

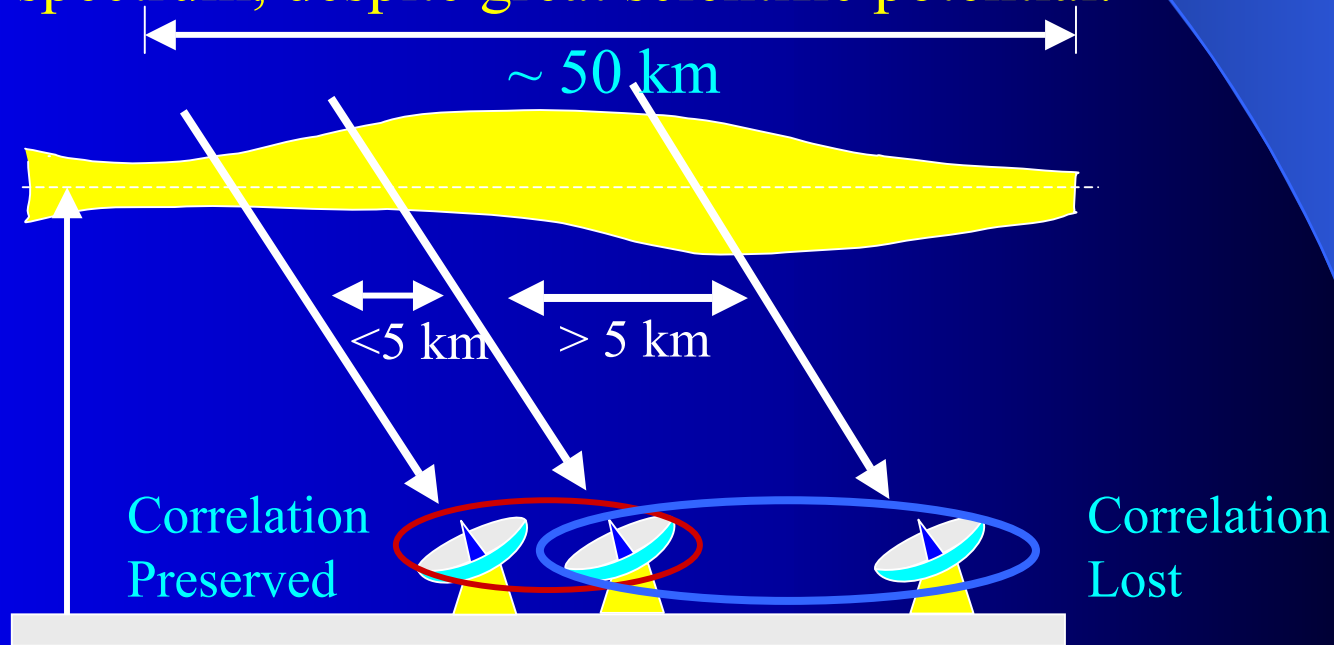
LOFAR Overview

(with emphasis on clusters)

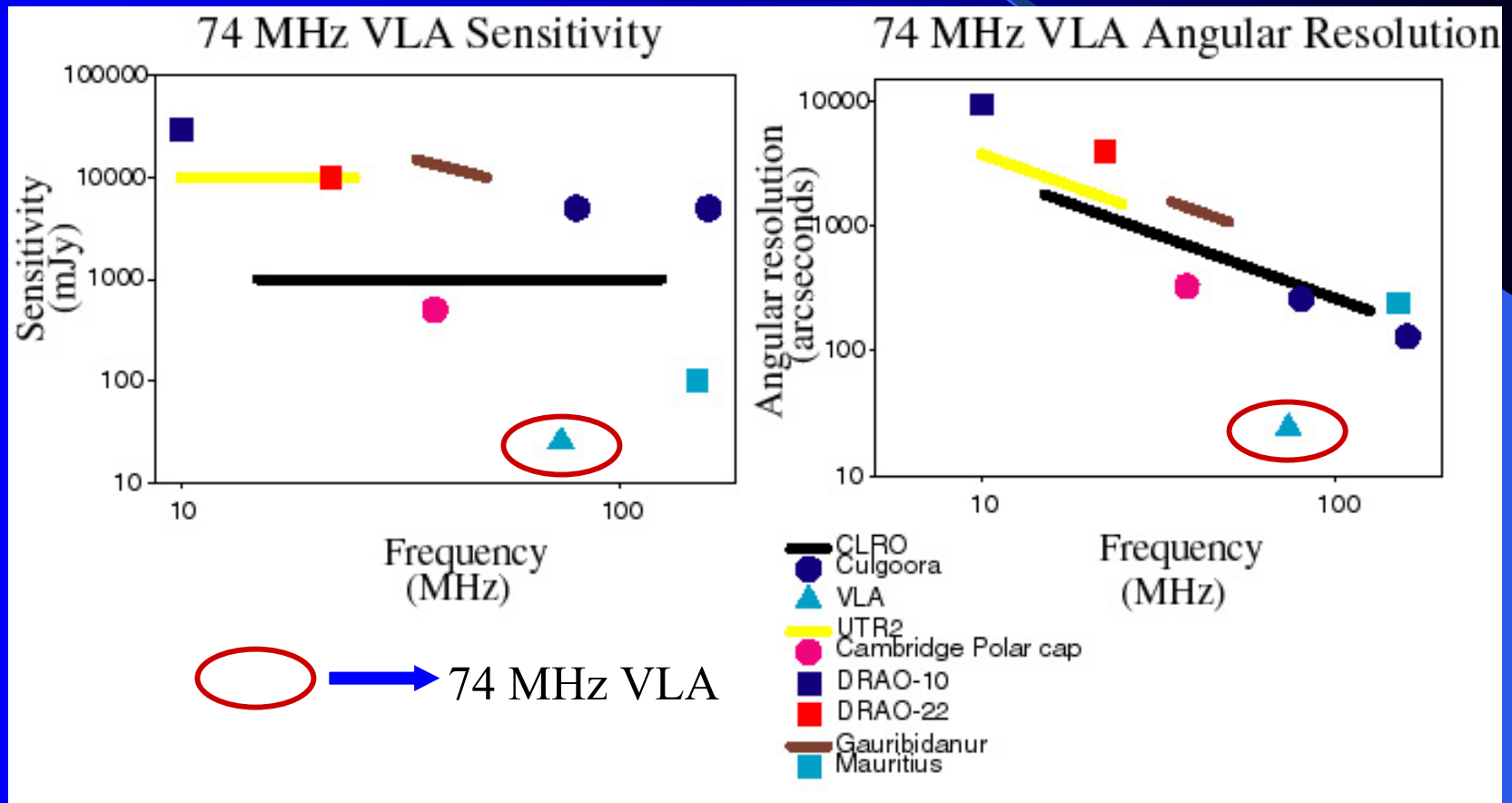
Namir Kassim
LOFAR Project Scientist
Naval Research Laboratory

Background of Low Frequency Radio Astronomy: Mired in the Dark Ages

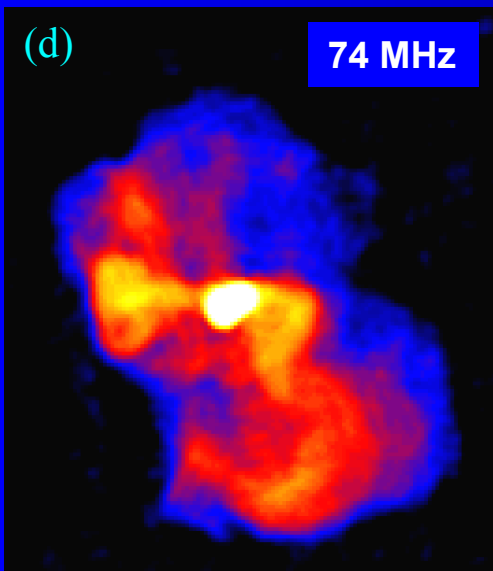
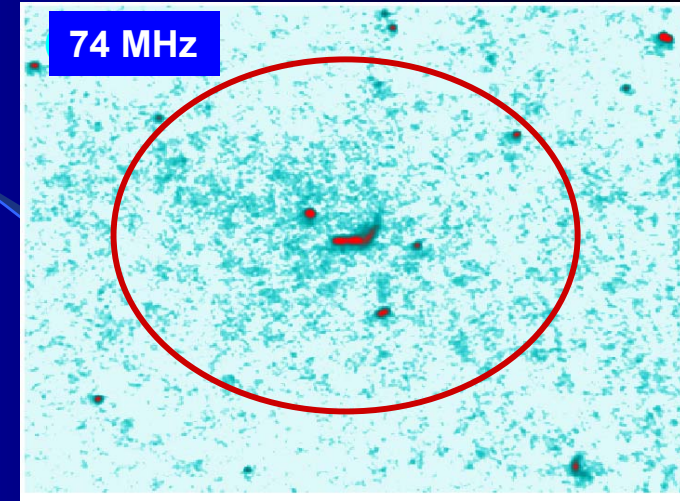
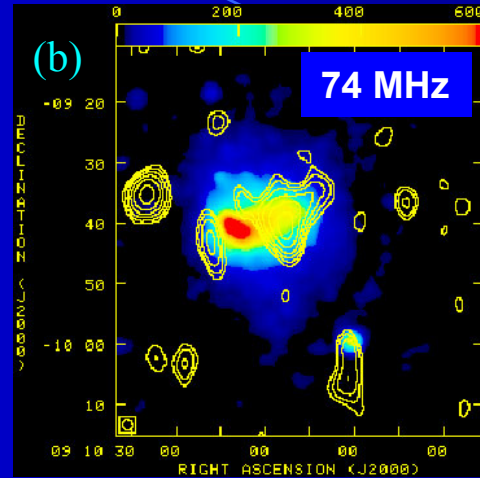
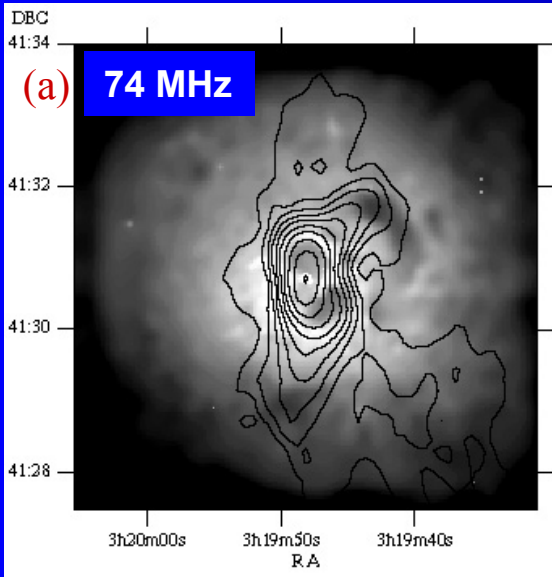
- Radio astronomy began at low frequencies: $\nu \sim 20$ MHz.
- Until recently, ionospheric effects severely limited angular resolution and sensitivity.
- Remains one of the most poorly explored regions of the EM spectrum, despite great scientific potential.



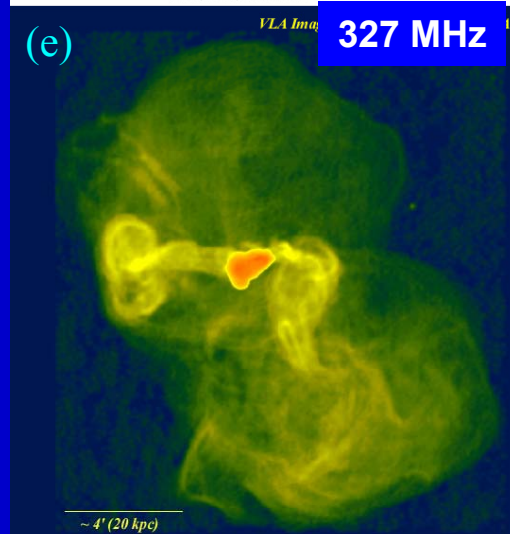
74 MHz VLA: Significant Improvement in Sensitivity and Resolution



Cluster results from 74 & 327 MHz VLA



The Virgo Cluster and the M87 Radio Halo: Outflow, not Cooling Flow
Owen, Eilek, & Kassim 1999



- (a) Per-A bubbles (Fabian *et al.* 2002)
- (b) A754 halo & relic (Kassim *et al.* 2001)
- (c) Coma cluster halo (Enßlin *et al.* 1999)
- (d,e) M87 (Kassim *et al.* 1993, Owen *et al.* 2000)

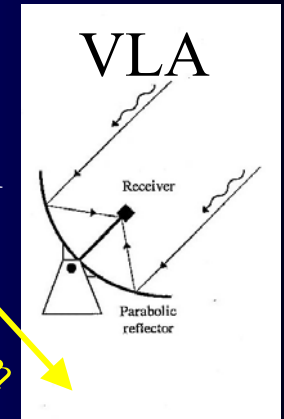
LOFAR (Low Frequency Array) Concept

(<http://www.lofar.org>)

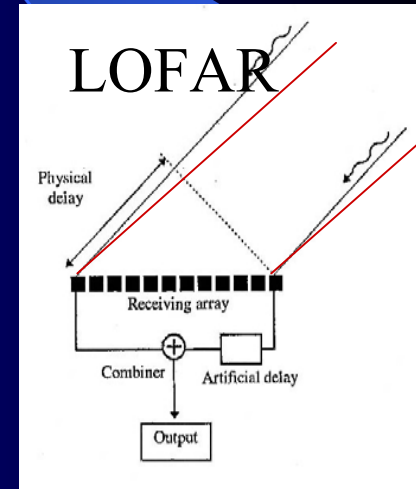
- Inspired by 74 MHz VLA, which demonstrated the ability to remove ionospheric effects to achieve better sensitivity and angular resolution.
- Fully electronic, **broad-band antenna array**
- Basic element is an active dipole receptor: $\Delta\nu \sim 10\text{--}240$ MHz
 - Low frequency limit: ionospheric absorption, scintillation
 - High frequency limit: λ^2 collecting area, better to use dishes above this
- “Stations” (dishes) are 160 m in size, comprised of 256 receptors
 - Good primary beam definition, low sidelobe levels
- **Large aperture:** baselines ≤ 500 km (no limit on baseline length)
 - Good angular resolution, low confusion
- **Large collecting area:** $\geq 10^6$ m²
 - 2–3 orders of magnitude improvement in resolution & sensitivity
 - 8”@15 MHz, 0.8”@150 MHz; < 1 mJy@15 MHz, < 300 μ Jy@ 150 MHz
- **Multiple beams:** new approach to astronomical observing

LOFAR Stations

200 Dipoles per "Station", 100 Total Stations over 500 km

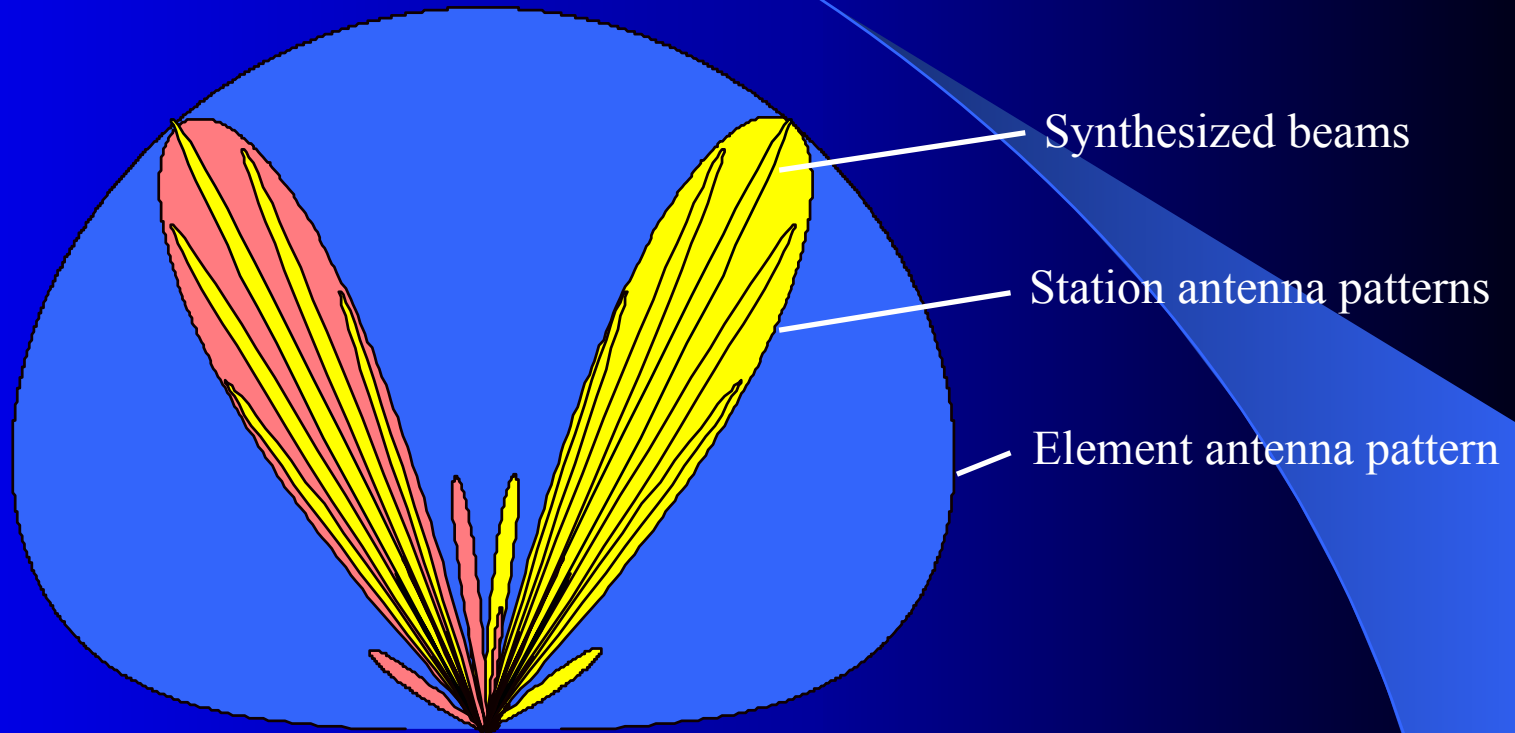


$$A_e \sim 100 \text{ m}^2$$



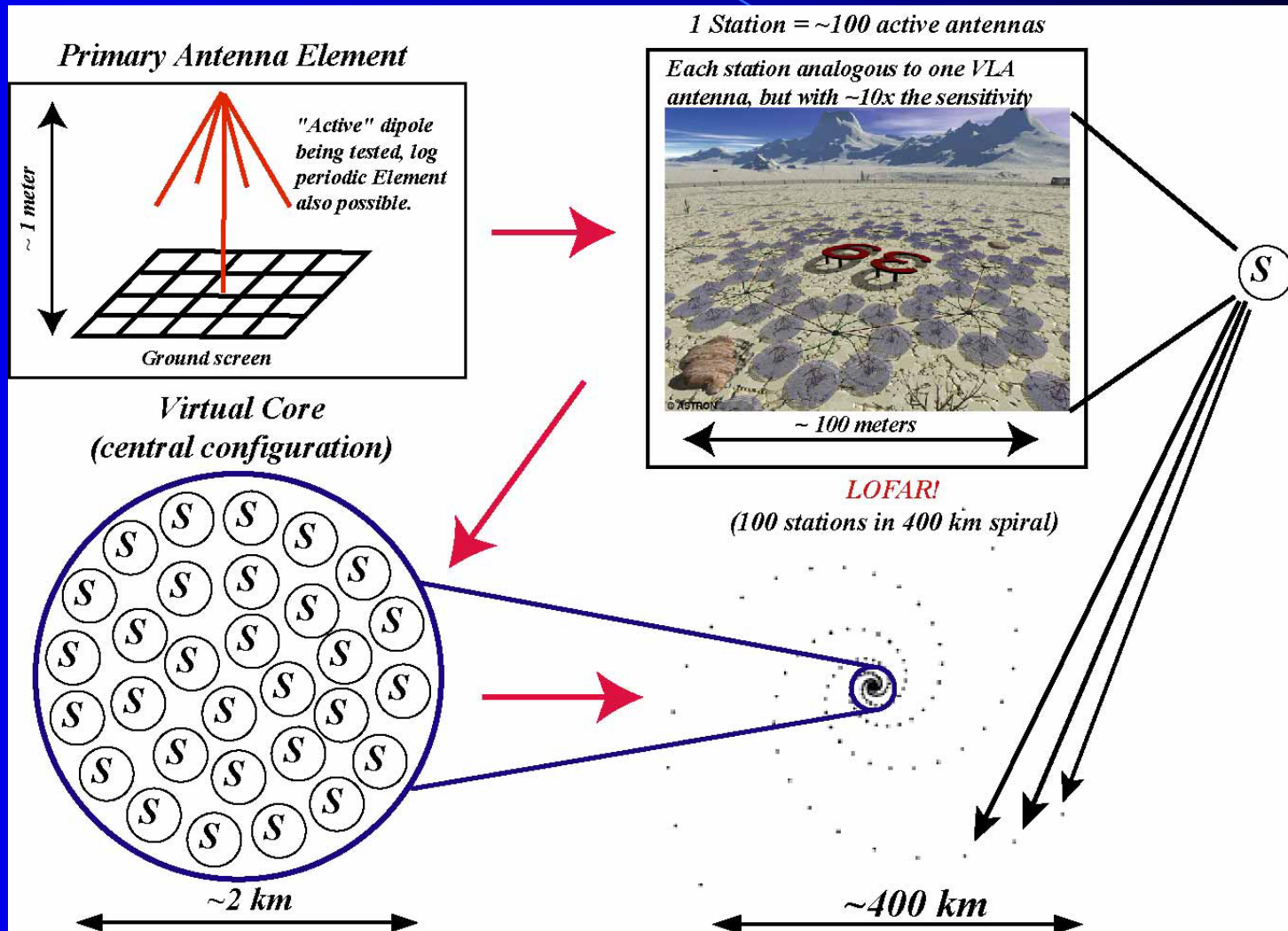
$$A_e \sim 1500 \text{ m}^2$$

Advantages of New Technology Electronic Arrays: Speed, Flexibility, Multibeaming



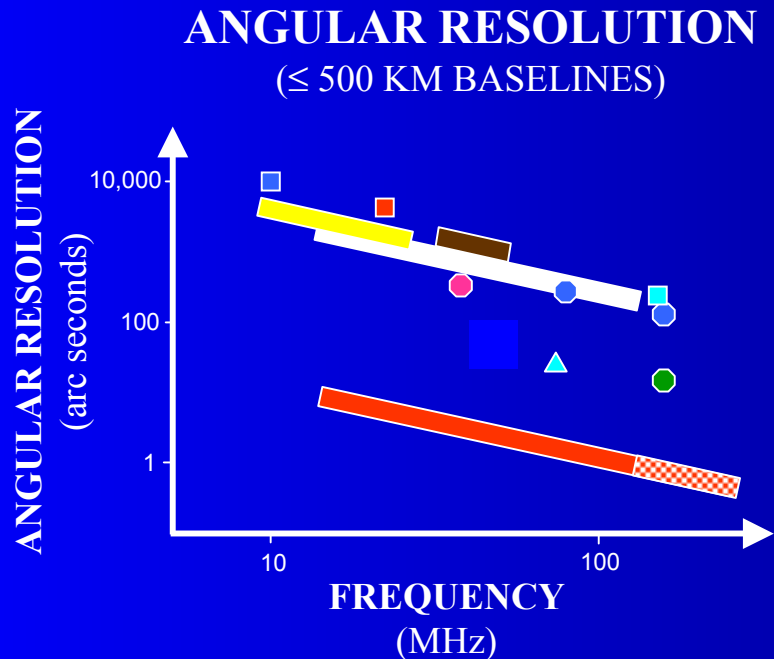
Multiple, independent beams \Rightarrow speed and flexibility
 \Rightarrow multiple, simultaneous science programs

LOFAR Layout

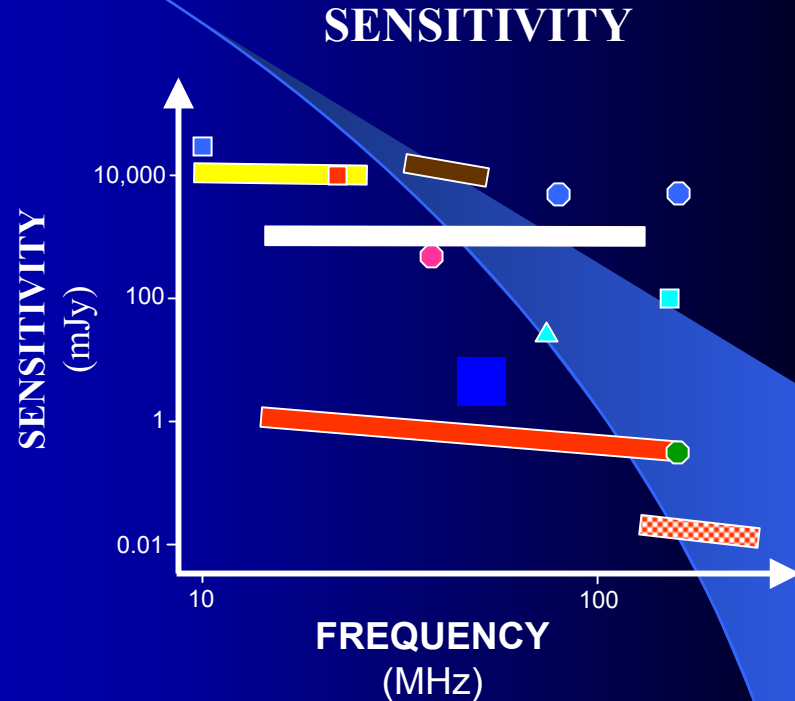


Opening A New Window On The Universe

(<http://www.lofar.org>)



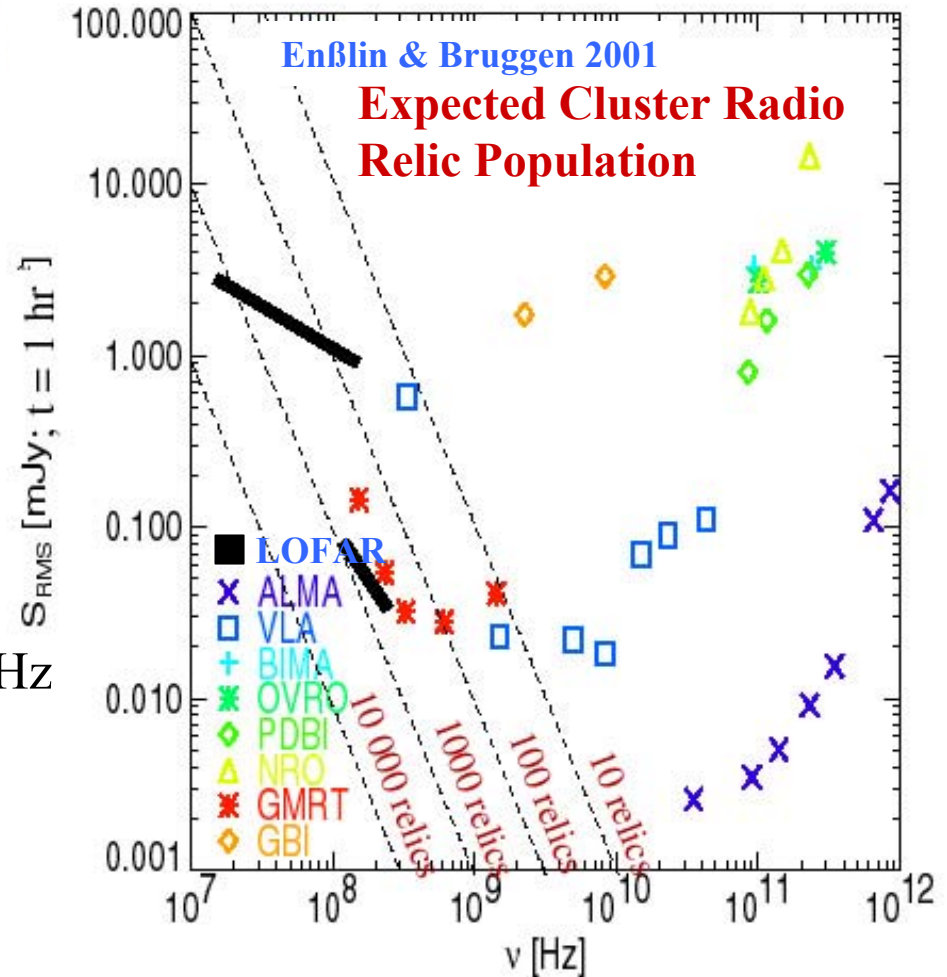
- ▬ LOFAR (Low Frequency Elements)
- ▨ LOFAR (High Frequency Elements)
- ▬ Clark Lake Radio Observatory
- ▬ Gauribidanur
- ▬ UTR-2



- ▲ VLA
- DRAO-10
- DRAO-22
- Mauritius
- GMRT
- Cambridge Polar Cap

LOFAR for Cluster Astrophysics

- (1) LOFAR will find/map many new clusters & relics
- (2) Improved interpretation of IC:
 IC from $\gamma=5000 e^-$:
 20 KeV X-rays, radio @ $\nu=100$ MHz



SUMMARY

- LOFAR will open one of the last and most poorly explored regions of the EM spectrum below 250 MHz
 - Multi-beam, multi-frequency electronic array which will herald revolutionary new approach to astronomical observations
 - **Science plan recommended by National Academy of Sciences Astronomy Survey Committee in the new Decade Report**
- Key science drivers:
 - High Z Universe: unbiased sky surveys, select high-z galaxies, epoch of reionization
 - **Find and map many new clusters & relics, better interpretation of IC measurements, trace IGM B fields, infalling shocks around clusters**
 - Acceleration, Turbulence, & Propagation in the ISM: probe the origin of cosmic rays, map the structure of the magneto-ionic components of the ISM
 - Bursting & Transient Universe: all-sky monitoring for variable & transient phenomena (GRBs, etc.), coherent emission processes
 - Solar-Terrestrial Relationships: study fine-scale ionospheric structures, image Earth-directed CMEs – synergy with FASR, Arecibo solar radar system
 - **Serendipity: new discoveries likely in unexplored regime**