Noise Rejection Method Using Spherical Harmonic Decomposition

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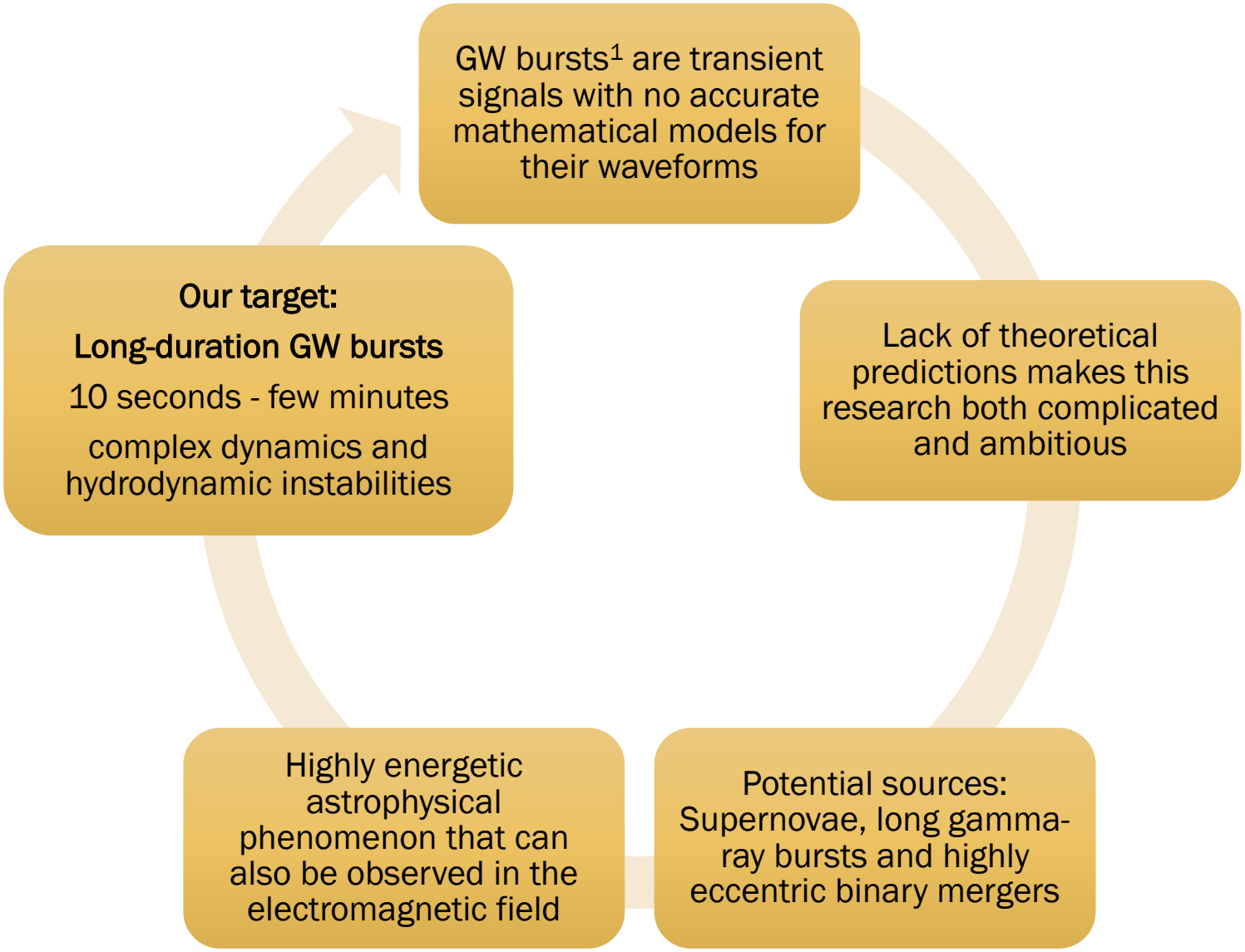
Noise Rejection Method Using Spherical Harmonic Decomposition

- Gravitational-wave burst-like signals: an introduction
- X-SphRad: software package for active research
- Glitch Rejection: method overview and first tests
- SWOT analysis

Gravitational-wave burst-like signals: an introduction



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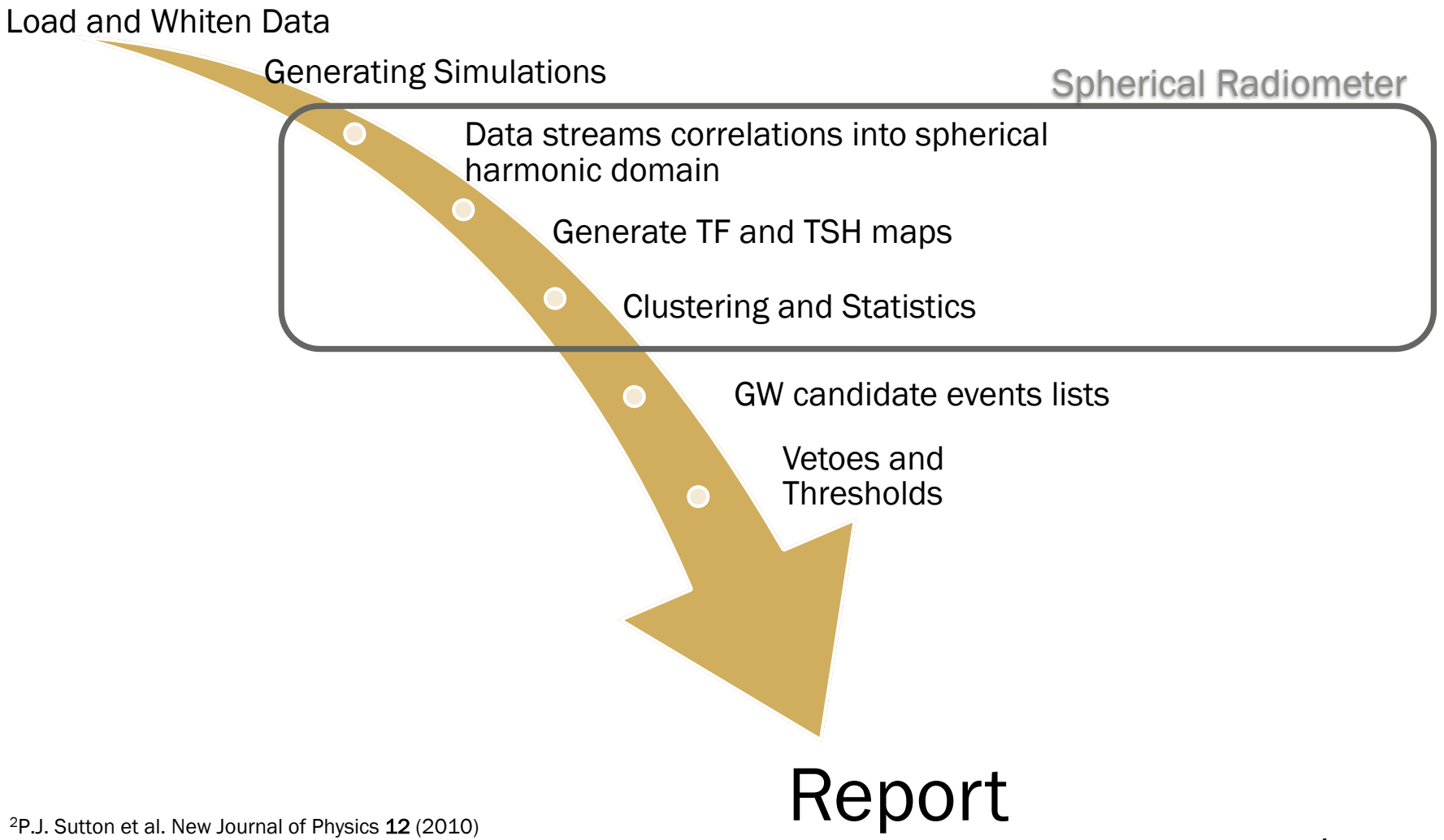
[1]E. E. Flanagan and S. A. Hughes, Phys. Rev. D **57**, 4535 (1998)

X-SphRad: The X-Pipeline Spherical Radiometer

- ✓ X-SphRad[2] is a standard tool in gravitational wave analysis for long-duration searches
- ✓ The radiometer pipeline[3] computes data streams correlations into a spherical harmonic domain



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[2]P.J. Sutton et al. New Journal of Physics **12** (2010)
[3]Kipp C. Cannon 2007 *Phys. Rev. D* **75** 123003

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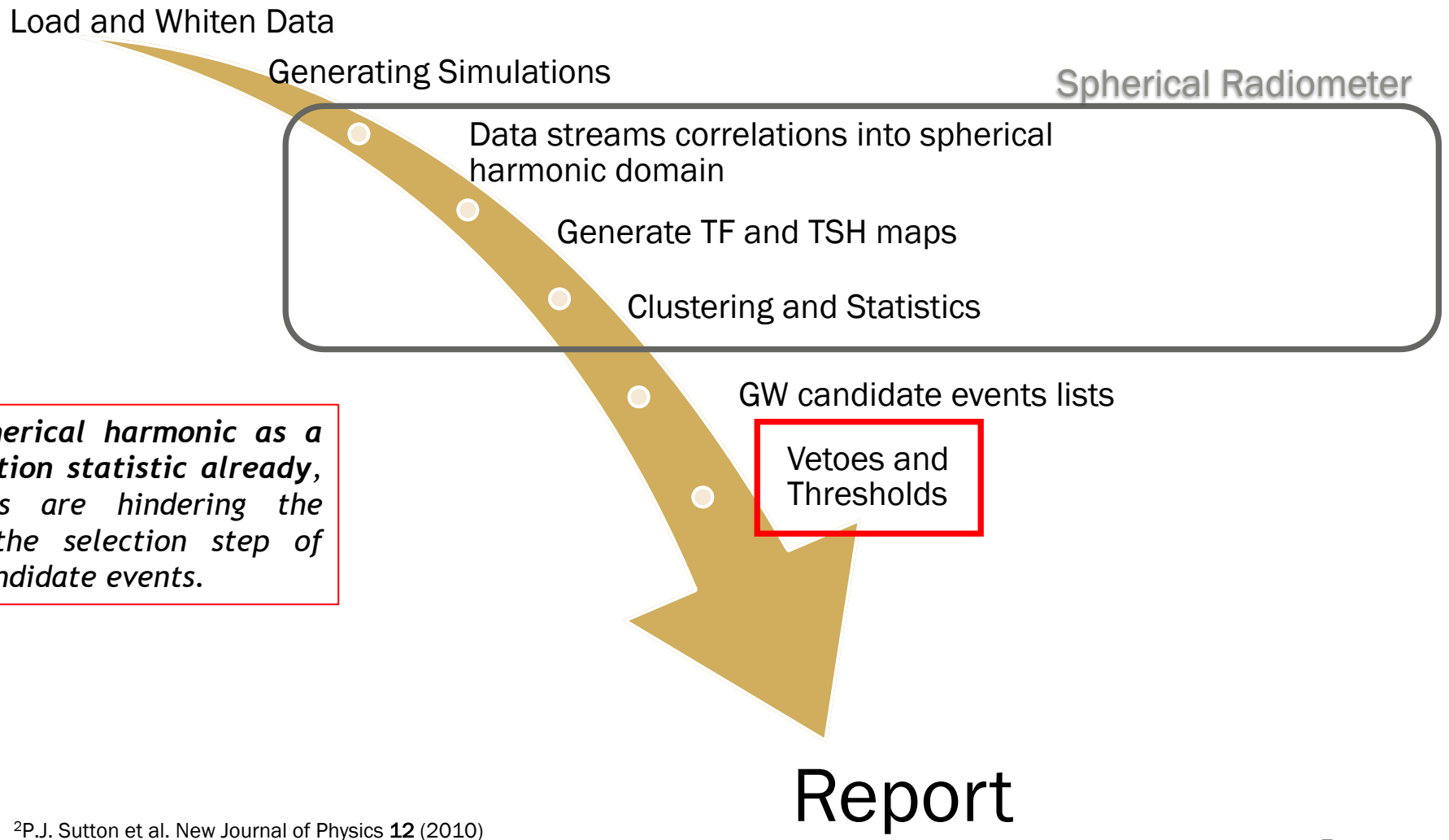

- ❖ ***We use spherical harmonic as a glitch rejection statistic already,*** *but glitches are hindering the search at the selection step of potential candidate events.*

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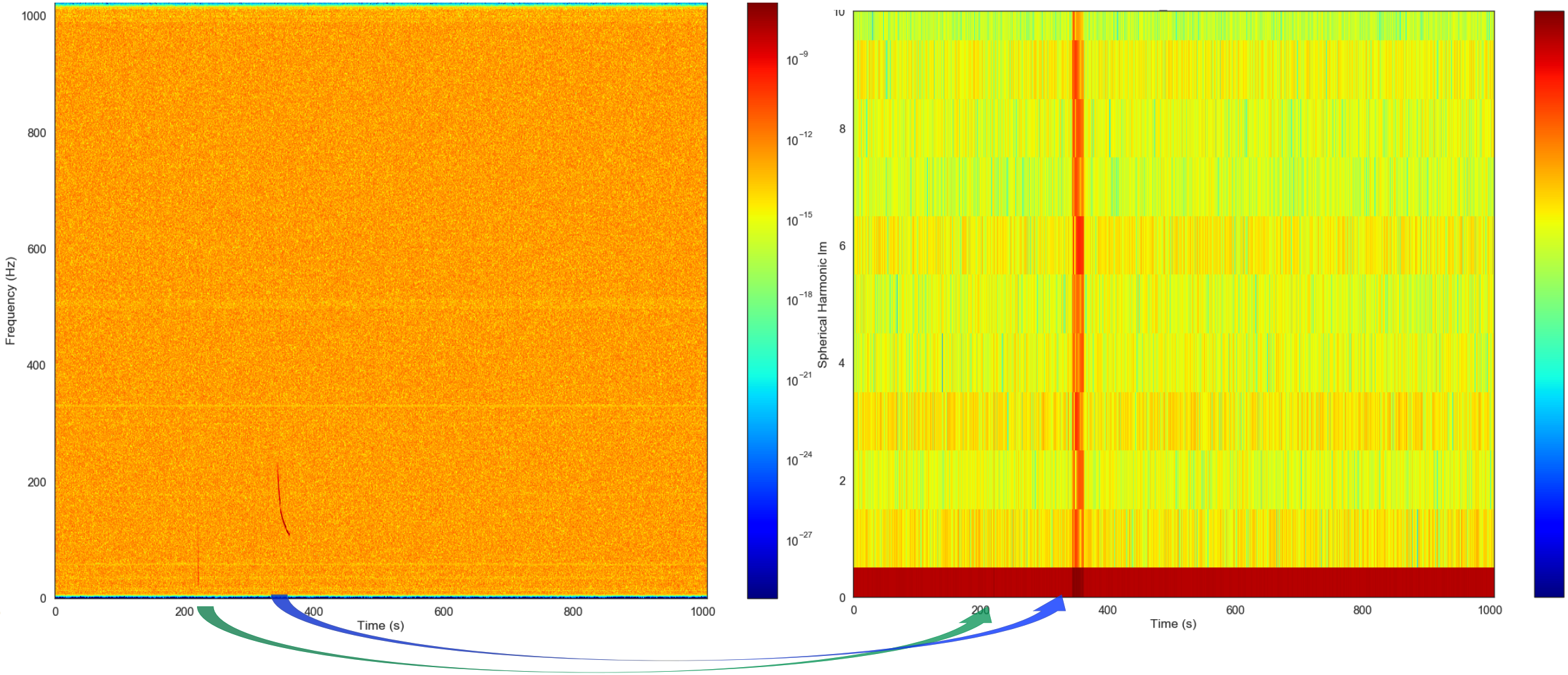
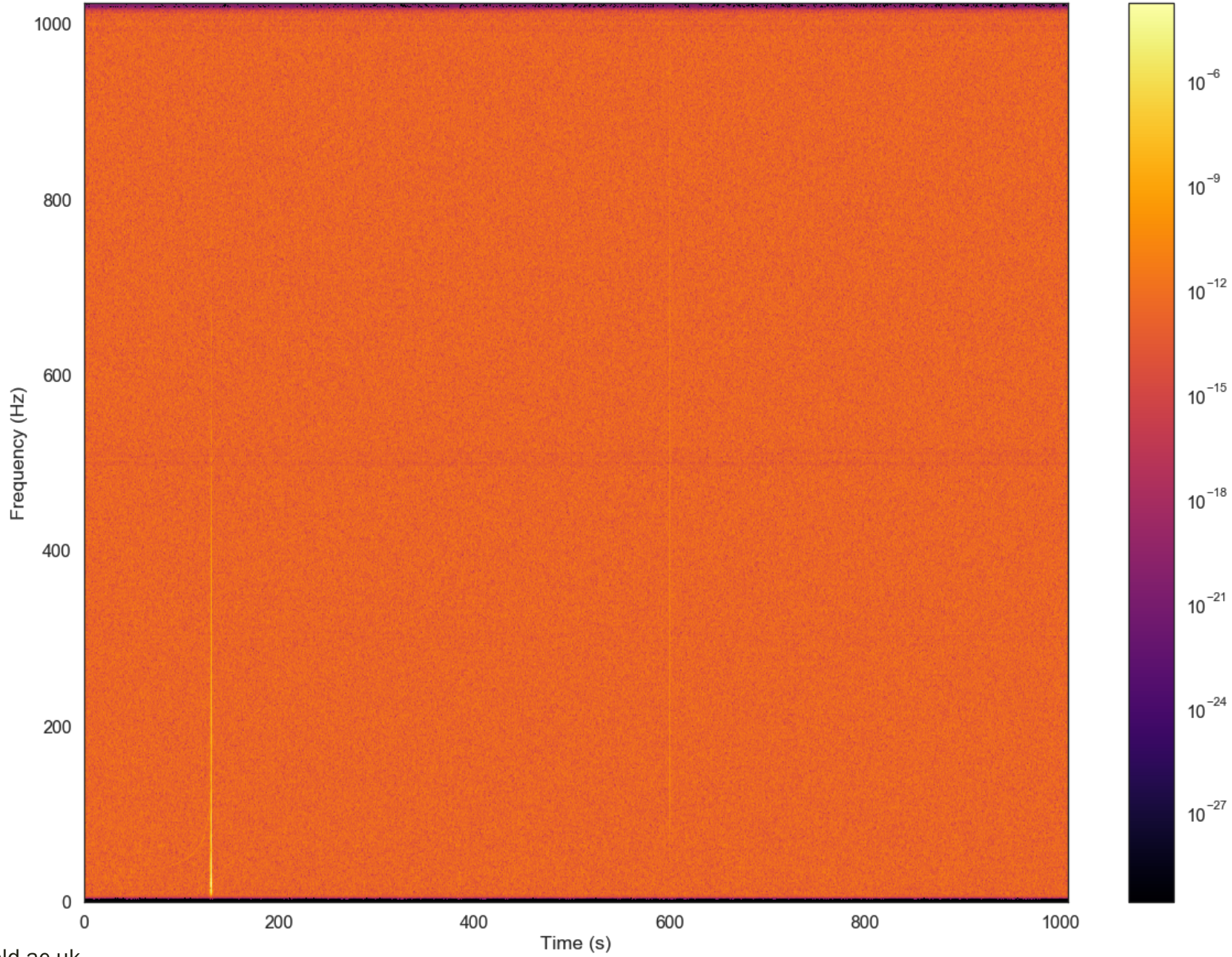
Spherical Harmonic Coefficients: definition and simulation[4]

- C_{00} : the zero*th* component is a measure of the **energy average** over all sky
- C_{lm} : **signal power** will be present in most of this coefficients - generally none will stand out more than any other



[4]Fays, M. *Exploring Long Duration Gravitational-Wave Transients with Second Generation Detectors.* PhD thesis, 2018

- Real data: from O2 run data (GPS time 1187008820)



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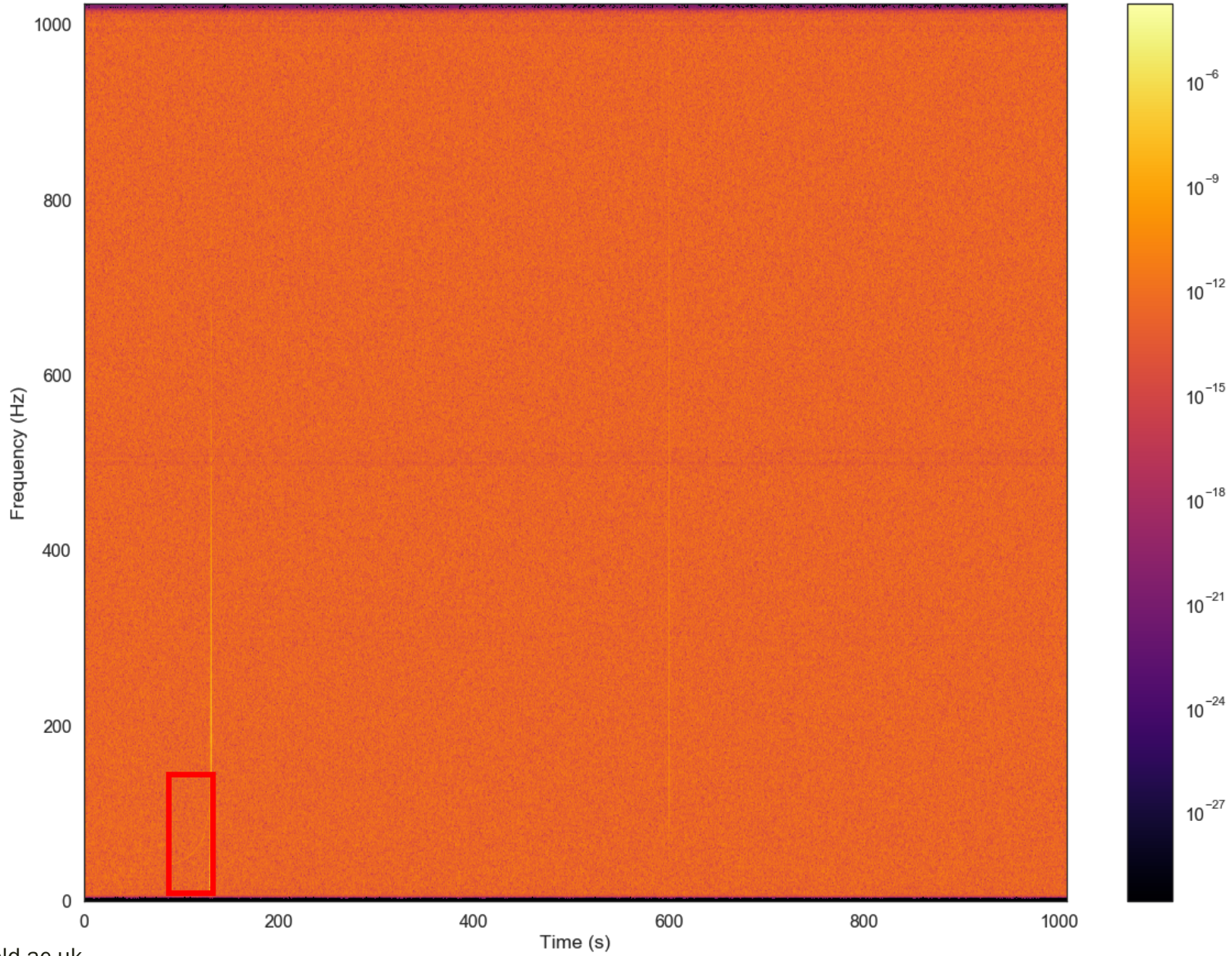

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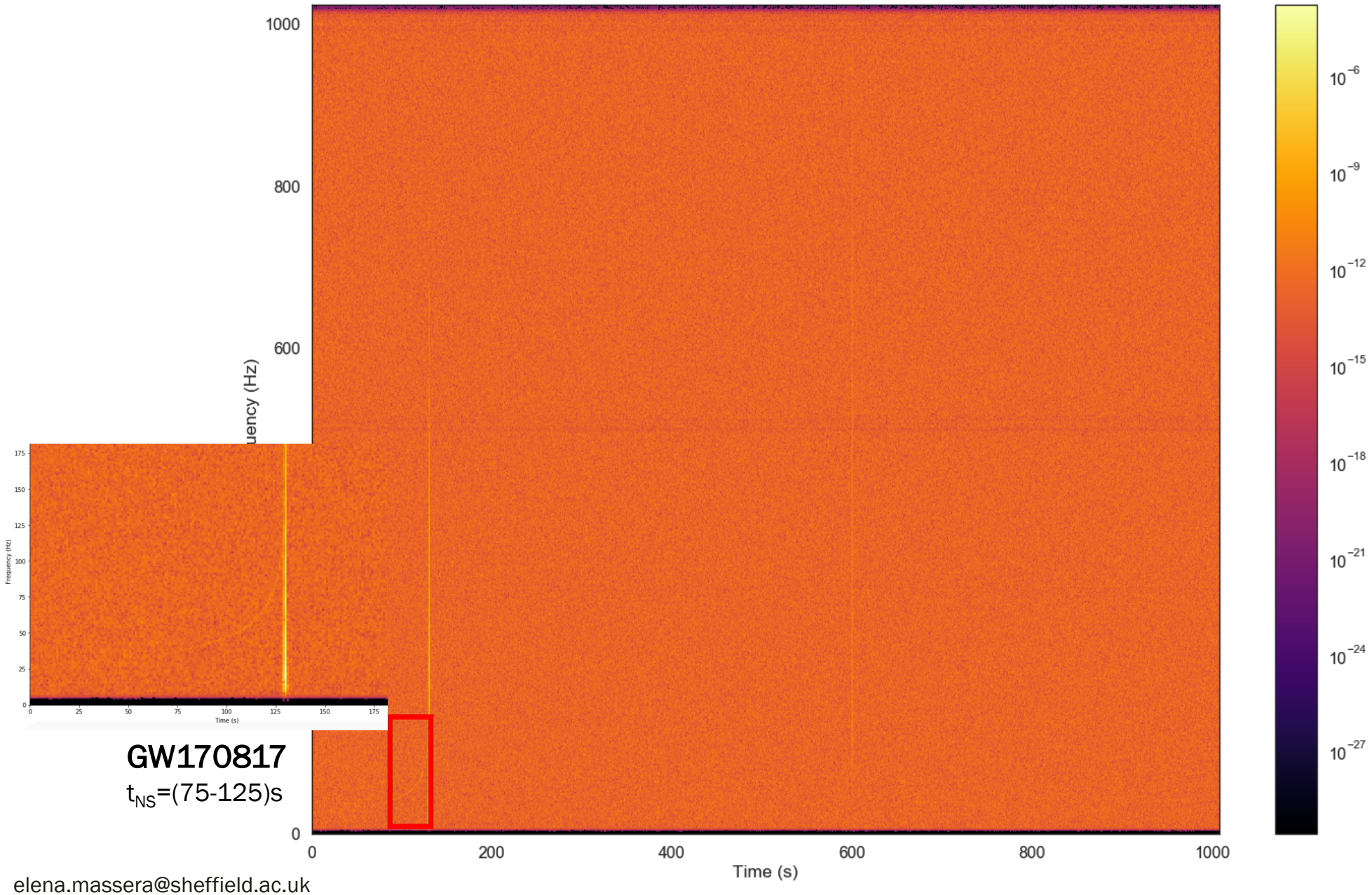

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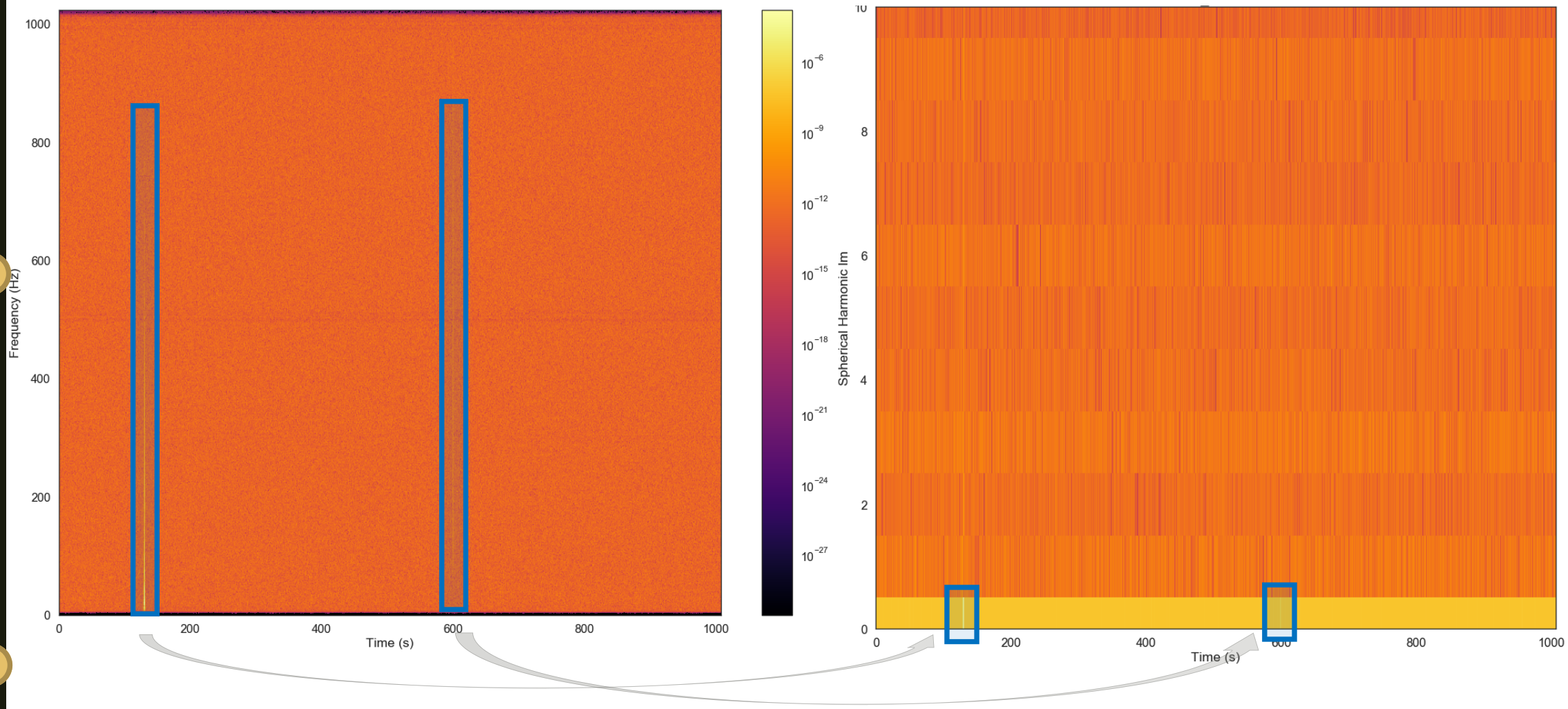
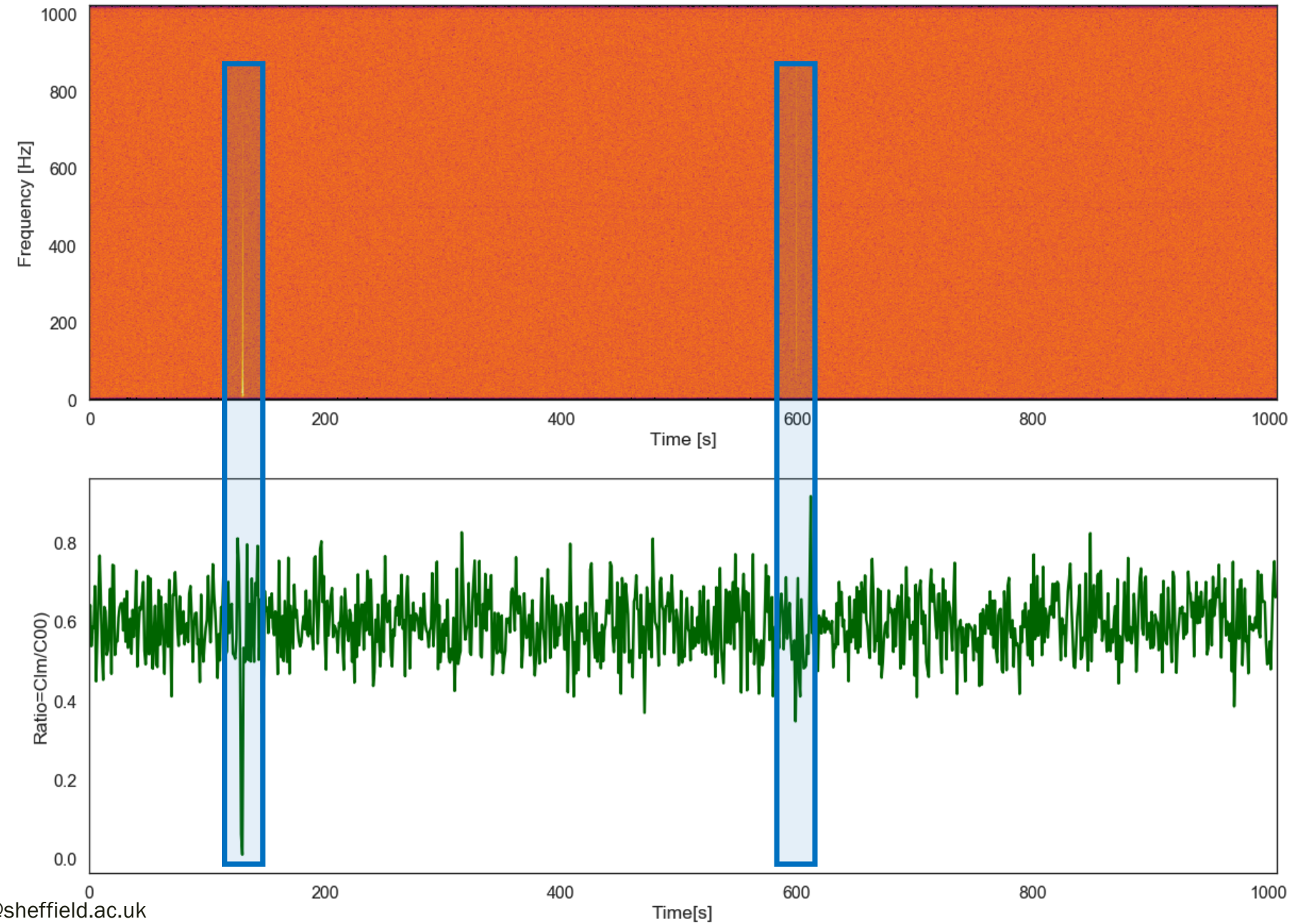


- Method: Identify Glitches using the ratio= $\frac{C_{lm}}{C_{00}}$



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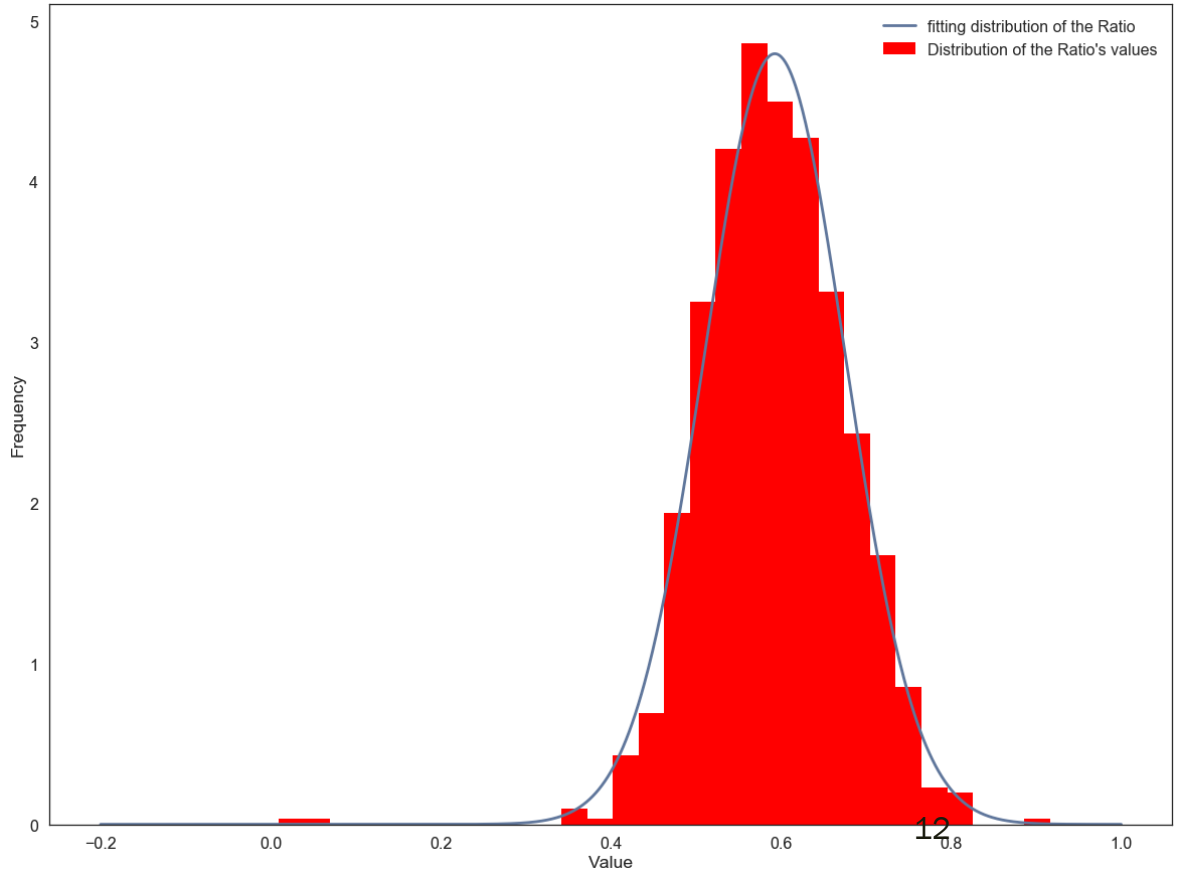
- Setting the Threshold on the Ratio

- The threshold is computed using the Standard Deviation --> 5% rejected



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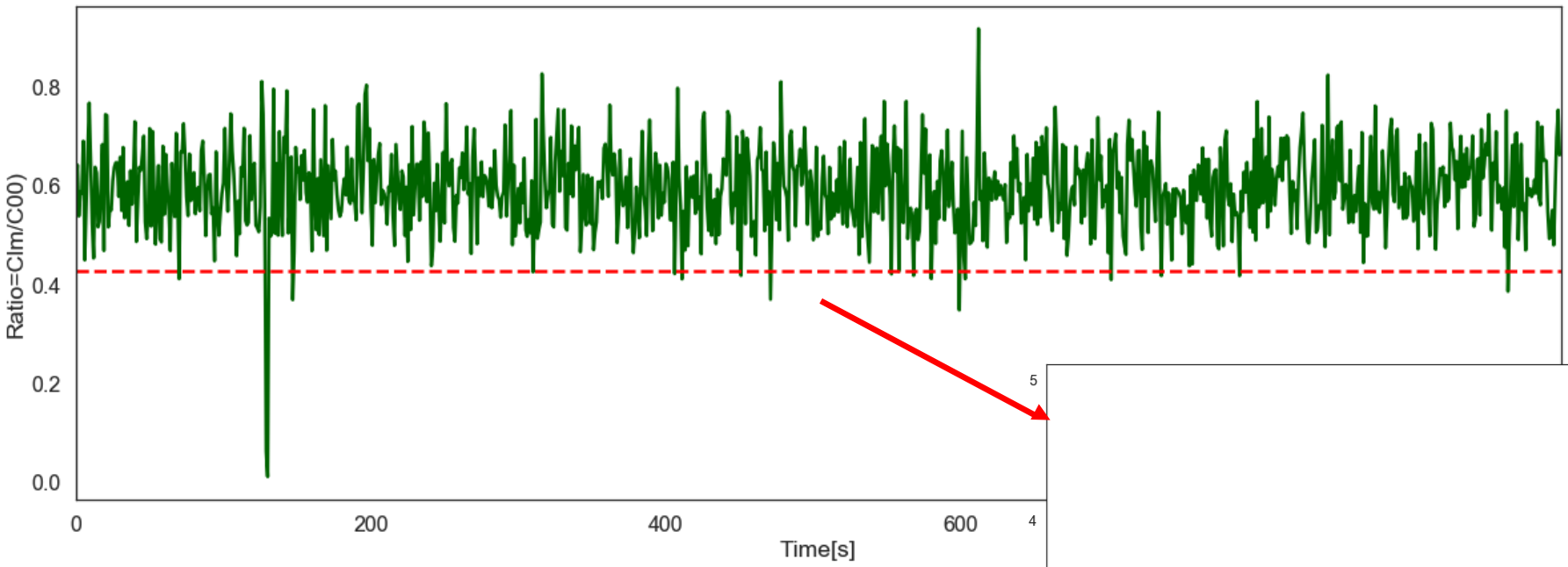

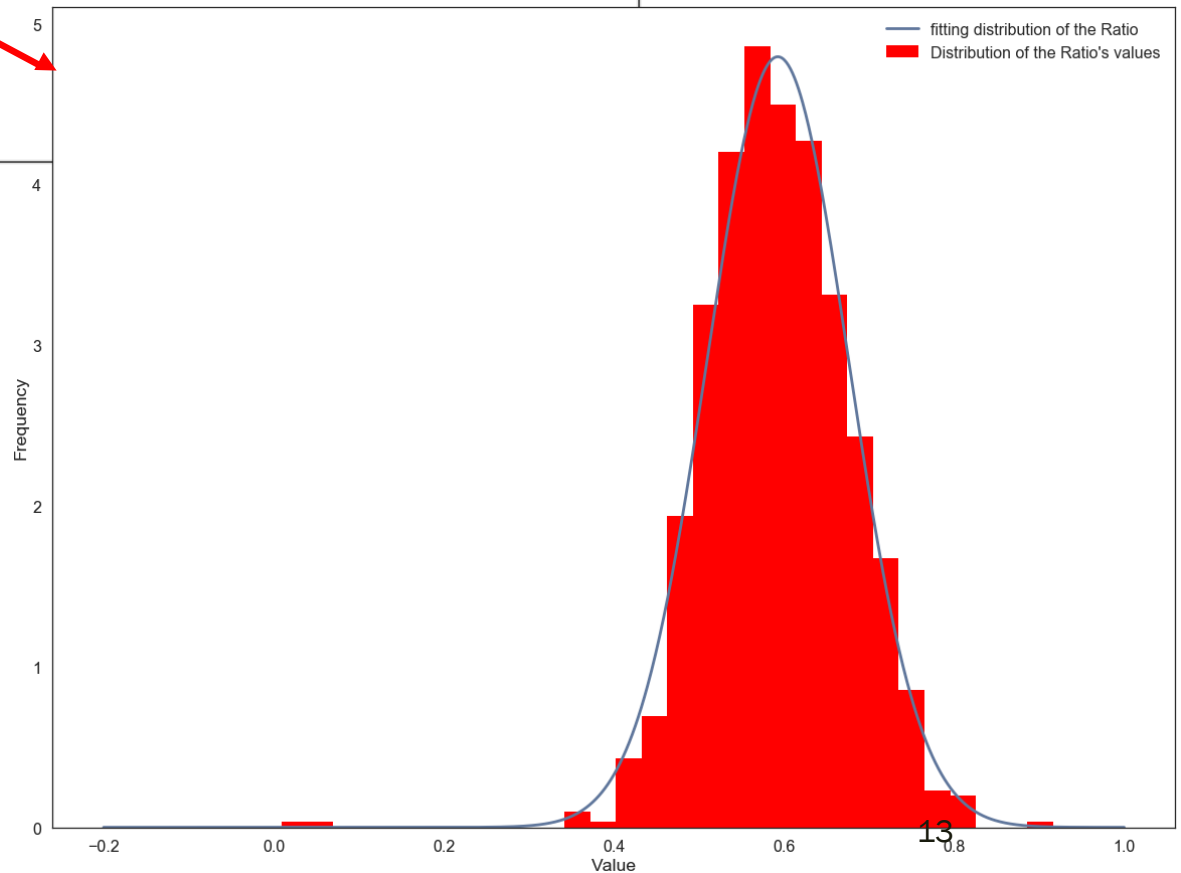

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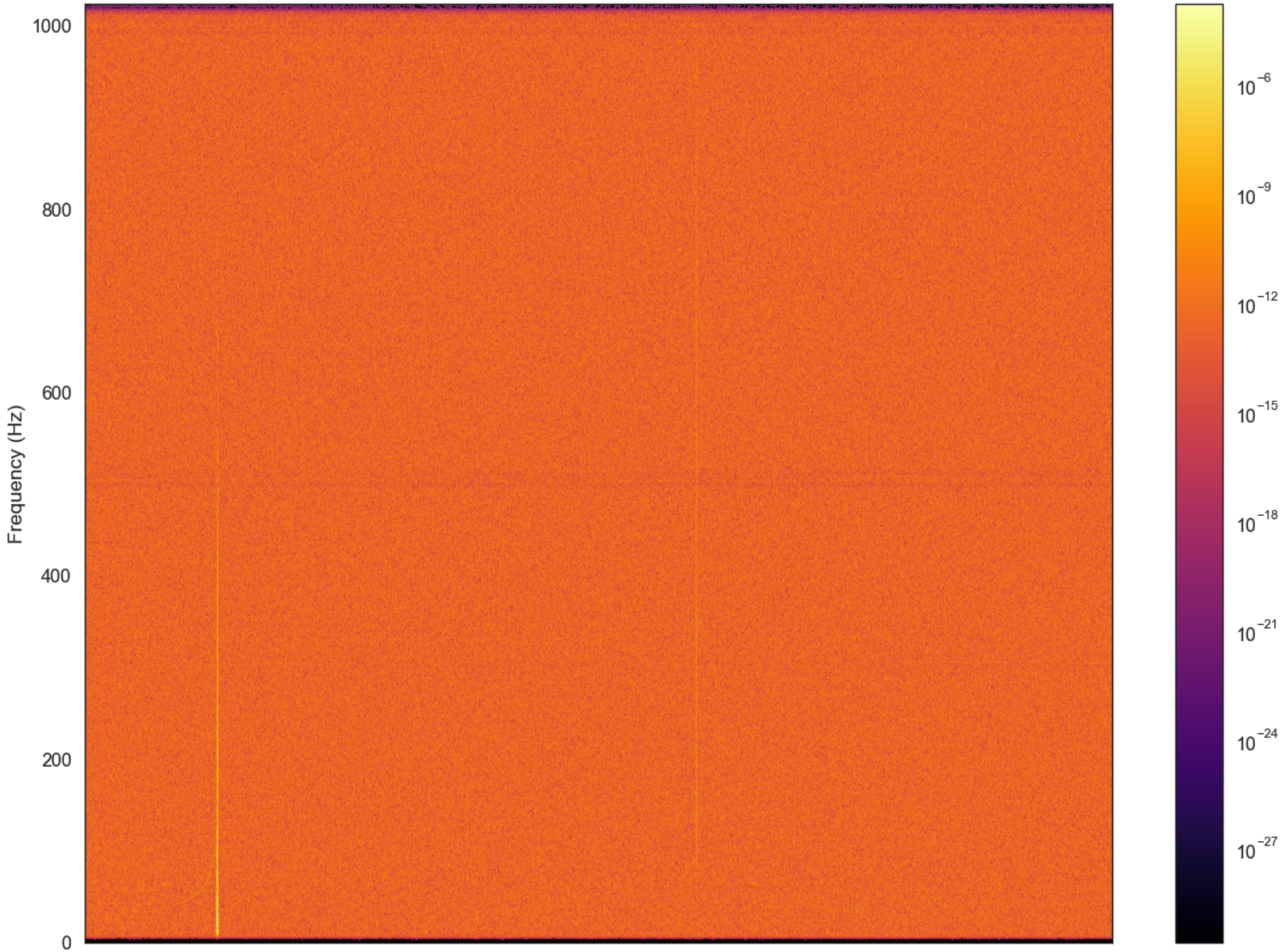
- Apply Threshold on TF map: **5% rejected**



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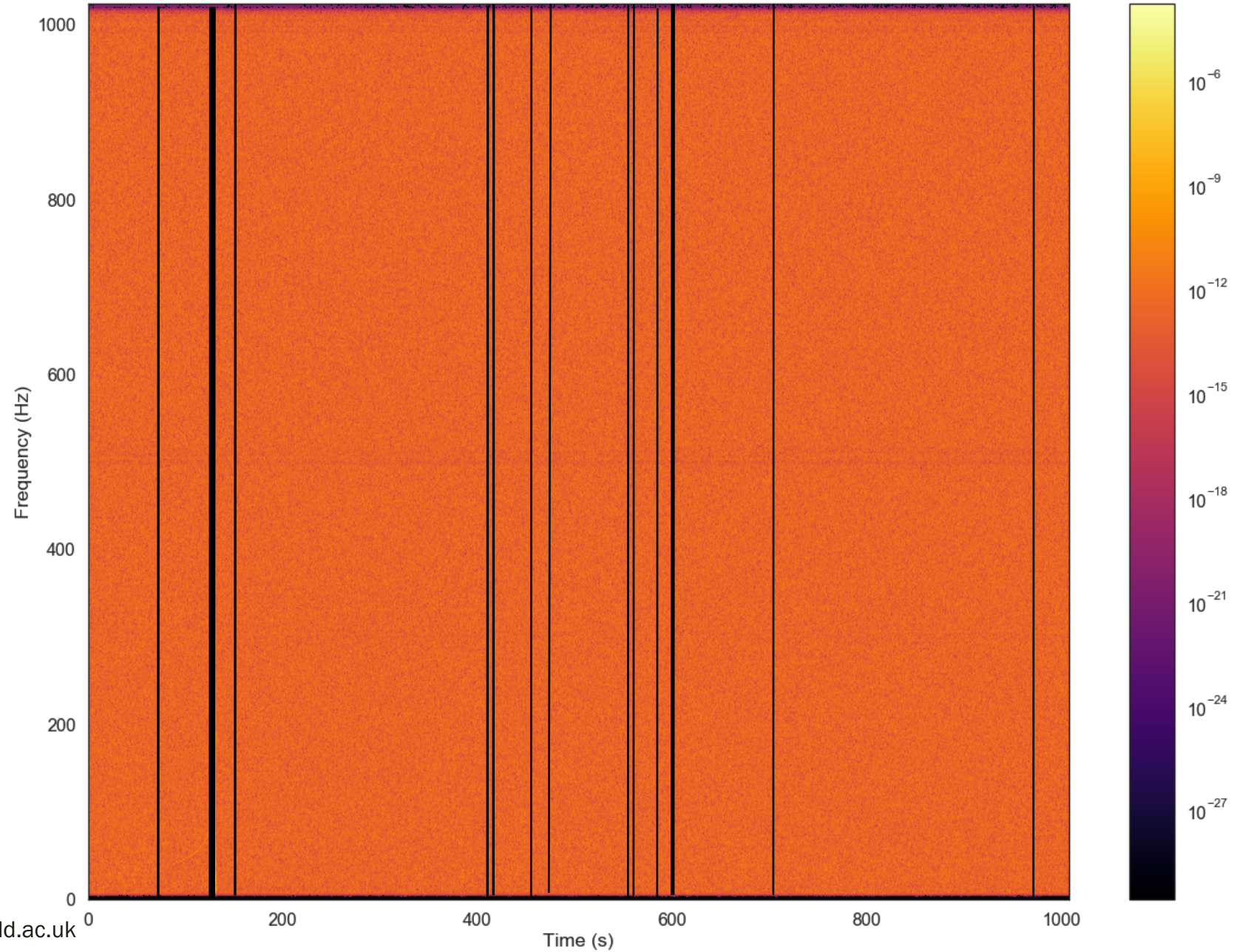

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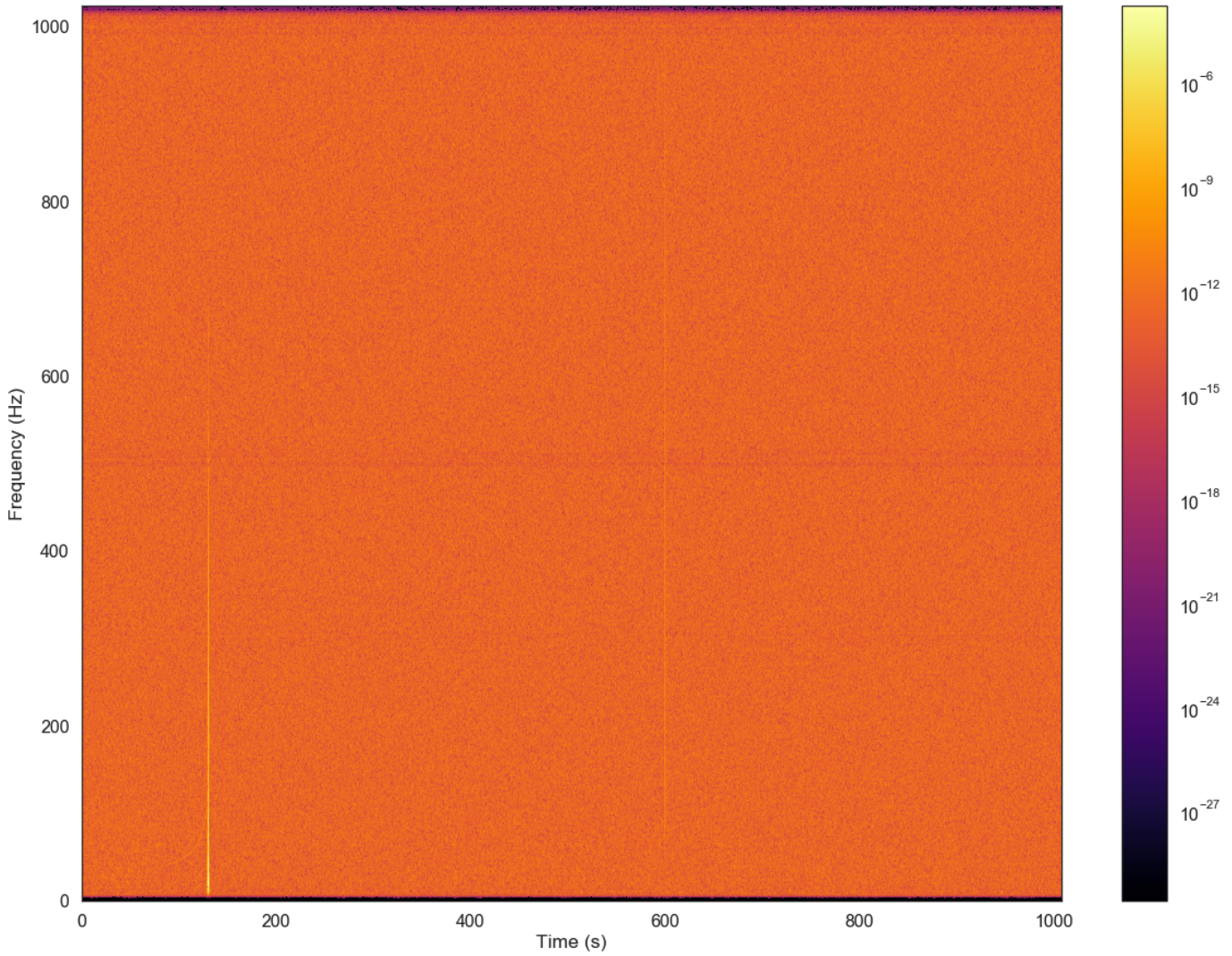
- No Rejection method: 30 Loudest Triggers



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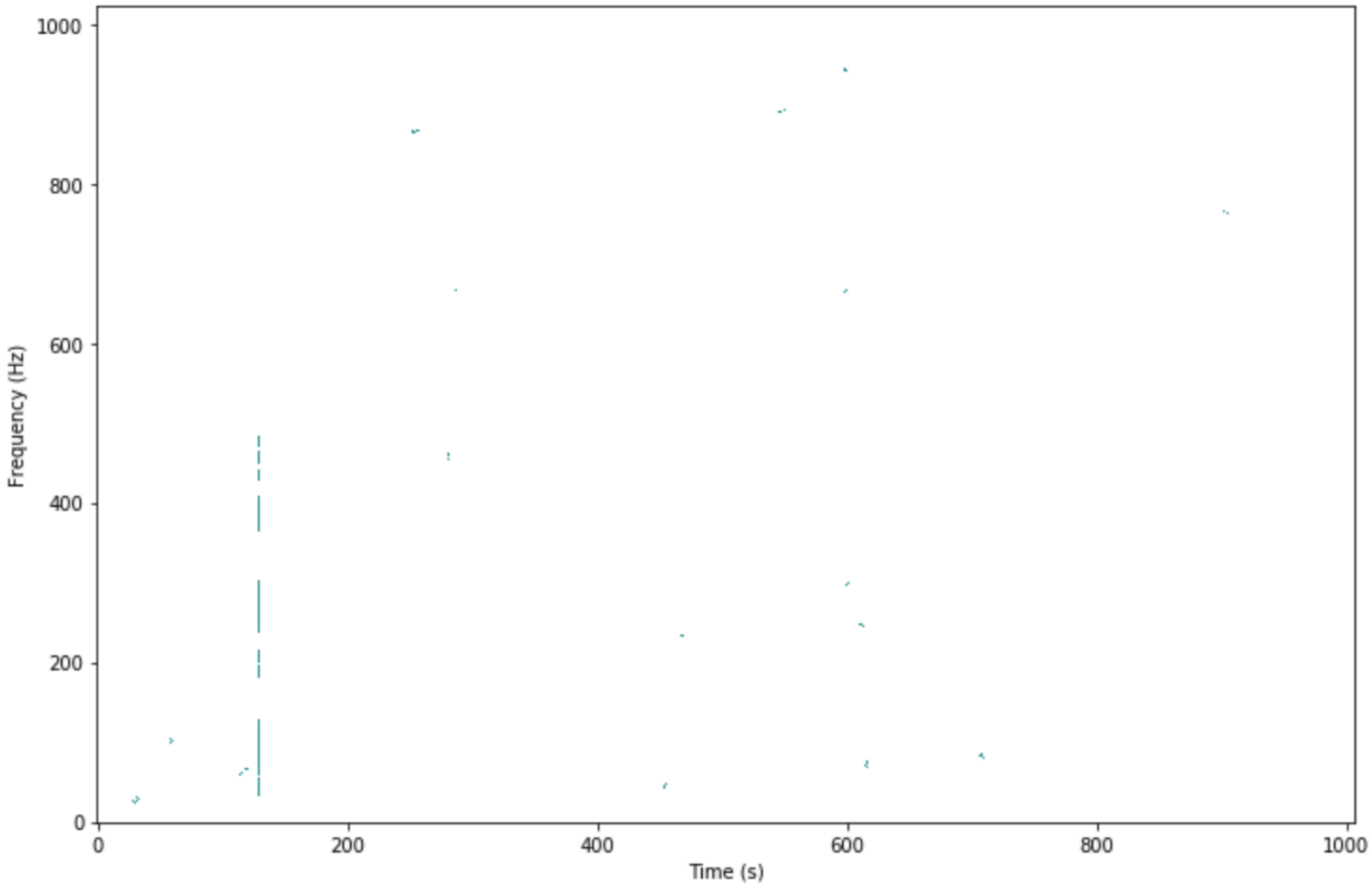

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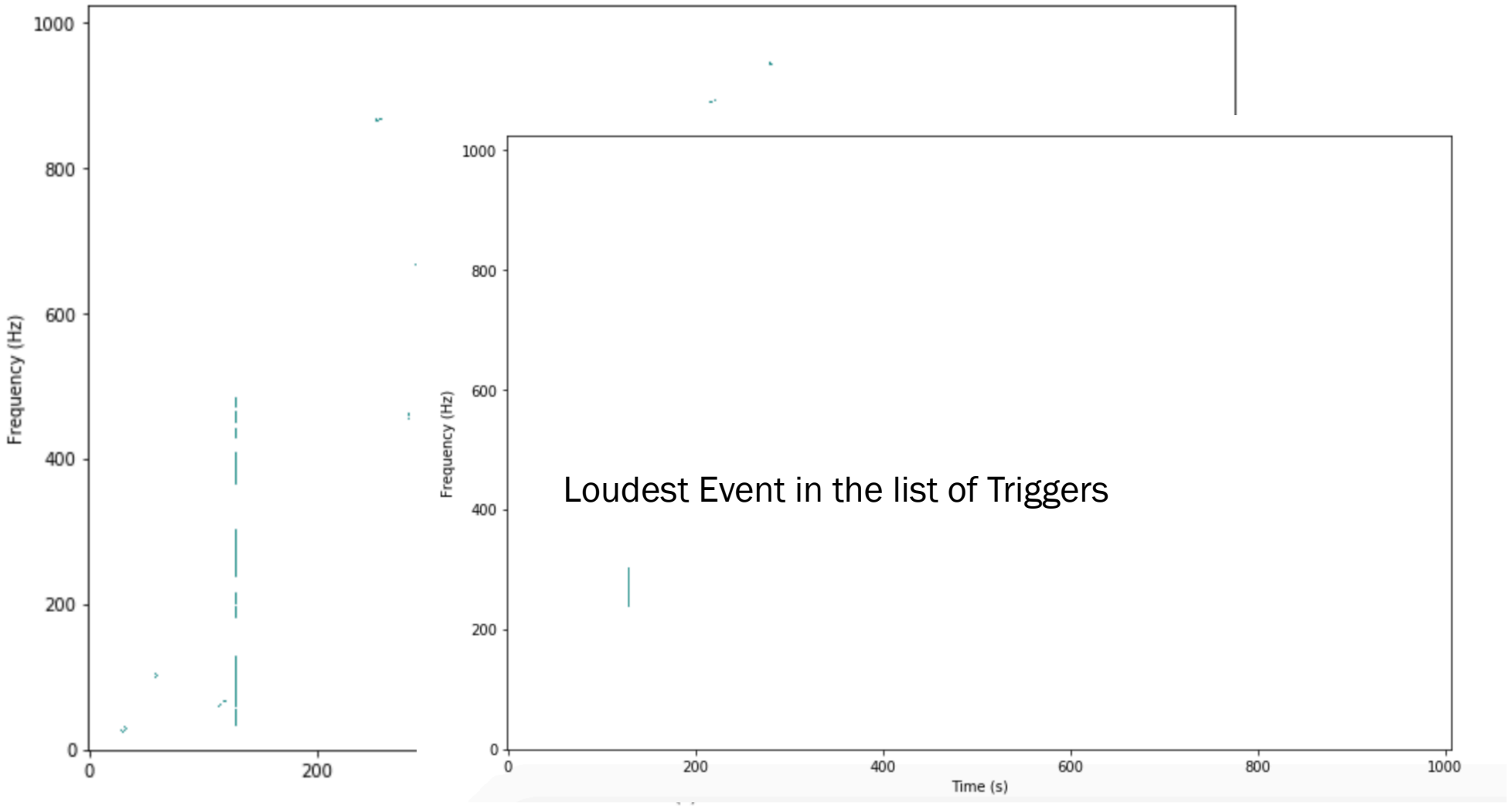

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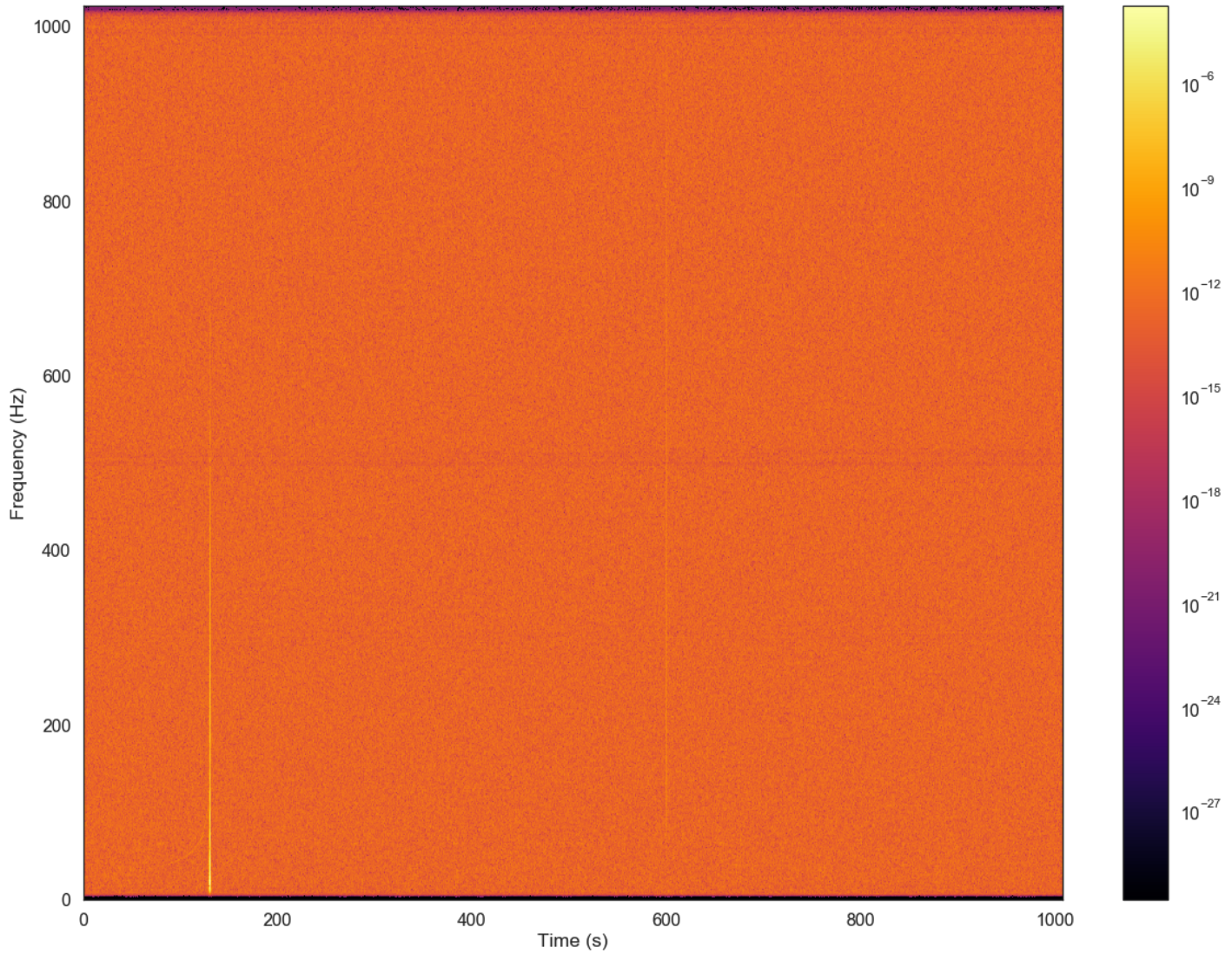
- Glitch Rejection method: 30 Loudest Triggers



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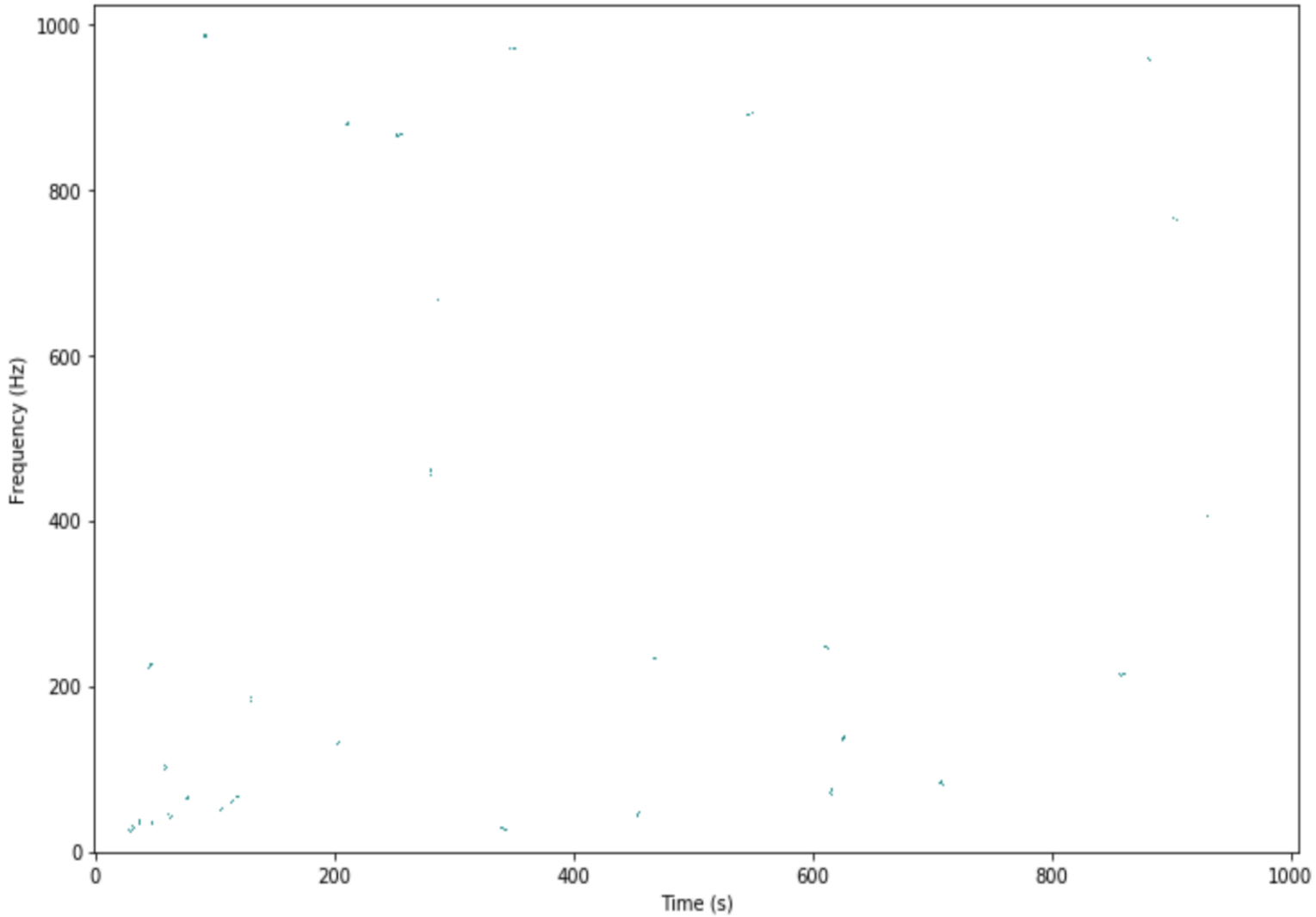

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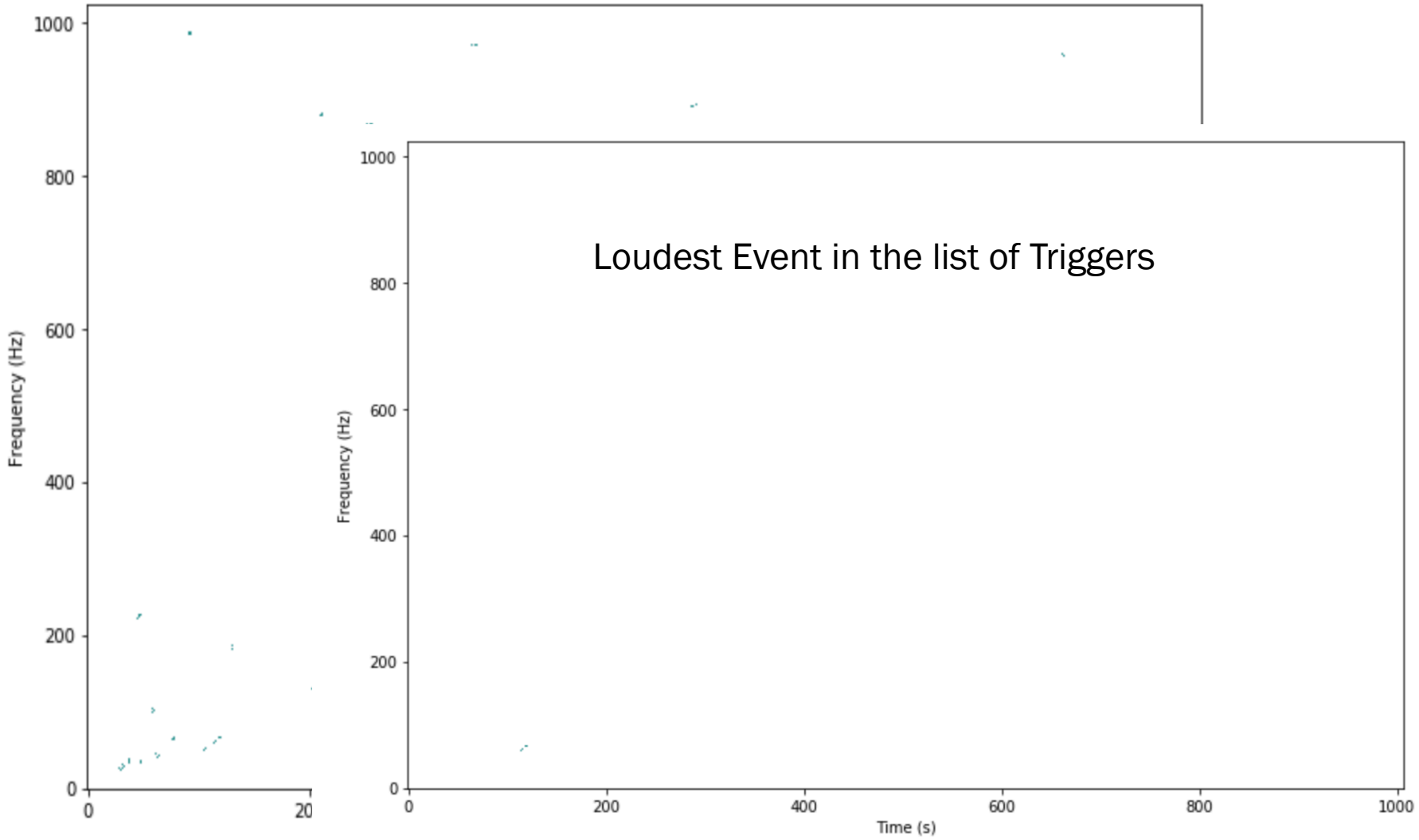

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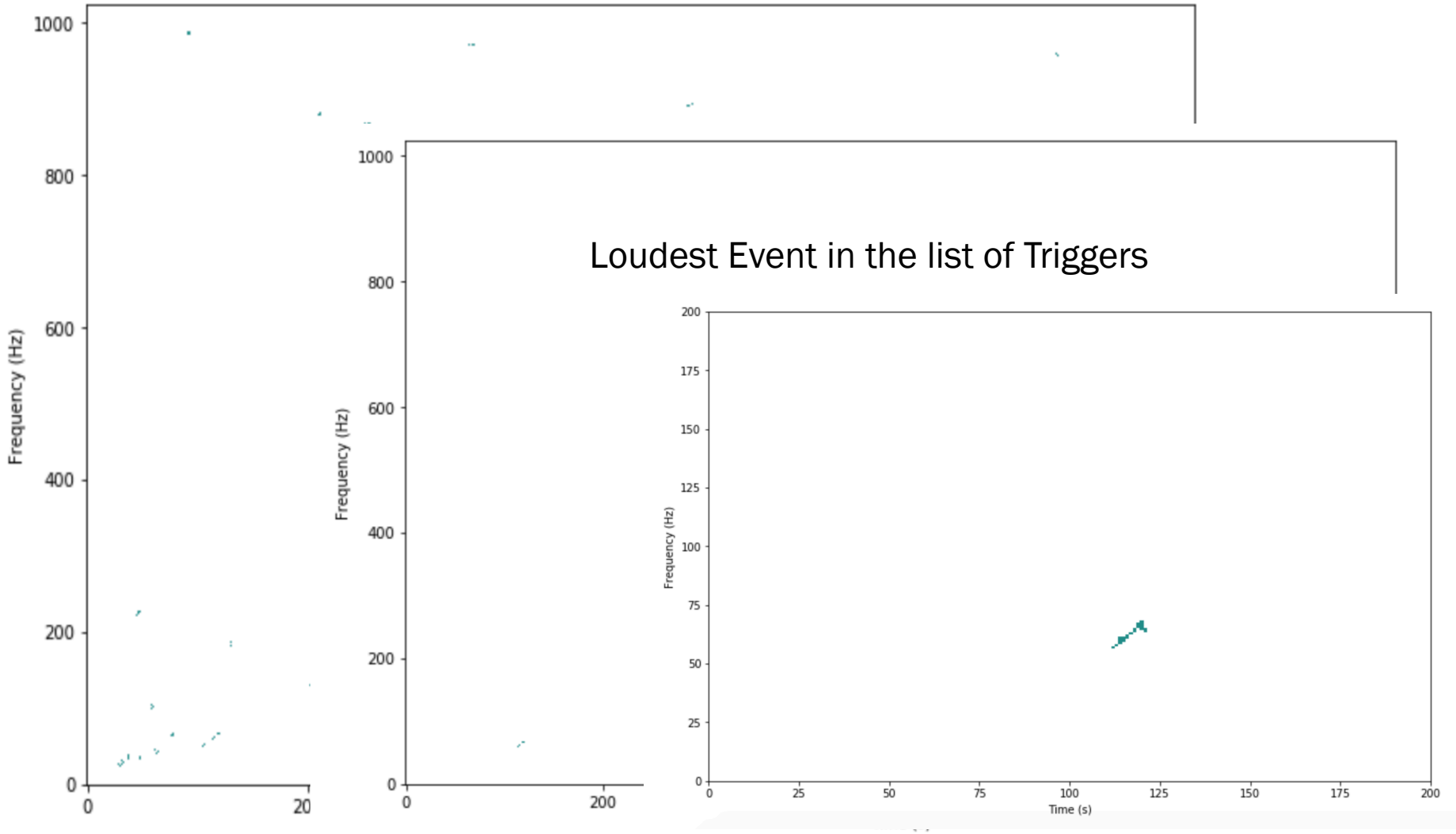
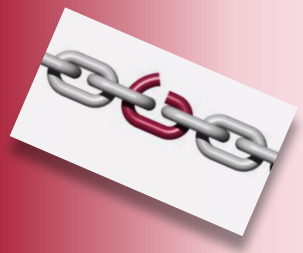


SWOT ANALYSIS

S*trengths*

- Pre-processing analysis
- Improving sensitivity
- Improving reliability

W*eaknesses*

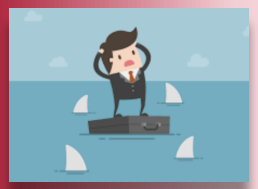


Multiplicity: Dependency on glitches features

O*pportunities*

Versatility: Application to signal processing where spherical harmonics are applicable

T*hreats*



Hard-working:
Less appealing

Thank you!!

Questions??

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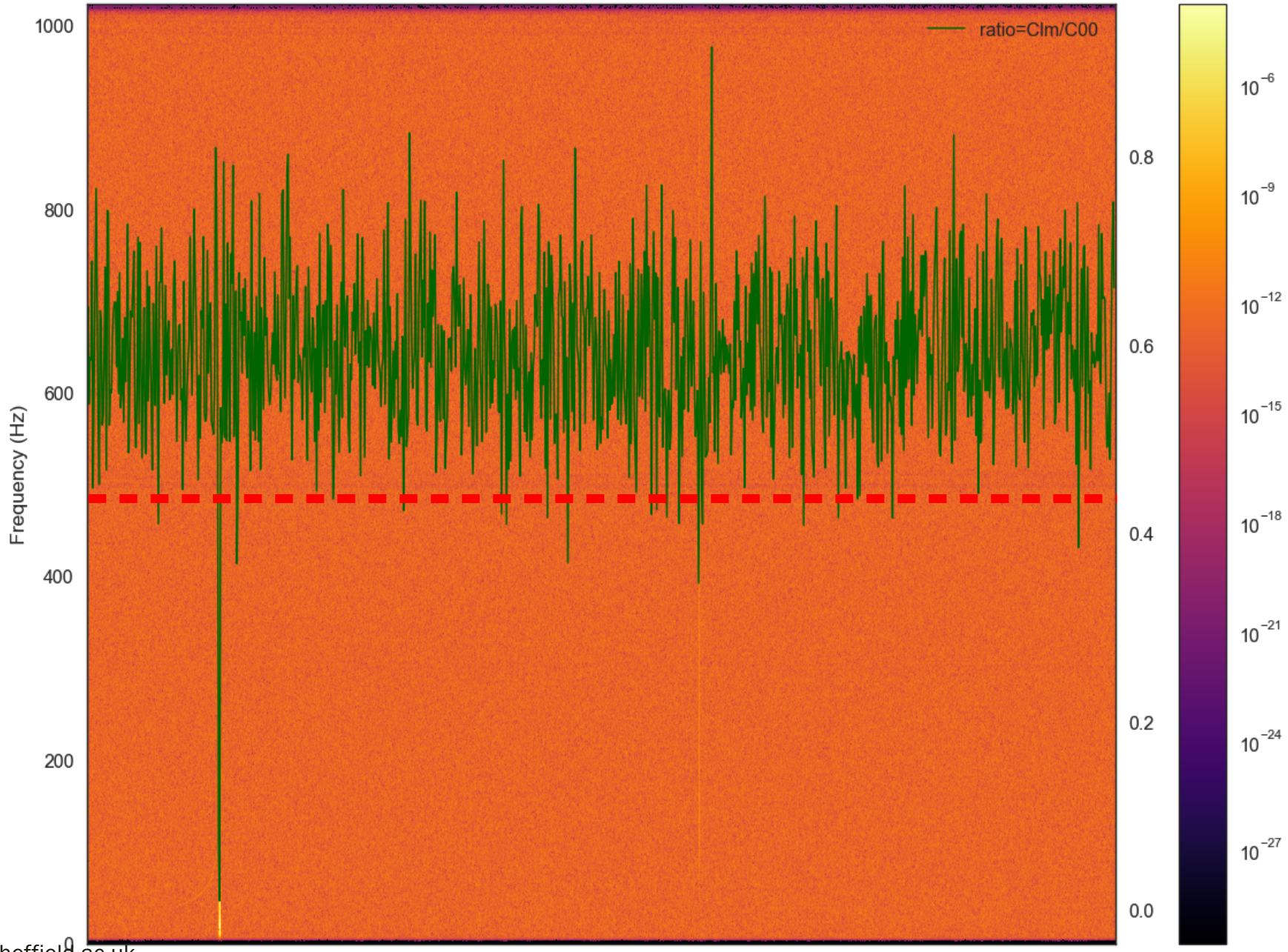
"The value of each pixel *P* on the time-frequency map is then a sum along the spherical harmonic coefficients *c* representing the energy in a time-frequency bin" [4]

$$P_{t,f} = \sum_{i,j=0}^{d} \xi_{ij}^{(lm)} = \sum_{l=0}^{l_{max}} \sum_{m=-l}^{m=l} (c_{lm})^2.$$

- Apply Threshold on TF map: **5% rejected**



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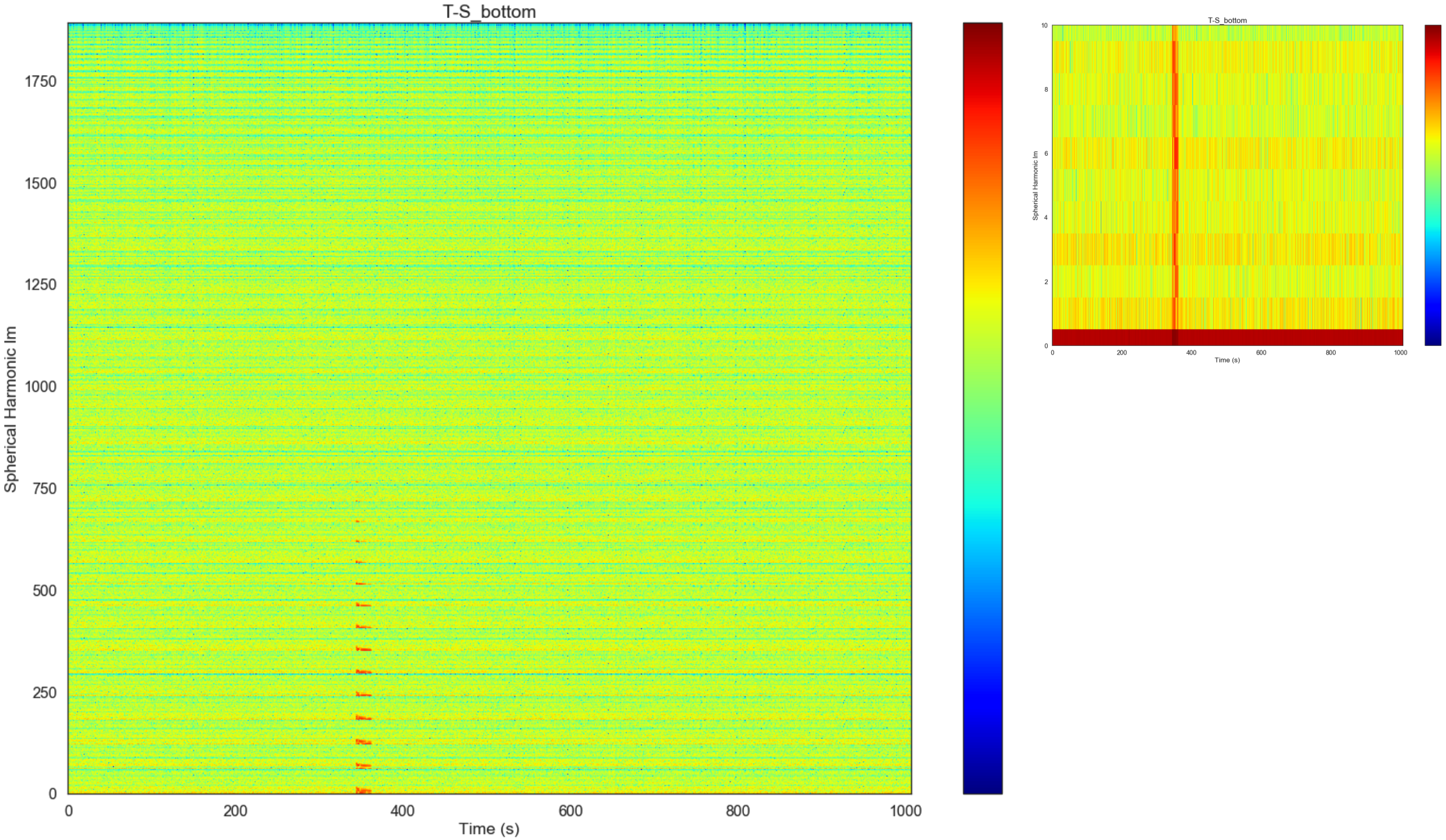
Spherical harmonics are an expansion of a function onto the sphere, expressed as the coefficients in a series of spherical harmonics up to and including order l = l_{max}. The ordering of the coefficients in memory is as follows (expressed as (l,m) pairs, read left to right and top to bottom:

m value of row	coefficients stored as (l, m) pairs
m=0	(0, 0), (1, 0), (2, 0), (3, 0), $\cdots$, ($l_{\max}$, 0)
m=1	(1,+1), (2,+1), (3,+1), $\cdots$, ($l_{\max}$,+1)
m=2	(2,+2), (3,+2), $\cdots$, ($l_{\max}$,+2)
m=3	(3,+3), $\cdots$, ($l_{\max}$,+3)
$\vdots$	$\vdots$
m=$l_{\max}$	($l_{\max}$,+$l_{\max}$)
m=-$l_{\max}$	($l_{\max}$,-$l_{\max}$)
$\vdots$	$\vdots$
m=-3	(3,-3), $\cdots$, ($l_{\max}$,-3)
m=-2	(2,-2), (3,-2), $\cdots$, ($l_{\max}$,-2)
m=-1	(1,-1), (2,-1), (3, -1), $\cdots$, ($l_{\max}$,-1)

TABLE B.1: Table showing the order of spherical harmonic coefficients, expressed as (l, m) pairs, read left to right and top to bottom. [2]



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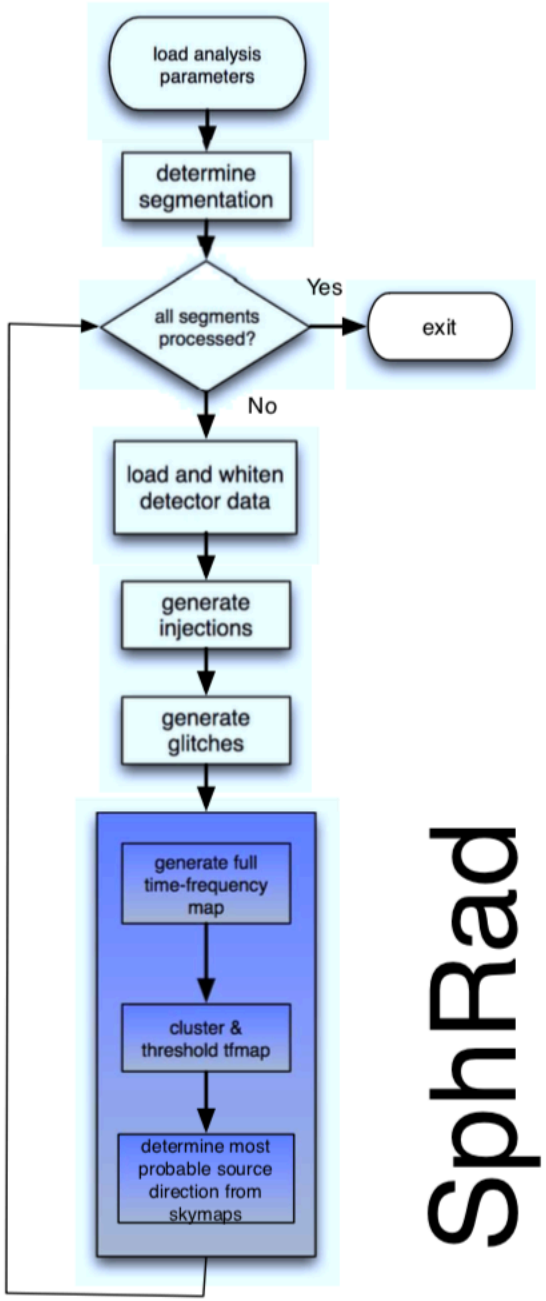
load analysis parameters
determine segmentation
all segments processed?
Yes
exit
No
load and whiten detector data
generate injections
generate glitches
generate full time-frequency map
cluster & threshold tfmap
determine most probable source direction from skymaps

SphRad

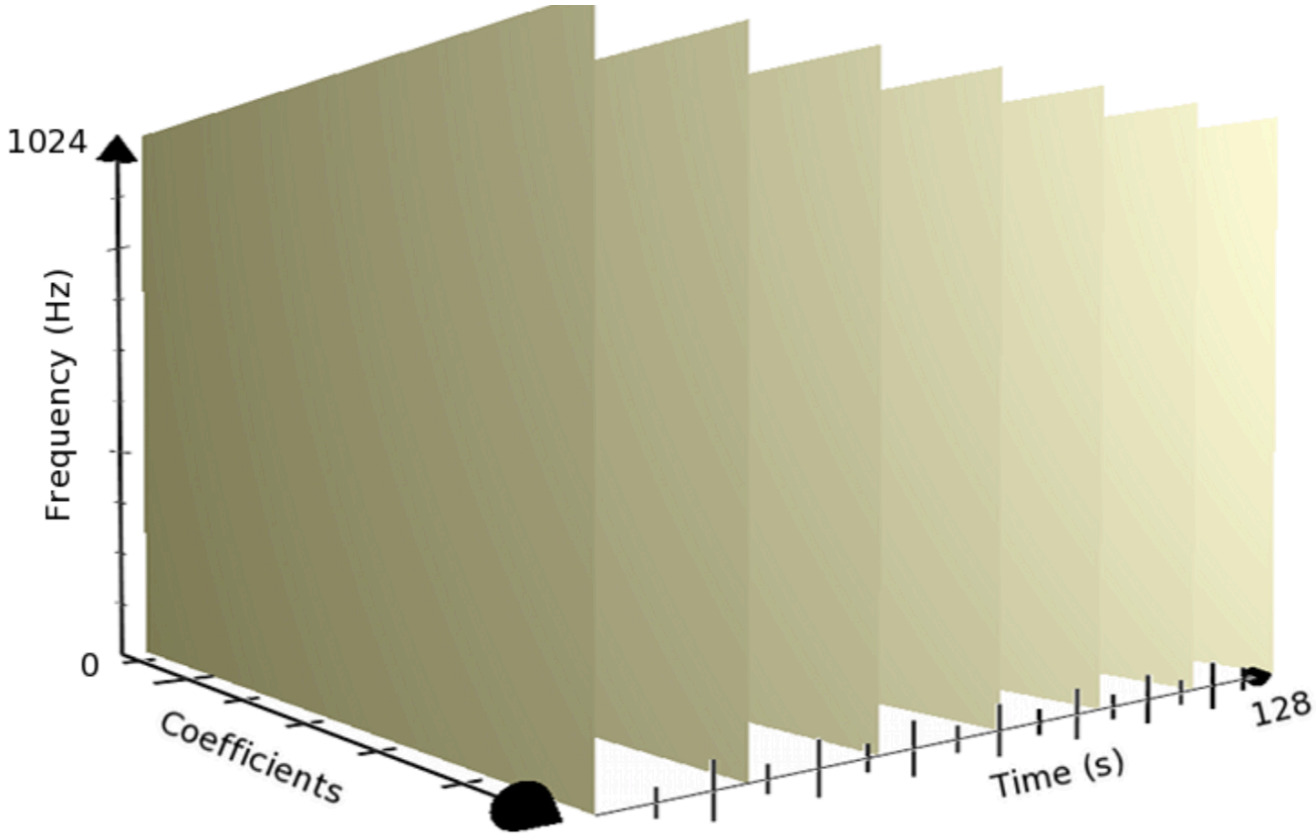

FIGURE 4.3: Illustration of a Time-Frequency-Spherical harmonic coefficients cube. Each plane represents the output of the correlator for a segment of data as in Figure 4.2