Commissioning Progress on the Dual Observation of 3C295 & M51: The Transfer of Gains Method

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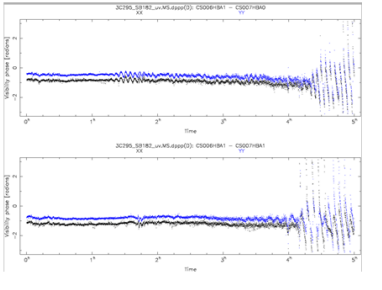
Outline

- Explanation of Transfer of Gains Method
- The 3C295 Field
- Progress on Commissioning Task:VI.11:
  Study of the Calibration Interpolation in Time & Frequency
- Creating spectral index map of M51
- Investigation of the extended disk of M51

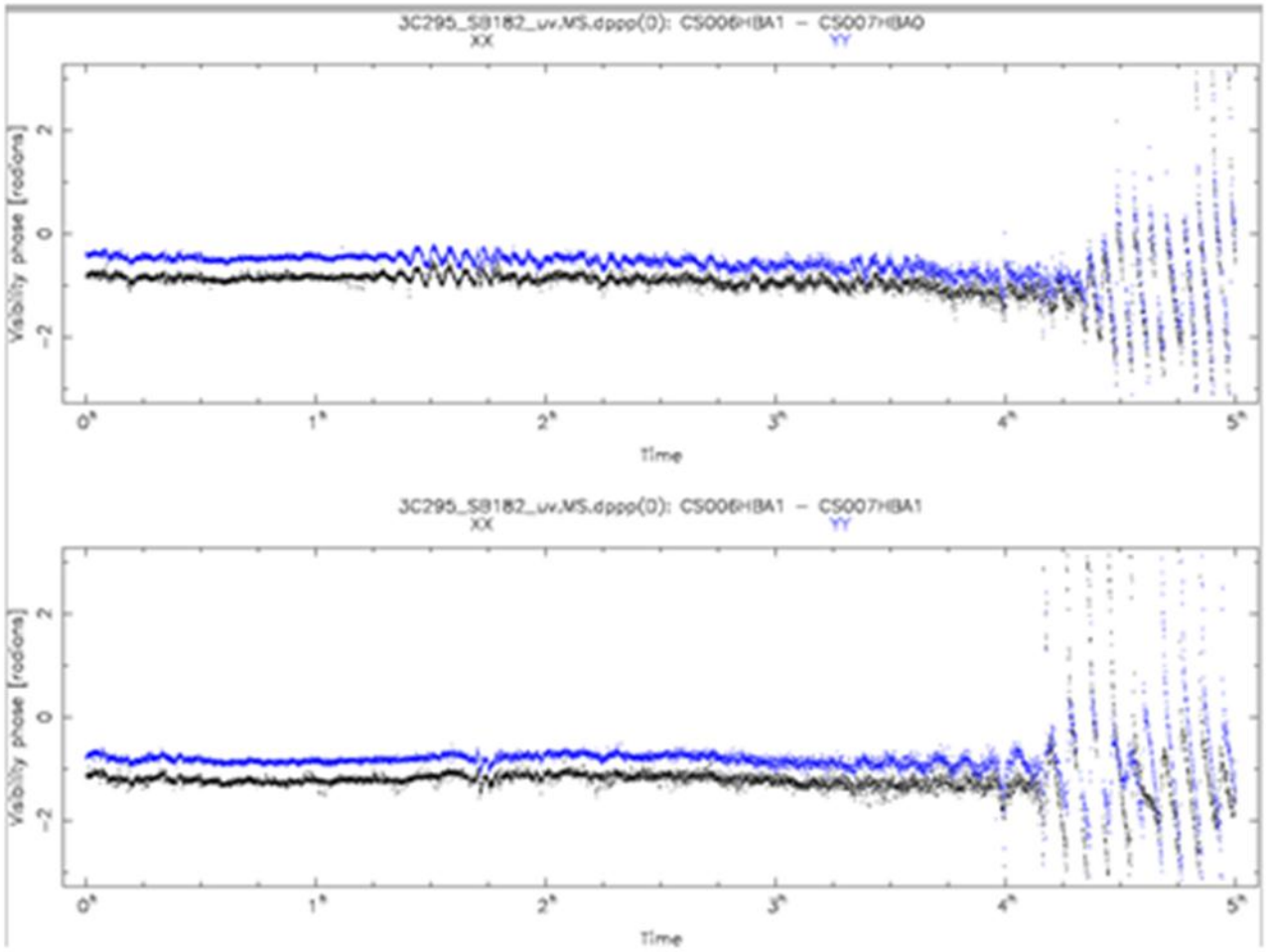
Observation Overview

- Observed calibrator 3C295 & M51 simultaneously.
- Same frequency coverage on both source & calibrator.
- 121 frequency channels of 210 kHz bandwidth for source & calibrator (114.84-162.89MHz).
- Calibrator 3C295 was calibrated and the Gain solutions were transferred to M51.

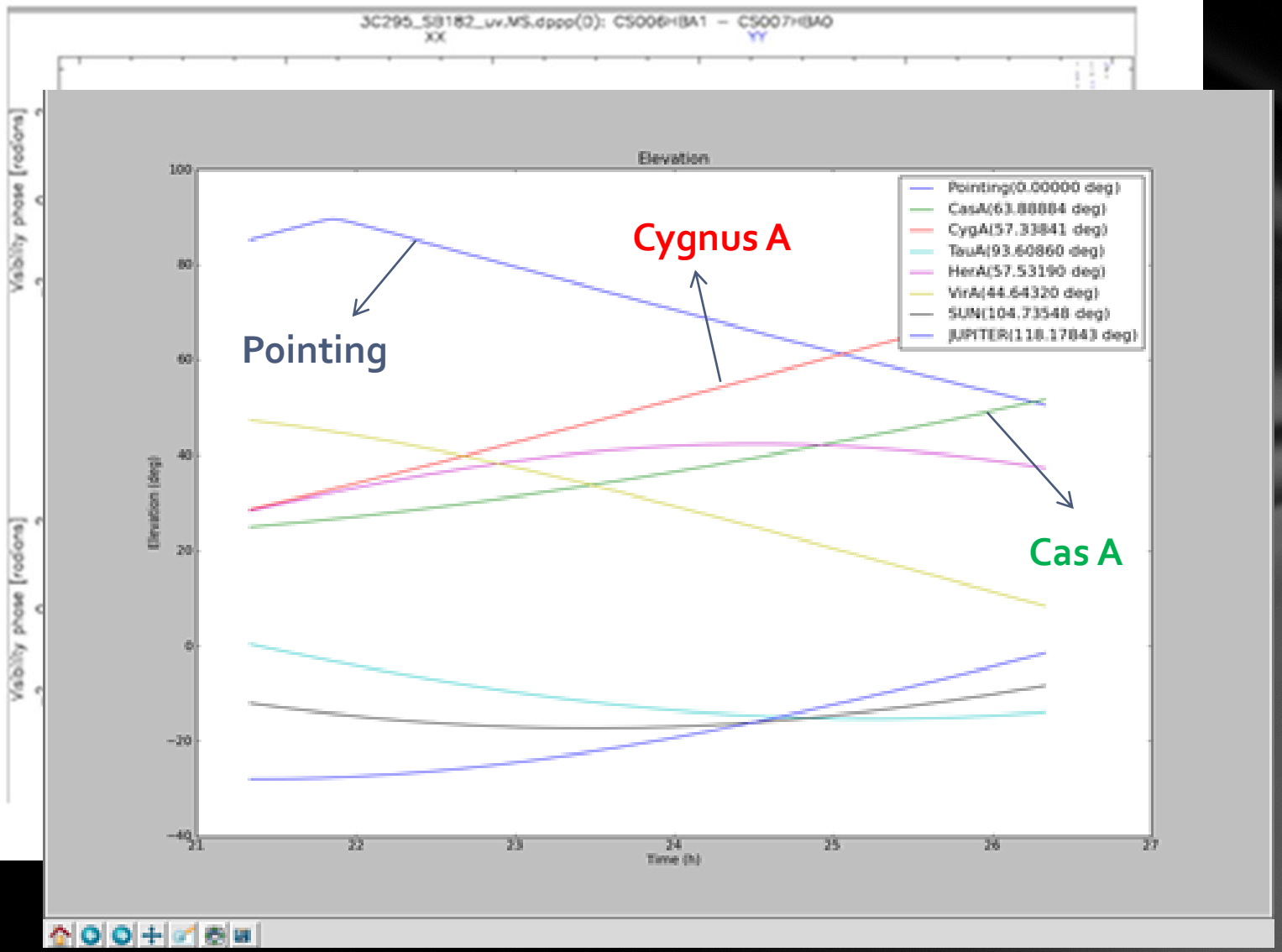
Flagging Data



Flagging Data

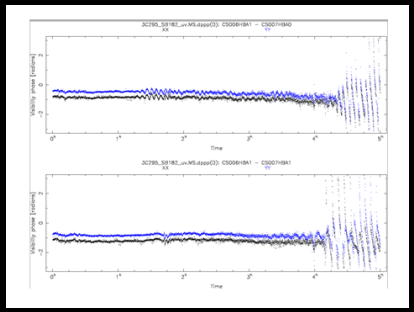


Flagged Data

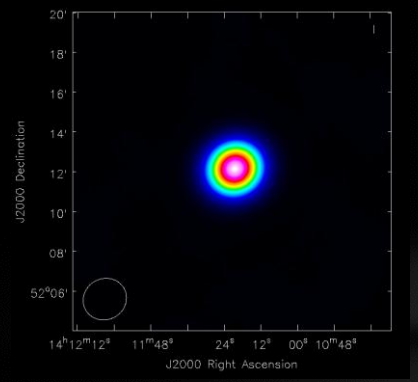


M51:
Final hour
Subtracted
-
Due to A-Team sources

Flagged Data



Calibrate the Calibrator



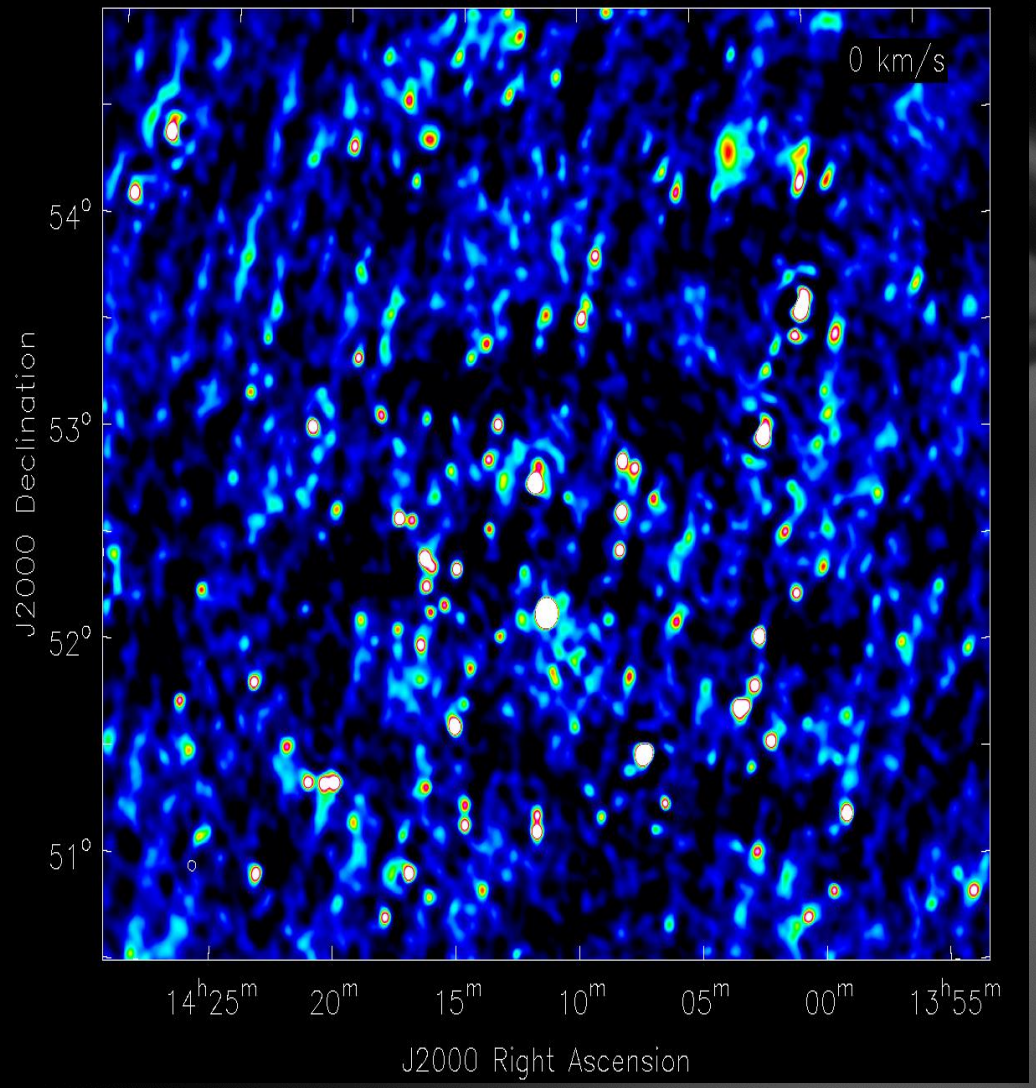
Calibrator: 3C295

uv-plane-cal-transfer.parset
Model.Beam.Enable = T
Solves for all 4 elements in the gain Jones' matrix

3C295.skymodel.new
Specifies direction only for target

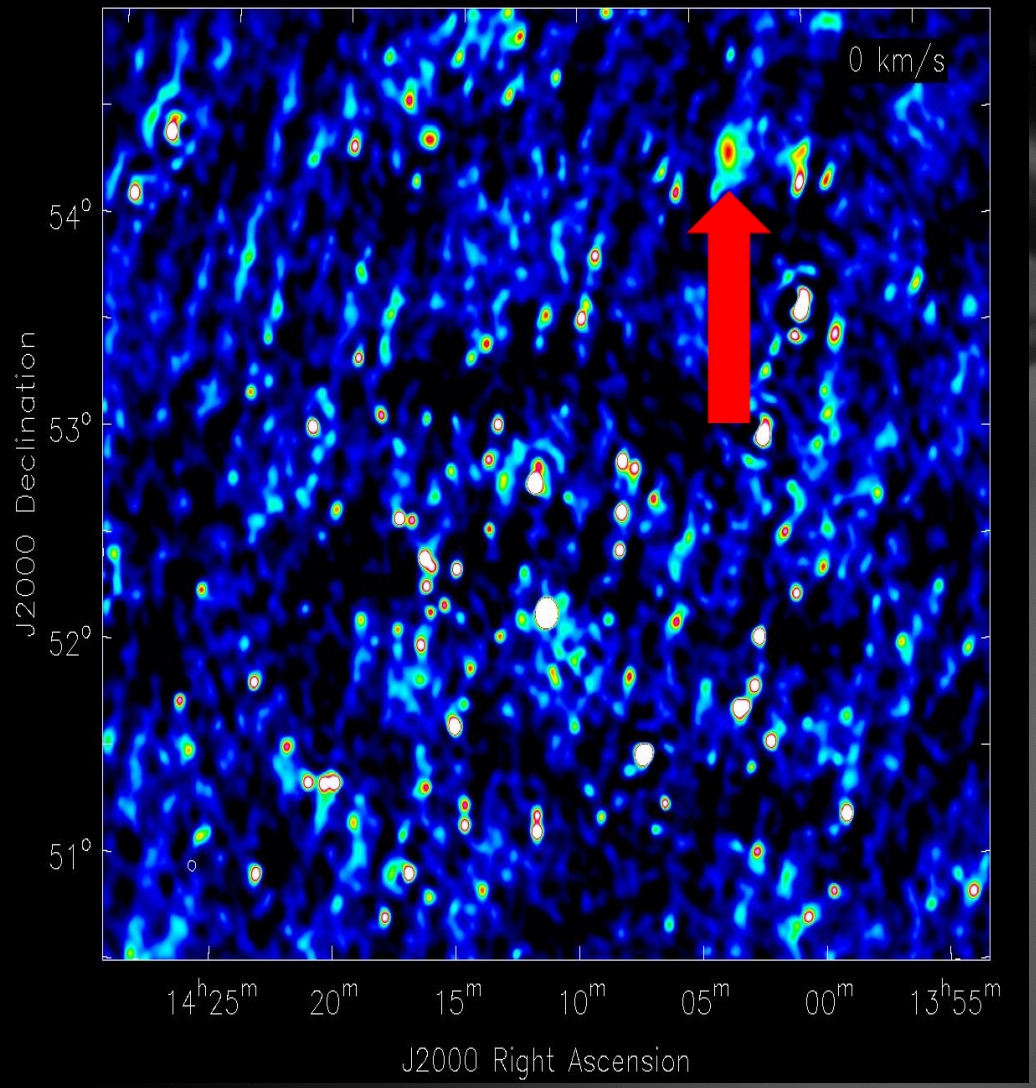
3C295 Field

- Image to the right shows the field around 3C295
- Comprises of 3 subbands averaged together
- Natural weighting was used to give lowest noise
- Smoothed beam to 120“ in order to detect extended emission
- However, image still quite noisy, demixing would be very beneficial.



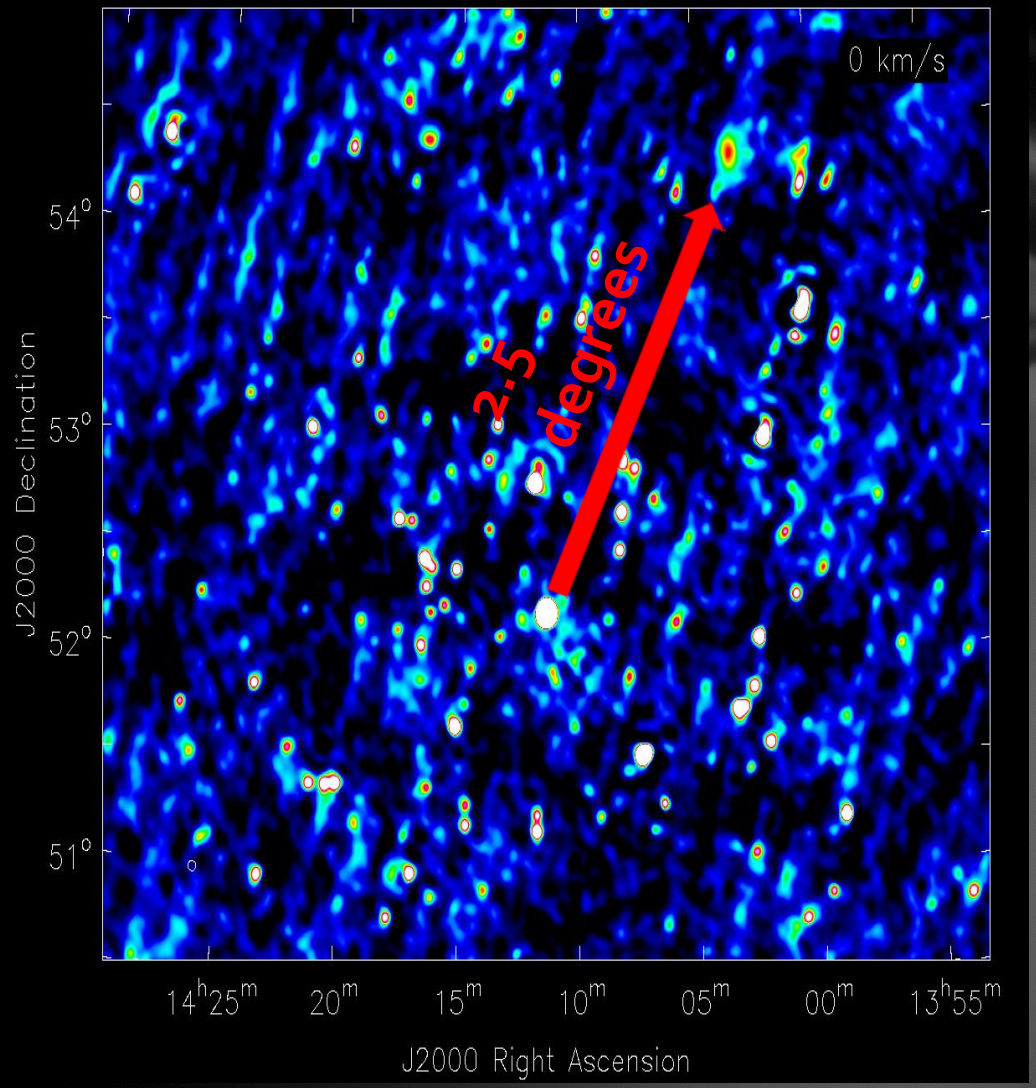
3C295 Field

- Extended object can be seen to the N.E of 3C295



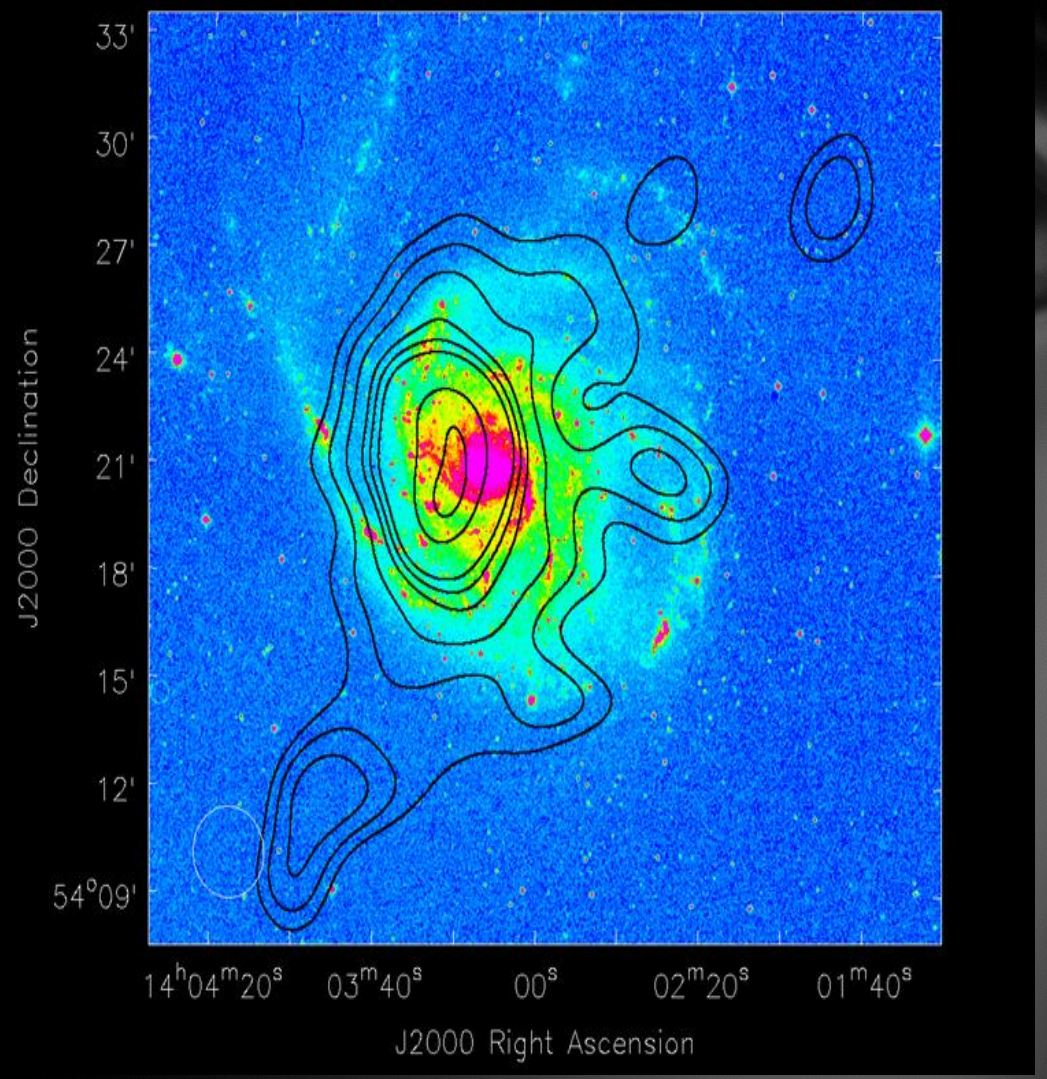
3C295 Field

- Extended object can be seen to the N.E of 3C295
- Object is 2.5 degrees away from phase center



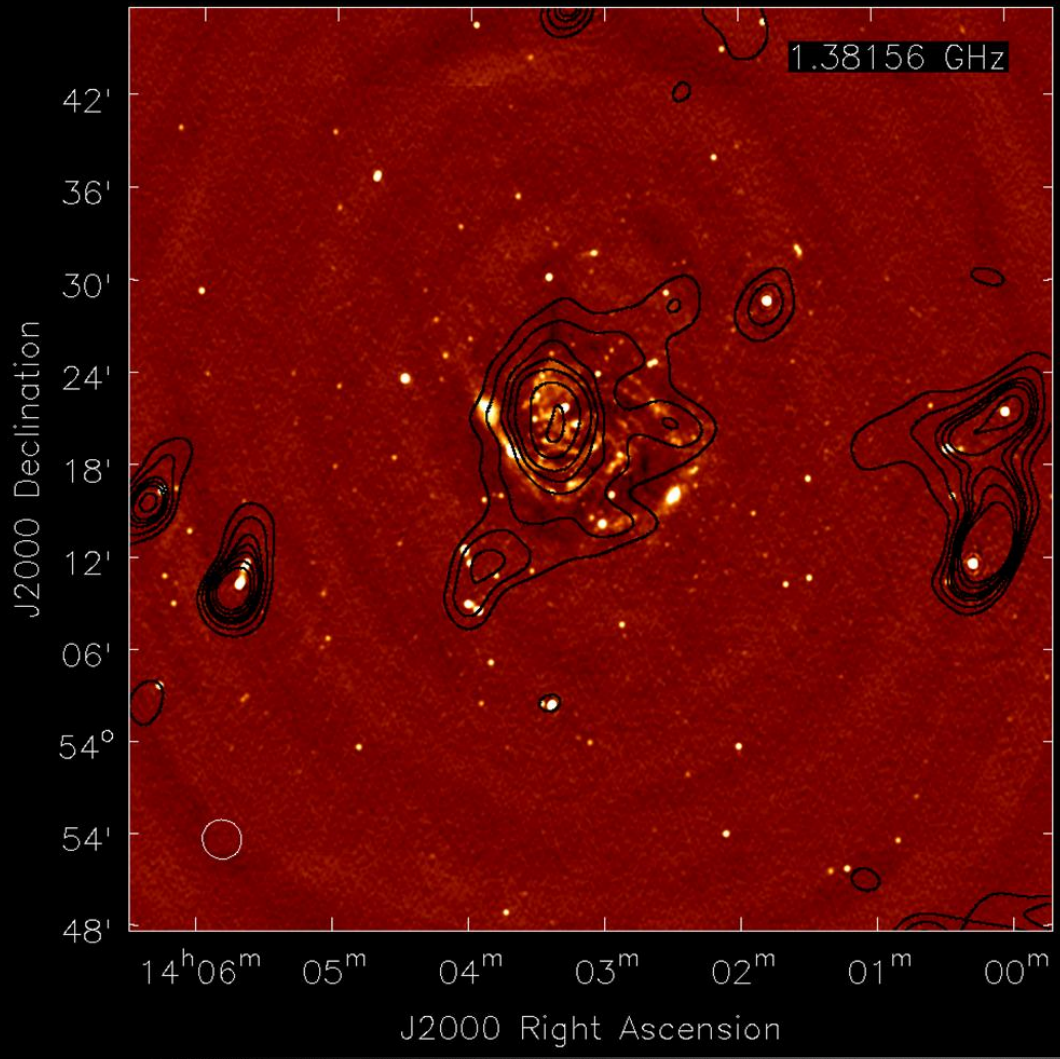
Detection of M101!

- Extended object can be seen to the N.E of 3C295
- Object is 2.5 degrees away from phase center
- Extended object turns out to be M101! Seen here overlayed onto a DSS image.



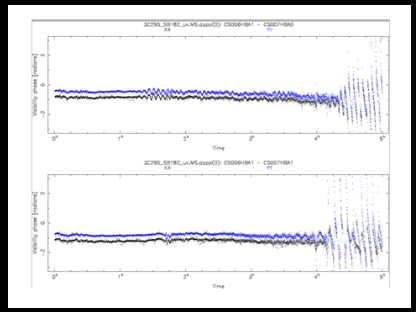
Detection of M101!

- Extended object can be seen to the N.E of 3C295
- Object is 2.5 degrees away from phase center
- Extended object turns out to be M101! Seen here overlayed onto a DSS image.
- LOFAR image agrees well with a recent WSRT 20cm map.
- Point sources match well and parts of the eastern spiral arm are visible.

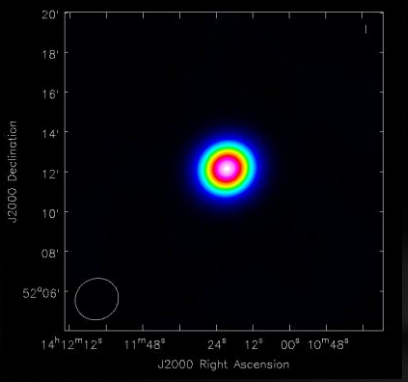


WSRT 20cm image courtesy of Ger De Bruyn (2011)

Flagging Data

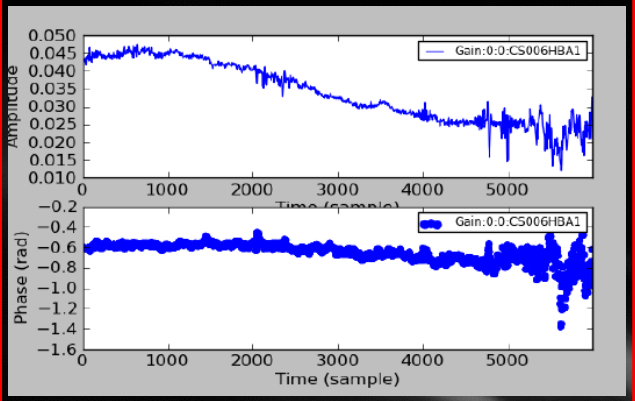


Calibrate the Calibrator



Calibrator: 3C295

Analyze Gains



uv-plane-cal-transfer.parset
Model.Beam.Enable = T
Solves for all 4 elements in the gain Jones' matrix

3C295.skymodel.new
Specifies direction only for target

Commissioning Task VI.11: Study of the Calibration Interpolation in Time & Frequency

- Study of Gain Solutions of the calibrated 3C295 measurement set through the Python package parmdb package. (import lofar.parmdb as pdb)
- Firstly, program had to retrieve the real & complex values of the gains from the instrument table, calculate the gain amplitude and phase.
- To check I compared program output to parmdbplot output:

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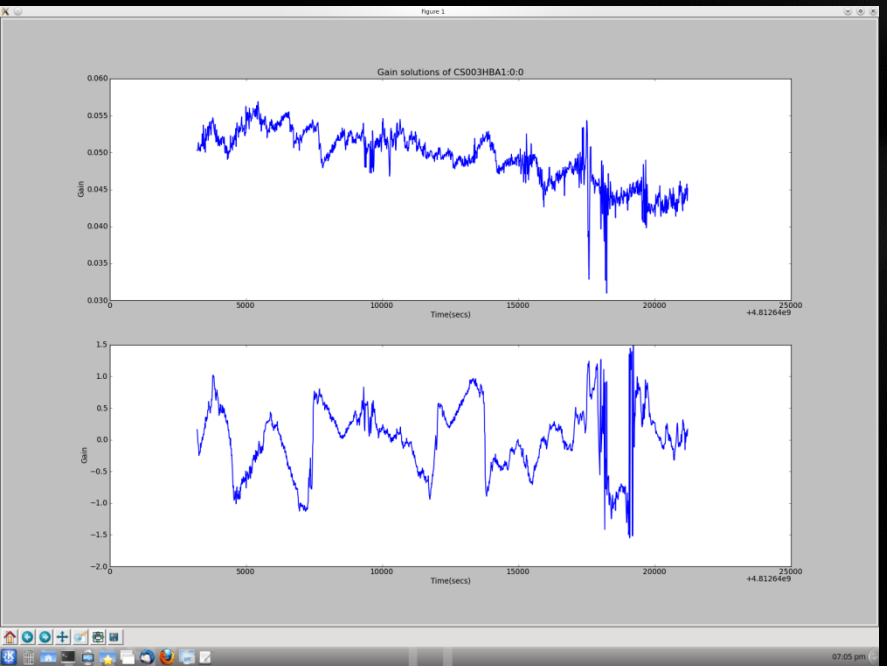
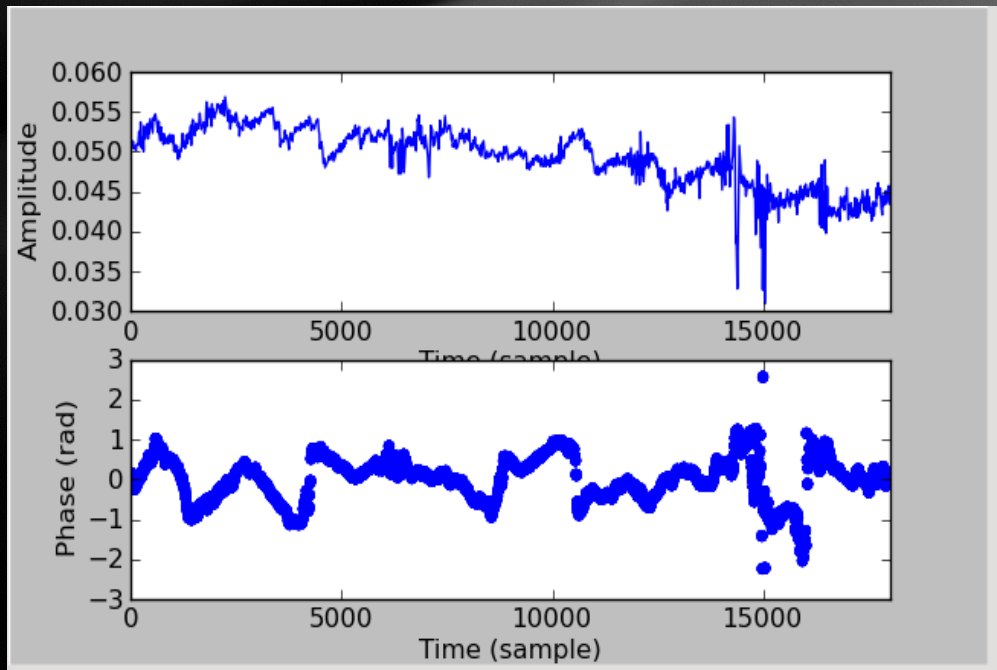
From Program



From Parmdbplot



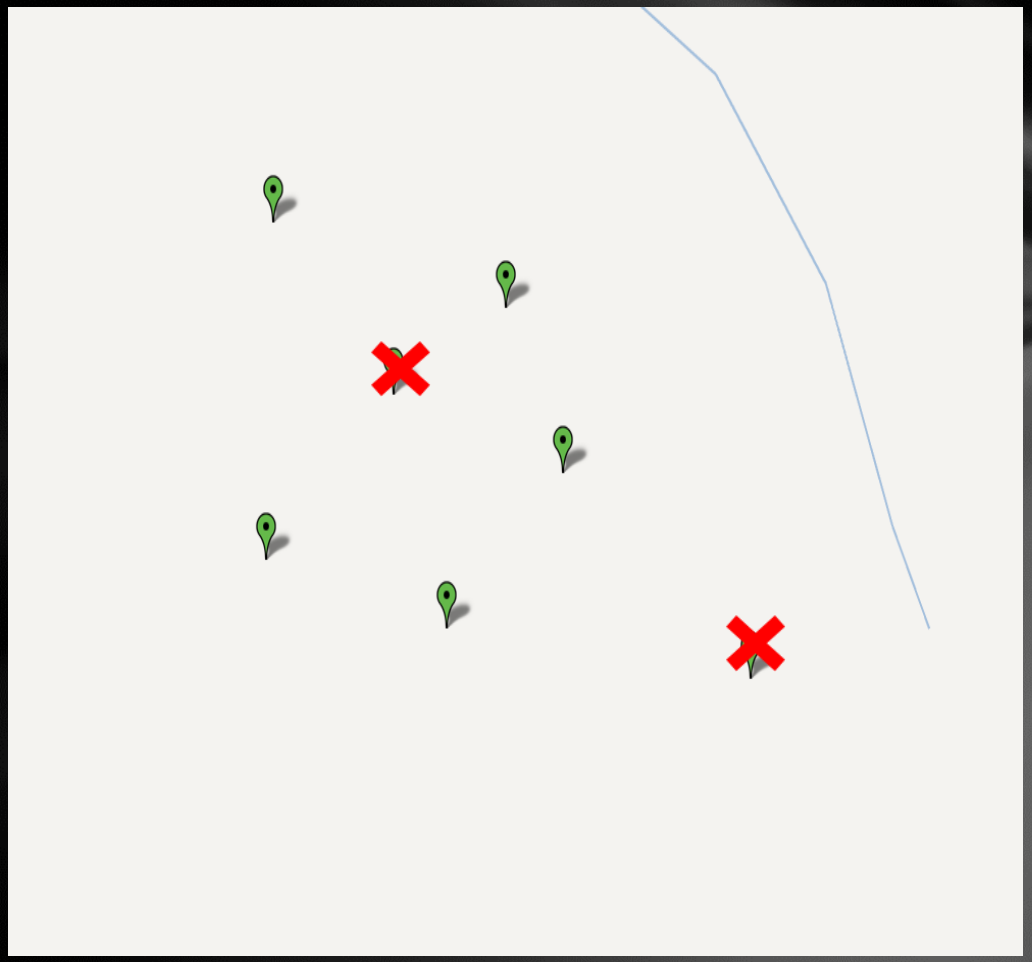
SUPERTERP GAINS

- Program can plot out a subset of stations for each correlation for a specified interval of time for a bandwidth of 10 MHz.
Separate station legend needs to be programmed to identify stations.

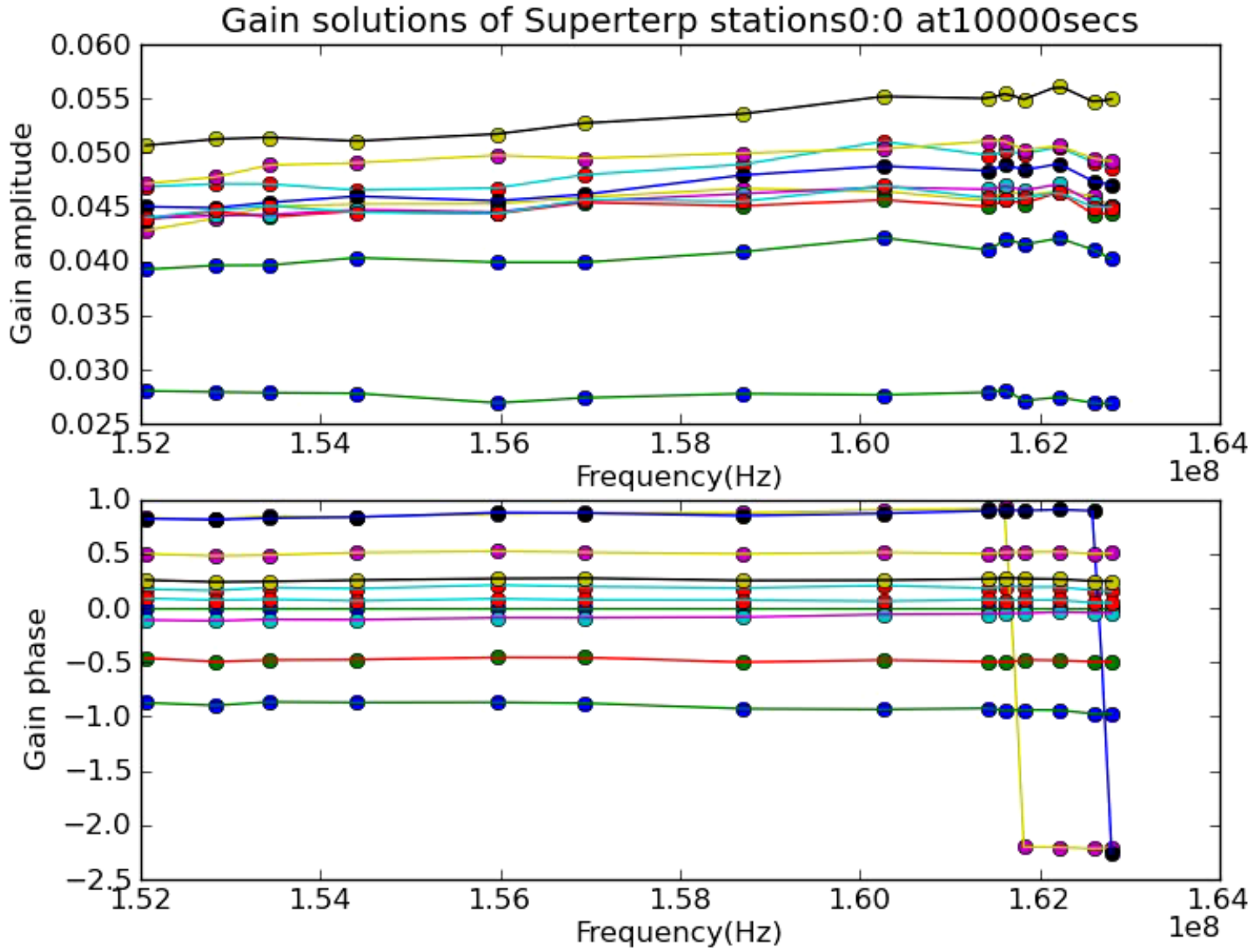
- Gains seem not to change much second to second

Superterp stations used
- CS003HBA0/1
- CS004HBA0/1
- CS005HBA0/1
- CS006HBA0/1
- CS007HBA0/1

Superterp stations not used
- CS002HBA0/1
- CS011HBA0/1



LOFAR Map courtesy of George Heald


Gain solutions of Superterp stations0:0 at10000secs
Gain amplitude
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
1.52
1.54
1.56
1.58
1.60
1.62
1.64
1e8
Frequency(Hz)
Gain phase
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
1.52
1.54
1.56
1.58
1.60
1.62
1.64
1e8
Frequency(Hz)

Core Stations used:

- CS017HBA0/1
- CS021HBA0/1
- CS024HBA0/1
- CS026HBA0/1
- CS032HBA0/1

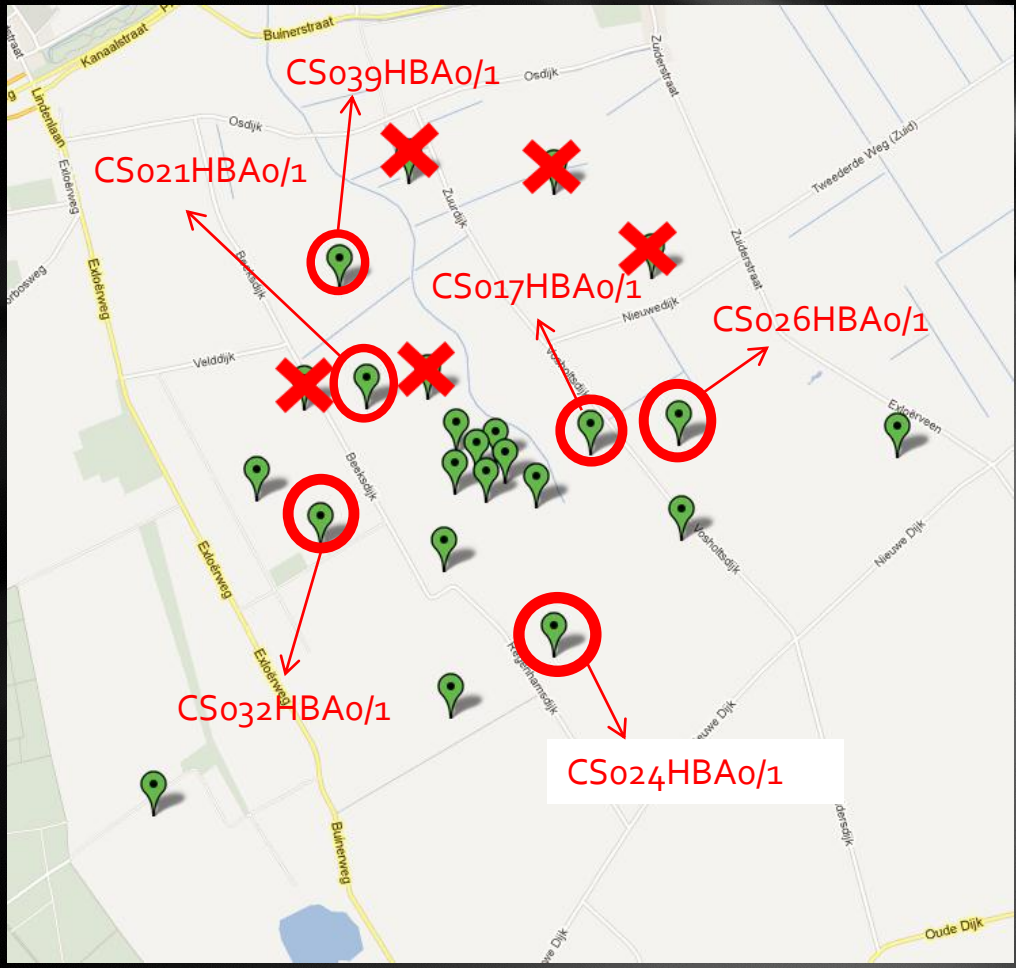
Stations not used:

- CS013HBA0/1
- CS031HBA0/1
- CS028HBA0/1
- CS501HBA0/1

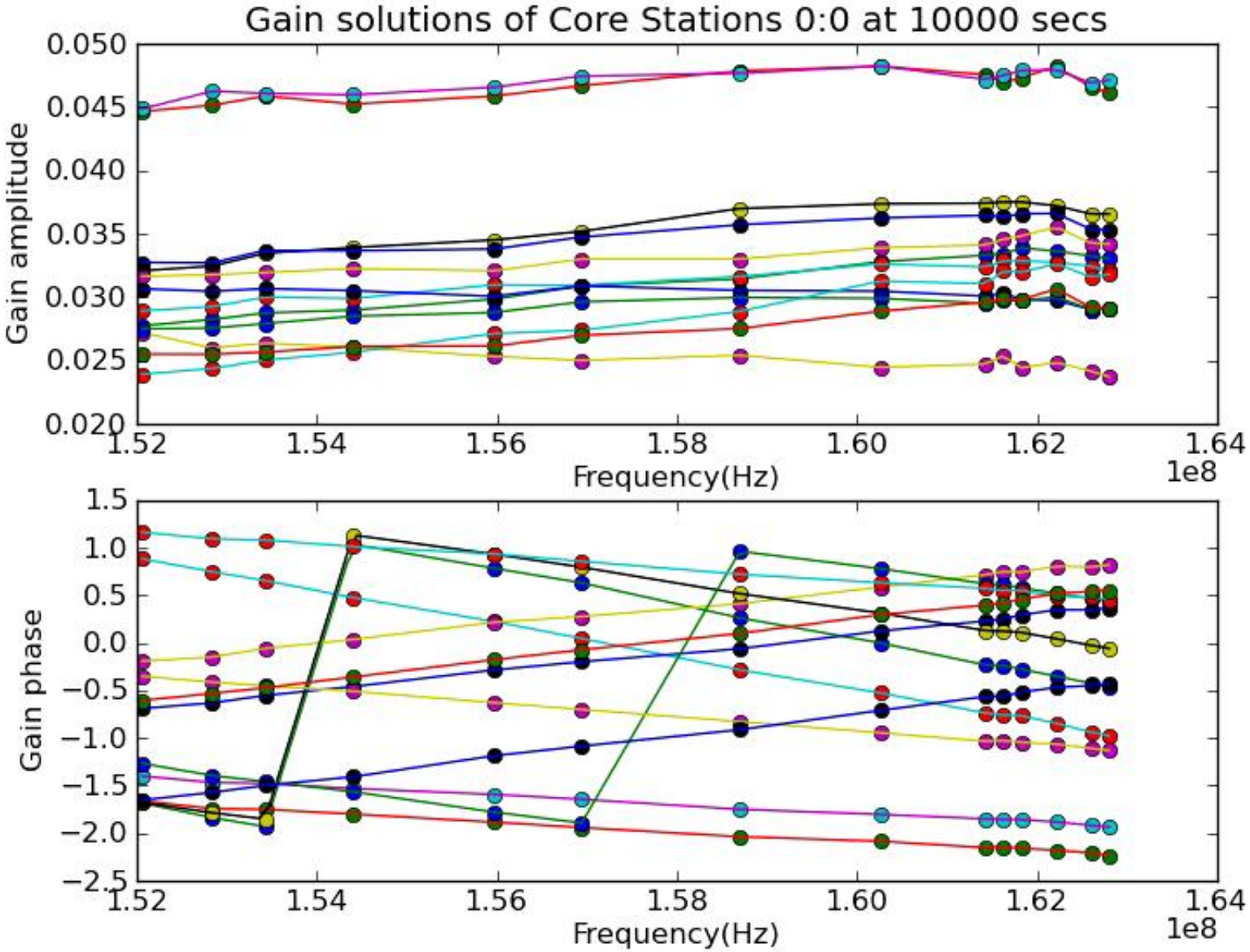
Stations flagged:

- CS101HBA0/1

CORE STATIONS BATCH 1



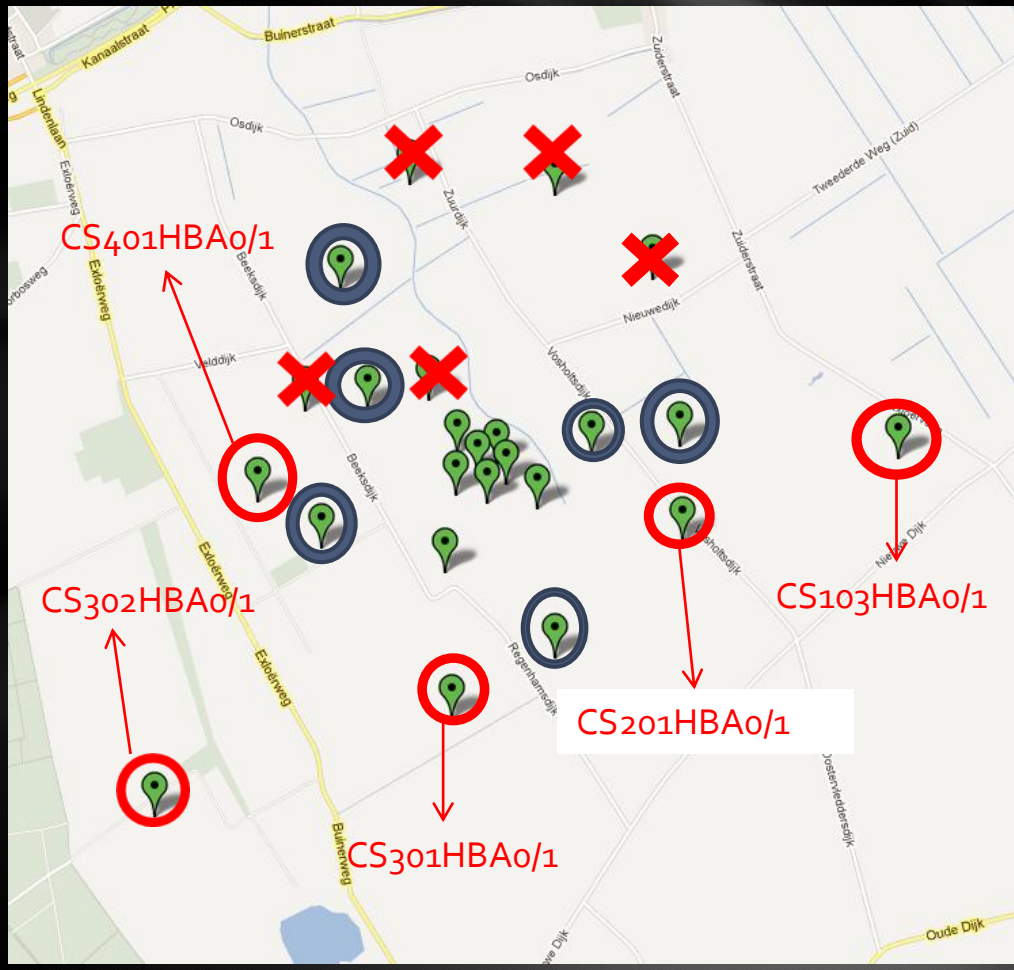
LOFAR Map courtesy of George Heald


Gain solutions of Core Stations 0:0 at 10000 secs
Gain amplitude
0.050
0.045
0.040
0.035
0.030
0.025
0.020
1.52
1.54
1.56
1.58
1.60
1.62
1.64
1e8
Frequency(Hz)
Gain phase
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
1.52
1.54
1.56
1.58
1.60
1.62
1.64
1e8
Frequency(Hz)

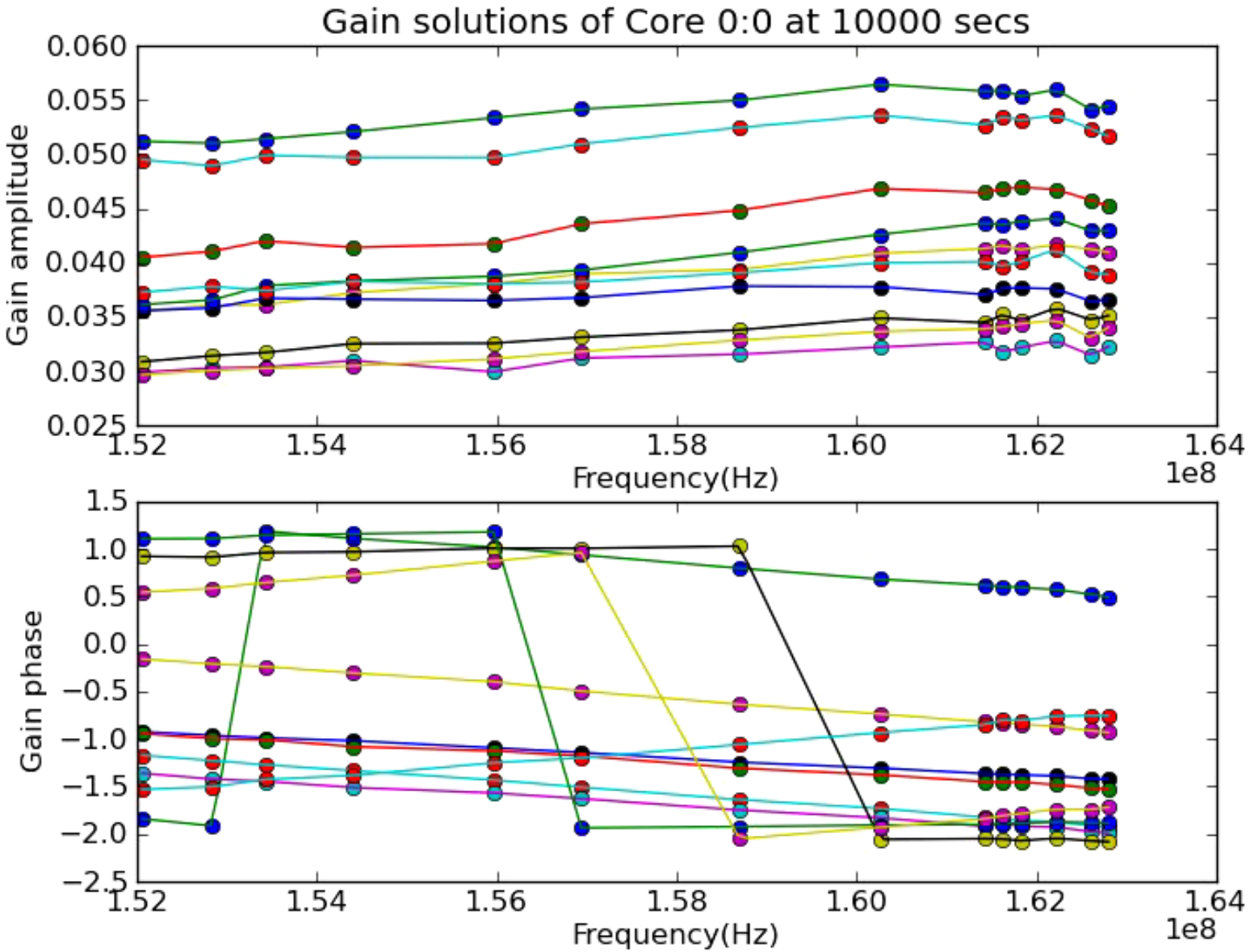
Stations used:

- CS103HBA0/1
- CS201HBA0/1
- CS301HBA0/1
- CS302HBA0/1
- CS401HBA0/1

CORE STATIONS BATCH 2



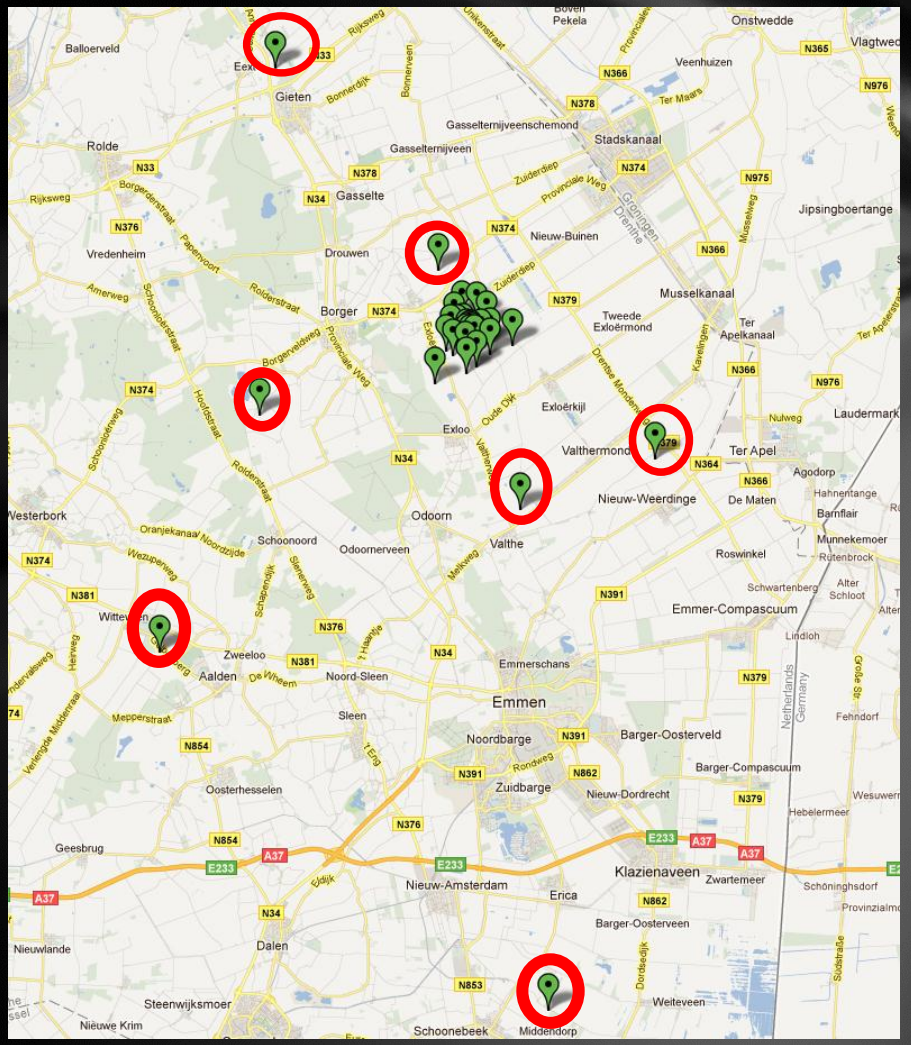
LOFAR Map courtesy of George Heald


Gain solutions of Core 0:0 at 10000 secs
Gain amplitude
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
1.52
1.54
1.56
1.58
1.60
1.62
1.64
1e8
Frequency(Hz)
Gain phase
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
1.52
1.54
1.56
1.58
1.60
1.62
1.64
1e8
Frequency(Hz)

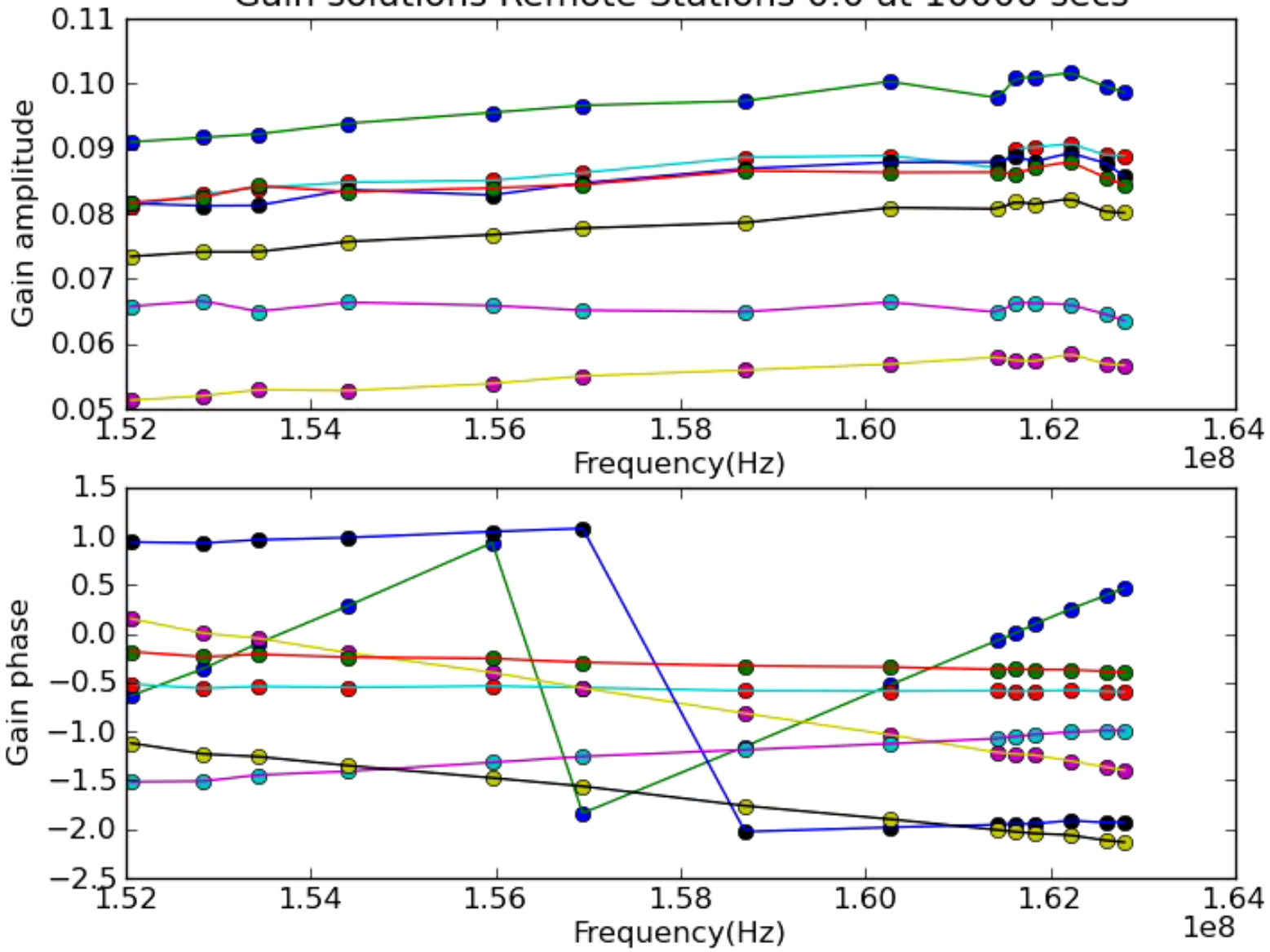
7 remote stations were used in the observation:

- RS106HBA
- RS205HBA
- RS208HBA
- RS306HBA
- RS307HBA
- RS406HBA
- RS503HBA

REMOTE STATIONS



LOFAR Map courtesy of George Heald

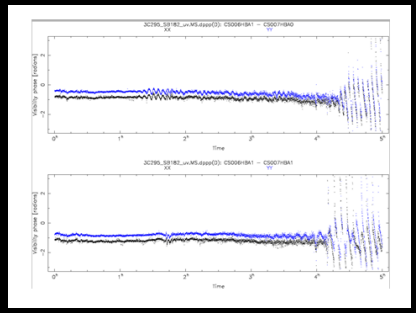

Gain solutions Remote Stations 0:0 at 10000 secs
Gain amplitude
0.11
0.10
0.09
0.08
0.07
0.06
0.05
1.52
1.54
1.56
1.58
1.60
1.62
1.64
1e8
Frequency(Hz)
Gain phase
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
1.52
1.54
1.56
1.58
1.60
1.62
1.64
1e8
Frequency(Hz)

Next Steps

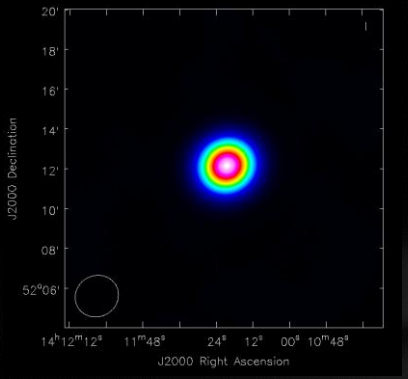
- Program will have to include:

1. The ability for the user to choose which stations and correlations to plot
2. Need a greater bandwidth, used only 14/122 SBS so far
3. Apply linear fitting to XX & YY correlations

Flagging Data

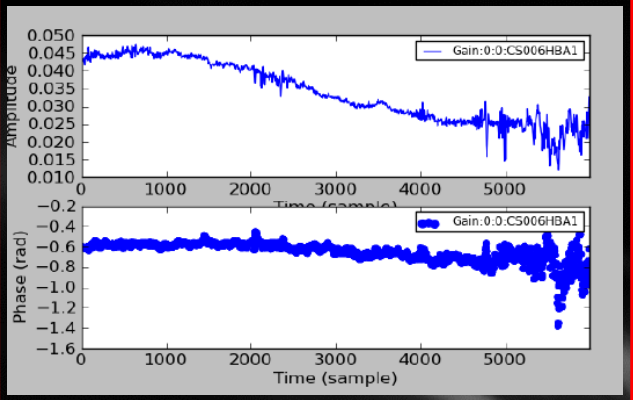


Calibrate the Calibrator



Calibrator: 3C295

Analyze Gains

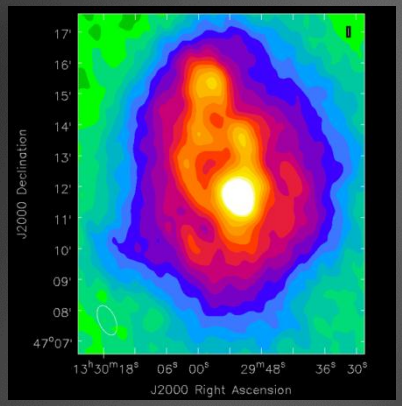


Apply Gains to the target field
--instrument-db
3C295.MS/instrument

uv-plane-cal-transfer.parset
Model.Beam.Enable = T
Solves for all 4 elements in the gain Jones' matrix

3C295.skymodel.new
Specifies direction only for target

Correct.parset – only solve steps
Model.Beam.Enable = T



Image!!!

M51

- M51 is a grand-design spiral galaxy with two very prominent spiral arms.
- Perturbed by its close companion NGC5195 which may have resulted in two systems of density waves.
- Orientation of the magnetic field lines follow very closely the spiral arms. (Berkhuijsen et al. 1996, Patrickeyev et al 2006, Fletcher et al. 2011)

Fletcher, Beck et al (2011)

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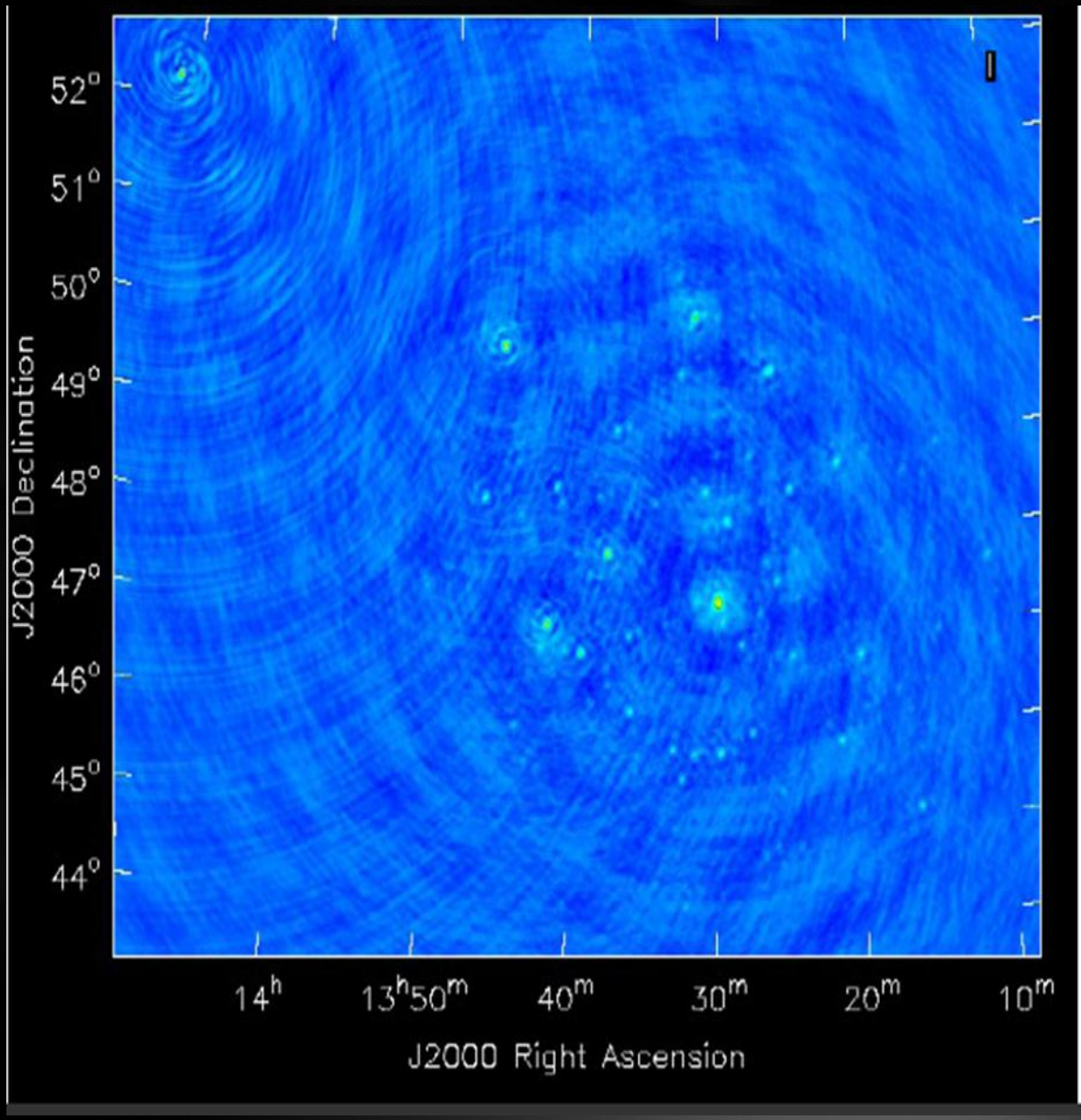
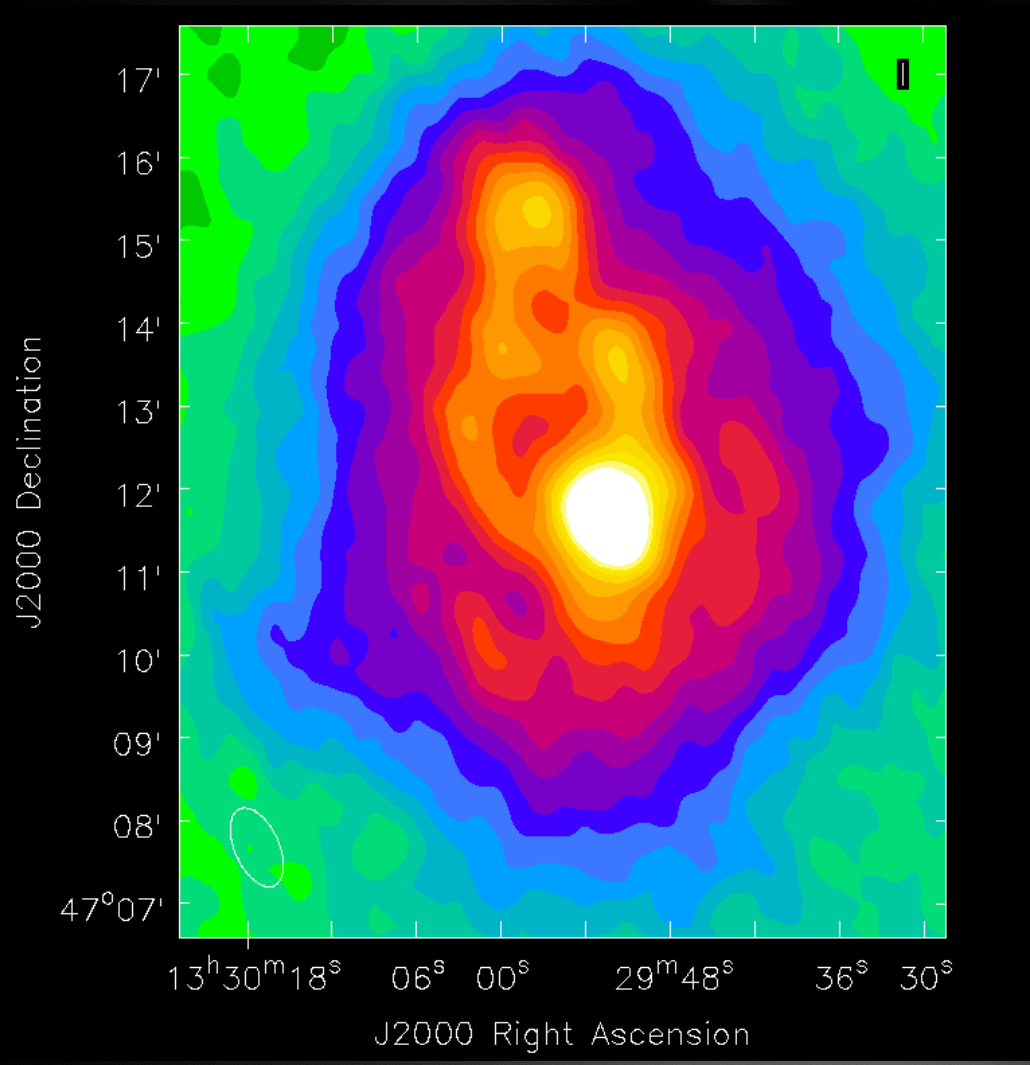
- Orientation of the magnetic field lines follow very closely the spiral arms. (Berkhuijsen et al. 1996, Patrickeyev et al 2006, Fletcher et al. 2011)



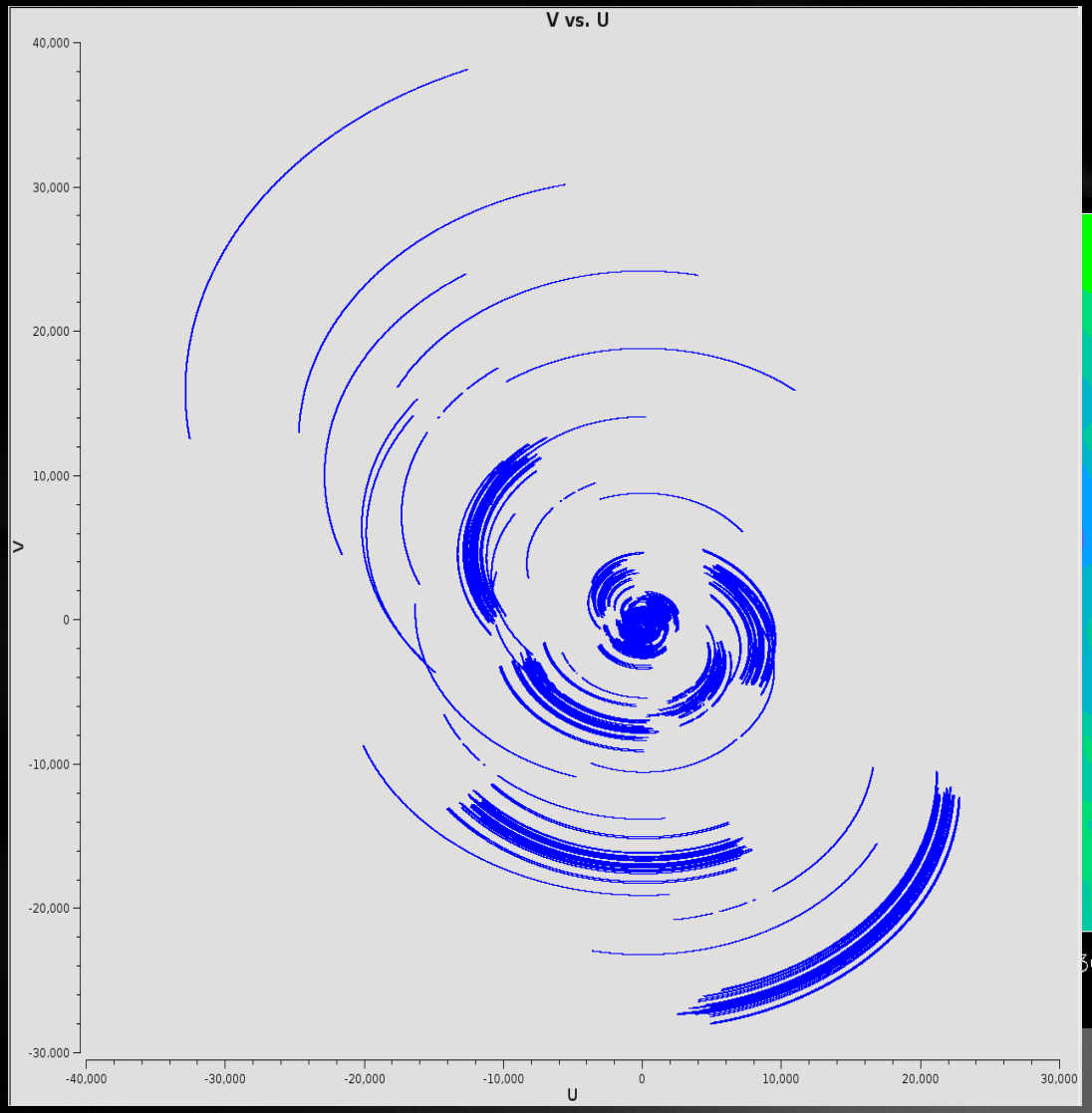
Map of M51

- Robust Weighting of 0.25 was used to produce image to the right.
- Single Subband at 145.7 MHz



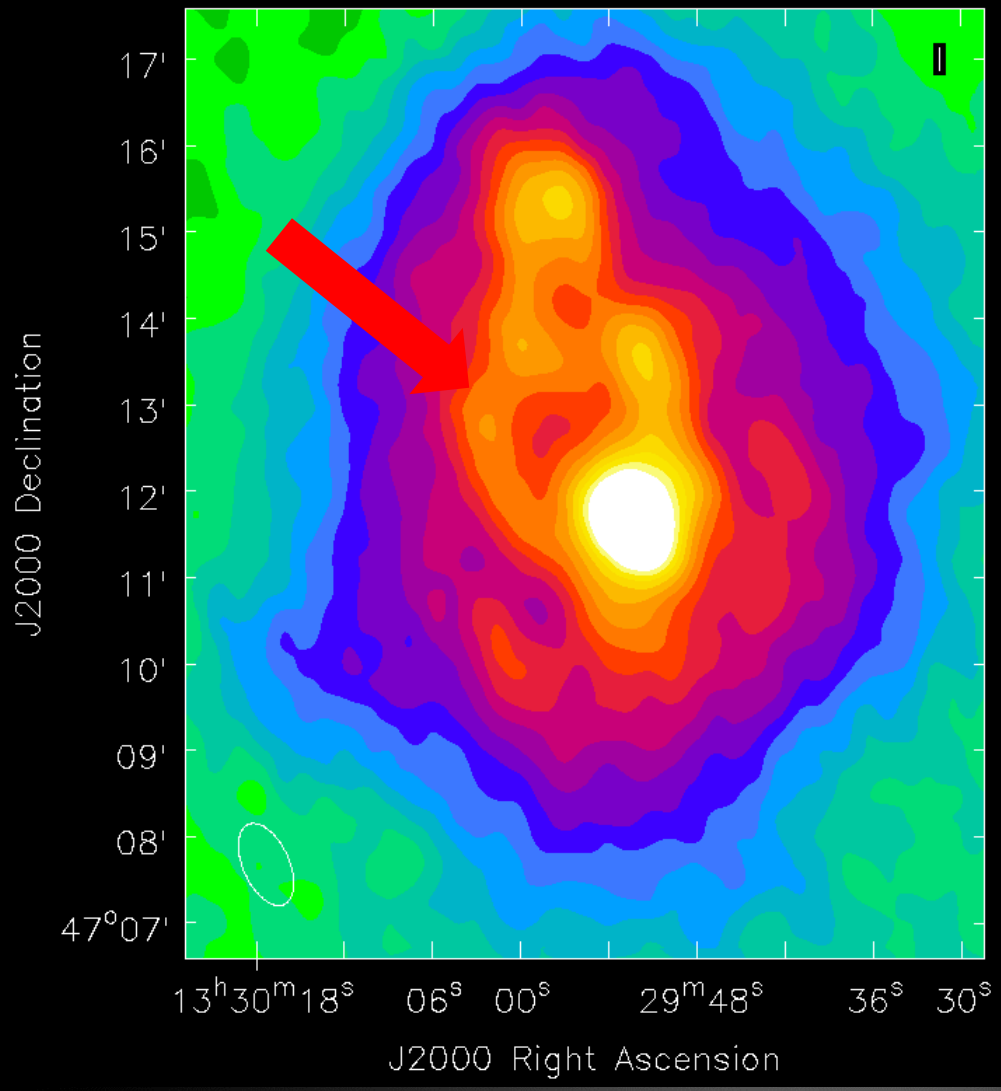
Map of M51

- Robust Weighting of 0.25 was used to produce image to the right.
- Single Subband at 145.7 MHz
- Due to uv-coverage, beam is quite elliptical



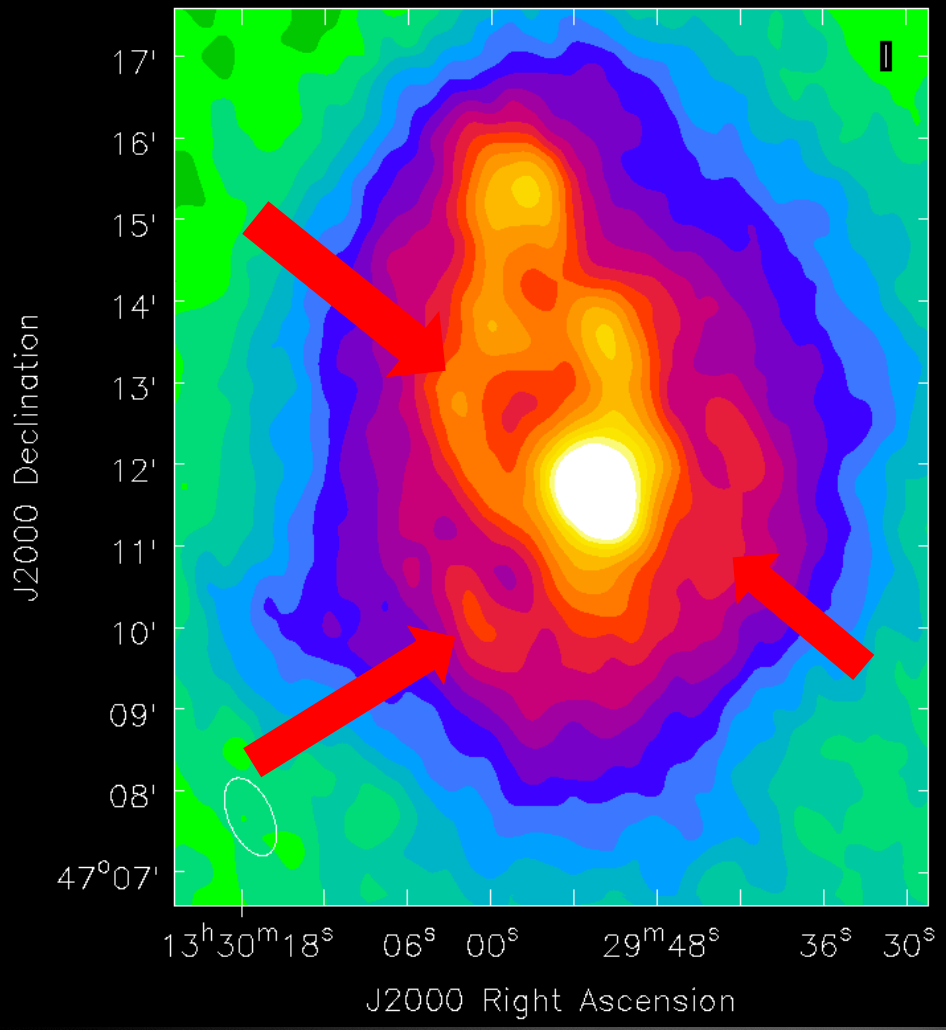
Map of M51

- Robust Weighting of 0.25 was used to produce image to the right.
- Single subband at 145.7 MHz
- Due to uv-coverage, beam is quite elliptical
- Left spiral arm can be seen.



Higher Resolution map of M51

- Robust Weighting of 0.25 was used to produce image to the right.
- Single subband at 145.7 MHz
- Due to uv-coverage, beam is quite elliptical
- Left spiral arm can be seen.
- As well as sections of the right spiral arm.



Map of M51

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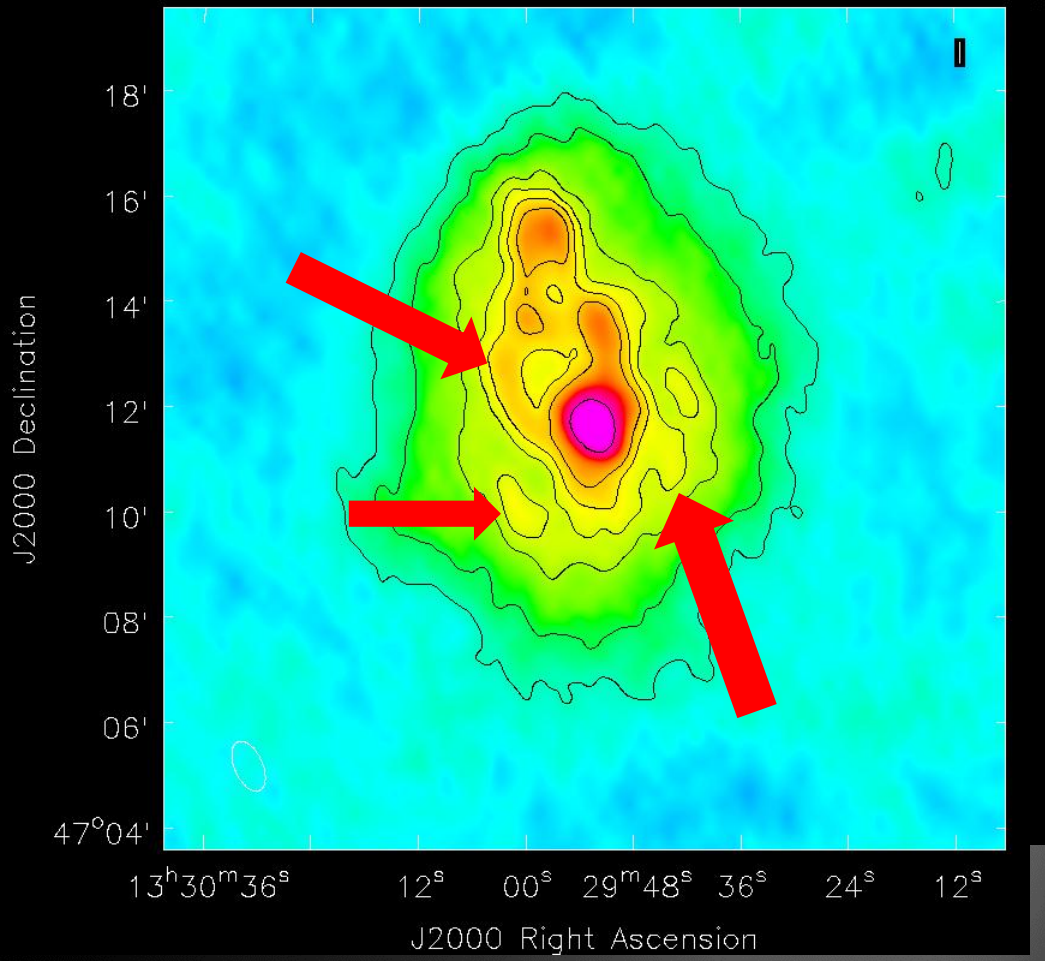
- Single subband at 145.7 MHz
- Due to uv-coverage, beam is quite elliptical
- Left spiral arm can be seen.
- As well as sections of the right spiral arm.
- Base contour is at the 3 sigma level.



Map of M51

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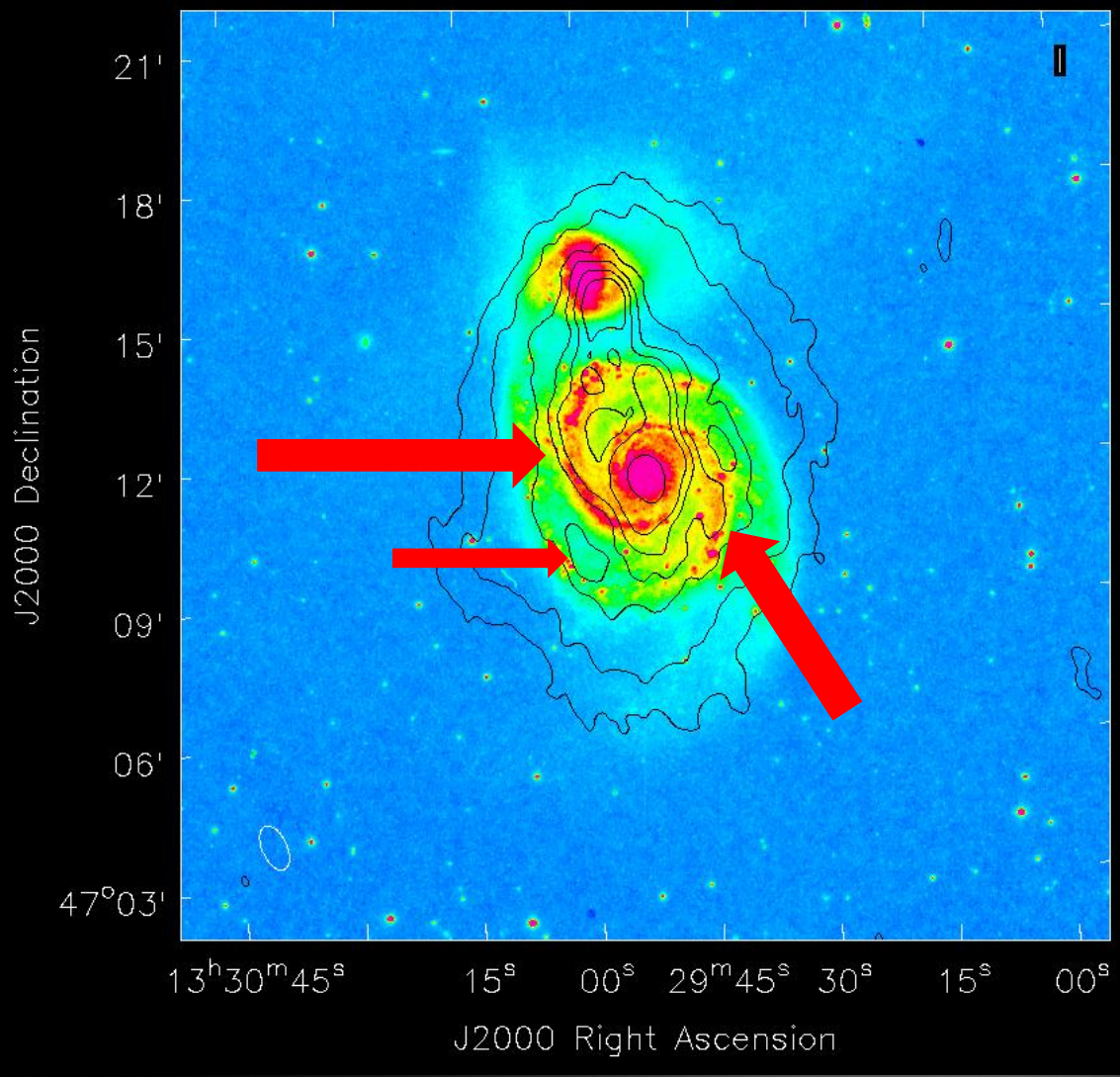
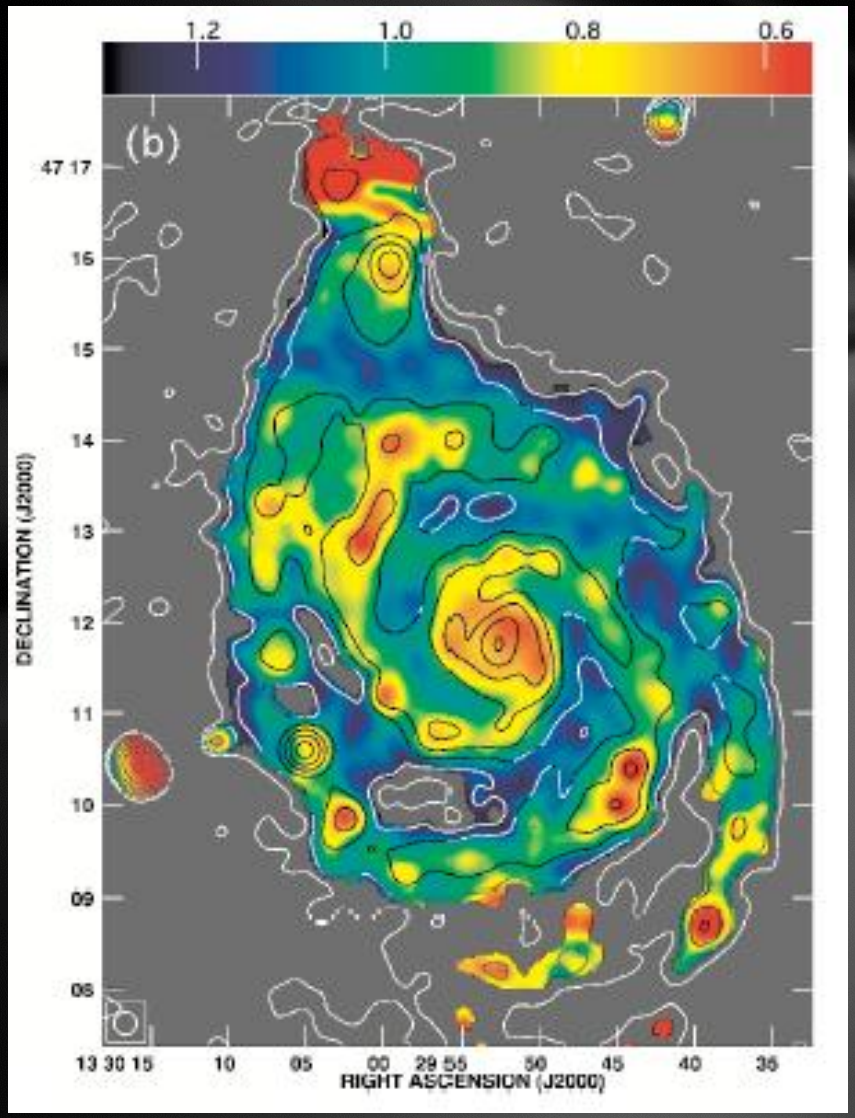
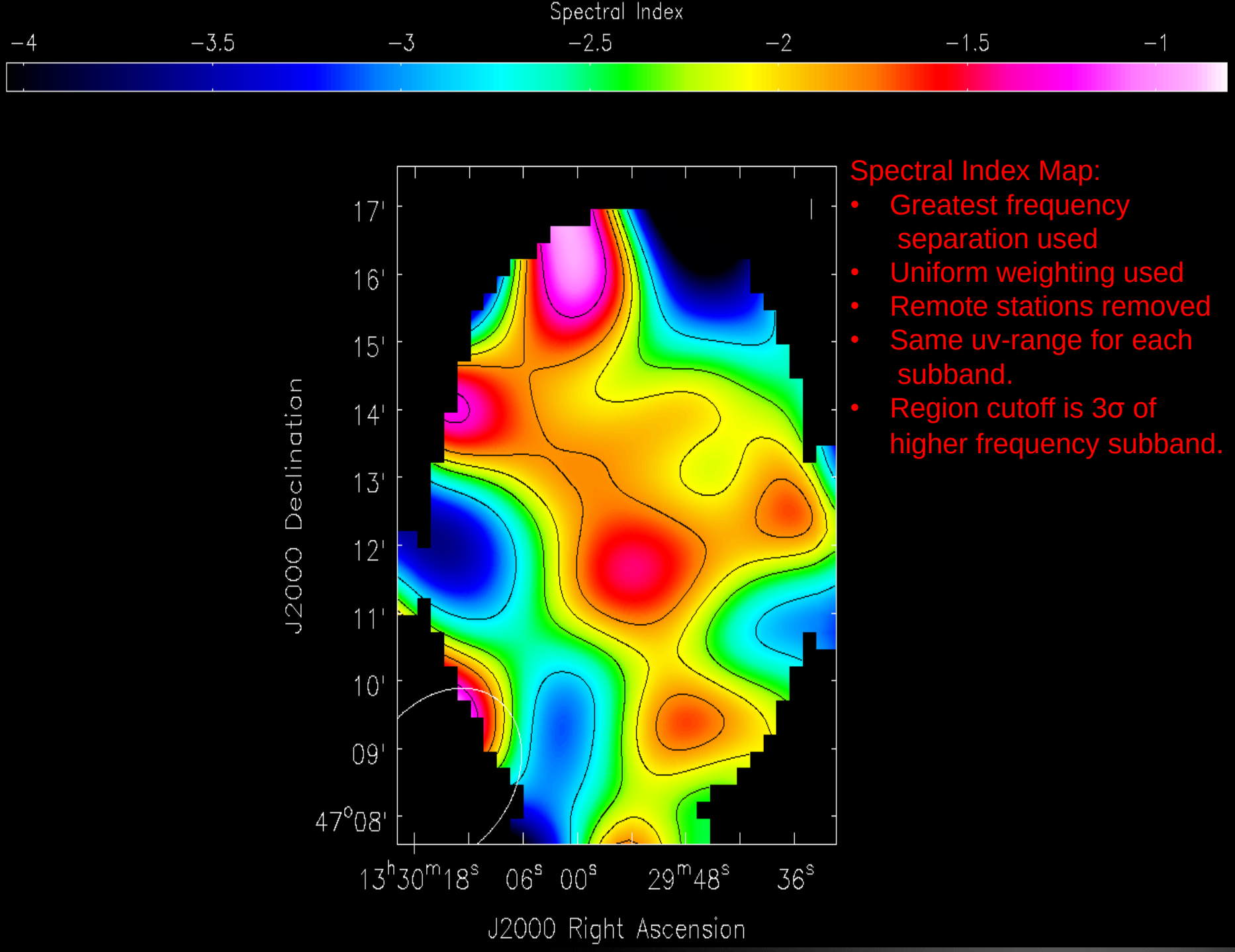
- Single subband at 145.7 MHz
- Due to uv-coverage, beam is quite elliptical
- Left spiral arm can be seen.
- As well as sections of the right spiral arm.
- Base contour is at the 3 sigma level.
- Extended disk can also be seen!



Spectral Index Maps of M51

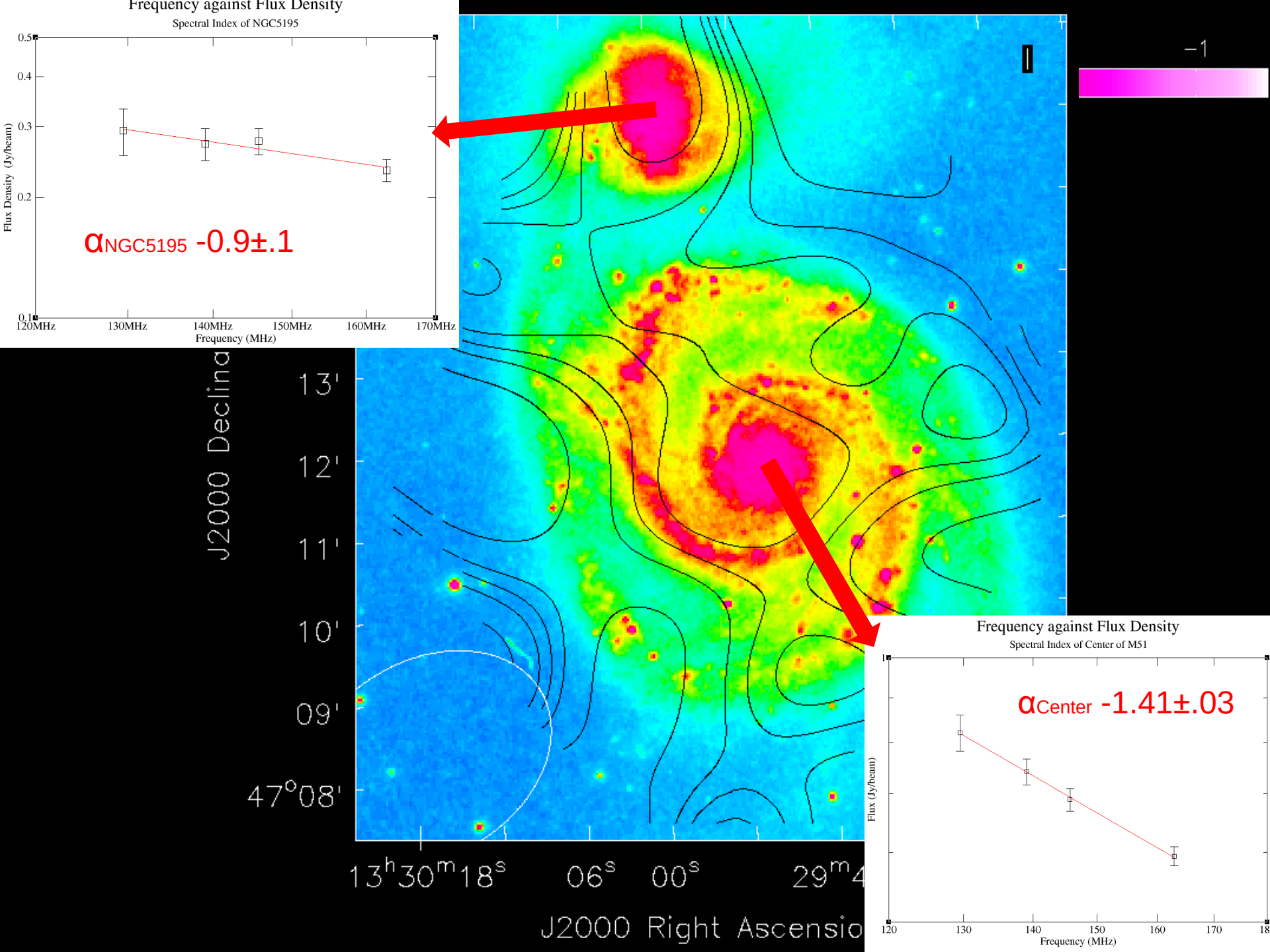
- At low frequencies, one expects a lower thermal fraction and older CR electrons; therefore a steeper spectral index.
- There should be spectral variations between arm & interarm regions and between disk & halo.
- Shown right is the spectral index between wavelengths 20-6cm from Fletcher et al (2011).

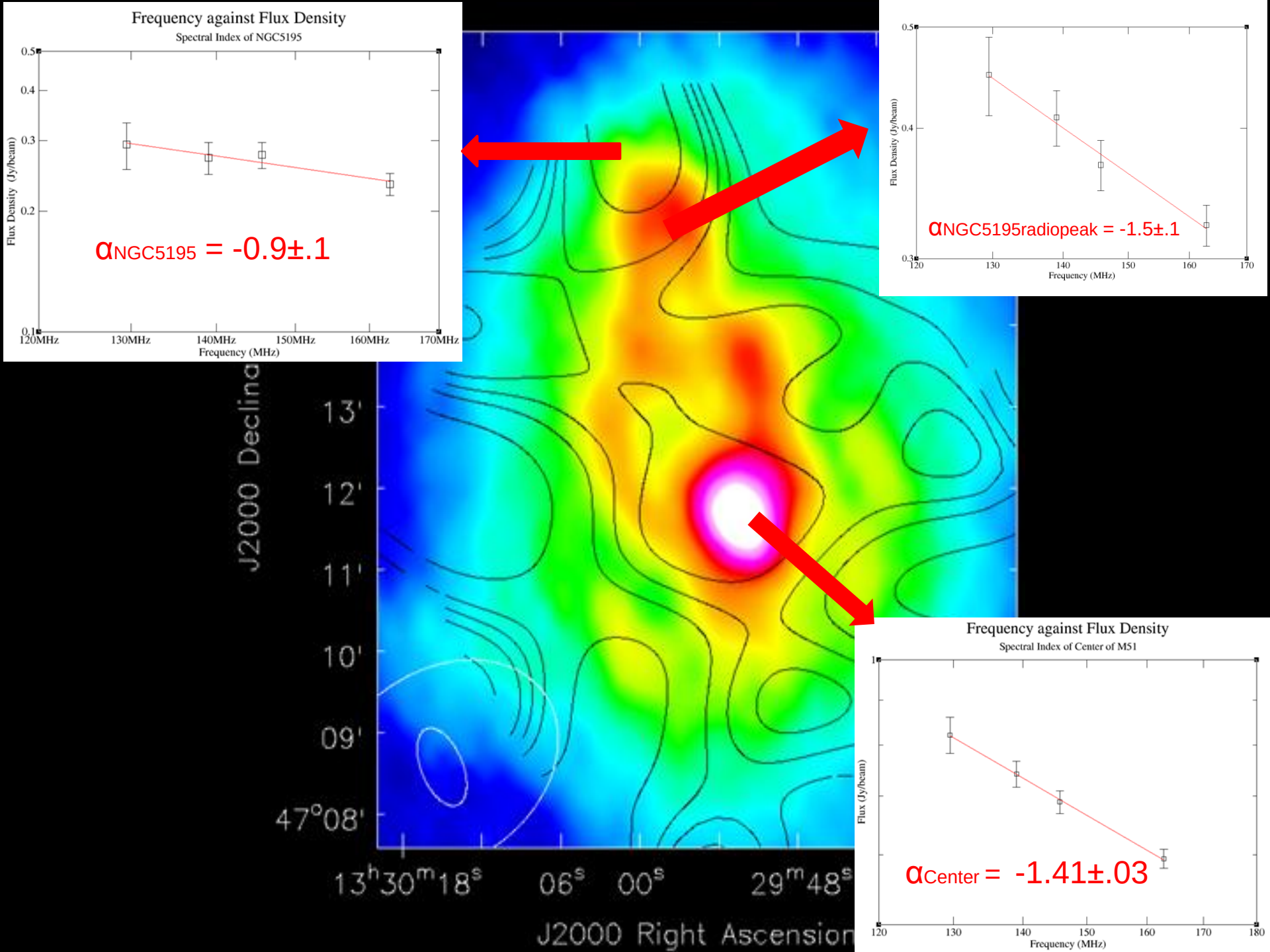




Spectral Index Map:

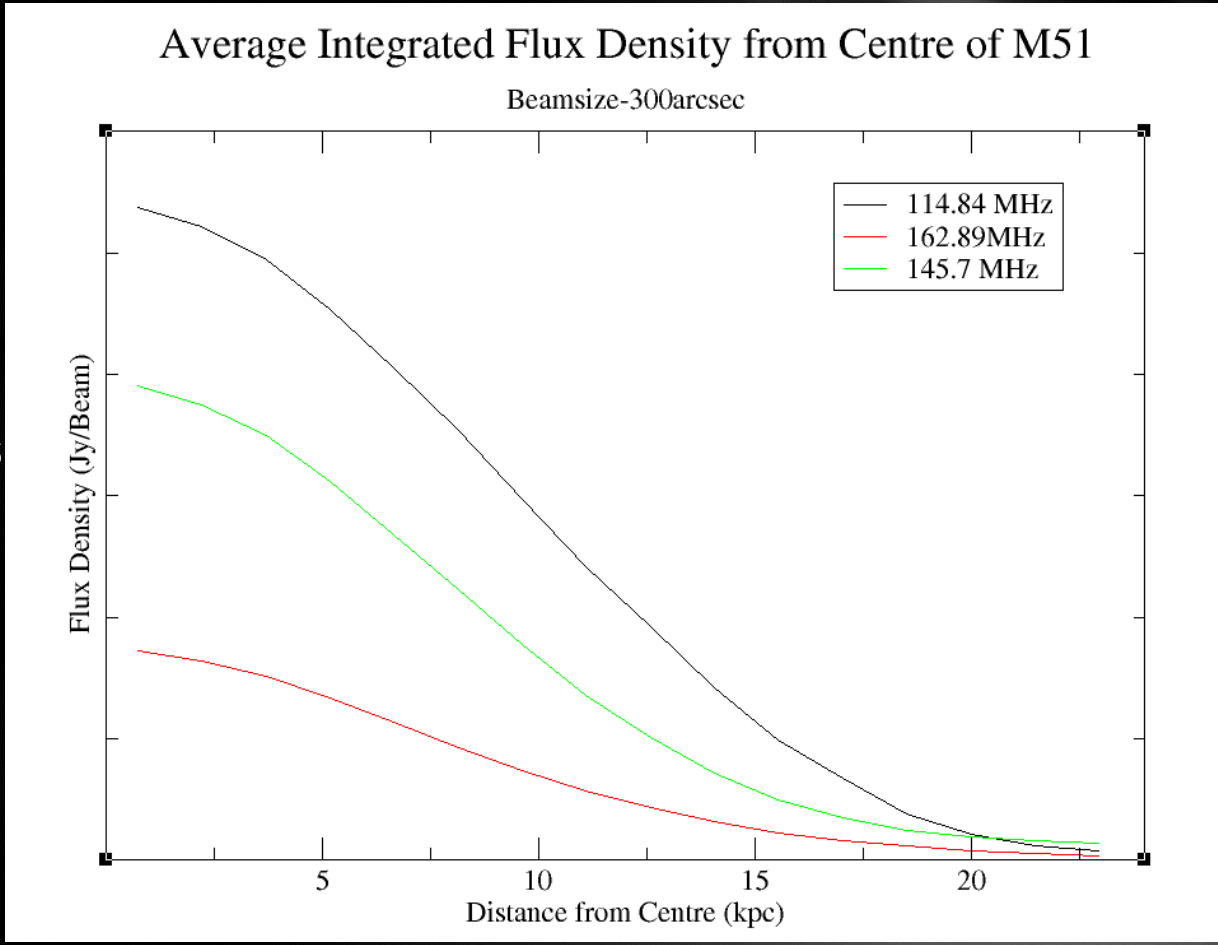
- Greatest frequency separation used
- Uniform weighting used
- Remote stations removed
- Same uv-range for each subband.
- Region cutoff is 3σ of higher frequency subband.


Frequency against Flux Density
Spectral Index of NGC5195
Flux Density (Jy/beam)
0.5
0.4
0.3
0.2
0.1
120MHz
130MHz
140MHz
150MHz
160MHz
170MHz
Frequency (MHz)
αNGC5195 -0.9±.1
−1
J2000 Declina
13'
12'
11'
10'
09'
47°08'
13h30m18s
06s
00s
29m4
J2000 Right Ascensio
Frequency against Flux Density
Spectral Index of Center of M51
αCenter -1.41±.03
Flux (Jy/beam)
120
130
140
150
160
170
Frequency (MHz)


Frequency against Flux Density
Spectral Index of NGC5195
Flux Density (Jy/beam)
0.5
0.4
0.3
0.2
0.1
120MHz
130MHz
140MHz
150MHz
160MHz
170MHz
Frequency (MHz)
αNGC5195 = -0.9±.1
Flux Density (Jy/beam)
0.5
0.4
0.3
120
130
140
150
160
170
Frequency (MHz)
αNGC5195radiopeak = -1.5±.1
J2000 Declina
13'
12'
11'
10'
09'
47°08'
13h30m18s
06s
00s
29m48s
J2000 Right Ascension
Frequency against Flux Density
Spectral Index of Center of M51
Flux (Jy/beam)
1
0.5
120
130
140
150
160
170
180
Frequency (MHz)
αCenter = -1.41±.03

The Disk of M51

- LOFAR subbands were compared to a recent Effelsberg observation at 2.65GHz.
- Radial surface brightness profile was produced.
- Lower frequency subbands show an extended disk



Conclusions

The extended disk of M51 is clearly visible at LOFAR frequencies.

A steep spectrum region is detected between M51 and its companion, perhaps a pool of old electrons or a shock at the interface region.

The Spectral Index of the M51 center is very steep (-1.4).

Images will be significantly improved when combining all subbands and removing 3C295 from the uv-data of the target observation.

Much more work is needed especially with respect to calibration and detection of diffuse polarized emission.