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Iniziative di ricerca interdisciplinare su temi di rilievo trasversale per il PNR.

Impact of coalescence signals on the search for continuous waves

GEMMA 2
Gravitational-waves, ElectroMagnetic and dark-MAtter Physics Workshop

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GEMMA, Roma, 17/09/2024

Università degli Studi di Cagliari
SAPIENZA Università di Roma
INFN
VIRGO
ET Einstein Telescope

Introduction

- ***Ground-based detectors***:
  2G detectors (LIGO/Virgo O5)
  2.5G detectors (KAGRA and post-O5)
  3G detectors (ET & CE)

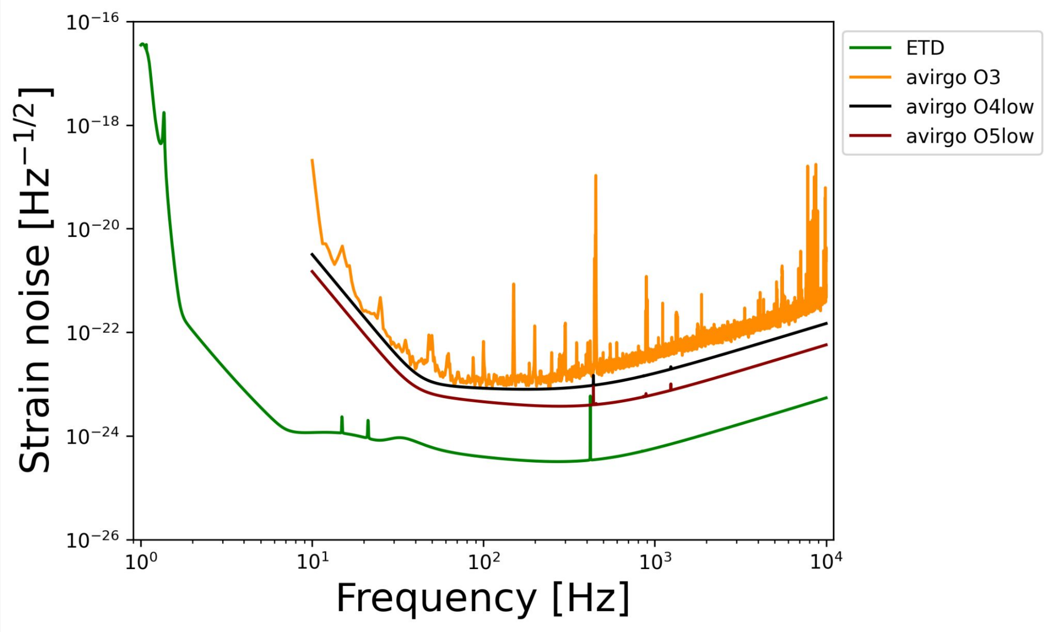
- ***Upgrades***:

  improved sensitivity
  extended frequency range (3G)

- ***Einstein Telescope***:

  Sensitivity gain up to one order of magnitude compared to LVK

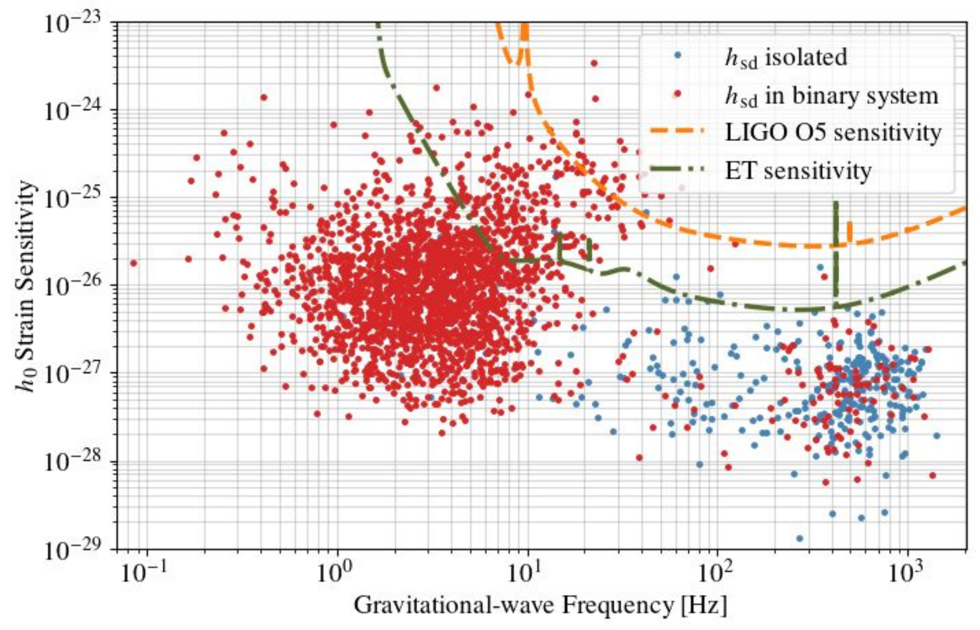
  Extended bandwidth down to 2 Hz



Credit:
Virgo: https://dcc.ligo.org/T2200043-v3/public
ET: DOI 10.1088/0264-9381/28/9/094013

Introduction

Credit: L. Mirasola, Pulsars from ATNF catalog



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

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

- GW amplitude:

$$h_0 = \frac{4\pi^2 G}{c^4}\frac{I_{zz}\varepsilon f_0^2}{d} \qquad \varepsilon \equiv \frac{|I_{xx} - I_{yy}|}{I_{zz}}$$

Motivation

- ➔ *Understanding the impact of CBC signals at low frequency, [2-30]Hz*
  We want to investigate whether signals from coalescing binaries in the low-frequency range act as noise that affects the detection of continuous waves .
- ➔ *Improving detection method*
  If such an impact is confirmed, the focus will be on refining current detection strategies to minimize or eliminate this influence.

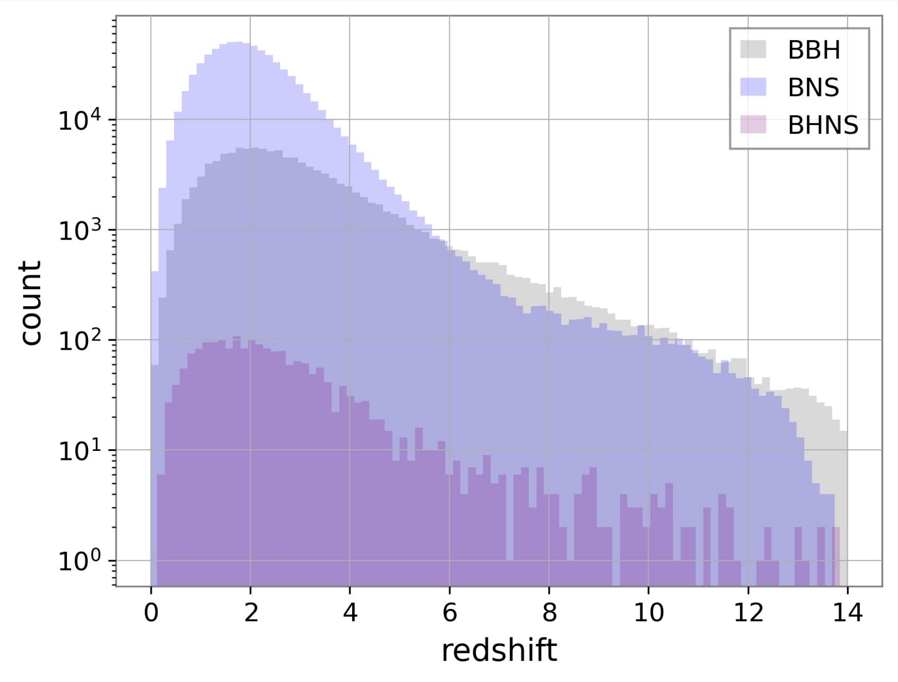
Methodology: background sources

- Population used
  - BBH ~ 10^5 /yr
  - BNS ~ $7\cdot10^5$ /yr
  - BHNS ~ $2\cdot10^3$ /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)

- Other populations
  - BBH (Pop III)
  - PBH



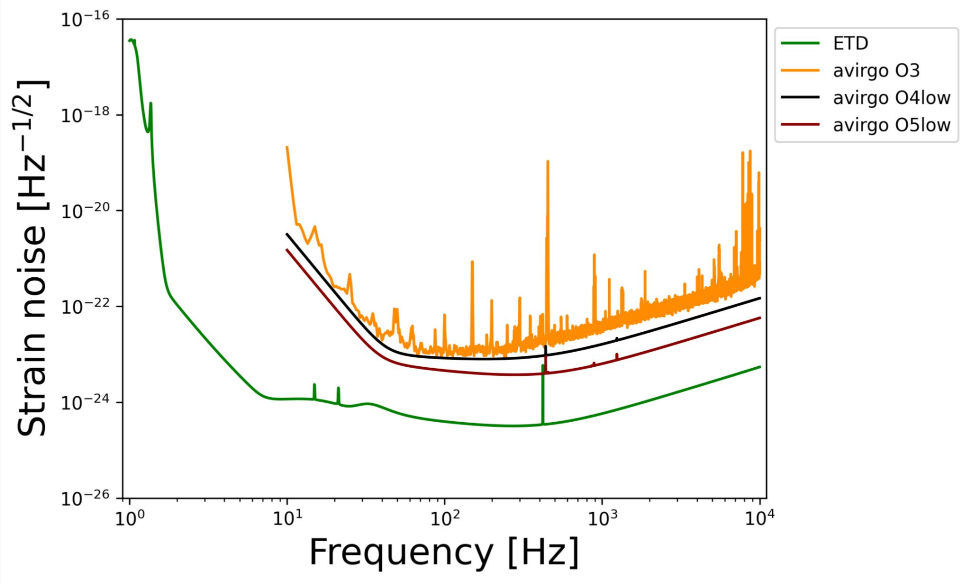
Methodology - *work in progress*

I. *Low frequency study with ET noise*

- Lower frequency: 2 Hz
- Generation of ET simulated noise

II. *Middle frequency study with ET and 2G O5 detectors noise*

- Lower frequency: 10 Hz
- Use of actual Virgo O3 noise rescaled to O5 sensitivity



Credit:
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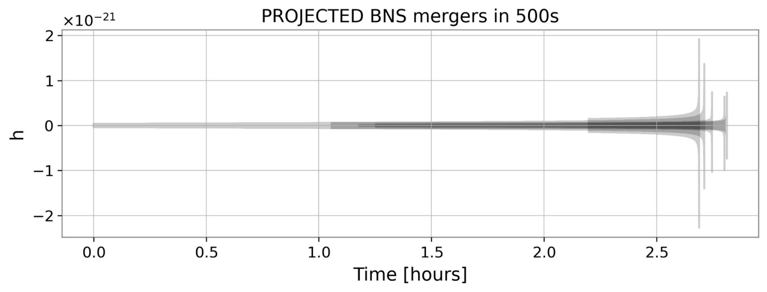
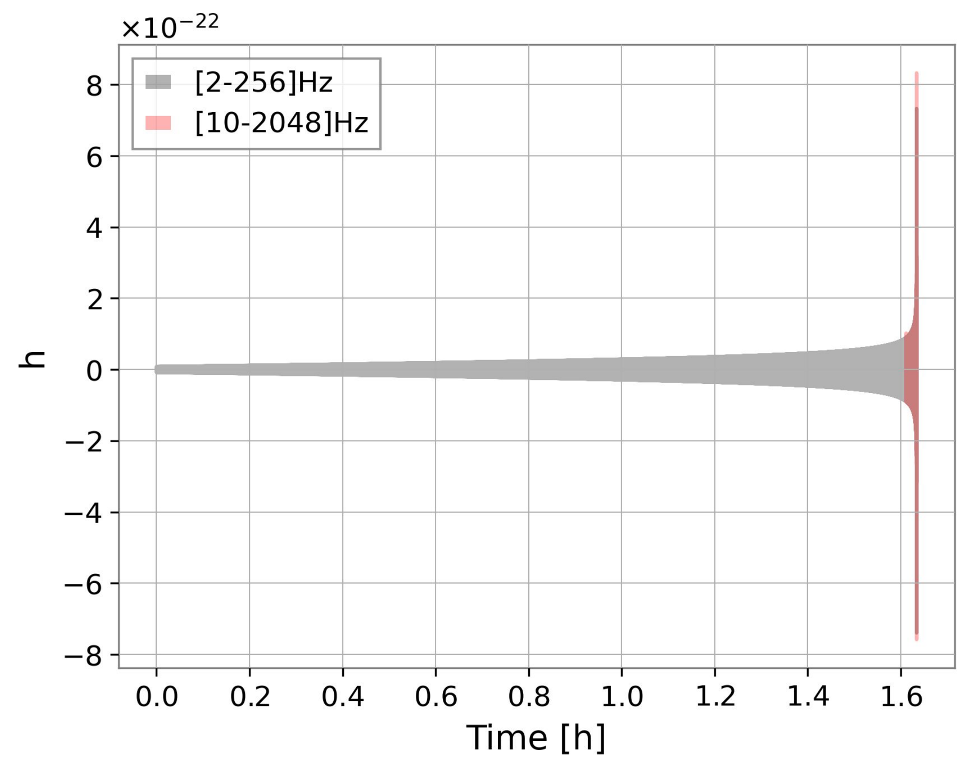
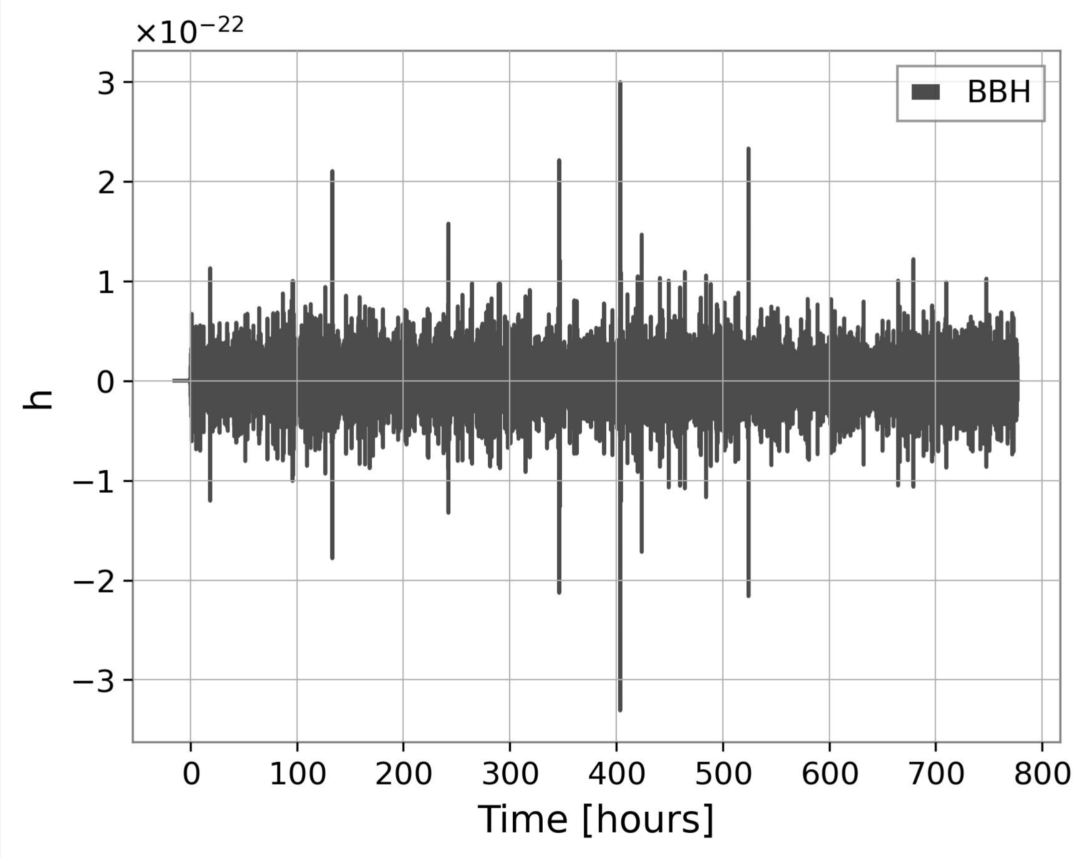
Methodology

- Waveform generation
  - TaylorT2 approximant
- Projection into the detector frame
  - Earth's rotation is taken into account
- Injection into ET simulated noise
  - ET noise generated from its theoretical PSD





Characterization of the signals



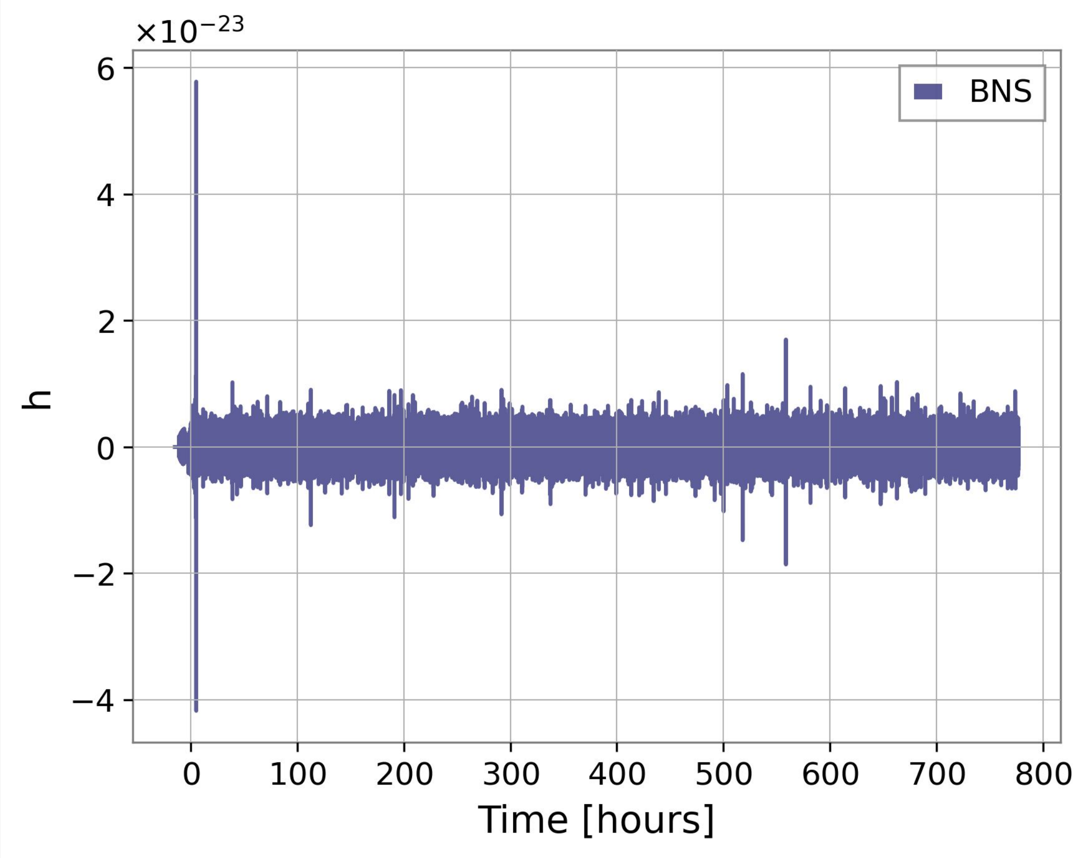
Timeseries of 1 month (33days) of BBH

√ 320 ~ signals/day

√ freq in [2-256] Hz

√ presence of mergers

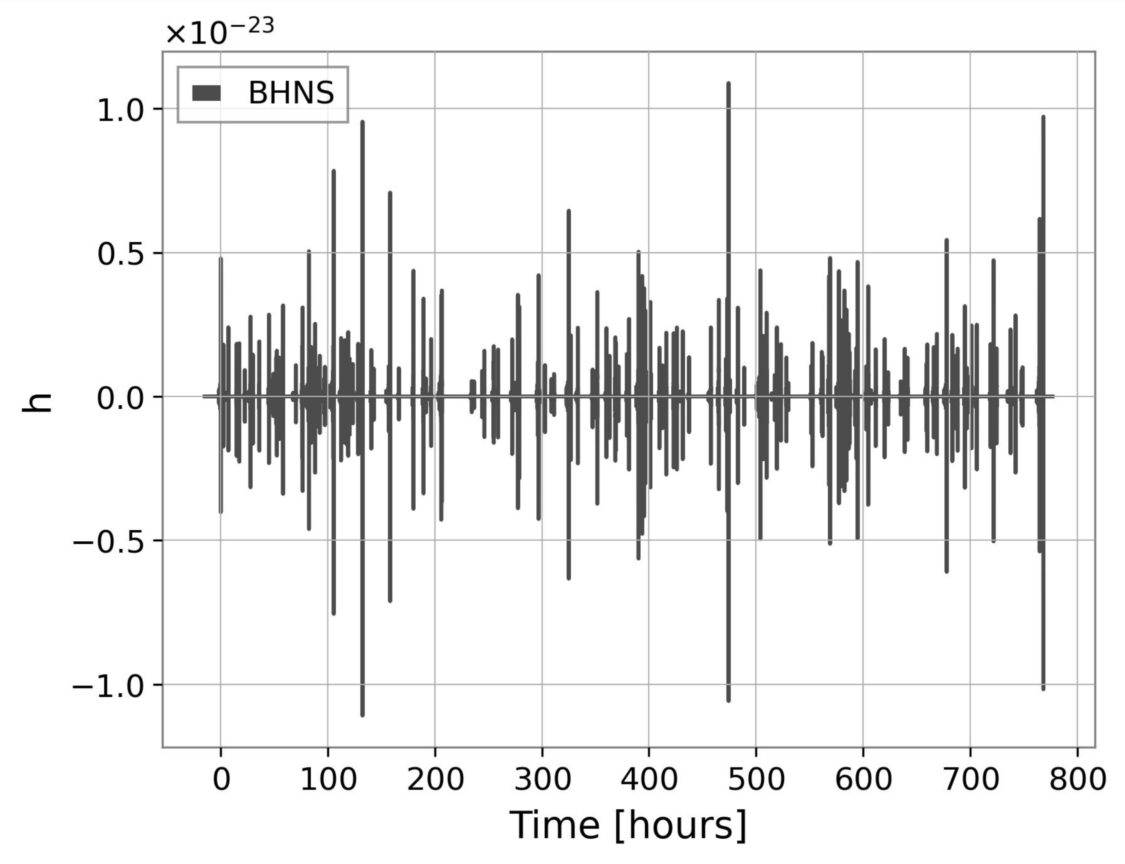
Characterization of the signals



Timeseries of 1 month (33days) of BNS

- √ 2000 ~ signals/day
- √ freq in [2-256] Hz
- √ many signals far from the merger

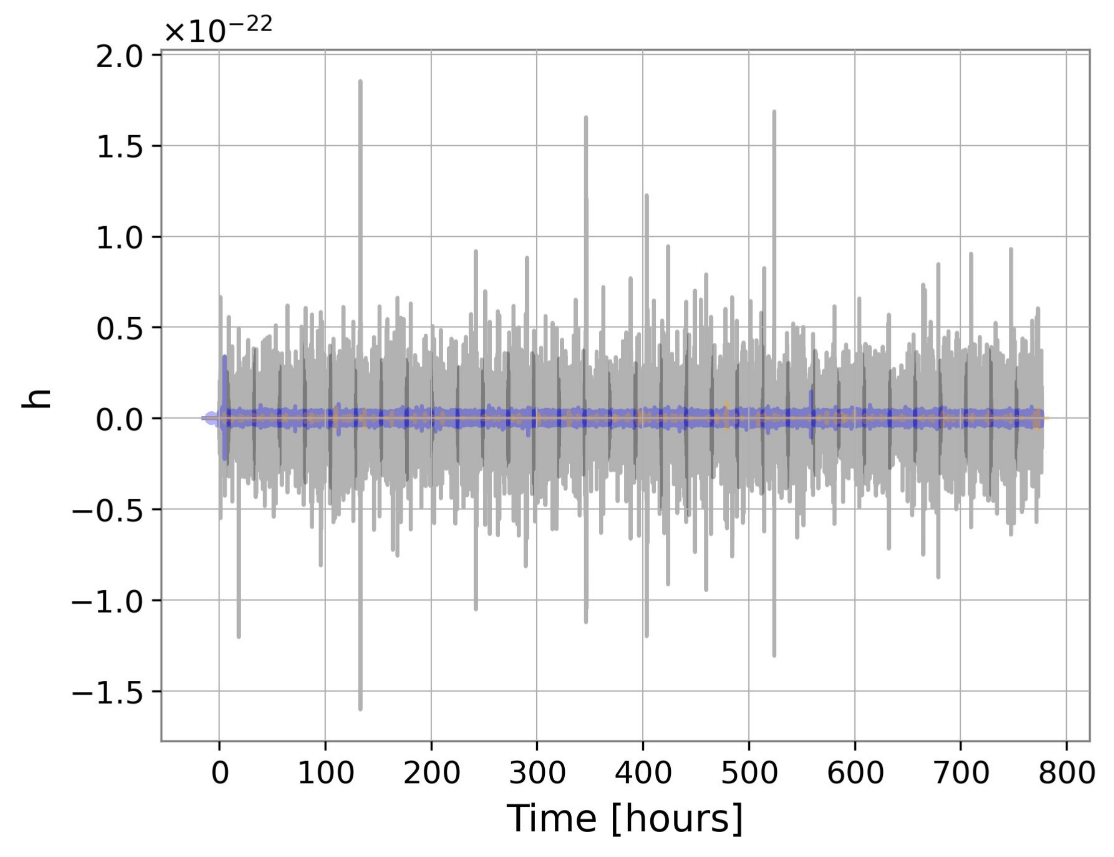
Characterization of the signals



Timeseries of 1 month (33days) of BHNS

- √ 5 ~ signals/day
- √ freq in [2-256] Hz
- √ many signals far from the merger

Characterization of the signals



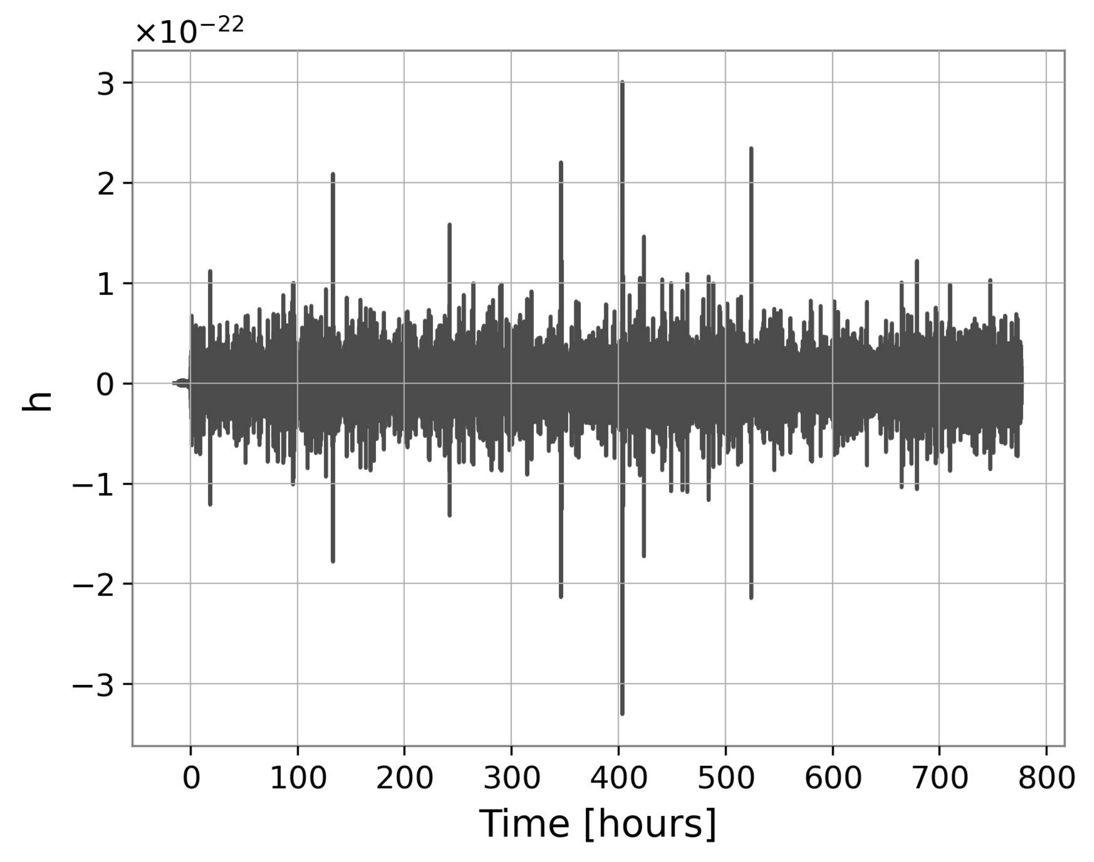
1 month (33days) all populations

- signals/day:

BBH	BNS	BHNS
320	2000	5

- freq in [2-256] Hz
- higher amplitude for BBH at low frequencies

Characterization of the signals



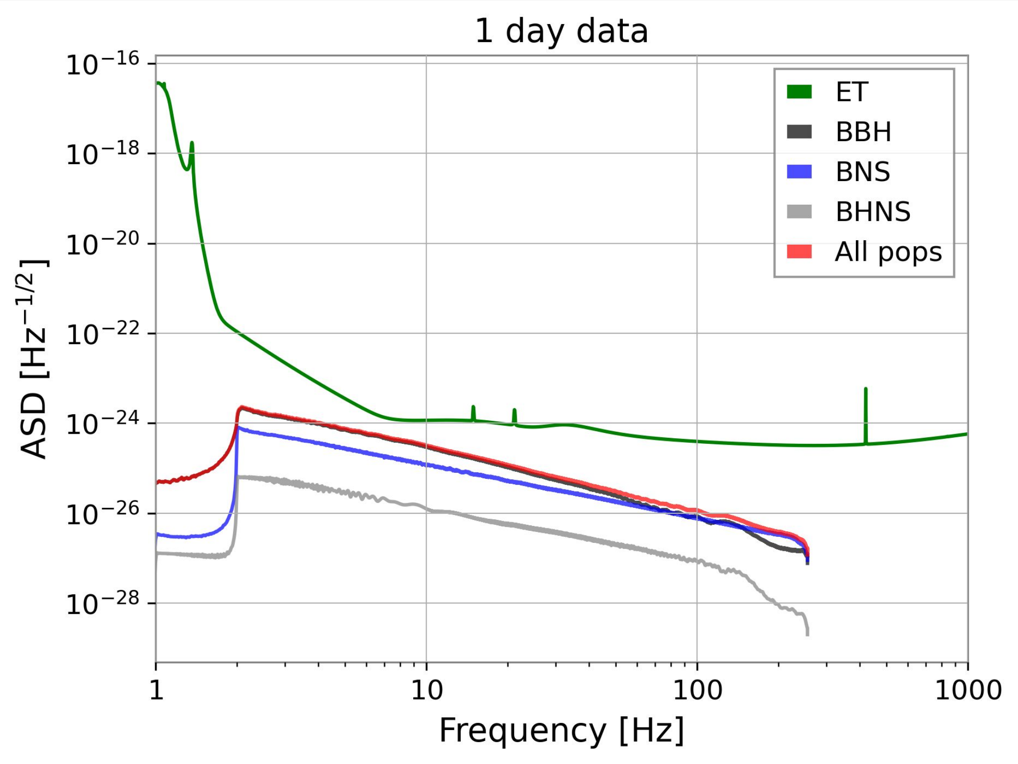
1 month (33days) all populations

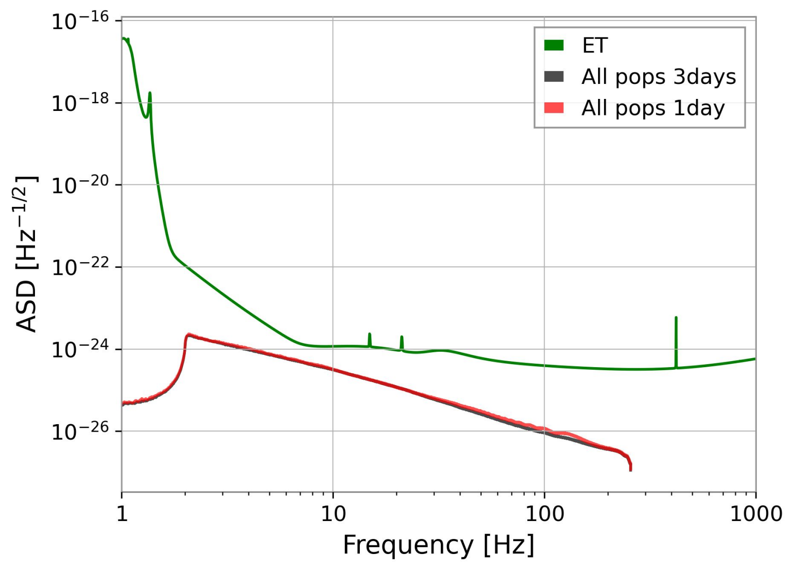
- signals/day:

BBH	BNS	BHNS
320	2000	5

- freq in [2-256] Hz
- higher amplitude for BBH at low frequencies

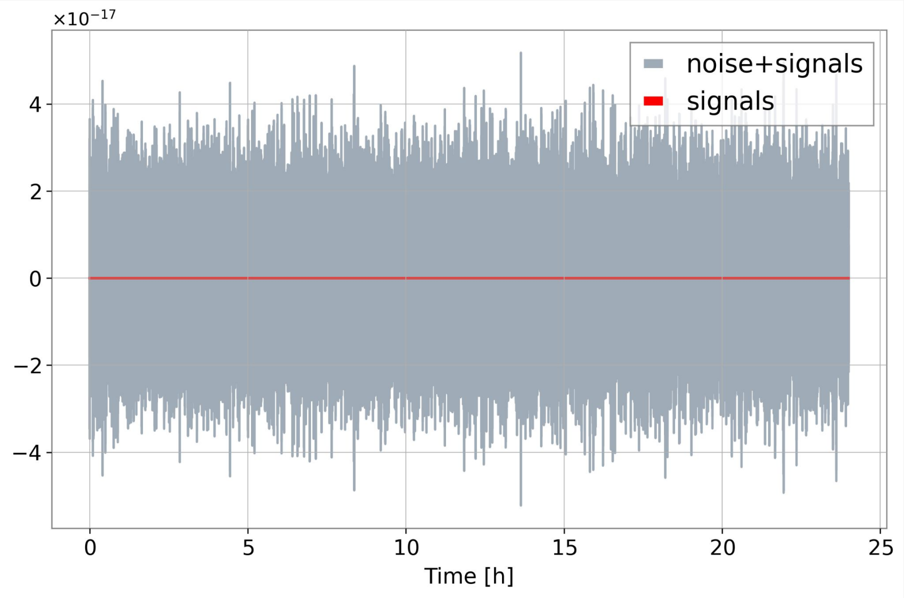
Amplitude spectral density

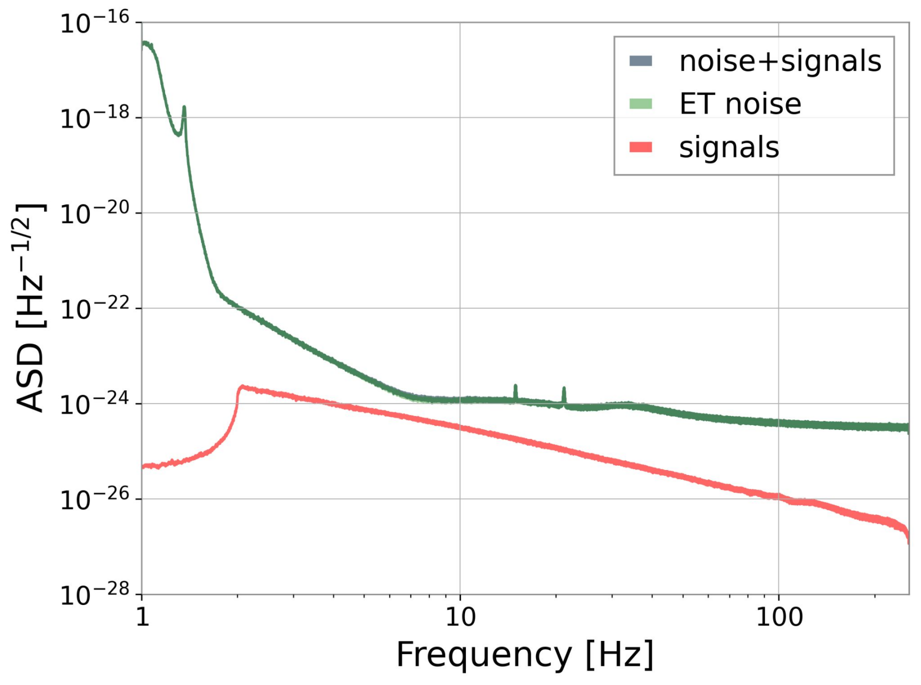




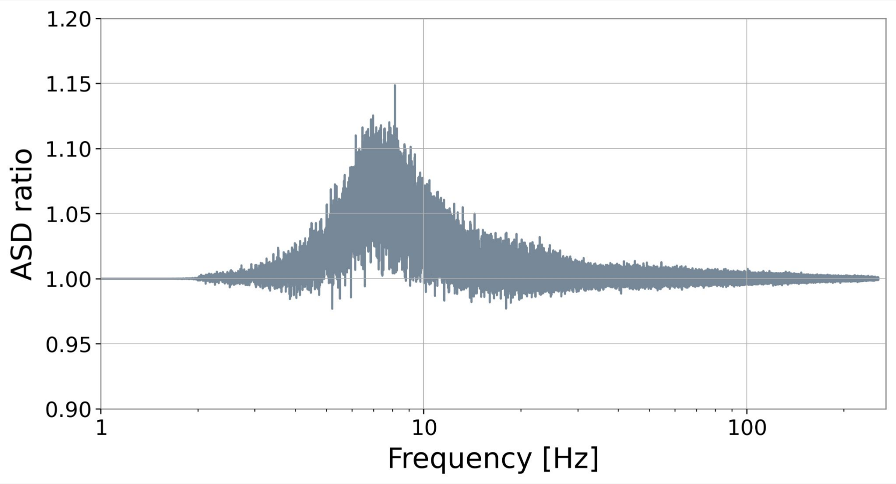
The background level reaches its asymptotic limit in a day

Injected signals in ET noise

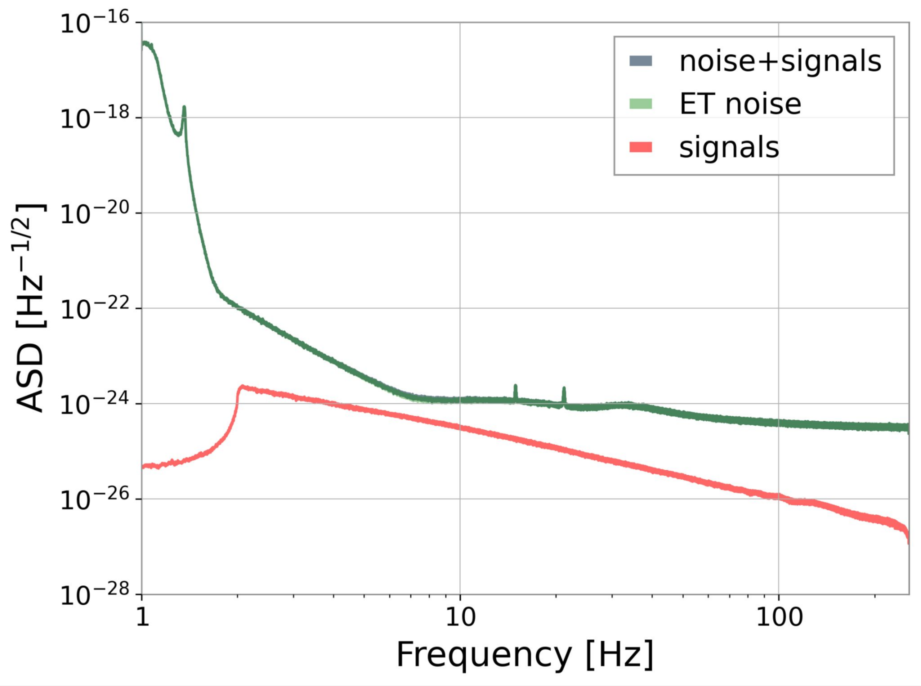




Injected signals in ET noise



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



Prospects

- We simulate **1 month of the astrophysical background** due to CBC sources.
  - → Determine if CBC signals affect the spectral estimation methods used for creating peakmaps in the CW searches.
- Hypothesis: *there is an impact*
  - → **Mitigation strategies**: is tuning the algorithm parameters sufficient to mitigate the effect? Otherwise, consider new strategies.
  - → Explore the possibility of **removing the CBC background** to improve spectral estimation accuracy.

Conclusion

- **Work completed** - ***preliminary results***
  - √ Constructed an astrophysical background for CBC sources (BBH, BNS, BHNS) over one month with the computation of its spectrum.
  - √ Computationally expensive but necessary for the CW analysis.

- **Next steps**
  - → Inject the CBC background in the current CW analysis.
  - → Evaluate the impact of this background on CW detection.

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