LOFAR

LBA

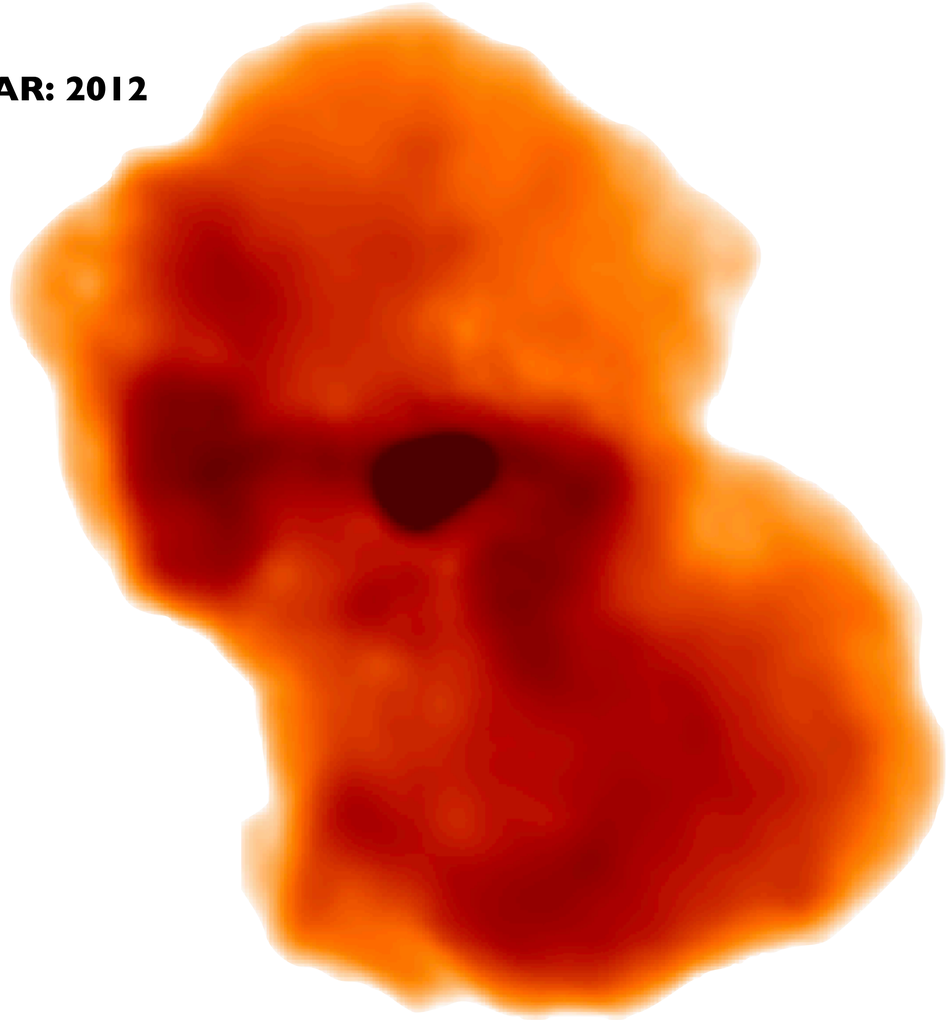
Survey first release and next steps

Francesco de Gasperin

LOFAR Family Meeting
06/2023

LOFAR evolution

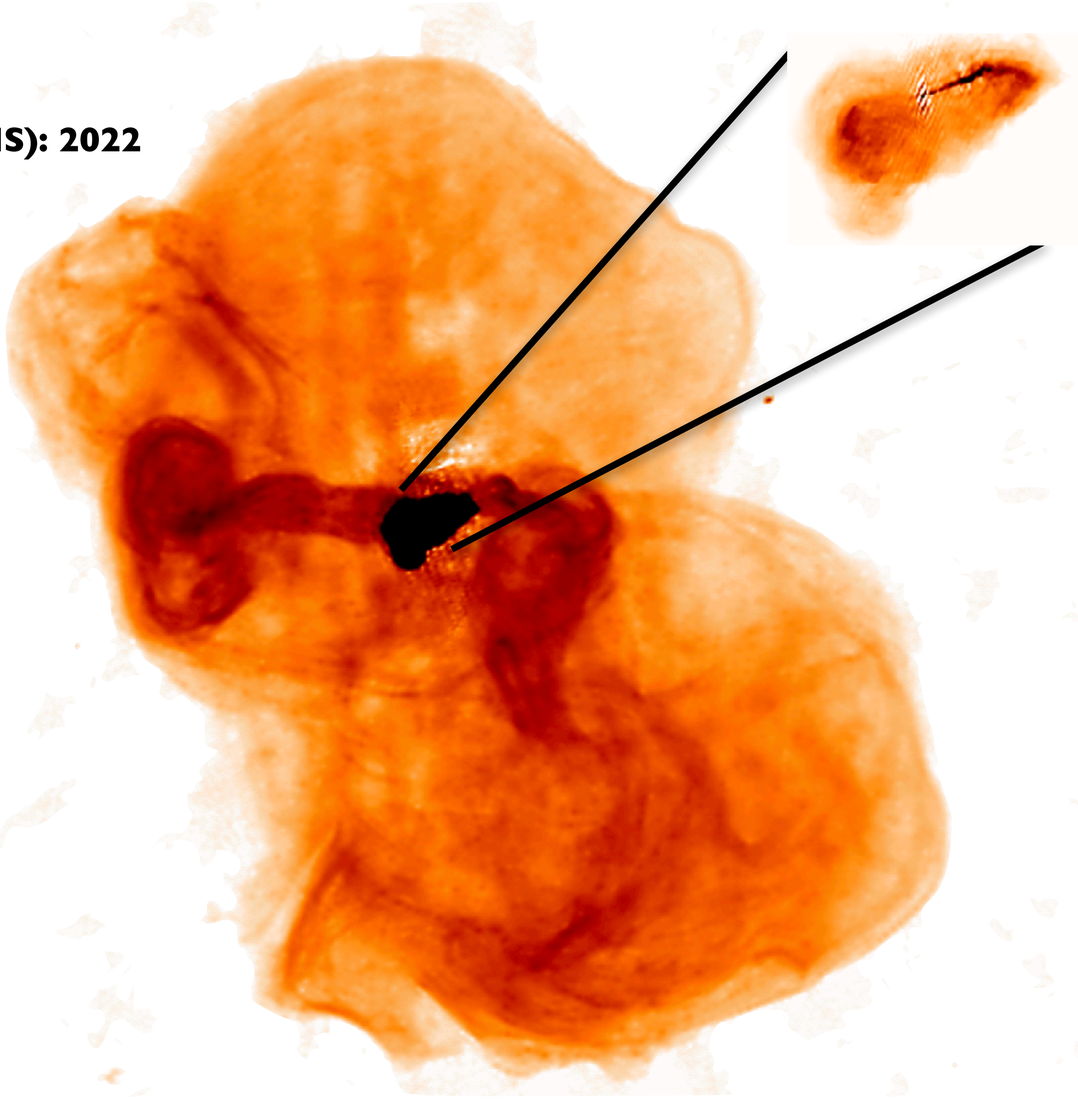
LOFAR: 2012



LOFAR (with IS): 2022

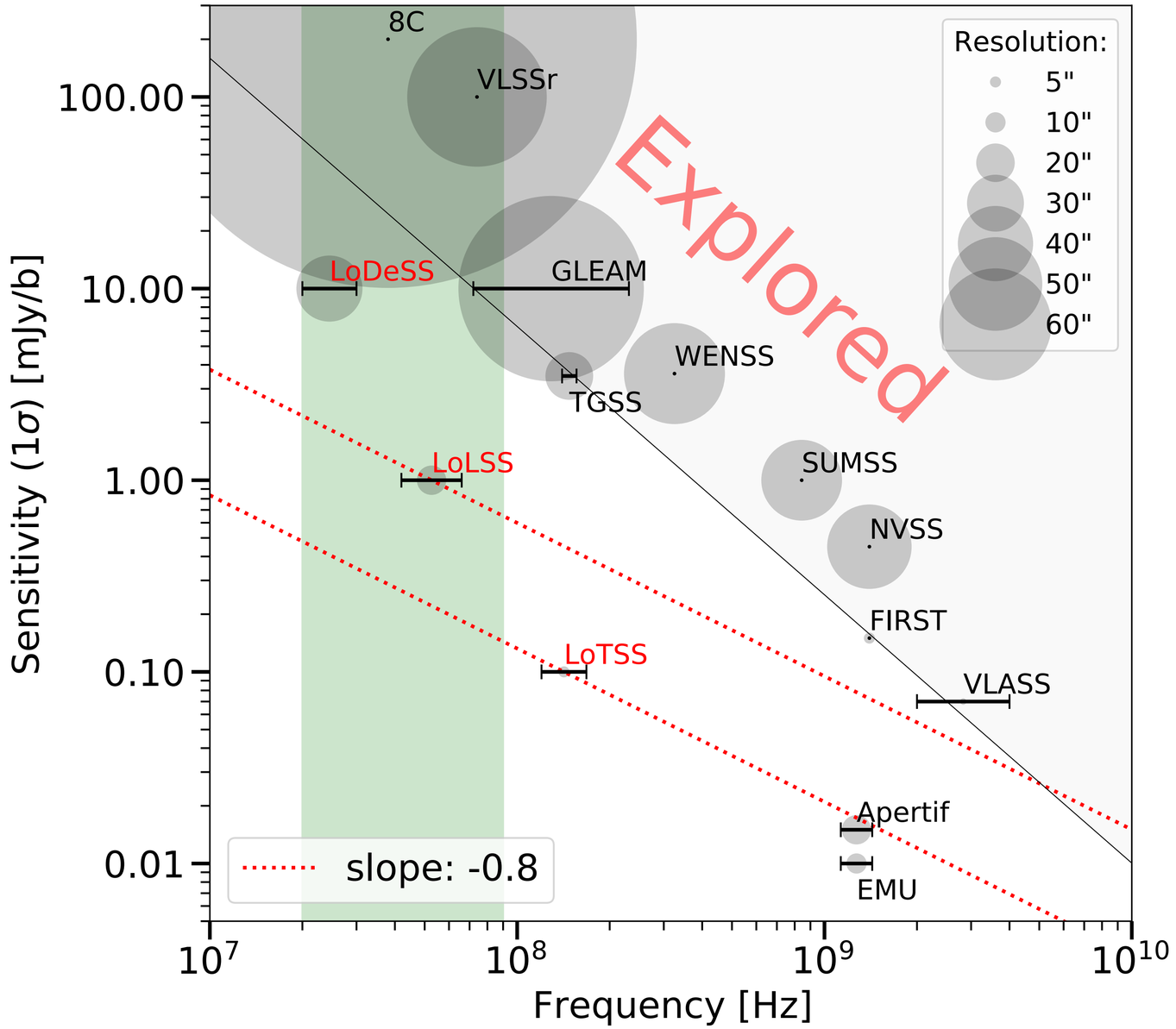
2”-3”

0.3”

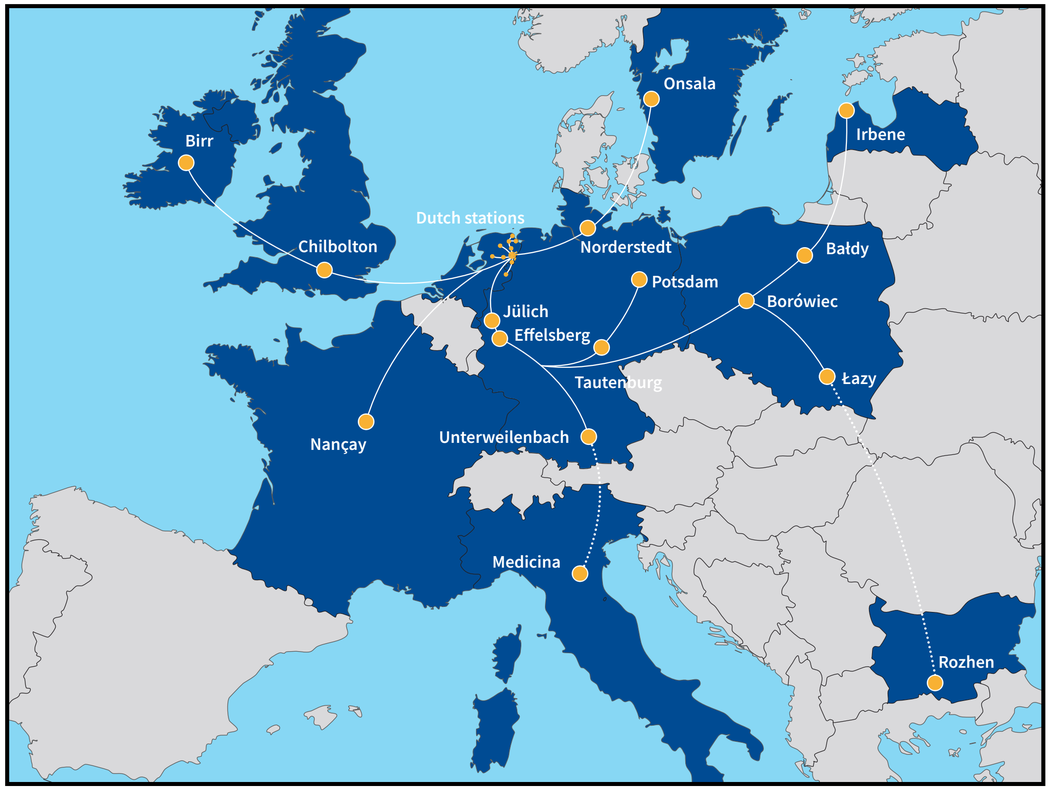


Credits: H. Edler

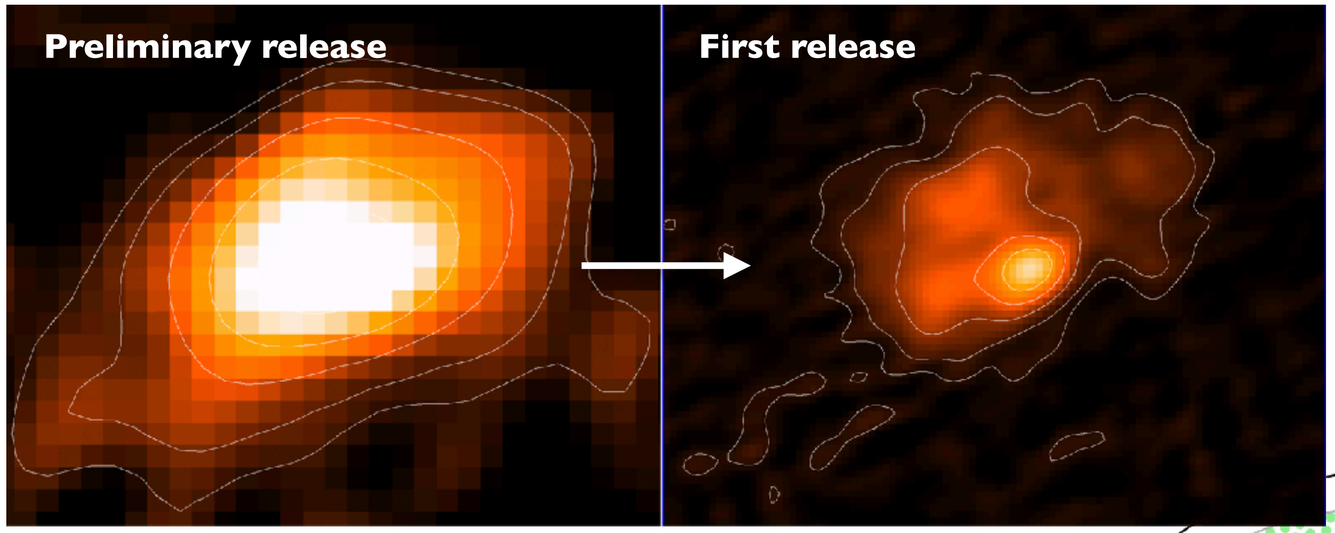
LOFAR Surveys



- **LOFAR Two Metre Sky Survey: 120 - 168 MHz**
- **LOFAR LBA Sky Survey: 42 - 66 MHz**
- **LOFAR Decametre Sky Survey: 14 - 30 MHz**

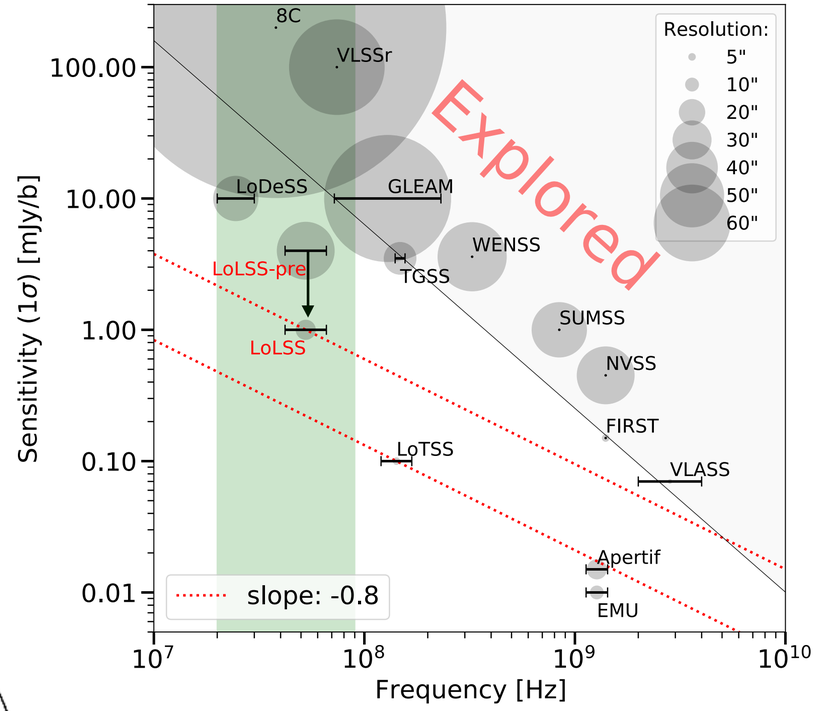


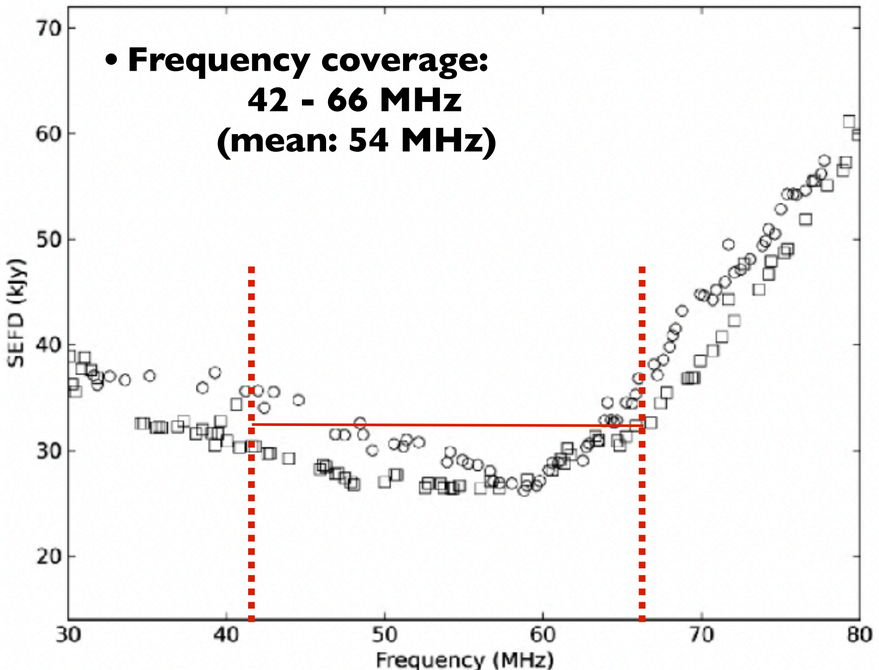
LoLSS status

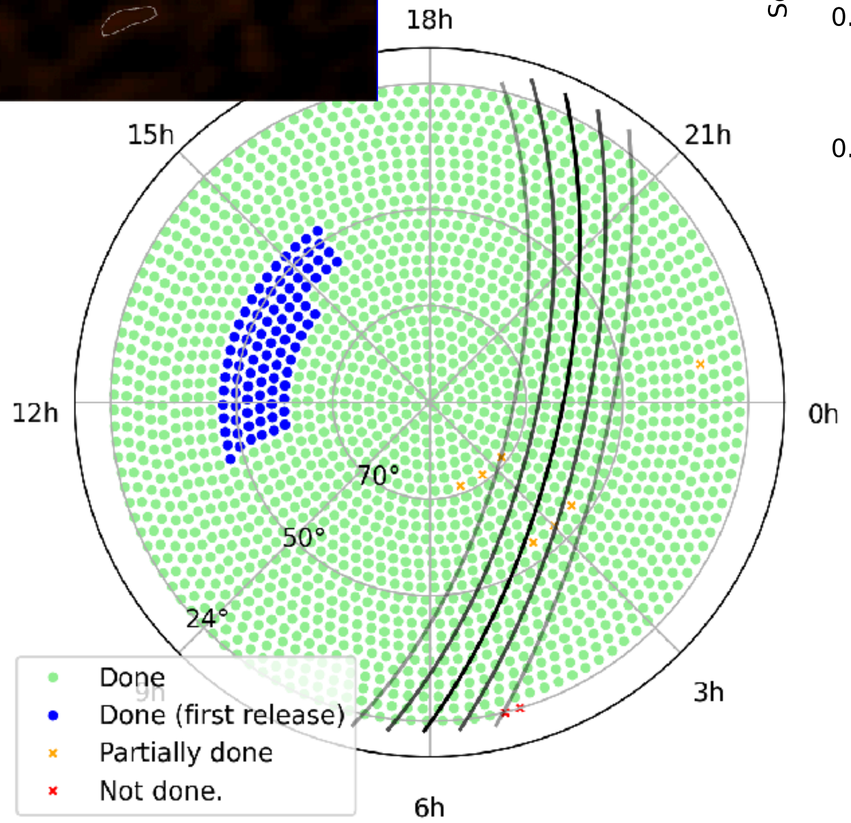


2021:
LoLSS Pr. release
- **res.: 45”**
- **sens.: 5 mJy/b**

2022:
LoLSS I release
- **res.: 15”**
- **sens.: 1 mJy/b**



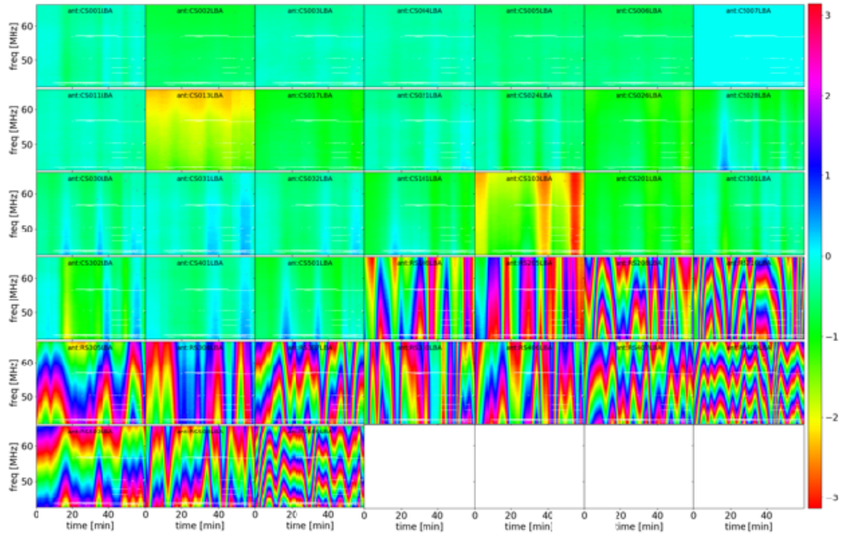


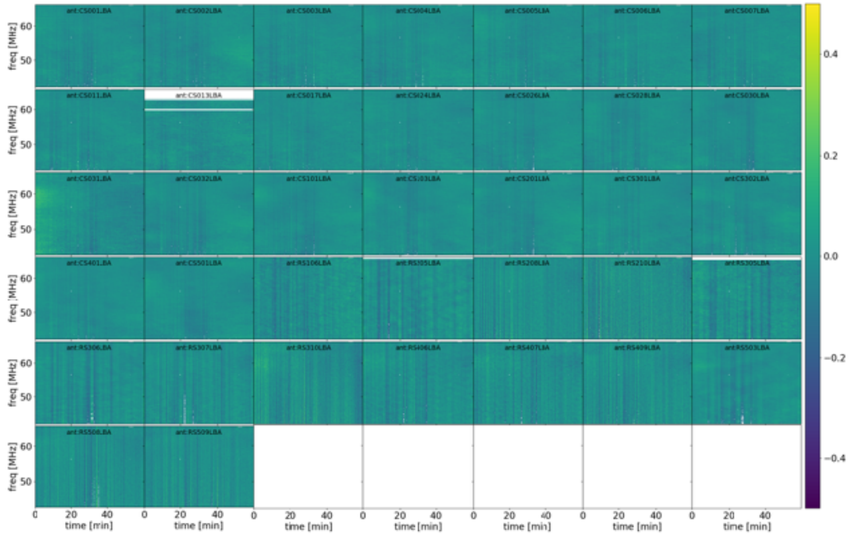


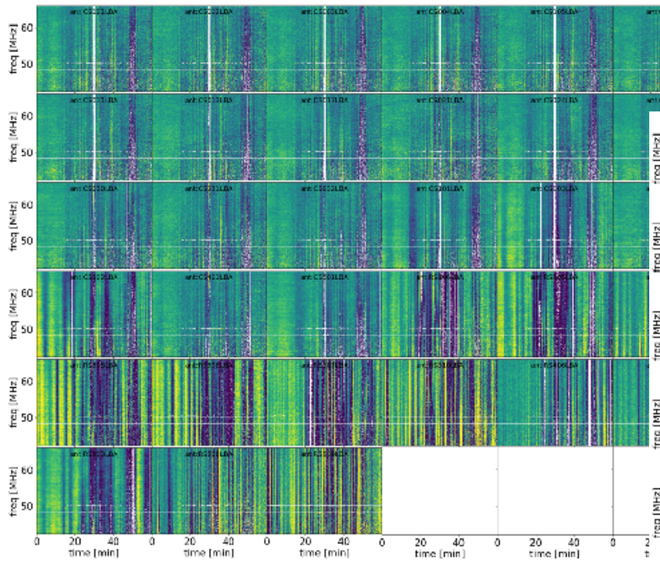
Coverage: Dec > 24°
99% complete

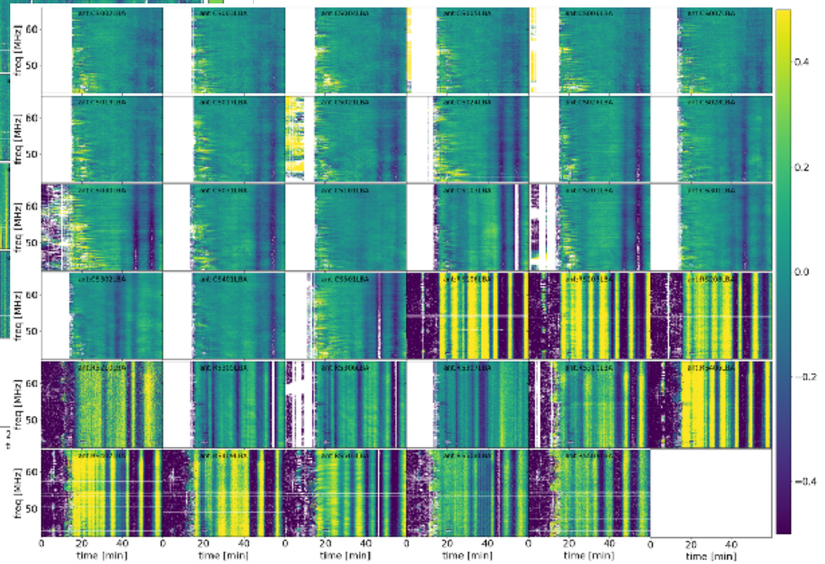
Current status

- calibrator processed and used to perform re-observations
- new singularity being prepared to enable advanced dp3/ wsclean modes
- test runs on 10 fields and polishing of the pipelines

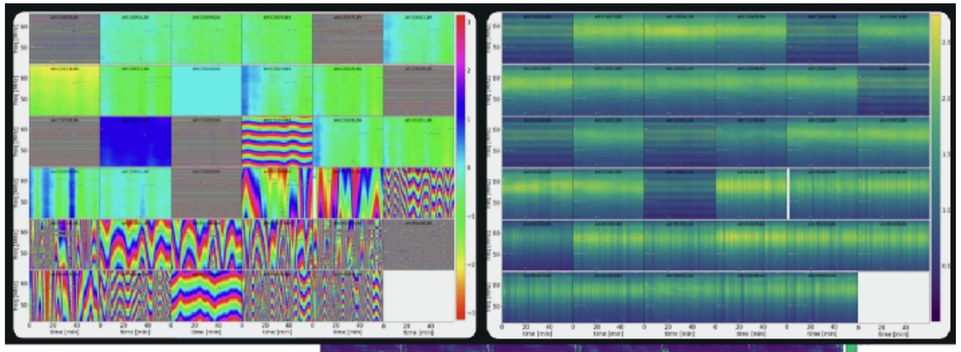


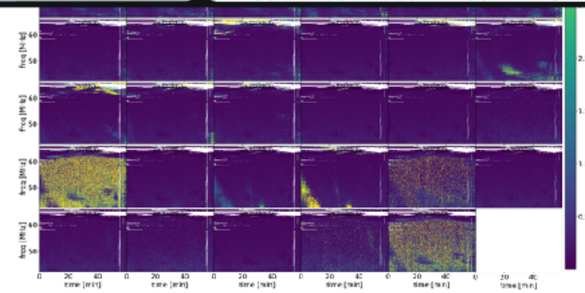






Scintillations



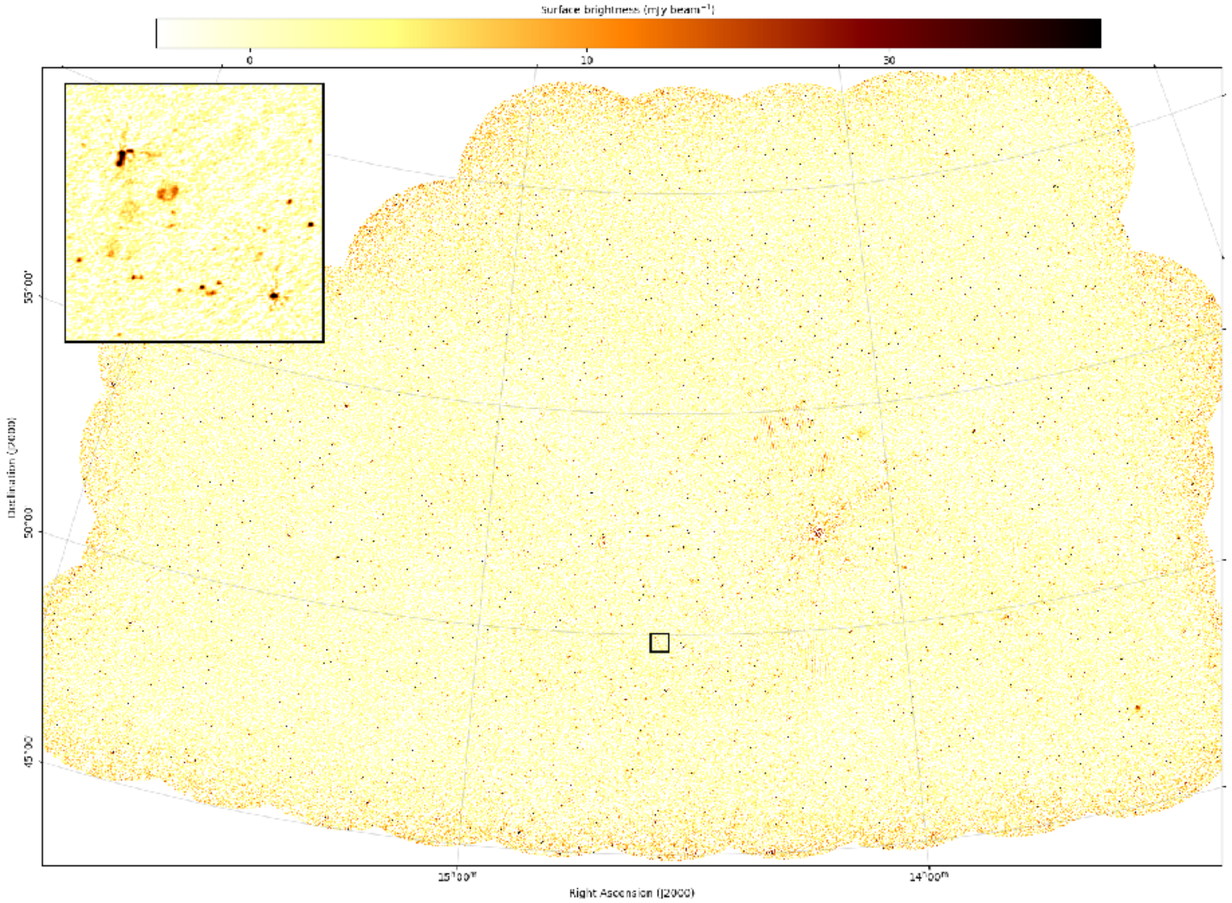


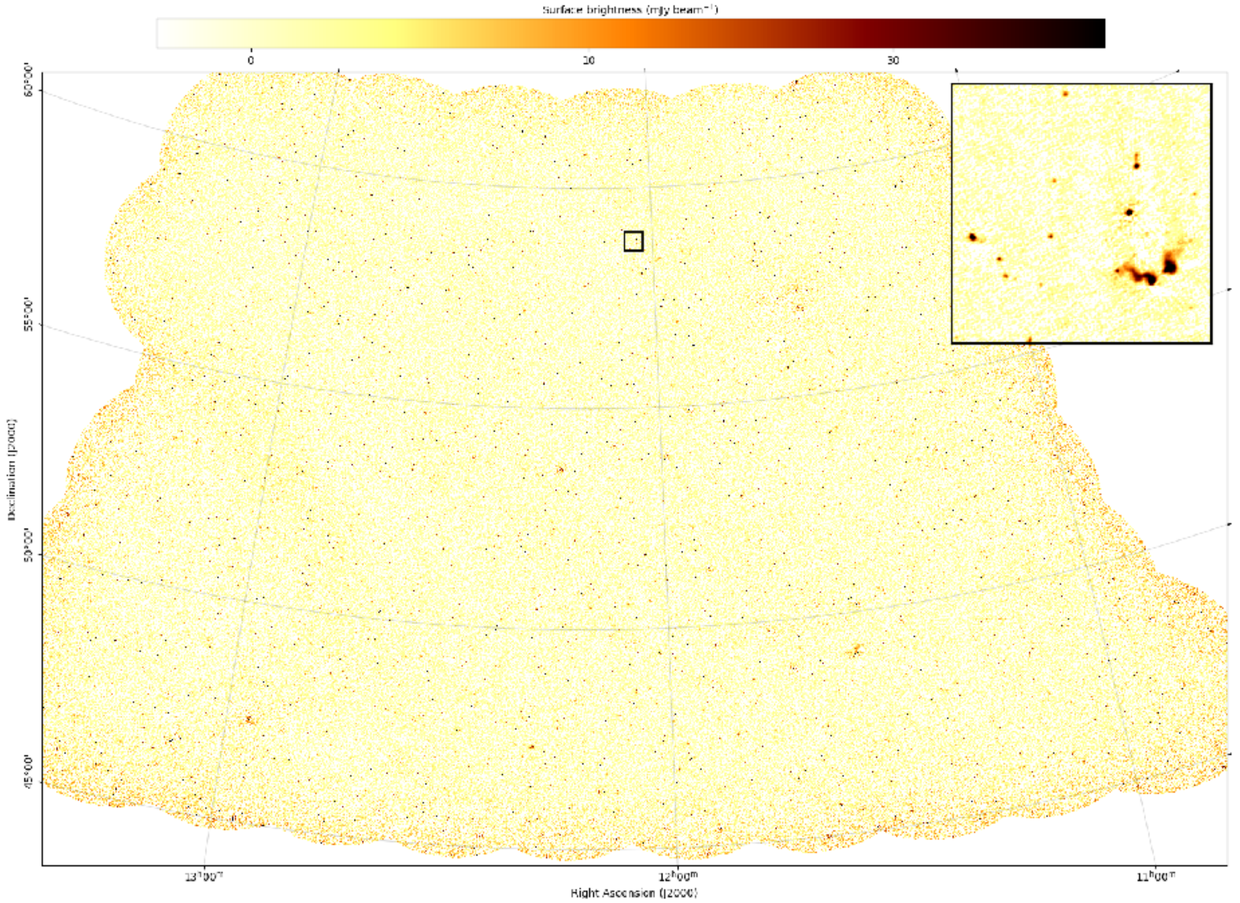
Telescope problems

LoLSS DR1 data

de Gasperin+ in prep.

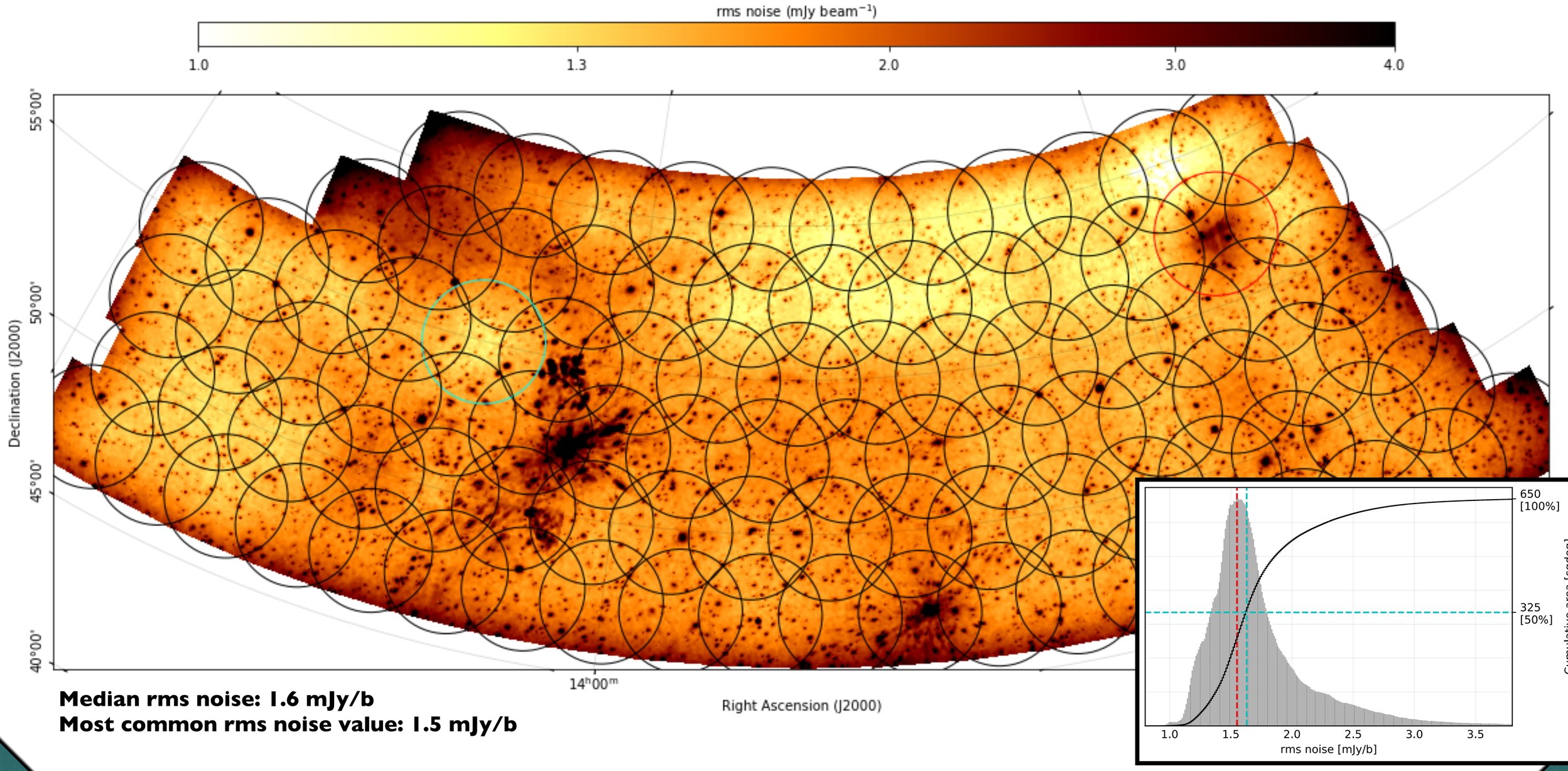
sky survey





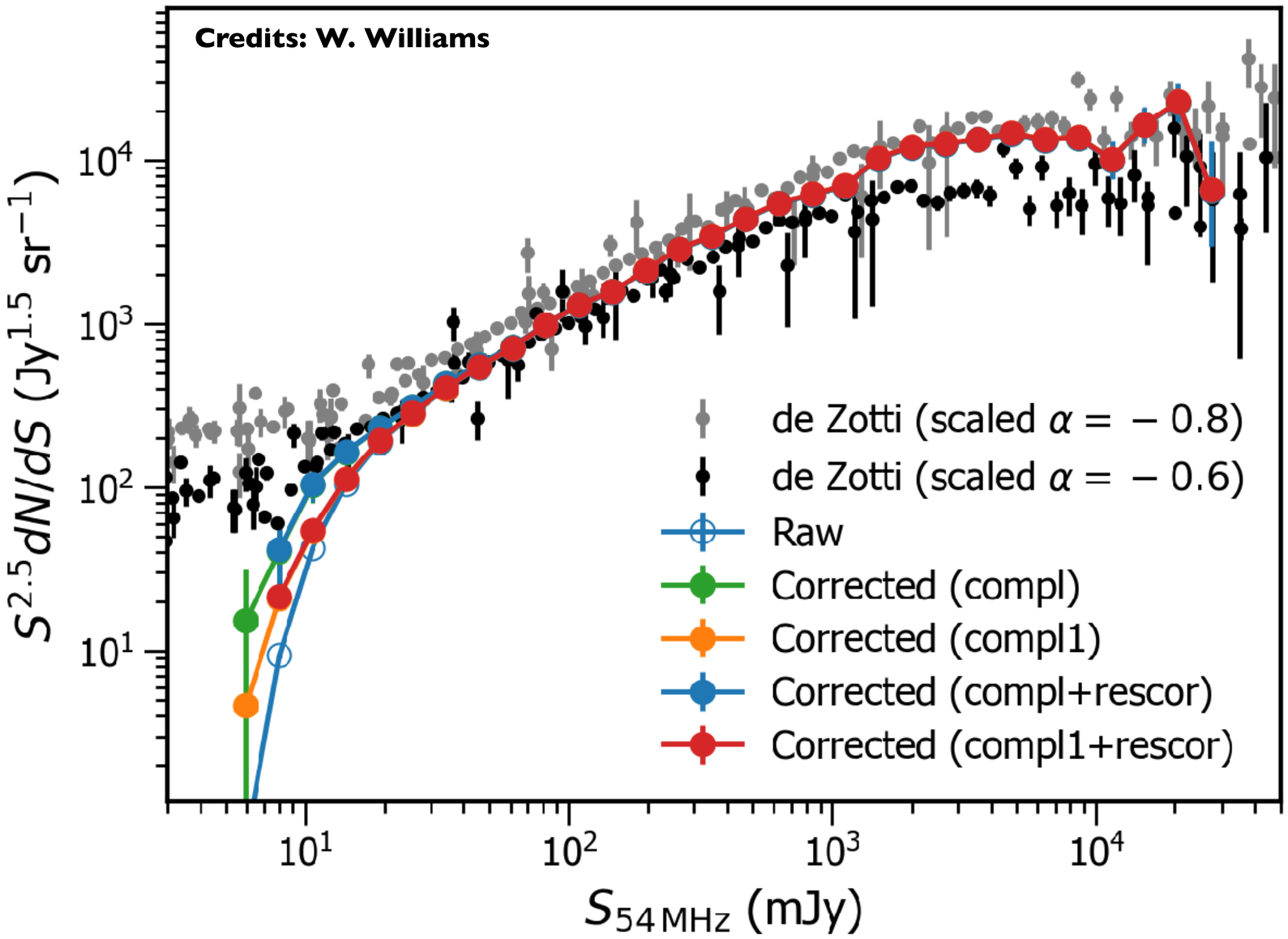
- **Area: 650 deg²**
- **Stokes: I, V**
  Image format: 2 large fits, 95 mosaic fits, hips
- **Catalogue: sources (42,463)**
- **Solutions: direction-dependent for re-imaging/extraction**

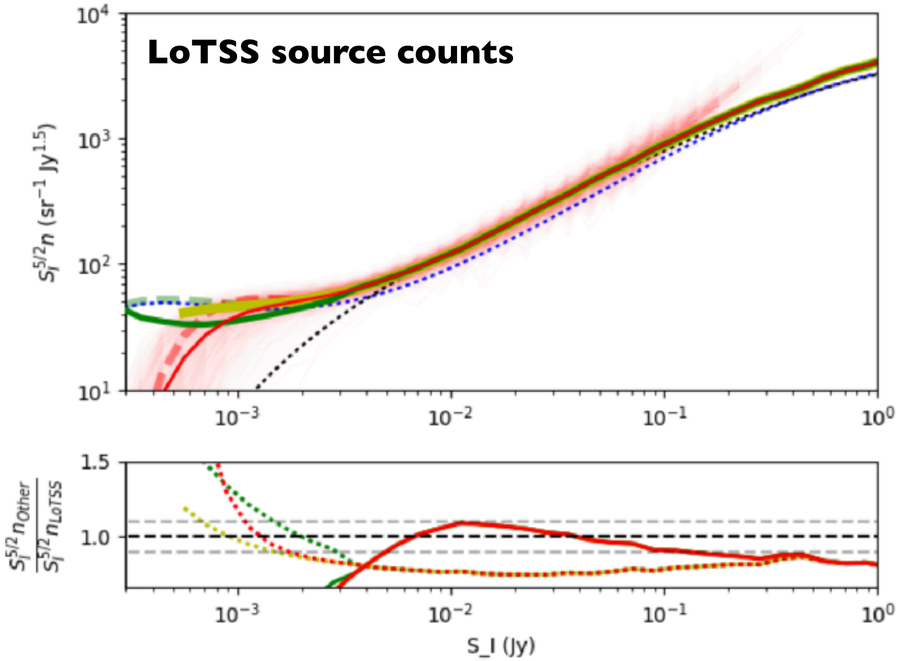
LoLSS sensitivity



Median rms noise: 1.6 mJy/b
Most common rms noise value: 1.5 mJy/b

LoLSS source count

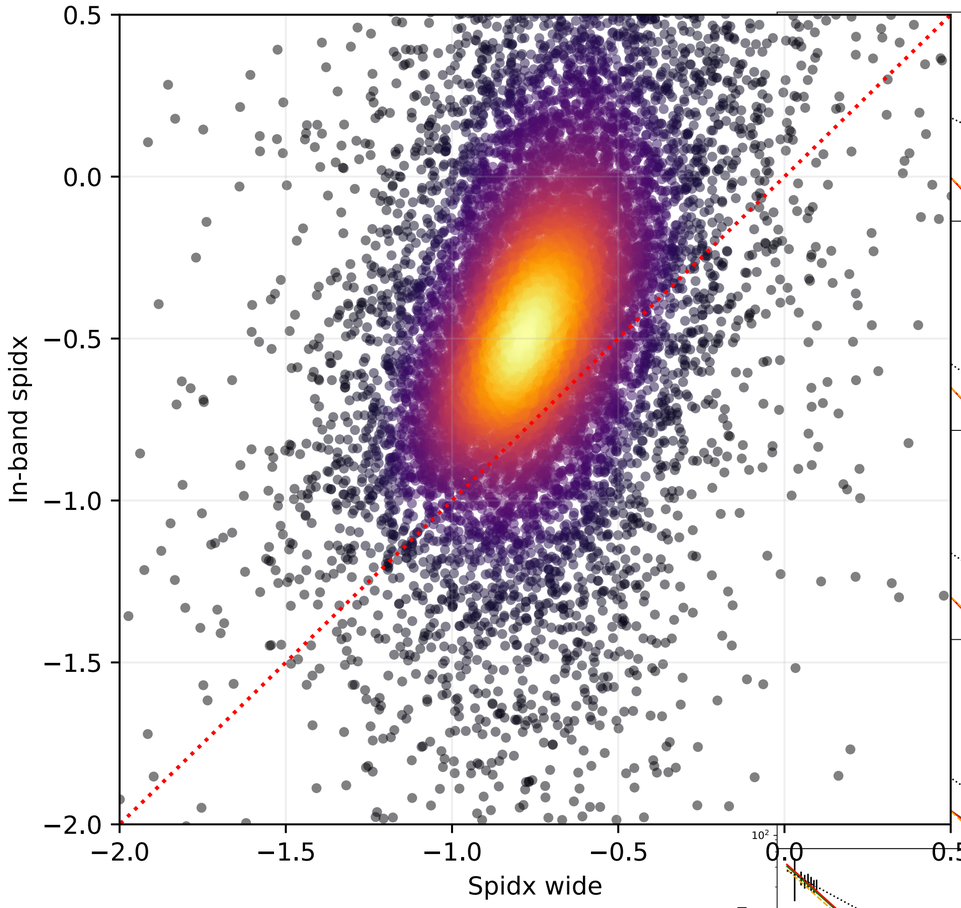


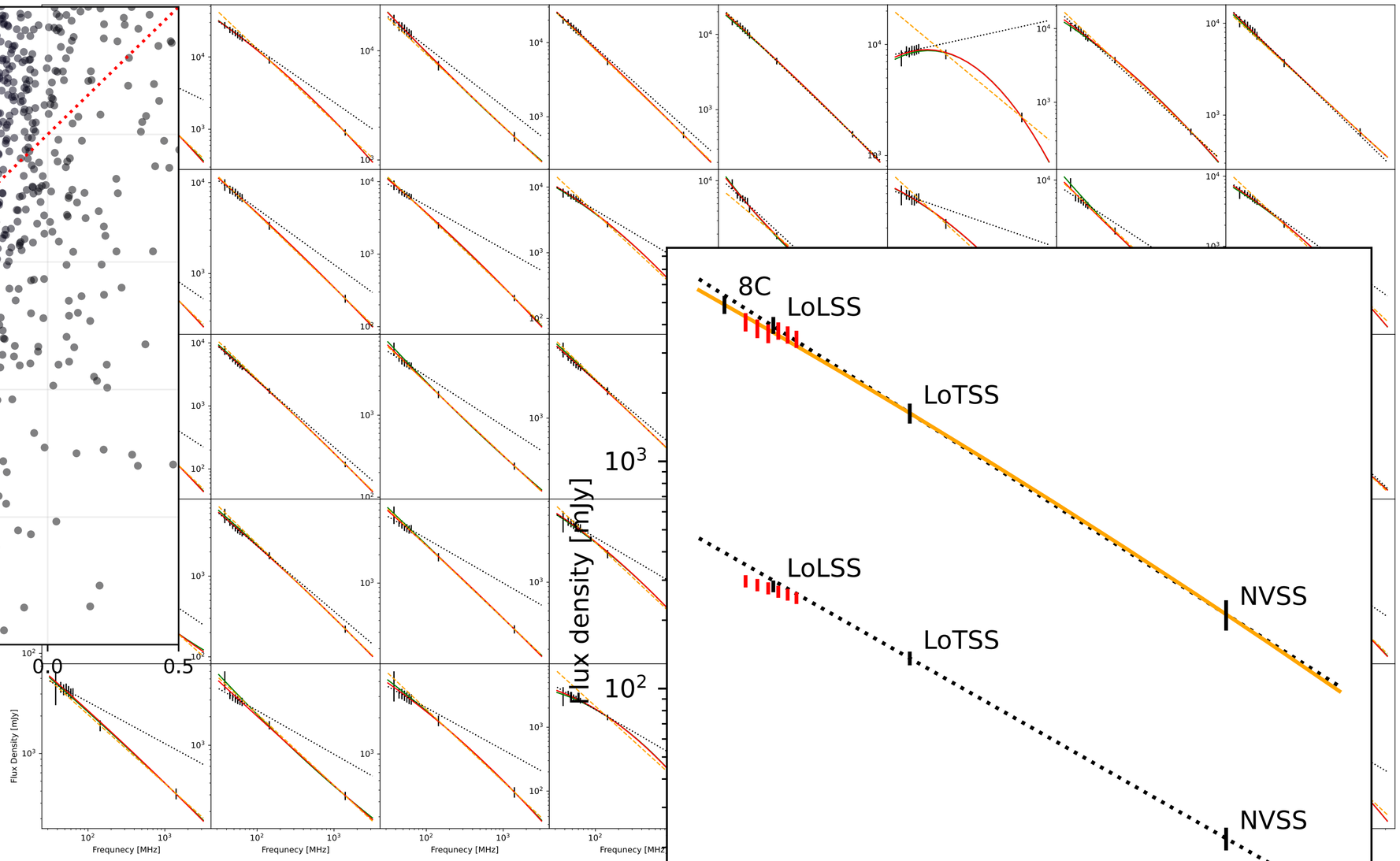


LoLSS not deep enough to see SF galaxy turnover: need deep fields

High flux sources: steep (-0.8)
Low flux sources: flat (-0.6)

LoLSS spectral properties





- **No friction with LoTSS flux scale**
- **We cannot check the flux scale of LBA extrapolating linear spectra**
- **Prediction for LoDeSS**

LoLSS: deliverables

Check out the data release 1 at:
https://www.lofar-surveys.org/lolss.html

Images:

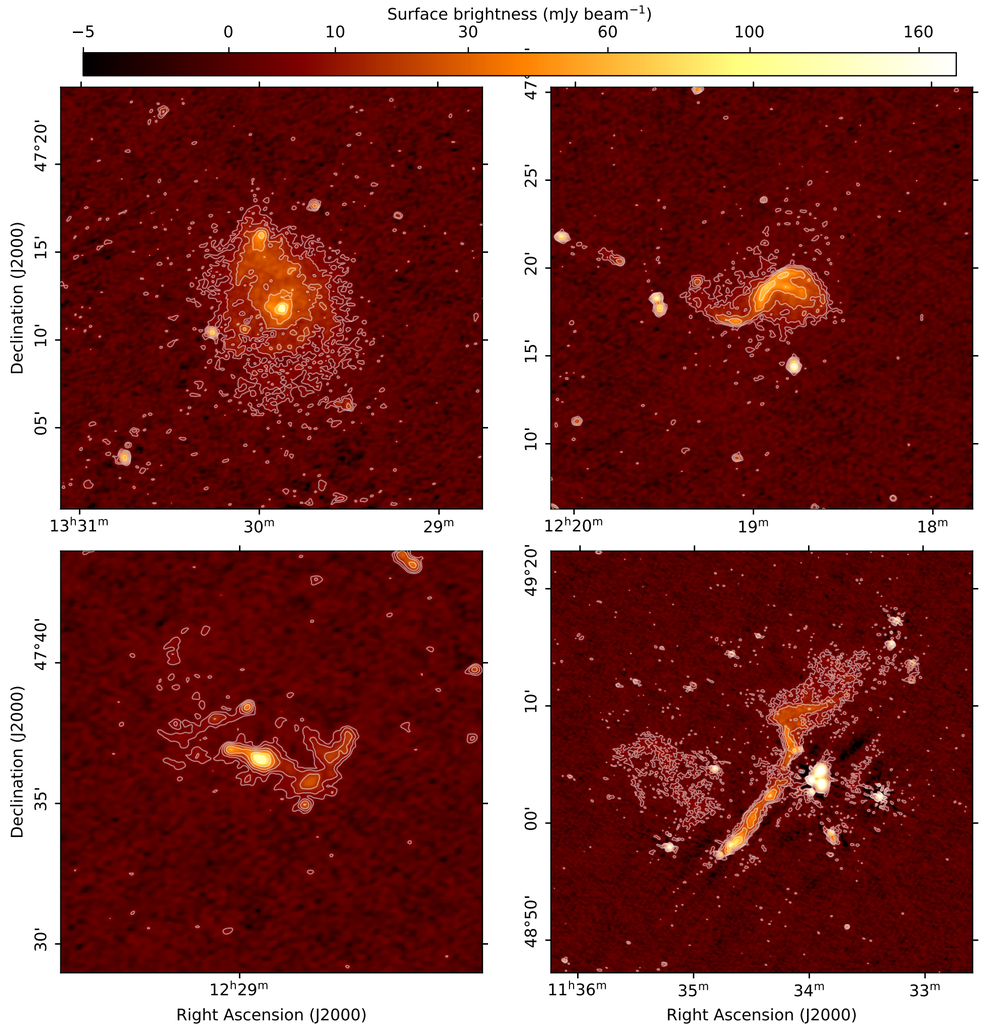
- Mosaiced images: Stokes-I & Stokes-V
  - ToUse: Download mosaic (no PB corr. needed) or cutouts (coming soon)
- HIPS images (Stokes-I only)
  - ToUse: Aladin → Load URL
- Low-resolution source-subtracted mosaiced image

Catalogues:

- Source catalogue (42,463 entries)
  - ToUse: download - good for cross-match and initial tests. Flux density estimation better from images
- Gaussian component catalogue
- Source+Gaussian component in-band catalogues: 44, 48, 52, 56, 60, and 64 MHz
- Spectral index catalogue (planned)

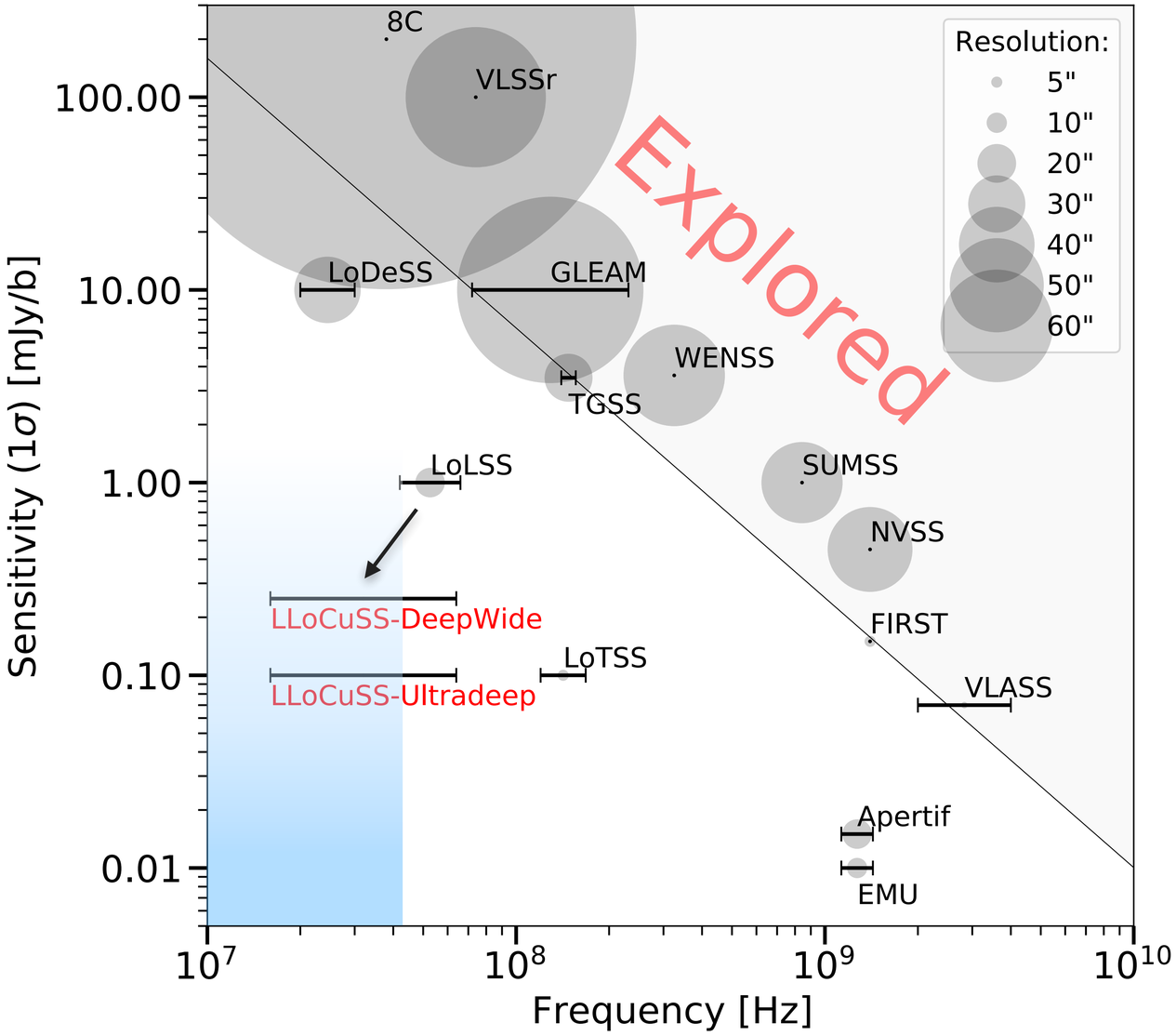
Data:

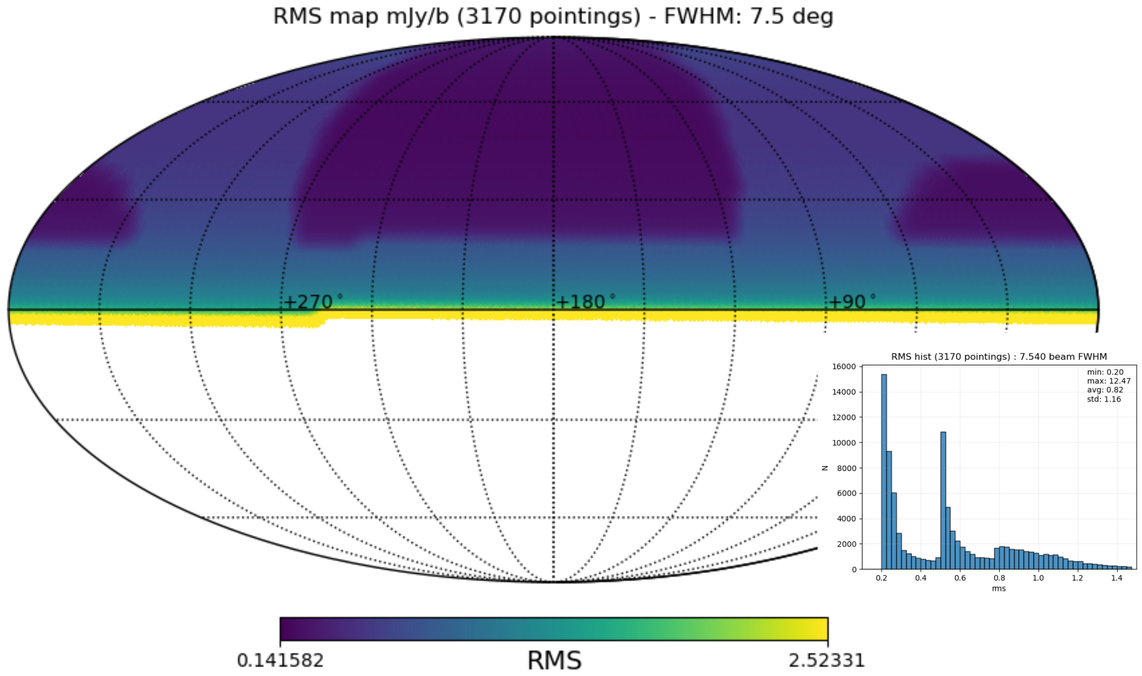
- DIE corrected + DDE solutions
  - ToUse: extract pipeline - currently has to be arranged



Interested in using the data?
Fill the SKSP wiki - LoLSS projects page

LBA LOFAR Community Sky Survey





- **Band:** 16 – 64 MHz
- **Resolution:**
  1” (upper half of the band)
  15” (lower half of the band)

<u>Wide Survey</u> (2004 hrs):
- Coverage: Dec > 0°
- Sensitivity: 500–800 μJy beam^{-1}

<u>Deep-Wide Survey</u> (5830 hrs):
- Coverage: Dec > 20°, $|b| > 23°$
- Sensitivity: 350 μJy beam^{-1}

<u>Ultra-deep Fields</u> (100 hrs per field):
- Sensitivity: 130 μJy beam^{-1}

Contacts

- **LOFAR LBA Sky Survey (LoLSS)**

  Reference person: Francesco de Gasperin
  For deep fields: Wendy Williams

  Data at: www.lofar-surveys.org/lolss.html

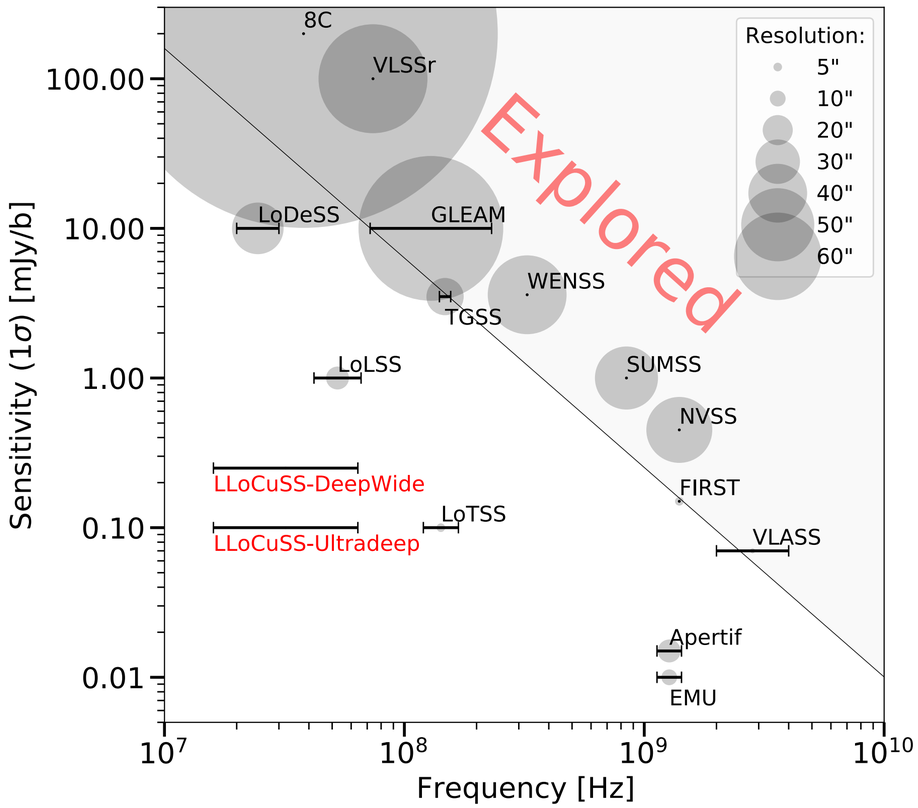
- **LBA LOFAR Community Sky Survey (LLoCuSS)**

  Reference persons: Francesco de Gasperin / Reinout van Weeren

- **LBA data reduction**

  Reference persons: Francesco de Gasperin
  and Henrik Edler (present at the conf.)

  Code, docker and docs at: github.com/revoltek/LiLF

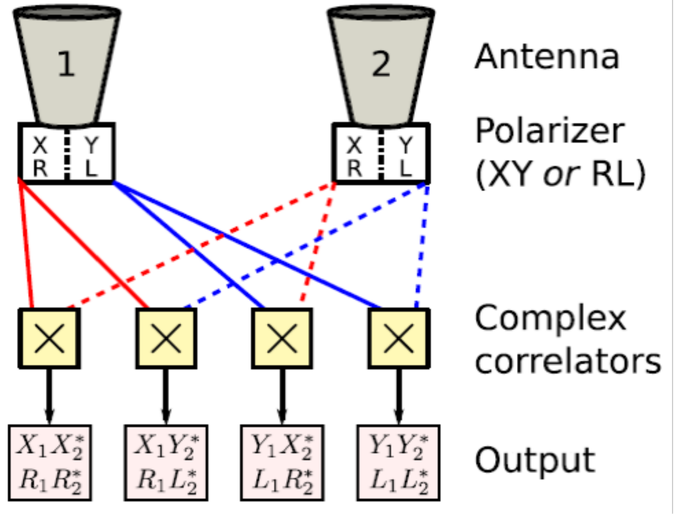


- Ideal visibilities (now in 2x2 matrix form):

$$\boldsymbol{V}(u,v) = \iint \boldsymbol{I}_c(l,m) e^{-2\pi i(ul+vm)} dl\, dm$$

- with $\boldsymbol{V} = \begin{pmatrix} V_{rr} & V_{rl} \\ V_{lr} & V_{ll} \end{pmatrix}$ or $\boldsymbol{V} = \begin{pmatrix} V_{xx} & V_{xy} \\ V_{yx} & V_{yy} \end{pmatrix}$

- A full polarization correlator produces visibilities for all cross-products:
  RR, RL, LR, LL or XX, XY, YX, YY
  - Short-hand notation: $RR_{ij} = R_i R_j^* = V_{rr,ij}$, etc.



RIME

- Measured visibilities on baseline j, k:

$$\boldsymbol{V}_{jk}^{obs} = \iint \left[\boldsymbol{J}_j \boldsymbol{I}_c(l,m) \boldsymbol{J}_k^{+}\right] e^{-2\pi i(u_{jk}l + v_{jk}m)} dl\, dm$$

- The Jones matrix $\boldsymbol{J}$ is a complex 2x2 matrix that captures antenna-based signal corruptions
- The format of $\boldsymbol{J}$ often depends on the feed basis (RL or XY)

- Examples for RL

$$\boldsymbol{J} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \qquad \boldsymbol{J} = \begin{pmatrix} g_R & 0 \\ 0 & g_L \end{pmatrix} \qquad \boldsymbol{J} = \begin{pmatrix} e^{2\pi i \nu \tau_R} & 0 \\ 0 & e^{2\pi i \nu \tau_L} \end{pmatrix}$$

$$\boldsymbol{J} = \begin{pmatrix} 1 & d_{LR} \\ d_{RL} & 1 \end{pmatrix} \qquad \boldsymbol{J} = \begin{pmatrix} e^{+i\theta} & 0 \\ 0 & e^{-i\theta} \end{pmatrix}$$

RIME

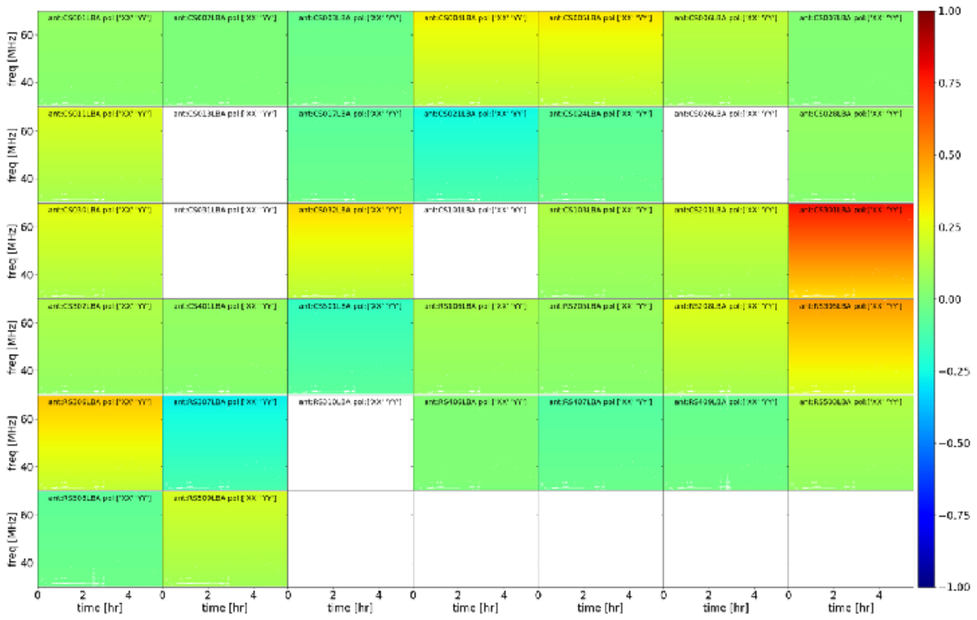
- In practice, a Jones matrix is a product of many(!) effects (components) along the signal path

- $J_i = F_i T_i P_i X_i E_i D_i G_i B_i K_i$
  - F_i = ionospheric effects
  - T_i = tropospheric effects
  - P_i = parallactic angle
  - X_i = linear polarisation position angle
  - E_i = antenna voltage pattern, gaincurve
  - D_i = polarisation leakage
  - G_i = electronic gain
  - B_i = bandpass response
  - K_i = geometry

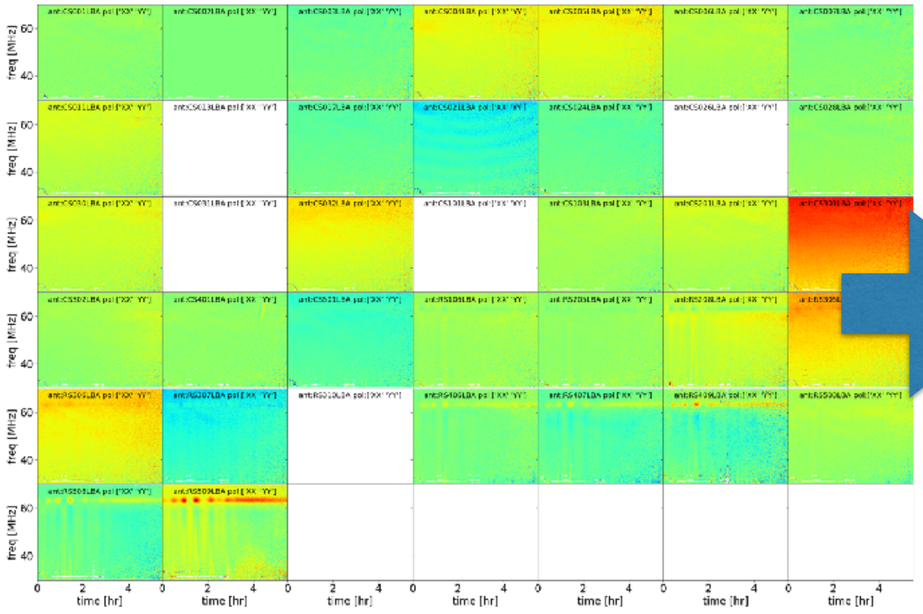
- Apply solutions left to right: opposite to signal path direction
- Components are typically difficult to separate.
- Some components commute (can reorder), some don’t

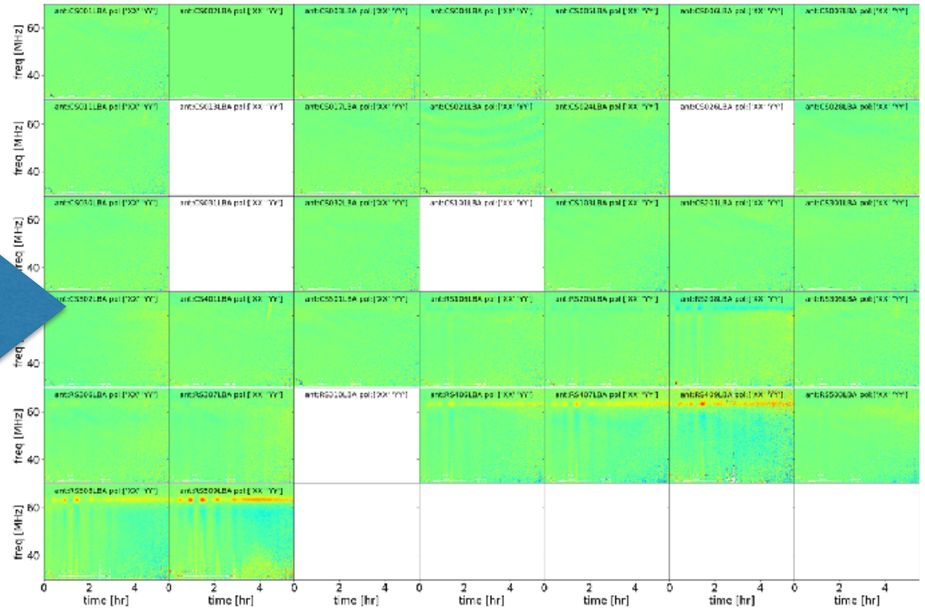
RIME

Polarisation alignment is calculated from XX-YY phases in LoSoTo

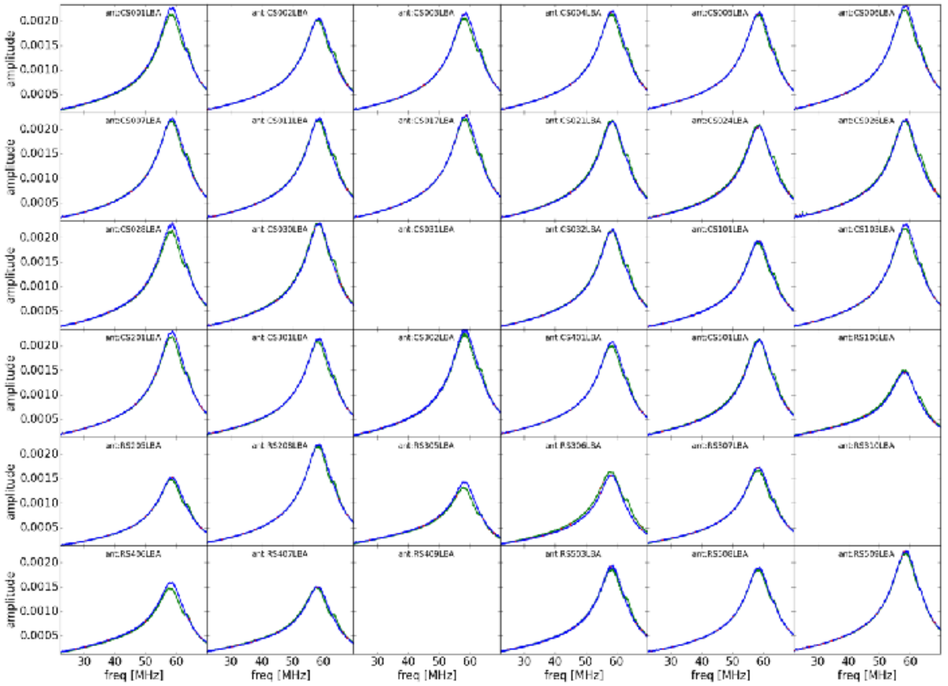


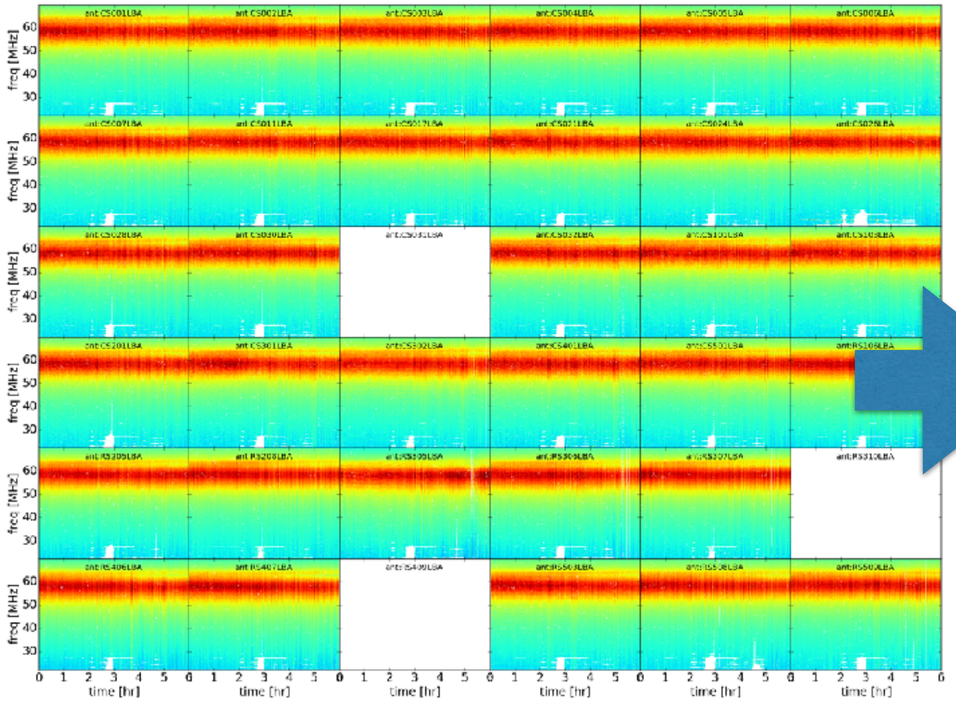
(very few free parameters: 1 delay per station)

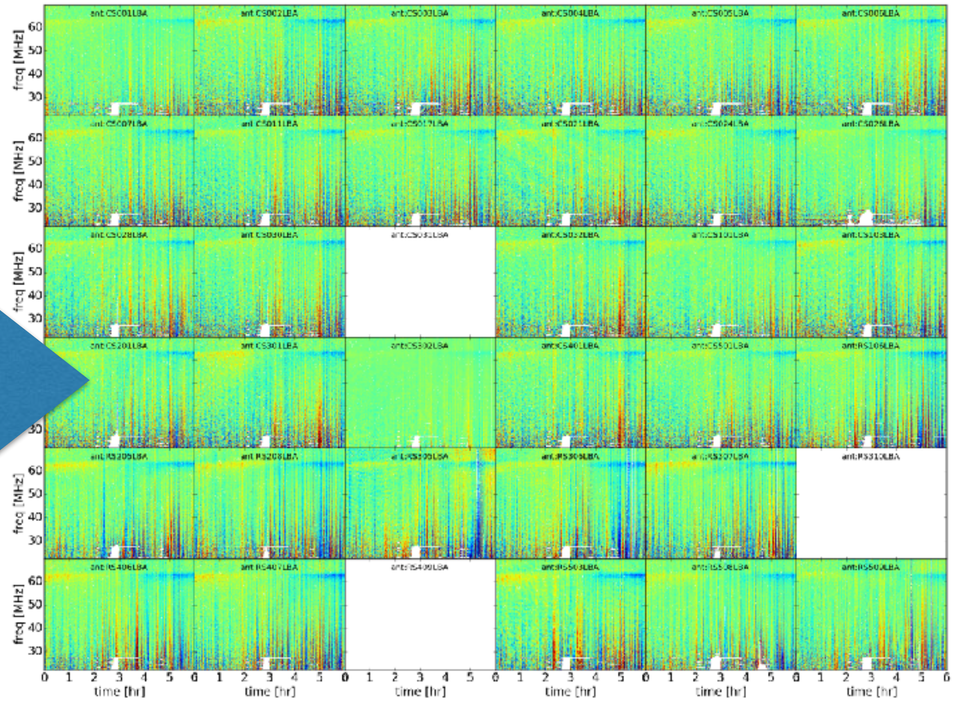




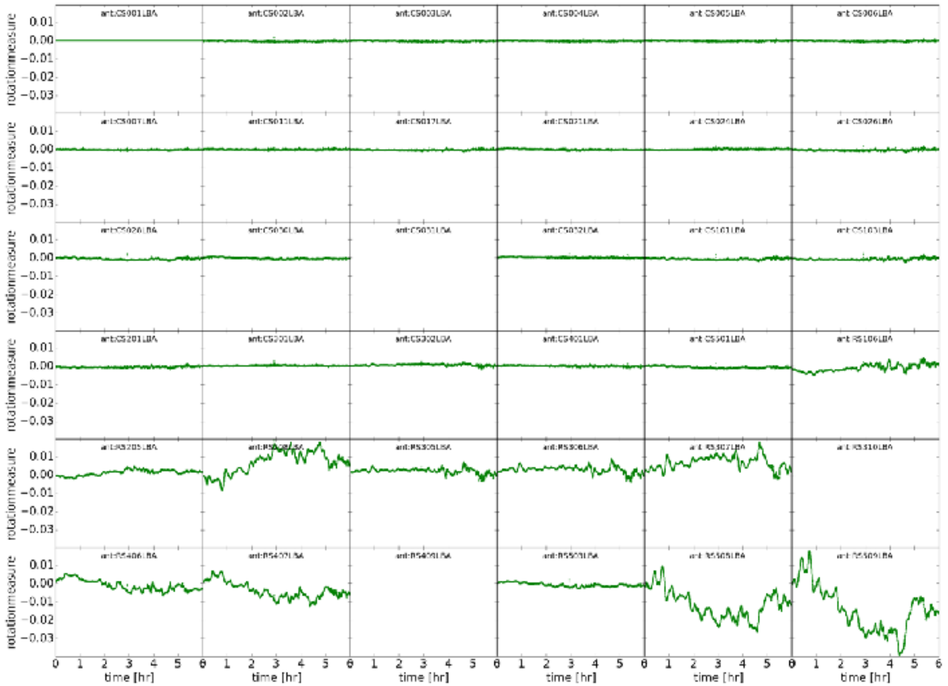
Bandpass is calculated from XX and YY amp solutions in LoSoTo averaging in time

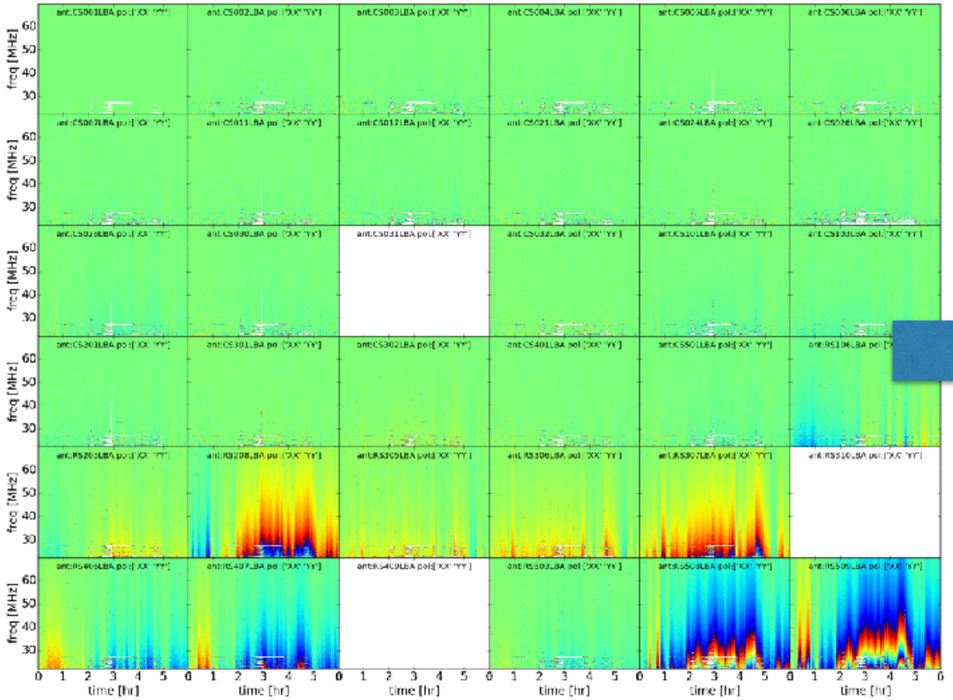


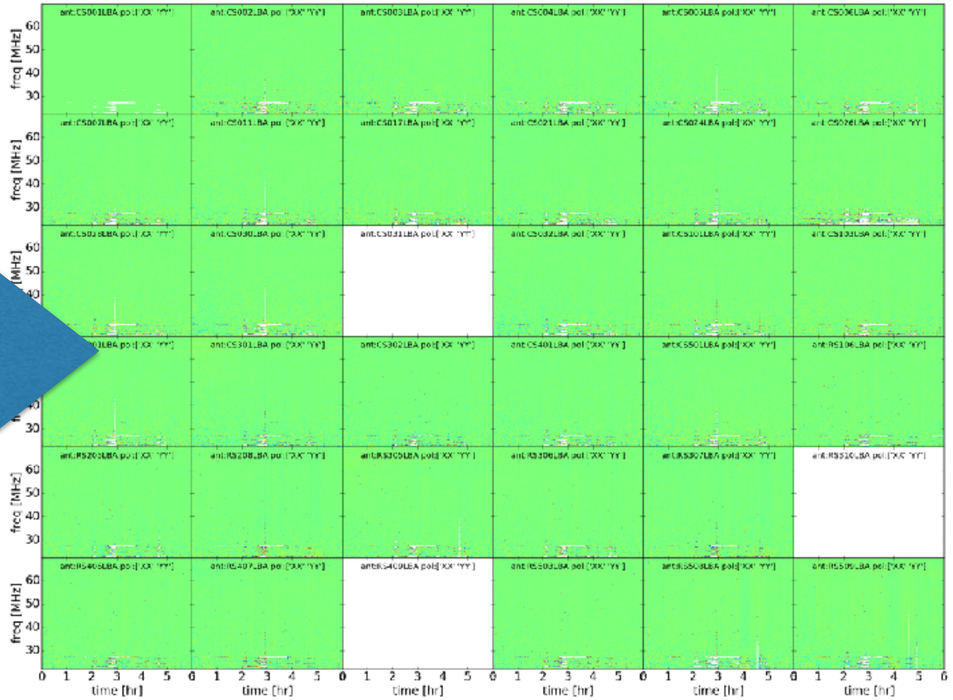




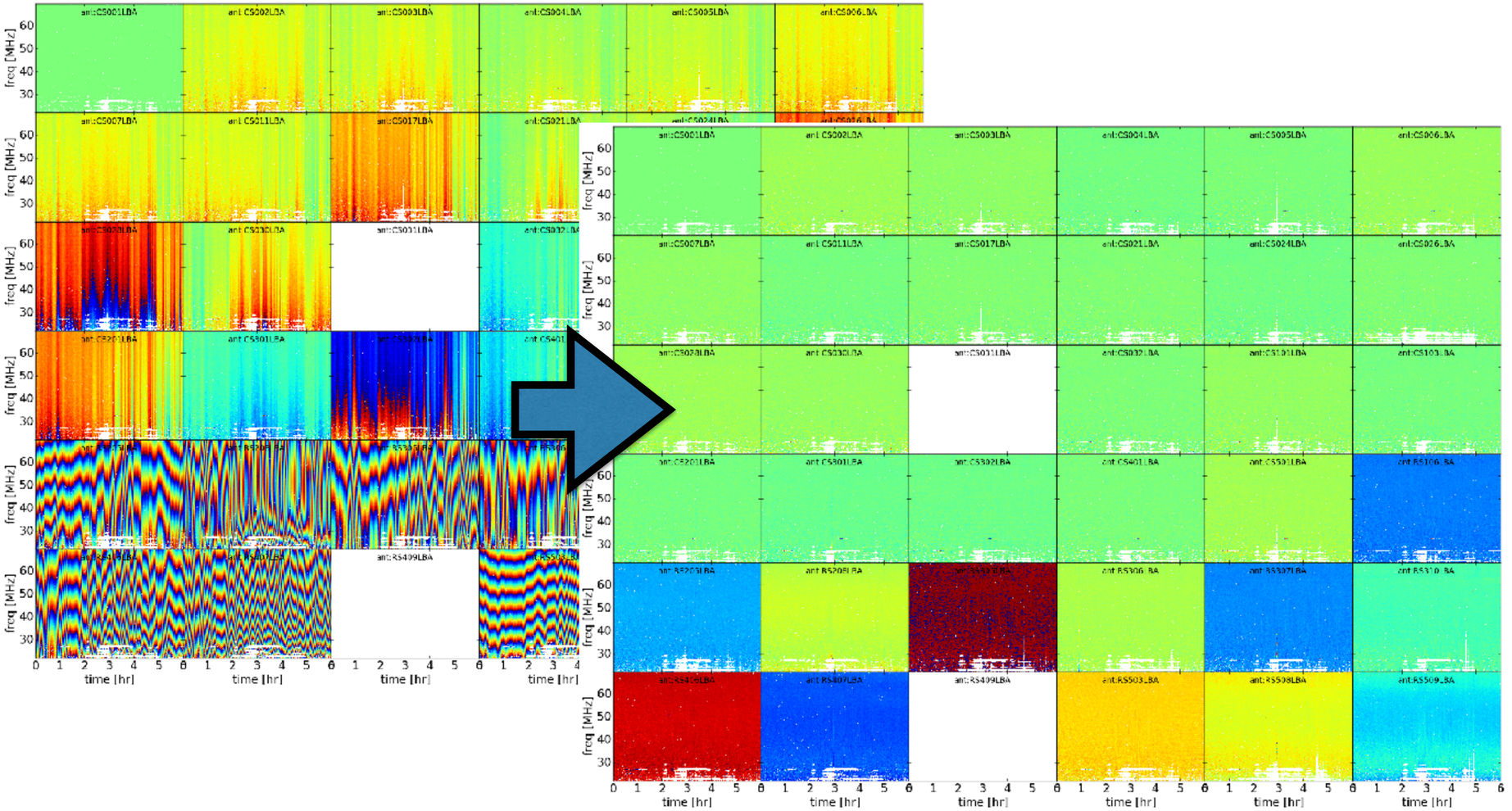
Faraday rotation is calculated from rotational phase Jones matrix ($\propto 1/f^2$) in LoSoTo



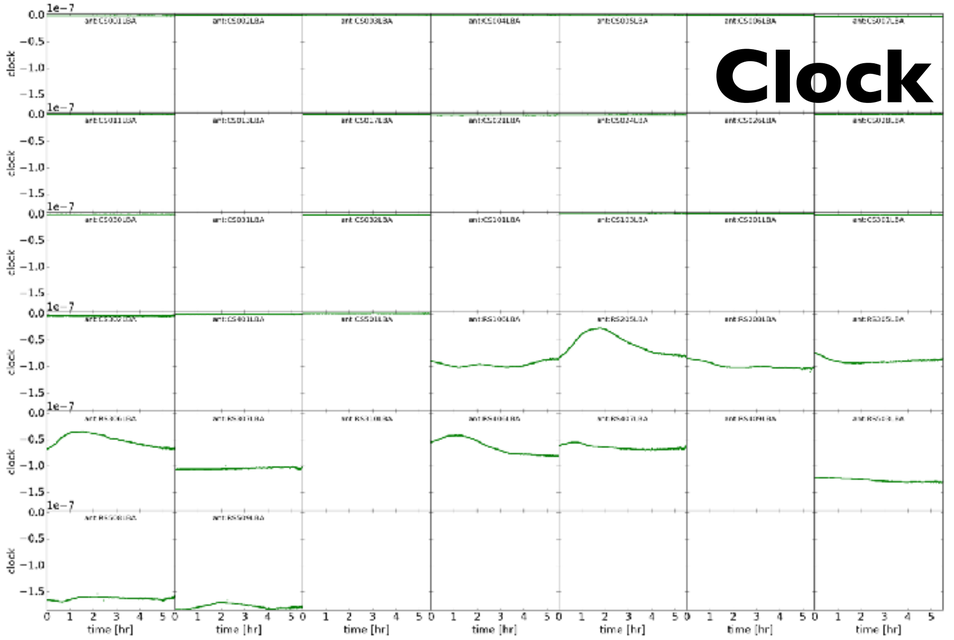


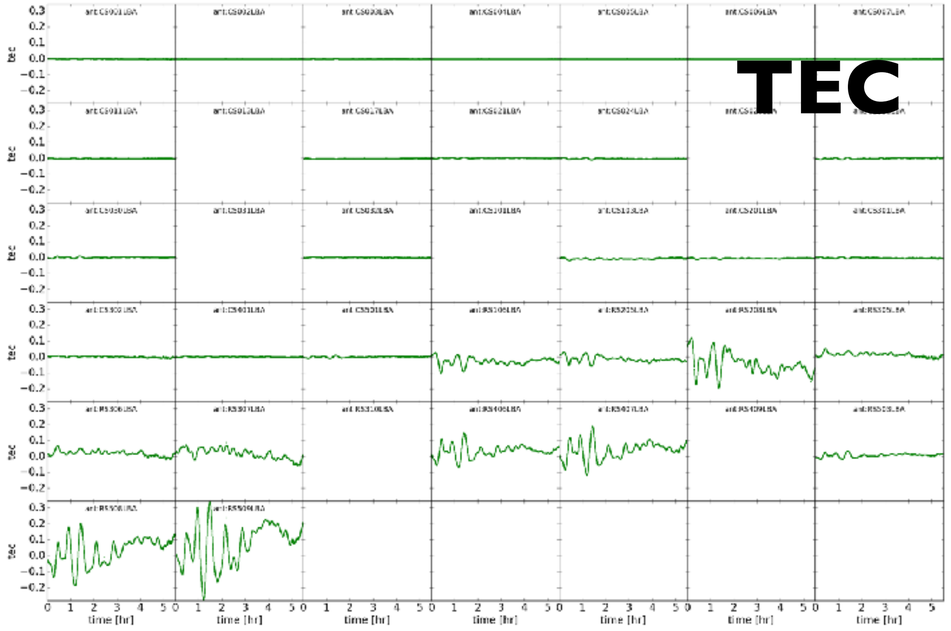


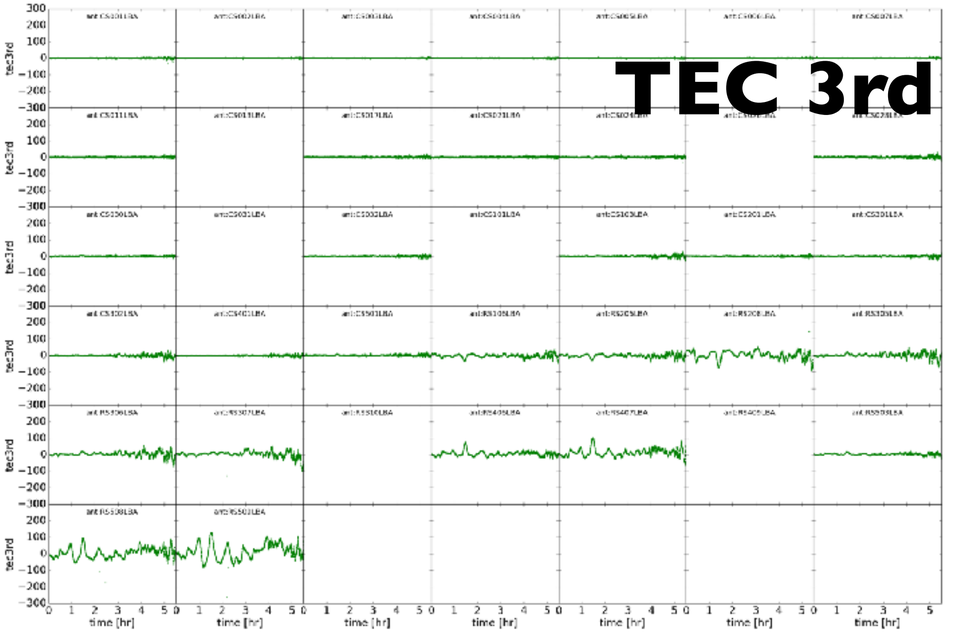
Systematic effect	Type of Jones matrix[a]	Ph/Amp/Both[b]	Frequency dependency	Direction dependent?	Time dependent?
Clock drift	Scalar	Ph	$\propto \nu$	No	Yes (many seconds)
Polarisation alignment	Diagonal	Ph	$\propto \nu$	No	No
Ionosphere - 1st ord. (dispersive delay)	Scalar	Ph	$\propto \nu^{-1}$	Yes	Yes (few seconds)
Ionosphere - 2sn ord. (Faraday rotation)	Rotation	Both	$\propto \nu^{-2}$	Yes	Yes (few seconds)
Ionosphere - 3rd ord.	Scalar	Ph	$\propto \nu^{-3}$	Yes	Yes (few seconds)
Ionosphere - scintillations	Diagonal	Amp	–	Yes	Yes (few seconds)
Dipole beam	Full-Jones	Both	–	Yes	Yes (minutes)
Bandpass	Diagonal	Amp	–	No	No



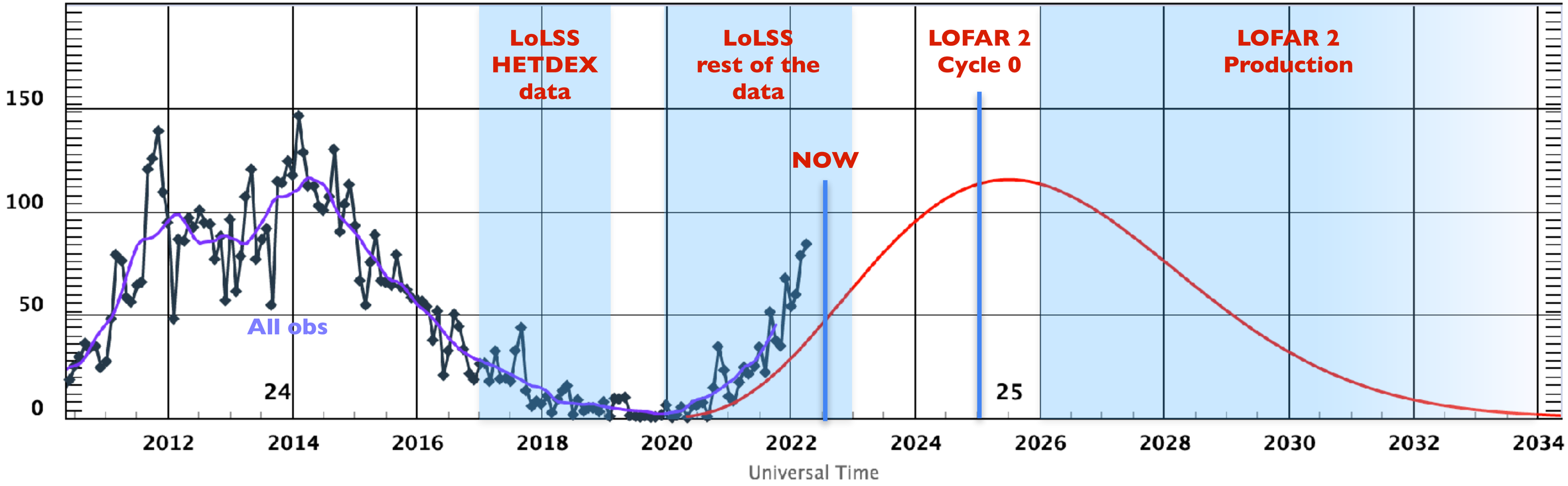
Clock/TEC/TEC3rd separations is calculated from XX+YY phase solutions in LoSoTo





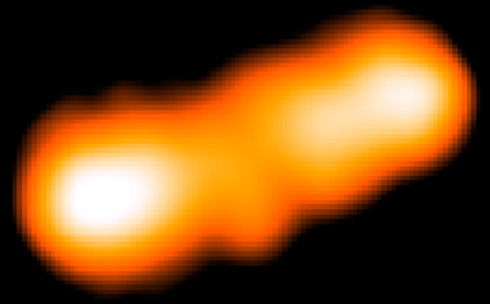


Solar Cycle

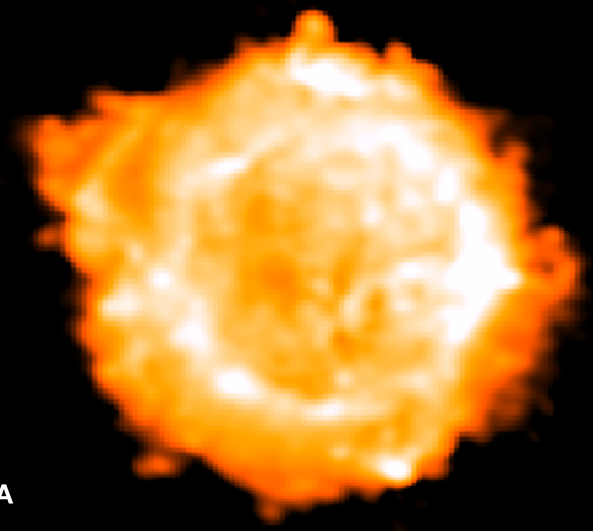

LoLSS
HETDEX
data
LoLSS
rest of the
data
LOFAR 2
Cycle 0
LOFAR 2
Production
NOW
All obs
24
25
150
100
50
0
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
Universal Time


1750
1800
1850
1900
1950
2000

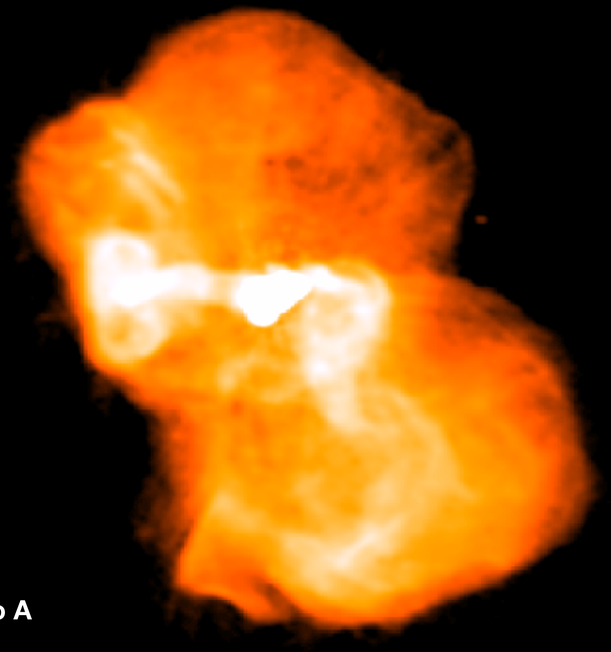
LOFAR LBA A-Team survey:
AIM: 5” resolution model
of the 4 brightest sources
in the northerns sky



Cygnus A

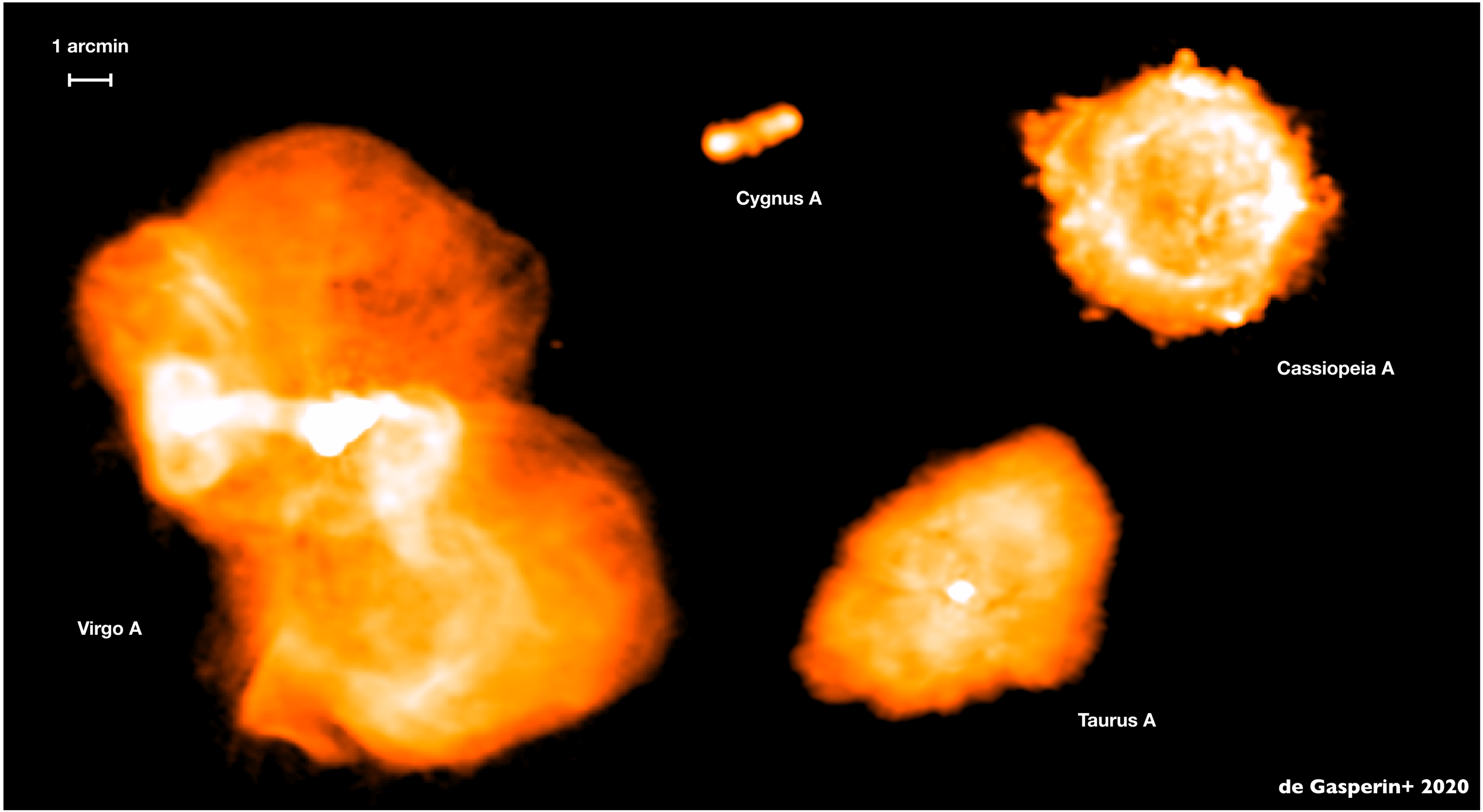


Cassiopeia A



Virgo A

Taurus A


1 arcmin
Cygnus A
Cassiopeia A
Virgo A
Taurus A
de Gasperin+ 2020