EVLA-II and LOFAR

Joseph Lazio & Namir Kassim
Naval Research Laboratory

EVLA-II vs. LOFAR

EVLA-II

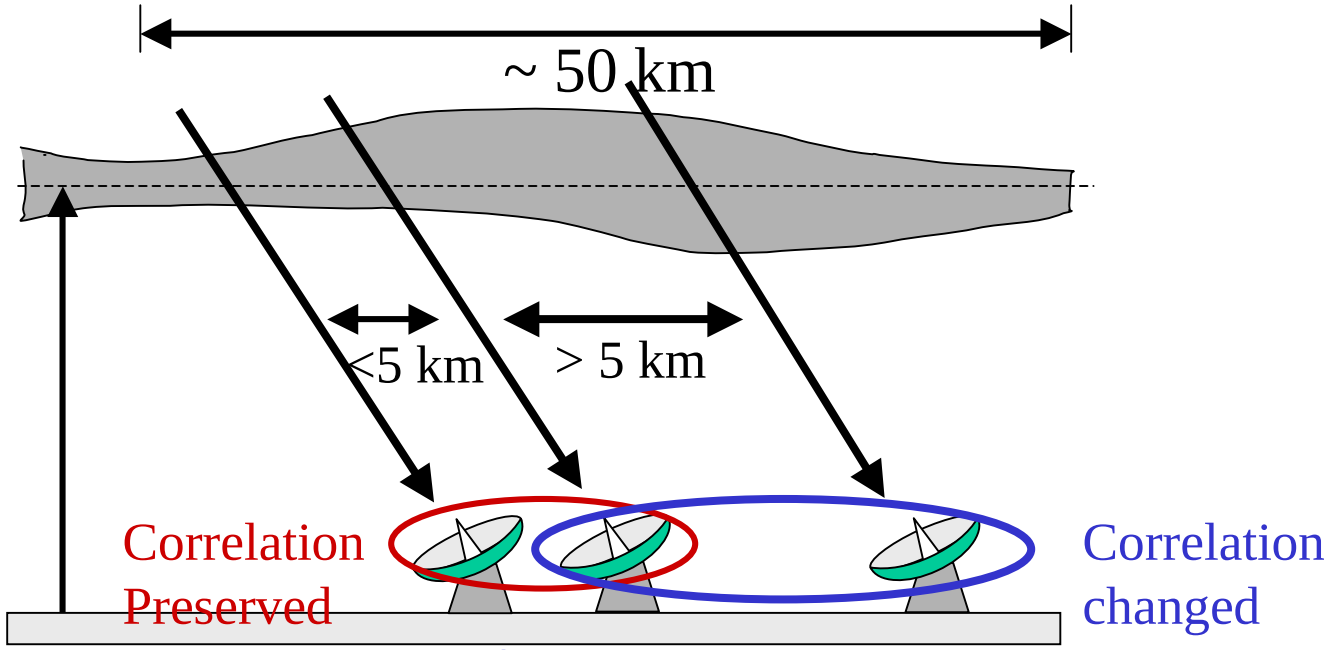
- Frequencies: 1–50 GHz
  (+ 300–1000 MHz?)
- Size: ~ 400 km
- Sensitivity: 3 μJy (continuum at 1 GHz)
- Resolution: 0.22" (at 1 GHz)
- Receptors: Parabolic antennas(?)

LOFAR

- Frequencies: 10–250 MHz
- Size: ~ 400 km
- Sensitivity: ~ mJy at 15 MHz $\Rightarrow$ 1 km^2 at 15 MHz
- Resolution: ~ arcseconds at 15 MHz
- Receptors: Banks of dipoles

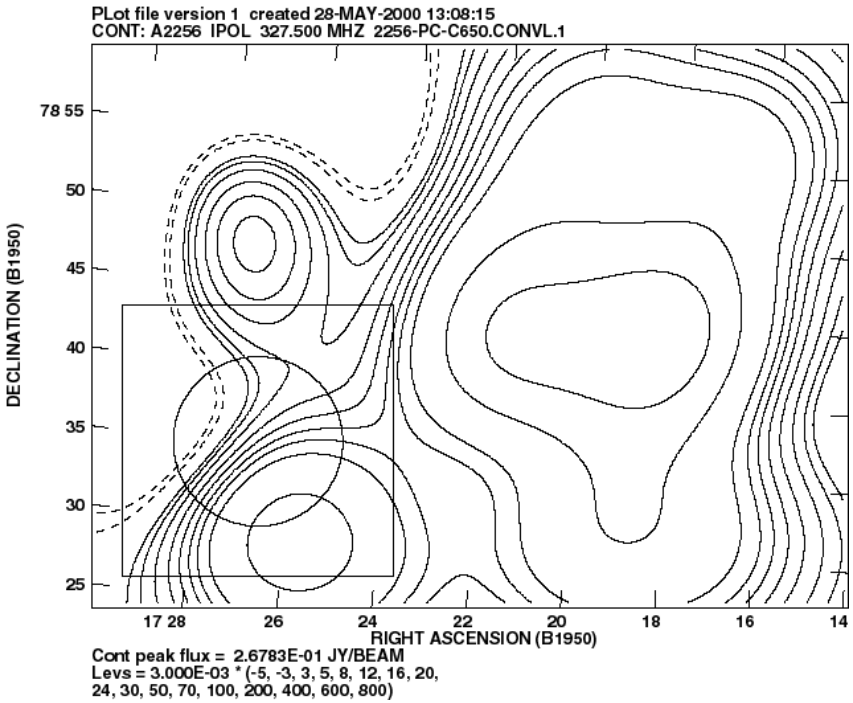
Background of Low Frequency Radio Astronomy: Mired in the Dark Ages

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

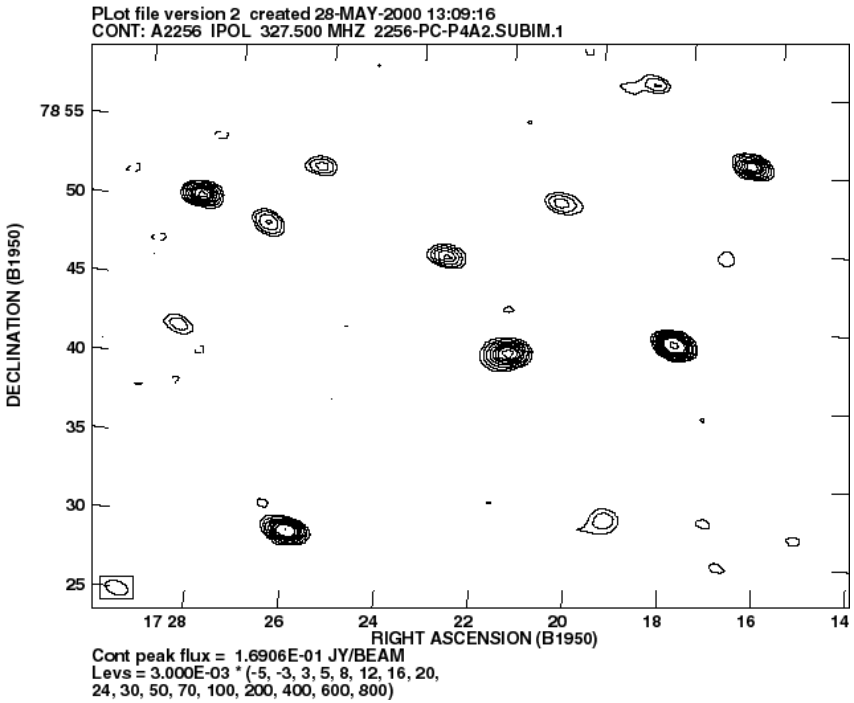


Low Angular Resolution: Limits Sensitivity Due to Confusion

θ ~ 10', rms ~ 30 mJy/beam



θ ~ 1', rms ~ 3 mJy/beam



THE 74 MHz NRL-NRAO VLA SYSTEM

74 MHz VLA system implemented 1993–1997.

•Demonstrated **self-calibration** can remove ionospheric effects

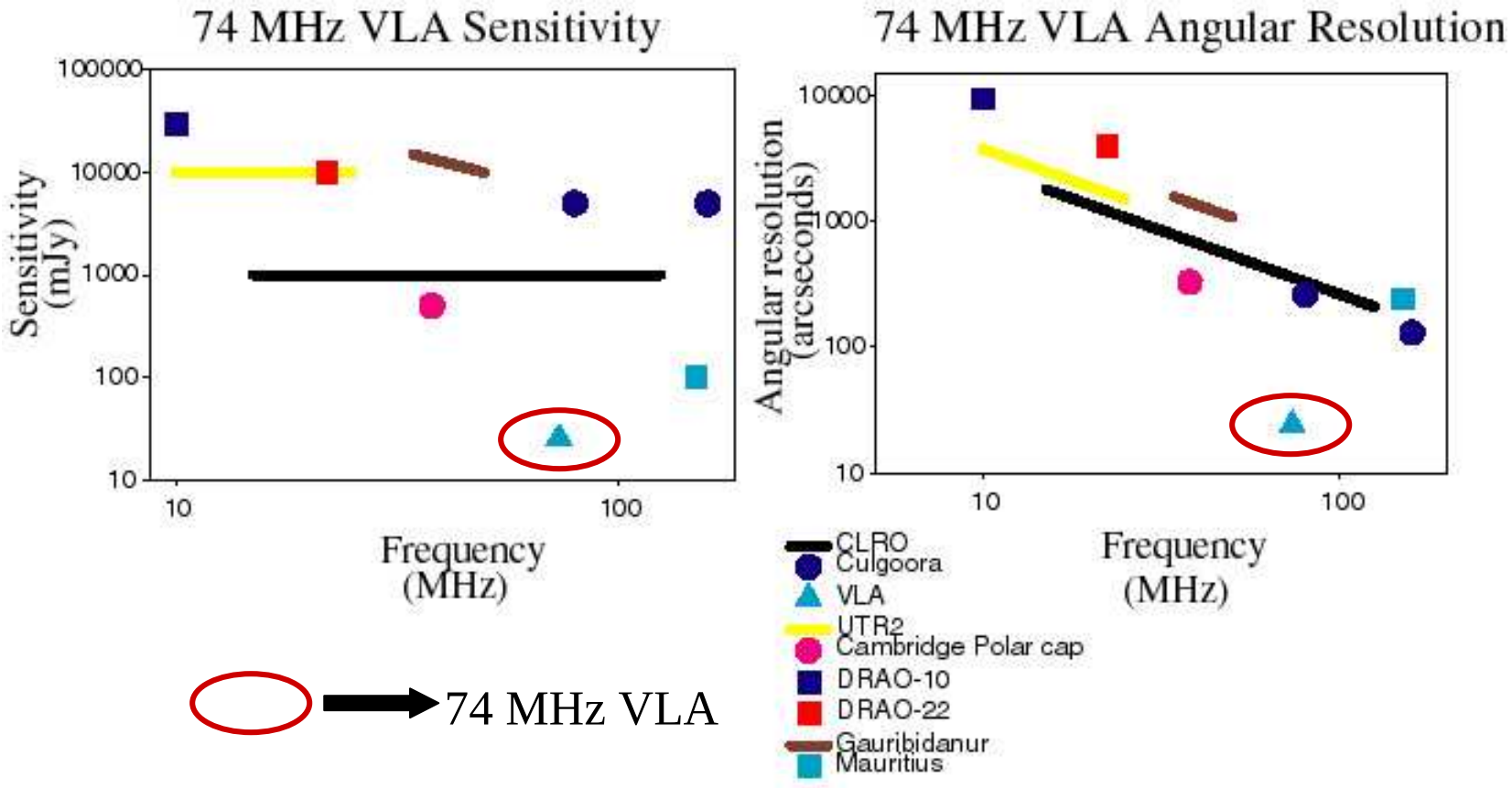
Overdetermined problem with large *N* array and initial model

•Works well at VLA (*N*=27)

•Originally motivated by recognition that *phase transfer* from higher frequencies can increase coherence times and S/N—rarely required

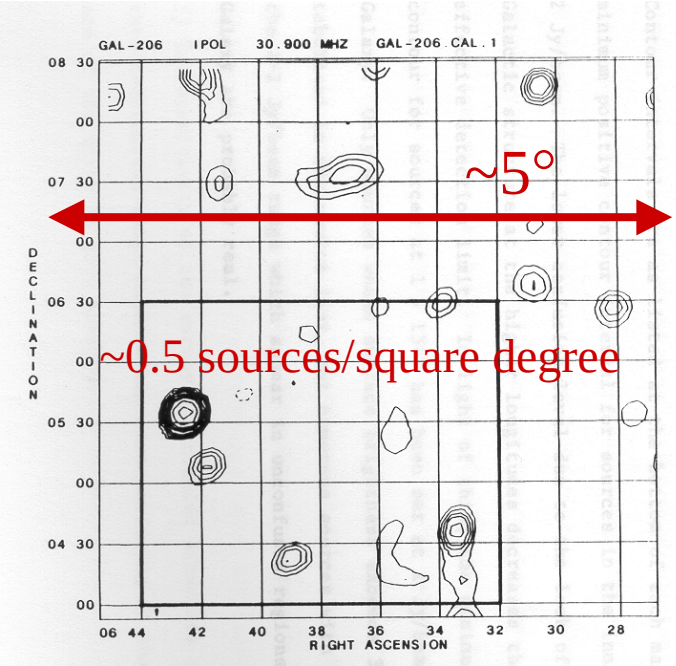
•VLA 74 MHz system is the *most powerful* long wavelength interferometer in the world.

74 MHz VLA: Significant Improvement in Sensitivity and Resolution



Comparison of Low Frequency Capabilities (past vs. present)

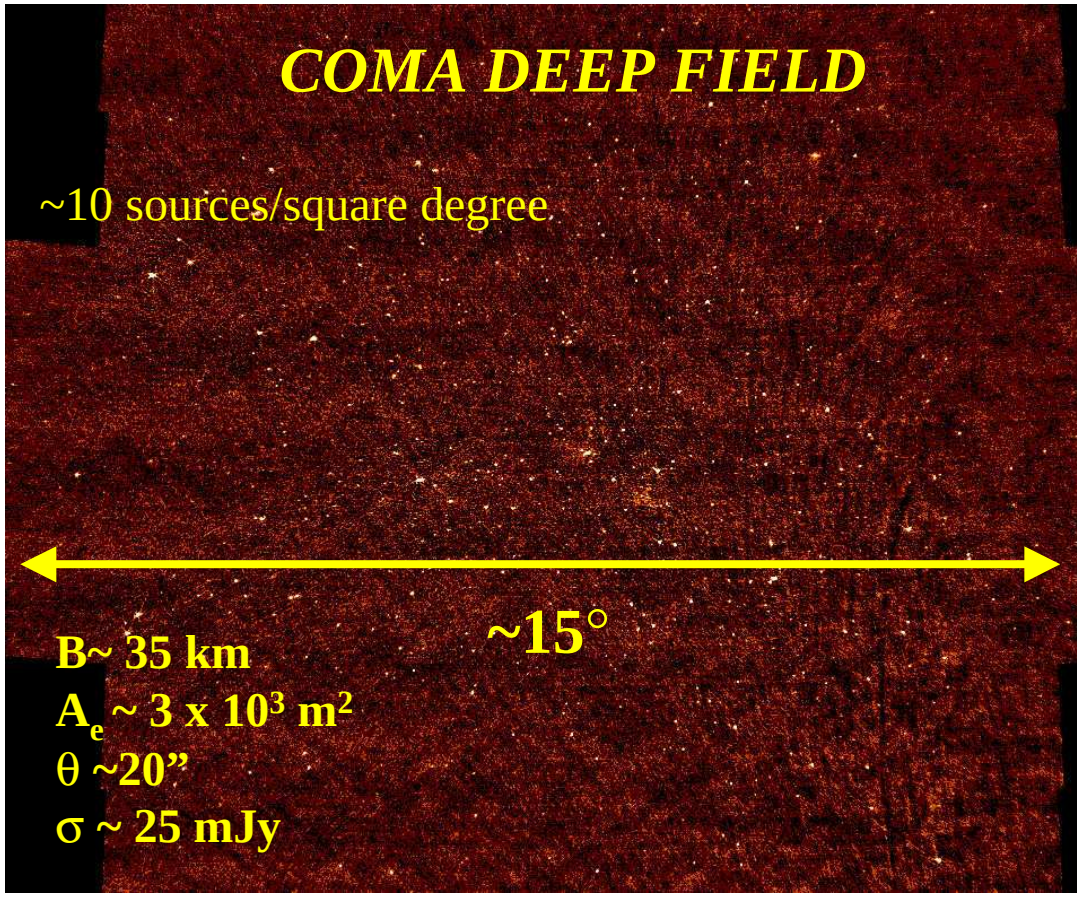
Clark Lake (30 MHz)



Kassim 1989

- B ~ 3 km
- A_e ~ 3 x 10^3 m^2
- θ ~ 15' (900")
- σ ~ 1 Jy

VLA (74 MHz)



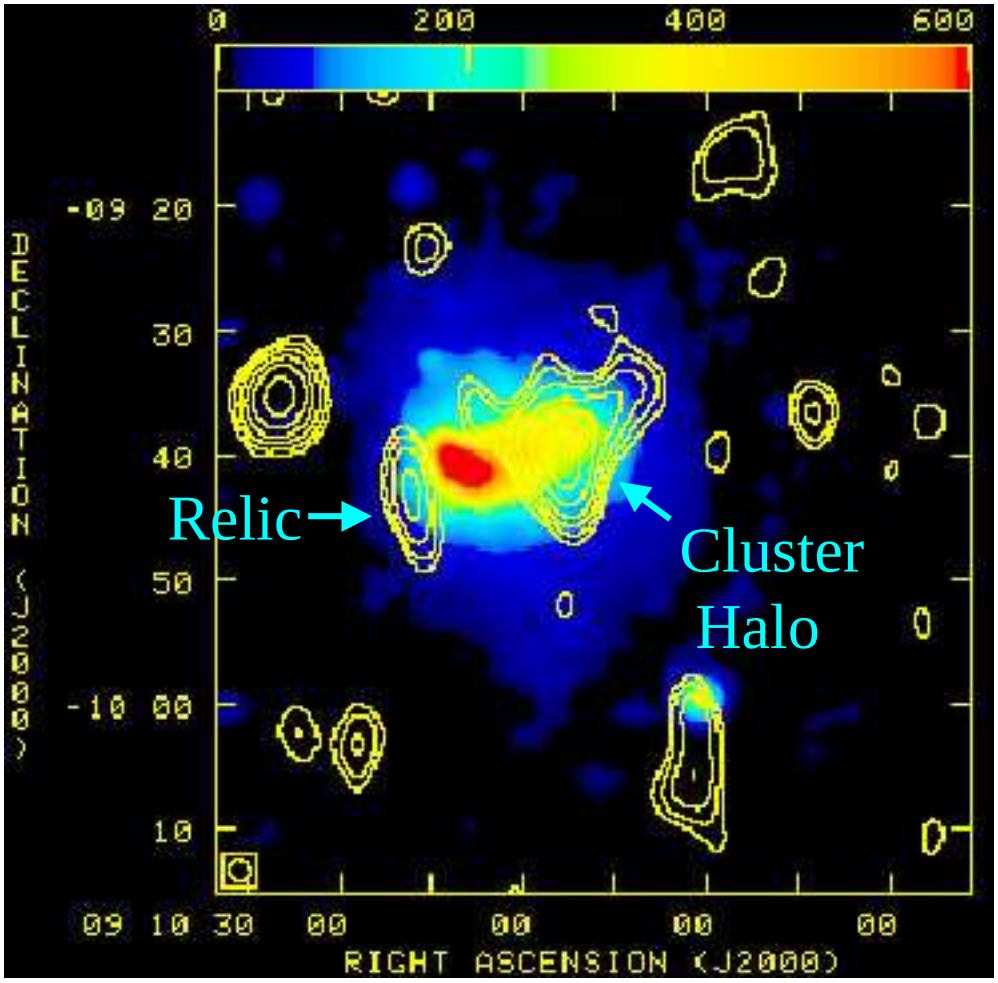
Enßlin *et al.* 1999

VLA 74 MHz: New Cluster/Relic System

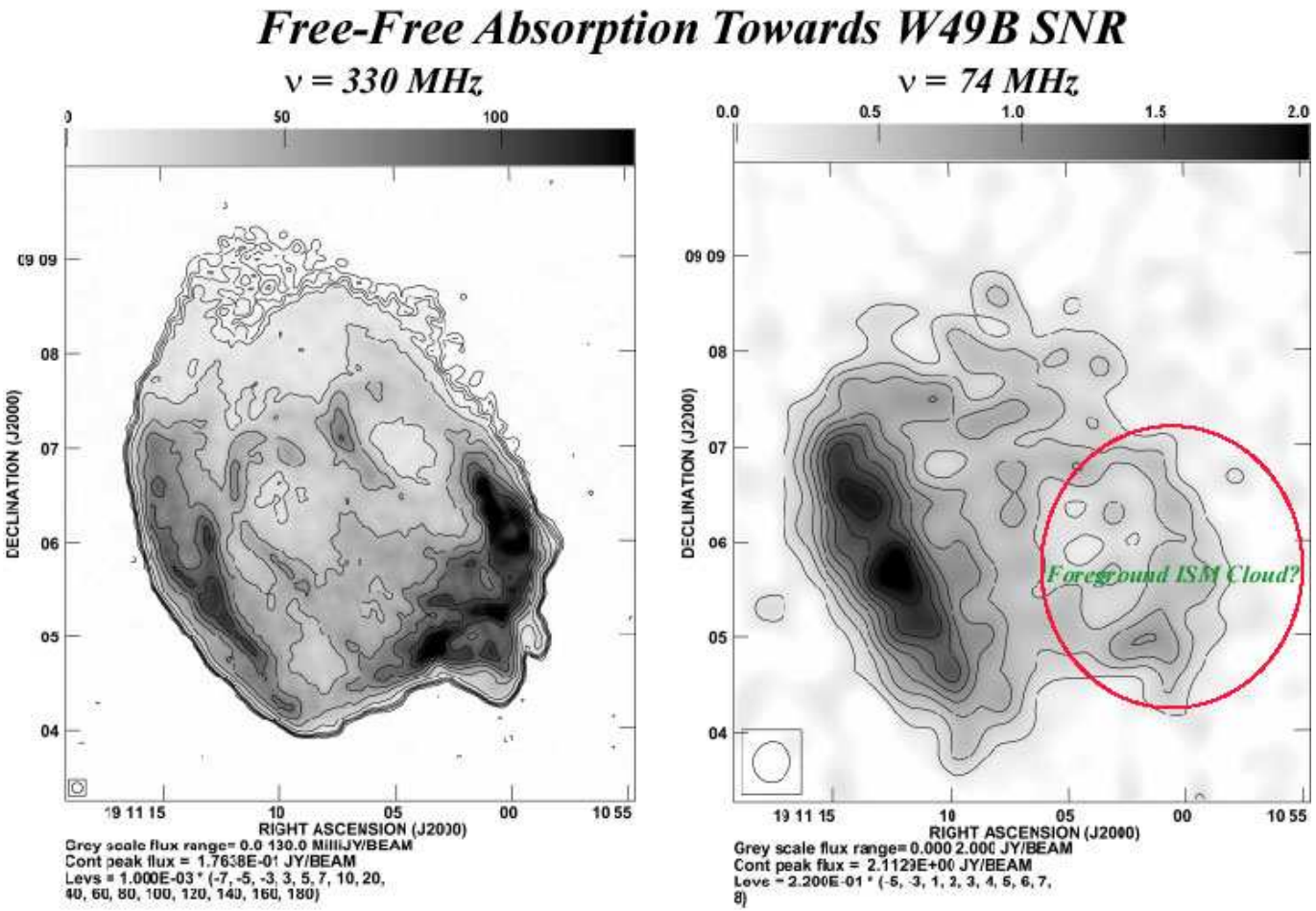
Kassim, Clarke, et al. 2001(ApJ, astro-ph/0103492)

A new halo-relic system in the Abell 754 cluster of galaxies discovered recently with the 74 MHz VLA.

Color: ROSAT X-ray image
Contours: 74 MHz VLA image



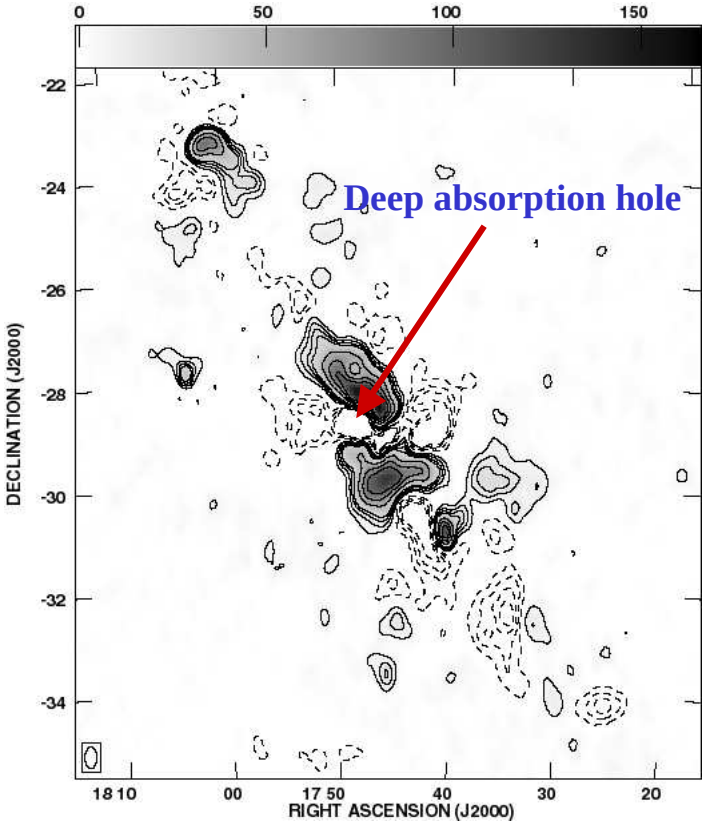
SNRs: Extrinsic ISM Absorption



First example of spatially resolved free-free absorption towards a Galactic SNR (Lacey et al. 2001)

VLA 74 MHz: Galactic Center Absorption Holes => Synchrotron Emissivity Vectors

74 MHz Galactic Center: Preliminary D-configuration Image (θ~10')
(Mike Nord, UNM-NRL PhD Thesis Project)



74 MHz VLA System Improvements

Main limitations of the present 74 MHz VLA are sensitivity and angular resolution

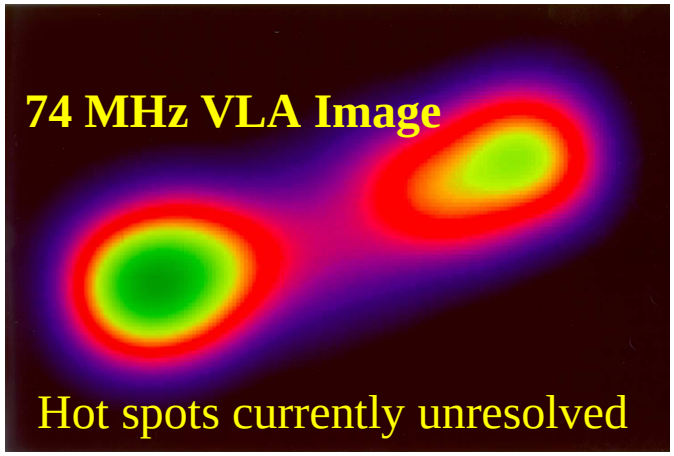
Near-term activities

- Improve current calibration/imaging algorithms
  - 4MASS project ⇒ initial LOFAR calibration grid
- Possible modest near term expansions:
  - Increase the bandwidth at 74 MHz
  - Outfit PT at 74 MHz and implement 74/330 MHz PT link tests
  - 74 MHz campaign on inner few VLBA antennas

Longer range: The VLA was not designed to provide good sensitivity at these wavelengths: sidelobes ~ 20dB, Tsys/Ae too high

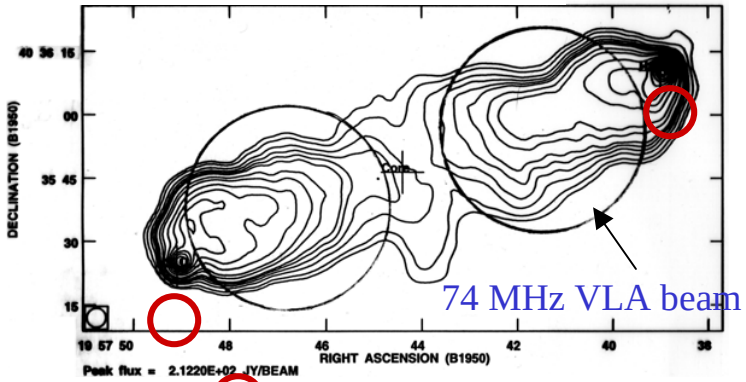
- Design a low frequency (10–90 MHz) "station" consisting of several hundred, electronically phased dipoles (for LOFAR).
- Build prototype stations and use them to enhance the capabilities of the present VLA 74 MHz system.
  - Station I—VLA center; Station II—VLA outlier (e.g., A+ site)

Benefits of Higher Angular Resolution

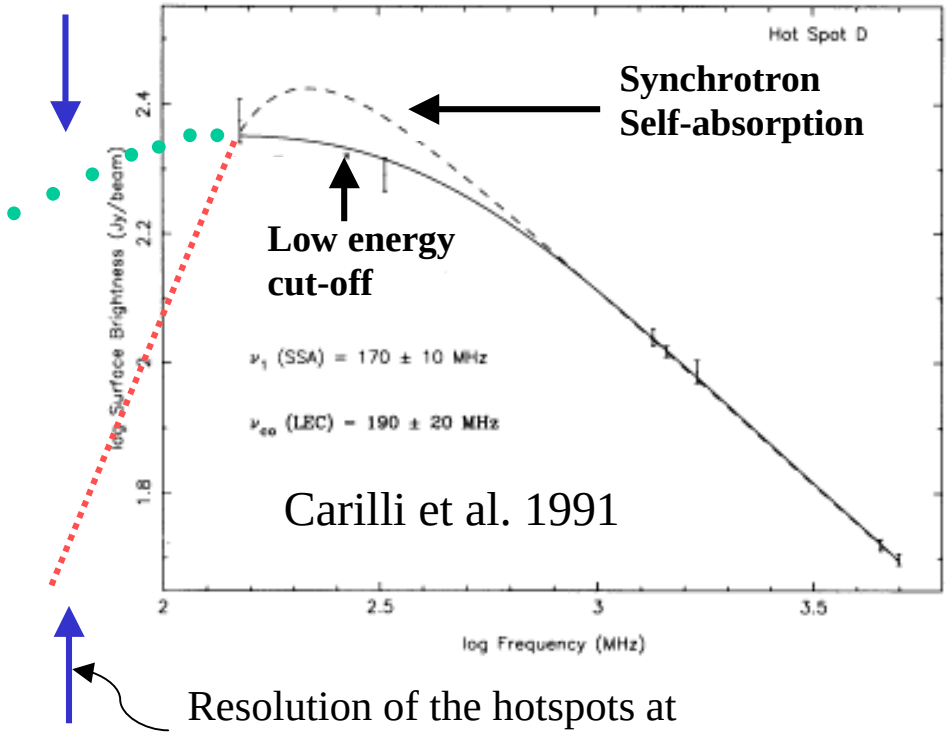


Kassim et al. 1996

330 MHz VLA Image



"Hotspots"

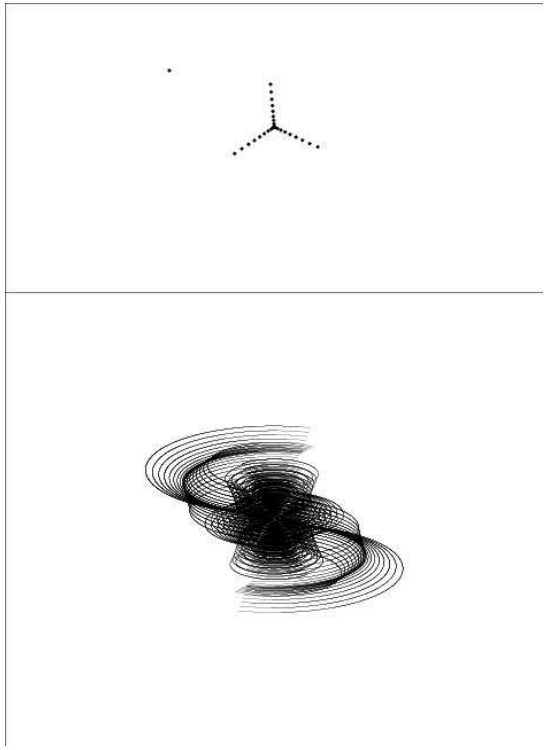


Resolution of the hotspots at 74 MHz will easily differentiate between competing models for spectral turnover

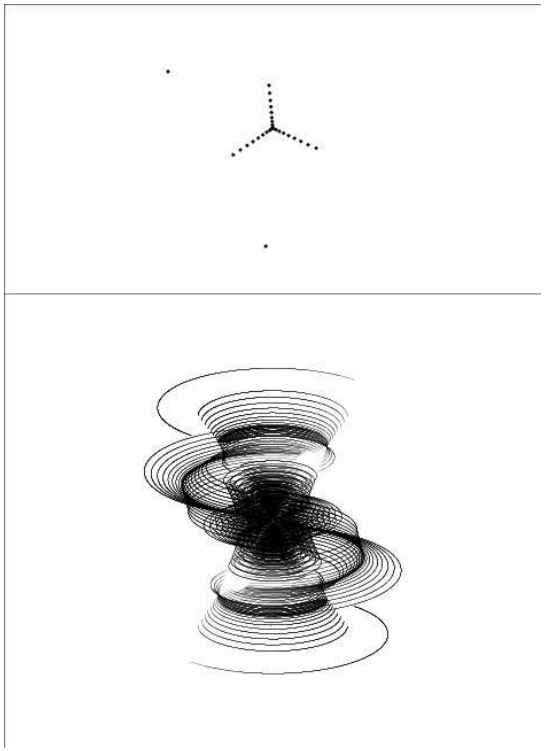
Outlier Station Objective
Extending resolution and *u-v* coverage

$\delta = +20^{o}$

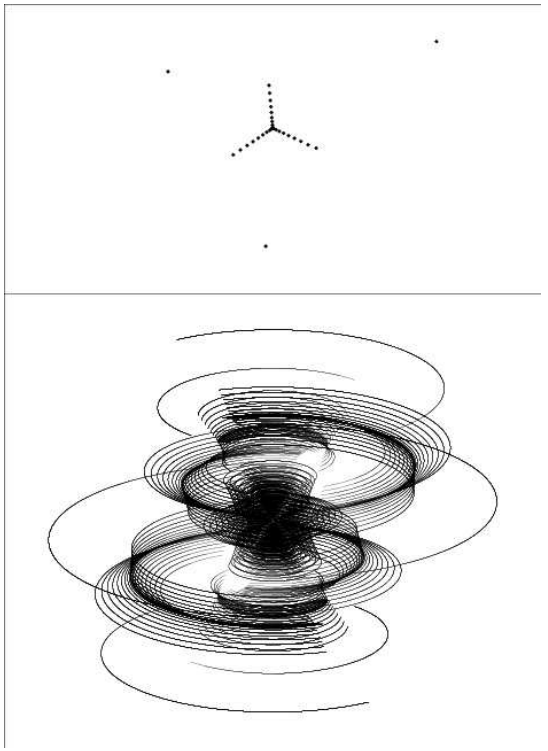
VLA+PT



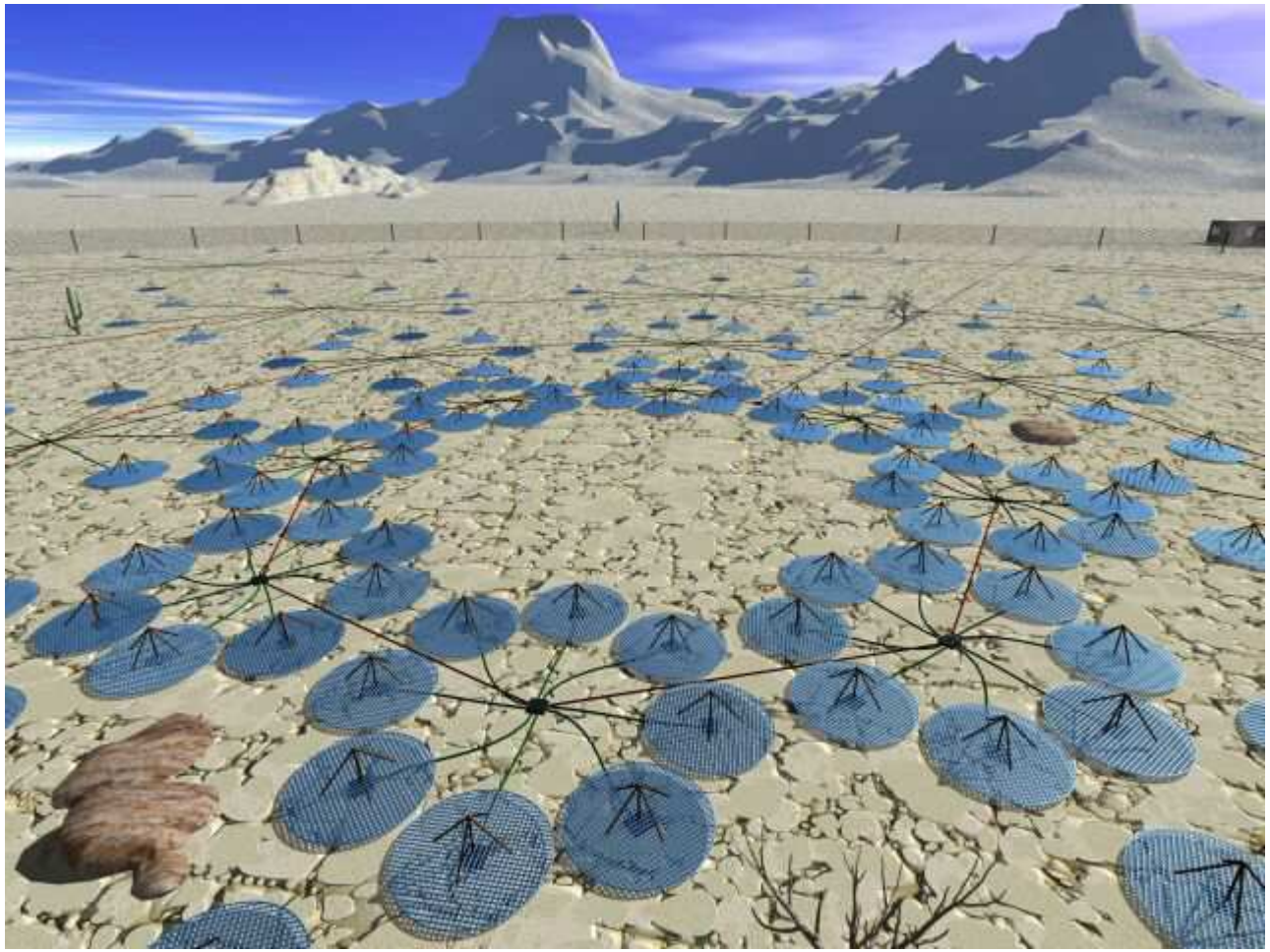
VLA+PT+Dusty



VLA+PT+Dusty+Bernardo



High Sensitivity Station
Prototype for LOFAR Low Frequency Antennas



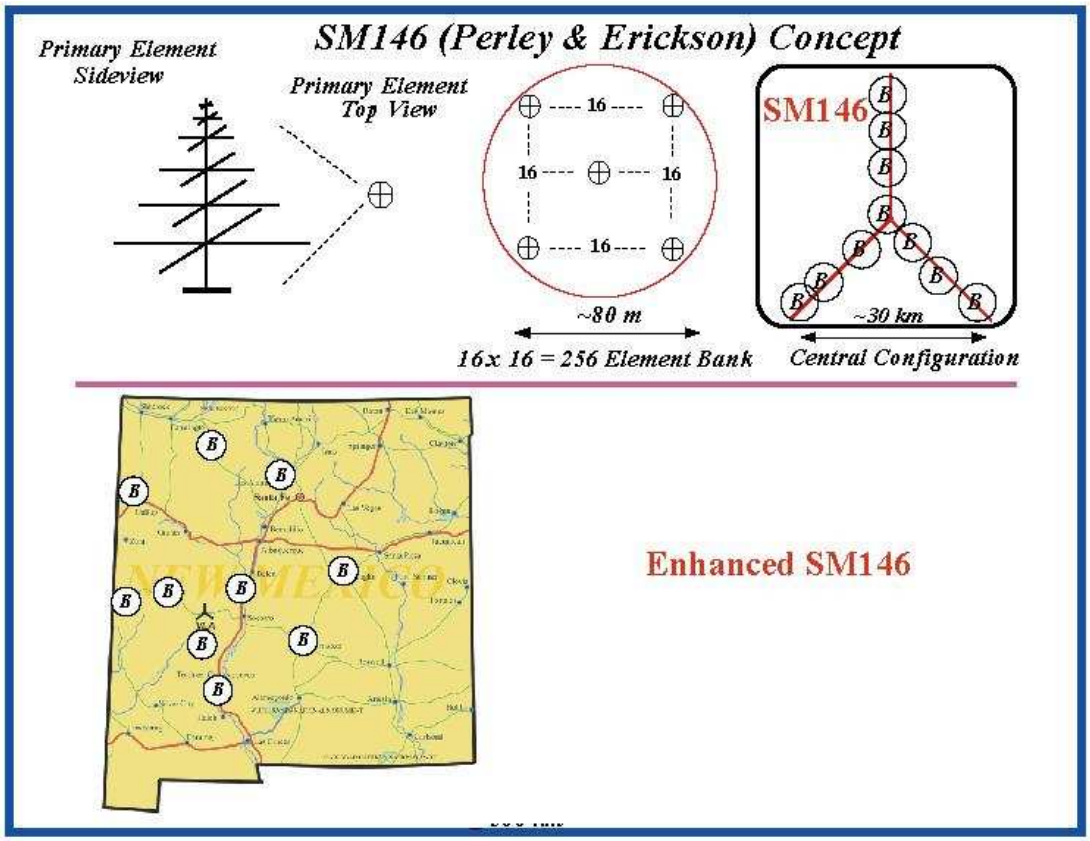
Analogous to one VLA antenna but with > 10x the sensitivity

~100 meter diameter

<u>@ 74MHz:</u>
VLA antenna ~ 125 m^2
LWA Station ≥ 1500 m^2

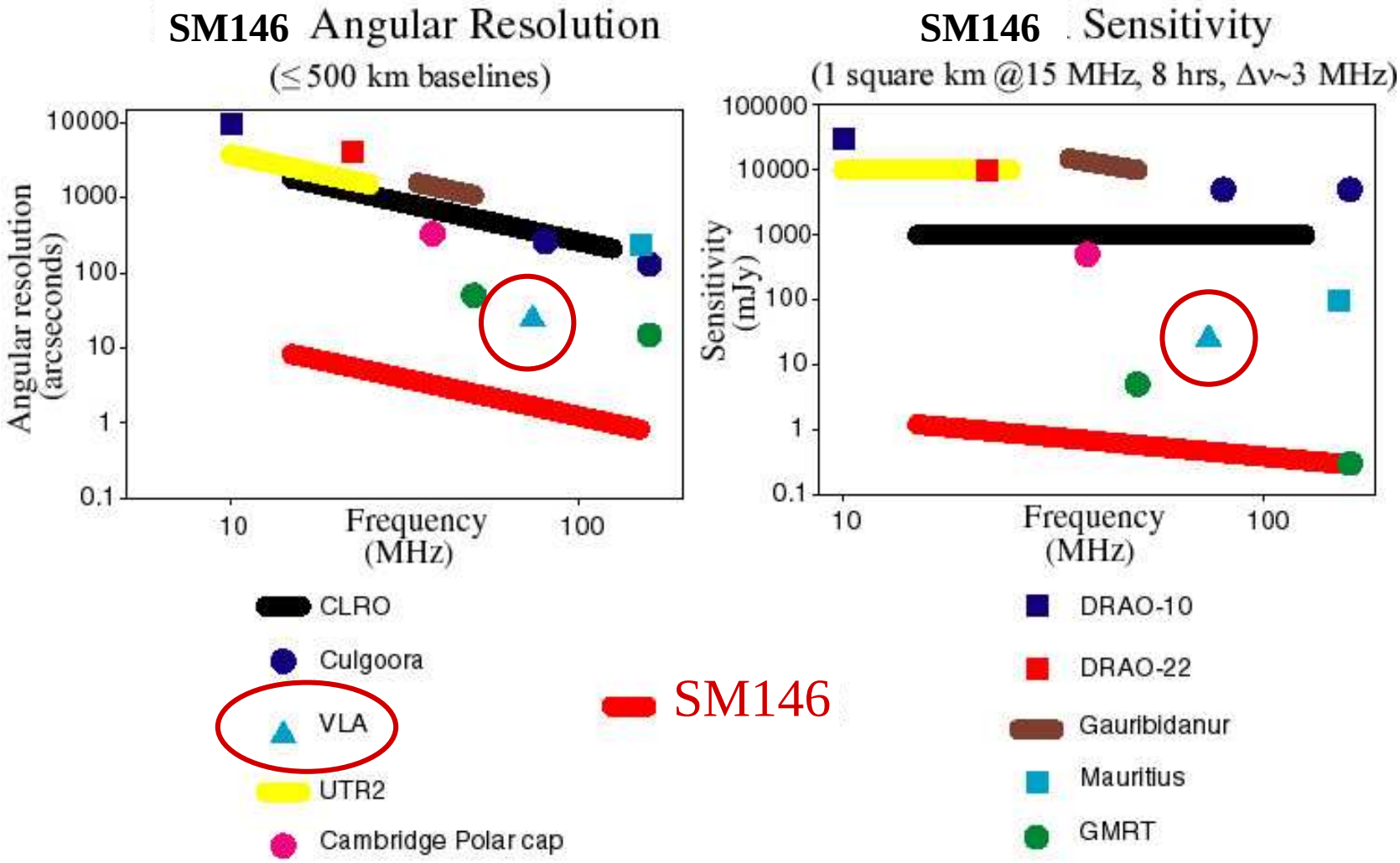
(Fractal element distribution shown here is not necessarily our favorite.)

VLA Scientific Memorandum #146
"A Proposal for a Large, LF Array Located at the VLA" (Perley & Erickson 1984)



- Provide a significant increase in the capabilities of an existing VLA system.
- Prototype a future standalone, broadband array in NM
  - SM146 concept
    - Standalone stations along VLA arms
    - Proceed with EVLA-I?
  - Augmented SM146
    - Addition of A+ capability
    - Proceed with EVLA-II?

SM146 CAPABILITY



Relationship to LOFAR

- **LOFAR is much more complex than SM146**

  It has a substantial technology development element as well as scientific goals

  - Larger Freq. Range (LOFAR: 10–240 MHz; SM146: 10–90 MHz)
  - Much larger bandwidth (larger than EVLA)
  - Many more stations (>100)
  - Complex configuration (log spiral)
  - ***much*** more software, etc …
- SM146 and LOFAR: parallel, mutually beneficial
- Independent of LOFAR, VLA-based SM146 makes sense

Summary
EVLA-II and LOFAR

- We are considering a modest, incremental program for enhancing the scientific and technical performance of an existing VLA system.
  - Some of these have synergetic overlap with planned EVLA activities, e.g., development of a common A+ outlier site
  - Some of these satisfy NRL's responsibilities for developing new technology for LOFAR, e.g., low frequency antennas/stations
- Our philosophy is to
  - realize these enhancements in a manner that translates to immediate scientific benefits to the user community;
  - implement them with minimum impact on VLA/VLBA operations.
- These plans also lay the ground work for a broadband standalone system as described in NRAO SM146
  - It could possibly proceed in parallel with EVLA I & II.
  - Lays the ground work/solves essential problems required for realizing LOFAR.