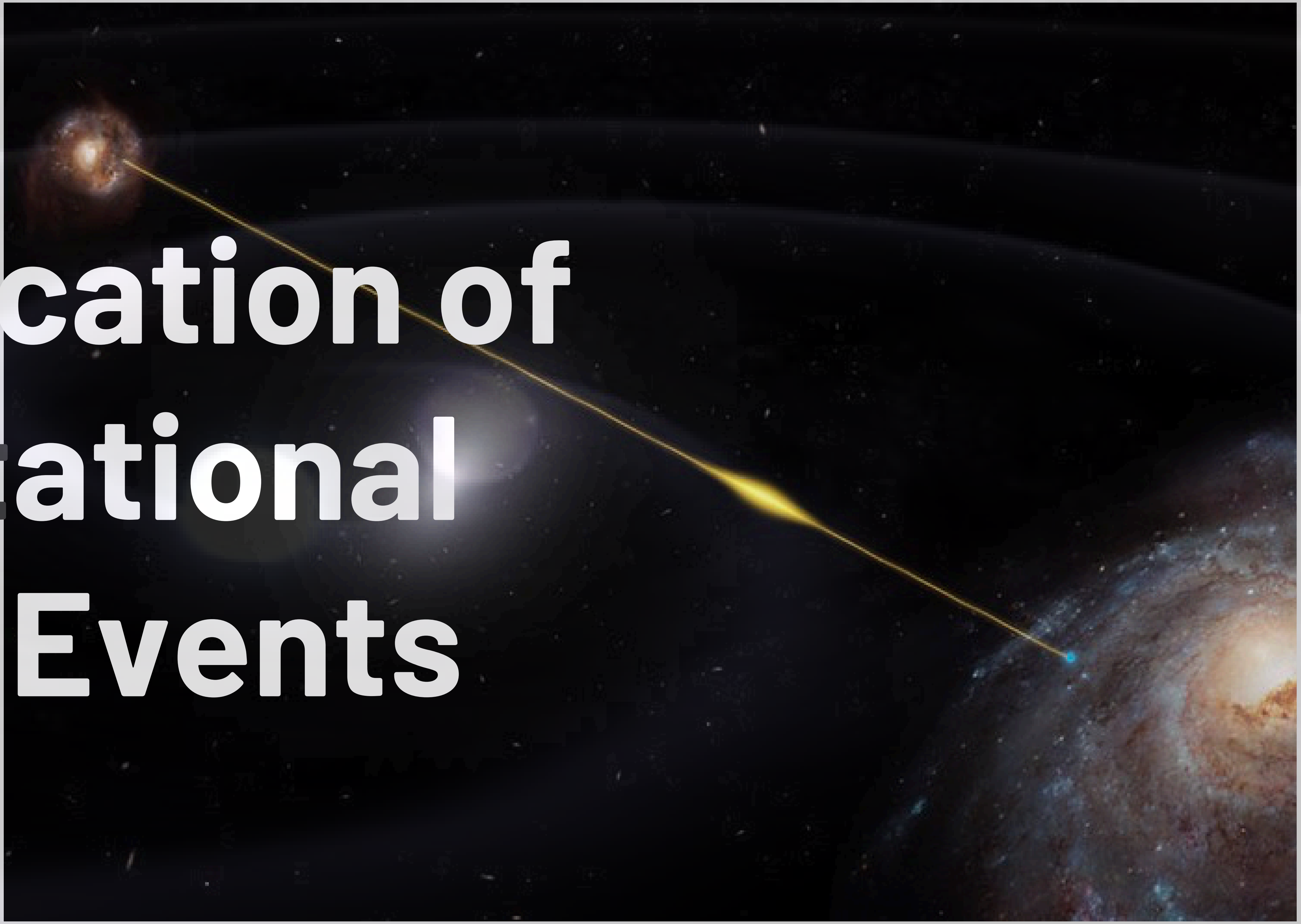
Classification of Gravitational Wave Events



Motivation: Understanding Cosmic Events through Gravitational Wave Analysis

WaveBusters‘s Members

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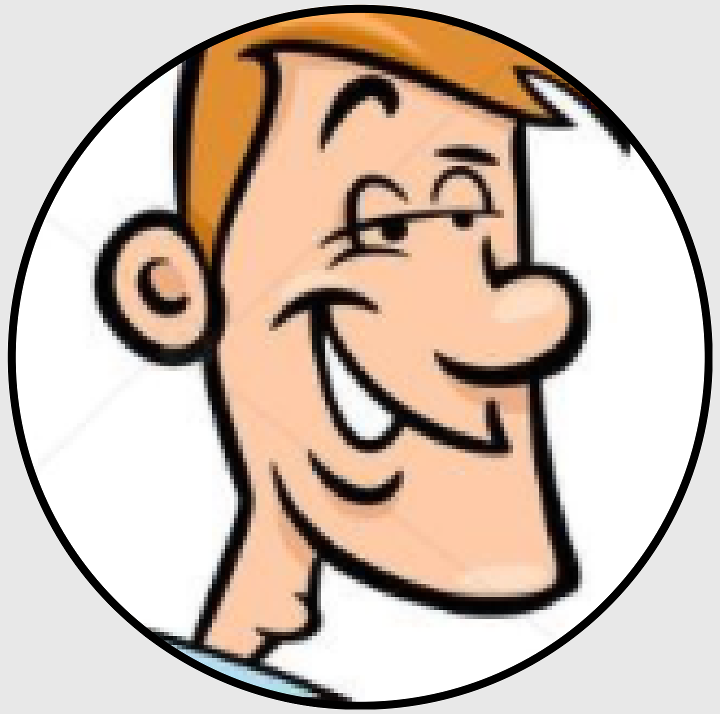

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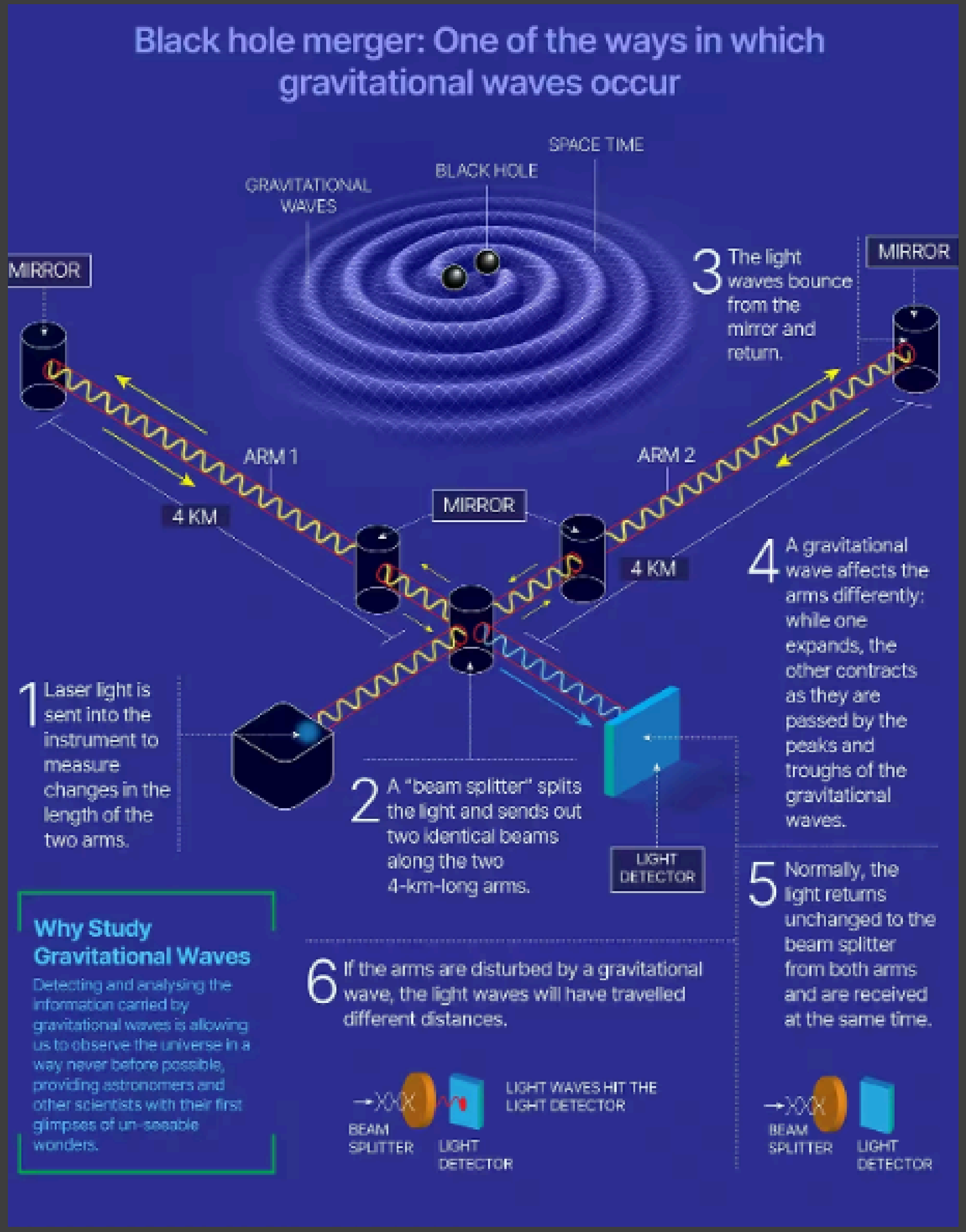
Motivation of the Project

Fast and accurate detection of gravitational waves

- The first direct gravitational waves detection in 2015 by LIGO
- O1, O2 and O3 observations LIGO and Virgo
- The GW170817 event
- New field: Multi-Messenger Astrophysics **(MMA)**
- Traditional methods: Matched Filtering & Burst search



LIGO- A Gigantic Interforemeter

Importance for Physics

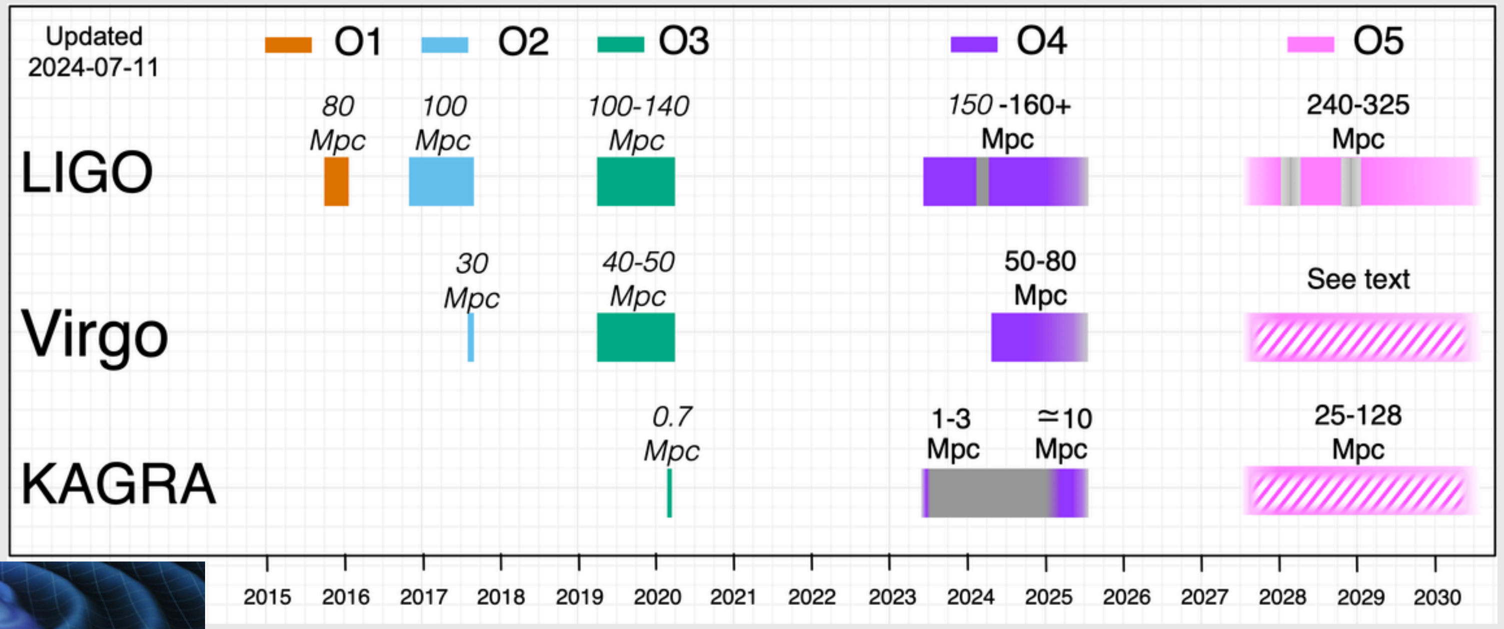
- Understanding the structure and secrets of the universe
- Importance of detection and analyzing black hole and neutron star mergers
- Increase in detected events with advanced gravitational wave detectors
- Critical role of deep learning projects in big data analysis

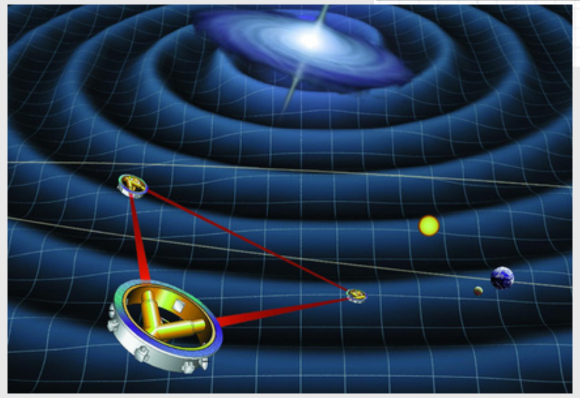
Literature Search

- Detection of 11 GW signals in O1 - O2 observing (BBH, BNS mergers)
- O3 and GWTC-3 catalog: 90+ events, including BNS and NSBH mergers
- Need for efficient and rapid analysis with increasing GW events
- Models capable of recognizing signals at low signal-to-noise ratios (SNR)

Current Situation

- O4 began in March 2023
- LISA (-2030) opens low frequency gravitaional universe
- Higher detector sensitivity expected to increase detection rates
- Anticipation of millions of events per year with Einstein Telescope and Cosmic Explorer
- Need for enhanced data analysis capacity and techniques with rising detection rates





About the Data

O3b Data Release

O3b Time Range: November 1, 2019 through March 27, 2020

Detectors: H1, L1 and V1

GEO Data around FRBs

Time Range: April 28, 2020 through Dec 2, 2022

Detectors: GEO600 (Select times only)

O2 Data Release

O2 Time Range: November 30, 2016 through August 25, 2017

Detectors: H1, L1 and V1

O3a Data Release

O3a Time Range: April 1, 2019 through October 1, 2019

Detectors: H1, L1 and V1

Dataset

Training Data: Gravitational wave signals will be generated using PyCBC, with noise added to these signals. Noise will either be generated synthetically or sourced directly from pre-existing data on GWOSC.

Testing Data: Real data from GWOSC, categorized as follows:

- FRB events: 4 instances
- Observing Runs O1 & O2: Total of 11 events (10 BBH, 1 BNS)
- Observing Runs O3a-b: Total of 70 events (1 BNS, 2 NSBH)

BBH: 2-95 M⊙ - SEOBNRv4

BNS: 1-2 M⊙ - TaylorF2

NSBH: 1-2 M⊙ ve 2-35 M⊙ - SEOBNRv4_ROM_NRTidalv2_NSBH

Data Soruces

Data is sourced from the **GWOSC website**.

Data Structure

The dataset is structured as time-series data.

Size Details

Initial testing will use a small dataset, with plans to expand as accordingly.

Analysis Details

Project Goal

An optimized Neural Network Architecture to classify GW events .

Model Structure

Possible Architectures:

- RNN
- CNN
- Transformers
- Physics Informed NN

ML Libraries

- PyTorch
- TensorFlow

Data Processing Libraries

- Pandas
- Polars
- Dask
- Prophet
- Statsmodels
- TSLearn

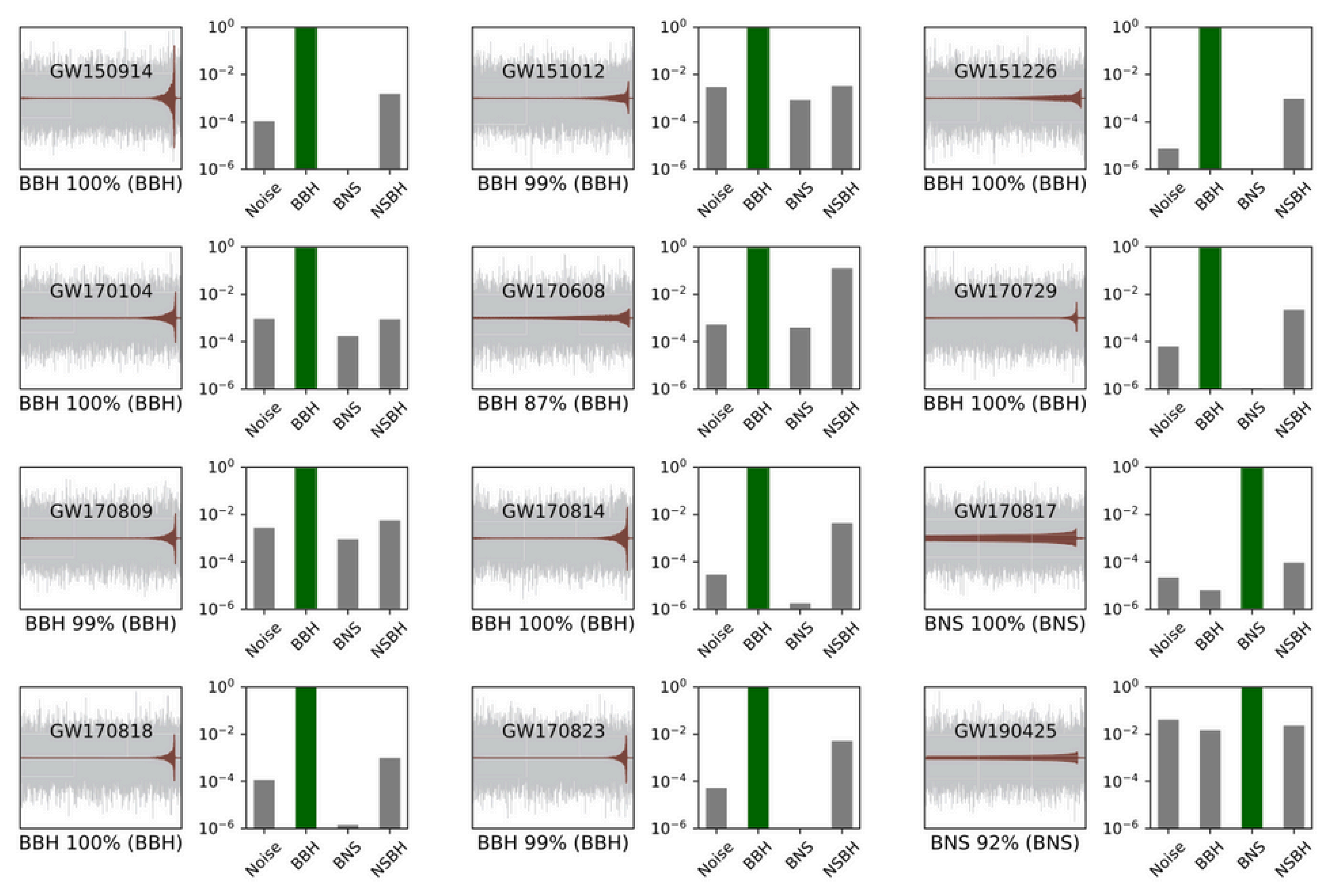
Dev Tools and Environments

- Ray
- JobLib
- Kubernetes
- GCP
- Azure

Project Timeline

Task	Weeek
Data Preparation • Generate synthetic data • Add noise to data • Prepare data for model	1-3
Model Training	4-6
Model Fine-Tuning	7-8
Paper Writing	9
Presentation Preparation	10

Possible Outcomes



Project Objective: Develop a model capable of accurately classifying gravitational wave events into four main categories:

- FRB (Fast Radio Bursts)
- BBH (Binary Black Hole Mergers)
- BNS (Binary Neutron Star Mergers)
- NSBH (Neutron Star - Black Hole Mergers)

Expected Outcome: The model is anticipated to accurately classify a total of 18 events as follows:

FRB:4 events **BNS: 2 events**
BBH: 10 events **NSBH: 2 events**

P**erformance Evaluation:**The model's success will be evaluated based on its accuracy and reliability across each class. Our goal is to achieve a high-precision classification model that can distinctly differentiate between event types.

Scientific Contribution: This model is expected to provide new insights into the classification of gravitational waves, offering a deeper understanding of the unique characteristics of each event type and contributing to knowledge advancement in this field.