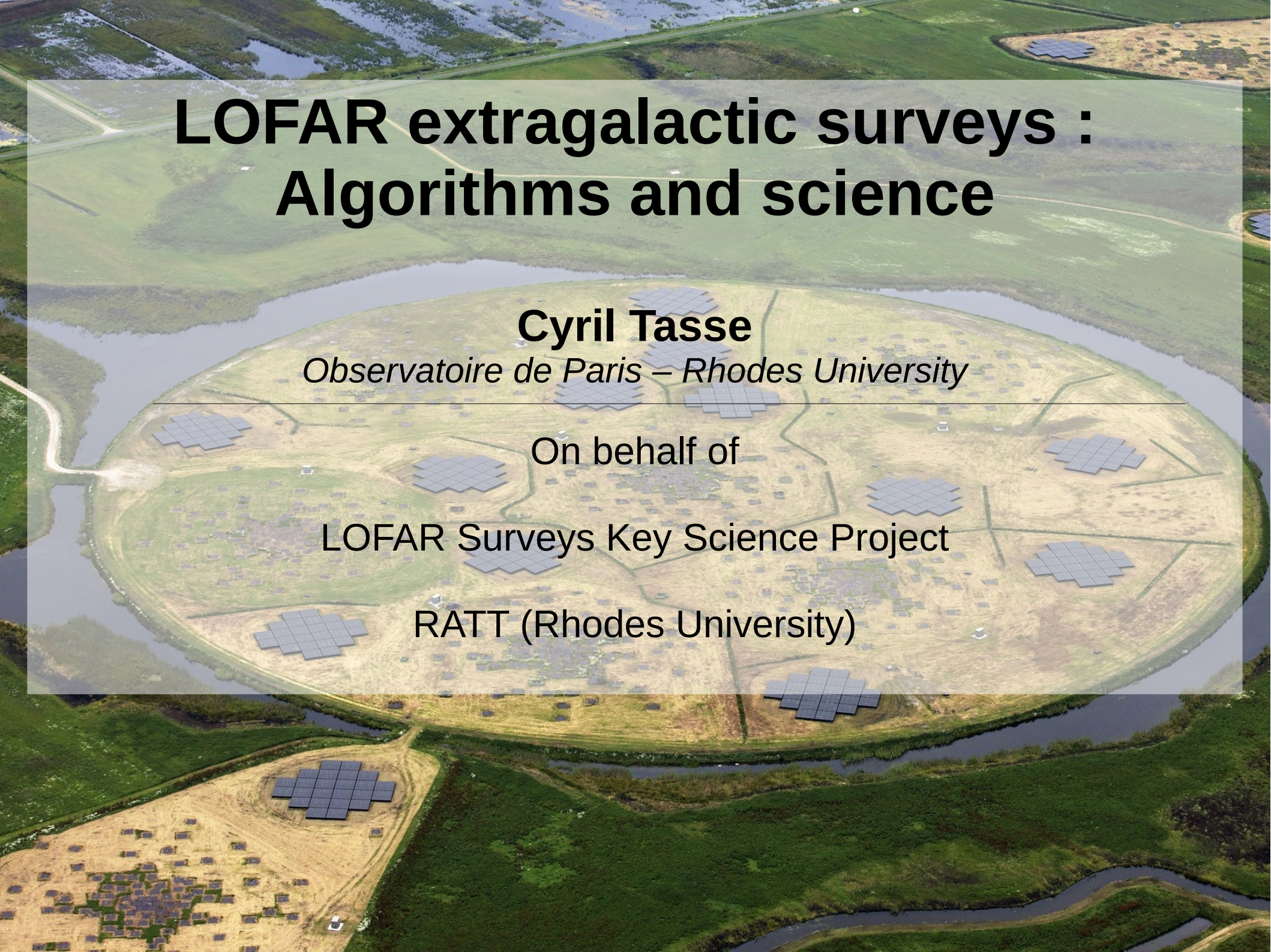


LOFAR extragalactic surveys : Algorithms and science

Cyril Tasse

Observatoire de Paris – Rhodes University

On behalf of

LOFAR Surveys Key Science Project

RATT (Rhodes University)

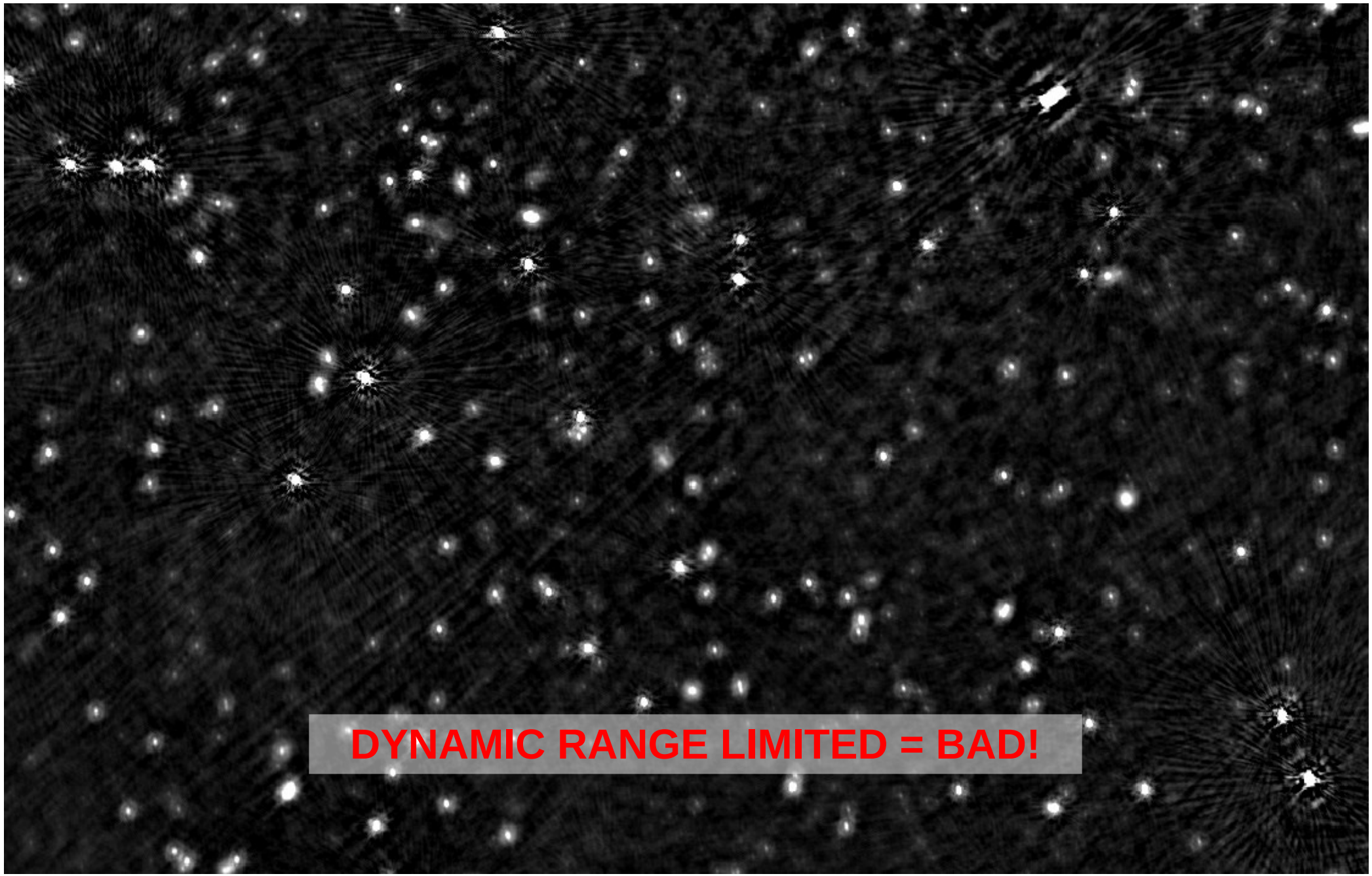
Layout

- LOFAR:
  - Problems
  - Algorithms for post-processing adaptative optics
- Extragalactic Surveys KSP
  - Surveys
  - Targetted observations

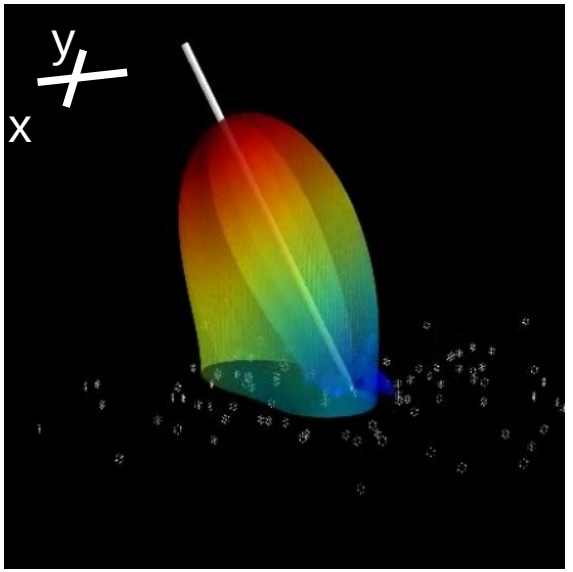
LOFAR

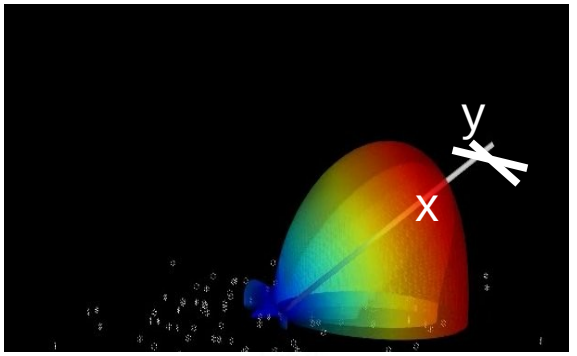
Roberto Pizzo

3C295 Observation (110-190 MHz)



… When Direction Dependent Effects (DDE) become a problem : Beam

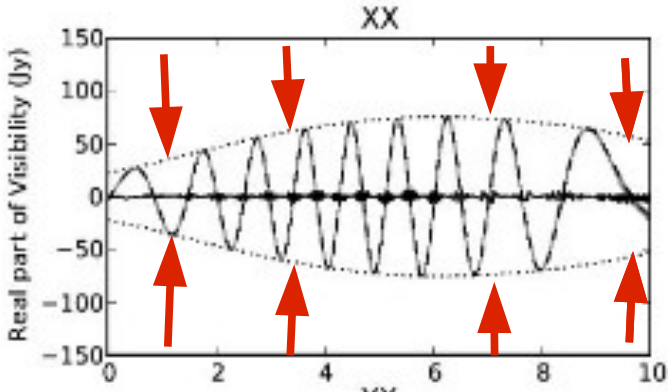




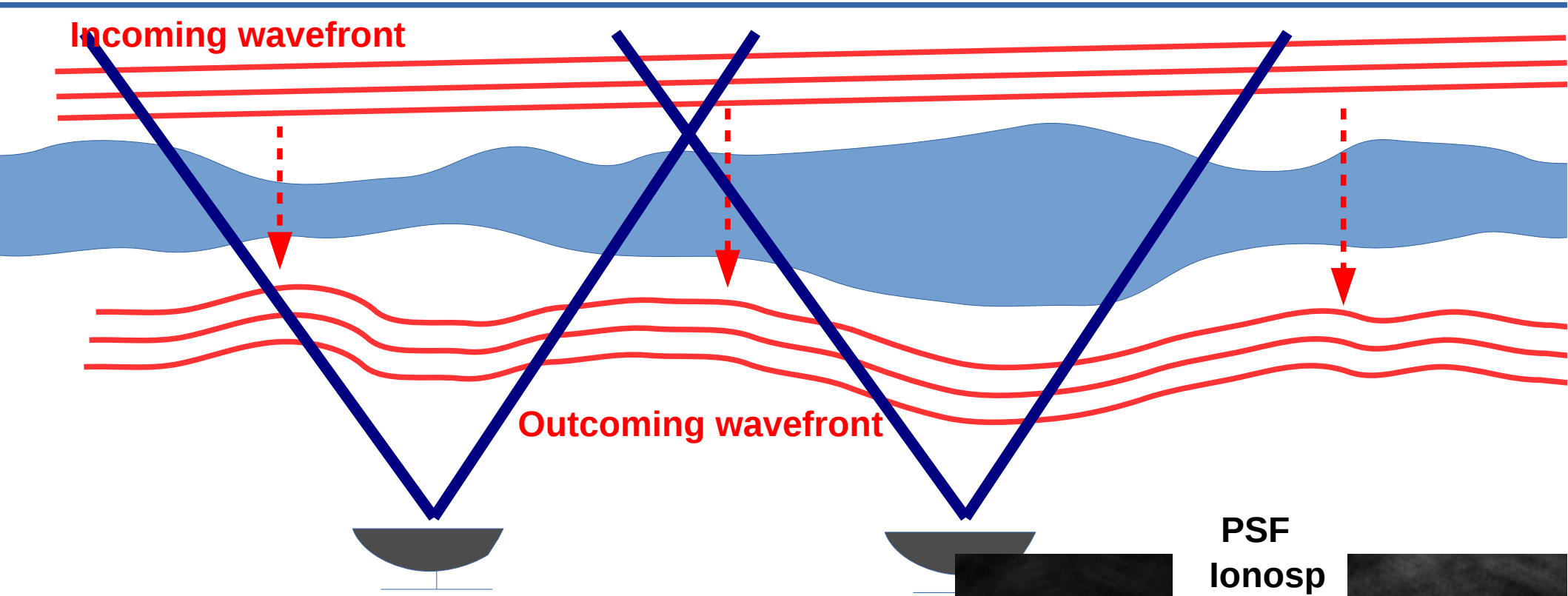
LOFAR stations are phased arrays

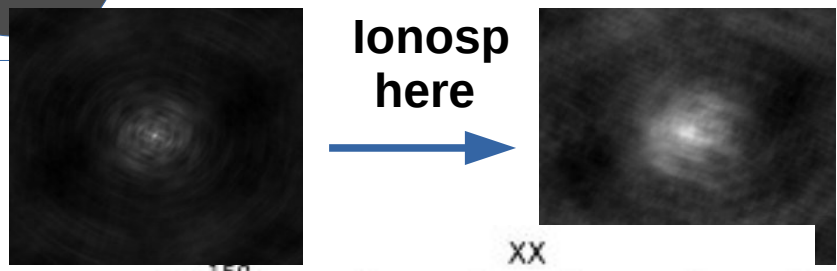
- Beam is variable in frequency and time
- Projection of the dipoles in the sky is non trivial
- Beam can be station-dependent
- Individual clock effects

--> Strong effects on polarisation



… When Direction Dependent Effects (DDE) become a problem : Ionosphere/troposphere



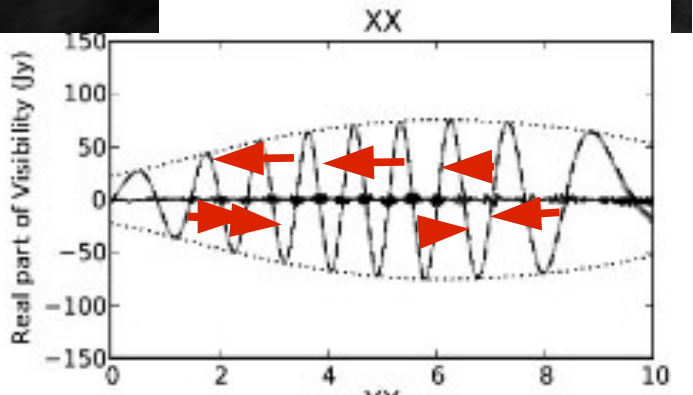


Large field of view : station, direction, time and frequency dependent

Other direction dependent effects :

- Faraday rotation

+ Effect on the polarisation



The Measurement Equation

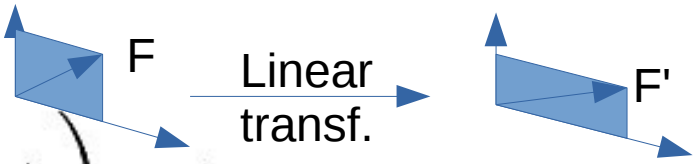
Hamaker 1996

Direction independent

Direction dependent

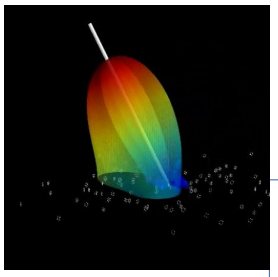
Source coherency

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



[Voltage antenna p] x [Voltage antenna q]*

Beam

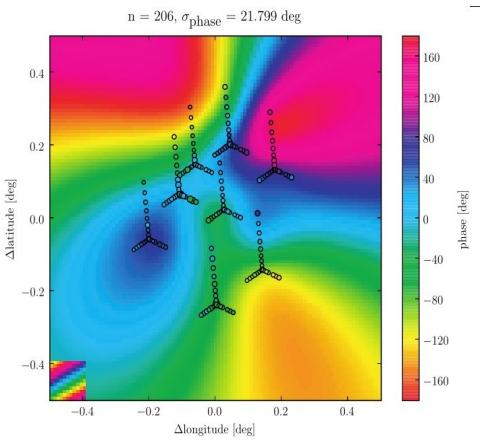


Geometrical delay
+Correlator

$$\mathrm{K}_p \mathrm{K}_q^{+} = \exp(-2i\pi\phi_{pq}) \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

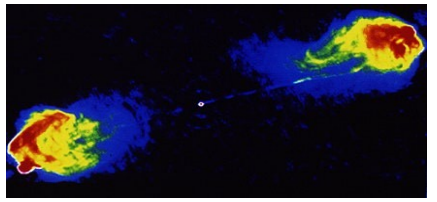
$$\phi_{pq} = u_{pq} l + v_{pq} m + w_{pq}(\sqrt{1 - l^2 - m^2} - 1)$$

Ionosphere



Van der Tol thesis

Electric field



The Measurement Equation

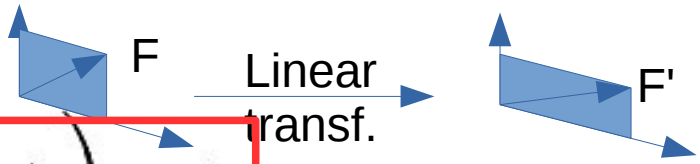
Hamaker 1996

Direction independent

Direction dependent

Source coherency

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



Finding those terms is extremely difficult and costy

The Measurement Equation

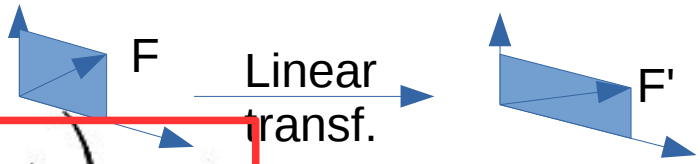
Hamaker 1996

Direction independent

Direction dependent

Source coherency

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



Finding those terms is extremely difficult and costy

- **Tasse 2014** and **Smirnov & Tasse 2015** :
  - We describe a new algorithm to solve this problem
  - Based on Wirtinger derivative

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

  - Jacobian & Hessian become sparse & compact
  - Huge algorithmic gain

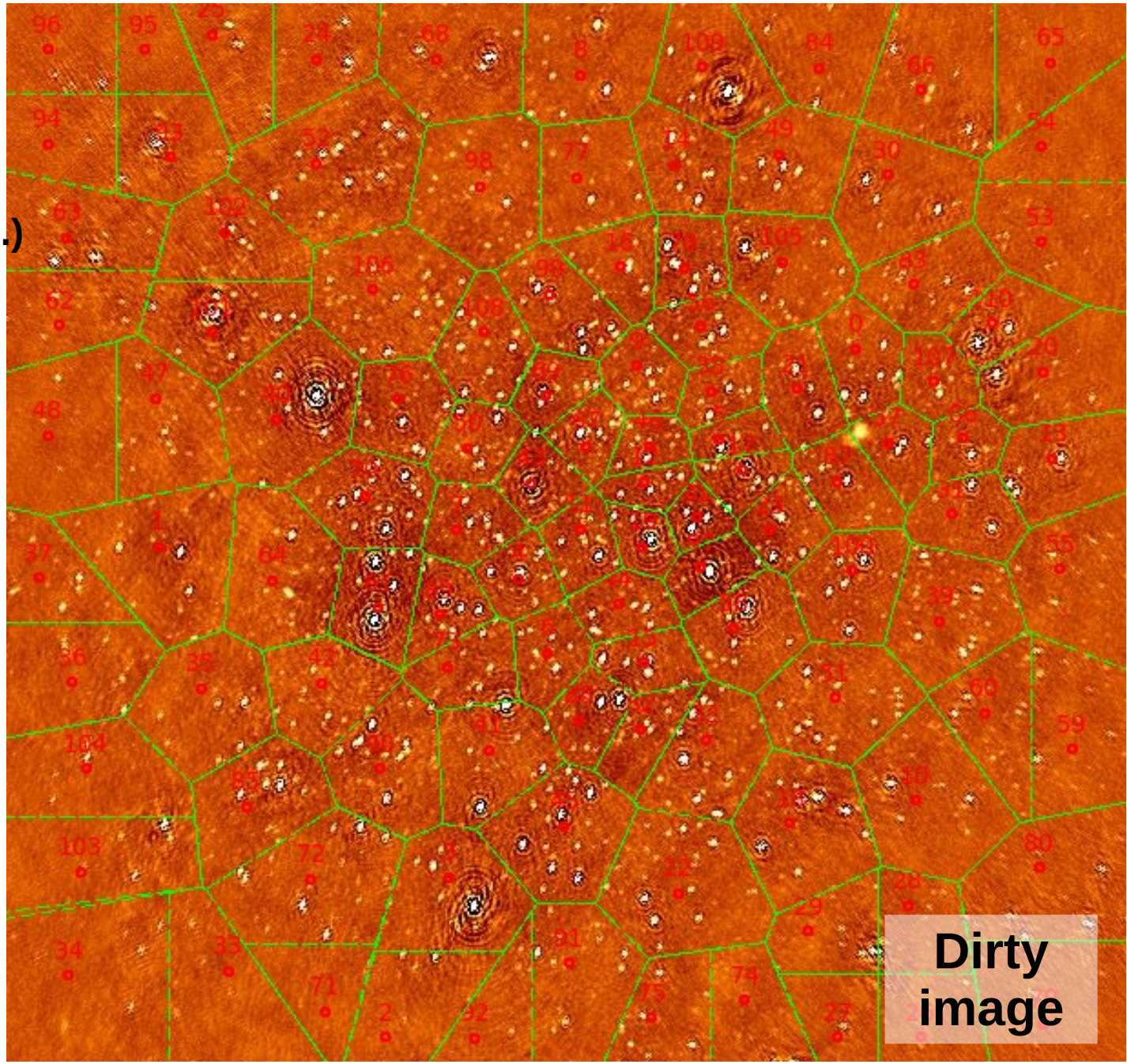
Bootes field (not selfcaled)

Precalibrated by Wendy Williams

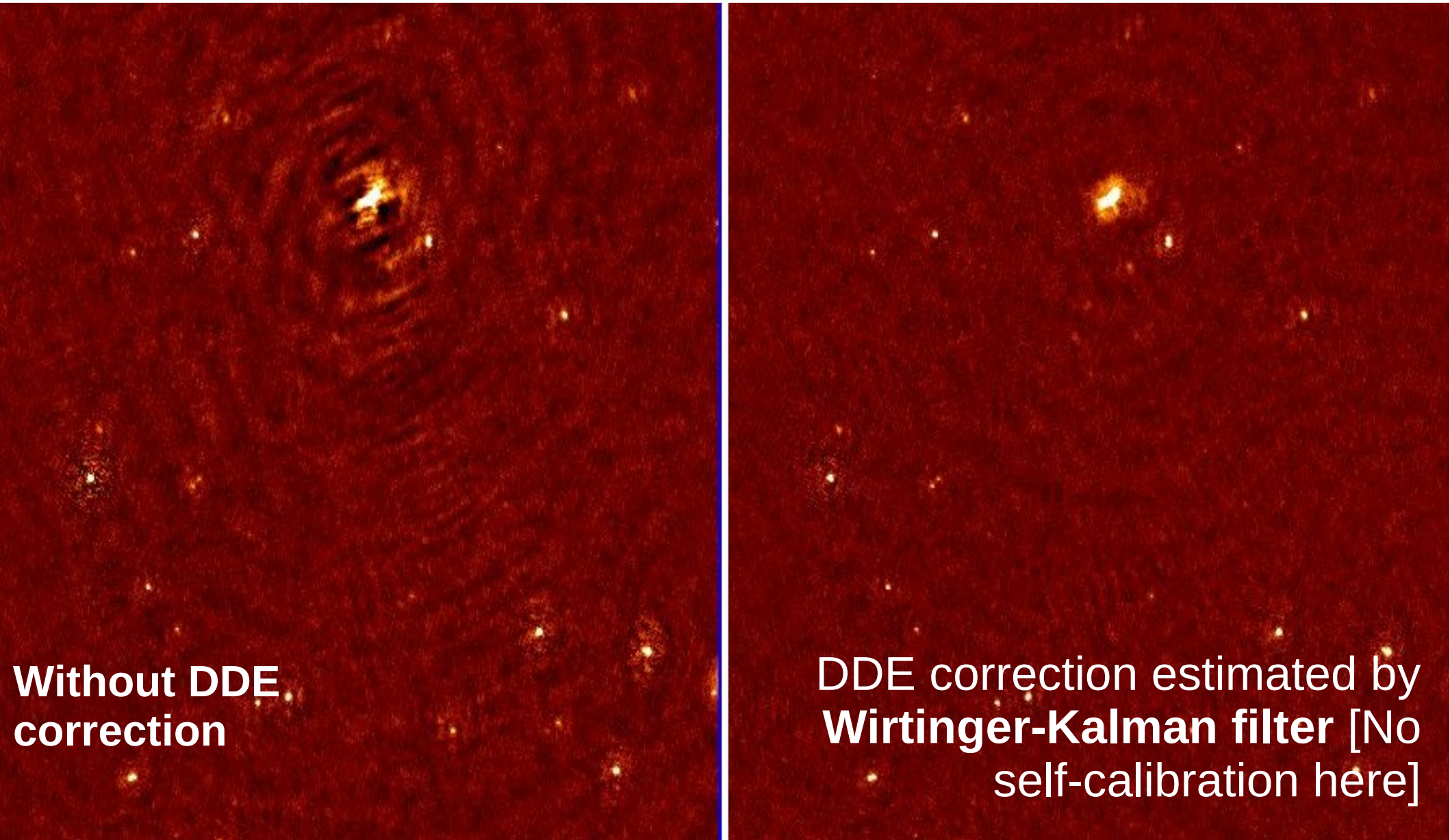
Using losoto (Gasperin et al.)
- Clock correction
- offset

DDFacet result :
- 9 degrees
- ~110 facets
- 20.000 pixels
- 2''/pixel
- 50 subbands
- ~310 uJy rms

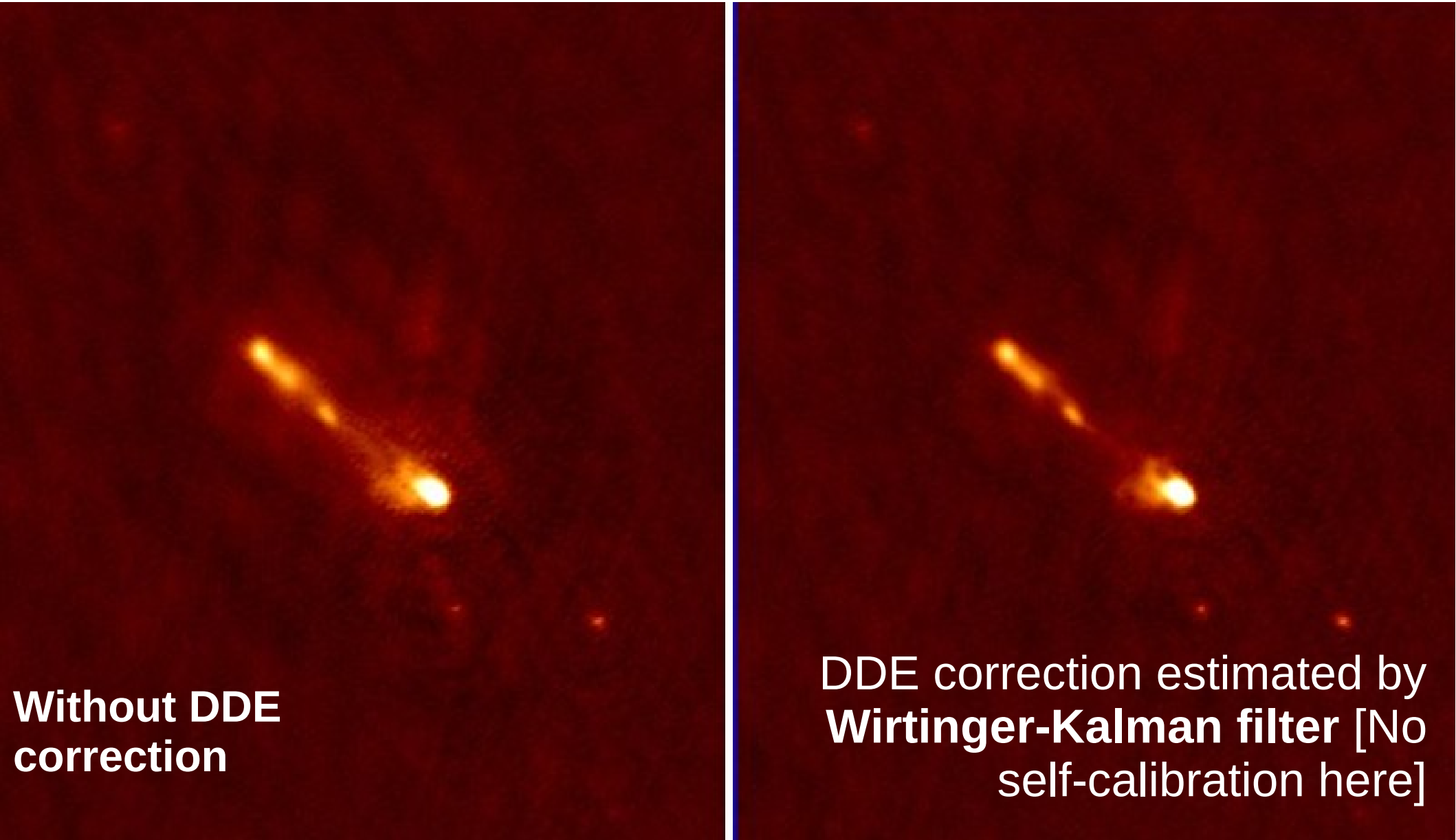
Computing time :
6 hours
(10 major cycles)



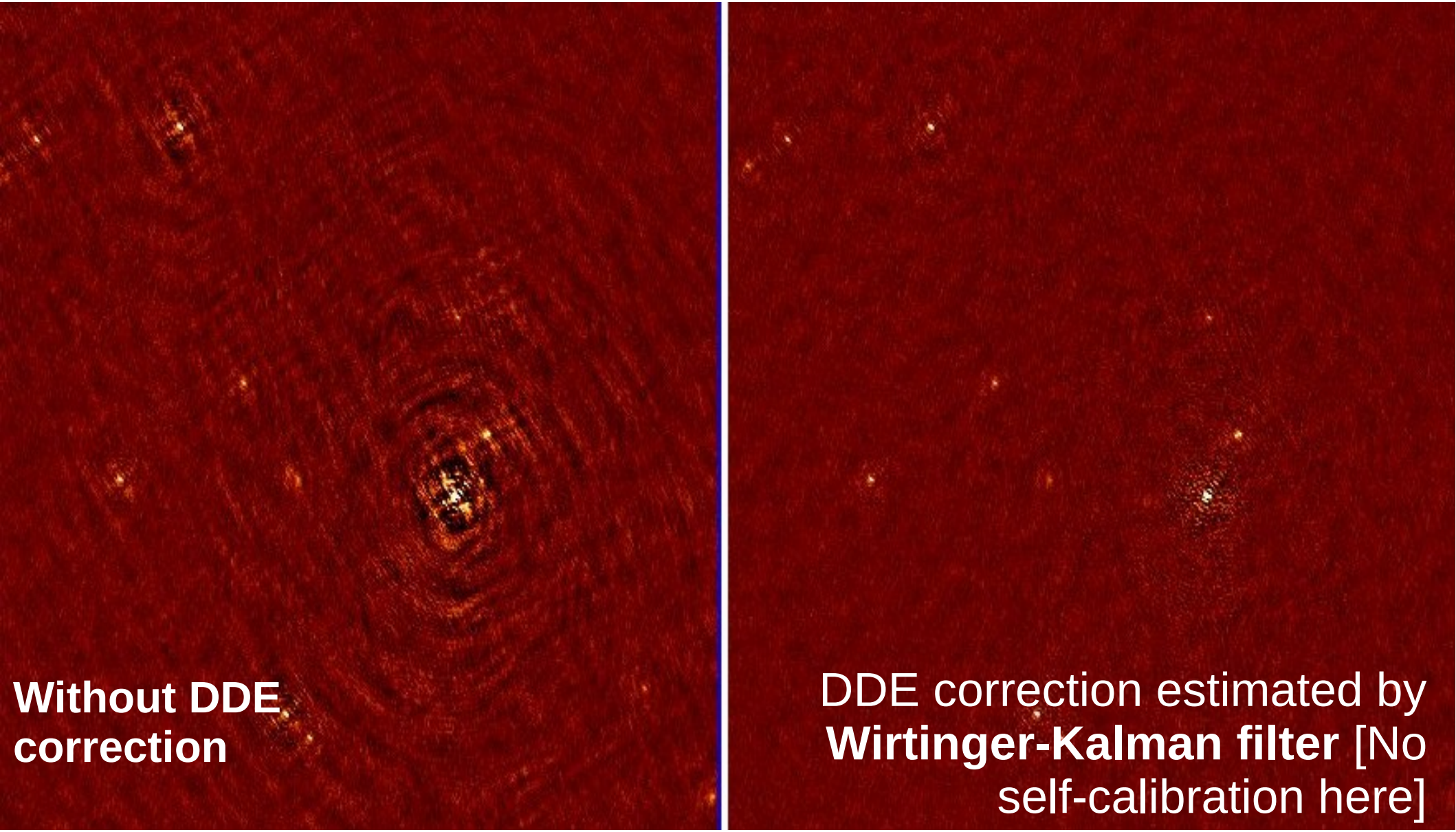
Bootes field : *WITHOUT* and *WITH* DDE correction



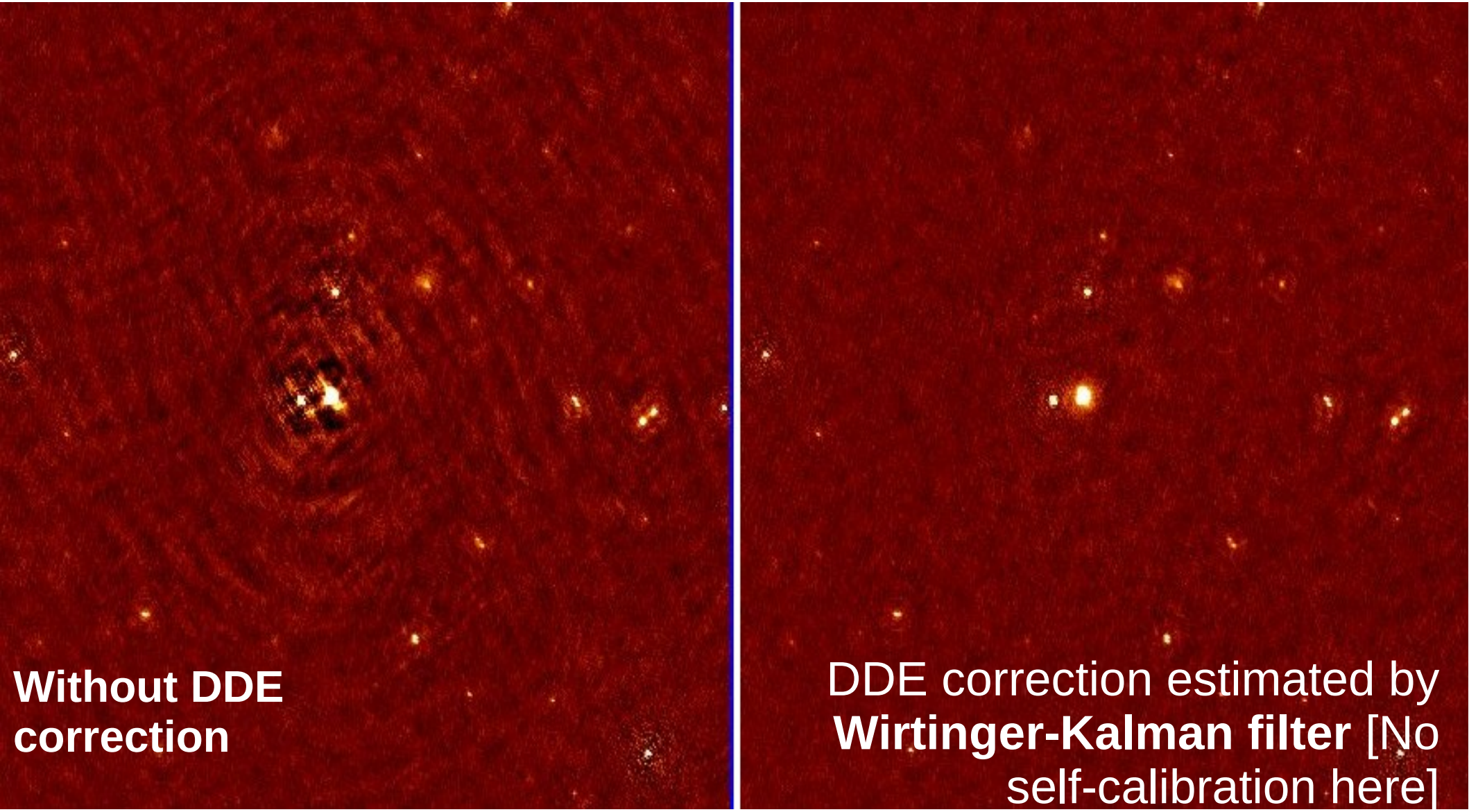
Bootes field :
WITHOUT and *WITH* DDE correction



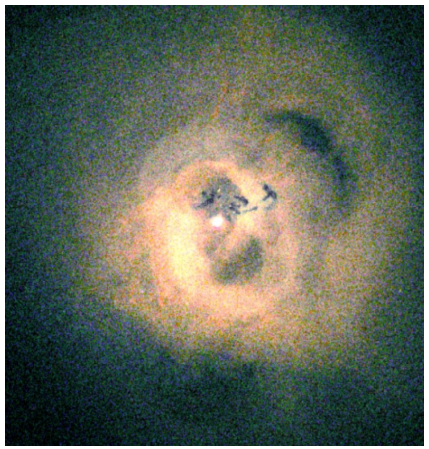
Bootes field : *WITHOUT* and *WITH* DDE correction

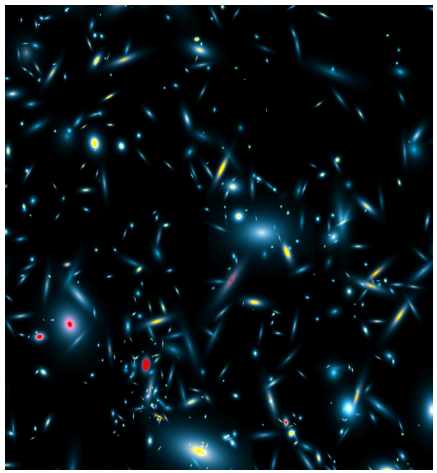


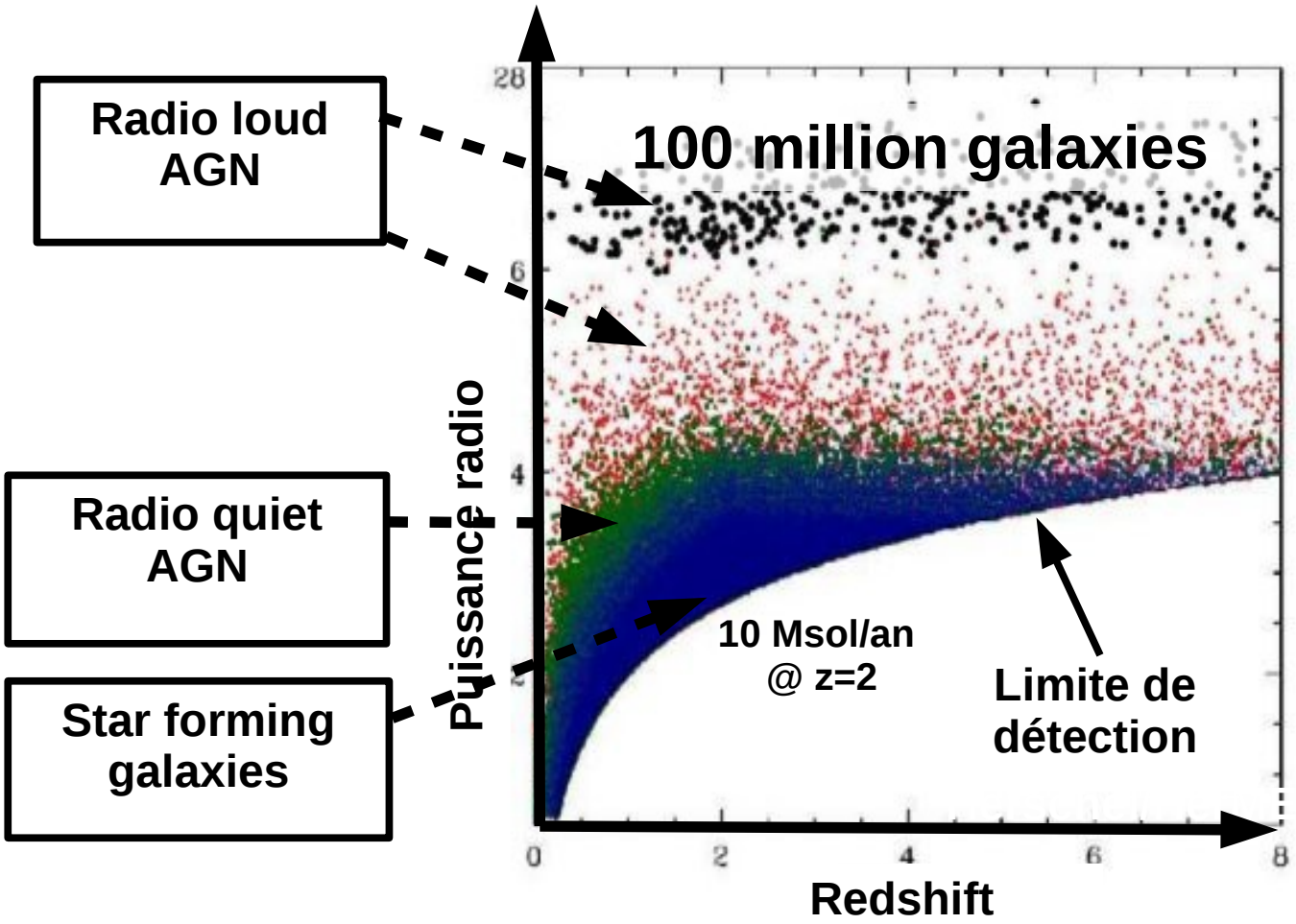
Bootes field : *WITHOUT* and *WITH* DDE correction



Galaxy formation and AGN evolution







LOFAR Tier-1 surveys

Thanks to Tim Shimwell for the slides

- **120-160 MHz : 5” resolution, 100μJy/beam sensitivity**
- **PI: Huub Röttgering**
- **Highest redshift radio sources:** George Miley
- **Clusters and cluster halo sources:**

  Gianfranco Brunetti & Marcus Brügen
- **Starforming galaxies at moderate and high redshifts:**

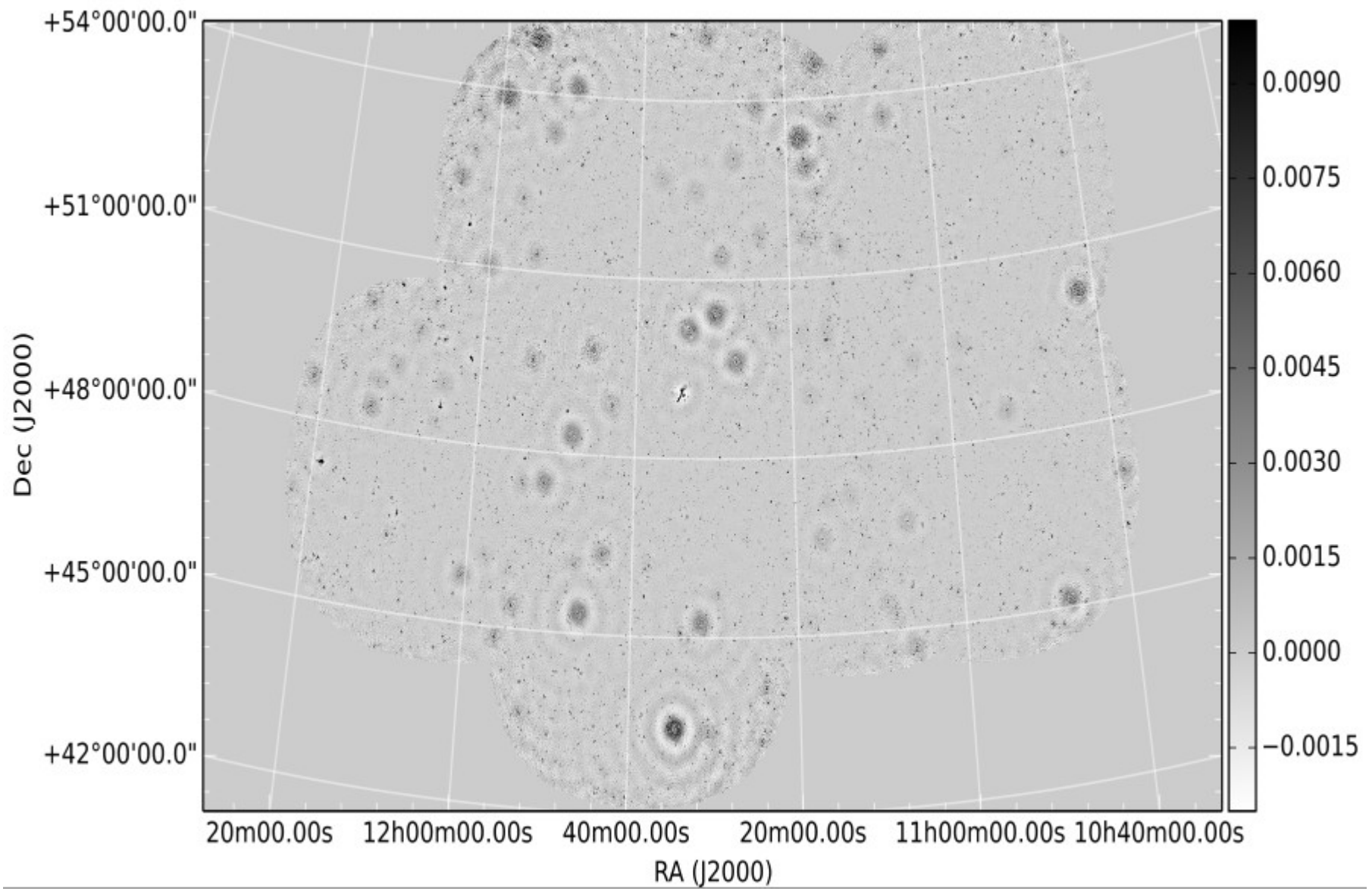
  Peter Barthel & Matt Lehnert
- **AGN at moderate redshift:** Philip Best
- **Detailed studies of low-redshift AGN:**

  Raffaella Morganti
- **Nearby Galaxies:**

  Krzysztof Chyzy & John Conway
- **Galactic radio sources:** Glenn White
- **Cosmological studies:** Matt Jarvis

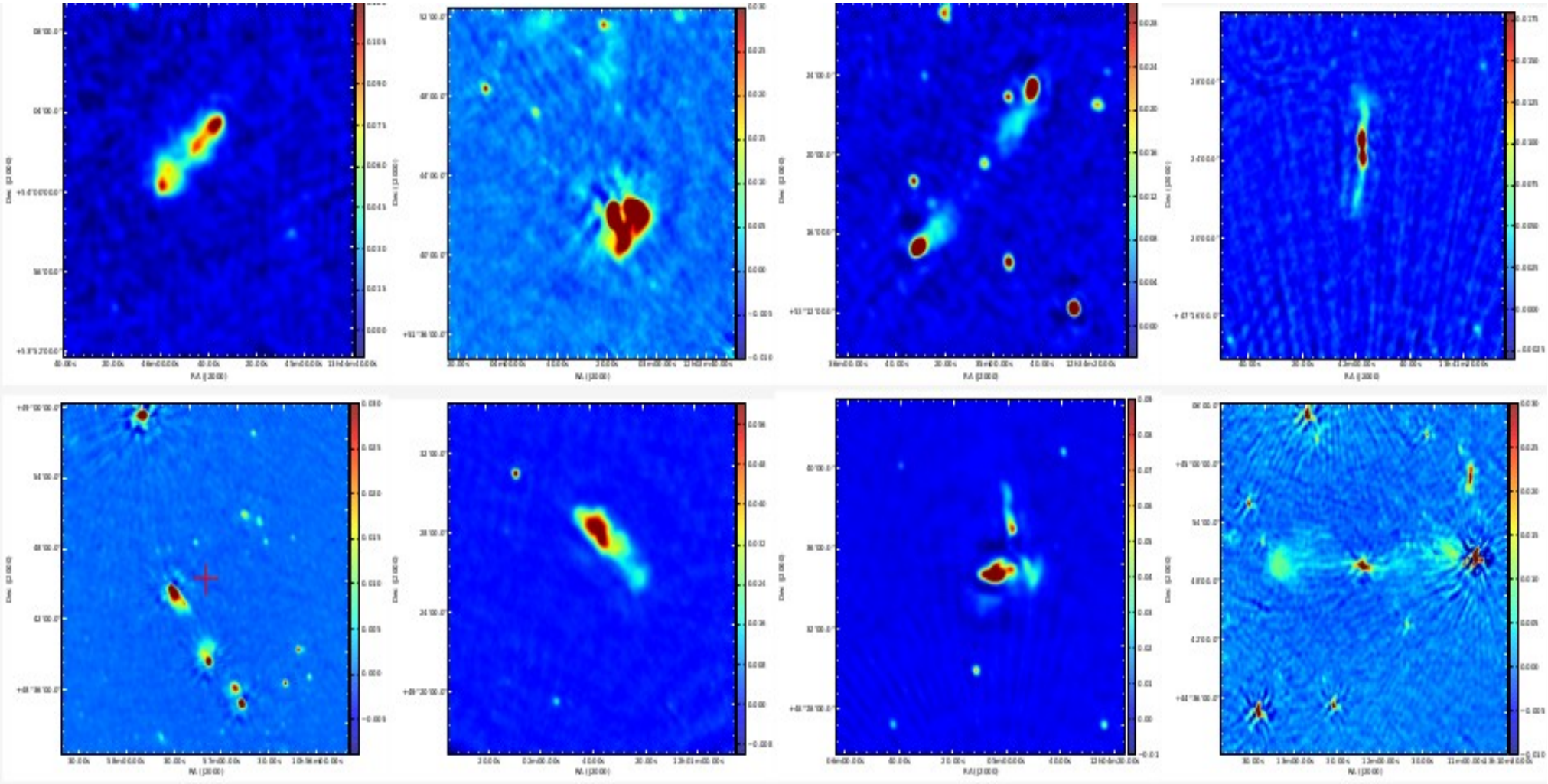
Mosaicing

Thanks to Tim Shimwell for the slides



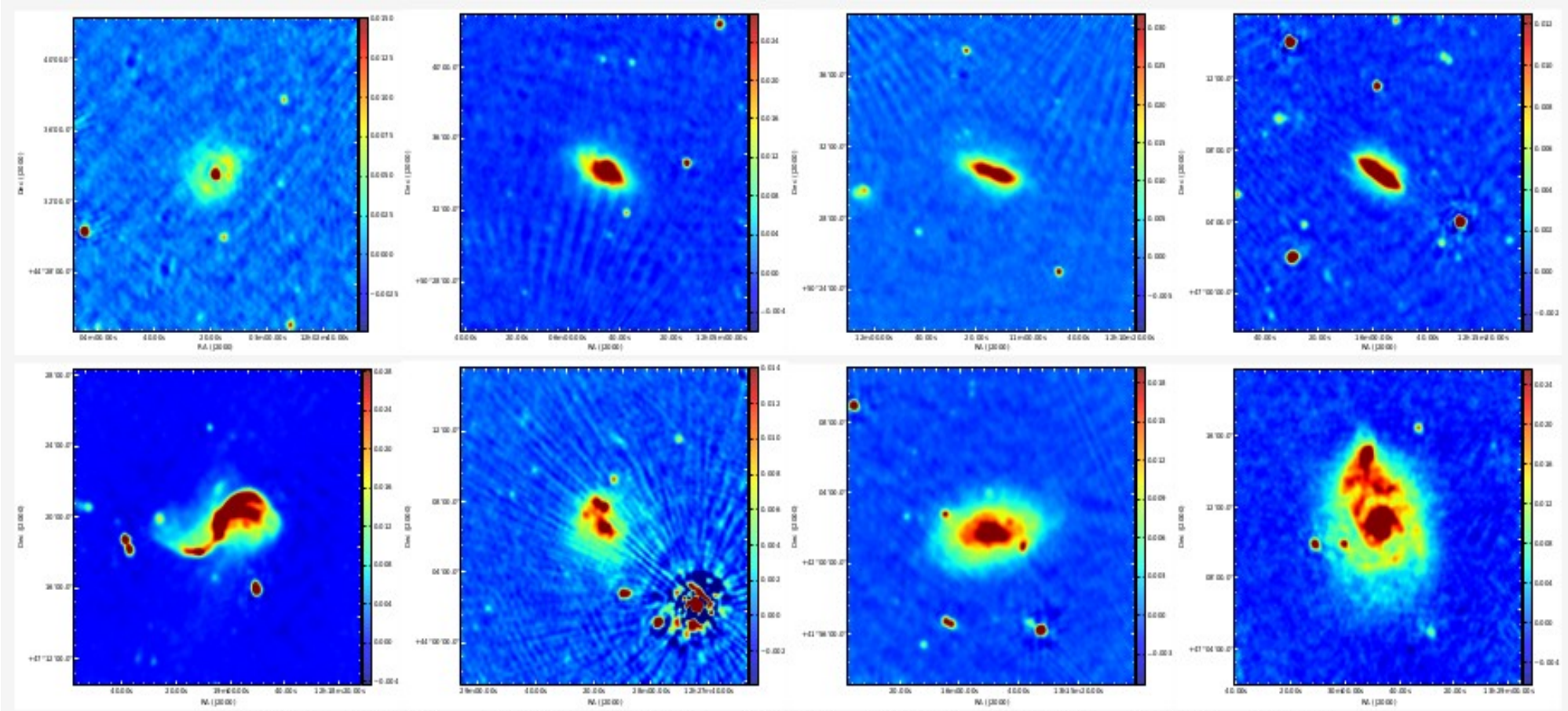
Jets

Thanks to Tim Shimwell for the slides



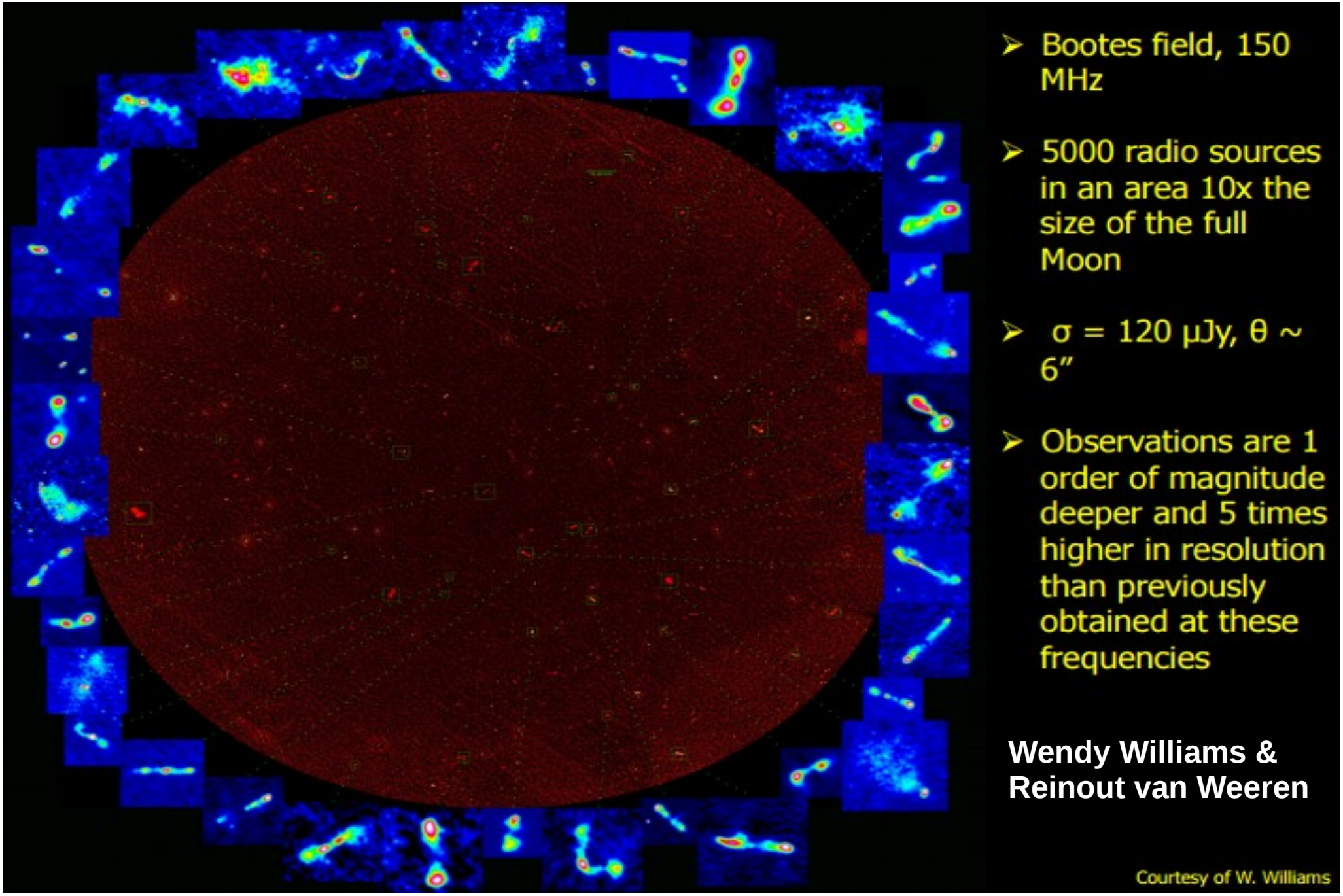
Nearby galaxies

Thanks to Tim Shimwell for the slides

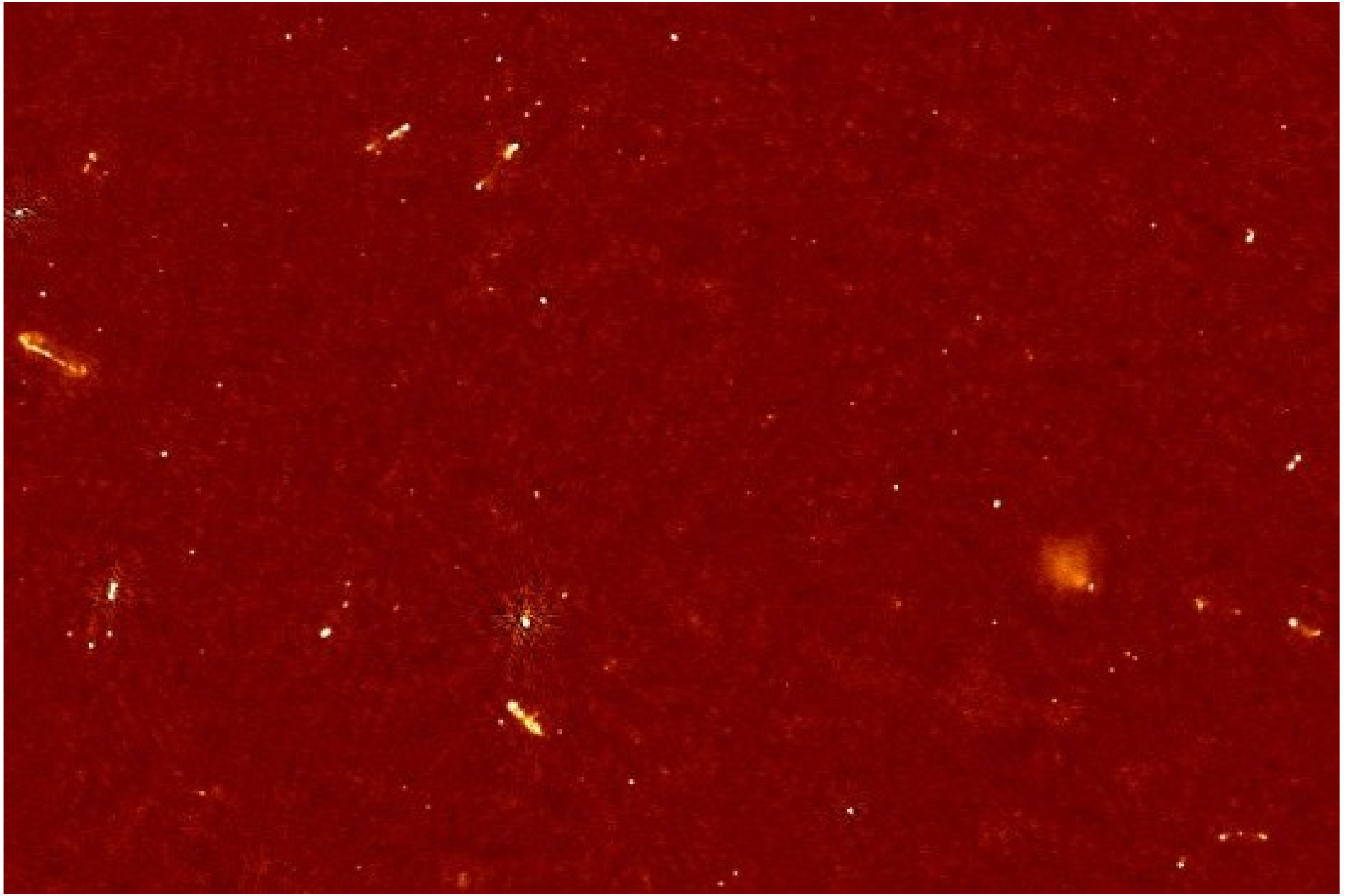


NGC 4051, 4088, 4157, 4217, 4258, 4449, 5055, 5194

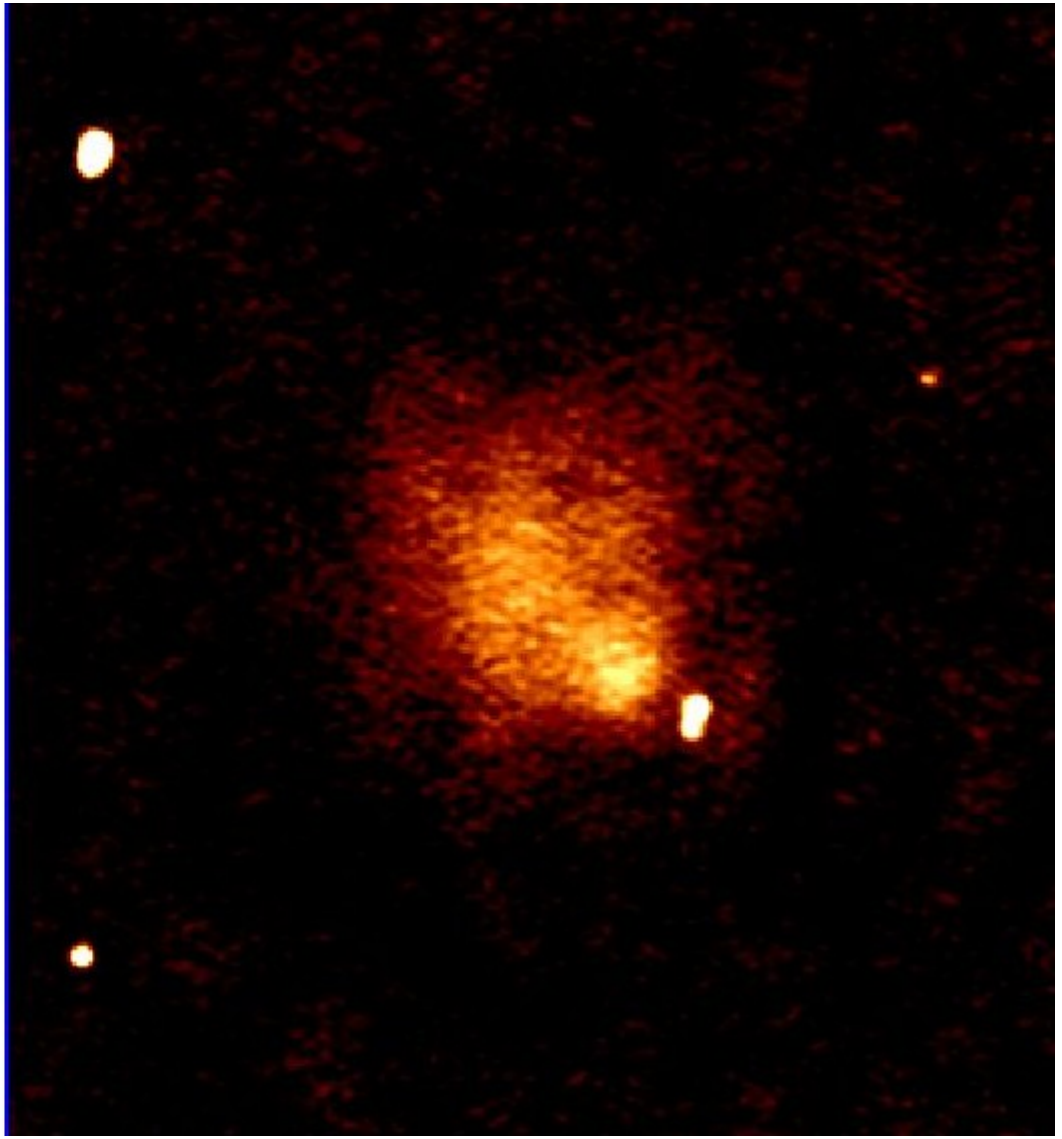
Bootes field 8-hour integration



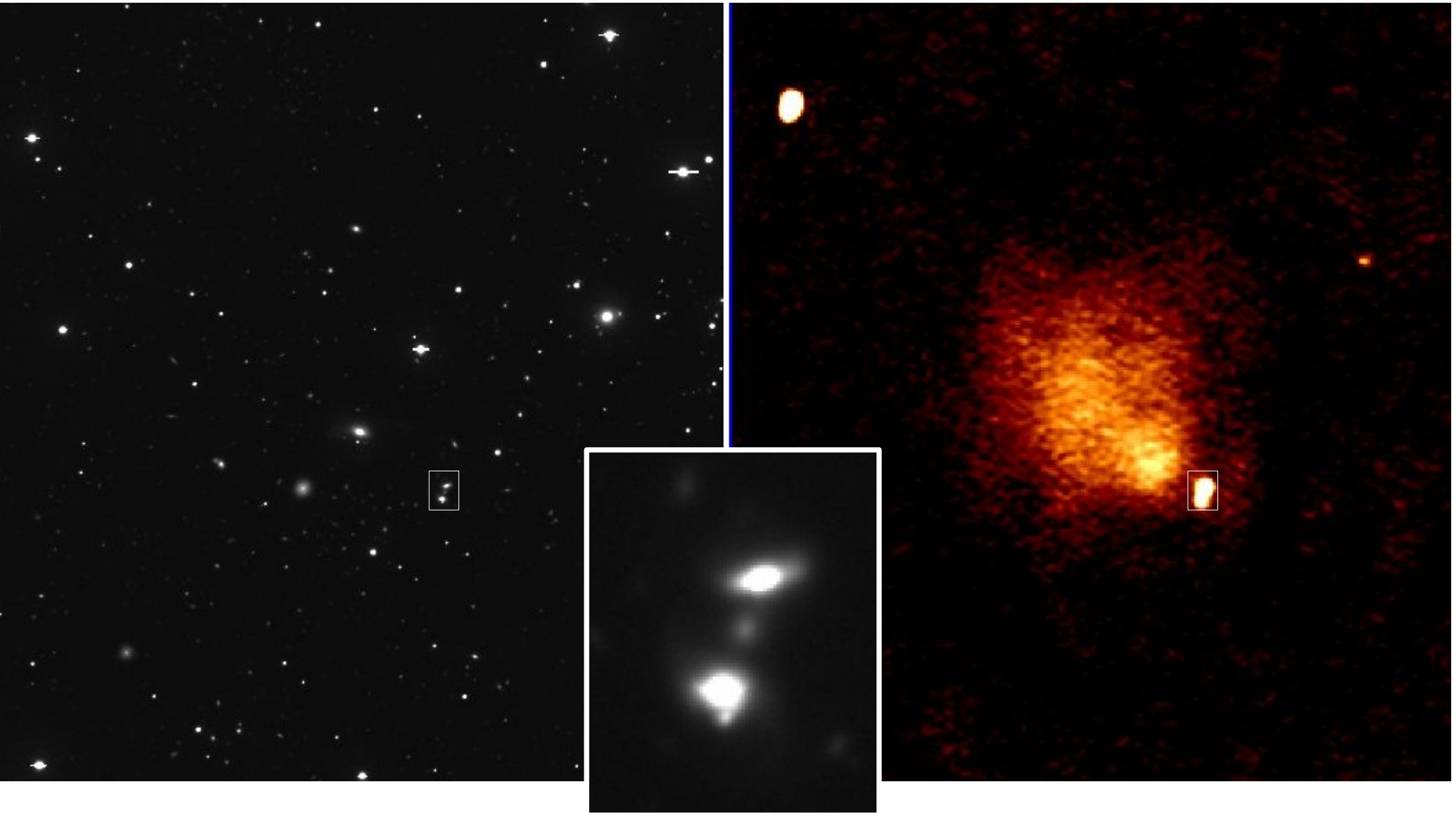
Somewhere in the Bootes field ...

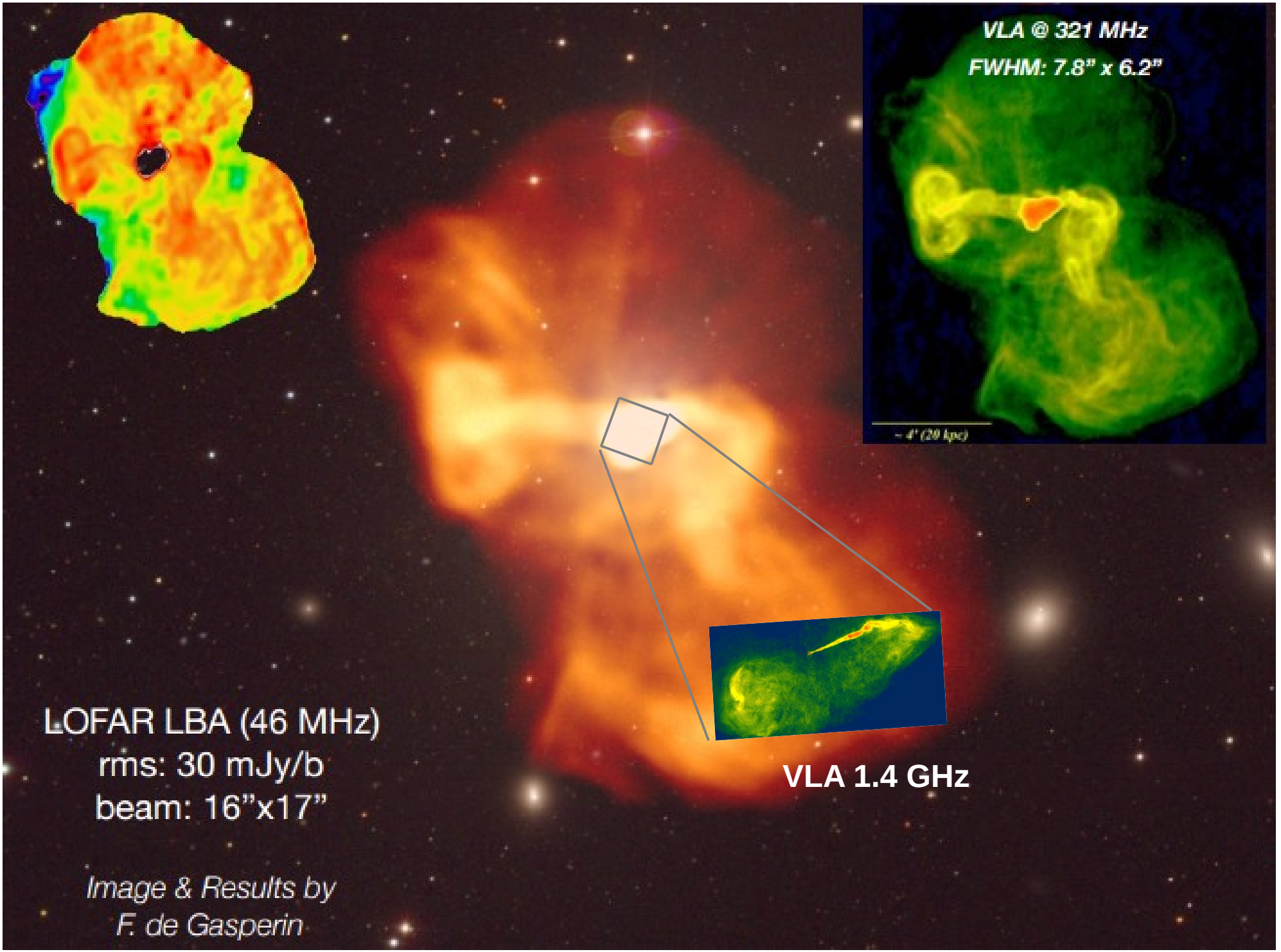


Somewhere in the Bootes field ...

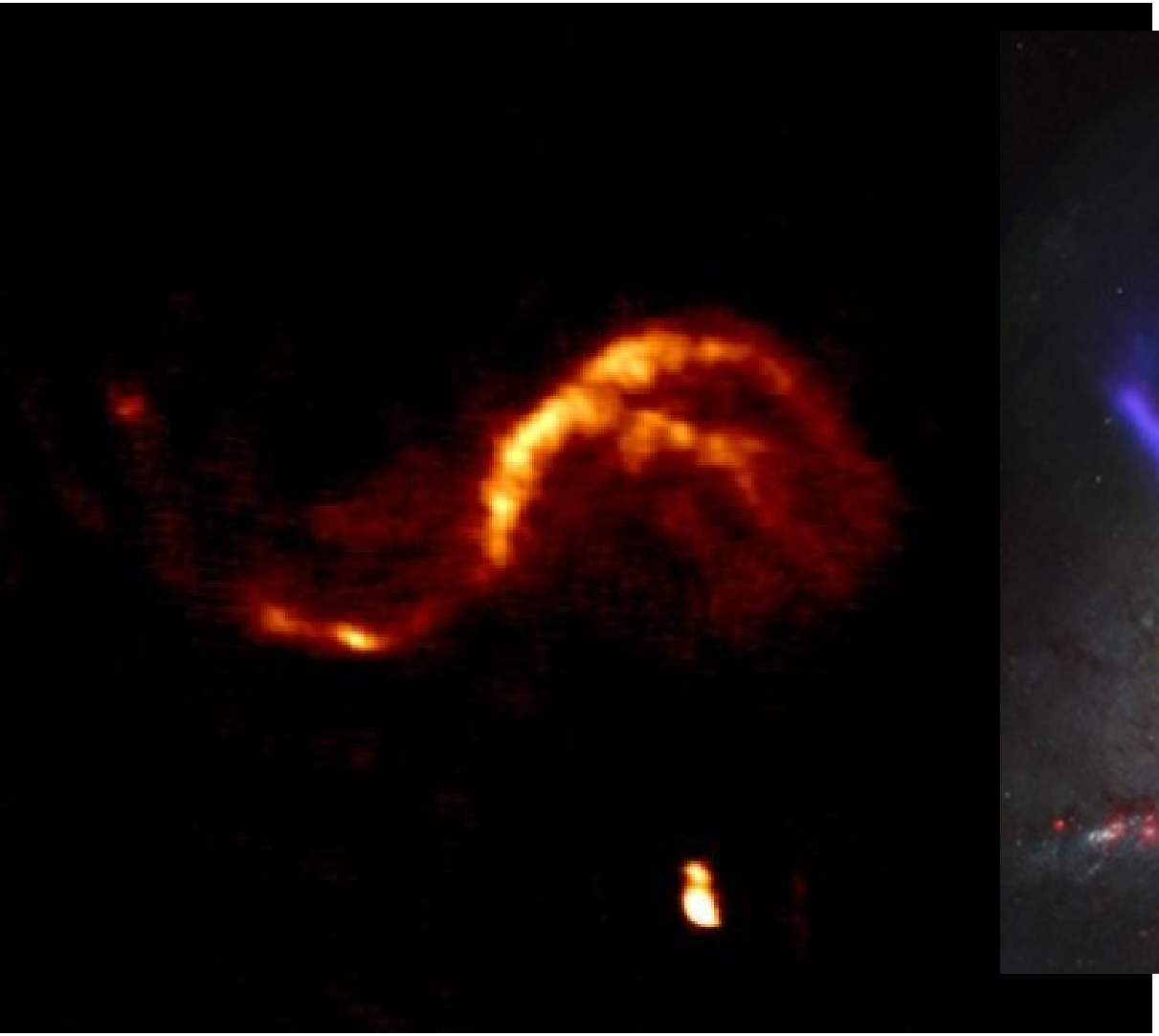


Somewhere in the Bootes field ...




VLA @ 321 MHz
FWHM: 7.8" x 6.2"
~ 4' (20 kpc)
LOFAR LBA (46 MHz)
rms: 30 mJy/b
beam: 16"x17"
Image & Results by
F. de Gasperin
VLA 1.4 GHz

NGC 4258 (M106)



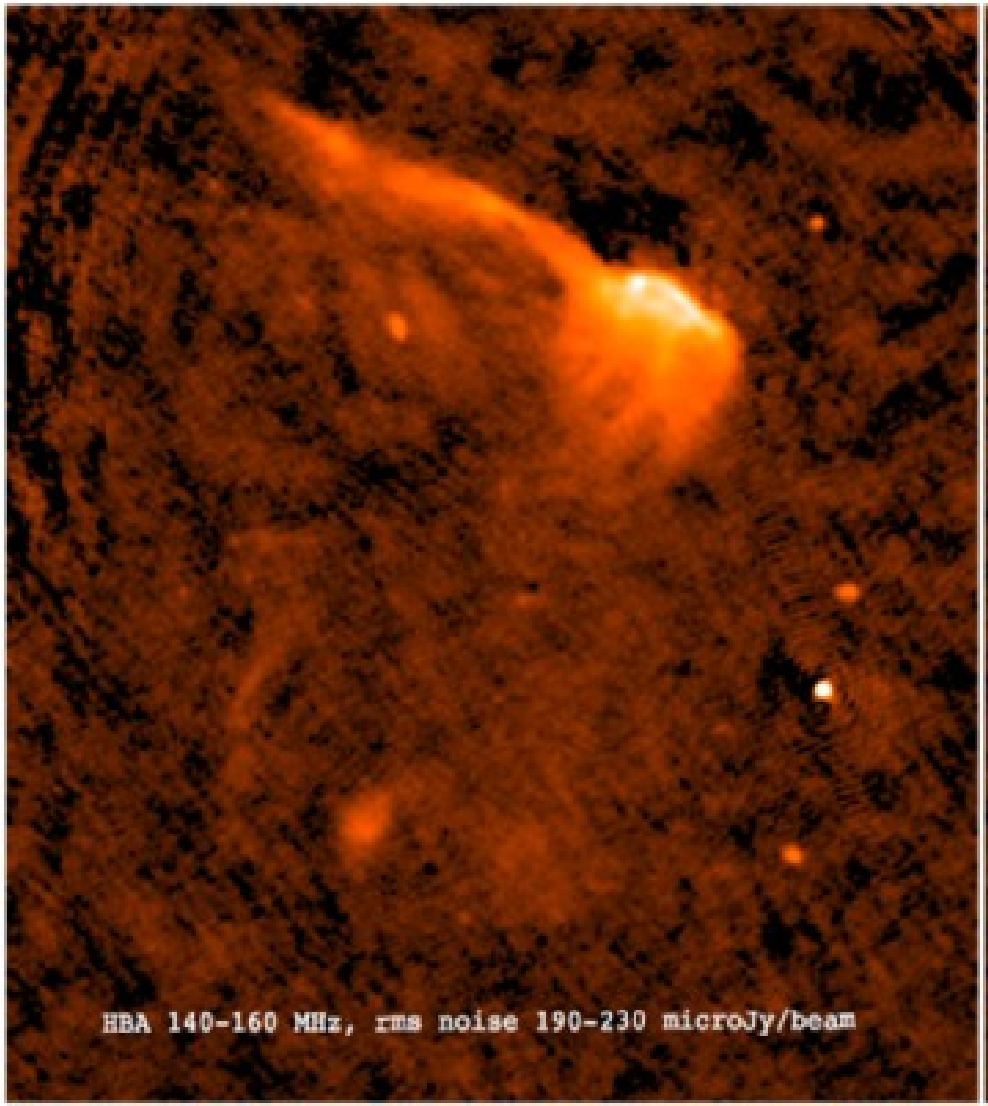
LOFAR ~ 130 MHz

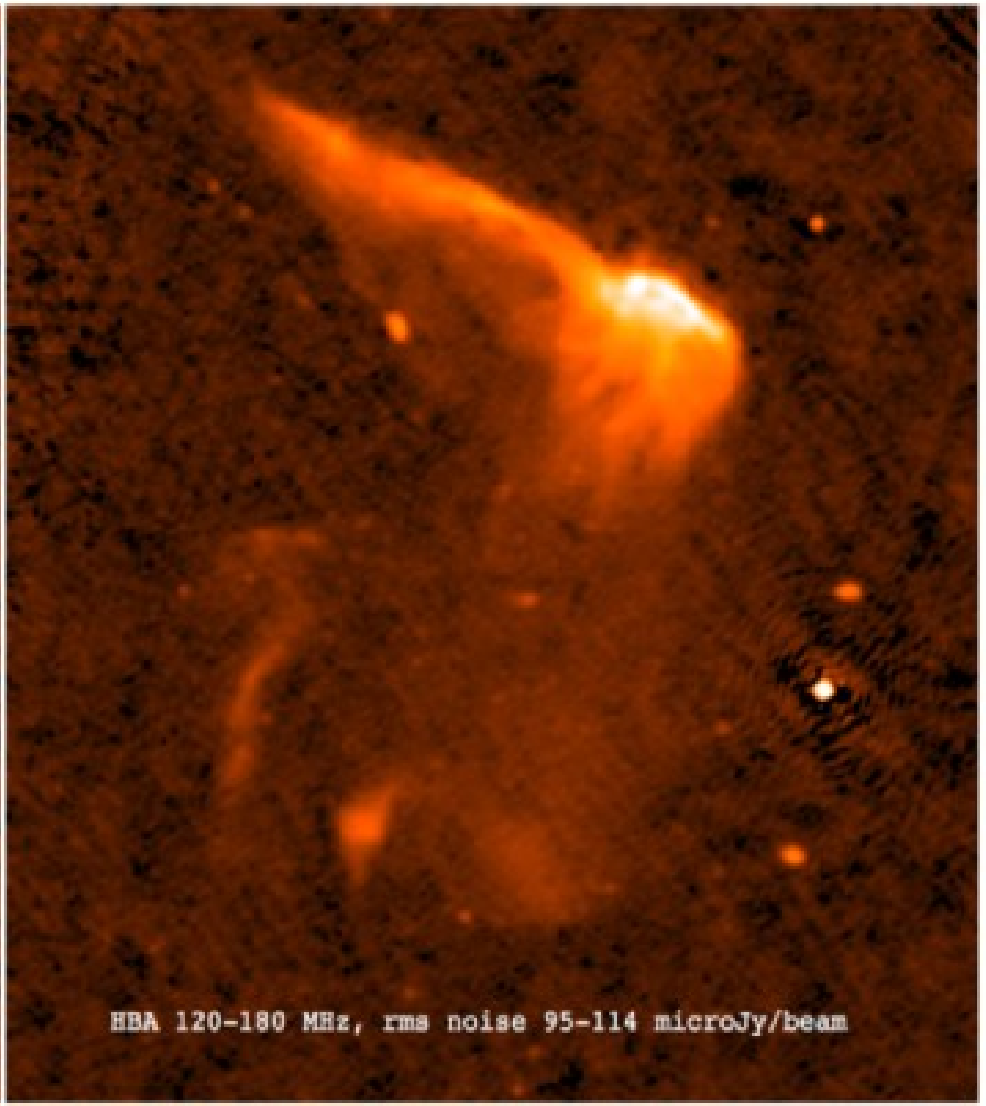
Optical + Chandra

Dataset from Tim Shimwell reduced with Wirtinger calibration

Toothbrush cluster

van Weeren 2014

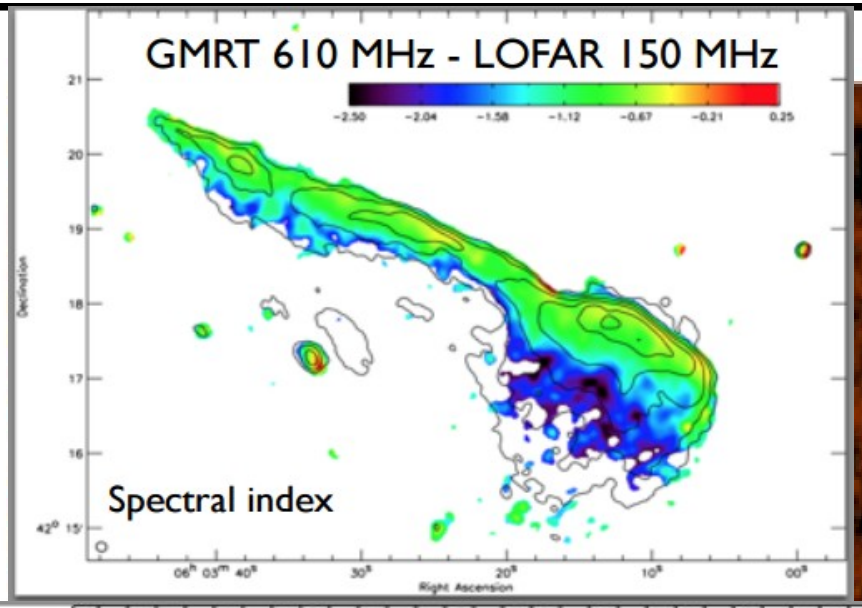


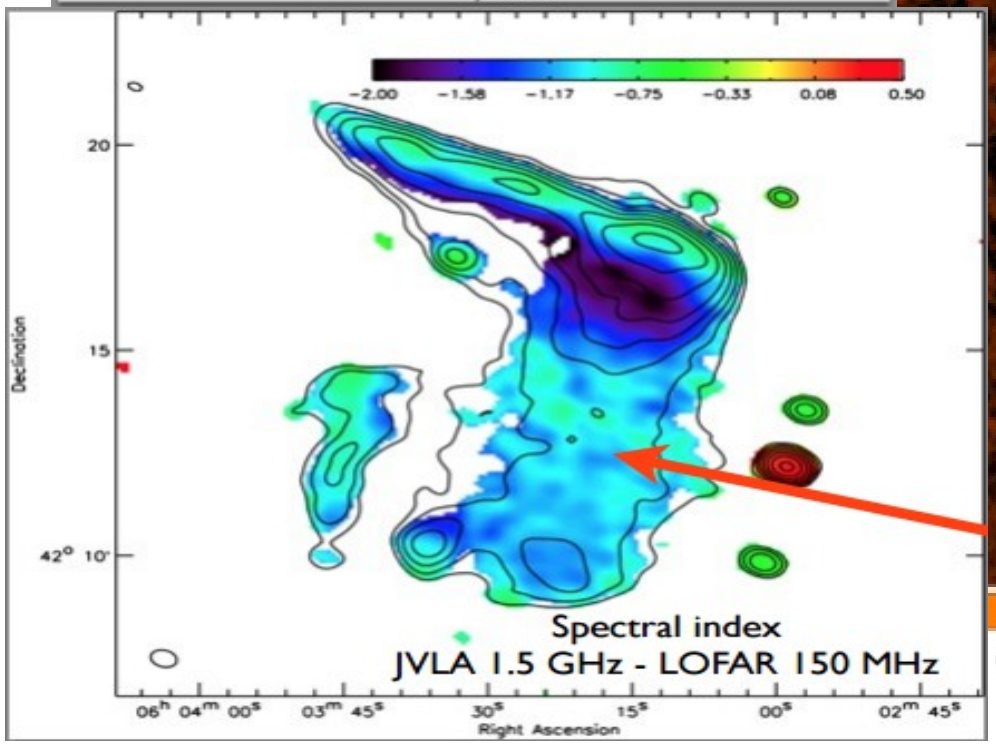


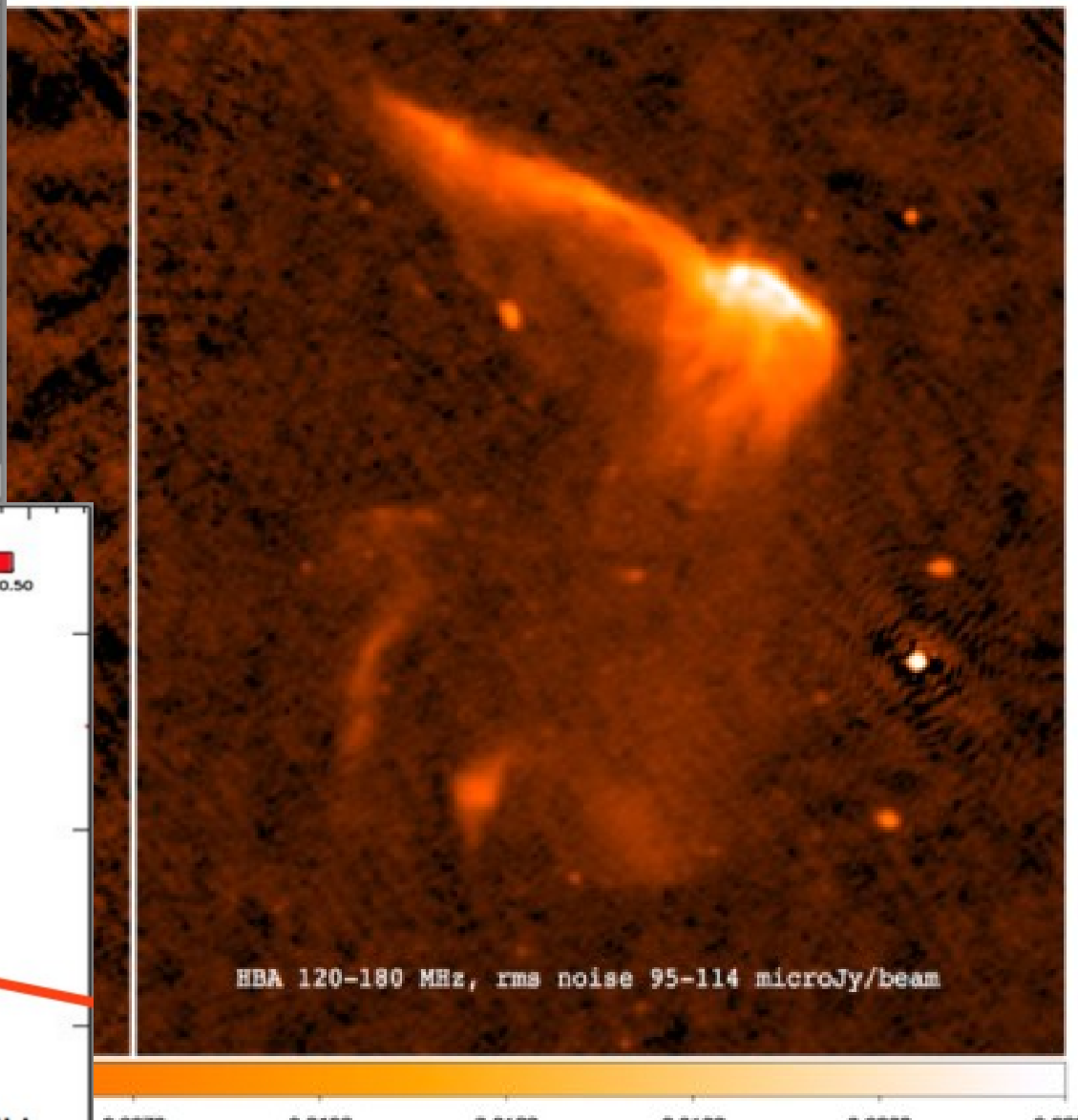
-0.0003 0.0000 0.0009 0.0024 0.0044 0.0070 0.0102 0.0139 0.0183 0.0232 0.0287

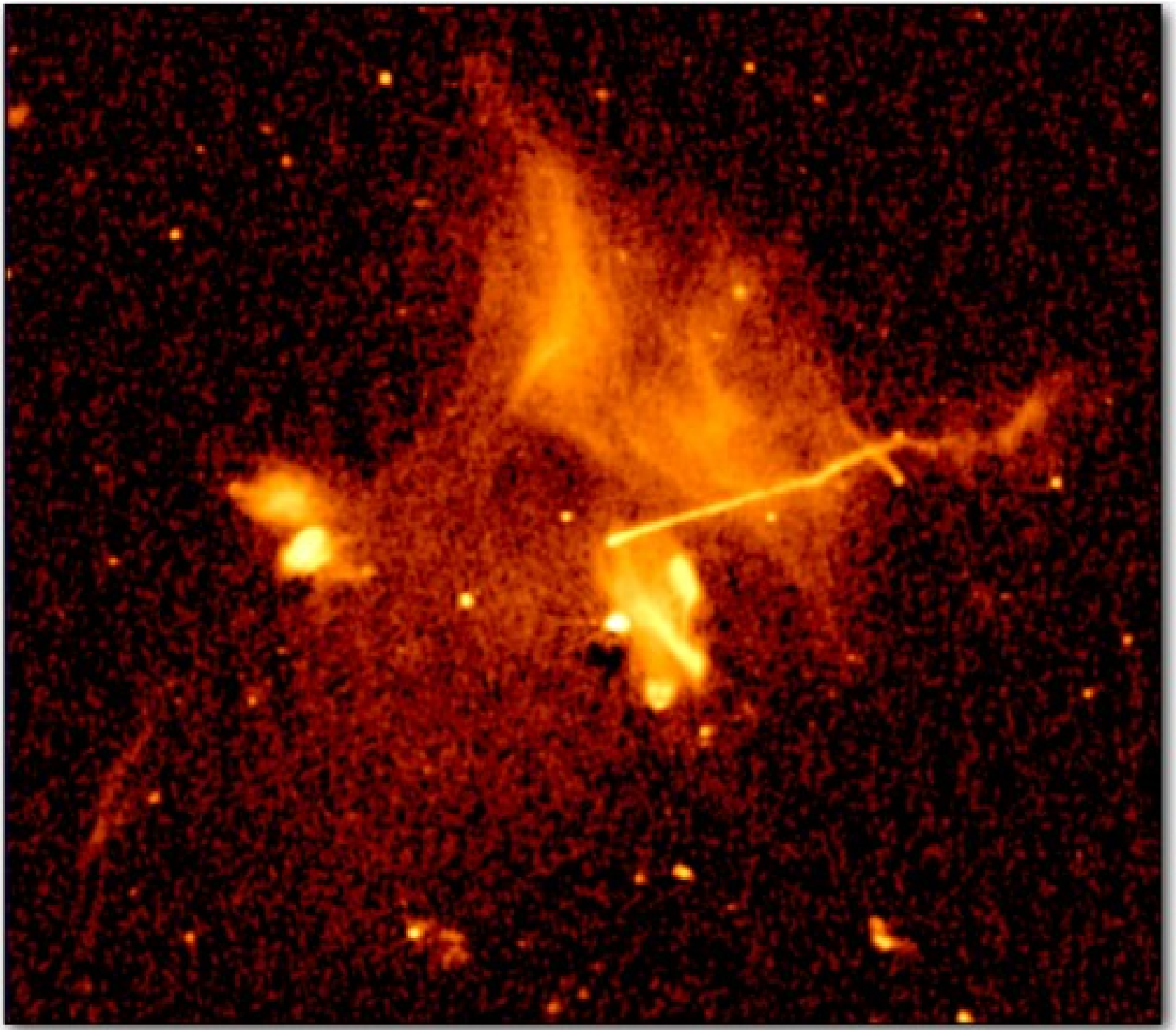
Toothbrush cluster

van Weeren 2014









Abell 2256

120-180 MHz
5 arcsec
130 μJy/beam

Image courtesy:
R. van Weeren

… and slide taken from Chiara Ferarri

Conclusion

- LOFAR is already producing great results
  - Feedback processes
  - Galaxy cluster physics
  - Detailed AGN Physics

- Single pointing observations (Lockman, XMM-LSS, COSMOS, BOOTES, ATLAS, etc) + Tier-1
  - Understand Radio-FIR correlation
  - Nearby AGN studies
  - Hot/Cold accretion modes at z<1
  - High redshift radio galaxies

- Tier 2-3 + Deep optical/IR/FIR
  - Large radio quiet AGN samples
  - AGN activity and SF at z~2-4
  + unknowns ?