






Radio Astronomy in Southern Africa

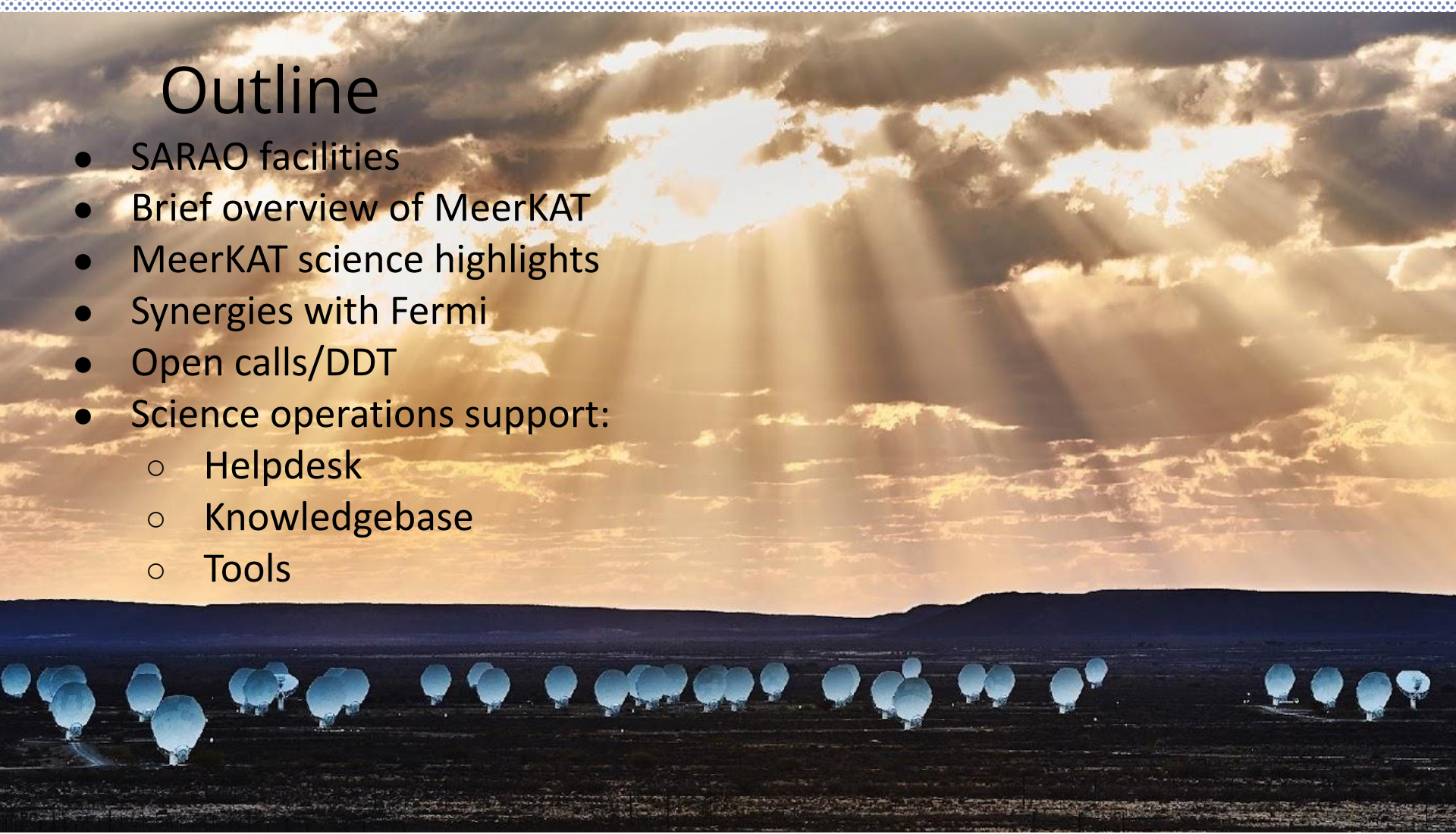
NRF National Research Foundation | SARAO South African Radio Astronomy Observatory

Tenth International Fermi Symposium 2022

Sharmila Goedhart
MeerKAT Science Operations

Outline

- SARAO facilities
- Brief overview of MeerKAT
- MeerKAT science highlights
- Synergies with Fermi
- Open calls/DDT
- Science operations support:
  - Helpdesk
  - Knowledgebase
  - Tools



What is SARAO?

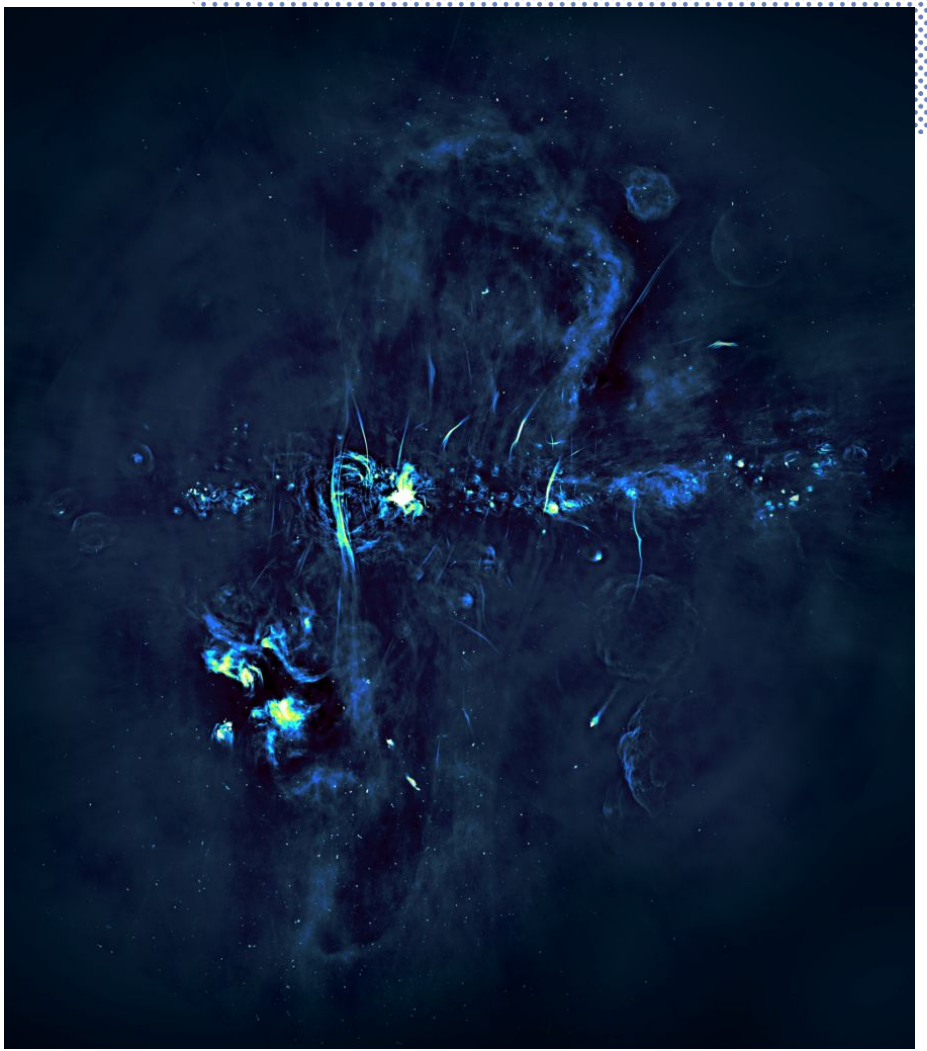
The South African Radio Astronomy Observatory (SARAO)

Merger of SKA South Africa and HartRAO

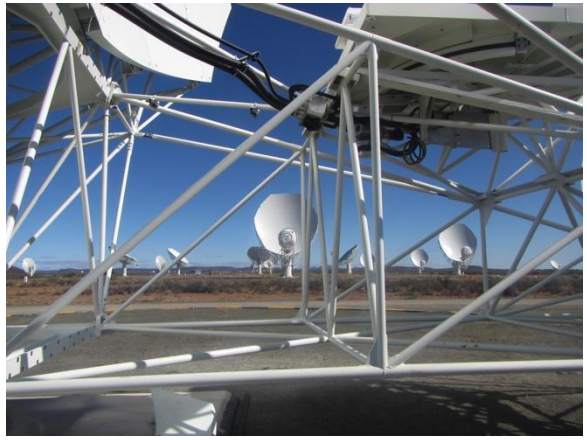
- Responsible for managing all radio astronomy initiatives and facilities in South Africa, including the
  - MeerKAT Radio Telescope in the Karoo, and the
  - Geodesy and VLBI activities at the HartRAO facility.
- Hosting of guest instruments
- SARAO also coordinates the African Very Long Baseline Interferometry Network (AVN) for the eight SKA partner countries in Africa, as well as South Africa's contribution to the infrastructure and engineering planning for the Square Kilometre Array Radio Telescope.
- To maximise the return on South Africa's investment in radio astronomy, SARAO is managing programmes to create capacity in radio astronomy science and engineering research, and the technical capacity required to support site operations.

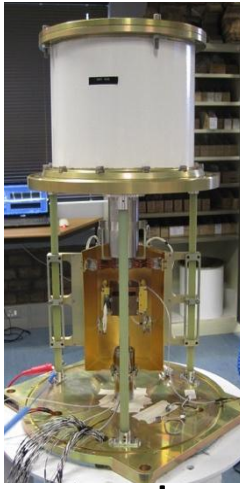
MeerKAT

- Upgrades and construction in progress since 2012
- First dish installed in 2014
- One year of single-dish qualification testing
- Rapid roll-out of dishes once design validated
- Two element correlator test system (RTS) - now being used to test SKA prototype
- 16-element correlator functional mid-2016 (ROACH-based)
- First fringes on 62 antennas recorded 29 March 2018
- First science observations with full array done in April 2018 (including Galactic centre) - L band
- UHF commissioning started in 2019, now fully functional



MeerKAT in the Karoo: SKA precursor





64 x 13.5-metre highly efficient **offset Gregorian dishes spread over 8 km** (70% within 1 km diameter); superb L-band receivers (**0.9–1.67 GHz**); also UHF (**0.58–1.0 GHz**) and S-band (**1.75–3.5 GHz** – by MPIfR)

Available correlator modes

Frequency range (L-band) : 900 - 1670 MHz [856 to 1712 MHz digitised]

Frequency range (UHF) : 580 - 1015 MHz [544 to 1088 MHz digitised]

Mode	Channels	L-band channel width	UHF-band channel width
Wideband coarse	4096 (4k)	208.984 kHz	132.812 kHz
Wideband fine	32768 (32k)	26.123 kHz	16.602 kHz
Narrowband extended (107 MHz bandwidth) *	32768 (32k)	3.3 kHz	-
Narrowband extended (54 MHz bandwidth)*	32768 (32k)	1.633 kHz	-

Sensitivity

Expected thermal noise for continuum observations in the L-band and UHF bands. We assume 58 antennas and consider only robust -0.5, which is a good default for continuum imaging, with no confusion noise estimates or Gaussian tapering. Confusion is not reflected in this table since it is dependent on declination and imaging parameters.

Integration time	**Thermal noise at robust=-0.5 (uJy/beam)** excluding persistent RFI channels	
	L-band	**UHF band**
12 minutes	20.4	26.6
1 hour	9.1	11.9
8 hours	3.2	4.2

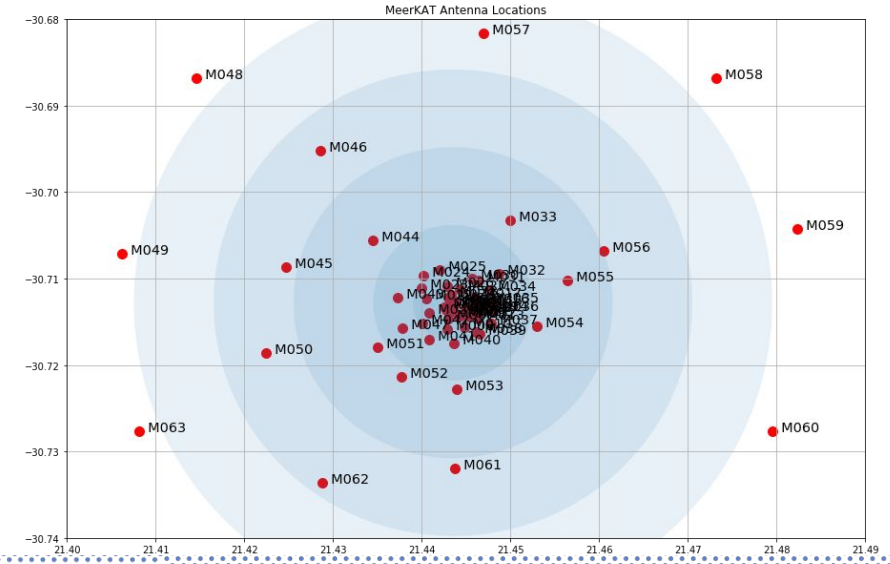
NB: Continuum confusion limits are reached quite rapidly. Weighting can help, at the cost of losing sensitivity.

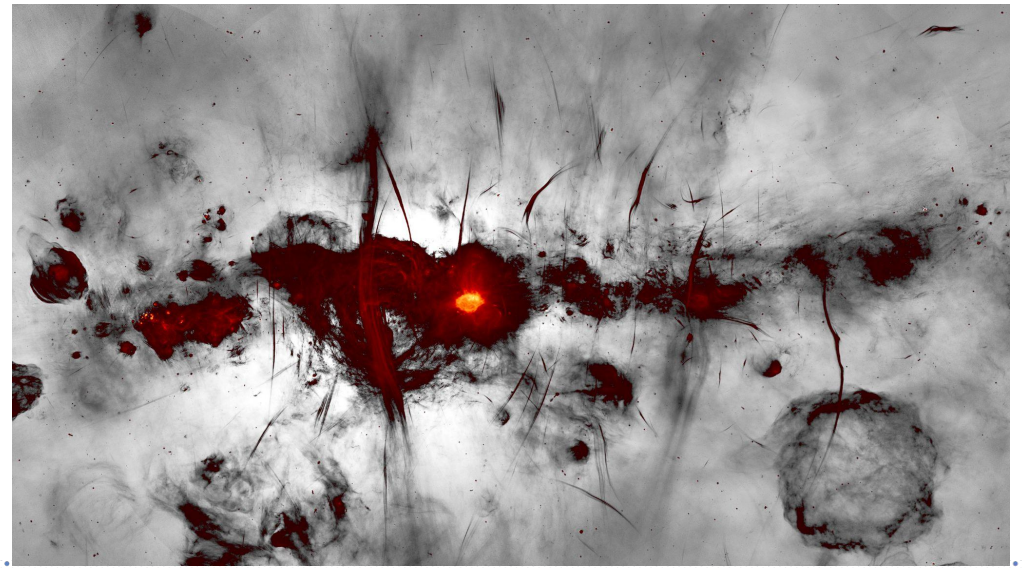
Please make use of the sensitivity calculators, taking into account the source declination.

Science with MeerKAT

- 2016 baselines
- exquisite sensitivity
- wide bandwidth
- short baselines unique among cm-wave telescopes

---> amazing image quality (and we're still doing advanced commissioning)





Approved MeerKAT LSP program

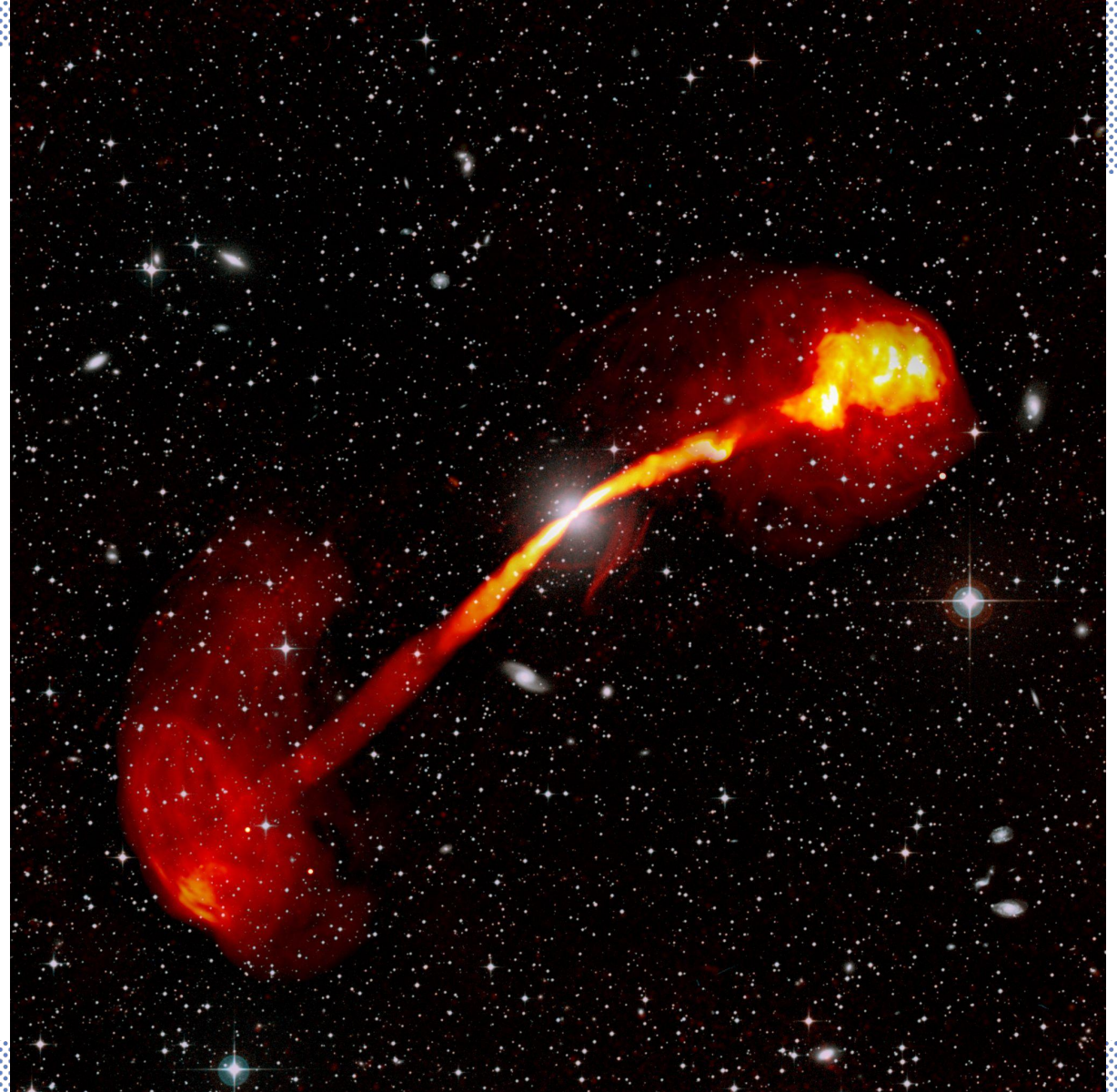
- Pulsar timing
- Deep HI studies in 30 isolated nearby galaxies; and in Fornax cluster
- Ultra-deep HI survey
- Pulsar searches
- Explosive / accreting transient studies
- Deep continuum survey in 4 fields
- Absorption line survey

MeerTIME Binary	1440
MHONGOOSE	1650
MeerTIME MSP	2160
LADUMA: L-band ECDFS	333
LADUMA: UHF ECDFS	3091
FORNAX Fornax	900
TRAPUM Fermi sources	338
MeerTIME 1000 PSR array	720
ThunderKAT CVs	250
MIGHTEE ELAIS-S1	134
MIGHTEE XMMLSS	384
MIGHTEE COSMOS	19
MIGHTEE ECDFS	442
ThunderKAT GRBs	330
MeerTIME Globular clusters	1080
MALS UHF	858
MALS L-Band	794
TRAPUM: nearby galaxies	226
TRAPUM: GCs	320
TRAPUM: SNR PWN TeV Galactic Centre	92
ThunderKAT: SNe Ia	200
MIGHTEE: Sband COSMOS	306
MIGHTEE: Sband ECDFS	642
ThunderKAT: (XRBs)	500
Total	**17209**

Threads, ribbons, and rings in IC 4296

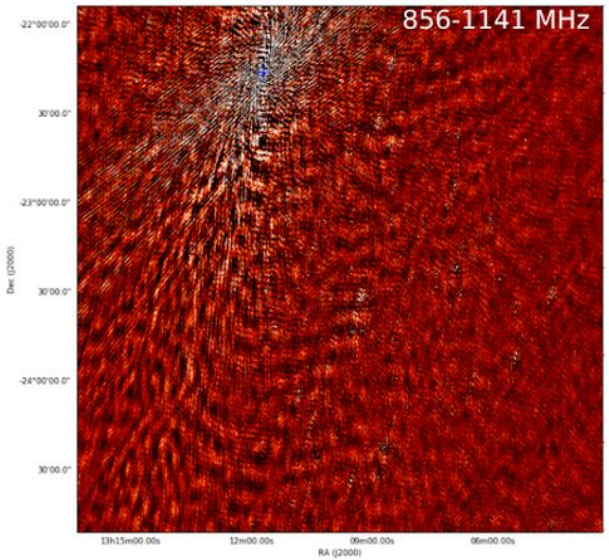
"New results like this from MeerKAT are set to overhaul our understanding of extragalactic radio sources"

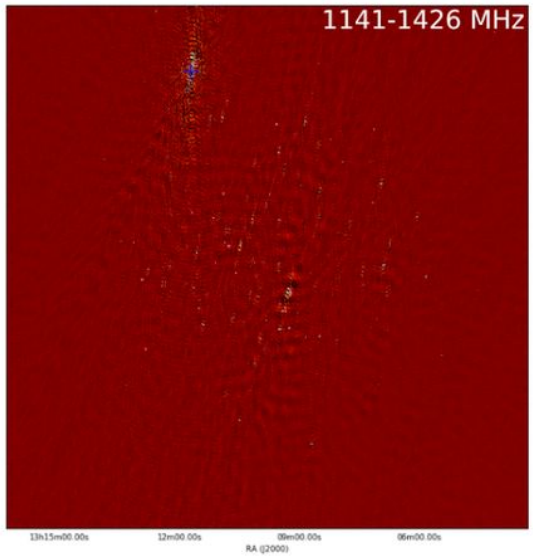
(Condon et al. 2021)

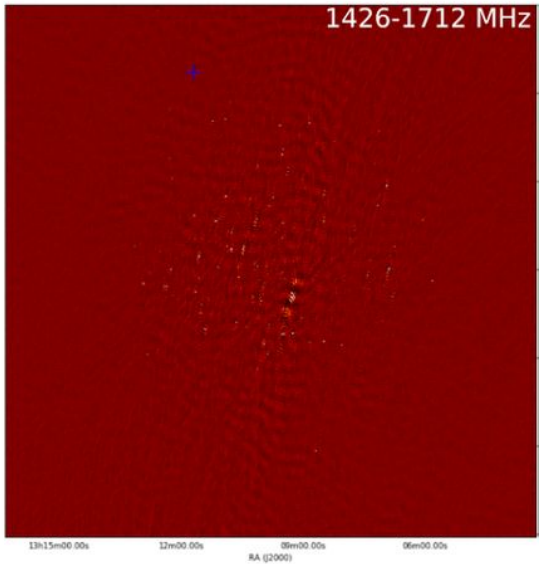


GW170817

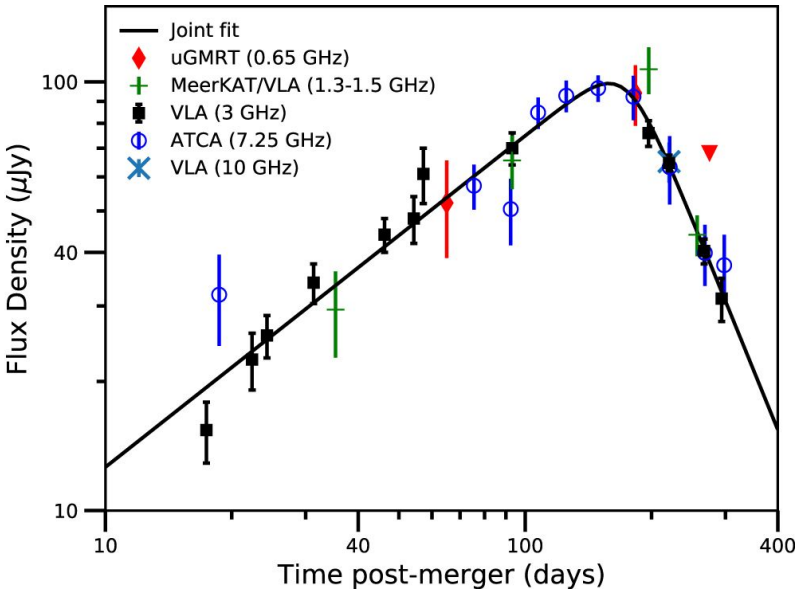
- GW170817 - No detection with MeerKAT-16 in August 2017 (Abbott et al. 2017)
- The best way to bring a telescope to its full capability is to start doing science with it!
- Beware strong sources lurking in the sidelobes!
  - Move pointing centre such that interfering sources are in a more stable part of the primary beam
  - Advanced calibration - direction dependent effects





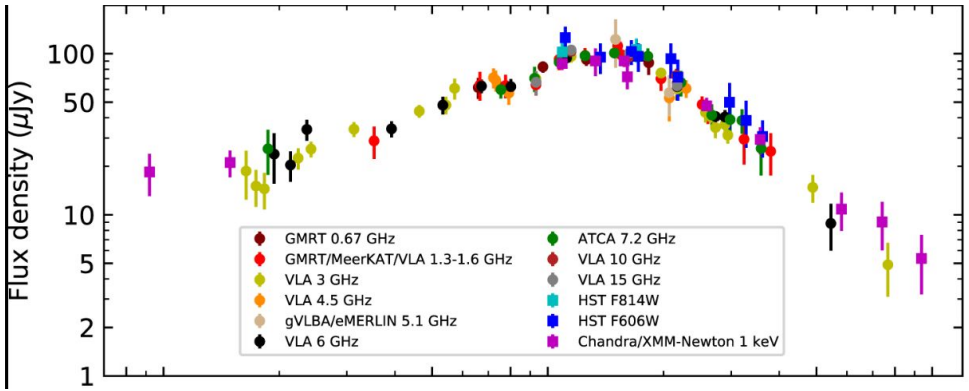


GW170817 - afterglow



- Mooley et al. 2018

- Makhatini et al. 2021
- Expanding relativistic jet



Future Observations of NS-NS mergers

- LIGO O4 to start in March 2023
- Two A-rated proposals accepted in current MeerKAT Open call cycle

2022 Open Time Call accepted proposals

Created by Sharmila Goedhart
Last updated: Aug 24, 2022 by Suleiman Hoosen (Unlicensed) • 3 min read • 17 people viewed

Proposal Title	Principal Investigator	Priority Group
Probing the Astrophysics of Neutron Star Mergers with Radio Afterglows	Kunal Mooley	A
Searching for off-axis radio emission from binary neutron star mergers using optically detected kilonovae	Lauren Rhodes	A

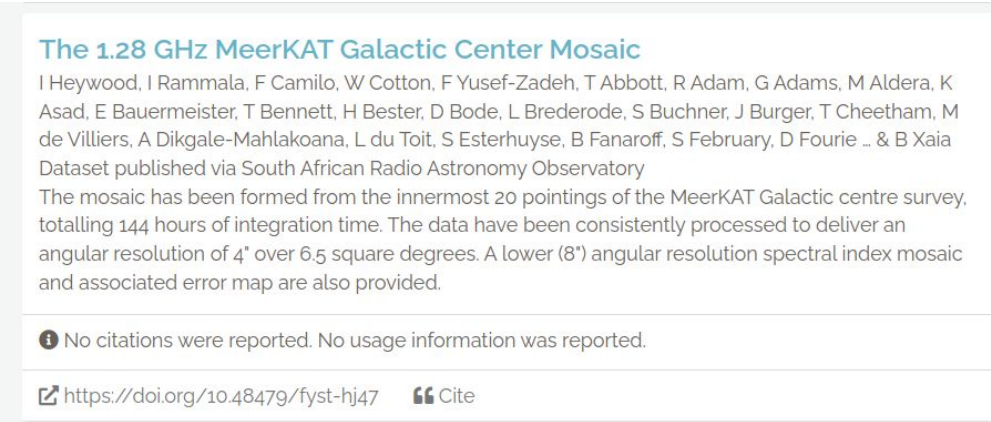
Other synergies with Fermi

- TRAPUM survey - Pulsars and Transients
  - Targeted pulsar searches of SNRs, PWNe, and unidentified Fermi gamma-ray sources
  - 21 Fermi sources discovered to date
- Gamma ray bursts (ThunderKAT and DDTs)
  - GRB 191221B, Buckley et al. 2021
  - GRBs 190829A and 180720B Rhodes et al. 2020

Data releases

- Many datasets are no longer proprietary, and (mainly visibilities) are available through the archive interface: https://apps.sarao.ac.za/katpaws/archive-search
- Note that visibilities older than 6 months need to be restaged to disk from long-term tape storage. This can take several weeks so plan in advance!
- SARAO repository contains calibrated data products

  https://search.datacite.org/repositories/whno.ljncxe?resource-type-id=dataset



The 1.28 GHz MeerKAT Galactic Center Mosaic

I Heywood, I Rammala, F Camilo, W Cotton, F Yusef-Zadeh, T Abbott, R Adam, G Adams, M Aldera, K Asad, E Bauermeister, T Bennett, H Bester, D Bode, L Brederode, S Buchner, J Burger, T Cheetham, M de Villiers, A Dikgale-Mahlakoana, L du Toit, S Esterhuyse, B Fanaroff, S February, D Fourie … & B Xaia

Dataset published via South African Radio Astronomy Observatory

The mosaic has been formed from the innermost 20 pointings of the MeerKAT Galactic centre survey, totalling 144 hours of integration time. The data have been consistently processed to deliver an angular resolution of 4" over 6.5 square degrees. A lower (8") angular resolution spectral index mosaic and associated error map are also provided.

No citations were reported. No usage information was reported.

https://doi.org/10.48479/fyst-hj47 Cite

The MeerKAT Galaxy Cluster Legacy Survey - Survey Overview and Highlights

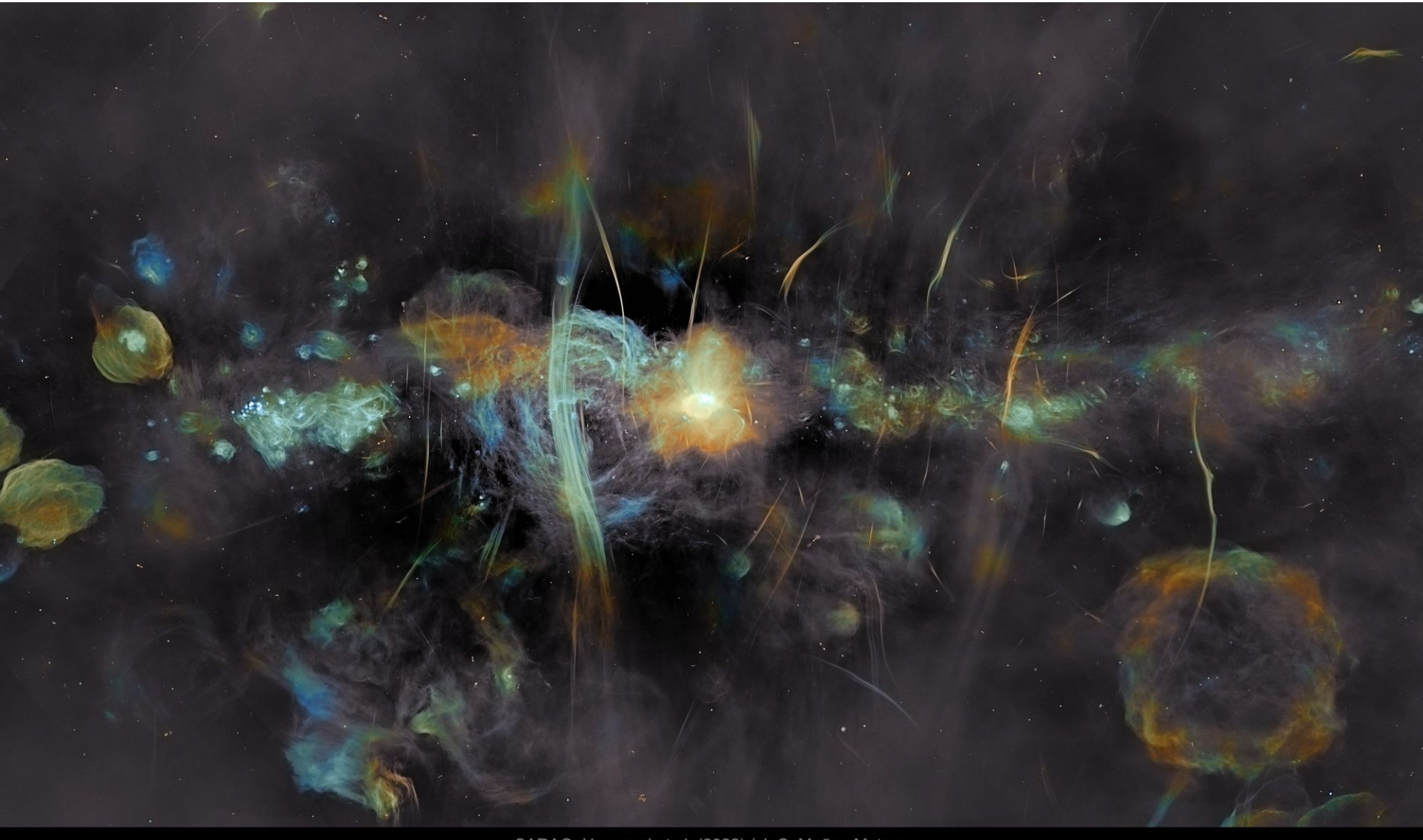
Kenda Knowles, William Cotton, Lawrence Rudnick, Fernando Camilo, Sharmila Goedhart, Roger Deane, Mpati Ramatsoku, Michael Bietenholz, Marcus Brüggen, Charissa Bronwyn Button, Hao Chen, James Okwe Chibueze, Tracy Clarke, Francesco de Gasperin, Roger Ianjamasimanana, Gyula I. G. Józsa, Matt Hilton, Kabelo Calvin Kesebonye, Konstantinos Kolokythas, Renee Christine Kraan-Korteweg, Graham Lawrie, Michelle Lochner, Ilani Loubser, Paolo Marchegiani, Nceba Mhlahlo … & Tiziana Venturi

Dataset published via South African Radio Astronomy Observatory

The first data release of the MeerKAT Galaxy Cluster Legacy Survey (MGCLS) consists of the uncalibrated visibilities, a set of continuum imaging products, and several source catalogues. All clusters have Stokes-I products, and approximately 40% have Stokes-Q and U products as well.

No citations were reported. No usage information was reported.

https://doi.org/10.48479/7epd-w356 Cite



SARAO, Heywood et al. (2022) / J. C. Muñoz-Mateos

SARAO legacy surveys

Galaxy clusters

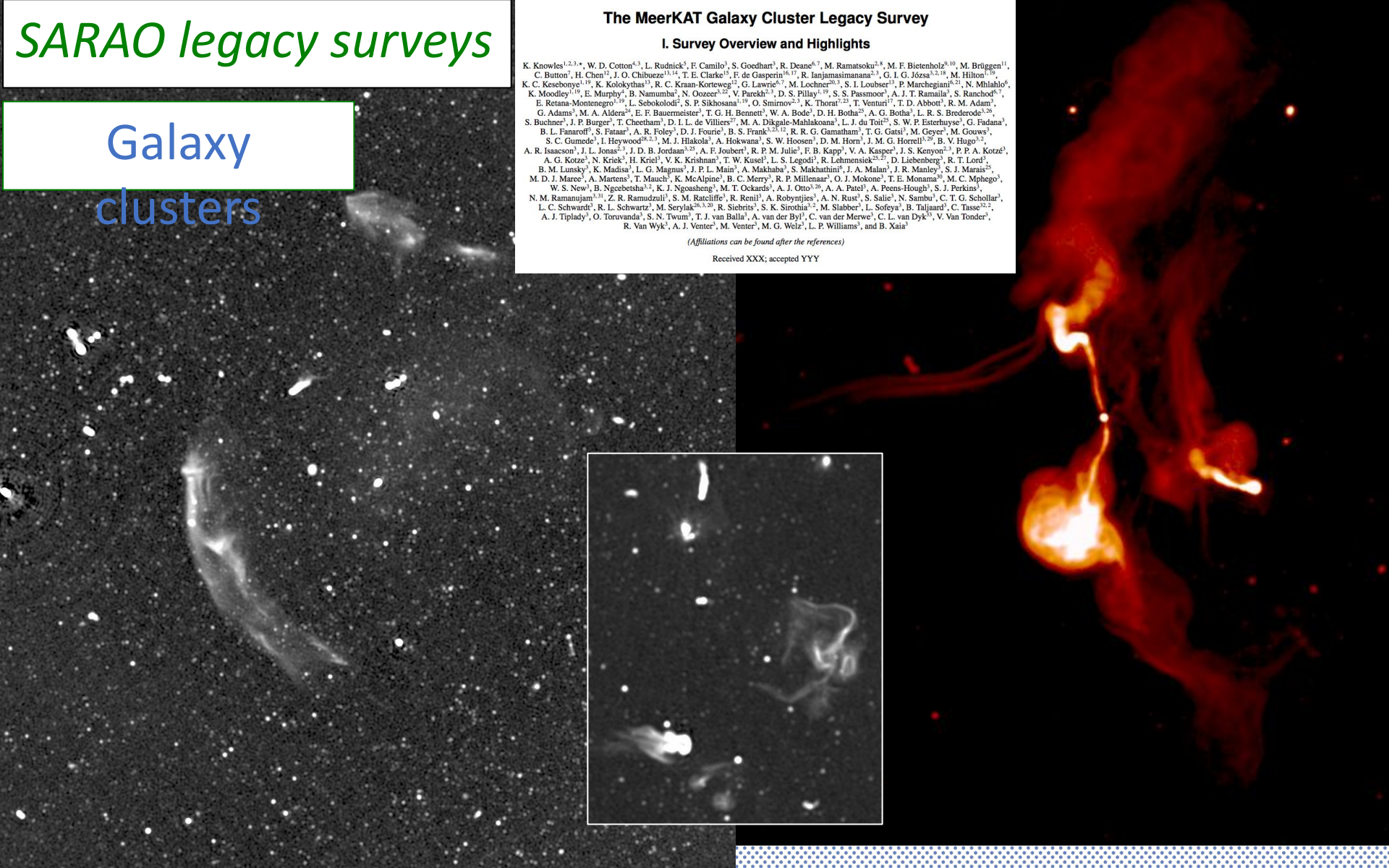
The MeerKAT Galaxy Cluster Legacy Survey

I. Survey Overview and Highlights

K. Knowles[1,2,3,⋆], W. D. Cotton[4,3], L. Rudnick[5], F. Camilo[3], S. Goedhart[3], R. Deane[6,7], M. Ramatsoku[2,8], M. F. Bietenholz[9,10], M. Brüggen[11], C. Button[7], H. Chen[12], J. O. Chibueze[13,14], T. E. Clarke[15], F. de Gasperin[16,17], R. Ianjamasimanana[2,3], G. I. G. Józsa[3,2,18], M. Hilton[1,19], K. C. Kesebonye[1,19], K. Kolokythas[13], R. C. Kraan-Korteweg[12], G. Lawrie[6,7], M. Lochner[20,3], S. I. Loubser[13], P. Marchegiani[8,21], N. Mhlahlo[6], K. Moodley[1,19], E. Murphy[4], B. Namumba[2], N. Oozeer[3,22], V. Parekh[2,3], D. S. Pillay[1,19], S. S. Passmoor[3], A. J. T. Ramaila[3], S. Ranchod[6,7], E. Retana-Montenegro[1,19], L. Sebokolodi[2], S. P. Sikhosana[1,19], O. Smirnov[2,3], K. Thorat[7,23], T. Venturi[17], T. D. Abbott[3], R. M. Adam[3], G. Adams[3], M. A. Aldera[24], E. F. Bauermeister[3], T. G. H. Bennett[3], W. A. Bode[3], D. H. Botha[25], A. G. Botha[3], L. R. S. Brederode[3,26], S. Buchner[3], J. P. Burger[3], T. Cheetham[3], D. I. L. de Villiers[27], M. A. Dikgale-Mahlakoana[3], L. J. du Toit[25], S. W. P. Esterhuyse[3], G. Fadana[3], B. L. Fanaroff[3], S. Fataar[3], A. R. Foley[3], D. J. Fourie[3], B. S. Frank[3,23,12], R. R. G. Gamatham[3], T. G. Gatsi[3], M. Geyer[3], M. Gouws[3], S. C. Gumede[3], I. Heywood[28,2,3], M. J. Hlakola[3], A. Hokwana[3], S. W. Hoosen[3], D. M. Horn[3], J. M. G. Horrell[3,29], B. V. Hugo[3,2], A. R. Isaacson[3], J. L. Jonas[2,3], J. D. B. Jordaan[3,25], A. F. Joubert[3], R. P. M. Julie[3], F. B. Kapp[3], V. A. Kasper[3], J. S. Kenyon[2,3], P. P. A. Kotzé[3], A. G. Kotze[3], N. Kriek[3], H. Kriel[3], V. K. Krishnan[3], T. W. Kusel[3], L. S. Legodi[3], R. Lehmensiek[25,27], D. Liebenberg[3], R. T. Lord[3], B. M. Lunsky[3], K. Madisa[3], L. G. Magnus[3], J. P. L. Main[3], A. Makhaba[3], S. Makhathini[6], J. A. Malan[3], J. R. Manley[3], S. J. Marais[25], M. D. J. Maree[3], A. Martens[3], T. Mauch[3], K. McAlpine[3], B. C. Merry[3], R. P. Millenaar[3], O. J. Mokone[3], T. E. Monama[30], M. C. Mphego[3], W. S. New[3], B. Ngcebetsha[3,2], K. J. Ngoasheng[3], M. T. Ockards[3], A. J. Otto[3,26], A. A. Patel[3], A. Peens-Hough[3], S. J. Perkins[3], N. M. Ramanujam[3,31], Z. R. Ramudzuli[3], S. M. Ratcliffe[3], R. Renil[3], A. Robyntjies[3], A. N. Rust[3], S. Salie[3], N. Sambu[3], C. T. G. Schollar[3], L. C. Schwardt[3], R. L. Schwartz[3], M. Serylak[26,3,20], R. Siebrits[3], S. K. Sirothia[3,2], M. Slabber[3], L. Sofeya[3], B. Taljaard[3], C. Tasse[32,2], A. J. Tiplady[3], O. Toruvanda[3], S. N. Twum[3], T. J. van Balla[3], A. van der Byl[3], C. van der Merwe[3], C. L. van Dyk[33], V. Van Tonder[3], R. Van Wyk[3], A. J. Venter[3], M. Venter[3], M. G. Welz[3], L. P. Williams[3], and B. Xaia[3]

(Affiliations can be found after the references)

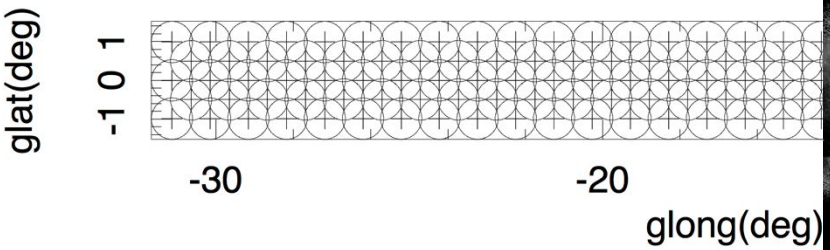
Received XXX; accepted YYY

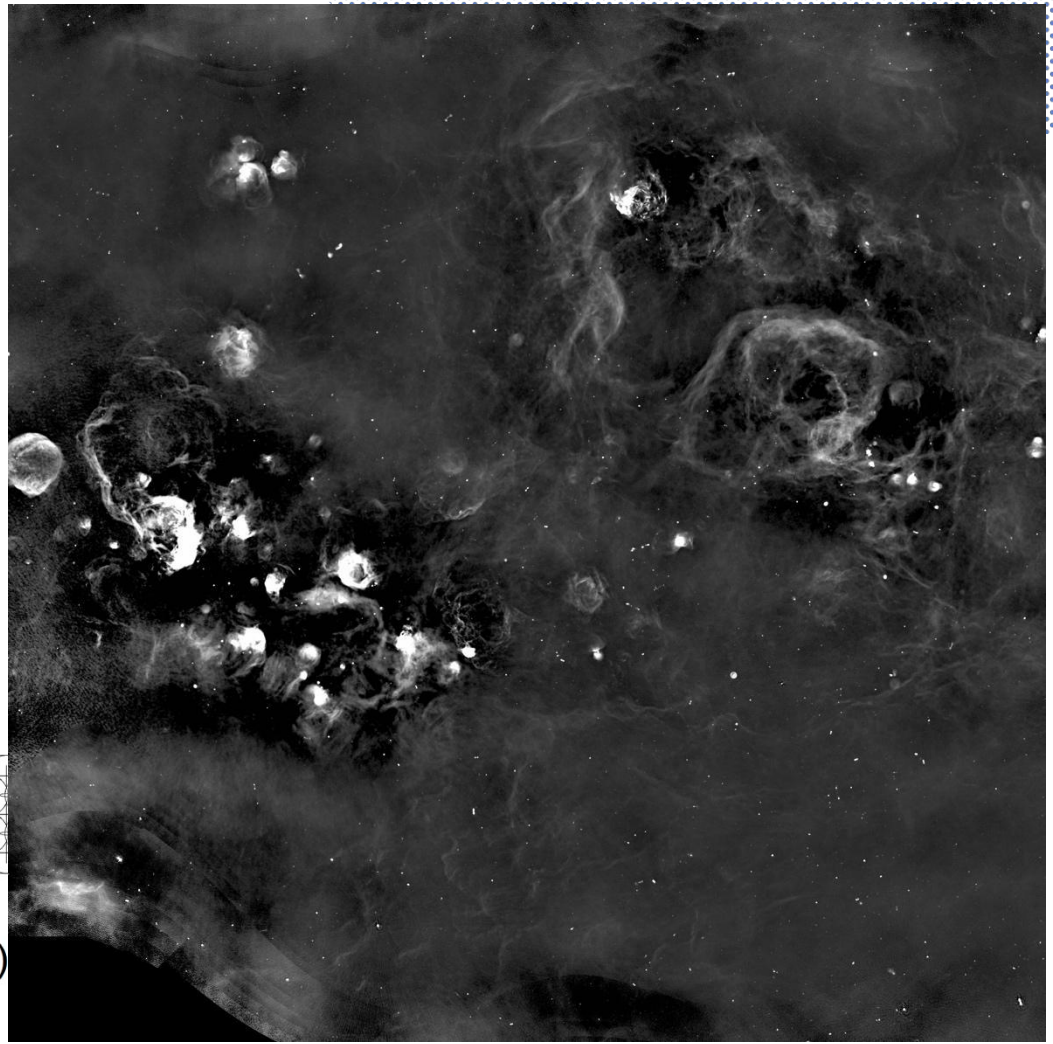


Galactic plane

- $250^o < l < 60^o$, $|b| < 1.5^o$
- 9-point mosaic observing
- ~1 hr on source per position
- Stitched in 3x3 deg^2 images

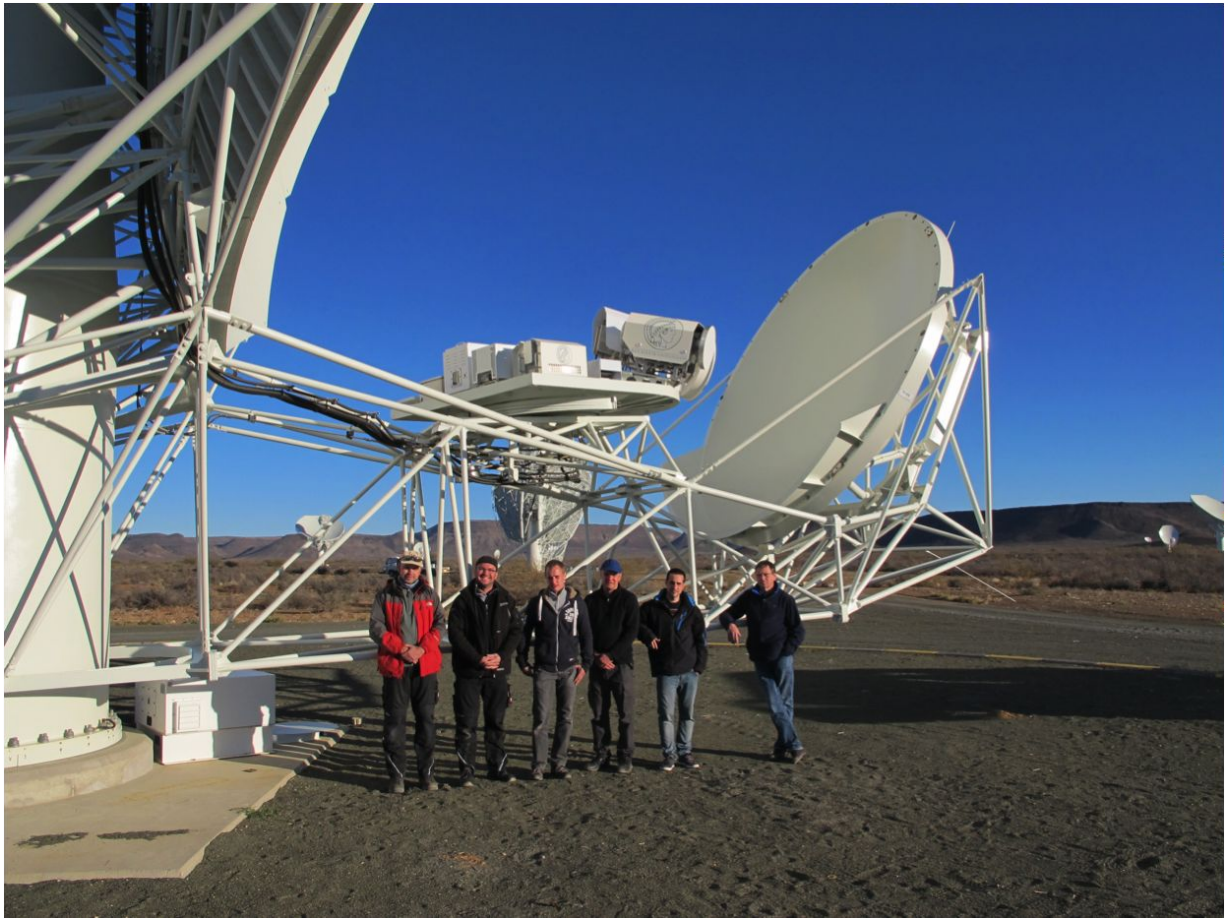
Goedhart et al (in prep)





S-band receivers (MPIfR)

- All 64 installed
- Experiencing operational issues with some receivers
- digitised bands S0 to S4
  - 1750-2625
  - 1968-2843
  - 2187-3062
  - 2406-3281
  - 2625-3500

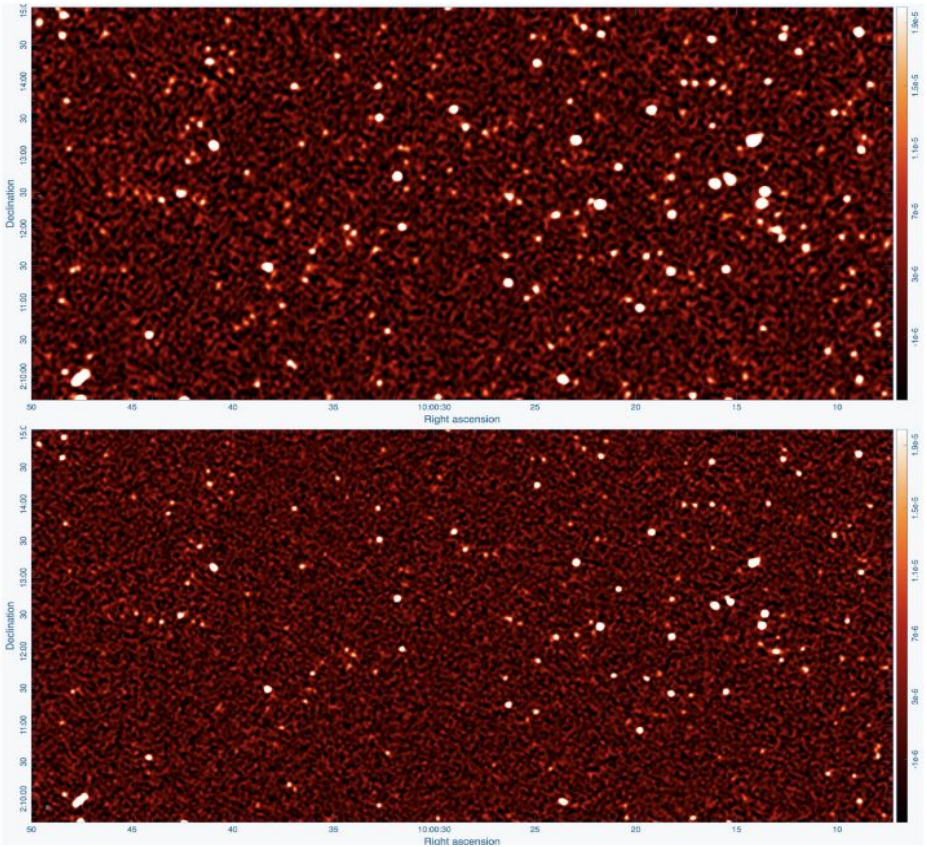


S-band commissioning

- Looks good in general, but
  - Need to find good phase calibrators
  - Understand gain and phase stability
  - Fix antenna pointing issues which are amplified at S-band
  - Understand polarisation performance (same issues as seen with L- and U band OMTs)
- Pulsar search and timing looks good
- About to start science verification and early science
- Due to constraints on telescope time, advanced commissioning will be done while attempting to do science.

S0/S4 observation of COSMOS

- Maps are noise-limited
- Astrometric offset previously seen confirmed to be due to unsuitable phase calibrator
- MeerKAT fluxes ~25% higher than VLA's. Could be due to different baseline distributions of 2 telescopes or inaccurate model for primary calibrator (J0408-6545, ATCA model used)
- Need to verify flux models of primary calibrators



Ian Heywood/MIGHTEE

Open Time Calls

- 2/3 of telescope time to be used by LSPs; 5% for DDT; rest awarded through periodic Calls:
- SARAO received 132 proposals in response to the March 2022 Call for Proposals, requesting 4843 hours of telescope time
- A minimum of 1500 hours are available for open time observations
- 48 proposals were A-rated (cumulative time 1410.8 hours)
- 24 proposals B rated (cumulative time up to 1846 hours)

The next Open Time call is expected to be issued in March 2023, with the aim to have a regular, one year cadence.

This year final reviews and time allocation was completed in August. We'll attempt to speed this up - expect observations to commence September at the latest.

Director's discretionary time

- Can be applied for at any time
- Data proprietary period is 3 months, rapid publication encouraged
- email ddt@ska.ac.za (currently not supported by the online proposal submission system), pdf of no more than 3 pages
  - Science justification, how MeerKAT observations address the problem
  - Technical justification (see later slides)
- Can usually observe within a few days on approval

The knowledge base

General documentation

- Telescope and data access guidelines
- MeerKAT specifications
- Narrowband modes
- Science with MeerKAT
- RFI
- Known issues
- Technical reports

Proposals

- Getting a SARAO account
- Submitting a proposal
- Preparing an observation
- Observation overheads

Observing

- Instructions to PIs of accepted proposals
- Data access
- Calibration
- The observation planning tool

Data access

- Archive access
- SDP data products
- Data formats

Calibration

- Calibration strategies
- Flux calibration
- Polarisation
- Gain calibrators
  - L-band
  - UHF

Data processing

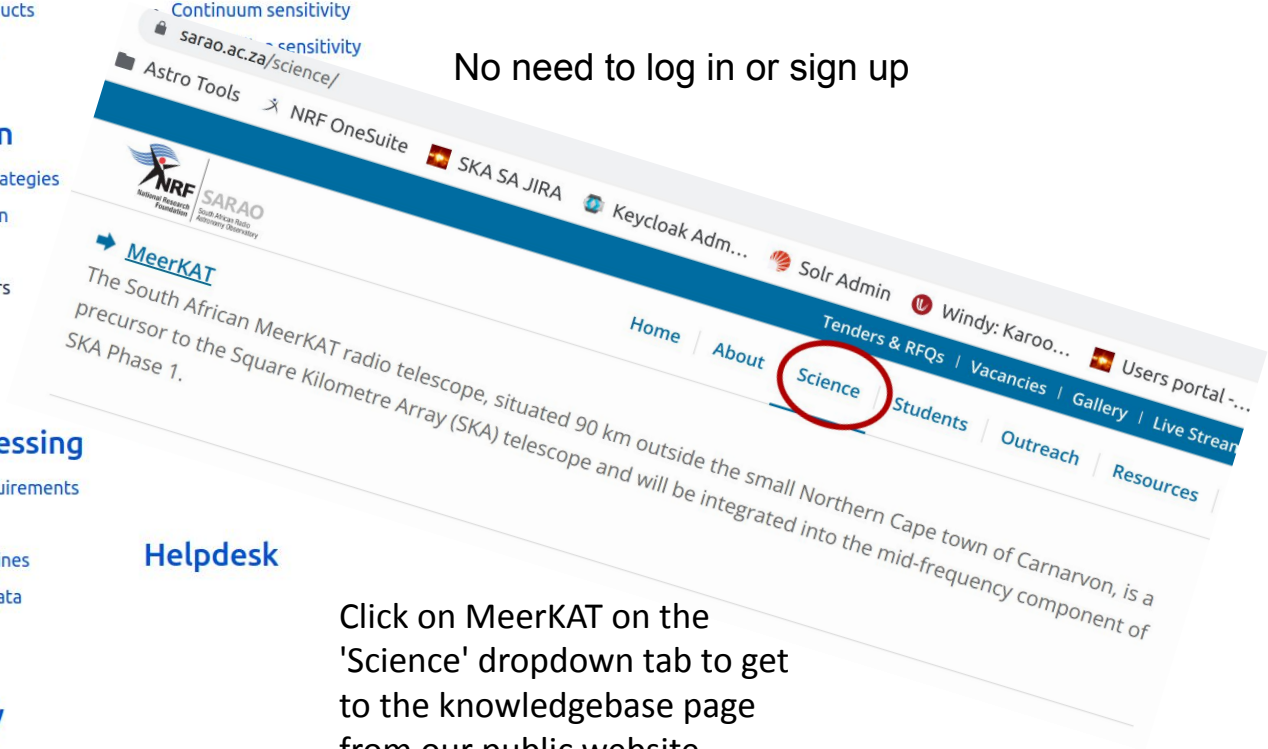
- Hardware requirements
- Using CASA
- External pipelines
- The Science Data Processor

Sensitivity

Tools

- Getting a SARAO account
- Continuum sensitivity
- [illegible] sensitivity

Helpdesk

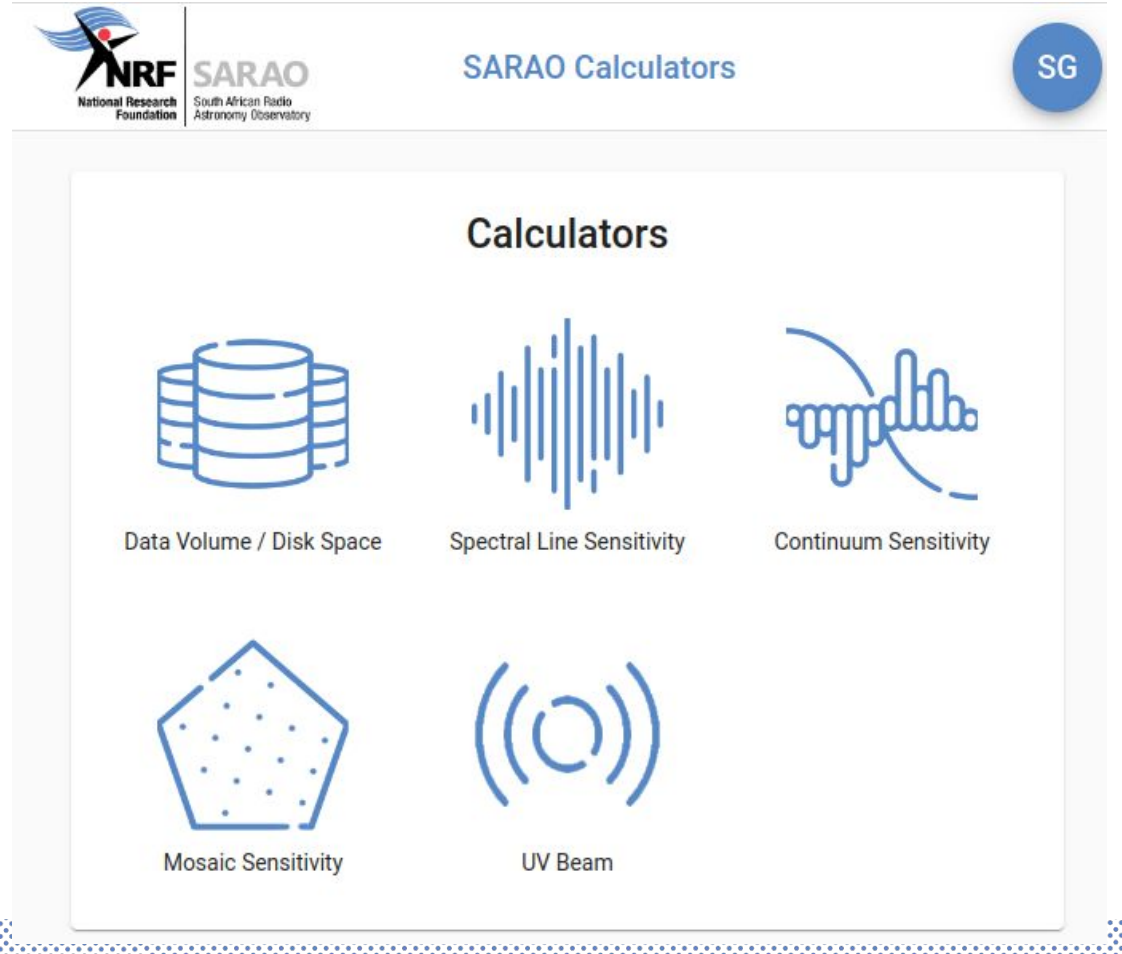


https://skaafrica.atlassian.net/wiki/spaces/ESDKB/overview

No need to log in or sign up

Click on MeerKAT on the 'Science' dropdown tab to get to the knowledgebase page from our public website

Calculators and tools

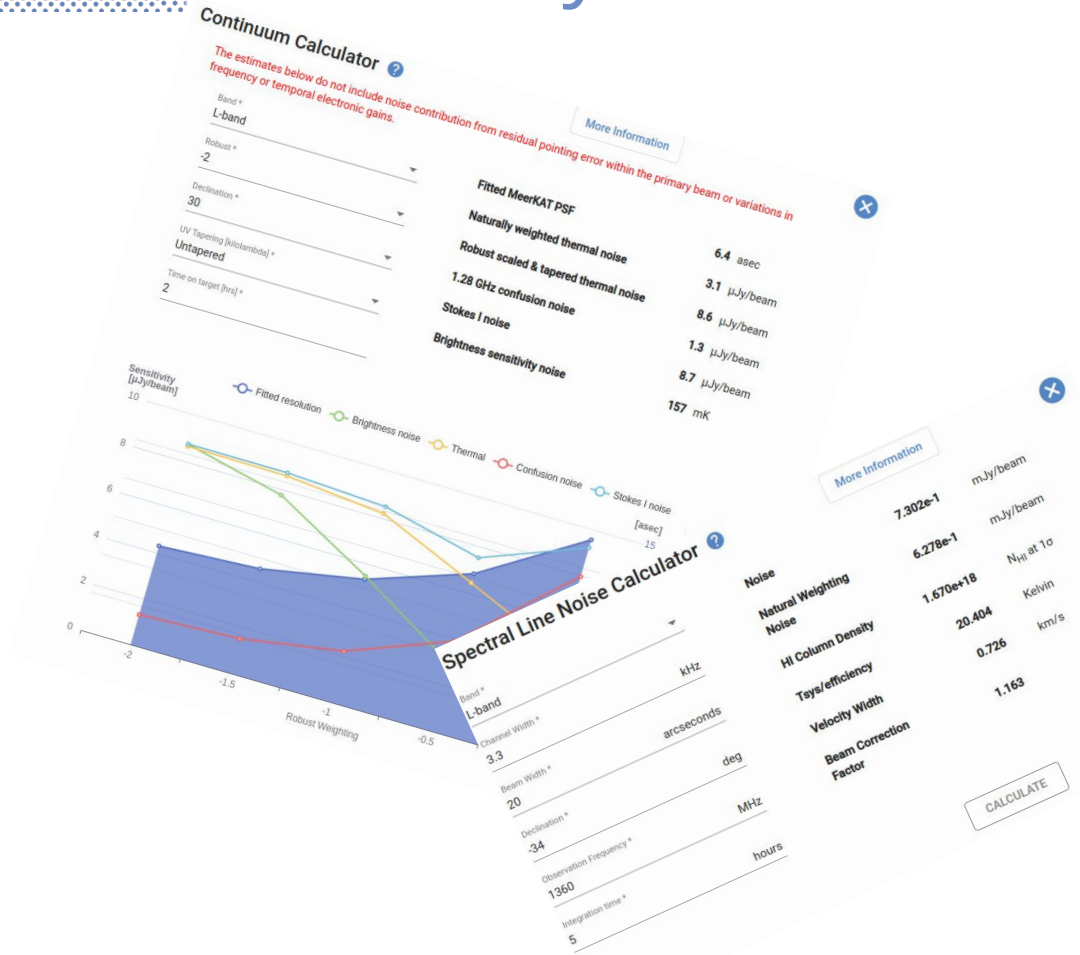


https://apps.sarao.ac.za/calculators

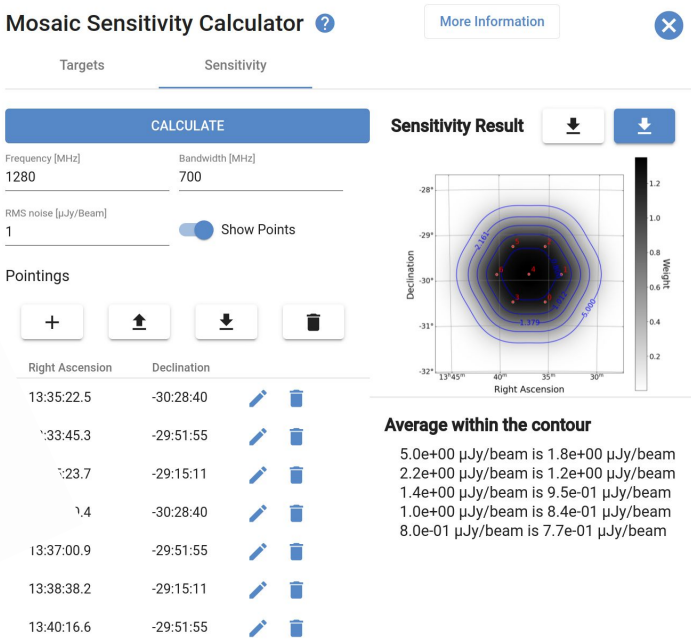
This will need a login (managed by keycloak), same login as the archive

Should you have trouble receiving a verification mail, please contact us on the helpdesk - the automated mails are getting caught in quarantine/spam filters and don't get through in time.
We can manually verify your registration for you.

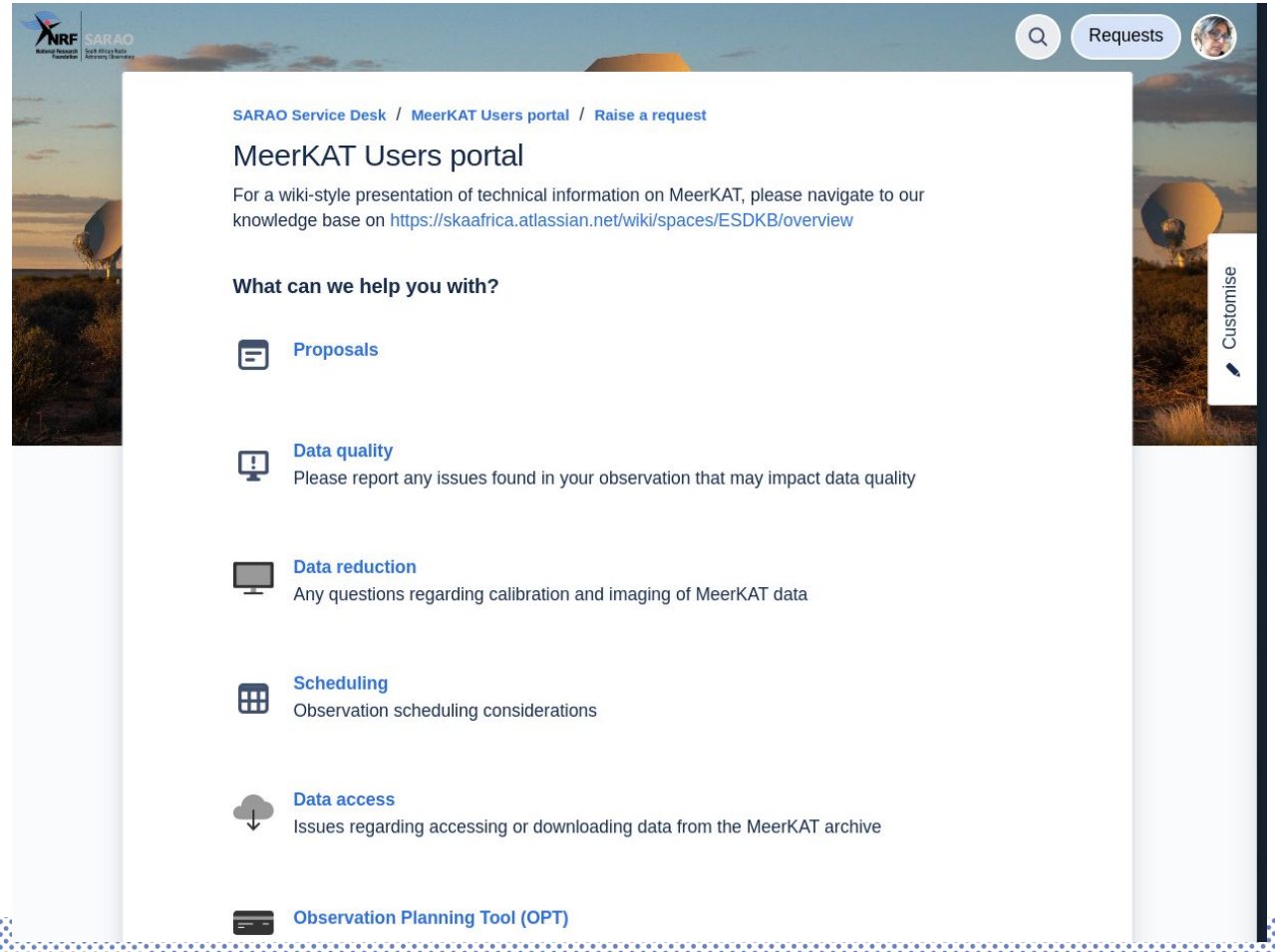
Sensitivity calculators



Click on 'More information' to go to the help pages



The helpdesk



No need to log in or sign up.

PS - don't email us directly - sometimes we're unavailable, but there are multiple eyes on the service desk requests.

https://skaafrica.atlassian.net/servicedesk/customer/portal/1/group/-1

Apologies for the horrible urls, we're doing the best with what we currently have available.

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NRF National Research Foundation | SARAO South African Radio Astronomy Observatory

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