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CCSNe detection perspectives with Einstein Telescope

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Abstract. Core collapse supernovae are the most energetic explosions in the modern Universe and, because of their properties, they are considered a potential source of detectable gravitational waveforms for long time. The main obstacles to their detection are the weakness of the signal and its complexity, which cannot be modeled, making it almost impossible to apply matching filter techniques as the ones used for detecting compact binary coalescences. Although the first obstacle will probably be overcome by next-generation gravitational wave detectors, the second one can be overcome by adopting machine learning techniques. In this contribution, a novel method based on a classification procedure of the time-frequency images using a convolutional neural network will be described, showing the CCSN detection capability of the next-generation gravitational wave detectors, with a focus on the Einstein Telescope.

1 Introduction

Core collapse supernovae (CCSN) have attracted the attention of Gravitational Wave (GW) astronomers for a long time. They are powerful explosions triggered by the collapse of massive stars, i.e. stars with a mass above $8M_{\odot}$. Accordingly to current models [1], in a supernova explosion, GWs are generated in the inner core of the source, thus carrying direct information about the inner mechanism of this phenomena. However, despite they are one of the most energetic events in the universe, the expected GW emission is too weak to be detected at extra-galactic distances, i.e. the expected GW strain amplitude from a CCSN in the center of Milky Way ranges between 10^{-21} and 10^{-23}. Furthermore, due to the high-level of complexity, the predicted GW signals are intrinsically stochastic, making not feasible the use of modelled techniques such as matched filtering. The current approaches used in CCSNe searches employ model-free algorithms that rely on excess of power to identify signals buried in detector noise, such as coherent Waveburst (cWB). Machine learning techniques represent a robust alternative because of their capability of resolving ambiguity and tolerate unpredictability with a minimal human supervision.

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2 The method

In [2] and [3] a novel and promising method based on a classification procedure of the time-frequency images using a Convolutional Neural Networks (CNNs) was explored, with the aim of recognizing the peculiarities of the CCSN GW signal. The method relies on the use of phenomenological waveform templates, they are built to mimic the signal most prominent features and they are used to feed the network during the learning phase. In this work, two classes of phenomenological waveform have been employed: standard, for progenitor masses above $10M_\odot$, and short, for progenitor masses between $8M_\odot$ and $10M_\odot$. These have been injected inside the detector noise obtained by considering the three main Einstein Telescope (ET) [4] detector configurations proposed so far. Once the network has completed the learning phase using these phenomenological template, waveforms taken from 3D numerical simulation are employed to test the classification performances.

3 Results and discussion

The results obtained are shown in Fig.1. Among the three detector configurations explored, the 2L with parallel and 45° inclined arms with 15 km length arms appeared to achieve the best results in term of detection efficiency with respect to the triangular shape with 10 km length arms. On the other hand, between the two signal classes, the short waveforms are more easily detectable accordingly to this method. The next step of this work will include new detector configurations, e.g. Cosmic Explorer, and refined phenomenological waveforms to better fit numerical simulation outcomes.

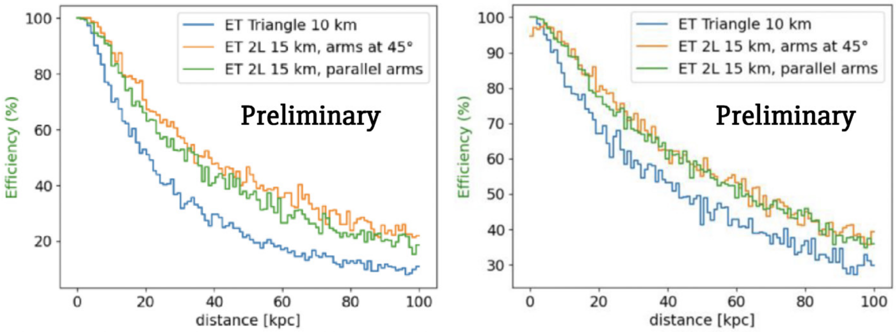

Figure 1. Detection efficiencies for the three ET detector configurations proposed. Standard waveforms on the left and short waveforms on the right.

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