Data Quality Vetoes in LIGO S5 Searches for Gravitational Wave Transients

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Data Quality Vetoes

- Goal: eliminate non-Gaussian transients in burst and inspiral searches
- Data quality flags are created for known artifacts, for “bad” and “so-and-so” data. Some flags are critical, others are advisory. Not all are appropriate as vetoes: choose!

Burst and Inspiral analysis cuts (coincidence, incoherent and semi-coherent consistency cuts) are already quite good at rejecting accidental coincidences due to noise transients.

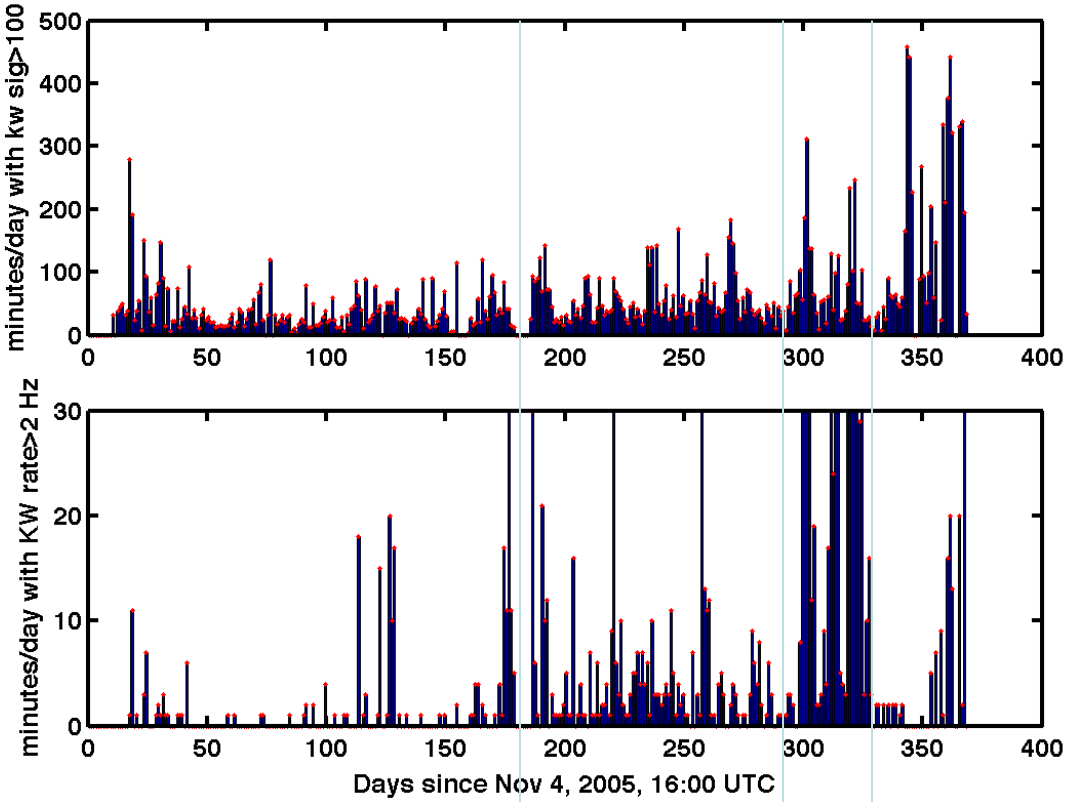
Vetoes take care of outliers that remain after analysis cuts.

- This talk presents:
  - Classification scheme for data quality vetoes
  - Details on some of the most interesting flags
  - Particular focus on the H1-H2 features

The first year of S5 in L1

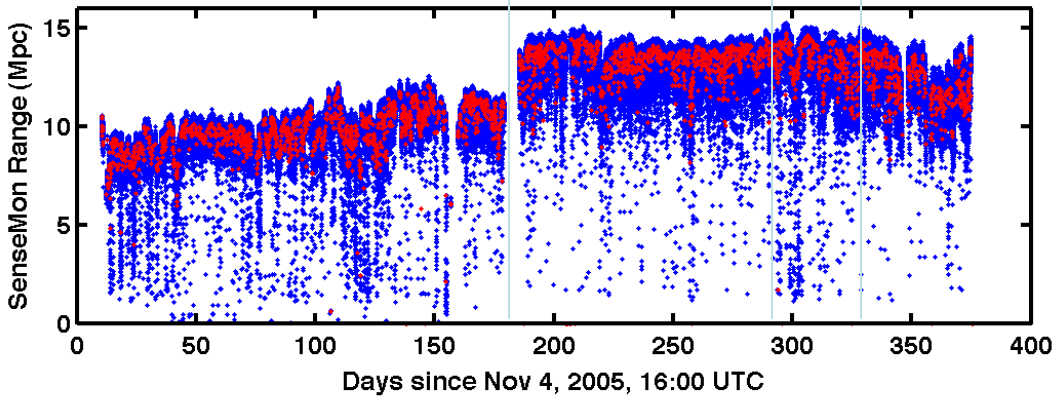
S5 data quality changed in time. Epochs definition is work in progress!

Affected by microseism, wind, instrument



Minutes/day with at least one "loud" glitch

Minutes/day with >2Hz glitch rate



Inspiral Range [MPc]
- minute in science mode
- median of science segments

The Glitch Group

A meeting point for data analysis and instrument
Goal: data quality, feedback to instrument, veto for Burst and Inspiral

DURING S5:

- On-line, off-site
  - Weekly assessment of transients on DARM_ERR and auxiliary channels with potential repercussion on astrophysical searches (burst and inspiral)
  - Feedback to detector team
- Off-line
  - Contributing to data quality assessment
  - Definition of vetoes for the burst and inspiral searches

Data Quality Veto Strategy

Cited examples are choices of Burst group, Inspiral are very similar, with some subleties in the Cat 1-2 distinction

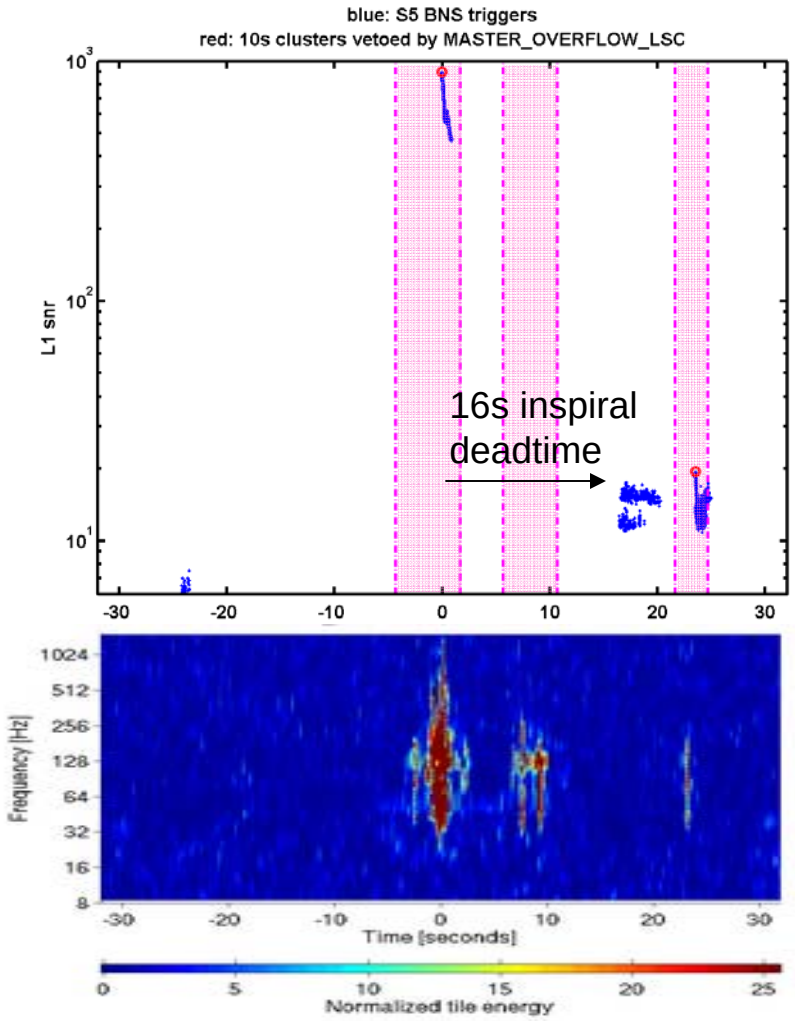
Category 1	Inspiral: data not worth analyzing Burst: Minimal data quality vetoes, for the selection of data segments to be analyzed *(e.g. calibration problems, test injections, photodiode saturations)*
Category 2	"Unconditional" post-processing vetoes: data is unreliable and there is an established one-on-one correlation with loud transients. *(e.g. saturations in the alignment control system, glitches in the power main)*
Category 3	"Conditional" post-processing vetoes, for upper limit: statistical correlation to loud transients. We still look for detection candidates at those times, exerting caution when establishing detection confidence. *(e.g. train/seismic flags, 1 minute pre-lockloss, "dips" of light stored in the arm cavities)*
Category 4	Advisory flags: no clear evidence of correlation to loud transients, but if we find a detection candidate at these time, we need to exert caution *(e.g. high wind and certain data validation issues)*

In addition: event-by-event veto based on correlated glitching on auxiliary channels, presented in the next talk by Erik Katsavounidis

Data Quality Veto Safety

- Data Quality veto safety tested on hardware injections
  - See talk by Myungkee Sung talk
- In all cases, these vetoes are ”safe” (coincidence with hardware injections consistent with random).
- One exception: LSC overflow can be triggered by very loud injections
  - Make sure in other ways that we are not vetoing a loud signal, looking at data from other interferometers.

LSC Overflows



some part of the length sensing and control system saturated, making it nonlinear and/or feeding back a glitch into the interferometer

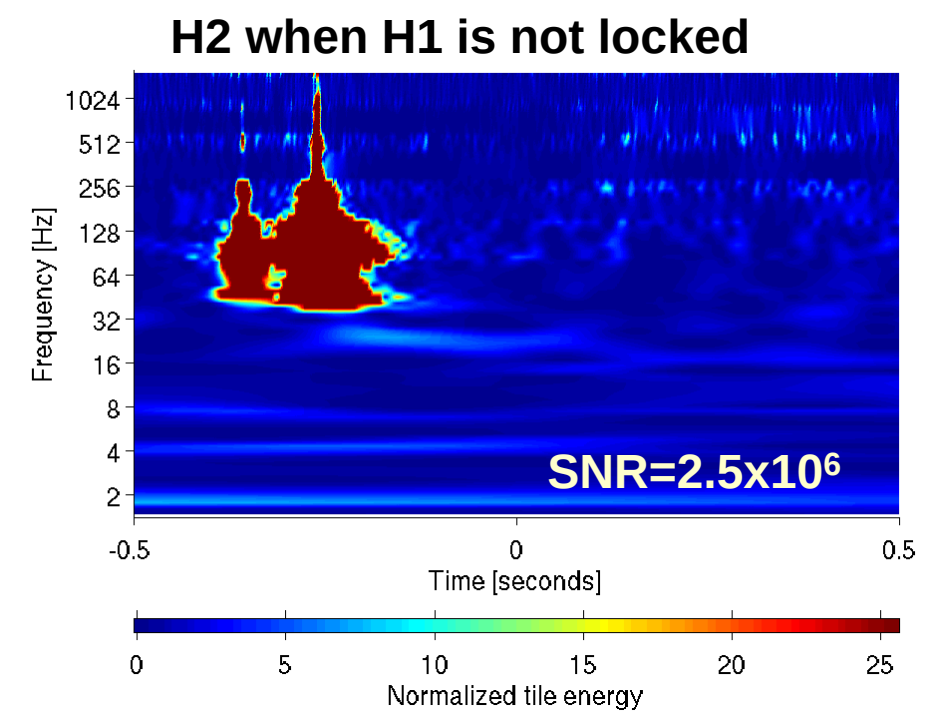
Category 1 veto for burst
Category 2 veto for inspiral

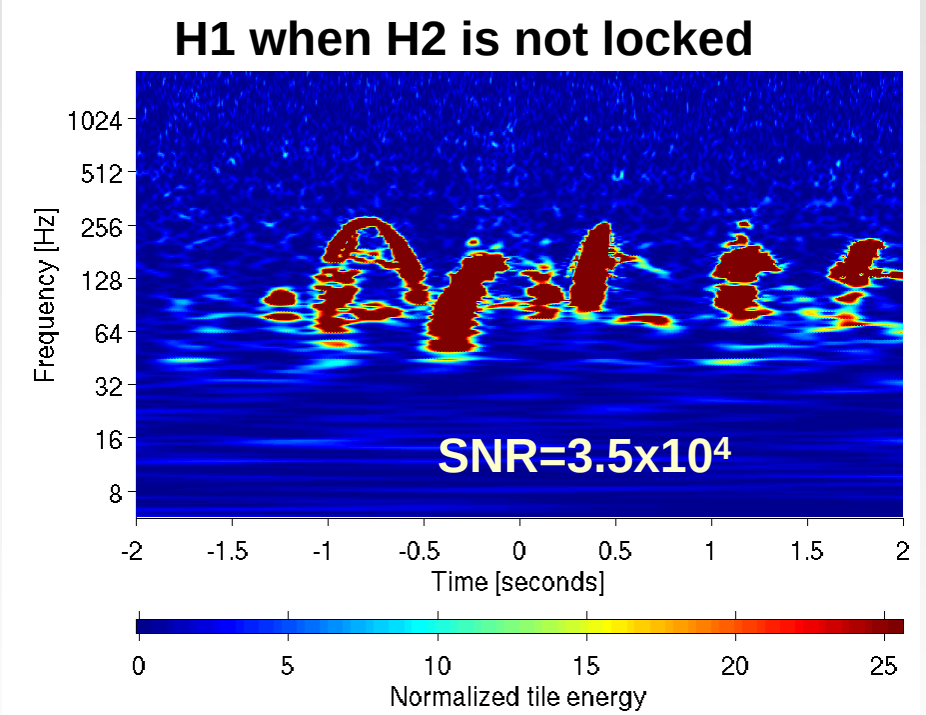
Veto buffer for inspiral: [-25,+1]

L1:
0.4% deadtime
88% vetoes an SNR>8
48% vetoes an SNR>50

Vetoes 54% of SNR>50
Vetoes 90% of SNR>500

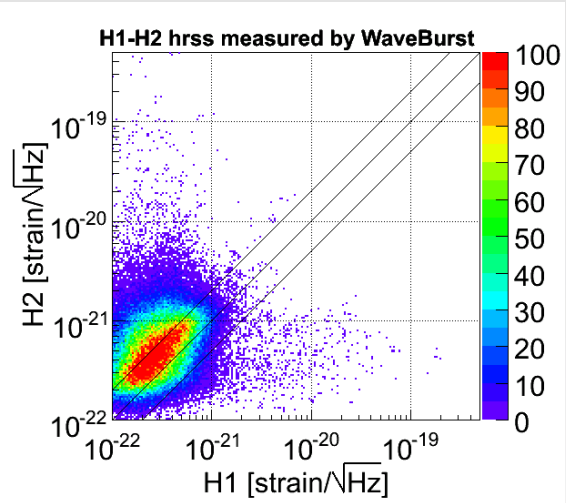
H1 and H2 talk to each other

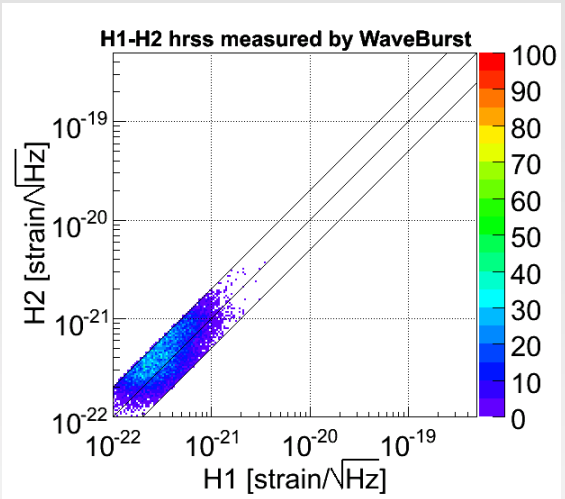




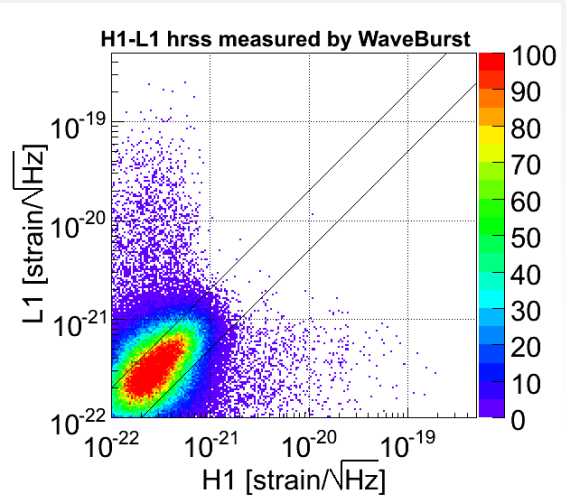
Category 1 veto for burst
Category 2 veto for inspiral

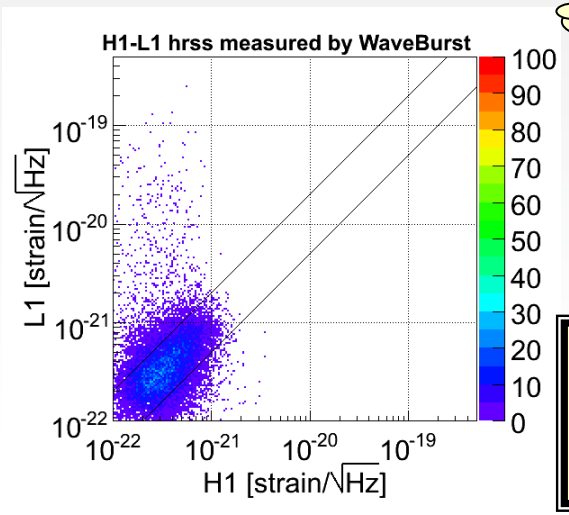
Analysis cuts are designed to address coincident transients





EXAMPLE:
Early S5 BURST analysis, Accidentals from time-slides before final thresholds
⇒ H1-H2 consistent amplitude, correlated sign
⇒ H1-L1 minimal correlation





Details in talk by Brian O'Reilly on Thursday

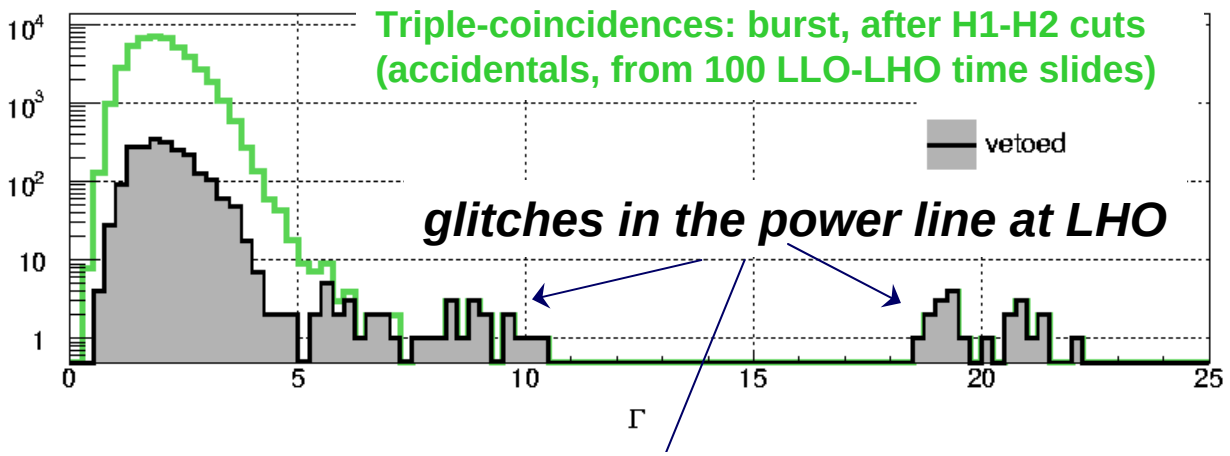
Combination of these analysis cuts and data quality vetoes effectively remove outliers

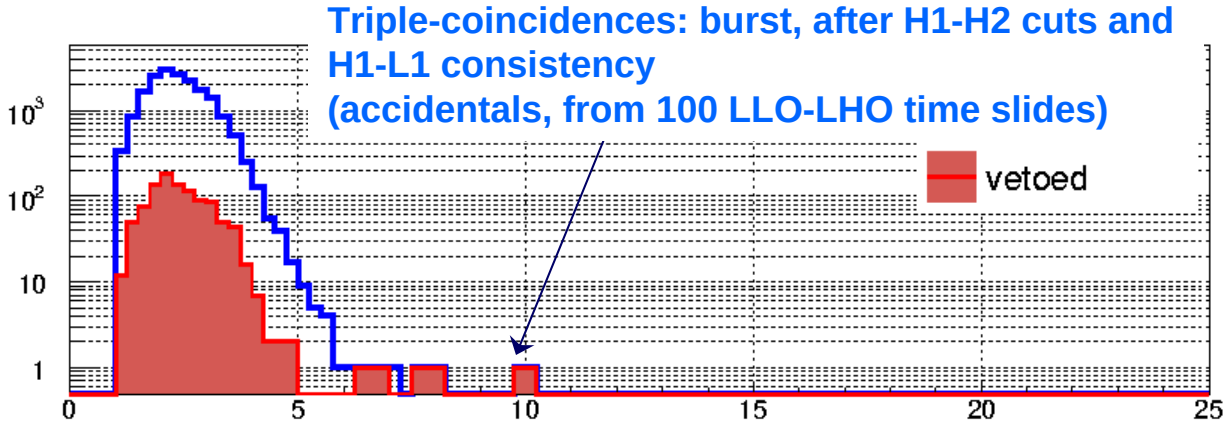
Effect of Category 2 vetoes on the early S5 burst search

EXAMPLE (continued):
Early S5 BURST analysis

Colored area: vetoed by Cat 2:
ASI_CORR_OVERFLOW (1.8% D.T.)
OVERFLOWS IN ASC
OVERFLOWS IN SUS_RM
CALIB_BAD_COEFF
OSEM_GLITCH (H2 only)
MMT3_OPTLEVER (H2 only)
POWMAG

Dead Time = 2.2%
Veto efficiency:
$\Gamma > 4$: 7.8%
$\Gamma > 5$: 27.6%

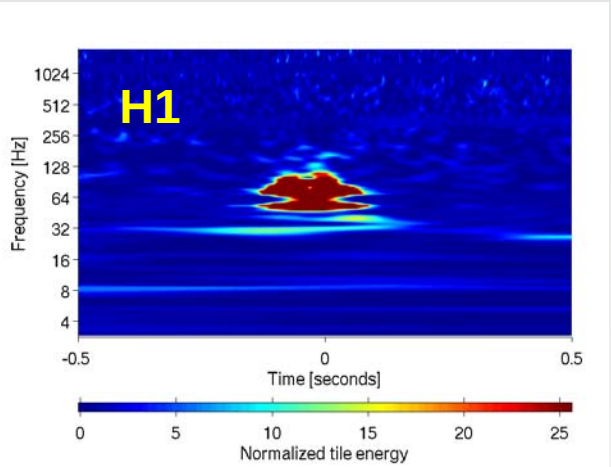




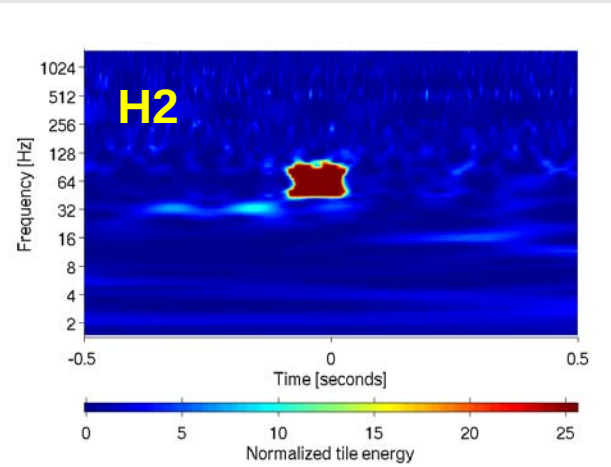
Γ= combined measure of for the linear correlation of detector pairs

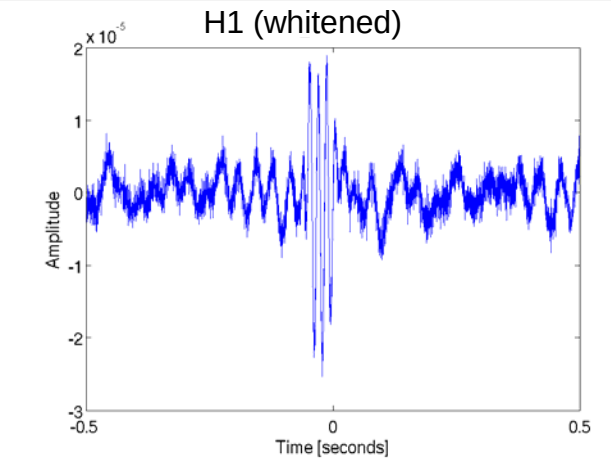
$\Gamma=(\Gamma_{H1H2}+\Gamma_{H1L1}+\Gamma_{H2L1})/3$

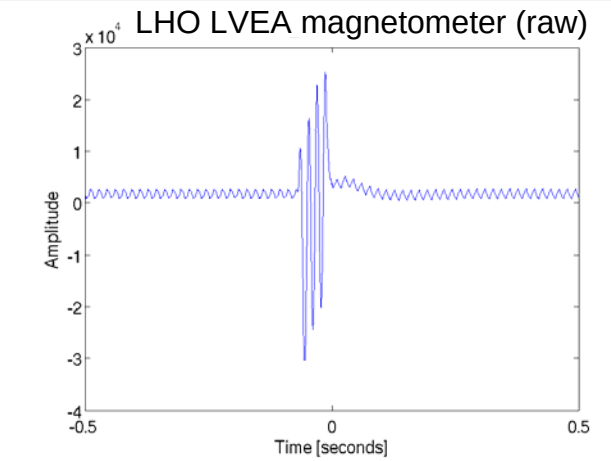
Glitches in the Power Line

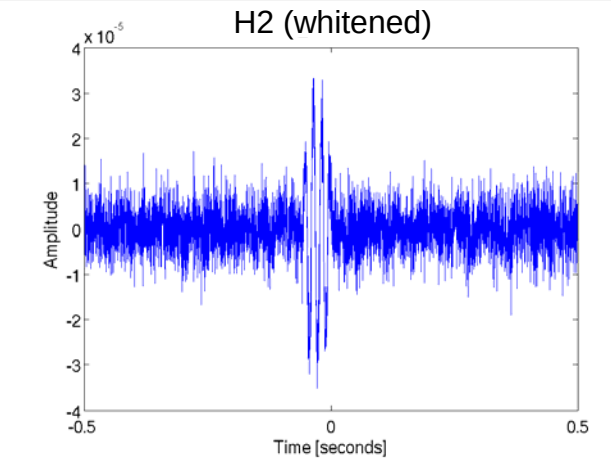


Glitches in the power line, magnetically coupled in the interferometer: a big transient in all magnetometers, volt-meters, IFO channels. Happens at LLO and LHO





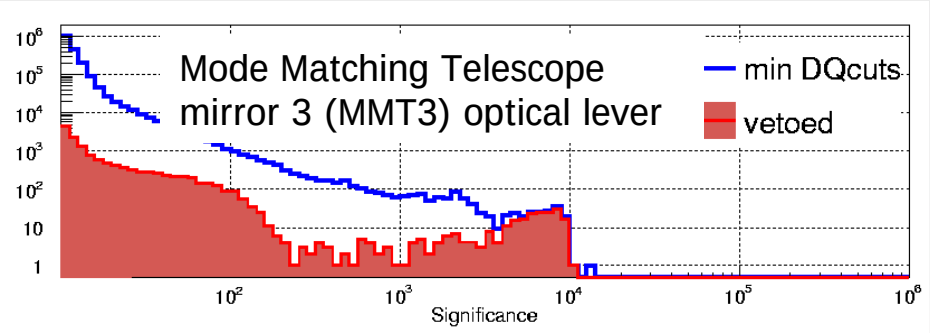


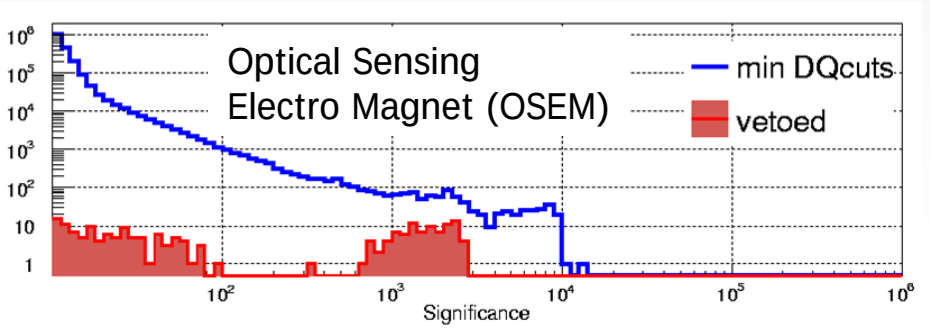


Coincidence, analysis cuts already effective

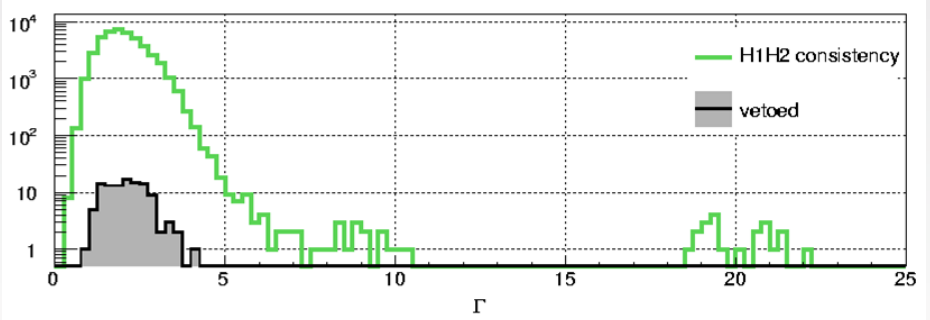
Not all Cat 2 flags are as effective on coincident events in the analysis, but if we know the physical coupling causing the single IFO transient, and the dead-time is small, we use the veto. Examples from the first 5 months of S5:

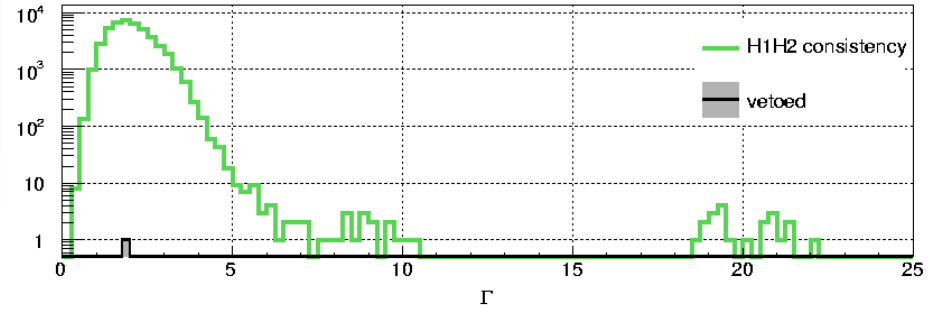
Single-IFO: Significance histogram of transients found by *KleineWelle* in H2





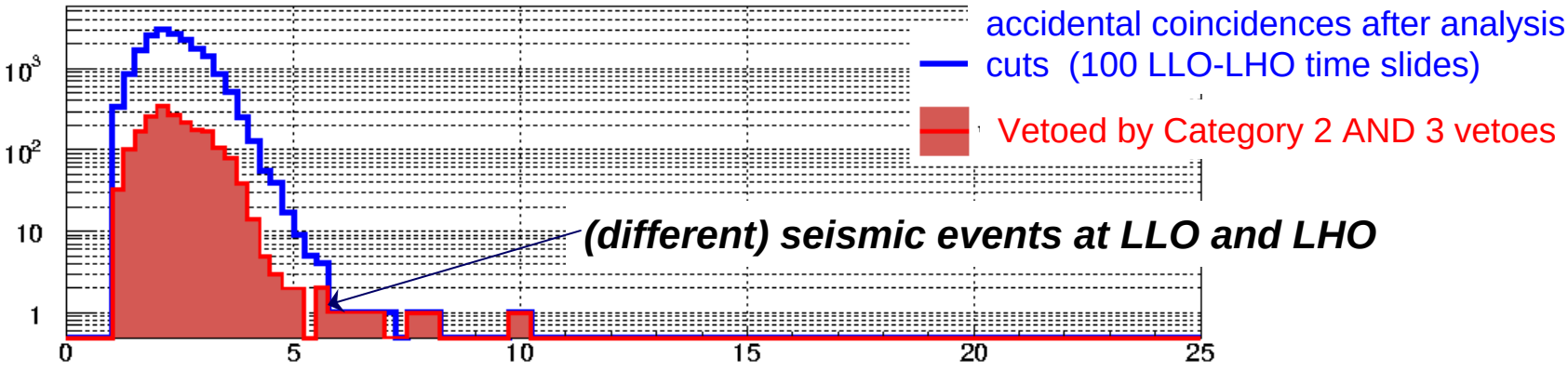
Triple-coincidences: burst, after H1-H2 cuts (accidentals, from 100 LLO-LHO time slides)



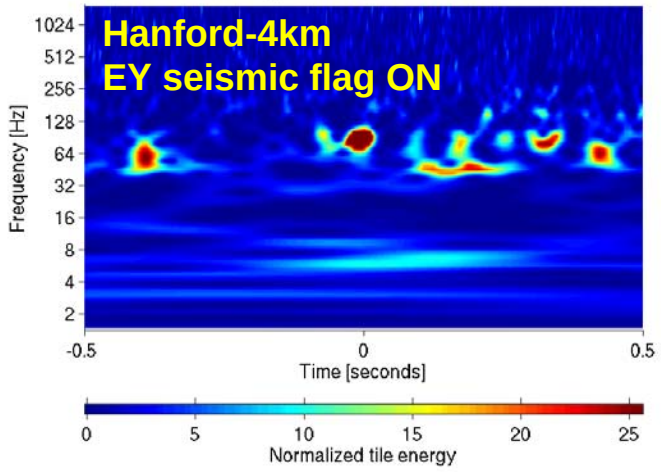


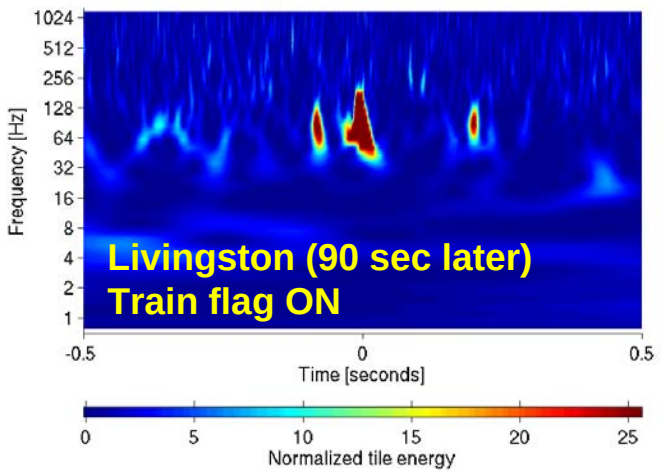
Category 2+3 Vetoes

Continued on the example of the Burst early S5 analysis:



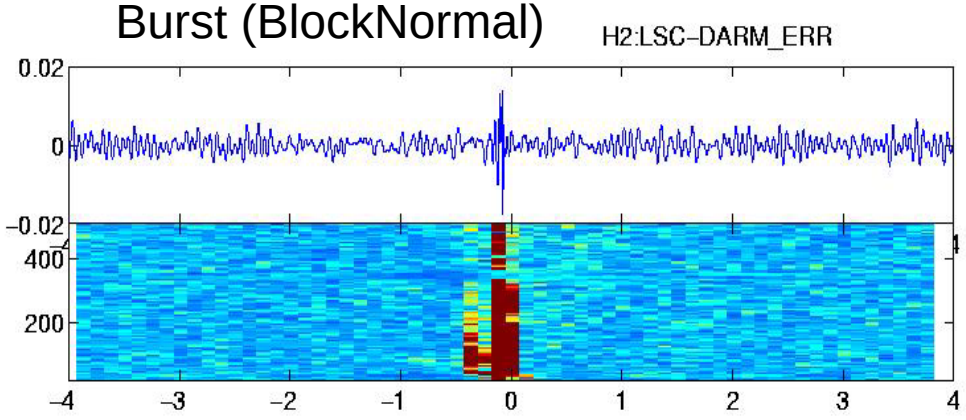
Γ= significance of the Burst waveform consistency test

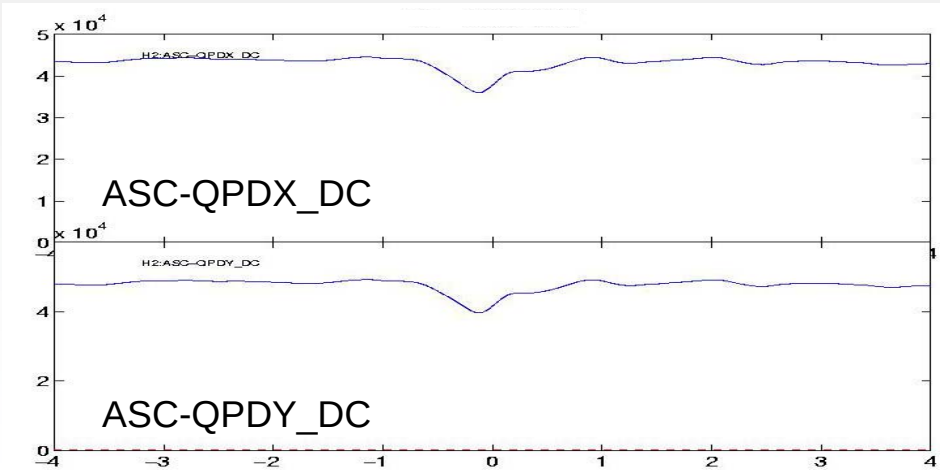




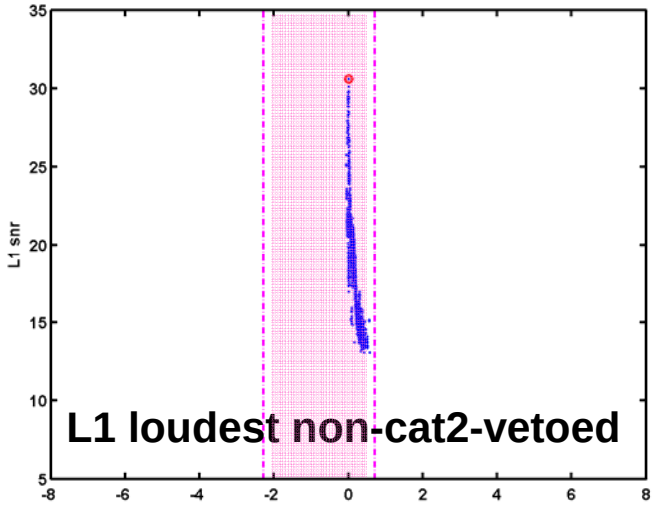
Light Dips

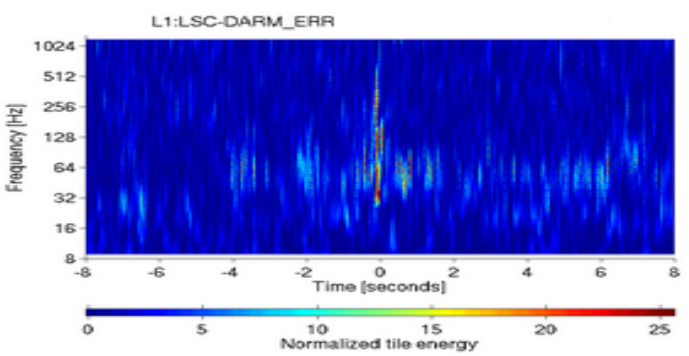
Burst (BlockNormal)





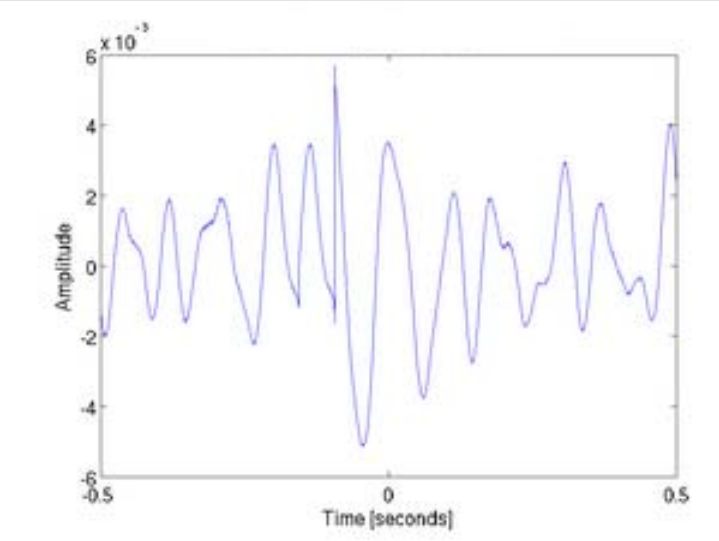
Inspiral BNS triggers



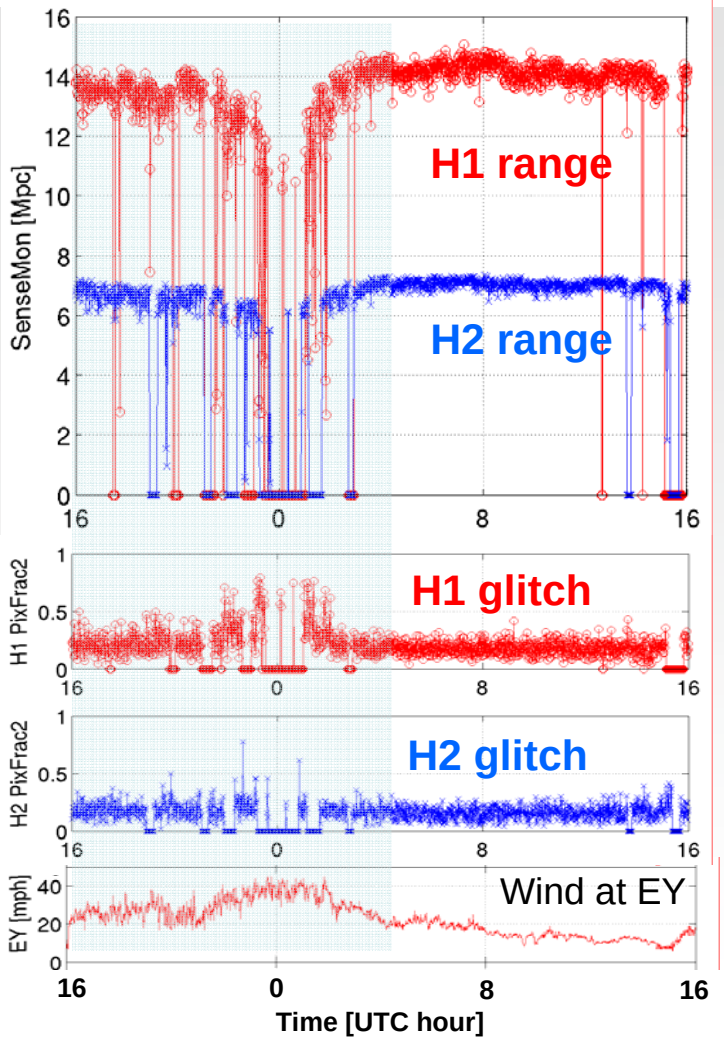


Also showing in several LSC channels

Category 4 flags



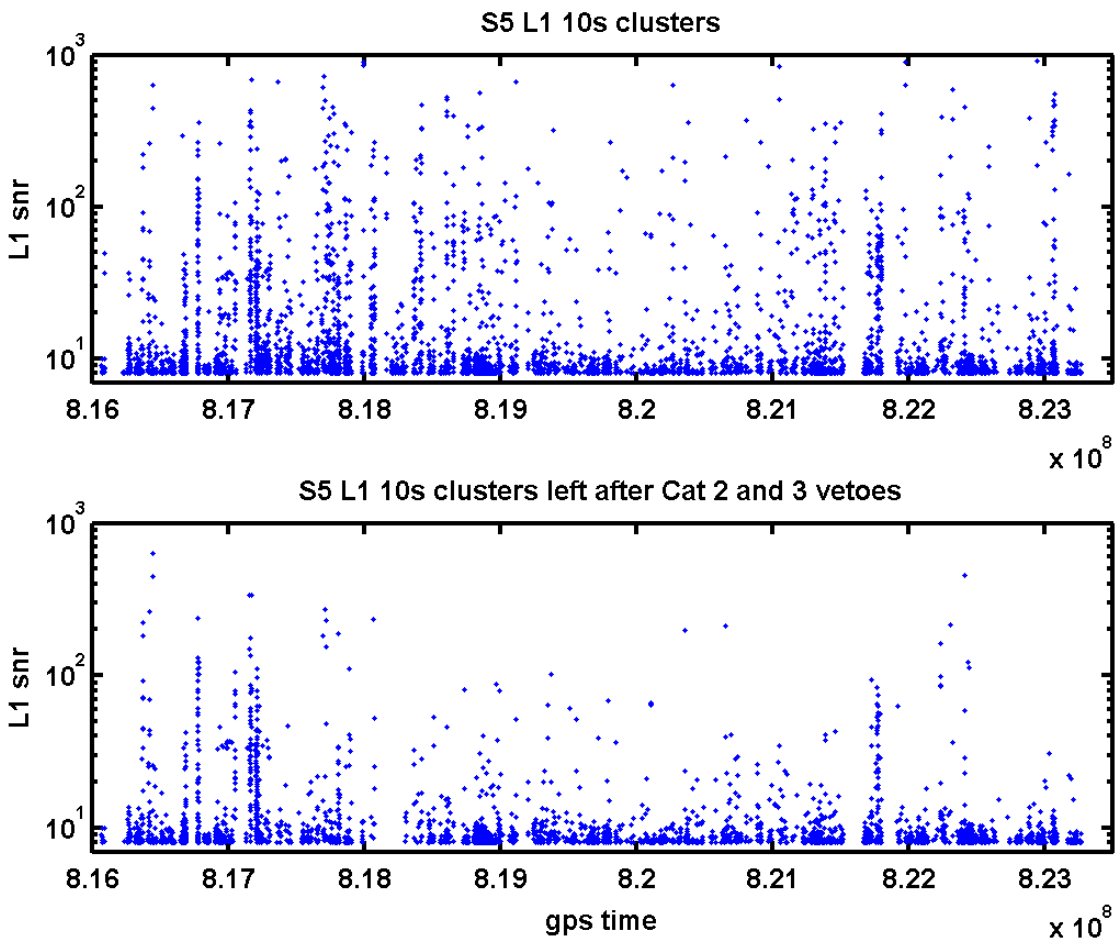
1/16 sec data repeats, inconsistency between the two frame-builders
CHECKSUM_MISMATCH flag



WIND_OVER_30MPH
Correlated with range loss and glitches

All Together

Inspiral BNS Single-IFO triggers as the cuts are applied



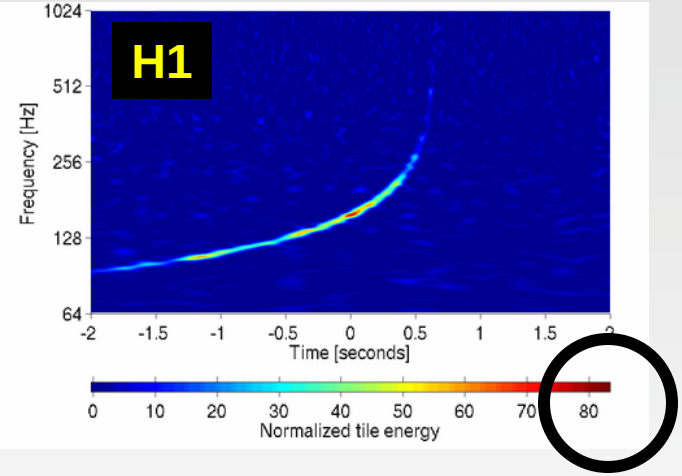
40 days of L1:

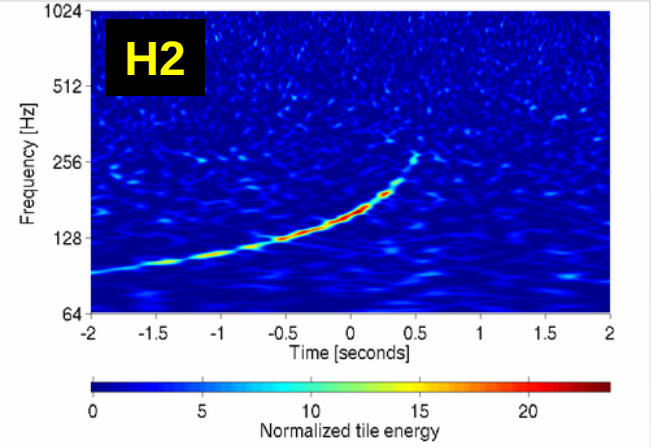
Veto Cat.	Deadtime fraction	veto efficiency SNR>8	SNR>50
2	7.2%	27%	80%
2+3	8.5%	32%	80%
2+3+4	9.1%	34%	82%

Residual glitches disappear with coincidence, χ^2, r^2 cut … AND (for LHO) with the H1-H2 distance cut

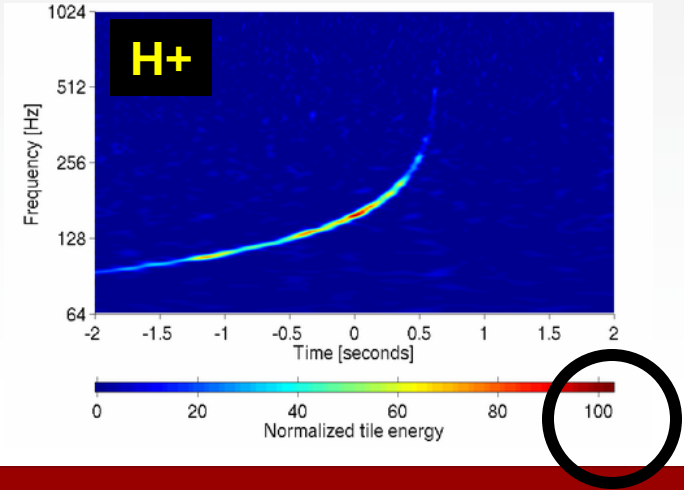
New analysis cuts will do even better

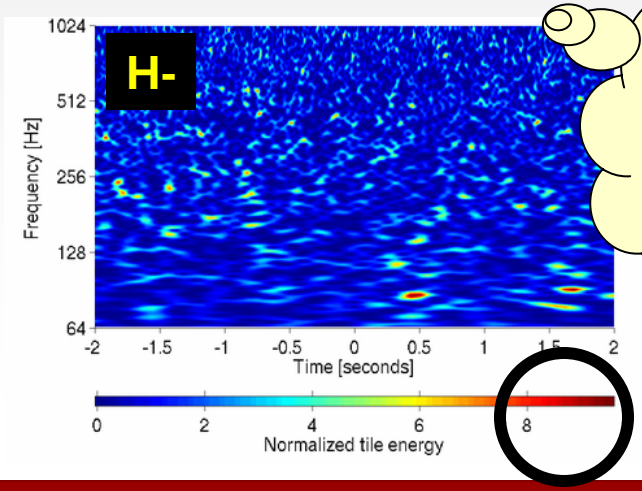
- 1.4/1.4 solar mass inspiral hardware injection at 5 Mpc





Plans for coherent analysis and H+,H- cuts





See talk by Shourov Chatterji on Thursday

Conclusion

- In S5, collaboration between search groups and detector characterization, through the glitch group: quasi-online data quality assessment
- Some features founds after looking at burst and inspiral triggers

  ⇒ **More on this in talk by Erik Katsavounidis**

- Burst and inspiral analysis have refined their cuts, but some instances of single-interferometer loud transients still sneak in
- Data quality cuts address residual coincident outliers (e.g. glitches in the power line or accidental coincidence of seismic up-conversion in different sites)
- The residual accidental coincidence histogram for burst and inspiral is quite clean