MeerKAT Simulation Studies

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Overview

"MeerKAT is South Africa's 1% SKA demonstrator interferometer. The 80 dish telescope is designed to be a versatile instrument ideal for a wide range of science cases. I will provide some insights into the configuration design and the simulation study currently being started. From a scientific perspective, I will also provide an overview of some of the large HI science cases that are being planned for MeerKAT, as well as some results from my current work in the comparison of HI and CO dynamics of local galaxies."

Overview

- MeerKAT Configuration
  - Background
  - Current Status
- Performance Simulations
  - Point Sources
  - Extended Emission

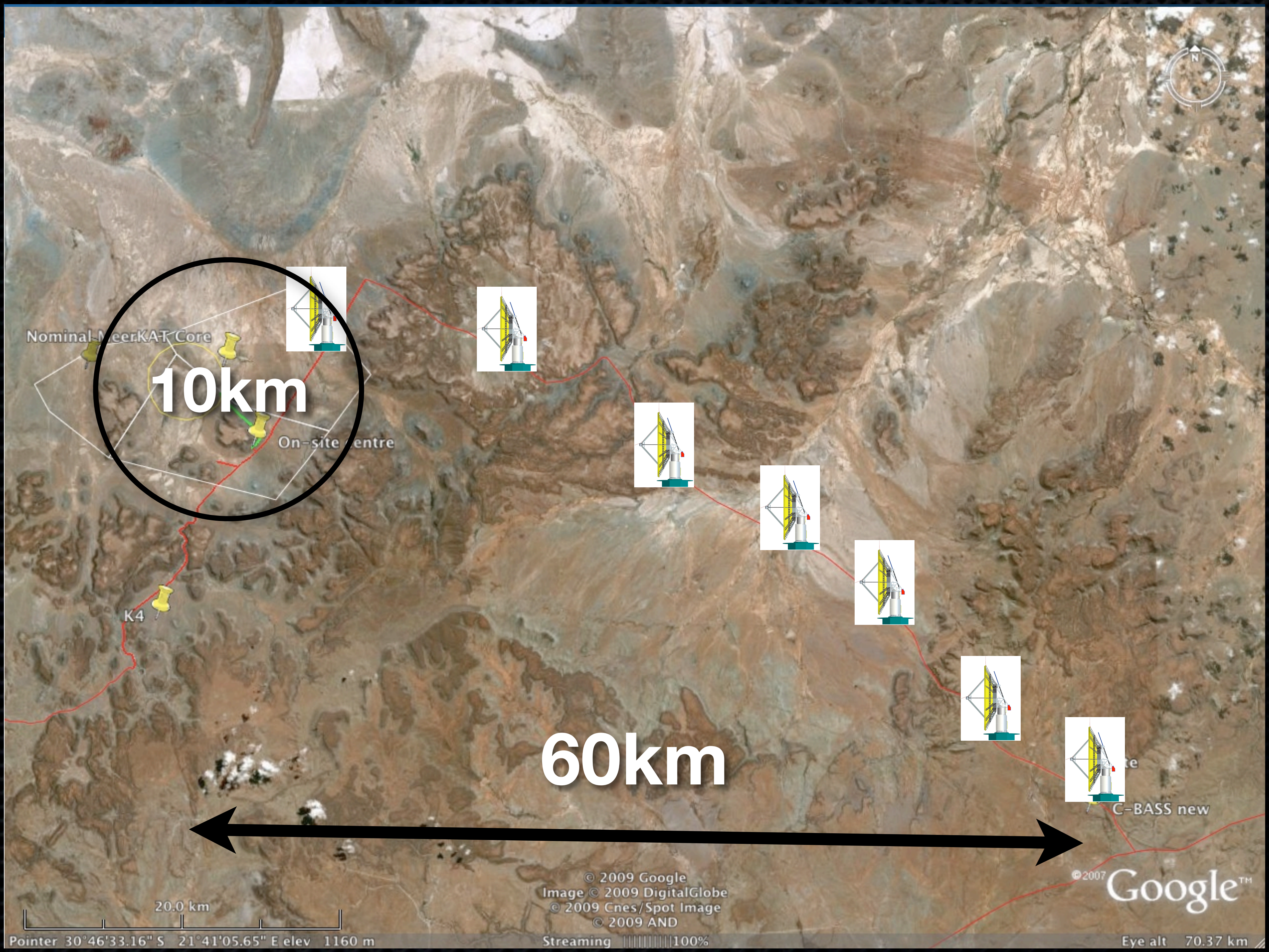
MeerKAT

Number of dishes[a]	80 (central array) + 7 (spur)
Dish diameter	12 m
Aperture efficiency	0.7
System temperature	30 K
Low frequency range[a]	0.58–2.5 GHz
High frequency range[a]	8–14.5 GHz
Field of view	1 deg^2 at 1.4 GHz 6 deg^2 at 580 MHz 0.5 deg^2 at 2 GHz
A_e/T_{sys}	200 m^2/K
Continuum imaging dynamic range[b]	1:10^5
Spectral dynamic range[b]	1:10^5
Instrumental linear polarisation purity	$-$25 dB across field
Minimum and maximum bandwidth per polarization[a]	8 MHz–4 GHz
Number of channels	16384
Minimum sample time	0.1 ms
Minimum baseline	20 m
Maximum baseline	8 km (without spur) 60 km (with spur)

	KAT-7 2010	Phase 1 2013	Phase 2 2014	Phase 3 2015	Phase 4 2016
Number of dishes	7	80	80	87	87
Low freq. range (GHz)	1.2–1.95	0.9–1.75	0.9–1.75	0.9–1.75	0.58–2.5
High freq. range (GHz)	—	—	8–14.5	8–14.5	8–14.5
Maximum processed bandwidth (GHz)	0.256	0.850	2	2	4
Min. baseline (m)	20	20	20	20	20
Max. baseline (km)	0.2	8	8	60	60

MeerKAT RFP

MeerKAT V1

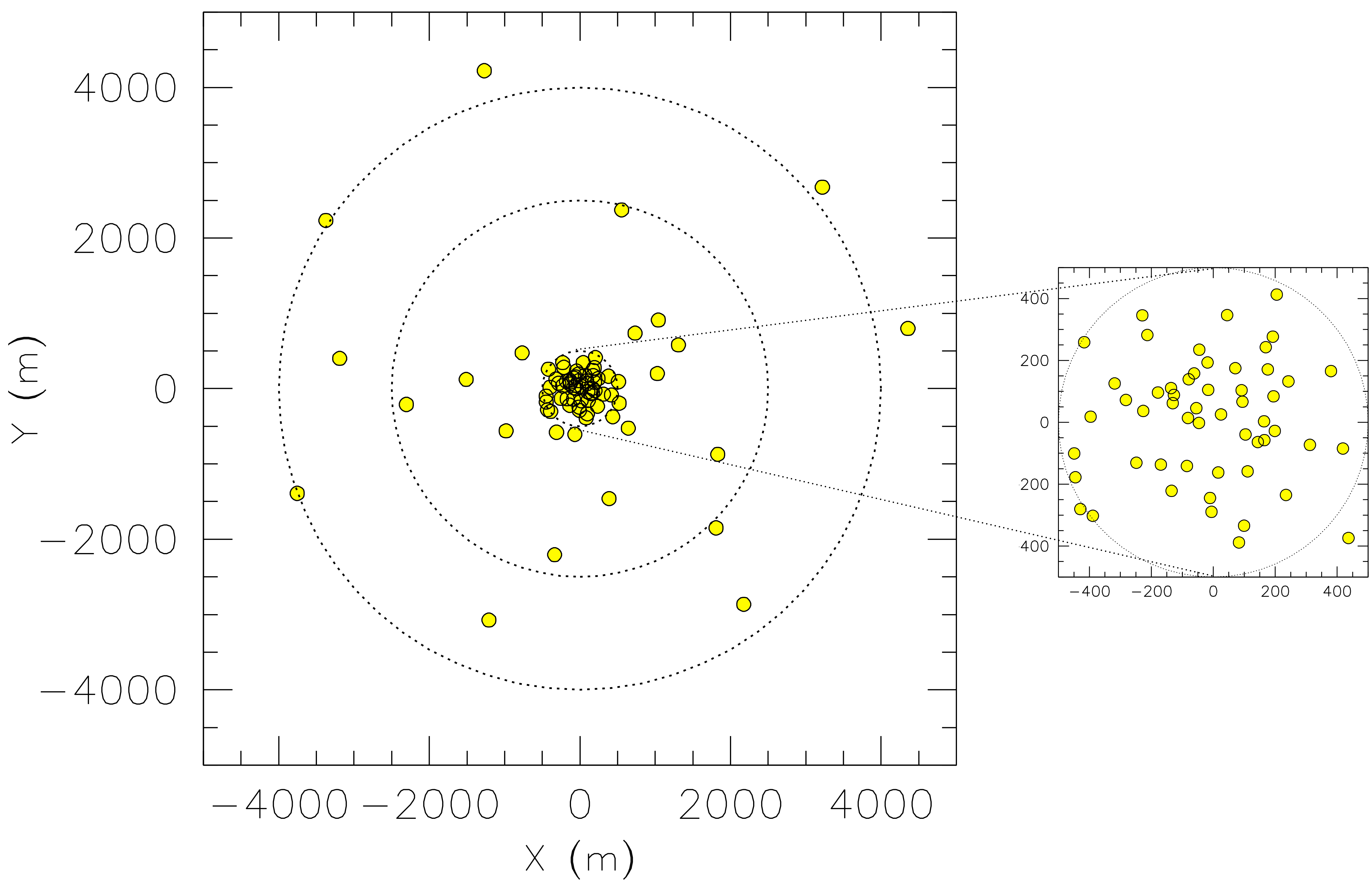


Justin Jonas

MeerKAT V1

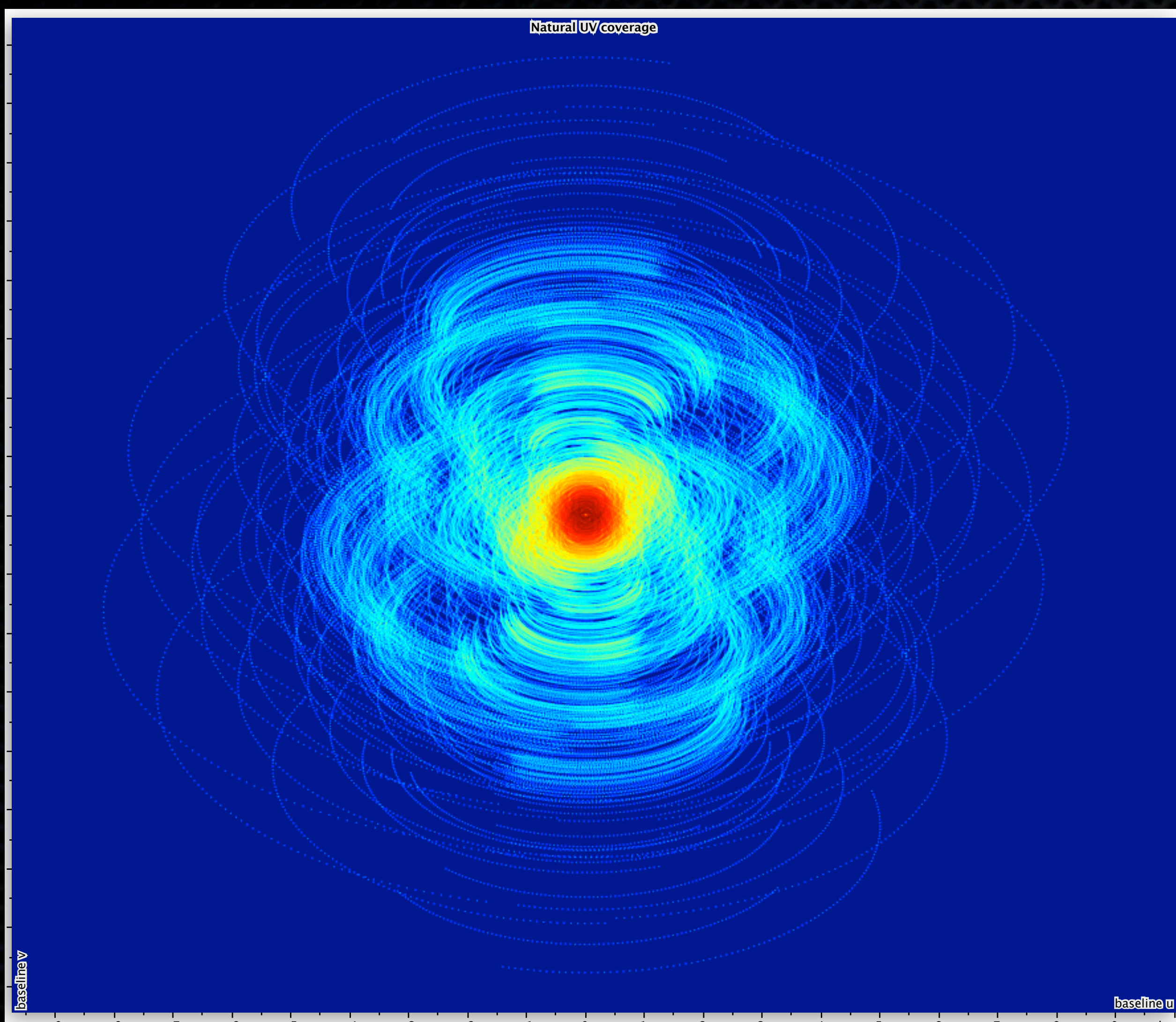
- MeerKAT RFP
- 80 x 12m Dishes
- 2 Gaussian Components
    - 56 Dishes in $\sigma_{inner} = 300$m
    - 24 Dishes in $\sigma_{outer} = 2500$m
- Optimized for 8hr, $\delta = -30^{\circ}$ pointing
- Used Weighted PSS as Measure of Imaging Performance

MeerKAT V1

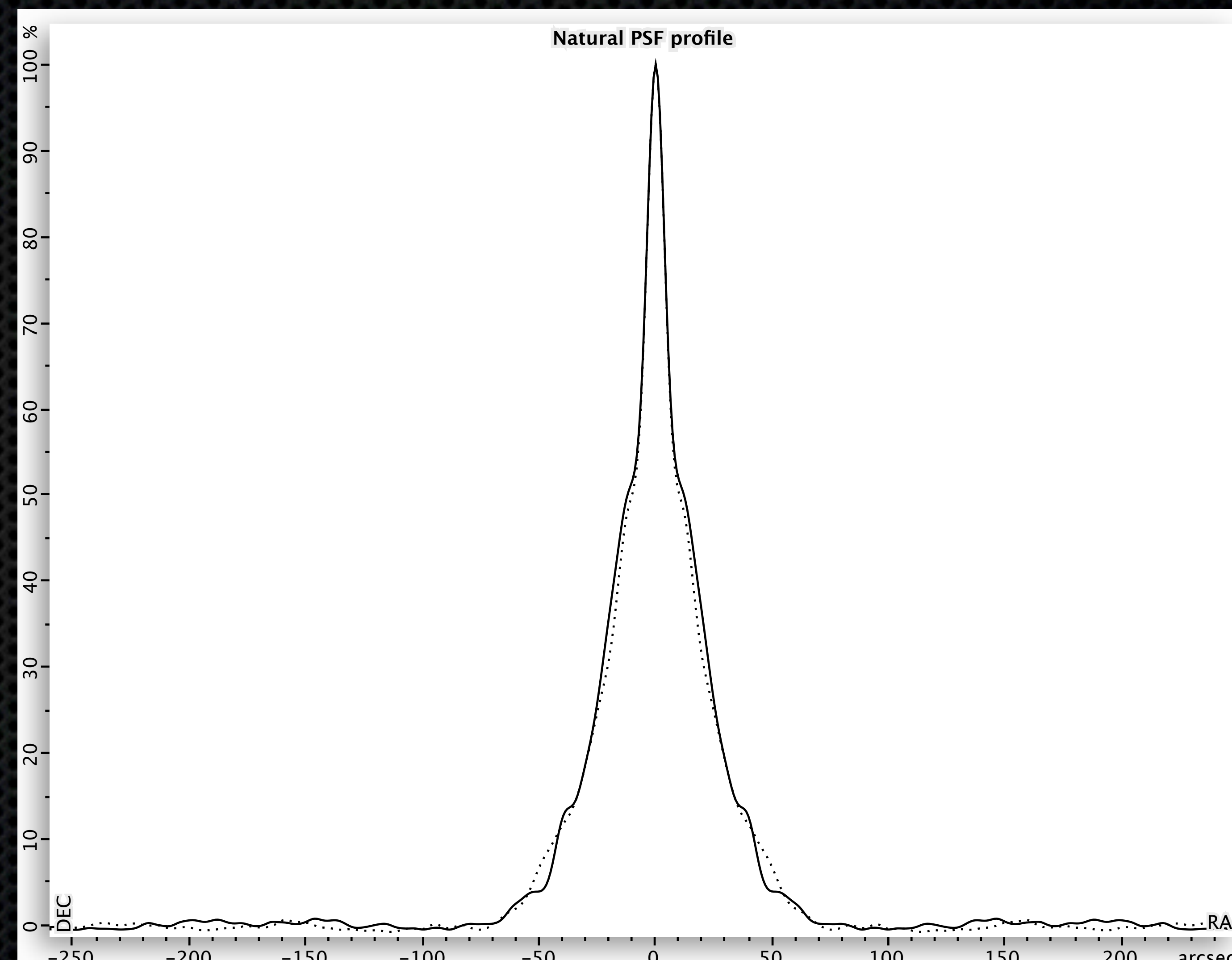


4000
2000
0
−2000
−4000
Y (m)
−4000 −2000 0 2000 4000
X (m)
400
200
0
200
400
−400 −200 0 200 400

MeerKAT V1



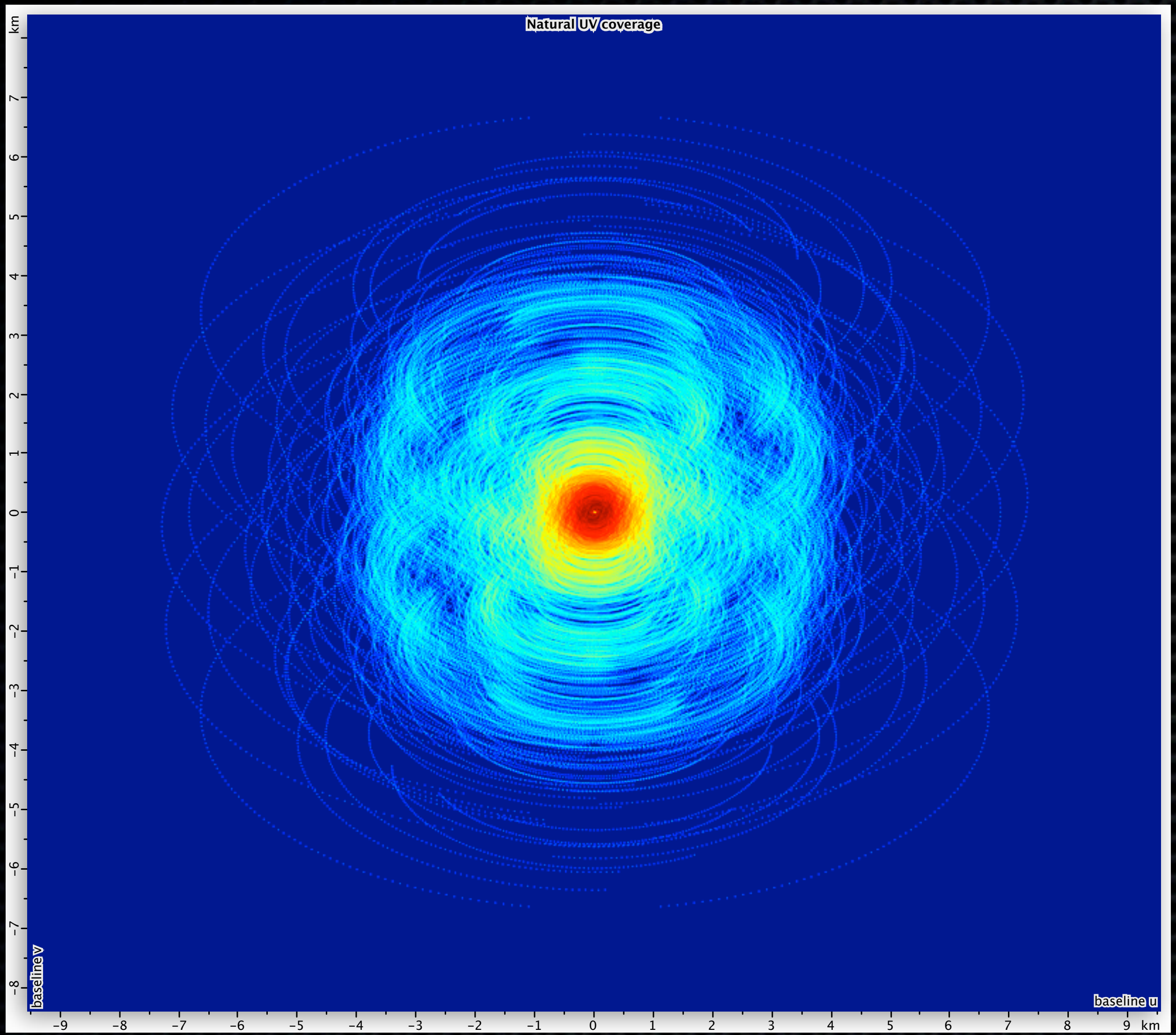
Natural UV coverage
baseline v
baseline u
-9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 km

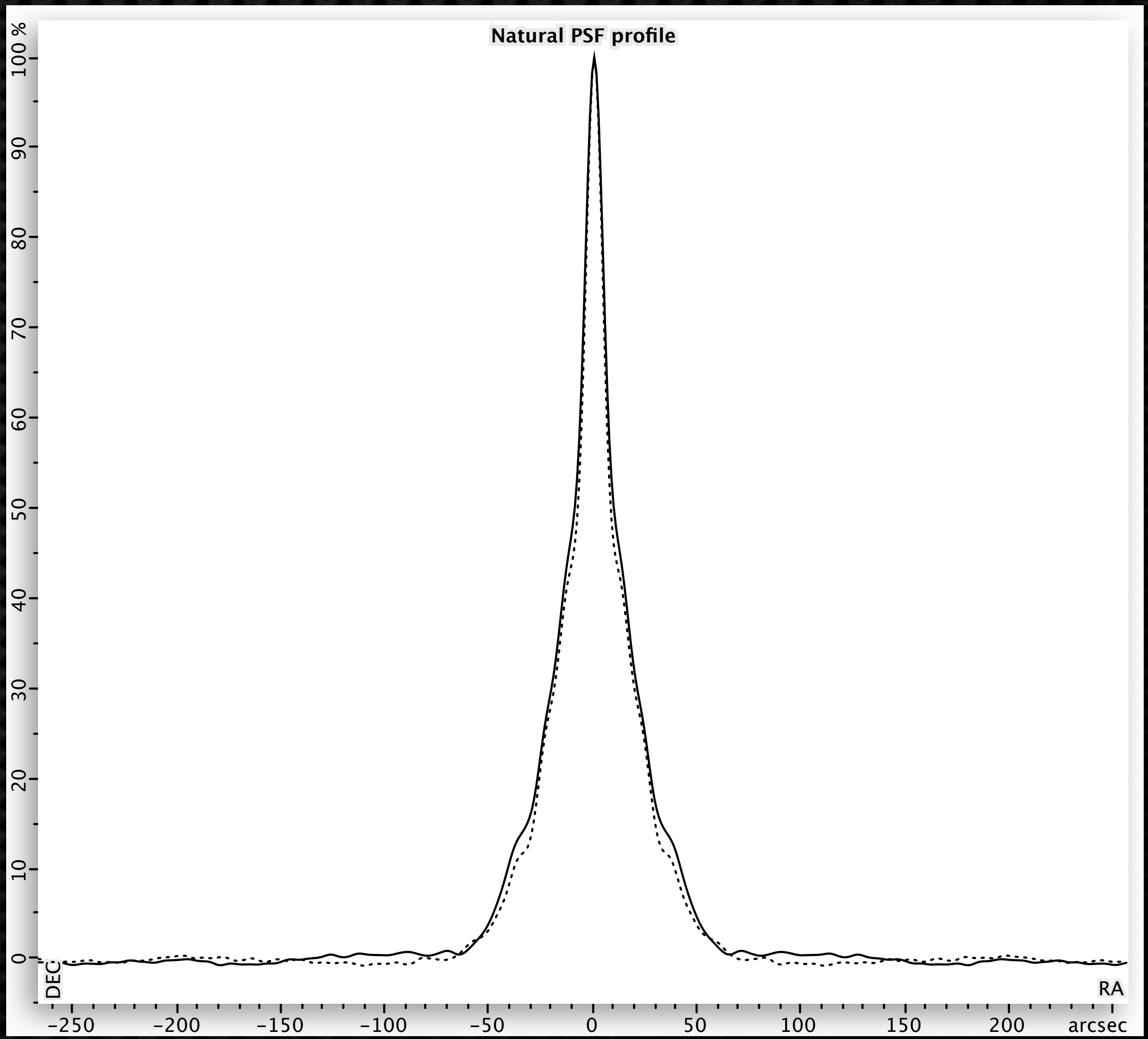


Natural PSF profile
100 %
90
80
70
60
50
40
30
20
10
0
DEC
RA
-250 -200 -150 -100 -50 0 50 100 150 200 arcsec

MeerKAT V3.6

MeerKAT V3.6


Natural UV coverage
baseline v
baseline u
km
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9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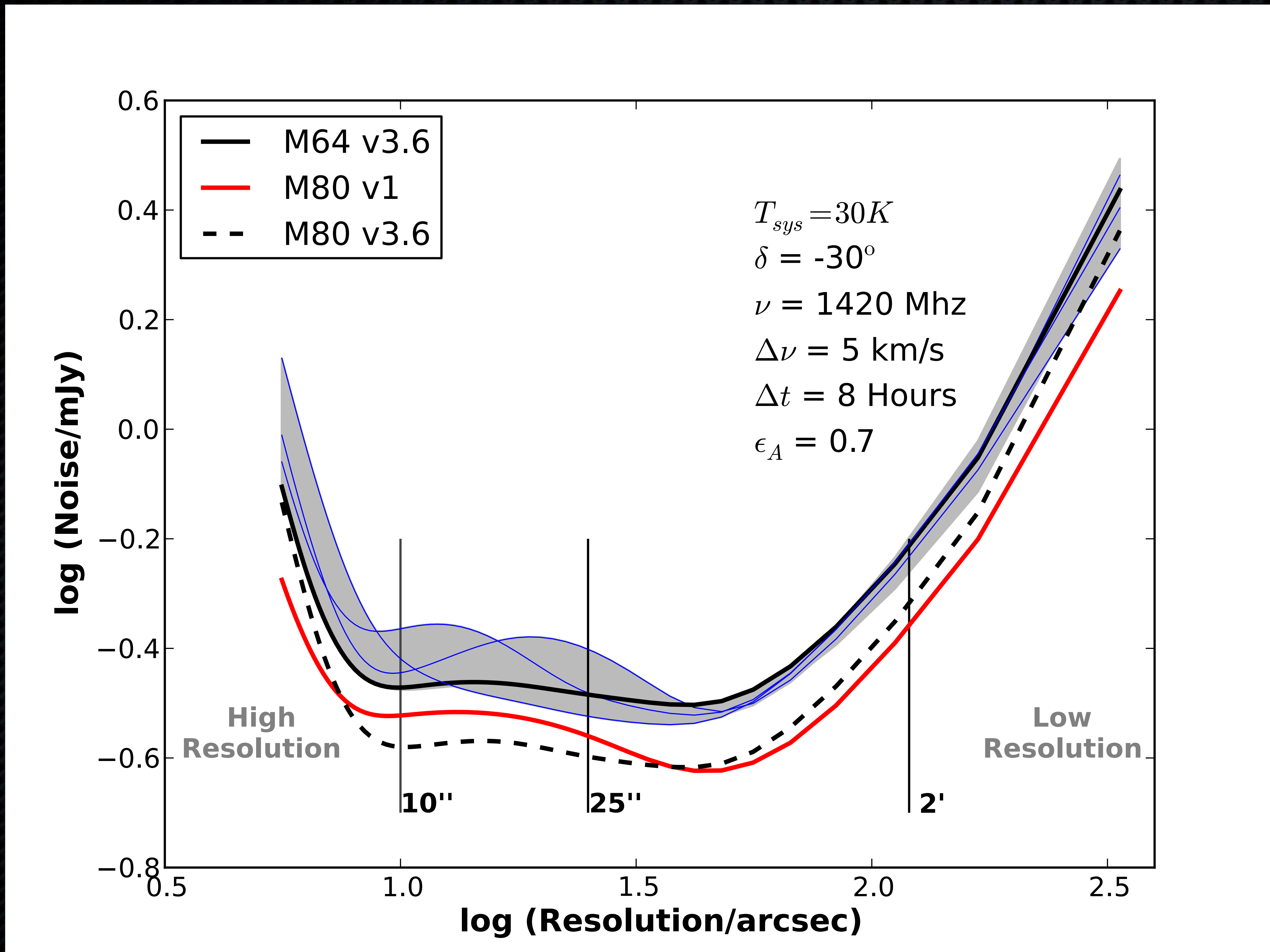
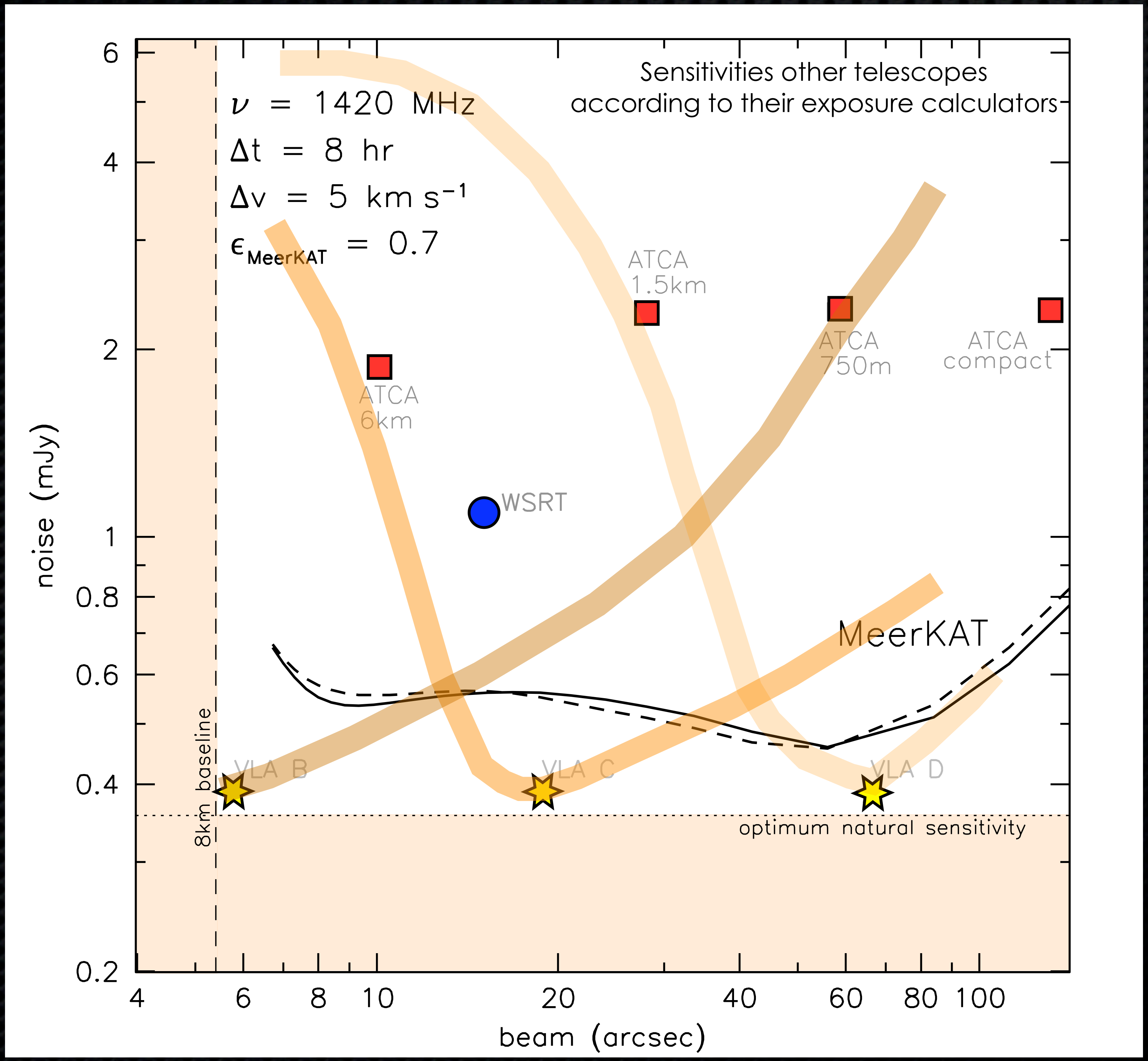
-150
-100
-50
0
50
100
150
200
arcsec

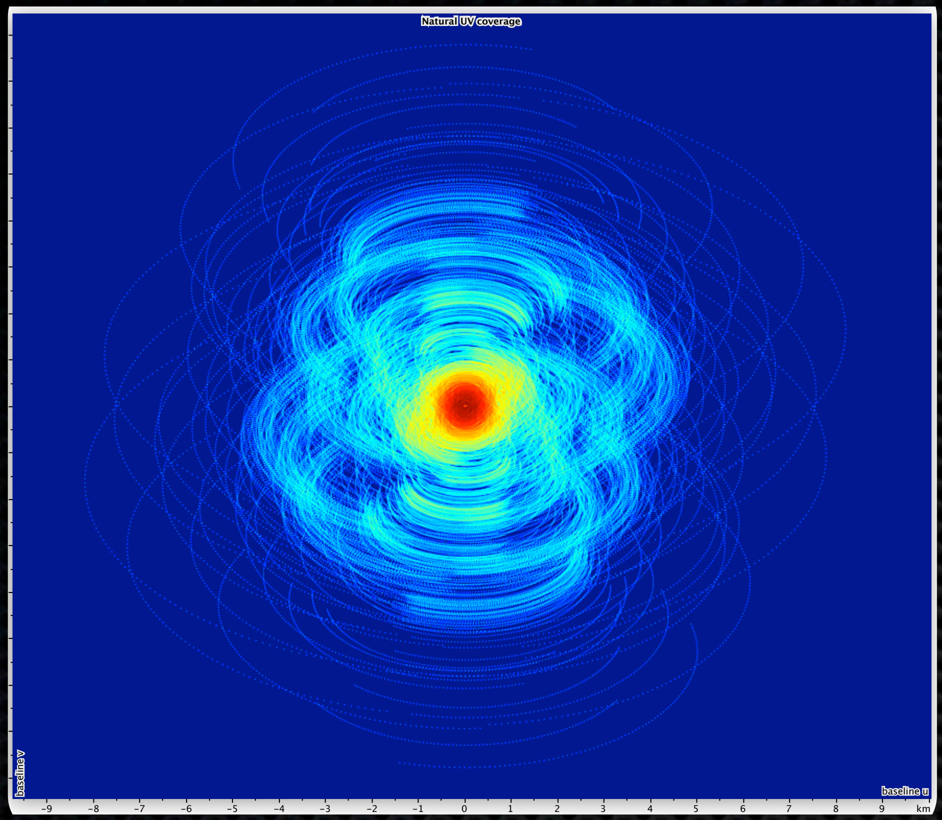
MeerKAT V3.6, 64-Dish

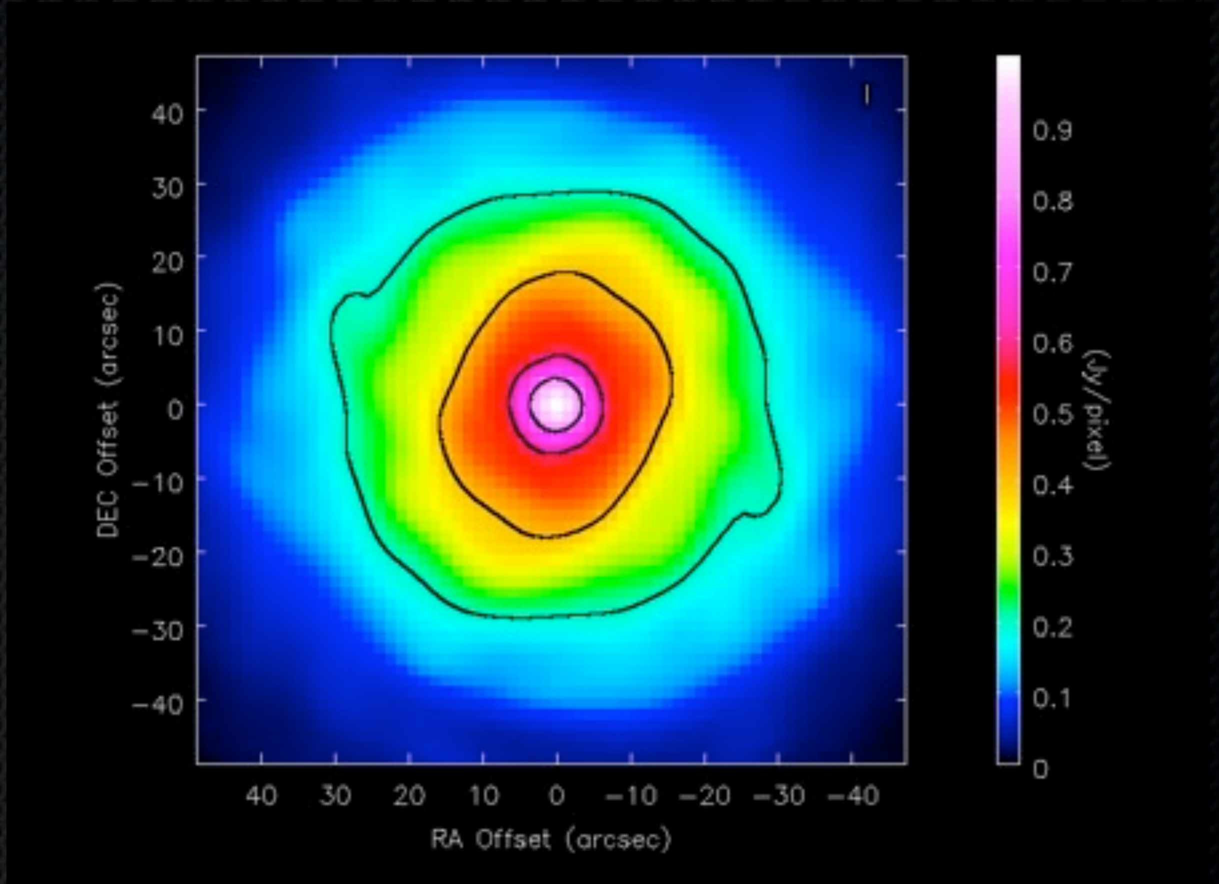


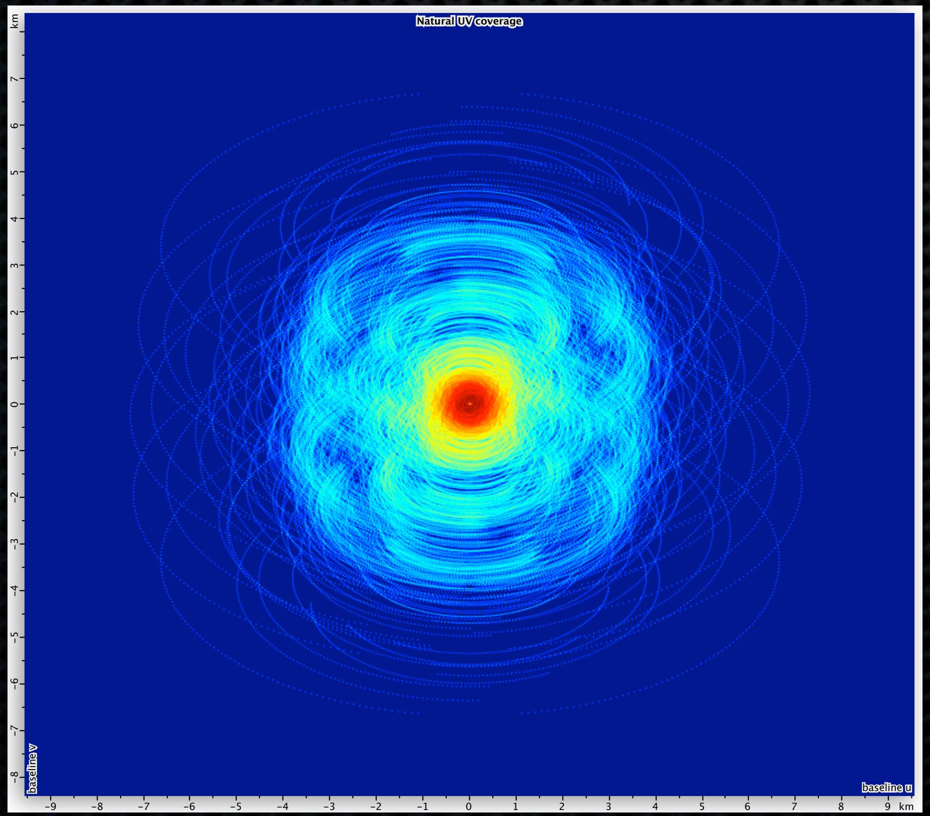
Sensitivities

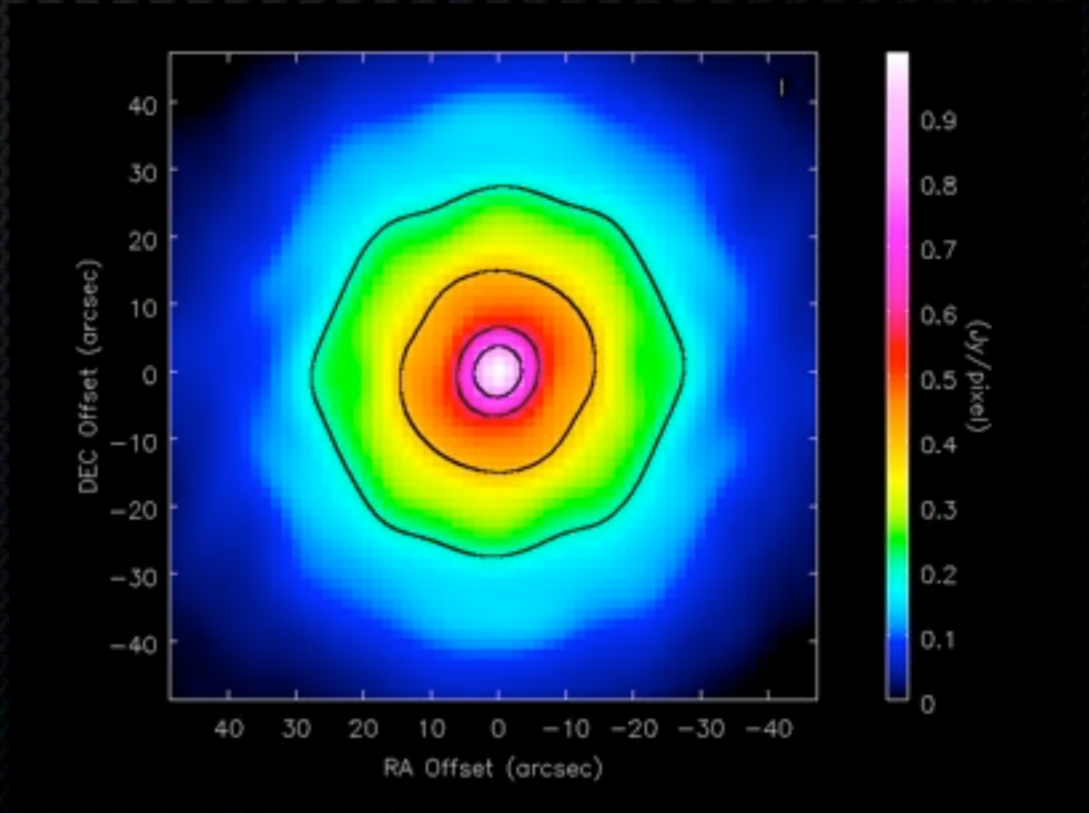


MeerKAT V1 and V3.6

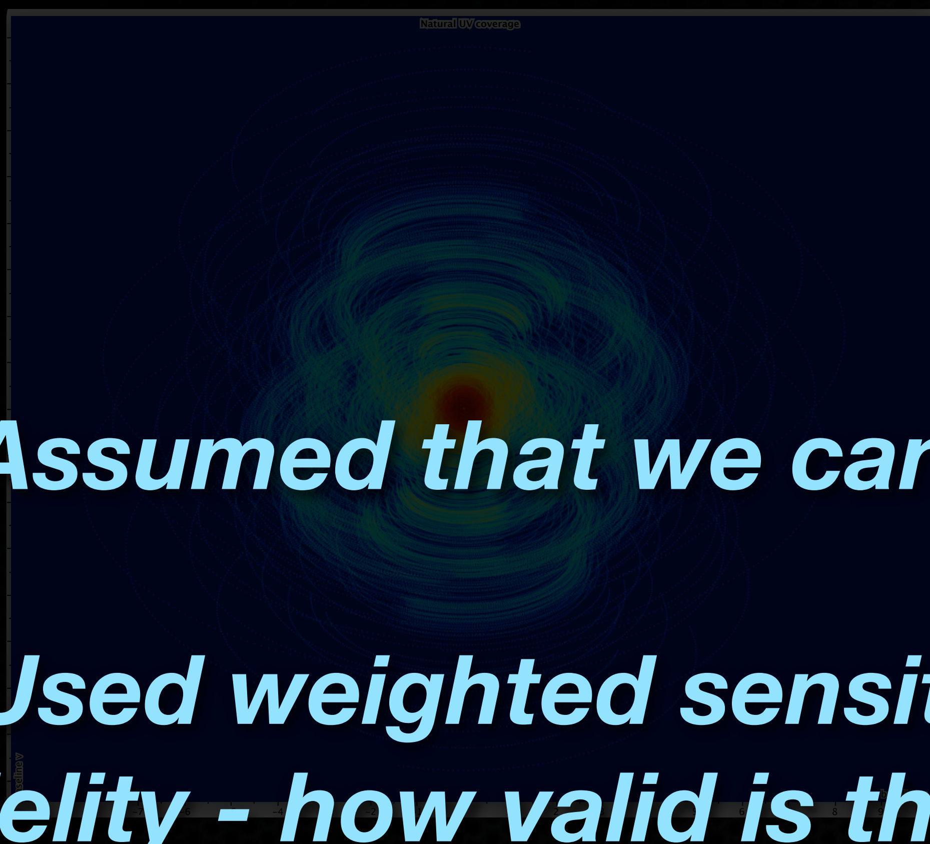


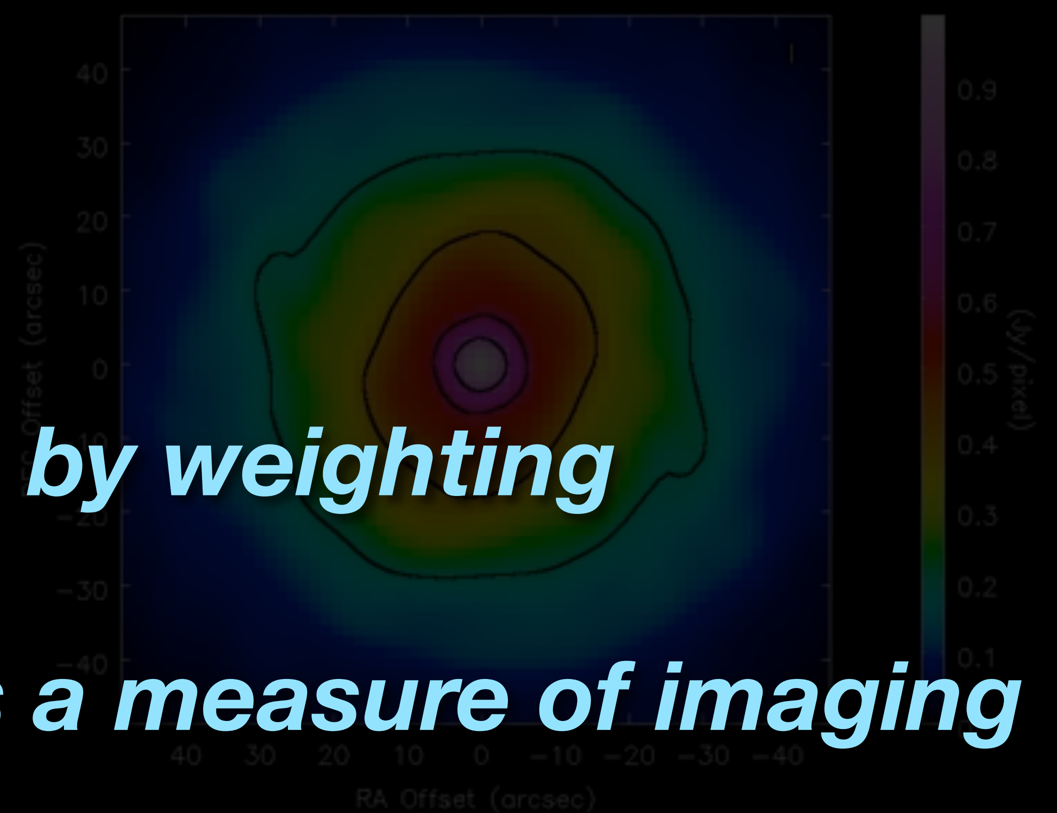




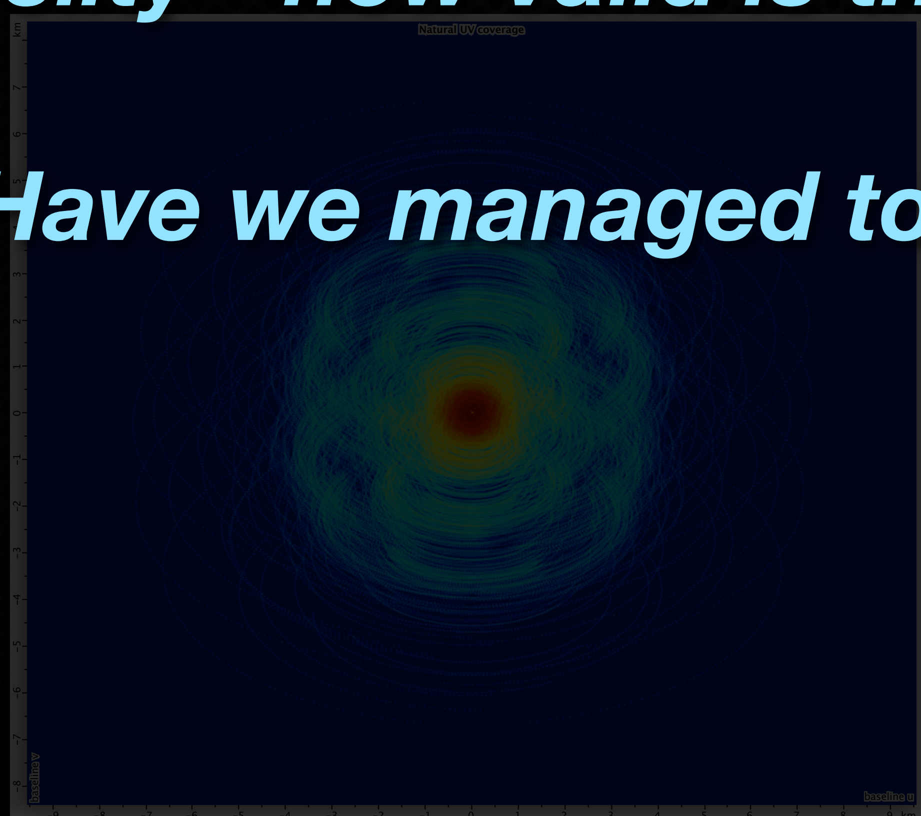


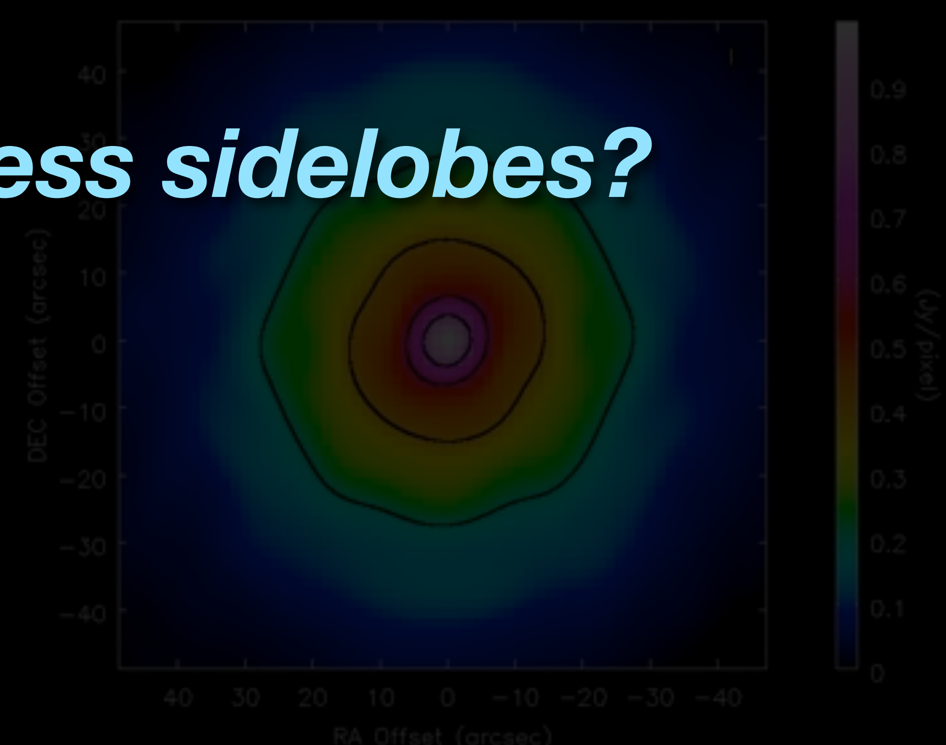
MeerKAT V1 and V3.6





- ***Assumed that we can image by weighting***
- ***Used weighted sensitivity as a measure of imaging fidelity - how valid is this?***
- ***Have we managed to suppress sidelobes?***





Simulation Studies

- In Support of Science Cases and Commissioning
- Uses CASA's simdata2 simulation task (hacked a little)
- Simulations
  - 10 Point Sources across FoV, Single Channel, Zenith Snapshot
  - NGC628 Clean Component Model (THINGS)
    - 58 Channel, 1.4GHz, $\Delta\nu$ = 12kHz, Fitted across 0.5° x 0.5°, 8hr, δ=-30°

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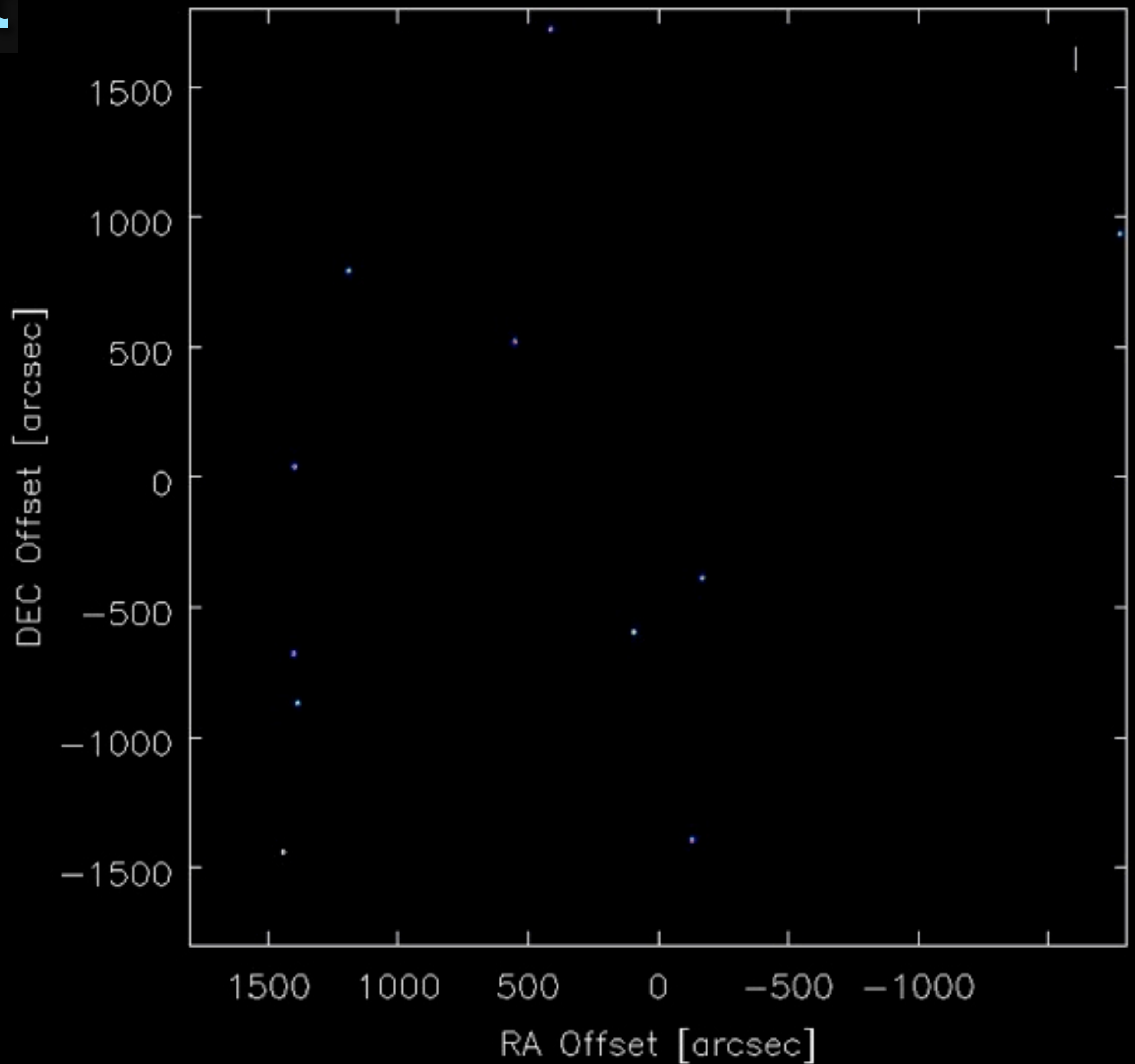
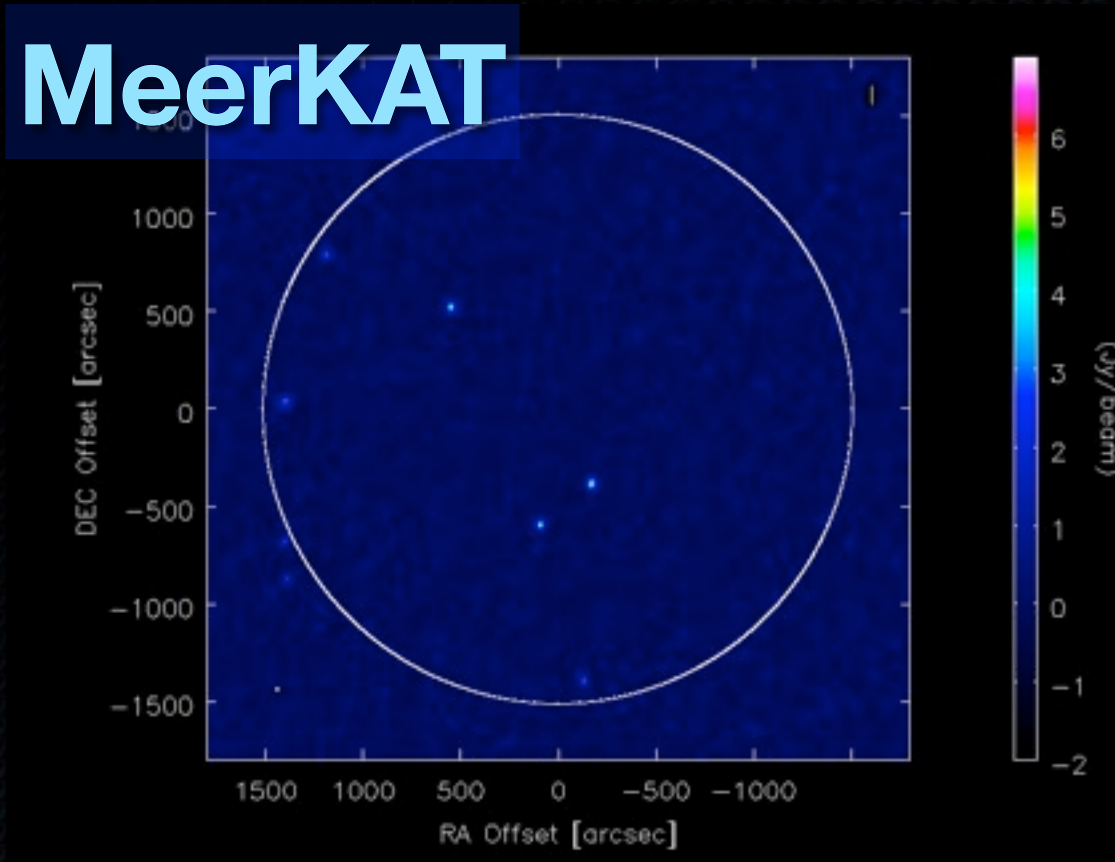
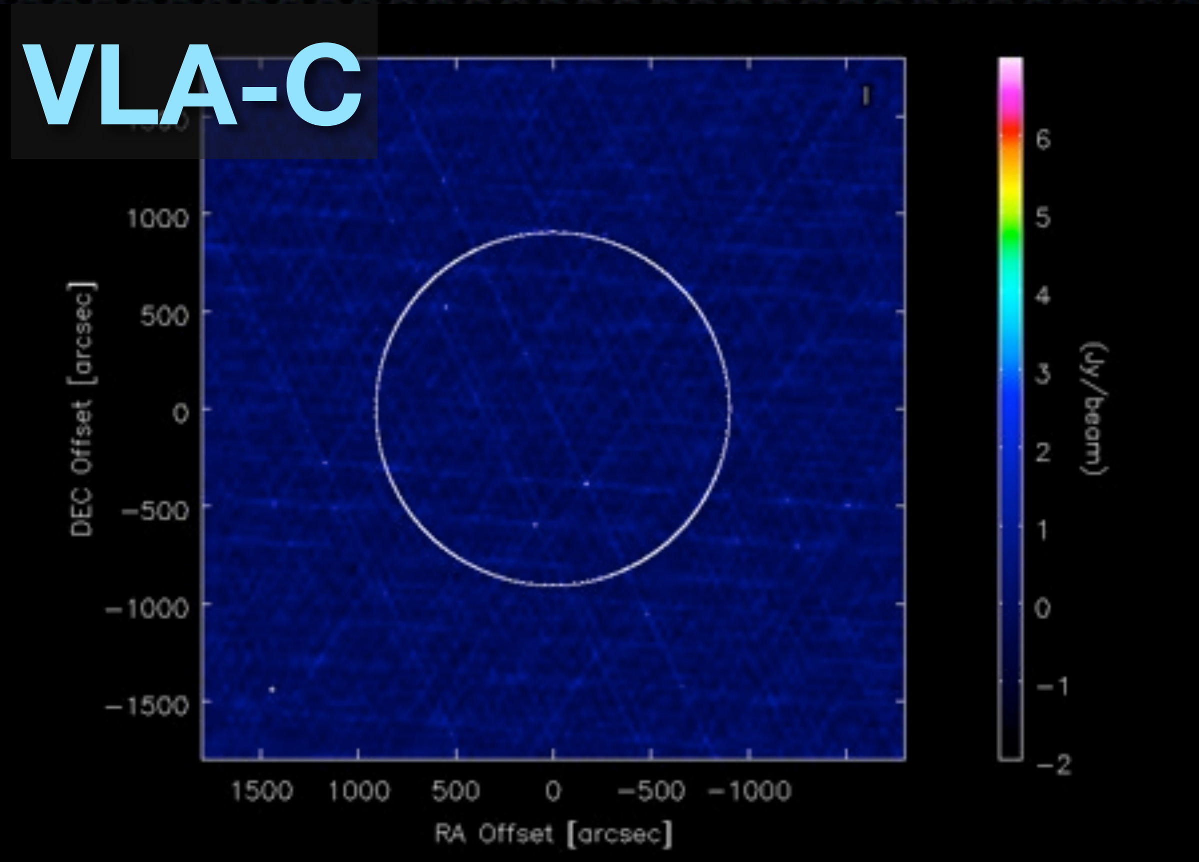
Point Sources

Input

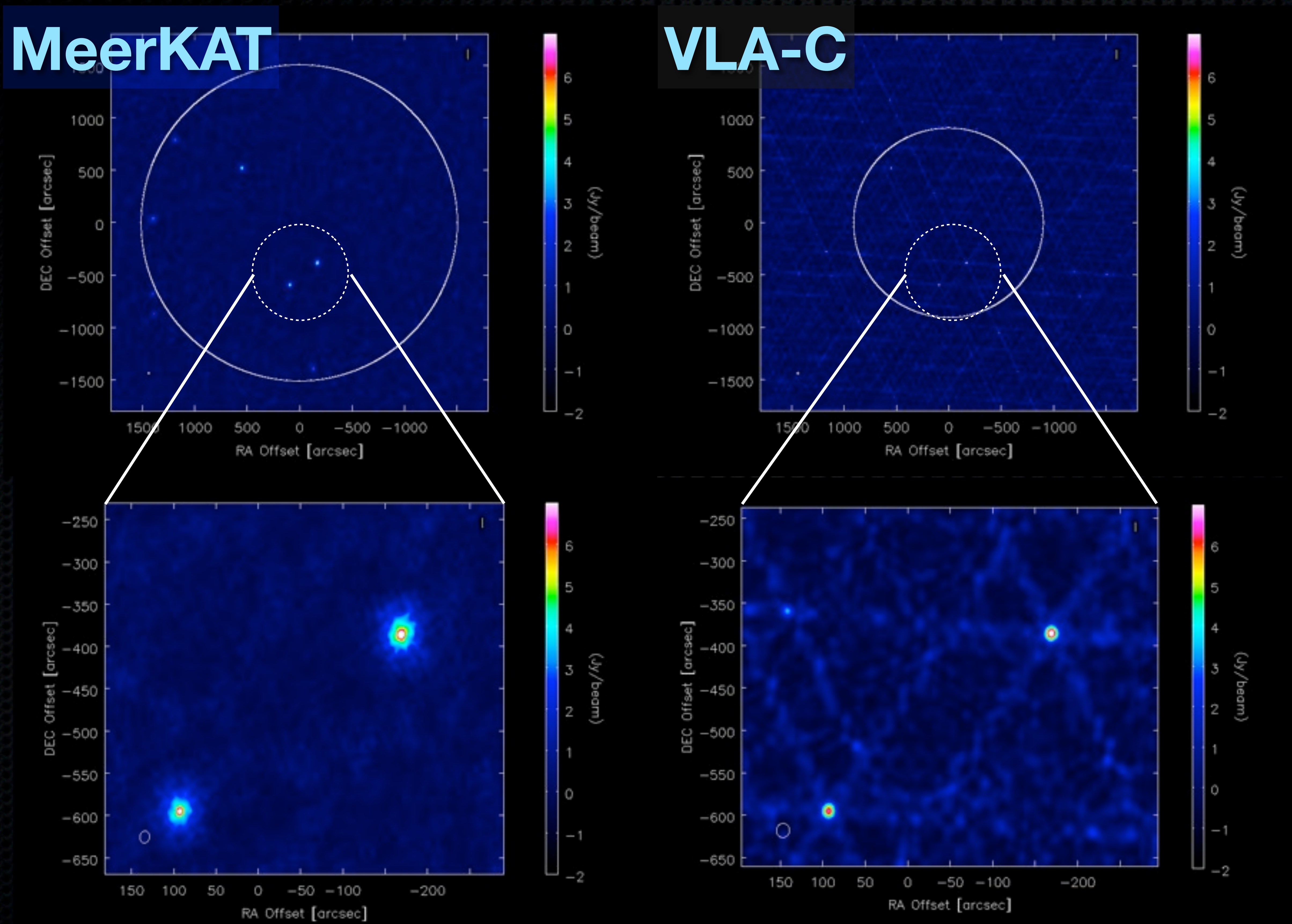


Point Sources





Point Sources



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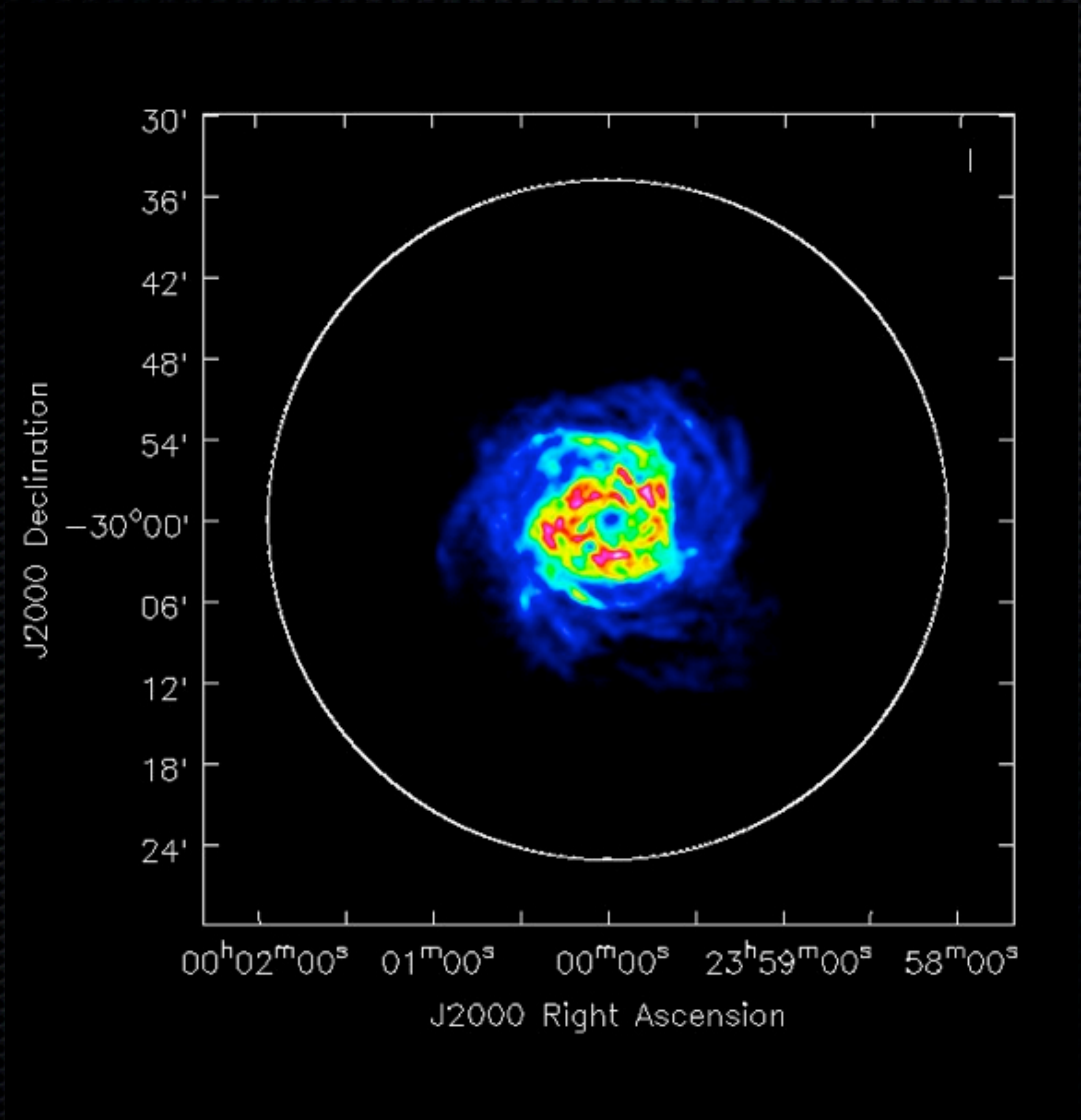
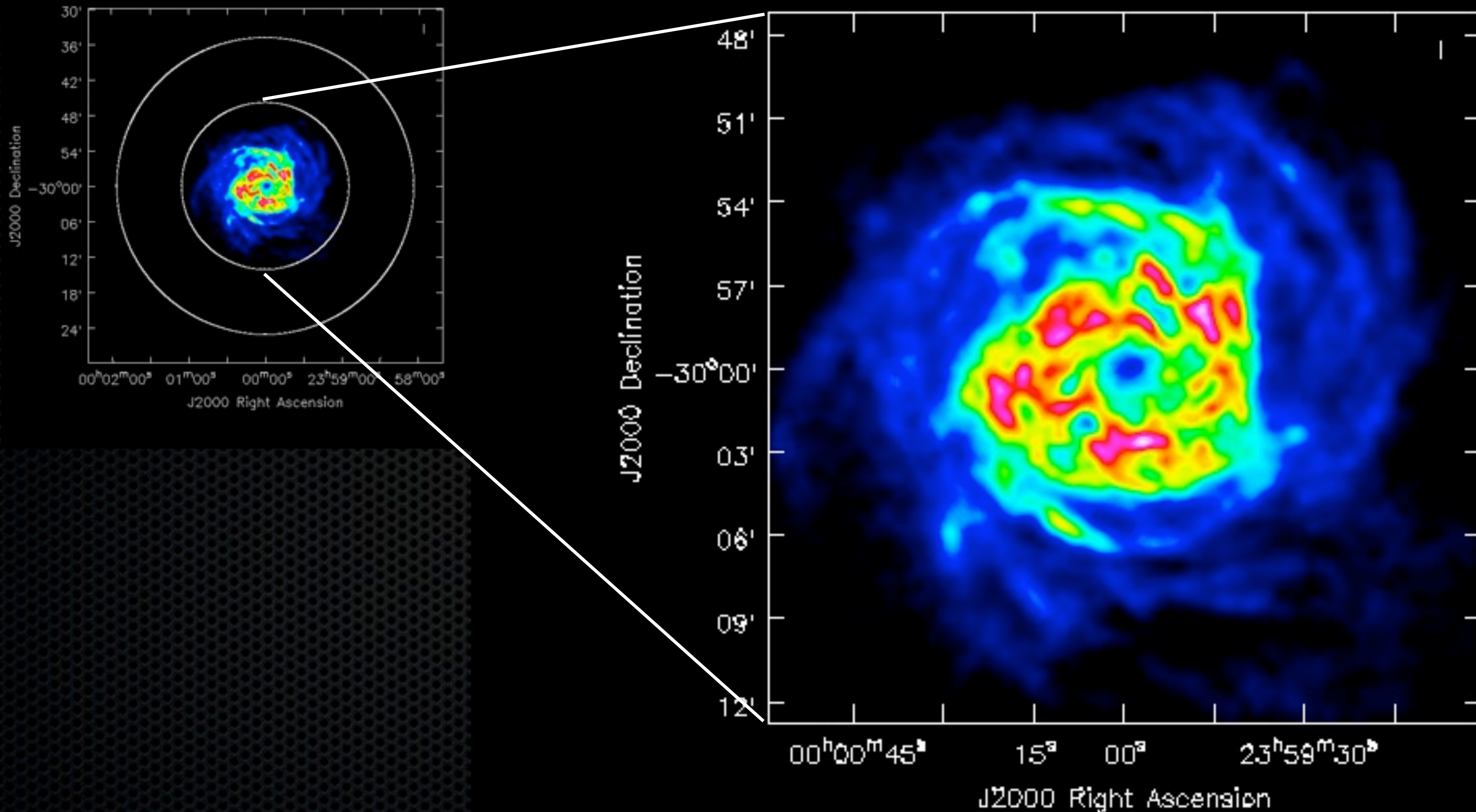
NGC628



30'
36'
42'
48'
54'
−30°00'
06'
12'
18'
24'
J2000 Declination
00h02m00s 01m00s 00m00s 23h59m00s 58m00s
J2000 Right Ascension

NGC628


30'
36'
42'
48'
54'
−30°00'
06'
12'
18'
24'
J2000 Declination
00h02m00s 01m00s 00m00s 23h59m00s 58m00s
J2000 Right Ascension
48'
51'
54'
57'
−30°00'
03'
06'
09'
12'
J2000 Declination
00h00m45s 15s 00s 23h59m30s
J2000 Right Ascension

Results

FLAT

Cleaned Image

Briggs

Robustness = 0

$N_{iter}(max) = 1000$

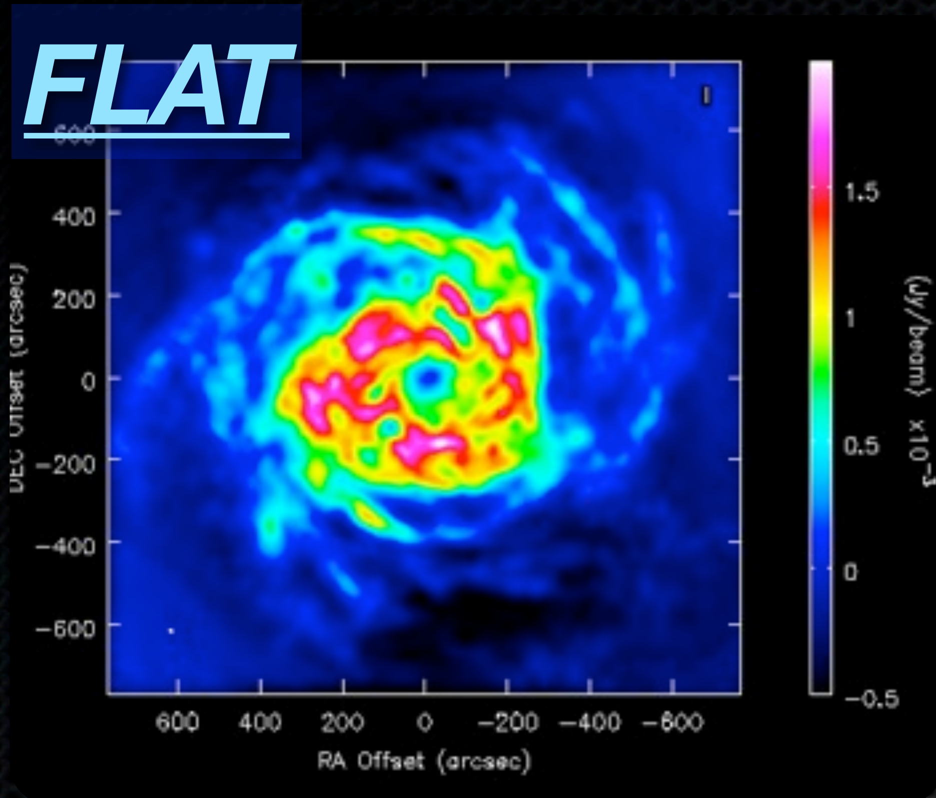
Abs. Diff.

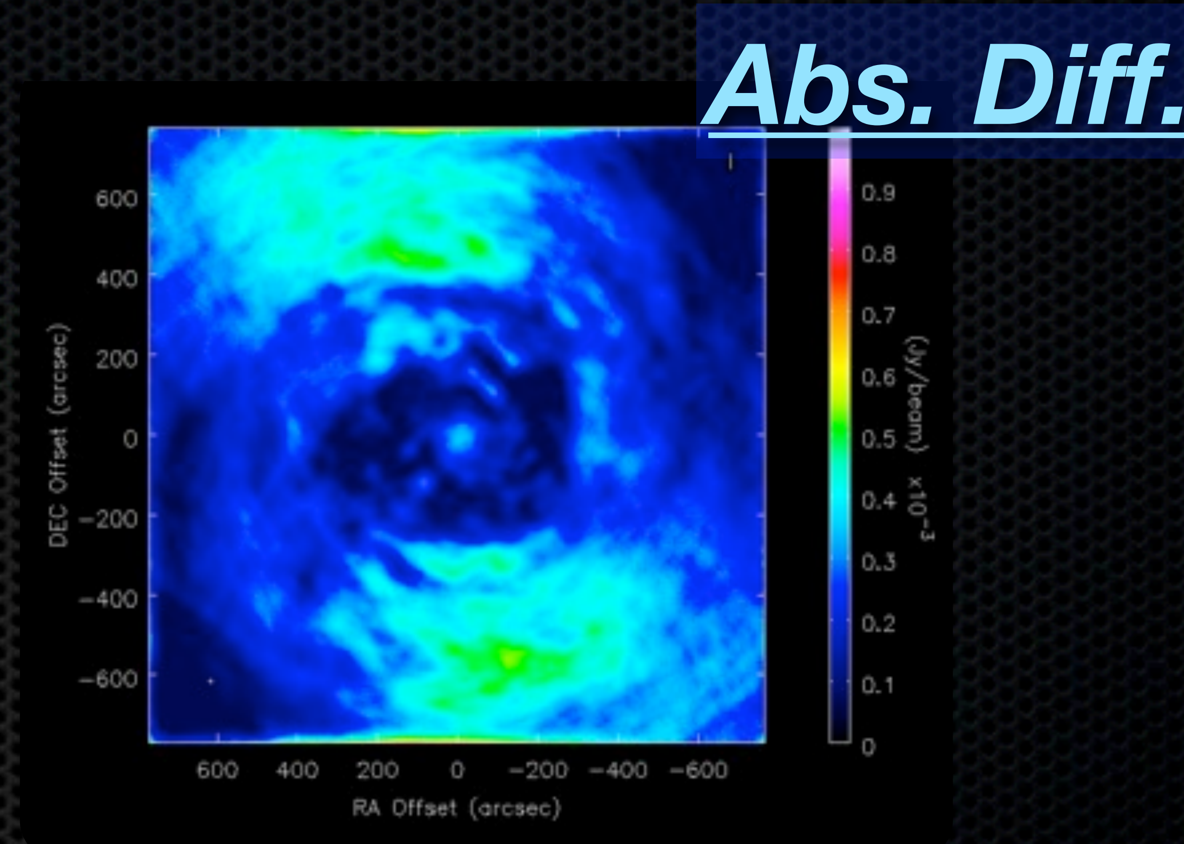
abs[Input - Cleaned]

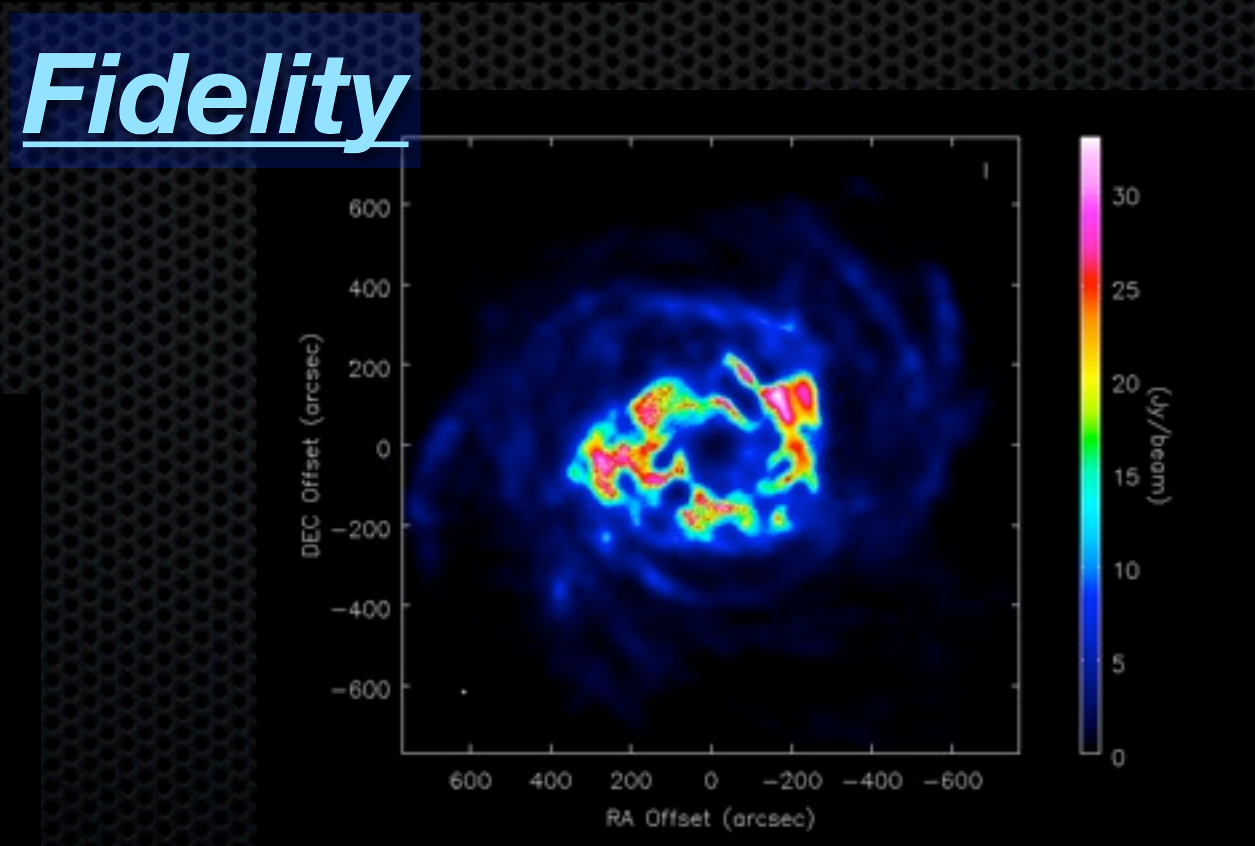
Fidelity

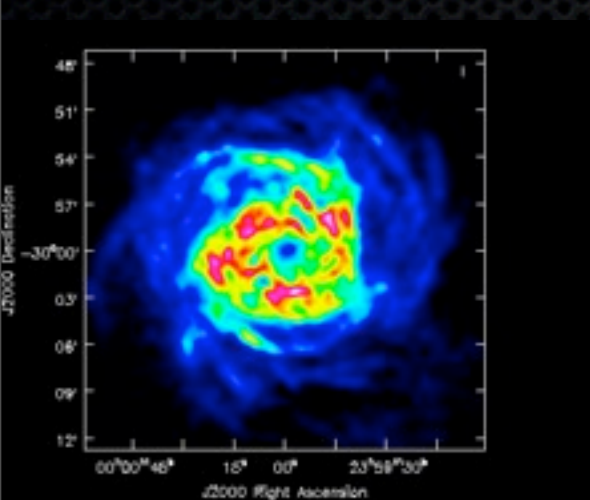
$$\frac{\text{Input}}{\text{max[difference, 0.7*rms(difference)]}}$$

MeerKAT V1


FLAT
DEC Offset (arcsec)
RA Offset (arcsec)
(Jy/beam) x10^-3
600
400
200
0
−200
−400
−600
1.5
1
0.5
0
−0.5

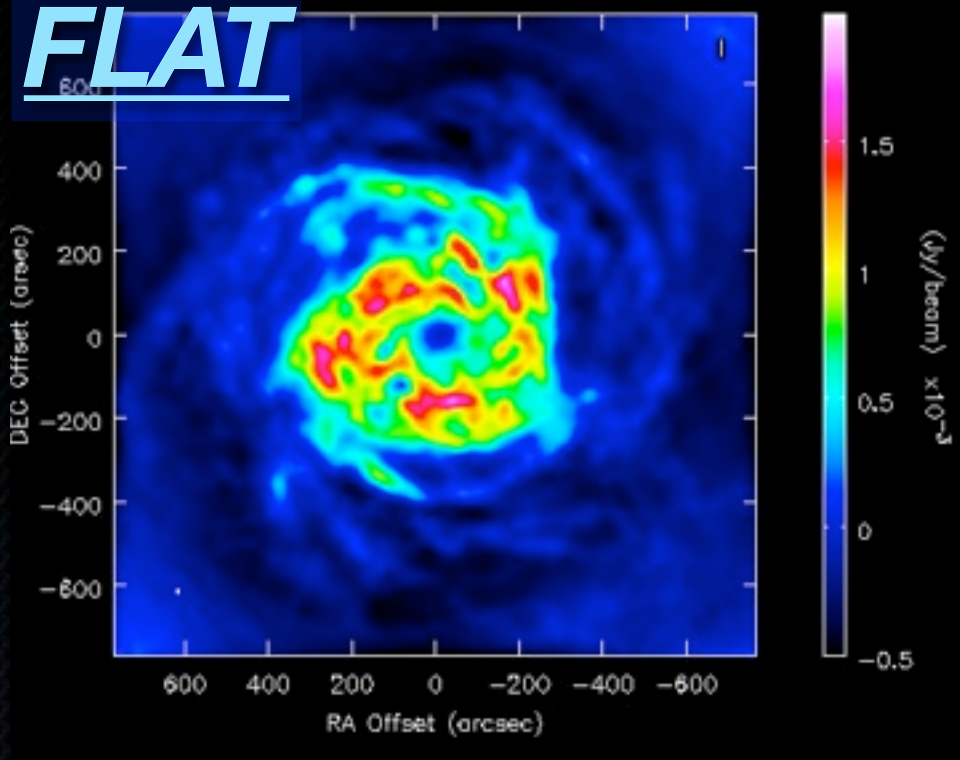

Abs. Diff.
DEC Offset (arcsec)
RA Offset (arcsec)
(Jy/beam) x10^-3
600
400
200
0
−200
−400
−600
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


Fidelity
DEC Offset (arcsec)
RA Offset (arcsec)
(Jy/beam)
600
400
200
0
−200
−400
−600
30
25
20
15
10
5
0

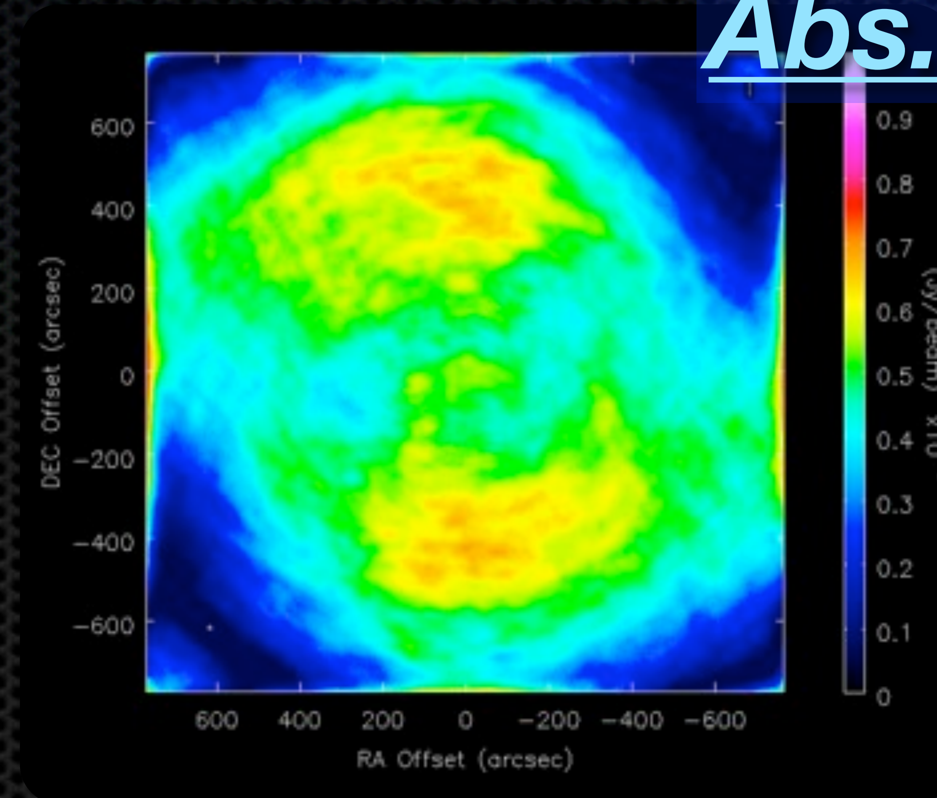

J2000 Declination
J2000 Right Ascension

MeerKAT V3.6

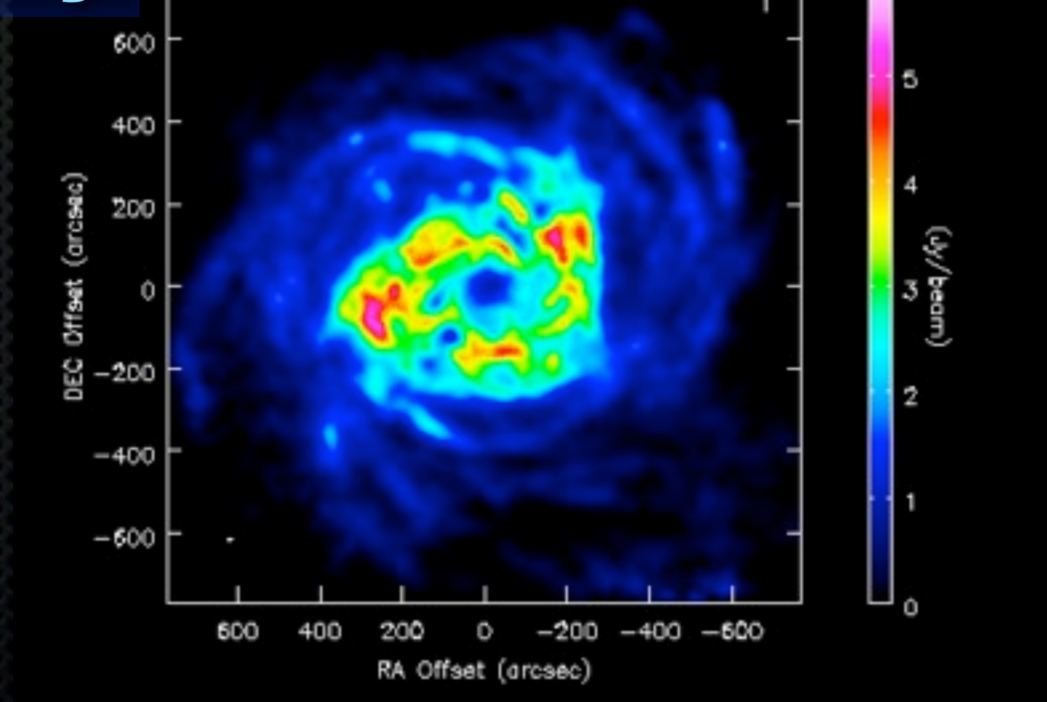
FLAT

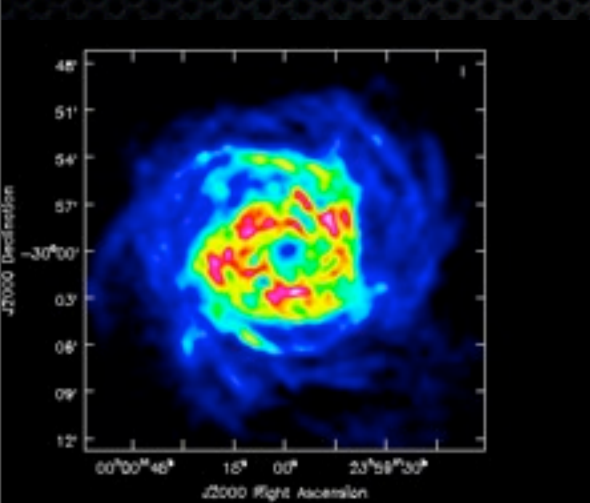


Abs. Diff.



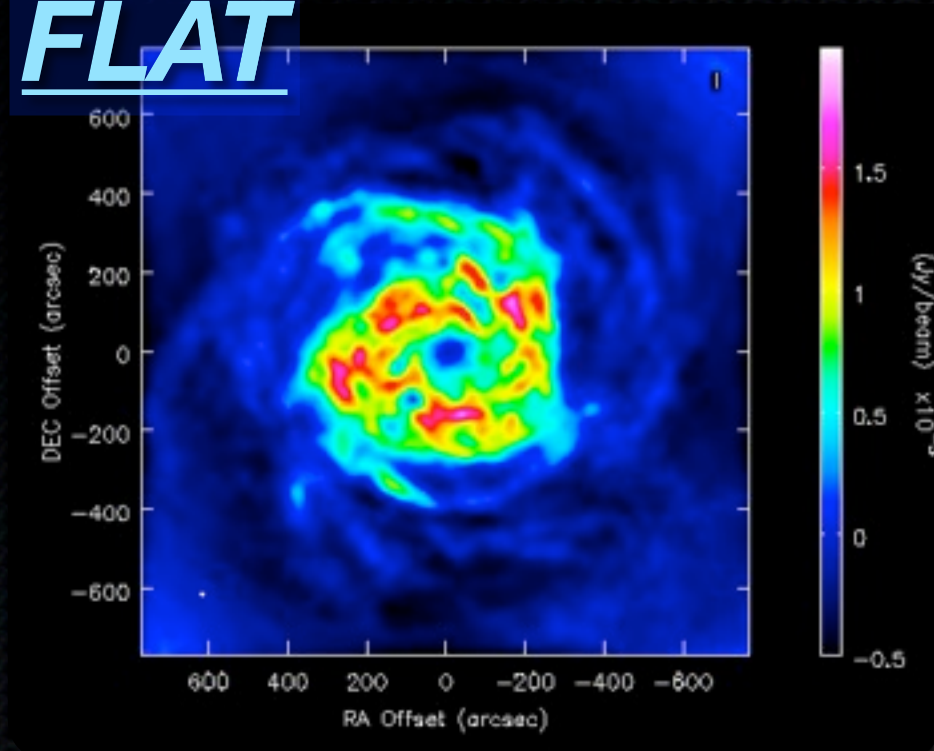
Fidelity



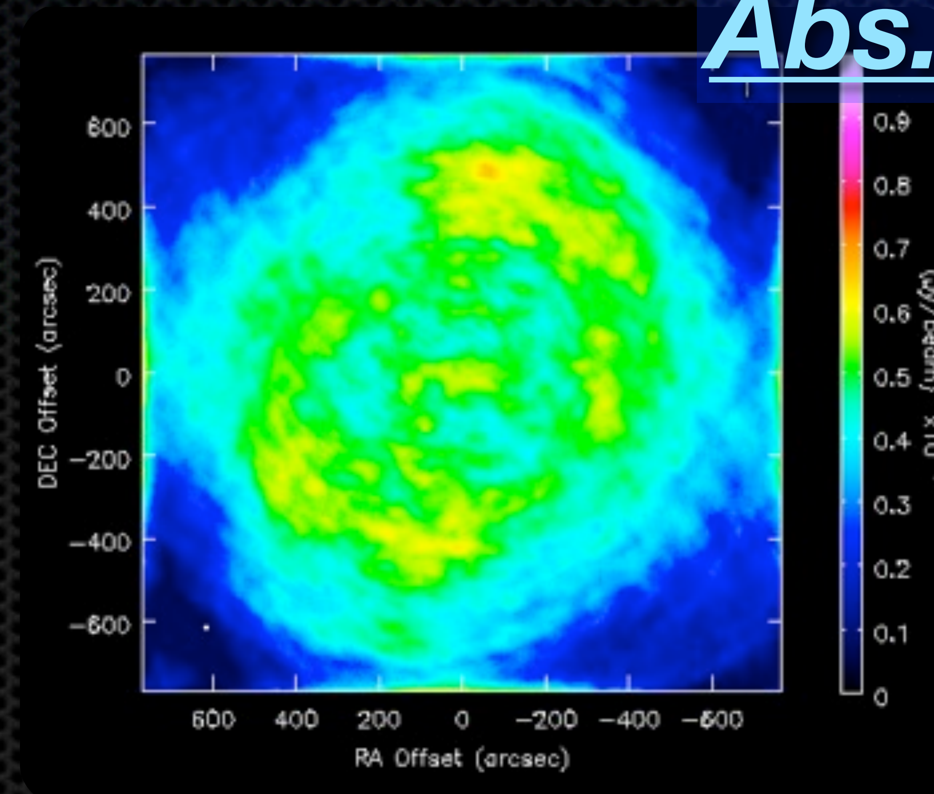


MeerKAT 64-Dish

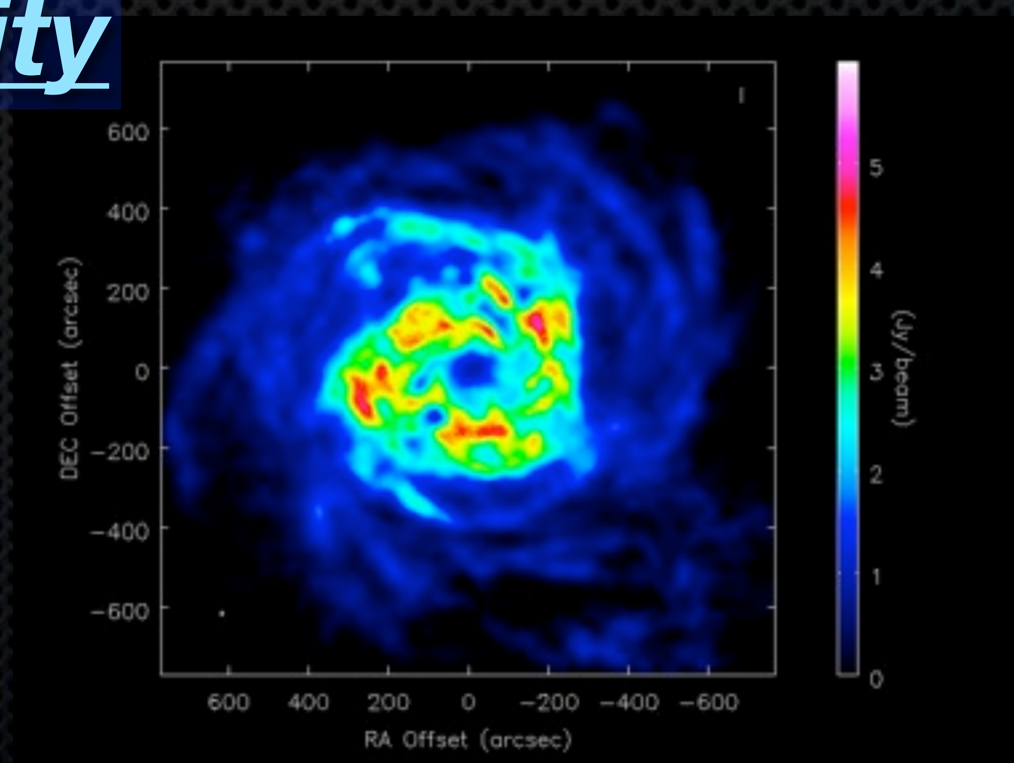
FLAT

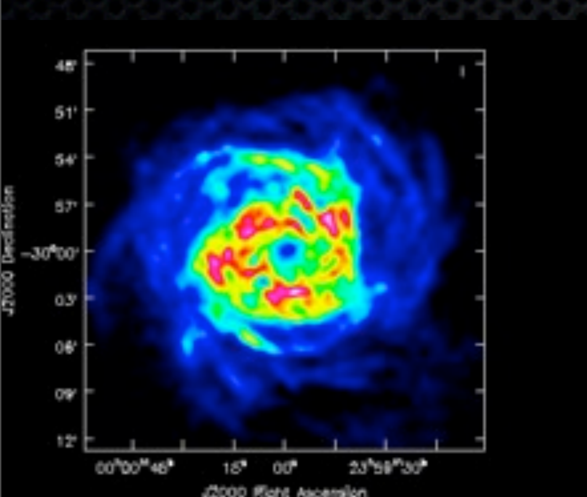


Abs. Diff.



Fidelity

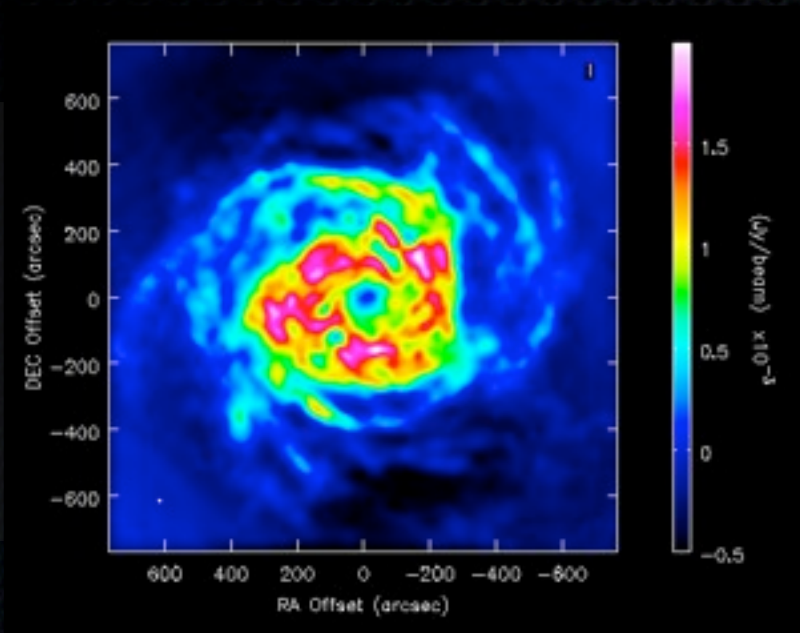


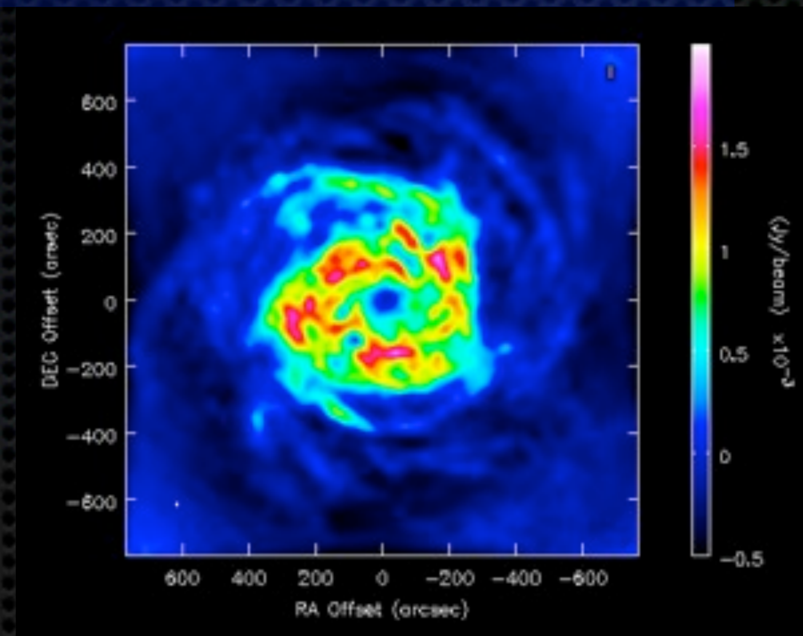


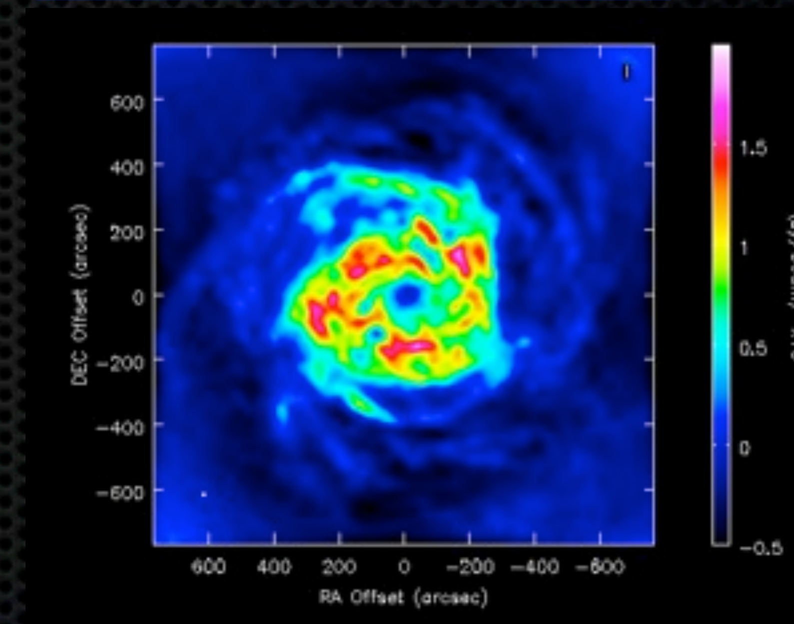
Comparisons

MeerKAT V1 | MeerKAT V3.6 | MeerKAT-64

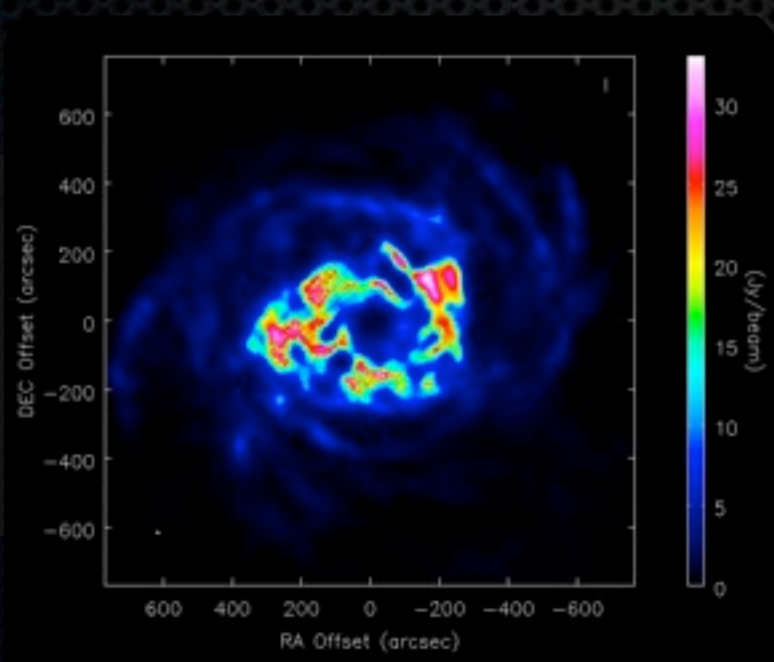
Cleaned

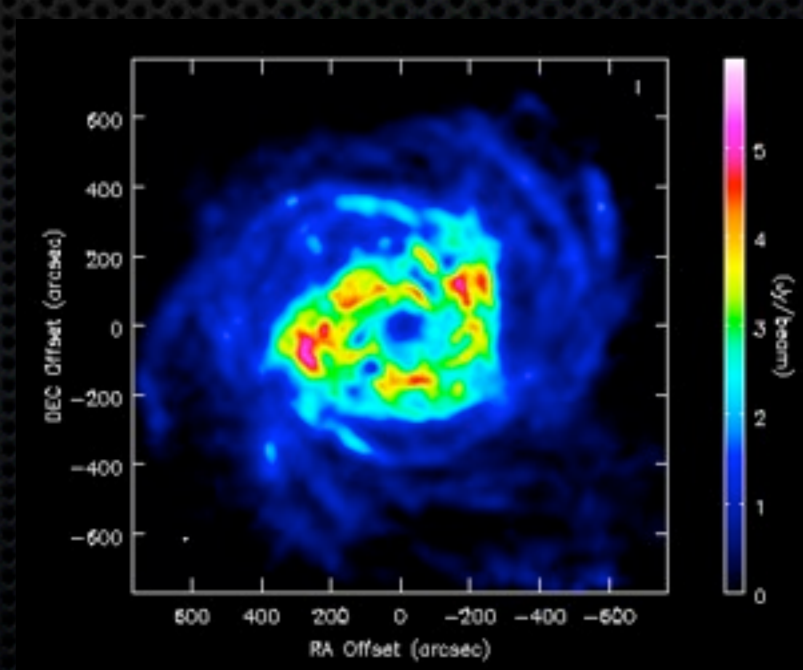


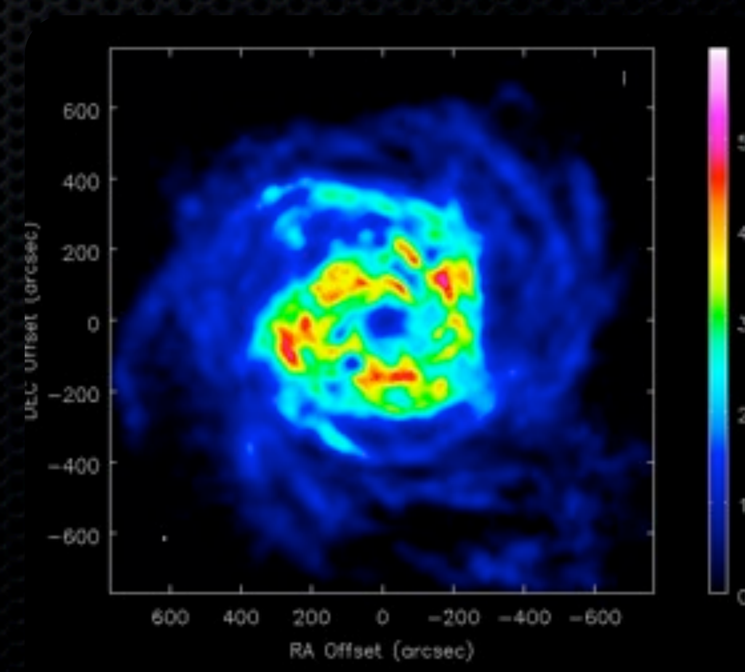




Fidelity



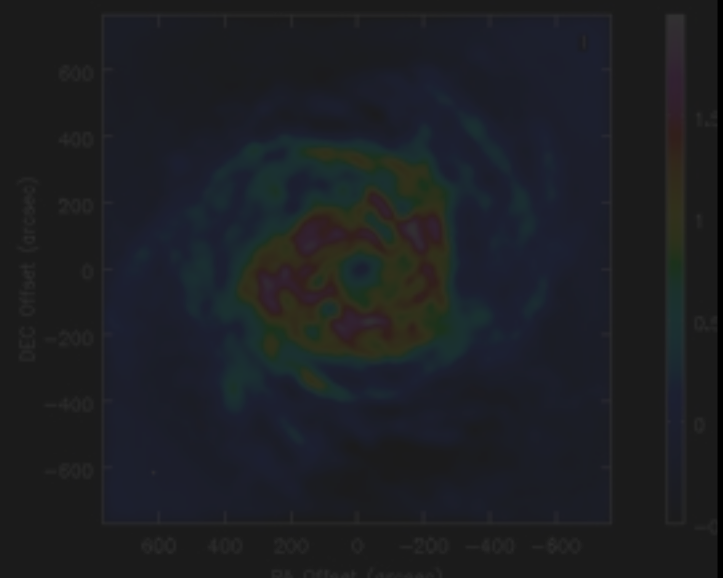


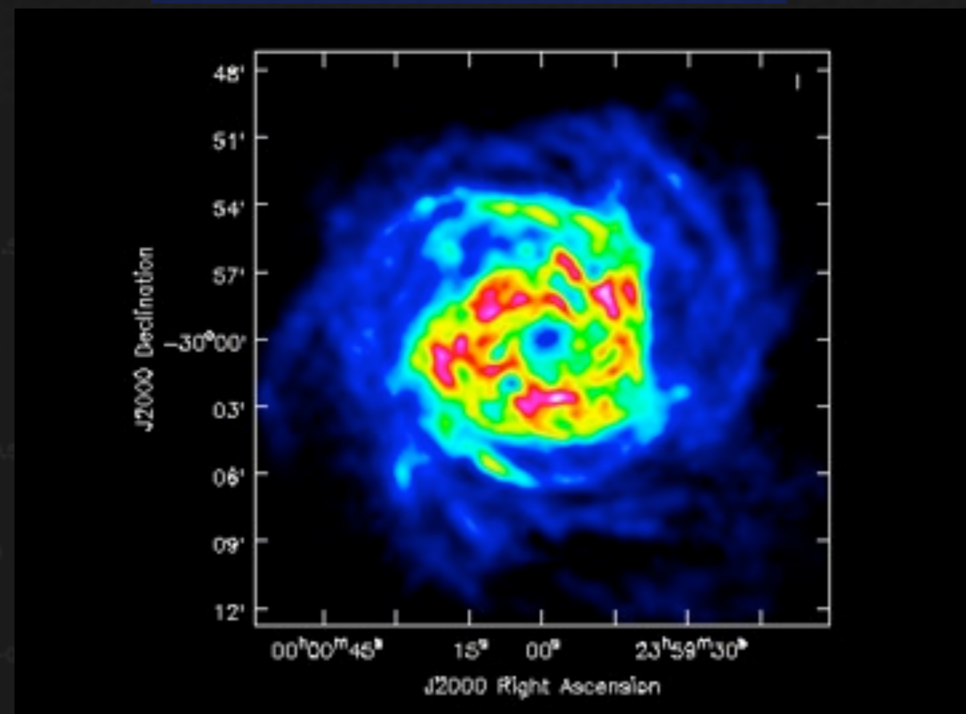


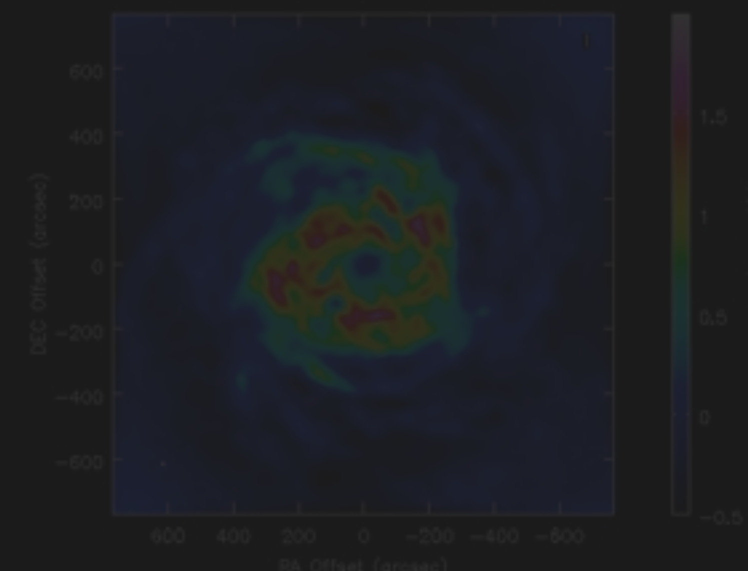
Comparisons

N628 Model

Cleaned





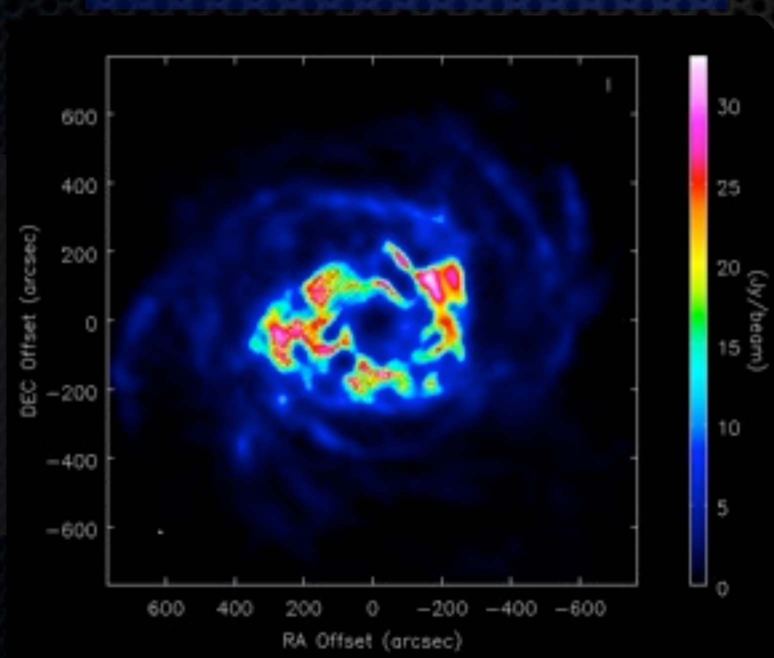


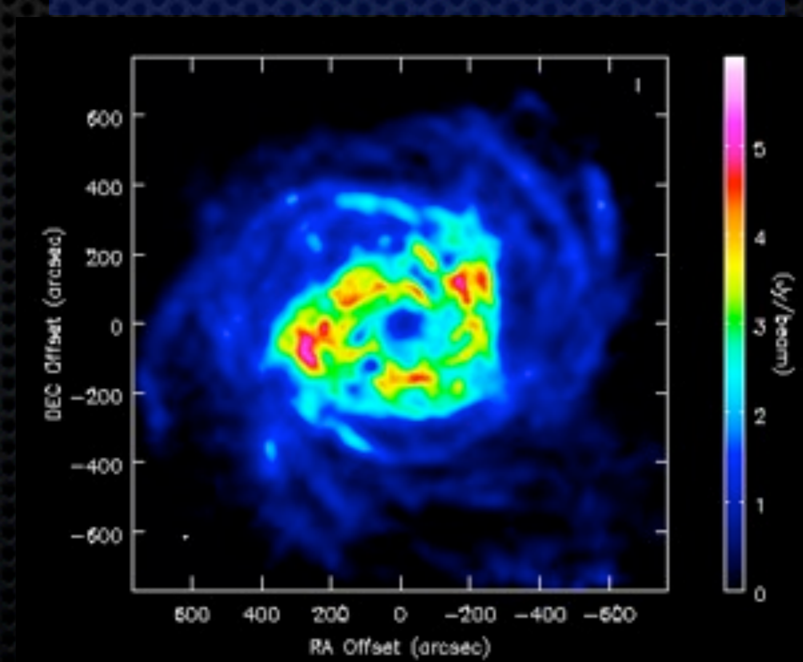
MeerKAT V1

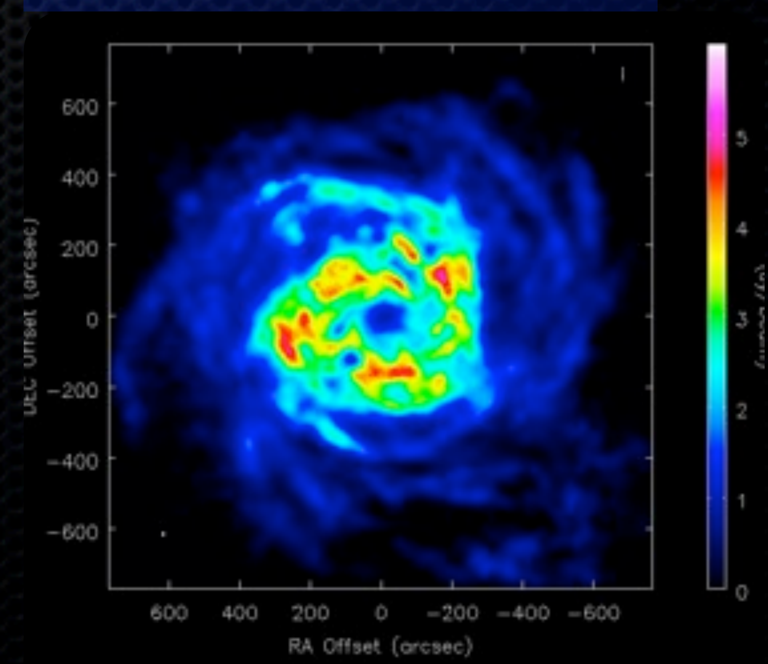
MeerKAT V3.6

MeerKAT-64

Fidelity







Moving Forward...

- Use S^3 for Model Inputs for Deep HI and Continuum
- More Imaging Simulations
- Noisify (only works properly for ALMA)
- Import MeerKAT Specs into CASA
- Release Documentation and Use Cases to Local Community (end of 2010)

Moving Forward...

- First Light Spectral Line Imaging with MeerKAT Demonstrator KAT-7 (2011)
  - Commissioning later this year
- Independent Scientific Component
  - Comparisons of CO and HI Dynamics of THINGS Galaxies
- Member of SKA-SA Configurations Working Group, consultant slave at MeerKAT Project Office

Friday, 7 May 2010