A View of Clusters, AGN, and GRBs from the Other Side of the Spectrum: the Long Wavelength Array (LWA)

The University of New Mexico

Los Alamos NATIONAL LABORATORY EST.1943

ARL The University of Texas at Austin

G. B. Taylor[3], T. E. Clarke[1], A. S. Cohen[1], P. C. Crane[1], T. Gaussiran[2], C. Gross[1], P. A. Henning[3], B. C. Hicks[1], W. Junor[4], N. E. Kassim[1], W. M. Lane[1], T. J. W. Lazio[1], N. Paravastu[1], Y. M. Pihlström[3], E. J. Polisensky[1], P. S. Ray[1], K. P. Stewart[1], J. R. Dickel[3], K. W. Weiler[1]

1: NRL, Washington, DC, USA
2: ARL-UT, Austin, USA
3: UNM, Albuquerque, USA
4: LANL, Los Alamos, USA

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/)*

2005-2007: Phase 1

- *Construction of the Long Wavelength Demonstrator Array* **(LWDA)**

2008-2009: Phase 2

- *~ 9 stations with baselines from 20-200 km*

2010-2012: Phases 3 & 4

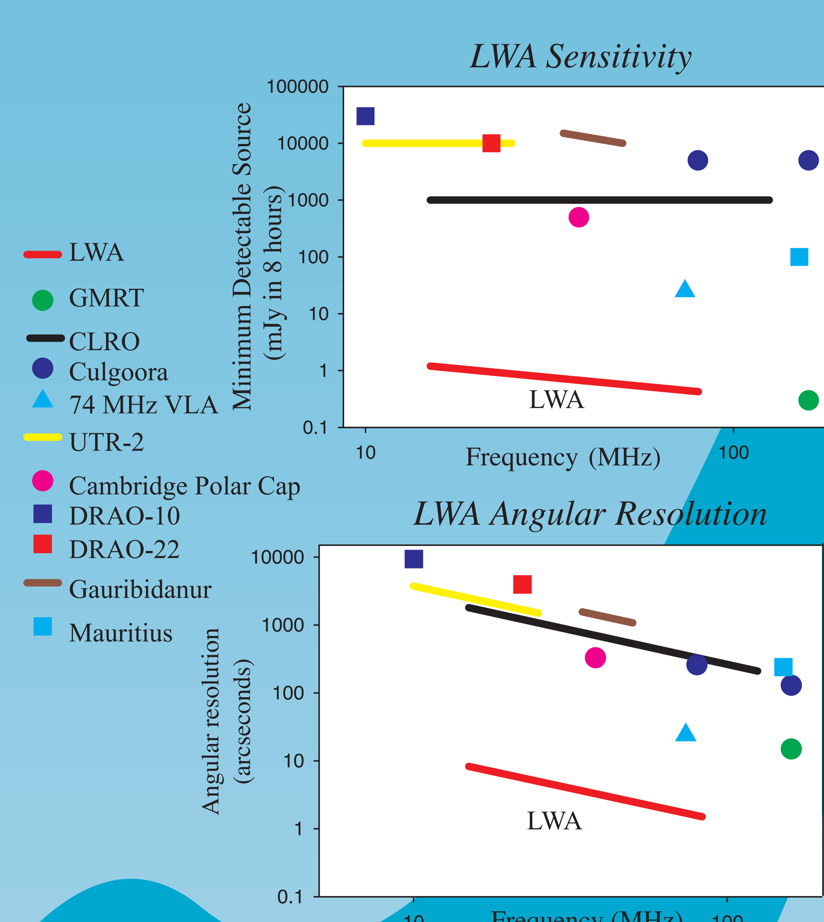
- *Phase 3: add compact core of ~7 stations to fill in short baselines*
- *Phase 4: addition of more stations to even out UV coverage with baselines up to 400 km*
- *Full LWA with ~50 stations and full imaging capability across entire 20-80 MHz range.*

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.unm.edu***

LWA Basic Specifications

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

$10\ MHz = 30\ meters = 4.1 \times 10^{-9}\ eV$



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

Great discoveries in astrophysics have coupled key technical innovations with the opening of new windows on the EM spectrum.

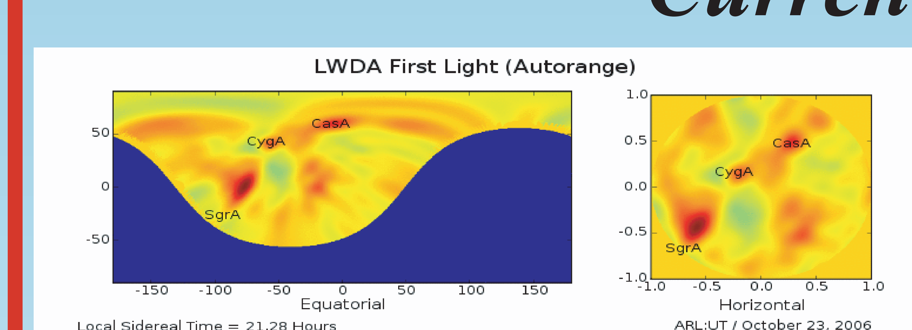
- Technical breakthrough: demonstration of interferometry on baselines >5 km (ionospheric calibration) with 74 MHz VLA.
- Last poorly explored spectral region: < 100 MHz.
- New observing paradigms: multi-beaming, wide-field sky monitoring.

Potential new horizons: transients, extra-solar planets, coherent emission sources.

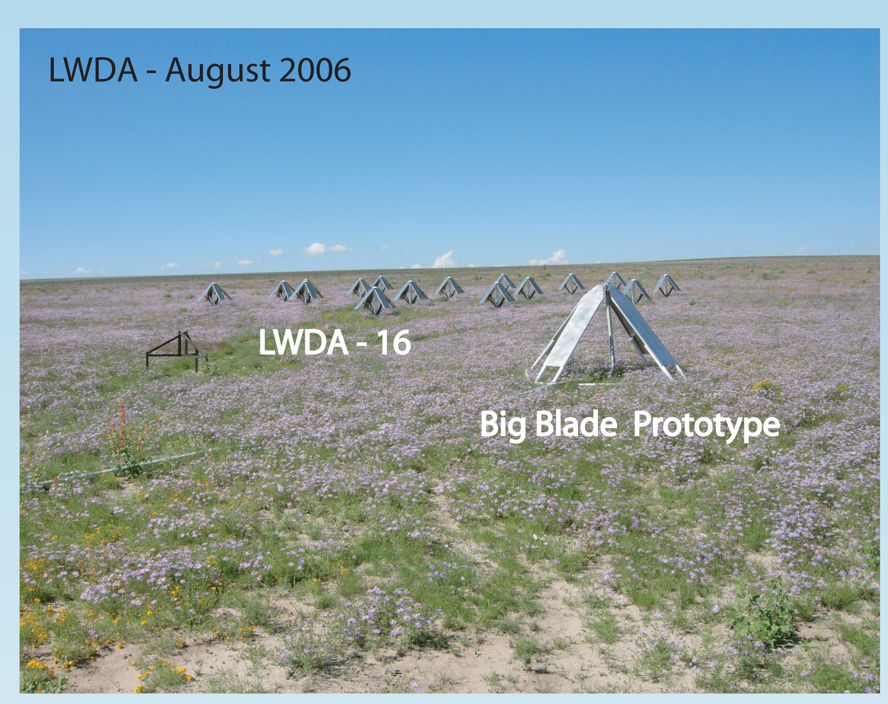
Vision of the Long Wavelength Array

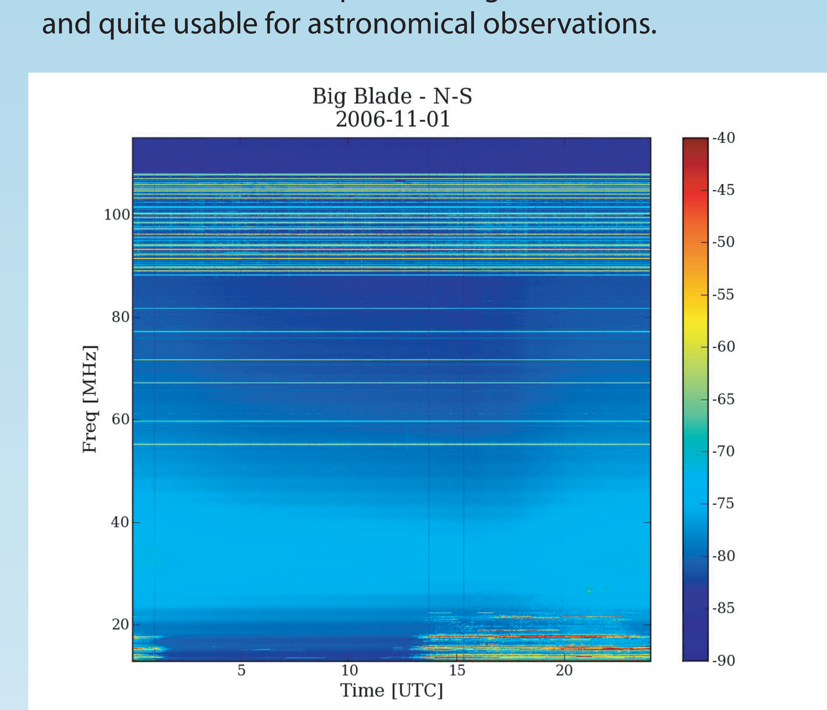
Summary: Nearly three decades ago, the Very Large Array (VLA) first opened the cm-wavelength radio sky to detailed study. Today, a path-finding VLA 74 MHz system is providing the first sub-arcminute resolution view of the meter-wavelength radio universe, a technical innovation that has inspired the US ***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 square kilometer (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.

Current Progress



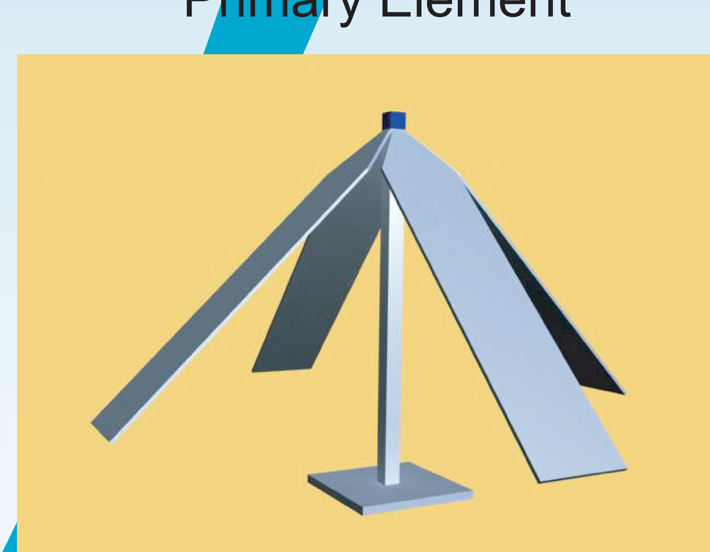
In October 2006 the LWDA, consisting of 16 crossed dipoles of the small-blade design (shown in picture at bottom left), was completed. A first-light image of the sky at 74 MHz taken with 2 minutes of data from the LWDA is shown at left. The big blade prototype antenna is being tested and also used to monitor the RFI environment from 15 to 115 MHz. Below the FM band much of the spectrum is galactic noise dominated and quite usable for astronomical observations.





Artist's View of the LWA

Primary Element

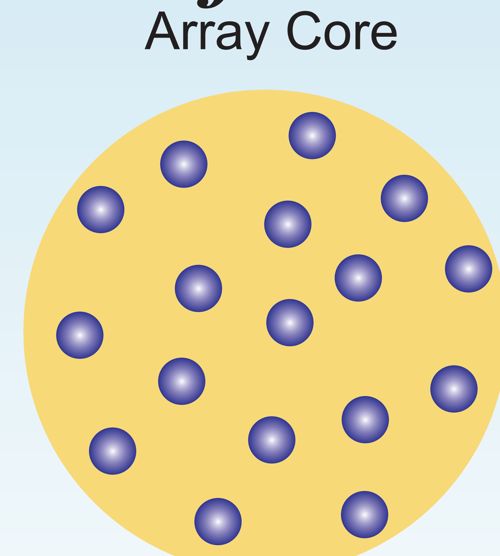


~3 m

Single Station

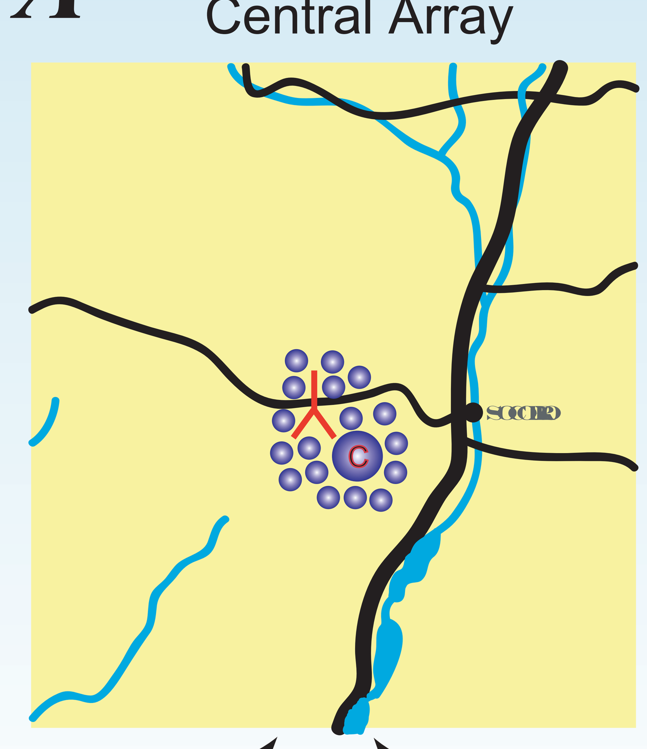
100 m

Array Core



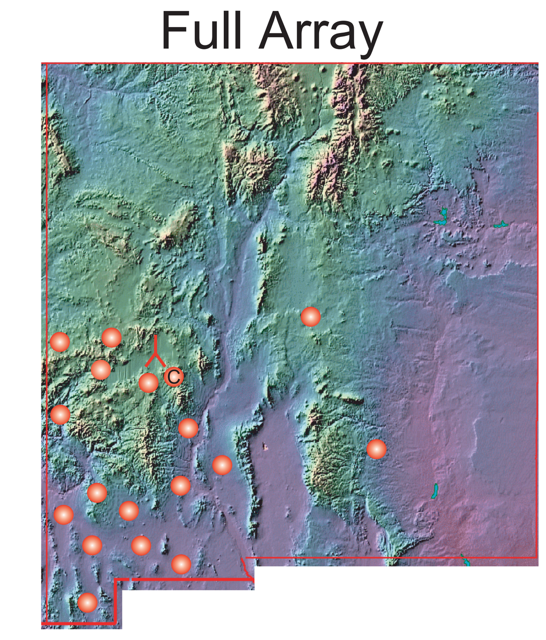
5 km

Central Array



50 km

Full Array



400 km

Basic research in radio astronomy at the Naval Research Laboratory is funded by the Office of Naval Research. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.