

# MeerKAT Status and Science Processing

*Jasper Horrell, CALIM2010, ASTRON, Netherlands*



**SKA** SOUTH AFRICA  
SQUARE KILOMETRE ARRAY



# Common Issues?

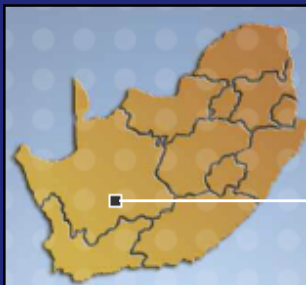
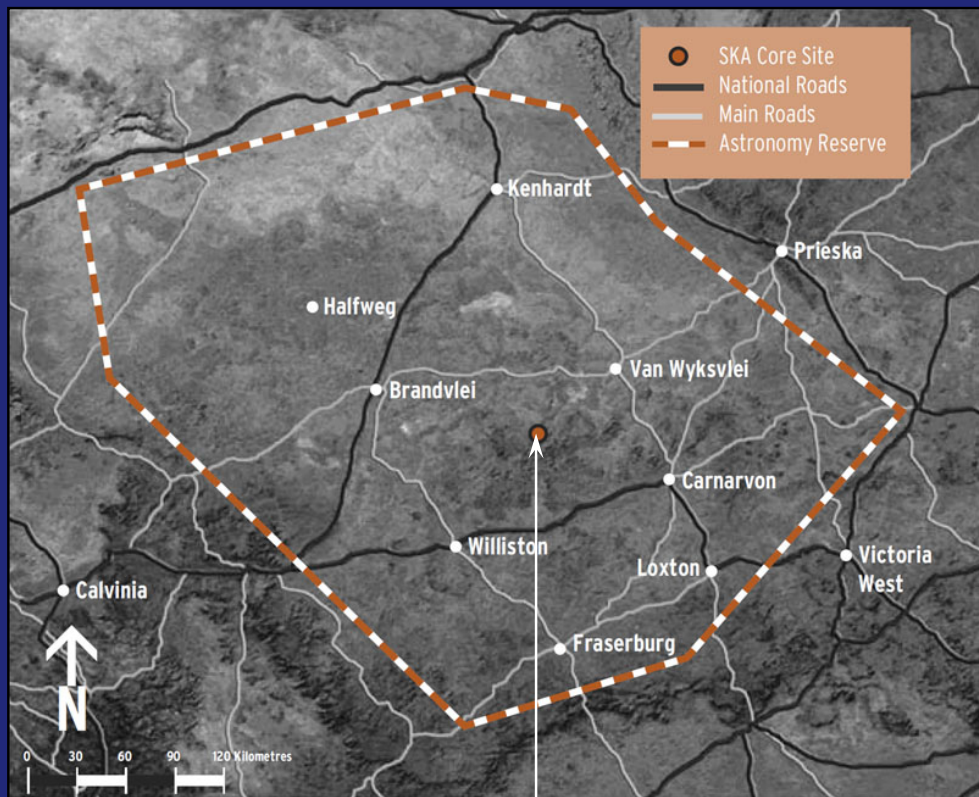
<b>Severity of issue (high, medium, low, none)</b>
Strong sources contaminating the data through primary beam sidelobes
Wide field calibration
Wide field imaging
Wide field deconvolution
Mosaicing in full polarization
Mosaicing with different primary beams
Large data volumes: require automated pipelines
Large data volumes: standardization of data formats and use of common tools
Large data volumes: processing power limitations exist and some shortcuts needed (e.g. in algorithms)
More sophistication in sky models
Solvability of calibration parameters (enough calibrators etc)
Time and frequency dependence of calibration parameters
Full polarization imaging
On-the-fly mapping
Long baselines / large fields of view: dumping fast enough

# MeerKAT Project Status

- Continues to enjoy good funding and political support
- KAT-7 engineering (and science) test-bed deployed on site and operated 24/7 3-4 days per week
- 3 centres: JHB (“business” and site bid); Cape Town (engineering and science); Karoo (site)
- About 75 people on the project currently (growing)
- MeerKAT Concept Design Review: 64x13.5m offset Gregorian dishes design awaits final approval
- MeerKAT major science proposals currently under evaluation

**It's going well!!**

# MeerKAT – SKA Precursor



MeerKAT:  
64 antennas

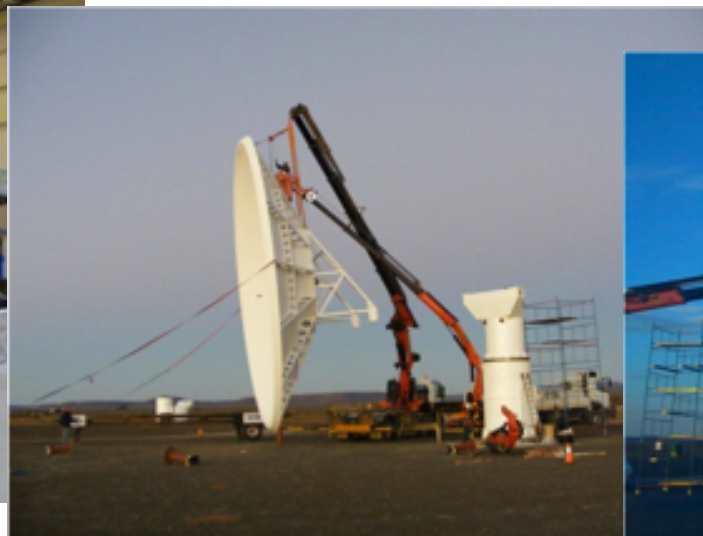
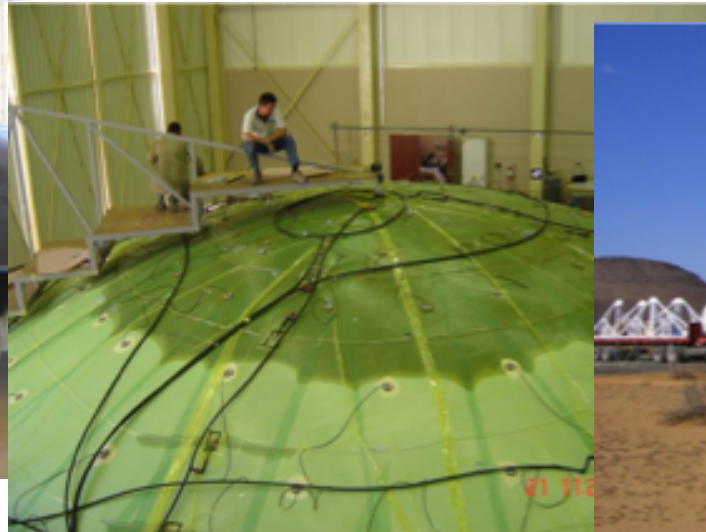
Slide: D. Shepherd



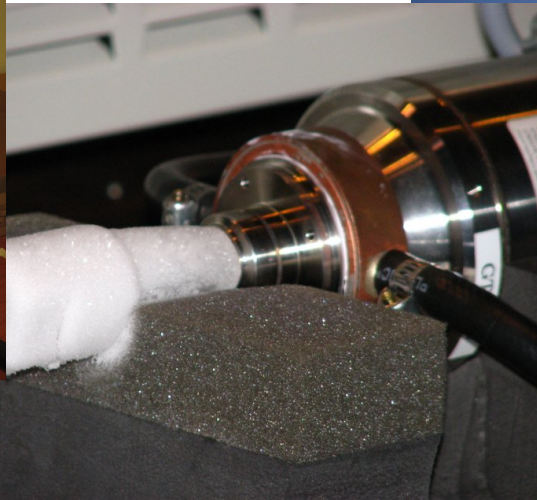
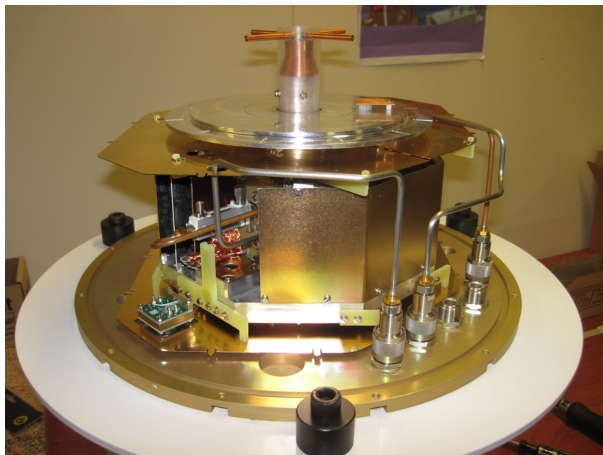
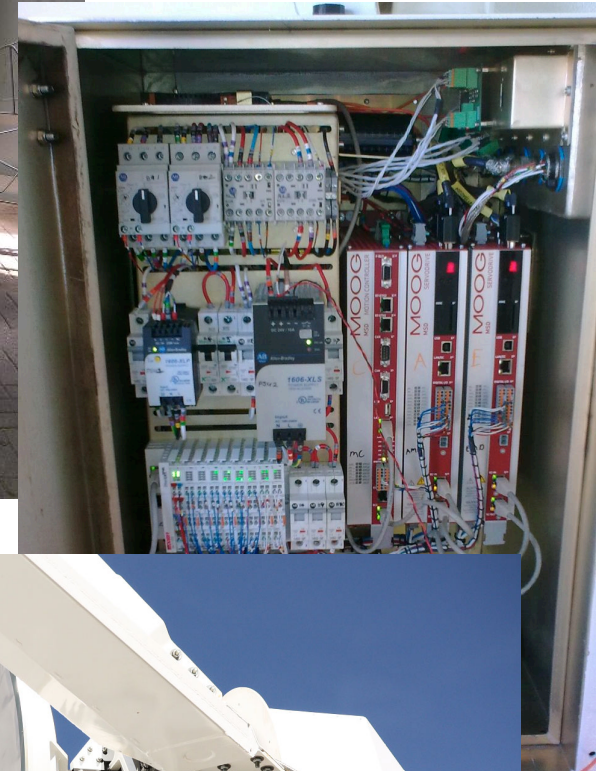
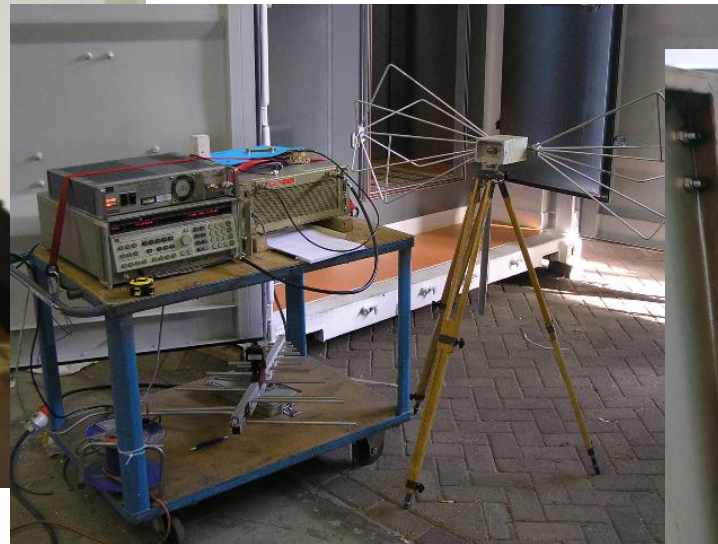
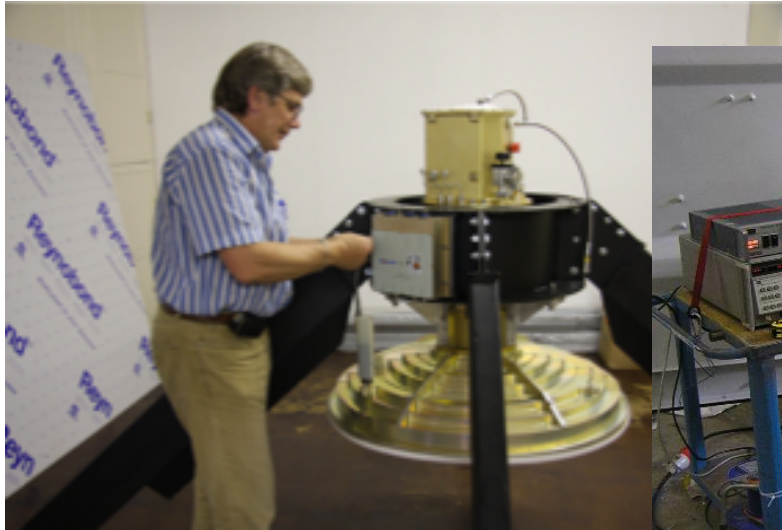
# Infrastructure



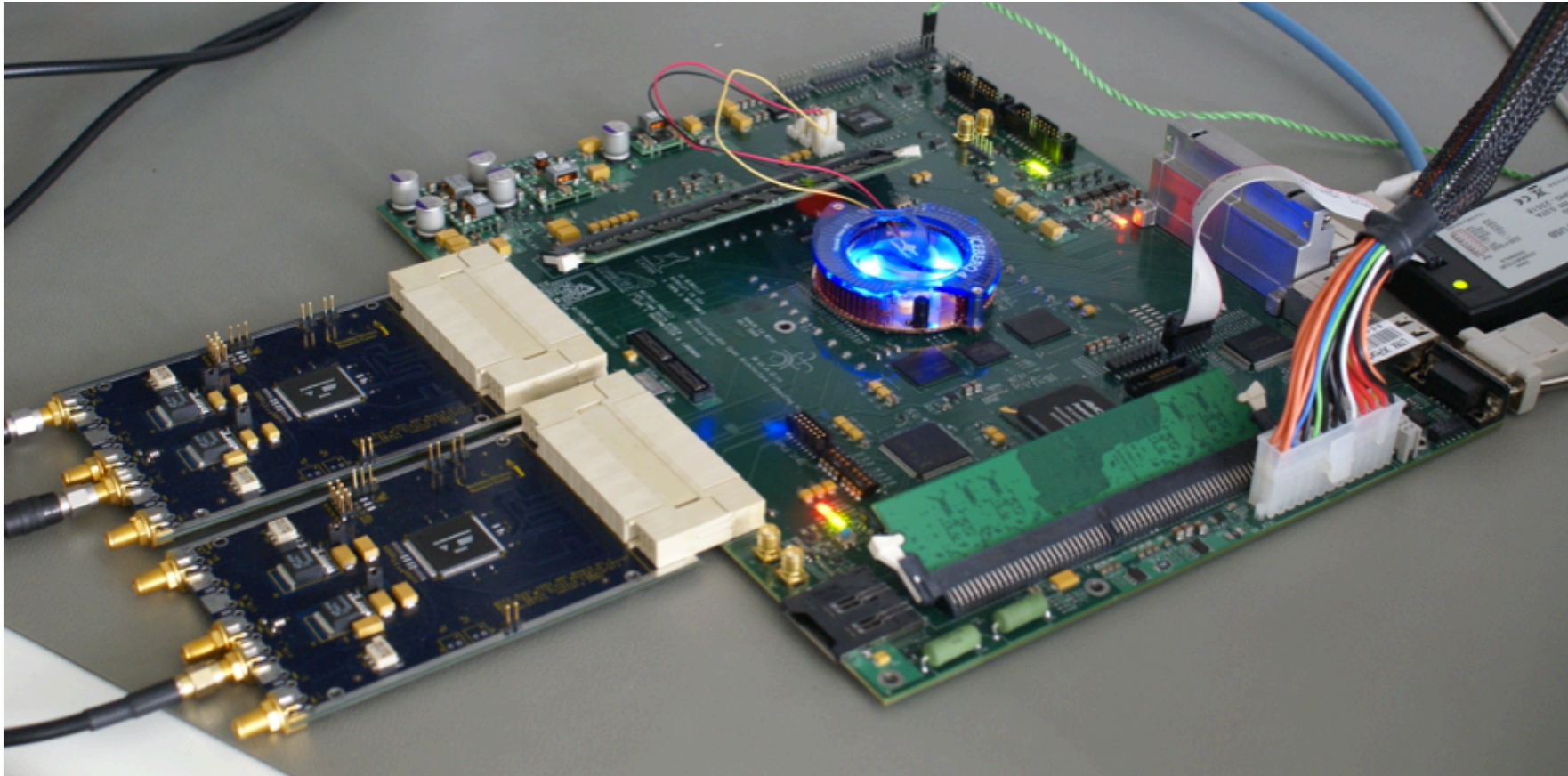
# Composite Dishes



# Feeds, Receivers & Electronics



# Digital Signal Processing



**2008:**  
ROACH1 (Virtex5)  
320 GMAC limit  
40 Gbps interconnect

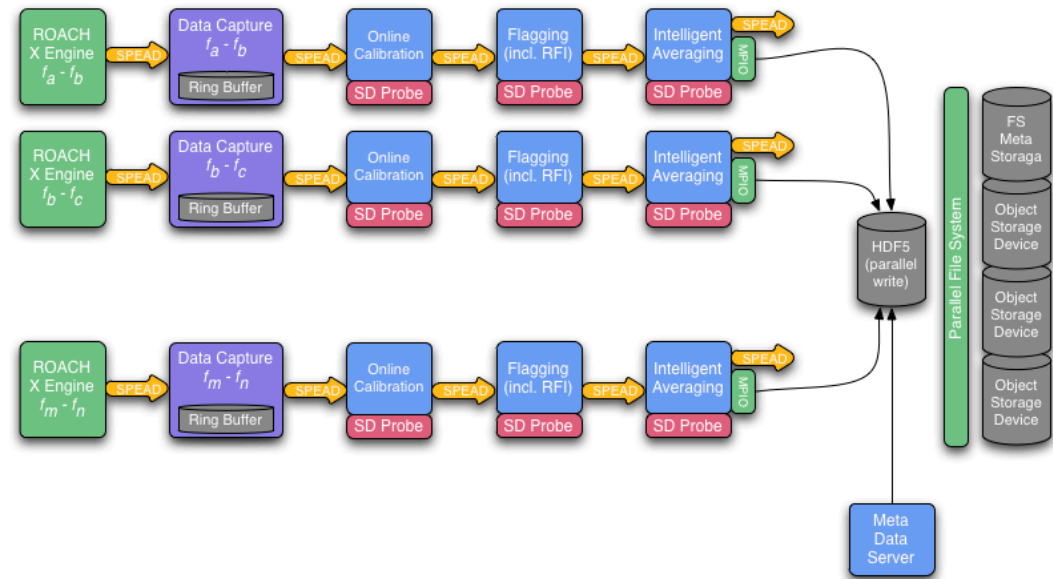
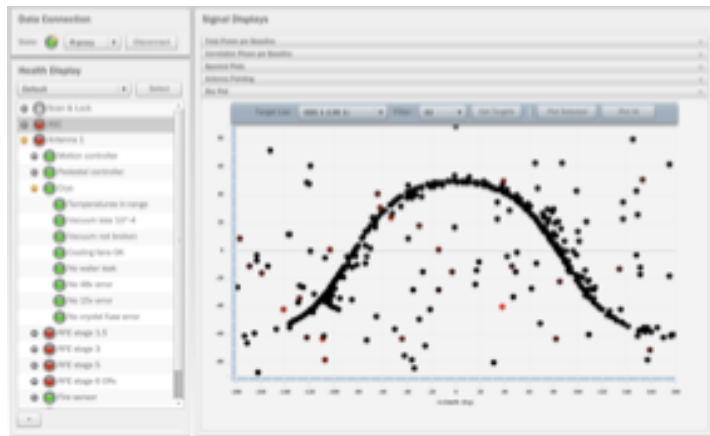
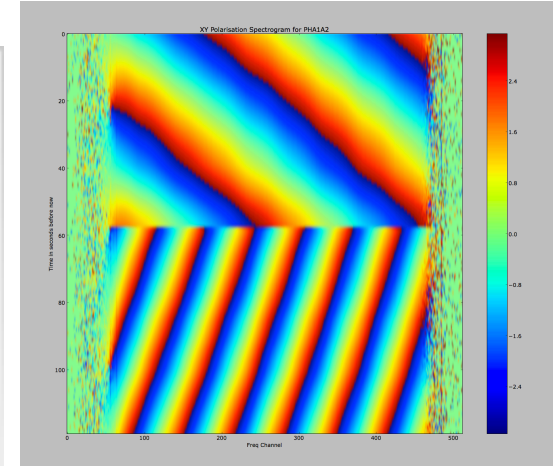
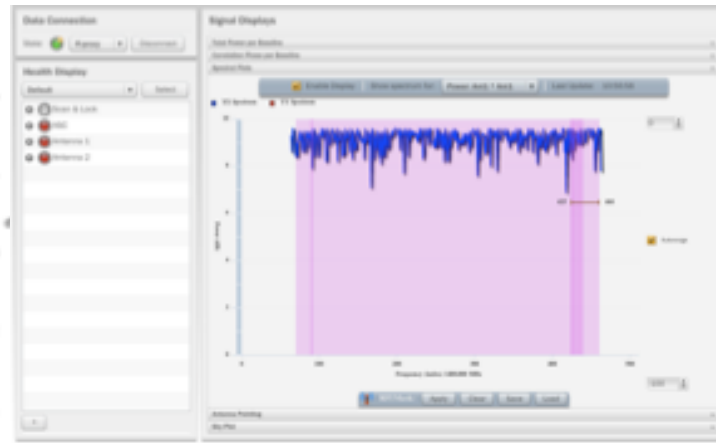
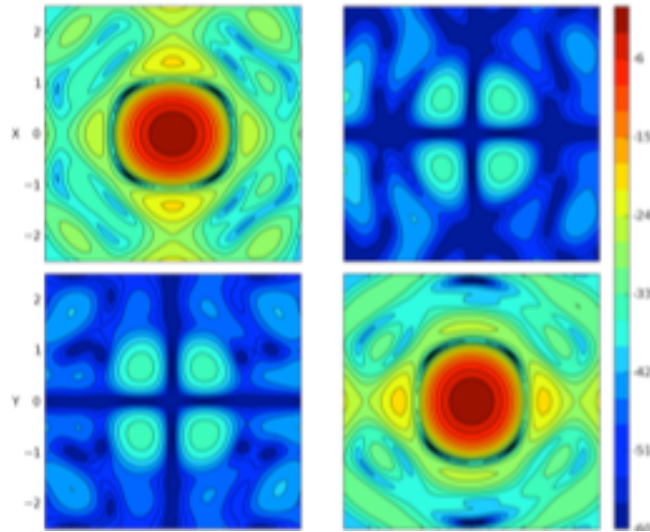
**2010:**  
ROACH2 (Virtex6)  
1.4 TMAC limit  
80 Gbps interconnect

**2012:**  
ROACH3 ('Virtex7')  
3 TMAC ?  
160 Gbps ?

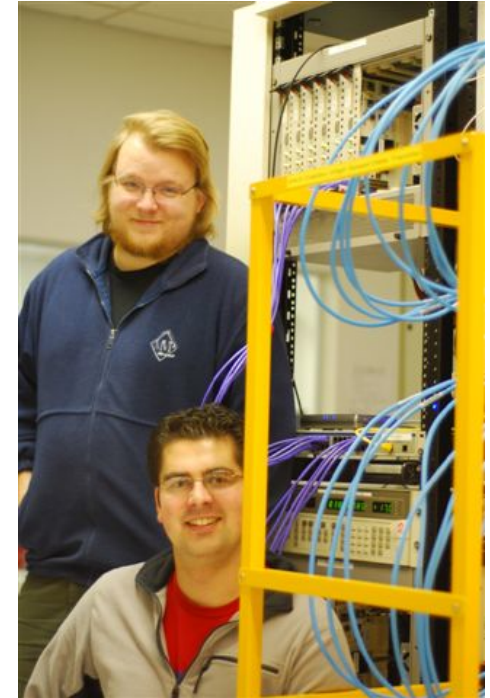
**2014:**  
ROACH4 ('Virtex8')  
6 TMAC ??  
320 Gbps ??



# Computing

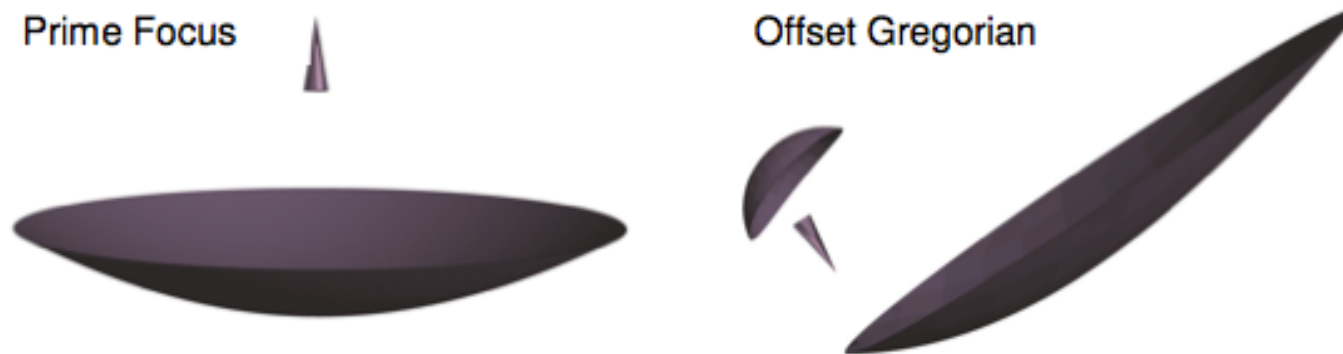


# People!



# MeerKAT Specifications

- 64x13.5m offset Gregorian dishes (likely). 1mm rms surface. 15 arcsec pointing accuracy (with approx 5 arcsec tracking consistency)
- Frequency range 0.59 – 14.5 GHz
- 65k freq channels (spread over 4 sub-bands)
- L-band sensitivity:  $A_e/T_{\text{sys}} = 220 \text{ m}^2/\text{K}$



# MeerKAT Phases/Specs

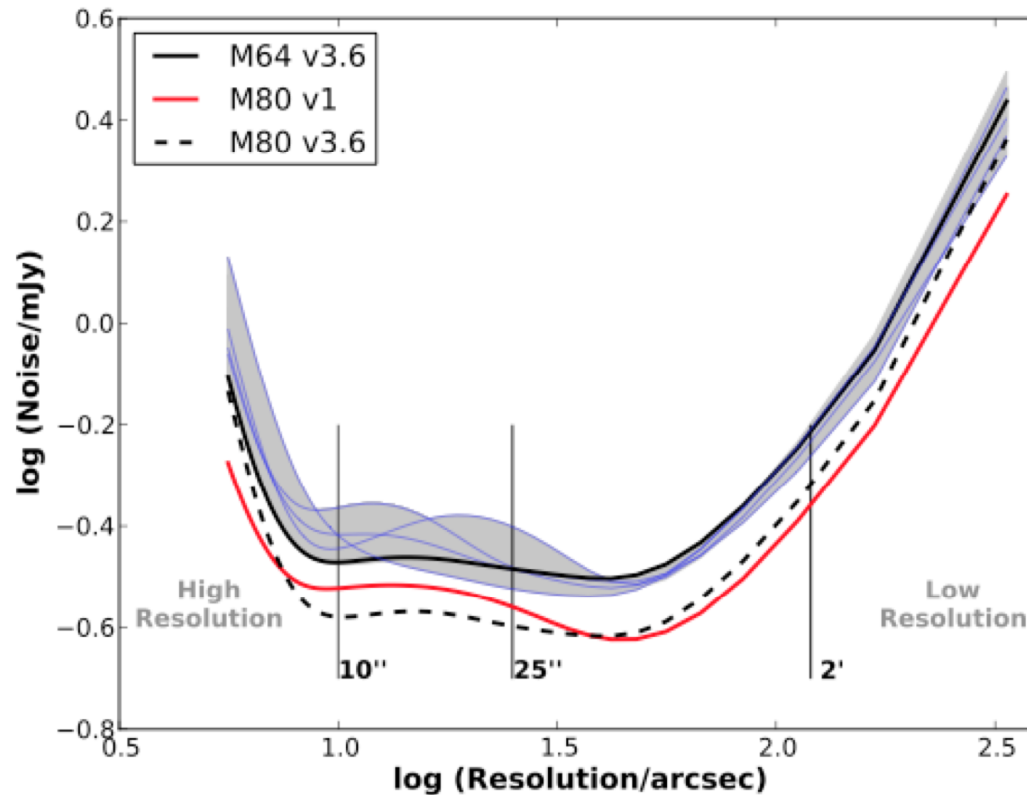
	Phase 1	Phase 2	Phase 3
Est. completion	2014	2016	2017
Frequency bands (GHz)	0.9 - 1.75	0.59 – 1.1 0.9 -1.75	0.59 – 1.1 0.9 – 1.75 8 – 14.5
RF bandwidth (MHz)	850	850	6500
Sampling frequency (Gsps)	4	4	30
Processed bandwidth (MHz)	850	850	6500
Max baseline (km)	8	50	50

# Array Layout

- Work by Brad Frank & Erwin de Blok
- 64-dish layout close to final (80-dish superset also exists). Some small tweaks may still occur.
- Designed with fairly compact core, but also with good sensitivity over range of resolutions (flat over 10-50 arcsecs)

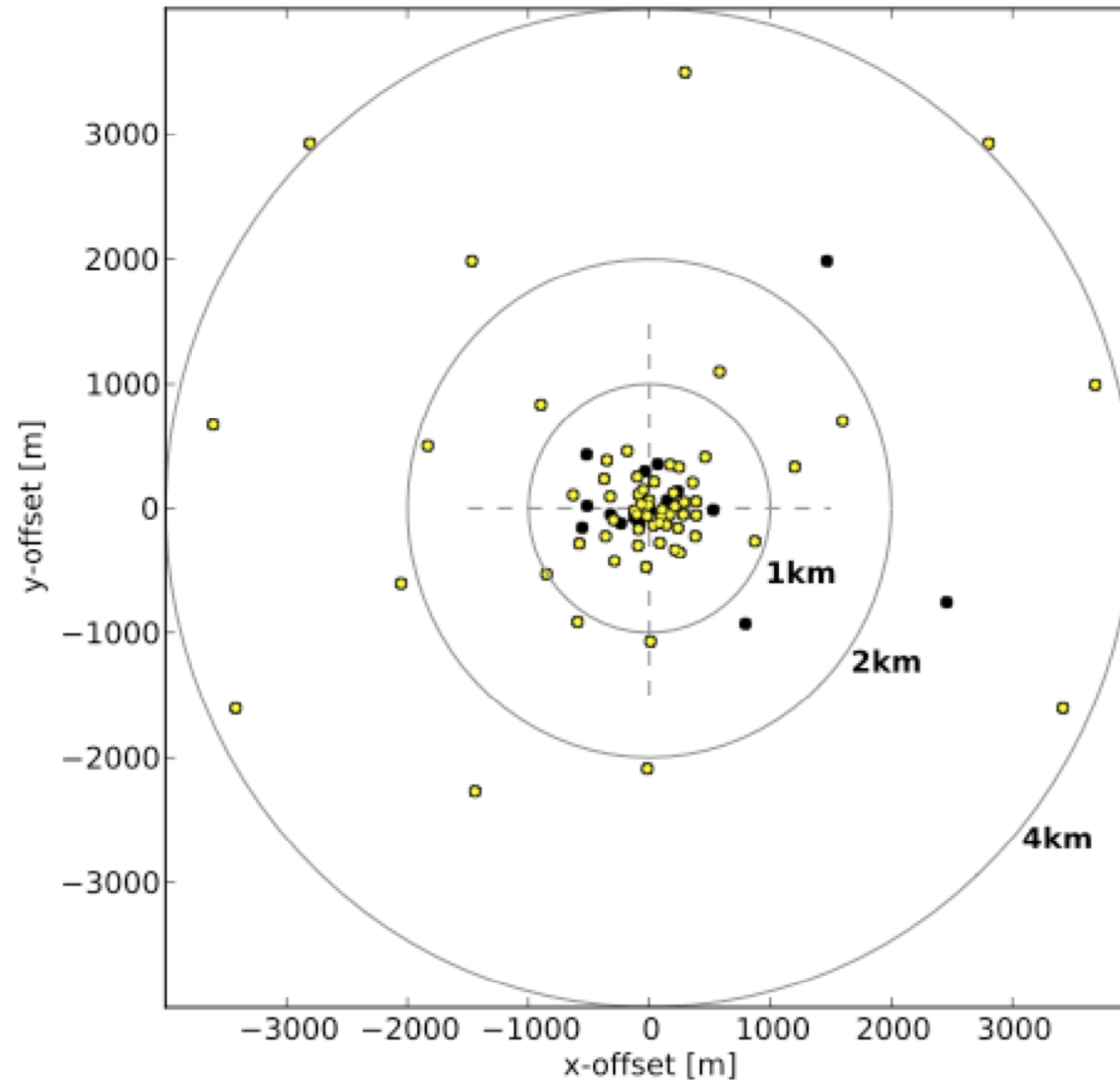
	<b>MeerKAT 80 (Ver. 3.6)</b>	<b>MeerKAT 64 (Ver. 3.6)</b>
<b>Min baseline</b>	29 m	29 m
<b>N(dishes) within 500 m</b>	48	39
<b>N(dishes) within 1 km</b>	58	45
<b>N(dishes) within 2 km</b>	67	53
<b>N(dishes) within 4 km</b>	78	62
<b>Max baseline</b>	7.7 km	7.7 km

# Array Layout



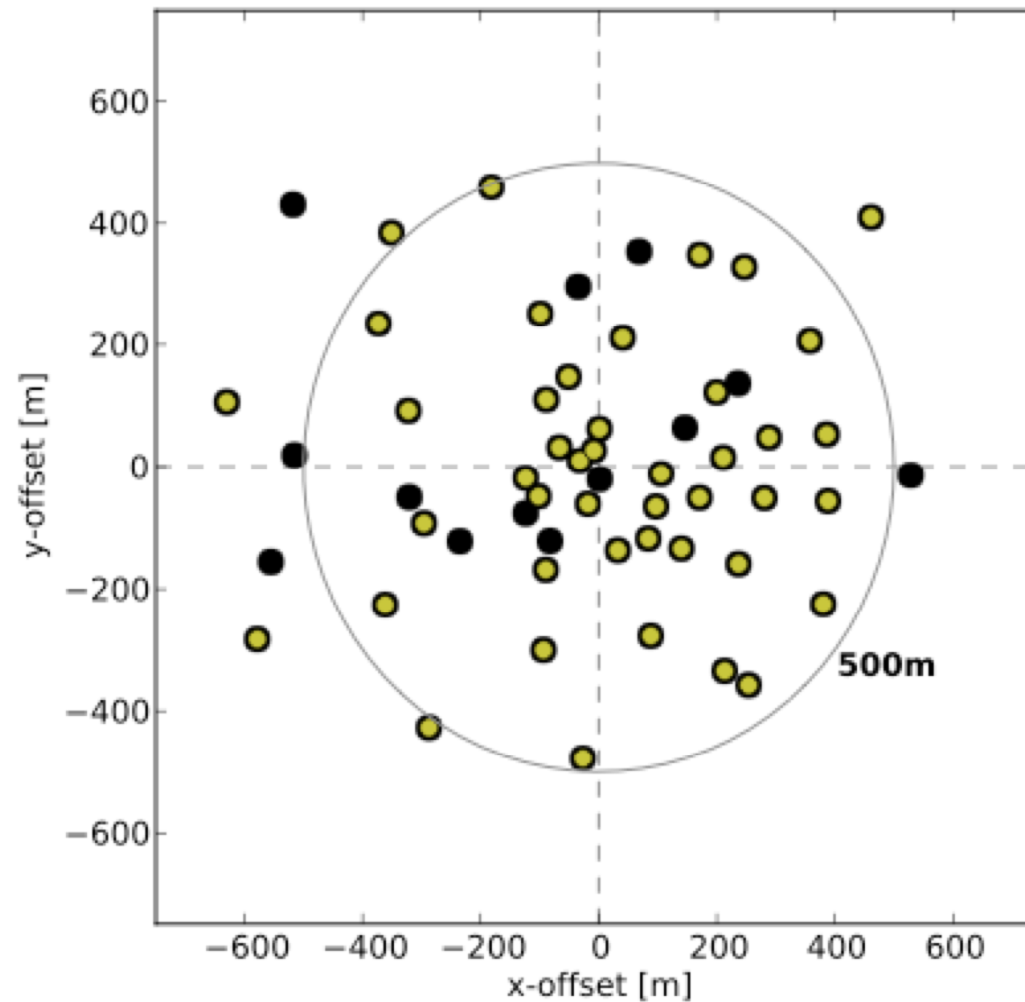
Sensitivity versus resolution for original 80-dish (ver1), 80-dish (ver 3.6) and 64-dish (ver 3.6) for constant size (12m) dish. Also shown (light blue) are some less good 64-dish configs.

# Array Layout



64-dish (yellow) and  
80-dish (yellow + black)  
physical layout

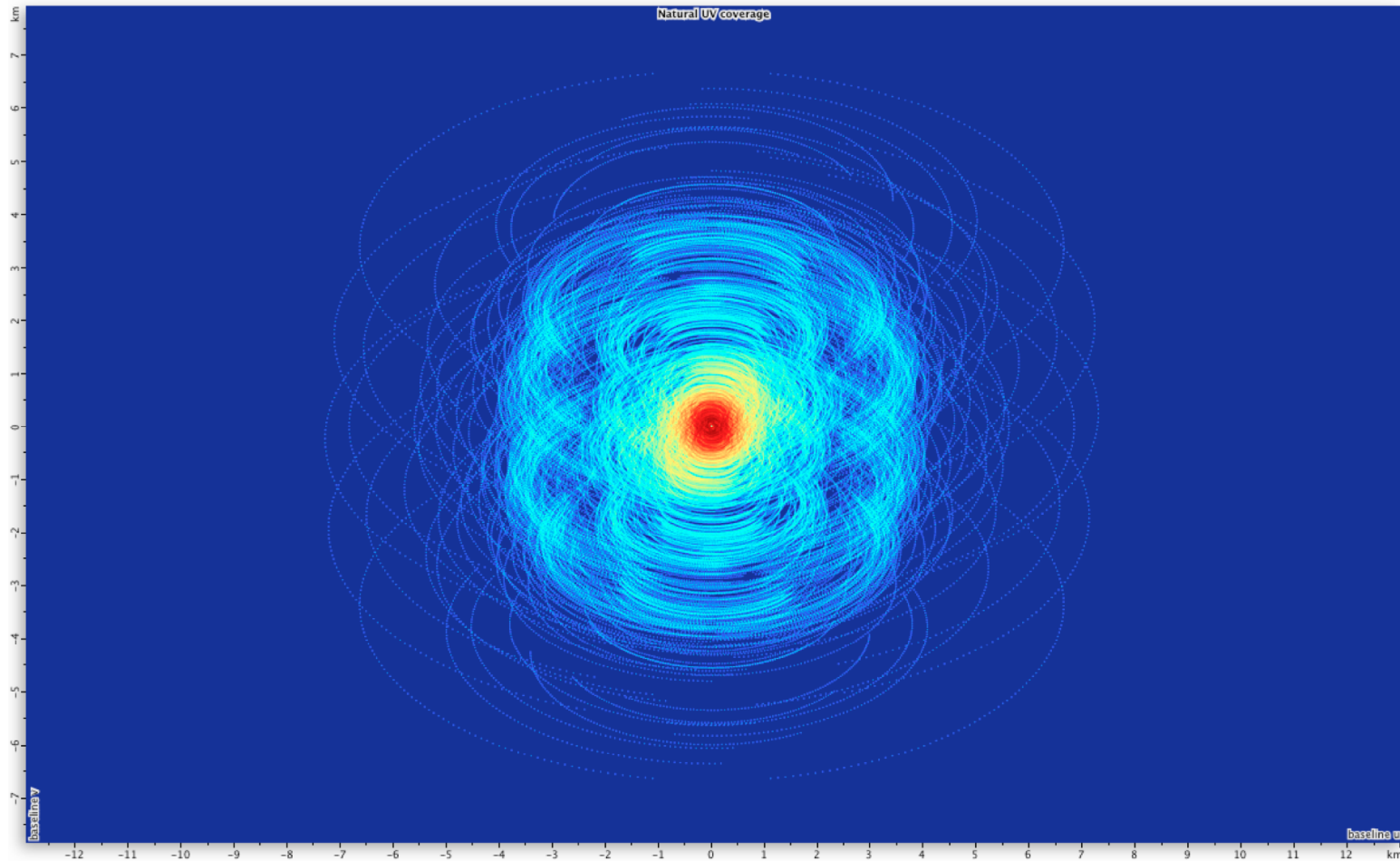
# Array Layout



64-dish (yellow) and  
80-dish (yellow + black)  
physical layout (zoom  
into core)

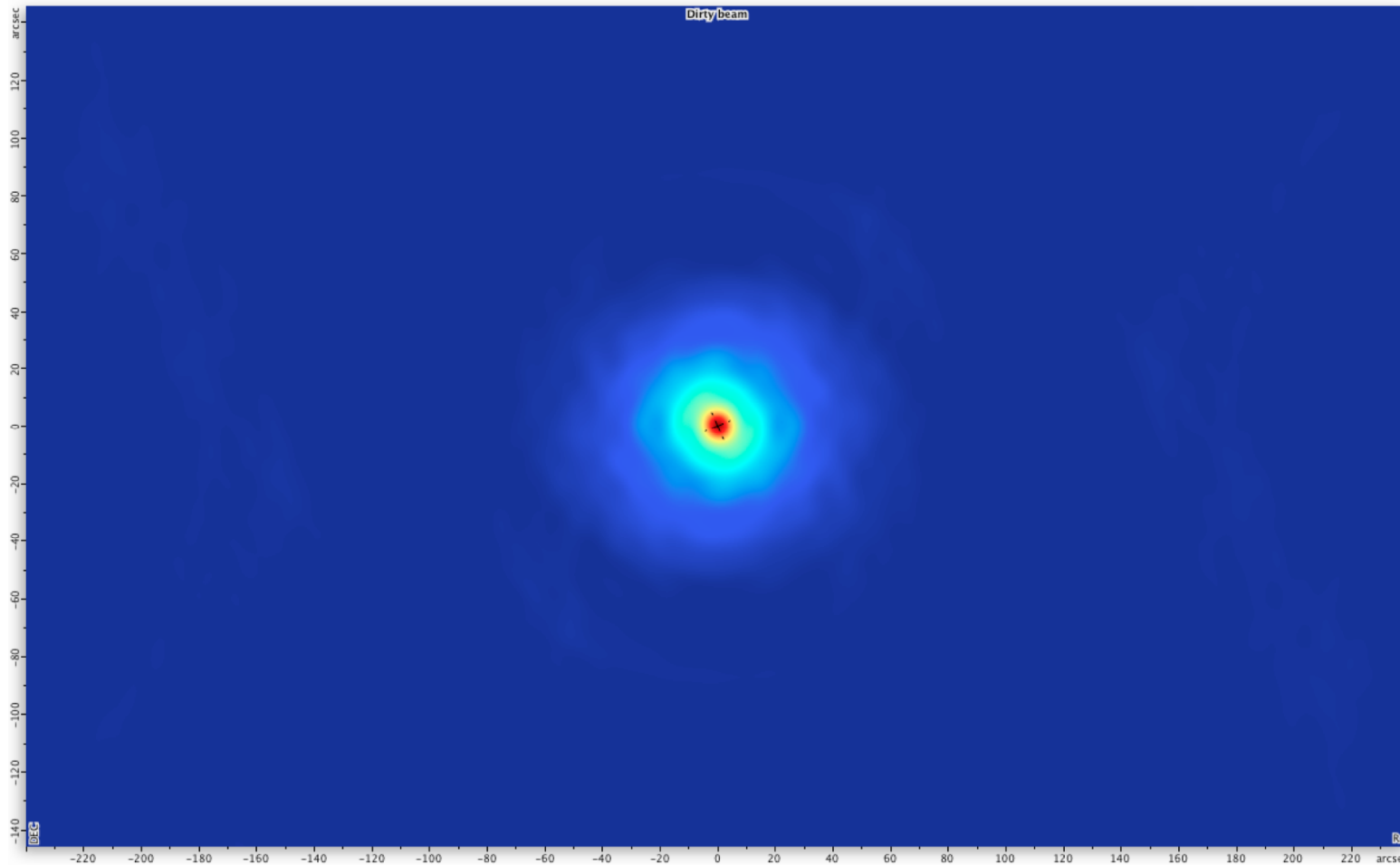


# Array Layout



64-dish uv coverage for 8 hour observation, zenith centered

# Array Layout

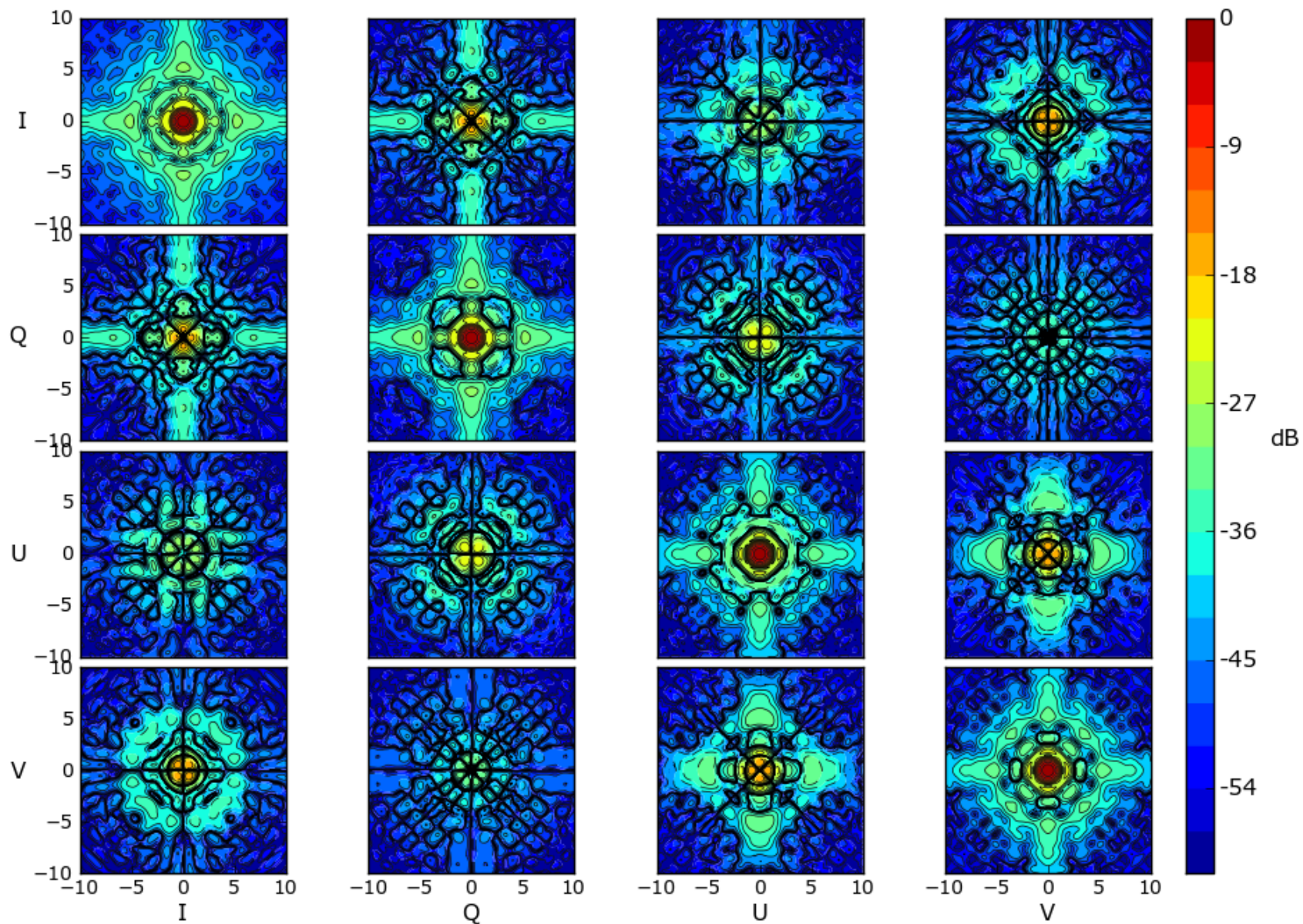


64-dish point spread function for 8 hour observation, zenith centered

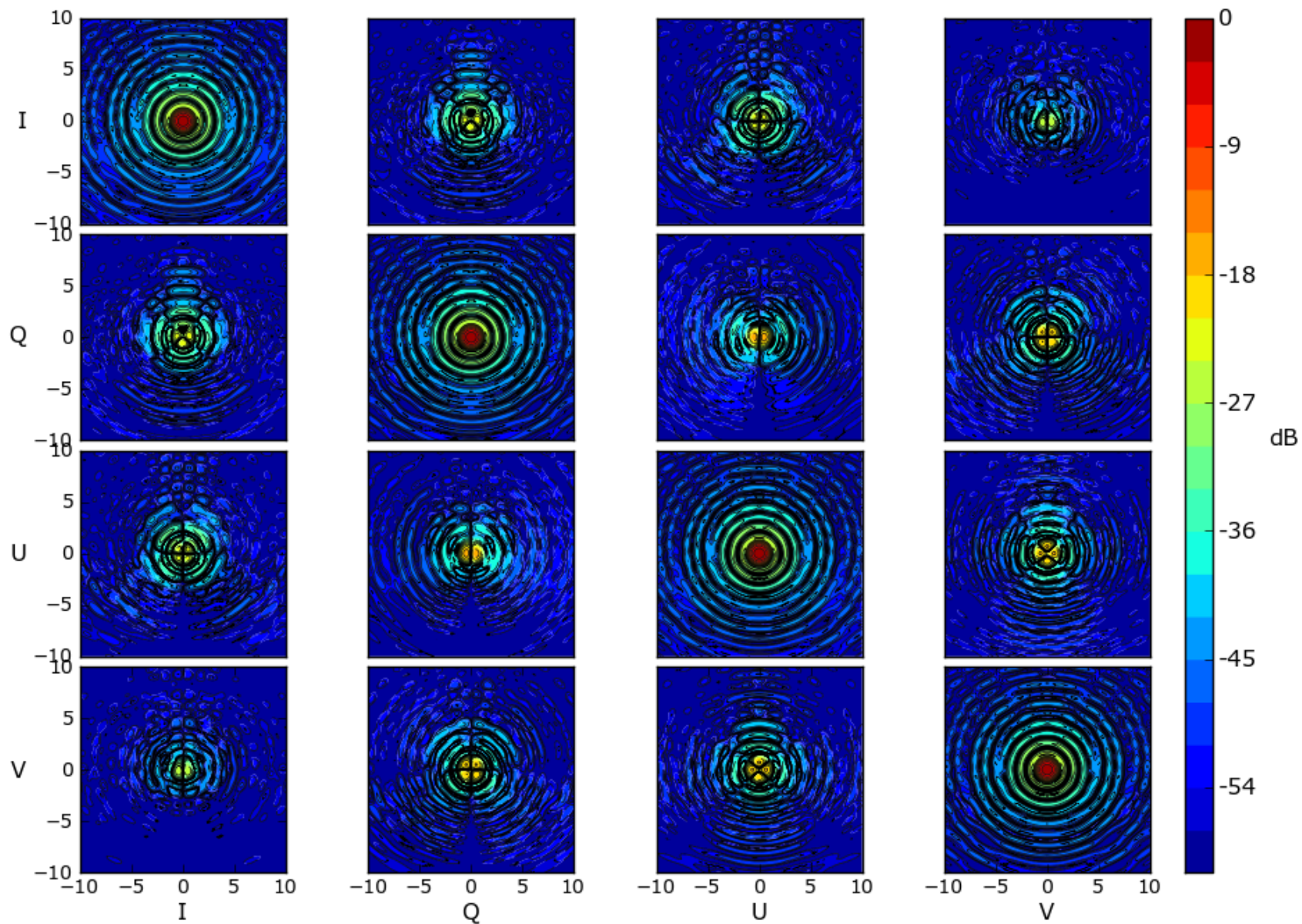
# Beam Patterns

- EMSS Antennas has modelled KAT-7 (prime focus) and MeerKAT (offset Gregorian) beam patterns using FEKO.
- Plots courtesy of Ludwig Schwardt
- Should be interesting to anyone working with primary beam effects...

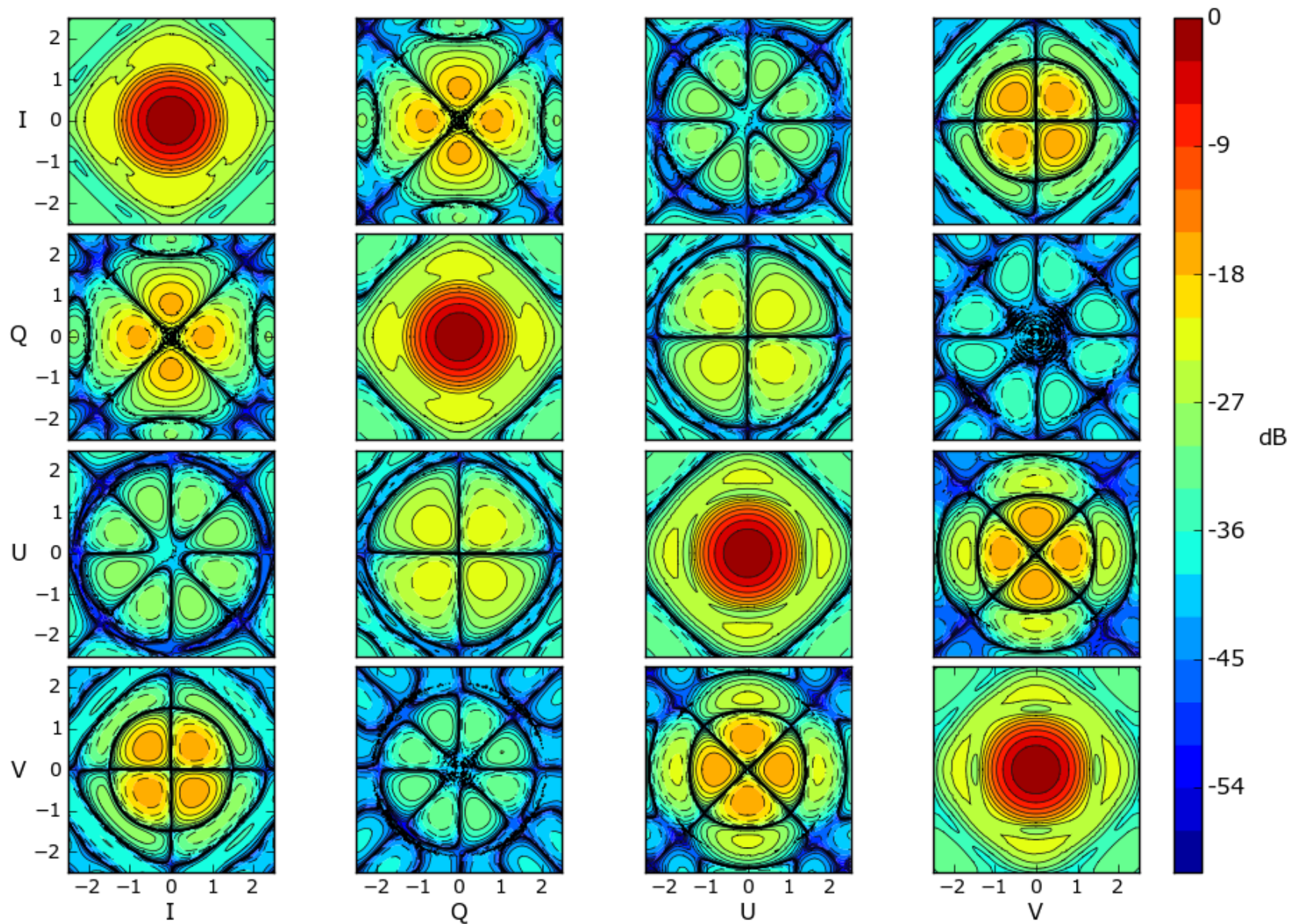
Prime focus: Beam Mueller matrix on  $20^\circ$  field at 1600.0 MHz



Offset: Beam Mueller matrix on  $20^\circ$  field at 1600.0 MHz

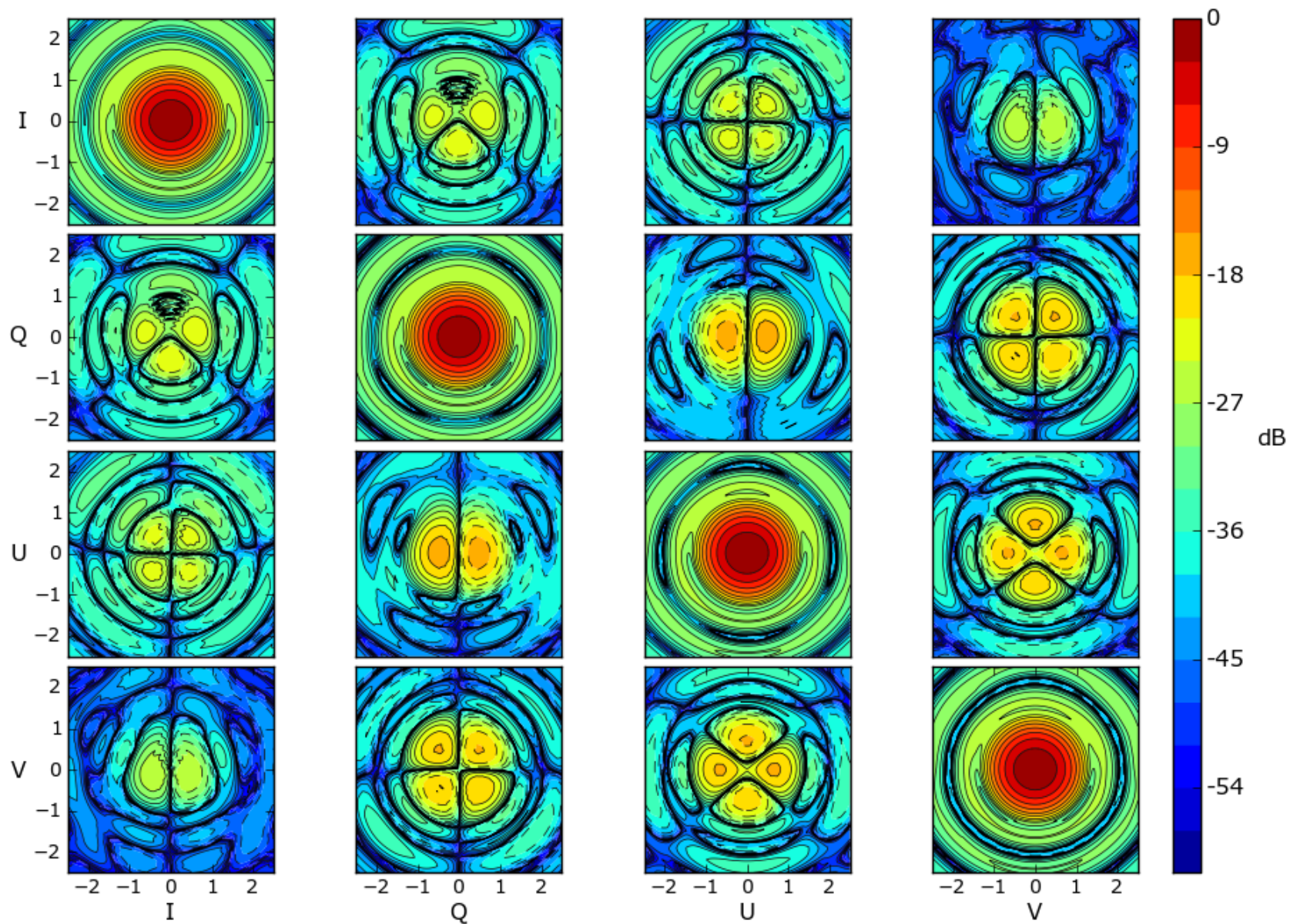


Prime focus: Beam Mueller matrix on  $5^\circ$  field at 1600.0 MHz

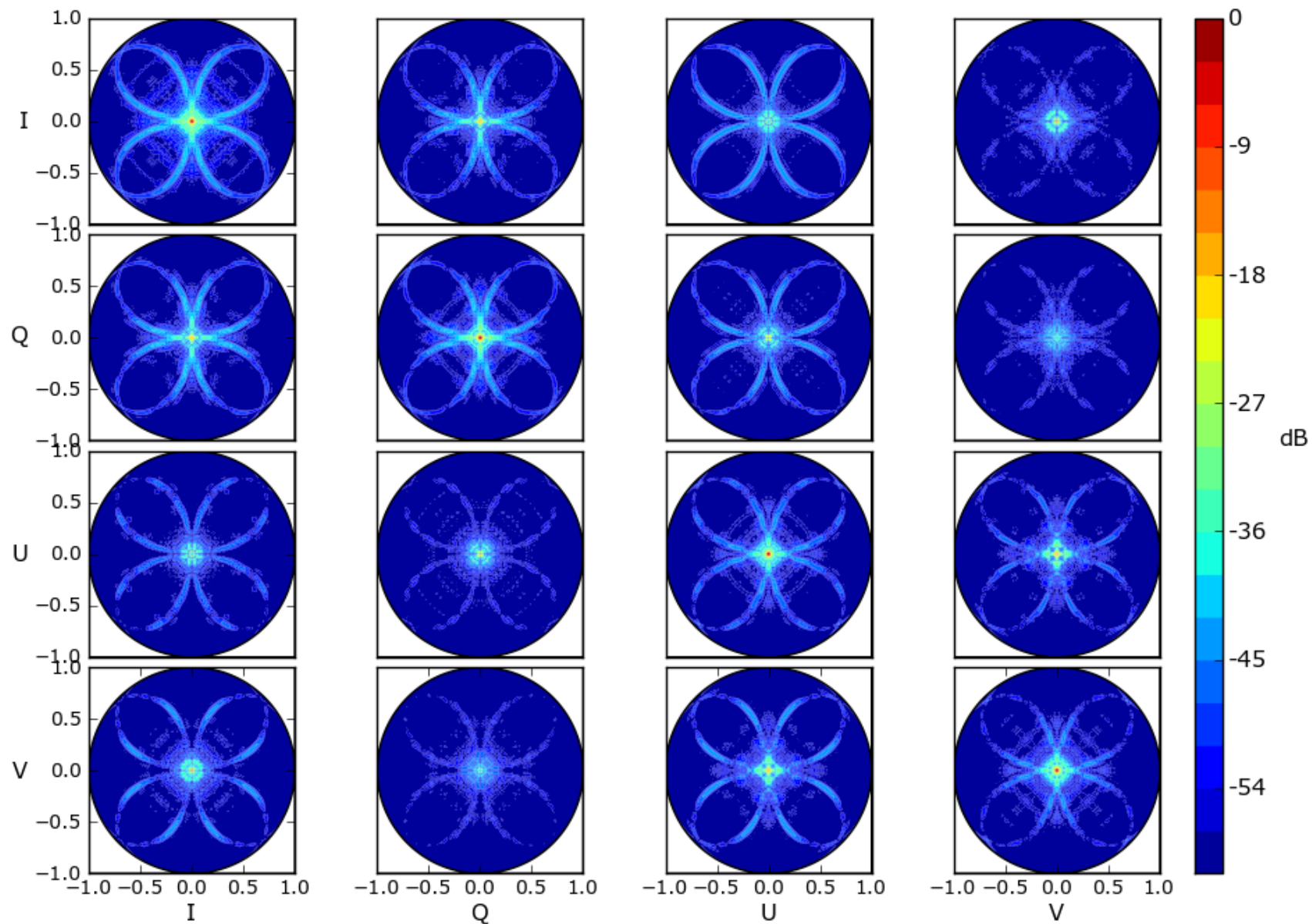


Offset:

Beam Mueller matrix on  $5^\circ$  field at 1600.0 MHz

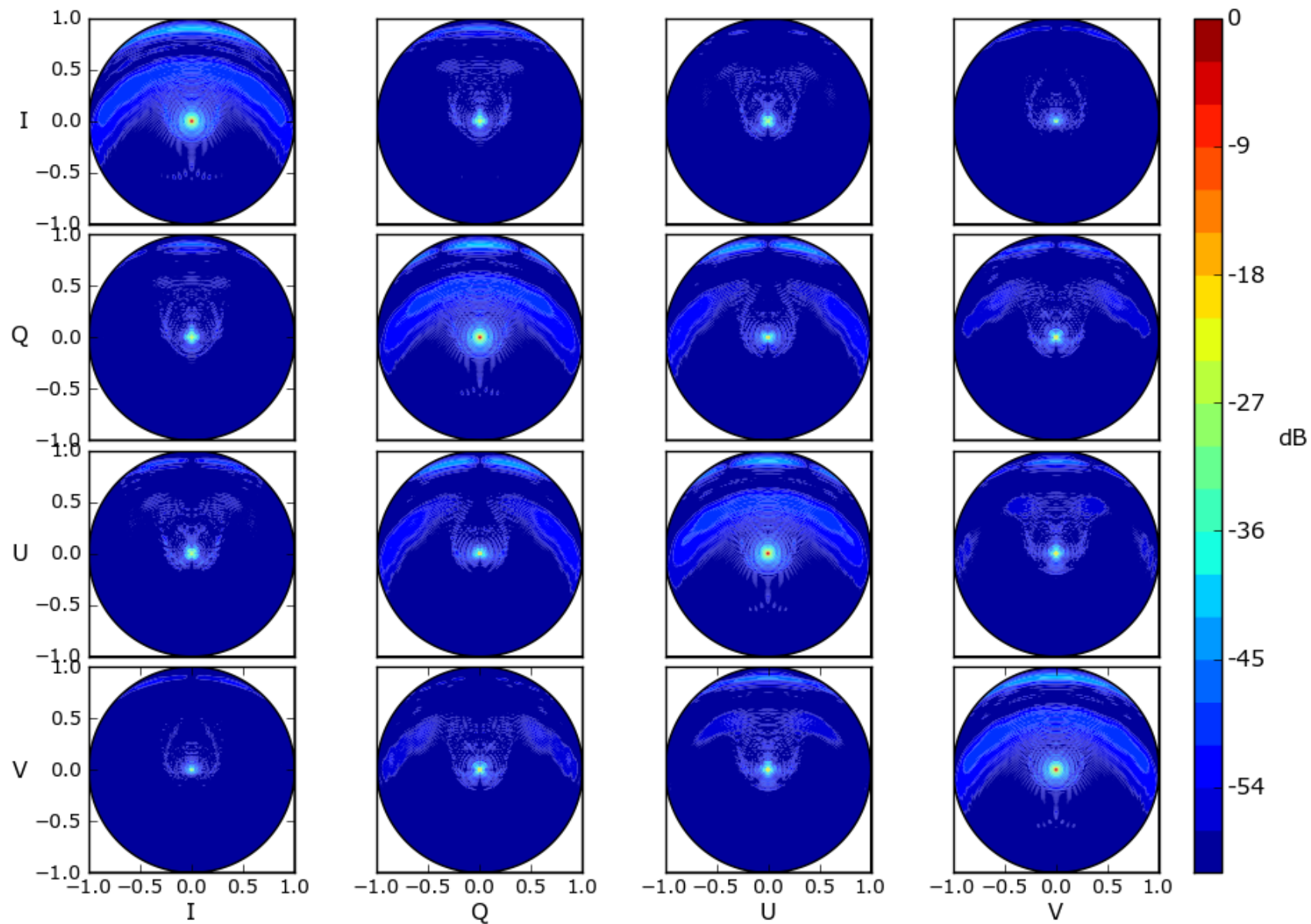


Prime focus: Beam Mueller matrix on 180° field at 1600.0 MHz

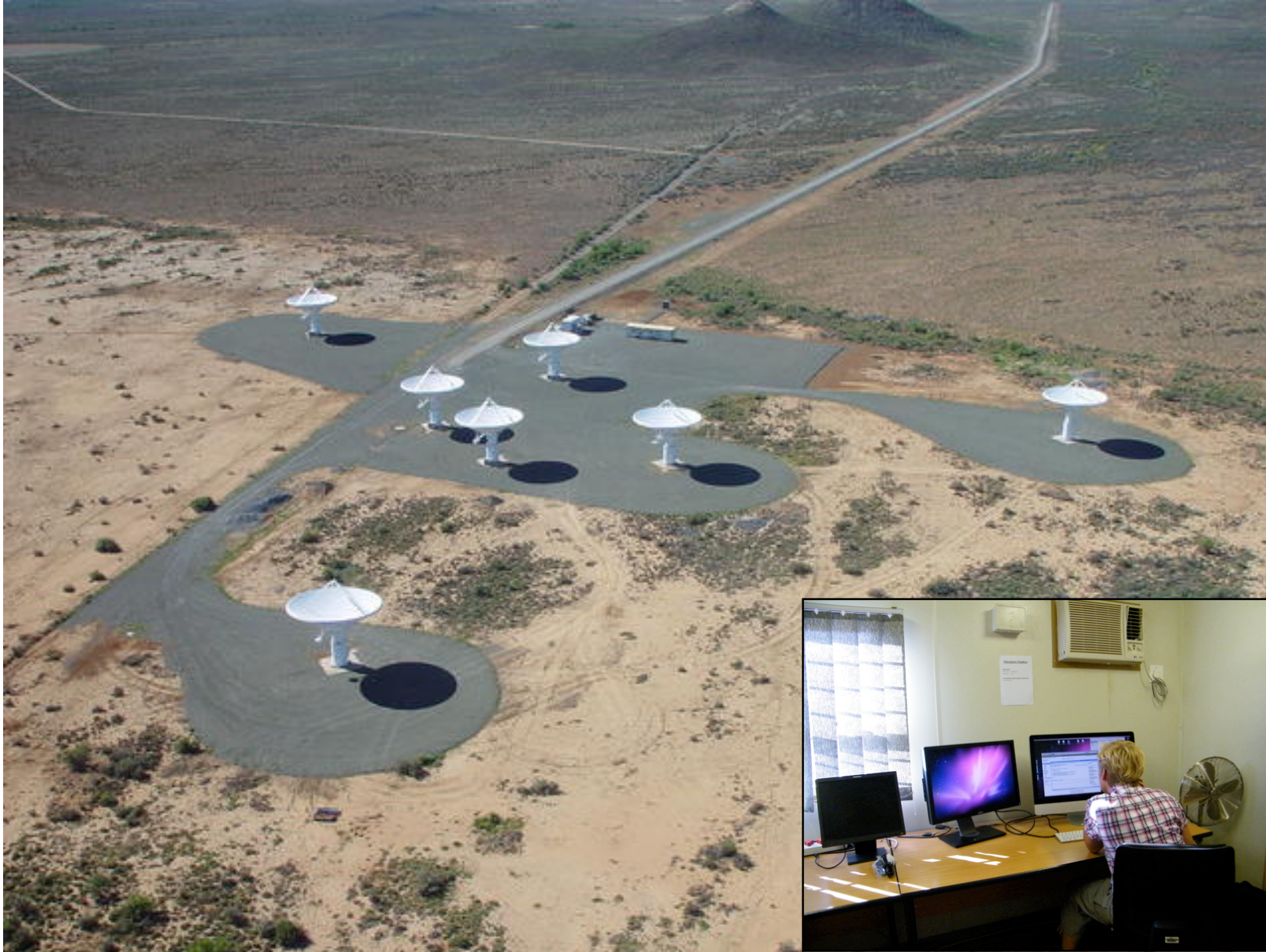




Offset: Beam Mueller matrix on  $180^\circ$  field at 1600.0 MHz

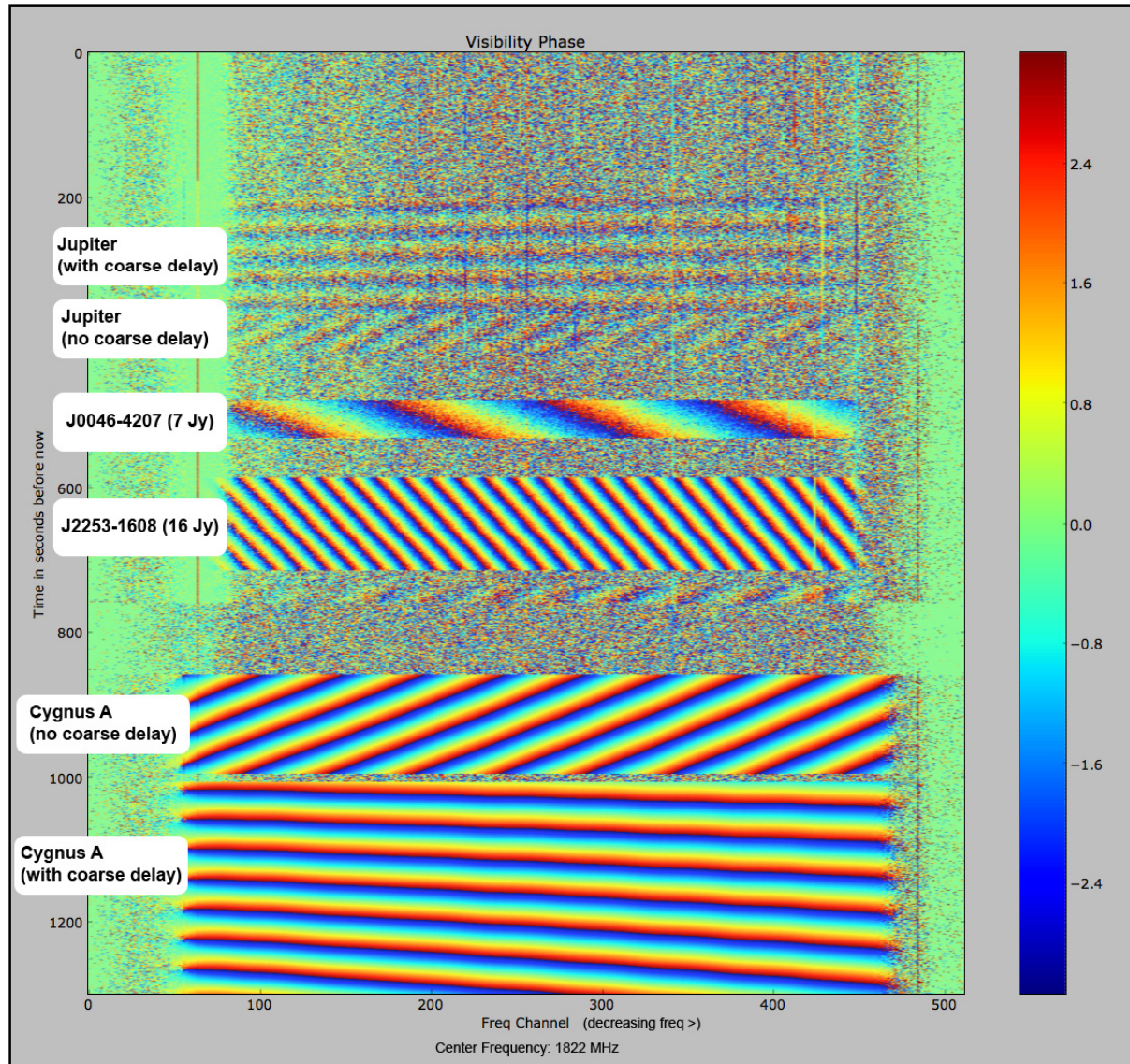


# KAT-7



SKA SOUTH AFRICA  
SQUARE KILOMETRE ARRAY

# KAT-7 Early Fringes (2009)

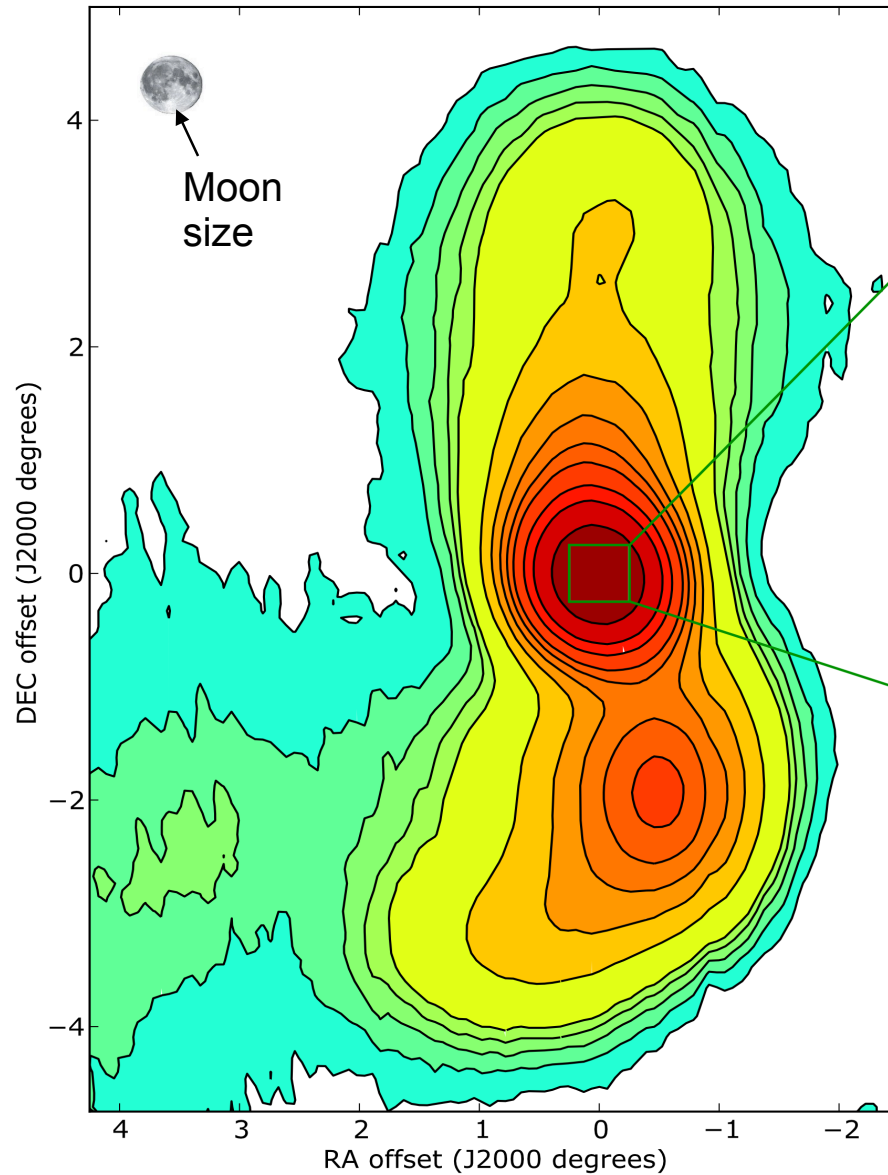


# Science Processing

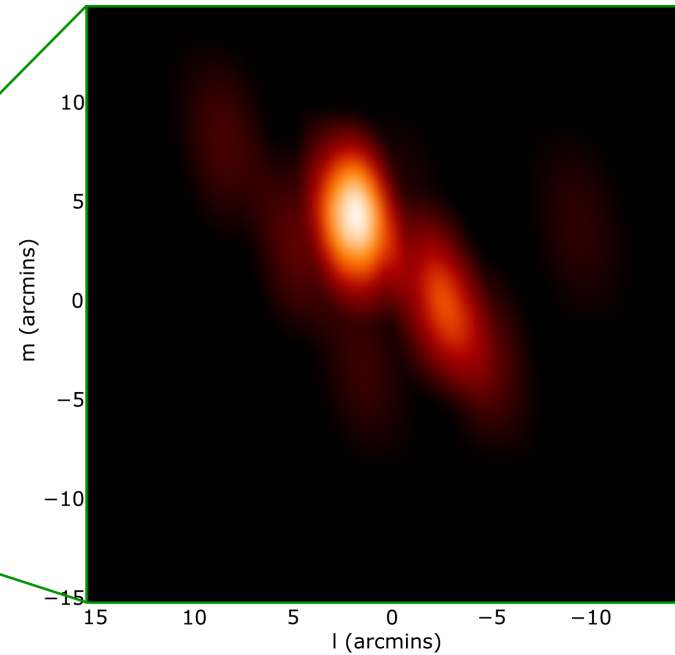
- Renewed 2010 focus on “science processing” with a dedicated team - mostly here!
- Focus on data processing and archive post correlation. Define, design and build the facility systems to support this.
- Interface to the approved major Science Proposal teams (data products, formats etc.)
- Simulations, prototypes, etc.

# KAT-7 Images (2010)

Raster scan image of Centaurus A



Interferometric image of Centaurus A

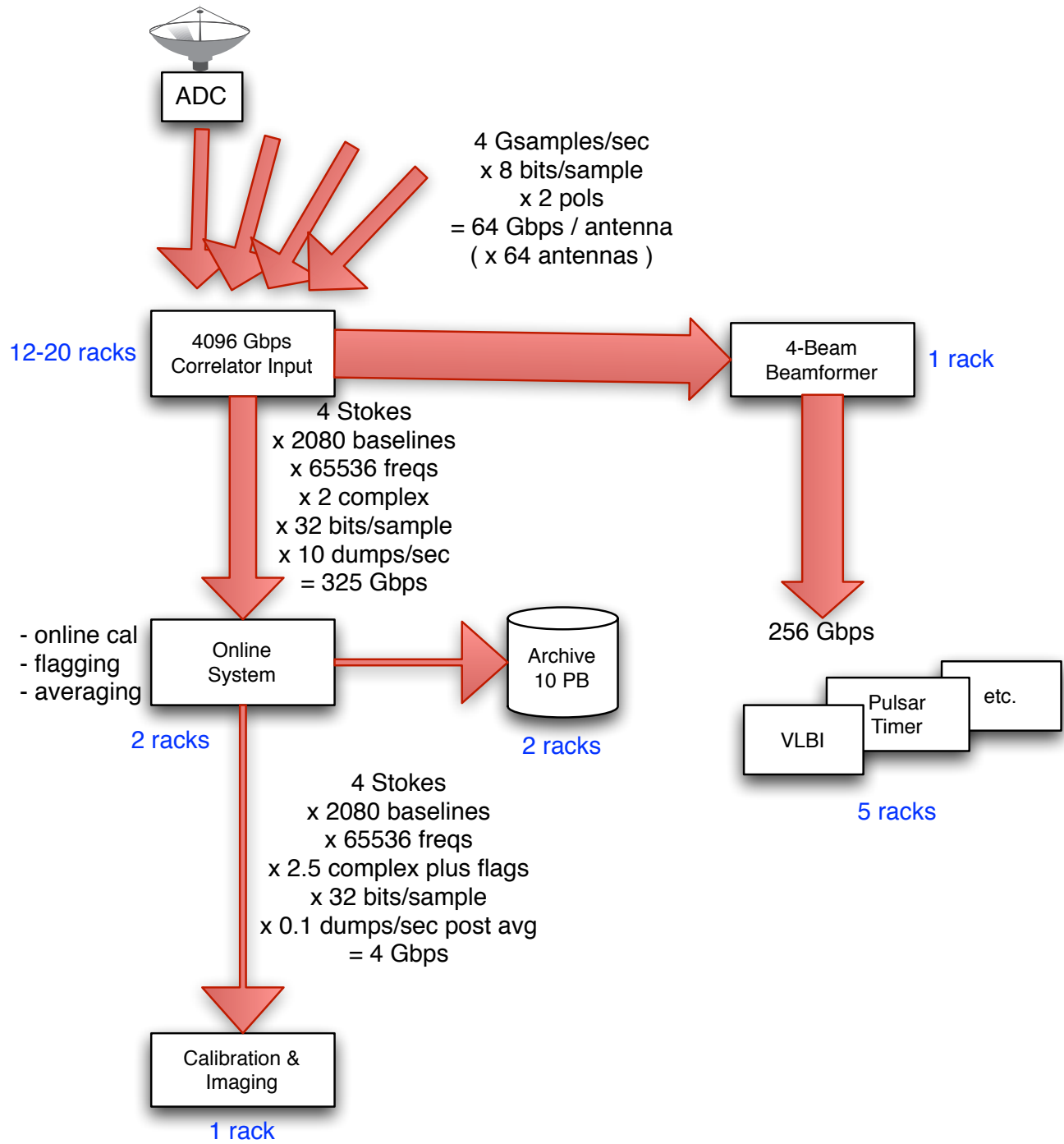


4-dishes



SKA SOUTH AFRICA  
SQUARE KILOMETRE ARRAY

# MeerKAT Data Flow



# MeerKAT to provide (?) :

- Calibrated visibilities
- Certain standard pipelines (spectral line image cubes, continuum images)
- Storage for visibility data (project disk quotas?)
- A 10 PB archive on site plus 3 PB in CT, plus likely European mirror
- Archive access and facilities to reprocess from archive
- Flexible architecture for “black belt” users
- Support for some re-use of existing mature packages where possible – mostly at extremities of system (support CASA, MeqTrees)
- Proposal management etc.

# What do we have now?

- Basic data capture framework to HDF5 file and MS writing capability
- Simple archive for commissioning purposes
- SCAPE commissioning package
- “Ludwig special” first imaging software
- Simulation and data reduction tests in Meqtrees (see work by Oleg).
- Emerging ASTRON and NRAO collaborations
- Some great early results on the KAT-7 system
- A lot of work to be done over the next few years.



# What's next (2010)?

- Streaming framework (online system) prototype for later this year on KAT-7 with new correlator (Simon's talk)
- More mature imaging on KAT-7 (CASA and MeqTrees)
- Parallelization investigations (CASA and BBS)
- Start of some pulsar tools on KAT-7 (in collaboration)
- Start of more formal engagement with approved major science proposal teams
- More detail design for MeerKAT (archive, data model etc)

# Common Issues?

<b>Severity of issue (high, medium, low, none)</b>	<b>MeerKAT</b>
Strong sources contaminating the data through primary beam sidelobes	medium. Smaller effect for offsets.
Wide field calibration	medium
Wide field imaging	medium
Wide field deconvolution	medium
Mosaicing in full polarization	TBD
Mosaicing with different primary beams	none
Large data volumes: require automated pipelines	high
Large data volumes: standardization of data formats and use of common tools	medium
Large data volumes: processing power limitations exist and some shortcuts needed (e.g. in algorithms)	high
More sophistication in sky models	TBD
Solvability of calibration parameters (enough calibrators etc)	low
Time and frequency dependence of calibration parameters	low. Designing with good hardware to reduce software corrections.
Full polarization imaging	high
On-the-fly mapping	medium
Long baselines / large fields of view: dumping fast enough	low



Questions?