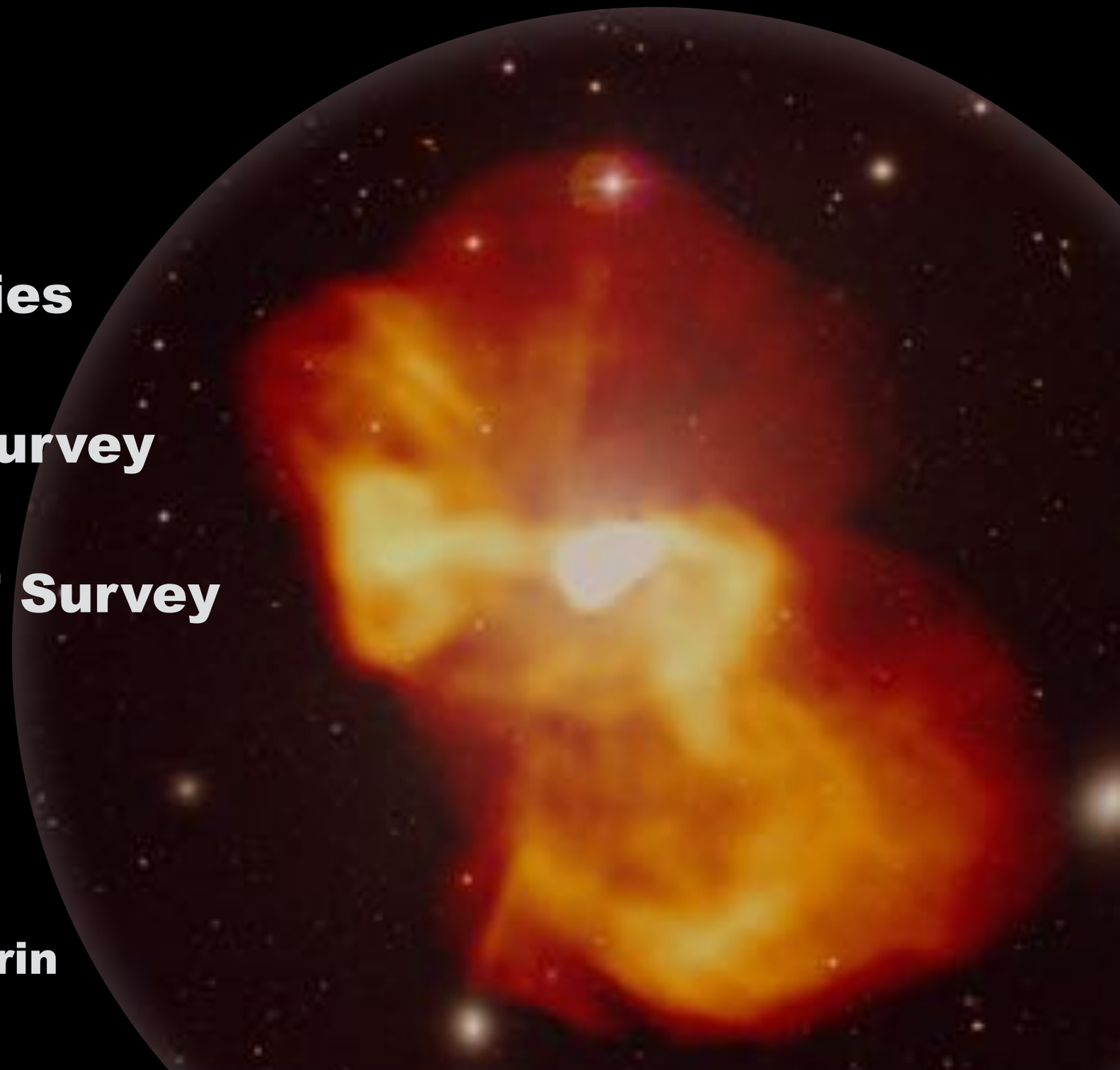
Challenges and solutions in upcoming low-frequency surveys

OUTLINE:

- **The lowest frequencies**
- **Survey status for:**
  1. **Lofar LBA Sky Survey (LoL-SS)**
  2. **400 MHz uGMRT Survey (400MUGS)**



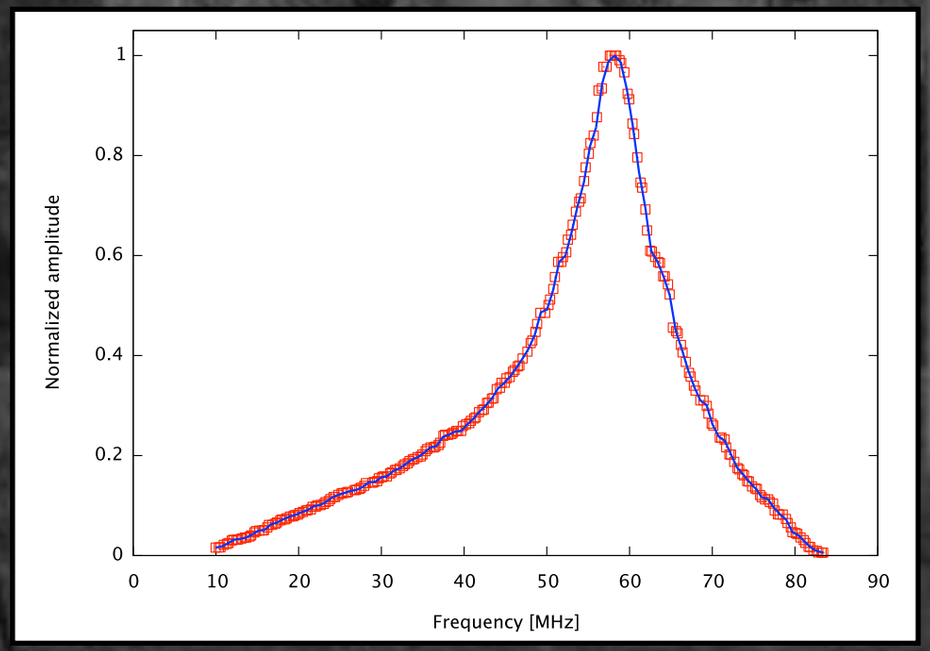
Francesco de Gasperin

Sterrewacht Leiden

Goa - 4 Nov 2016

LOFAR LBA

- Frequency: 10-90 MHz
- Resolution: 15”
- FoV: 4 deg x 4 deg
- Multi-beam



Phases

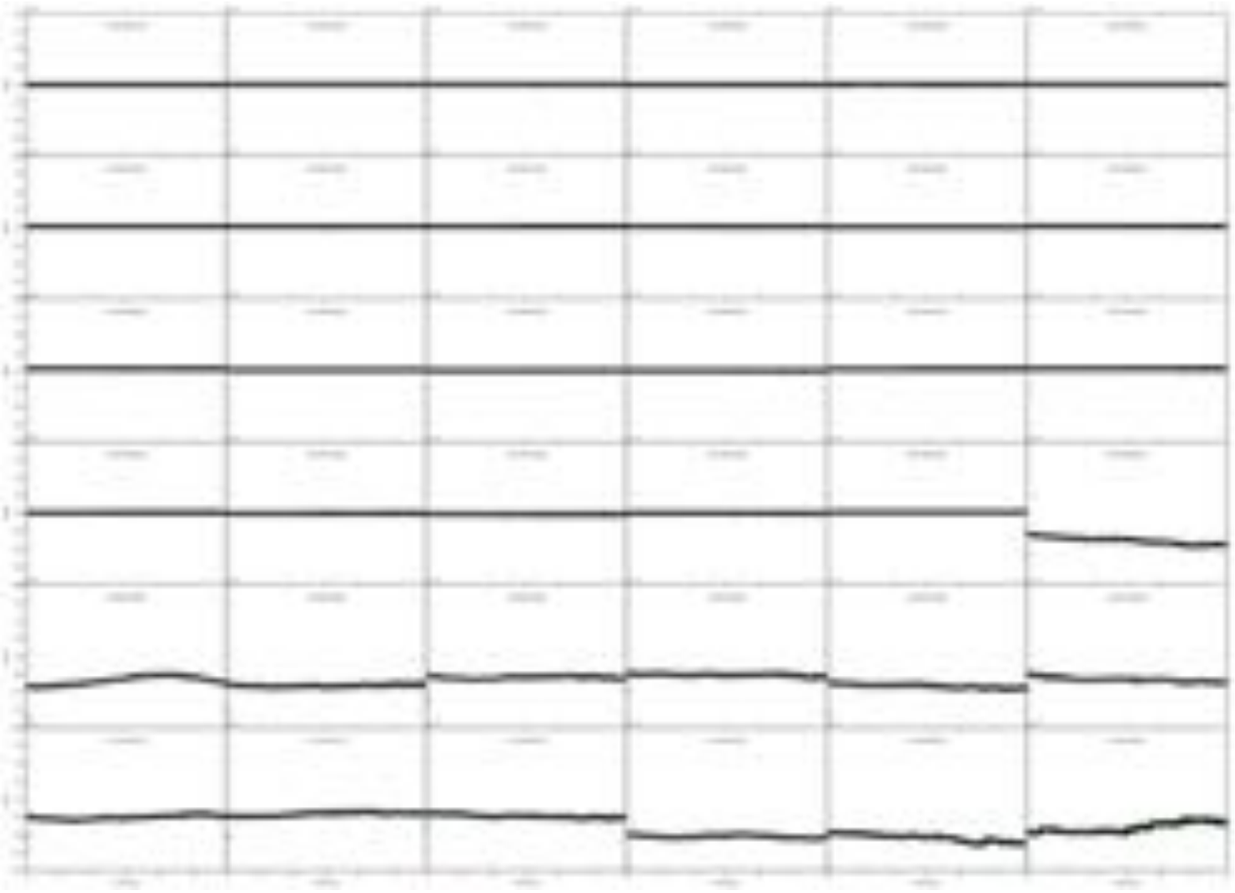
Frequency >>

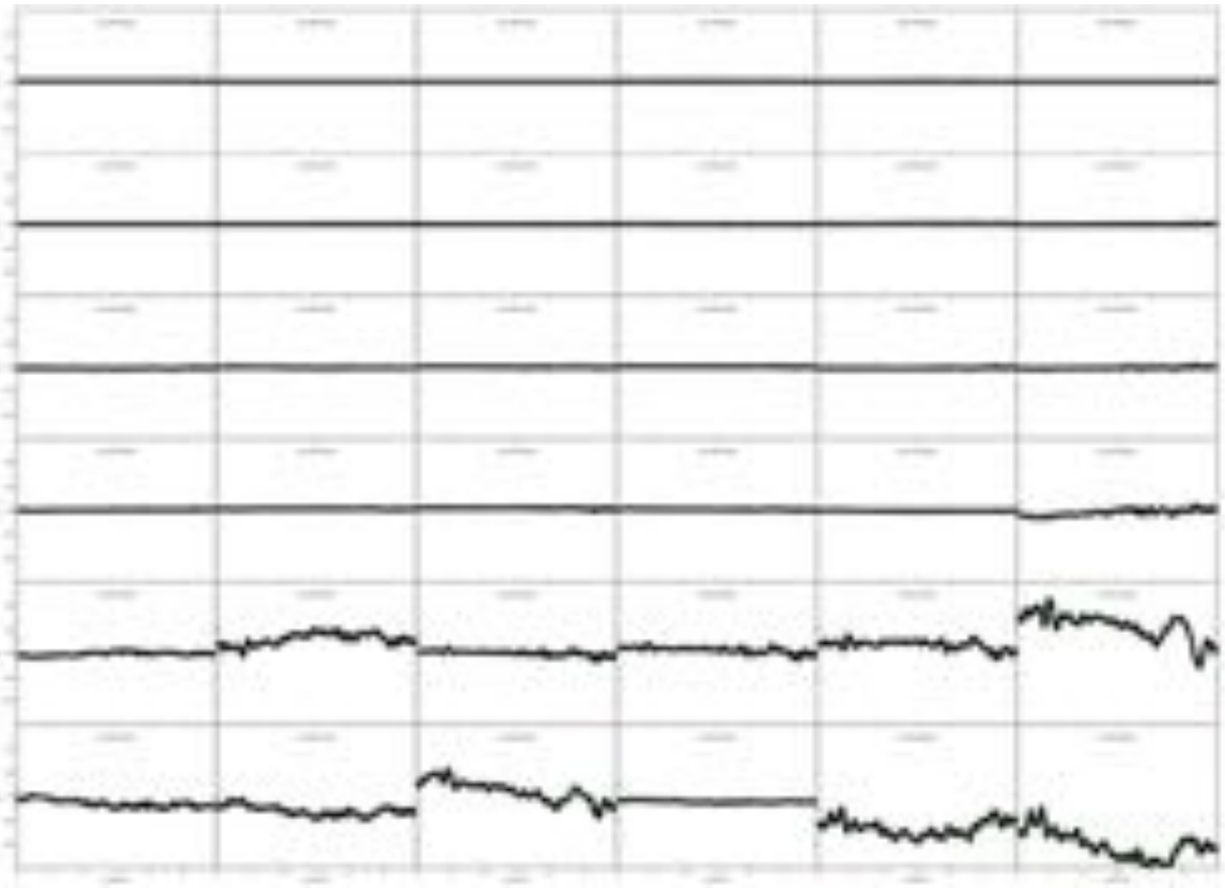
Time >>

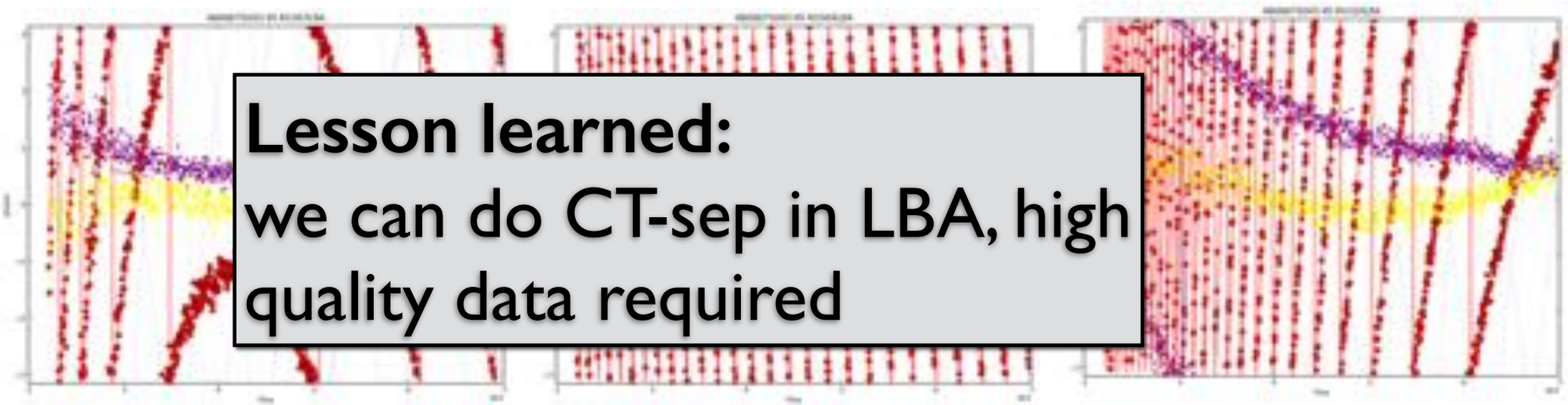
Clock/TEC separation

Clock

TEC



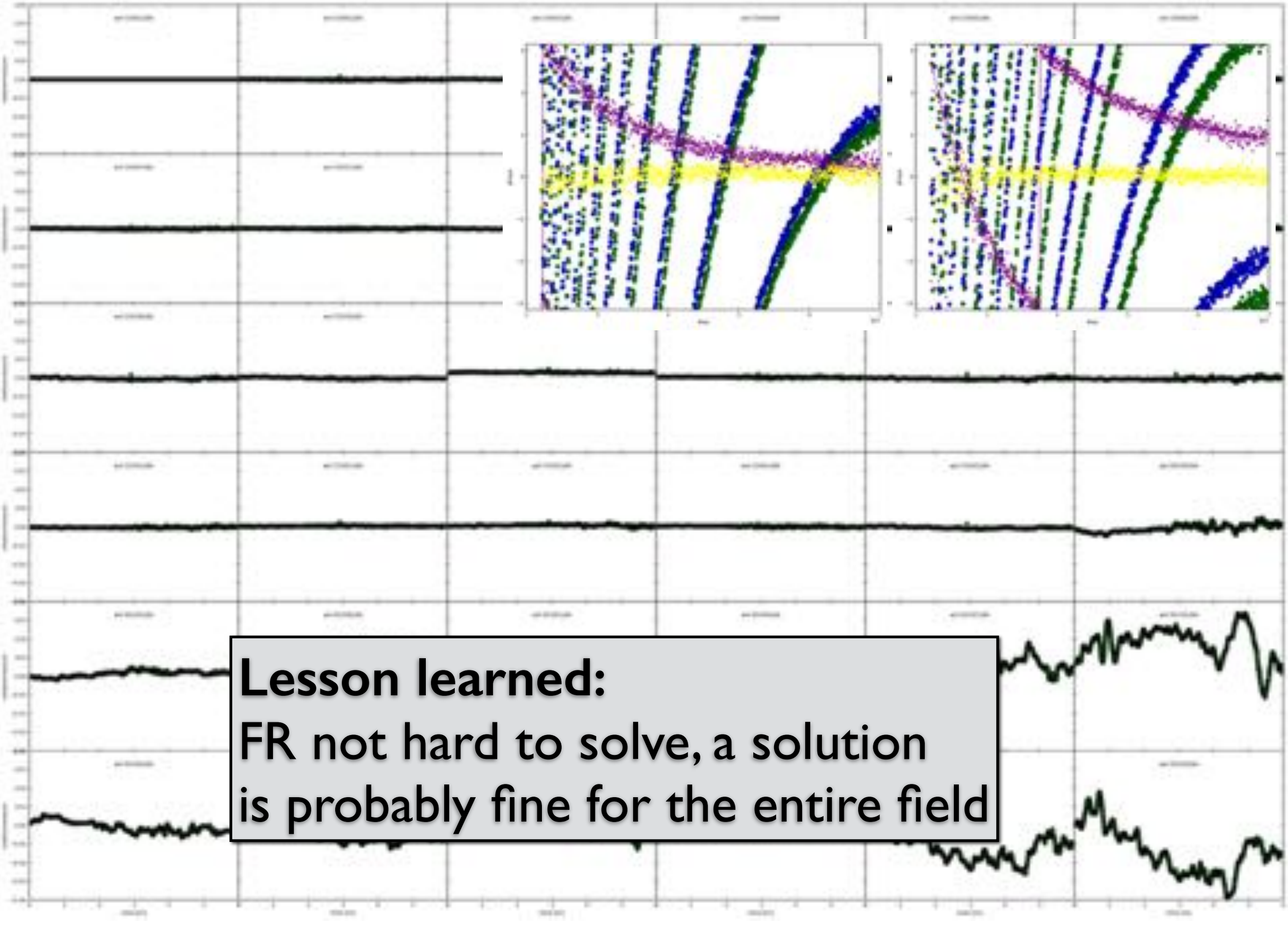




Lesson learned:
we can do CT-sep in LBA, high quality data required

$$\Delta\theta = 2\pi f \Delta t + 8.44797245 \times 10^9 \Delta TEC/f + \Delta\theta_0$$

Rotation Measure



Lesson learned:
FR not hard to solve, a solution is probably fine for the entire field

RR

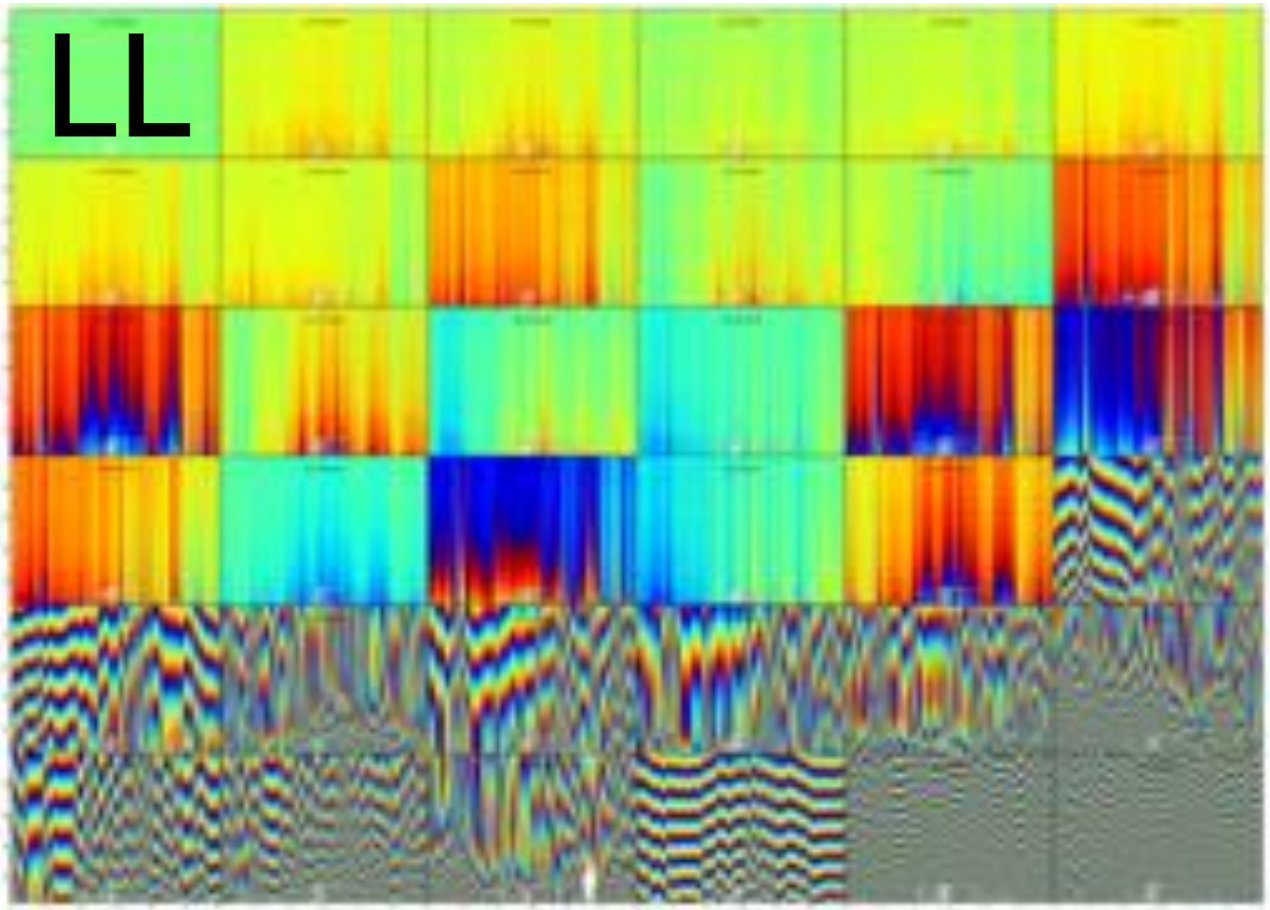
- clock

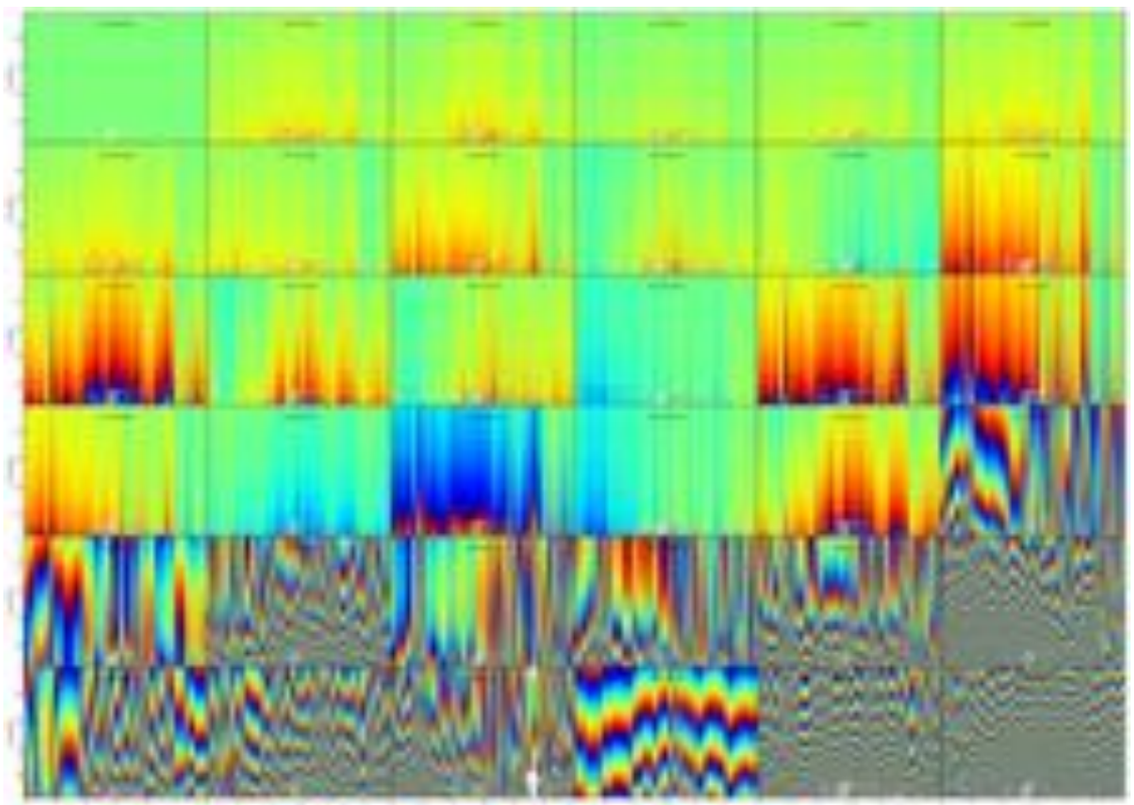
- TEC - FR

- FR

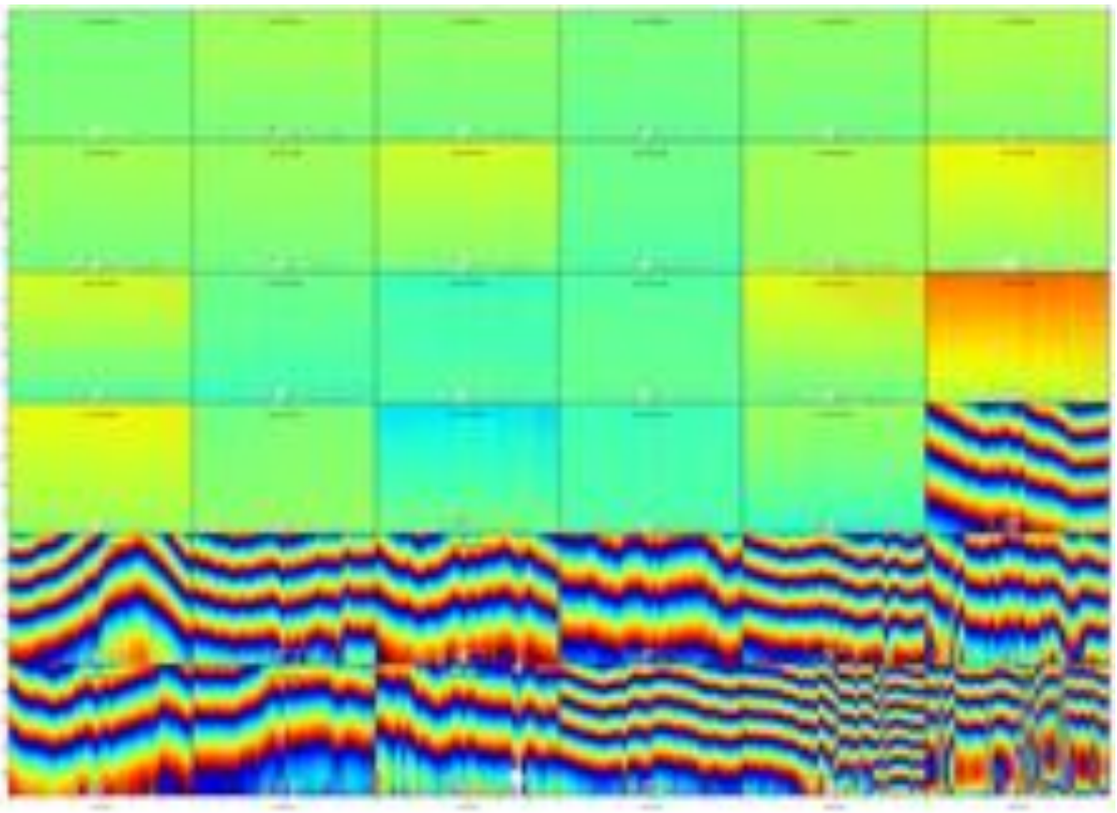
LL

- clock

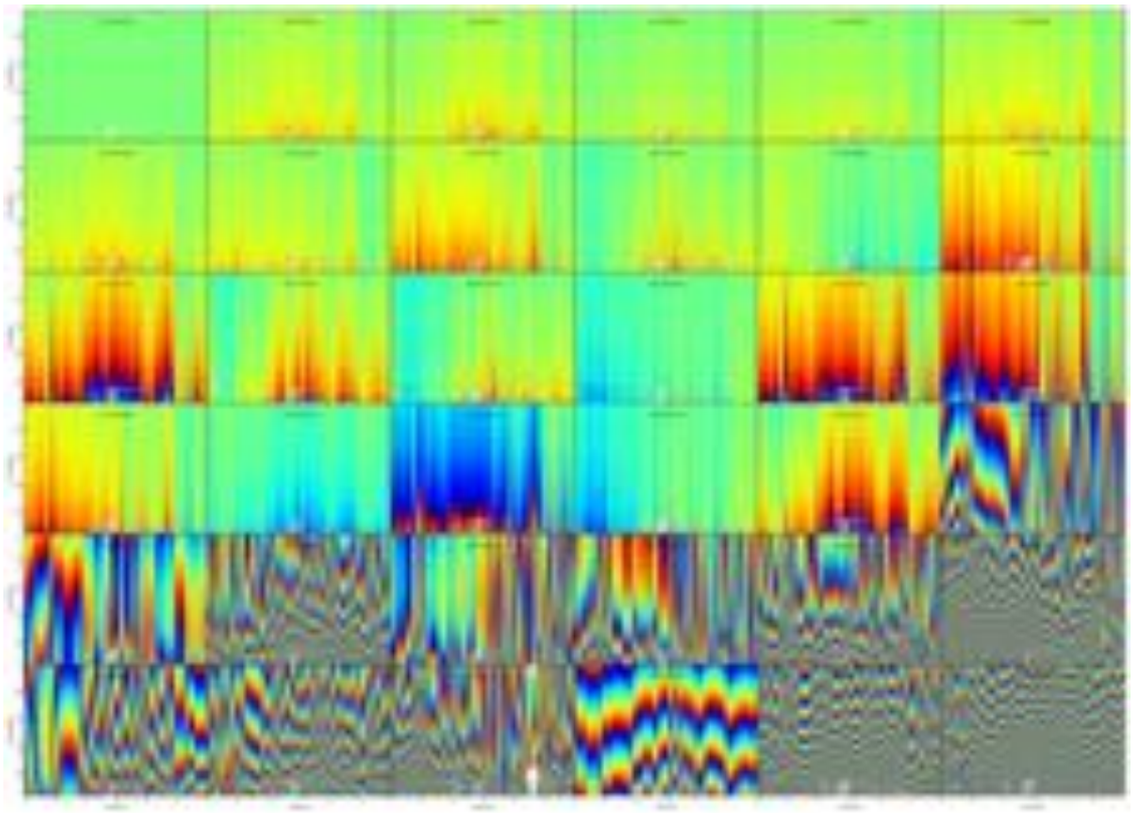




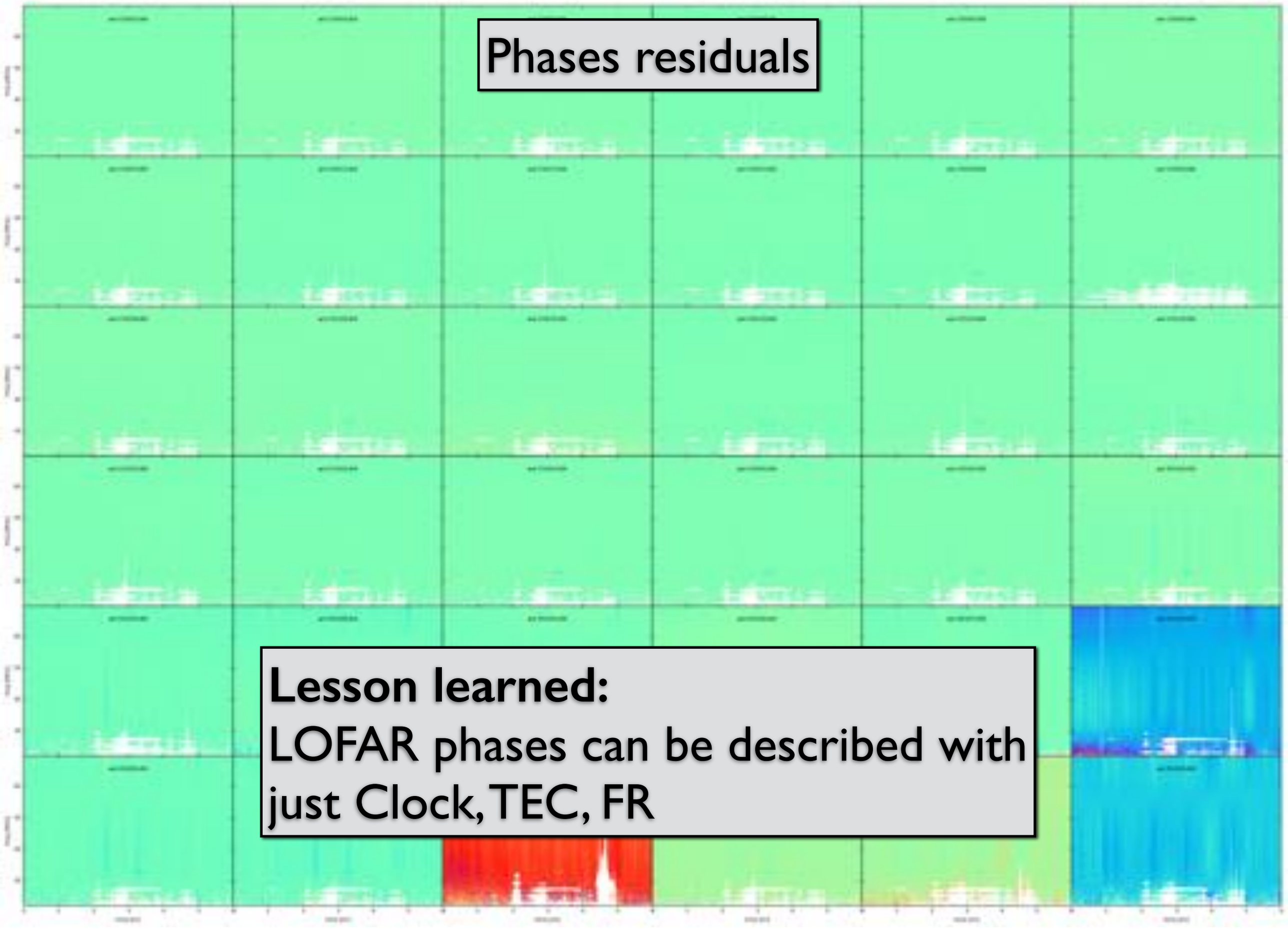
↓ - TEC - FR



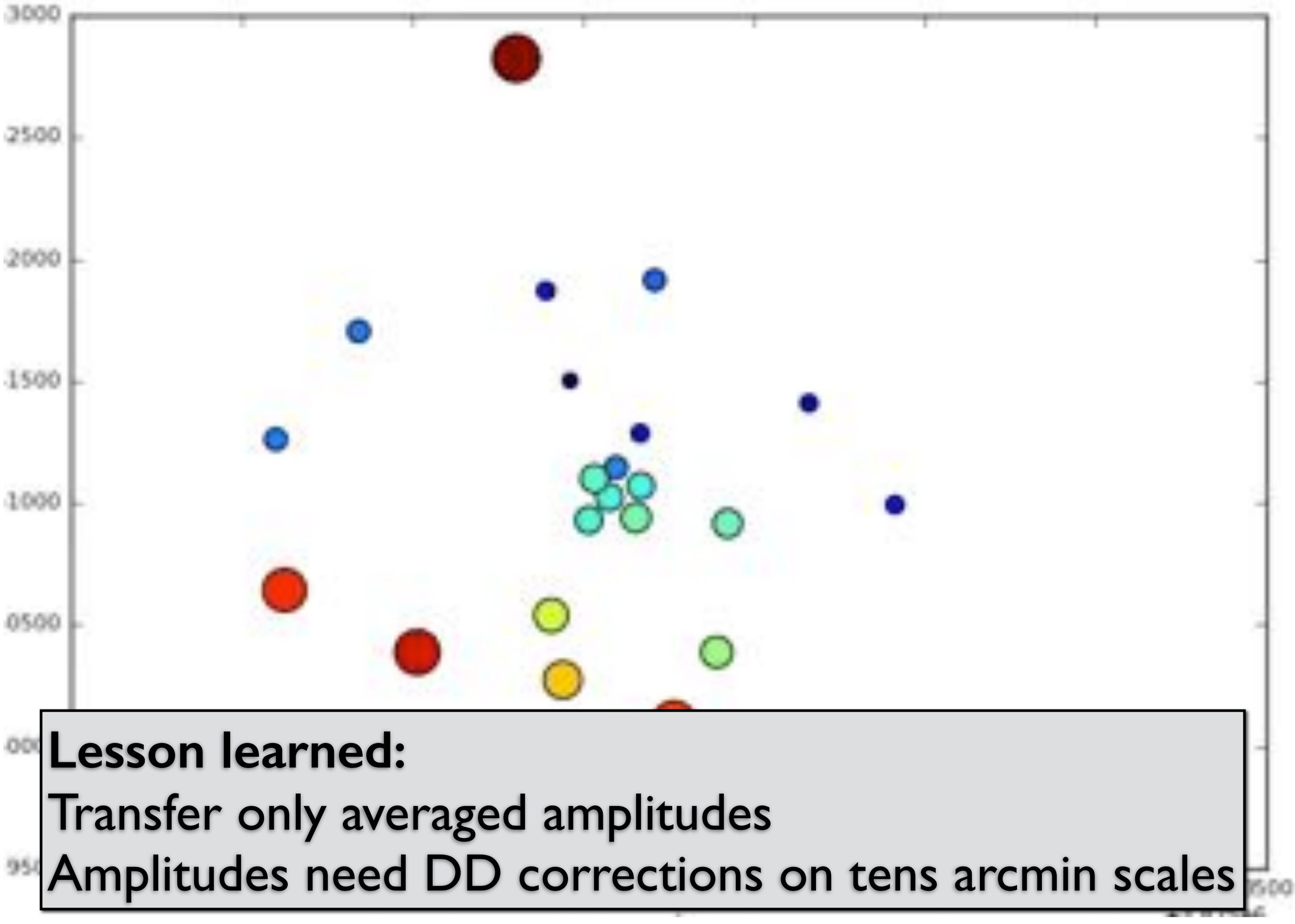
↓ - FR



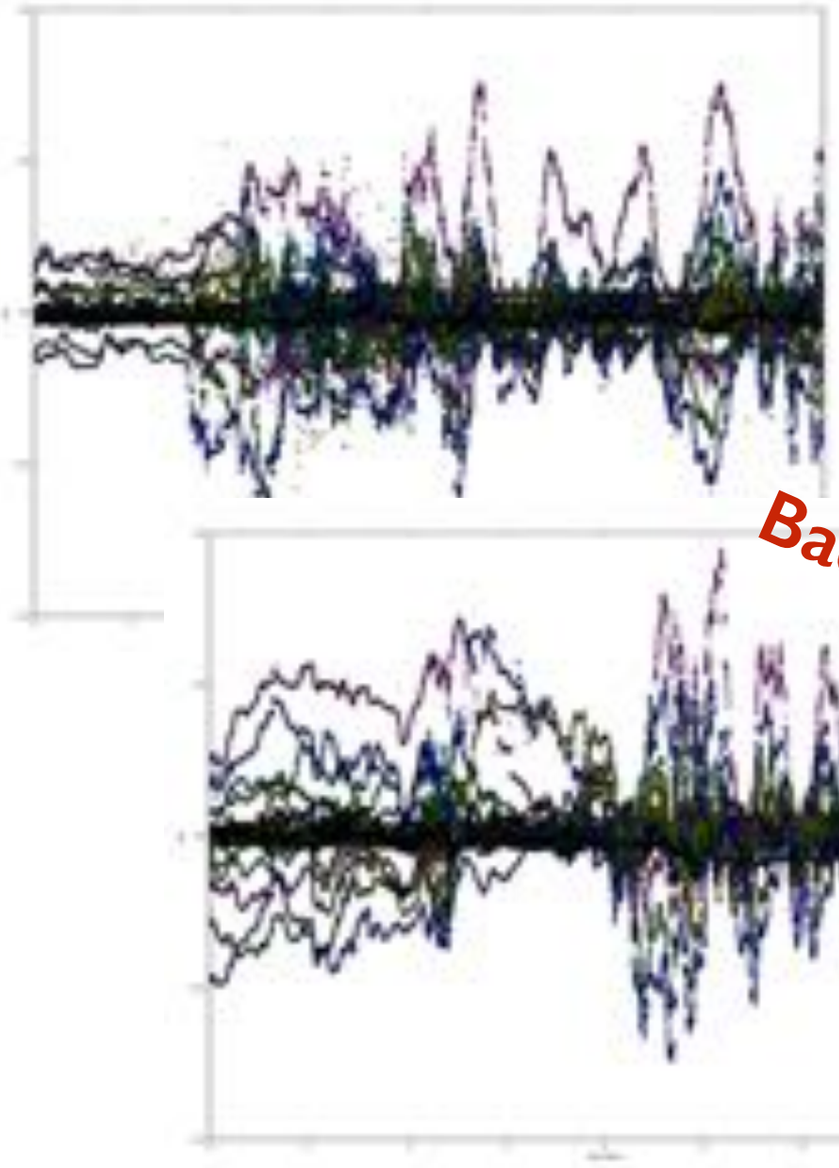
Phases residuals



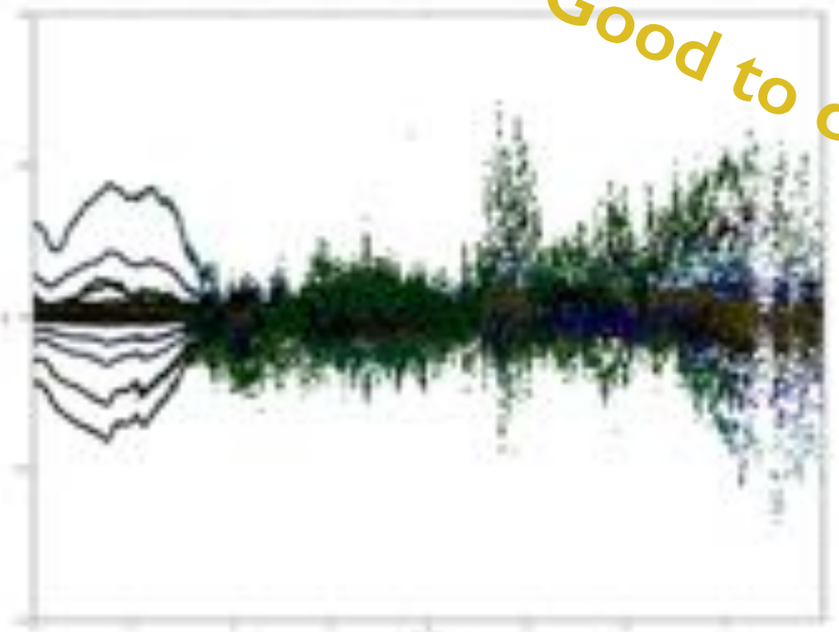
Lesson learned:
LOFAR phases can be described with just Clock, TEC, FR



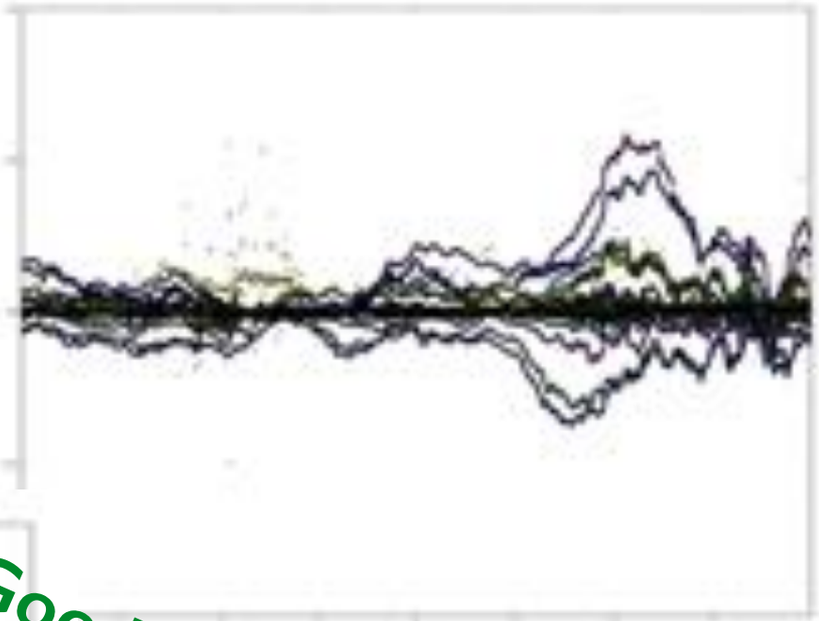
Lesson learned:
Transfer only averaged amplitudes
Amplitudes need DD corrections on tens arcmin scales

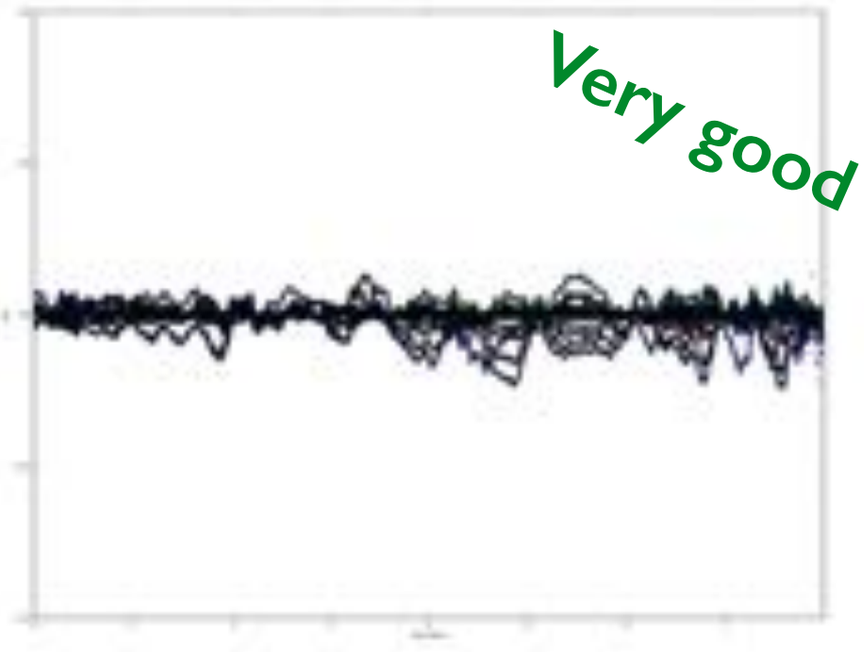


Bad

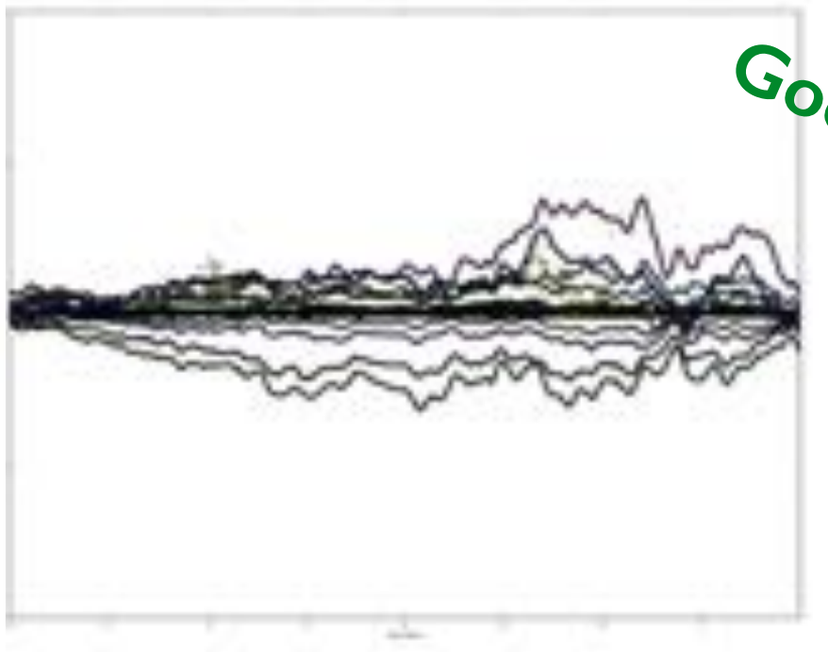


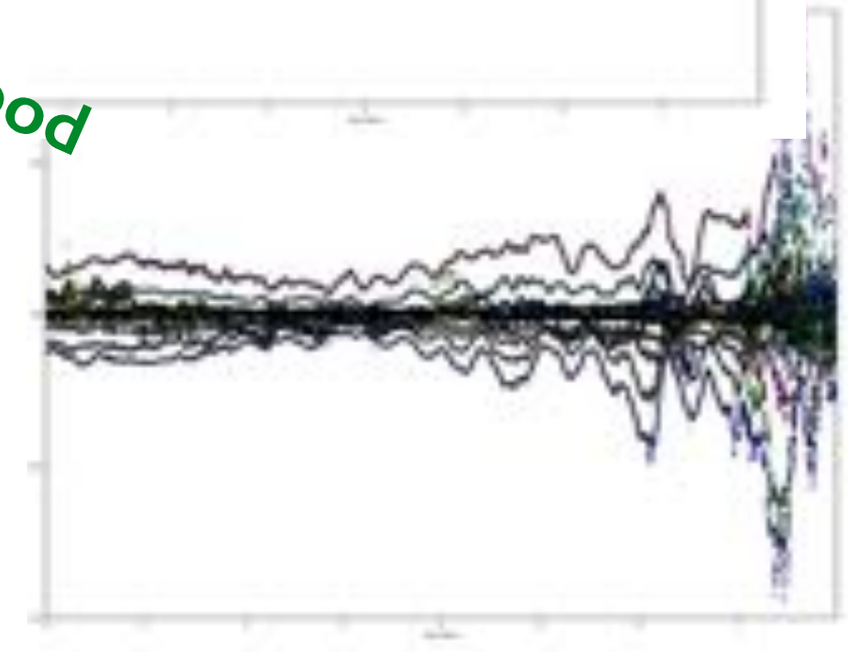
Good to crazy





Very good





Good

Outline

1. **Challenges at the lowest frequencies**

2. **Survey status for:**

   I. **LOFAR LBA Sky Survey (LoL-SS)**

   II. **400 MHz Upgraded GMRT Survey (400MUGS)**

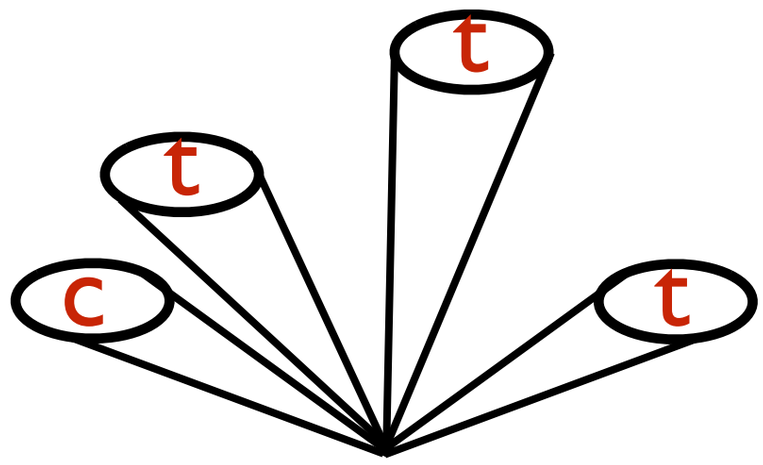
LoL-SS: LOFAR-LBA Sky Survey

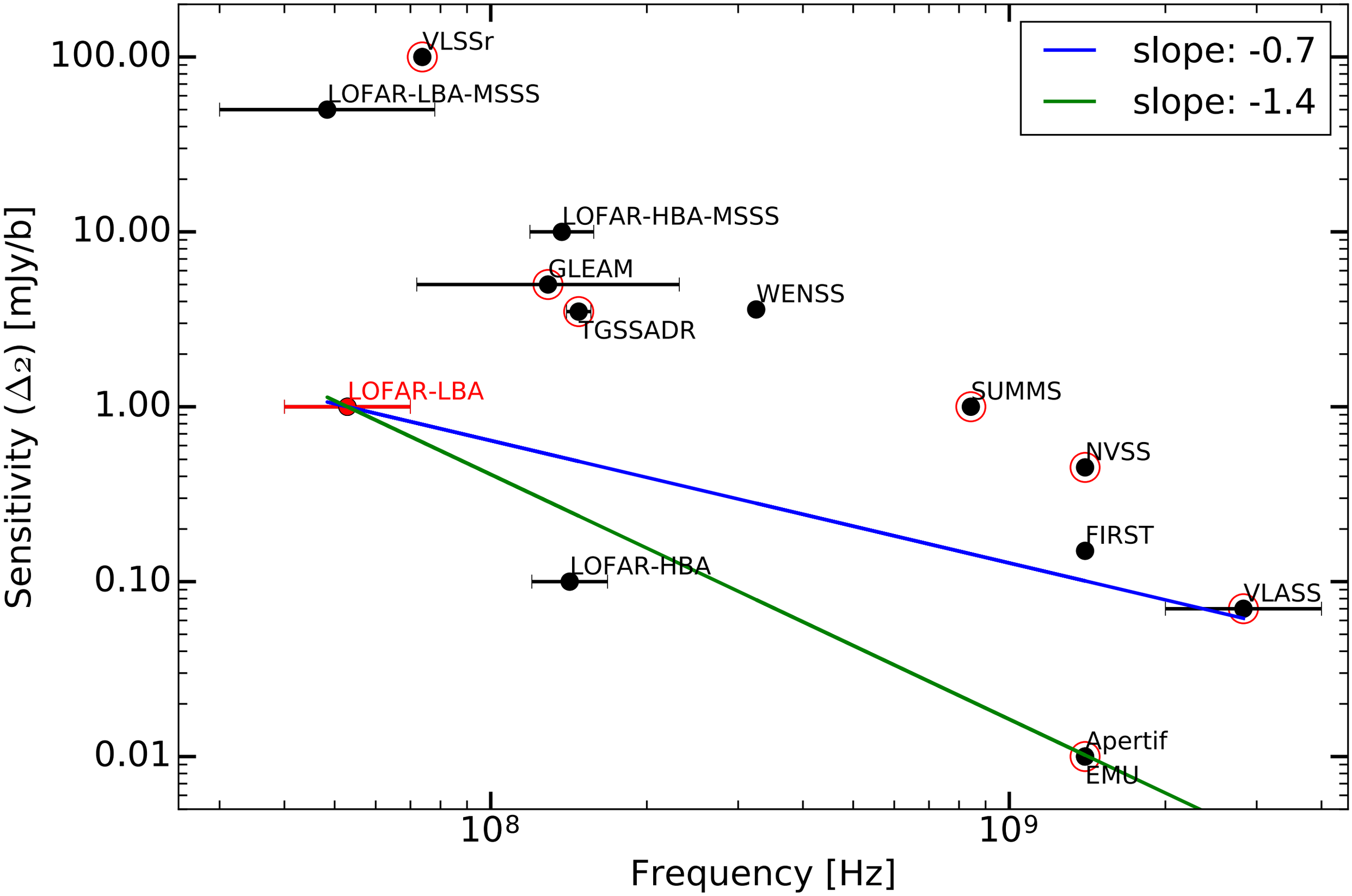
Lowest frequency point in any radio spectra

Beams: 4 (1 calibrator + 3 targets)
Mode: LBA_OUTER (4 deg FWHM)
Obs time: 8 hrs per pointing - 3170 pointings

Frequency coverage: 42 - 66 MHz
Resolution: 15” to 30”
Noise level: 5 mJy/b (DIE) - 1 mJy/b (expected DDE)
Sky coverage: 50% (northern sky)

LoLSS - Vs - VLSS
10 - 20 times better noise
2 - 3 times better resolution





Sensitivity: 1 mJy/b

Freq: 42-66MHz

Scientific cases:

- **High-z** radio galaxies

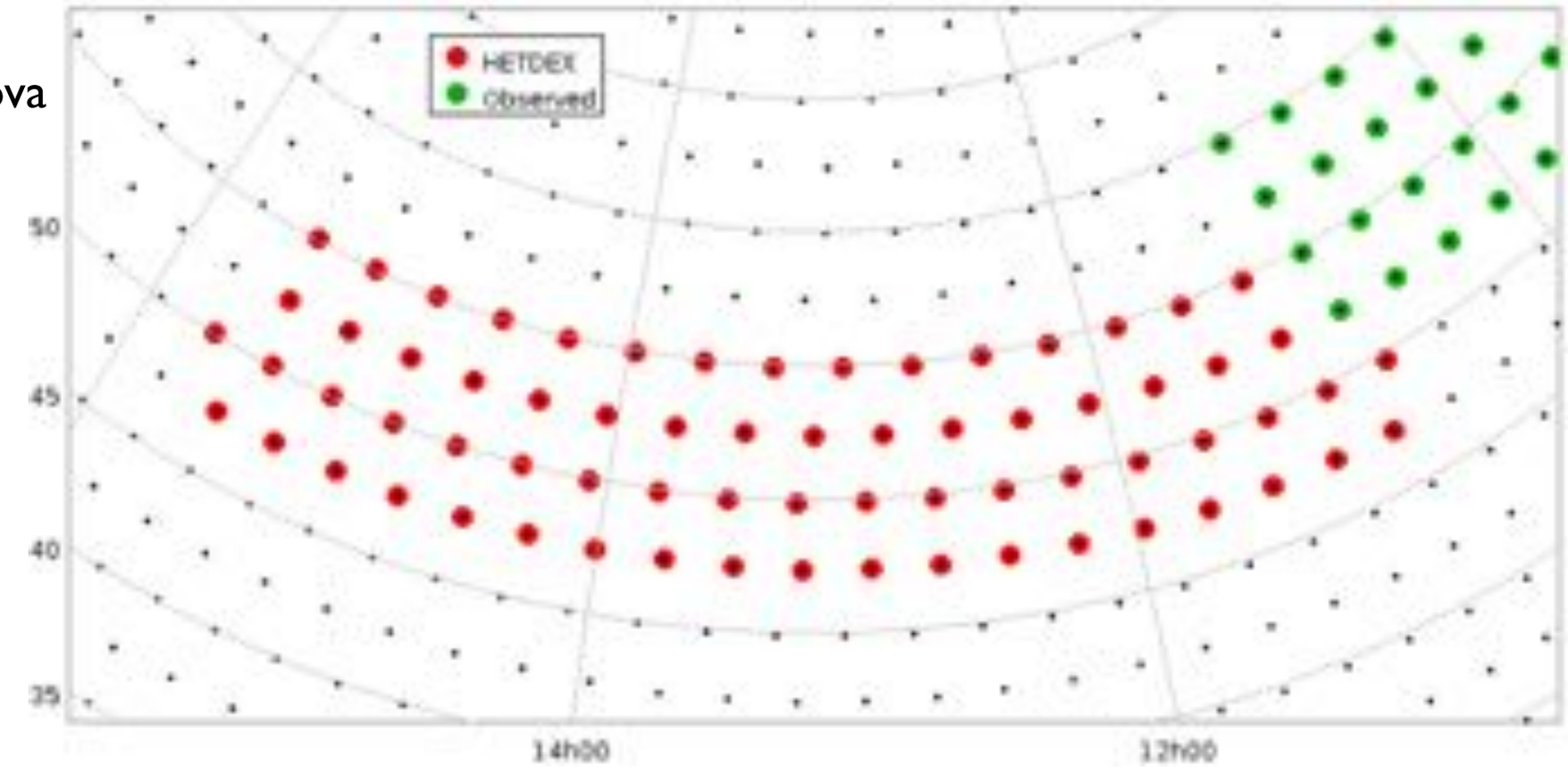
- Ultra steep, extended emission in galaxy **clusters** (halos, relics)
- Old plasma in clusters (AGN relics, phoenixes)

- **AGN** SED study at unexplored frequencies: MHz-piked RG, giant RG, turnover
- AGN recurring activity

- **Galaxy** radio-FIR relation at the lowest frequencies
- Cold gas with RRL

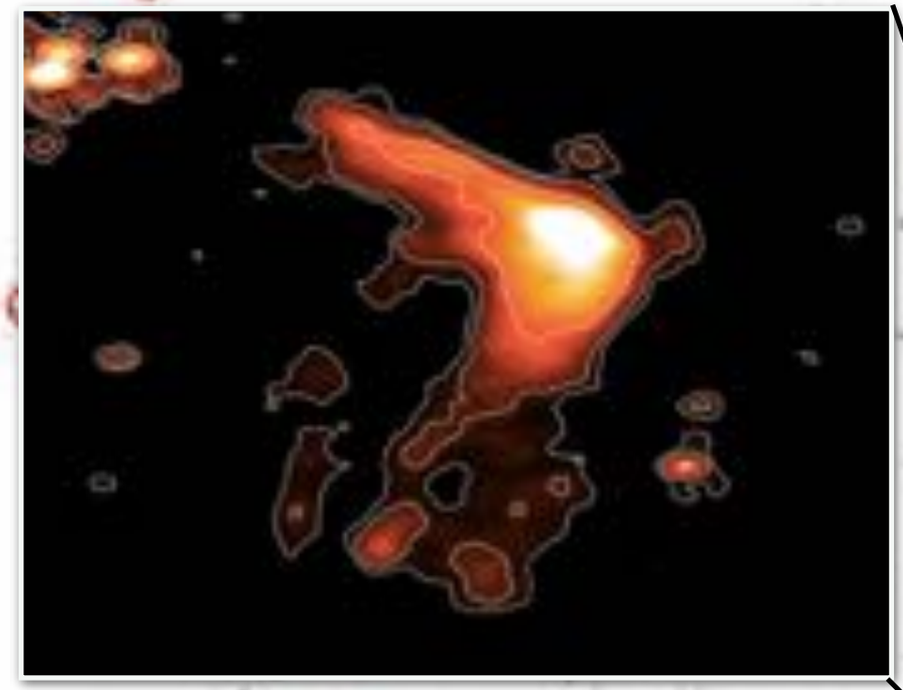
- **Galactic** census of supernova remnant, HII regions
- Galactic gas properties through RRL

- **Ionosphere** properties

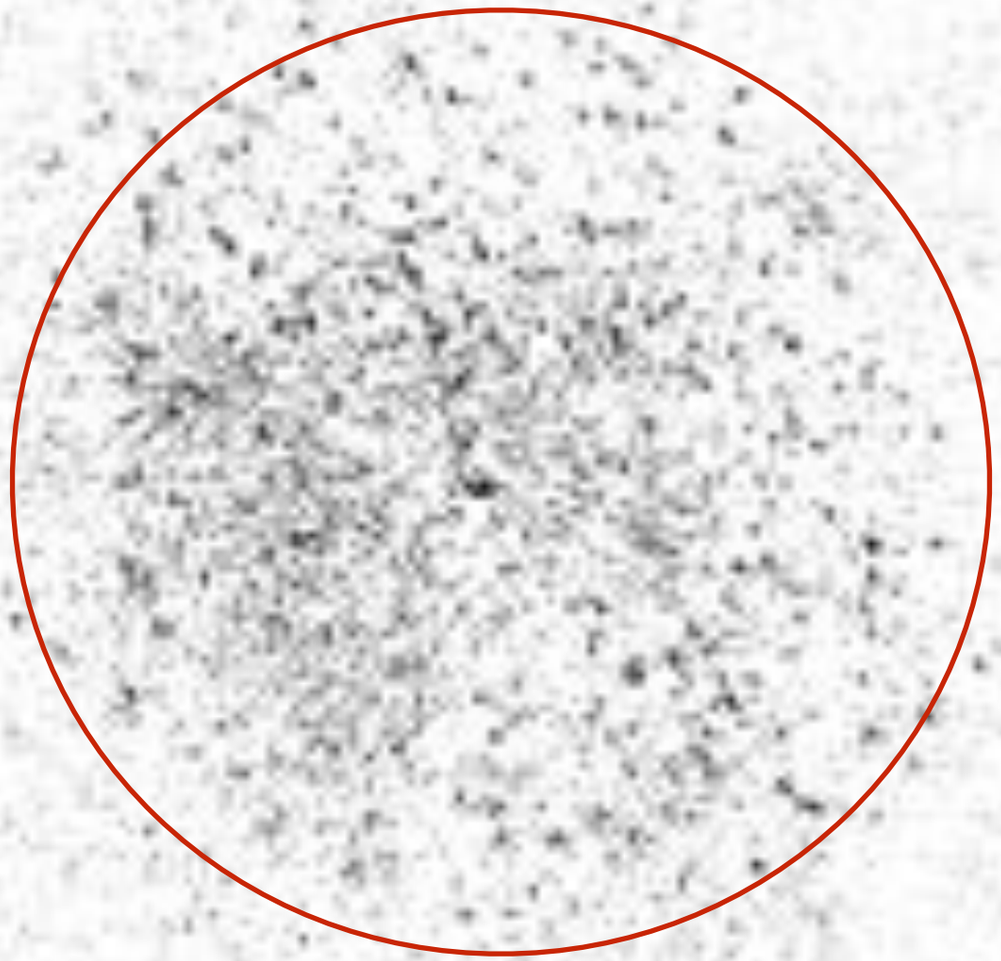


Status:

64 hrs observed (cycle 5)
184 hrs proposed (cycle 7) — the LOFAR LBA HETDEX survey



Frequency: 60 MHz
Rms noise: 3 mJy/b
Resolution: 30”
Detections: ~700
FWHM: 4 deg



FoV: 20 deg x 20 deg

Outline

1. Challenges at the lowest frequencies

2. Survey status for:

   I. LOFAR LBA Sky Survey (LoL-SS)

   II. 400 MHz Upgraded GMRT Survey (400MUGS)

400MUGS: 400 MHz uGMRT Sky Survey

de Gasperin F. , Intema H., Best P., Cotton B., Frail D., Gupta Y., Hardcastle M. J., Heald G., Kharb P., Ishwara Chandra C. H., Jagannathan P., Lal D.V., Mooley K., Norris R., Rottgering H., Shimwell T., van Weeren R., Wadadekar Y.

No competitors in the southern sky.
"Third point" in the spectrum between
(low) MWA/LOFAR and (high) VLA/ASKAP/Meerkat.

Obs time: 5 min per pointing - 40k pointings (phase I+II)
Epochs: 3 (100s each)

Frequency coverage: 300 - 500 MHz ("band 3")
Resolution: 7"
Noise level: 300 uJy/b (6 times expected thermal noise)
Sky coverage: 40% (phase I) - 90% (phase I+II)

400MUGS - Vs - WENSS
10 times better noise
10 times better resolution

Scientific cases:

- **AGN** accretion modes >> galaxy evolution
- Unbiased selection of tens of thousands of LLAGN
- Morphological studies (including X-shaped, double-double, HYMORS)
- AGN radio SED studies

FR1/FR2 dichotomy, the physics of AGN jet re-orientation and AGN duty-cycle

- 10k **starforming** across cosmic time
- SED and radio-FIR relation

- Fast **transients** (brown dwarfs, magnetically active main-sequence stars, neutron stars and unknown classes)

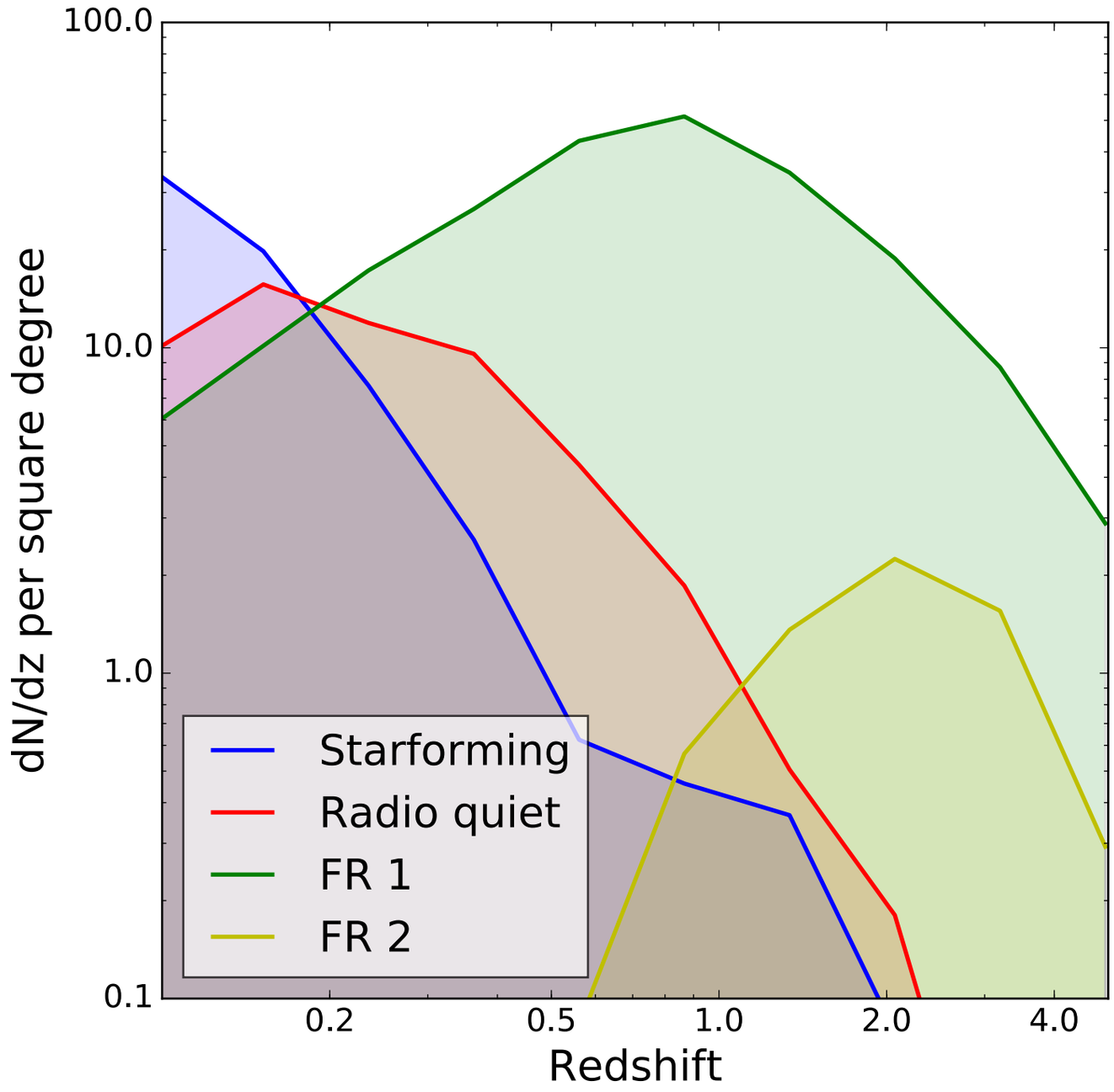
- strength, morphology and evolution of **magnetic fields**
- Faraday tomography of the Galaxy

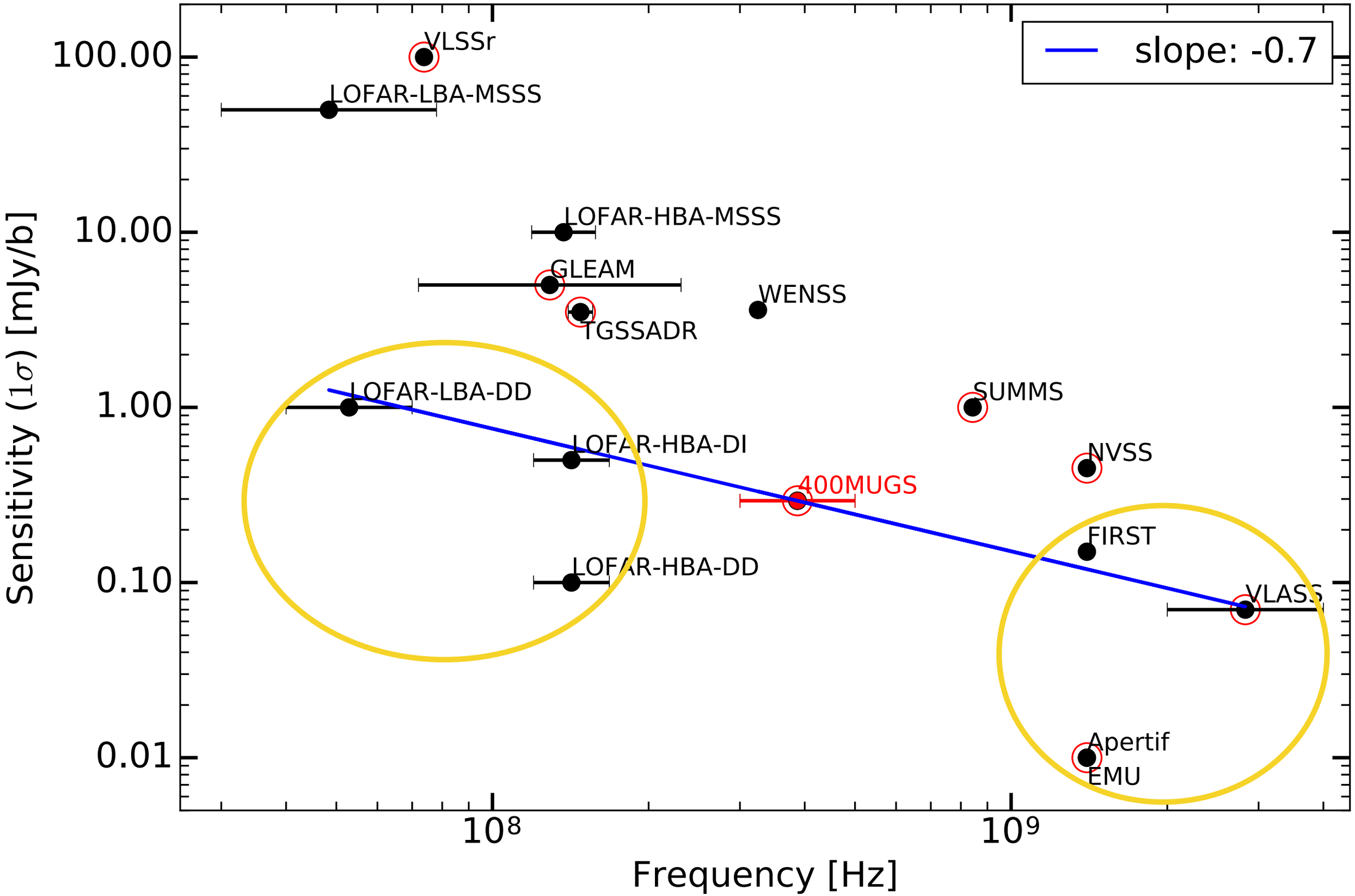
- Unbiased mass- redshift-dependent sample of extended emission in **clusters**
- Old plasma in clusters (AGN relics, phoenixes)

- **High-z** radio galaxies

- Millisecond **pulsars**

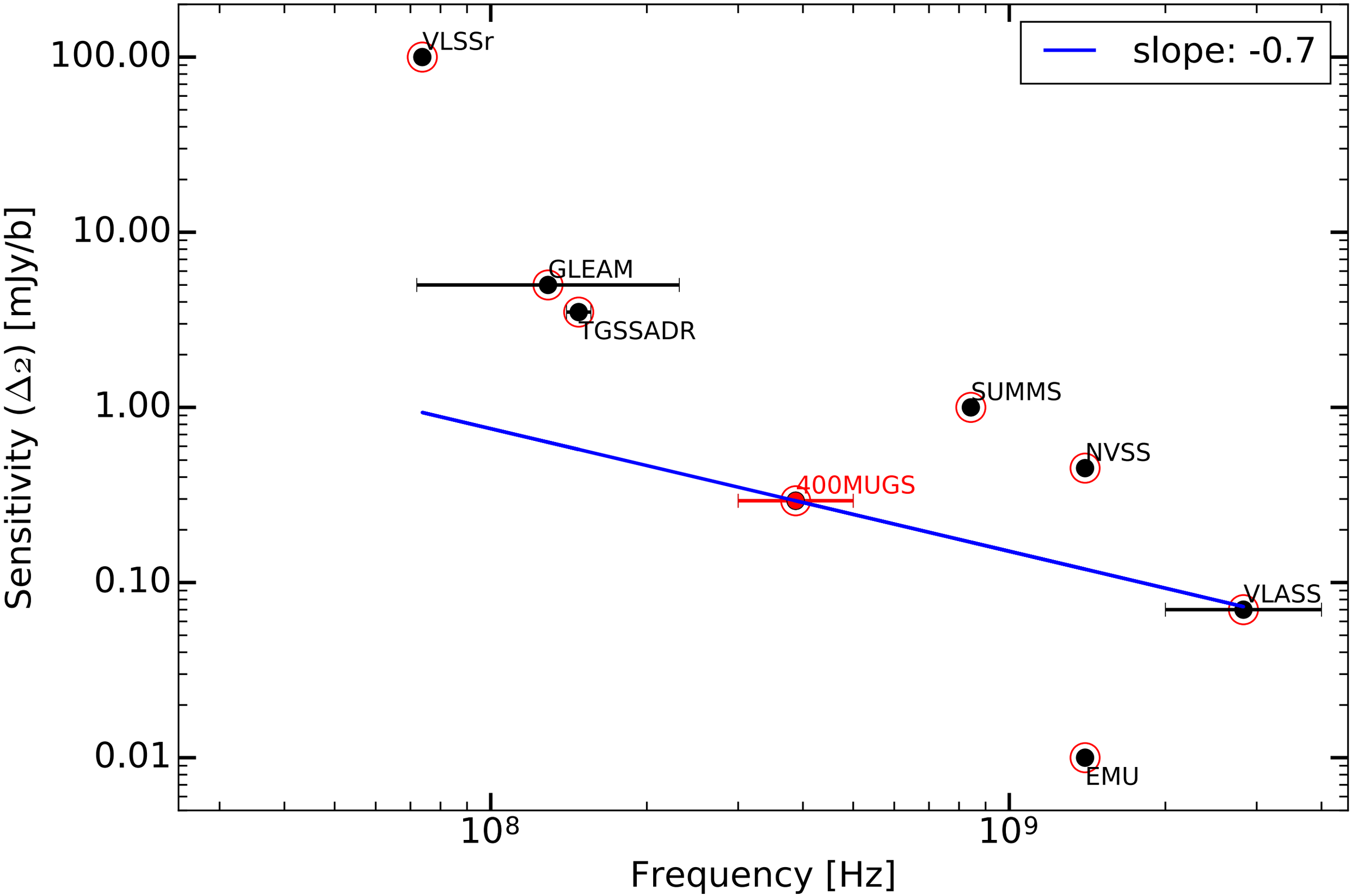
- **Cosmology**: clustering, alignment, cosmic dipole





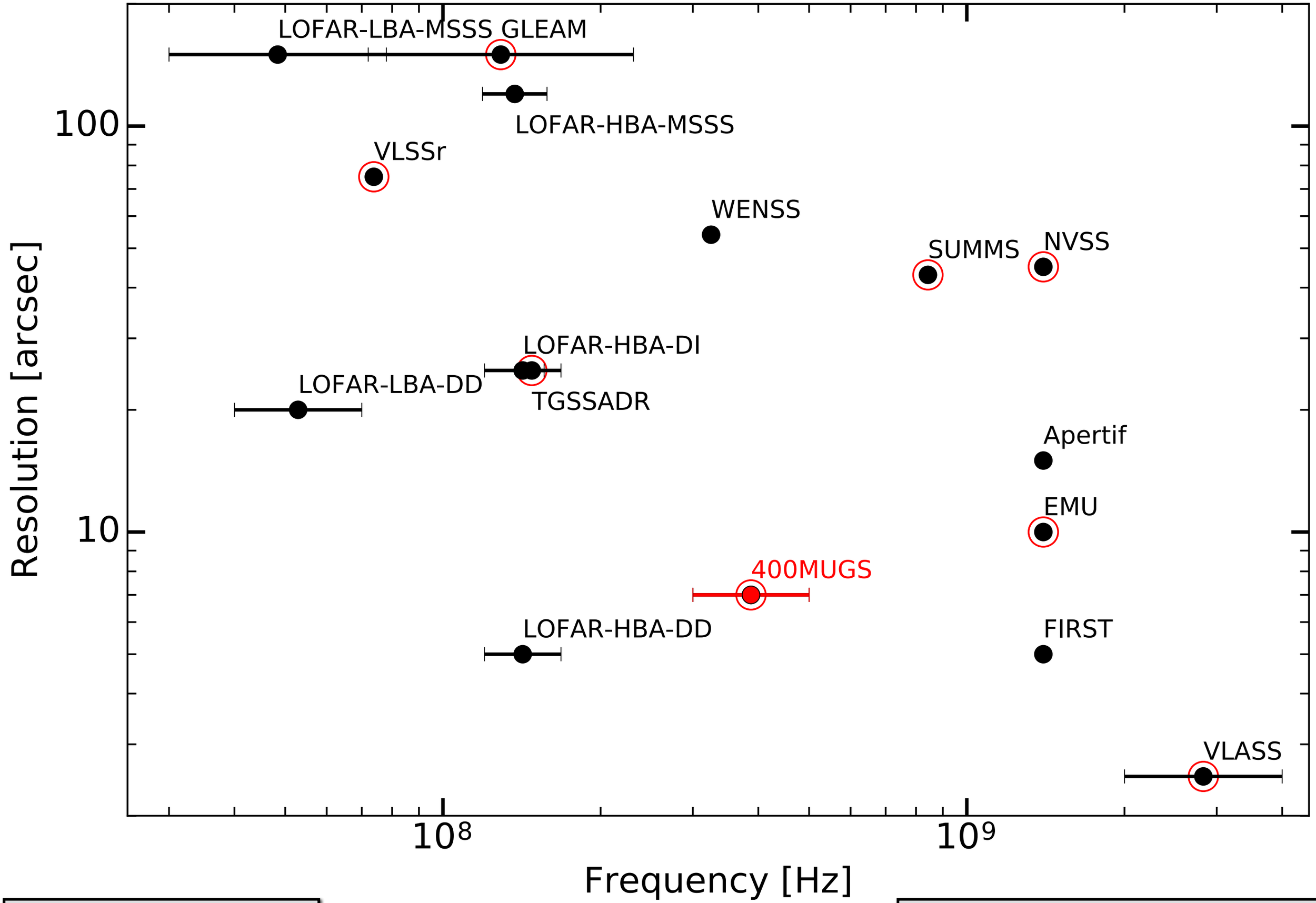
Sensitivity: <300 uJy/b

Freq: 300-500 MHz



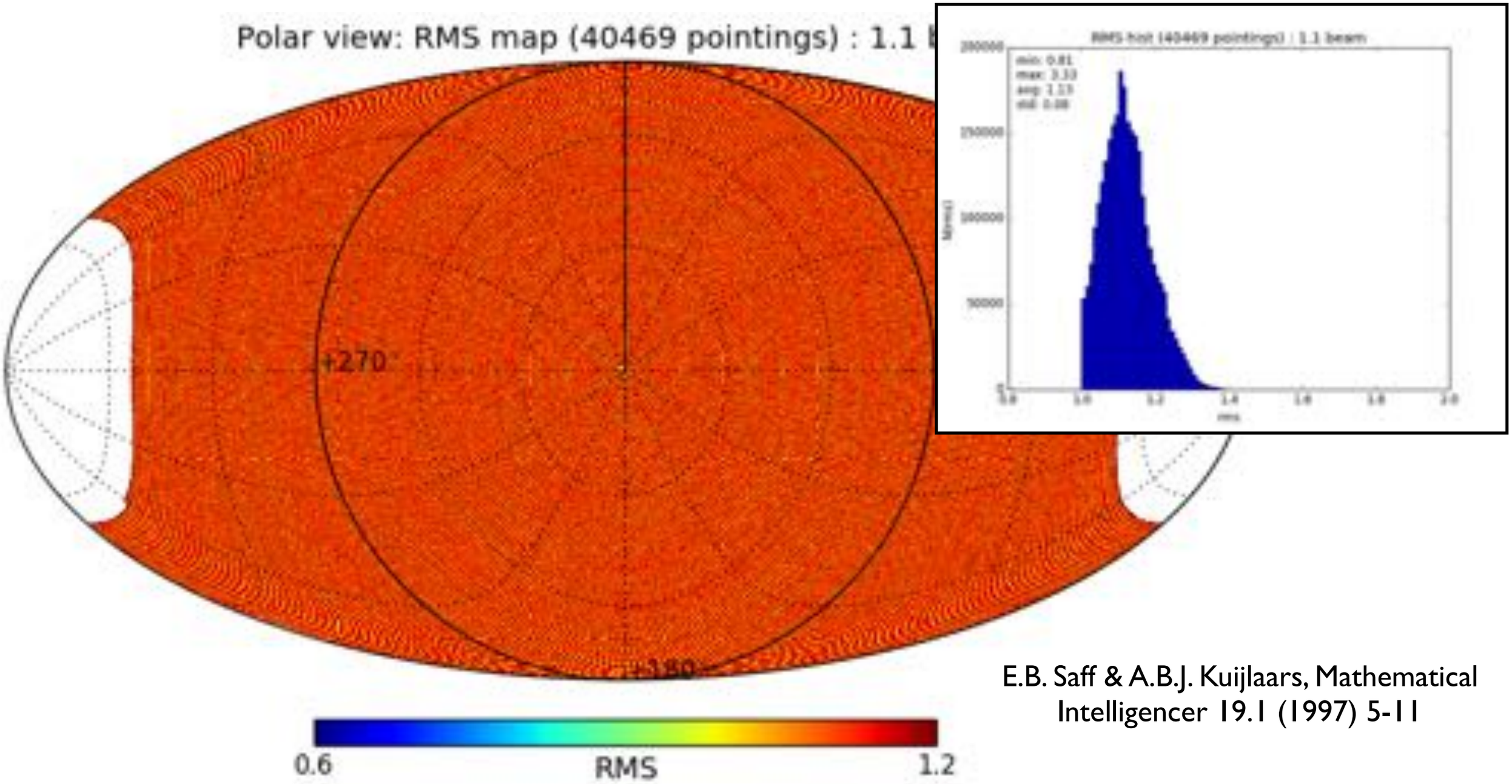
Sensitivity: <300 uJy/b

Freq: 300-500 MHz

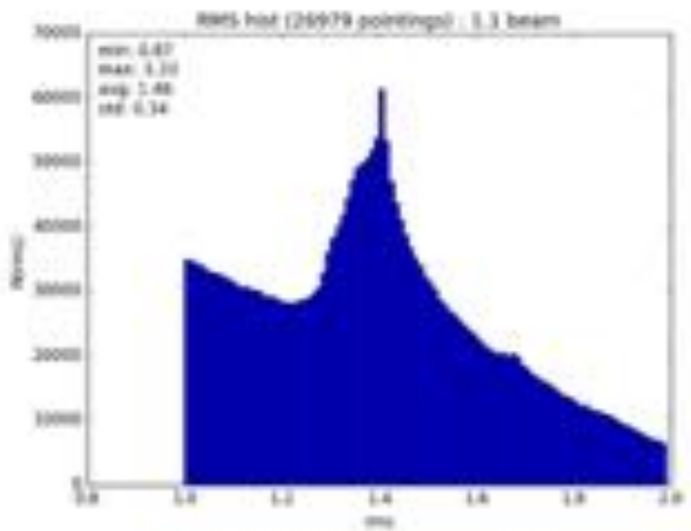


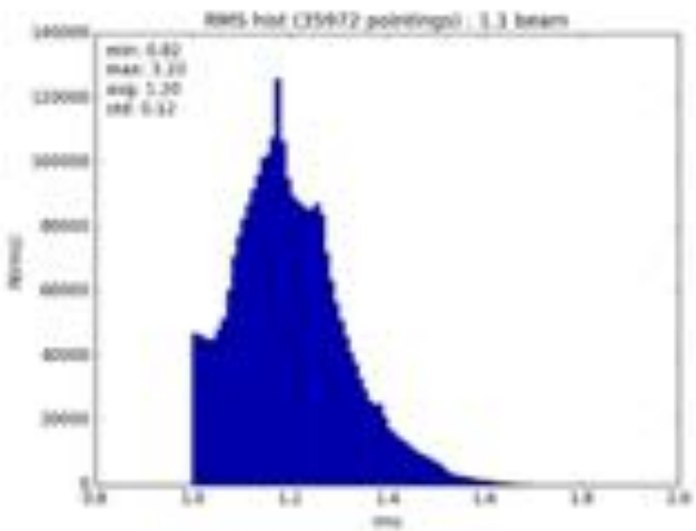
Resolution: 7”

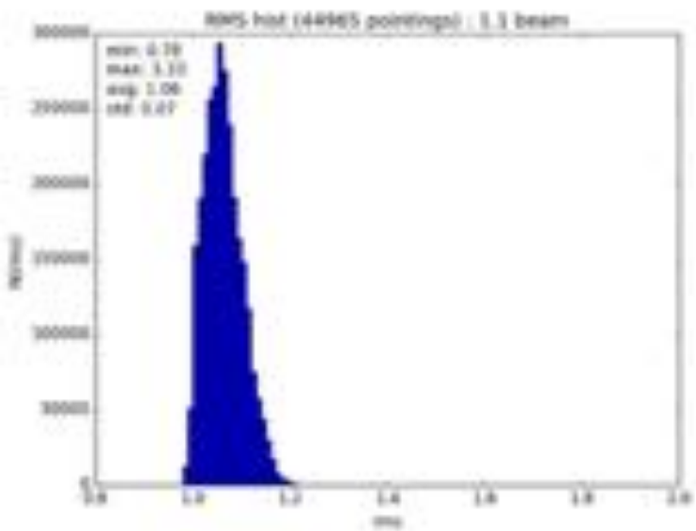
Freq: 300-500 MHz

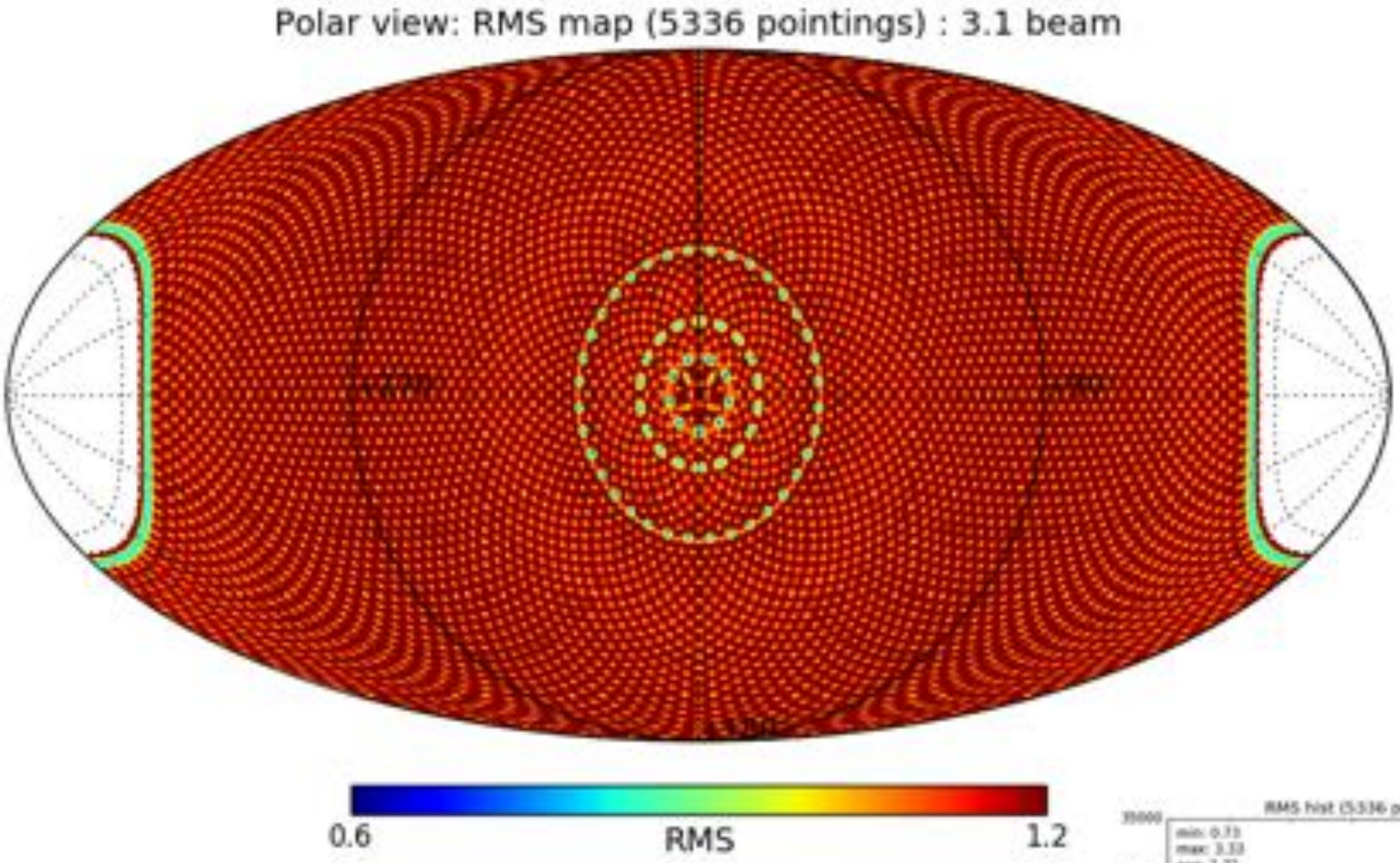


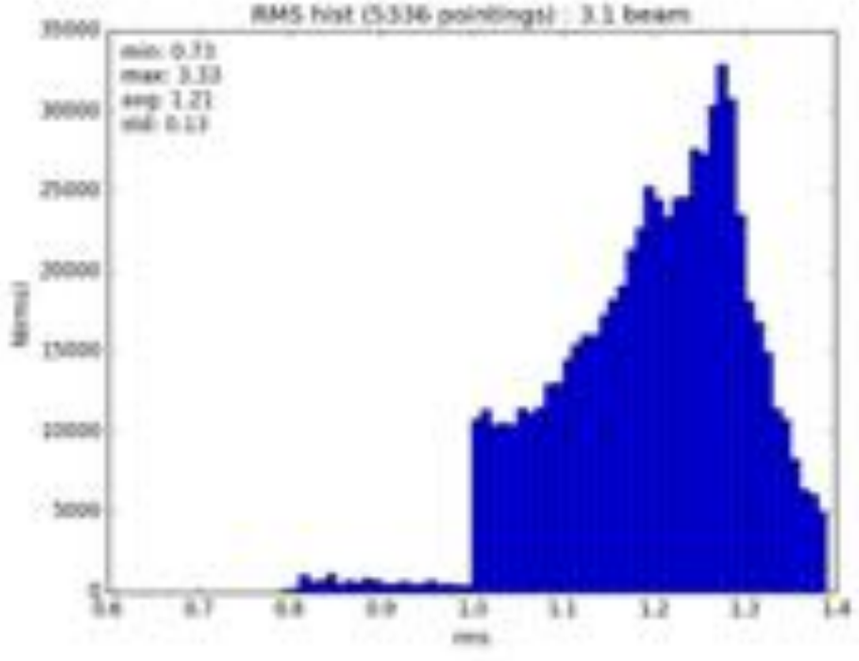
E.B. Saff & A.B.J. Kuijlaars, Mathematical Intelligencer 19.1 (1997) 5-11







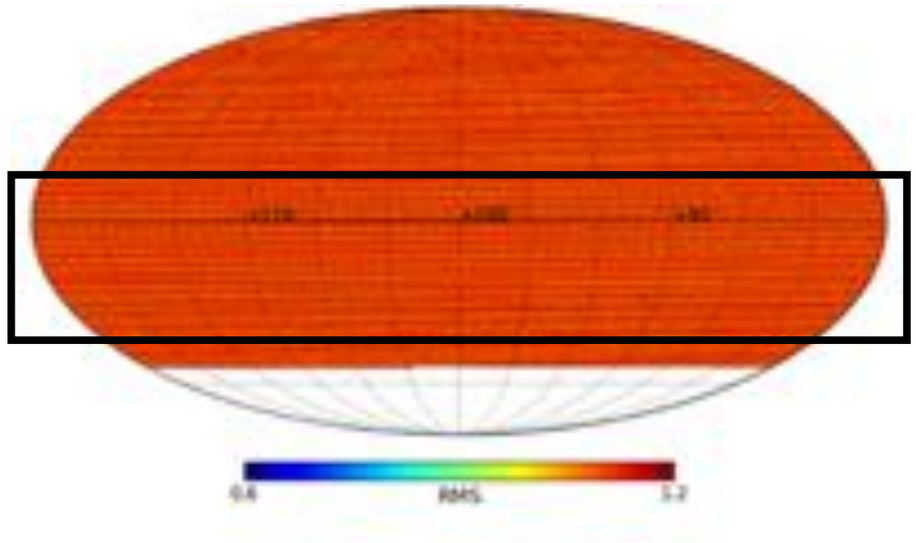

Polar view: RMS map (5336 pointings) : 3.1 beam
0.6
RMS
1.2


RMS hist (5336 pointings) : 3.1 beam
min: 0.71
max: 3.33
avg: 1.21
std: 0.13
35000
30000
25000
20000
15000
10000
5000
0
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
rms

Sky region	Dec range	Coverage	Total hours	Number of sources
Phase 1 - Southern sky	$-40° < \delta < 10°$	40%	2271	2.0 millions
Phase 2 - Full sky	$\delta > -53°$	90%	5110	4.4 millions

Phase 1:

- southern sky
- + equatorial region
- - extreme south



Status:

- Pointing strategy study and pipeline commissioning:

  5 hrs DDT time allotted (obs end of Nov)

- Technical exploratory survey

  52 hrs allotted (obs end of Feb)

  - *GAMA12 >> alignment study*
  - *COSMOS*
  - *Galactic plane*
  - *Hydra A*

Summary

- **Systematic effects down to 50 MHz reasonably understood**
- **Most relevant effects (LOFAR): TEC/delay, clock/delay, FR, scintillations, beam, bandpass**

Next generation low-frequency surveys:

- **LoL-SS: LOFAR-LBA Sky Survey @ 60 MHz**
  - **first data taken**
  - **reduction underway**

- **400MUGS: 400 MHz Upgraded GMRT Survey**
  - **exploratory survey planned**
  - **first data early 2017**

M87 - LOFAR LBA 60 MHz

	Clock drift	Ionospheric delay	Faraday rotation	Scintillations
Affects	Phase	Phase	Phase (circ) Amp+Ph (lin)	Amplitudes
Type	Scalar	Scalar	Diag (circ) Rot (lin)	Scalar?
Freq. dep.	$\propto f$	$\propto 1/f$; $\propto 1/f^3$	$\propto 1/f^2$	some
Dir. dep.	No	Yes (tens arcmin)	Yes (degrees)	Yes (tens arcmin)

Beam and bandpass excluded