RESEARCH PROJECT: Gravitational Wave Observational Science: Detection and Analysis of Gravitational Waves Data.

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Research Area: Fis/01(PE2)

Gravitational Wave (GW) physics is one of the most outstanding research fields of these years. Since the discovery of the first GW signal back in 2015, this area of studies has been incredibly developed and largely widened. The use of interferometers, actually in the LHV configuration, but foreseen also the LHVK with Kagra, has shown us the capability of these instruments to detect GW from various astrophysical phenomena. In the future also the Einstein Telescope is expected in GW discoveries. Detecting such signals is a challenge, from the high-tech hardware component to the advanced algorithms and pipelines developed in order to simulate GW signal or for data analysis, this research area is highly promising for future scientific discoveries.

Gravitational Wave physics is my interest. I have worked in this field since my Master Thesis. In my work I have studied the detection and reconstruction of a Long Duration Gravitational Wave signal using coherent WaveBurst algorithm. For this reason I have been associated with the LIGO-VIRGO collaboration.
The coherent WaveBurst (cWB) Pipeline is employed by the LIGO-Virgo collaboration to search for Gravitational Wave transient signals with unmodeled techniques; it has been developed with the contribution, among others, of the Florida LIGO and Padova-Trento Virgo group. My thesis work focuses on the optimization and the set-up of the pipeline for the incoming O4 data taking, tuned for the three detector network configuration formed by LIGO-Virgo interferometers. Goals of the thesis work are also the capability of the pipeline to inspect parameters of the signals such as frequency, length etc. In particular several configurations of parameters of the incoming O4 data acquisition campaign have been taken into account, comparing the results in order to study the response of the algorithm to these new sets. Morphologies of GW signals produced by different astrophysical phenomena have been taken into account in order to test the capability of the pipeline to reconstruct a wide variety of signals.
In order to discover GW signals among the noise we must face a wide range of challenges. In order to do so, the post production phase of analysis, where cuts are applied to the triggers obtained in the production, must be performed. To solve this problem, we can also rely on Artificial Intelligence, which can help us in tuning the parameters to apply in the post production phase and maximizing the efficiency.

In my work the tuning parameters of the machine learning algorithm XGBoost which features the pipeline has been studied in order to optimize the performances of the reconstructing signal algorithm. A test which includes a wide range of morphologies of GW has been used to train the algorithm in order to test the capability of the XGBoost to detect an unknown GW signal.

My proposal of research for this PhD opportunity is to contribute in developing the coherent WaveBurst pipeline in continuity with my thesis and to use it to analyze the data of the O4 LIGO-Virgo science run, since the next data acquisition campaign for the LIGO-VIRGO detectors network is scheduled to start in mid december 2022 this is a great opportunity for relevant scientific discoveries: in particular not relying on templates, cWB has the potentiality to detect new GW signals with respect to the compact binary coalescence.
More generally, contributing to the research using other algorithms and data analysis techniques is in my scientific and academic interests. Developing codes for statistical analysis of triggers and the efficiency of the pipelines in analyzing the data is deeply important for an effective study: also, the background and the monte carlo analysis for the mock-data challenge is fundamental in this research area, especially for the foreseen sensitivity of O4. The main results of this PhD project is to detect Gravitational Waves Signals and/or set upper limits of their magnitude

For this PhD experience a possible roadmap could be the online data analysis of O4 for the first year, the offline data analysis of O4 for the second year and the preparation for O5 in the last year.

My hope for this PhD opportunity in Università degli Studi di Urbino is to go into detail about this research field, using cWB algorithm, but also considering other algorithms and developing techniques for data analysis for Gravitational Physics discovery.

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