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(ngLOBO) High Resolution, Low-Frequency Imaging and High-z HI Cosmology: The Long View Towards Instrumental Convergence

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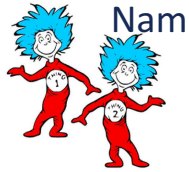
Technical Drivers for LF Astronomy: Thing 1 & Thing 2

Driven by Cosmology

- Targets – HI (HII eventually)
- Techniques – Spectroscopy
- Baselines – Condensed
- Angular Resolution - Low
- Science Themes: Epoch of Reionization, Dark Ages
- Analogy: CMB experiments

Aaron & Judd Namir



Driven by Astrophysics

- Technique – High angular resolution Imaging
- Baselines – Extended
- Discrete Targets: Sun, planets, stars, SNRs, AGN, Clusters … & Transients
- Science Themes: Astrophysics, Heliophysics
- Analogy: JVLA targeted obs. & surveys

The underlying technical requirements and scientific motivations are very different.*

*** Foreground removal**

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Technical Requirements

EOR & Dark Ages

- Baselines: < 5 km - redundant good
- High T_B sensitivity (~1 mK)
- Approach: Rapidly evolving
- E.G.: EDGES, MWA, LOFAR (core)*, LEDA, CHIME, HERA, LFAA, DARE
- ***Detection required*** to define next major instrument design

Astrophysics

- Baselines: > 100 km
- Arc-second resolution, sub-mJy
- Approach: Aperture synthesis
- Examples: LWA (NM, OVRO), LOFAR (extended)*, JVLA/VLITE, GMRT, ngLOBO, LFAA, SUNRISE
- Robust concepts since 1980s

Cosmology: Innovative progress within limited parameter space.
Astrophysics: Poised for major step to explore broad parameter space.

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Technology Synergies: Relevant *now* and being exploited

Both pursuits share common technical needs, including:

- Stable, wideband, linear receivers
- RFI avoidance
- Calibration & Imaging, e.g. ionosphere, wide fields, etc.
- Feeds (in some cases)
  - Example: LEDA utilizing LWA stations for Dark Ages
- Innovations in DSP, GPU-based correlators, etc.

Cross-fertilization and sharing has been good.

ngLOBO: "Cheaper, Faster" Concept for Thing 2 (Astrophysics)

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ngLOBO Low – embedded within ngVLA

- 50 stations, 256 dipoles per 100 m station, $B_{max} \geq 400$ km
- BW: . . . . . 5 – 150 MHz
- FoV: . . . . . 120' @ 80 MHz
- FWHM: . . 1.4" @ 80 MHz
- σ = 0.5 mJy @ 80 MHz [1 hr, 4 MHz]
- **1 beam commensal with ngVLA**
- 3+ beams for ionosphere, solar, space science & applications ($$)

- *Pathfinder: LWA (4 beams + all-sky)*

ngLOBO High - commensal on ngVLA

- Feed near ngVLA antennas prime focus
- BW: . . . . . 150 – 1500 MHz
- FoV: . . . . . 193' @ 300 MHz
- FWHM: . . 0.6" @ 300 MHz
- σ < 7.15 μJy @ 300 MHz [1 hr, 500 MHz]
- **Single beam commensal with ngVLA**
- *Pathfinder: VLITE - prime focus commensal on JVLA,* ***>6000 hrs/yr***

Commensal with ngVLA: Leveraging tremendous infrastructure.

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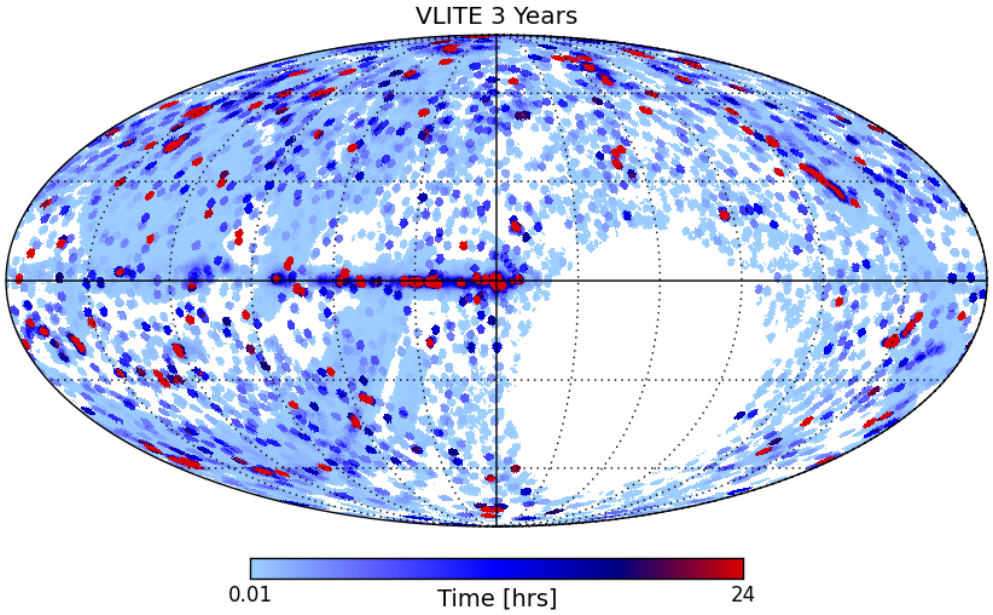
Commensal *LF Power*

VLITE

After 3 years:
20,000 hrs,
72000 images,
90% @ 30 s, 50%
@ 30 min, 25%
@ 2 hrs

http://vlite.nrao.edu



VLITE heaving lifting:
Clarke, Peters,
Giancintucci,
Polisensky

A sub-GHz commensal system on a GHz telescope throws a wide net (& does not have to be perfect).

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Near Term: Separate Tracks

A distant, cold Universe (z>6)

- Detection of an EOR signature is a prerequisite to follow-on radio imaging
- Effort best pursued by experiment-class instruments (e.g. HERA, Aaron's talk)
- Frequency and technology overlap between but no baseline overlap

The warm Universe next door (z<6)

- Next major step in low frequency astrophysics has been known since self-calibration propagated to radio interferometry (Perley & Erickson 1984)
- As the [VLA ➡ JVLA ➡ ngVLA] evolves, we know the footprint of the required low frequency instrument looks the same

Cosmology: Immersed in an Epoch of Experimentation.
Astrophysics: Shovel ready for next major step!

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Cautionary Thoughts of Premature Mergers

- While politically attractive at the outset, a single instrument (or even project) to pursue both ***Things*** now is unwise
- For the EOR, a large follow-on project should await an experimental detection – Penzias & Wilson preceded *WMAP*
- Barring infinite funding, coupling both themes in a single project risks fragmenting critical scientific advocacy groups
- Situation exacerbated when de-scoping becomes inevitable

Been there, done that, keep seeing that ...

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Longer Term: It's the same Universe

- HERA targets emission corresponding to global structure in the early Universe
- Over time EOR structure evolves to smaller scales detectable by ngLOBO, e.g. radio galaxies and clusters
- Between the largest and smallest scales accessible to ngLOBO and the EOR experiments, respectively, lies a common regime of *Large Scale Structure* (LSS).

Eventually, both approaches could be driven by technical requirements requiring a commonality in frequency, **baseline coverage, and imaging**.

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Summary

- The Cosmology projects are embedded in a baseline regime with little commonality with the Astrophysics driven projects
  - Progress towards a detection is ongoing, but steps after that are TBD
- The Astrophysics+ driven projects know their next step: A midscale project that fits naturally within the extended infrastructure of ngVLA is one approach
  - Experience with aperture arrays and commensal observing has helped a lot
- There is a regime of overlapping scales too large and small for ngLOBO and HERA, respectively, that may motivate a condensed core embedded in the ngVLA
  - Let there be convergence (eventually)!

A low frequency, ngVLA-core for large scale structure and EOR imaging could unify technical requirements across astrophysics & cosmology.