THE LOW-FREQUENCY ARRAY

Yunqi Sun, 2018. 6. 1
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OUTLINE

- Low Frequency Astronomy
- Introduction to Low Frequency Array (LOFAR)
- Scientific Discoveries
- Conclusion

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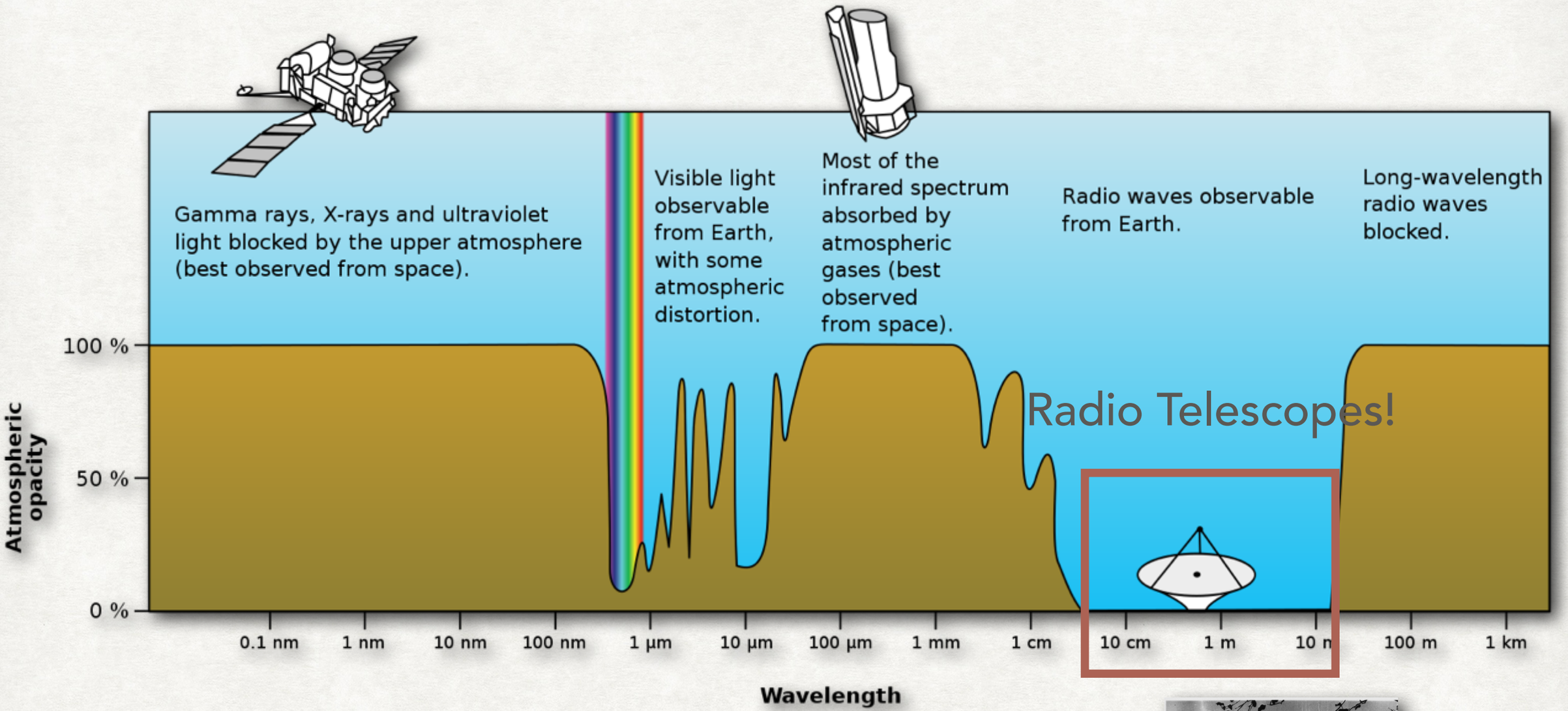
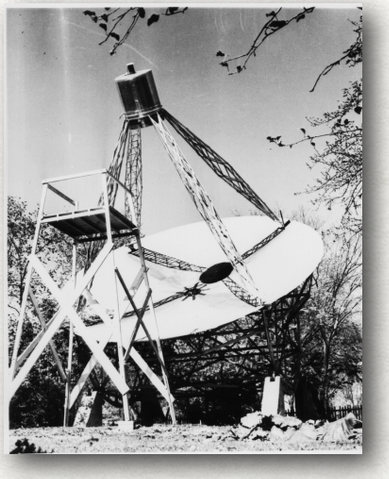
LOW FREQUENCY ASTRONOMY



Karl Jansky's dipole antennes, 1932

Grote Reber's dish telescope, 1937



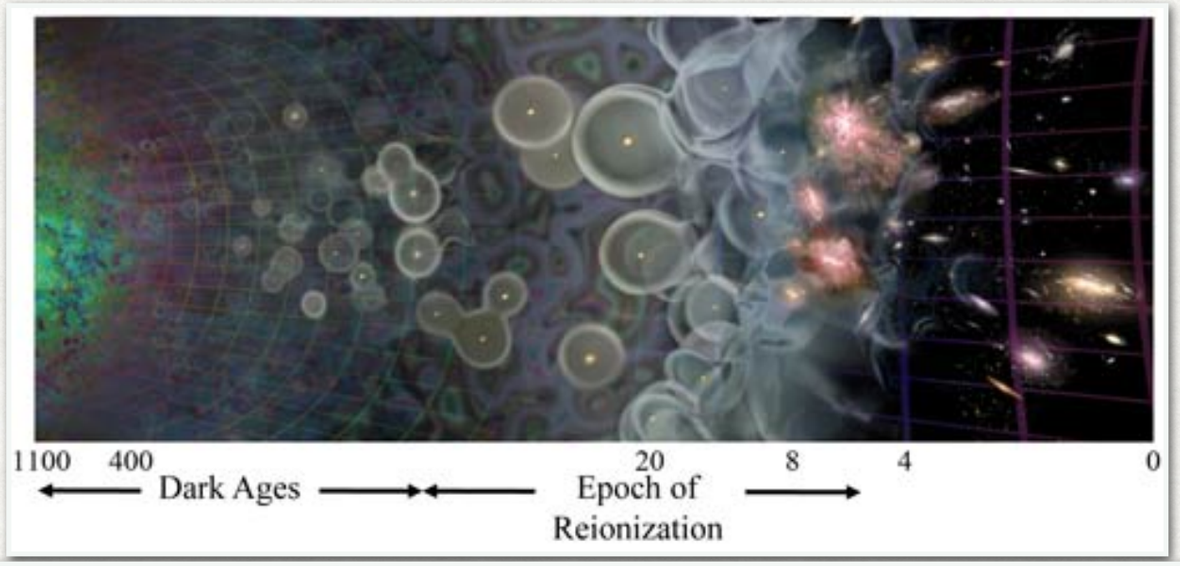
LOW FREQUENCY ASTRONOMY

- ***Epoch of reionization, especially at high z(~11)***

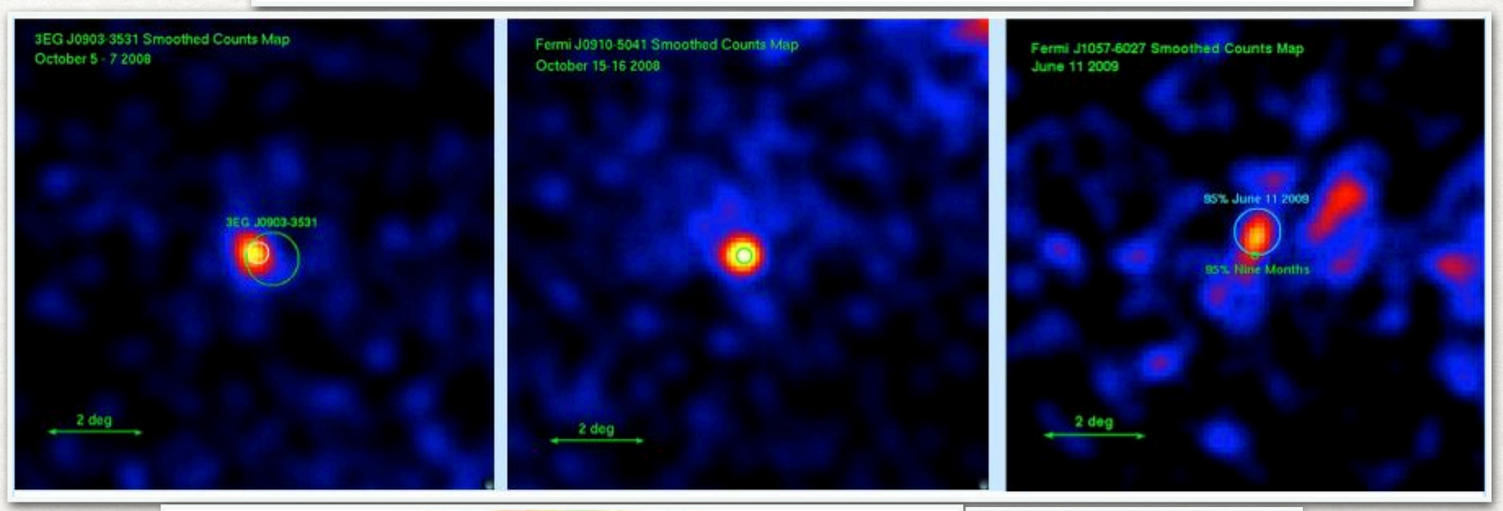
  Redshift of H I Line (21cm):

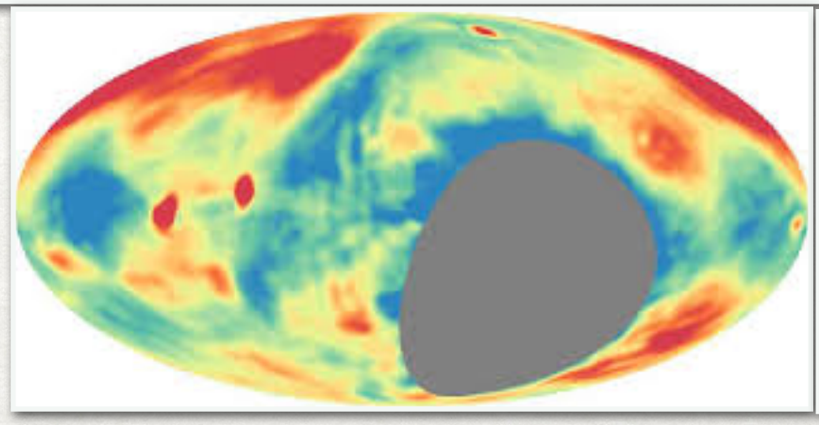
  $\nu = 1420/(1+z)$ MHz

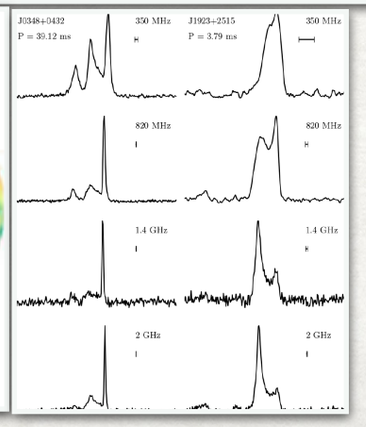
  ~120 MHz



- ***Transient Radio Sky***
- ***Surveying the low-frequency sky***
- ***Pulsar studies and surveys***

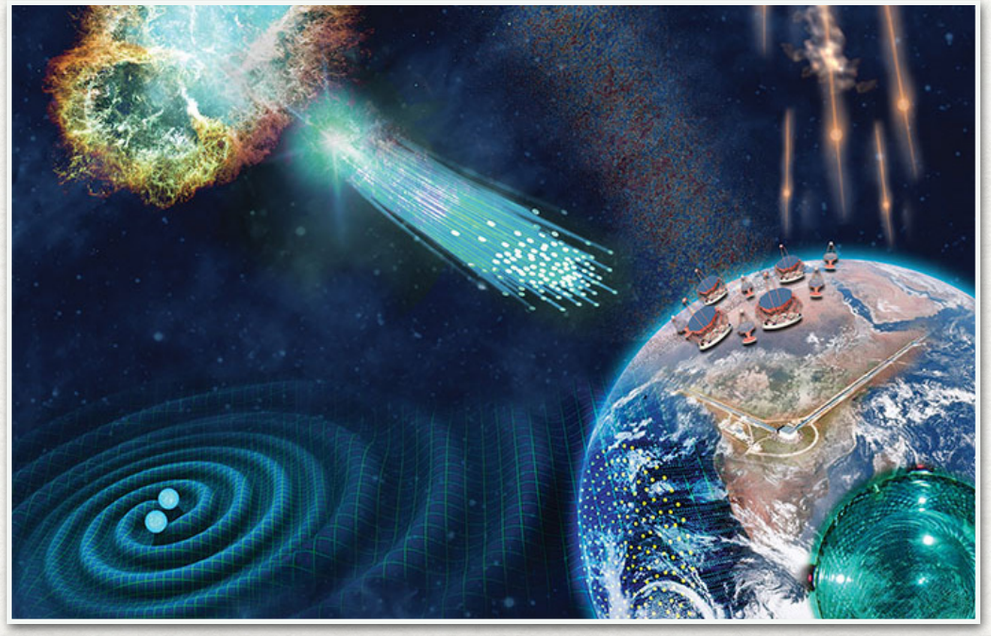


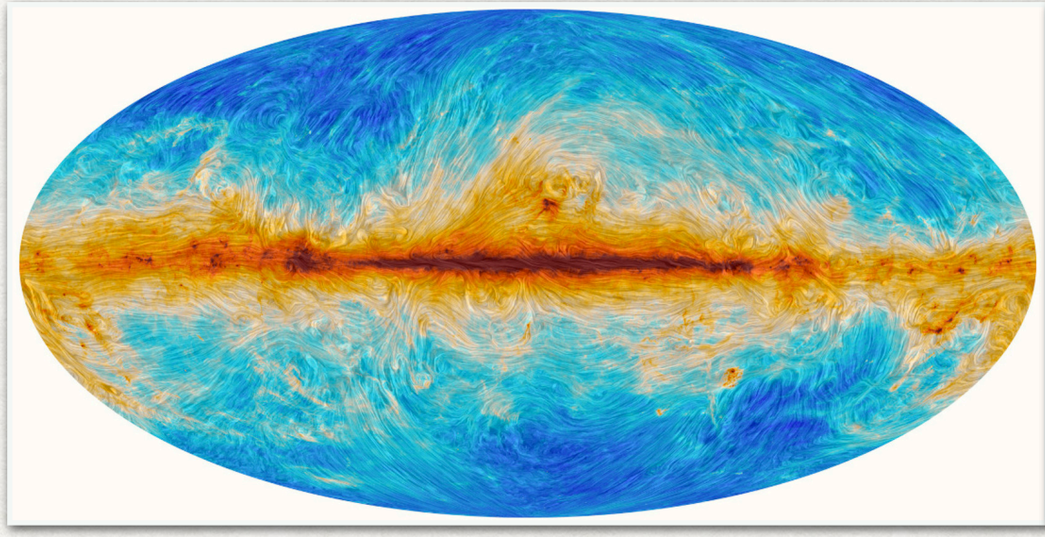


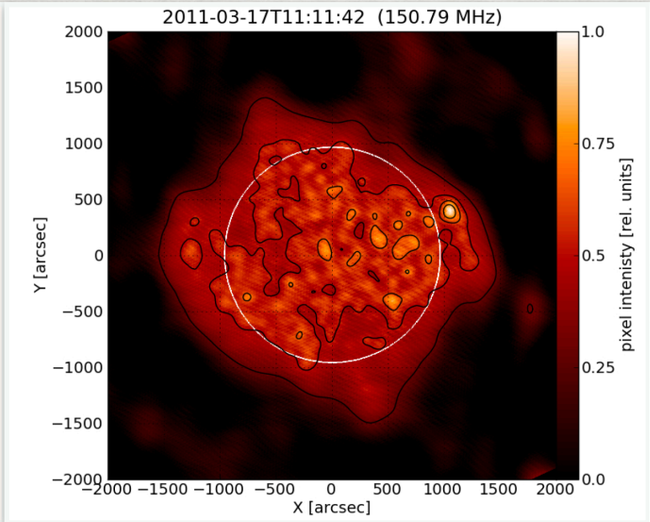


LOW FREQUENCY ASTRONOMY

- *Astropartical physics*
- *Magnetic fields of the universe*
- *Solar Bursts & space weather*
- *FRB…*







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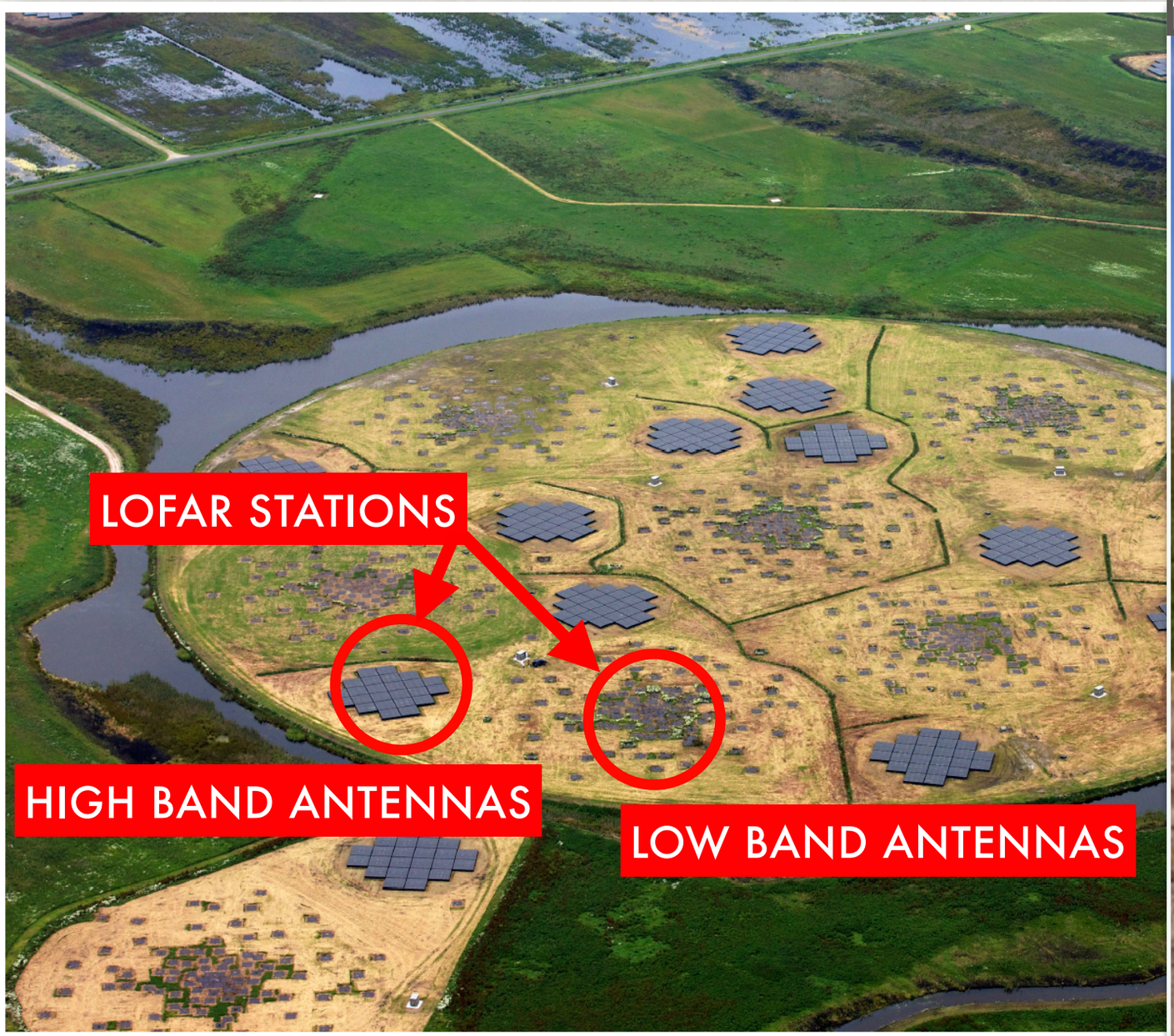
DISTRIBUTIONS OF LOFAR STATIONS

- Location: Netherland (mainly) and Europe with 54 Stations

M. P. van Haarlem, et. al, (2013)

LOFAR STATIONS

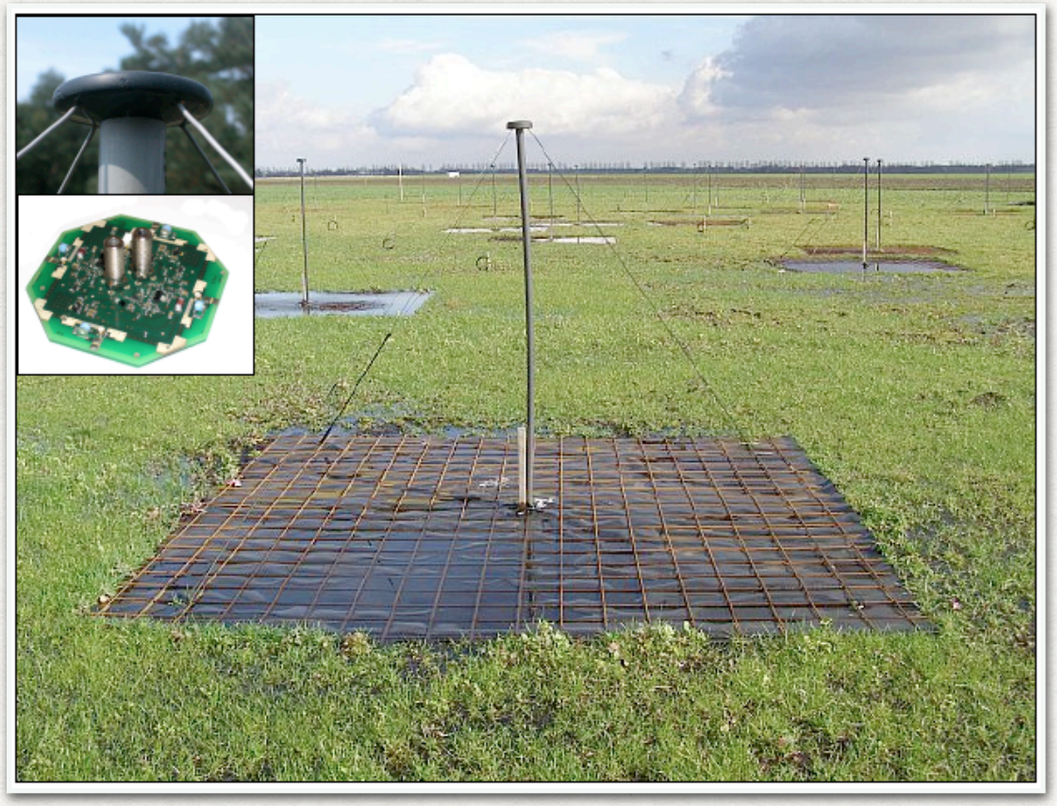
SUPERTERP AND CORE STATIONS OF LOFAR IN NETHERLAND

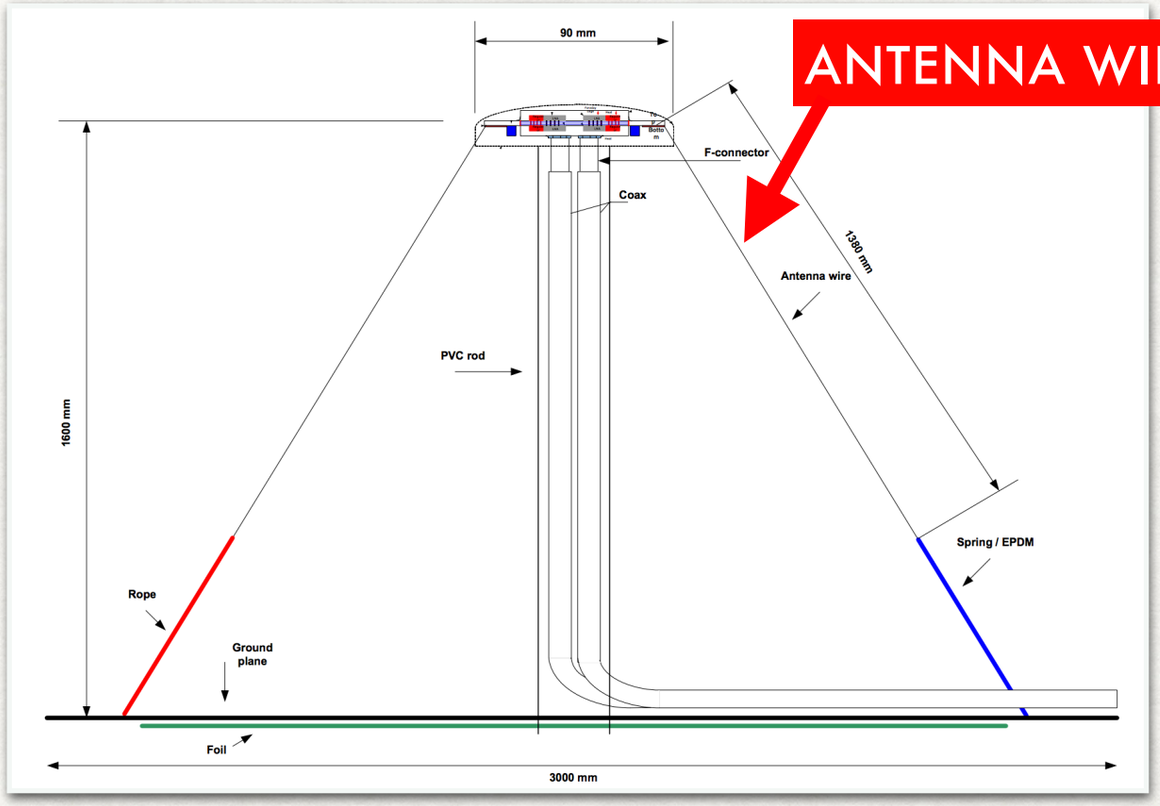


EFFELSBERG 100M RADIO TELESCOPE TOGETHER WITH 60M DIAMETER LOFAR ANTENNAS

LOFAR ANTENNA ARRAYS

Low Band Antennas (10-90 MHz)



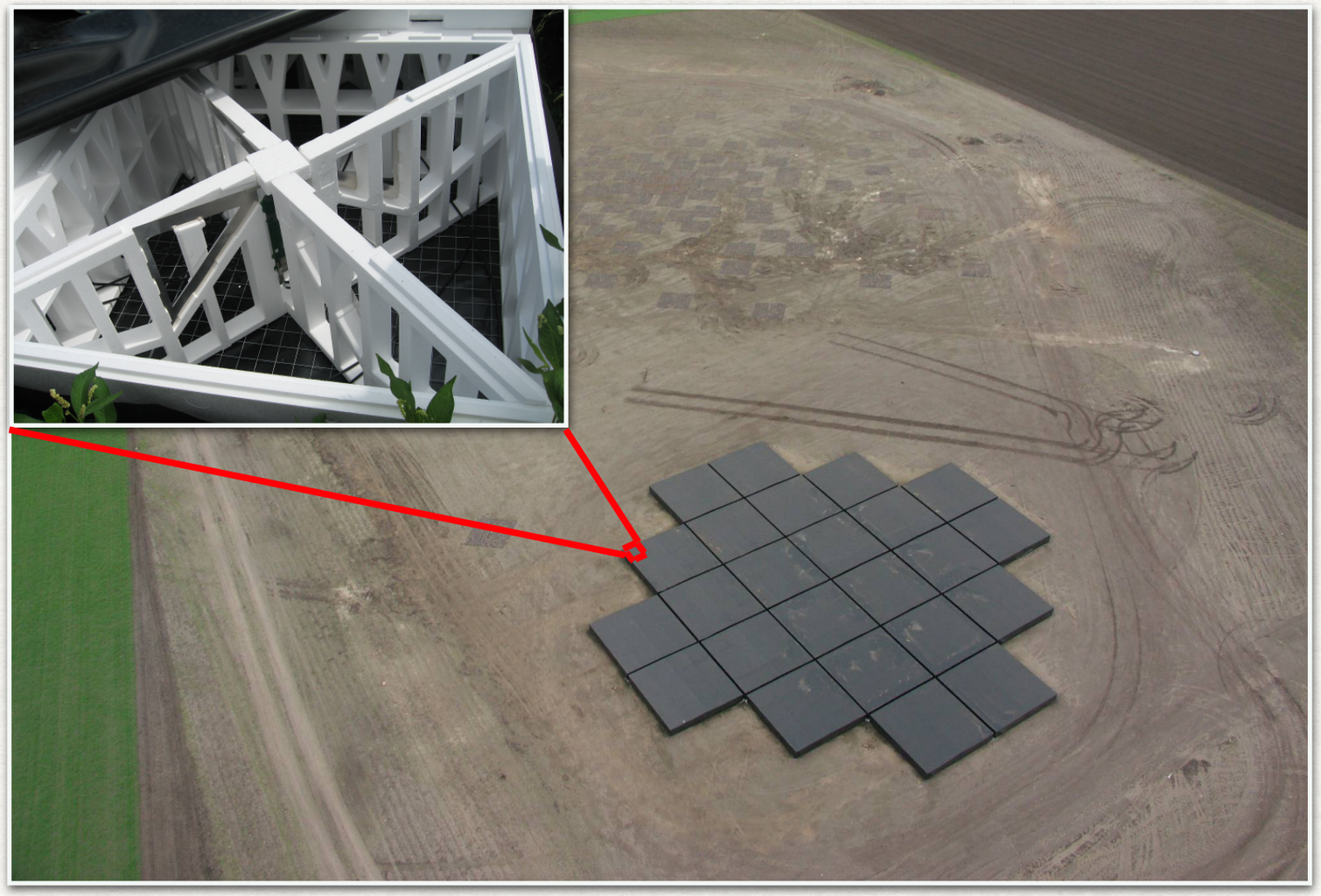


- 96 Low Band Antennas per station
- Station diameter: 45 – 85 m (LBA)
- Sparse pseudo-random configuration

LOFAR ANTENNA ARRAYS

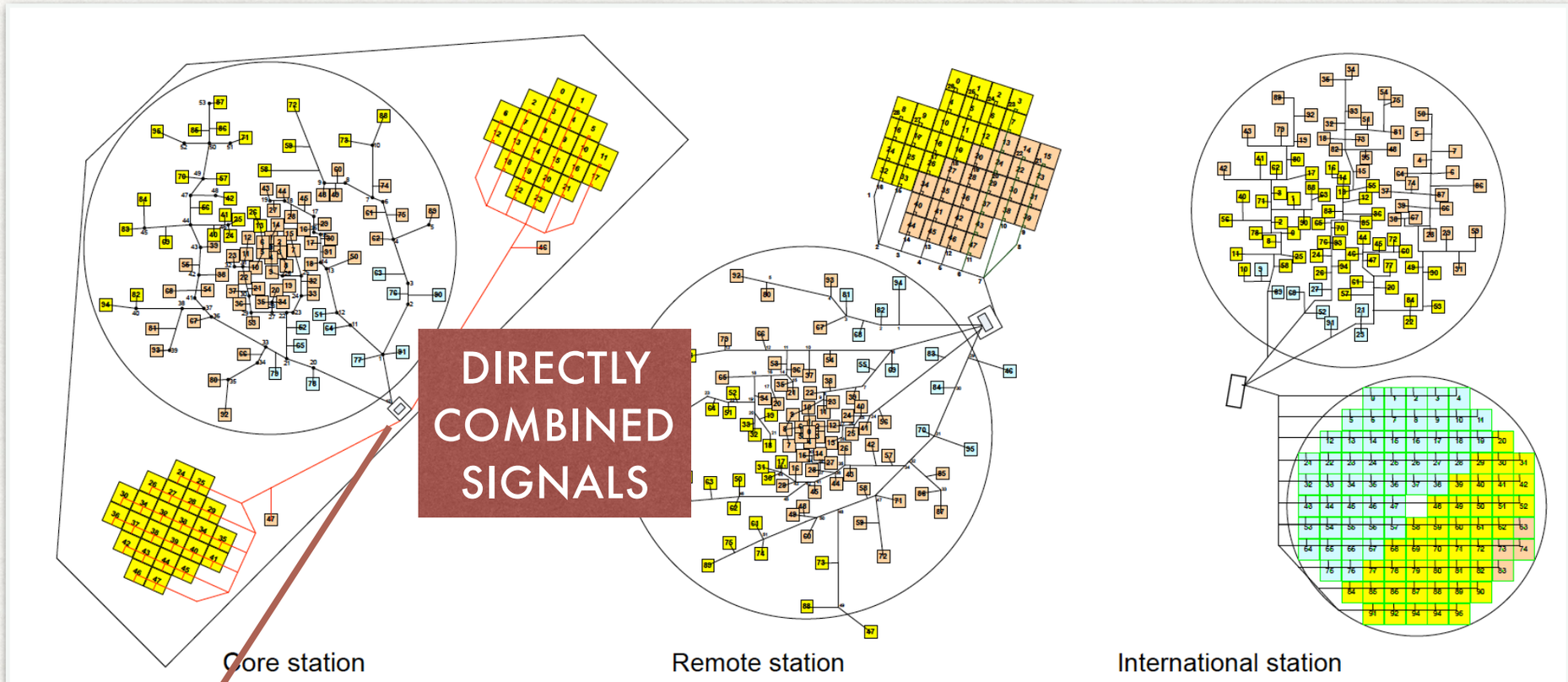
High Band Antennas (110-250 MHz)

- 768 x 2 dipoles per station
- Sparse rectangular grid
- Analog beamformer per tile (4x4 elements)



ANGULAR RESOLUTION & SENSITIVITY

TECHNICAL DETAILS



Sensitivity

Freq. (MHz)	λ (m)	Superterp (mJy)	NL Core (mJy)	Full NL (mJy)	Full EU (mJy)
15	20.0	...	...	...	...
30	10.0	36	9.0	5.7	3.8
45	6.67	29	7.4	4.7	3.1
60	5.00	25	6.2	3.9	2.6
75	4.00	44	10.8	6.8	4.5
120	2.50	1.5	0.38	0.30	0.20
150	2.00	1.3	0.31	0.24	0.16
180	1.67	1.5	0.38	0.30	0.20
200	1.50	(2.5)	(0.62)	(0.48)	(0.32)
210	1.43	(2.5)	(0.62)	(0.48)	(0.32)
240	1.25	(5.6)	(1.4)	(1.1)	(0.73)

Resolution

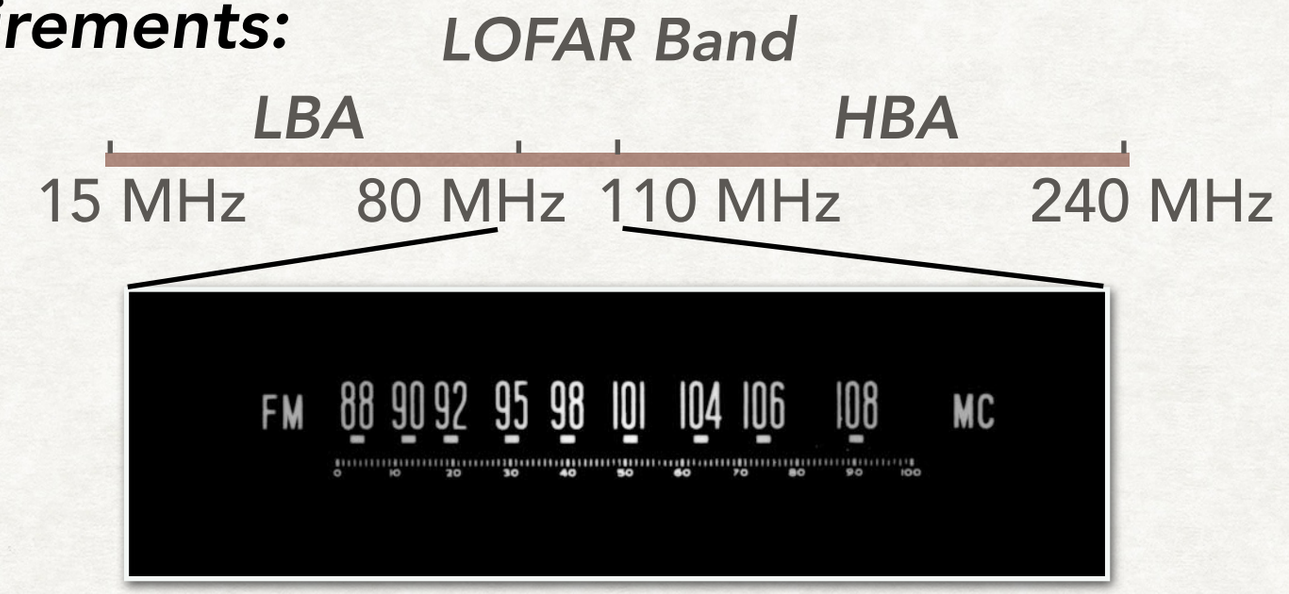
Freq. (MHz)	λ (m)	L = 320 m (arcsec)	L = 2 km (arcsec)	L = 100 km (arcsec)	L = 1000 km (arcsec)
15	20.0	10 310.00	1650.00	33.00	3.30
30	10.0	5157.00	825.00	16.50	1.65
45	6.67	3438.00	550.00	11.00	1.10
60	5.00	2578.00	412.50	8.25	0.83
75	4.00	2063.00	330.00	6.60	0.66
120	2.50	1289.00	206.30	4.13	0.41
150	2.00	1031.00	165.00	3.30	0.33
180	1.67	859.40	137.50	2.75	0.28
200	1.50	773.50	123.80	2.48	0.25
210	1.43	736.70	117.90	2.36	0.24
240	1.25	644.60	103.10	2.06	0.21

WHY NEED TWO TYPES OF ANTENNAS

Key LOFAR Antenna Requirements:

- Frequency Band:
  15-240 MHz, Exclude FM-Band

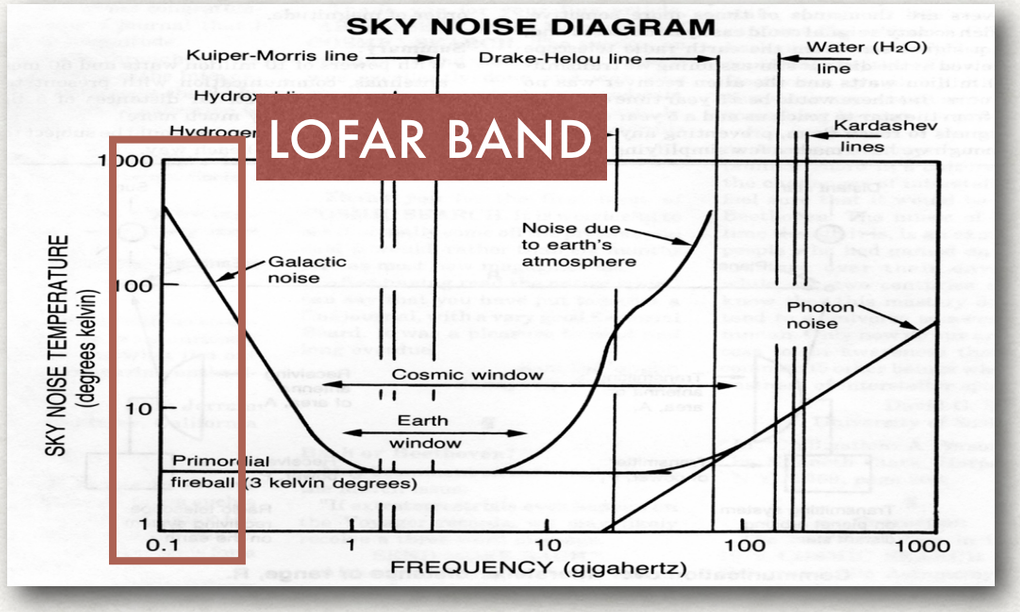
  RFI (FM band) in the middle of LOFAR band



FM Band

- Sky ***NOISE*** Dominated

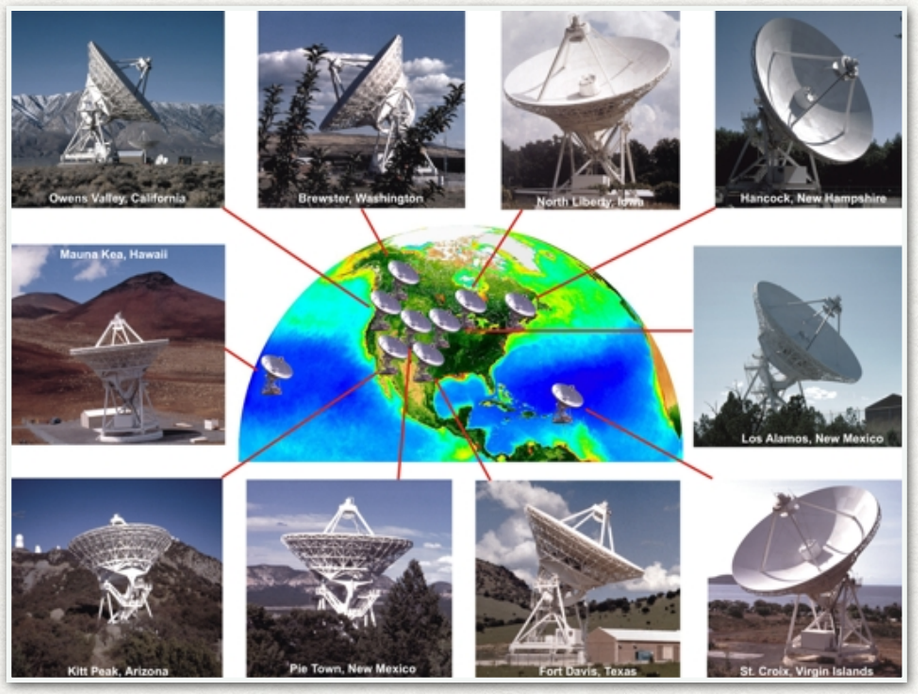
  Completely different sky noise temperatures in low and high bands!



COST

LOFAR €100 million

LWA&MWA $ 50 million



VLBA $ 85 million

FAST ¥1.2 billion or $180 million

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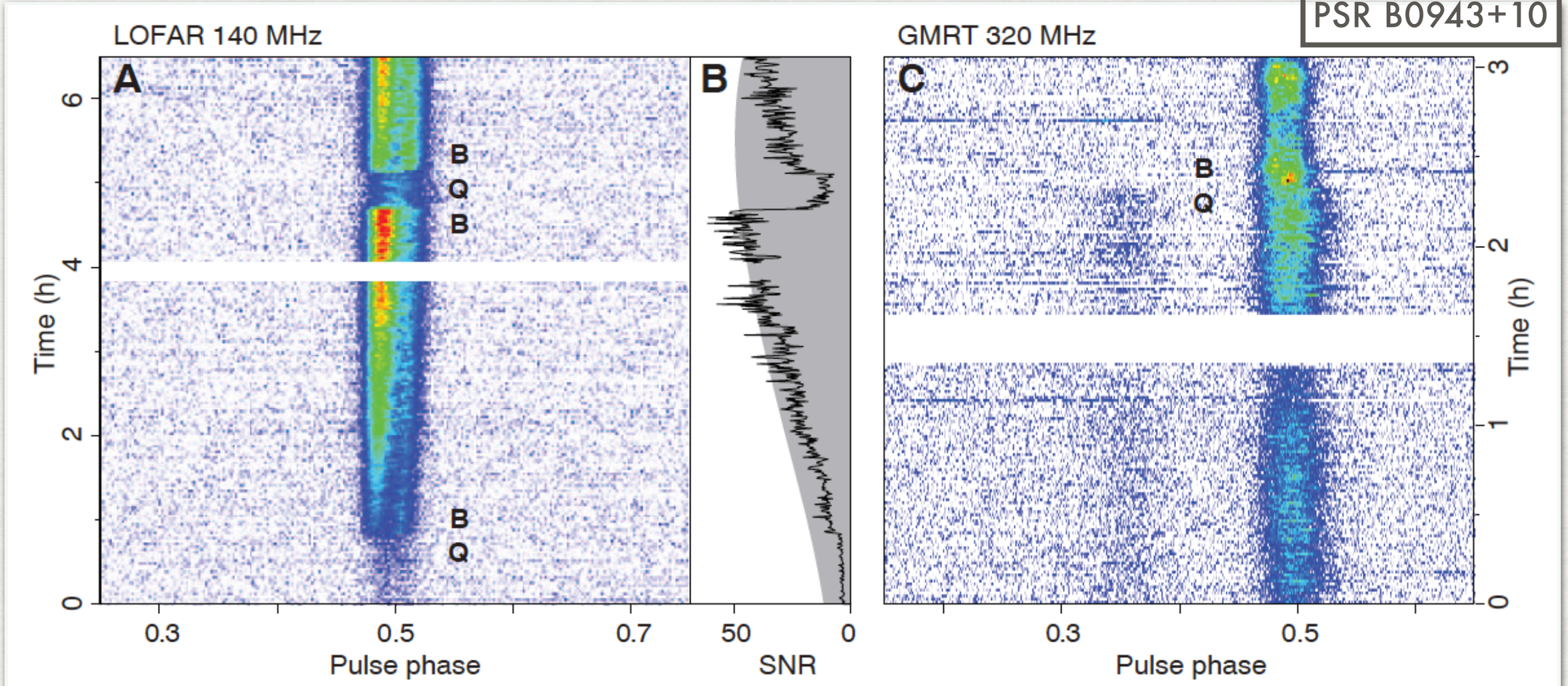
PULSAR MODE SWITCH

PSR B0943+10



Identification of the B and Q modes with LOFAR at 140 MHz in PSR B0943+10, showing pulse intensity versus rotational phase and time.

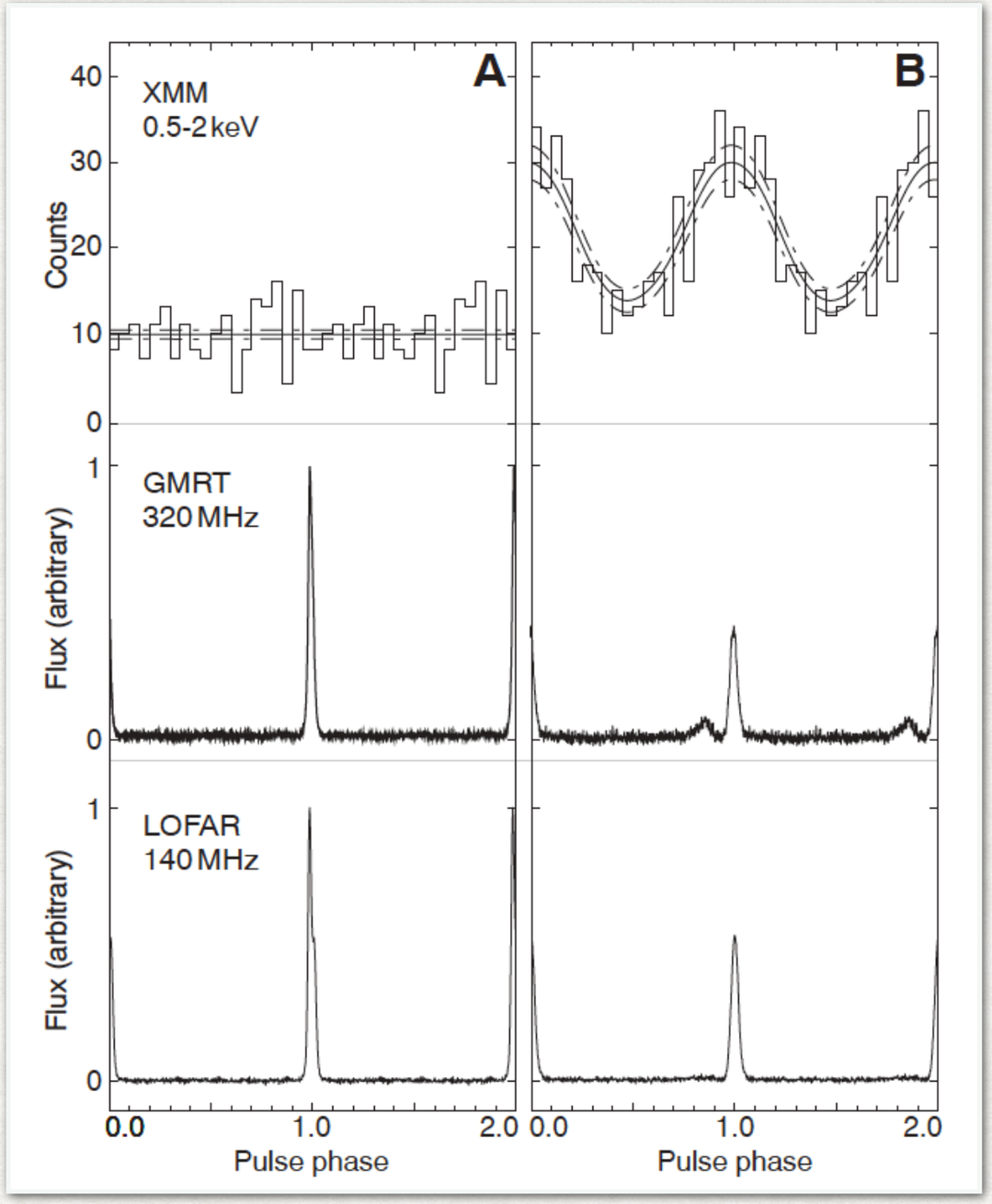
(W. Hermsen, et al., 2013)

PULSAR MODE SWITCH

Mode Switches

A. B mode: no evidence for a pulsed signal in the B-mode x-ray data, the flat distribution showing constant emission from the pulsar.

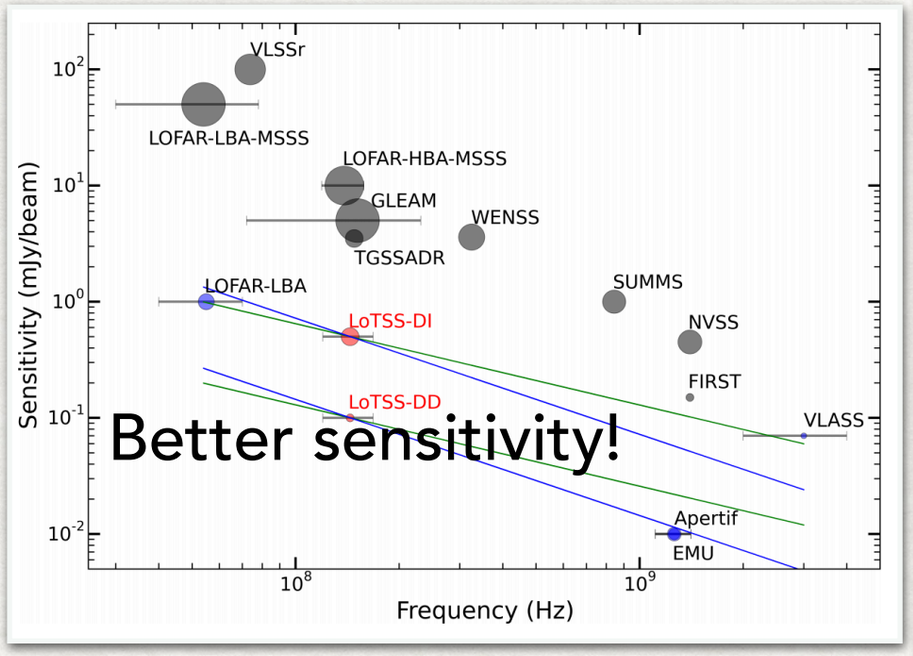
B. Q mode: The x-ray profile in the Q mode represents a 6.6sigma detection on top of a flat constant level.



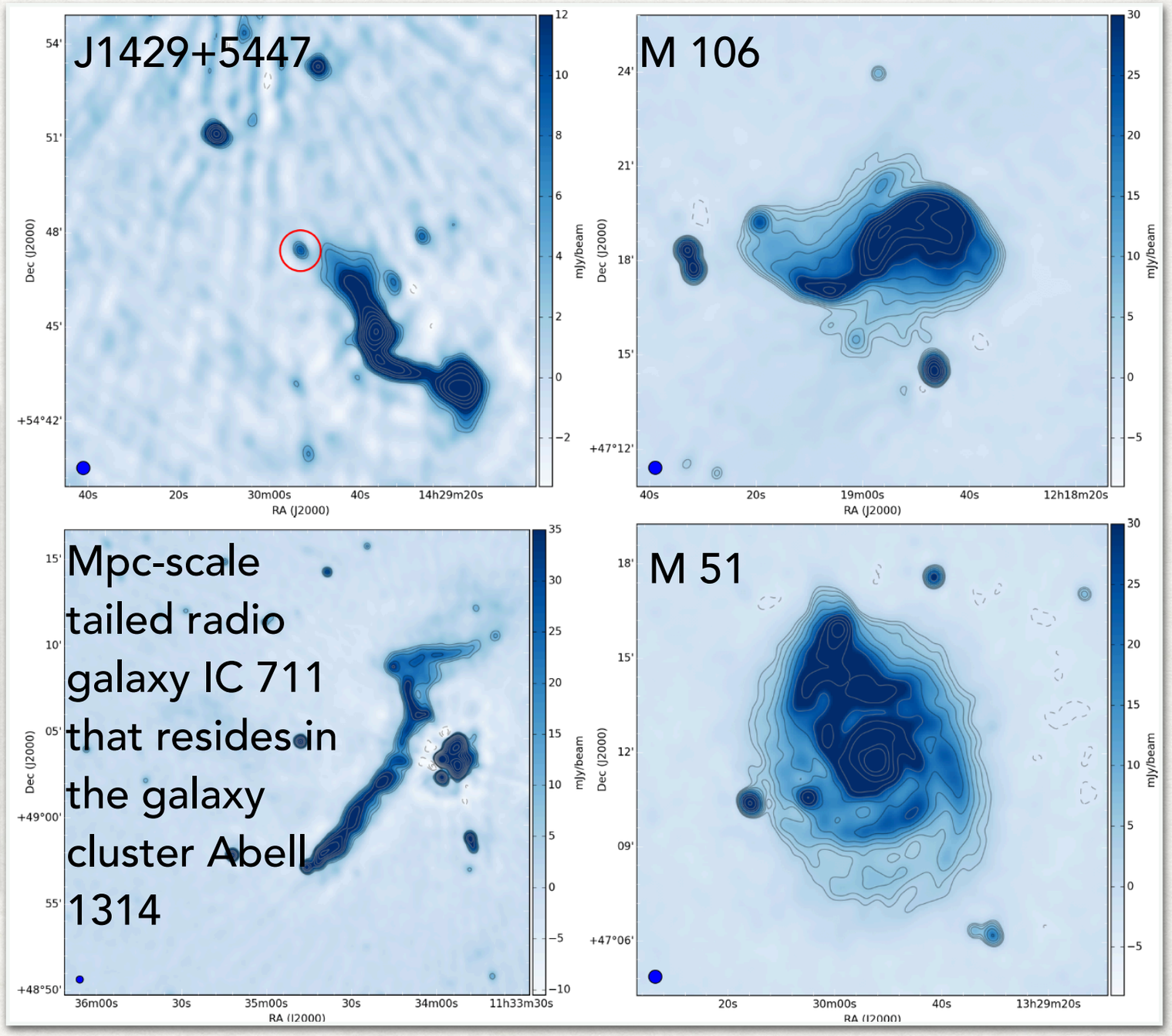
Conclusion: B field changes in several hours. (W. Hermsen, et al., 2013)

LOFAR TWO-METER SKY SURVEY (LOTSS)

Explore the formation and evolution of massive black holes, galaxies, clusters of galaxies, and large-scale structure.

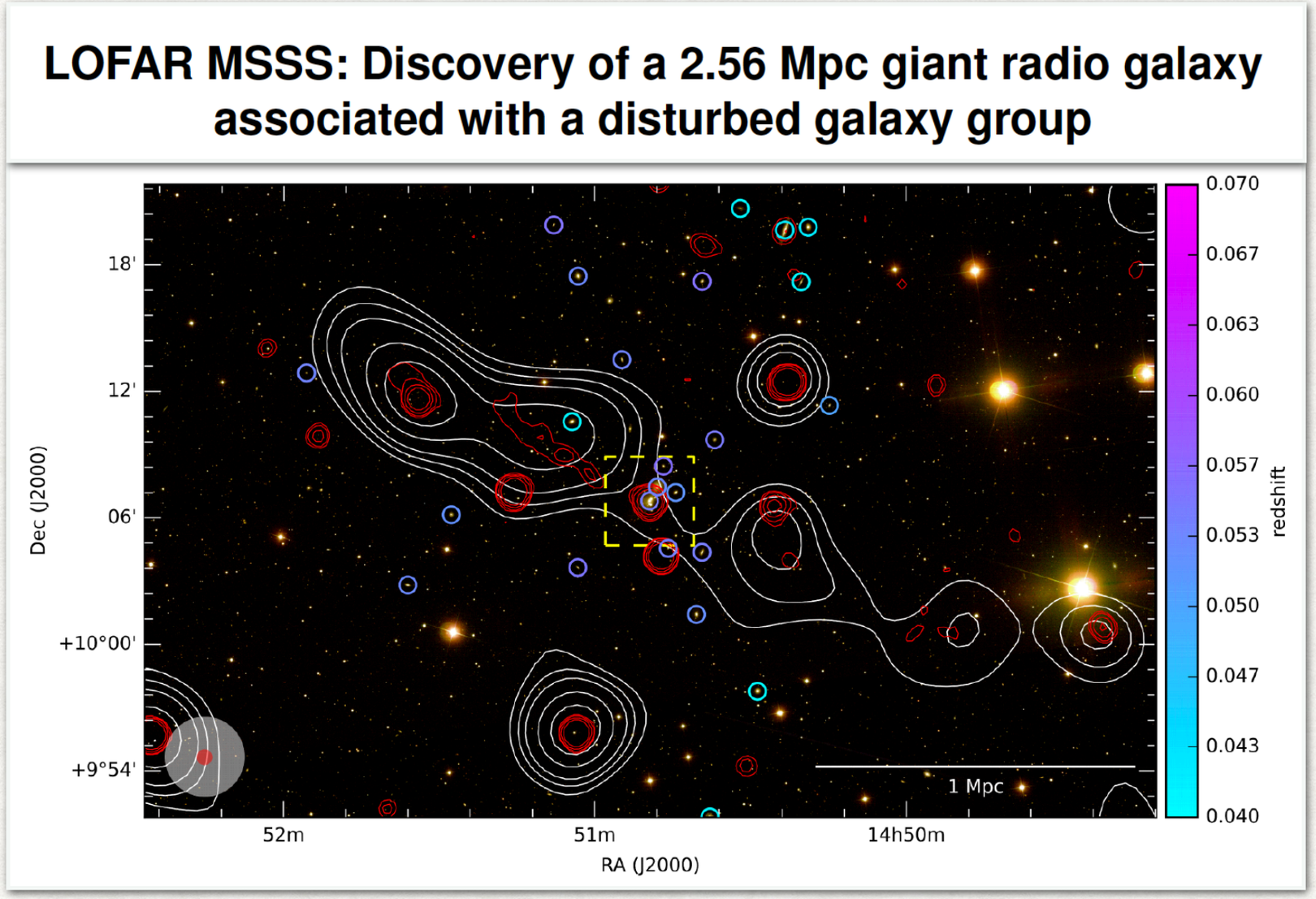


(T. W. Shimwell et al., 2017)



LOFAR MULTIFREQUENCY SNAPSHOT SKY SURVEY (MSSS)

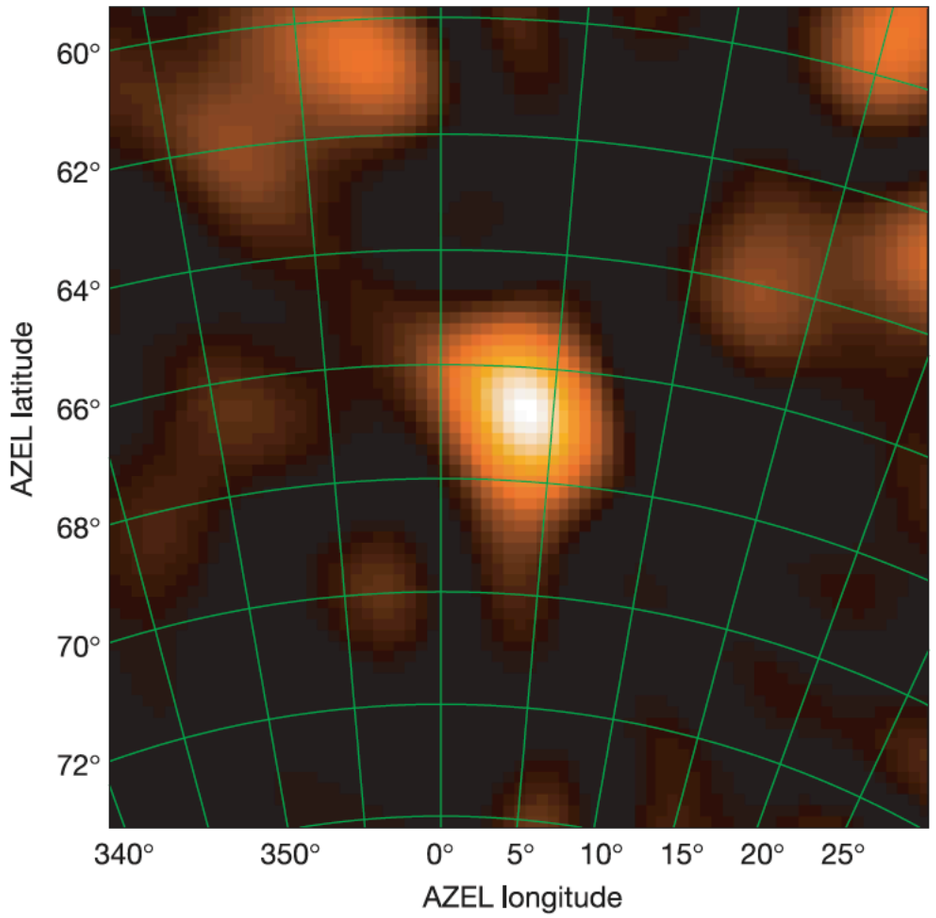
- Broadband frequency coverage, 119–158 MHz
- Fast survey speed generated by LOFAR's multibeaming capabilities
- First survey of the sort anticipated to be carried out with the forthcoming Square Kilometre Array (SKA).



Biggest radio galaxy discovered ever!

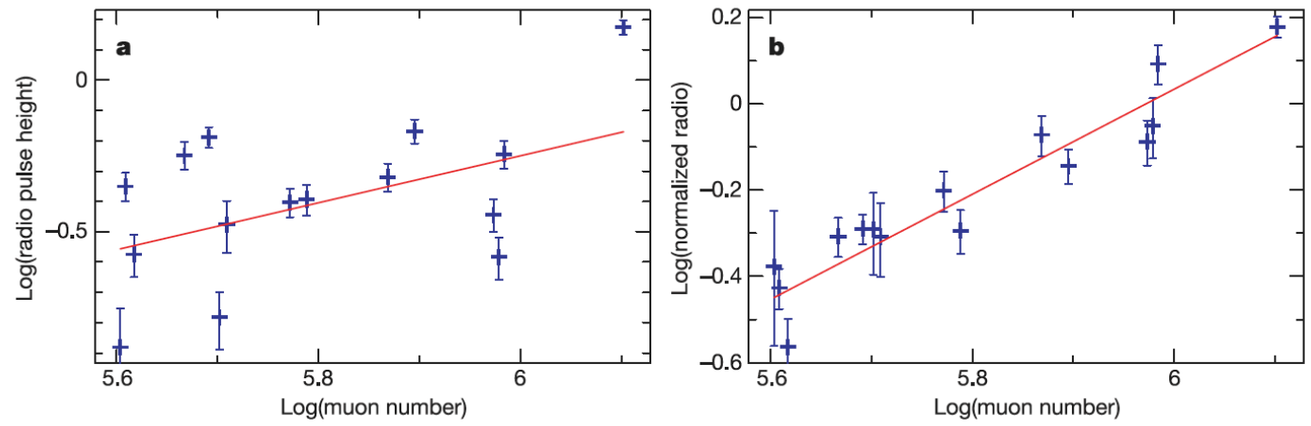
(A. O. Clarke et al., 2017)

COSMIC RAY SHOWERS



Direct image of cosmic ray detected by LOPES, a LOFAR prototype.

Detection and imaging of atmospheric radio flashes from cosmic ray air showers



Strong linear connection with radio flashes and air showers.

(H. Falcke, et al., 2005)

CONCLUSION

- LOFAR's high sensitivity and angular resolution improve low frequency surveys and low frequency astronomy.
- LOFAR's design is quite efficient and effective.
- More discoveries are to be revealed by LOFAR data.
- Next generation low frequency arrays, SKA, moon?

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