Long Baseline Capabilities of the ngVLA

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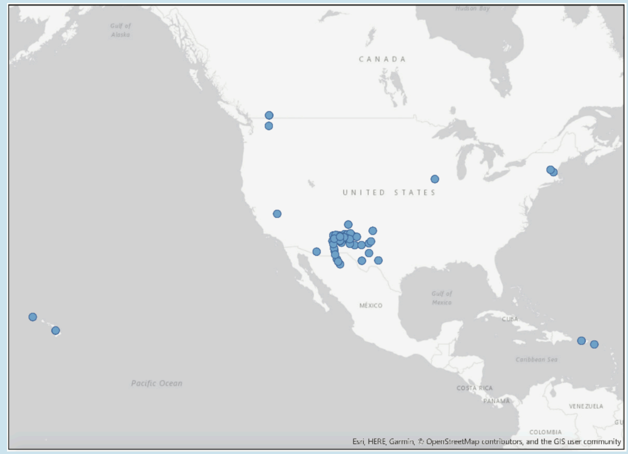
The ngVLA reference design includes three primary subarrays: the main interferometric array (MA), a short baseline array (SBA), and a long baseline array (LBA). Together these provide sensitivity on a large range of angular scales. The LBA, which enables imaging and astrometry at the highest angular resolutions, will consist of thirty 18-m dishes that will extend across North America and beyond. The ngVLA LBA antennas will be grouped into 10 clusters of two to four each and will leverage infrastructure from existing facilities. LBA Baselines will reach continental scales ($B_{max} \cong 8860$ km), providing angular resolutions as fine as 0.6 mas at 10 GHz. The LBA is designed to operate both as a stand-alone sub-array, and for integrated operations with the main array. LBA antennas will operate at the full frequency range of the main array, 1.2 to 116 GHz. We highlight one science case for the LBA involving observations of extragalactic water vapor megamasers at 22 GHz. These observations with the ngVLA will permit a geometric, percent-level measurement of the Hubble Constant and significantly expand the number of megamaser systems used to measure gold-standard masses of supermassive black holes. The Next Generation Very Large Array is a design and development project of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.



LBA Design Characteristics and Science Opportunities

- LBA will consist of 30 antennas, each 18 m in diameter, clustered at ten remote sites in groups of two to four. Table 1 shows possible sites. LBA stations are selected to minimize site impact and leverage existing infrastructure.

Antenna Quantity	Location	Possible Site
3	Arecibo, Puerto Rico	Arecibo Observatory
3	St. Croix, US Virgin Islands	VLBA Site
3	Kauai, HI	Kokee Park Geophysical Observatory
3	Hawaii, HI	New Site
2	Hancock, NH	VLBA Site
3	Westford, MA	Haystack Observatory
2	Brewster, WA	VLBA Site
3	Penticton, BC, Canada	Dominion Radio Astrophysical Observatory
4	North Liberty, IA	VLBA Site
4	Owens Valley, CA	Owens Valley Radio Observatory

Table 1: Possible antenna sites and cluster configurations for LBA anennas. The sites include VLBA stations and other existing radio observatories.

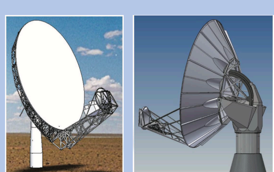


Figure 1: Antenna design concepts prepared by General Dynamics Mission Systems (left) and the National Research Council of Canada (right)

- Maximum baselines of 8860 km will enable an E-W beam of 0.6 mas at 10 GHz, meeting a science use case to measure proper motions of GW events at 200 Mpc.
- Smallest E-W synthesized beam size will be 0.07 mas at the "Band 6" central frequency of 93 GHz.

- LBA also includes intermediate (1000 km) and short (30 m) baselines, making it suitable for imaging or astrometry even without the main array.
- The ngVLA opens new parameter space for wide-ranging science applications, with astrometric accuracy approaching 1 μas.
- Far-reaching science applications include, for example, detecting binary black holes, measuring Milky Way structure, and tests of anisotropic cosmological expansion.

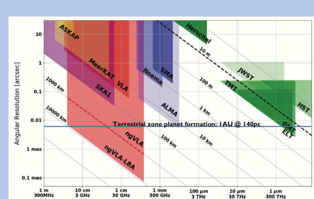


Figure 2: ngVLA+LBA coverage of spatial resolution vs. observing frequency, compared to other existing and planned facilities.

Science Highlight: Cosmology with H_2O Megamasers

- Observations of H_2O megamasers in edge-on accretion disks of AGN, as in UGC 3789 (Fig. 3), probe gas on sub-pc scales within the black hole sphere of influence and provide gold-standard black hole masses. When combined with spectral line monitoring, megamasers provide geometric distances to the host galaxies and determine H_0 directly.
- Megamasers in accretion disks are rare and faint, pushing current telescope facilities to their sensitivity limits. About 10 megamasers have measured distances with existing facilities, including those shown in Fig. 4.

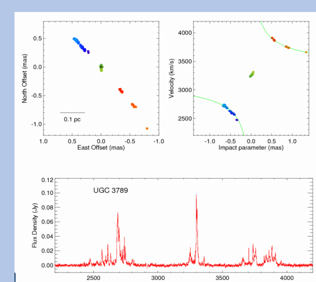


Figure 3: VLBI map made with the High Sensitivity Array (top left); P-V diagram with fitted Keplerian rotation curve (top right); and a representative GBT spectrum (bottom).

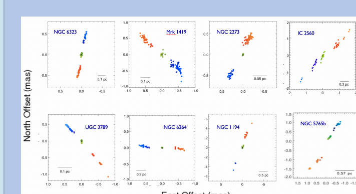


Figure 4: VLBI maps of megamaser systems measured by the Megamaser Cosmology Project

- With order-of-magnitude gains in sensitivity, the ngVLA will enable detection and measurement of dozens of new megamaser systems.
- A goal of the observational cosmology community is 1% H_0 measurements from multiple, independent methods. The megamaser method requires the ngVLA to reach this goal.

- The megamaser-based method currently gives: $H_0 = 73.9 \pm 3.0$ km s^{-1} yr^{-1} (4%) (Pesce et al.).
- This value is in agreement with standard candle measurements and in tension with LCDM predictions calibrated by the CMB.

References

- Braatz, J. et al. ASTRO2020 science white paper #446, 2019
- Braatz, J. et al. "Science with the Next-Generation VLA", ed. E.J. Murphy, 2018
- Pesce et al., "MCP XIII: Combined Hubble Constant Constraints, in prep.

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