Data analysis in the context of Gravitational Waves detection

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Complexity is ubiquitous behavior in the nature and any conceivable approaches to deal with data acquisition essentially includes stochastic notion. In astronomy and cosmology, especially due to initial conditions and because of other relevant phenomena such as foreground effects, the stochastic behavior has vital impact on extracting reliable information from recorded data. Such data sets are usually manipulated by trends and noises. Statistical model buildings for noises, trends, and signals play crucial roles in any parametric detection. Subsequently, it is necessary to implement robust and novel methods for detrending and denoting of underlying signals. For high precision measurements in many modern experiments, traditional methods which are affected by unknown trends and noises and almost rely on model dependent data reconstruction may result in spurious results [1], therefore, the probabilistic frameworks according to statistical points of view lead to robust method not only in data analysis but also in preparing reliable strategy to predict the evolution of underlying process. In this context, topological, geometrical and scaling properties of underlying processes play crucial roles and prepare prominent approaches [2–7].

Utilizing mentioned features to examine Gravitational Waves (GWs) produced by different sources which are superimposed by various trends, noises and intervening complex phenomena such as seismic, gravity-gradient, anthropogenic noise and foreground can be more useful tools not only for GWs detection but also for determining the type of corresponding sources in wide frequency range [8–11]. Both direct and indirect detections of GWs are almost elusive compared to other observations and to obtain any measurable signature, the incorporating much more complicated data analysis methods undoubtedly leads to more reliable and robust results [12]. To do furtherer investigation, topological data analysis in the banner of algebraic topology is another convenient method for searching GWs and to discriminate between noise and signal. Making the feature vectors according to topological and geometrical methods and using the so-called machine learning method as exploring in the algorithms and measures to build data-driving approaches for classification and clustering is also able to elucidate which measures are more sensitive with respect to the different types of GWs and other cosmological exotic features [13–21]. Particularly, deep convolutional neural networks as a complementary aspect of matched filtering techniques, to detect the GW signature of merging black holes have been proposed [21]. In addition, making a sequence of various measures to construct optimum pipeline is another feasible approach, accordingly a considerable improvement in capability of combined algorithms arises compared to utilize methods, separately. As an illustration, recently, I. Eghdami et al., relied on the self-similarity properties of fluctuation function constructed from Pulsar timing residuals to explore the footprint of stochastic gravitational waves. In the presence of GWs, the undulation of spacetime would squeeze and stretch the interspace that the pulsars radiation propagates through it and consequently, there would be a signature on the high precise measurement of residuals [22–24]. They proposed new measure to compute quadrupolar signature in the presence of irregularity in recorded observed data sets [25]. They also demonstrated that new quadrupolar signature is more robust in the presence of noise and trends compared to common feature called Hellings-Down curve [26].

Finally, it is worth noting that, there is a good opportunity in the precision era of GW detection from speculative events for producing GWs ranging from late phenomena to early and primordial sources to take into account facilities provided in the notion of data science and complex systems points of view. There is no doubt that to encompass the challenges for gravitational wave detection at high and low frequencies, we should combine different methods and ultimately, make pipelines for detection, classification purposes, to carry out more stringent evaluations of Einstein general theory of relativity and even to explore our mysterious cosmos with new probe [12, 27–29].

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