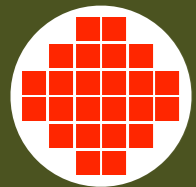


LOFAR MSSS

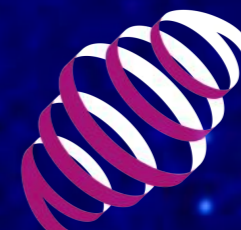
Multifrequency Snapshot Sky Survey



M * S * S * S

MULTIFREQUENCY SNAPSHOT SKY SURVEY

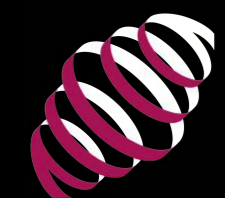
**George Heald (MSSS Project Leader)
(on behalf of the MSSS Team)
MFU-V, 9 October 2015**





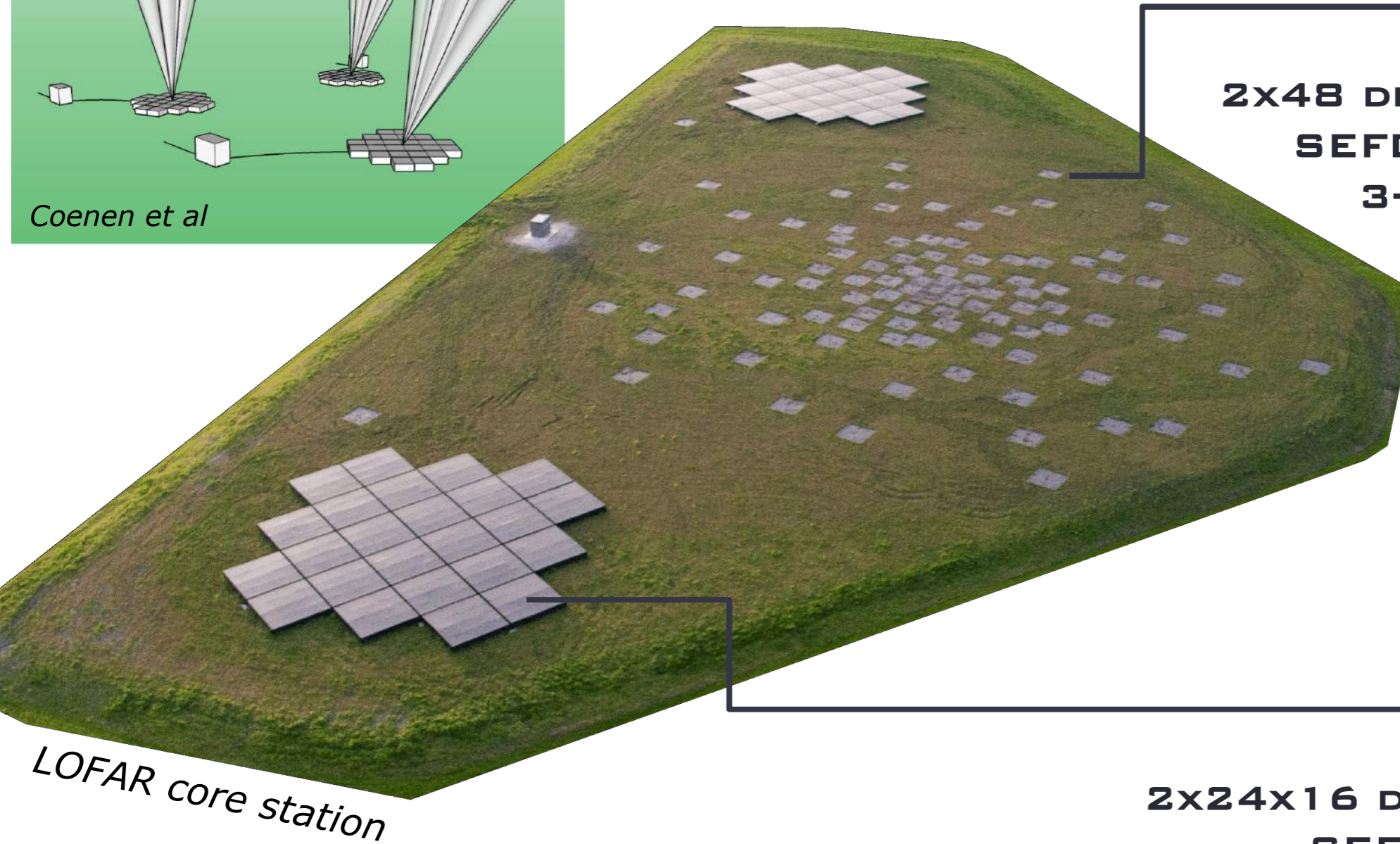
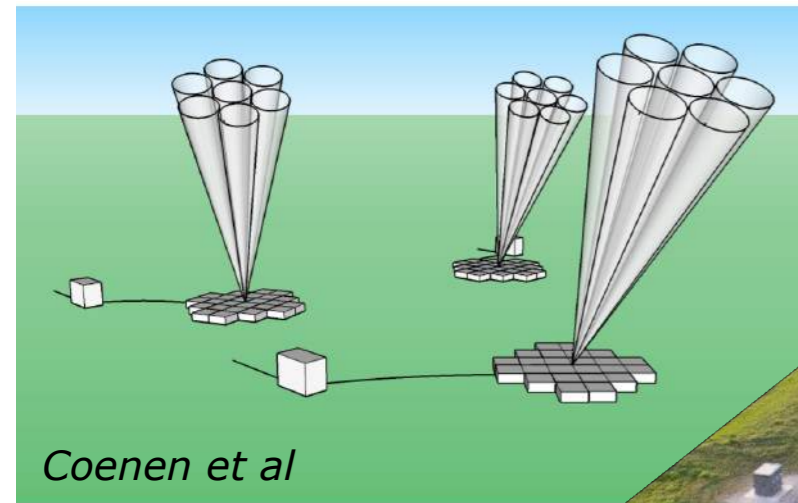
Outline

- **LOFAR overview**
- **MSSS motivation & setup**
- **MSSS results & data releases**
- **Forthcoming LOFAR surveys**



LOFAR

- Highly flexible digital beamforming (“beams for bandwidth”)

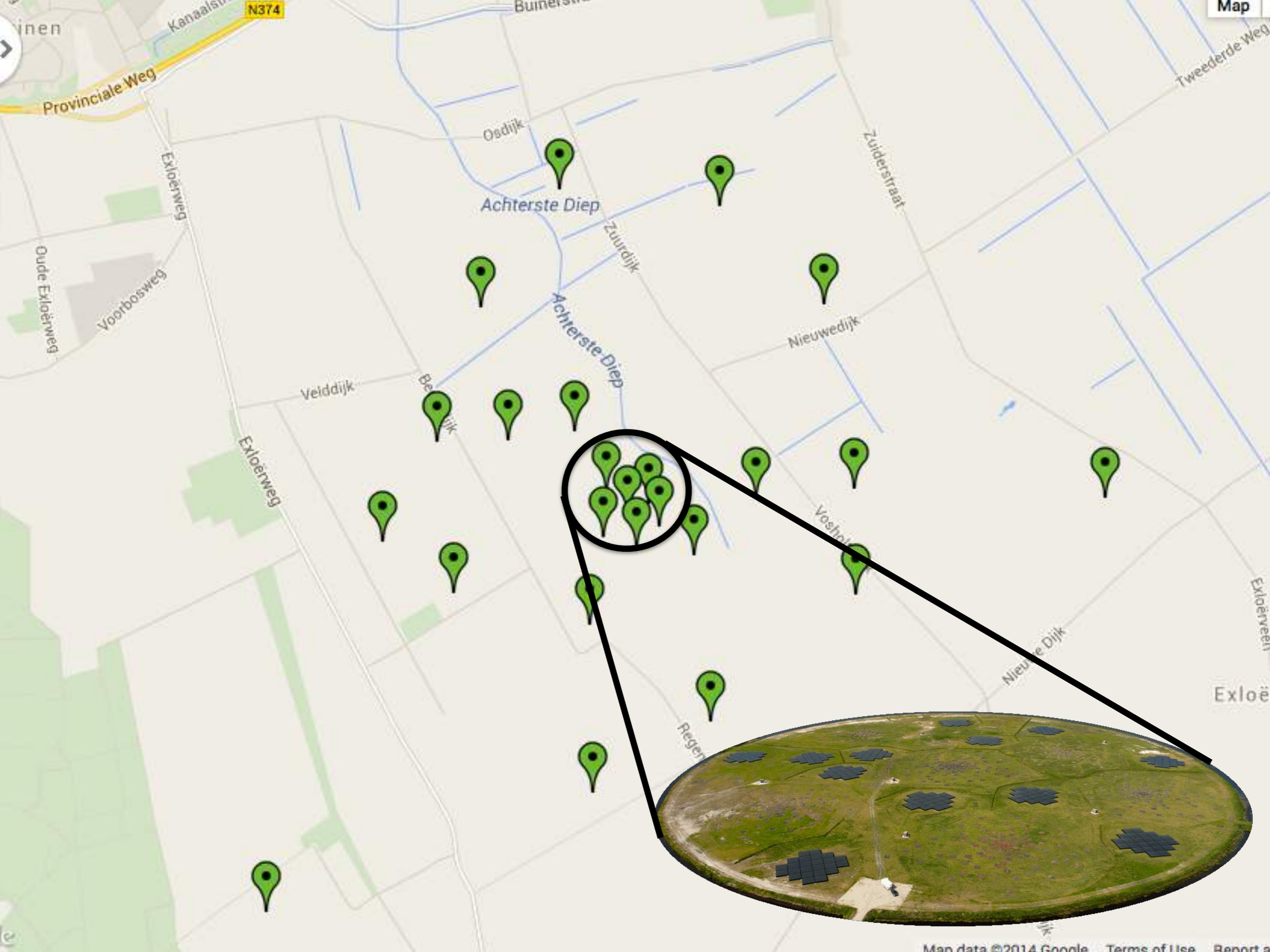


LOFAR LBA

10-80 MHz
2x48 DIPOLE PAIRS / STATION
SEFD 25 KJY AT 60 MHz
3-40 DEG FOV (FWHM)

LOFAR HBA

1 10-250 MHz
2x24x16 DIPOLE PAIRS / STATION
SEFD 2 KJY AT 150 MHz
1-5 DEG FOV (FWHM)







~120 km



Chilbolton

Dutch stations

LOFAR Core (NL)

~1500 km

Onsala

Norderstedt

Baldy

Potsdam

Borówiec

Jülich

Effelsberg

Tautenburg

Unterweilenbach

Lazy

Nançay



Goals: obtain broadband sky model, shakedown LOFAR operations

MSSS-LBA



Frequency: 30-75 MHz
(8 x 2 MHz bands)

Resolution: ≤ 100 arcsec

Sensitivity: ≤ 15 mJy/beam

Area: 20,000 square degrees

Number of Fields: 660

Simultaneous $\sim 10^\circ$ beams: 5

Test observations resuming

MSSS-HBA



Frequency: 120-160 MHz
(8 x 2 MHz bands)

Resolution: ≤ 120 arcsec

Sensitivity: ≤ 5 mJy/beam

Area: 20,000 square degrees

Number of Fields: 3616

Simultaneous $\sim 4^\circ$ beams: 6

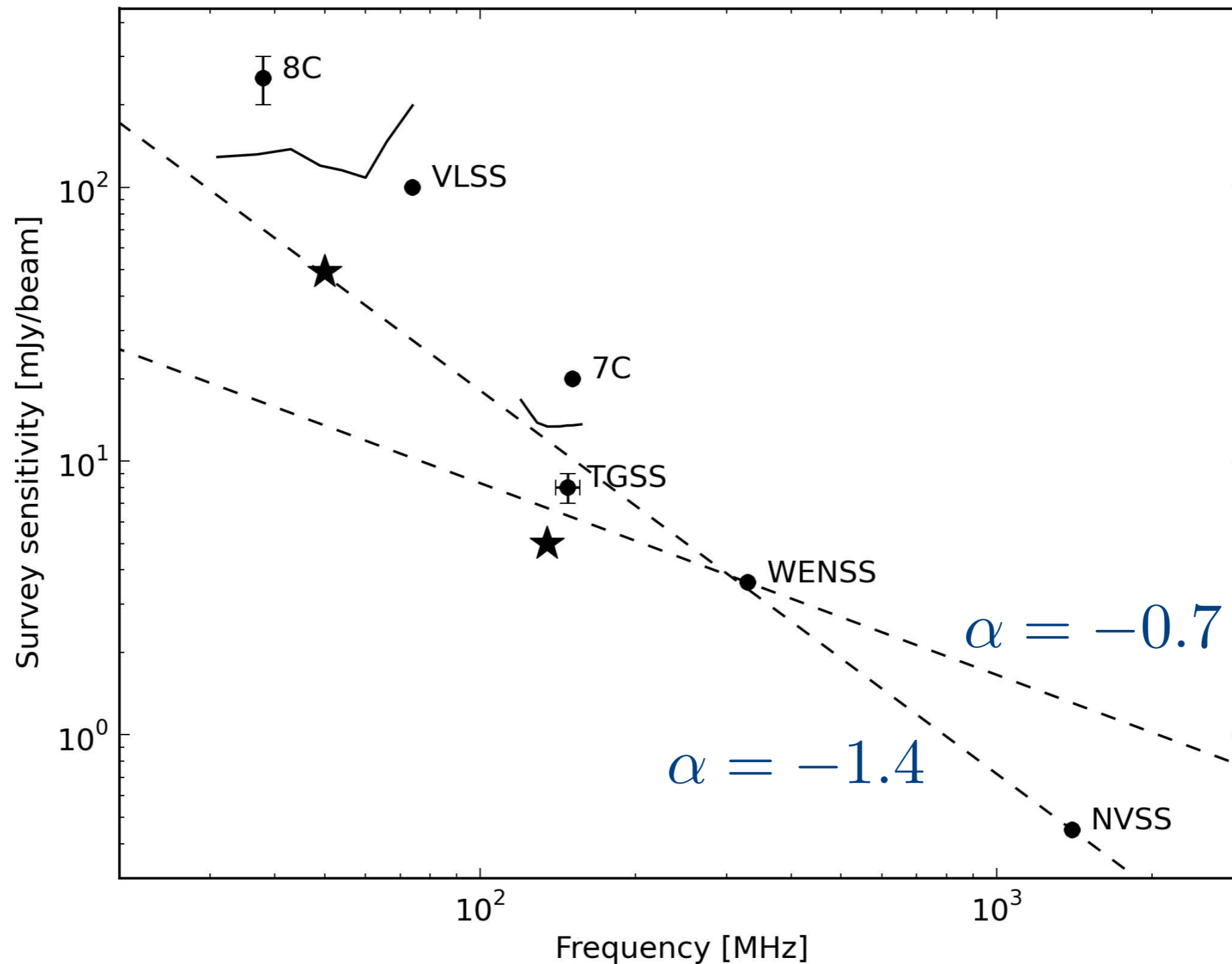
Observations 100% complete

Thanks to the MSSS Team!

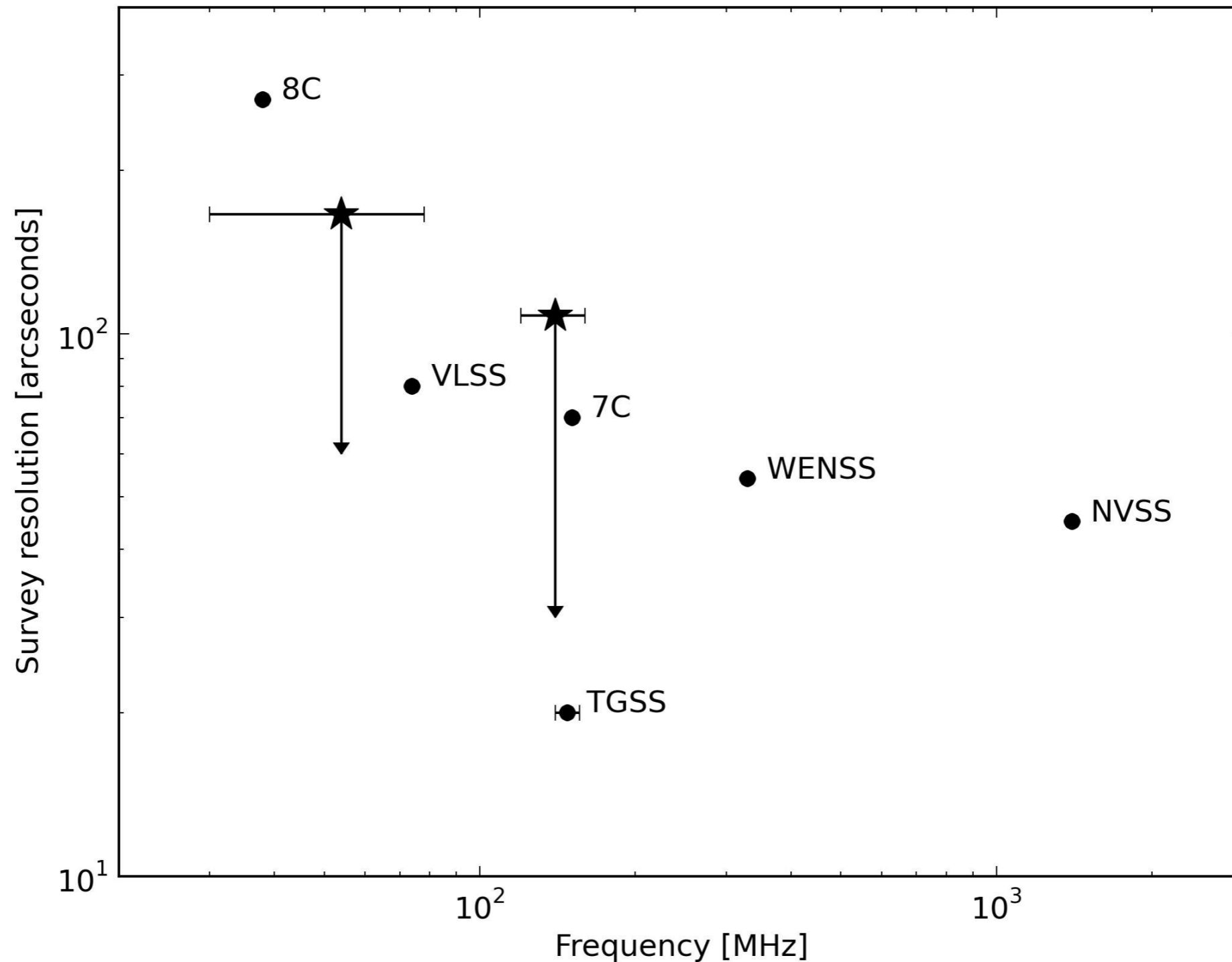
Björn Adebahr, Mike Bell, Laura Bîrzan, Annalisa Bonafede, Justin Bray, Rene Breton, Jess Broderick, Ger de Bruyn, Therese Cantwell, Dario Carbone, Patti Carroll, Yvette Cendes, Alex Clarke, Judith Croston, Soobash Daiboo, Francesco De Gasperin, Emilio Enriquez, Richard Fallows, Chiara Ferrari, Jon Gregson, Martin Hardcastle, Jeremy Harwood, Tom Hassall, Volker Heesen, Andreas Horneffer, Alexander van der Horst, Marco Iacobelli, Vibor Jelic, David Jones, Wojciech Jurusik, Georgi Kokotanekov, Giulia Macario, Poppy Martin, Carlos Martinez, John McKean, Leah Morabito, David Mulcahy, Ronald Nijboer, Błażej Nikiel-Wroczyński, Andre Offringa, Emanuela Orrú, V.N. Pandey, Gosia Pietka, Roberto Pizzo, Mamta Pommier, Peeyush Prasad, Luke Pratley, Chris Riseley, Huub Röttgering, Antonia Rowlinson, Pepe Sabater, Anna Scaife, Bart Scheers, Kati Sendlinger, Aleksandar Shulevski, Charlotte Sobey, Carlos Sotomayor, Adam Stewart, Andra Stroe, John Swinbank, Cyril Tasse, Bas van der Tol, Jonas Trüstedt, Sander ter Veen, Sjoert van Velzen, Reinout van Weeren, Wendy Williams, Michael Wise

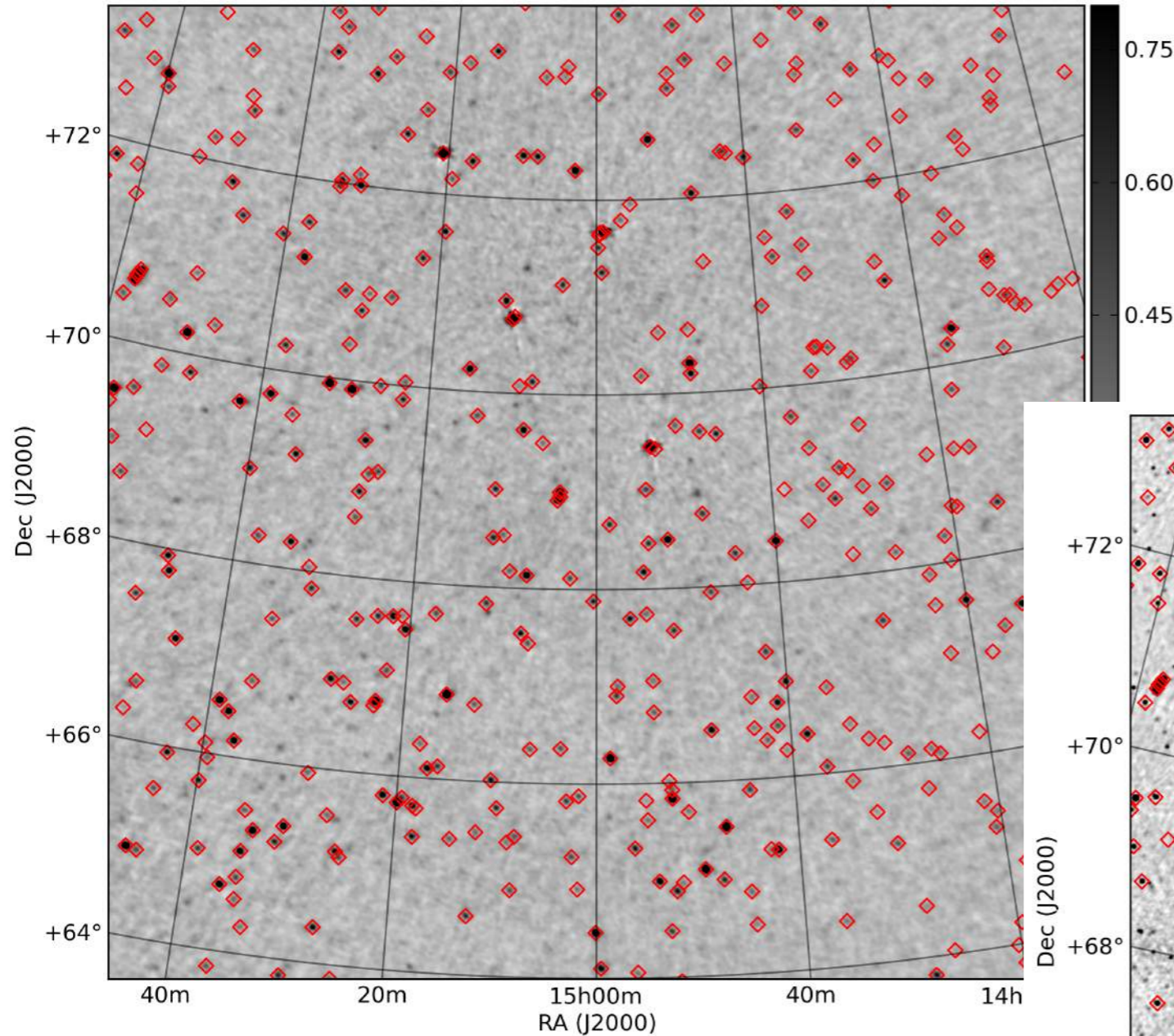


- Highly complementary to MWA's GLEAM: together these surveys will provide a truly all-sky interferometric radio catalog!

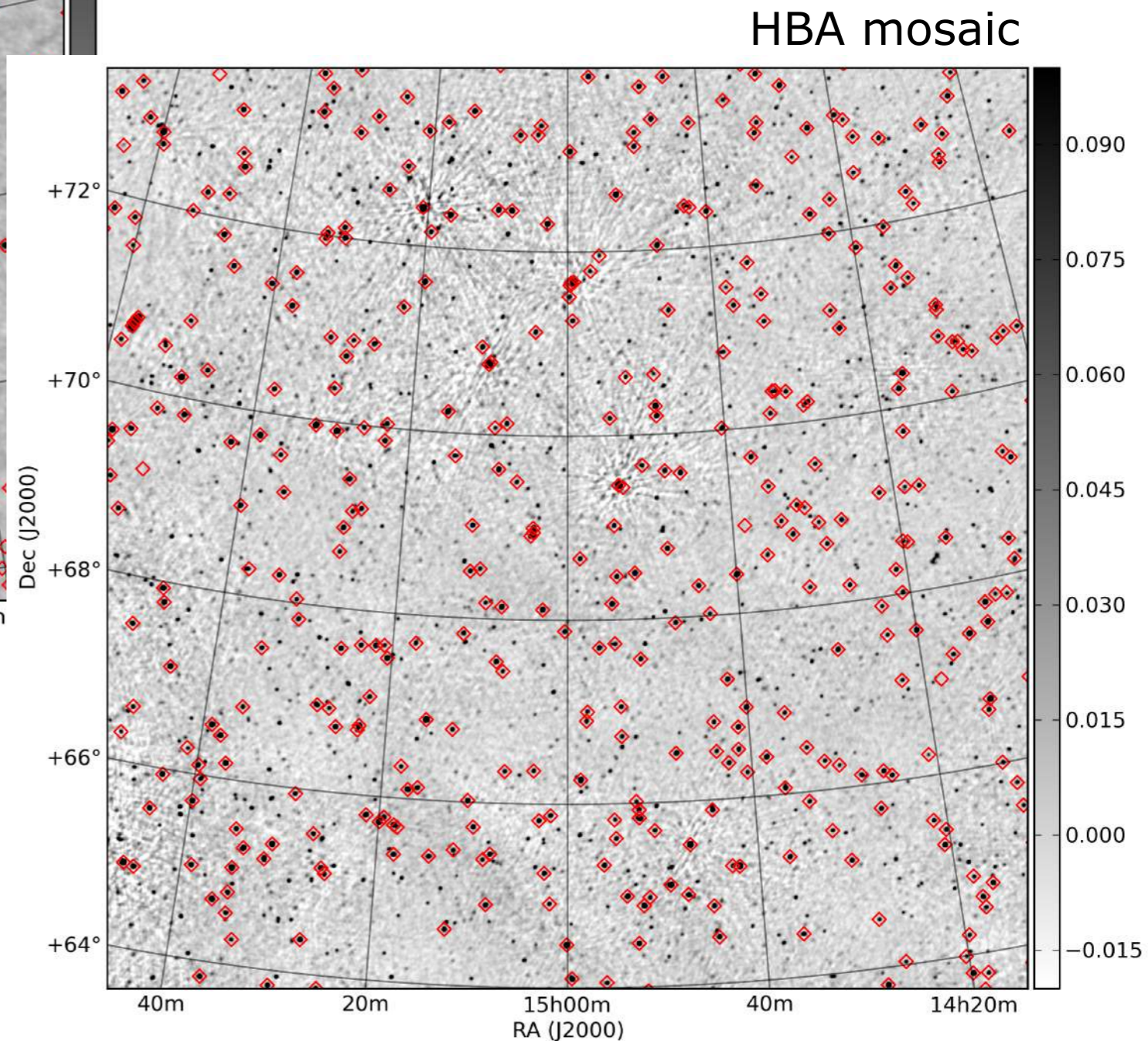


- Highly complementary to MWA's GLEAM: together these surveys will provide a truly all-sky interferometric radio catalog!





LBA
Ionospheric correction applied



- Paper accepted in A&A (arxiv:1509.01257)
- Key facts & figures:
 - 100 square degrees, ~ 1200 sources
 - HBA completeness 100 mJy, LBA completeness 550 mJy
 - $\sim 2'$ resolution



We gratefully acknowledge support from the Simons Foundation and the Alliance of Science Organisations in Germany, coordinated by TIB, MPG and HGF

arXiv.org > astro-ph > arXiv:1509.01257

Search or Article-id (Help | Advanced search)
All papers

Astrophysics > Instrumentation and Methods for Astrophysics

The LOFAR Multifrequency Snapshot Sky Survey (MSSS) I. Survey description and first results

G.H. Heald, R.F. Pizzo, E. Orrú, R.P. Breton, D. Carbone, C. Ferrari, M.J. Hardcastle, W. Jurusik, G. Macario, D. Mulcahy, D. Rafferty, A. Asgekar, M. Brentjens, R.A. Fallows, W. Frieswijk, M.C. Toribio, B. Adebahr, M. Arts, M.R. Bell, A. Bonafede, J. Bray, J. Broderick, T. Cantwell, P. Carroll, Y. Cendes, A.O. Clarke, J. Croston, S. Daiboo, F. de Gasperin, J. Gregson, J. Harwood, T. Hassall, V. Heesen, A. Horneffer, A.J. van der Horst, M. Iacobelli, V. Jelić, D. Jones, D. Kant, G. Kokotanekov, P. Martin, J.P. McKean, L.K. Morabito, B. Nikiel-Wroczyński, A. Offringa, V.N. Pandey, M. Pandey-Pommier, M. Pietka, L. Pratley, C. Riseley, A. Rowlinson, J. Sabater, A.M.M. Scaife, L.H.A. Scheers, K. Sendlinger, A. Shulevski, M. Sipior, C. Sobey, A.J. Stewart, A. Stroe, J. Swinbank, et al. (89 additional authors not shown)

(Submitted on 3 Sep 2015)

We present the Multifrequency Snapshot Sky Survey (MSSS), the first northern-sky LOFAR imaging survey. In this introductory paper, we first describe in detail the motivation and design of the survey. Compared to previous radio surveys, MSSS is exceptional due to its intrinsic multifrequency nature providing information about the spectral properties of the detected sources over more than two octaves (from 30 to 160 MHz). The broadband frequency coverage, together with the fast survey speed

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Current browse context:

astro-ph.IM
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new | recent | 1509

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References & Citations

- NASA ADS

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- vo.astron.nl ... take note of SAMP connection

MSSH Verification Field Sources

Parameters

- Position/Name: 15 00 00 70 00 00
- Search radius: 60.0

Result

Matched: 28

Send via SAMP Quick Plot

Current Table Properties

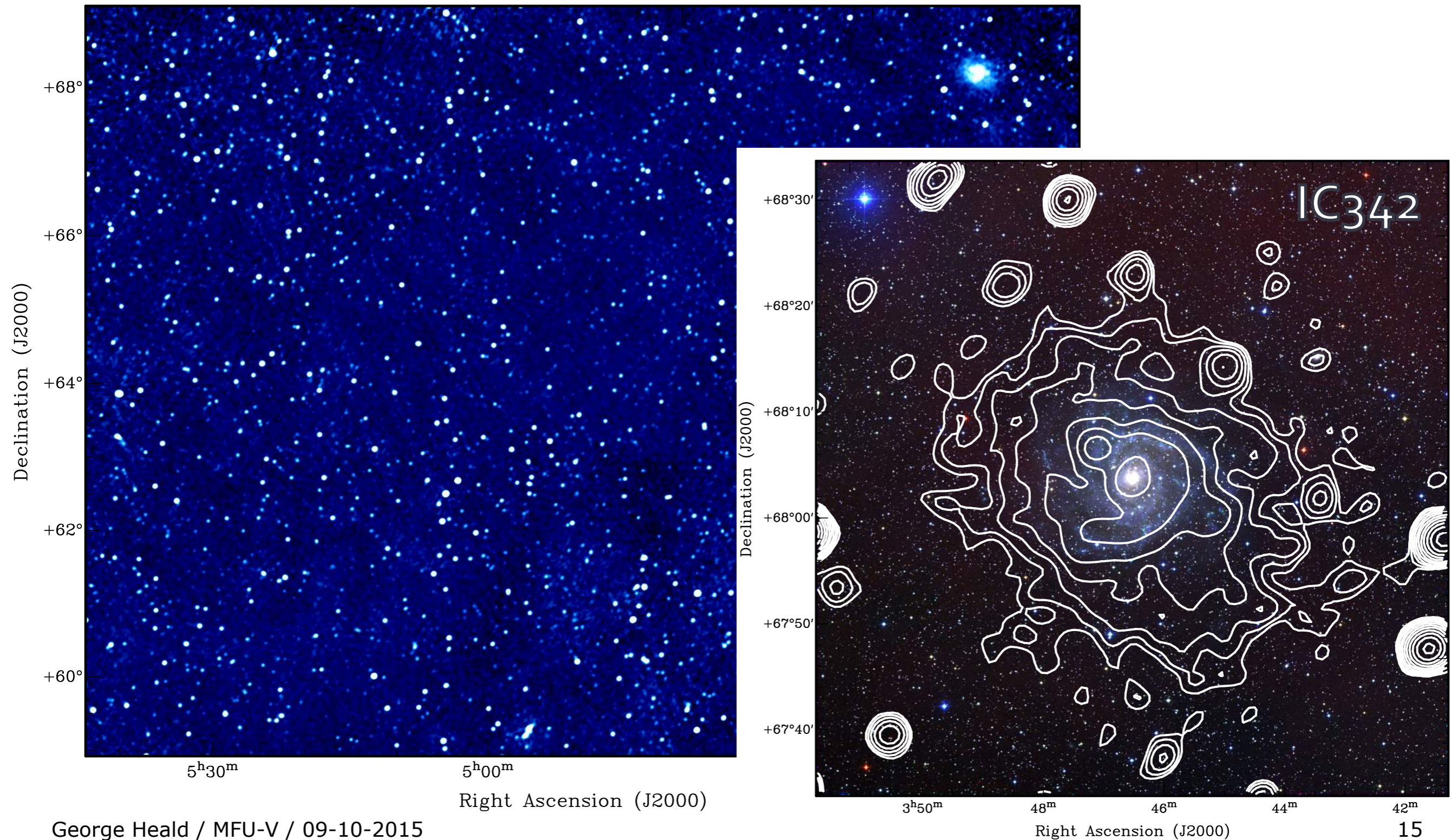
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 Columns: 204
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SAMP

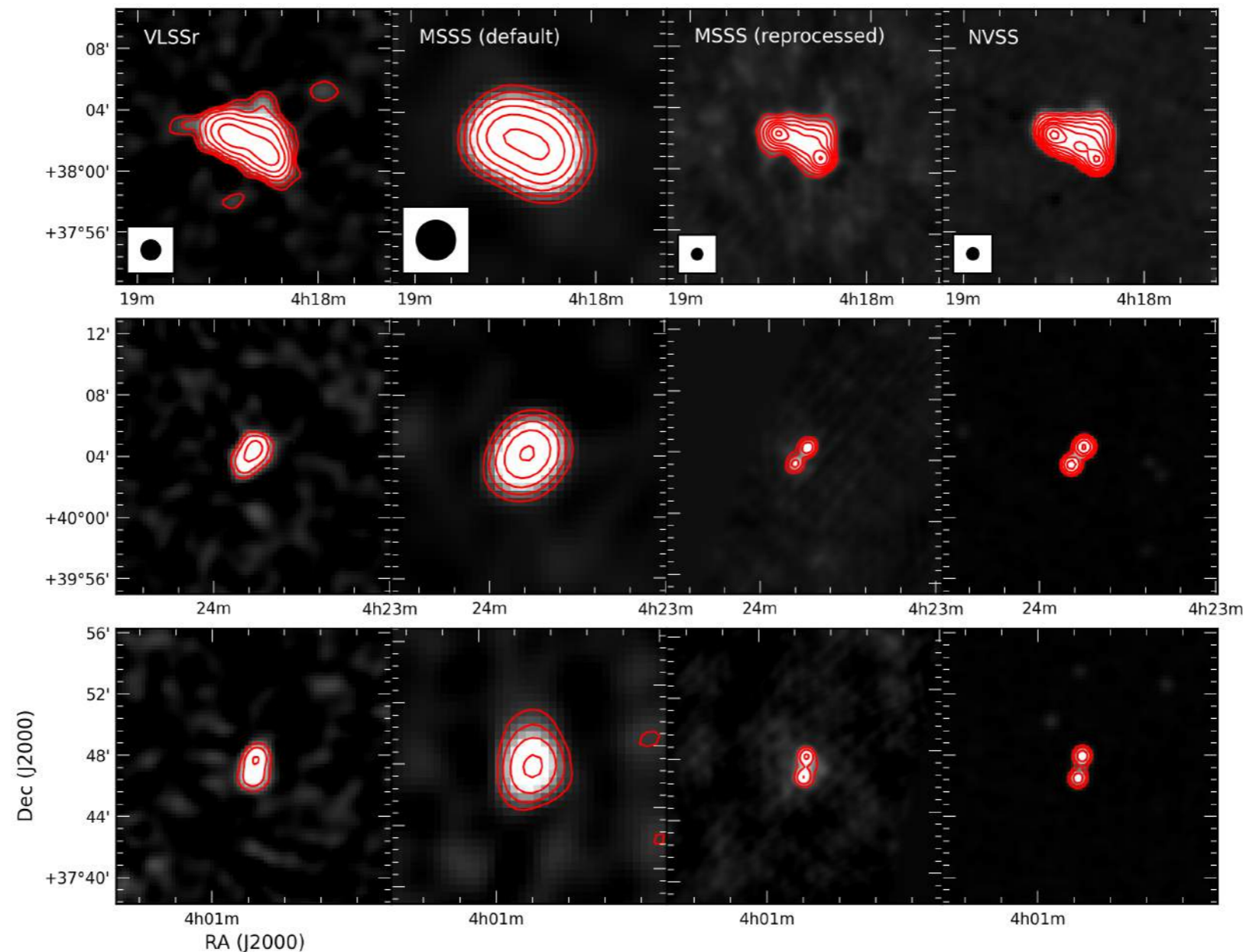
Messages: Clients:

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MSSSVF J144837+701157	222.155644398	70.1993786273	8.93426808364e-05	7.35528382713e-05	0.000816016757908	0.000684518724518	MVF	3C196	3C295
MSSSVF J145041+693952	222.674758491	69.6645500623	0.000442171287856	0.000320085410761	0.000923805543592	0.000752070830693	MVF	3C196	3C295
MSSSVF J145155+695829	222.980731296	69.9749139605	0.00056287173152	0.000408355492084	0.000987282037065	0.000793668742054	MVF	N/A	3C295
MSSSVF J145225+703752	223.105885017	70.6313104273	0.000372967557692	0.000288693327429	0.00089275194408	0.000739256181239	MVF	N/A	3C295
MSSSVF J145341+692732	223.42415154	69.4590201518	2.3375973815e-05	1.73553393707e-05	0.0008114478854	0.000680776815118	MVF	3C196	3C295
MSSSVF J145436+701116	223.653141022	70.1878043548	0.000383174596627	0.00031986643914	0.000897064103656	0.000751977661294	MVF	3C196	3C295
MSSSVF J145436+701116	223.653141022	70.1878043548	0.000383174596627	0.00031986643914	0.000897064103656	0.000751977661294	MVF	3C196	3C295

- Standard imaging product: 100 square degree mosaics, each composed of 10s of individual HBA fields

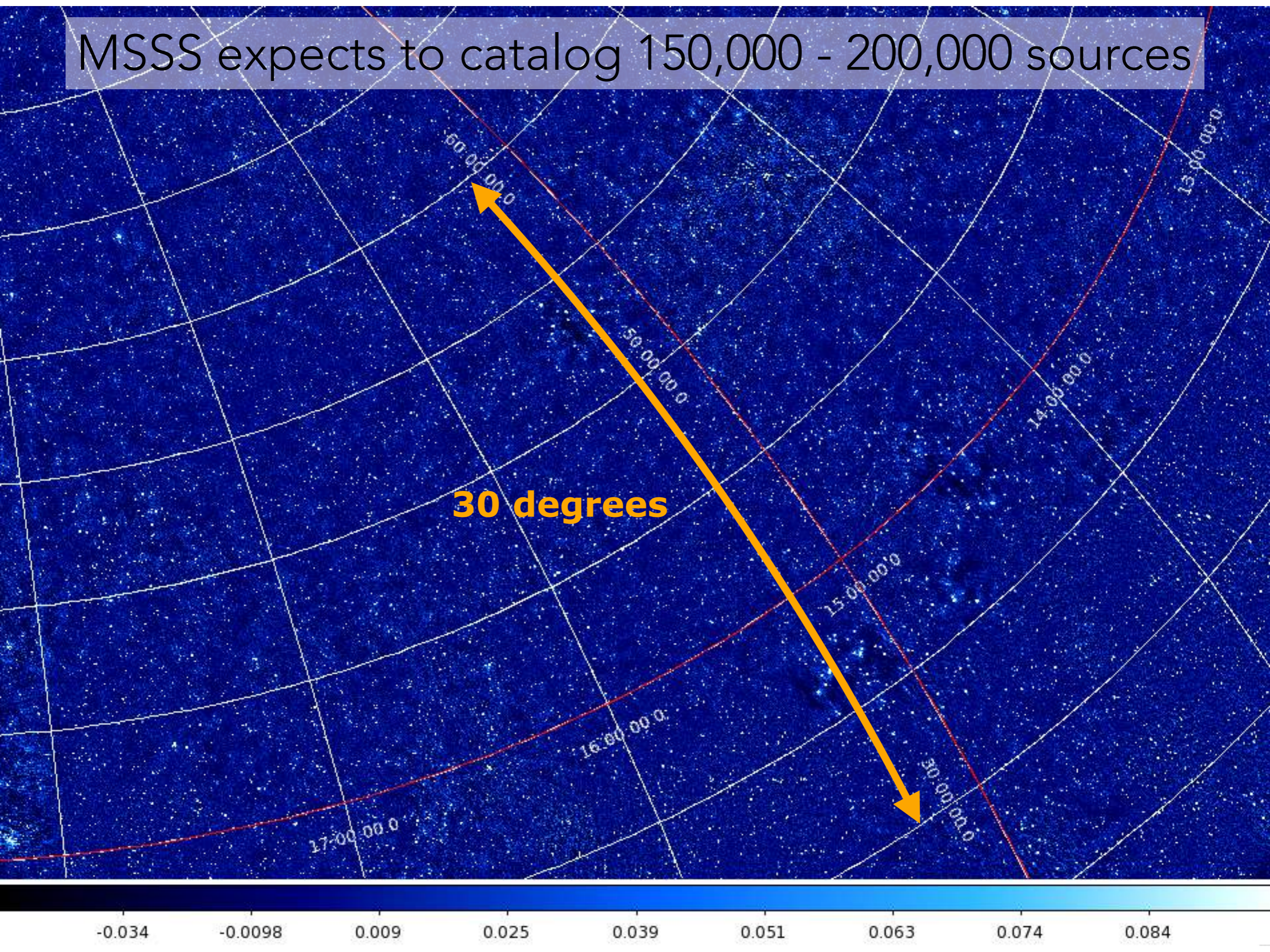


- All Dutch station baselines included in MSSS-HBA observations
- Imaging at 20-30'' resolution feasible with modest computing



- Planned for v2 catalog - AWS/SKA funding granted to facilitate this stage of the MSSS development

MSSS expects to catalog 150,000 - 200,000 sources



30 degrees

-0.034

-0.0098

0.009

0.025

0.039

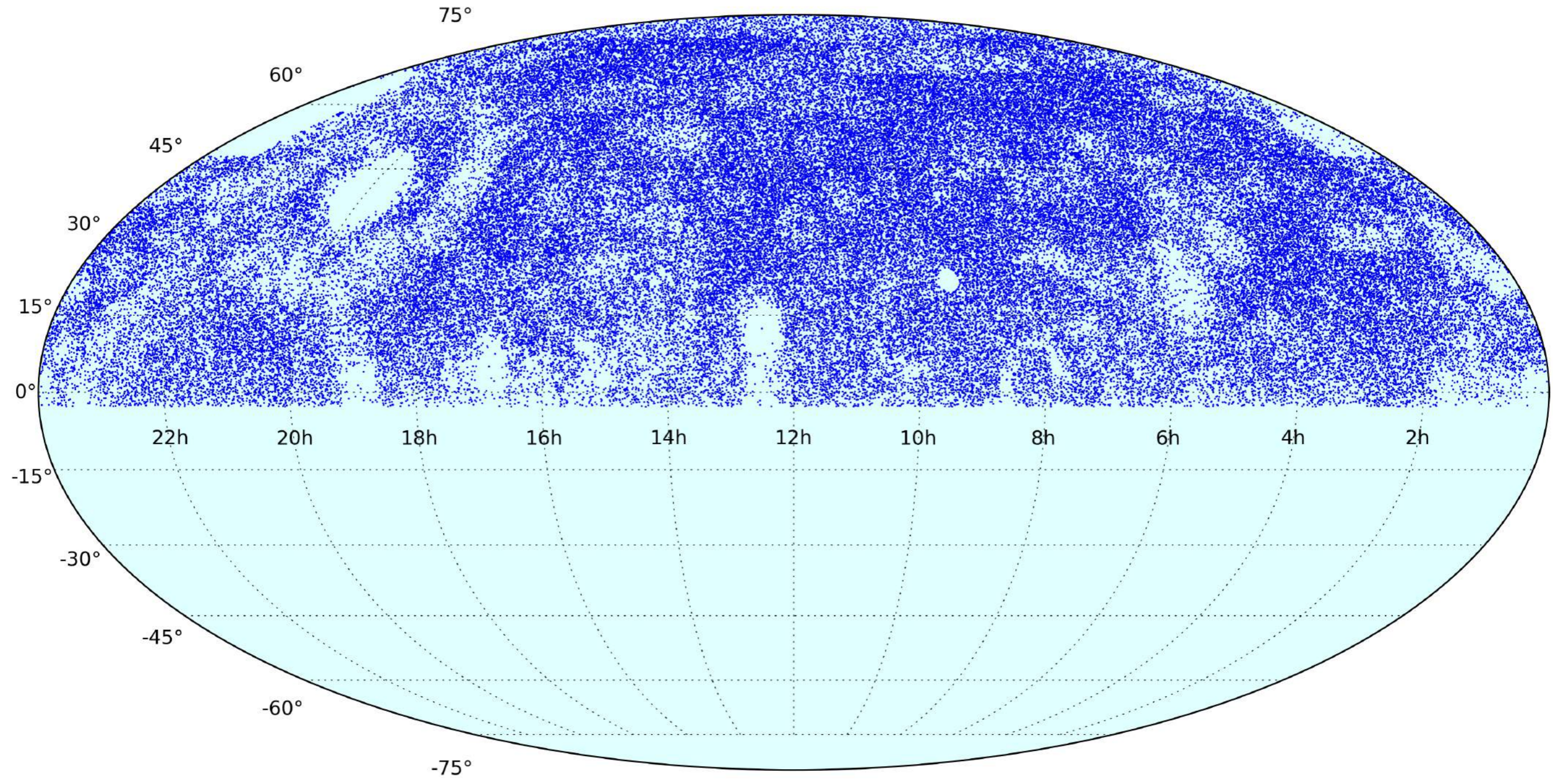
0.051

0.063

0.074

0.084

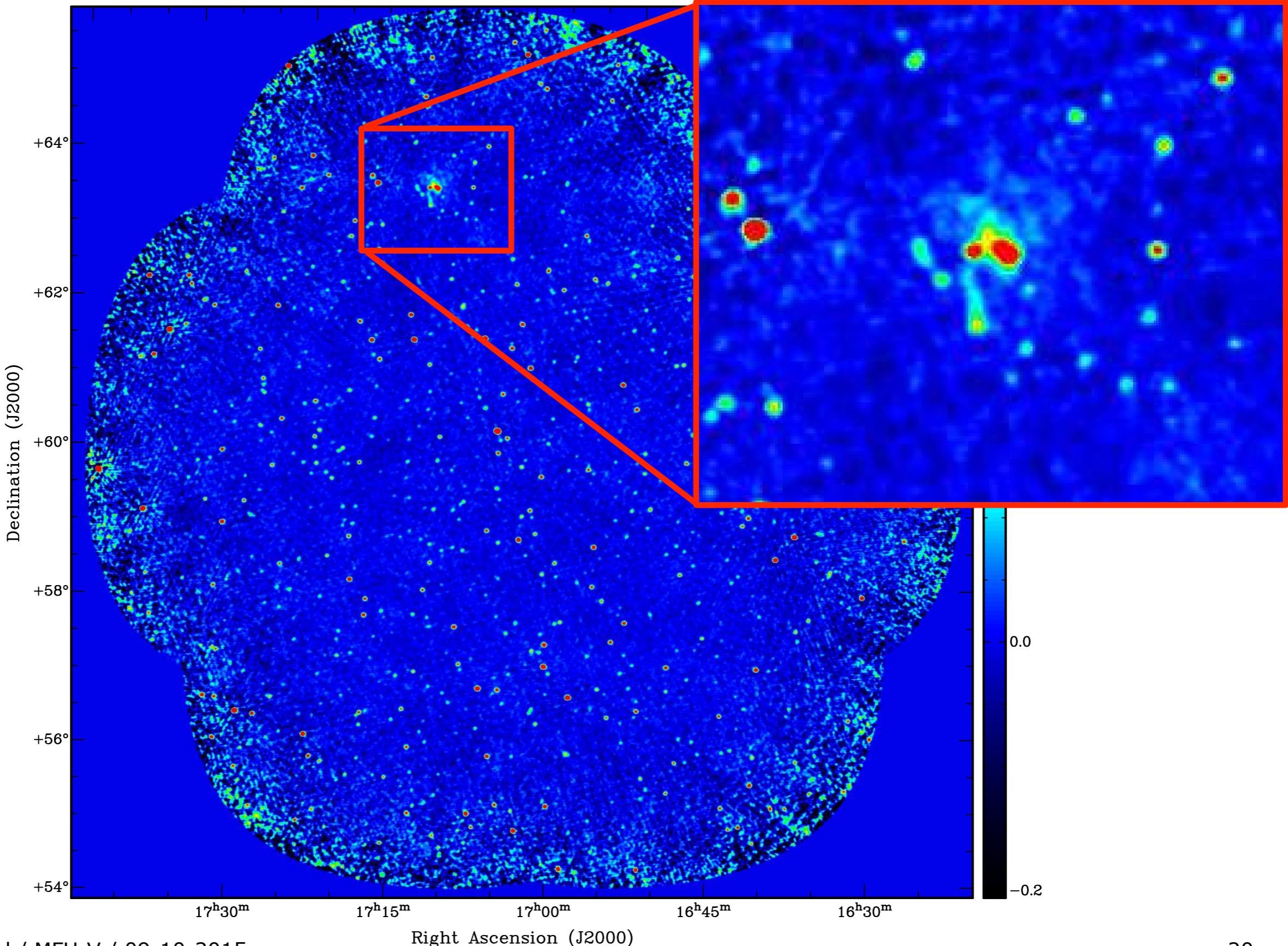
MSSS-HBA catalog (v0): $\sim 140,000$ sources



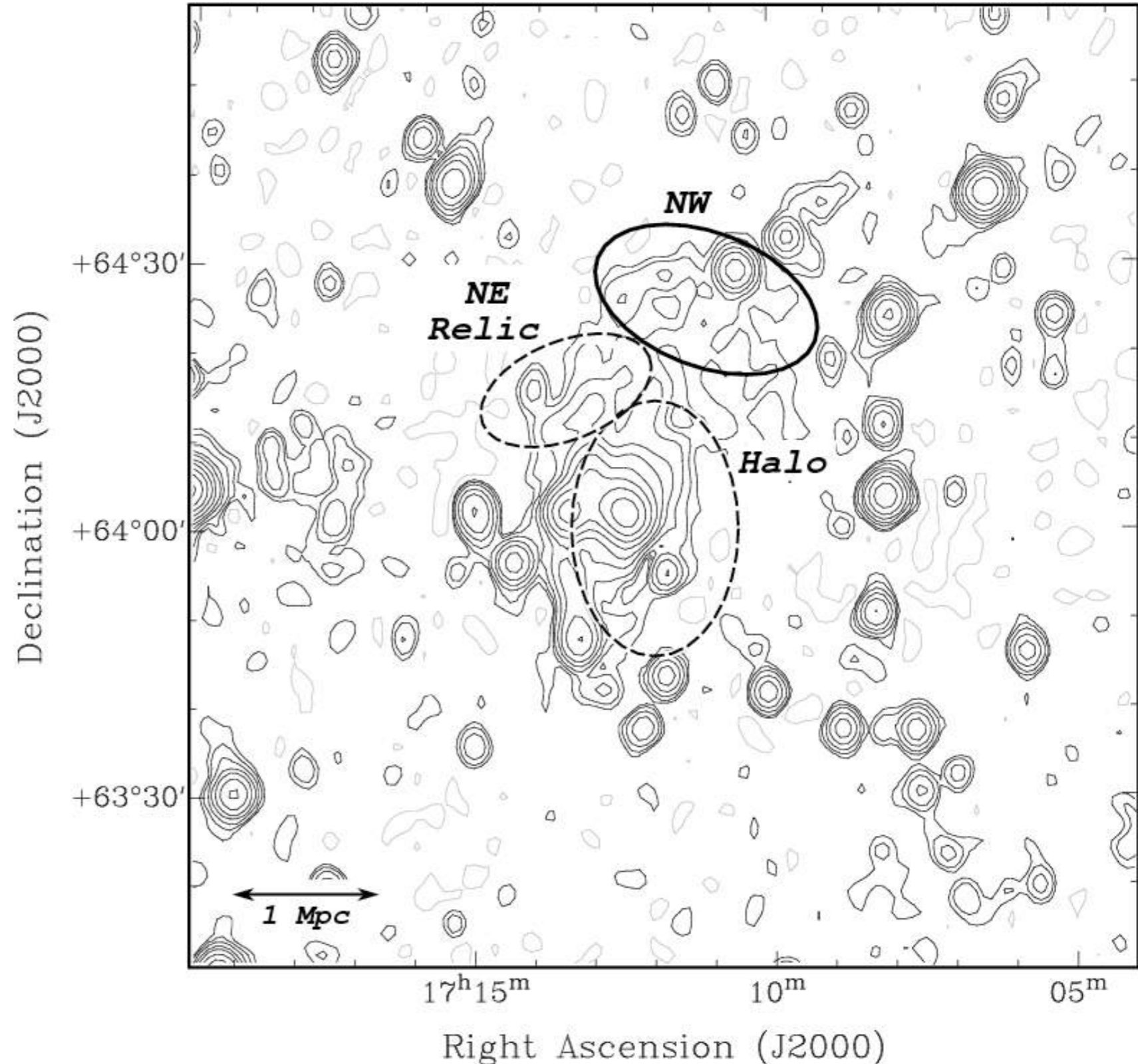
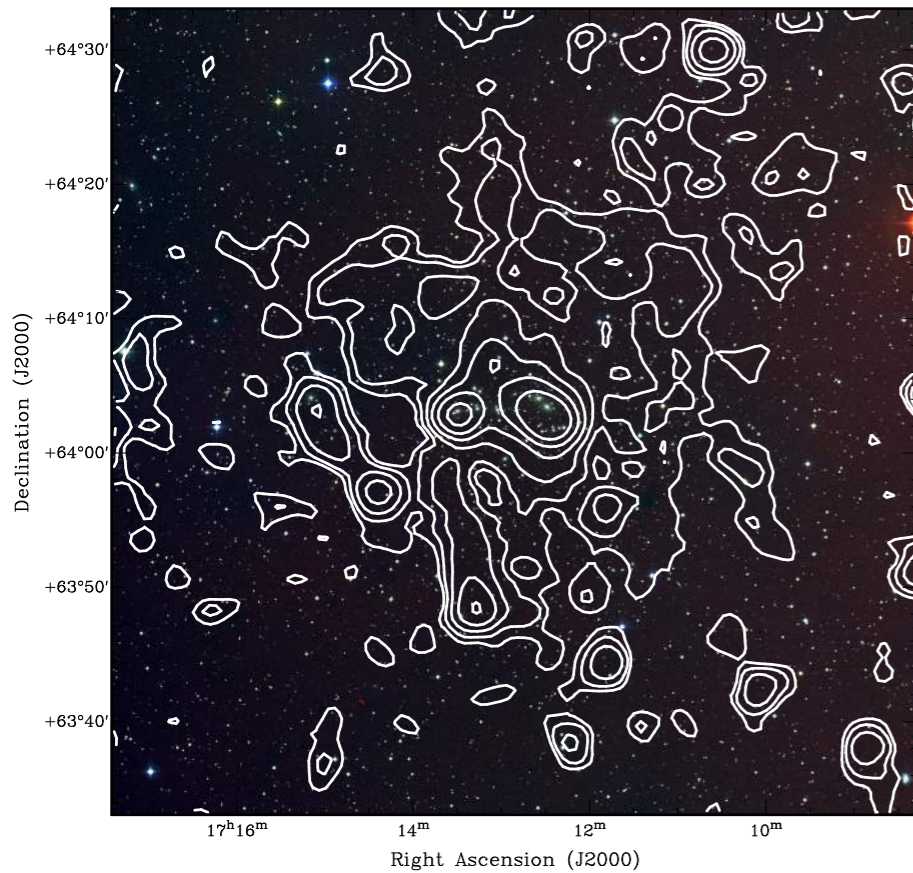
Science with MSSS



One of the first MSSS-HBA mosaics



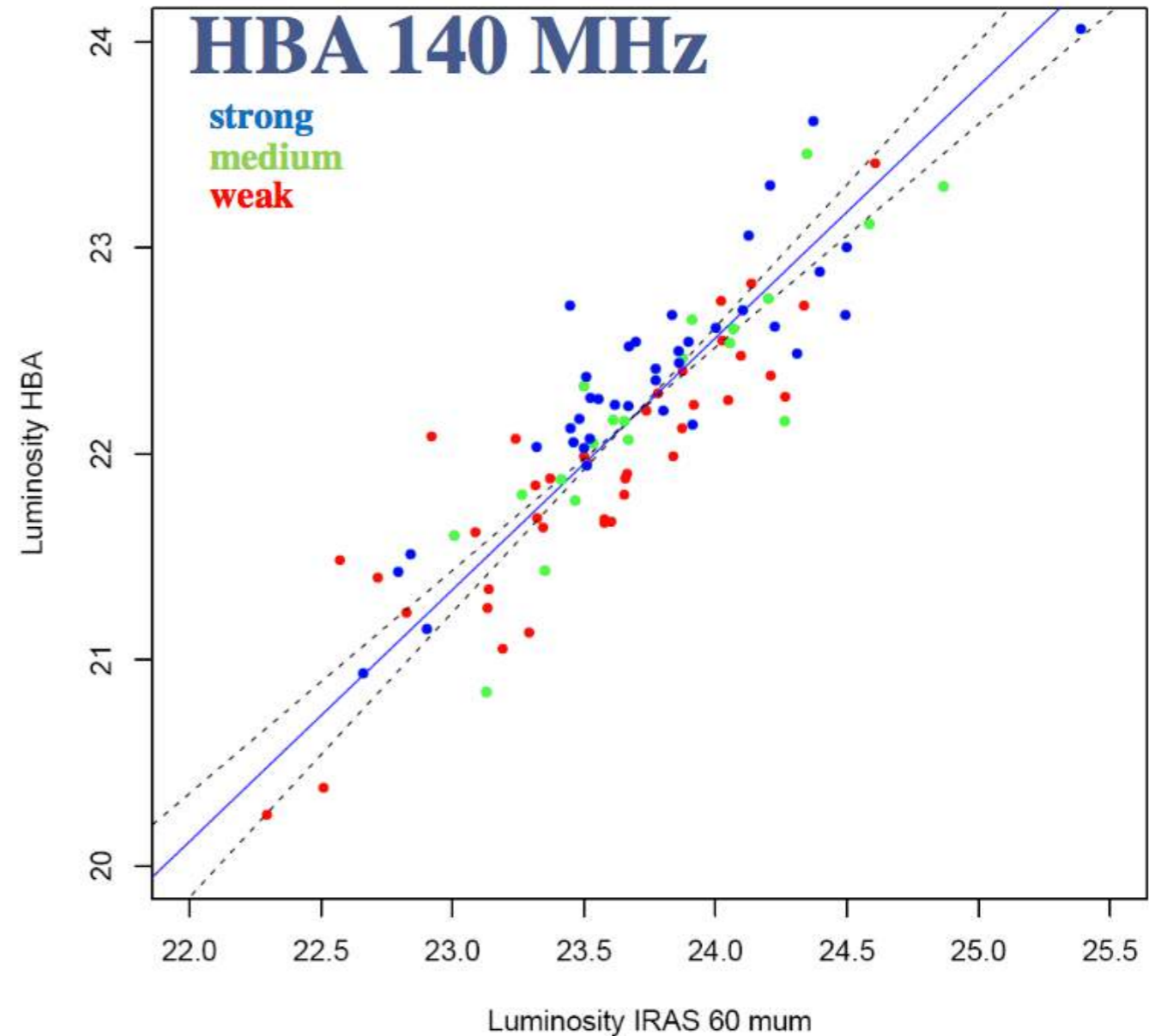
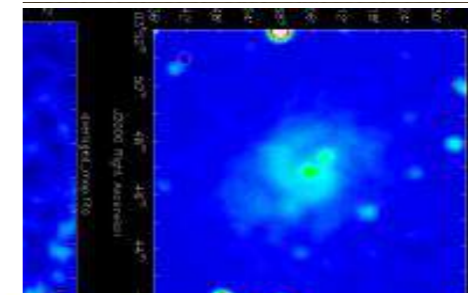
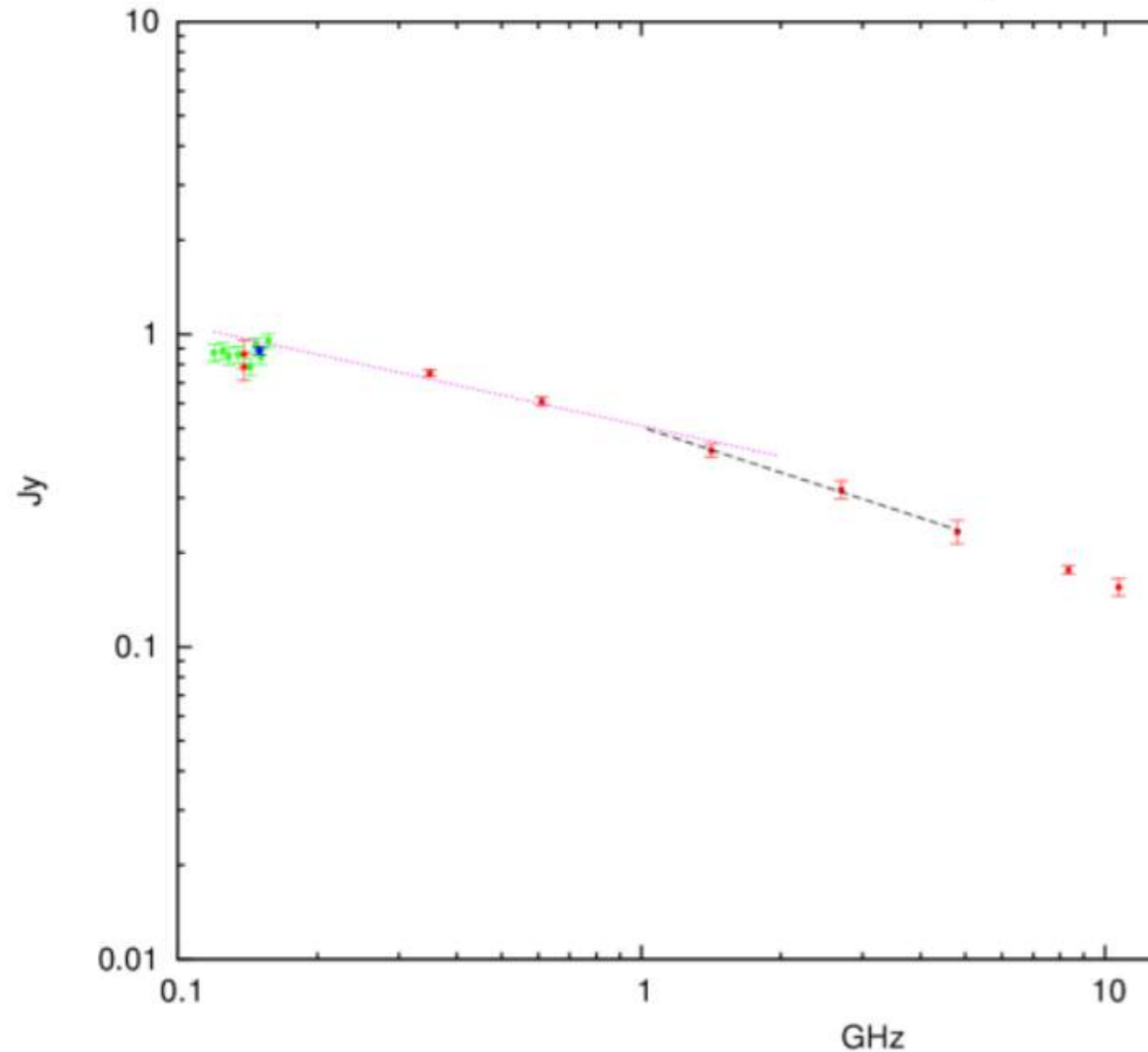
- cf Pizzo & de Bruyn (2009)
WSRT, 150 MHz



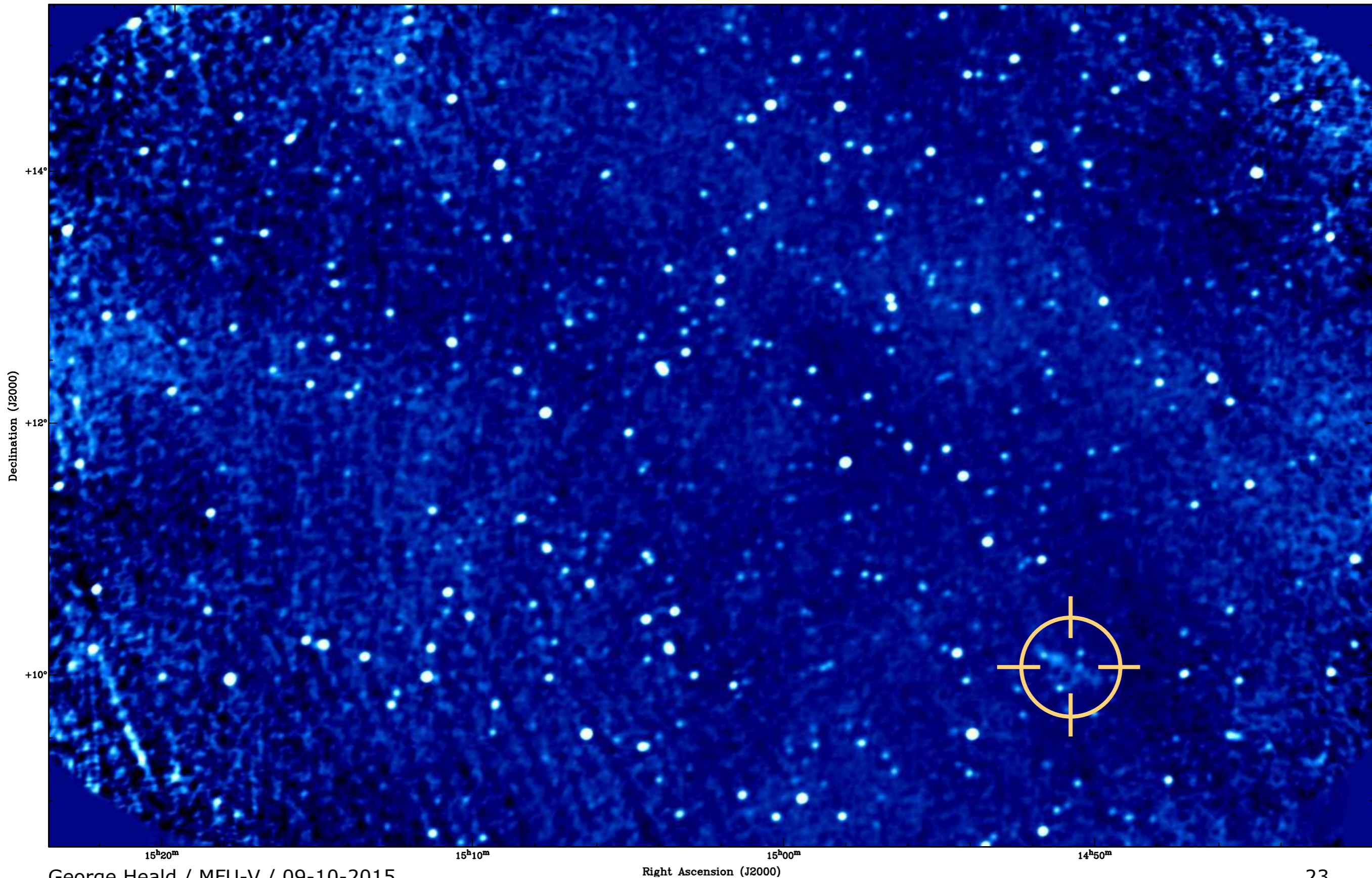
MSSS-HBA: 14 min!

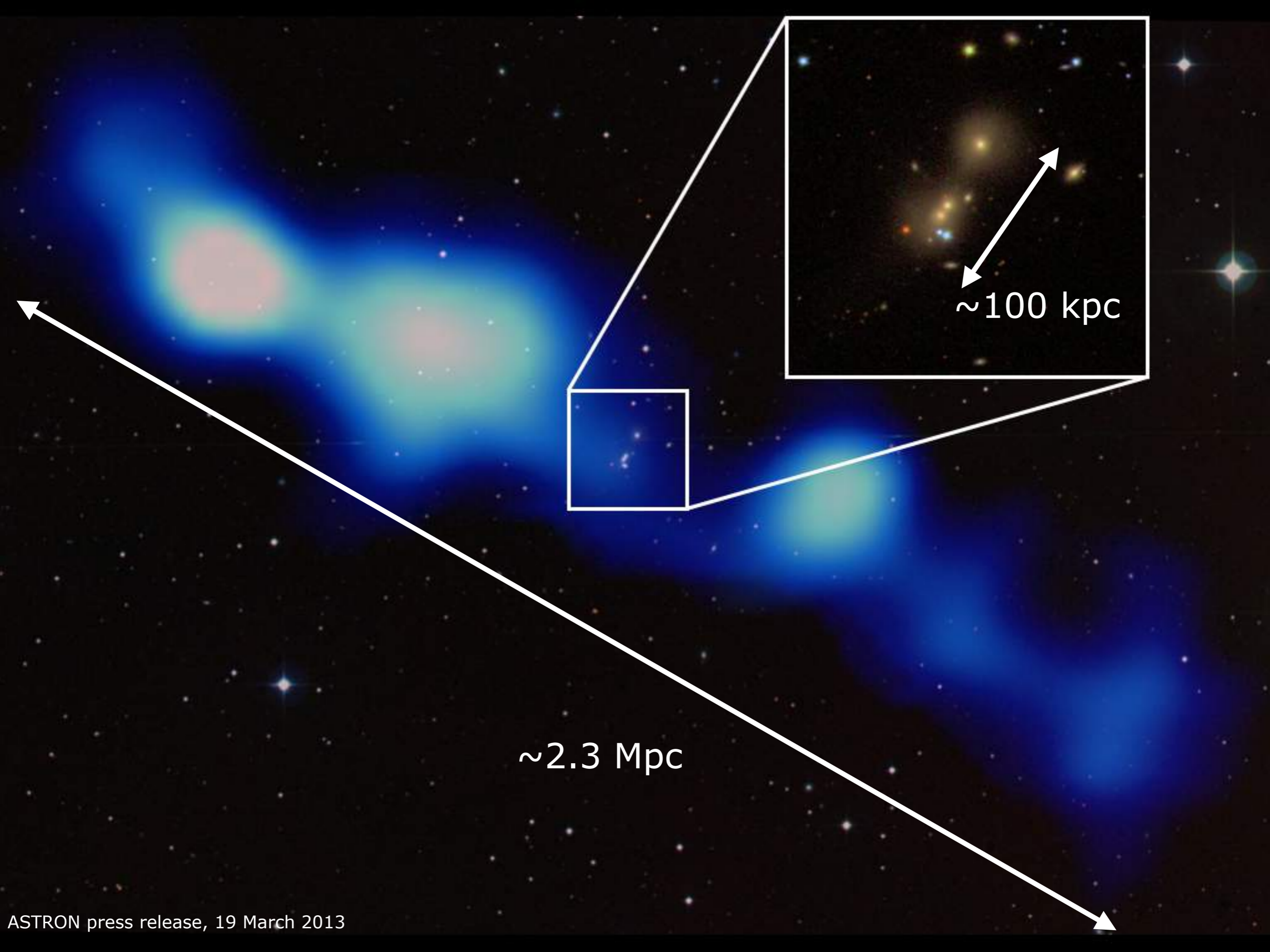
- Key goals: integrated spectra at low frequency; radio-FIR correlation

NGC1569 catalog



Co-authors: Uli Klein, Enno M
Conway, Eskil Varen





~ 100 kpc

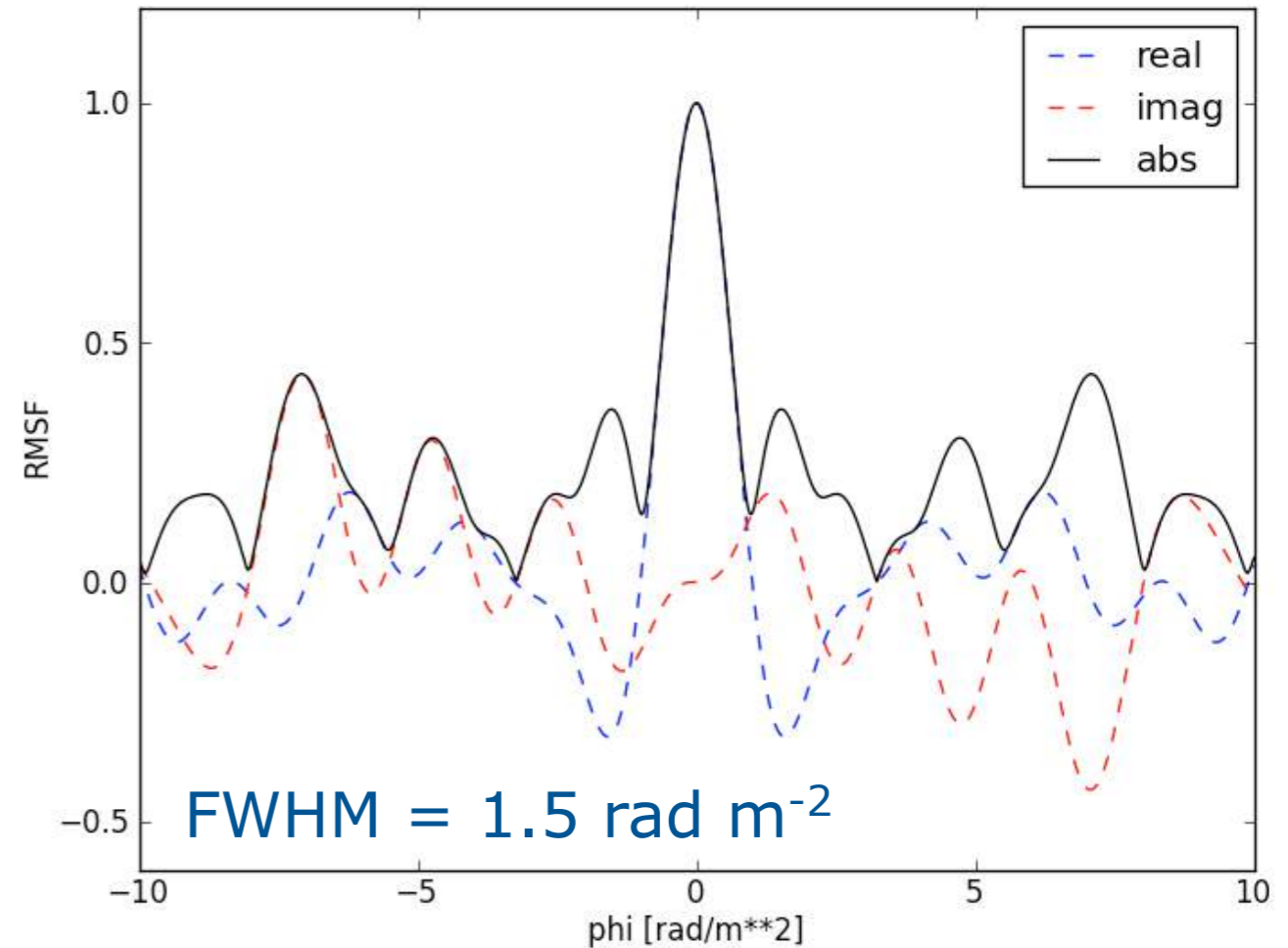
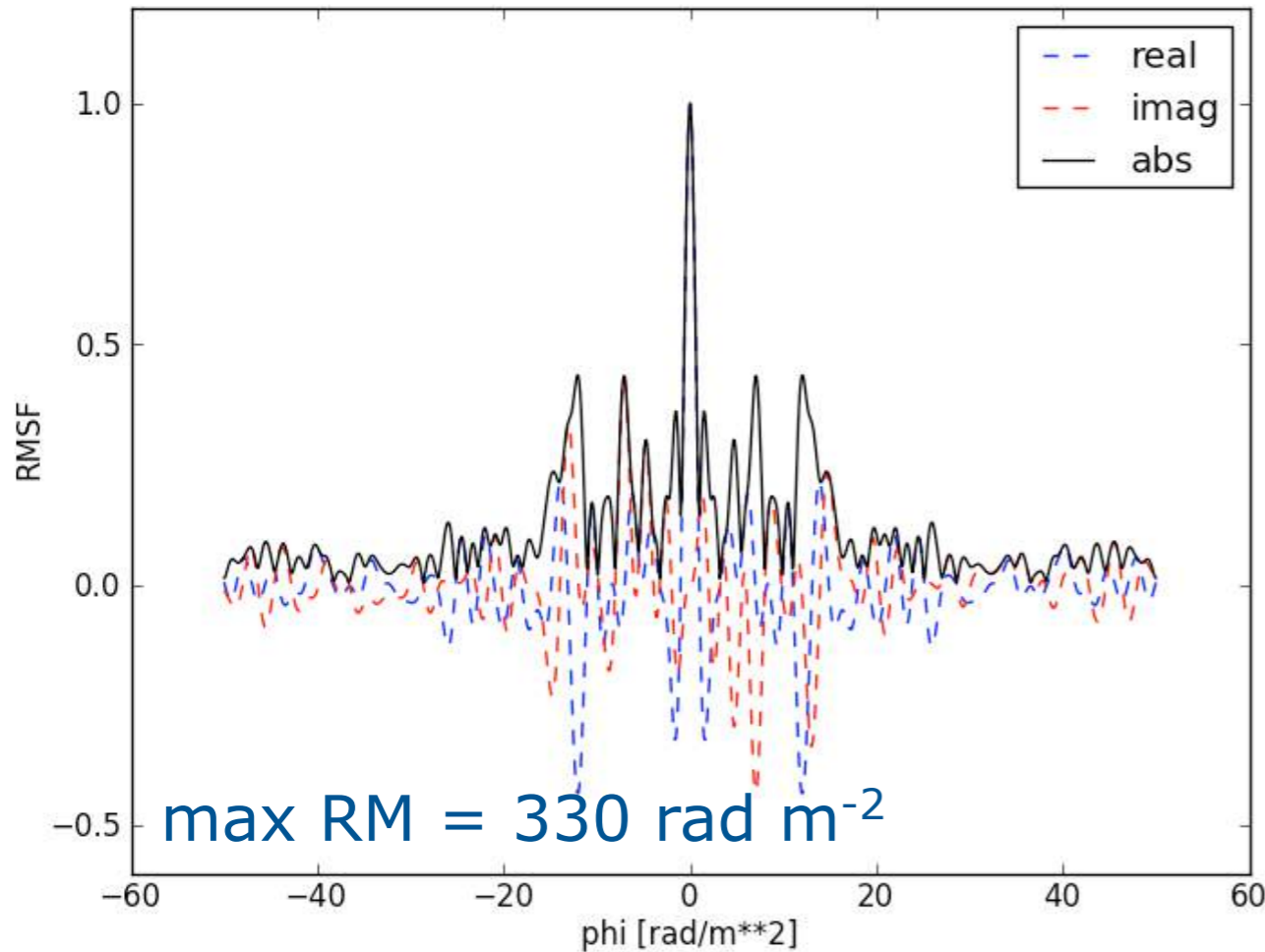
~ 2.3 Mpc



“Great MSSS Supernova Remnant Hunt”

Mulcahy et al

- Frequency coverage in HBA allows for shallow polarization search

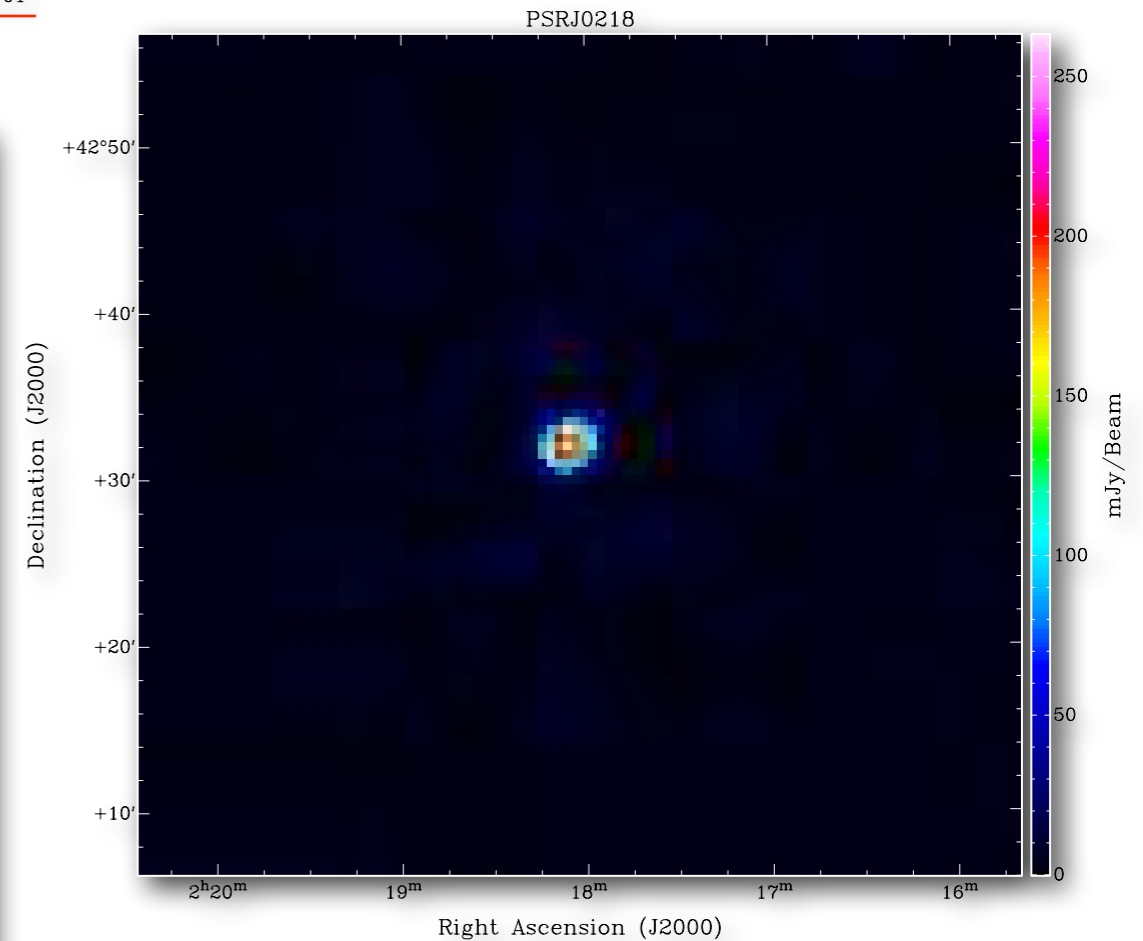
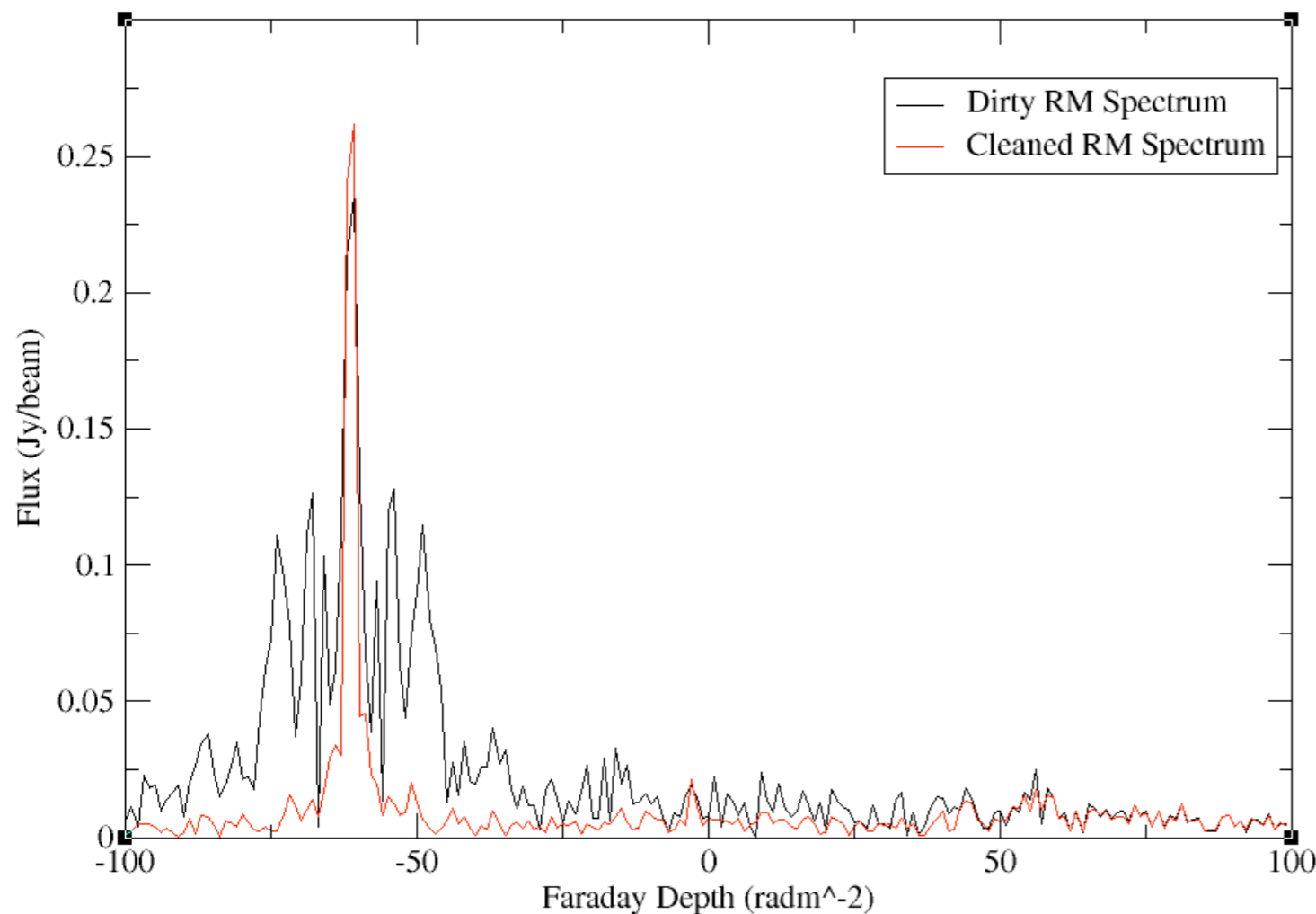


- Calibration and imaging needs a bit of work but no show stoppers:
 - ionospheric RM (predictions) can be applied
 - imaging step is a bit awkward for non-MFS use
- Fields with bright polarization (Fan region and some polarized pulsars) have been observed

- Polarized pulsar (PSRJ0218) detected with MSSS image data!
- 51% polarized, and with correct RM of -61 rad m^2 (ionospheric RM correction was applied to the data)

FARDEPTH: $-6.10000\text{e}+01$

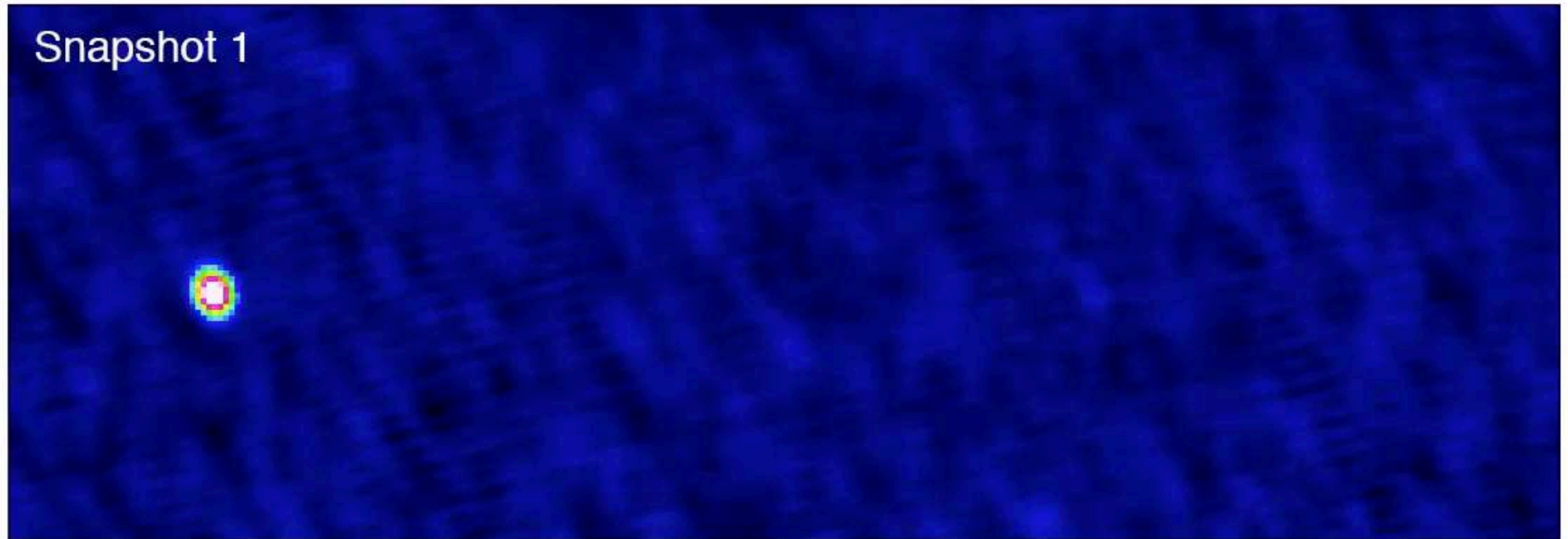
Detection of PSRJ0218 in MSSS



David Mulcahy

- In MSSS-LBA, 1 subband always on NCP (200 kHz bw at 60 MHz)
- In both MSSS-LBA and MSSS-HBA, multiple epochs (9,2 resp)

Transient Candidate #1



- First MSSS(-LBA) transient candidate (***Stewart et al, submitted***)
 - Appears in one 11-min snapshot, flux density 15-25 Jy beam⁻¹
 - Implied rate for $\Delta t=11\text{min}$ is $1 \pm 1/2538$ transients day⁻¹ deg⁻² (~1 transient per square degree per 7 years!)

- HBA: upgrade to first all-sky public data release, and beyond...
 - Application of final flux scale definition
 - Production of HBA v1 (late 2015)
 - Verification of LOFAR broadband flux scale across the sky
 - Publication and release of HBA v1 (early 2016)
 - High resolution, polarization (late 2016)
 - Science papers! (starting now)
- LBA: resume observational testing soon

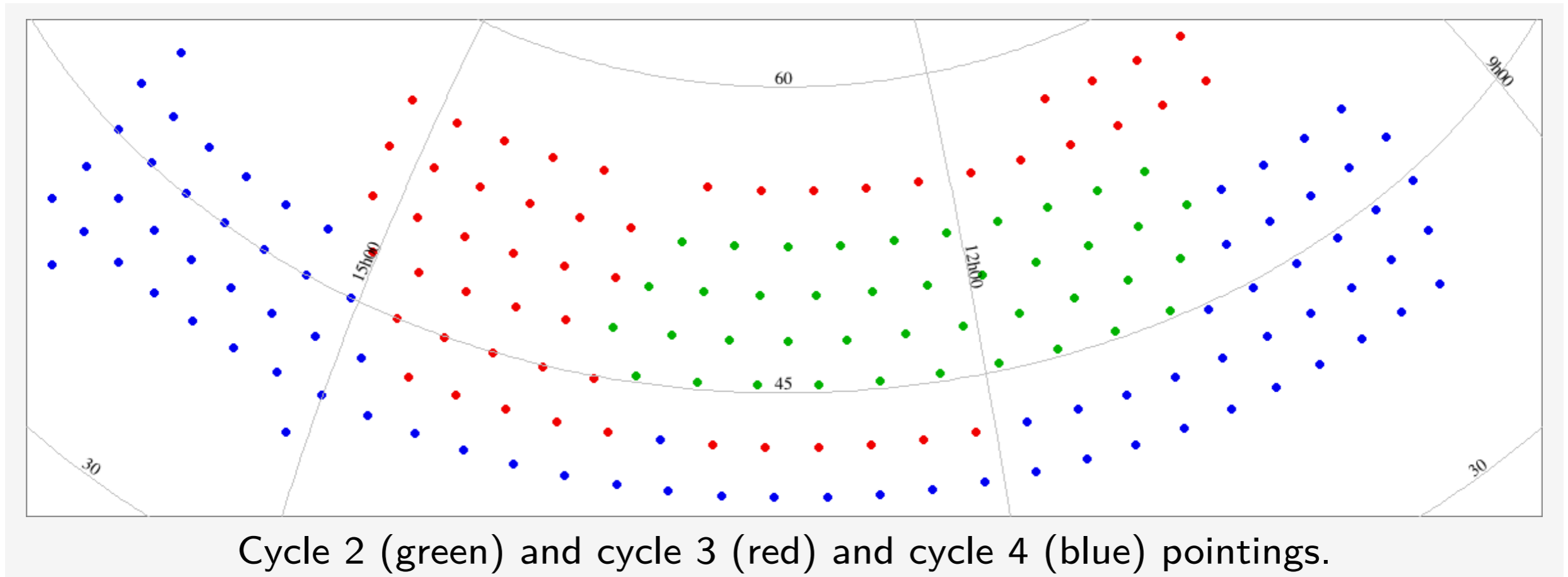
Deeper LOFAR surveys

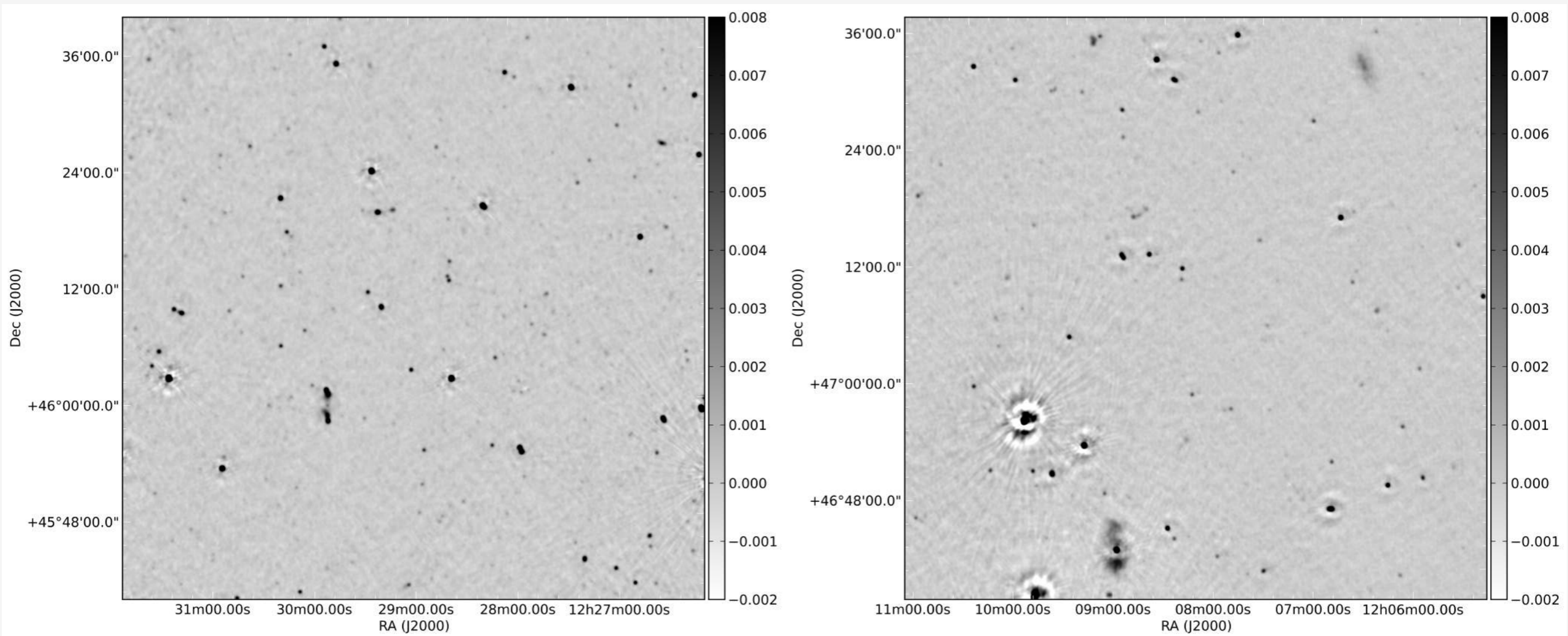
A deep-field astronomical image showing a vast field of stars and galaxies. The background is a dense field of small, faint stars. Several larger, more prominent objects are visible, including a bright, blueish-white star in the upper left, a large, irregularly shaped galaxy in the lower right, and a smaller, more compact galaxy in the lower right. The overall color palette is dominated by blues and whites, with some reddish-brown hues in the galaxy structures.

Special thanks to Tim Shimwell and Wendy Williams



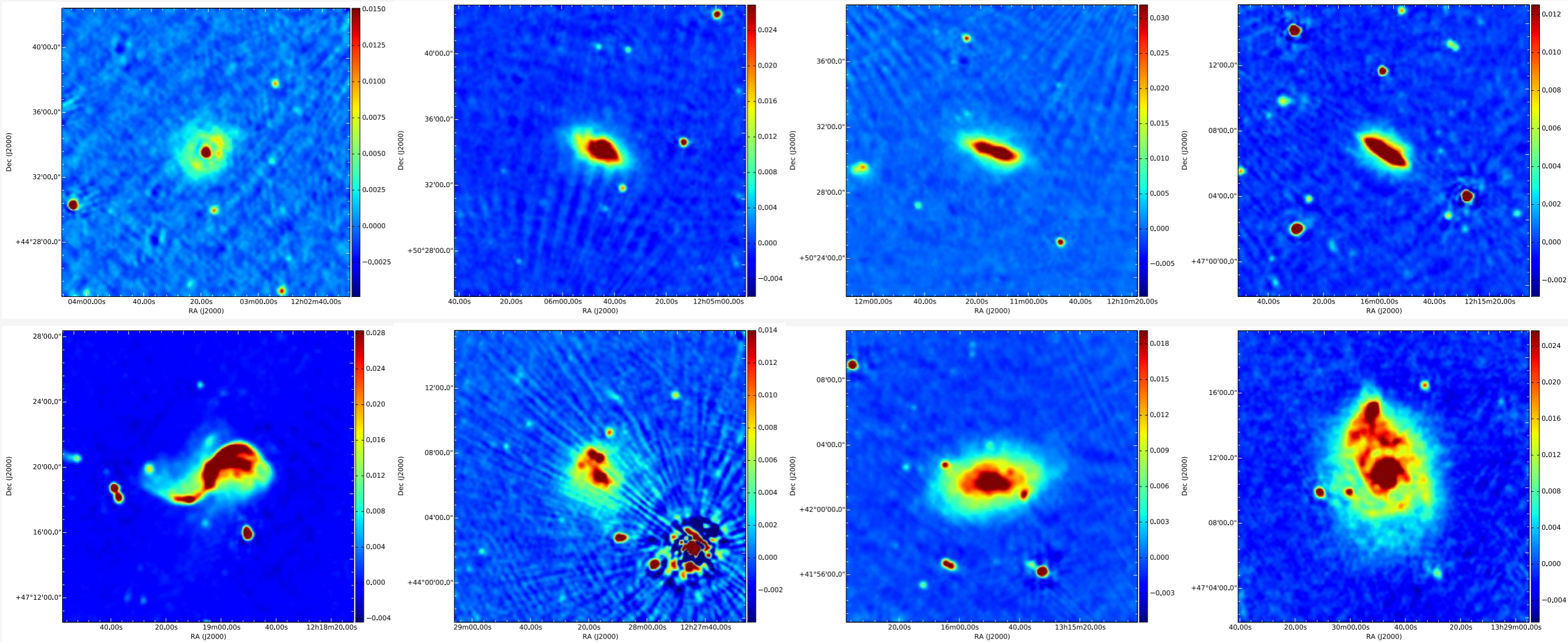
- $\sim 100 \mu\text{Jy}/\text{beam}$ sensitivity at $\sim 5''$ resolution
- 48 MHz bandwidth (120-168 MHz) toward each pointing
- 3200 pointings to cover the northern sky
(pointings separated by 2.6° ; beam FWHM from 3.35° to 4.75°)
- Observations began in June 2014
- $\sim 100 \times 8\text{h}$ pointings observed, ~ 80 more scheduled





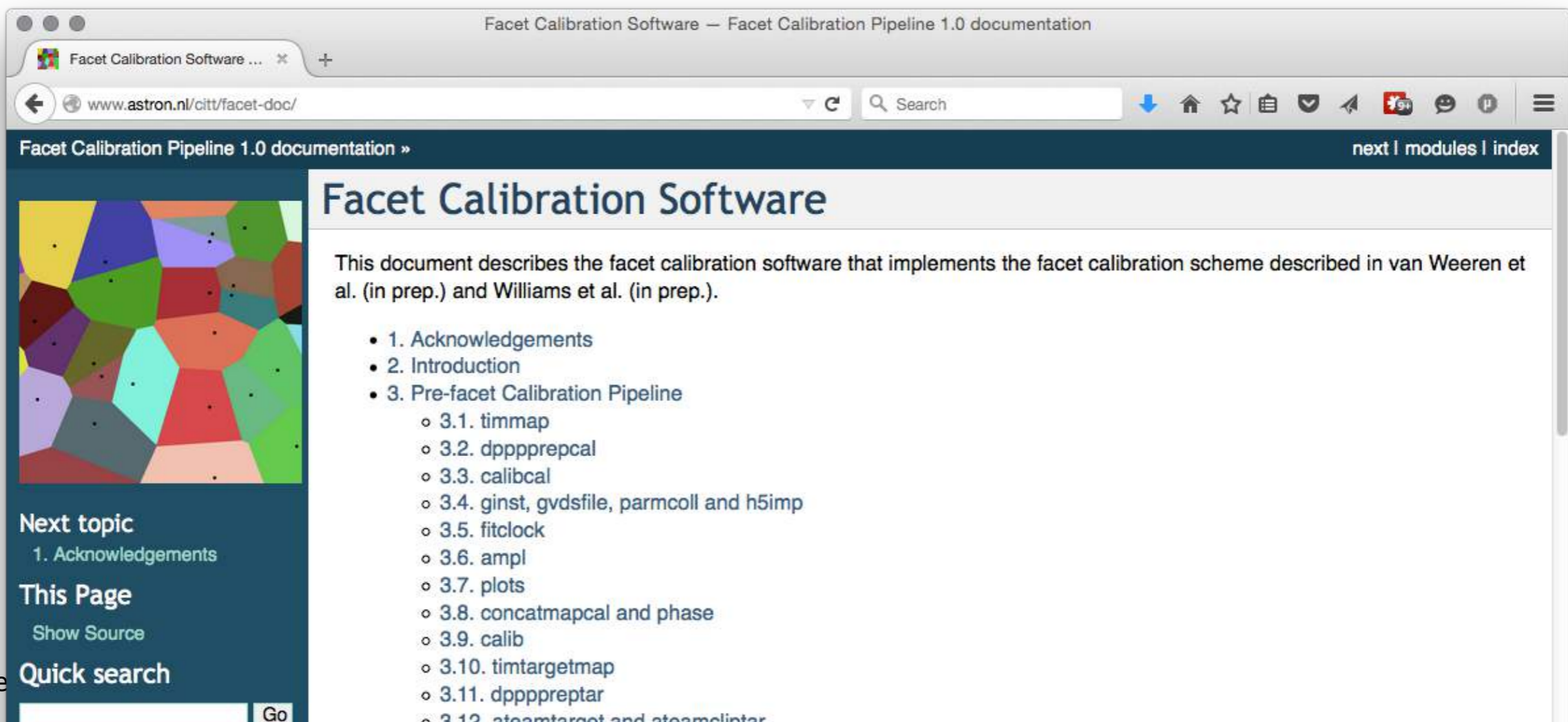
Two example degree square regions from the mosaiced image.

Current (DI) reduction - galaxies



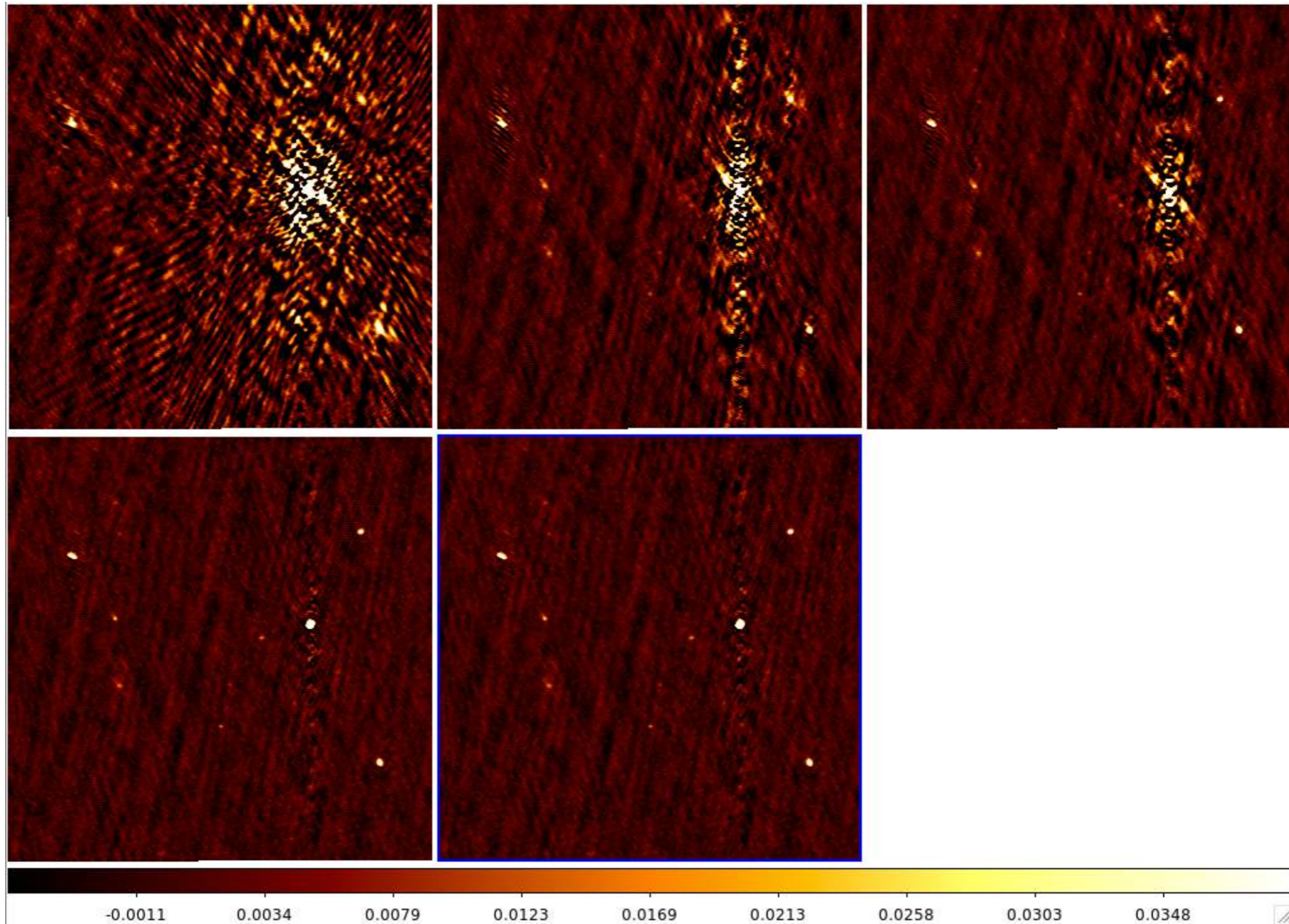
NGC 4051, 4088, 4157, 4217, 4258, 4449, 5055, 5194

- Facet calibration is a form of direction-dependent calibration and imaging developed by Reinout van Weeren (CfA)
 - Corrects for ionospheric distortions and beam errors
 - Enables imaging at 5" resolution and 100 μ Jy/beam rms
- Automated version developed by ASTRON's Calibration & Imaging Tiger Team, available to the community for general use

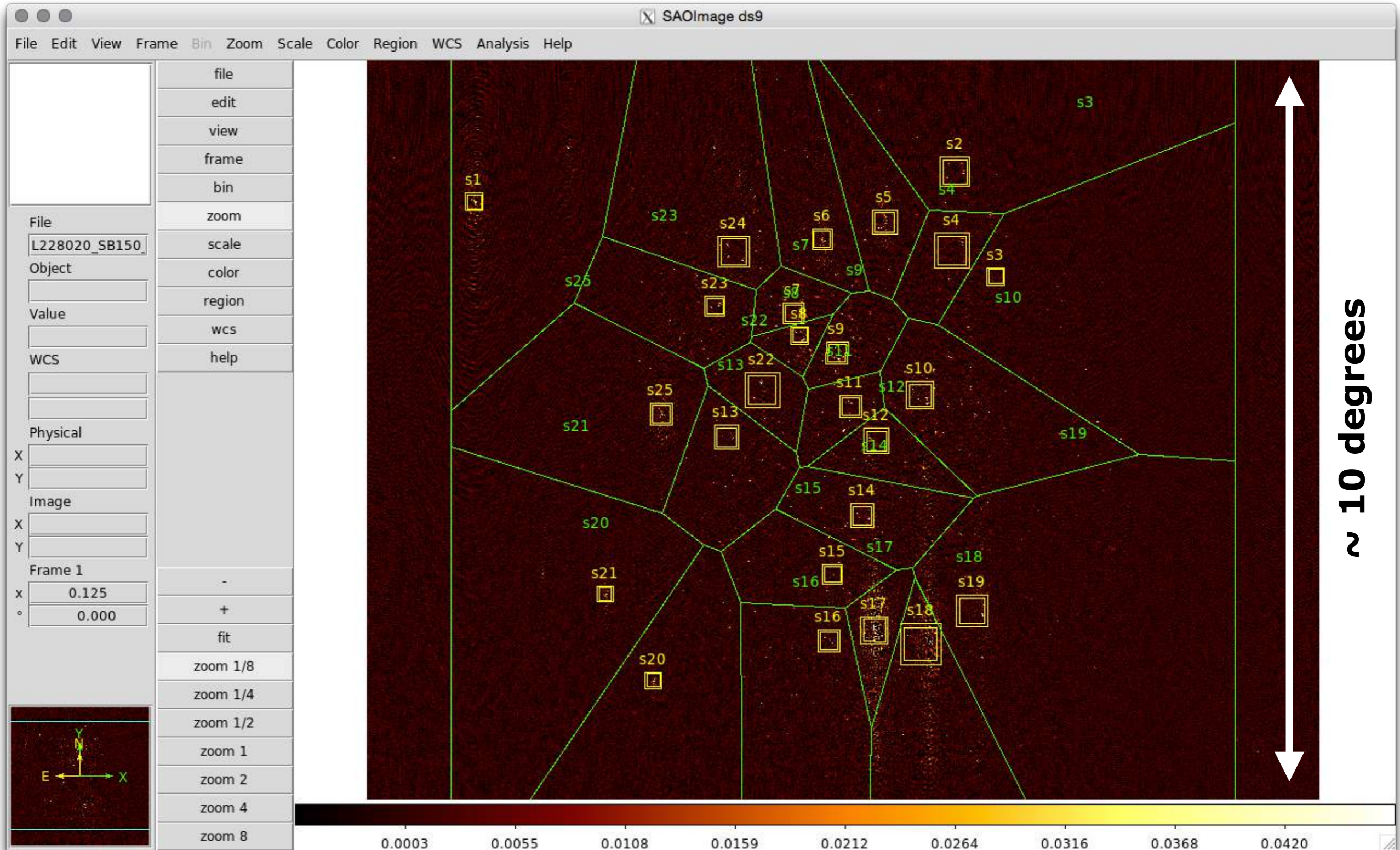


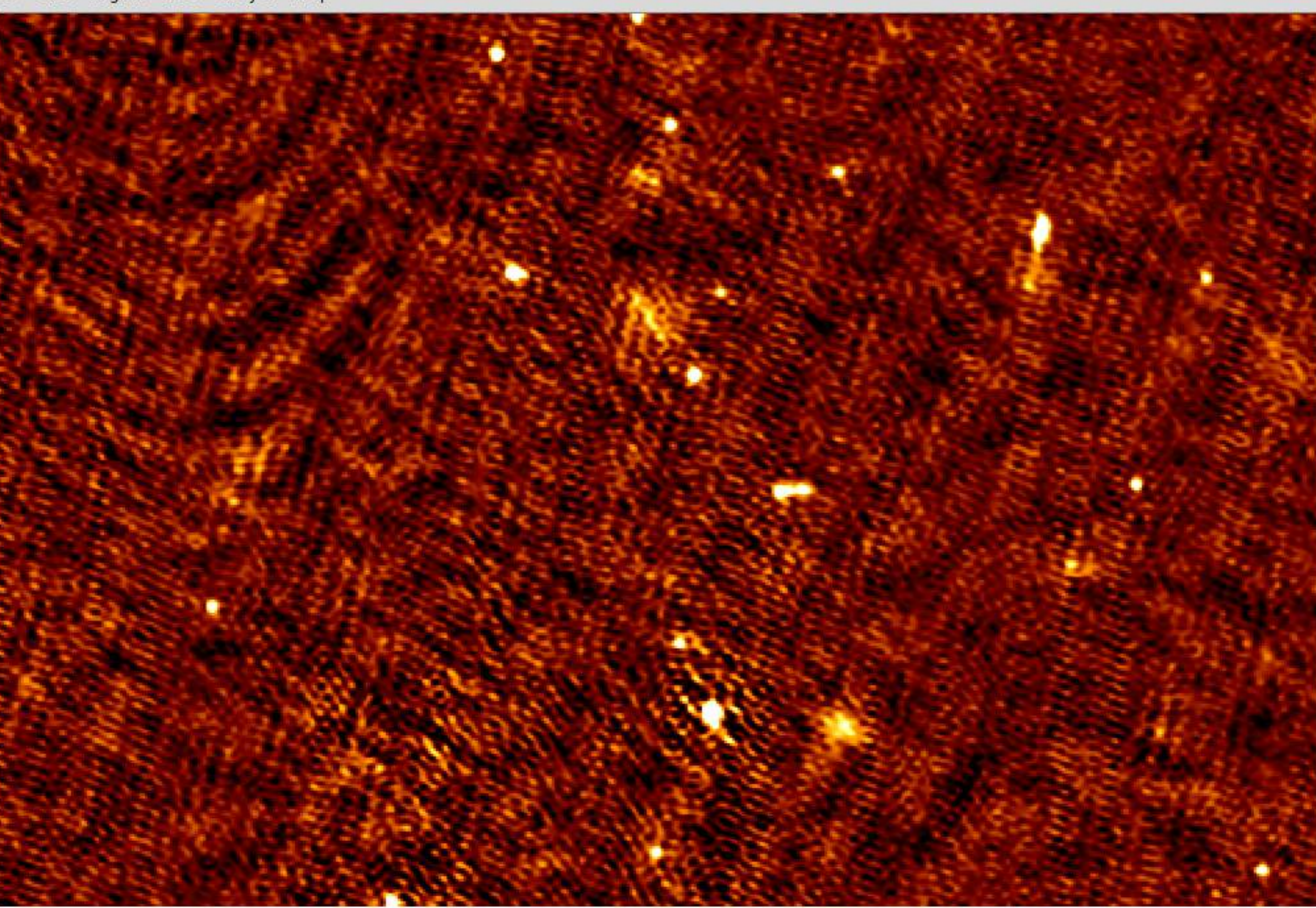
The screenshot shows a web browser window displaying the documentation for the Facet Calibration Pipeline 1.0. The browser's address bar shows the URL www.astron.nl/citt/facet-doc/. The page title is "Facet Calibration Pipeline 1.0 documentation". The main heading is "Facet Calibration Software". Below the heading, there is a paragraph: "This document describes the facet calibration software that implements the facet calibration scheme described in van Weeren et al. (in prep.) and Williams et al. (in prep.)." A table of contents is listed below, including sections for Acknowledgements, Introduction, and Pre-facet Calibration Pipeline, with sub-sections for various software modules like timmap, dpppprepcal, calibcal, ginst, gvdsfile, parmcoll, h5imp, fitclock, ampl, plots, concatmapcal, phase, calib, timtargetmap, dppppreptar, and ateamtarget and ateamelintar. On the left side, there is a sidebar with a "Next topic" section pointing to "1. Acknowledgements", a "This Page" section with a "Show Source" link, and a "Quick search" section with a search input field and a "Go" button.

- Typical improvement per direction:



- Field broken up into many directions, each treated separately





-0.0048

-0.0006

0.0037

0.0080

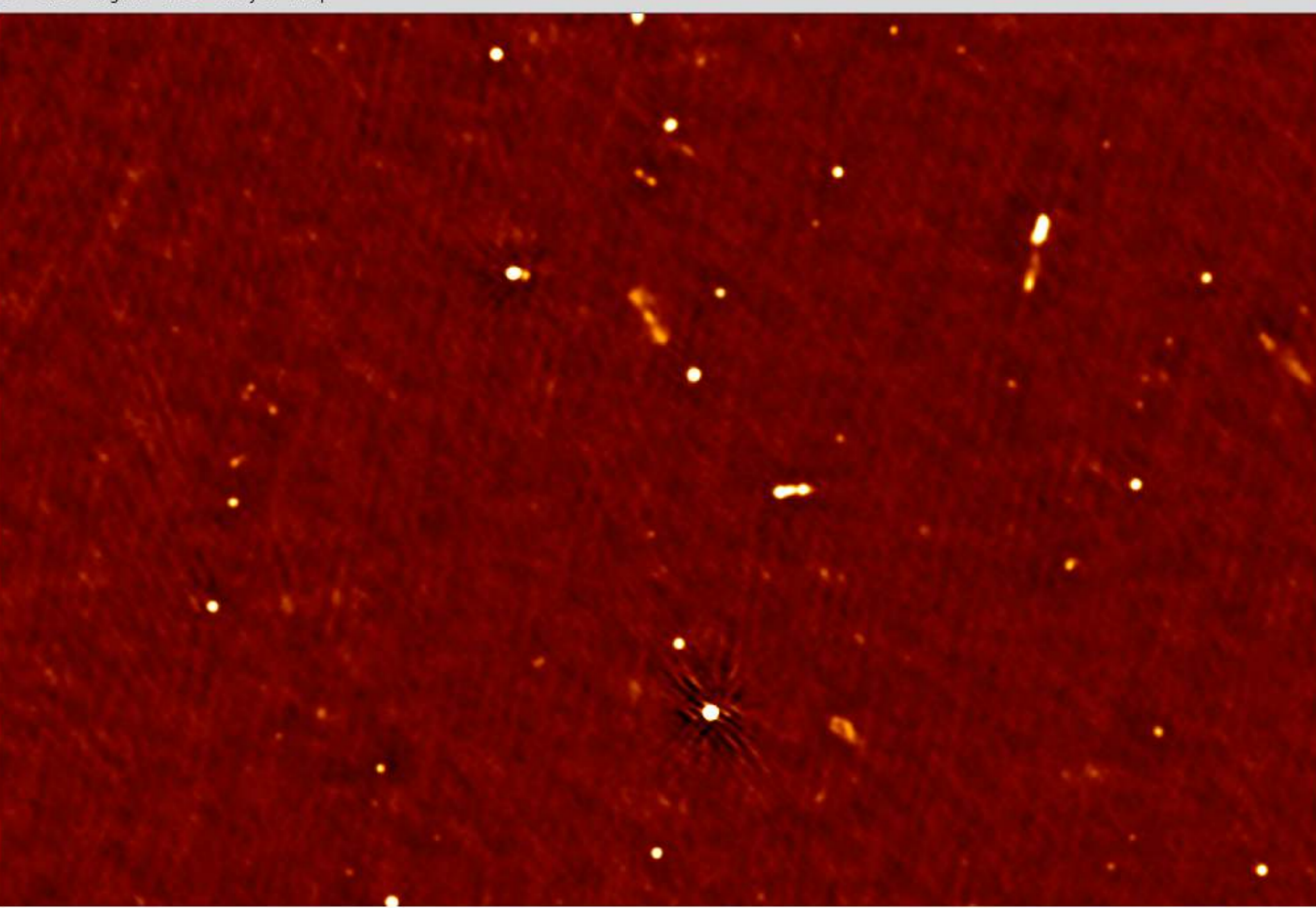
0.0123

0.0165

0.0208

0.0251

0.0293



-0.0048

-0.0006

0.0037

0.0080

0.0123

0.0165

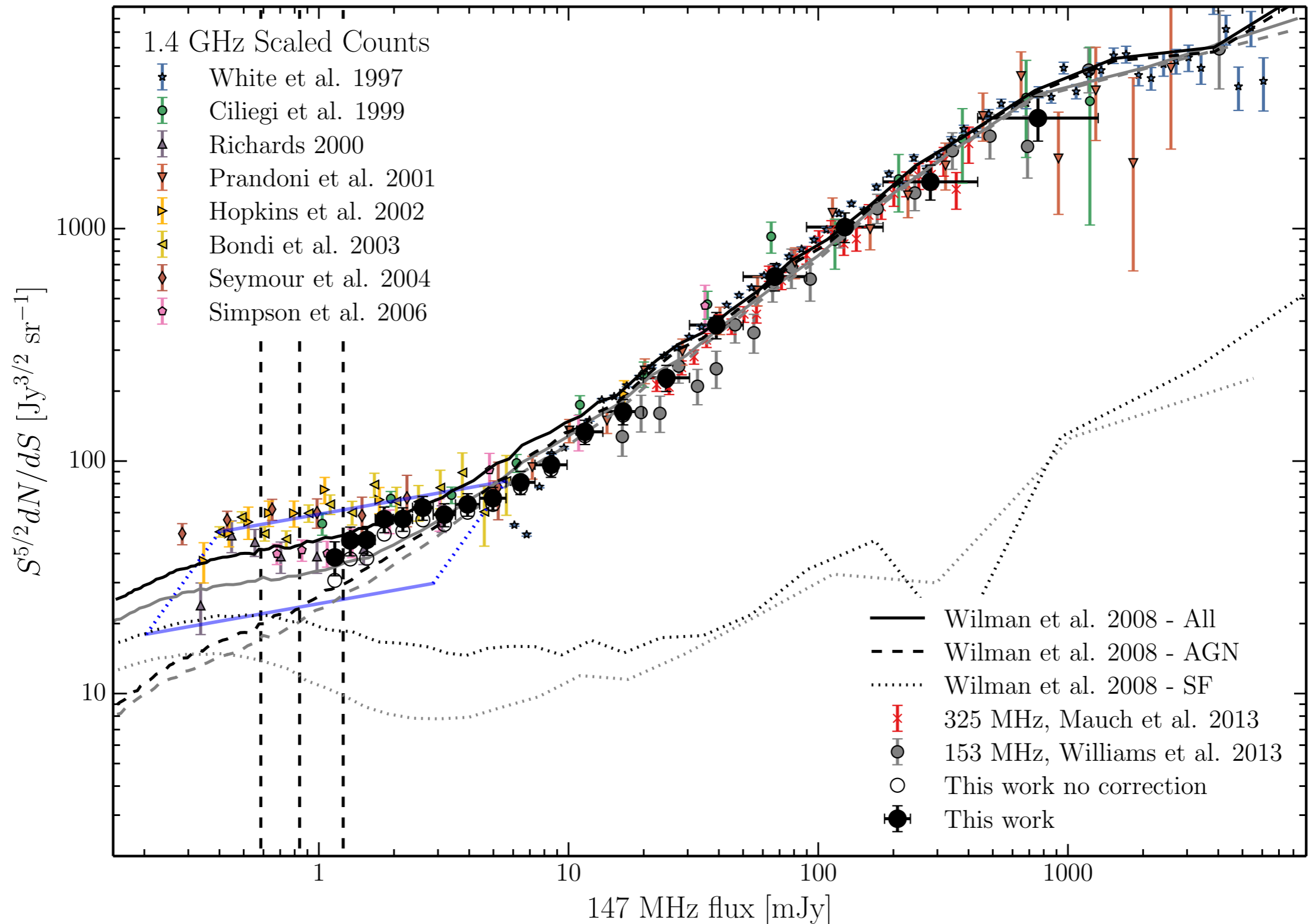
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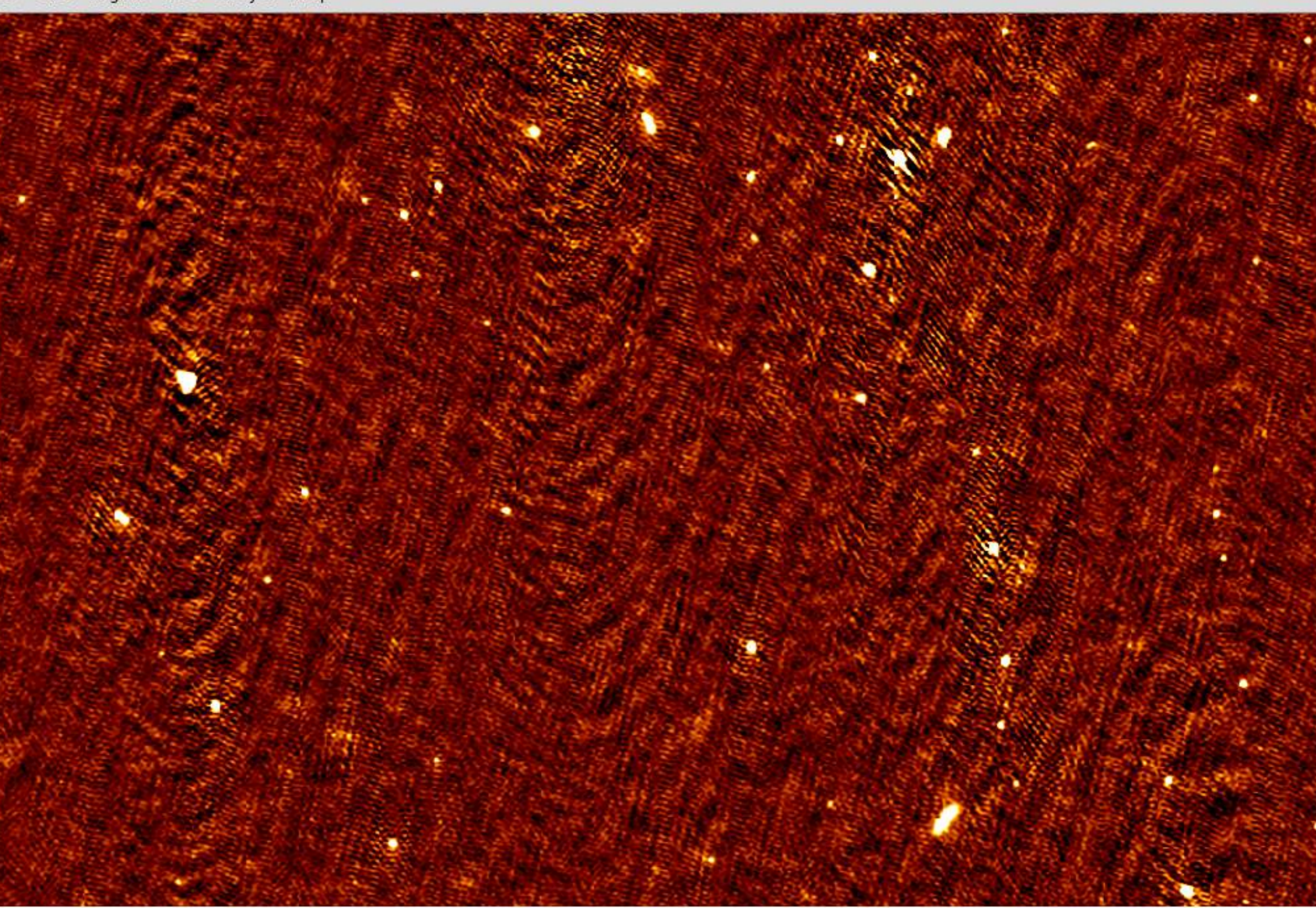
0.0251

0.0293



- Boötes field source counts (Wendy Williams, submitted)





-0.0048

-0.0006

0.0037

0.0080

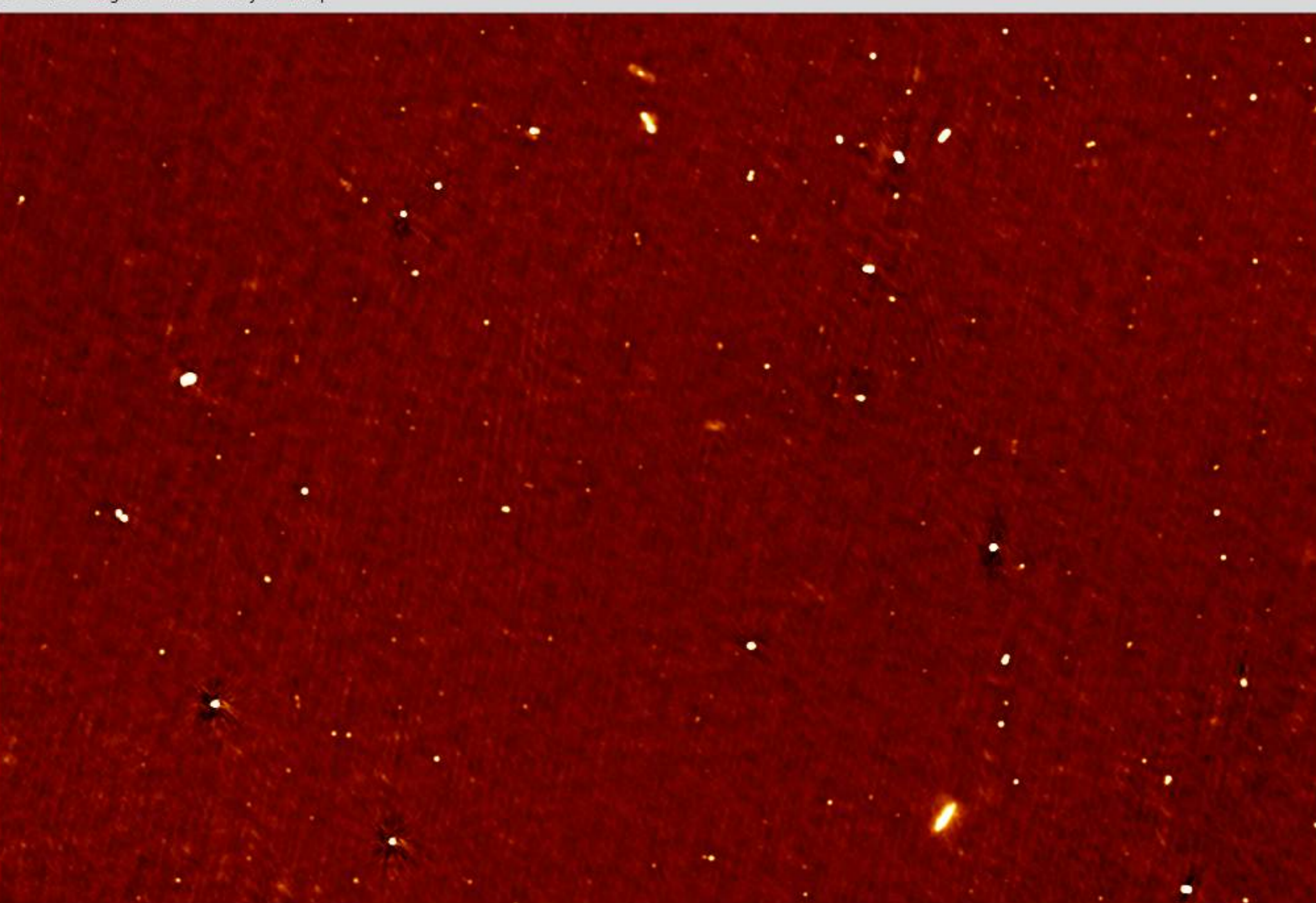
0.0123

0.0165

0.0208

0.0251

0.0293



-0.0048

-0.0006

0.0037

0.0080

0.0123

0.0165

0.0208

0.0251

0.0293



NGC 5775

Declination (J2000)

3°45'

40'

35'

30'

25'

20'

14^h54^m30^s

54^m00^s

53^m30^s

53^m00^s

Right Ascension (J2000)

mJy/Beam

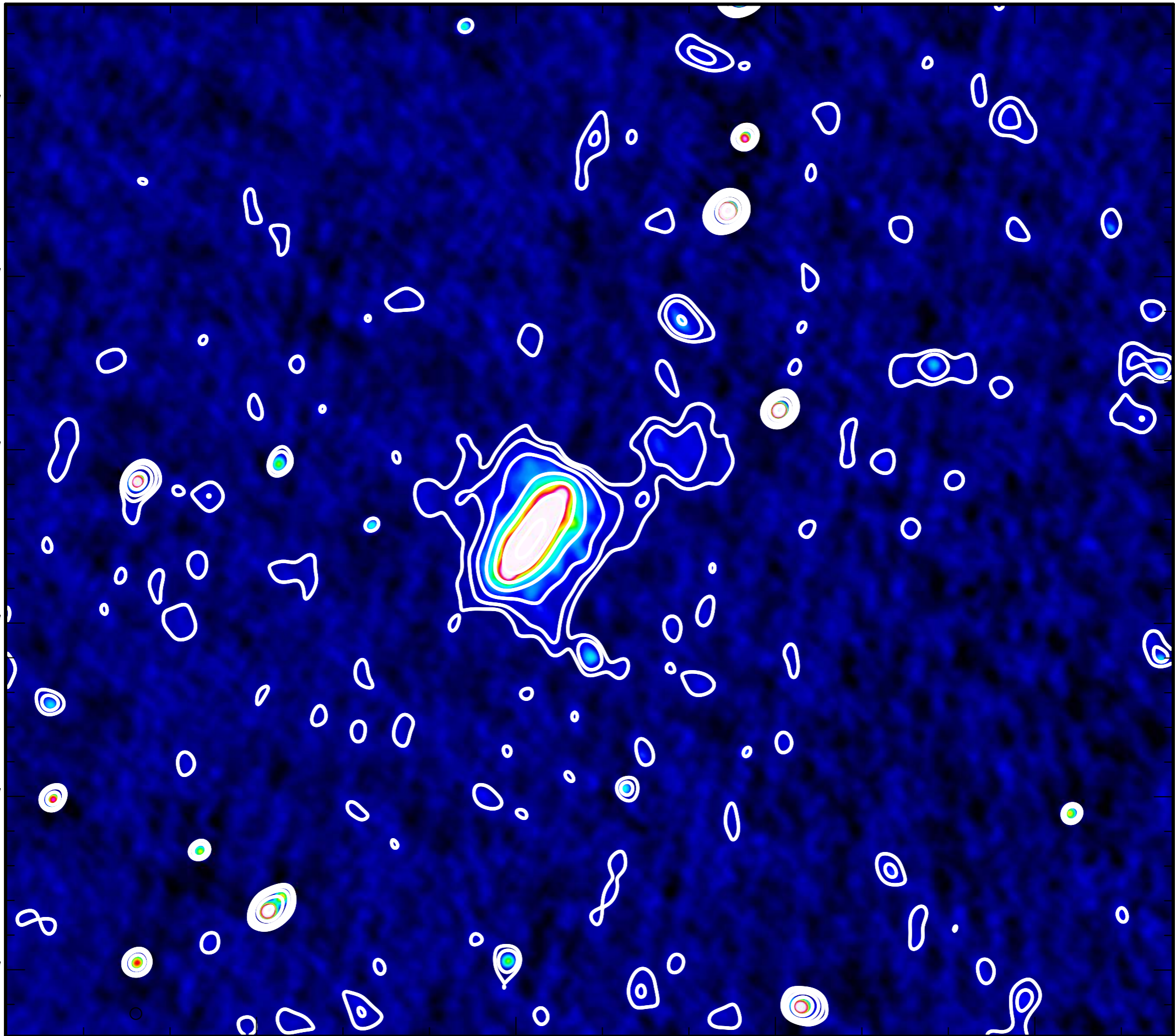
20

15

10

5

0



- MSSS initial data products online now (**vo.astron.nl**)
- MSSS-HBA to be completed and released early next year
- Will initially provide 150,000 sources at 2' resolution
 - Later: $\sim 30''$ resolution, including polarization!

LOFAR TIER-1 SURVEY

- Over the next couple of years we will complete a 4200 deg² region (568 pointings) that overlaps both FIRST and SDSS (7.5h < RA < 17.5h; 25d < dec < 65d)
- Volume sufficient to contain e.g. 25 z>6 radio galaxies, 125 Planck clusters, 4000 nearby galaxies and 4000 lensed radio sources
- Will provide ~ 100 μ Jy/beam sensitivity at $\sim 5''$ resolution