The LOBO Concept and its VLITE Pathfinder

LOBO ≡ LOw Band Observatory

VLITE ≡ VLA Low Frequency Ionosphere and Transient Experiment

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VLA Below 1 GHz

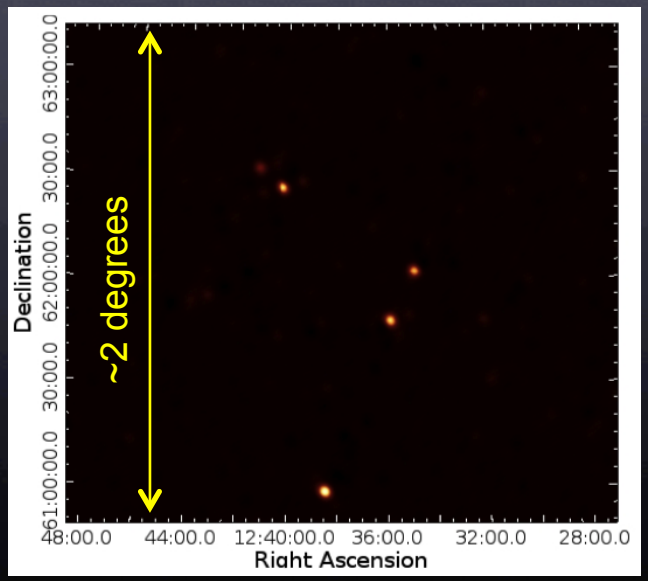
- 330 MHz (λ=90 cm): ~1990-2009
- 74 MHz (λ=400 cm): ~1998-2009
- Both systems widely utilized, state-of-the art over much of their lifetime
  - Two narrow-band legacy receivers: 74 MHz: Δν=1.6 MHz, 330 MHz: Δν= 6 MHz
  - **Decommissioned by VLA upgrade**
- ***Back as "Low Band" & much better than before!***
  - ***1 single receiver enables access to ~50-500 MHz of spectrum***
  - ***Current feeds utilizing 54-86 MHz, 236-492 MHz***

Early Commissioning Results

Early commissioning indicates the new LB system will significantly surpass prior VLA performance.
Most of the improvement is from the bandwidth: >15X at both frequencies
Current continuum spec: 200 μJy, 20 antennas, 1 hr, Δv = 200 MHz

GOODSN Field at 330 MHz

1st Light Image, Spring 2012, 4 antennas



4 antennas, ~10 min,
Δv ~ 115 MHz, σ ~ 20 mJy

Deeper Integration, Fall 2012, 7 antennas

~7 antennas, ~ 2 hrs,
Δv ~ 87.5 MHz, σ ~ 0.85 mJy, θ ~15”

The Inspiration for LOBO

- ASTRO 2010: Great discoveries lurk in the mysterious transient Universe
- Radio Transients poorly explored – why?
  - Traditional radio telescopes have limited FoV & transient observing time
- Ergo the current stampede to*:
  - Dipole arrays at low frequencies
    - Multiple-beams with large FoV
    - LOFAR, LWA, MWA, PAPER, HERA, SKA-Low
  - Upgrade cm-telescopes with focal plane arrays
    - Parkes multi-beam, ASKAP, MEERKAT, SKA-Mid
- ***What about the VLA?***
  - While developing LB: let's resurrect legacy VLA ***commensal*** modes: e.g. 4P, PL – useful for transients
  - Follow-on chat with eminent CV astronomer: "it's obvious, you want to take data at the prime focus all the time."

* EOR & Dark Ages *might* have something to do with it, too.

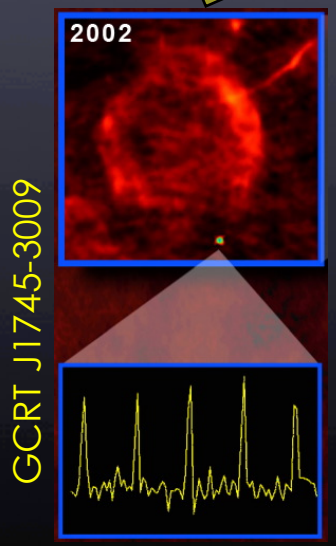
Birth of LOBO: Duh! Use the Primary Focus in parallel with Cassegrain observing *24/7*.

LOBO Concept: LOw Band Observatory

- VLA synoptic, high-z spectroscopy, transient & ionospheric monitoring facility.
- Primary focus in parallel with Cassegrain observing.
- Scheme 1: use VLA backend including a corner of WIDAR
- Scheme 2: Dedicated sampling, fiber transmission, & backend including correlator & pipelined data processing – ***minimal impact on VLA, more flexibility***
- NRL had seed funding for a commensal system but not enough for the full VLA, so what to do …

VLITE: A Pathfinder to LOBO

- VLITE: 10 antennas, 64 MHz BW, 3 yr lifetime
- More than 6000 hours/year potentially available.
- SRR 11/13 ✔, PDR 12/13 ✔, CDR 04/14 ✔
- Commissioning now underway
- Concept not new, being pursued at other observatories (GMRT, LOFAR, MWA, LWA, Molonglo, etc)
- **Scientific Focus**
  - **Transients**: VLITE Maximizes Ω*t, explores parameters space where known transients have been found – slow & fast transient searches planned
  - **Ionosphere**: A new field of remote sensing is calling out for continuous, real-time monitoring - ionospheric waves can be well characterized with 10 antennas
  - Both applications require full-time 'all-sky' monitoring, and can be useful even as a limited system



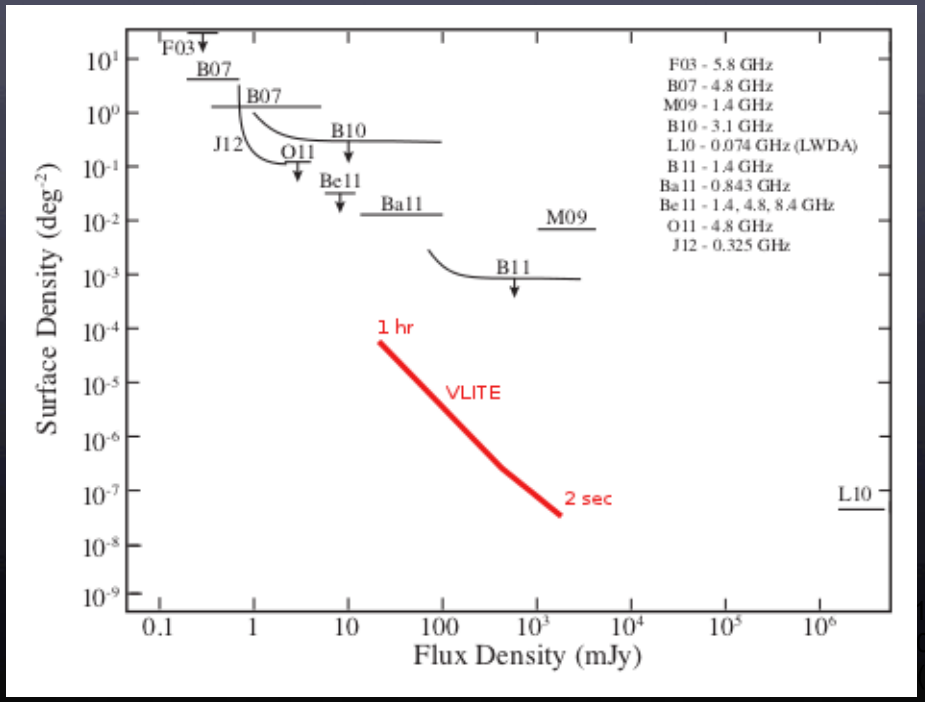
Hyman et al., Nature, 434, 7029, 2005

Above right: One of the most exotic radio transients known was discovered by the 330 MHz VLA [illegible]

VLITE Transient Pipeline

Motivation: Why are we doing this?

- Compared to previous transient surveys, we can set competetive limits
- Because VLITE will be on the sky for thousands of hours per year
- Efficient use of free photons - little impact on VLA's primary mission

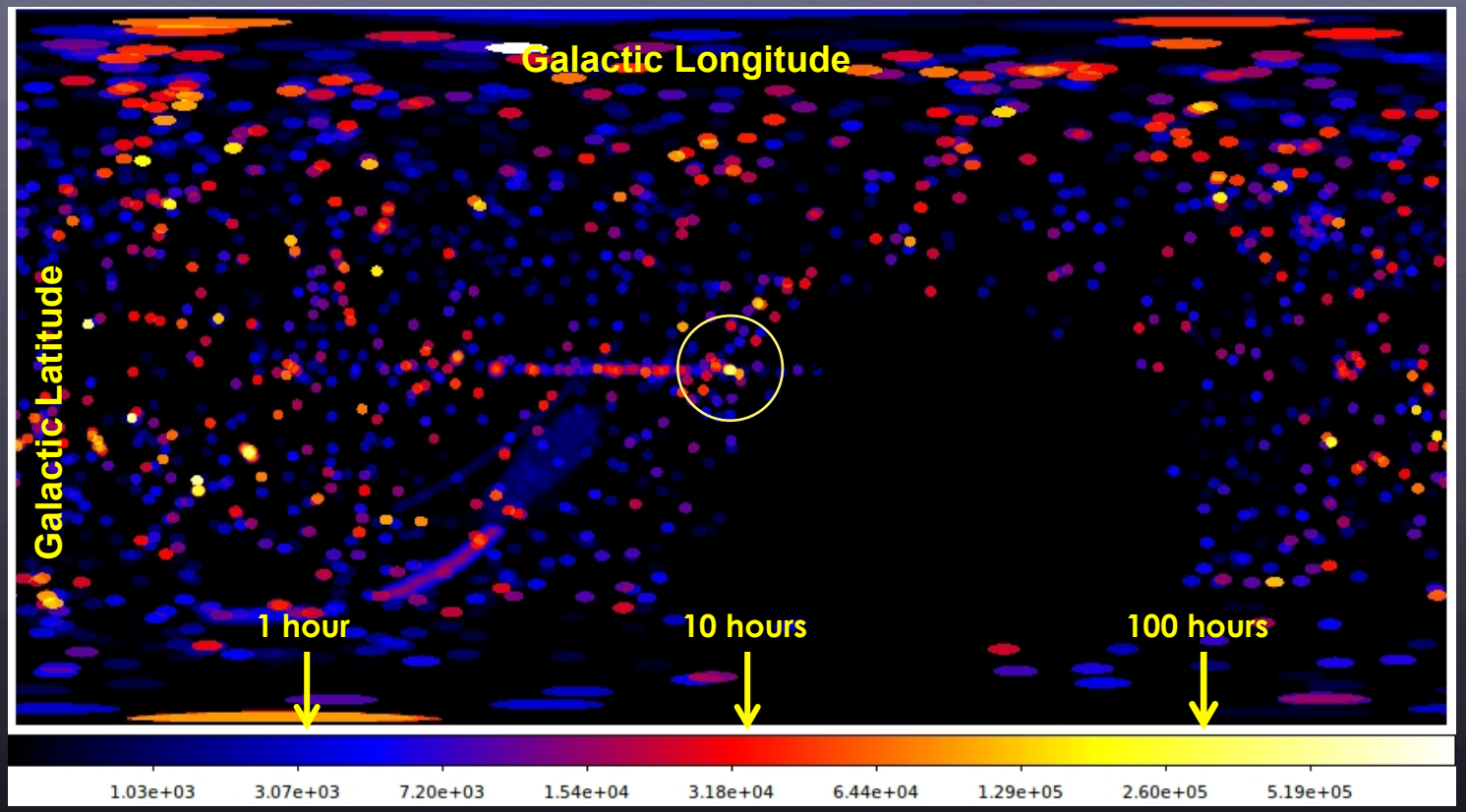


- Surface density vs. radio flux density for transient searches with sub-day time resolution.
- Arrows indicate 95% confidence upper limits for searches resulting in no detections.
- Estimates based on one-year of VLITE observations are shown in red.
- Assumes 30% on-sky for 2A+2B configurations. (~2/3 for 2 sec, 10 sec, 5 min transients, ~1/3 for 1 hr transients.)
- FoV 5 square degrees

0); Bower & Saul (2011)
011) (Ba11), Bell et al.
2012) (J12).

The VLITE (or LOBO) Sky in 1 Year

VLA Yearly Sky Coverage (330 MHz) vs. Dwell Time



VLITE Exposure Map

About [25,10]% of the accessible sky is observed for at least [100 sec, 1 hr] per year, respectively

LOBO is a proposed, dedicated, radio synoptic, high-z spectroscopy, and real time transient capability of the VLA – VLITE is its funded pathfinder.

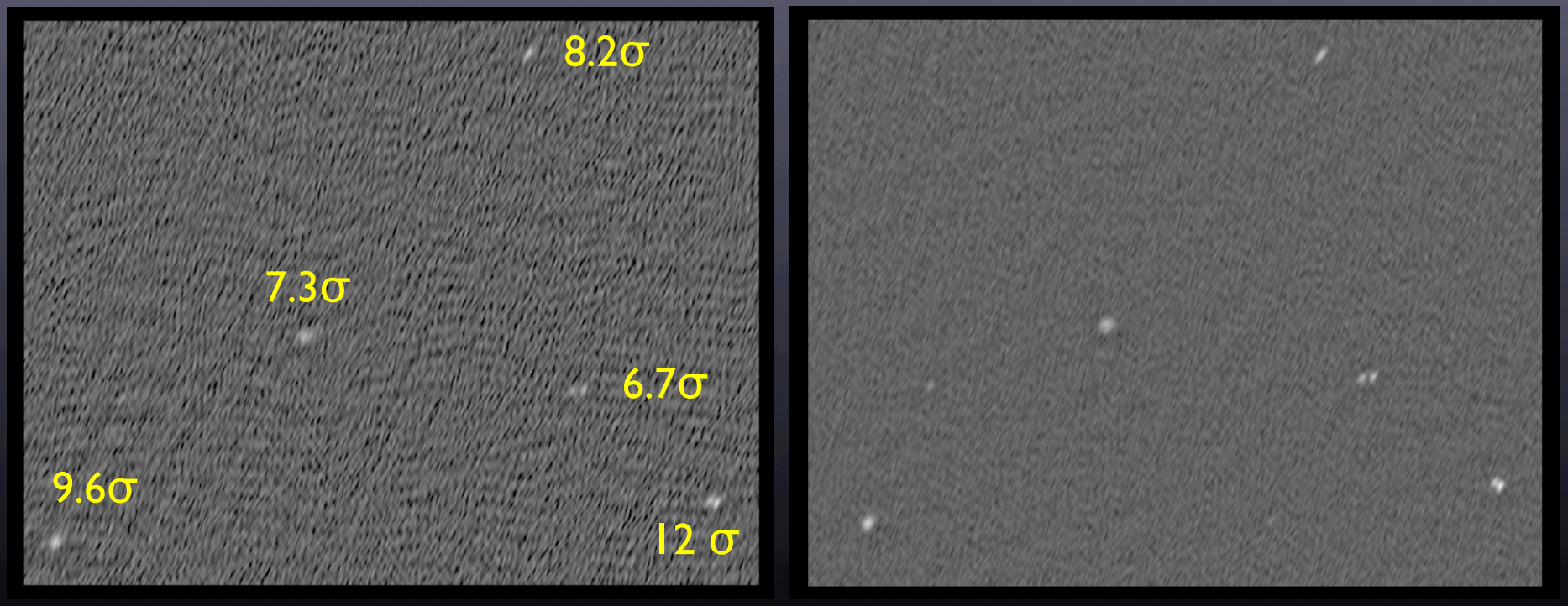

DiFX FITS-IDI
Append contiguous scans, discard small scans
Get scan (Δt)
5 s < Δt < 1 hr
Learned RFI mask & self-mitigation
Apply last BP & flux cal w/ focus correction
Enter OBIT
Deloop, keep Δt ≥ 5 m
Are sources above model threshold?
BP, phase & flux cal, RFI, self-cal & 3D image
Catalog @7σ, find @10σ
Find N > 10 σ
N=0
TO INTRA-SCAN SEARCH
n=0
Find n > Mod$_t$
Use PBCOR integrated fluxes
May be necessary depending on beam size and source spectra.
p=n
Find p counterparts
Model thresholds initially WENSS- or NVSS-based, later VLITE model
n-p>0
Sources missing in sky model?
q=0
Find q in both time half images
Transient Scan Pipeline
q triggers
Make IF images. Tag uv & all images
Visually inspect maps, IF & any pol checks. Initiate follow-ups as needed.
Alert
Human Intervention

Proxy VLITE Scan Images

- 10σ catalog threshold in current strawman pipeline is conservative
- Don't want to be swamped in triggers
- Almost all catalogued sources will be NVSS or WENSS sources

10 antennas, σ = 3.4 mJy

27 antennas, σ = 1.4 mJy



Both images $\Delta\nu$=64 MHz, t_{obs}= 64 min

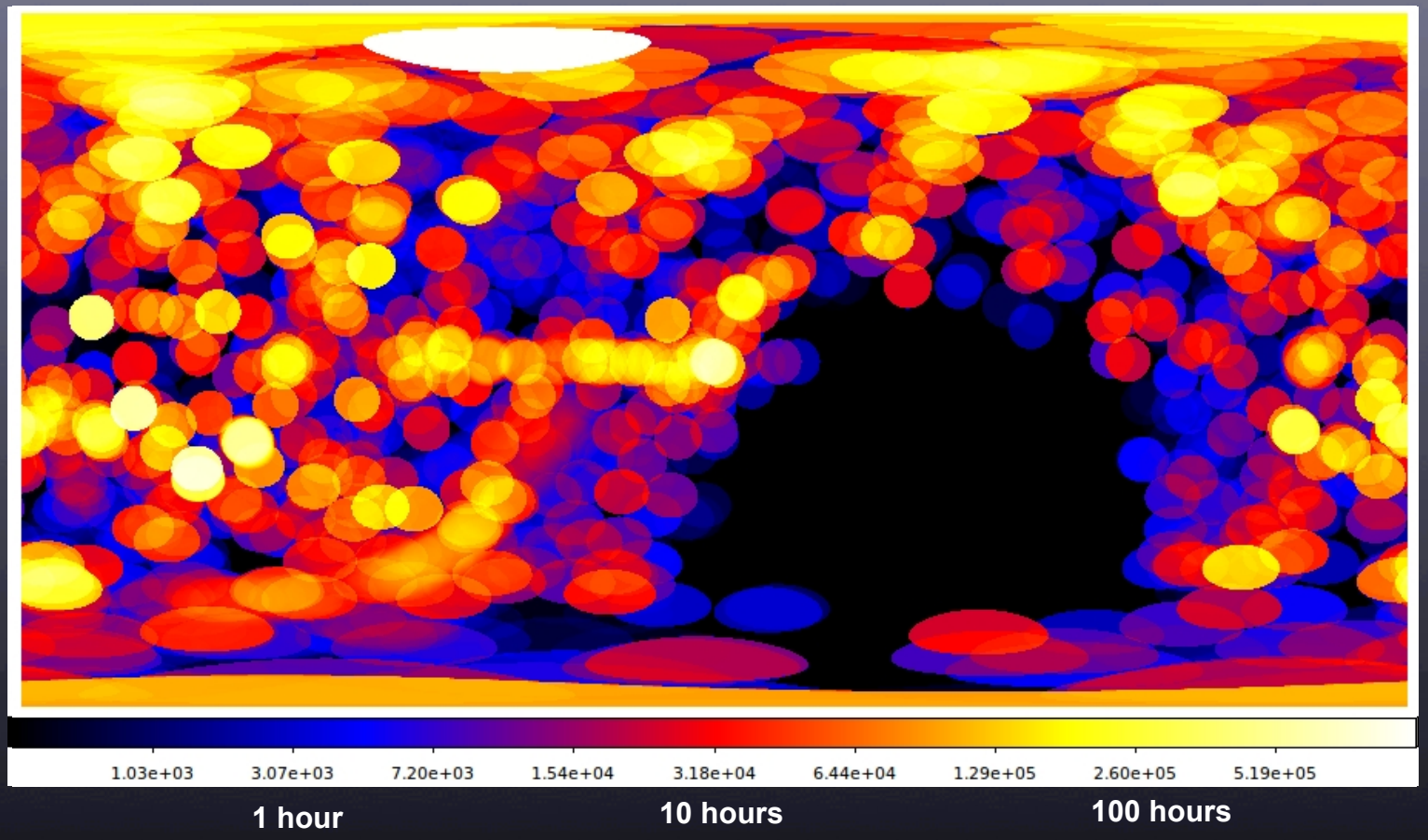
VLI
TE

Consider a Merger Dream: VLITE and LWA

- VLITE utilizes the 330 MHz band within Low Band, but the receivers can handle ~50-500 MHz
- On a parallel front, efforts by Subramanyan and Ellingson have developed improved “4-band” feeds for the VLA
  - If successful, better than the old 74 MHz narrow band feeds
  - 60-80 MHz, permanently mounted
- It is possible that these feeds would initially populate VLITE antennas
- ***If completed, VLITE with LWA1 and LWA-SV comprise a genuine12-element imaging instrument with thousands of hours on the sky each year!***
- The system could grow with the addition of more LWA stations or VLA dishes

The LWA-VLA Sky: 1 Yr Exposure Map

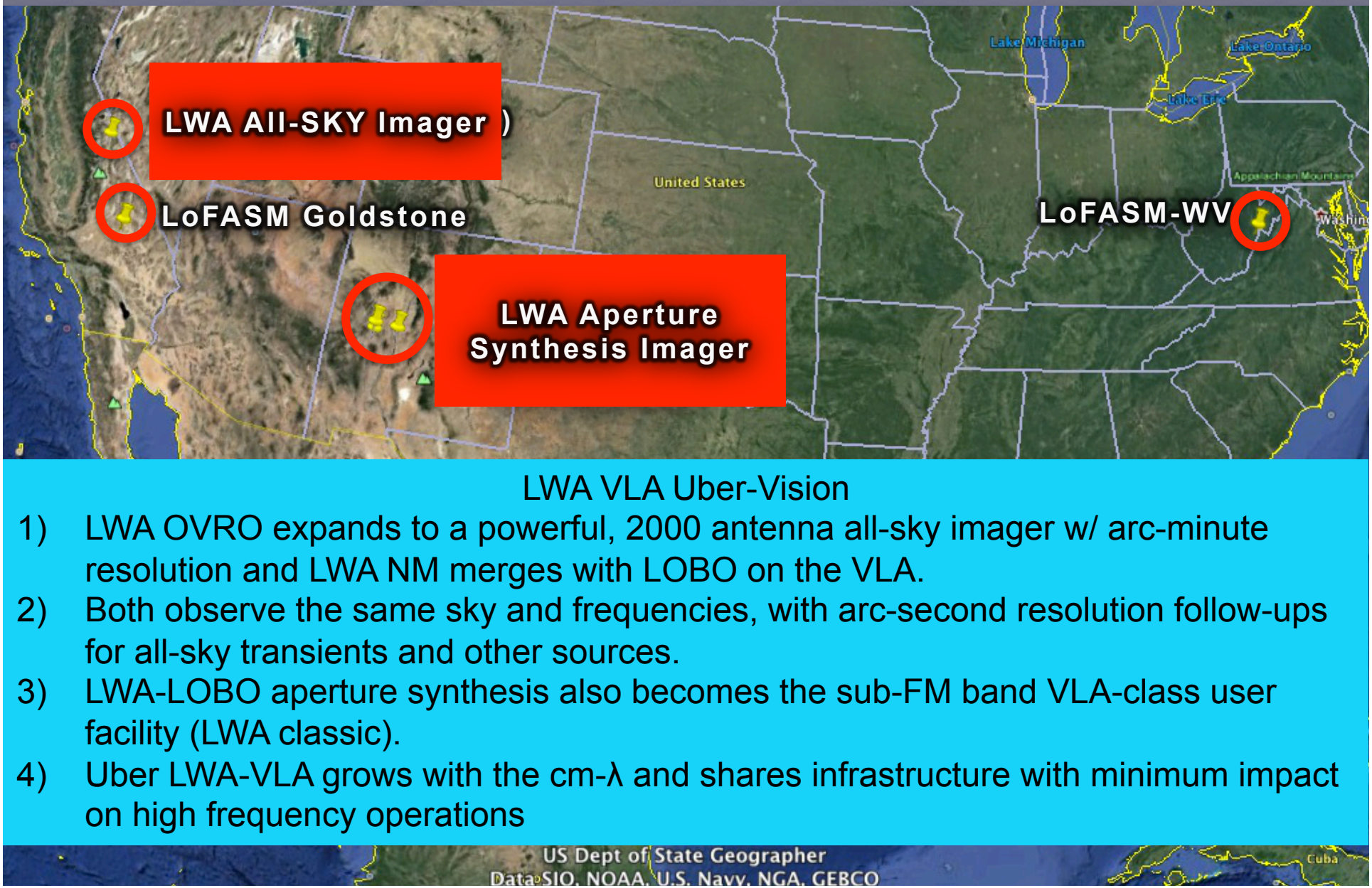
74 MHz FoV



1 YEAR @ 330 MHz:

- ~6000 hrs on sky, ~25% of the VLA sky (~20% of full sky)
- 74 MHz: > 30,000 deg^2 or ~97% of the VLA sky
- VLA accessible sky ~ 33,000 deg^2

Expansion of LW Radio Astronomy in the US
LWA Magna Americana



LWA VLA Uber-Vision

1) LWA OVRO expands to a powerful, 2000 antenna all-sky imager w/ arc-minute resolution and LWA NM merges with LOBO on the VLA.
2) Both observe the same sky and frequencies, with arc-second resolution follow-ups for all-sky transients and other sources.
3) LWA-LOBO aperture synthesis also becomes the sub-FM band VLA-class user facility (LWA classic).
4) Uber LWA-VLA grows with the cm-λ and shares infrastructure with minimum impact on high frequency operations

Summary

VLITE is a pathfinder for a full VLA commensal system
- A seamless copy of the VLA with a large FoV
- Initially 10 antennas @330 MHz, expandable to LOBO
- Initial Science: Transients & ionospheric science

- If VLITE is instrumented to LWA frequencies, it would provide a path for integrating the LWA into a commensal VLA system
  - For the 74 MHz VLA: improved calibration and angular resolution
  - For the LWA: Imaging!!
  - Growth path for both by expanding VLITE to LOBO, and growing LWA stations with an expansion of the VLA, inc. to the inner VLBA stations

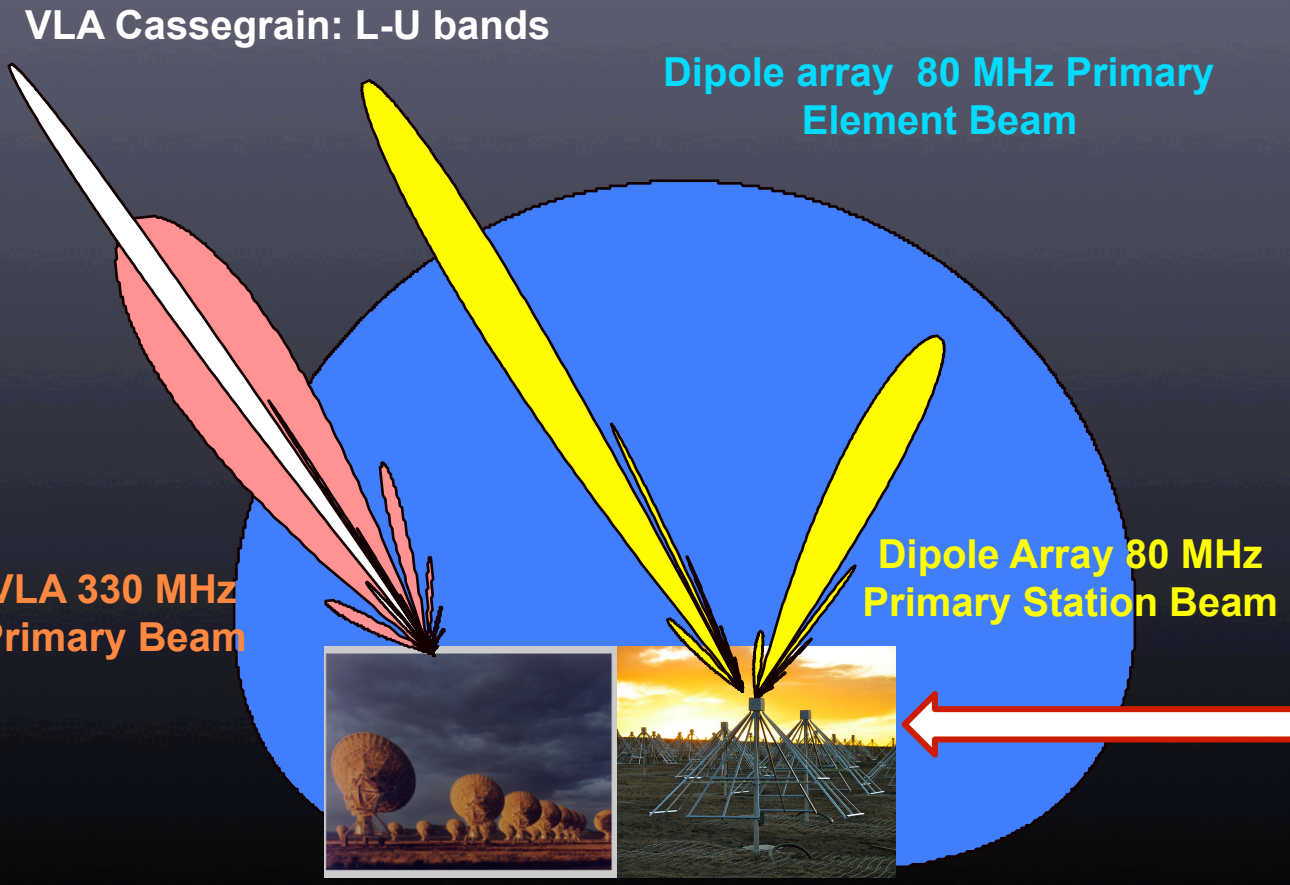
- LWA-LOBO could eventually provide the arc-second resolution follow-up imaging required to fully exploit all-sky imaging at OVRO

A merged LWA & VLA Low Band commensal system, complimenting an all-sky imaging LWA OVRO, would enrich an expanded VLA at a fraction of the total cost.

Backup

Synergy with Other Instruments

Telescopes sharing the VLA sky, especially dipole arrays e.g. LWA1, LoFASM, LWA-OVRO, LOFAR can track the LOBO FoV. Everyone trigger everyone.



LWA1: poster child of instruments that can interface efficiently with LOBO