Low-frequency radio surveys & (potential) synergies with eROSITA

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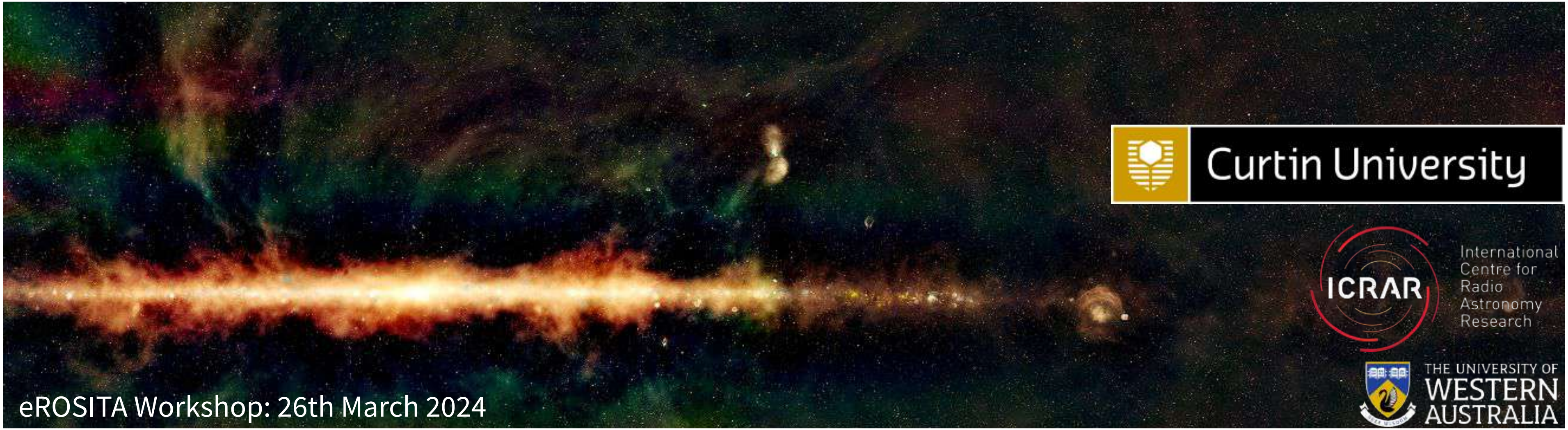

MWA & SKA-Low

Murchison Widefield Array; mwatelescope.org

128 → 256 tiles (by end of 2024)
Operational until ~2029

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Milestone Event		SKA-Low (end date)
AA0.5	4 dishes 6 stations	2024 Nov
AA1	8 dishes 18 stations	2025 Nov
AA2	64 dishes 64 stations	2026 Oct
AA*	144 dishes 307 stations	2028 Jan
Operations Readiness Review		2028 Apr
End of Construction		2029 Mar

Credit: Jimi Green (SKAO)

Square Kilometer Array (LOW); skatelescope.org
Stations ~20m wide → smaller FOV but far more flexibility

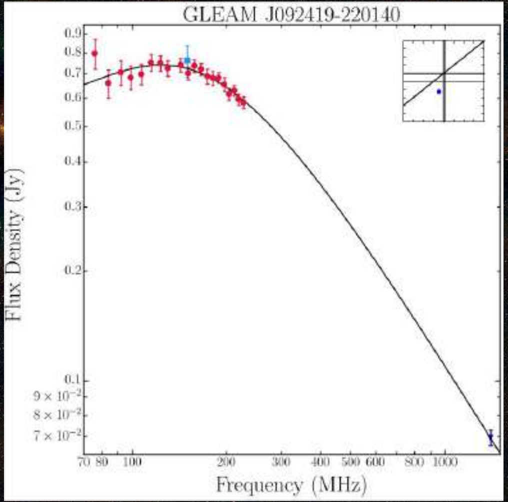
→ 60 uJy/beam RMS surveys

GLEAM

GaLactic and Extragalactic All-sky MWA survey

Images
- 72 – 231 MHz
- 8-MHz sub-bands
- 30- and 60-MHz wide-band images

Catalogue
- 307,455 sources
- ~35mJy/beam flux limit
- 20 flux densities
- Spectral indices for ~70% of sources



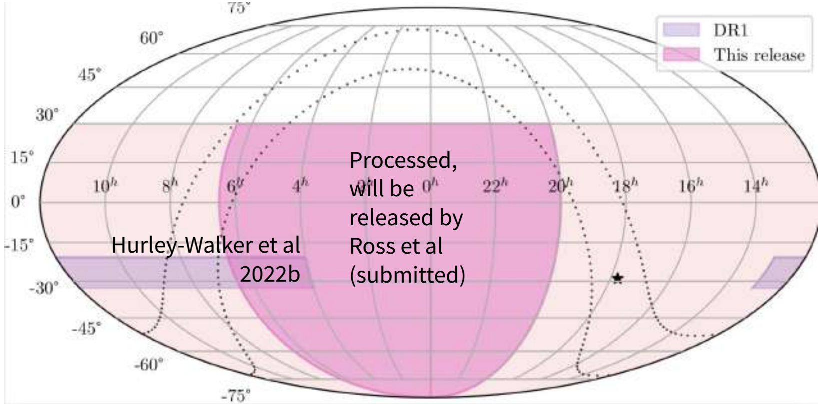
https://www.mwatelescope.org/gleam
Survey description: Wayth et al. 2015
Large data releases: Hurley-Walker et al. 2017, 2019, For et al. 2018, Franzen et al. 2020
Circular polarisation: Lenc et al. 2018
Linear polarisation (POGS-X): Riseley et al. 2018, 2020
~50 science papers & >500 citations to data releases

GLEAM-X: GaLactic and Extragalactic All-Sky MWA eXtended survey

GLEAM and GLEAM-X compared for ~20 sq. deg.

Resolution **45”**
(2x better than GLEAM)

RMS noise
1 mJy/beam
(10x deeper than GLEAM)



Publications of the Astronomical Society of Australia (PASA)
doi: 10.1017/pas.2022.xxx.

GaLactic and Extragalactic All-sky Murchison Widefield Array survey eXtended (GLEAM-X) I: Survey Description and Initial Data Release

N. Hurley-Walker[1], T. J. Galvin[1,2], S. W. Duchesne[1,2], X. Zhang[2,3], J. Morgan[1], P. J. Hancock[1,4], T. An[3], T. M. O. Franzen[5], G. Heald[2], K. Ross[1], T. Vernstrom[2,6], G. E. Anderson[1], B. M. Gaensler[7], M. Johnston-Hollitt[4], D. L. Kaplan[8], C. J. Riseley[2,9,10], S. J. Tingay[1], M. Walker[1]
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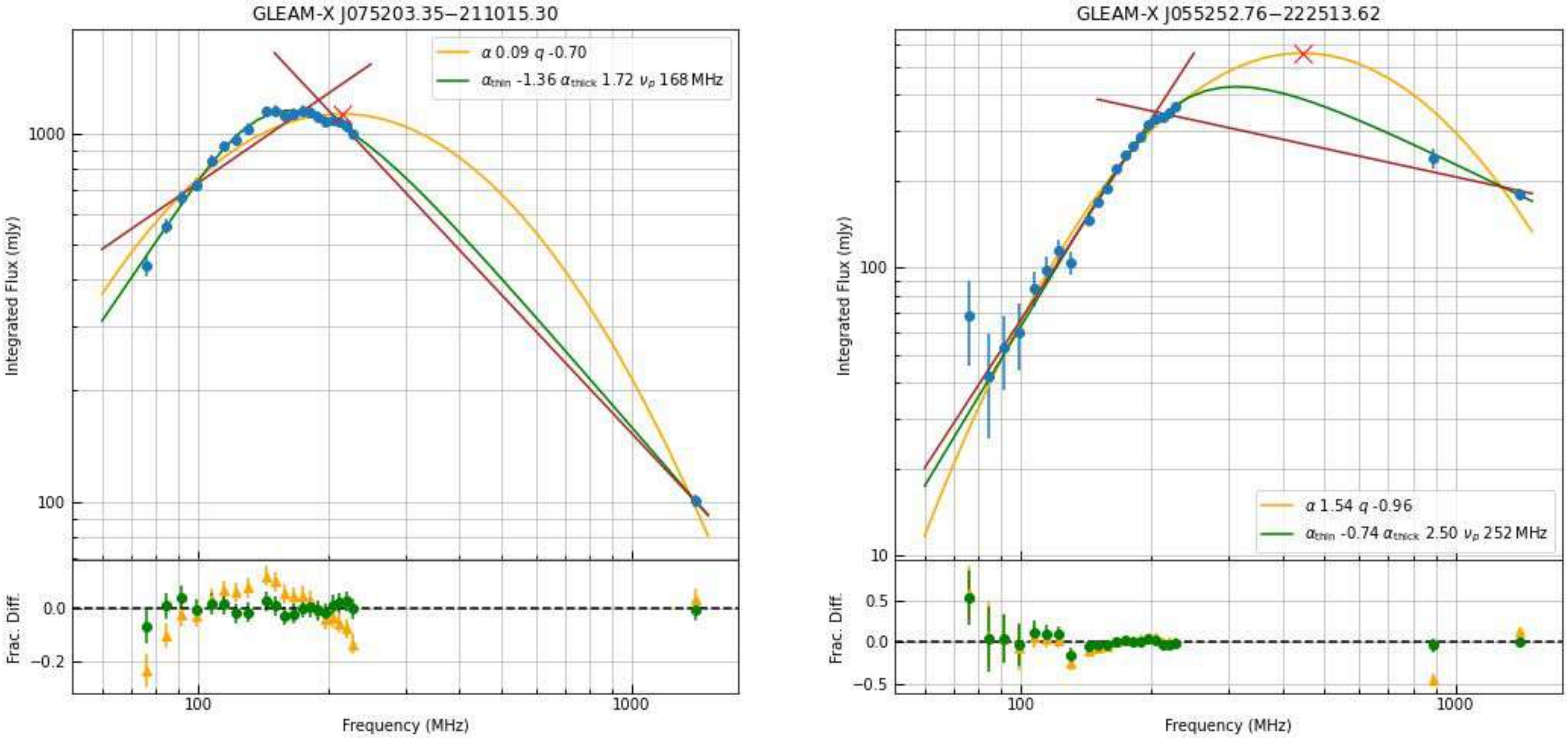
[3] Shanghai Astronomical Observatory, Chinese Academy of Sciences, 80 Nandan Rd, Shanghai, 200030, China

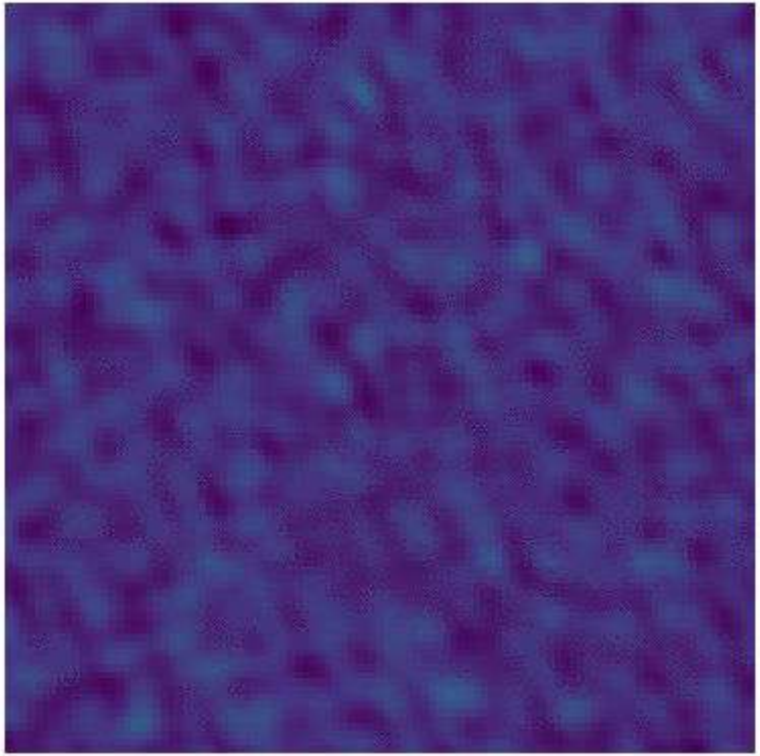
Two radio galaxy SEDs (from 500,000+ so far)



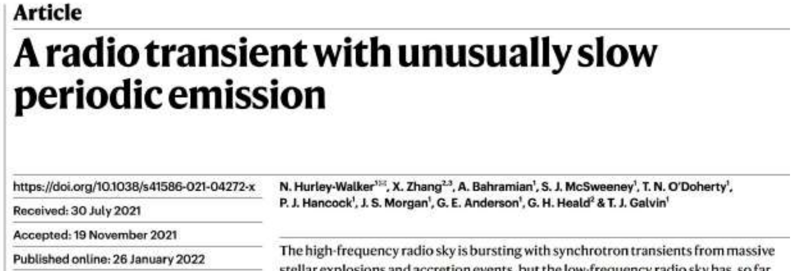
Using *Aegean* Priorised fitting (Hancock+2020)

Tim Galvin

Found in GLEAM-X: New (type of) long-period radio transient



- Detection of a new class of radio-loud object:
  - 18.18-minute period
  - 90% linearly polarised
  - Spectral index ~ -1.2
  - Pulse luminosity up to 4 x 10^{31} erg/s
  - Activity window of ~3 months (in ~8yr)
- Interpreted as an ultra-long period magnetar
  - A new population waiting to be found?
  - Potential FRB progenitor(s)



Article

A radio transient with unusually slow periodic emission

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N. Hurley-Walker[1✉], X. Zhang[2,3], A. Bahramian[1], S. J. McSweeney[1], T. N. O'Doherty[1], P. J. Hancock[1], J. S. Morgan[1], G. E. Anderson[1], G. H. Heald[2] & T. J. Galvin[1]

The high-frequency radio sky is bursting with synchrotron transients from massive

Galactic Plane processing

GLEAM alone in this region:
Resolution: 2’, noise ~ 30 mJy/beam

Joint deconvolution of
GLEAM-X & GLEAM
Resolution: 1’, noise ~ 5 mJy/beam

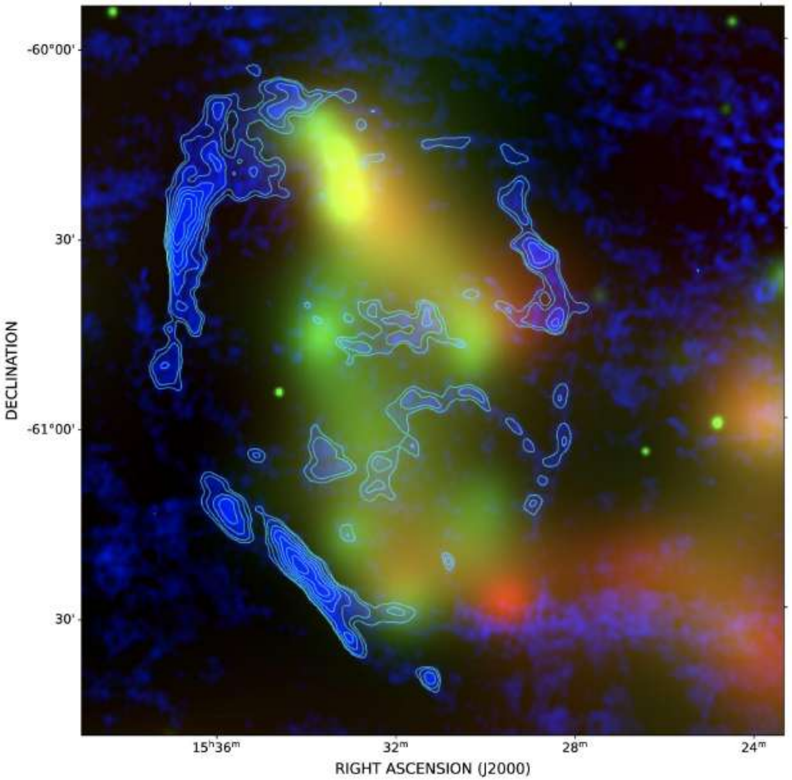
Silvia Mantovanini via
Image Domain Gridding
(van der Tol et al. 2019)

Joint radio/ eROSITA detection

- Project 2020/06: Radio and X-ray Observations of SNRs and SNR Candidates
- Non-thermal emission → particle acceleration
- X-ray spectroscopy investigates the composition of the object and its evolution
- Both provide age and distance estimates

G321.3-3.9

- Elliptical shell shaped
- 1 kpc < Distance < 1.7 kpc
- 14 kyr < age < 75 kyr
- Radio $\alpha \simeq -0.83 \pm 0.39$



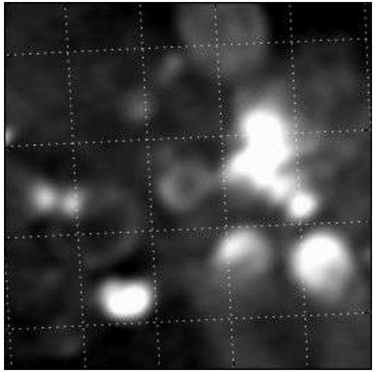
Mantovanini et al. 2024 (in review)
https://arxiv.org/abs/2401.17294

Galactic Plane Monitoring at 200 MHz

- 10 pointings
- 30 minutes integration per pointing
- Bi-weekly cadence
- 2022 July to September
- = 12 hours integration time
- Shown: ~2/3rds of the data, integrated mosaic
- Noise level ~2 mJy/beam (away from bright sources)
- Next epoch: April — September 2024 → 33 hours integration time!

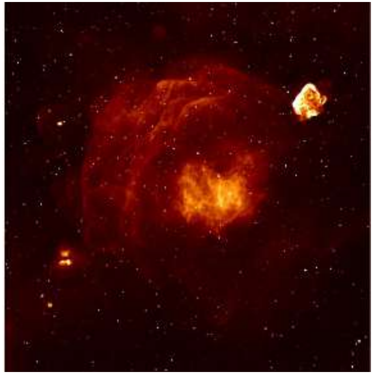
Hurley-Walker et al. in prep: survey description and first data release
Mantovanini et al. in prep: 20 new supernova remnants

Low-frequency Galactic Science prospects



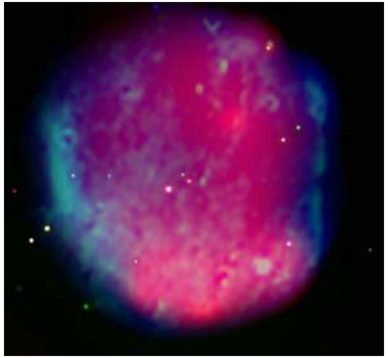
Radio spectral imaging

- Disentangle synchrotron SNRs from thermal HII regions
- Perform Cosmic Ray Tomography (Su et al. 2017, 2018)
- Explore unshocked ejecta in 3D (Arias et al. 2019)
- Probe interactions with environment (Castelletti et al. 2021)



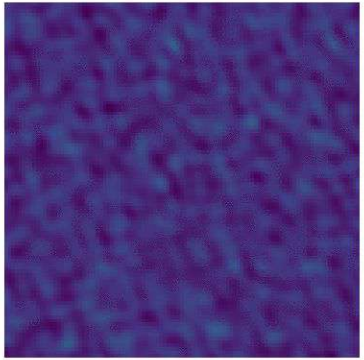
Finding the missing SNRs with MWA observations

- Low frequencies -> find steep-spectrum sources
- Higher resolution (45”) but *also* large spatial scales
- Lower noise (~5 mJy/beam)
- Southern Galactic plane (and indeed sky — 34k deg^2)



High-latitude SNRs

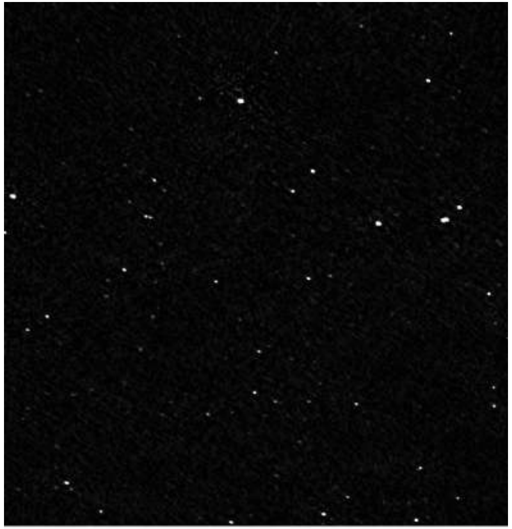
- Low surface-brightness (e.g. Hurley-Walker et al. 2019a)
- Potentially large and nearby (Becker, Hurley-Walker et al. 2021)
- “Quiet” environment to probe emission processes in otherwise inaccessible ISM (Araya, Hurley-Walker et al. 2022)



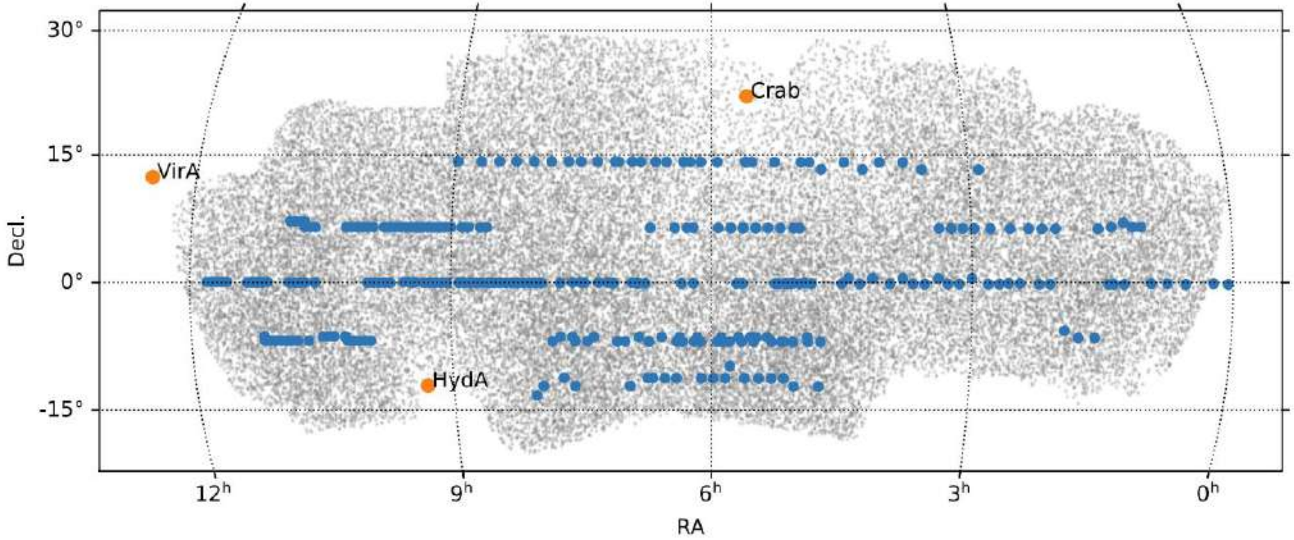
Long-period radio transients

- Monitoring campaigns with MWA at 200 MHz
- Transient searches at second to hour cadence
- New detection: GPMJ1839-10; more in preparation!

Interplanetary Scintillation Survey at 162 MHz



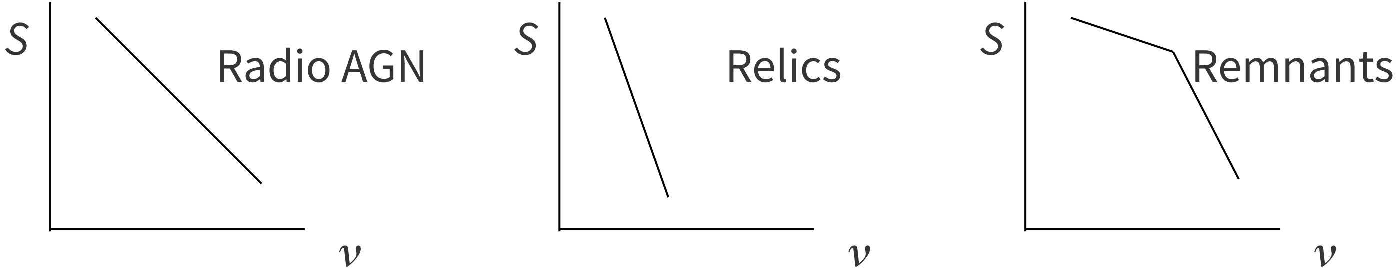
RMS image vs. normal image
Credit: John Morgan (CSIRO)



- Compact sources “twinkle” in the solar wind;
- IPS survey consists of 162 MHz imaging along the ecliptic;
- Scintillation enhancement → source structure on sub-arcsec scales;
- Contact John Morgan for IPS DR2 (larger area).

Ideas for low-frequency surveys & eROSITA synergies

- Population (wide-area) studies of galaxy clusters:
  - GLEAM-X (+ RACS, EMU) provide broadband SEDs; IPS excludes compact sources
  - eROSITA provides measure of cluster mass, cavity formation, merger status
  - → e.g. examine radio power — cavity power scaling, see how cluster environment changes AGN lifecycles, find new radio relics



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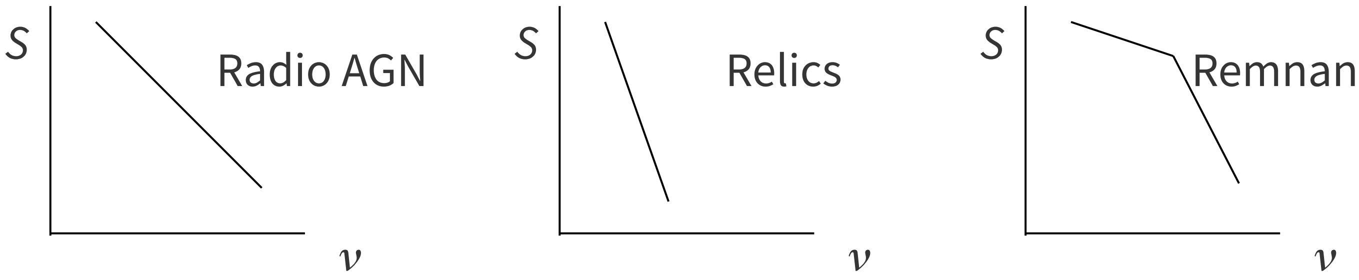

- Searching for aligned-rotator pulsars, magnetars and other compact objects:
  - eROSITA point sources show high-energy emission
  - IPS determines compactness; GLEAM-X can determine pulsar-like spectrum

Data access

Images:

- GLEAM: Skyview, Aladin HIPS will be updated soon, on AAO data central ~April
- GLEAM-X: https://datacentral.org.au/search/cone/ (DR1 now; DR2 ~May)
- GPM: Contact me (nhw@icrar.org)
- IPS: Contact John (john.morgan@csiro.au)

Catalogues: Vizier / CDS