

# Pulsar Coffee

Jay Smallwood

3rd September, 2025

## Introduction

XDB engine

extraterrena /  
Signal Simulator

What's Next?

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

- ▶ 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

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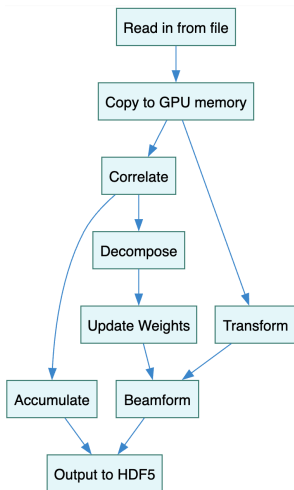
Introduction

**XDB engine**

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What's Next?

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



- ▶ 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

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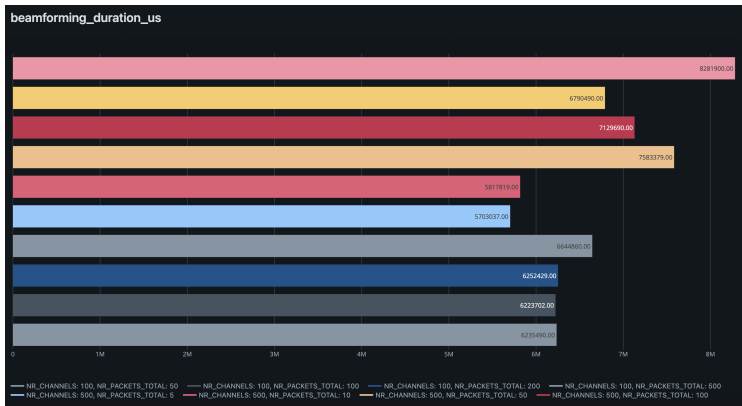
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What's Next?



# Profiling & Pipelining

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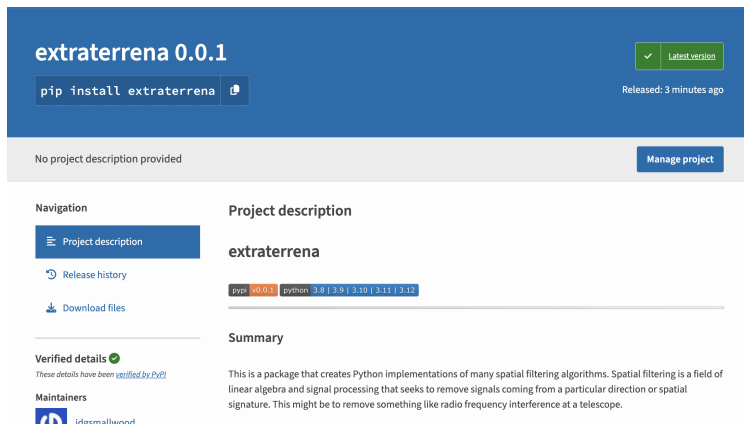
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What's Next?



Figure: NSight-Systems report on the XDB engine.

- ▶ 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!



The screenshot shows the PyPI page for the 'extraterrena' package. The header is dark blue with the package name 'extraterrena 0.0.1' in white. Below the name is a button with the command 'pip install extraterrena' and a download icon. To the right, there's a green 'Latest version' button with a checkmark and a release timestamp 'Released: 3 minutes ago'. A grey bar below the header states 'No project description provided' with a 'Manage project' button. The main content area has a 'Navigation' sidebar with links to 'Project description' (active), 'Release history', and 'Download files'. The 'Project description' section shows the package name 'extraterrena' and supported versions for 'pypi' (v0.0.1) and 'python' (3.8, 3.9, 3.10, 3.11, 3.12). The 'Summary' section contains a paragraph about spatial filtering algorithms. The 'Verified details' section has a green checkmark and a link to 'verified by PyPI'. The 'Maintainers' section shows the maintainer 'idesmallwood' with their profile picture.

**extraterrena 0.0.1**

`pip install extraterrena`

Released: 3 minutes ago

No project description provided

**Navigation**

- Project description
- Release history
- Download files

**Project description**

**extraterrena**

pypi v0.0.1 python 3.8 | 3.9 | 3.10 | 3.11 | 3.12

**Summary**

This is a package that creates Python implementations of many spatial filtering algorithms. Spatial filtering is a field of linear algebra and signal processing that seeks to remove signals coming from a particular direction or spatial signature. This might be to remove something like radio frequency interference at a telescope.

**Verified details** ✓

These details have been [verified by PyPI](#)

**Maintainers**

 idesmallwood

Figure: Up on PyPI! `pip install 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>

- ▶ 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?

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What's Next?

**Latin:**

Extra

Beyond, Not of

Terrena

Earthly things, acc. plural

# extraterrena - What's in a name?

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What's Next?

**Latin:**      Extra                      Terrena  
Beyond, Not of      Earthly things, acc. plural

**English:** Beyond Earthly things

# extraterrena - What's in a name?

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What's Next?

**Latin:**      Extra                      Terrena  
Beyond, Not of      Earthly things, acc. plural

**English:** Beyond Earthly things

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

BY CREATORS OF THE ONE RING

## Elvish Translator

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beyond earthly things

---

*melkor nót hāg*

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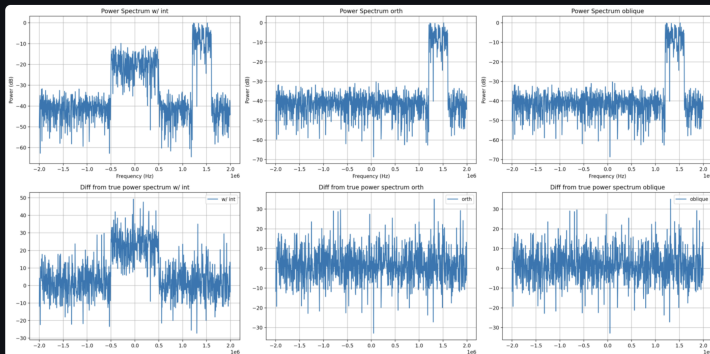
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[What's Next?](#)

- ▶ 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/>

## Frequency plots...



# Signal Simulator - Polar DoA

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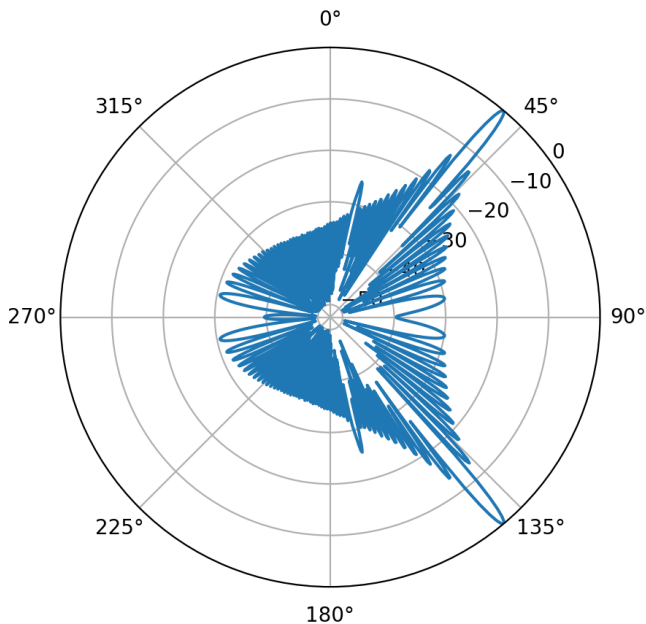
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# Signal Simulator

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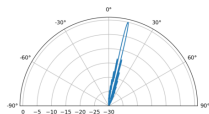
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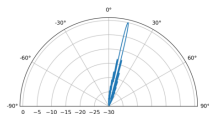
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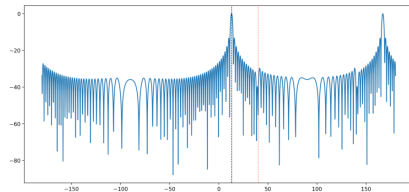
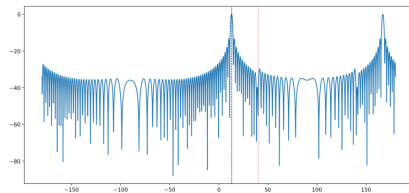
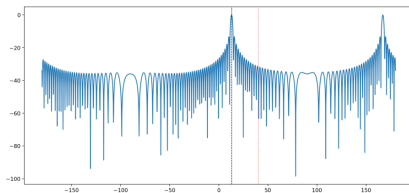
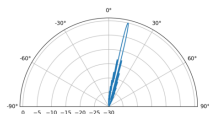
Identity



orthogonal 167.0



oblique 167.0



## 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?

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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.