European Union AstroCeNT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952480

Dark Wave

NICOLAUS COPERNICUS ASTRONOMICAL CENTER OF THE POLISH ACADEMY OF SCIENCES

PyMerger: Detecting Binary Black Hole mergers from the Einstein Telescope Using Deep Learning

Wathela Alhassan[1]

Advisors: Prof Tomasz Bulik[2] , Dr. M. Suchenek[1] , Prof. Piotr Gawron[1]

[1]Particle Astrophysics Science and Technology Centre, Nicolaus Copernicus Astronomical Center,

[2]Astronomical Observatory of the University of Warsaw

CAMK Annual Meeting, 22 - 23 January 2025

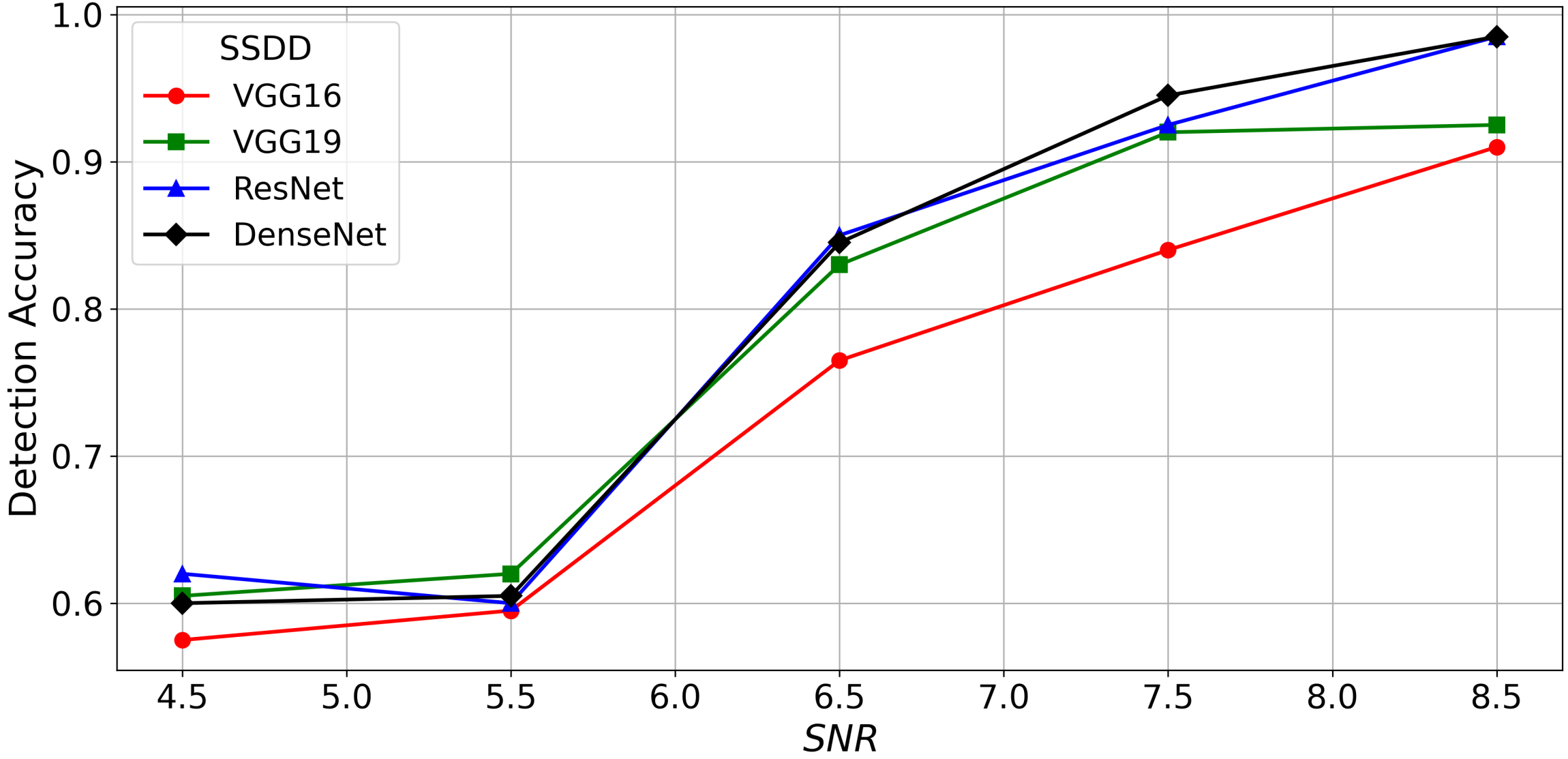
European Funds Smart Growth

Republic of Poland

FNP Foundation for Polish Science

European Union European Regional Development Fund

Single Subdetector Data (SSDD) Results



Alhassan et al. (2023), MNRAS

PRELAUDIUM 2024 Grant

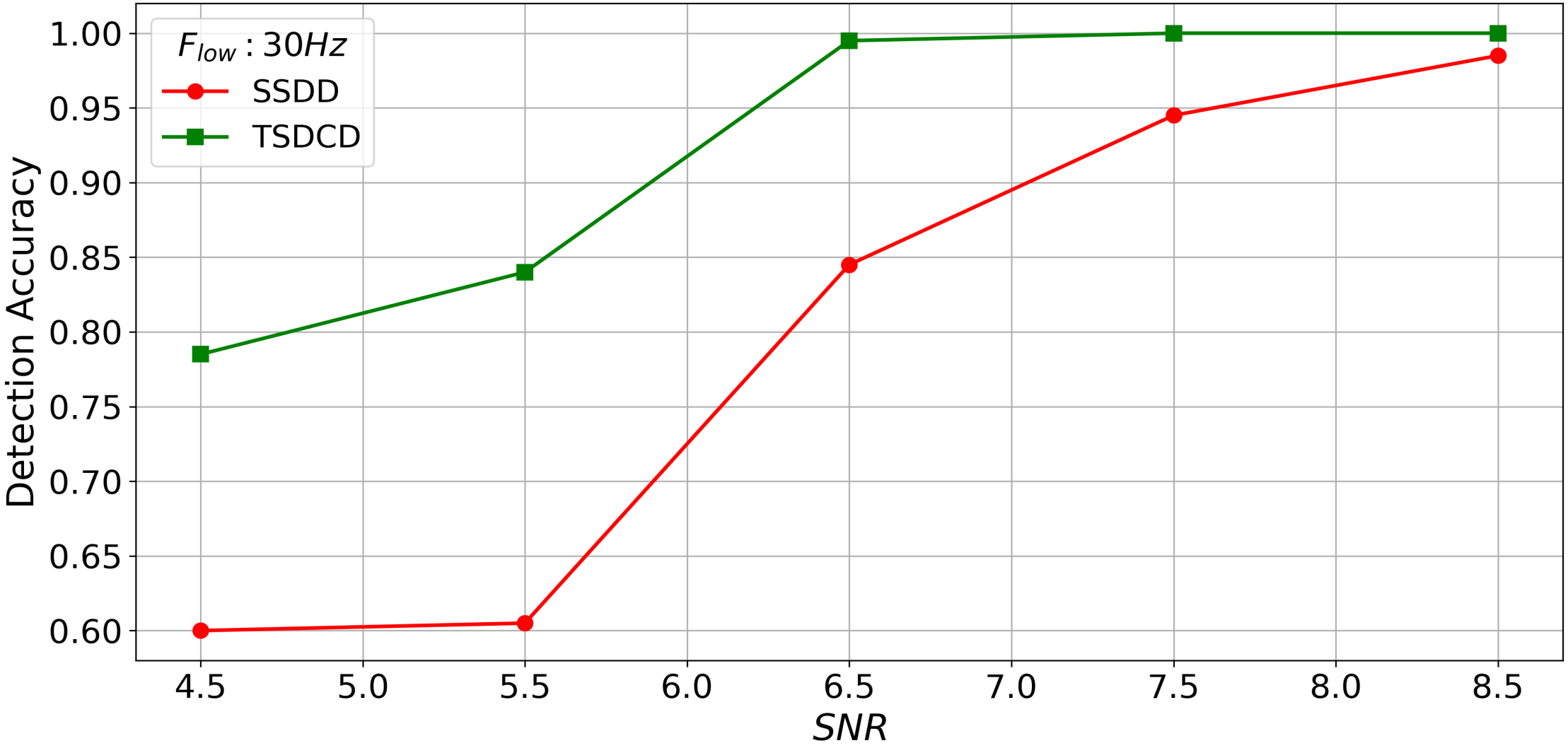
Objectives:

- **Three Subdetector Combined Data (TSDCD): Five different lower frequency [5, 10, 15, 20 and 30 Hz].**

- **Evaluate on the Einstein Telescope mock Data Challenge (ET-MDC1).**

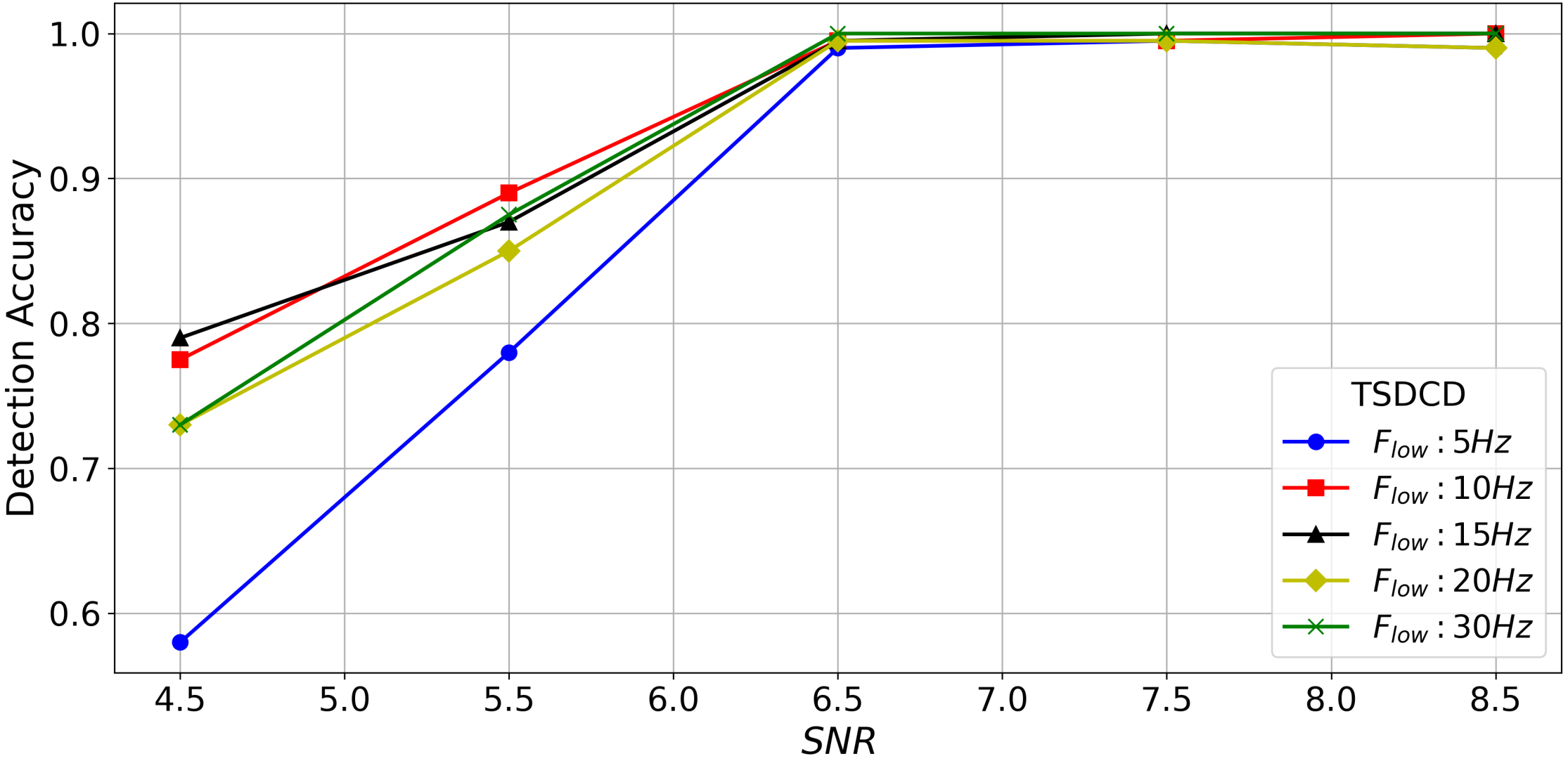
- **Develop software for inference and provide pre-trained models for use.**

TSDCD Results



SSDD (Alhassan et al. (2022)) versus TSDCD for sources with $Flow$ of 30 $H\ z$.

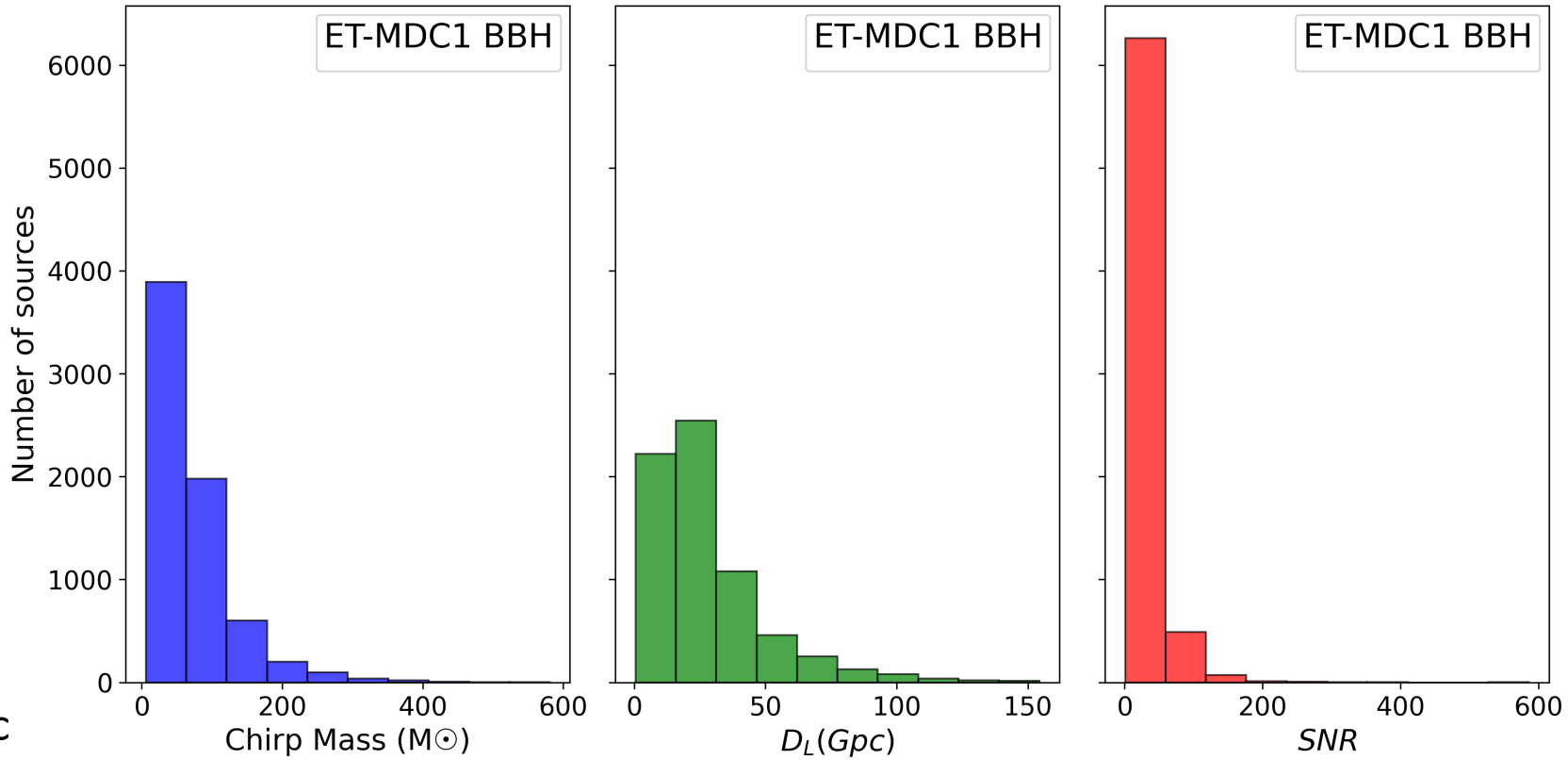
TSDCD Results



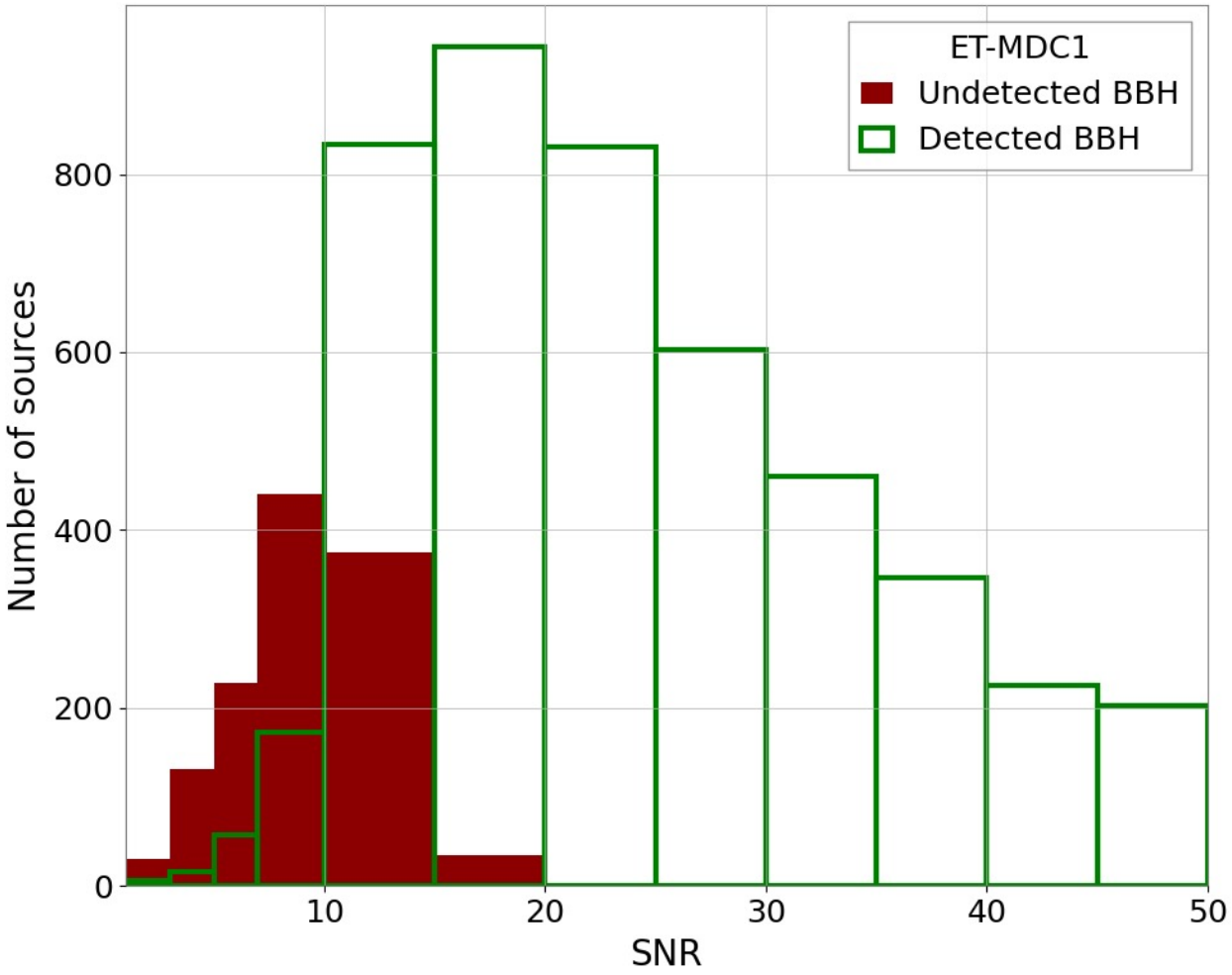
TSDCD for sources with F_{low} of 5 $H\ z$, 10 $H\ z$, 15 $H\ z$, 20 $H\ z$ and 30 $H\ z$.

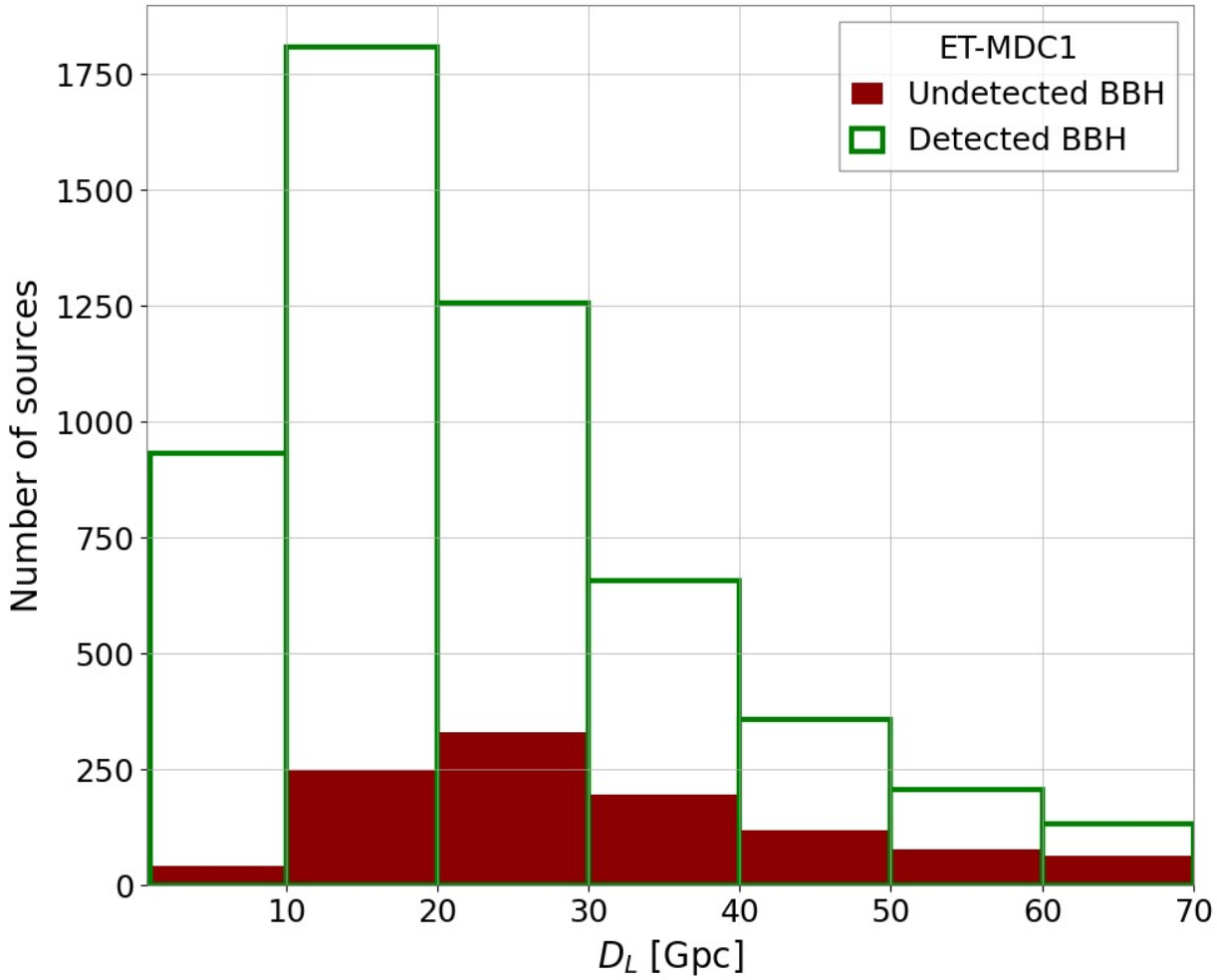
ET-MDC1: Einstein Telescope mock Data Challenge

- First released in 2012 and updated in early 2024.
- 30.8 days (1.3 Terabytes).
- Contains a continuous GW signal plus noise, noise only and null stream.
- Overlapping signals.
- Sampled at 8192 Hz.
- 59,540 BNS | 6,578 BBH | 1,977 BHNS
- Optimal SNR ranges between 0.13 and 586.12.
- D_L of BBH systems ranges from 0.5 Gpc to 154.37 Gpc.

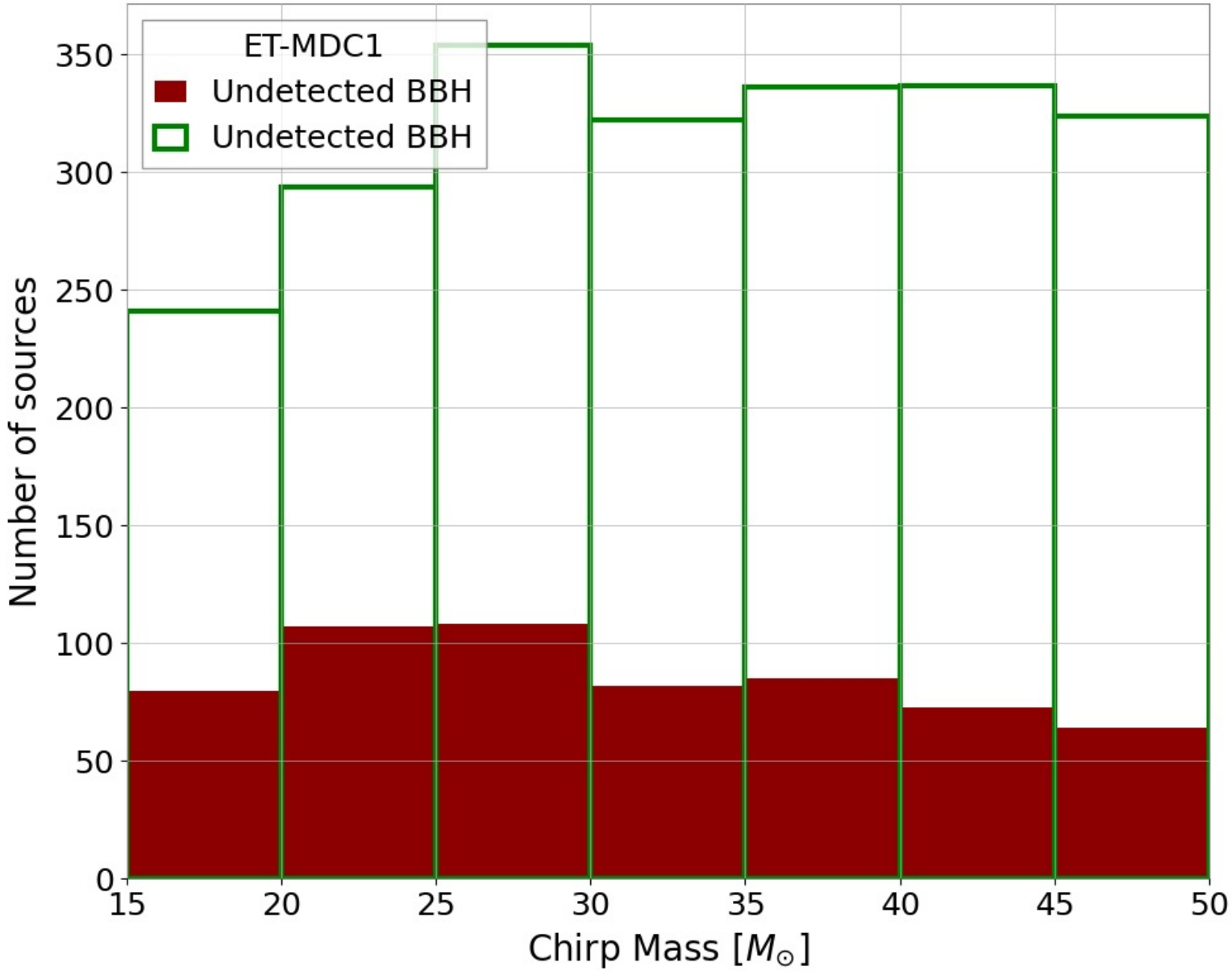


ET-MDC1 Results

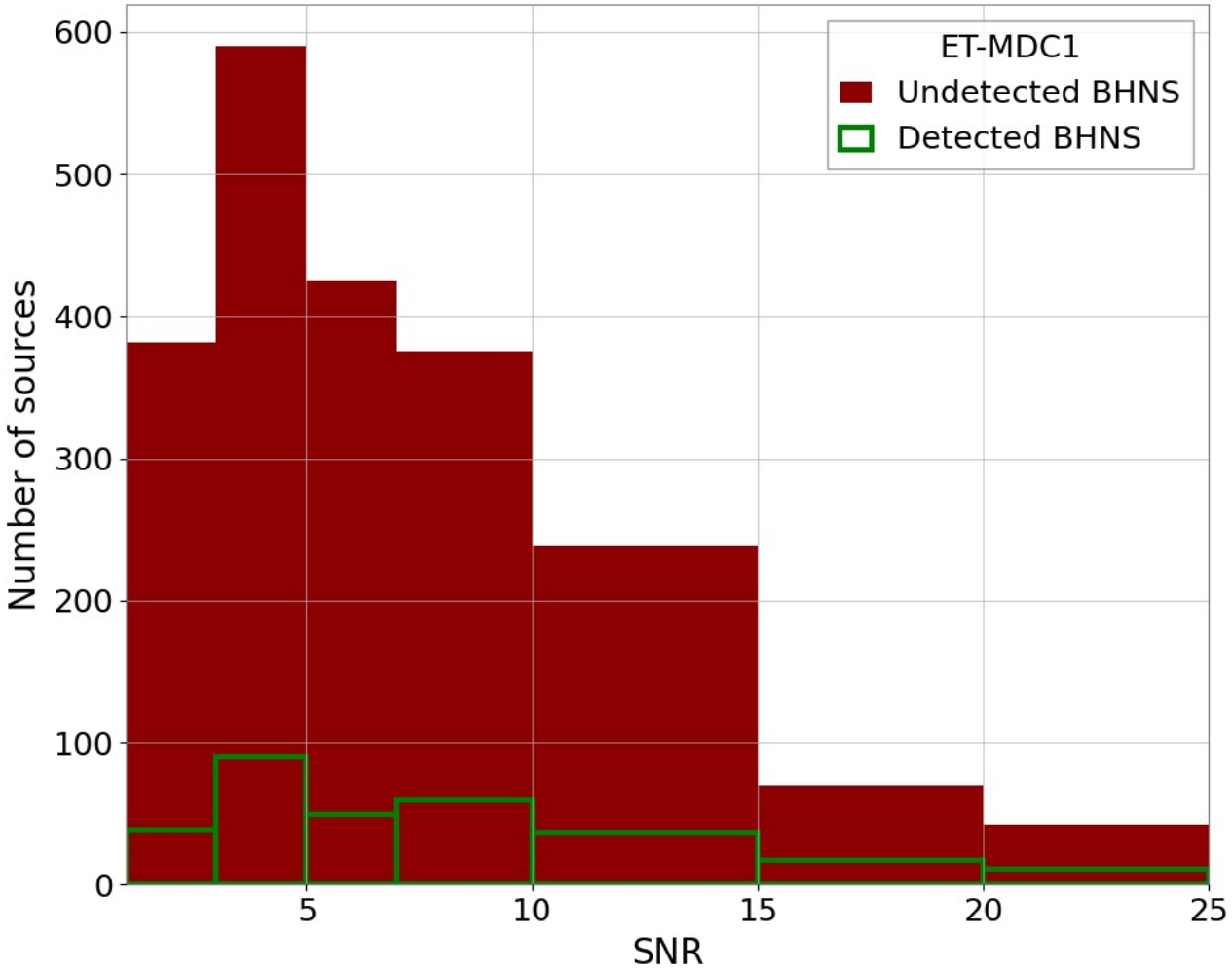


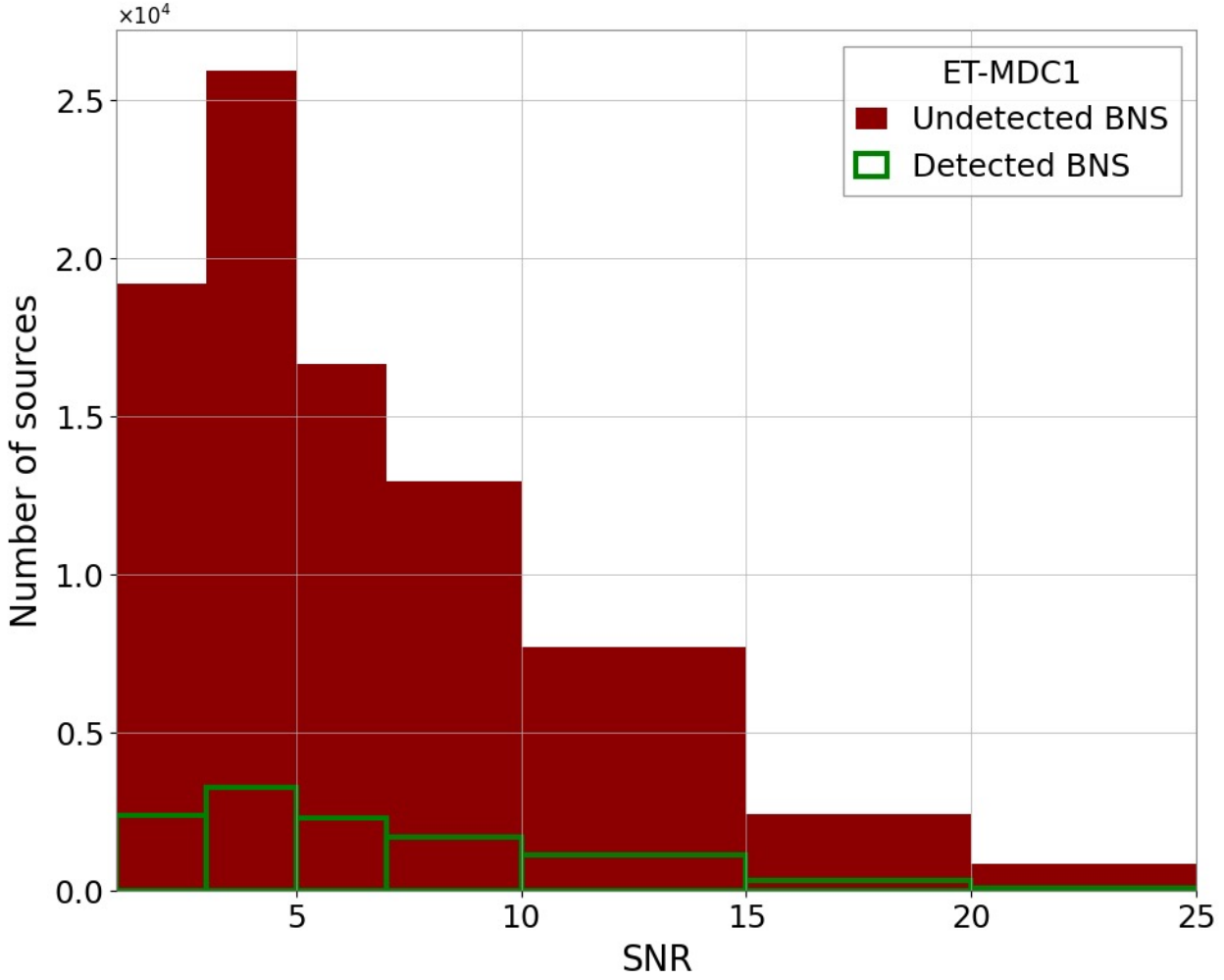


ET-MDC1 Results



ET-MDC1 Results





- ✓ 11,477 BNS mergers (with optimal SNR starting from 0.2).
- ✓ 323 BHNS mergers (with optimal SNR starting from 0.1).

PyMerger

- PyMerger is a Python tool for detecting BBH mergers from ET, built based on our trained ResNet model.
- The current version handles only gravitational wave frame file format (.gwf)
- 1.9 minutes to scan one hour of data on an average laptop without GPUs.

https://github.com/wathela/PyMerger

```
pip install PyMergers
```

Installation

1. Clone the repository:

```
git clone https://github.com/your-username/PyMerger.git
cd PyMerger
```

2. Install the required Python packages:

```
pip install -r requirements.txt
```

Usage

PyMerger assumes that each sub-detector of ET will have a separate .gwf file in three separate directories (E1, E2, E3). The data input path should point to the folder where these three directories are located.

```
usage: pymerger.py [-h] [-r {8192,4096}] [-n NO_SEGMENT] [-c CHANNELS CHANNELS CHANNELS] [-t T

optional arguments:
  -h, --help            show this help message and exit
  -r {8192,4096}, --sampling-rate {8192,4096}
                        Sampling rate of the input data (either 8192 or 4096). Default is 8192
  -n NO_SEGMENT, --no-segment NO_SEGMENT
                        Number of data segments to be processed for each detector (i.e., numbe
                        Files in the input directory will be sorted, and the first 'n' files u
                        Default is 1 which means there are 1 unique file from each detector.
  -c CHANNELS CHANNELS CHANNELS, --channels CHANNELS CHANNELS CHANNELS
                        List of the THREE channels to be processed. Default is ['E1:STRAIN', '
  -t THRESHOLD, --threshold THRESHOLD
                        Threshold value for merger detection. A value between 0.5 and 0, where
                        a lower false positive rate. Default is 0.1 (accepting detection with
  -i INPUT_FILE_DIR, --input-file-dir INPUT_FILE_DIR
                        Directory containing the input .gwf files.
  -f OUTPUT_DIR, --output-dir OUTPUT_DIR
                        Directory to store the results.
  --verbose             Enable verbose mode to print update messages. Default is true.
```

Participation

European AI for Fundamental Physics Conference April 30 - May 3, 2024 Amsterdam.

Eastern European Machine Learning (EEML) July 2024, Novi Sad, Serbia.

XXXII IAU General Assembly, 6-15 August 2024, Cape Town, South Africa

The Astronomical Data Analysis Software & Systems, 10-14 November 2024, Valletta, Malta

PyMerger: Detecting Binary Black Hole merger from Einstein Telescope Using Deep Learning

ApJ, DOI: 10.3847/1538-4357/ad901e

OPEN ACCESS

PyMerger: Detecting Binary Black Hole Mergers from the Einstein Telescope Using Deep Learning

Wathela Alhassan, T. Bulik, and M. Suchenek

Published 2024 December 16 • © 2024. The Author(s). Published by the American Astronomical Society.

The Astrophysical Journal, Volume 977, Number 2

Citation Wathela Alhassan *et al* 2024 *ApJ* **977** 222

DOI 10.3847/1538-4357/ad901e

Thank you!