



LOFAR *An update on MSSS*



M*S*S*S

MULTIFREQUENCY SNAPSHOT SKY SURVEY

**Jess Broderick (ASTRON)
& George Heald (CASS)**

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

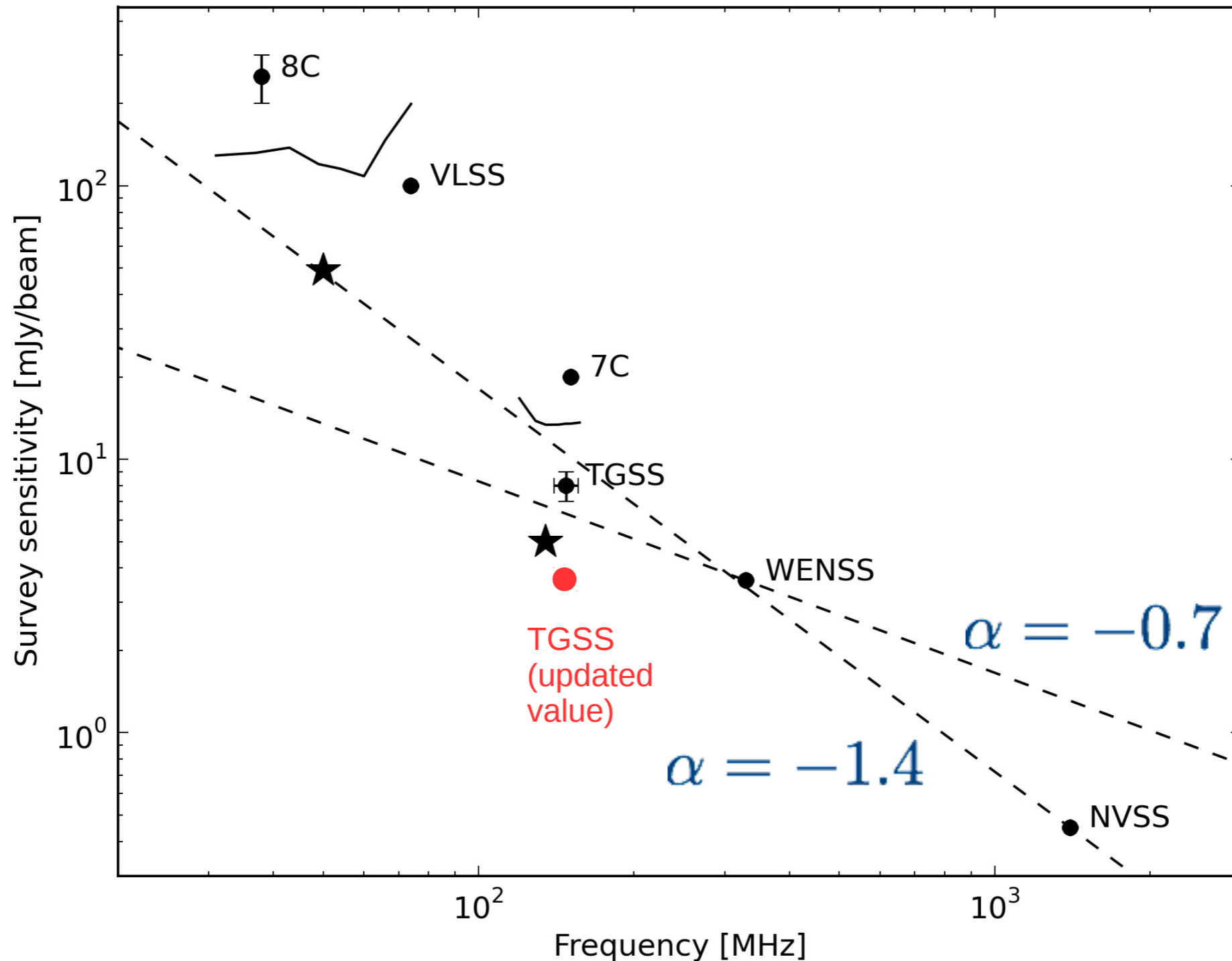
Observations 100% complete

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

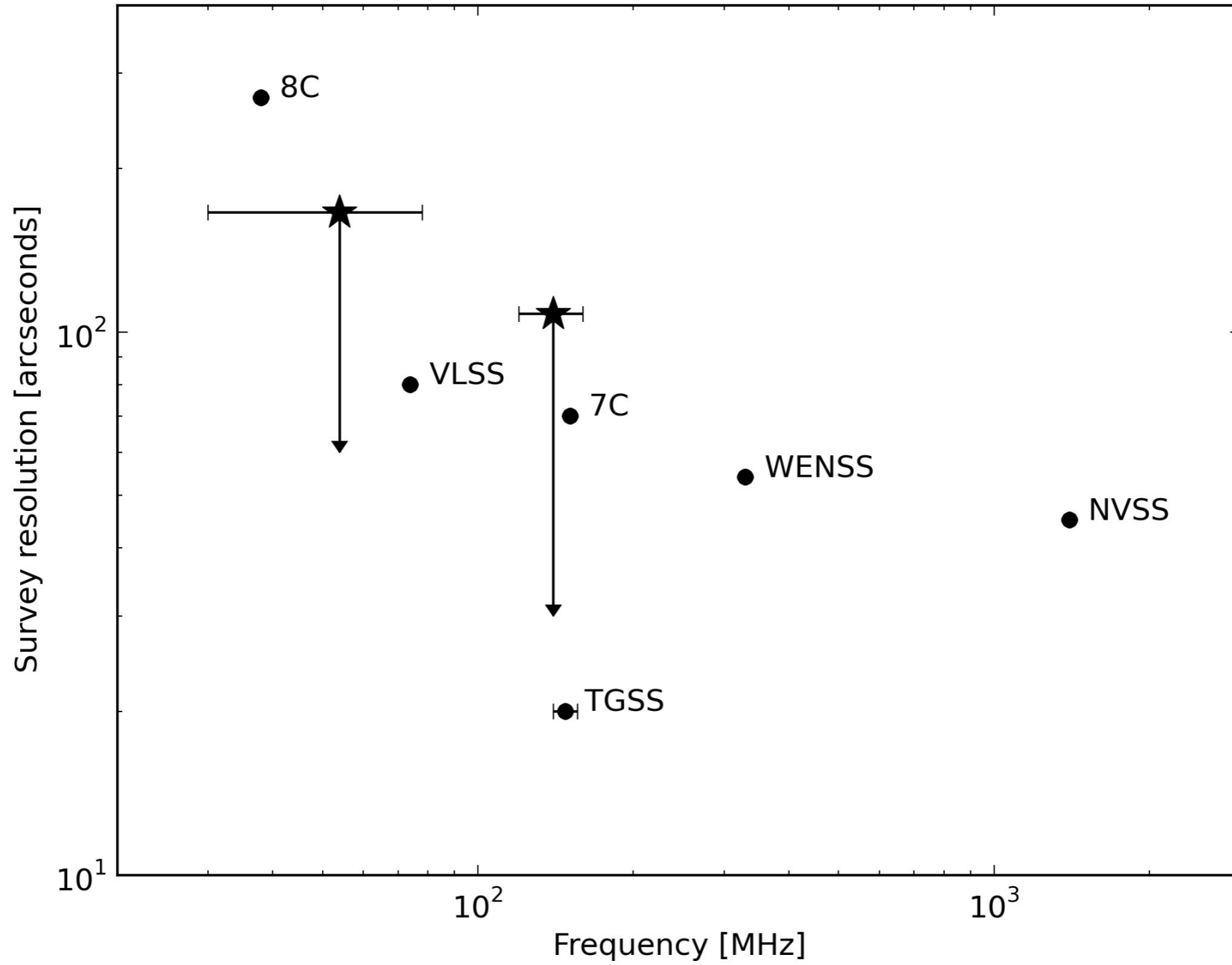


Heald et al. (2015)



* MSSS also highly complementary to MWA's GLEAM: together these surveys, and TGSS, will provide a truly all-sky interferometric radio catalogue!

* Studies of steep-spectrum sources strongly enhanced by MSSS.



* Longer baselines need to be processed for MSSS to have more competitive angular resolution.

* *Heald et al. 2015, A&A, 582, A123*

* Key facts & figures:

- 100 deg², centred at RA=15^h, Dec. = +69°

~1200 sources

- HBA completeness 100 mJy, LBA completeness 550 mJy

- ~2 arcmin resolution



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We gratefully acknowledge support from
the Simons Foundation
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arXiv.org > astro-ph > arXiv:1509.01257

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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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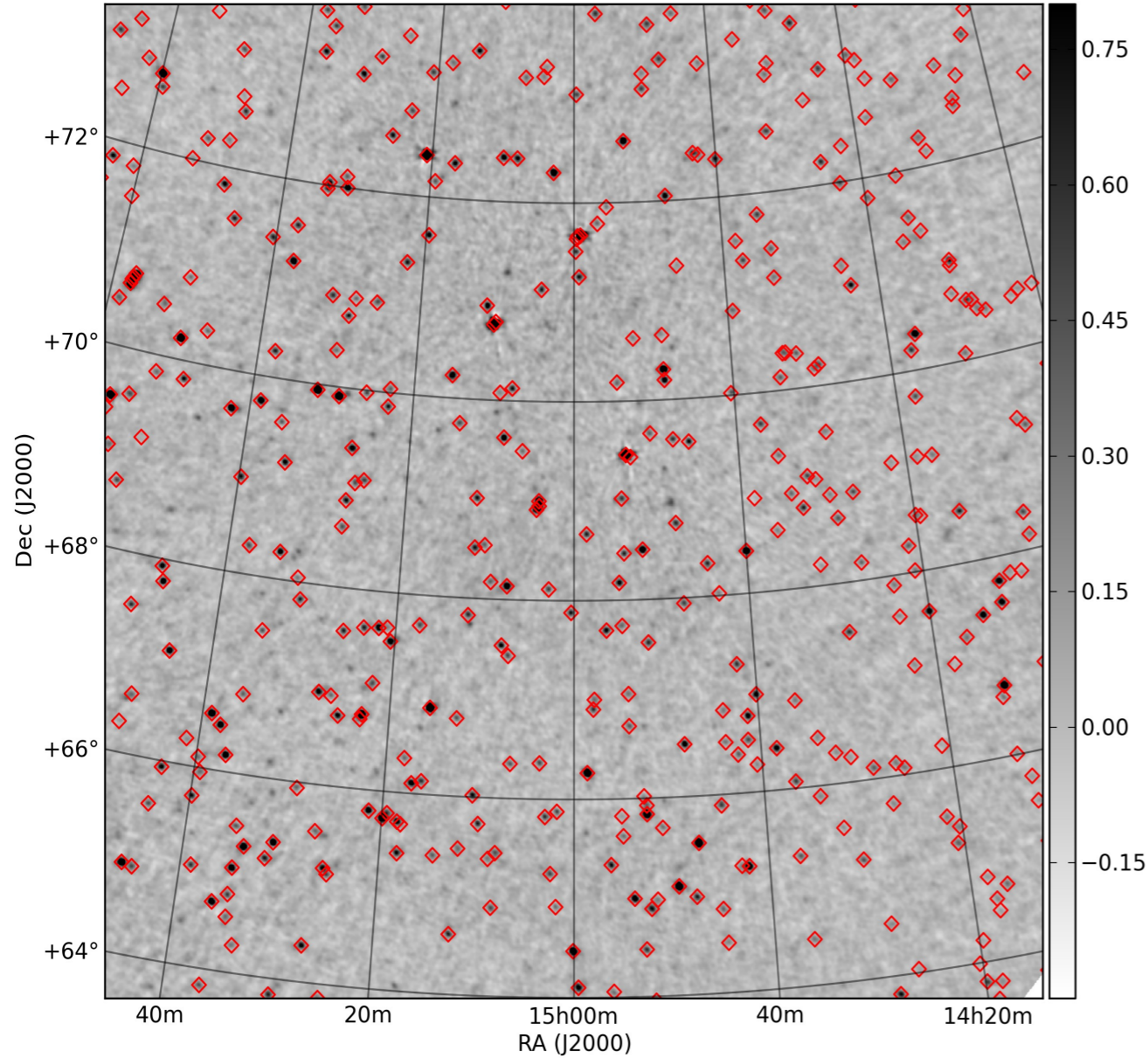
astro-ph

References & Citations

- NASA ADS

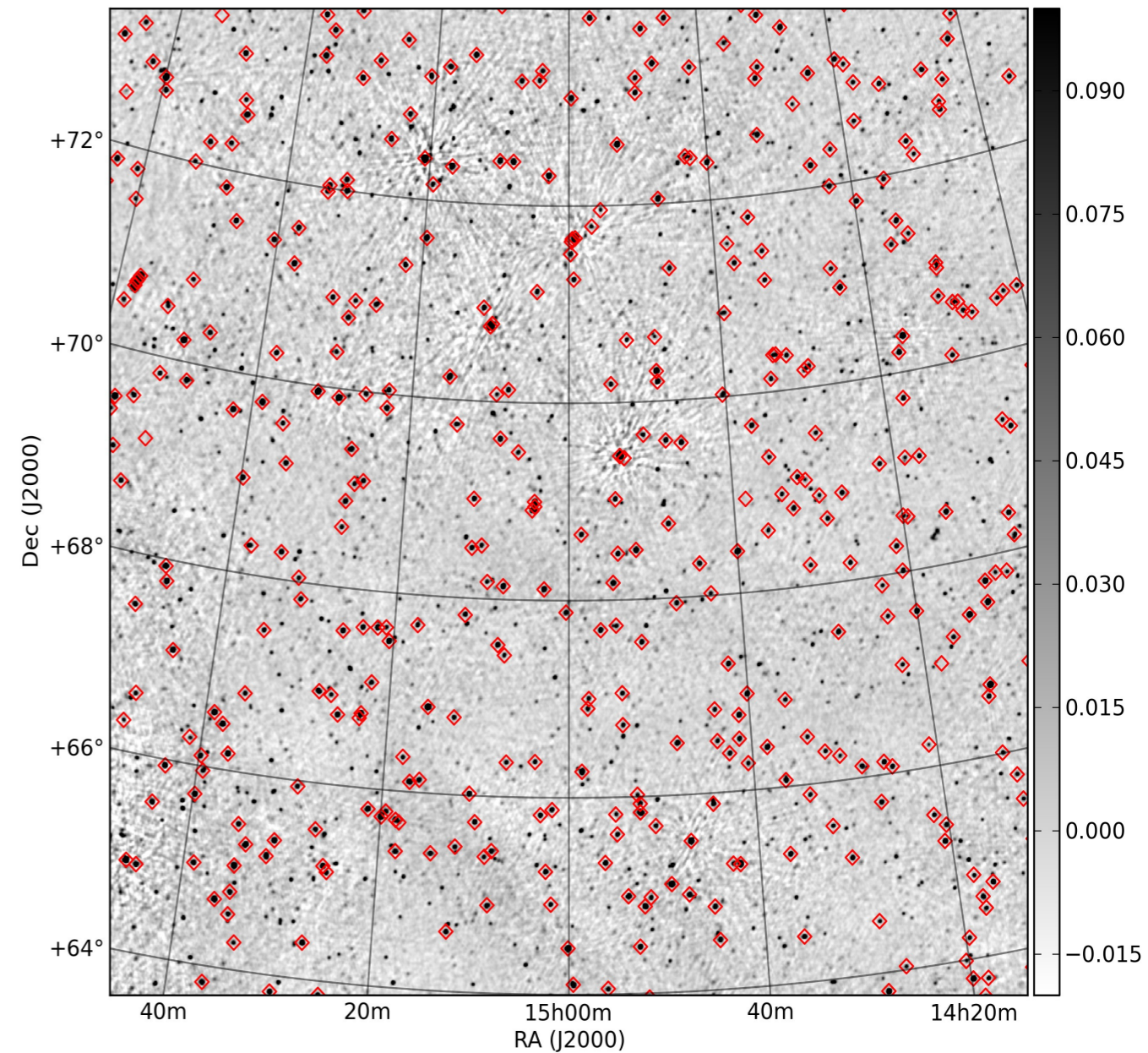
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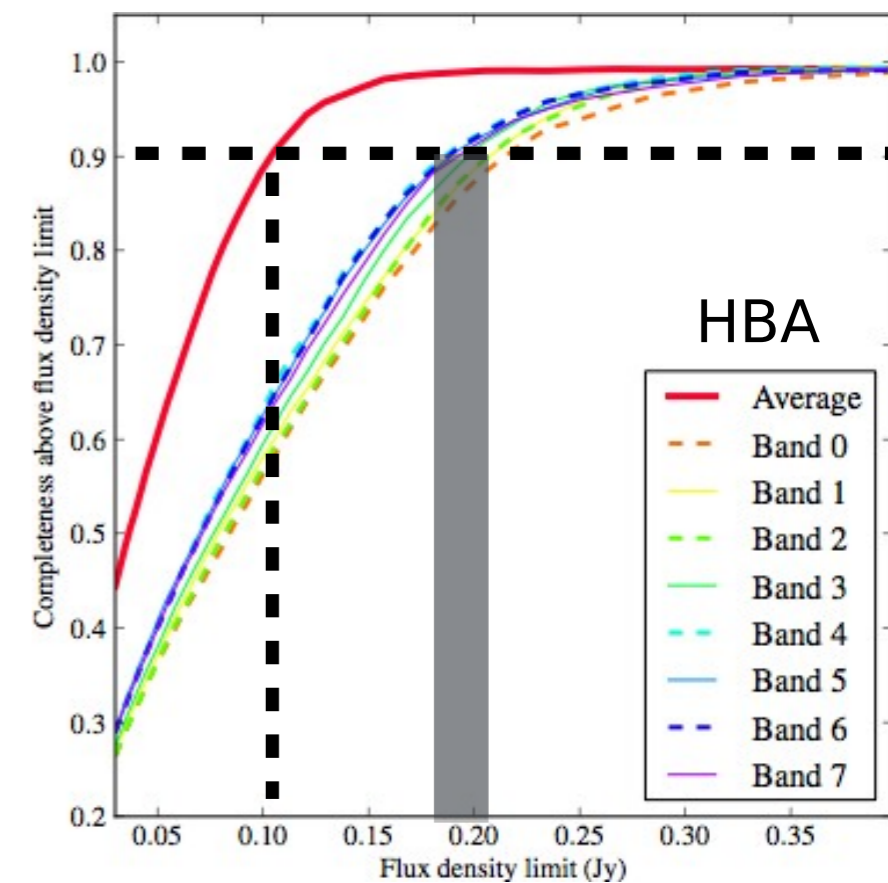
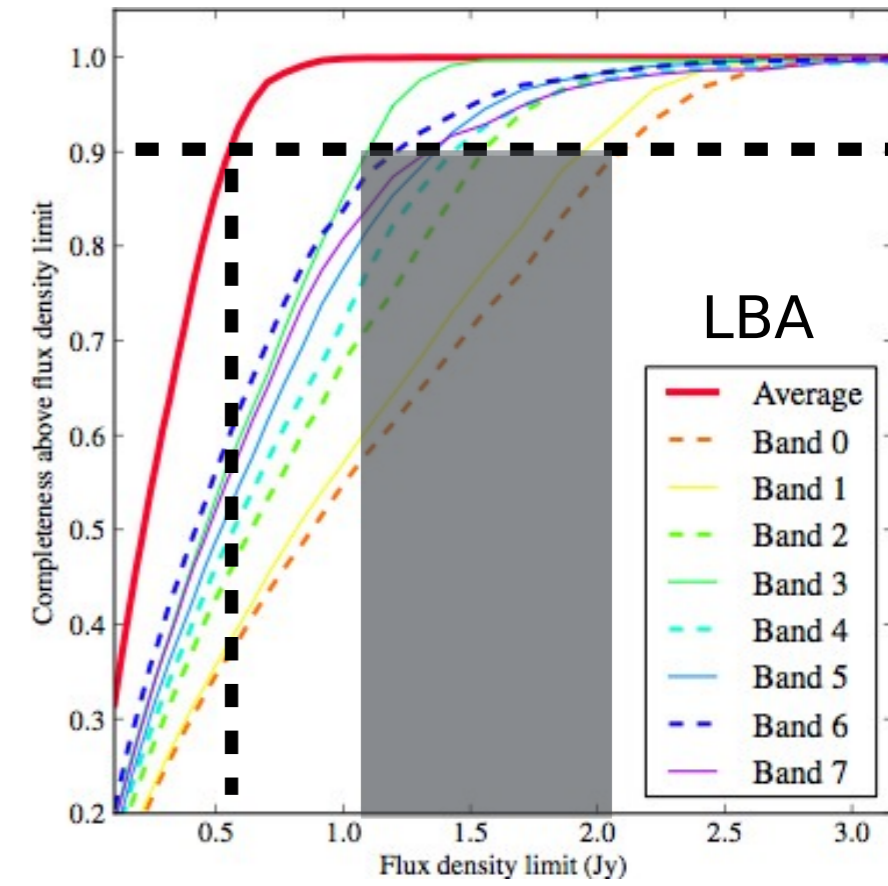
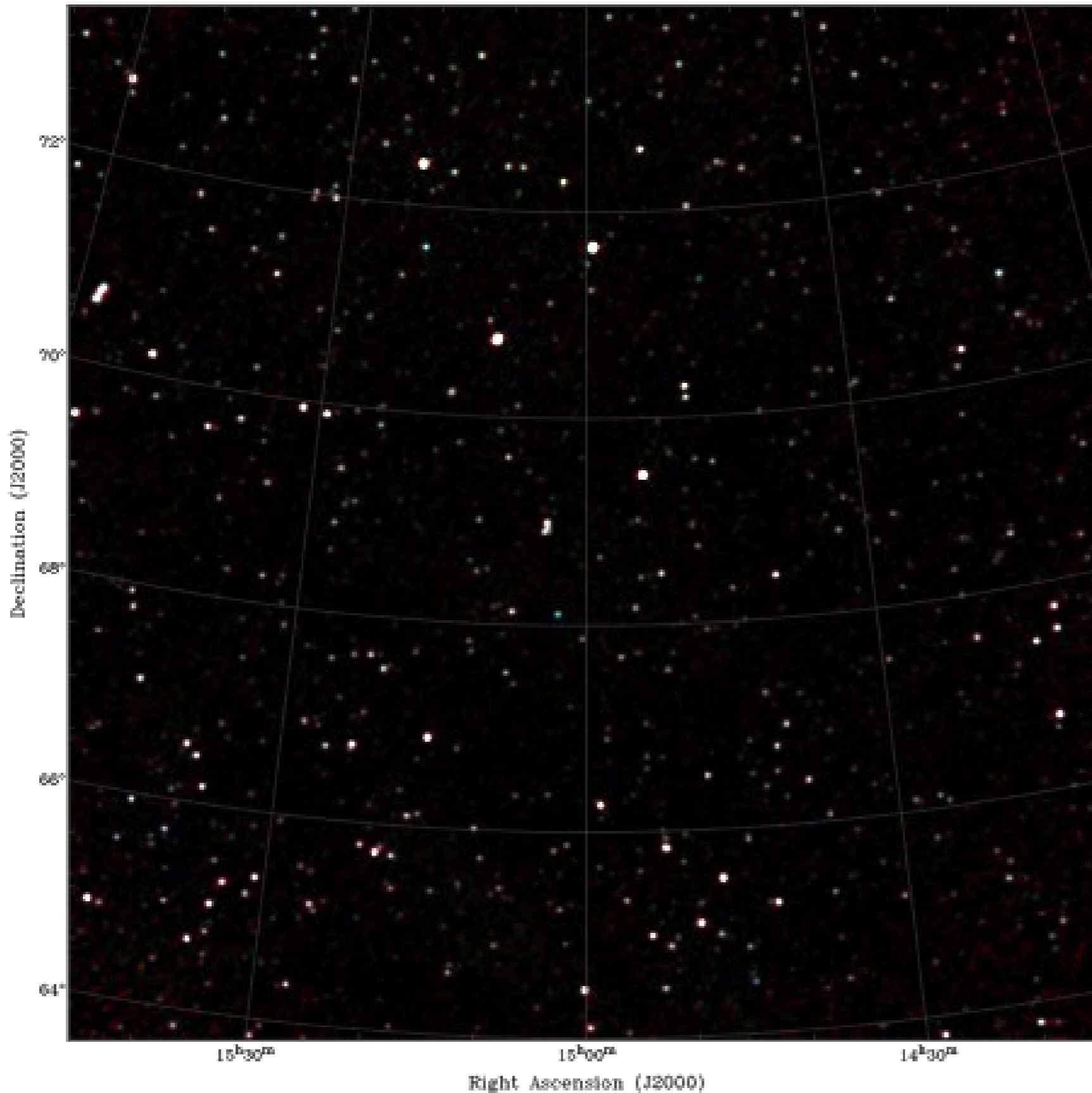
LBA
Ionospheric correction applied
Noise level 39 mJy beam⁻¹
Resolution 166 arcsec

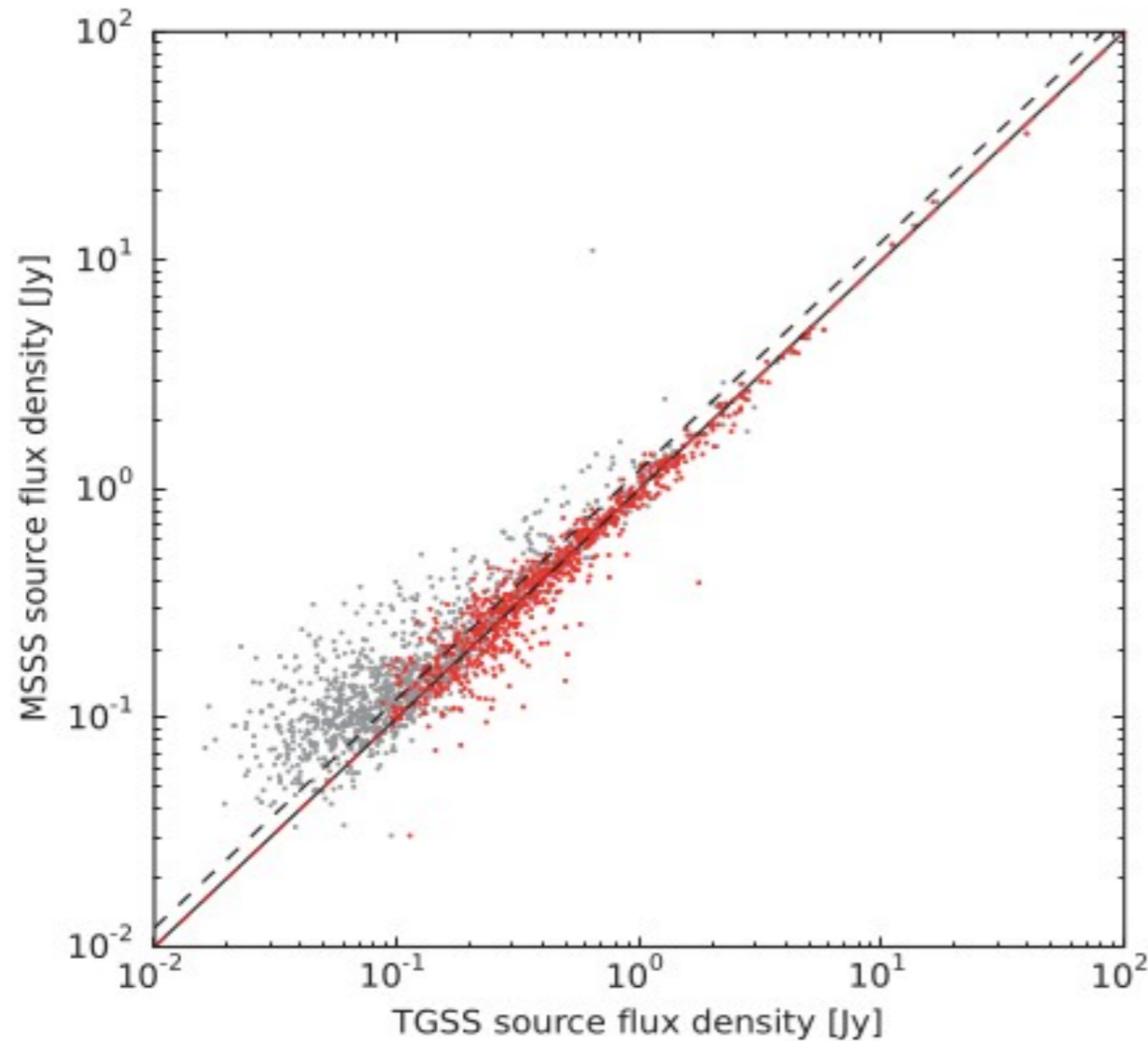
HBA
Noise level 5 mJy beam⁻¹
Resolution 108 arcsec



Diamonds – VLSSr sources
(Lane et al. 2014; noise level ~100 mJy beam⁻¹)

MSSS Verification Field





Comparison of TGSS and MSSS-HBA flux densities

Grey - normal resolutions

Red - TGSS convolved to resolution of MSSS

Intema et al. (2016)

Property	TGSS	TGSSc	MSSS
Average RMS noise	5.3 mJy beam ⁻¹	28 mJy beam ⁻¹	7.3 mJy beam ⁻¹
Total source flux	580 Jy	523 Jy	622 Jy
Source detections	2198	724	1591
False detections	49	2	1
NVSS unique matches	1988	719	1561
NVSS no matches	123	5	30

- * vo.astron.nl ... take note of SAMP connection
- * Catalog: 108 columns for point sources, 204 for extended sources

MSSS Verification Field Sources

Parameters

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

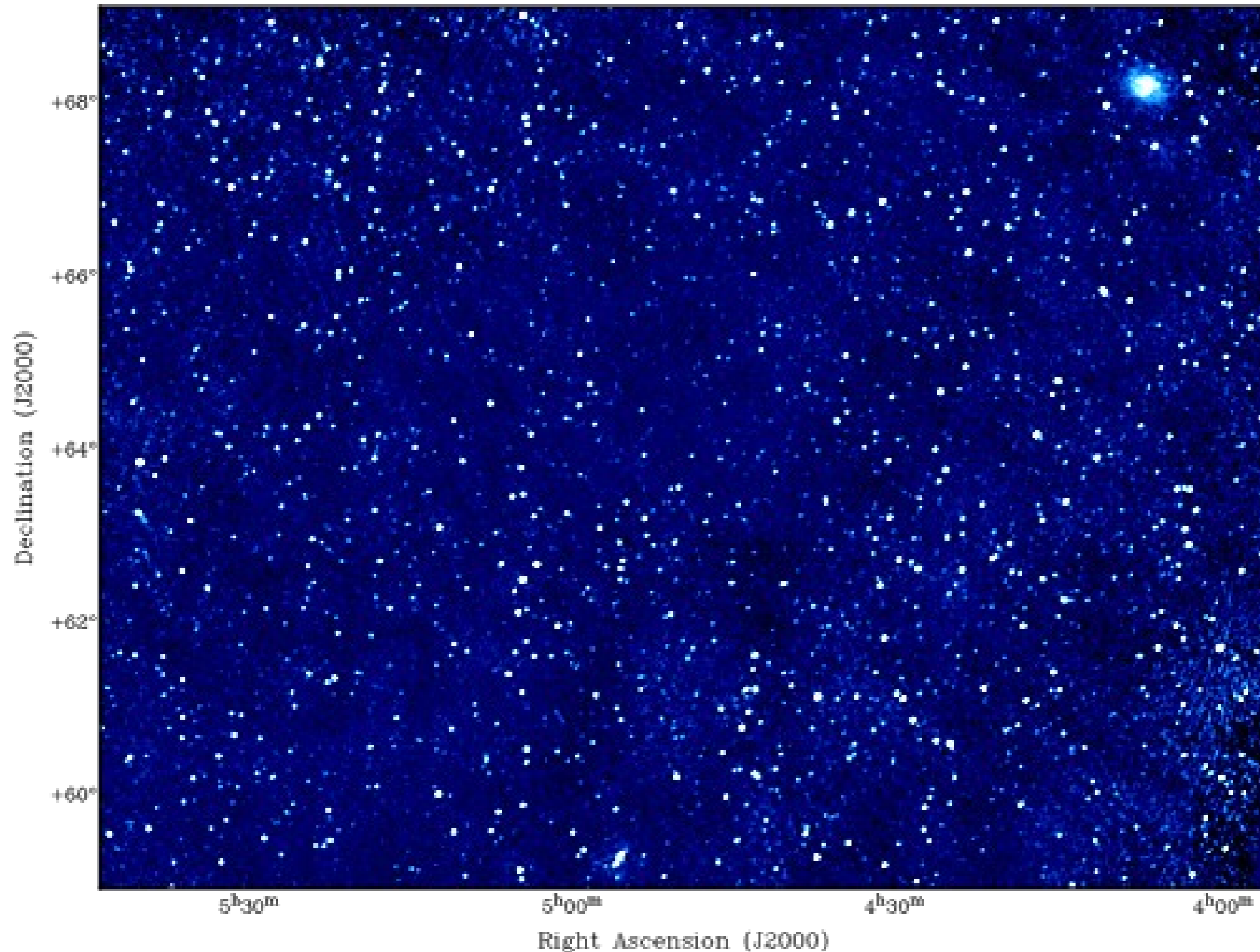
Result

Matched: 28

[Send via SAMP](#) [Quick Plot](#)

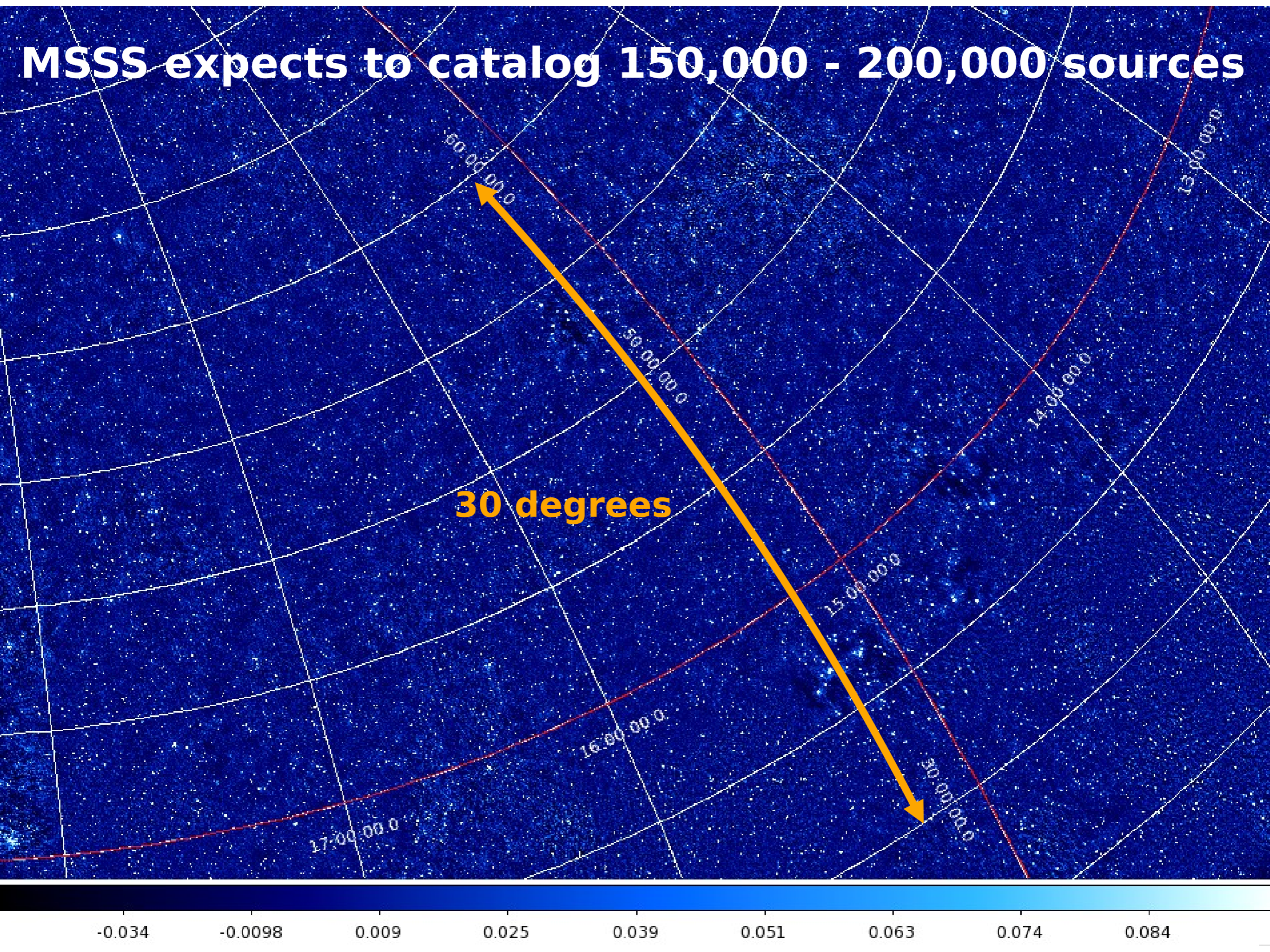
ID	RA [deg]	Dec [deg]	error RA [s]	error Dec [arcsec]	e_RA_sys [s]	e_DEC_sys [arcsec]	MOS_ID	CAL_ID_LBA	CAL_ID
MSSSVF J144837+701157	222.155644398	70.1993786273	8.93426808364e-05	7.35528382713e-05	0.000816016757908	0.000684518724518	MVF	3C196	3C295
MSSSVF J145041+693952	222.674758491	69.6645500623	0.000442171287856	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 J145452+701116	223.688452747	70.1878043548	0.000383174596627	0.00031986643914	0.000897064103656	0.000751977661294	MVF	3C196	3C295

- * Full MSSS strategy same as MVF – very similar general characteristics expected.
- * Standard imaging product: 100 deg² mosaics, each composed of 10s of individual HBA fields.



- * Simultaneously-observed overlapping fields → correlated noise.
- * Noise "flatness" across survey area is impacted by this effect at the ~10% level.

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

13:00:00.0

14:00:00.0

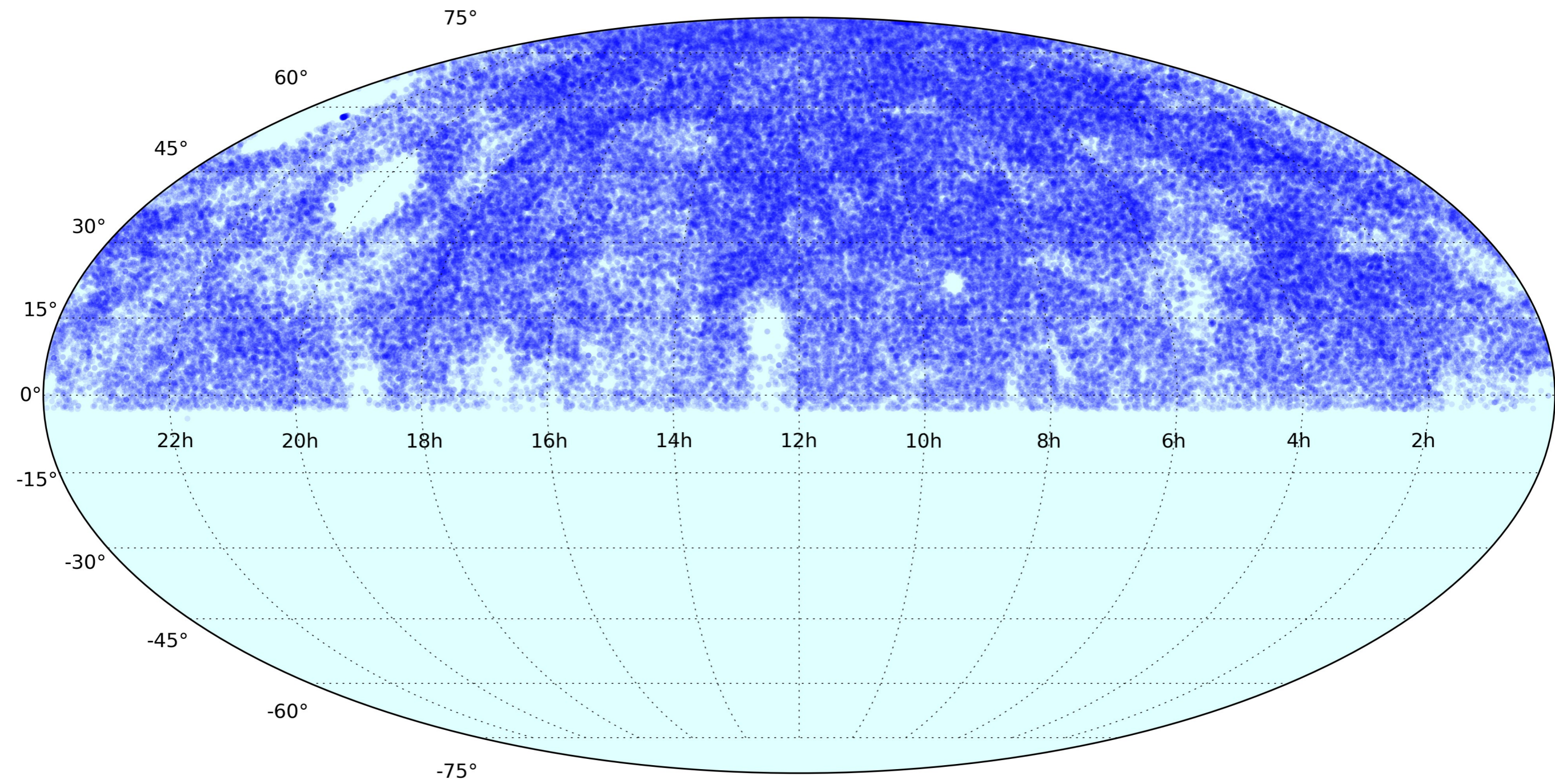
15:00:00.0

16:00:00.0

17:00:00.0

MSSS-HBA catalog (v0.1): ~130,000 sources

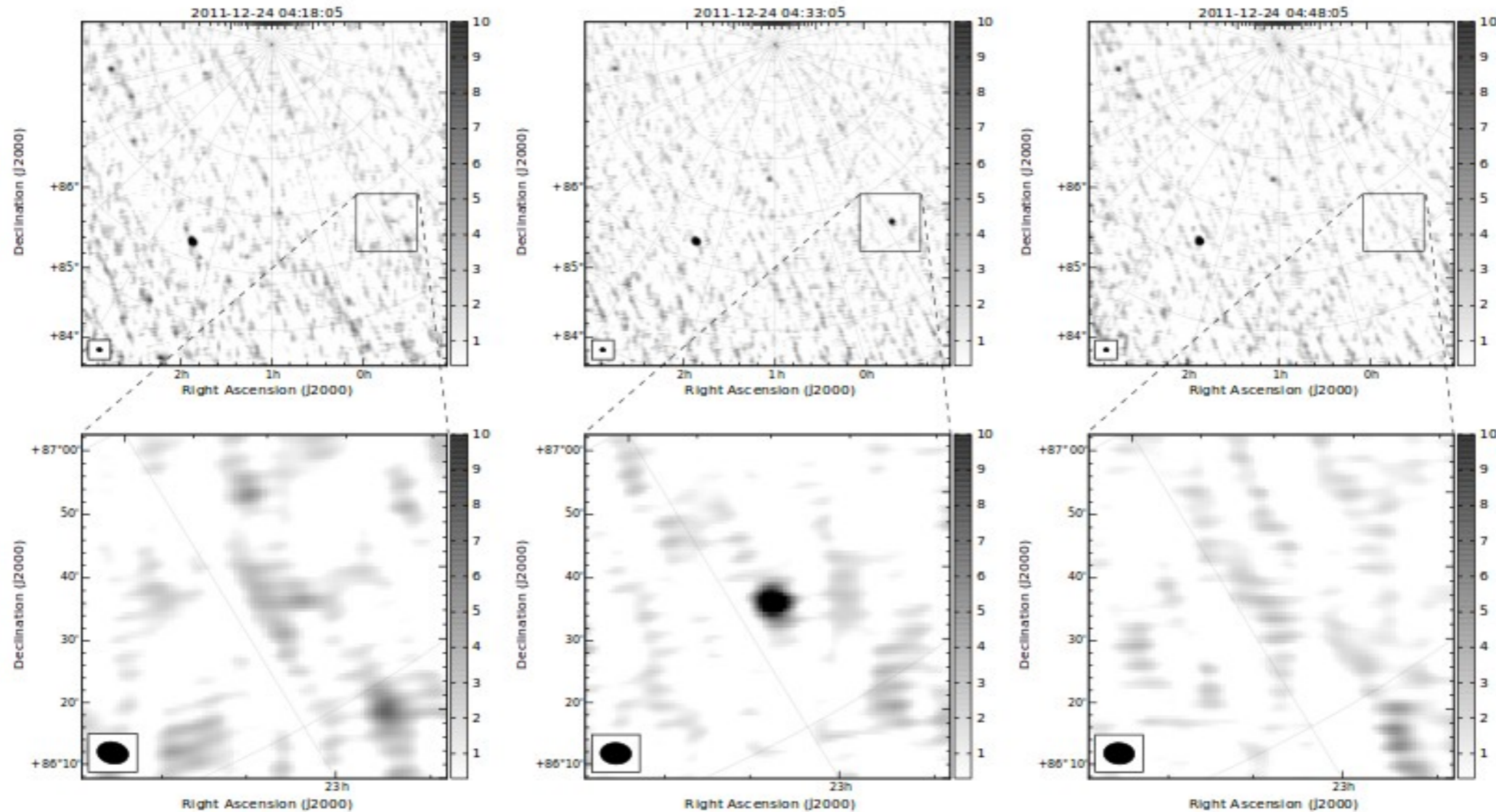
- * *Final catalog still under development*
- * *All fields and catalog loaded into MSSS VO server for use by initial group of testers (active MSSS participants) ... identifying bugs in system. MSSS Forum being used to collect issues.*
- * *Data products are password-protected before data release.*



Science with MSSS

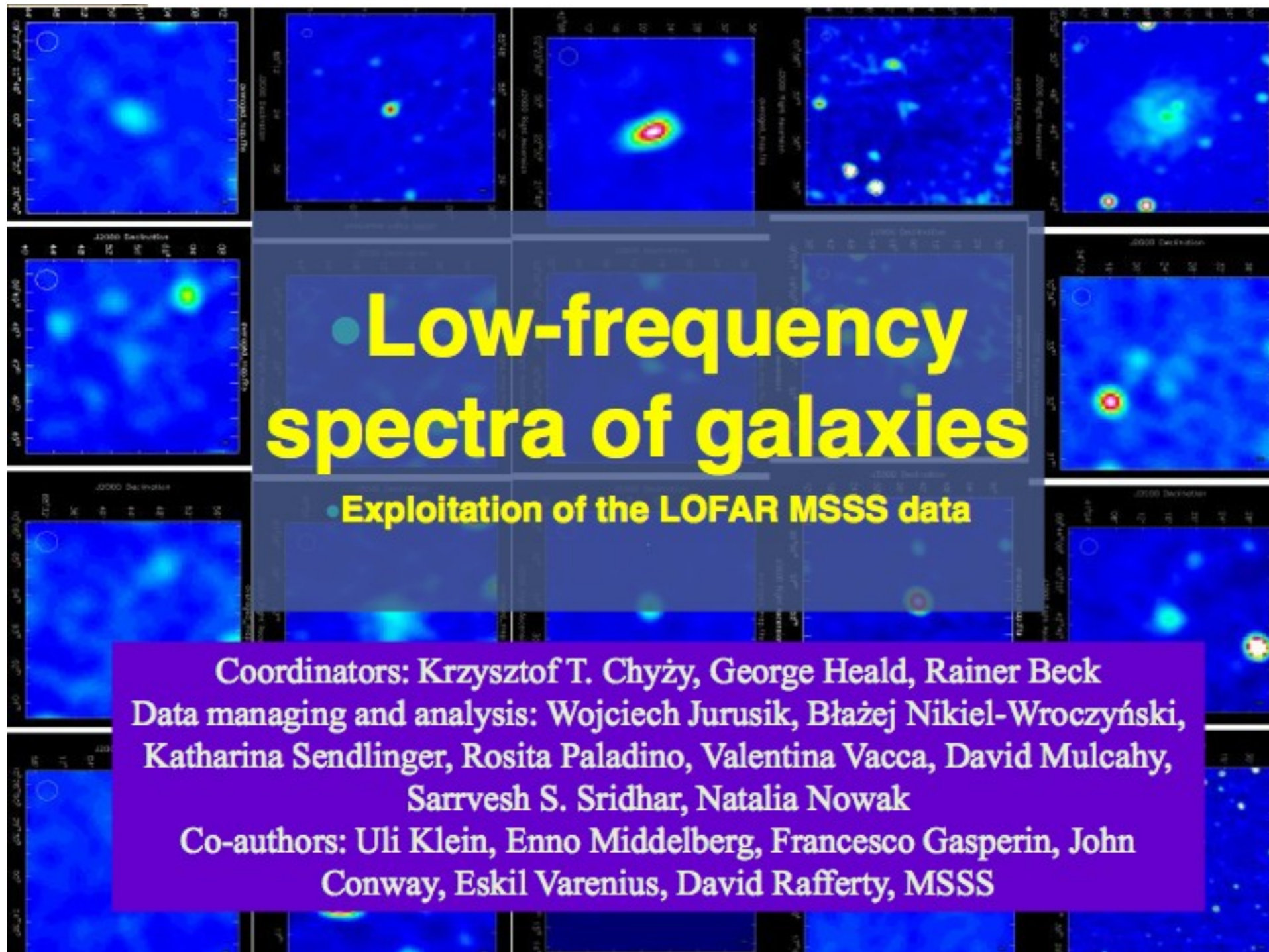


- * In MSSS-LBA, one sub-band always on NCP (200 kHz BW at 60 MHz)
- * In both MSSS-LBA and MSSS-HBA, multiple epochs (9 & 2 resp.). Also possible comparisons with TGSS and GLEAM.



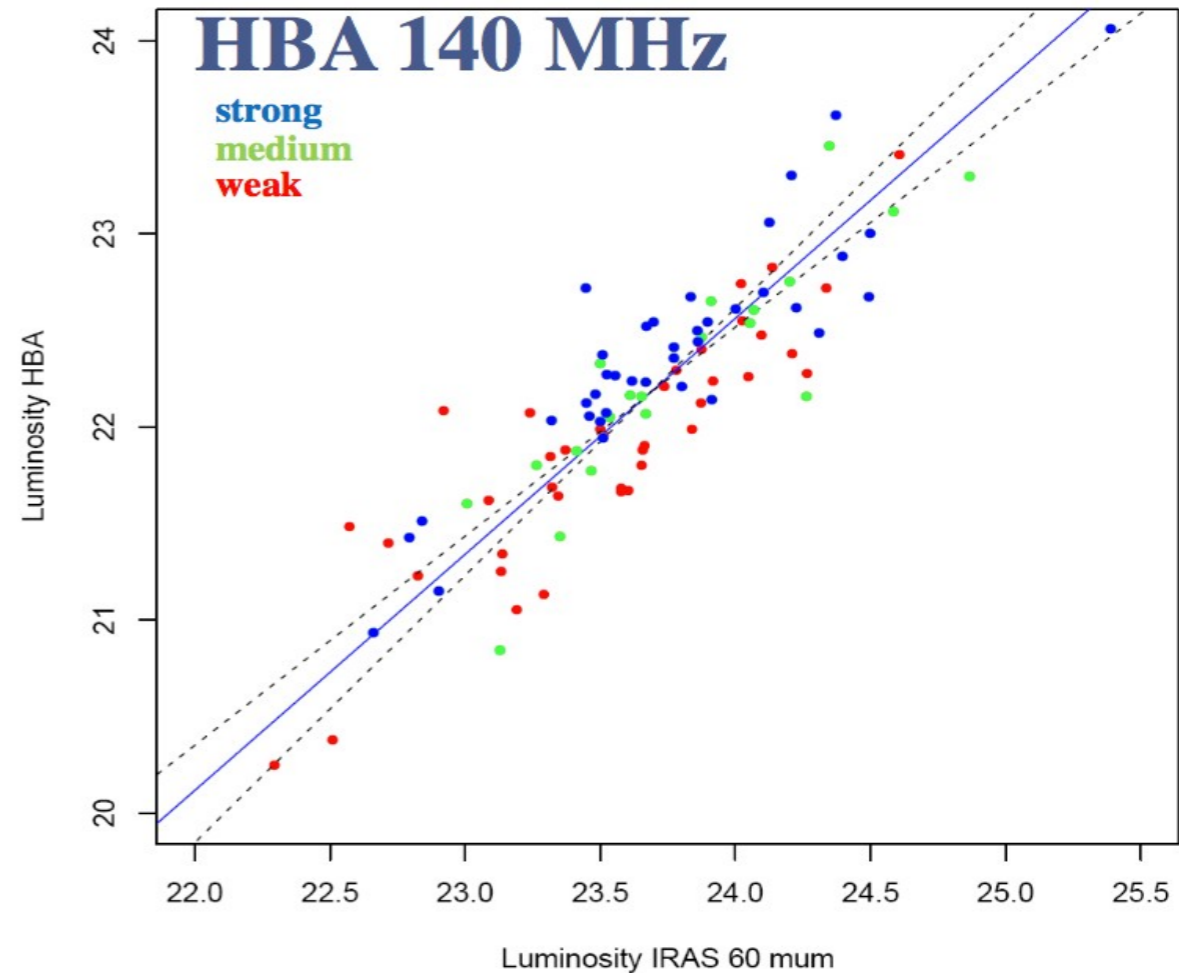
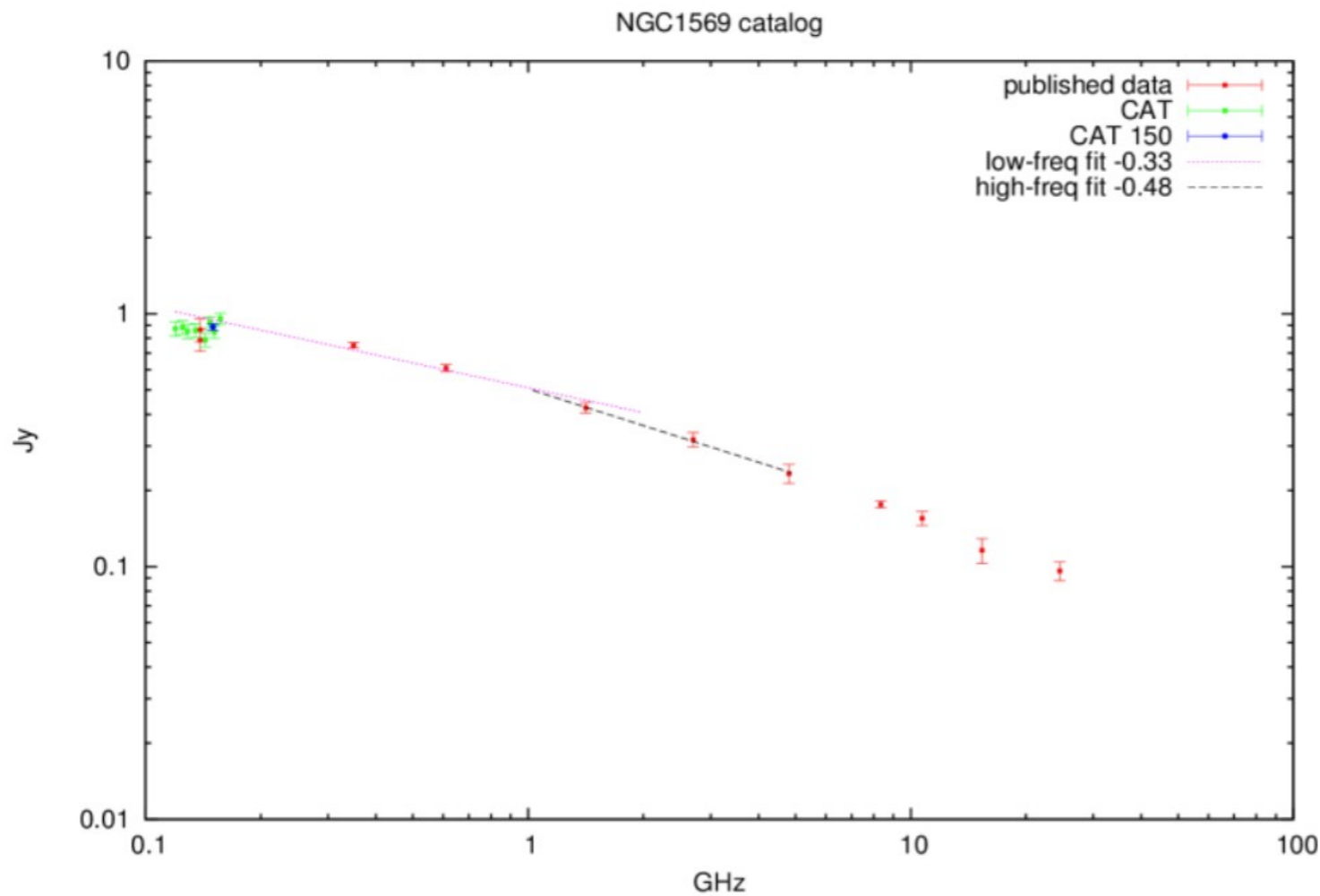
- * First MSSS-LBA transient ([Stewart et al. 2016, MNRAS, 456, 2321](#))
- * Appears in one 11-min snapshot, flux density 15-25 Jy beam⁻¹
- * Implied rate for $\Delta t \sim 10$ min is $3.9 (+14.7, -3.7) \times 10^{-4} \text{ day}^{-1} \text{ deg}^{-2}$ (~8 transients of this nature per hemisphere per day!)

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

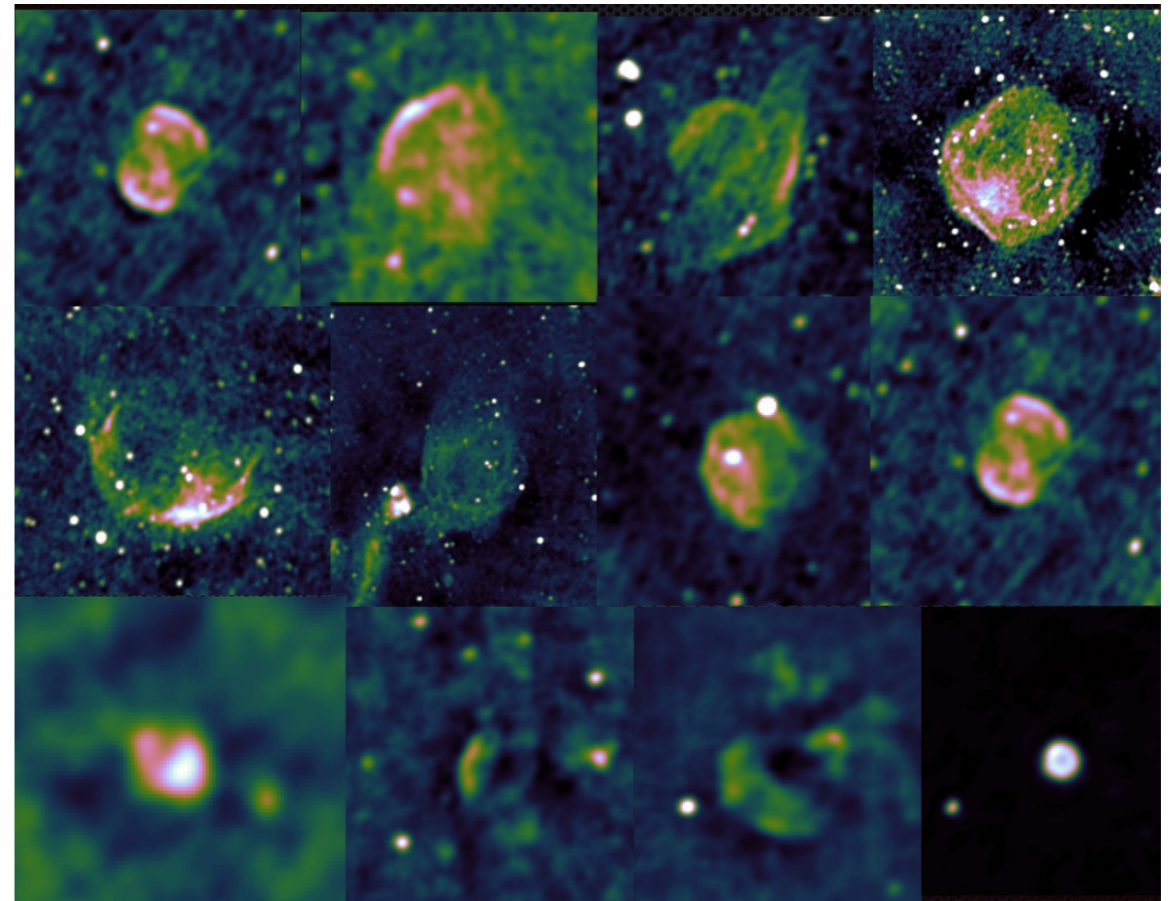
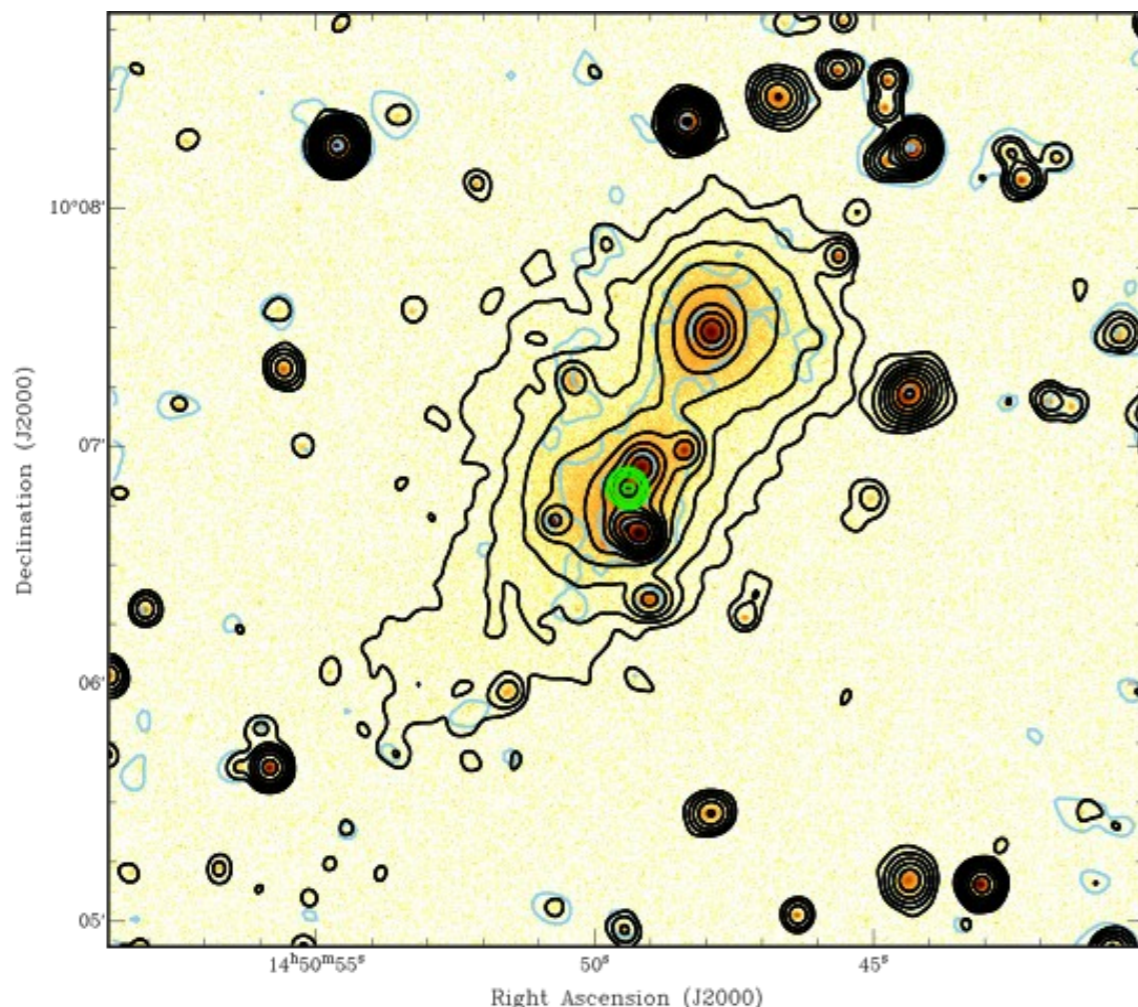


- Extracting reliable total fluxes for extended sources and comparing with literature values. Very important quality control work. More progress to be made with next release of HBA catalogue.

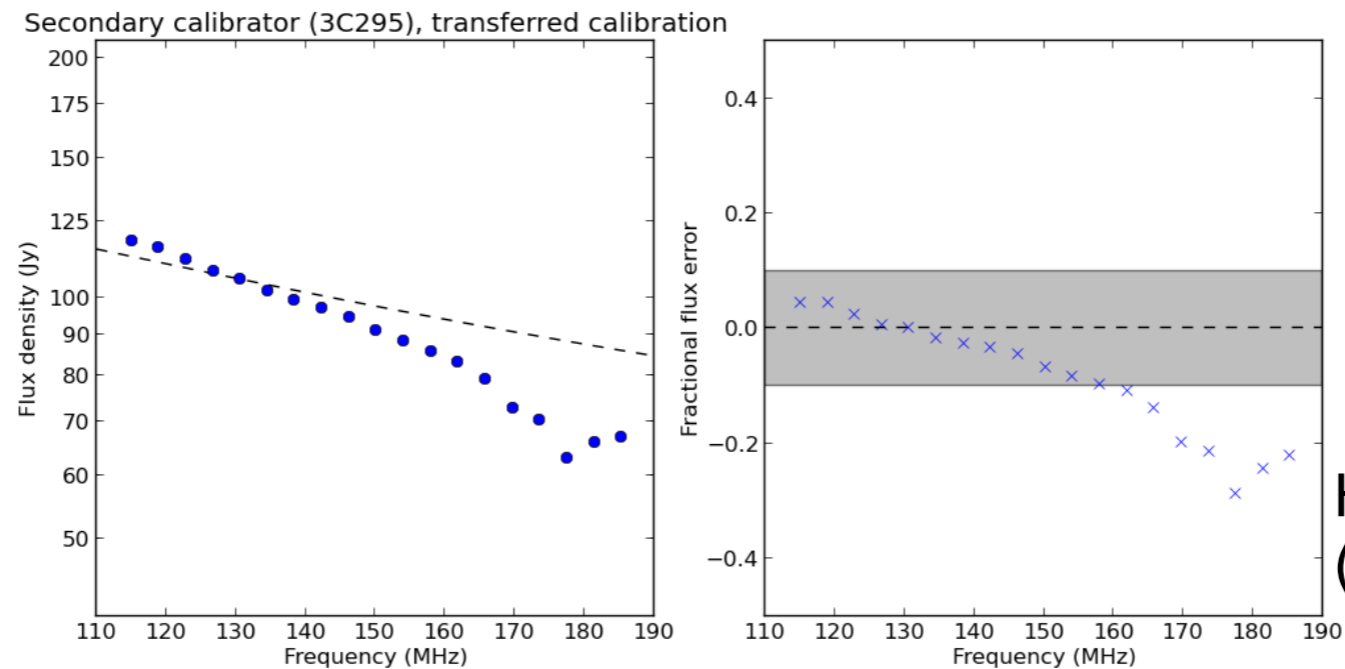
* First radio-FIR correlation at low frequencies; similar slope, larger scatter



- * Polarization: Efforts planned / underway: low-resolution polarization (foreground Milky Way), high-resolution polarization (extragalactic sources). RMSF FWHM $\approx 1.3 \text{ rad m}^{-2}$
- * MSSS discovered GRG. Followed up with deep high-resolution HBA observation. Facet calibration underway and images are looking very good (Clarke et al. in prep.).
- * “Great MSSS Supernova Remnant Hunt” (Mulcahy et al.).



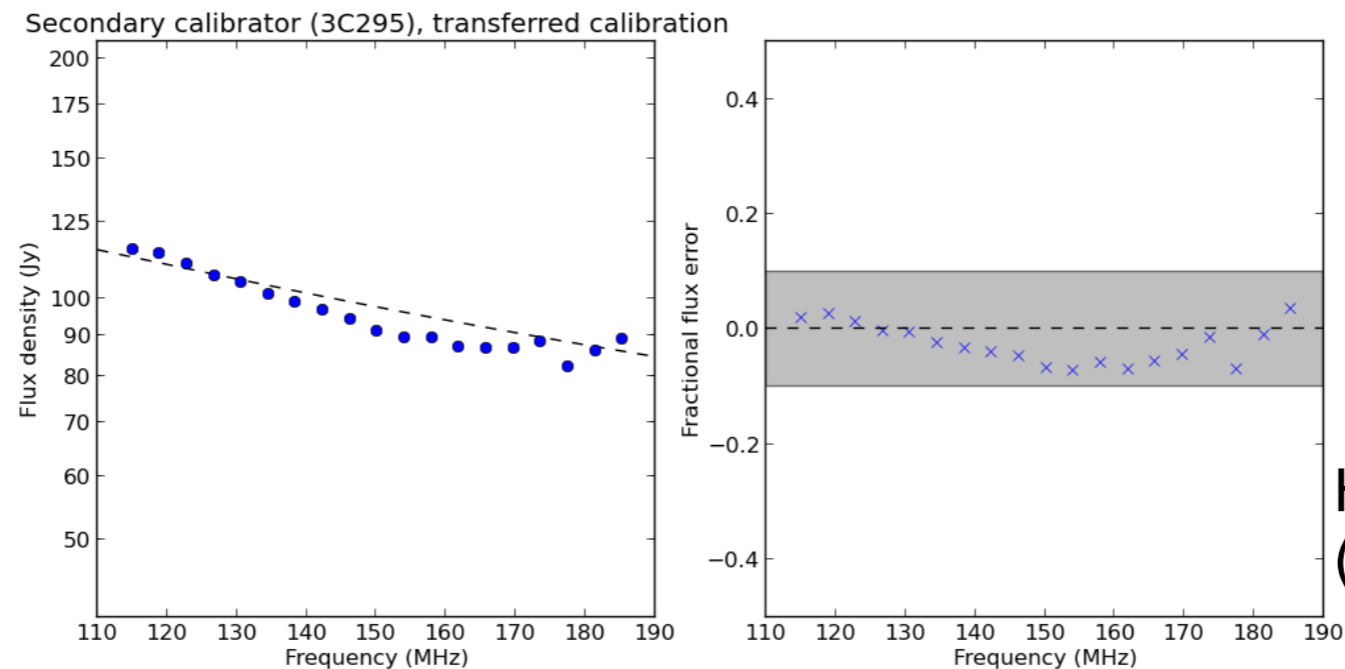
* Application of final flux scale definition



Heald & Dijkema
(in prep.)

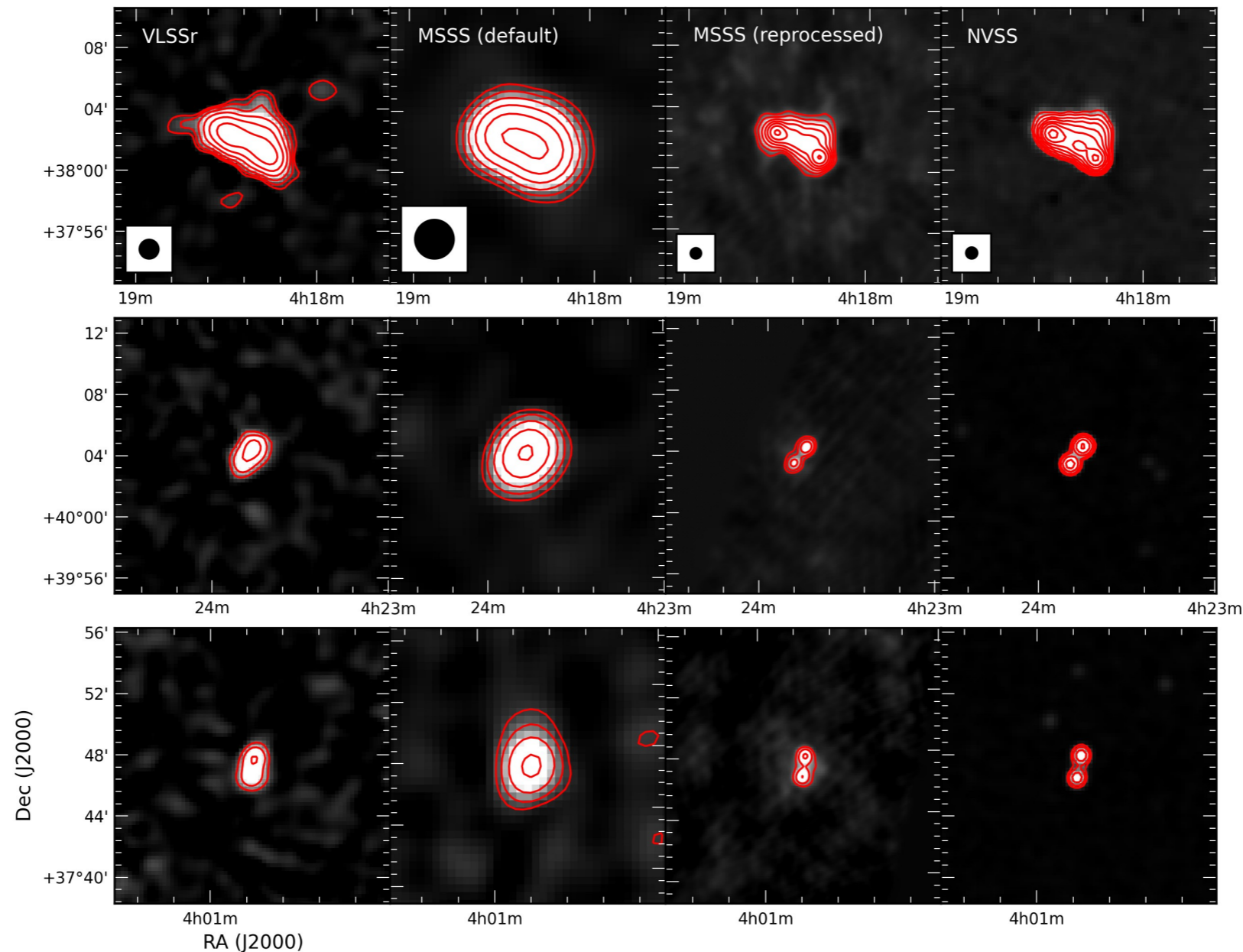
- * Directly tackled using calibrator-to-calibrator gain transfers and beam adjustments.
- * Goal: flux scale correct within 10% from 110-190 MHz, if primary flux calibrator $< \sim 30$ degrees from target field.
- * Systematics go up beyond this radius.

* Application of final flux scale definition



- * Directly tackled using calibrator-to-calibrator gain transfers and beam adjustments.
- * Goal: flux scale correct within 10% from 110-190 MHz, if primary flux calibrator $< \sim 30$ degrees from target field.
- * Systematics go up beyond this radius.

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



- * Planned for v2 catalog - AWS/SKA funding to facilitate this stage of the MSSS development. Potential use of CEP2 also?



- * HBA: upgrade to first all-sky public data release, and beyond...
- * Newest flux scale correction factors about to be applied, mosaics remade, and catalog reformed by Alex Clarke. Stay tuned....
- * Serious bug in the catalog formation script recently fixed by Rene Breton. Some sources counted twice due to a subtle bug in either PyBDSM or PySE (still under investigation).
- * Comparison work with GLEAM is now continuing.
- * Publication and release of HBA v1 (mid 2016)
- * High resolution, polarization (early 2017)
- * Science papers! (starting now)

- * LBA: now resuming observational testing.
- * Initial key goal: define the processing strategy and show that it works on some well-defined observations.
- * If you are interested in being involved, please get in contact!
(broderick@astron.nl)

