Exploring the Last Electromagnetic Frontier with the Long Wavelength Array (LWA)

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Timeline

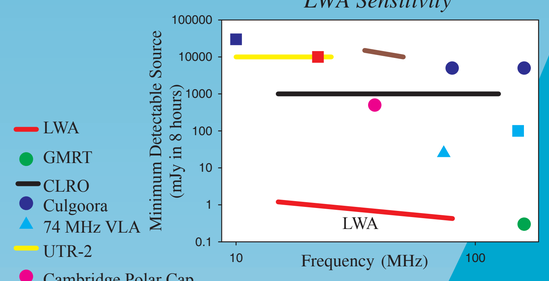
- **1998-Present: Phase 0**
  - *74 MHz capacity to the NRAO VLA (completed in 1998)*
  - *VLA Low-frequency Sky Survey (VLSS: http://lwa.nrl.navy.mil/VLSS/)*
- **2006-2007: Phase 1**
  - *Construction of the Long Wavelength Demonstrator Array* (LWDA)
- **2008-2009: Phase 2**
  - *~ 9 stations with baselines up to 150-200 km*
- **2010-2012: Phases 3 & 4**
  - *Phase 3: compact core of ~15 stations to fill in short baselines*
  - *Phase 4: addition of more stations to even out UV coverage with baselines up to 400 km*
  - *Full LWA with ~50 stations and full imaging capability across entire 20-80 MHz range.*

The LWA project is being developed by the Southwest Consortium (SWC) - a university-based consortium led by UNM, & including ARL-UT, NRL, & LANL:
http://lwa.nrl.navy.mil & http://lwa.unm.edu

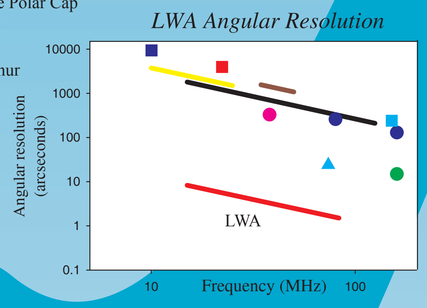
LWA Basic Specifications

Frequency Range	*10-88 MHz (20-80 MHz optimized)*
Effective Collecting Area	*10^6 (20/ν(MHz))^2 m^2*
Number of Dipole Elements	*~10^4*
Number of Dipole Stations	*~50*
Baseline Range	*0.1-400 km*
Point-Source Sensitivity	*1.0 mJy @ 20 MHz*
(2 polarizations, 1 hour, 4 MHz BW)	*0.5 mJy @ 80 MHz*
Angular Resolution	*5" @ 30 MHz*
	2" @ 80 MHz
Field of View	*~2° @ 80 MHz (~ν)*
Number of Independent Beams	*≥ 4*
Maximum Observable Bandwidth	*32 MHz*
Spectral Resolution	*≤ 1 KHz*
Image Dynamic Range	*≥ 10^4*
Digitized Bandwidth	*Full RF*

LWA Sensitivity



LWA Angular Resolution



LWA Science Drivers

- ***Cosmic Evolution***
  - The High Redshift Universe
    - Detection and study of the first supermassive black holes
    - Search for localized HI absorption during the Epoch of Reionization
  - The Evolution of Large Scale Structure, Dark Matter & Dark Energy
    - Merging galaxy clusters and large scale structure filaments identified through diffuse synchrotron emission
    - Cluster emission used to study Dark Matter dominated merging systems
    - Relaxed or non-merging systems sample for study of Dark Energy
- ***Acceleration of Relativistic Particles***
  - In SNRs in normal galaxies at energies up to 10^{15} eV.
    - Cosmic ray tomography to study the distribution, spectrum, and origin of Galactic cosmic rays
    - Spectral SNR studies to probe shock acceleration, SNR evolution, interactions with the surrounding environment
  - In radio galaxies & clusters at energies up to 10^{19} eV.
    - Self-absorption processes, the low-γ electron population, Intra-cluster magnetic fields, and merger shocks
    - Radio galaxy lifecycles and radio jet composition
  - In ultra high energy cosmic rays at energies up to 10^{21} eV and beyond.
    - Cosmic-Ray induced coherent radio "air-showers"; ultimate source unknown.
- ***Plasma Physics & Astrophysics***
  - Ionospheric waves & turbulence
    - Including traveling ionospheric distrubances (TIDs)
  - Solar and Planetary Science
    - Active & quiet sun studies, measurements of Coronal Mass Ejections, IP shocks & scintillations
  - The Interstellar Medium (ISM) and beyond
    - Propagation, scattering, & absorption in the ISM of the Milky Way & normal galaxies.
    - Scattering from the inter-galactic medium
    - Full census of Galactic SNRs with distances.
- ***Opportunity: Discovery Science***
  - The greatest discoveries in astrophysics have coupled key technical innovations with the opening of new windows on the EM spectrum.
    - Technical breakthrough: demonstration of interferometry on baselines >5 km (ionospheric calibration) with 74 MHz VLA.
    - Last poorly explored spectral region: < 100 MHz.
    - New observing paradigms: multi-beaming, wide-field sky monitoring.
  - Potential new horizons: transients, extra-solar planets, coherent emission sources.

A text description of these goals can be found at http://lwa.nrl.navy.mil/LWA/LWA_science_summary.html

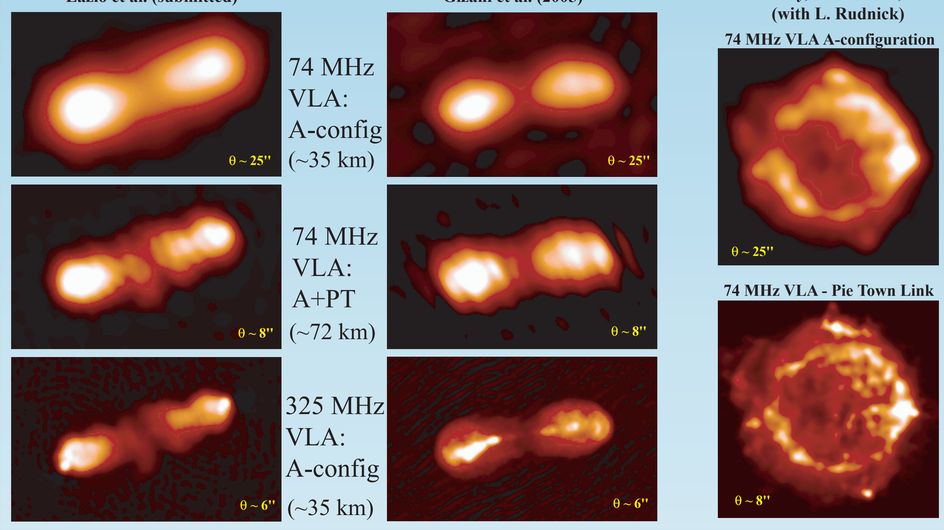
Vision of the Long Wavelength Array

Summary: Nearly three decades ago, the Very Large Array (VLA) first opened the cm-wavelength radio sky to detailed study. Today, a path-finding VLA 74 MHz system is providing the first sub-arcminute resolution view of the meter-wavelength radio universe, a technical innovation that has inspired the US ***Long Wavelength Array*** (LWA) and the Dutch-based ***Low Frequency Array*** (LOFAR) projects. Located in New Mexico near the VLA, the LWA will be a versatile, user-oriented electronic array poised to open the 20-80 MHz frequency range to detailed exploration for the first time. With a collecting area of one million square meters (at 20 MHz), the 400 km LWA's milli-Jansky sensitivity and arc-second resolution will surpass, by 2-3 orders of magnitude, the imaging power of previous low frequency interferometers. Because it will explore one of the last and most poorly investigated regions of the spectrum, the potential for unexpected new discoveries is high.

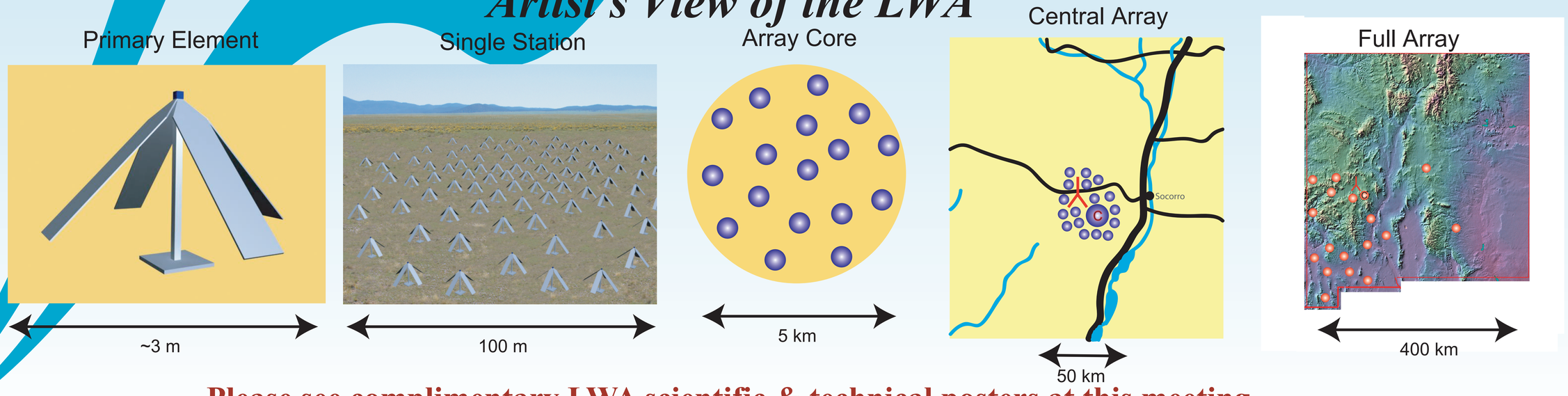
Until the advent of the new much larger instruments, the VLA 74 MHz system continues to be the path-finding interferometer operating below 100 MHz. The images at the right represent another milestone in low frequency interferometry - these 73 km baseline VLA+PT link images are the highest resolution images obtained below 100 MHz with a connected element interferometer, and will only be surpassed with the emergence of LWA and LOFAR.

Highest Resolution Low Frequency Images (VLA + Pie Town Link)

A 74 MHz receiver has been added to the Pie Town VLBA antenna, bringing the full resolving power of the VLA - Pie Town link to this frequency. With baselines up to 73 km, the first images at 74 MHz shown below mark another major milestone in low frequency radio astronomy. For comparison, 330 MHz images are also shown. These images are being used to study evolution (e.g. via synchrotron aging) and self-absorption processes (e.g. via synchrotron self-absorption) and acceleration in radio galaxies (Cyg A and Her A), and for studying shock acceleration and ejecta in SNRs (Cas A).



Artist's View of the LWA



Please see complimentary LWA scientific & technical posters at this meeting.

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