Glitch or Gravitational Wave? Removing Noise Events in Cross-Correlation Analyses
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Introduction
The Stochastic Transient Analysis Multi-Detector Pipeline (STAMP) uses data that are cross-correlated between detectors to search for gravitational-wave candidates. STAMP searches are expected to identify some GW candidates that disagree with our noise model but are inconsistent with signal. These candidates are likely to be "glitches," or short-duration noise transients, which can be caused by environmental effects near a detector.

Glitches may trick search algorithms into generating a GW trigger, but it is unlikely that they will imitate all characteristics of a true GW event. Thus, we propose a maximum likelihood algorithm for evaluating the consistency of STAMP candidates with a true GW signal. This will allow us to veto glitch-like candidates by quantitatively answering the question of whether a particular event is consistent with our noise model plus a signal.

Glitch Identification
Our likelihood function will be based on three parameters that facilitate glitch identification:

- Relative signal amplitude in each detector
  Glitches caused by environmental effects at one detector will not affect the other detector.

- Significant negative SNR in cross-correlated data
  Real GW signals should produce only positive definite cross-correlation signal (when the direction-dependent phase is correctly accounted for); thus, a true GW signal should contain no more negative SNR than well-behaved noise. We expect glitches to contain high-magnitude positive and negative SNR.

- Imaginary part of GW estimator
  We have defined a complex estimator for GW power ($\hat{W}$) such that the real part ($\hat{Y}$) is an unbiased estimator for GW power $[1]$. 

$$\hat{W} = \bar{Q}_I(t; f, \Omega) \hat{s}_I(t; f) \hat{s}_I(t; f) = \hat{Y} + i\hat{Z}$$

Here $\bar{Q}_I$ is the filter function for the interferometer pair $I$, assuming a source located at $\Omega$, and $\hat{s}_I, \hat{s}_I$ represent the FFT of the time-series from each detector. GWs produce structure in Z maps, while the GW injection does not. We explored the use of a box search statistic $[1]$ to quantify this structure in the Z-SNR ft-map. A PDF of this statistic for well-behaved noise is shown here:

Next Steps
It will be necessary to formally define a metric for each of the three parameters, similar to what is shown in the Example section. Then, we will empirically calculate the PDF of each metric using GW software injections. Lastly, we will determine the likelihood function, which will be the product of the PDFs (if they are independent).

Once complete, this likelihood algorithm will be used to evaluate candidates from STAMP GW searches.

How do other pipelines handle glitches?
X-Pipeline
- Vetoes glitches by comparing coherent energy and incoherent energy (usually strongly correlated in noise glitches) $[2]$.

Coherent Waveburst
- Uses a maximum likelihood statistic to determine waveforms for detection and reconstruction of burst signals.
- Glitch rejection involves a ratio of coherent energy to total energy (coherent energy plus null energy). Glitches are expected to have little coherent energy and large null energy $[3]$.

Compact Binary Coalescence (CBC)
- Confidence in a candidate is assessed by comparing its location in multi-dimensional parameter space to expectations of background, which is determined using time-slides $[4]$.

Example: $\hat{Z}$ Maps
It is evident that the glitch has clearly defined structure in both the Y-SNR and Z-SNR ft-maps, while the GW injection does not. We explored the use of a box search statistic $[1]$ to quantify this structure in the Z-SNR ft-map. A PDF of this statistic for well-behaved noise is shown here:

References

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