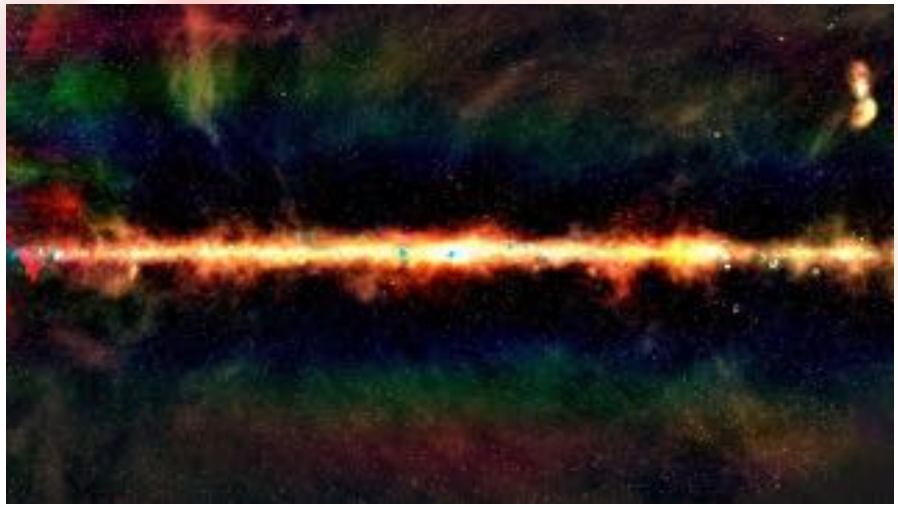


Using GLEAM to unravel the nature of the low-frequency radio source population

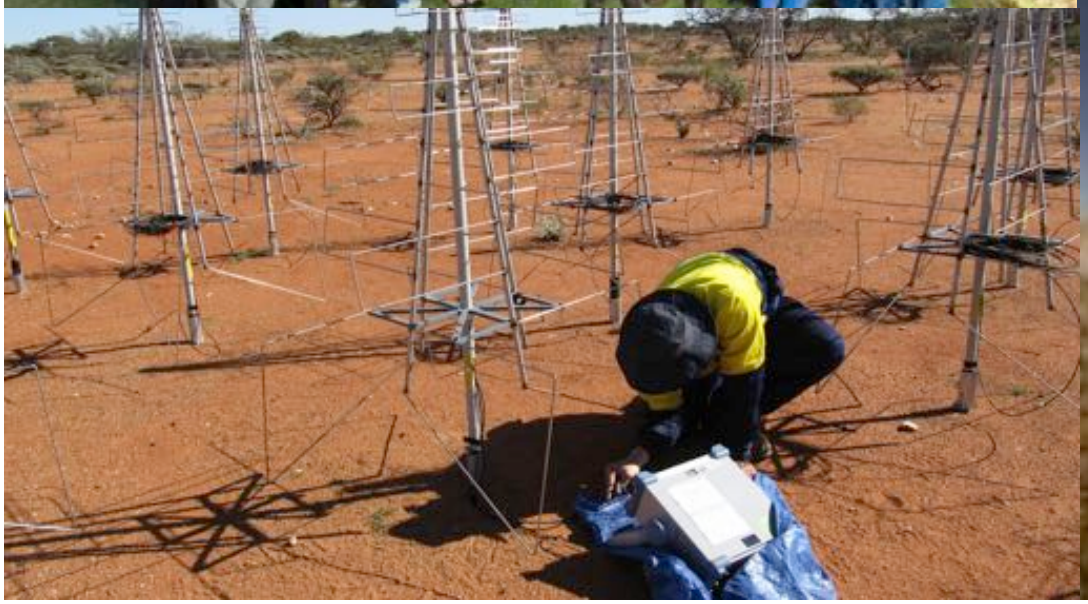
Tom Franzen | Postdoctoral Researcher
ICRAR-Curtin University
4 November 2016

International Centre for Radio Astronomy Research

Curtin University

The University of Western Australia

ICRAR-Curtin – science & engineering



ineering

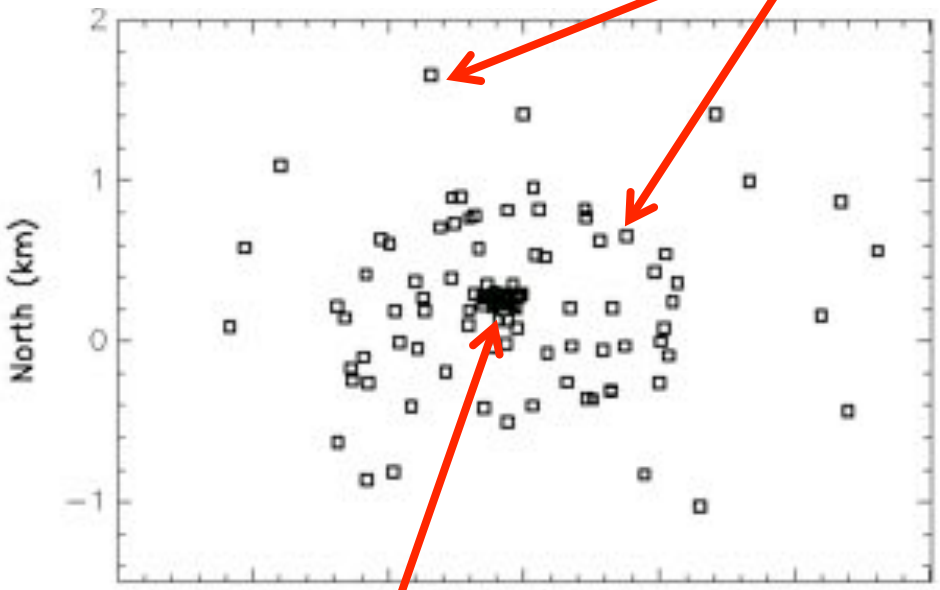
Murchison Widefield Array

- Low-frequency precursor telescope for SKA
- Managed & operated by Curtin University
- 128 tiles (collecting area 2752 m^2 at 150 MHz) each of 16 dipoles
- Frequency range 72-300 MHz (30.72 MHz bandwidth)
- Maximum baseline 3 km
- System description: Tingay et al. (2013)
- Primary science objectives: Bowman et al. (2013)

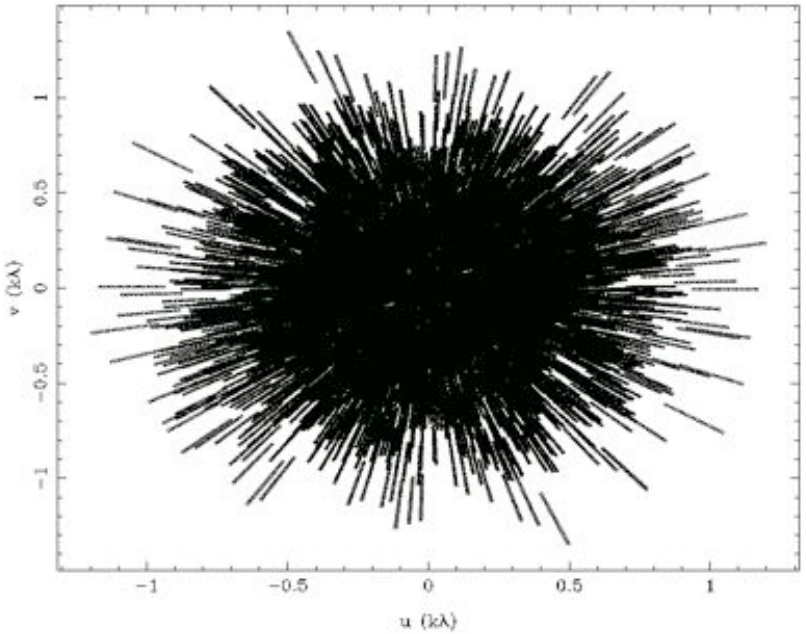
MWA instantaneous *uv* coverage

Mid/outer regions
Resolution, calibration
uv coverage

Array layout



Snapshot, full bandwidth *uv* coverage



Compact core
(surface brightness)

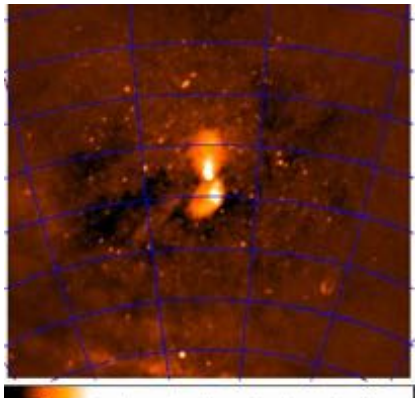
See Tingay et al. (2013)

Angular resolution at 154 MHz: ≈ 2.5 arcmin

Field-of-view at 154 MHz: ≈ 30 deg

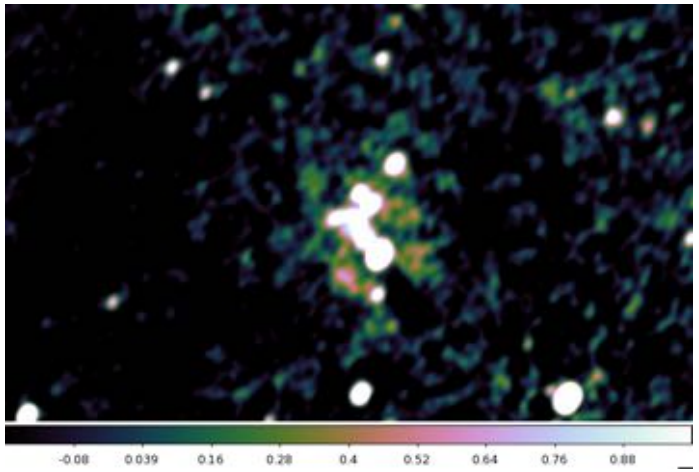
Why GLEAM?

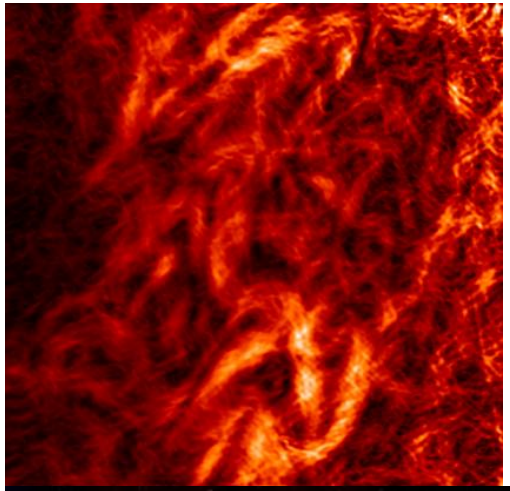
Designed to service 30+ MWA science programs



Radio galaxies & AGN

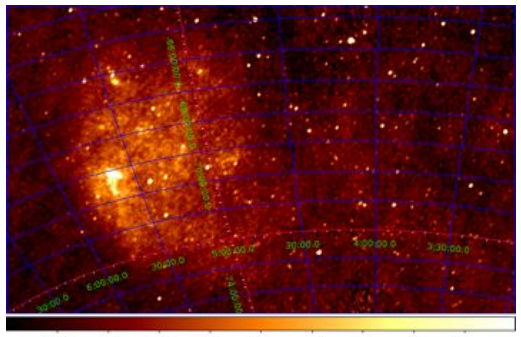
Galaxy clusters





Diffuse Galaxy & B field

Magellanic clouds

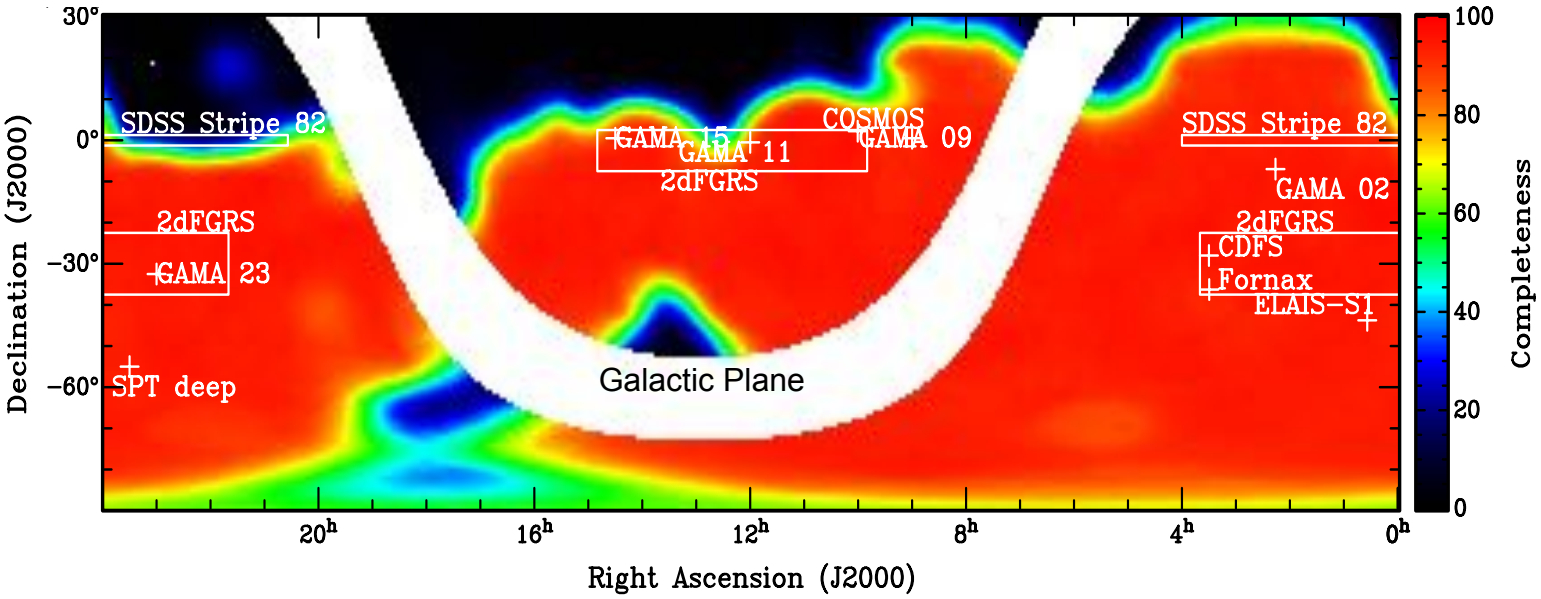


SNRs & HII regions

GLEAM extragalactic source catalogue (Hurley-Walker et al. 2016)

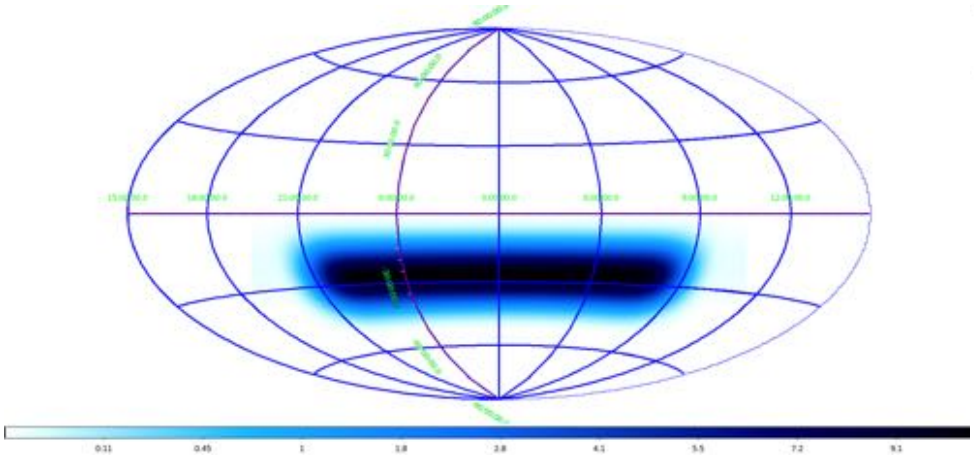
- Based on 1st year of GLEAM obs. (4 weeks between June 2013 & July 2014)
- Covers sky area of 24,402 deg^2 below Dec +30° at 72-231 MHz
- 307,801 components to 5-10 mJy rms
- Catalogue and images available online:
  - http://www.mwatelescope.org/science/gleam-survey
- 2nd year observations complete; data analysis ongoing

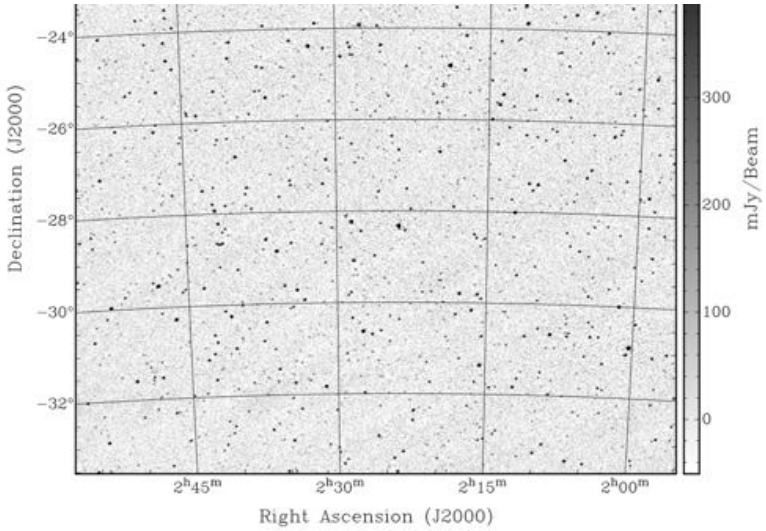
Completeness at $S_{200\ MHz}$ = 100 mJy



Imaging strategy - snapshot imaging

- Meridian drift scans as 2-minute snapshots, cycling through frequencies
  - 7 DEC bands: 18.6, 1.6, -13.0, -26.7, -40.2, -55.0, -72.0
  - 5 frequency ranges covering 72-231 MHz
- In a 2-minute snapshot, MWA is close to coplanar - small *w*-terms can be fixed with appropriate imager
- CLEAN each snapshot separately using WSClean (Offringa et al. 2014)
- Generate mosaics via image-plane co-addition after correcting for ionospheric shifts and primary beam

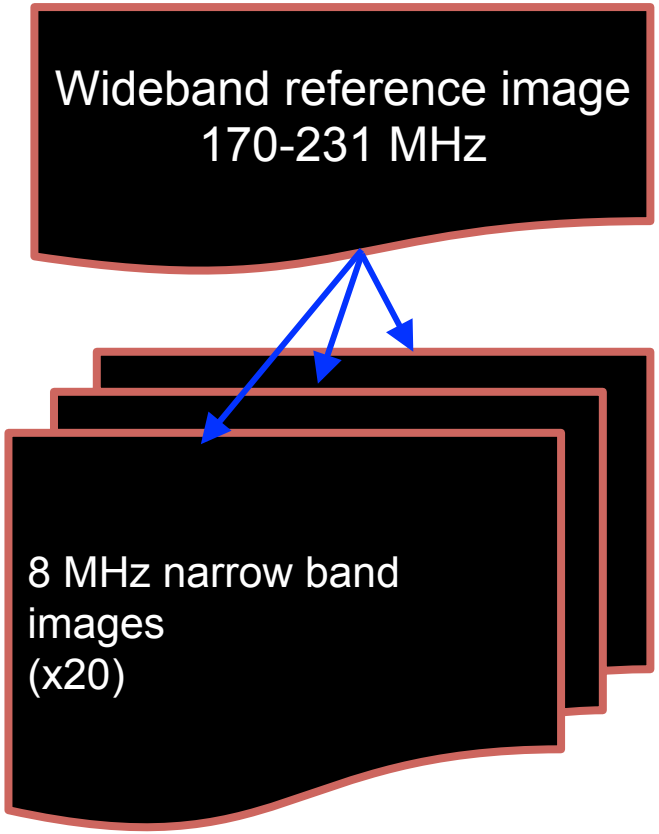




Example snapshot (full bandwidth)

Catalogue strategy

Use Aegean source finder (Hancock et al. 2012)
https://github.com/PaulHancock/Aegean



Create reference catalogue from wideband reference image ('white' image)

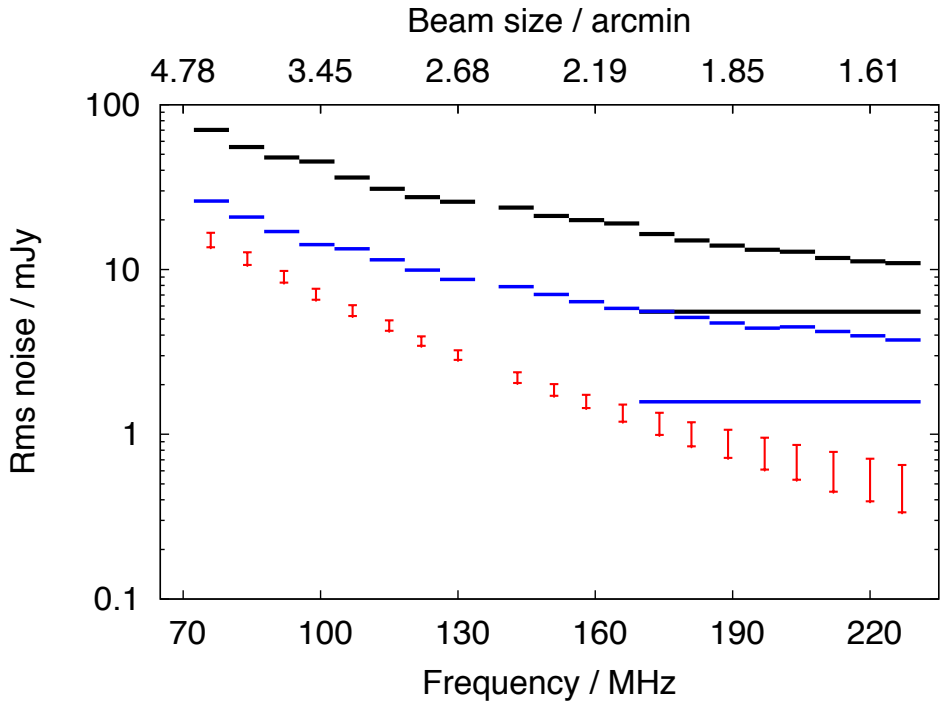
For each narrow band image do a fit with priors from the reference catalogue

Catalogue contains

- all sources from deep image
- fluxes from each subband for each source
- zero false cross IDs

Limits of noise & confusion

- 3 basic sources of error: system noise, classical confusion and sidelobe confusion
- Estimate classical confusion noise across band using deep GMRT counts at 154 MHz (Williams, Intema & Röttgering 2013, Intema et al. 2011 & Ghosh et al. 2012)
- Use thermal noise estimates in cold region of extragalactic sky from Wayth et al. (2015)
- Compare with measured rms noise in deepest region of GLEAM



Background noise primarily due to sidelobe confusion

- Limited CLEANing depth
- Source smearing due to ionosphere
- Far-field sources that have not been deconvolved

Franzen et al. (2016)

Extragalactic science

In progress:

- Callingham et al.: Searching for GPS & CSS sources
- Drouart et al.: Searching for high-redshift radio galaxies
- Franzen et al.: Source counts and confusion across 70-230 MHz band
- Hurley-Walker, Heald et al.: GLEAM and MSSS
- Jackson, Franzen, White et al.: 4 Jy sample
- Johnston-Hollitt et et.: New cluster relics and haloes
- Kapinska et al.: Dying and relic radio galaxies
- Line et al.: Automated multi-resolution cross-matching
- Murphy et al.: GLEAM/TGSS search for transients
- Sadler et al.: Low frequency radio source populations in the local universe
- Seymour et al.: Low frequency SEDs of star-forming galaxies
- White et al.: Angular two-point correlation function
- More to come…

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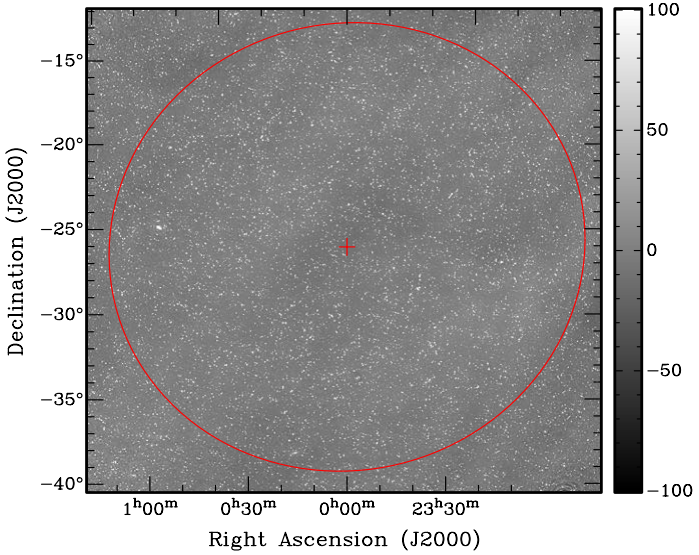
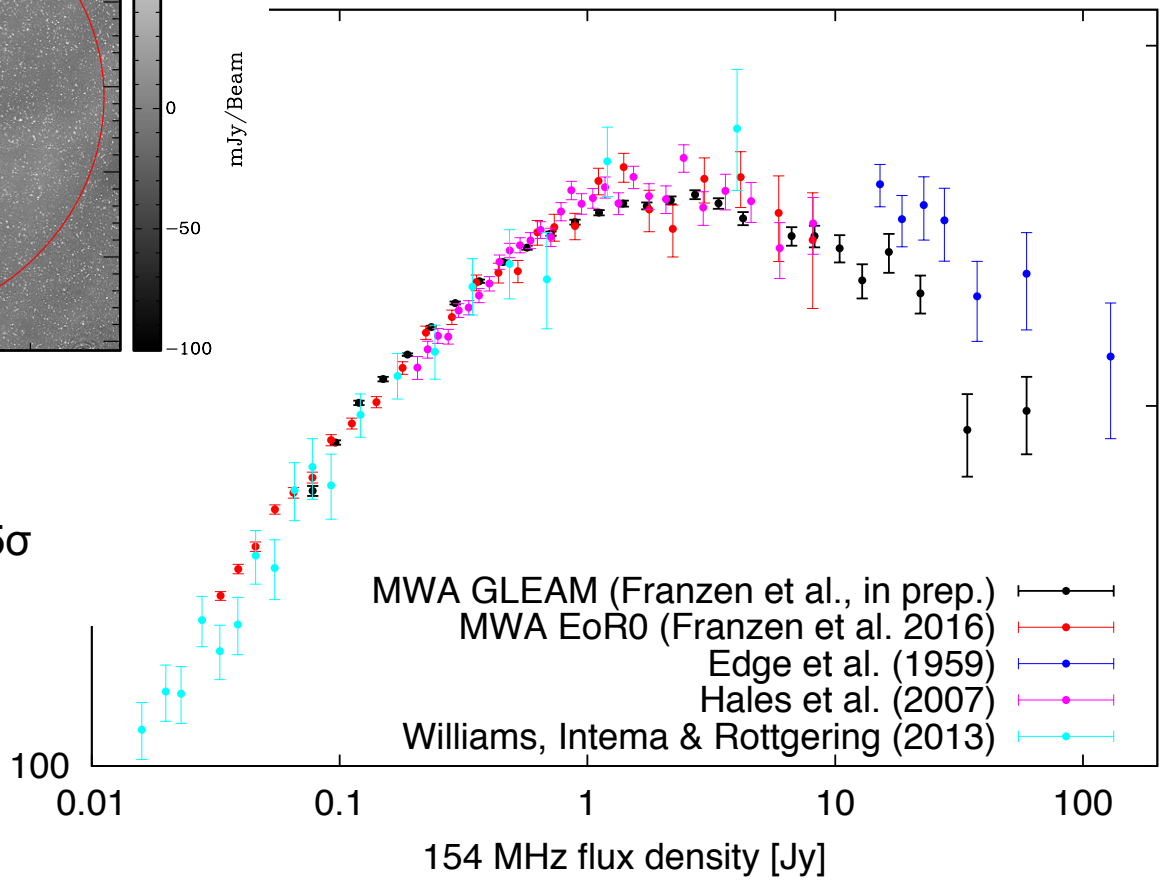
GLEAM source counts at 154 MHz

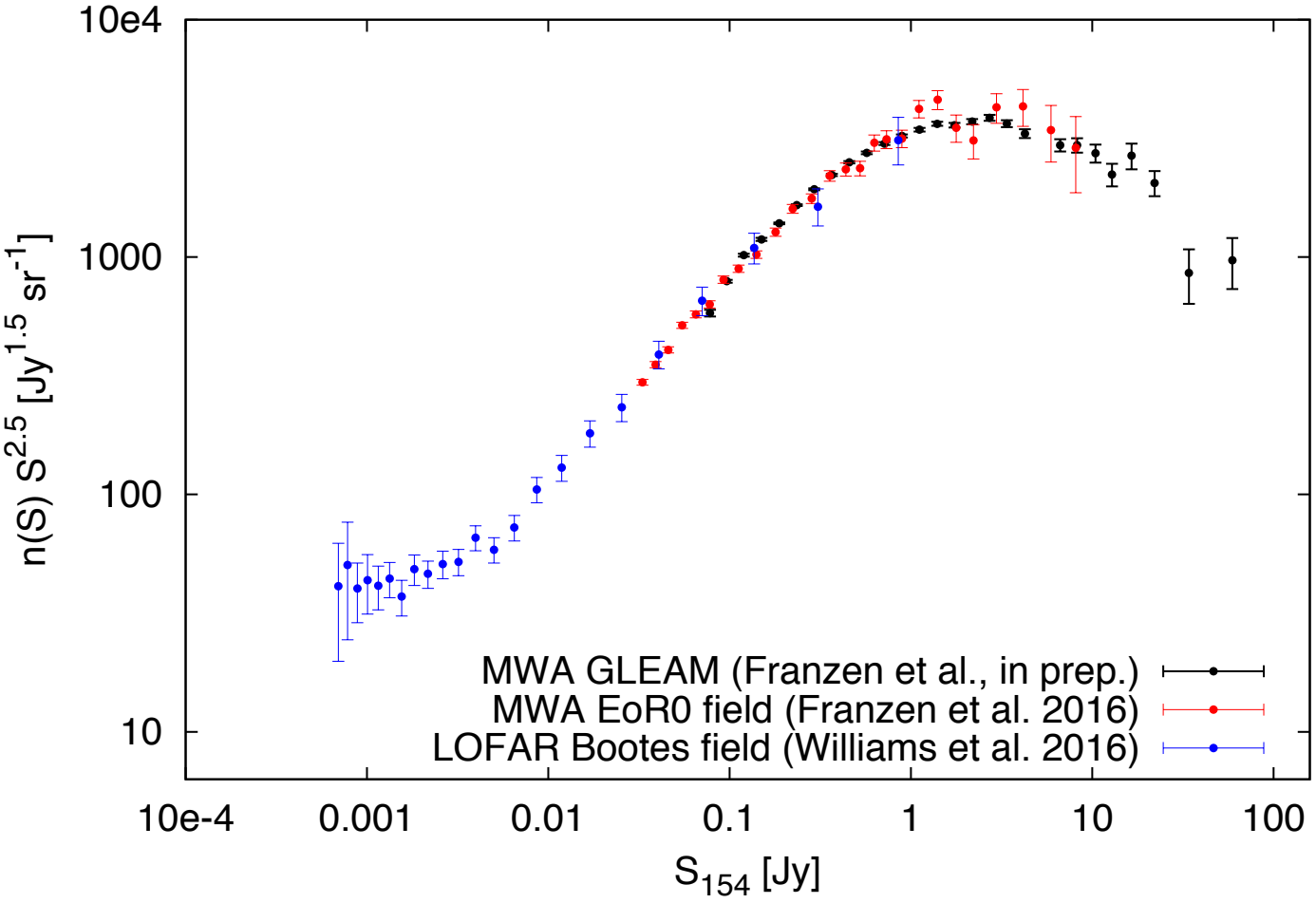


FoV = 570 deg^2

13,458 sources > 5σ



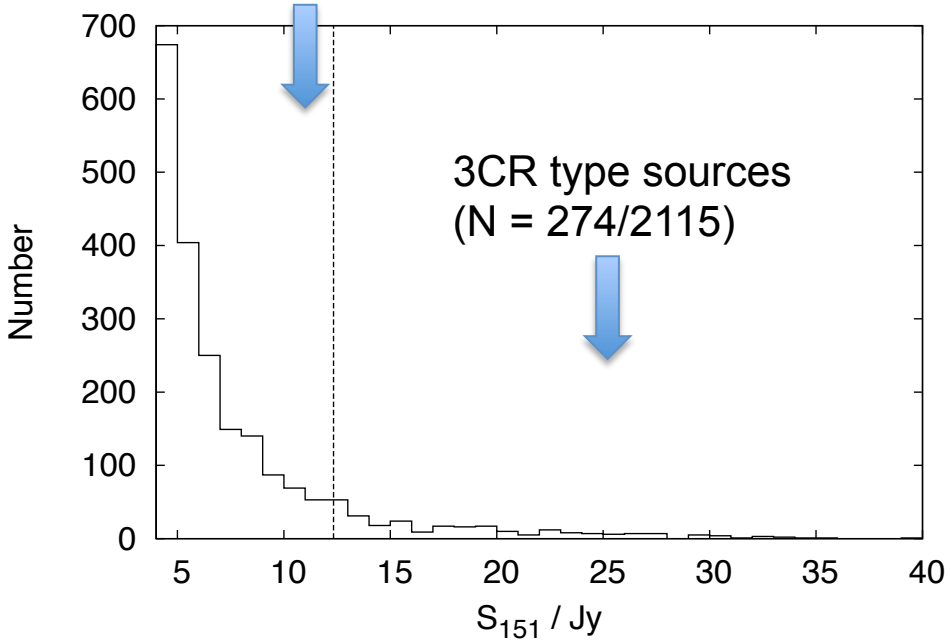
154 MHz source counts



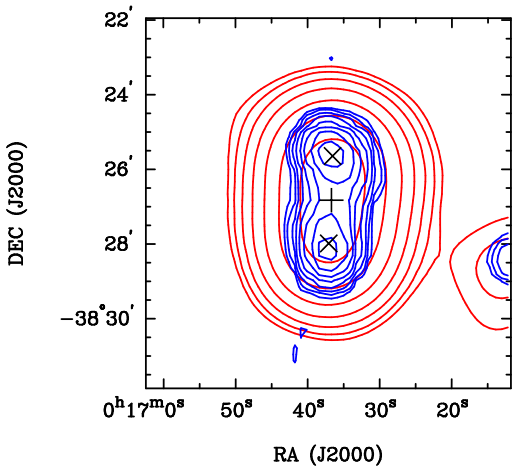
GLEAM 4 Jy sample

- A fundamental southern sky sample of bright radio sources akin to 3CR
- About 10 times larger: 2115 sources versus 173 in 3CR
- Direct insight to source populations & their evolution (space density) + GLEAM 72-231 MHz SED

Fainter RGs (lower power or higher z)



NVSS double

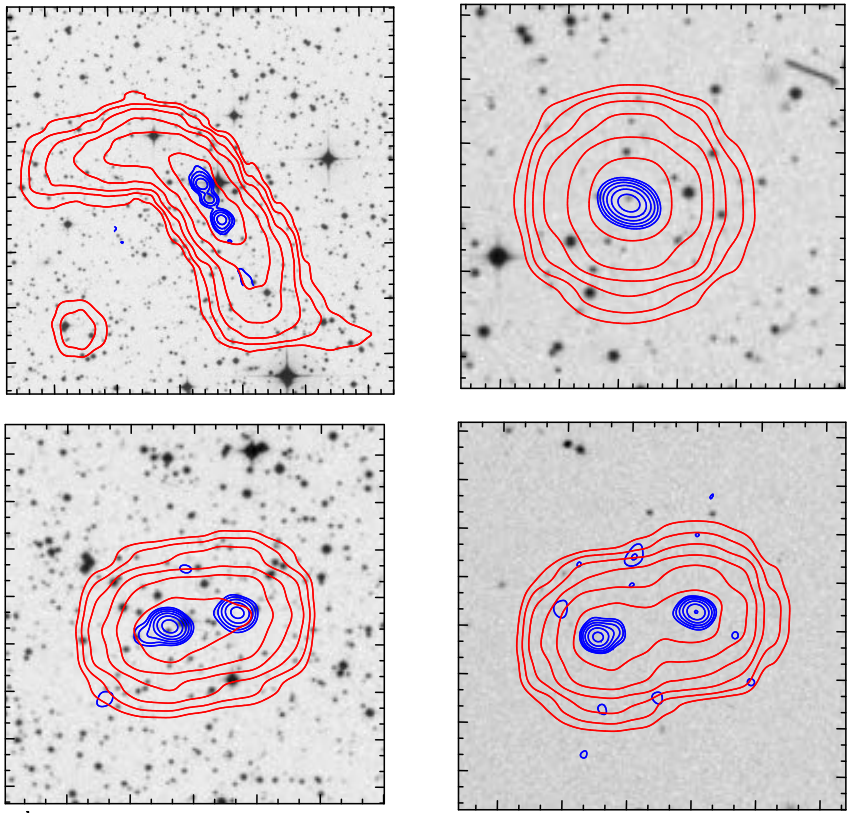


24% of all GLEAM sources are multiples in NVSS/SUMSS

Jackson et al. (2016)

ATCA follow-up observations at 5.5, 9 and 18 GHz

- Of 1491 GLEAM 4 Jy sources below Dec 0, only ≈ 40% have match in AT20G
- ATCA follow-up at 5.5, 9 and 18 GHz of sources not detected in AT20G
- Preliminary results suggest that emission is lobe-dominated for majority of these sources at all 3 frequencies



Grey scale:

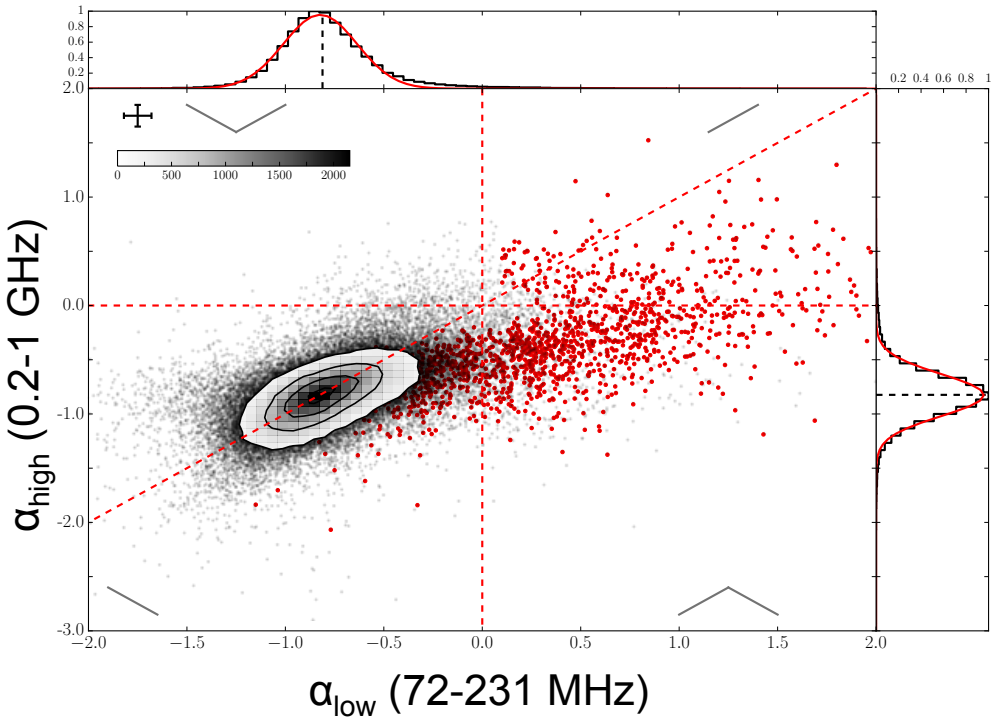
SuperCOSMOS J-band

NVSS

ATCA 18 GHz (follow-up)

Searching for GPS & CSS sources

- Construct largest sample of peaked-spectrum sources to-date with contemporaneous observations below spectral peak
  - Spectral comparison of different absorption models
  - Search for young & high-redshift AGN
- Select 96,628 unresolved GLEAM sources with $S_{200\ MHz} > 160$ mJy
- 1484 of these (≈ 1.5%) are peaked-spectrum candidates

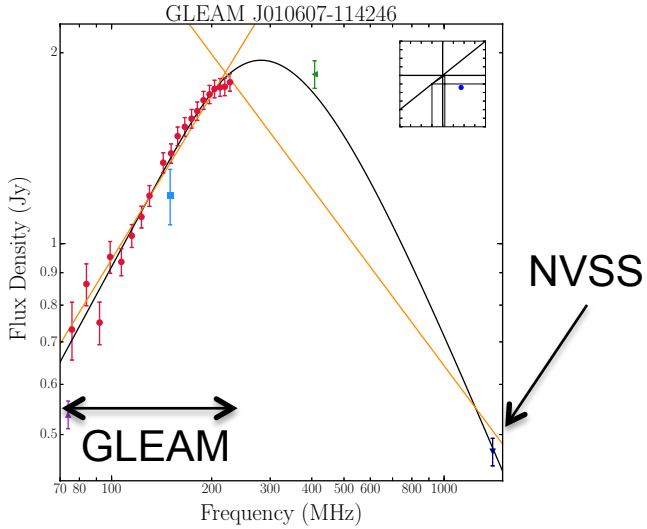


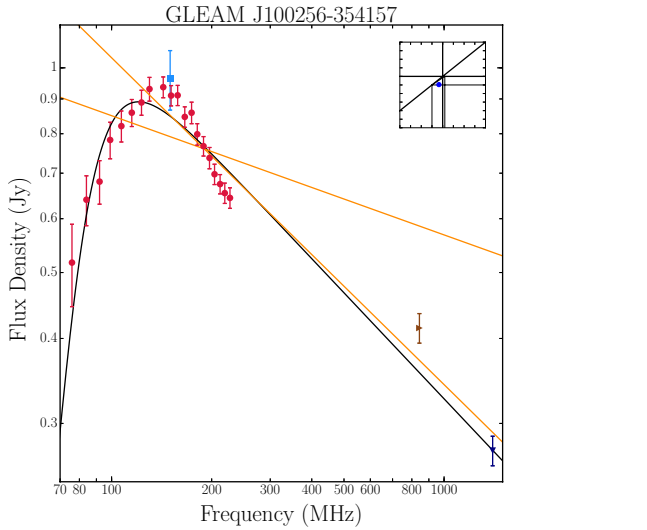
Radio colour-colour plot from 72 MHz to 0.843/1.4 GHz

Callingham et al., in prep.

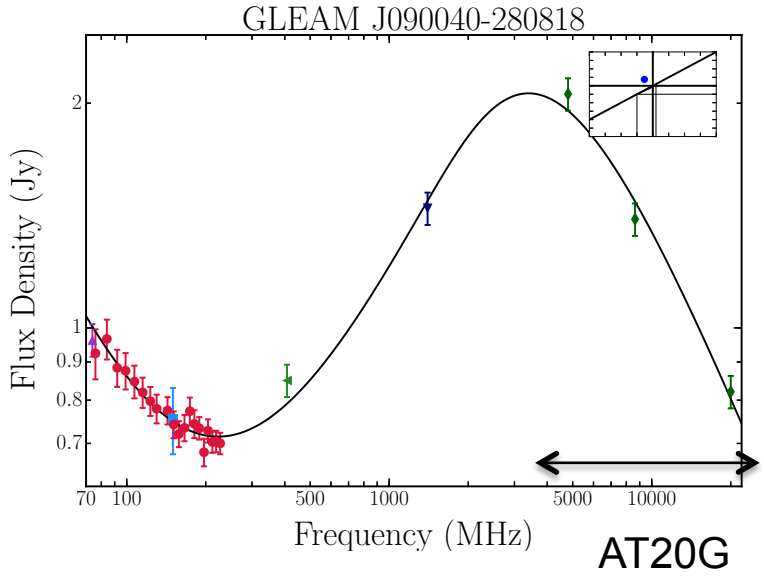
Example SEDs

Identified peaked-spectrum sources



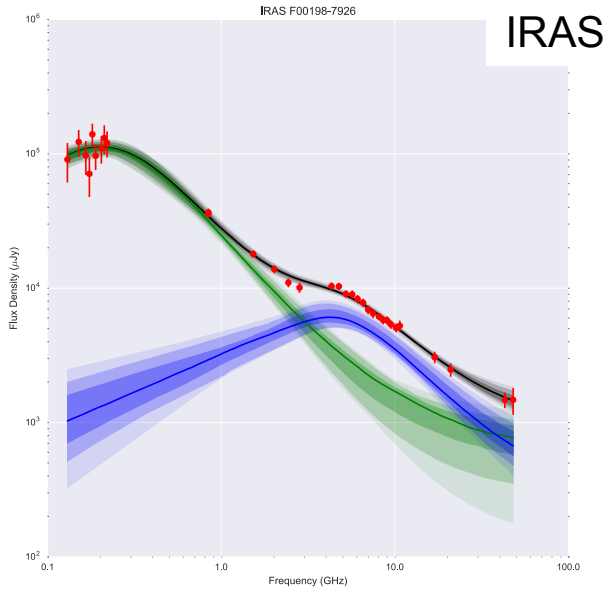


Known GPS source with convex pattern between 72 MHz and 1.4 GHz



Low frequency spectra of star-forming galaxies

- Measured radio SEDs of 19 ULIRGs at 0.067 < z < 0.227 using GLEAM + ATCA follow-up (2.1-40 GHz)
- About 40% show turnover at low frequency due to free-free absorption
- Use WiFeS data to calibrate radio emission against SFR and investigate geometry of star formation
- Relate radio SED to geometry of star formation



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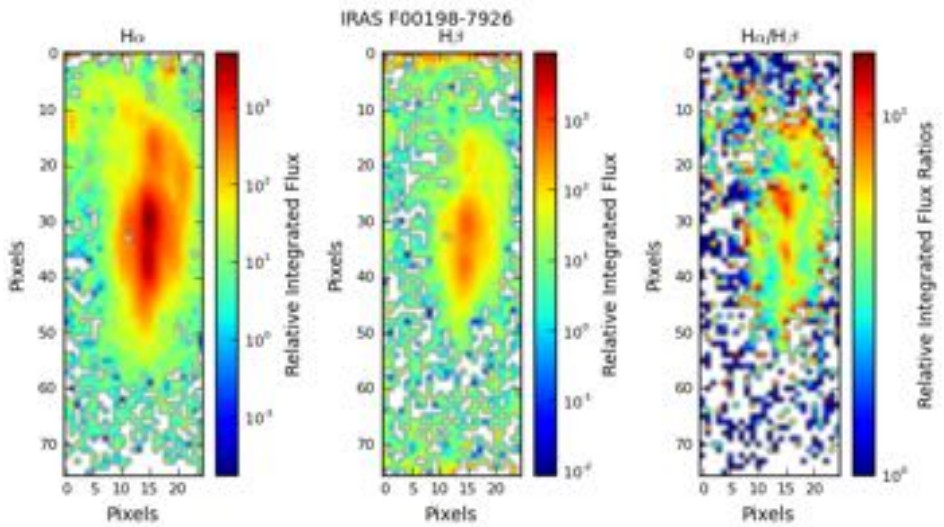

Galvin, Seymour, McDermid et al., in prep.

Conclusions

- New southern radio sky survey
- Widest fractional bandwidth and largest sky area survey at radio frequencies to date
- Calibrate low frequency flux scale of southern sky to better than 10%
- Catalogue of 300,000+ extragalactic sources with 20 separate flux measurements across 72-231 MHz (Hurley-Walker et al. 2016)
  - http://www.mwatelescope.org/science/gleam-survey
- Huge range of science papers arriving in 2016-2018
- MWA is being upgraded, roughly doubling the array resolution; raises possibility of conducting large-area, sub-mJy continuum surveys