The LSC Glitch Hunters: Monitoring noise transients during S5

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The LIGO Scientific Collaboration (LSC) "glitch group" is part of the detector characterization effort, consisting of members of the burst and inspiral analysis teams and detector experts. Goals of the glitch group during the fifth LIGO science run (S5) included (1) offline assessment of the detector data, with focus on noise transients, (2) veto recommendations for the analysis teams and (3) reports to the commissioning team of any anomalies seen in gravitational wave and auxiliary channels. These goals were achieved through off-site data analysis shifts and the examination of loud transients found by online burst and inspiral search algorithms, using customized event visualization tools. Other activities included the study of auto-correlation of transients, stationarity of the detector noise and various flavors of vetoes. This poster shall provide an overview of these activities around the S5 LSC run.

LSC Glitch group

- The term **Glitch** indicates short-duration (few ms to sec.) noise transients, which could be a potential background for burst and inspiral searches.
- Formally, the "Glitches" working group is a sub-group of "Detector Characterization working group", whose main aim is the study of noise transients.
- The group mainly consists of members from the burst and inspiral analysis groups as well as operators and other onsite detector experts from both the LIGO sites.
- There is substantial interaction between the glitch group and some of the other detector characterization sub-groups such as `Environmental Disturbances`, `Data Quality`, `Hardware Injections`, `Calibration`, `Data Set Reduction`.
- This presentation will focus on the main activities of the glitch group during **S5** (which was the fifth LIGO science run from November 2005 to October 2007).

Goals of the glitch group during S5

- Off-site "Brain-storming" on the performance LIGO detectors including trouble-shooting (mainly around the start of S5), which complements onsite real-time investigations.
- Classification and statistical description of transients in the gravitational wave channel. (*See poster by S. Mukherjee*)
- Study of Data quality epochs.
- Data quality assessment and guidance to the burst and inspiral analysis groups in the choice of data quality flags for analysis searches.(*See posters by L. Blackburn and J. Slutsky*)
- Event-by-event veto analysis and veto safety studies by looking for correlation between gravitational wave channels and other auxiliary channels.
- Event-by-event scanning of outlier triggers from various burst and inspiral searches using customized event visualization tools.
- Investigation of causes of lock-loss.
- Listening to the audio of the data from various channels.
- Monitoring and reporting any malfunctioning auxiliary channels.
- Other data acquisition problems, such as incorrect state vector, segment numbers not in sequential order, injections incorrectly flagged.
- Studies of the detector noise stationarity.
- Looking for anomalous peaks in the auto-correlation of transient events from burst searches.
- Monitoring other environmental effects such as wind, micro-seismic noise, etc.

Functioning of the glitch group during S5

- Throughout S5, members of the glitch group took "offline" shifts with each shift consisting of monitoring 3-4 days of LIGO data.
- Results of these shifts were discussed in a teleconference, whose frequency of occurrence ranged from thrice a week (near start of S5) to once a week.
- Highlights from these shifts were reported in the weekly run-coordination and detector characterization calls.
- Sometimes, detailed focused investigations were carried out by individual glitch group members, based on some of the findings in a shift, resulting in the production of new data quality flags.
- The glitch group maintained an electronic notebook,containing all reports and investigations.

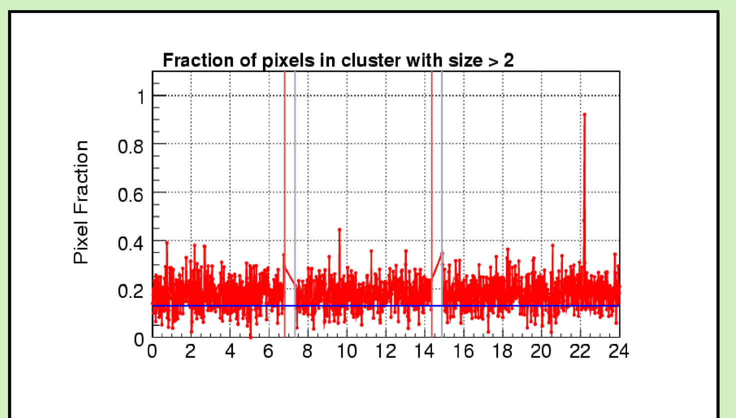
Details of a glitch shift

A typical glitch shift contains the following reports :

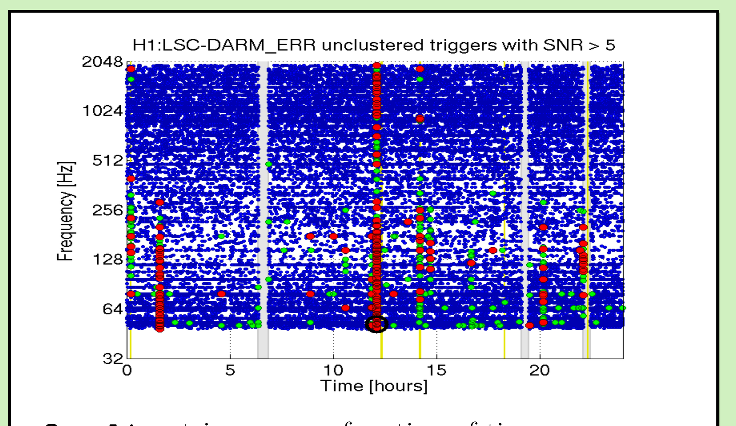
- Highlights from the detector elogs.
- Plots of `SenseMon` [1] Range
- `BurstMon` [2] quantities such as pixel fraction, hrss and SNR vs frequency, which monitor various aspects of detector noise stationarity.
- Studies of various aspects of online `Kleine-welle` [3] triggers such as significance vs frequency, significance vs time, auto-correlations.
- `Q-online` [4] trigger properties.
- Output from `NoiseFloorMon` [5] (*See poster by R. Stone*).
- Micro-seismic noise at LHO and LLO
- Event-by-event scanning of outlier transients :
  - Double-coincident `Kleine-welle` triggers with significance > 35
  - Triple-coincident `Kleine-welle` triggers with significance > 10
  - Single-ifo `Block-Normal` [6] triggers with power threshold > 1000
  - Single-ifo inspiral triggers [7] with SNR > 15 after clustering within a 15 s window.

A automated script was written to collect all the above reports on one webpage.

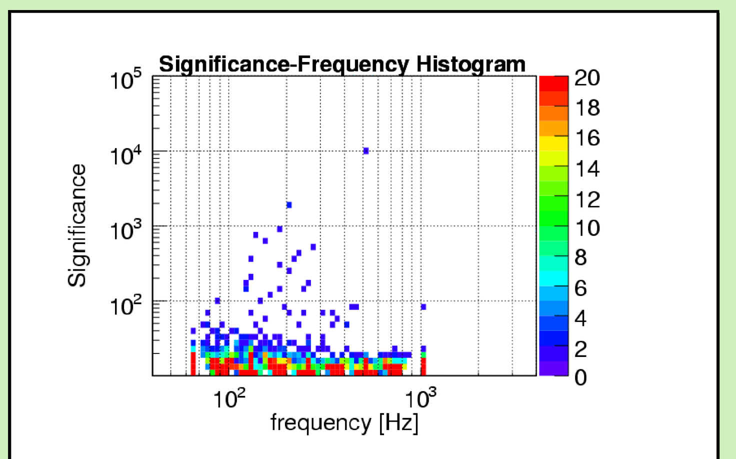
Sample plots from glitch shifts



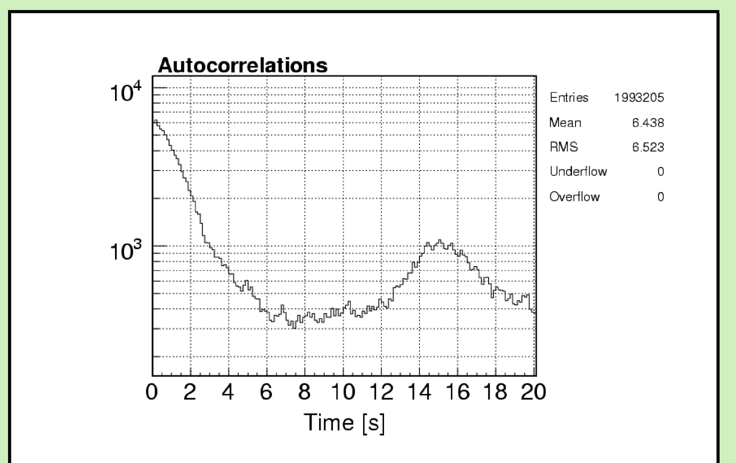
`BurstMon` pixel fraction as a function of time (hours)



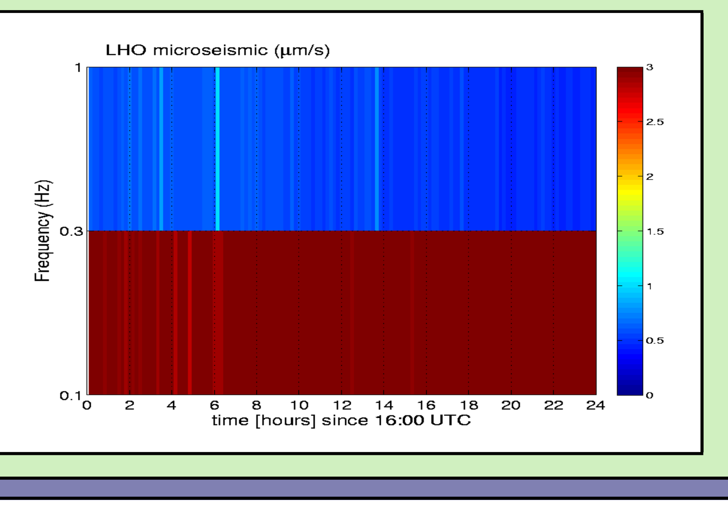
`Q-online` triggers as a function of time



`Kleine-welle` significance vs frequency



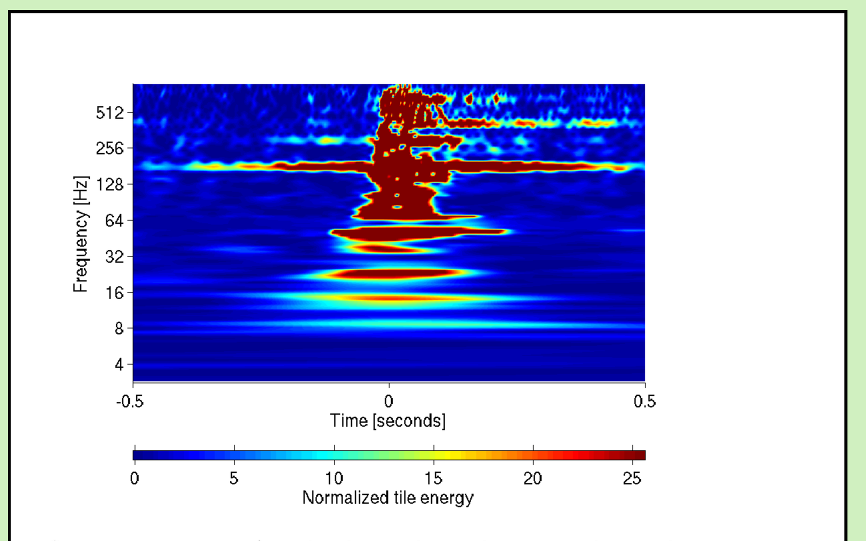
Auto-correlation plots of `Kleine-welle` triggers



Event visualization tools

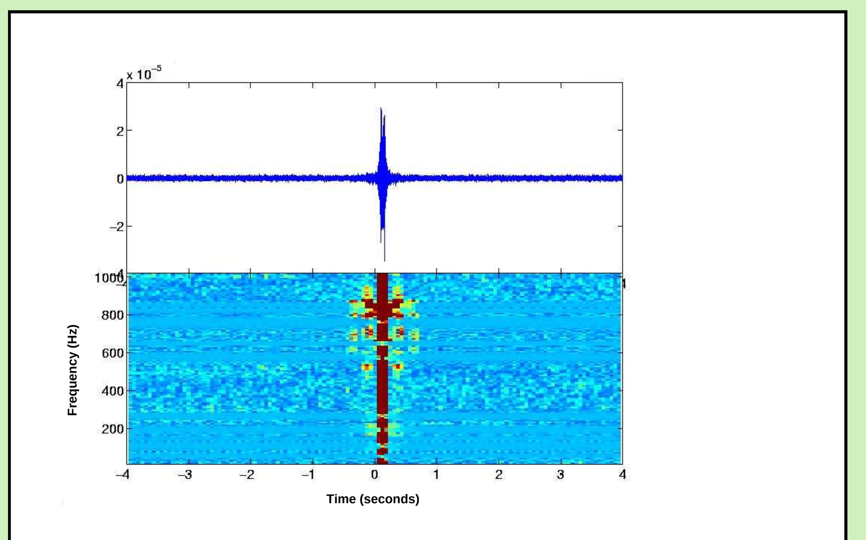
During S5, we carefully examined many transients (mostly outliers, in online single-interferometer analysis) to get some insight on the behavior of the detectors at those time. The main tools used were :

- `Q-scan` : This displays Q-spectrograms of all channels (which display statistically significant energy content in the time-frequency plane), after application of linear predictive error filter (LPEF), along with various diagnostic information on a single webpage.



Q-spectrogram of a glitch in the voltmeter channel

- `Event Display` : This displays the median-normalized time-frequency spectrograms of a fixed set of auxiliary channels after application of LPEF filter, along with various diagnostic information on a single webpage.



Spectrogram of the calibration channel during a glitch

Achievements of the glitch group

- The glitch group provided valuable offline feedback on the state of the detector (from an analysis perspective) which was important for the success of the S5 run.
- Many new data-quality flags were developed during S5 based on studies of outlier events and identification of their causes by glitch group members.
- New `DMT` monitors were written based on glitches identified by glitch group members.
- Based on glitch group studies, members of commissioning team carried out more detailed investigations to diagnose and mitigate the glitches.

Post-S5 activities

- Wrap up of all S5 studies of glitches.
- Followups of interesting coincident event candidates. (*See talk by R. Gouaty*)
- Study of artificially-induced glitches during post-S5 commissioning period.
- Guidance to the `Dataset Reduction` subgroup for any new channels to be included in a reduced set, along with any changes to the sampling rates
- Getting ready for **Astrowatch** and **S6**.

References

[1] Sutton, P.S, 2003, Technical Note, LIGO-T030276-00-Z
[2] Klimenko, S. 2004, LIGO Document, G040173-00
[3] Chatterji, S. et al, 2004, *Class. Quant. Gravity* 21, S1809
[4] Chatterji, S., 2005, Ph.D thesis, MIT
[5] Mukherjee, S., 2006, *Class. Quant. Gravity* 20, S925
[6] McNabb, J.W.C et al, 2004, *Class. Quant. Gravity* 21, S1705
[7] LIGO Scientific Collaboration Technical Note, 2007, LIGO-T070109-01-Z

LIGO-G070807-00-Z. This poster was prepared by Shantanu Desai from The Center for Gravitational Wave Physics at Pennsylvania State University, University Park, PA, 16802. His research is supported by NSF grant 428-51 29NV0