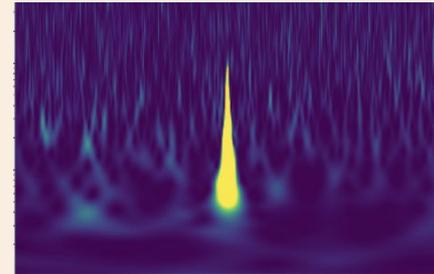# Glitch Characterization and Statistical Analyses - II

Tabata Aira Ferreira, INPE
IUCAA - DetChar Workshop

December 18, 2025

Outline

- Omicron

- Unclustered vs. Clustered Omicron information

- Effects of Q-value on the signal morphology

- Analysis Using Omicron
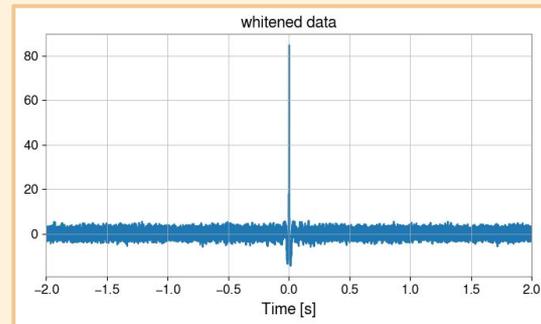 - Examples

- Analysis Using Gravity Spy
  - Examples

Omicron

Glitch studies rely on Omicron

Omicron looks for excess power in the data **using the Q-transform**

$$X(\tau, \phi, Q) = \int_{-\infty}^{+\infty} x(t)w(t - \tau, \phi, Q)e^{-2i\pi\phi t}dt.$$
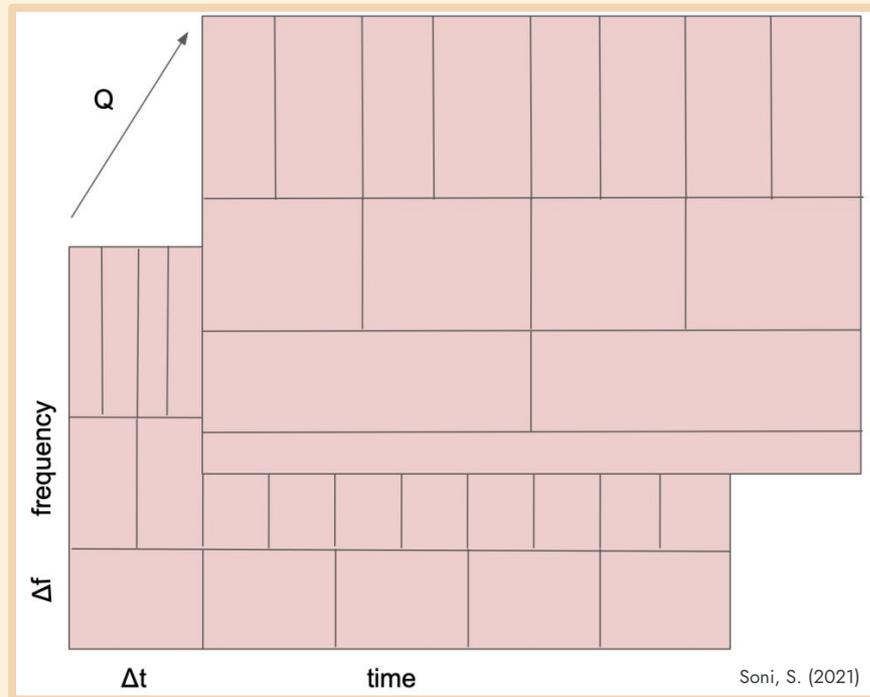
$$Q \propto \frac{f_0}{\Delta f_0}$$

whitened data

Glitch studies rely on Omicron

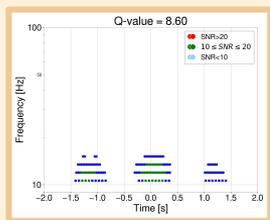$$X(\tau, \phi, Q) = \int_{-\infty}^{+\infty} x(t)w(t - \tau, \phi, Q)e^{-2i\pi\phi t}dt.$$

$$Q \propto \frac{f_0}{\Delta f_0}$$

All this information is saved in .root files.

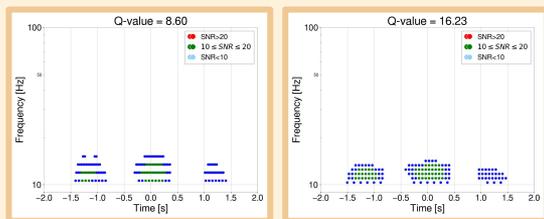
Soni, S. (2021)
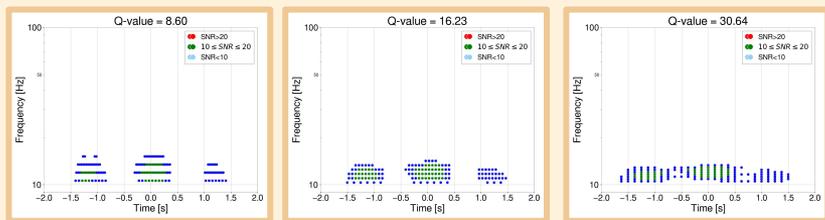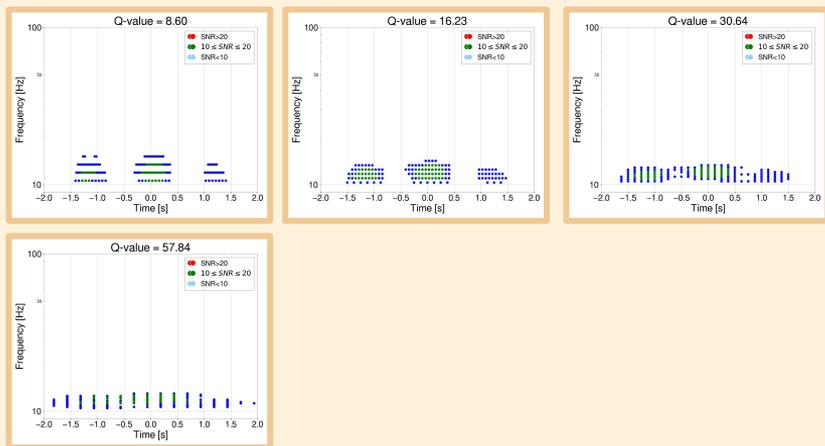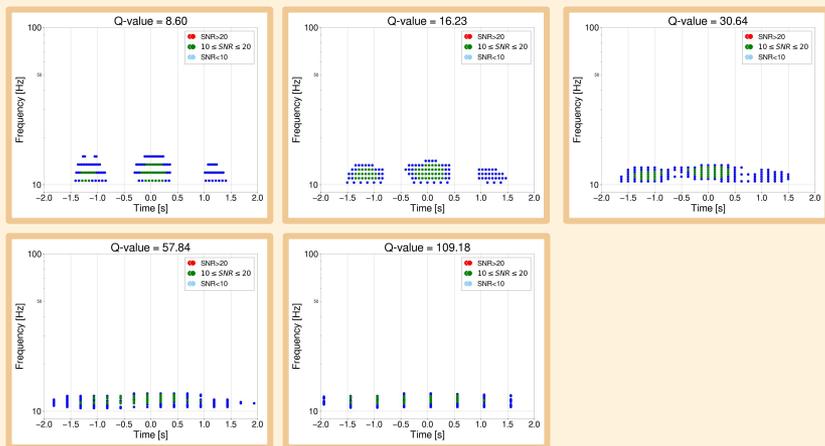
Unclustered Omicron

The same glitch can generate multiple Omicron triggers at different Q-values

Ferreira, T.A. & Gonzalez, G.
(2025)

Unclustered Omicron

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Ferreira, T.A. & Gonzalez, G.
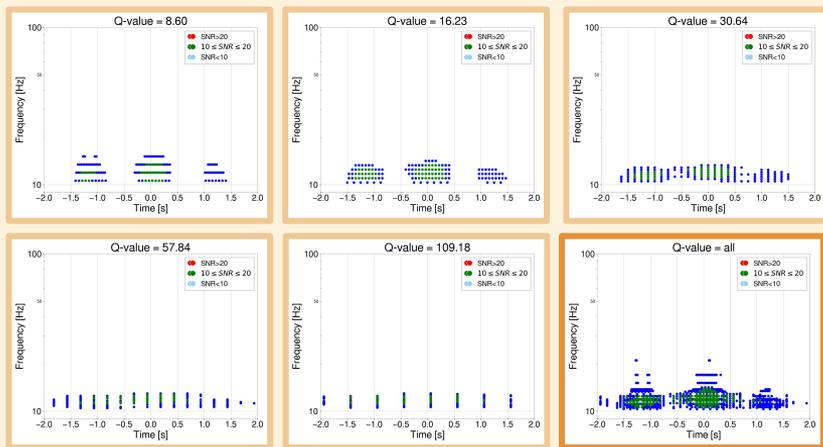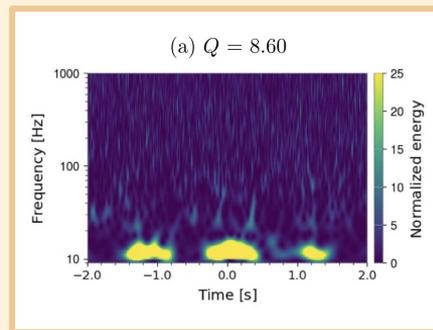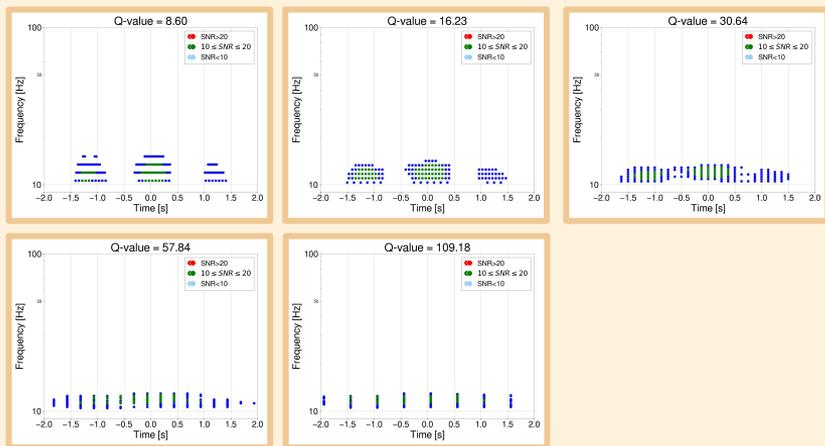(2025)

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Unclustered Omicron

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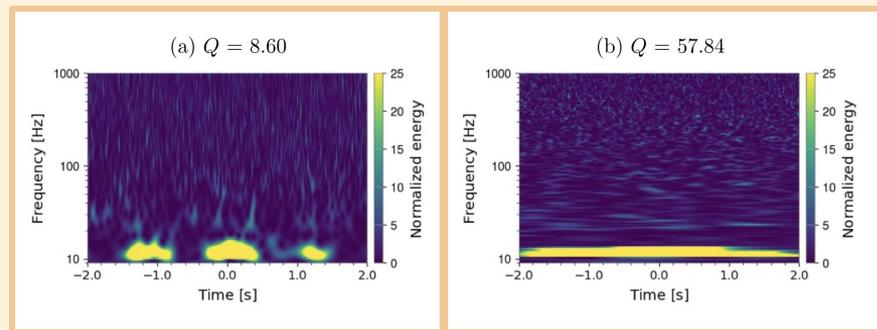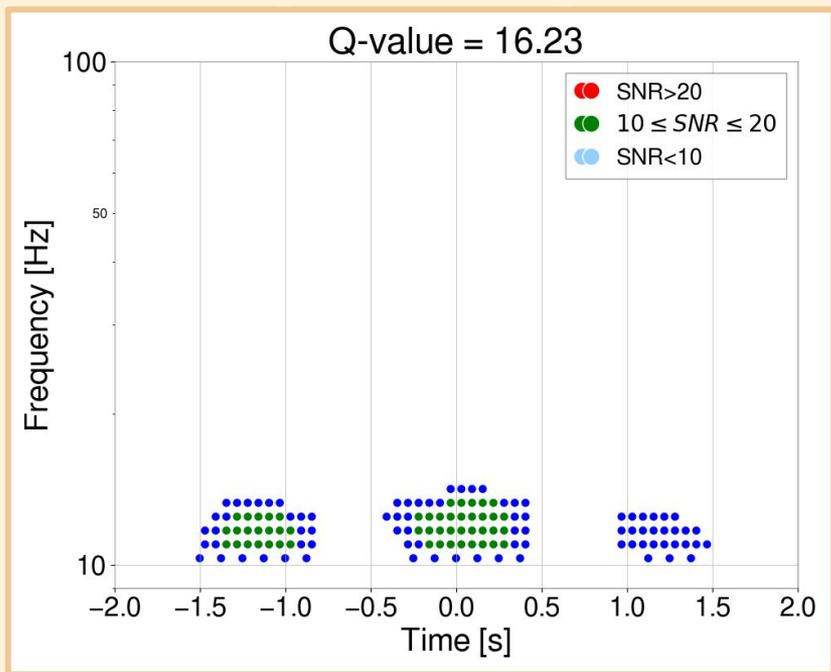Ferreira, T.A. & Gonzalez, G. (2025)

Unclustered Omicron

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Ferreira, T.A. & Gonzalez, G.
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Unclustered Omicron

The same glitch can generate multiple Omicron triggers at different Q-values

Clustered Omicron

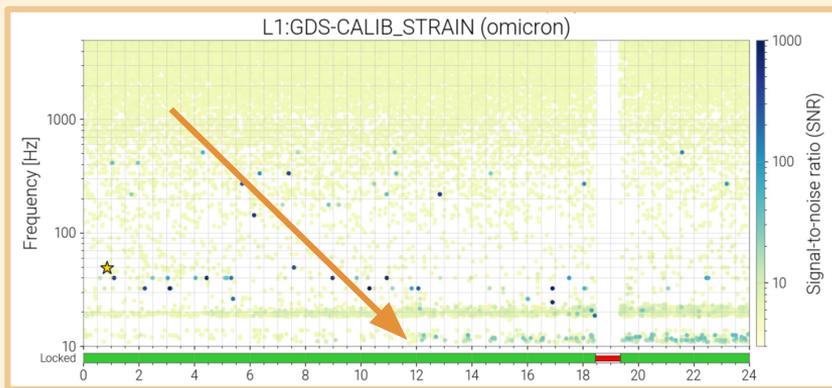One representative Q-plane will be chosen for each glitch

Clustered Omicron

One representative Q-plane will be chosen for each glitch
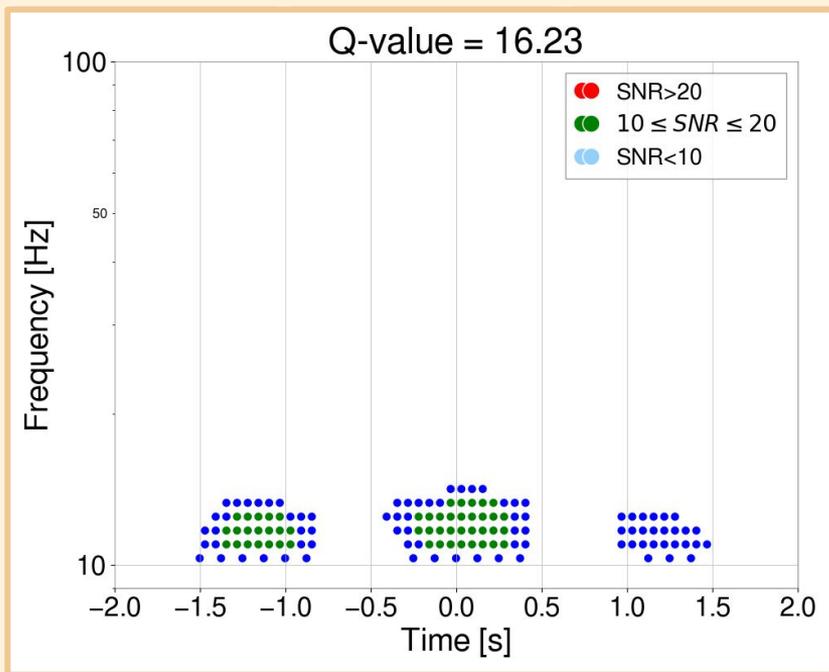
Parameters

GPS time
Duration
Peak Frequency
SNR
…

All this information is saved in .h5 files.

Difference in file size: .root vs .h5 files (same time period)

Using 10 hours of data, from December 23, 2023, 13:00 to 23:00.

There are **3906843** triggers from unclustered Omicron

There are **34510** glitches from clustered Omicron

Difference in file size: .root vs .h5 files (same time period)

Using 10 hours of data, from December 20, 13:00

There are 3906843 triggers in unclustered Omicron

There are **34510** glitches from clustered Omicron

These numbers will vary depending on the size of the data and the type of glitch
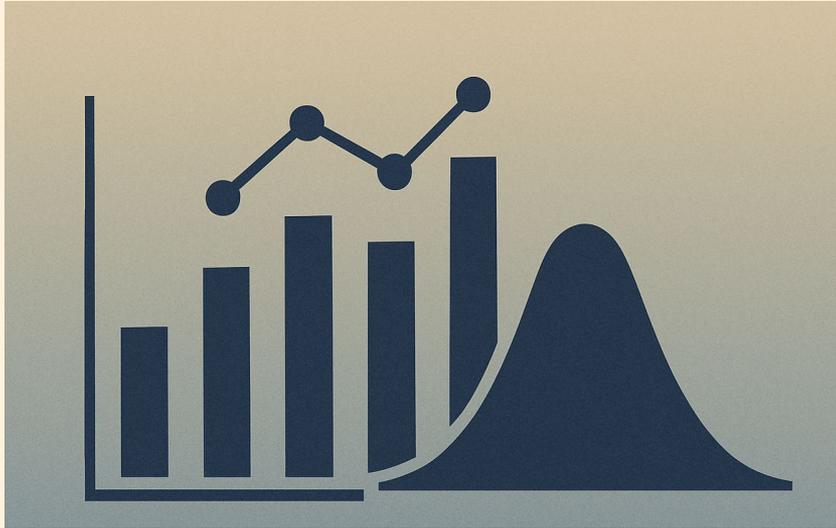
Statistical analyses can be performed on both clustered and unclustered Omicron triggers, although the clustered information is more commonly used

Statistical analyses can be performed on both clustered and unclustered Omicron triggers, although the clustered information is more commonly used

What can we learn statistically once glitches are properly represented (especially clustered)?

Examples and Some Applications

Using clustered information

It is very common to focus on frequency regions with glitches above a minimum SNR.

```python
len(o4a_l1)
```
14931958

```python
len(o4a_l1[(o4a_l1['frequency']>=10) & (o4a_l1['frequency']<=2048)])
```
1672247

```python
len(o4a_l1[o4a_l1['snr']>=7.5])
```
673284

```python
len(o4a_l1.loc[(o4a_l1['frequency'] >= 10) & (o4a_l1['frequency'] <= 2048) & (o4a_l1['snr'] >= 7.5)])
```
166139

Using clustered information
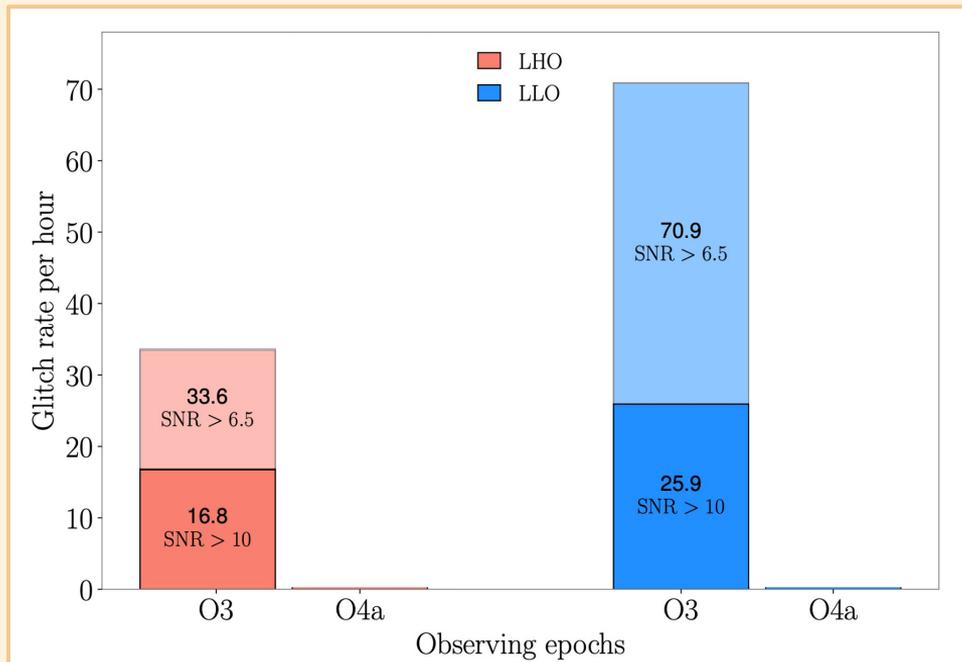
It is very common to

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len(o4a_l1)
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1672247

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673284

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len(o4a_l1.loc[(o4a_l1['frequenc
```
166139

Using clustered information

Comparison between different observing epochs

10 - 2048 Hz
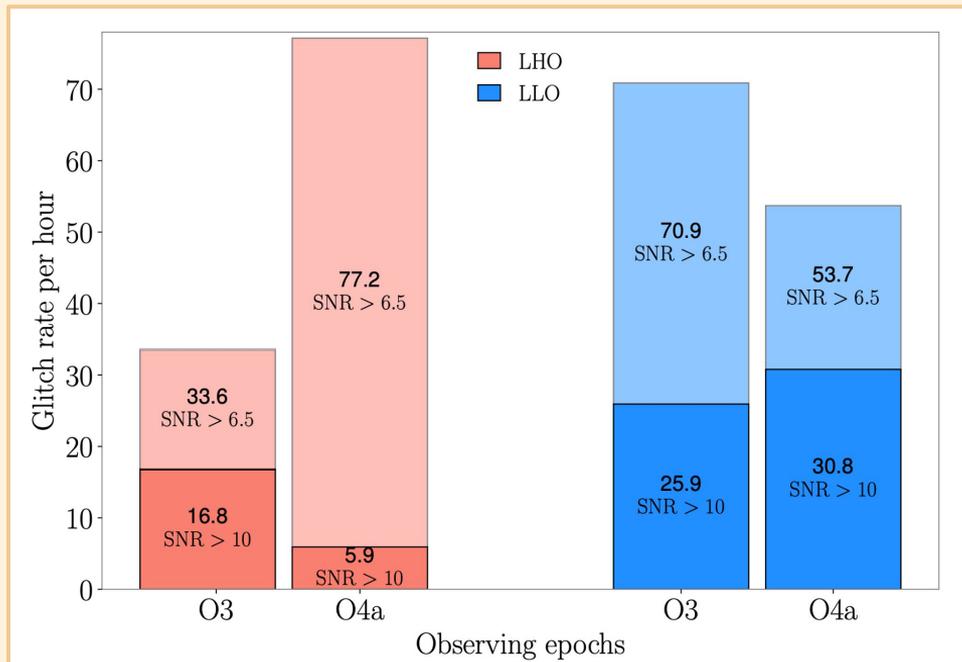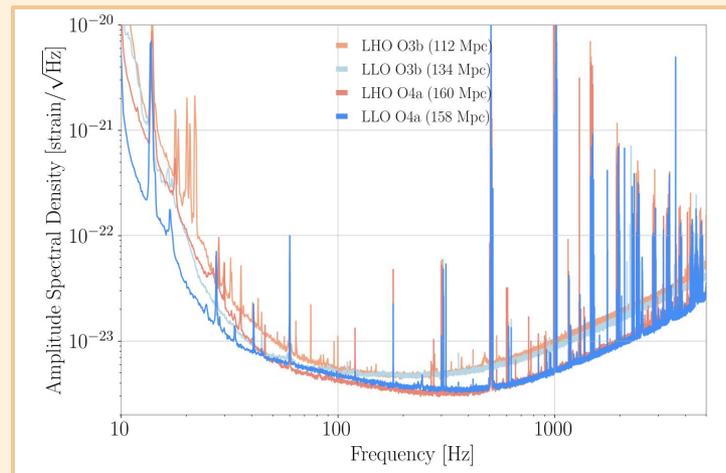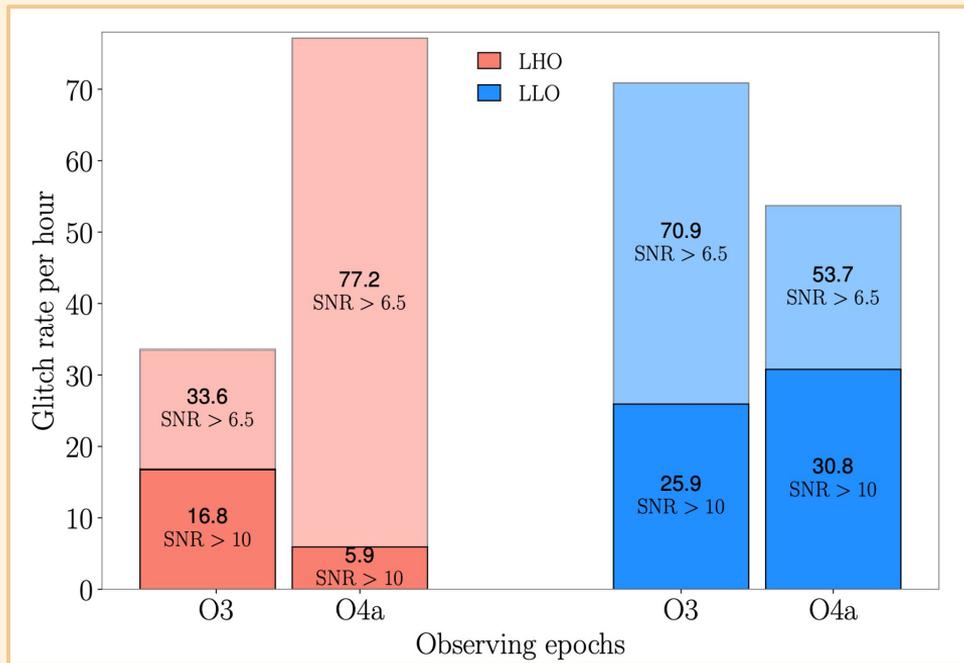
Soni et al. (2025)

Using clustered information

Comparison between different observing epochs

Soni et al. (2025)

10 - 2048 Hz

Using clustered information

Comparison between different observing epochs

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Using clustered information

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Comparison between different observing epochs
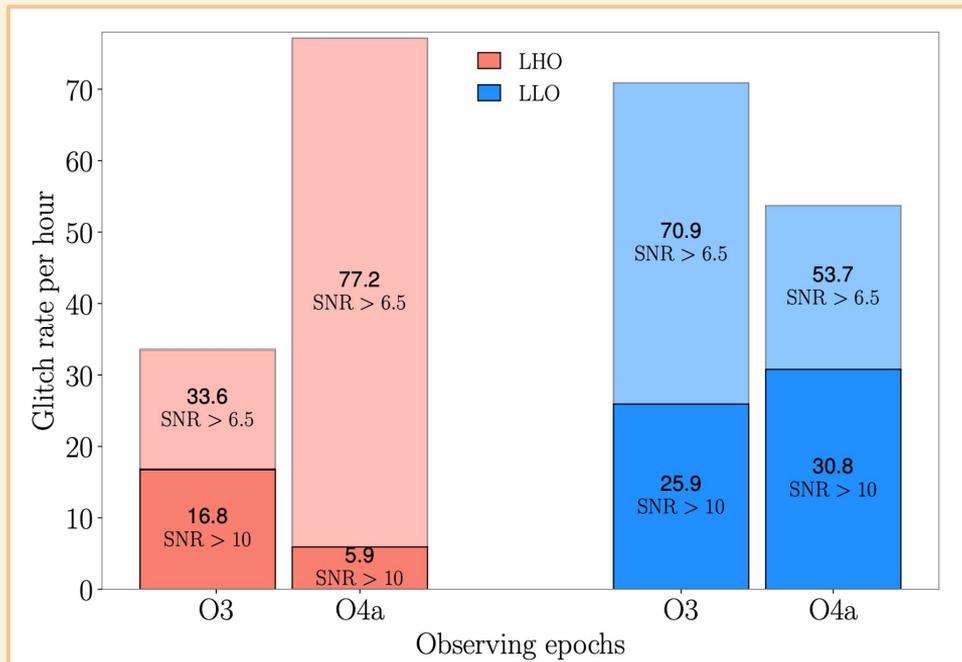
Questions we can try to answer:

Why did the glitch rate increase or decrease?

Which detector was more affected, and why?

Were the glitches evenly distributed over time, or were there periods of higher dominance? If so, what happened during those periods?

Using clustered information

Comparison between different months in a same observing run (O4a)

LLO

Ferreira, T.A. et al. (2025)

Using clustered in

LLO
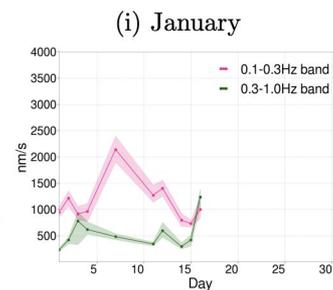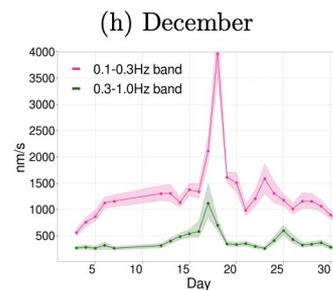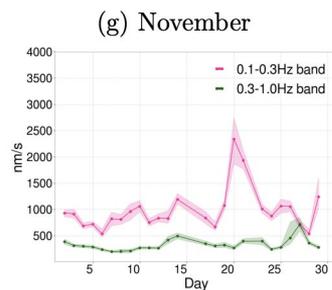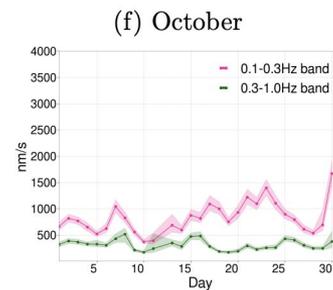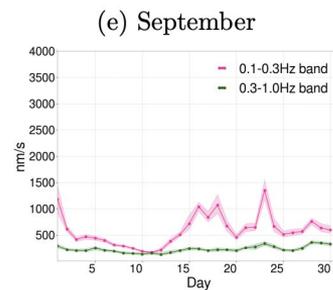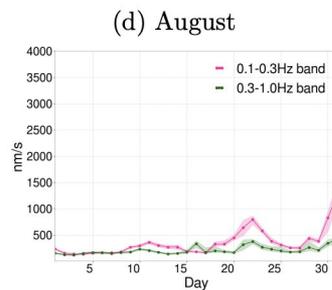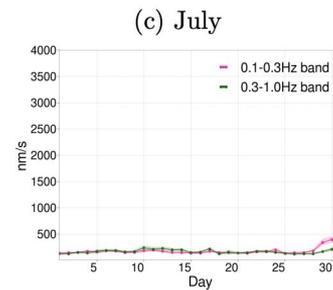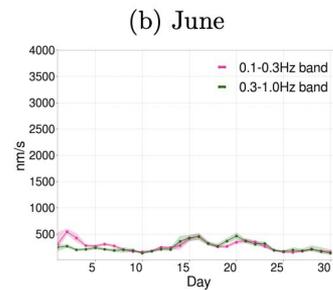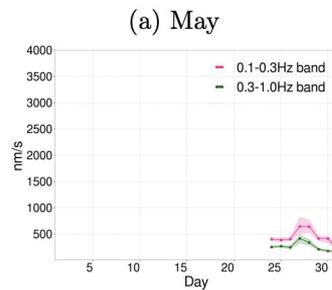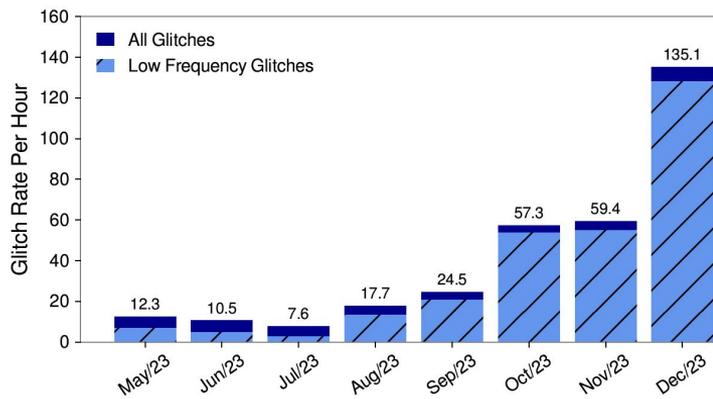
(a) May (b) June (c) July
(d) August (e) September (f) October
(g) November (h) December (i) January

Using clustered information

Comparison between different months in a same observing run (O4a)

LLO

Ferreira, T.A. et al. (2025)
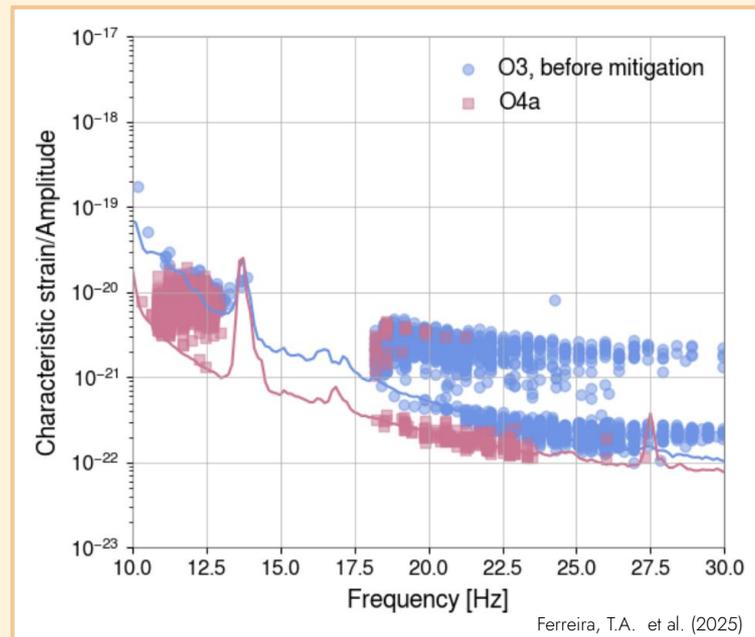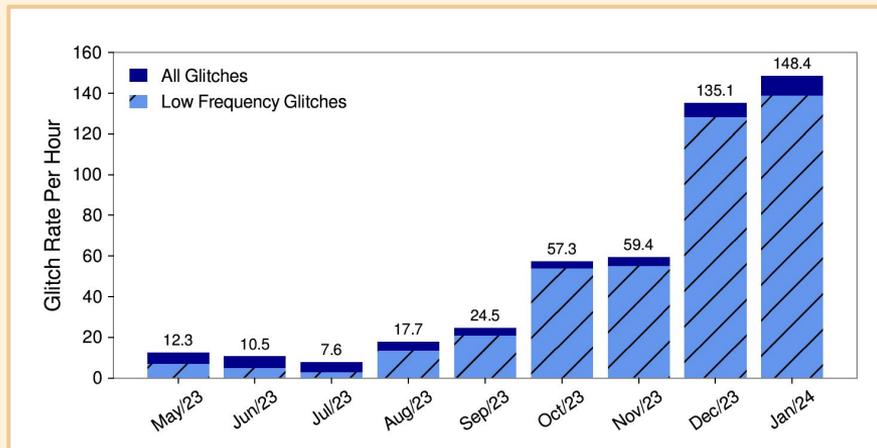
Using clustered information

Comparison between different months in a same observing run (O4a)

LLO

LHO
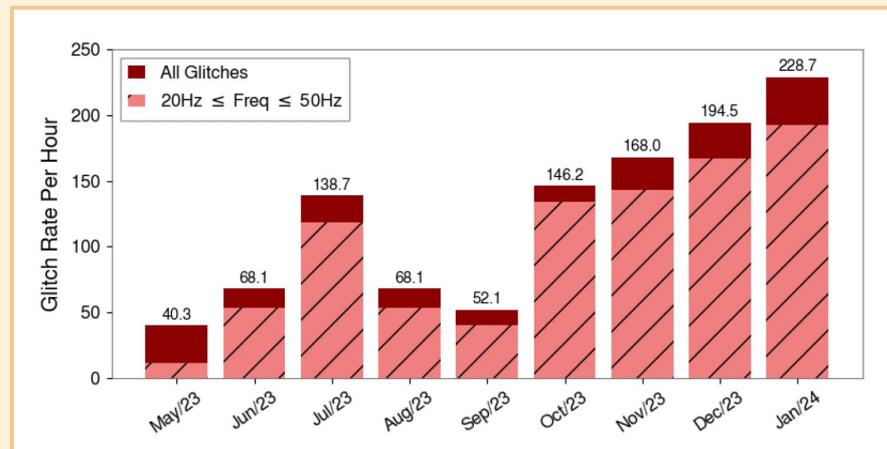

Ferreira, T.A. et al. (2025)

Parameter characteristics

Using clustered information
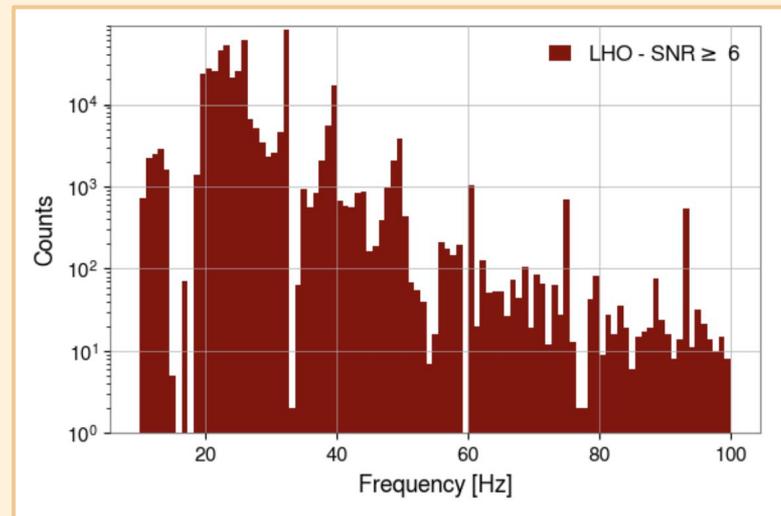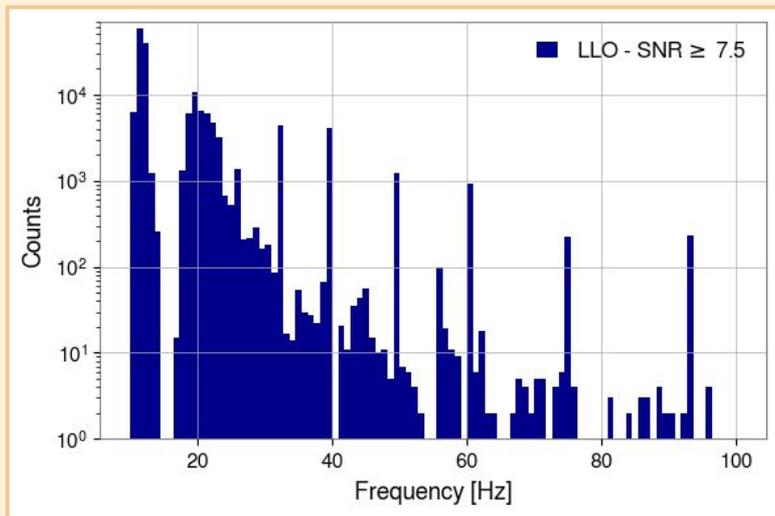
Parameter distributions

Using clustered information

Parameter distributions
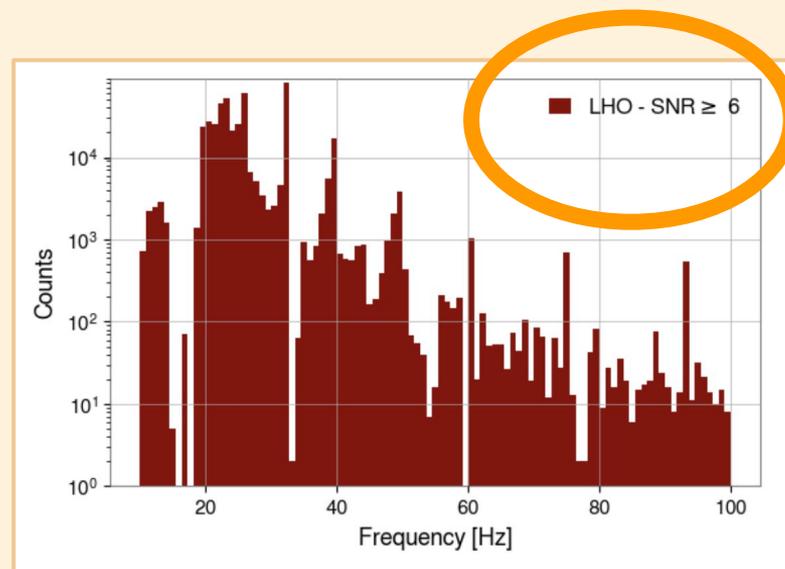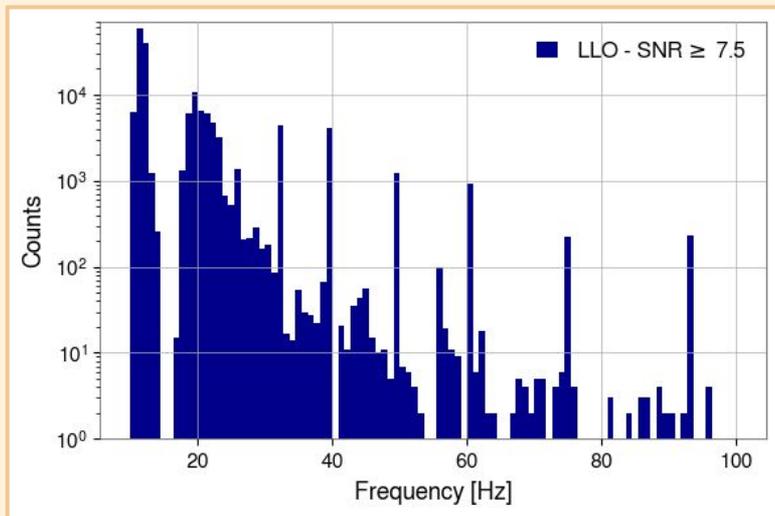
Using clustered information
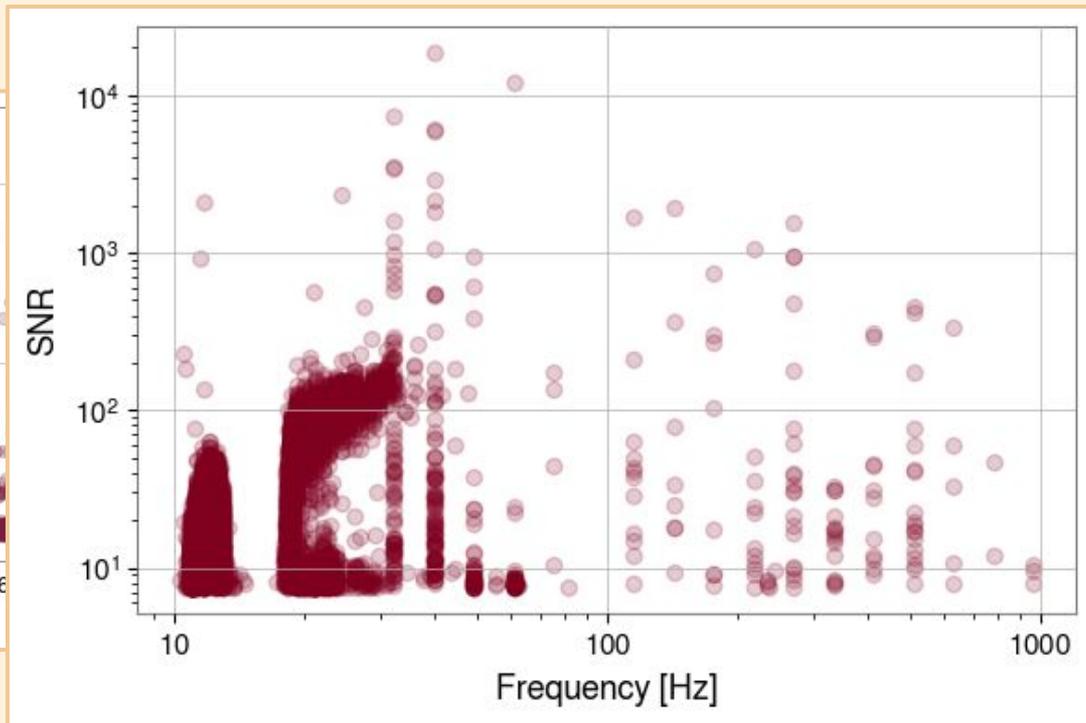
Parameter distributions
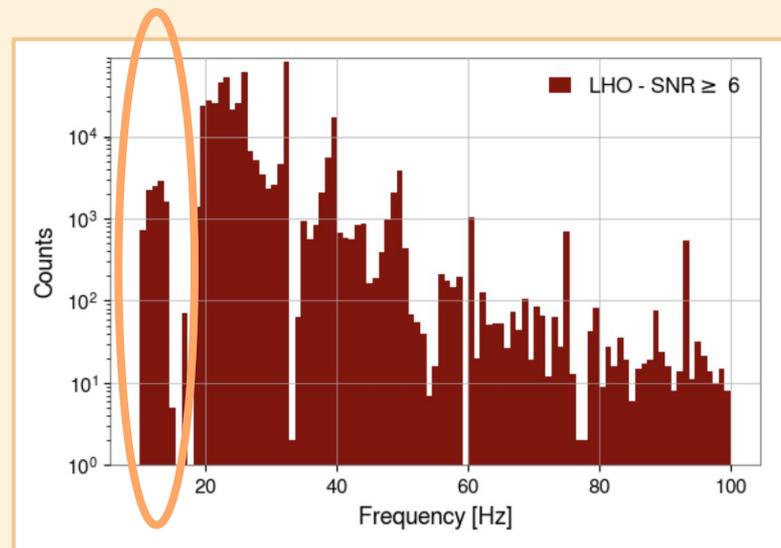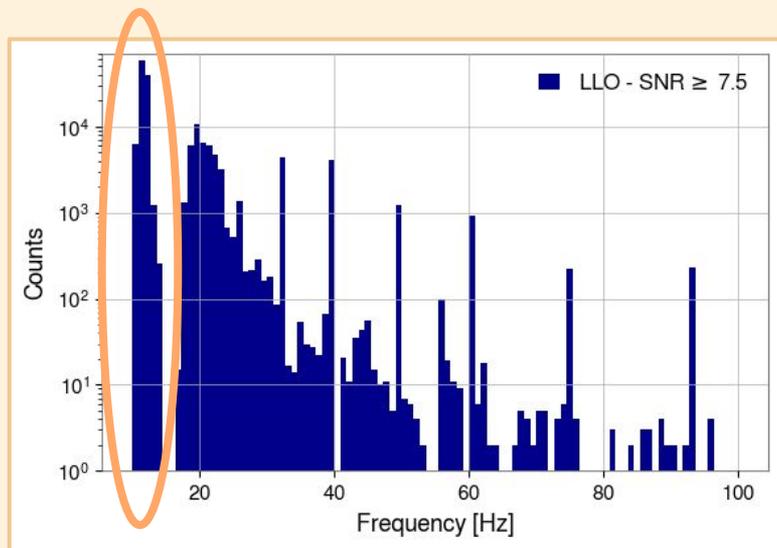
Using clustered information

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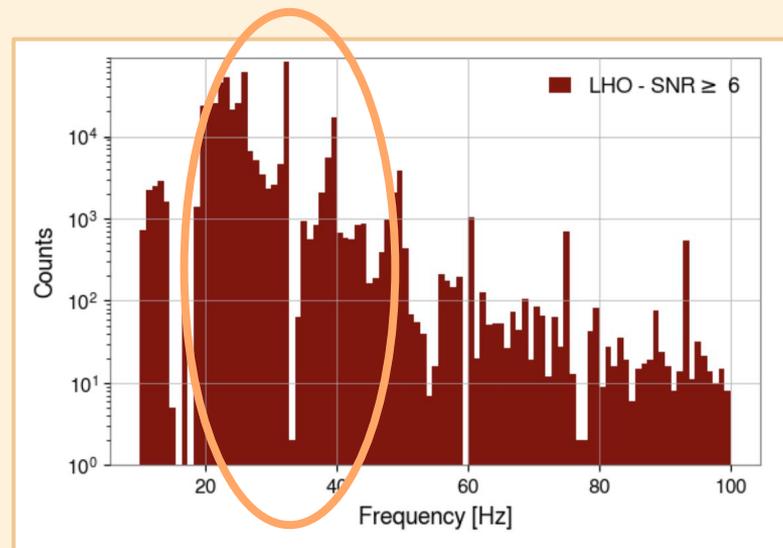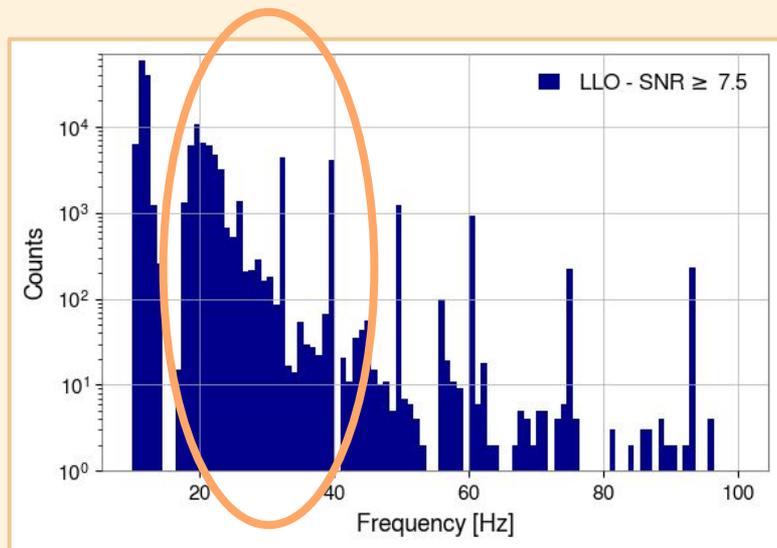
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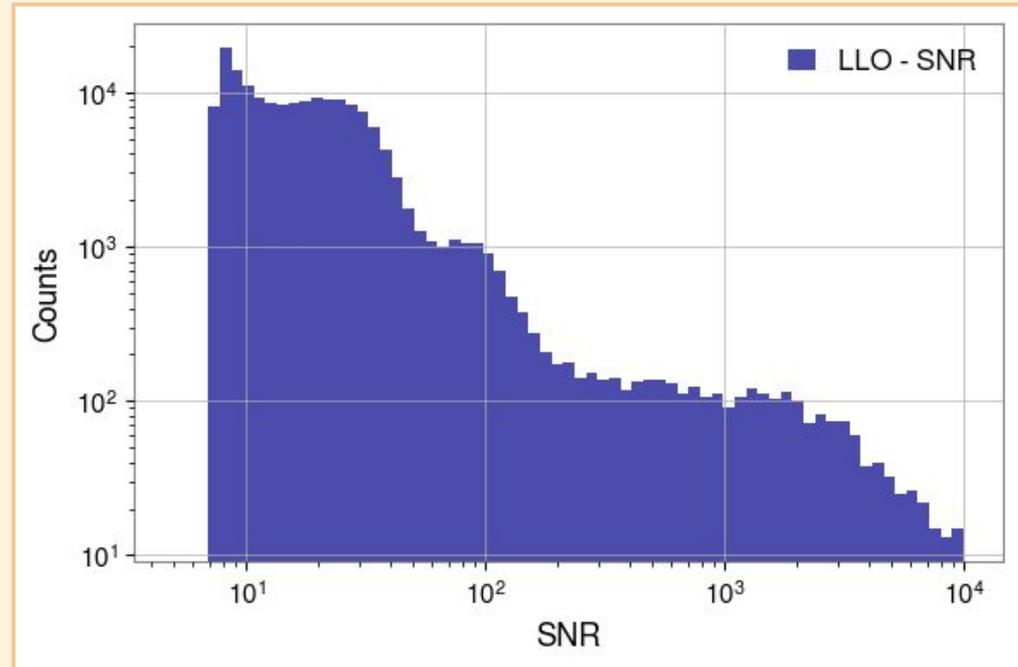
Using clustered information

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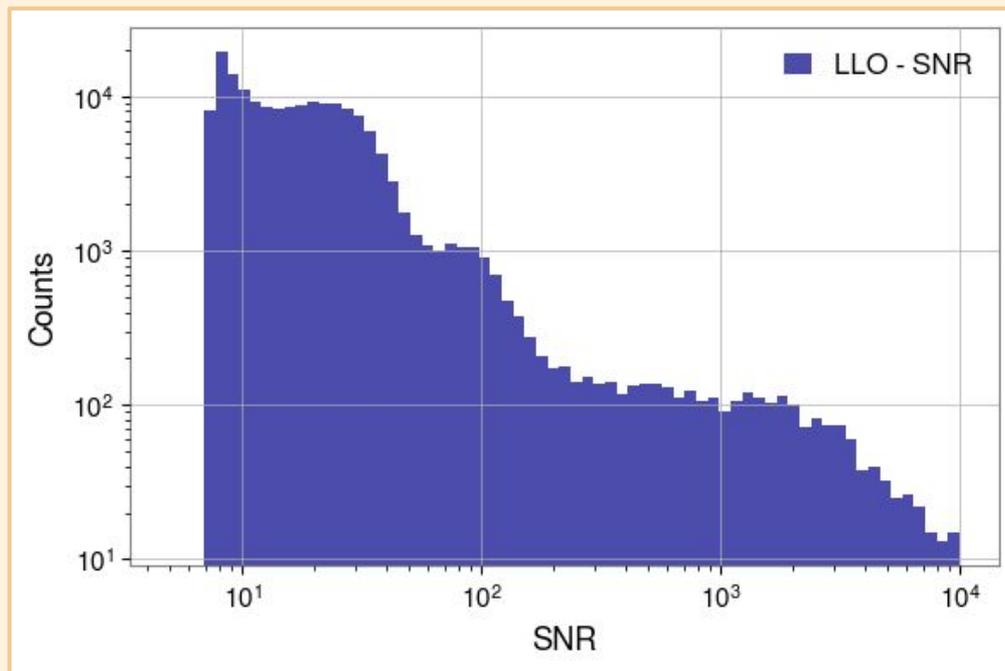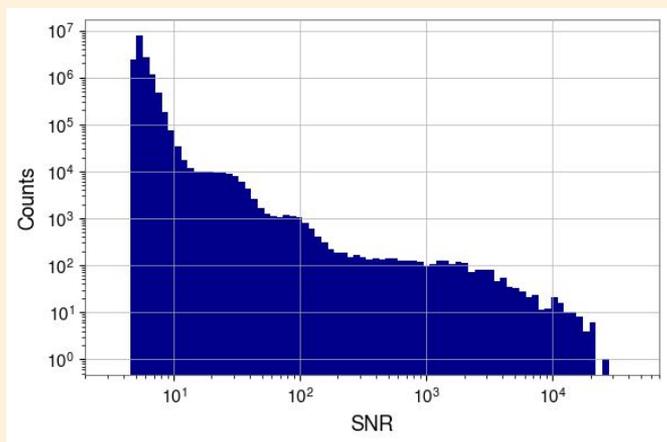
Using clustered information

Scatter plot
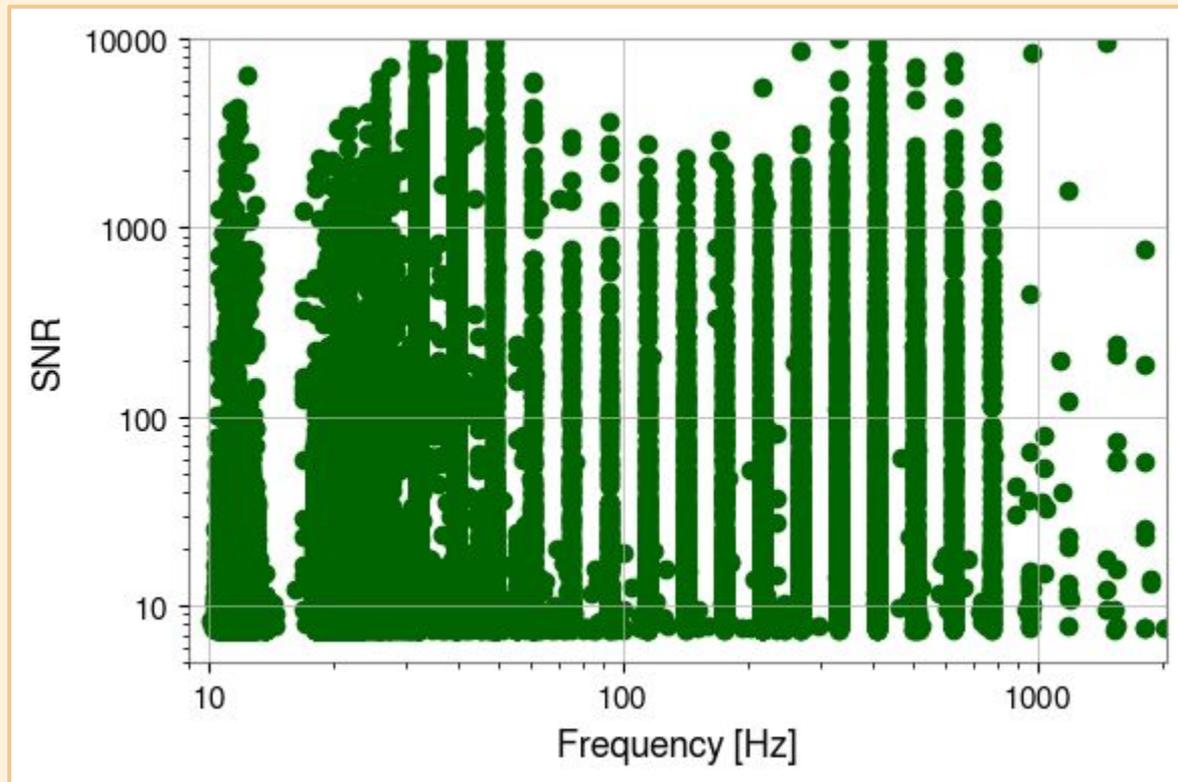
Using clustered information
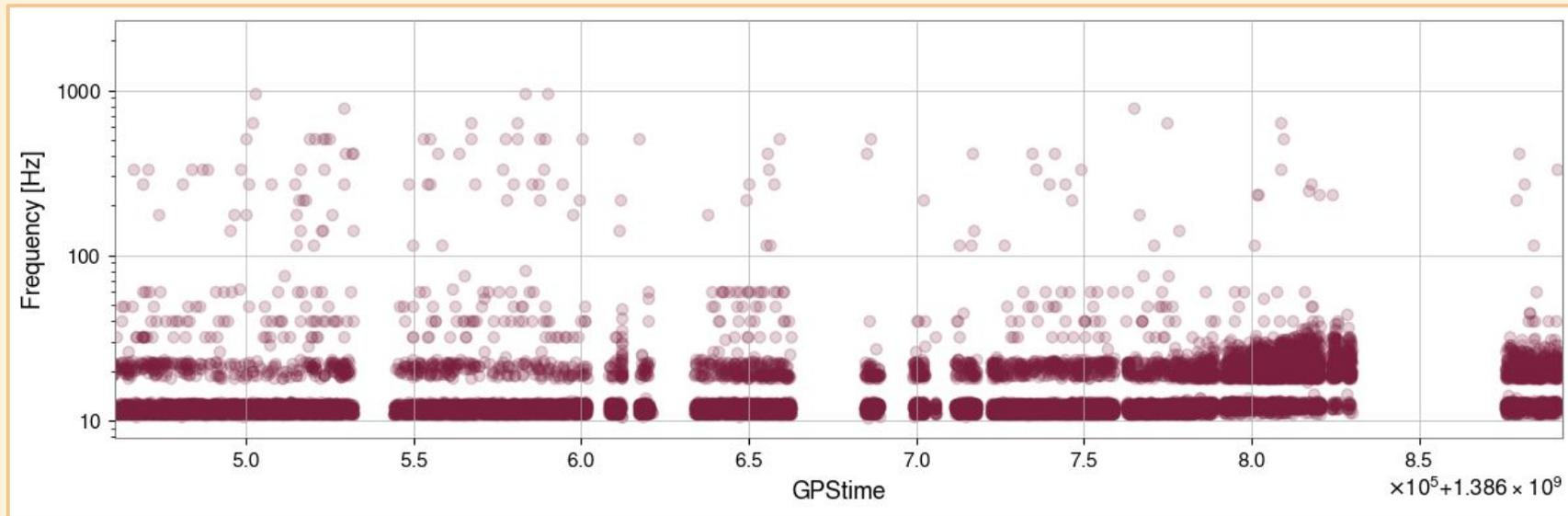
Glitches over time (short time period, in this case)

Using clustered information
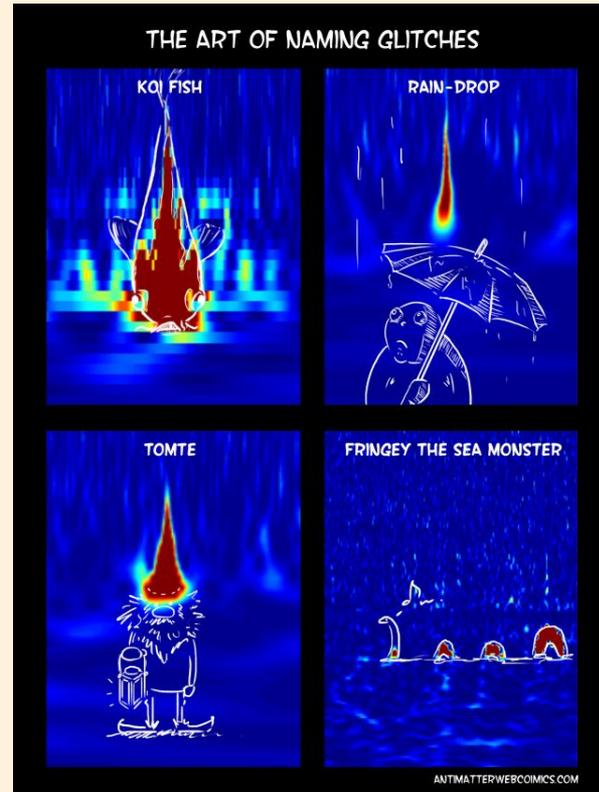
Glitches over time (short time period, in this case)
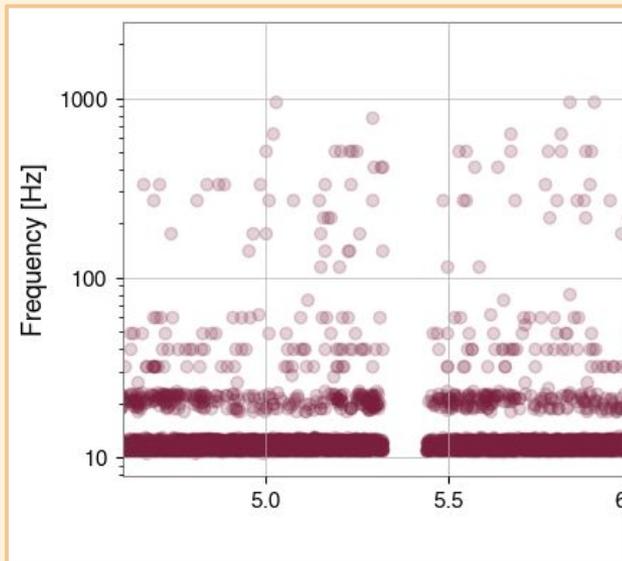
Using clustered information

Glitches over time (short time period, in this case)

Glitch Classes

THE ART OF NAMING GLITCHES

KOI FISH

RAIN-DROP

TOMTE

FRINGEY THE SEA MONSTER

ANTIMATTERWEBCOMICS.COM
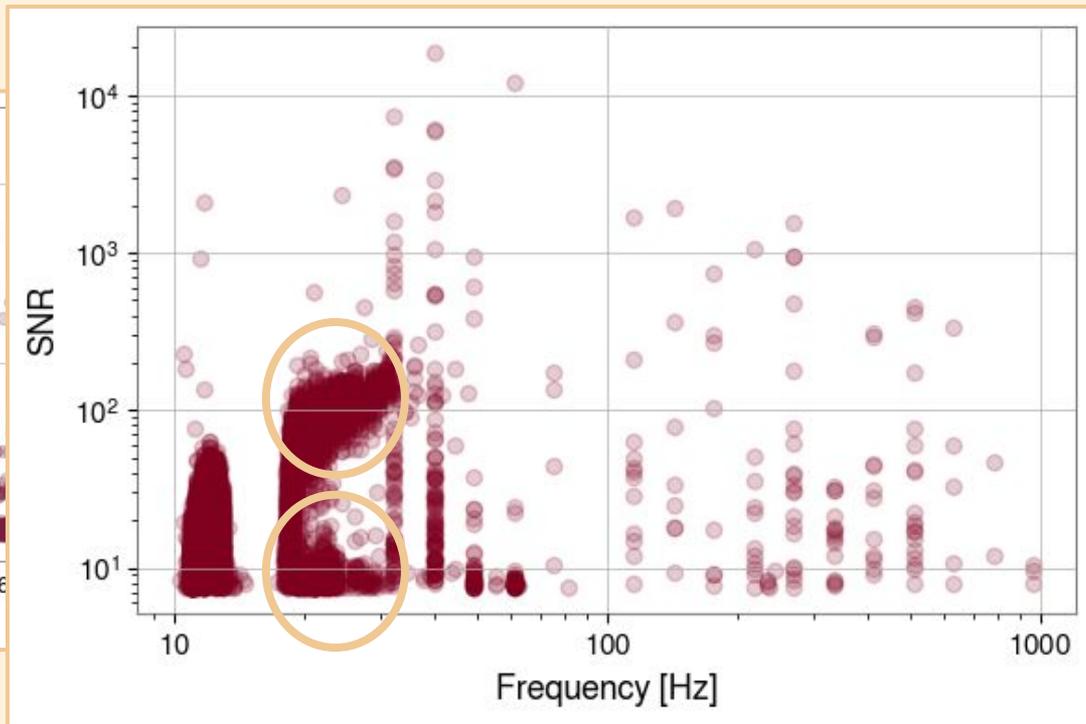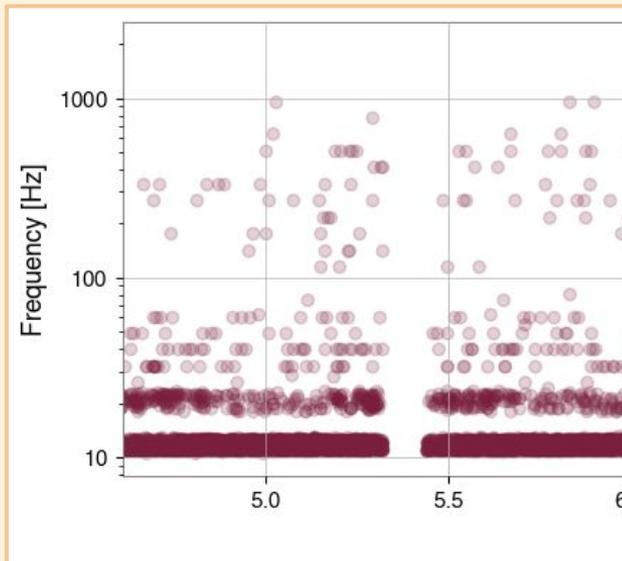
https://cqgplus.wordpress.com/2016/06/06/how-do-we-know-ligo-detected-gravitational-waves/

Class names

```
print(gs_o4['label'].unique())
```

```
['Extremely_Loud' 'Koi_Fish' 'Tomte' 'Low_Frequency_Burst'
 'Low_Frequency_Lines' 'Blip_Low_Frequency' 'Fast_Scattering'
 'Scattered_Light' 'Light_Modulation' 'Whistle' 'Blip'
 'Repeating_Blips' 'Scratchy' 'Power_Line' 'Air_Compressor'
 'Violin_Mode' 'Paired_Doves' 'Wandering_Line' 'No_Glitch'
 'Helix' '1080Lines' 'Chirp' '1400Ripples']
```
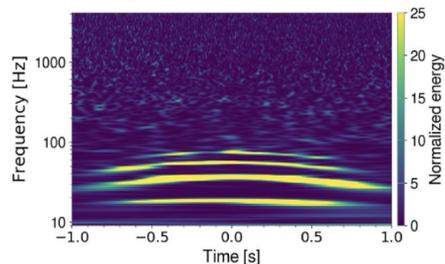

(a) *Scattered Light*　(b) *Tomte*　(c) *Blip*　(d) *Extremely Loud*
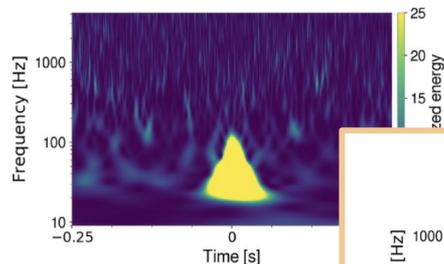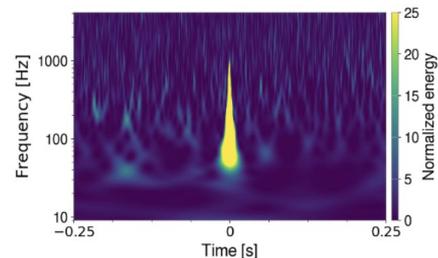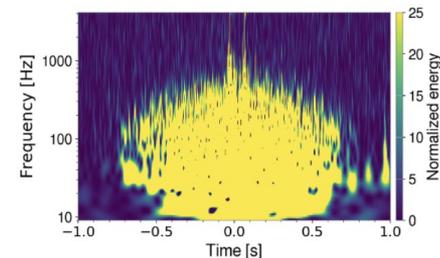
The most common classes and comparisons between interferometers

LLO
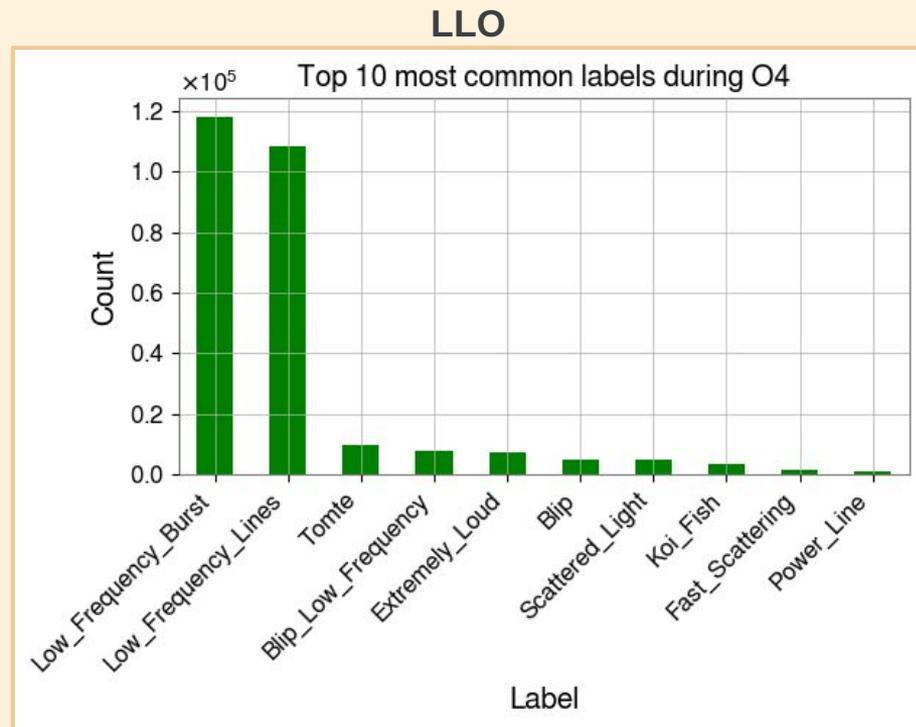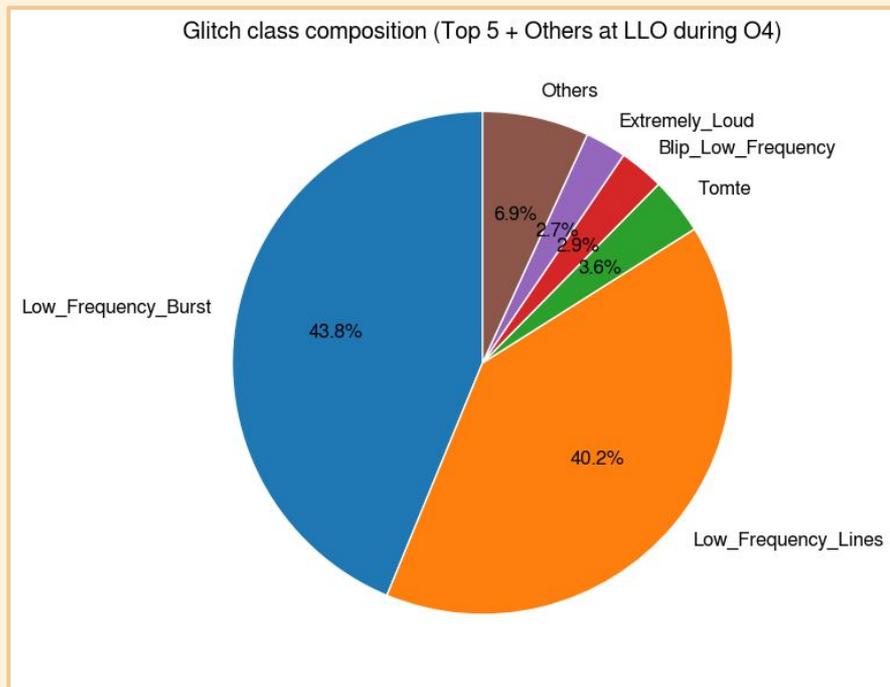
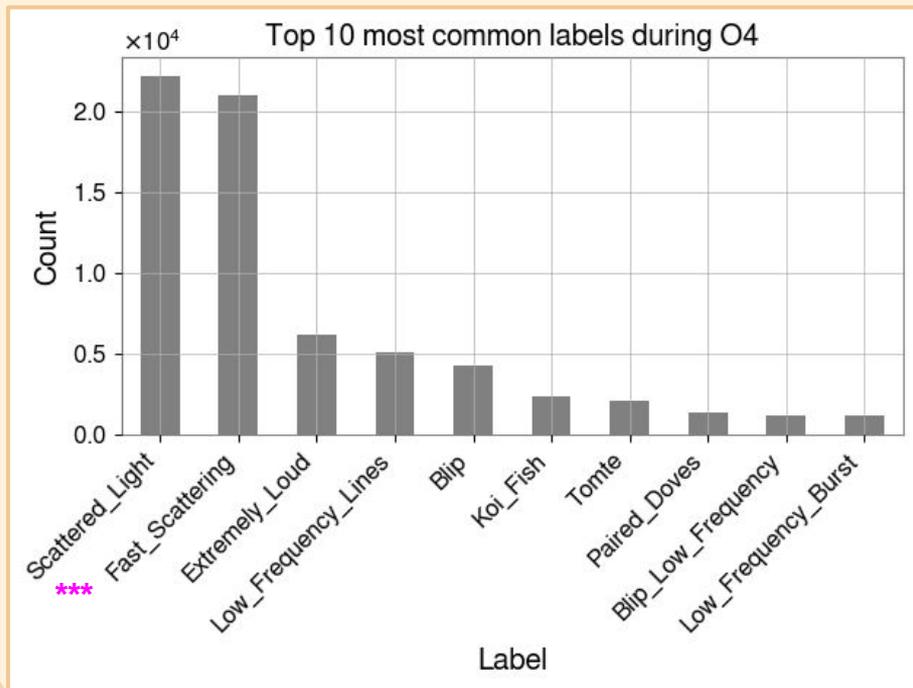# The most common classes and comparisons between interferometers

LHO
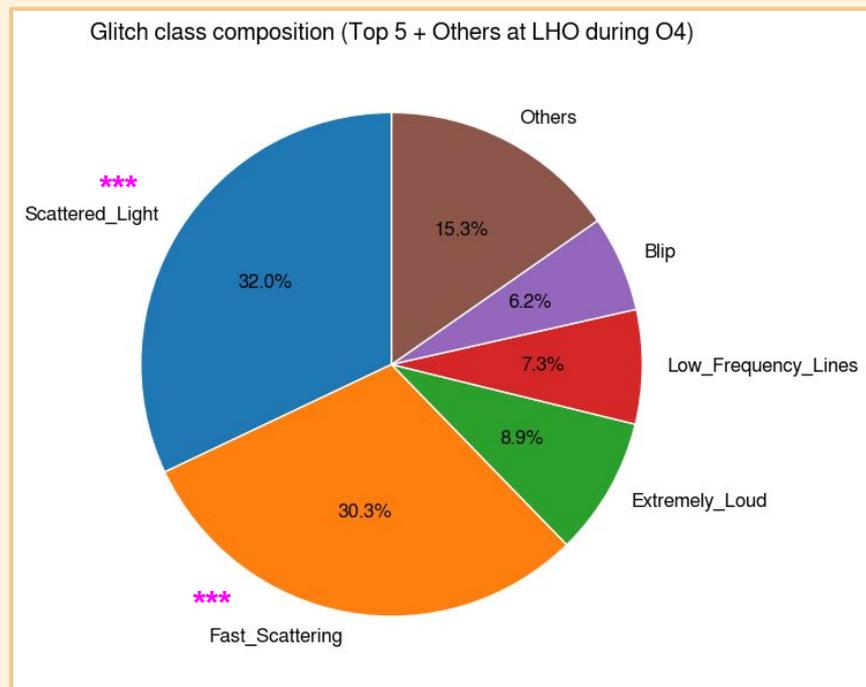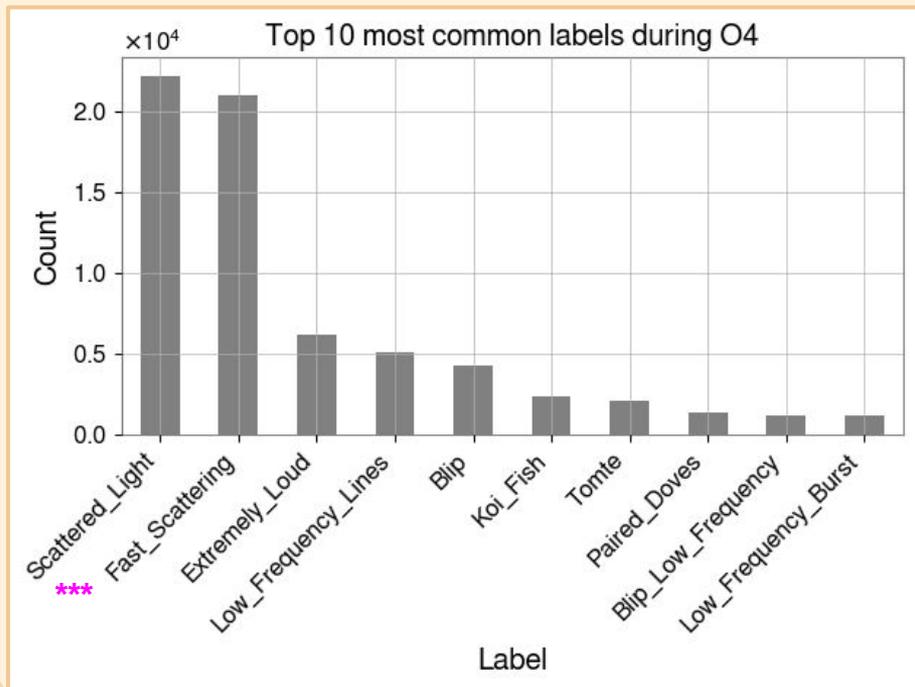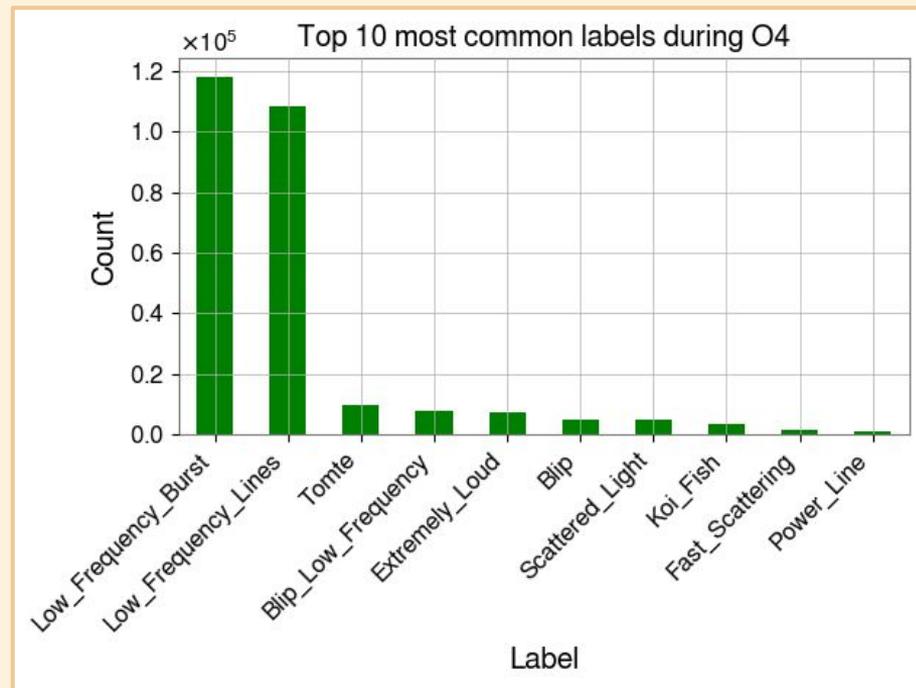
*** Broadband glitches

The most common classes and comparisons between interferometers
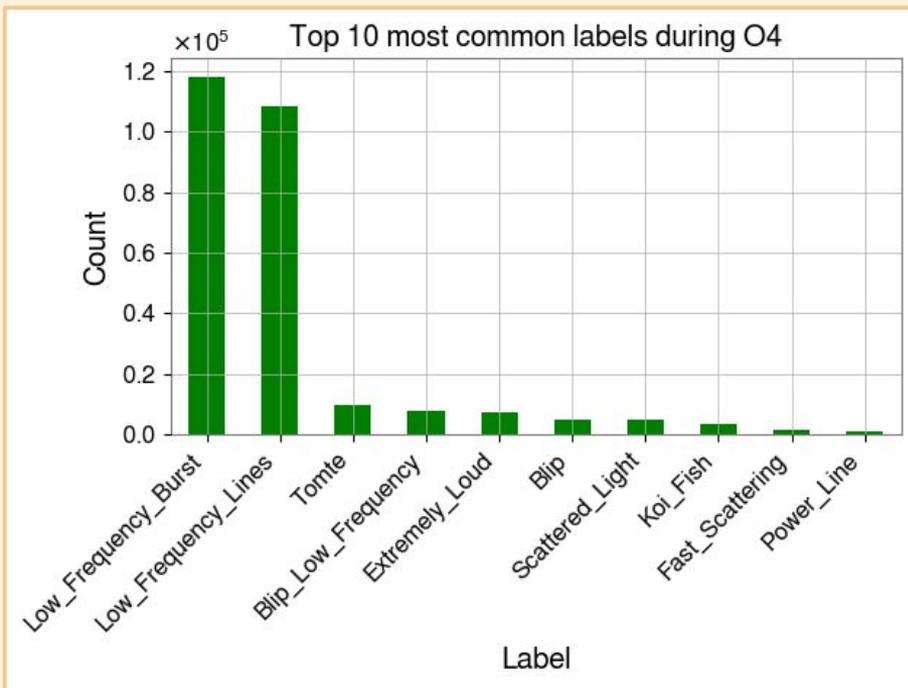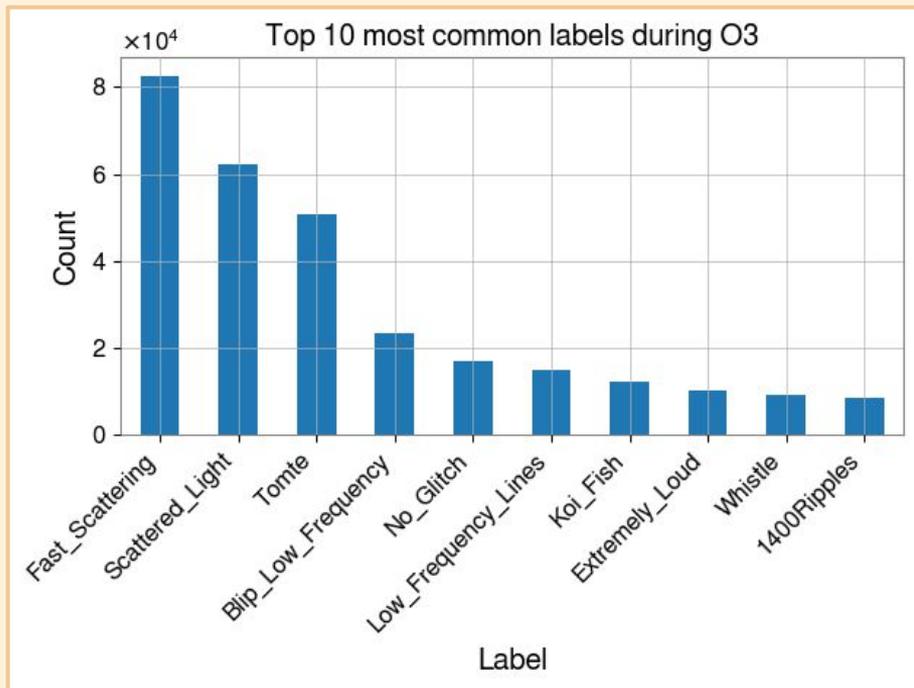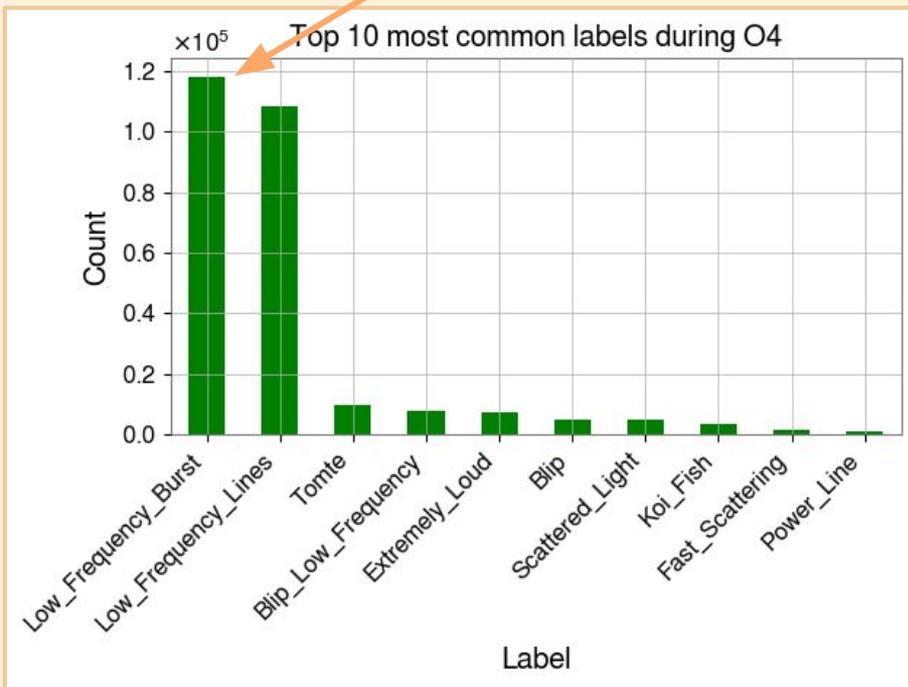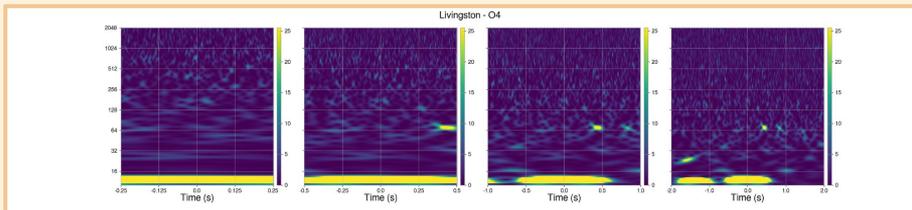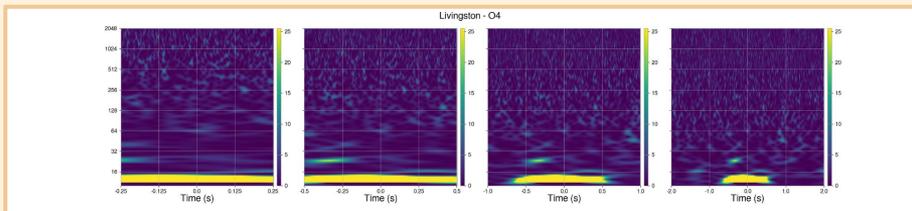

LHO

LLO

*** Broadband glitches

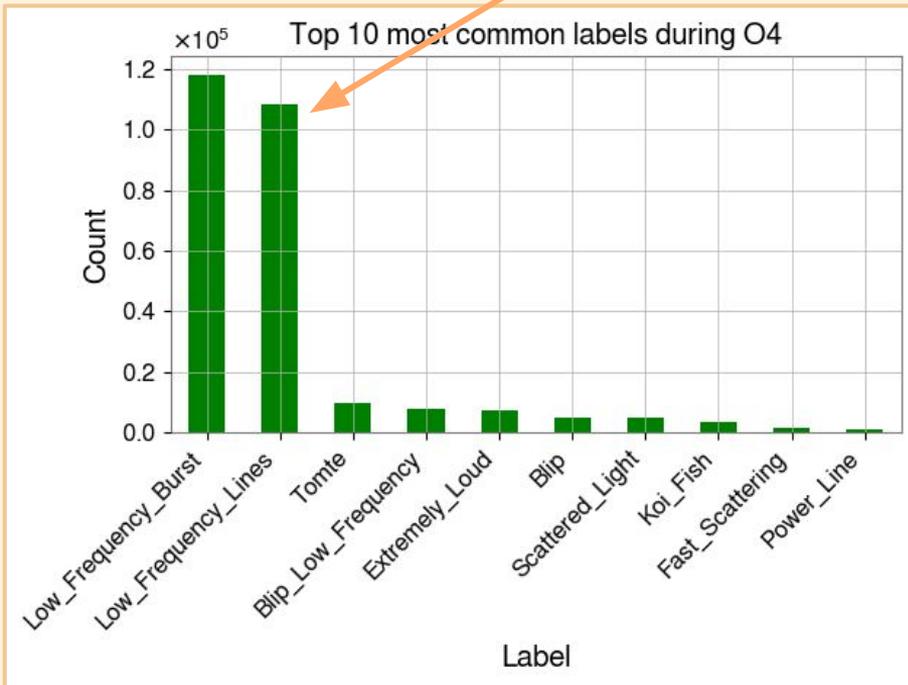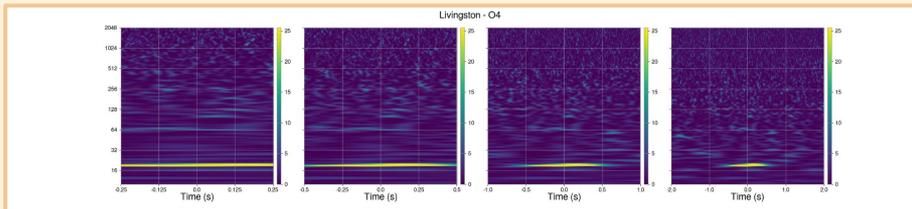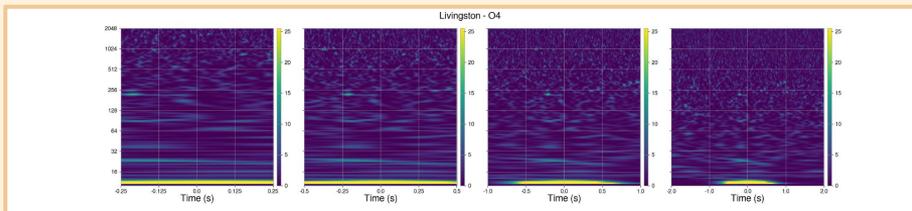# Comparison between different observing runs

The most common classes and comparisons between different runs (LLO)

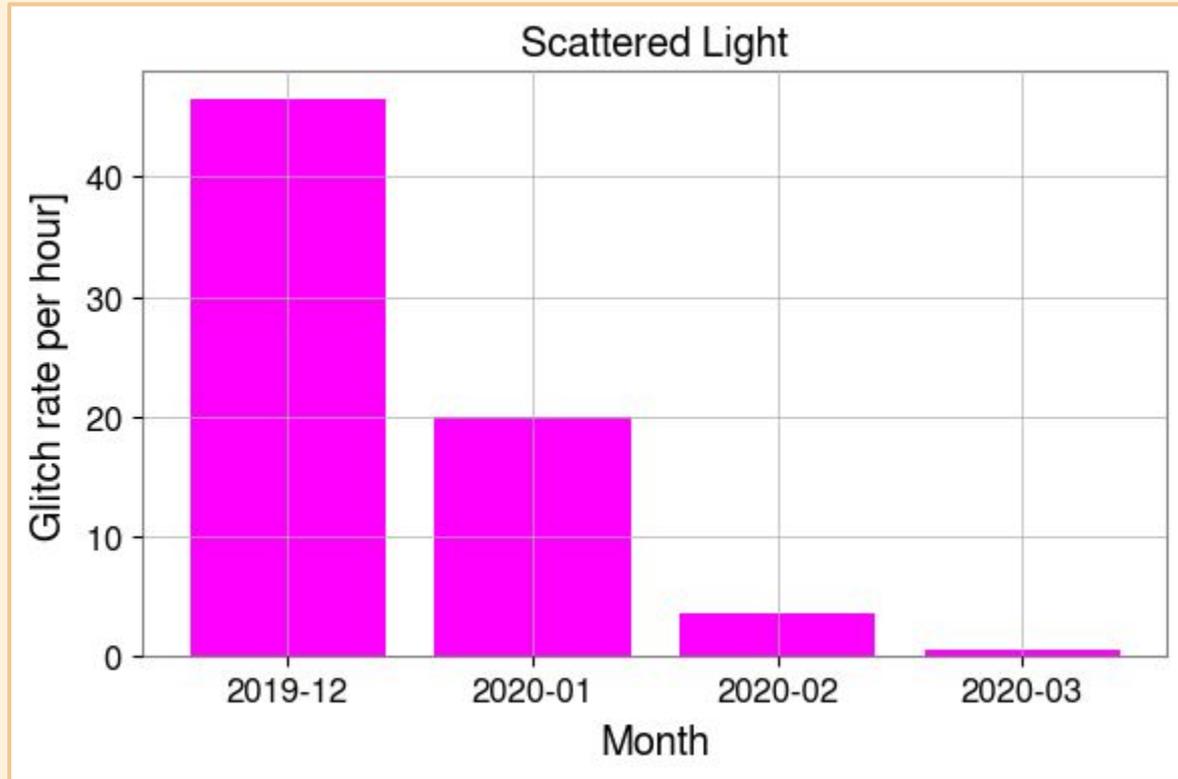# The most common classes and comparisons (LLO)
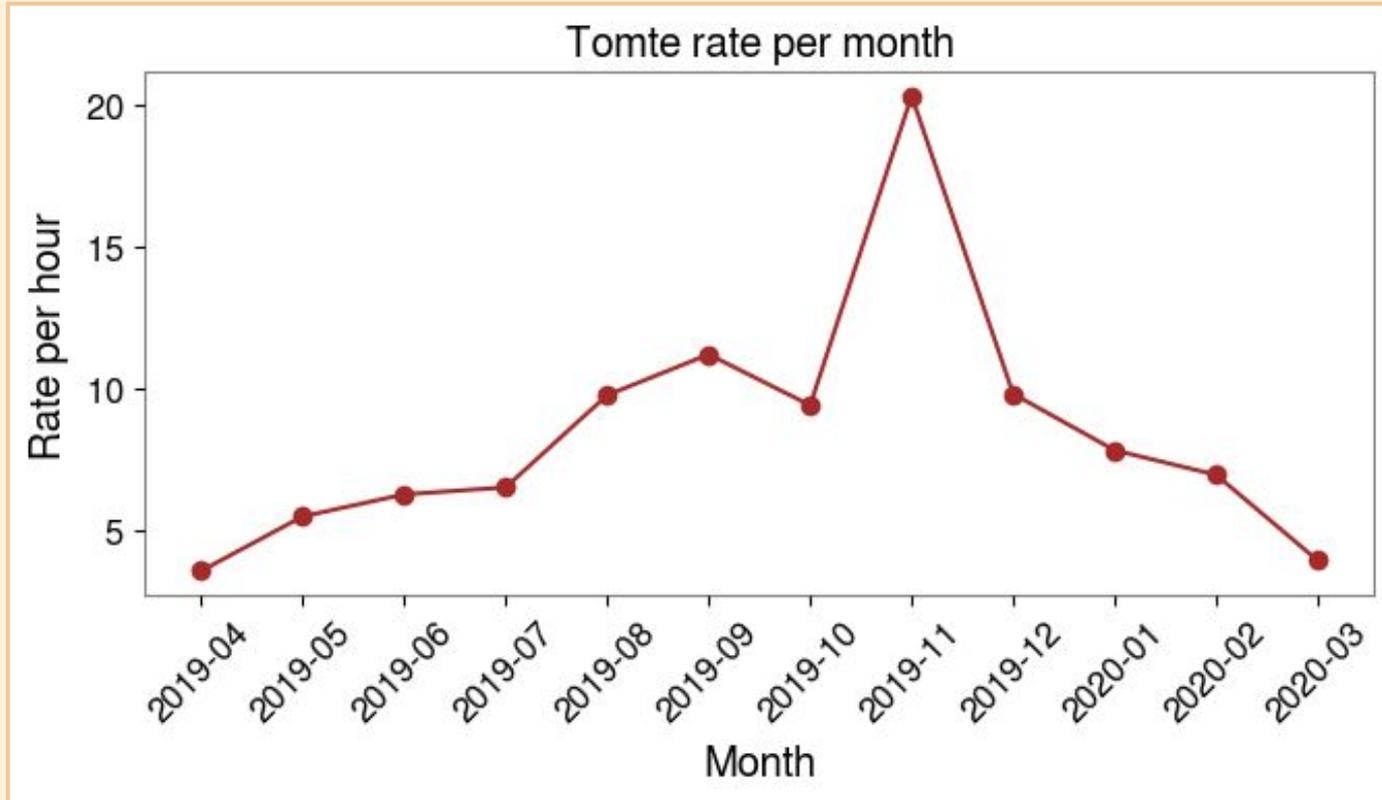
The most common classes and comparisons (LLO)

Class rate over time
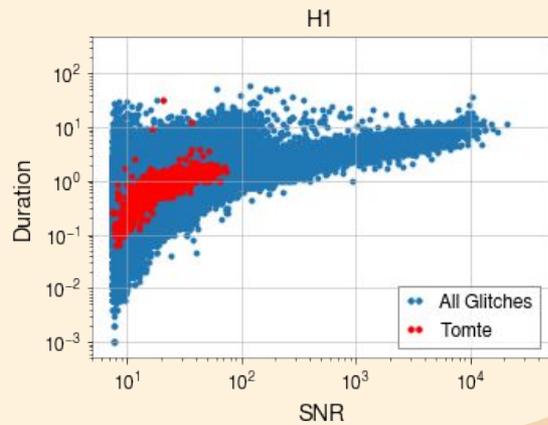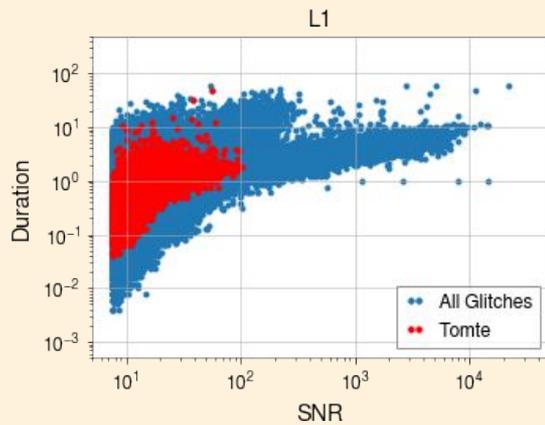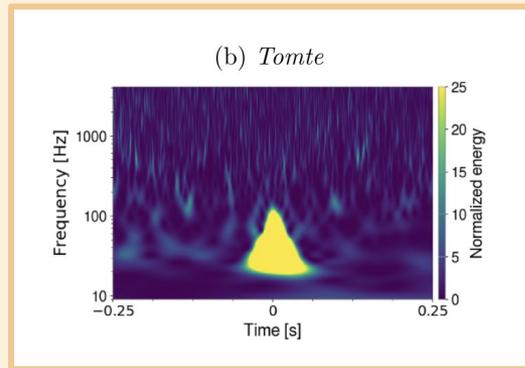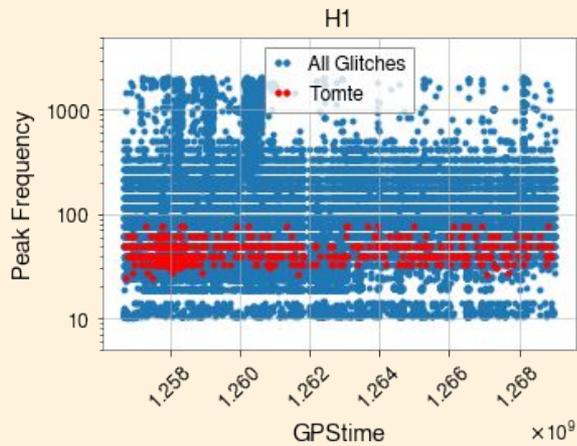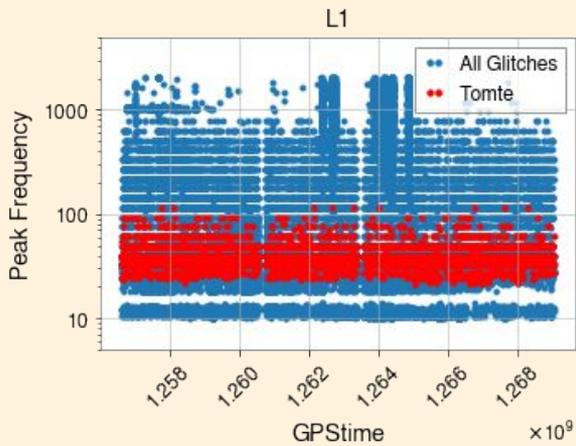
Class rate over time (LLO - 03)

Class rate over time

What happened in November?

Tomte rate per month

Comparisons

Tomte

Tomte
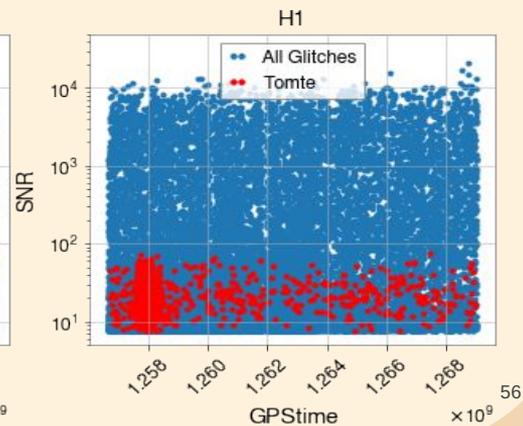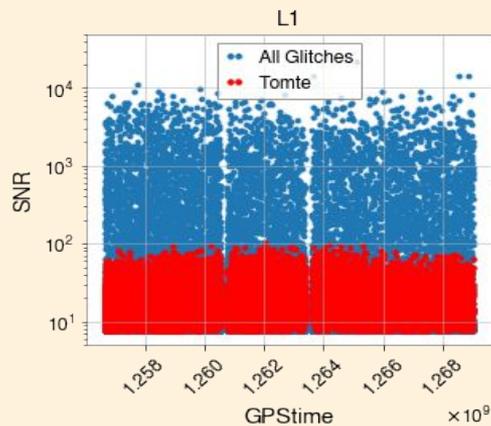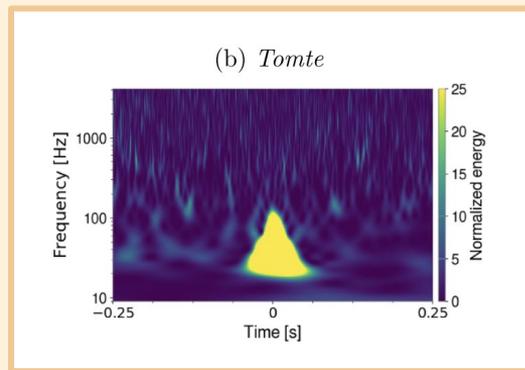
(b) *Tomte*

Tomte vs. Extremely Loud

(b) *Tomte*
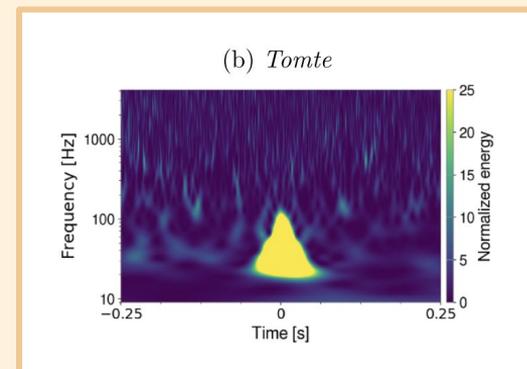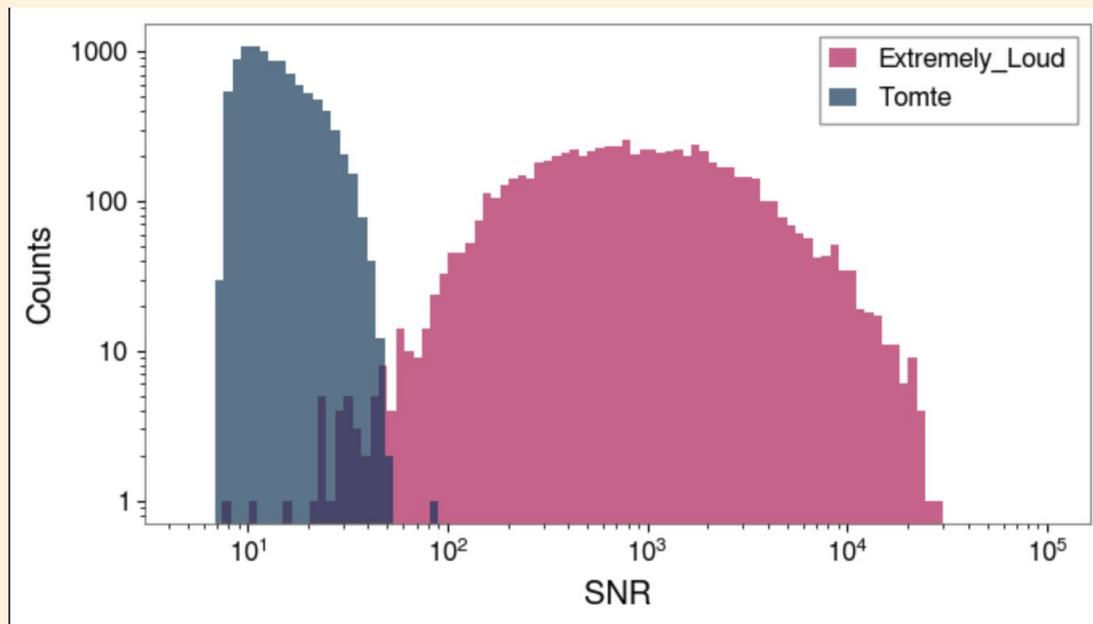
(d) *Extremely Loud*

Using unclustered information

Using **unclustered** information

Comparison between the number of unclustered triggers for two different classes
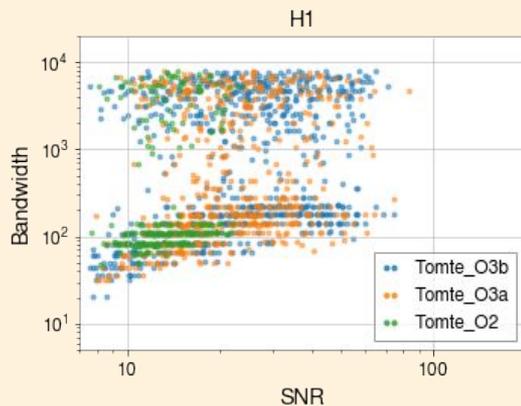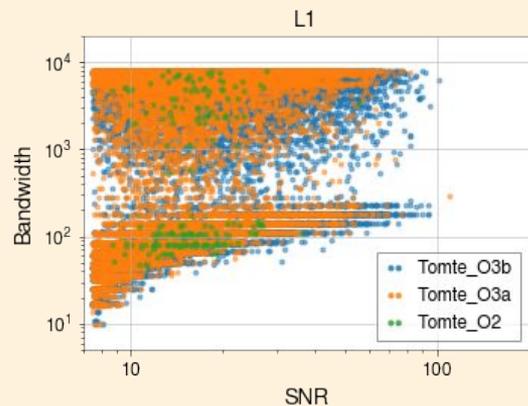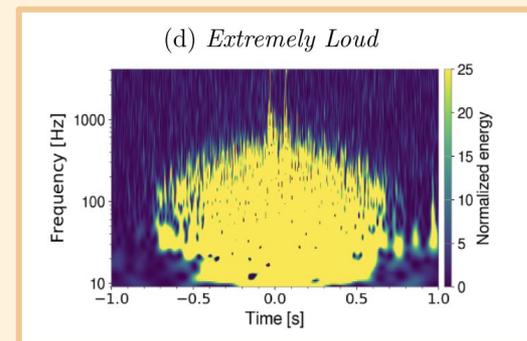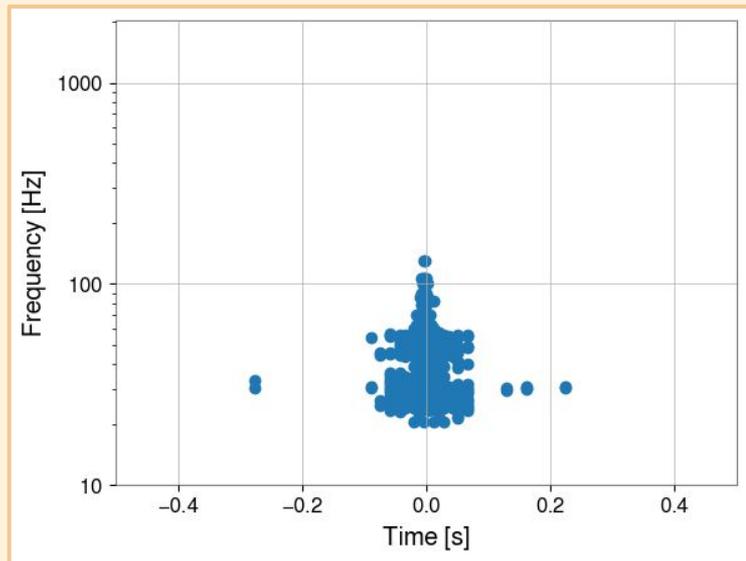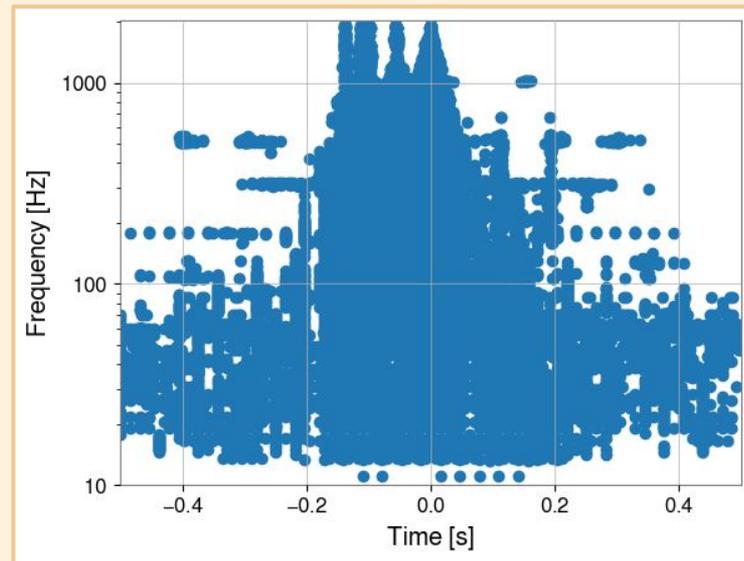
Tomte (308 triggers)

Extremely Loud (21202 triggers)

Subclasses

Finding subclasses within a specific class (Fast Scattering, O3: 2–4 Hz)
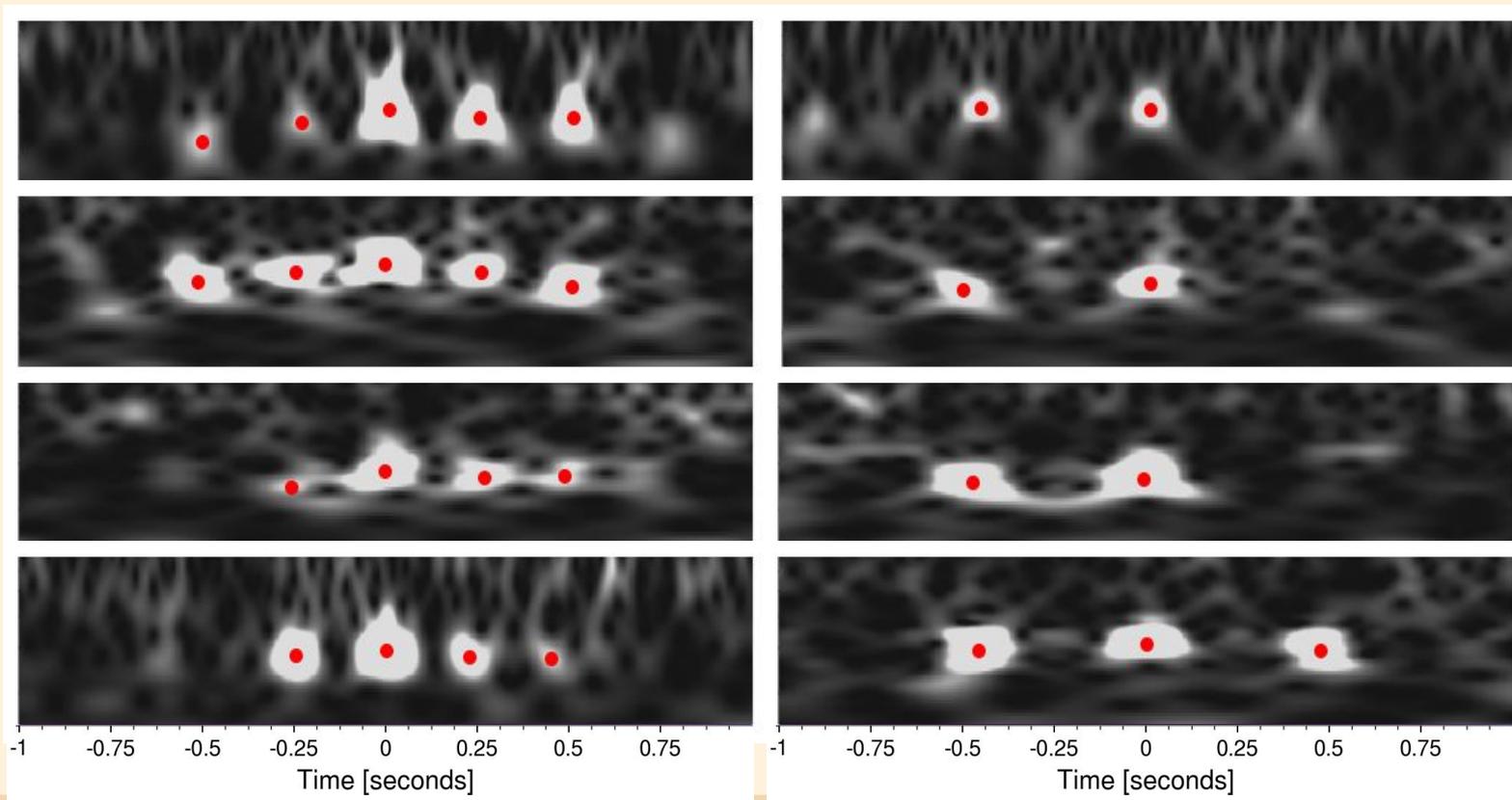
Finding subclasses within a specific class (Fast Scattering, O3: 2–4 Hz)
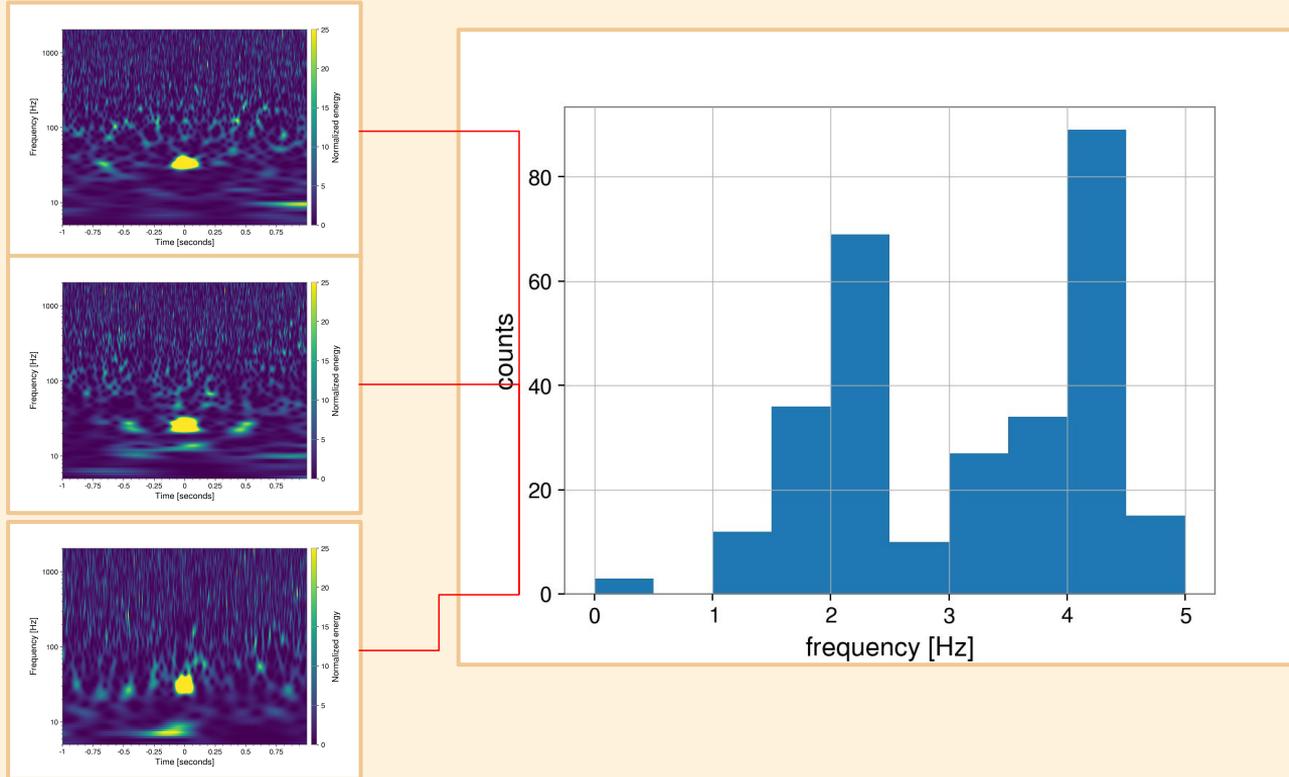
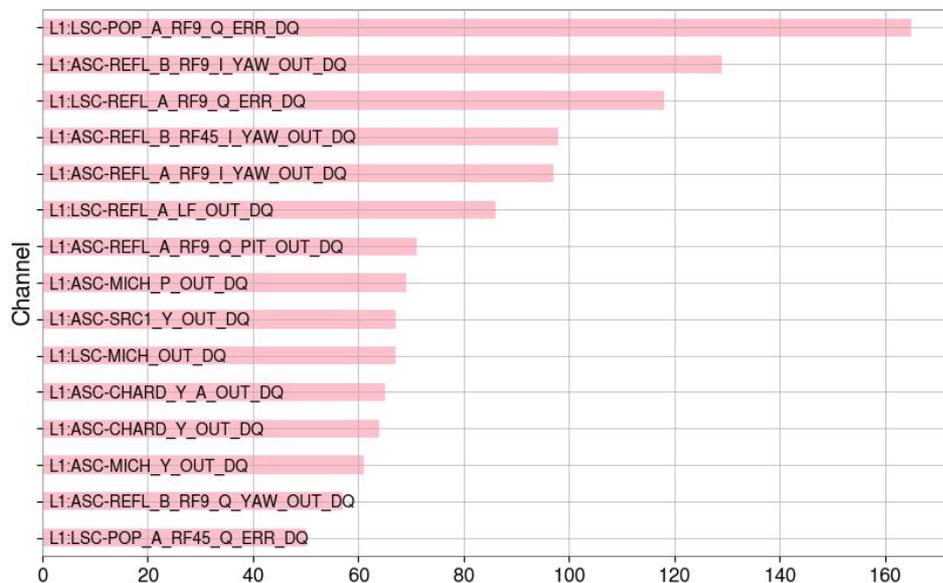# Statistics from Omega Scan

Omega scan for a class

After selecting GPS times for a given glitch class:

How often do auxiliary channels exceed a minimum correlation threshold?

Do any channels appear consistently?

Can such channels be used as witnesses?

What can we infer about the underlying noise coupling?

Summary and conclusions

- Statistical studies of glitches are essential for understanding detector behavior and identifying underlying noise sources.

- Omicron information enables a wide range of statistical analyses, including comparisons between interferometers, studies of glitch parameters and their distributions, and tracking glitch populations over time.

- The same analyses can be performed by focusing on a single glitch class, allowing for more targeted studies that reveal class-specific characteristics and help uncover potential noise coupling mechanisms.

Thank you!