Impact of the Newtonian Noise on Einstein Telescope science

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ET in Italia: scienza e tecnologia per la candidature - Cagliari 2025 March 18-19

Motivation of the study

We want to observe **BHs with higher masses (IMBH mergers)** and **BNS mergers as earlier as possible.**

We need **Third generation** of gravitational wave interferometers

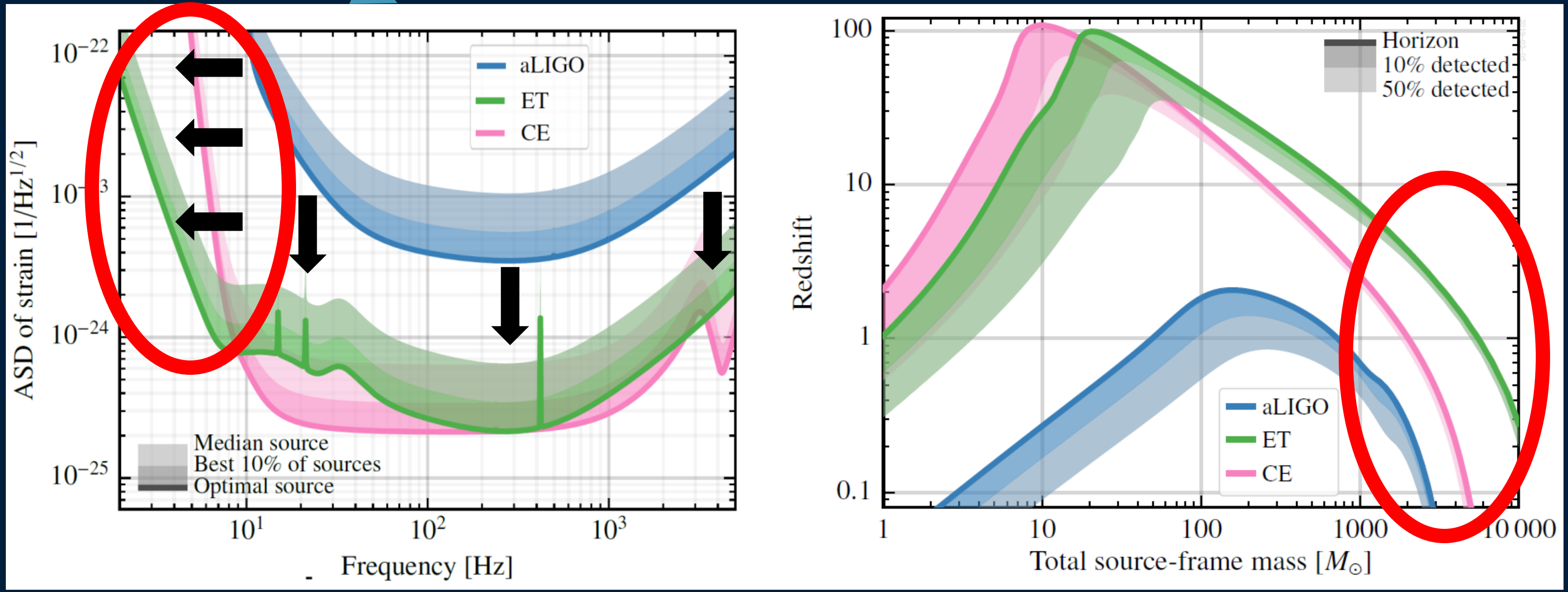
with **wider frequency range,**

reducing the local environmental noise,

to obtain an extraordinary sensitivity at low frequency

Motivation of the study

The low frequency range is needed to access new physics channels

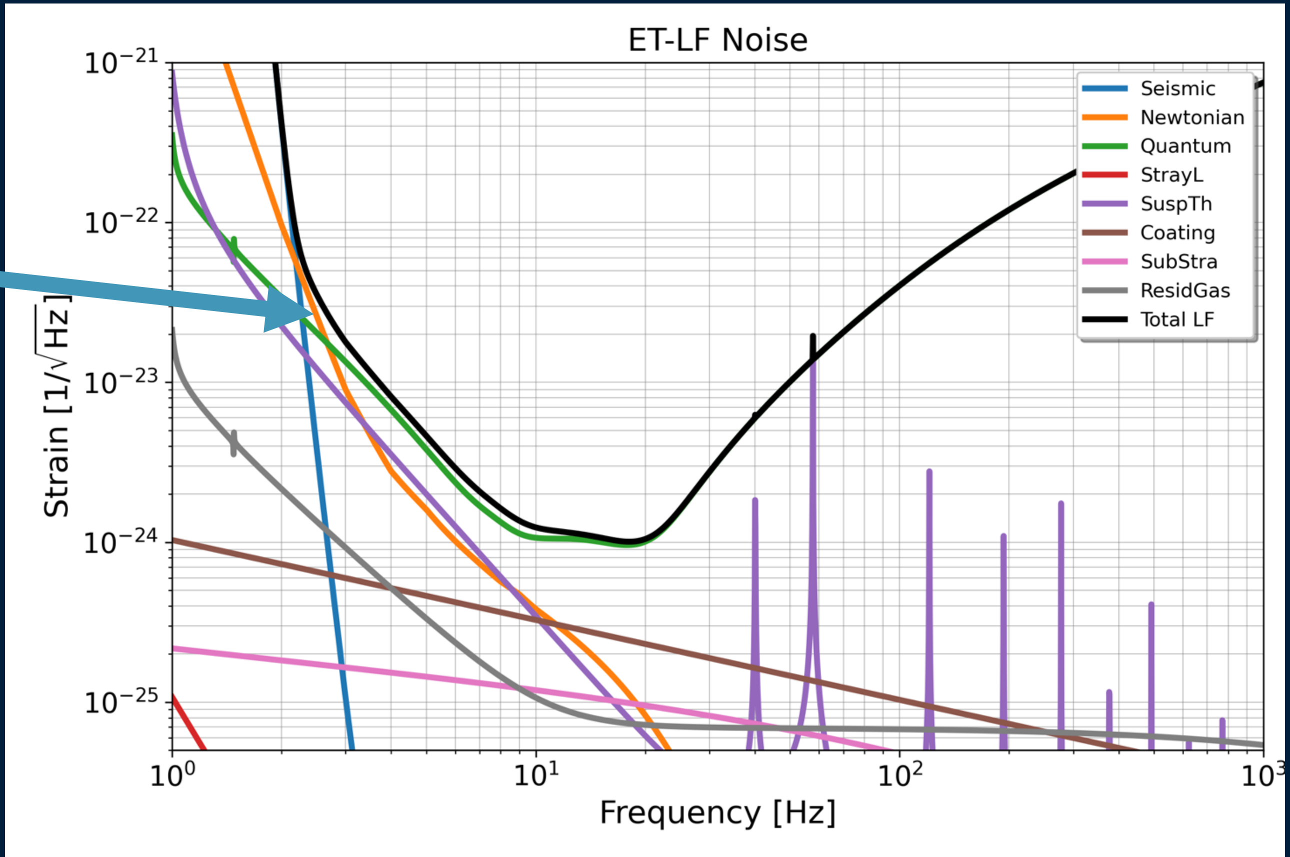


Motivation of the study

The low frequency range is needed to access new physics channels

The highest contribution is due to Seismic and Newtonian noise

FACTOR 3 OF ATTENUATION FOR ET-LF-NN



https://gitlab.et-gw.eu/et/isb/interferometer/ET-NoiseBudget/

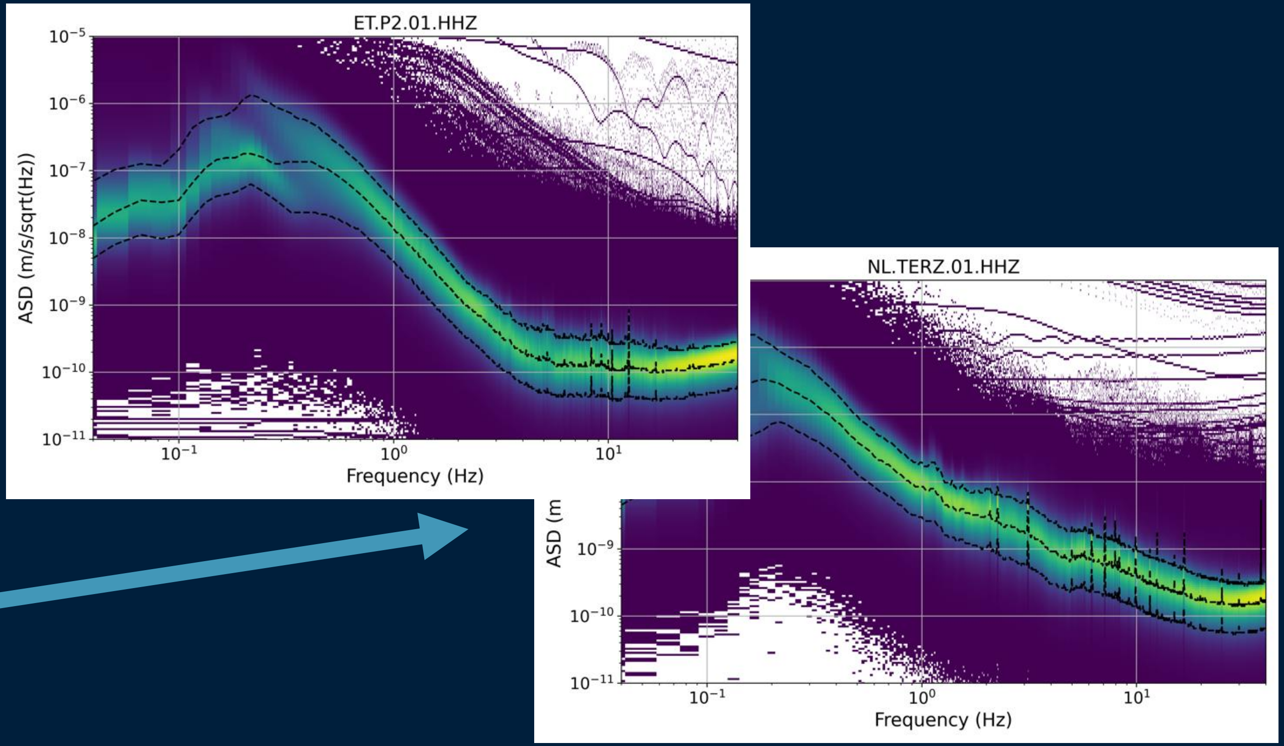
Motivation of the study

The low frequency range is needed to access new physics channels

The highest contribution is due to Seismic and Newtonian noise

Noise level at the candidate sites can affect positively or negatively the noise budget

(e.g. Di Giovanni et al 2021, Allocca et al 2021, Di Giovanni et al 2023)



The **ET site preparation board (SPB)** ensures that all aspects that can positively/negatively affect the correct operation of the ET apparatus are thoroughly investigated at the ET candidate sites.

CAVEAT EMPTOR: this is not a science case, nor we want to modify the ET Science Case (Maggiore et al. [2020]) after our results.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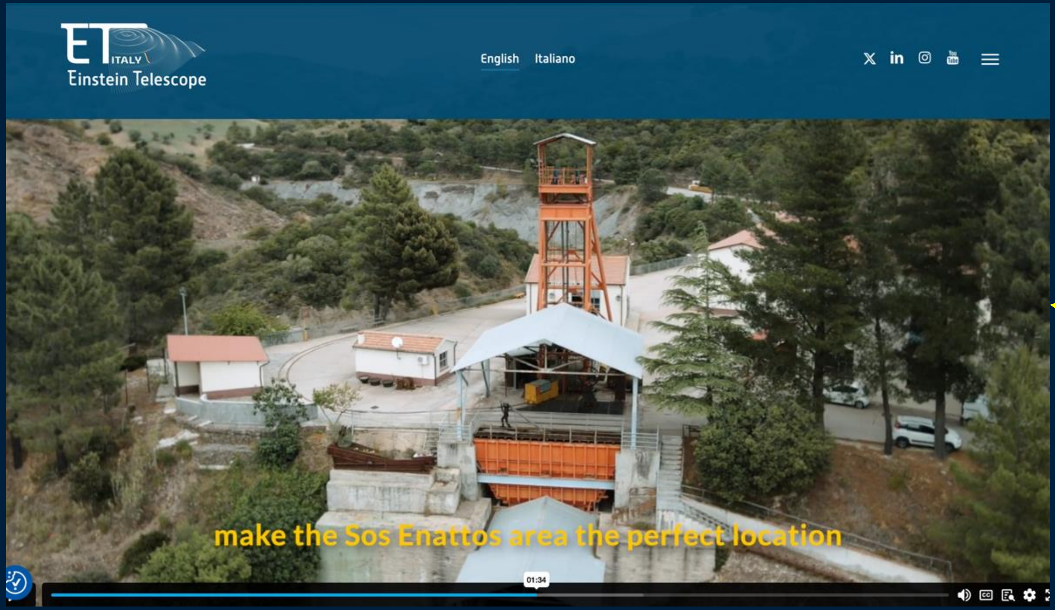

ET ITALY
Einstein Telescope
English
Italiano
make the Sos Enattos area the perfect location
01:34

Procedure of the analysis

An excess of Newtonian Noise, even for a short time interval, could even completely hide short duration signals in the low frequency band.

The First assessment of the impact of glitches related to site noise on the detectability of IMBH

Eur. Phys. J. Plus (2021) 136:511
https://doi.org/10.1140/epjp/s13360-021-01450-8

THE EUROPEAN PHYSICAL JOURNAL PLUS

Regular Article

Check for updates

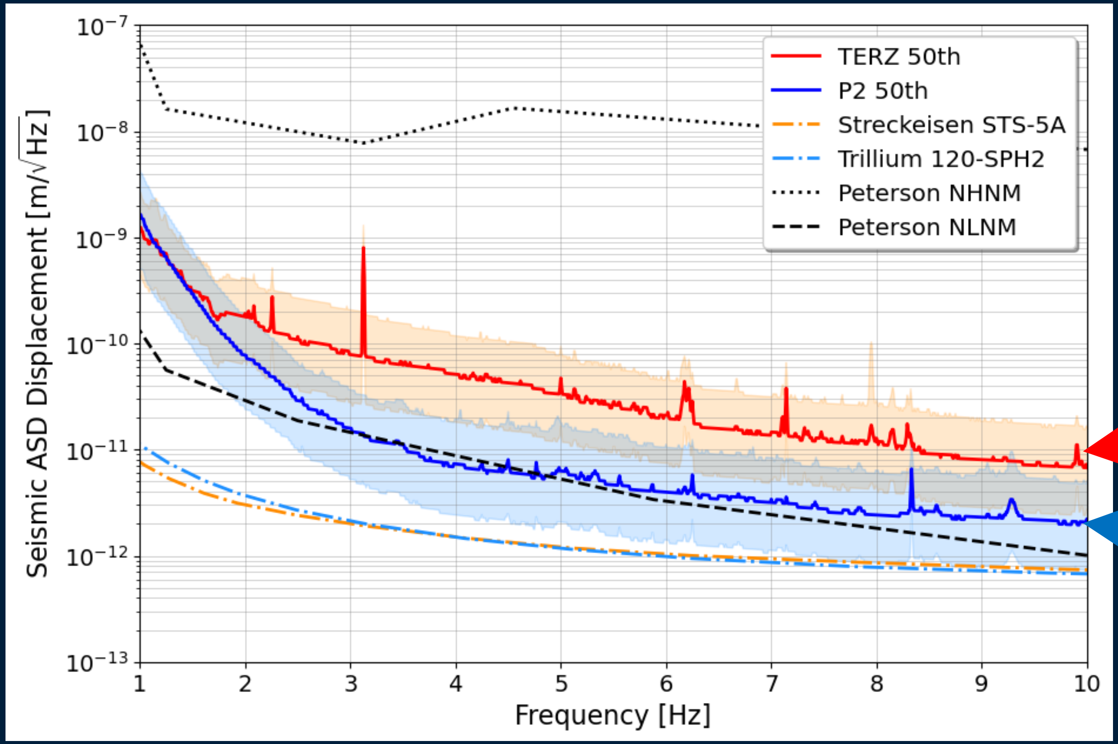
Seismic glitchness at Sos Enattos site: impact on intermediate black hole binaries detection efficiency

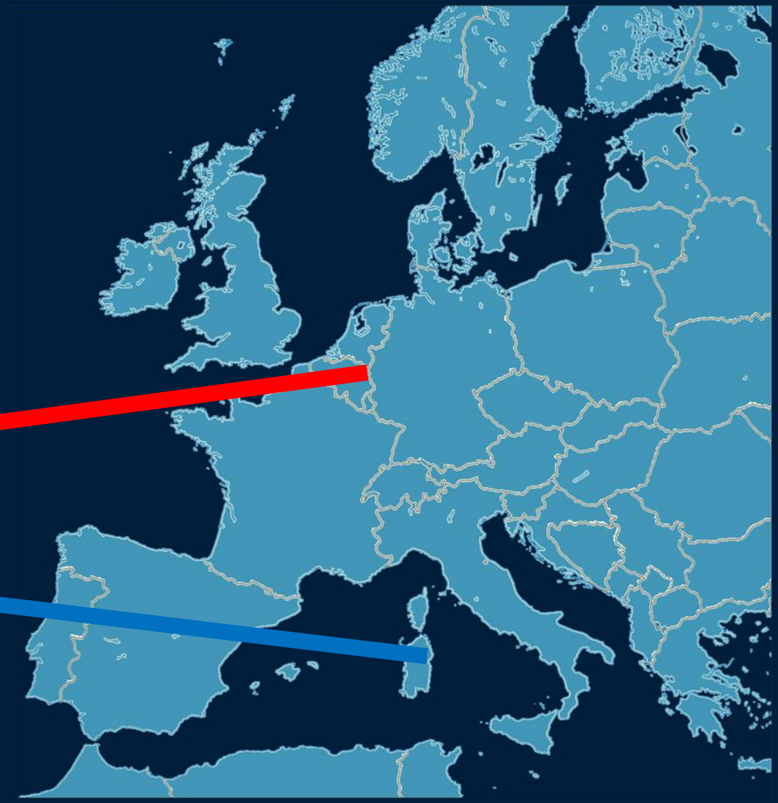
A. Allocca[1,2], A. Berbellini[3], L. Boschi[3,4,5], E. Calloni[1,2,a], G. L. Cardello[6,7], A. Cardini[8], M. Carpinelli[6,7,9], A. Contu[8,10], L. D'Onofrio[1,2], D. D'Urso[6,7], D. Dell'Aquila[6,7], R. De Rosa[1,2], L. Di Fiore[2], M. Di Giovanni[11,12,13], S. Di Pace[14,15], L. Errico[1,2], I. Fiori[9], C. Giunchi[11], A. Grado[16], J. Harms[12], E. Majorana[14,15], V. Mangano[14,15], M Marsella[14,15], C. Migoni[8], L. Naticchioni[14,15], M. Olivieri[3], G. Oggiano[6,7], F. Paoletti[17], M. Punturo[18], P. Puppo[15], P. Rapagnani[14,15], F. Ricci[14,15], D. Rozza[6,7], G. Saccorotti[11], V. Sequino[1,2], V. Sipala[6,7], I. Tosta E Melo[6,7], L. Trozzo[2]

That study just considered the typical time window of IMBH signals in ET to infer in how many of these windows we were above or below ET target sensitivity

Procedure of the analysis

Seismic analysis performed over two years of data from the candidate sites





Procedure of the analysis

Seismic analysis performed over two years of data from the candidate sites

Evaluation of the Newtonian Noise contribution from only seismic waves

F. Badaracco, J. Harms, Class. Quant. Grav. 36 (2019) 14, 145006 assuming:

- Contribution only from body waves
- 1/3 of the seismic noise coming from compressional waves
- Spherical or cubic cave
- Uncorrelated NN on the ITF Test Masses

$$\tilde{h}_{NN} = \frac{4\pi}{3} G \rho_0 \frac{2\sqrt{2}}{L} \frac{1}{(2\pi f)^2} \tilde{x}$$

ASD of NN

ASD of Seismic Displacement

See also **credible lower limit** J. Harms et al., Eur. Phys. J. Plus (2022) 137:687

Procedure of the analysis

Seismic analysis performed over two years of data from the candidate sites

Evaluation of the Newtonian Noise contribution from only seismic waves

Evaluation of the new ET noise budget characterized by the candidate site noise

PSD of NN from seismic measurement of the site

$$S_{n,*F} = S_{S,*F} + S_{NN,*F} + S_{Q,*F} + S_{SL,*F} + S_{STH,*F} + S_{C,*F} + S_{SubS,*F} + S_{RG,*F}$$

* = Low or High

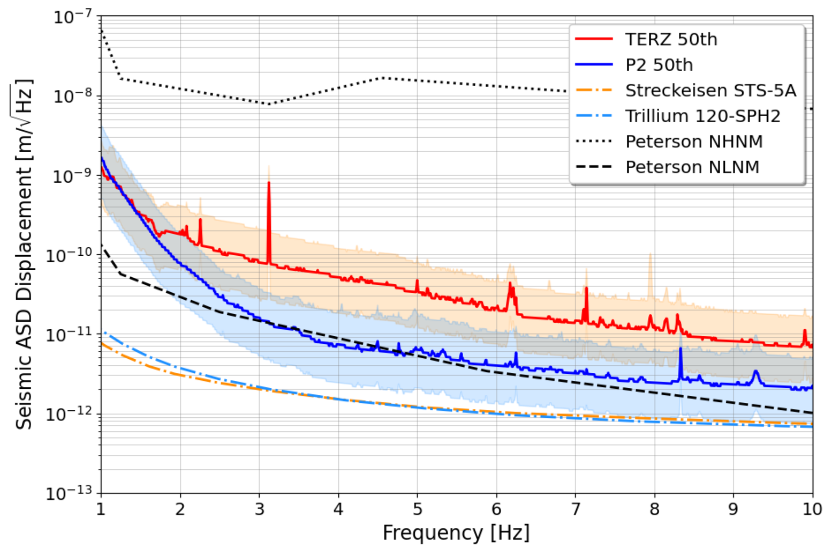
$$S_{n,ET} = \frac{1}{\frac{1}{S_{n,LF}} + \frac{1}{S_{n,HF}}}$$

$$Strain = \sqrt{S_{n,ET}}$$

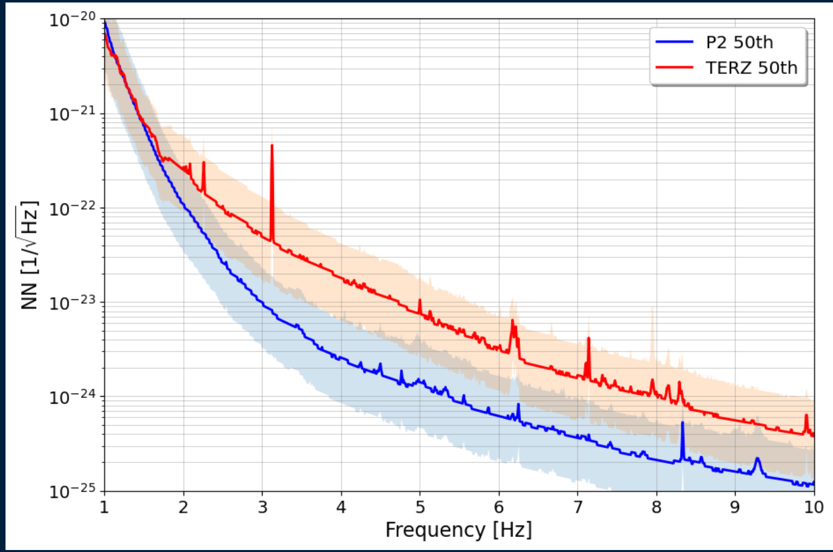
Other sources of NN (like atmospheric…) are not kept into account because we still need to collect data from other sensors and implement them inside the ET noise budget.

Procedure of the analysis

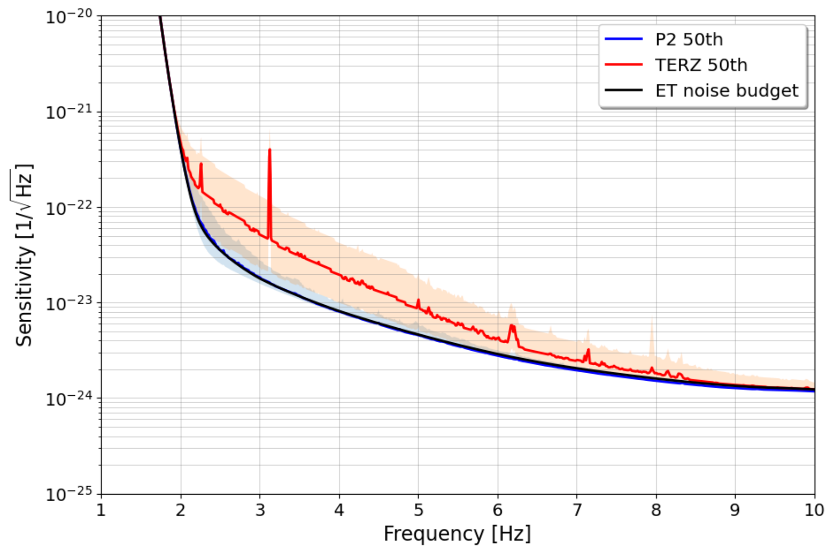
Seismic ASD Displ.



NN ASD



ET sensitivity

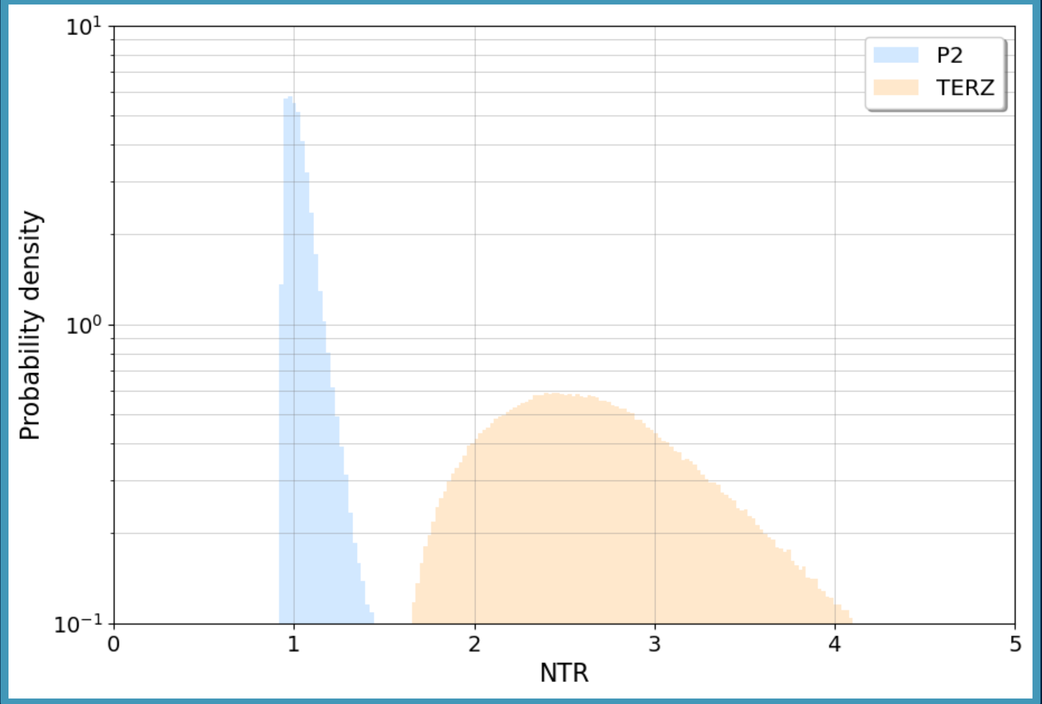


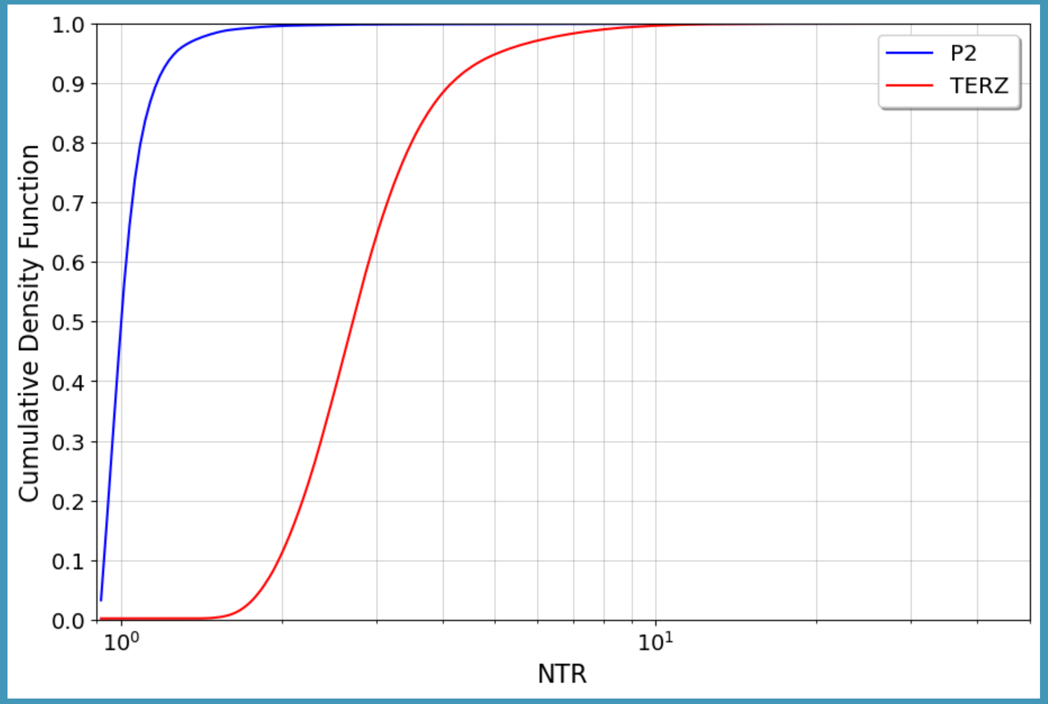
Noise to Target Ratio (NTR) indicator defined as:

$$NTR = \sqrt{\frac{1}{\Delta f}\int_{f_1}^{f_2} df\, \frac{S_{n,real}}{S_{n,ET}}}$$

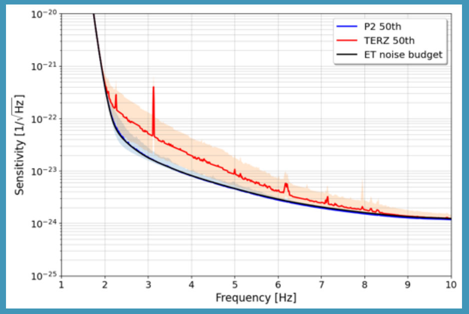
$S_{n,real}$ → Modified curve from candidate site

$S_{n,ET}$ → ET design noise budget

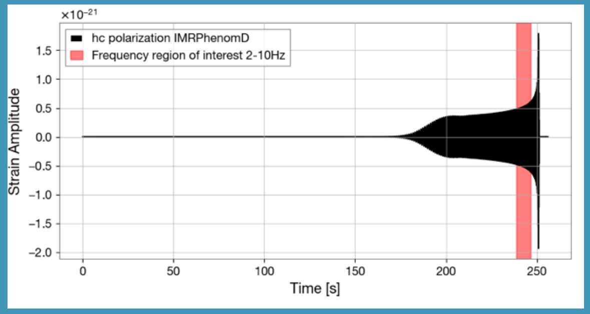




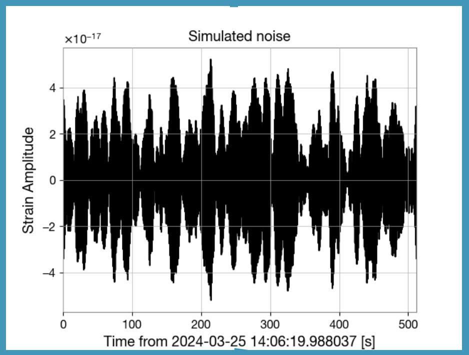
Procedure of the analysis



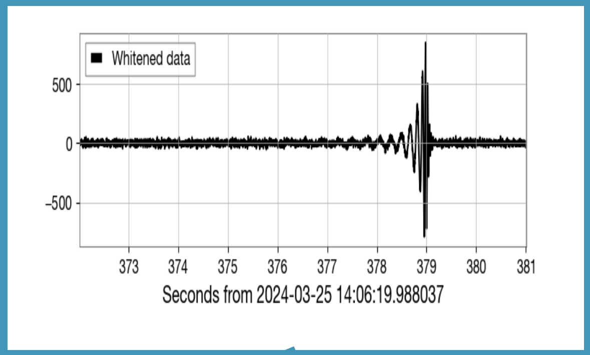
Calculate the modified ET sensitivity curves and NTR



Get astrophysical events of interest from catalogs and generate the waveforms



Simulate ET noise with the modified sensitivity curves



Inject signals into noise

Calculate the signal SNR between 2 Hz and 10 Hz

Compare the SNRs with the design case

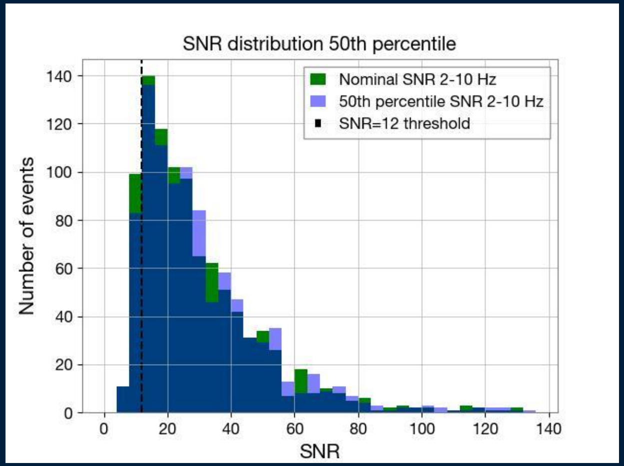
The procedure uses the pyCBC, astropy and gwpy python modules downloadable with conda

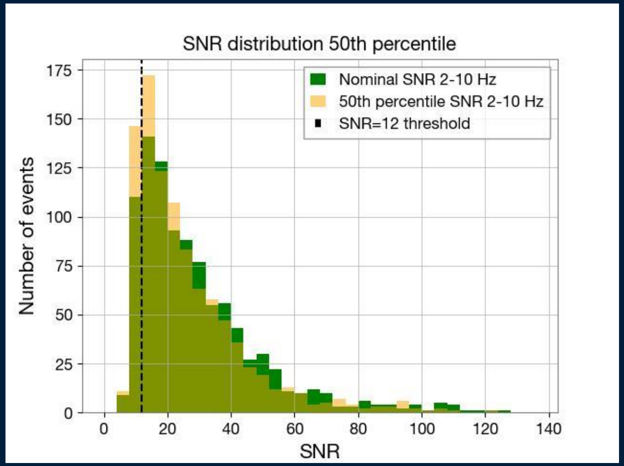
IMBH
About 1000 events

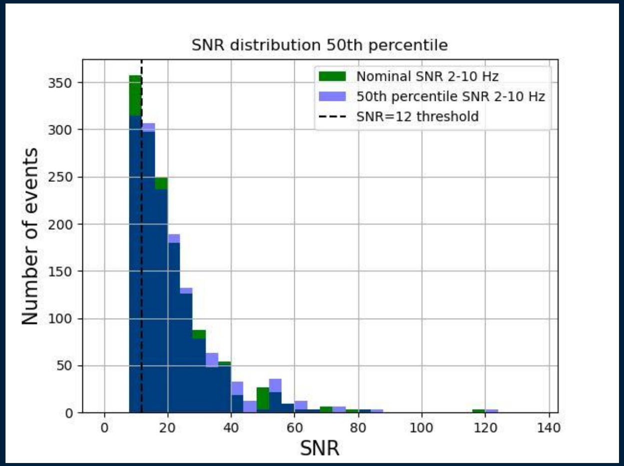
BNS
About 1500 events

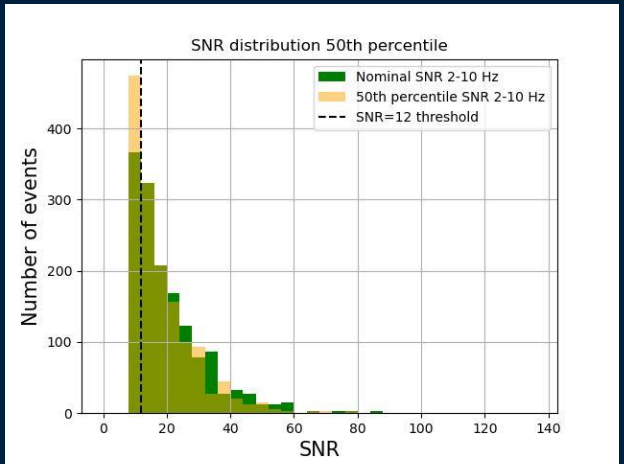
Sardinia | EMR | Sardinia | EMR

Nominal SNR distribution and 50th percentile

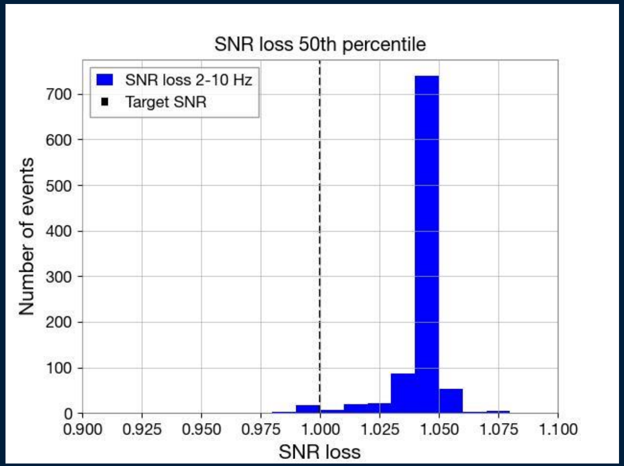


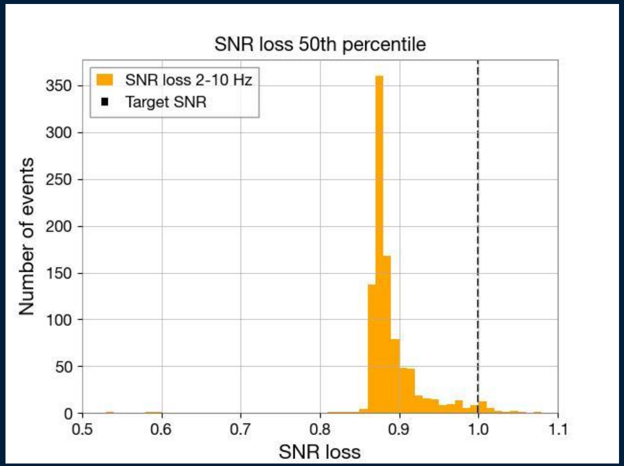


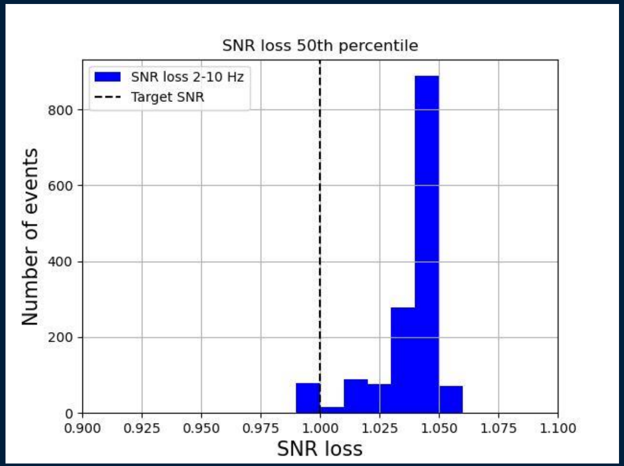


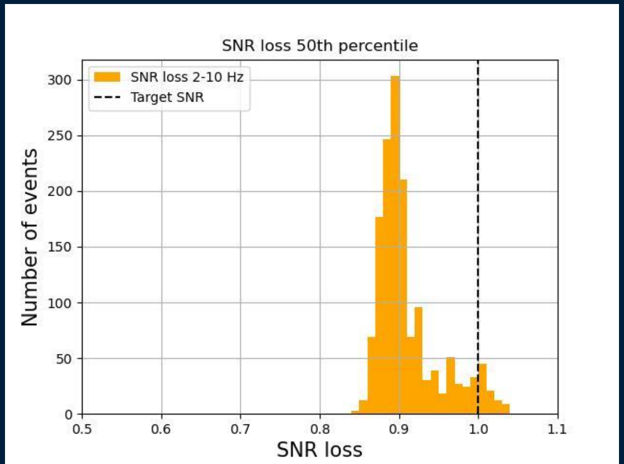


SNR/SNR design using 50th percentile









Conclusions

This preliminary study therefore aims at assessing the **impact** of site dependent noise over a class of particular GW source.

The **Newtonian noise** can limit the ET sensitivity between 2 and 10 Hz.

The high noise level at the **EMR** site translate into a degradation of the ET-LF sensitivity; **Sardinia** is compliant with the ET requirements, showing only a marginal impact on ET-LF sensitivity.

Reduced SNR at low frequency **can seriously hinder early warnings** for compact object mergers.

This study is needed for the site selection process for ET.

All the material needed for the analysis can be pulled from this repo (required python packages are astropy, gwpy, pycbc):

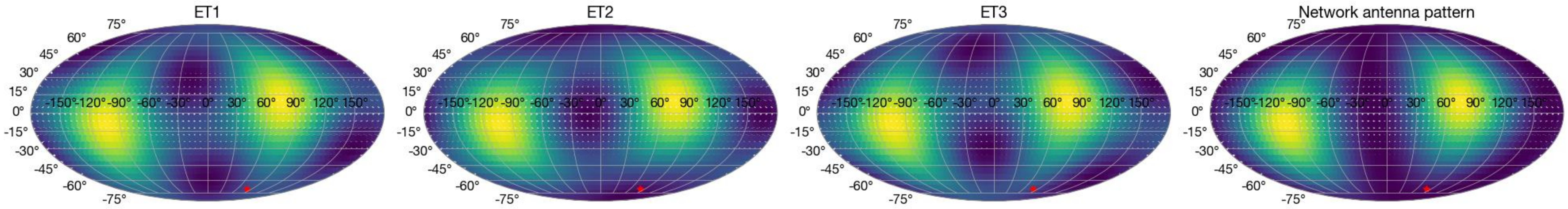
https://gitlab.et-gw.eu/digiovanni/et_glitchness

BACKUP

Defining a procedure to quantify site dependent effects on GW detections

The procedure uses the pyCBC, astropy and gwpy python modules downloadable with conda;

The triangular configuration of ET is simulated by generating three co-located detectors with different orientations and with appropriate arm angles;



Signal generation

Signals are generated using appropriate GW waveform approximants (IMRPhenomD or IMRPhenomPv2_NRTidalv2).
The signals take into account the antenna pattern of the detectors.
Signals are generated starting from 1 Hz.