

LOFAR imaging surveys

LOFAR Multifrequency Snapshot Sky Survey (MSSS) and beyond

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Outline

- MSSS motivation & setup
- MSSS results & data releases
- Forthcoming & ongoing LOFAR survey efforts



LOFAR MSSS

Multifrequency Snapshot Sky Survey



MSSS: LOFAR's first imaging survey

MSSS-LBA



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

Resolution: ≤ 100 arcsec

Sensitivity: ≤ 15 mJy/beam

Area: 20,000 square degrees

Number of Fields: 660

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

Test observations continue

MSSS-HBA



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

Resolution: ≤ 120 arcsec

Sensitivity: ≤ 5 mJy/beam

Area: 20,000 square degrees

Number of Fields: 3616

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

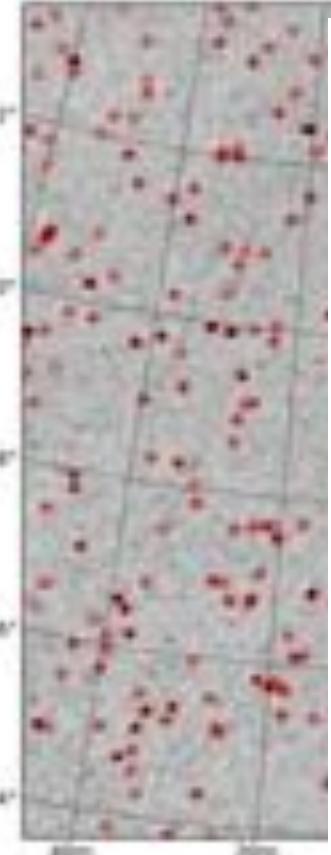
First large-area public catalog in prep

Thanks to the MSSS team!

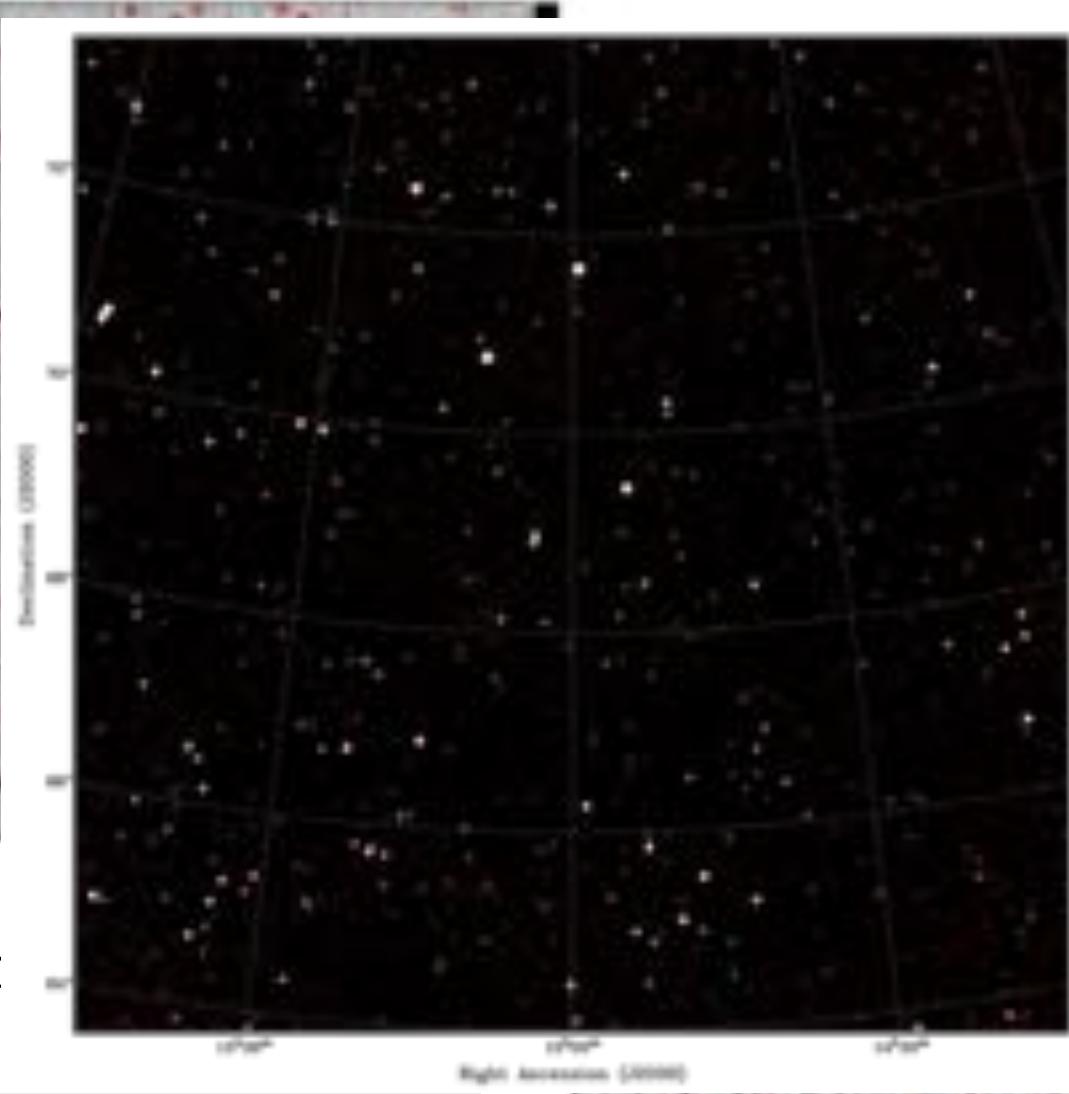
Björn Adebahr, Mike Bell, Laura Bîrzan, Annalisa Bonafede, Justin Bray, Rene Breton, Jess Broderick, Ger de Bruyn, Therese Cantwell, Dario Carbone, Patti Carroll, Yvette Cendes, Alex Clarke, Judith Croston, Soobash Daiboo, Francesco De Gasperin, Emilio Enriquez, Richard Fallows, Chiara Ferrari, Jon Gregson, 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



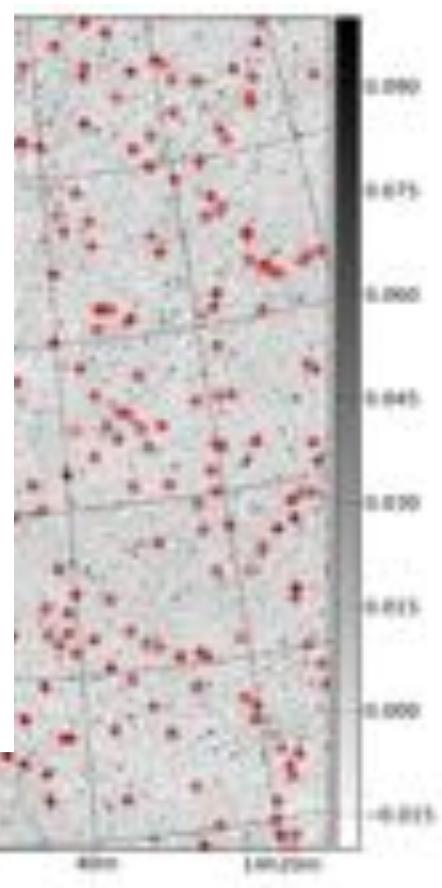
MSSS Verification Field



LBA
Ionospheric cor



HBA mosaic



MSSS Verification Field

- Survey overview published in A&A (2015, A&A 582, 123)
- Key facts & figures:
 - Verification field of 100 square degrees, ~1200 sources
 - HBA completeness 100 mJy
 - LBA completeness 550 mJy
 - ~2' resolution
 - >100,000 sources in full catalog

A&A 582, A123 (2015)
DOI: 10.1051/0004-6361/201424204
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Astronomy & Astrophysics

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

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ABSTRACT

We present the Multifrequency Snapshot Sky Survey (MSSS), the first multifrequency (4–160 MHz) imaging survey in the northern sky. Our first results to detail the motivation and design of the survey, Component separation methodology, MSSS as a reference for its detection completeness curves (providing information about the spectral properties of the detected sources and how they are detected across frequency bands), the broad-band frequency coverage, registration with the best catalog generated by LOFAR’s commissioning experiments.

MVF data release

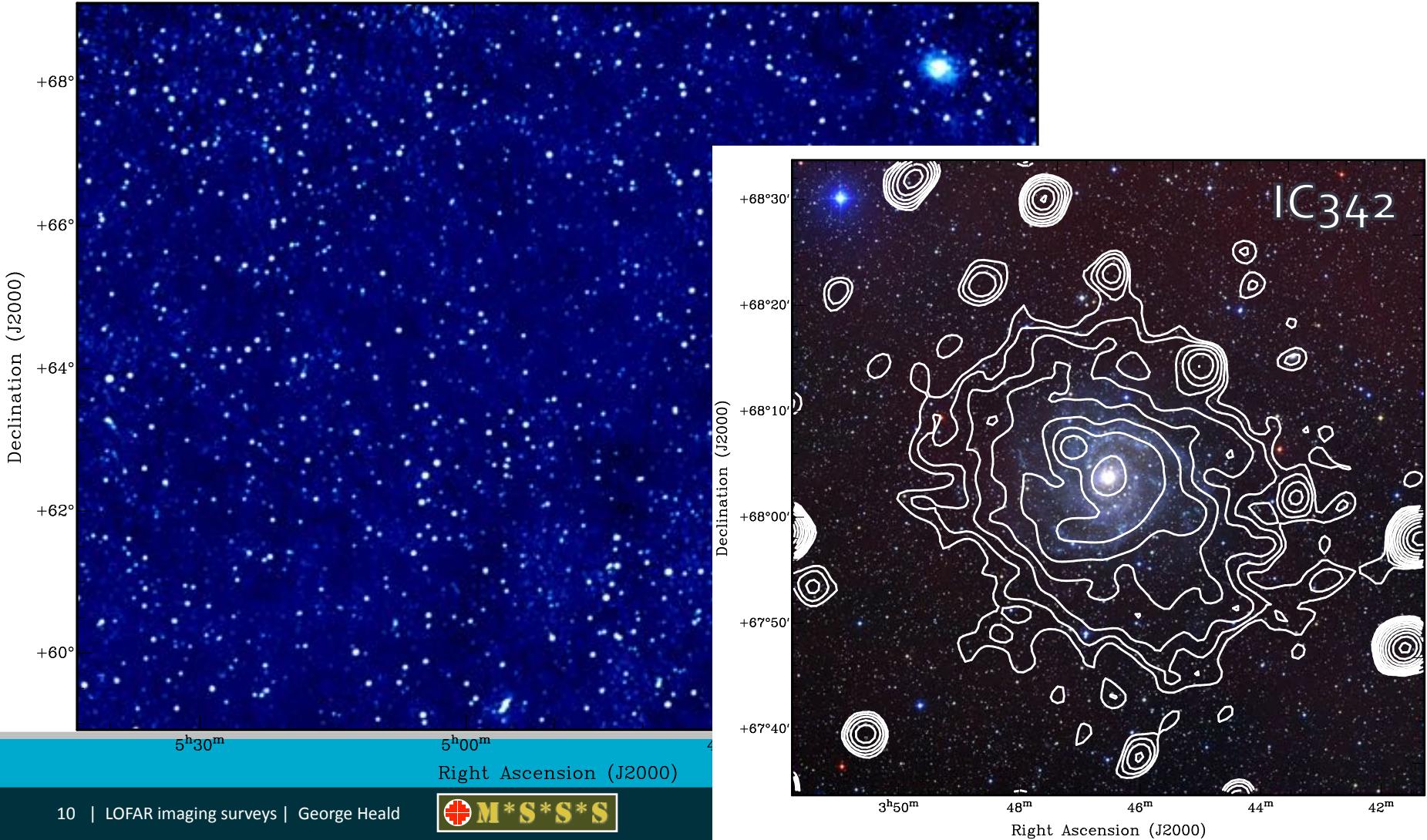
- Hosted at <http://vo.astron.nl>

The screenshot shows a web-based application interface for astronomical data analysis. On the left, a sidebar menu includes options like Help, Service Info, MSSS, MSSS Data, MSSS Catalogues, MSSS Results, MSSS Data Release, and MSSS Data Release 2. The main content area has a title "MSSS Verification Field Sources". Below it, a "Parameters" section lists "Position/Name: 18:00:00.70:00:00" and "Search radius: 85.0". A green arrow points to the "Result" section, which displays a table with 28 rows. The table has columns: ID, RA [hh:mm], Dec [mm], error RA [arcsec], error Dec [arcsec], α_{J2000} [deg], δ_{J2000} [deg], and WGS84_ECEF_LLA_ECEF_LLA. The first few rows of the table are:

ID	RA [hh:mm]	Dec [mm]	error RA [arcsec]	error Dec [arcsec]	α_{J2000} [deg]	δ_{J2000} [deg]	WGS84_ECEF_LLA_ECEF_LLA		
M0555VF J180007-001118	023.155440388	70.1003794273	0.00428603044e-05	7.300000007134e-05	0.00018018757808	0.00004570724818	MVF	3C196	3C295
M0555VF J180007-001119	023.1571756451	70.09990000023	0.000442771287988	0.000220084107181	0.000632800042982	0.000725270630090	MVF	3C196	3C295
M0555VF J180007-001120	023.1580717028	70.09913703138605	0.00096287173132	0.00046839592084	0.000817280037080	0.000798884742004	MVF	NA	3C295
M0555VF J180007-001121	023.158880017	70.0981104273	0.000374980767982	0.00026883327428	0.0003737194408	0.000736276191336	MVF	NA	3C295
M0555VF J180007-001122	023.1594717154	70.0980001118	2.373847784e-05	1.7300000070e-05	0.0003714479894	0.00060778619719	MVF	3C196	3C295
M0555VF J180007-001123	023.159851402	70.097642548	0.00036277459827	0.00027988649314	0.000870410886	0.0007947981254	MVF	3C196	3C295
M0555VF	023.159999999	70.097642548	0.00036277459827	0.00027988649314	0.000870410886	0.0007947981254	MVF	4C4	4C144

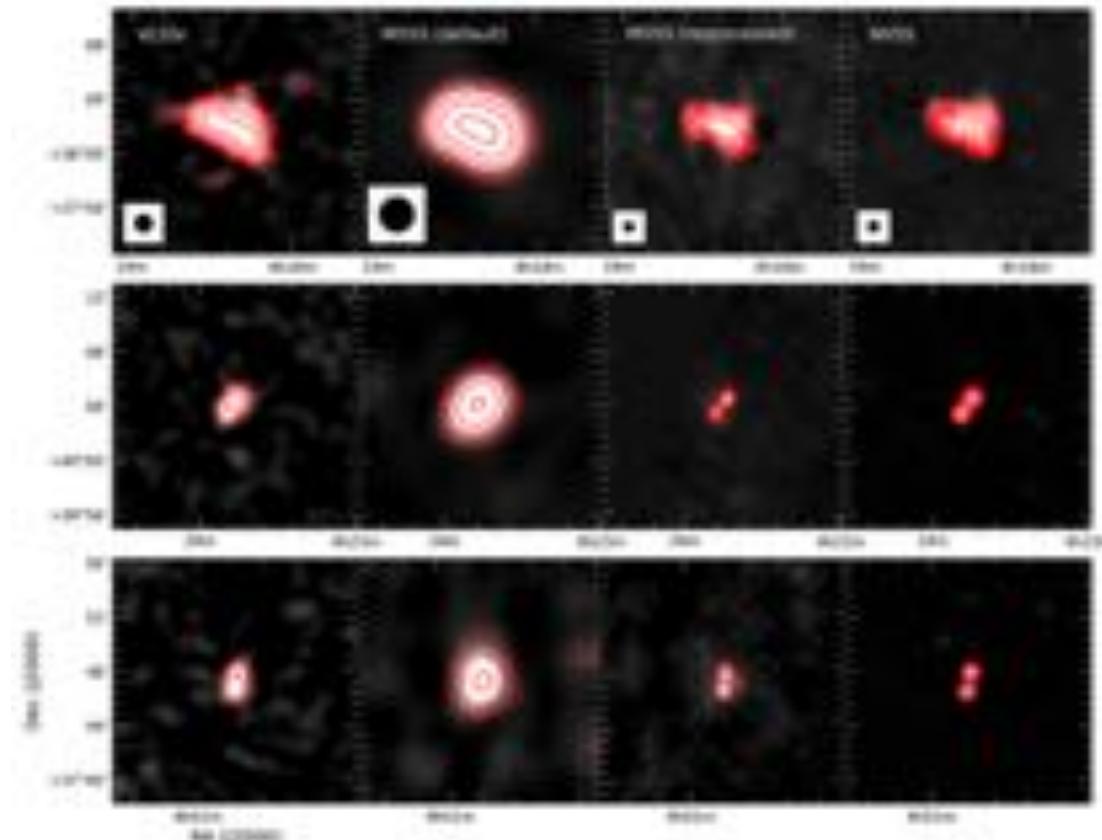
MSSS mosaics

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



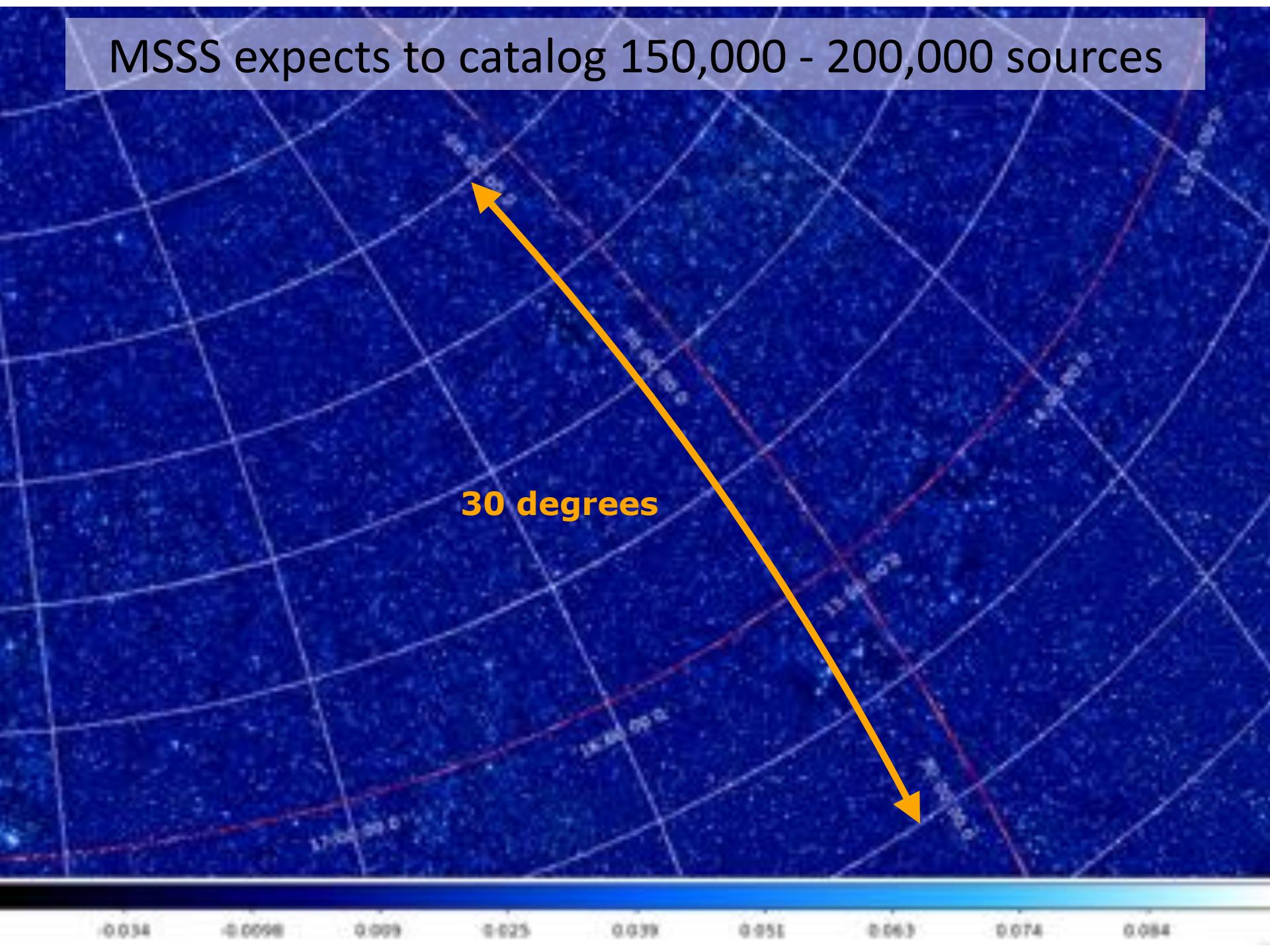
MSSS at higher resolution (target v2)

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



- Planned for v2 catalog - updated pipeline in development

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

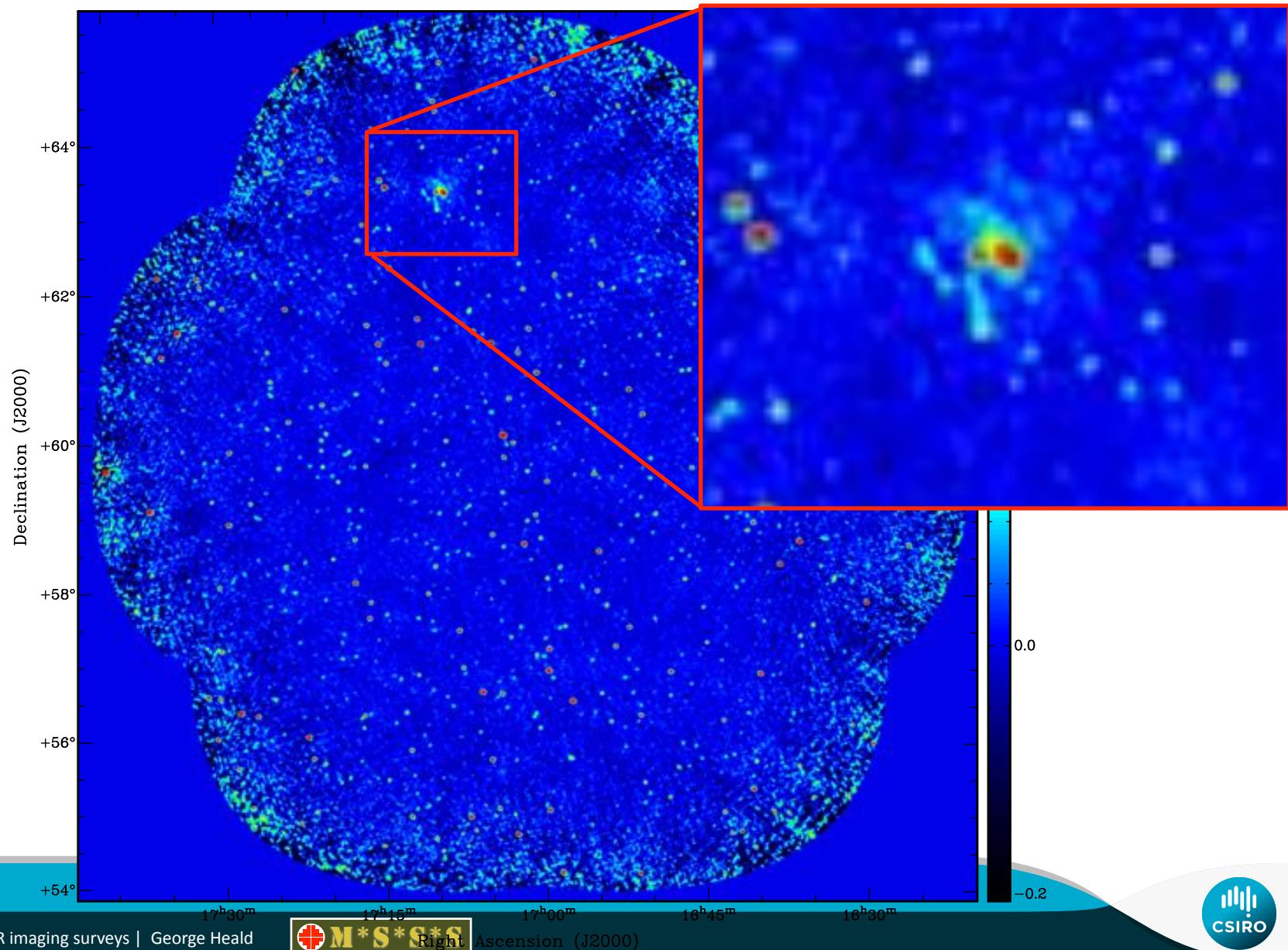


Science from MSSS

Some highlights

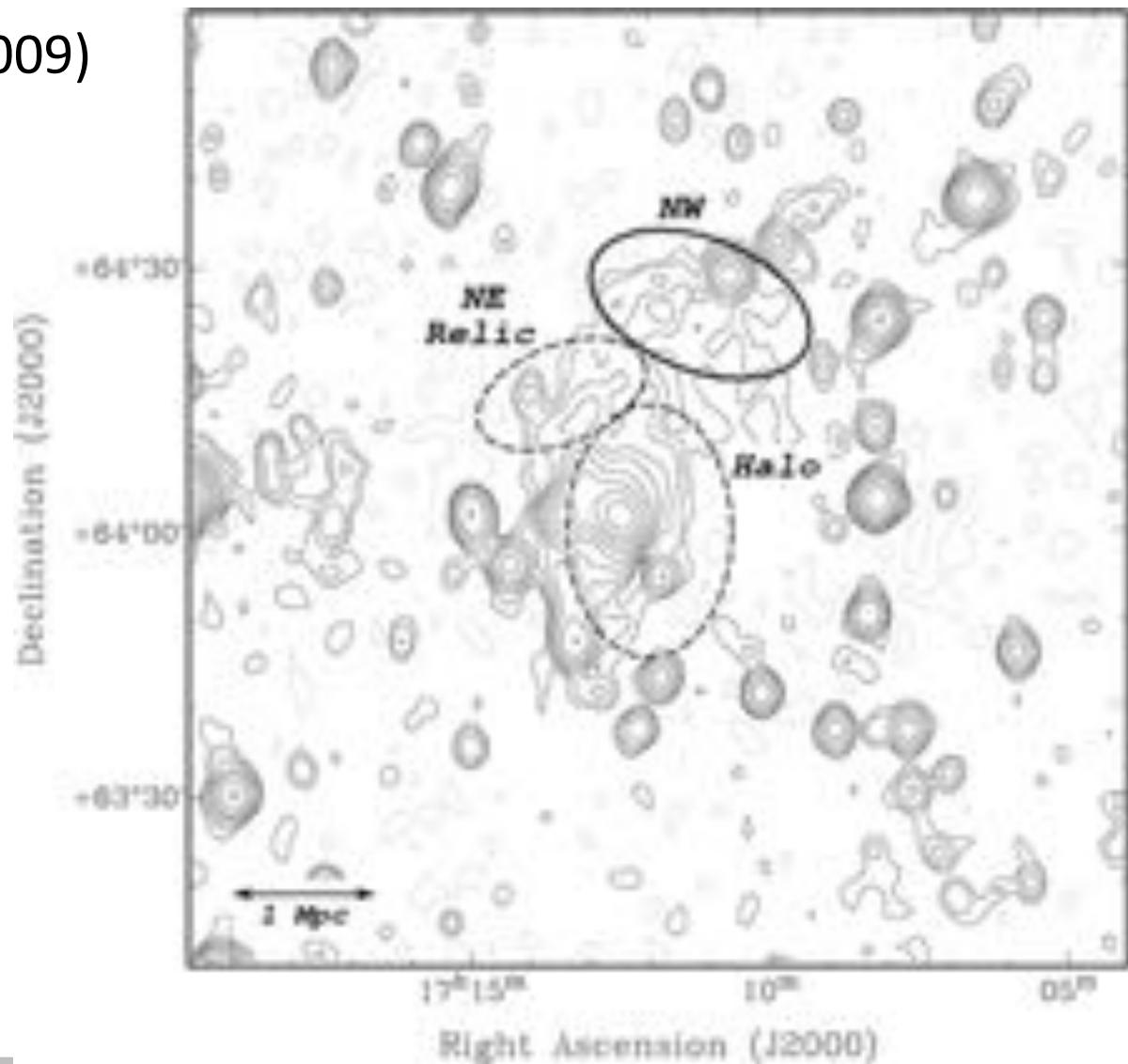
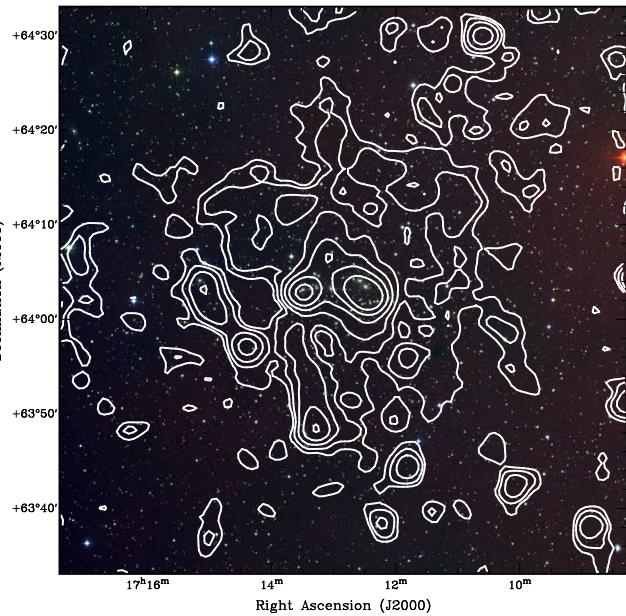


An early MSSS mosaic

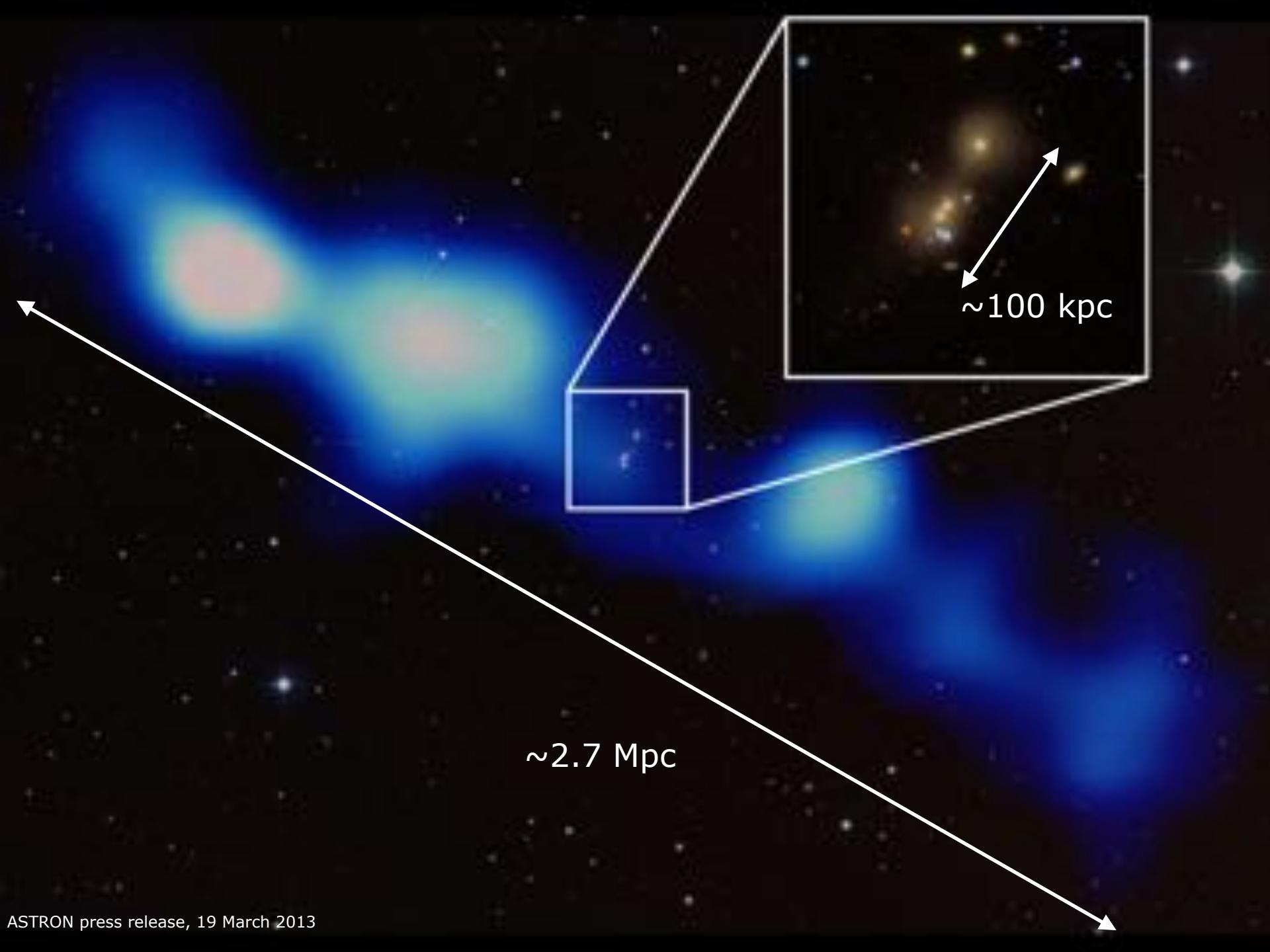


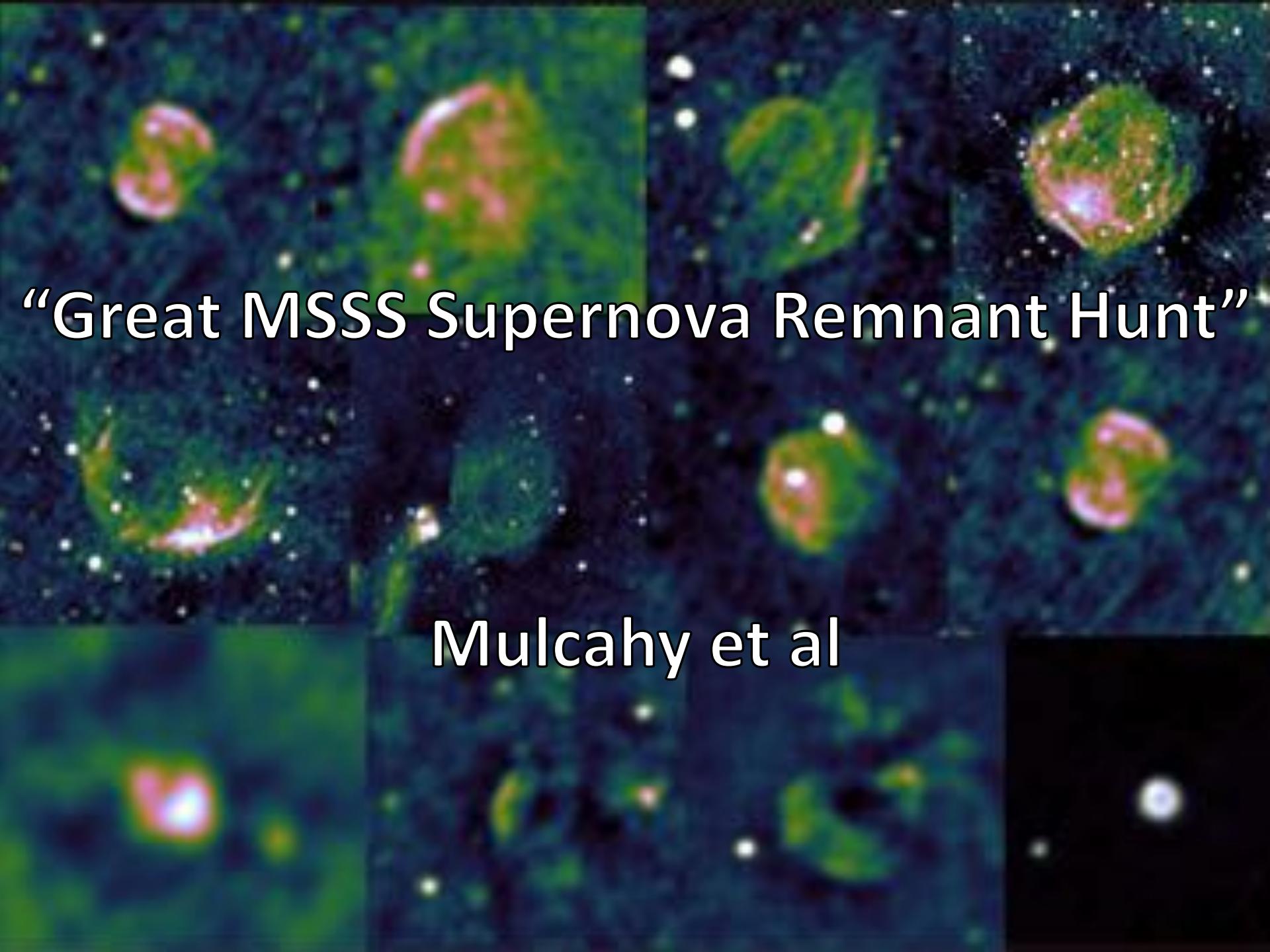
MSSS-HBA: Abell 2255

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



MSSS-HBA: 14 min!



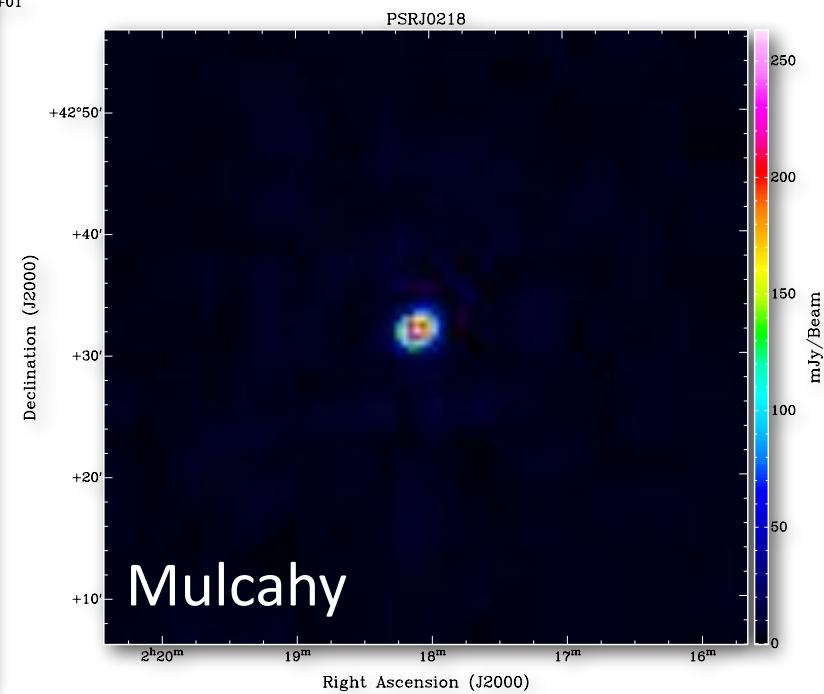
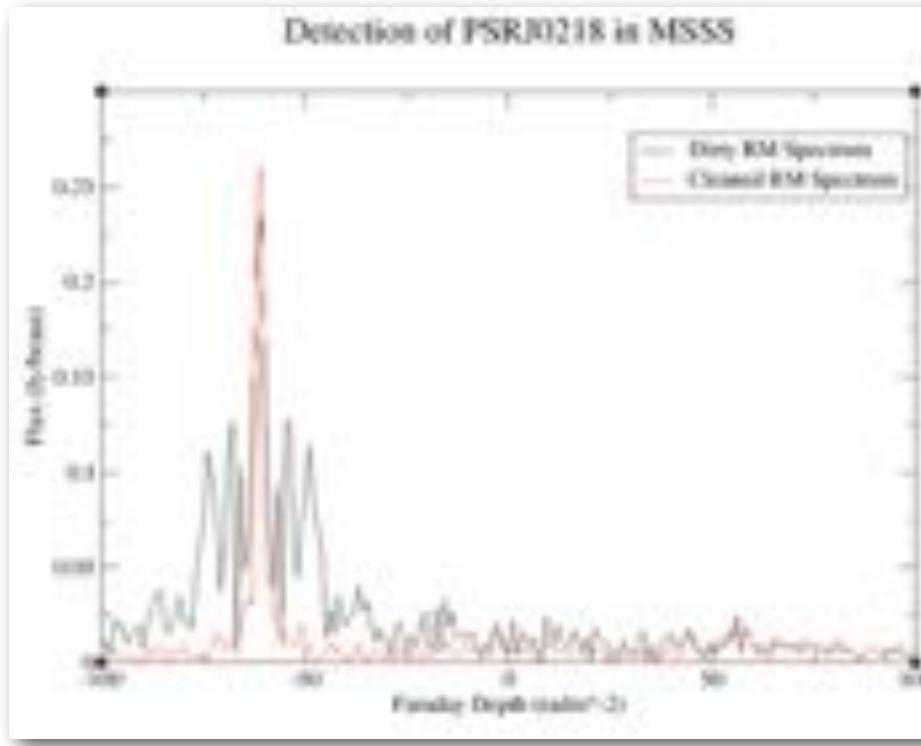


“Great MSSS Supernova Remnant Hunt”

Mulcahy et al

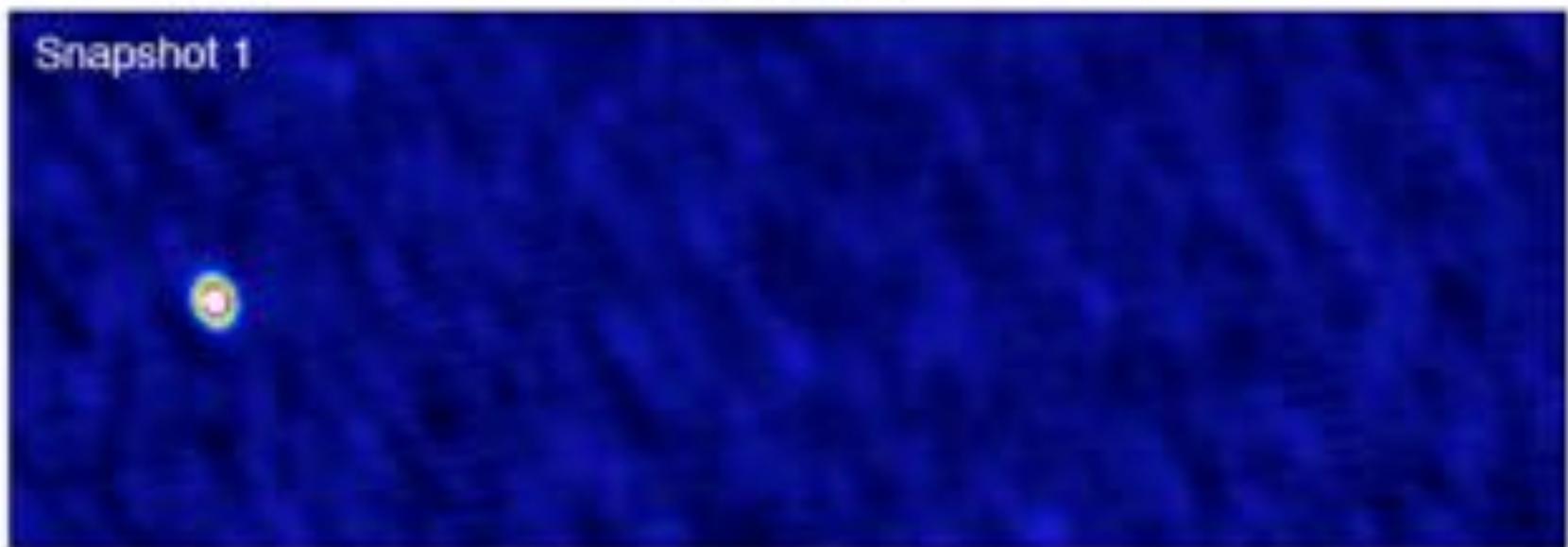
MSSS-HBA polarization

- Polarized pulsars (e.g. PSRJ0218) detected with MSSS image data
- This case: 51% polarized, and with correct RM of -61 rad m⁻² (ionospheric RM correction was applied to the data)
- Diffuse (MW foreground) polarization imaging also ongoing



MSSS Transients

- 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.)



- First MSSS-LBA transient (Stewart et al 2016, MNRAS 456, 2321)
- Appears in one 11-min snapshot, flux density $15\text{-}25 \text{ Jy beam}^{-1}$
- Implied rate for $\Delta t \sim 10\text{min}$ 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!)

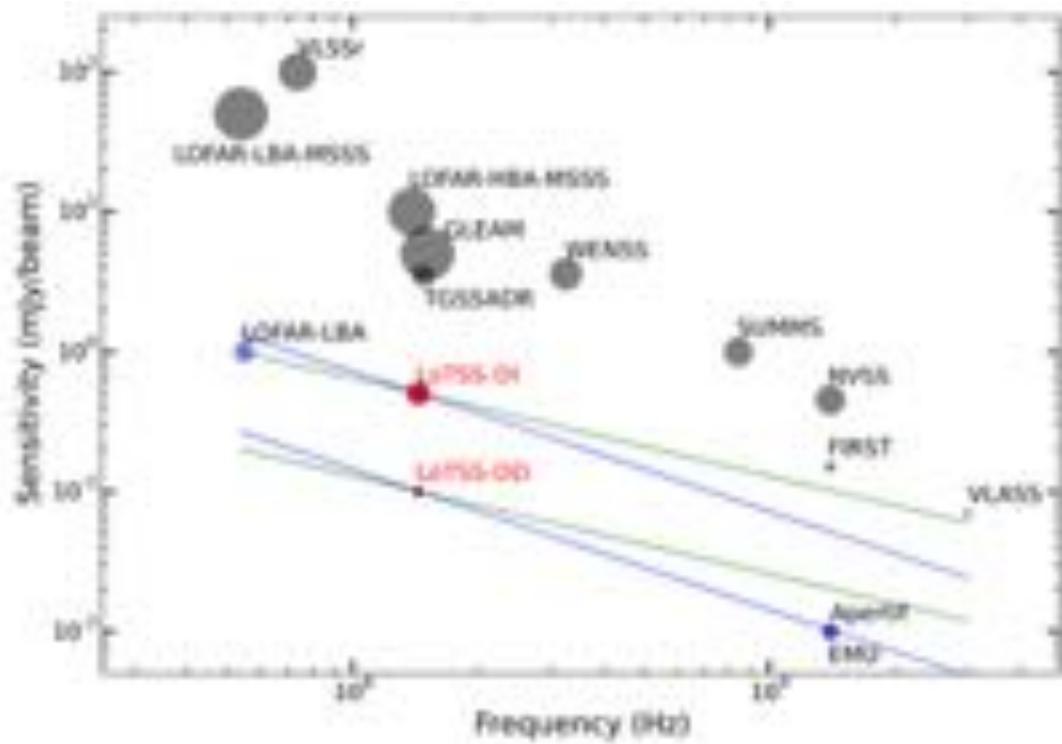
Further LOFAR surveys

To arcsecond resolution and beyond!



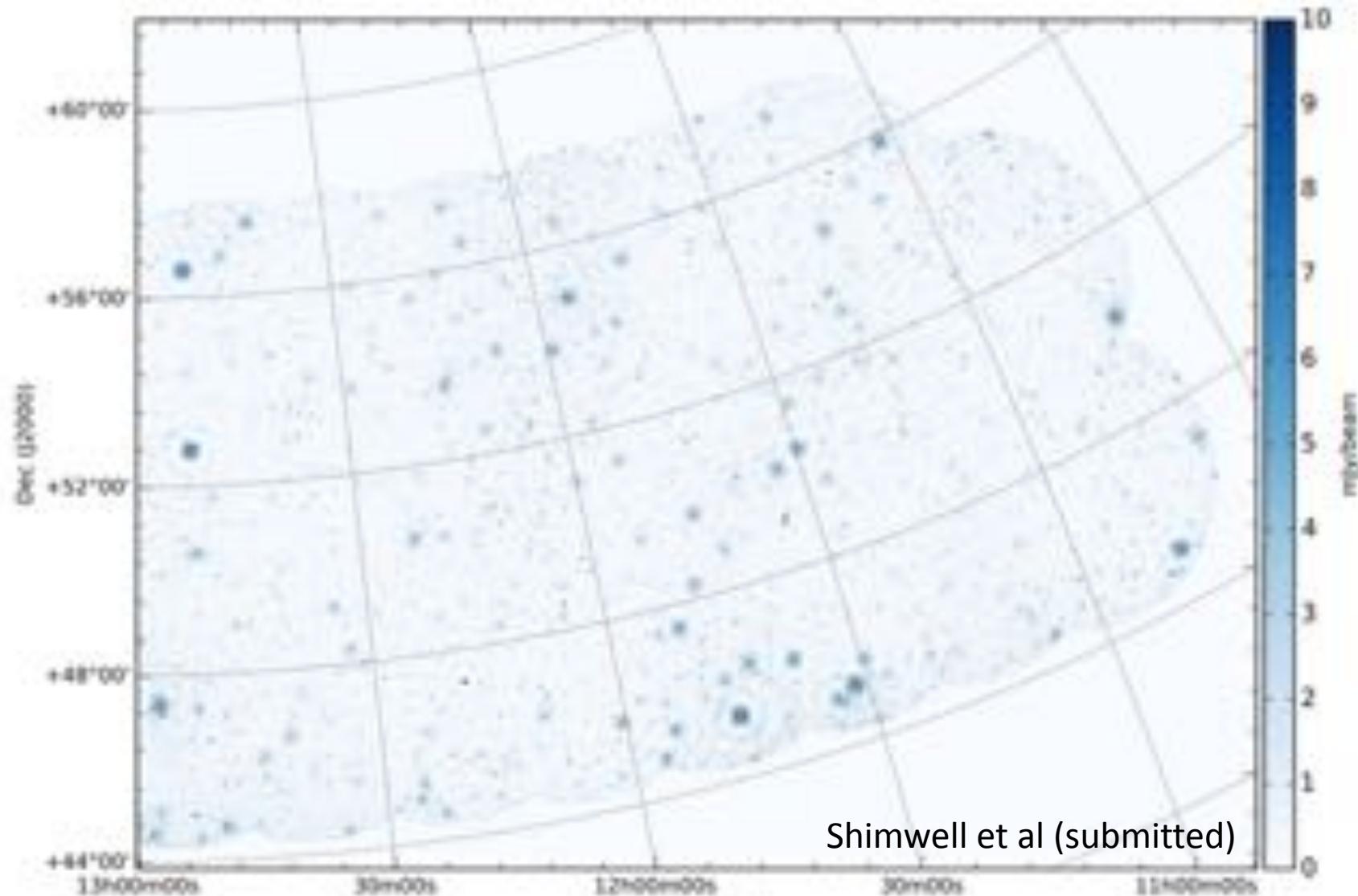
LoTSS of new survey data are on the way...

- LOFAR Two-metre Sky Survey (LoTSS; Shimwell et al, submitted)
 - 120-168 MHz, 5-10", 100 uJy/beam, >2.5 million sources

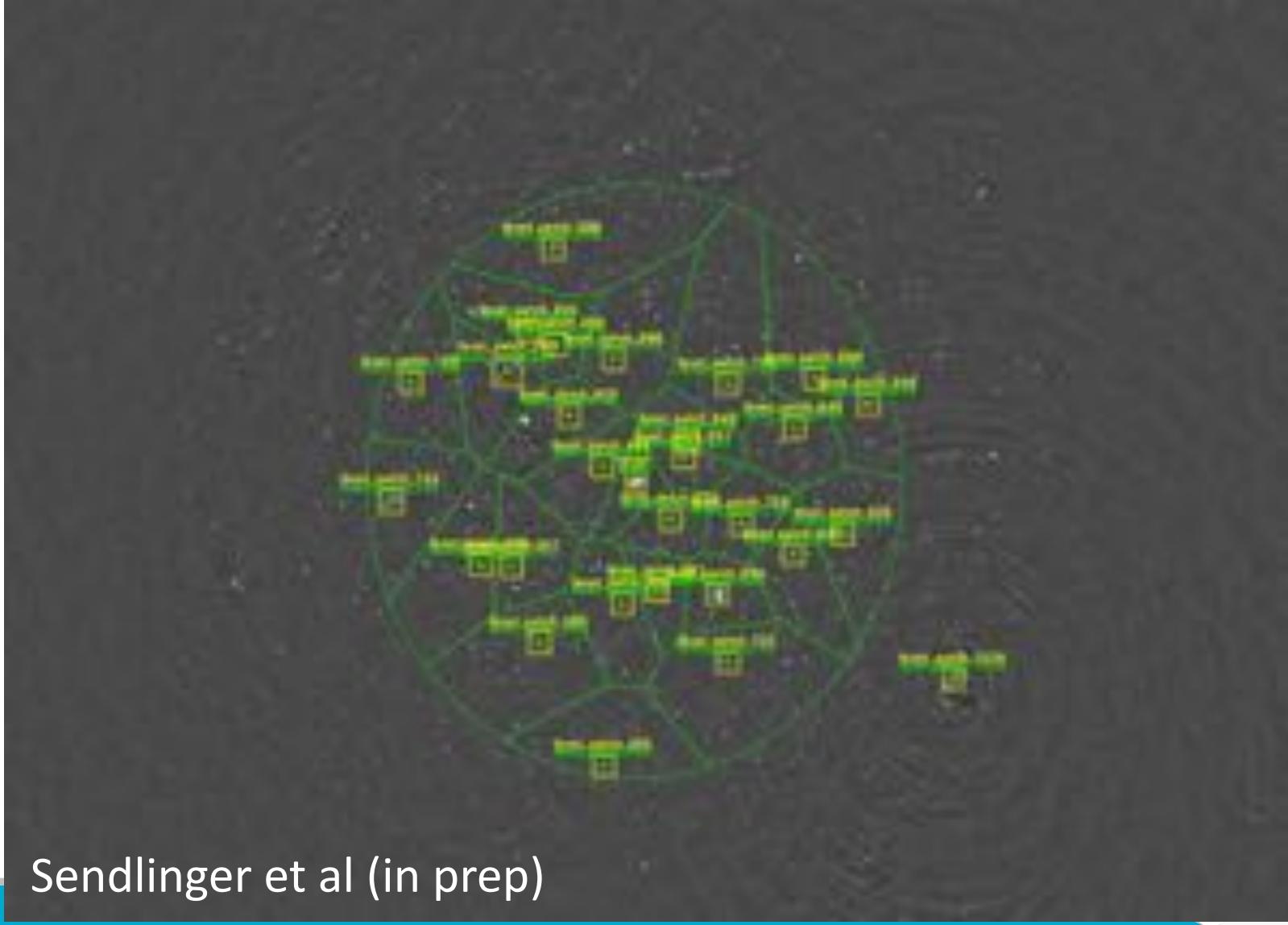


LoTSS: Direction independent survey products

- After robust initial processing stage, image products with typical resolution of 25" and sensitivity of 0.5 mJy/beam are reached

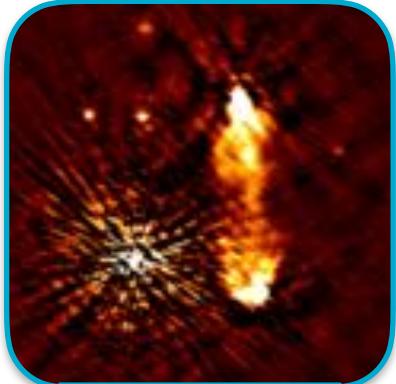


Direction dependent calibration: Factor



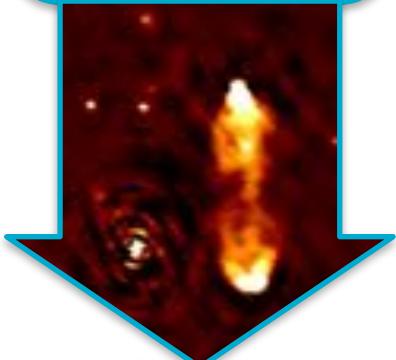
Sendlinger et al (in prep)

Direction dependent calibration: Factor



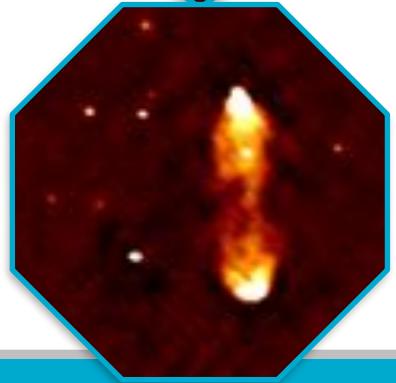
Step 0:

Begin with direction-independent data per facet



Step 1:

Solve and correct ionosphere (fast phase selfcal)



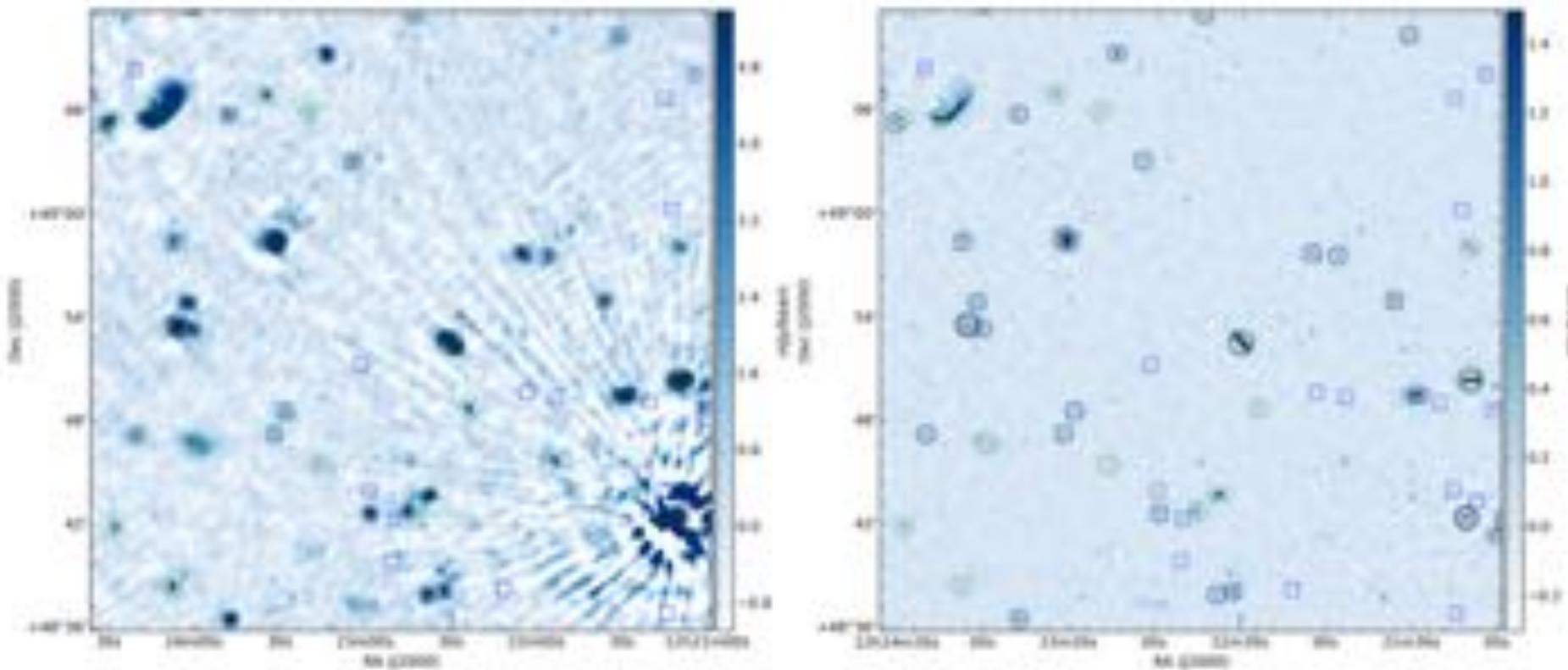
Step 2:

Solve and correct beam errors (slow amp selfcal)

LoTSS: direction dependent survey products

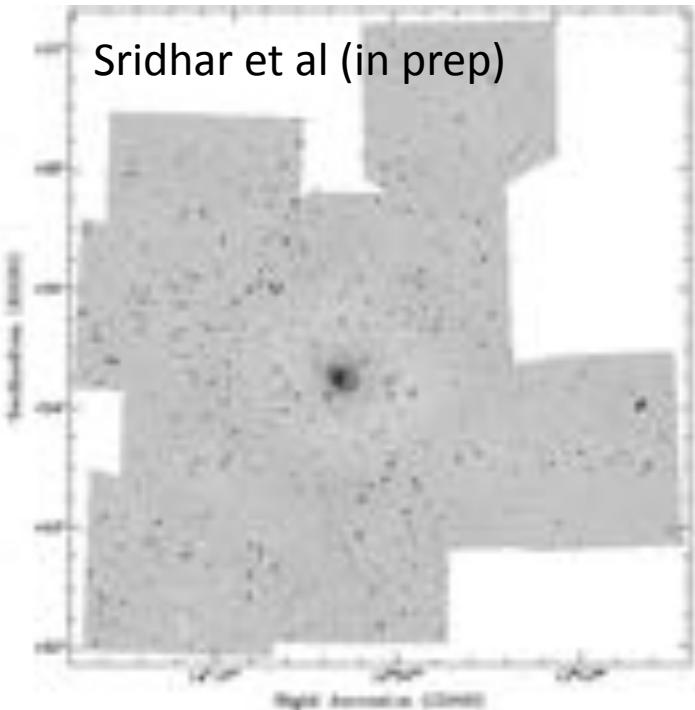
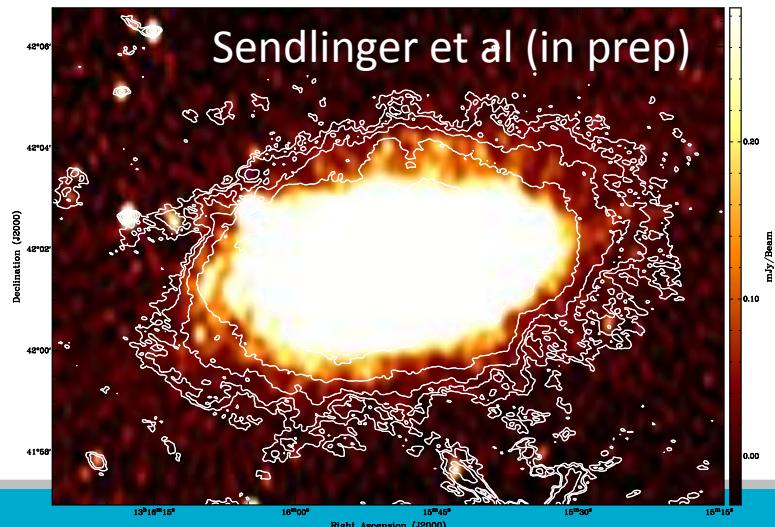
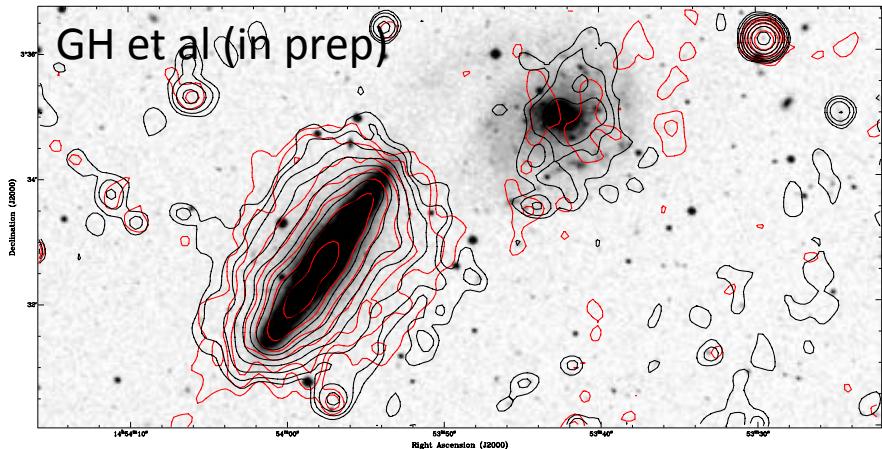
- After Factor, typical improvement:
 - 25" \rightarrow 5-10"
 - 0.5 mJy/beam \rightarrow 0.1 mJy/beam

Shimwell et al (submitted)



Single objects with Factor

- Individual targets and fields are being studied with these techniques in the leadup to LoTSS (DD):



Deep fields
... see Elizabeth Mahony's presentation tomorrow!

LBCS: LOFAR Long-Baseline Calibrator Survey

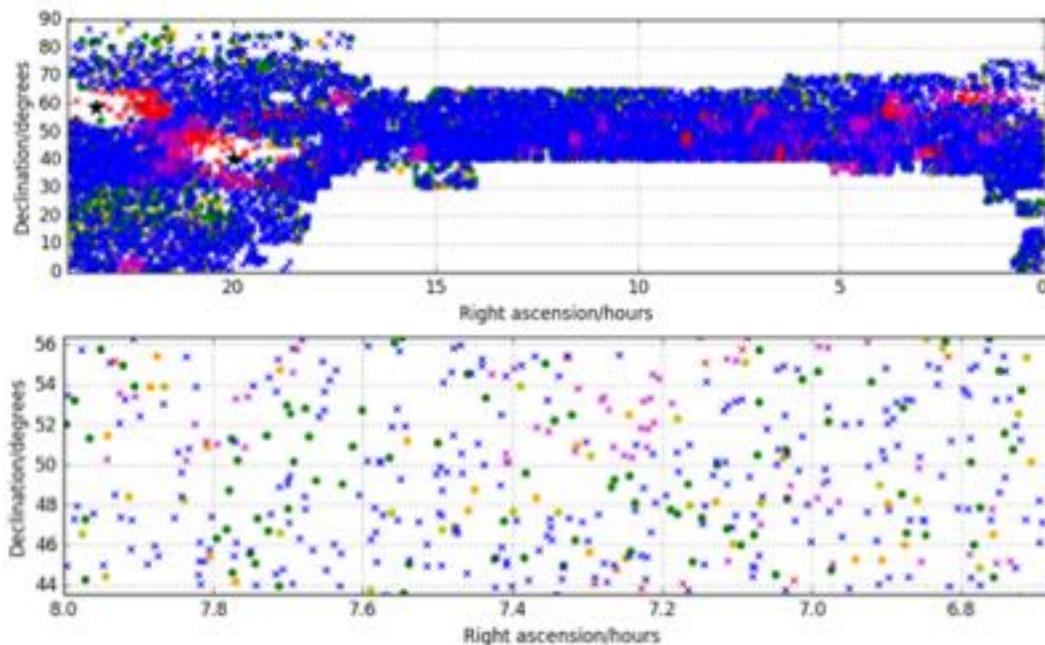
- Jackson et al (A&A, accepted; arxiv:1608.02133)
 - ~15,000 sources observed so far (16-49% detection rates)
 - Typical density of calibrator sources: 1 per square degree
(Transferability expected within isoplanatic patch, <~ 1 degree)
 - Typical coherence time: 1-3 minutes



^aInformation was not available after the submission.

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Final remarks

- LOFAR survey work proceeding well on all angular scales (arcminute to sub-arcsecond)
- MSSS data release slated for this year
- Techniques being developed are well suited for application to forthcoming MWA long baselines, and SKA1-LOW

Thank you

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