# Pulsar Coffee

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3rd September, 2025

# Outline

- GPU Correlation, Decomposition, & Beamforming Pipeline (XDB engine)
- extraterrena / Signal Simulator

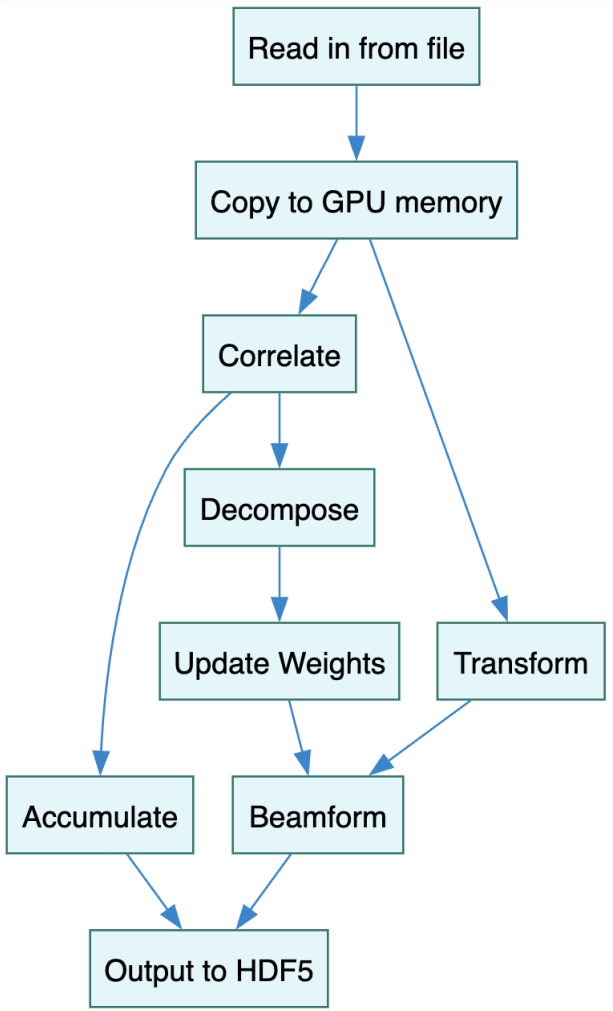
# GPU Pipeline

- A pipeline to process raw voltage packets from telescope.
- Aims to be a test & benchmarking system for real-time RFI cancellation.
- Uses cuTENSOR & cuSOLVER from NVIDIA.
  Tensor Core Correlator / ccglib from ASTRON.

# XDB Engine

- X = Correlate
- D = Decompose
- B = Beamform

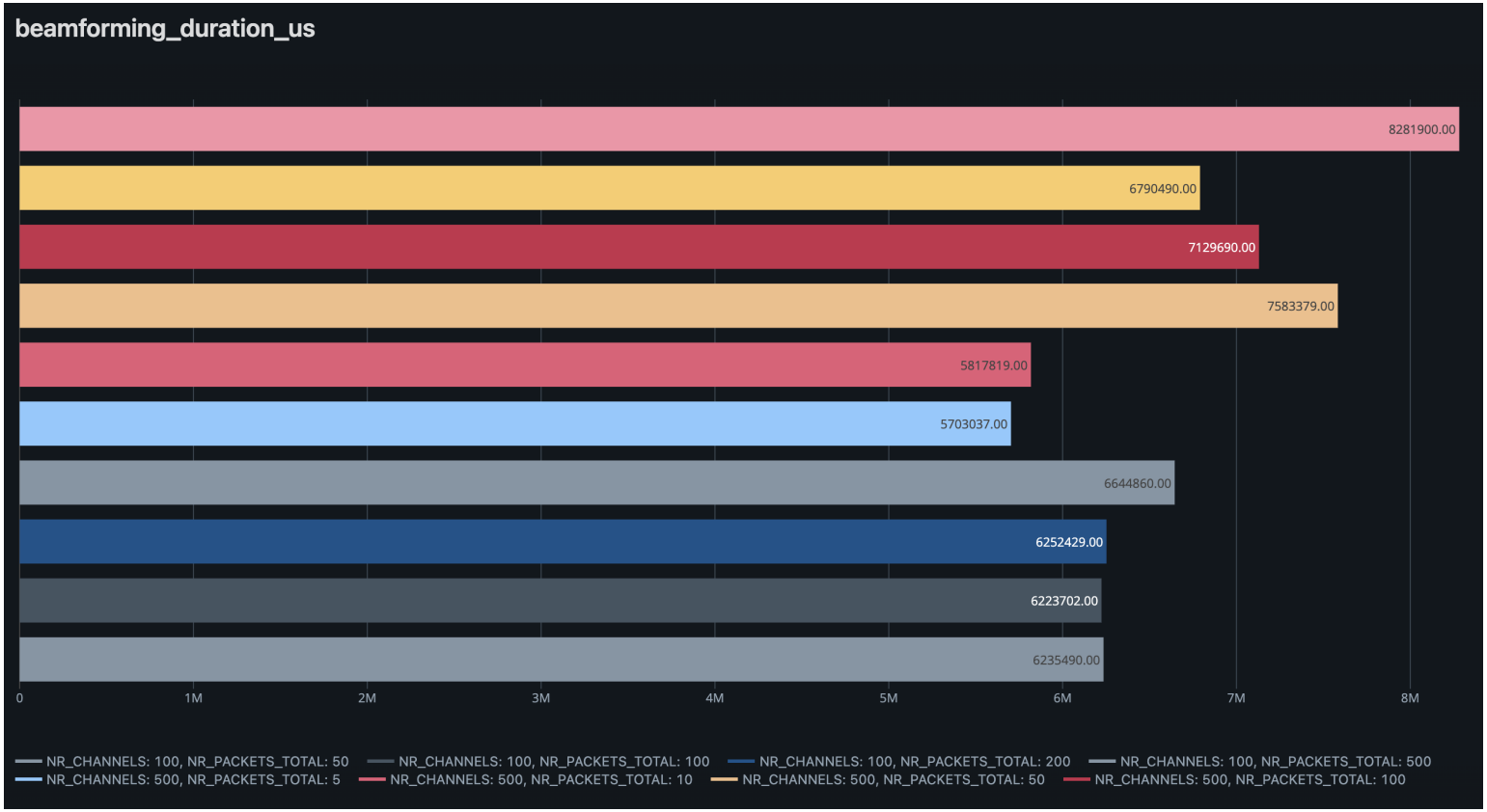
# XDB Engine


Read in from file
Copy to GPU memory
Correlate
Decompose
Update Weights
Transform
Accumulate
Beamform
Output to HDF5

# Profiling

- Carries out correlation & beamforming on 500 packets x 500 channels x 64 obs x 32 receivers x 2 polarizations (3.9 GB) in $\approx$ 6-8 seconds including set up time.
- Actual CUDA processing time excluding setup & allocations was around 400 ms on an A100.

# Total Duration



# Profiling & Pipelining

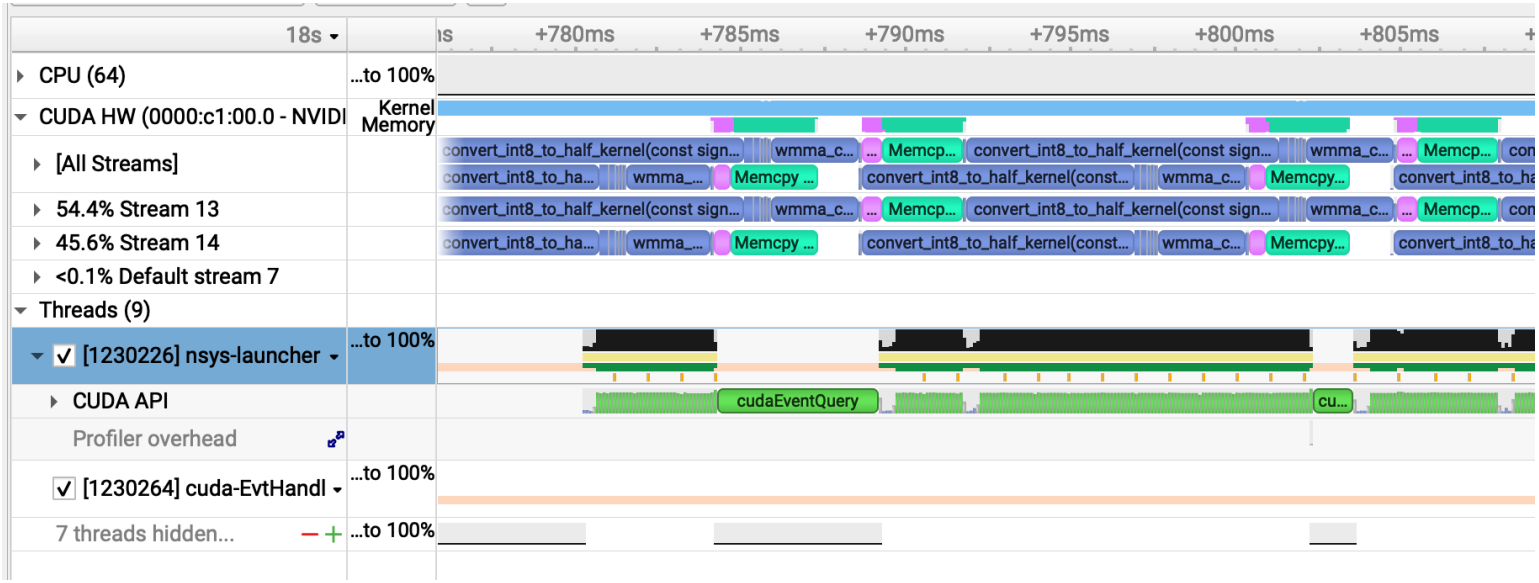



Figure: NSight-Systems report on the XDB engine.

# What's Next

- Working with folks at ATNF to run lab tests (CASATTA / LAMBDA).
- Adding short-term correlation matrix decomposition & weight updates.
- Add known direction nulling - i.e. the sun!

# extraterrena

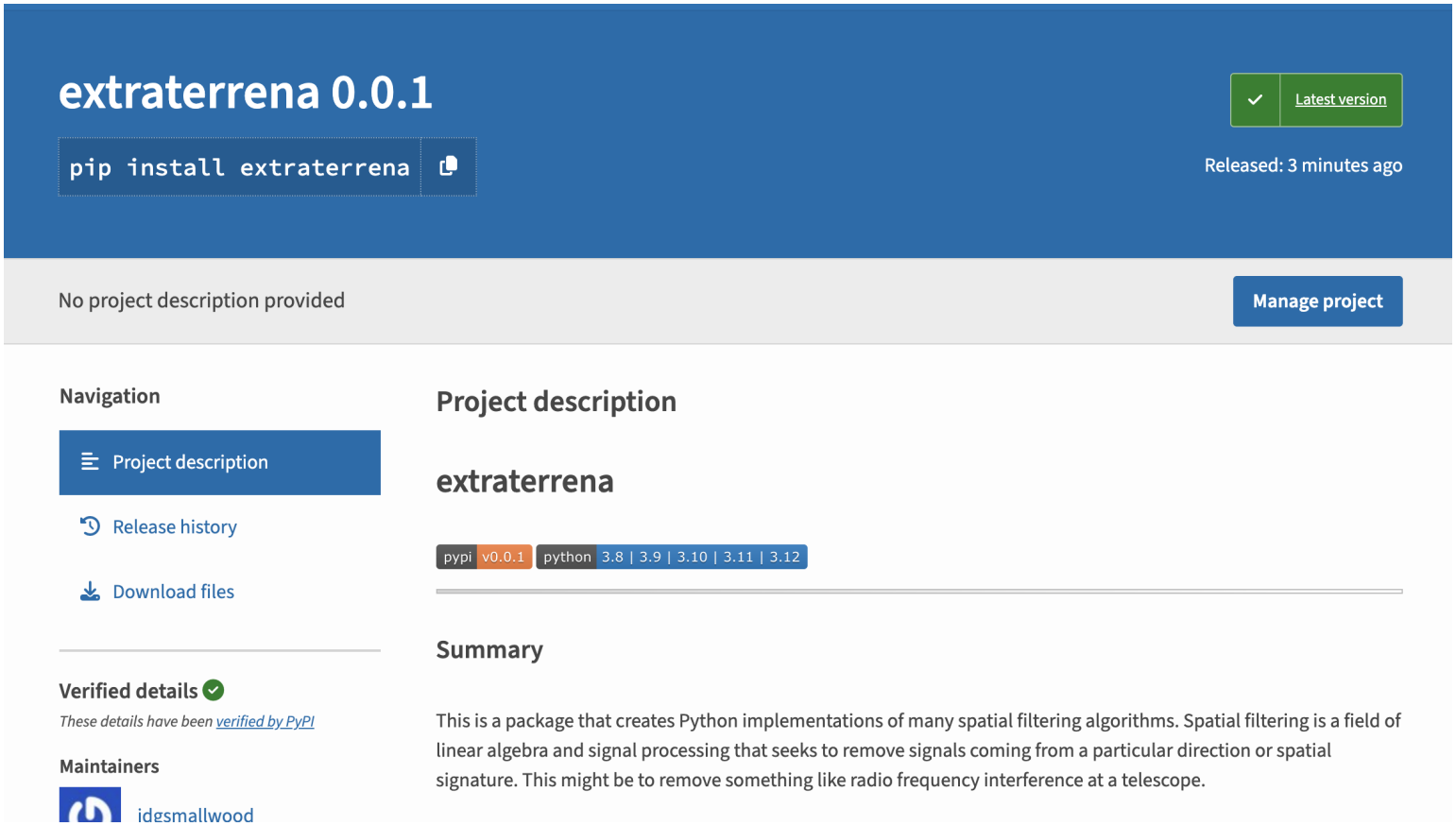



Figure: Up on PyPI! pip install extraterrena.

# extraterrena

- A library of tools for investigating signals and spatial filtering using phased arrays.
- Calculates steering vectors / phase delays between arrays of arbitrary geometry. (Not too large!)
- Simulation of wideband signals.
- https://github.com/jdgsmallwood/extraterrena

# extraterrena

- Implemented spatial filtering & DoA algorithms:
  - Eigenvalue Nulling
  - Eigenvalue Shrinking
  - Subspace Projection
  - MUSIC
  - MUSIC-NF
- https://github.com/jdgsmallwood/extraterrena

# extraterrena - What's in a name?

**Latin:** $\underbrace{\text{Extra}}_{\text{Beyond, Not of}}$ $\underbrace{\text{Terrena}}_{\text{Earthly things, acc. plural}}$

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**English:** Beyond Earthly things

**Spanish:** Más allá de las cosas terrenales

# extraterrena - What's in a name?

BY CREATORS OF THE ONE RING

## Elvish Translator

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beyond earthly things

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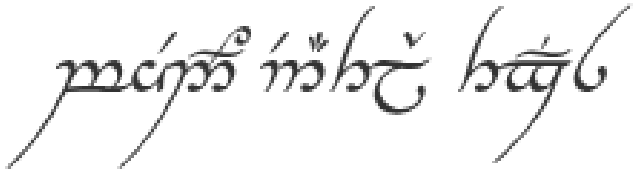
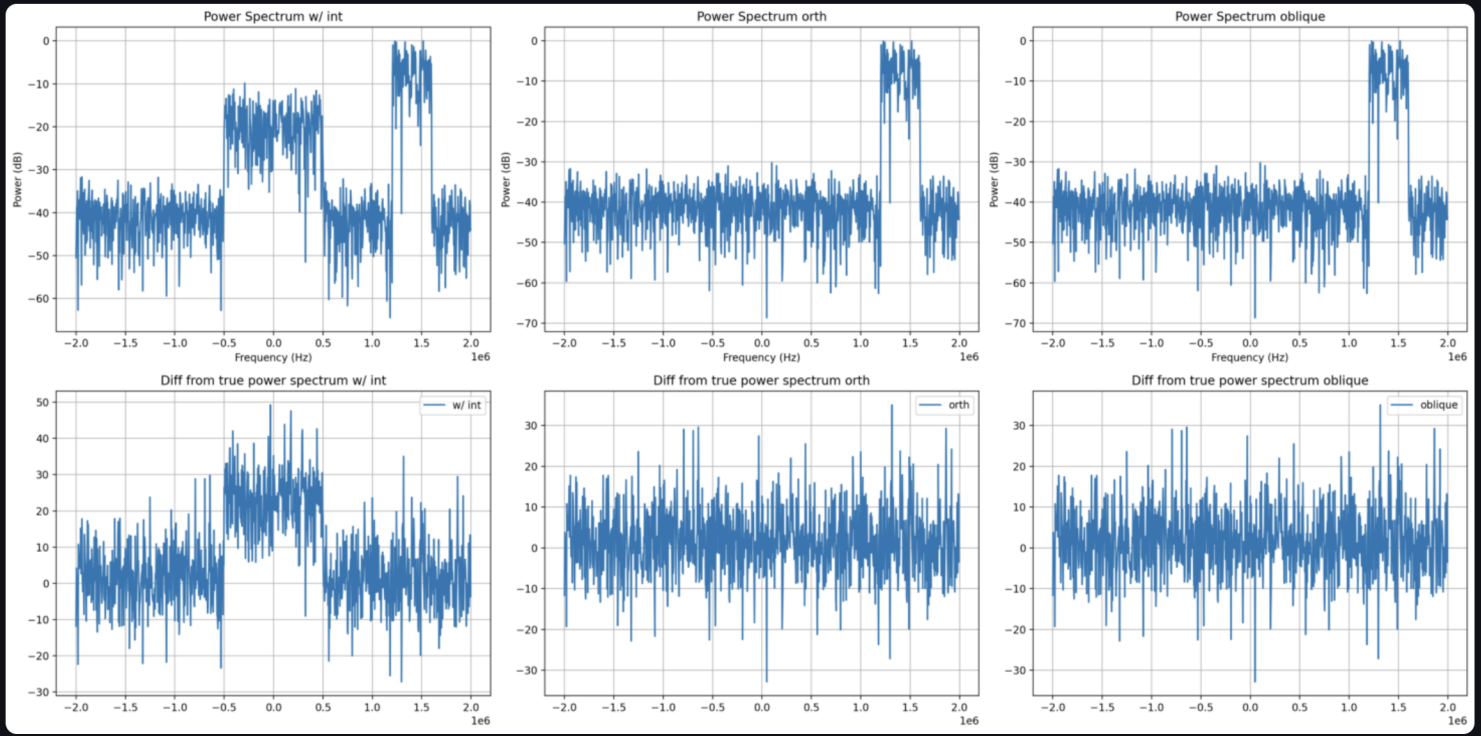


# Signal Simulator

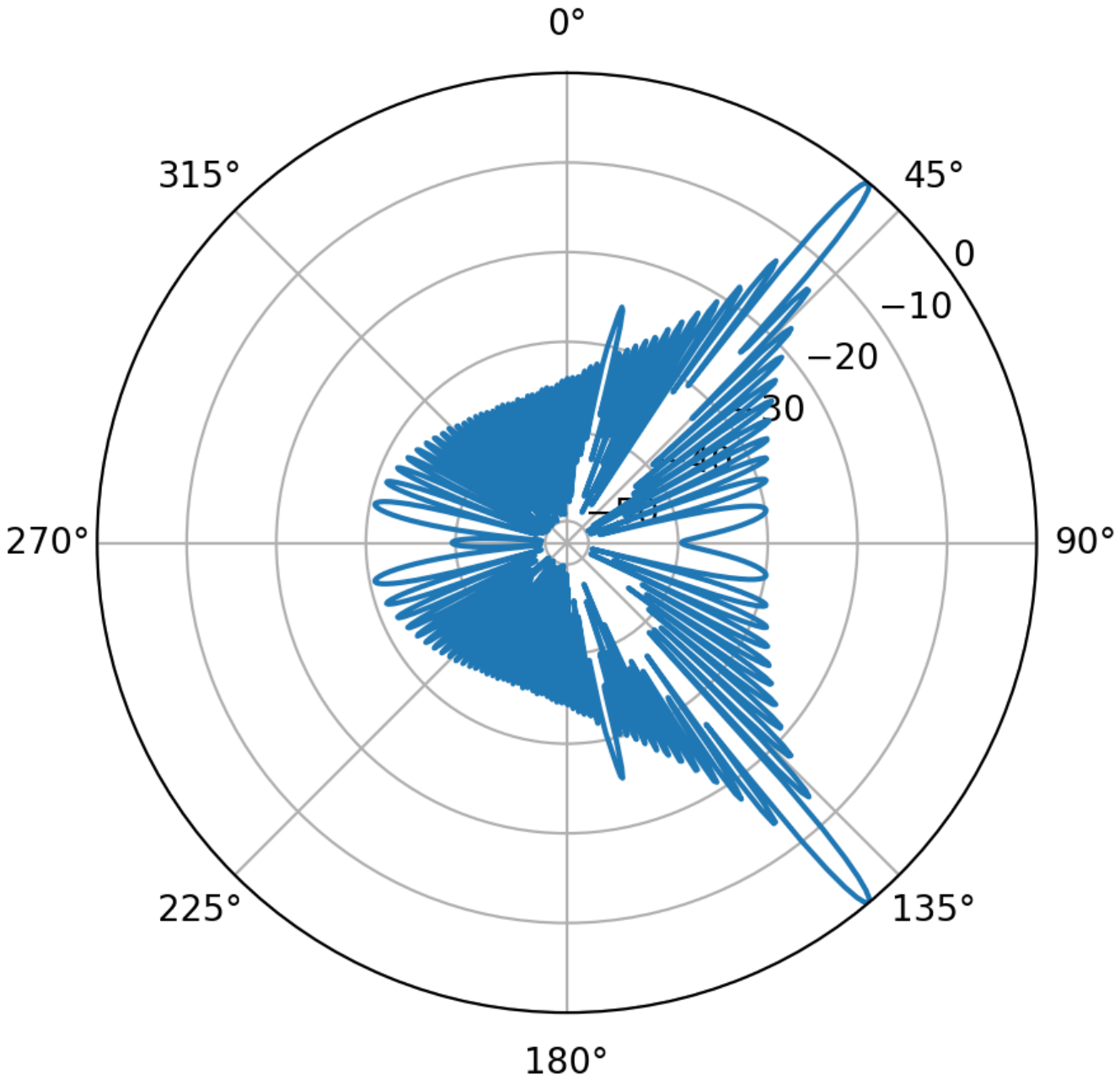
- Created a basic wideband signal simulator w/ Streamlit.
- Can choose direction of signal of interest & add interferers.
- Can then apply eigenvalue-based subspace projection as well as known direction nulling.
- https://apps.jsmallwood.net/extraterrena/

# Signal Simulator

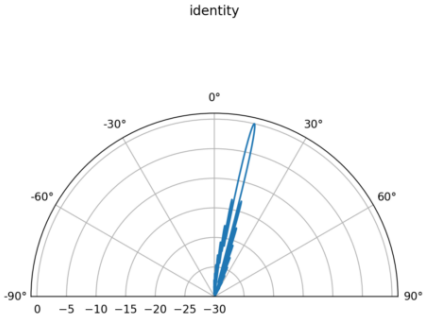
## Frequency plots...

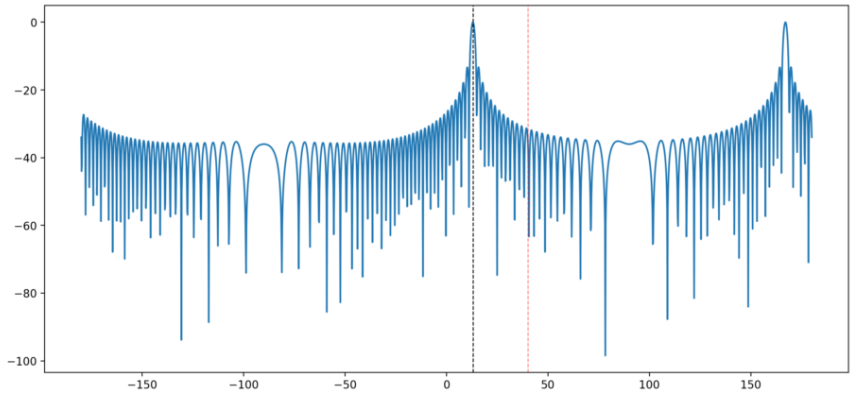


# Signal Simulator - Polar DoA

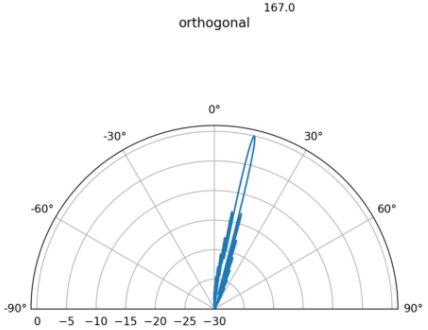


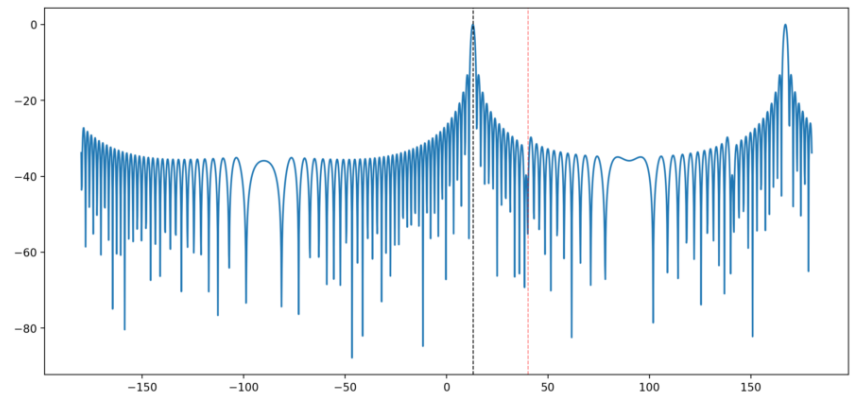
# Signal Simulator




167.0

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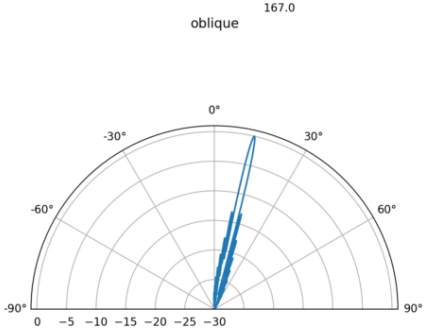


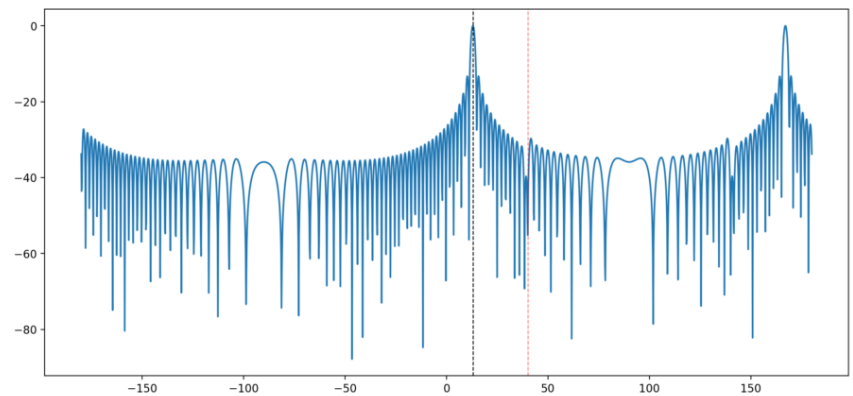


167.0

# Signal Simulator

## Eigenvalue analysis

Last 2 eigenvalues...

[ 61250.02484946 26169588.51238938]

| | Evec | eval | dot_prod_w_steering | dot_prod_w_int_1 |
|---|---|---|---|---|
| 0 | 0 | 330.5553 | 0.0007 | 0.0000 |
| 1 | 1 | 337.7289 | 0.0019 | 0.0000 |
| 2 | 2 | 341.0550 | 0.0004 | 0.0002 |
| 3 | 3 | 348.1297 | 0.0039 | 0.0001 |
| 4 | 4 | 354.0350 | 0.0026 | 0.0000 |
| 5 | 5 | 361.9793 | 0.0012 | 0.0001 |
| 6 | 6 | 364.9123 | 0.0011 | 0.0000 |
| 7 | 7 | 371.5626 | 0.0009 | 0.0001 |
| 8 | 8 | 3,287.3405 | 0.0024 | 0.0002 |
| 9 | 9 | 61,250.0248 | 0.9997 | 0.0001 |
| 10 | 10 | 26,169,588.5124 | 0.0199 | 1.0000 |

# What's Next?

- Clean up the API & docs.
- Add pulses, not just random noise.
- Add new filtering techniques and create new ones!

# Overall - What's Next?

- Finish first draft of lit review by end of September.
- Working on packet processor for XDB engine. (RDMA is hard).
- Adding eigenvalue-based nulling to the XDB engine.