THE UNIVERSITY OF BRITISH COLUMBIA

Natural Sciences and Engineering Research Council of Canada

Conseil de recherches en sciences naturelles et en génie du Canada

Canada

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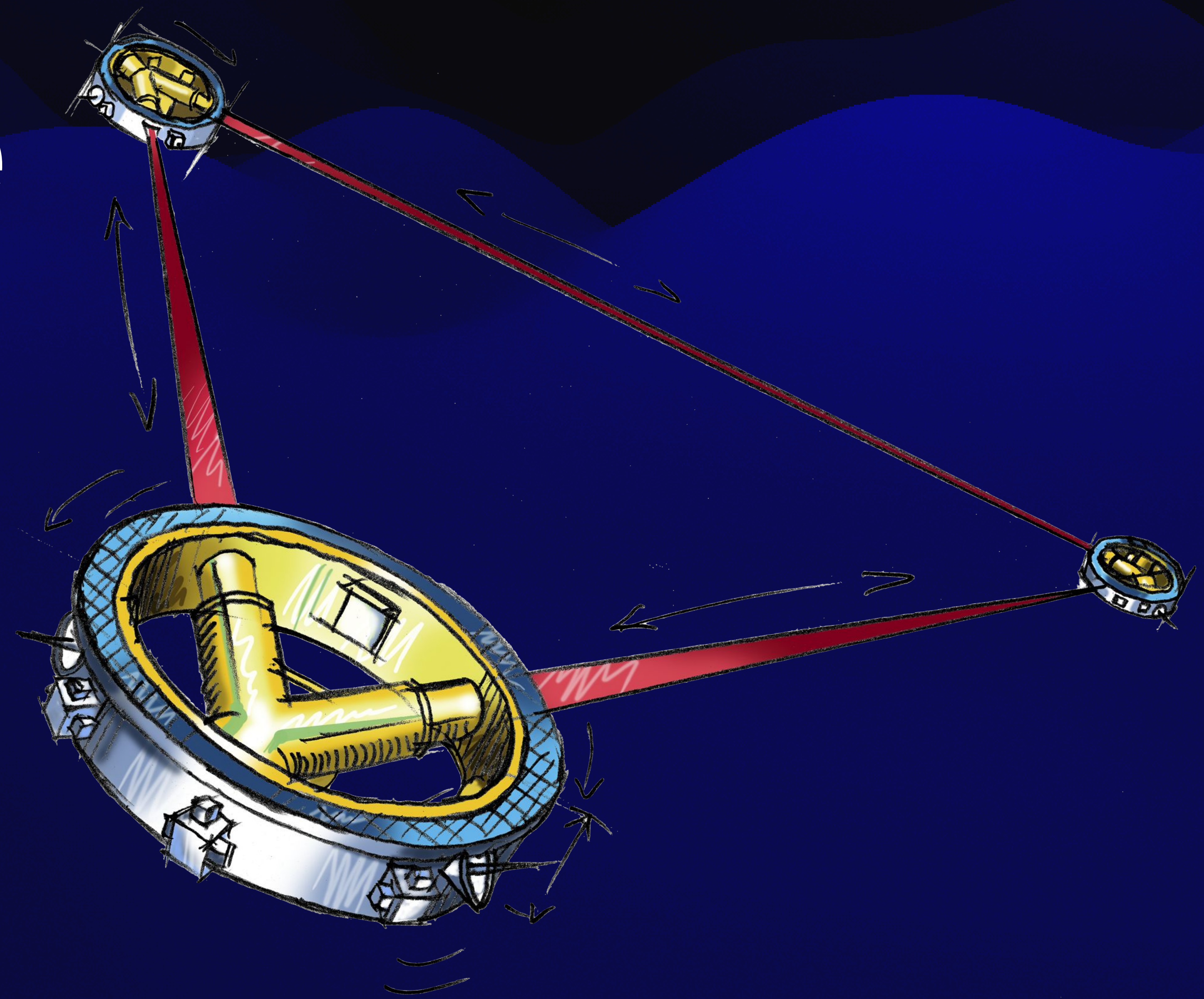
Nous remercions le Conseil de recherches en sciences naturelles et en génie du Canada (CRSNG) de son soutien.

LISA Data Challenge

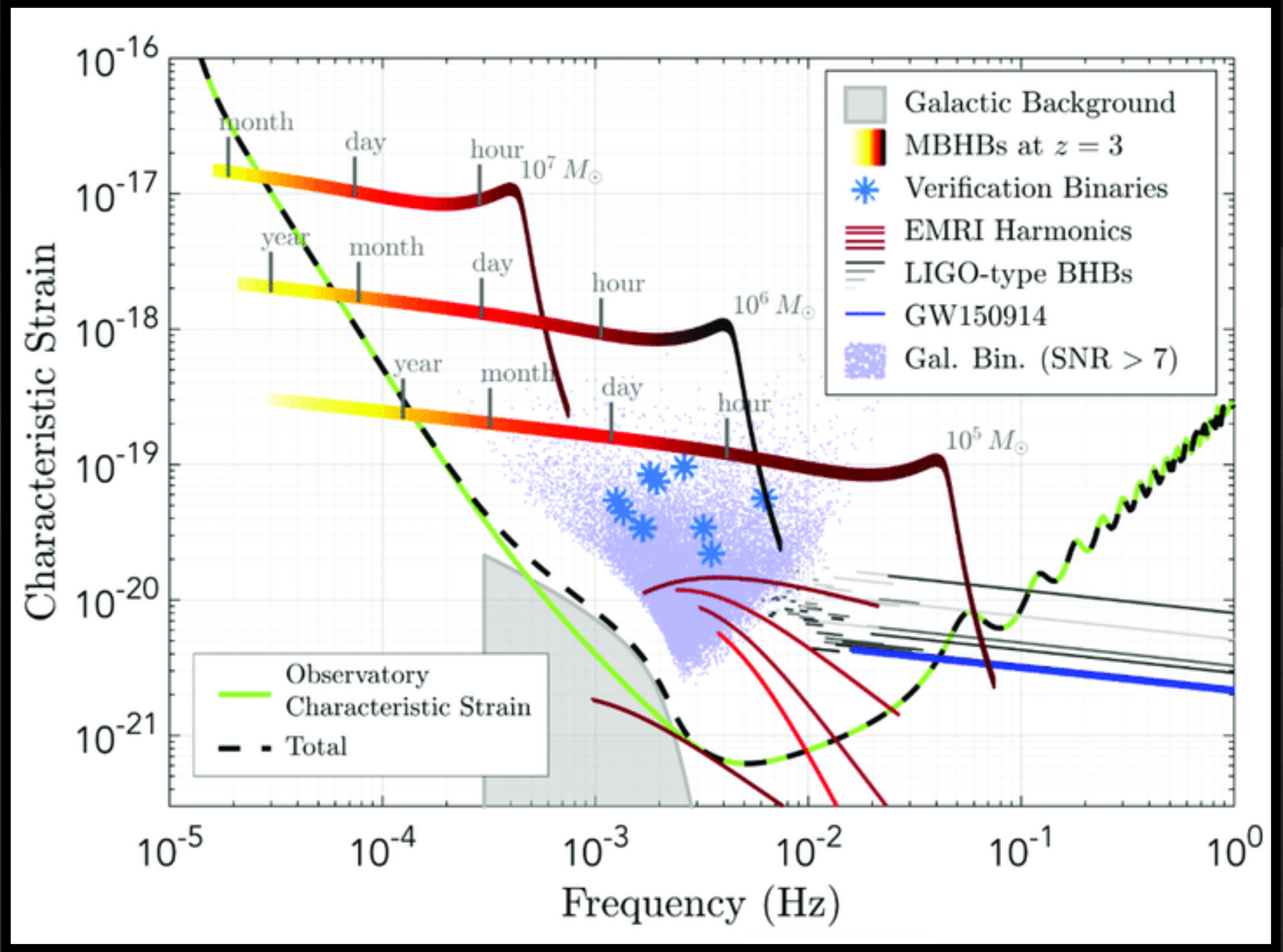
Glitch Mitigation in Verification Binaries

Kye Emond, Jess McIver, Scott Oser



Verification Binaries

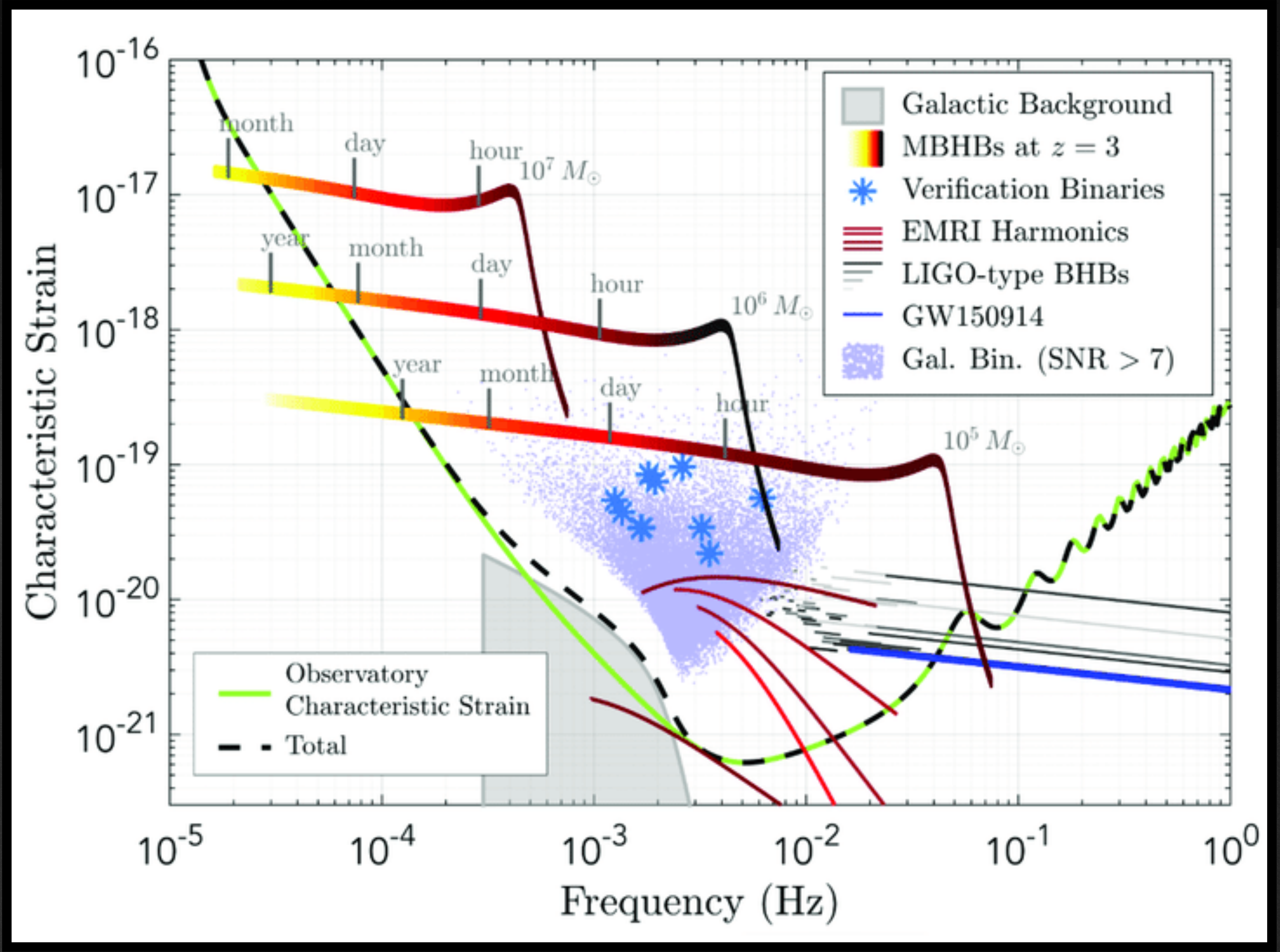
What are they?



Verification Binaries

What are they?

- LISA can detect GWs in the 10^{-4} to 1 Hz range



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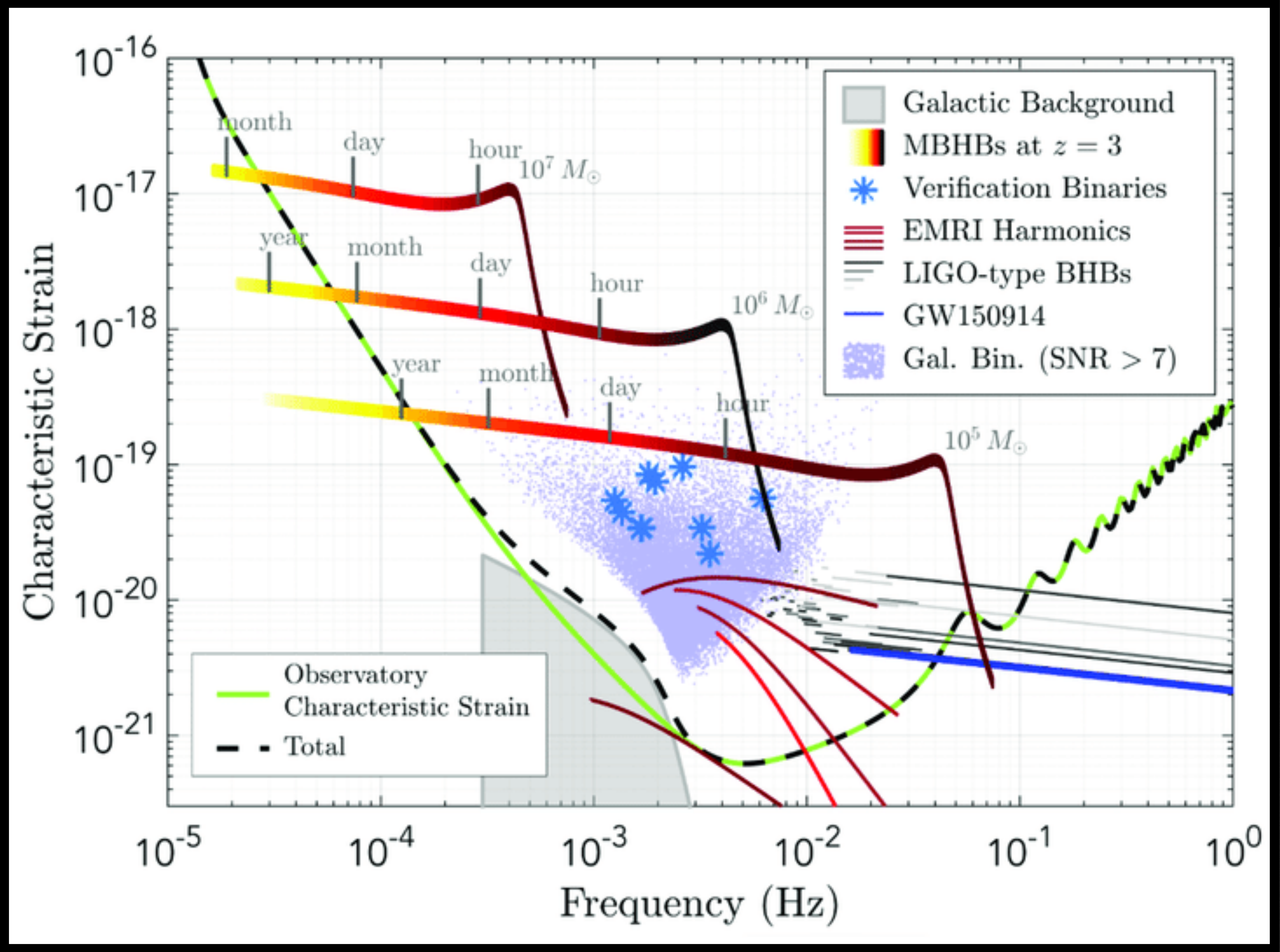

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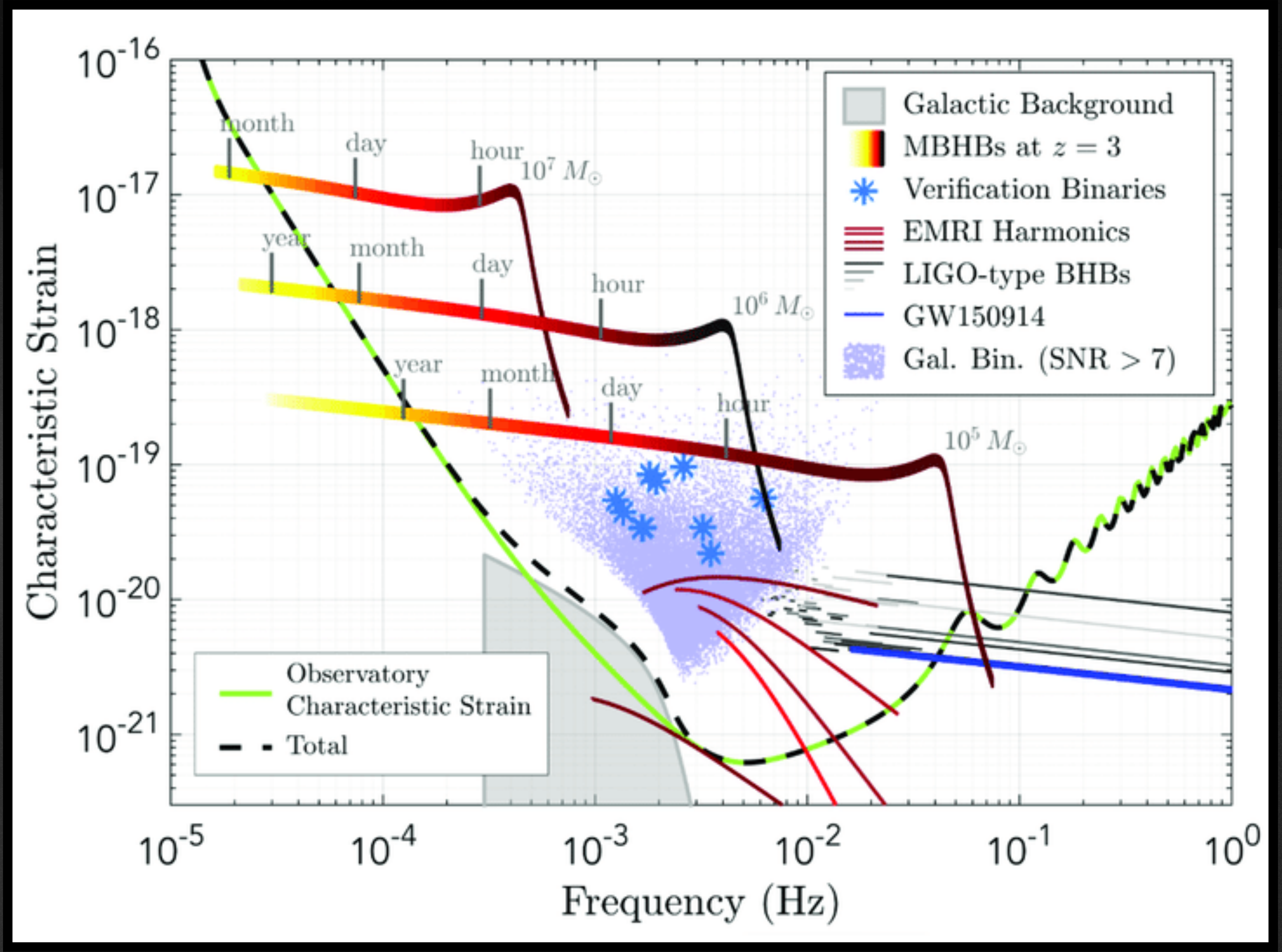

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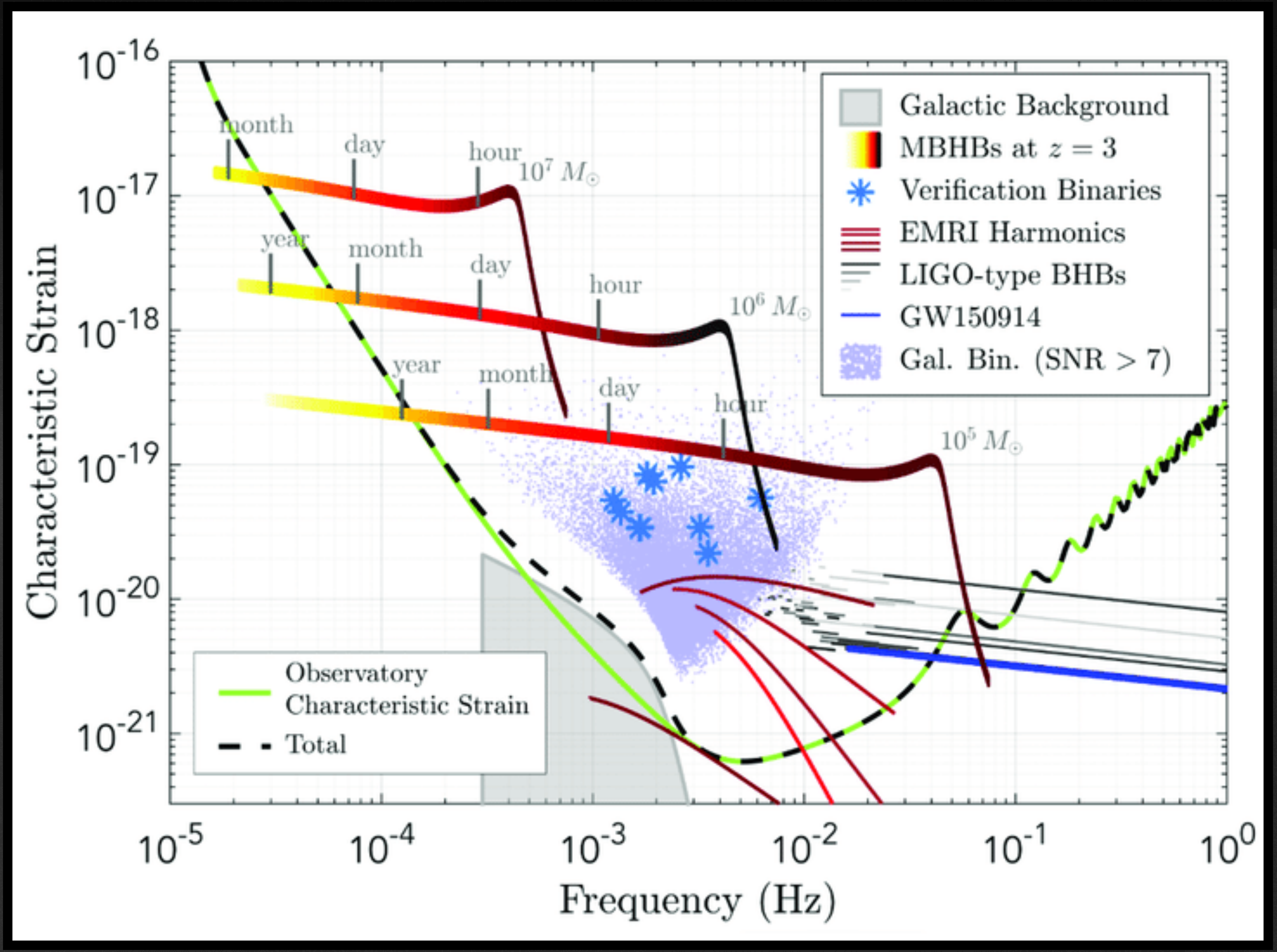

Verification Binaries

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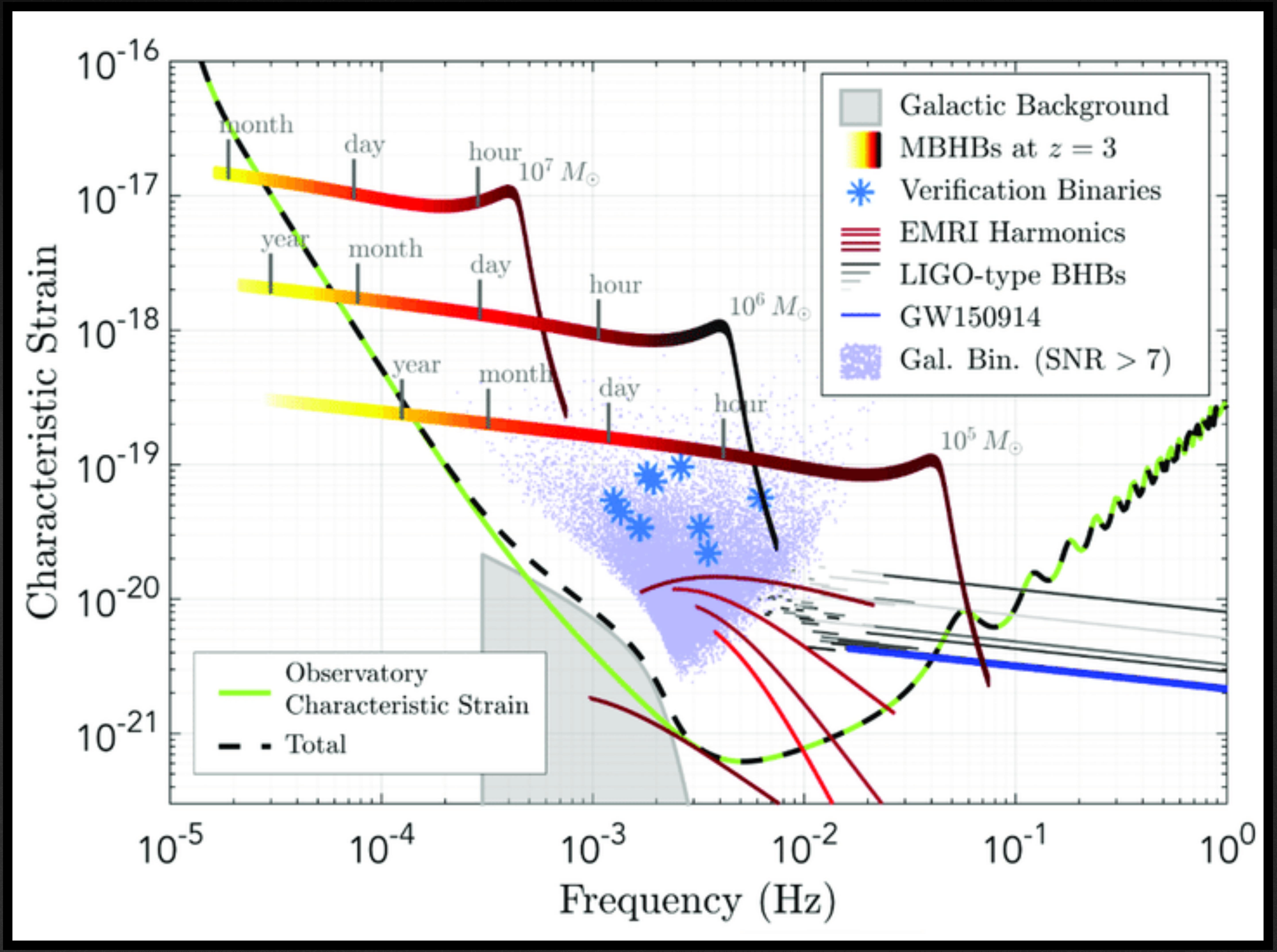
- LISA can detect GWs in the 10^{-4} to 1 Hz range
  - Includes galactic binaries
- We know parameters of ~30 binaries from other observations
- We can *verify* LISA is working by checking that we get predicted GWs
- These are *verification binaries*



LISA Data Challenges

Spritz: Verification Binaries

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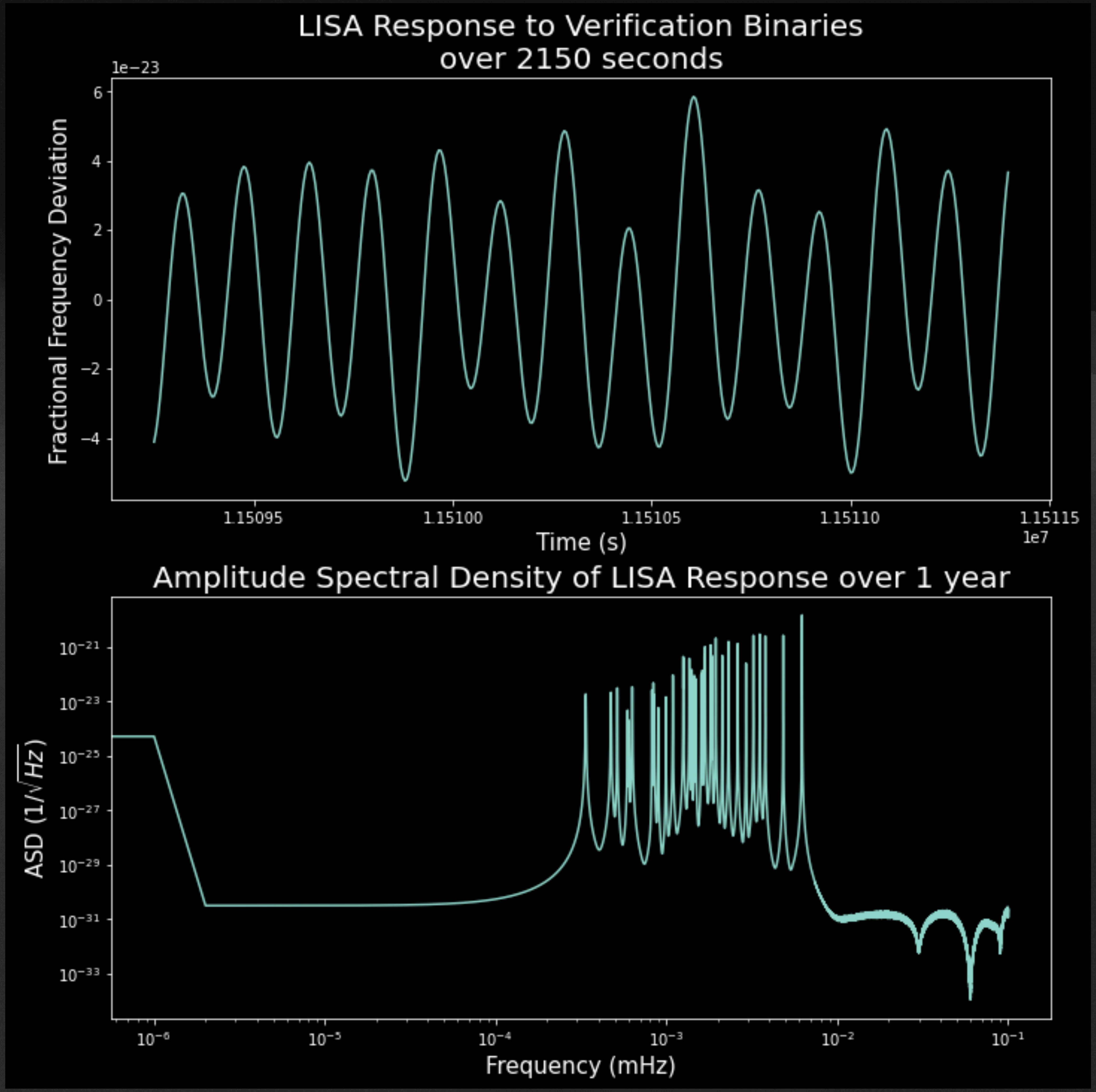
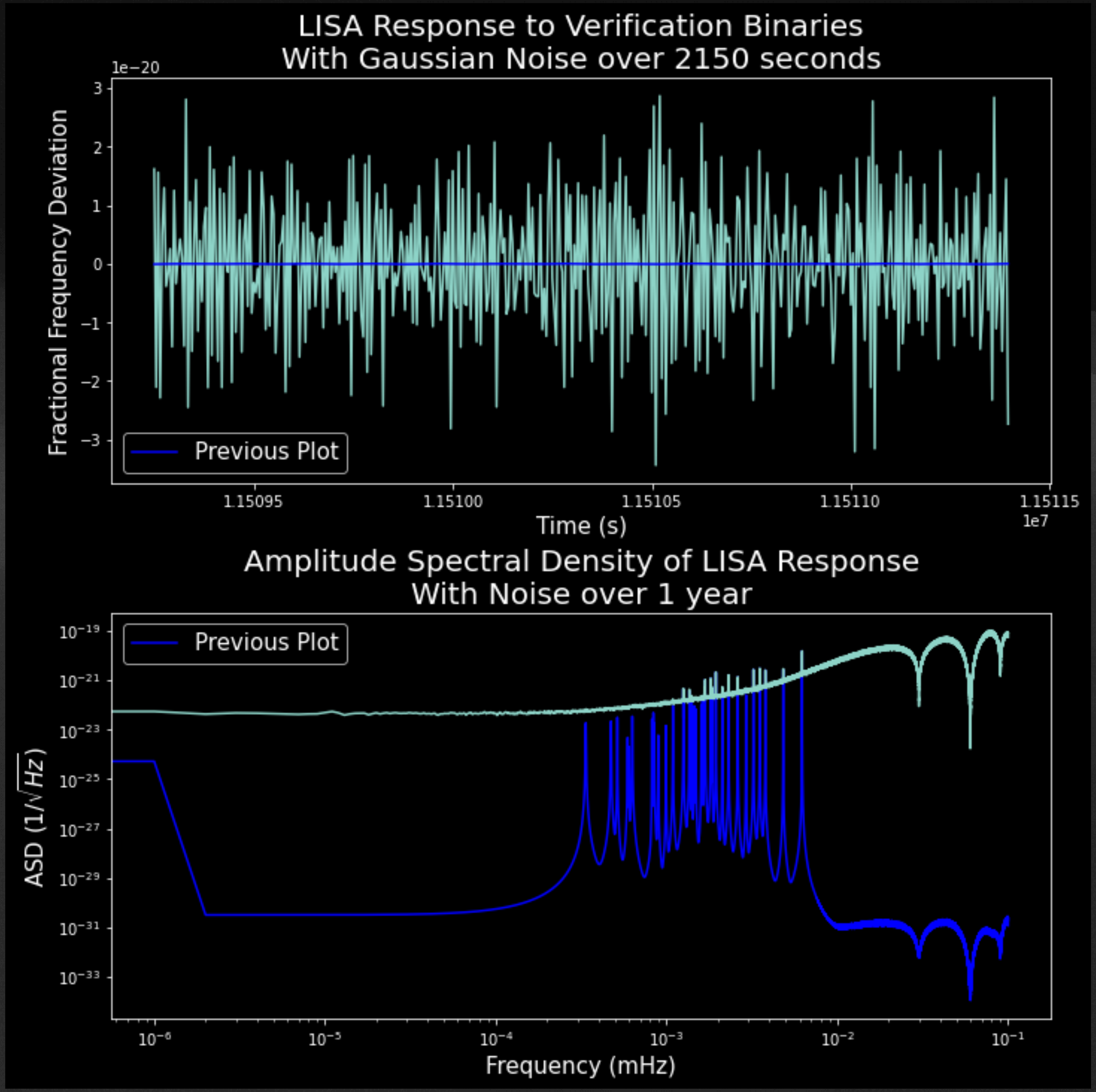
- GW signal from verification binaries



LISA Data Challenges

Spritz: Verification Binaries

- GW signal from verification binaries
- Plus instrumental noise



LISA Data Challenges

Spritz: Verification Binaries

- GW signal from verification binaries
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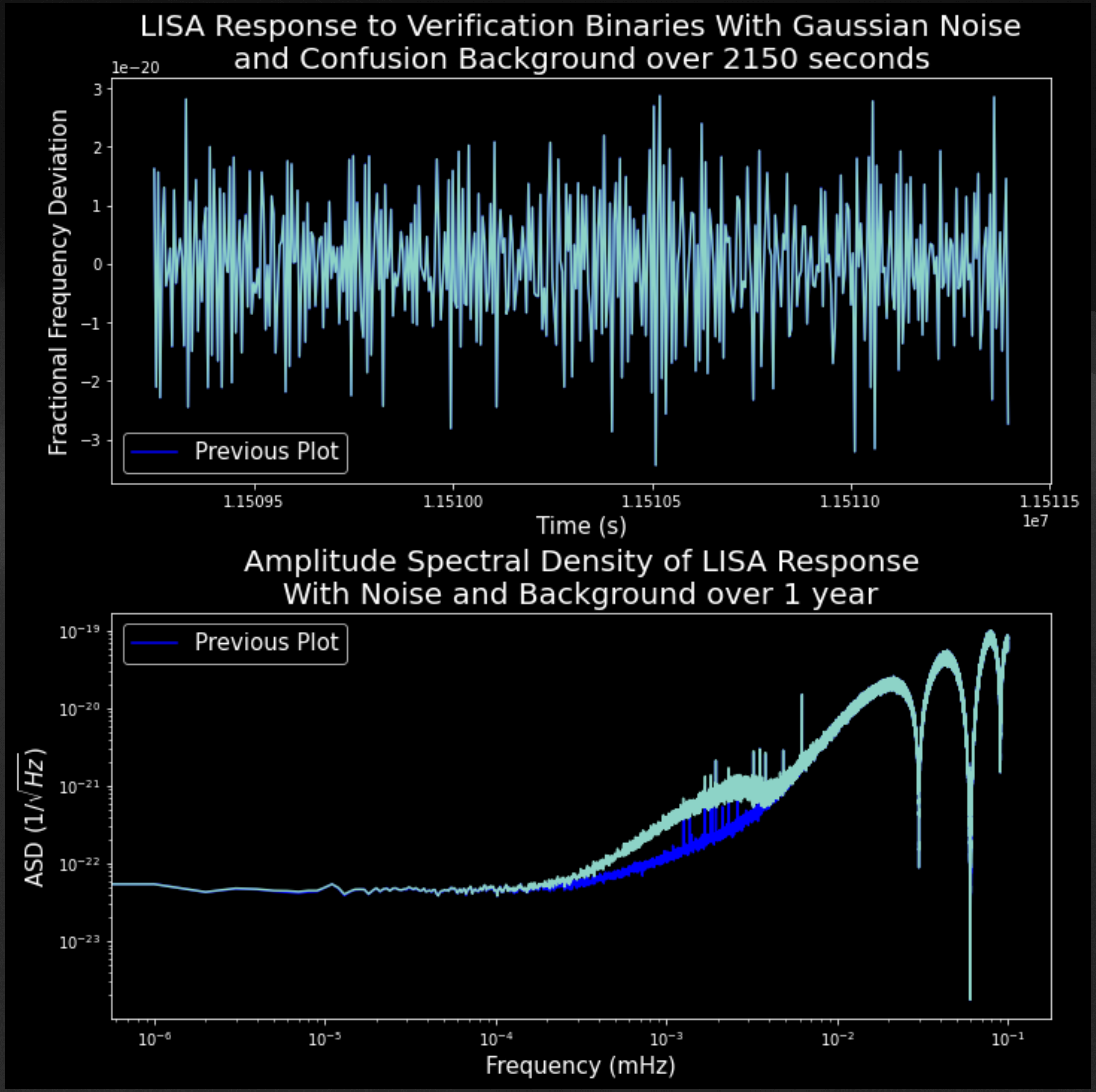
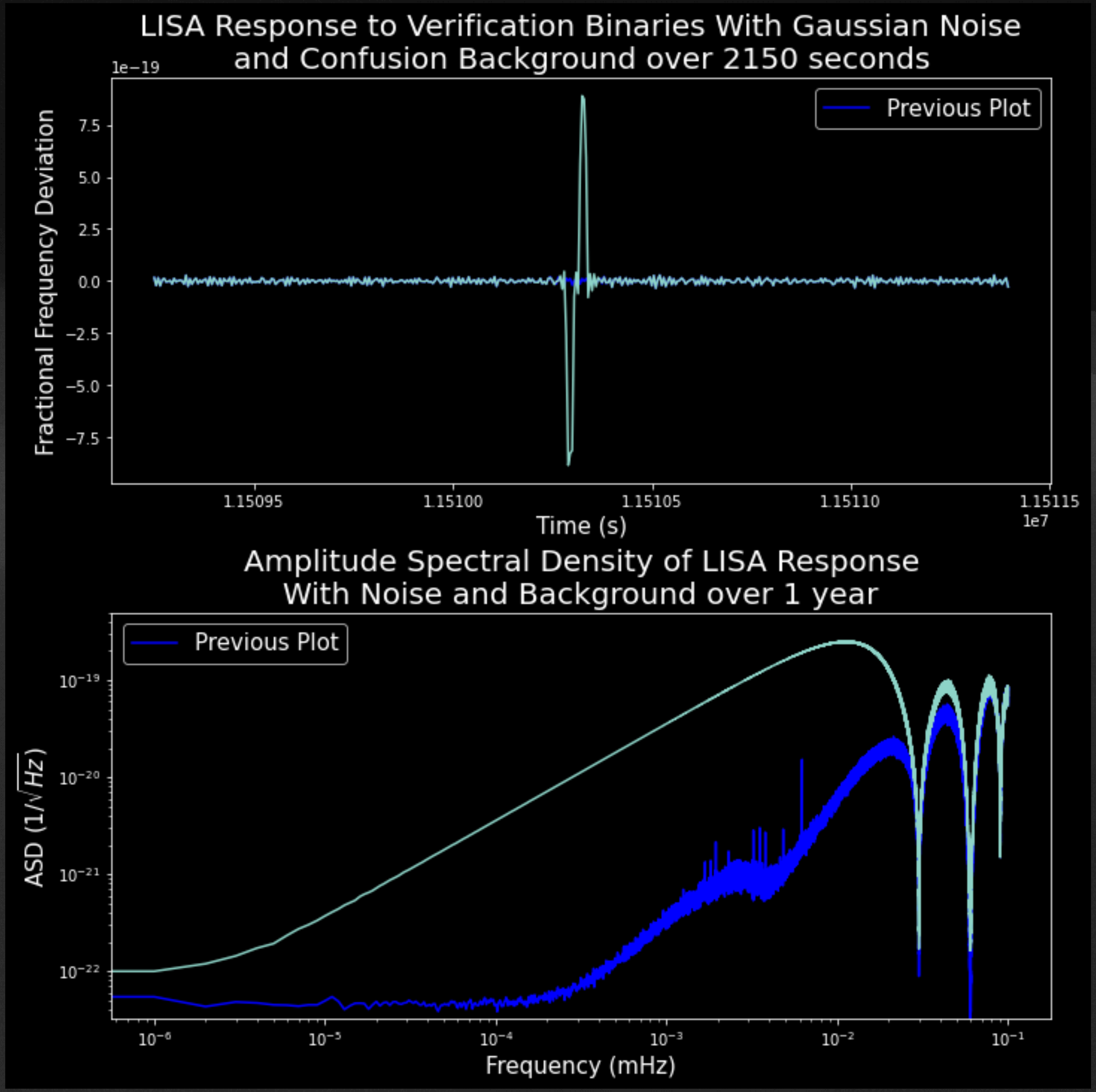


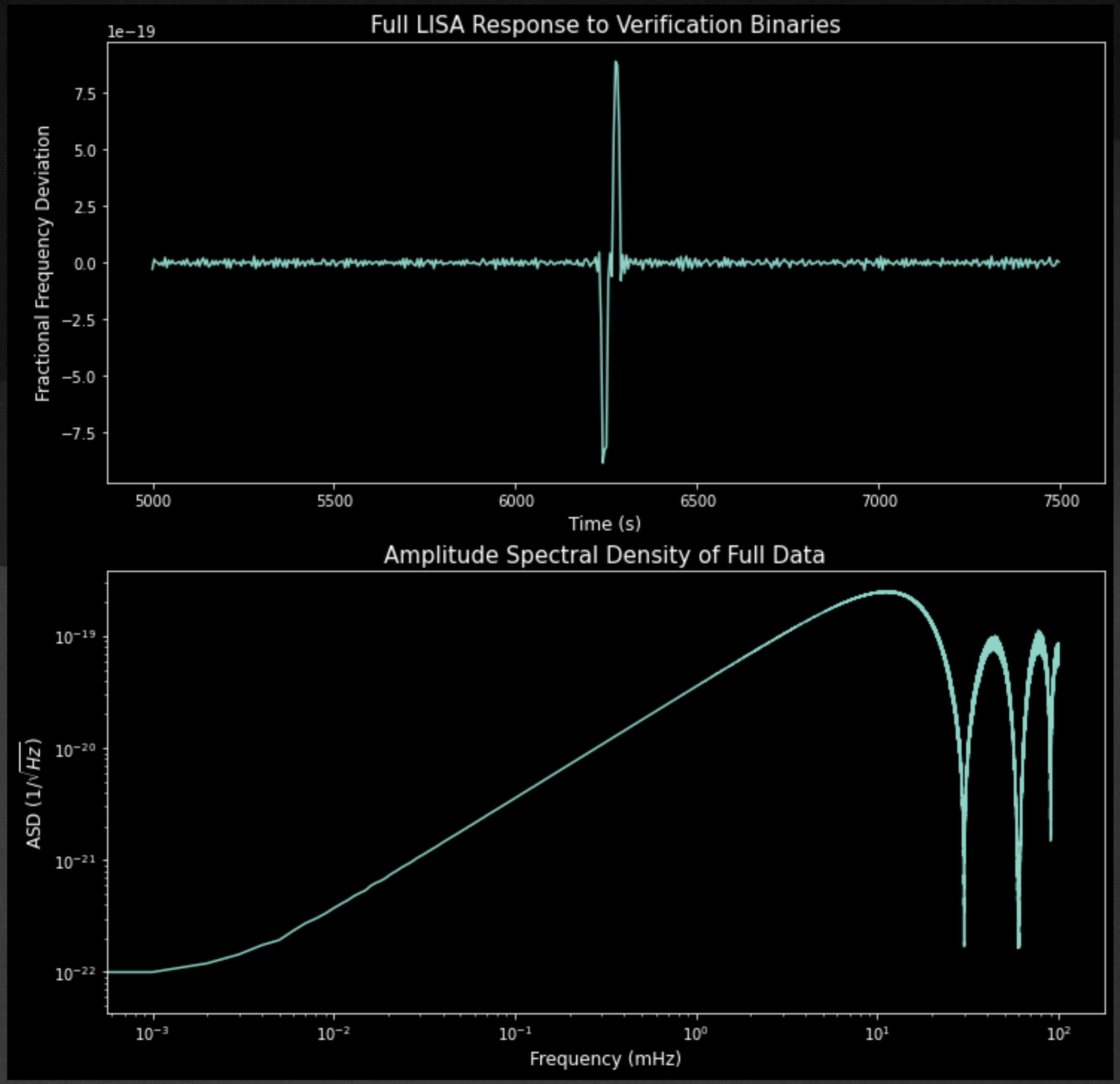
LISA Data Challenges

Spritz: Verification Binaries

- GW signal from verification binaries
- Plus instrumental noise
- Plus a lot of low-amplitude, unresolvable GWs from events in galaxy
- Plus glitches and gaps (from LISA Pathfinder mission)



Goal



→

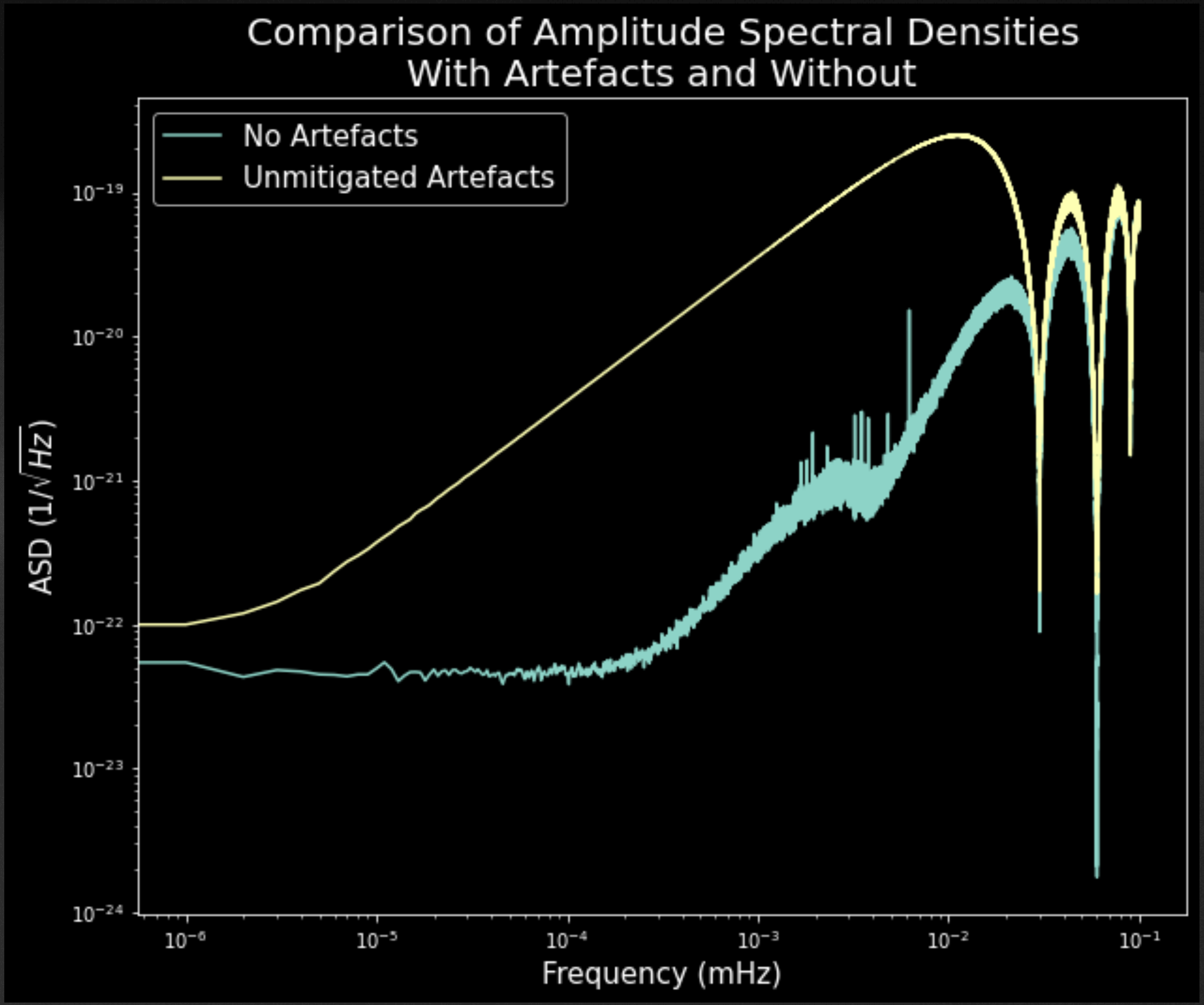
Parameter	Value	Unit
Amplitude	1.6e-22	1
EclipticLatitude	0.087	rad
EclipticLongitude	4.1	rad
Frequency	0.0018	Hz
FrequencyDerivative	2.5e-18	Hz^2
Inclination	0.52	rad
InitialPhase	5.1	rad
Polarization	6.1	rad

× 36

Go from full data to accurate parameter estimations

Artefact Mitigation

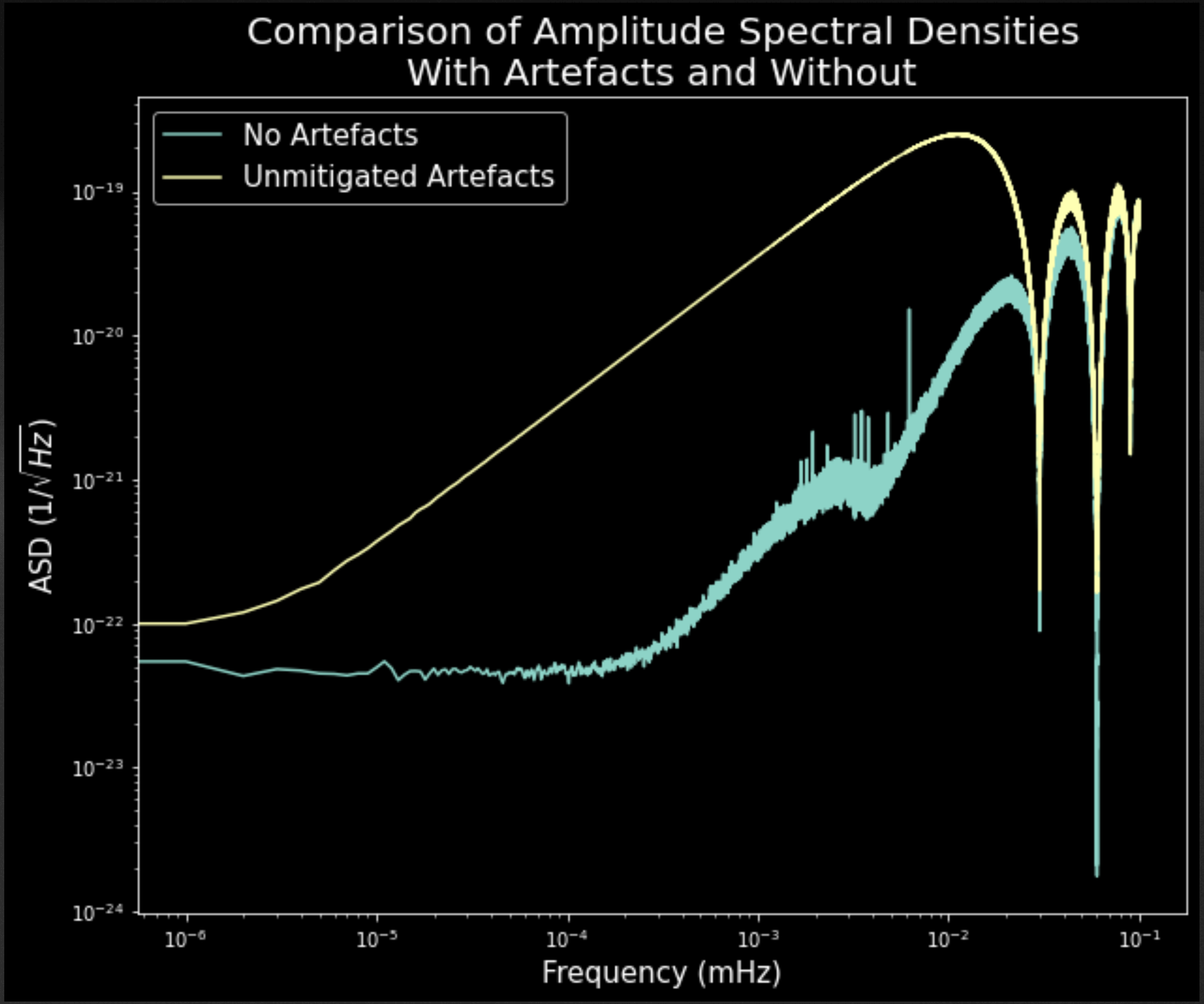
Dealing With Artefacts



Artefact Mitigation

Dealing With Artefacts

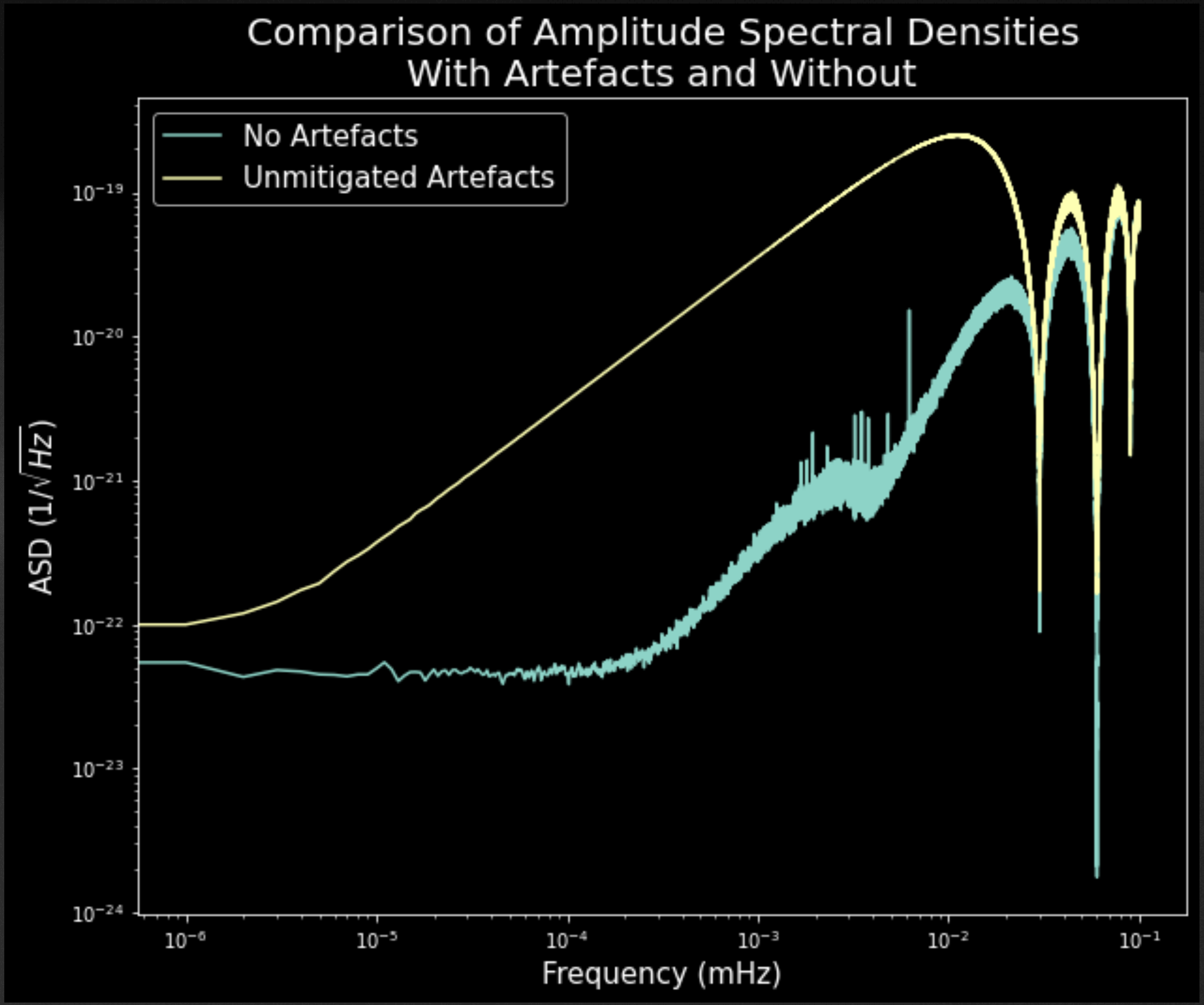
- Main issue to solve is artefacts completely drown out binaries



Artefact Mitigation
Dealing With Artefacts

- Main issue to solve is artefacts completely drown out binaries

- Need to mitigate that



Artefact Mitigation

Gaps

Artefact Mitigation

Gaps

- Detect gaps by looking for missing data

Artefact Mitigation
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Artefact Mitigation

Gaps

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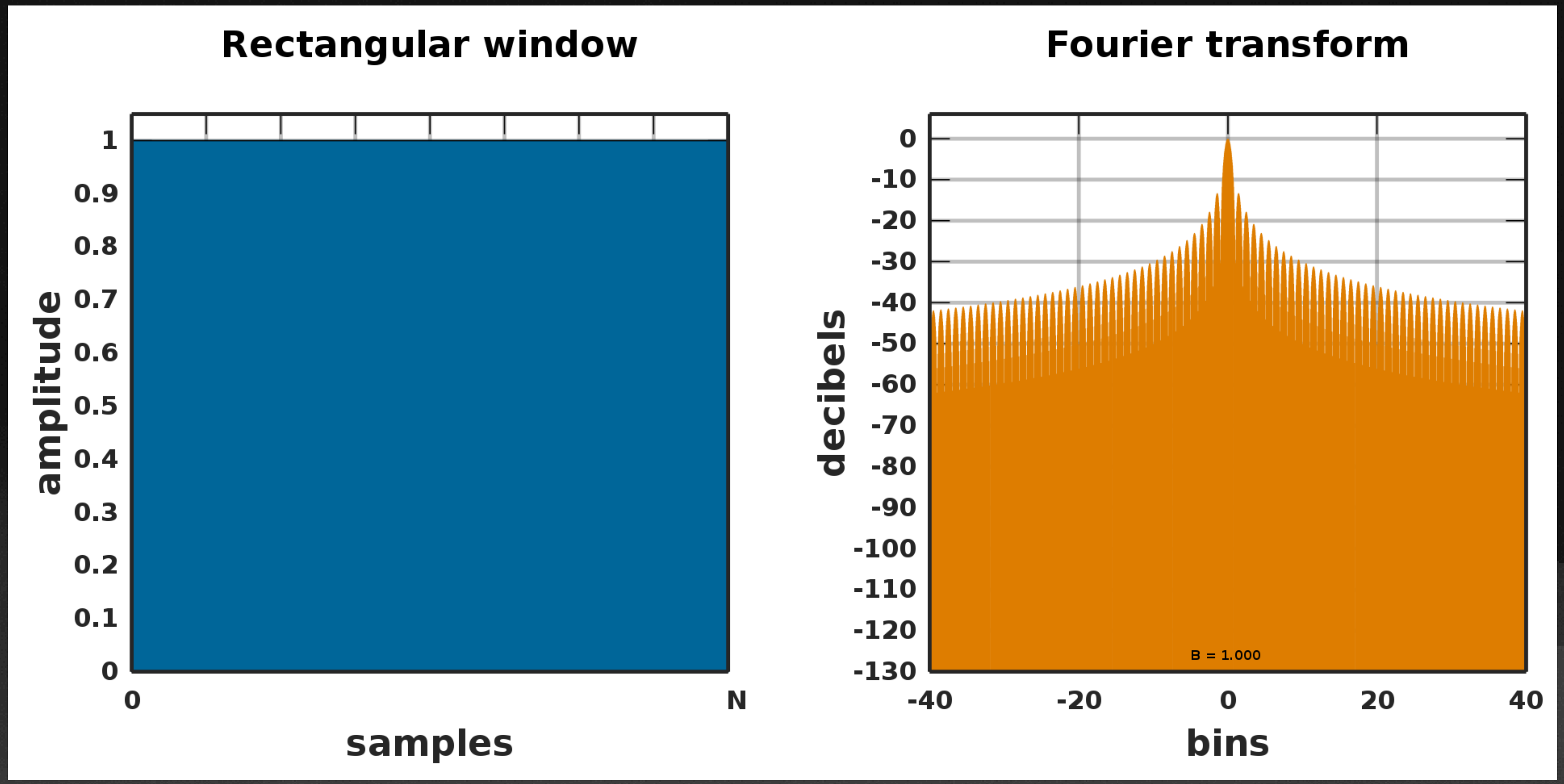
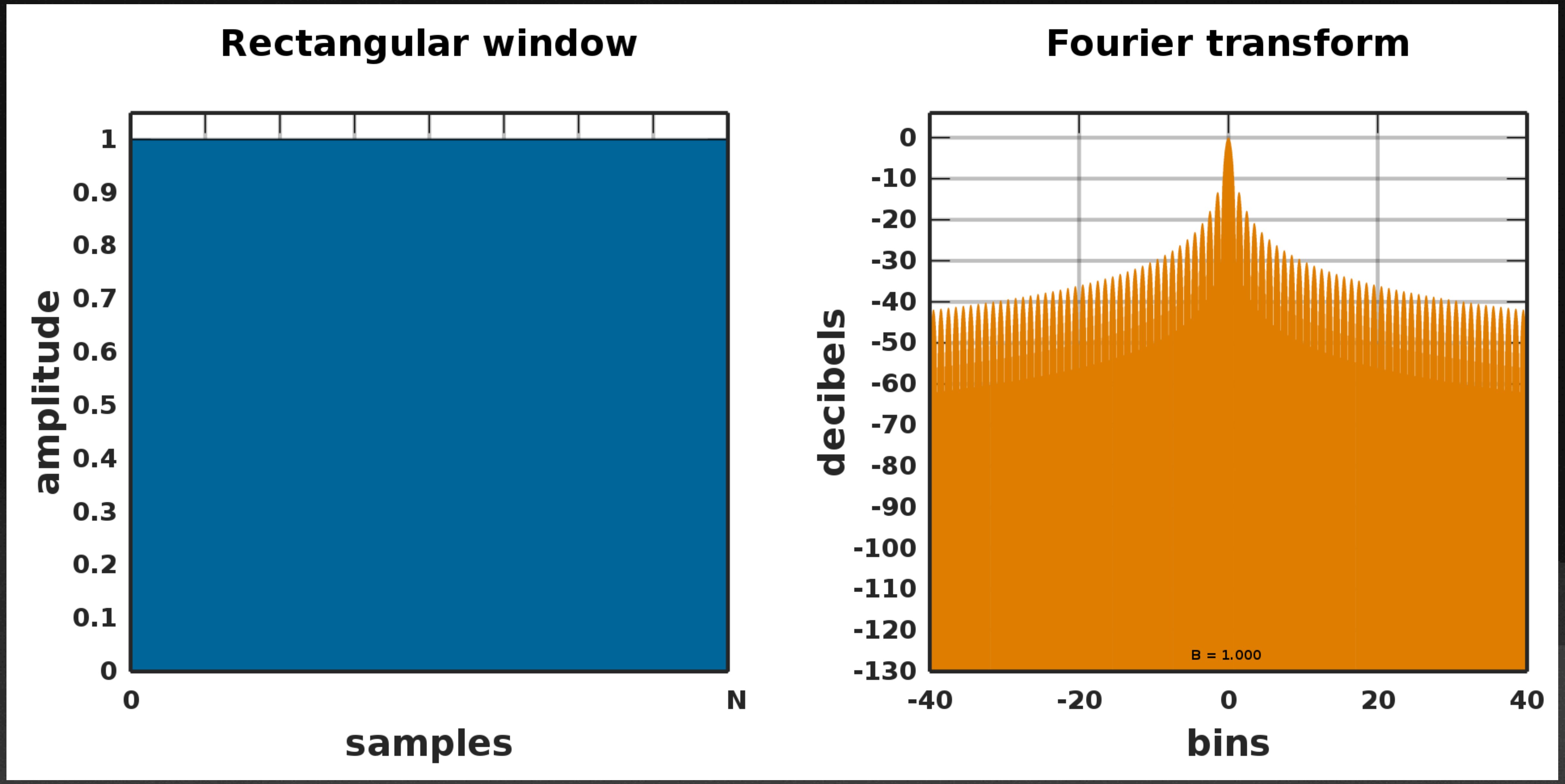
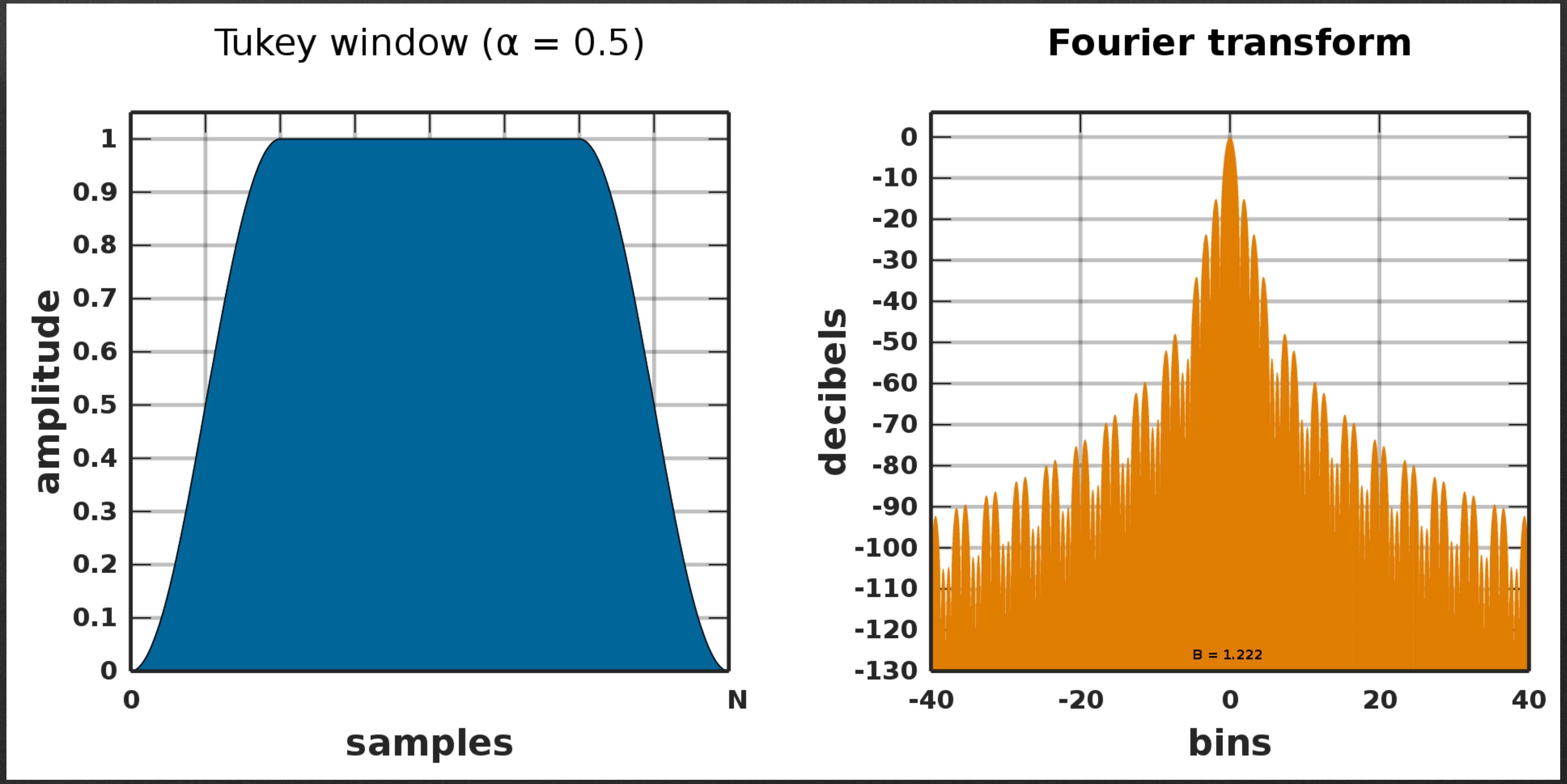


Artefact Mitigation

Gaps

- Detect gaps by looking for missing data
- Set missing data to 0
    - Results in spectral leakage
- Window the data smoothly in/out





Artefact Mitigation

Gaps

- Detect gaps by looking for missing data
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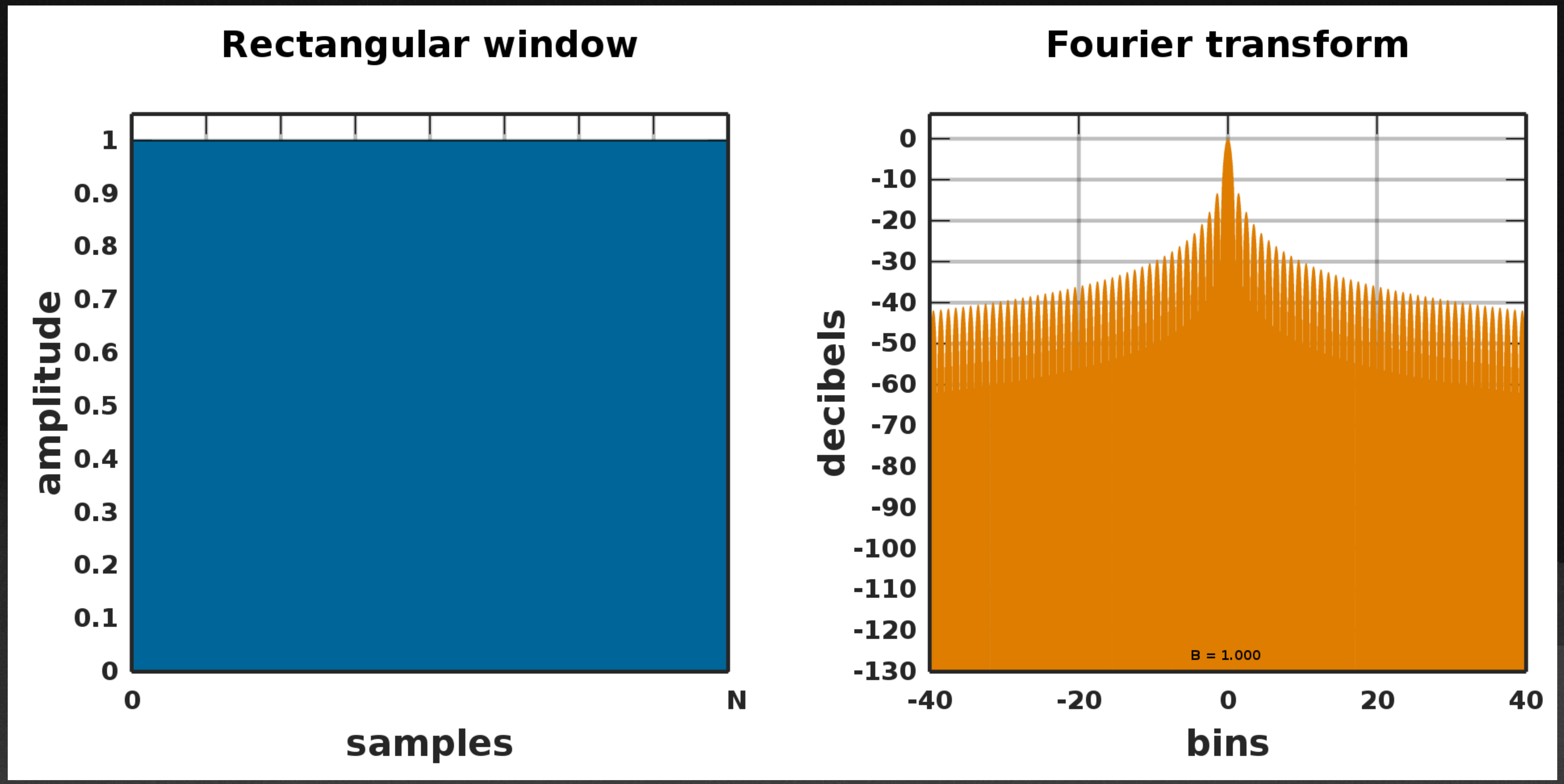
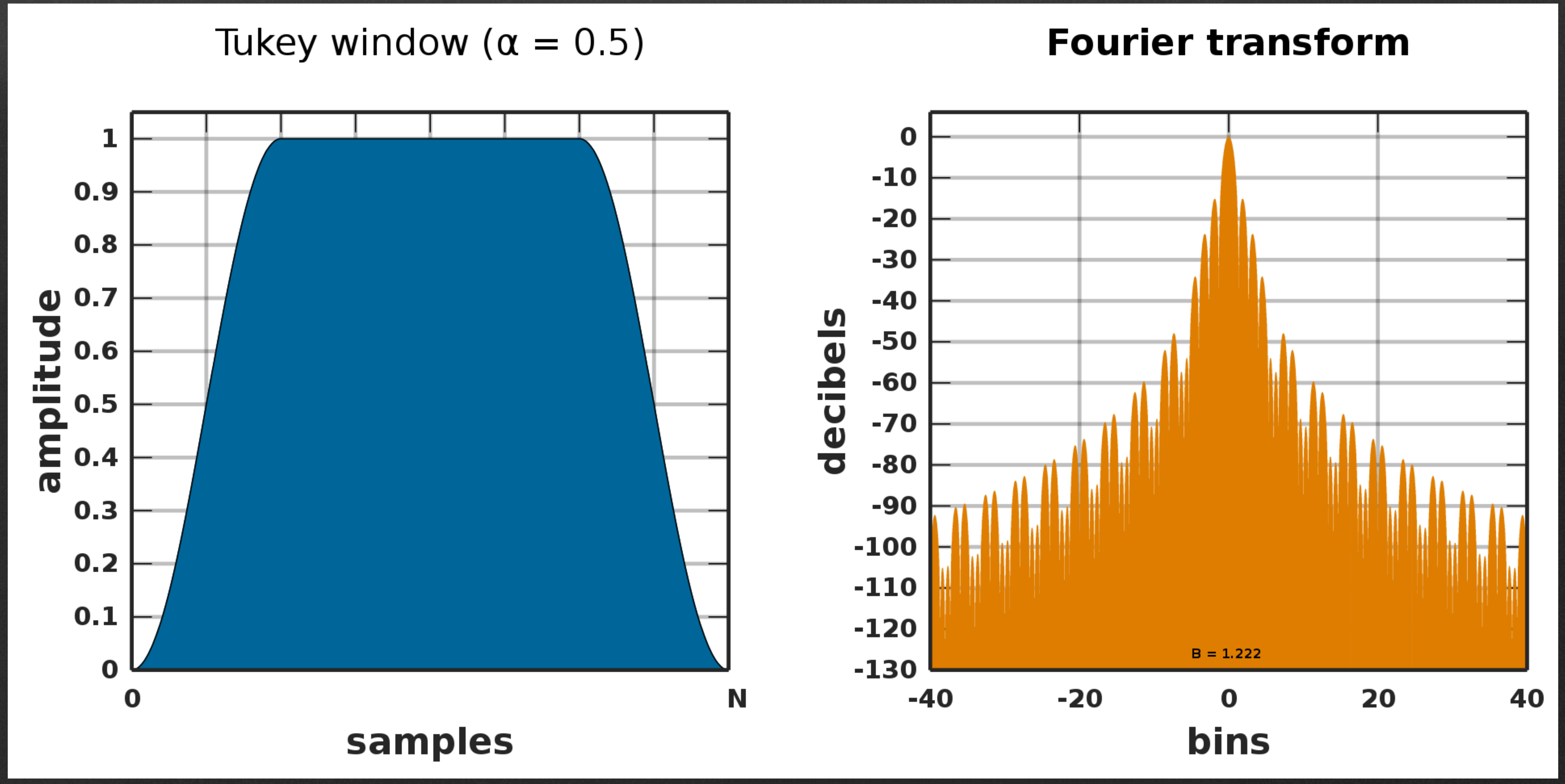
- Window the data smoothly in/out
  - Multiply data by half of a very long cosine

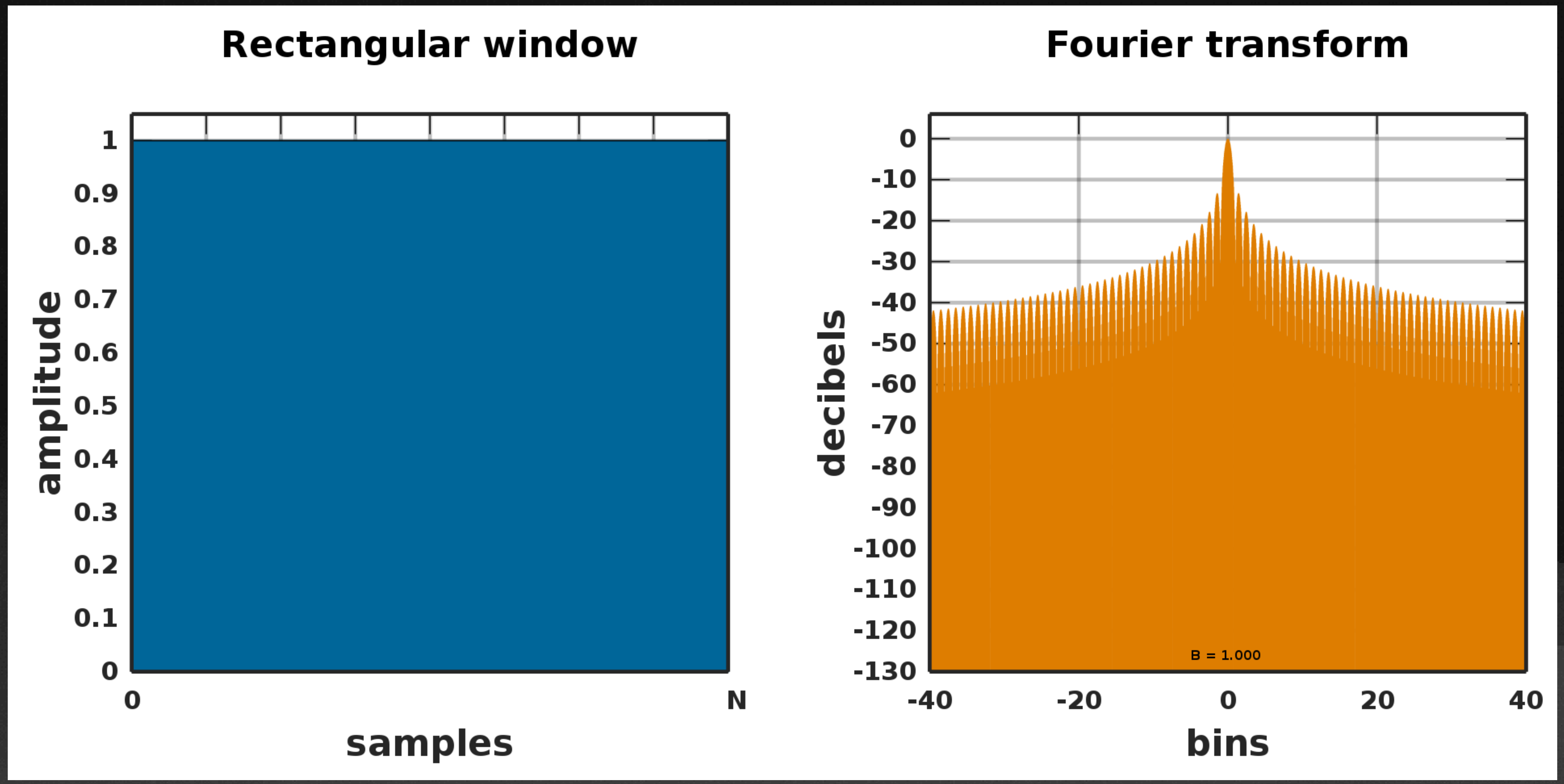


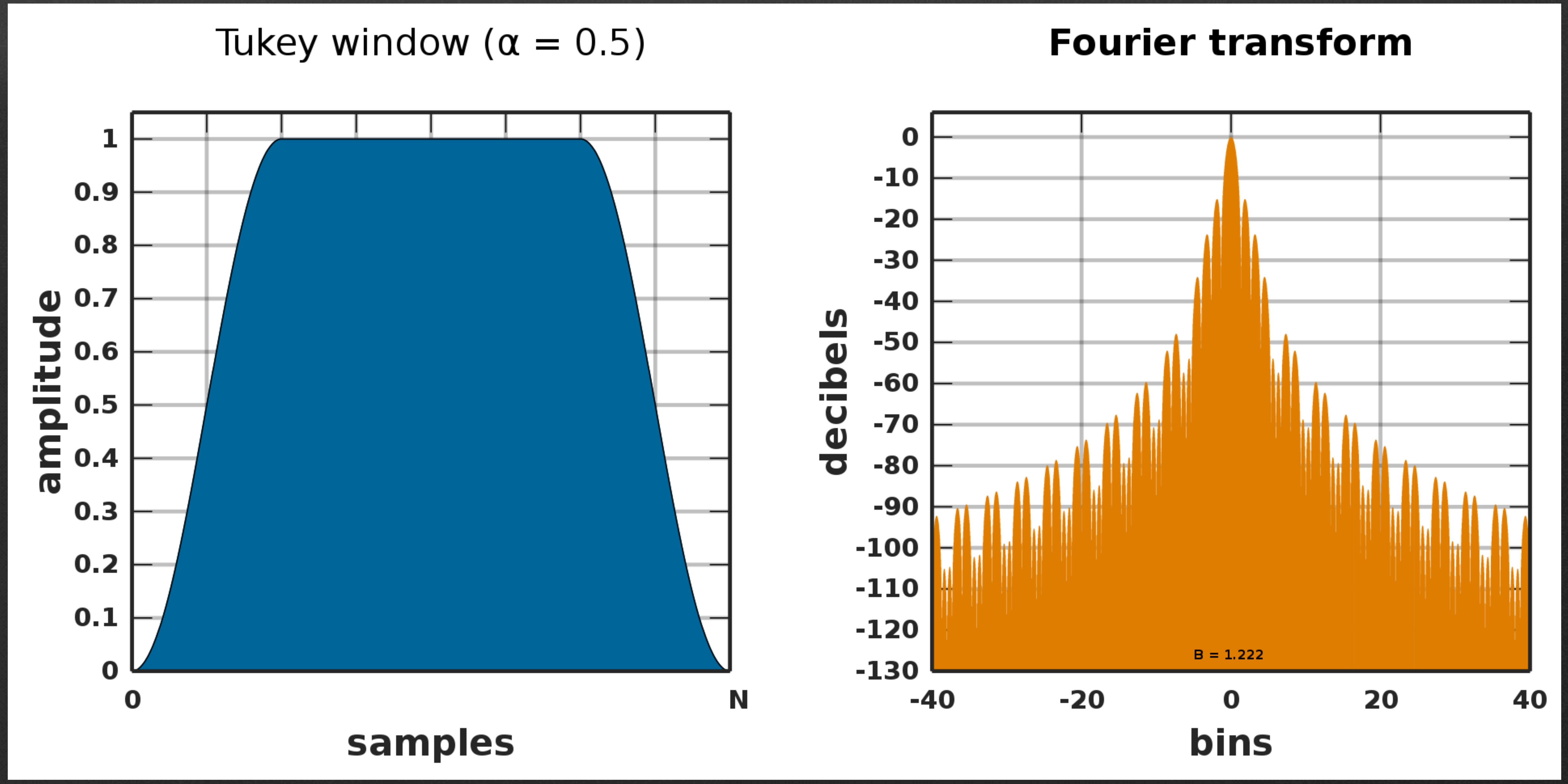


Artefact Mitigation

Gaps

- Detect gaps by looking for missing data
- Set missing data to 0
    - Results in spectral leakage
- Window the data smoothly in/out
    - Multiply data by half of a very long cosine
    - Reduces leakage





Artefact Mitigation

Glitches

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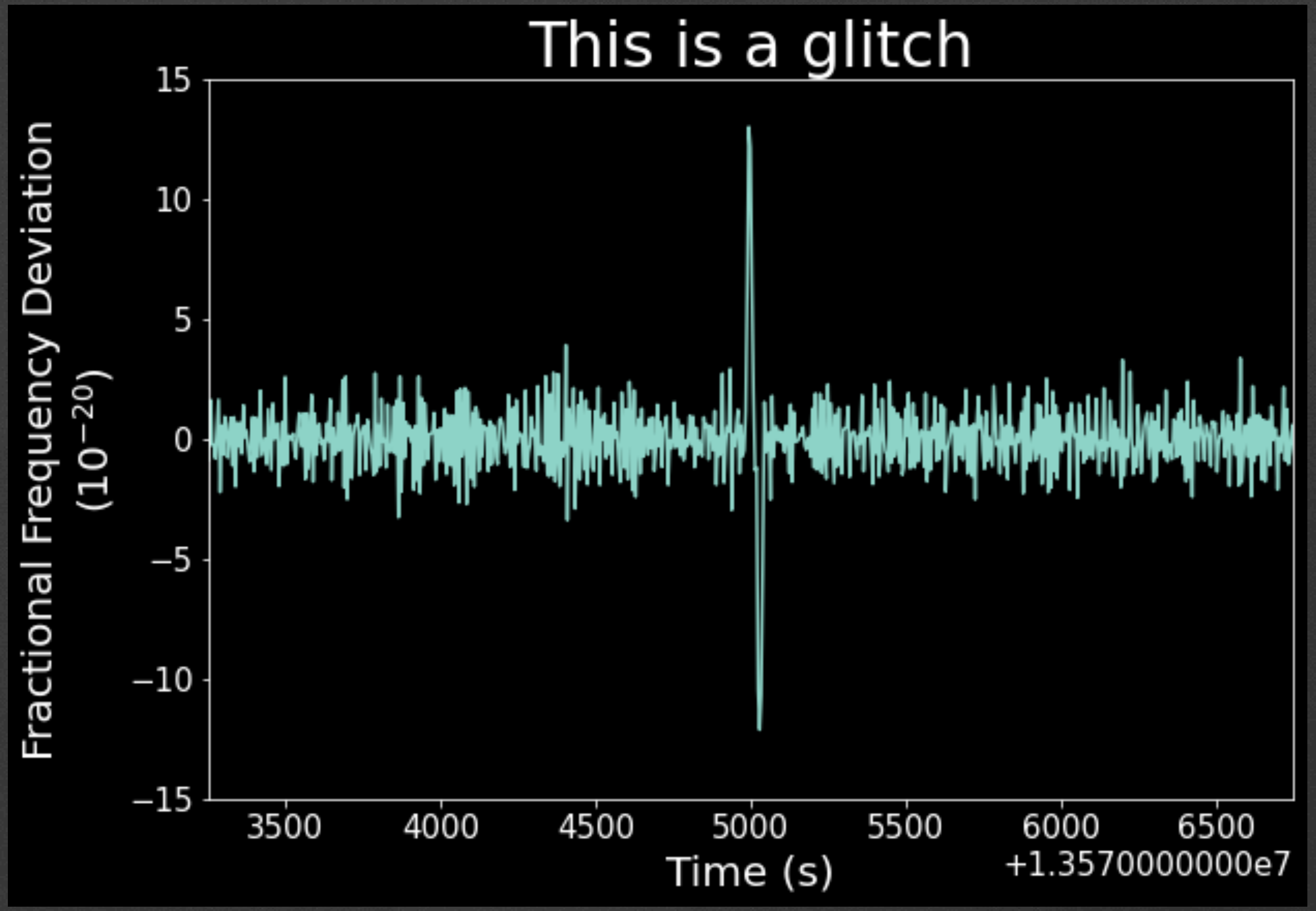

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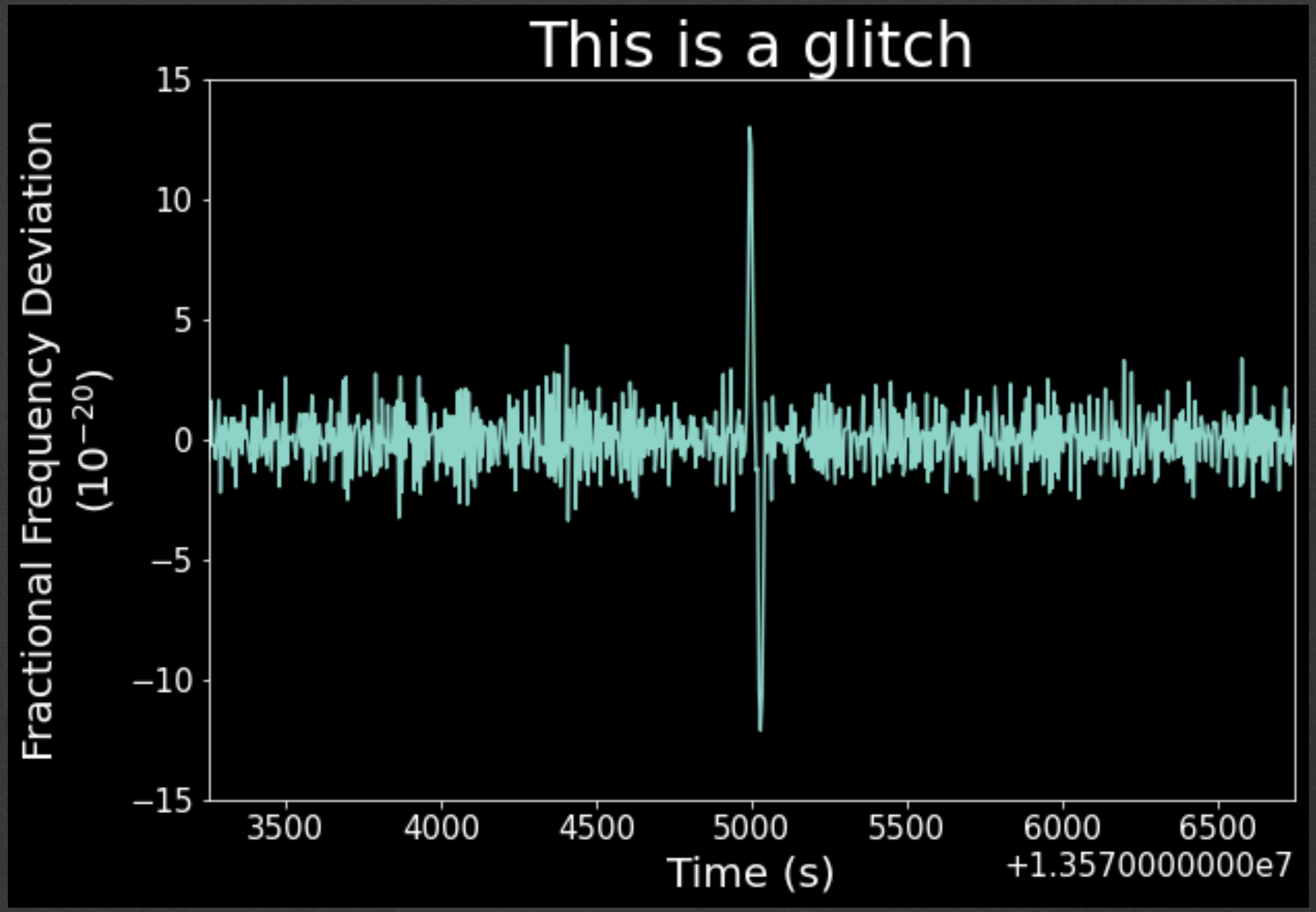

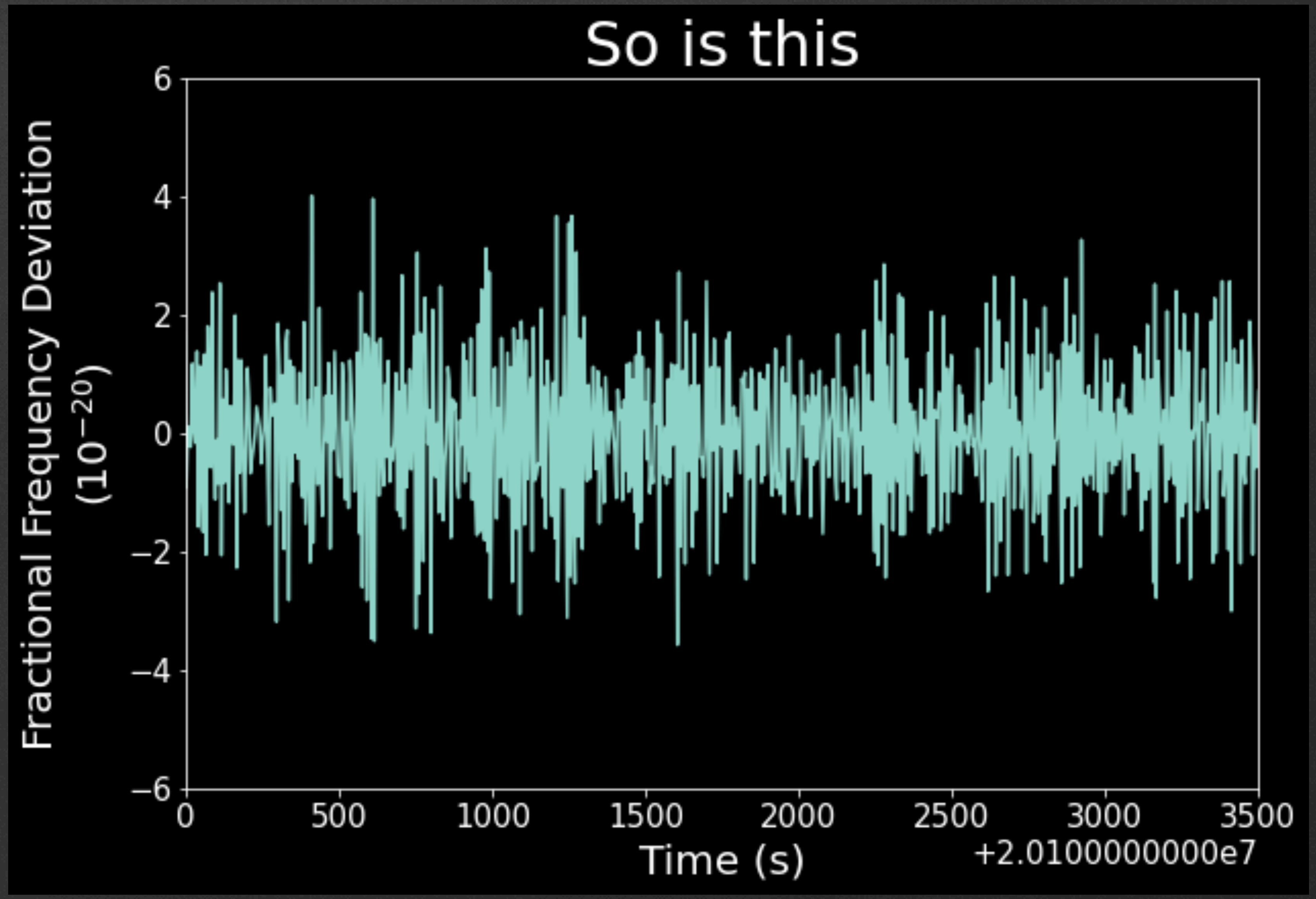

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Artefact Mitigation

Detection Methods

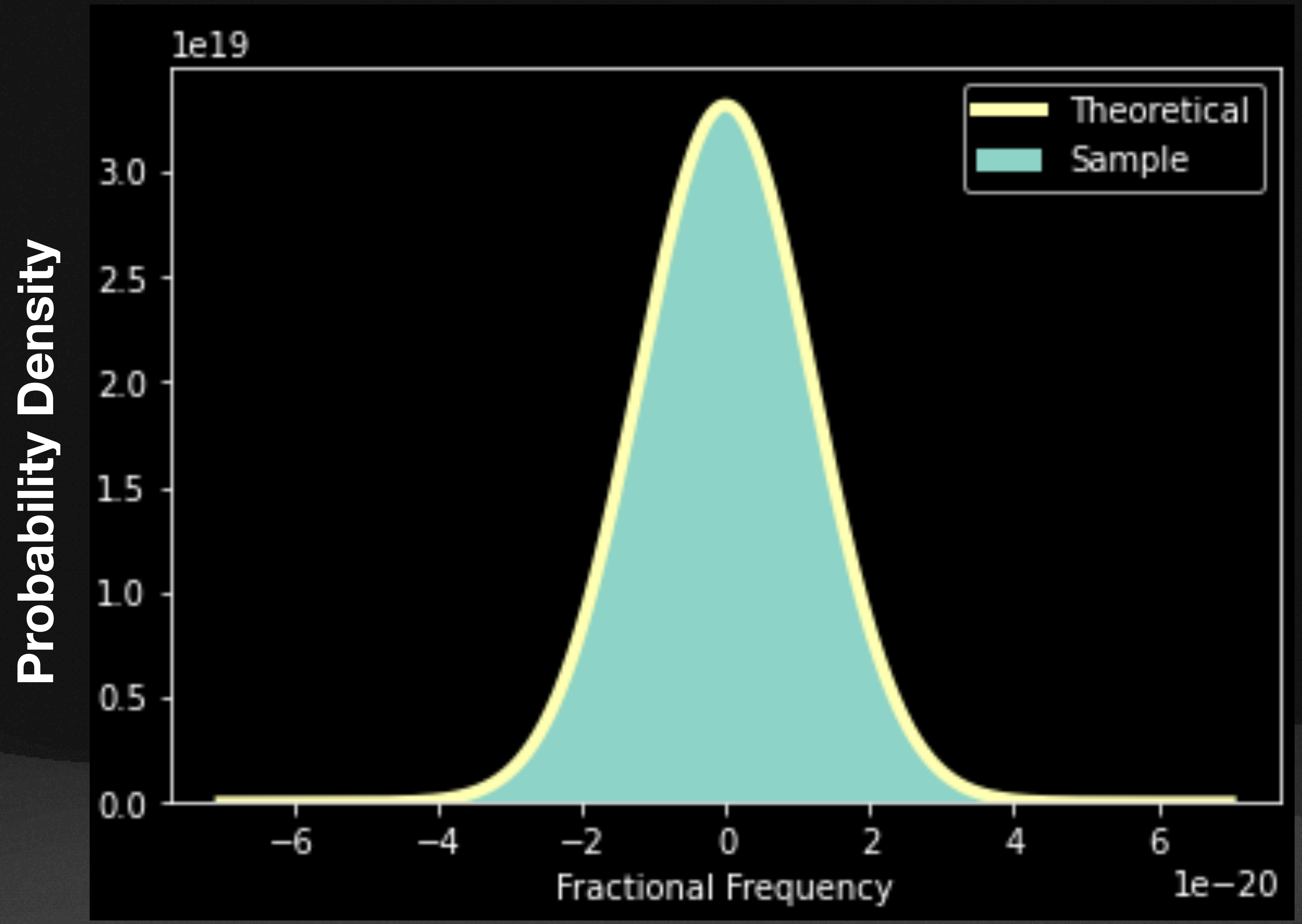
Artefact Mitigation
Detection Methods

- Method I use is cut out glitches based on:

Artefact Mitigation

Detection Methods

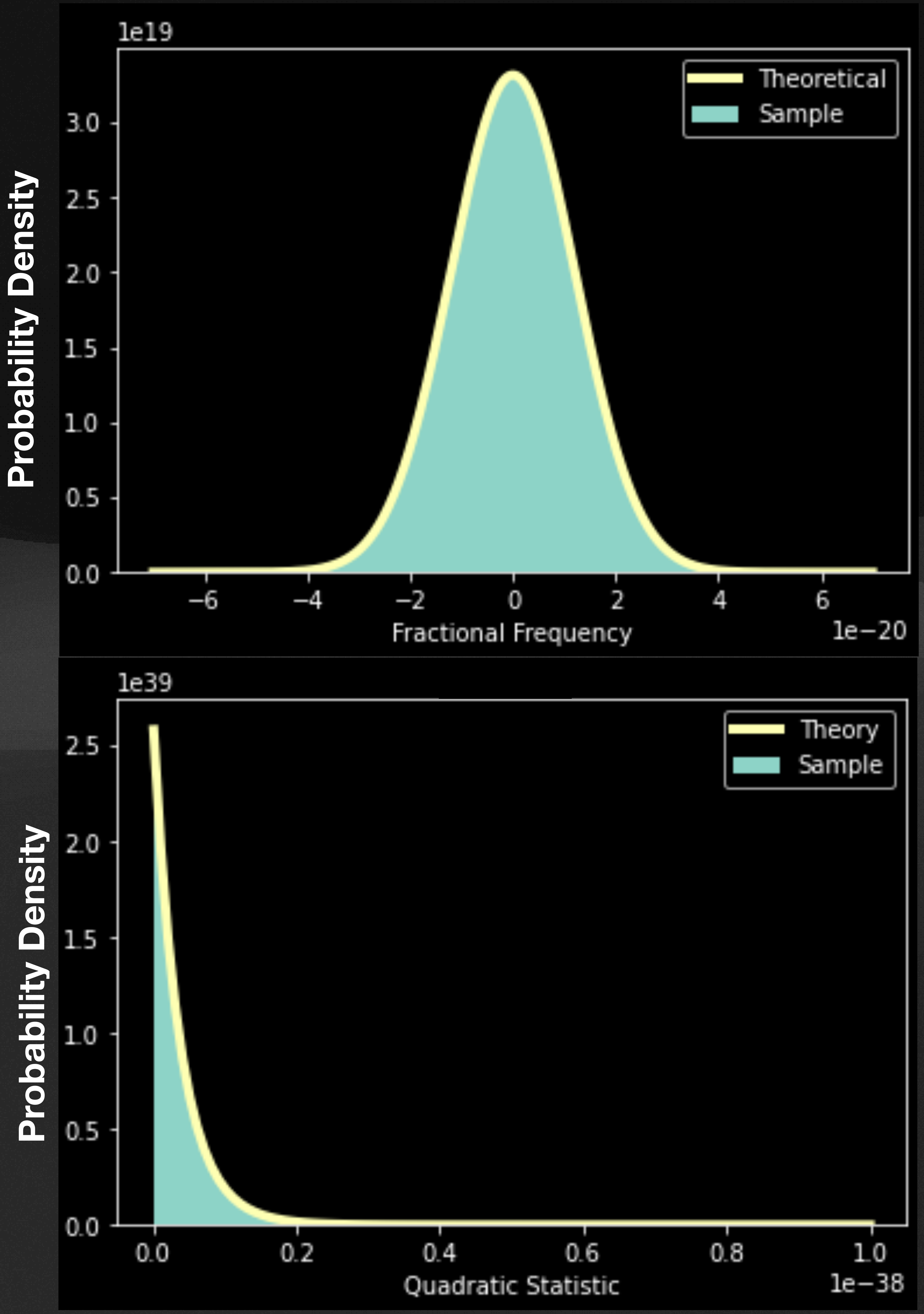
- Method I use is cut out glitches based on:
  - Data amplitude (A)



Artefact Mitigation

Detection Methods

- Method I use is cut out glitches based on:
  - Data amplitude (A)
  - "Quadratic Statistic" $A^2 + (\frac{d}{dt}A)^2$



Artefact Mitigation
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- Method I use is cut out glitches based on:
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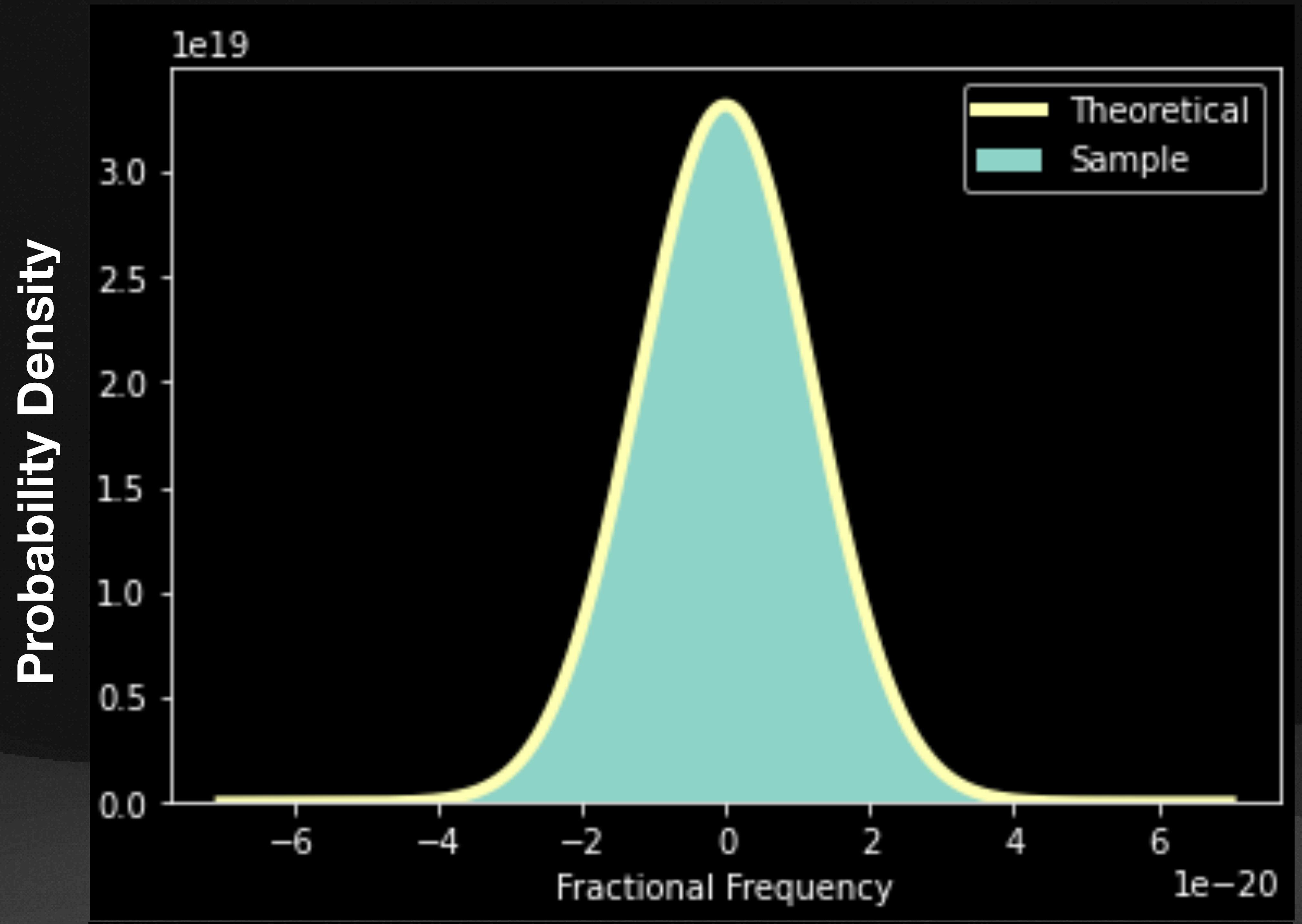

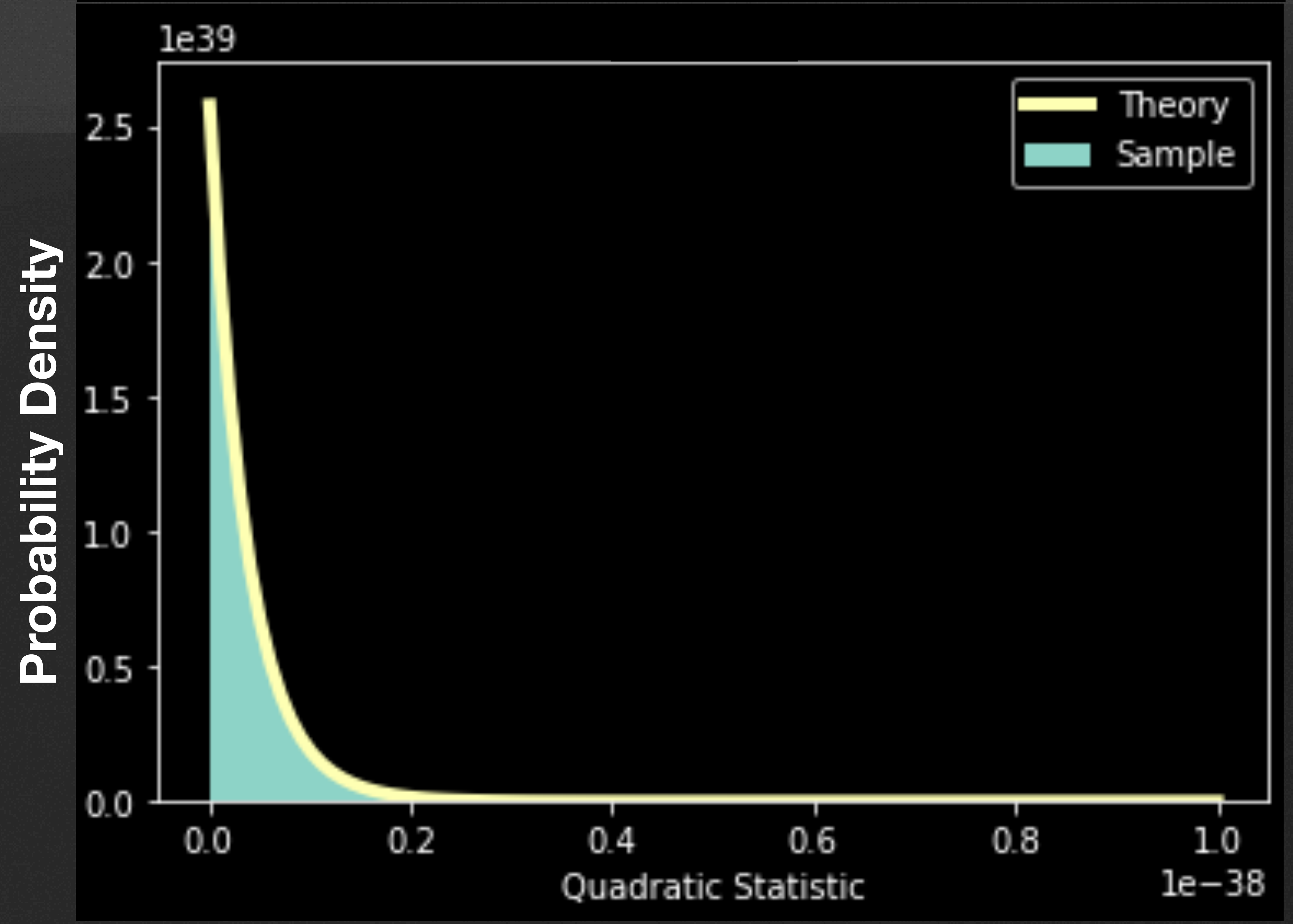

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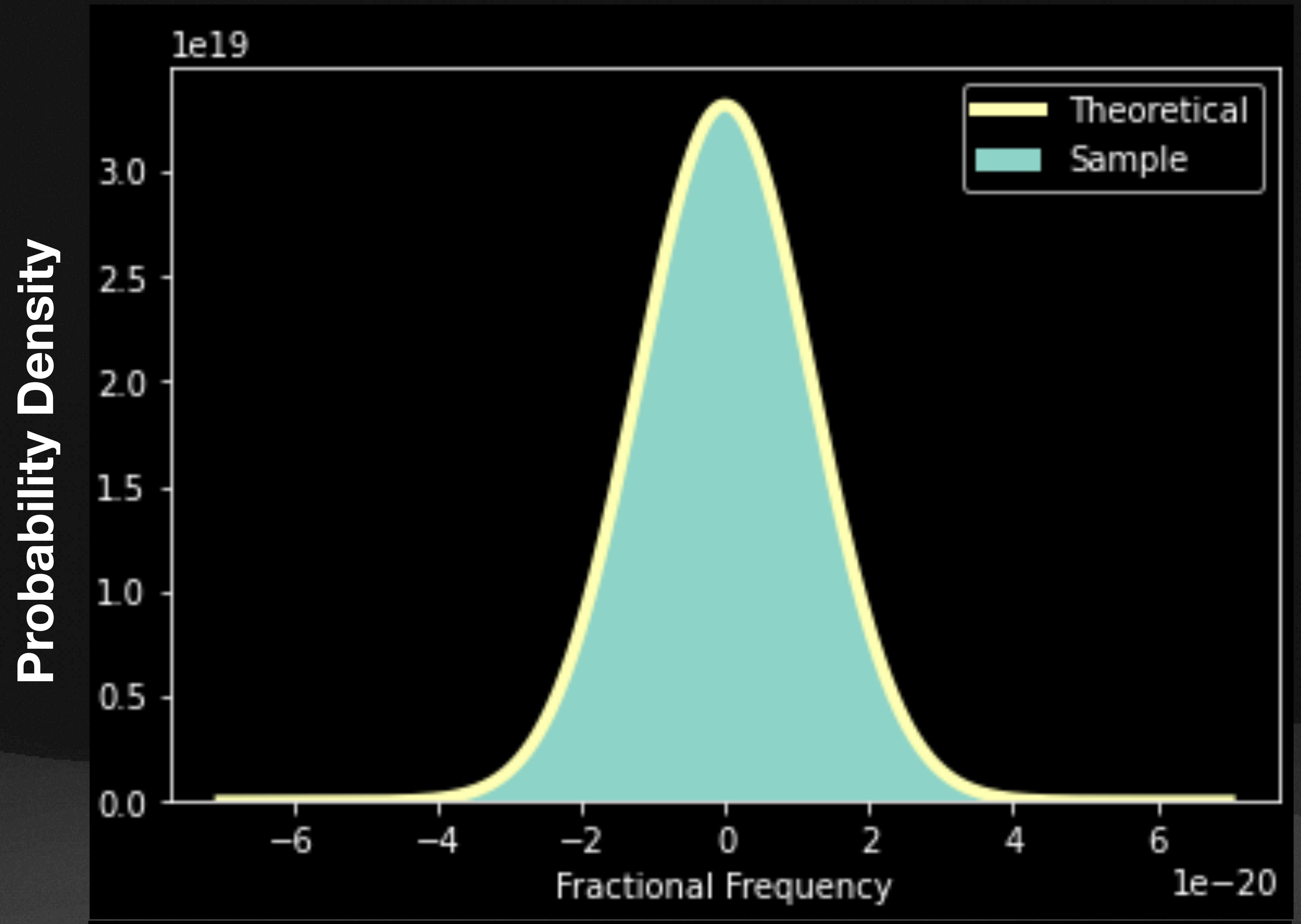
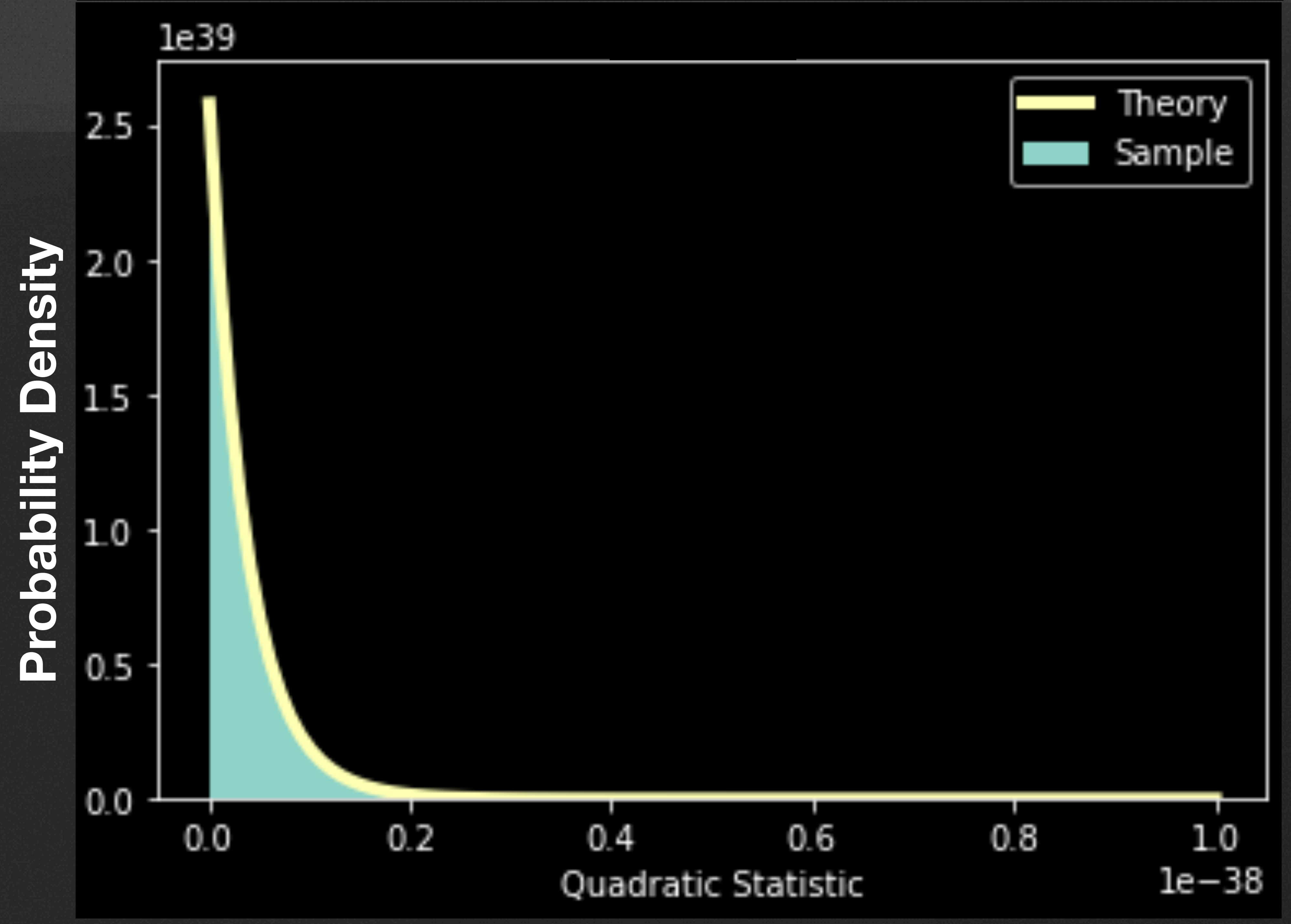
  - Data amplitude (A)
  - "Quadratic Statistic" $A^2 + (\frac{d}{dt}A)^2$
- Can derive expressions for PDFs in both regular and whitened data
- Choose how much data to lose, cut glitches based on choice





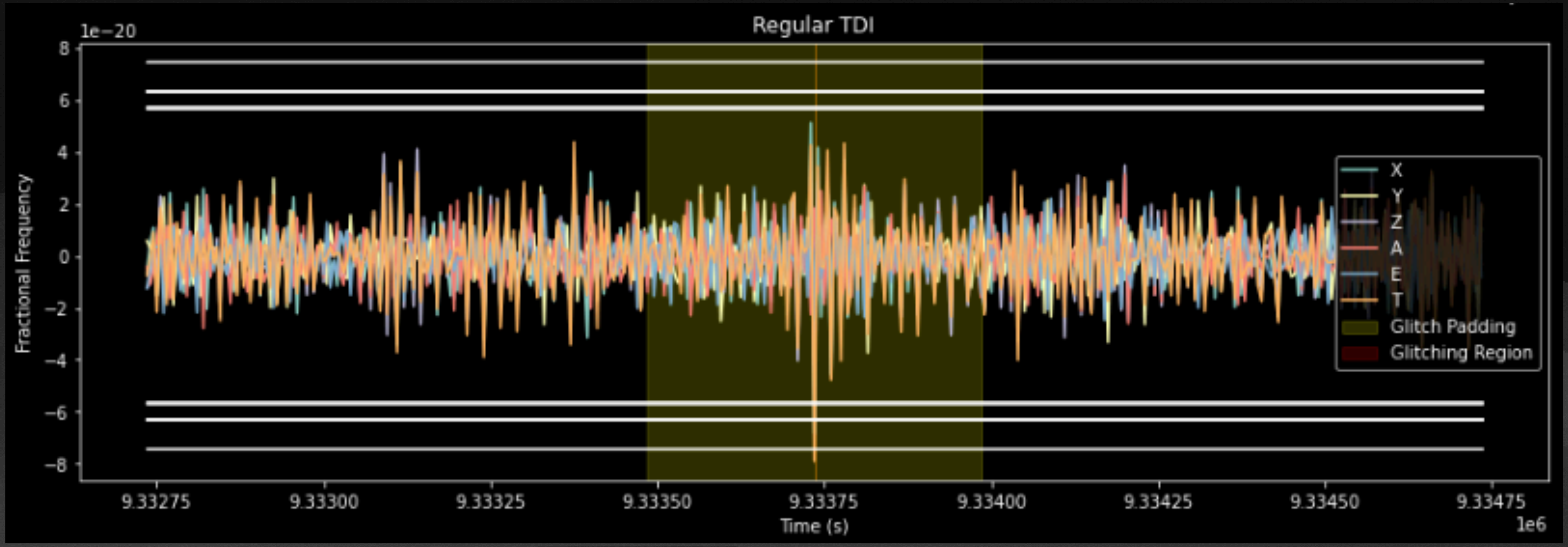
Artefact Mitigation

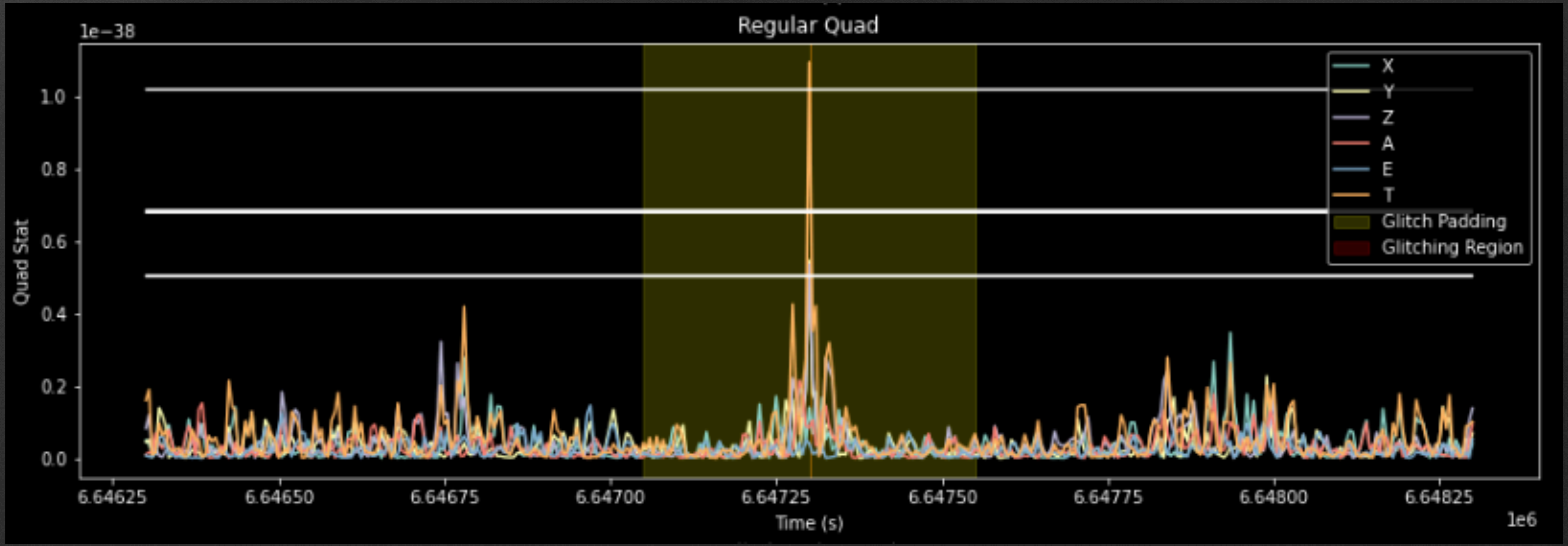
Detection Methods

Artefact Mitigation

Detection Methods

- Both methods incorrectly identify lots of data as glitches





Artefact Mitigation

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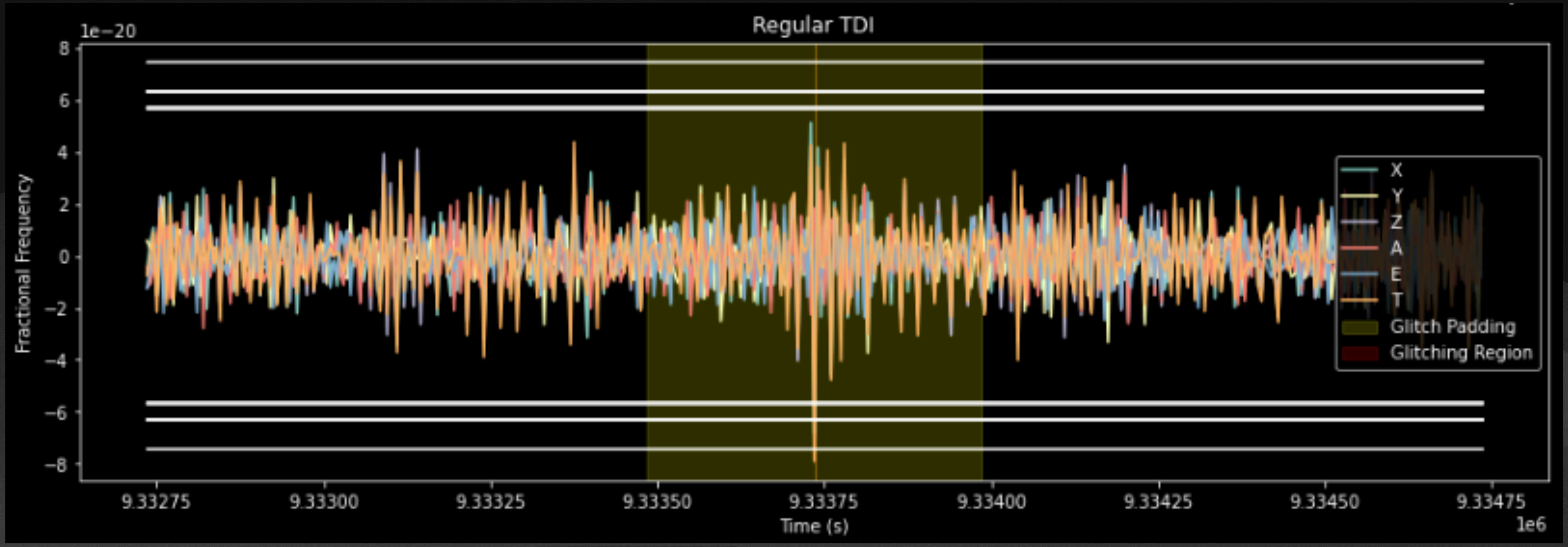
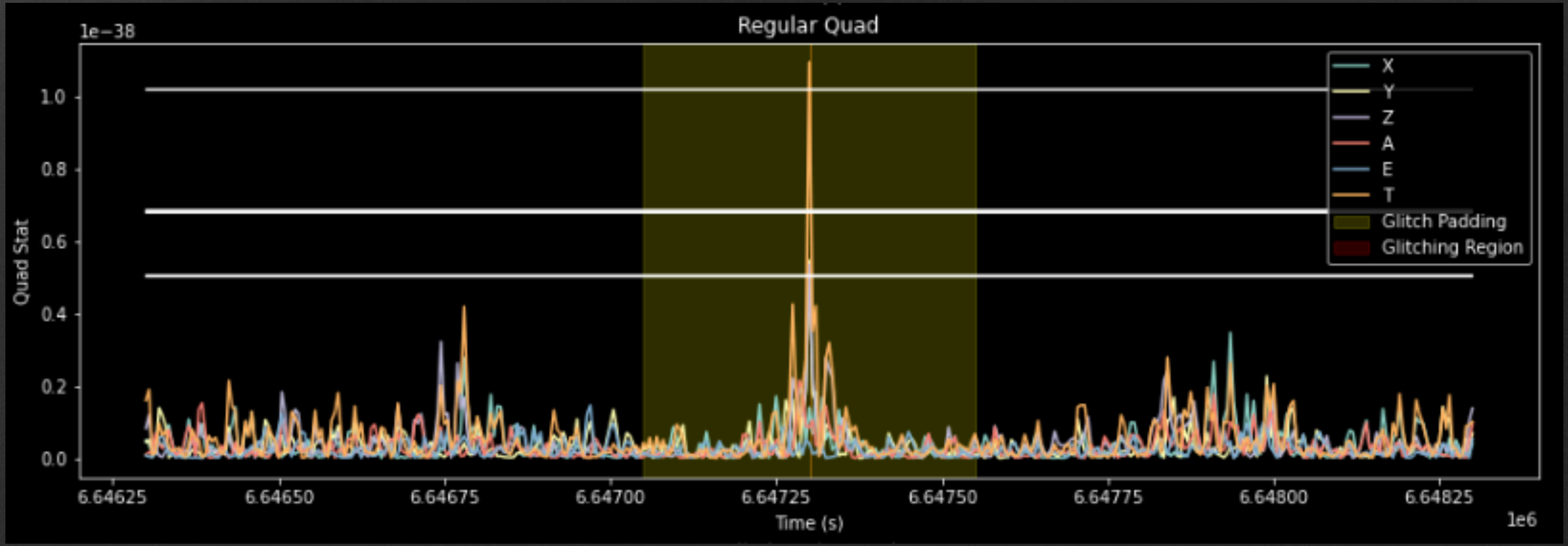
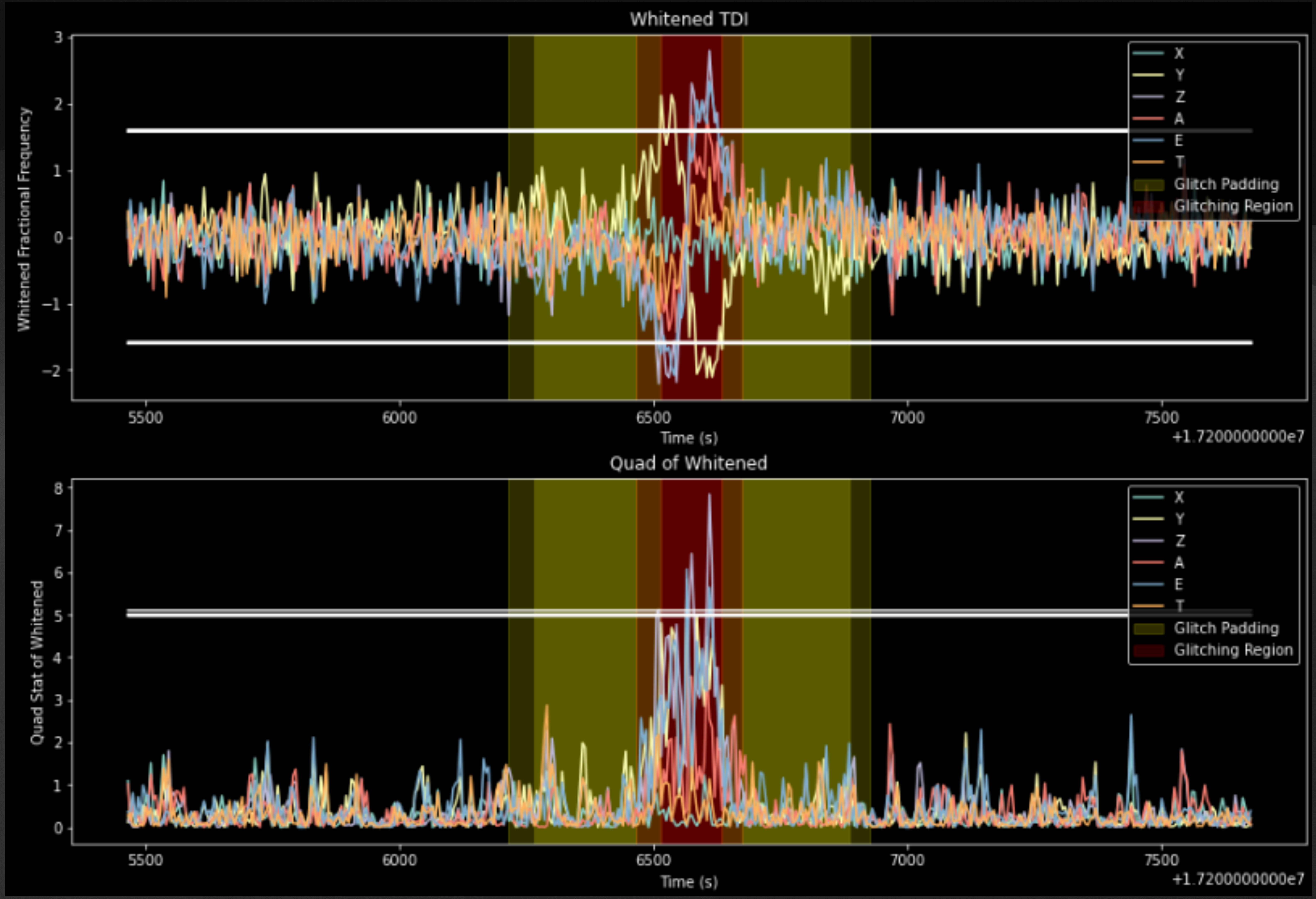




Artefact Mitigation

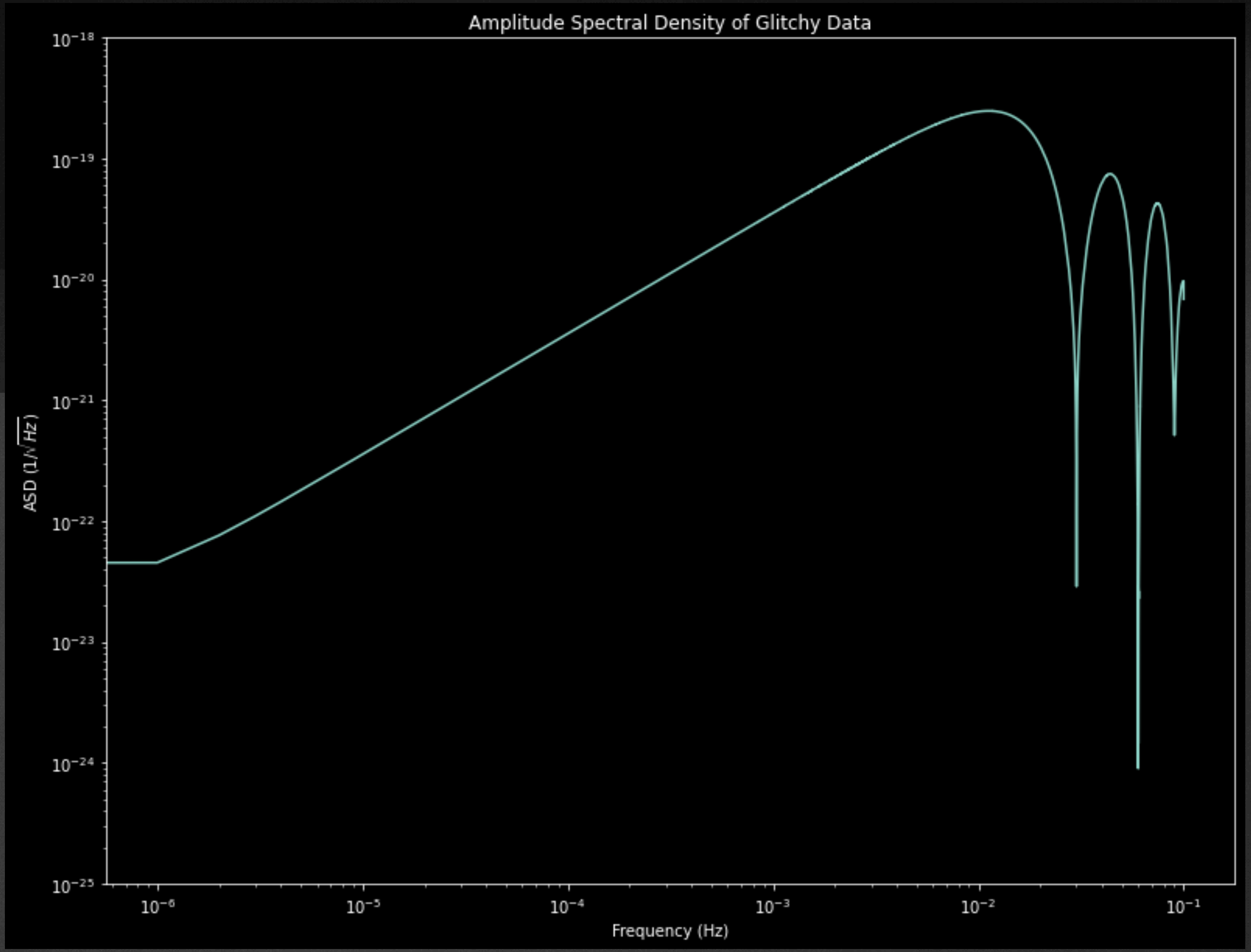
Detection Methods

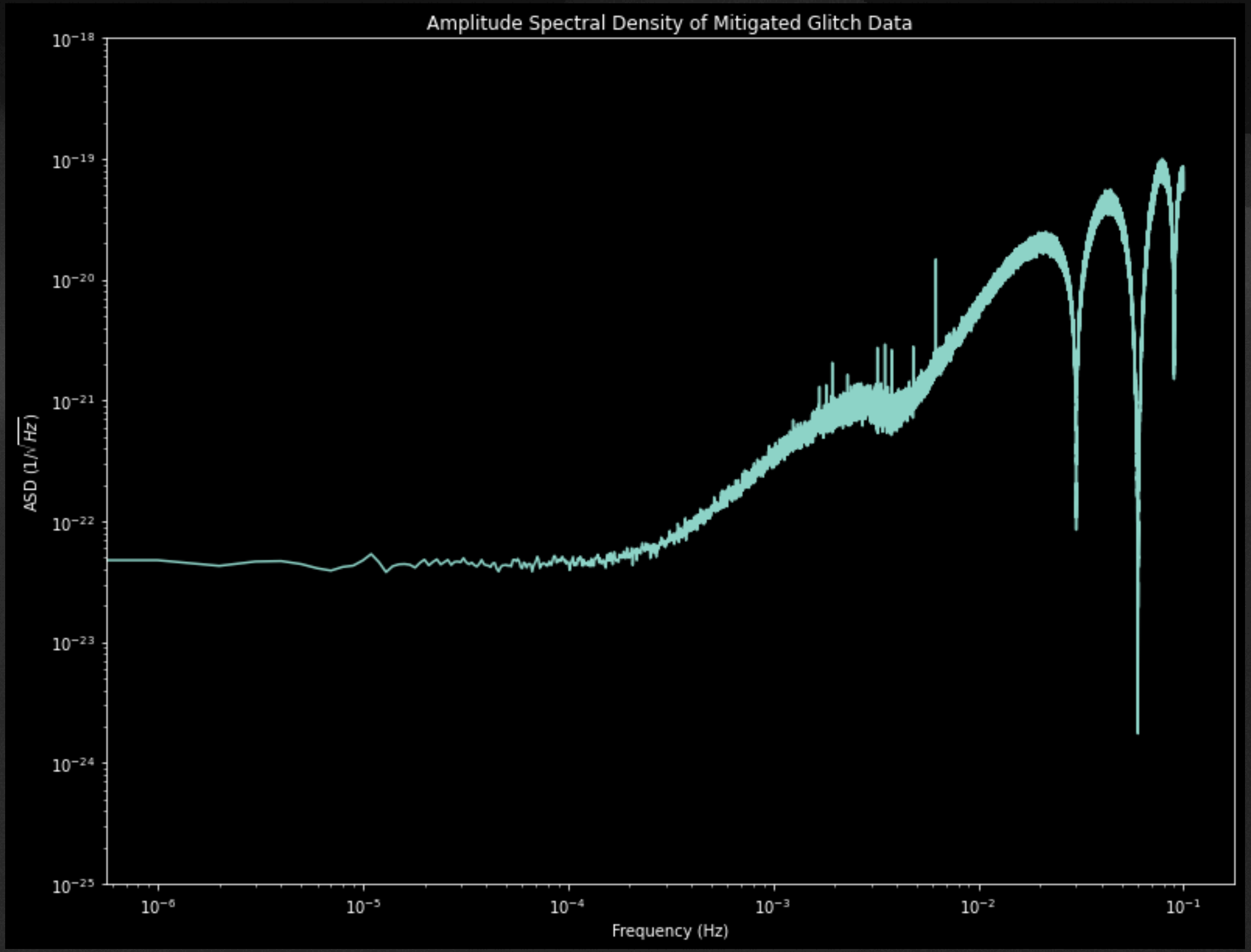
- Both methods incorrectly identify lots of data as glitches
- BUT
- Intersection of the two reduces false alarm rate drastically without affecting glitch detection



Artefact Mitigation

Results





Parameter Estimation

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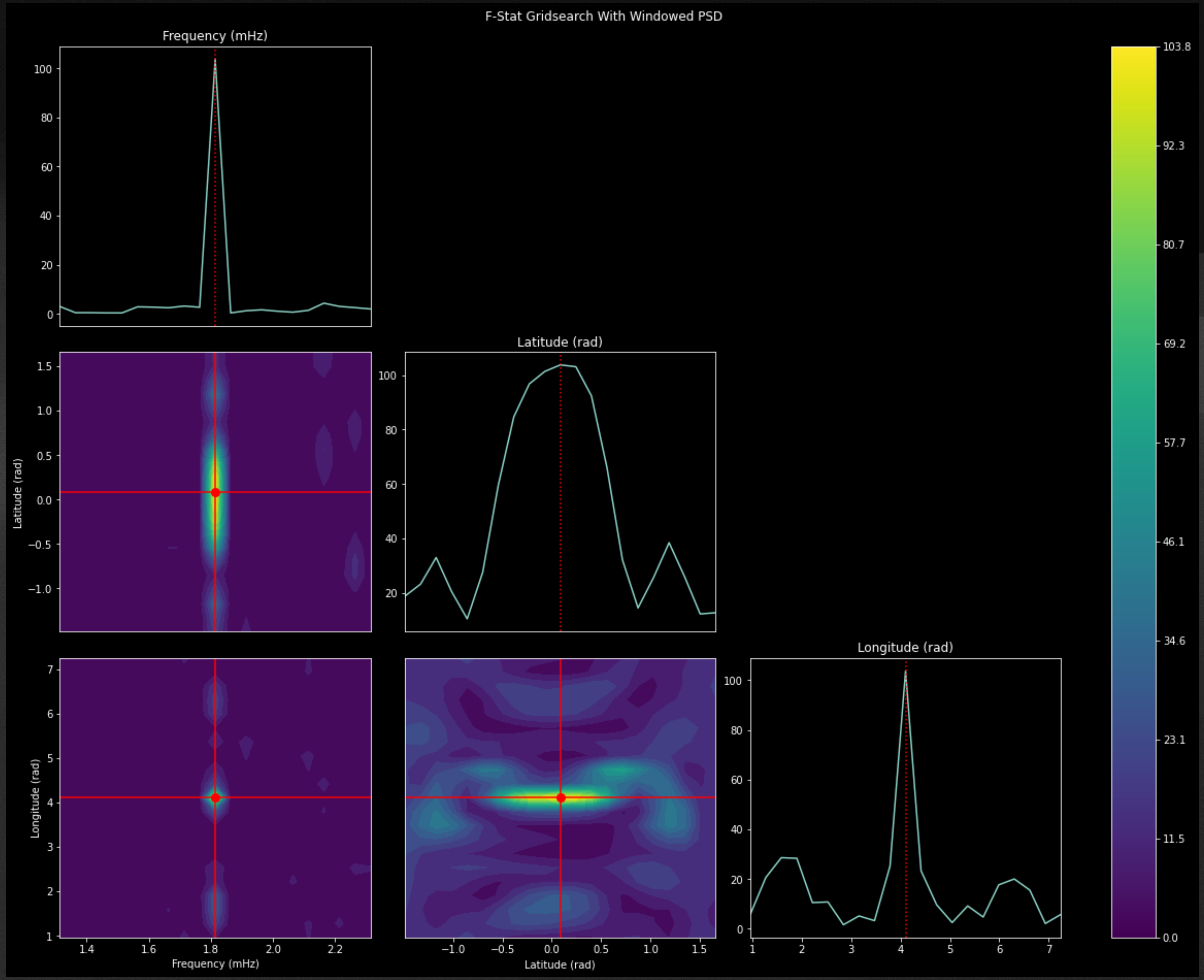
- Analytically maximize likelihood of four parameters, gridsearch over remainder



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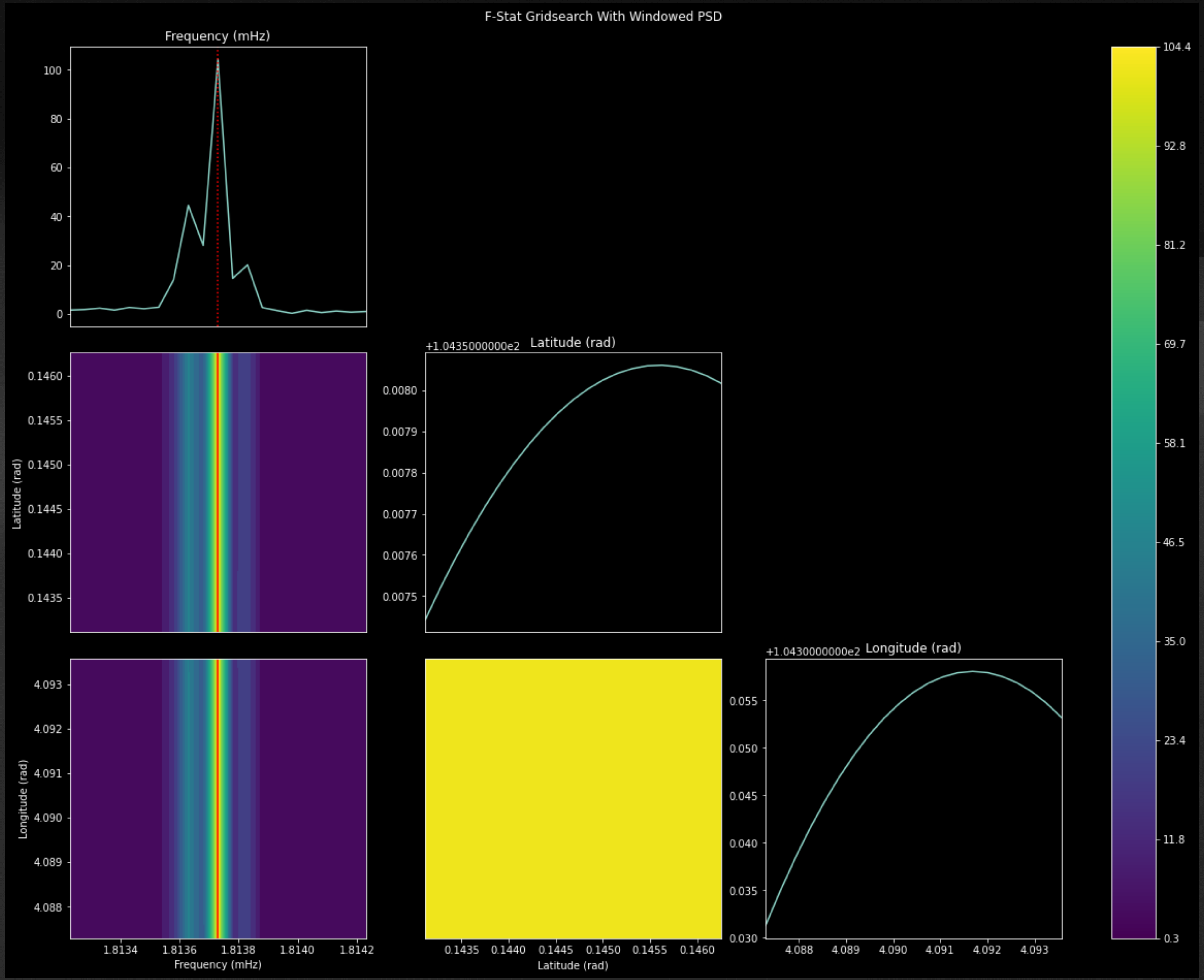

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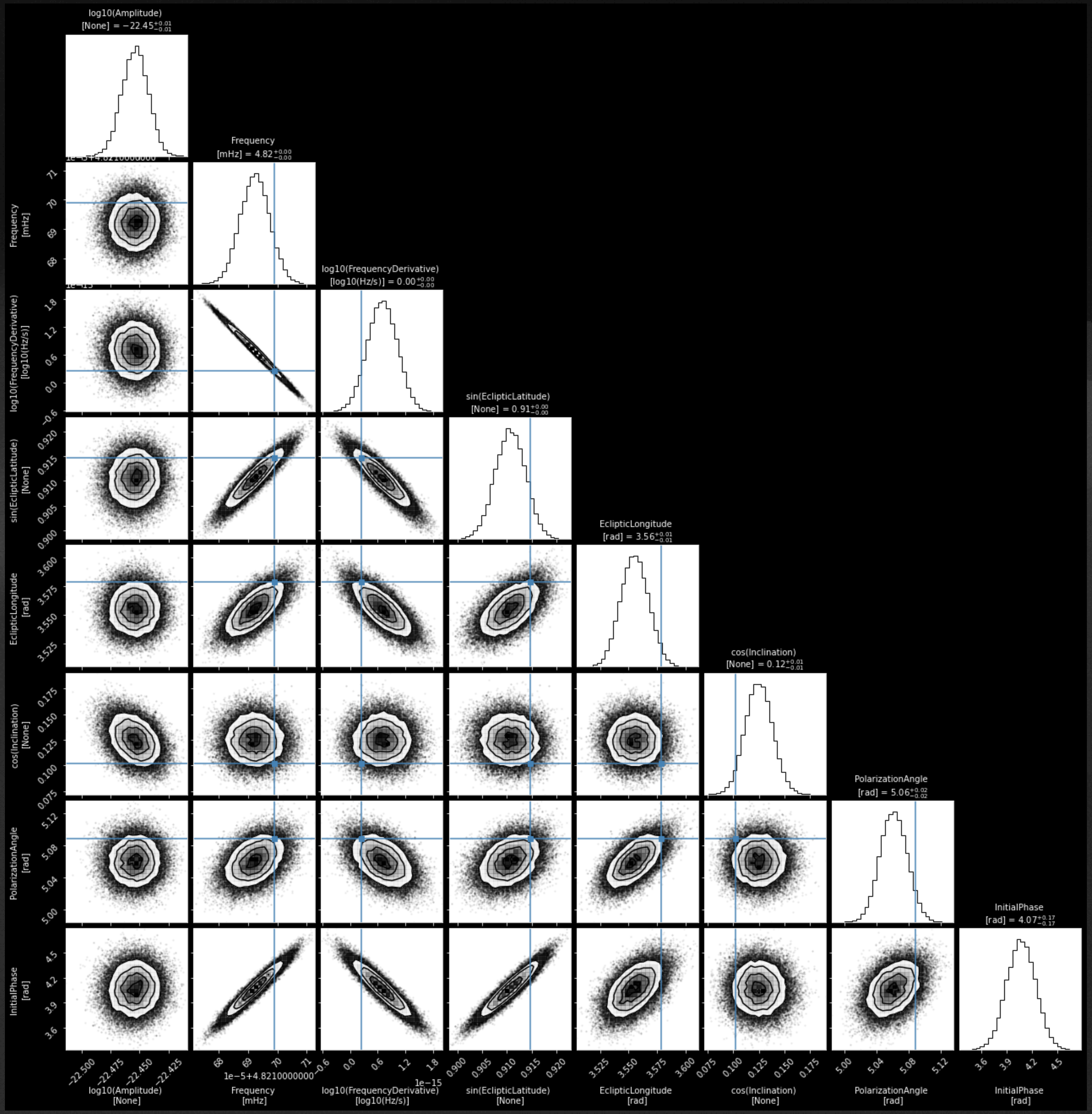
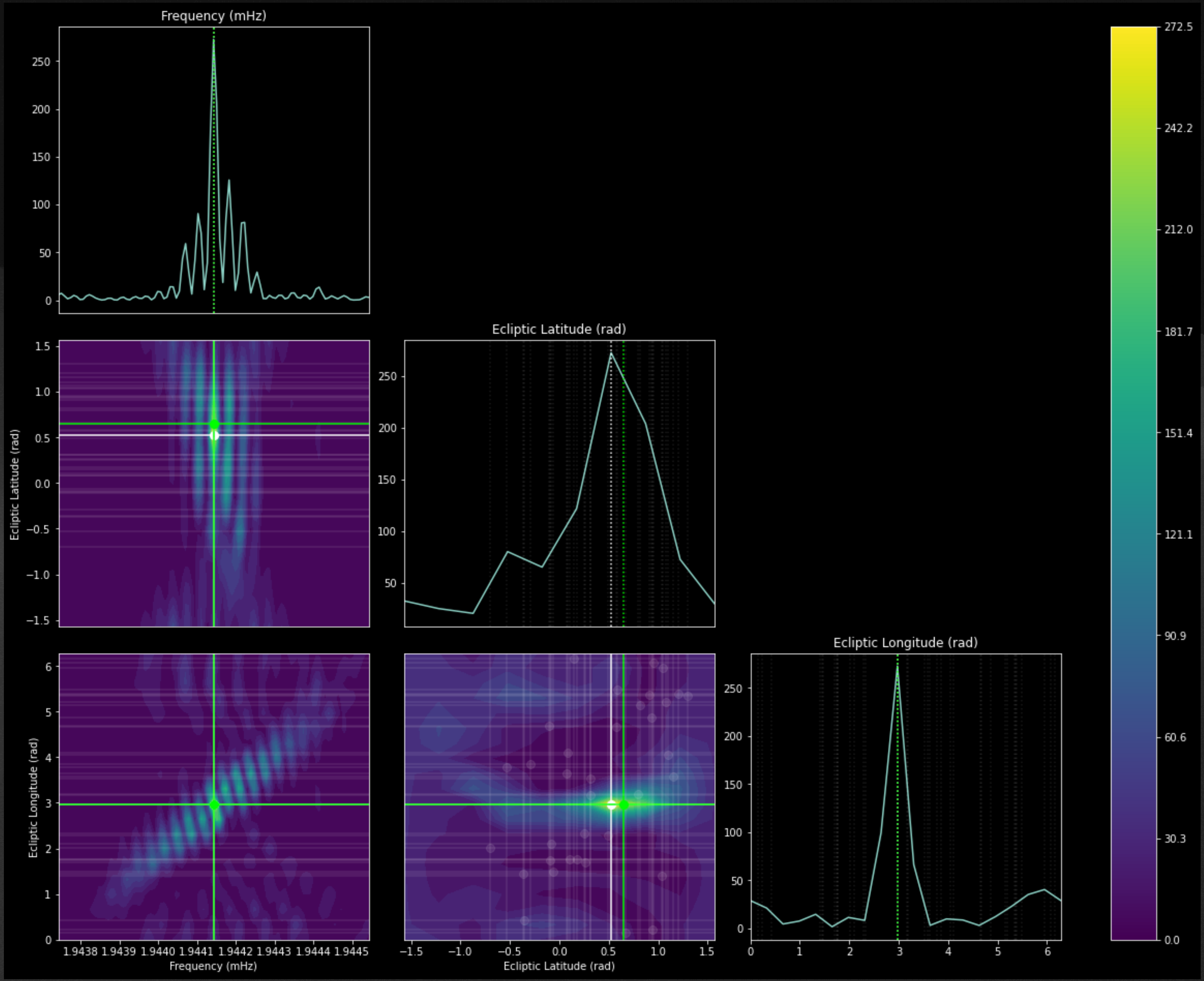
- Start an MCMC sampler in the maxima and let it map out the posterior



Results

Example of Maximal Likelihood Gridsearch



Results

- All sources detected in provided artefact-free dataset also detected in full dataset using this procedure

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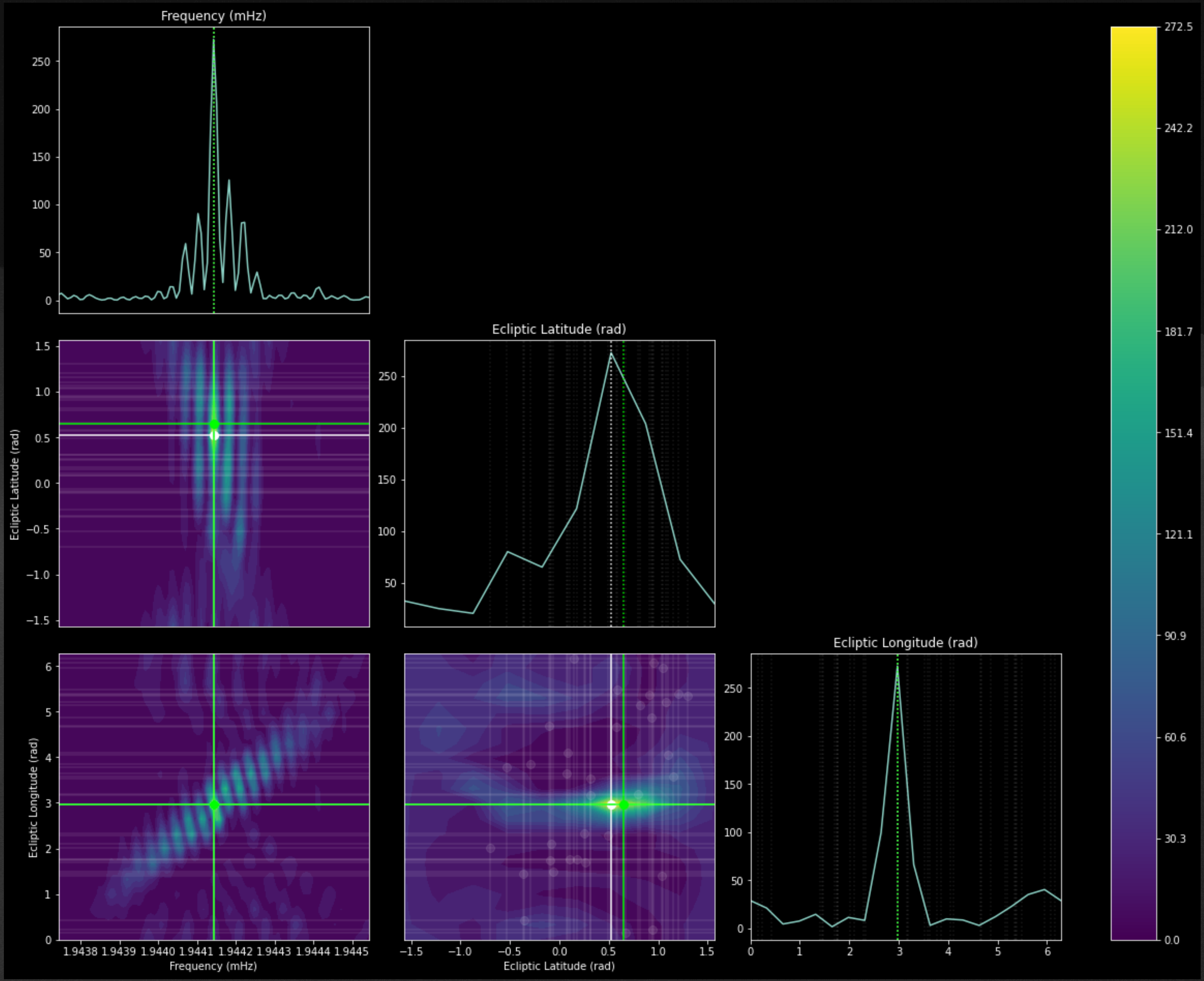

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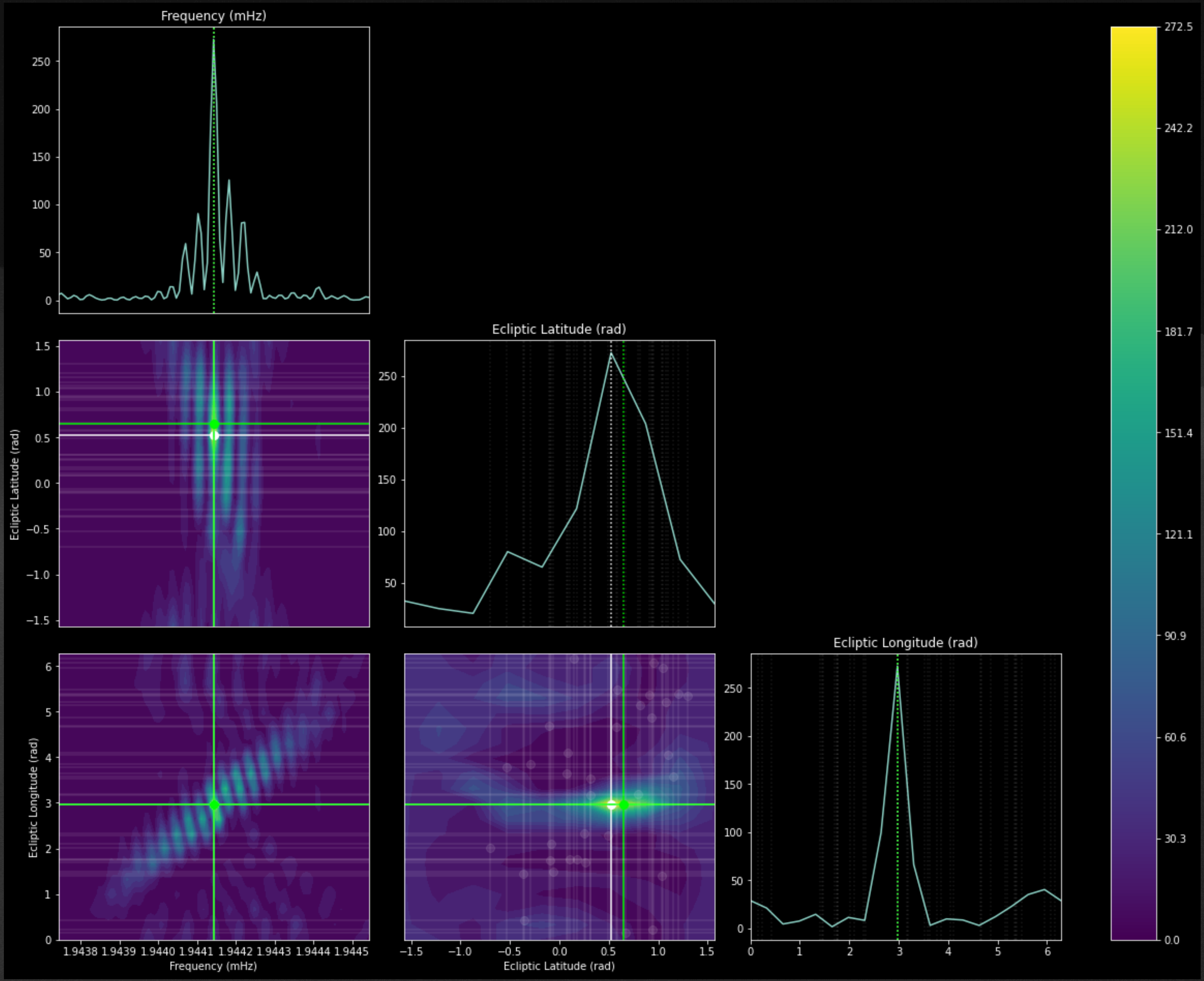

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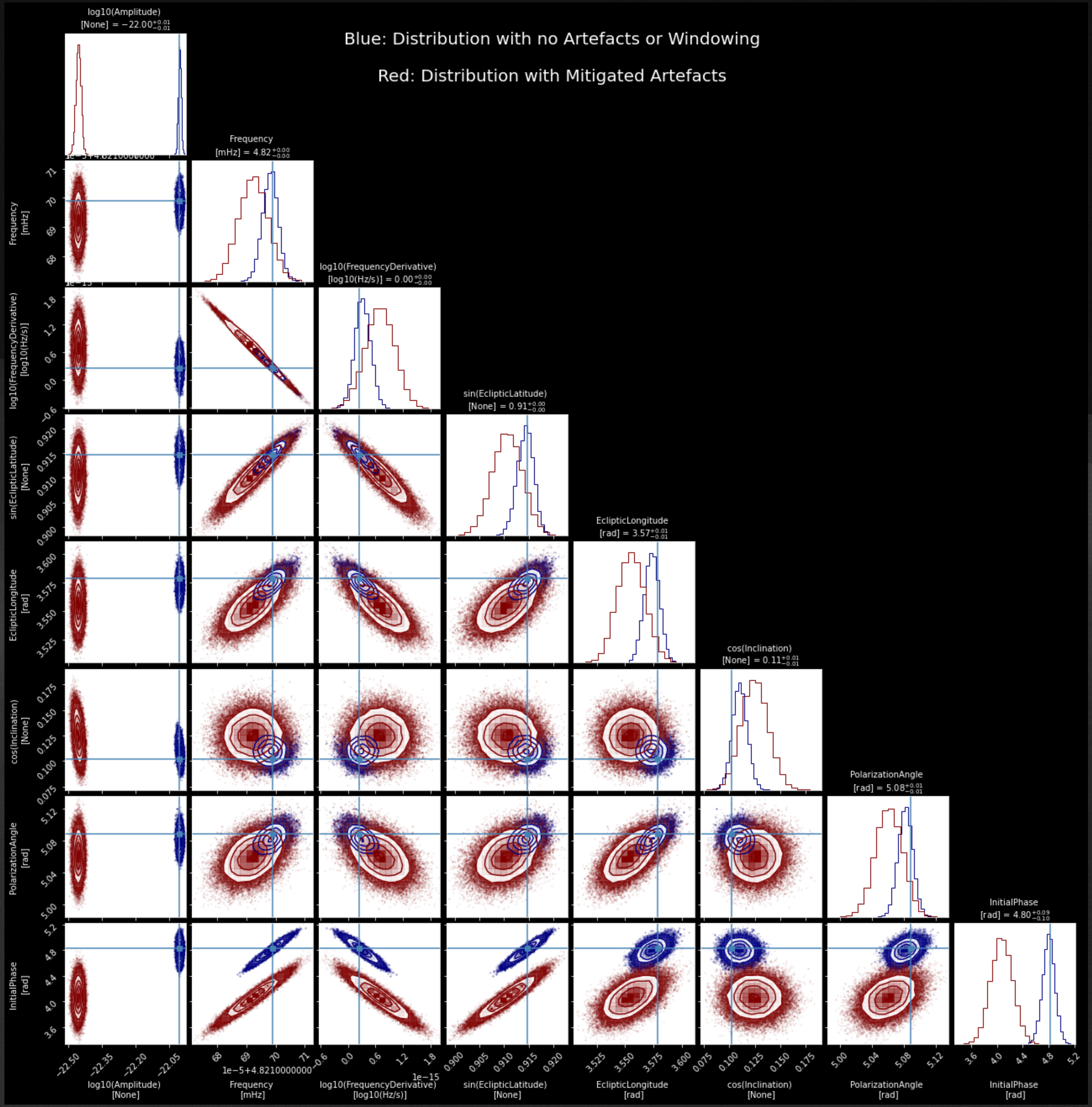
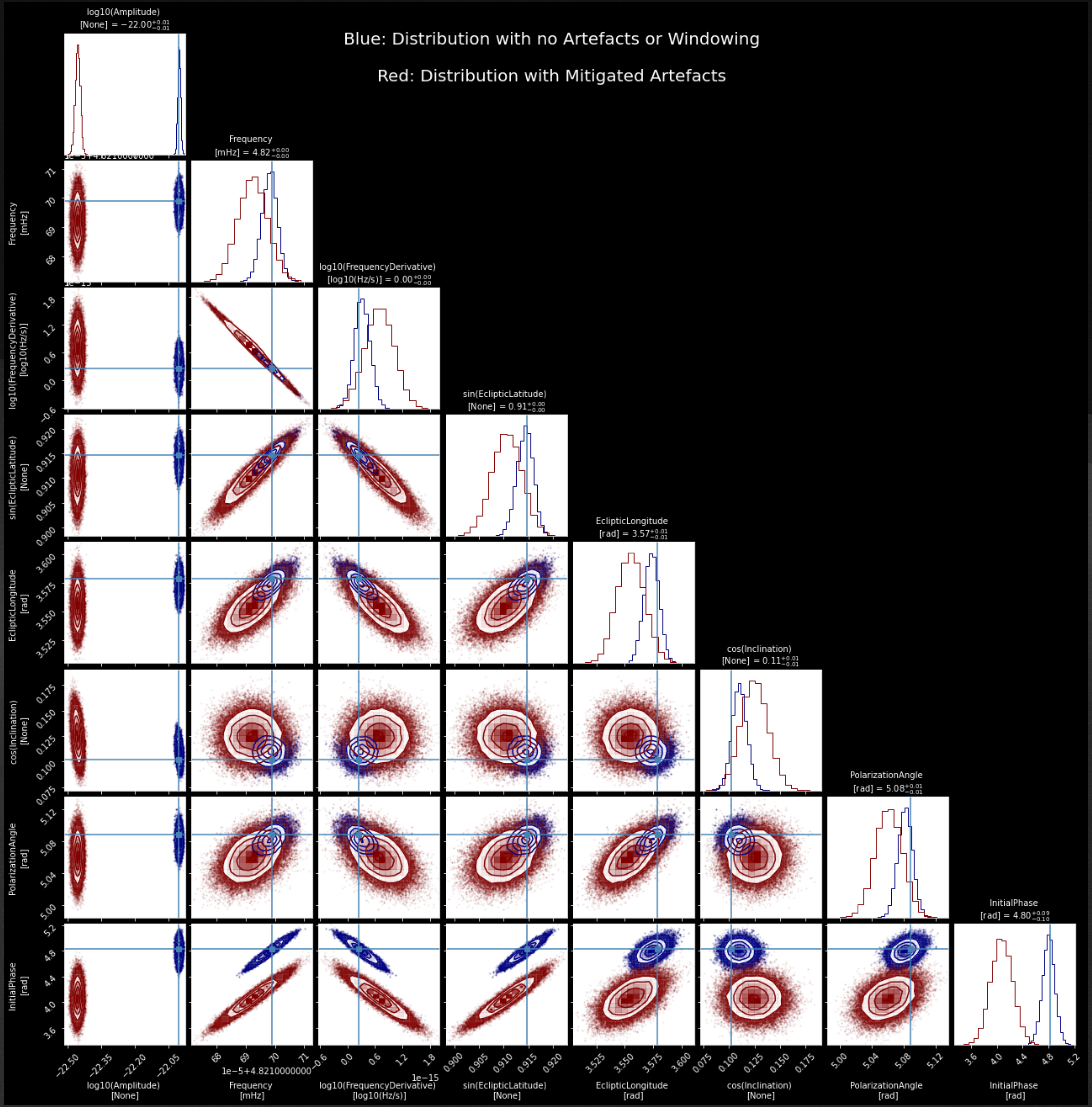


Results

- All sources detected in provided artefact-free dataset also detected in full dataset using this procedure
- Maximized likelihood gridsearch effective at narrowing in on true source parameters
- MCMC after artefact mitigation is biased, especially in amplitude and initial phase
- Including the windowing from mitigation in likelihood function probably helpful - Working on this now



Questions