Evaluating Significance of IMBH Triggers Using the Bayes-Coherence Ratio (BCR)

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The Bayes Coherence Ratio

- Paper: `https://arxiv.org/pdf/1803.09783.pdf`
- Bayes-Coherence Ratio (BCR)- $\frac{\alpha Z^S}{\prod_{i=1}^{D} \beta Z_i^G + (1-\beta) Z_i^N}$
- Z^S, Z^G, and Z^N are the evidences for hypotheses that the data comes from coherent CBC signals, glitches, or pure Gaussian noise, respectively.
- Can be used to help separate coherent signals from glitches
- α, β, and $1 - \beta$ represent the prior beliefs in the signal, glitch, and noise models. These parameters can be tuned to separate the signal and background distributions.

The Bayes Coherence Ratio

Main Idea:

- Run a bunch of PE runs on background triggers.
- Run a bunch of PE runs on software-injected data.
- Calculate the BCR for each, tune α and β to create the largest amount of separation between injections and background.
- If the BCR of a possible event falls within the injection distribution, significance can be increased depending on how many background events fall below the threshhold (generally a LogBCR of 0 with normalized weights).
- If the BCR of a possible event falls below the threshold, it can be thrown out as a glitch

- With this method 98% of background triggers identified by the O1 PyCBC pipeline were found to have a LogBCR below zero.

Previous results using background triggers from the O1 PyCBC pipeline

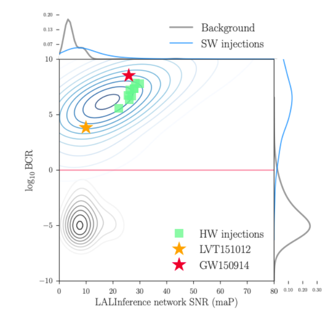


Figure: Weighted BCR vs SNR distributions with α = 1e-6, β = 1e-4 from https://arxiv.org/pdf/1803.09783.pdf

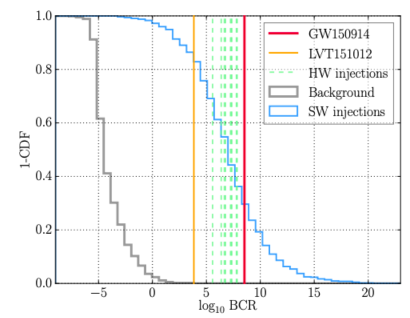


Figure: Weighted BCR distributions with α = 1e-6, β = 1e-4 from https://arxiv.org/pdf/1803.09783.pdf

Using this technique for IMBH triggers

- In the paper the BCR was only used on injections and background triggers with total mass <100 solar masses. High mass triggers have much shorter signals, so glitches can be much more coherent between detectors in the smaller timeframe.
- This would make it much harder to separate the signal and background distributions.
- However, even if a 98% improvement is out of reach, something on the order of 70-90% improvement could possibly be useful in throwing out glitches.

PE Runs on IMBH triggers

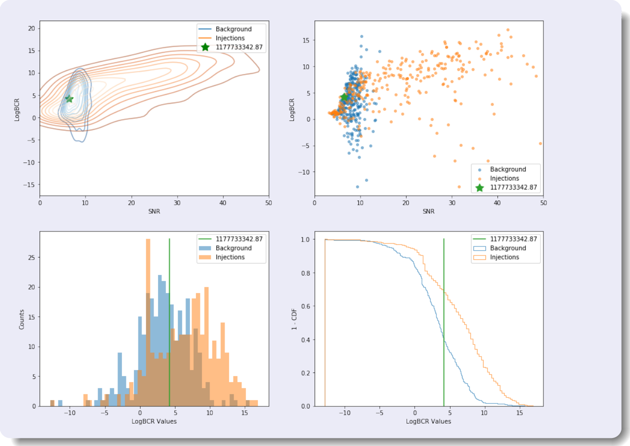
Methods

- Ran using Bilby for parameter estimation, on 4s long data segments for each trigger and injection. Used the IMRPhenomPv2 waveform model.
- Ran PE runs over the 300 loudest IMBH background triggers found from the CWB pipeline.
- Additionally ran on 300 software injections with SNRs ranging up to 50. These software injections ranged from 100-400 total solar masses.

Finally, ran a PE run on data around the 170502 trigger:

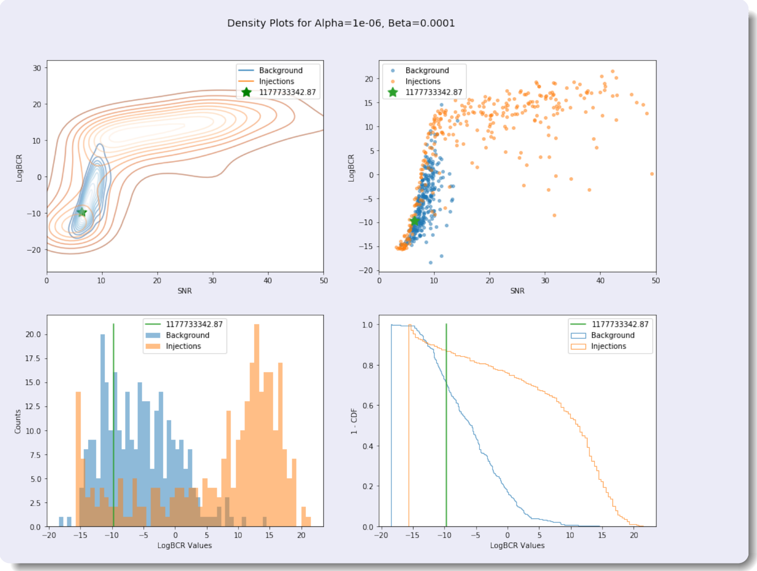
- Was the most significant trigger observed in the O1+O2 IMBH search
- FAR at .34 yr^{-1}. Not enough to call a real event
- Checks also identified a correlation between the trigger time and an optical lever laser glitch.
- However, if its BCR fell above the noise threshold, its FAR could be decreased accordingly.

Results ($\beta = 1$, $\alpha = 1$)



- Here the BCI (BCR with α and β set to 1) doesn't yield a good separation, if any, between the injections and background.

Results (β = 1e-4, α = 1e-6)



Analysis

- These weights were some of the best in separating the background from the injections. The BCR paper `https://arxiv.org/pdf/1803.09783.pdf` also used these weights.
- We see that at a cutoff of LogBCR $= 0$ we can eliminate around 80% of glitches
- While there are a decent amount of injections below this threshold as well, their SNRs are generally quite small. Most high-SNR injections are above the cutoff.
- Additionally from the data it actually looks like this IMBH trigger at GPS time 1177733342.87 is likely a glitch, as its BCR is much below the cutoff.

Background Trigger Rates, Before

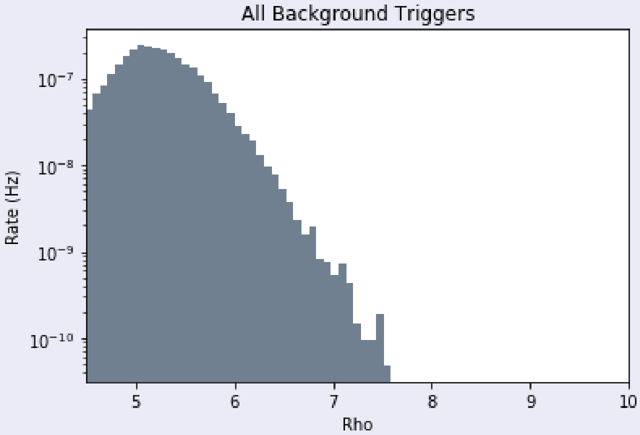


Figure: Total background trigger rho distributions

Background Trigger Rates, After

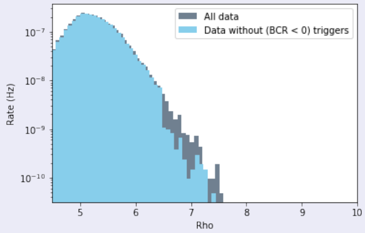


Figure: Background rho distributions with and without PE runs with BCR < 0.

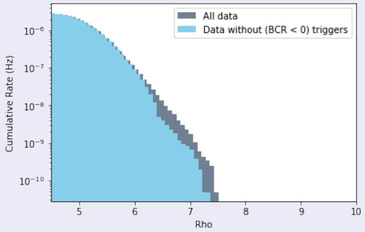


Figure: Background rho distributions, cumulative

Background Trigger Rates, After

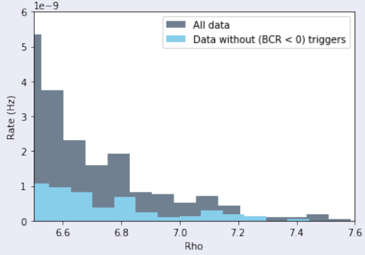


Figure: Background rho distributions with linear scaling in rates

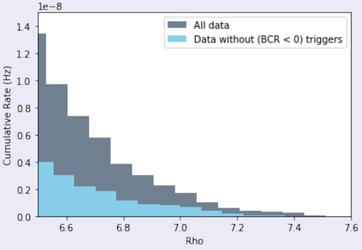


Figure: Cumulative rho distributions, linear

- Here we've removed quite a few glitches from the very far end of the distribution using the LogBCR < 0 cutoff. This looks promising in reducing glitch rates and increasing significance for IMBH events.