



High Sensitivity Imaging with MeerKAT and uGMRT: Exploring the Deep GHz Universe

MWsky 2, Pune, 19 March 2019



- MeerKAT and MIGHTEE
- Complementarity of uGMRT and MeerKAT
- superMIGHTEE and the deep GHz Sky

SKA-mid 0: MeerKAT completed at the SA SKA Site

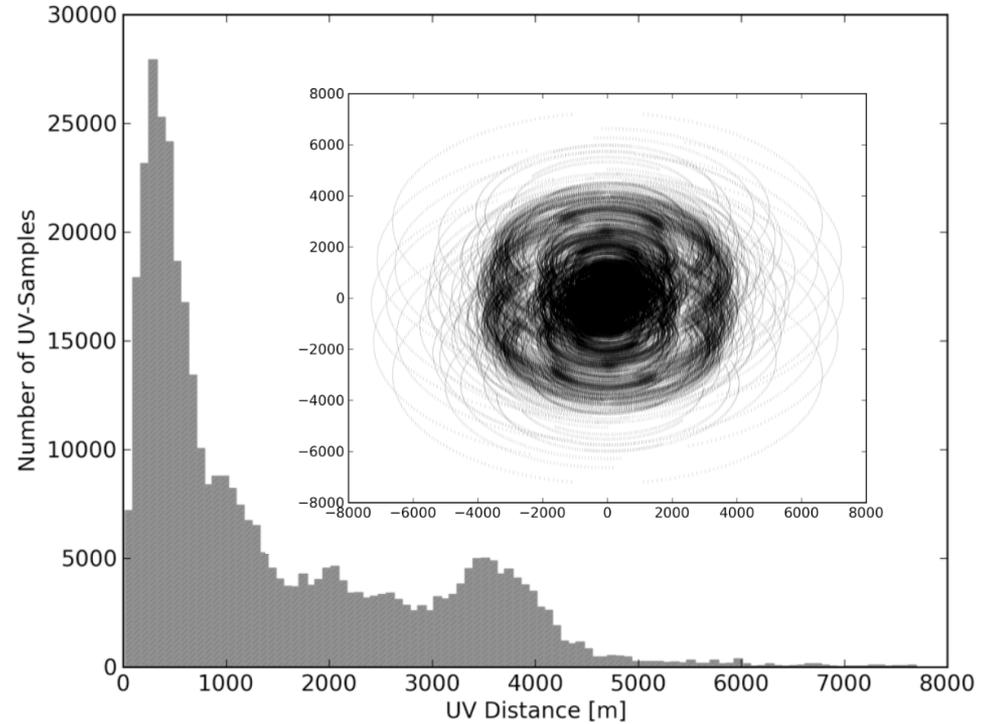
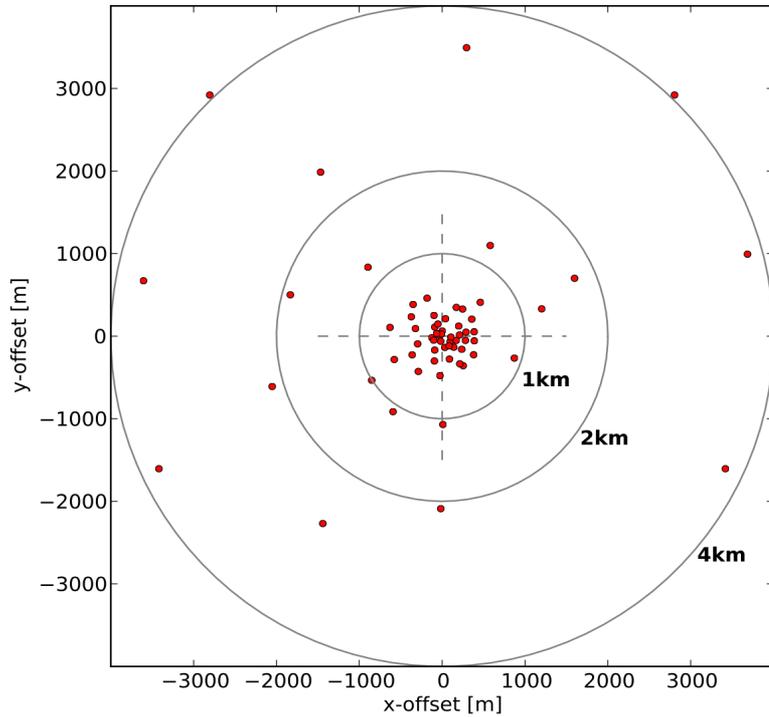
13 July 2018



SKA-mid 0: MeerKAT completed at the SA SKA Site



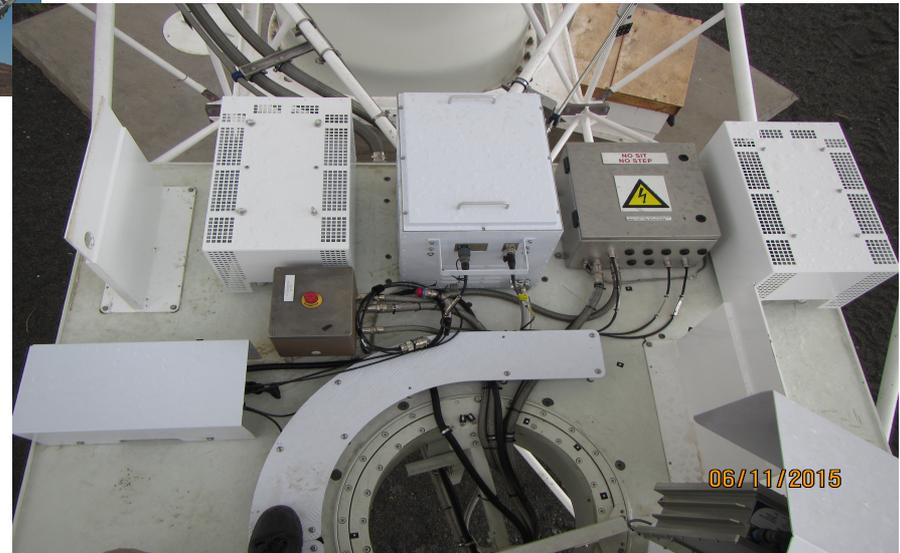
MeerKAT Configuration



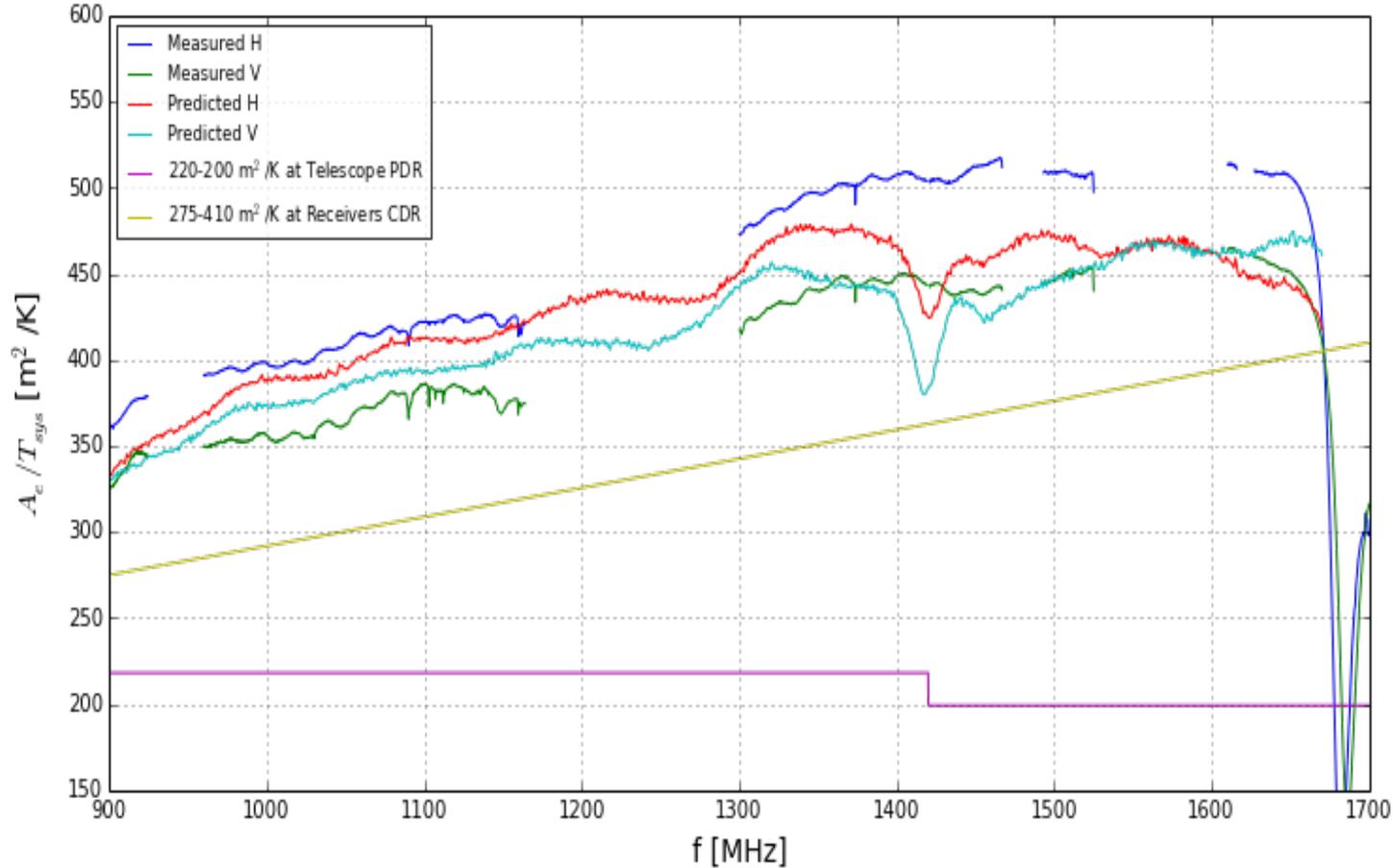
MeerKAT Receivers



- 0.58-1.015 GHz (UHF-band)
- 0.9 – 1.67 GHz (L-band)
- 1.75 - 3.75 GHz (S-band)



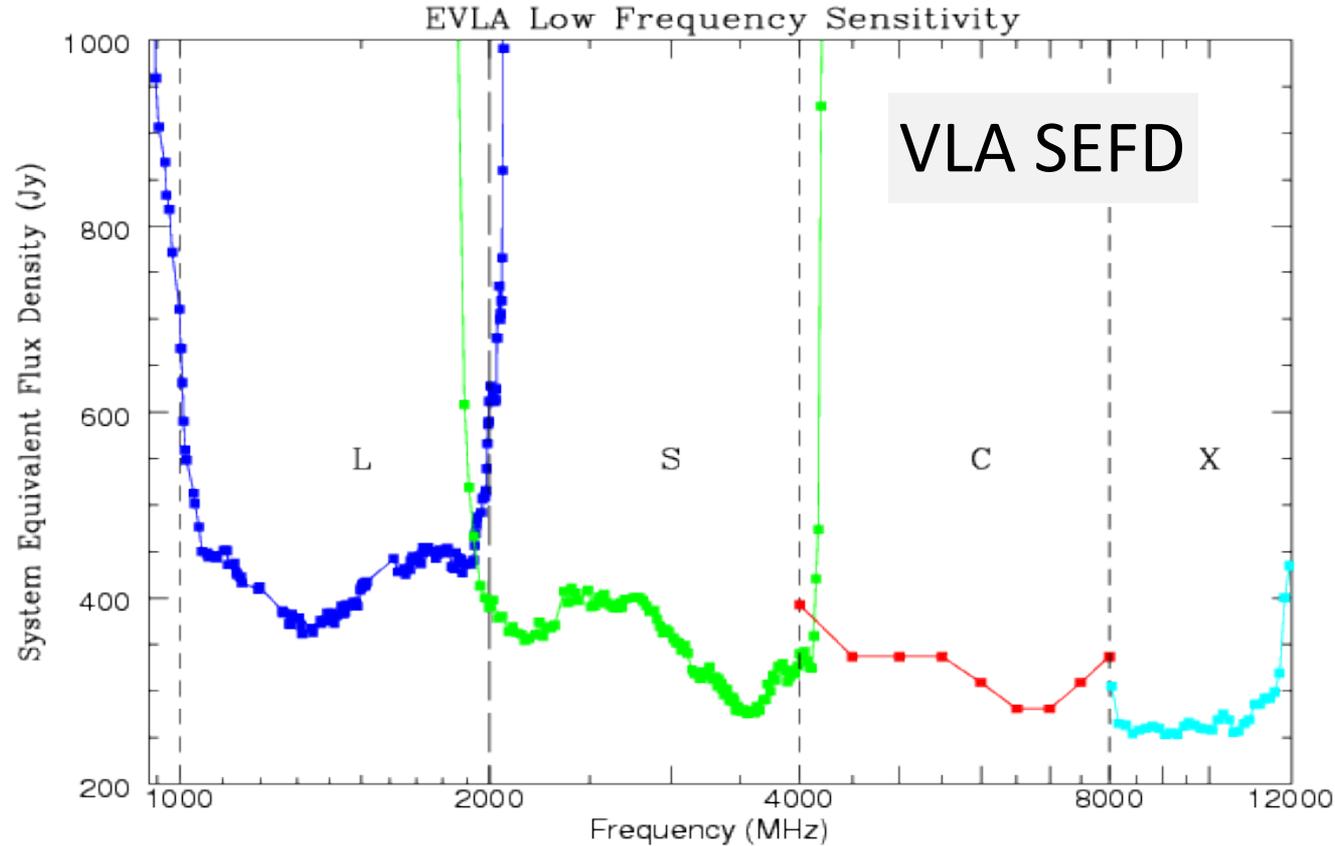
MeerKAT L-band performance



$$SEFD = \frac{2kT_{sys}}{\eta_a \frac{\pi}{4} D^2}$$

@400 SEFD for a single antenna = 441 Jy

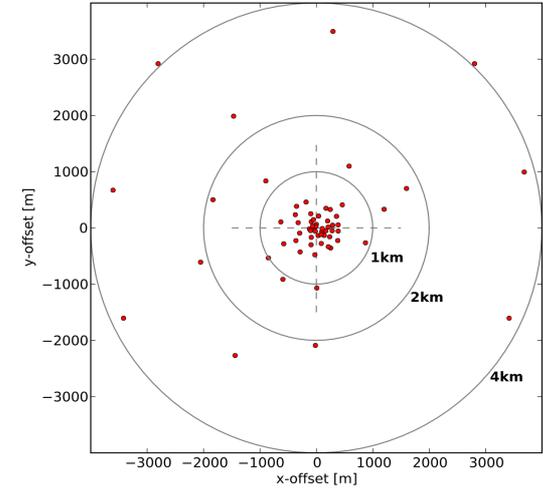
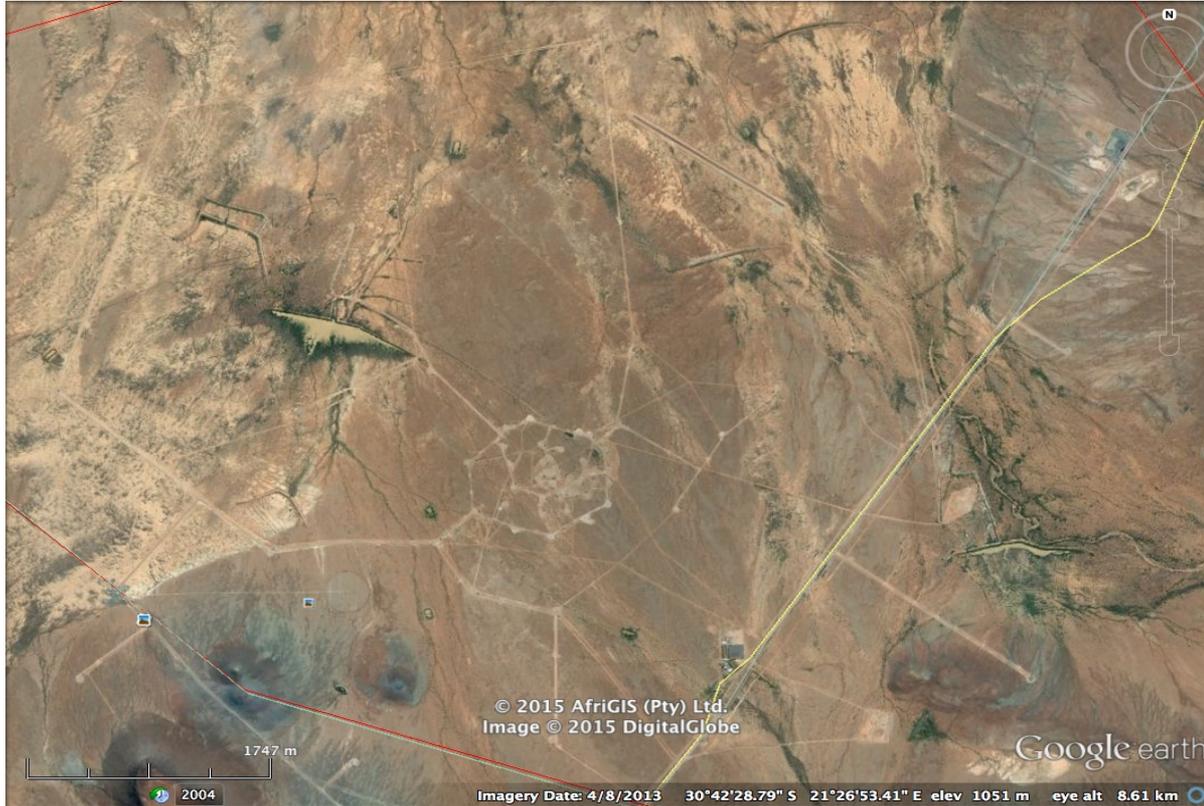
Extremely good L-band performance



$$SEFD = \frac{2kT_{sys}}{\eta_a \frac{\pi}{4} D^2}$$

@ A/T=400, SEFD for a single antenna = 441 Jy

MeerKAT Array: A powerful imaging telescope



VLA 'E'+D+C+B configuration all at once, with 4 times the FoV.

MeerKAT Large Survey Projects

Imaging domain

- LADUMA (Deep atomic hydrogen)
- **MIGHTEE (Deep imaging for galaxy evolution)**
- Fornax (Deep HI Survey of the Fornax cluster)
- MHONGOOSE (targeted nearby galaxies HI)
- MeerKAT Absorption Line Survey (extragalactic HI absorption)

Time domain

- ThunderKAT (exotic phenomena, variables and transients)
- TRAPUM (pulsar search)
- MeerTime (pulsar timing)



MIGHTEE: Observing Plan (4-5 years)

1960 hours

MIGHTEE MID L-band: $2 \mu\text{Jy rms}$

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

MIGHTEE MID S-band: $1 \mu\text{Jy rms}$

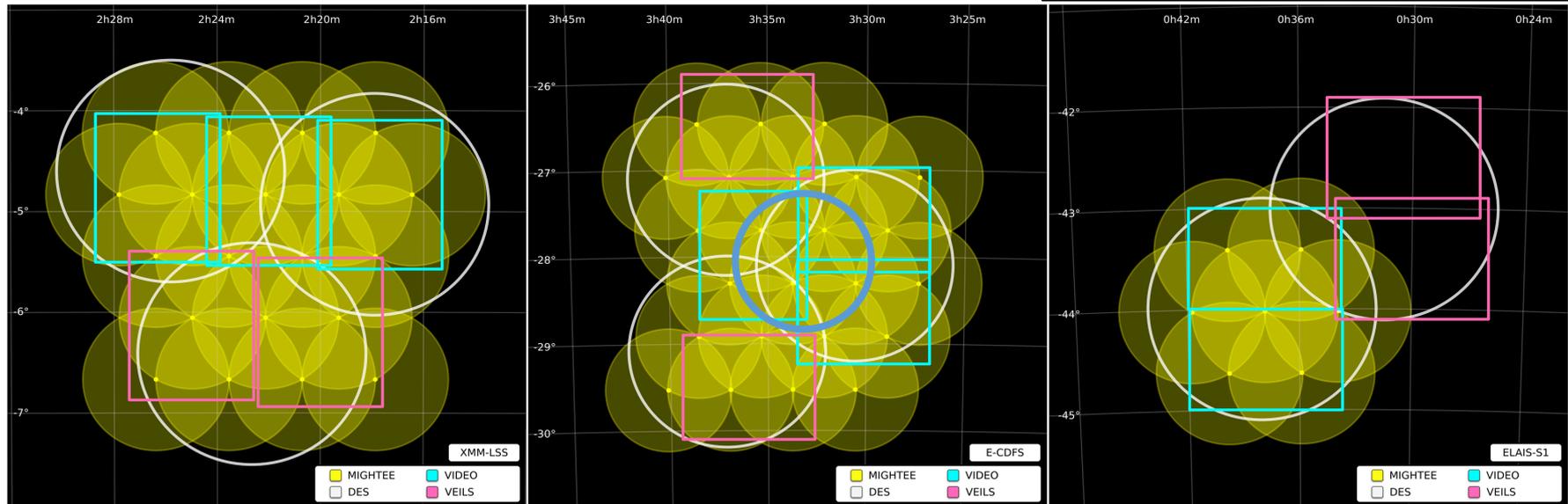
- CDFS – 5 deg^2
- COSMOS – 1 deg^2

5000 hours

MIGHTEE DEEP L-band: $0.1 \mu\text{Jy rms}$ UHF: $0.1 \mu\text{Jy rms}$

- CDFS – 1 deg^2

LADUMA COMMENSAL



Principal Investigators: Matt Jarvis (Oxford), Russ Taylor (IDIA)

MIGHTEE: Observing Plan (4-5 years)

1960 hours

5000 hours

MIGHTEE MID L-band: 2 μJy rms

- XMSS – 6.7 deg²
- CDFS – 8.3 deg²
- ELAIS S1 – 1.6 deg²
- COSMOS – 1 deg²

MIGHTEE MID S-band: 1 μJy rms

- CDFS – 4 deg²
- COSMOS – 1 deg²

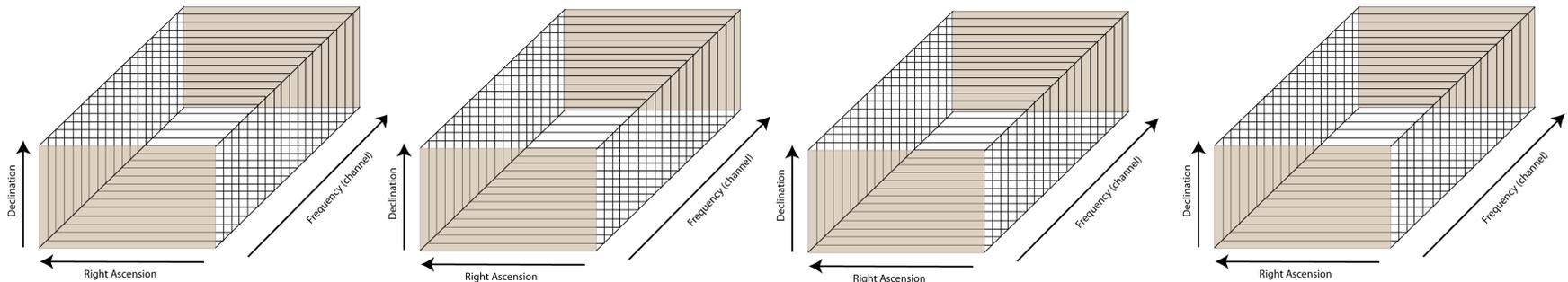
MIGHTEE DEEP L-band: 0.1 μJy rms UHF: 0.1 μJy rms

- CDFS – 1 deg²

LADUMA COMMENSAL

Data products

- Broad band multi-frequency synthesis images
- 4D spectro-polarimetric data cubes (1k channels)
- 3D HI spectral cubes (32 k channels)



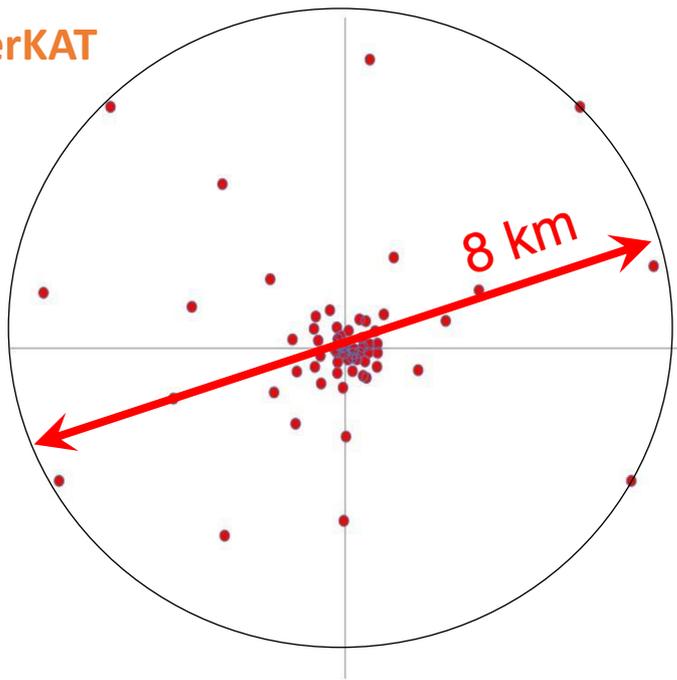
uGMRT–MeerKAT

Angular Resolution Complementarity

$$\theta_{1.8 \text{ GHz}} = 5''$$

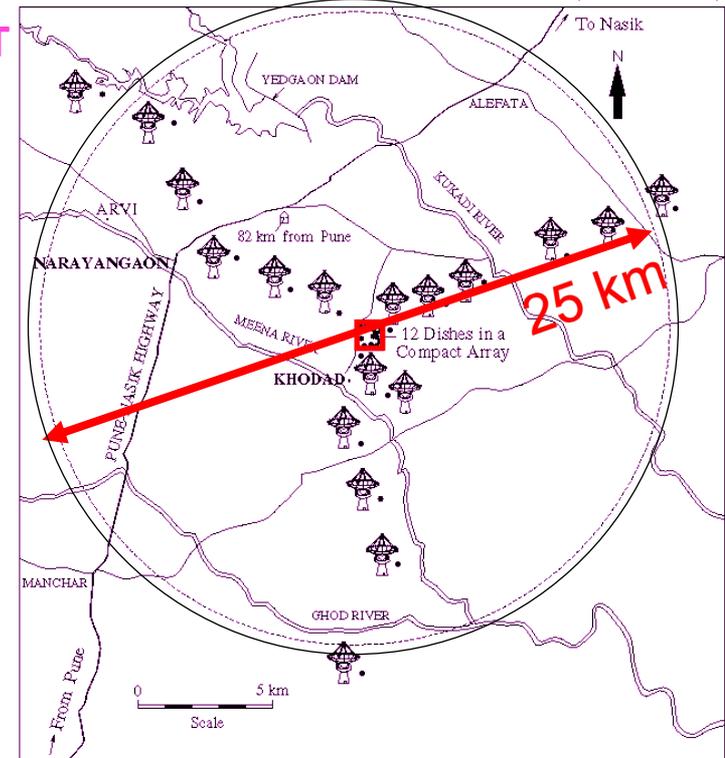
$$\theta_{0.6 \text{ GHz}} = 5''$$

MeerKAT



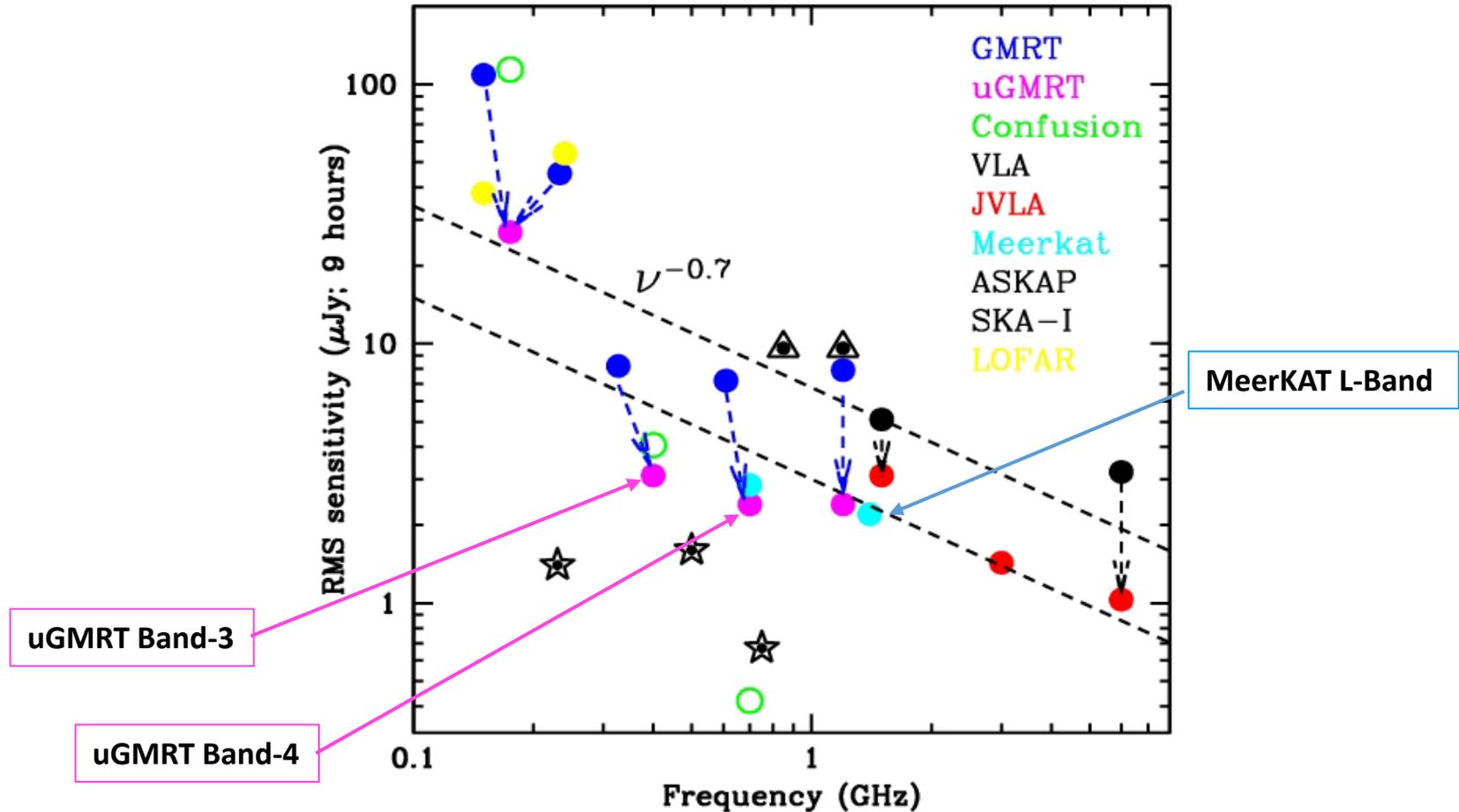
GMRT

LOCATIONS OF GMRT ANTENNAS (30 dishes)



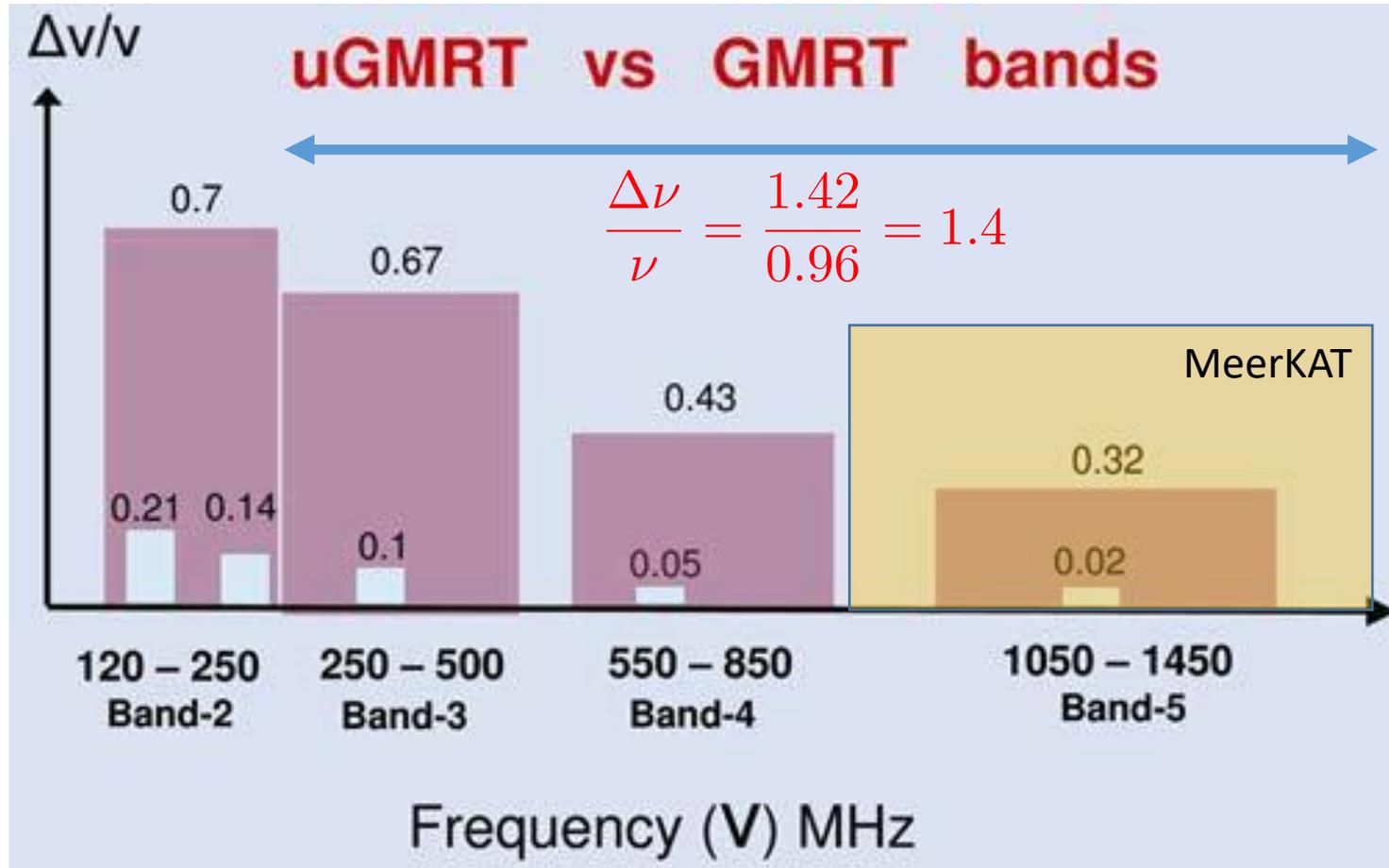
uGMRT-MeerKAT

Sensitivity Complementarity



uGMRT-MeerKAT

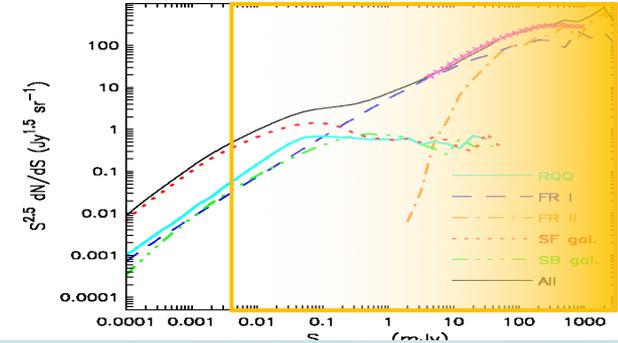
Frequency Complementarity



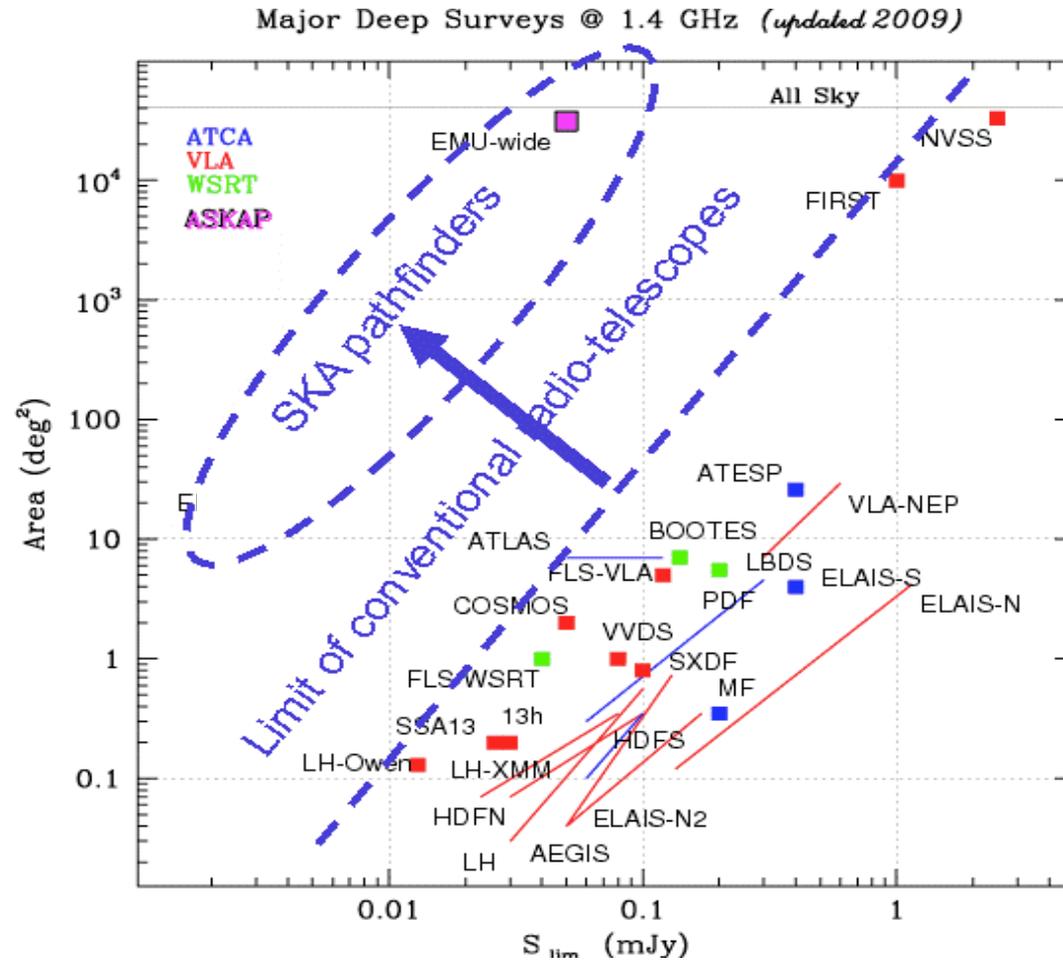
SuperMIGHTEE

An uGMRT-MIGHTEE ultra-broad band Deep full Stokes Survey

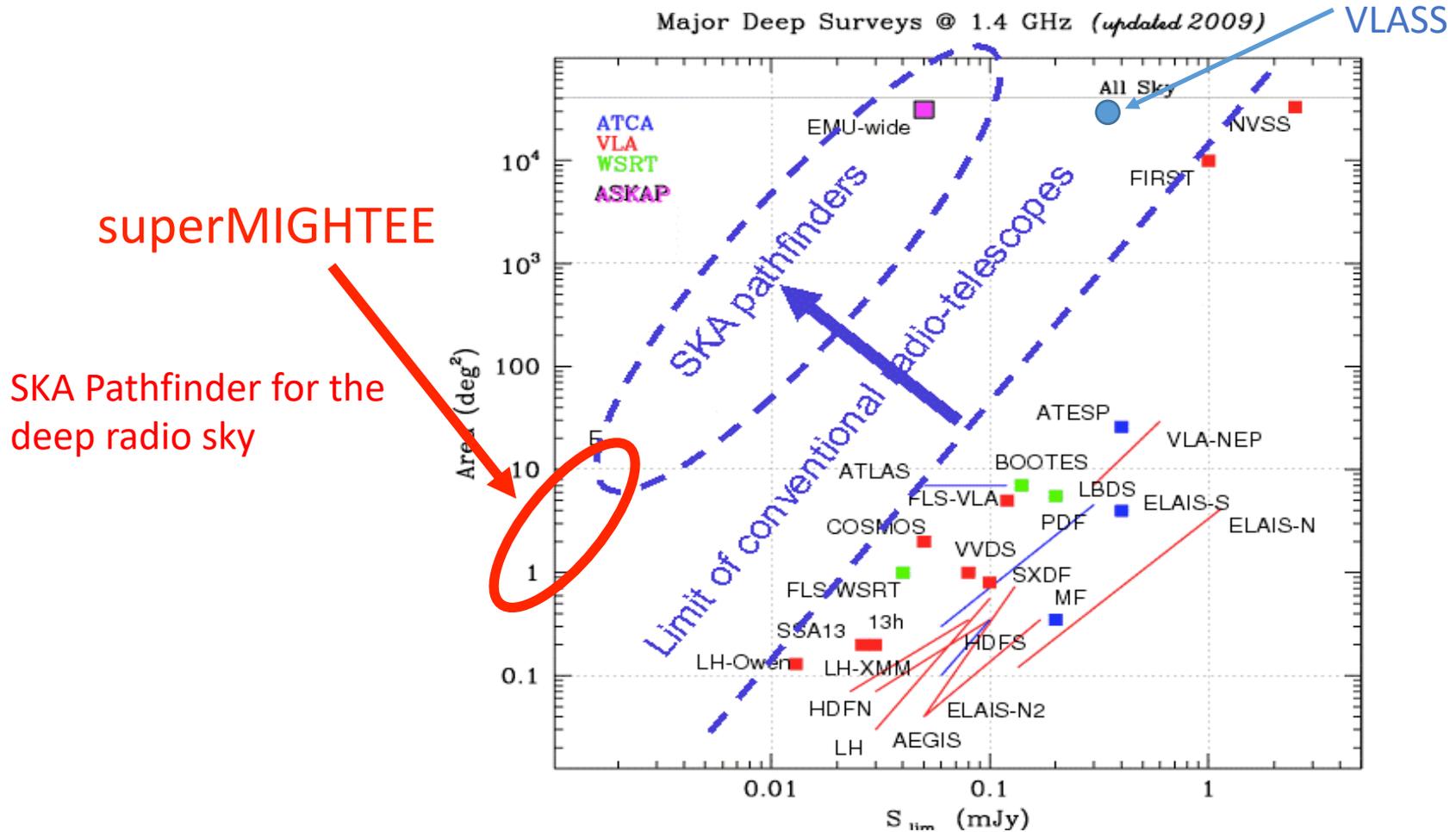
- 0.25 – 1.7 GHz (14 deg²), 0.25 – 2.7 GHz (6 deg²)
- rms 2 μ Jy per band
- 5" resolution



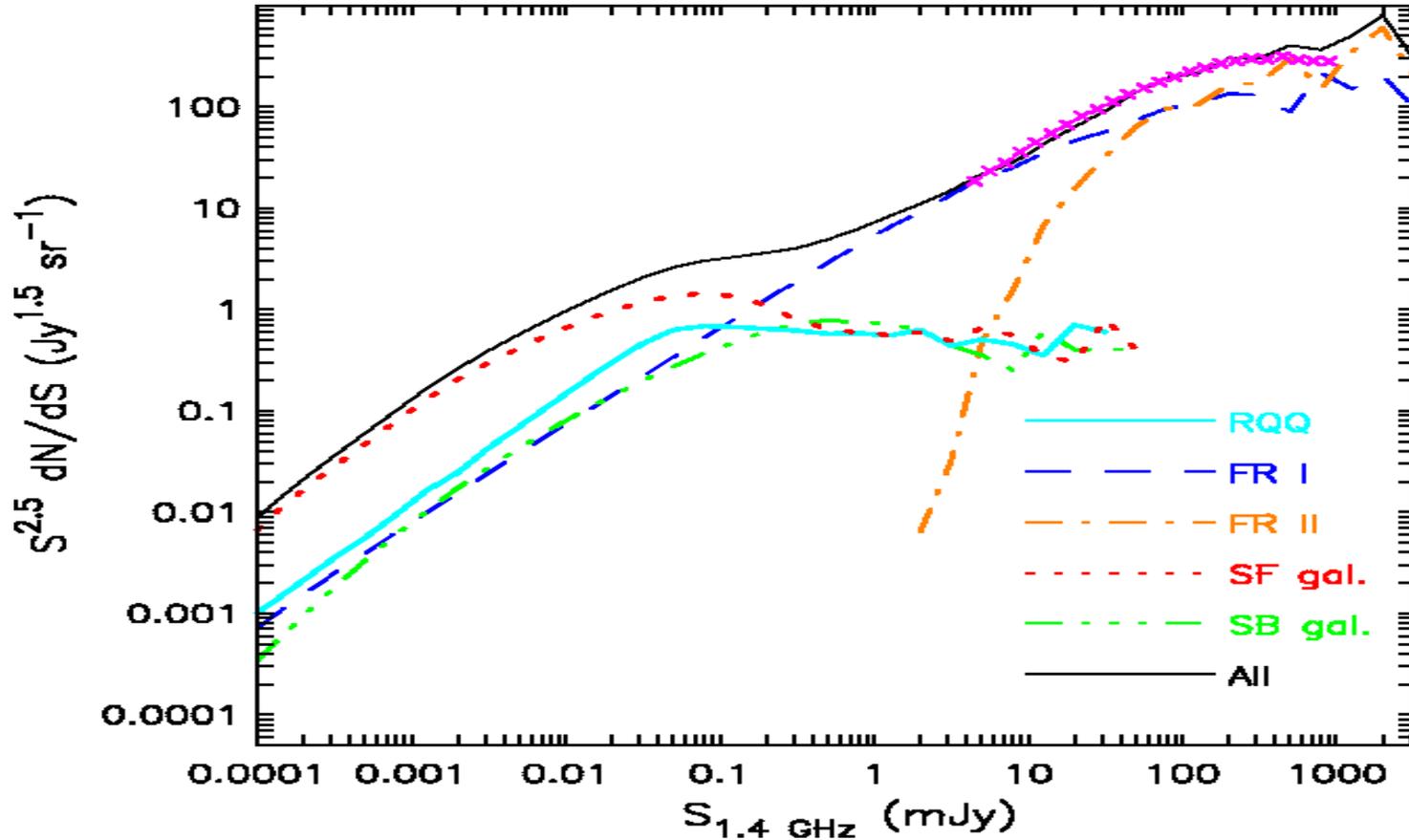
SKA Pathfinder Continuum Surveys



SKA Pathfinder Continuum Surveys

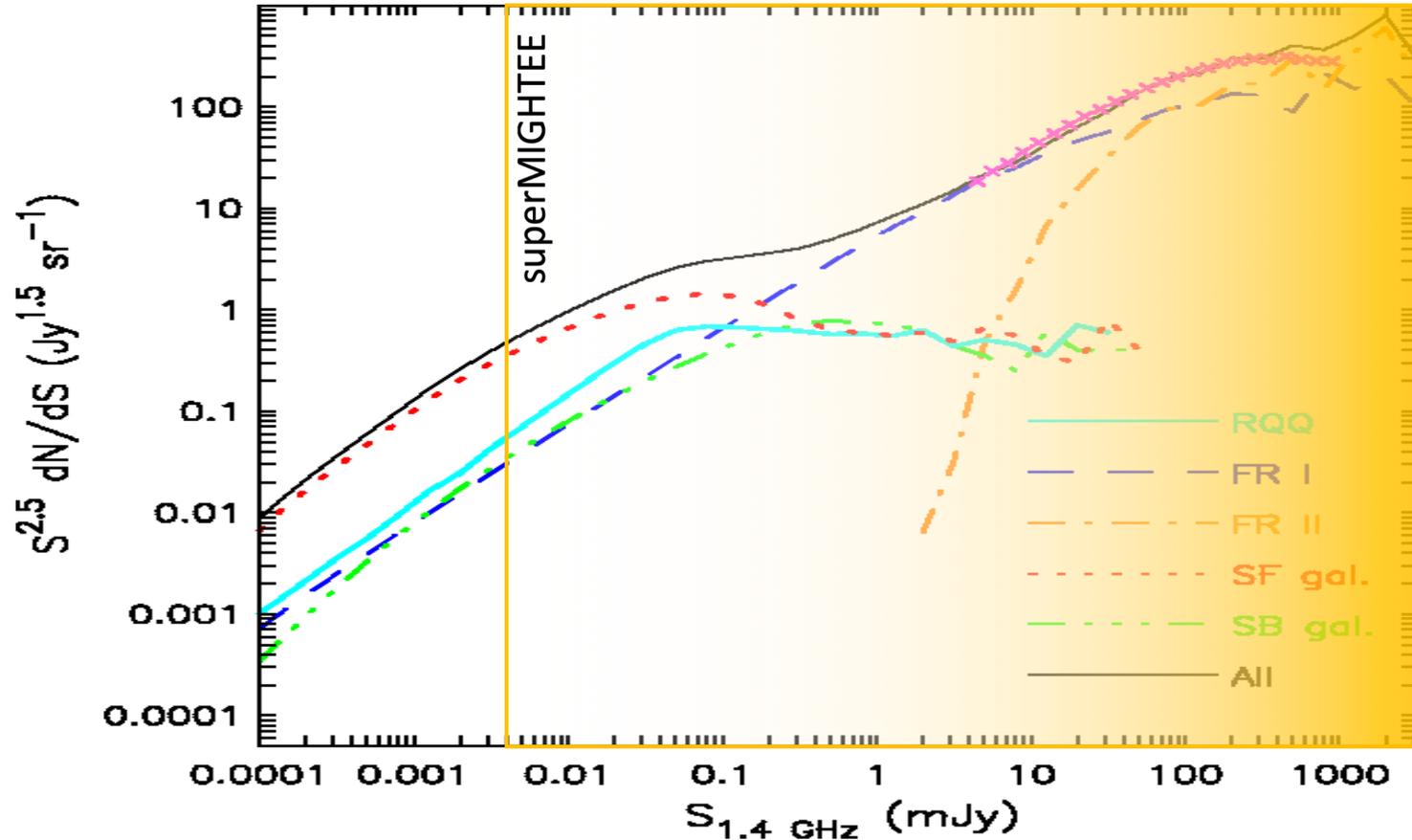


Radio Source Populations



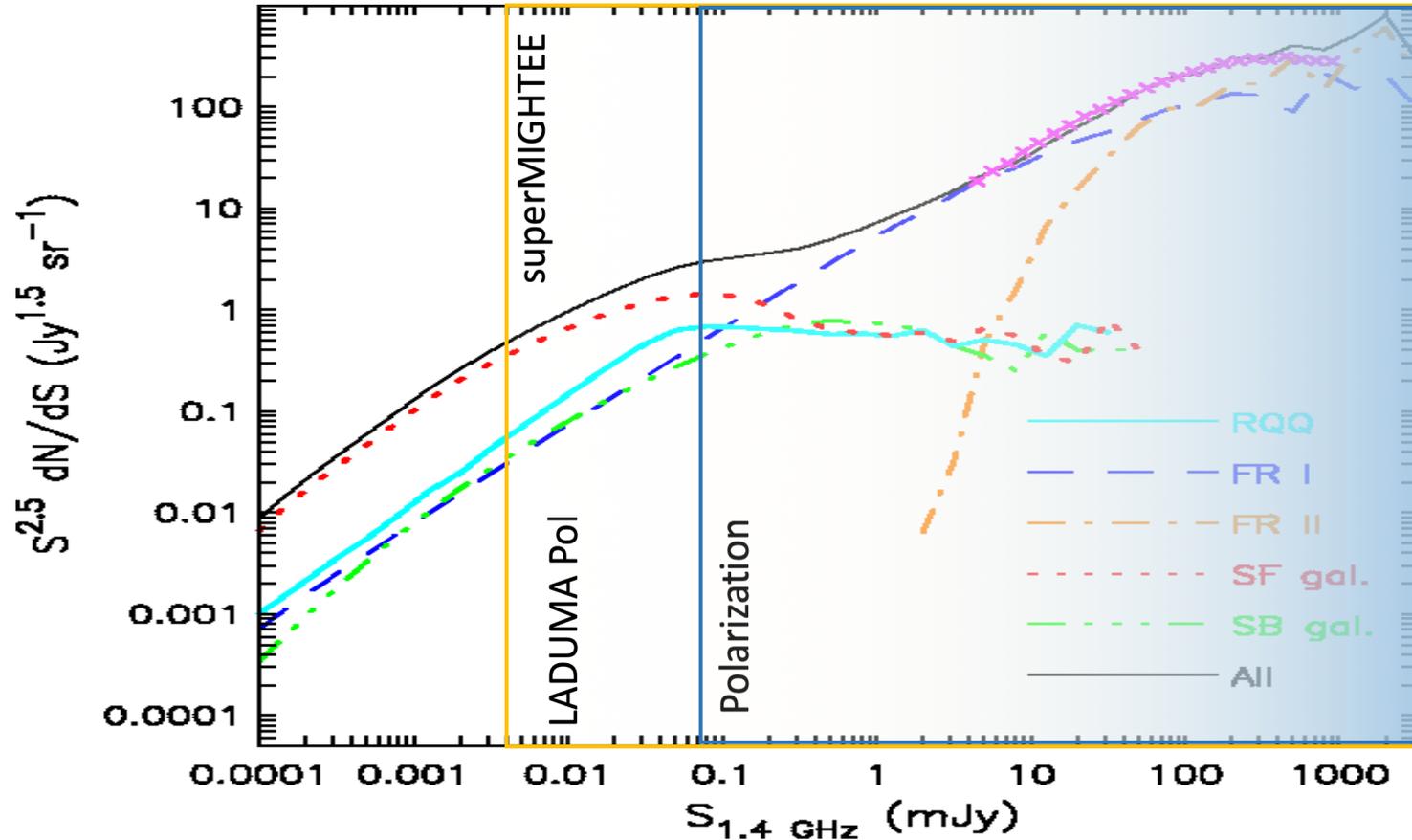
Total intensity source populations counts: SKADS Simulation (Wilman et al. 2008)

Radio Source Populations – superMIGHTEE



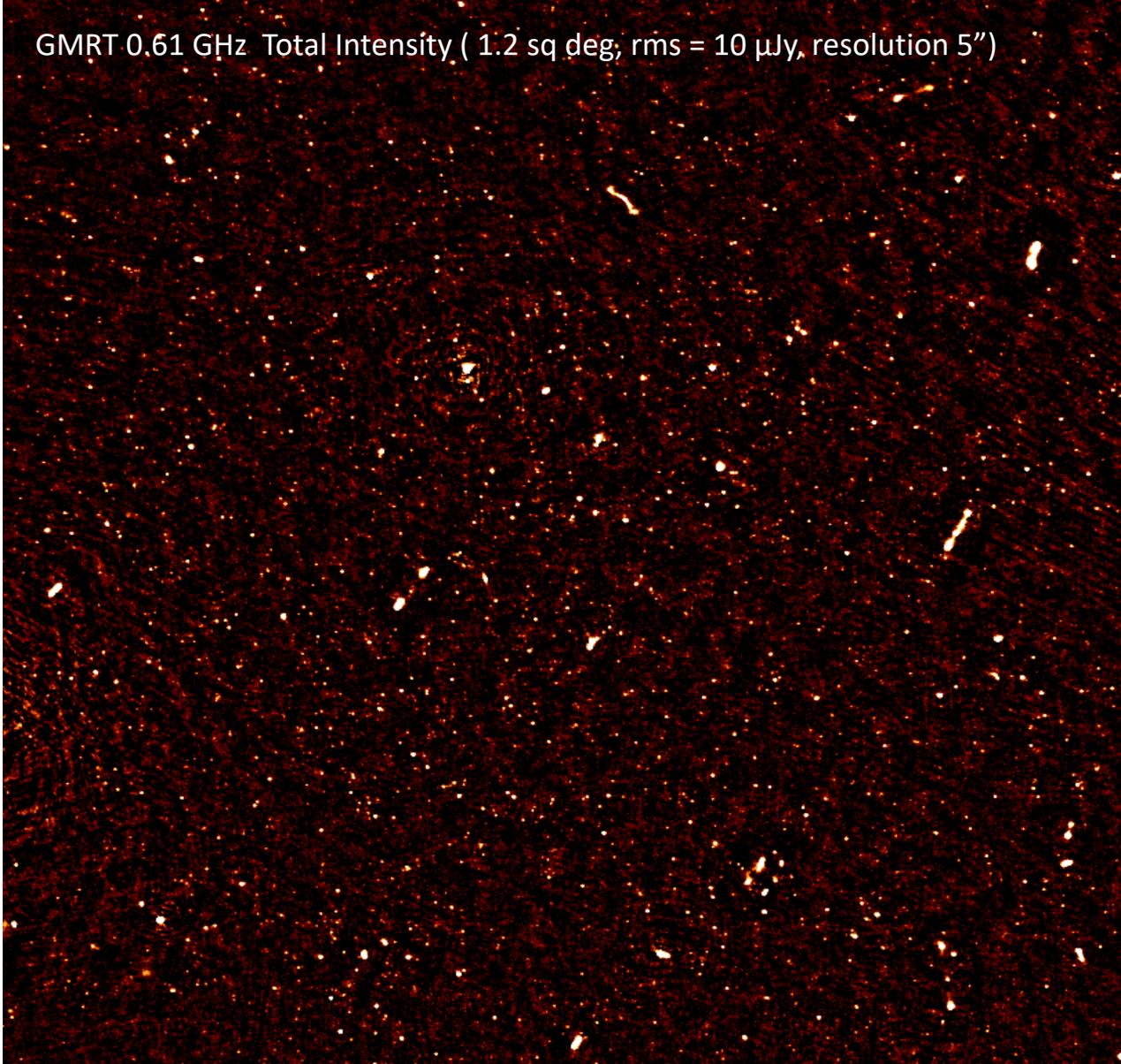
Total intensity source populations counts: SKADS Simulation (Wilman et al. 2008)

Radio Source Populations – superMIGHTEE PoI



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

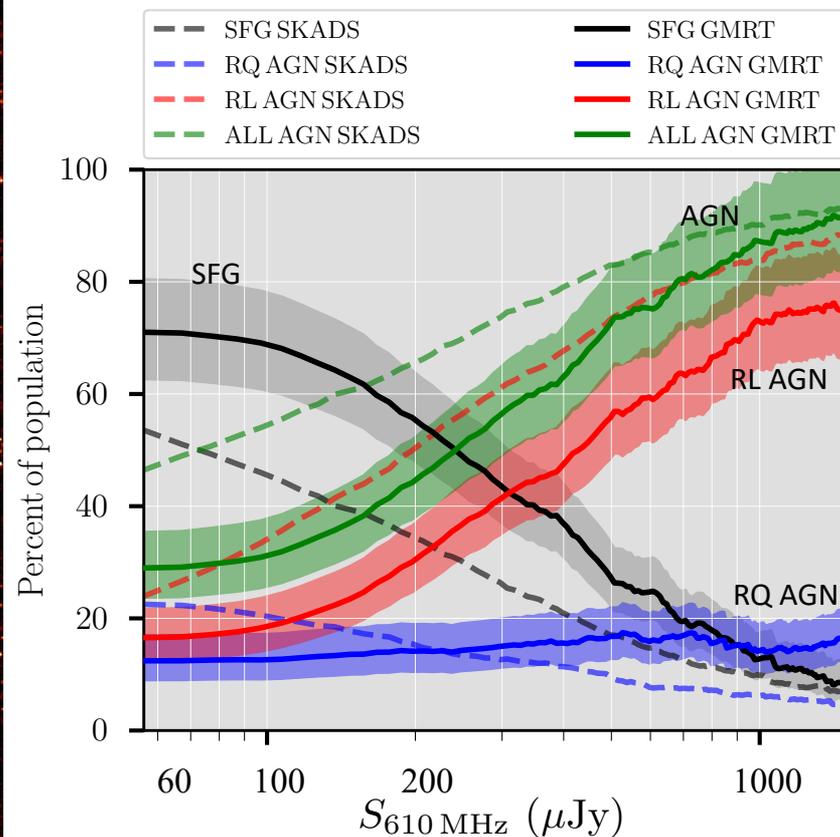
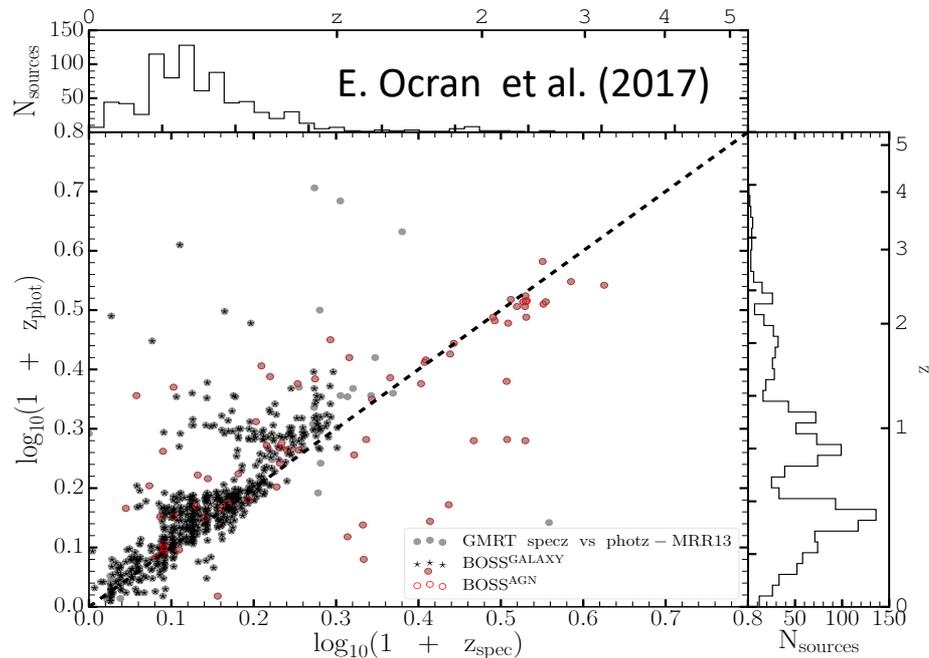
GMRT 0.61 GHz Total Intensity (1.2 sq deg; rms = 10 μ Jy, resolution 5")



GMRT



Multi-wavelength Analysis



See poster by Emmanuel Ocran

MIGHTEE Early Observations (L-band)

CYBERSKA

A Cyberinfrastructure platform to meet the needs of data intensive radio astronomy on route to the SKA

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Pages > MIGHTEE > MIGHTEE MeerKAT Observation Summary

Create a sub-pag



MIGHTEE
MeerKAT International GigaHertz
Tiered Extragalactic Exploration
survey

Closed group

Subgroups:

- MIGHTEE-GMRT
- MIGHTEE-Continuum
- MIGHTEE-Noise
- MIGHTEE-HI-absorption
- MIGHTEE-HI-emission
- MIGHTEE-XID
- MIGHTEE-POL
- MIGHTEE-Data
- MIGHTEE Management Team

Group Applications

Group activity

Group blog

Group bookmarks

Group calendar

Group discussion

Group file folders

Group files

Group pages

Group tasks

Related groups

Edit group settings

Edit widget layout

Invite to group

MIGHTEE MeerKAT Observation Summary

Last updated just now by Russ Taylor Comments (1)

 mightee, observations

Group: MIGHTEE Edit 

This page contains a summary listing of MIGHTEE MeerKAT observations. The pointing coordinate for all of MIGHTEE target fields are [listed here](#).

Summary of MIGHTEE MeerKAT observations

DATE	ID	POINTING	TARGET	PRIMARY	SECONDARY	POL	T_int [s]	N_chan	Track [h]	N_ant
2018-04-11	1523464709	COSMOS	COSMOS	J0408-6545	3C237	J1331+3030	8	4096	6.74	54
2018-04-12	1523518570	CDFS_16	CDFS16	J1939-6342	J0240-2309	J0521+1638	4	4096	4.26	55
2018-04-12	1523541036	CDFS_16	CDFS16	J1939-6342	J0240-2309	J0521+1638	4	4096	4.33	55
2018-04-19	1524147354	COSMOS	COSMOS	J0408-6545	3C237	J1331+3030	4	4096	8.65	64
2018-05-06	1525613583	COSMOS	COSMOS	J0408-6545	3C237	J1331+3030	4	4096	8.39	62
2018-10-06	1538856059	XMMLSS_12	J0217-0449	J1939-6342	J0201-1132	J0521+1638	8	4096	8.02	59
2018-10-07	1538942495	XMMLSS_13	J0220-0449	J1939-6342	J0201-1132	J0521+1638	8	4096	8.07	59
2018-10-08	1539028868	XMMLSS_14	J0223-0449	J1939-6342	J0201-1132	J0521+1638	8	4096	8.03	60
2018-10-09	1539109858	ELAIS-S1_4	J0037-4359	J1939-6342	J0224-4202	J0521+1638	8	4096	8.02	62
2018-10-11	1539286252	XMMLSS_12	J0217-0449	J1939-6342	J0201-1132	J0521+1638	8	4096	8.05	63
2018-10-12	1539372679	XMMLSS_13	J0220-0449	J1939-6342	J0201-1132	J0521+1638	8	4096	8.03	62
2018-10-13	1539460932	XMMLSS_14	J0223-0449	J1939-6342	J0201-1132	J0521+1638	8	4096	8	62
2018-10-14	1539540056	ELAIS-S1_4	J0037-4359	J1939-6342	J0224-4202	J0521+1638	8	4096	8.03	62

Comments

 Ian Heywood 28 days ago

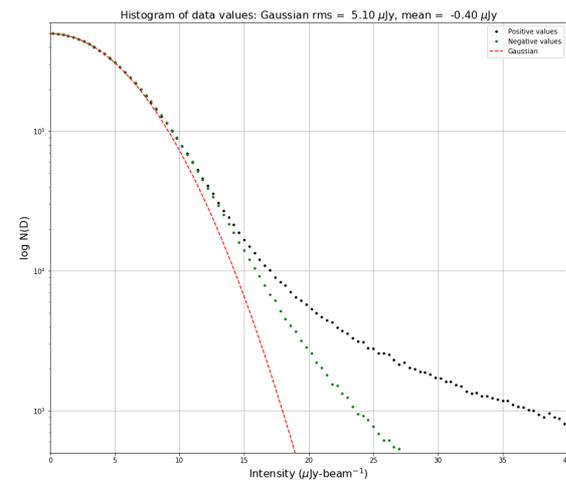
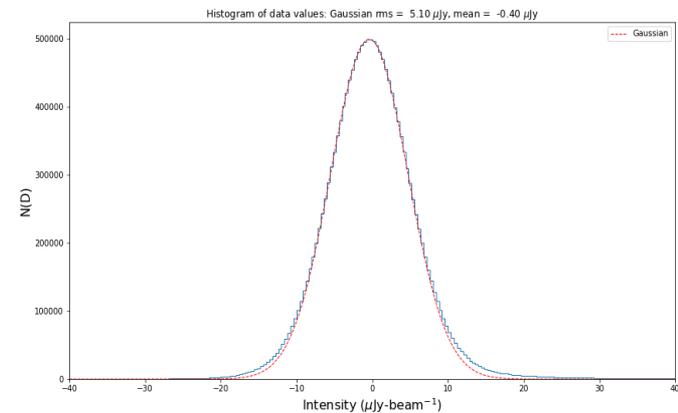
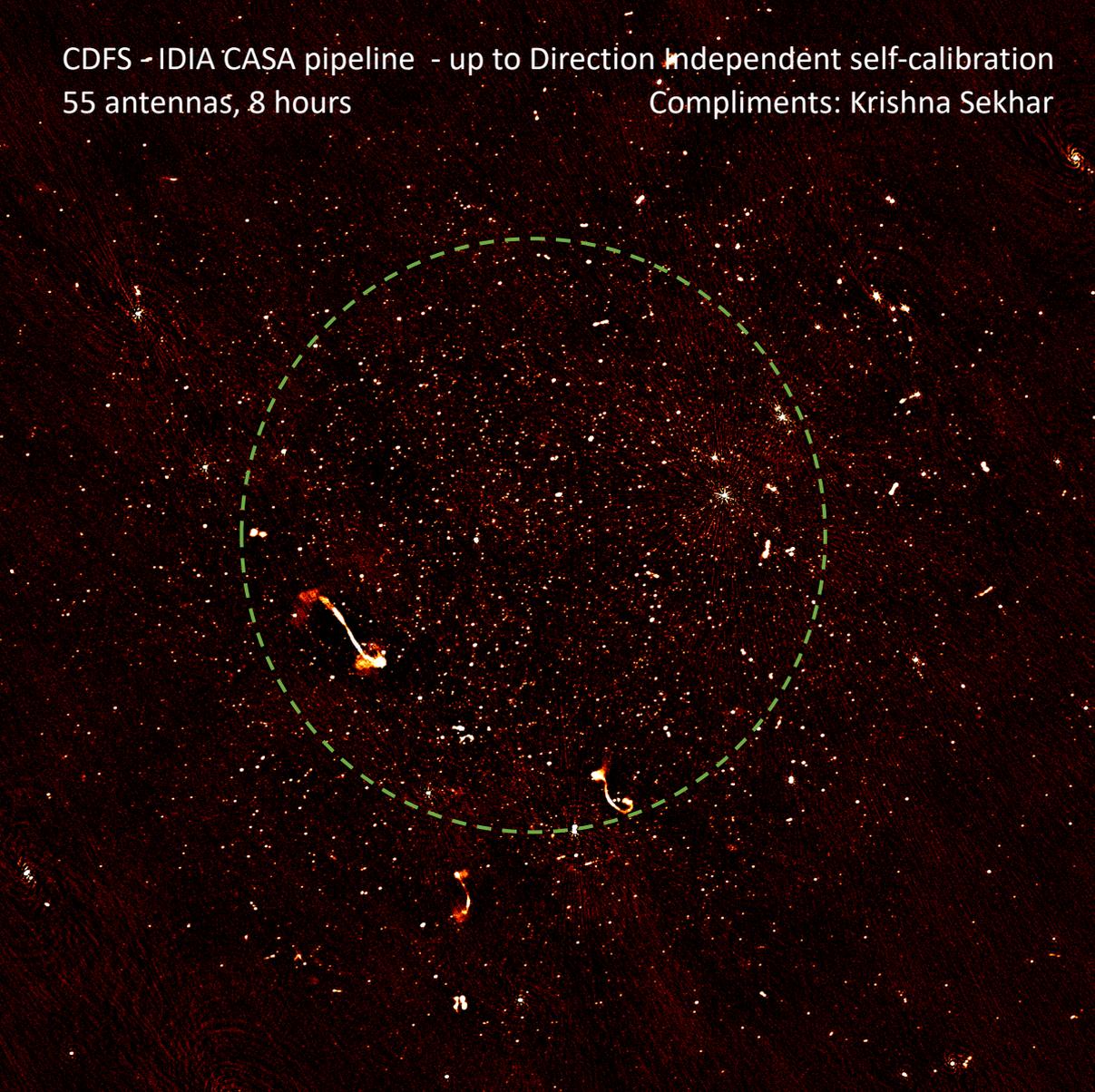
Here is a spreadsheet with details of the most recent observations in.

Edit comment



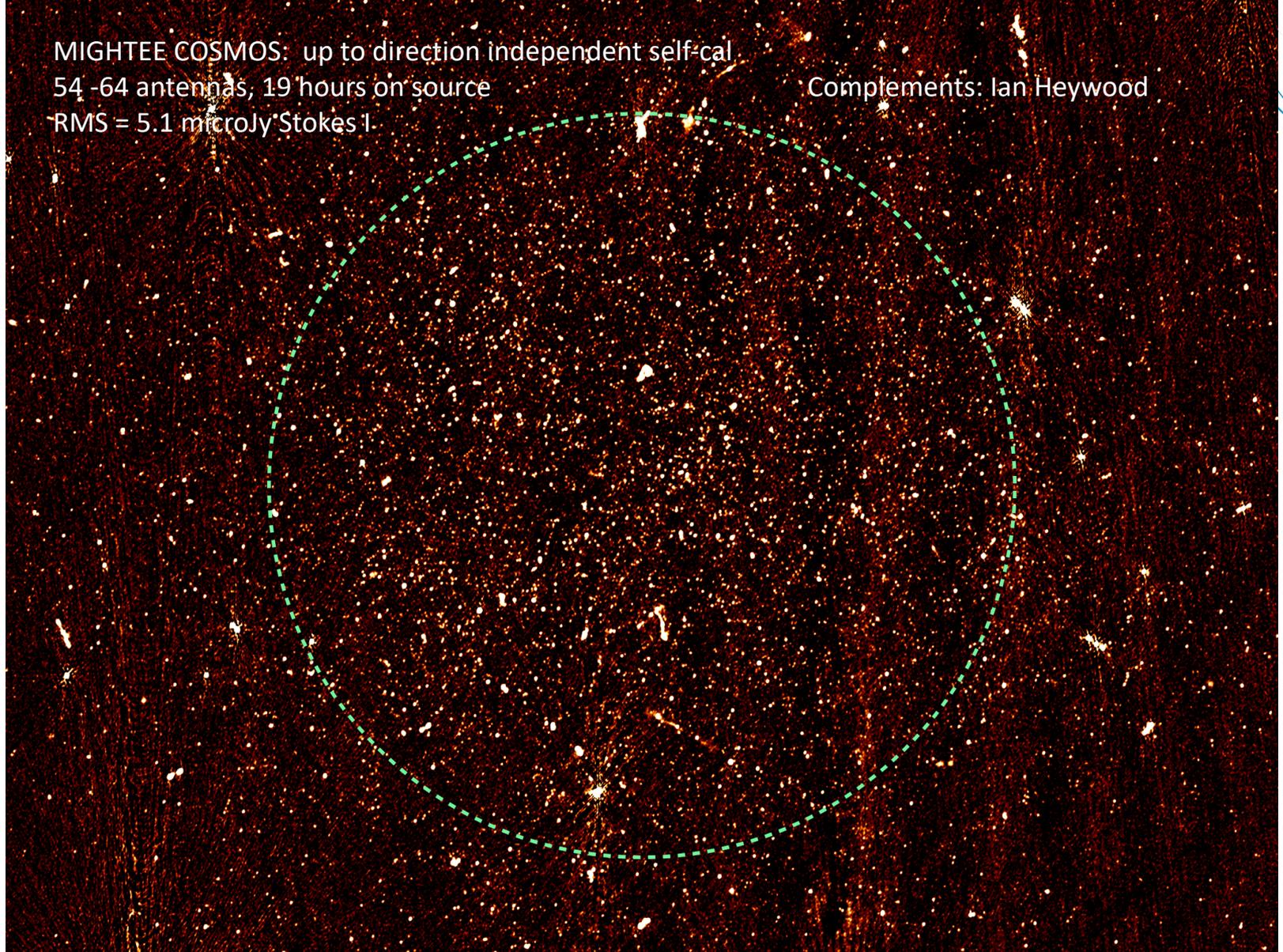
CDFS - IDIA CASA pipeline - up to Direction Independent self-calibration
55 antennas, 8 hours

Compliments: Krishna Sekhar



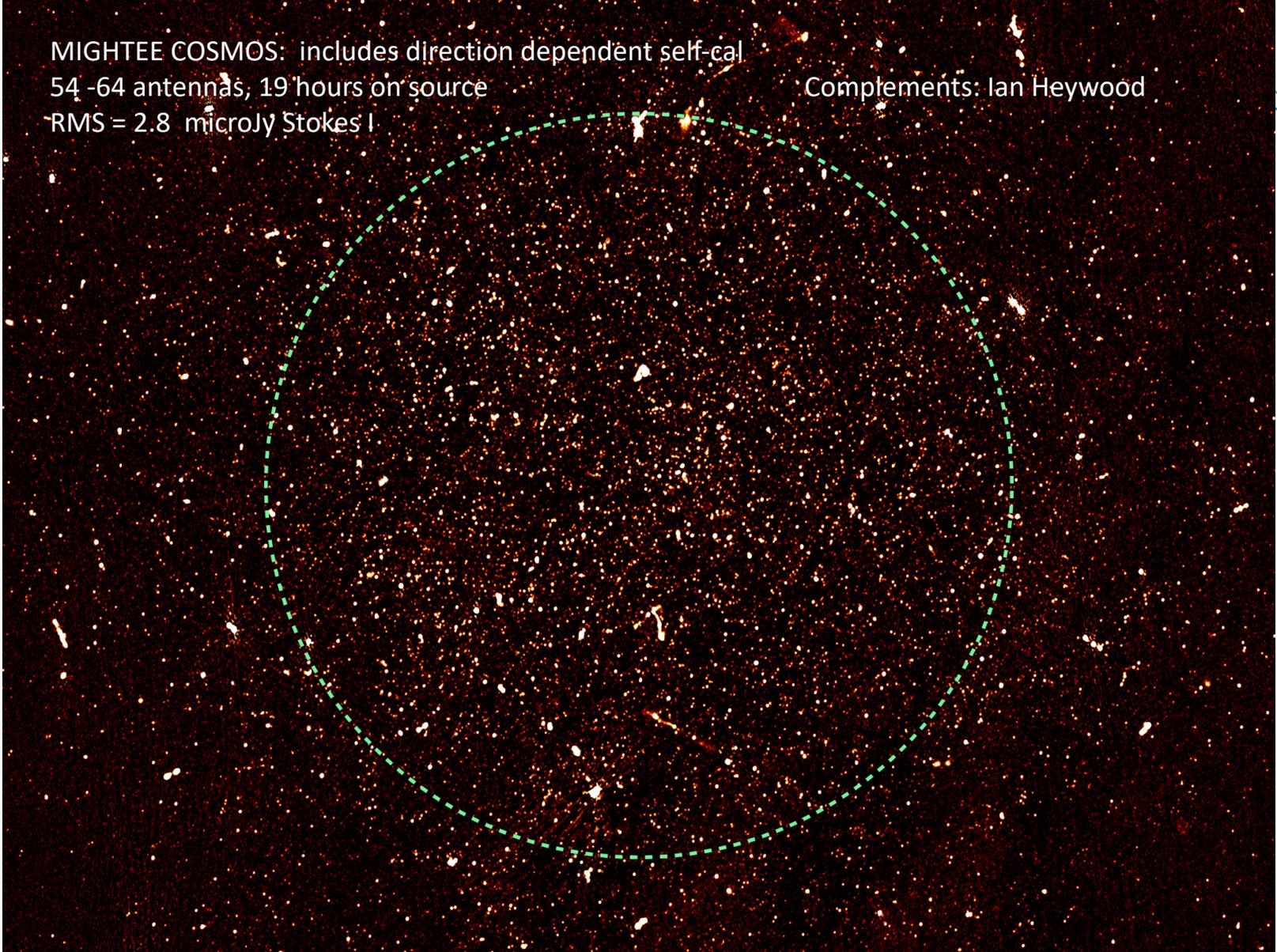
MIGHTEE COSMOS: up to direction independent self-cal
54 -64 antennas, 19 hours on source
RMS = 5.1 microJy Stokes I

Complements: Ian Heywood



MIGHTEE COSMOS: includes direction dependent self-cal
54 -64 antennas, 19 hours on source
RMS = 2.8 microJy Stokes I

Complements: Ian Heywood



Direction Dependent Mueller Matrix

Direction Dependent Self-Cal solves for this component only →

Collaboration with NRAO on full-Stokes AW projection in CASA (JVLA, ALMA, MeerKAT, uGMRT)

$$\vec{I}^M = \sum_k \begin{pmatrix} M_{II}^k I + M_{IQ}^k Q + M_{IU}^k U + M_{IV}^k V \\ M_{QI}^k I + M_{QQ}^k Q + M_{QU}^k U + M_{QV}^k V \\ M_{UI}^k I + M_{UQ}^k Q + M_{UU}^k U + M_{UV}^k V \\ M_{VI}^k I + M_{VQ}^k Q + M_{VU}^k U + M_{VV}^k V \end{pmatrix}$$

VLA L-band

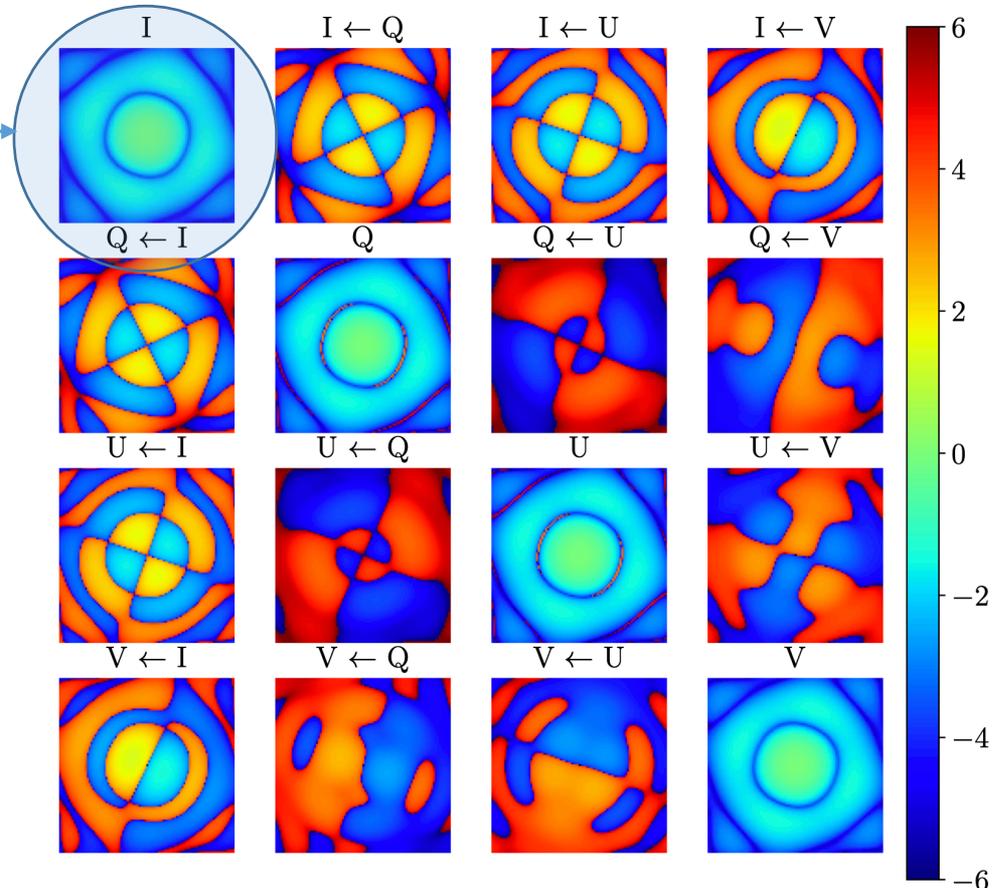


Image compliments: Preshanth Jagannathan (NRAO)

Direction Dependent Mueller Matrix

Collaboration with NRAO on full-Stokes AW projection in CASA (JVLA, ALMA, MeerKAT, uGMRT)

MeerKAT L-band

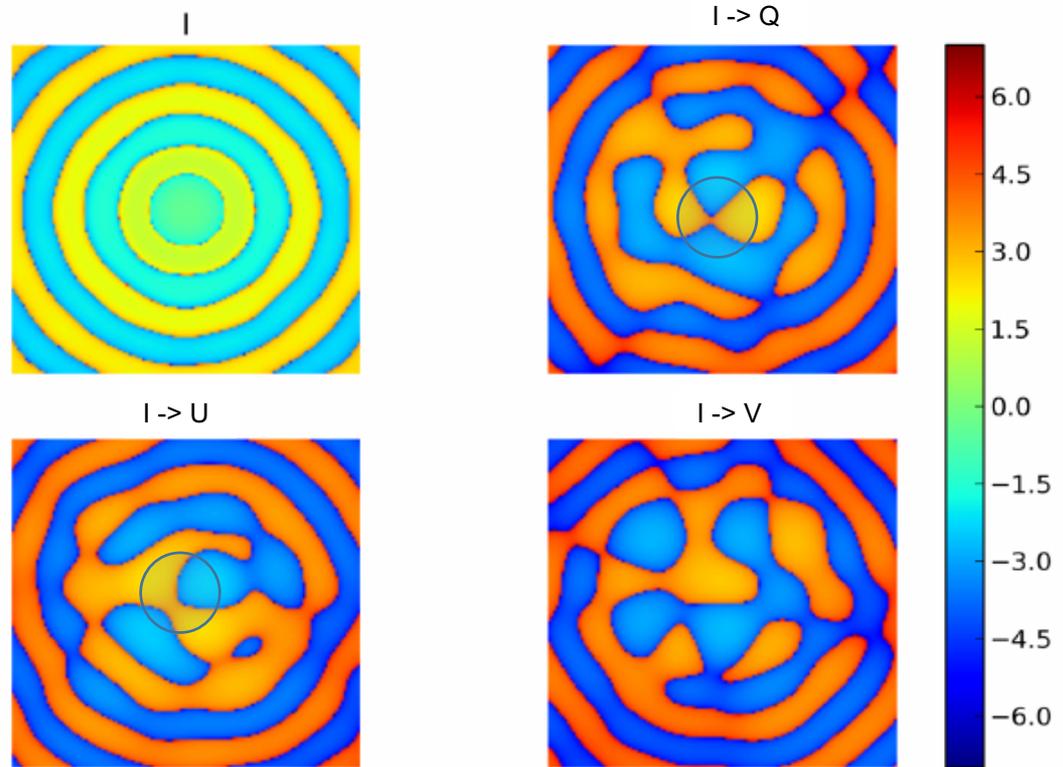
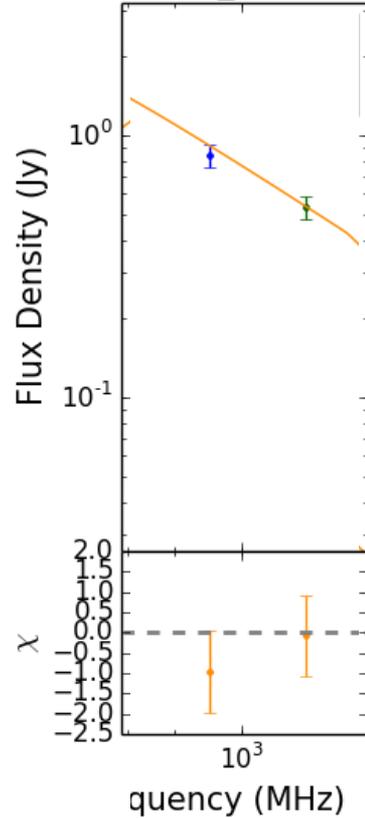
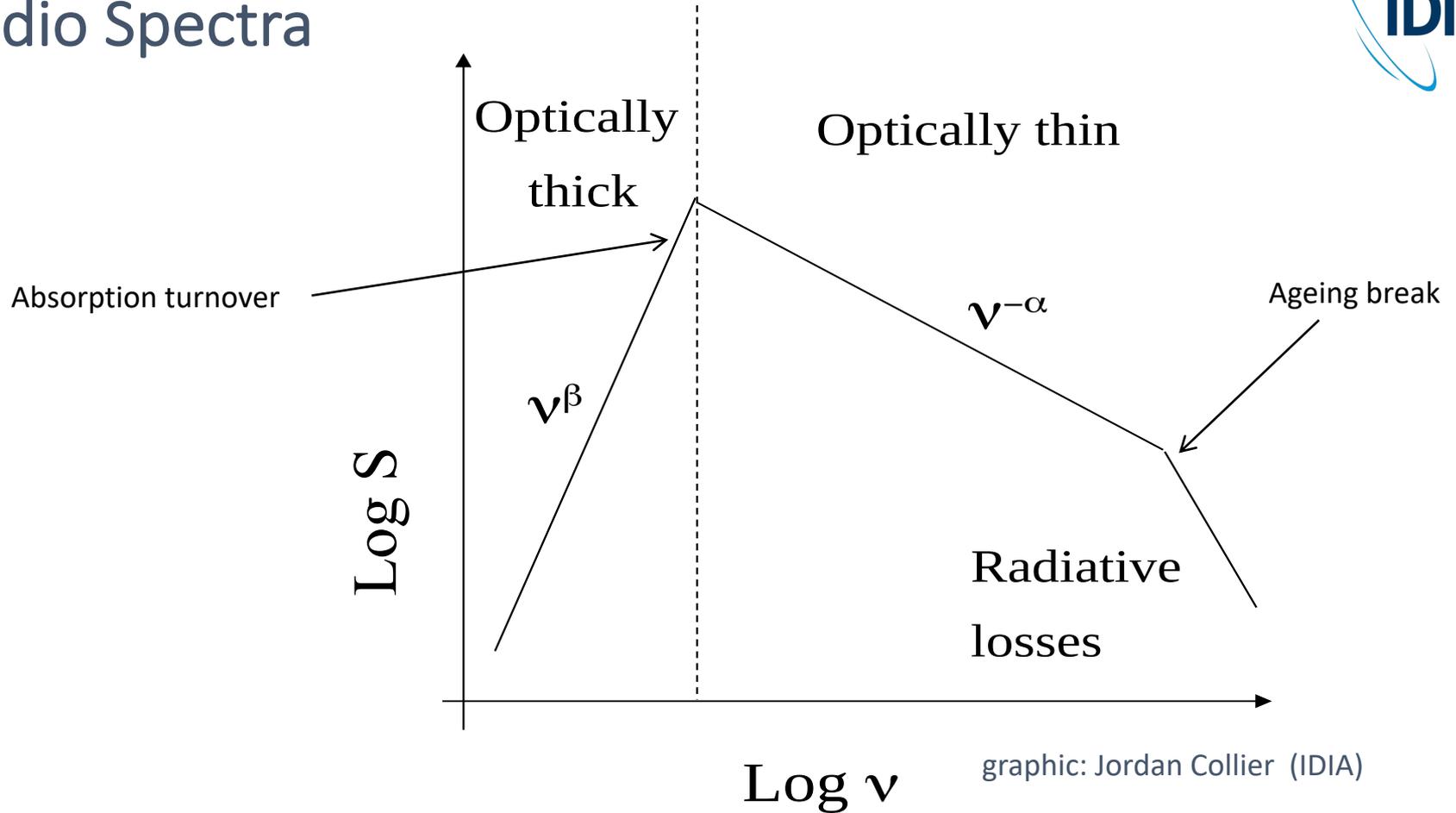


Image compliments: Srikrishna Sekhar (IDIA)

“There’s nothing as useless as a radio source” - J. Condon



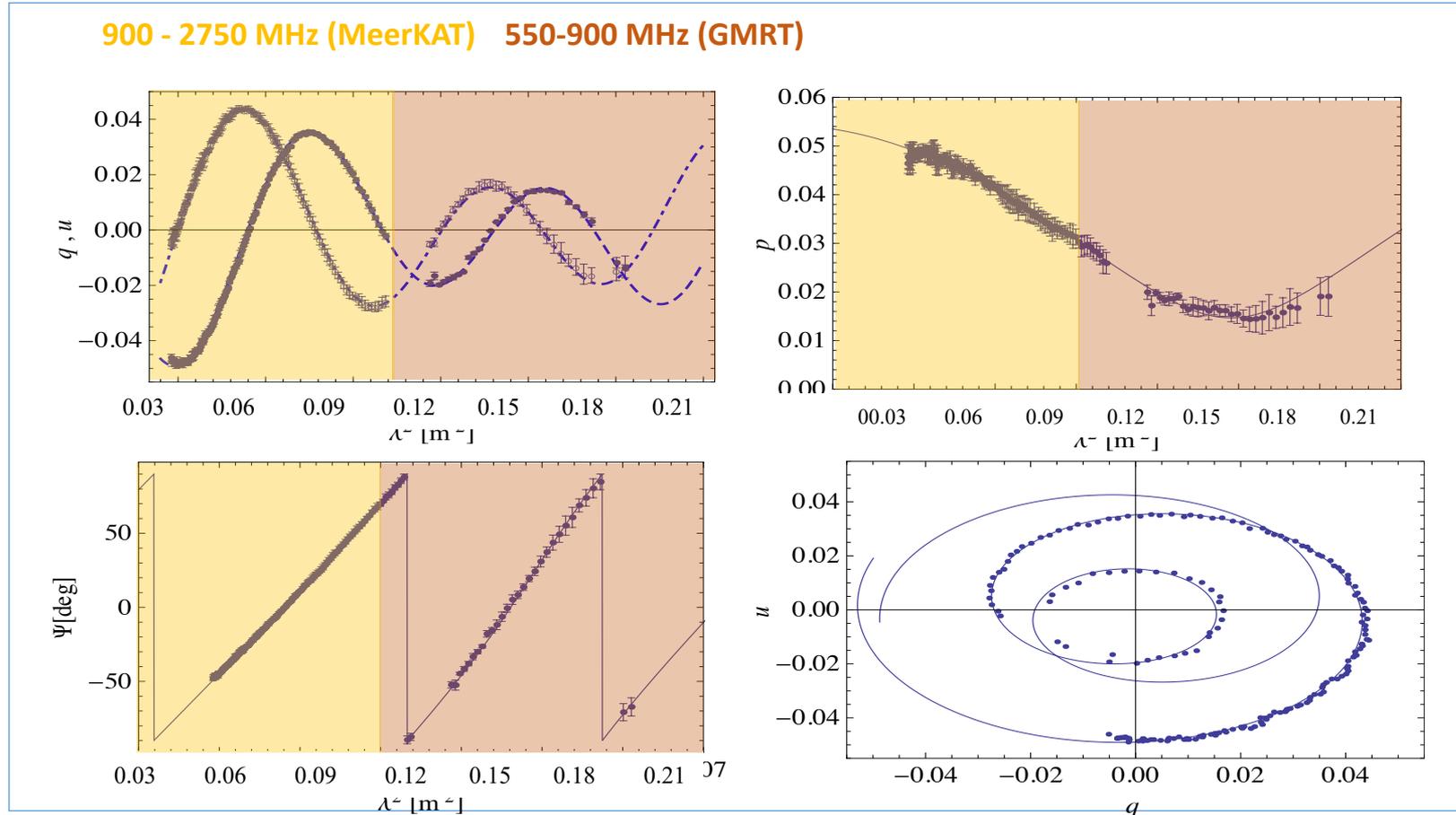
Radio Spectra



superMIGTHEE: Evolutionary spectra for $\sim 100,000$ microJy radio sources

See poster by Zara Radriamanakoto for an example.

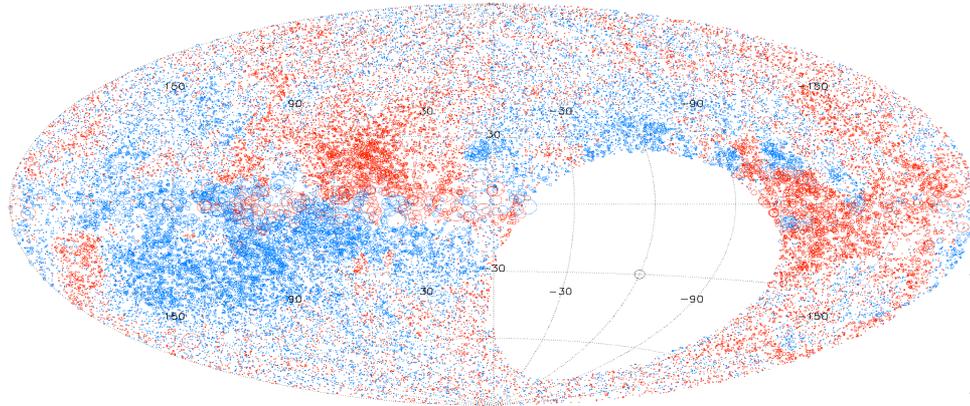
Polarimetry: Bandwidth is key



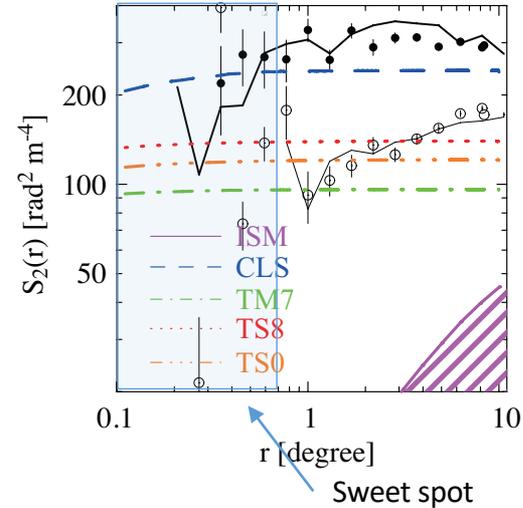
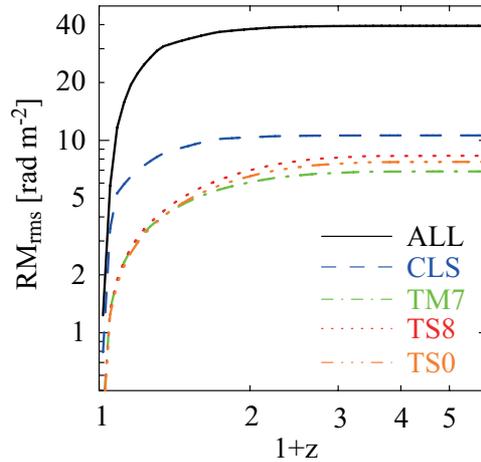
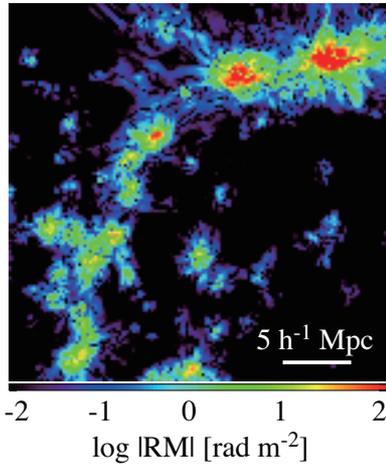
Polarimetry of PKS B1610-771 (O'Sullivan et al. 2012)

Slide modified from Bryan Gaensler

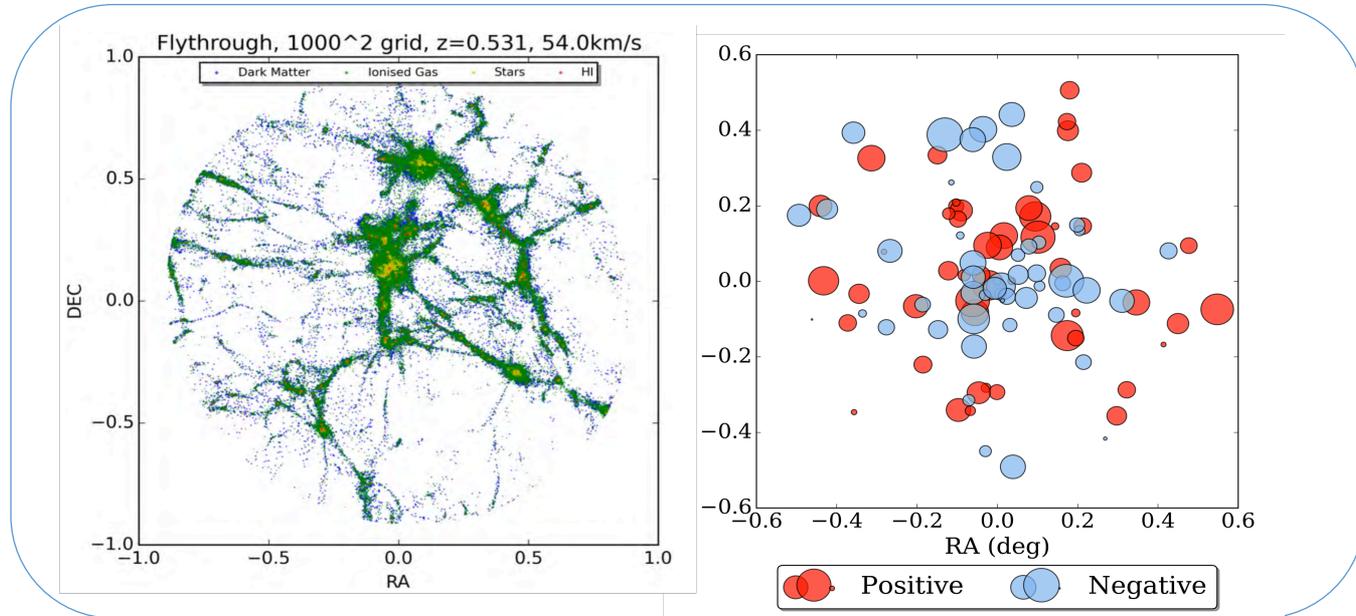
Detecting the Magnetic Cosmic Web



Taylor et al 2009



Detecting the Magnetic Cosmic Web



Requires:

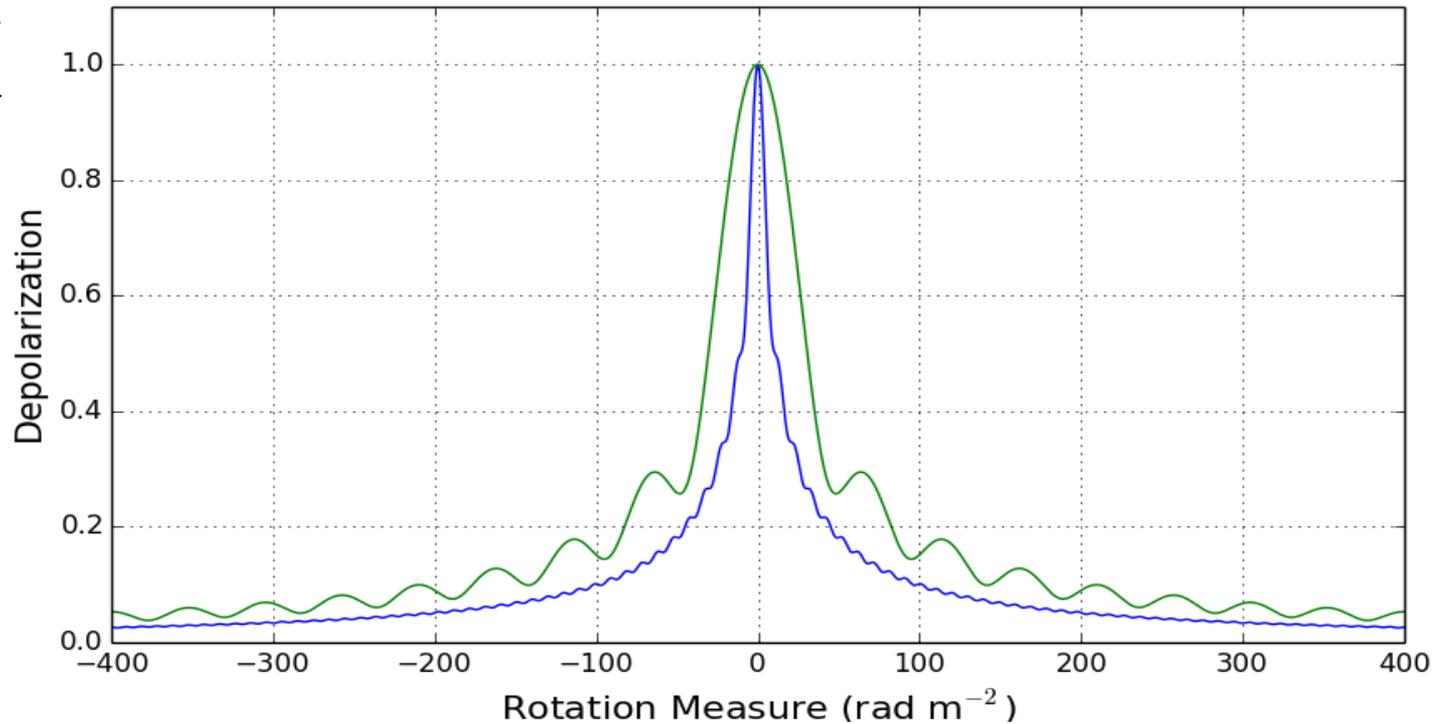
- RM precision of ~ 1 rad m^{-2}
- Density of several 100 sources per square degree

MIGHTEE simulations: L. Hunt (MSc. Thesis UCT)

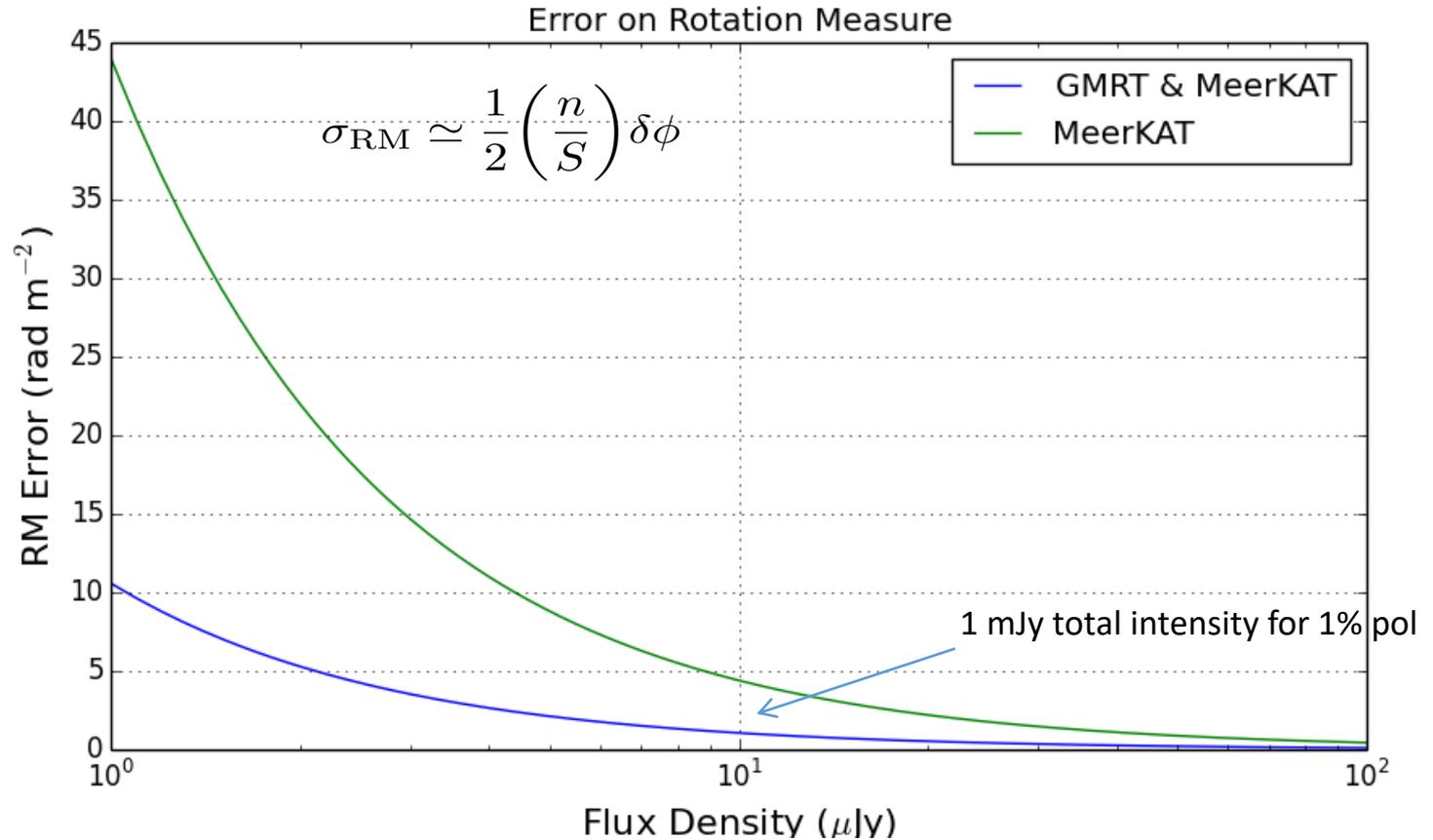
FWHM of RM Transfer Function

MeerKAT (L-band)	GMRT (550-900 MHz)	GMRT & MeerKAT
44.0	18.6	13.1

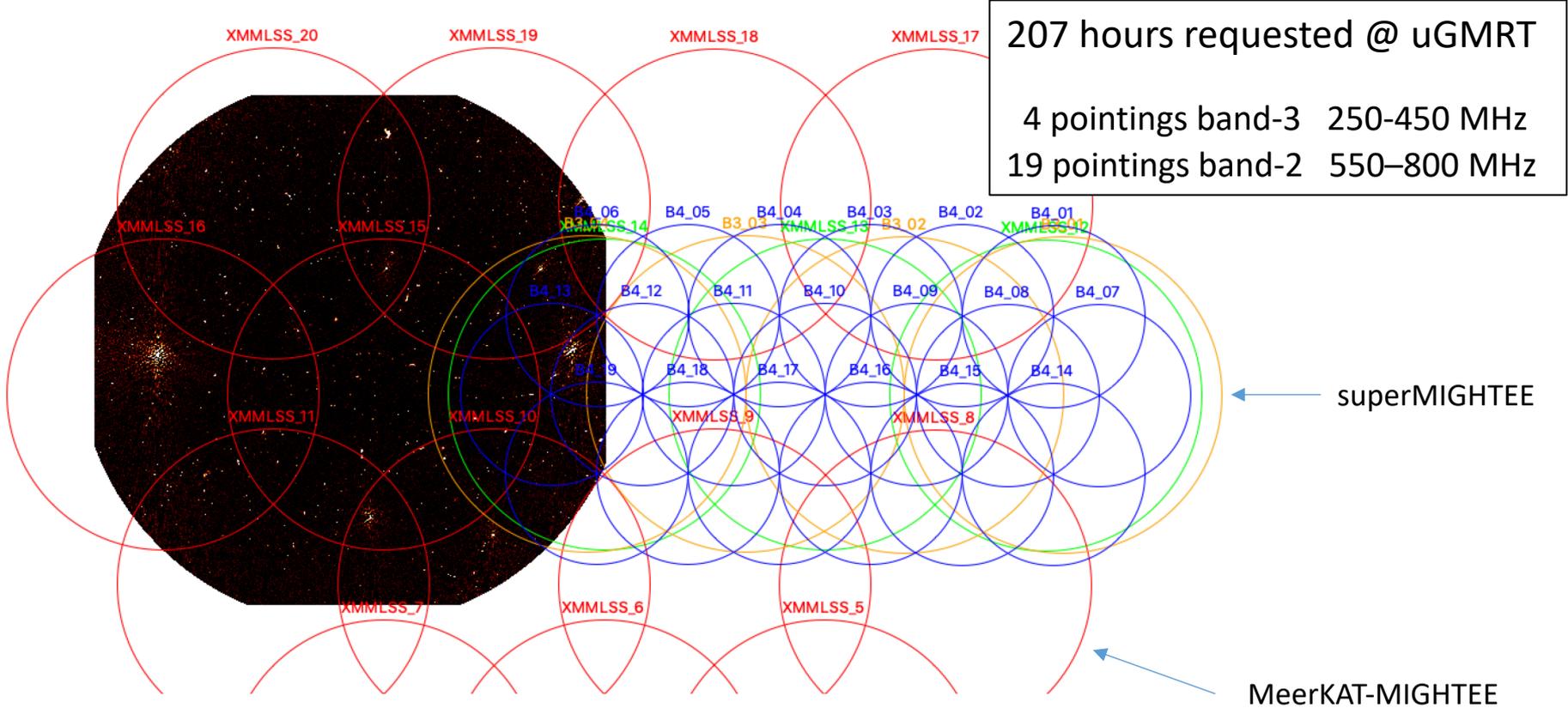
$$\delta\phi \simeq \frac{2\sqrt{3}}{\Delta\lambda^2}$$



FWHM of RM Transfer Function



First SuperMIGHTEE Observing Proposal



Summary: SuperMIGHTEE

- Combined data sensitivity to $<1 \mu\text{Jy}$ (0.25-2.7 GHz)
- Well matched resolution (a few arcseconds) from 0.25-2.7 GHz
- Spectral analysis from 0.25 – (1.7-2.7) GHz for very large sample of μJy radio sources
- Ultra-broad band polarimetry to measure Faraday complexity
 - 3.2 times the Faraday synthesis precision over MIGHTEE alone
 - Samples important frequency range for complex de/repolarization
- HI science to high redshift and higher resolution for stacking

