MeerKAT
International GHz Tiered Extragalactic Exploration
MIGHTEE

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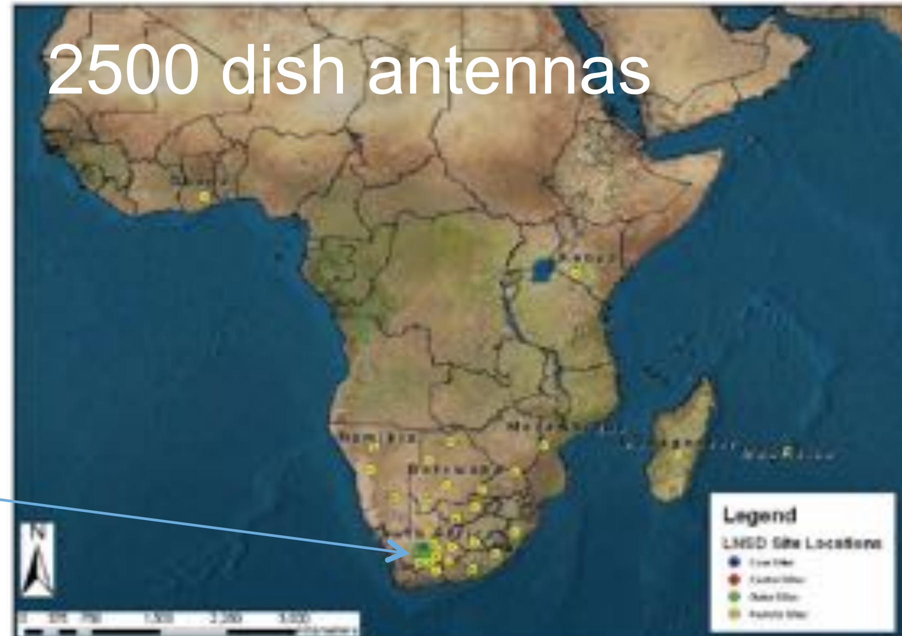
Director
Inter-University Institute for Data Intensive Astronomy

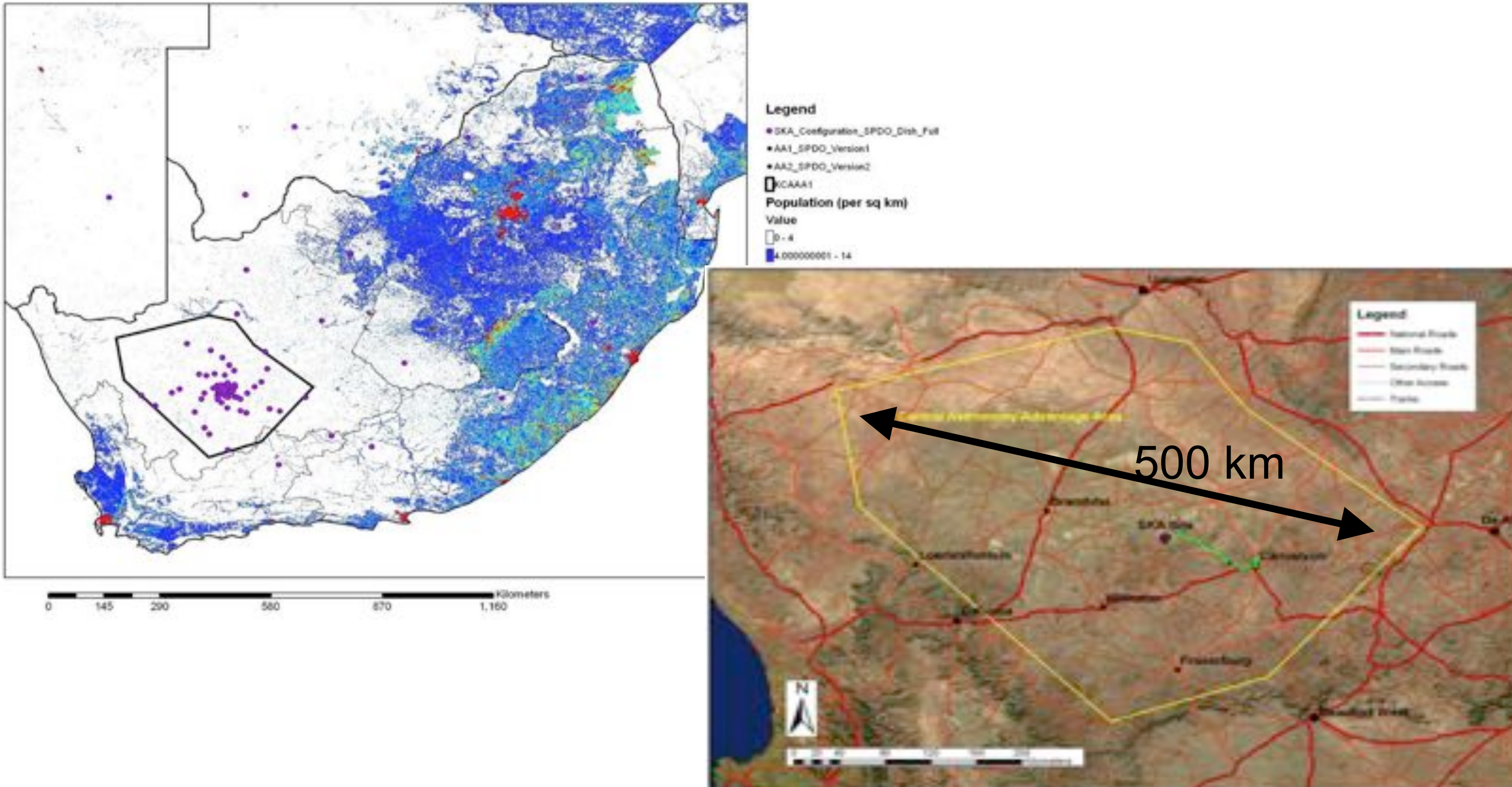
Southern Africa: SKA-mid frequency dish array



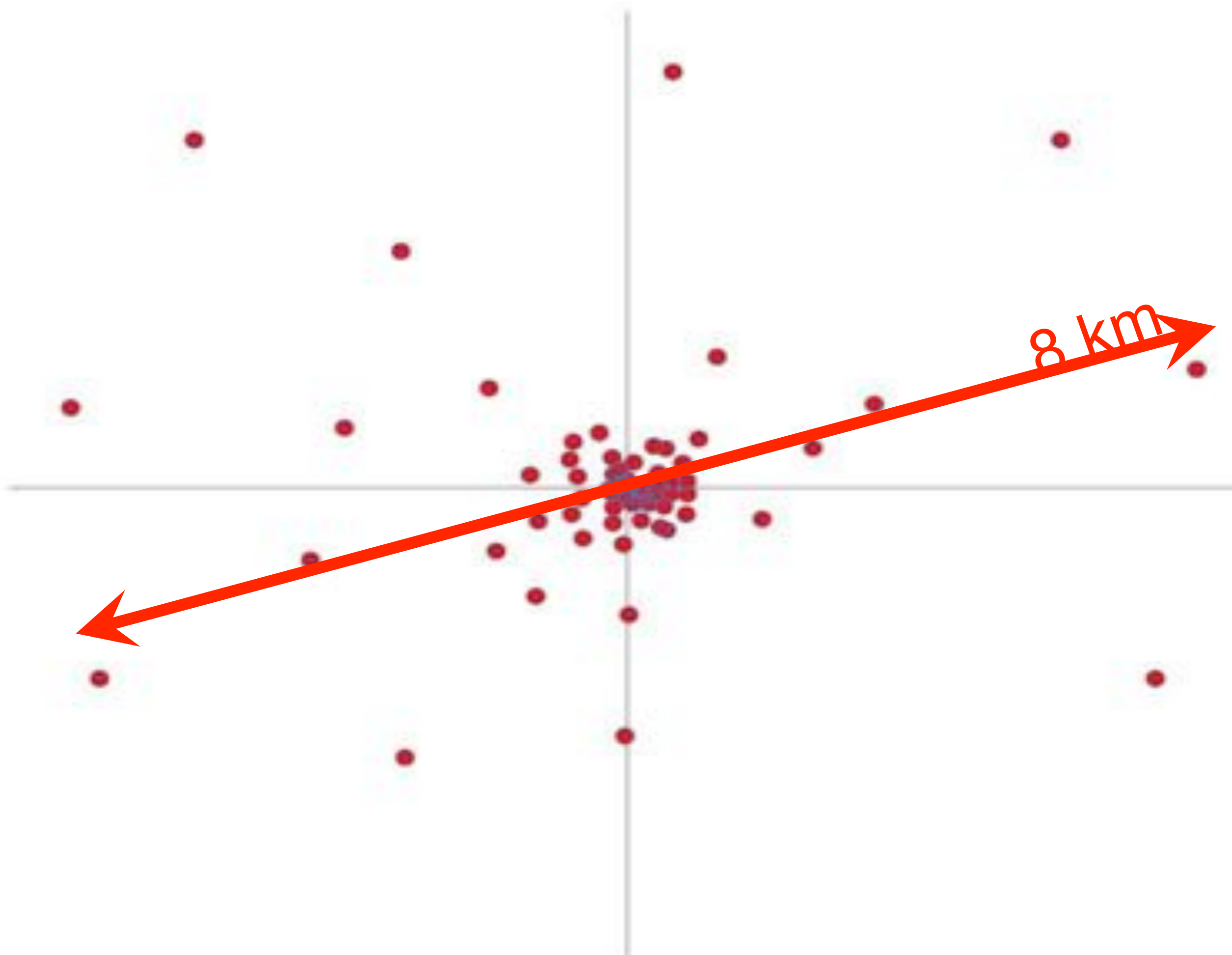
MeerKAT - phase 0 of SKA-mid

- 64 13.5m parabolic dish array
- Constructed at SA SKA Site for incorporation into SKA1

KAROO Radio Astronomy Reserve



MeerKAT Array Configuration



MeerKAT Array

VLA D+C+B configuration all at once, with 4 times the FoV and shorter baselines.

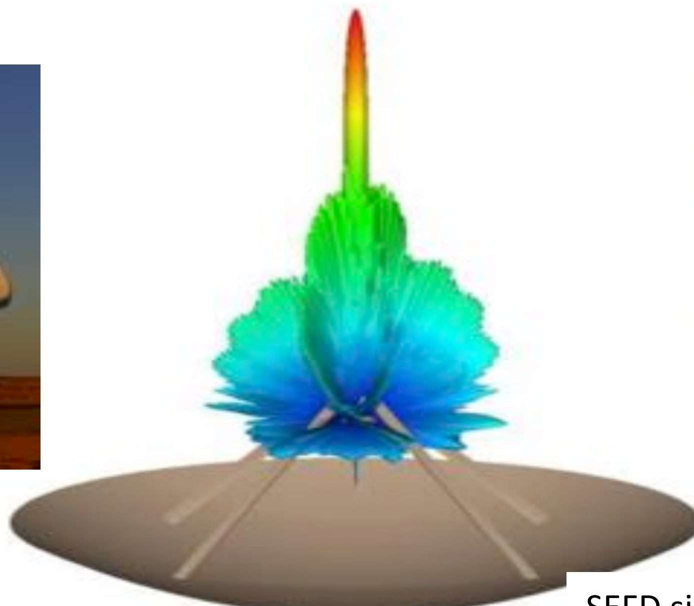
MeerKAT Array

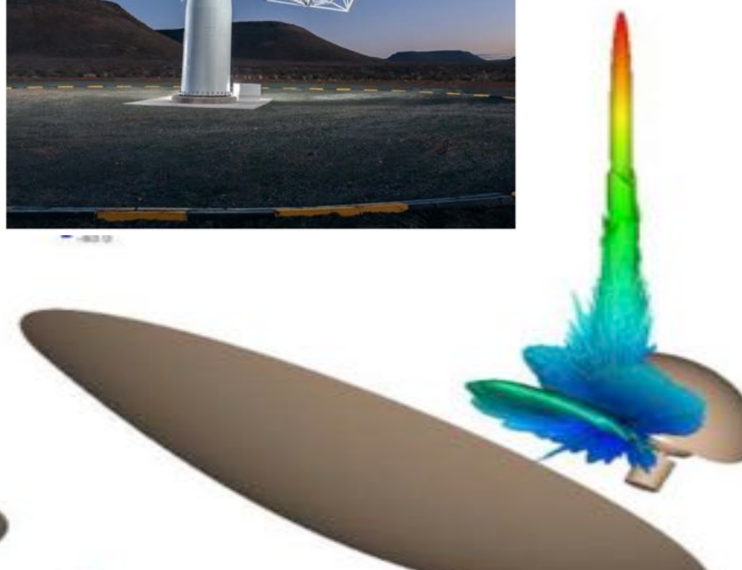
MeerKAT Array

MeerKAT

- High main-beam efficiency (high sensitivity)
- Wide antenna pattern (large field-of-view)
- Reduced scattering (clean response and low scattering)

Powerful wide field imaging telescope





SEFD similar to at VLA antenna

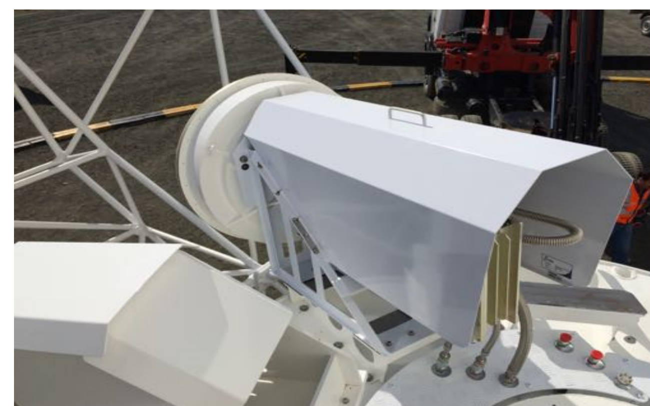
MeerKAT Receivers

- 0.58-1.015 GHz cryogenic single-pixel receiver (UHF-band)
    - 435 MHz RF bandwidth digitized and processed (×2 polarizations)

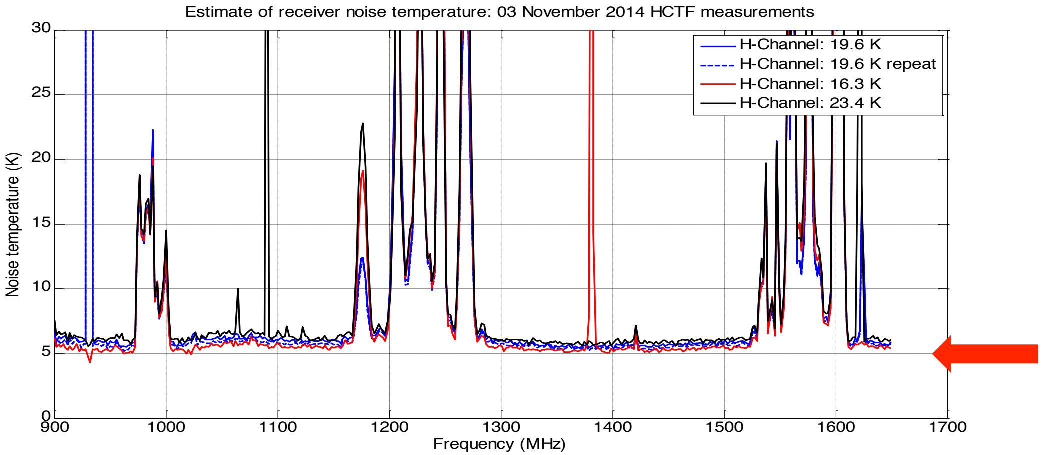
- 0.9 – 1.67 GHz cryogenic single-pixel receiver (L-band)
    - 770 MHz RF bandwidth digitized and processed (×2 polarization)

- 1.75-3.75 GHz (S-band)
    - 1 GHz RF bandwidth digitized and processed (×2 polarizations)



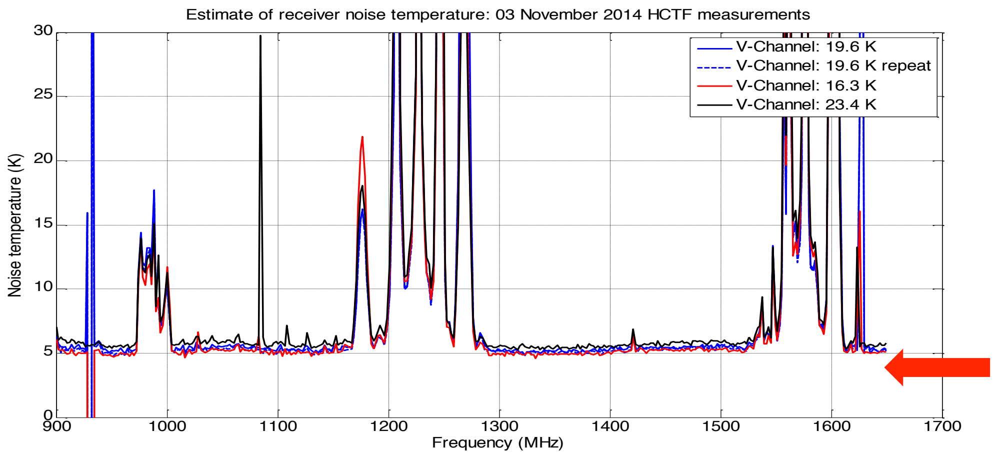


Results from Penticton (DVA-1)



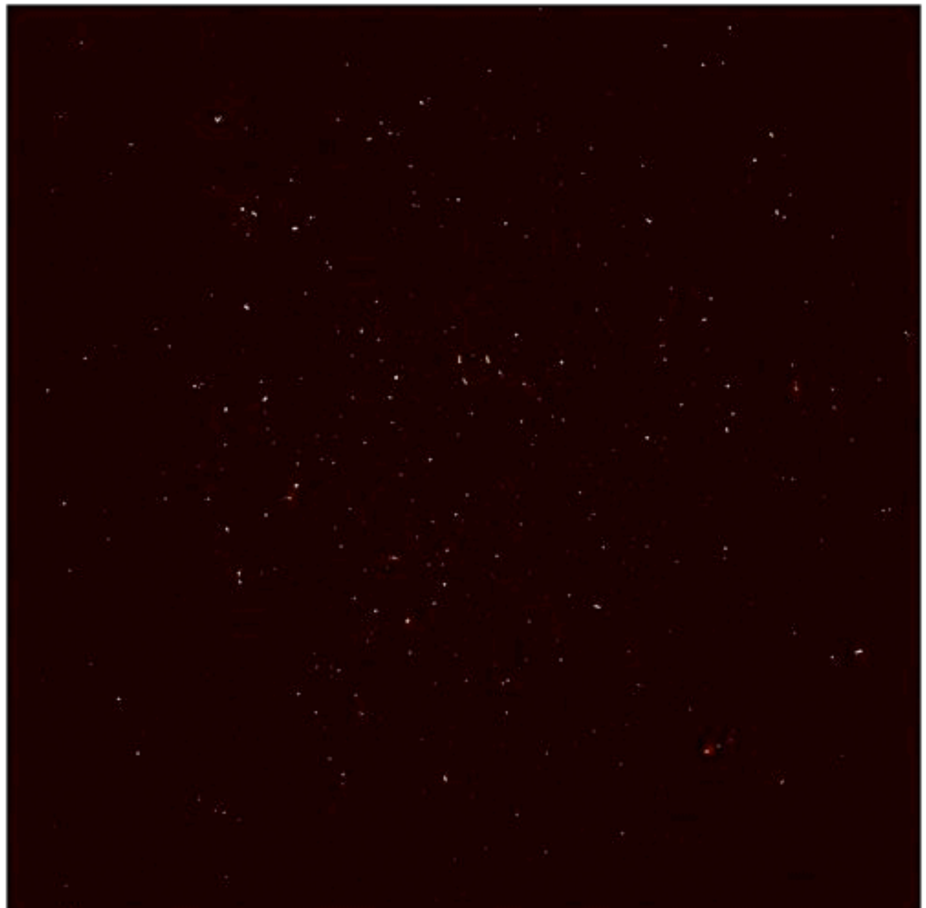
- MeerKAT L-band receiver installed on SKA DVA-1
- Results from Penticton Hot/Cold Test Facility

- Receiver noise temperature $T_{rx} < 7$ K
- Translates to $T_{sys} \approx 18$ K (see next slide)

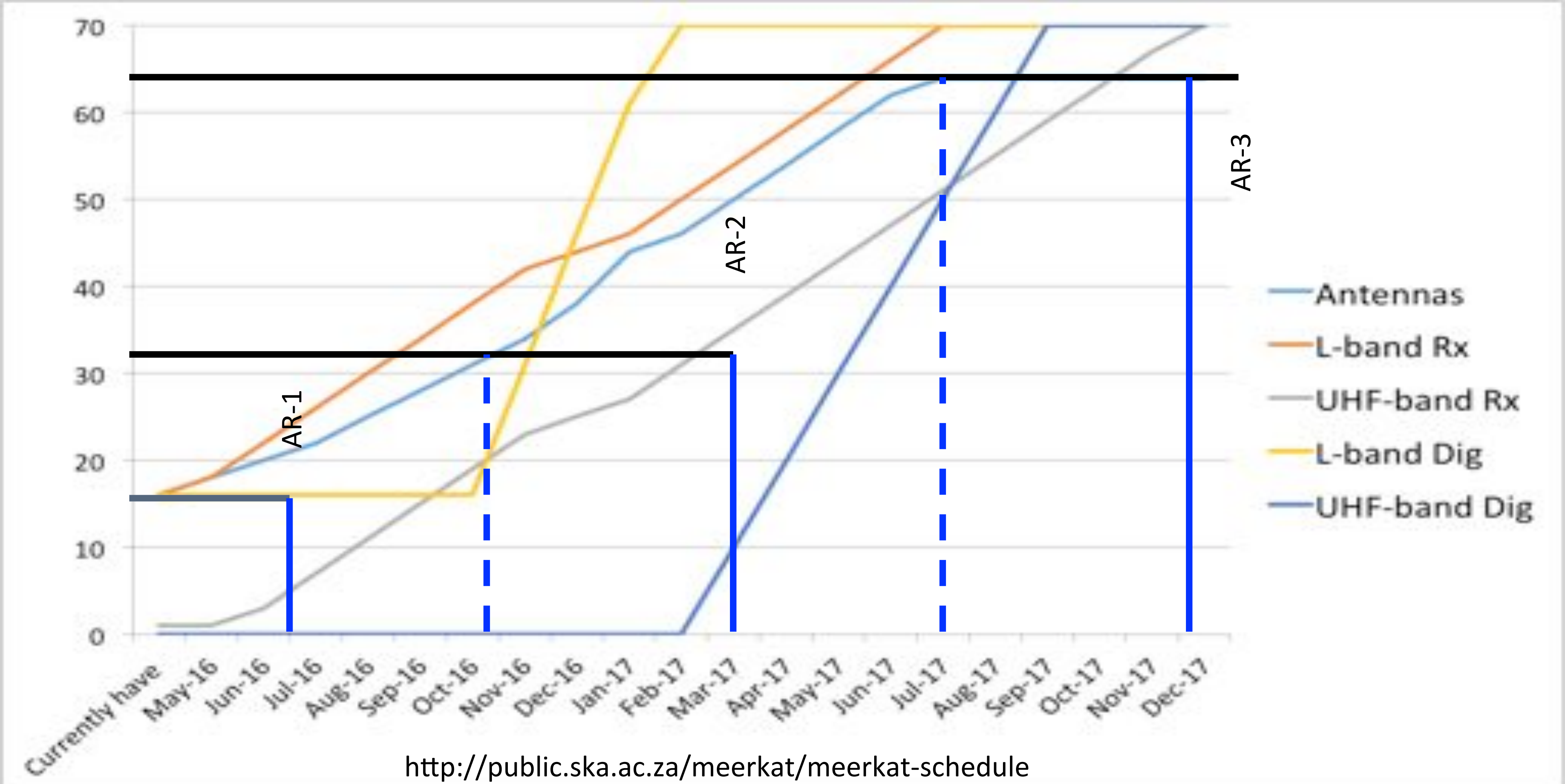


First MeerKAT image with AR1: 16 antennas

7” resolution
12 µJy rms
7.5 hours on-source
Freq: 1285 MHz

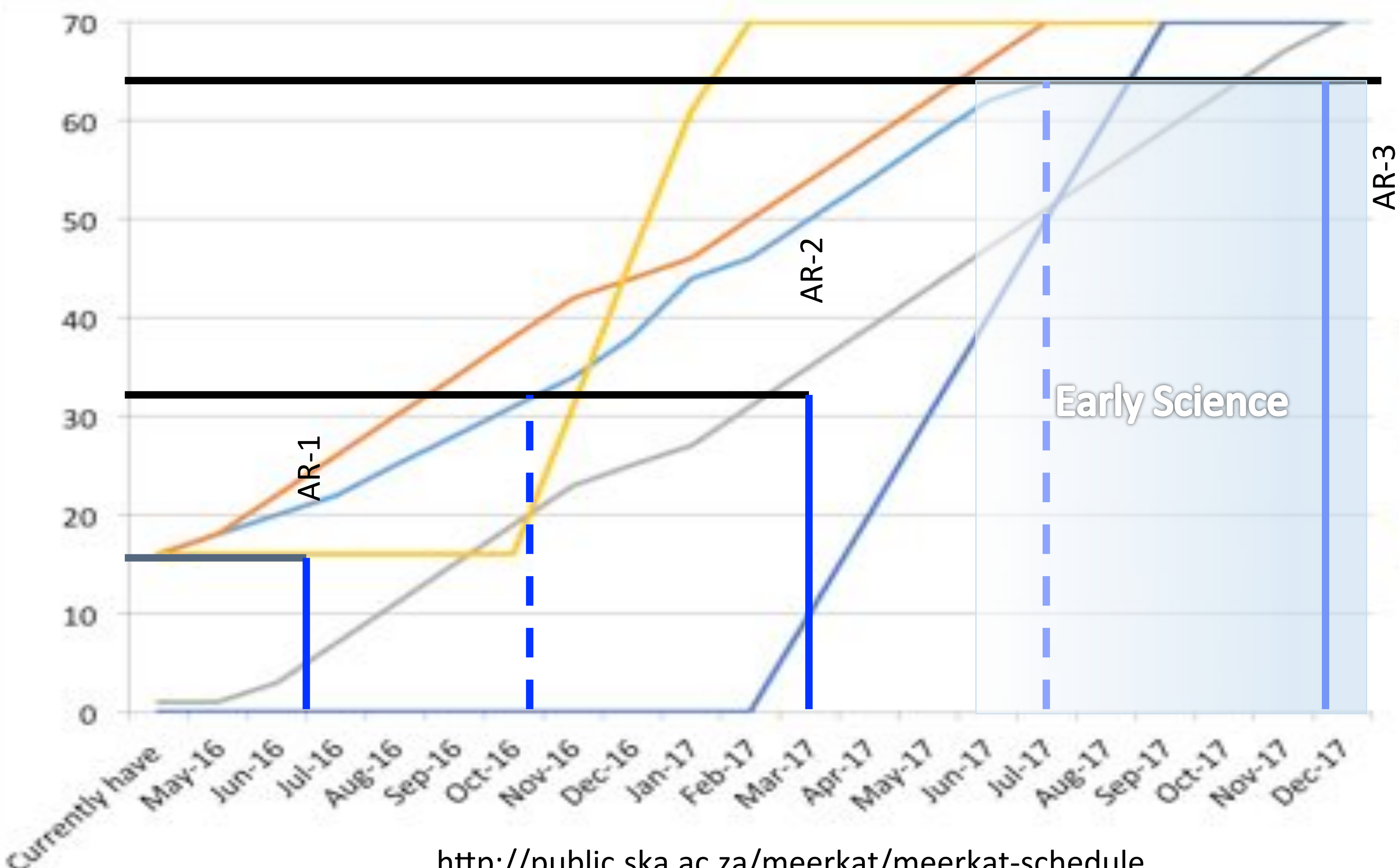


Schedule



http://public.ska.ac.za/meerkat/meerkat-schedule

MeerKAT Schedule



S-band simultaneous with UHF

http://public.ska.ac.za/meerkat/meerkat-schedule

MeerKAT Large Survey Projects: 2018 - 2022

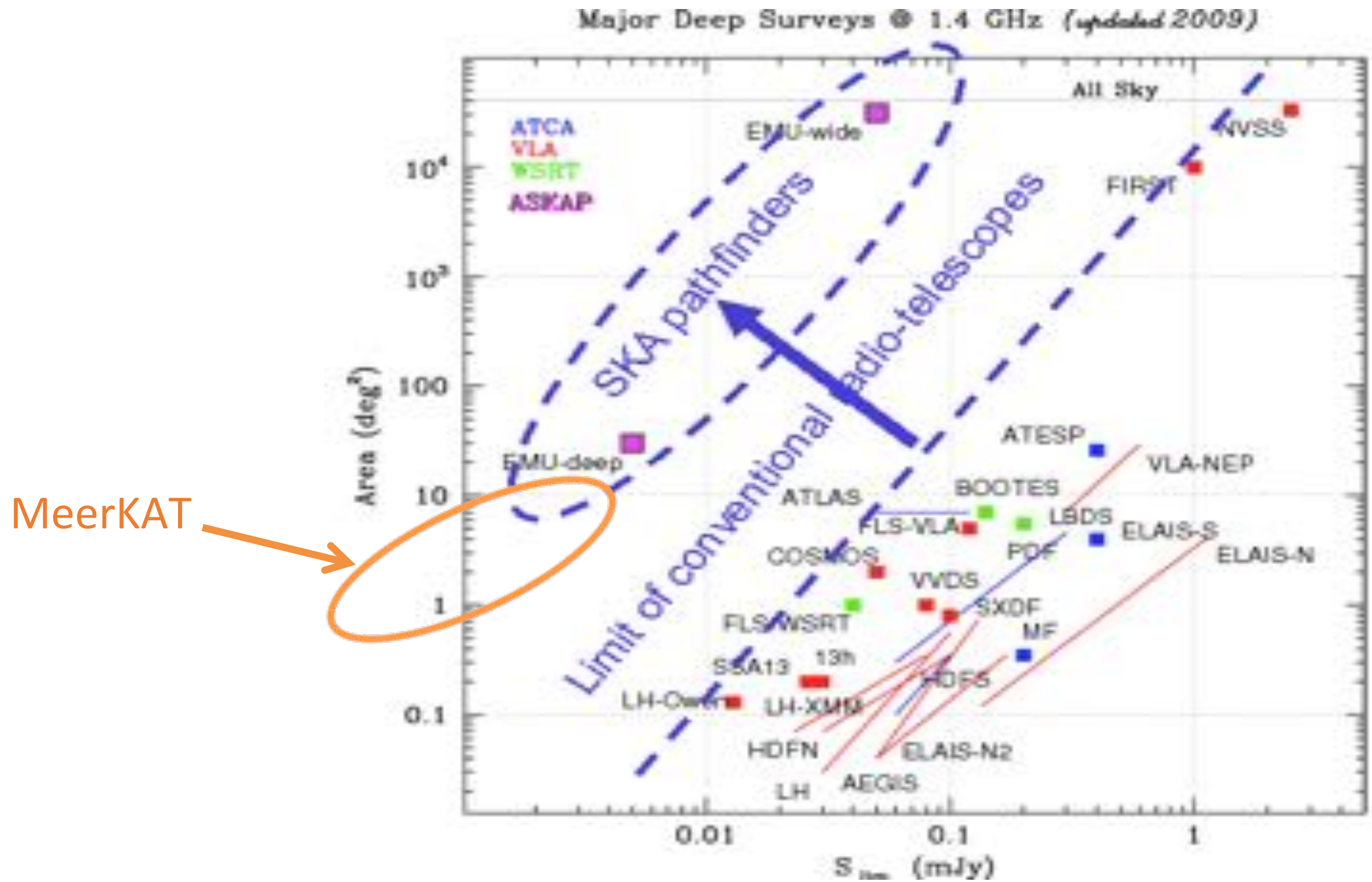
imaging

Time domain

- LADUMA (Deep atomic hydrogen)
- MIGHTEE (Deep continuum imaging of the early universe)
- Fornax (Deep HI Survey of the Fornax cluster)
- MHONGOOSE (targeted nearby galaxies HI)
- MeerKAT Absorption Line Survey (extagalactic HI absorption)
- ThunderKAT (exotic phenomena, variables and transients)
- TRAPUM (pulsar search)
- Pulsar Timing (no acronym)
- MESMER (High-z CO)
- MeerGAL (Galactic Plane Survey)

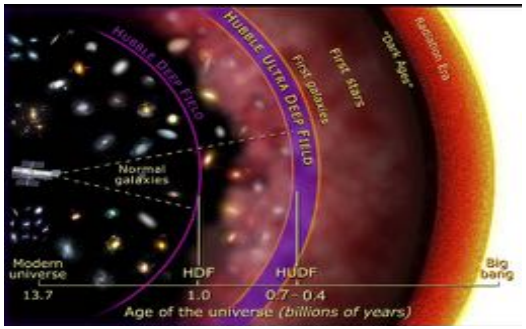
http://public.ska.ac.za/meerkat/meerkat-large-survey-projects

MIGHTEE: Deep "Continuum" Survey

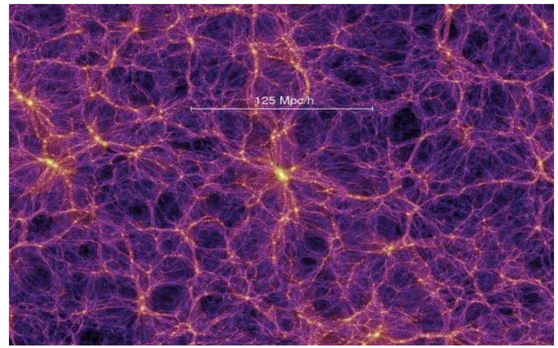


MIGHTEE: Galaxy Formation, Cosmology and Cosmic Magnetism

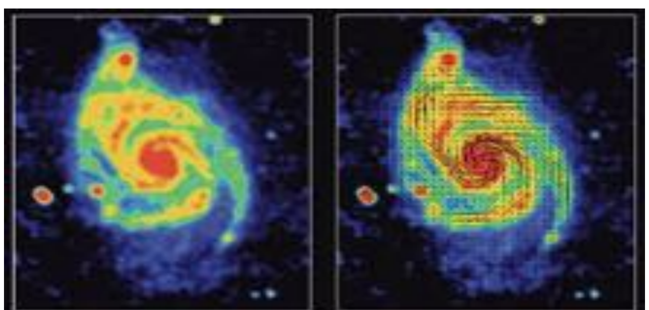
How and when were the first galaxies formed?



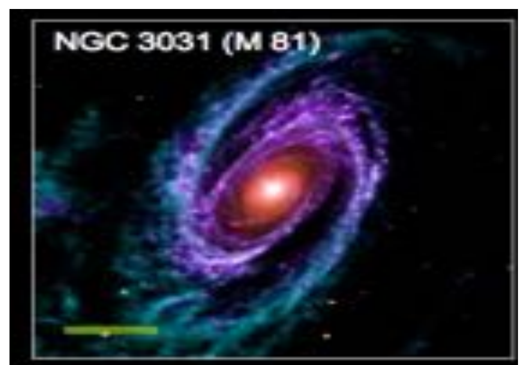
How does visible matter trace and affect the Dark Matter distribution?



How are BHs fueled and how does BH accretion affect the evolution of galaxies?

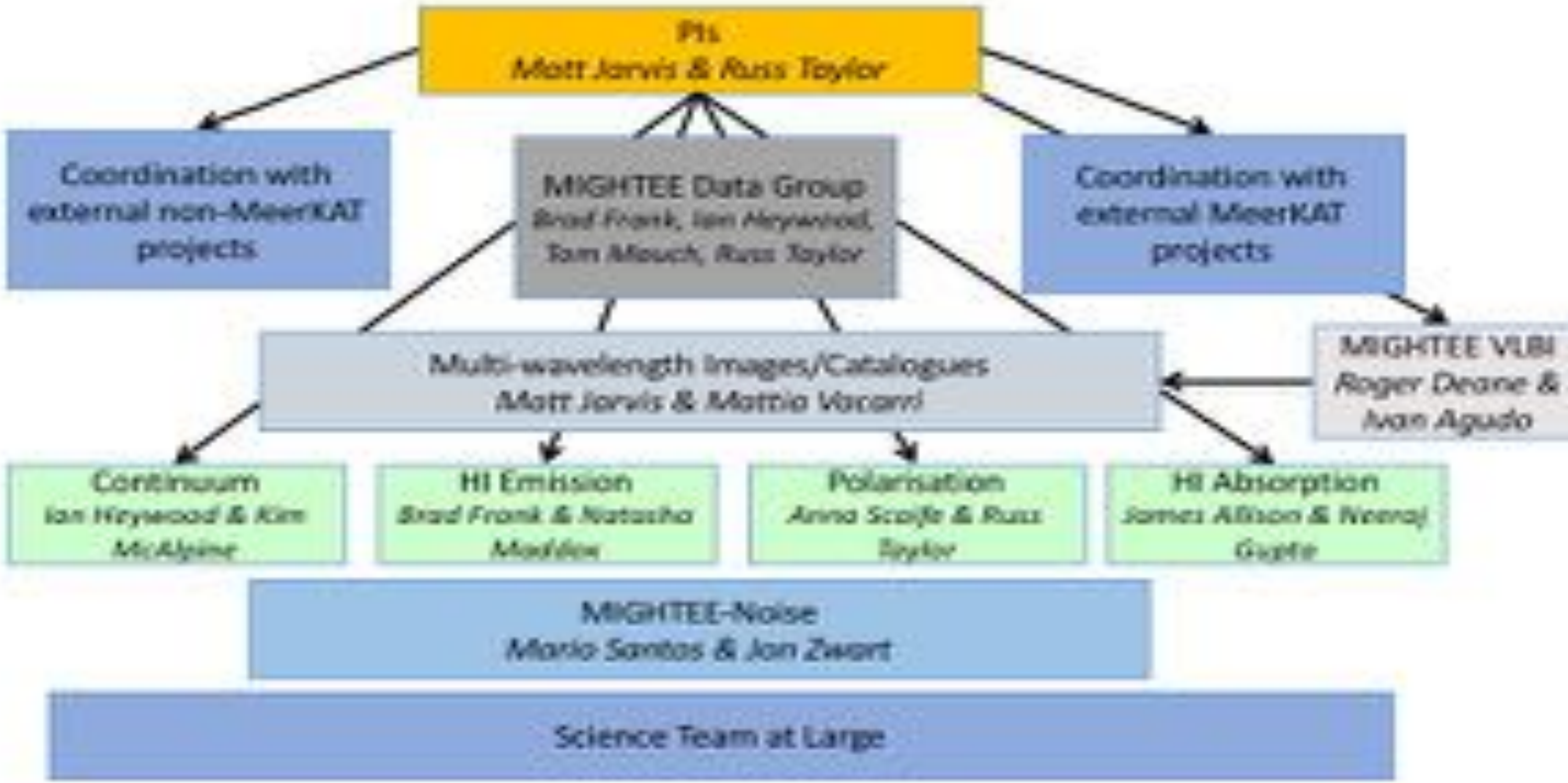


What is the origin of cosmic magnetism, and how do magnetic fields influence global galaxy evolution?



How do we go from gas to stars in galaxies?

How is galaxy evolution effected by environment?


PIs
Matt Jarvis & Russ Taylor
Coordination with external non-MeerKAT projects
MIGHTEE Data Group
Brad Frank, Ian Heywood, Tom Mauch, Russ Taylor
Coordination with external MeerKAT projects
Multi-wavelength Images/Catalogues
Matt Jarvis & Mattia Vaccari
MIGHTEE VLBI
Roger Deane & Ivan Agudo
Continuum
Ian Heywood & Kim McAlpine
HI Emission
Brad Frank & Natasha Maddox
Polarisation
Anna Scaife & Russ Taylor
HI Absorption
James Allison & Neeraj Gupta
MIGHTEE-Noise
Mario Santos & Jon Zwart
Science Team at Large

MIGHTEE: Observing Plan

1960 hours

MIGHTEE MID L-band: 2 μJy rms

- XMSS – 6.7 deg^2
- CDFS – 8.3 deg^2
- ELAIS S1 – 1.6 deg^2
- COSMOS – 1 deg^2

MIGHTEE MID S-band: 1 μJy rms

- CDFS – 4 deg^2
- COSMOS – 1 deg^2

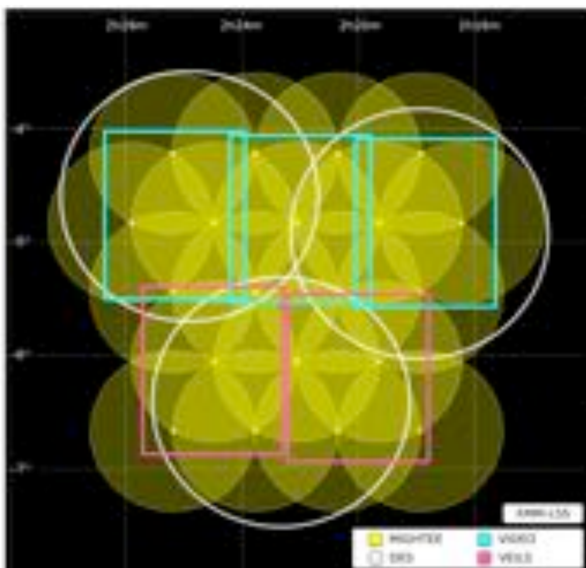
5000 hours

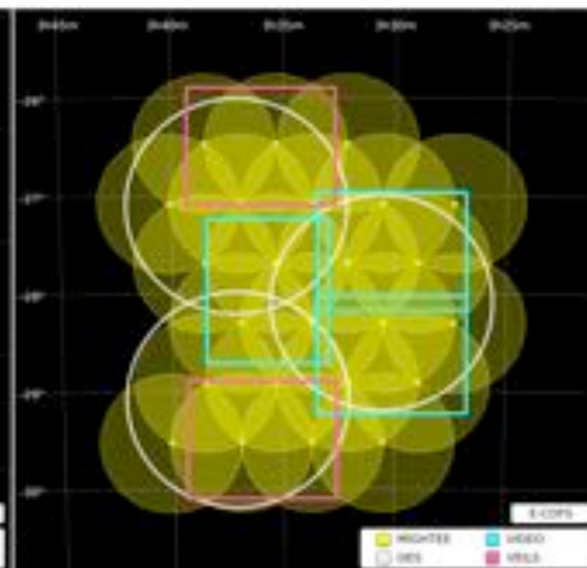
MIGHTEE DEEP L-band: 0.1 μJy rms

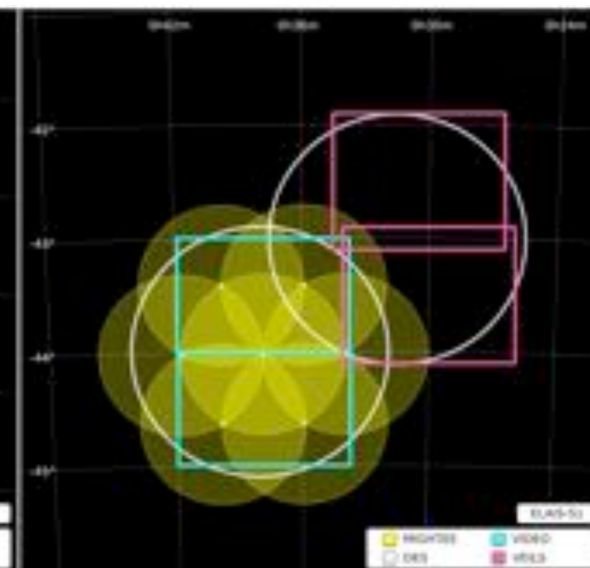
UHF: 0.1 μJy rms

- CDFS – 1 deg^2

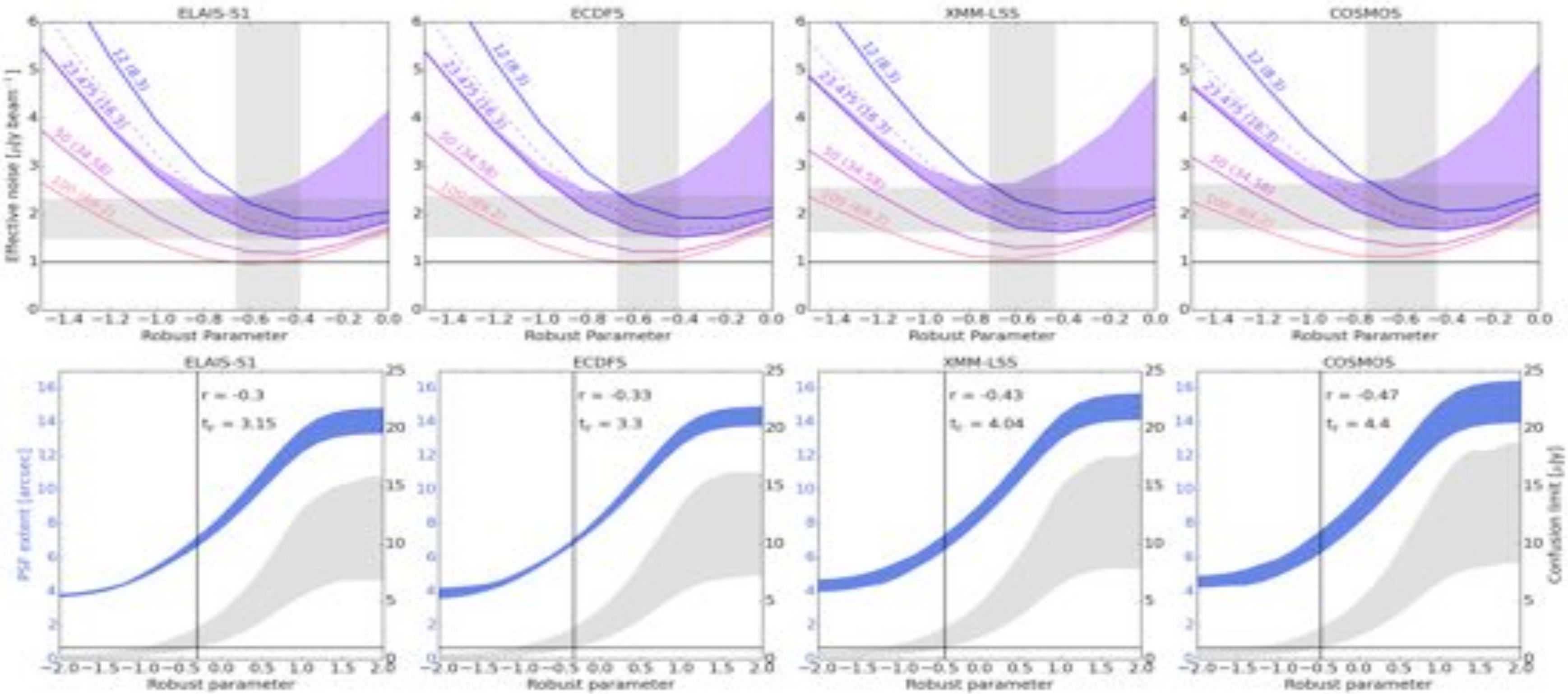
LADUMA COMMENSAL



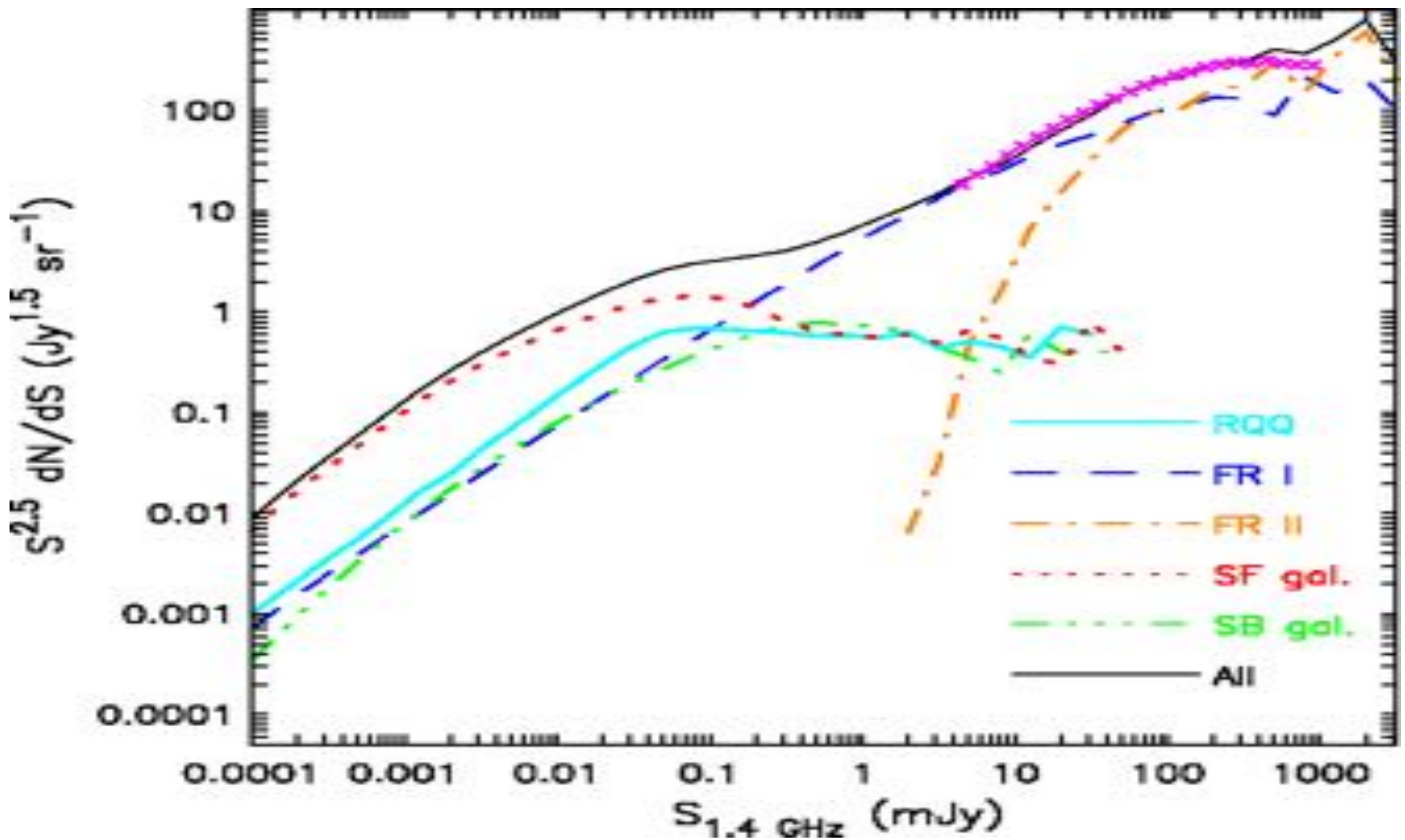




MIGHTEE Total Intensity Sensitivity

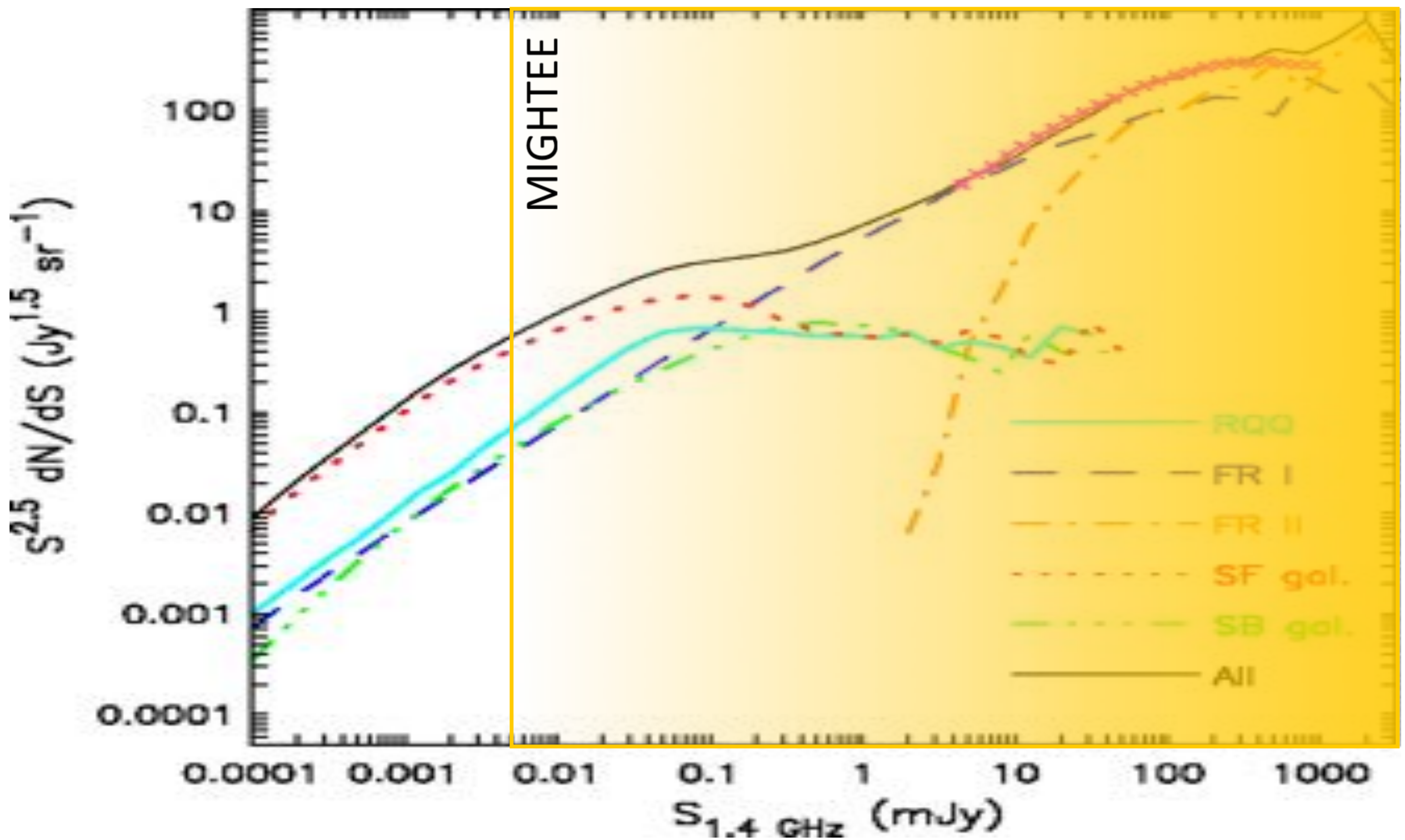


Radio Source Populations

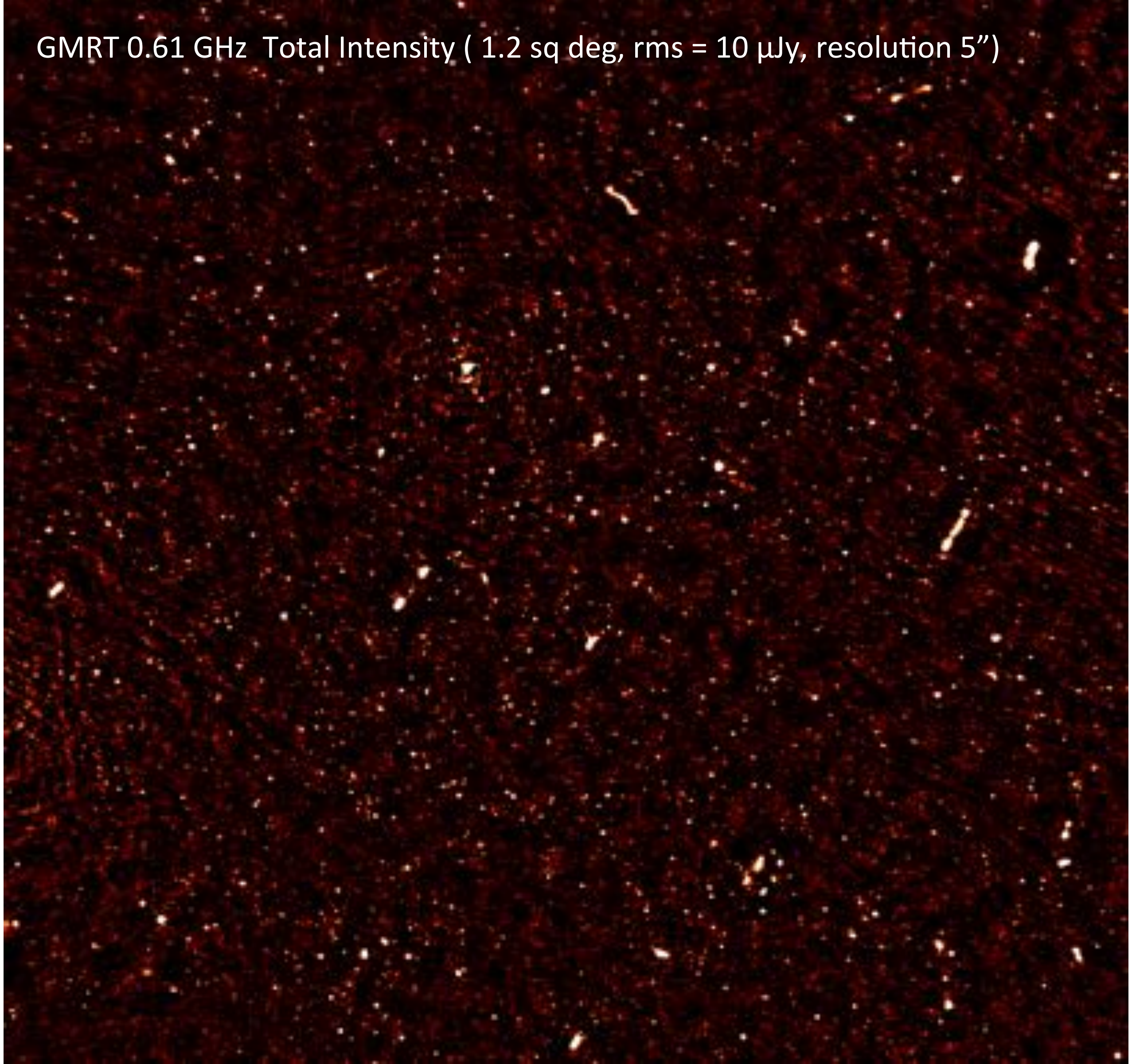


Total intensity source populations counts: SKADS Simulation (Wilman et al. 2008)

Radio Source Populations - MIGHTEE



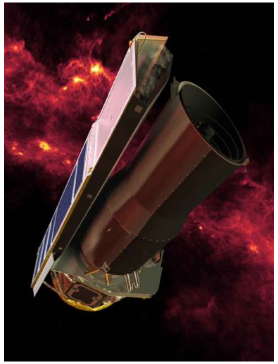
Total intensity source populations counts: SKADS Simulation (Wilman et al. 2008)

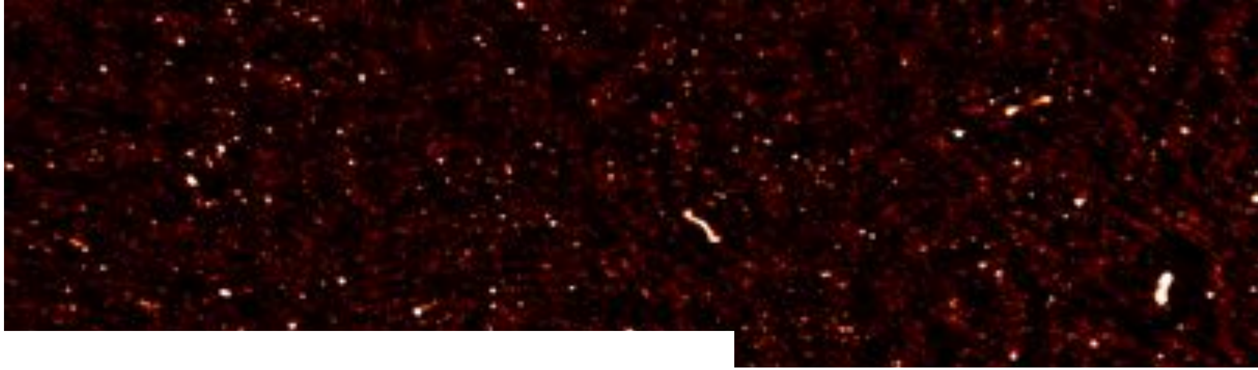

GMRT 0.61 GHz Total Intensity (1.2 sq deg, rms = 10 μJy, resolution 5”)

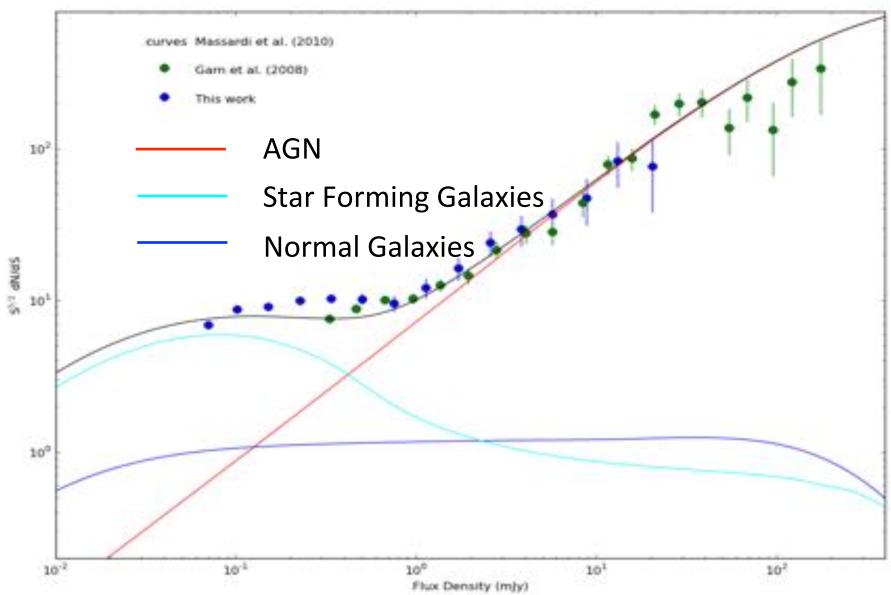
GMRT

IDIA

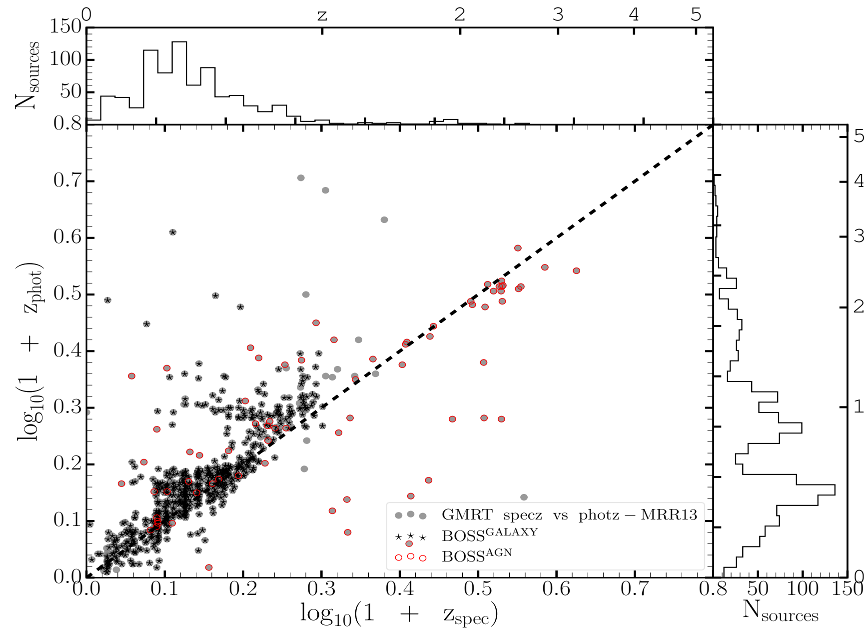
Spitzer







curves Massardi et al. (2010)
Garn et al. (2008)
This work
AGN
Star Forming Galaxies
Normal Galaxies
Flux Density (mJy)



$N_{sources}$
z
$\log_{10}(1 + z_{phot})$
$\log_{10}(1 + z_{spec})$
GMRT specz vs photz − MRR13
$BOSS^{GALAXY}$
$BOSS^{AGN}$

E. Ocran , M.Sc. Thesis, UWC

Multi-wavelength data critical to MIGHTEE Science

- MIGHTEE consortium members involved in multi-wavelength surveys over MIGHTEE fields
- key involvement in VISTA, *Herschel*, *Spitzer*, *XMM* surveys
- In the future, team members are playing leading roles in ESO-MOONs and ESO-4MOST multi-object spectroscopic surveys that will target the MIGHTEE fields.
- The MIGHTEE fields are also the LSST Deep Drilling Fields

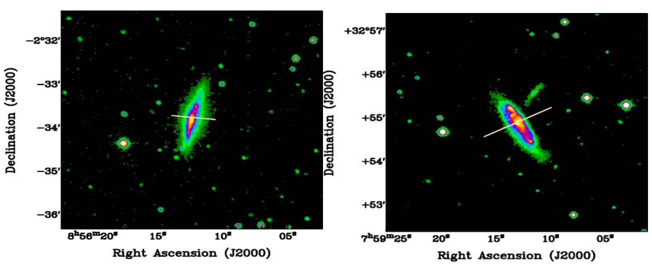
MIGHTEE Polarization Science Questions

- How do magnetic fields emerge and grow in galaxies and what is their role in galaxy formation and evolution?
- Is there a magnetic counterpart to the large-scale structure of the universe?
- What is the role of magnetic fields in galaxy cluster formation and evolution?
- Polarization as a probe of the cosmic evolution of the physical properties of AGN and magnetic fields in radio galaxies
- Polarization data may play a key role in weak lensing studies

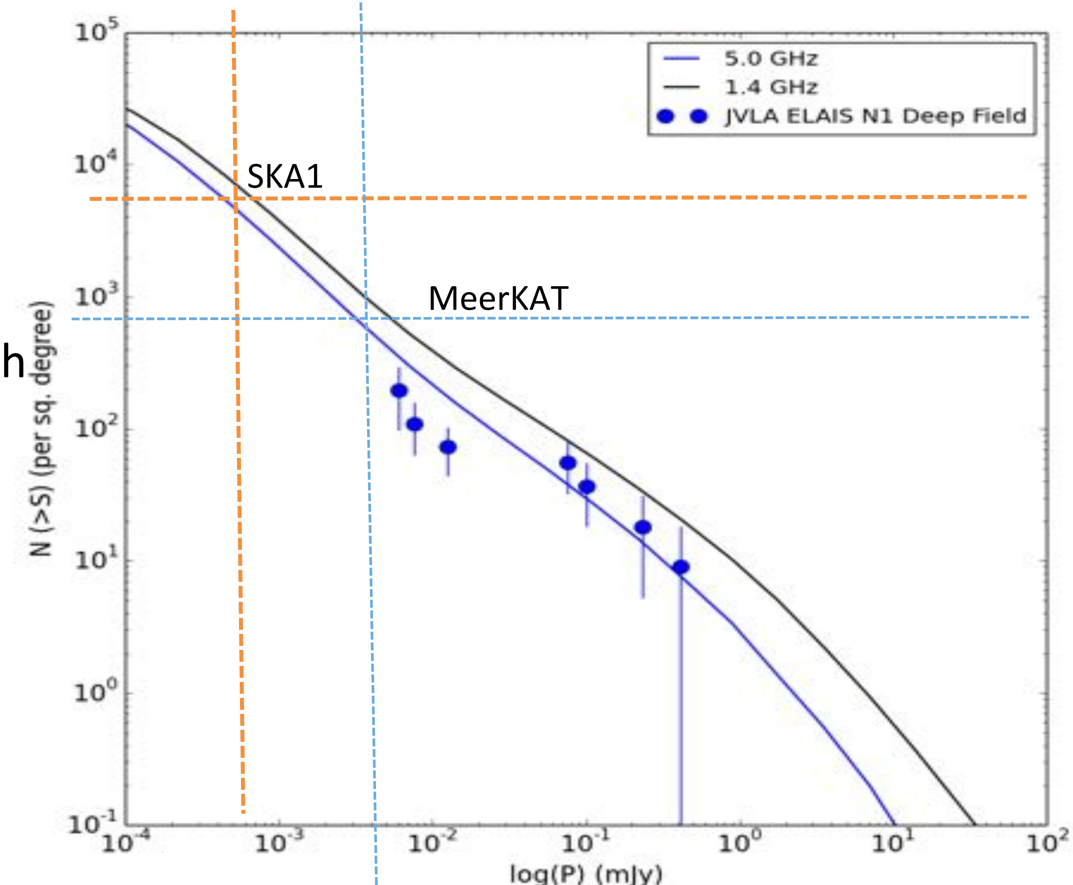
How many star forming galaxies?

- MeerKAT
  500-1000 galaxies per sq deg
  15,000 galaxies

- RM with 1 rad m^{-1} precision with average separation of a few arcminutes



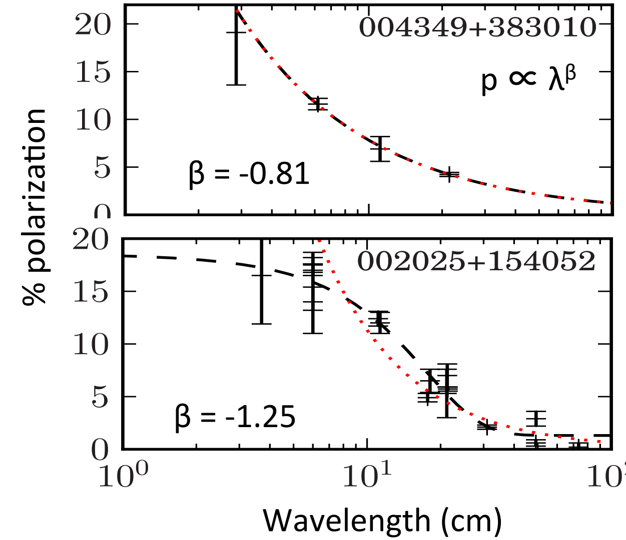
Stil et al. 2009



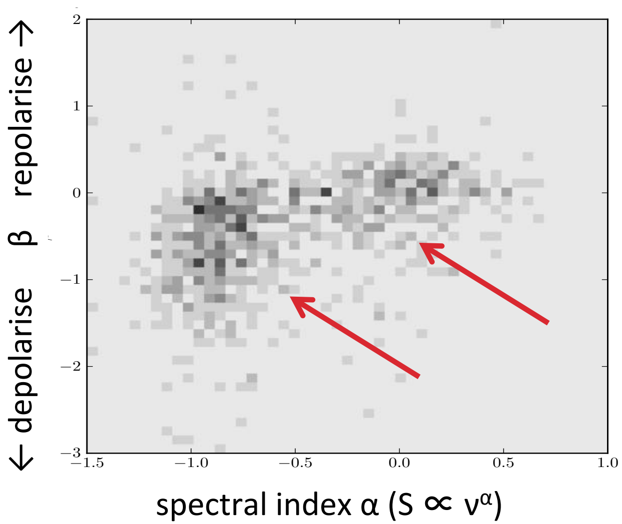
Farnes et al. (2014)

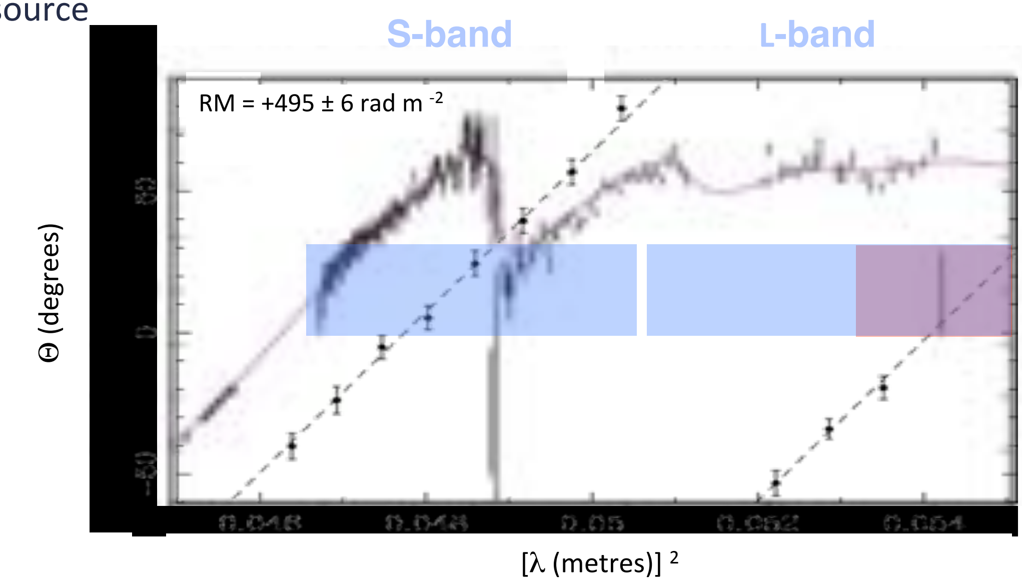
Broadband Polarization of Complete samples of AGN

- Sources can “depolarize” as function of wavelength
  - interference between multiple pol. components and rotators
  - depolarizing material: in the source? or in intervening material?
- New catalogue of 951 sources with broadband polarization SEDs (Farnes et al. 2014)
  - steep and flat spectrum sources have different depolarization
  - depolarization must be intrinsic to the source



Farnes et al. (2014)

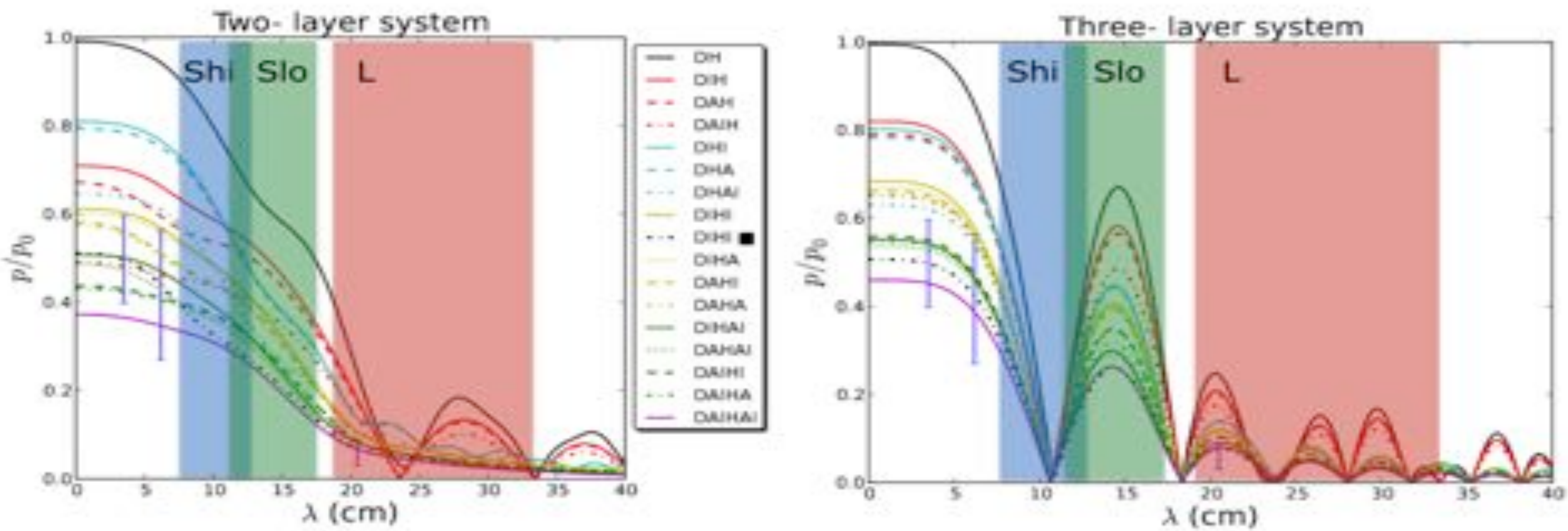




Spectral Polarization Signature of large Scale Galactic Fields

xies

Trace coherent magnetic fields in galaxies to z>1

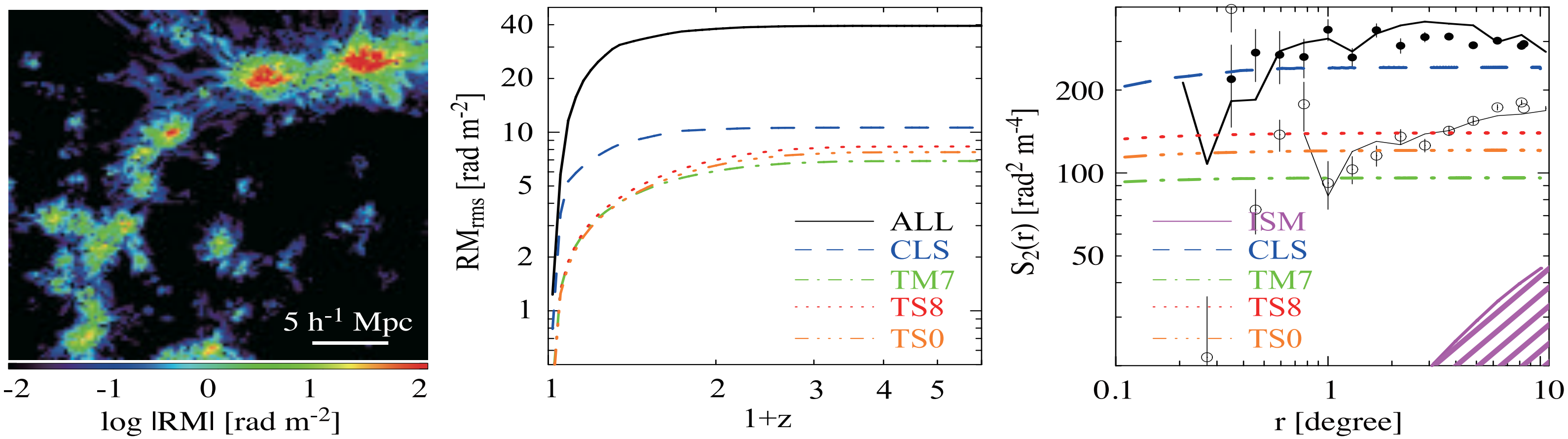


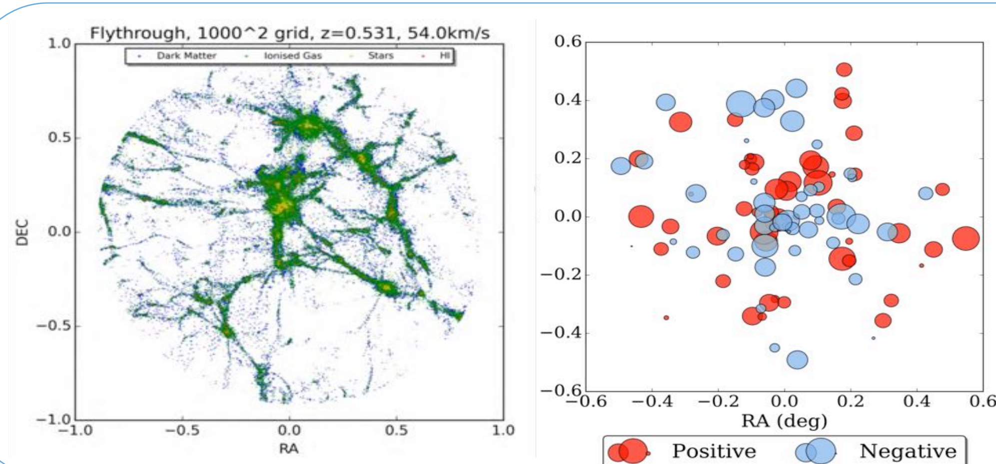
depolarisation models from Shneider et al (2014)

- MeerKAT bands: L (0.9-1.6 GHz); Slo (1.75-2.75 GHz); Shi (2.5-3.5 GHz)

RM Signature of the Magnetism in the Cosmic Web

Takuya & Rhy (2011)





Hunt, M.Sc. Thesis UCT

Data Plan: MIGHTEE-DATA

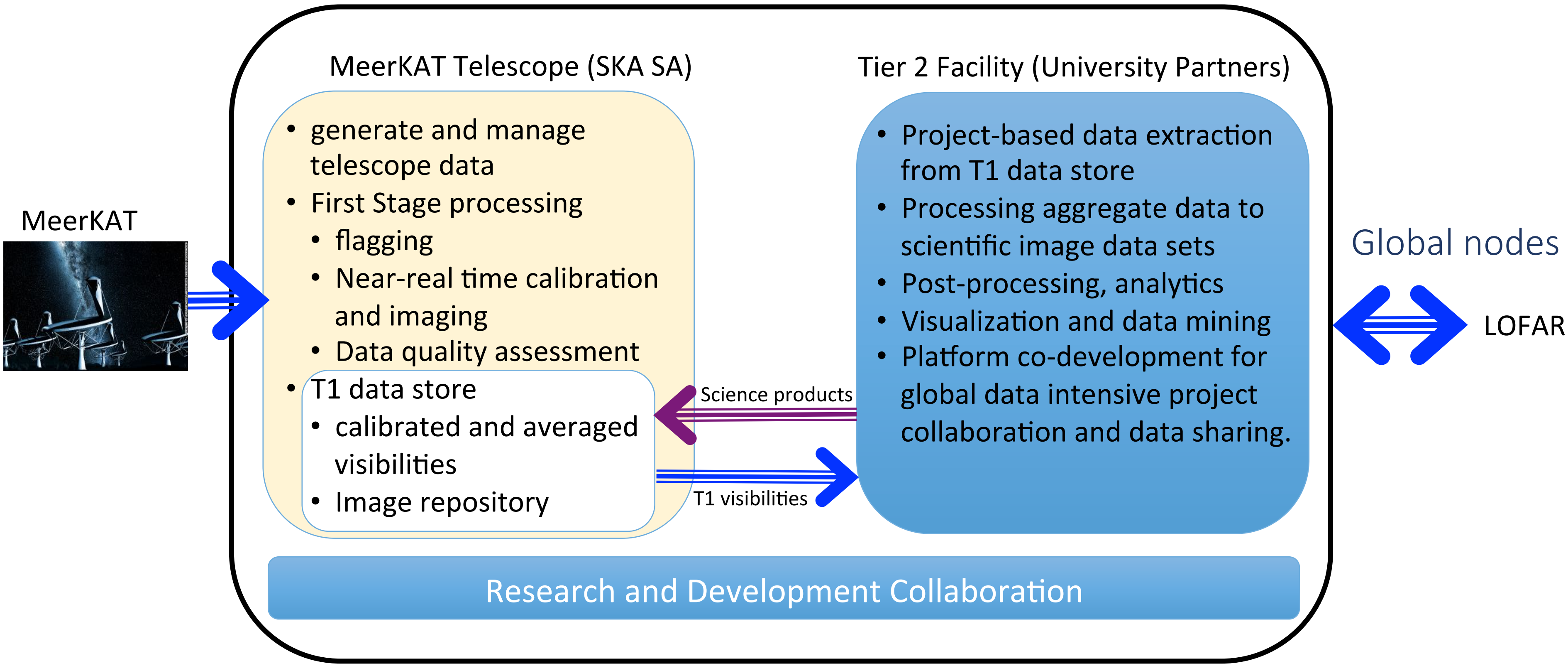
- Brad Frank, Ian Heywood, Tom Mauch, Russ Taylor

- Processing Continuum, polarization and HI developed by survey project teams
  - **Aggregation** of visibility data over the course of the survey
  - **Pipelines:** full-Stokes calibration, complex band pass, u-v weighting, gridding, de-convolution, multi-frequency synthesis, self-calibration, wide-band direction dependent corrections (A-projection), mosaiking, Faraday synthesis, full-Stokes and spectral source finding, …
  - **Experimental visibility plane analyses**,
    - Multi-frequency synthesis over very large bandwidths, different bands and different telescopes.
    - Faraday Synthesis in visibilities (merge MFS and FS)
    - Confusion analysis, stacking, P(D),....

- Take advantage of developments and best practices for other large survey projects, eg. VLASS, POSSUM,WALLABY,LOFAR ...

SKA Precursor Regional Science Data Centres

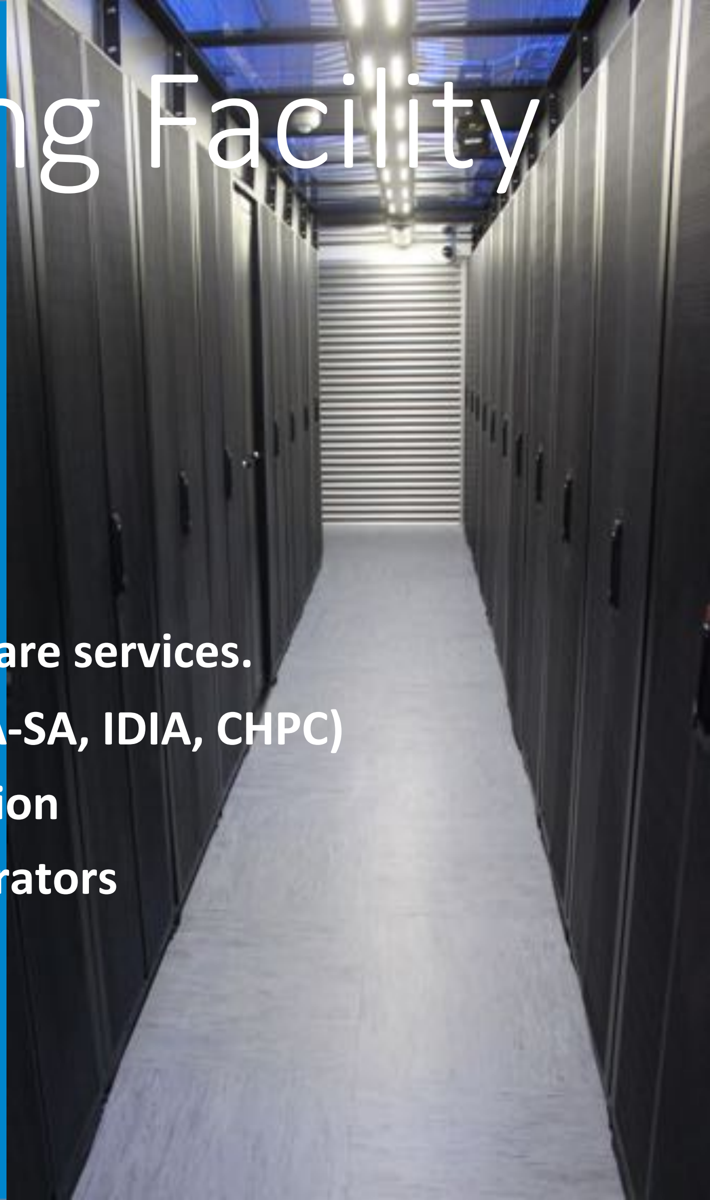
MeerKAT and LOFAR data and use cases



IDIA Tier 2 Processing Facility

- 22 nodes with 256 GB (32 cores each)
- 16 – 32 nodes with 256 GB (32 cores each)
- 8 GPU nodes (32 cores each)
- 5 – 7 PB fast attached storage (disk)

- Cloud-based provisioning, and platform and software services.
- Part of African Data Intensive Research Cloud (SKA-SA, IDIA, CHPC)
- Available for all LSPs with South African Participation
- Management and operations governed by collaborators




Stay tuned…