The Long Wavelength Array

Greg Taylor (UNM)

New Mexico Symposium

November 5, 2010

http://lwa.unm.edu

and see Poster by Joe Craig et al.

LWA Science

Astrophysics

Cosmology
Observing cosmic dawn through redshift 30 absorption of the 21 cm line. High redshift radio galaxies, containing the earliest black holes

Acceleration, Propagation & Turbulence in the Interstellar Medium
Origin, spectrum & distribution of Galactic cosmic rays
Supernova remnants & Galactic evolution
Pulsars

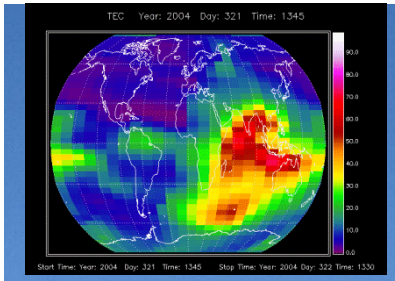
Solar Science & Space Weather
Radio heliography of solar bursts & coronal mass ejections
Solar radar

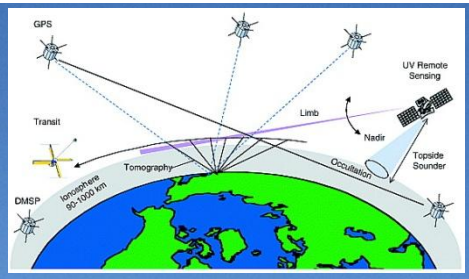
Exploration of the Transient Universe
New coherent sources (More GCRT J1745-3009s?)
GRB Prompt Emission
Magnetar Flares
Extra-Solar Jupiters: Detect magnetic field; conditions for life?
Poorly explored parameter space…new sources

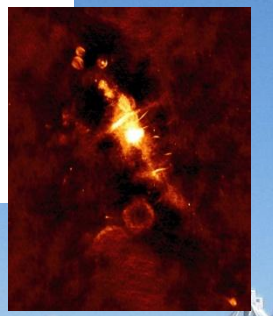
Ionospheric Physics

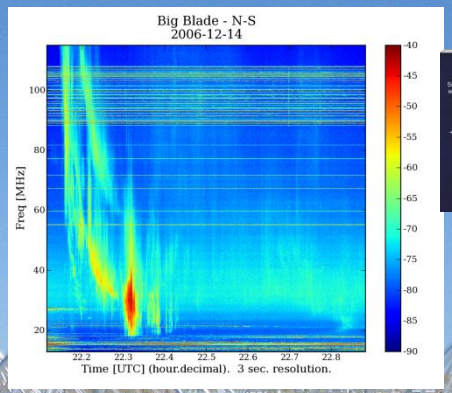
Unprecedented continuous spatial & temporal imaging of the ionosphere

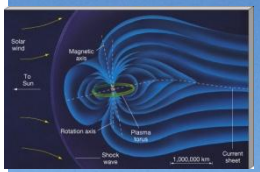
Test and improve global ionospheric models









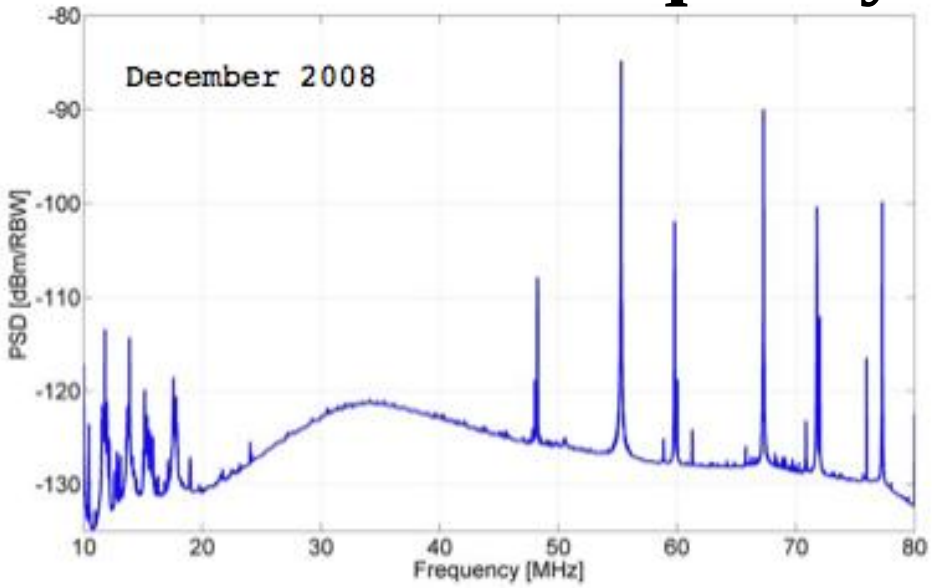


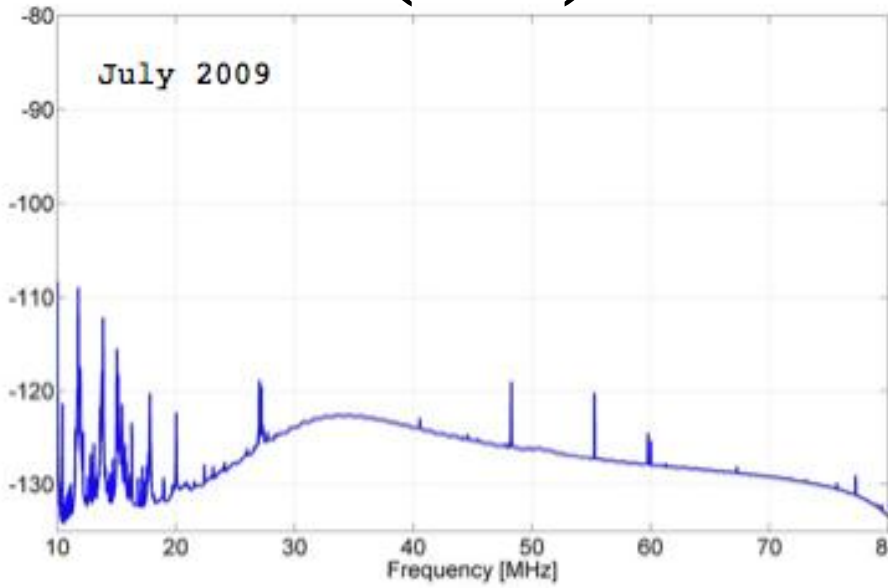
LWA-1 Ribbon Cutting, April 2010

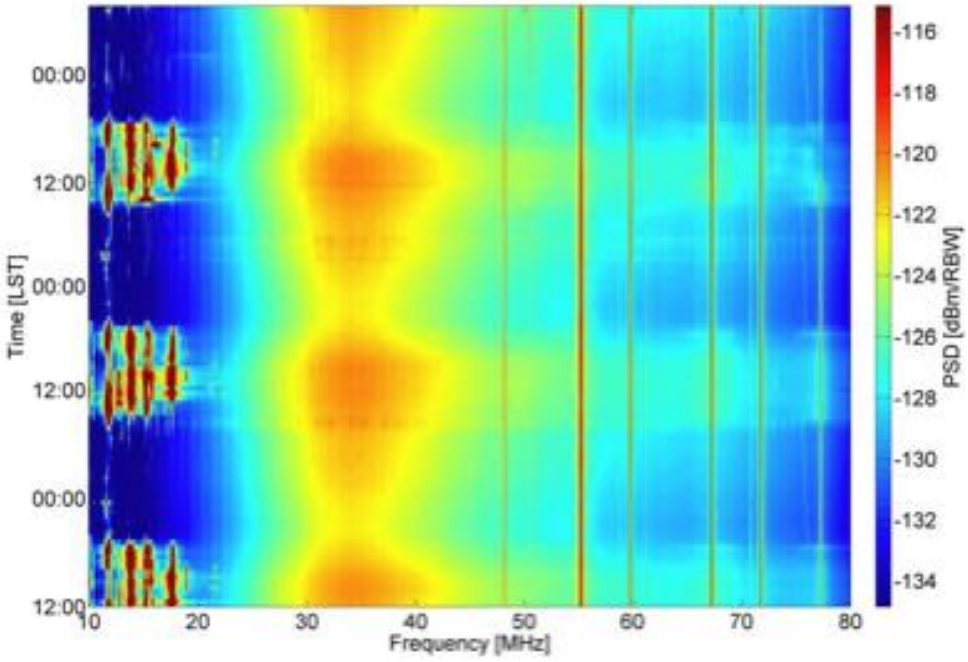
The LWA Instrument

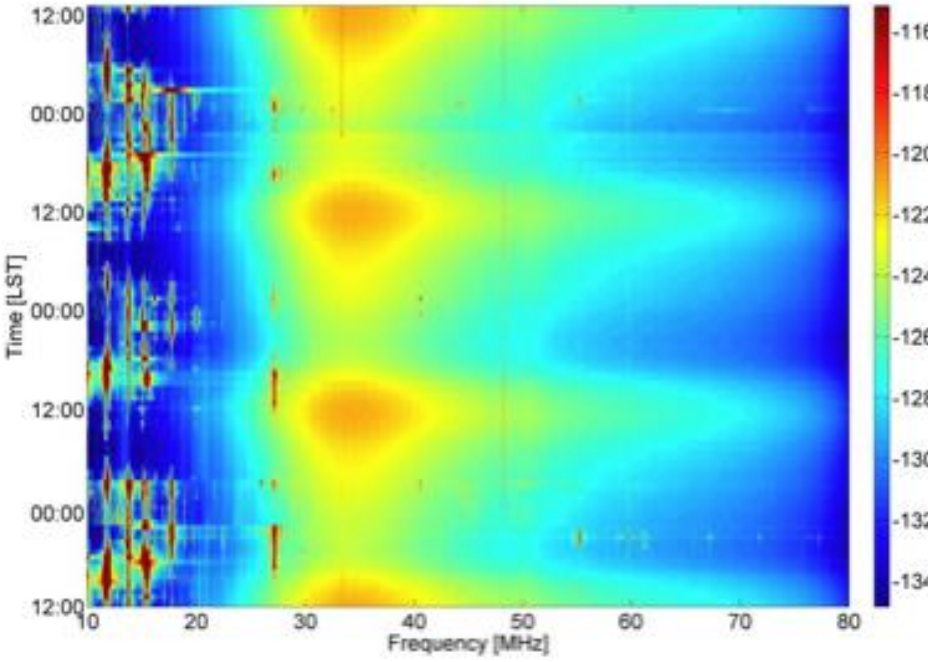
- **Frequency Range: 10-88 MHz**
- **4 beams x 2 pol. x 2 tunings x 16 MHz**
- **2 all-sky transient obs. modes**

Radio Frequency Interference (RFI)

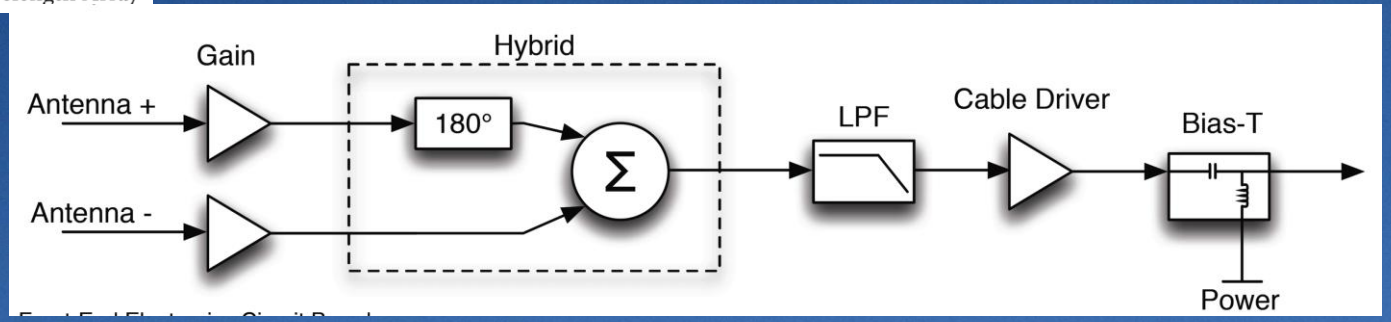




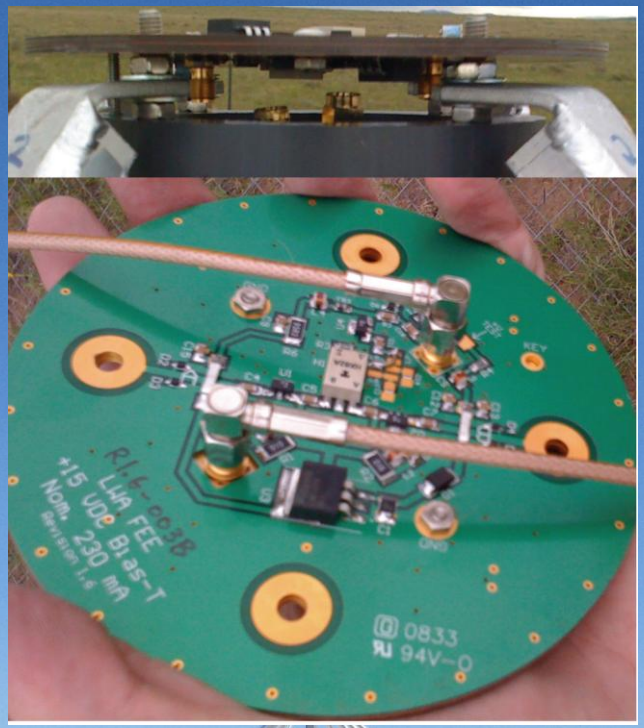




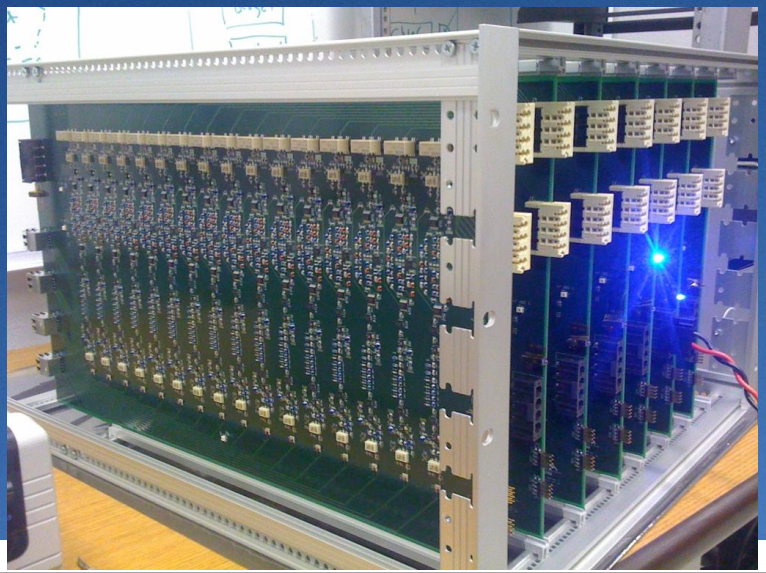
Front-End Electronics (FEE)



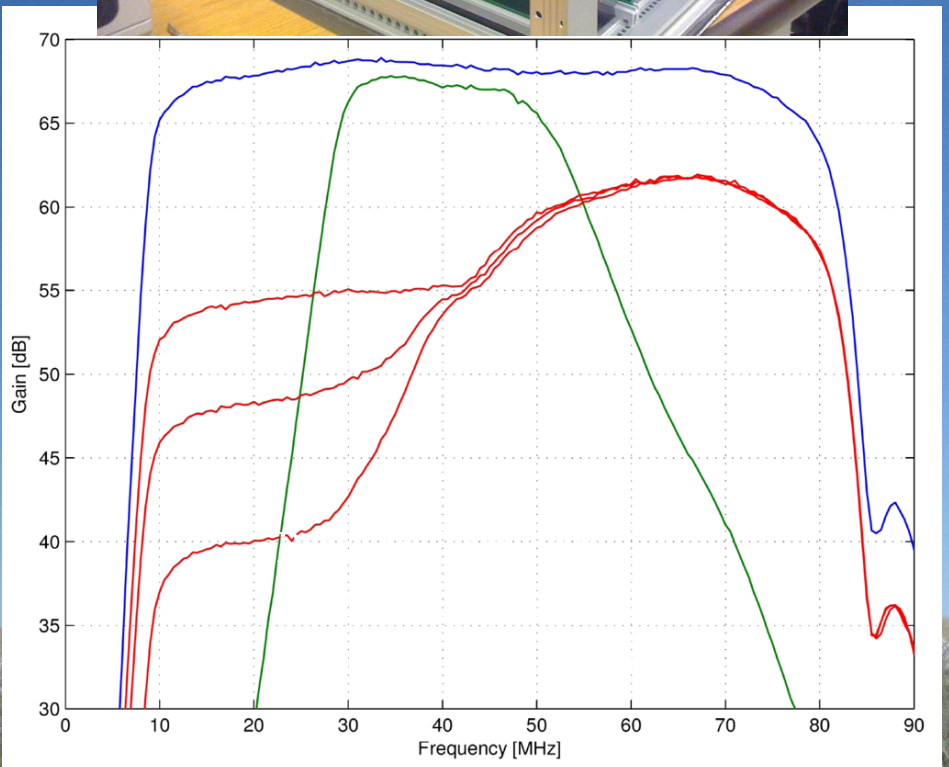
Gain	36 dB
Noise Temperature	250 K
Input P1dB	-18.3 dBm
Input IP3	-1.8 dBm
Current Draw @ +15VDC	230 mA



Analog Receiver (ARX)

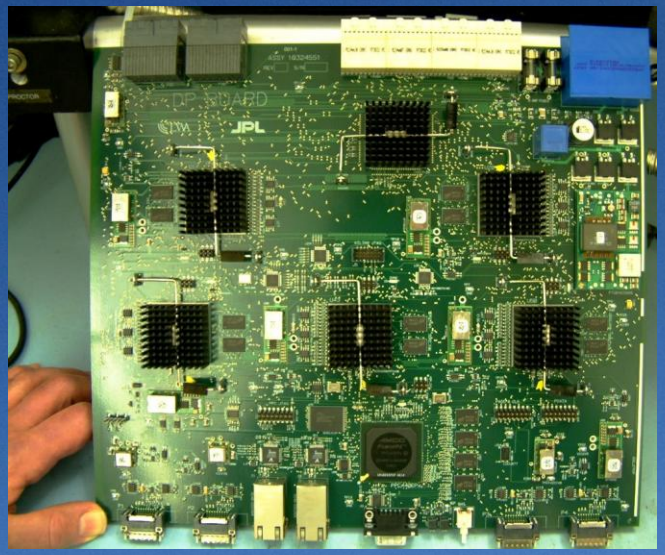


- 8 - 68 dB Gain (2 dB steps)
- Filterbank with 3 configurations
  - Full Bandwidth: 10 - 88 MHz
  - Reduced Bandwidth: 28 - 54 MHz
  - Split Bandwidth: 10 - 88 MHz, 30 dB of gain control over the low-frequency portion of the passband (equalizer)
- Integrated bias-tee to power FEE



32 ARX boards per station

Digital Processor (DP)

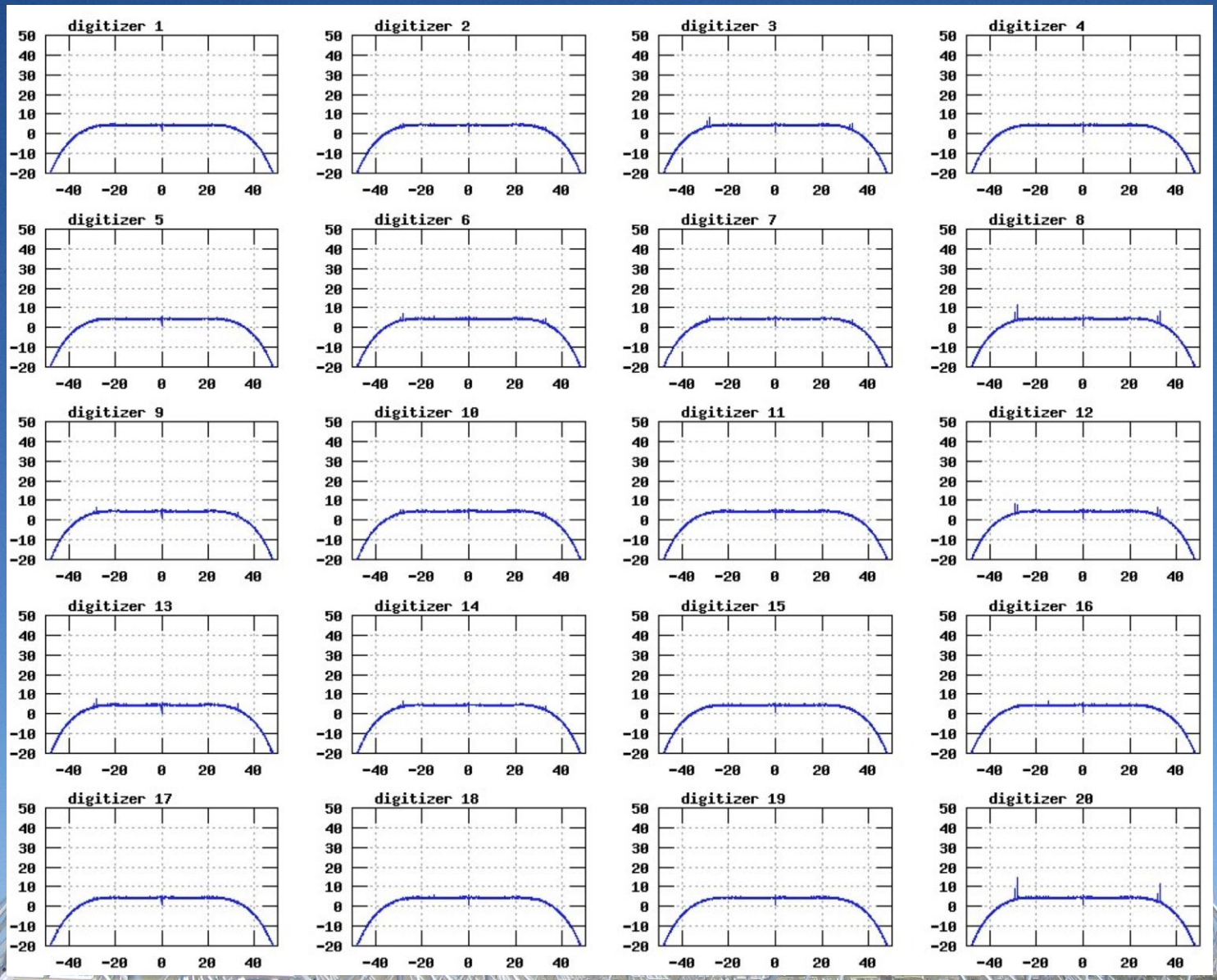


One of 28 “DP” boards
5 Xilinx Virtex-5 SX50T FPGAs

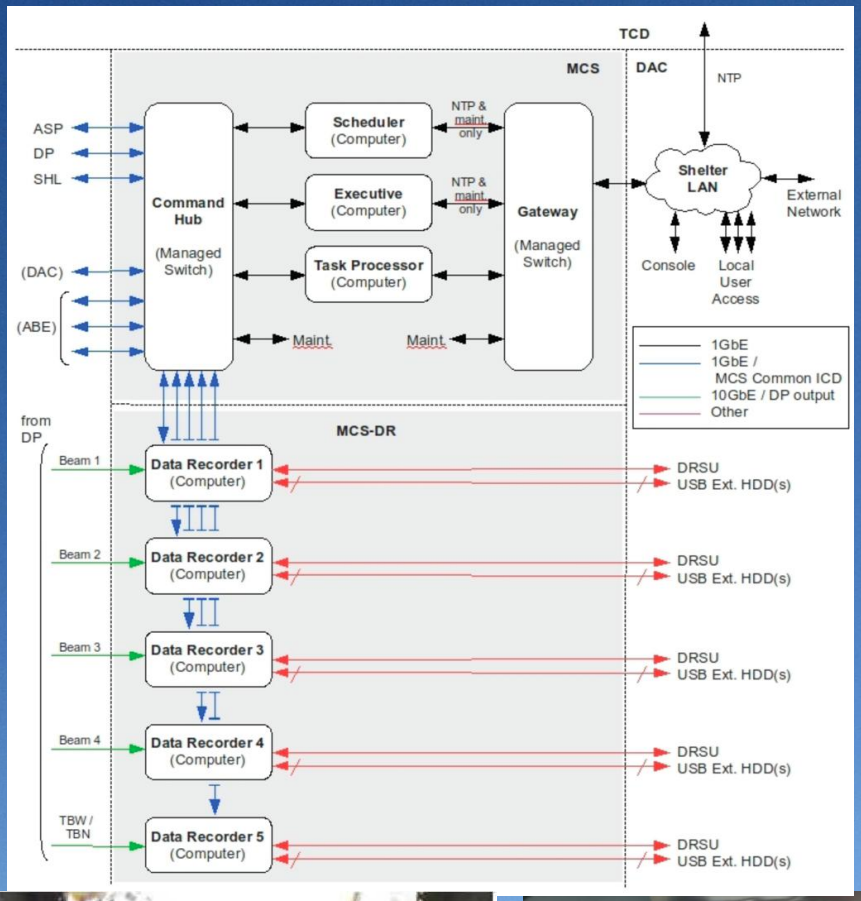
- 12 bit x 196 MSPS direct sampling
- 10-88 MHz operations
- About to start production boards
- Output Modes
  - DRX: 4 beams (x 2 pol x 2 tunings) at 19.6 MSPS
  - TBW: Full RF in a 61 ms burst
  - TBN: 100 kHz from all antennas continuously

ATCA Chassis
Fits 13 DP/DIG boards

TBN mode


digitizer 1
digitizer 2
digitizer 3
digitizer 4
digitizer 5
digitizer 6
digitizer 7
digitizer 8
digitizer 9
digitizer 10
digitizer 11
digitizer 12
digitizer 13
digitizer 14
digitizer 15
digitizer 16
digitizer 17
digitizer 18
digitizer 19
digitizer 20
50 40 30 20 10 0 -10 -20
-40 -20 0 20 40

MCS & Data Recorders

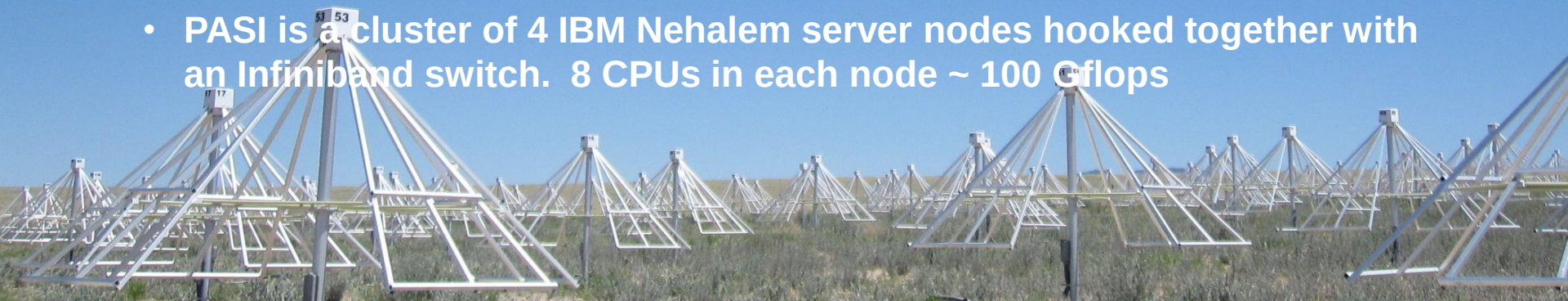


- **Scalable, open-architecture Monitoring & Control System (MCS)**
- **On-site data recording & off-line processing in lieu of correlator**
- **Using new PC-based data recorders**
- **Each PC streams 115 MB/s continuously for 10 hours onto a 5 TB "DRSU" (hard drive array)**
- **Low cost: PCs are US$2K/ea, DRSUs are US$875/ea**

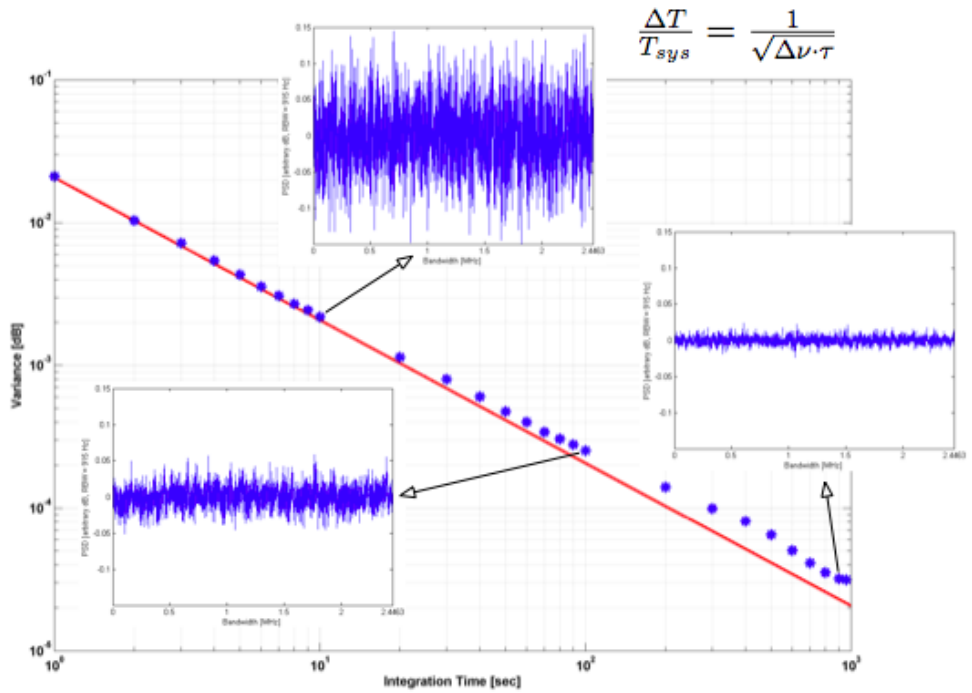
Prototype All-Sky Imager (PASI)

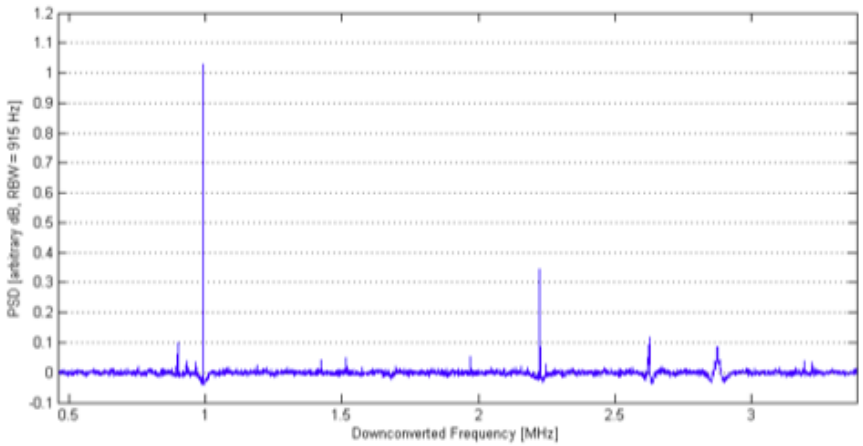
- **A backend for LWA-1 station**
- **Funding ($70k) provided by the NMCIAS**
- **PASI is a computer cluster supporting software to do real-time correlation of TBN data for all-sky imaging in a narrow (100 kHz) band**
- **Goals:**
  - **Source-agnostic survey of the entire sky every day to a depth of 10 Jy/beam (confusion limit)**
  - **Searches for known transients (e.g., Jovian bursts) and new types of transients**
  - **Development test-bed for new algorithms (e.g., RFI rejection, wide-field imaging)**
  - **Educational tool**

- **PASI is a cluster of 4 IBM Nehalem server nodes hooked together with an Infiniband switch. 8 CPUs in each node ~ 100 Gflops**



Radiometric Stability



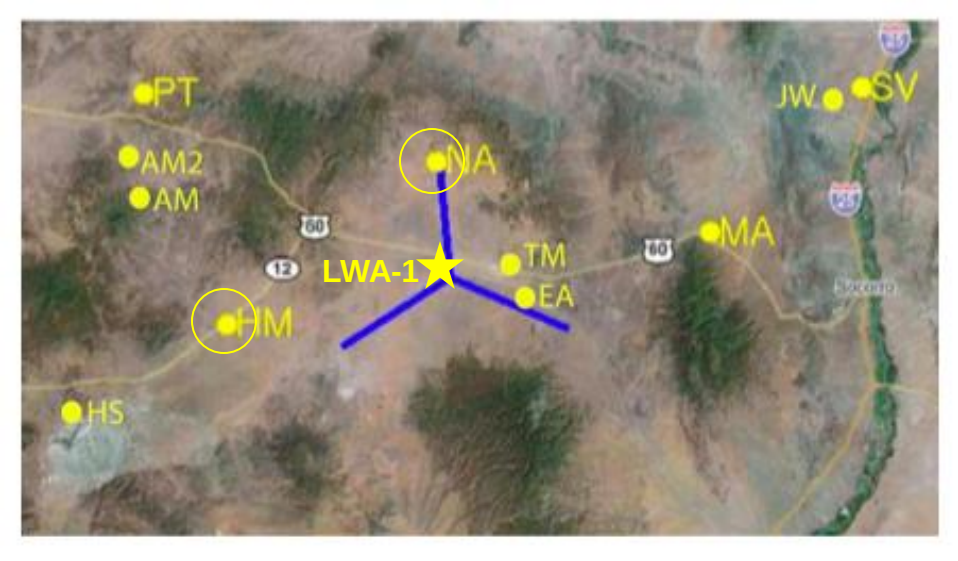


- Center Freq: 72.24 MHz
- 2.45 MHz Bandpass
- 915 Hz per channel
- 2600 channels shown
- RFI...

- Freq. domain blanking only
- Discarded 20% of band (generous) due to weak RFI

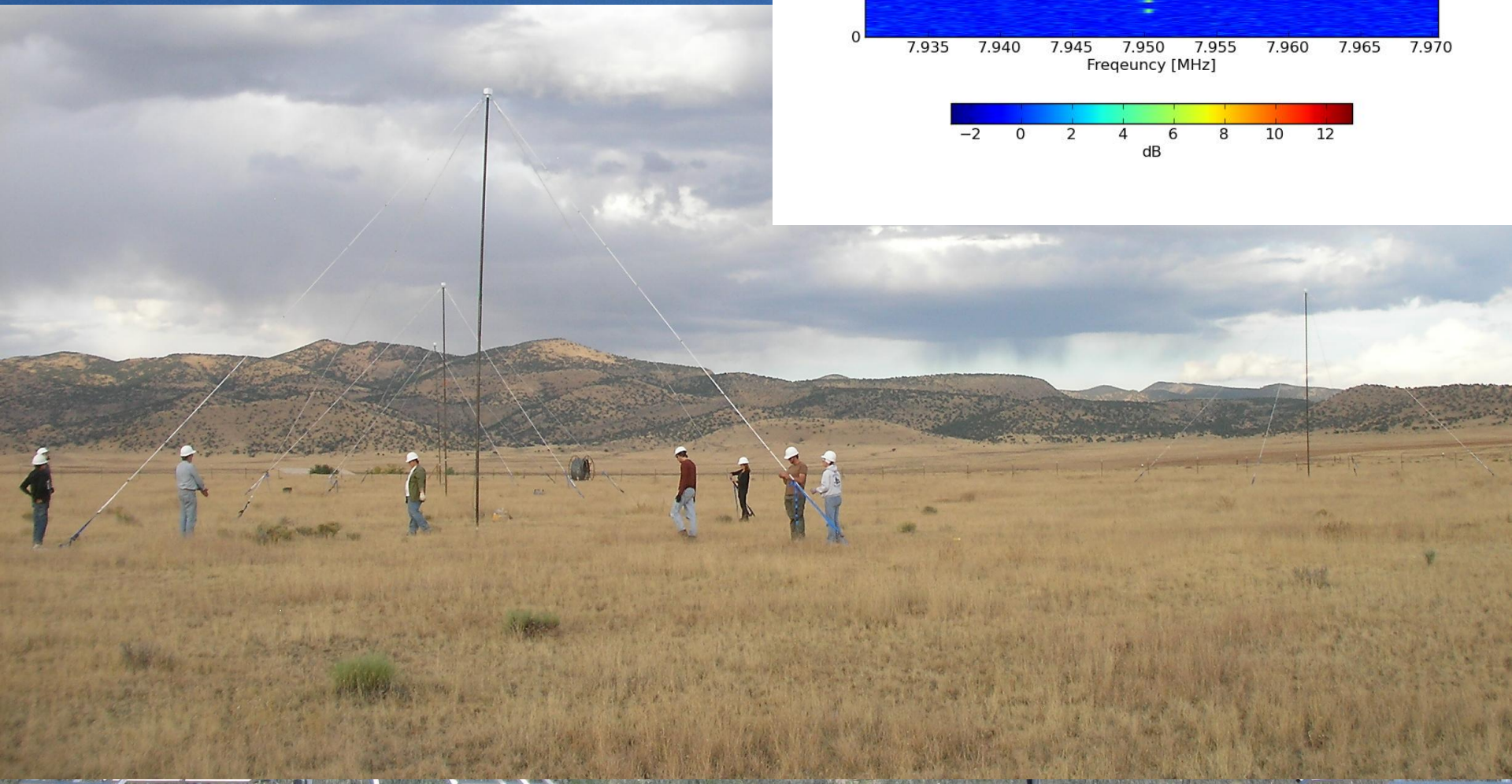
- Data collected between 2 - 3 AM continuously
- Production hardware from antennas to ARX
- Analog beamforming of 8 dipoles (static pointing)
- Sampled & downconverted by s60 system
- Model fit the diurnal total power, measured every 1 sec
- Spline interpolant model fit of bandpass

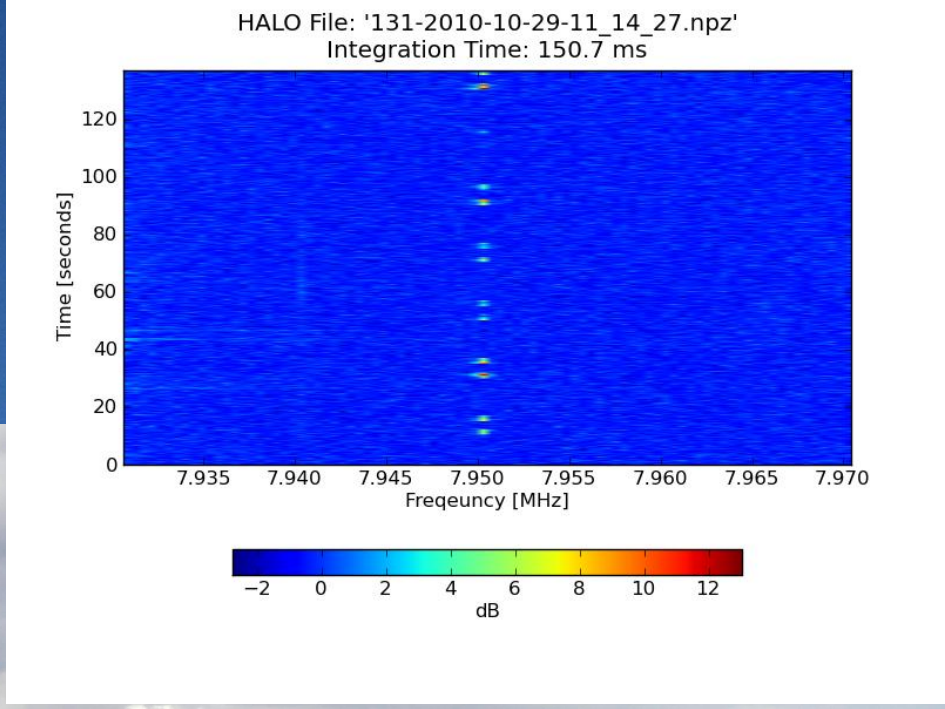
LWA-2 Site (NA)



LWA-2 Site (NA)

HALO array working at 6-10 MHz





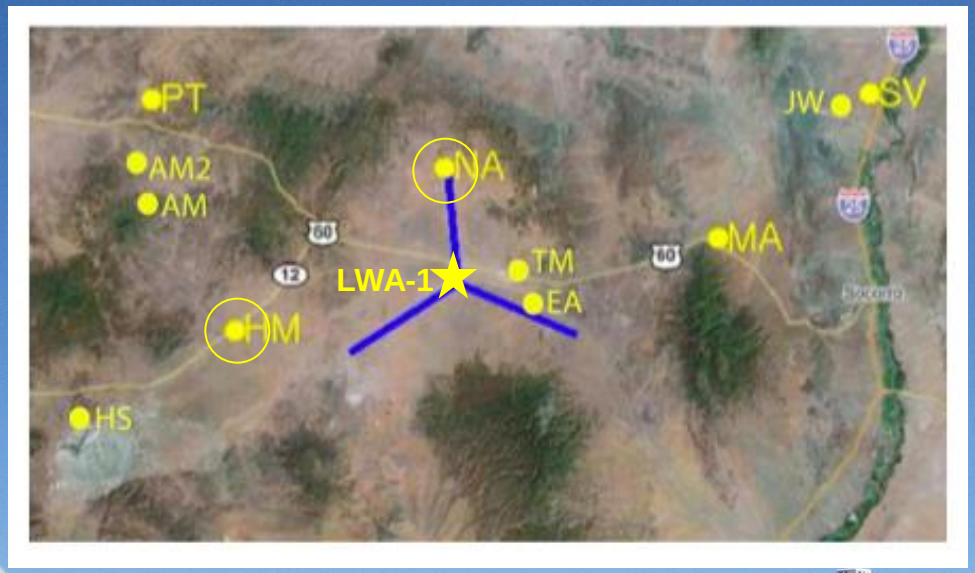
Future

Support from primary sponsor formally ends September 2011

- **Sufficient to complete LWA-1 commissioning, but not much more**
- **Furiously writing proposals**

Some alternative funding obtained; additional proposals pending

- **Development/preparation of sites for LWA-2 (NA) + LWA-3 (HM) with baselines 19 km, 35 km, and 43 km**
- **Leases and CatEx's for these sites already obtained**

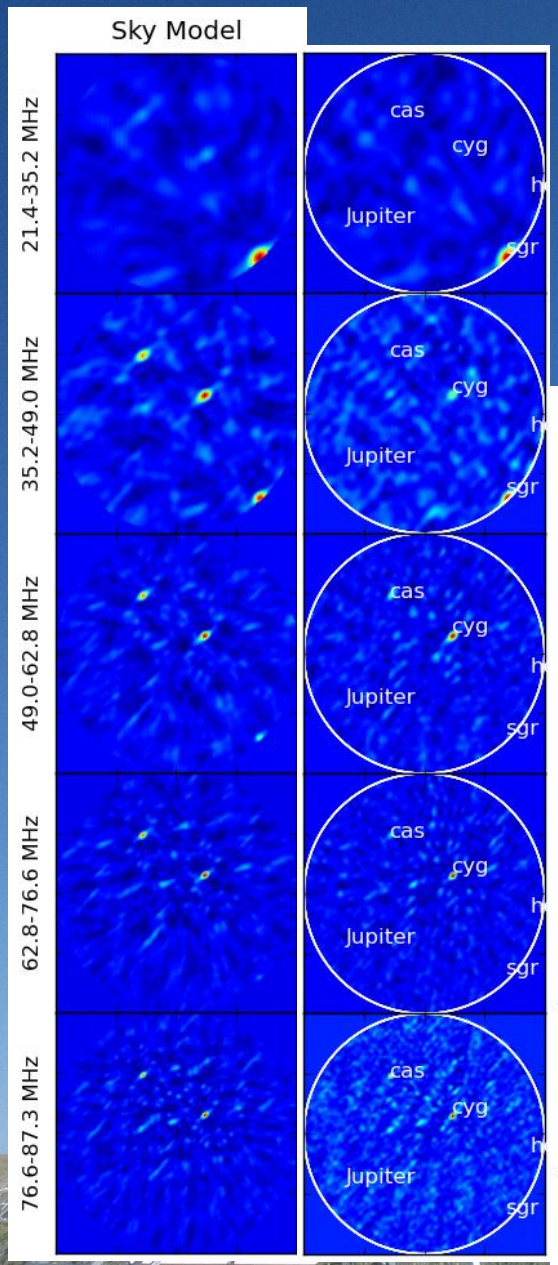


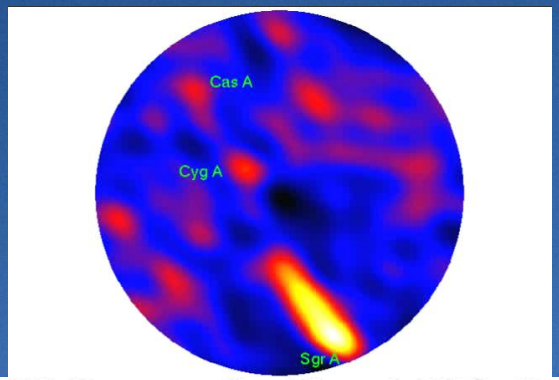
Technical Specifications:

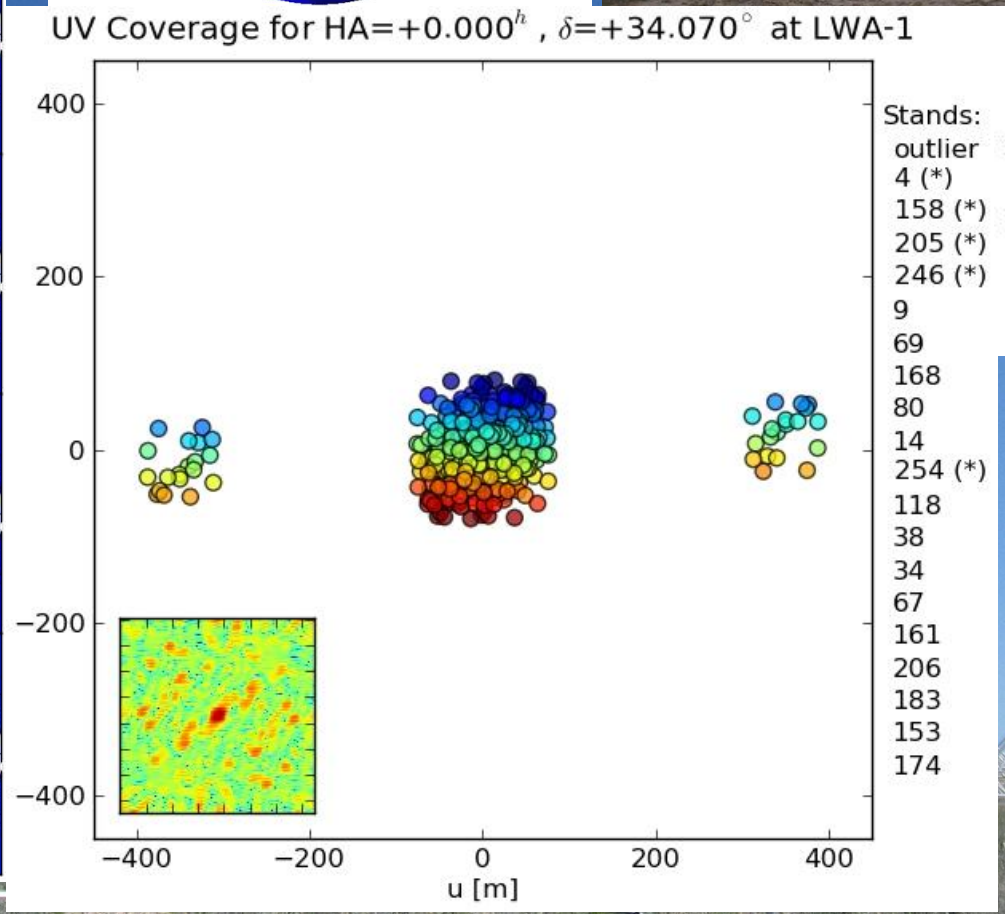
	Required	Achieved
Frequency Range:	20 MHz to 80 MHz	10 MHz to 88 MHz
Angular resolution:	$\theta \leq [8,2]$"	$\theta \leq [7,1.4]$"
LAS at [20,80] MHz	$\geq [8,2]^\circ$	$\geq [16,4]^\circ$
Baseline range:	100 m to 400 km	50 m to 600 km
Sensitivity [20,80 MHz]:	$\sigma \leq [1.0,0.5]$	$\sigma \leq [0.5,0.1]$
Collecting Area (m^2)	$A_e = 1 \times 10^6$	$A_e = 4 \times 10^6$
Dynamic range:	$DR \geq [1 \times 10^3, 2 \times 10^3]$	$DR \geq [2 \times 10^3, 8 \times 10^3]$
$\Delta\nu_{max}$ (per beam)	$\Delta\nu \geq 4$ MHz	$\Delta\nu = 20$ MHz
$\Delta\nu_{min}$	$\Delta\nu \leq 100$ Hz	$\Delta\nu \leq 10$ Hz
Temporal Res	$\Delta\tau = 10$ msec	$\Delta\tau \leq 0.1$ msec
Polarization:	1 circular	Full
Sky Coverage:	$z \geq 40^\circ$	$z \geq 15^\circ$
FoV [20,80] MHz	$[8,2]^\circ$	$\leq [16,4]^\circ$
# of beams:	4 single pol.	4 single pol.
Configuration:	2D array, N = 53 stations	2D array, N≥53

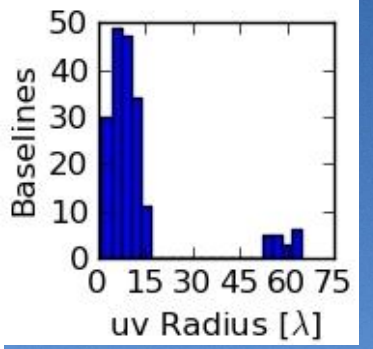
Backup Slides

All-Sky Imaging



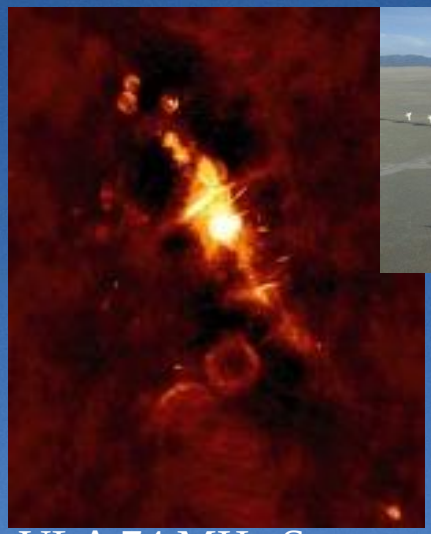






LWA Collaboration

- Antennas - NRL
- Analog Signal Processor - UNM
- Digital Signal Processor - JPL
- Monitoring & Control System - VT
- Shelter and Site - UNM
- Correlator - not started



VLA 74 MHz System

ETA: 29-47 MHz

Deep Space Network

LWA's Future

Support from primary sponsor formally ends Sept. 2011

Funds in-hand sufficient to complete LWA-1 and start commissioning, but...

LWA Phased Deployment

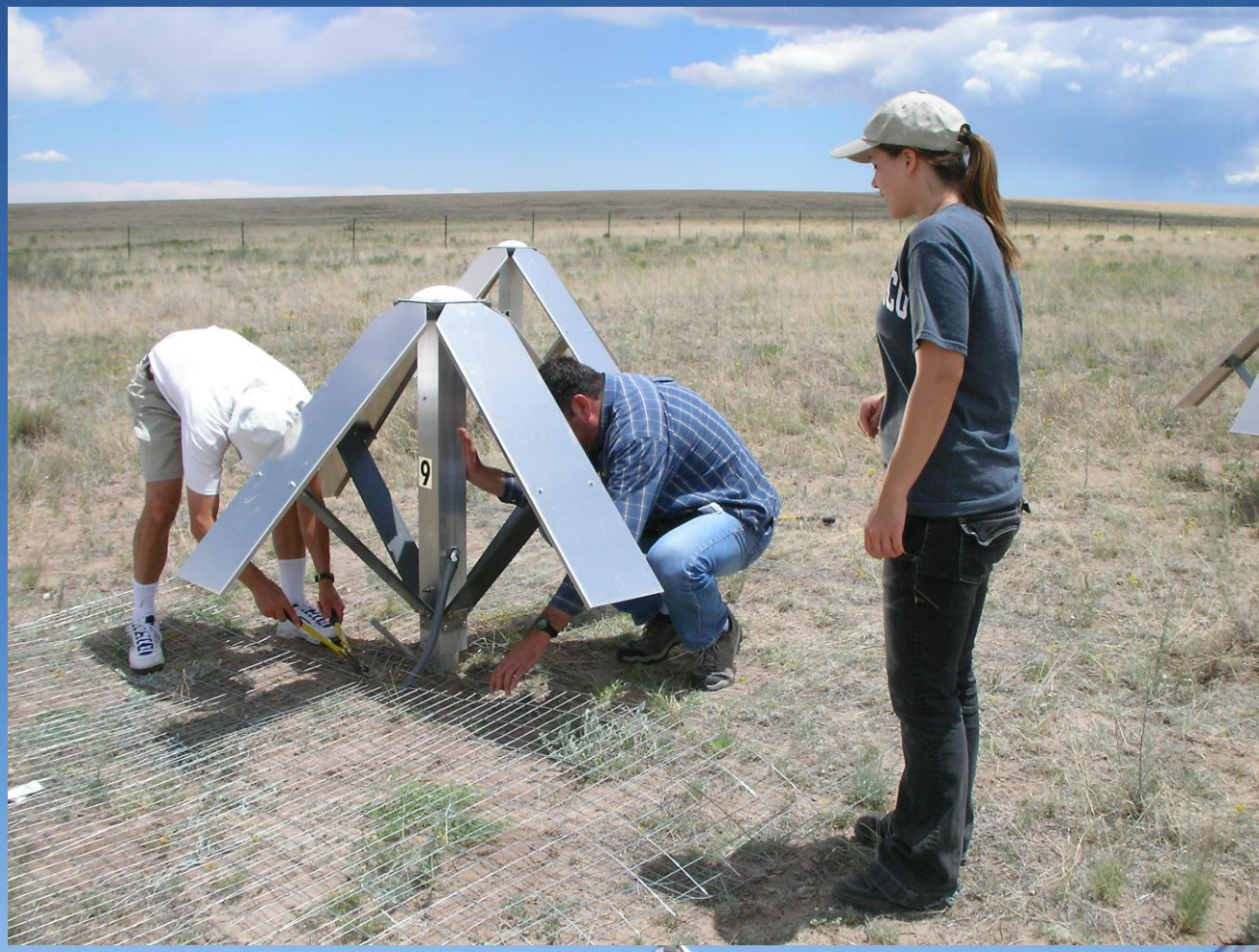
	LWA-1(+)	LWIA	LWA	Remarks
Freq Range	[20,80] MHz	→	→	[10,88] MHz ext.
No. of Stations	1 (+2 small)	16	53	
Max Baseline	(TBD)	200 km	400 km	min: 100 m (core)
Image Resolution	(TBD)	[15,4]"	[8,2]"	
T_{sys}	G.N.D.*	→	→	9000 K @ 38 MHz
Sensitivity/beam	[40, 25] mJy	[3, 2] mJy	[0.8, 0.5] mJy	2 pol, 1 h, 8 MHz
sky coverage	$\theta < 74^o$	→	→	includes GC
FOV size	$[8,2]^o$	→	→	zenith pointing
Simult. beams	3	→	→	ortho. circ. pols.
Time resolution	1 ms (5 ns)	→	→	(raw sample mode)
Freq resolution	100 Hz	→	→	
data rate	576 Mb/s	9.3 Gb/s	30 Gb/s	sum of stations


LWA
Dutchmen
Classic
UNM

Engaging Students

UNM

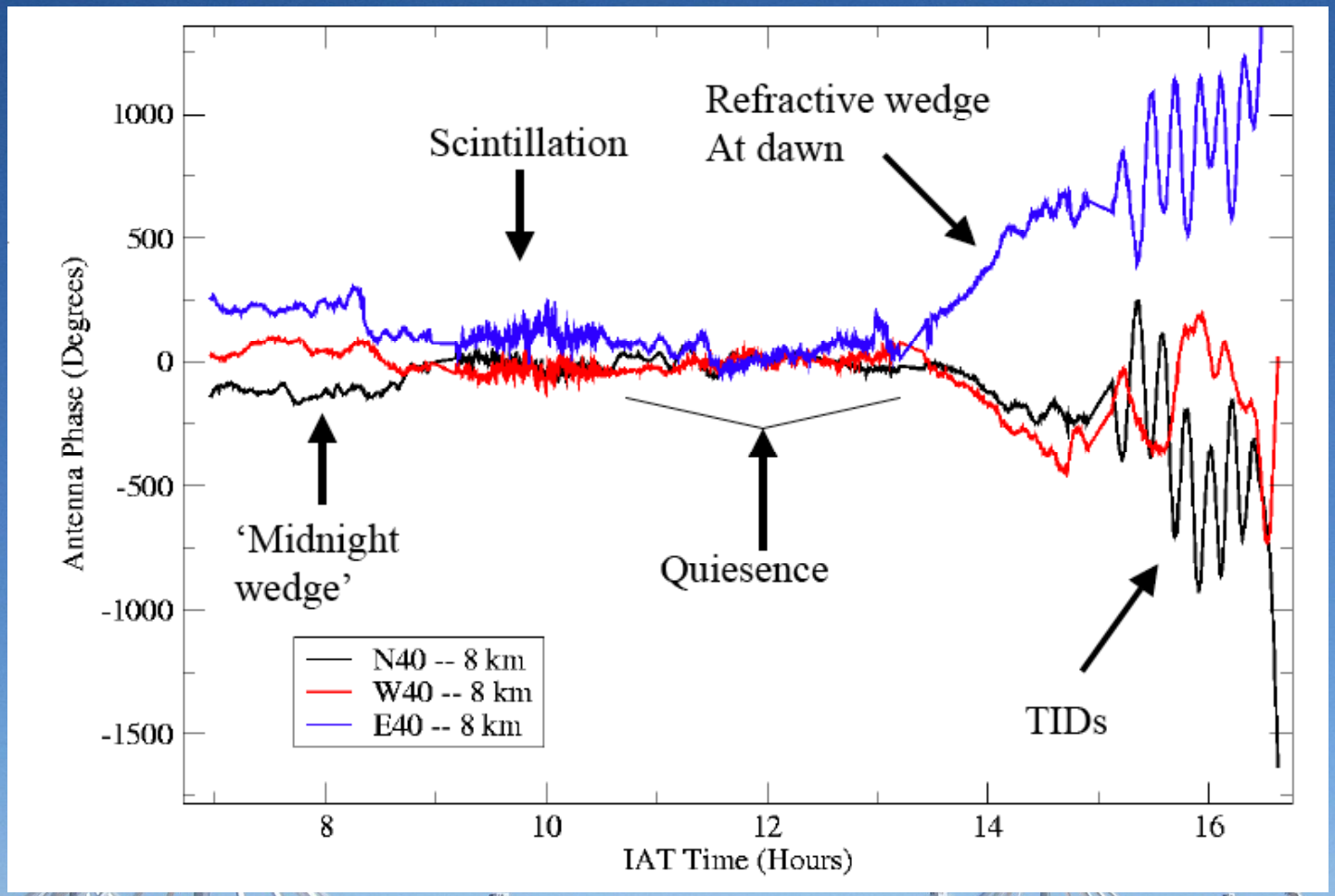
- PhDs awarded ~1 Mike Nord (2005) using VLA 74 MHz system
- graduate students: Frank Schinzel, Steve Tremblay, Eduardo Gonzalez, Su Zhang, Adam Martinez
- undergrads: Stefanie Moats, Dave Martin, Anthony Ortiz, Bobby Edmonds, and others



Key LWA Science Drivers

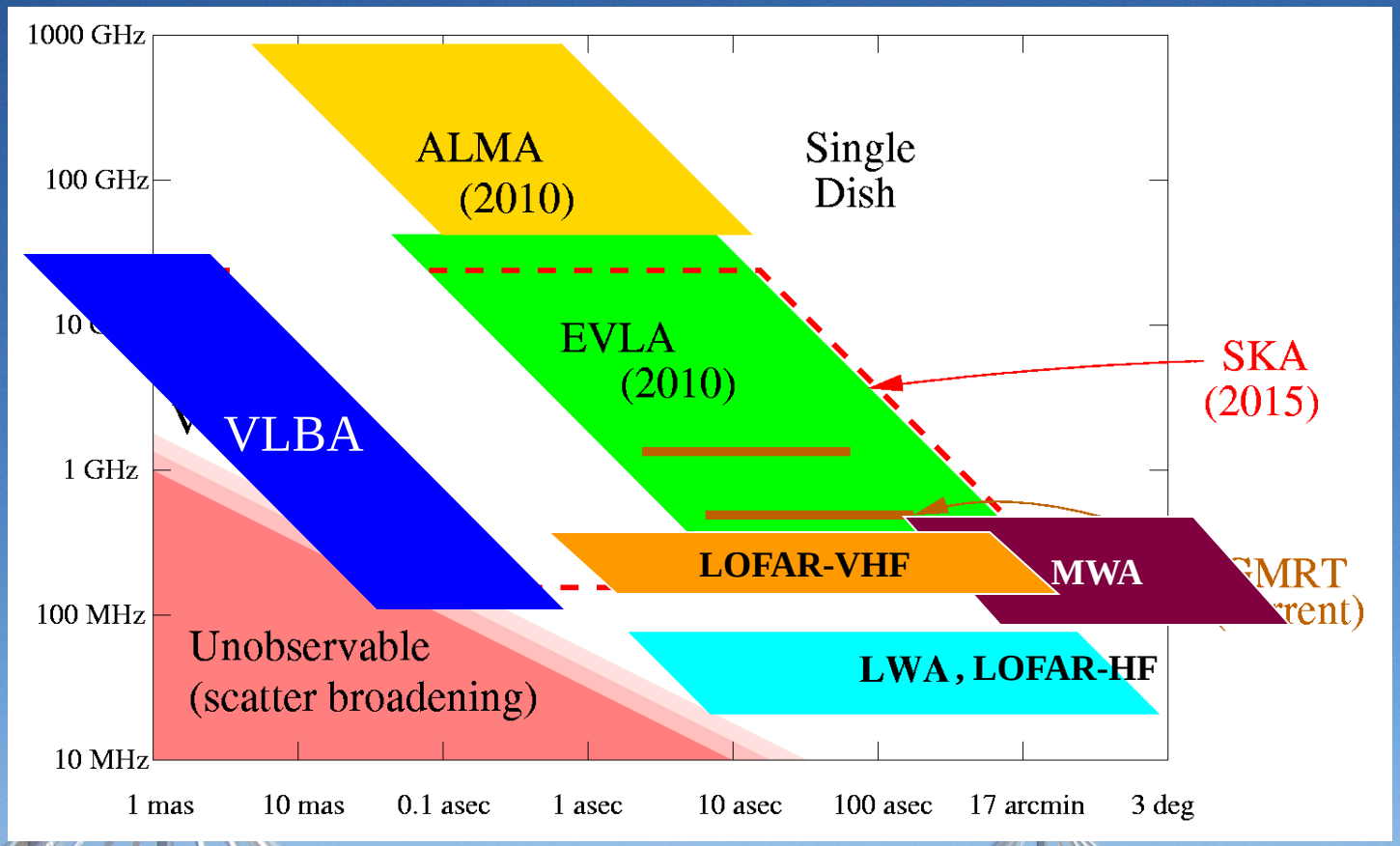
1. Acceleration of Relativistic Particles in:
   - Hundreds of SNRs in normal galaxies at energies up to 10^{15} eV.
   - In thousands of radio galaxies & clusters at energies up to 10^{19} eV
   - In ultra high energy cosmic rays at energies up to 10^{21} eV and beyond.
2. Cosmic Evolution & The High Redshift Universe
   - Evolution of Dark Matter & Energy by differentiating relaxed & merging clusters
   - Study of the 1st black holes & the search for HI during the EOR & beyond
3. Plasma Astrophysics & Space Science
   - Ionospheric waves & turbulence
   - Acceleration, Turbulence, & Propagation in the ISM of Milky Way & normal galaxies.
   - Solar, Planetary, & Space Weather Science
4. Transient Universe
   - ***Possible new classes of sources (coherent transients like GCRT J1745-3009)***
   - ***Magnetar Giant Flares***
   - ***Extra-solar planets***
   - ***Prompt emission from GRBs***

VLA Ionospheric studies at 74 MHz



LWA Discovery Space

in frequency and resolution



Path to the LWA