MALS - The first steps towards a kilo square degrees continuum sky

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MeerKAT Absorption Line Survey (MALS)

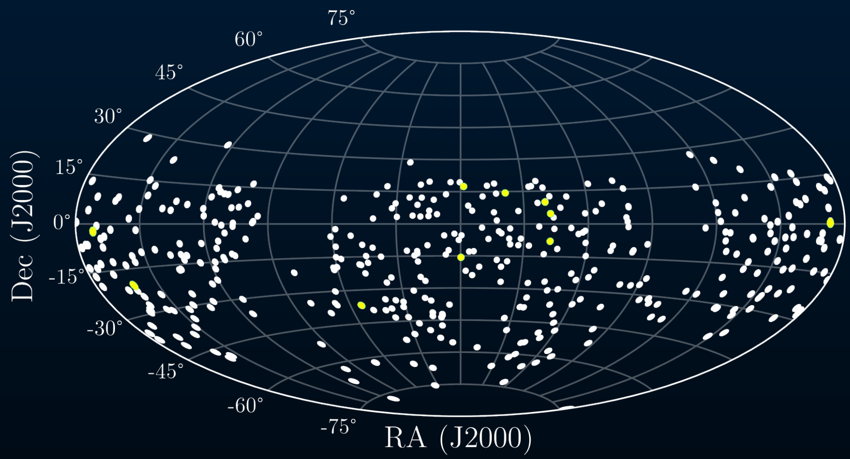
- Search for HI and OH absorption lines at redshifts $0 < z < 2$
- Observations in the L- (900-1670 MHz) and UHF-bands (580-1015 MHz)
- Pointings centered on bright radio AGN (Gupta et al. 2021)
- MeerKAT field of view will enable widefield continuum imaging, which enables novel science into the subjects of e.g. magnetic fields, galaxy clusters, the evolution and properties of radio galaxies, and cosmology

MALS

MeerKAT Absorption Line Survey

A kilo square degrees of continuum sky

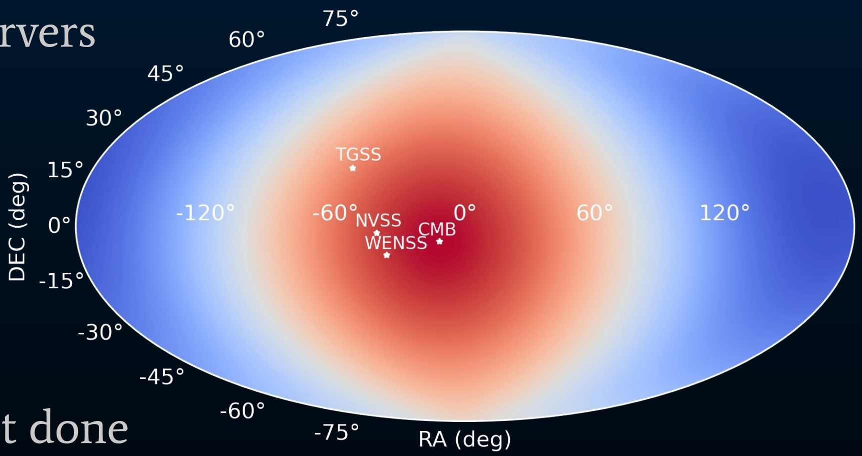
- MeerKAT will observe 1000 pointings for the MALS project (400 already observed in L-band)
- Field of view of MeerKAT ~ a square degree at 1.4 GHz
- Sensitivity ~ 10 μJy/beam for an hour of integration time in L-band
- Expectation: up to 4×10^3 sources per pointing in L-band, 5×10^3 in UHF (Wilman et al. 2008)



Observed pointings in L-band as of February 26 (equatorial coordinates)

The cosmic radio dipole

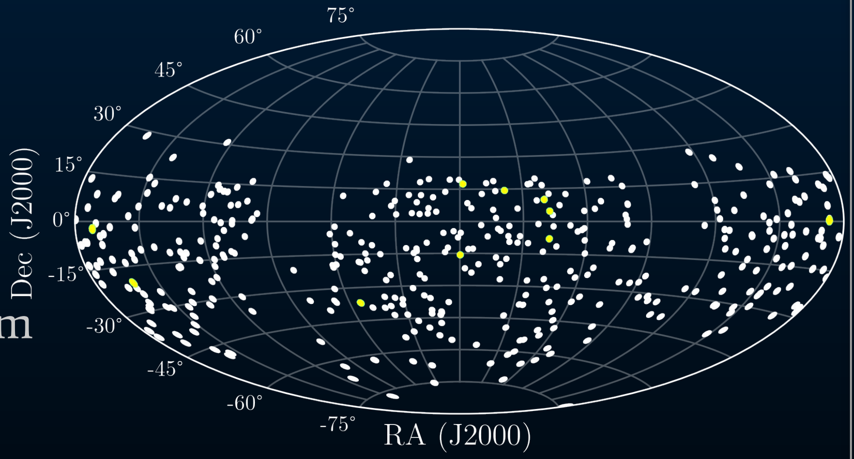
- Largest anistropy in the CMB at $\Delta T \simeq 10^{-3}$ K
- Generally interpreted as the result of observers motion w.r.t the CMB rest frame
- Can be observed in the in the number counts of radio galaxies
- The strength of the radio dipole has been found to be double that of the CMB
- Most significant radio dipole measurement done in NVSS (e.g. Blake & Wall 2002, Rubart & Schwarz 2013)



CMB Dipole direction from Planck 2018

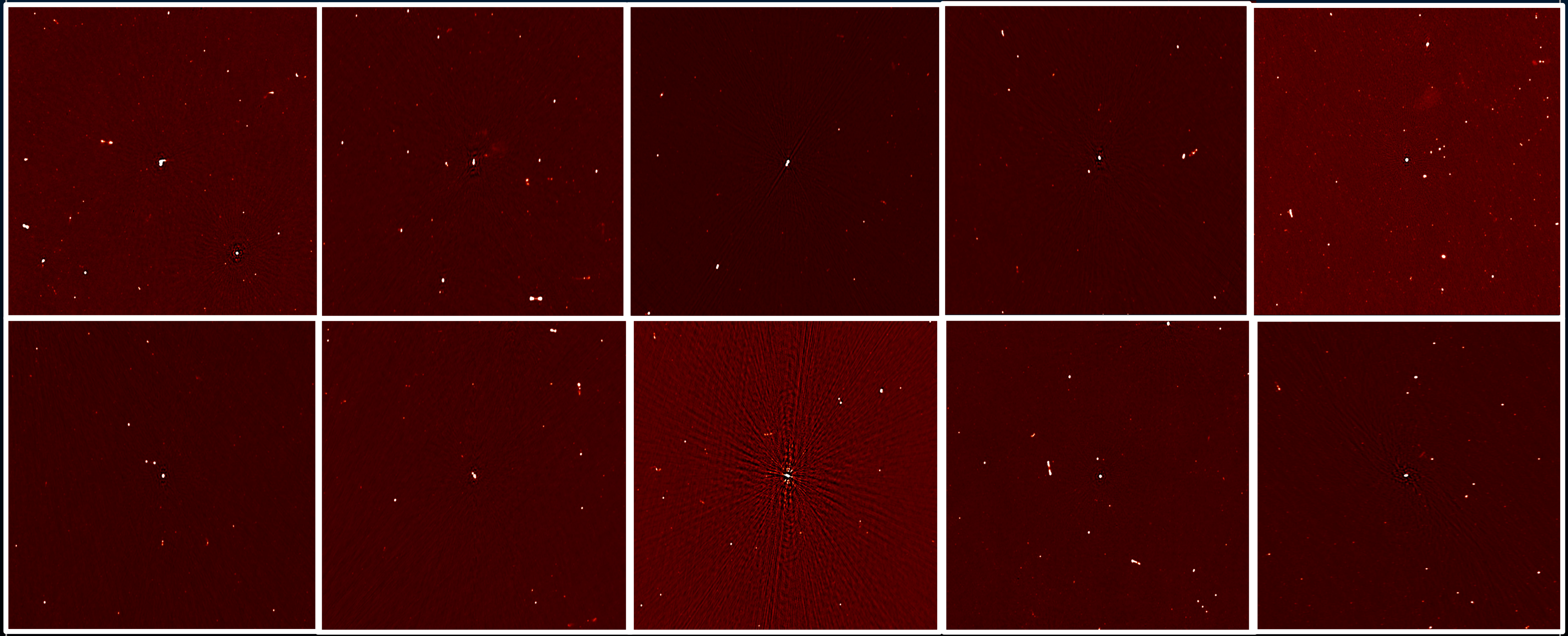
The cosmic dipole in MALS

- At least 2×10^5 sources required for a 3σ dipole detection (Ellis & Baldwin, 1984)
- Though not an all sky survey, pointings are homogeneously distributed
- Enables a dipole measurement in continuum as well as in polarization
- Compiling a survey fit for a dipole measurement requires consistent processing
- Being involved in data processing gives us a unique opportunity to get a full handle on systematics



Observed pointings in L-band as of February 26 (equatorial coordinates)

The first 10 pointings of MALS



Overview - MALS pointings

- All data calibrated, self-calibrated, and imaged through the Automated Radio Telescope Imaging Pipeline (ARTIP, Gupta et al. 2020)
- Primary beam corrections applied with katbeam[1], pending integration into ARTIP
- Sourcefinding performed on all images, along with cross-matching with overlapping surveys to check astrometric and flux systematics
- Three out of 10 pointings show significant artifacts from strong sources in the field, and thus have increased noise and lower source counts
- Average source counts of 'good' pointings around 2000
- Full analysis to be published (Wagenveld et al. 2021, in prep)

[1]https://github.com/ska-sa/katbeam

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github: JonahDW/Image-processing

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Image quality

- RMS noise images output of the sourcefinding routine
- Primary contributors are strong source at pointing centre and primary beam pattern
- Main takeaway: noise is not uniform across the image, and this must be taken into account

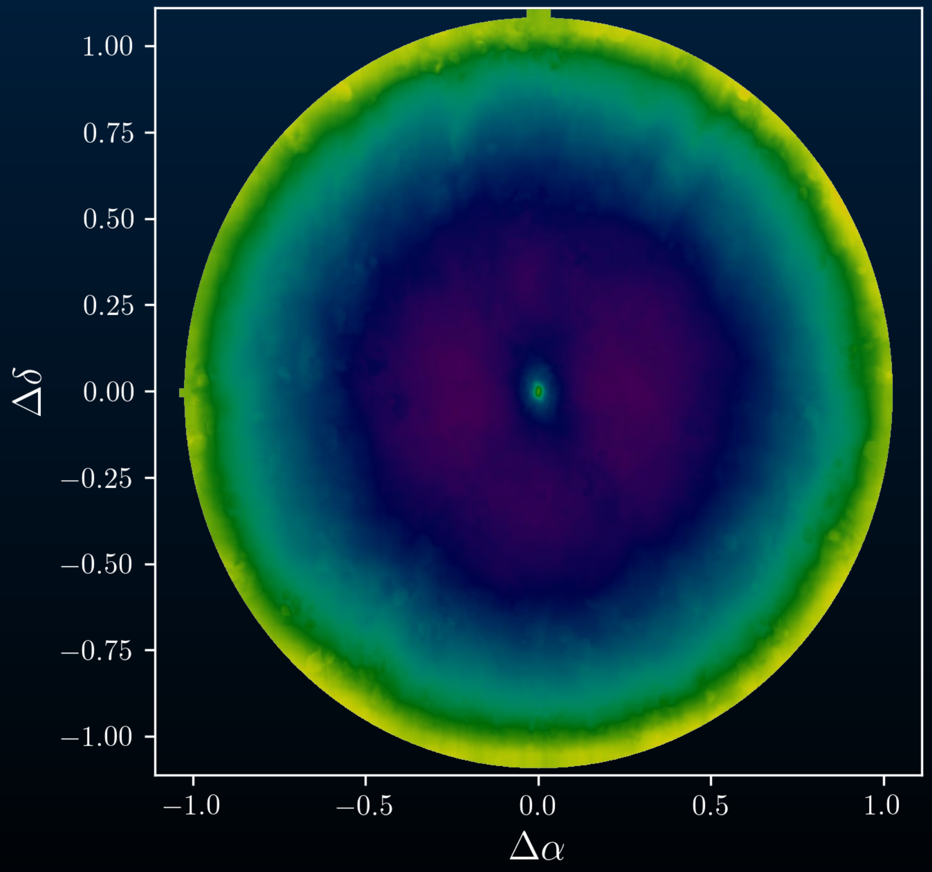
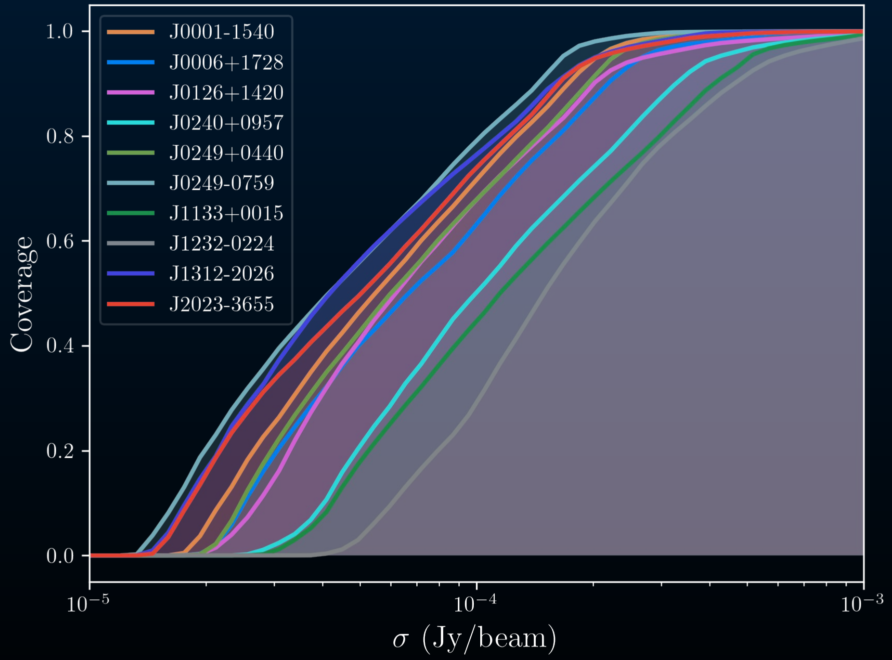


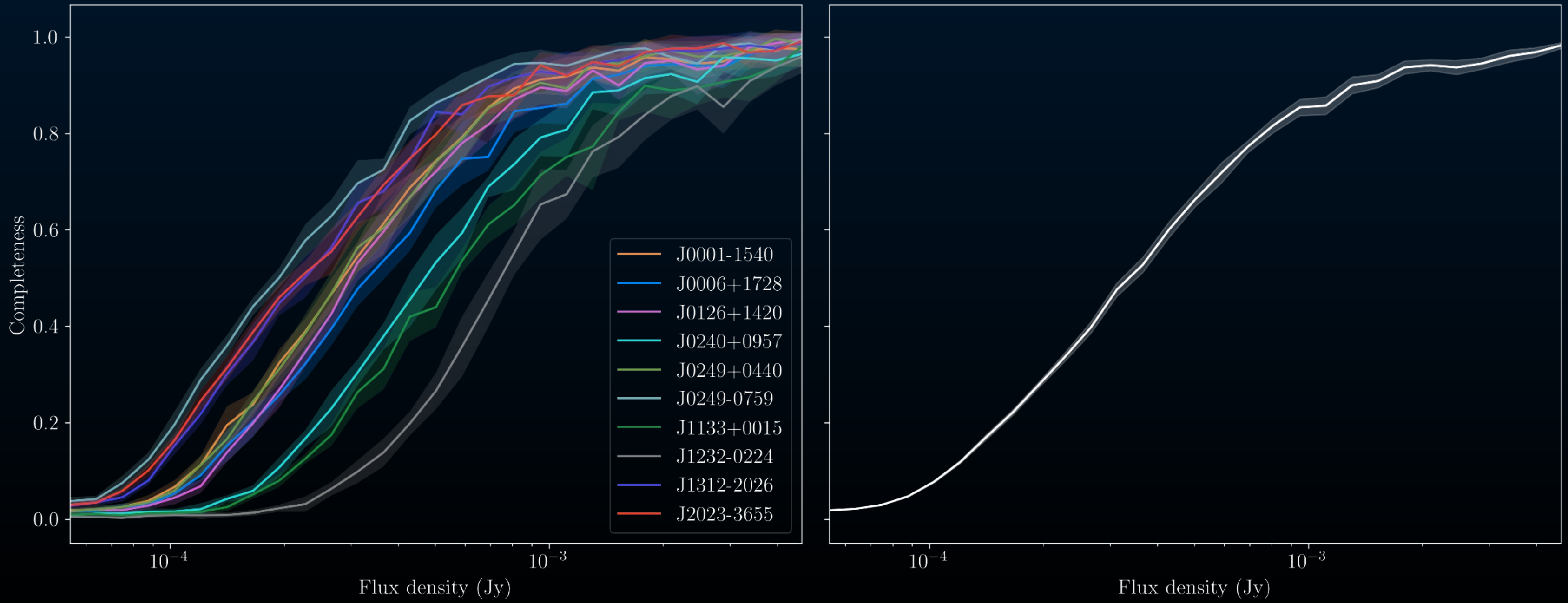
Image quality

- RMS coverage: cumulative noise across the image
- Assess quality of individual images
- We can define a reference noise level as the noise level at e.g. coverage of 20% (inner region of the image)
- Noise is not equal between different pointings!



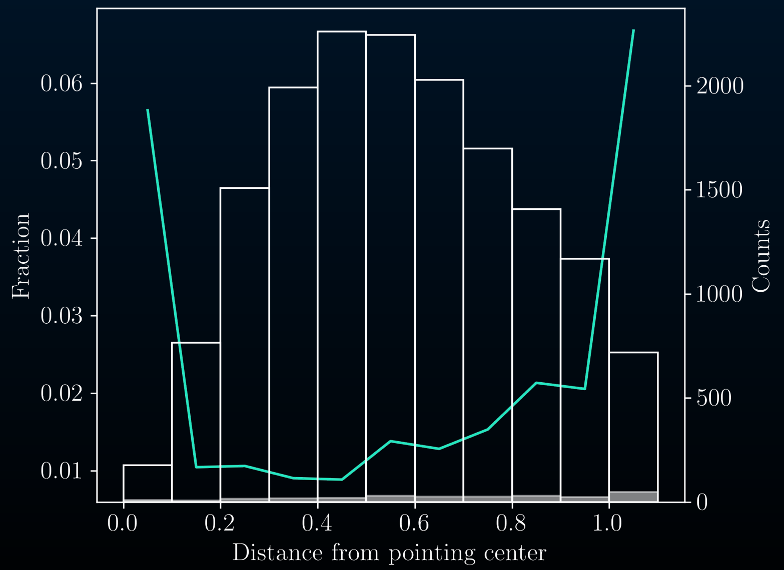
Completeness

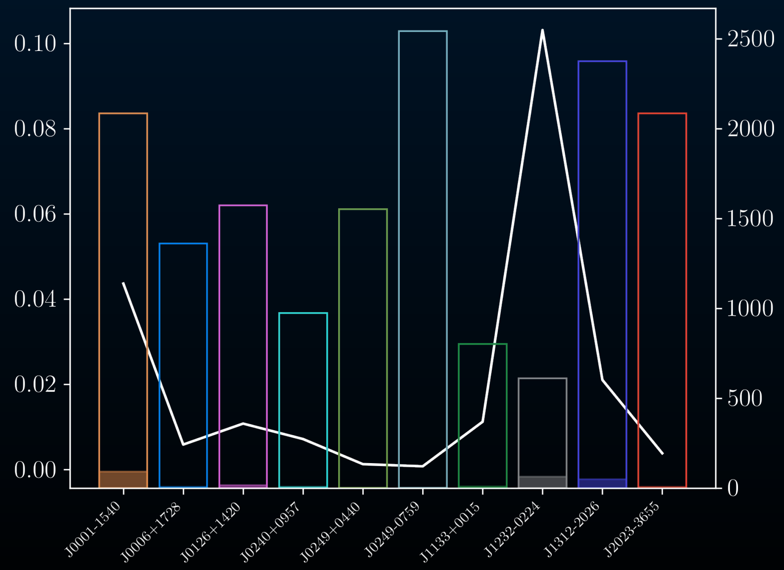
- Completeness - what fraction of sources can I recover at a certain flux density
- Insert sources into residual images and run sourcefinding



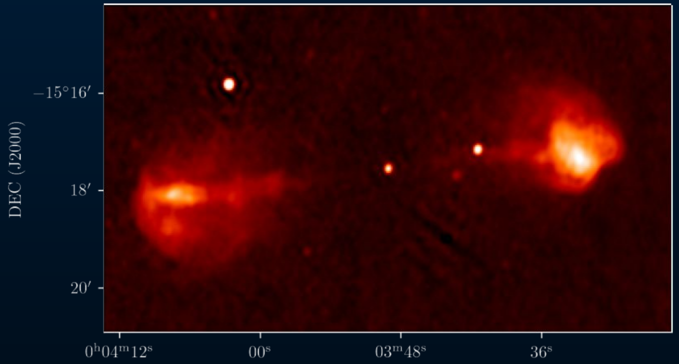
Purity

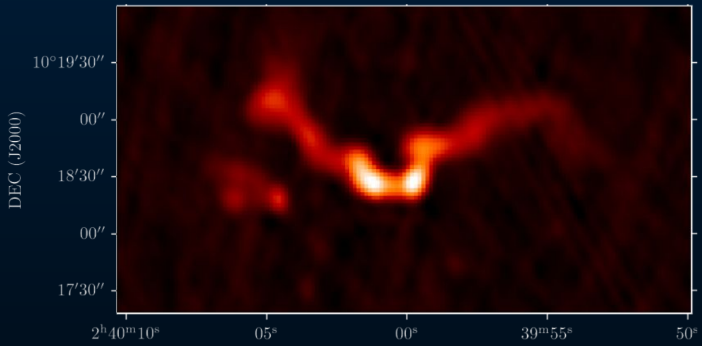
- Purity - what fraction of sources are false positives?
- Invert images and sourcefinding will recover only noise peaks

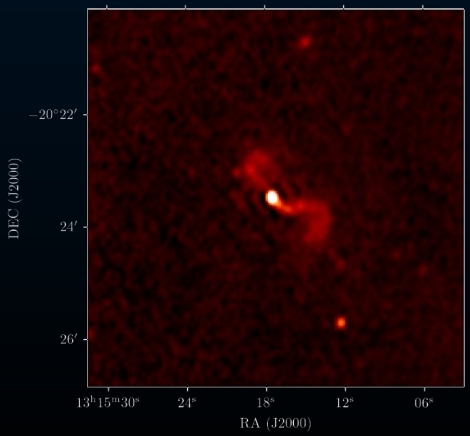


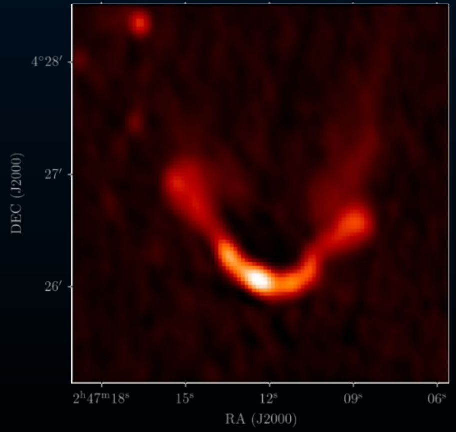


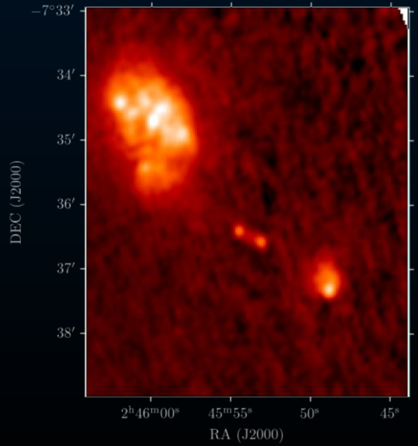
Source (count) populations





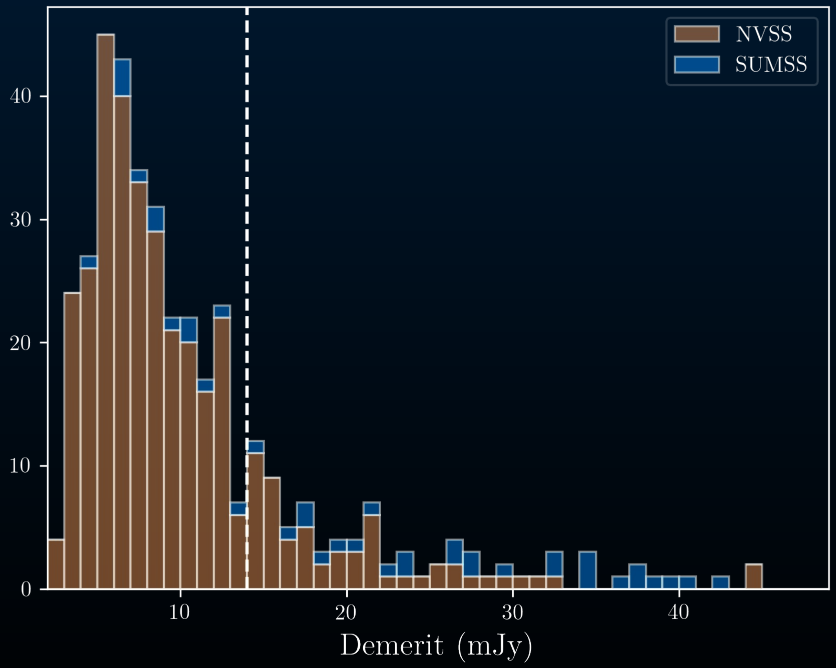






Extrapolating to a dipole measurement

- If strong sources are present in the image, baseline rms noise is strongly correlated with flux of these sources
- Use demerit score (Mauch et al. 2020) to predict image quality
- Extrapolate to rest of pointings - 300/400 pointings 'good' (~2000 sources/pointing) quality
- 100 such pointings needed for a 3σ dipole measurement!



Conclusion

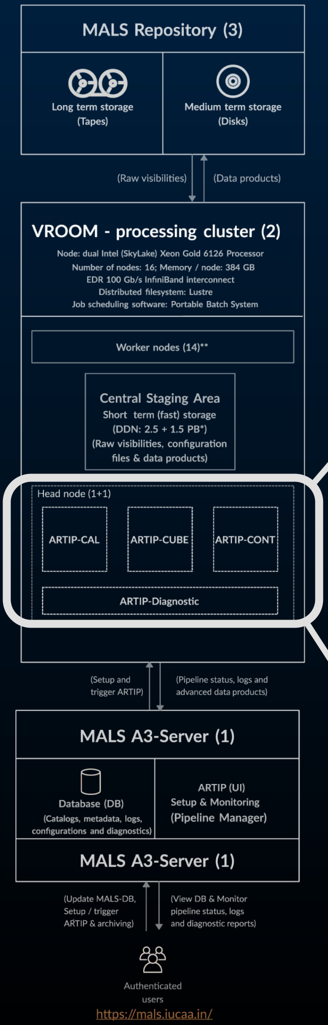
- MALS continuum imaging will enable novel science into the subjects of e.g. magnetic fields, galaxy clusters, the evolution and properties of radio galaxies, and cosmology
- End to end calibration in place and producing images
  - SPW2/9 images for 350 pointings nearly complete
  - Full bandwidth images for 100 pointings to be completed by mid-2022
- Results from first 10 pointings promises a large amount of good quality data
- MALS will boast enough sources for an investigation into the cosmic radio dipole
- Characterizing systematics and patterns inside the data will help us to accurately estimate the dipole while accounting for these effects, such that we can optimally use the data provided

Questions?

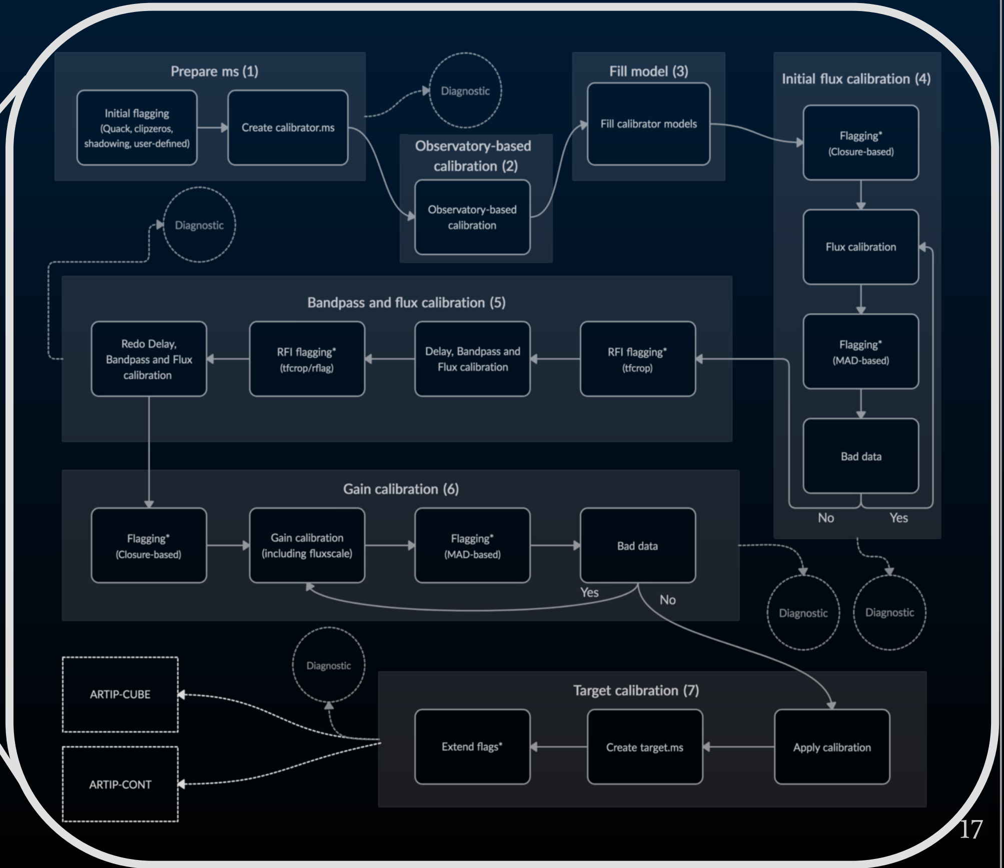
Credit: Expert Africa

ARTIP

Data processing: One hour of MeerKAT observation produces a terabyte of raw data



Gupta et al. 2020



The dipole in recent literature

- Secrest et al. (2020): Dipole in the distribution of quasars >2x the CMB dipole amplitude
- Singal et al. (2021): Dipole in SN1a aligned with CMB dipole, 4x amplitude
- Luongo et al. (2021): Higher values of H0 from quasars and GRBs in the direction of the dipole
- Colin et al. (2019): A dipole in the cosmic deceleration parameter from SN1a