Machine Learning for Gravitational waves. Deep learning methods to study the noise of interferometer

E. Cuoco and M. Razzano
CCR workshop, Rimini 14/06/2018

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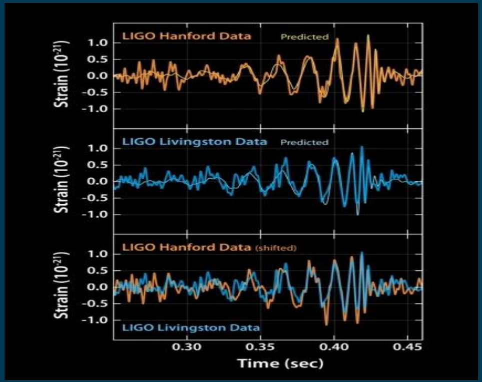
EGO EUROPEAN GRAVITATIONAL OBSERVATORY
SCUOLA NORMALE SUPERIORE
INFN Istituto Nazionale di Fisica Nucleare

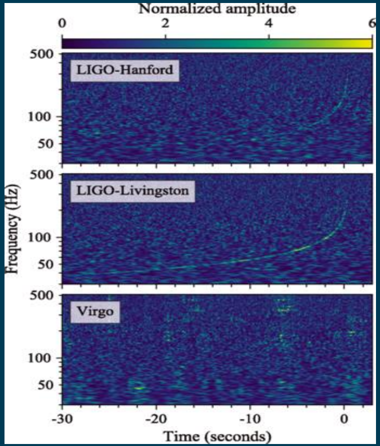
VIR-0343A-18

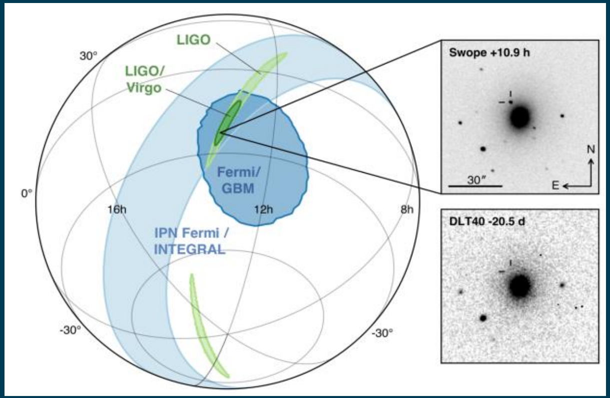
Gravitational wave astronomy: A global effort

GW discoveries: new era in Astronomy

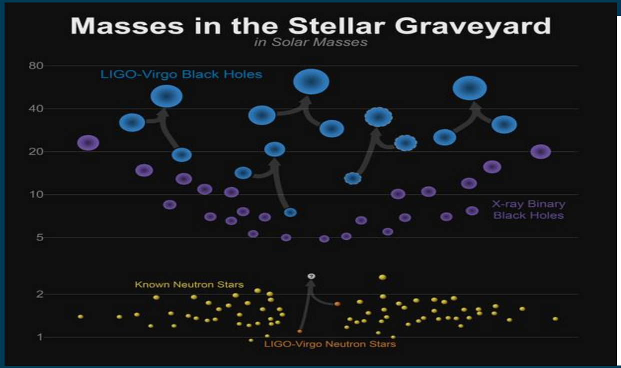


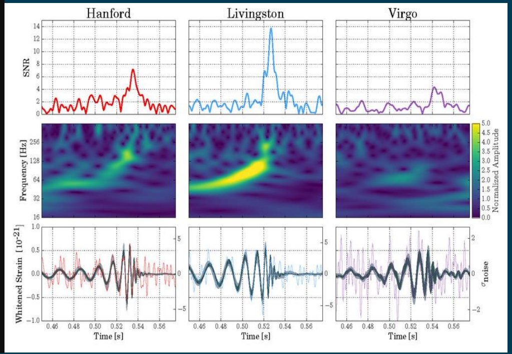
Phys. Rev. Lett., 116 (6), pp. 061102, 2016.





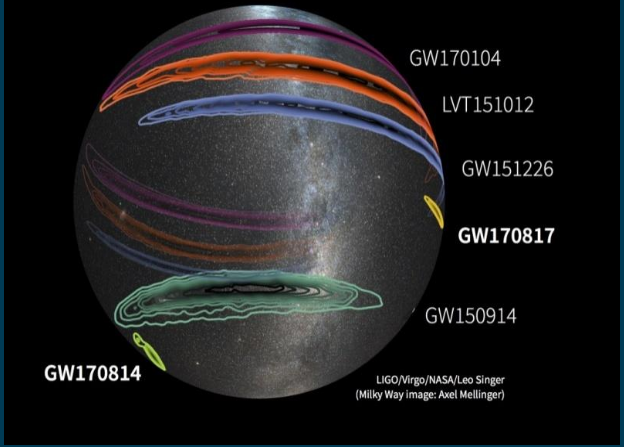
DOI:10.1103/PhysRevLett.119.161101.



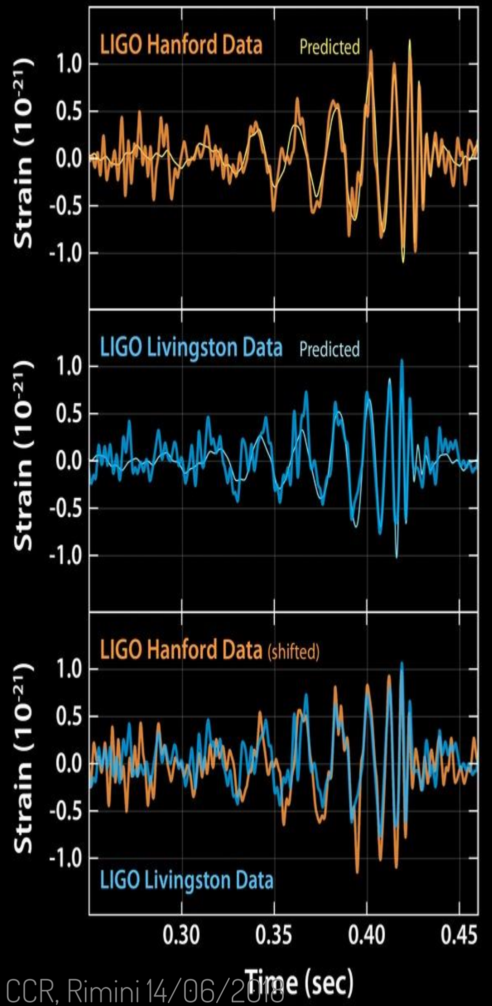


Phys. Rev. Lett., 119 (14), pp. 141101, 2017.

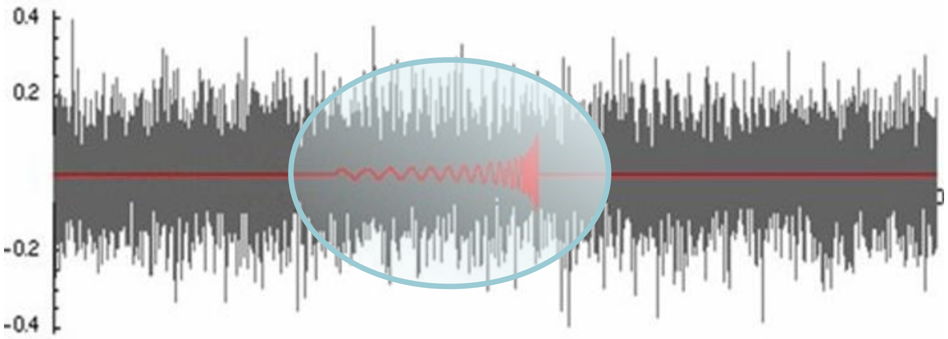
LIGO/Virgo/NASA/Leo Singer (Milky Way image: Axel Mellinger)

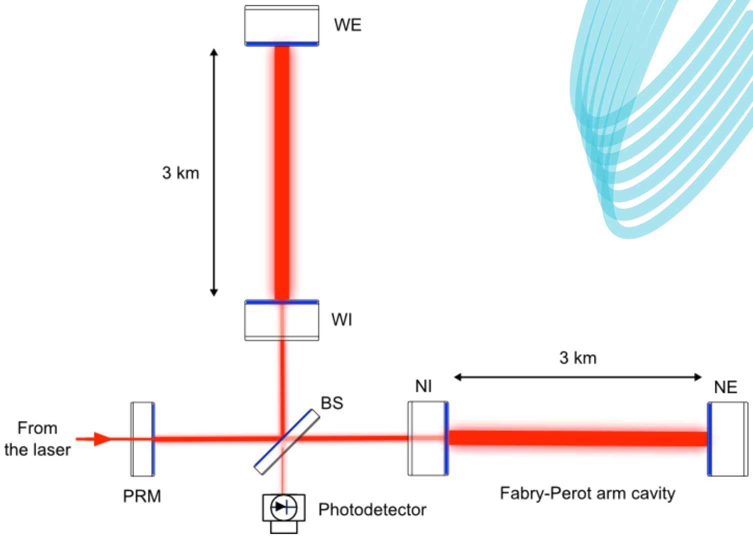


Gravitational wave astronomy: A global effort



Why Machine Learning in Gravitational Wave research





LIGO/Virgo data

are time series sequences… **noisy time series** with low amplitude GW signal buried in

Our "signals"

Known GW signals

Compact coalescing binaries has known theoretical waveforms

Optimal filter: Matched filter

Too many templates to test

Unknown GW signals

Core collapse supernovae

No Optimal filter

Parameters estimation

Noise

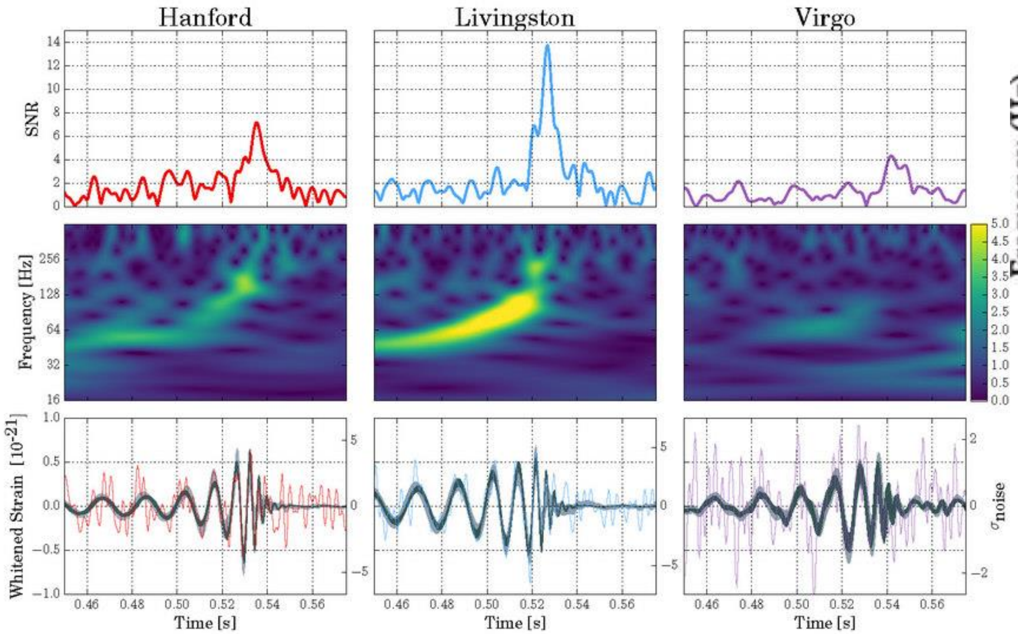
Moving lines

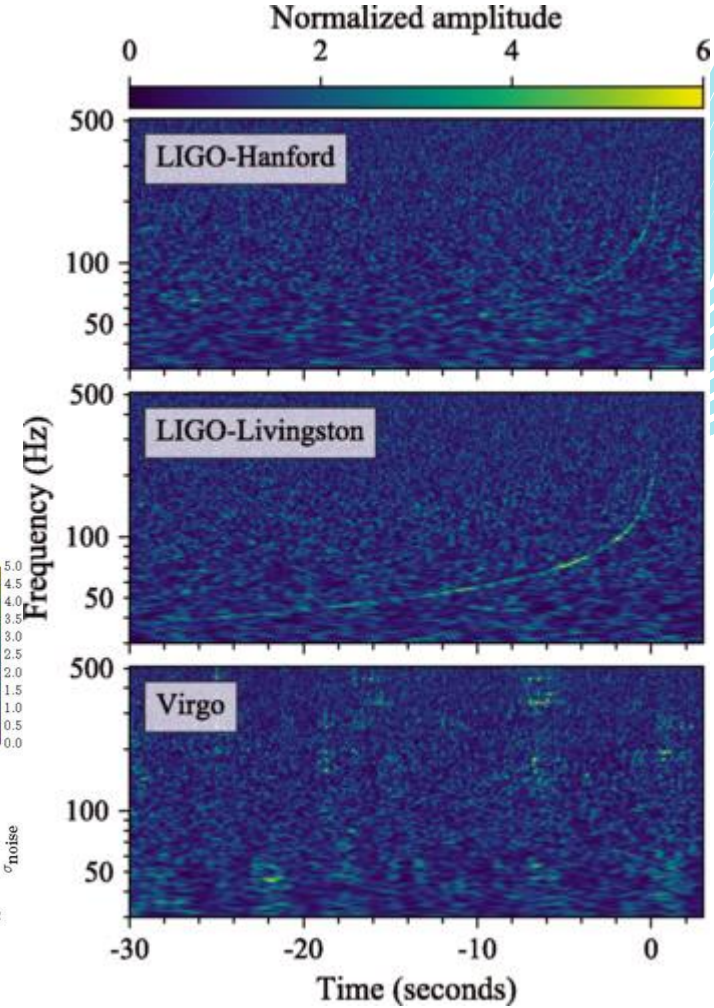
Broad band noise

Glitch noise

"Pattern recognition" by visual inspection

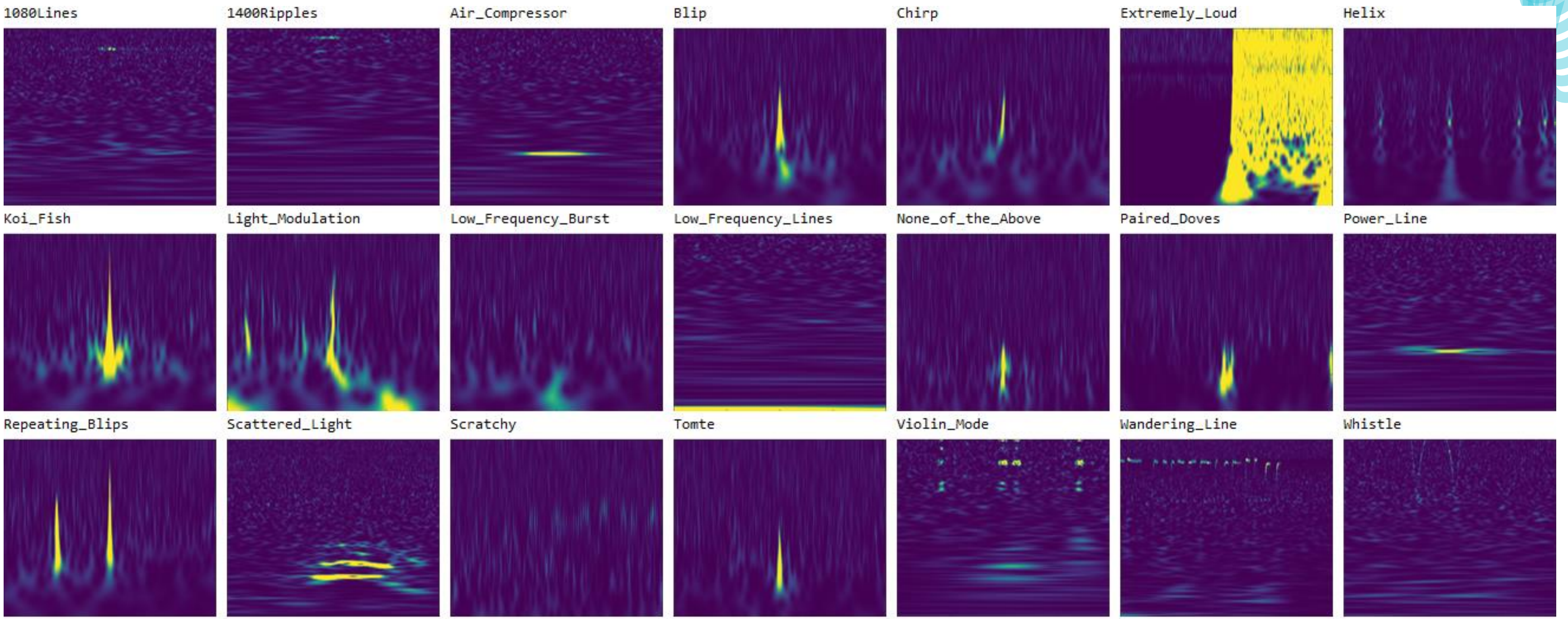
Example of GW signals



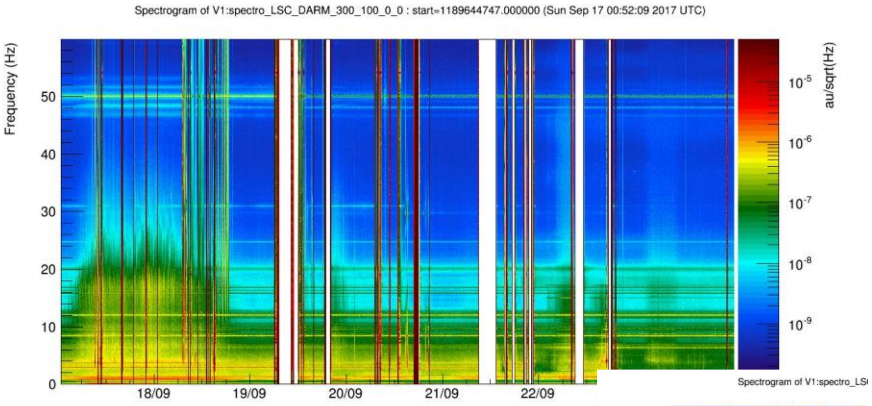


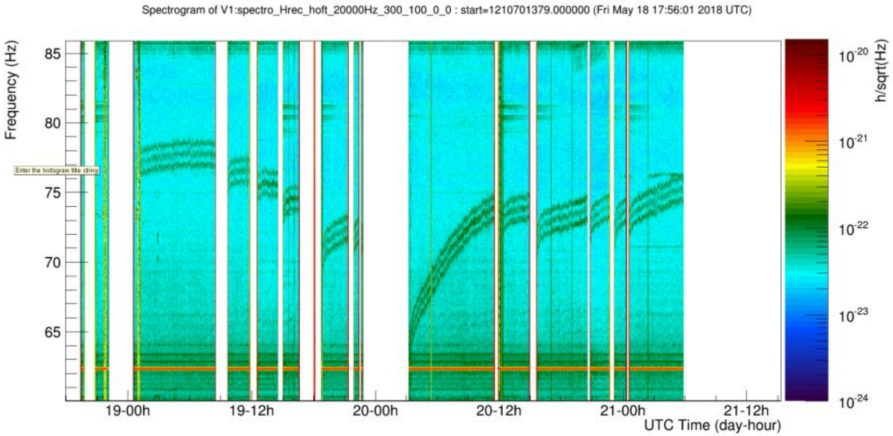
https://www.zooniverse.org/projects/zooniverse/gravity-spy

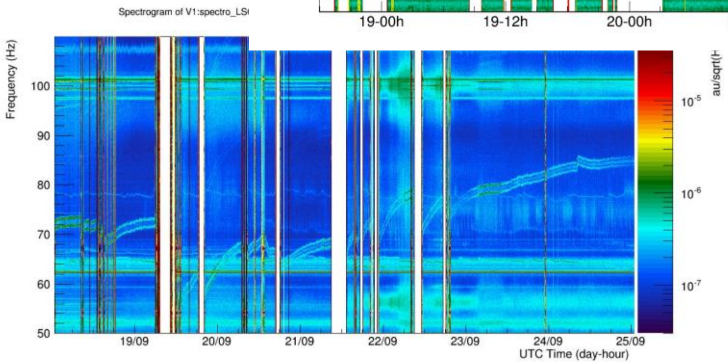
Example of Glitch signals



Example of other noise signals







I. Fiori courtesy

Numbers about data

Data Stream Flux	Data on disk	Number of events	Number of glitches
• 50MB/s	• 1-3PB	• 1/week • 1/day?	• 1/sec • 0.1/sec?

Should be analysed in less than 1min

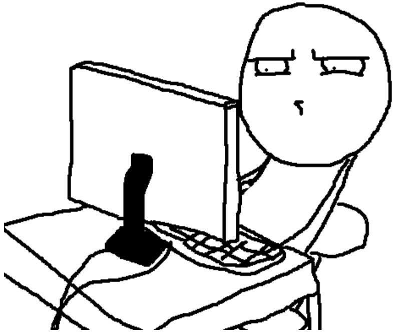
How Machine Learning can help

Data conditioning

- Non linear noise coupling
- Use Neural Network to learn noise
- Use Neural Network to remove noise

Signal Detection/Classification/PE

- A lot of fake signals due to noise
- Fast alert system
- Manage parameter estimation



What is going in the ML LIGO/Virgo group

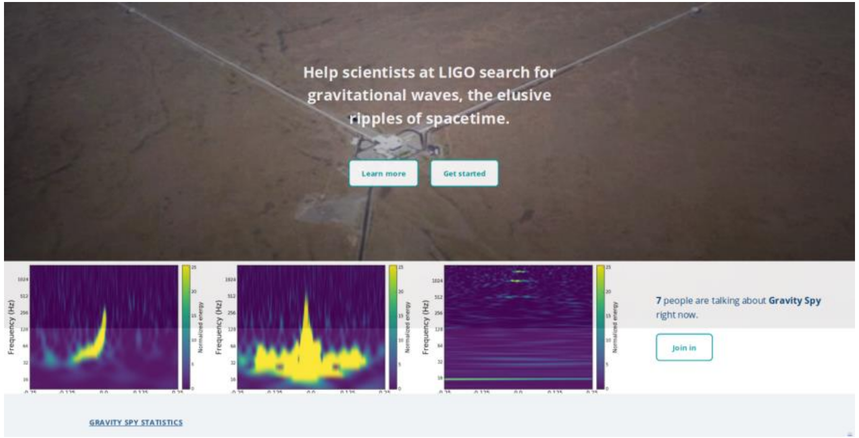
136 LIGO/Virgo members

30 active projects

>60 members at the last f2f meeting

Example of interesting works

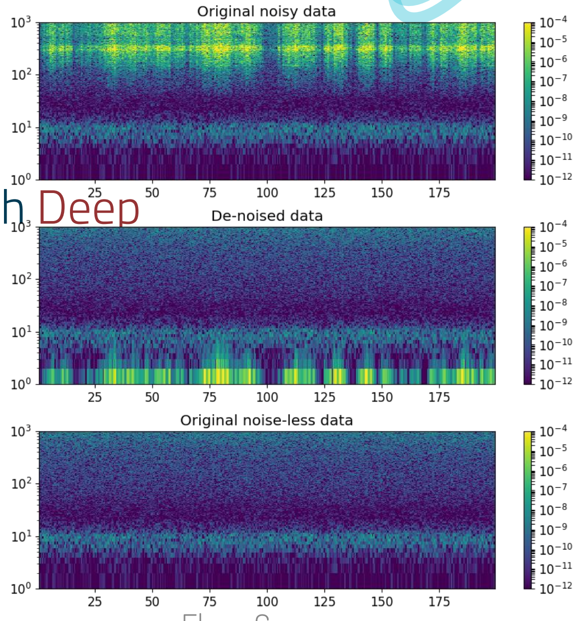
- Labelling glitches: Gravity Spy



S. Coughlin courtesy

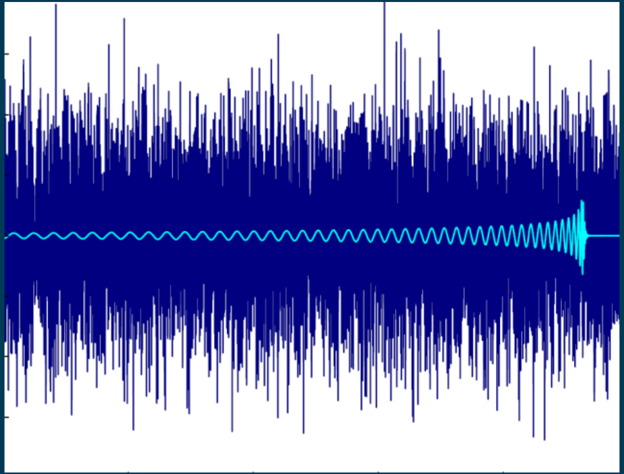
- Noise Removal

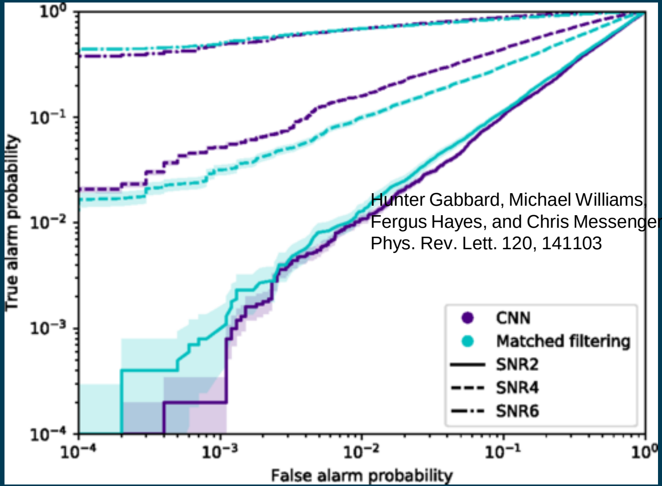
Non-linear and non-stationary noise subtraction with Deep Learning



G. Vajente courtesy

Signal detection





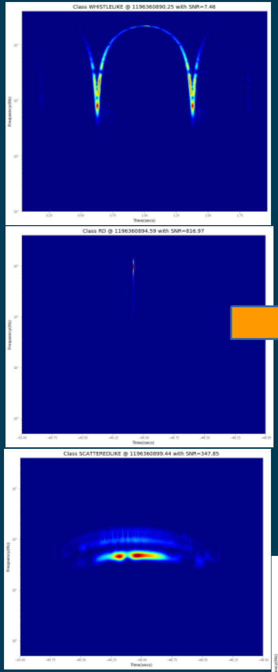
- Deep learning procedure requiring only the raw data time series as input with minimal signal pre-processing.
- Perfomance similar to Optimal Wiener Filter

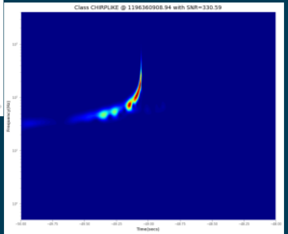
Glitch classification (M. Razzano's talk)

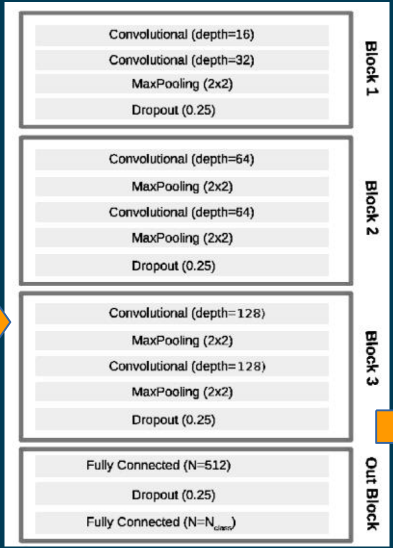
Massimiliano Razzano and Elena Cuoco

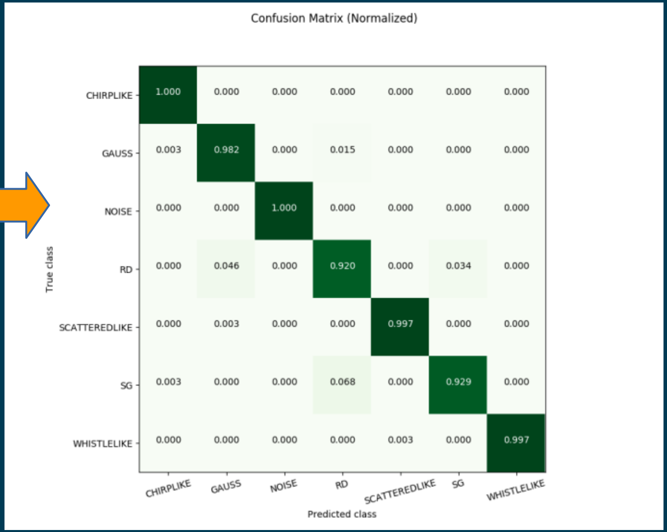
2018 Class. Quantum Grav. 35 095016

Deep learning with CNN



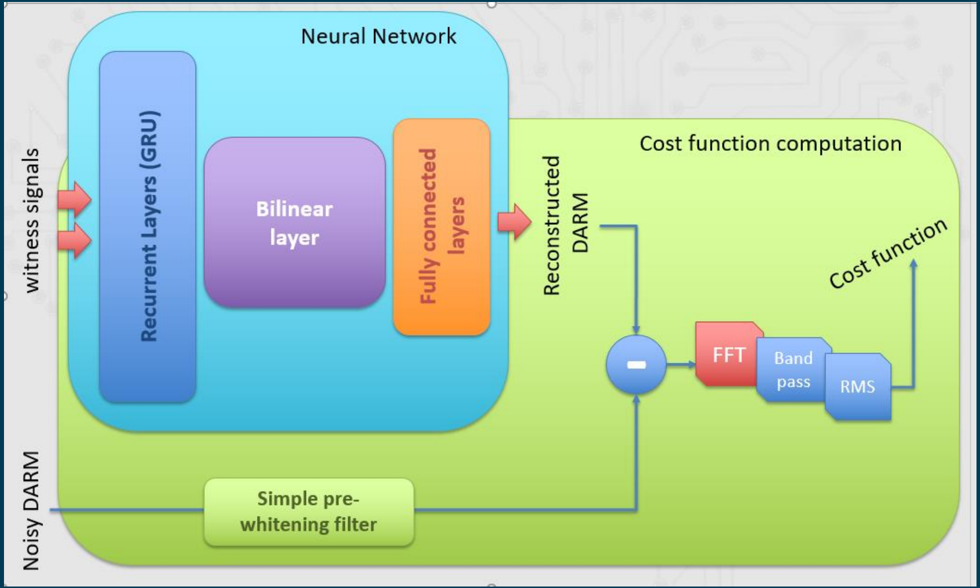


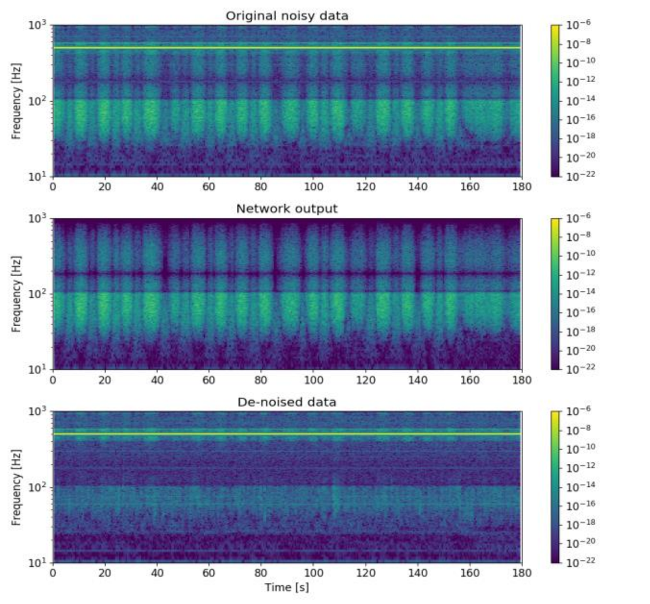




Noise removal trough Deep learning

Gabriele Vajente[1],
Michael Coughlin[1],
Rich Ormistom[2]
[1]LIGO Laboratory Caltech
[2]University of Minnesota Twin Cities





G2net: A network for Gravitational Waves, Geophysics and Machine Learning (COST Action 17137)

Main Proposer: E. Cuoco, EGO

G2net: goals of the ACTION

Facilitate conceiving innovative solutions for the analysis of the data of Gravitational Wave (GW) detectors.

Investigate possible solutions to monitor the low-frequency Newtonian noise through the use of adaptive robots.

Train a new generation of young scientists with broad skills in Machine Learning, GW, Control and Robotics.

Investigate new strategies for the handling/suppression of instrumental and environmental noise using Machine Learning techniques.

Bridge the gap between the disciplines of GW physics, geophysics, computer science and robotics

THANKS!

Questions after Max Razzano’s talk

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CREDITS: Presentation template by SlidesCarnival