Results and implications from the new optimal SNR implementation in PyGRB

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Gamma-Ray Bursts (GRBs) are currently one of the most promising multimessenger sources, with short and long GRBs being long believed to be powered by the coalescence of compact binary systems (CBCs) and by the core-collapse of massive stars, respectively. This means that, in principle, every GRB emitted has also produced Gravitational Waves (GWs), regardless of our ability to detect the source.
In this scenario, externally-triggered GW searches perform an offline analysis of GW data coincident with a GRB trigger to look for any potential GW counterpart. In the case of short GRBs specifically, since we expect a CBC GW signal powering the emission, this search can be performed with a matched filtering technique with NSBH and NSNS templates, and it is currently done by PyGRB.
PyGRB is a tool that generates a data analysis workflow for a targeted, coherent, externally-triggered GW search. When submitted, this workflow runs a pipeline to analyse data from multiple GW detectors coherently. It then performs various signal-based veto cuts and data quality cuts to determine whether or not a CBC signal (the GW counterpart) is present in the given data coming from the same point in the sky and at the same time as an observed short GRB.
The sensitivity of the search is tested by injecting simulated CBC signals in the data and by quantifying the capability of the pipeline to recover such signals.
In this work, we exploit the **optimal signal-to-noise ratio** (SNR) calculation, which we have implemented in the PyGRB workflow, to provide a further test of the sensitivity of the search performed by PyGRB, and of the optimal SNR calculation that we have implemented in the workflow as well.

What is the optimal SNR?

The optimal SNR represents the maximum value theoretically obtainable for a GW signal, assuming **Gaussian stationary noise**, **accurate modelling of the signal waveform** and **ideal matched filtering** with the template perfectly equal to the injected signal.

For a single detector one can define the optimal SNR as:

$$\rho^2_{opt} = 4\int_0^\infty \frac{|\tilde{h}(f)|^2}{S_n(f)} df \,,$$

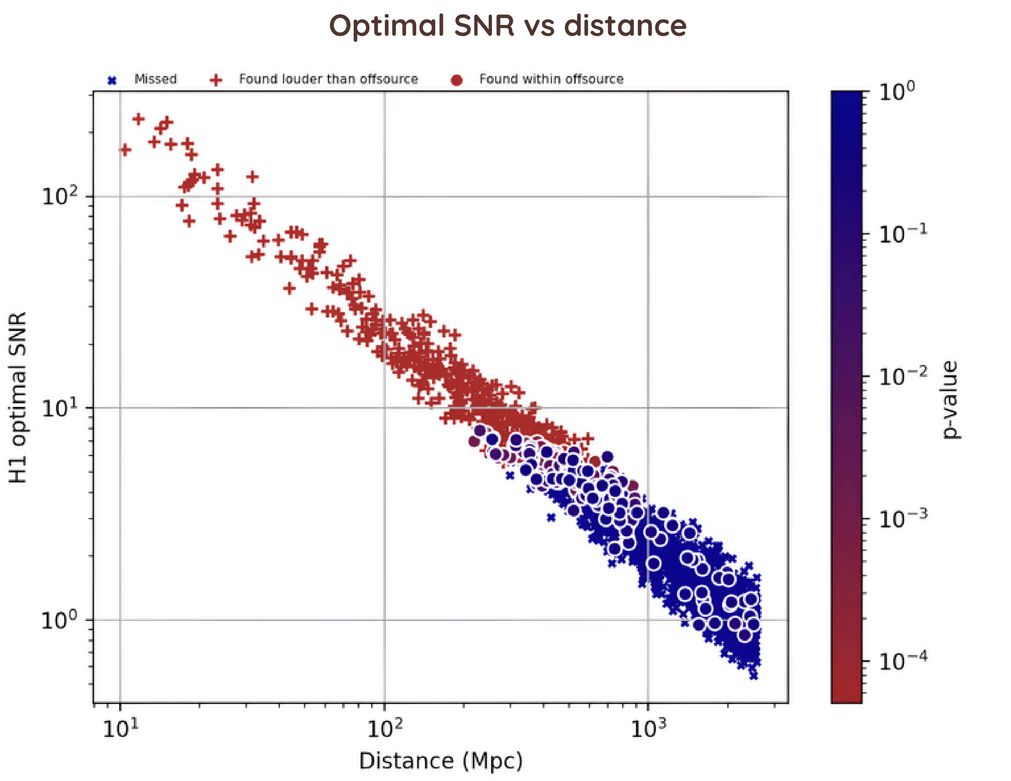
Fourier transform of the injected GW signal

PSD of the detector's noise.

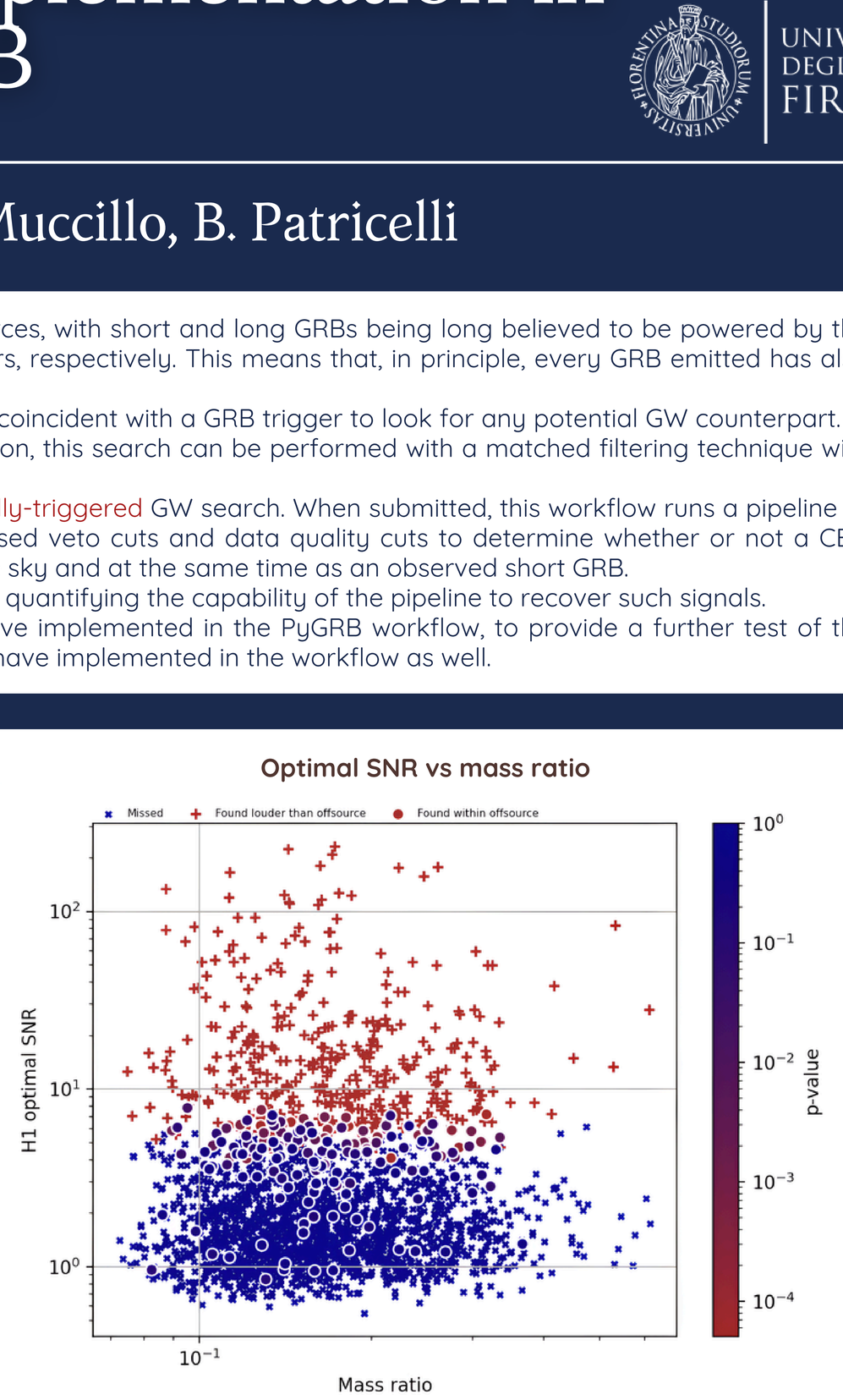
Hence...

Good diagnostic for the pipeline's ability to recover GW signals!

Tests on GRB240115A (NSBH injections)

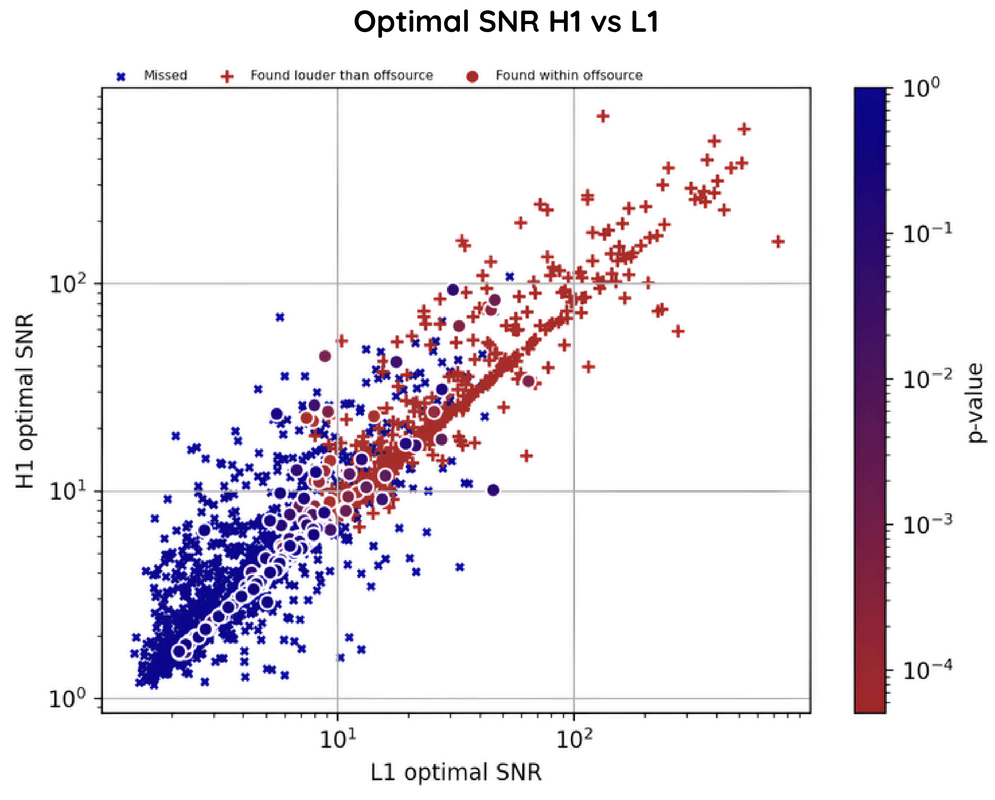


- The optimal SNR scales as ~ 1/d
- Injections are missed at high distances and low optimal SNRs



- No evident relation between the optimal SNR and the mass ratio
- Injections are missed at low mass ratio and low optimal SNRs

(NSNS injections)



- The two optimal SNRs are correlated
- Injections are missed at low optimal SNRs both for H1 and L1

Previous work

See **LIGO Document G2600231** for the implementation in the PyGRB workflow

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