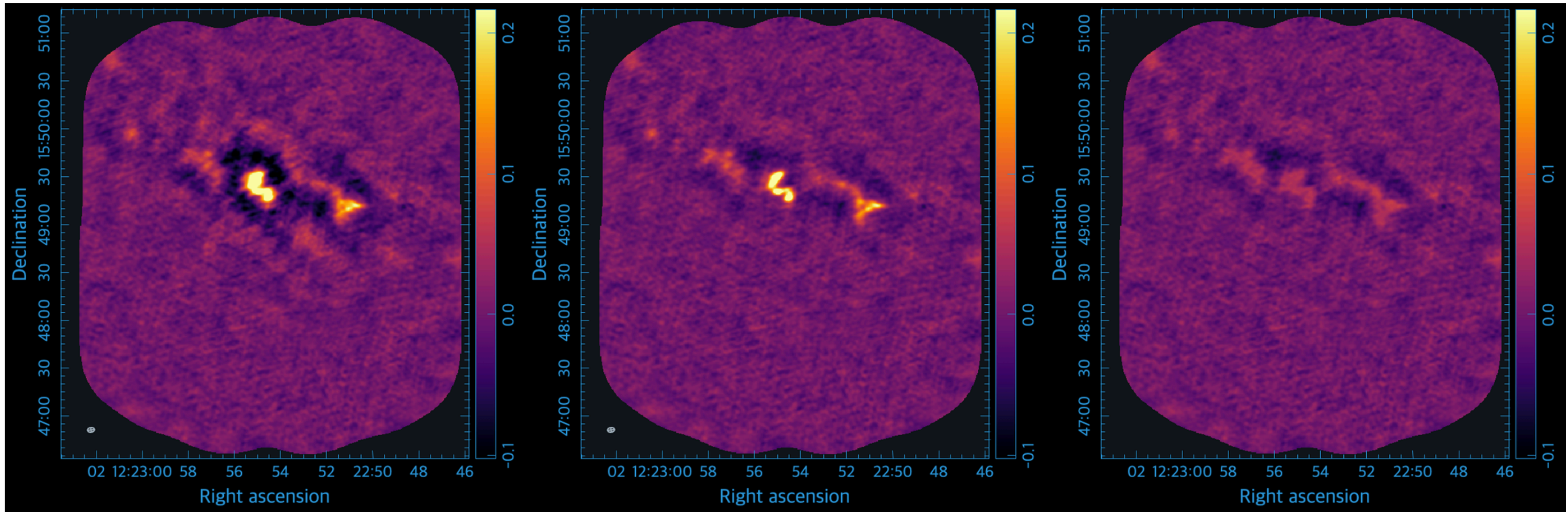
12m Field: 47

Combine 7m + 12m Task: tclean

gridder	'mosaic'	specmode	'cube'
deconvolver	'hogbom'	width	'5km/s'
pbmask	0.2	start	'1400m/s'
imsize	800	nchan	70
cell	'5 arcsec'	restfreq	'115.271201800GHz'
weighting	'briggsbwtaper'	outframe	'LSRK'
robust	0.2	veltype	'radio'
phasecenter	'J2000 12h22m54.9 +15d49m15'	restoringbeam	'common'

Clean map

Ch 30



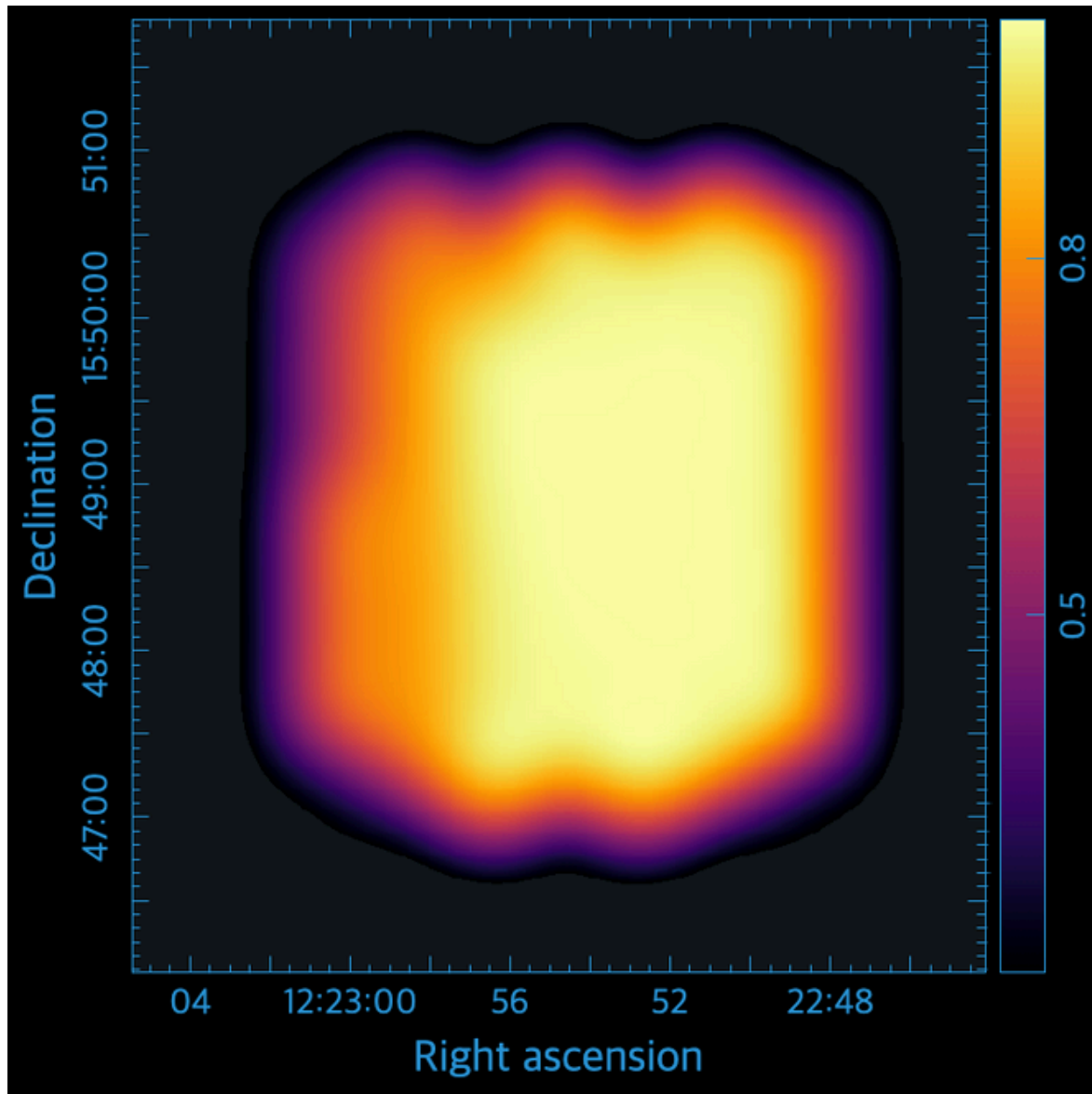
Dirty map

Clean map

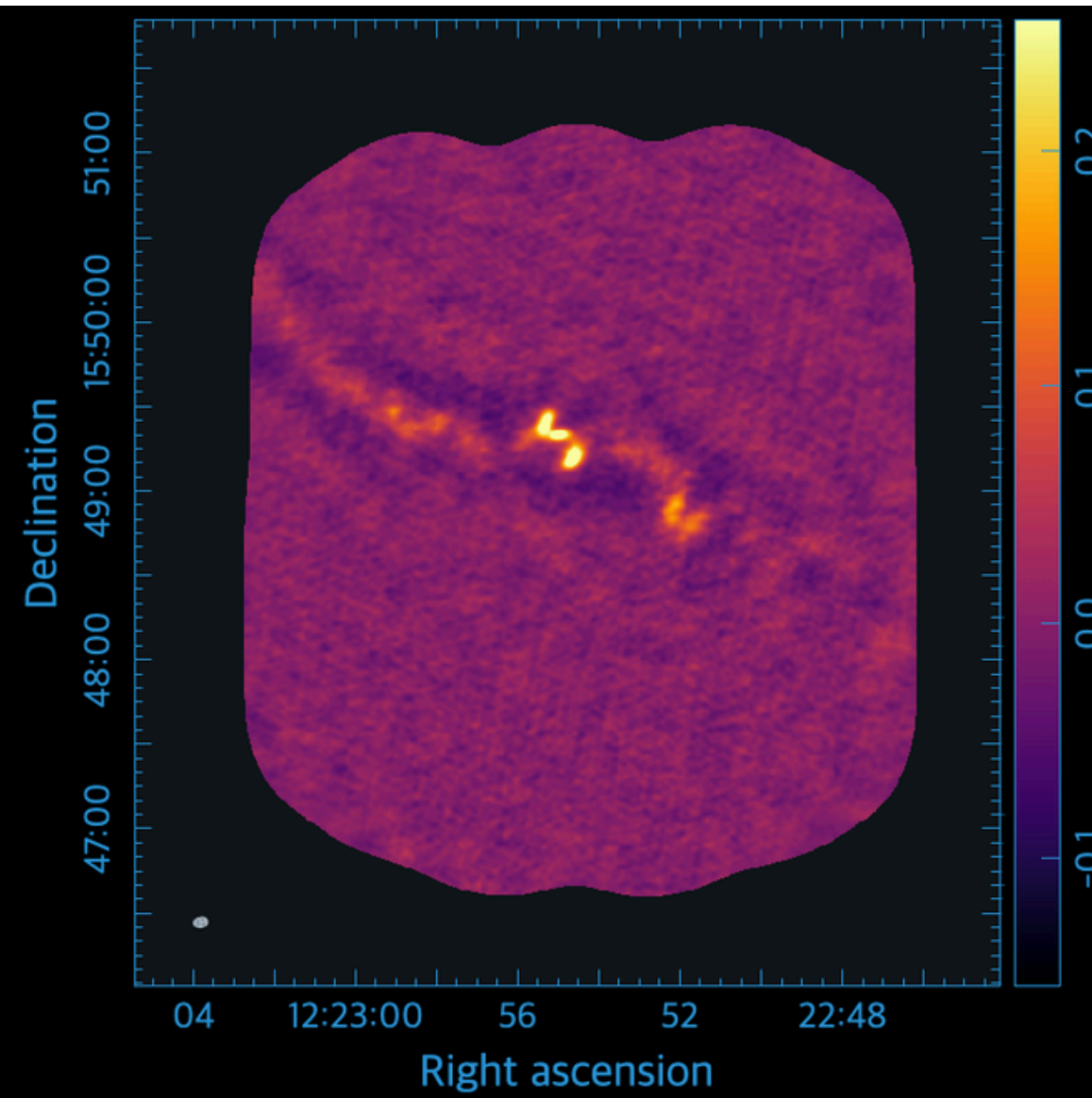
Residual map

Primary beam correction

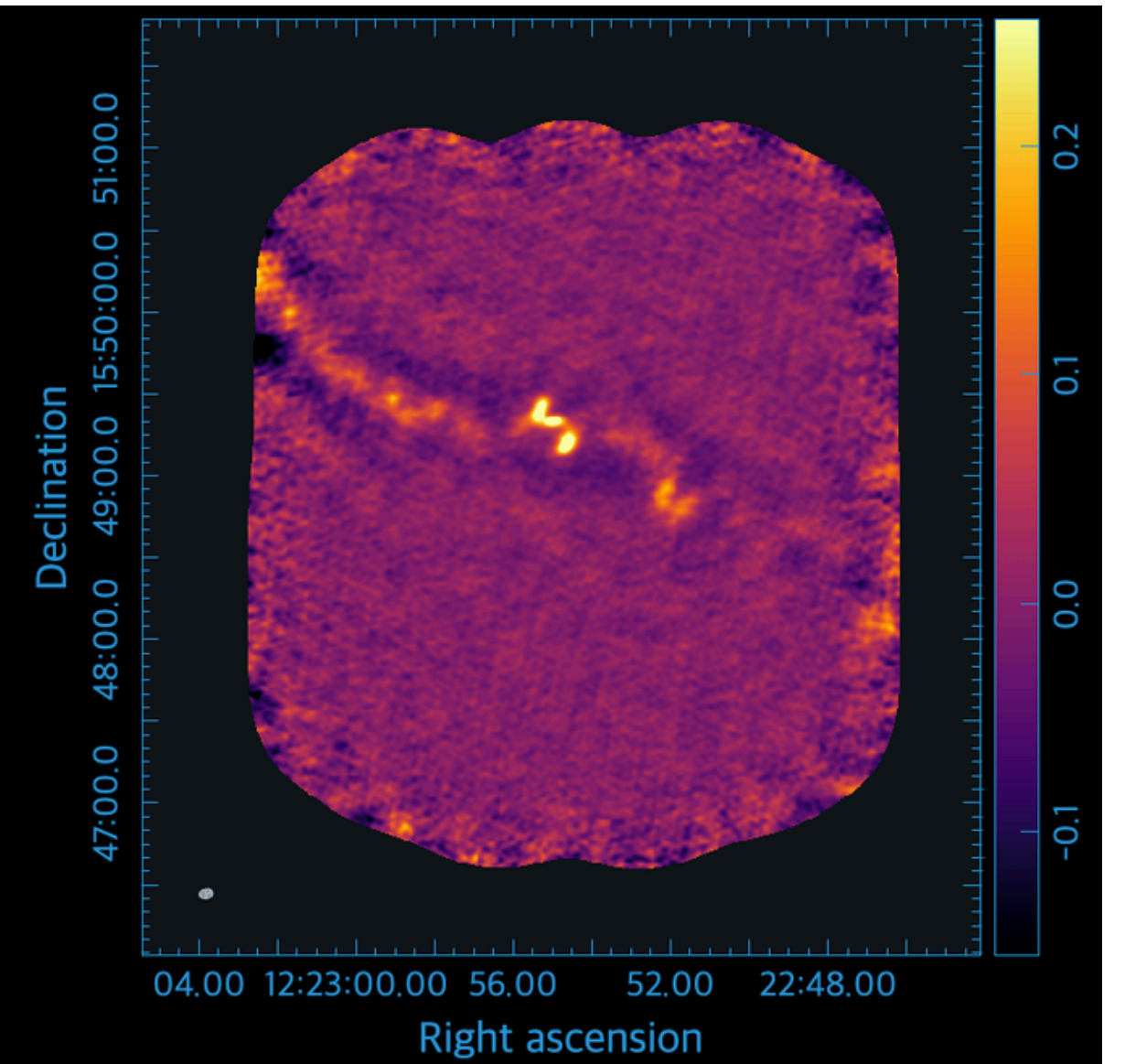
primary beam map



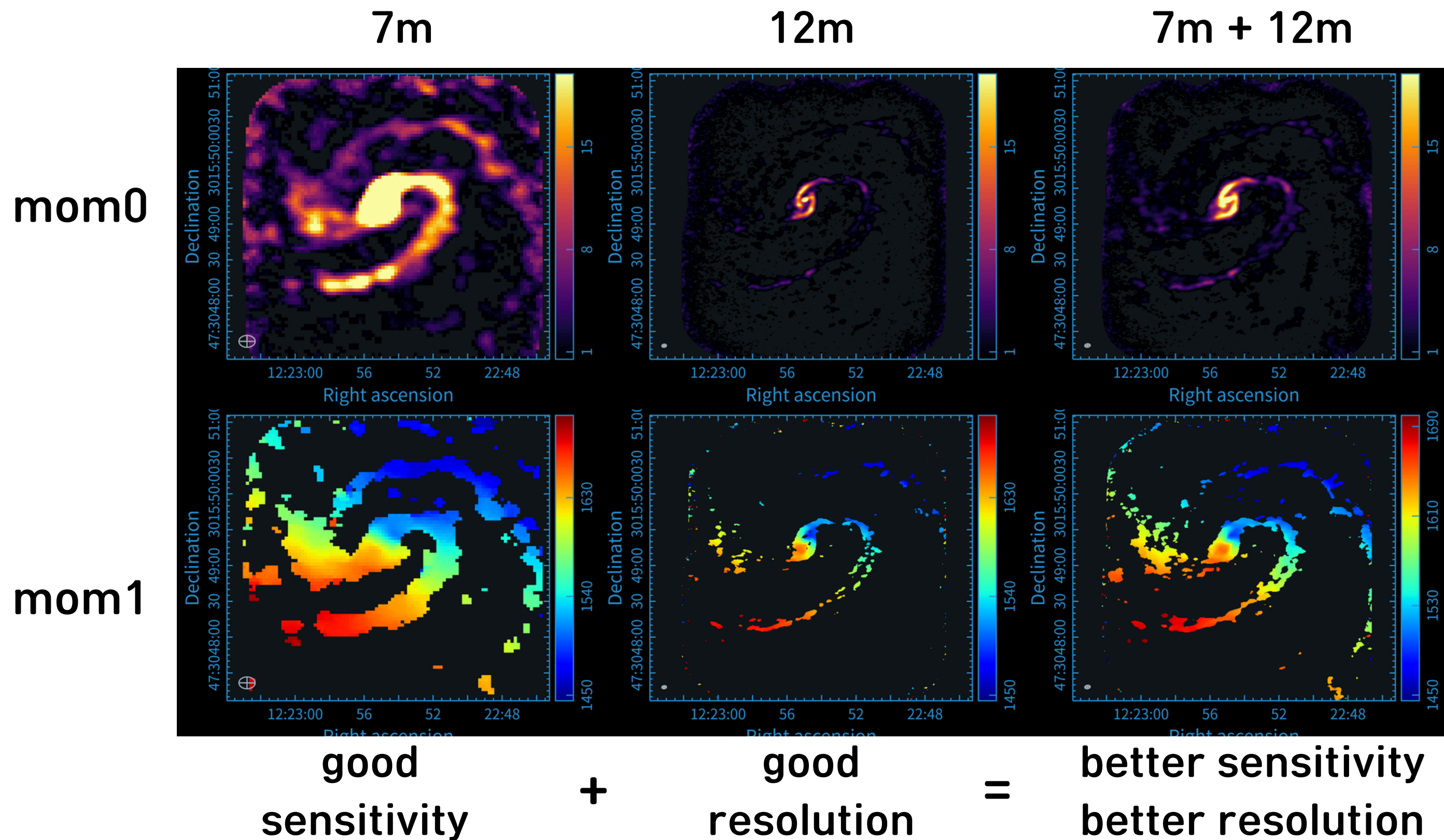
before correction



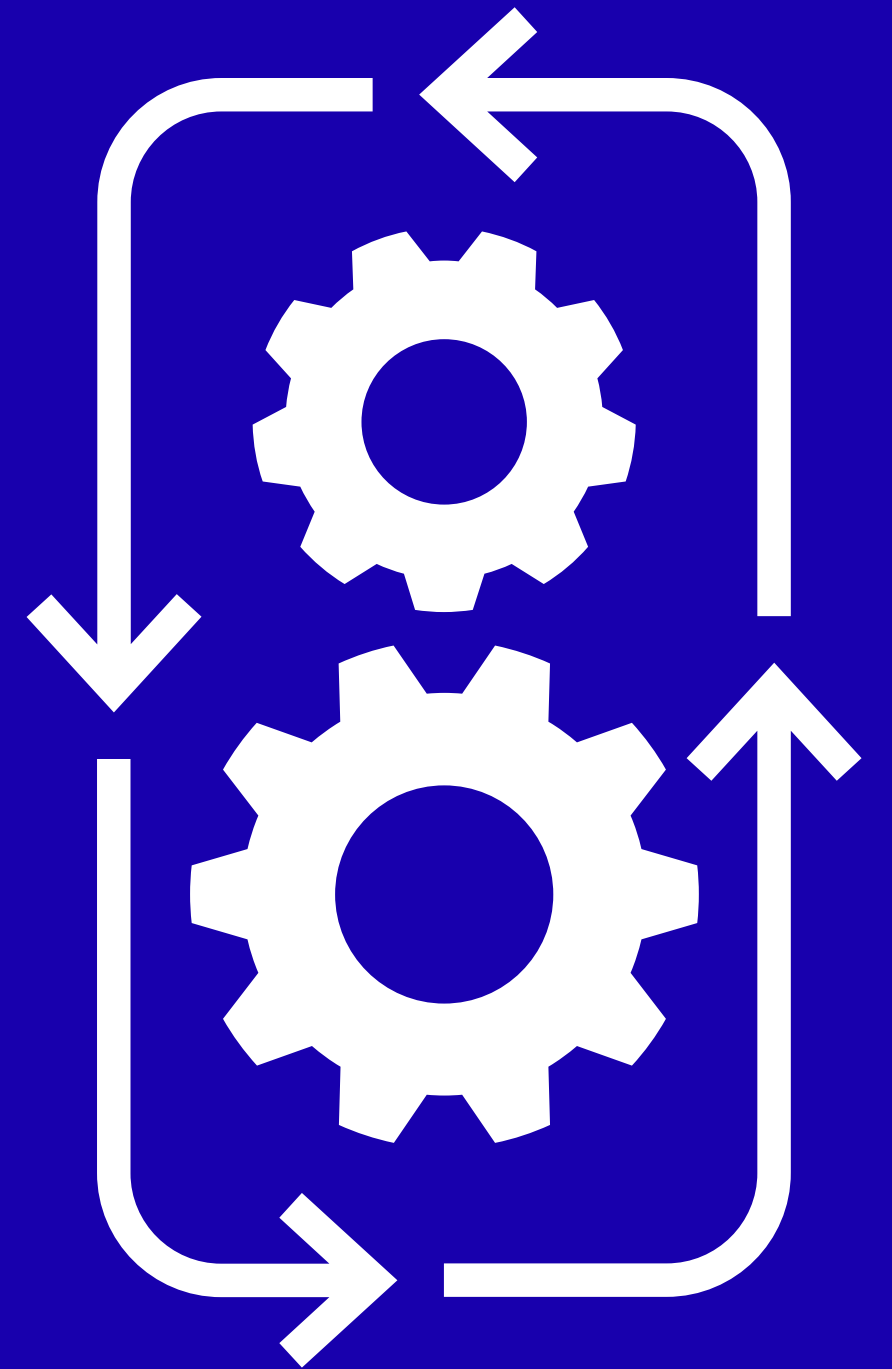
after correction



Moment map



Combining SD & Int image



Combining TP & 7m+12m

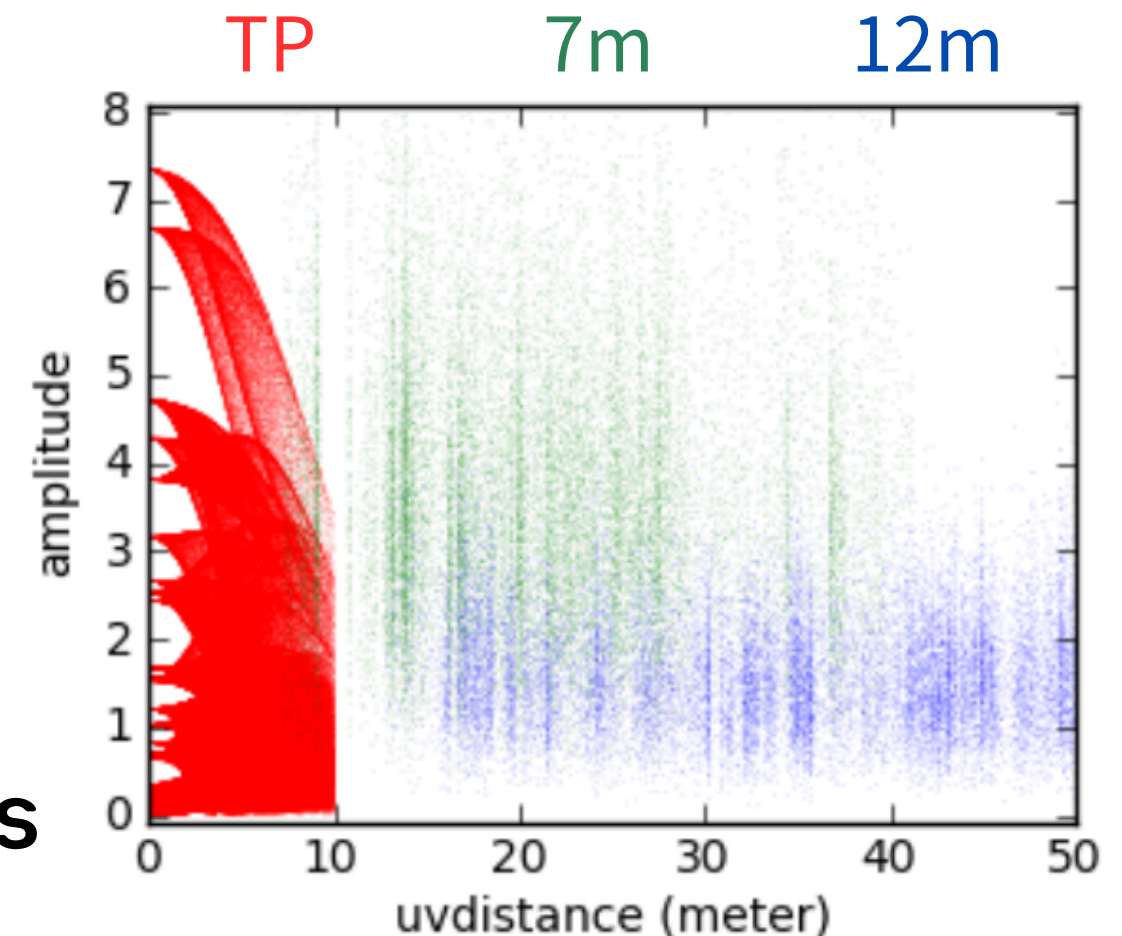
Interferometry

- Can resolve fine structure than SD
- Filters out larger spatial scales

+ Single-dish

- Can recover extended structure

=> To sample the complete (u,v) space for spatical scales



Combining TP & 7m+12m

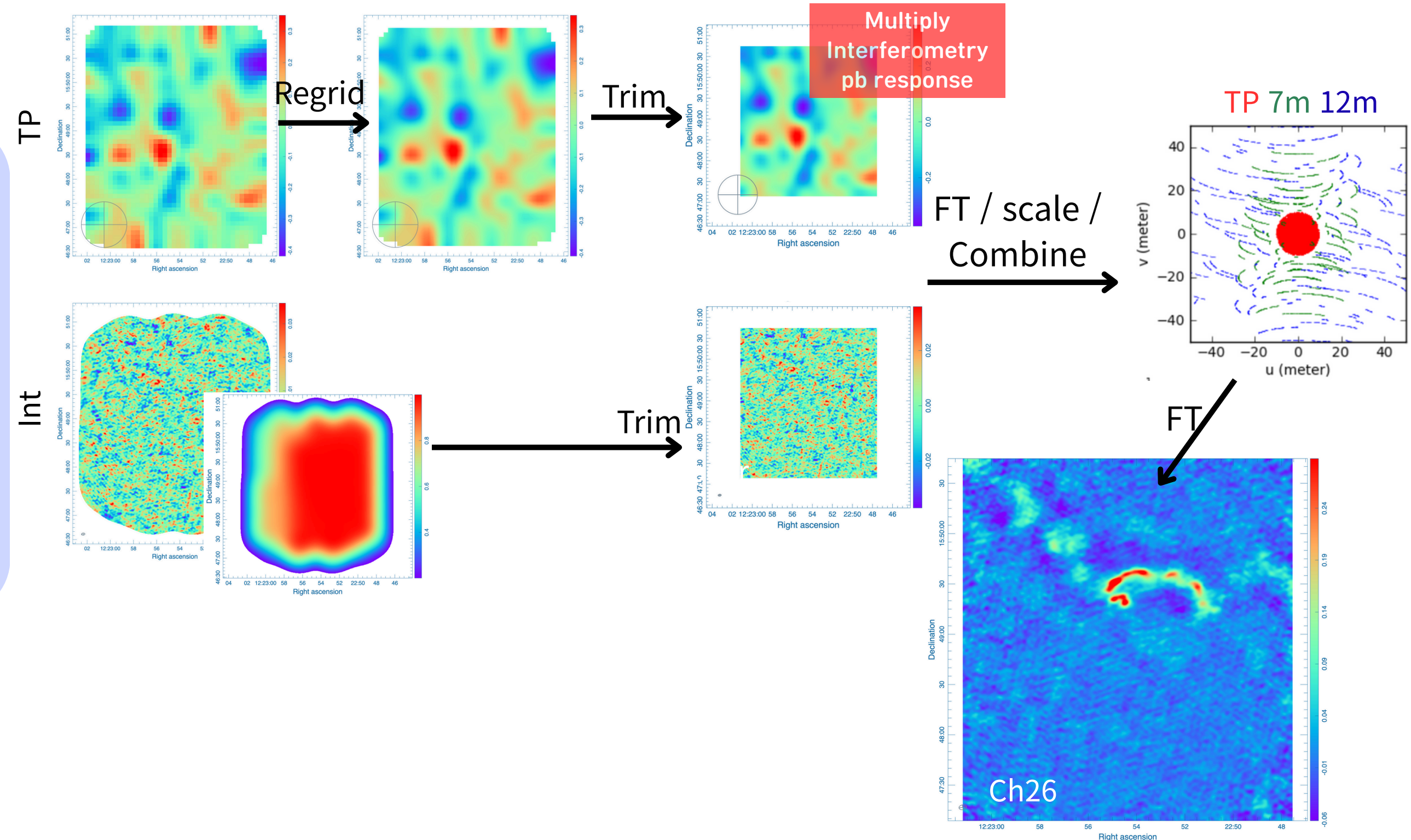
Methods

Method	Combined	Domain	Task Name	Input		Output
				Int	SD	
Feather	after deconvolution	F	feather	Image	Image	Image
SDINT	before deconvolution	F/I	sdintimaging	Vis.	Image	Image

Combining TP & 7m+12m

Feather

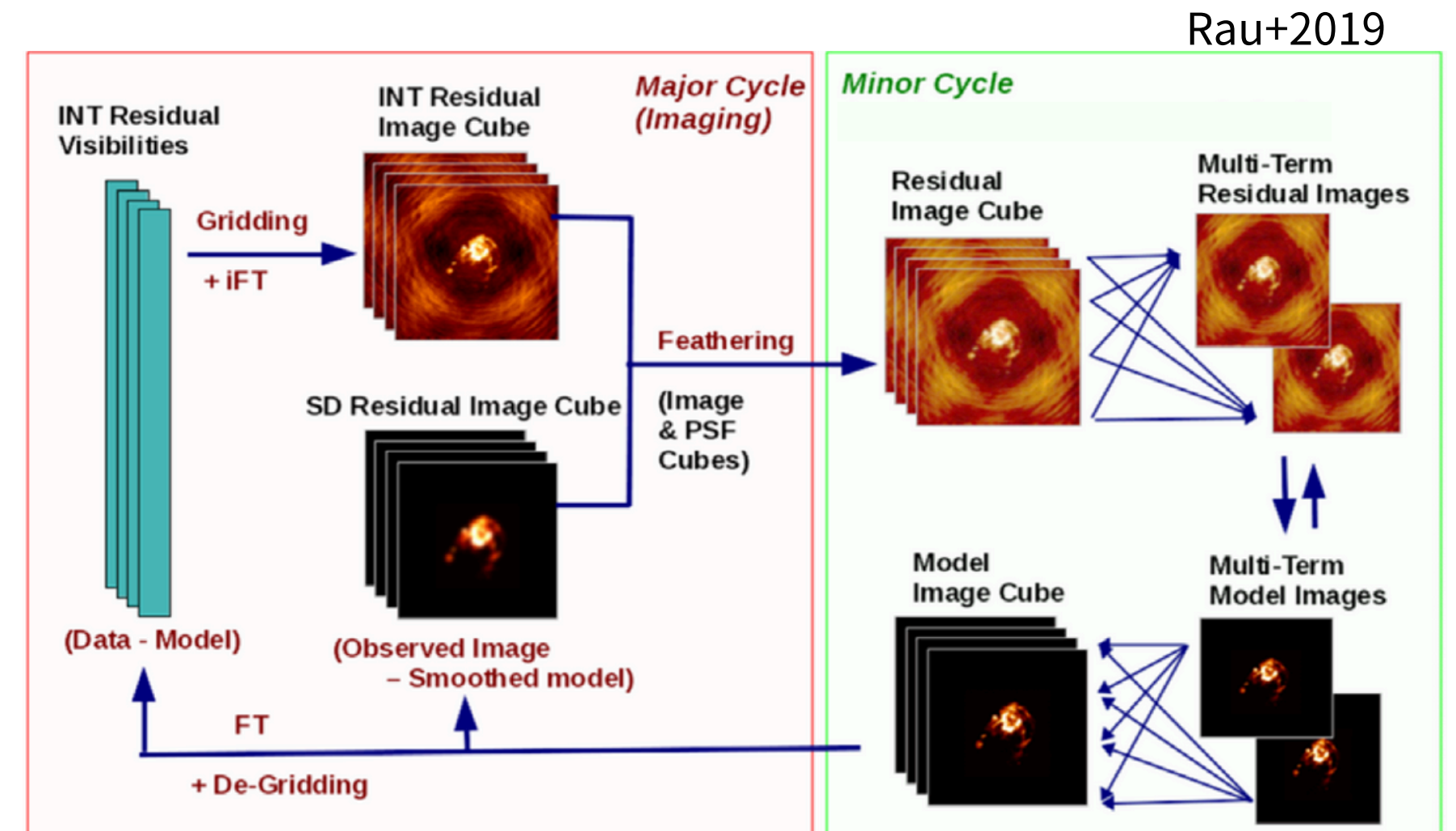
1. Regrid/trim/pbcor the SD image
2. FT both images
3. Scaling the FTed SD image ("sdfactor")
4. Combine in the (u,v)-plane
5. FT back to the image plane



Combining TP & 7m+12m

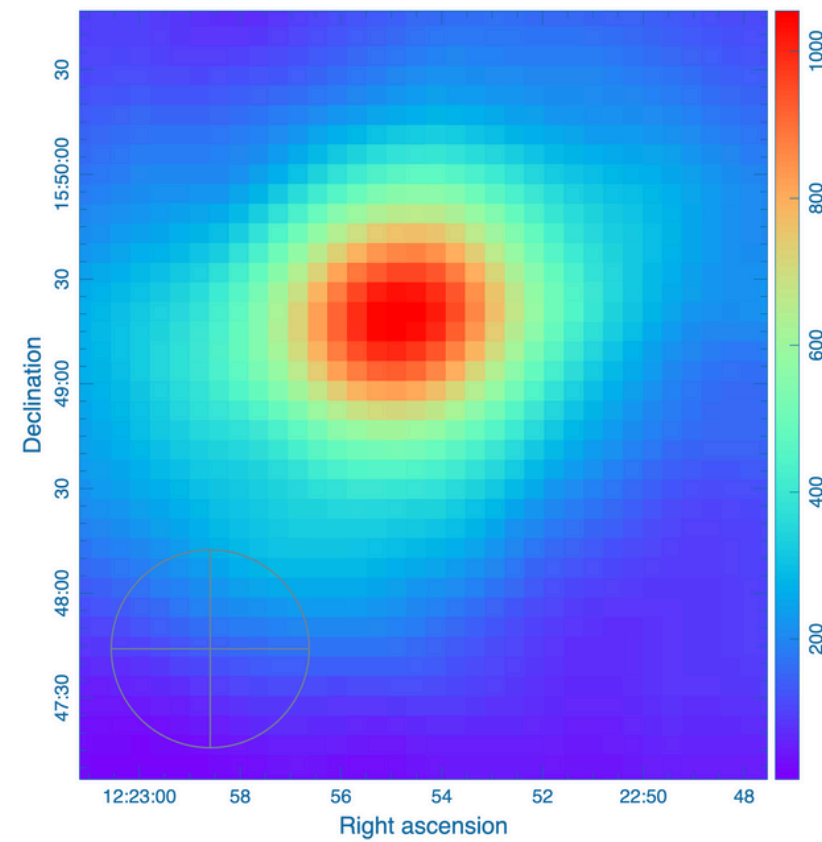
SDINT

1. (Major cycle) CLEAN int. data \rightarrow psf (dirty beam) & dirty image generated
2. load SD image cube
3. feathering (INT dirty image, SD image) \rightarrow combined image generated
4. (Minor cycle) CLEAN combined image \rightarrow joint psf & joint dirty image generated
5. new residual SD image and new residual INT residual
6. degriding
7. feathering (new INT residual map, new SD residual map)
8. (4-5) repeated

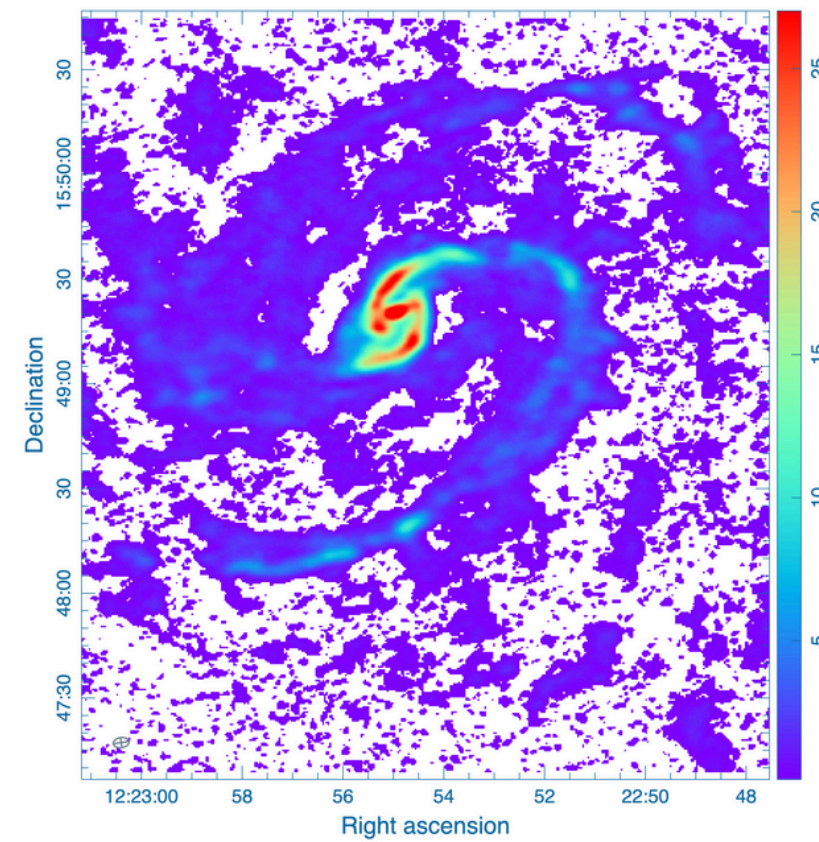


Combining TP & 7m+12m

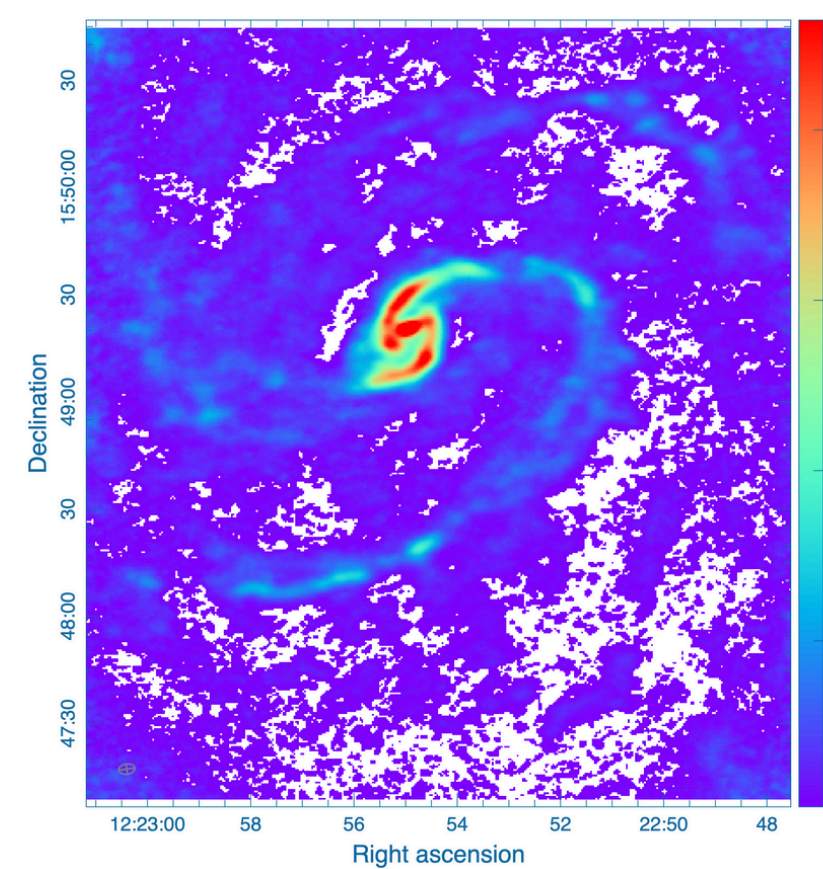
TP



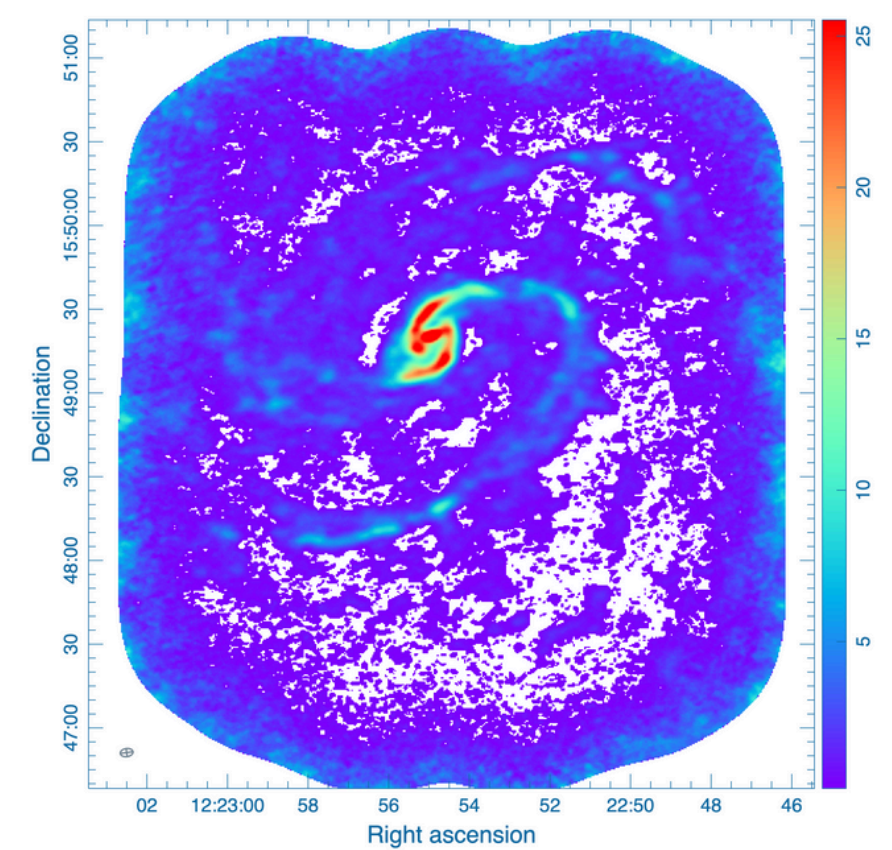
7m+12m



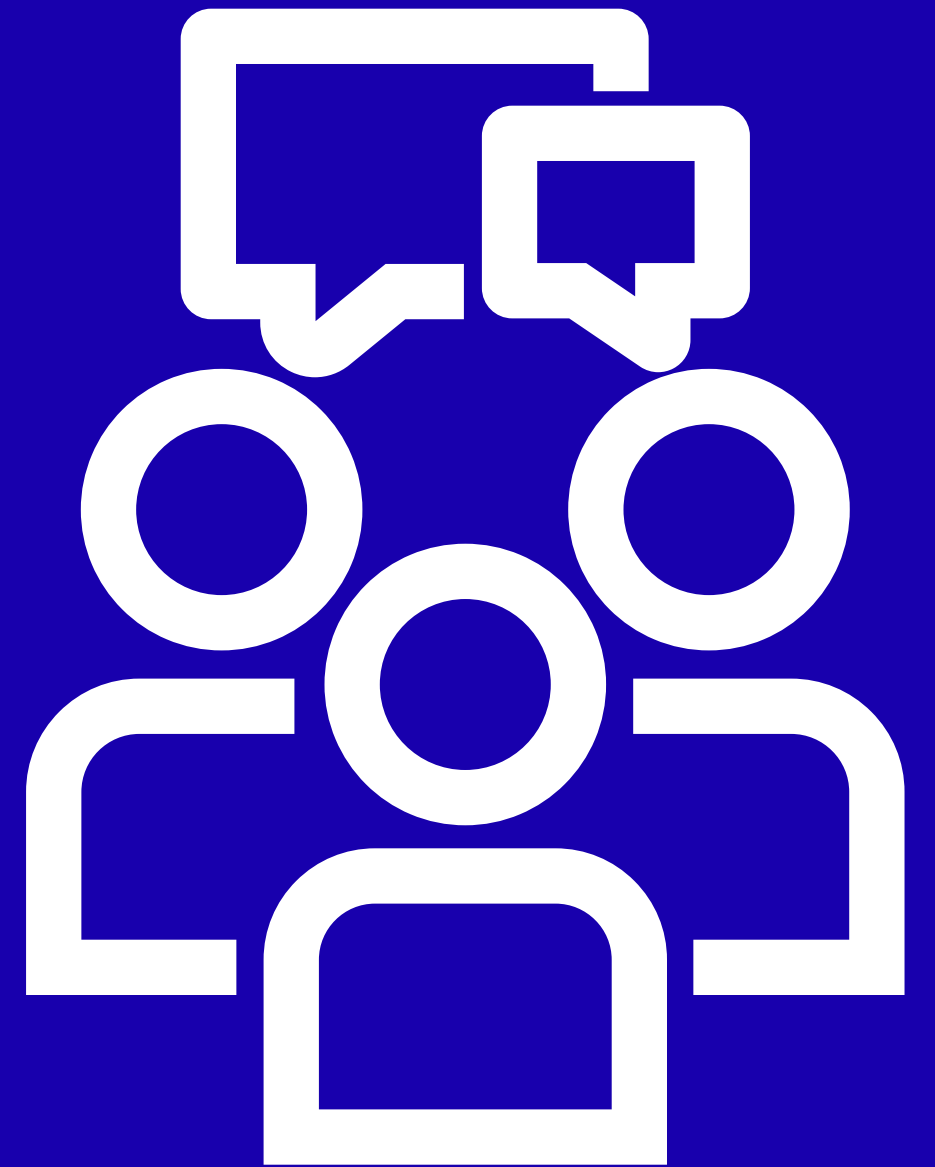
Feather



SDINT



Discussions.



Discussions

01

RESULTS FROM COMBINATION

02

FEATHER VS SDINT

03

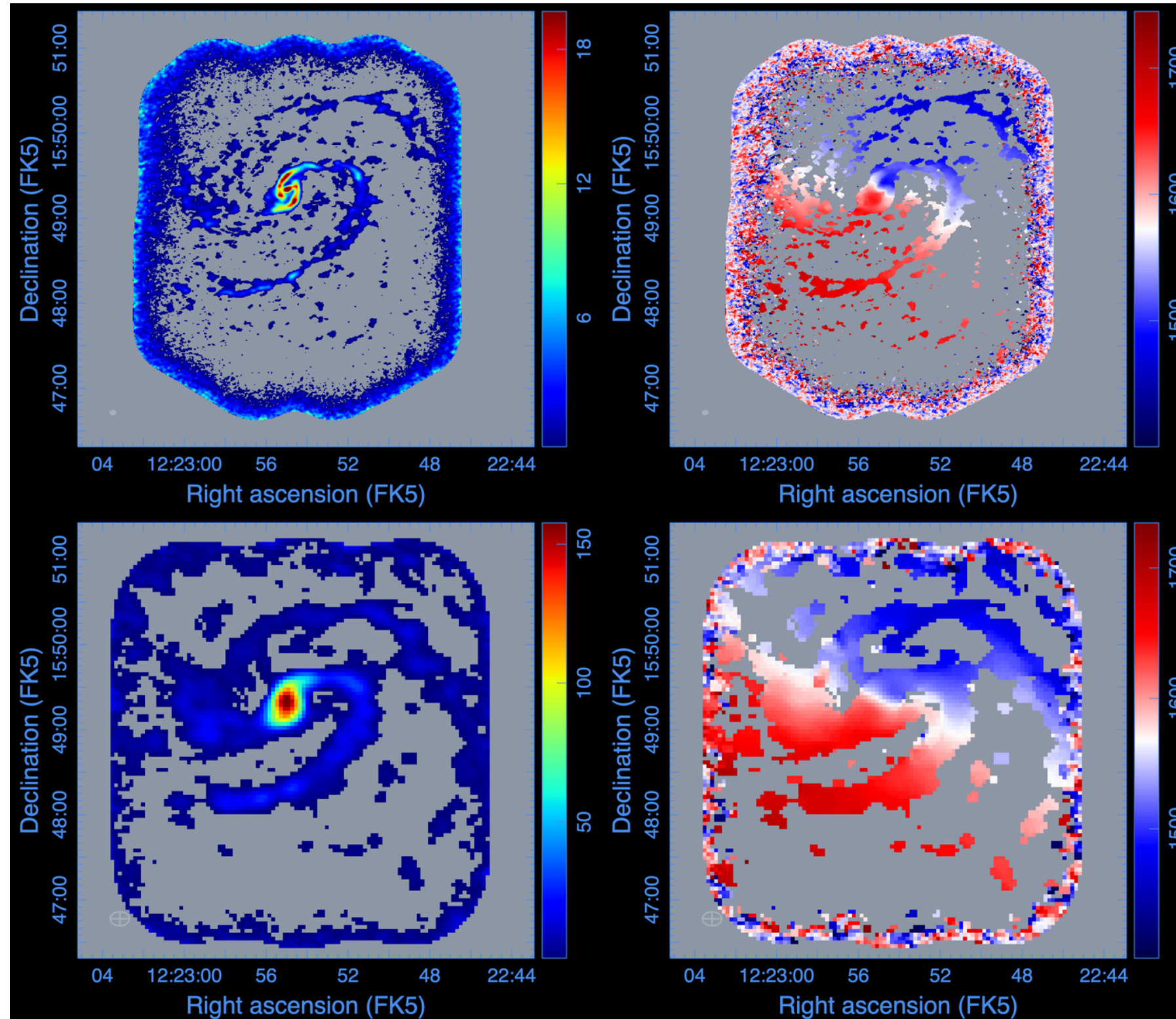
ROLE OF VARIOUS FACTORS IN
COMBINATION

M100 Band3 12m & 7m

Moment 0

Moment 1

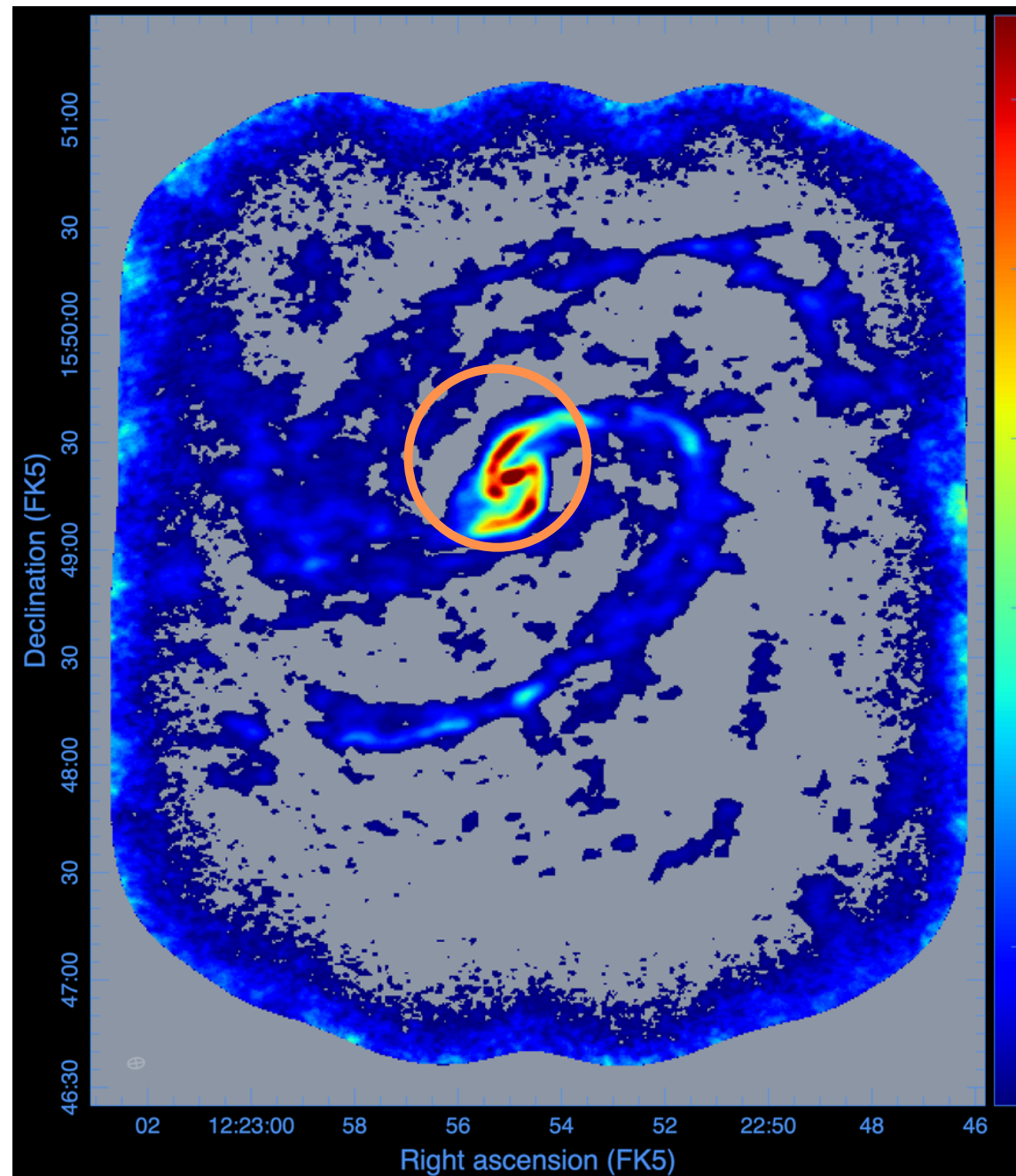
12m



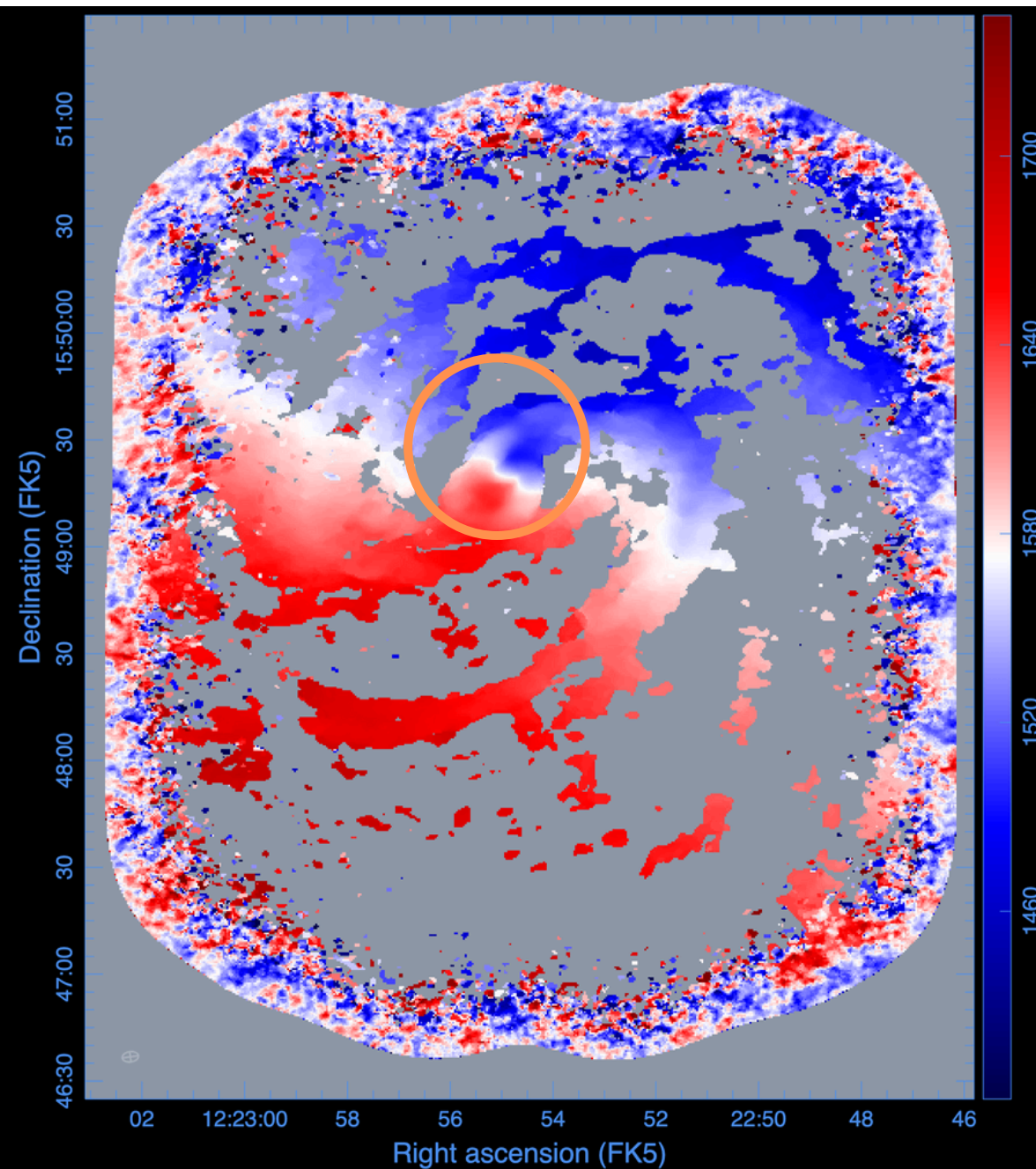
- 12m images lack extended emission.
- 7m images lack finer details compared to the 12m image.

M100 Band3 12m + 7m

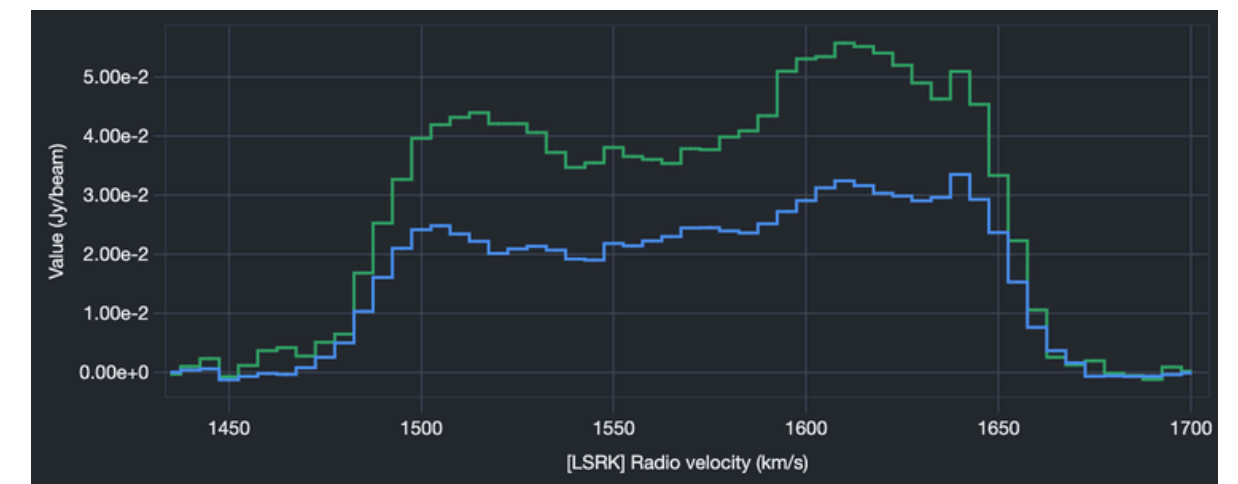
Moment 0



Moment 1



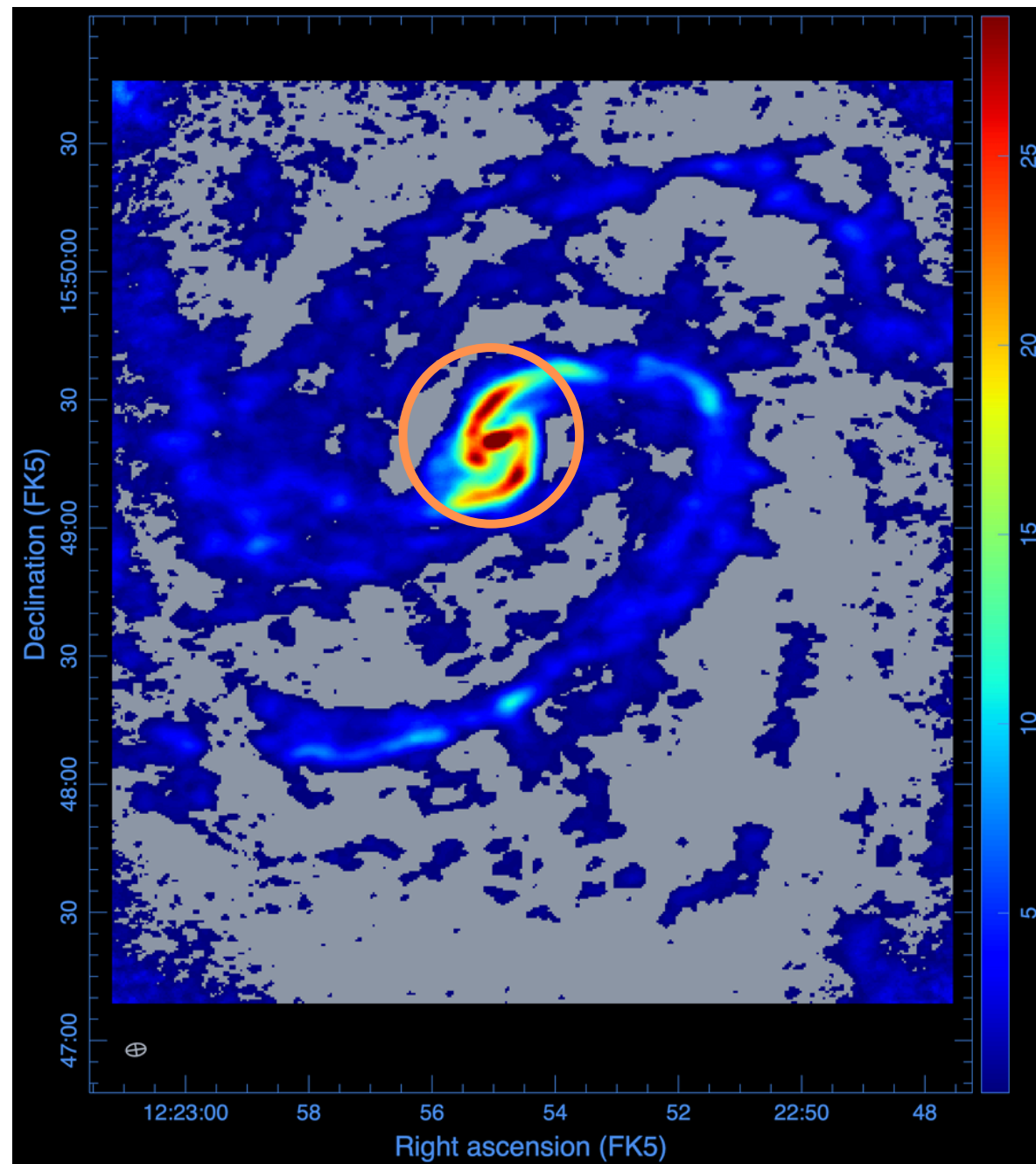
12m 12m+7m



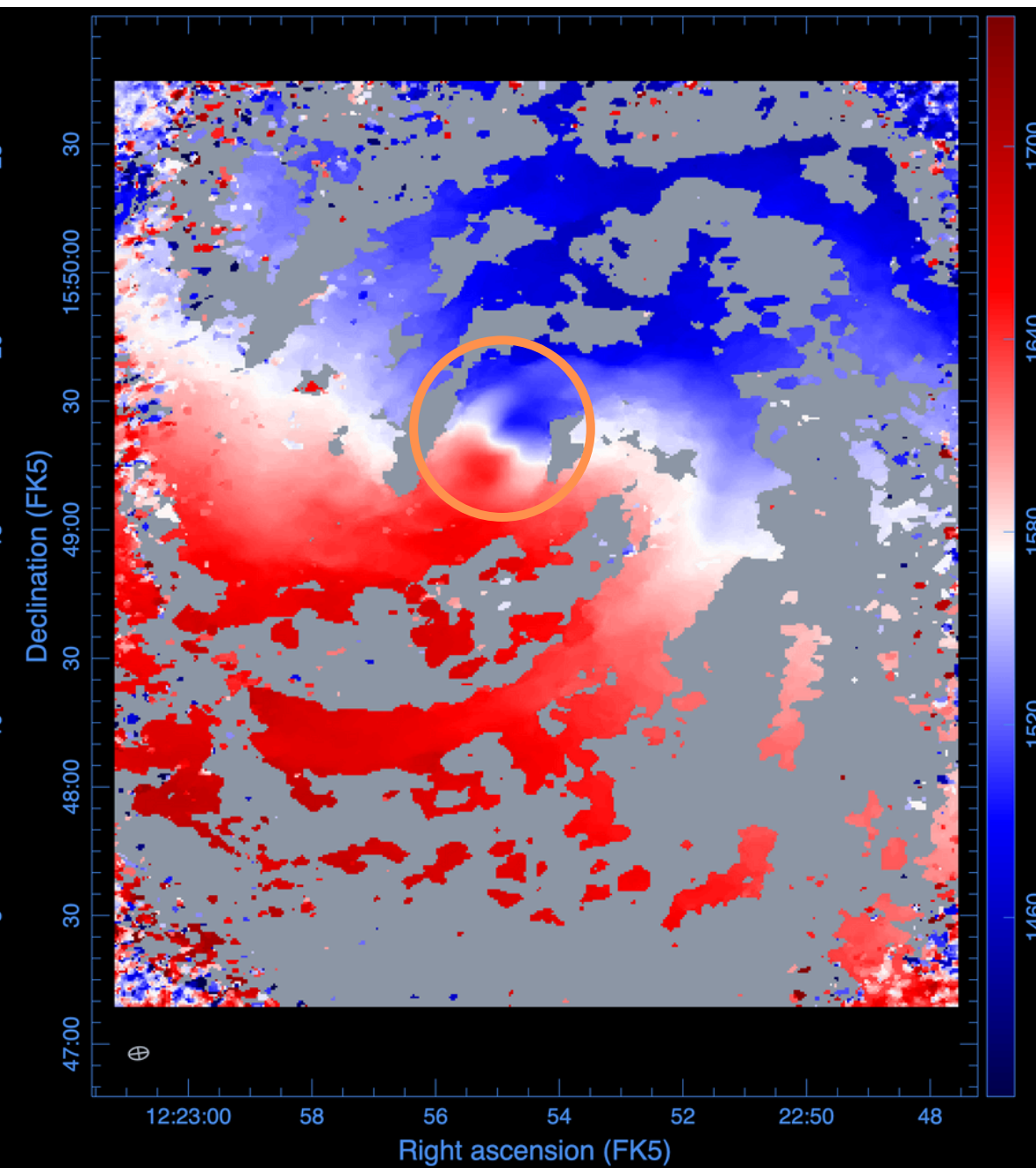
Extended emission is recovered and the image has finer details compared to 7m alone.

M100 Band3 12m + 7m + TP (Feather)

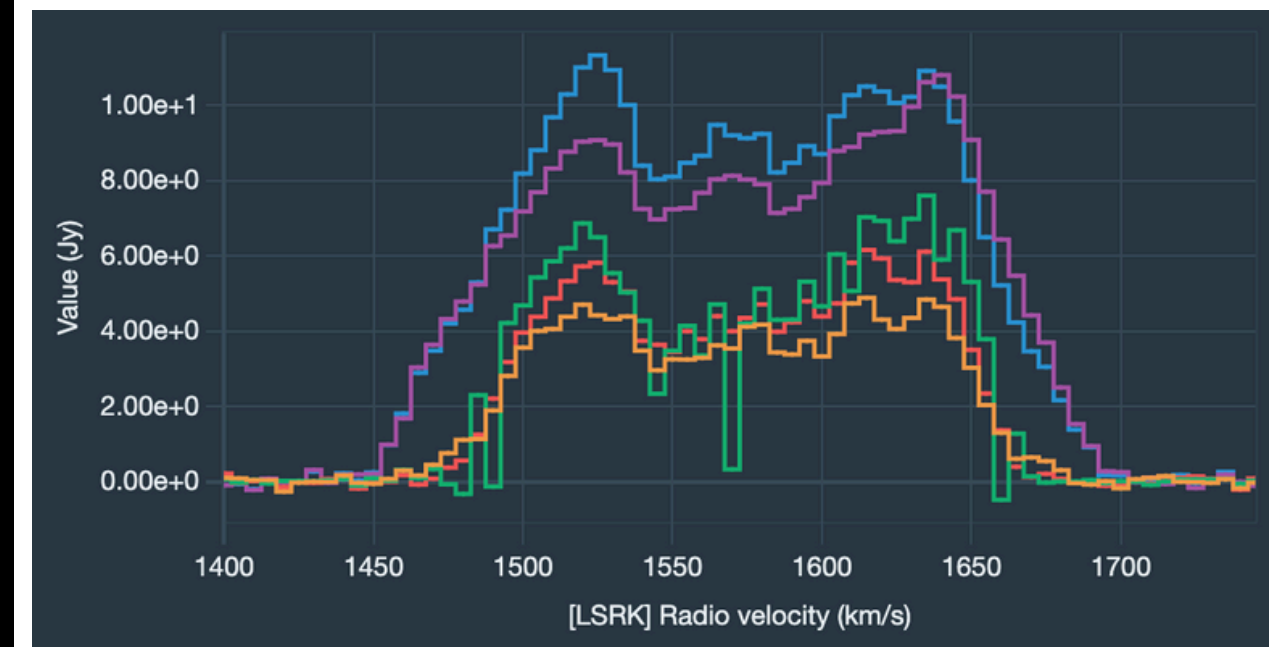
Moment 0



Moment 1



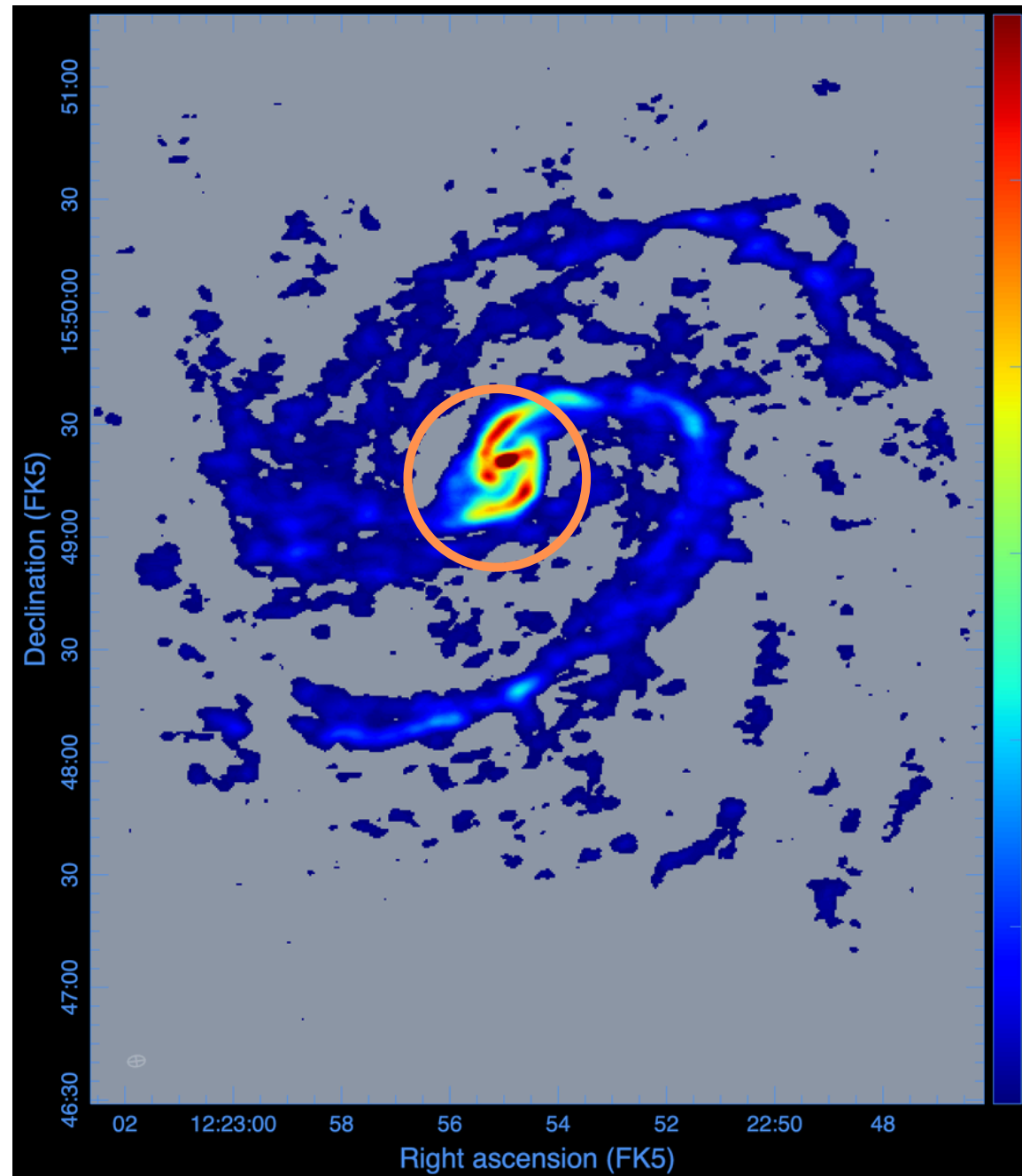
12m 7m 12m+7m TP All



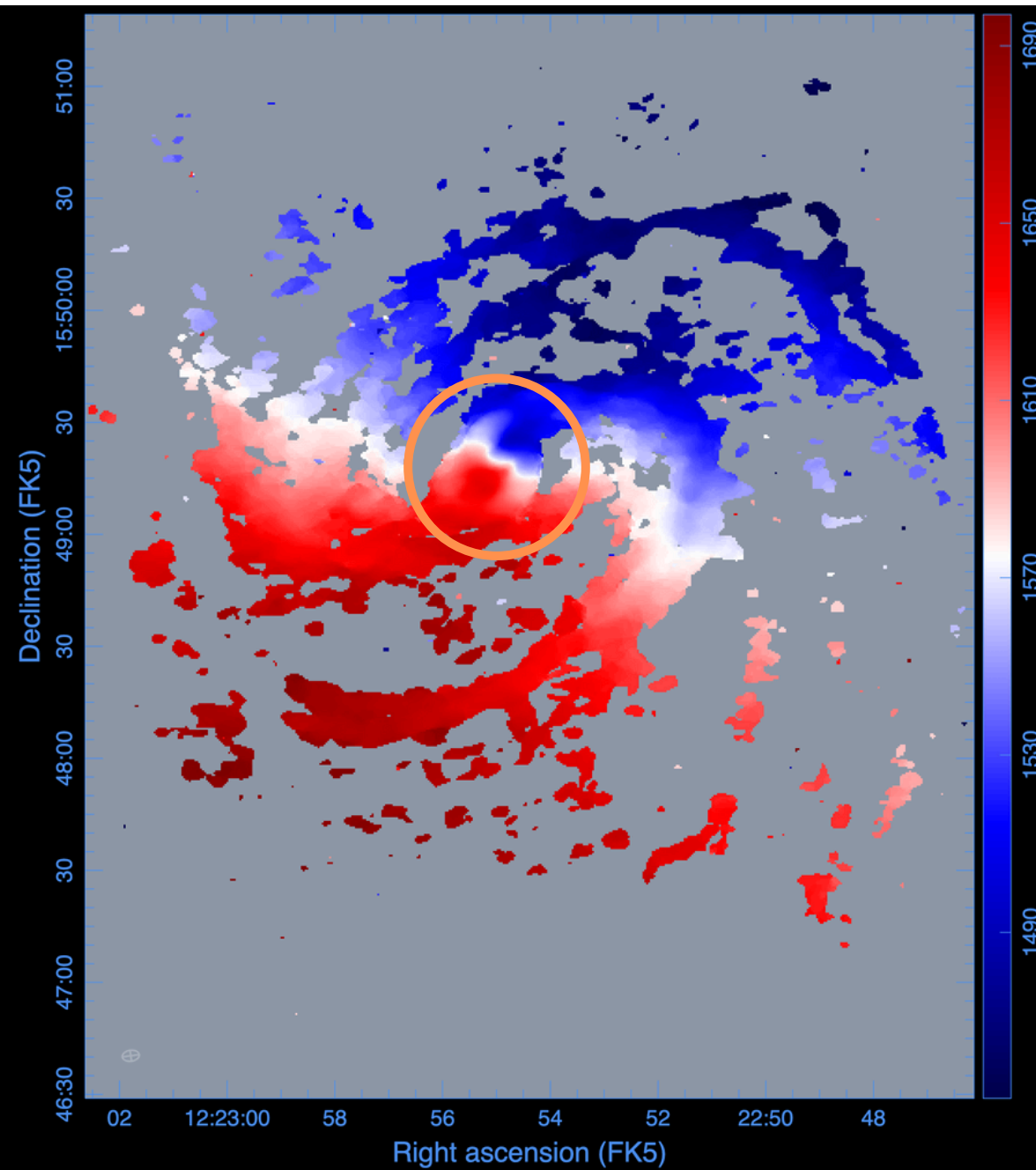
More extended emission is recovered by adding the TP data to the interferometric data.

M100 Band3 12m + 7m + TP (SDINT)

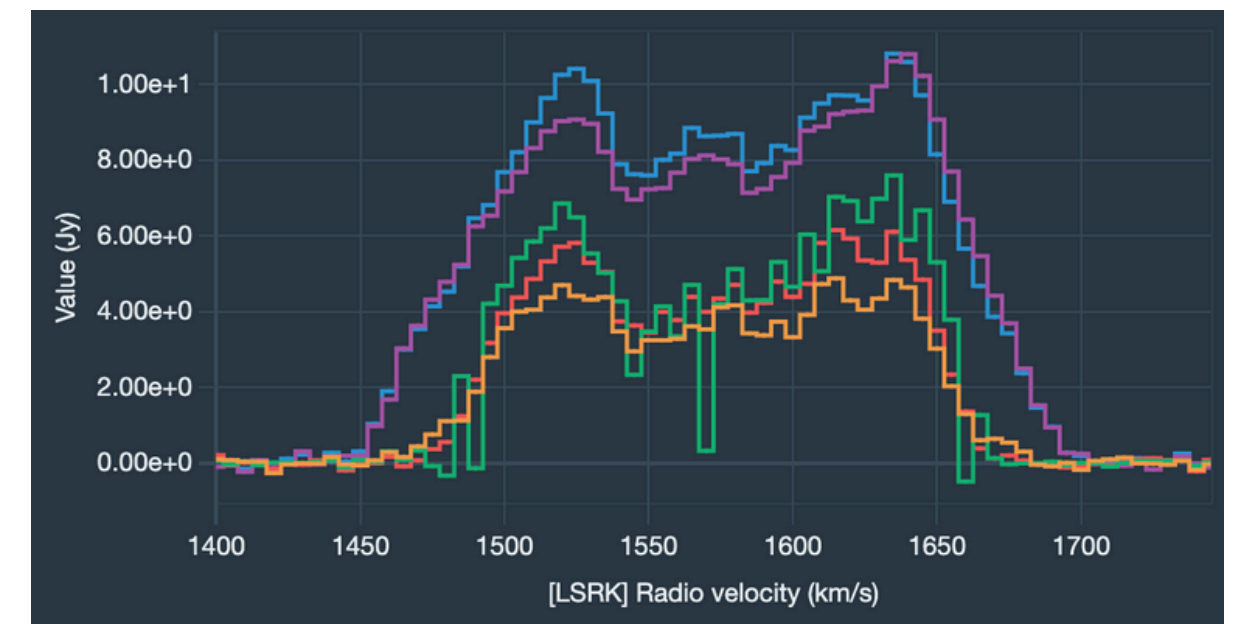
Moment 0



Moment 1



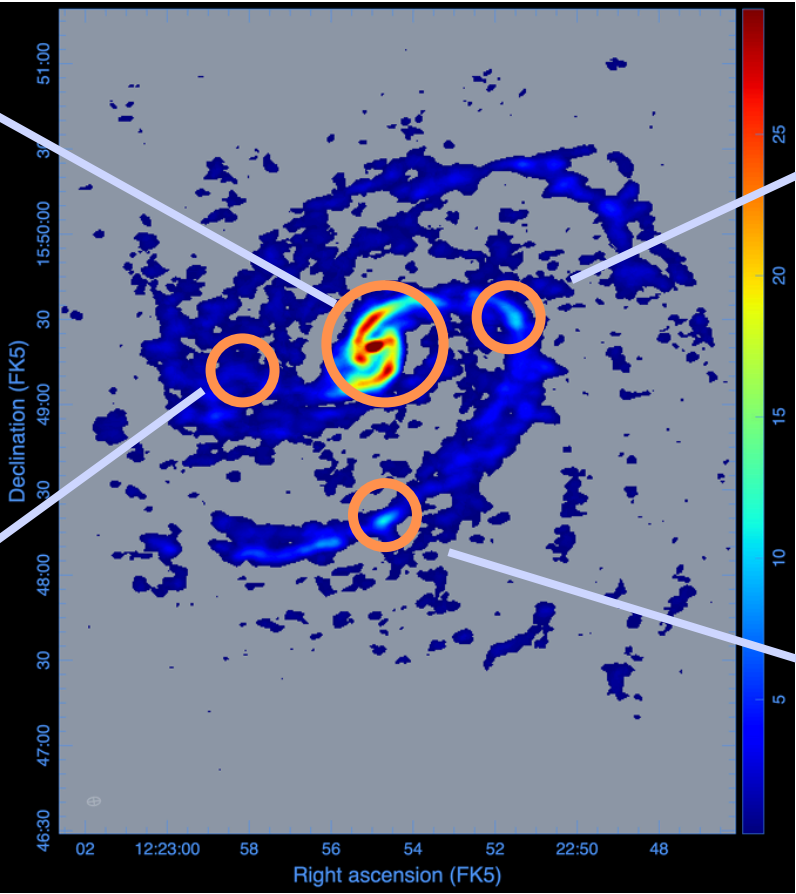
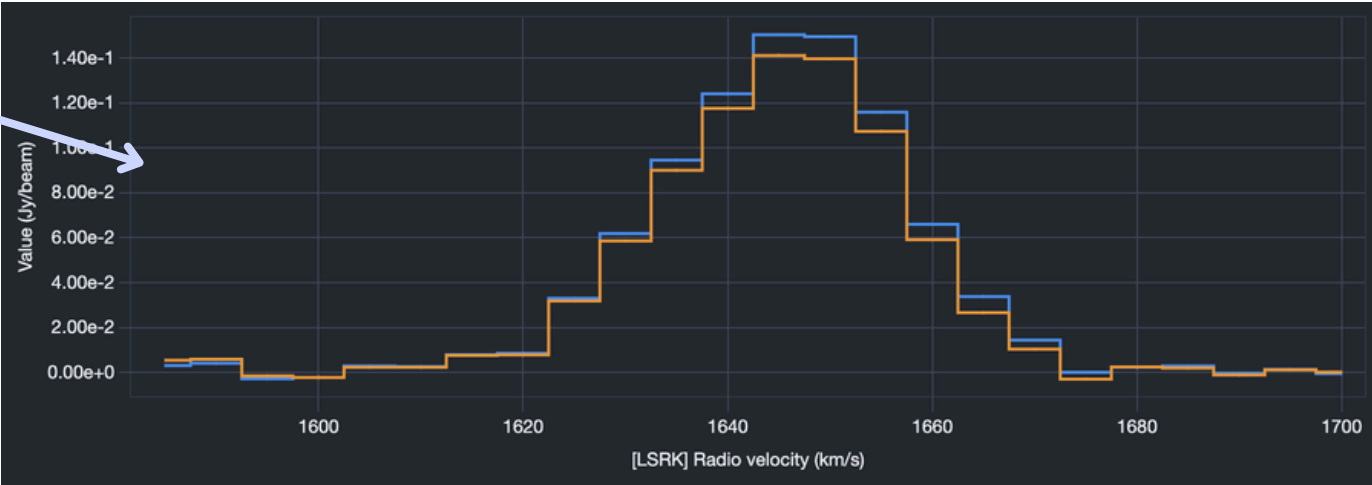
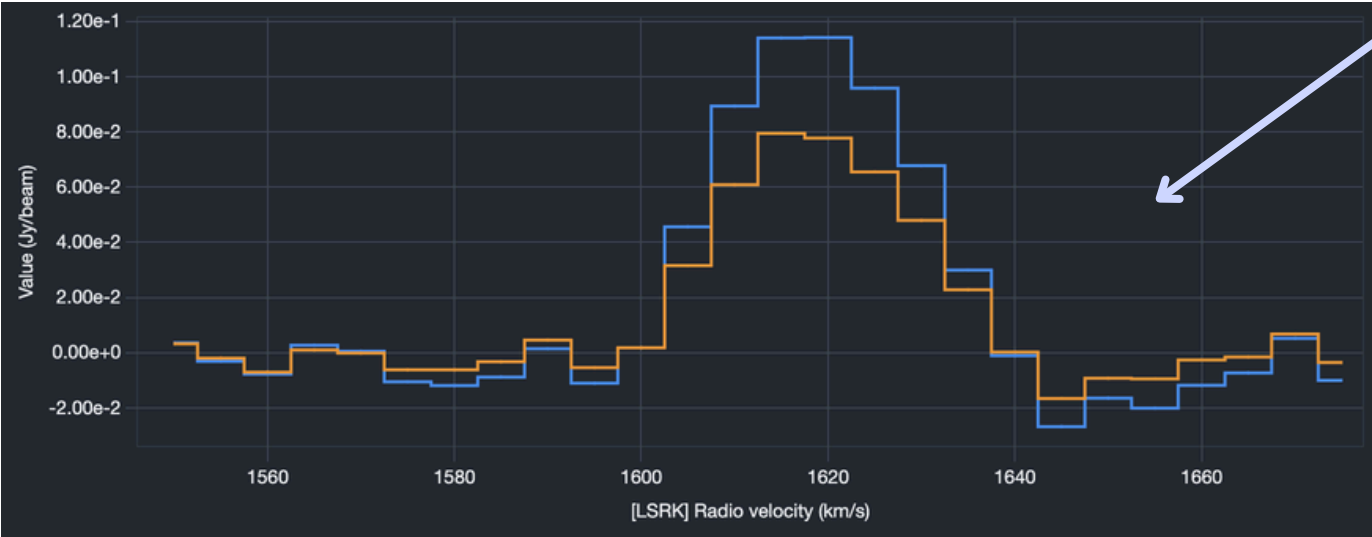
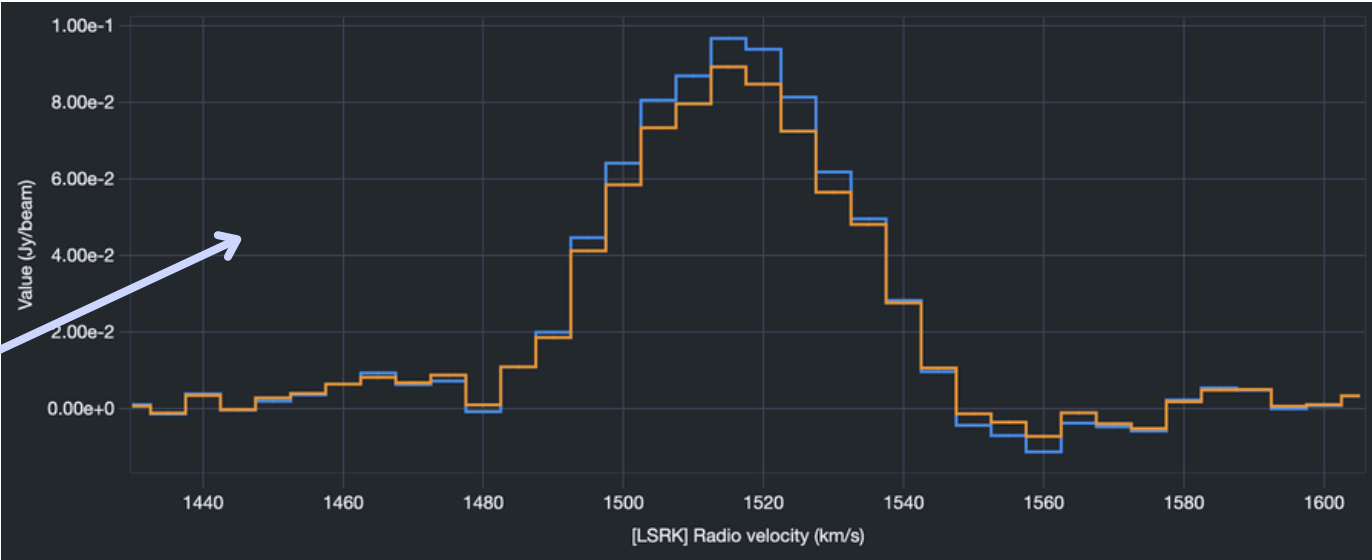
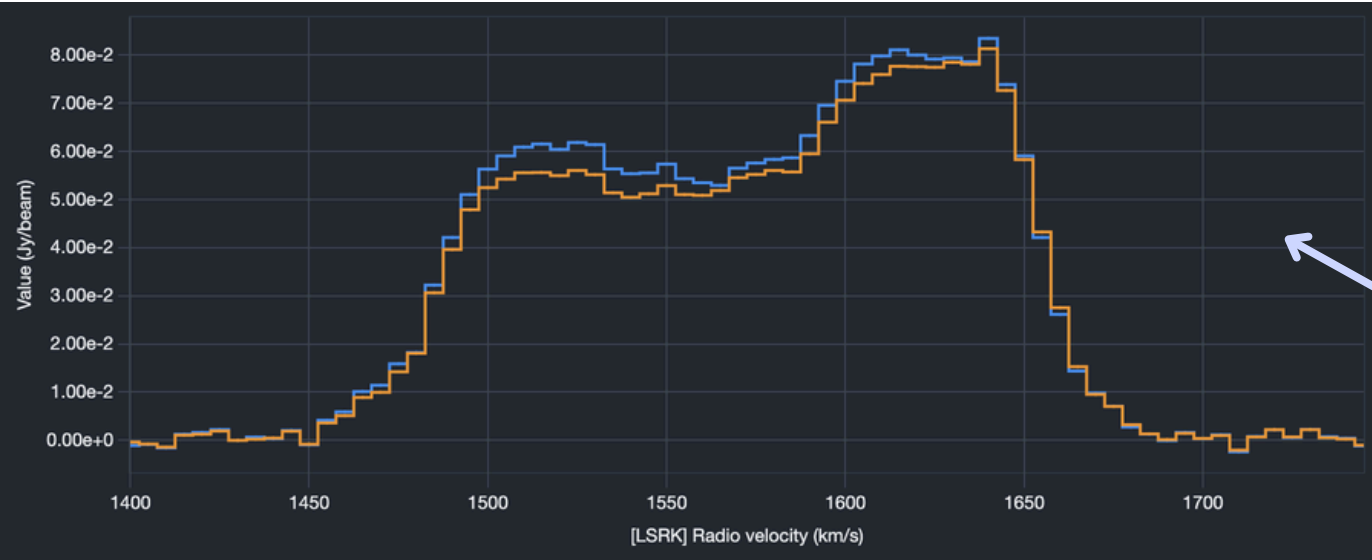
12m 7m 12m+7m TP All



More extended emission is recovered by adding the TP data to the interferometric data.

Feather vs SDINT

Feather
SDINT
Moment 0



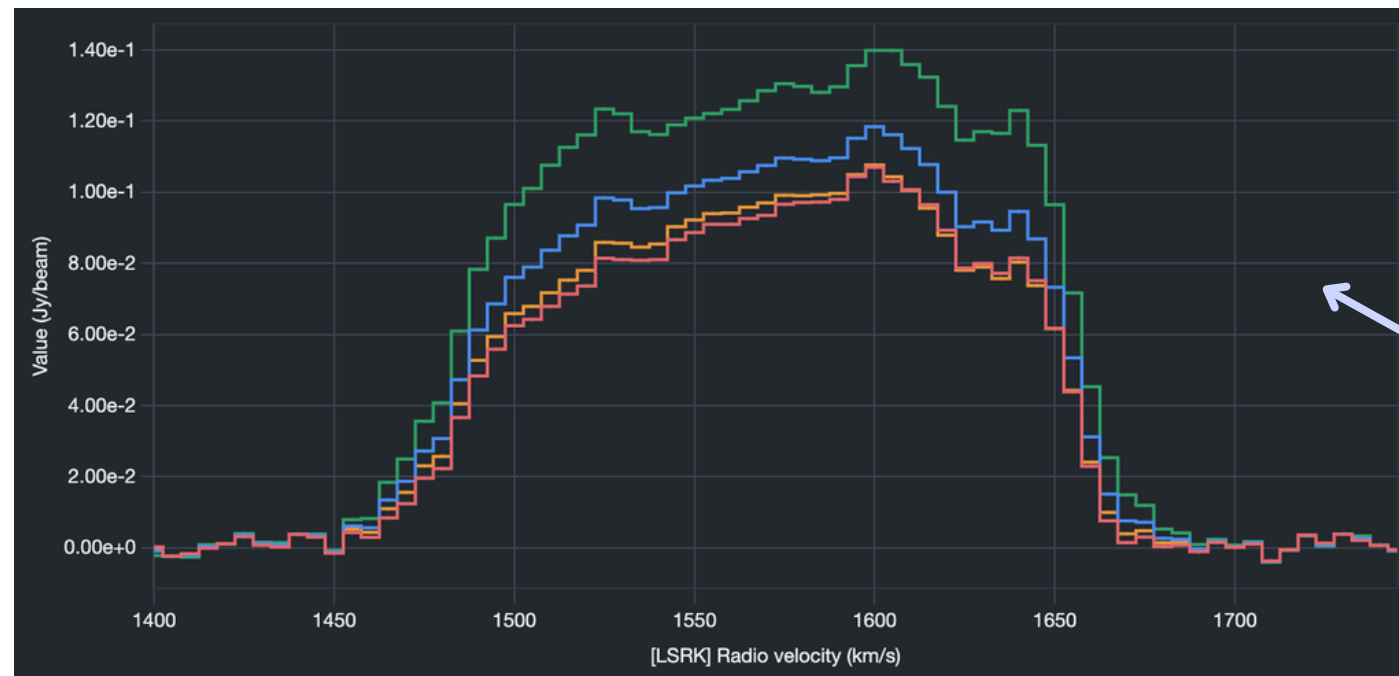
Feather vs SDINT

No noticable difference found between the results obtained from the two methods for our target M100. However, we observed that the spectra from Feather has slightly higher peak compared to SDINT.

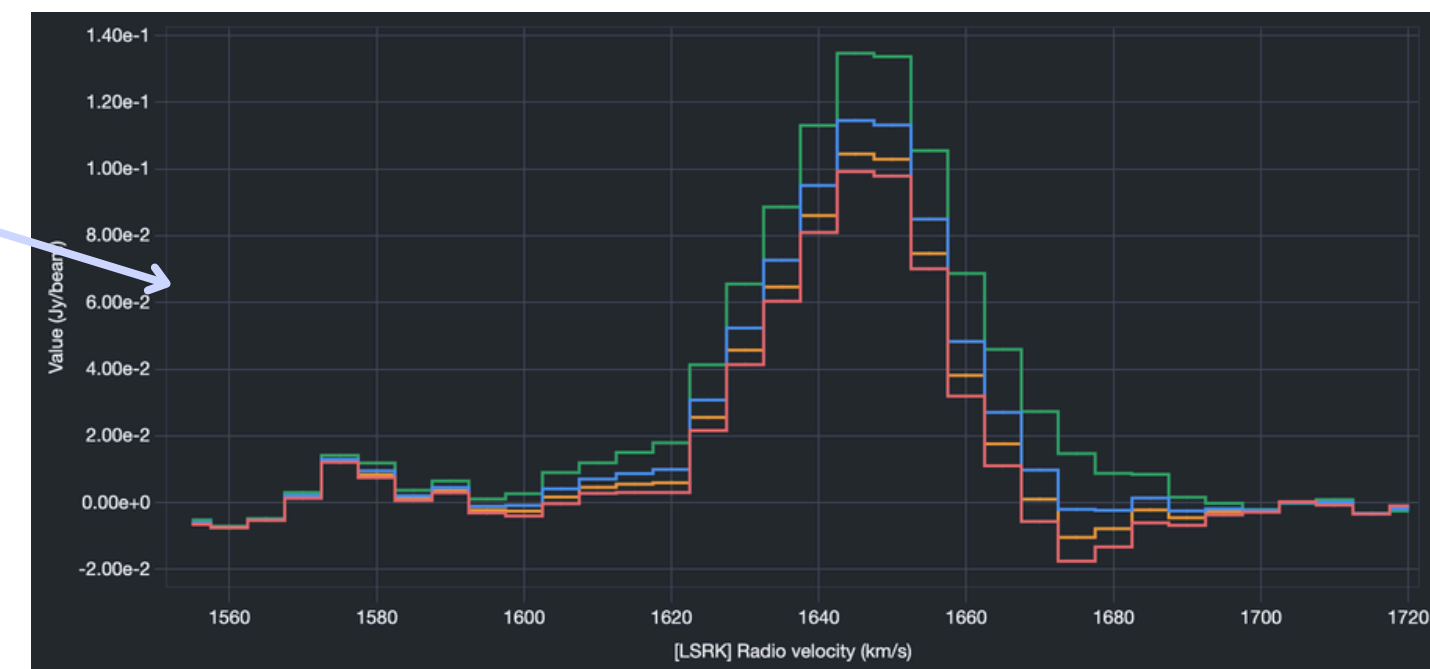
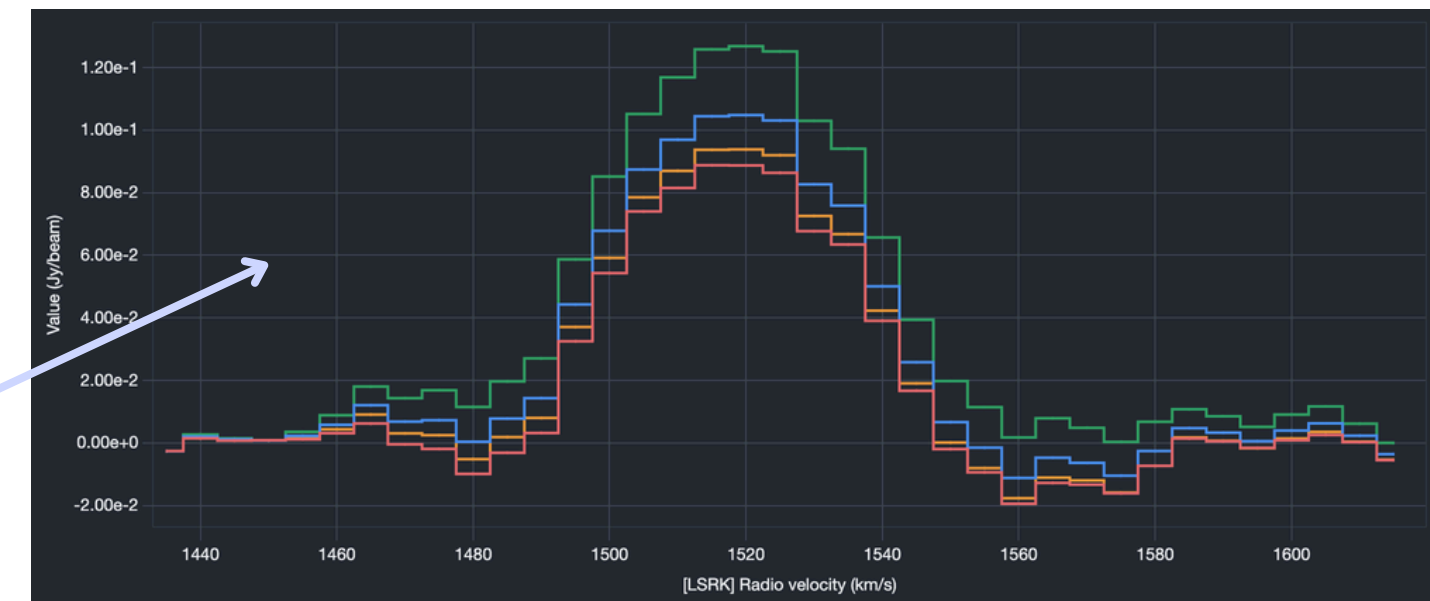
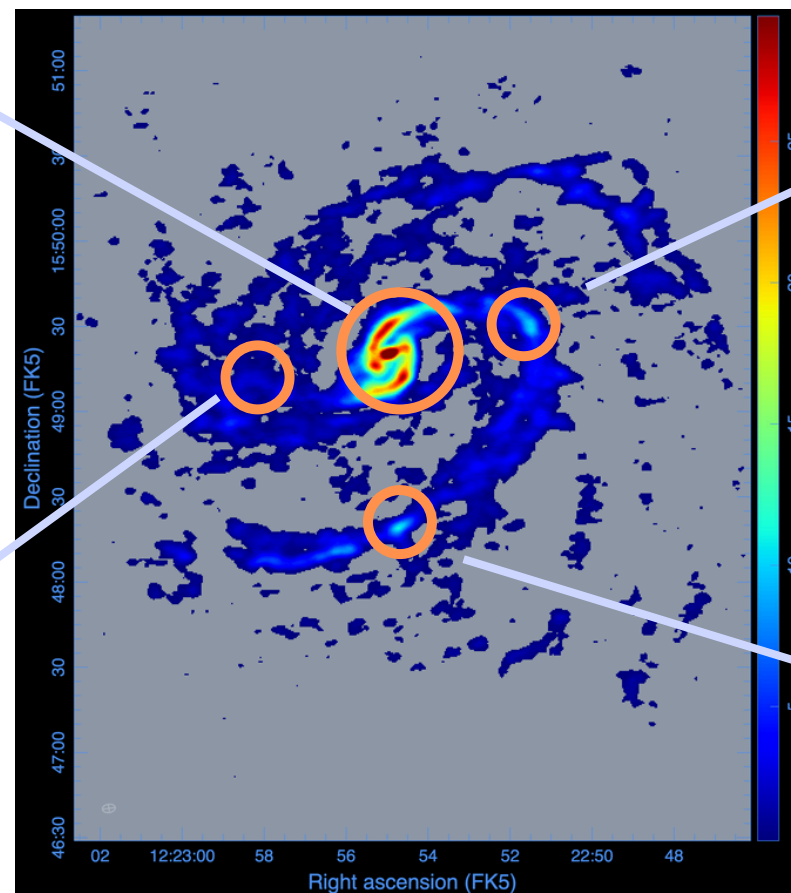
Method	Combined	Domain	Task Name	Input		Output	Processing Time
				Int	SD		
Feather	after deconvolution	F	feather	Image	Image	Image	Faster
SDINT	before deconvolution	F/I	sdintimaging	Vis.	Image	Image	Slow

Role of various factors in combination

1. sdfactor in Feather



Moment 0

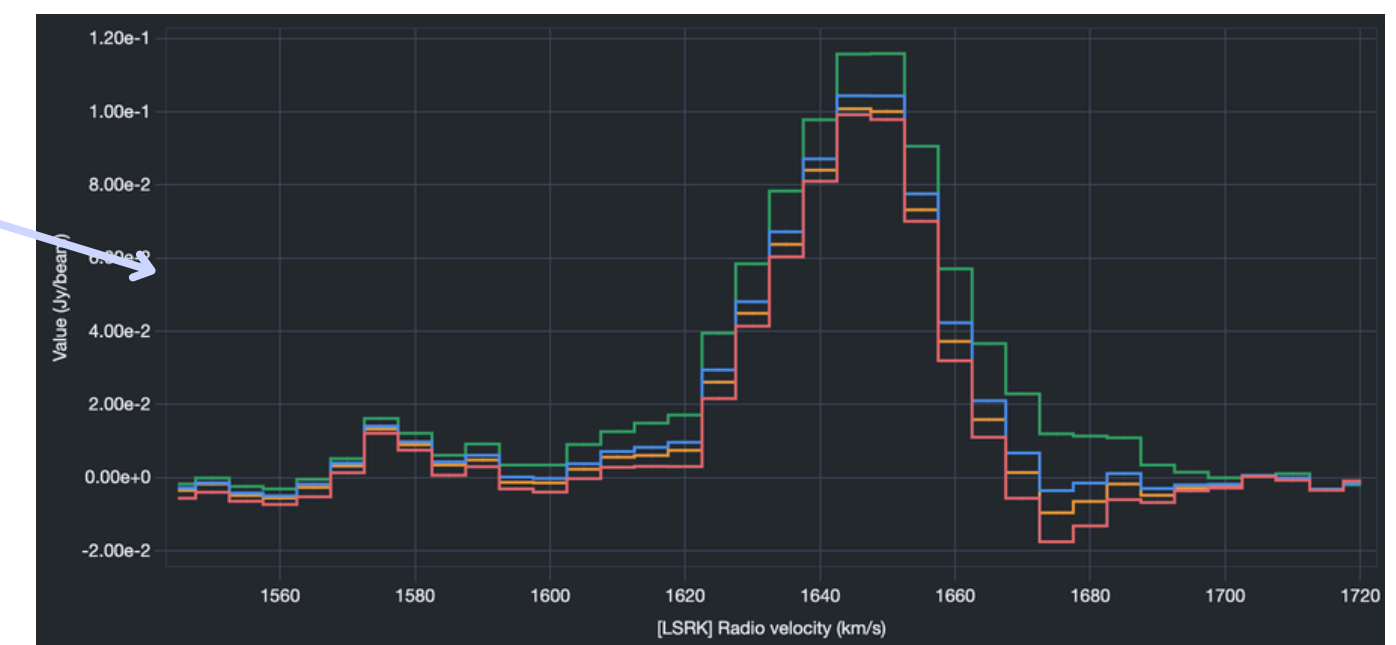
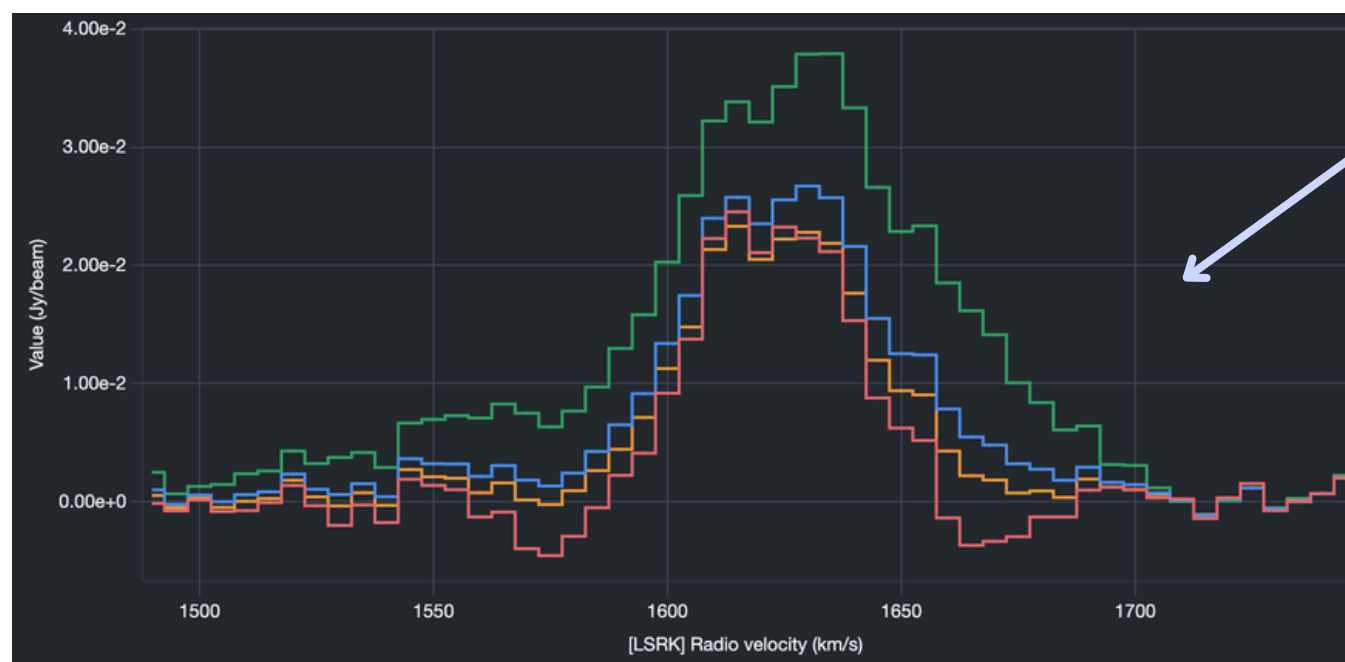
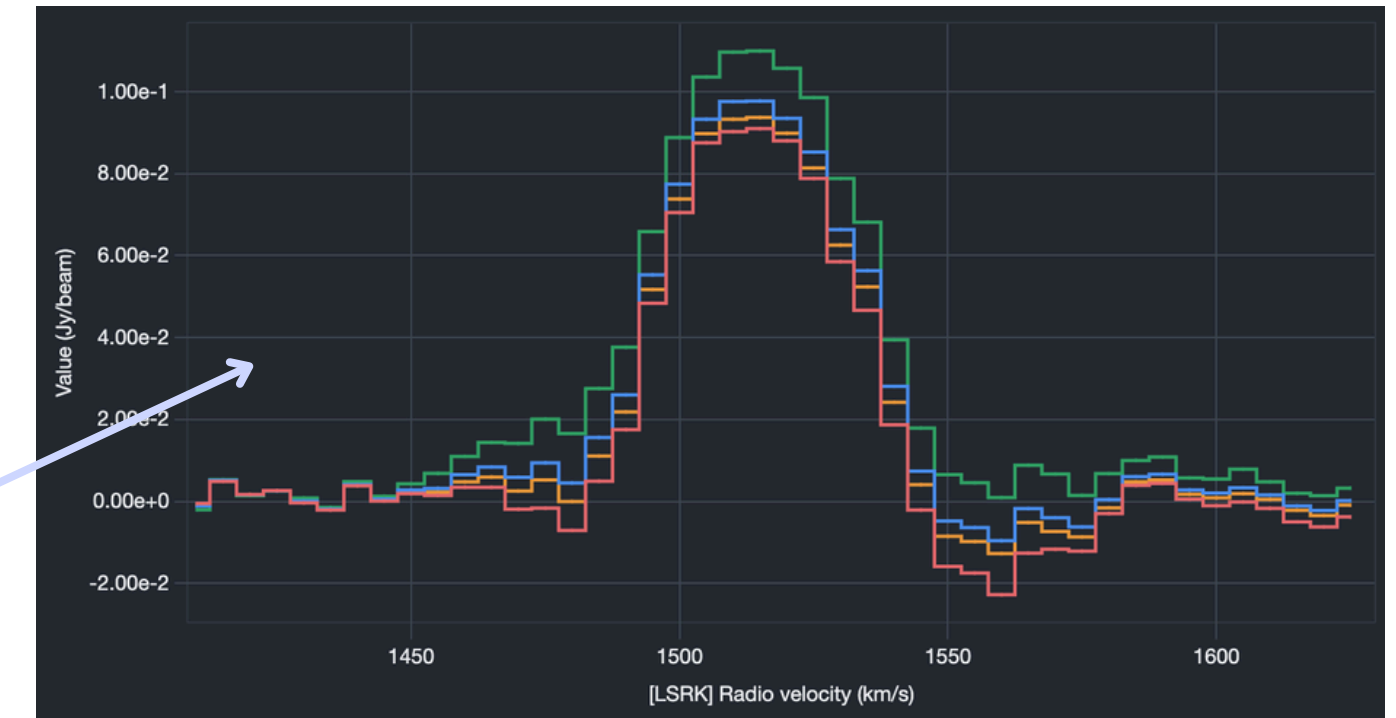
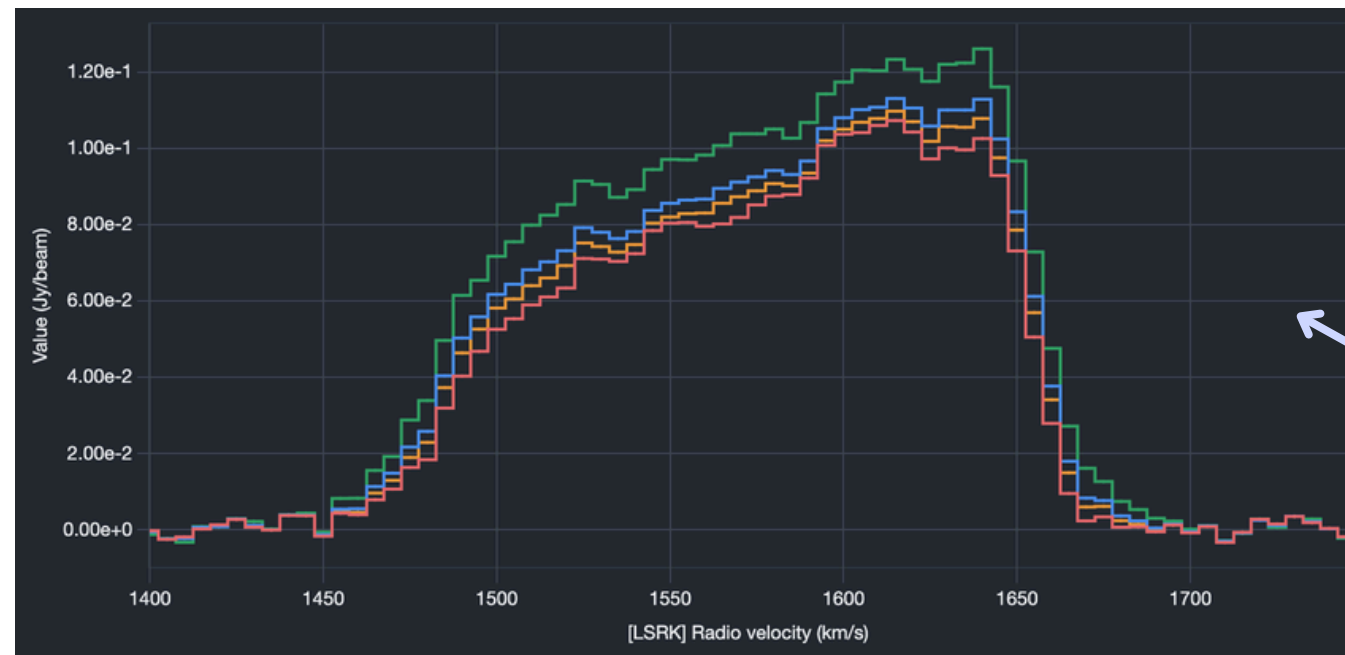


12m + 7m

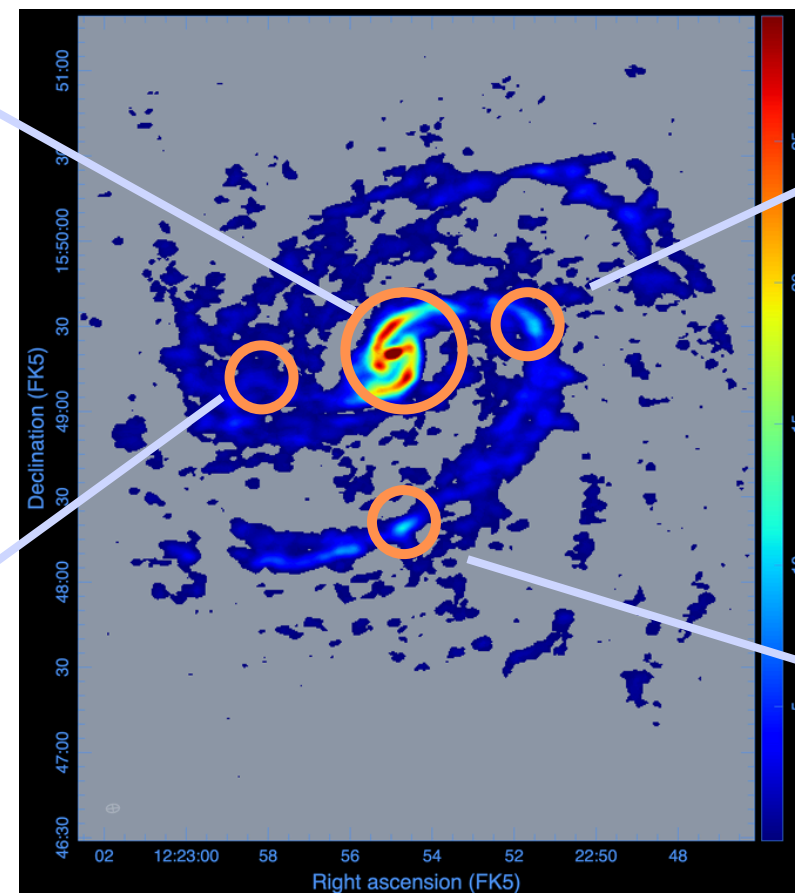
sdfactor: 0.5, 1.0, 2.0

Role of various factors in combination

2. sdgain in SDINT



Moment 0



12m + 7m

sdgain: 0.5, 1.0, 3.0

Role of various factors in combination

1. Both `sdfactor` and `sdgain` parameters regulate the relative weighting of the total power (TP) data during the combination process with interferometric data.
2. An increase in the value of these parameters results in greater contribution of the TP data, thereby enhancing the total flux in the final combined image or spectrum.
3. The optimal choice of parameter value depends on the characteristics of the emission. For regions with weak or sparse emission, a higher value is typically recommended to ensure that faint structures are not suppressed. Conversely, for regions exhibiting strong emission, a default value of unity is commonly adopted to maintain balanced flux contributions.

Thank you!

