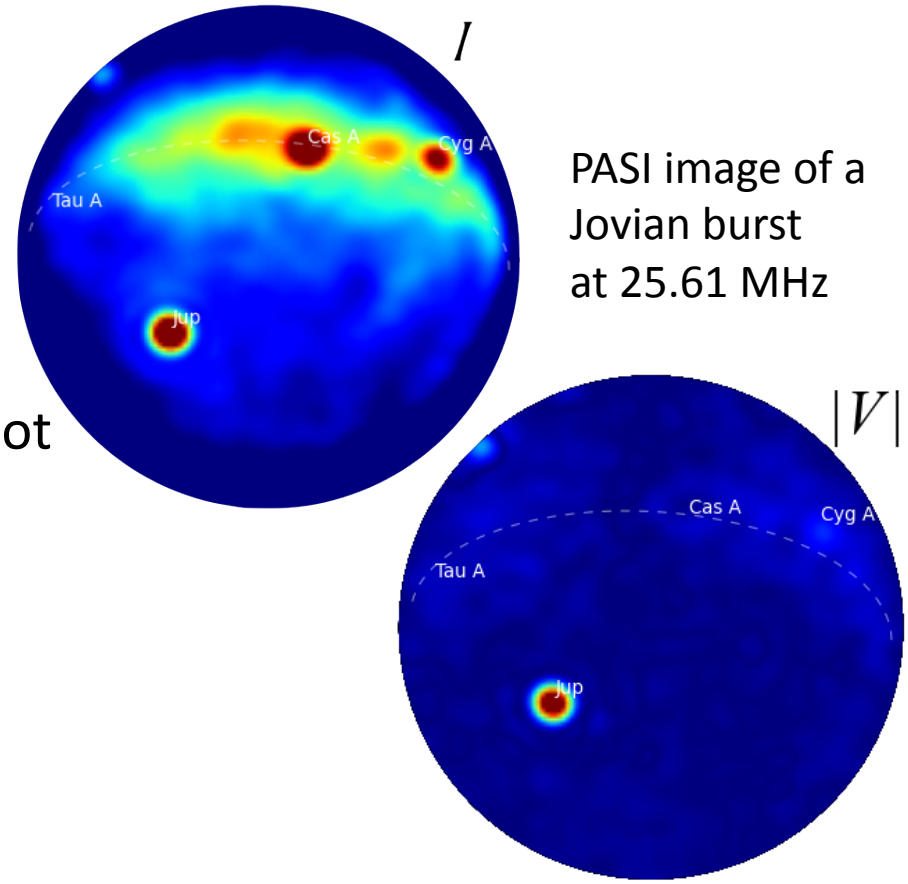
Steps Toward the Long Wavelength Array

Greg Taylor (UNM)

LWA Users Meeting
July 11, 2014

Emission from Exo-Planets

- Low frequency:
  $eB / 2\pi m_e$ = 28 MHz at 10 G
- Measurement of Magnetic Field strengths
- Bright!
  ~100 mJy fluxes predicted from hot Jupiters – high SNR for LWA
- High circular polarization:
  LWA is very good at this
- Predictably time-variable:
- pulsar-like emission
- secondary eclipses

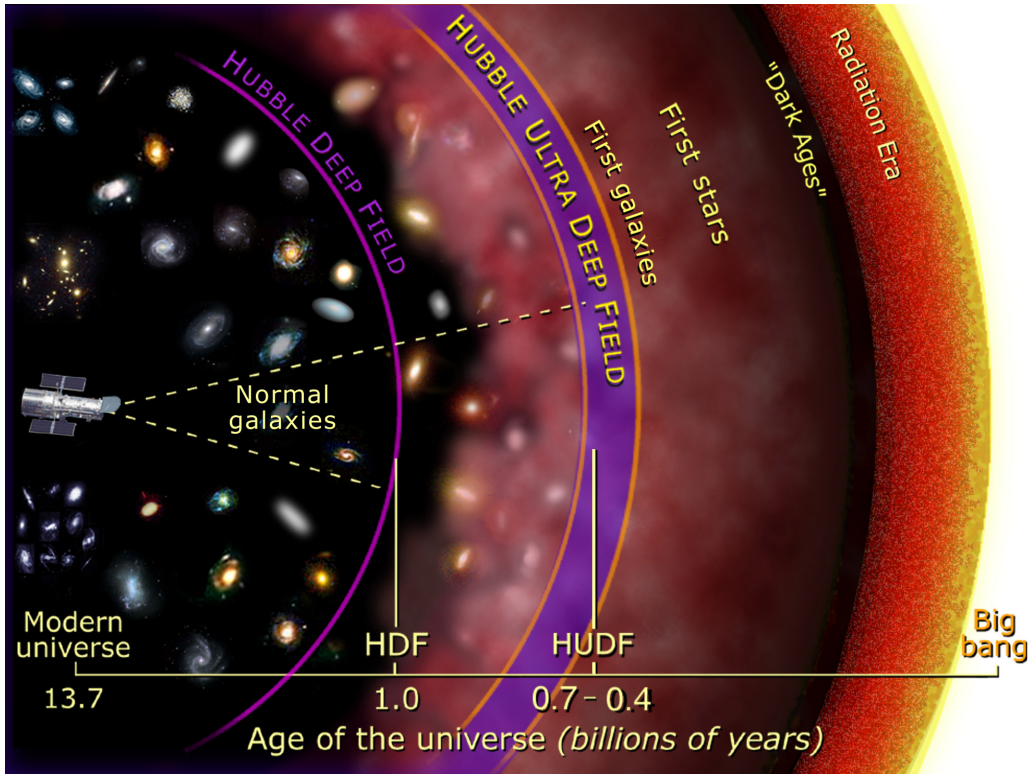


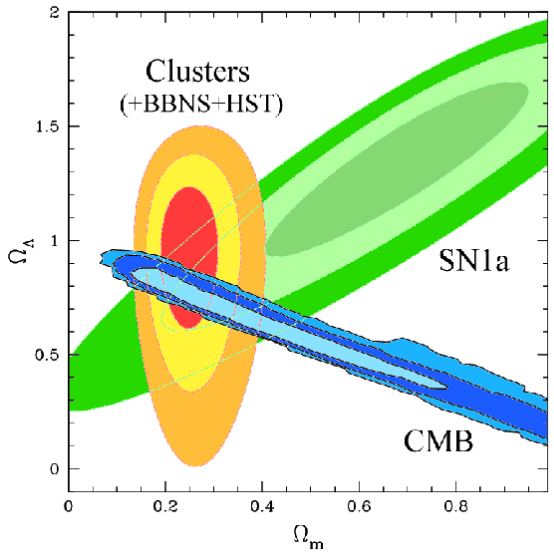
PASI image of a Jovian burst at 25.61 MHz

LWA
Long Wavelength Array

High Redshift Universe

- Ultra Steep Spectrum Radio Sources as a signpost of high redshift and dense environments
- Study HI and CO in absorption to explore environments of the early universe
- Constrain models of galaxy and black hole growth



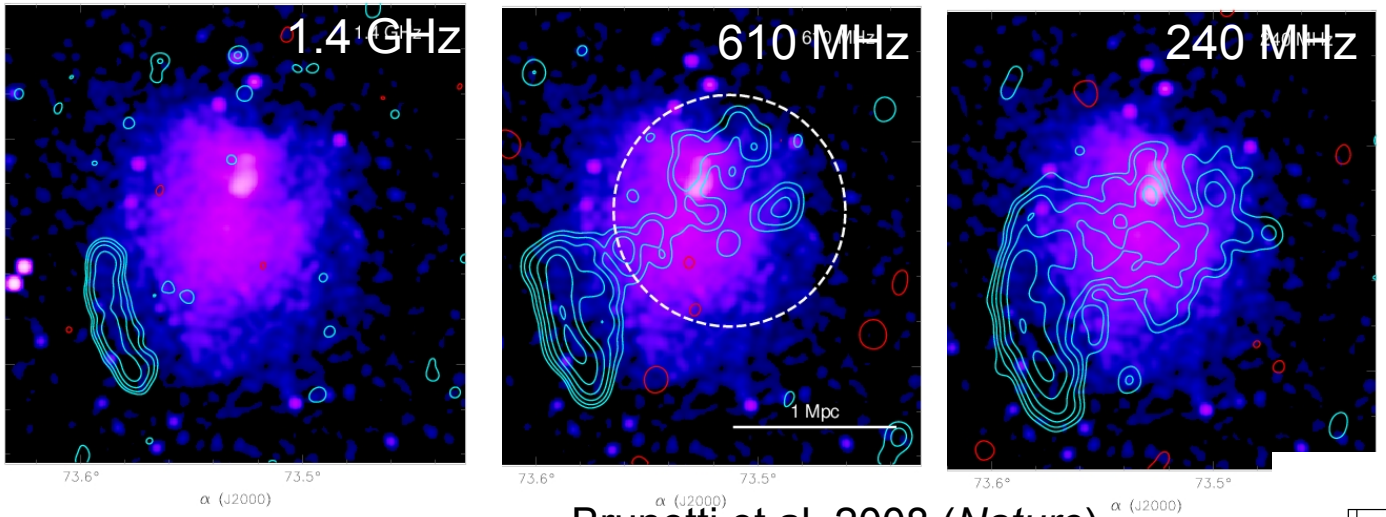


- Find high redshift relaxed clusters for X-ray follow-up and cosmological studies

LWA
Long Wavelength Array

LWA Discovery Space - Formation & Evolution of Large Scale Structure: HF/VHF Emission from Galaxy Clusters

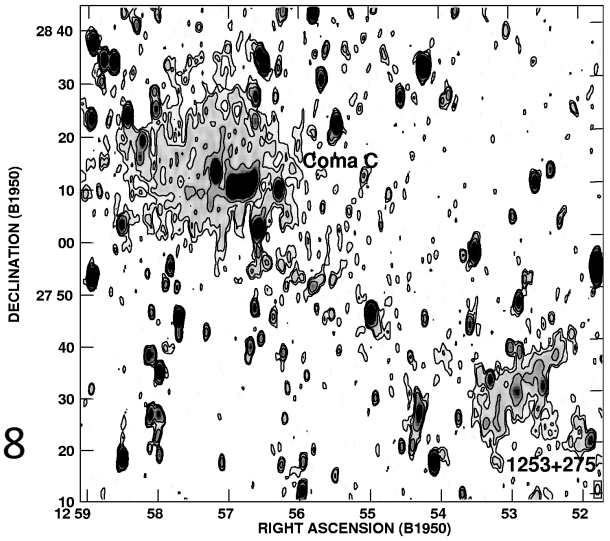
Abell A521 Contours: radio synchrotron; Color: *Chandra* thermal X-ray



30 MHz with sensitive large HF/VHF arrays ??

Brunetti et al. 2008 (*Nature*)

- Growing evidence that merging clusters produce bright HF/VHF "halo" or "relic" emission
- HF/VHF sky could "light up" with previously unseen population of >10^3 merging cluster systems
  - Cosmological probe of ***Dark Matter*** driven cluster formation
  - Cosmic Web



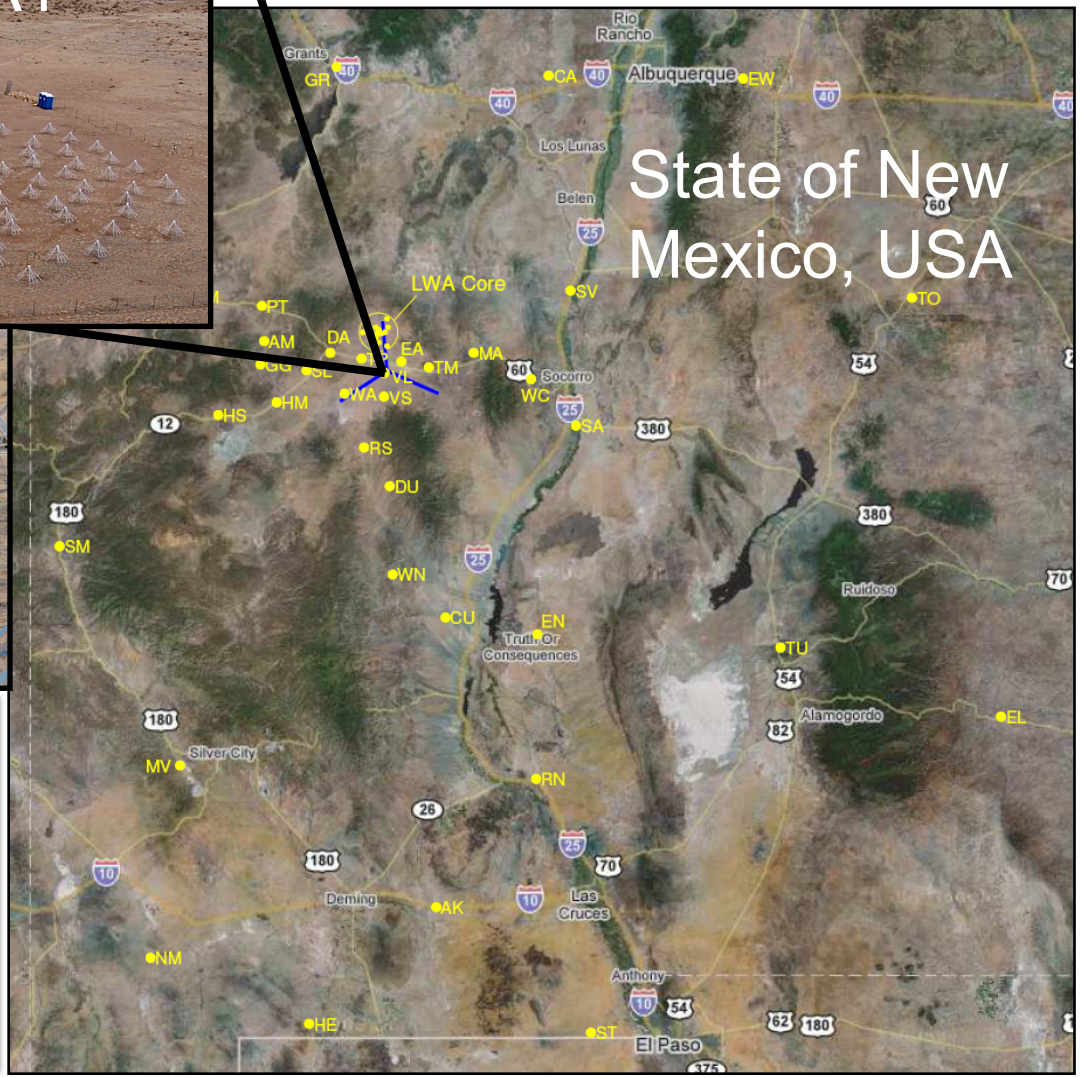
Feretti & Giovannini 1998
WSRT at 300 MHz

LWA Science Drivers

1. Cosmic Evolution & The High Redshift Universe
   a) Study of the 1st black holes & the search for HI from Cosmic Dawn
   b) LWA high-angular resolution observations of Cosmic Dawn Foregrounds (DARE, CDA)
   c) Evolution of Dark Matter & Energy by differentiating relaxed & merging clusters
2. Transient Universe
   a) Explore physics of Fireballs
   b) Magnetar Giant Flares
   c) Prompt emission from GRBs
   d) Other transients?
3. Cosmic Accelerators:
   a) Hundreds of SNRs in normal galaxies at energies up to 10^{15} eV.
   b) In thousands of radio galaxies & clusters at energies up to 10^{19} eV
   c) In ultra high energy cosmic rays at energies up to 10^{21} eV and beyond.
4. Planetary, Solar & Space Science
   a) Ionospheric waves & turbulence
   b) Extra-Solar Planet Searches
   c) Solar and Space Weather Science

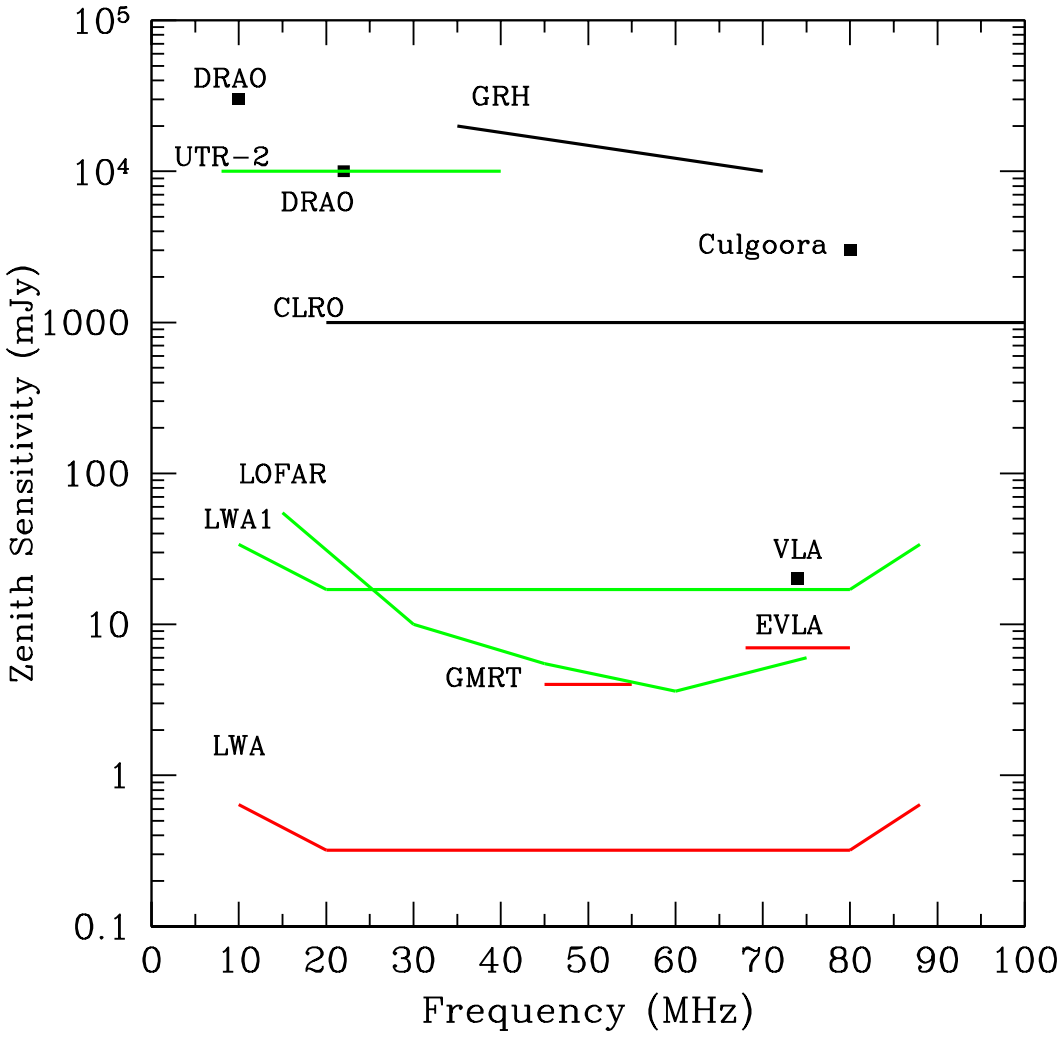
The LWA Instrument

- **10-88 MHz Aperture Synthesis Telescope**
- **4 beams x 2 pol. x 2 tunings x 16 MHz**
- **2 all-sky transient obs. modes**



- LWA1 operational in 2011
- Goal of 53 LWA stations, baselines up to 400 km for resolution 2” at 80 MHz with sub-mJy sensitivity
- Cost is ~$1M/station

Comparison to other instruments



Declination Range		Δν (MHz)
UTR2:	-30° to +60°	33
LOFAR:	-11° to +90°	16
Y=VLA:	-35° to +90°	3
LWA1:	-30° to +90°	16
GMRT:	-53° to +90°	10

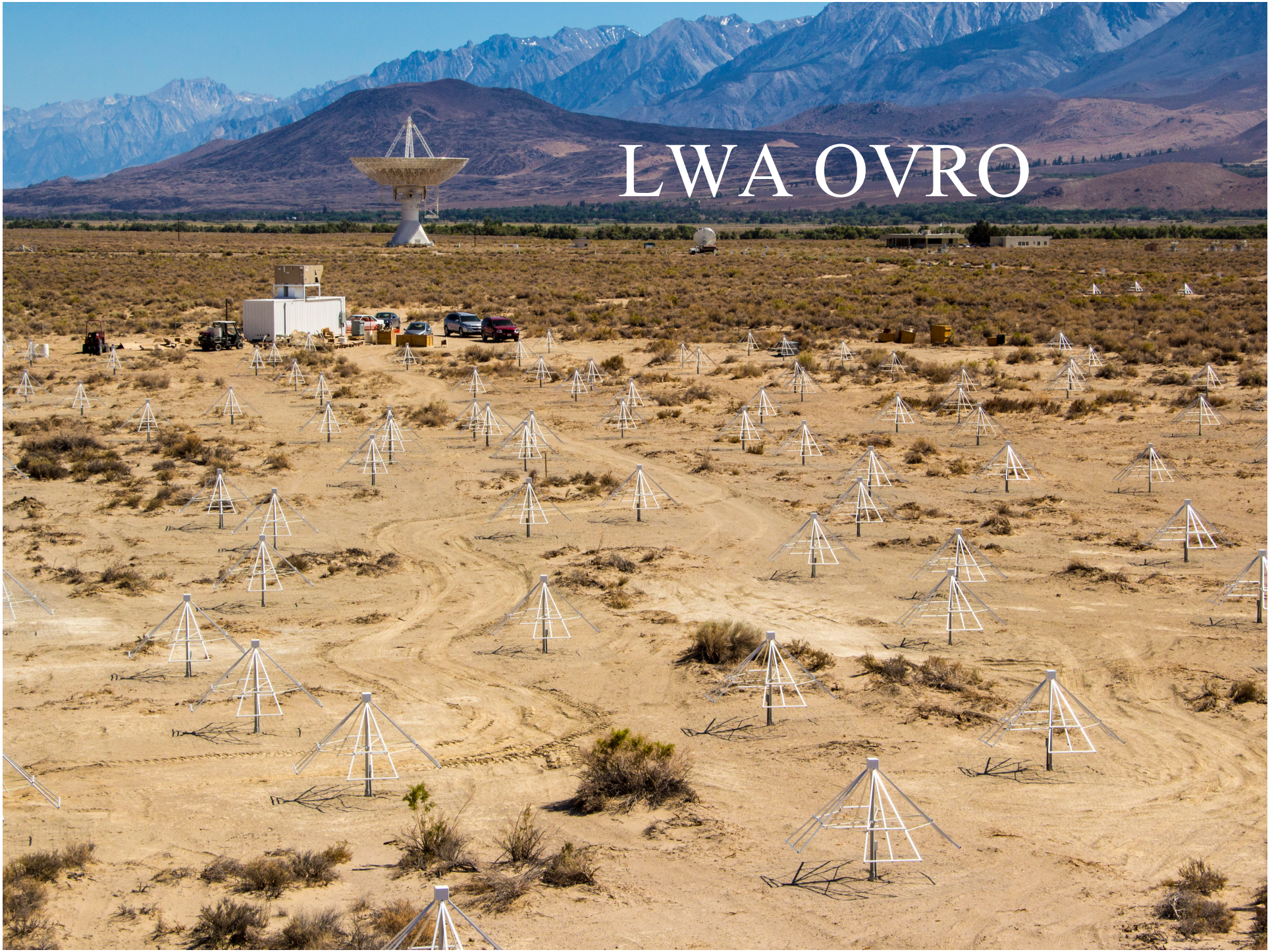
See Taylor et al 2012, JAI

LWA1 has sensitivity ~25% of all of LOFAR

Adding another station and the VLA would equal it

LWA Long Wavelength Array

LWA NA – stub station 20 dipoles

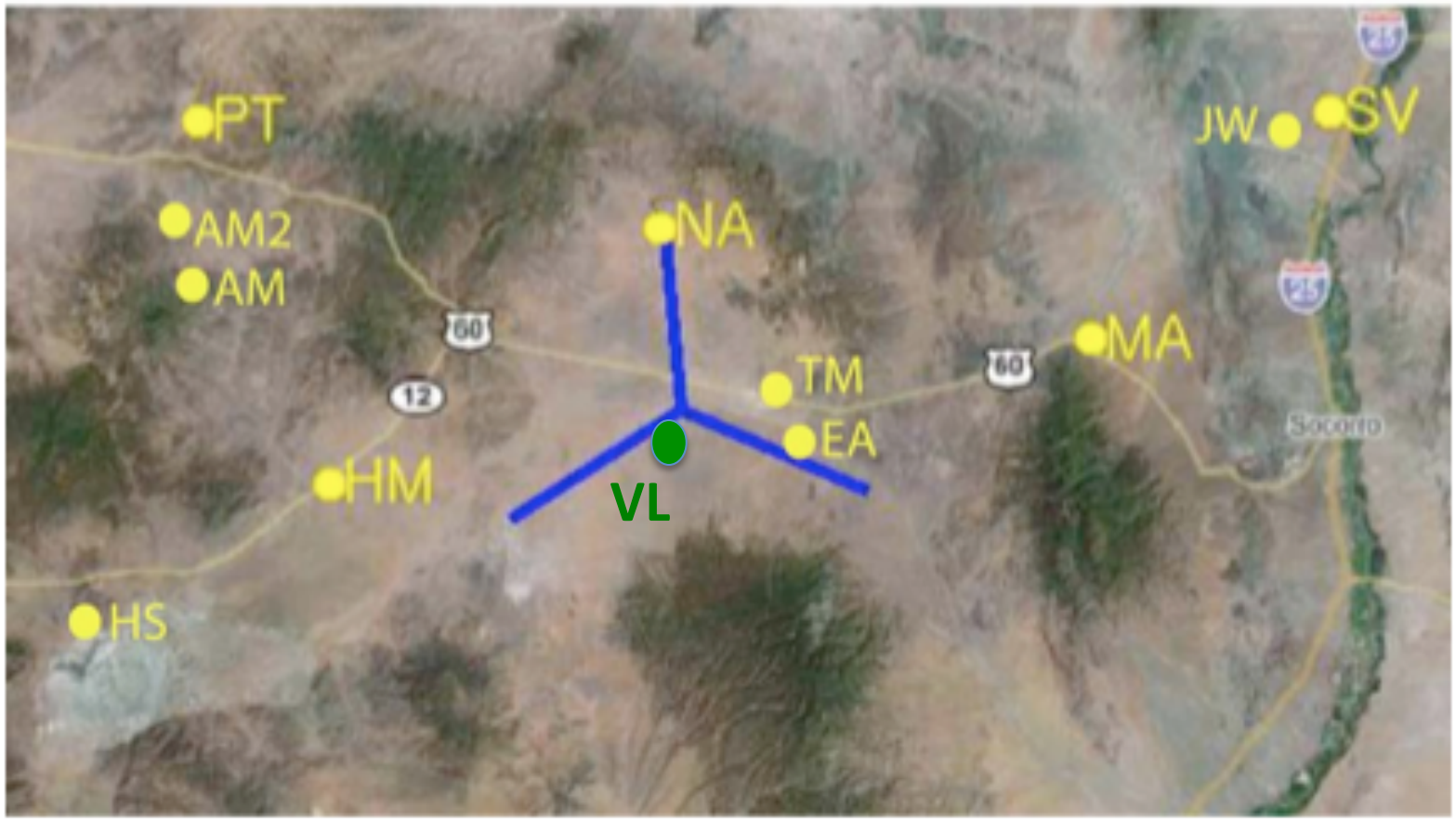

LWA OVRO

LWA SV under construction

LEDA-style Beamformer

- Beamforming is O(n), Correlating is $O(n^2)$
- Practical limit is set by data rate
  4 dual-pol beams 2 tunings of 16 MHz → 2 Gbps
- Same architecture as LEDA 512 correlator
- Pile-of-parts cost = $240k Fits in one full rack

Early LWA Sites



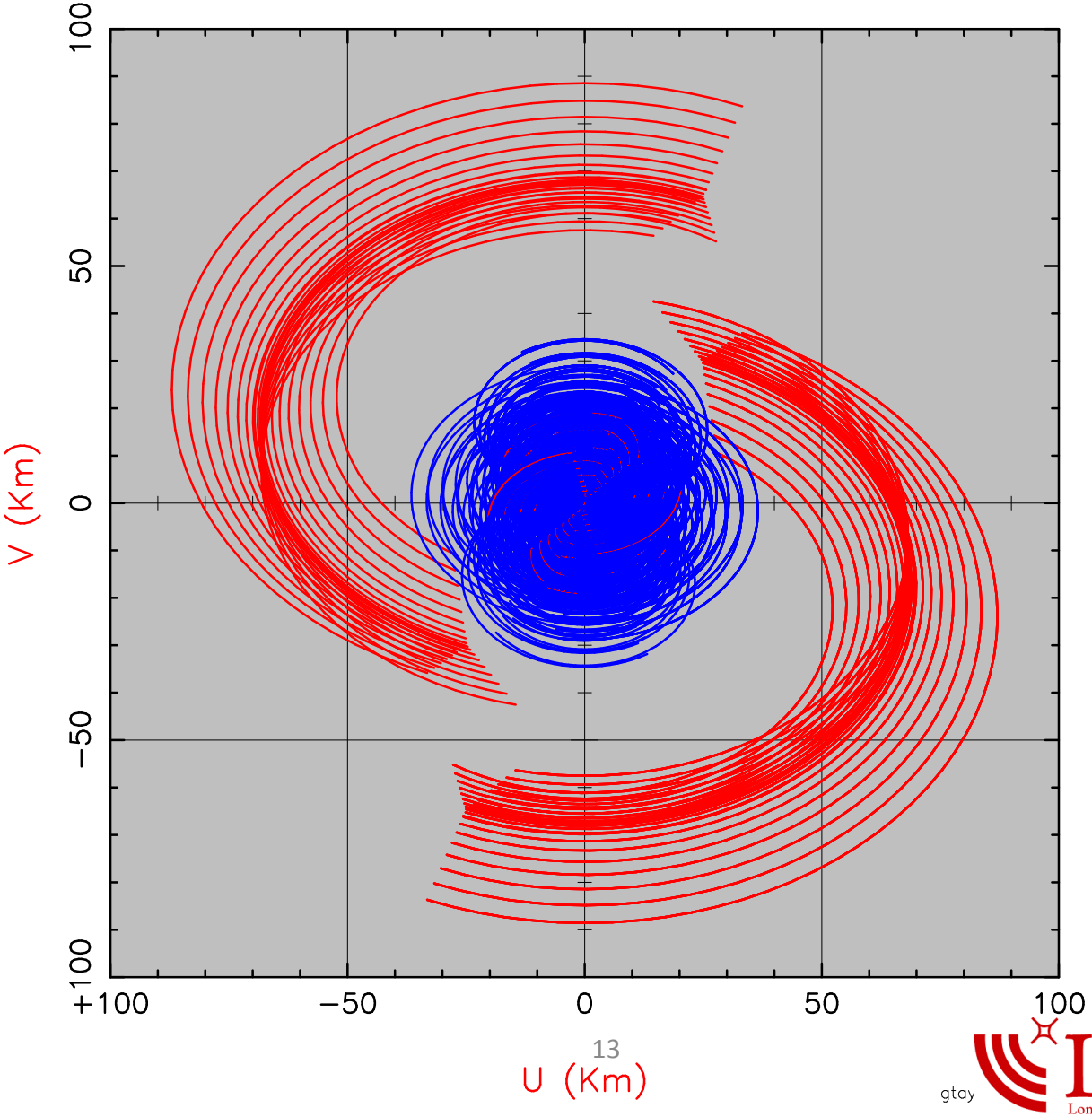
LWA
Long Wavelength Array

VLA + SV

LWA_SV
LWA_VL
VLA1
VLA2
VLA3
VLA4
VLA5
VLA6
VLA7
VLA8
VLA9
VLA10
VLA11
VLA12
VLA13
VLA14
VLA15
VLA16
VLA17
VLA18
VLA19
VLA20
VLA21
VLA22
VLA23
VLA24
VLA25
VLA26
VLA28

J0136+4751

10 arcsec resolution at 74 MHz



gtay

What is needed?

Low Frequency Sky is complex, thousands of bright sources

- Need minimum 15 stations in an imaging array

High Payoff targets (exoplanets, GRB prompt emission) are faint

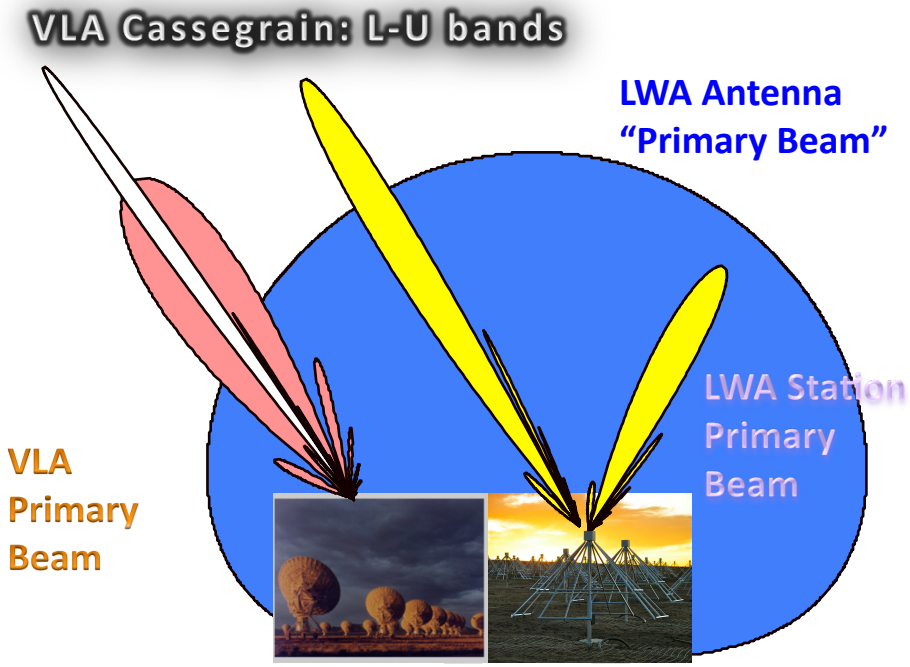
- Need good sensitivity obtained with more LWA stations

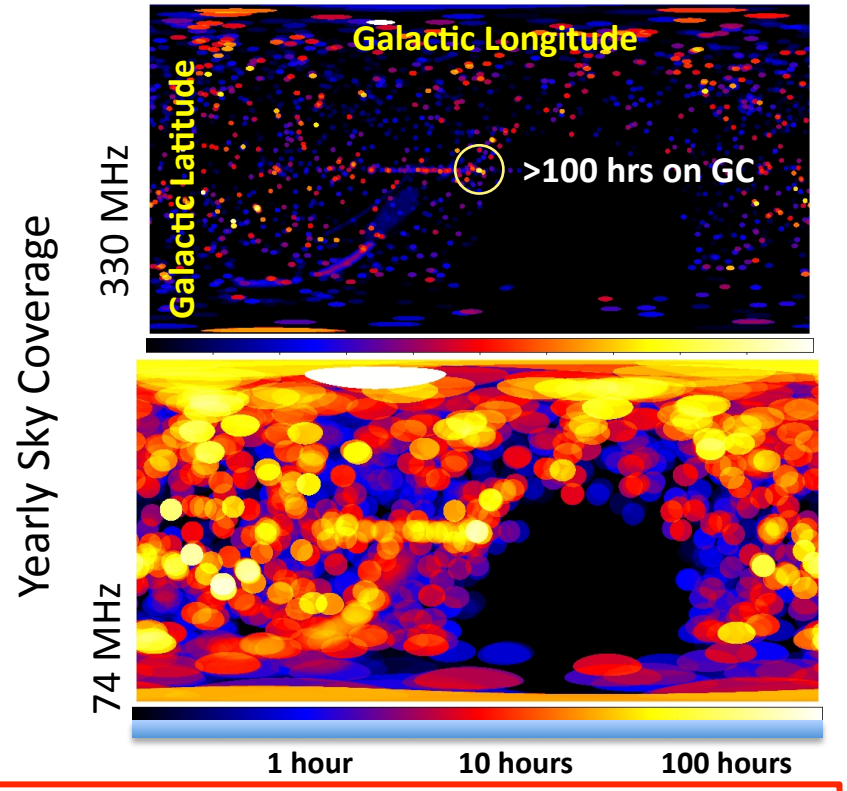
Beating Confusion and Comparison with other wavebands

- Need sub-arcminute resolution
- Need arcsecond-level astrometry

LWA and VLA Synergy

- The VLA is back on the sky at low frequencies, aka "Low Band"
  - Broad-band receivers 50-500 MHz initially targeting 240-470 MHz & 55-80 MHz bands
- A VLA commensal concept (LOBO) can deliver 6000 hours of VLA time per year
  - A 10 antenna system called VLITE will test the concept for ionospheric science & transients (PI: Kassim)
- LWSC instruments can target the VLA P band FoV (~5 sq. deg.) & continuously monitor phenomena across 20 octaves of spectrum – possibly more
  - VLA 74 MHz a surrogate core for early LWA stations



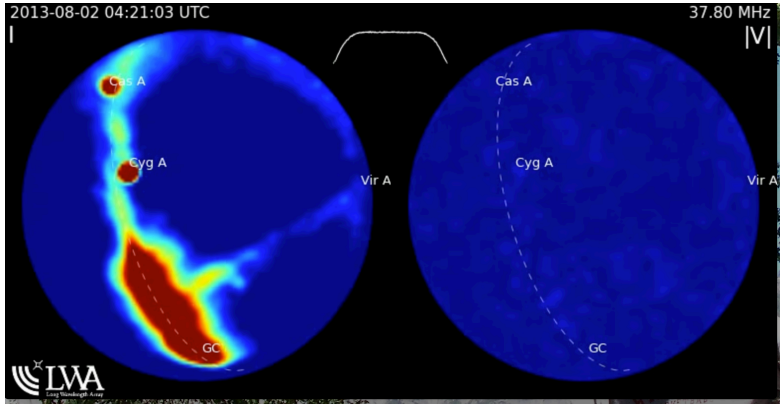


VLA P band: incoherent processes; LWSC instruments & VLA 74 MHz – coherent processes.

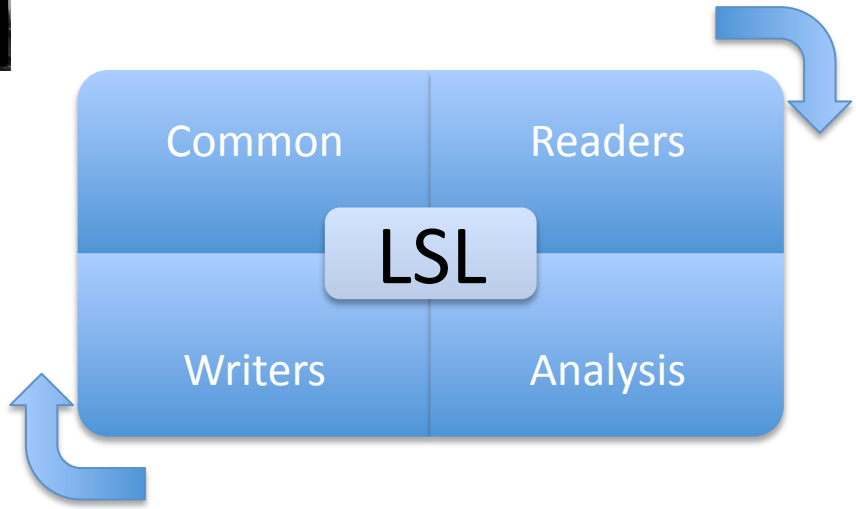
Software Development

- Monitor and Control

- All-Sky Near Real Time Correlator (PASI/LWA-TV)



- User Software for Reading/Writing/Analysis



Science with LWA1+OV+SV+VLA

1. Cosmic Evolution & The High Redshift Universe
   a) Study of the 1st black holes & the search for HI from Cosmic Dawn
   b) LWA high-angular resolution observations of Cosmic Dawn Foregrounds (DARE, CDA)
   c) Evolution of Dark Matter & Energy by differentiating relaxed & merging clusters
2. Transient Universe
   a) Explore Physics of Fireballs
   b) Magnetar Giant Flares
   c) Prompt emission from GRBs
3. Cosmic Accelerators:
   a) Hundreds of SNRs in normal galaxies at energies up to 10^{15} eV.
   b) In thousands of radio galaxies & clusters at energies up to 10^{19} eV
   c) In ultra high energy cosmic rays at energies up to 10^{21} eV and beyond.
4. Planetary, Solar & Space Science
   a) Ionospheric waves & turbulence
   b) Extra-Solar Planet Searches
   c) Solar and Space Weather Science
5. Technical Development
   a) Determine maximum baseline length for LWA

Summary

Lots of exciting science at low frequencies. Progress requires:

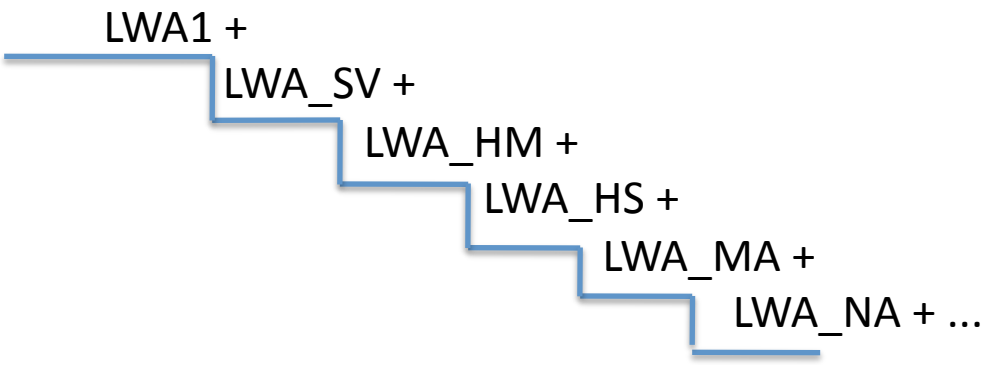
- High temporal, spectral, and spatial resolution
- Sensitivity
- Software development

Current experiments are providing new hardware and software, and a better understanding of the sky at long wavelengths

Eyes on the Prize – Interferometry with LWA stations

Next Steps

- Original plan with ONR was 15 stations
- de-scoped to 1 full station in 2007, operational 2011
- Using DURIP to add another station, LWA-SV
- 10 VLA antennas are getting 50-80 MHz receivers
- Use LWA1 and LWA-SV for ionospheric studies, anticoincidence, …
- Combine LWA1+LWA_SV+VLA
- Continue to expand array as science demands
- Explore all avenues (NSF/AFRL/DoD) for additional stations

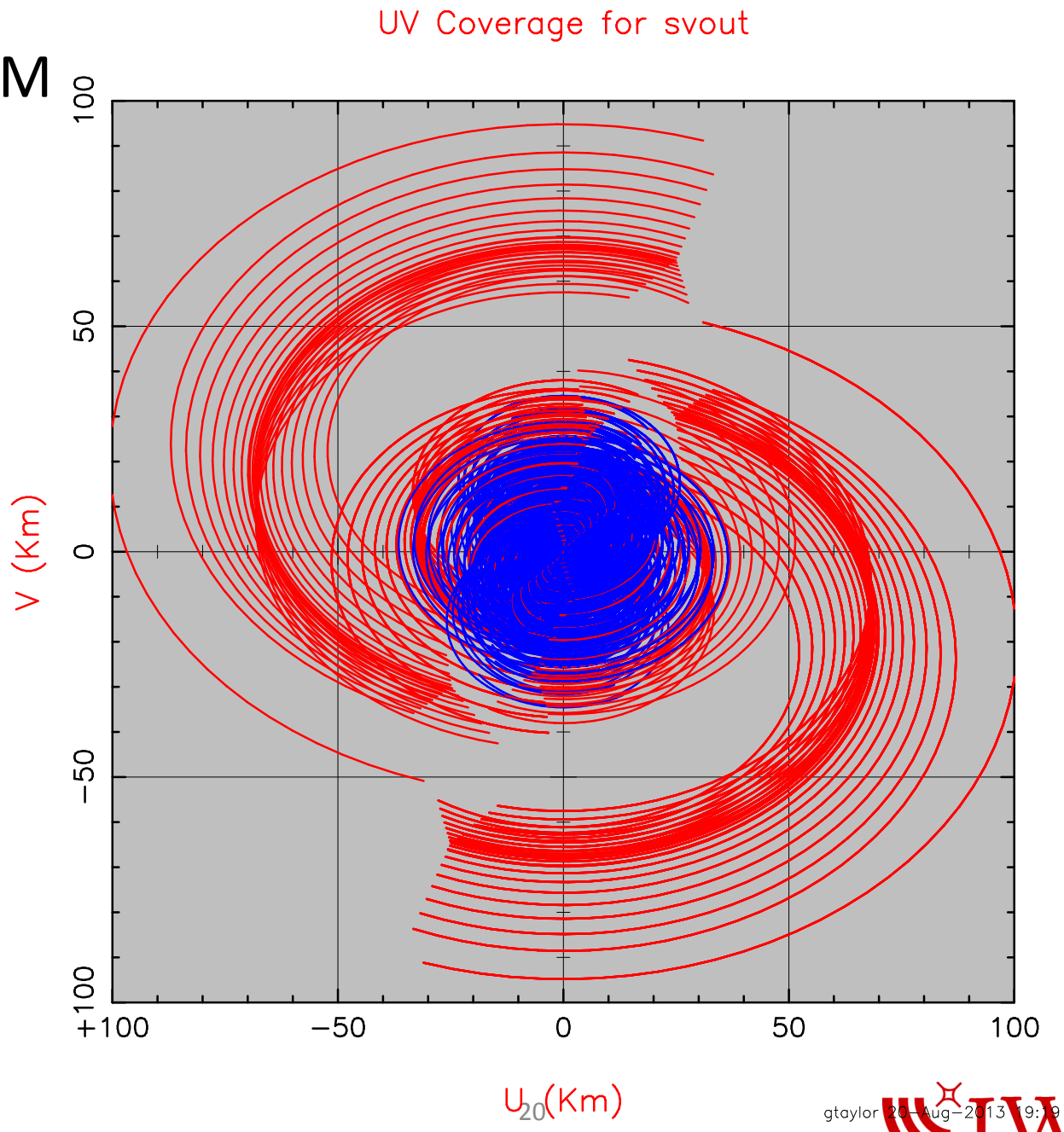


LWA
Long Wavelength Array

VLA + SV + HM

VLBA_SV
VLBA_HM
VLBA_VL
VLA1
VLA2
VLA3
VLA4
VLA5
VLA6
VLA7
VLA8
VLA9
VLA10
VLA11
VLA12
VLA13
VLA14
VLA15
VLA16
VLA17
VLA18
VLA19
VLA20
VLA21
VLA22
VLA23
VLA24
VLA25
VLA26
VLA28

J0136+4751



LWA
Long Wavelength Array

Backup Slides