Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

Project ***E.T. Start-up*** (F25F21002720001) D.M. 737/2021 - Linea d'intervento Iniziative di ricerca interdisciplinare su temi di rilievo trasversale per il PNR.

# Continuous wave search with ET: impact of an astrophysical background from coalescing binaries.

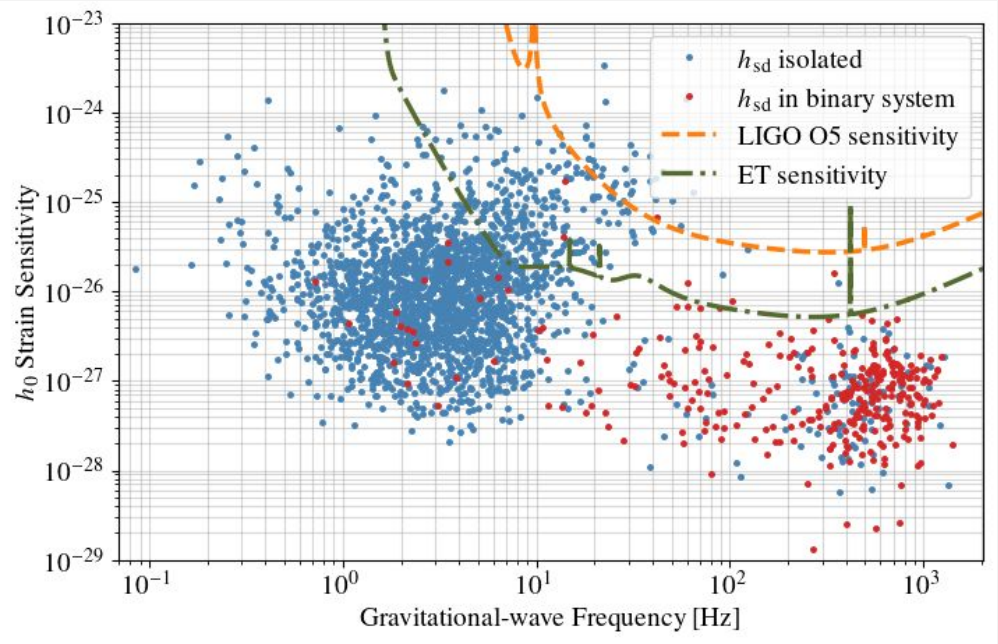
Elena Codazzo
M. Di Giovanni, P. Astone, S. D'Antonio, C. Palomba, L. Mirasola, C. Lazzaro, A. Sanna.

ET Symposium, Bologna, 28/05/2025.

Università degli Studi di Cagliari
Sapienza Università di Roma
INFN
VIRGO
EINSTEIN TELESCOPE

# Introduction

*Credit: L. Mirasola, Pulsars from ATNF catalog*




- ***Continuous Waves***: quasi-monochromatic GW, long duration
- *Source like*: asymmetric spinning NS
- Emission frequency: $f_{gw} = 2f_{rot}$
- *Searches*: targeted, narrow-band, directed, all-sky
- Spin-down limit:

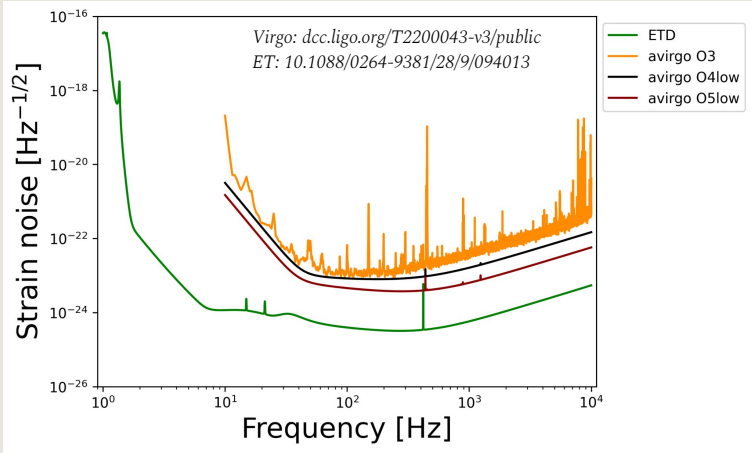
$$h_0^{sd} = \frac{1}{d}\left(\frac{5GI_{zz}}{2c^3}\frac{|\dot{f}_{rot}|}{f_{rot}}\right)^{1/2}$$

# Motivation

**Einstein Telescope**:

- Sensitivity gain up to one order of magnitude compared to LVK
- Extended bandwidth down to 2 Hz

In the search for **continuous gravitational waves**, signals from **coalescing binaries** act as a source of **noise**.

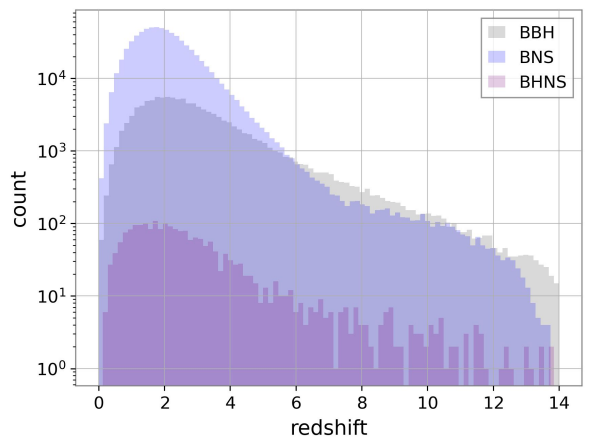



***Aim***

- Evaluation of the **impact** of signals produced by coalescent binaries in detection and reconstruction of CW with the ***Frequency Hough pipeline*** *(Astone et al. PhysRevD.90.042002)*.
- Implementation of **new methodologies** for future analyses.

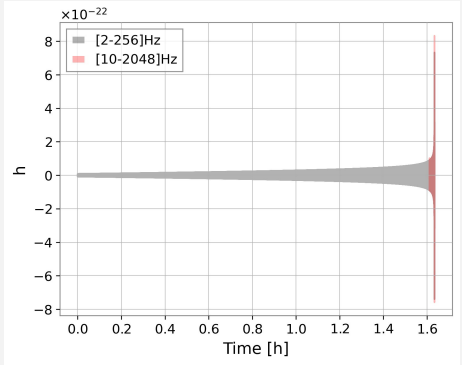
# Methodology: background sources

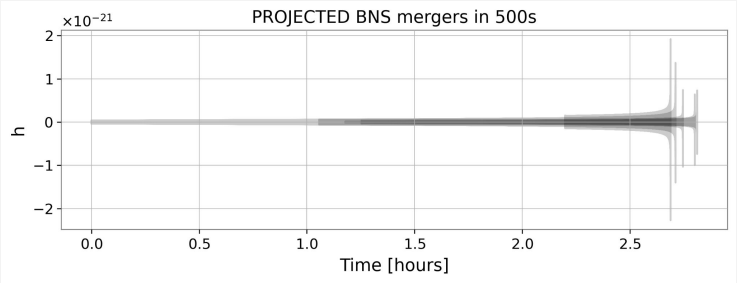
- Population used
  - BBH ~ $10^5$ /yr
  - BNS ~ $7 \cdot 10^5$ /yr
  - BHNS ~ $2 \cdot 10^3$ /yr



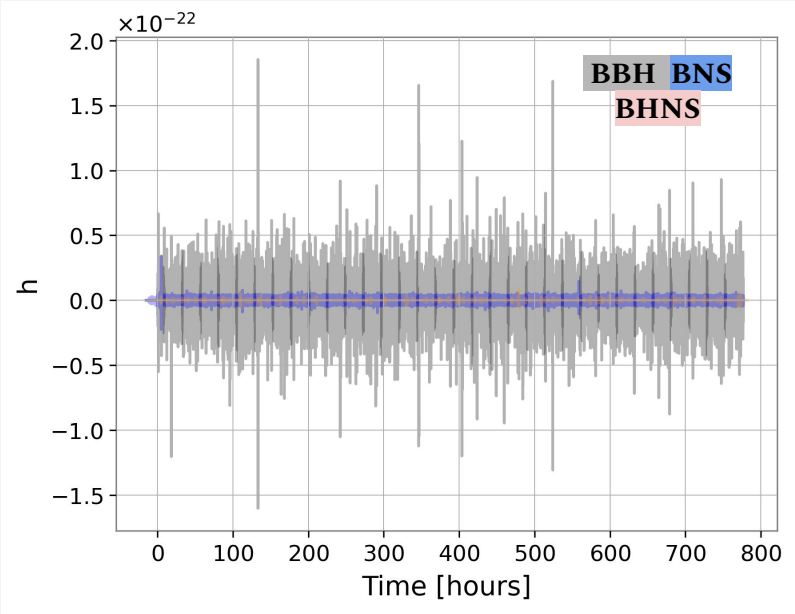

Credit:
- BBH and BNS source catalogs used for the CoBA Science study (doi:10.1088/1475-7516/2023/07/068)
- BHNS (doi: 10.1093/mnras/stad1630)

- Waveform generation
  - TaylorT2 approximant, minimum frequency: 2Hz
- Projection into the detector frame
  - Earth's rotation is taken into account
- Injection into ET simulated noise
  - ET noise generated from its theoretical PSD ( *10.1088/0264-9381/28/9/094013)*



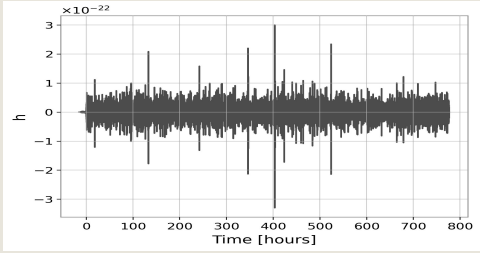
# Characterization of the signals

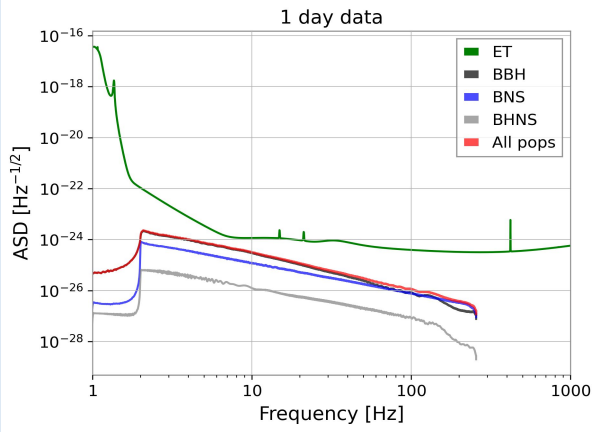



**frequency in [2-256] Hz**

➢ higher amplitude for BBH at low frequencies (presence of mergers).

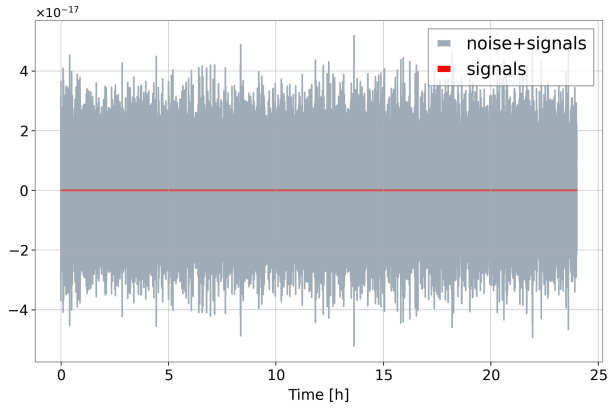
**TS of 1 month - 33days - all populations**

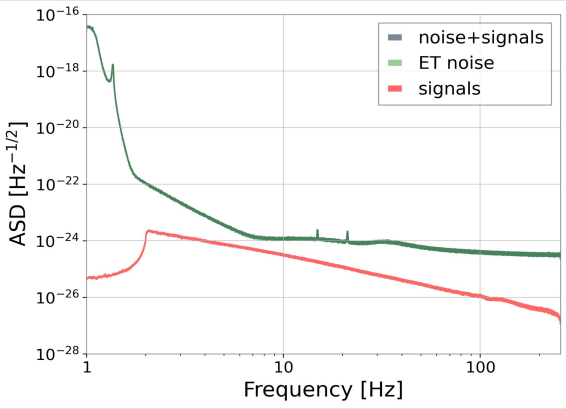


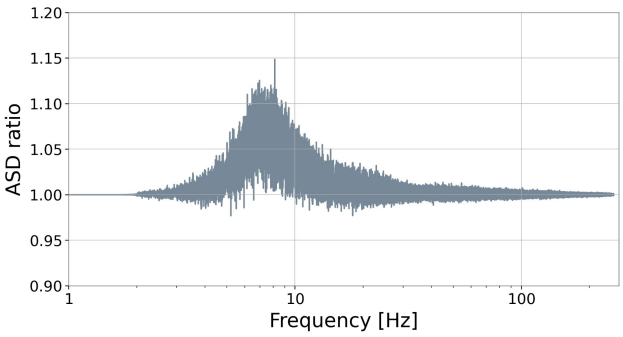




The background level reaches its asymptotic limit in one day.

# Injected signals in ET noise



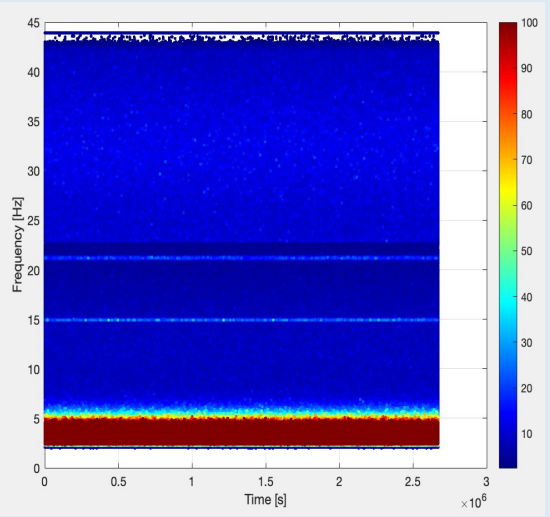

$$\text{ASD ratio} = \frac{\text{ASD noise} + \text{signal}}{\text{ASD noise}}$$

- ➔ The ratio between the two ASDs highlights a contribution from the CBC background with a maximum increase of **~10% around 7 Hz**.
- ➔ This motivates dedicated strategies to account for the CBC background in future CW analyses below 20 Hz.

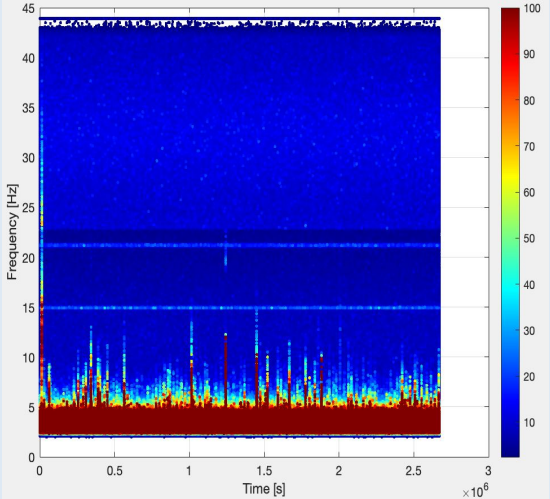
# CW injections

- **10 CW signals injected per 1 Hz frequency band**
- Injected into **18 bands**
  with $h = 1.1 \cdot h_{min}$ *(Astone et al. 2014 PhysRevD.90.042002)*.
- For each **sky position**, the same 10 random CW parameters are fixed across all bands:
  cos ι, ψ, spin-down in $[-10^{-10}, 10^{10}]$ Hz/s.
- **41 different sky positions** considered → each with a new set of 10 CW parameters.
- Two identical analysis with the ***Frequency Hough pipeline*** *(Astone et al. PhysRevD.90.042002)* :
  - **ET noise only**
  - **ET noise + CBC**

**ET noise only**

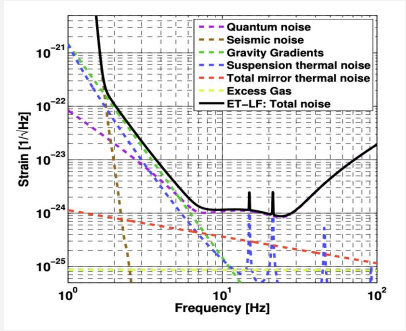


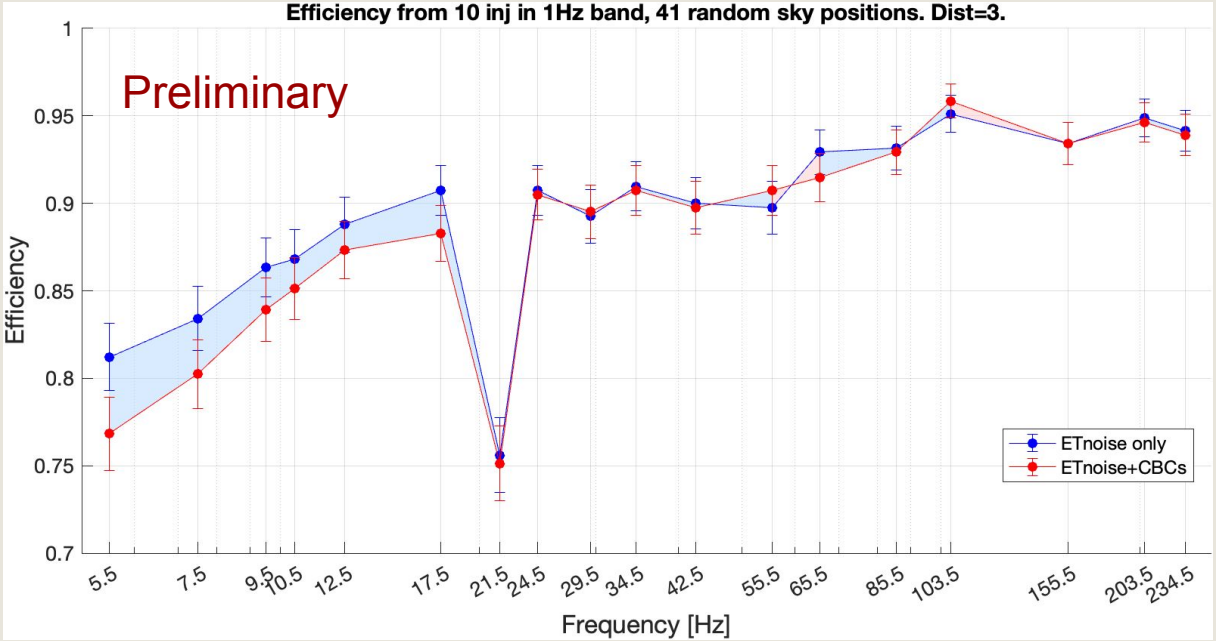

**ET noise + CBC**

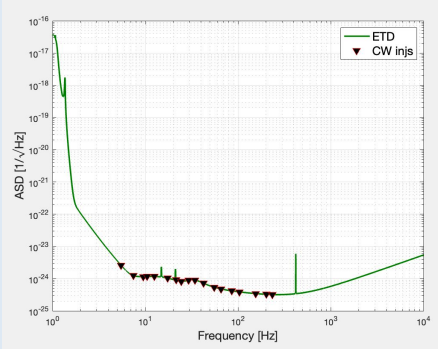


# Efficiency

S Hild *et al* 2011, *CQG*, 28 094013

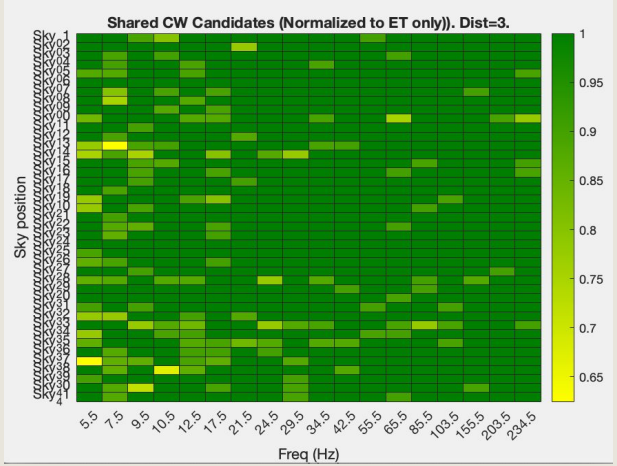


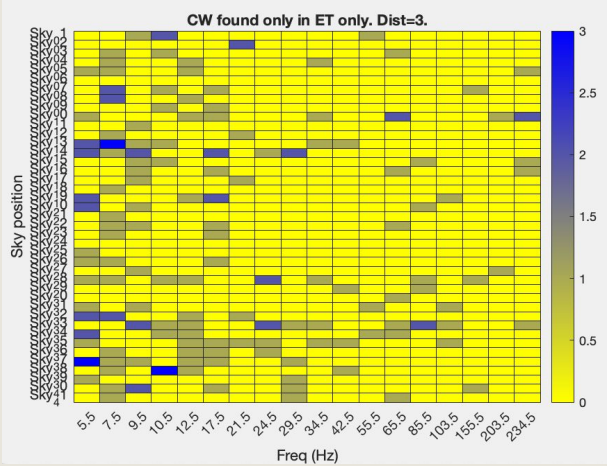



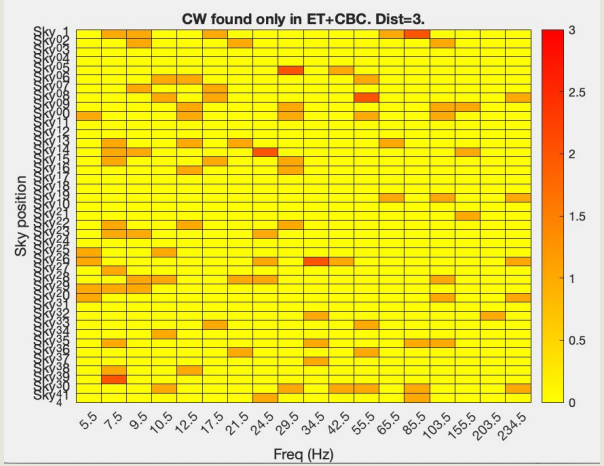




- ➔ In the **5–20 Hz range**, a **systematic reduction in efficiency** is observed in presence of the CBC background.
- ➔ Above ~20 Hz, the efficiency in the two studied cases are **compatible**, in line with the expected drop of the CBC spectrum.

# Lost & Found




**Left**: Common CW found in both *ET noise only* case and *ET+CBC* case

**Middle**: CW found **only** in *ET noise only*

➔ Slight differences appear at low frequencies

**Right**: CW found **only** in *ET+CBC*

➔ No evident pattern

Preliminary

# Summary and Outlook

- ✓ We simulated **1 month of the astrophysical background** due to CBC sources.
- ✓ Preliminary results show a small but clear **reduction in CW detection efficiency below 20 Hz** when CBCs are added.

***Next steps:***

- Extend the analysis to **longer observation times** and **higher CW injection statistics**.
- Investigate how the presence of the CBC background affects the **recovered amplitude and parameters of CW** signals.
- Develop **mitigation strategies** to account for the CBC background at low frequencies.

Contact: elena.codazzo@ca.infn.it