# Hearing the Signal through the Static: Real-time Noise Reduction in the Hunt for Binary Black Holes and other Gravitational Wave Transients

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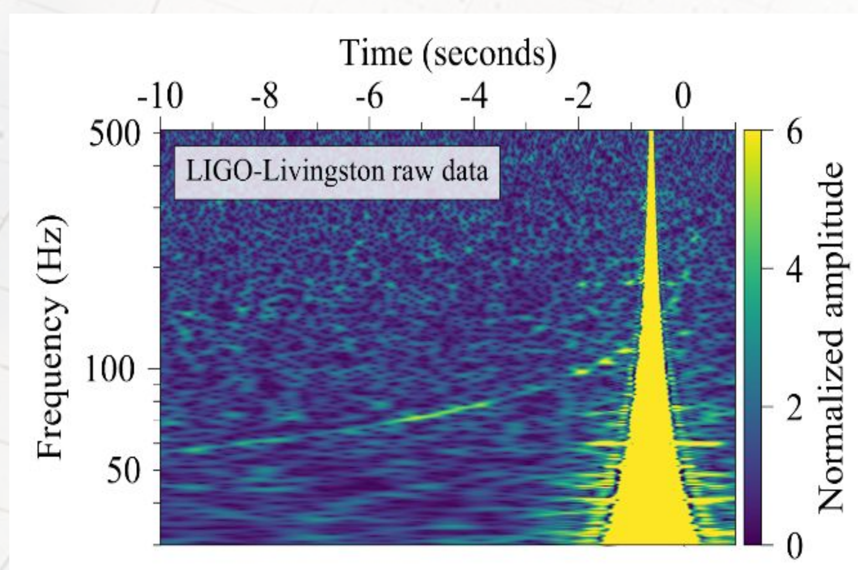
## Goal: Identify non-stationary noise in LIGO gravitational wave (GW) detectors in real-time.

LIGO detects GWs from black hole and binary neutron star collisions providing real-time alerts. Non-stationary noise limits our ability to detect GWs in real-time.

LIGO also has many auxiliary data streams recording environmental and instrumental noise.

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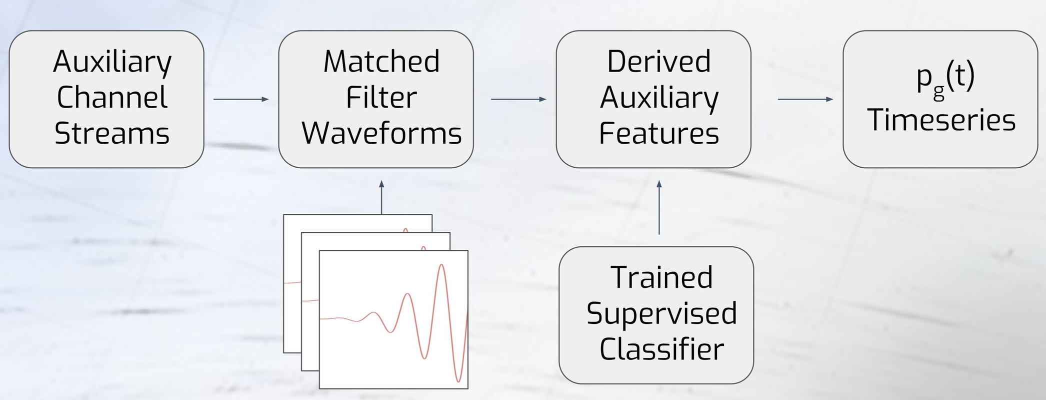
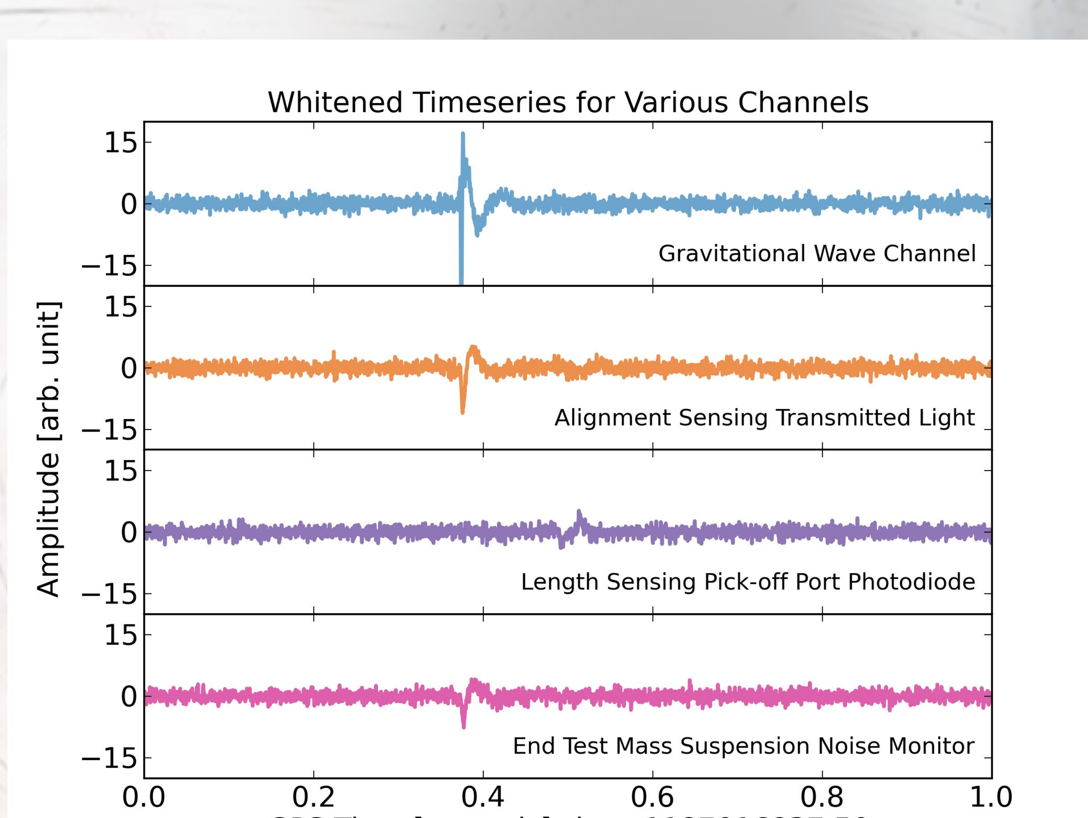
We aim to infer the presence of nonstationary noise using auxiliary channel information in **real-time** to improve the reliability of automated GW alerts and remove the need for human vetting.

## Method: Use stream-based feature extraction and machine learning.




We use a combination of signal processing and machine learning techniques on auxiliary channels to infer the presence of nonstationary noise in gravitational wave data. This is done in two steps:

1) Apply matched filtering on streaming auxiliary channel timeseries using noise waveforms to extract meaningful quantities that describe important features of the noise.

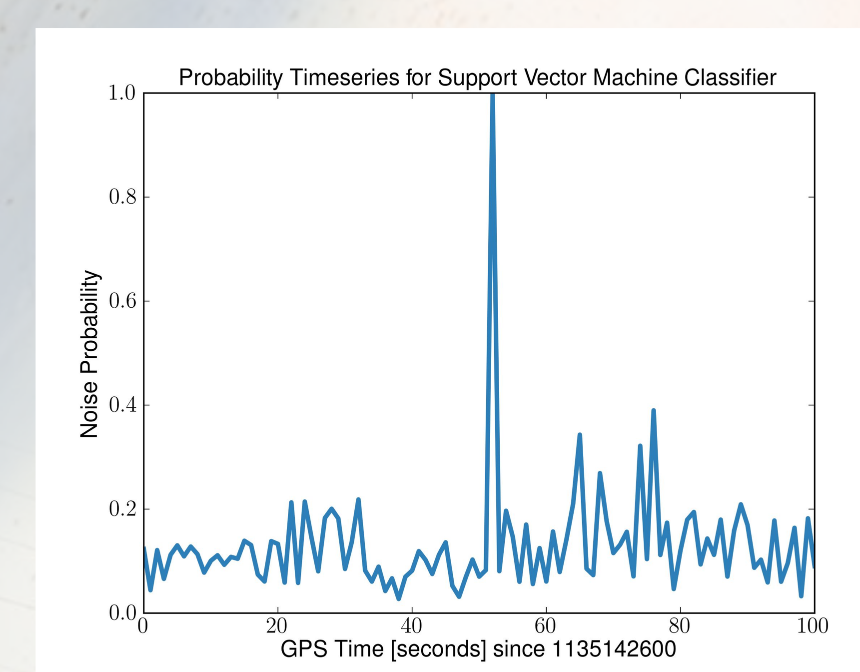


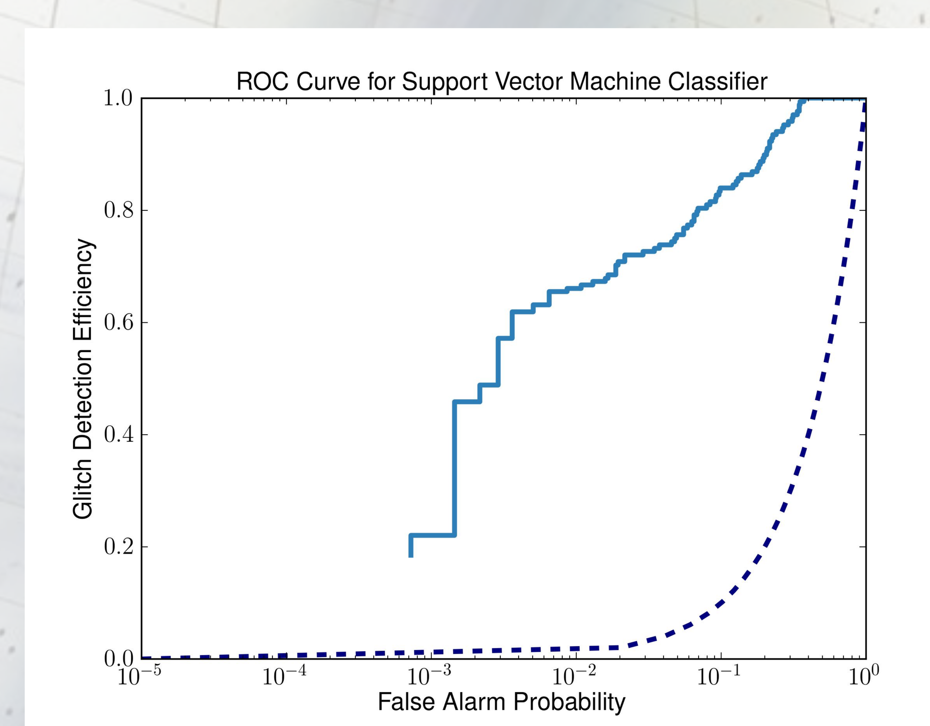

Nonstationary noise is present in auxiliary channels. The coupling to gravitational wave data can be inferred by supervised classifiers.

2) Feed these derived features into supervised learning classifiers that infer the presence of noise in the gravitational wave channel. The end product is a probability of the presence of nonstationary noise in gravitational wave data, given auxiliary channel data, produced as a streaming timeseries and available in real-time.

## Results:

Supervised classifiers were trained on 500000 seconds of data taken during O1 containing about 5500 training samples. Depicted here are results from a Support Vector Machine classifier using a radial basis function kernel. Evaluation was done on 70000 seconds of data, shown on the right for a 100 second timespan.




Performance metrics described by a Receiver Operator Characteristic (ROC) Curve is shown on the left, and characterizes the performance of a classifier in distinguishing noise from gravitational waves.

## Projected outcomes:

The data products generated here will aid gravitational wave search detection pipelines in using real-time data quality information alongside gravitational wave data to produce significance estimates from gravitational wave events.

This is crucial in reducing the time to send out alerts generated from gravitational wave events from tens of minutes to seconds, which allows astronomers to detect electromagnetic counterparts from astrophysical sources at the time of the event.

Another outcome of real-time noise detection is in enabling data quality investigations to identify and mitigate possible sources of nonstationary noise, as this allows real time feedback in the monitoring of the interferometer's auxiliary state.

## Details:

https://git.ligo.org/lscsoft/gstlal
https://git.ligo.org/reed.essick/iDQ
https://docs.ligo.org/reed.essick/iDQ/

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