

# Training a new model for GravitySpy

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# List of Acronyms and terminologies for non LIGO folks

1. aLIGO - Advanced laser interferometer gravitational-wave observatory.
2. O3 - Observing run 3, the third aLIGO run of gravitational-wave detection that began on April 1, 2019 and ended on March 28, 2020
3. H1 and L1 - Gravitational wave detector at Hanford and Livingston respectively
4. Glitch/Trigger - short duration events with high energy aka noise
5. Omega scans - Time-frequency spectrograms of noise events

# Overview

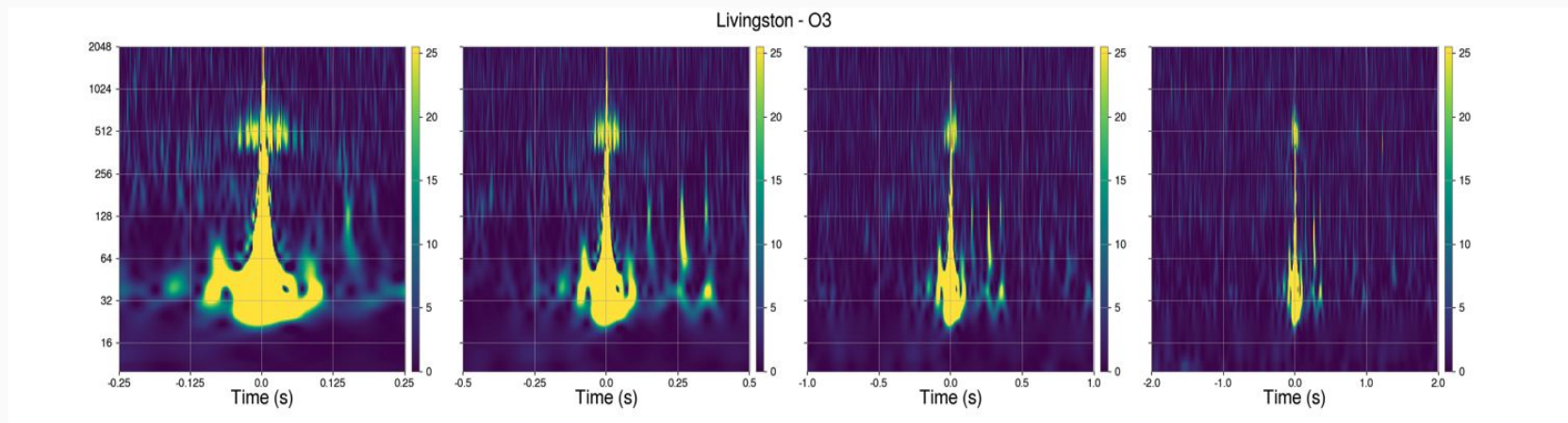
1. Introduction to GravitySpy
2. Introduction to Fast scattering and Low frequency blips
3. Training the model
4. Old and new model output comparison

# What is GravitySpy?

- It is an image recognition algorithm based on convolutional neural networks (CNN)
- Classifies transient noise at LIGO in 22 classes/labels
- <https://ldvw.ligo.caltech.edu/ldvw/gspySearch> web interface of GravitySpy
- Download the data in csv format for further analysis
- GravitySpy [paper](#)

# Training set

- The algorithm is trained on time-frequency spectrograms of noise transients
- For each event, the training set contains 4 images of 0.5, 1, 2 and 4 secs.



- These 4 images are then concatenated to form a single image used for training.

# Model details

- Number of layers: 5
  - 4 CNN layers and 1 fully connected Softmax layer.
- The output of softmax layer is:

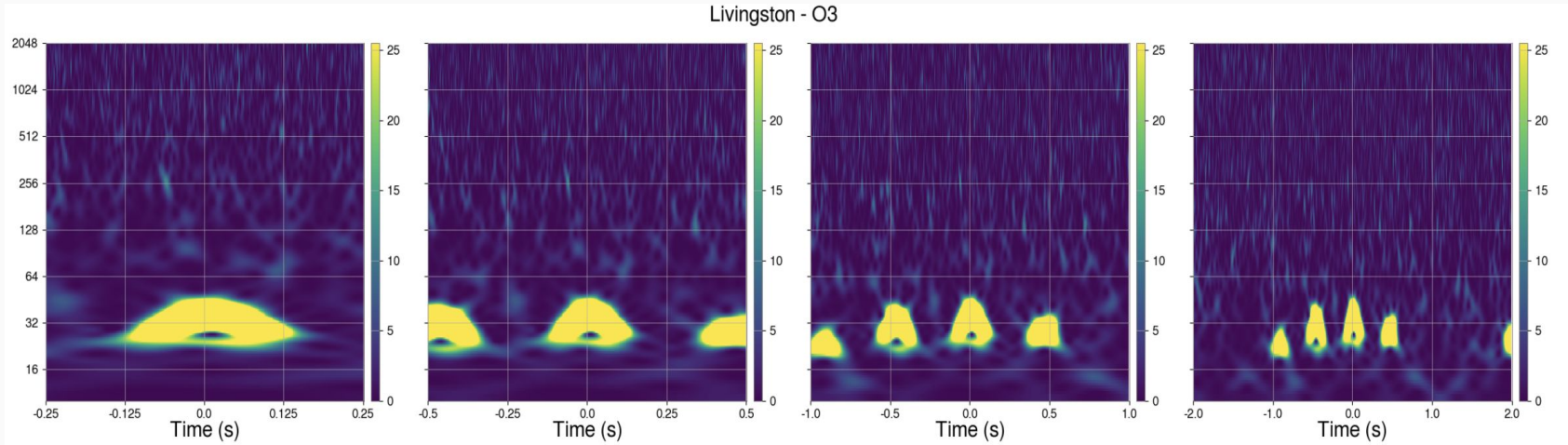
$$o_c^i = \frac{e^{w_c^T x}}{\sum_{c=1}^C e^{w_c^T x}} \quad \text{for } i\text{th image, } c = 1 \text{ to } C, \text{ the number of classes}$$

- Loss function : Cross entropy

$$-\sum_{i=1}^N \sum_{c=1}^C y_c^i \log o_c^i \quad y^i \text{ denotes the binary label for sample } i.$$

- More details in this [paper](#)

# Fast scattering

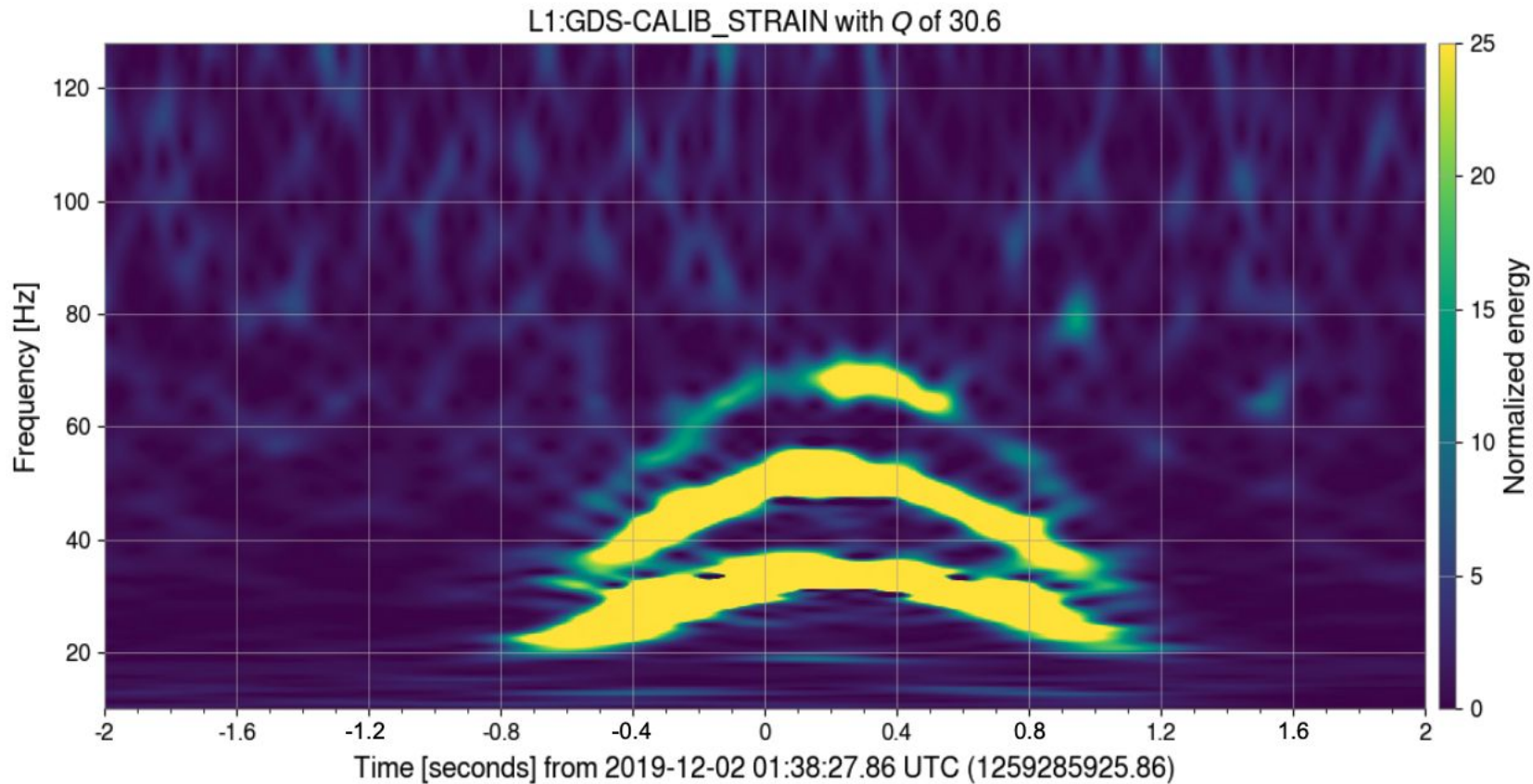


Short duration fast scattering arches

These triggers are currently classified as `Scattered_Light` or `Slow scattering` which is another population of scattering noise

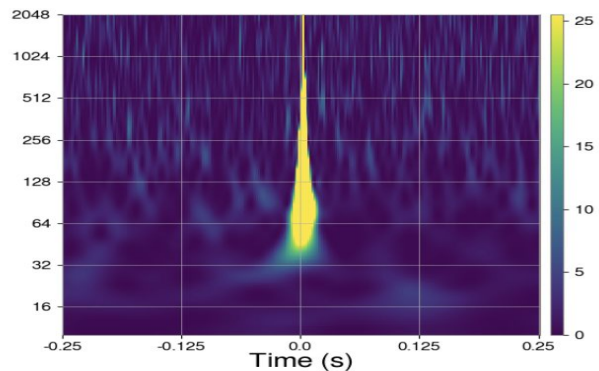
Next slide shows an example of `Slow scattering`

# Slow scattering



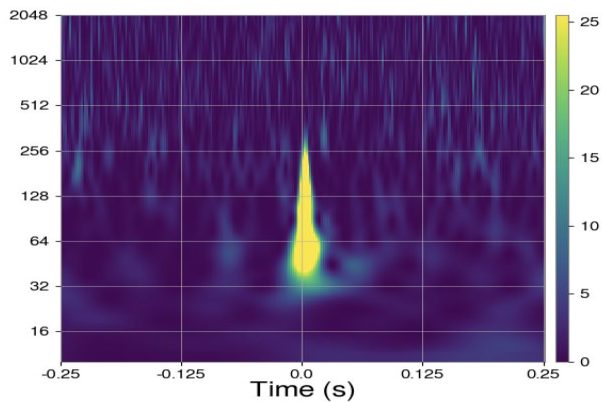


# Blips and Low frequency blips

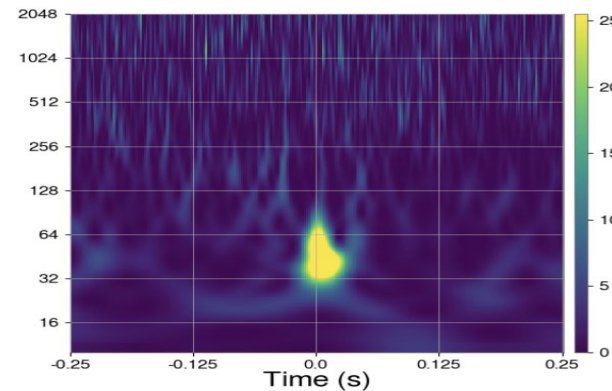
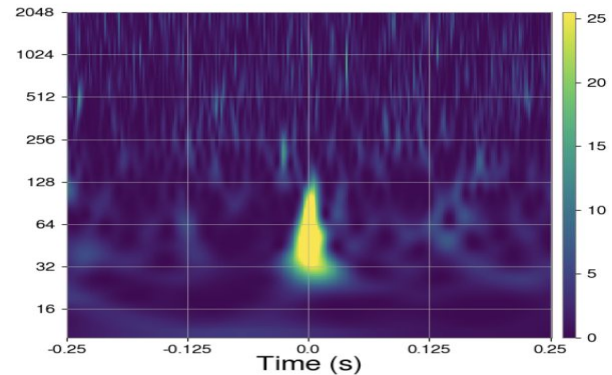


All four triggers assigned as Blips with confidence above 0.95 by the current GravitySpy model

They may have different origins due to different bandwidth



Blips



Low frequency blips

# Training

- All training images taken from O3 classification are with confidence above 0.95
- For fast scattering, 400 triggers currently classified as scattering with Q-value between 8 and 14
- For low frequency blips, 630 Blips with peak frequency between 10 and 50 Hz
- 150 slow scattering (Scattered\_Light) images
- 300 Tomte
- Removed None\_of\_the\_Above
- Valid acc: 0.988, Training acc: 0.999

- Total 23 classes
- Addition of two new classes
  - Fast scattering
  - Low frequency blips
- Removed None of the above glitch category

```
df_fastblip2['Label'].value_counts()
```

```
Blip                1821
Koi_Fish            706
Tomte               703
Blip_Low_Frequency  630
Low_Frequency_Burst 621
Scattered_Light    593
Light_Modulation   512
Power_Line         449
Low_Frequency_Lines 447
Extremely_Loud     447
Violin_Mode        412
Fast_Scattering    400
Scratchy           337
1080Lines          327
Whistle            299
Helix              279
Repeating_Blips    263
No_Glitch          117
1400Ripples        81
Chirp              60
Air_Compressor     58
Wandering_Line     42
Paired_Doves       27
Name: Label, dtype: int64
```

# Testing the model

- Is the model recognizing fast scattering?
- Is the model recognizing low frequency blips?
- Does it affect other glitch categories?

# Testing on Fast scattering and Low frequency Blips

- Randomly sample 100 triggers currently classified as **Scattering** at L1 by GravitySpy between June, 1, 2019 and June, 30, 2019, with q between 8 and 14
- The new model classified all of them as **Fast Scattering**
- Random visual inspection of the omega scans of these 100 triggers to confirm correct classification
- These scans are stored [here](#)
- Randomly sampled 79 triggers currently classified as **Blip** at L1 by GravitySpy between Feb, 1, 2020 and Mar, 1, 2020 with peak frequency between 10 and 50 Hz
- The new model classified 78 of these as **Blip\_Low\_Frequency** and 1 as **Tomte**
- Visually inspected the scans
- These scans are stored [here](#)

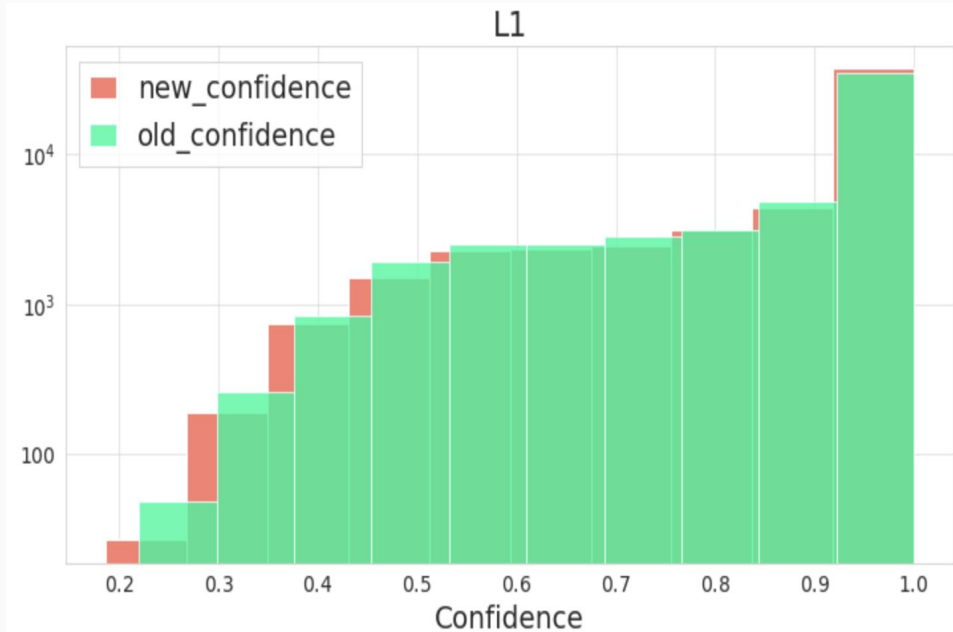
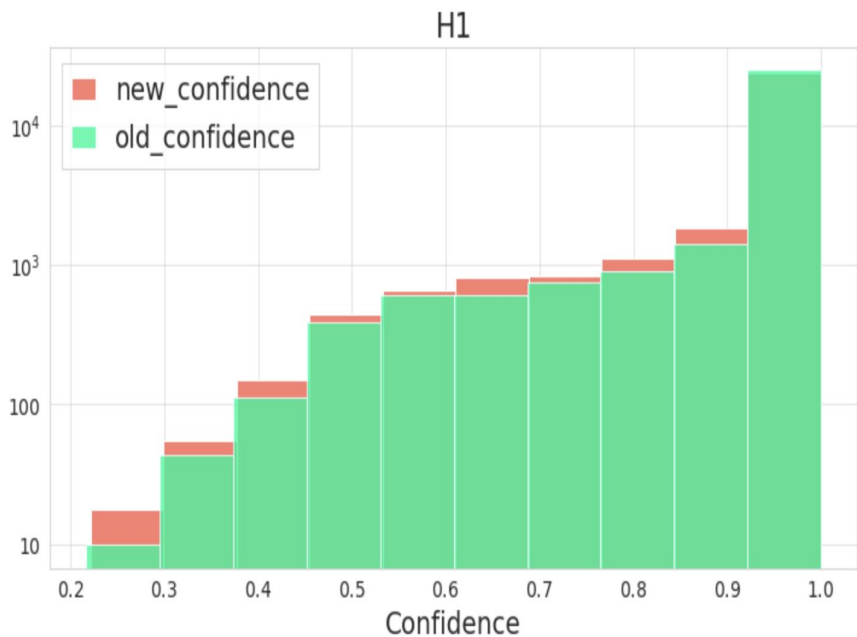
**Fast\_Scattering**

**Blip\_Low\_Frequency**

## Testing on O3 sample

- Relabelled 20% of the O3 gravity spy triggers at L1 and H1 with the new model
- Some of the questions we can ask are:
  - Is there a big change in confidence assigned to the triggers by the new model?
  - What percentage of triggers are labelled with a different classification?
  - For triggers assigned a different class, what is the distribution of new labels?
  - What glitch classes were assigned to these new labels by the original model?
  - Does the change make sense?

# Confidence comparison

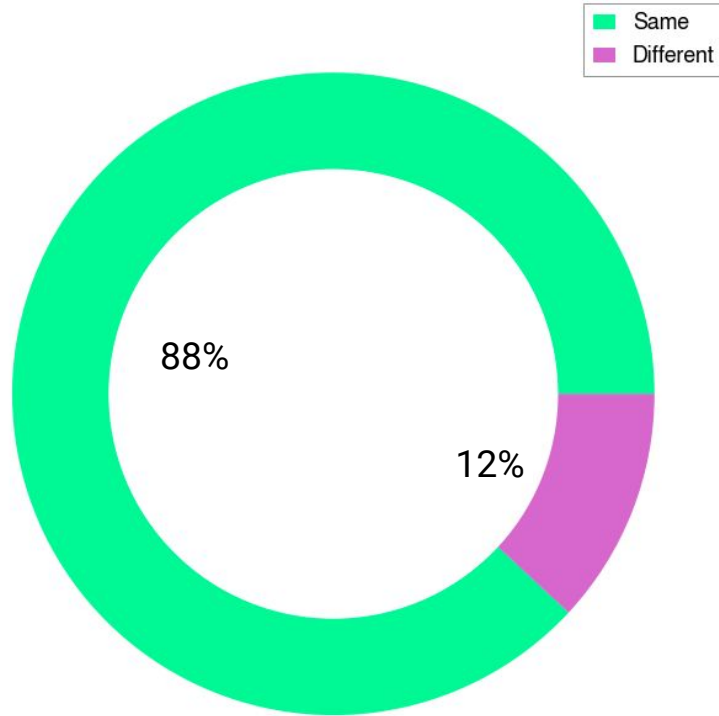


Change in confidence assigned to the glitches is minimal

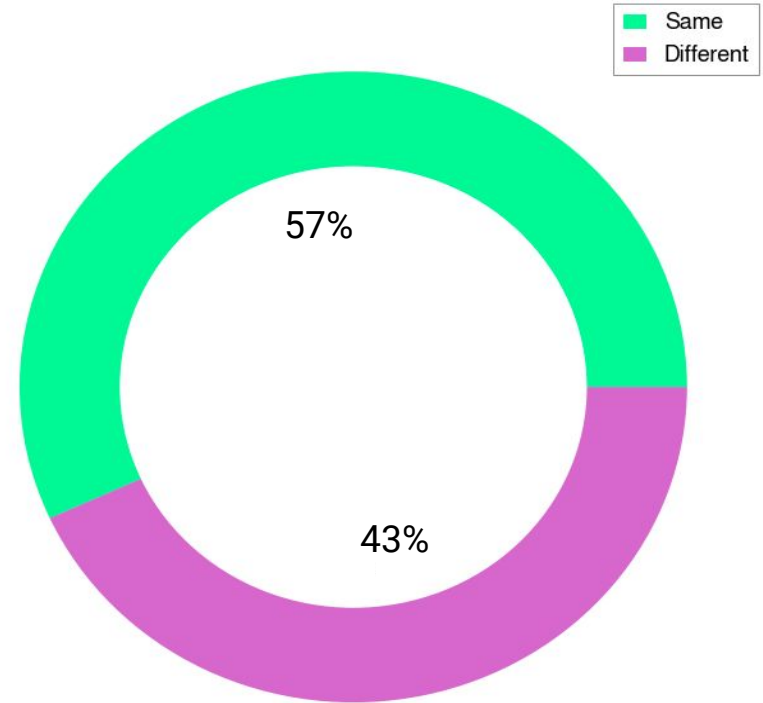


# Change in class labels

O3 classification by the new model wrt old model at H1

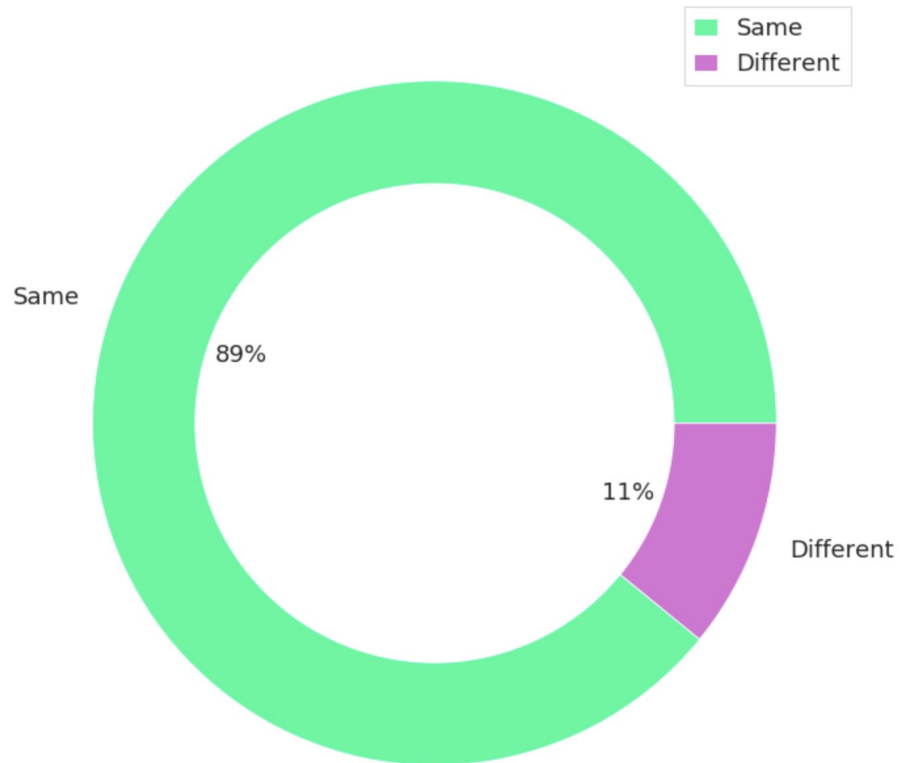


O3 classification by the new model wrt old model at L1

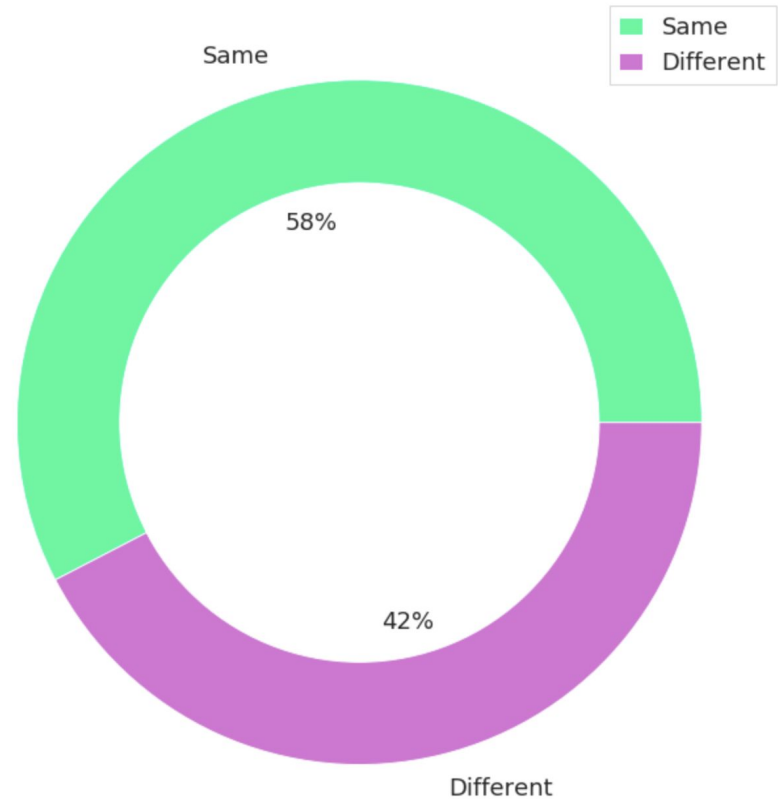


# Change in class labels

O3 classification by the new model wrt old model at H1

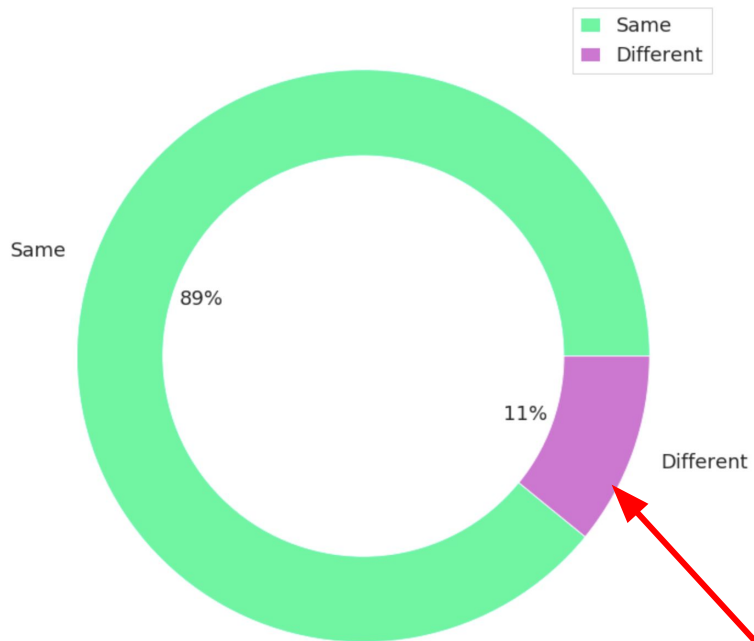


O3 classification by the new model wrt old model at L1

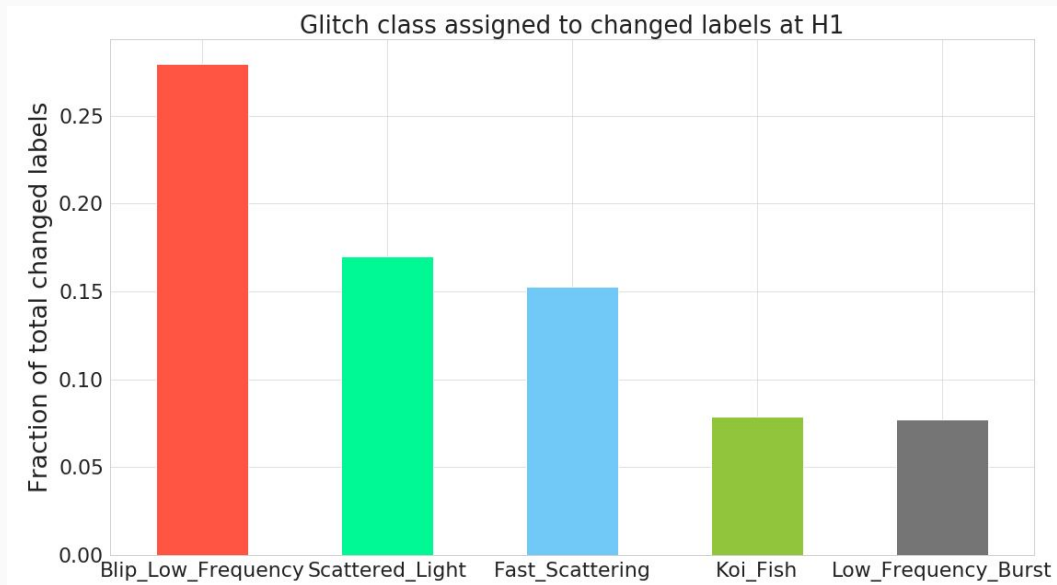


# Distribution of new labels at H1

O3 classification by the new model wrt old model at H1



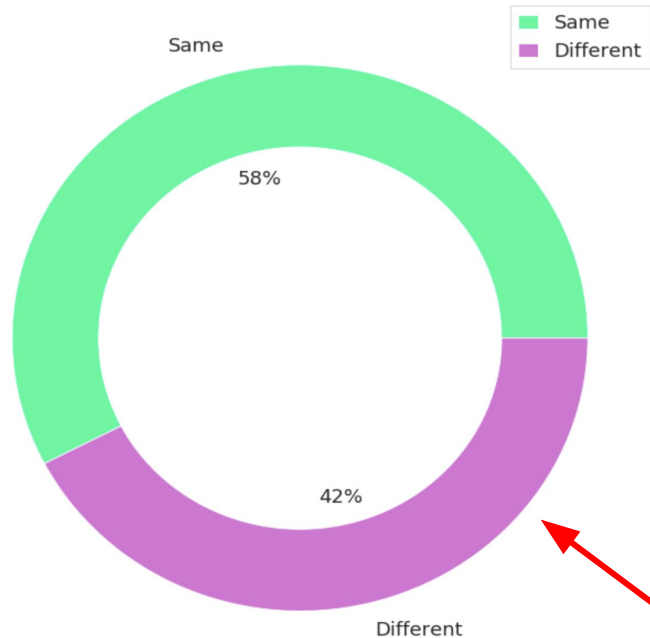
Glitch class assigned to changed labels at H1



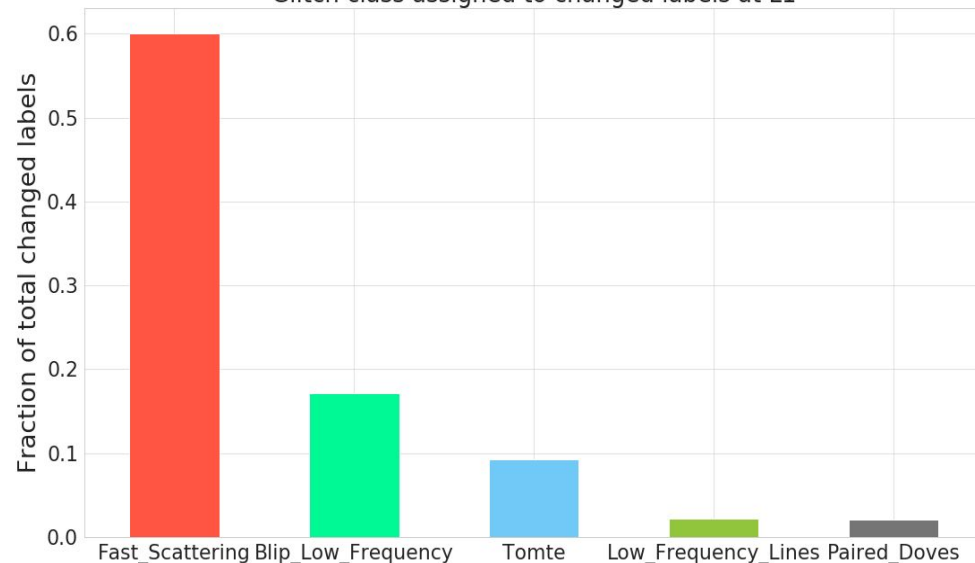
Glitch class assigned to these triggers

# Distribution of new labels at L1

O3 classification by the new model wrt old model at L1



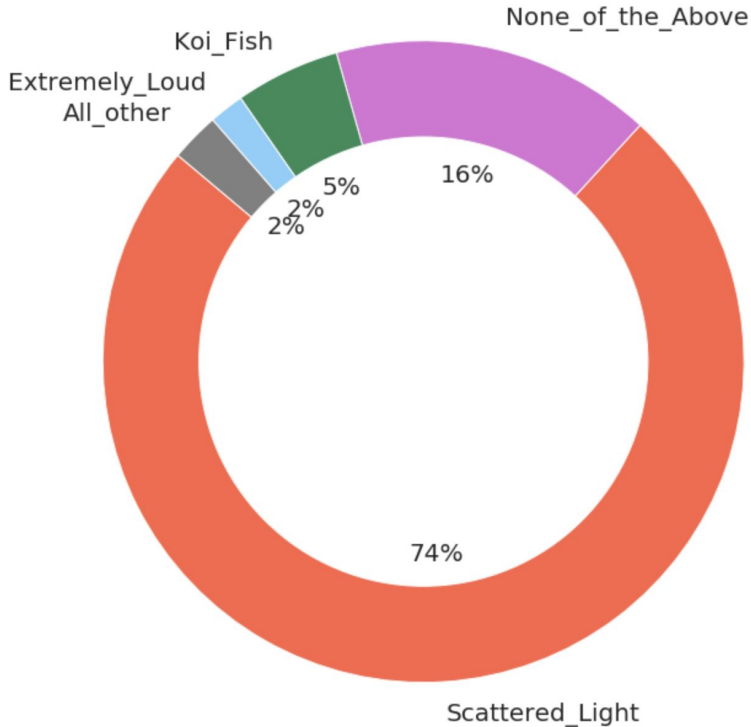
Glitch class assigned to changed labels at L1



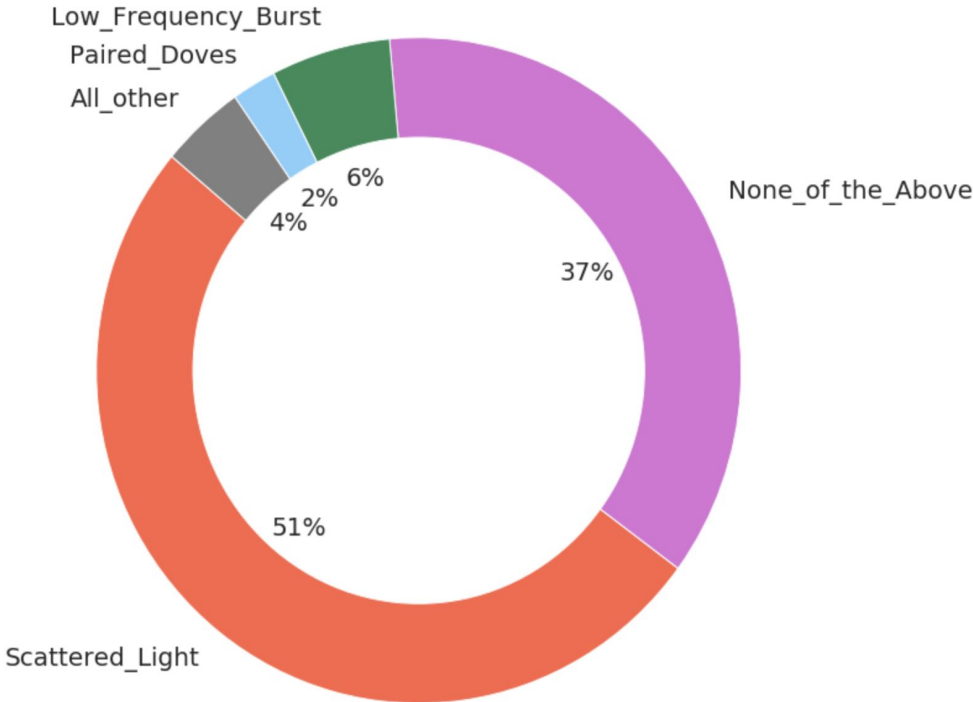
Glitch class assigned to these triggers

# Previous classification of Fast scattering

## H1

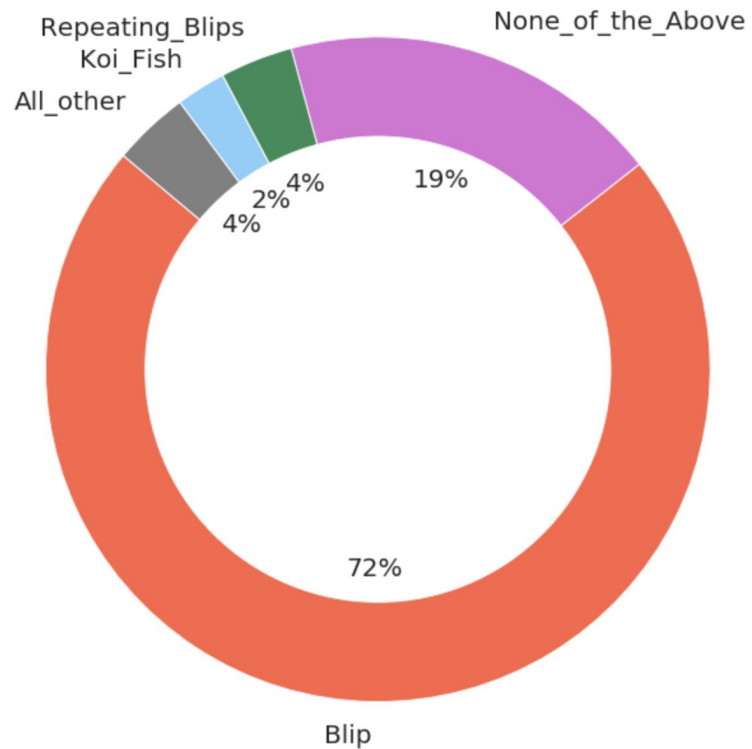


## L1

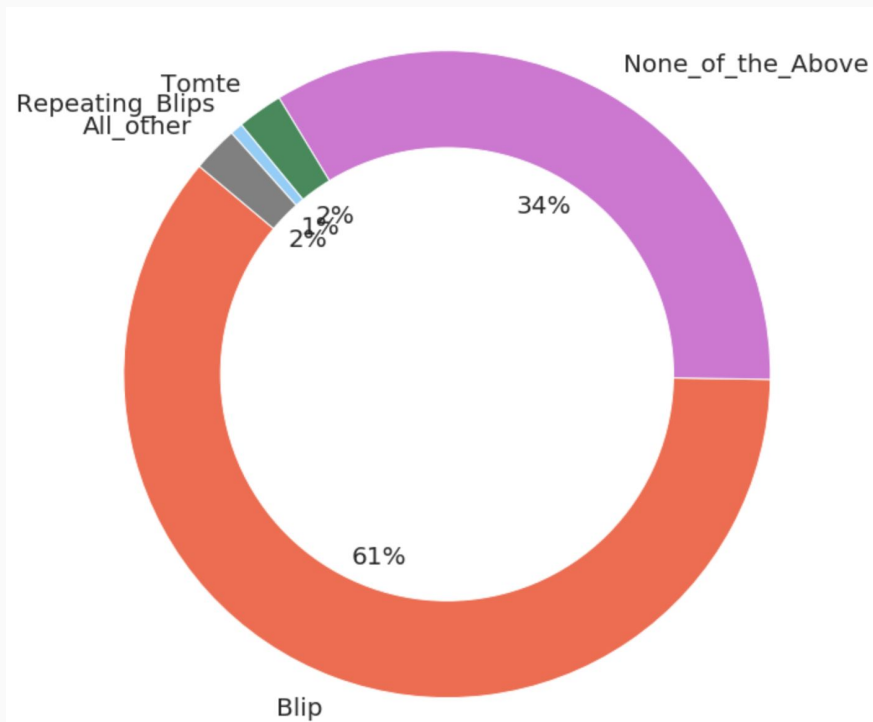


# Previous classification of low frequency blips

## H1



## L1



- New model to identify
  - Fast scattering
  - Low frequency blips
- It should not affect other classes

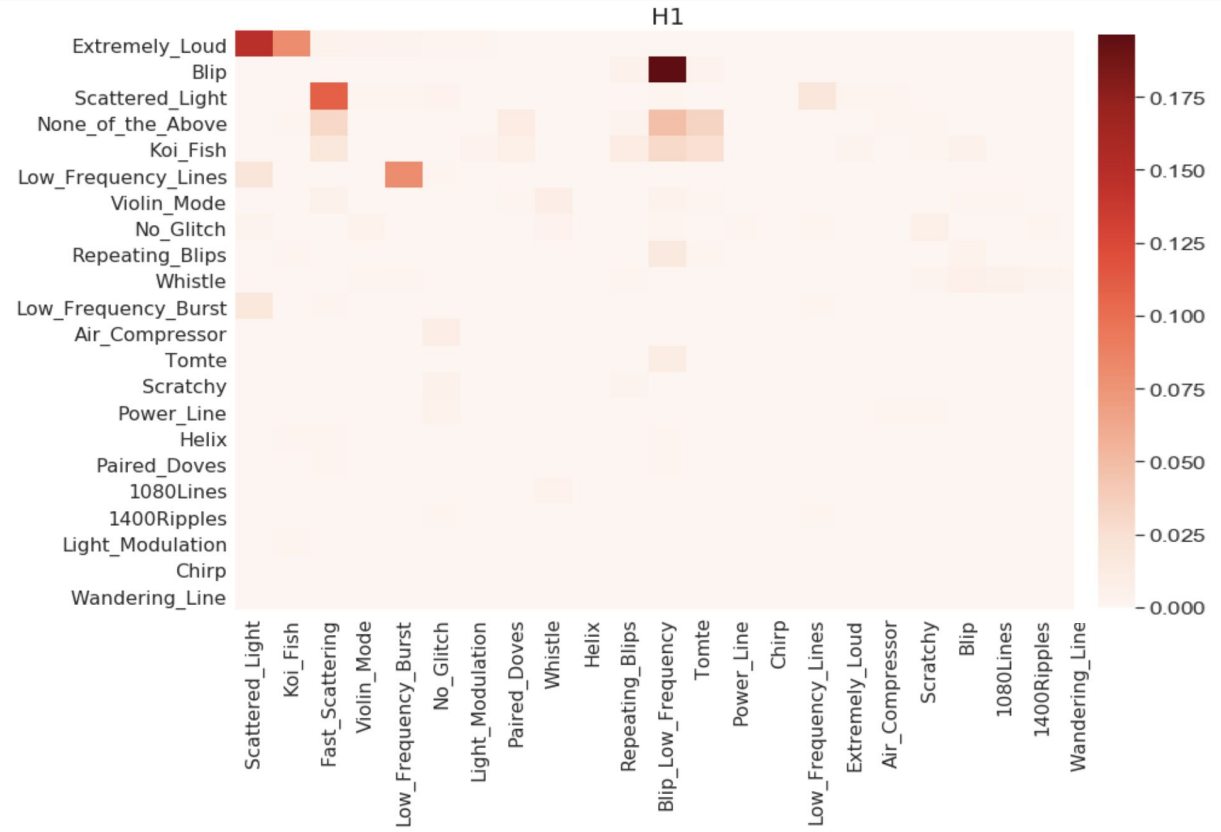
## Heatmap on next two slides

- We consider those glitches that are assigned a different glitch class by the new model
- For each old label we look at the distribution of new labels assigned

# H1 old to new

- A fraction of Extremely\_Loud triggers classified as scattering.
- [Omega scans](#) show those triggers are indeed scattered light noise.

Old classification

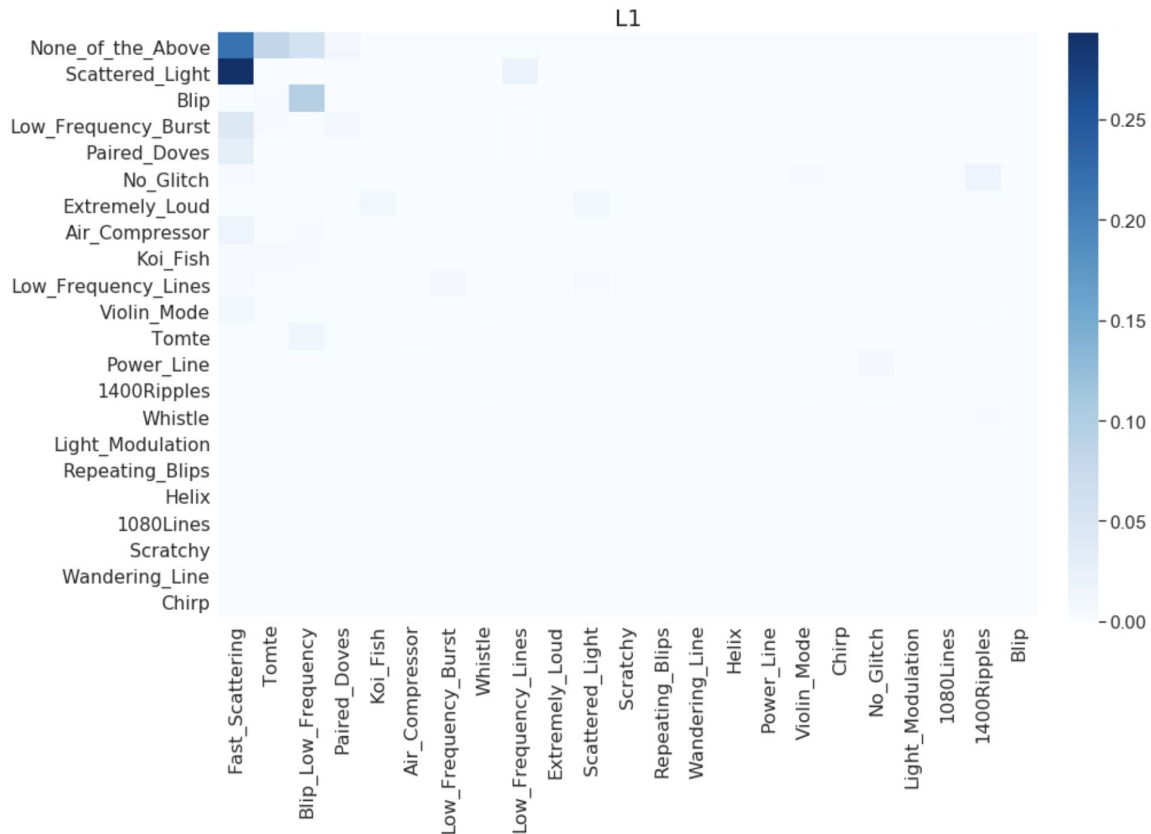


New classification



- The H1 and L1 heatmap shows that the new model does not meddle with the old glitch classes.
- Correctly recognizes **Scattered\_light** at H1 misclassified as **Extremely\_Loud** by the older model

## Old classification

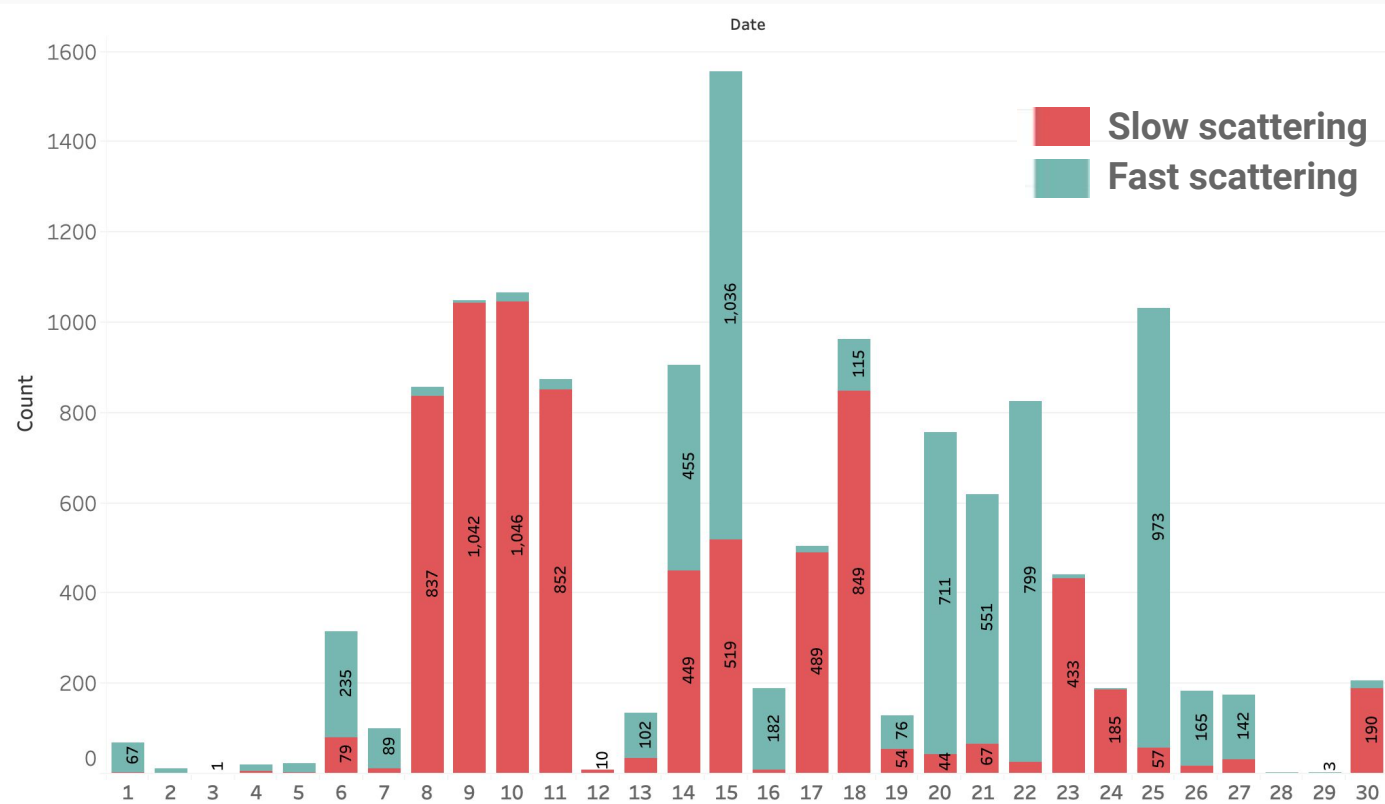


## New classification

## Next steps

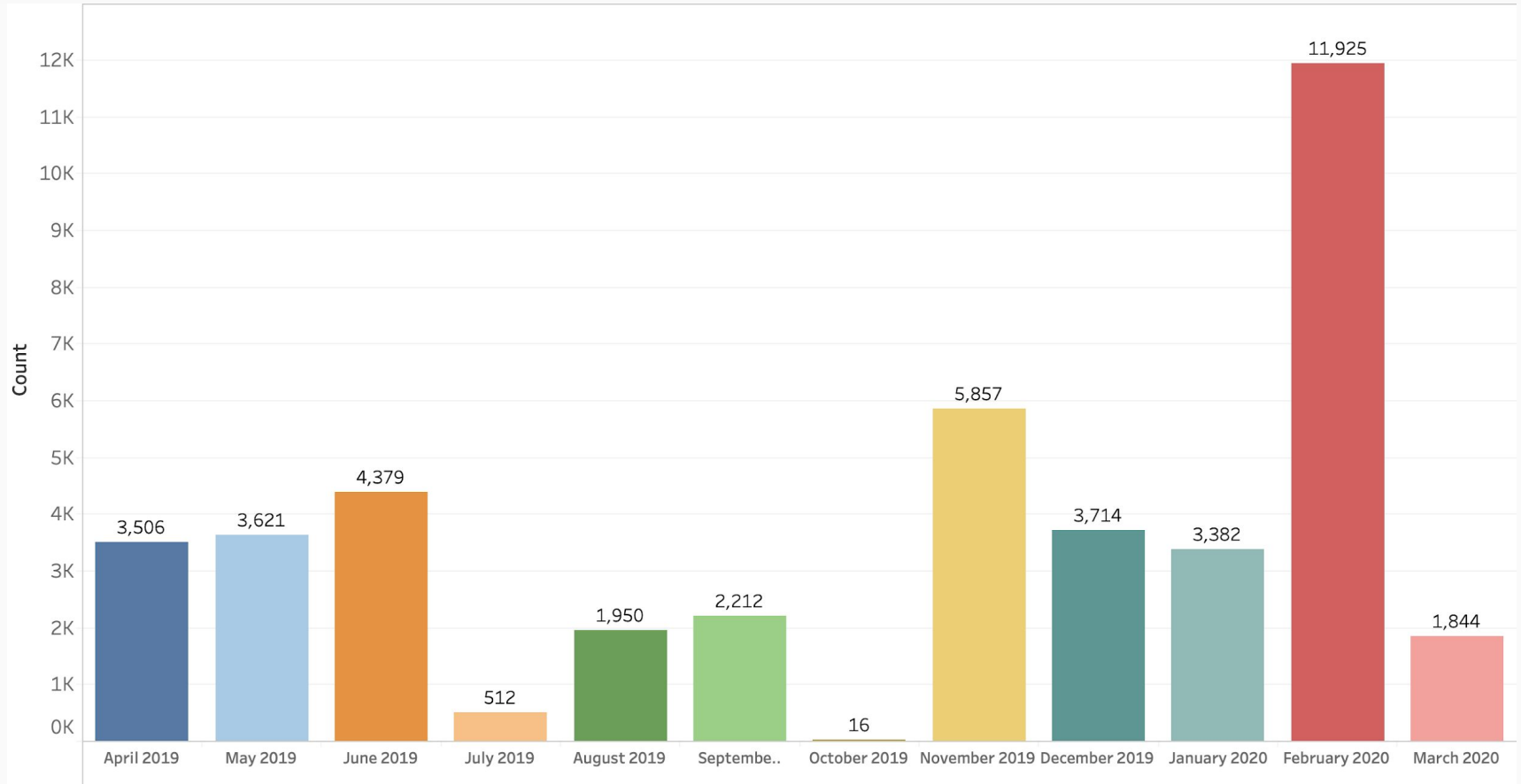
1. Update the model on [Ligo-dv-web](#) (ldvw) and on the GravitySpy SQL Table (Done)
2. Update the model and the data on the GravitySpy [repository](#) (Done)
3. Separate training set for L1 and H1?

# Slow and Fast scattering



Slow and fast scattering in Nov 2019

# Fast scattering in O3 at L1



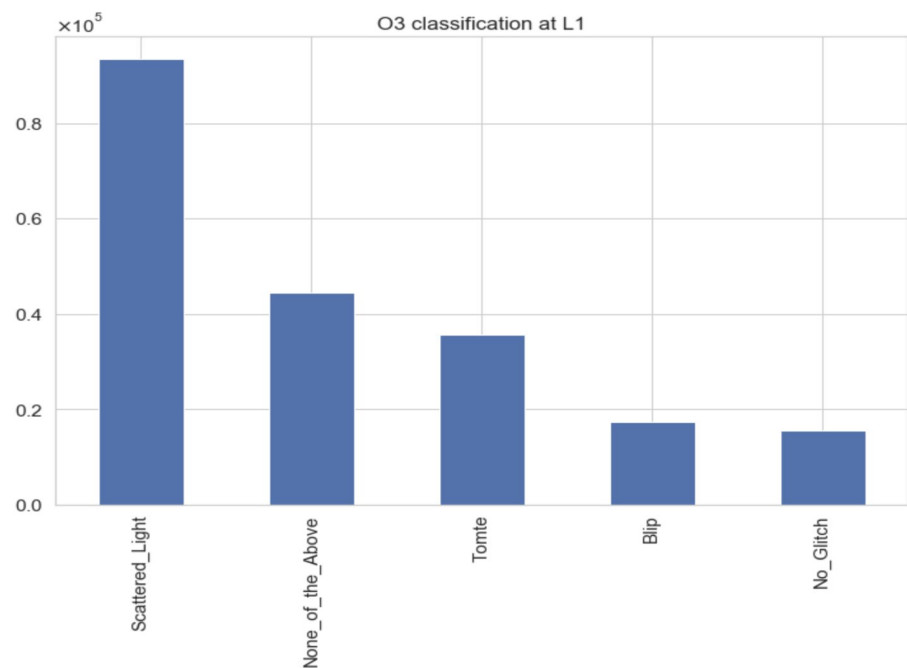
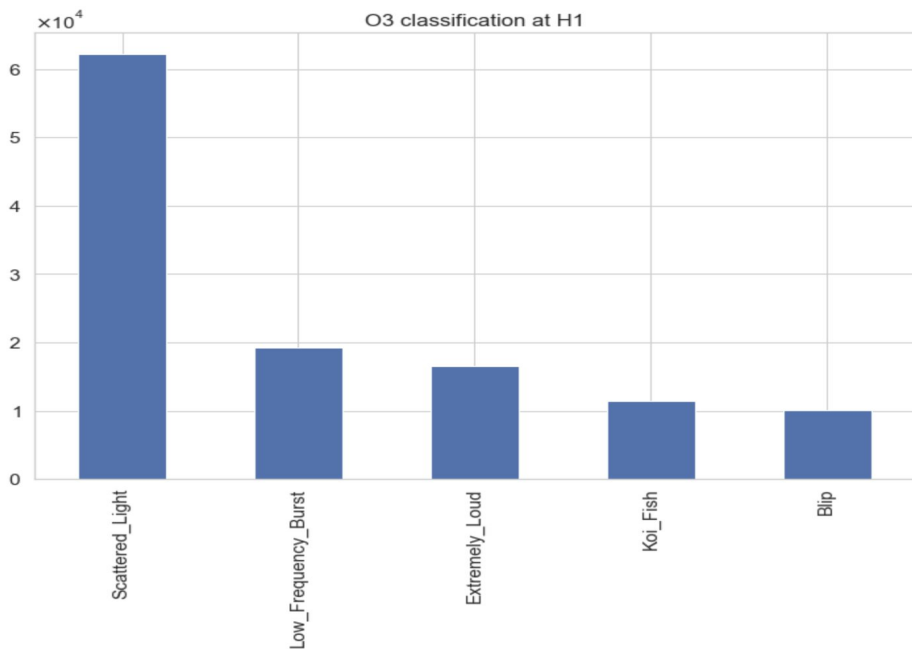
Thank you  
Questions and comments

# Extra slides

# L1 heatmap

	Fast_Scattering	Tomte	Blip_Low_Frequency	Air_Compressor	Paired_Doves	Koi_Fish	Whistle	Extremely_Loud	Light_Modulation	Scratchy	...	Scattered_Light	Low_Frequency_Lines	Low_Frequency_...
None_of_the_Above	0.216472	0.088272	0.041611	0.001165	0.000863	0.000820	0.000345	0.000129	0.000129	0.000129	...	0.000043	0.000000	0.000000
Scattered_Light	0.293262	0.000086	0.000734	0.001986	0.000043	0.000043	0.000000	0.000086	0.000173	0.000129	...	0.000000	0.012604	0.000000
Blip	0.000000	0.009151	0.078172	0.000000	0.000000	0.000086	0.000000	0.000000	0.000000	0.000000	...	0.000000	0.000000	0.000000
Low_Frequency_Burst	0.048863	0.001381	0.000043	0.000000	0.000561	0.000000	0.000000	0.000000	0.000043	0.000000	...	0.000647	0.000820	0.000000
No_Glitch	0.002849	0.000173	0.003712	0.001511	0.000043	0.000000	0.002417	0.000086	0.000000	0.004575	...	0.000475	0.001986	0.000000
Paired_Doves	0.036172	0.000691	0.000432	0.000388	0.000000	0.000043	0.000000	0.000000	0.000000	0.000000	...	0.000000	0.000388	0.000000
Koi_Fish	0.002158	0.007899	0.004014	0.000000	0.000259	0.000000	0.000173	0.000604	0.000647	0.000000	...	0.000129	0.000000	0.000000
Low_Frequency_Lines	0.012949	0.000000	0.000043	0.000000	0.000000	0.000000	0.000000	0.000000	0.000432	0.000043	...	0.002633	0.000000	0.000000
Extremely_Loud	0.001122	0.000086	0.000000	0.000000	0.000000	0.007424	0.000820	0.000000	0.000302	0.000259	...	0.007468	0.000086	0.000000
Violin_Mode	0.009971	0.001554	0.000820	0.000000	0.000000	0.000043	0.003151	0.000043	0.000043	0.000000	...	0.000000	0.000173	0.000000
Air_Compressor	0.010662	0.000000	0.002806	0.000000	0.000086	0.000000	0.000000	0.000000	0.000000	0.000000	...	0.000129	0.000000	0.000000
1400Ripples	0.000129	0.000000	0.000043	0.000043	0.000000	0.000000	0.006129	0.000000	0.000043	0.000000	...	0.000129	0.000173	0.000000
1080Lines	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004101	0.000000	0.000000	0.000000	...	0.000000	0.000000	0.000000
Power_Line	0.000000	0.000000	0.000820	0.002029	0.000043	0.000000	0.000000	0.000000	0.000000	0.000691	...	0.000173	0.000086	0.000000
Light_Modulation	0.000302	0.001079	0.000432	0.000000	0.000129	0.000820	0.000000	0.000000	0.000000	0.000000	...	0.000000	0.000086	0.000000
Repeating_Blips	0.000173	0.000173	0.001295	0.000000	0.000000	0.000388	0.000043	0.000000	0.000000	0.000000	...	0.000000	0.000000	0.000000
Whistle	0.000000	0.000000	0.000173	0.000000	0.000000	0.000000	0.000000	0.000000	0.000043	0.000000	...	0.000000	0.000000	0.000000
Helix	0.000518	0.000388	0.000388	0.000000	0.000000	0.000173	0.000000	0.000000	0.000043	0.000000	...	0.000000	0.000000	0.000000
Tomte	0.000000	0.000000	0.001683	0.000000	0.000043	0.000000	0.000000	0.000000	0.000000	0.000000	...	0.000000	0.000000	0.000000
Wandering_Line	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000302	0.000043	0.000000	0.000000	...	0.000000	0.000000	0.000000
Chirp	0.000086	0.000000	0.000173	0.000043	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	...	0.000000	0.000000	0.000000
Scratchy	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	...	0.000000	0.000043	0.000000

# Glitch classification at L1 and H1 during O3

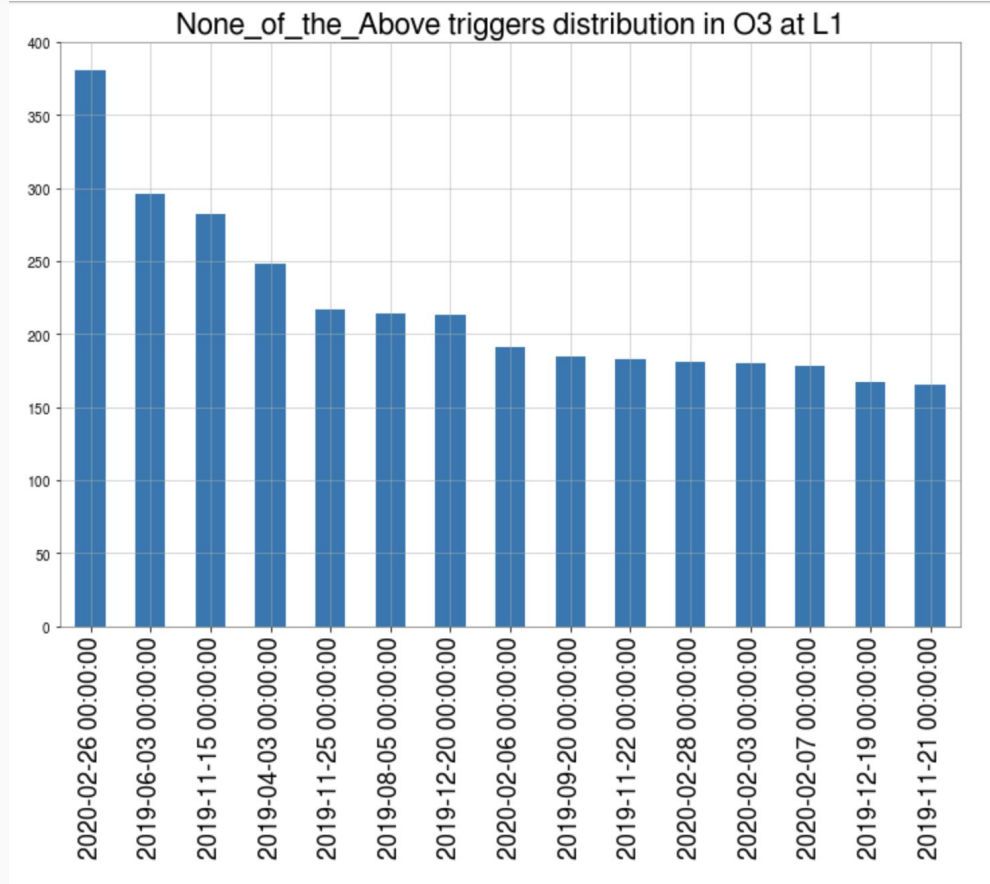


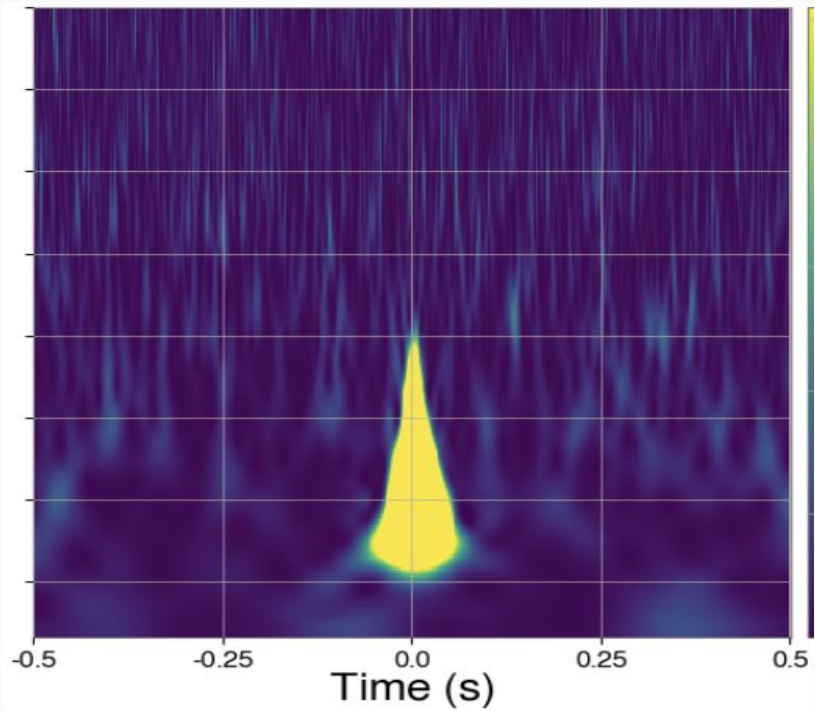
- 20% relabelled sample of L1, around 53k triggers
- 20% relabelled sample of H1, around 29k triggers



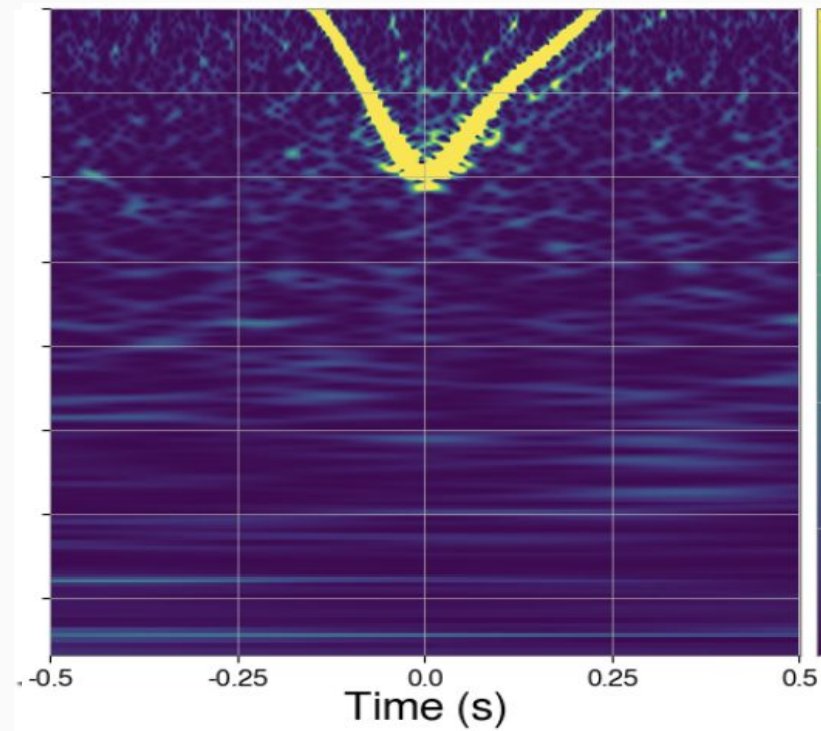
# Fast scattering as none of the above

Days with high number of None\_of\_the\_Above are days with high ground motion at L1





**Tomte**



**Whistle**

```
[11]: Blip 1821
      Koi_Fish 706
      Low_Frequency_Burst 621
      Light_Modulation 512
      Power_Line 449
      Extremely_Loud 447
      Low_Frequency_Lines 447
      Scattered_Light 443
      Violin_Mode 412
      Scratchy 337
      1080Lines 327
      Whistle 299
      Helix 279
      Repeating_Blips 263
      No_Glitch 117
      Tomte 103
      None_of_the_Above 81
      1400Ripples 81
      Chirp 60
      Air_Compressor 58
      Wandering_Line 42
      Paired_Doves 27
      Name: true_label, dtype: int64
```

Old training set

```
df_fastblip2['Label'].value_counts()
```

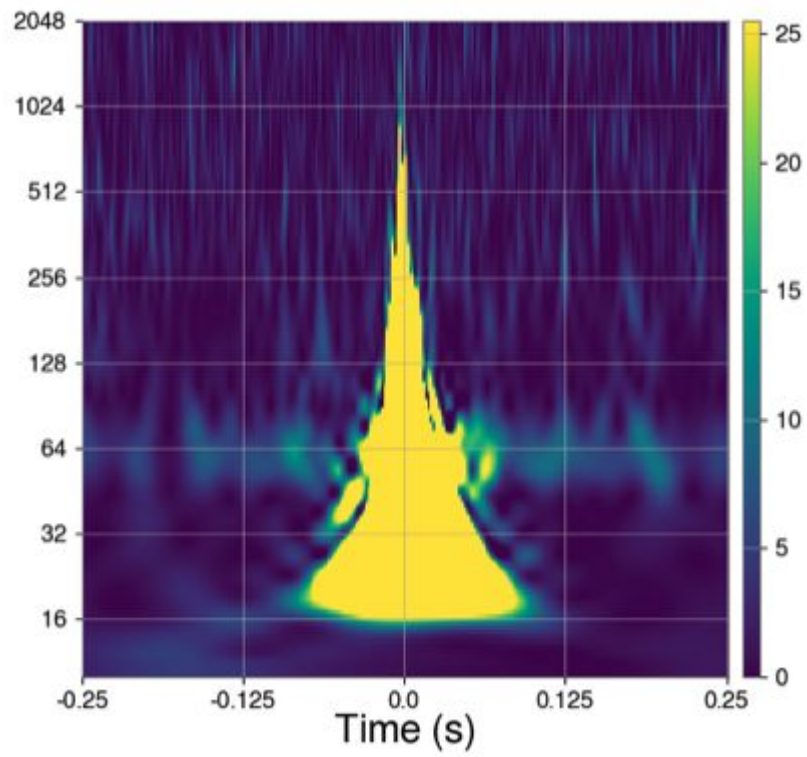
```
Blip 1821
Koi_Fish 706
Tomte 703
Blip_Low_Frequency 630
Low_Frequency_Burst 621
Scattered_Light 593
Light_Modulation 512
Power_Line 449
Low_Frequency_Lines 447
Extremely_Loud 447
Violin_Mode 412
Fast_Scattering 400
Scratchy 337
1080Lines 327
Whistle 299
Helix 279
Repeating_Blips 263
No_Glitch 117
1400Ripples 81
Chirp 60
Air_Compressor 58
Wandering_Line 42
Paired_Doves 27
Name: Label, dtype: int64
```

New training set

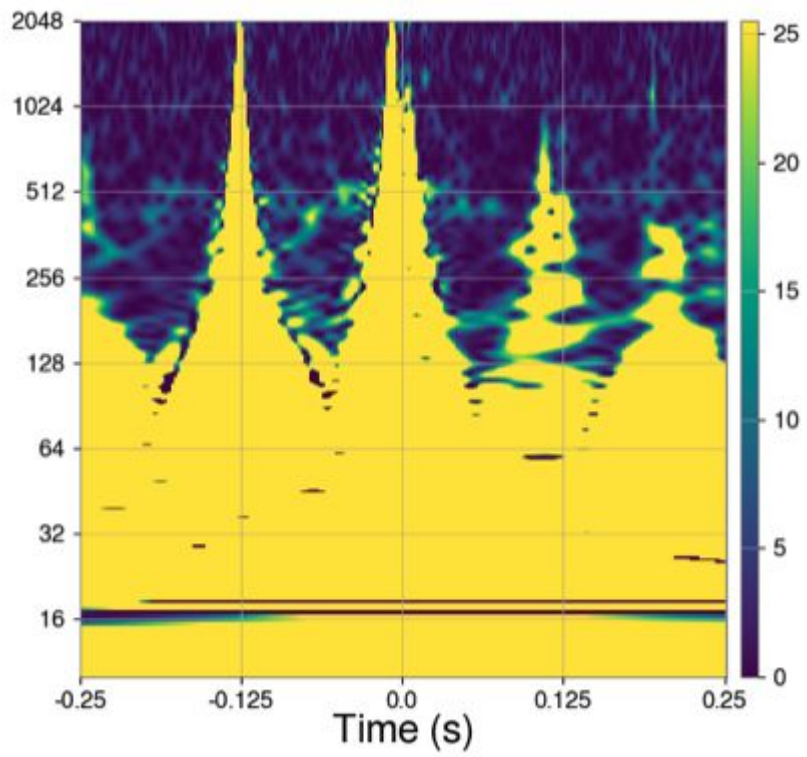
1. Blip
2. Koi\_Fish
3. Tomte
4. Low\_Frequency\_Burst
5. Low\_Frequency\_Lines
6. Light\_Modulation
7. Power\_Line
8. Extremely\_Loud
9. Violin\_Mode
10. Scattered\_Light
11. Scratchy
12. 1080Lines
13. Whistle
14. Helix
15. Paired\_Doves
16. Repeating\_Blips
17. No\_Glitch
18. None\_of\_the\_Above
19. 1400Ripples
20. Chirp
21. Air\_compressor
22. Wandering\_Lines

**Glitch classes identified by the older model**

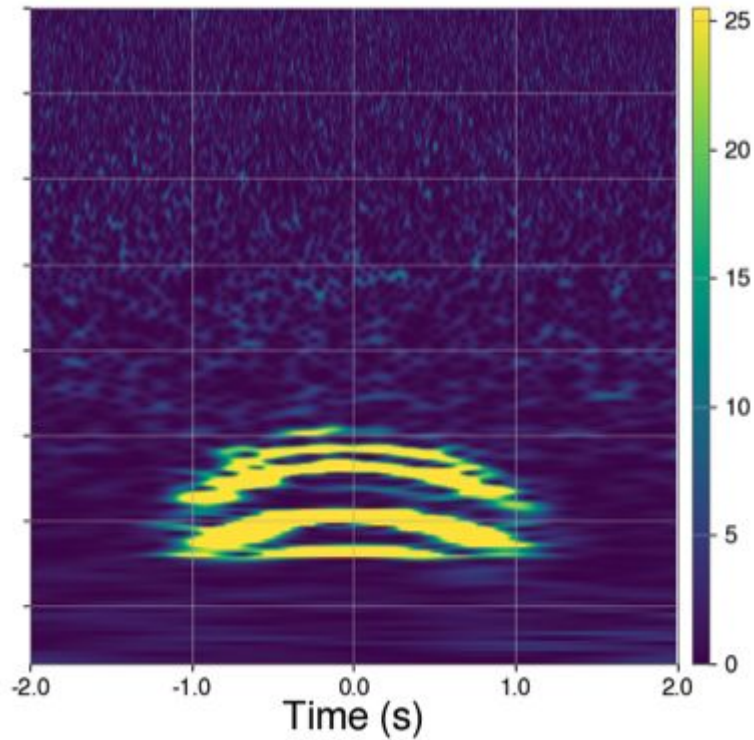
- Is the model recognizing Fast Scattering?
- Is the model recognizing Low frequency Blips?
- Compared to the older model what percentage of triggers are labelled with a different classification?
- For glitches assigned a different class, what is the distribution of new labels?
- What glitch classes were assigned to these new labels by the original model?
- Does the change make sense?



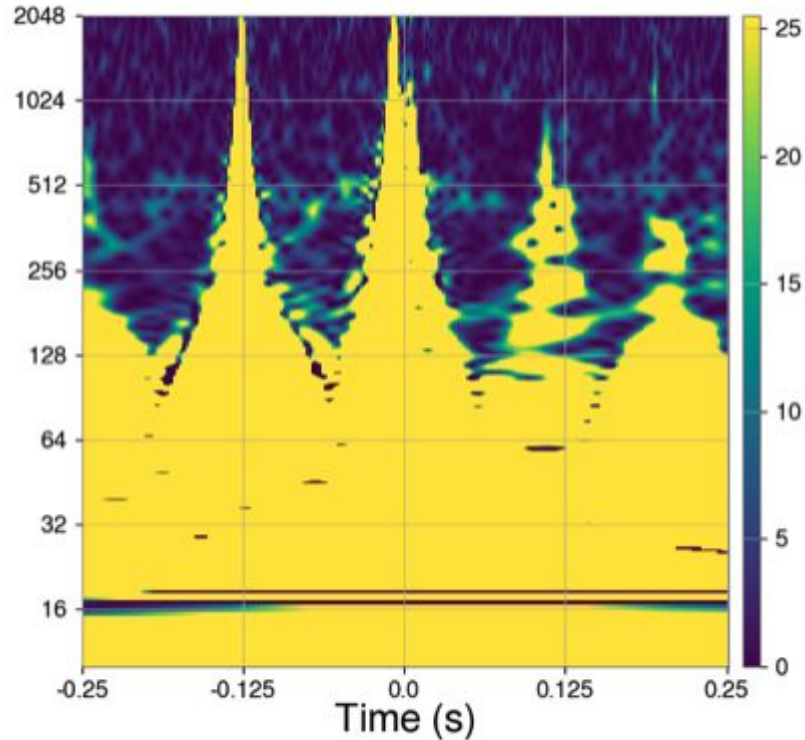
**Koi\_Fish**



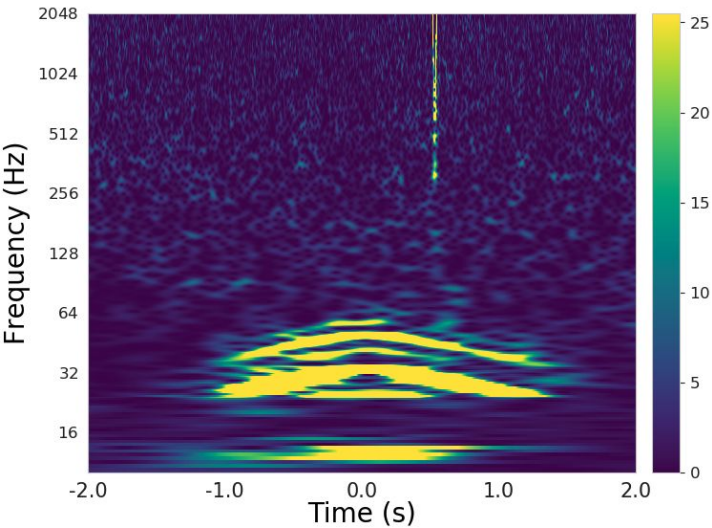
**Extremely\_Loud**



Scattered\_Light



Extremely\_Loud



**Scattered\_Light  
triggers wrongly  
classified as  
Extremely\_Loud  
by  
the older model**

