Einstein Telescope
Mock Data and Science Challenge

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for OSB-Div10 and EIB-Div1

Einstein Telescope Symposium, 09/05/2024

Why mock data challenges

- Common training simulated data sets
- Used to test, develop, optimize, compare data analysis and parameter estimation techniques, adapted to the the new challenges/requirements of XG detectors.
- Assess the science potential with ET or XG
- Assess the requirements for computing infrastructure

MDC 1.0

- A month duration with both noise and GW signal
- Triangle configuration
- Gaussian colored noise (PSD LF+HF for 10 km)
- Population of BBHs (10%) (Mapelli et al. 2022), BNSs (87%) and NSBHs (3%) (Santoliquido et al. 2021) with isotropic distribution in the sky
- Waveforms: IMRPhenomXPHM for BBHs and BHNSs, and IMRPhenomPv2 with tidal effects NRTidalv2_V for BNSs

The Data

- Frame files for E1, E2, E3 and E0 (set 0: noise only, set 1: noise+GWs)

1300 frames per detector of length 2048s and sampling rate 8192 Hz (1.3 TB)

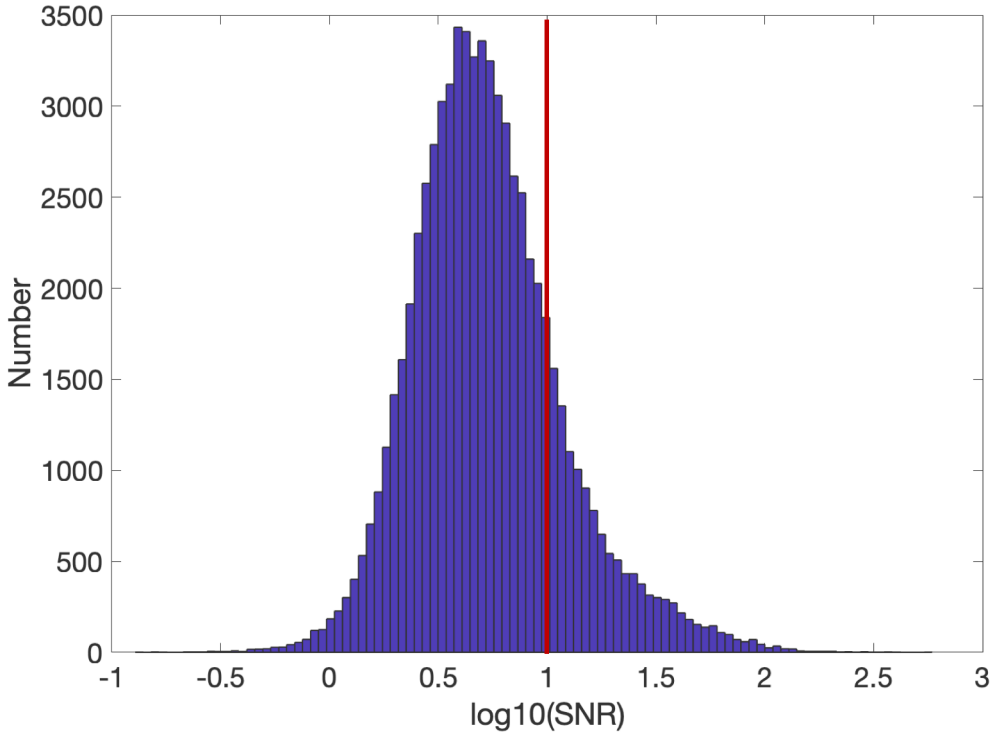
+ frames for Cosmic Explorer, CEA and CEB

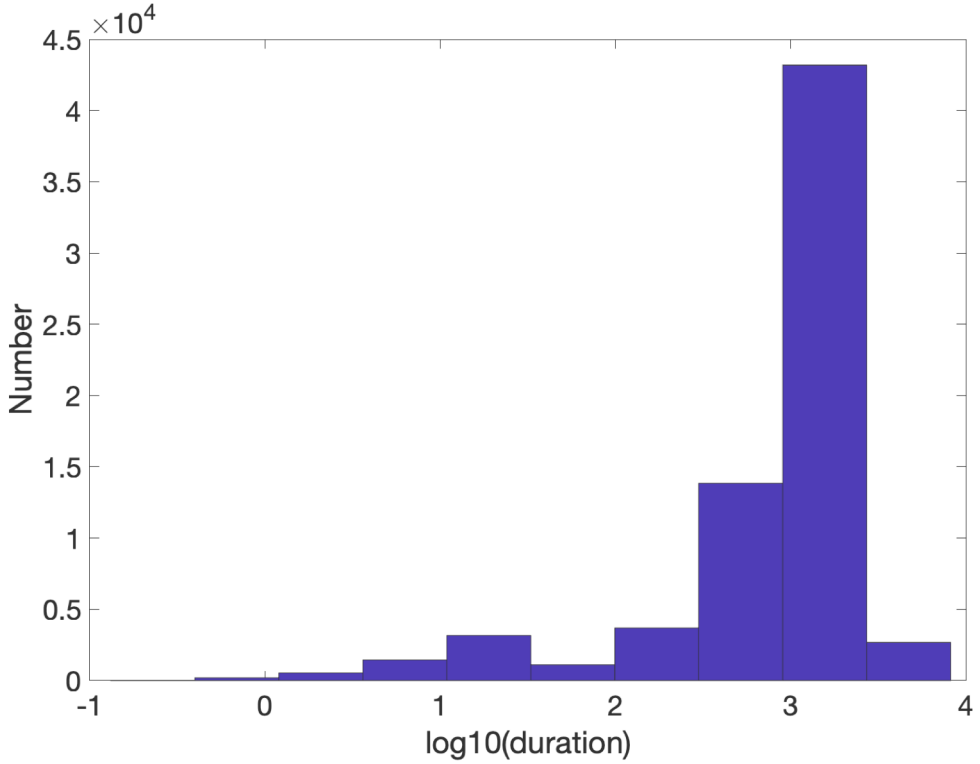
- Instructions to access the data in CVMFS:

https://wiki.et-gw.eu/EIB/SoftwareFrameworks/WebHome?validationkey=e2698d03b6eff5856cfab4654d3fbfe5

- We also provide a list with the source parameters (masses, spins, redshift, localisation, orientation, time at coalescence) and the optimal SNR

Some Statistics





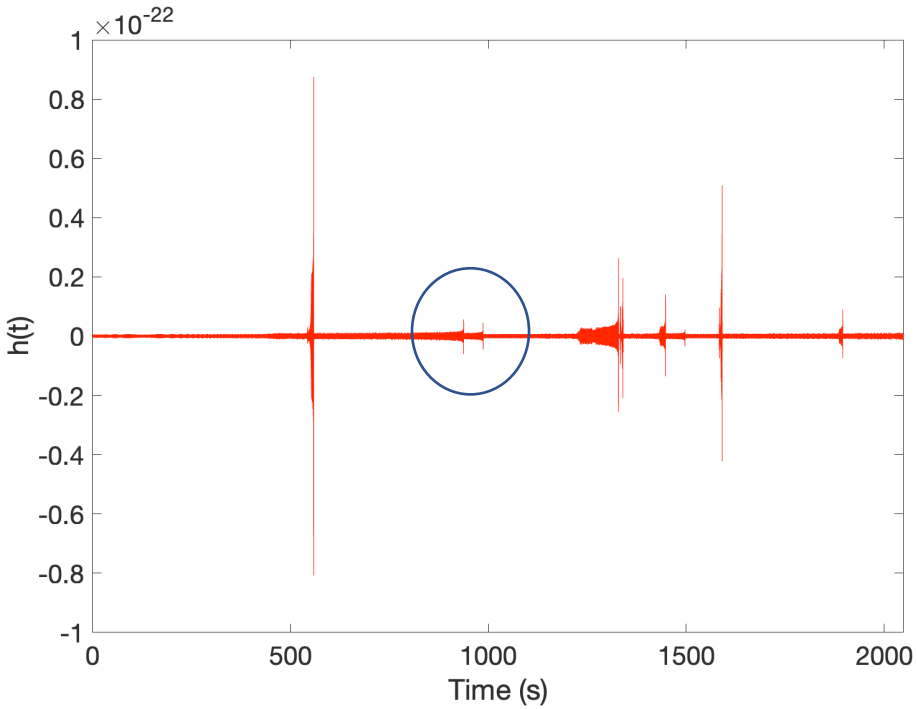
SNR>8: 11551 BNSs , 537 BHNSs, 6119 BBHs,

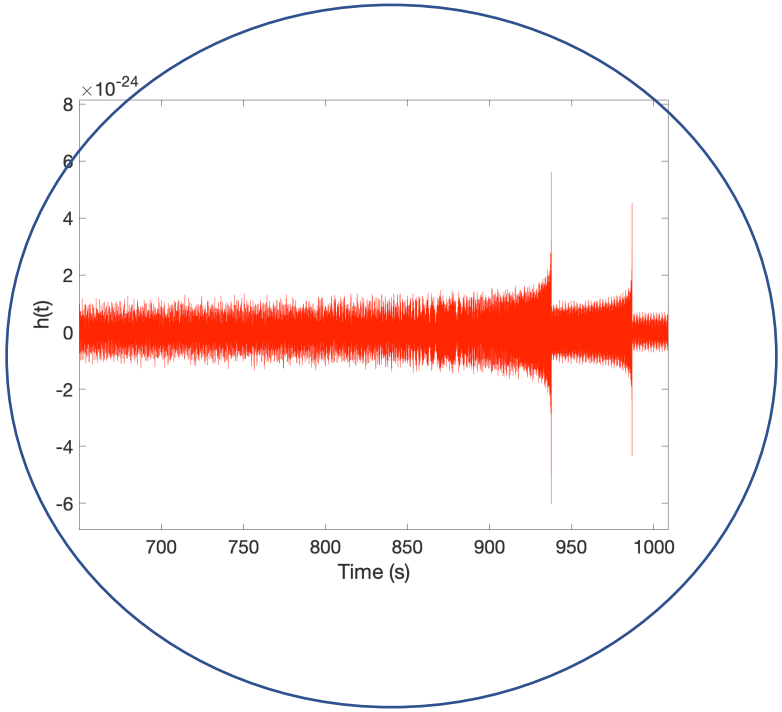
SNR>12: 4048 BNSs , 238 BHNSs, 5228 BBHs

Example of the GW data

28 signals with SNR>6, largest at SNR=85

BNSs merging at 937s and 986s, that are both long duration and overlapping





Challenges

Beginner

- Recovery of high-SNR signals within given time windows

SNR = 597, 386, 383 (BNS), 374, 343, 306

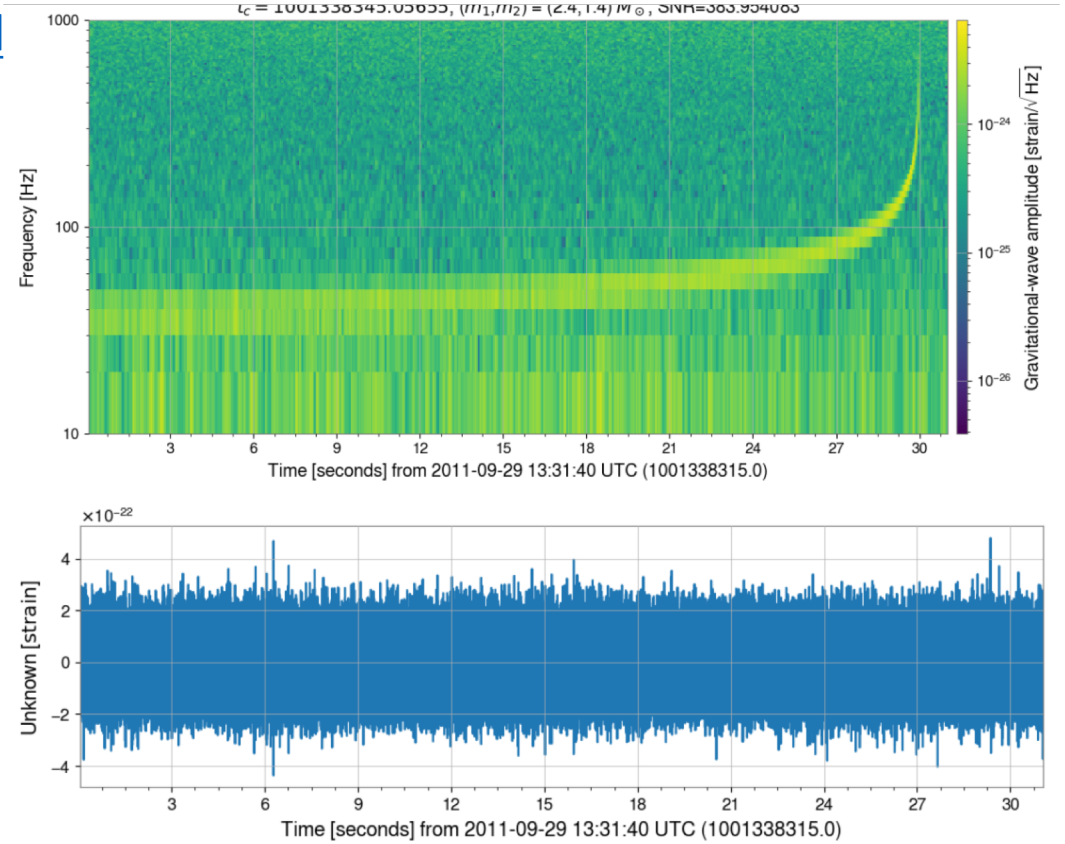
Expert

- Parameter estimation of ultra-high SNR BBH signals
- Long duration binary neutron stars
- Overlapping signals

Tutorials

https://gitlab.et-gw.eu/osb/div10/mdc-tutorial

Jupyter scripts to access the data, plot the time series, or basics analysis on the data.
(J. Veitch)



Simulation code

- MDC_Generation (ETMDC 2012-2015, LVK stochastic)
https://gitlab.et-gw.eu/osb/div10/mdc-generation

- Updates for the current ET MDC: new waveforms in the frequency domain, continuity of the noise

- Formation of a code review team
a code is only asymptotically correct! (S. Vitale)

- Expect new data release within a month as MDC 1.1

Current activities

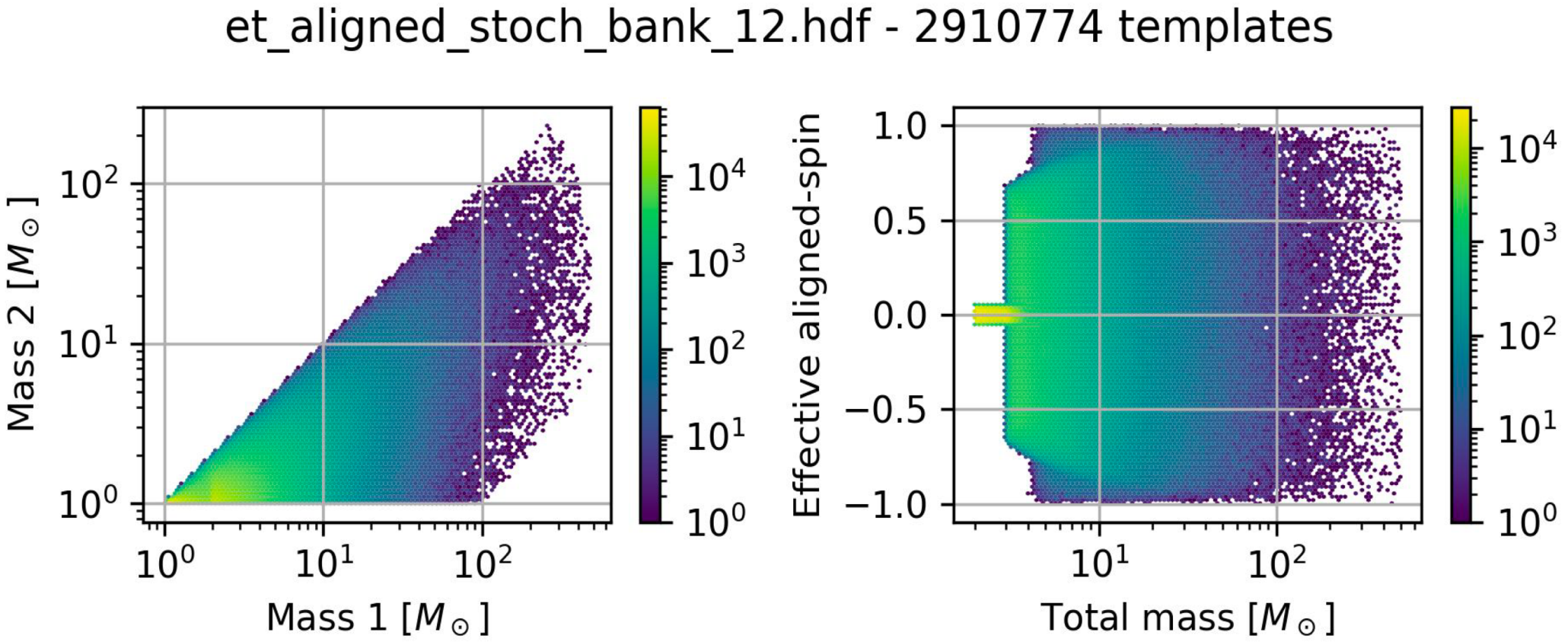
- Run of existing pipelines ongoing (PyCBC, MBTA, Gwastro, PySTAMPAS, PyGWB)
- Many presentations at the div 10 session yesterday about new techniques to deal with long waveforms and overlapping signals
- Coordination with EIB (common session yesterday)

Current activities

The following is a table with the details of groups working on ET DA within obs-da div 10. Please indicate if you are running on MDC1 in the remarks :

Group	Expertise level	Brief explanation of aims	Software used	Contact person	Remarks
Utrecht University	Experts	Parameter estimation (automated classifier for telling number of overlapped signals), joint parameter estimation, Searches (template bank versus global optimisers, null stream background), Machine-learning	PyCBC, other software developed in UU...	Bhooshan Gadre, Thibeau Wouters, Harsh Narola, Justin Janquart, Anuradha Samajdar,	MDC1
ICCUB	Medium	PE, searches	cWB, PyCBC	Tomas Andrade, Pablo barneo, Ruxandra Bondarescu	MDC1
University of Geneva	Beginners	CBC signals, early-inspiral regime	Not final, machine-learning related	Carlos Moreno Martinez, Sarah Baimukhametova, Steven Schramm	MDC1
IJCLab	Experts	Test existing searches based on PySTAMPAS and PyCBC; develop template banks for CBC searches	PySTAMPAS, PyCBC	Tito Dal Canton	MDC1
Annecy, Urbino	Experts	Test existing searches based on MBTA	MBTA, pycbc	Buskulic, Grimaud, Fabrizi, Guidi	MDC1
RWTH Aachen	Medium	Parameter estimation (Fast machine learning based posterior reconstruction)	LAL, pytorch, own developed software	Markus Bachlechner, Tobias Reike, Johannes Erdmann, Achim Stahl	MDC1
APC-Paris	Experts	BNS parameter estimation (DNN based Hamiltonian Monte Carlo)	Bilby, pytorch, own developed software	Ed Porter, Jules Perret	MDC1
Ewha Womans University (Korea)	Beginners	CBC signal search pipeline review/test with matched filtering, (plan) PE focusing on mass distributions of the detected sample (in relation with div3)	LAL, pyCBC (plan) Bilby	Sumi Lee, Seohyun Park, Chunglee Kim	MDC1
University of Pisa	Medium	Detection, PE and Early Warning for high SNR sources with Deep Learning	Pytorch, own developed software	Federico De Santi, Lucia Papalini, Massimiliano Razzano	MDC1

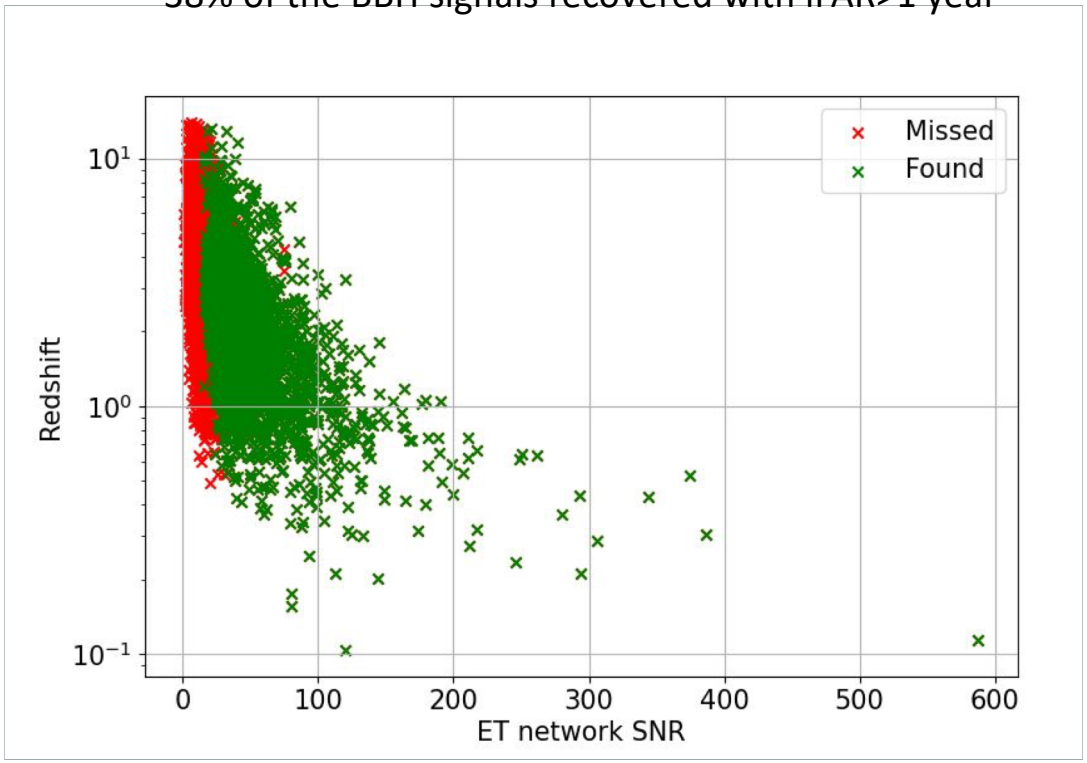
PyCBC

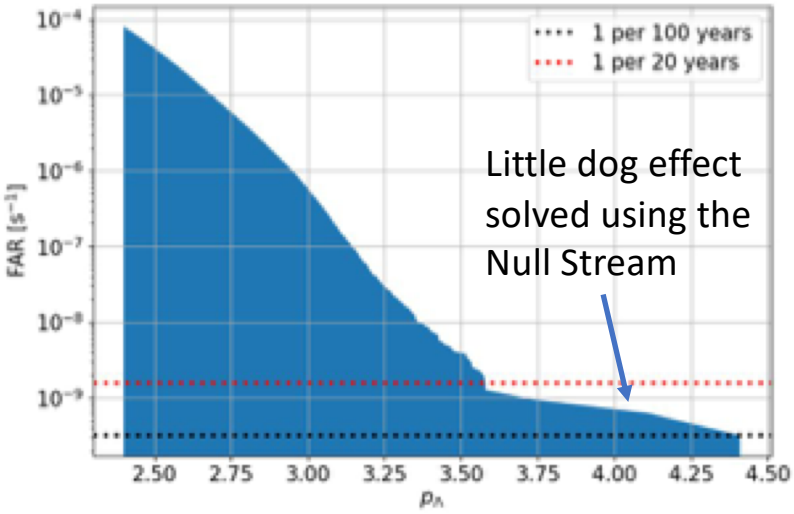


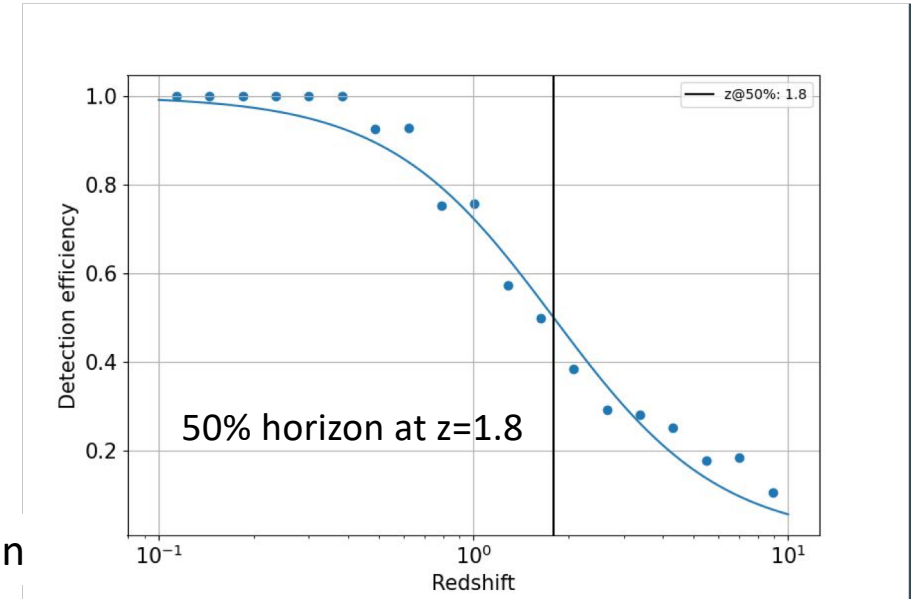
Tito Dal Canto, slides presented at div 10 telecon

PySTAMPAS

38% of the BBH signals recovered with iFAR>1 year

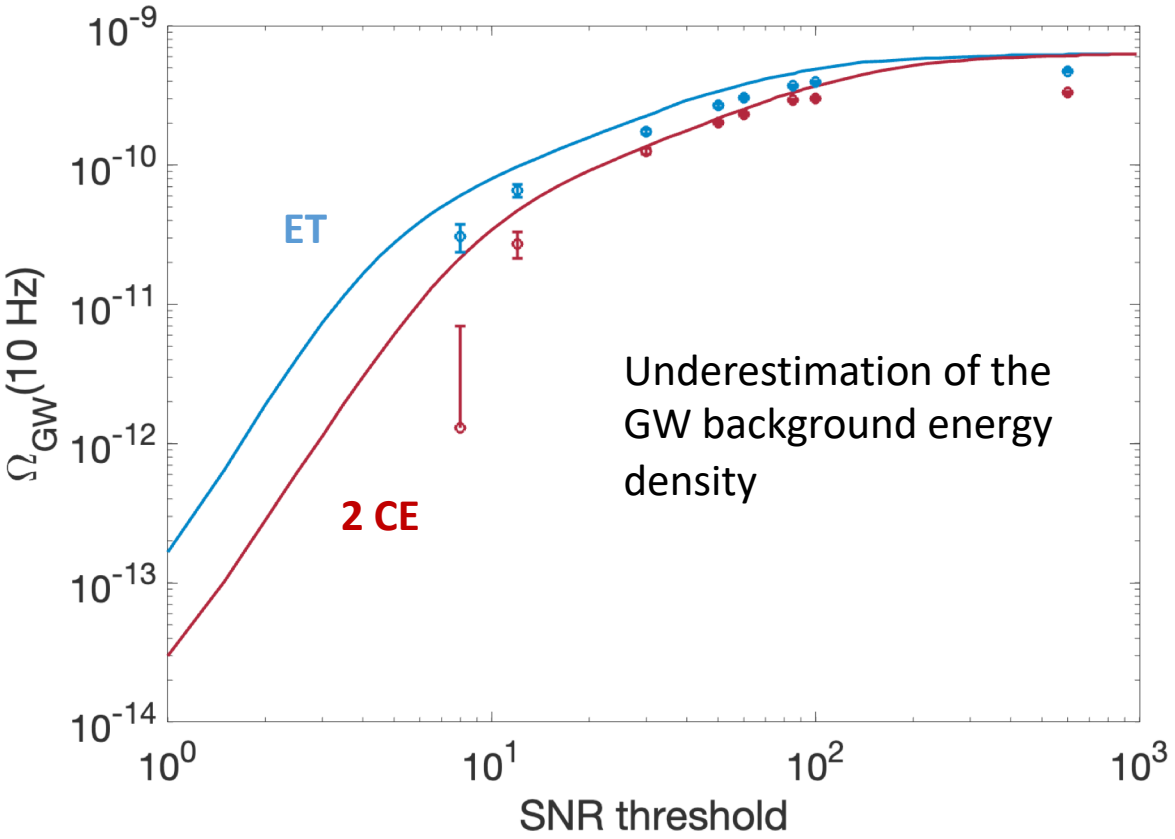






Adrian Macquet & Tito Dal Canto slides presented at div 10 telecon

PyGWB



Ebersold, Suresh & Regimbau, slides presented at div 10 telecon

Wish list for the next MDC(s)

- Variety of network configurations: 2 Ls, aligned or 45 deg, 10/15/20 km
- More realistic noise: glitches, correlated noise, missing data
- Other types of sources: population III binaries, primordial BBHs, IMBHs, bursts, continuous waves, cosmological backgrounds
- Eccentric waveforms
- Non isotropic sky localisation
- …
- multiband (LISA) and multimessenger

Expertise and personpower needed for the models, the code development and the review

Summary

- First ET MDC ongoing with Gaussian noise and only CBCs
- Have revealed some limitations/challenges of actual pipelines
- Many new development (see presentations at the div10 session)
- Starting to organize the next rounds of the MDC