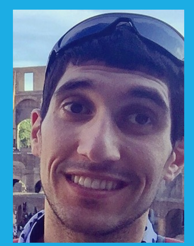

ENVISIONING A SETI PROJECT FOR THE ngVLA

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BACKGROUND

The search for extraterrestrial intelligence (SETI) relies on our ability to detect and recognize **technosignatures**—signs of activity from a technologically advanced civilization. We expect that, similarly to humans, alien civilizations may utilize electromagnetic radiation in the radio bands to send and receive information.

Technosignatures are expected to:

√ have very narrow bandwidth (~ 1 Hz),

√ display a Doppler drift due to relative accelerations between source and receiver,

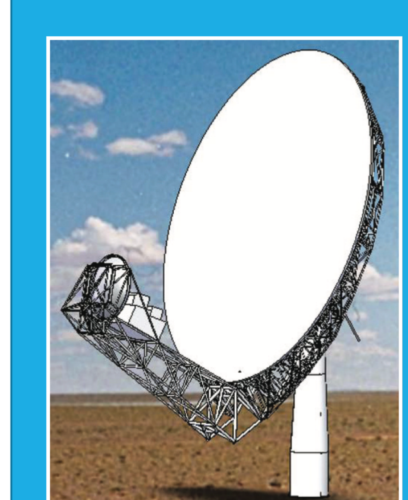
√ not be explainable as radio frequency interference (RFI).

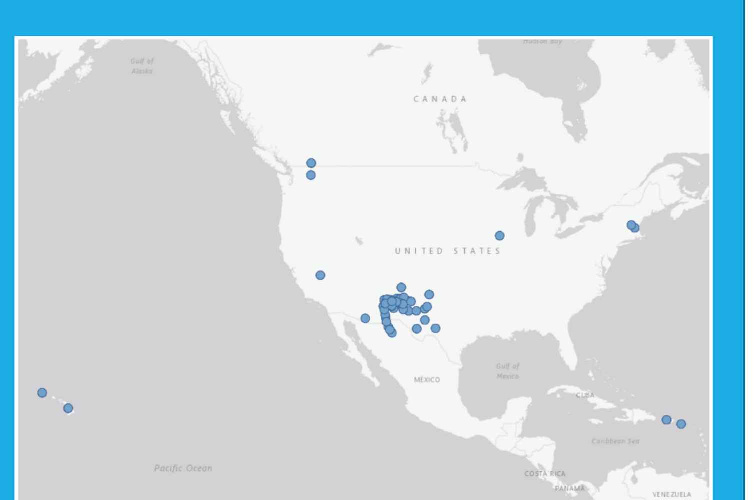
The **Next Generation Very Large Array (ngVLA)** promises to achieve exceptional resolutions and would become an invaluable tool for SETI once it is operational.

QUESTIONS

- **How much sky area** have searches covered?
- From **how far away** can we detect a signal at least as strong as what humans can generate?
- What **improvements** can ngVLA bring to SETI?
- What are the most **optimal search parameters** for a SETI project using ngVLA?

ngVLA QUICK FACTS





Composition:	244 18-m dishes + 19 6-m dishes across North America
Frequency range:	1.2 GHz to 116 GHz (6 receivers)
Best resolution:	2.91 mas (2.4-GHz receiver) to 0.07 mas (93-GHz receiver)
SEFD (coherent sum):	4.7 Jy (93-GHz receiver) to 1.2 Jy (8-GHz receiver)
Timeline:	Construction start: 2025 Earliest operations: 2028

Figures from: *ngVLA System Reference Design Vol. 1: System-Level Design.* [1]

RESULTS

Figure 1 illustrates **where in the radio frequency band** SETI projects have searched as well as the **solid angle of the sky** that was observed. For reference, the whole sky represents a total solid angle of 41,253 deg^2.

Sensitivity is classified into four tiers, depending on how far the search could detect a 1-Hz-wide signal with the power of **Arecibo** (10^{13} W), considered the most powerful signal our own civilization can emit.

Figure 1 demonstrates how more recent and future searches are generally greater in extent and in sensitivity. ngVLA stands out for its superior sensitivity and its ability to better search higher radio frequencies.

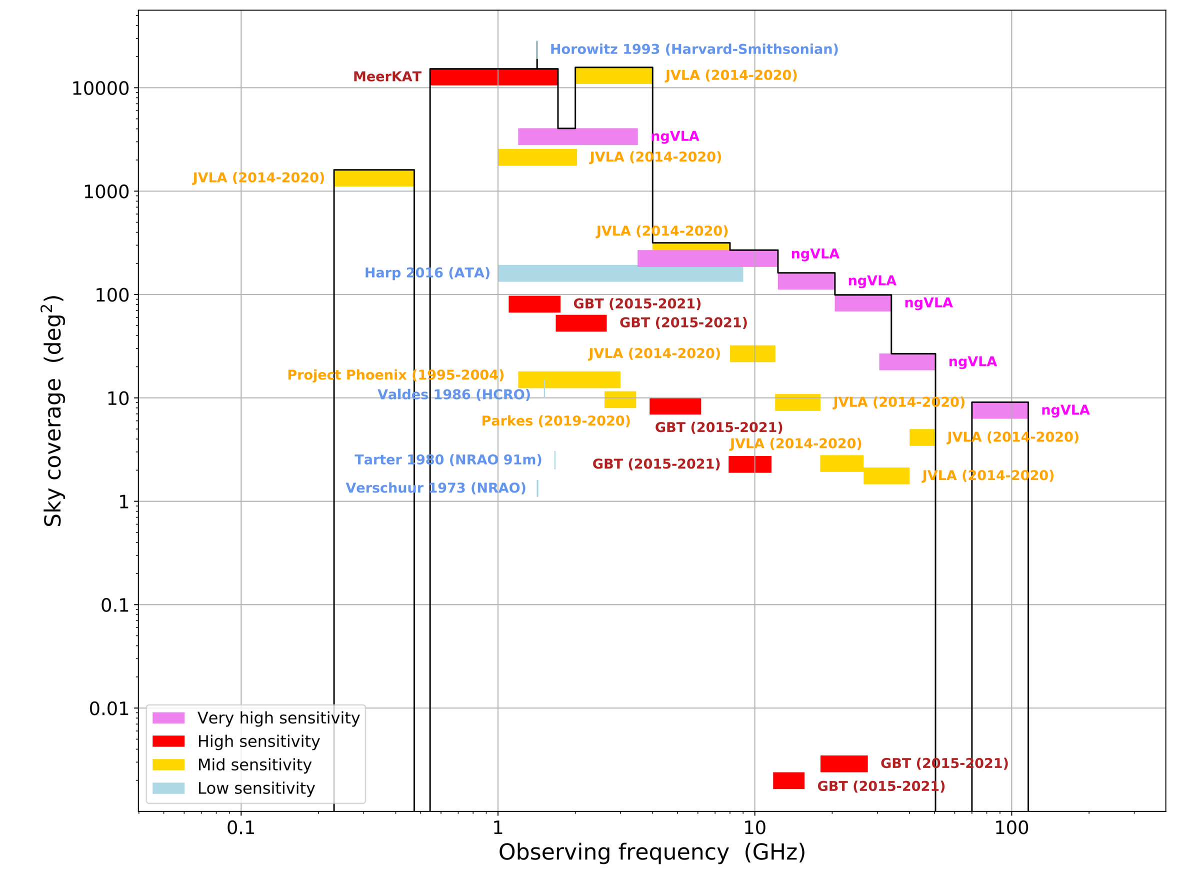


Figure 1: Extent of SETI projects in frequency space and in sky area

Figure 2 further examines search **sensitivities**. The top horizontal axis shows **minimum detectable flux** on a while the bottom horizontal axis translates this value into the **maximum distance** for the detection of a 1-Hz-wide Arecibo-like signal.

ngVLA's most sensitive receiver (8-GHz receiver) would have the ability to detect such a signal as far as just over **300 pc away**.

Considering our own galactic disc is over 30 kpc in diameter, even our most ambitious search cannot look beyond our immediate neighbourhood for civilizations emitting signals similar to our own.

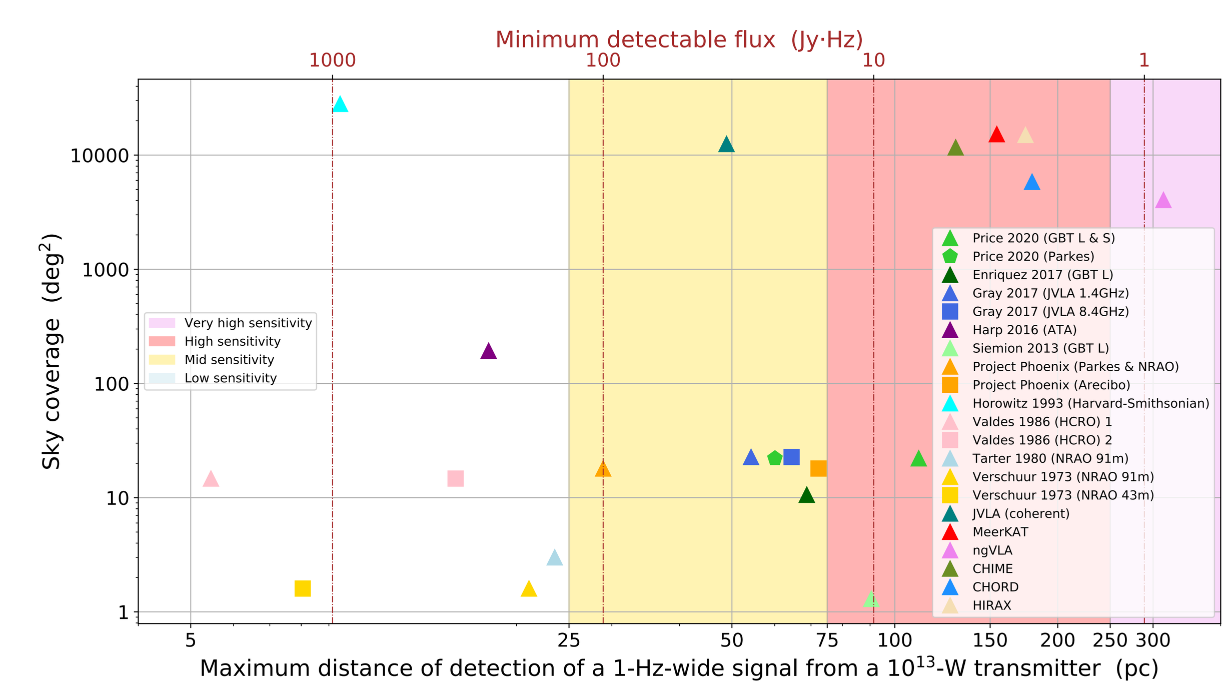


Figure 2: Sensitivity of SETI projects

For more descriptions of the other surveys included in this figure, see discussions in Enriquez et al. [2]

Figure 3 shows the predicted **receiver usage** in a typical year for ngVLA based on the notional Envelope Observing Program (EOP). [3]

Future science goals will spend more time observing in **higher frequencies** compared to the current Very Large Array (VLA).

Since SETI using ngVLA is expected to be **commensal**, i.e. by obtaining the data that was collected for other science goals, Figure 3 provides a preview of the frequency bands that will be searched for technosignatures. These frequencies have so far been poorly explored by other SETI projects.

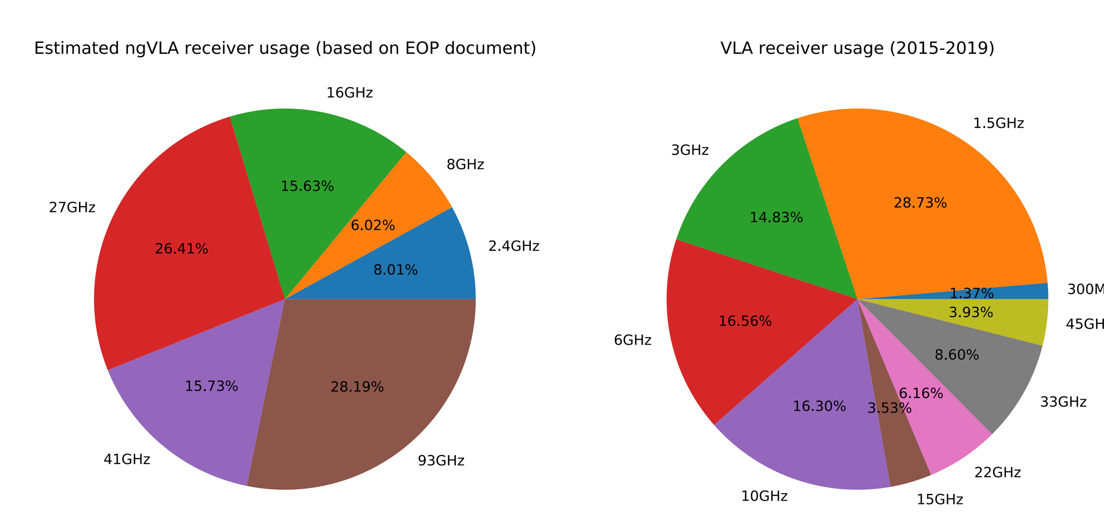


Figure 3: Receiver usage of the ngVLA (left) compared to that of the VLA (right)

DISCUSSION

Assuming a commensal SETI project with ngVLA, targets, frequencies, and observing times will be predetermined by other science goals. However, if raw voltage data is obtainable, multiple targets of interest can be observed in the same field of view through **coherent beamforming**.

According to Shiekh et al., [4] SETI projects should optimally aim to detect a **maximum drift rate of 200 nHz** (200 Hz/s at 1 GHz). The ability to detect high drift rates with ngVLA will be limited by computing power. The search must run at least as fast as the observation data is recorded multiplied by the number of coherent beams.

Detection of a technosignature is highly dependent on the chosen **signal-to-noise ratio** (SNR) threshold. A lower threshold allows us to pick up more candidates but also results in more RFI detection and a slower search algorithm.

CONCLUSIONS

Over the years, SETI surveys have improved in their sensitivity and in the observation frequency range. Soon, SETI efforts will have observed a varying amount of sky area between 200 MHz and 100 GHz.

Our best efforts with ngVLA will detect signals like our own up to 300 pc away and allow us to explore higher radio frequencies more extensively.

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ACKNOWLEDGEMENTS

This work is supported by the Summer Undergraduate Research Program (SURP) in astronomy & astrophysics at the University of Toronto. This work is also supported by the ngVLA Community Studies program, coordinated by the National Radio Astronomy Observatory (NRAO).

Thank you to Evan Keane and Caoimhe Mannion of the National University of Ireland Galway for their collaborative help and useful discussion.