Judging an excessive power as glitch or core-collapse supernova

With machine learning

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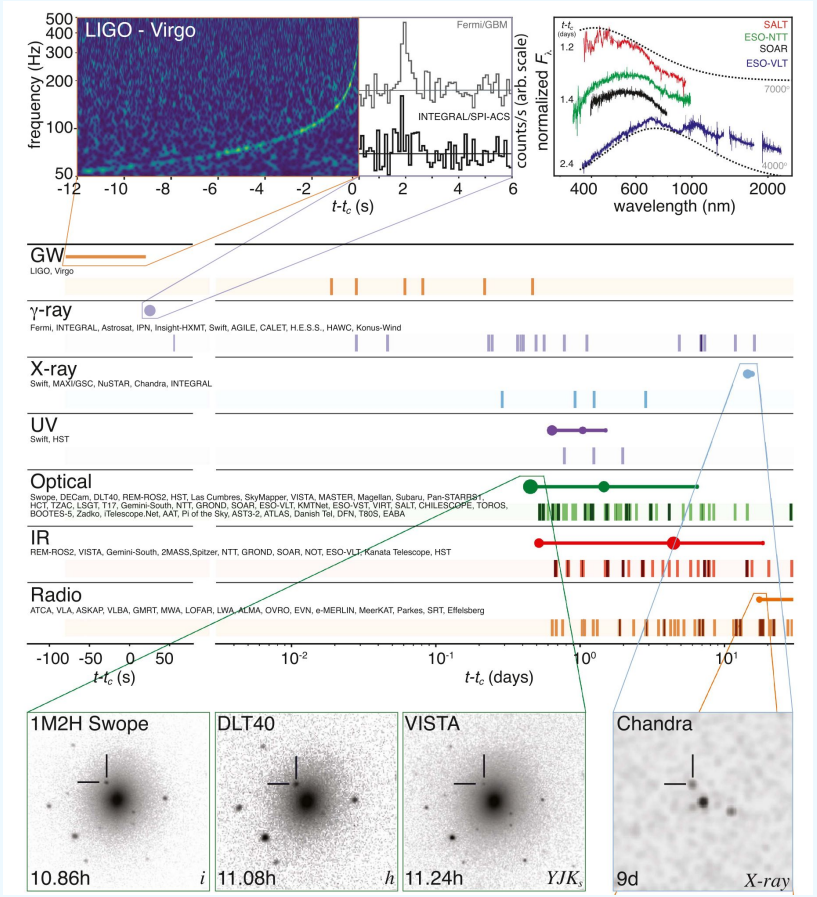
Contents

MMA Introduction

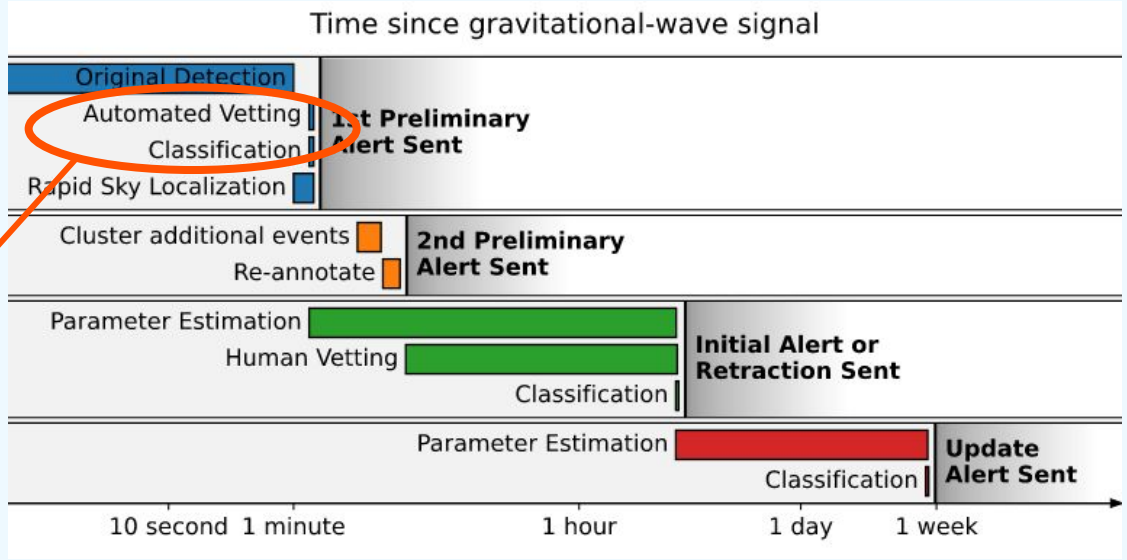
- Early alert from the GW detector can provide prior information for EM counterparts.
- Possible candidate for MMA includes BNS merger, Core-Collapse Supernova(CCSN) etc.



https://iopscience.iop.org/article/10.3847/2041-8213/aa91c9/pdf

MMA Introduction

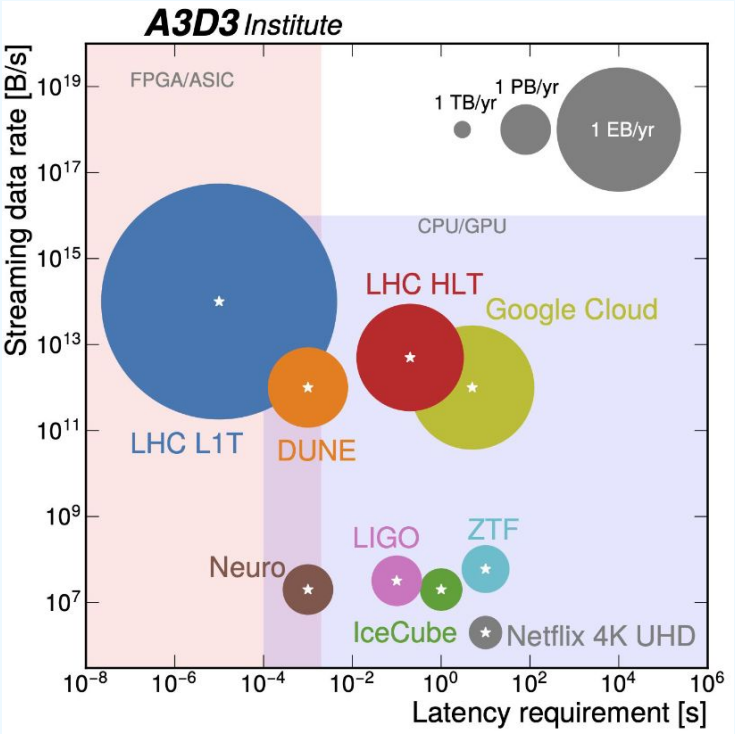
- We focus on recognizing the difference of glitch and GW signals after the detection



https://rtd.igwn.org/projects/userguide/en/latest/analysis/index.html

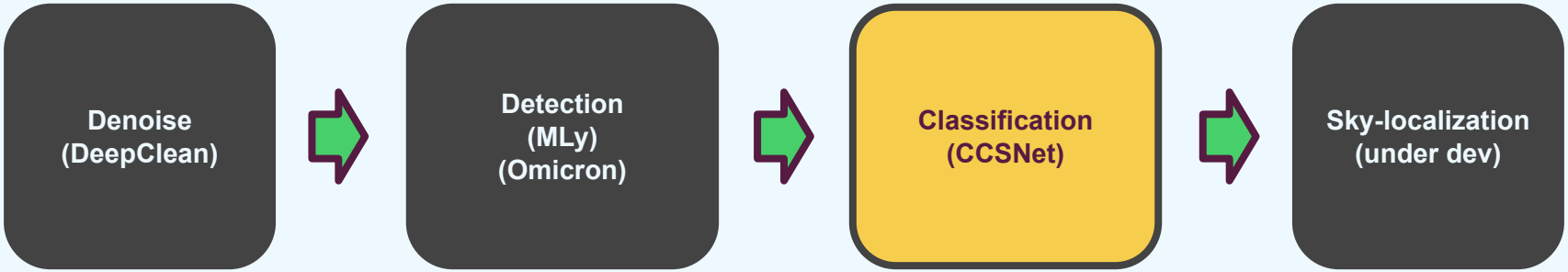
MMA Introduction

- GW Inference-as-a-Service(GW-IaaS) provide efficient machine learning usage for speedy and accurate analysis.
- GW-IaaS:
  - Hardware: Nvidia Triton inference server
  - Software: ML4GW packages



A3D3, A3D3

Example of Machine learning Alert system

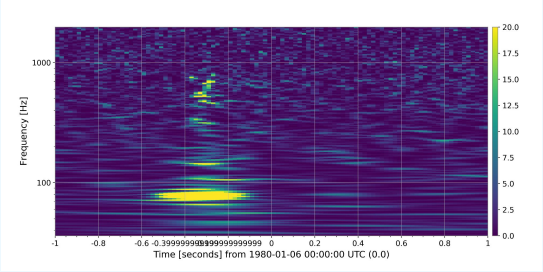


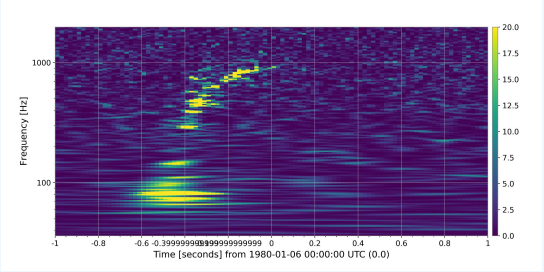
- DeepClean: Non-gaussian noise reduction according to environmental noise 2005.06534, 2108.12430
- MLy: Machine Learning based coherent detection method 2009.14611
- CCSNet: Detection trigger classifier for glitch vs CCSN
- Sky-location: Still Under development

Data preparation

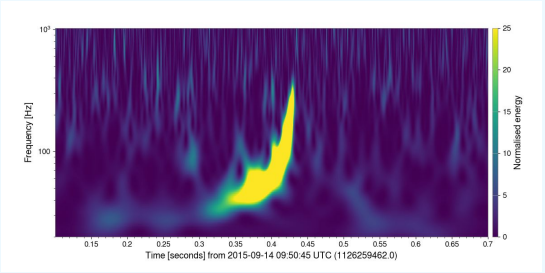
Signals in detector

CCSNs

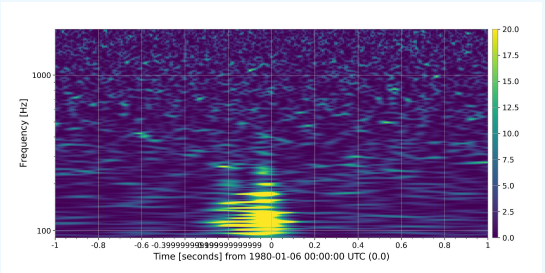




BBH



Glitch



Unlike CBC's chirp like structure in time frequency space

CCSN waveform have various time frequency structure

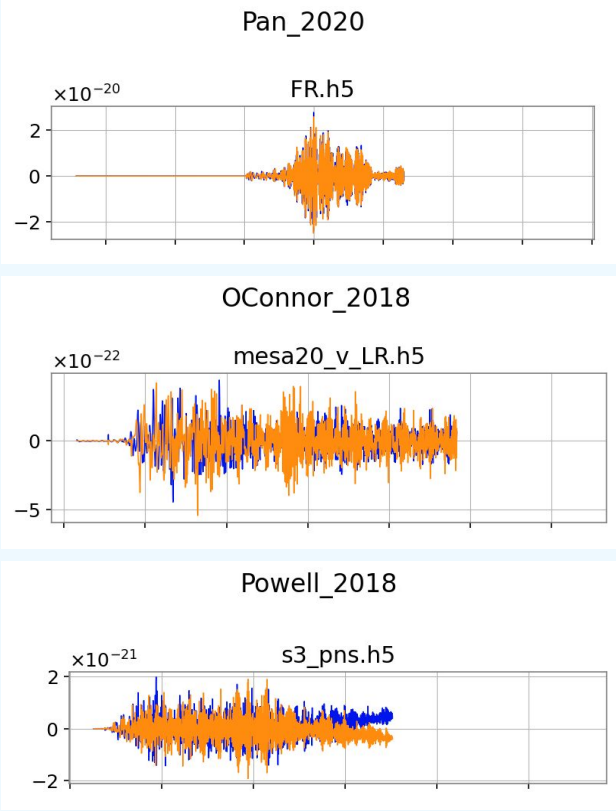
Distribution of CCSN

Generating the two polarizations

- 34 different progenitor star (3D simulation)
- Uniform distribution for orientation, polarization, and sky-location in its parameter space

Injection to Handford, Livingston

- 4096 sampling rate
- Core bounce at different time
- Dynamic SNR

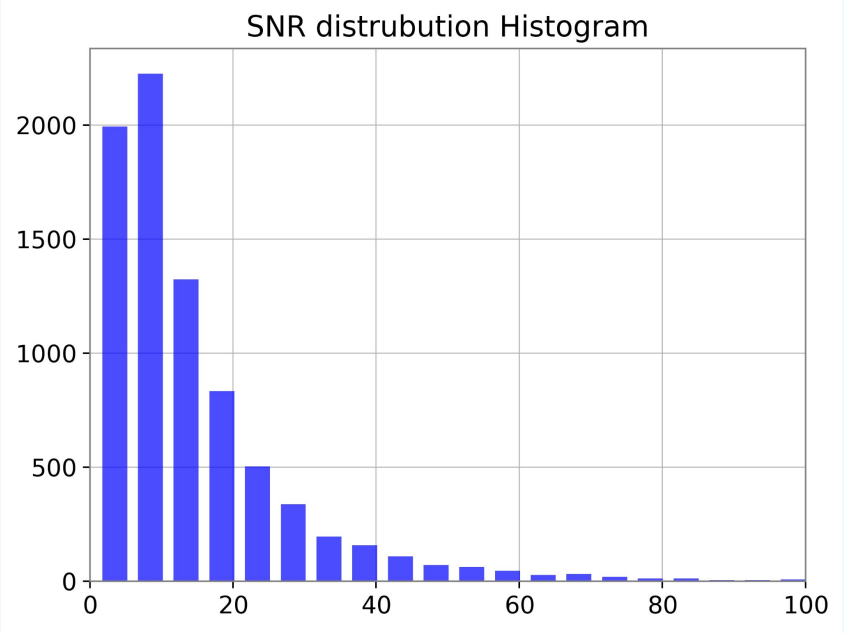


Distribution of CCSN

ML4GW provide fast SNR rescaling during training

Log normal SNR distribution:

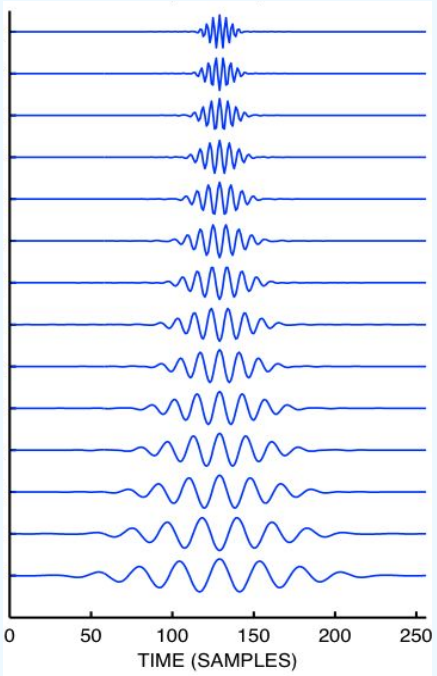
- Mean = 15
- Variance = 15
- Low bound cut off = 1



Collecting Glitch using Omicron

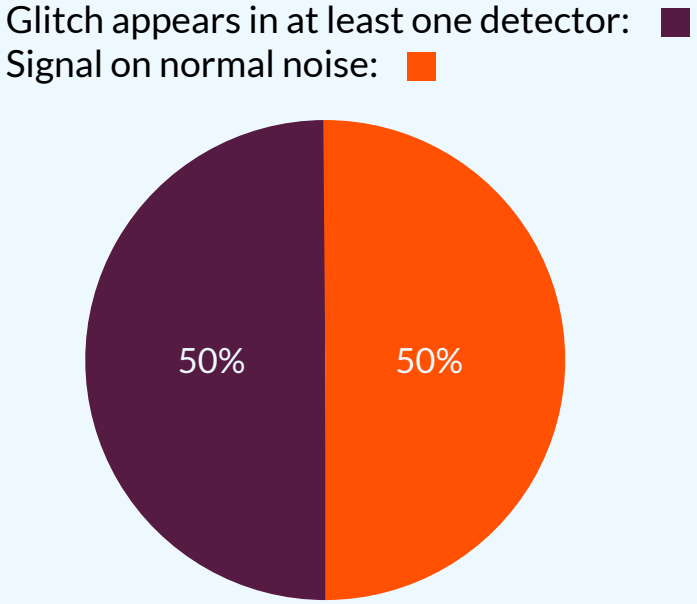
- Omicron pipeline pick up “excessive power” using Q-Transform
- Q-Transform are similar to applying wavelet transformation to whitened signals
- Wavelet transformation is like a modified Fourier transformation, it replace the sine wave with a sine Gaussian wavelet for integration.

Wavelets with same q value



Training & Validation Data

- Glitch from 53K seconds of strain data from O3
  - Hanford 8K
  - Livingston 12K
- 4096Hz, 1 Second, 2 IFOs, whiten strain data
- 16K of CCSN injection in total for training and validation
- 75% for training 25 % for validation

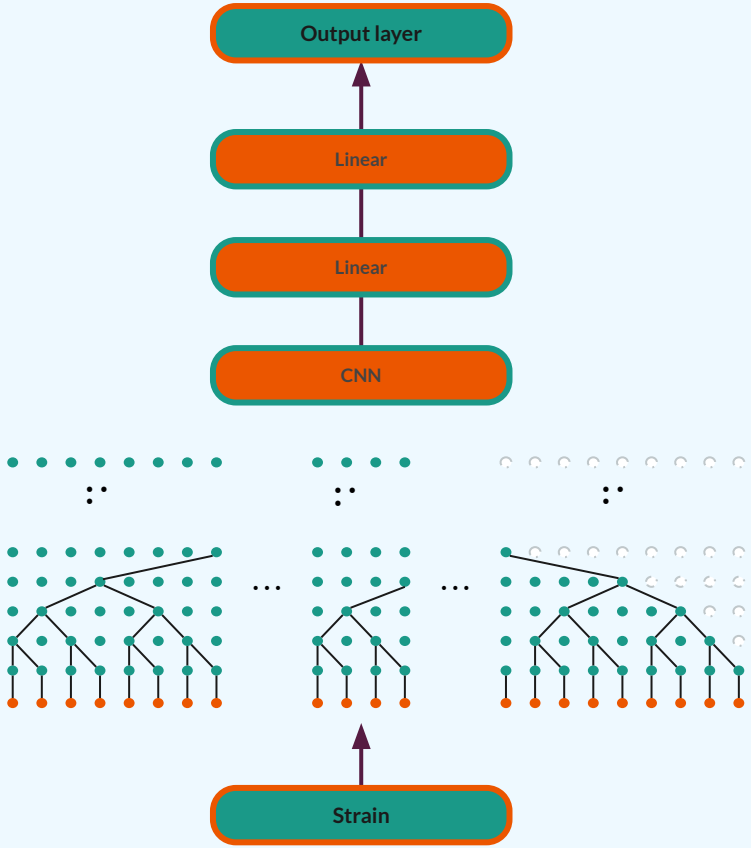


The ML model and training method

WaveNet

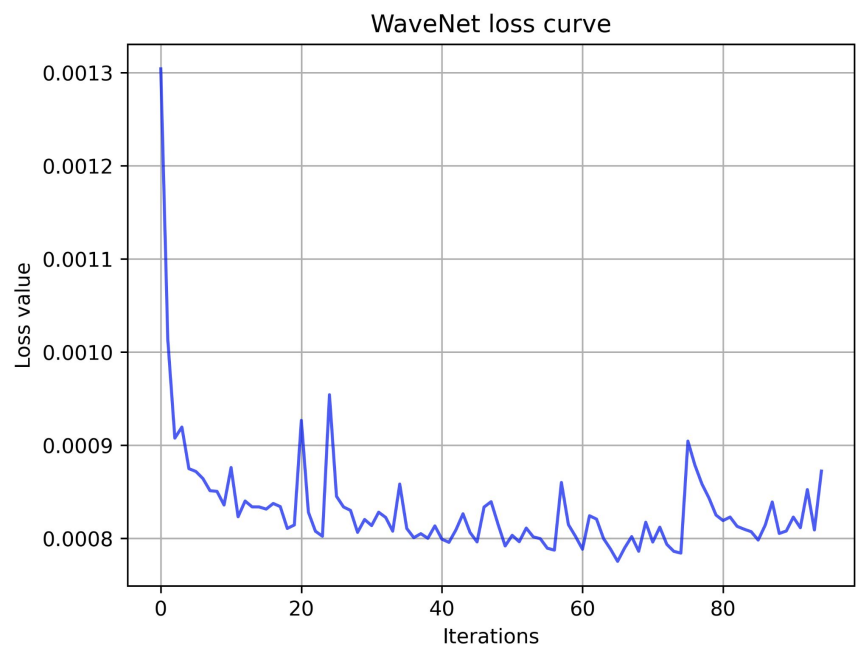
We use dilation feature from WaveNet

- The dilation feature provide a larger receptive field for deep CNN layers
- For deep layer of CNN less neuron is required to capture same kernel width of the input data



Training performance

- Loss function: Cross Entropy
- Optimizer: Adam
- Scheduler: Learning rate schedule every batch

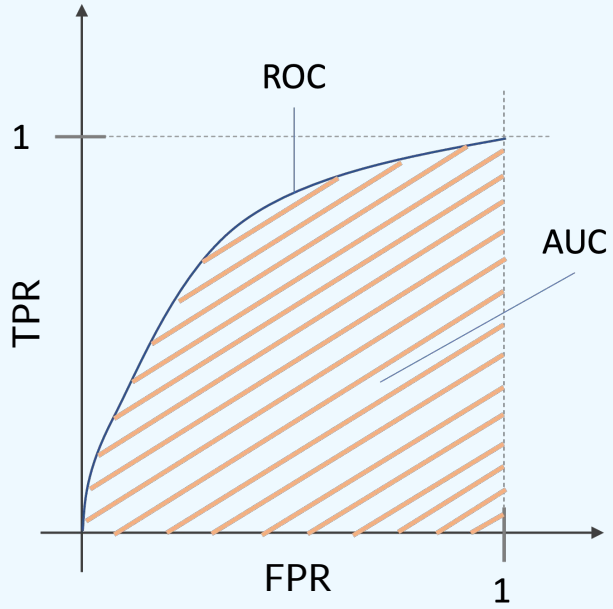


Validation metric

Predict Class \ True Class		
	True Positive (TP)	False Positive (FP)
	False Negative (FN)	True Negative (TN)

- Recall, True Positivity Rate (TPR) = TP / (TP + FN)
- False Positivity Rate (FPR) = FP / (TN + FP)

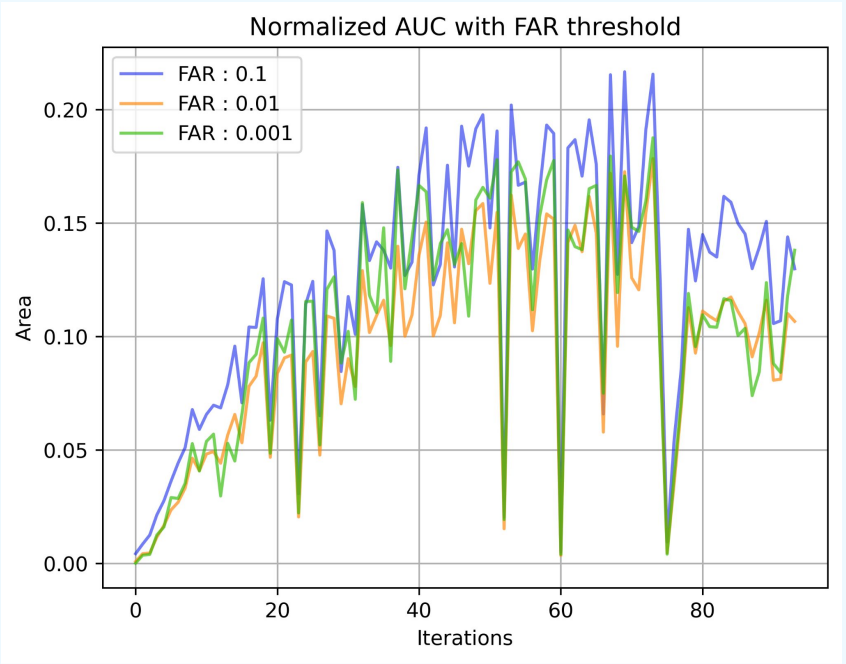
- Receiver operating characteristic (ROC)
- AUC: Area Under ROC



AUCurve

Model Performance

- We normalize the AUC with it's max possible area, so that the max area is still equal to one
- The performance may look worse but can be improved by hyperparameter tuning



Summary

- Machine learning method is at booming stage for Multi-messenger Astrophysics.
- The GW Inference-as-a-service(GW IaaS) can provide an end-to-end alert pipeline for MMA.
- We trained a classifier for distinguish lots of different CCSN waveforms from unmodeled glitches.
- The performance of the current NN model is poor but it can be improved by hyperparameter tuning.
- We would like to test the model with Omicron triggered CCSN injection versus glitch in near future.

Thank You!!

Appendix

ML4GW framework

- ML4GW provides the software utils that accelerate the training and inference process.
- The Triton server helps to save the latest pre-trained model and schedule the computational resource for inference.
- ML4GW provide the software tools for data preprocess on GPU, and high throughput inference.