Deep learning for intermittent gravitational waves

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Abstract

- Many black hole binary mergers that can not be detected as individual events will form a stochastic gravitational-wave background. If the merger rate is low so that each waveform is not overlapped, the stochastic gravitational-wave background is expected to have non-Gaussianity.

- We propose the use of deep learning to capture the non-Gaussianity. We demonstrated our method for toy model of stochastic background and showed the neural network can extract the non-Gaussianity.

23rd International conference on General relativity and gravitation, 3rd-8th July 2022

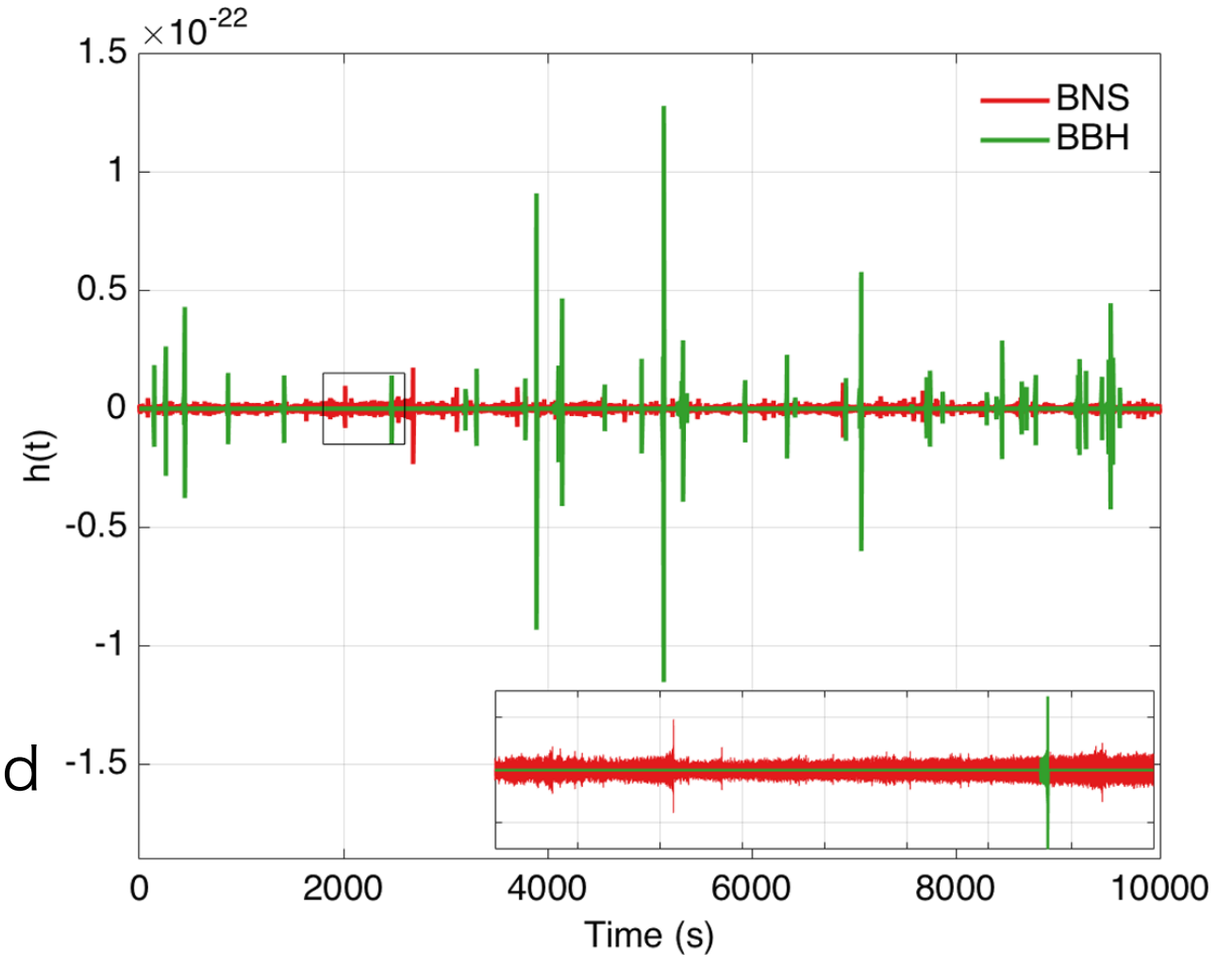
Astrophysical SGWB

Continuous or intermittent

Ensemble of BBH signals
is considered to emerge as
stochastic background.

Ensembles of BBH signals have
intermittency. (Rarely overlapped)

Considering the intermittency is expected
to improve the detection efficiency.



LIGO/Virgo, PRL120, 091101 (2018)

Duty cycle

$$\xi \sim R_{\mathrm{event}} T_{\mathrm{dur}}$$

R_{event} :event rate, T_{dur} :burst duration

Deep learning application

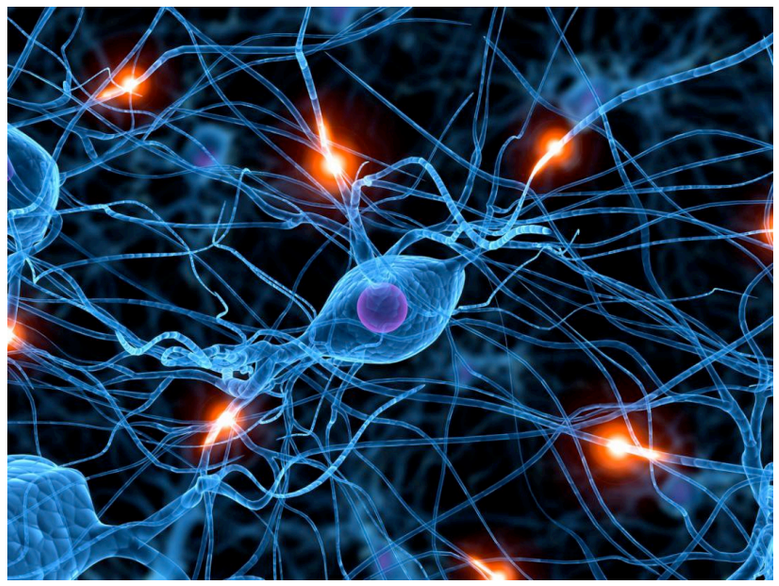
Artificial neural network (ANN) in a nutshell

e.g. Goodfellow *et al.*, “Deep learning” as a textbook

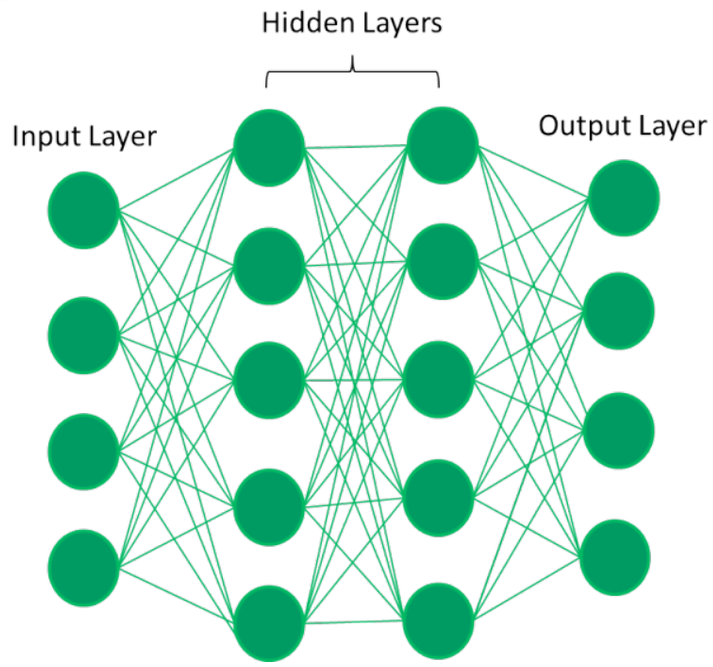
✓ ANN is inspired by the structure of a human brain, mimicking the way that biological neurons signal to one another.

✓ Highly non-linear function controlled by many parameters.

✓ ANN’s parameters are optimized using a training dataset before we apply ANN to test data or a real event.



https://medium.com/predict/artificial-neural-networks-mapping-the-human-brain-2e0bd4a93160



https://developer.nvidia.com/blog/digits-deep-learning-gpu-training-system/

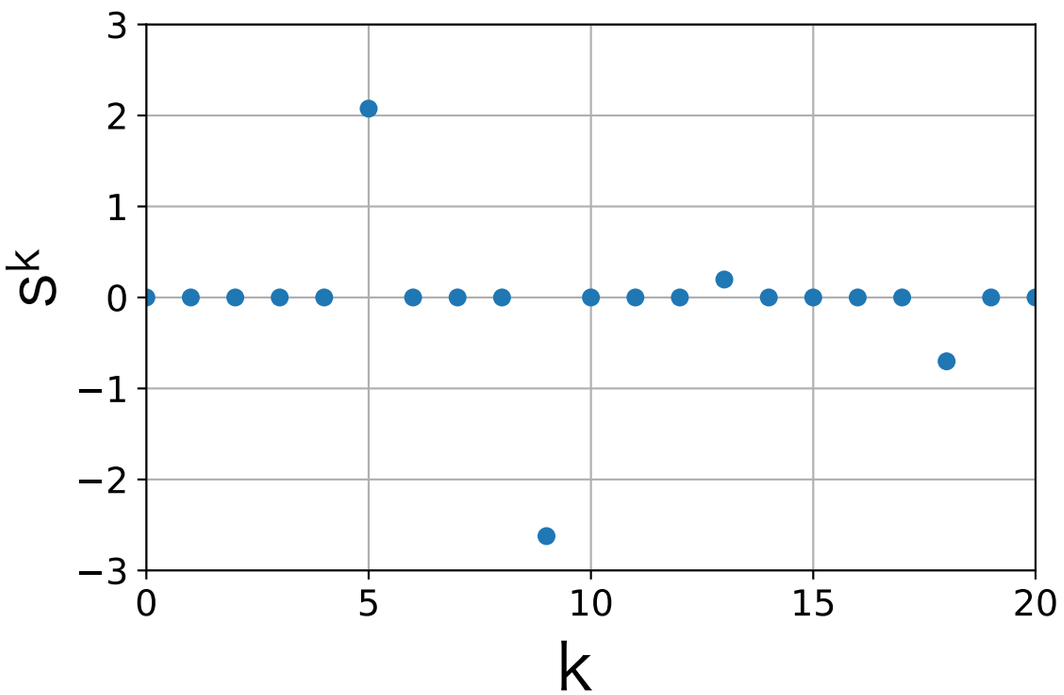
Toy model of SGWB

Signal model

Drasco & Flanagan, PRD67, 082003 (2003)

- A burst is modeled by a peak at one time bin
- Signal model

$$p(s^k \mid \xi, \alpha^2) = \xi \frac{1}{\sqrt{2\pi\alpha^2}} \exp\left[-\frac{(s^k)^2}{2\alpha^2}\right] + (1-\xi)\delta(s^k)$$

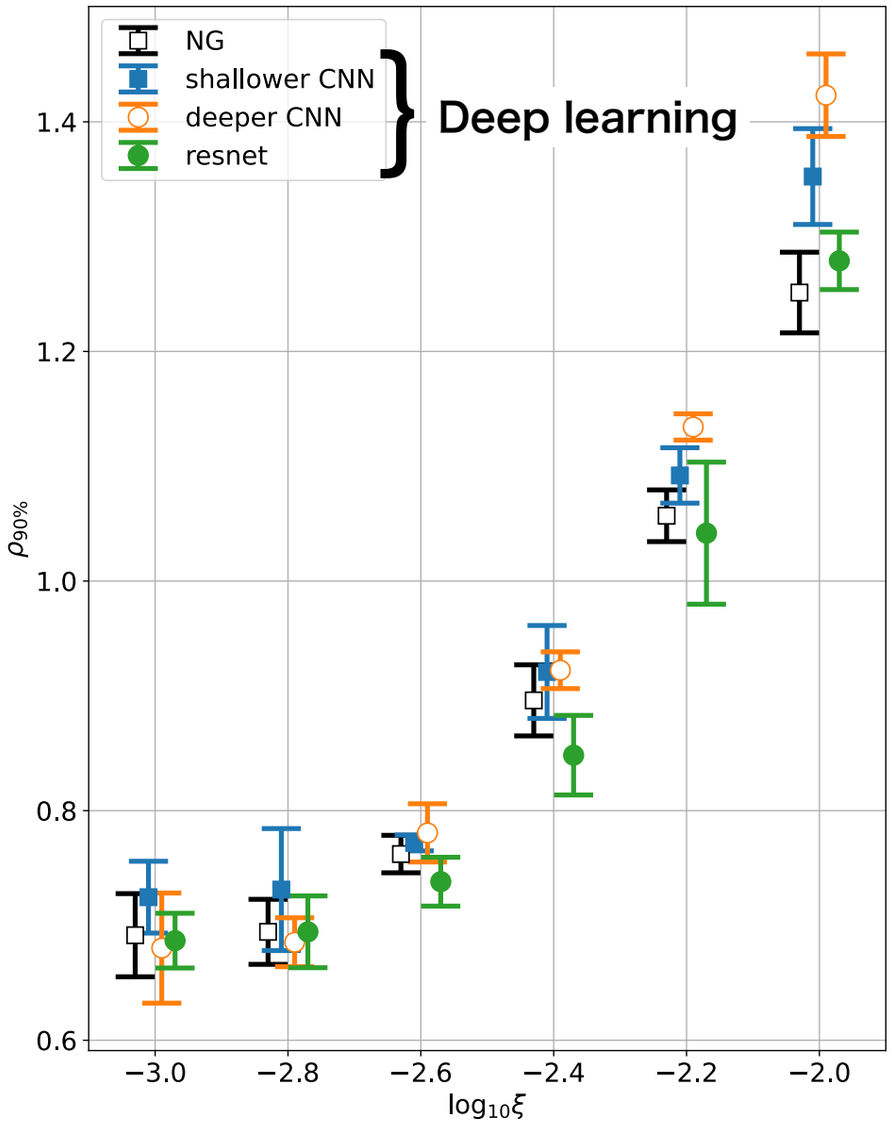


$\xi \in [0,1]$:duty cycle, ($\xi \to 1$: Gaussian)

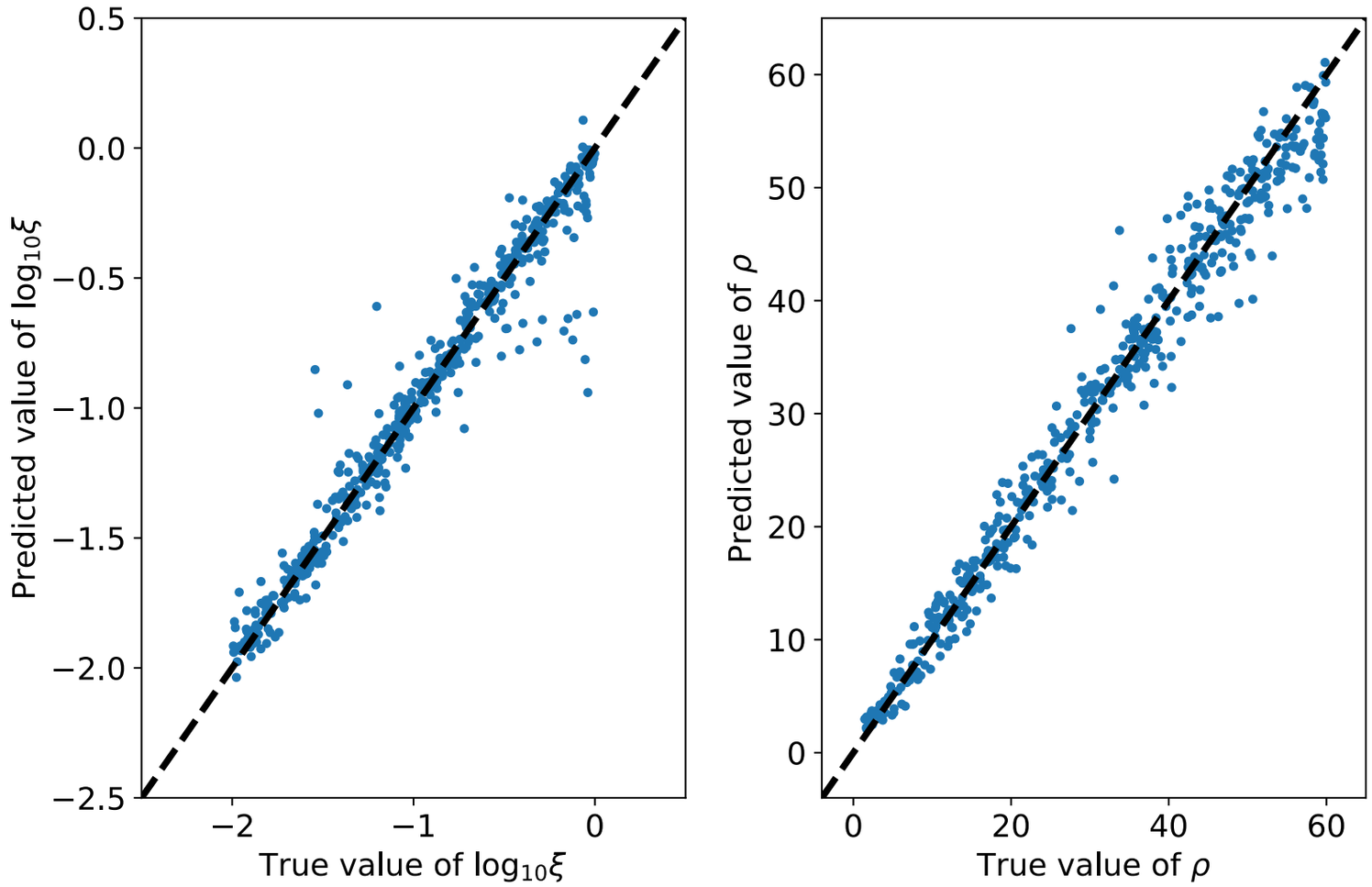
α^2 : amplitude variance of each burst

Results

Demonstration with toy model



Minimum SNR that the signal can be detected with 90% efficiency.



Scatter plot of true values vs predicted values of duty cycle and SNR.