Frequency Targeted Noise Characterization for Advanced LIGO

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Introduction

- LIGO observatories in Louisiana and Washington were built to detected gravitational waves from cataclysmic events in the Universe, like the merging of two black holes into a larger one.
- LIGO must be extremely sensitivity to detect gravitational waves. Because of this, one of the largest difficulties is background noise.

Abstract

- Many different algorithms are used to find the sources of false positives at LIGO. One of these is the Hierarchical Veto algorithm, or "Hveto."
- Our work was to run Hveto at different frequency ranges to improve the method and improve the process of background noise detection at LIGO.

Hveto

- Hveto is a tool used to identify sources of false positives in the gravitational wave channel $h(t)$.
- By figuring out the source of these false positives, or *triggers*, we are able to reduce the amount of background noise and narrow gravitational wave searches.
- Hveto calculates the probability that noise in an auxiliary sensor channel is correlated to noise in $h(t)$. This metric is called "significance".

1. Hveto finds the number of coincident triggers between $h(t)$ and each auxiliary channel.
2. Hveto calculates how many triggers are expected to be coincident by random chance.
3. Significance of each channel is calculated.
   1. The more actual coincidences (step 1) opposed to expected coincidences (step 2), the more likely that triggers in the $h(t)$ are caused by the auxiliary channel and the higher the significance.
4. The channel with the highest significance is called a "round winner". All time segments corresponding with this channel are removed. By removing these time segments, Hveto removes repetitive results from channels with similar glitches.
5. Steps 1 through 4 are repeated until no channel has a significance greater than a configured threshold.

Improving Hveto

- Much of the background noise at LIGO is relatively low and high frequency ($0 - 30\ Hz$ and above $2kHz$).
- This makes it difficult for Hveto to identify the source of noise in middle frequency ranges, like $0 - 2000\ Hz$.
- Our work was to improve the Hveto method by running at different frequency bands to account for this obfuscation.
- Results we were looking for included:
  - Higher significance.
  - Better diagnostics of which channels are useful for identifying $h(t)$ transient noise.
- Two methods were used for this.
  - Running the Hveto algorithm on all bands of auxiliary triggers, to allow for frequency upconversion.
  - Use the same frequency band for all channels, which may allow for internal upconversion.

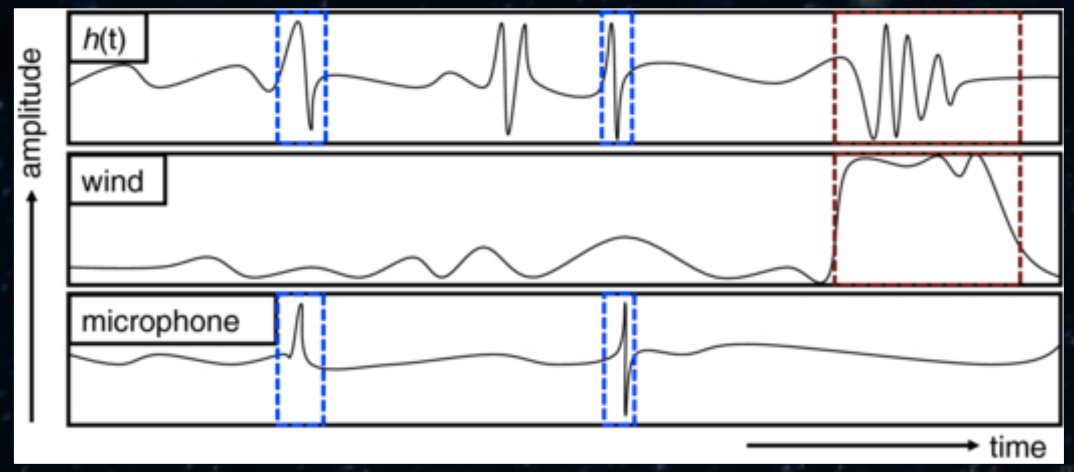

Figure 1.
Noise detected in gravitational wave channel $h(t)$ is coincident with noise detected in the wind and the microphone channels.

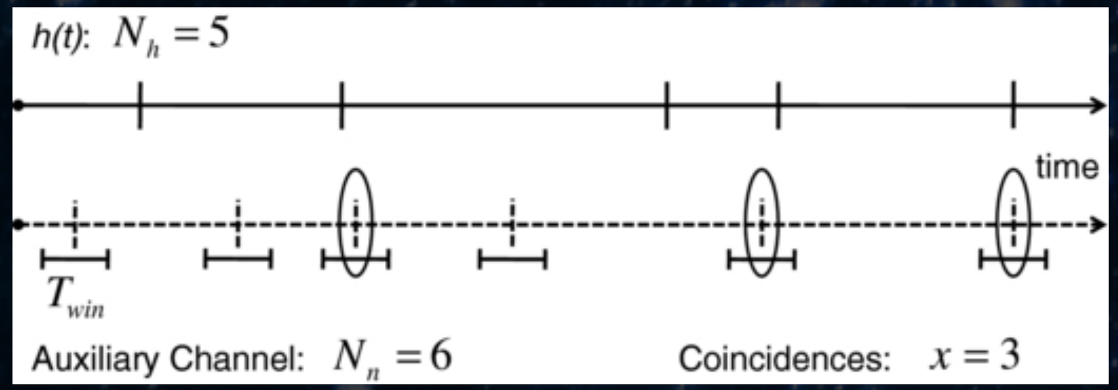

Figure 2 – Hveto Trigger Coincidences
The top and bottom traces show $h(t)$ and auxiliary triggers.
Auxiliary triggers are given a time window. Trigger are "coincident" with $h(t)$ if an $h(t)$ trigger lies within the trigger's time window.

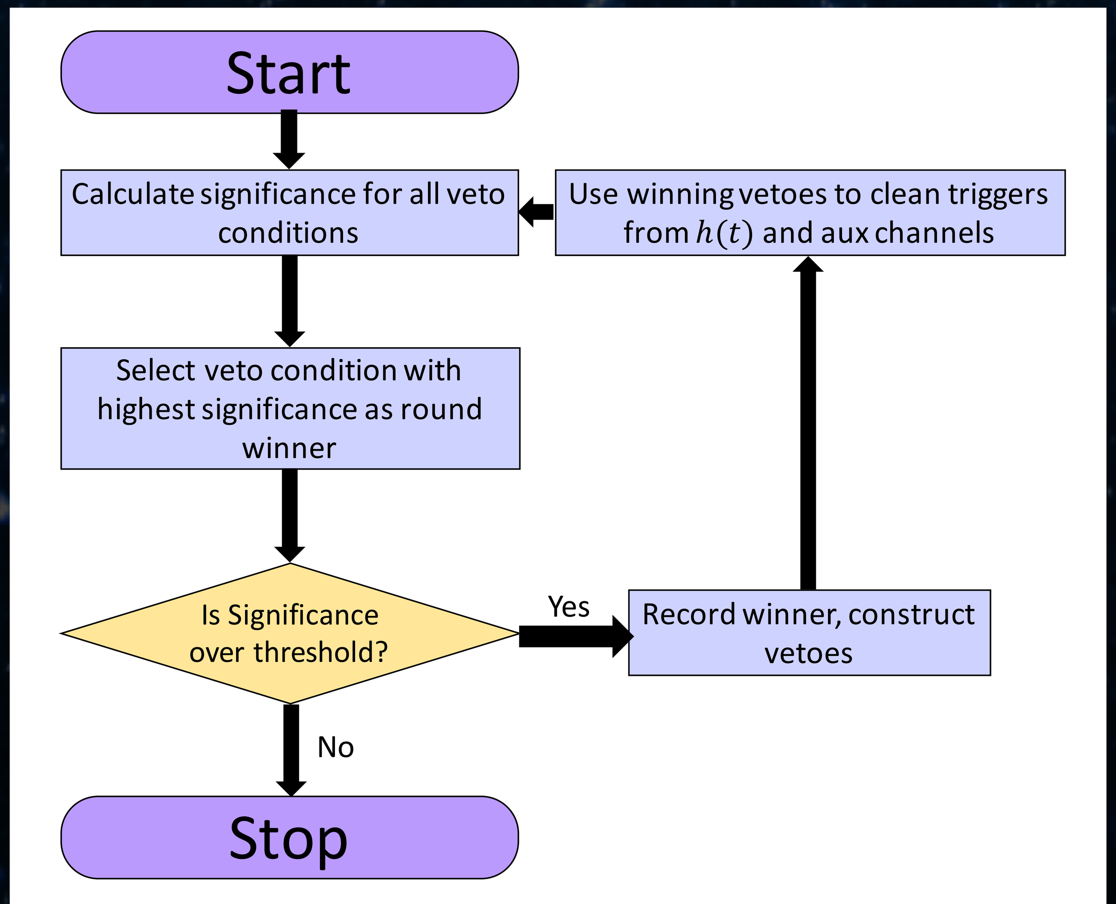

Figure 3 – A flowchart of the Hveto algorithm.

Results

By running Hveto with different frequency configurations, we were able to identify the source of more non-astronomical noise.

15/12/12

- Figure 4 displays triggers for one day of data taking at the Livingston observatory (L1). We were interested in identifying the source of the triggers enclosed by the oval.
- Figure 5 shows the original Hveto results.
- Figure 6 shows Hveto run excluding low-frequency $h(t)$ triggers. Doing this led to Hveto identifying different sources of the noise.

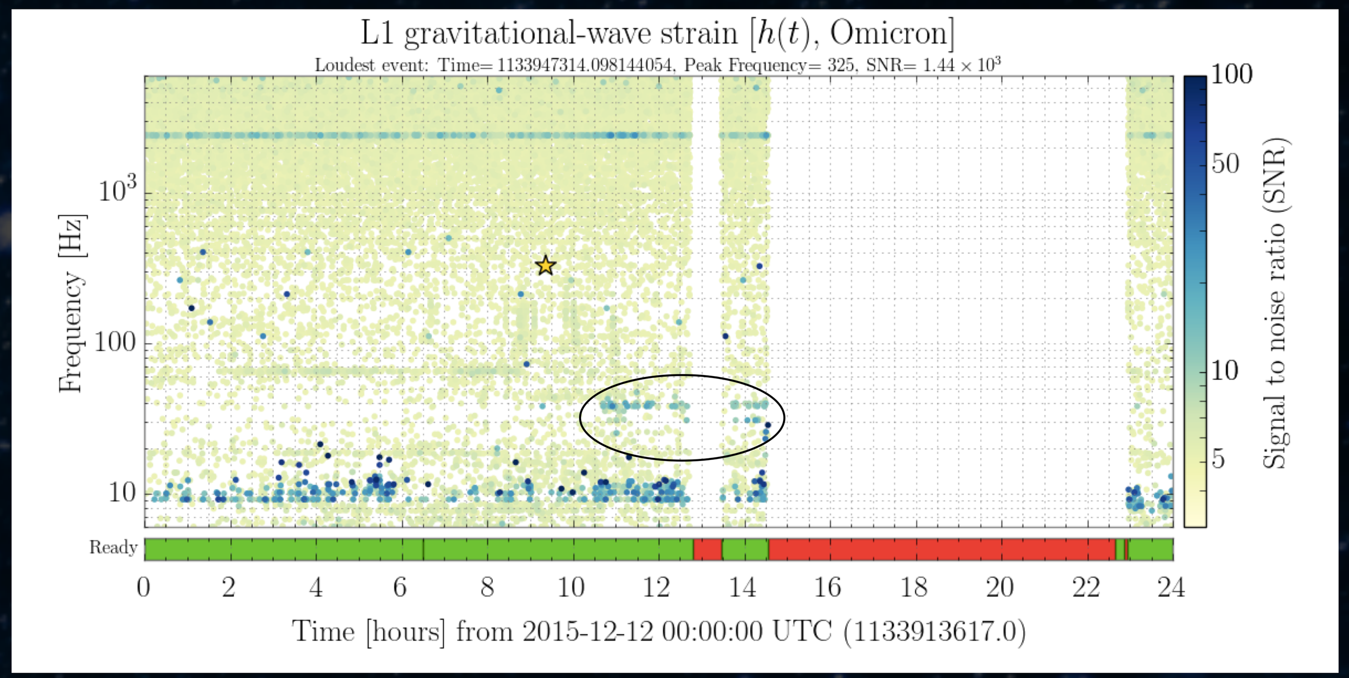

Figure 4. Drop plot (or "glitchgram") of triggers at the L1 observatory on 15/12/12.
There is a lot of loud, low frequency noise. I'm interested in the source of the triggers enclosed by the oval.
These triggers are between 20 and 50 Hz.

15/12/26

- Figure 7 displays triggers on December 26 2015.
- Figure 8 shows the original Hveto results.
- Figure 9 shows Hveto run excluding low-frequency triggers. This configuration leads to identifying less noise than the original results, meaning there is coincidental vetoing due to low noise obfuscation..

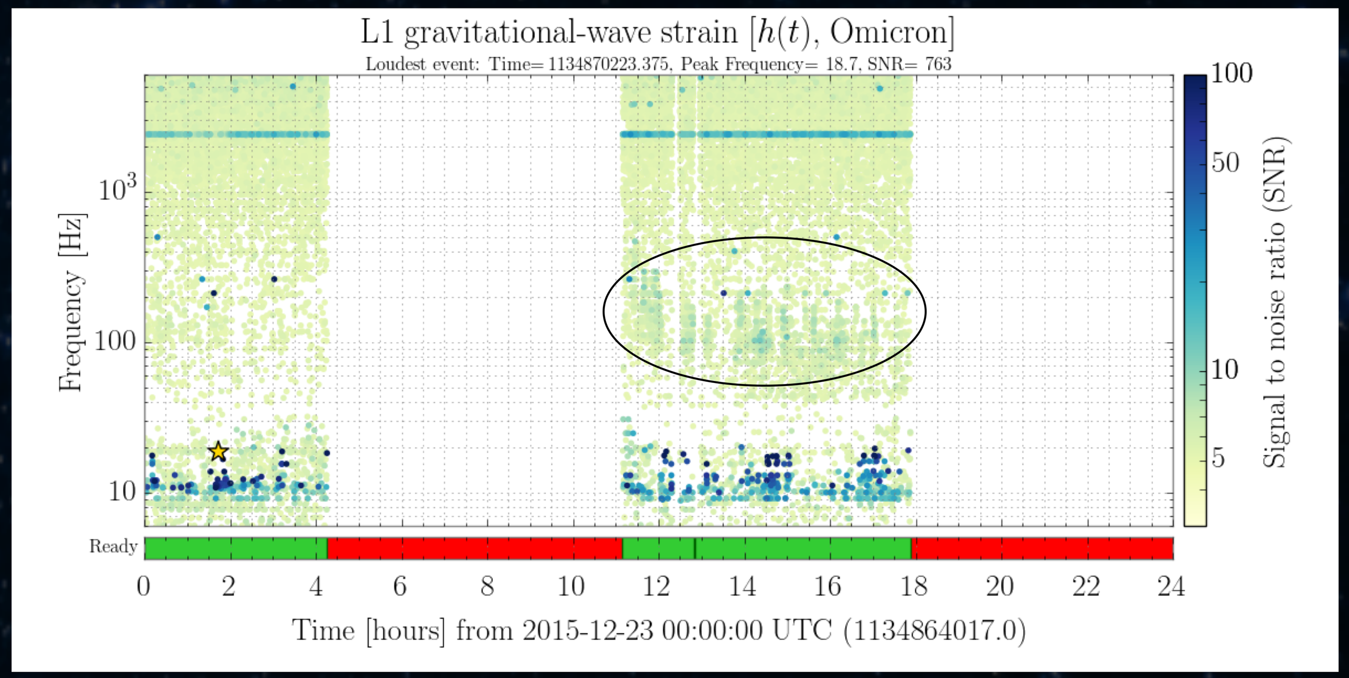

Figure 7. Drop plot (or "glitchgram") of triggers at the L1 observatory on 15/12/12.
I'm interested in the source of the column-like high SNR triggers enclosed by the oval.
These triggers are between 80 and 300 Hz.

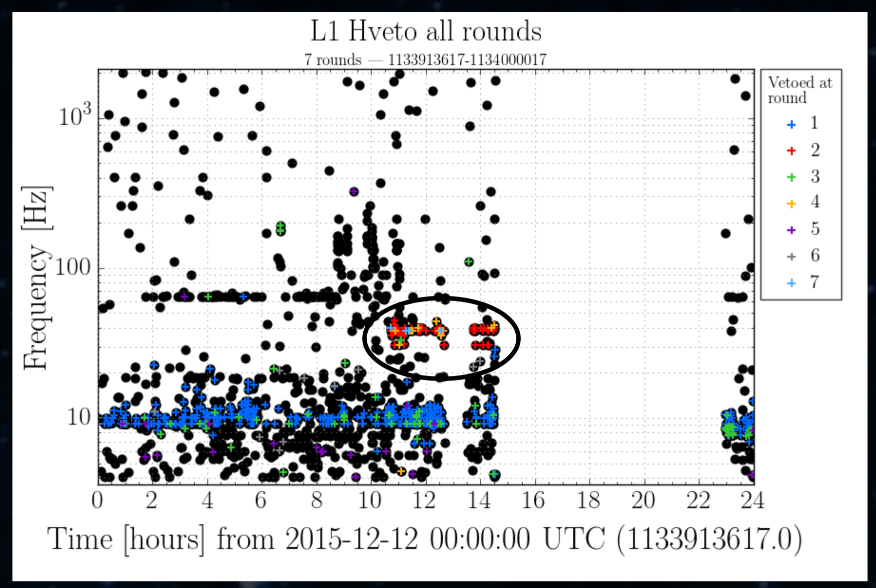

Figure 5 - Hveto results on all normal frequencies (0-2048 Hz).
Circles represent triggers. Circles with pluses represent vetoed triggers A vetoed trigger is an $h(t)$ whose source Hveto identified.
Hveto identifies the source of much of the noise in question.

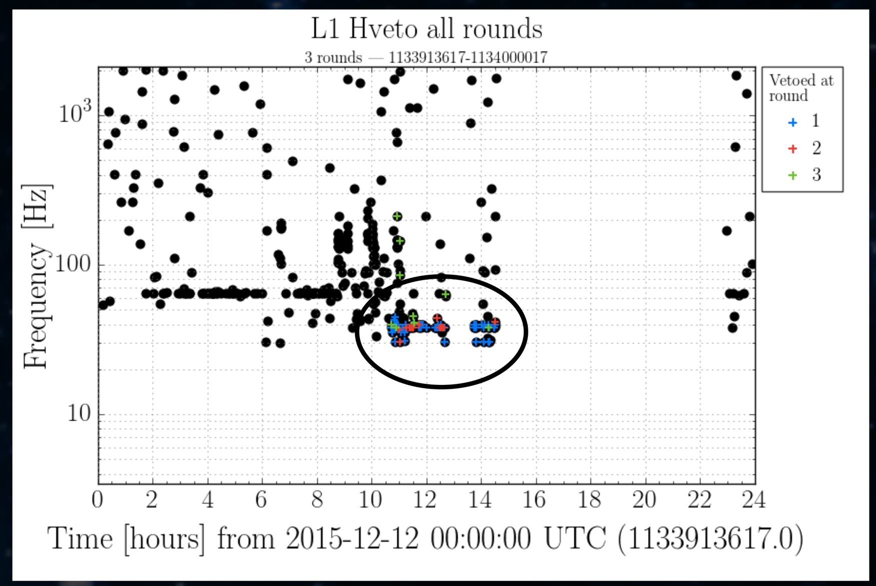

Figure 6 - Hveto run on all triggers between 30 and 2048 Hz.
Compared to Figure 10, similar noise is vetoed, but by slightly different channels.

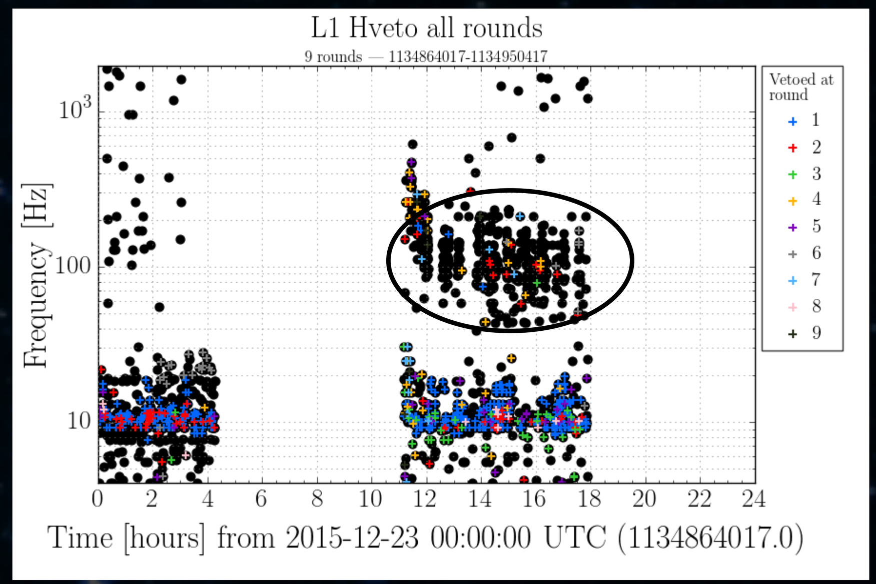

Figure 7 - Hveto results on all normal frequencies (0-2048 Hz).
Circles represent triggers. Circles with pluses represent a "vetoed" trigger – i.e. a trigger in $h(t)$ whose source Hveto identified.
Little of the noise in question was vetoed.

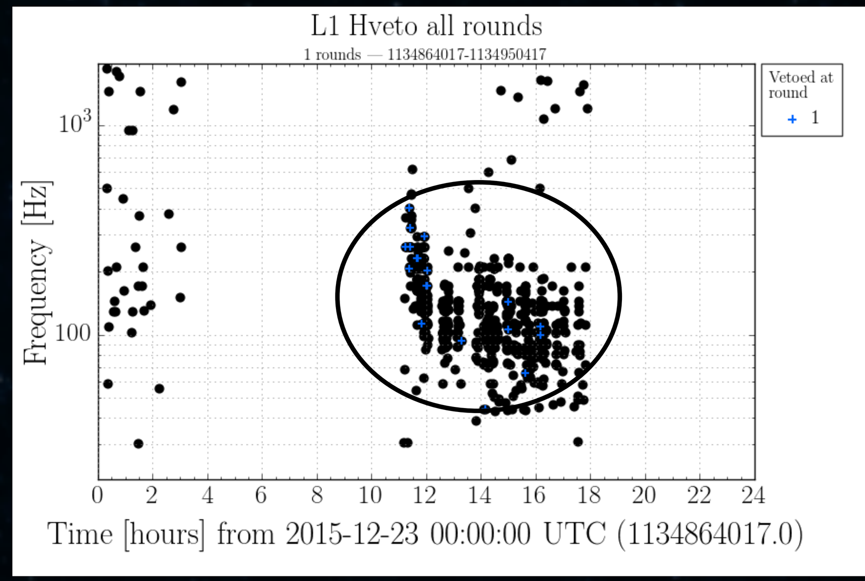

Figure 5 - Hveto run on all triggers between 30 and 2048 Hz.
Compared to the full Hveto run, less noise is vetoed.

Conclusions

- Running Hveto at different frequencies sometimes led the identification of new noise sources.
- Low frequency noise sometimes "confused" Hveto, leading to coincidental triggering of higher frequency triggers.
- We are working on implementing this method into LIGO's data summary software.

Acknowledgement

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