Training a new model for GravitySpy

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CIERA 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

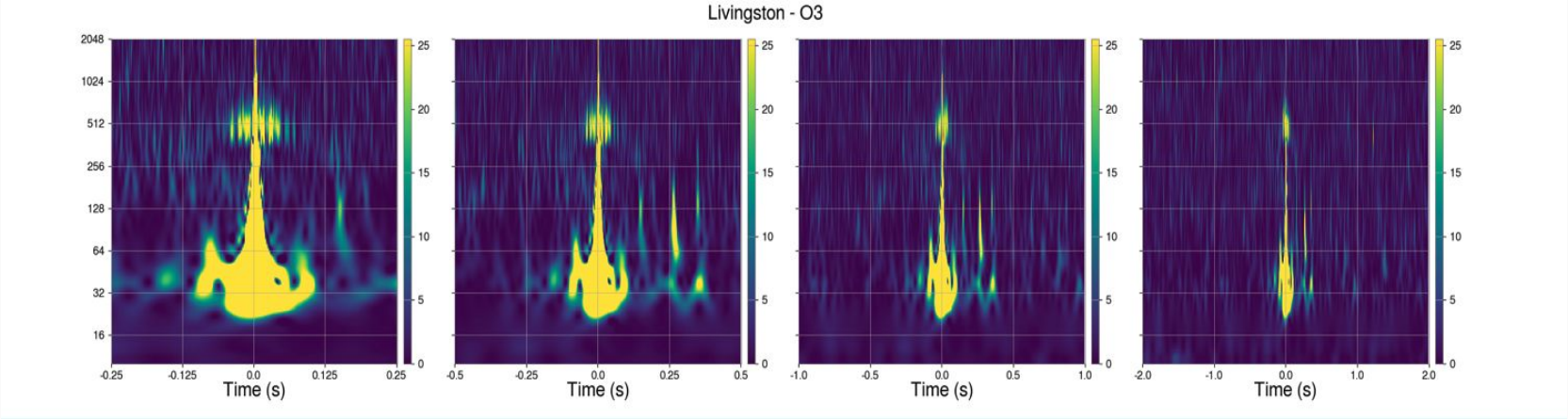
1. Introduction to GravitySpy
2. Introduction to Fast scattering and Low frequency blips
3. Training the model
4. Old and new model output comparison

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:

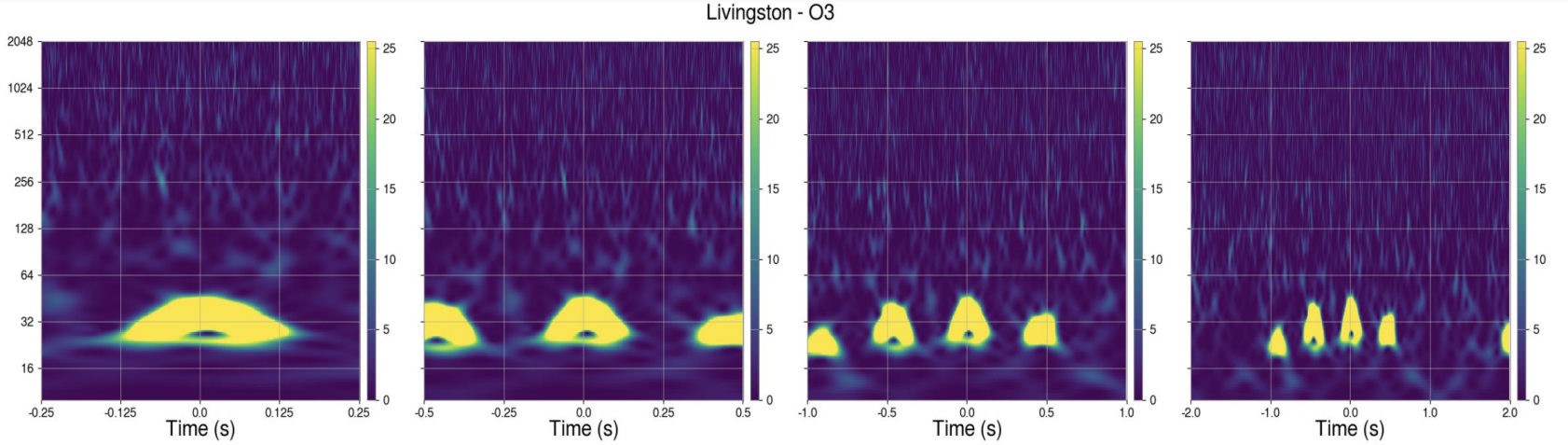
$$o_c^i = \frac{e^{w_c^T x}}{\sum_{c=1}^{C} e^{w_c^T x}}$$ for ith image, c = 1 to C, the number of classes

- Loss function : Cross entropy

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

- More details in this paper

Fast scattering

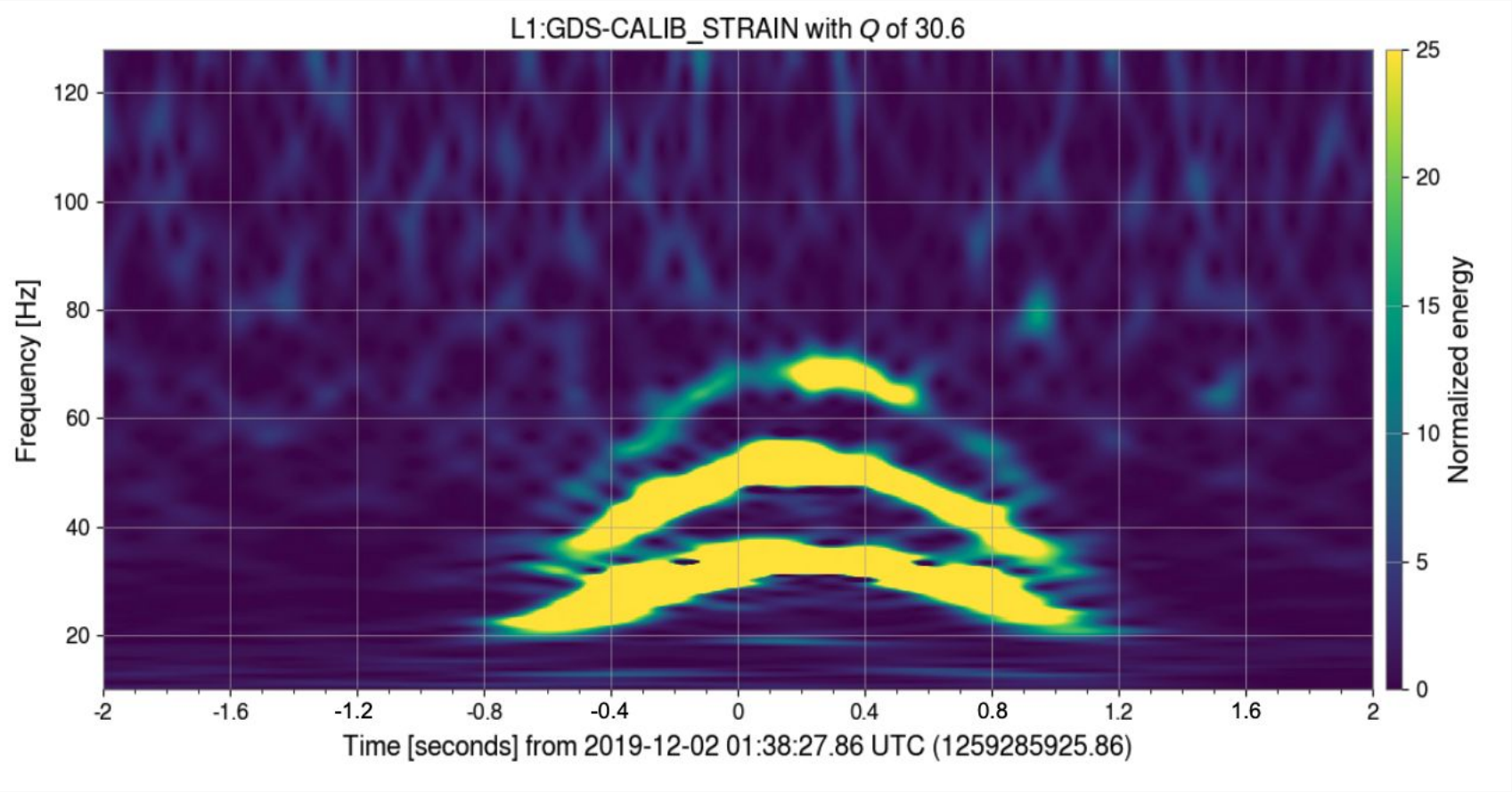


Short duration fast scattering arches

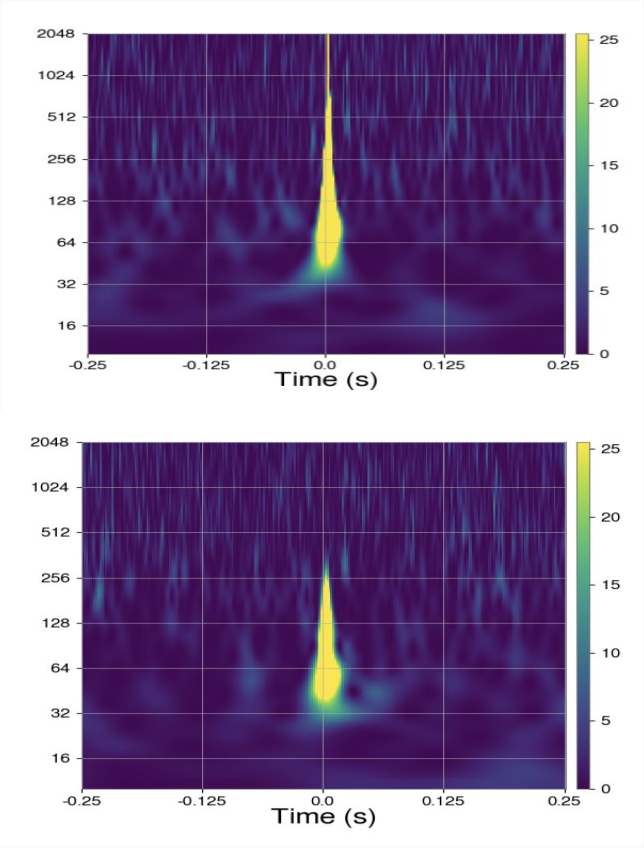
These triggers are currently classified as Scattered_Light or Slow scattering which is another population of scattering noise

Next slide shows an example of Slow scattering

Slow scattering



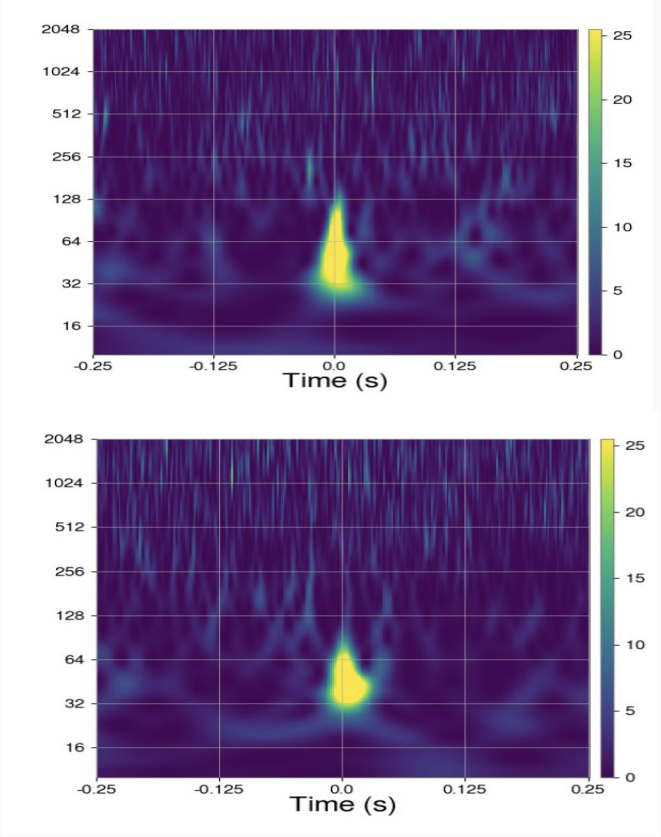
Blips and Low frequency blips



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



Low frequency blips

Training

Training set

- 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

Training set

- 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
```

Training set

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

Fast_Scattering

- 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

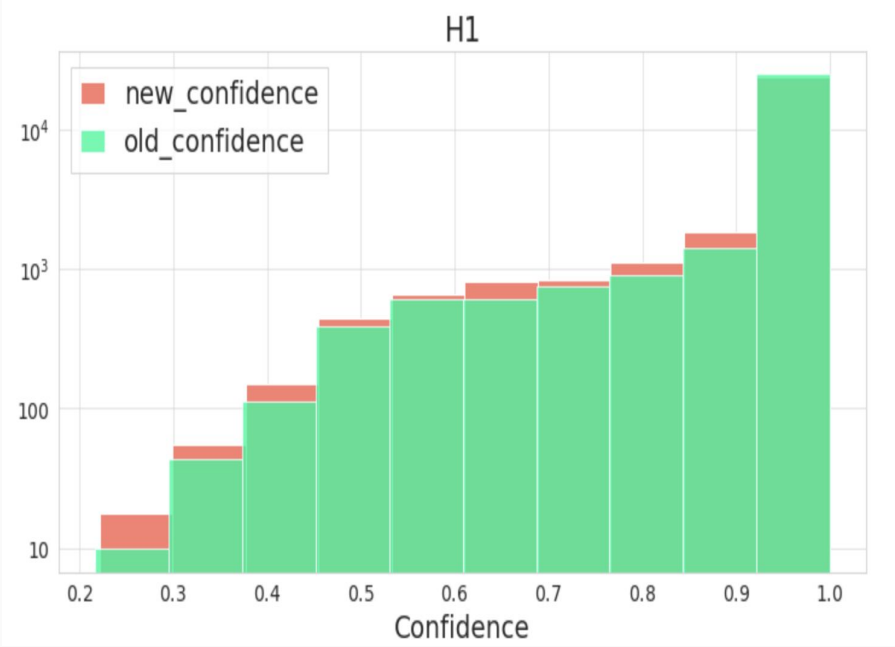
Blip_Low_Frequency

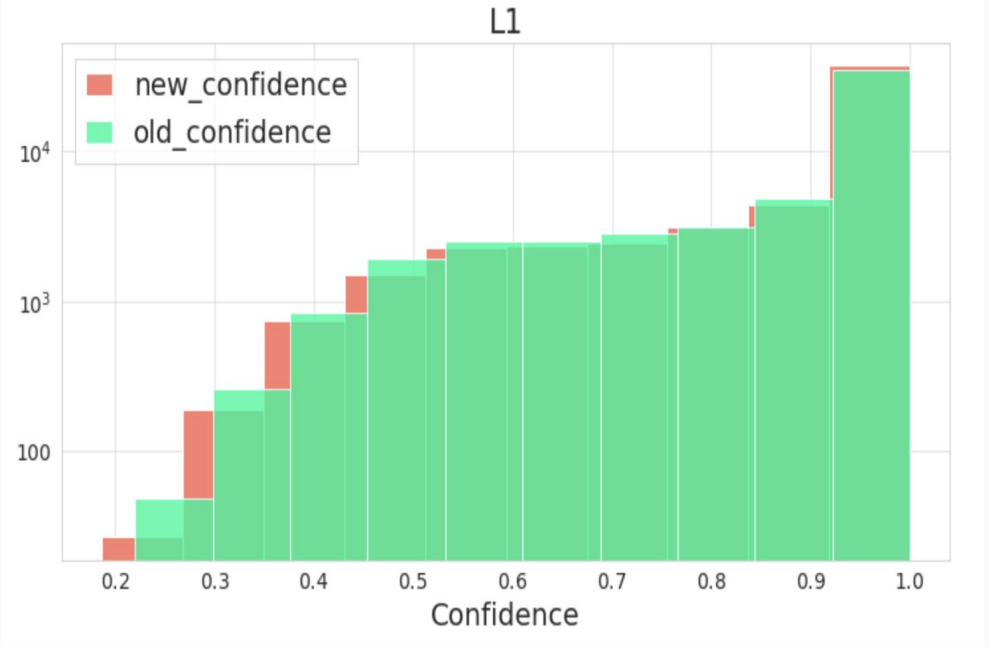
Testing on O3 sample

- 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?

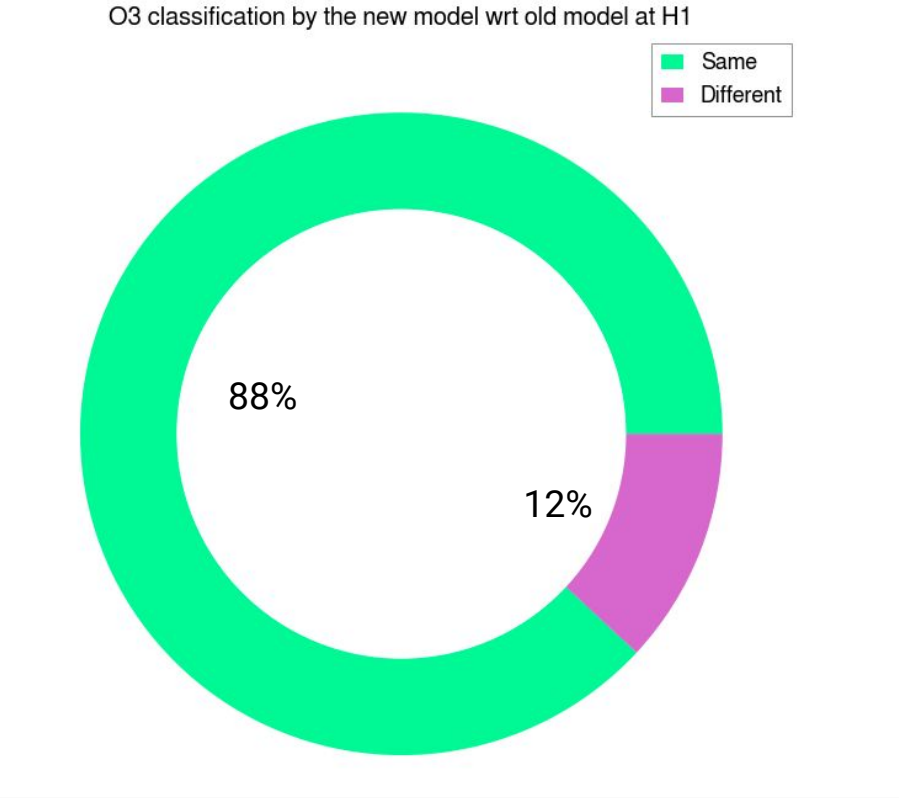
Confidence comparison

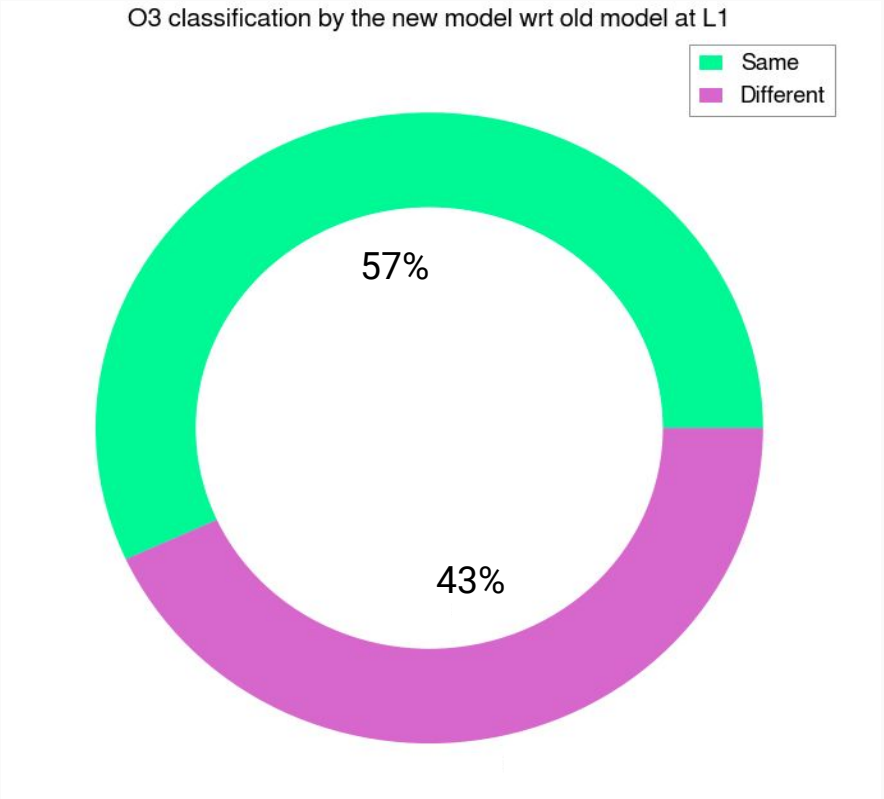




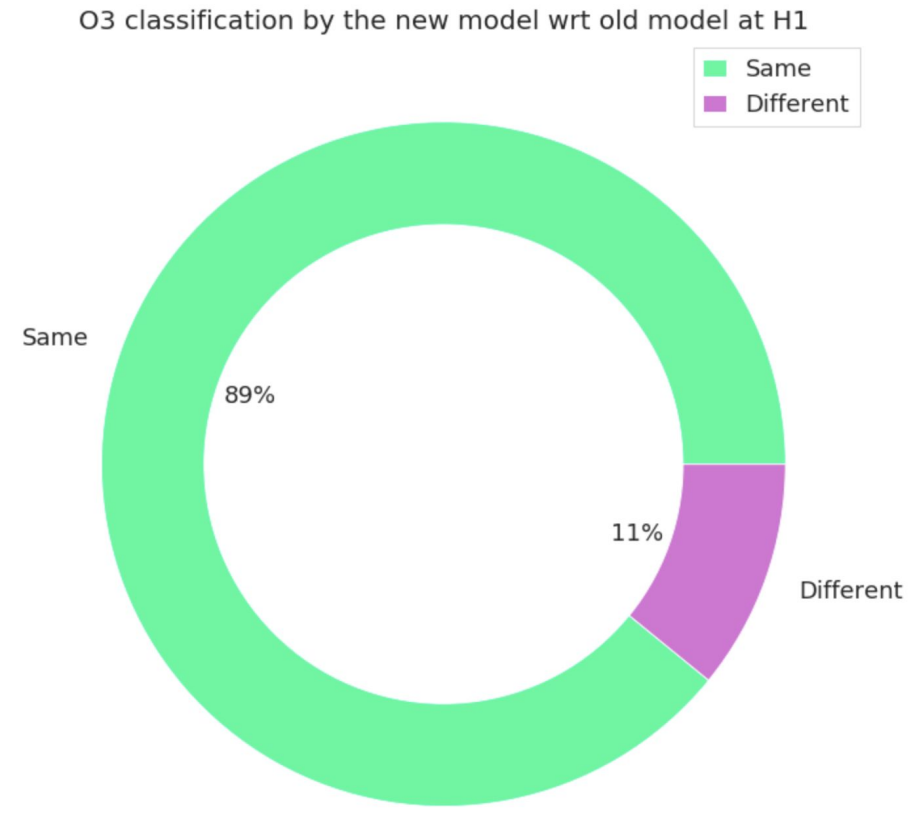
Change in confidence assigned to the glitches is minimal

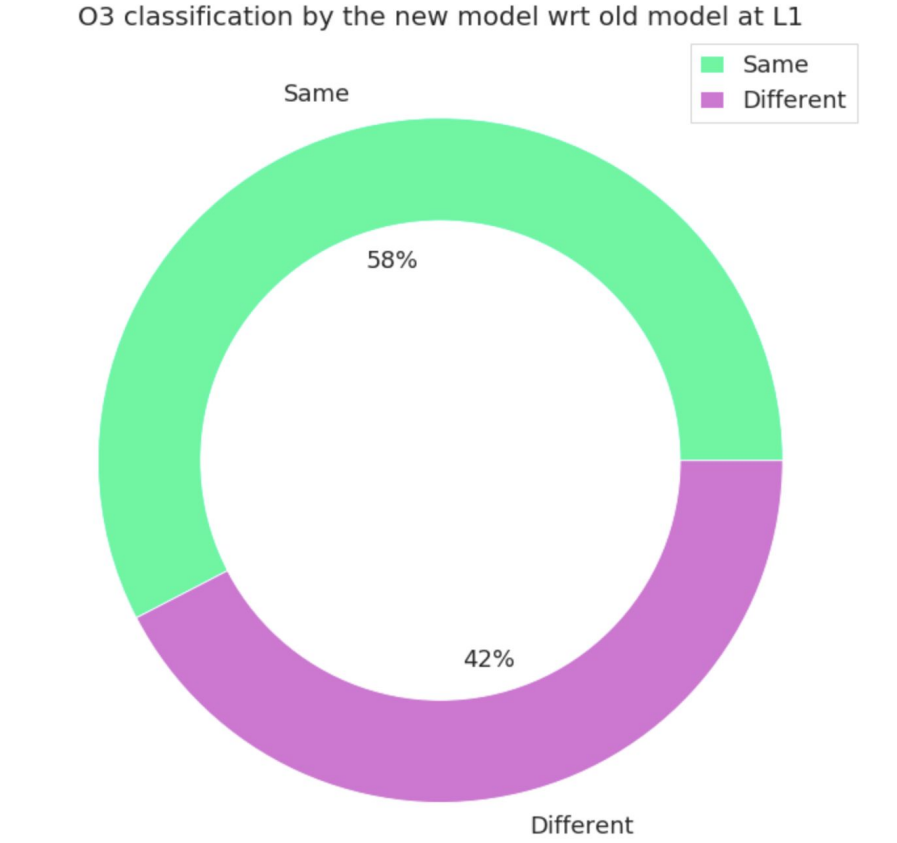
Change in class labels



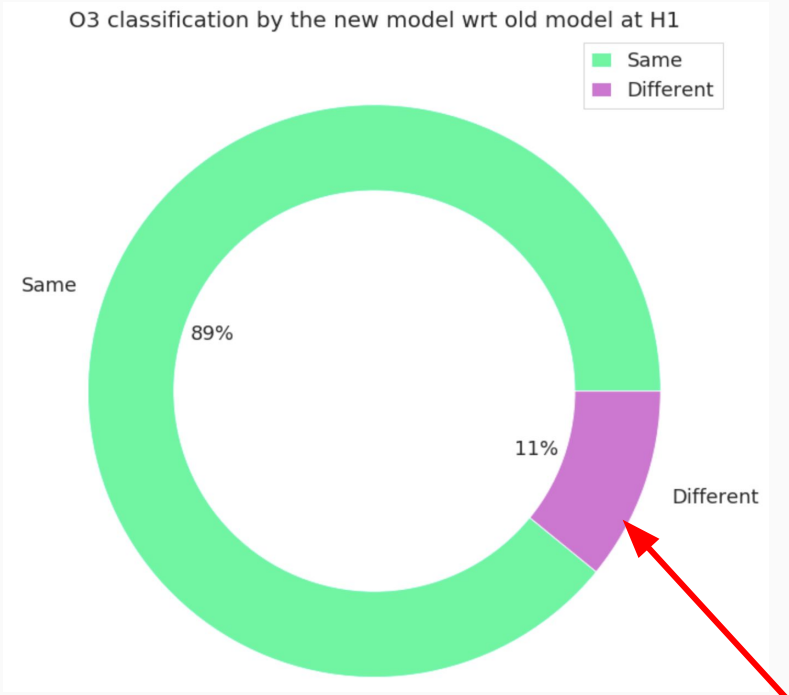


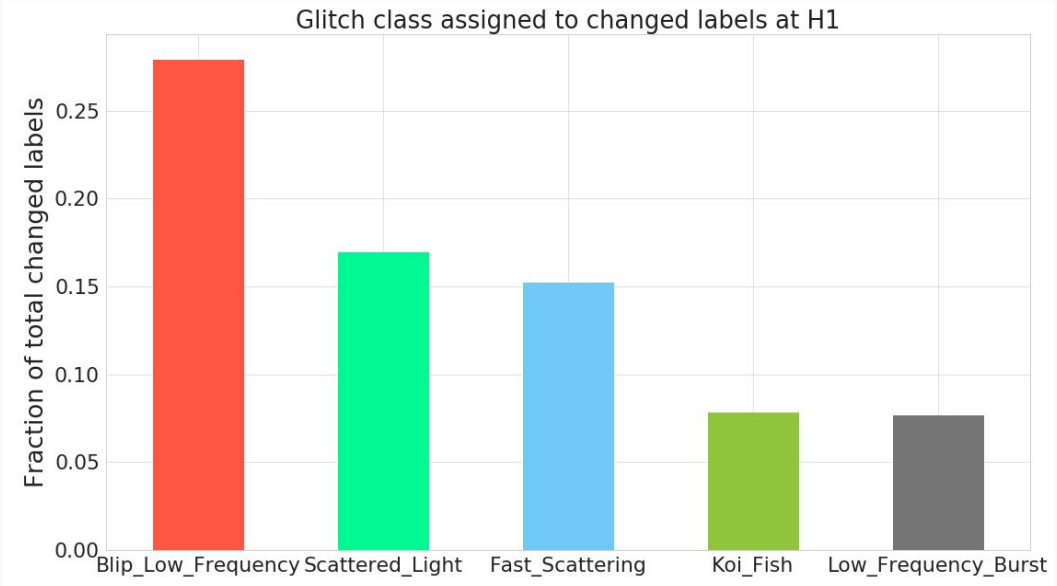
Change in class labels





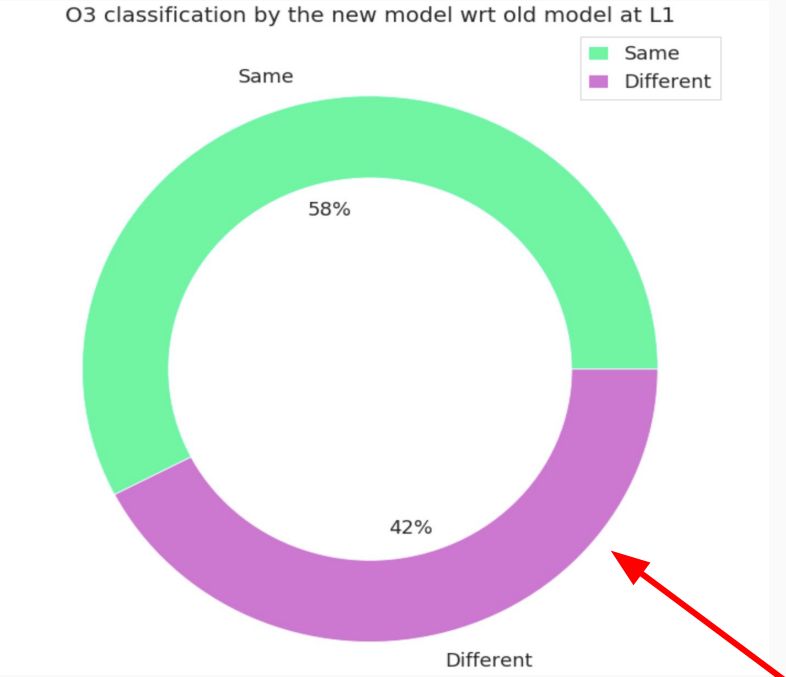
Distribution of new labels at H1

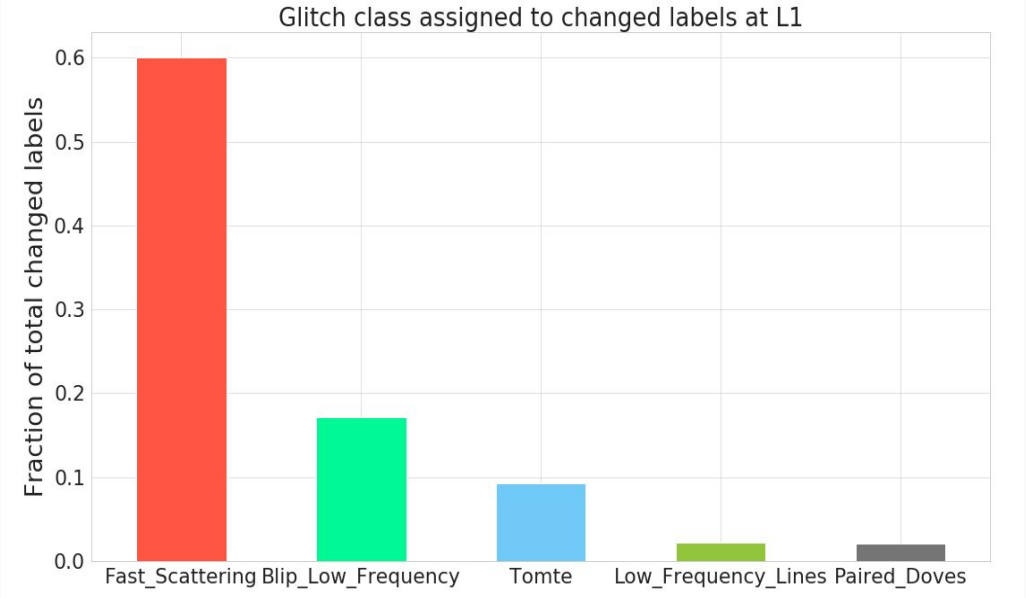




Glitch class assigned to these triggers

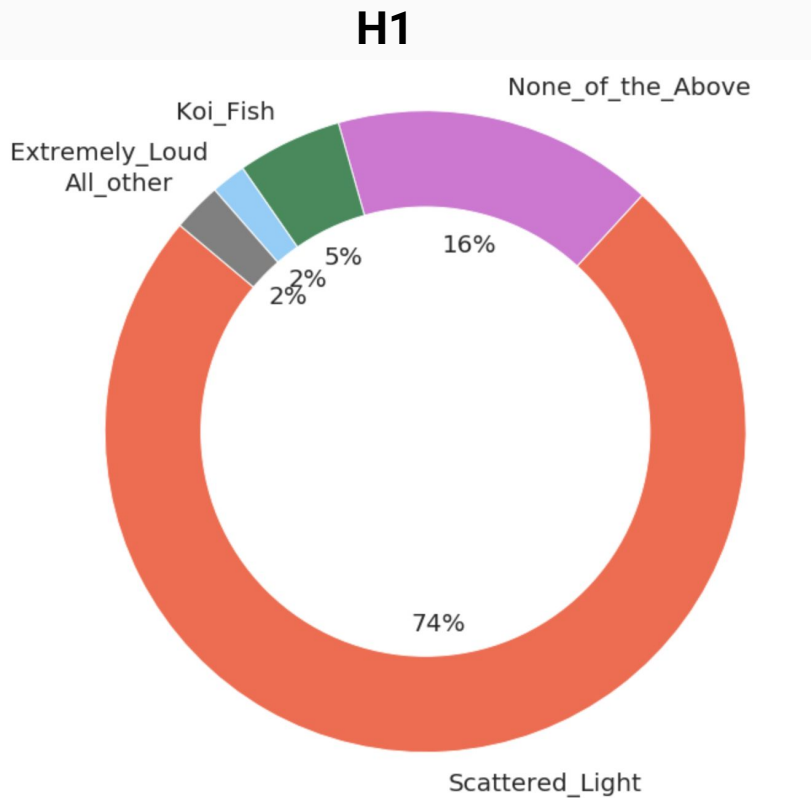
Distribution of new labels at L1

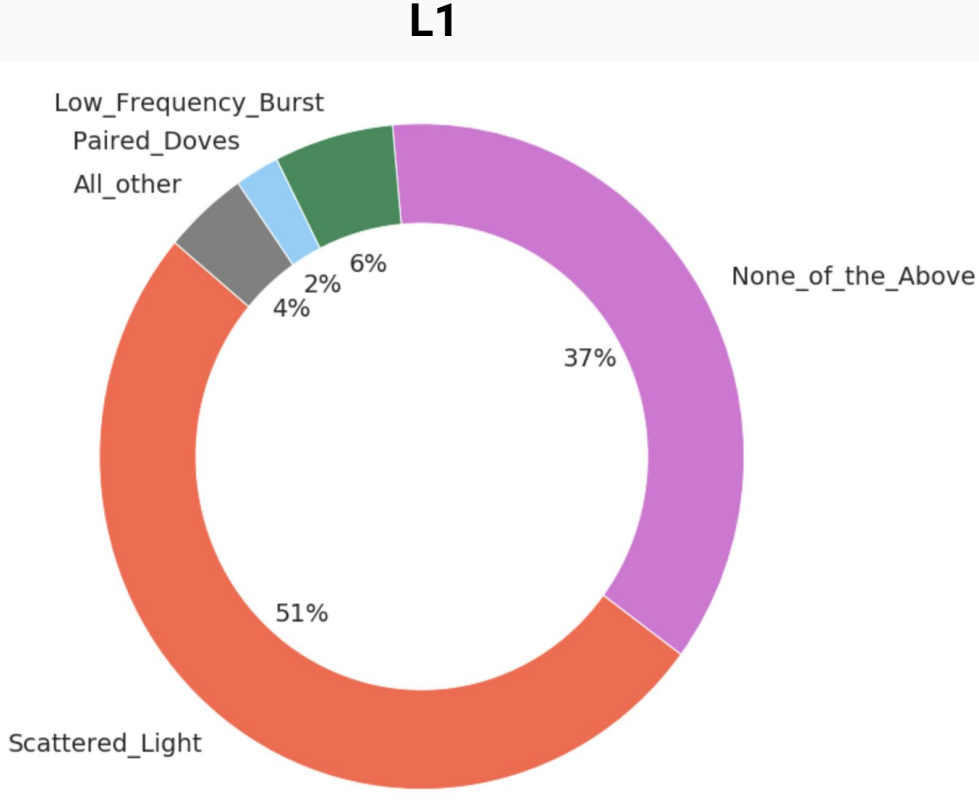




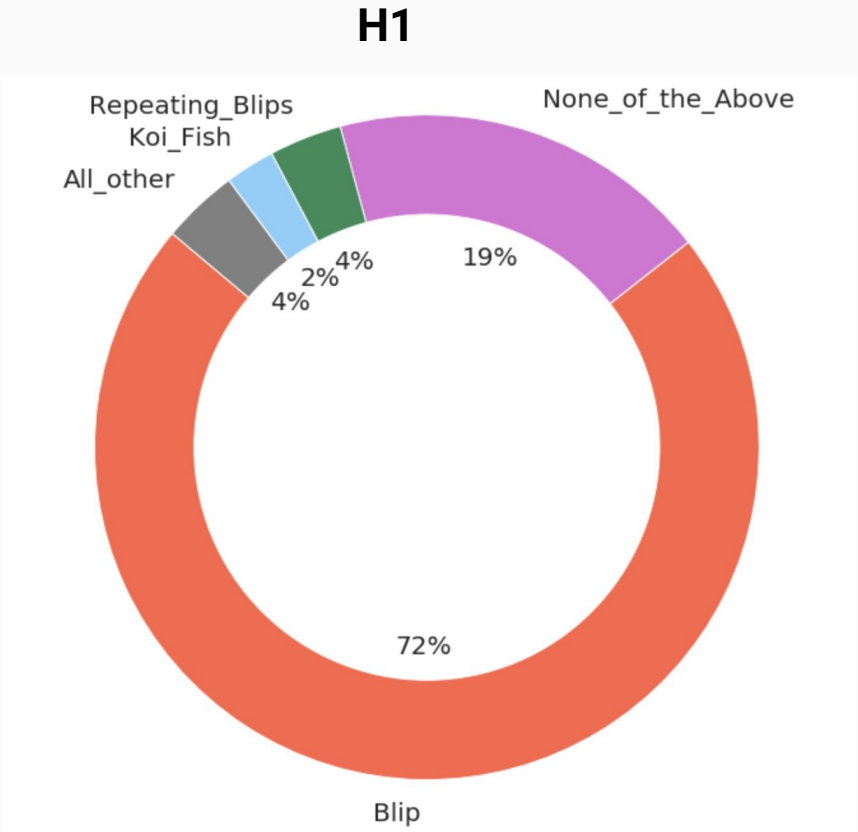
Glitch class assigned to these triggers

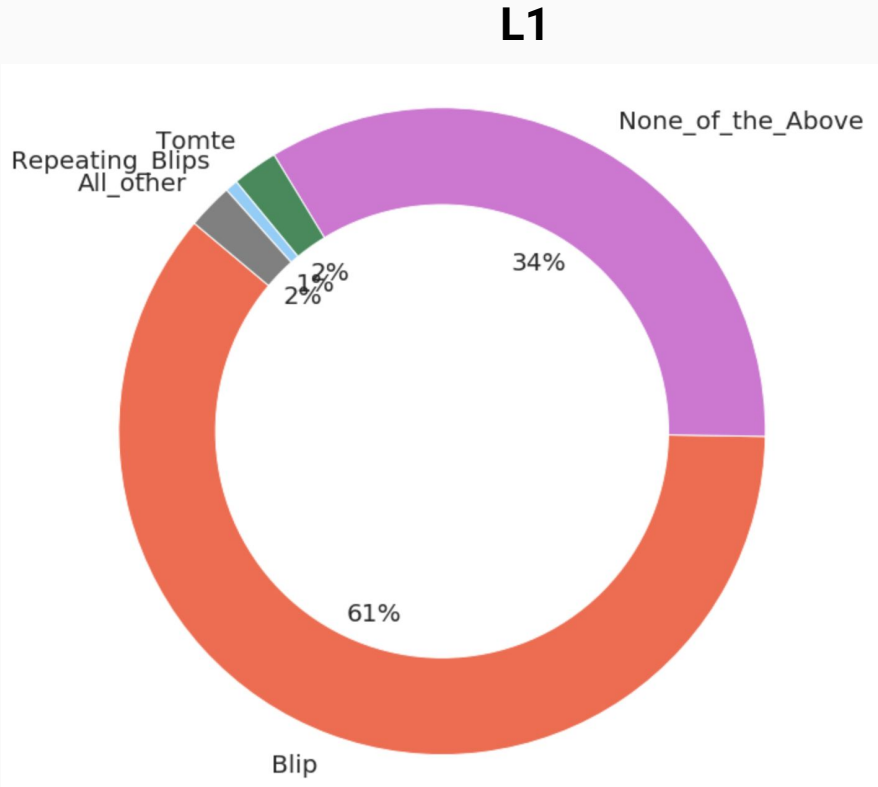
Previous classification of Fast scattering





Previous classification of low frequency blips





Old classification to new

- New model to identify
  - Fast scattering
  - Low frequency blips

- It should not affect other classes

Heatmap on next two slides

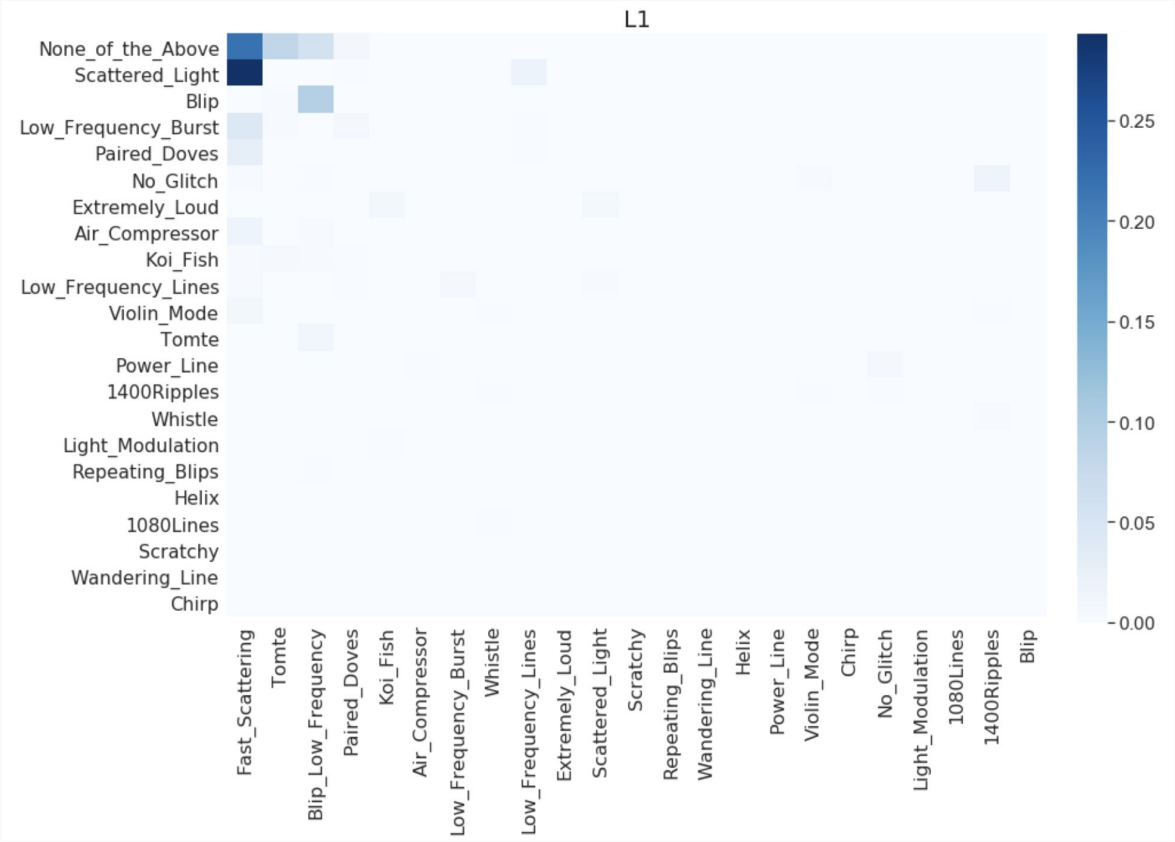
- We consider those glitches that are assigned a different glitch class by the new model
- For each old label we look at the distribution of new labels assigned

H1 old to new

- A fraction of Extremely_Loud triggers classified as scattering.
- Omega scans show those triggers are indeed scattered light noise.

L1 old to new

- 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



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?

Thank you
Questions and comments