# Autoencoders for VIRGO GW signal analysis

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## Fourth ML-INFN hackathon

1. Università di Pisa 2. INFN Pisa 3. INFN Genova 4. INFN Roma

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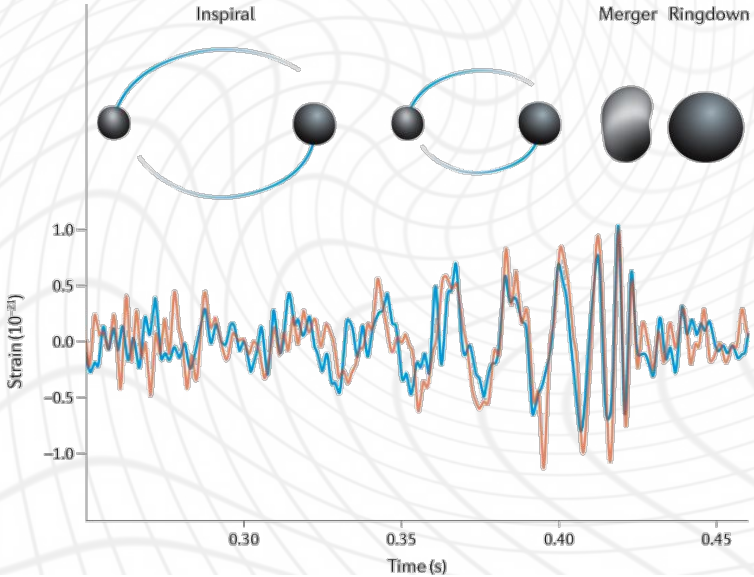
# Gravitational Waves



...are propagating ripples in the fabric of spacetime, originated from **accelerating masses**, such as the inspiral of a binary black hole system.

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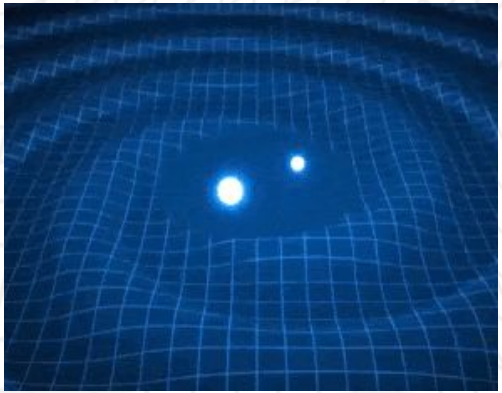
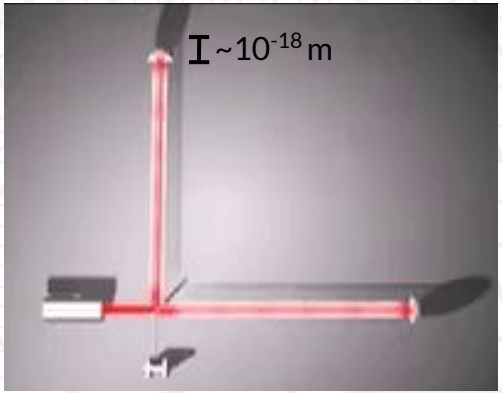
# Gravitational wave detectors



- GWs propagates through space at the speed of light;
- Their effect is an alternate *stretch* and *squeeze* of the distances between the masses;
- We can user Michelson interferometers to detect them.



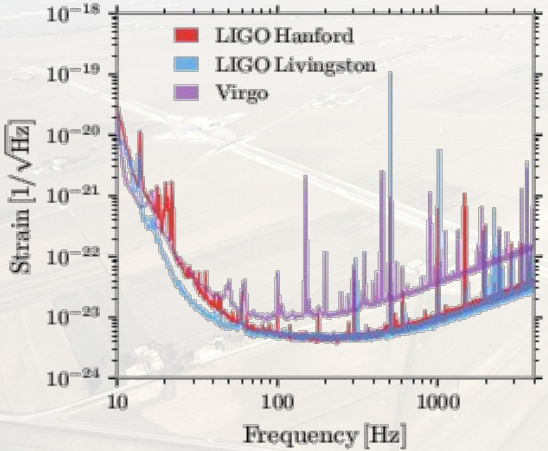


# Detector noise



Many instrumental or environmental sources produce a *strain equivalent noise*.

**Detection problem:** our ability to extract the information about the astrophysical signal depends on how good we know the (statistical) properties of the noise.



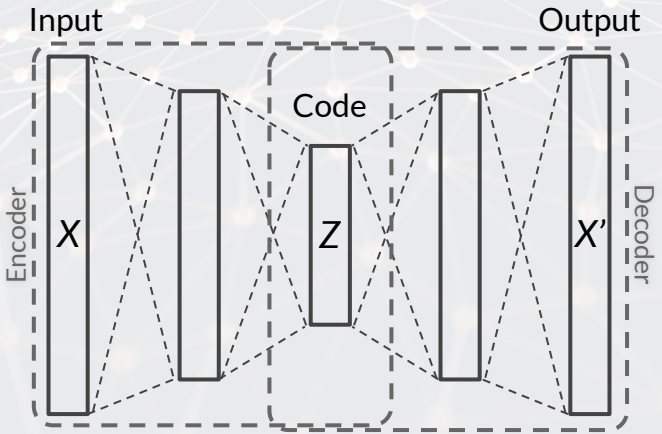

If the data is **stationary** and **Gaussian**, we can fully characterize the noise from its Power Spectral Density, whos square root provides a measure of the *strain sensitivity*.

But this is true only in first approximation: ***we need better modeling!***

# Autoencoders

...are an unsupervised learning technique in which we leverage neural networks for the task of **representation learning**.

We force a compressed representation of the original input; if some sort of structure exists in the data, this can be learned and used for "de-noising".



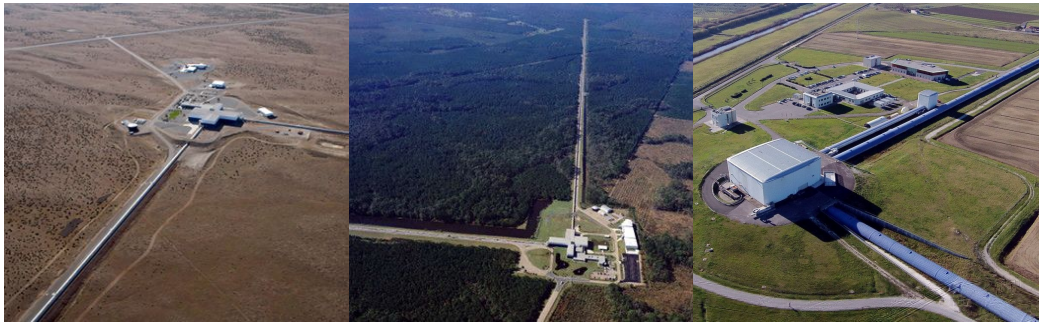

- *Dim(X') = Dim(X)*
- *Dim(Z) < Dim(X)*
- *X' → X*

*AIChE Journal.* 37 (2): 233–243

# Open access to GW public data

GW data is made available by the International Gravitational Wave Observatory Network (IGWN) and the GW Open Science Center (GWOSC).

- Strain data of GW events and observing runs;
- Tutorials to learn more about GW science;
- Software for signal analysis.



# Hackathon workflow



- Download and explore GW data;
- Learn the basics of GW data processing and visualization;
- Create your autoencoder model;
- Experiment with hyperparameters: batch size, epochs, layers and regularization;
- Test it with random Gaussian data;
- Apply it to real GW data.

# More about ML in GW research

- Gravitational Waves
- GW detectors
- Detector noise
- Autoencoders
- Open access to GW public data
- Hackathon Workflow
- **More about ML in GW research**

GWitchHunters citizen science project:

https://www.zooniverse.org/projects/reinforce/gwitchhunters, or just