The LOFAR Two-metre Sky Survey (LoTSS)

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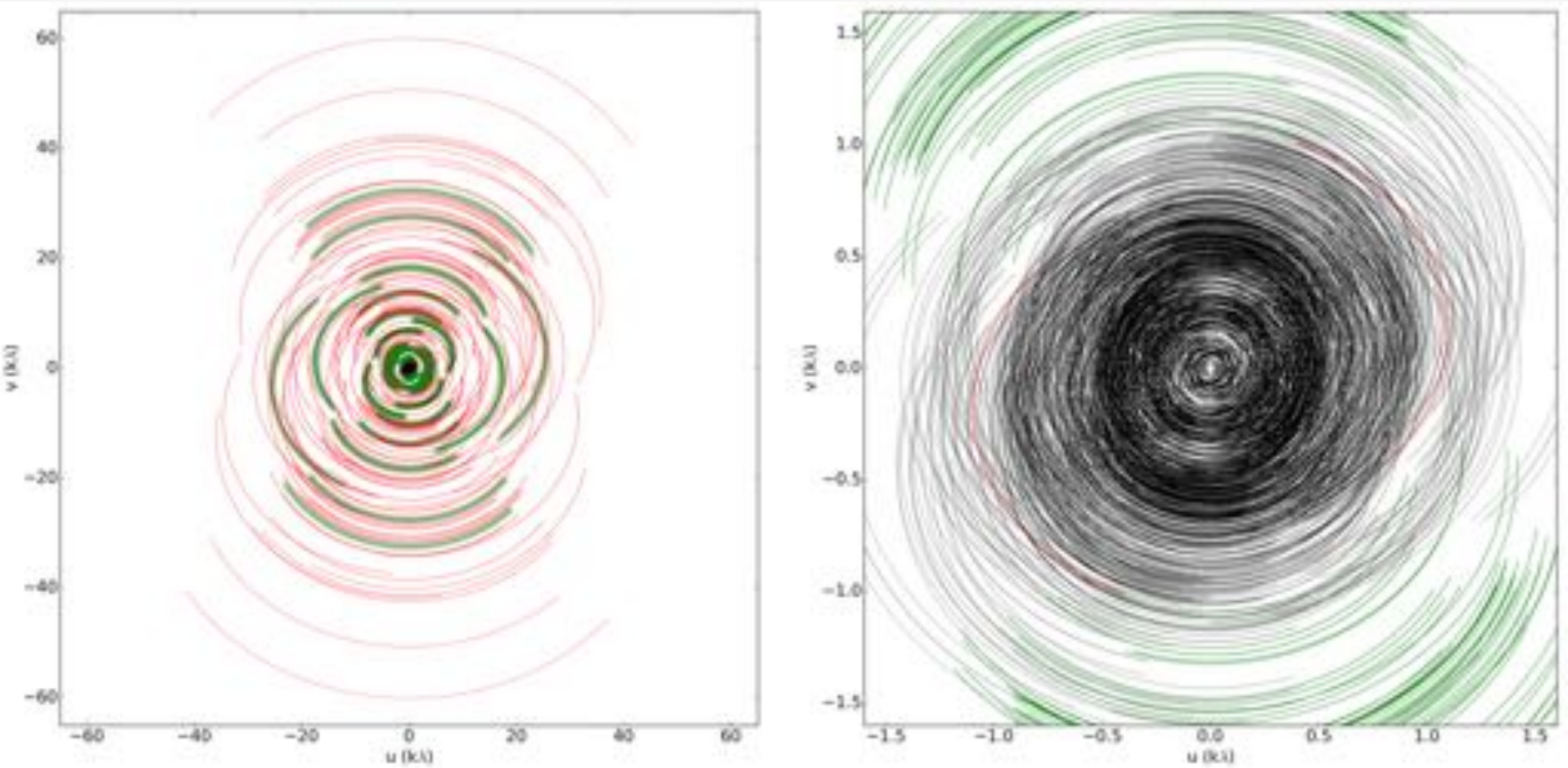
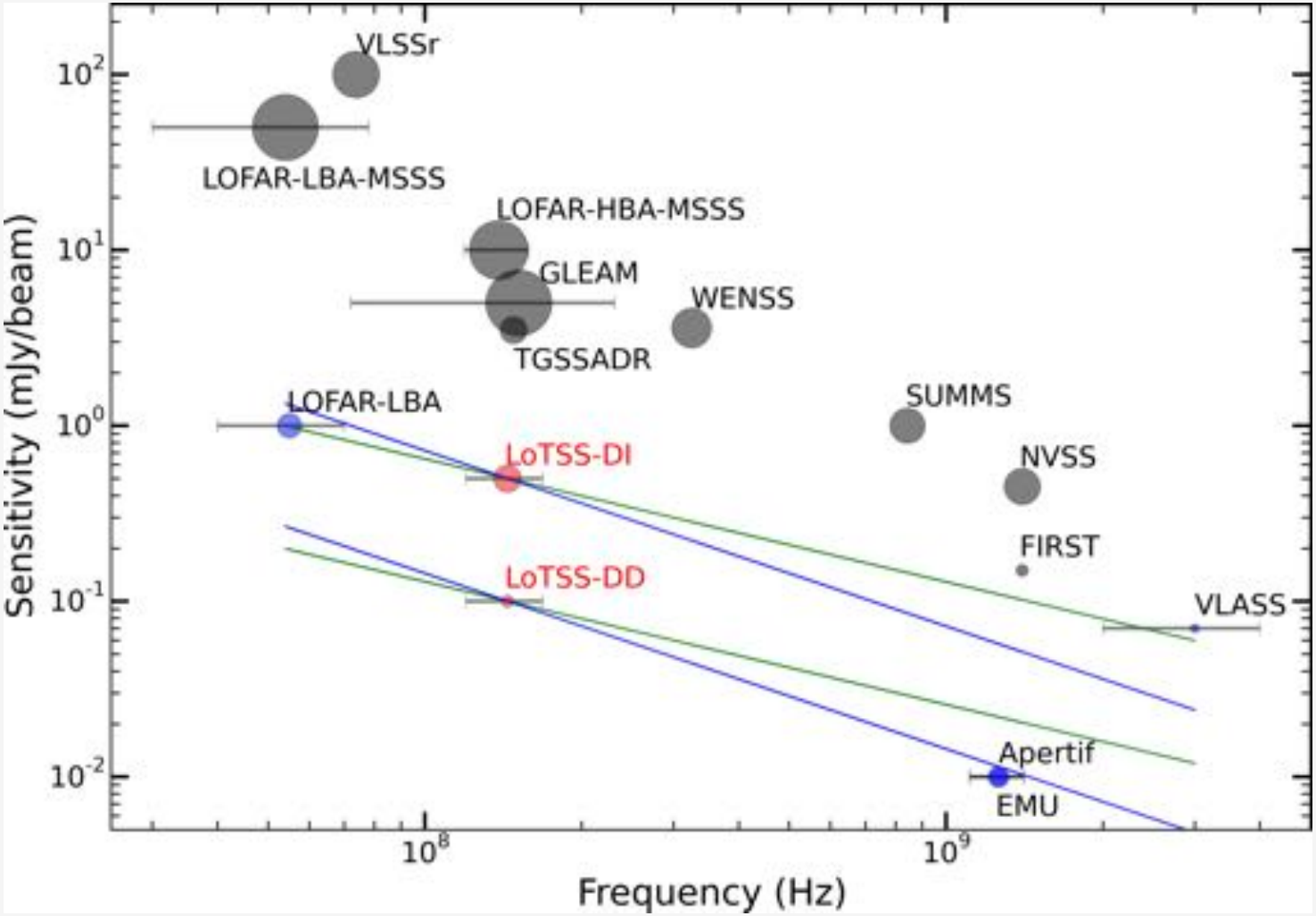
Slide from Roberto Pizzo.



Monochromatic uv-coverage of 8 hr LOFAR observation at 150 MHz (24 core stations and 12 remote).

LOFAR can perform two 120-168 MHz observations simultaneously. Each is capable of producing 5" resolution and 100μJy/beam sensitivity images over a FWHM of $\sim$4deg.

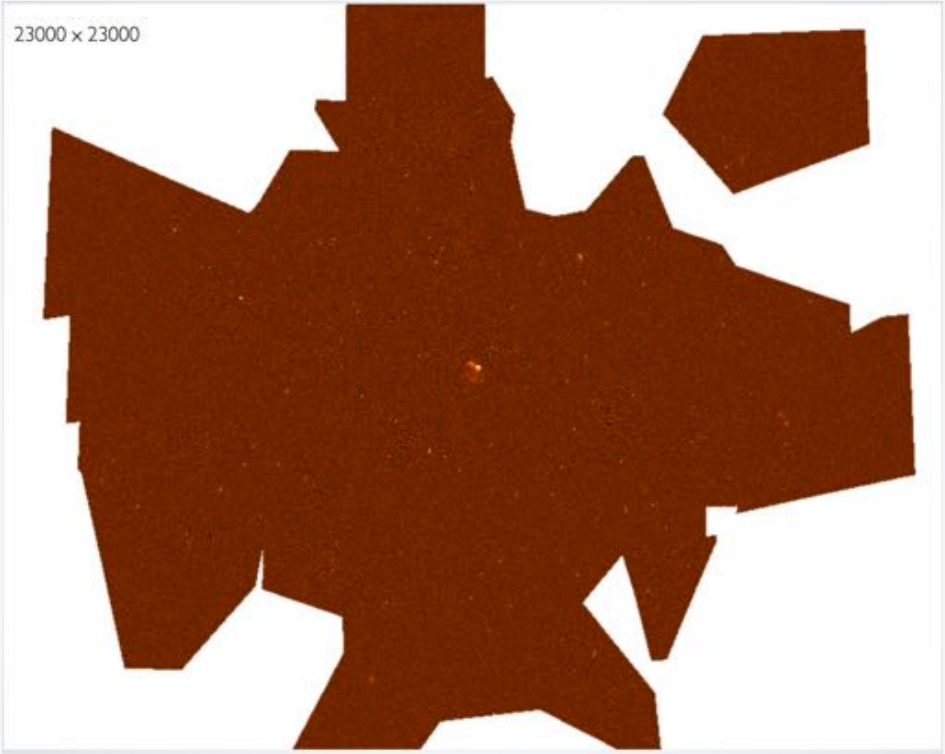
Why do a low frequency survey



Green $\alpha = -0.7$. Blue $\alpha = -1.0$.

The observational aims of LoTSS

- ≈5" resolution
- ≈100μJy/beam sensitivity at most declinations
- 48 MHz bandwidth (from 120 MHz to 168 MHz) towards each pointing
- 3170 8hr pointings to cover the northern sky (∼14,000 hrs)
- Data archived at 1 s and 12.2 kHz resolution to facilitate spectral line and international baseline studies.



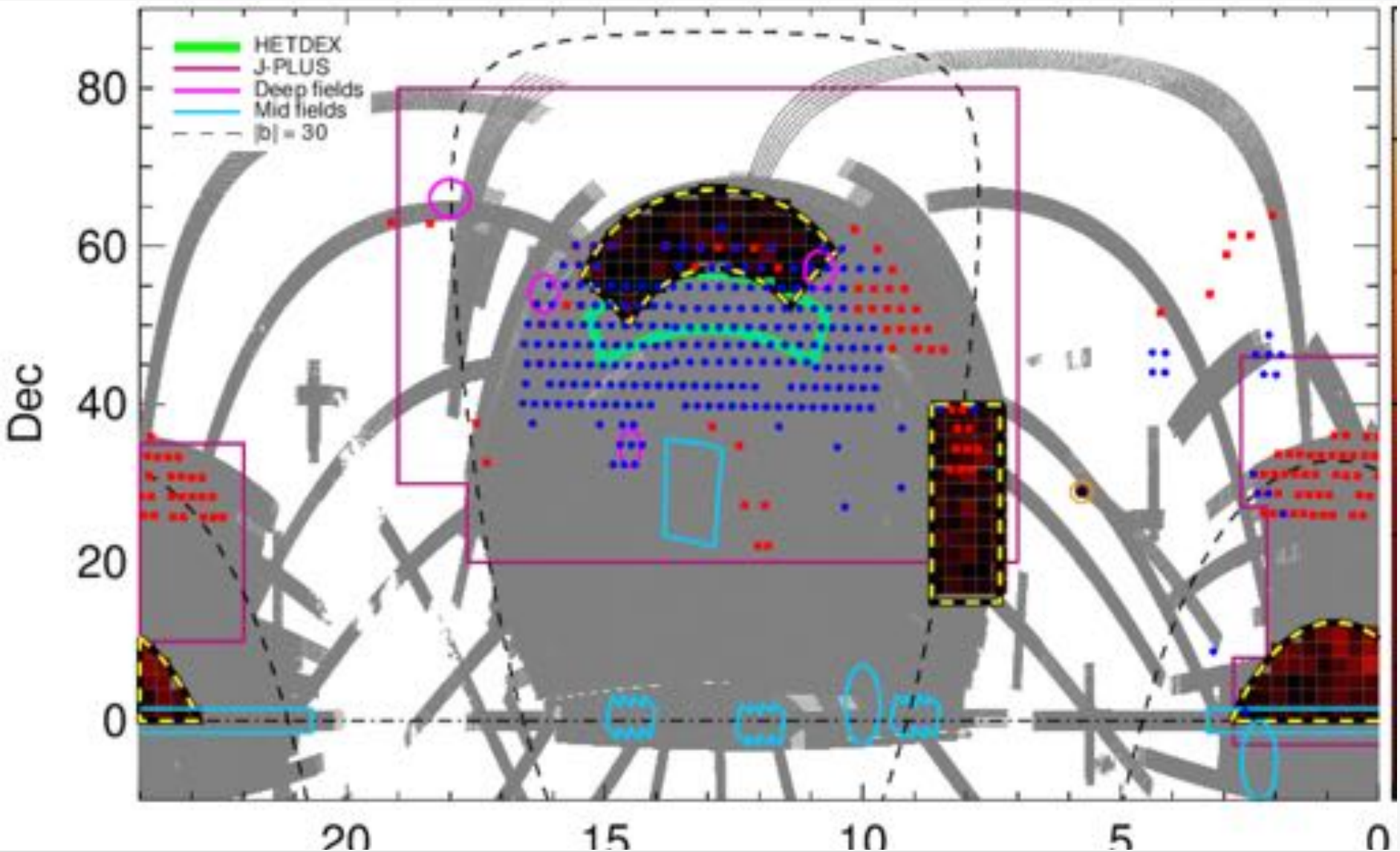
Demonstrating the LOFAR capabilities with a 10 hr observation of a cluster field. The image noise level is 100μJy/beam and the resolution is 5" (by Reinout van Weeren).

The scientific aims of the survey

- PI: Huub Röttgering
- Highest redshift radio sources: George Miley
- Clusters and cluster halo sources: Gianfranco Brunetti & Marcus Brügen
- Starforming galaxies at moderate and high redshifts: Peter Barthel & Matt Lehnert
- AGN at moderate redshift: Philip Best
- Detailed studies of low-redshift AGN: Raffaella Morganti
- Nearby Galaxies: Krzysztof Chyzy & John Conway
- Gravitational lensing: Neal Jackson
- Galactic radio sources: Glenn White
- Cosmological studies: Matt Jarvis
- 164 members from 54 institutions.

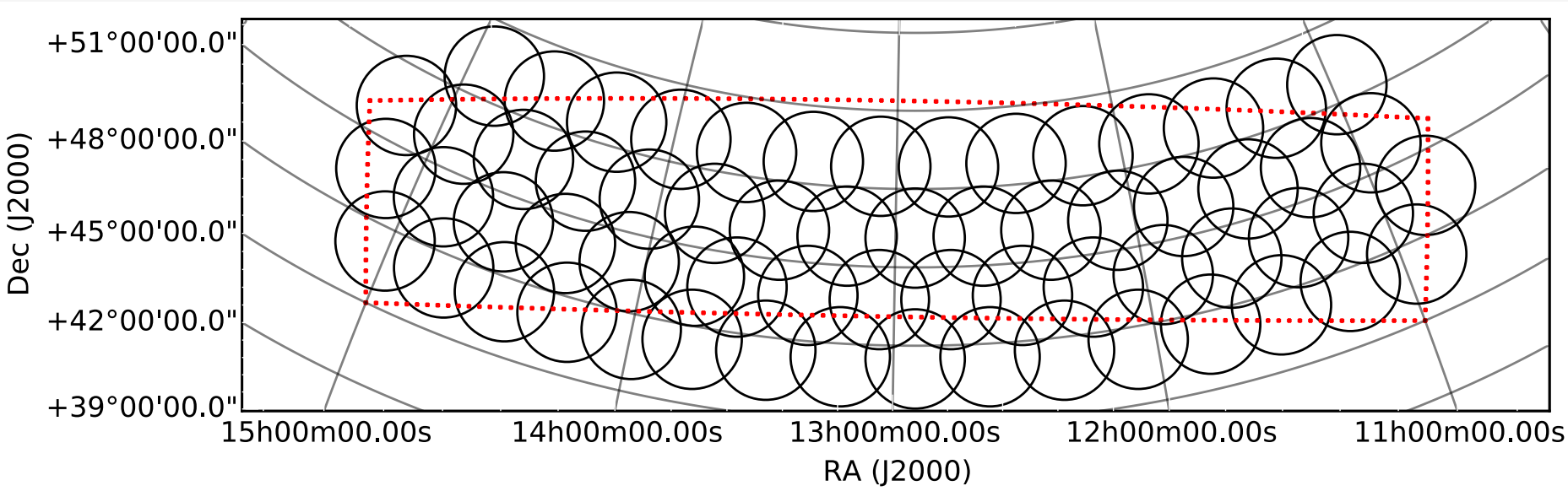
Status of LoTSS observations

- By November 2016 ≈1300hrs of HBA observations (350 pointings).

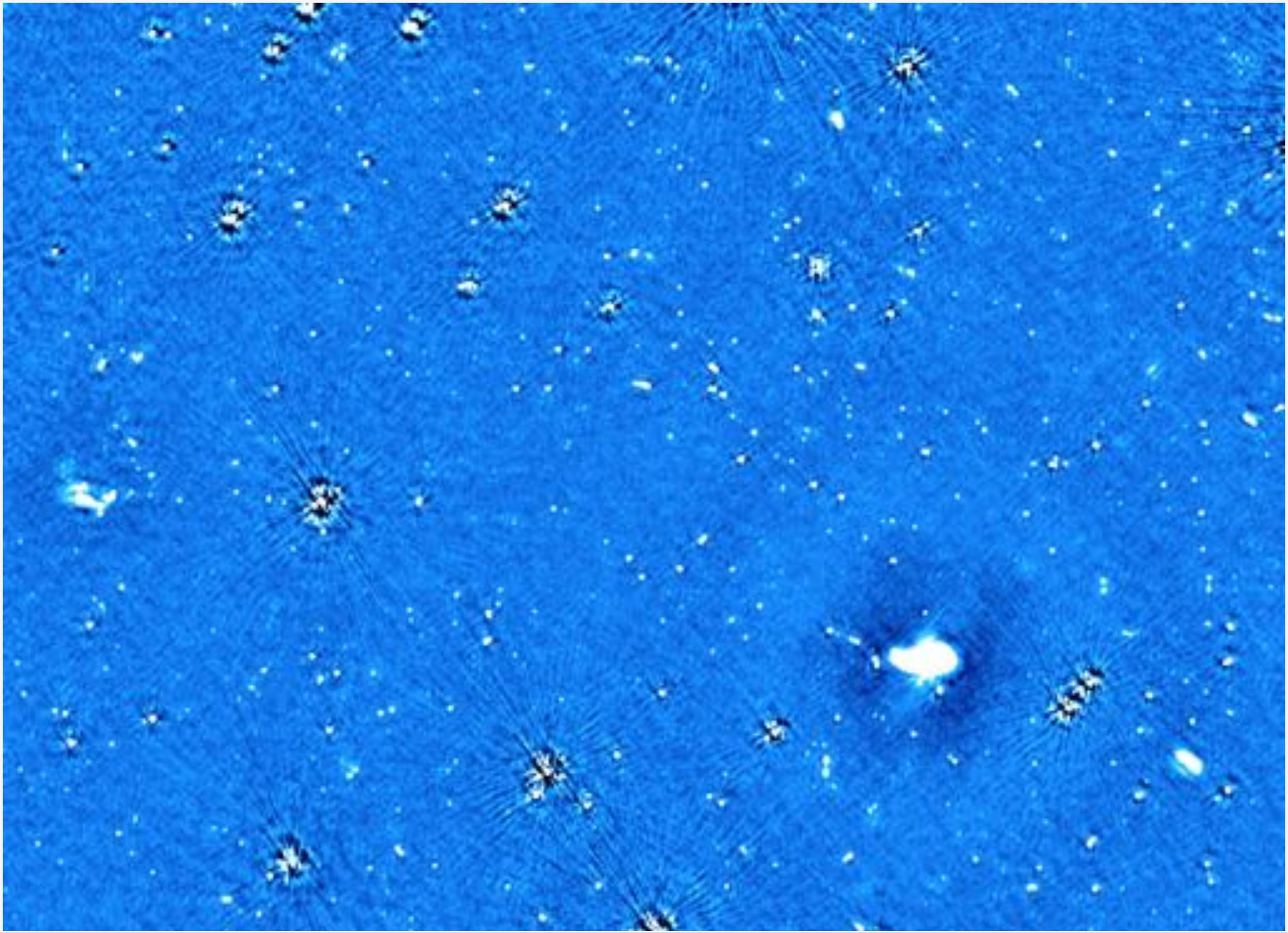


LoTSS – preliminary data release

A release of 25" resolution images and catalogues made from 63 direction independent calibrated datasets. The area covered is 381 square degrees in the region of the HETDEX Spring Field and the catalogue contains over 44,000 sources.

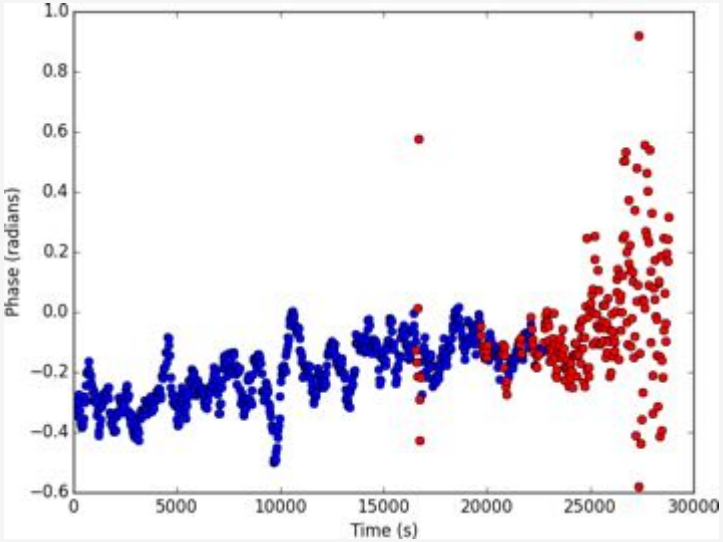


Shimwell et al., A&A submitted `http://lofar.strw.leidenuniv.nl`



Identifying poor ionospheric conditions

- Rapidly varying phase.
- High integrated/peak flux.
- 9/63 pointings identified as bad.



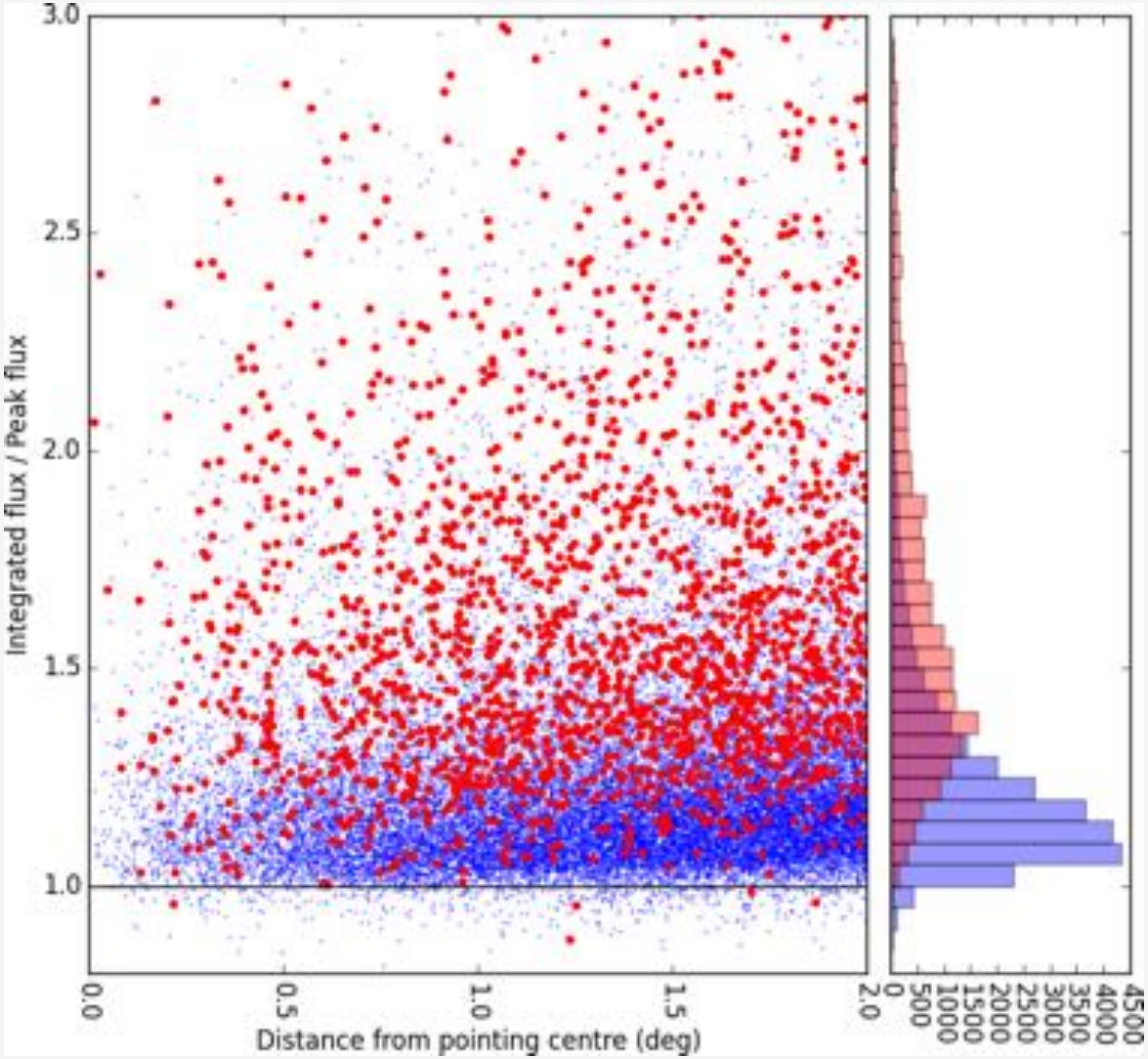


Image quality – positional accuracy

- Astrometric accuracy determined from FIRST.
- Error on positions is 1.7" in RA and DEC.

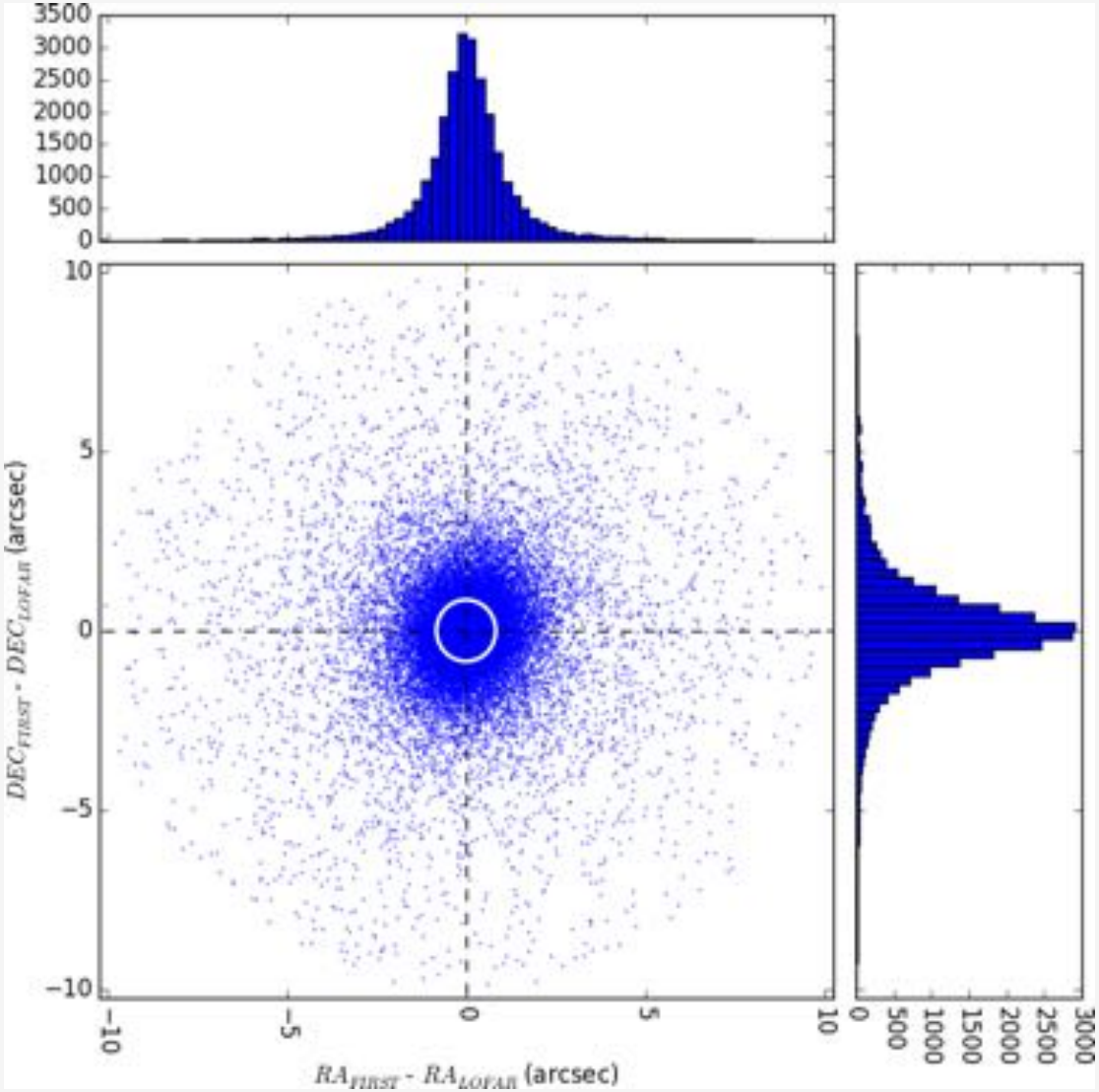
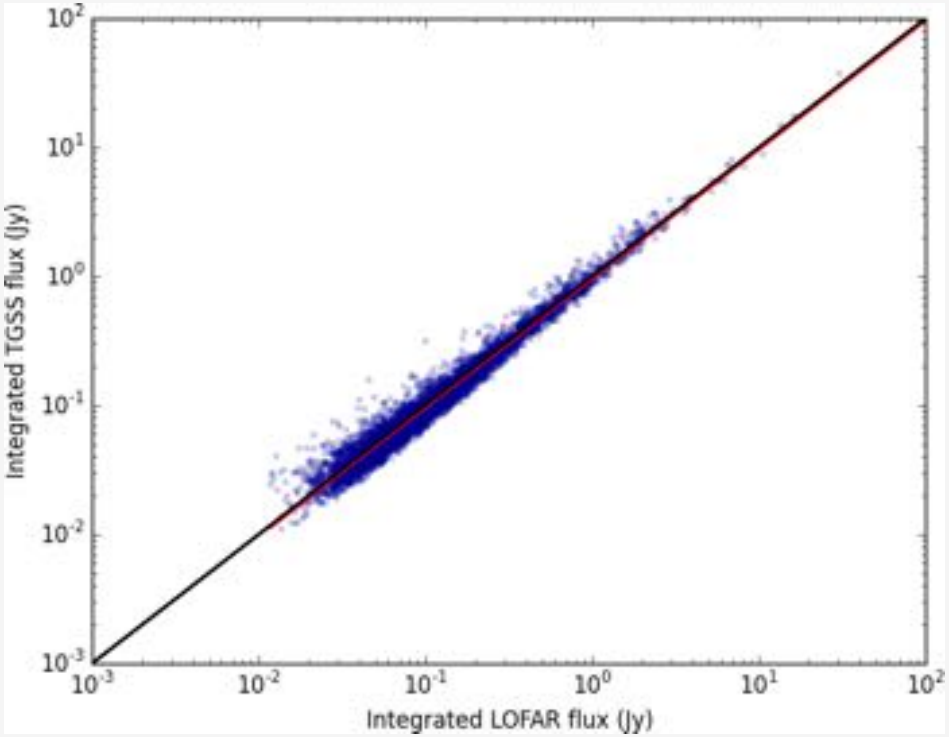


Image quality – flux accuracy

The fluxes are found to be within 20% of the TGSS and 7C values.



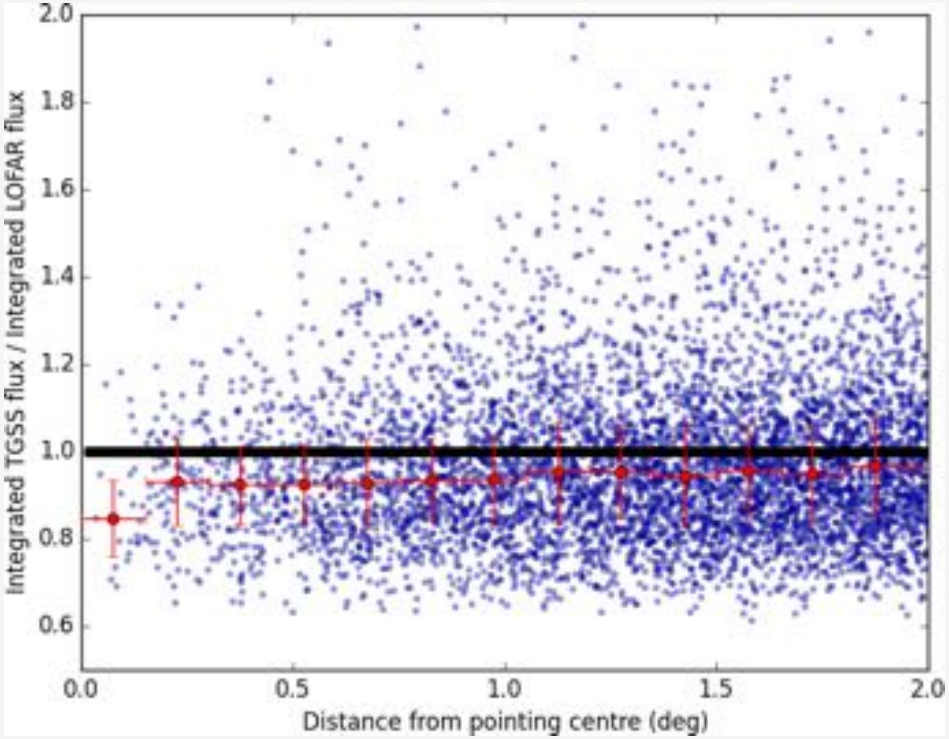
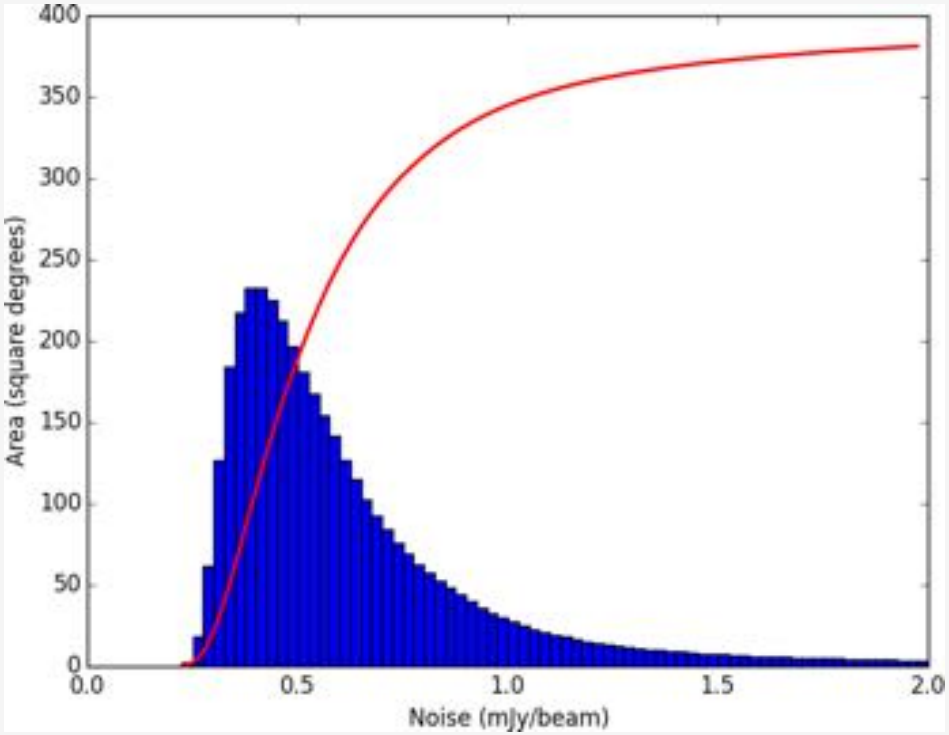
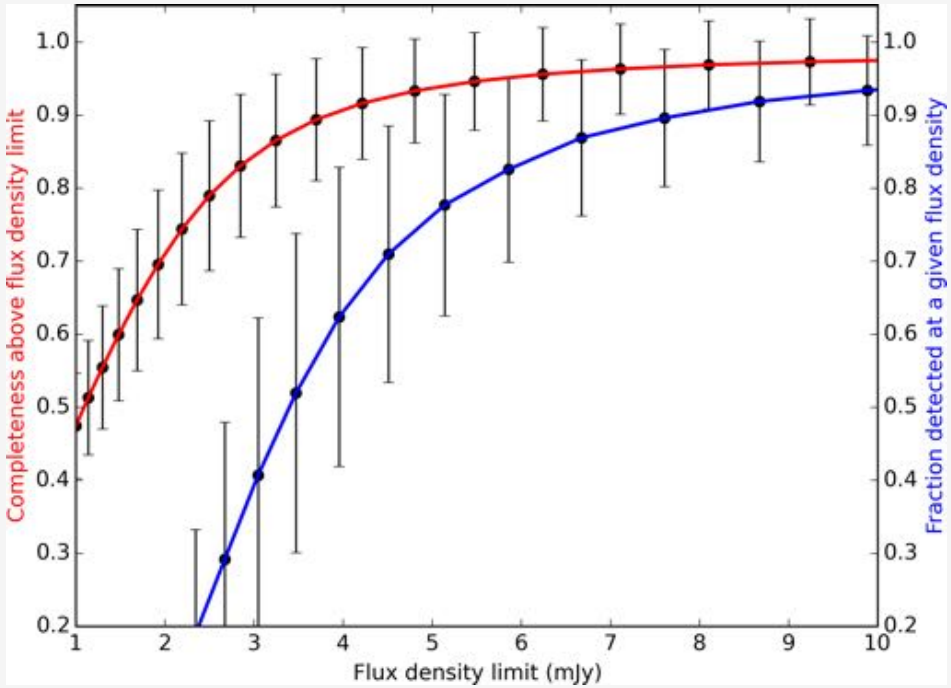


Image quality – sensitivity and completeness

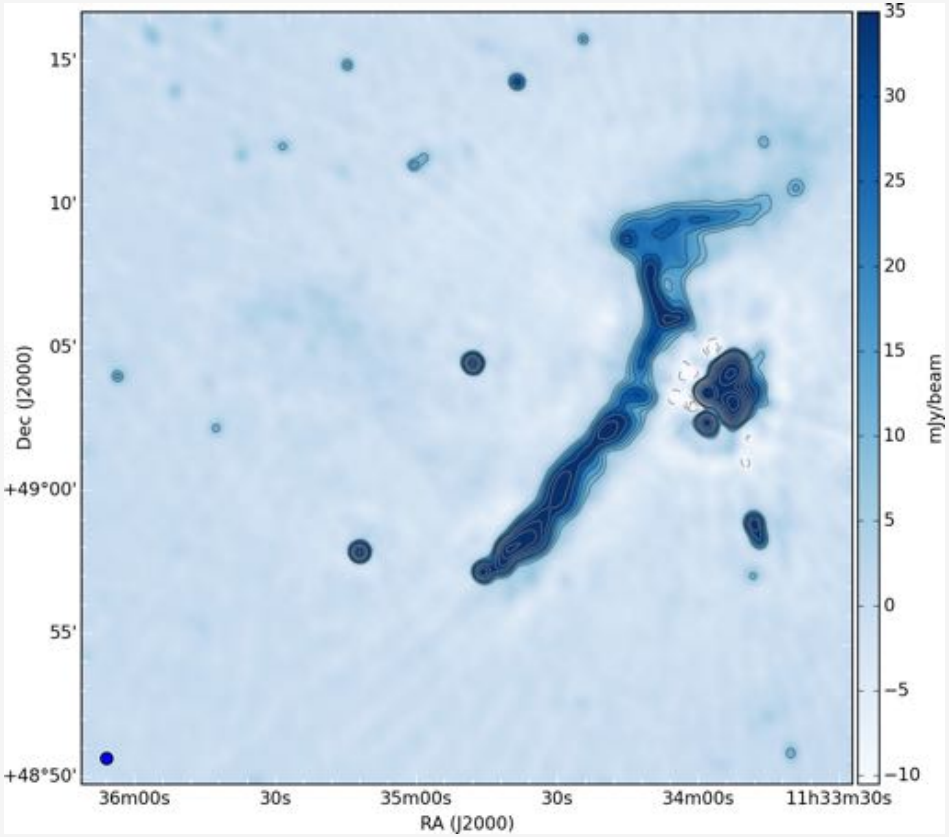


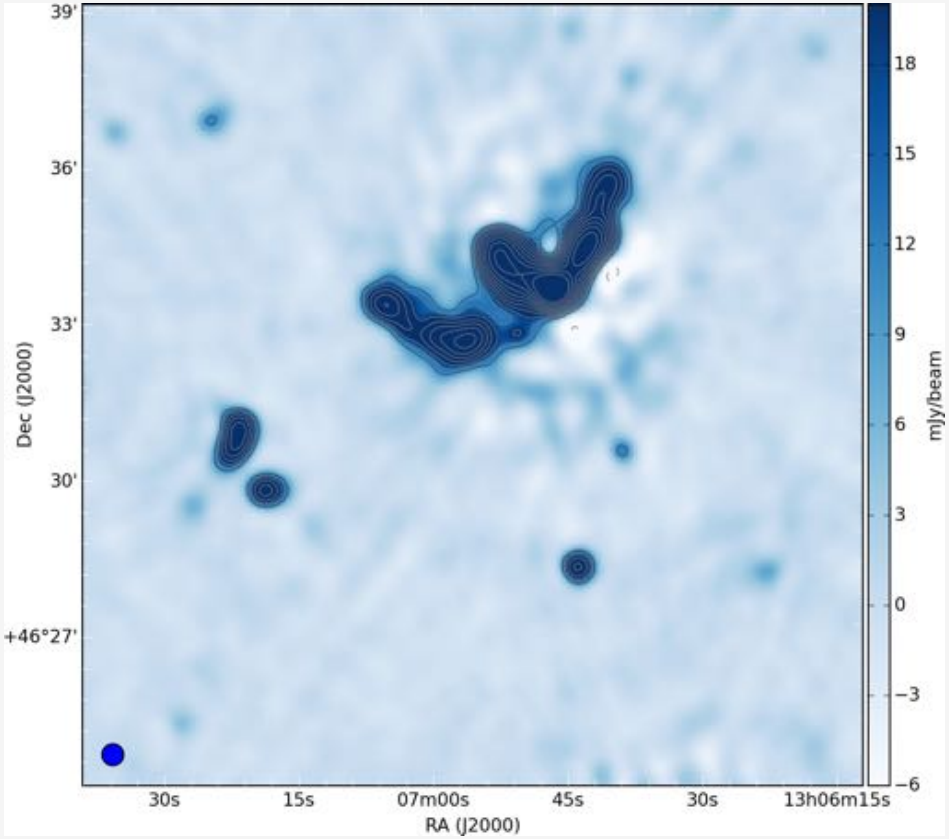


The sensitivity is less than 0.5 mJy/beam and 1.0 mJy/beam in 54% and 91% of the mosaiced region respectively.

The catalogue is 50% complete at 1.1 mJy and 90% complete at 3.9 mJy.

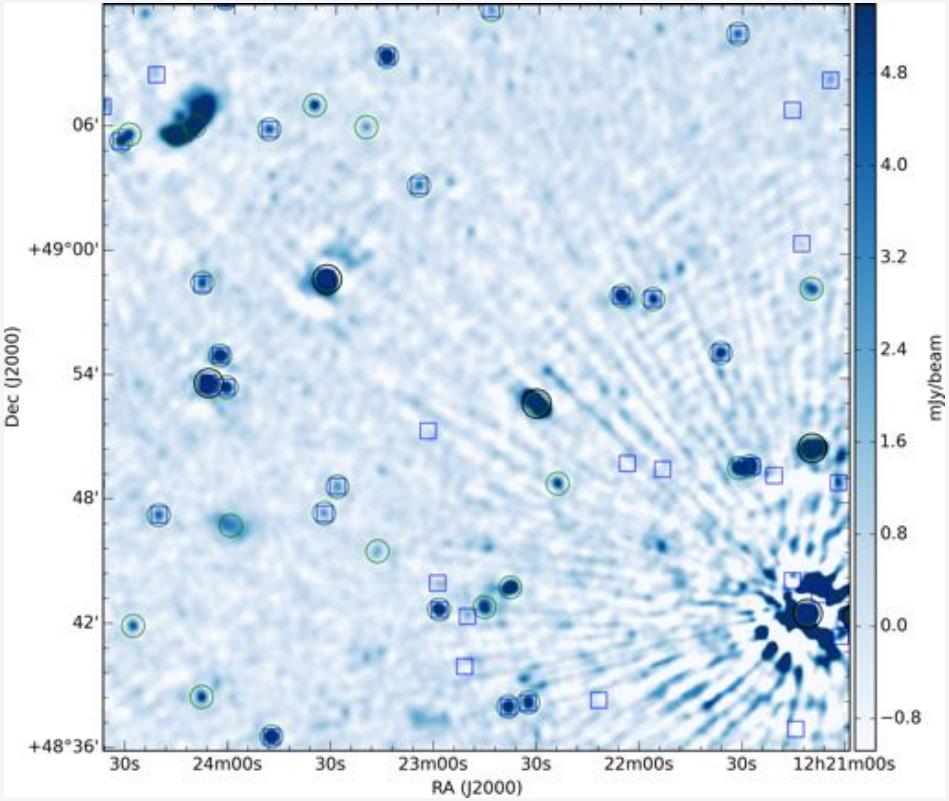
Scientific potential

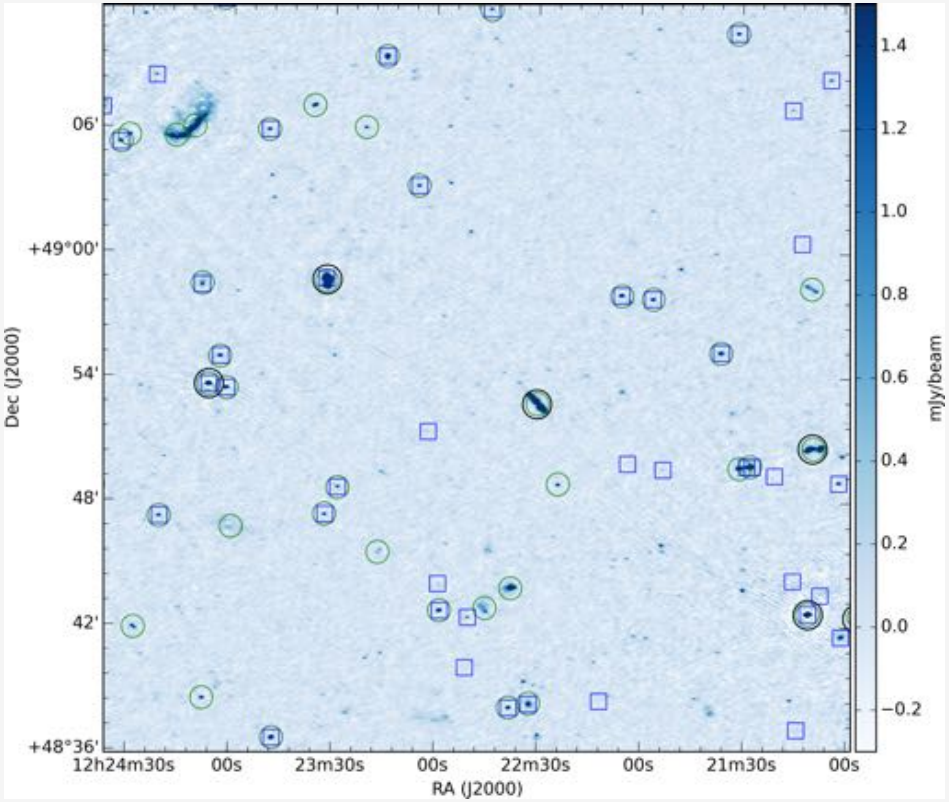




Abell 1314 and Abell 1682.

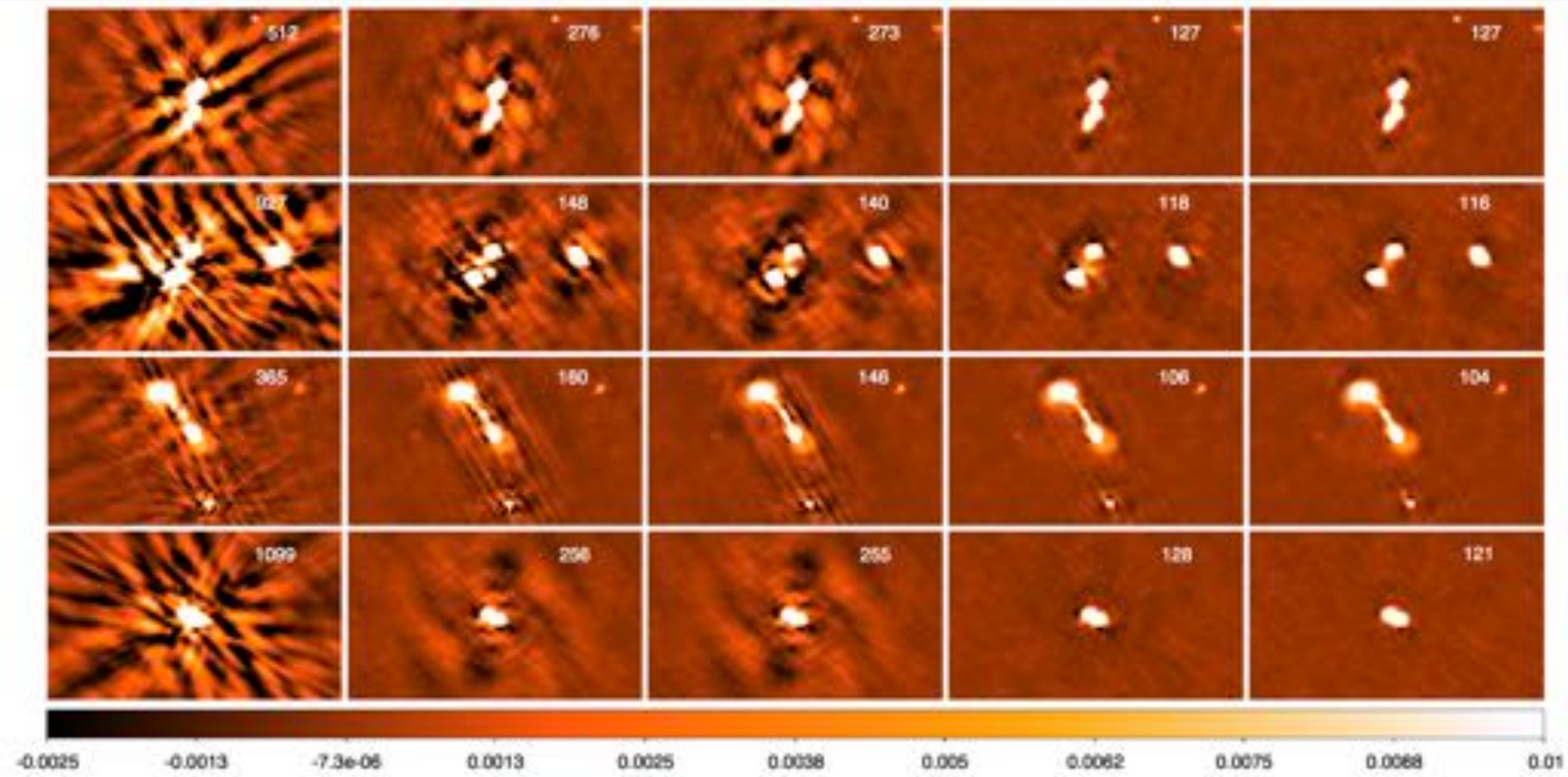
LoTSS future data releases – direction dependent calibration



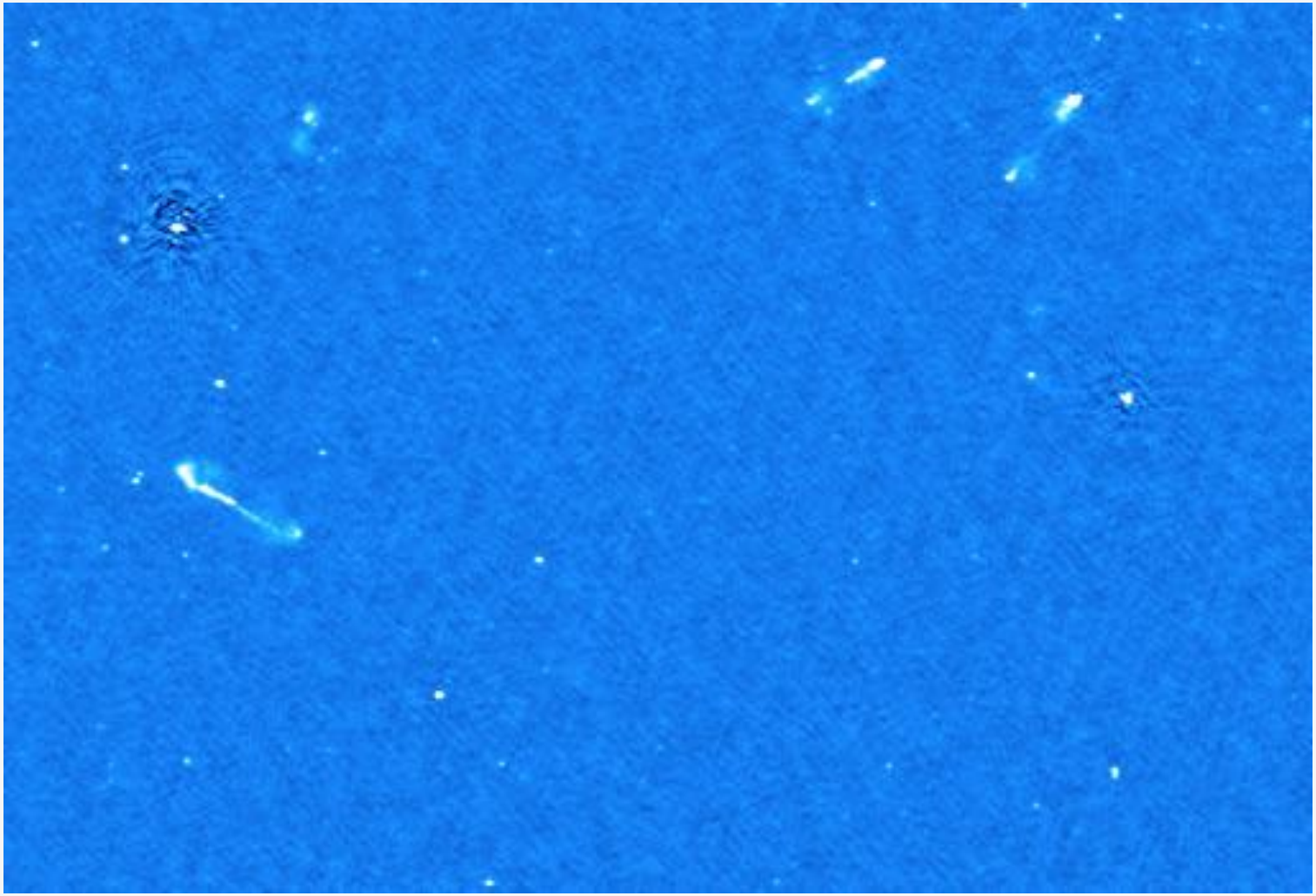


From 25“ and 400μJy/beam to $5-8$“ and $\sim 100-120\mu$Jy/beam.

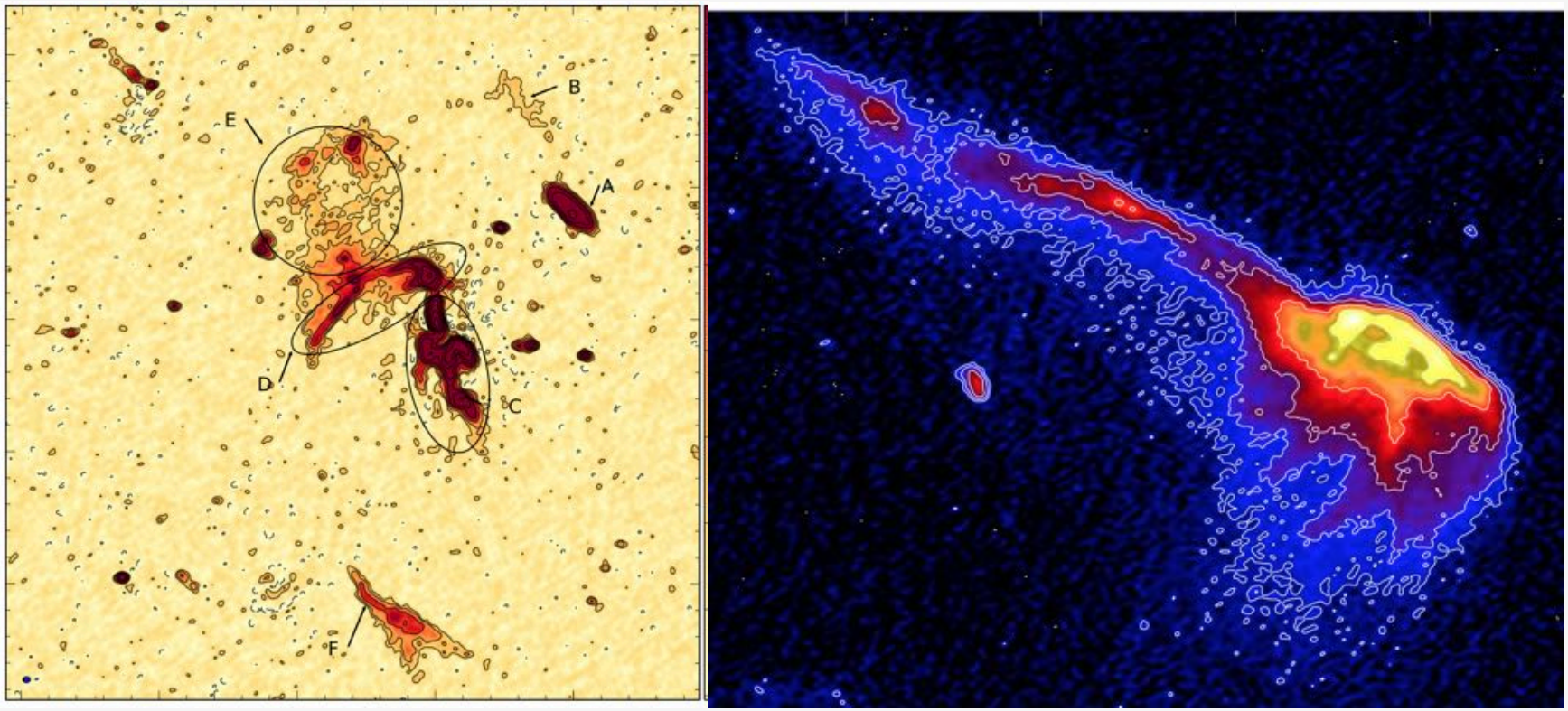
Demonstrating direction dependent calibration



The facet calibration method (van Weeren R. J., et al., 2016, ApJS, 223, 2)

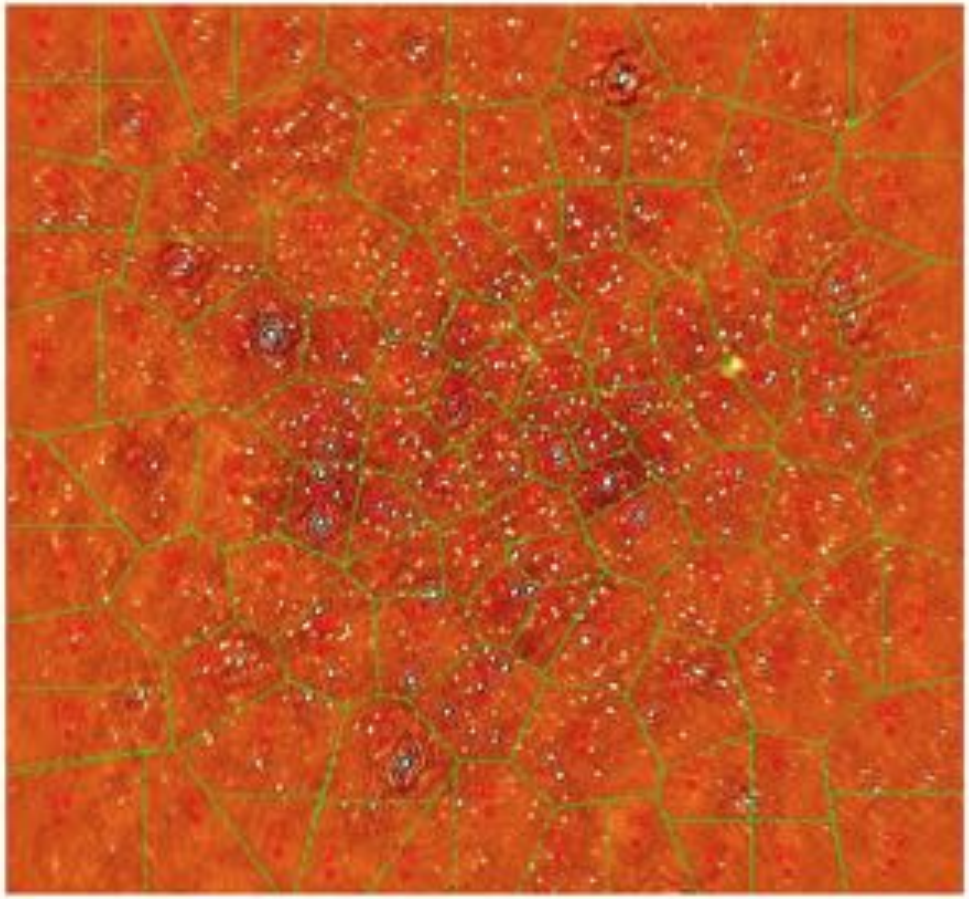


Thermal noise limited wide-field images at 5" resolution. Bootes (Williams W., et al., 2016, MNRAS, 936W) and H-ATLAS (Hardcastle M. J., et al., 2016, MNRAS, 462, 1910)



Sensitive, high fidelity images of diffuse emission. Abell 2034 (Shimwell T. W., et al., 2016, MNRAS, 459, 277). Toothbrush cluster (van Weeren R. J., et al., 2016, ApJ, 818, 204).

Direction dependent calibration – killms/ddfacet



(1) Produces a single tengential plane !

(2) Does full polarisation DDE correction

(3) Baseline Dependent Averaging
90 % of the data can be compressed
(collaboration with O.Smirnov and M. Atemkeng)

(4) Does tesselated images

(5) Does take the beam into account

(6) Continuity between facets

(7) Takes variable PSF into account

(8) Two wide-band deconvolution algorithms are implemented

Tasse et al. in prep.

Towards production mode for LoTSS

We are performing a trail production mode to build up 500 square degrees of sky imaged at $5-8$" and $\sim 100-120\mu$Jy/beam within the next few months. There are many challenges:

- Each archived observation is 16 TB
- Direction independent calibration takes $\sim$3 days per pointing
- Direction dependent calibration takes as little as 4 days

Towards production mode for LoTSS – dealing with the data

Archived data are stored at SURFsara, Juelich and Poznan. Each site contains:

- Large distributed processing networks (100-1000 nodes/site)
- Very fast data transfer ($>$ 100MB/s)

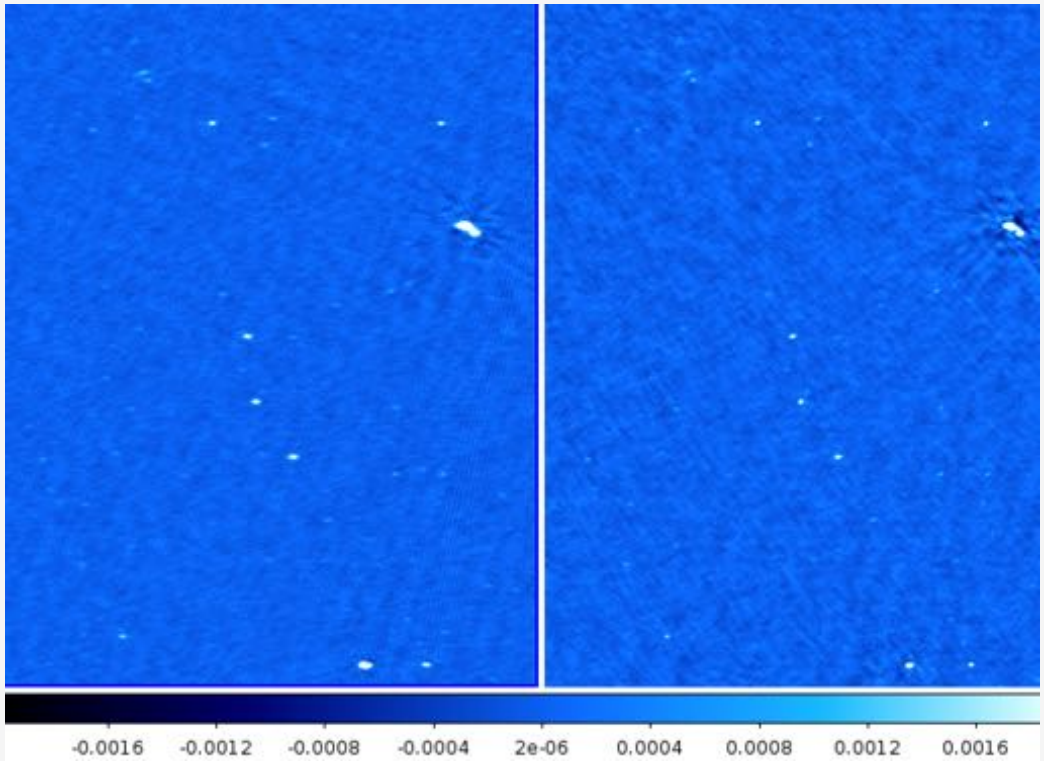
This is vital to reduce LoTSS data.

- We have implemented our direction independent calibration pipeline at SURFsara.
- Each dataset is reduced to just 2 TB and can be downloaded in less than a day
- We are also implementing our direction dependent calibration pipelines at SURFsara

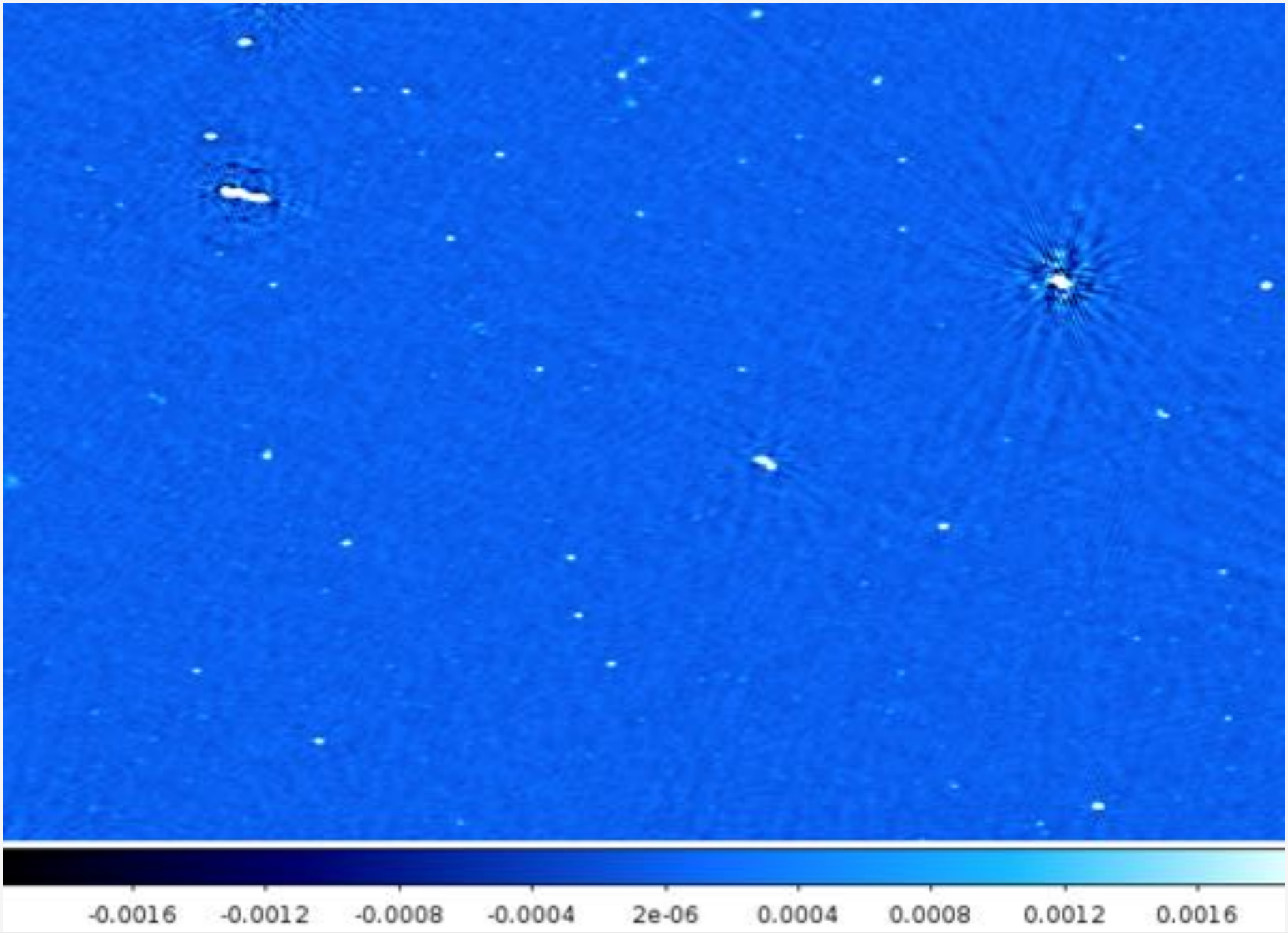
By Oonk, Mechev, Shimwell, Danezi, Schrijvers

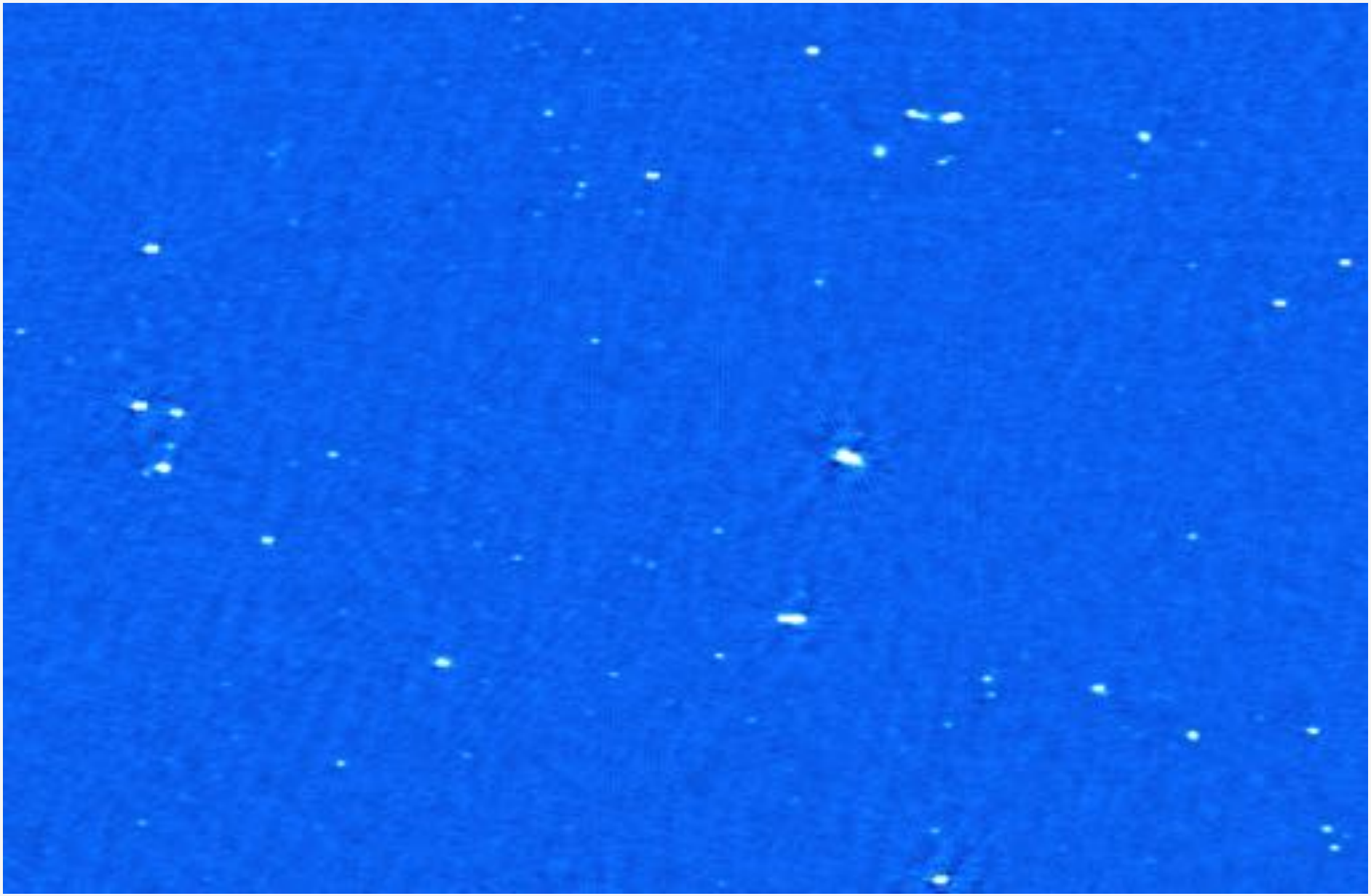
Towards production mode for LoTSS – direction dependent calibration

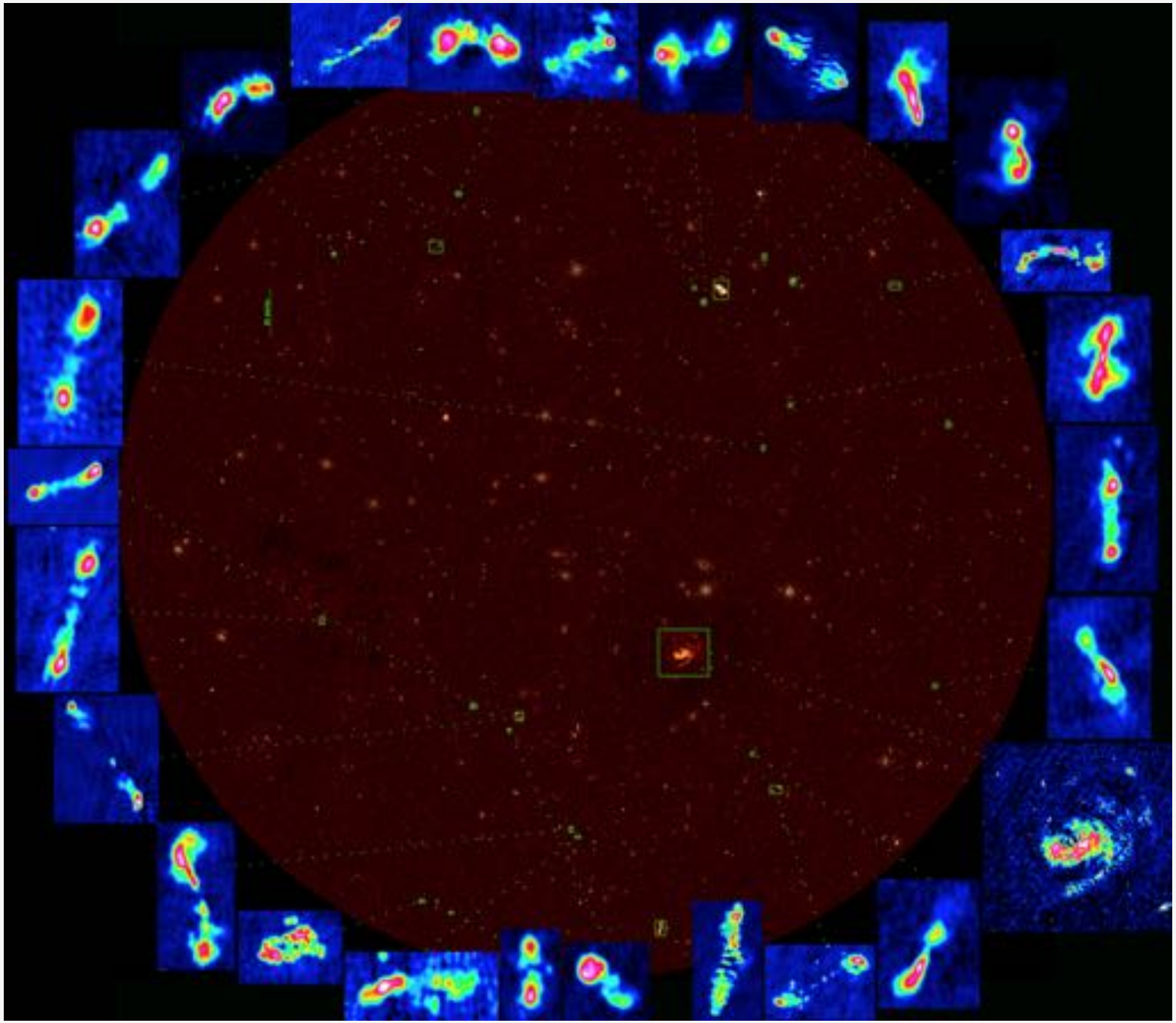
Two direction dependent calibration algorithms are working well and small or no levels of manual interference are required.



Left: DDFacet. Right: Facet calibration.
(Hardcastle, Horneffer, Rafferty, Shimwell, Tasse, van Weeren, Williams et al.)

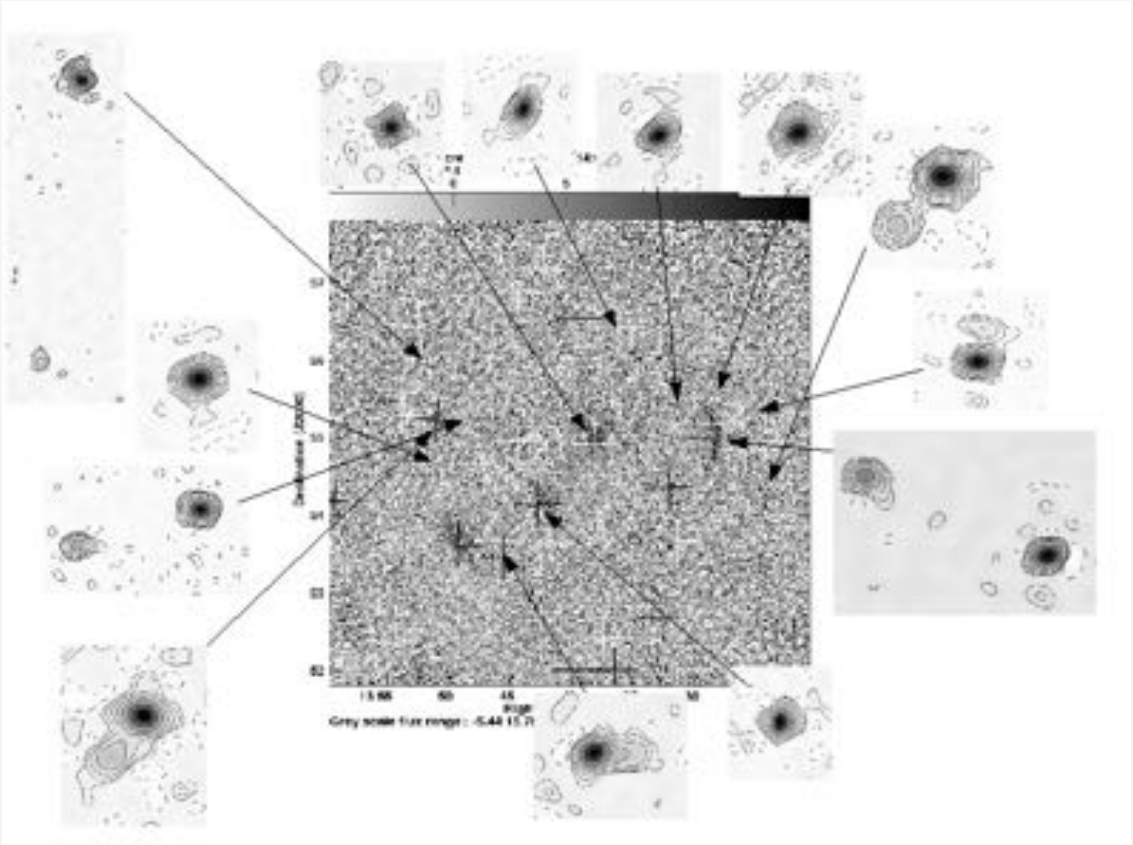

-0.0016
-0.0012
-0.0008
-0.0004
2e-06
0.0004
0.0008
0.0012
0.0016





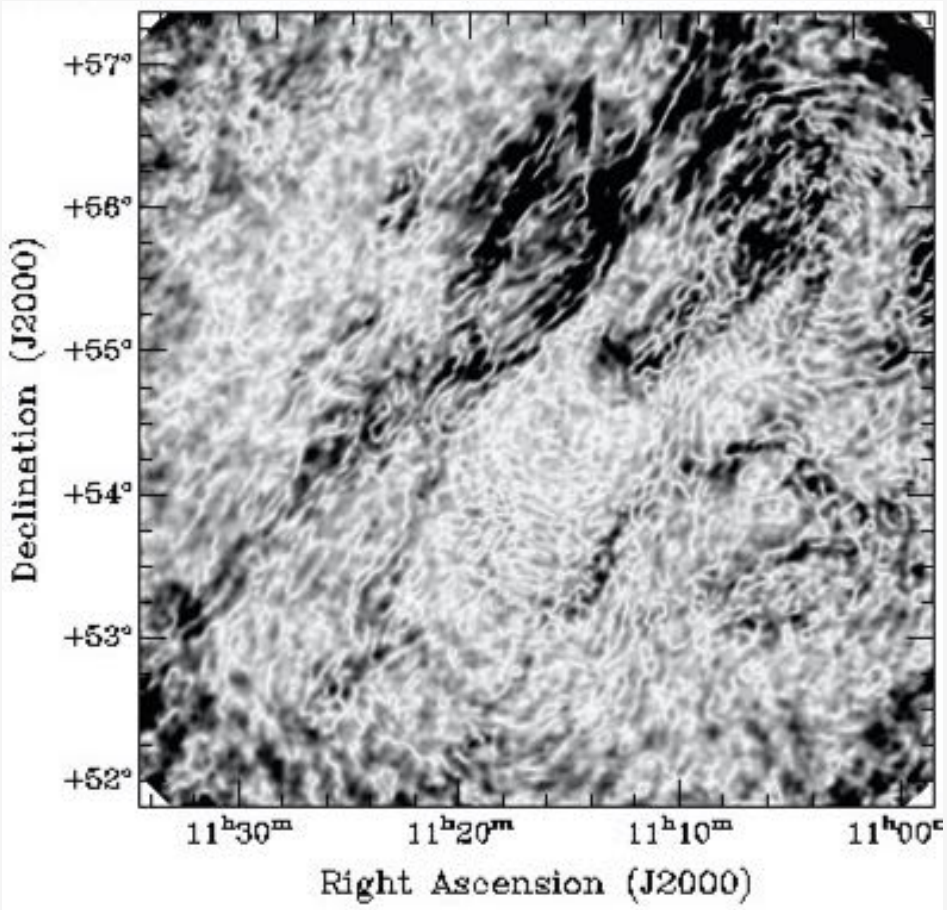
Lots of exciting prospects for the future

LoTSS data also contains international baselines, polarisation and spectral information.



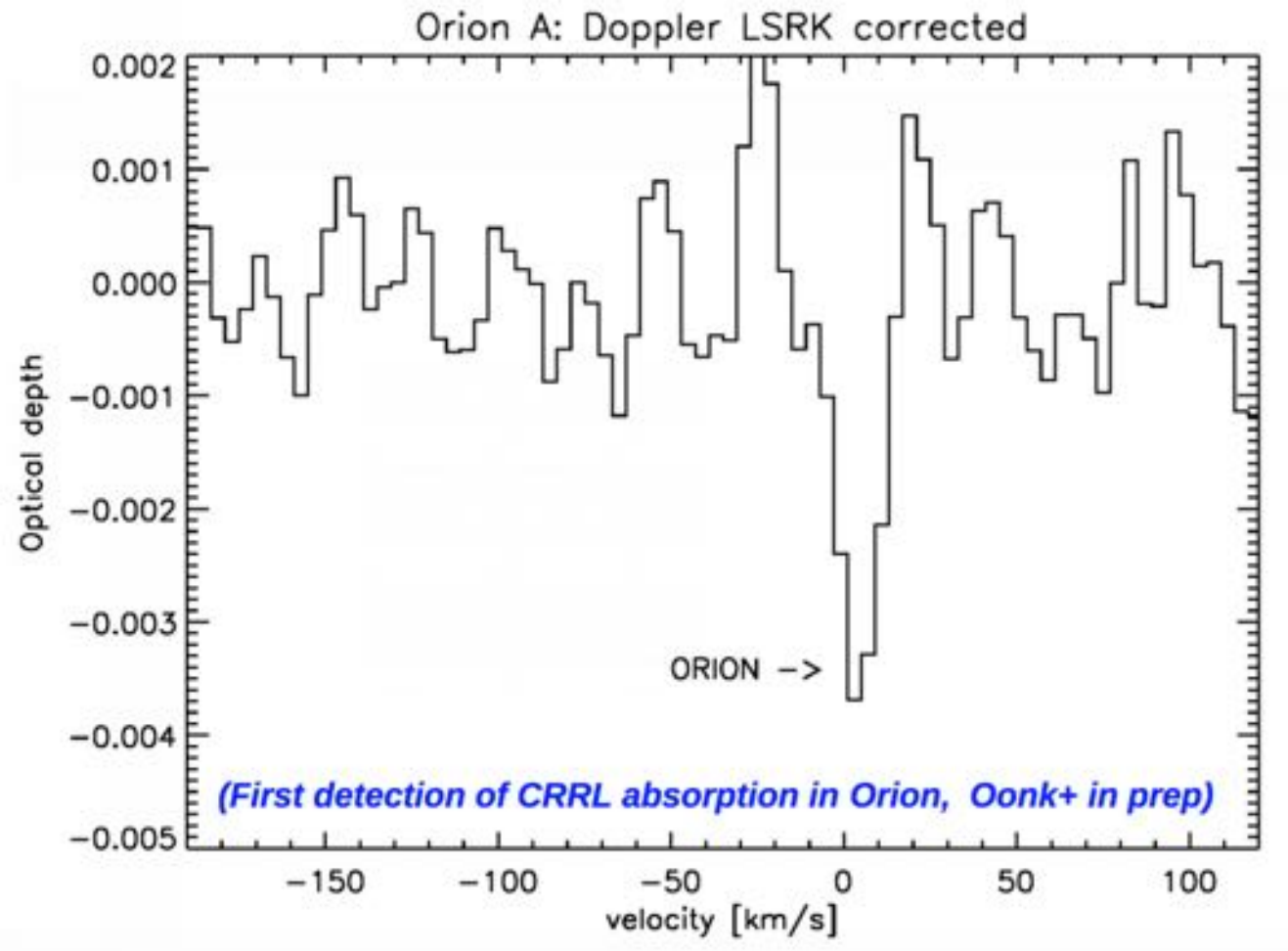
450mas resolution images of sources up to 3 degrees from the pointing centre (by Neal Jackson and the long baseline working group)

Lots of exciting prospects for the future



A slice from a Faraday rotation cube. The field shows polarised filaments and depolarisation canals. C. van Eck et al. in prep

Lots of exciting prospects for the future



The detection of carbon radio recombination lines in Orion (27 lines stacked). R. Oonk et al. in prep

Conclusions

- By November 2016 over 10% of the LoTSS observations will have been conducted. The observing rate must increase.
- The LoTSS survey description and preliminary data release has been submitted for publication. The images can be used for science.
- Pipelines for routinely producing direction dependent calibrated images with little or no manual intervention in as little as 4 days processing.
- We have doing a trail production mode where we are attempting to produce $\approx$5" resolution images with a sensitivity of $\approx 100 \mu$Jy/beam over a 500 square degree region with minimal manual interaction over just a few months.