Développements algorithmiques : applications aux précurseurs et éclaireurs de SKA (LOFAR + MeerKAT)

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for the LOFAR Surveys KSP

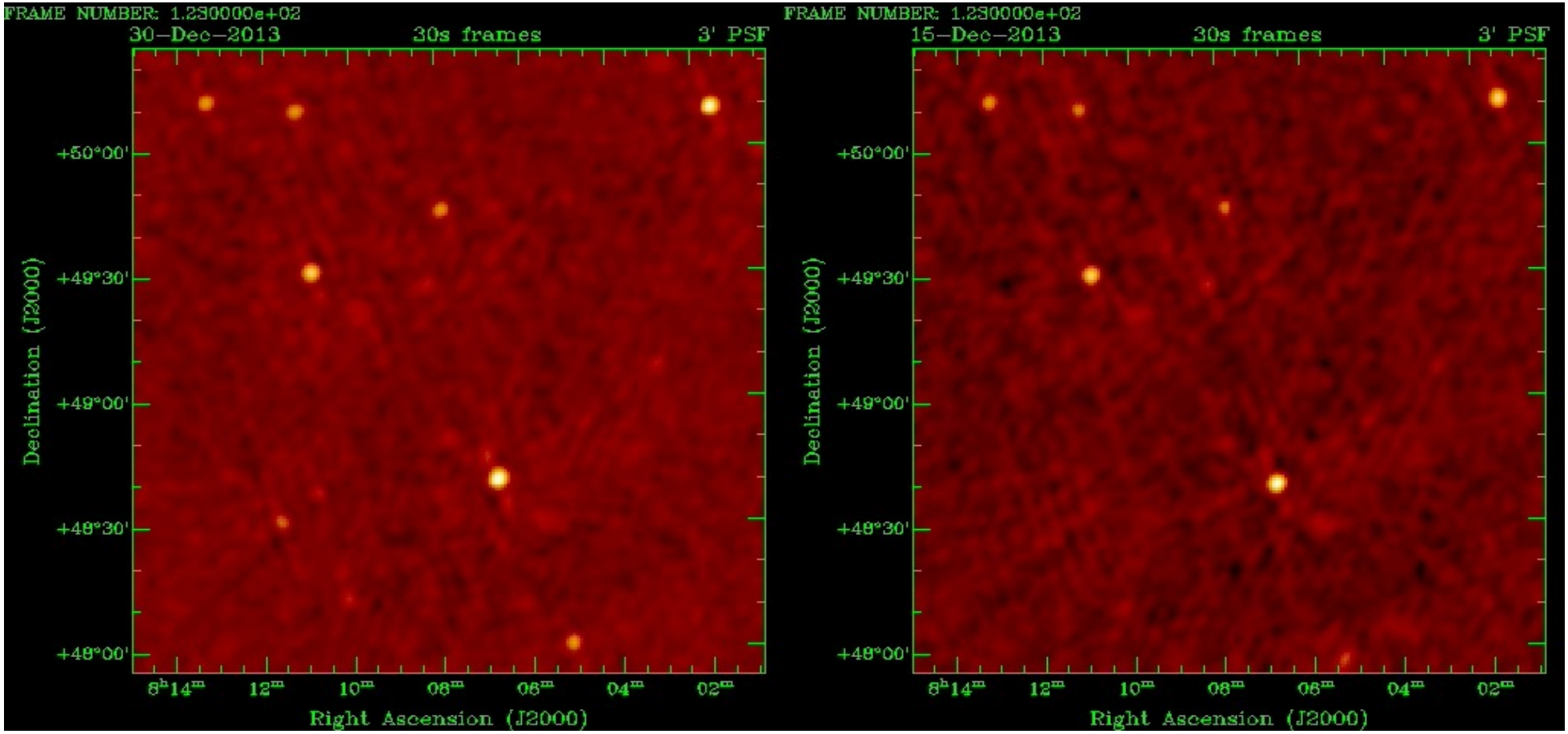
With many slides from :
Tim Shimwell, Reinout van Weeren, Federica Savini, Amanda Wilber, Shane O'Sullivan, Leah Morabito, Vijay Mahatma

Paris - 23/11/2018

Ionosphere

Good ionosphere

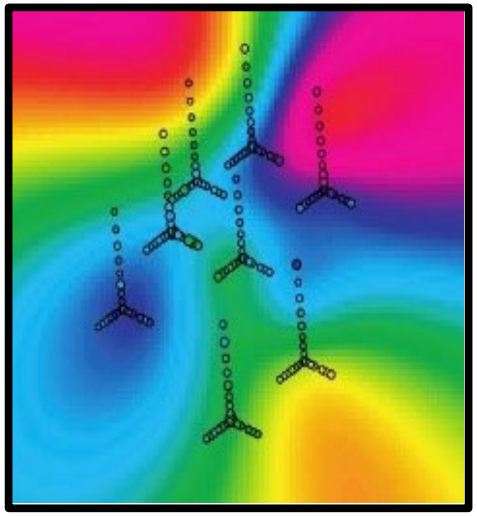
Bad ionosphere



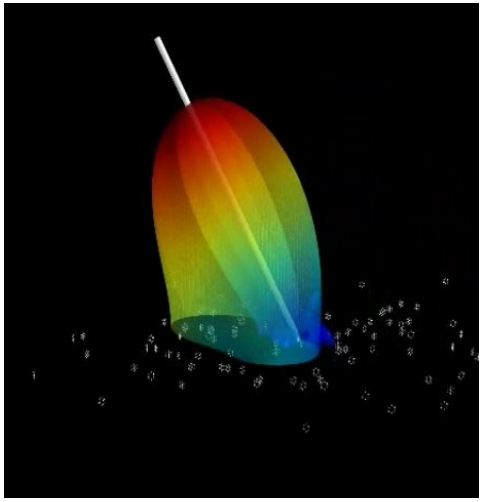
Images have 3 arcmin resolution

Ger de Bruyn & LOFAR EoR team

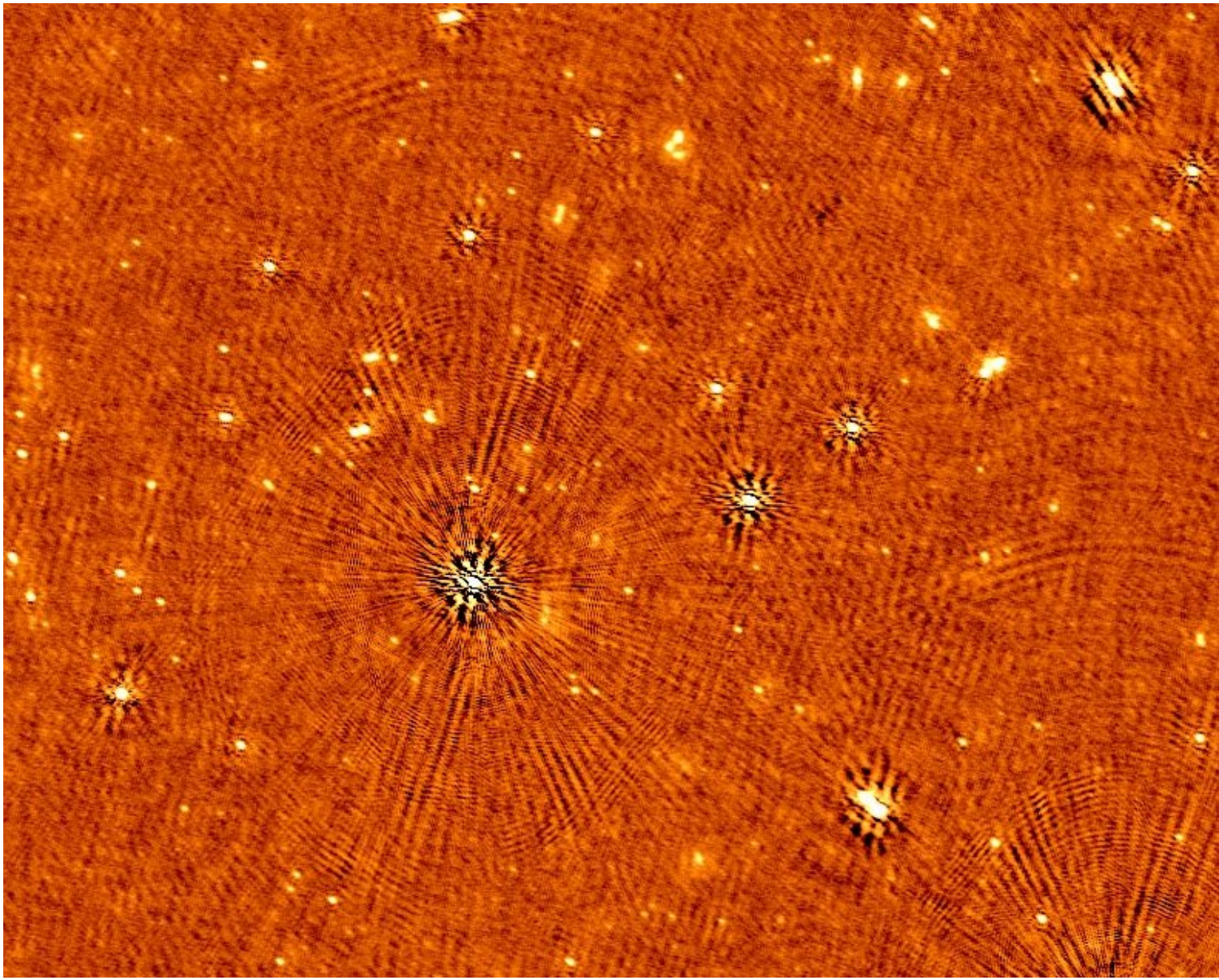
The best image you can ever get in selfcal



Ionospheric disturbance + Faraday rotation



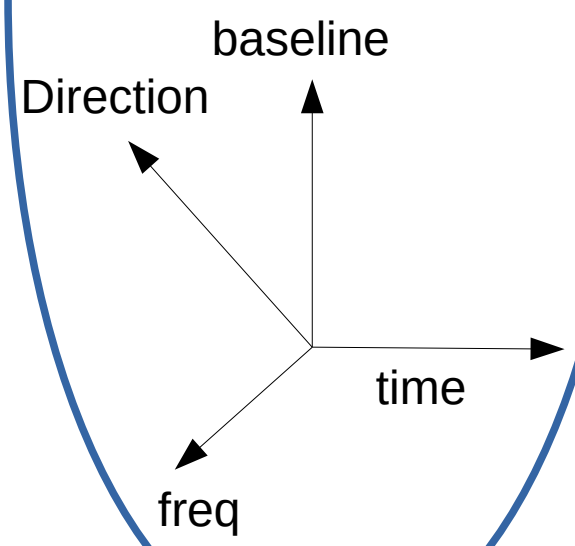
Station lobes



Interferometry

TRUTH domain

- **Ionosphere**
- **Troposphere**
- **Beam**
- **Sky**
- **Faraday rotation**
- **Electronics**
- **etc**



?

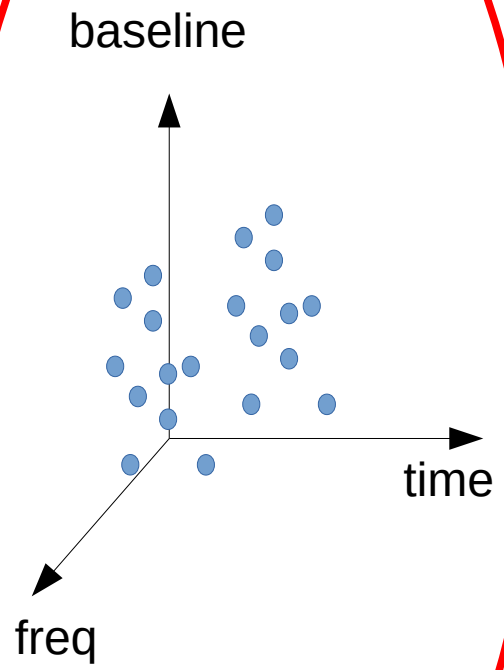
« Calibration & imaging algorithms »

Non-linear operator **h**

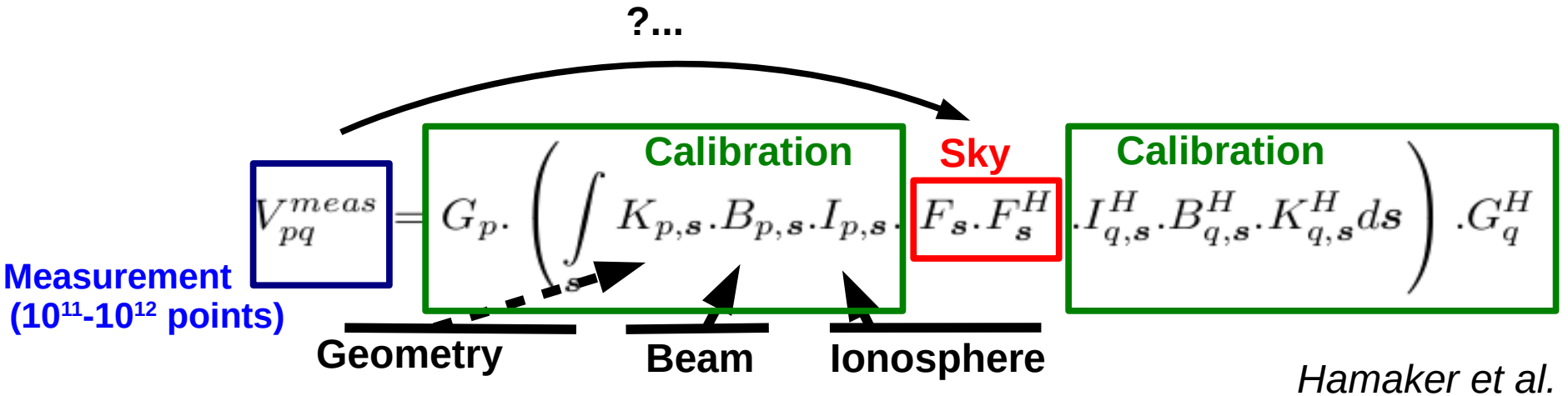
$$V_{pq} = G_p \left(\sum_{i=1}^{N} \mathrm{B}_{pi} \mathrm{K}_{pi} \mathrm{I}_{pi} F_i \; . \; F_i^{+} \mathrm{I}_{qi}^{+} \mathrm{K}_{qi}^{+} \mathrm{B}_{qi}^{+} \right) G_q^{+}$$

Hamaker et al. 1994

Measurement domain



«Third» generation calibration and imaging



Hamaker et al. 94

…. A pretty difficult problem to invert (a post-processing adaptative optics)

(1)- Wirtinger optimisation for Direction Dependent Calibration

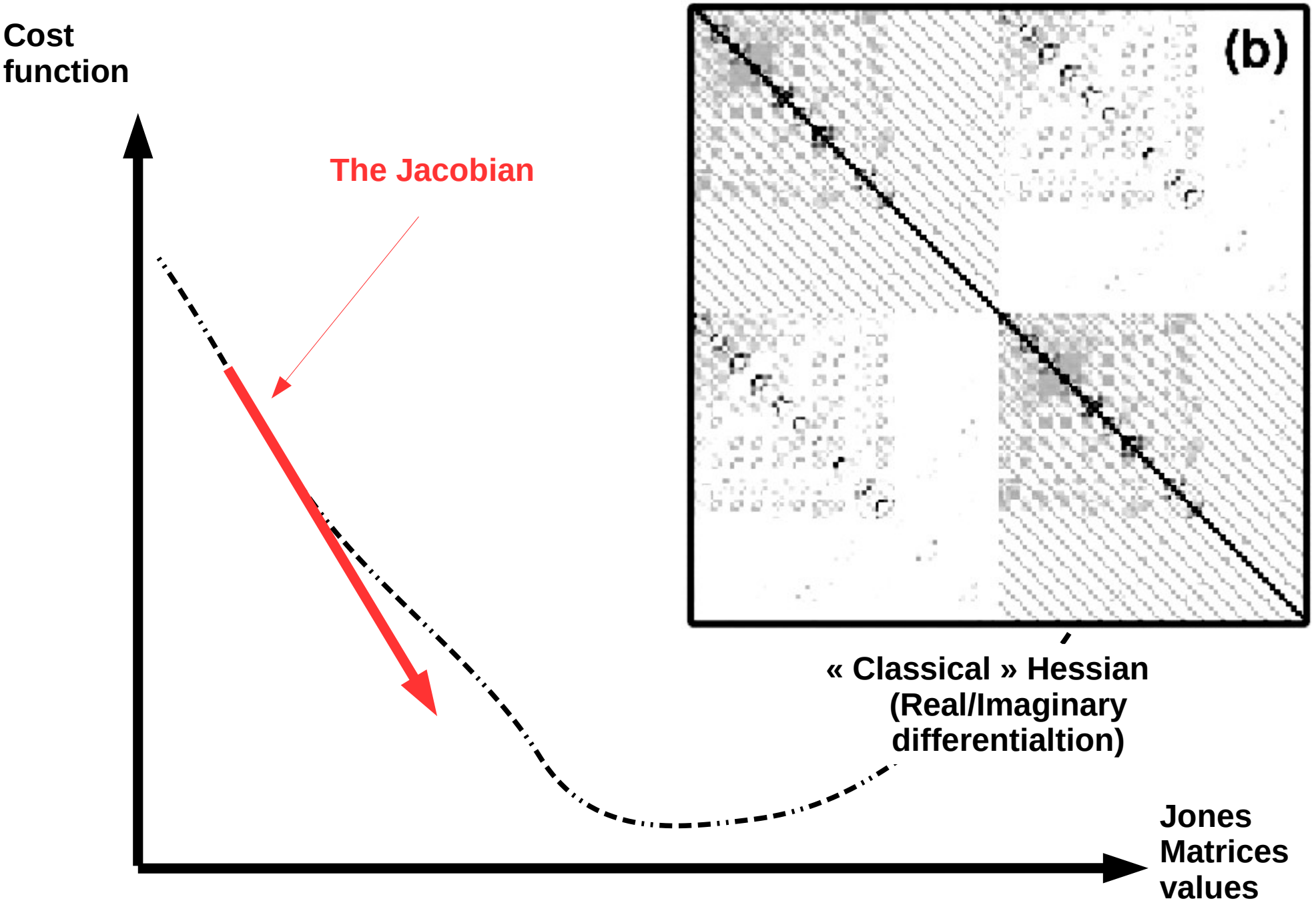
Tasse 2014
Smirnov & Tasse 2015

(2)- Imaging and deconvolution taking into account

- Direction Dependent effects (Beam, ionosphere, etc)
- Sources' spectral properties
- Variable PSF
- … and many more cool stuff

→ **kMS/DDFacet (Tasse et al. 2018)**

RIME Calibration

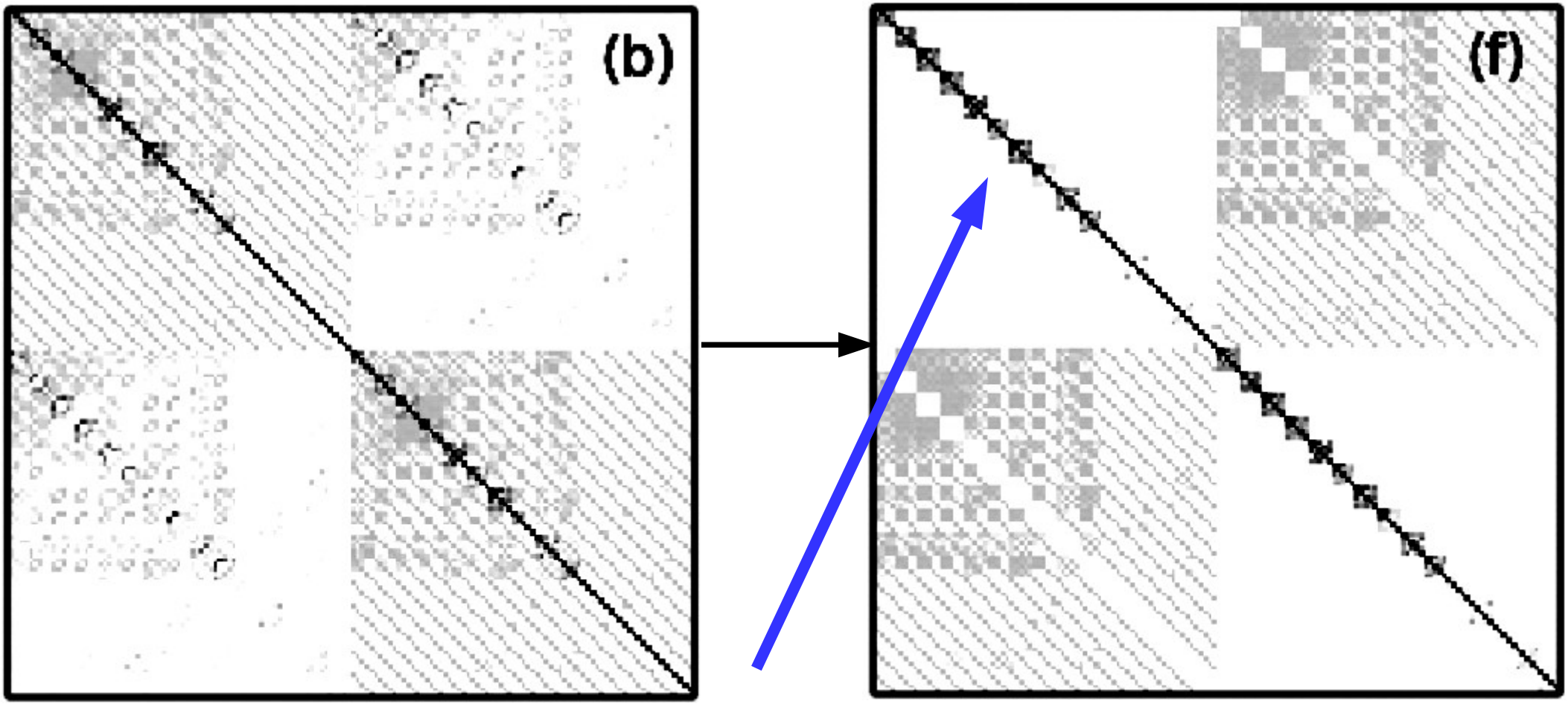


Wirtinger Optimisation: Jacobian & Hessian

(Read Tasse 2014, Smirnov & Tasse 2015)

Wirtinger derivative definition « reorganises » the process and data : the Jacobian and Hessian become sparse and compact

$$\frac{\partial \overline{z}}{\partial z} = 0 \text{ and } \frac{\partial z}{\partial \overline{z}} = 0$$



« Classical » Hessian

Those Blocks are (Nd x Nd)

Wirtinger Hessian

Wirtinger Optimisation: Jacobian & Hessian

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Wirtinger derivative definition « reorganises » the process and data : the Jacobian and Hessian become sparse and compact

$$\frac{\partial \overline{z}}{\partial z} = 0 \text{ and } \frac{\partial z}{\partial \overline{z}} = 0$$

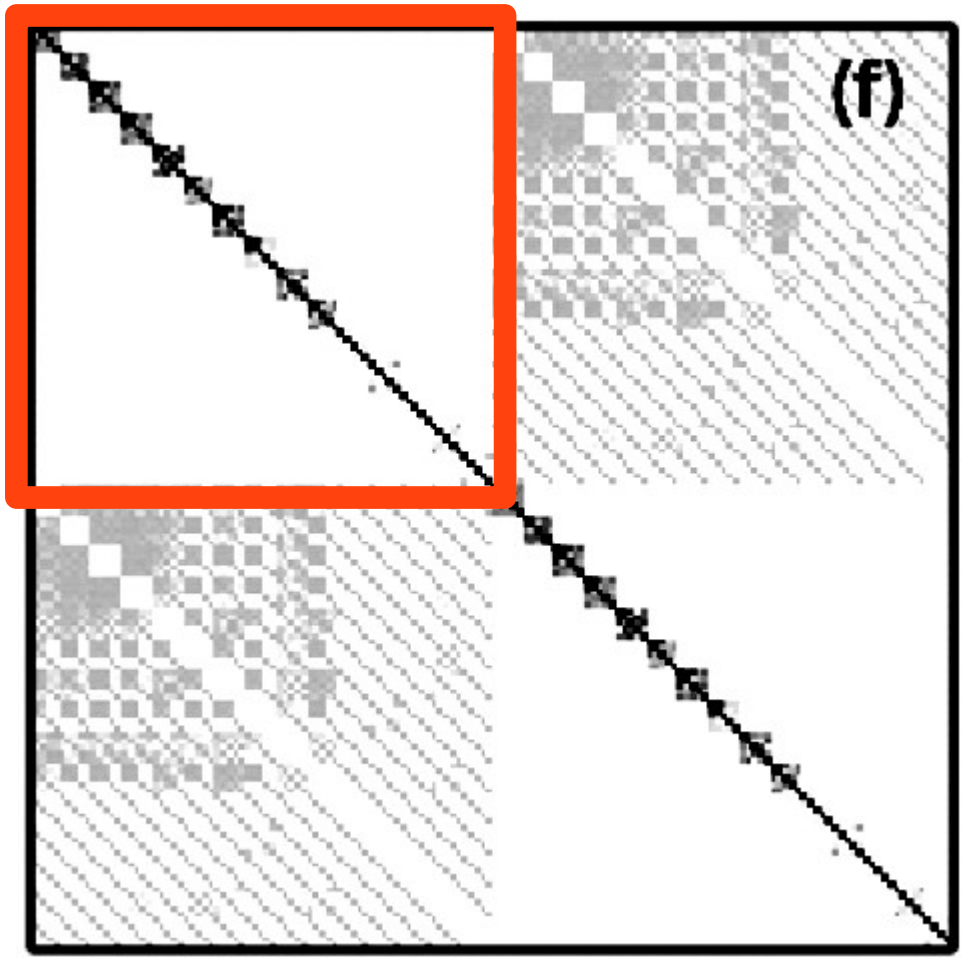
The fantastic property of Wirtinger Jacobian and Hessian for the RIME:

We can cut it in two !!!

- The result just needs to be devided by 2 !

- Very non trivial to prove

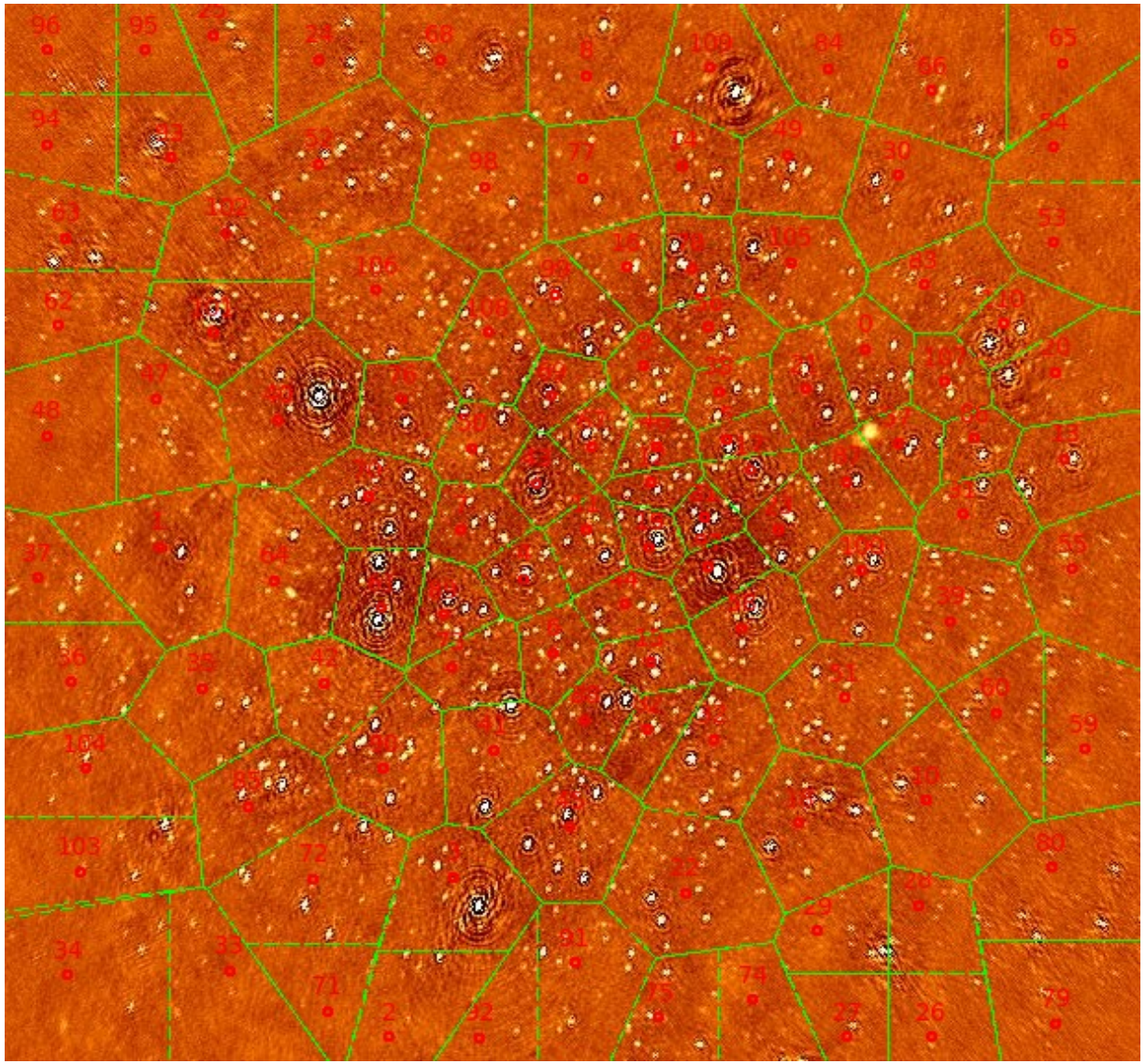
  - **Full** Wirtinger-Jacobian LM with lambda=0 is *the same as*
  - **Half** Wirtinger-Jacobian LM with lambda=1



Wirtinger Hessian

DDFacet

… A facet based imager



(1) Produces a single tengential plane ! (no « noise jumps » thanks to the kalman filter, and facetting mode) – *largely insprired from Kogan&Greisen 2009*

(2) Does full polarisation DDE correction

(3) Baseline Dependent Averaging
90 % of the data can be compressed
(collaboration with O.Smirnov and M. Atemkeng)

(4) Does tesselated images

(5) Does take time-freq-baseline-direction dependent beam into account

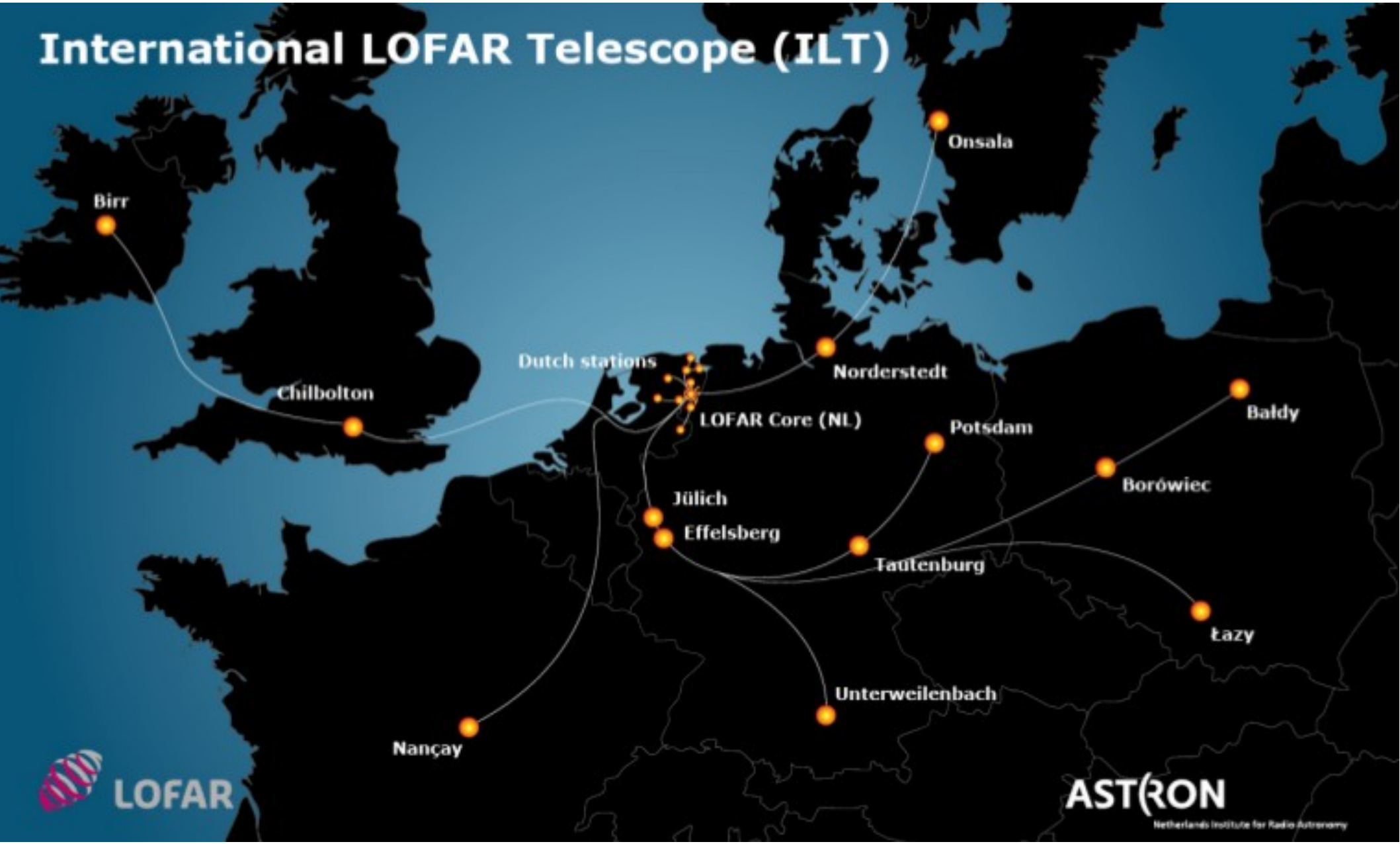
(6) Continuity between facets

(7) Takes variable PSF into account (DDE, Smearing/Decorrelation)

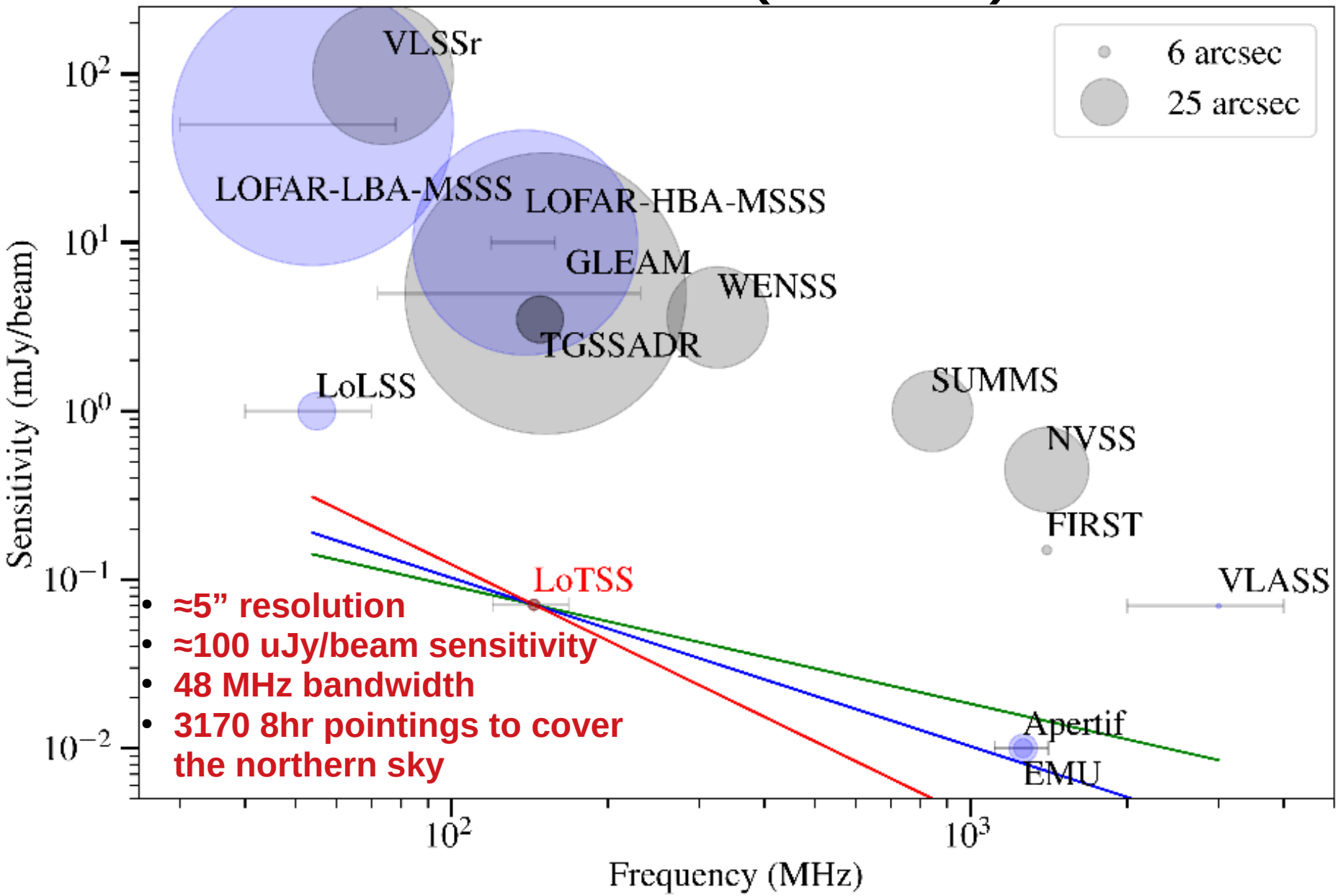
(8) Mosaicing (!)

(9) Does spectral deconvolution (Spectral indices + taking beam into account) - 8a : Hybrid Matching Poursuit
- 8b : SubSpace Deconvolution

Application à LOFAR



The LOFAR Two-meter Sky Survey : LOTSS (Tier-1)



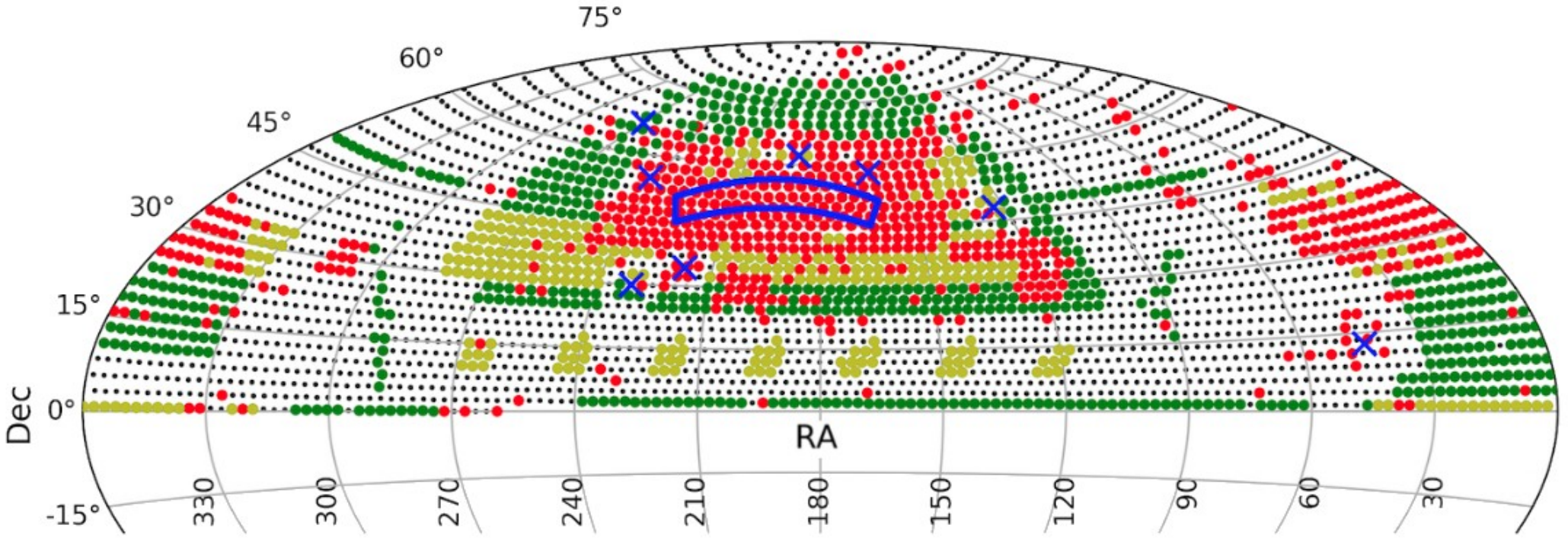
- **≈5” resolution**
- **≈100 uJy/beam sensitivity**
- **48 MHz bandwidth**
- **3170 8hr pointings to cover the northern sky**

LOTSS : LOFAR Two-meter Sky Survey

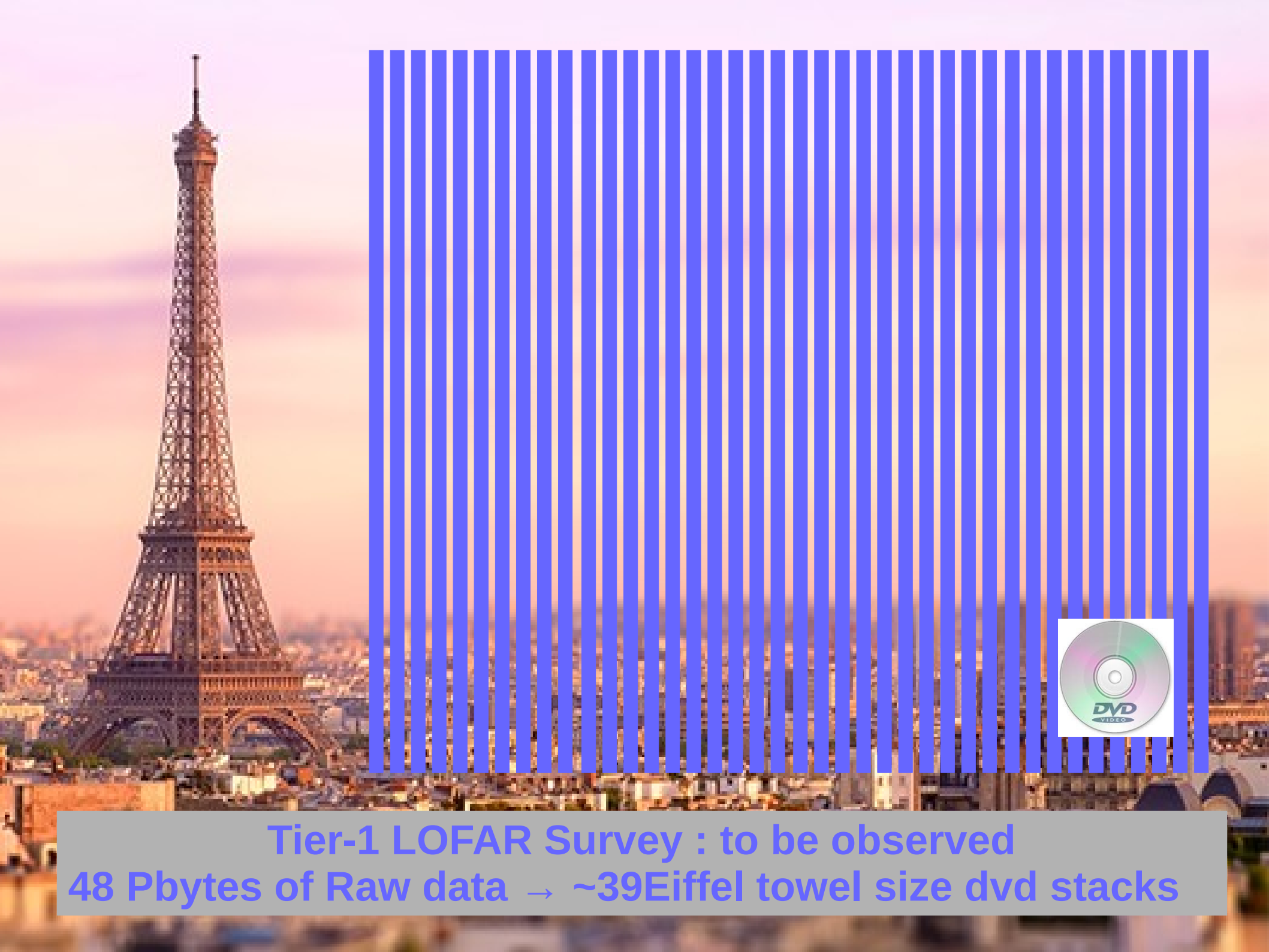
20% of the northern sky is observed.

50% of the observed data is partially processed.

Allocated 3750 hrs of observations to reach 50% completeness in 2 years



Red observed, yellow observed in next 6 months, green observed in next 2 years.

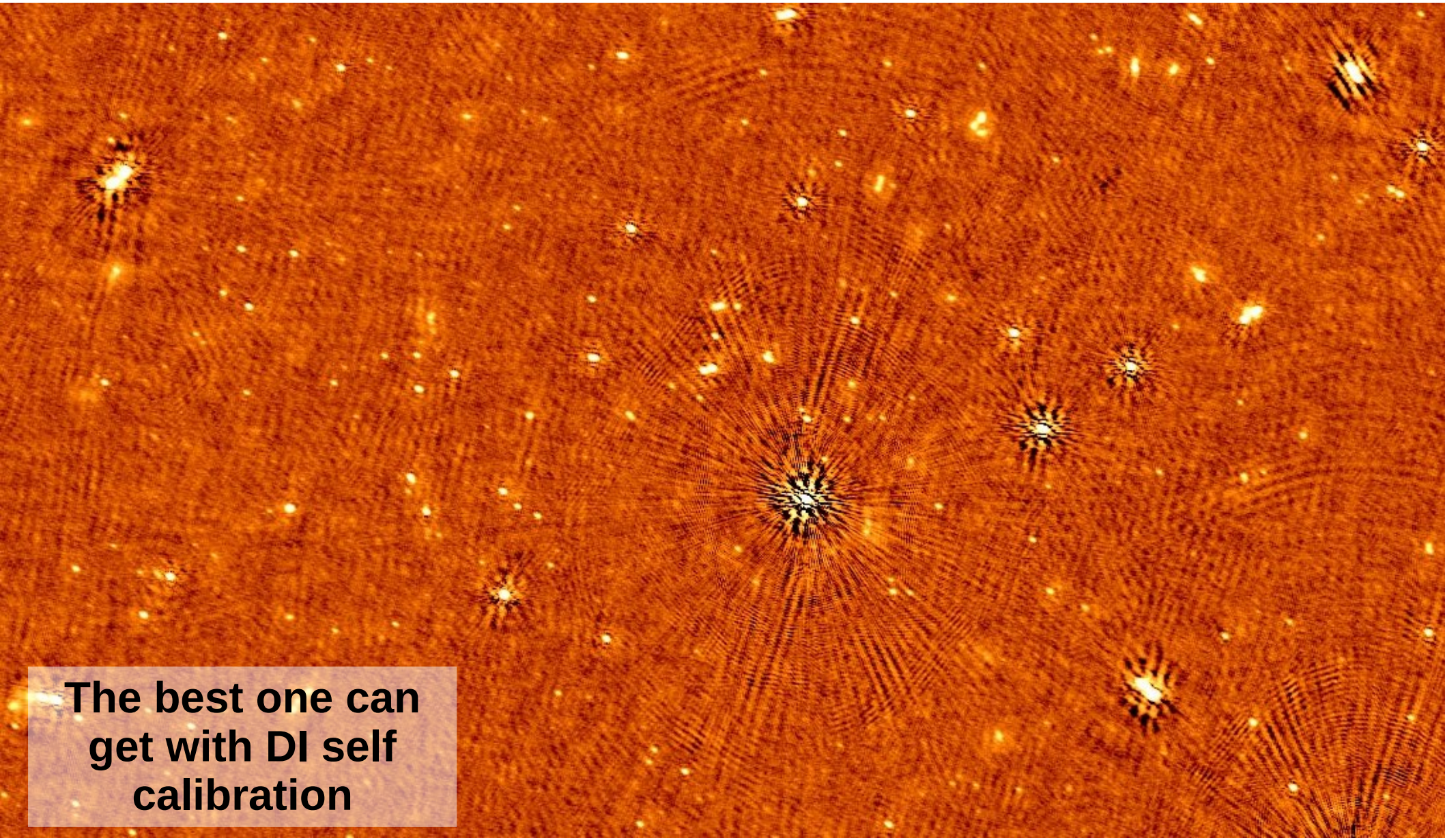


Tier-1 LOFAR Survey : to be observed

48 Pbytes of Raw data → ~39Eiffel towel size dvd stacks

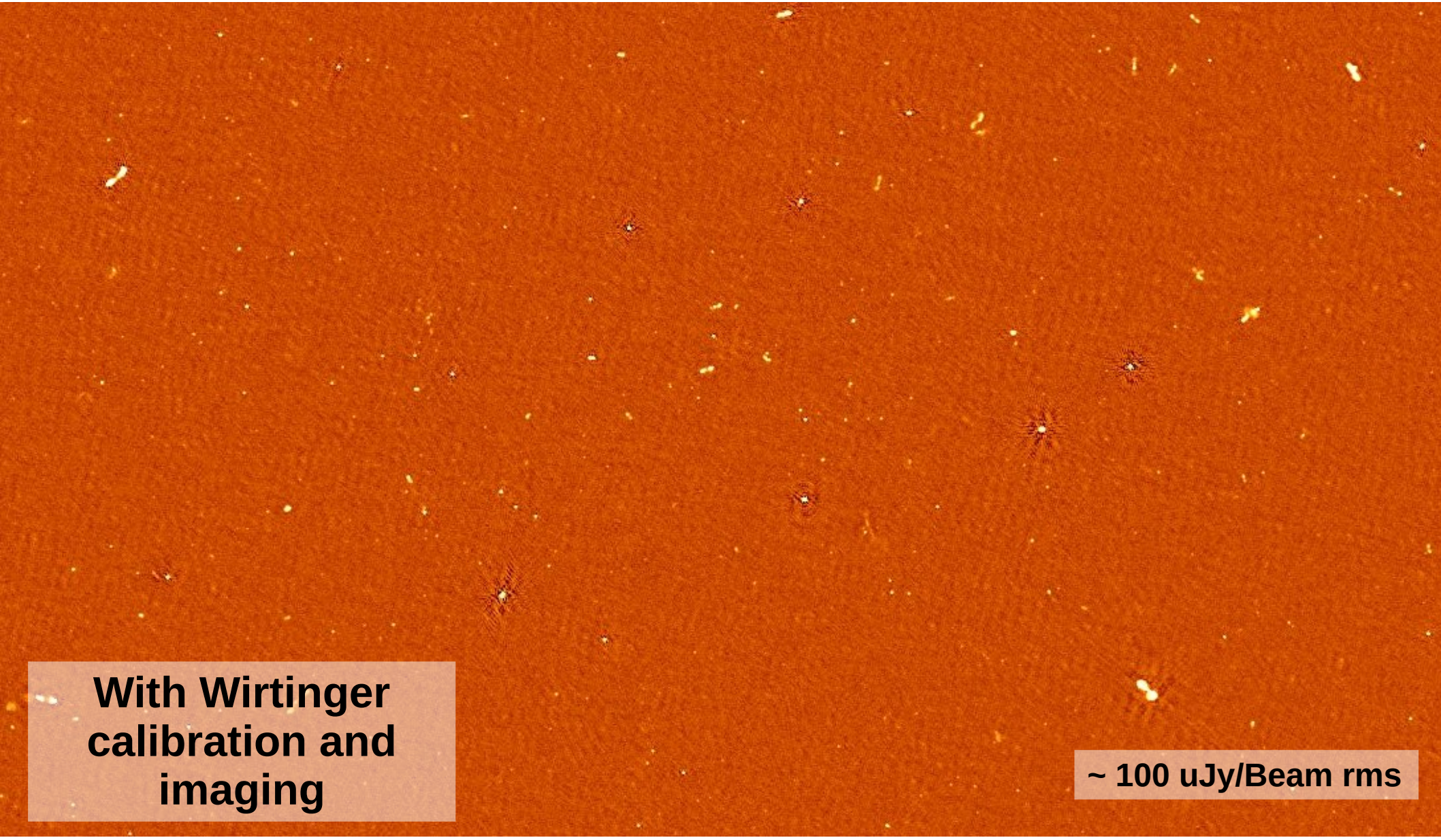
Wirtinger calibration

Tasse 14, Smirnov&Tasse15, Tasse+ 17



Wirtinger calibration

Tasse 14, Smirnov&Tasse15, Tasse+ 17



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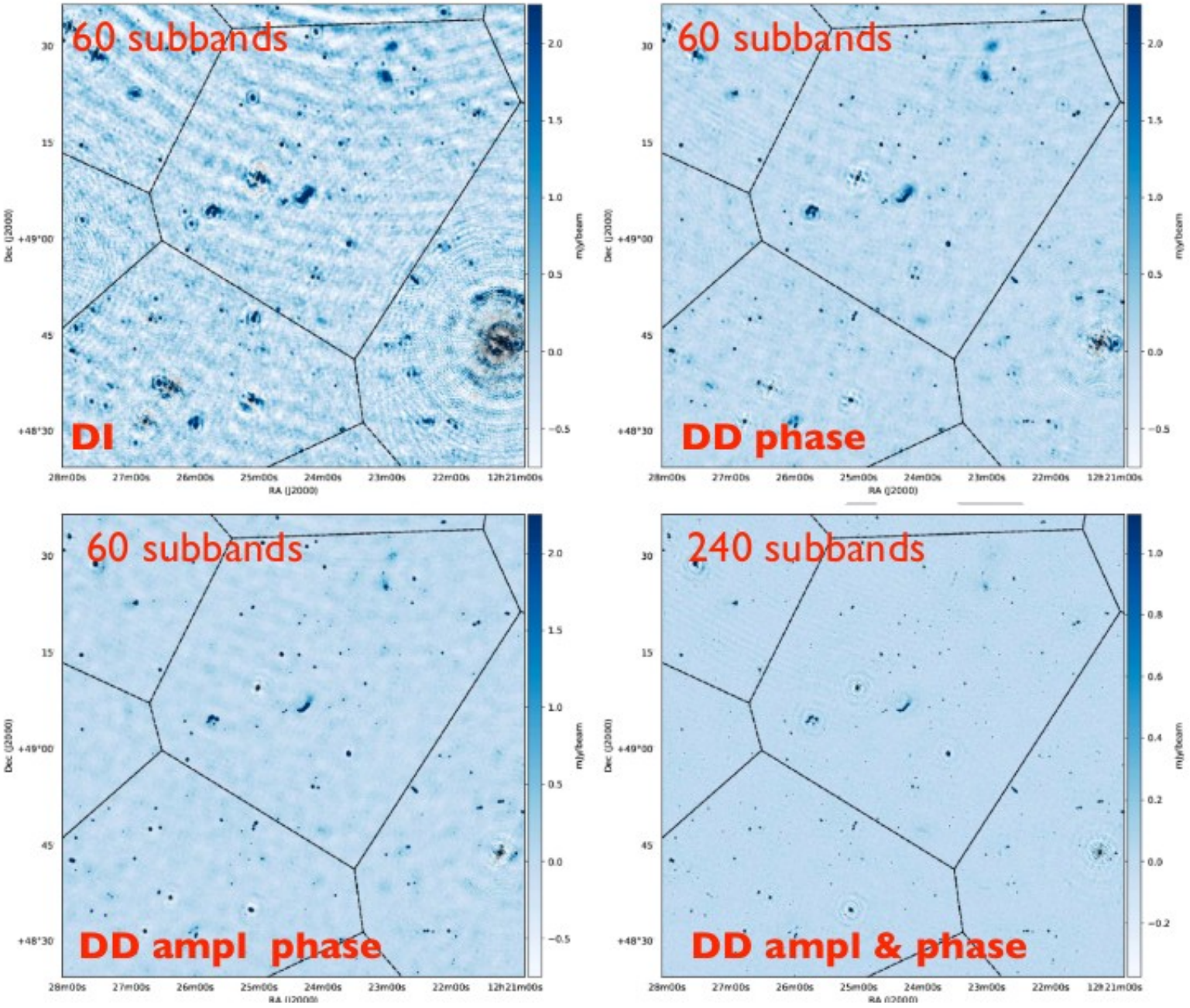
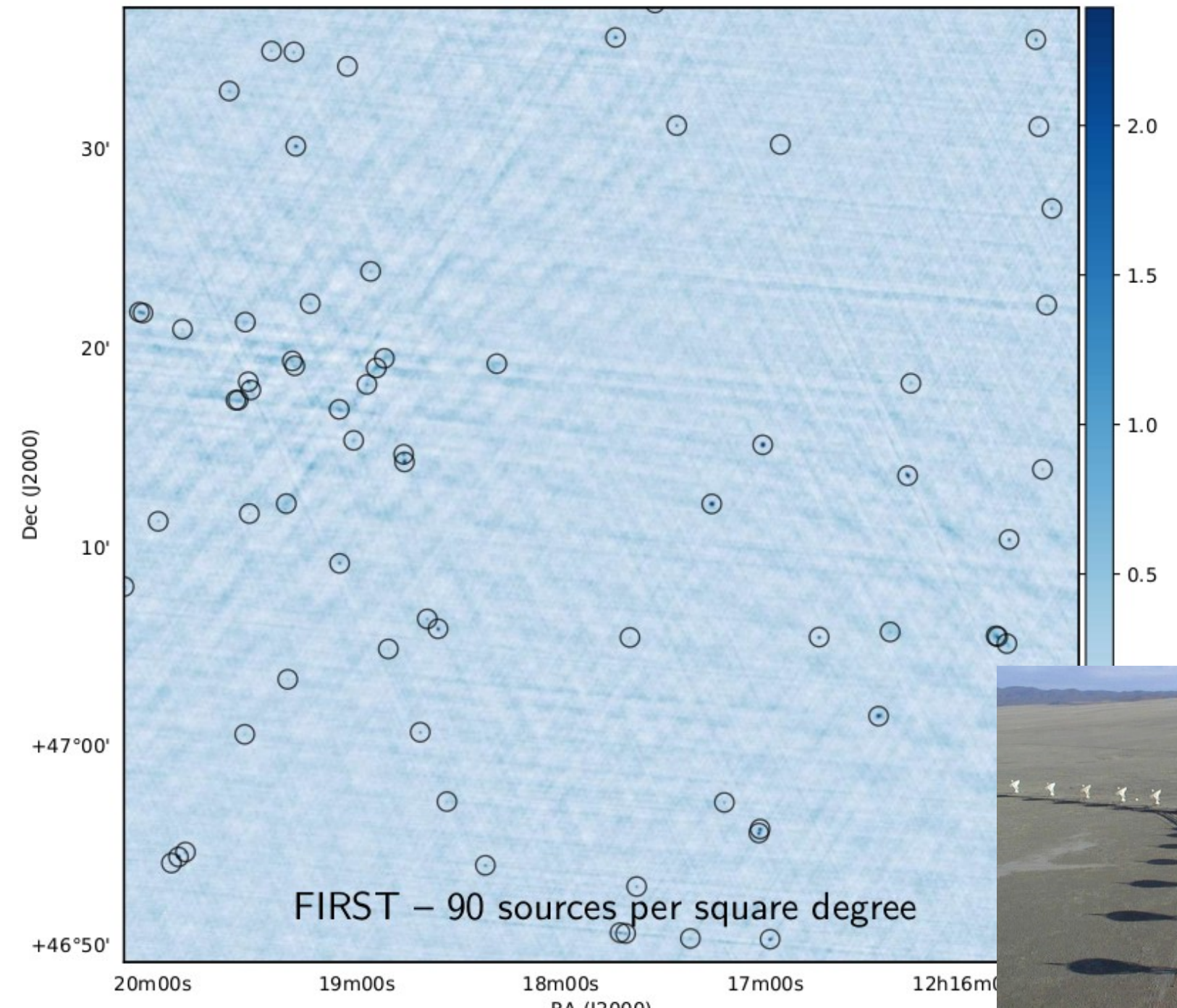


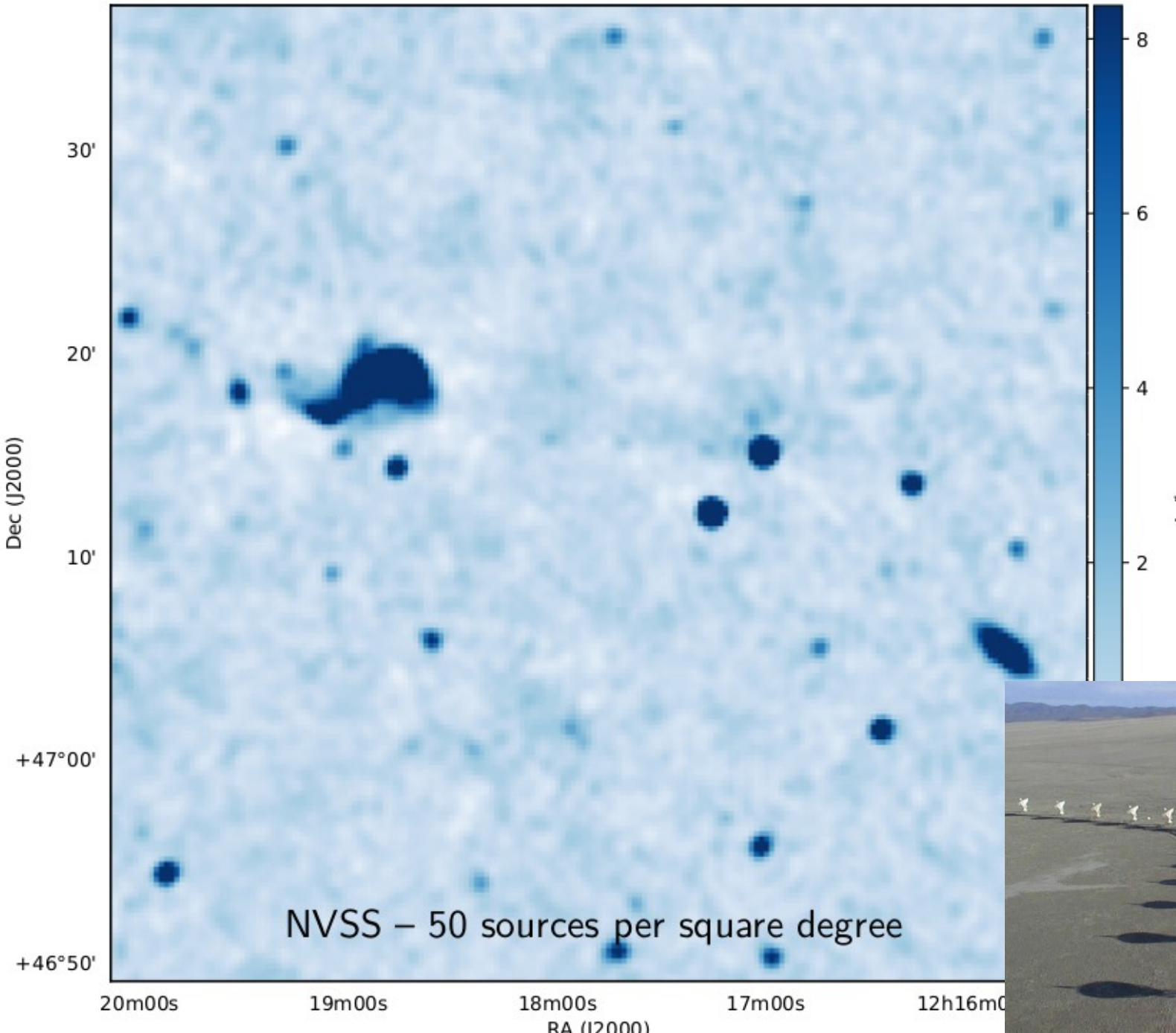
LOTSS – First Data Release



Extended configuration

VLA

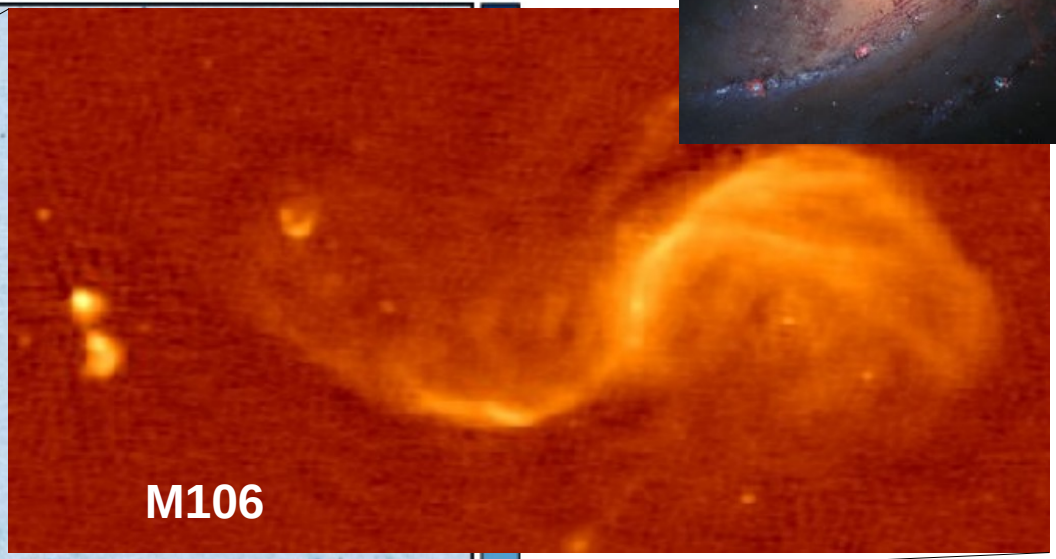
LOTSS – First Data Release

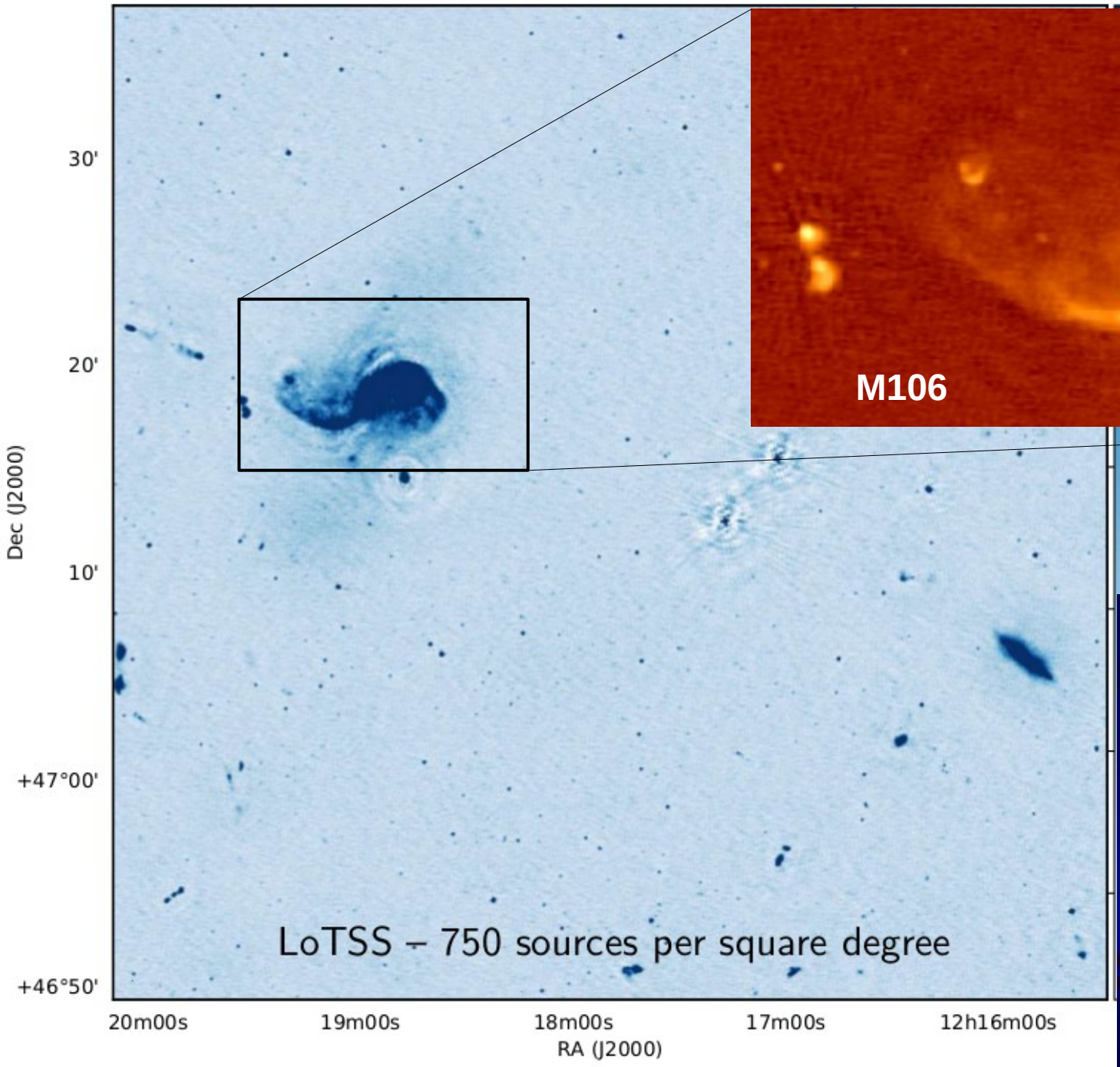


Compact configuration

VLA

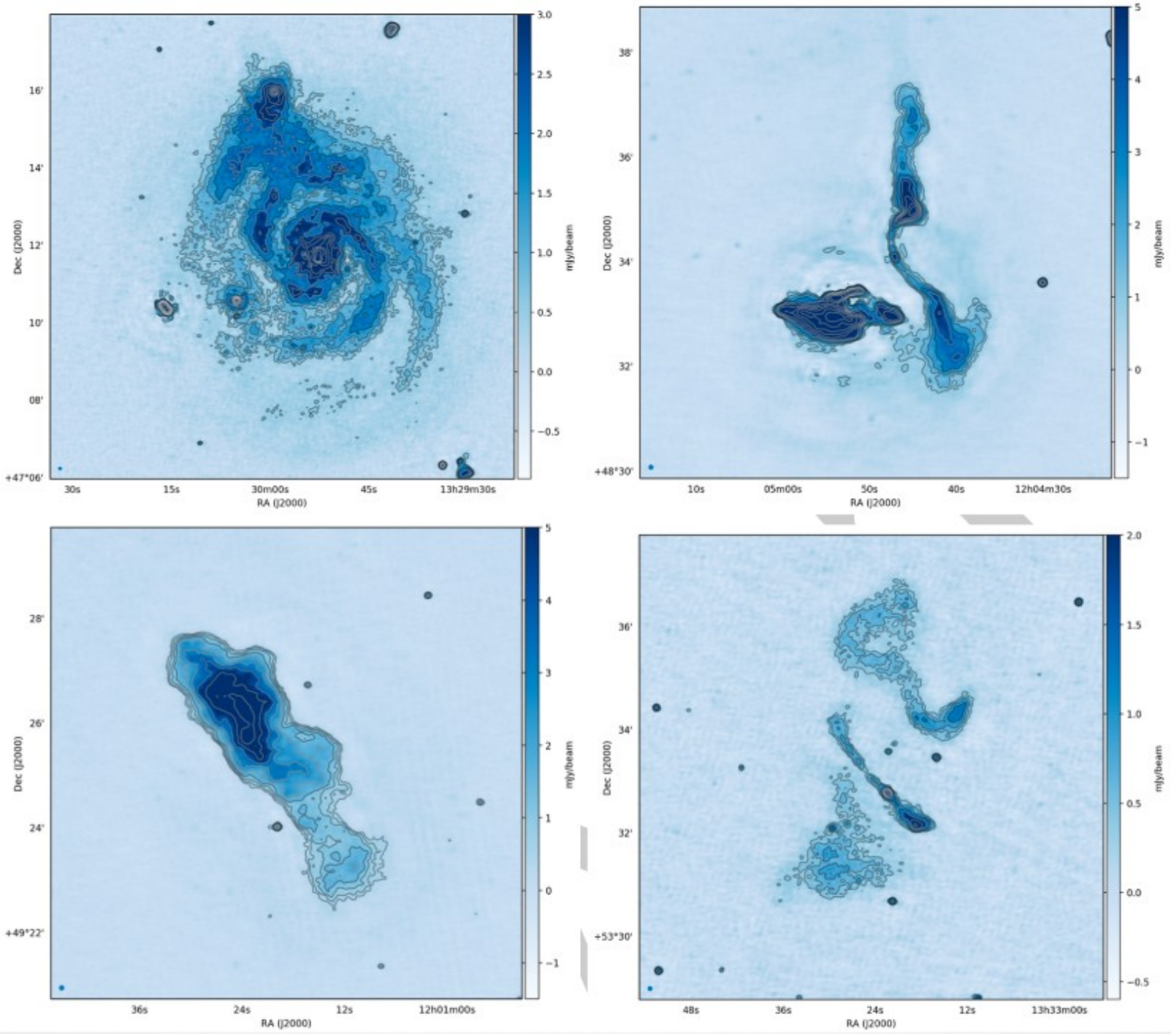
LOTSS – First Data Release





LOFAR

LOTSS – First Data Release



Session interactive

The LOFAR extragalactic surveys Key Science Project

PI: Röttgering

Core team: Best, Brüggen, Brunetti, Chyży, Conway, Haverkorn, Heald, Jackson, Jarvis, Lehnert, McKean, Miley, Morganti, Scaife, Tasse, White, Wise

The 2019 « paper splash » :

More than 25 papers published together (already on ArXiv!!)

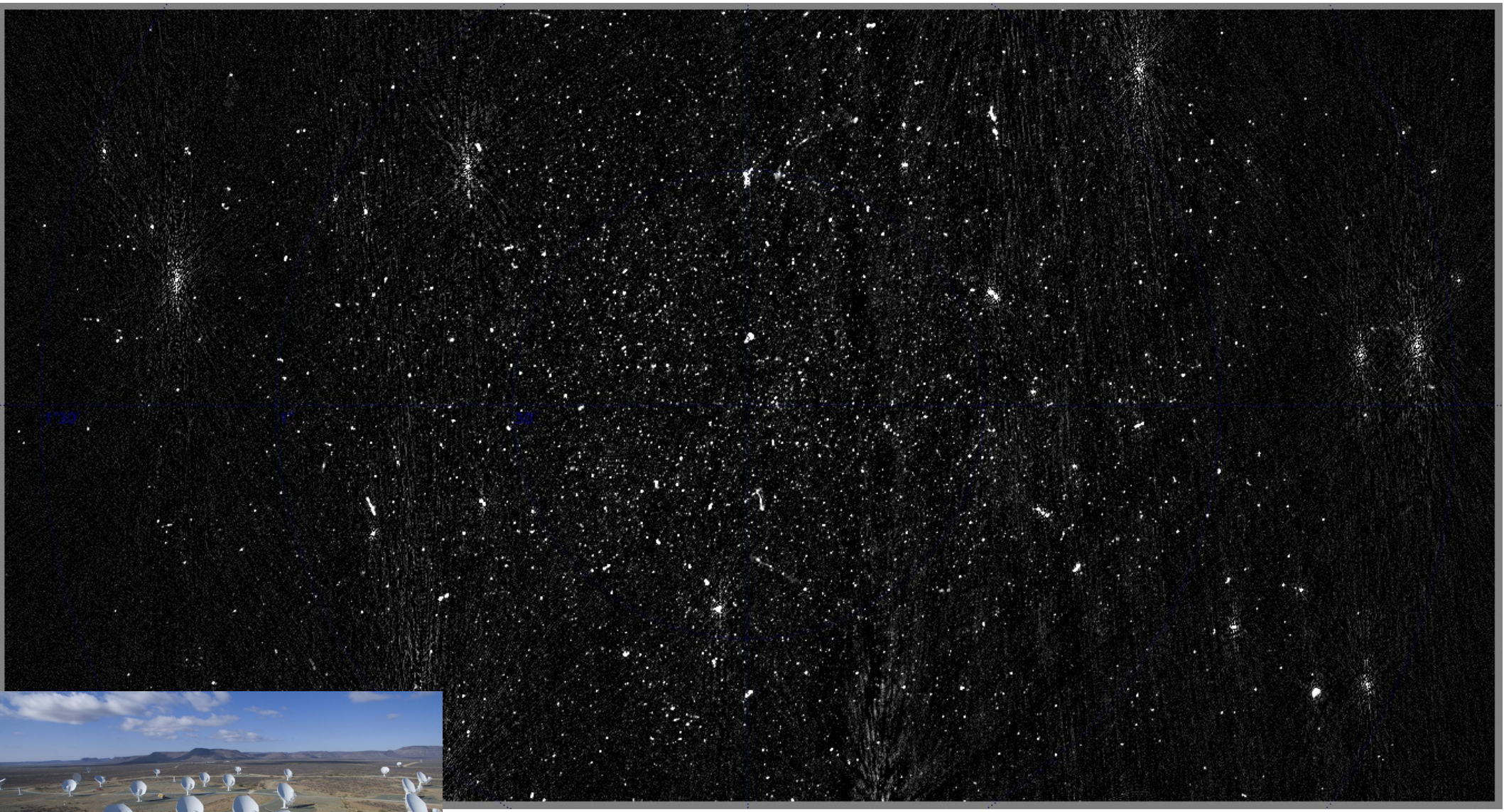
Table of papers

Title	Lead author
The LOFAR Two-metre Sky Survey -- II. First Data Release	T Shimwell
The LOFAR Two-metre Sky Survey -- III. First Data Release: Optical identifications and Value-added catalogue	W.L. Williams
The LOFAR Two-metre Sky Survey -- IV. First Data Release: Photometric redshifts and rest-frame magnitudes	K. J. Duncan
The cluster chain Abell 781 as observed with LOFAR and XMM-Newton	A. Botteon
Elucidating the radio properties of Broad Absorption Line Quasars using the LOFAR Two-metre Sky Survey	L. Morabito
Ultra steep spectrum emission in merging galaxy cluster Abell 1914	S. Mandal
LOFAR Observations of the XMM-LSS field	C. Hale
LoTSS: Radio-loud AGN in the HETDEX field	M.J. Hardcastle
Systematic effects in LOFAR data: a unified LOFAR-LBA and LOFAR-HBA calibration strategy for calibrator fields	F. de Gasperin
Signatures from a merging galaxy cluster its AGN population: LOFAR observations of Abell 1682	A.O. Clarke
The LOFAR view on the merging galaxy cluster Abell 2069	A. Drabent
The low-frequency radio–SFR relation in nearby galaxies at 1-kpc scale with LOFAR	V. Heesen
Restarting radio galaxies in the HETDEX Spring field	V. H. Mahatma
Blazars in the LOFAR Two-Metre Sky Survey First Data Release	S. Mooney
A double radio halo in Abell 1430	C Dumba
A LOFAR study of non-merging massive galaxy clusters	F. Savini
LoTSS/HETDEX: Optical quasars -I. Low-frequency radio properties of optically selected quasars	G. Gurkan
The intergalactic magnetic field probed by a giant radio galaxy	S. P. O'Sullivan
The evolutionary phases of merging clusters as seen by LOFAR	A. Wilber
Exploring the properties of low-frequency radio emission and magnetic fields of a sample of compact galaxy groups using the LOFAR Two-Metre Sky Skurvey (LoTSS)	B.Nikiel-Wroczyński
CHANG-ES XIV: A LOFAR and JVLA View of the Star-forming Galaxy NGC 3556	A. Miskolczi
Radio observations of the merging galaxy cluster Abell 520	D. N. Hoang
A LOFAR view on the merging galaxy cluster Abell 2146	D. N. Hoang
The LoTSS view of radio-AGN in the local Universe. The most massive galaxies are always switched on	J. Sabater
LOFAR first look at the giant radio galaxy 3C 236	A. Shulevski

Application à MeerKAT

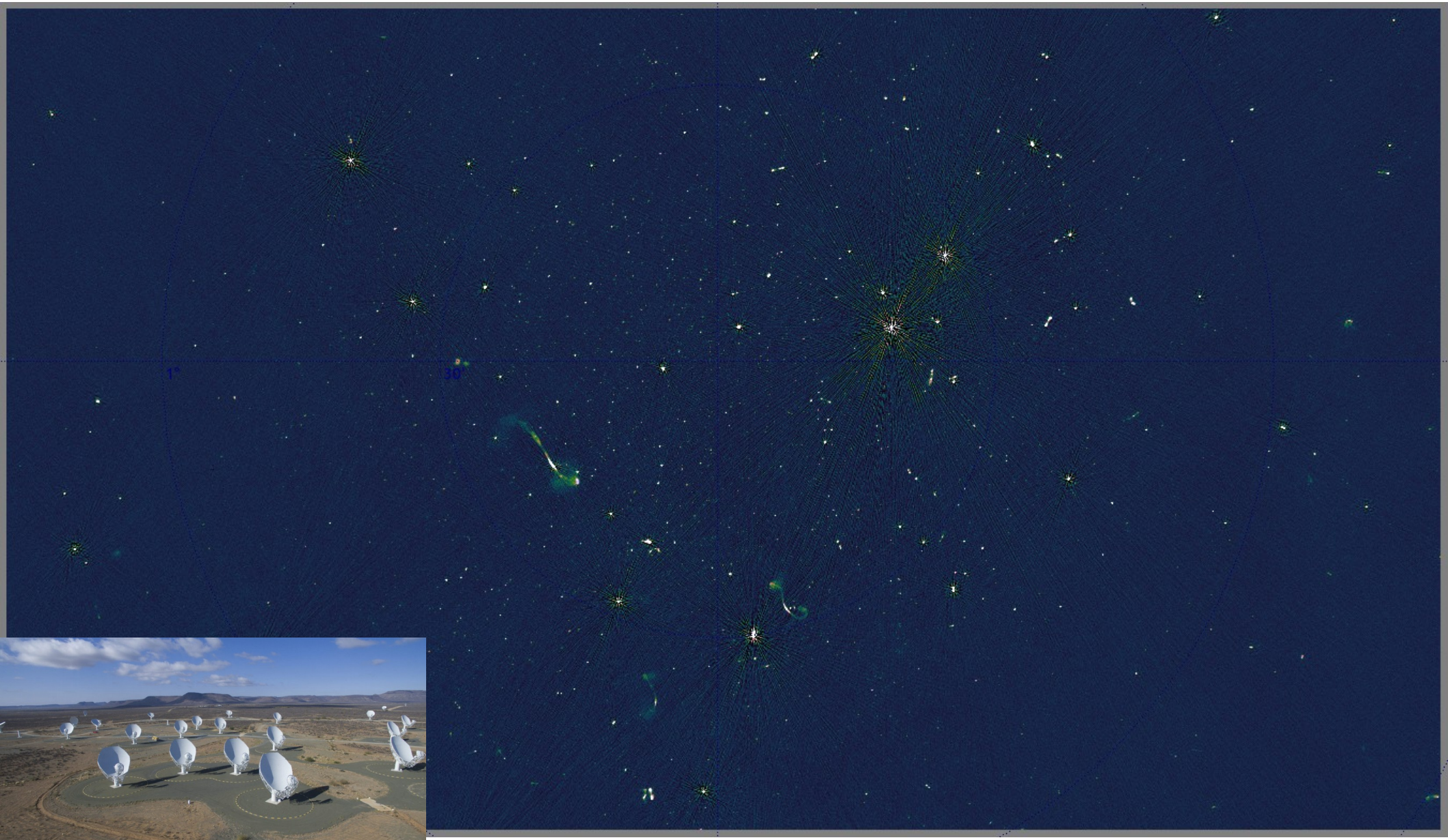
COSMOS field with kMS/DDF

Credit : **Ian Heywood** for
MeerKAT/Mightee collaboration



Chandra Deep Field South with kMS/DDF

Credit : **Ian Heywood** for MeerKAT/Mightee collaboration




Merci !