Detection of Einstein Telescope gravitational wave signals from binary black holes using CNNs

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Abstract

The recent detection of Gravitational Waves has opened a new era of multimessenger astrophysics, where vast amount of data is expected to be delivered from the current observatories such as the advanced Laser Interferometer Gravitational-wave Observatory and the upcoming ones such as the Einstein Telescope (ET). The ET will revolutionise the field of GWs in every sense including and most importantly the better sensitivity of one order of magnitude that will provide, which will allow the detection at lower frequency. The ET -compared to second generation detectors- will have a wider accessible frequency band that can be used to investigate a huge number of key issues related to astrophysics, fundamental physics and cosmology. The ET will have an annual detection rate for BBHs and BNSs of order $10^5 - 10^6$ and 7×10^4 respectively, which will make the traditional methods for detections and parameters estimation inefficient, and computationally expensive. This motivates the necessity for developing an automated procedures to handle the detection process and parameters estimation.

Task

Explore the possibility of using frequency-time domain (spectrograms) for the detection of BBHs in the ET data using Convolutional Neural Networks (CNNs).

Simulation

LALSimulation and PYCBC Software packages were used for the generation of our GW signals and noise samples. 10,000 signal were generated with: SNR: 4 – 280 and signals duration: 0.29 – 0.93 Second. Each source was injected into 5 seconds long noise.

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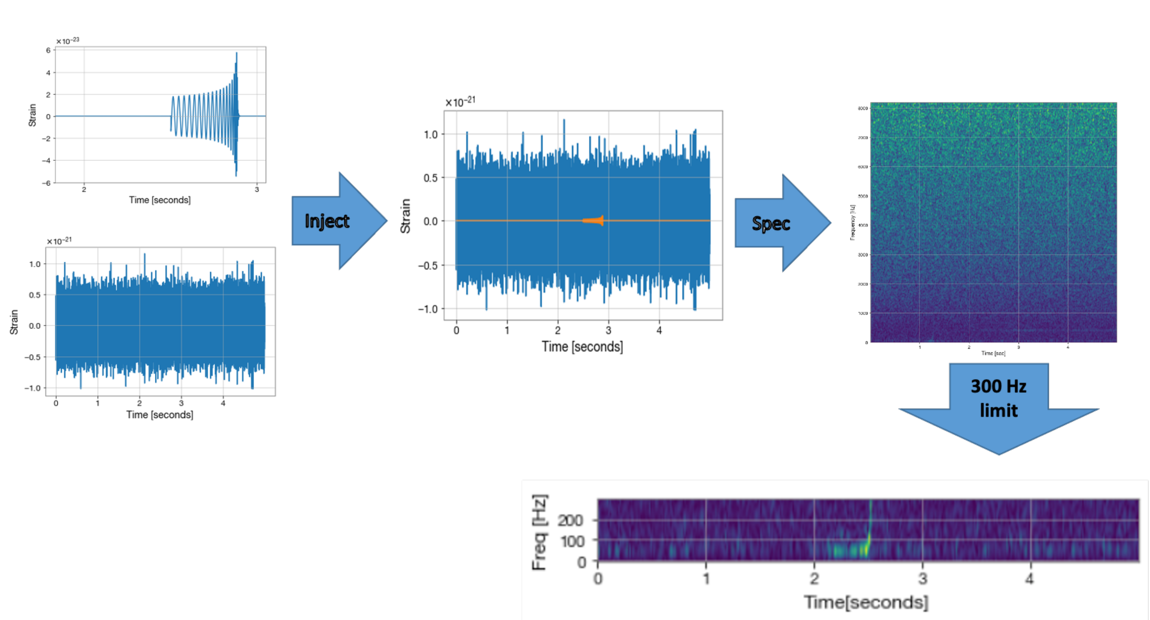
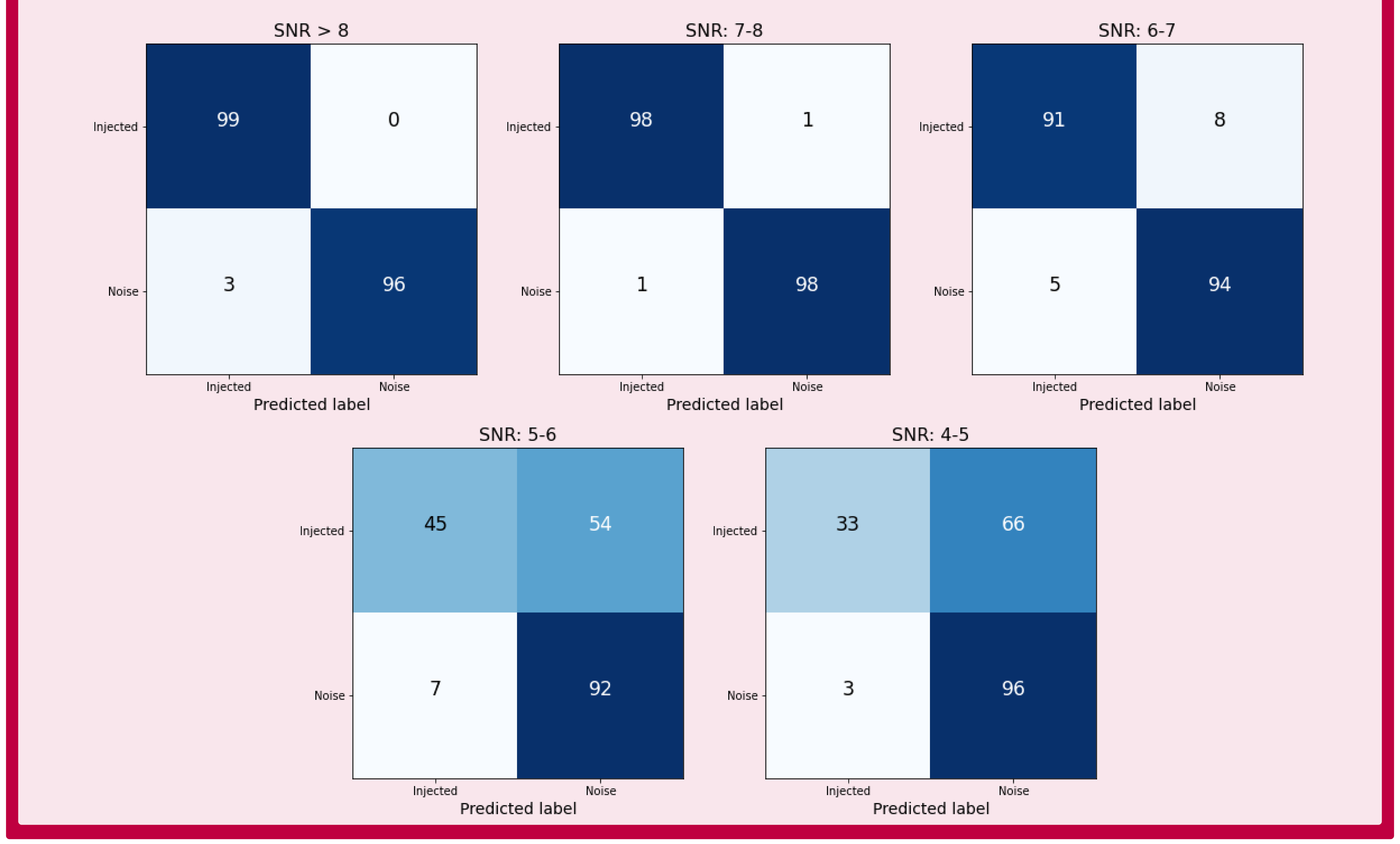
Pycbc parameters	Values
Detector	Einstein Telescope (E1)
RA and Dec	Random (uniform distribution)
Type of sources	BBHs
M1 and M2	15 – 56 Solar mass
Distance	149 – 40,174 Mpc
Inclination angel	Random choice between 0.5 and pi
Starting frequency (f_low)	30 Hz
Delta_t	1.0/16384
Polarization phase	Random choices between 0.5 and 2 pi
Coalesence phase	Random choices between 0.5 and 2 pi

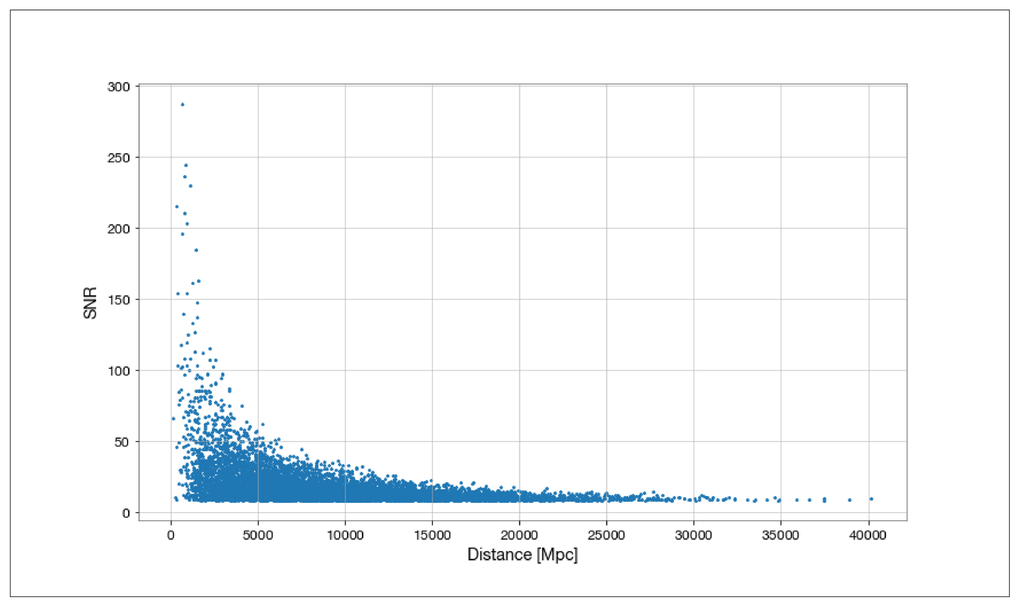
Data Preparation



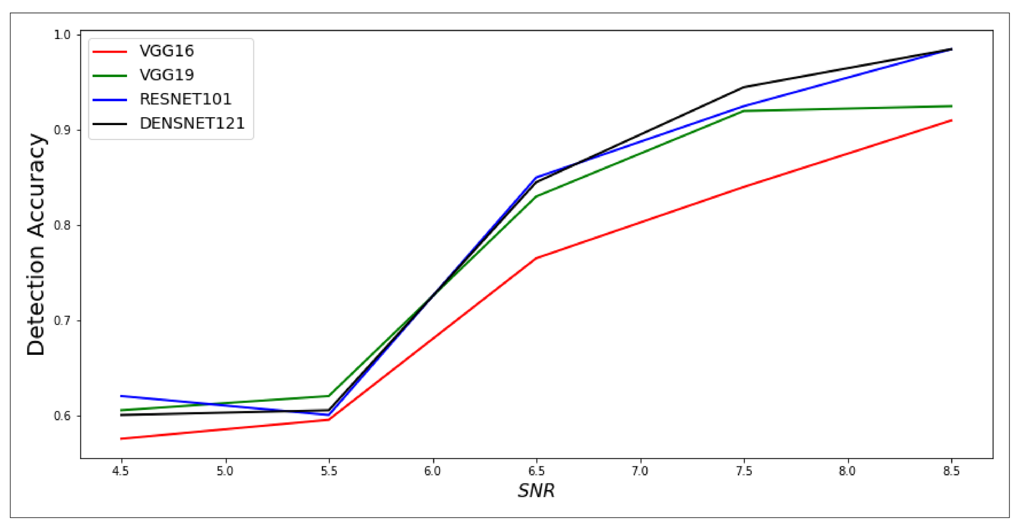
Model Results



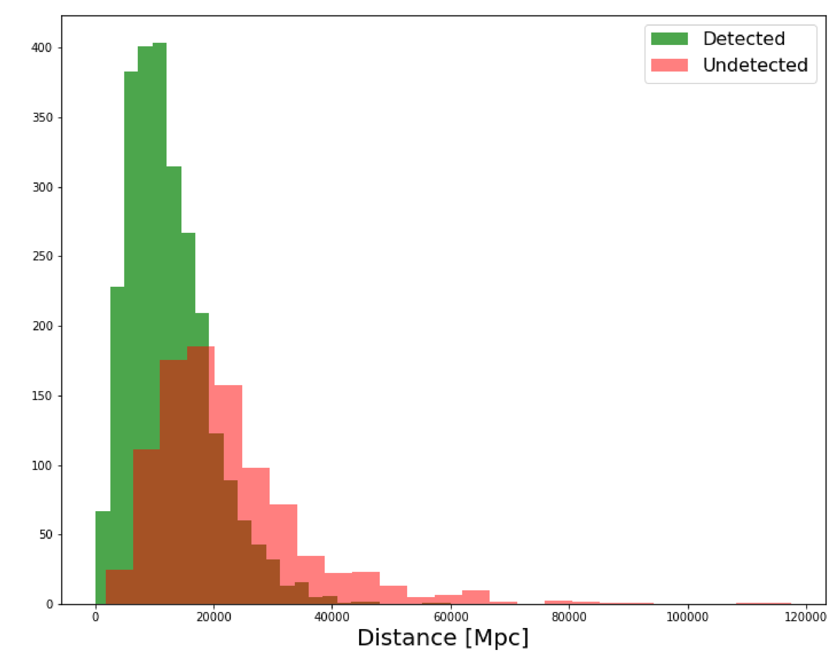
BBHs sources

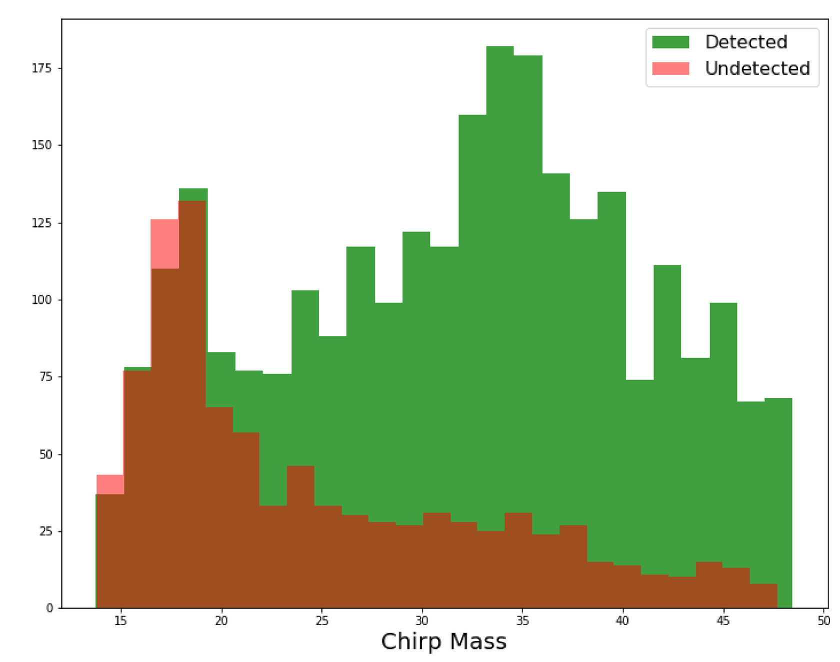


Accuracy VS SNR

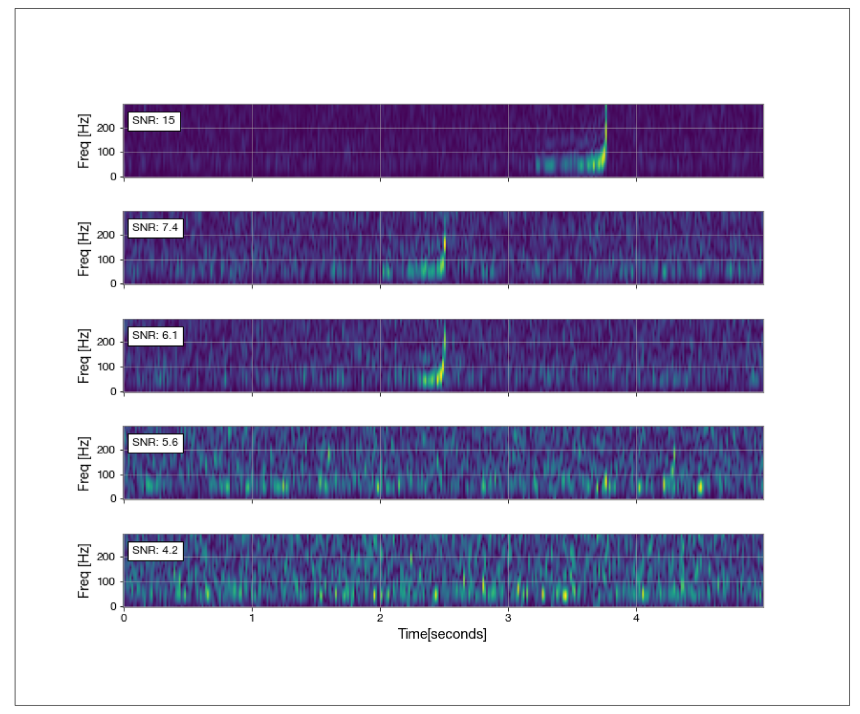


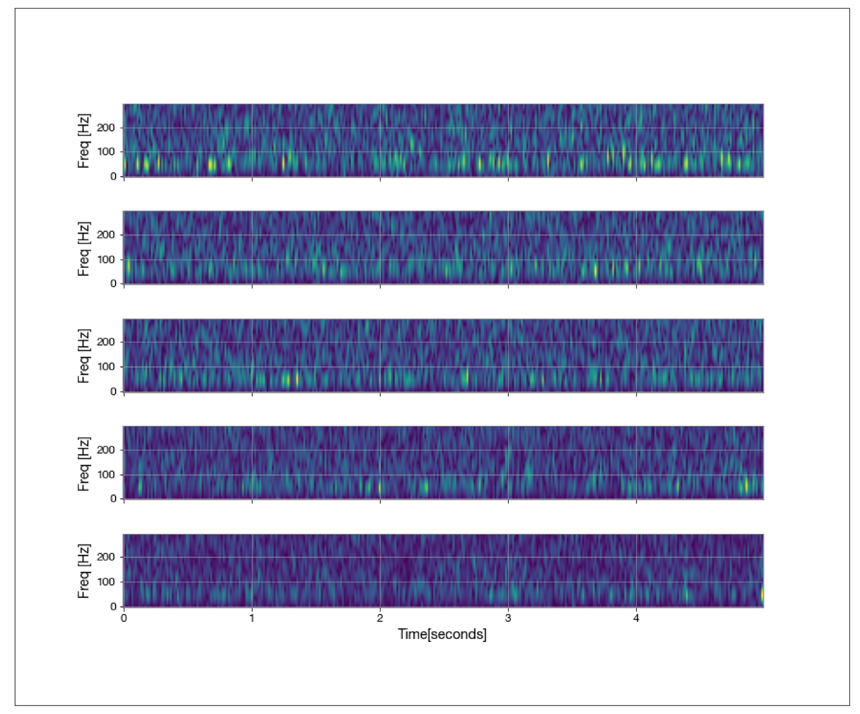
Detected and undetected sources



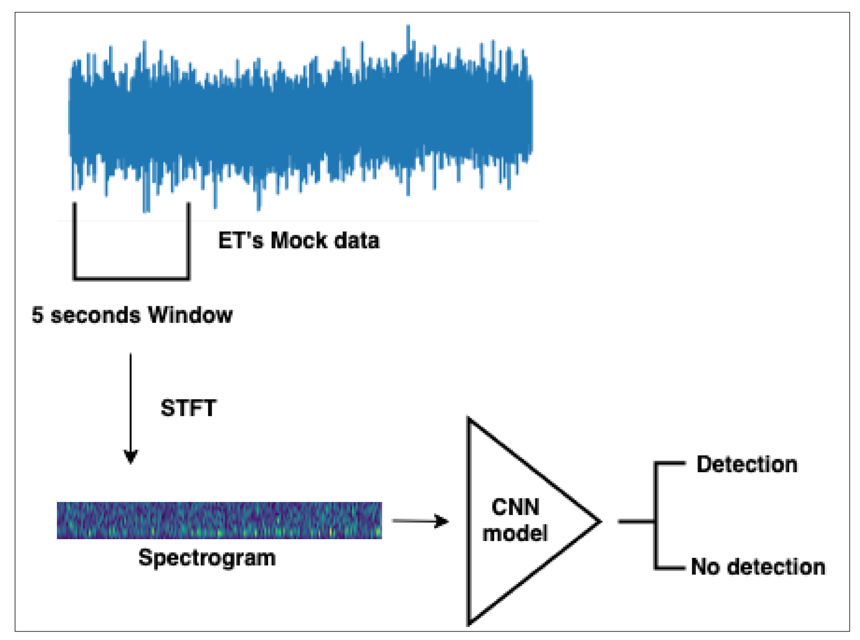


Data samples





Evaluation on ET's synthetic data



Hours	SNR range	Total	Detected	FAR
1st	>8	723	722	0.001
2nd	7-8	723	713	0.014
3rd	6-7	723	687	0.050
4th	5-6	723	336	0.535
5th	4-5	723	208	0.712
6th	Noise only	0	24	0.033

References

All ref. listed at: https://github.com/wathela/et-detector.

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