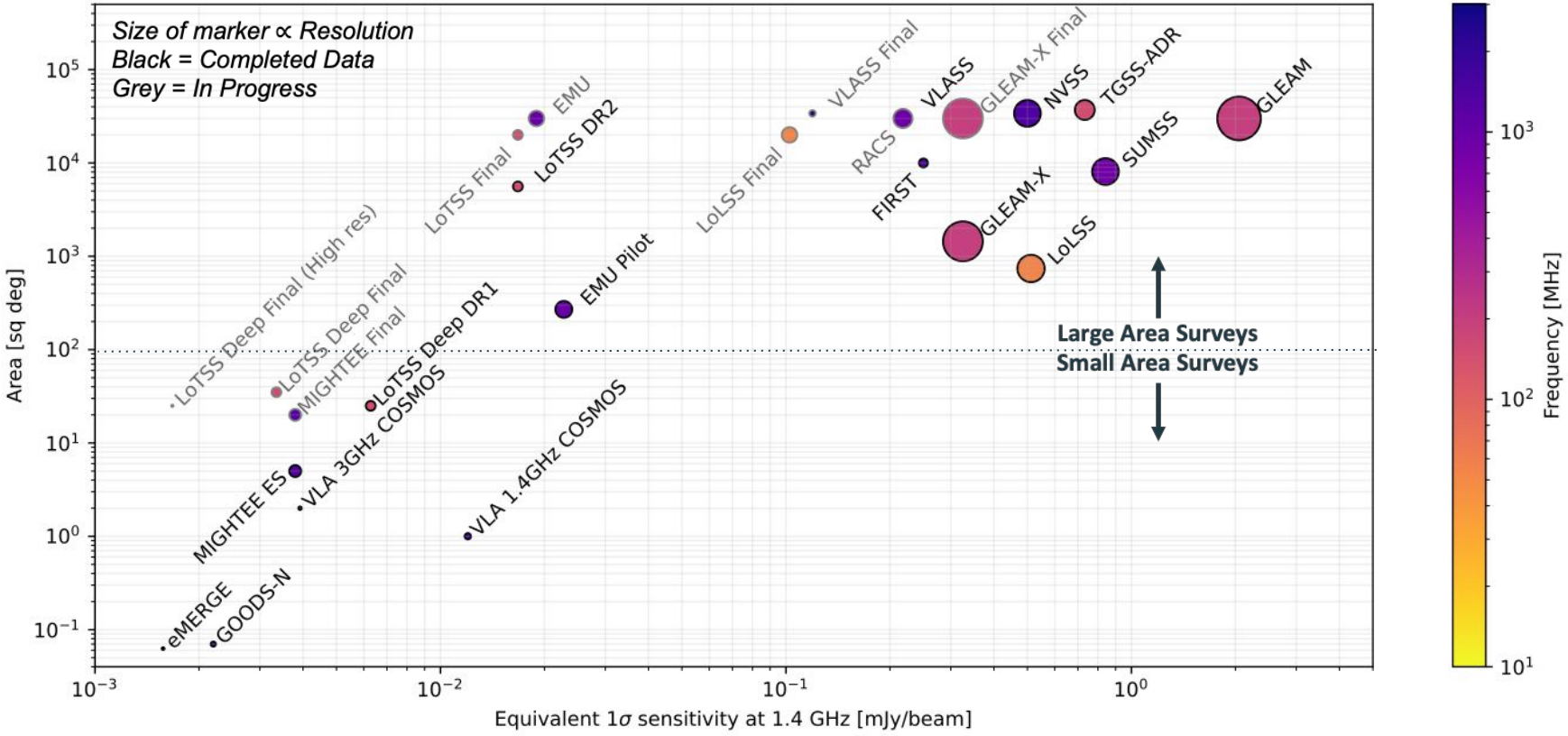
Continuum precursor surveys

Catherine Hale and Dominik Schwarz

Radio Continuum Surveys



LOFAR

Covers low radio frequencies across two observing bands:

- **Low** Band Antennas **(10-90 MHz)**
- **High** Band Antennas **(110-240 MHz)**

Dishes across Netherlands and Europe.
At HBA resolution is:

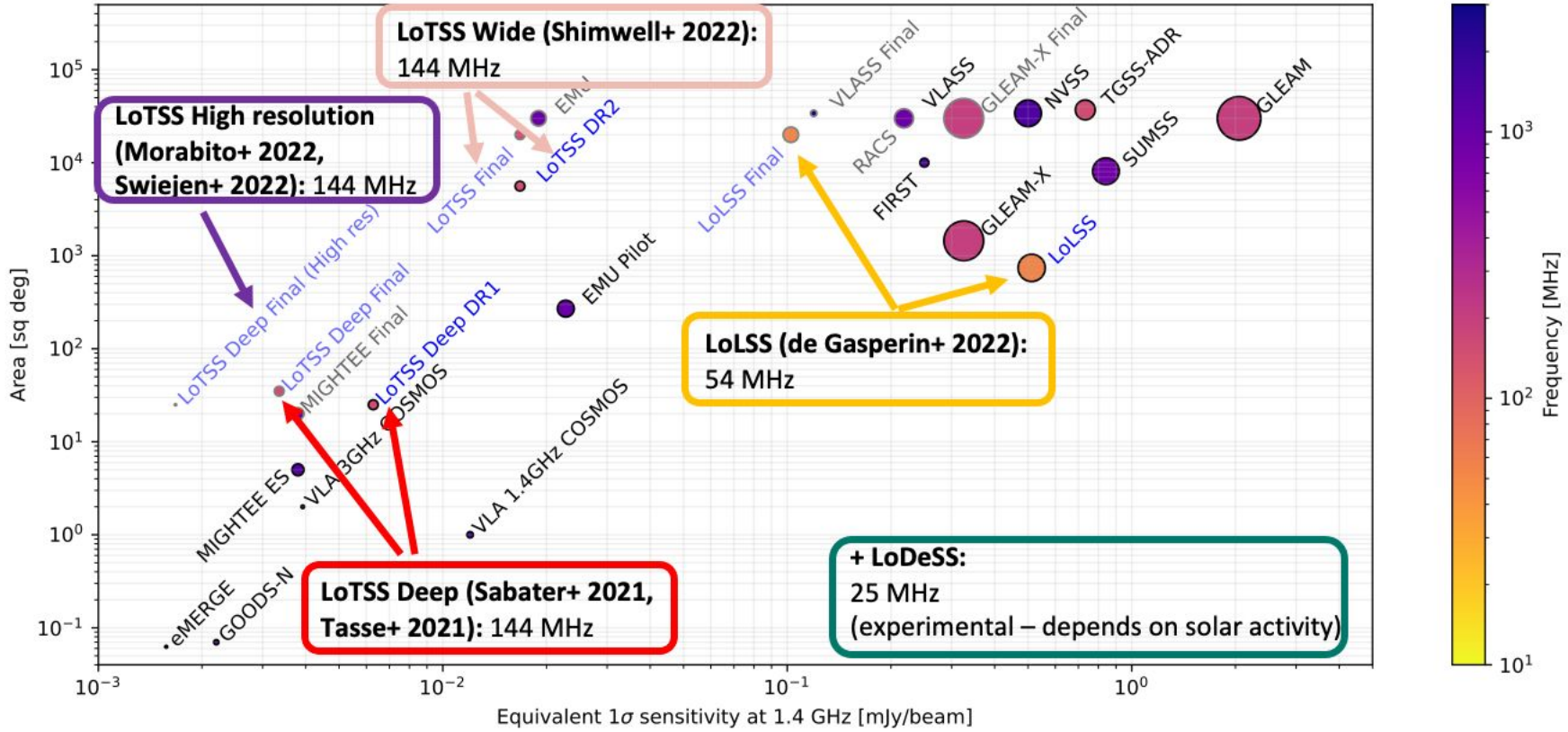
- 6” with Dutch stations only
- 0.3” including international

LOFAR Surveys Key Science Programme runs a coordinated suite of surveys: LoTSS (150 MHz); LoLSS wide (54 MHz), LoDeSS (25 MHz), WEAVE-LOFAR (complementary programme with WEAVE)

Credit: ASTRON

See www.lofar-surveys.org

Summary of LOFAR Surveys



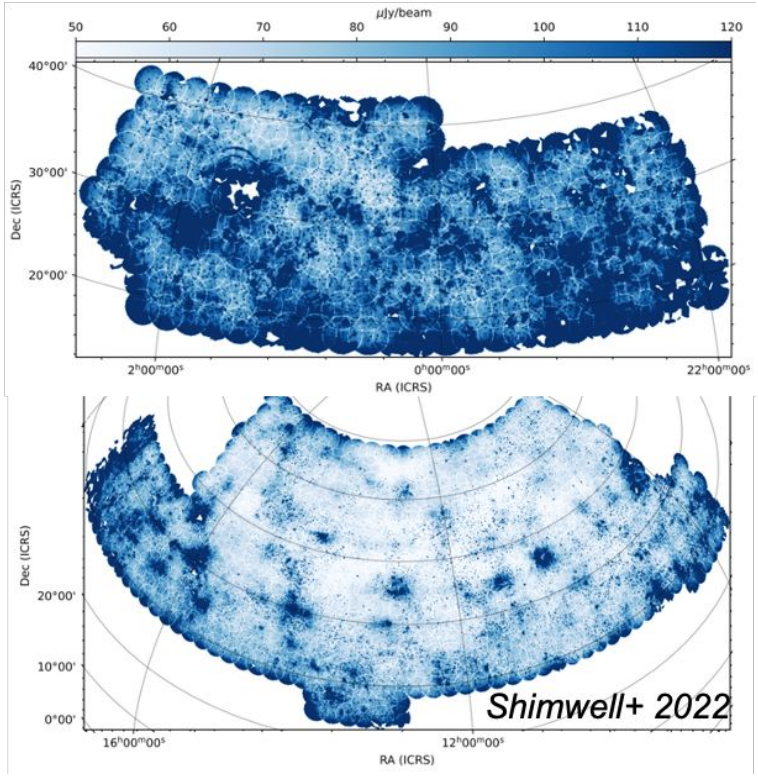
Ongoing LOFAR Surveys – Wide Area, 144 MHz

LOFAR Two-metre Sky Survey (LoTSS)

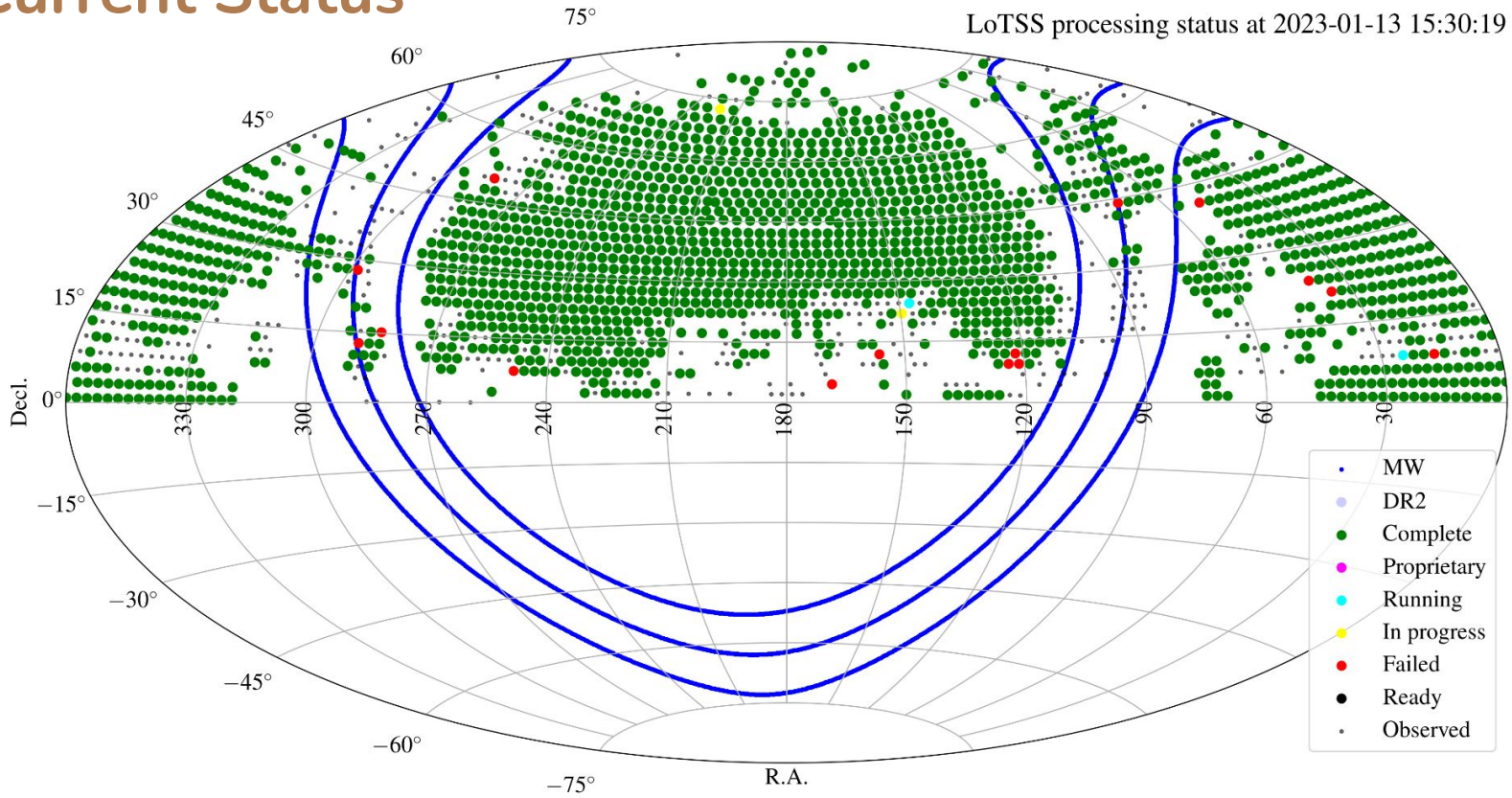
Shimwell et al. 2019, 2022

DR2:

- 4.4 million sources (current largest radio catalogue)
- 6” resolution, ~80 uJy/beam rms
- 5600 sq deg in two regions:
  - 1457 sq deg. Centred on 1h field
  - 4178 sq. deg centered on 13h field
- Will eventually cover all extragalactic Northern sky
- 90% complete above 0.8 mJy/beam peak-brightness
- 95 uJy/beam in Stokes V, less sensitive in Q and U



Current Status



Ongoing LOFAR Surveys – Deep Fields

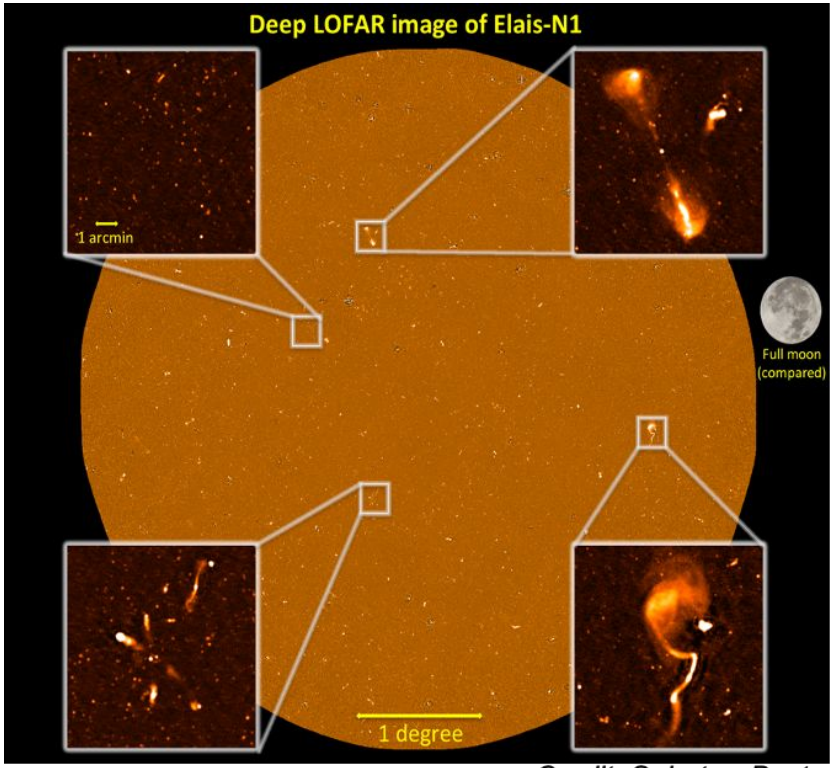
LOFAR Two-metre Sky Survey (LoTSS) Deep Fields
DR1: Tasse et al. 2021, Sabater et al. 2021

DR1:

- Three deep fields at 144 MHz and 6”
- **Boötes, Lockman, Elais N1**
- ~30 uJy/beam rms
- **Cross-match to Multi-wavelength sources:** Kondapally+ 2021 – 25 sq deg cross matched area, 80,000 sources
- **Photometric redshifts**, Duncan et al. 2021

DR2:

- 3 Deep fields + North Ecliptic Pole (NEP)
- ~35 sq deg multi-wavelength coverage
- ~15 uJy/beam rms



Credit: Sabater, Best

Ongoing LOFAR Surveys – High resolution

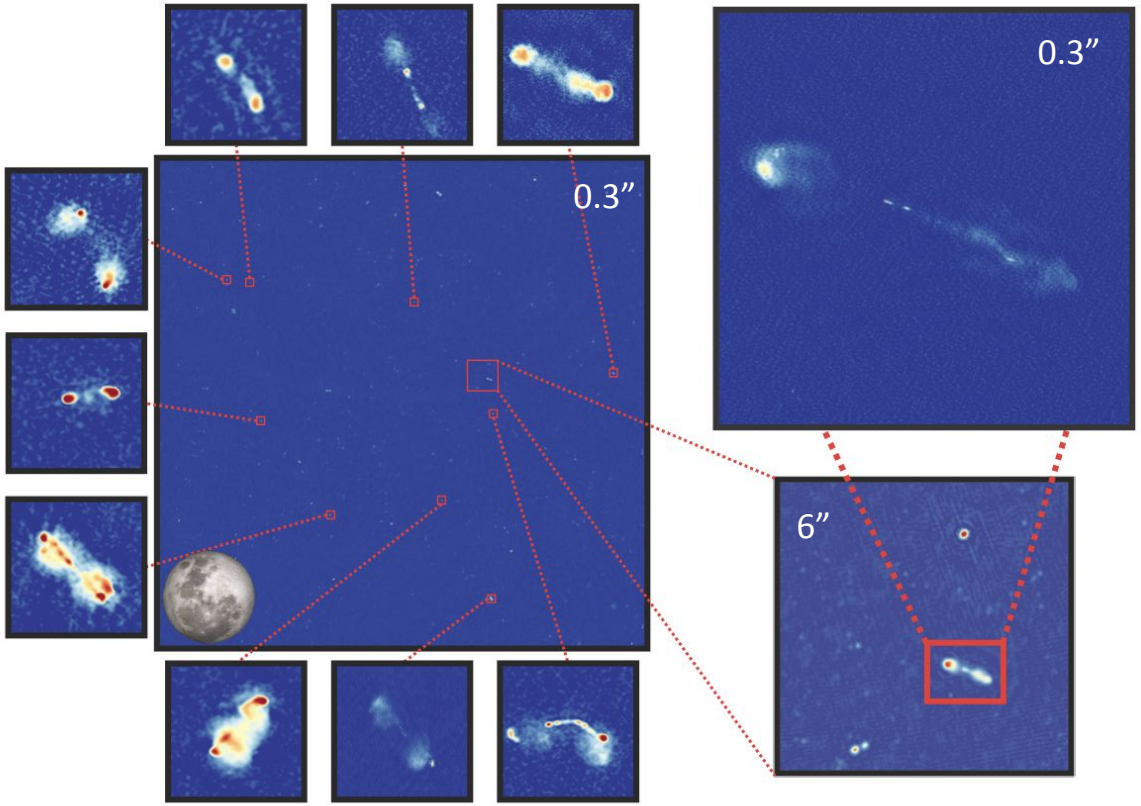


Image: Sweijen+ 2022

Recent advances in **wide field VLBI** imaging with **LOFAR**: Sweijen+ 2022

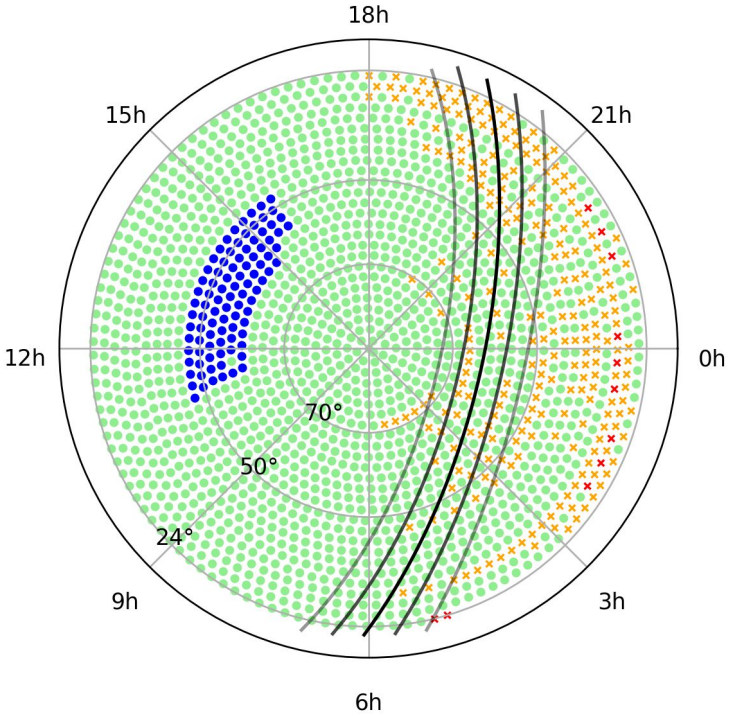
7.4 sq deg image of the **Lockman Hole** field

0.3 arcsec resolution is achieved with international LOFAR stations

8hr LOFAR observation:

- 6” = 80-100 uJy/beam
- 0.3” = 25 uJy/beam

Ongoing LOFAR Surveys – Lowest Frequencies



Lofar LBA Sky Survey (LoLSS)

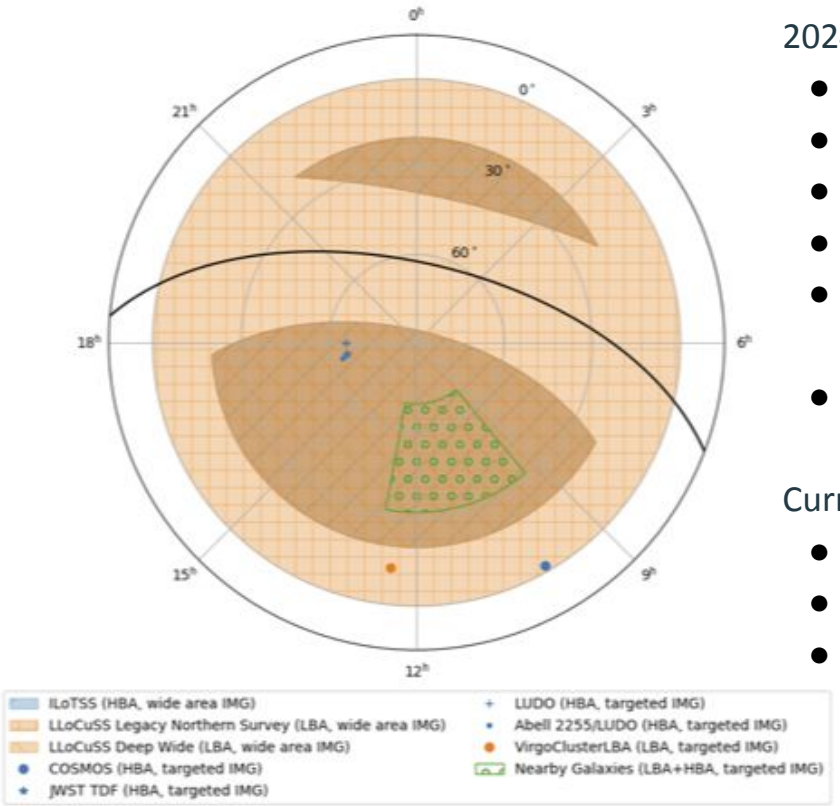
PR: de Gasperin+ 2022:

- 54 MHz, 47” resolution, 5uJy/beam
- 740 sq deg

Future observations (DR1 submitted, Blue):

- 15” resolution, 1uJy/beam – including direction dependent calibration
- Green and Yellow are already observed
- Red will be observed in 2023

LOFAR 2.0



LOFAR will undergo a **major upgrade to LOFAR2.0** (roll-out 2024-2025):

- Increased LBA sensitivity (2x more antennas)
- Increased angular resolution (0.2 arcsec)
- More robust against RFI (will improve sensitivity)
- More simultaneous bandwidth
- All Dutch stations on a single clock (reduces impact of ionosphere)
- Integration of NenuFAR

Currently **Expression of Interests** have been collected with e.g.

- HBA high resolution matching Euclid extragalactic fields
- LBA wide area of all Northern Sky
- Several deep fields

MeerKAT

64 Offset Gregorian dishes

Based in **Karoo Desert** in South Africa

Several **Large Survey** projects:

LADUMA, MALS, MeerKAT Fornax Survey, MHONGOOSE and **MIGHTEE** (extragalactic)

MeerTime, ThunderKAT, TRAPUM (Transients and Pulsars)

MIGHTEE

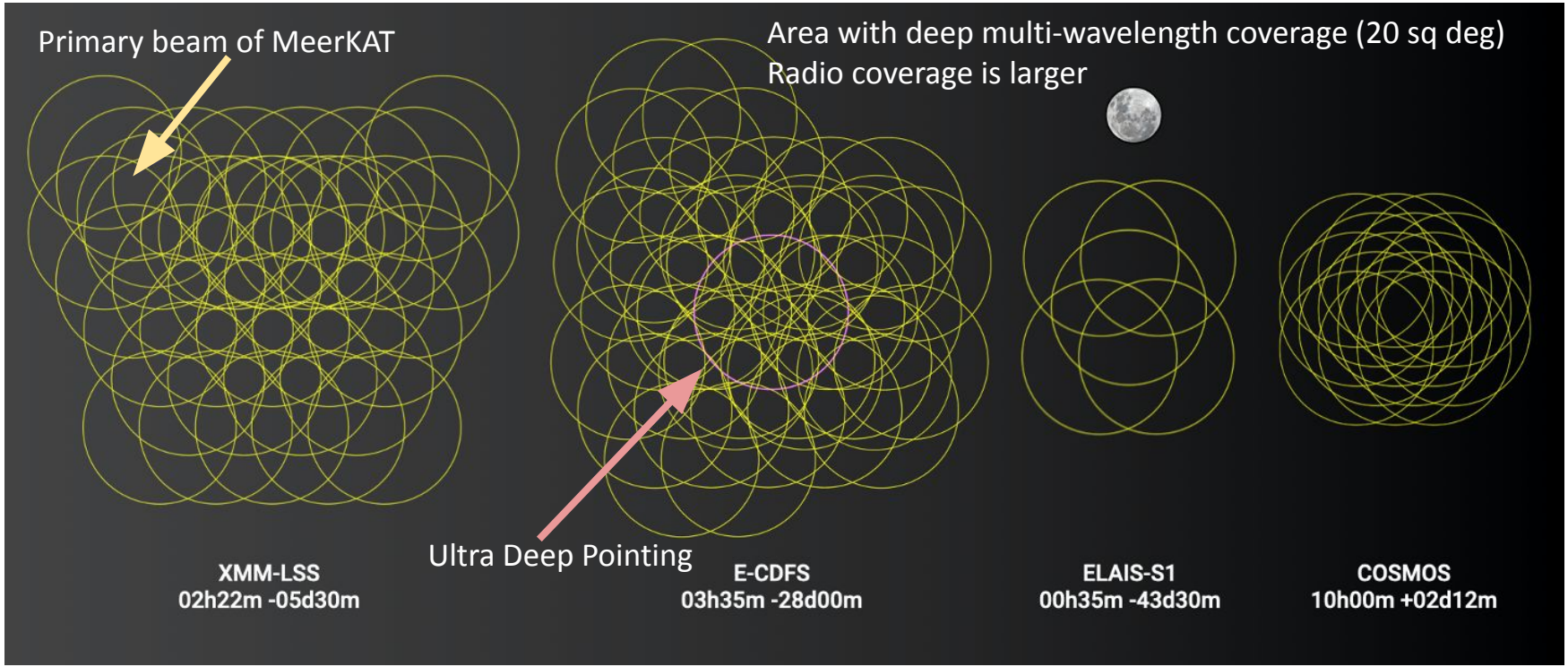
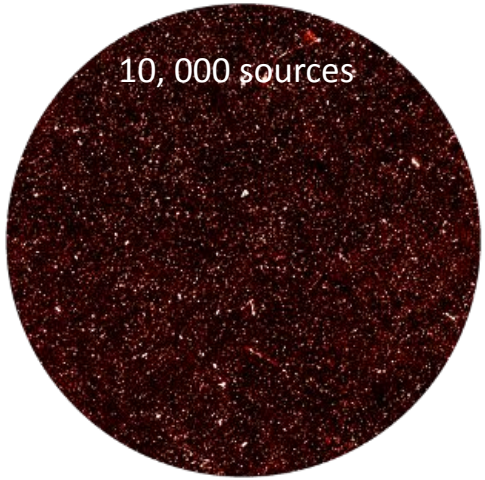
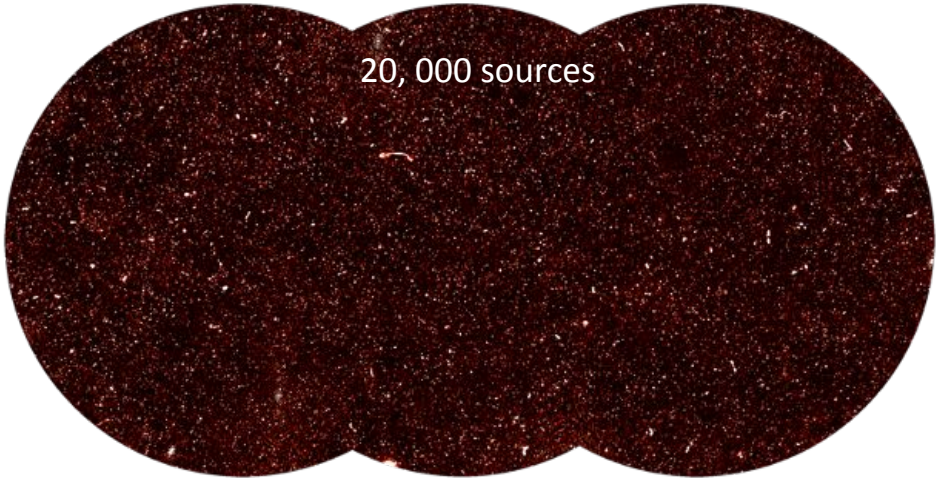


Image credit: I Heywood

Low resolution:

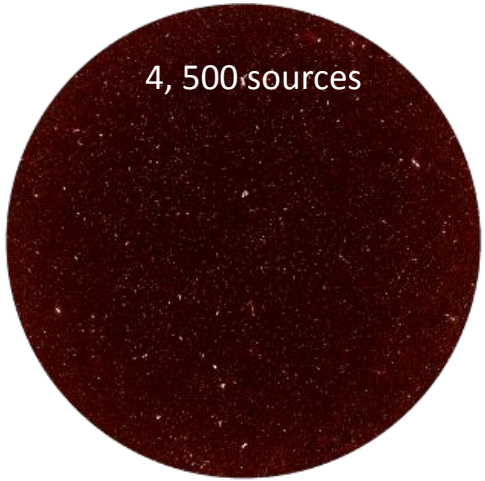
- 9 arcsec
- Maximize sensitivity
- BUT Confusion noise limited

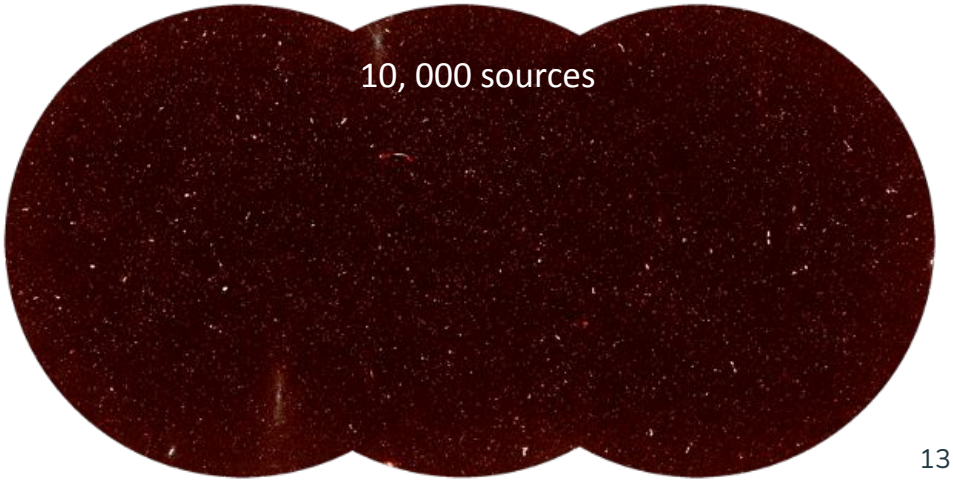




High resolution:

- 5 arcsec
- Maximize resolution
- Not Confusion noise limited
- A factor of 2 fewer sources

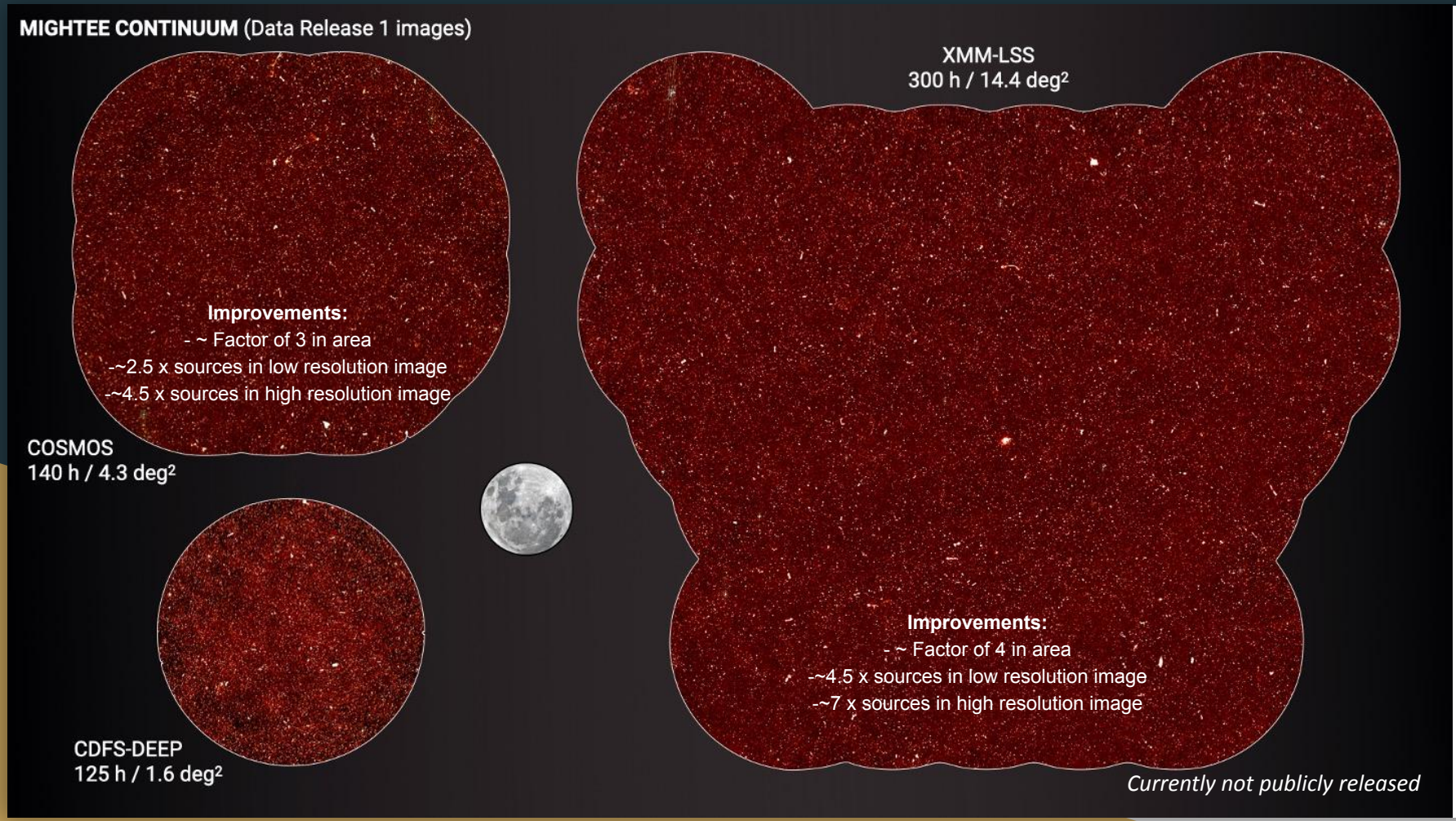




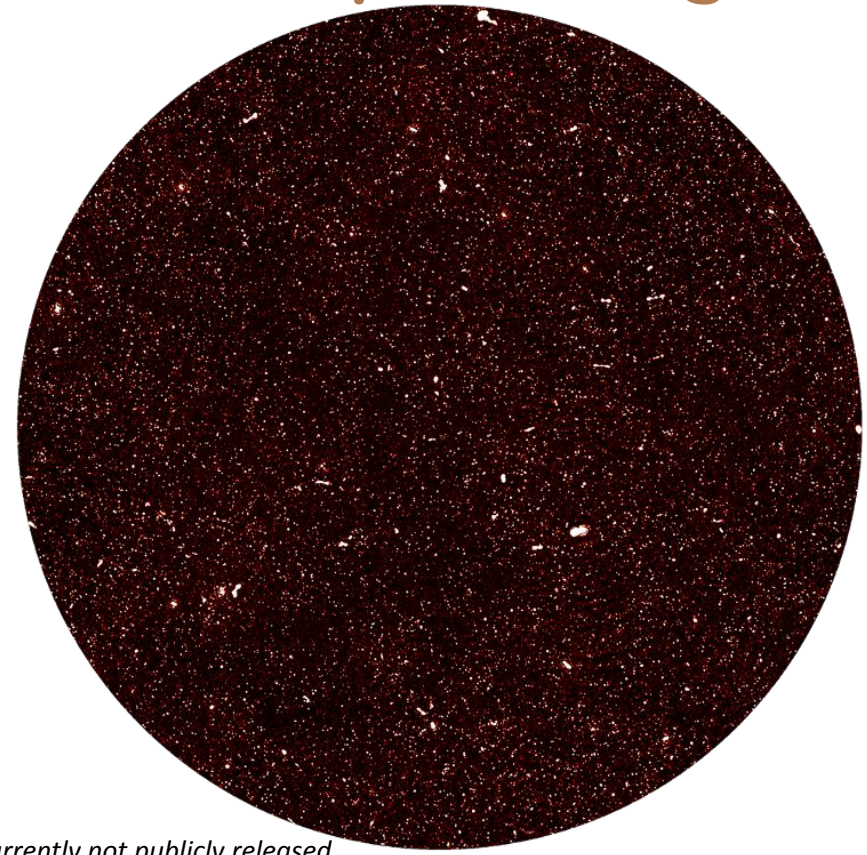
MIGHTEE CONTINUUM (Early Science images, Heywood et al., MNRAS, 2022)

XMM-LSS
37 h / 3.5 deg²

COSMOS
19.5 h / 1.6 deg²


MIGHTEE CONTINUUM (Data Release 1 images)
XMM-LSS
300 h / 14.4 deg²
Improvements:
- ~ Factor of 3 in area
-~2.5 x sources in low resolution image
-~4.5 x sources in high resolution image
COSMOS
140 h / 4.3 deg²
CDFS-DEEP
125 h / 1.6 deg²
Improvements:
- ~ Factor of 4 in area
-~4.5 x sources in low resolution image
-~7 x sources in high resolution image
Currently not publicly released

Ultra Deep Pointing in CDFS



Currently not publicly released

Same **area** as Early Science COSMOS

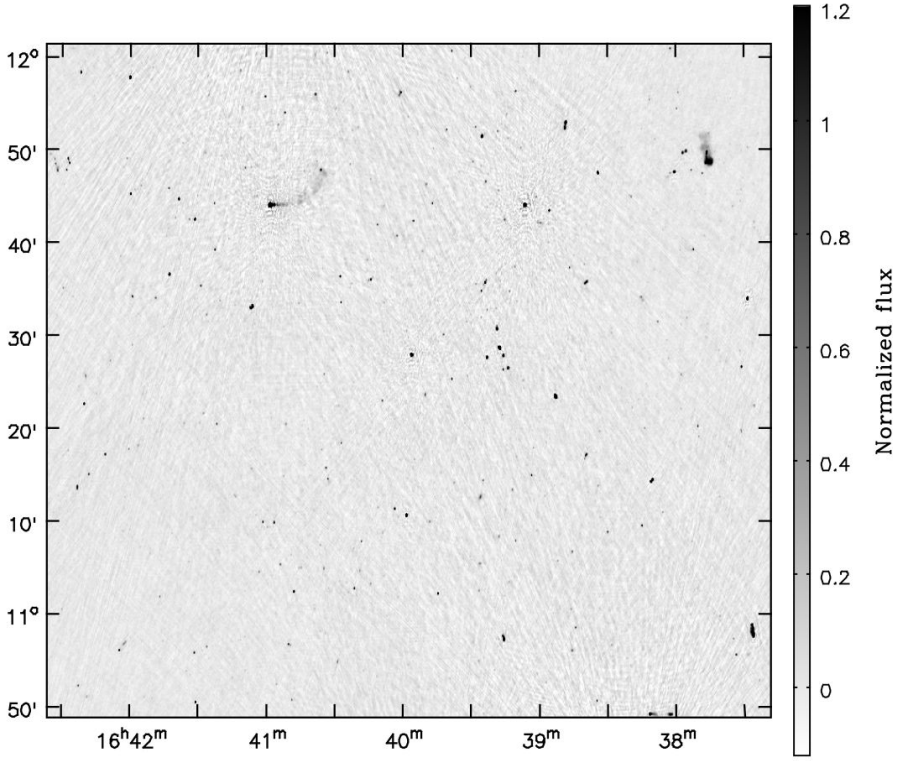
Same **resolution** as High resolution Early science COSMOS

CDFS-Deep is **~4 x smaller rms**
(~7-8 uJy/beam COSMOS, ~1.5-2 uJy beam CDFS-Deep)

CDFS-Deep has **~5x the number of sources**
(~4500 COSMOS, ~23000 CDFS-Deep)

MALS

- Observations of HI and OH Absorption Lines
- Use bright radio sources to select pointings to observe
- Continuum images produced as well
- Gives larger area coverage across the sky



Gupta+ 2021

ASKAP

Credit: CSIRO

36 dishes with 12 m diameter

Uses **Phased Array Feed** Technology

Has **~30 sq deg field of view**

Several **Large survey** projects:

DINGO, **EMU**, FLASH (extragalactic)
GASKAP OH, GASKAP HI (galactic)
POSSUM (Polarisation)
CRAFT, VAST (Transients)

Observatory led project:
RACS

RACS (McConnell+ 2020

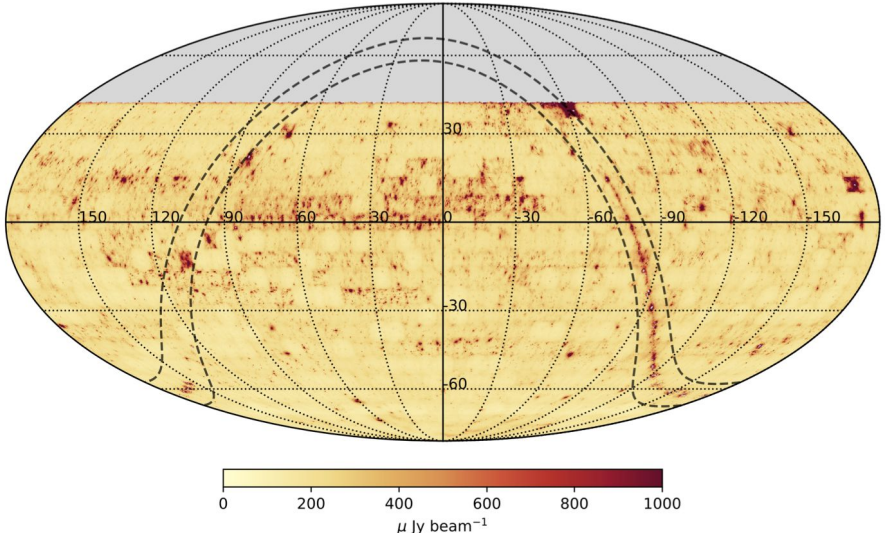
Observatory led project to do **rapid** survey of the sky using ASKAP

15 min observations across **903 tiles** across the sky **to +40deg** in declination.

Catalogue released in Hale+ 2021 of **25" common resolution** contiguous catalogue to **+30deg** in declination

Observations at other frequencies **(~1.3 GHz and ~1.7 GHz)** in progress/taken to be released in updated catalogues

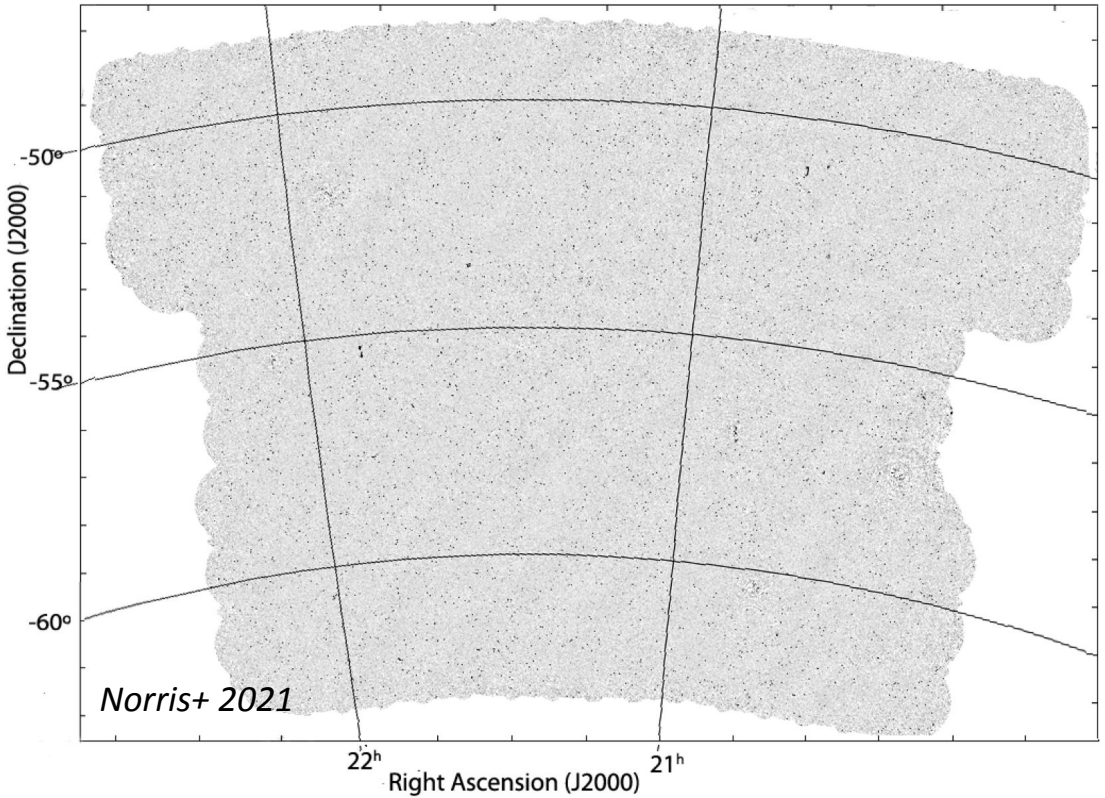
Polarisation information also available (Thomson+ in prep)



Survey	Frequency (MHz)	Bandwidth (MHz)	Resolution (arcsec)	Sky coverage (sq deg)	Sensitivity (mJy/beam)	Polarization	$N_{sources}$ ($\times 10^6$)
VLSSr	73.8	3.12	75	30,793	100	I	0.93
GLEAM	87, 118, 154, 185, 215	30.72	120	27,691	6–10	I,Q,U,V	0.33
TGSS	150	16.7	25	36,900	2–5	I	0.62
RACS[1]	887.5 1295.5 1655.5	288	15	36,656	~0.25	I,Q,U,V	4
RACS[2]	887.5	288	15–25	34,240	0.2–0.4	I	2.8
SUMSS +MGPS-2	843	3	45	10,300	1.5	RC	0.2
NVSS	1346, 1435	42	45	33,800	0.45	I,Q,U	2
VLASS	3000	2000	2.5	33,885	0.07	I,Q,U	5.3

[1]RACS full survey capability.
[2]RACS first data release.

EMU



Pilot Observations released in **Norris+ 2021**

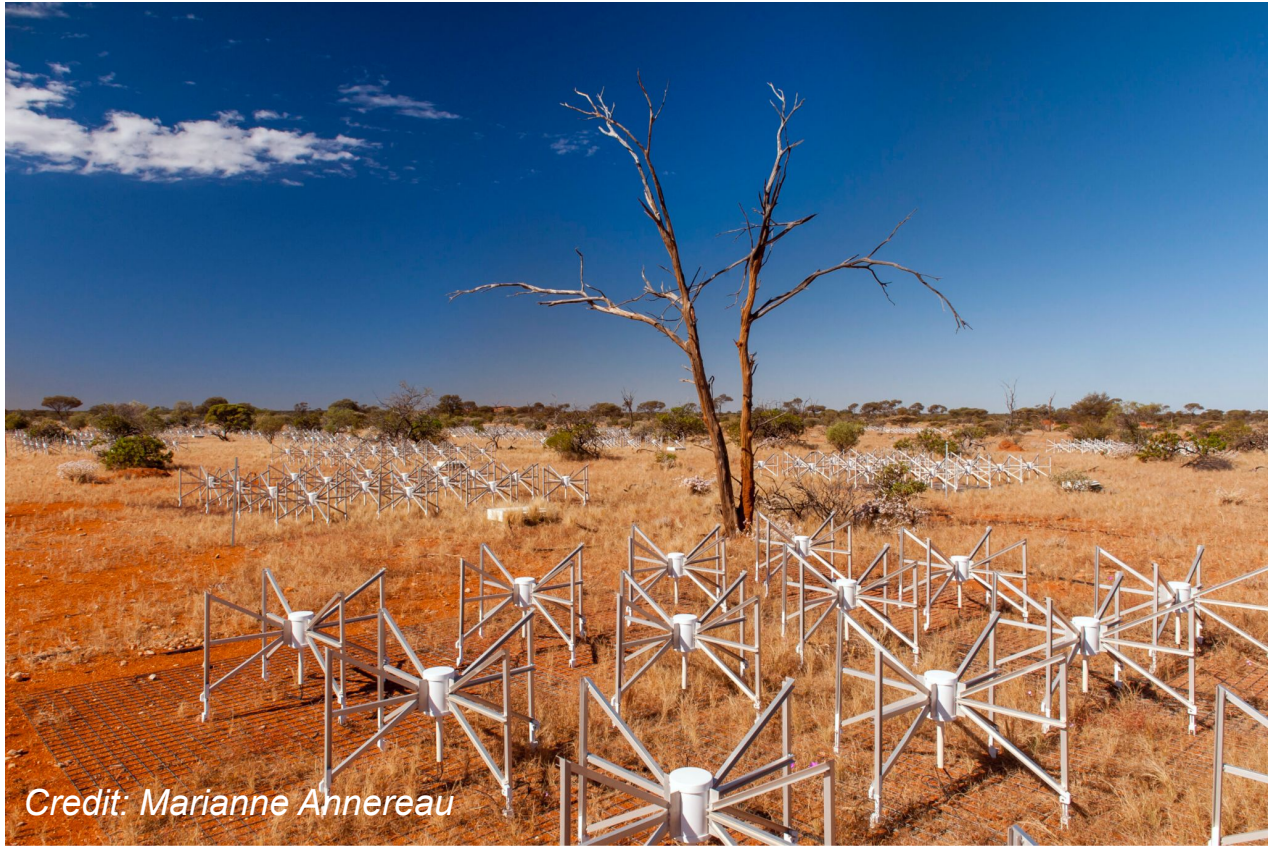
270 sq. deg overlapping with the **Dark Energy Survey**

ASKAP has **now started** the full survey observations

Aim is **large sky survey** (2π sr, eventually 3π sr) at ~15” to ~20-30 uJy/beam at 940 MHz

Over 3π sr expect ~43 million sources with ~80% SFGs

MWA



Low frequency array in Western **Australia**

4096 of these “spider” antennas

GLEAM:

- Observations of sky to max declination of **+30 deg**
- **70-230** MHz
- Spectral index measurement
- **~100**” resolution
- **6-10** mJy/beam

GLEAM-X

GLEAM: -> GLEAM-X

- Observations of sky to max declination of **+30 deg** -> ~1500 sq deg in Pilot
- **70-230** MHz
- Spectral index measurements
- ~**100**" resolution -> 2' - 45" resolution
- **6-10** mJy/beam -> ~1.3 mJy/beam

Credit: Hurley-Walker+ 2022

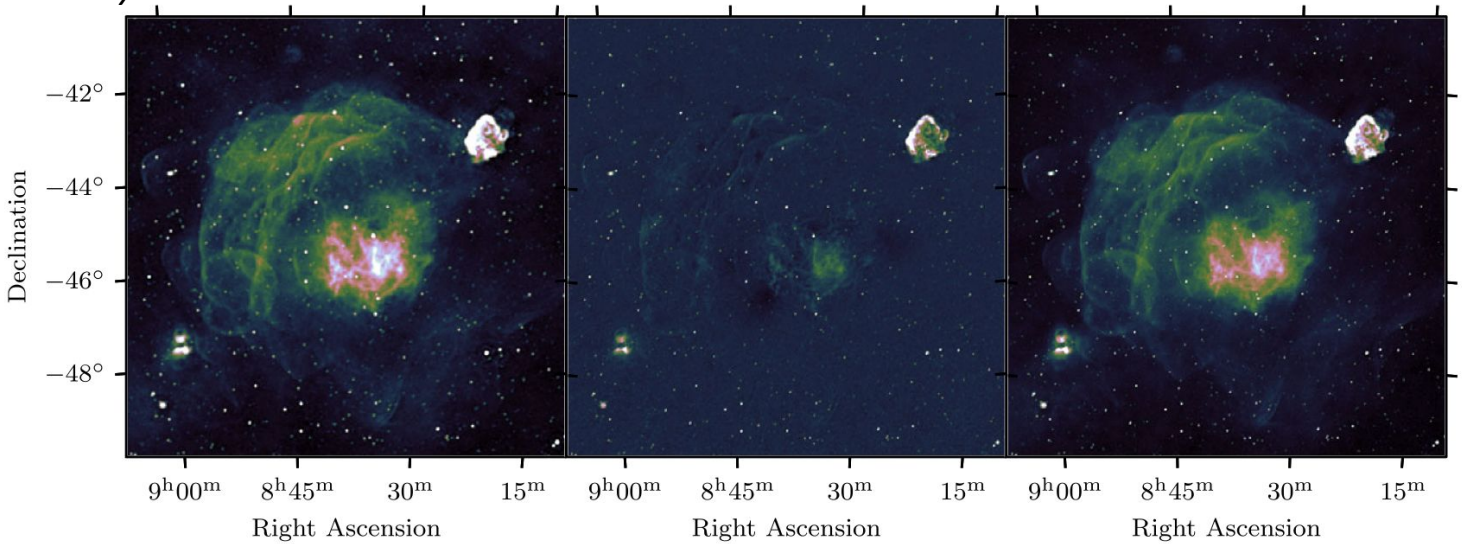


Figure 3. 90 sq. deg. around the Vela supernova remnant at 139–170 MHz. The left panel shows a GLEAM mosaic at 2.′6 resolution; the middle panel shows a GLEAM-X mosaic at 1.′3 resolution; the right panel shows a joint deconvolution of the two datasets yielding the same high resolution, and also the sensitivity to structures on 10′–5° scales.

Radio Continuum Surveys