# SpecGrav - Detection of Gravitational Waves using Deep Learning

Authors: Hrithika Dodia, Himanshu Tandel Mentor: Prof. Lynette D'Mello
Affiliation: Dwarkadas J. Sanghvi College of Engineering, Vile Parle, Mumbai, Maharashtra, India.

## INTRODUCTION:

Gravitational waves are ripples in the fabric of space-time that travel at the speed of light. The detection of gravitational waves by LIGO is a major breakthrough in the field of astronomy. It is a Nobel Prize winning discovery that substantiates Einstein's general theory of relativity. When gravitational waves reach us their amplitude is smaller than the diameter of a proton. Therefore, highly sensitive instruments are required to detect them. To find these waves in detector noise is a meticulous task. In case of binary neutron star merger, gravitational waves are accompanied by their electromagnetic counterparts. Therefore, rapid detection of gravitational waves in such events is very crucial. We present the solution for swift detection of gravitational waves from binary black hole (BBH) merger and binary neutron star (BNS) merger from spectrograms of signals using 2D Convolutional Neural Network.

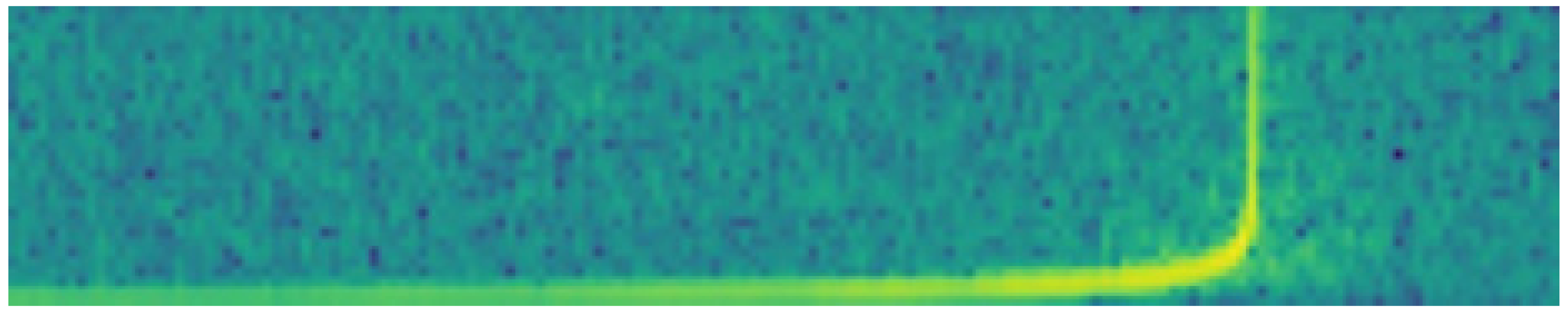
## METHOD:

- Our dataset contains spectrograms of signals belonging to three classes:
  1. BBH merger
  2. BNS merger
  3. Noise
- We use 2D Convolutional Neural Network for detecting gravitational waves from these spectrograms.
- Building a deep learning model with spectrogram instead of time series is a far more resource conservative way and also saves time required in the training phase of the neural network.
- We had first tried to achieve this task by training our model on simulated noise but it had poor performance on real LIGO events despite of having 100% validation and test accuracy.
- However, our final model is trained on data having real LIGO noise and thus gives very good results when evaluated on real LIGO GW events.

## HIGHLIGHTS:

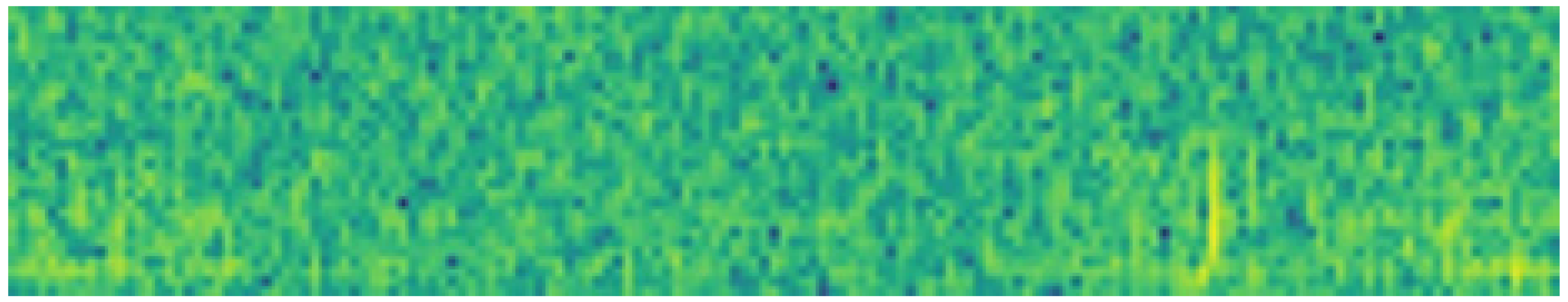
- Very less training time of about just 19 min.
- Very less memory requirements (trained on a 2 GB GPU).
- Better results produced by model trained on data containing real LIGO noise as compared to model trained on data having simulated LIGO noise.

### How different is the spectrogram of GW signals in simulated noise from spectrogram of GW signal in real LIGO noise?



Spectrogram of BBH merger gravitational wave signal injected in simulated noise with optimal SNR = 15

VERSUS



Spectrogram of BBH merger gravitational wave signal injected in real LIGO noise with optimal SNR = 24

AUTHOR CONTACT
Hrithika Dodia
hrithikadodia19@gmail.com

## RESULTS:

Results of our final model trained with data containing LIGO detector noise tested on real LIGO GW events:

| NAME OF EVENT | TYPE | RESULT |
|---|---|---|
| GW150914 | BBH MERGER | ✓ |
| GW151012 | BBH MERGER | ✗ |
| GW151226 | BBH MERGER | ✗ |
| GW170104 | BBH MERGER | ✓ |
| GW170608 | BBH MERGER | ✓ |
| GW170729 | BBH MERGER | ✓ |
| GW170809 | BBH MERGER | ✓ |
| GW170814 | BBH MERGER | ✓ |
| GW170817 | BNS MERGER | ✓ |
| GW170818 | BBH MERGER | ✓ |
| GW170823 | BBH MERGER | ✓ |

NOTE: In the above table ✓ indicates correct prediction and ✗ indicates incorrect prediction.

## REFERENCES:

[1] D. George and E. Huerta, "Deep neural networks to enable real-time multimessenger astrophysics," Physical Review D, vol. 97, no. 4, 2018.
[2] D. George and E. Huerta, "Deep Learning for real-time gravitational wave detection and parameter estimation: Results with Advanced LIGO data," Physics Letters B, vol. 778, pp. 64-70, 2018.
[3] P. G. Krastev, "Real-time detection of gravitational waves from binary neutron stars using artificial neural networks," Physics Letters B, vol. 803, 2020.
[4] P. G. Krastev, K. Gill, V. A. Villar and E. Berger, "Detection and parameter estimation of gravitational waves from binary neutron star mergers in real LIGO data using deep learning," Physics Letters B, vol. 815, 2021.
[5] W. Wei and E. Huerta, "Deep learning for gravitational waves forecasting of neutron star mergers," Physics Letters B, vol. 816, 2021.
[6] T. D. Gebhard, N. Kilbertus, I. Harry and B. Schölkopf, "Convolutional neural networks: A magic bullet for gravitational-wave detection?," Physical Review D, vol. 100, no. 6, 2019.
[7] J. P. Marulanda, A. E. Romano and C. Santa, "Deep learning merger masses estimation from gravitational waves signals in frequency domain," Physics Letters B, vol. 810, 2020.