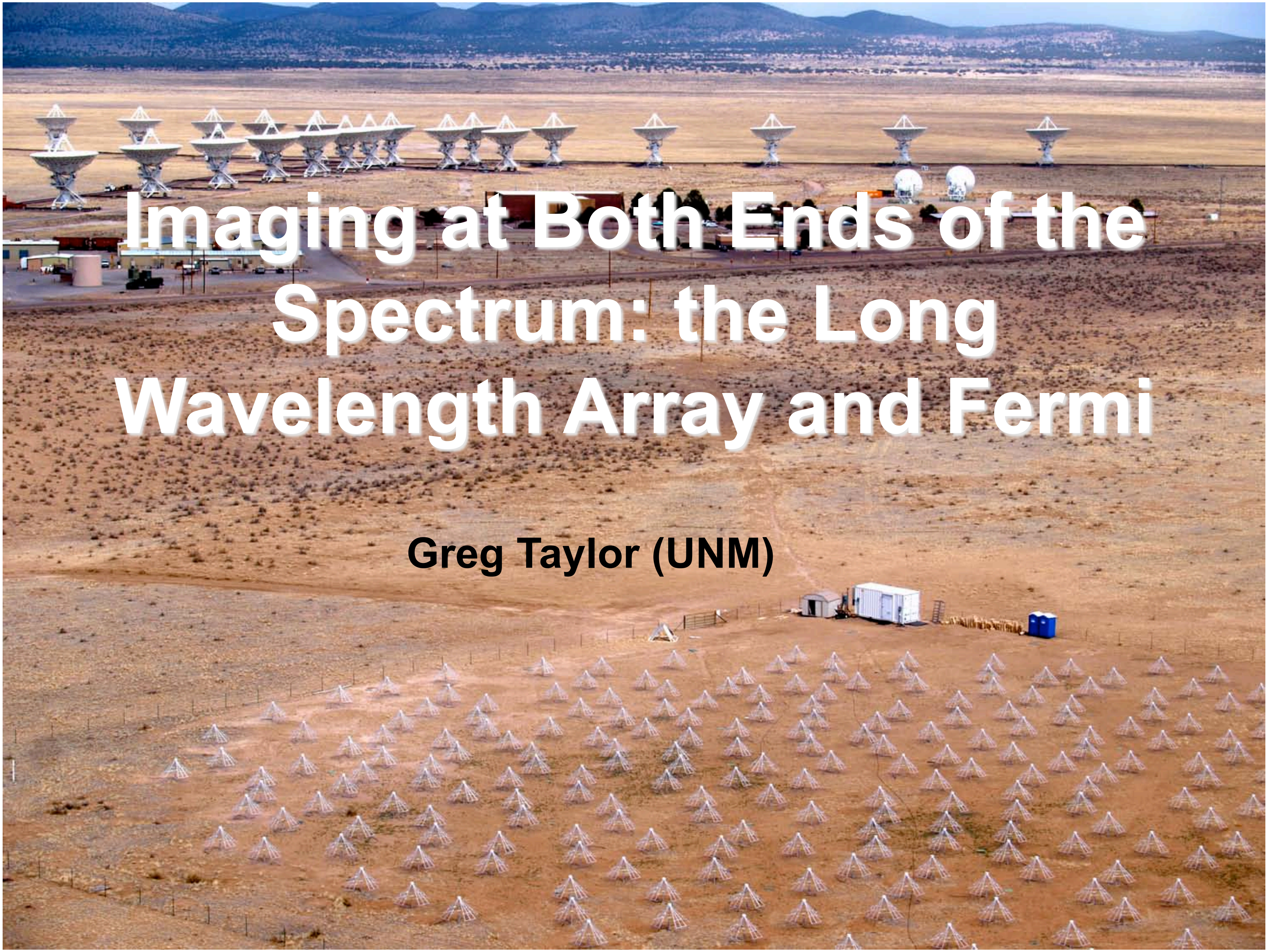
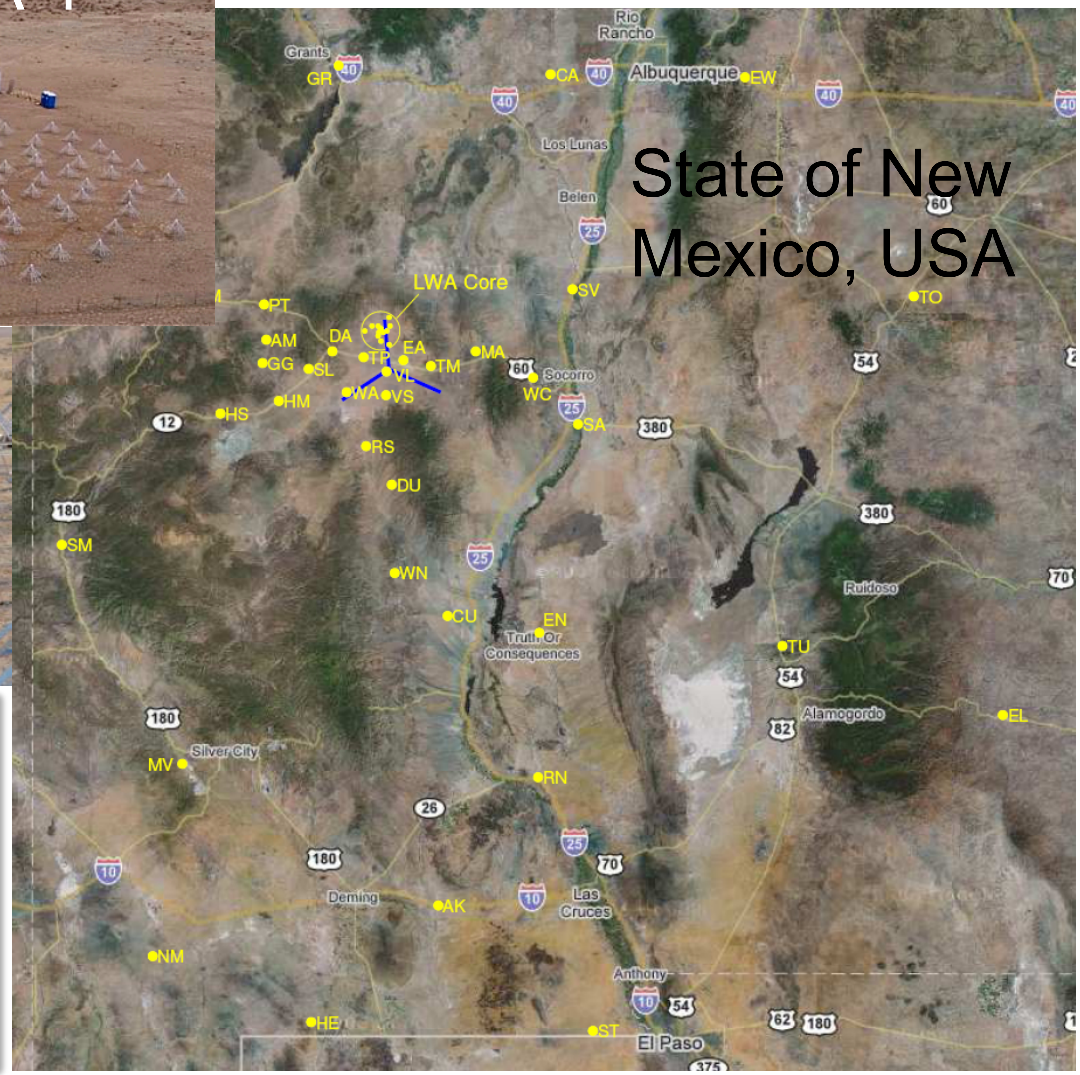


Imaging at Both Ends of the Spectrum: the Long Wavelength Array and Fermi

Greg Taylor (UNM)

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**



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

10-88 MHz usable Galactic noise-dominated (>4:1) 24-87 MHz

4 independent beams x 2 pol. X 2 tunings each ~16 MHz bandwidth

SEFD ~ 3 kJy (zenith) S_{min} ~ 5 Jy (5σ, 1 s, 16 MHz, zenith)

All sky (all dipoles) modes: TBN (67 kHz-bandwidth; continuous)

TBW (78 MHz-bandwidth, 61 ms burst)

One “outrigger” antenna ~300 m to the East

LWA1 science emphasis: transients, pulsars, Sun, Jupiter & Ionosphere

Open skies

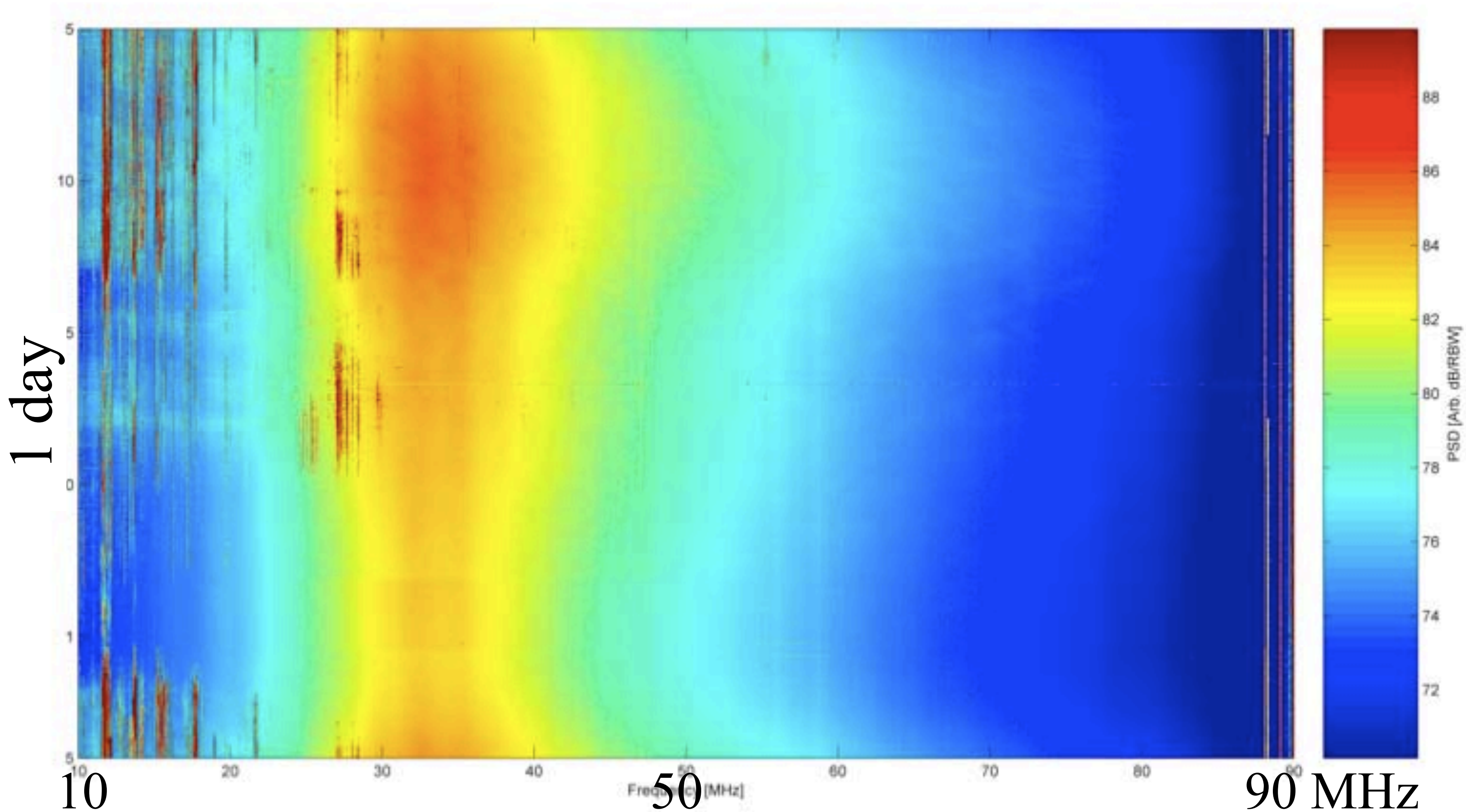
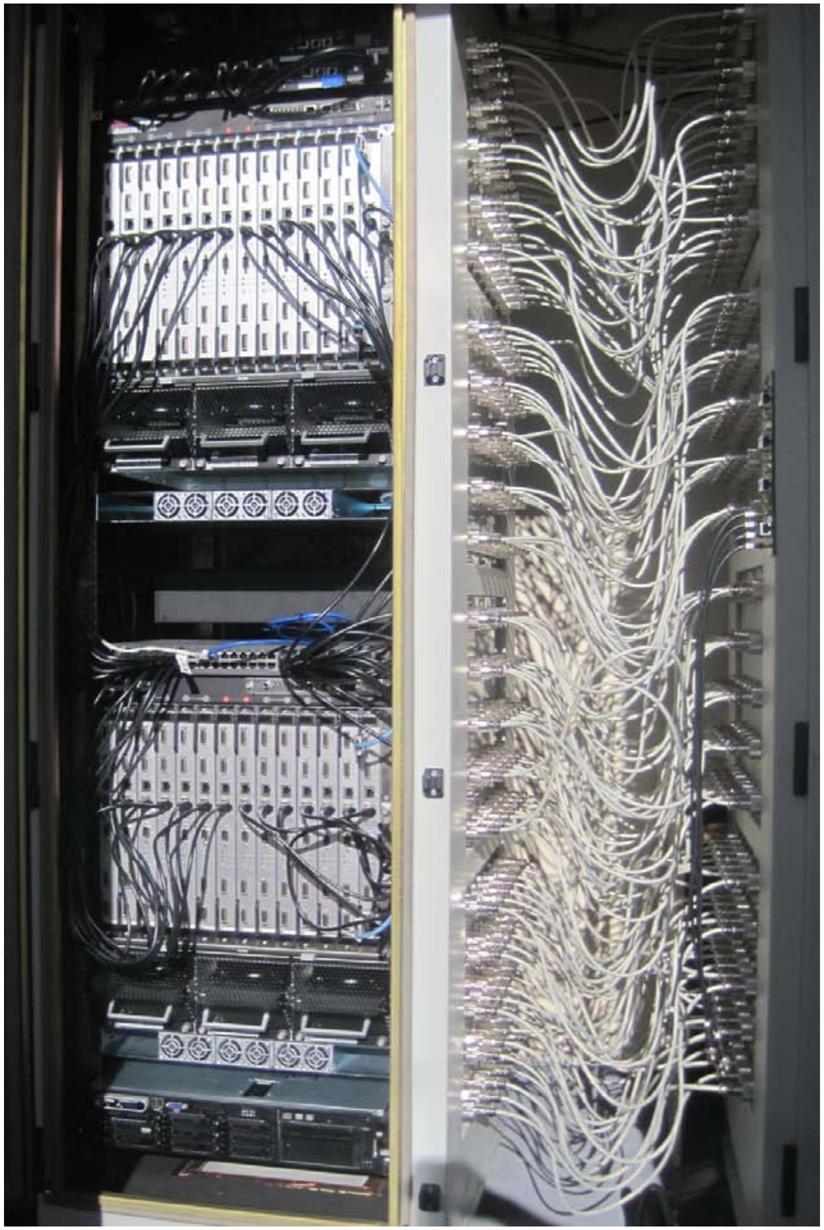


Figure 4: Spectrum using the TBW capture mode for 20 dipoles phased at zenith for 24 hours. The time and frequency variation of the background are real; the contribution of the active antenna appears as a steep role-off below 30 MHz. Note that 30-88 MHz is always useable, and even frequencies as low as 13 MHz are usable for a few hours each day.


114 114
146
176
178
204

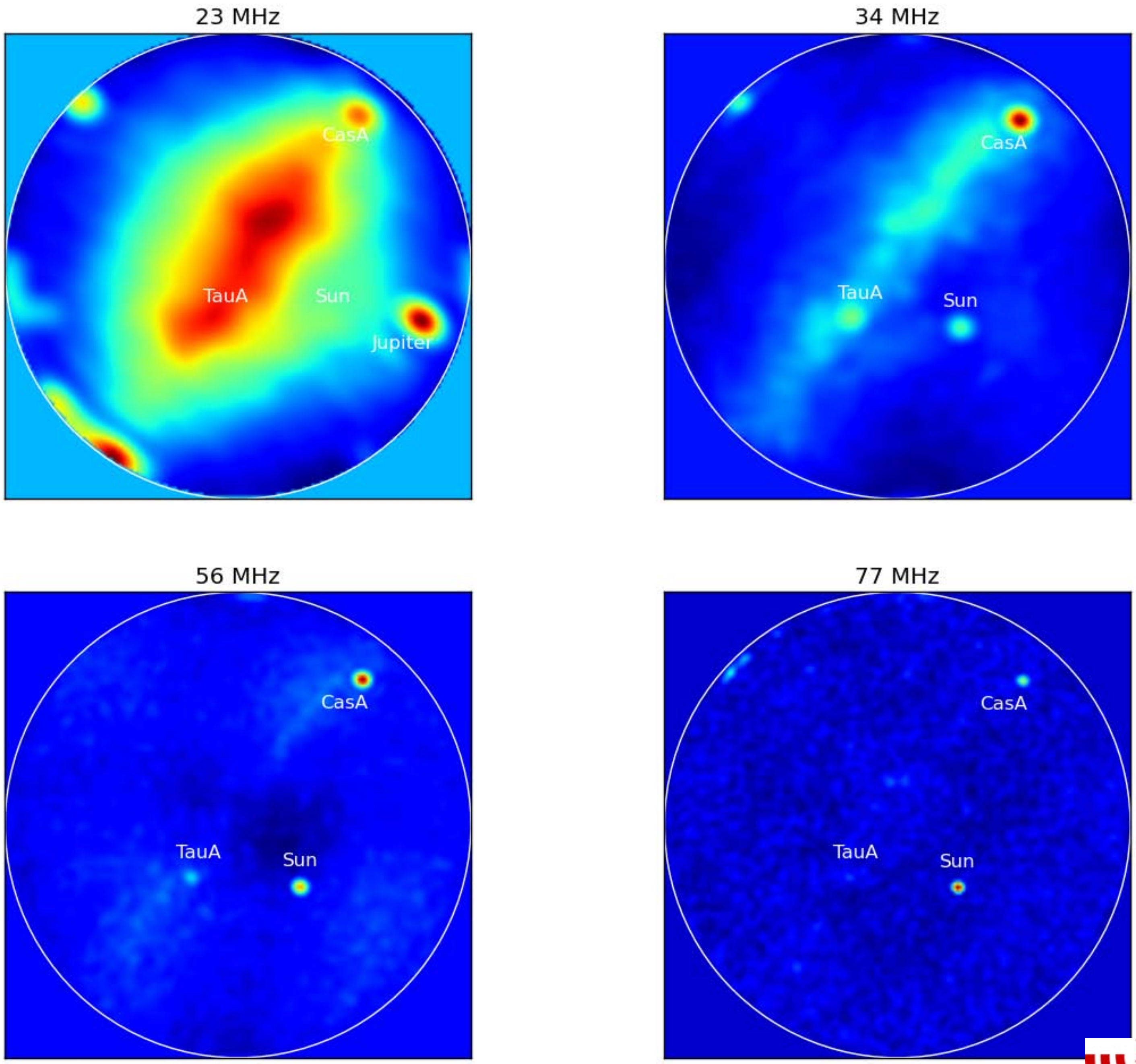


Digital Processor (DP)

Analog Signal Processor (ASP)

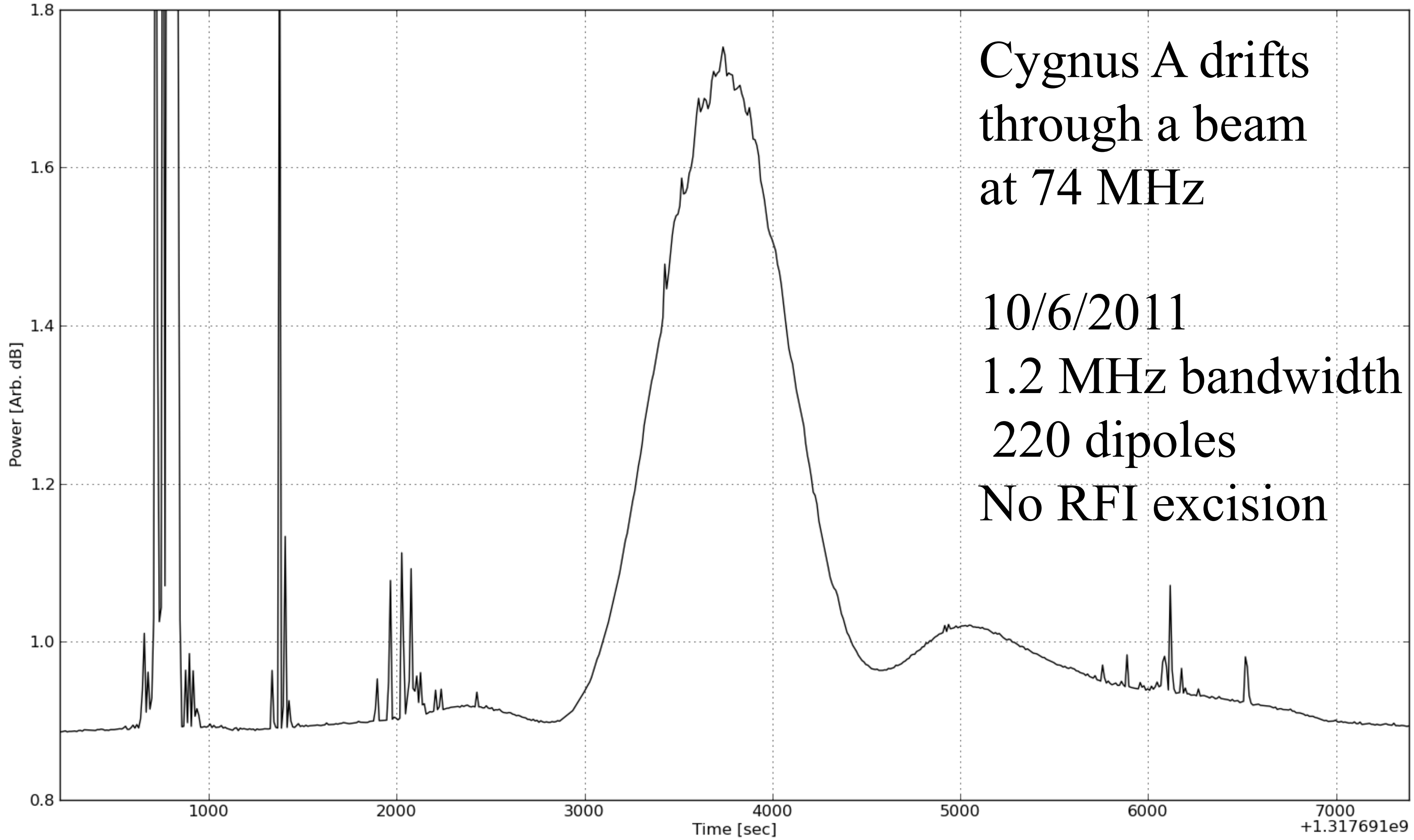
Images

10 sec
50 kHz



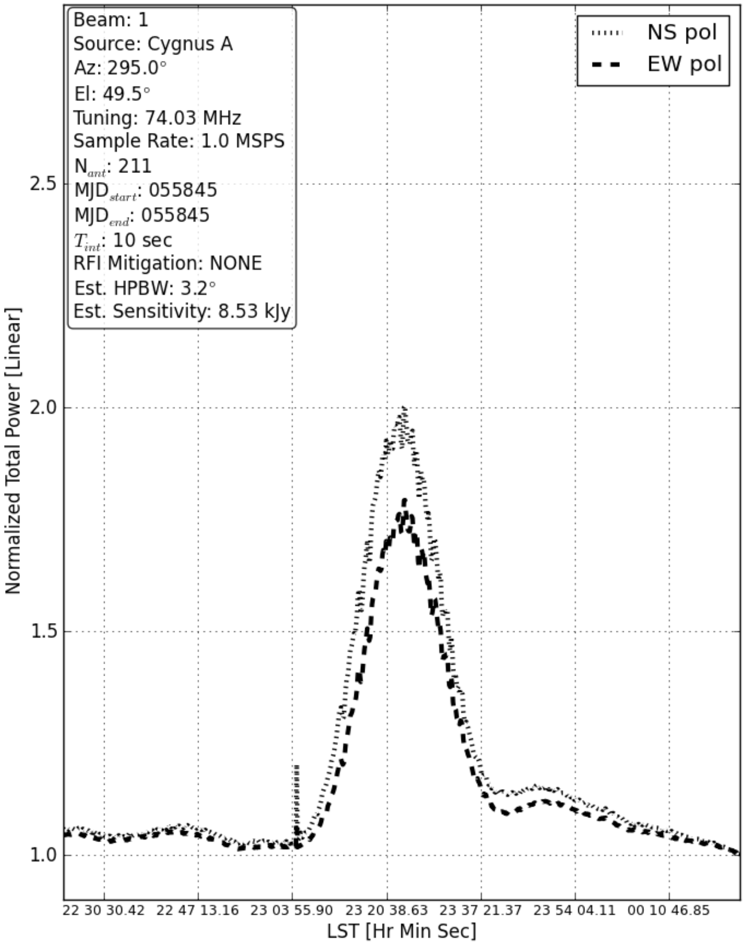
LWA
Long Wavelength Array

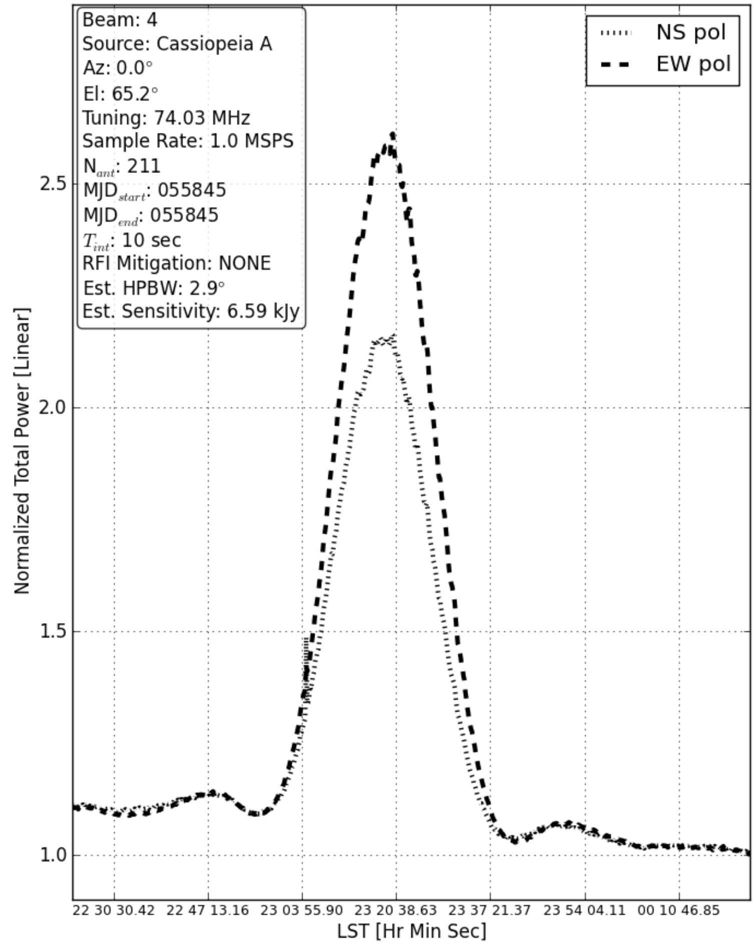
Cygnus A Drift Scan



Time (seconds)

Multi-beaming



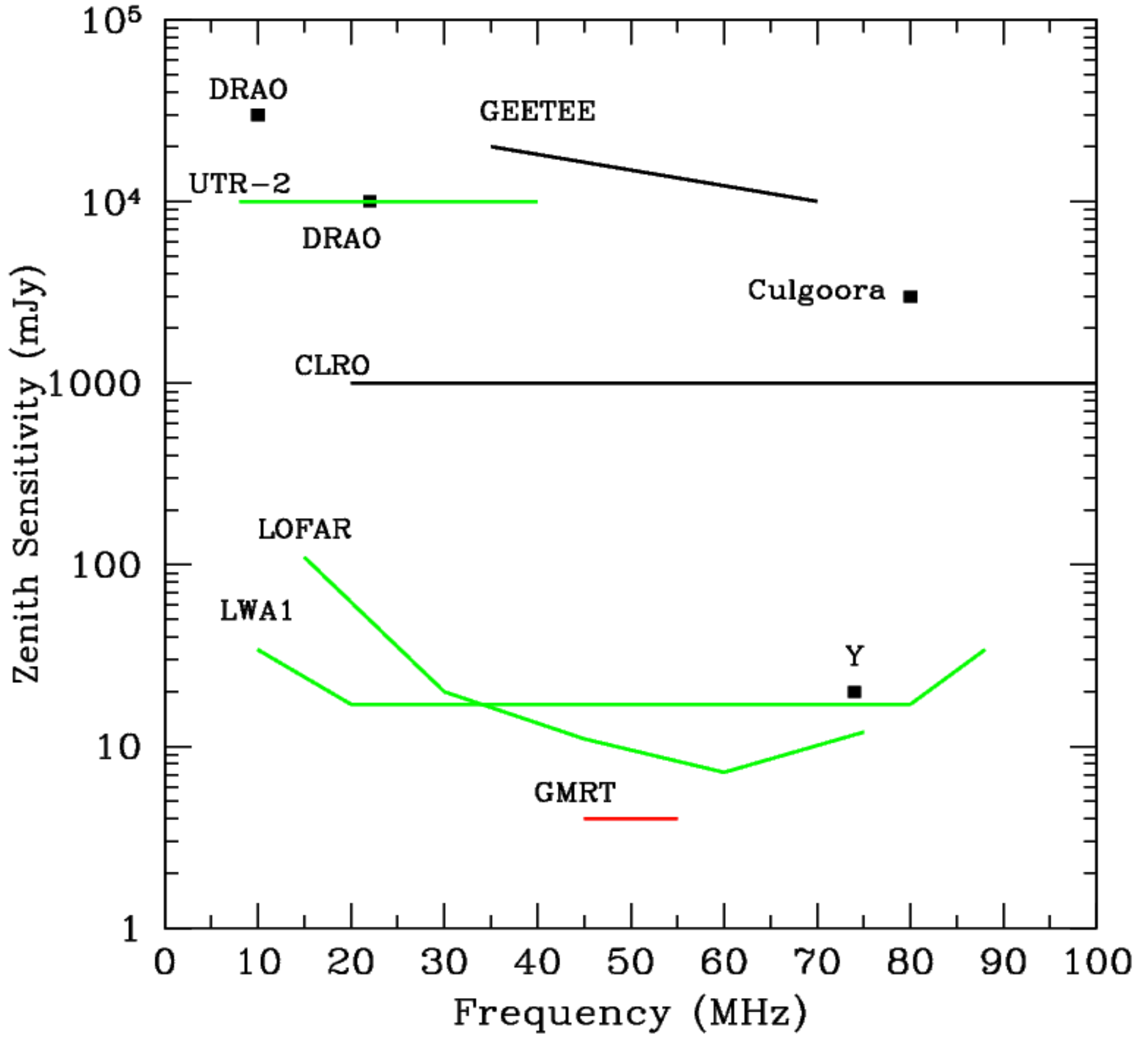


Cyg A: 295.0 az., 49.5 el.

Cas A: 0.0 az., 65.2 el.

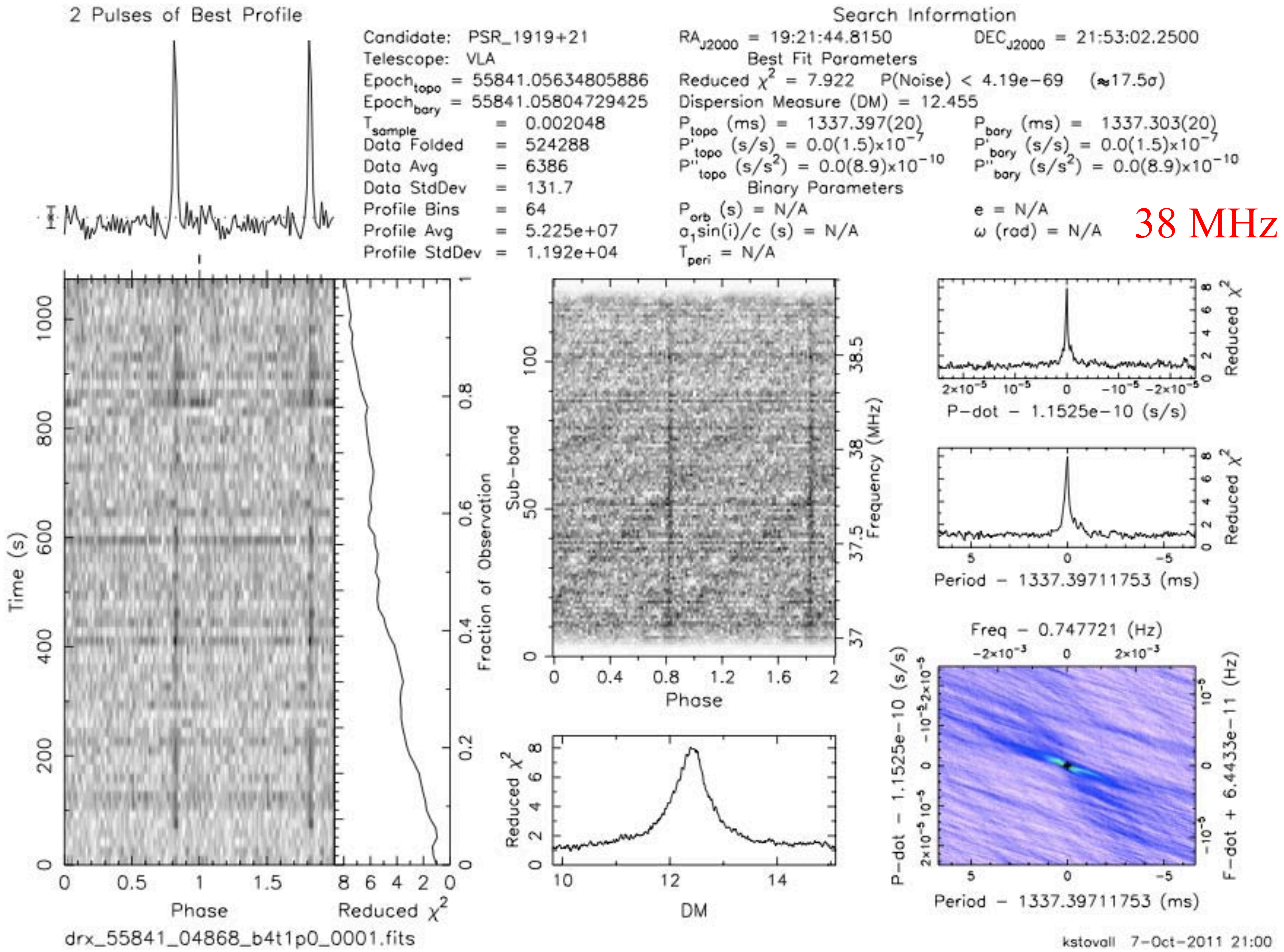
LWA Long Wavelength Array

Comparison to other instruments



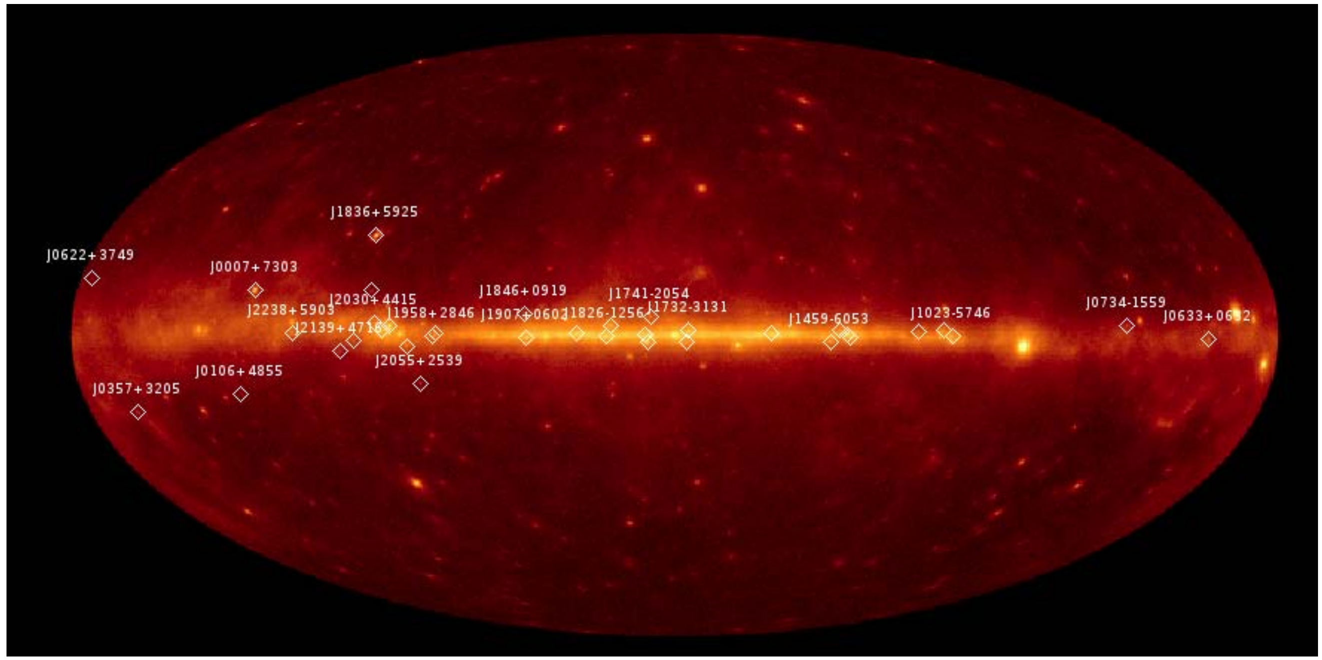
	Declination Range	Δν (MHz)
UTR2:	-30° to +60°	33
LOFAR:	-11° to +90°	3.6
Y=VLA:	-35° to +90°	3
LWA1:	-30° to +90°	16
GMRT:	-53° to +90°	10

LWA1 has sensitivity comparable to all of LOFAR


2 Pulses of Best Profile
Search Information
Candidate: PSR_1919+21
Telescope: VLA
Epoch_topo = 55841.05634805886
Epoch_bary = 55841.05804729425
T_sample = 0.002048
Data Folded = 524288
Data Avg = 6386
Data StdDev = 131.7
Profile Bins = 64
Profile Avg = 5.225e+07
Profile StdDev = 1.192e+04
RA_J2000 = 19:21:44.8150
DEC_J2000 = 21:53:02.2500
Best Fit Parameters
Reduced χ2 = 7.922 P(Noise) < 4.19e-69 (≈17.5σ)
Dispersion Measure (DM) = 12.455
P_topo (ms) = 1337.397(20)
P'_topo (s/s) = 0.0(1.5)x10^-7
P''_topo (s/s^2) = 0.0(8.9)x10^-10
P_bary (ms) = 1337.303(20)
P'_bary (s/s) = 0.0(1.5)x10^-7
P''_bary (s/s^2) = 0.0(8.9)x10^-10
Binary Parameters
P_orb (s) = N/A
a_1sin(i)/c (s) = N/A
T_peri = N/A
e = N/A
ω (rad) = N/A
38 MHz
Time (s)
Phase
Reduced χ2
Fraction of Observation
Sub-band
Frequency (MHz)
DM
P-dot - 1.1525e-10 (s/s)
Period - 1337.39711753 (ms)
Freq - 0.747721 (Hz)
P-dot - 1.1525e-10 (s/s)
F-dot + 6.4433e-11 (Hz)
drx_55841_04868_b4t1p0_0001.fits
kstovall 7-Oct-2011 21:00

Steep Spectrum Pulsars and Connection to Fermi

- Before 2008, Geminga was the only known radio-quiet gamma-ray pulsar
- Blind searches of Fermi LAT data have discovered over 36 pulsars in the gamma-ray band!
- So far, only 4 have been found to pulse in radio, despite very deep searches



Is this a beaming effect or some other physical mechanism?

•Low frequency searches are promising because beaming fractions appear to increase

•Some pulsars appear to be very steep spectrum ($S \sim \nu^{-4}$)

LWA Long Wavelength Array

LWA1 Science Overview

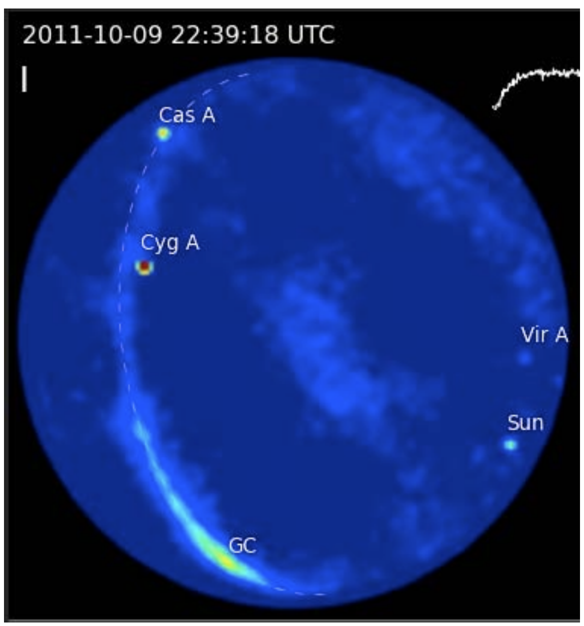
Key LWA Science Drivers (LWA1 subset in red)

- Acceleration of Relativistic Particles in:
  - Hundreds of supernova remnants in normal galaxies at energies up to 10^{15} eV
  - Thousands of radio galaxies & clusters at energies up to 10^{19} eV
  - ***Ultra-high energetic cosmic rays at energies up to 10^{21} ev and beyond***
- Cosmic Evolution & the High Redshift Universe
  - Evolution of Dark Matter & Energy by differentiating relaxed and merging clusters
  - ***Study of the 1st black holes & the search for HI during the EOR & beyond***
- Plasma Astrophysics & Space Science
  - ***Ionospheric Waves & Turbulence***
  - ***Acceleration, Turbulence, & Propagation in the ISM of Milky Way & normal galaxies***
  - ***Solar, Planetary, & Space Weather Science***
- Transient Universe
  - ***Possible new classes of sources (coherent transients like GCRT J1745-3009)***
  - ***Magnetar Giant Flares***
  - ***Extrasolar planets***
  - ***Prompt emission from gamma ray bursts (GRBs)***

- ***LWA1 will do excellent science from the transformational to the modest***
  - Both extremes represent excellent science, serendipitous discoveries likely, viable student thesis projects – made possible because LWA1 is BIG!

The Prototype All-Sky Imager (PASI)

- A backend to the LWA1's digital processor
- Receives the TBN data stream: continuous 100 kSPS data from all the dipoles
- Using a software FX correlator, PASI images most of the sky (≈1.5 π sr) many times per minute at 100% duty cycle
- This is a virtually unexplored region of transient phase space! (radio frequency, sky coverage, imaging cadence, uptime)

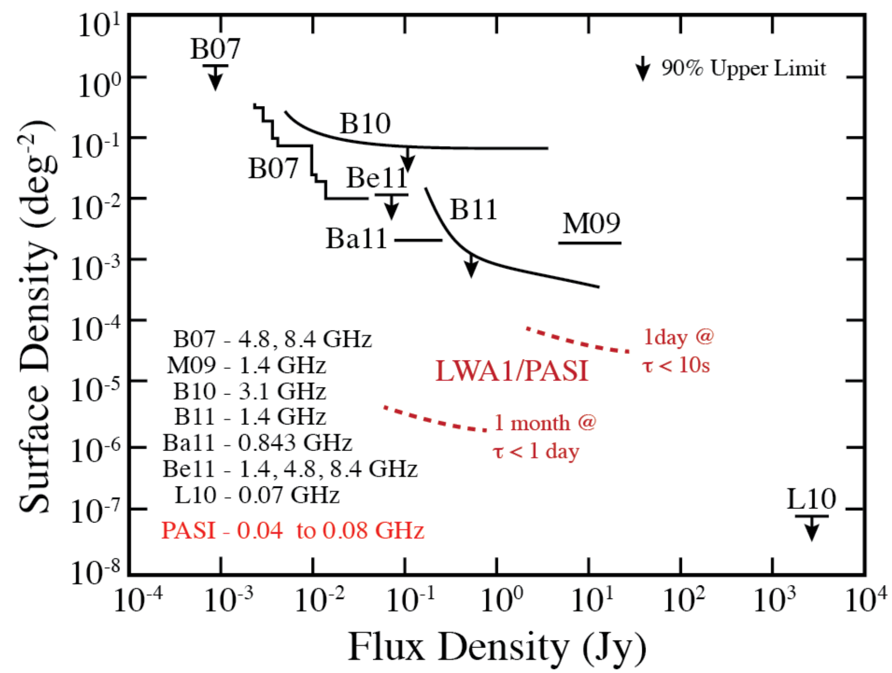


LWA Long Wavelength Array

Targets and Strategy

Transients that are BRIGHT and RARE:

- Bright flares from Hot Jupiters
- Giant flares from magnetars
- Prompt GRB emission
- The unknown …

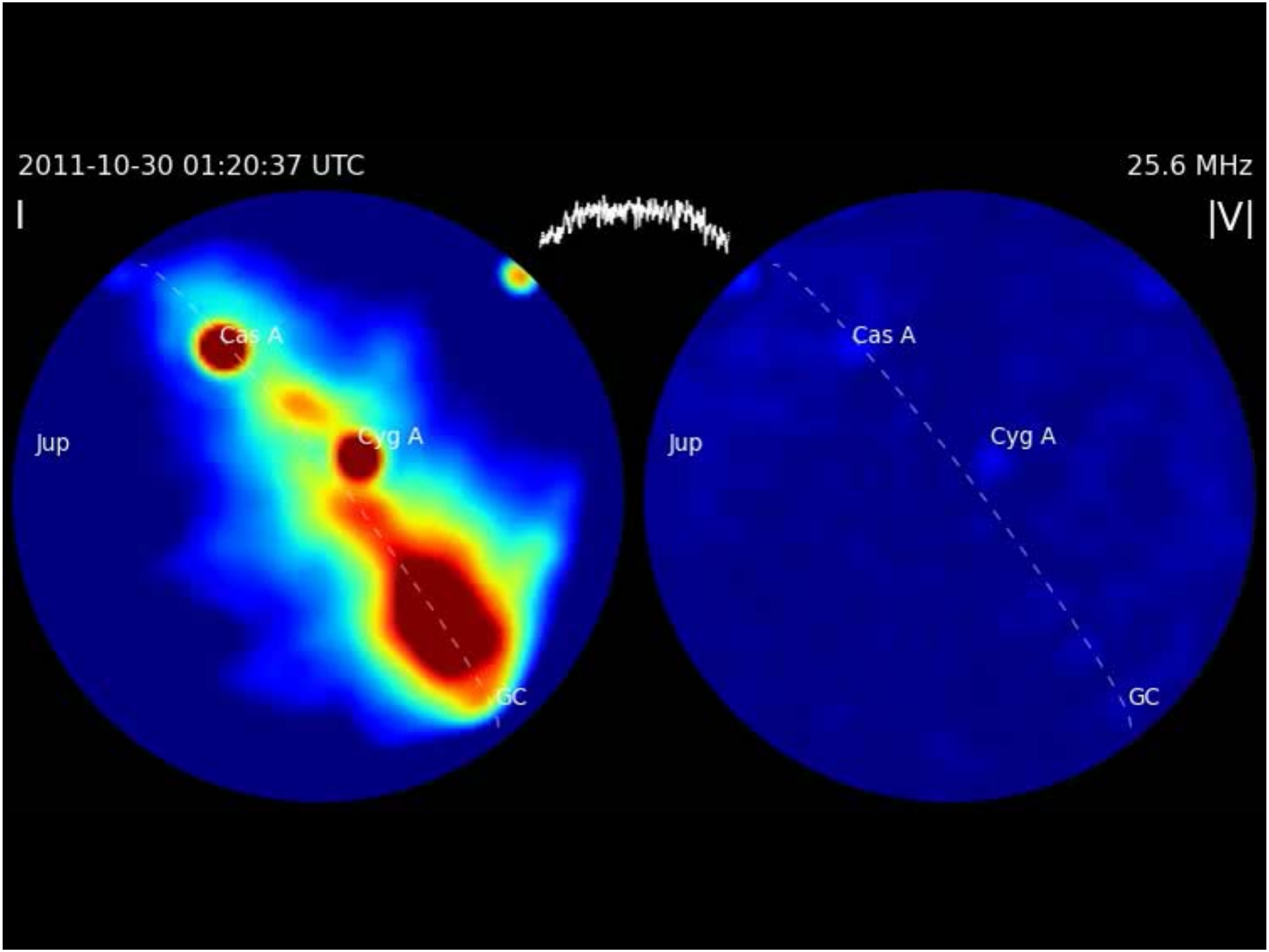


Bower et al. (B07, B10), Banister et al. (BA10), Croft et al. (C10), Frail et al. (F03), Gal-Yam et al. (G06), Lazio et al. (L10)

Strategy for candidate detections:

- Automatic follow-up with an LWA1 beam: raster scanning over the candidate transient's location
- Ultimately, confirmed detections will trigger rapid alerts for multi-wavelength follow-up

LWA Long Wavelength Array


2011-10-30 01:20:37 UTC
25.6 MHz
I
|V|
Cas A
Cyg A
Jup
GC
Cas A
Cyg A
Jup
GC

Summary

LWA1 is an operational, world-class instrument

There are many opportunities for discovery: pulsars, transients, cosmology…

LWA1 is an early example of a large N array – 32,640 baselines

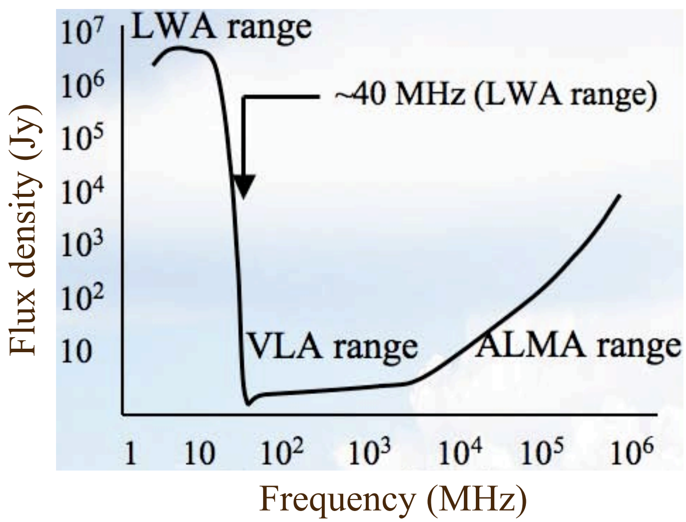
Images of the sky are available 24/7 on LWA TV

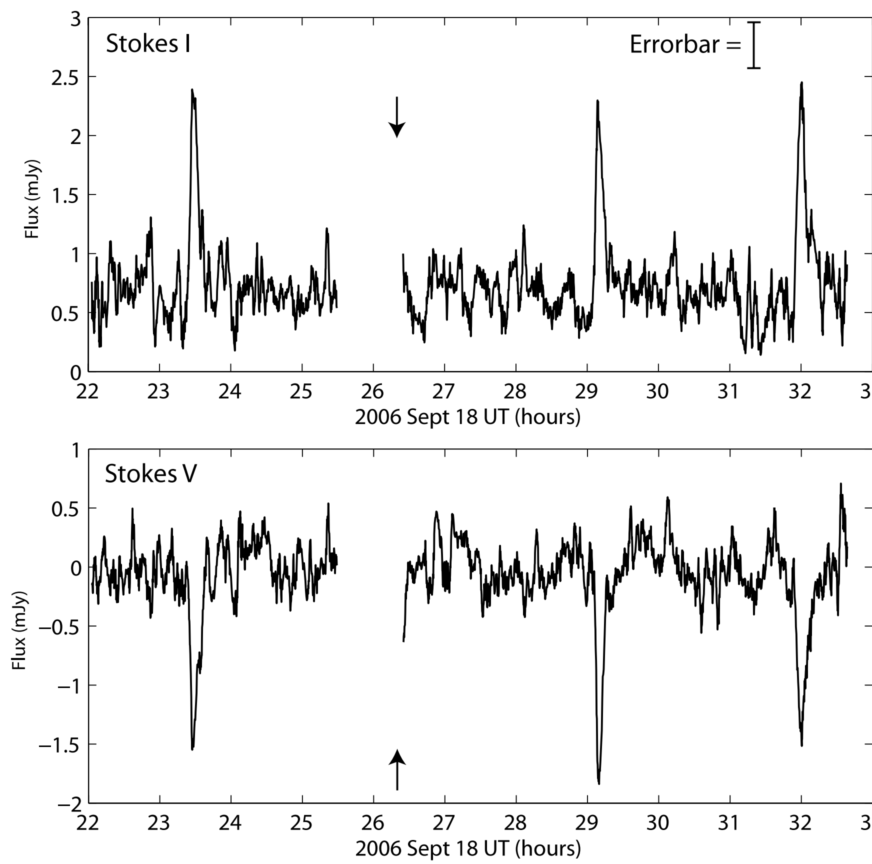
http://www.phys.unm.edu/~lwa/lwatv.html

Long Wavelength Array

Backup Slides

Hot Jupiter Emission





Hallinan et al. (2008)

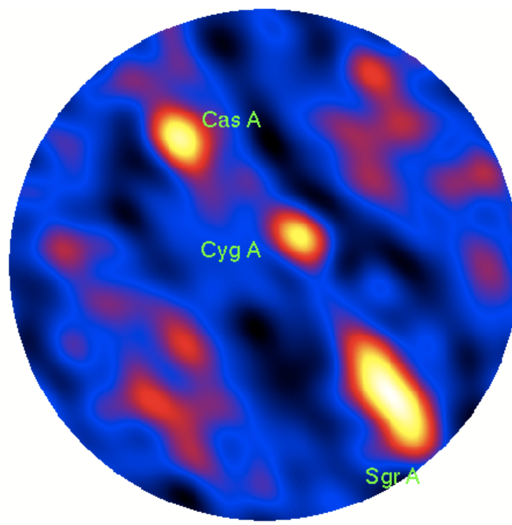
- Low frequency (only)
- Highly polarized
- Time-variable emission:
  + Only present during (small) subset of rotational phase
  + Bursty on ~ms to ~min time scales

Sensitivity

- Confusion limit is 25 Jy/beam at 74 MHz, but this limit is dominated by constant sources
- Search strategies:
  - Image differencing (good to 10% ⇒ 2.5 Jy limit)
  - Polarization filtering (potentially much better; ~30 dB isolation)
- Noise limits for 74 MHz frequency, 80 kHz bandwidth —

  10 s integration: 2 Jy/beam

  2 hr integration: 100 mJy/beam
- Few comparable studies: LWDA prototype transient search had a noise level of 500 Jy/beam



Lazio et al. (2010)

LWA Long Wavelength Array