

# Search for 21cm Reionization

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# Beacons of Darkness

- Reionizing sources create a network of billions of holes in the diffuse 21cm background with precise redshifts
- Can be used as beacons to measure dark matter through gravitational lensing
- Are a tracer for cosmological power spectra. Similar to CMB, but much more precise.

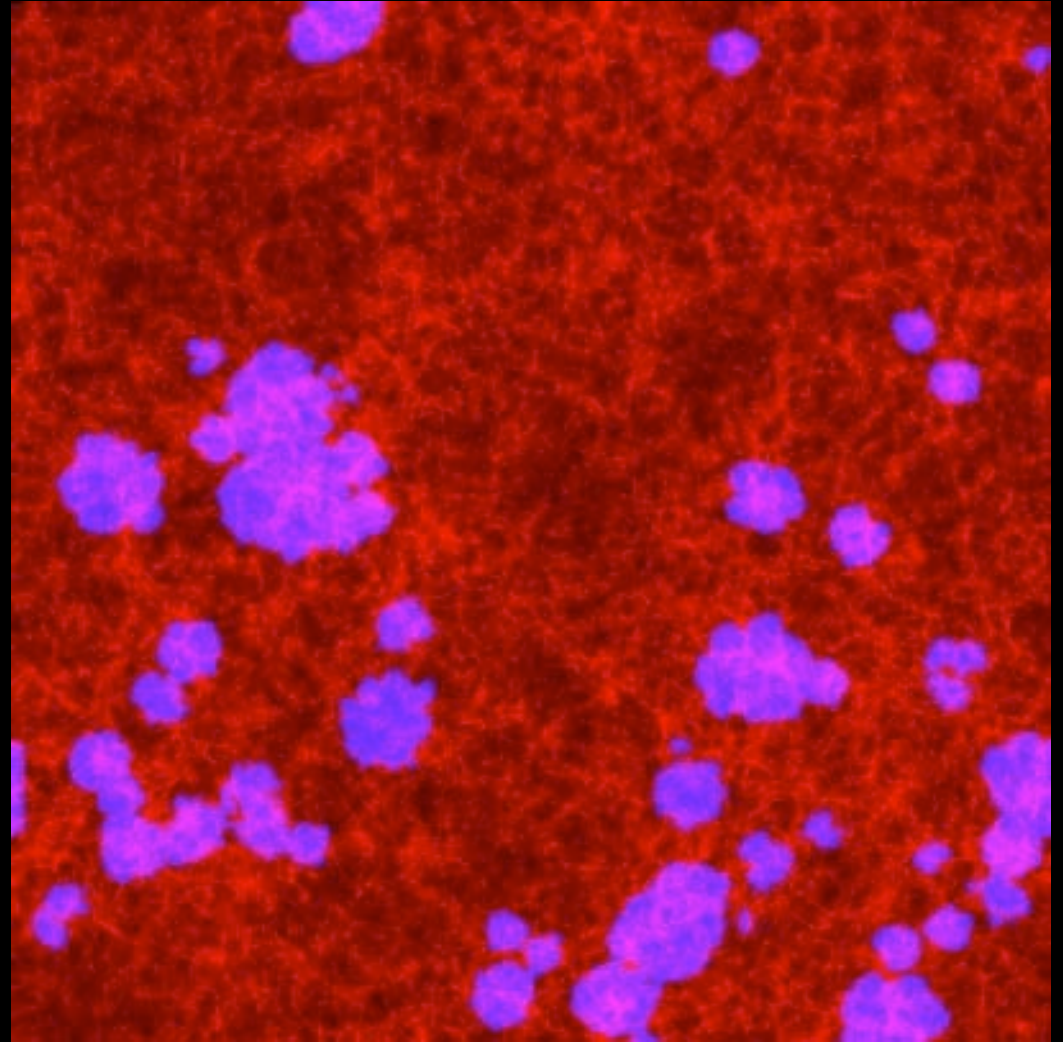
# Searching for Hydrogen

- Most abundant element in universe (75% of baryons)
- Lines: electronic transitions, e.g. Lyman alpha: redshifted to infrared, angular scales too large for existing telescopes.
- Hyperfine transition:  $\nu=1.4$  GHz,  $\lambda=21$ cm.
- Line excitation mechanisms: CMB photons, collision, optical photon pumping. Also in absorption.



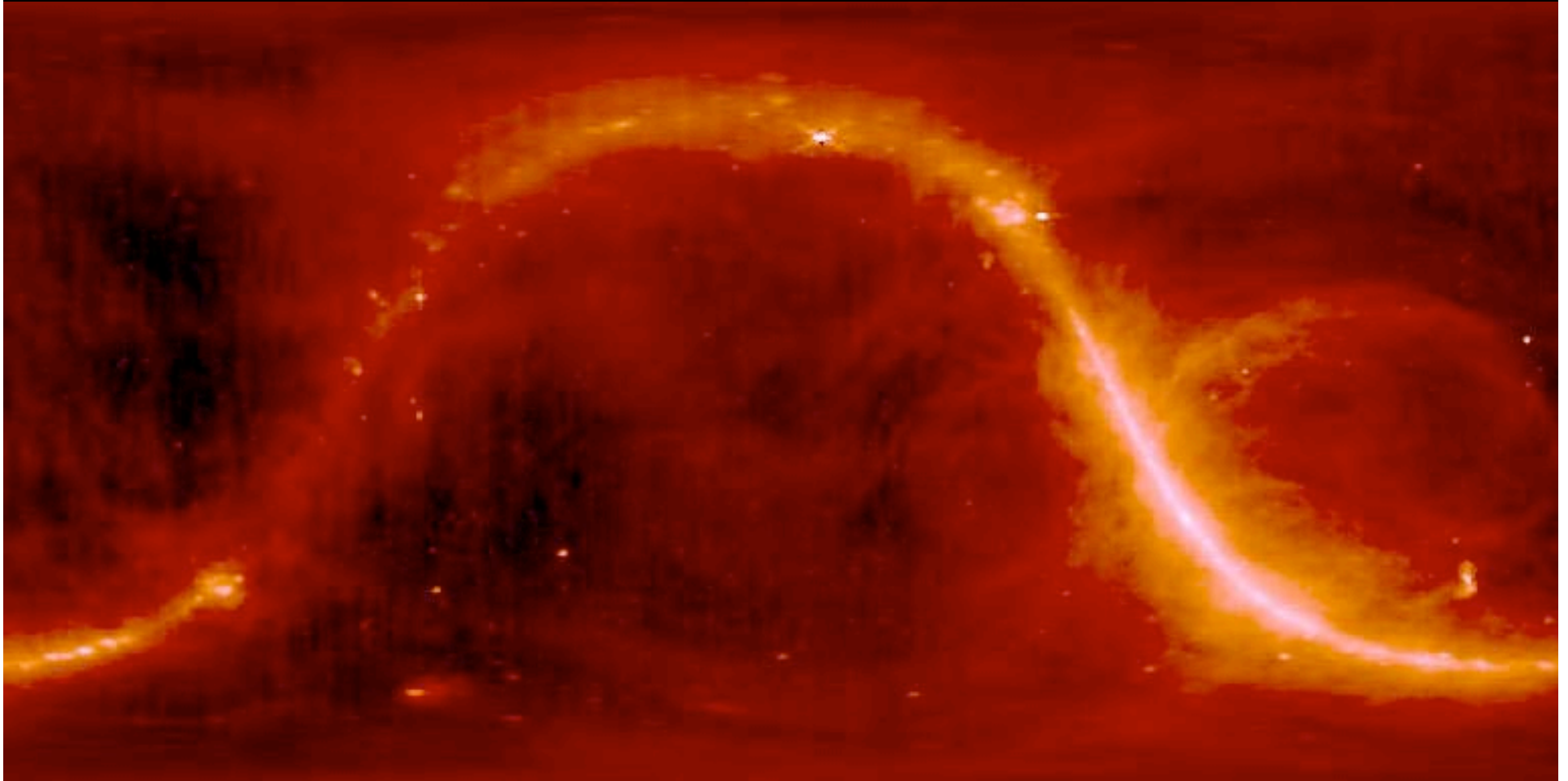
# Reionization

- First objects:
- 21cm @  $z=6-25$
- 50-200 Mhz
- $\Delta T = 23$  mK,  $\sim 0.1$  mJy
- Angular scale  
 $5' < \Theta < 20'$ , freq res  
500 khz



$z=13$  simulation, Iliev, Mellema, Pen 2005.  $1^\circ$  FOV

# Foreground: Galactic Synchrotron



Haslam 408 MHz

Much brighter than signal, but no spectral structure

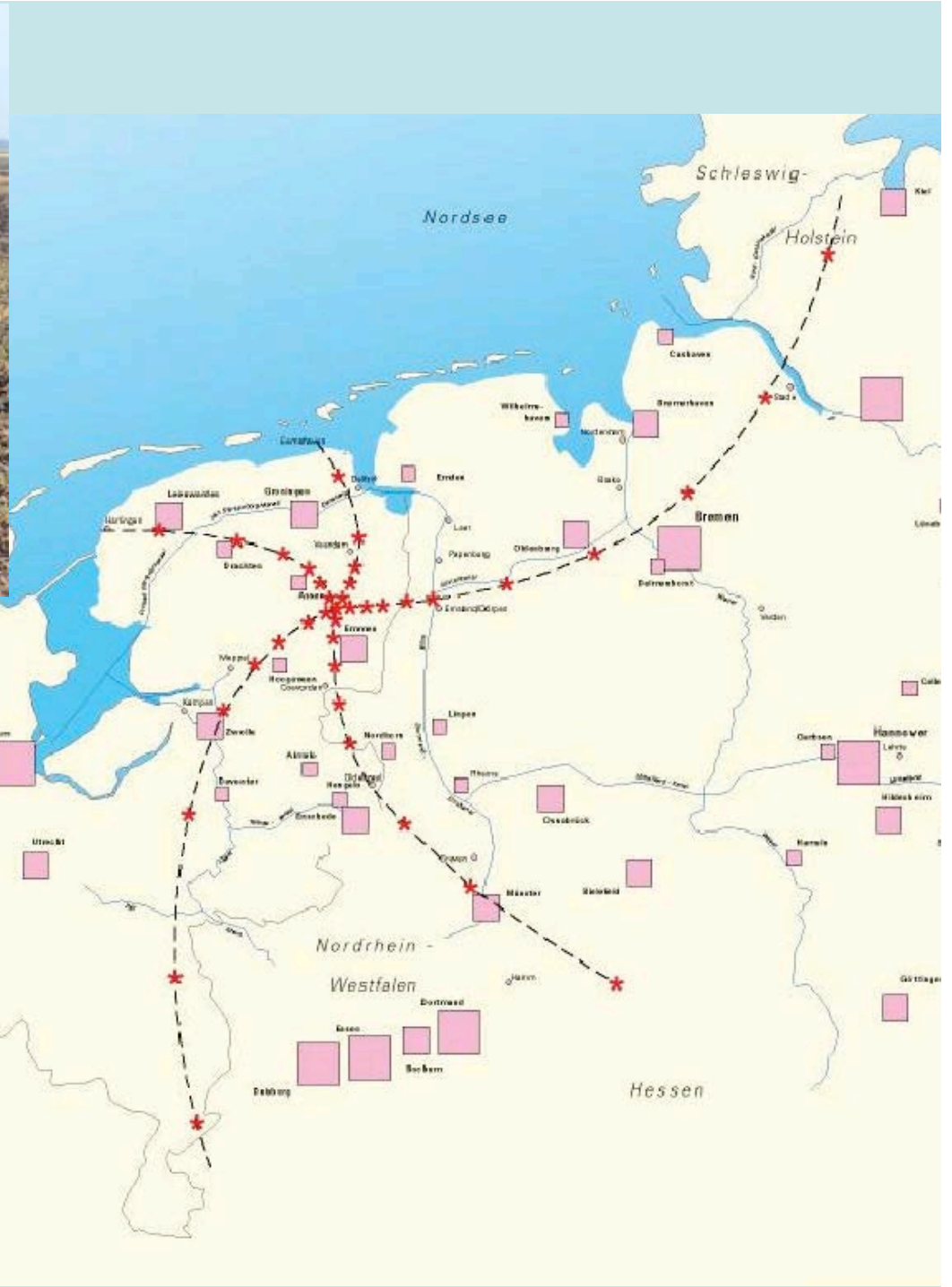
# Observational Challenges

- Instrumental/RFI: all existing low frequency instruments are systematics limited at wide angles: VLA-4m, WSRT-LFFE, GMRT
- Combination of Man-made interference (radio transmission, power lines), celestial (synchrotron, ionosphere).

# Current EOR 21cm Instruments

- LOFAR (Dutch, funded in 2003), first observations 2007: 320000 dipoles
- 21CMA (China, funded in 2004 formerly called *PAST*), first observations in 2005: 10000 high gain log periodics (TV antenna)
- MWA (Australia/MIT, waiting for funding): 10000 dipoles
- GMRT: operational, currently modelling RFI
- VLA-VHF: in progress
- Step search: T-REX (Nedeljkovic, Netterfield, Pen), ATNF: Subramanian/Ekers.





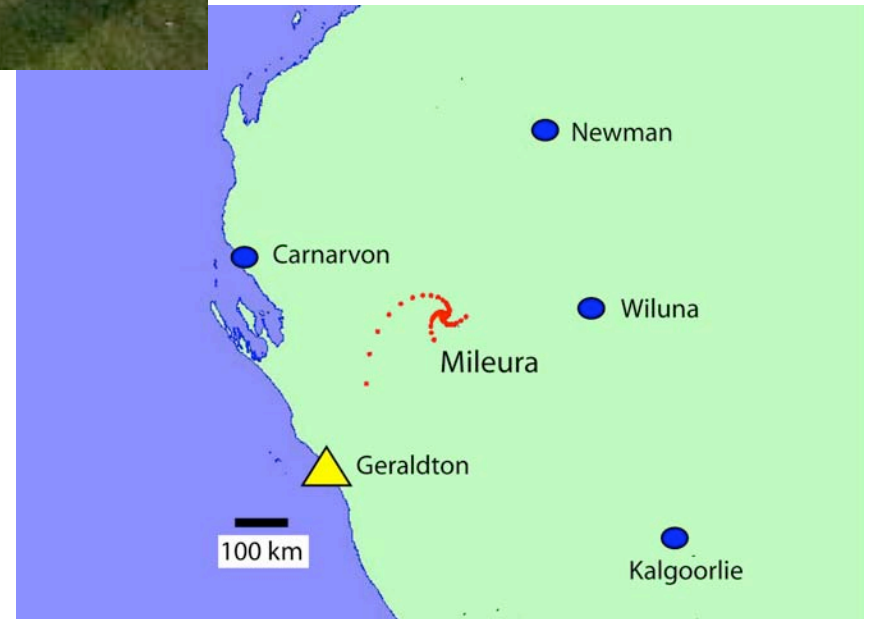
# LOFAR





# Mileura Wide-angle Array

Photos: Brian Corey and Eric  
Kratzenberg, MIT Haystack  
Observatory





# 21CMA/PAST Site



# 21CMA/PAST Strategy

- Fast track to data: avoid custom design, off-the-shelf only.
- Use existing TV technology, commodity PC's for correlations
- Learn as you build: fast turnaround, flexibility



# Ulastai

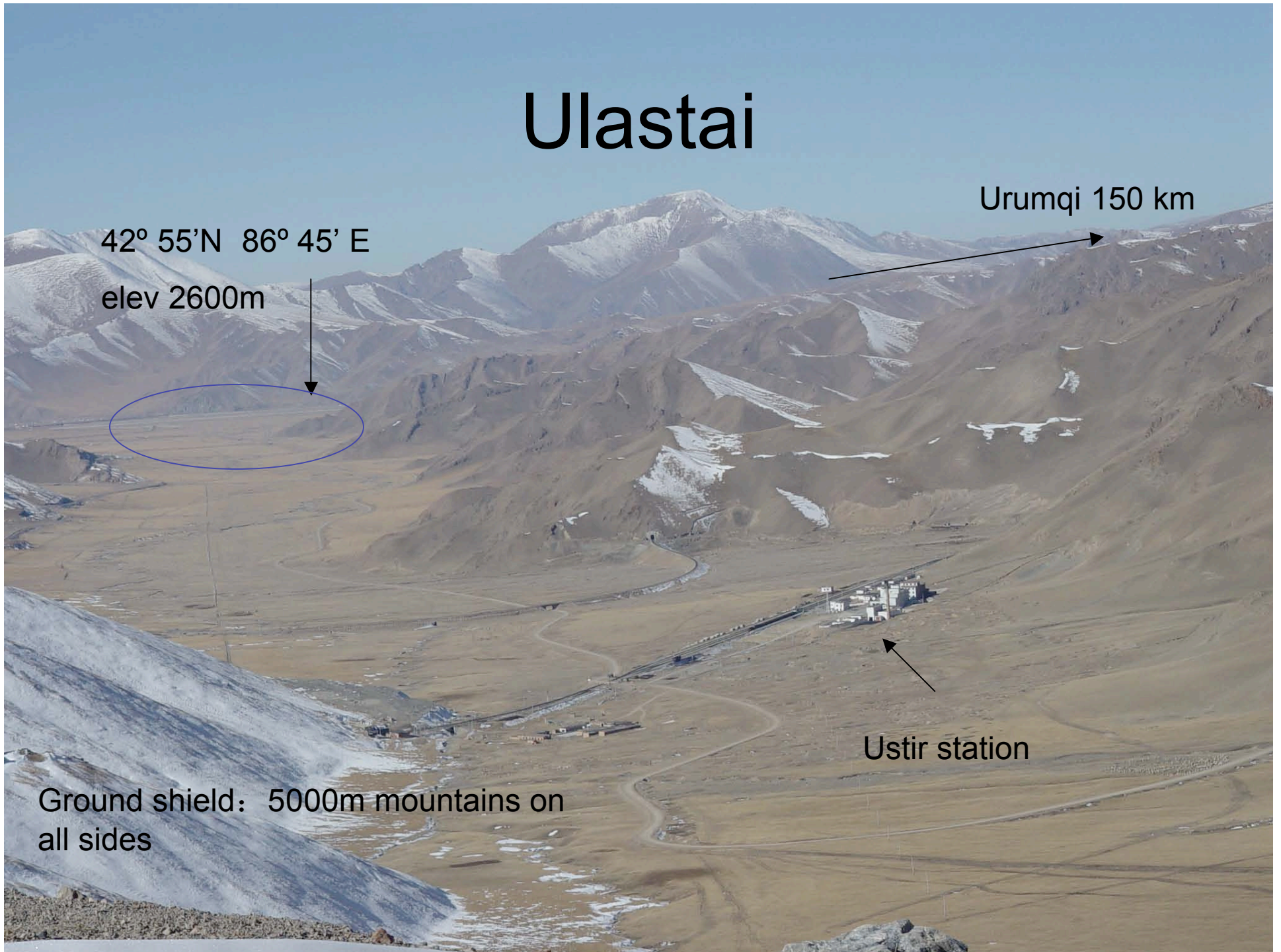
42° 55' N 86° 45' E

elev 2600m

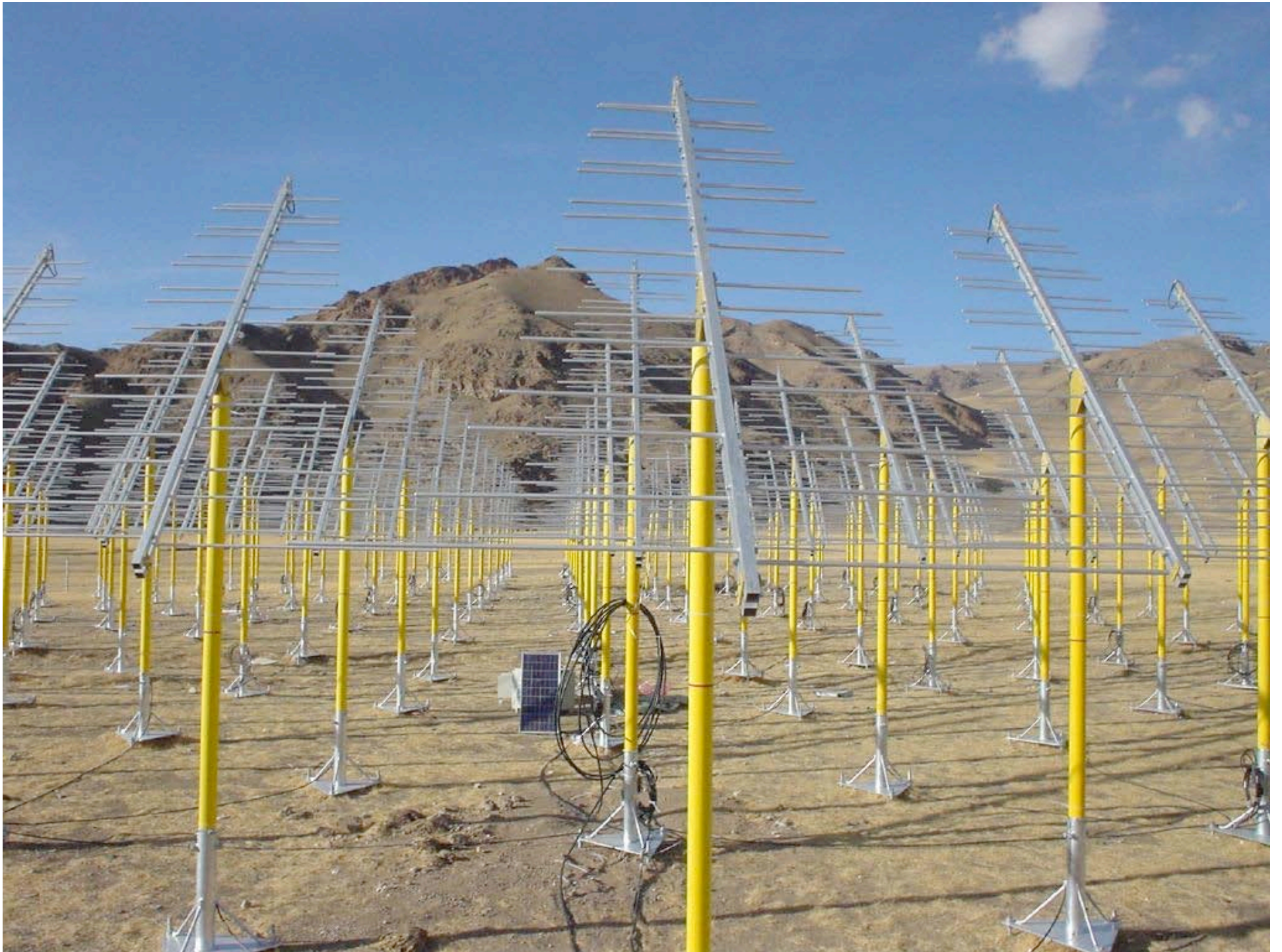
Urumqi 150 km

Ustir station

Ground shield: 5000m mountains on all sides









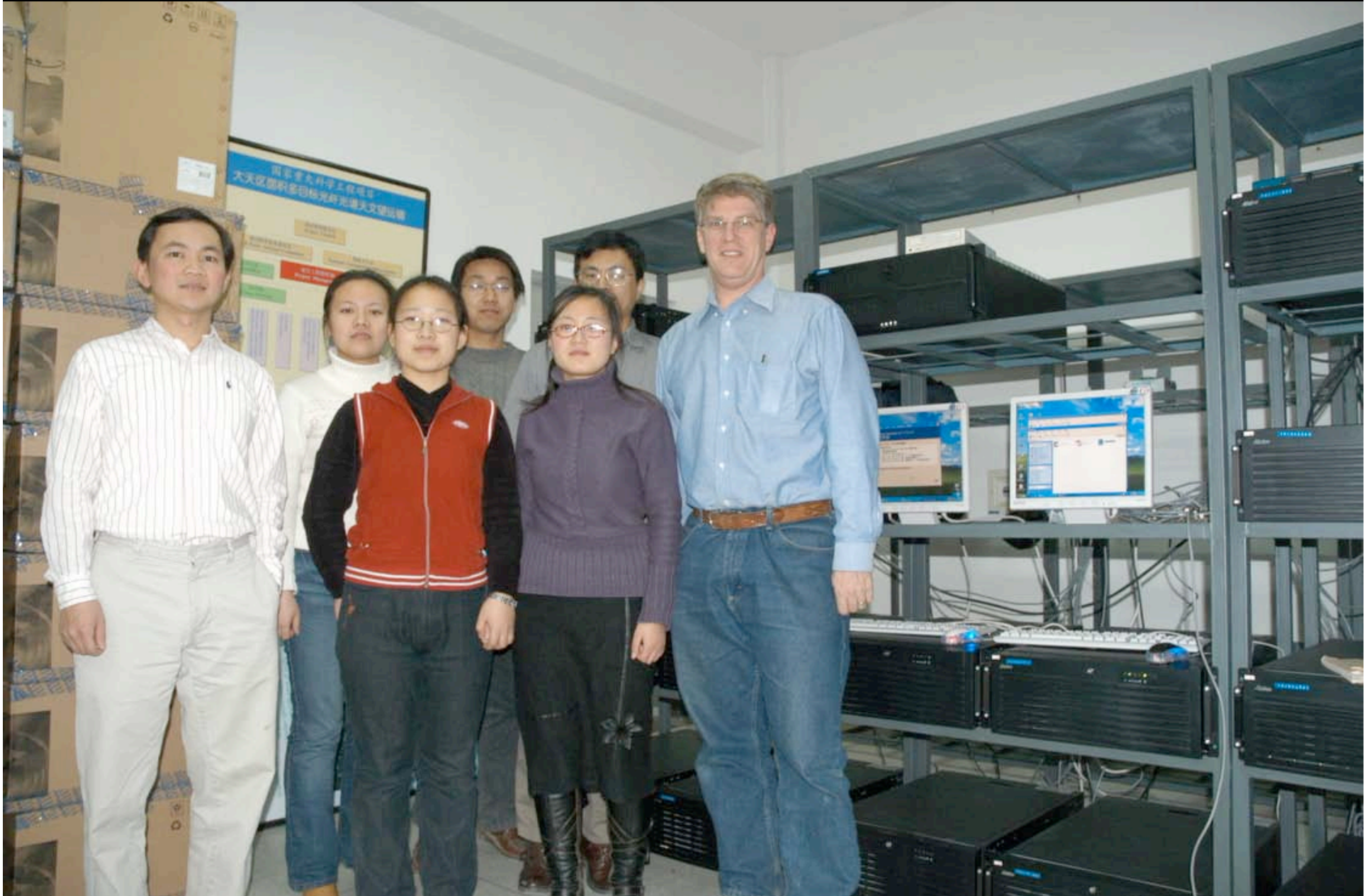






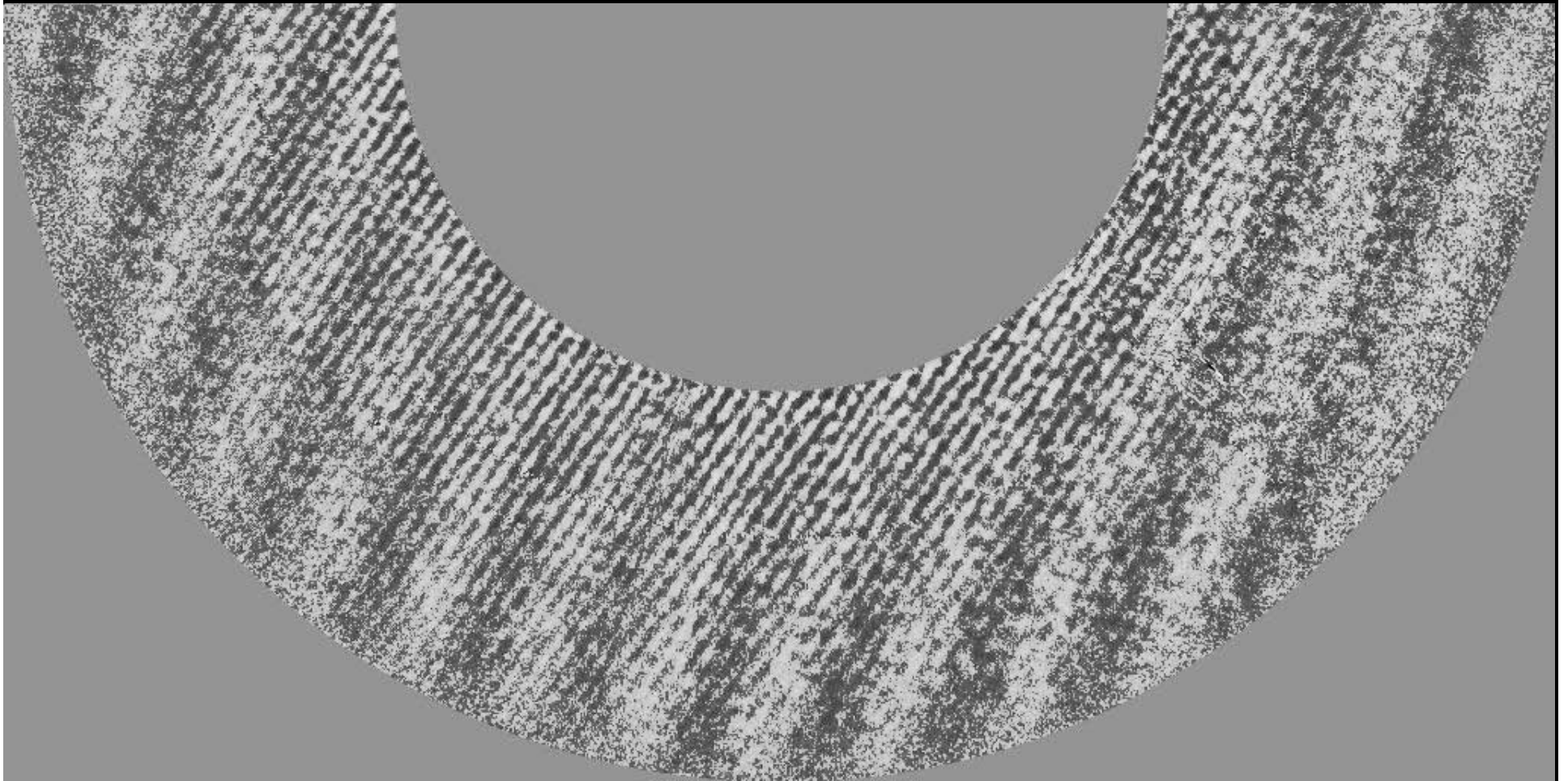


# Software correlator





# U-V map data



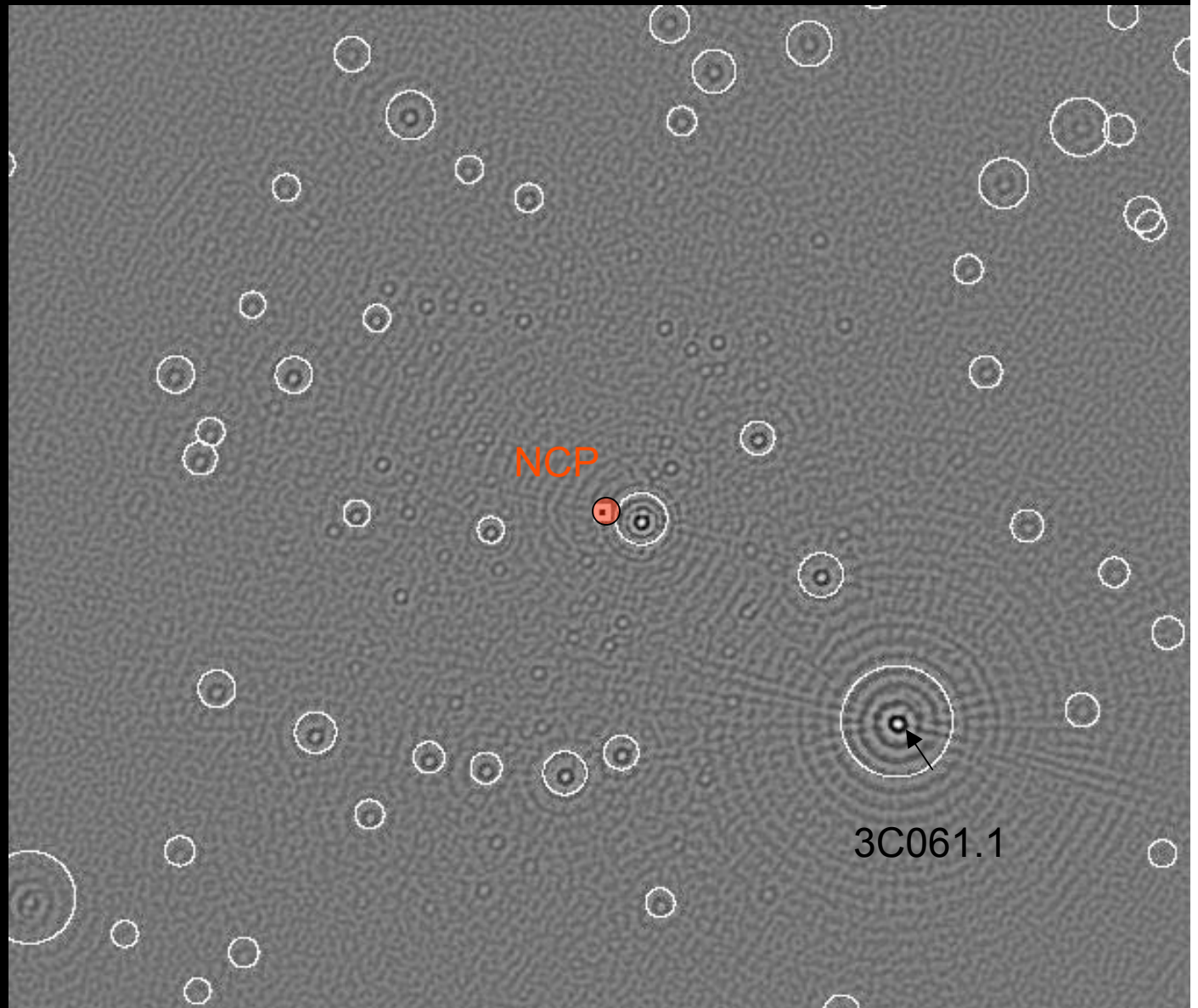
Almost no interference, excellent u-v coverage

# Current data

23 working pods of  
127 antenna each

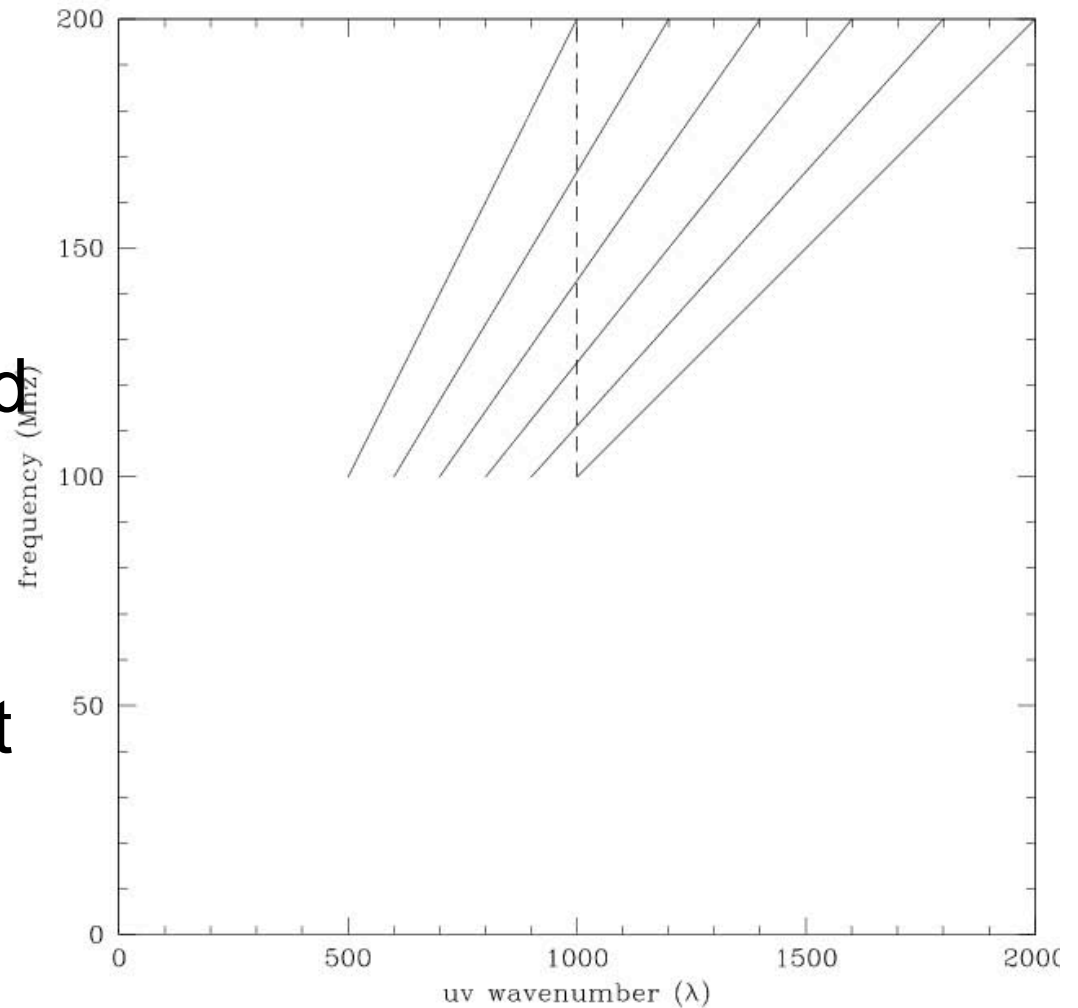
24h integration on one  
baseline: many  
extragalactic sources

100-200 Mhz, 10° FOV



# Analysis

- From CMB field: generalized pixels
- Eg. CBI, DASI
- Linear algebra based on Fisher matrices, Wiener filters for foregrounds
- Linear measurement equation (Beam solving)





# Indian Giant Meterwave Radio Telescope

30 dishes @45m ea.

Operates in 2m band

Collaborators: Y. Gupta  
(chief scientist), Rajaram  
Nityananda (director), R.  
Subramanian (Raman)





# GMRT Search

- Operating telescope, 47713m<sup>2</sup>, up to 32 Mhz BW, polarized correlator, lowest band 100-200 Mhz. Biggest collecting area in this band.
- Half in central 1km core, rest in 50 km Y.
- Currently hits RFI limit after a few minutes of integration: power lines, TV stations, HAM amateurs, faulty home electronics. Exploration of new RFI mitigation schemes, software correlator.



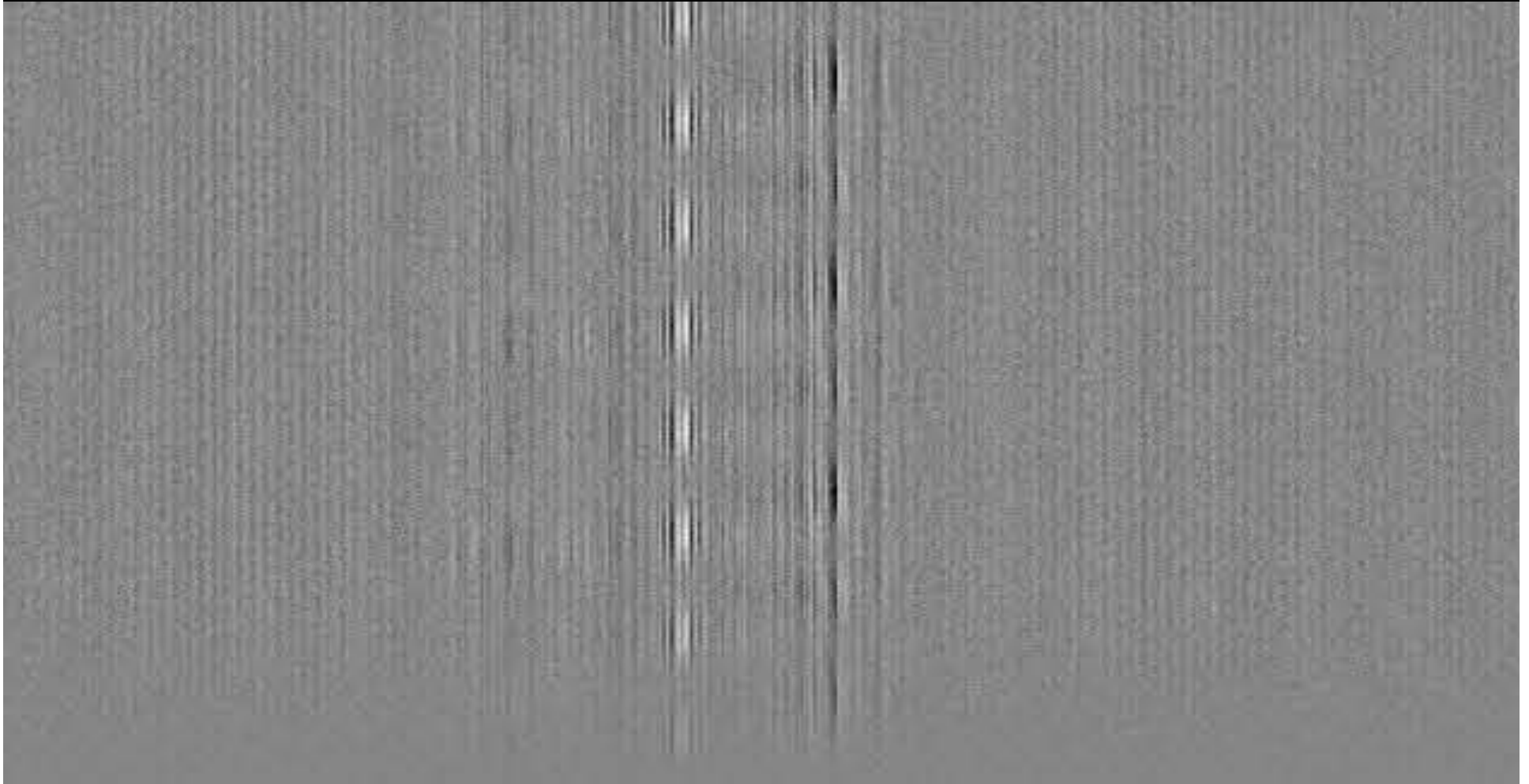
GMRT 150 Mhz image

By Ishwara Chandra  
(NCRA)

Image noise 2 mJy

Thermal limit 0.5 mJy

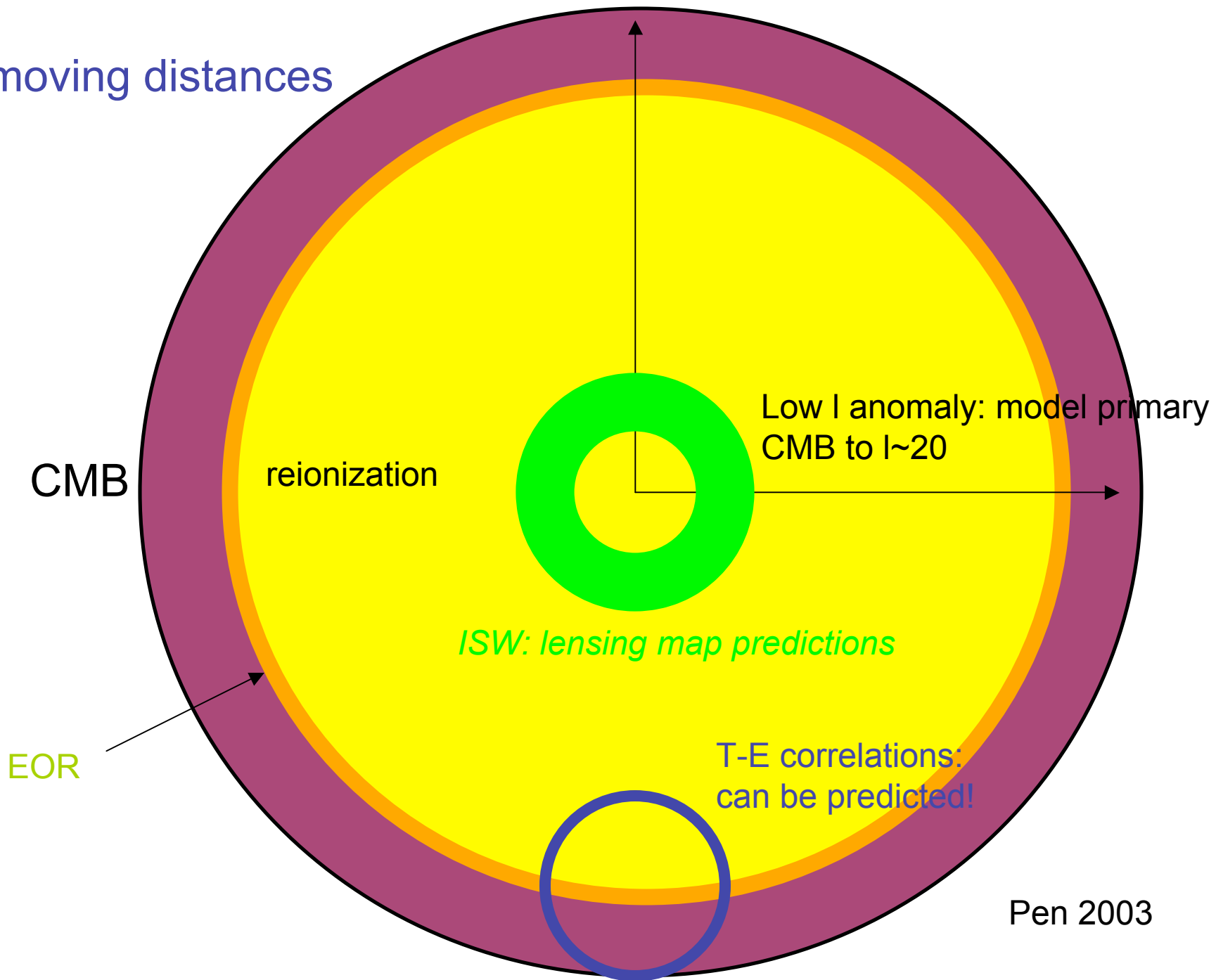
# Power Line Noise



Folded 70ms data on short baseline



Comoving distances



# Potential Theoretical Benefits

- Precision measurement of power spectrum at  $10^{-8}$  accuracy
- Dark energy dynamics:  $q_0$ ,  $a(t)$ , ISW, dark matter dynamics/clustering (through lensing), gravity waves.
- Initial conditions: 2<sup>nd</sup> order inflation effects, backreaction, curvature, etc. (through hydrogen matter  $P(k)$  and 3pcf).

# The next generation: Square Kilometer Array





# Outlook

- current: initial ulastai data analysis, ionospheric solution (Hirata)
- Second prototype software correlator on GMRT in October 2005
- Goals: re-ionizing sources, lensing, cosmic acceleration, A-P test (Yu 2004)
- Bright outlook: several 21cm experiments underway or planned to tap the next cosmic horizon