# Malvasia: MAchine Learning to Value Single Interferometer Analysis

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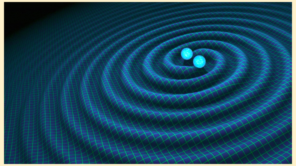
## What are gravitational waves ?



**Gravitational waves** are disturbances in the curvature of spacetime, generated by accelerated masses. The existence of those waves is a consequence of **Einstein's theory of general relativity**. Gravitational waves were **first detected in 2015** by the LIGO detectors, celebrated by the Nobel prize in Physics in 2017. The sources observed so far are **mergers of binary systems** composed of compact astrophysical objects such black **holes**.

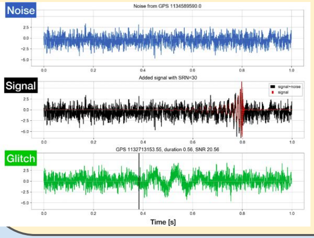
Virgo

LIGO

## How are they observed ?


The **Virgo and LIGO detectors** are Michelson interferometers. Those instruments measure the difference in the optical path length followed by two laser beams propagating through their arms. This difference relative to the total arm length is proportional to the gravitational wave amplitude. This measurement is however limited by **non-Gaussian noise artifacts (glitches)** caused by instrumental and external sources. **A careful analysis is thus required for making confident detections.**

## How are they currently detected ?




The search for gravitational signals in the noisy data is based on **matched filtering**, which consists in correlating the data with a large sample of theoretical signal models. Triggers are obtained when the correlation score exceeds a threshold. Coincident triggers in different instruments allow to **reject spurious noise disturbances**. This method is **computationally expensive** and it is **intrinsically limited to the times when more than one detector operate**.

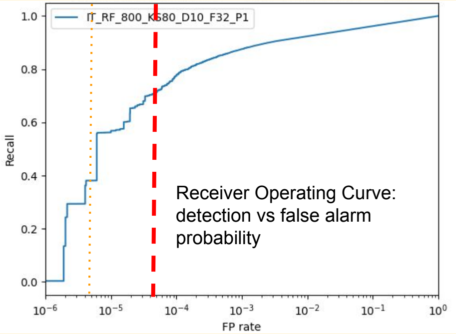
## How can machine learning help ?

**Deep learning** has proven to reach state-of-the-art levels in fields like computer vision, and also time series classification. Notably, **convolutional neural networks (CNN)** have shown to be very good at recognizing localized and complex patterns in noisy inputs. The expected benefits of using neural networks for GW data are their **computational efficiency** and their ability to **learn complex noise statistical models** (that can capture the glitch variability).

*Can they allow to search when only one detector is up?*

## Our results

We trained various classifiers (CNNs, and other architectures) over ~500k samples of 1 second with three classes: noise, **signal** and glitch. The goal is to reach a false-alarm rate (noise or glitch classified as signal) of about 10/month (p ~ 4 x $10^{-6}$) with a detection efficiency > 50 %.




We succeeded to achieve a performance close to the target objectives.

**For a false alarm rate of 0.01%, we reach a detection efficiency of 0.7, which means that with 300 false alarm per month.**