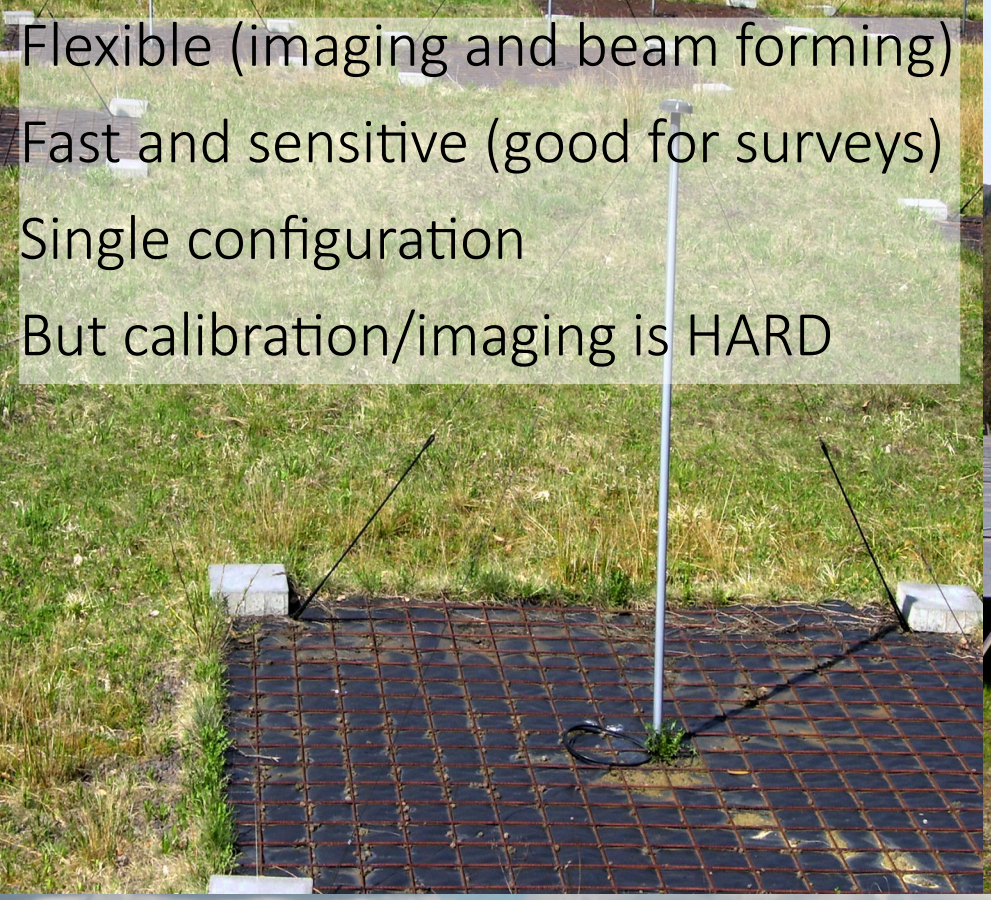
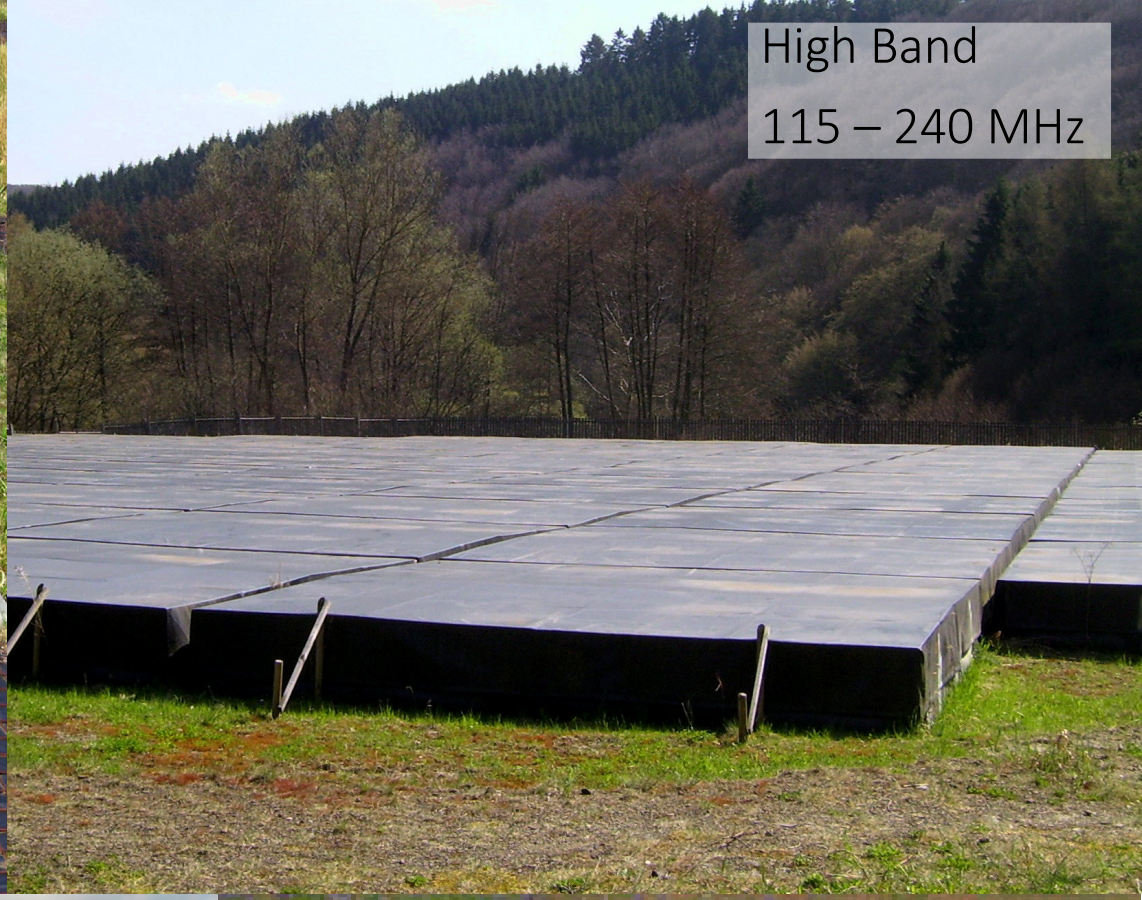
The LOFAR Two-metre Sky Survey (LoTSS) first data release

Wendy Williams (U. Herts)
T. Shimwell, M. Hardcastle, C. Tasse, A. Mechev, P. Best, J. Sabater, J. Croston, H. Rottgering
+LOFAR Surveys KSP

University of Hertfordshire


Flexible (imaging and beam forming)
Fast and sensitive (good for surveys)
Single configuration
But calibration/imaging is HARD

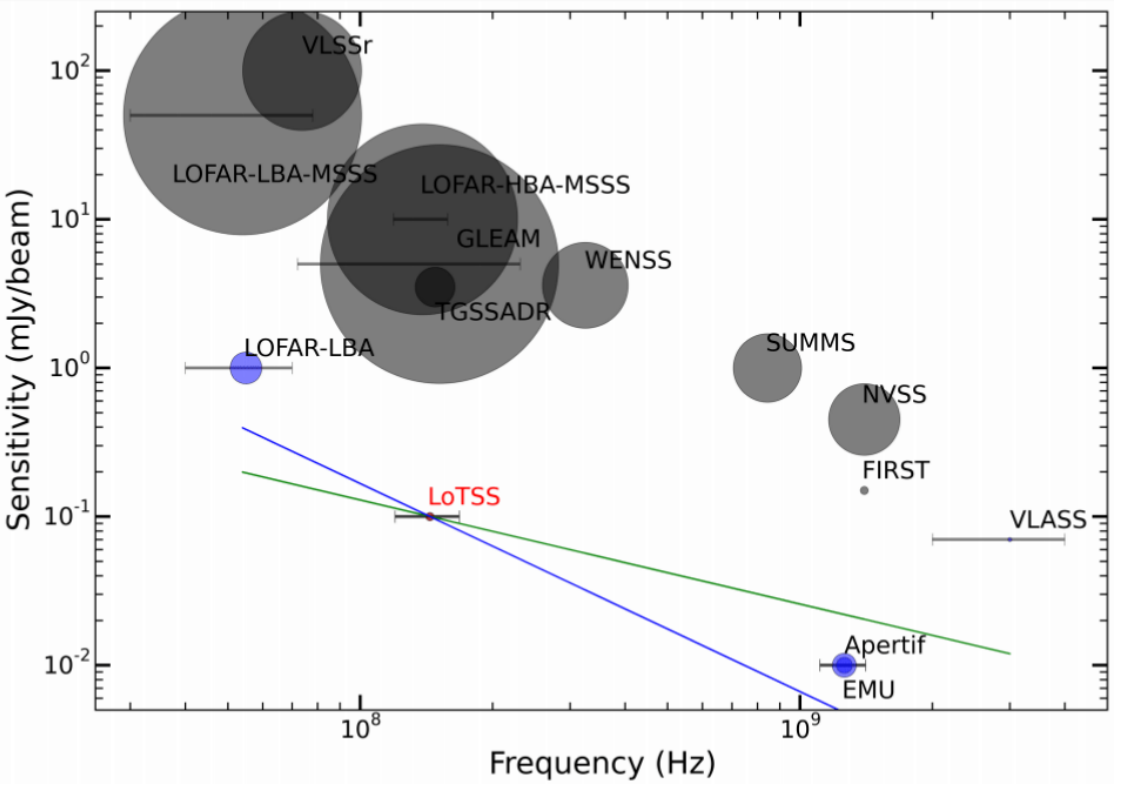

High Band
115 – 240 MHz

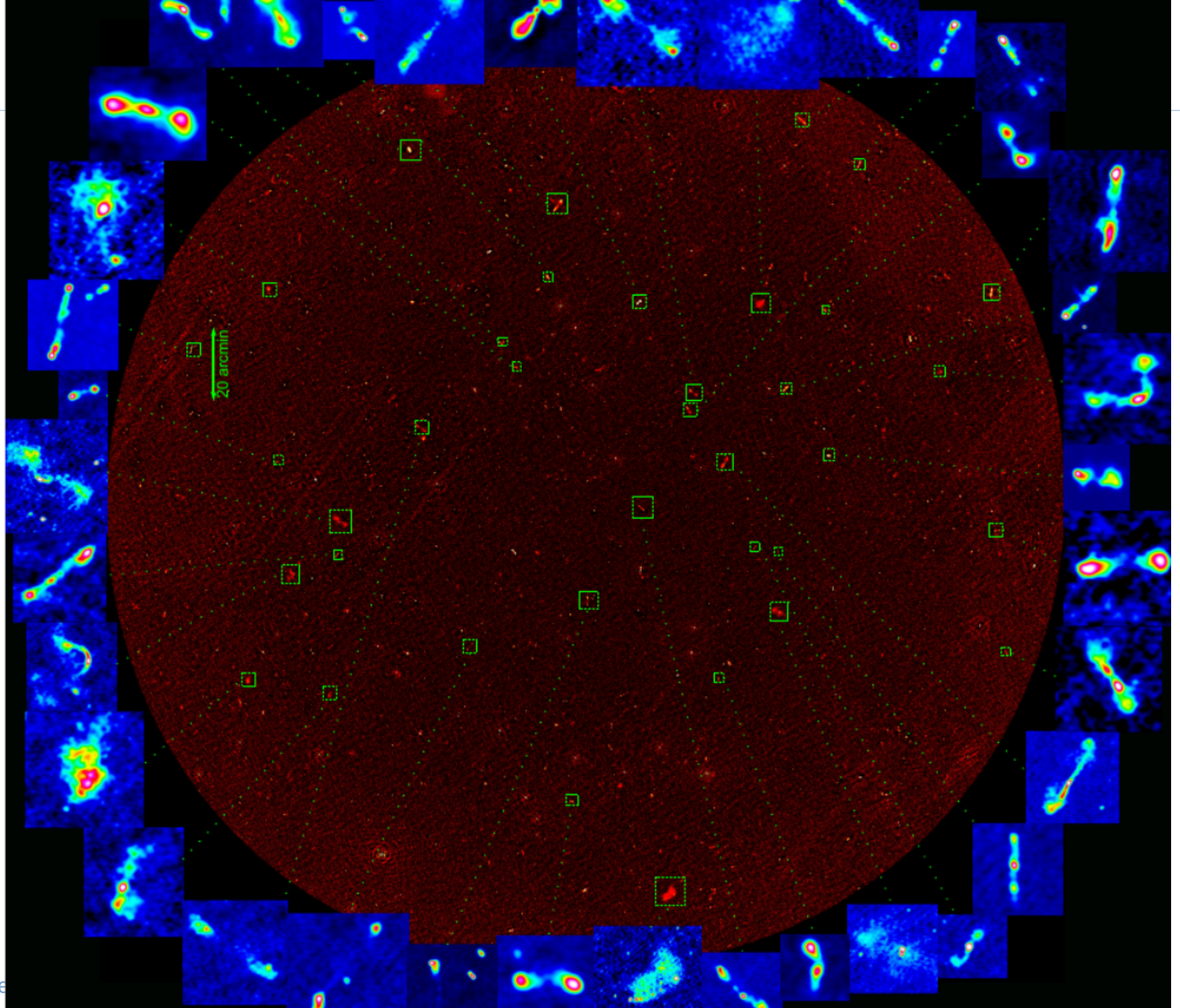

Low Band
(10) 30 – 80 MHz

The LOFAR Two-metre Sky Survey (LoTSS)

- Half the sky
- 5” resolution (and sensitivity to large scales)
- 100 µJy/bm noise
- 150 MHz

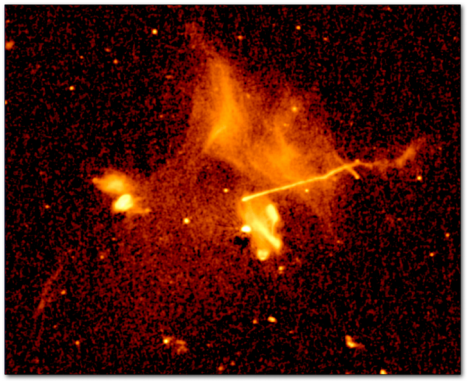
- + deeper tiers
- ++ LOFAR vlbi

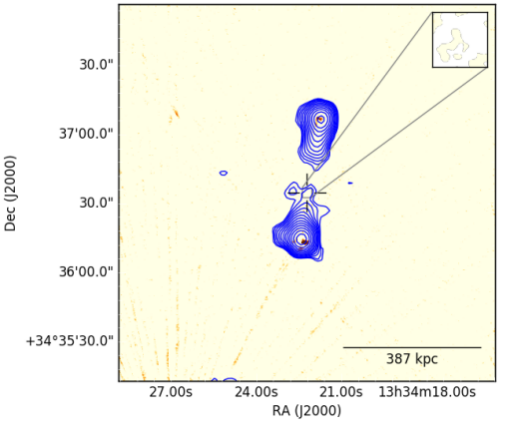


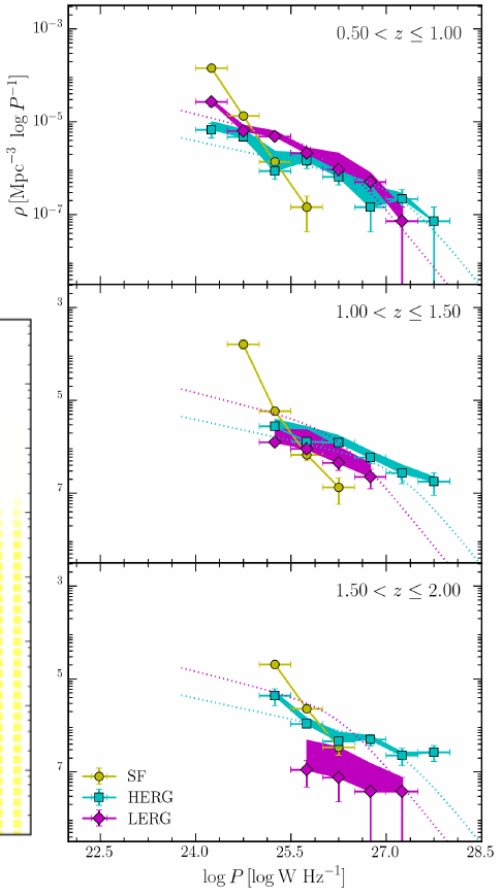

20 arcmin

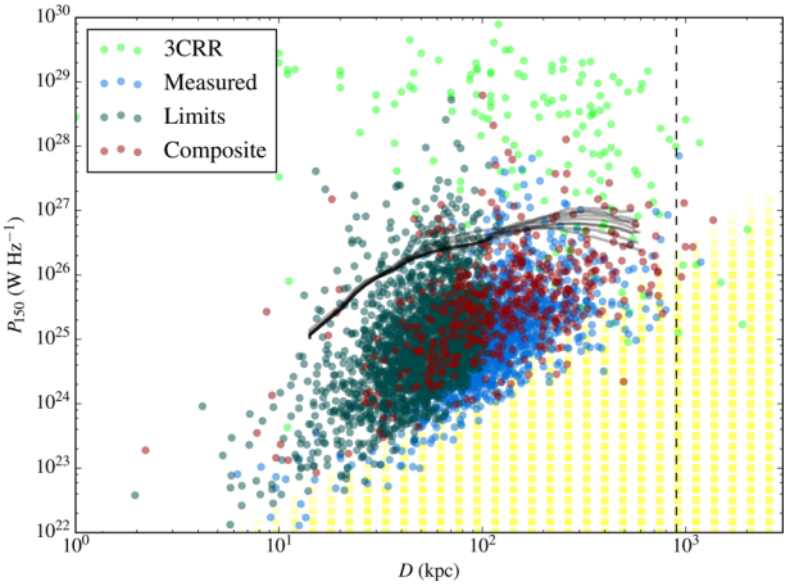
LoTSS of science

- **Highest z radio sources**
- Starforming galaxies at moderate z
- **Detailed studies of low-z AGN**
- Nearby galaxies
- Clusters and cluster halo sources
- Cosmology
- Gravitational lensing
- Galactic radio sources
- **AGN at moderate z**



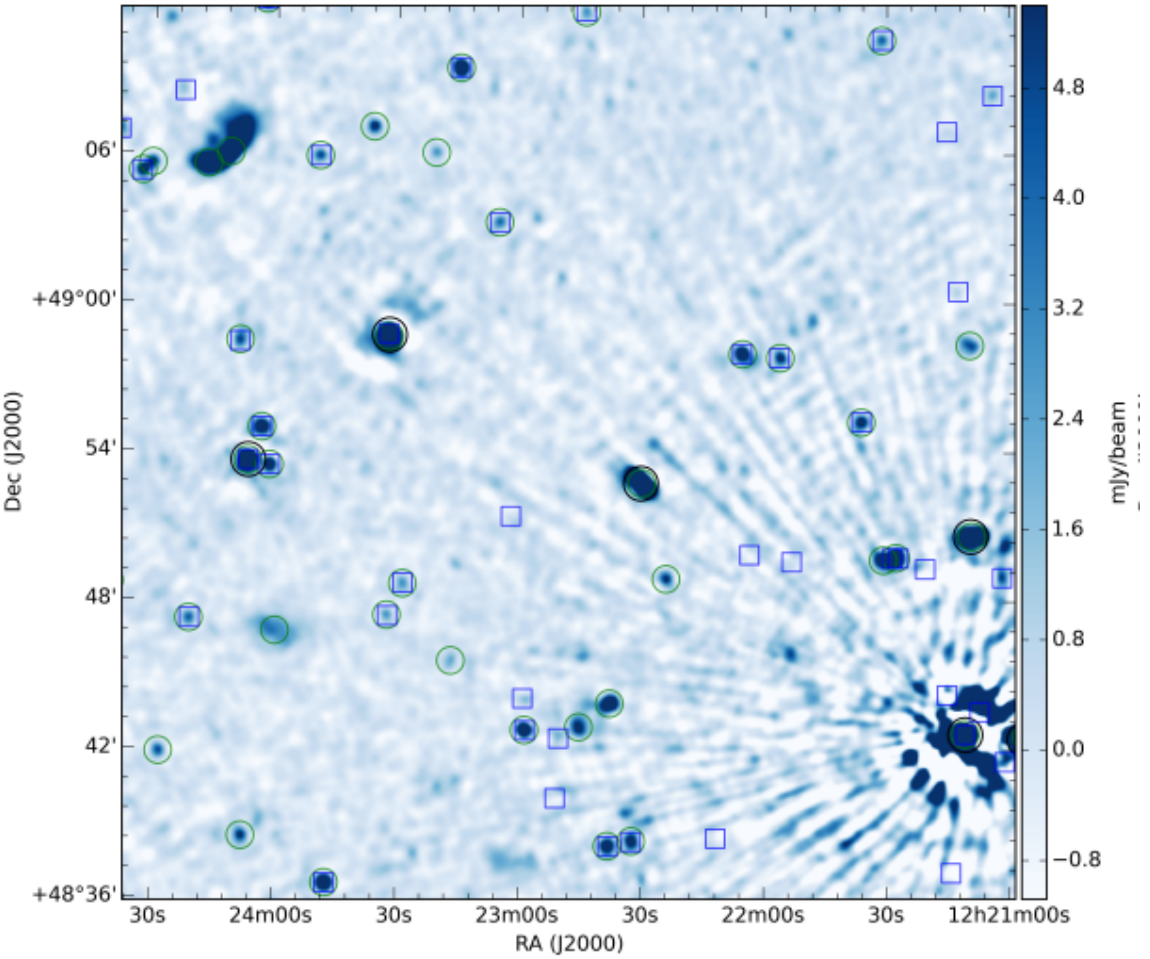




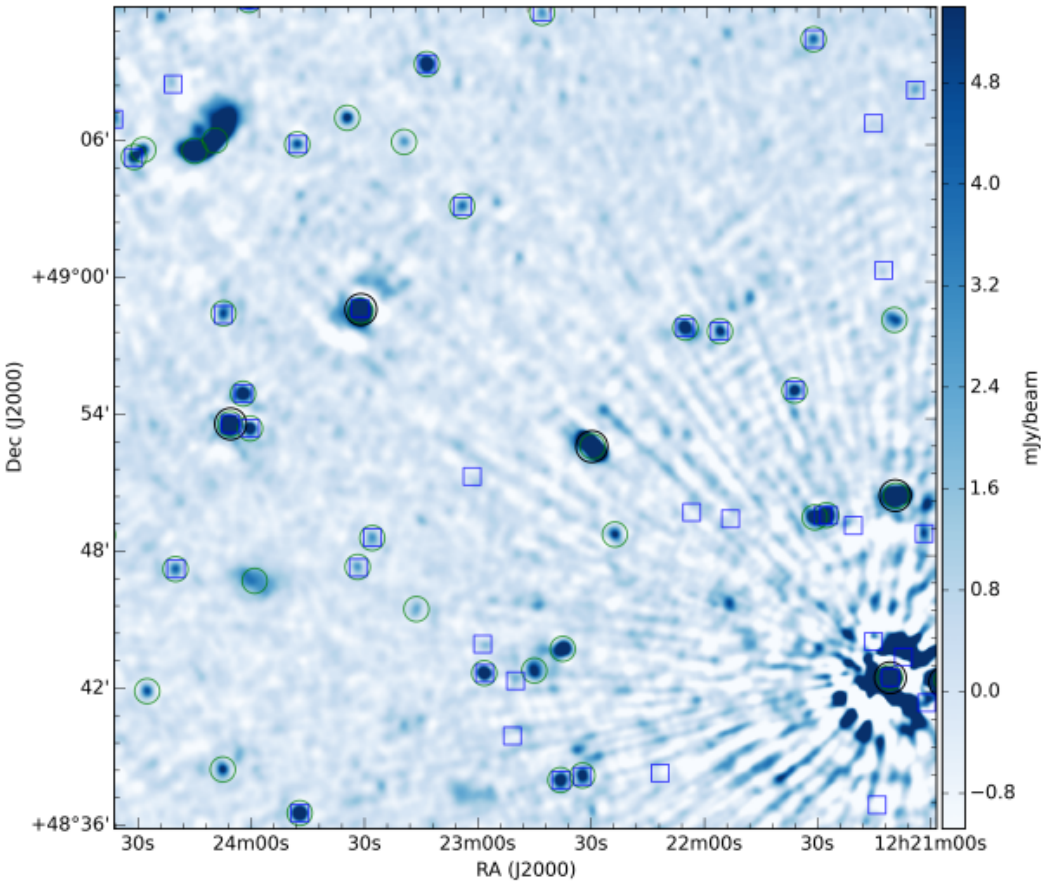


LoTSS Preliminary Data Release

- HETDEX Spring Field
  - RA 10h45m – 15h30m
  - DEC 45° – 57°
  - 350 sq deg area
  - 25” resolution
  - 0.5 mJy/bm noise
  - 44k sources
- Shimwell+ 2017 (2017A&A...598A.104S)
- Image/catalogue VO service
  - http://lofar.strw.leidenuniv.nl doku.php?id=tier1_hba_pdr

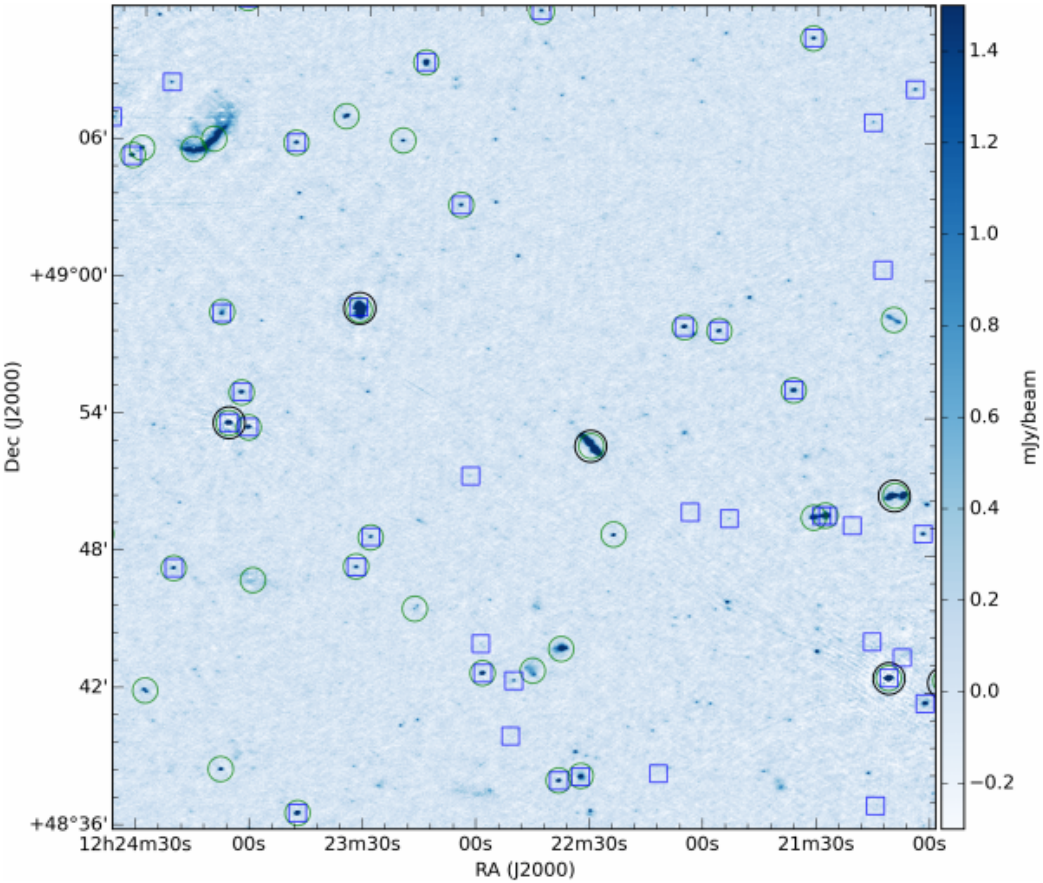


Direction-dependent calibration



Preliminary release

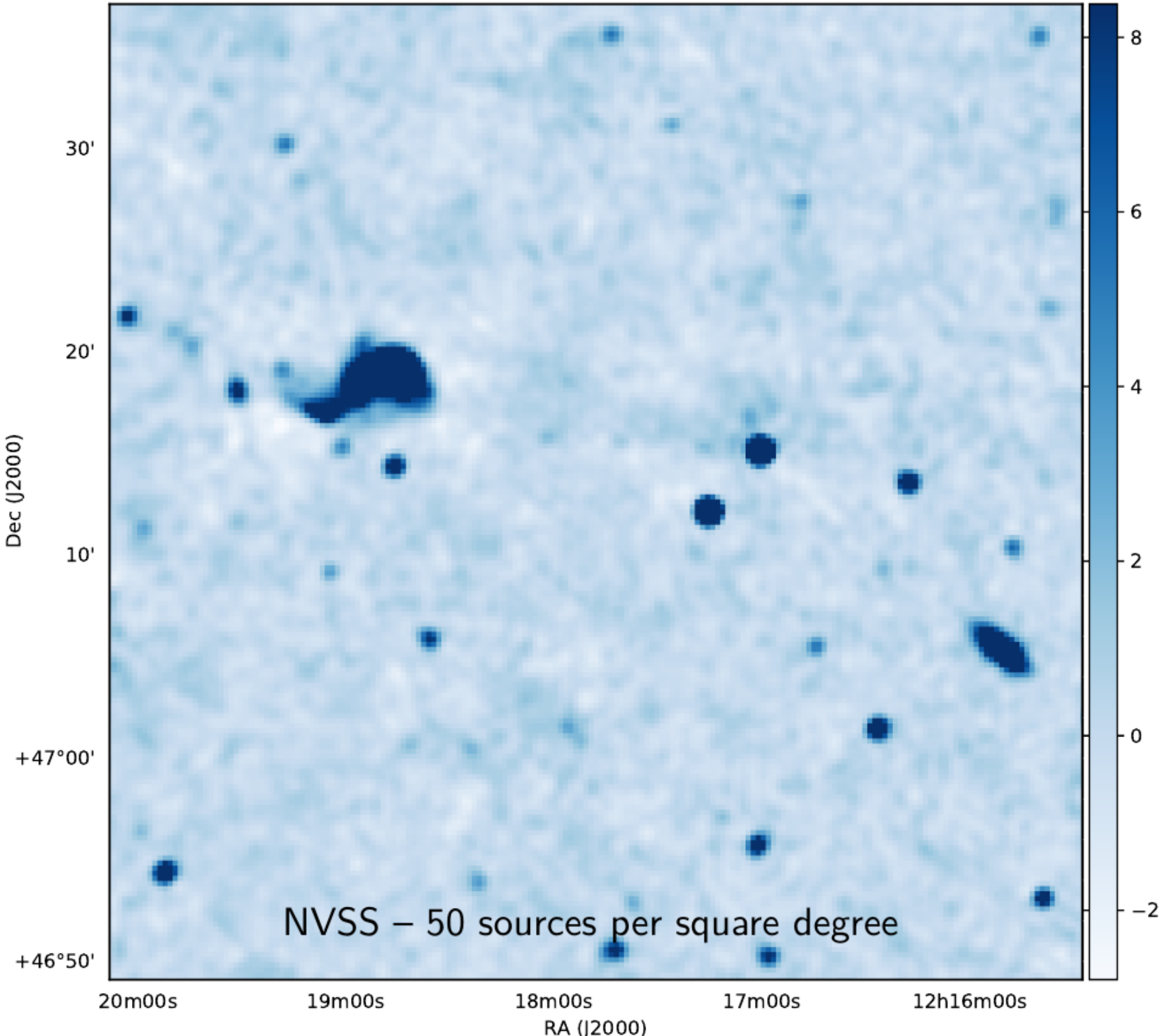
Direction-independent calibration

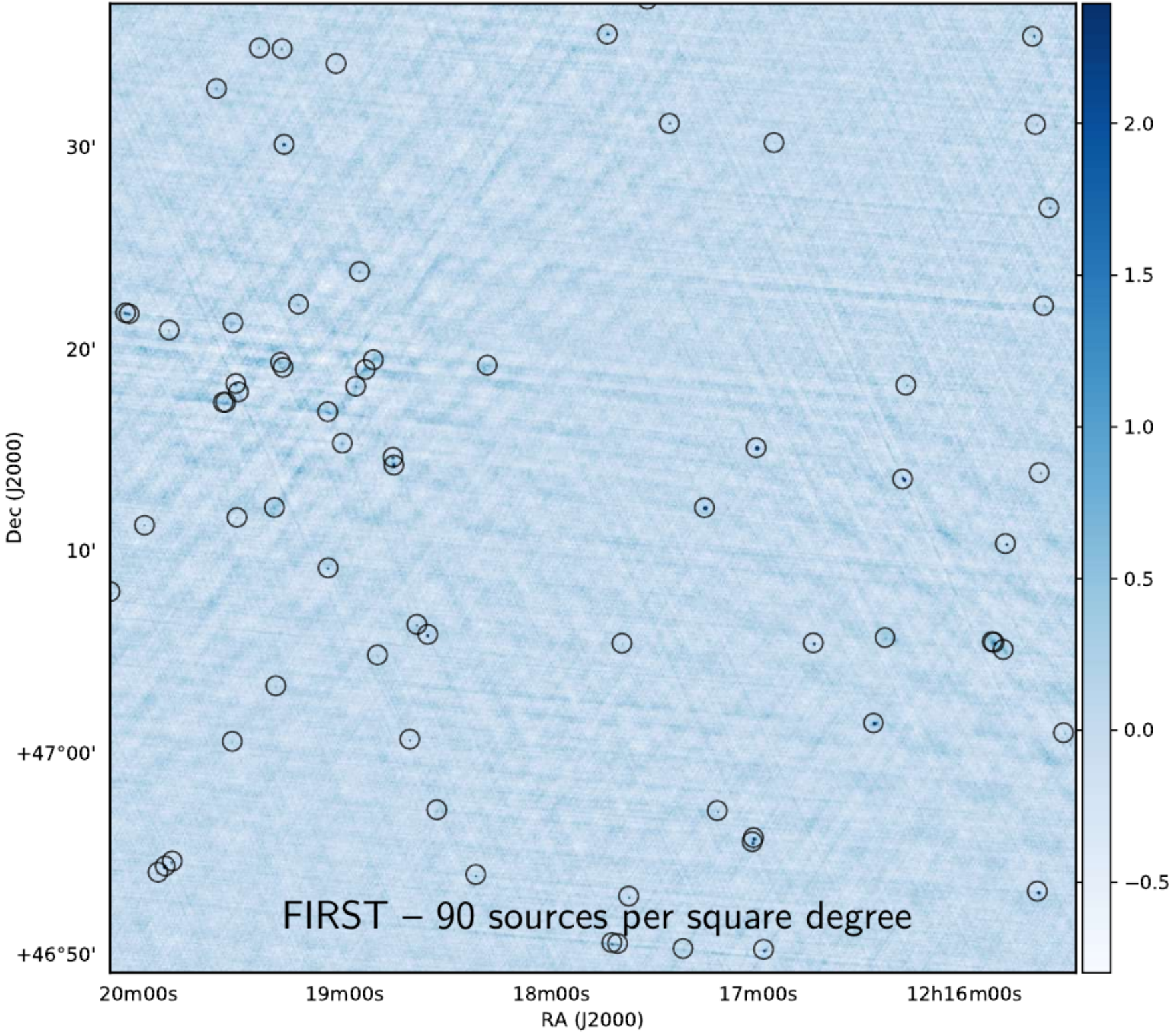


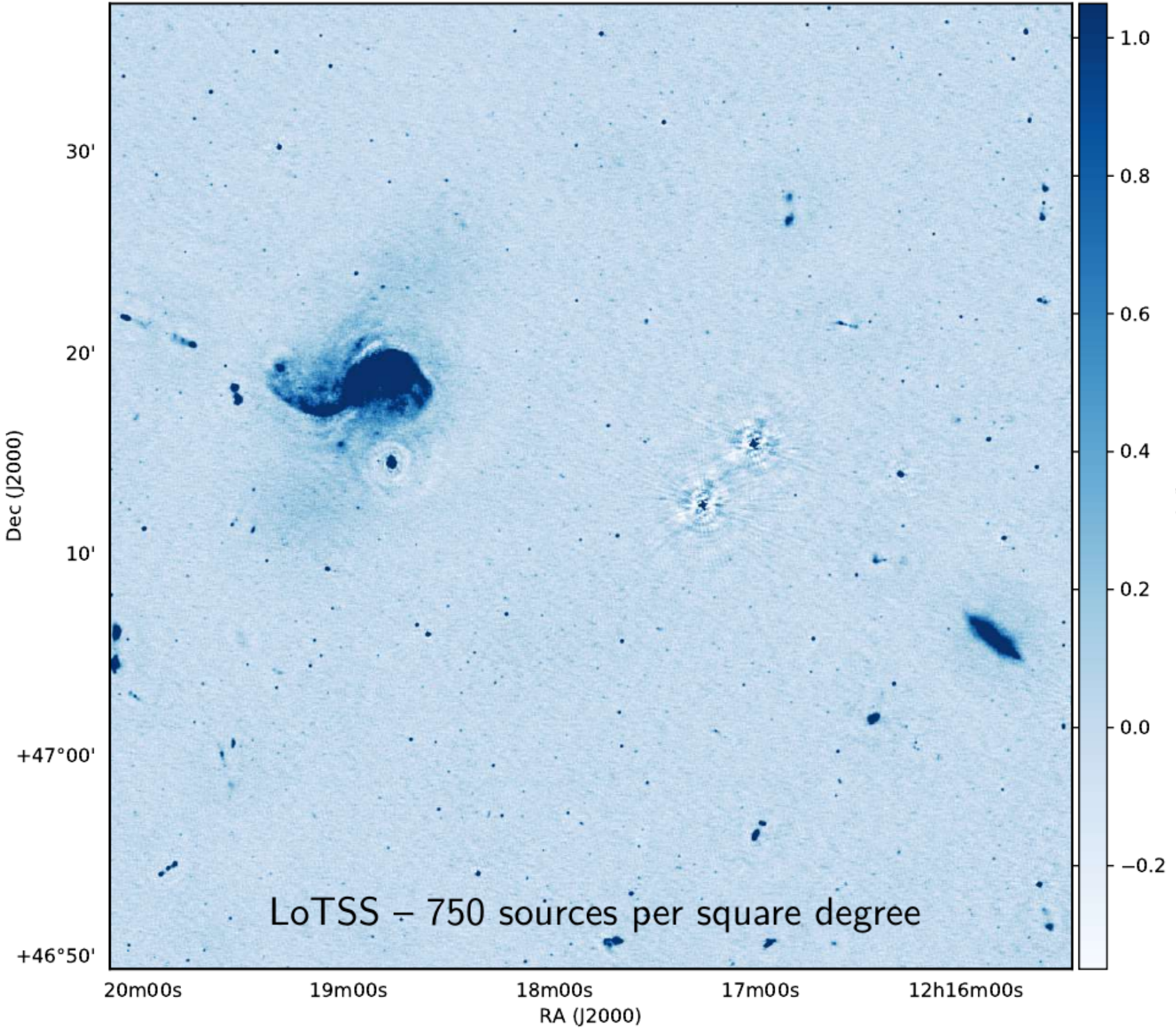
First data release

Direction-dependent calibration

KillMS + DDFacet

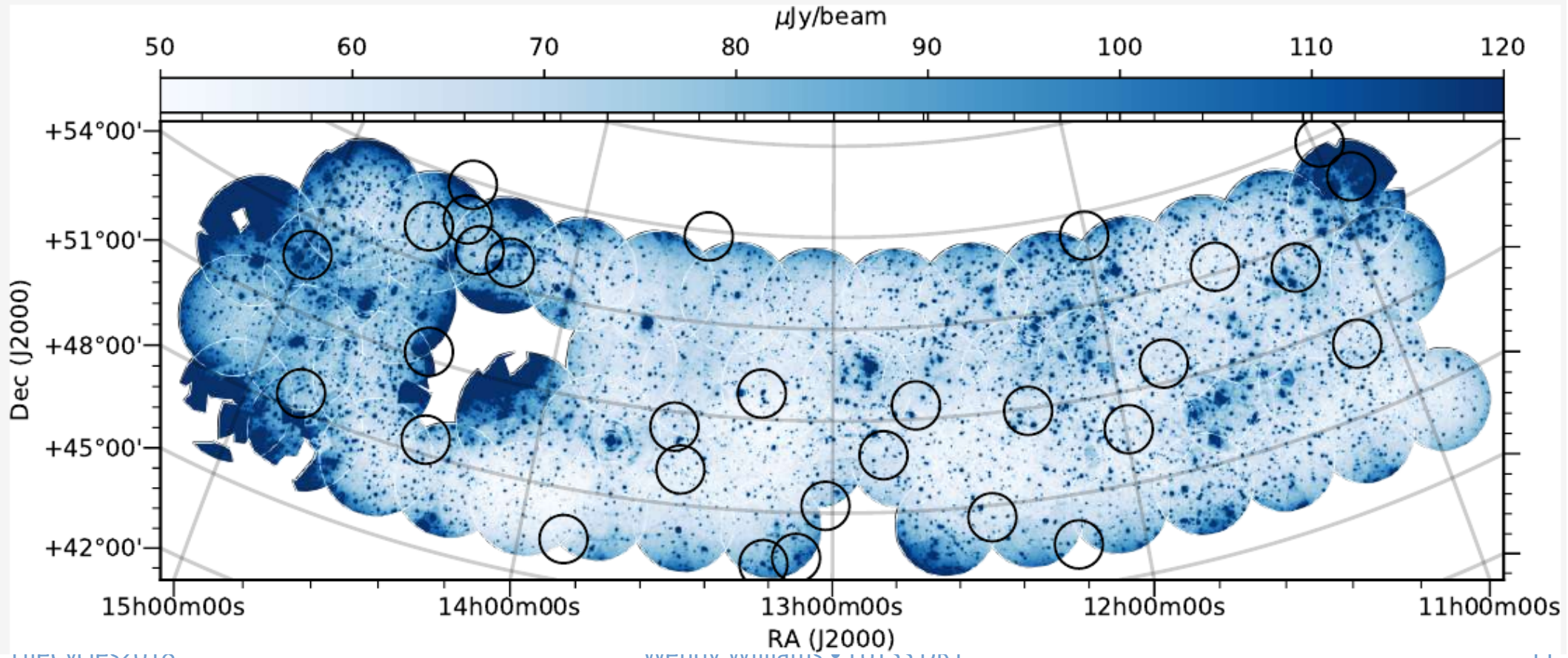

30'
20'
10'
+47°00'
+46°50'
Dec (J2000)
20m00s
19m00s
18m00s
17m00s
12h16m00s
RA (J2000)
8
6
4
2
0
−2
mJy/beam
NVSS – 50 sources per square degree


30'
20'
10'
+47°00'
+46°50'
Dec (J2000)
20m00s
19m00s
18m00s
17m00s
12h16m00s
RA (J2000)
2.0
1.5
1.0
0.5
0.0
−0.5
mJy/beam
FIRST – 90 sources per square degree


30'
20'
10'
+47°00'
+46°50'
Dec (J2000)
20m00s
19m00s
18m00s
17m00s
12h16m00s
RA (J2000)
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
mJy/beam
LoTSS – 750 sources per square degree

LoTSS First Data Release

- 6" resolution images with a sensitivity of 71μJy/beam
- 424 square degrees in the HETDEX Spring Field region
- The catalogue contains 325,694 radio sources (Shimwell+ in prep)
  - Raw PyBDSF source catalogues



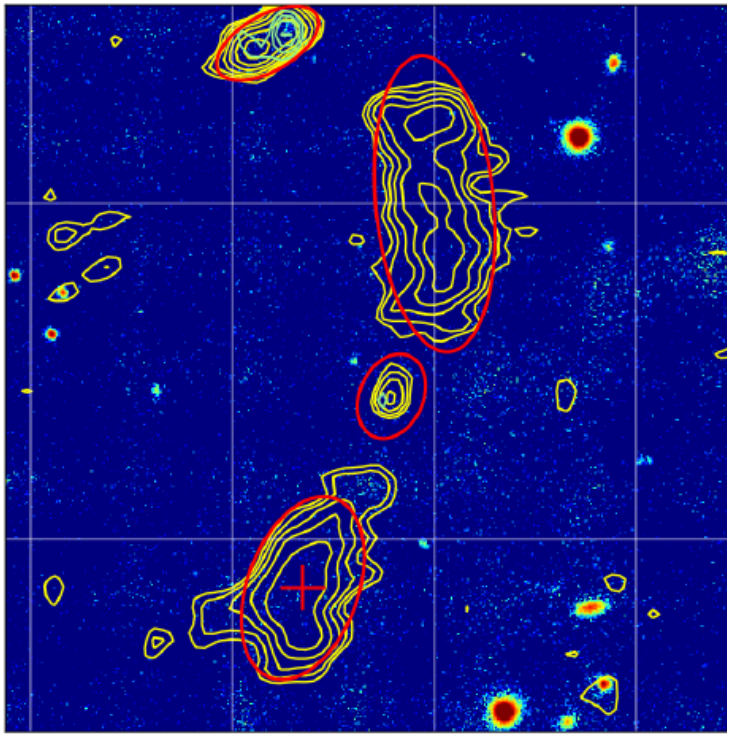
T. W. Shimwell C. Tasse M. J. Hardcastle A. P. Mechev
W. L. Williams P. N. Best H. J. A. Röttgering J. R. Callingham
T. J. Dijkema F. de Gasperin D. N. Hoang A. Horneffer B. Hugo
M. Mirmont J. B. R. Oonk I. Prandoni D. Rafferty J. Sabater
O. Smirnov R. J. van Weeren G. J. White M. Atemkeng L. Bester
E. Bonnassieux M. Brüggen G. Brunetti K. T. Chyży R. Cochrane
J. E. Conway J. Croston N. Danezi K. Duncan M. Haverkorn
G. H. Heald M. Iacobelli H. Intema M. Jamrozy N. Jackson
M. J. Jarvis R. Lakhoo M. Mevius G. K. Miley L. Morabito
R. Morganti D. Nisbet A. Offringa E. Orrú S. Perkins
R. F. Pizzo C. Schrijvers D. J. B. Smith S. van der Tol
R. Vermeulen M. W. Wise L. Alegre R. J. Beswick A. Botteon
S. Bourke A. Bonafede C. J. Conselice A. Drabent A. O. Clarke
C. Ferrari M. A. Garrett A. Goyal G. Gurkan C. Hale V. Heesen
M. Hoeft C. Horellou G. Kokotanekov R. Kondapally
M. Kunert-Bajraszewska V. Mahatma E. K. Mahony S. Mandal
A. Merloni B. Mingo S. Mooney B. Nikiel-Wroczyński S. O'Sullivan
C. Roskowiński A. Rowlinson A. Saxena A. Shulevski
S. Urquhart M. H. D. van der Wiel B. Webster et al

DR1 value-added catalogues

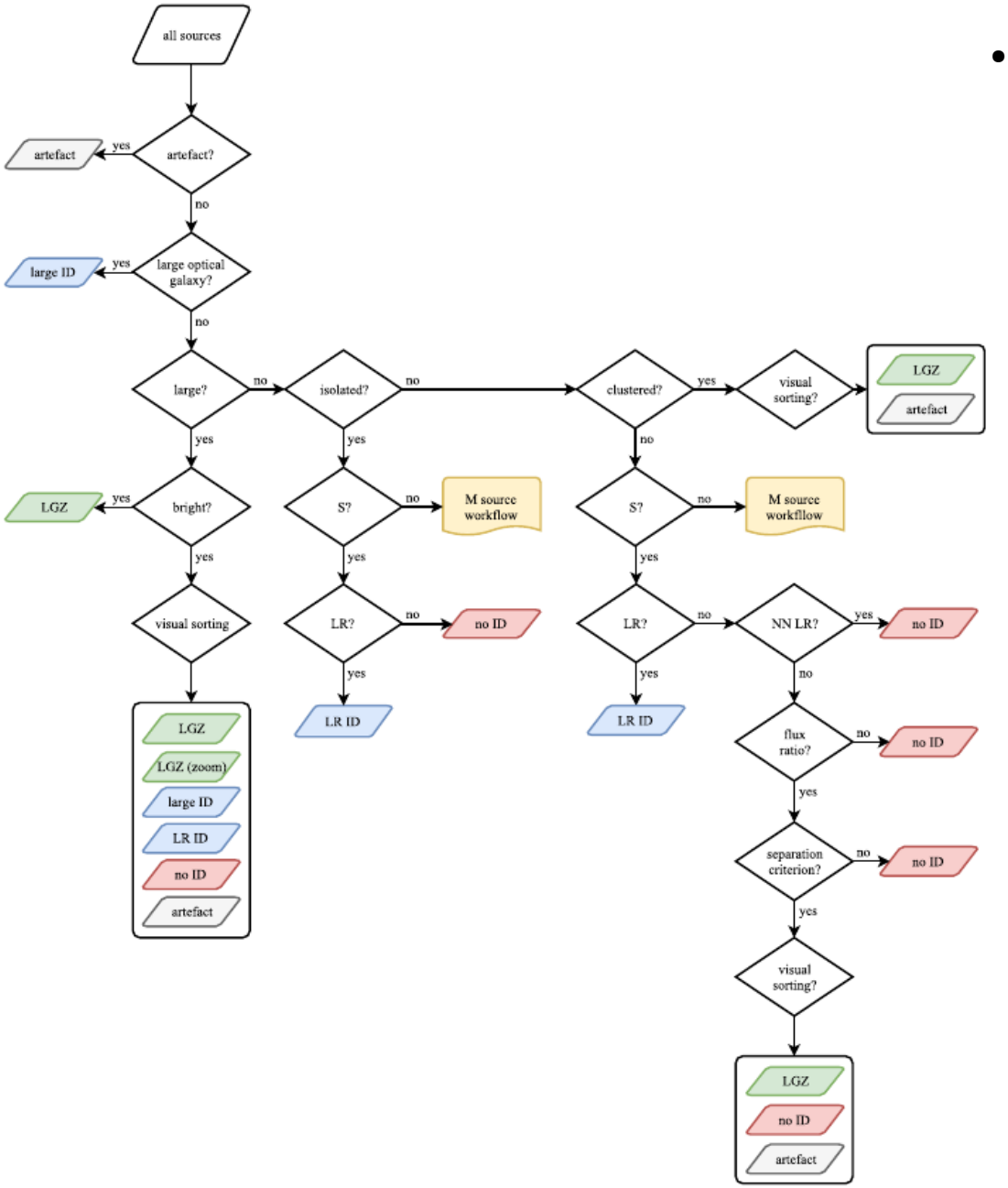
- Williams+ in prep

W. L. Williams[1⋆], M. J. Hardcastle[1], P. N. Best[2], J. Sabater[2], J. Croston[3], K. Duncan[4], T. W. Shimwell[5,4], H. J. A. Röttgering[4], D. Nisbet[2], L. Alegre[2], R. K. Cochrane[2], A. Goyal[6], G. Gürkan[7], C. L. Hale[8], N. Jackson[9], M. Jamrozy[6], R. Kondapally[2], M. Kunert-Bajraszewska[10], V. H. Mahatma[1], B. Mingo[3], L. K. Morabito[8], I. Prandoni[11], C. Roskowinski[10], A. Shulevski[12], D. J. B. Smith[1], C. Tasse[13,14], S. Urquhart[3], B. Webster[3], G. J. White[3,15], et al.

- Source association and deblending
- Optical identifications
  - likelihood ratios
  - visual association and identification
- PanSTARRS (grizy) & AllWISE (3.4, 4.6, 12, 22 μm)



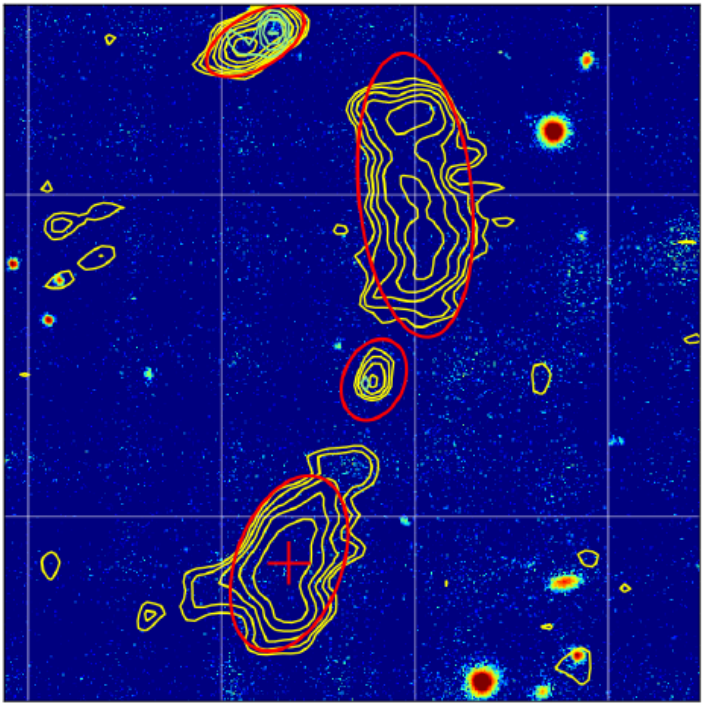
Identifying complex sources



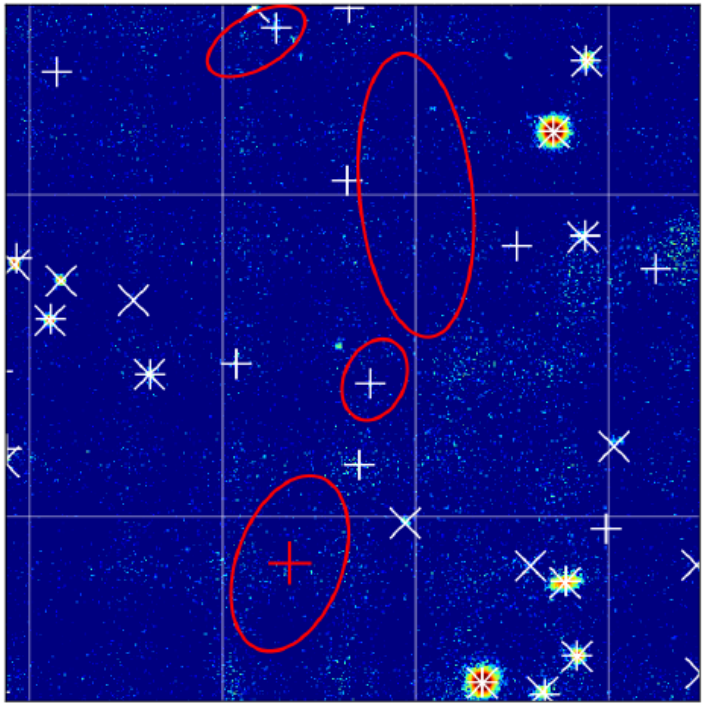
- Filtering based on PyBDSF source properties
  - Size
  - Flux
  - Distance to neighbours
  - ML matches
  - Gaussian components

LOFAR Galaxy Zoo

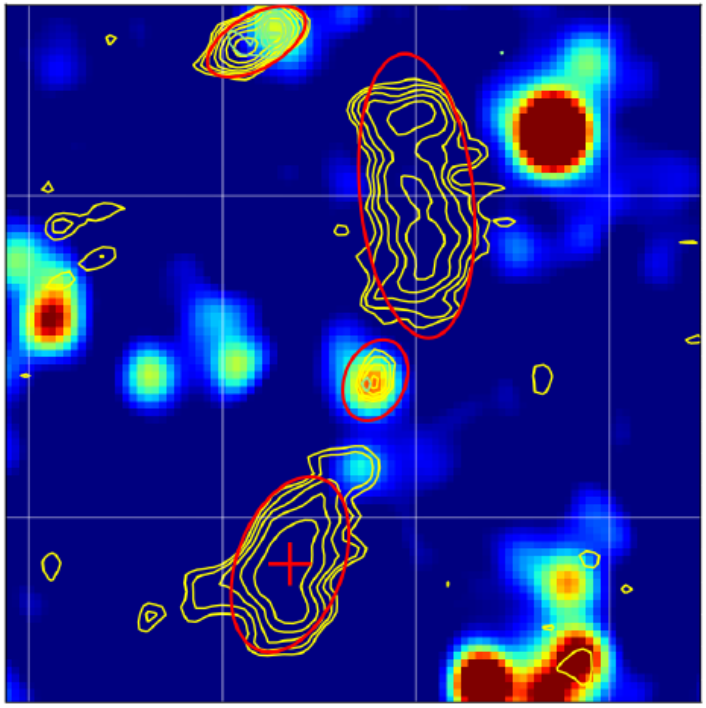
- Expert volunteers / KSP members
- 5 views per ‘source’
- Final outputs merged



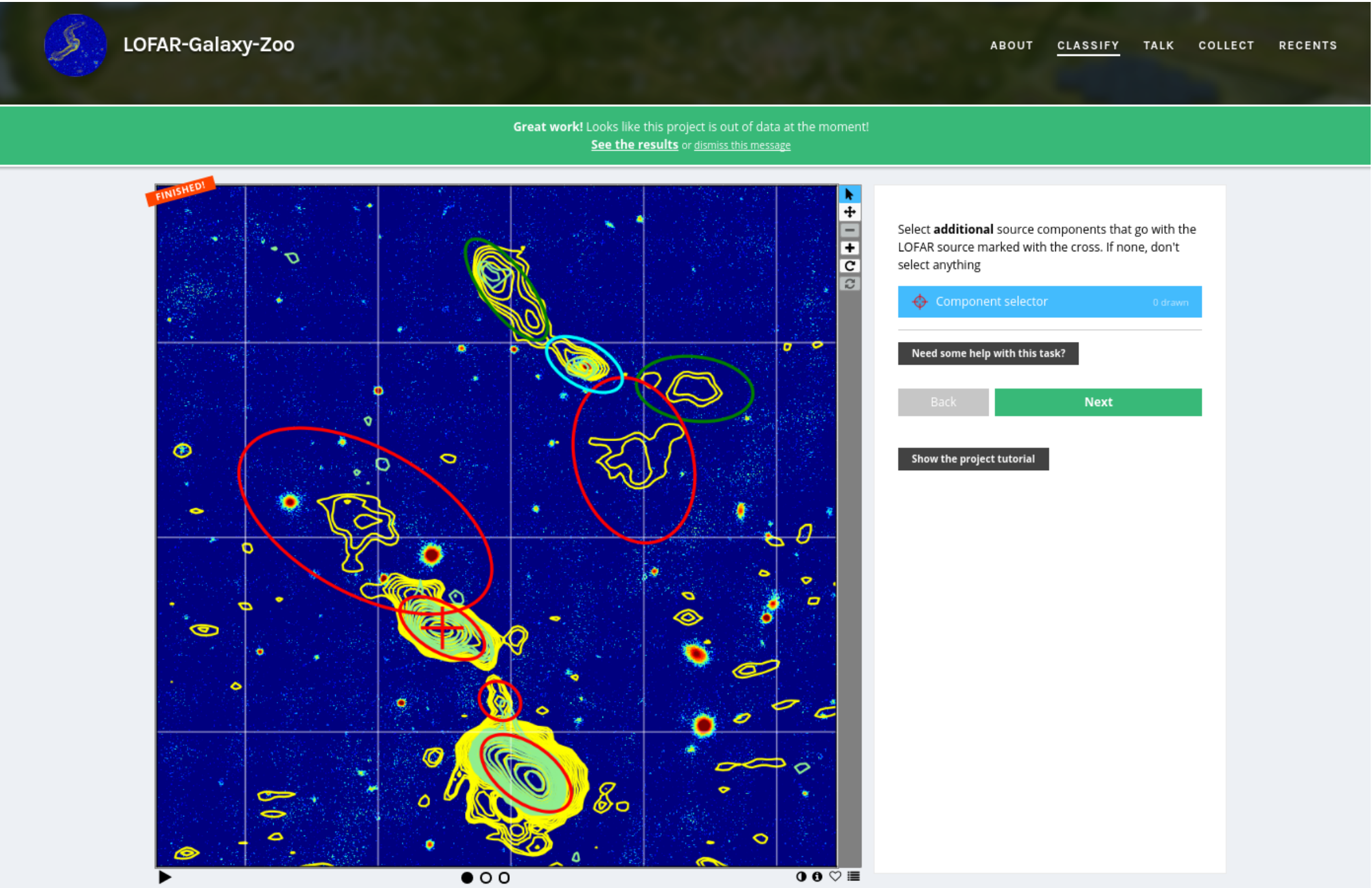
PanSTARRS r +LOFAR

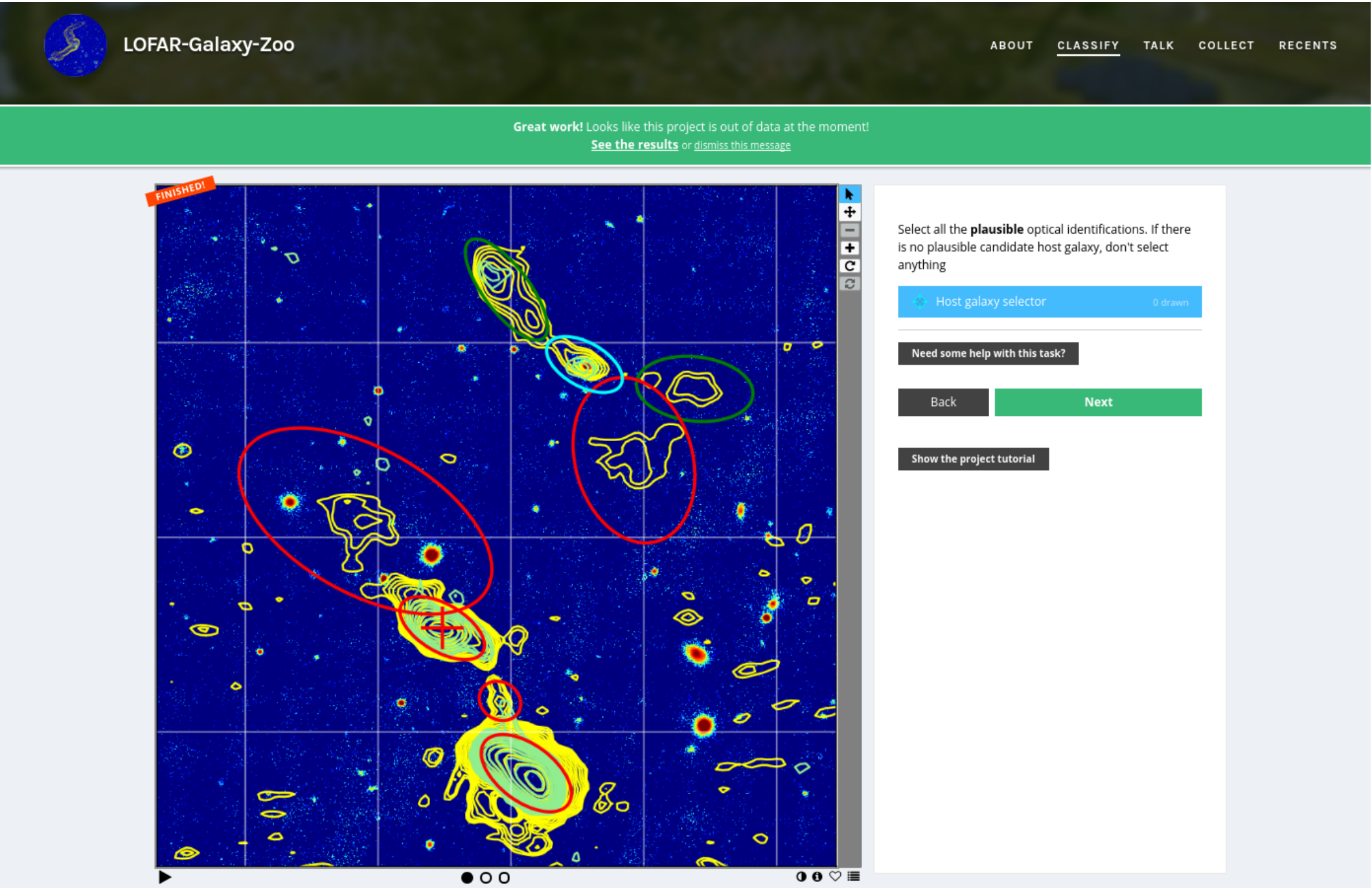


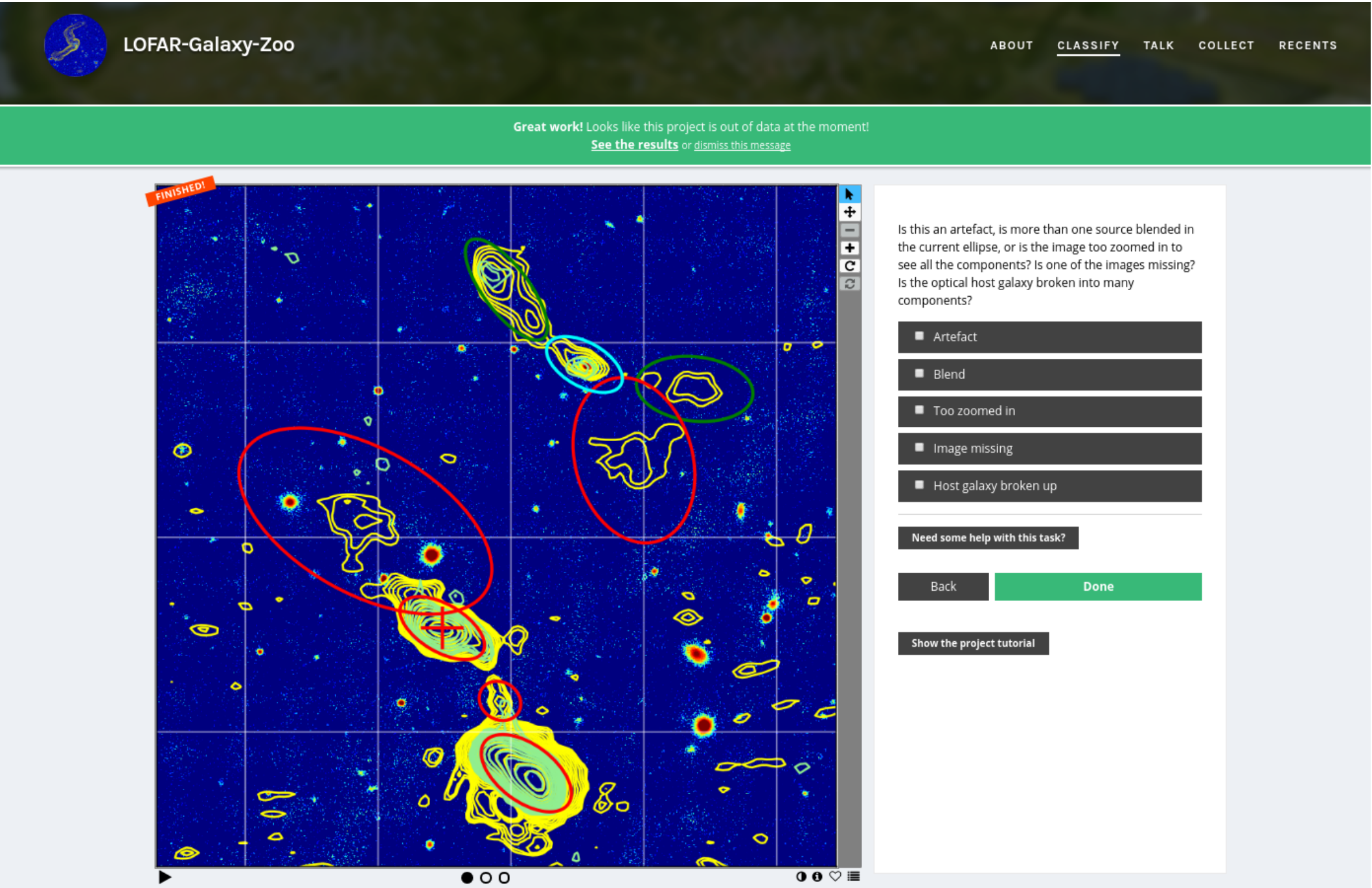
Catalogues only



WISE W1 + LOFAR

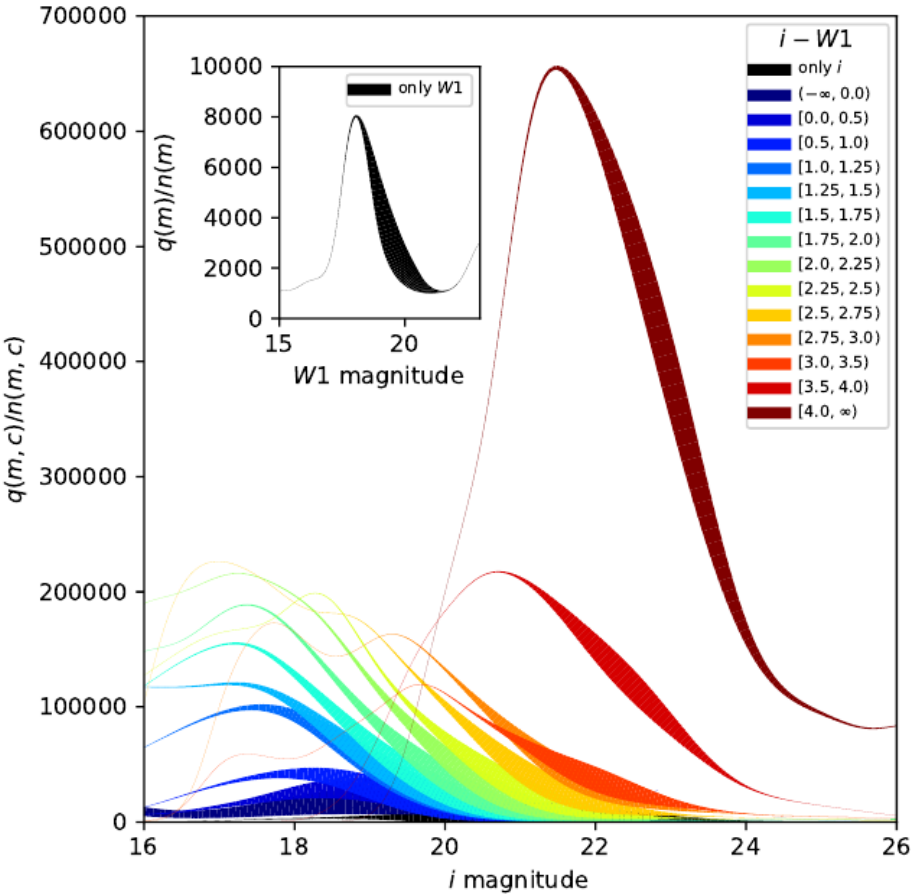

LOFAR-Galaxy-Zoo
ABOUT
CLASSIFY
TALK
COLLECT
RECENTS
Great work! Looks like this project is out of data at the moment!
See the results or dismiss this message
FINISHED!
Select additional source components that go with the LOFAR source marked with the cross. If none, don't select anything
Component selector
0 drawn
Need some help with this task?
Back
Next
Show the project tutorial

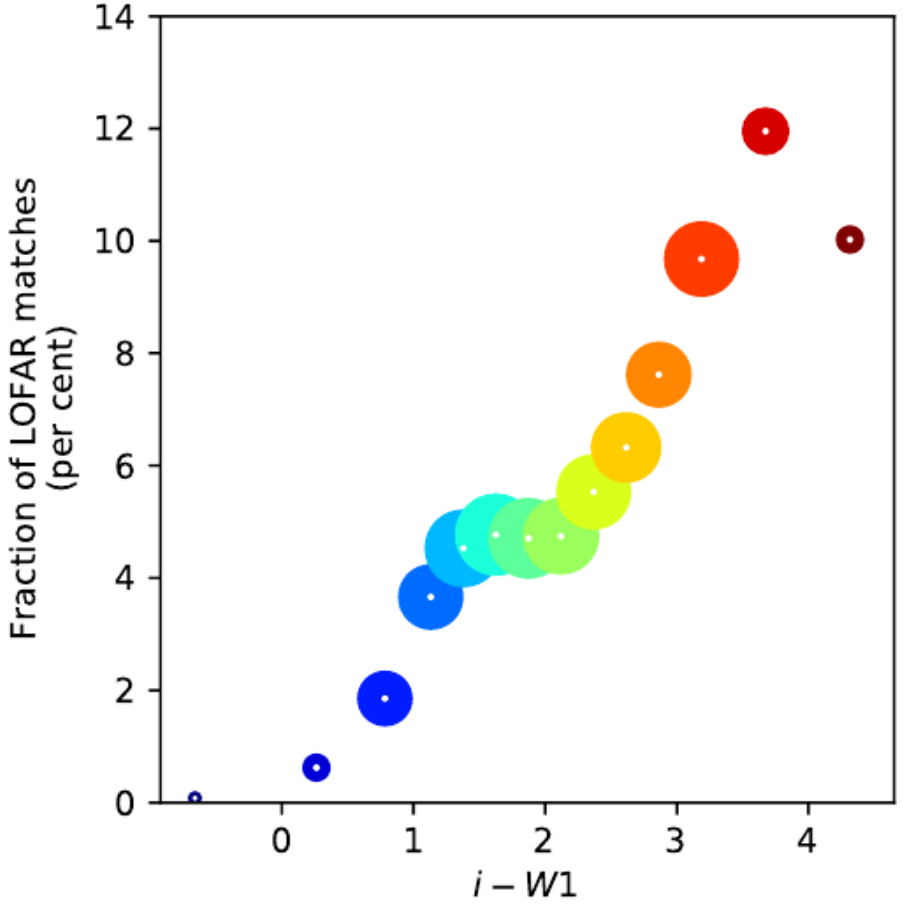

LOFAR-Galaxy-Zoo
ABOUT
CLASSIFY
TALK
COLLECT
RECENTS
Great work! Looks like this project is out of data at the moment!
See the results or dismiss this message
FINISHED!
Select all the plausible optical identifications. If there is no plausible candidate host galaxy, don't select anything
Host galaxy selector
0 drawn
Need some help with this task?
Back
Next
Show the project tutorial


LOFAR-Galaxy-Zoo
ABOUT
CLASSIFY
TALK
COLLECT
RECENTS
Great work! Looks like this project is out of data at the moment!
See the results or dismiss this message
FINISHED!
Is this an artefact, is more than one source blended in the current ellipse, or is the image too zoomed in to see all the components? Is one of the images missing? Is the optical host galaxy broken into many components?
Artefact
Blend
Too zoomed in
Image missing
Host galaxy broken up
Need some help with this task?
Back
Done
Show the project tutorial

Maximum likelihood matches

- For non-complex sources the optical IDs are determined from colour- and magnitude-dependent likelihood ratios





DR1 value added catalogue

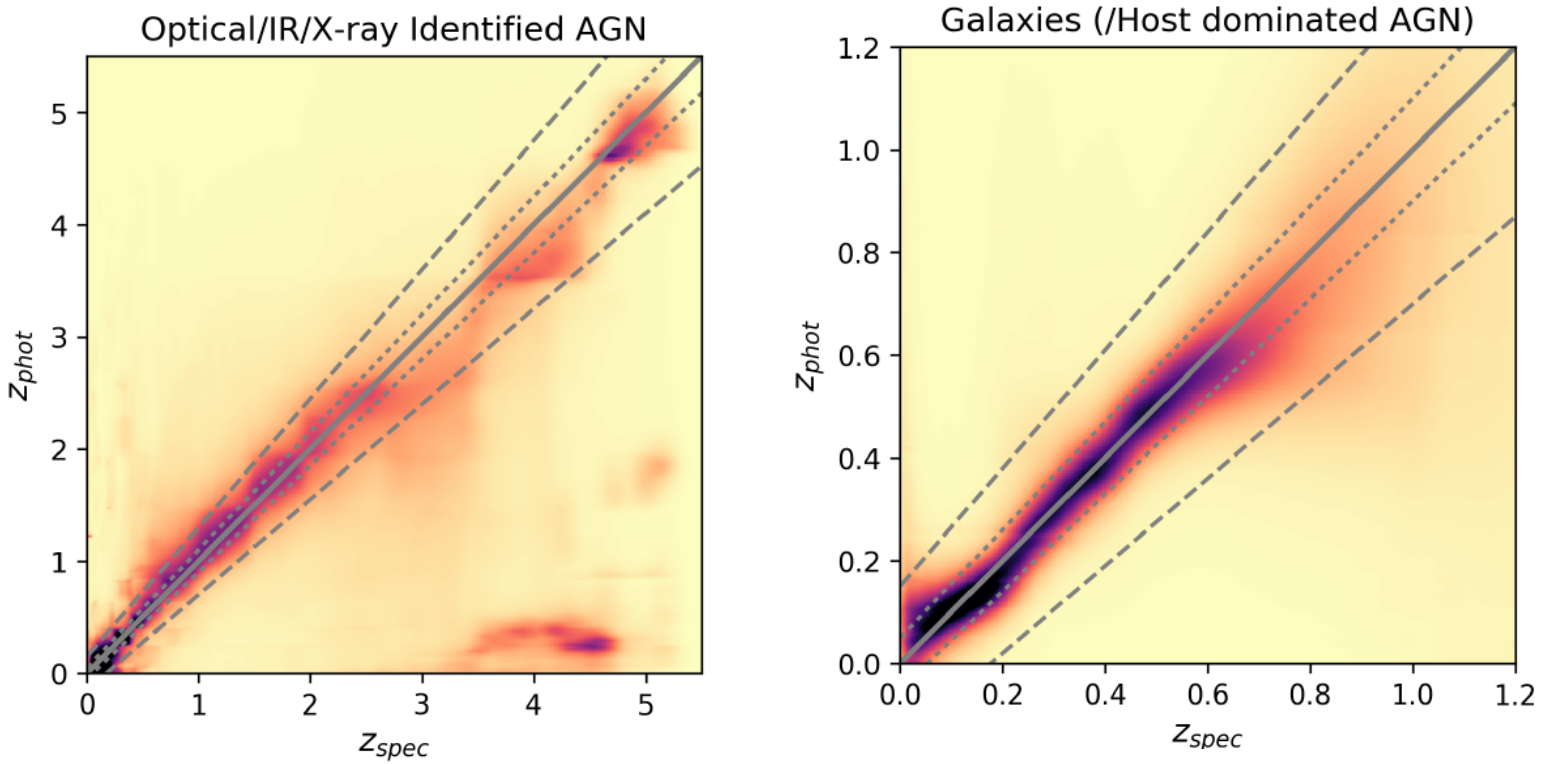
- Merged outputs of ML and LGZ IDs and deblending
- IDs for 225,457 sources (~70%)
  - Most from LR
  - But many interesting/bright source IDs/associations from LGZ

	Number	Number with ID	ID fraction
All Sources	318,602	225,457	0.71
LR	299,803	215,018	0.72
LGZ	12,028	7,161	0.60
De-blending	2,399	2,312	0.96
Bright galaxy	966	966	1.00
No ID possible	3,406	0	0.00

Photometric redshifts

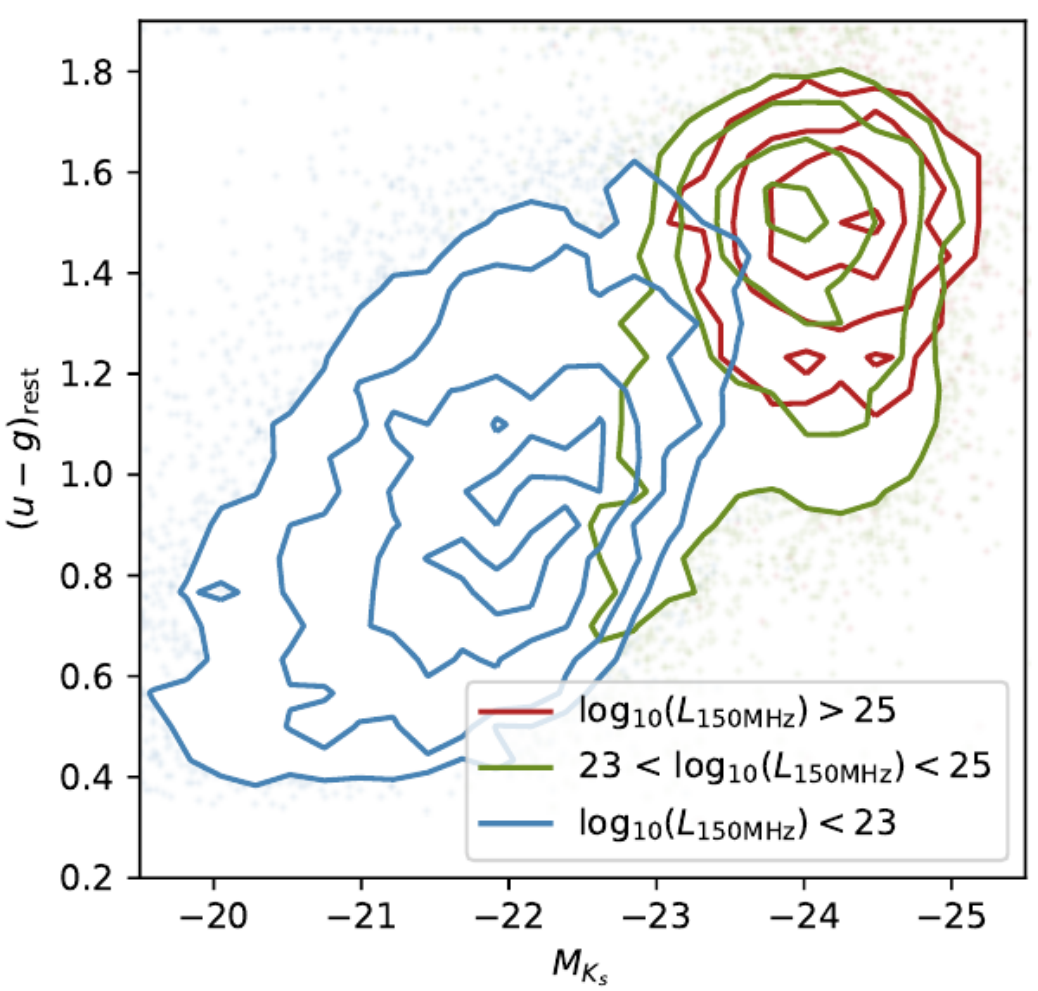
- photometric redshift estimates (Duncan+ in prep)
  - Using a combination of traditional template fitting and empirical training (ML) methods (Duncan+ 2017, 2018) for the diverse radio source population

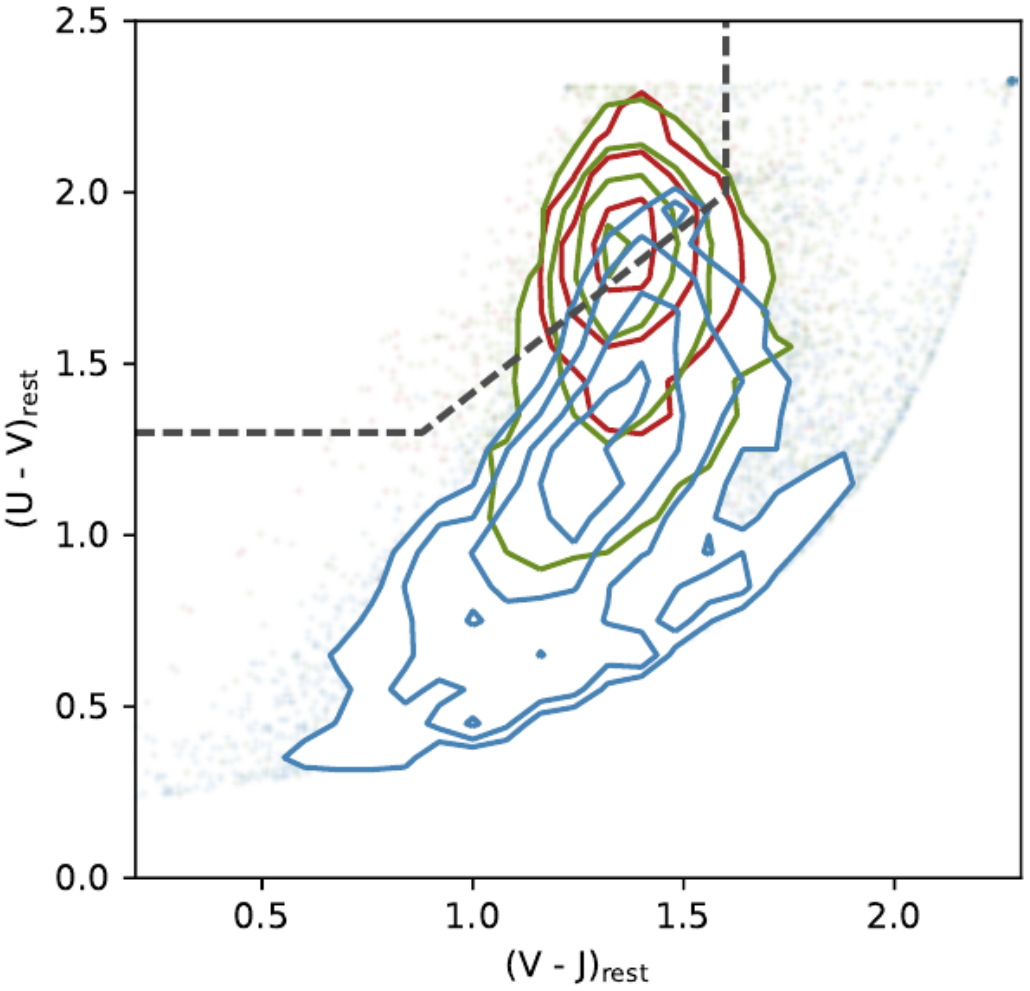
Kenneth J Duncan[⋆⋆1], J. Sabater Montes[2], H. J. A. Röttgering[1], M. J. Jarvis[3], P. N. Best[2], J. Callingham[4], R. Cochrane[2], J. Croston[5], M. J. Hardcastle[6], B. Mingo[5], L. Morabito[3], D. Nisbet[2], I. Prandoni[7], T. W. Shimwell[4,1], D. J. B. Smith[6], C. Tasse[8], G. J. White[5], and W. L. Williams[6]



Rest-frame colours

(Duncan+ in prep)



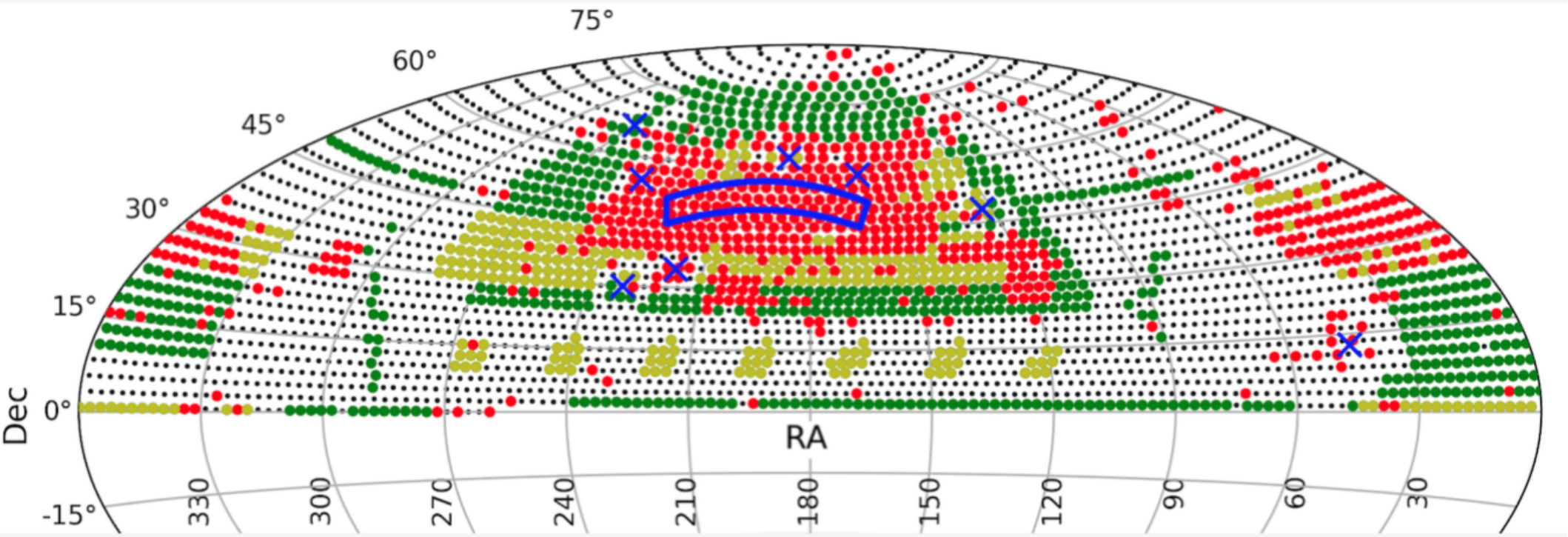


What's next...

- Wider area
- And deeper sensitivity
  - tier-2 fields: Bootes, ELAIS-N1, Lockman Hole
- And lower frequency
  - LBA
- And higher resolution
  - International stations

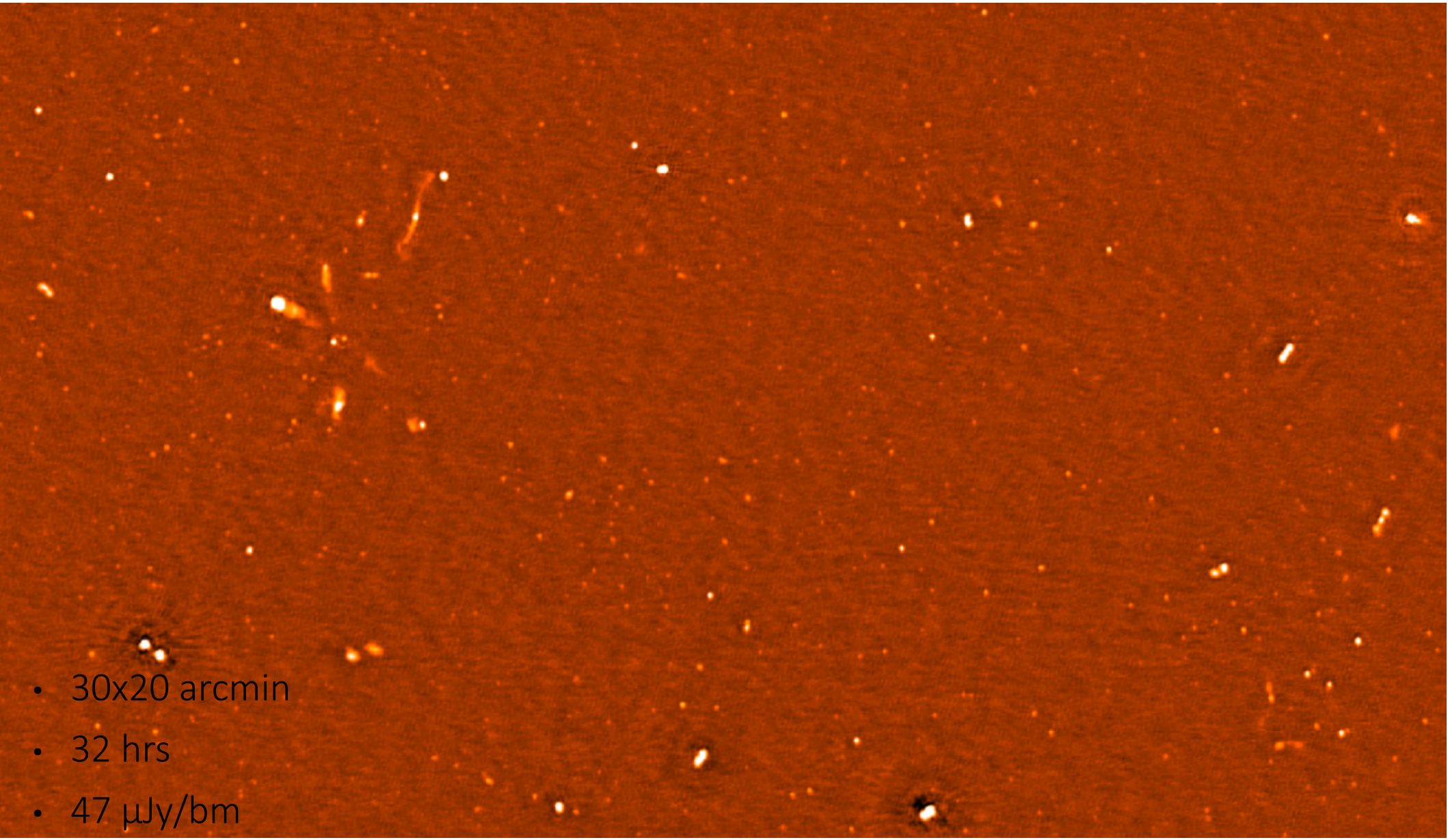
LoTSS progress

- 20% of northern sky observed
- 50% of the observed data is partially processed
- Proposal to take survey to 50% completeness in 2.5 yrs is under review



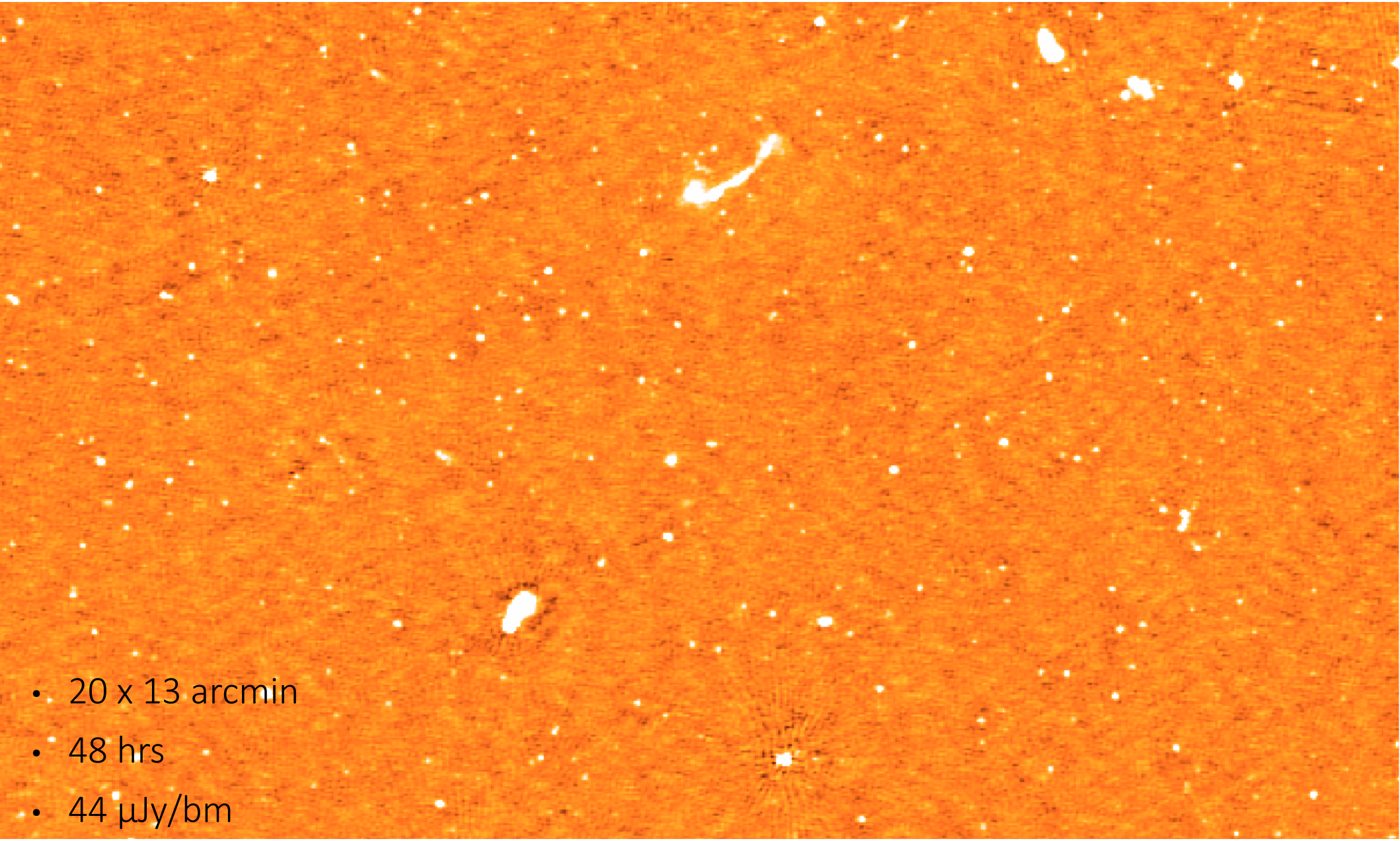
red – observed, yellow – proposed (priority high), green – proposed (priority low)

Tier 2 – Elais N1



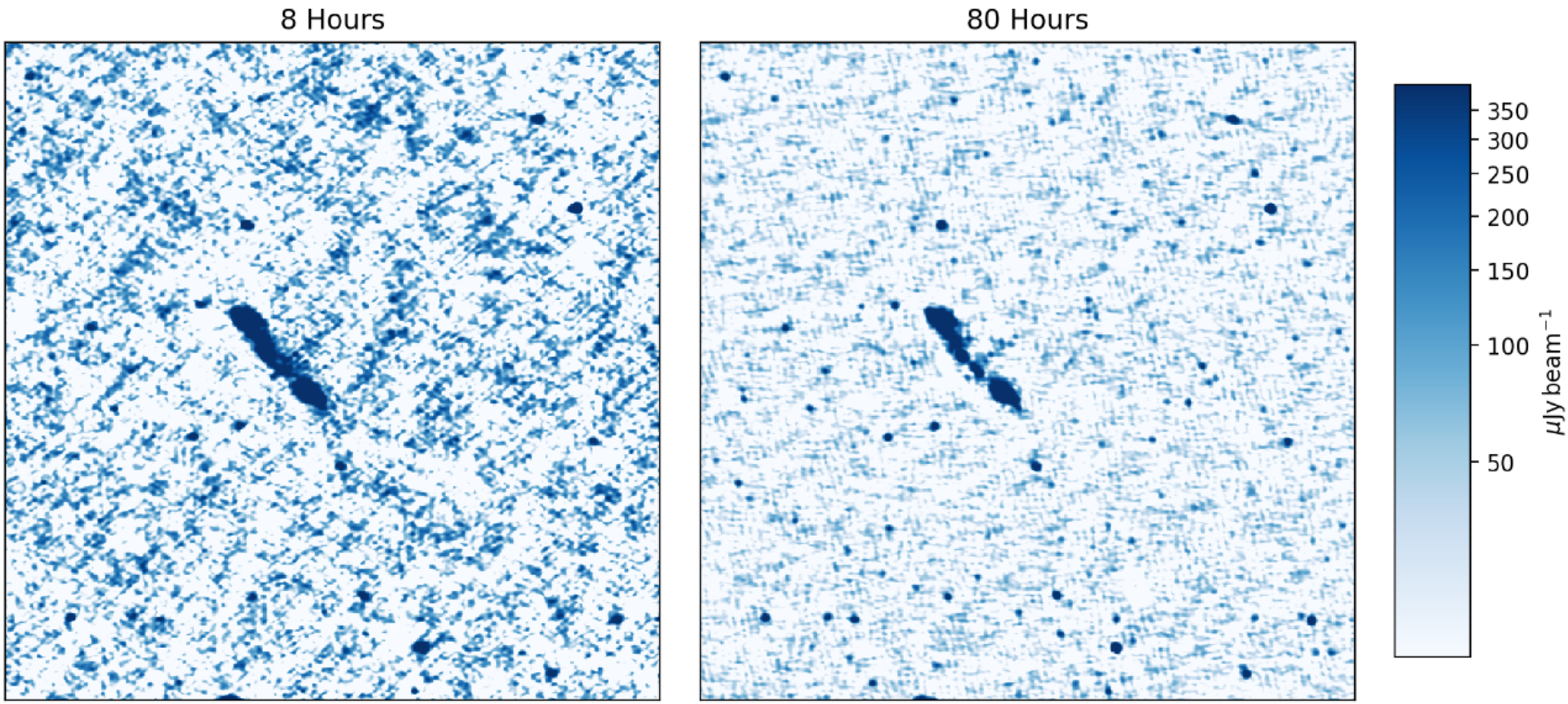
- 30x20 arcmin
- 32 hrs
- 47 μJy/bm

Tier 2 – Lockman Hole

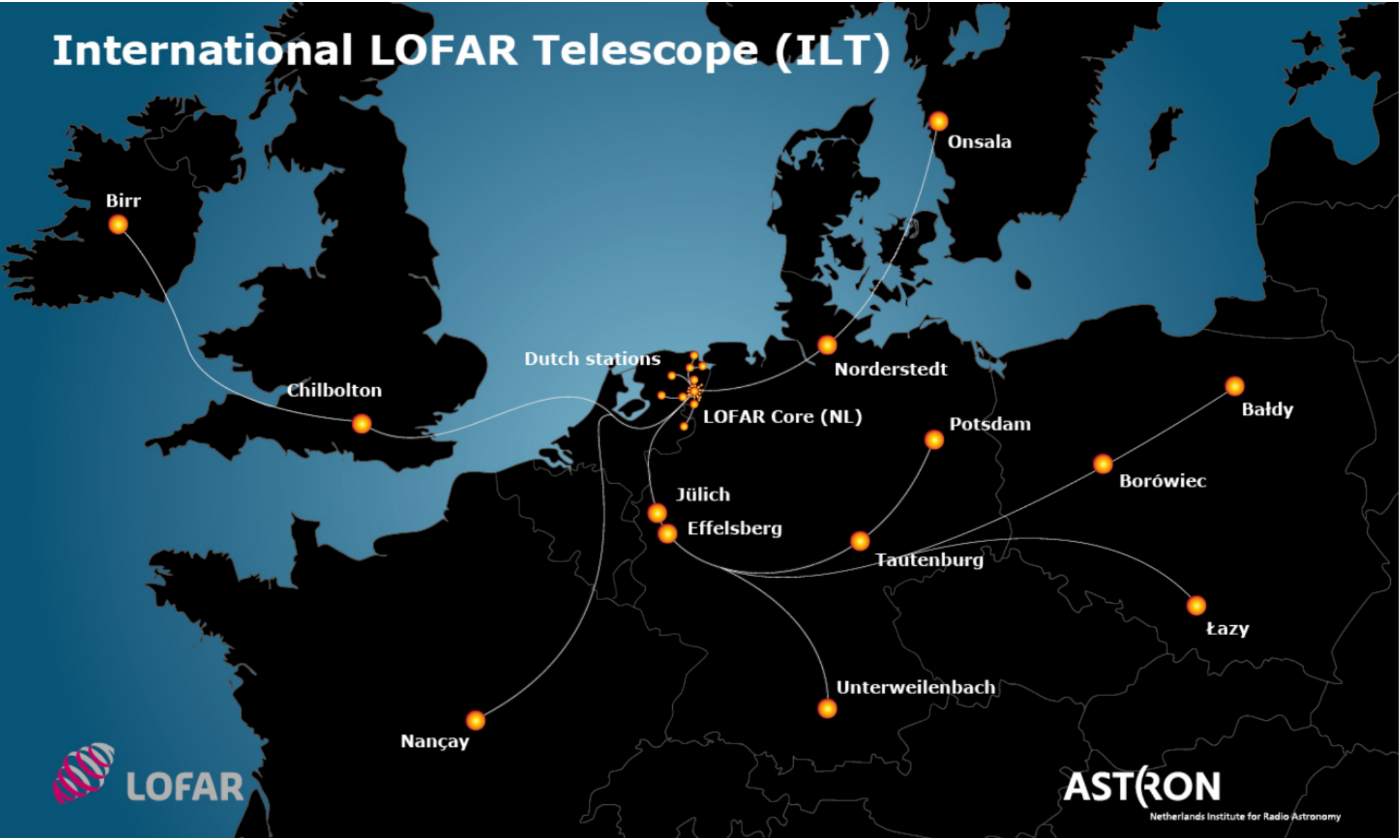


- 20 x 13 arcmin
- 48 hrs
- 44 μJy/bm

Tier 2 – Bootes

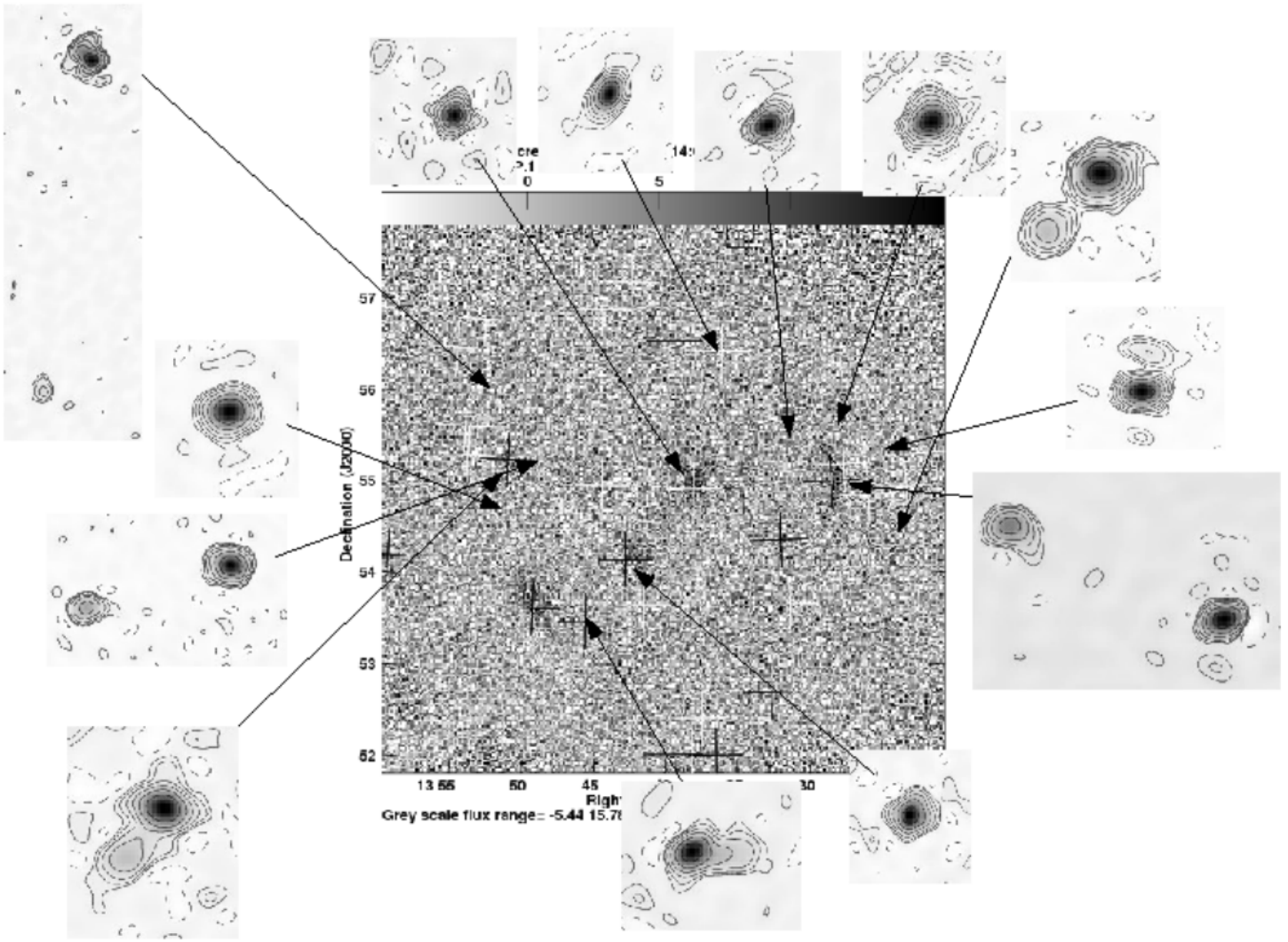


- 12x12 arcmin
- 80 hrs
- 40 μJy/bm
- (120 μJy/bm in 8 hrs)

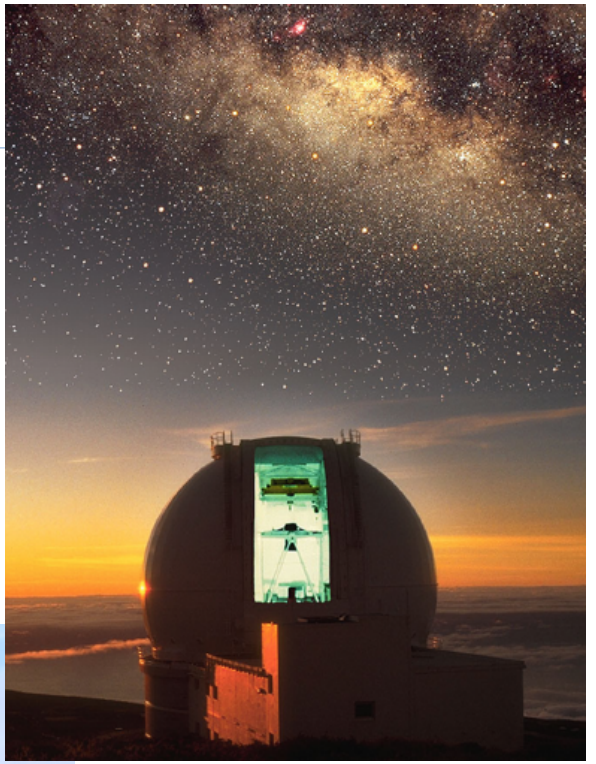

International LOFAR Telescope (ILT)
Onsala
Birr
Dutch stations
Norderstedt
Chilbolton
LOFAR Core (NL)
Potsdam
Bałdy
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Unterweilenbach
Nançay
LOFAR
ASTRON
Netherlands Institute for Radio Astronomy

International stations

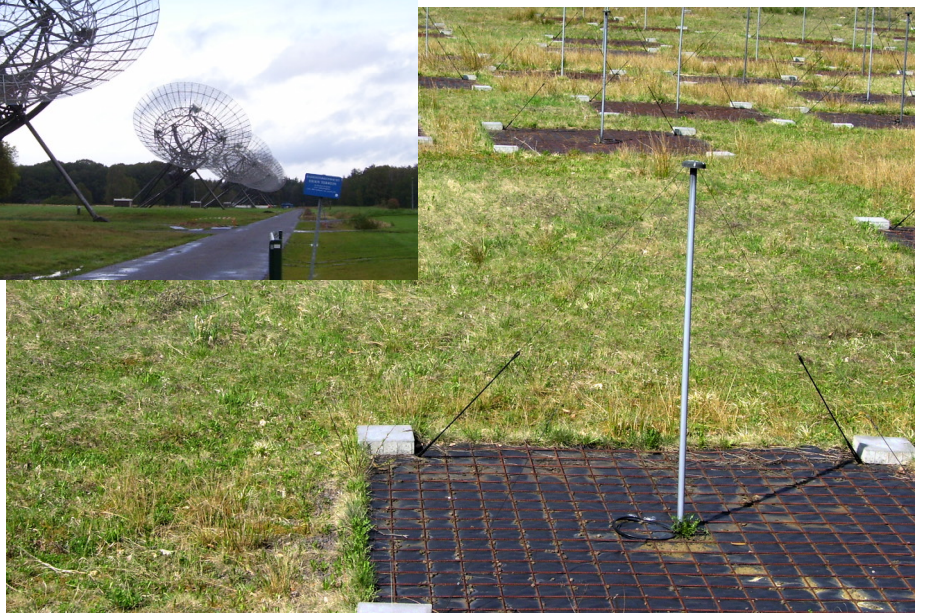
- 450mas resolution LoTSS images of sources up to 3 degrees from the pointing centre (by Neal Jackson and the long baseline working group)

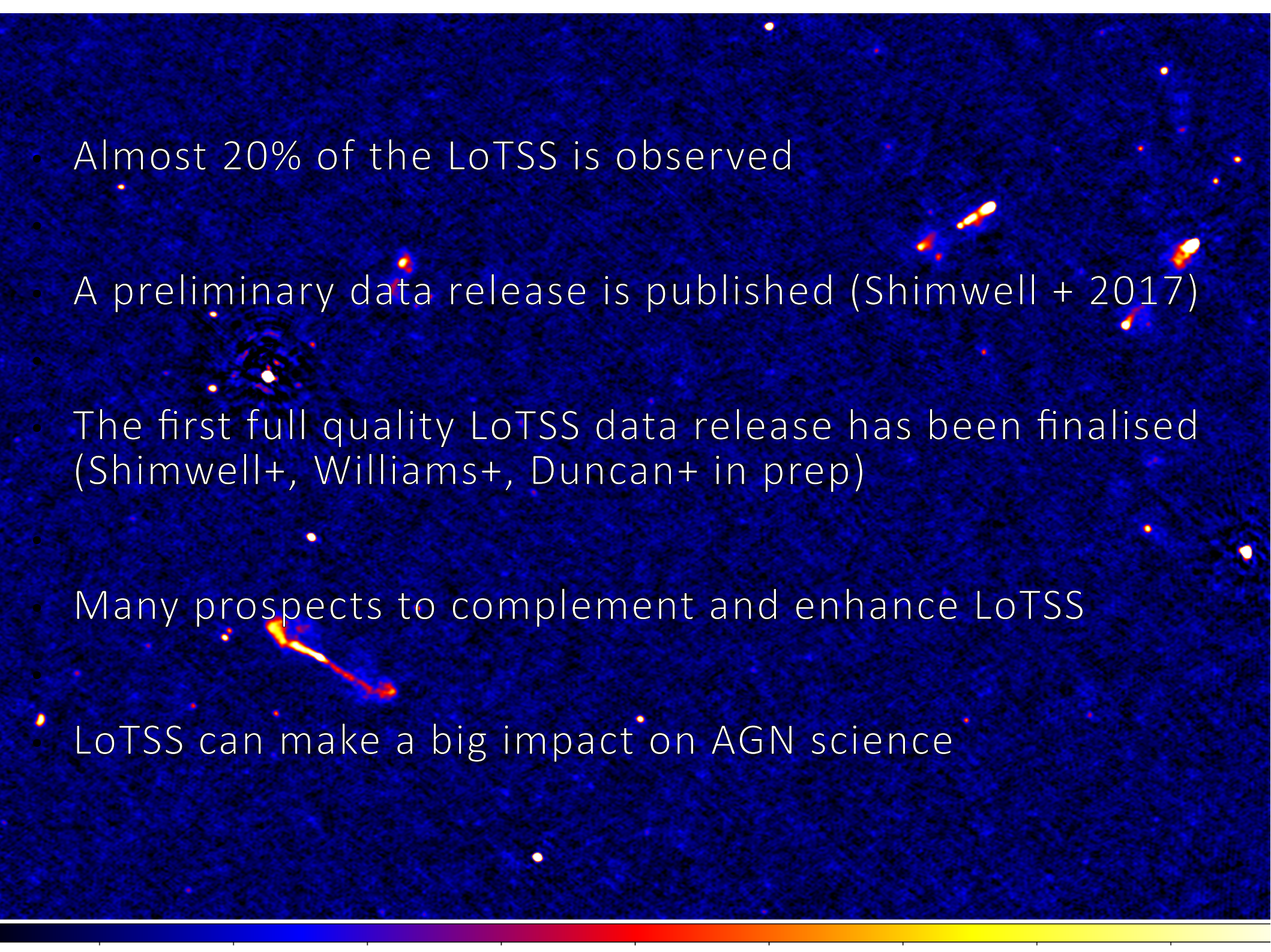


Follow-up surveys



- WEAVE-LOFAR:
  - WEAVE on the William Hershel Telescope
  - Spectroscopic follow up of half a million LOFAR sources.
  - starting in 2018
  - Smith et al. 2016
- LOFAR-LBA:
  - ~1mJy/beam
  - survey at 50-70 MHz
- Apertif/EMU:
  - 10μJy/beam
  - surveys at 1.1-1.4 GHz




Almost 20% of the LoTSS is observed
A preliminary data release is published (Shimwell + 2017)
The first full quality LoTSS data release has been finalised (Shimwell+, Williams+, Duncan+ in prep)
Many prospects to complement and enhance LoTSS
LoTSS can make a big impact on AGN science