GWitchHunters

Machine Learning and citizen science to improve the performance of Gravitational Wave detectors

Massimiliano Razzano[1,2]

Francesco Di Renzo[1,2], **Francesco Fidecaro**[1,2]

Gary Hemming[3], **Stavros Katsanevas**[3]

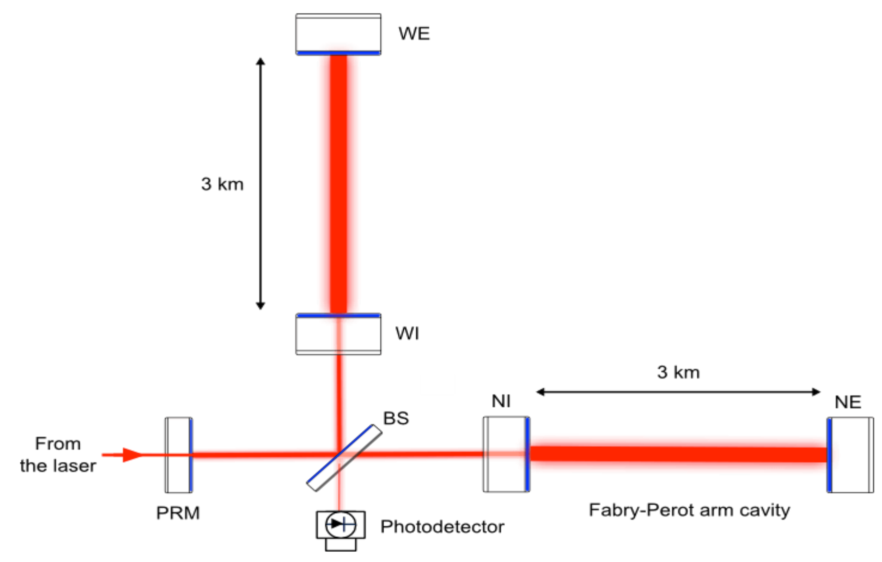
[1]Department of Physics, University of Pisa, [2]INFN, Sezione di Pisa,
[3]European Gravitational Observatory, Email: massimiliano.razzano@unipi.it

The Gravitational waves have opened a new window on the Universe and paved the way to a new era of multimessenger observations of cosmic sources. Second-generation ground-based detectors such as Advanced LIGO and Advanced Virgo have been extremely successful in detecting gravitational wave signals from coalescence of black holes and/or neutron stars. However, in order to reach the required sensitivities, the background noise must be investigated and removed. In particular, transient noise events called "glitches" can affect data quality and mimic real astrophysical signals, and it is therefore of paramount importance to characterize them and find their origin, a task that will support the activities of detector characterization of Virgo and other interferometers. Machine learning is one of the most promising approaches to characterize and remove noise glitches in real time, thus improving the sensitivity of interferometers. A key input to the preparation of a training datasets for these machine learning algorithms can originate from citizen science initiatives, where volunteers contribute to classify and analyze signals collected by detectors. We will present GWitchHunters, a new citizen science project focused on the study of gravitational wave noise, that has been developed within the REINFORCE project (a "Science With And For Society" project funded under the EU's H2020 program). We will present the project, its development and the key tasks that citizens are participating in, as well as its impact on the study of noise in the Advanced Virgo detector.

Citizen Science and Machine Learning

We have entered the era of Advanced detectors, with 3 observing runs successfully completed by LIGO and Virgo

- First joint LIGO-Virgo run in 2017 at the end of O2
- 90 event detected so far (Third GW Transient Catalog, GWTC-3)
- Detector characterization is crucial to assess data quality
- Transient noise events that impact data quality and mimic astrophysical signals
- Machine learning is a promising tool to classify and characterize glitches
- Citizen Science is a powerful tool for public outreach and contributing to GW science. GravitySpy project very successful



The Advanced Virgo detector (left) and its optical scheme (right). Credits: EGO/Virgo Collaboration

A Research & Innovation Project, supported by the EU H2020 SWAFS "Science with and for Society" work programme. Will create a series of cutting-edge **citizen science** projects on Frontier **Physics** research, including GWs, and with the goal of engaging>100,000 citizens.

The Project

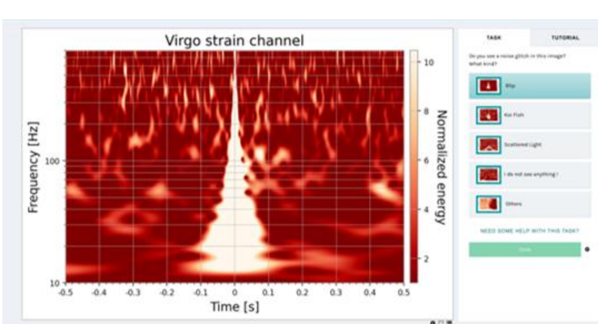
GWitchHunters is a REINFORCE project focused on citizen science to improve sensitivity of GW detectors

- Hosted on Zooniverse, the popular citizen science platform
- Data from Virgo O3
- Focused on glitch analysis and classification
- Different levels of increasing difficulty
- Playground Level with self-assessment and feedback
- Multilanguage support
- Data presented as spectrograms of GW main channel (hrec) + auxiliary channels
- Designed to complement and extend the GravitySpy project
- Launched in Nov 2021, after ~1 year development

The Tasks

Different tasks are offered to citizens, including glitch identification and classification

Levels of increasing difficulty, including Playground and Mobile Levels

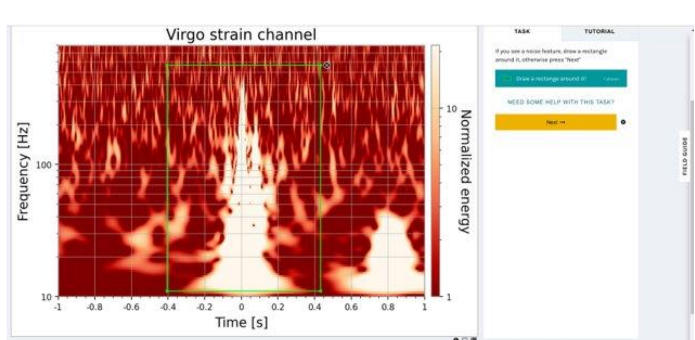


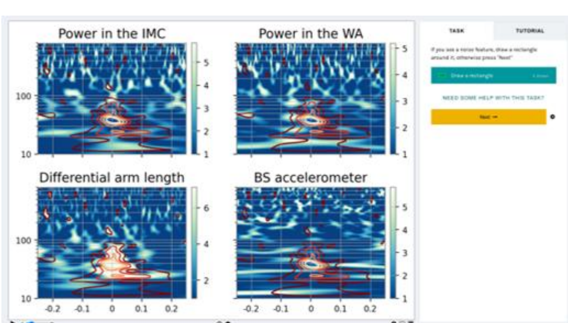
Classification

- Data as spectrograms
- Choose among known classes
- Search and propose new glitch classes

Identification

- Draw rectangles around glitches
- More glitches in images
- Linked with classification





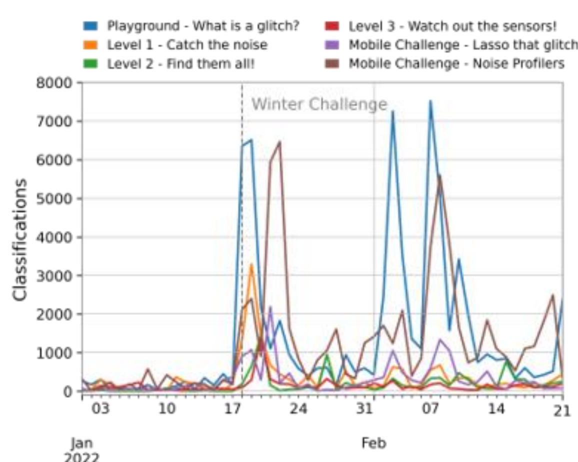
Auxiliary Channels

- 8 aux channels from local sensors
- Compare morphology with main channel $h_{rec}(t)$
- Search for glitch origin

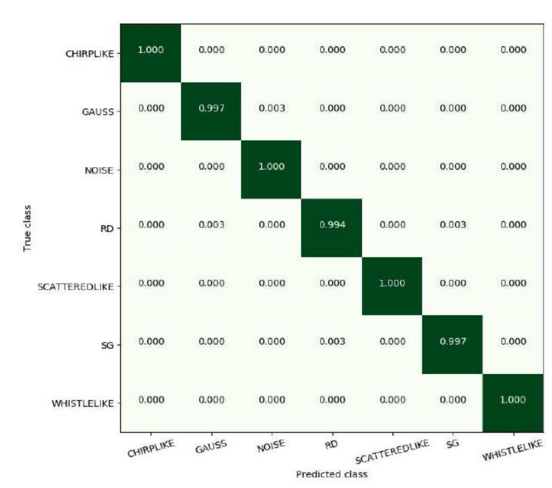
First Results

Data produced by the GWitchHunters platform serve as input for Machine Learning tools

- Officially launched on Nov 2021
- First Dataset (O3a data) almost done
- Added a new dataset (+2000 glitches from O3b)
- >2500 registered users
- 22% total completion
- Winter and Easter Challenges to boost engaging



- Dedicated Machine Learning tools to analyze data
- Spectrograms as 2D input for Convolutional Neural Networks
- Test on simulations, work in progress on data
- Output send to Virgo Glitch Database to be used in detector characterization work
- Fully automatic pipeline aiming at O4 (Dec 2022)



CNN 2D Confusion matrix for simulated data (Razzano&Cuoco 2018)

References

- Acernese et al., 205, CQG, 32, 024001
- Abbott B.P., et al., 2016, PRL, 116, 061102
- Abbott B.P. et al 2022, arXiv:2111.03606
- Zevin et al, 2017, CQG,34,6
- George, D., and Huerta, E., 2018, PRD,97,044039
- Razzano, M. and Cuoco, E., 2018, CQG,35,9

This Project has received funding from the EU H2020 project call H2020-SwafS-2018-2020 funded project Grant Agreement no. 872859