Gravitational-wave burst vetoes in the S5 data of GEO 600

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GEO600 gravitational-wave detector

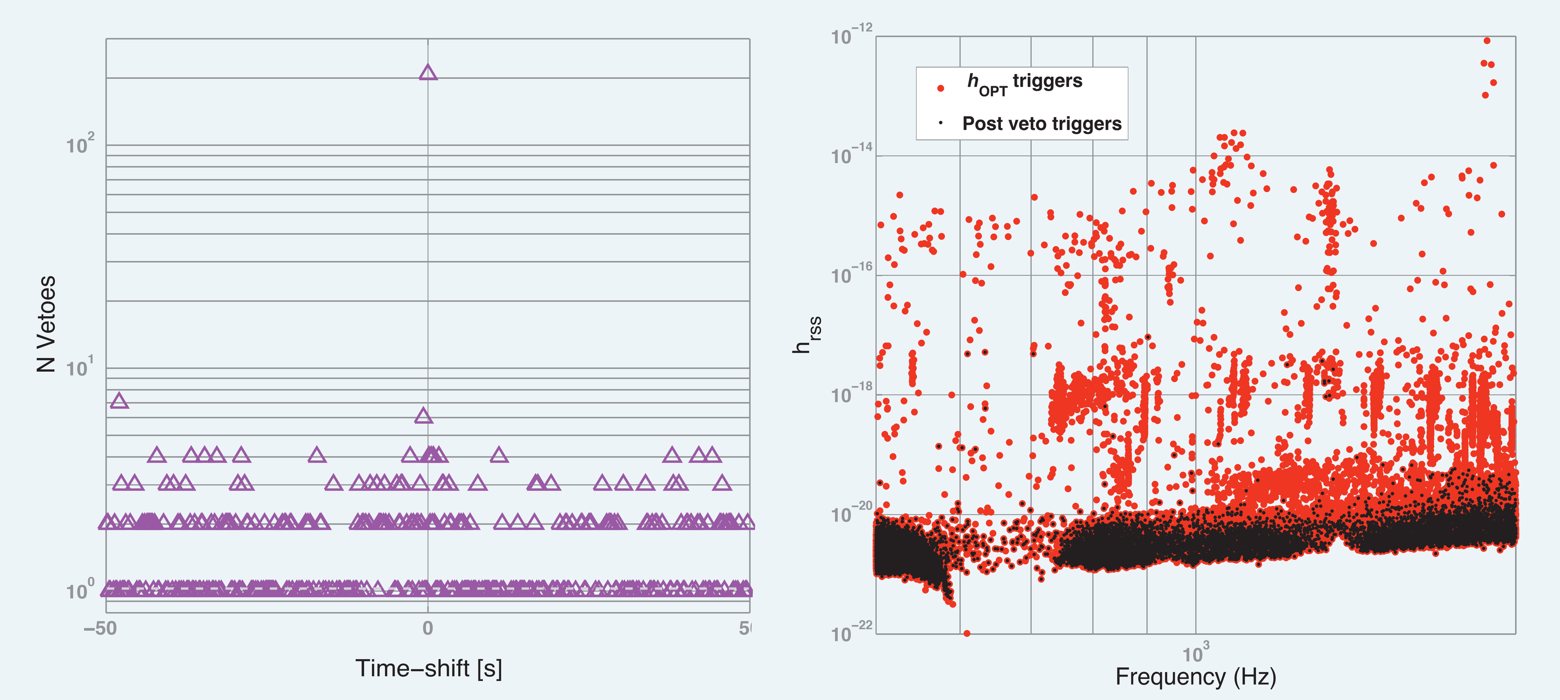
GEO 600 is an interferometric gravitational-wave (GW) detector located near Hannover, Germany. Because of the novel '*dual recycled*' optical scheme, the 600m-baseline interferometer has a sensitivity comparable to that of other km-baseline detectors.

GEO 600 participated in the 'Fifth Science (S5) Run' in coincidence with the LIGO detectors from May to October, 2006. This data, along with the data from the LIGO detectors, will be used to search for GW signatures produced by transient, unmodelled astrophysical sources.

Instrumental vetoes for burst triggers

The search for unmodelled GW bursts typically employs '*excess power*' detection algorithms. Since the current detectors are highly complex instruments, the data usually contains a large number of noise transients ('glitches'), which cause the detection algorithms to generate spurious triggers. It is important to distinguish these instrumental glitches from actual GW burst signals in order to reduce the false alarm rate of the search. This is customarily done by 'vetoing' the triggers using triggers detected in auxiliary channels.

Null-stream veto



LEFT Time-shift analysis between H and H_{NULL}. Horizontal axis shows the time-shift applied between the two channels and vertical axis the number of coincident triggers (one day of data from Sep. 2006). RIGHT Frequency-amplitude plot of the burst triggers from the full month of Sep. 2006, before and after applying the veto (veto efficiency 13%, 1 Accidental veto per day).

In GEO 600, because of the '*signal recycling*' scheme, the GW information will be spread between the two orthogonal demodulation quadratures of the detector output. Both of these output quadratures are calibrated to GW strain. The (time domain) calibration produces two data streams, $h_P(t)$ and $h_Q(t)$, which, up to the level of the accuracy of the calibration, contain the same GW signal, but different noises.

$h_P(t)$ and $h_Q(t)$ are '*optimally*' combined to form $h(t)$. A '*null-stream*' is also constructed from $h_P(t)$ and $h_Q(t)$, which contains no GW information:

$$h_{NULL}(t) = h_P(t) - h_Q(t).$$

The null-stream can be used as a powerful veto [1]. If $h_{NULL}(t)$ contains excess power that is inconsistent with a GW burst, we veto the trigger in $h(t)$. *i.e.*, triggers with the 'amplitude ratio' A_{NULL}/A_H greater than a threshold are vetoed. Veto threshold corresponding to a particular accidental veto rate is estimated by doing time-shift analysis.

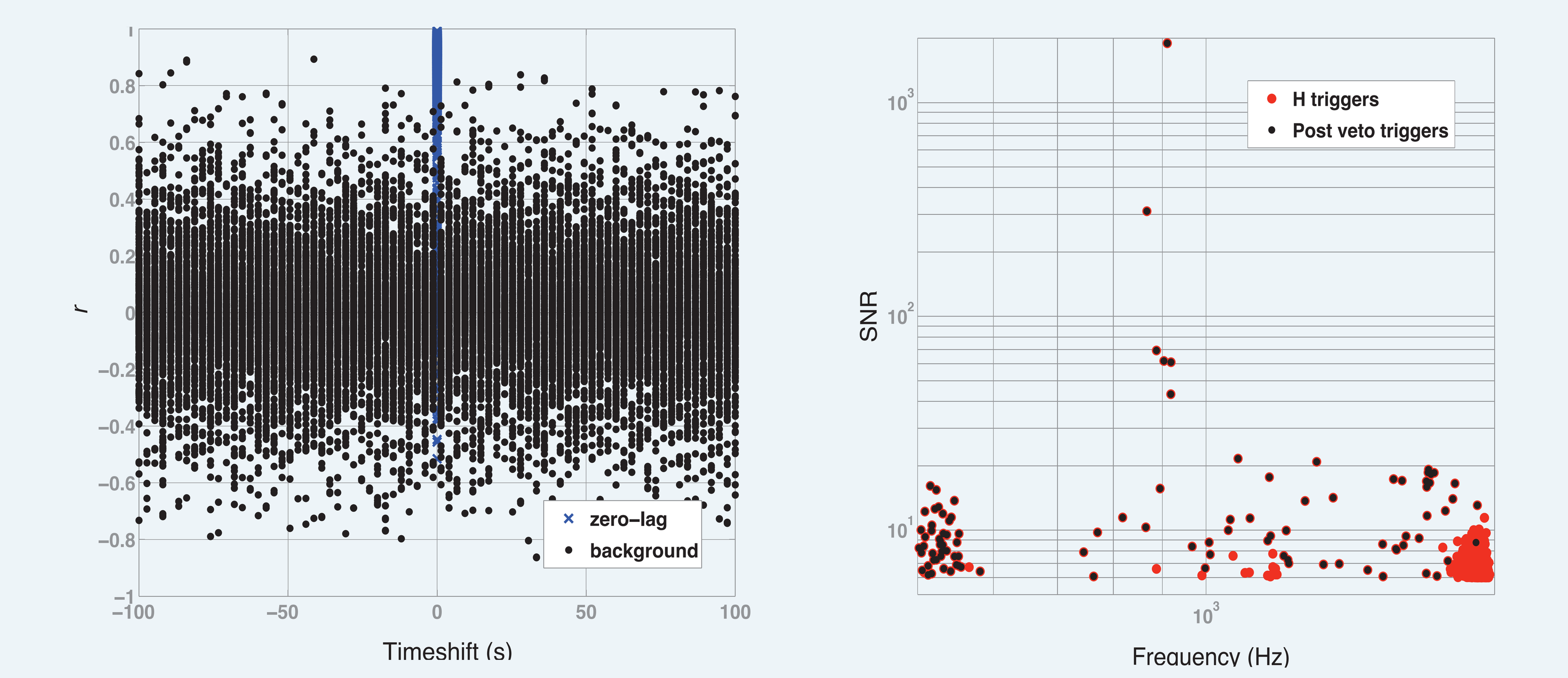
'Physical' instrumental vetoes

If the coupling of noise between and instrumental channel X and the GW channel H is linear, and the '*transfer function*' $T_{XH}(f)$ is unique and time-invariant, the Fourier transform $x(f)$ of noise measured at channel X can be transferred to channel H using the transfer function

$$x'(f) = x(f)\ T_{XH}(f).$$

This allows us to formulate a powerful strategy to veto noise transients originating in a detector subsystem [2]. If a burst trigger in H originates in subsystem X, the noise vectors $x'(f)$ and $h(f)$ should exhibit a high correlation.

We first identify coincident burst triggers in channels X and H. From a short segment of data surrounding the burst triggers, we compute the linear cross-correlation coefficient r between $x'(f)$ and $h(f)$. If r is greater than a threshold, we veto the trigger in H. Veto threshold corresponding to an acceptable accidental veto rate is estimated by doing time-shift analysis.

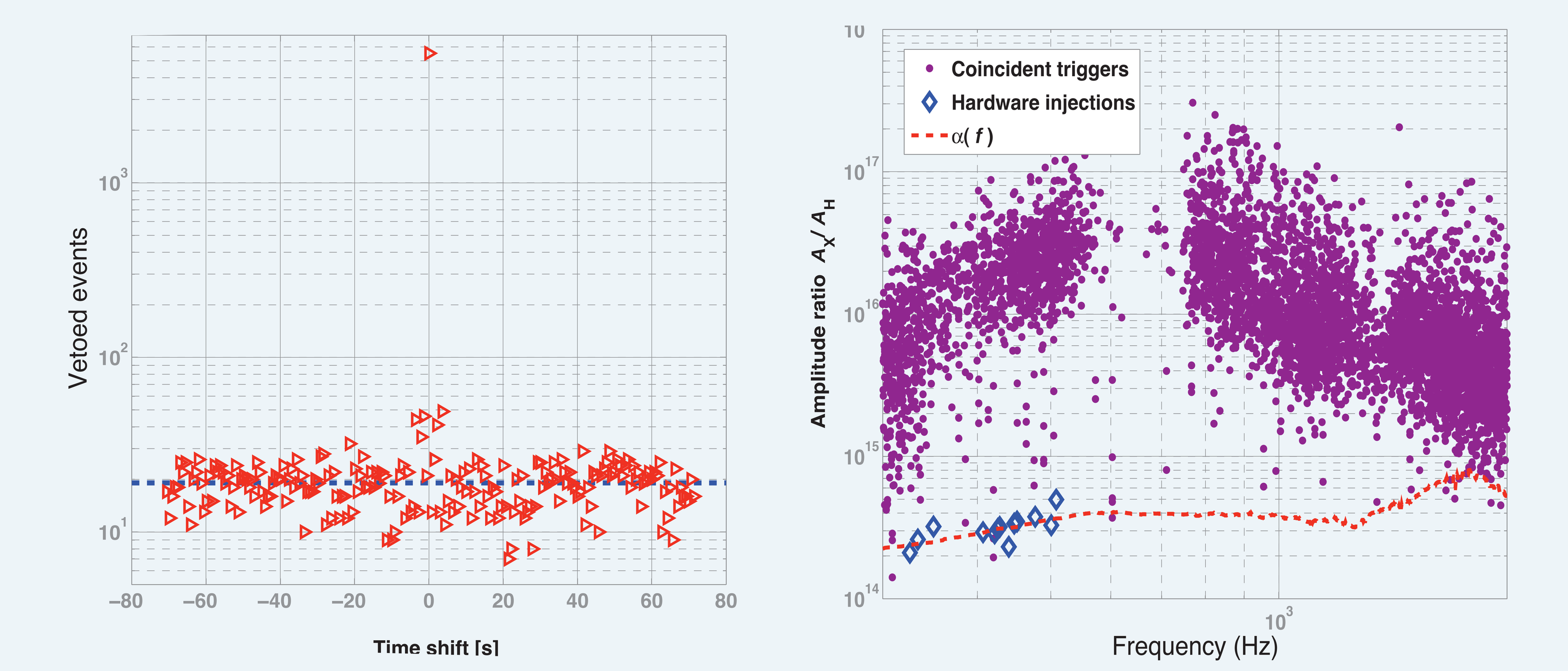


LEFT Time-shift analysis between H and laser frequency noise channel. Horizontal axis shows the time-shift applied between the two channels and vertical axis shows r computed from coincident triggers. RIGHT Frequency-SNR plot of the burst triggers from 5 days from June 2006, before and after applying the veto (veto efficiency 35%, 1 Accidental veto per day).

Statistical vetoes using amplitude consistency check

Even if the coupling of a subsystem to the GW channel is not known, the standard statistical veto method can be used to reject spurious triggers. But care should be exercised when using instrumental channels which are sensitive to GWs as veto channels.

The expected level of coupling of GWs to an instrumental channel can be estimated by doing hardware injections. If $\alpha_{HX}(f)$ is the '*sensitivity ratio*' of channel X to channel H (or, to GWs), only those coincident triggers whose 'amplitude ratio' A_X/A_H is greater than $\alpha_{HX}(f)$ are vetoed [3]. The coincidence windows are tuned by doing time-shift analysis.



LEFT Time-shift analysis between H and the 'DC power channel'. Horizontal axis shows the time-shift applied between the two channels and vertical axis the number of coincident triggers (one day of data from Sep. 2006). RIGHT Amplitude ratio of the coincident triggers from Sep. 2006 plotted against the frequency (veto efficiency 5.7%, 1.5 Accidental veto per day).

References

[1] M. Hewitson and P. Ajith, *Class. Quantum Grav.* **22** 4903 (2005).

[2] P. Ajith, M. Hewitson, J. R. Smith, H. Grote, S. Hild and K. A. Strain, *To appear in Phys. Rev. D* (2007). arXiv:0705.1111[gr-qc]

[3] S. Hild, P. Ajith, M. Hewitson, H. Grote and J. R. Smith, *To appear in Class. Quantum Grav.* (2007).

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