
ALL THE SKY ALL THE TIME:
The Owens Valley LWA (LWA-OVRO)

LEDA @ Owens Valley LWA (LOL) Genesis

UNM

LWA Long Wavelength Array

LWA Current and Future Users Meeting
Agenda v2

Time: **Thursday, May 12, 9:00am – 6:00pm; Friday, May 13, 9:00am-12:30pm**
Venue: **CHTM 101** - 1313 Goddard SE, Albuquerque,NM 87106 (behind LWA project office)

Thursday Morning Session on LWA1 Hardware and Capabilities

9:00 – 9:15 am	Welcome and Goals	Greg Taylor
9:15 – 9:45 am	LWA1 As Built Architecture and Status	Joe Craig
9:45 – 10:15 am	How to Observe with LWA1	Steve Ellingson
10:15 - 10:45 am	Break	
10:45 – 11:10 am	Scheduling and Archiving	Ylva Philstrom
11:10 – 11:30 am	LWA Software Library	Jayce Dowell
11:30 – 11:50 am	DP Capabilities	Robert Navarro
11:50 – 1:30 pm	Lunch	

1st Afternoon Session on Preliminary Results with LWA1

1:30 – 1:45 pm	LWA1 Science Overview	Namir Kassim
1:45 – 2:00 pm	RRLs at Decameter Wavelengths	Wendy Peters
2:00 – 2:15 pm	Jovian Bursts	Tracy Clarke & Ted Jaeger
2:15 – 2:35 pm	Solar Bursts	Stephen White
2:35 – 2:55 pm	Crab Giant Pulses and Other Short Dispersed Transients	Steve Ellingson
2:55 – 3:15 pm	Early Results from PASI	Jake Hartman
3:15 – 3:40 pm	Break	

2nd Afternoon Session on New Instrumentation

3:40 – 4:00 pm	Real-Time Data Analysis Using LWA1 Data Recorders	Chris Wolfe
4:00 – 4:20 pm	LEDA	Lincoln Greenhill
4:20 – 4:40 pm	Observing Cosmic Dawn with LWA1	Jake Hartman
4:40 – 5:00 pm	LWAST	Rick Jenet
5:00 – 5:20 pm	Observing Cosmic Rays with LWA1	Dave Besson
5:20 – 6:00 pm	Discussion	

6:15pm Dinner at local restaurant

Friday Half-Day Session on Future Observations with LWA1

9:00 – 9:20 am	Low Frequency Ionospheric Measurements	Joe Helmboldt
9:20 – 9:40 am	Sky Surveys	Emil Polisensky
9:40 – 10:00 am	LWA1 Riometry for DTRA	Lee J Rickard
10:00 – 10:20 am	Hot Jupiters	Gregg Hallinan
10:20 – 11:00 am	Break	
11:00 – 11:20 am	Pulsars	Tim Hankins
11:40 – 12:00 pm	LWA Outreach across the Border	Stan Kurtz
12:00 – 12:20 pm	LWA Future/URO Proposal Plans	Greg Taylor
12:20 – 12:40 pm	Discussion	

Contact Information:

Greg Taylor
505-270-2929 (cell)

Participants:

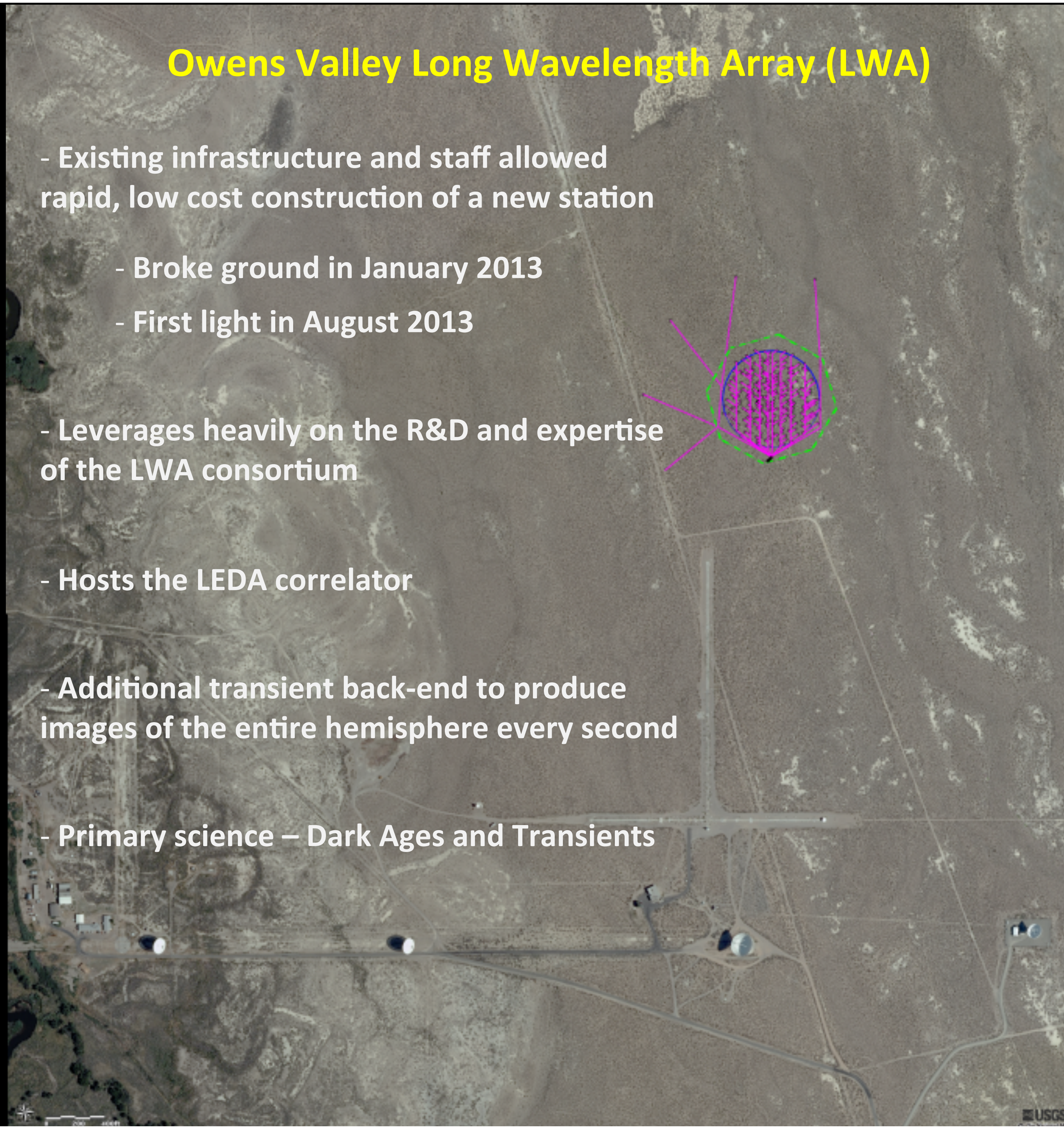
Dave Besson (KU)
Joe Craig (UNM)
Pat Crane
John Dickel (UNM)
Lanie Dickel (UNM)
Jayce Dowell (UNM)
Steve Ellingson (VT)
Lincoln Greenhill (CfA)
Gregg Hallinan (UCB)
Tim Hankins (NMT)
Jake Hartman (NRL)
Trish Henning (UNM)
Clint Janes (NRAO)
Anders Jorgensen (NMT)
Rick Jenet (UTB)
Mike Kavic (TCNJ)
Leonia Kogan (NRAO)
Paul Krehbiel (NMT)
Stan Kurtz (UNAM)
Joe Lazio (JPL)
Justin Linford (UNM)
Walid Majid (JPL)
Robert Navarro (JPL)
Frazer Owen (NRAO)
Ylva Pihlstrom (UNM)
Lee Rickard (UNM)
Nirupam Roy (NRAO)
Greg Taylor (UNM)
Chenoa Tremblay (UNM)
Steve Tremblay (UNM)
Kiri Wagstaff (JPL)
Stephen White (AFRL)
Chris Wolfe (VT)

Attending by video from NRL:

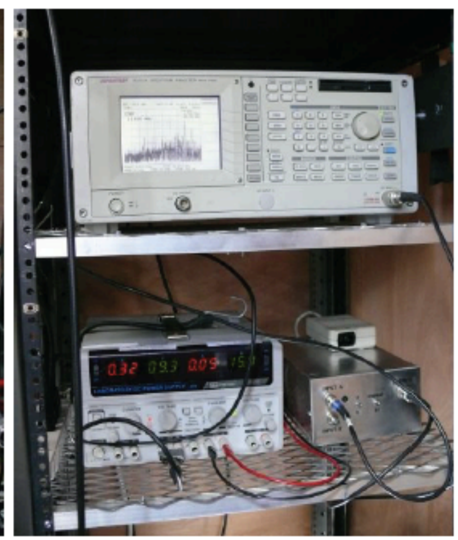
Tracy Clarke (NRL)
Brian Hicks (NRL)
Joe Helmboldt (NRL)
Namir Kassim (NRL)
Ted Jaeger (NRL)
Emil Polisensky (NRL)

Owens Valley Long Wavelength Array (LWA)

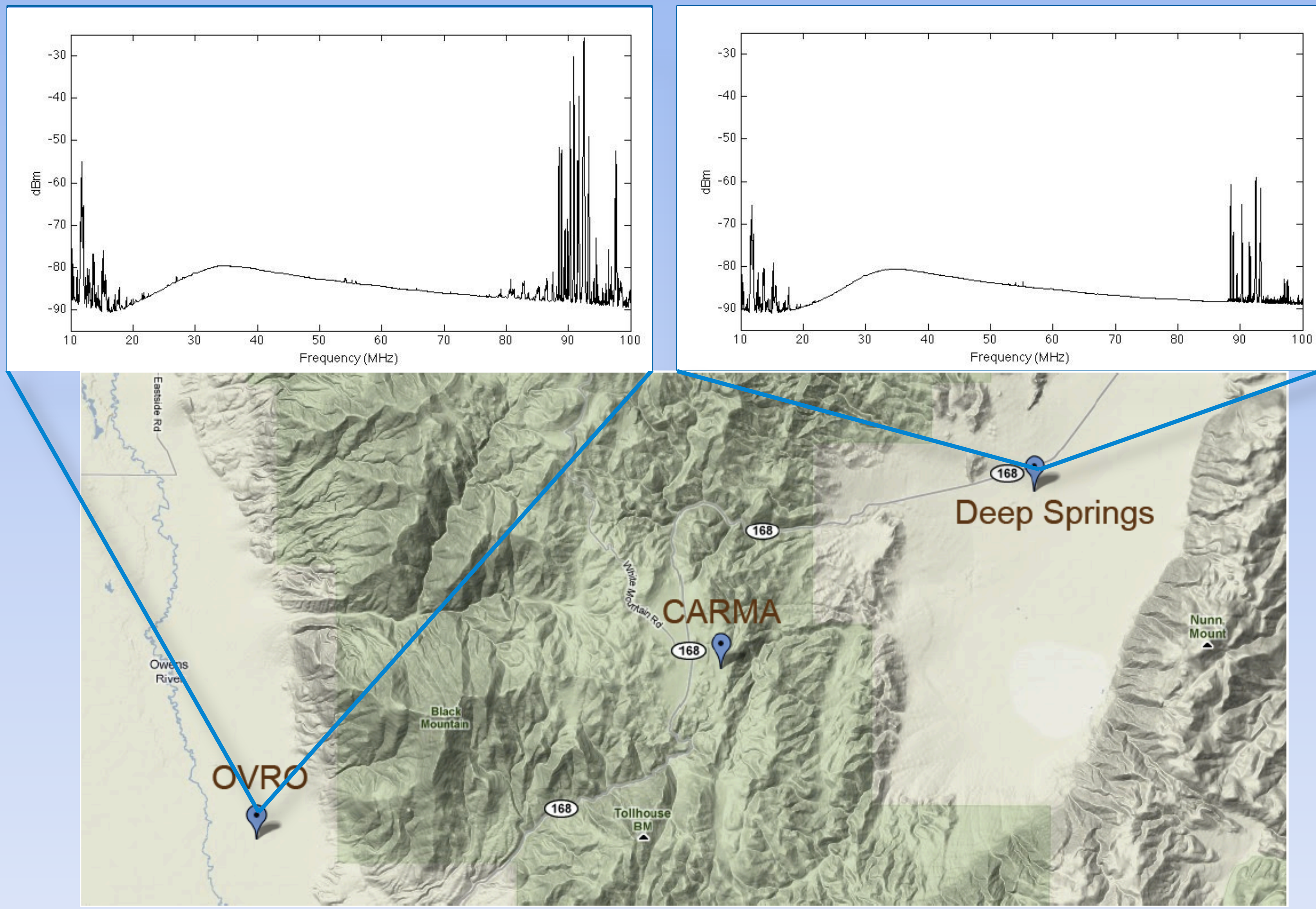
- Existing infrastructure and staff allowed rapid, low cost construction of a new station
  - Broke ground in January 2013
  - First light in August 2013
- Leverages heavily on the R&D and expertise of the LWA consortium
- Hosts the LEDA correlator
- Additional transient back-end to produce images of the entire hemisphere every second
- Primary science – Dark Ages and Transients



LWA RFI survey at and around OVRO



LWA
Long Wavelength Array

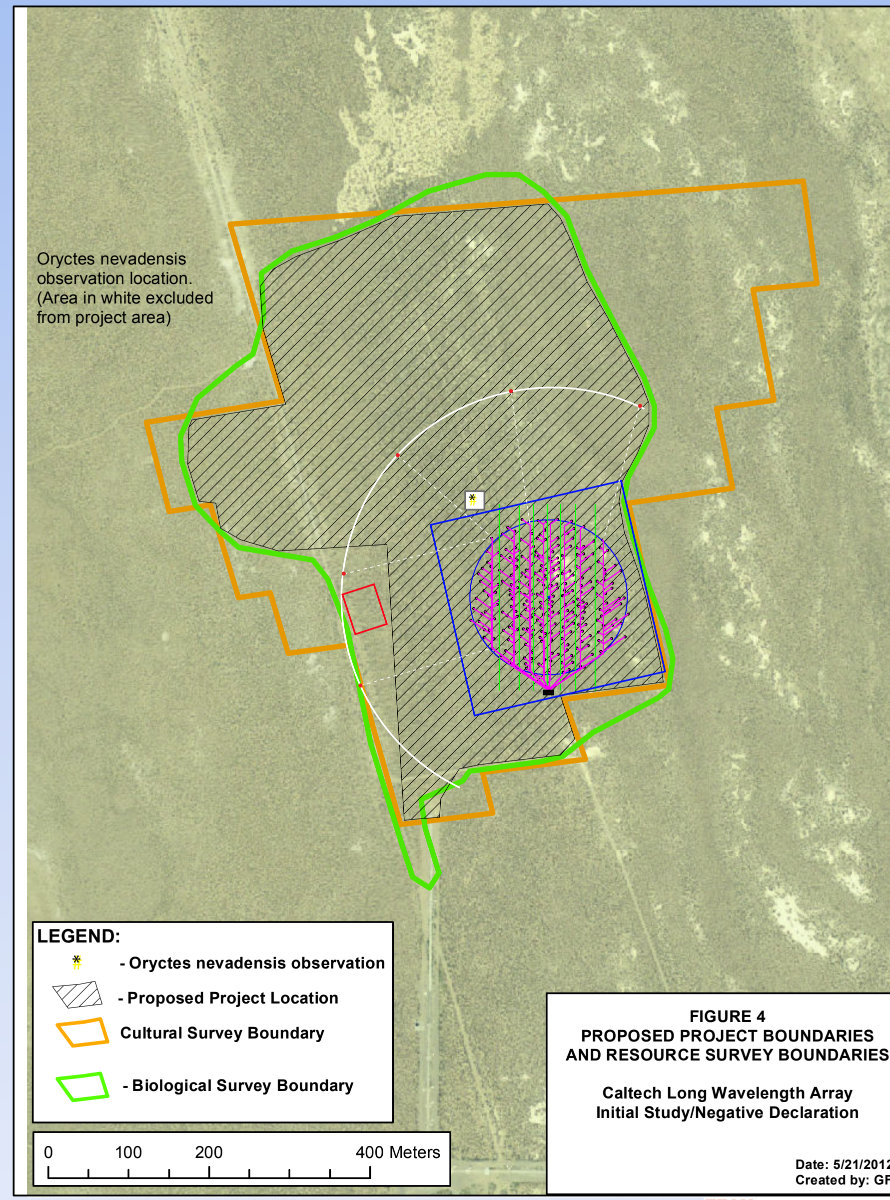


Aug 2011 – Jan 2012: RFI surveys of 3 sites (OVRO, CARMA, Deep Springs)

RFI Environment: Deep Springs is excellent, but OVRO was better than expected and already had infrastructure in place for quick deployment

Design Modifications

- **June 2012 – Oct 2012**:
- Core array increased to ~220m diameter
- Antennas positions were optimized to minimize sidelobes (-17 dB), while maintaining a minimum antenna spacing of 5m to minimize mutual coupling
- Further optimization to reduce cabling costs
- Modifications to receiver boards to minimize cost and delivery time
- New custom built electronics shelter to host LEDA and transient back-end



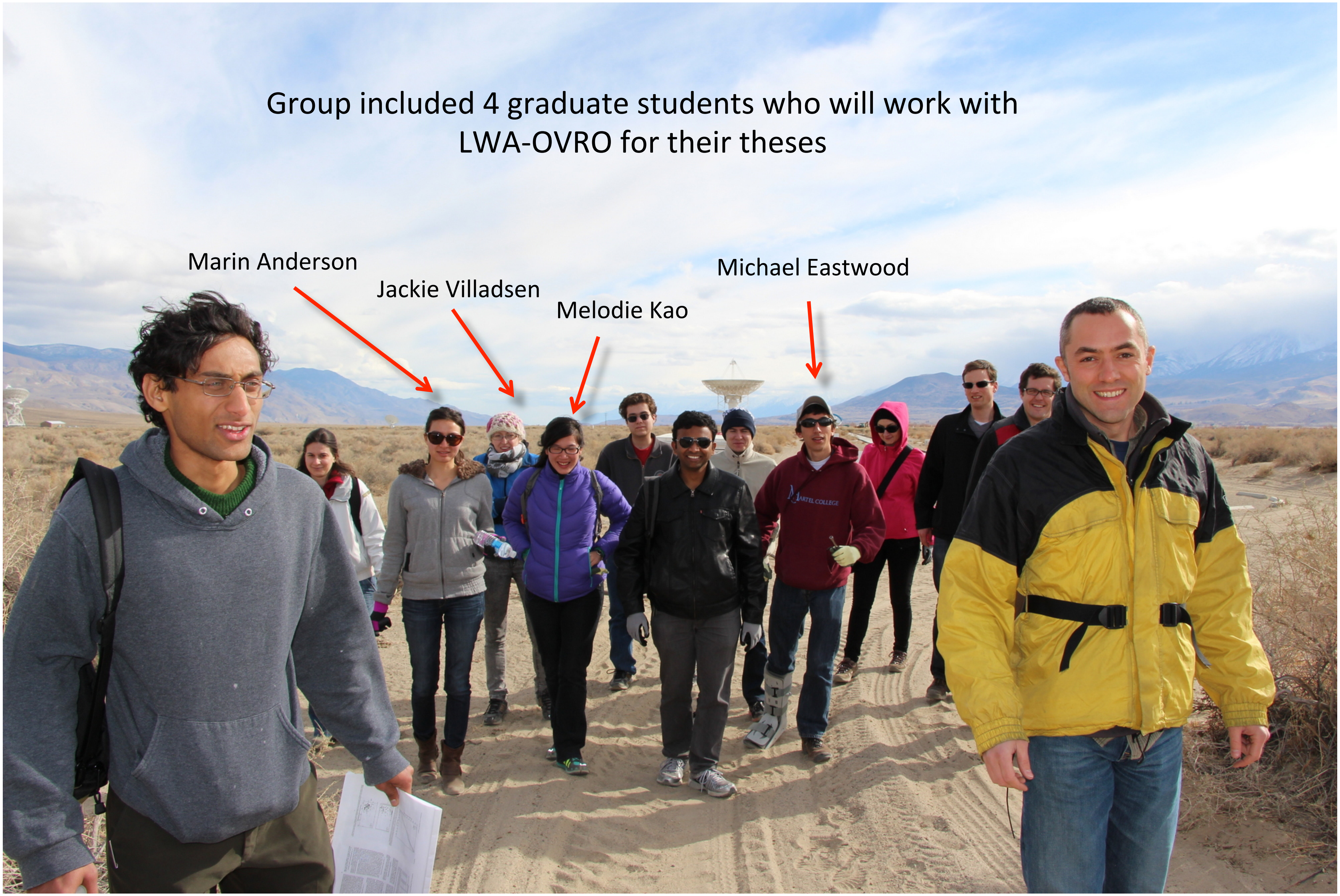
LWA-OVRO core array, outriggers and electronics unit positioning, G. Hallinan, 10/18/12

TEAM ENGINEERING & MANAGEMENT, INC. Bishop and Mammoth Lakes, California

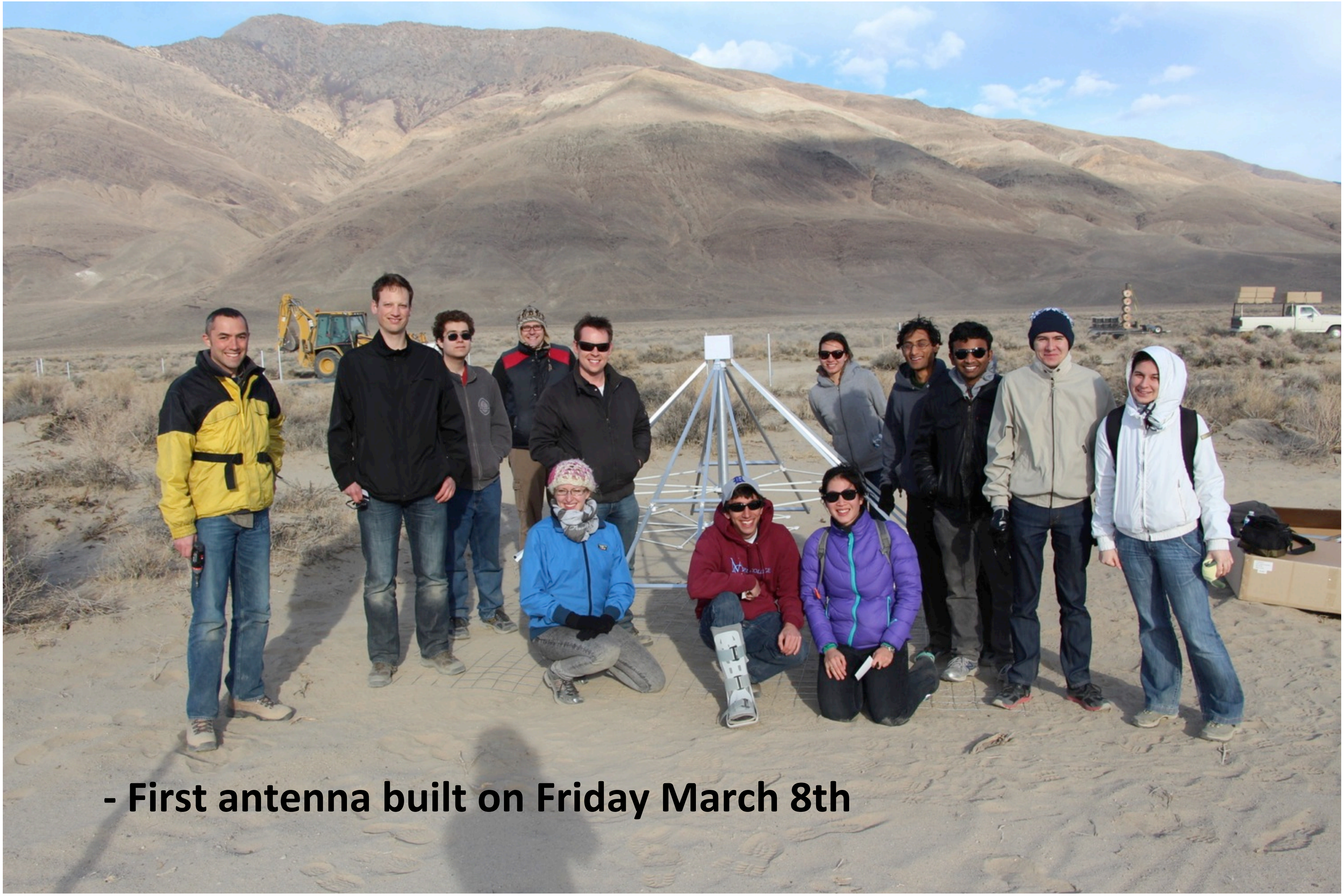
Construction Commences…

- **Jan 2013:** Arrival of 88,000m of cables, 256 antennas, FEEs, ARX boards
- **Jan 2013:** Erection of 1000m of fencing in hexagonal pattern
- **Feb - Apr 2013:** Trenching (5km), laying of cables and installing of antenna masts
- **Mar - Apr 2013:** Main antenna assembly and installation

Student and Postdoc Field Trip Mar 8-11 2013



Student and Postdoc Field Trip Mar 8-11 2013



Student and Postdoc Field Trip Mar 8-11 2013

- Antenna design allows construction of frame by 3 people in < 15 mins

Student and Postdoc Field Trip Mar 8-11 2013

- **Three teams competed over the weekend to build the most antennas**

- **Each antenna was labeled with the names of each team member to keep track of the competition**

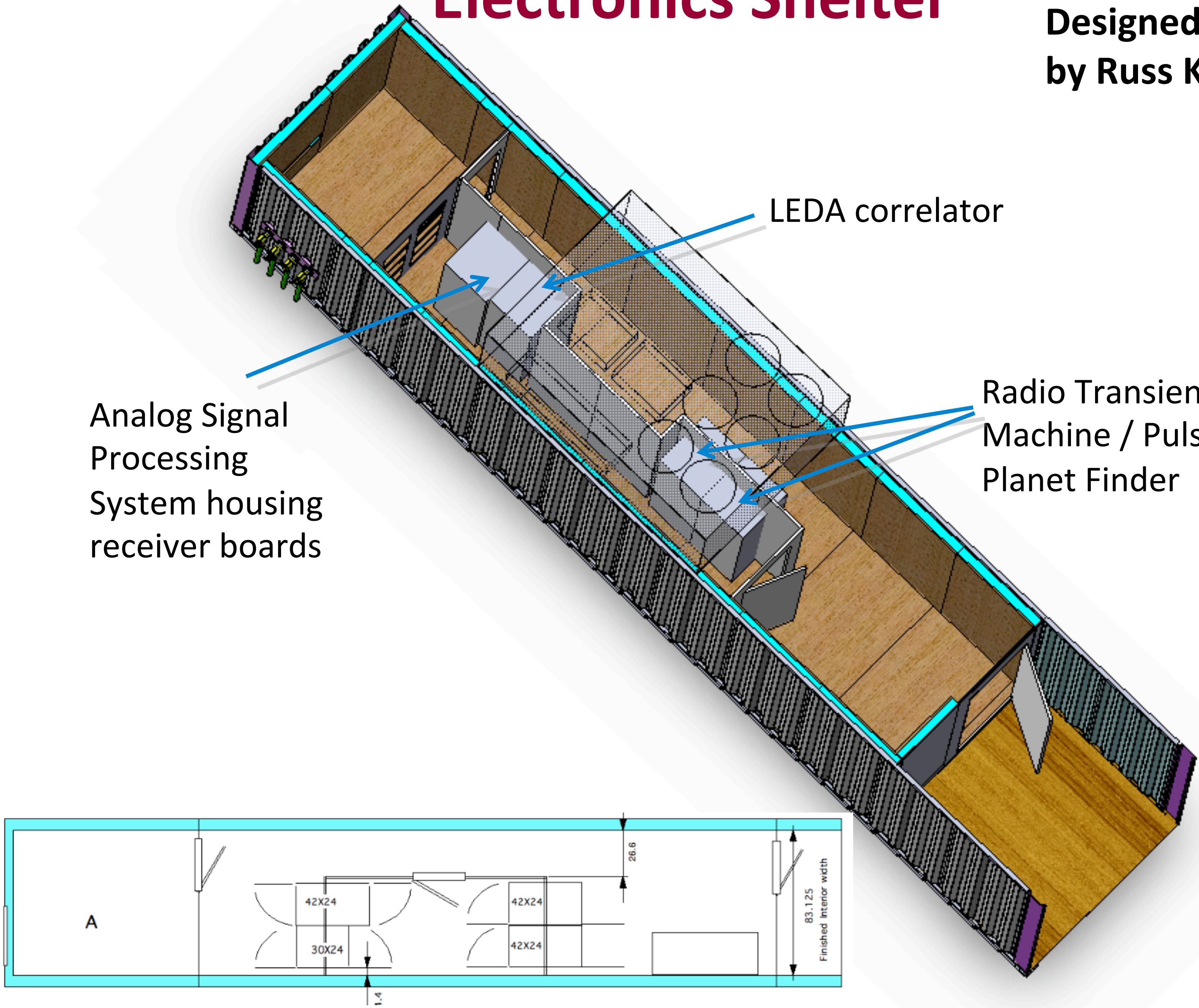
Electronics Shelter

Designed and built by Russ Keeney

LEDA correlator

Radio Transient Machine / Pulsing Planet Finder

Analog Signal Processing System housing receiver boards

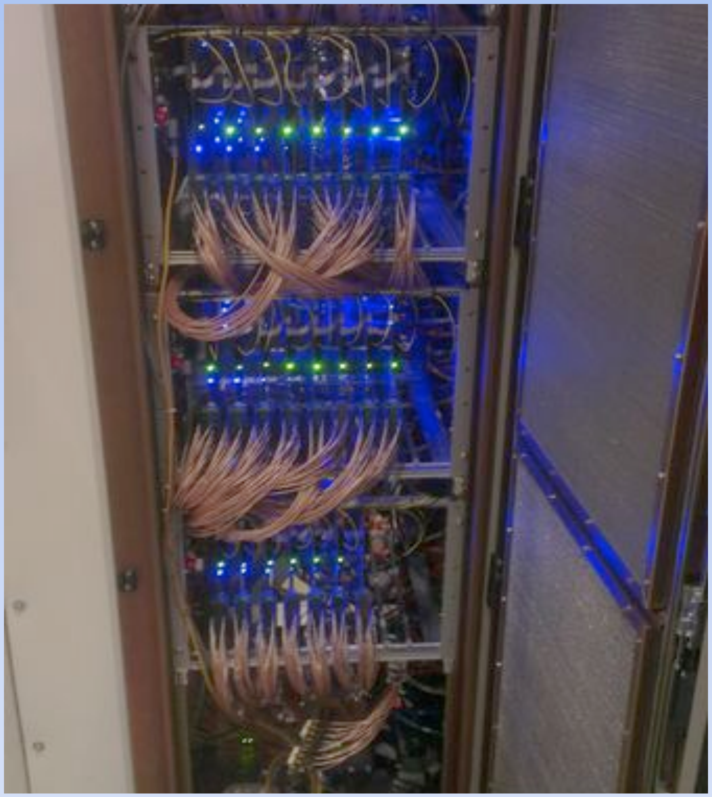


Electronics Shelter

Connecting it all together…

Construction Completed: July 27th

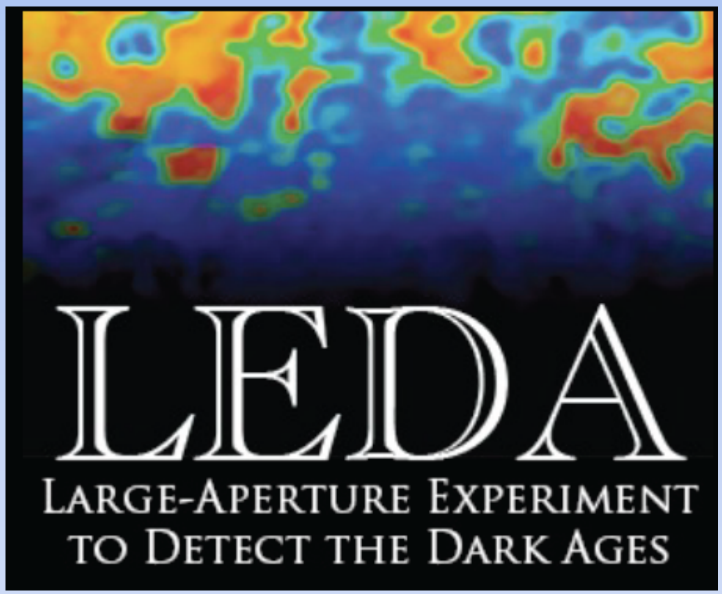
Current Status

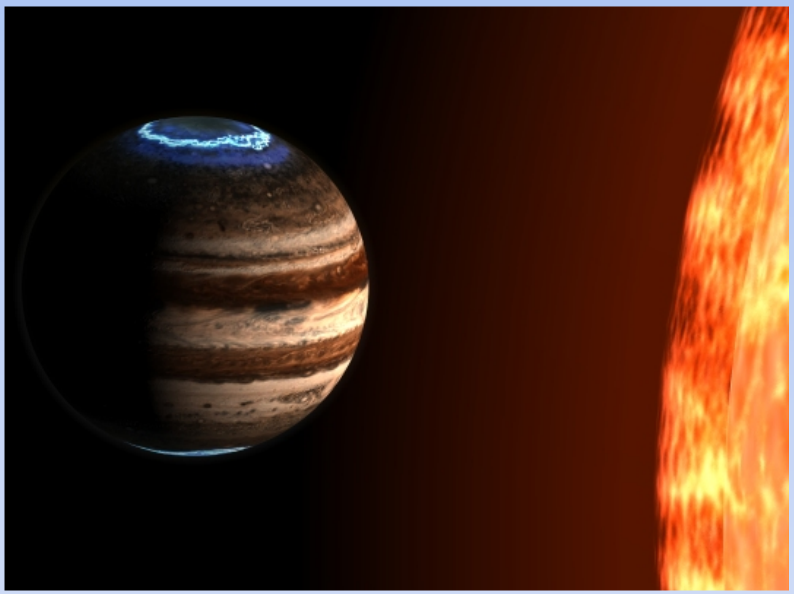


July-August: 506 of 512 signal paths commissioned end to end and confirmed to deliver sky noise dominated signal to LEDA

June 16: LEDA-64 arrives and successfully installed
Aug 1: LEDA-512 arrives and successfully installed

LWA-OVRO Primary Science



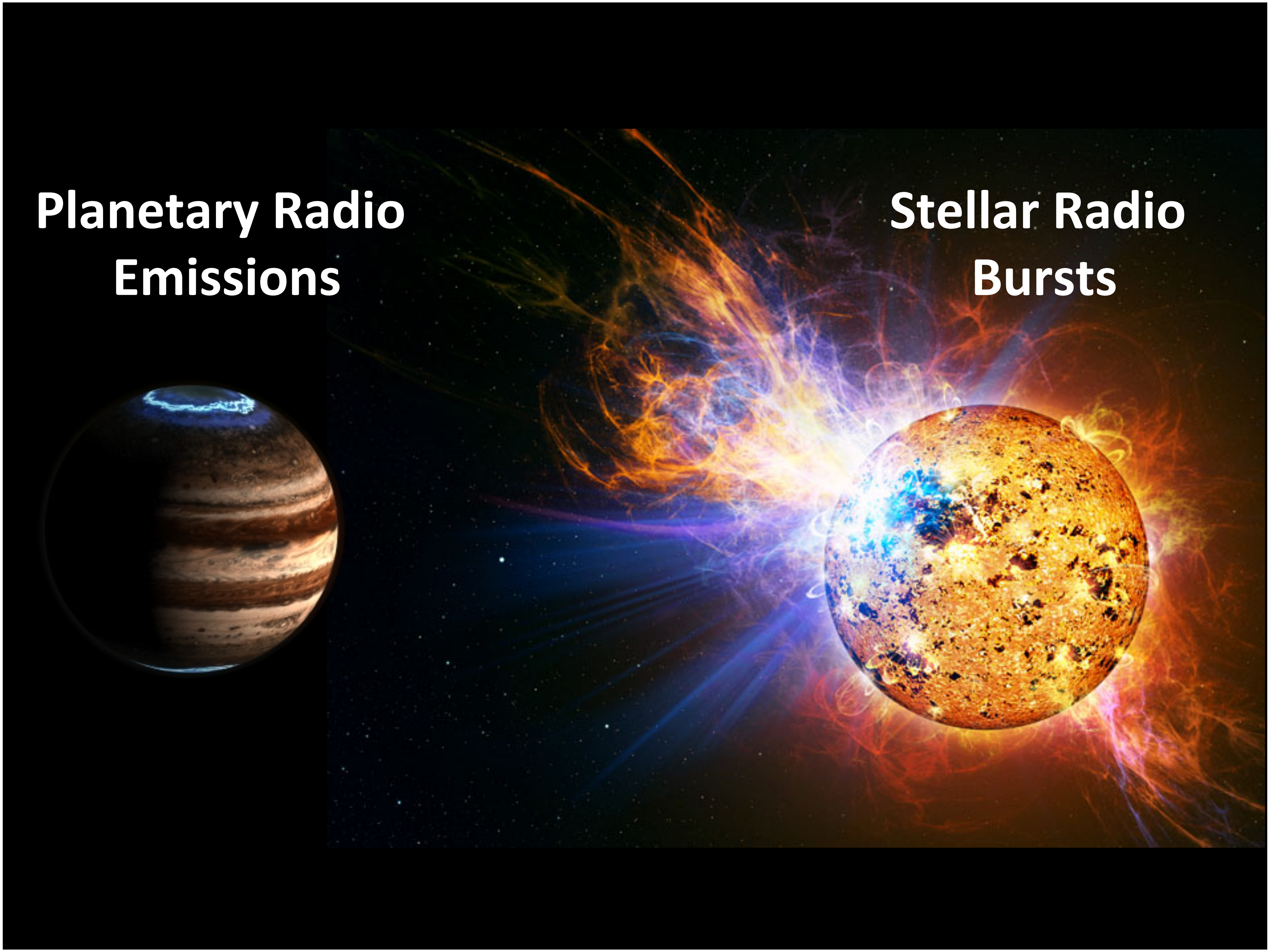


Constrain sky averaged HI signal at z~20

Power spectrum constraints?

Lincoln's talk…

Image the entire viewable hemisphere each second. Key objectives include first radio exoplanet detection, stellar CMEs


Planetary Radio Emissions
Stellar Radio Bursts

Why look for radio emission from exoplanets?

- It's a direct detection
- Allows measurement of rotation rate
- Possible use as a detection method for exoplanets
- The only method currently viable for measurement of magnetic field strengths for exoplanets...

a) Leads to constraints on scaling laws based on magnetic fields of solar system planets

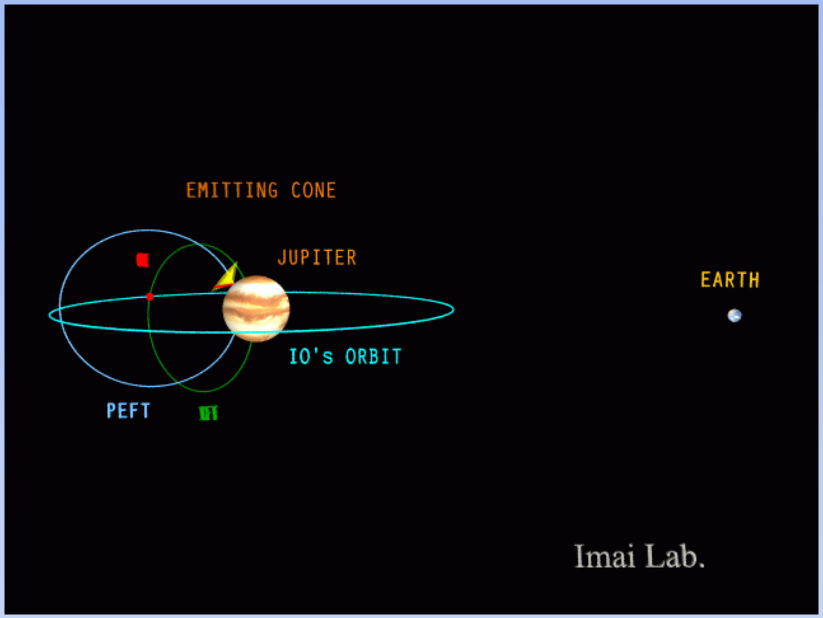
b) Provides insight into internal structure of planet.

The radio emission is extremely bright, T_B up to 10^{20} K and highly polarized

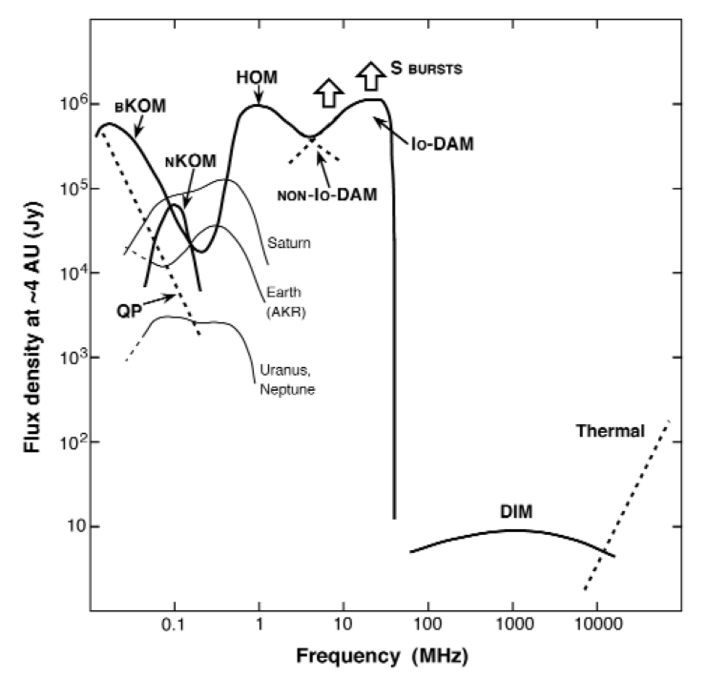
It is beamed into conical patterns ranging from as large as 60˚ to as thin as 5˚ in beam width

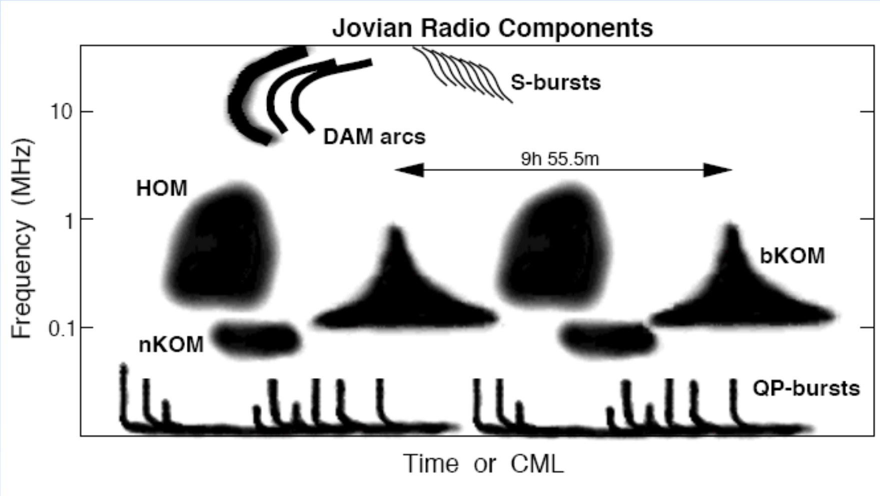
Jupiter can outshine the Sun at low frequencies

Electron maser emission produced at the electron cyclotron frequency



Credit: Kazumasa Imai





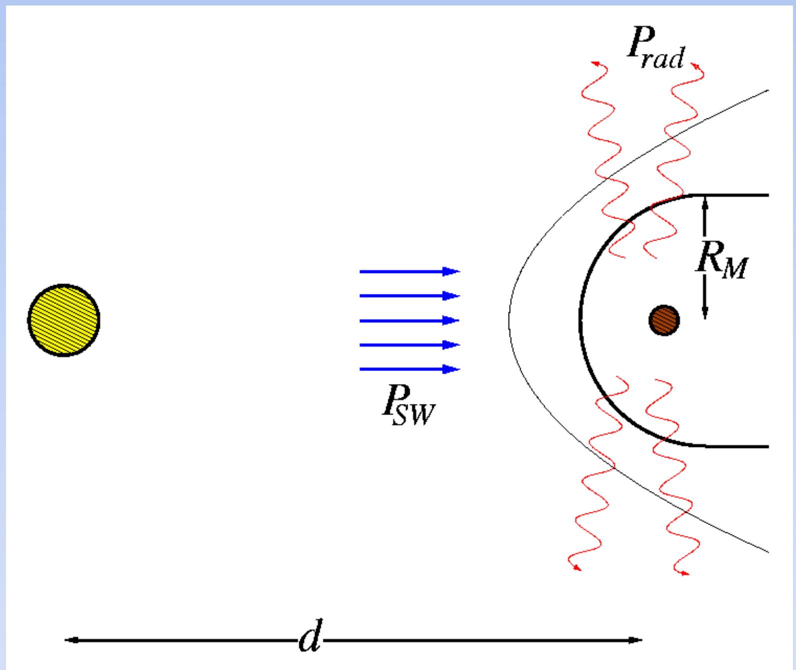
Zarka (1998)

Expected Flux…

• Strong correlation between Solar Wind (P & V) and auroral radio emissions.

• The emitted power scales with the received stellar wind power - $P_{rad} \propto P_{SW}^{x}$

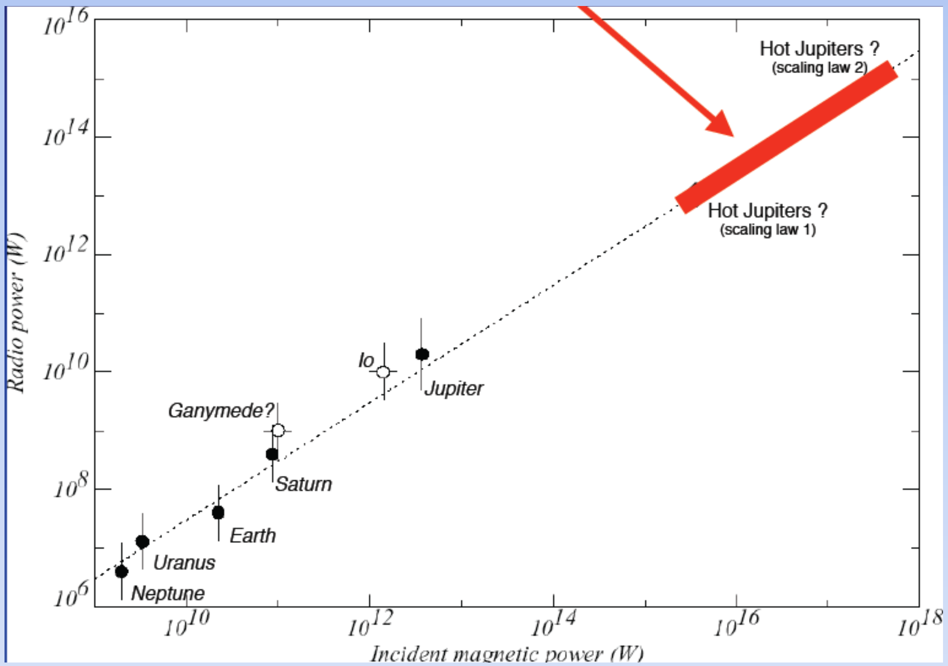
•The received stellar wind power depends on the distance and the cross-section of the magnetosphere - $P_{SW} \propto R_{M}^{2} d^{-2}$



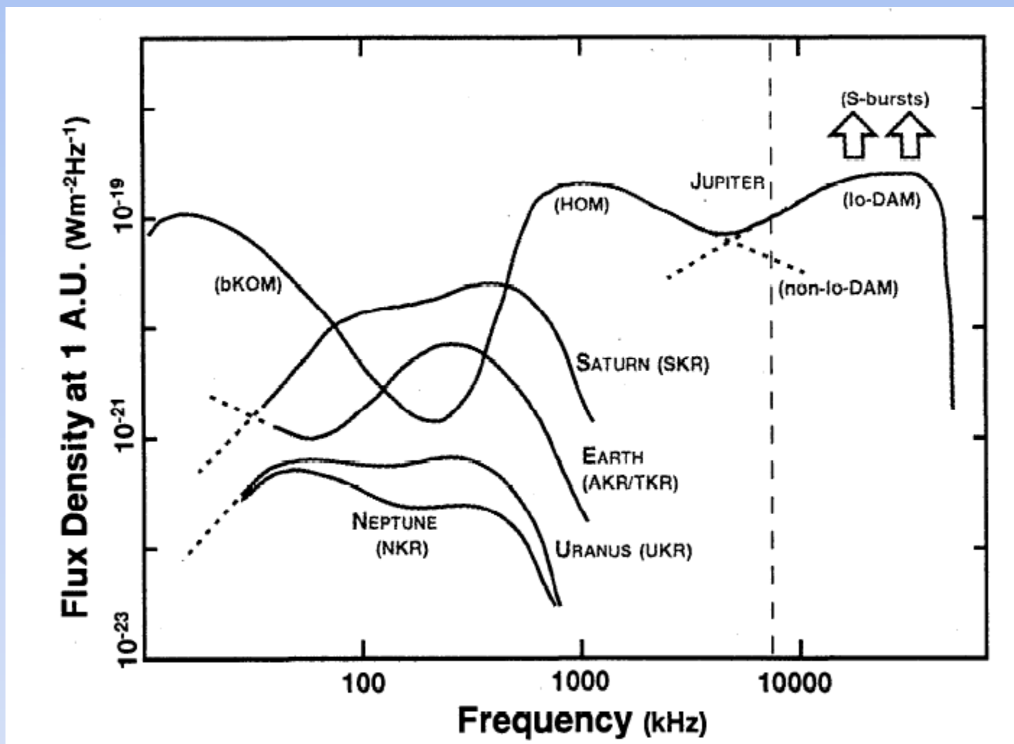
Zarka et al, ApSS. 2001

Radiometric Bode' s Law

- 'Hot Jupiters' with expected radio luminosities many thousands of times brighter than Jupiter
- Should outshine the parent star
- Predicted detectable fluxes from a number of planets up a few hundred mJy in some cases



Zarka et al, ApSS. 2001



- Forget Hot Jupiters for a minute…

- Chuck Higgins talk (and Zarka et al. 2007)

a) Jupiter average L burst flux ~ 10^6 Jy
b) Jupiter peak L burst flux ~ 10^7 Jy
c) Jupiter peak S burst flux ~ 10^9 Jy
d) Jupiter peak HOM ~10^7 Jy (non-Io)

- Jupiter at 5pc
  a) 20 μJy
  b) 0.2 mJy
  c) 20 mJy
  d) 0.2 mJy

- Jupiter at 5pc orbiting at 1 AU -> 5 mJy

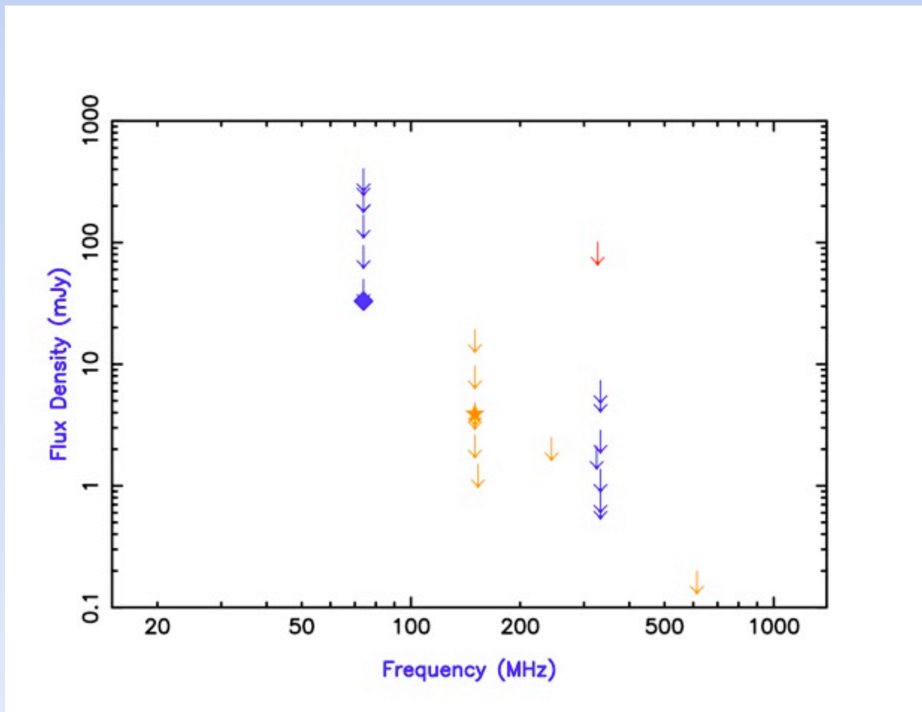
Searches Thus Far...

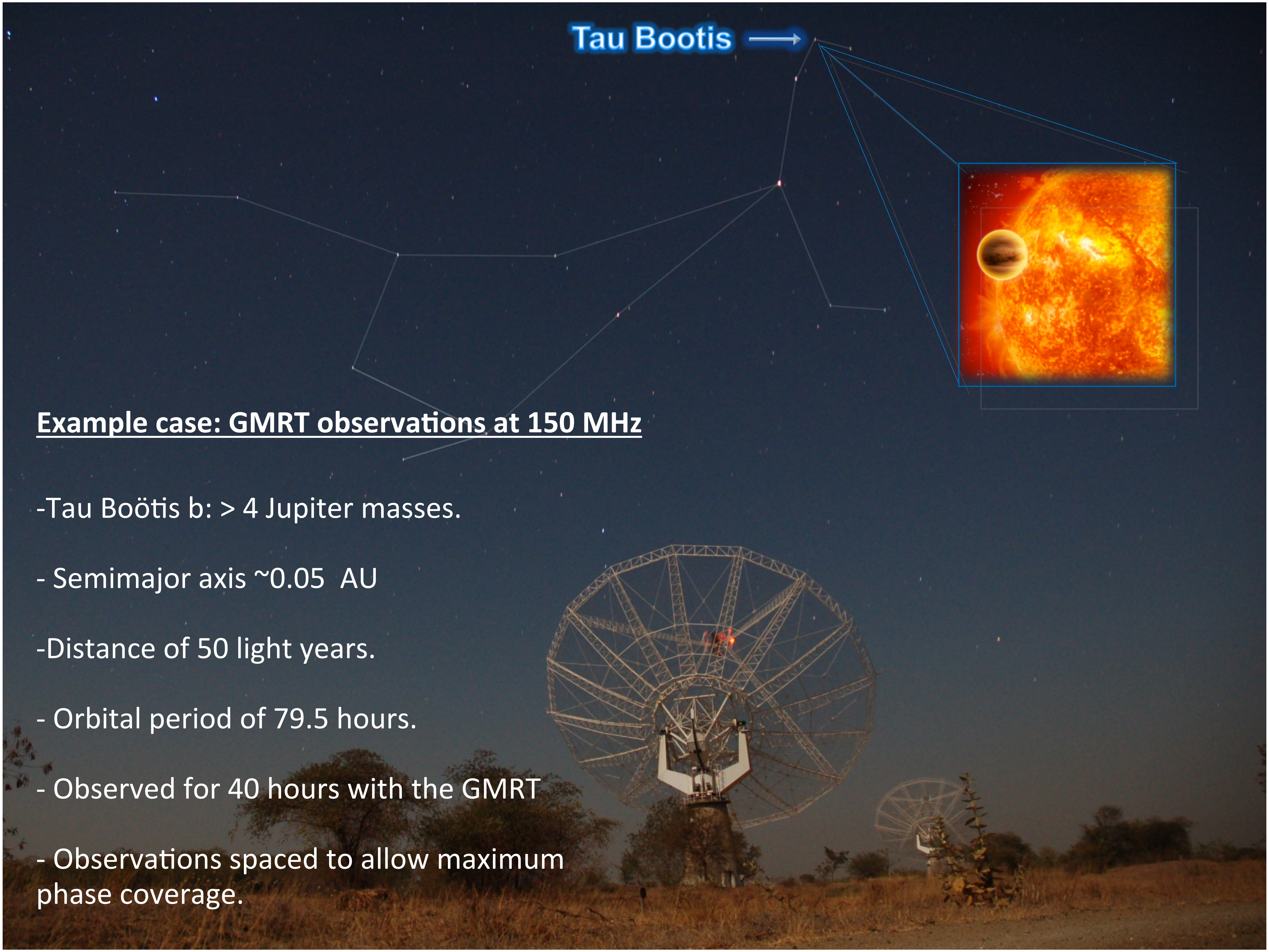
- Searches have been ongoing for > 30 years – no detections

- Involve targeted pointings of small sample of Hot Jupiters (<10)

- See Lazio et al. 2009 for review – 2010 Decadal Survey White Paper

- Need to observe large sample at low frequencies (< 100 MHz) to overcome geometrical selection effects

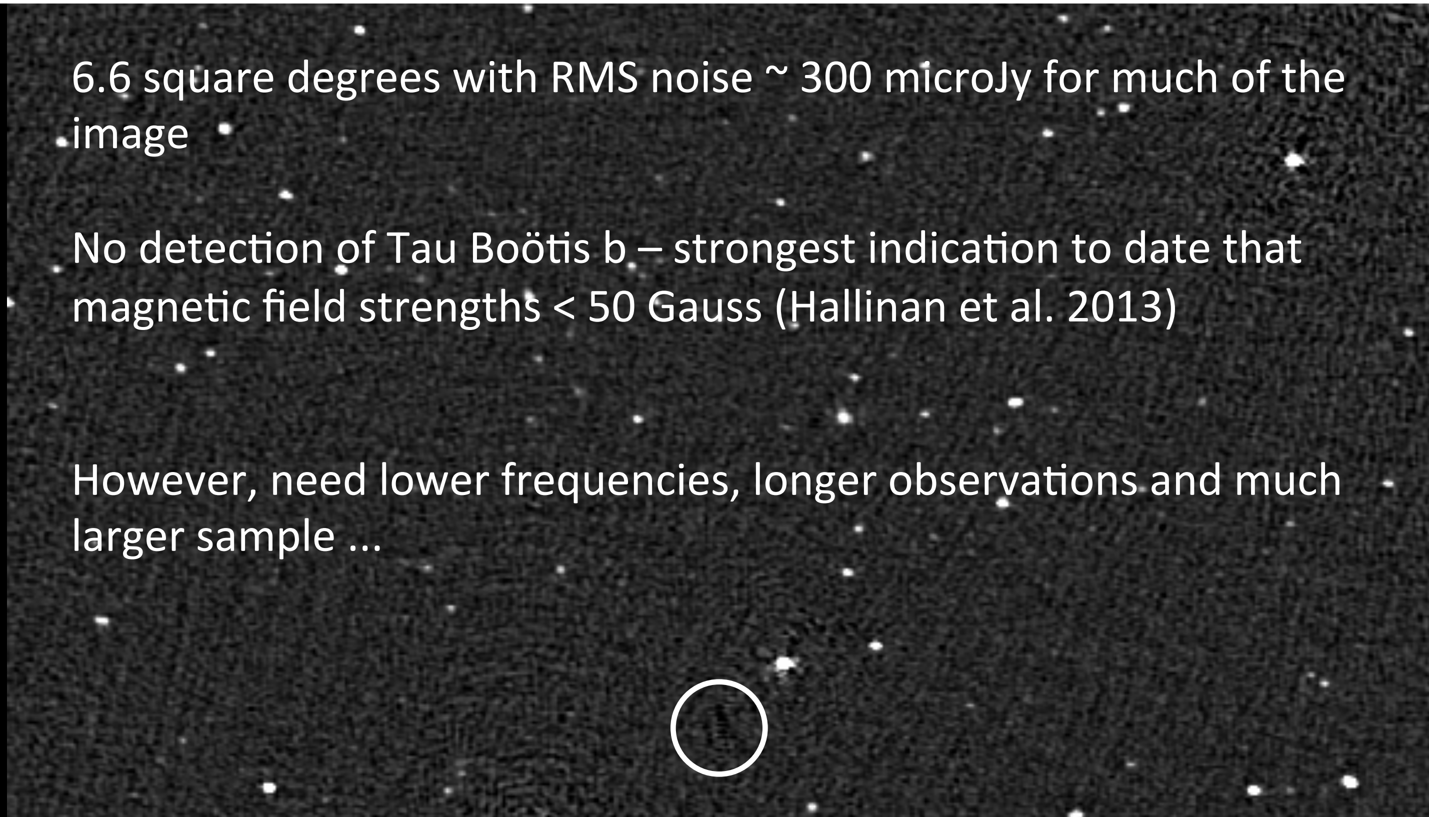


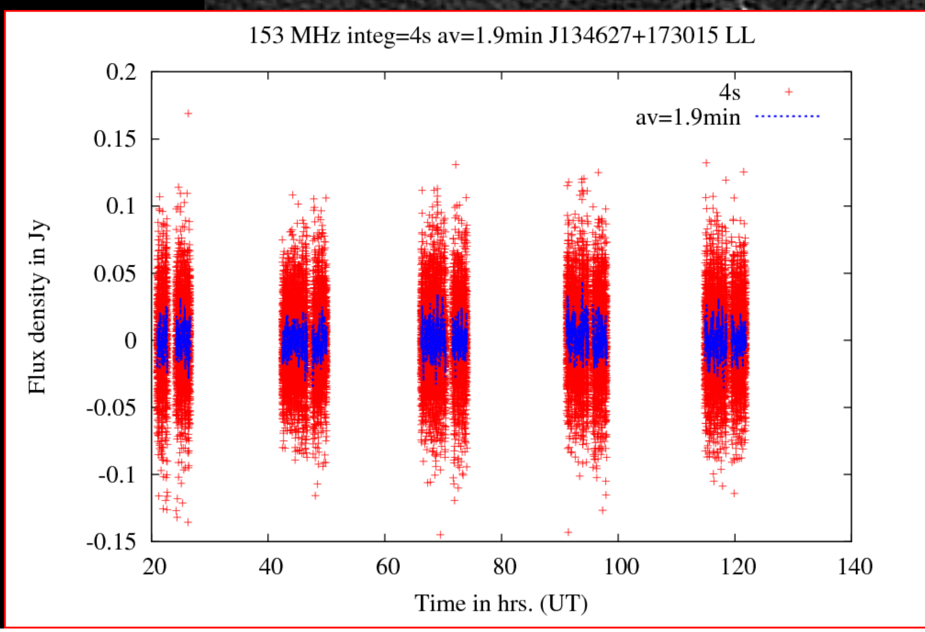

Tau Bootis
Example case: GMRT observations at 150 MHz
-Tau Boötis b: > 4 Jupiter masses.
- Semimajor axis ~0.05 AU
-Distance of 50 light years.
- Orbital period of 79.5 hours.
- Observed for 40 hours with the GMRT
- Observations spaced to allow maximum phase coverage.

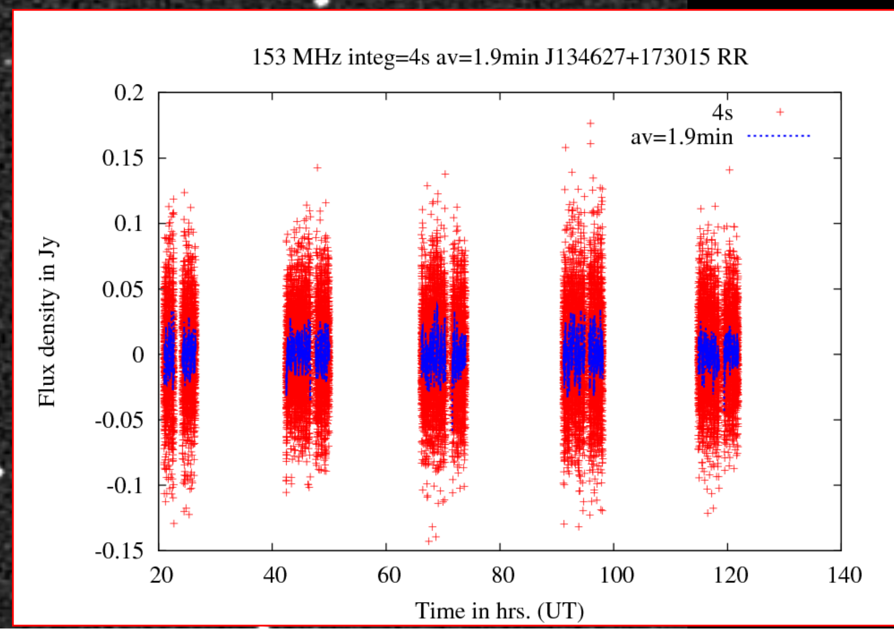
6.6 square degrees with RMS noise ~ 300 microJy for much of the image

No detection of Tau Boötis b – strongest indication to date that magnetic field strengths < 50 Gauss (Hallinan et al. 2013)

However, need lower frequencies, longer observations and much larger sample ...







HJUDE – Hot Jupiter Detection Experiment with the LWA

-The Long Wavelength Array (LWA) in Socorro NM

- 512 dipoles

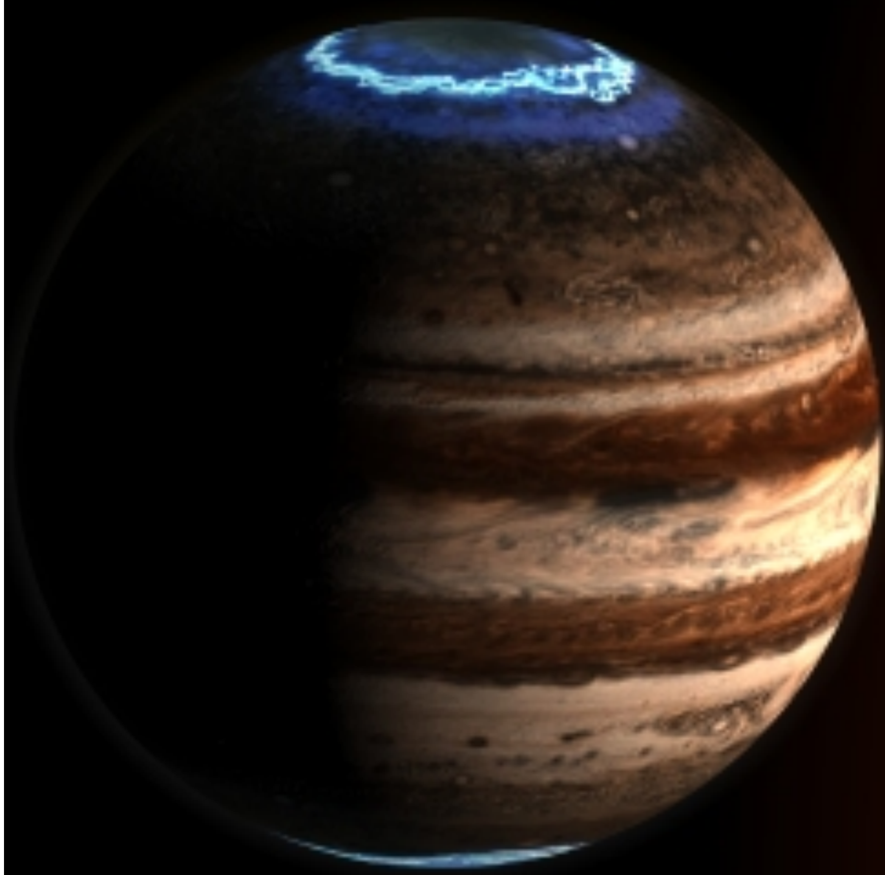
- 10-88 MHz

- Sensitivity of a few mJy

- HJUDE has been allocated 5000 beam hours

Jake's Talk

All Sky Transient Monitor (Pulsing Planet Finder)



Developed by Caltech and JPL

160 CPU cores, 1 TB of RAM, 144 TB of high speed Lustre storage

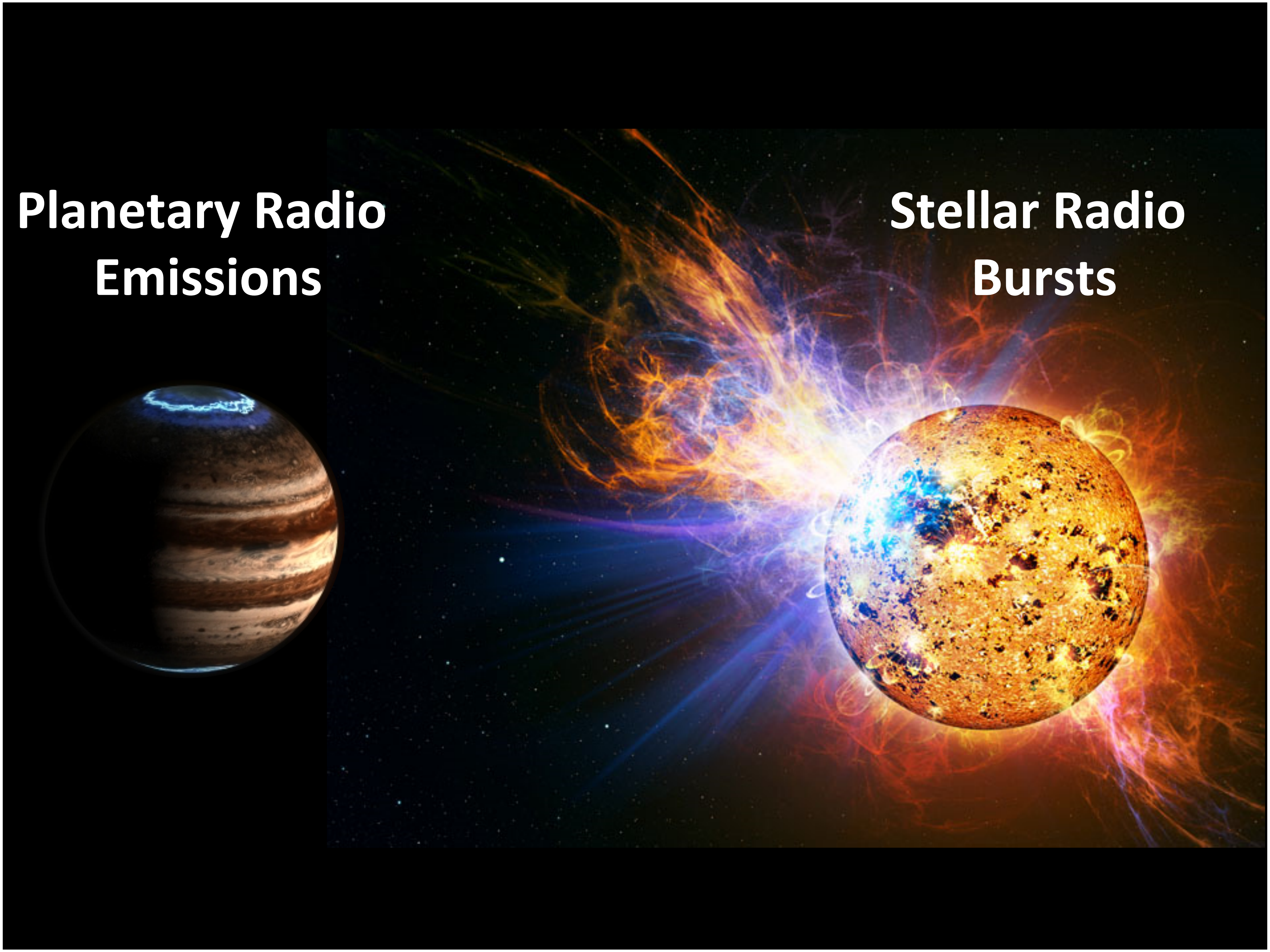
Data volume: up to 20 Gbps

LEDA data will be processed and archived in real time (60 MHz)

Can monitor the entire viewable hemisphere continuously to detect pulsing emission from exoplanets

Will detect many other classes of transient

<u>Faster survey speed than entire LOFAR-LBA</u>

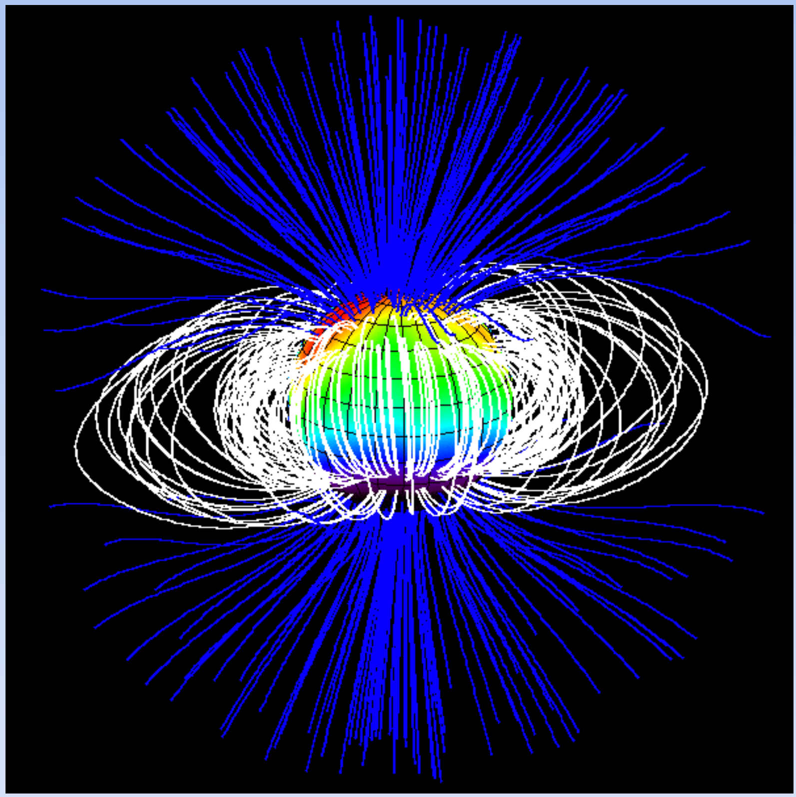

Planetary Radio Emissions
Stellar Radio Bursts

Exoplanets – Implications of Activity

- Kepler has shown that lower mass planets are frequent around M dwarfs – likely the nearest habitable planet orbits an M dwarf
- Habitability may be need to be redefined based on magnetic activity (stellar age and mass dependent)
- During flares – higher X-ray and ultraviolet -> photochemical reactions leading to significant atmospheric loss (eg. Segura et al. 2010)
- Possible associated coronal mass ejections (CMEs) can severely affect atmospheric retention – eg. ion pick-up of a CO^2-rich atmosphere (eg. Lattimer et al 2007)

M dwarf Magnetic Fields

- Very different from the αΩ dynamo operating in the Sun
- Large-scale high strength poloidal magnetic fields
- May funnel/direct the outflows associated with flares and CMEs
- Plenty of theory, but no empirical data exists on the possible impact of stellar CMEs on planetary atmospheres



Donati et al. Science (2006)

Radio Emission from the Sun

- Quiescent emission dominated by thermal emission from the chromosphere and corona

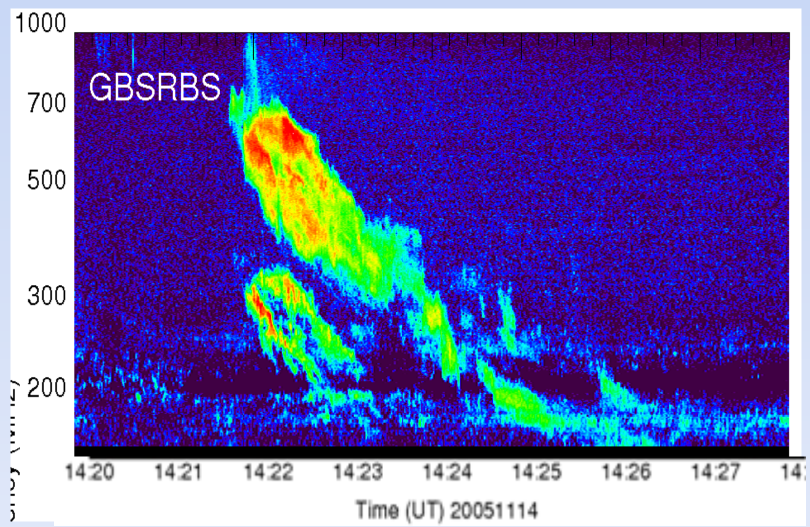
- Non-thermal emission powered by particle acceleration during ***impulsive events***, i.e., flares and coronal mass ejections (CMEs)

- Powerful diagnostic of plasma density and magnetic field strength

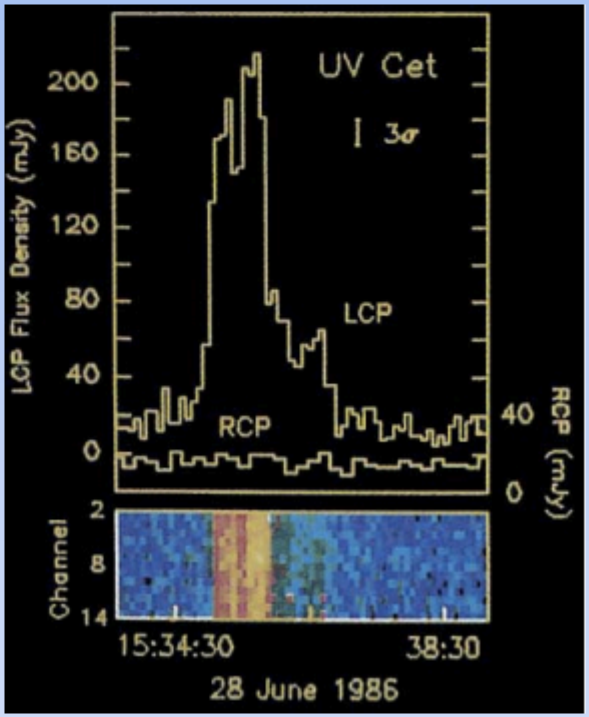
Gyrosynchrotron flares

Credit: Stephen White

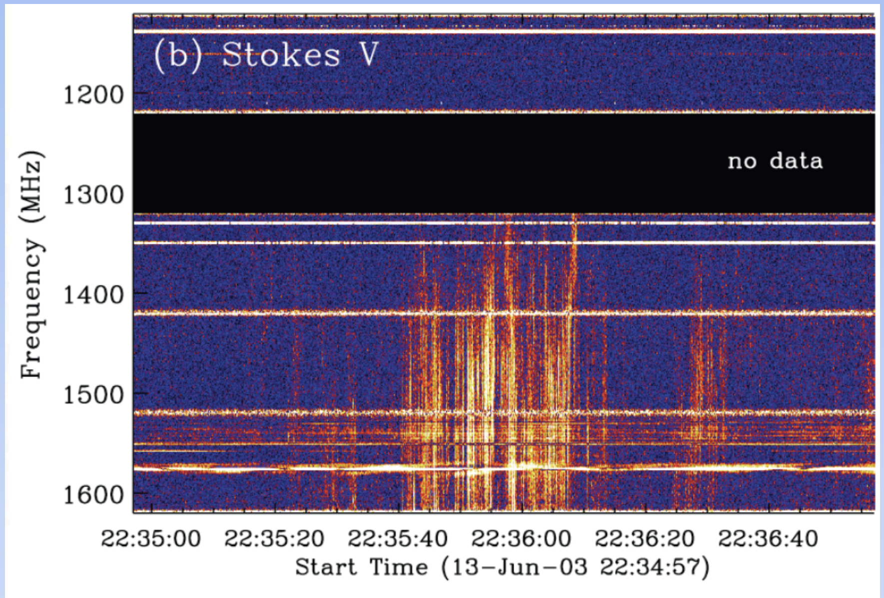
Coherent bursts (Type II, Type III…)



Dynamic Spectra of Radio Bursts from M dwarfs



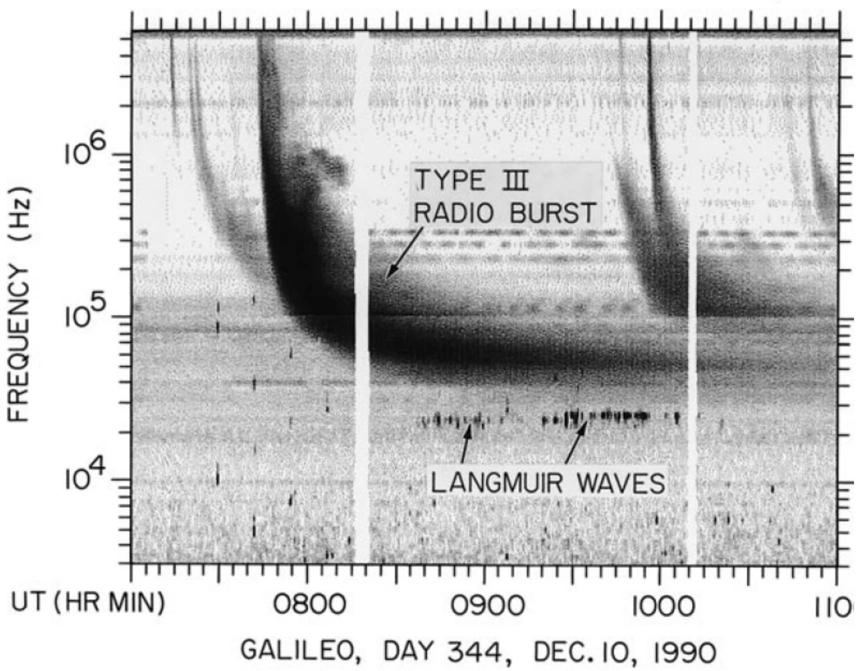
Bastian et al. Nature (1987)



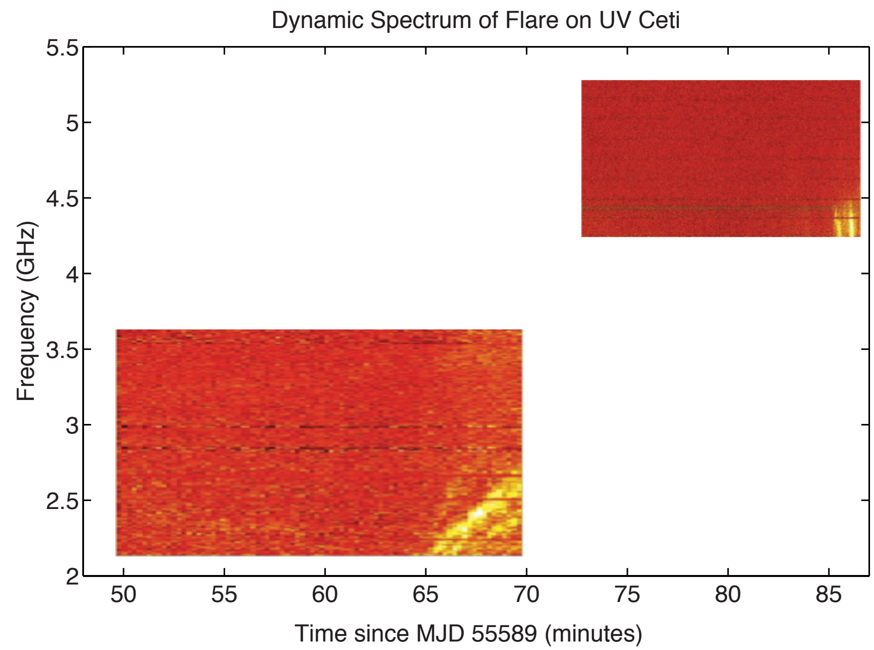
Osten & Bastian, ApJ (2006)

- First achieved in with the VLA in 1987
- Very bright bursts detected ~ 1 Jy
- However, bandwidth very limited – cannot track mass motion of the plasma

Sweeping Radio Burst Detected with the Upgraded VLA

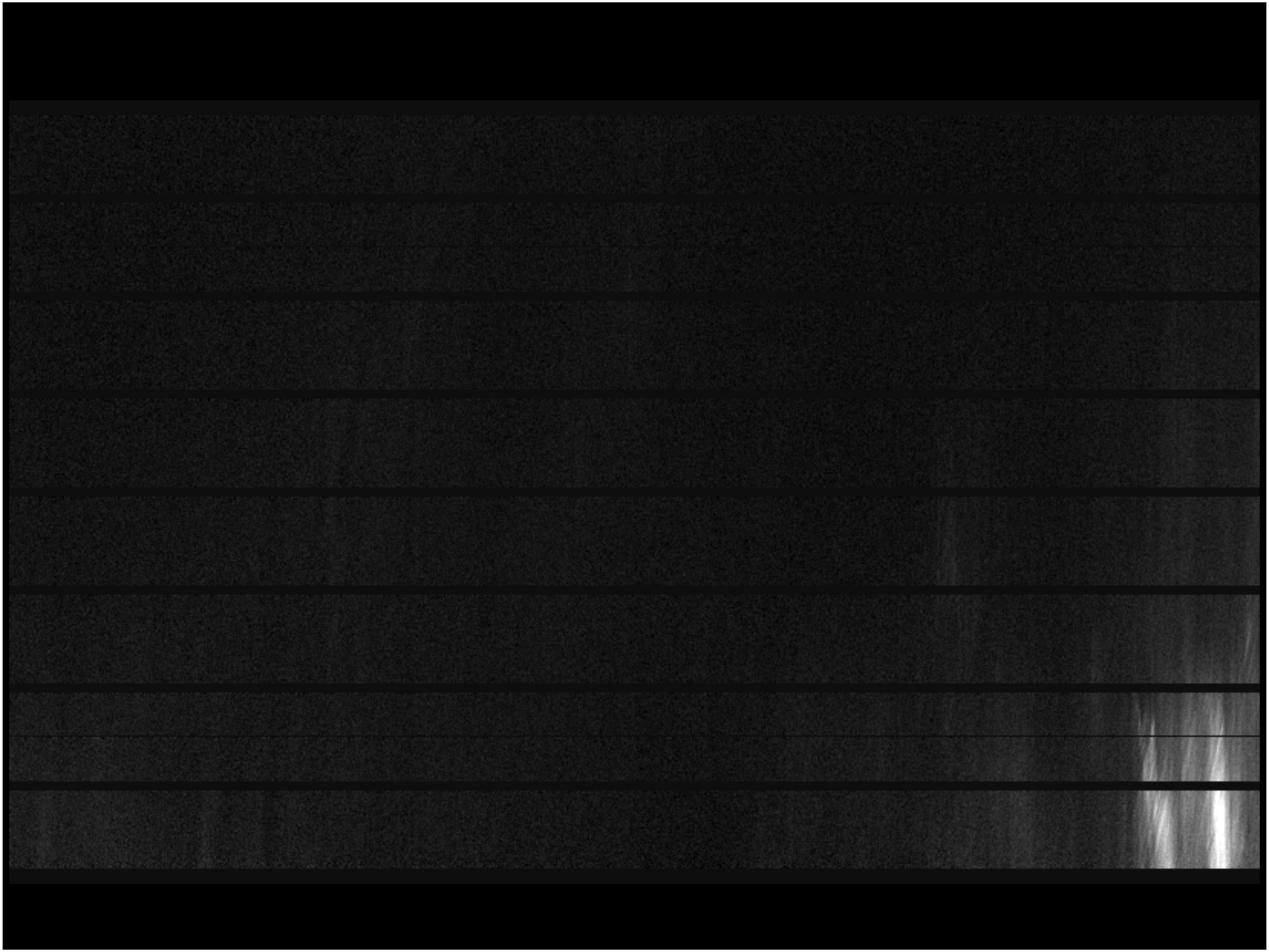


Type III solar burst: (Gurnett et al. 1993)



Stellar radio burst from UV Ceti

- A bright (150 mJy) 100% highly circularly polarized sweeping radio burst was detected from UV Ceti
- Signals mass transport of plasma within the corona of this star



The Starburst Program

Detect, monitor and image coronal mass ejections (CMEs) on nearby active stars

Owens Valley 27m dishes & LWA-OVRO

- 27m dishes currently being upgraded as part of the new Owens Valley Solar Array

- New receivers cover 1-6 GHz instantaneously

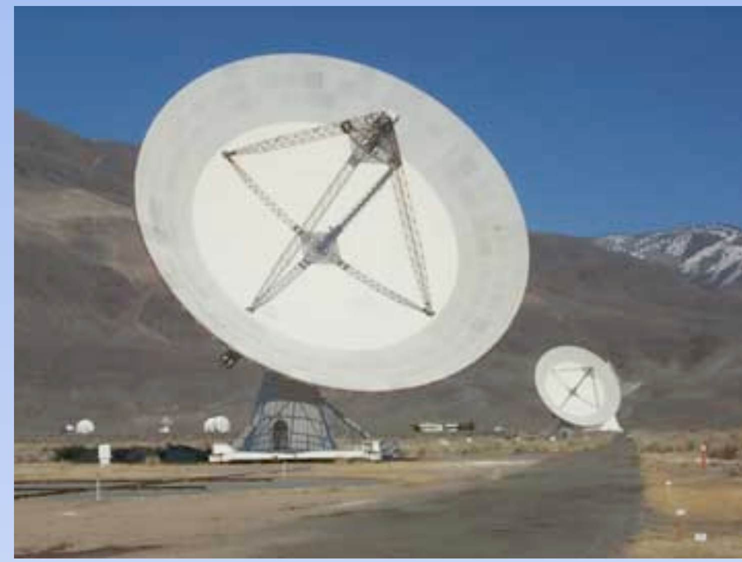
- Night time observing will be dedicated to the Starburst program

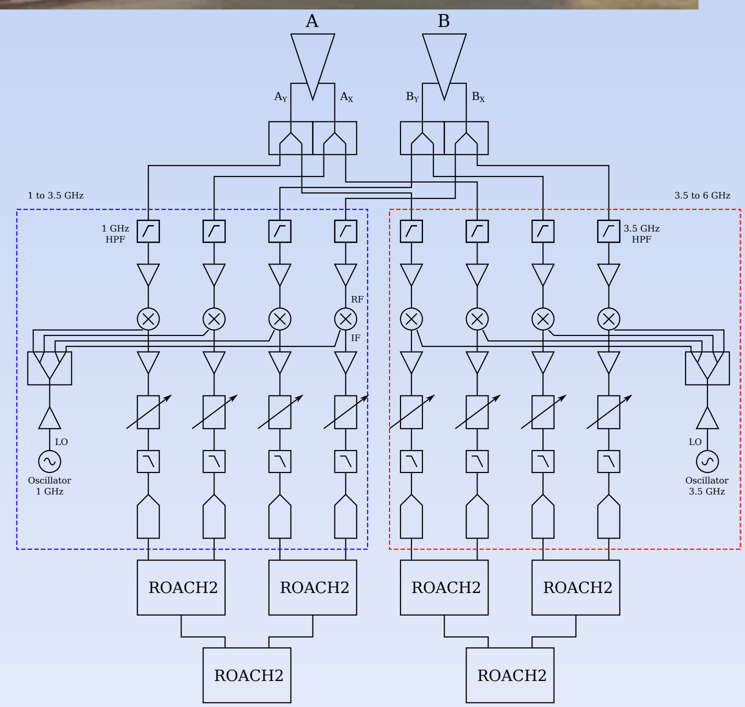
- Single baseline correlator using CASPER-based hardware

- Will observe sample of 15 nearby active stars

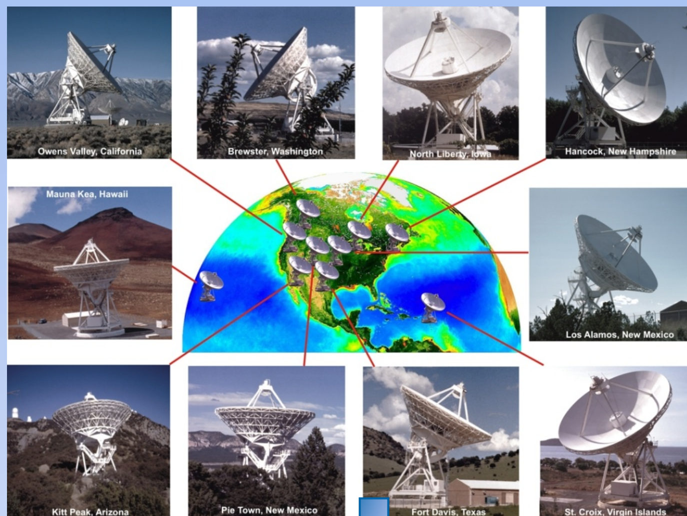
LWA-OVRO can monitor entire population of nearby stars

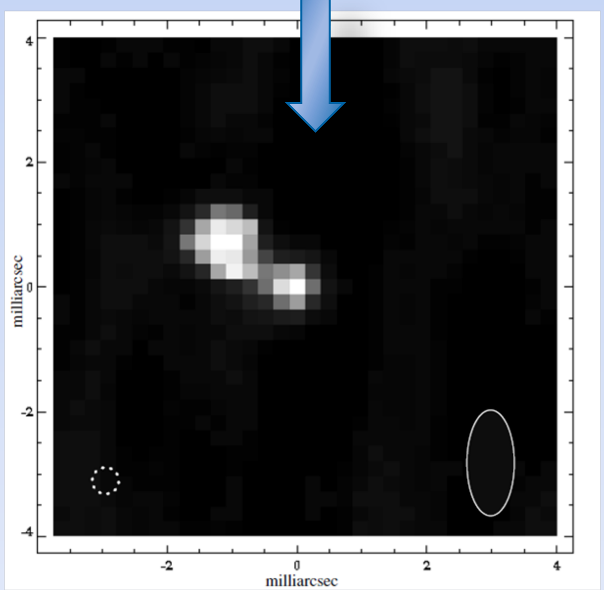
- NSF ATI: 2013-2016



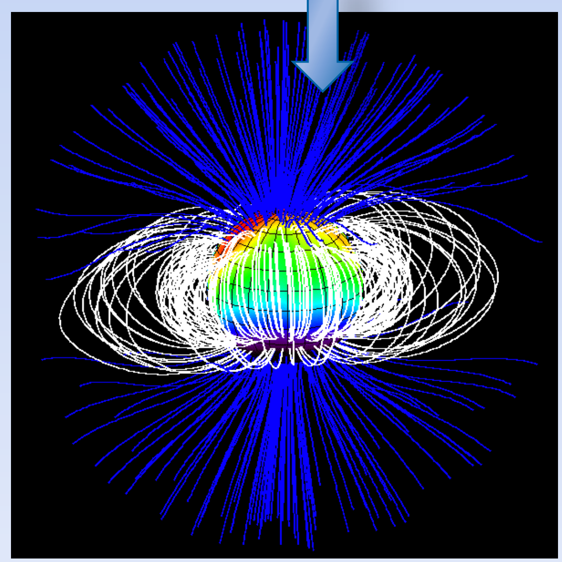


Triggered Imaging with the VLBA



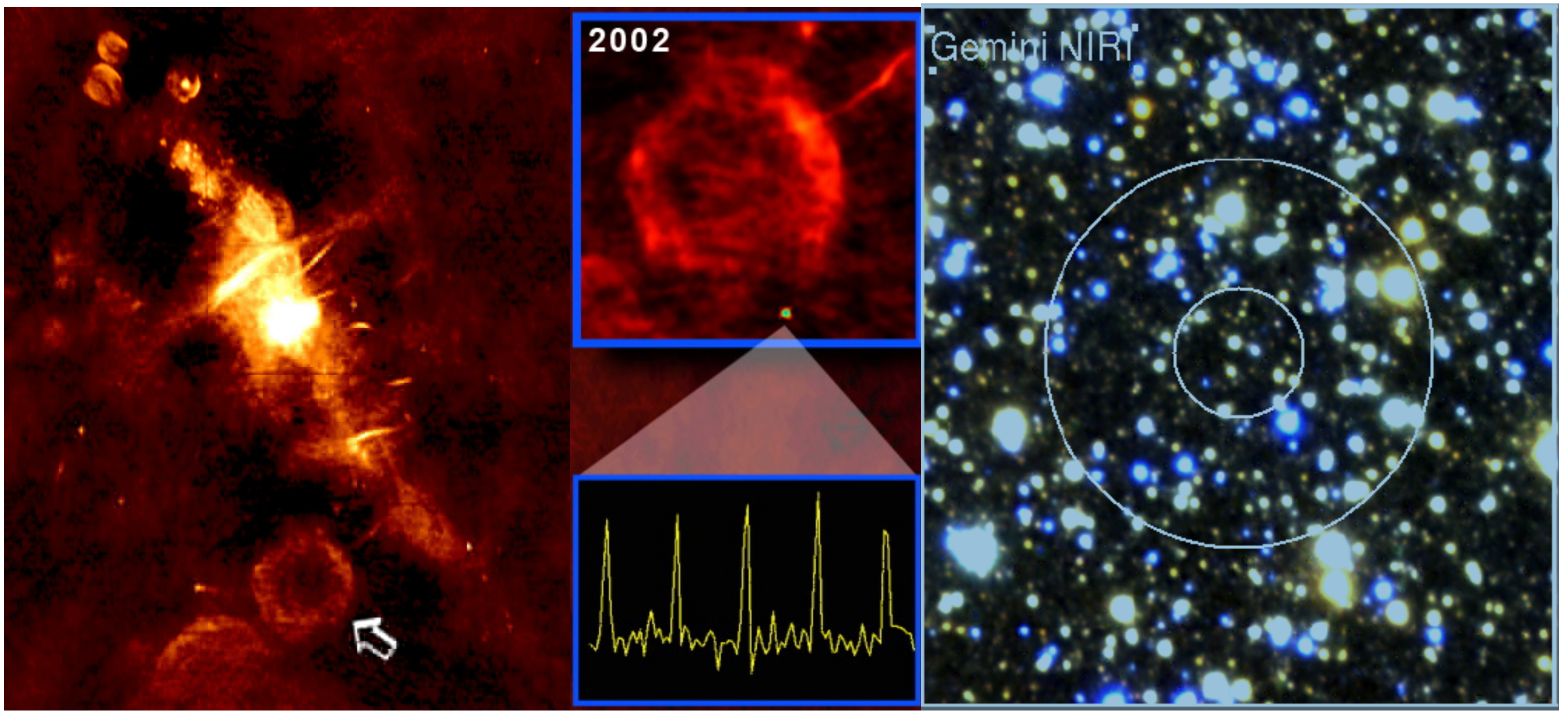


Benz et al. A&A (1998)



Donati et al. (2006)

Galactic -The Mysterious GCRT J1745-3009



- Pulsing source (period 77 mins) discovered in archival 330 MHz VLA data Hyman et al 2007)
- Localization too poor to establish an optical counterpart
- Nulling pulsar? White dwarf pulsar? Brown dwarf?

Roadmap forward

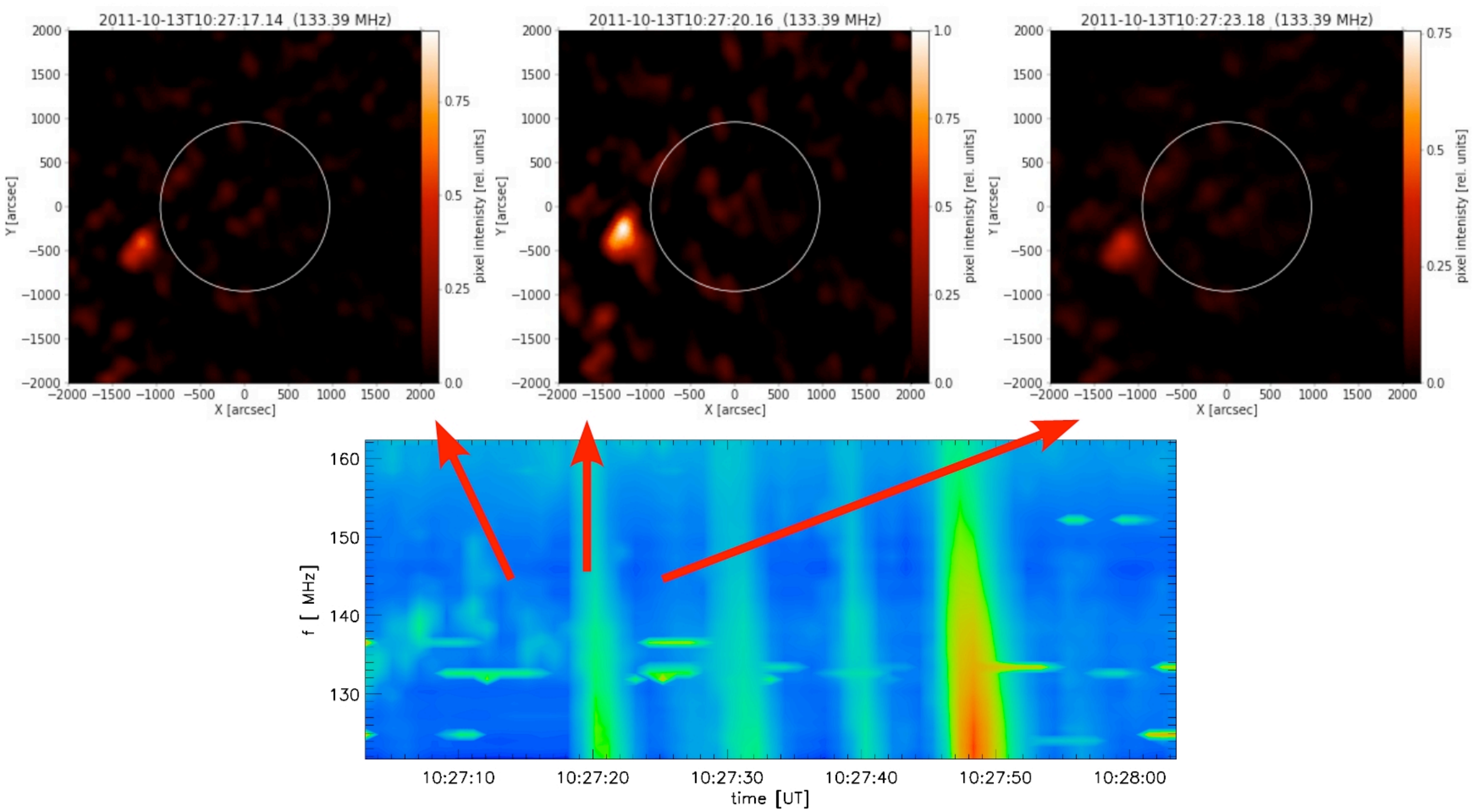
- Sept 2013 – June 2014: Installation of 32 additional antennas spanning a 2 km radius to give a 10-fold increase in resolution

- Powered by solar panels with data transport via optical fiber, delivering longer baselines up to 2km and eventually yielding all-sky images of resolution 5' at the top of the band

- This latter upgrade will facilitate:
    1) Better localization of transients
    2) A higher resolution all-sky catalog
    3) Solar dynamic imaging spectroscopy observations
    4) Longer baselines for LEDA calibration

Dynamic Imaging Spectroscopy of Solar Radio Bursts

- Day time observing with the Owens Valley LWA will be devoted to dynamic imaging spectroscopy of solar radio bursts
- Eg – LOFAR high band (http://www.aip.de/en/news/science/Lofar)
- Good synergy with LWA-1



The Cosmic Dawn Array

- Technology development at Caltech (Hallinan+) and JPL (Lazio+) for a much larger (>10^3 dipole) full cross-correlation array

- Funded 2013-2015 by a President and Director's Fund Award (internal to Caltech and JPL)

- Work underway includes
  1) migration to data transport via optical fiber
  2) solar-powered antennas and data processing nodes (digitization at the antenna)
  3) extended RFI surveys at and near OVRO
  4) data processing and archiving capabilities

- Concept to be developed with the LWA and LEDA collaborations (Super-LEDA); technology will migrate into ongoing LWA efforts

- Will serve as a survey instrument for a multi-station LWA

- **Key science:**

- **1) Power spectrum measurement of red-shifted HI at z~20 (Visbal et al 2012; McQuinn & O'Leary 2012)**

- **2) Detection of Jovian planets orbiting at 1 AU out to 10 pc**