International Centre for Radio Astronomy Research

The AT20G & MWA surveys: new insights to high & low frequency radio sources

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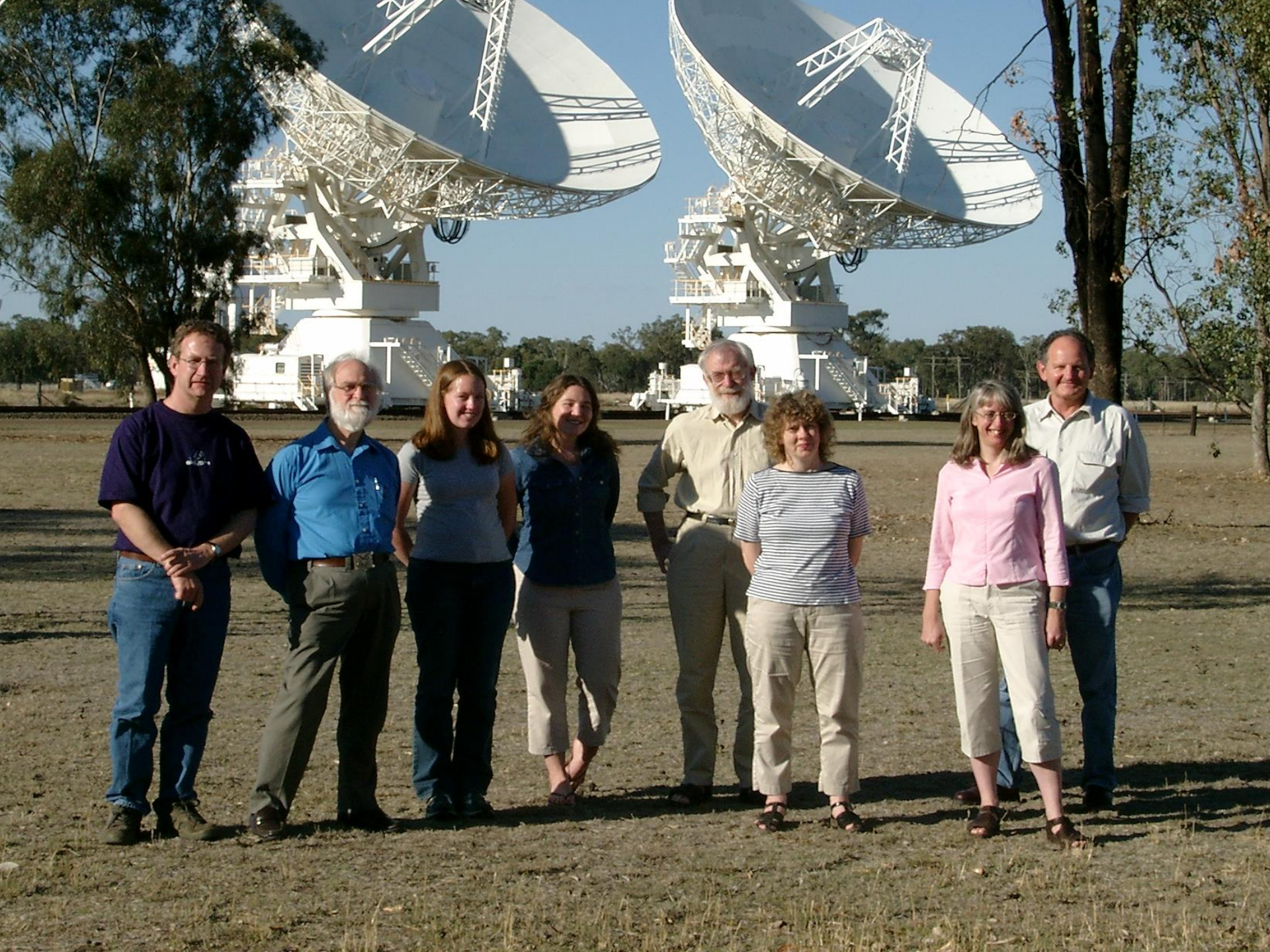
Curtin University

THE UNIVERSITY OF WESTERN AUSTRALIA

Government of Western Australia
Department of the Premier and Cabinet
Office of Science



The extragalactic low frequency sky

AIM: Derive precision sky models for SKA-era galaxy surveys,
Foreground extraction for EOR,
Insights into AGN lifetimes (fueling, feedback) etc.

Current analyses rely on significant extrapolation from higher ν data
Samples at low frequencies are tiny
& are highly degenerate to model fits

Use (new) low-frequency samples (< few hundred MHz)
LOFAR (10-250 MHz) and MWA GLEAM (72 – 231 MHz)

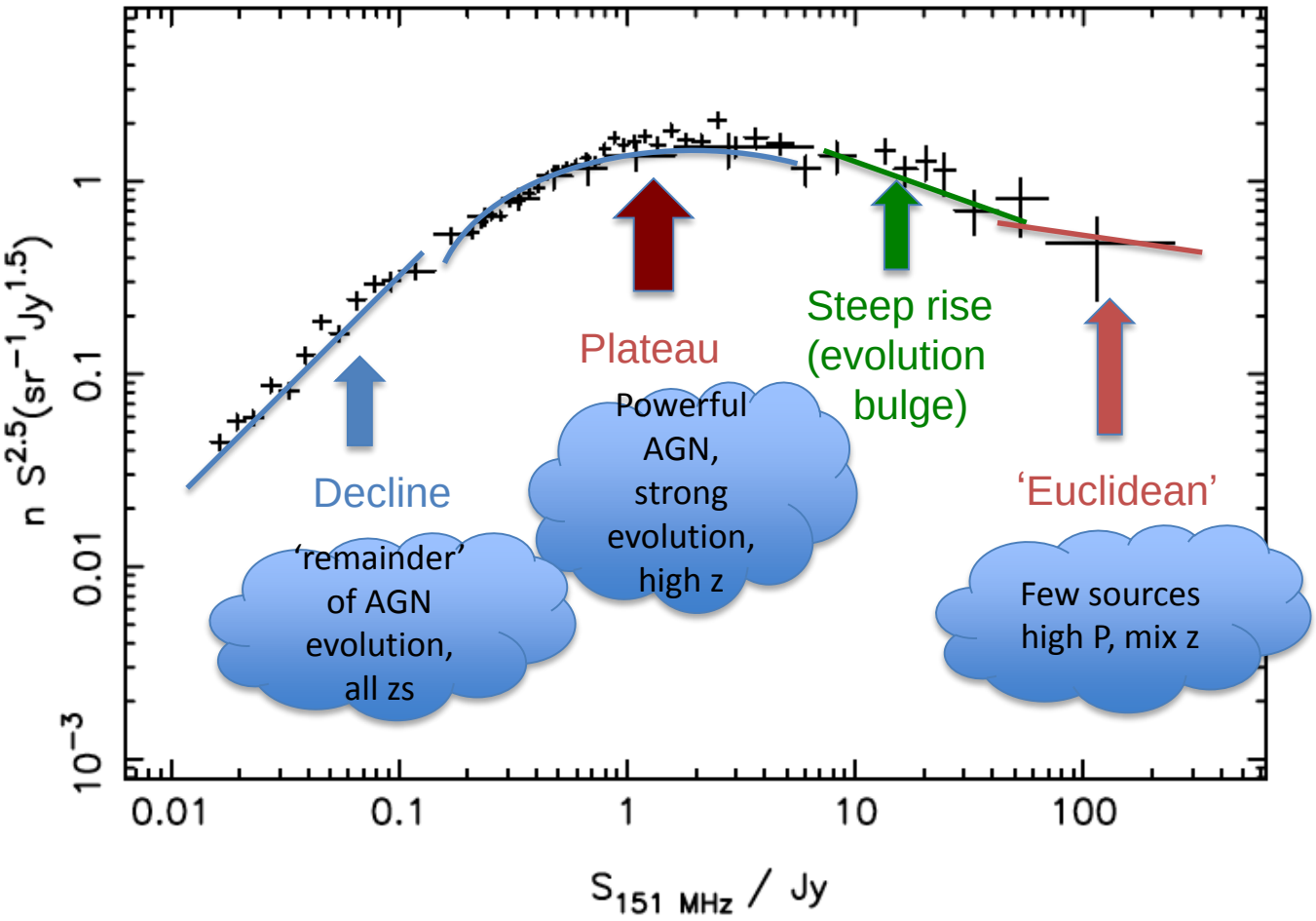
This is a tale of high and low frequency data (old & new)

Radio source counts as cosmological probes

- **Radio source counts embody information about the source populations & their evolution (space density) over cosmic time**

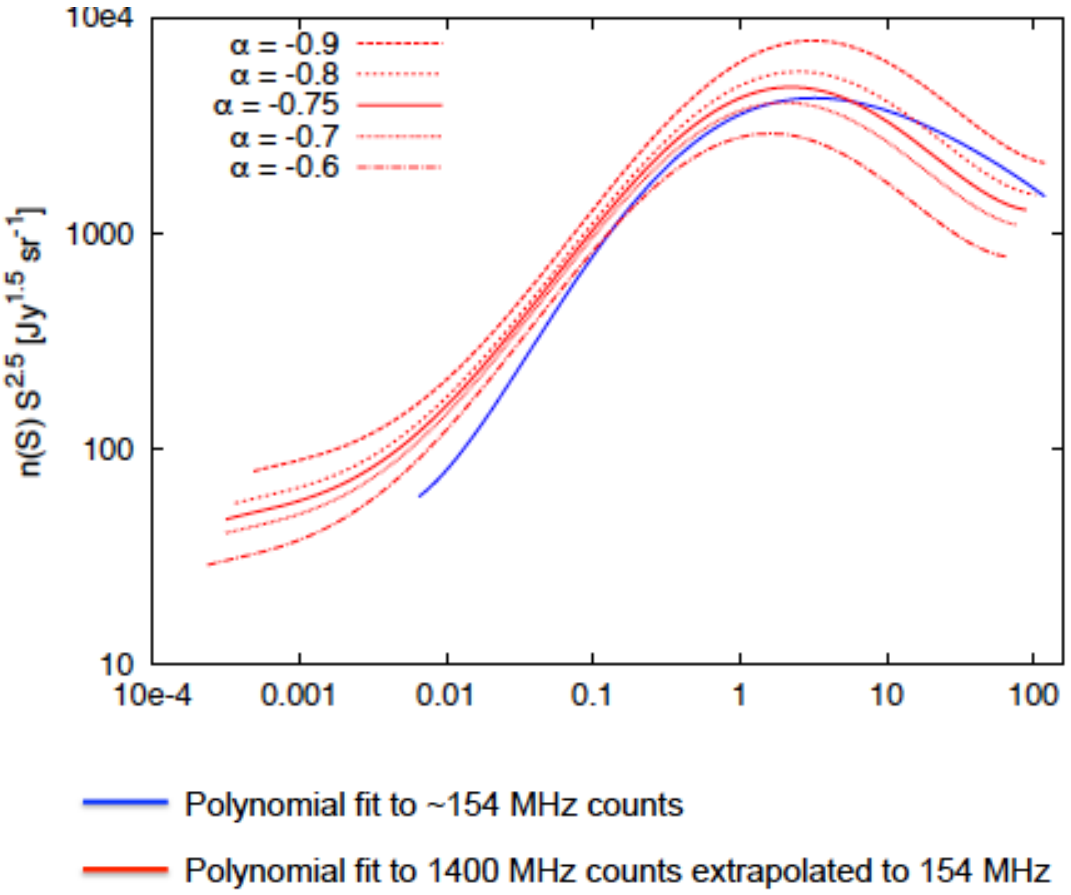
The Radio Sky – counting sources

cartoon: for all counts (10 MHz – 20 GHz)



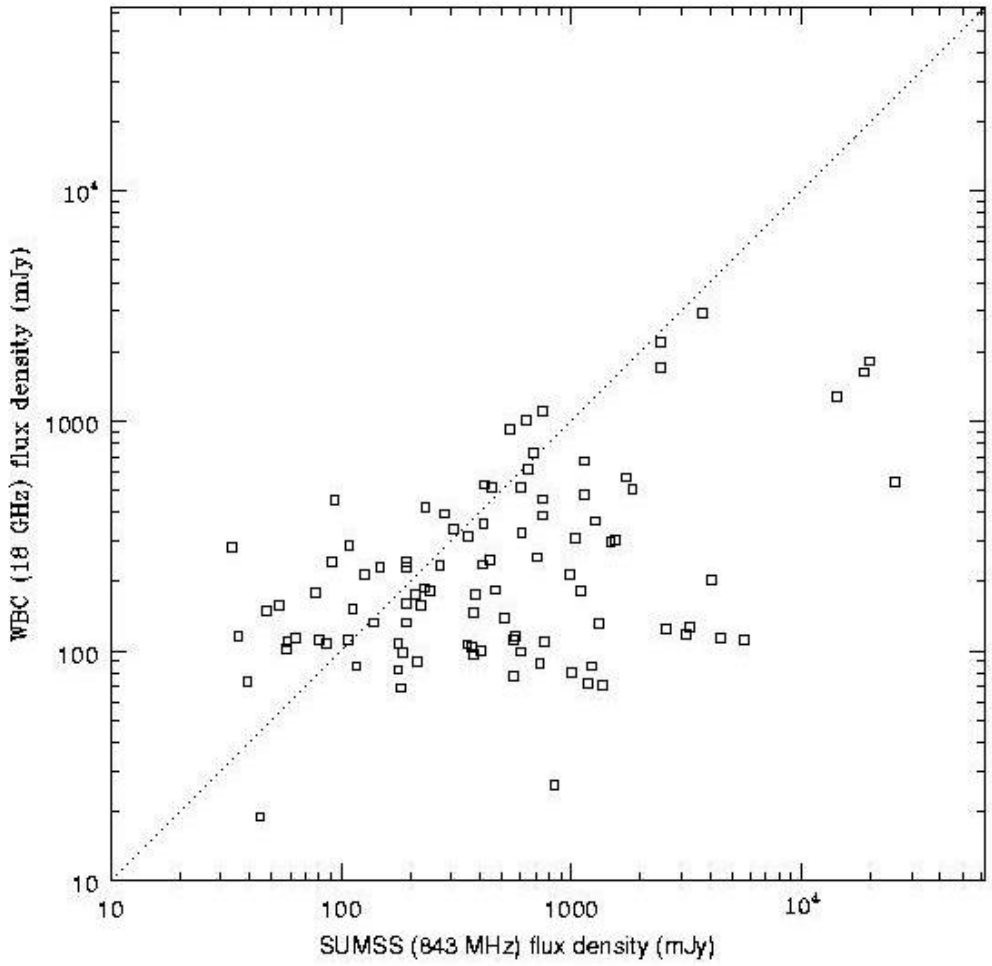
Radio source counts as cosmological probes

- **Radio source counts embody information about the source populations & their evolution (space density) over cosmic time**
- **Low frequency radio surveys are sensitive to sources with steep synchroton spectra, unbiased by beaming effects: complementary view to GHz surveys**
- **At low frequencies <200 MHz large-area surveys limited by large beams (confusion) and lack of sizable complete samples to define RLF**



Franzen et al (2016)

AT20G 18 GHz - 843 MHz cross-match



- All 82 $|b|>10^o$ sources detected at 18 GHz are present in 843 MHz SUMSS catalogue
- High optical id rate (85%)
- Majority flat spectrum

Sadler et al (2006)
(AT20G pilot survey, 2002-2004)

AT20G Publications

Spectral properties and the effect on redshift cut-off, *Chhetri, R. et al.* 2012, MNRAS, 422, 2274.

Australia Telescope 20 GHz survey: hardware, observing strategy, and scanning survey catalog, *Hancock, P.J. et al.* 2011, Experimental Astronomy, Volume 32, Issue 2, pp.147.

Optical Properties of High-Frequency Radio Sources, *Mahony E.K. et al.* 2011, MNRAS, 417, 2651.

The Australia Telescope 20GHz (AT20G) Survey: analysis of the extragalactic source sample, *Massardi, M. et al.* 2011, MNRAS, 412, 318.

Observations and properties of candidate high-frequency GPS radio sources, *Hancock, P.J. et al.* 2010, MNRAS, 408, 1187.

High-frequency Radio Properties of Sources in the Fermi-LAT 1 year Point Source Catalog, *Mahony, E.K. et al.* 2010, ApJ, 718, 587.

Ultra- and hyper-compact HII regions at 20 GHz, *Murphy, T. et al.* 2010, MNRAS, 405, 1560.

The Australia Telescope 20 GHz Survey: The Source Catalogue, *Murphy, T. et al.* 2010, MNRAS, 402, 2403.

e-VLBI observations of GHz-Peaked Spectrum (GPS) radio sources, *Hancock, P.J. et al.* 2009, MNRAS, 397, 2030.

Wide-field imaging and polarimetry for the biggest and brightest, *Burke-Spolaor, S. et al.* 2009, MNRAS, 395, 504.

The extragalactic radio-source population at 95GHz *Sadler et al.* 2008, MNRAS, 385, 1656.

The Australia Telescope 20 GHz (AT20G) Survey: The Bright Source Sample, *Massardi et al.* 2008 MNRAS, 384, 775.

High-frequency large-area surveys of extragalactic sources, *Ron Ekers, Elaine Sadler and Roberto Ricci*.
Paper presented at "CMB and Physics of the Early Universe", Ischia, Italy, April 21 2006. Published in *Proceedings of Science.*

The properties of extragalactic radio sources selected at 20GHz, *Sadler et al.* 2006, MNRAS, 371, 898.

First results from the ATCA 18GHz pilot survey, *Ricci et al.* 2004, MNRAS, 354, 305.

MWA – Murchison Widefield Array

Murchison Radio-Astronomy Observatory (MRO)

S26° 42′ 15″, E116° 39′ 32″

Perth

Murchison Widefield Array (MWA)

- World's first operational SKA precursor (August 2013)
- Managed & operated by Curtin University
- 128 tiles*2 (Area~2750 m^2 at 150 MHz) – 16 dipoles per tile
- Frequency range 72 MHz - 300 MHz (30 MHz BW)
- Maximum baseline 3 km -> 5km
- MWA System description

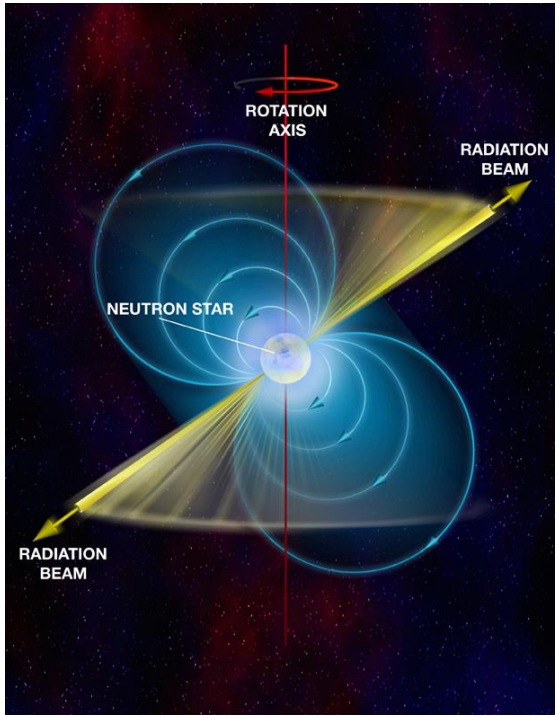
  Tingay et al. PASA, 2013

MWA
MURCHISON
WIDEFIELD
ARRAY

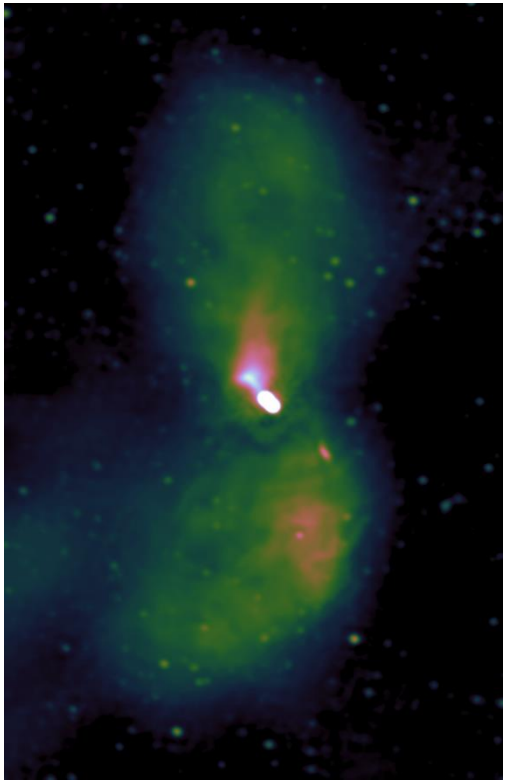
Curtin University

MWA astronomy @ Curtin

SC1.1
Pulsars and transients



SC1.2
Extragalactic science



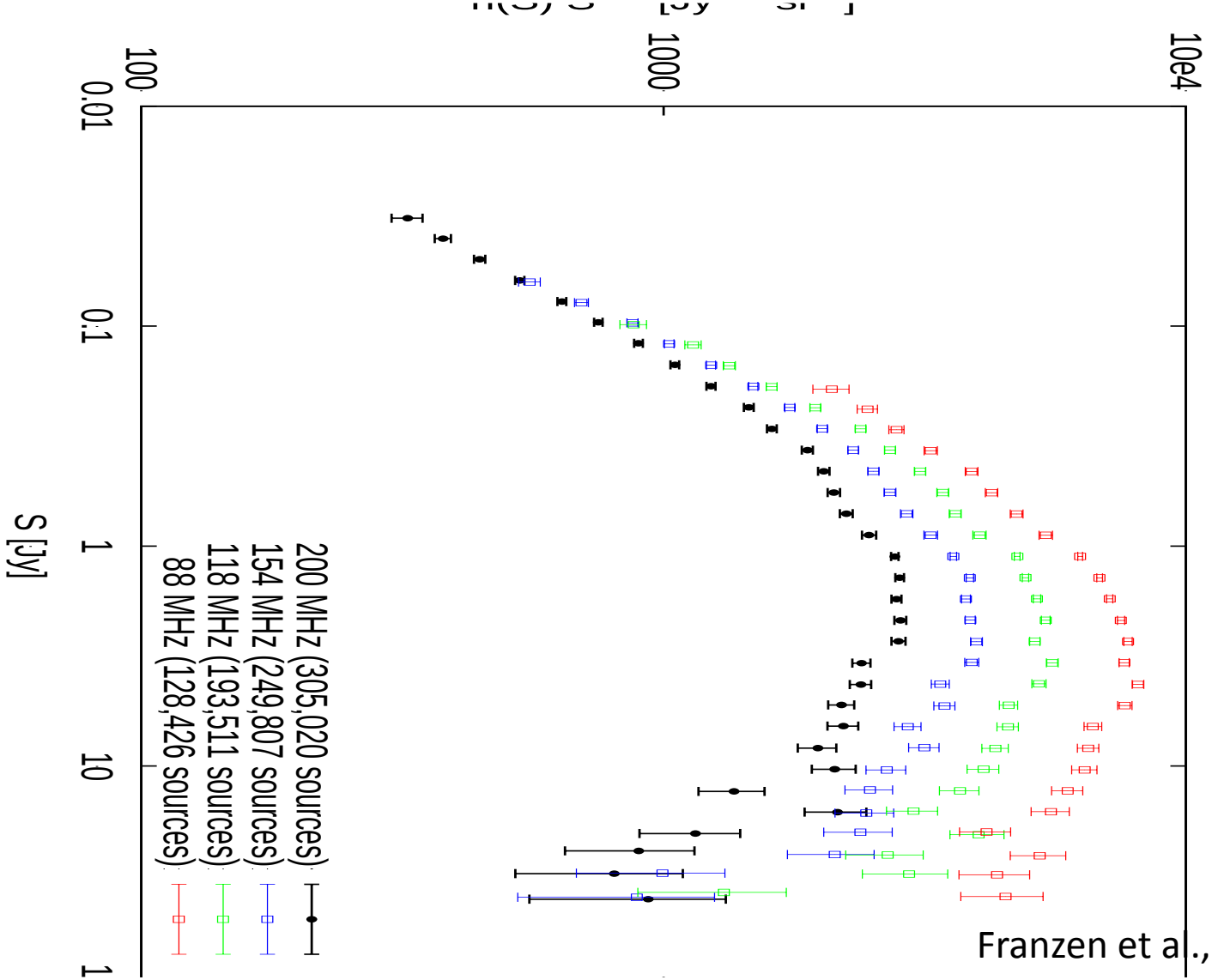
Credit: Randall Wayth and the MWA team

SC1.3
The Galaxy and other astrophysics with the MWA

SC2: Accretion Physics & scintillation

SC3: EOR

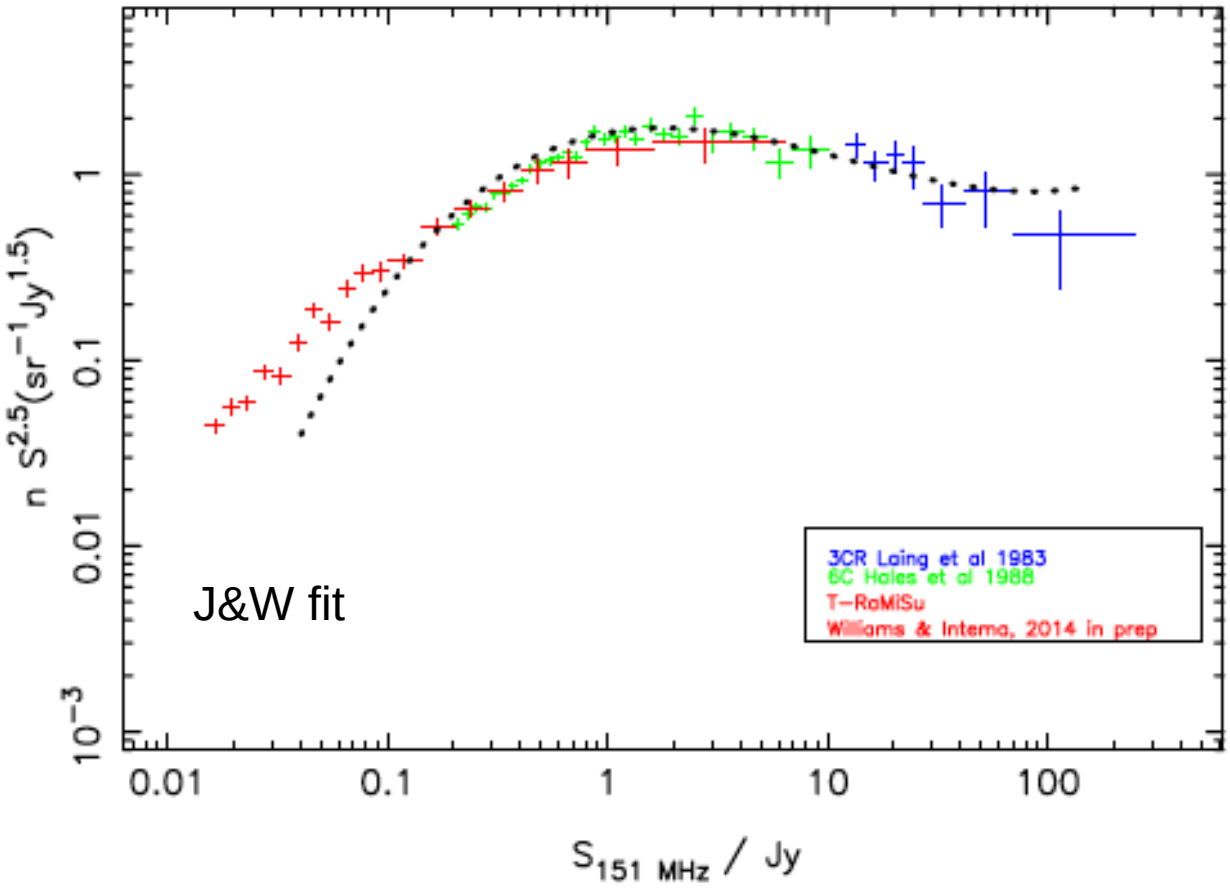
MWA GLEAM multi-frequency counts



Franzen et al., in prep.

Radio source counts @ low radio-frequencies

New data (TGSS) & low frequency model fit at 154 MHz (2014)
Old model now fails to fit deep source count data
What's going on? Lack of constraint (RLF, deep counts)

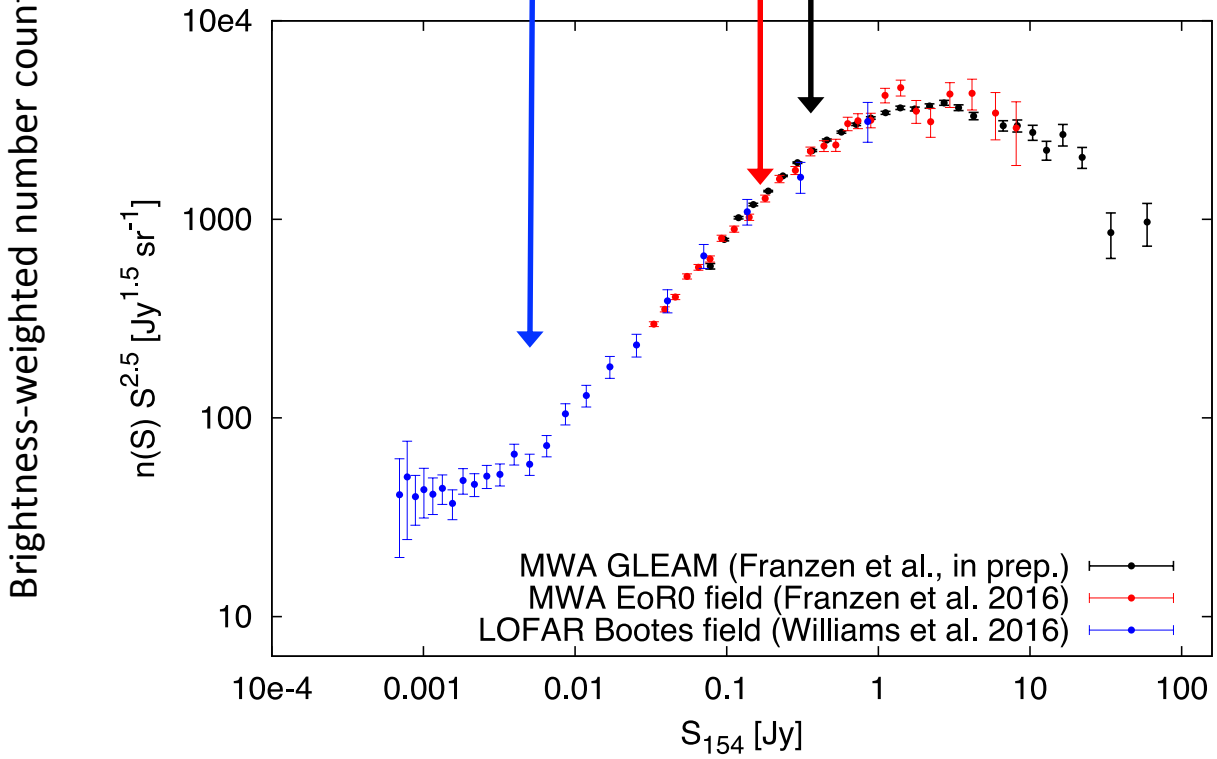


Radio source counts @ low radio-frequencies

2016

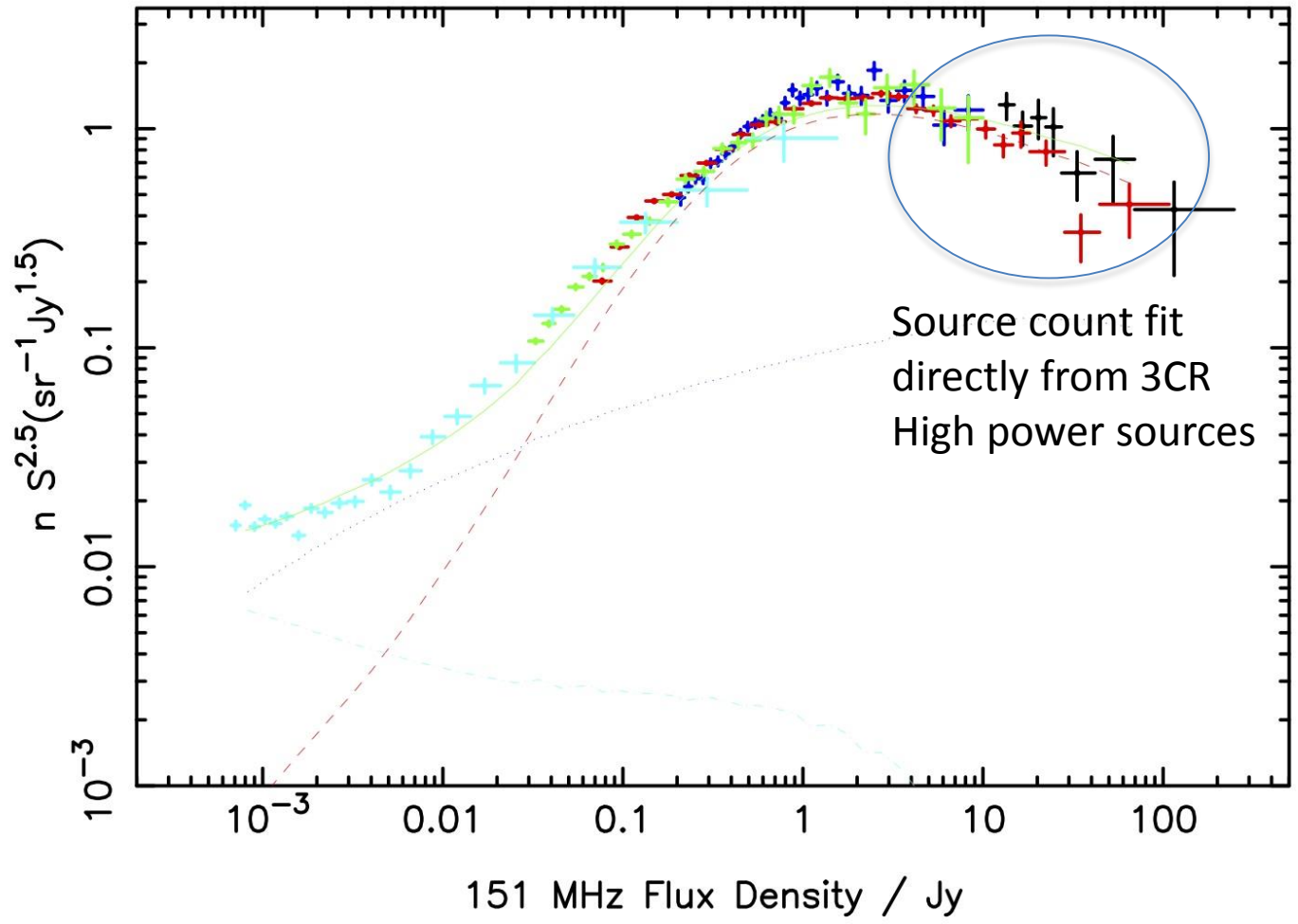
LOFAR counts

MWA counts

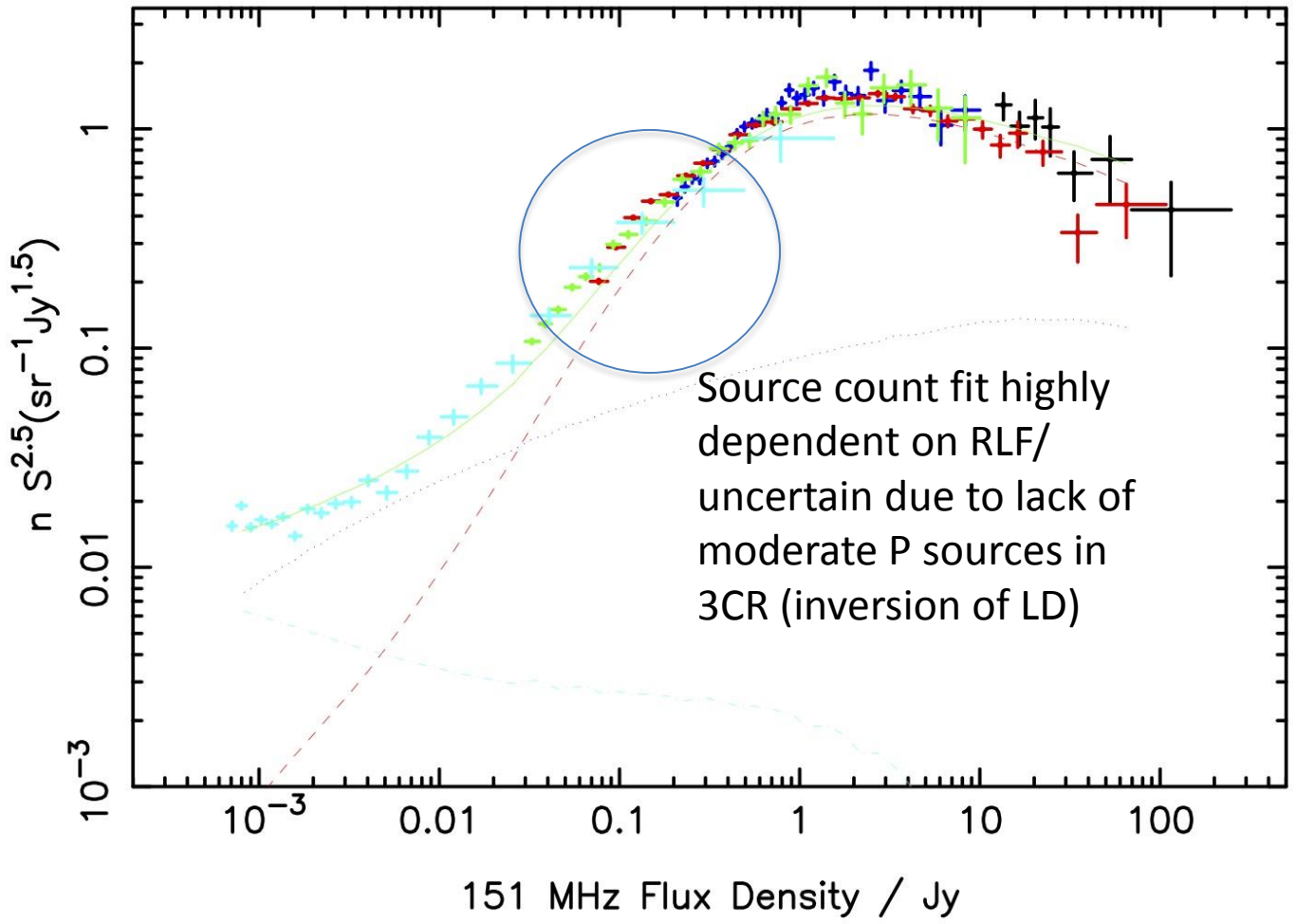


Jackson, Franzen

Radio source counts @ low radio-frequencies

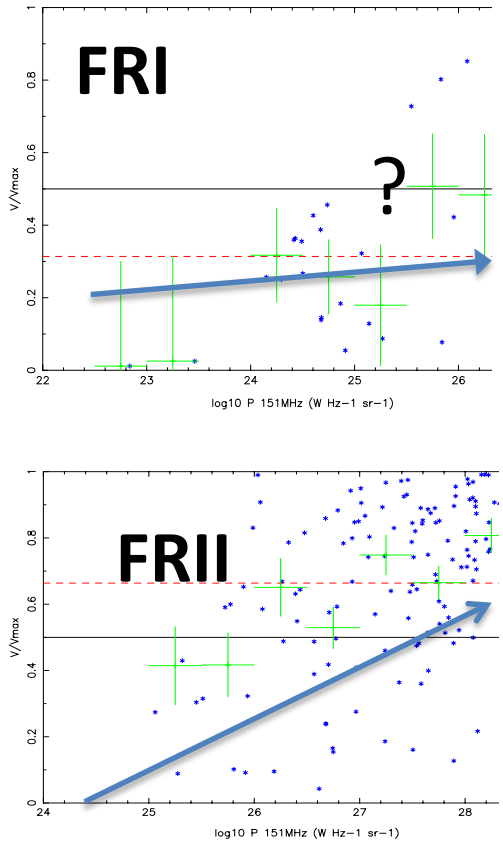


Radio source counts @ low radio-frequencies

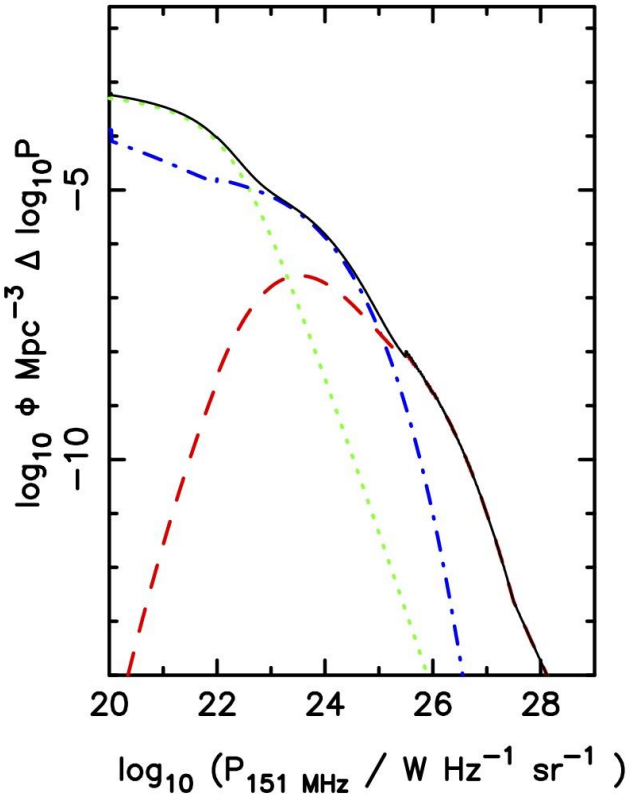


Radio source counts @ low radio-frequencies

V/Vmax (3C Qs: Longair & Scheuer, 1970)



Problem: extremely broad evolving (L)RLF derived from too few radio sources at known z

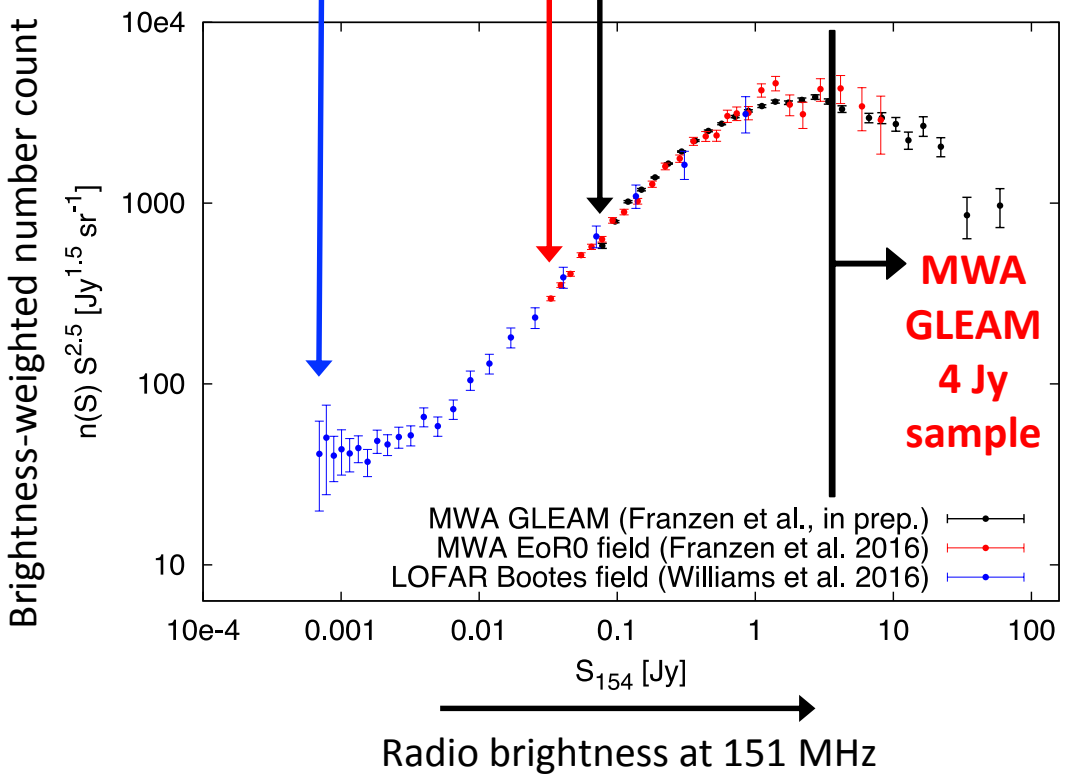


Model fit LRLF (derived)

Radio source counts @ low radio-frequencies

LOFAR number counts

MWA number counts

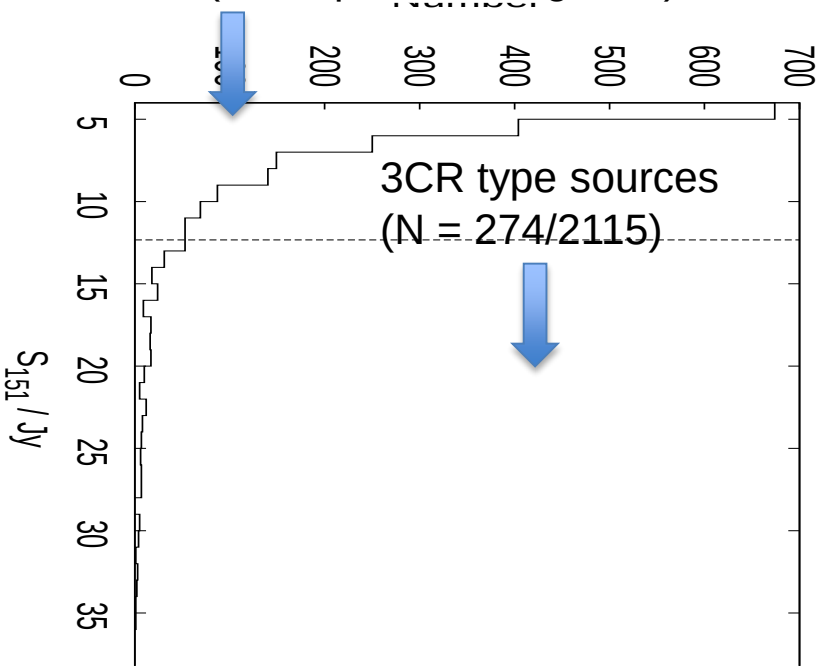


Jackson, Franzen

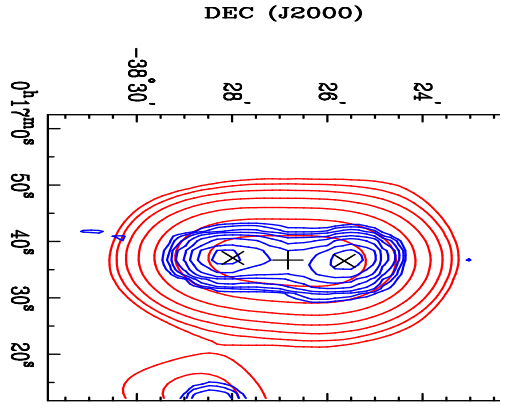
The MWA GLEAM 4 Jy sample

- A fundamental southern sky sample of bright radio sources akin to 3CR
- ~10 * larger: 2115 sources compared to 173 in 3CR
- Direct insight to source populations & their evolution (space density)
- Plus SED 72 – 231 MHz

Fainter RGs (lower power or higher z)



NVSS double

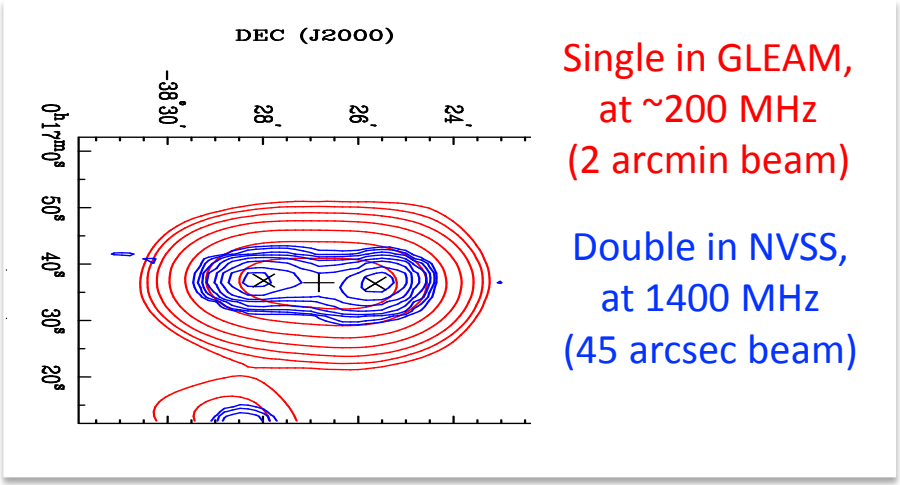


24% of all GLEAM sources are multiples in NVSS/SUMSS

Jackson et al. (2016)

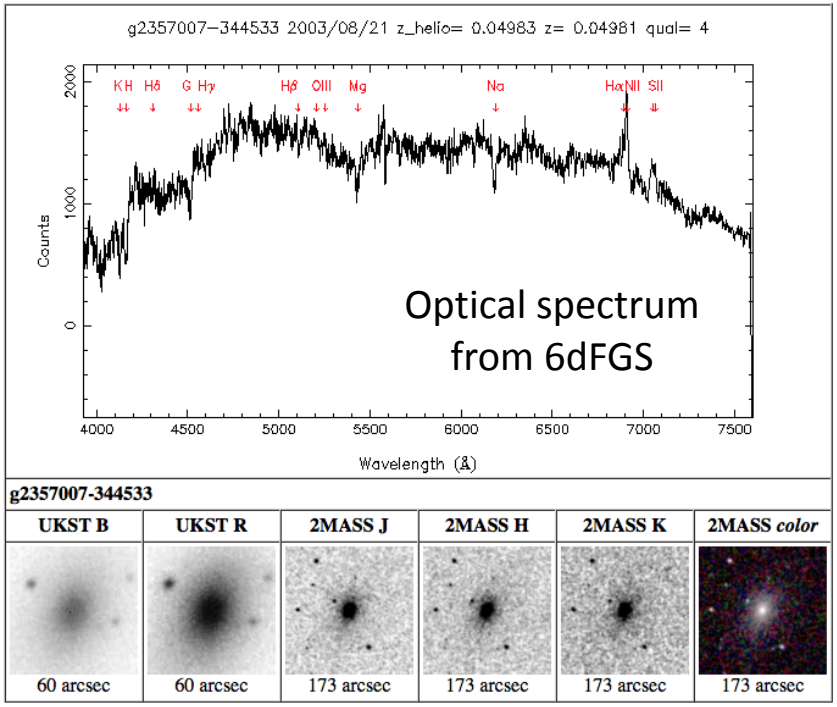
The MWA GLEAM 4 Jy sample

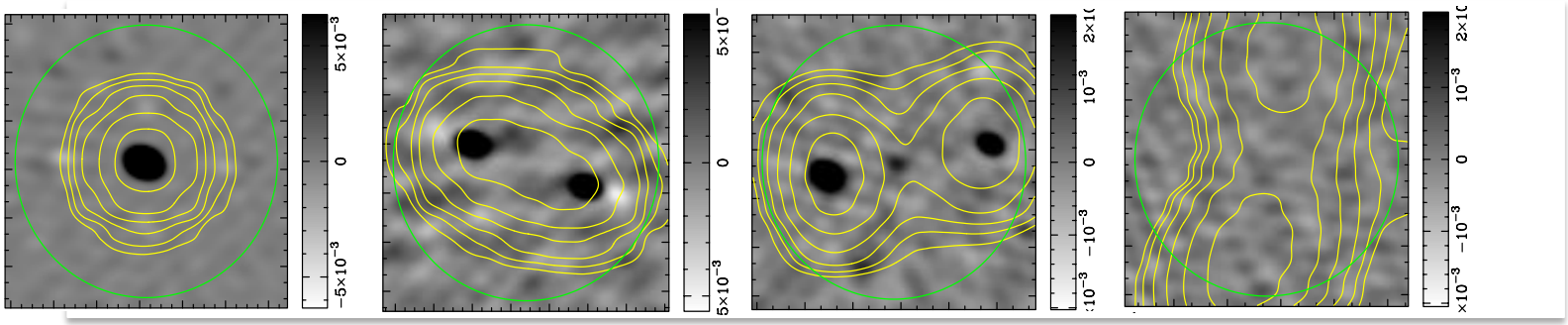
Exploit higher radio frequency data to access optical data to identify the host galaxy



Single in GLEAM, at ~200 MHz (2 arcmin beam)

Double in NVSS, at 1400 MHz (45 arcsec beam)



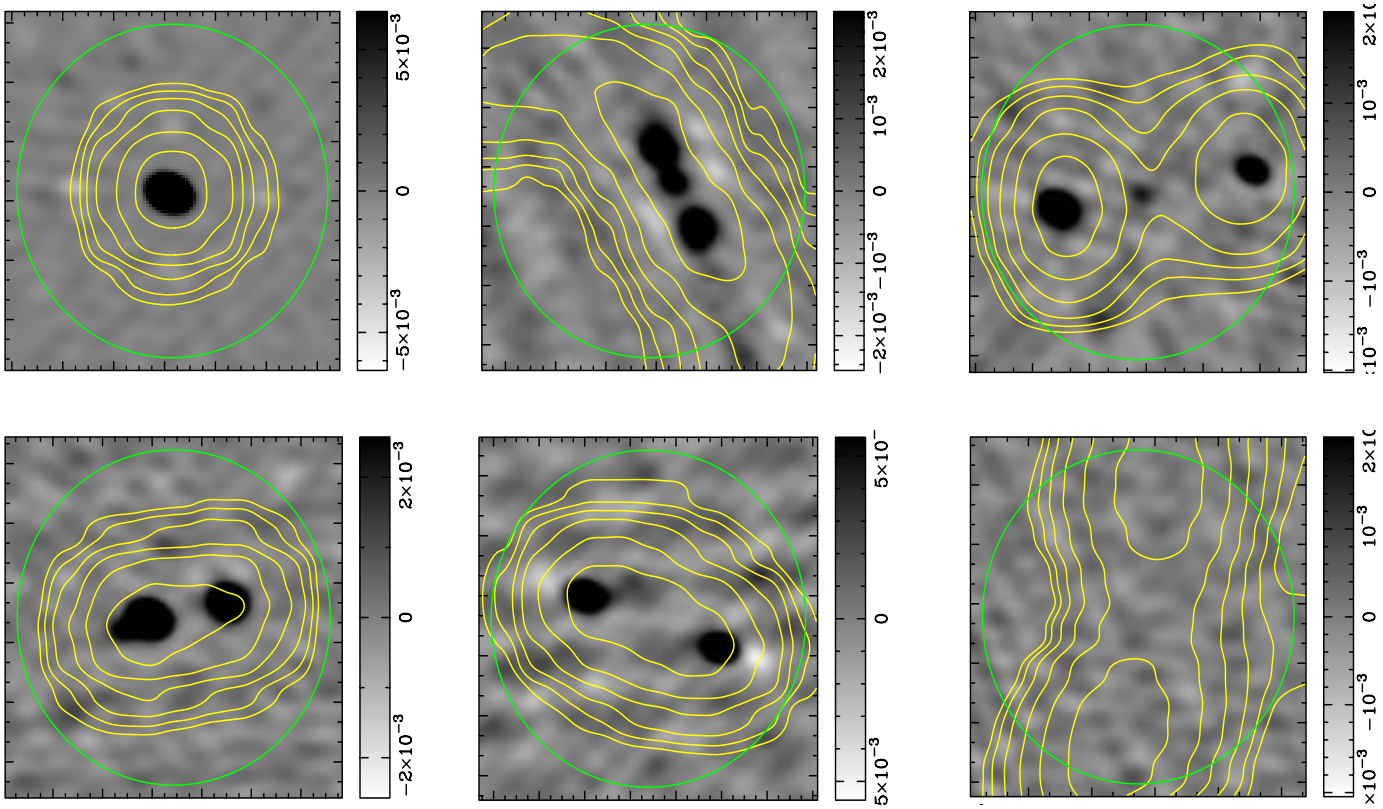


Franzen, White

Grey-scale: ATCA follow-up at 18 GHz (13 arcsec beam) NVSS emission (45 arcsec beam)

The MWA GLEAM 4 Jy sample : AT20G

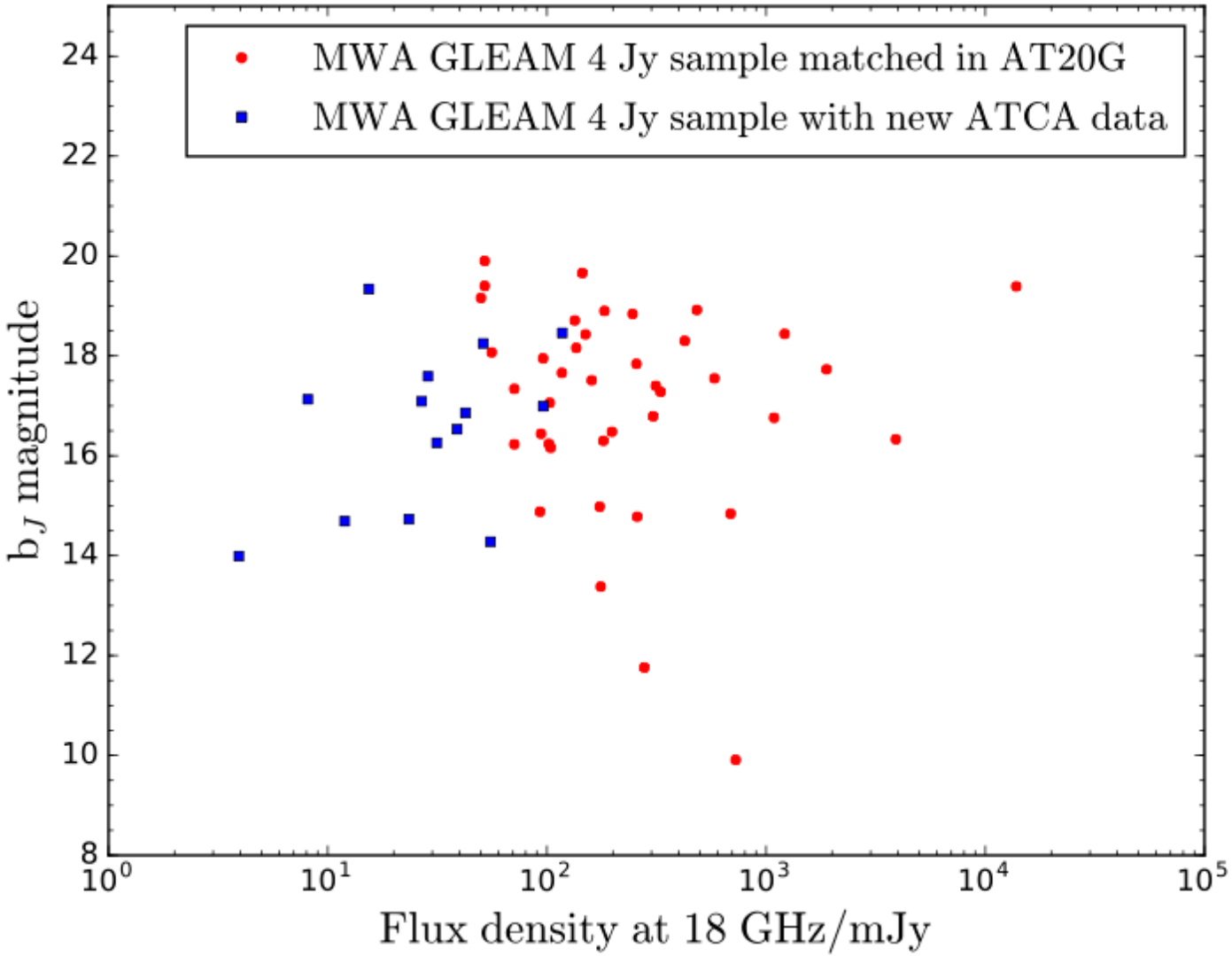
- 1,491 GLEAM 4 Jy sources lie at Dec < 0, ≈ 40% have match in AT20G
- New ATCA obs at 5.5, 9 and 18 GHz (2016)
- Observations reveal emission is lobe-dominated for the majority at 5, 8 & 20 GHz



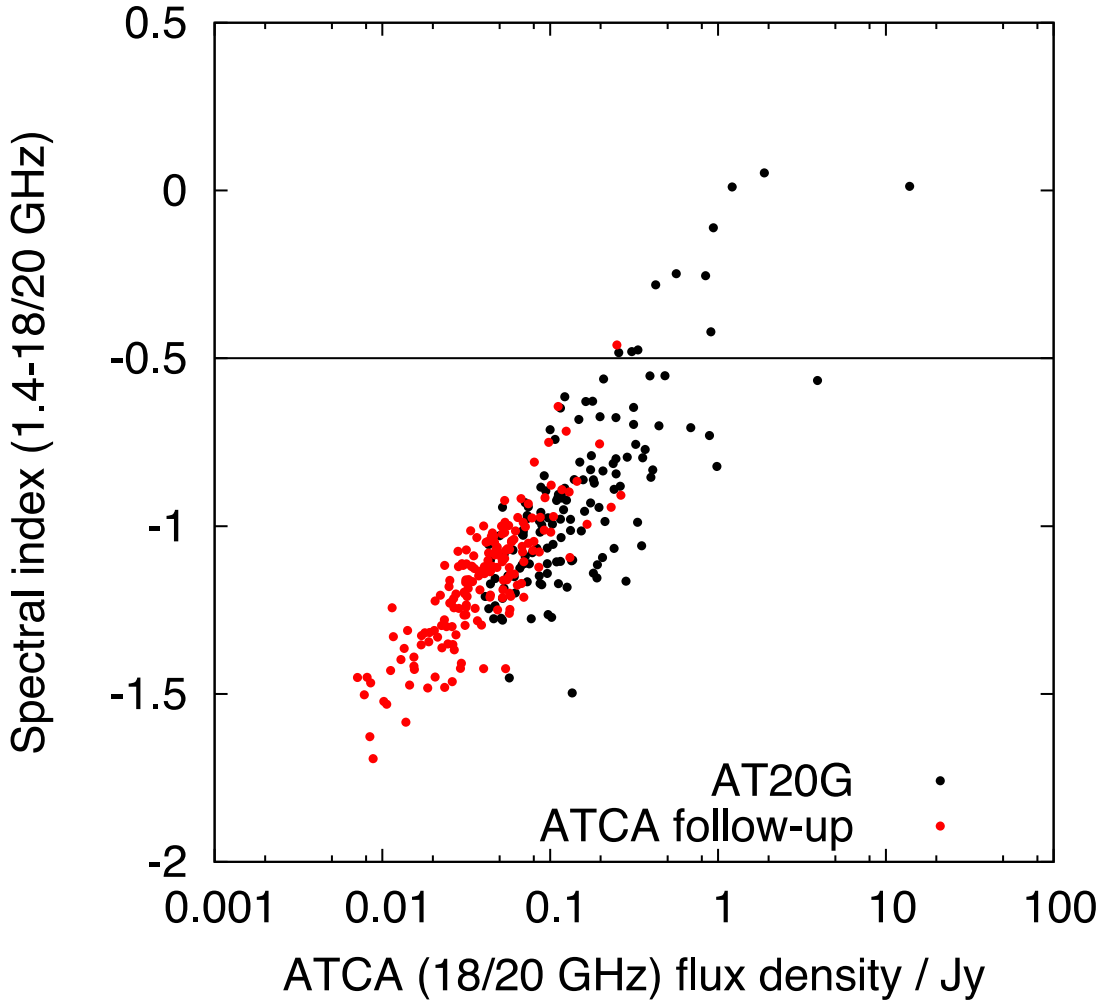
Grey-scale: ATCA 18 GHz emission (13 arcsec beam)

NVSS emission (45 arcsec beam)

The MWA GLEAM 4 Jy sample : AT20G

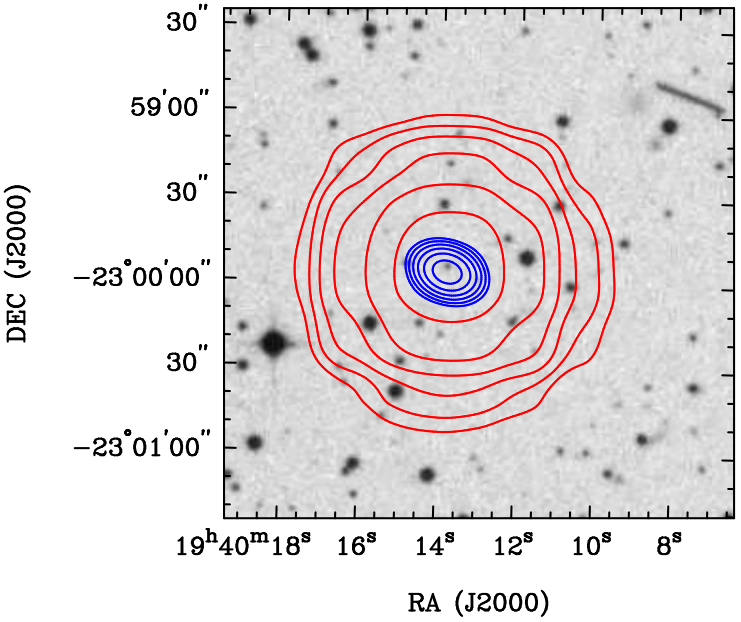


The MWA GLEAM 4 Jy sample : AT20G +



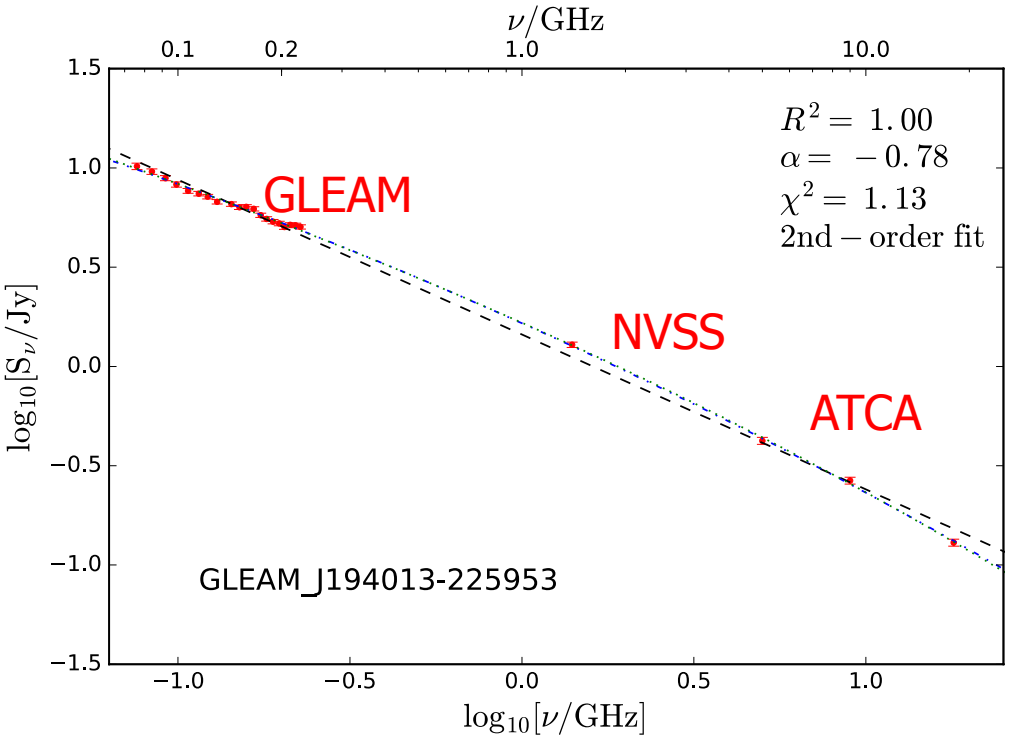
- **MWA 4Jy 151 MHz-selected sample: dominated by sources with steep spectra**

The MWA GLEAM 4 Jy sample : AT20G +

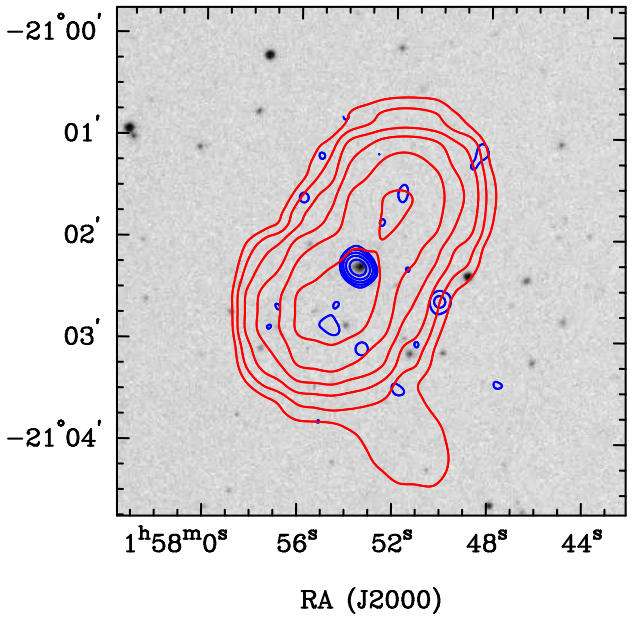


GLEAM J194013-225953
Text book SED

NVSS
ATCA 18 GHz new obs

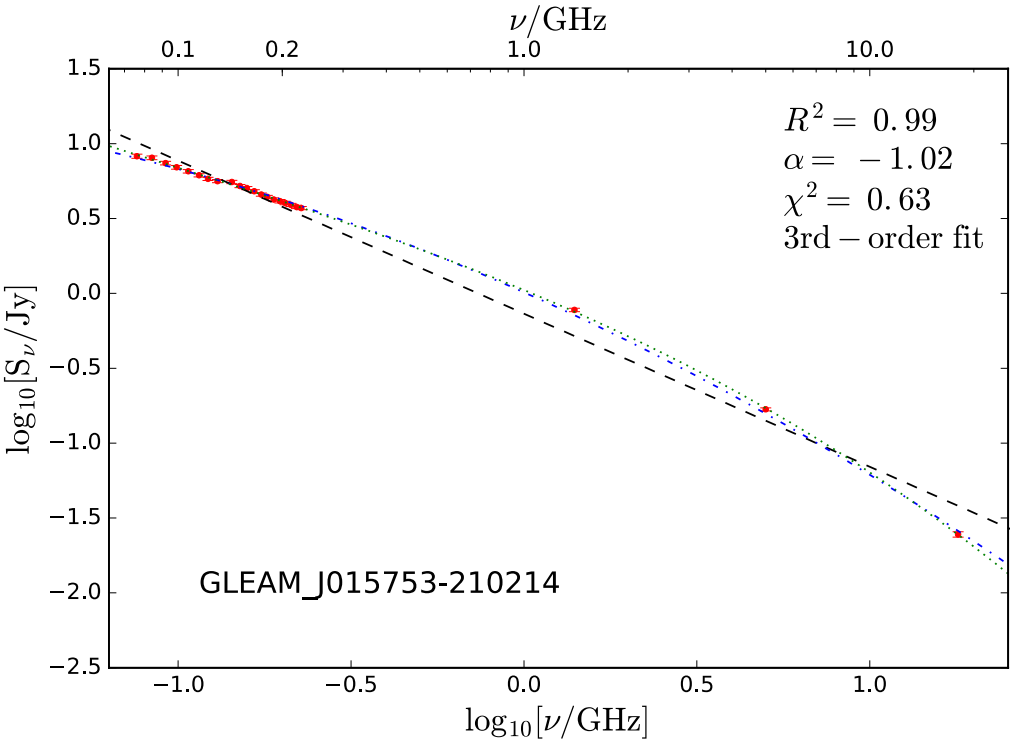


The MWA GLEAM 4 Jy sample : AT20G +



GLEAM J015753-210214
Radio source: optical id

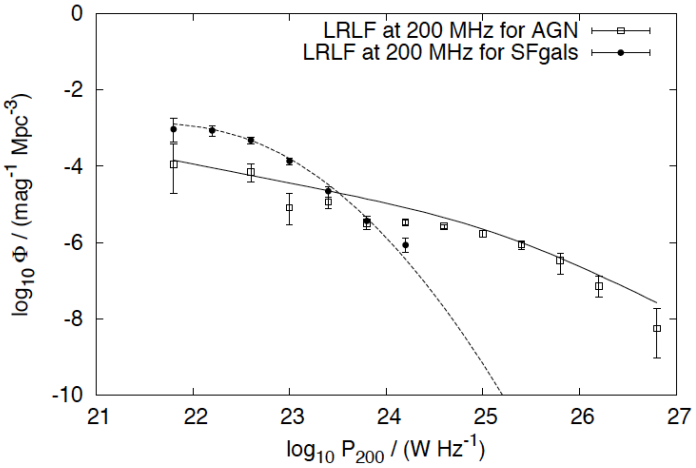
NVSS (double)
ATCA 18 GHz new obs (complex)



Radio source counts @ low radio-frequencies

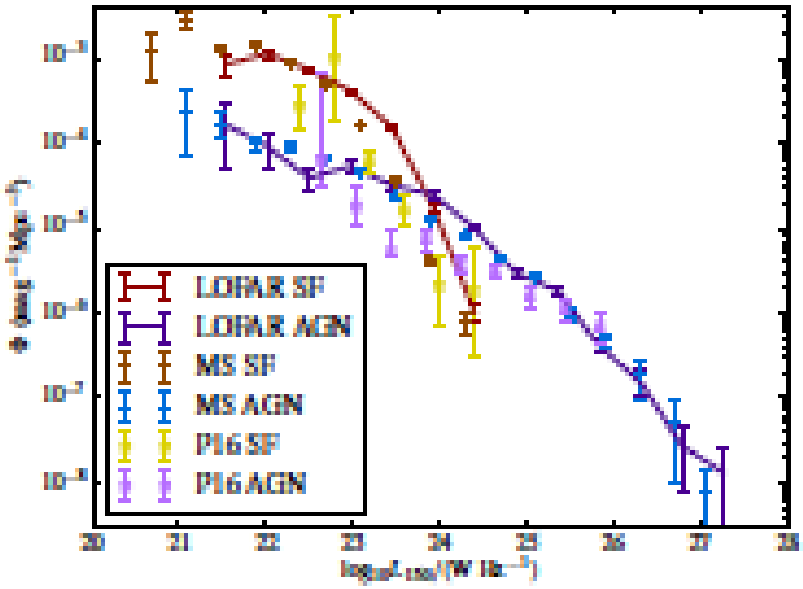
Another option to assist models; measure the (L)RLF directly

MWA GLEAM (all sources) : 6dFGS
Franzen et al (in prep)

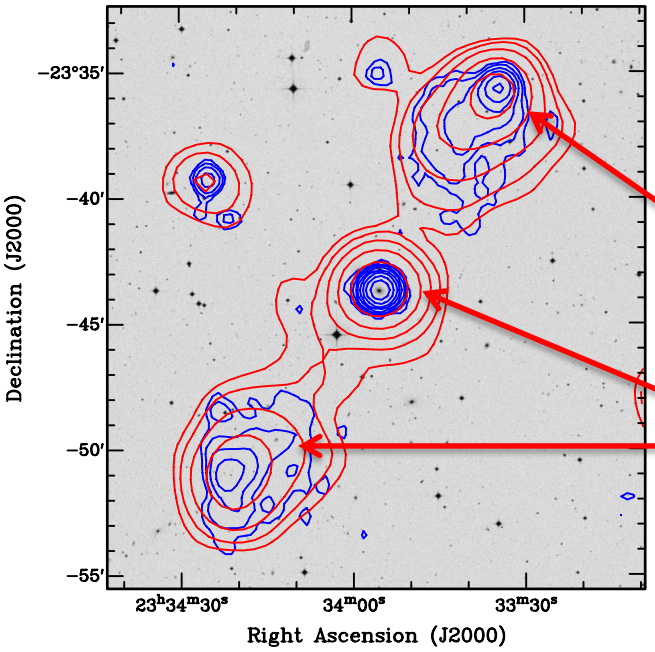


Lines are not fits to data, but are
An extrapolation of 1.4 GHz LRLF
(Mauch & Sadler)

LOFAR H-ATLAS NGP survey
(Hardcastle et al: arXiv 1606.09437



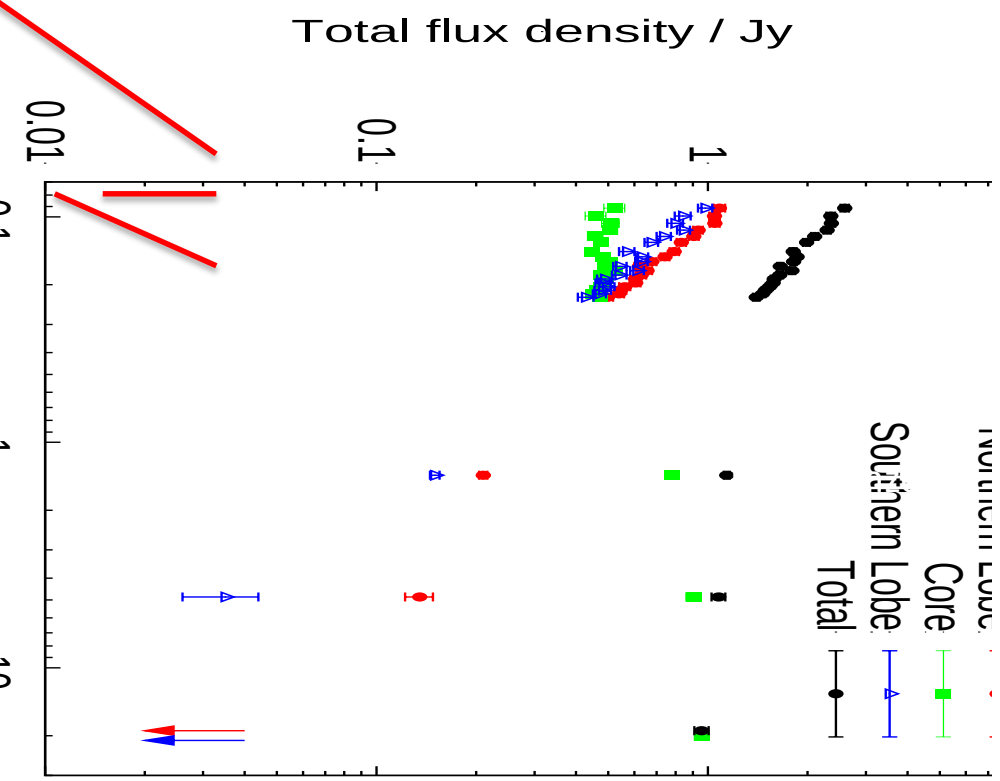
AGN lifecycles & restarted radio galaxies



Giant radio galaxy B2331-241

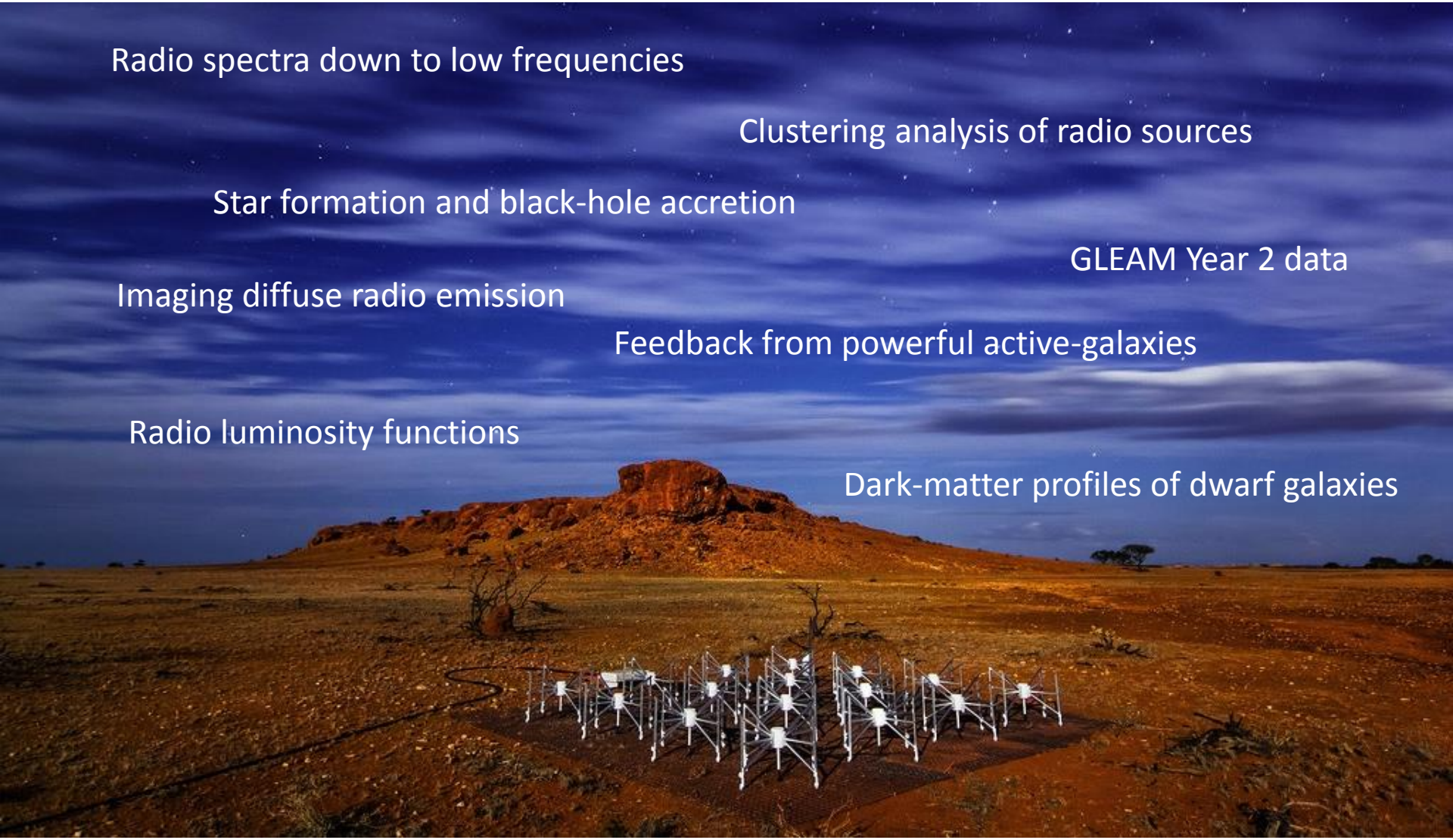
GLEAM (70-231 MHz)
NVSS (1.4 GHz)
PMN (4.85 GHz)
AT20G (20 GHz)

Giant radio galaxy B2331-241, z=0.0477
Projected size 1.07 Mpc
Log10(P) (1.4 GHz) 24. 8 W Hz^{-1} sr^{-1}



Tom Franzen

More MWA extragalactic science ….



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