# Thoughts on LWA/FASR Synergy

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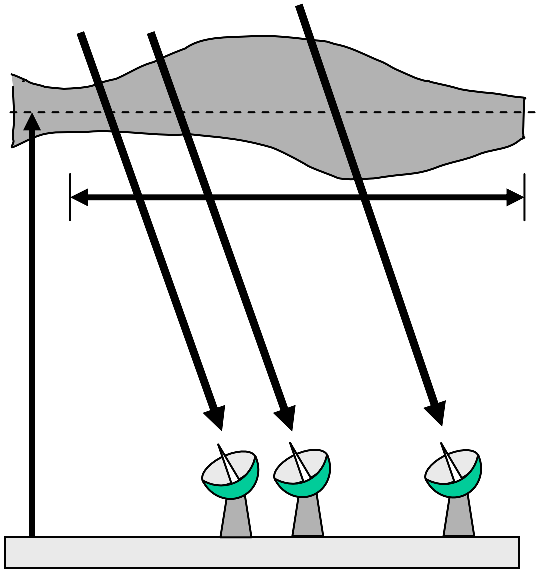
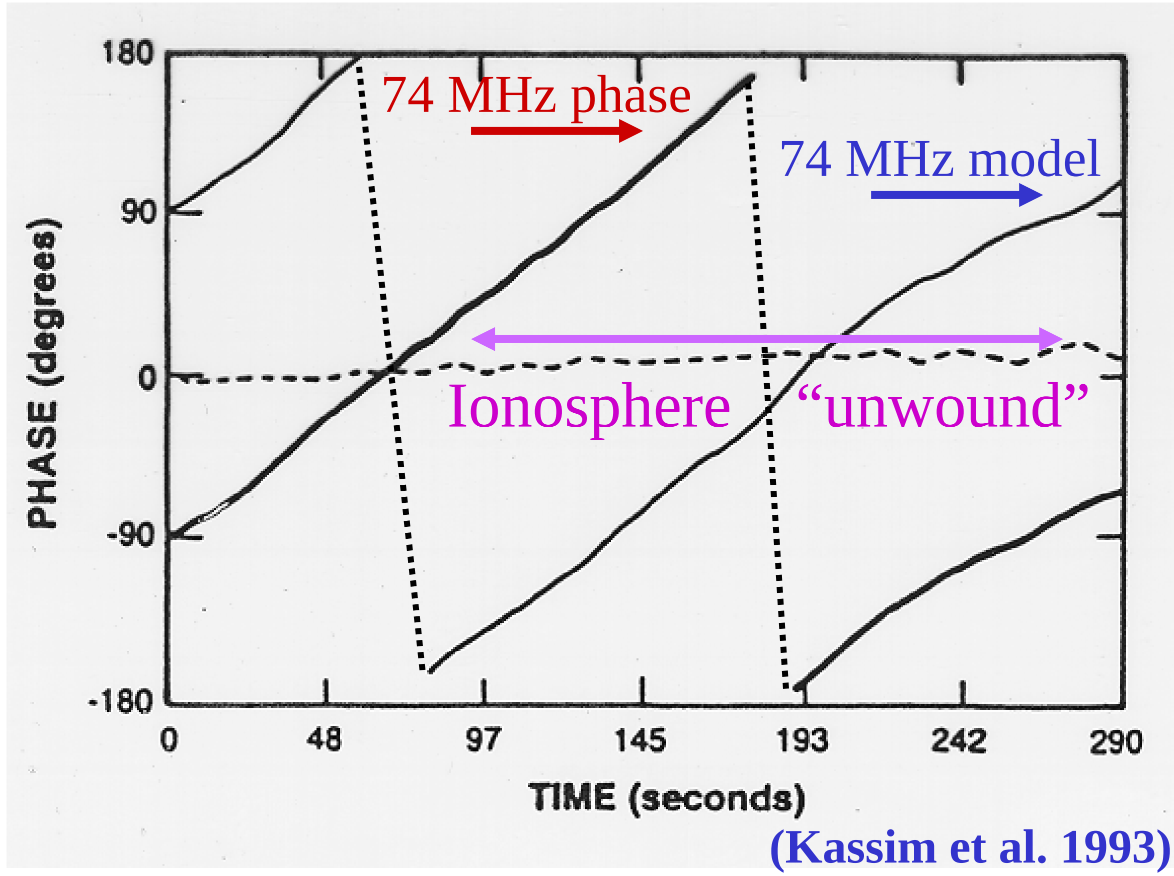
<http://lwa.nrl.navy.mil/>

# Ionospheric Waves

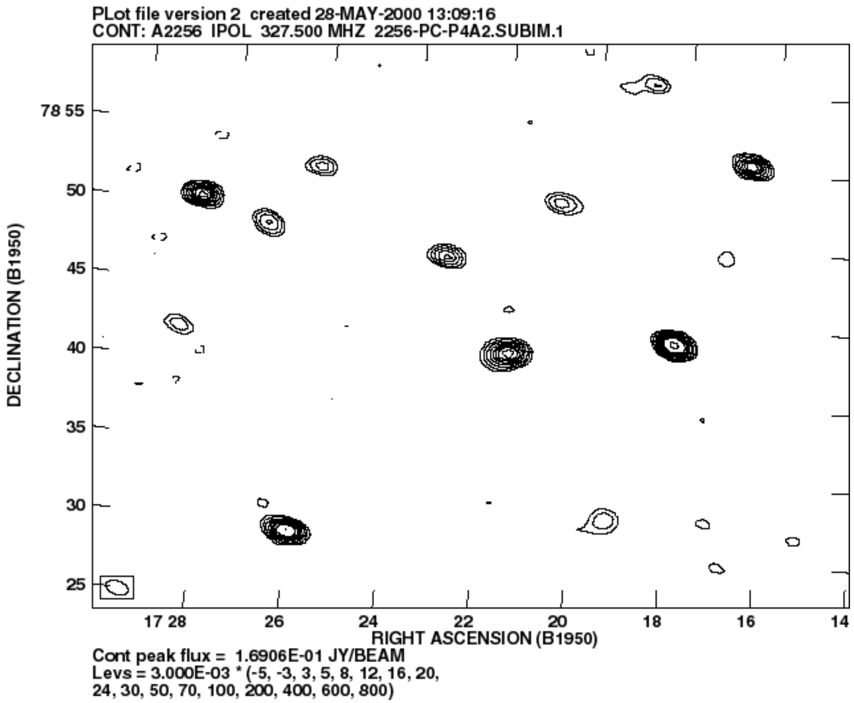




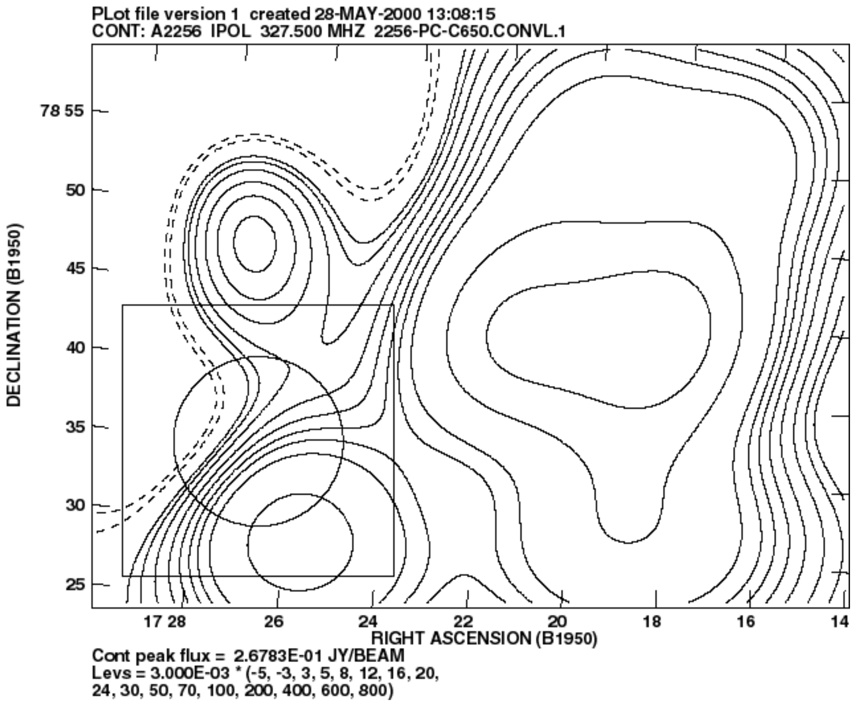

- Ionospheric waves introduce rapid phase variations
  ~ 1° $s^{-1}$ for A-configuration (35 km) VLA
- Disrupt phase measurements and limit coherence times
- 1980s: Self-calibration predicted to remove ionospheric effects from LF data
- 1990: NRL-NRAO propose to "break ionospheric barrier" with 74 MHz VLA

# Low Angular Resolution: Limits Sensitivity Due to Confusion

$\theta \sim 1'$, rms ~ 3 mJy/beam

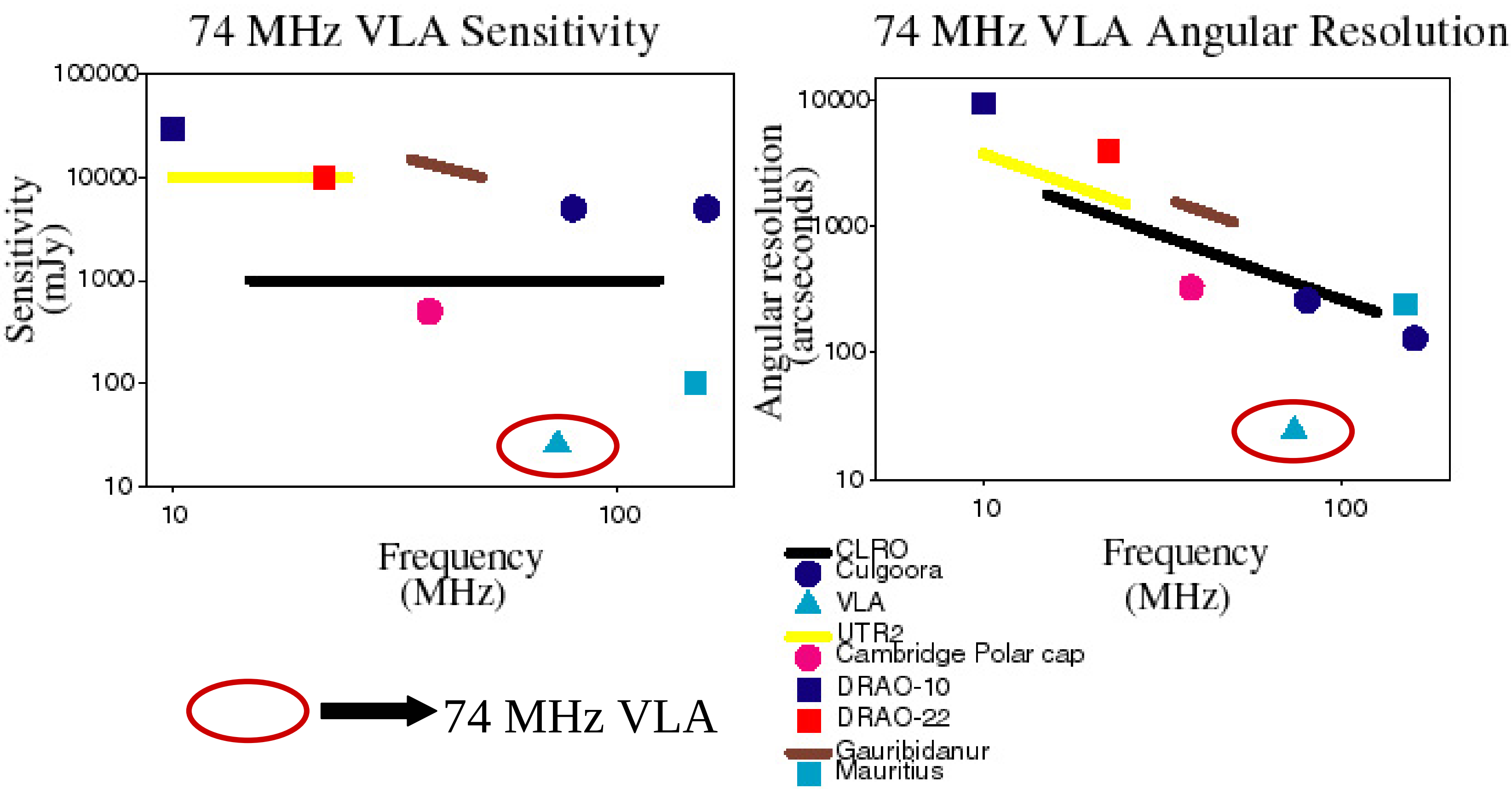



$\theta \sim 10'$, rms ~ 30 mJy/beam



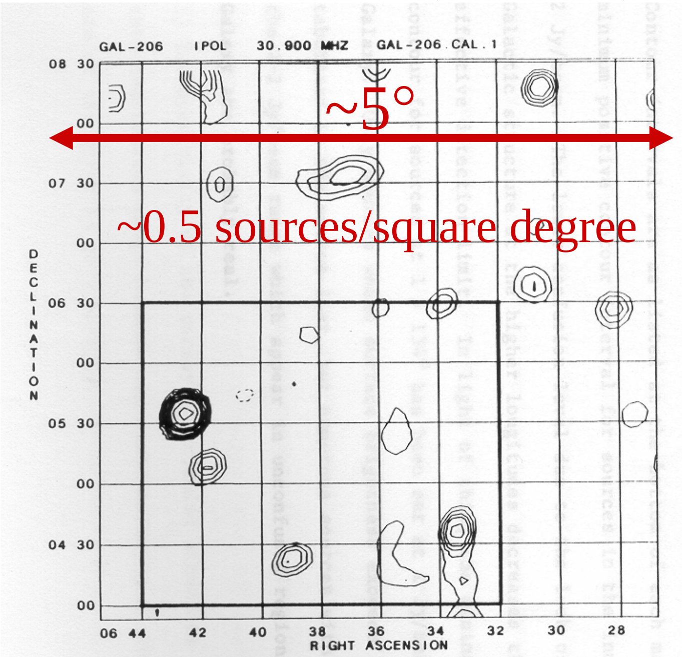
# 74 MHz Receiving System: Dipoles

# 74 MHz VLA: Significant Improvement in Sensitivity and Resolution



# Comparison of Low Frequency Capabilities (past vs. present)

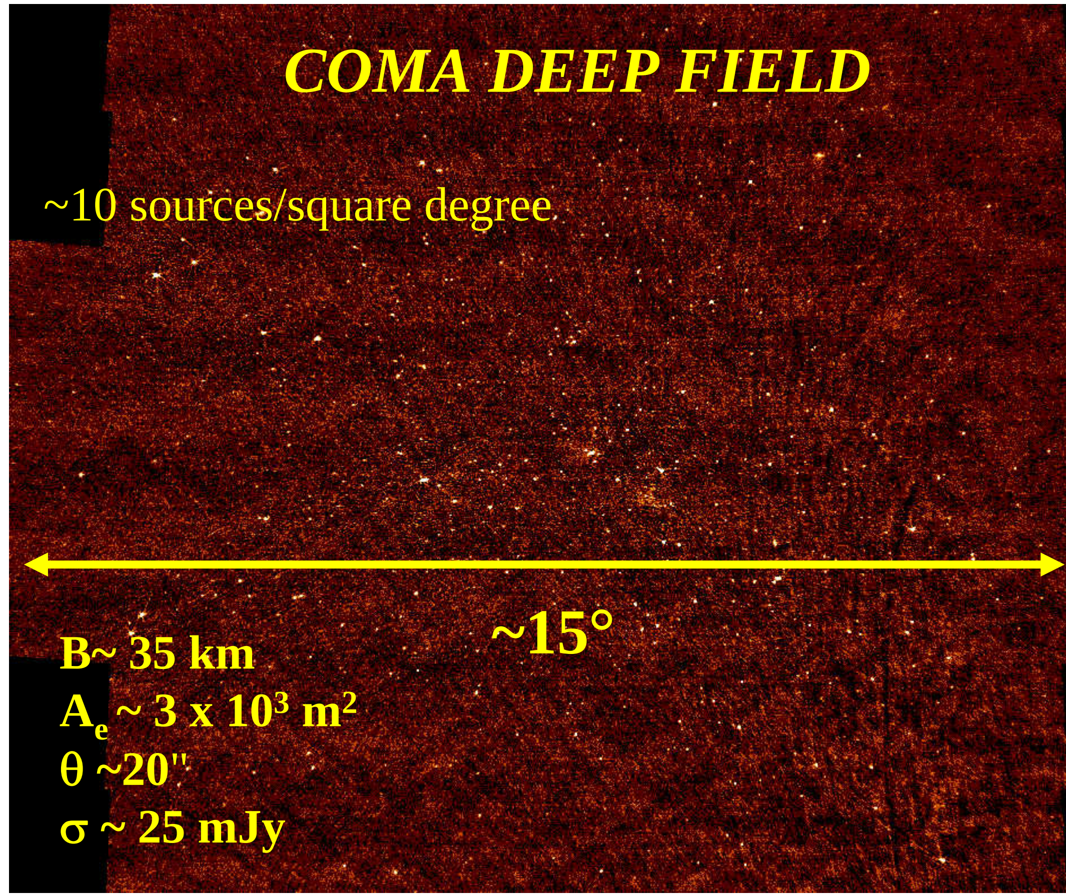
**Clark Lake (30 MHz)**




Kassim 1989

- $B \sim 3$ km
- $A_e \sim 3 \times 10^3$ m$^2$
- $\theta \sim 15'$ (900'')
- $\sigma \sim 1$ Jy

**VLA (74 MHz)**



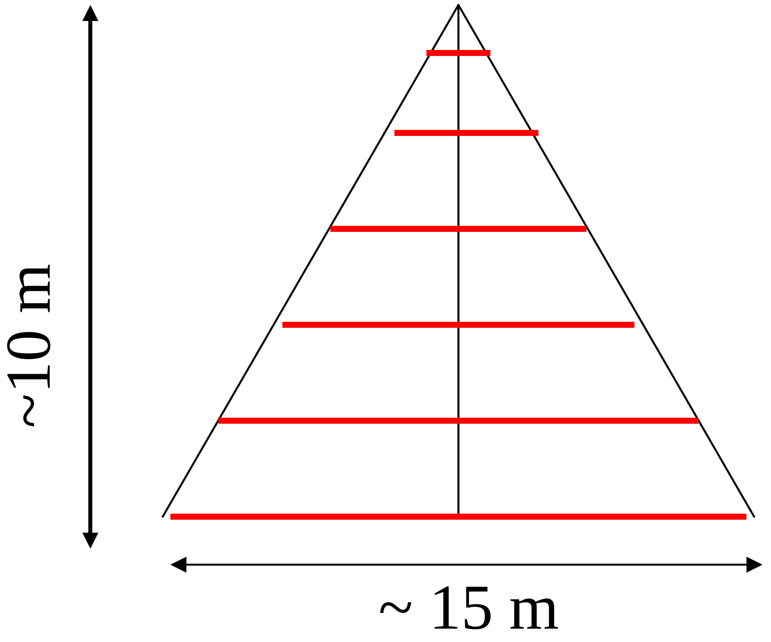

Enßlin *et al*. 1999

# LWA Concept
## (presented to Astronomy Decade Committee)

- Inspired by 74 MHz VLA, which demonstrates major breakthrough in sensitivity and angular resolution:
  - Reflects impact of self-calibration, ability to emerge from confusion
- Fully electronic, **broad-band antenna array**
- Basic element is an active dipole receptor: $\Delta\nu \sim$ 10–90 MHz
  - Low frequency limit: ionospheric absorption, scintillation
  - High frequency limit: $\lambda^2$ collecting area, better to use dishes above this
- "Stations" (dishes) are 160 m in size, comprised of 256 receptors
  - Good primary beam definition, low sidelobe levels
- **Large aperture**: baselines $\leq$ 500 km (no limit on baseline length)
  - Good angular resolution, low confusion
- **Large collecting area**: $\geq 10^6$ m$^2$
  - 2–3 orders of magnitude improvement in resolution & sensitivity
  - 8"@15 MHz, 2"@75 MHz; ~ 1 mJy@30 MHz (1 hr, 2 pol, 4 MHz BW)
- Multiple beams: new approach to astronomical observing

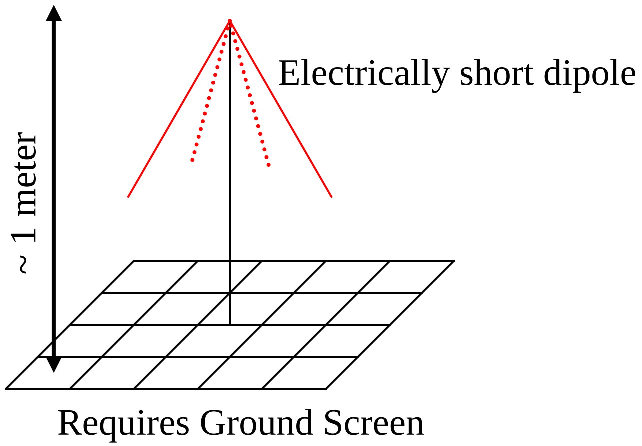
# Antenna Design

- Conventional approach: Log-Periodic Array
  - Pro: well studied, good frequency & sky coverage
  - Con: large



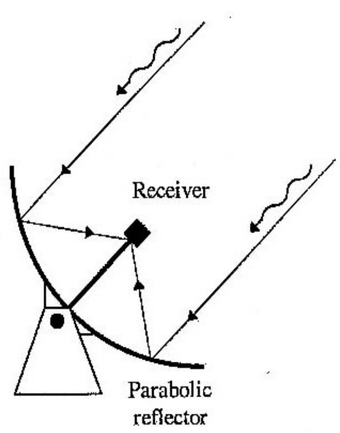

- New-technology approach: "Active" Dipoles
  - Pro: small
  - Con: impedance matching, sensitivity, sky coverage, ground plane, strong inter-element coupling

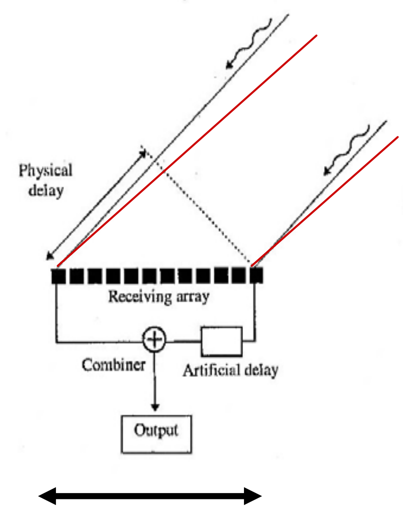
NRL testing underway



# Station Design

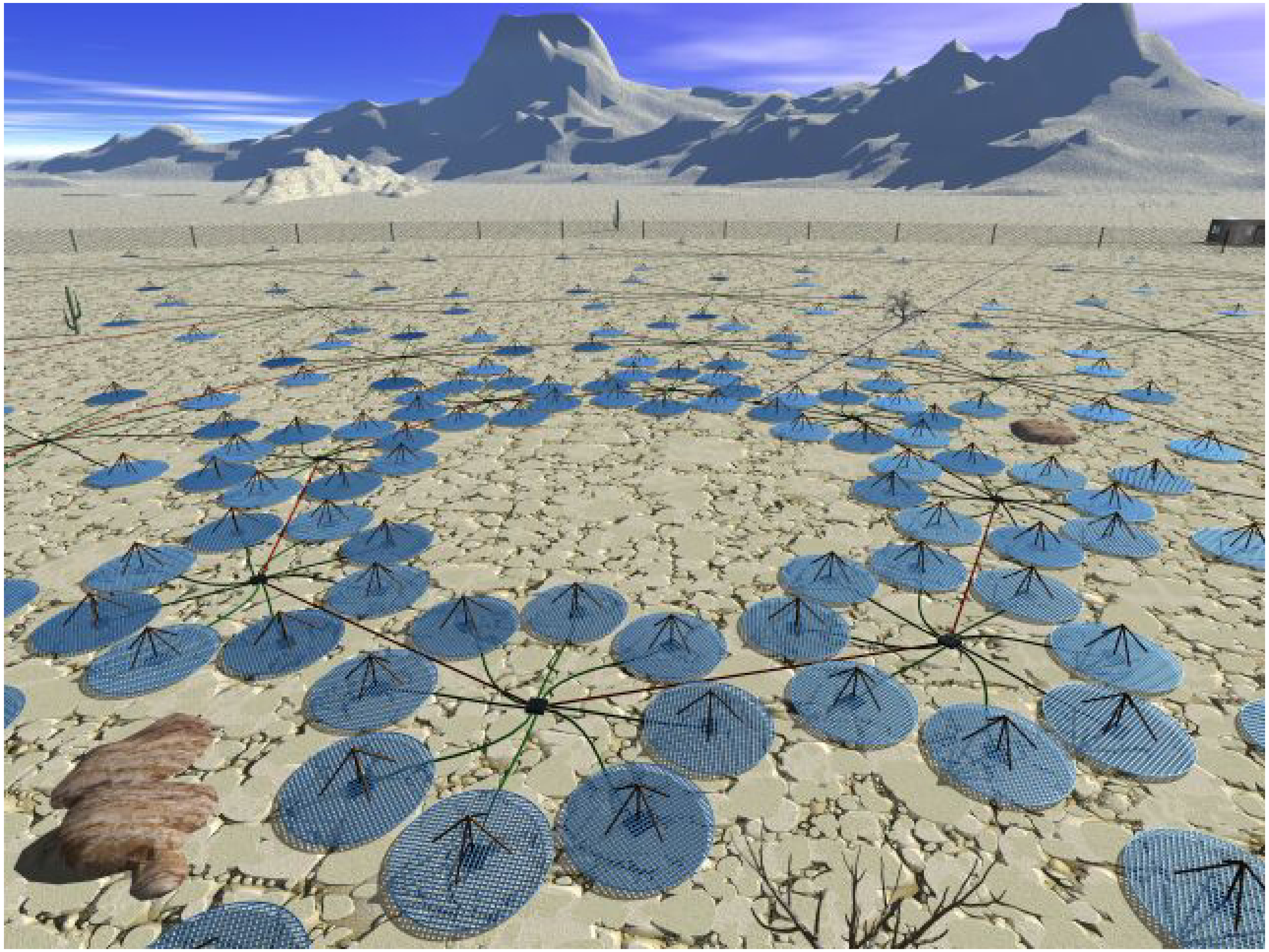
- Consists of 256–1000 broad-band wire antenna elements
- Phased array will deliver one signal that looks like the signal from a single VLA antenna
  - Plug & play philosophy for VLA integration
  - Will serve as prototypes for LWA lower frequency antennas




~100 m

# High Sensitivity LWA Station

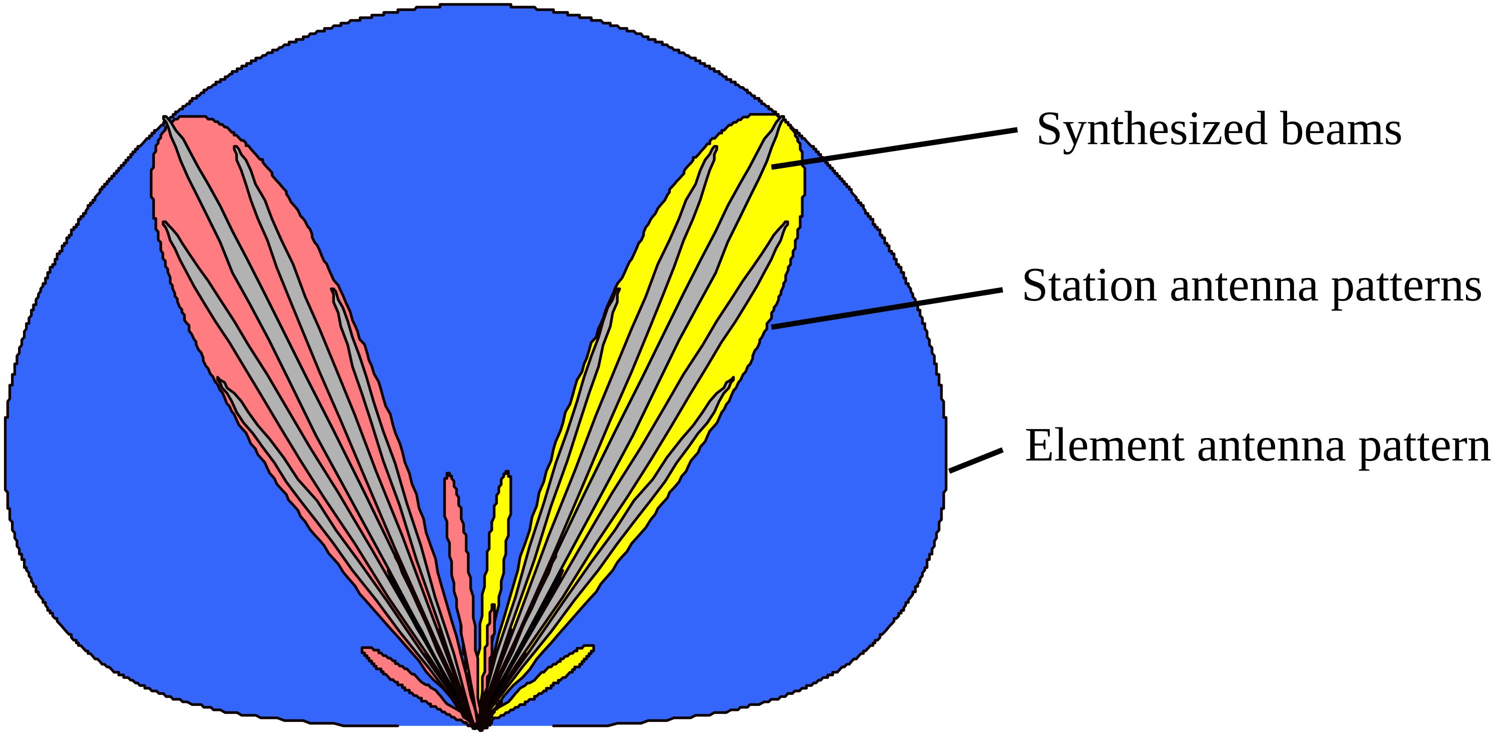


Analogous to one VLA antenna but with > 10x the sensitivity

~ 100 meter diameter

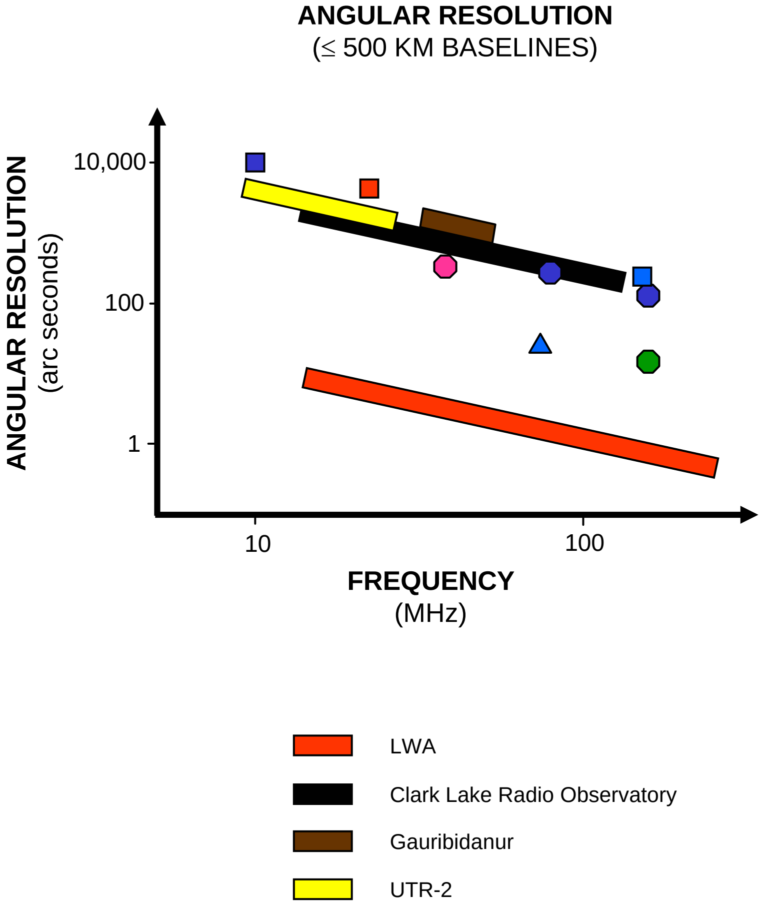
<u>@74MHz:</u>
VLA antenna ~ 125 $m^2$
LWA Station ≥ 1500 $m^2$

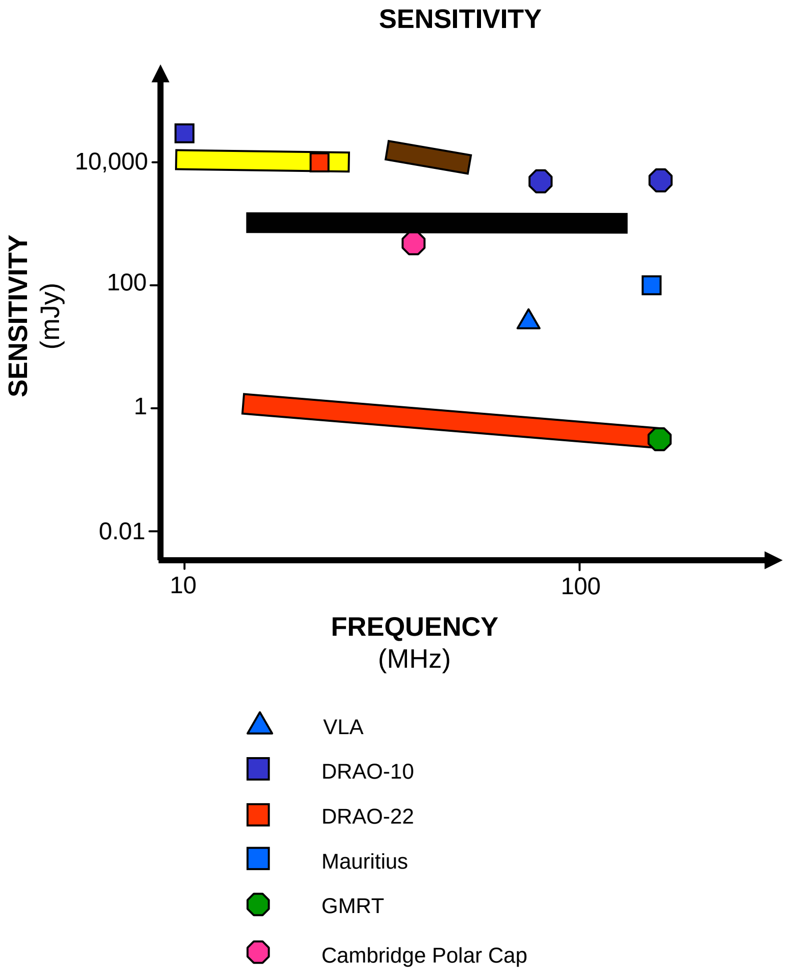
# New Technology Electronic Arrays: Fast, Flexible, Multibeamed




Multiple, independent beams $\Rightarrow$ speed and flexibility
$\Rightarrow$ multiple, simultaneous science programs

# Opening A New Window On The Universe



# Key LWA Science Projects

- High Redshift Universe
  - unbiased sky surveys, select highest $z$ galaxies
  - trace Galactic & intergalactic **B** fields, infalling shocks around clusters
  - HI absorption at the Epoch of Reionization
- Cosmic Ray Electrons and Galactic Nonthermal Emission

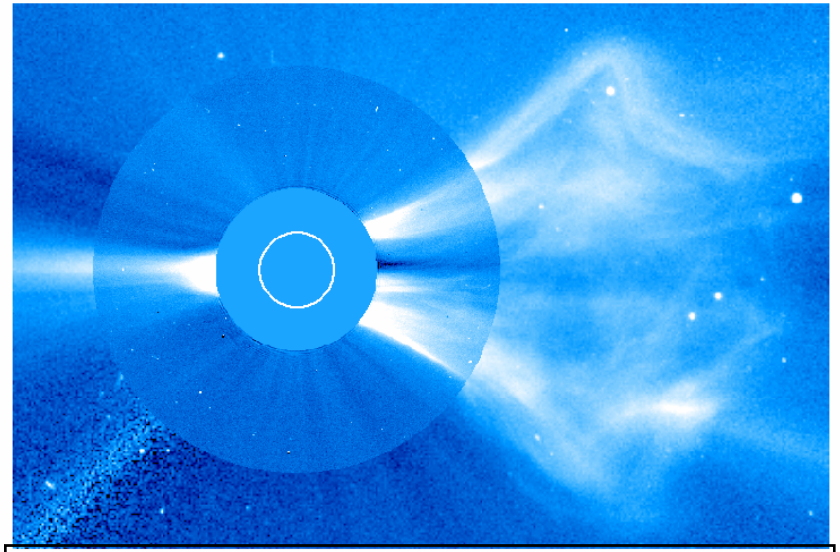
  map 3D distribution & spectrum, study propagation: clues for expected origin & acceleration in SNRs?
- Bursting and Transient Universe
  - broad-band, all-sky monitoring for variable/transient sources (GRBs, etc …)
  - search for coherent emission sources; e.g., stars, quasars, exoplanets
- **Solar-Terrestrial Relationships**
  - **study fine-scale ionospheric structures**
  - **image Earth-directed CMEs (as radar receiver)**
  - **plan for dedicated solar beam**

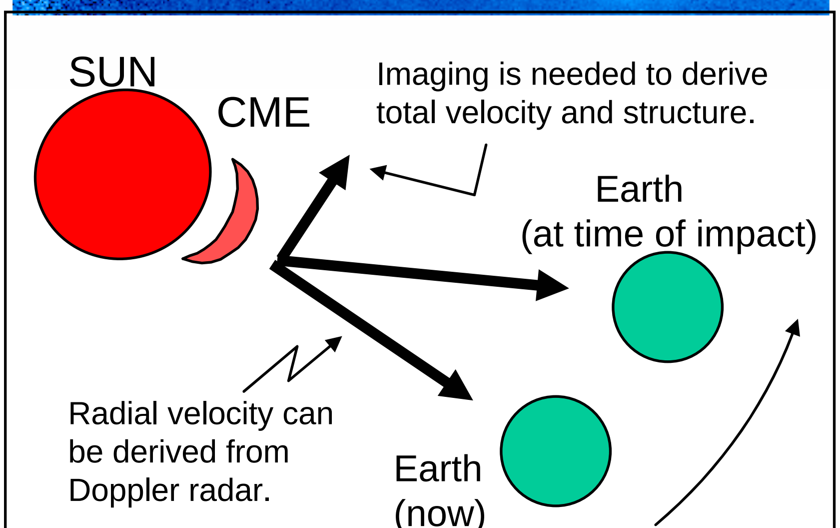
LWA science plan was recommended by the NAS Astronomy Survey Committee in the Decadal Report.

# Broad Range of Scientific Applications

- Steep spectrum clusters and fossil galaxies, including polarization studies using background sources
- Surveying (Galactic & extragalactic), studies of variable source populations
- Galactic center mapping, transient source monitoring
- Pulsars - detecting, finding new steep spectrum fast pulsars
- Supernova remnants and their interaction with pulsars and the ISM
- Thermal absorption from low density, ionized gas in ISM
- Recombination lines, emission and absorption lines from the cool ISM (carbon clouds)
- **Propagation and scattering, in the solar wind, the IPM, the Galaxy, and towards extragalactic sources**
- **Steep spectrum emission from Flare Stars, Binary Star systems**
- **Passive emission from solar flares, storms, CMEs, quiet sun**
- **Solar and Planetary radar**
- Tracking Ionospheric TIDs, real-time ionospheric modelling from self-cal solutions
- Magnetospheric, ionospheric sounding

# Coronal Mass Ejections

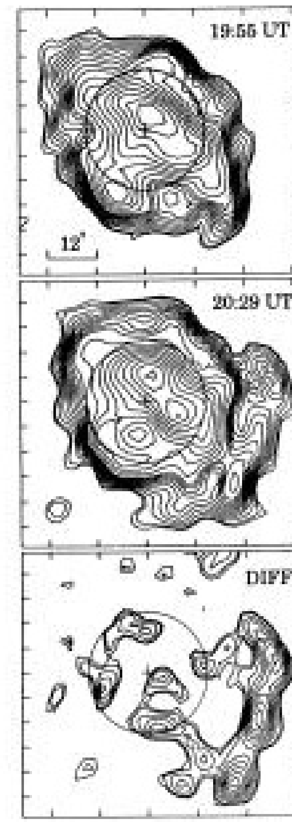





Coronal Mass Ejections (CMEs) are both significant science problems for solar physics and significant dangers for DoD and commercial space missions.

LWA could map out the structure of CMEs and determine space velocities to predict their impacts.

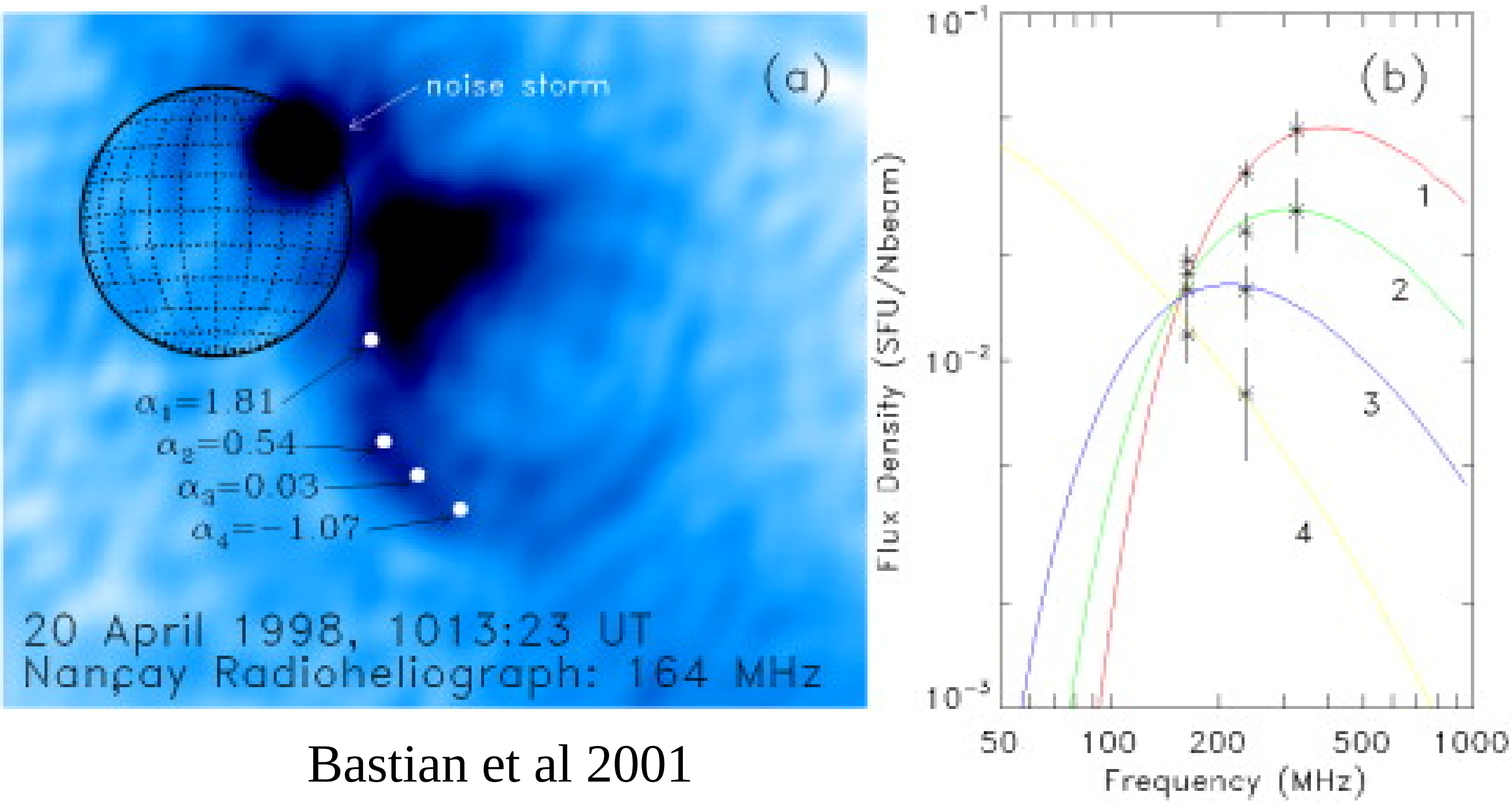
Although LWA is a passive instrument, it could also be used in combination with a suitably located radar transmitter to completely probe the density structure and space velocity.




Clark Lake
(73.8 MHz)

# CMEs: Synchrotron Emitting Sources

## Nancay Image at 164 MHz




Bastian et al 2001

# LWA/FASR Synergy

- Develop common tools for simulation studies
  - System, configuration, etc …
- Advantage of Co-Location
  - Scientific
    - A LWA dedicated solar beam would continuously monitor the sun, with observations below 100 MHz acting as a trigger for FASR follow-ups
    - **LWA could "calibrate out" the ionosphere for FASR**, since LWA will see a myriad of background sources of known positions
  - Technical
    - Shared site characterization (e.g. RFI surveying)
    - If co-located - shared infrastructure, etc …
- Shared technologies
  - Active antenna technology
  - After the antennas, much overlap: correlator, transmission, etc …
  - Common need for high DR, RFI resistant systems
  - Common need for high time resolution
    - For LWA: transients and pulsars
- High Data Rates
  - Common massive data management, visualization, manipulation techniques

# SUMMARY
## (http://lwa.nrl.navy.mil)

- LWA will open one of the last and most poorly explored regions of the EM spectrum below 100 MHz
  - Sophisticated, multi-beam, multi-frequency electronic array which will herald revolutionary new approach to astronomical observations
  - **Science plan recommended by National Academy of Sciences Astronomy Survey Committee in the new Decade Report**
- Key science drivers:
  - High Z Universe, Epoch of Reionization, Cosmic Rays, Bursting & Transient Universe
  - **Solar-Terrestrial Relationships**: study fine-scale ionospheric structures, image Earth-directed CMEs
    - **One beam dedicated for solar use**
    - **Co-location seals success of LWA as solar instrument – does LWA help FASR?**
  - Lots of “regular science” too
  - **Serendipity: new discoveries likely in unexplored regime**