Follow up of the Equinox Event

Can we claim a detection?

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LVC Meeting, Amsterdam
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LIGO-G080498-00-Z

History

- Observed exactly one year on ago on Sept. 22, 2007 in the online search
- S5 1yr box opened in March, no events
- S5 2yr box for cWB opened in August
- Equinox event is the only cWB zero lag event above threshold in year 2
- The event is below threshold in the Q/W Search

Event Details

- Saturday September 22, 2007 03:06 UTC
- Friday September 21, 2007 20:06 PDT
- Low frequency triggers..

detector	GPS time	f	Q	SNR
H1	874465554.7158	96.8 Hz	4.7	11.8
H2	874465554.7119	110.9 Hz	22.6	5.4
L1	874465554.7100	118.3 Hz	4.7	11.3

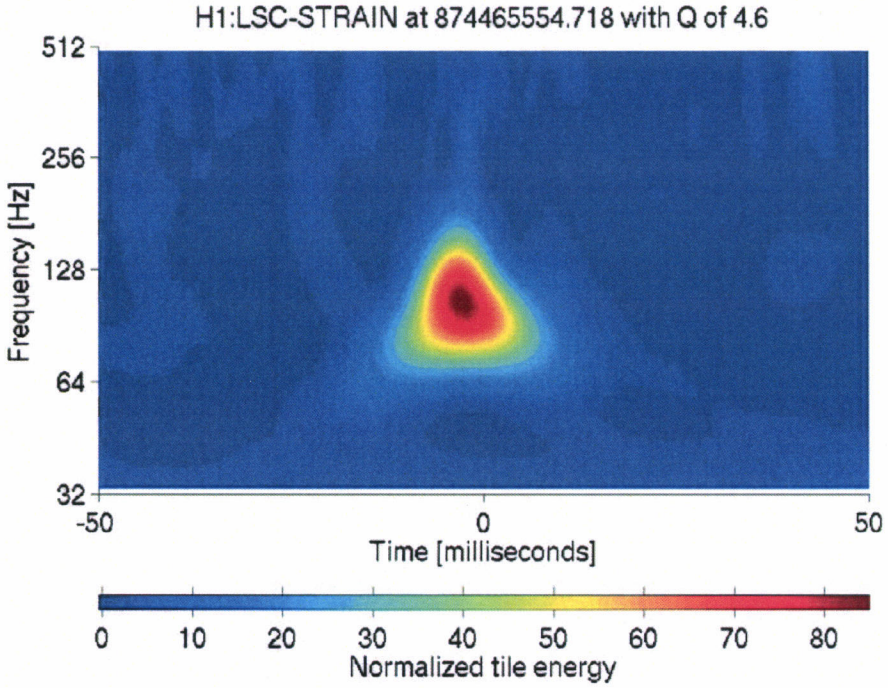
- All five detectors in science mode..

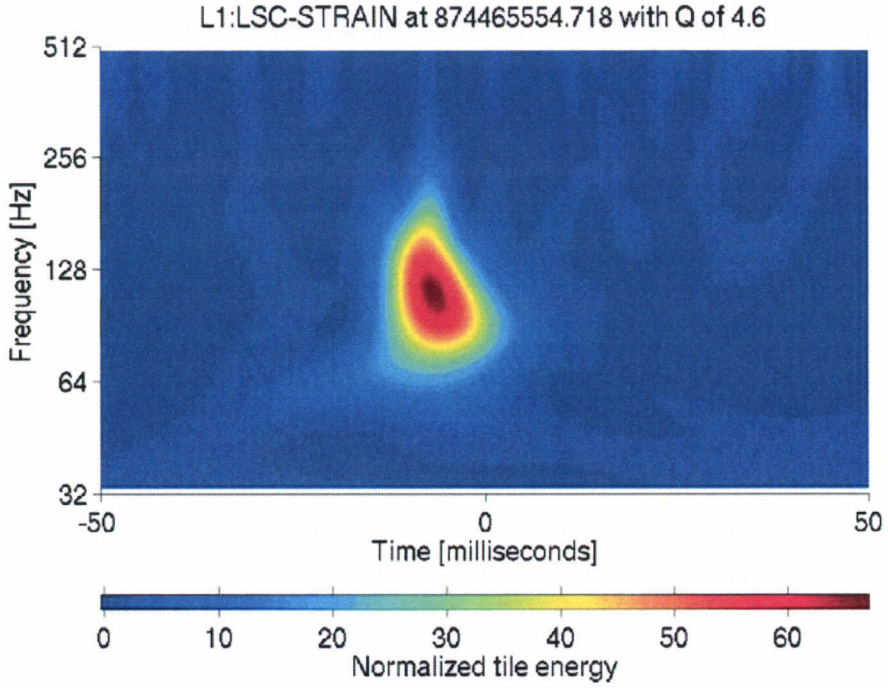
detector	state	start time	relative	stop time	relative
G1	Science Mode	874453140	-12414	874479600	+14046
H1	Science Mode	874438904	-26650	874501515	+35961
H2	Science Mode	874441095	-24459	874478798	+13244
L1	Science Mode	874452909	-12645	874488229	+22675
V1	Science Mode	874449546	-16008	874547216	+81662

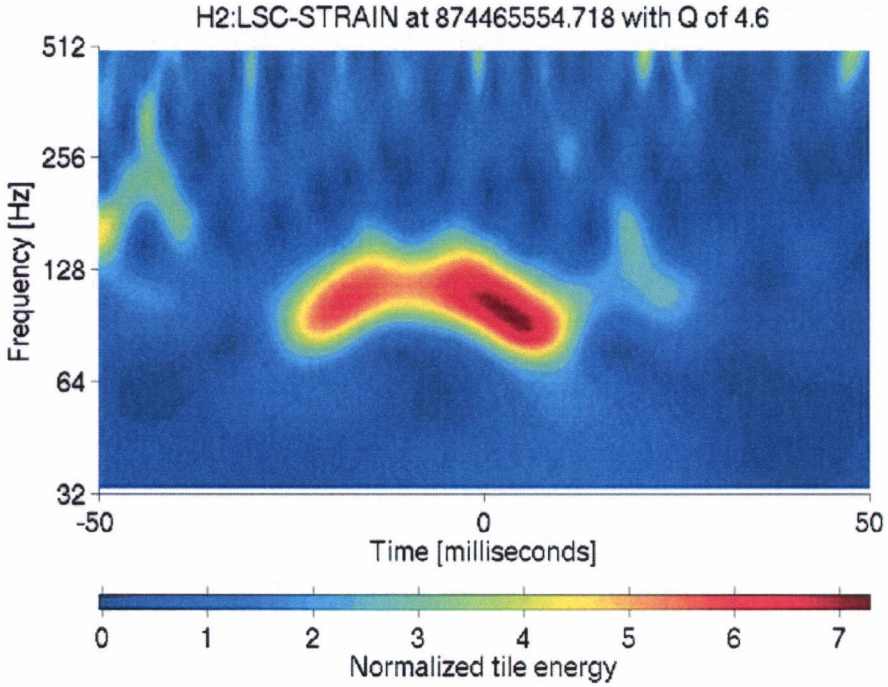
- So far no Data Quality, significant vetoes..

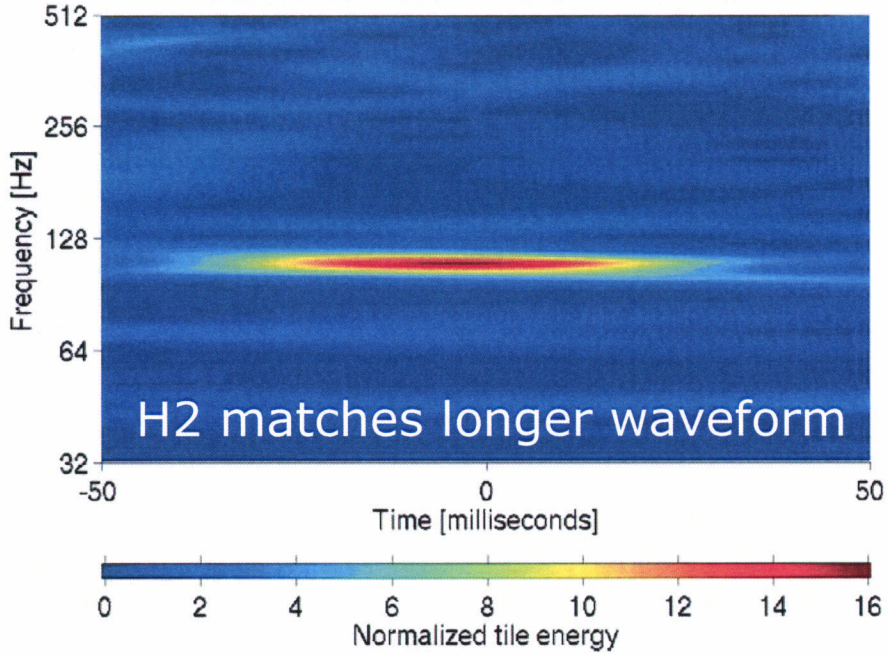
Q scans

- The Q transform provides a smooth time-frequency spectrogram by projecting onto (complex) sine-Gaussian basis waveforms at constant Q
- The Q transform matches to minimal-uncertainty waveforms, so the "best-match" sine-Gaussian is not always the most useful information for a broadband signal
- The next slide shows H1 and L1 Q scans at low Q (best match), and H2 at two different values of Q


H1:LSC-STRAIN at 874465554.718 with Q of 4.6
512
256
128
64
32
Frequency [Hz]
-50
0
50
Time [milliseconds]
0 10 20 30 40 50 60 70 80
Normalized tile energy

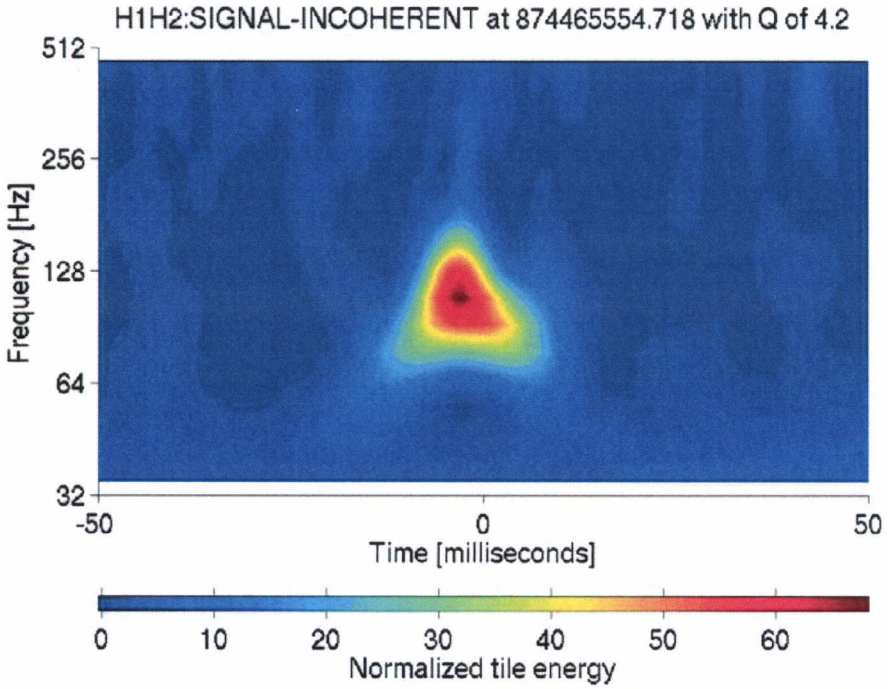

L1:LSC-STRAIN at 874465554.718 with Q of 4.6
512
256
128
64
32
Frequency [Hz]
-50
0
50
Time [milliseconds]
0 10 20 30 40 50 60
Normalized tile energy

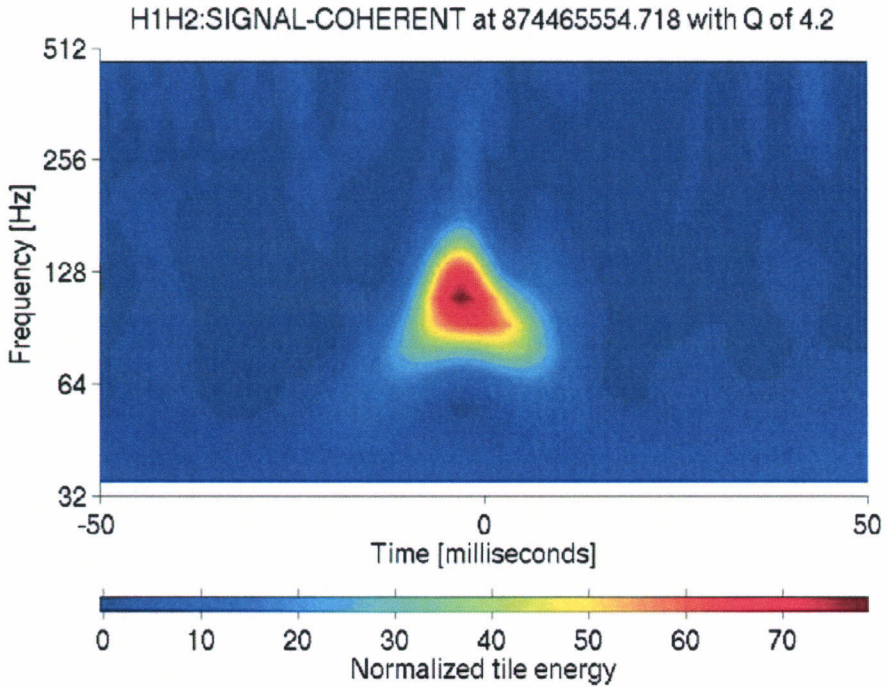

H2:LSC-STRAIN at 874465554.718 with Q of 4.6
512
256
128
64
32
Frequency [Hz]
-50
0
50
Time [milliseconds]
0 1 2 3 4 5 6 7
Normalized tile energy

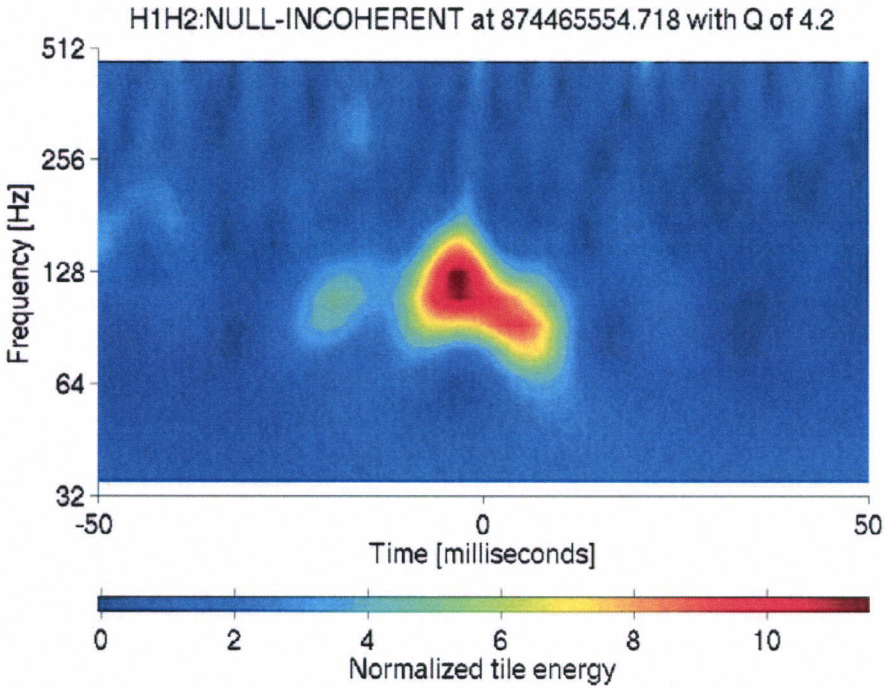

H2:LSC-STRAIN at 874465554.718 with Q of 27.1
512
256
128
64
32
Frequency [Hz]
H2 matches longer waveform
-50
0
50
Time [milliseconds]
0 2 4 6 8 10 12 14 16
Normalized tile energy

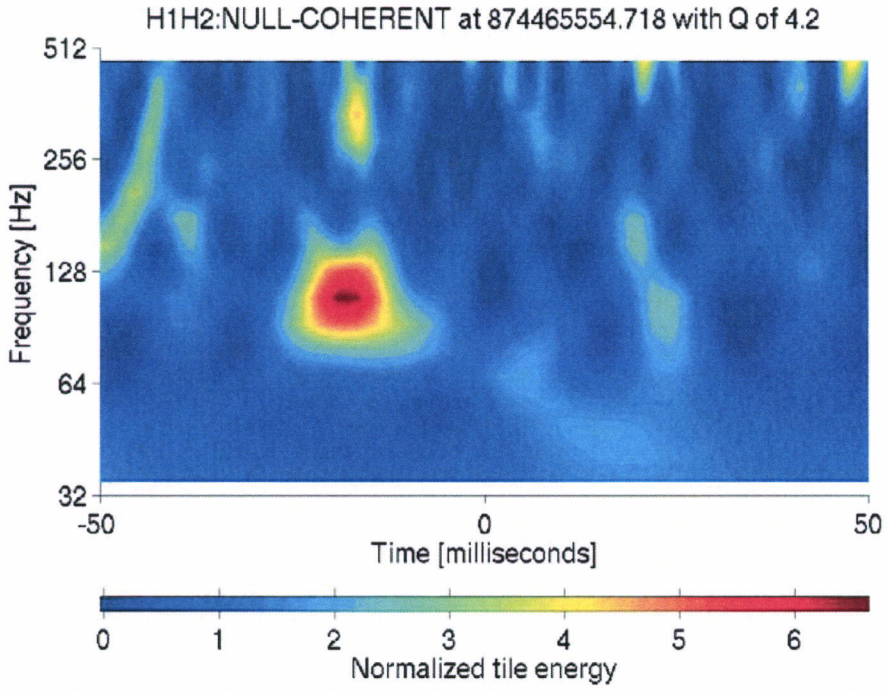
H1H2 consistency

- The following slide shows combinations of H1 and H2 data which assume a common signal in both detectors
- The "signal" sum is weighted by the inverse of each detector noise curve to get the best estimate (SNR) of the common waveform
- The "null" stream is H1-H2 in order to completely remove the waveform
- The "incoherent" version of each is an expectation value for the strength of each combined signal if the detectors are not correlated at all (random glitches)

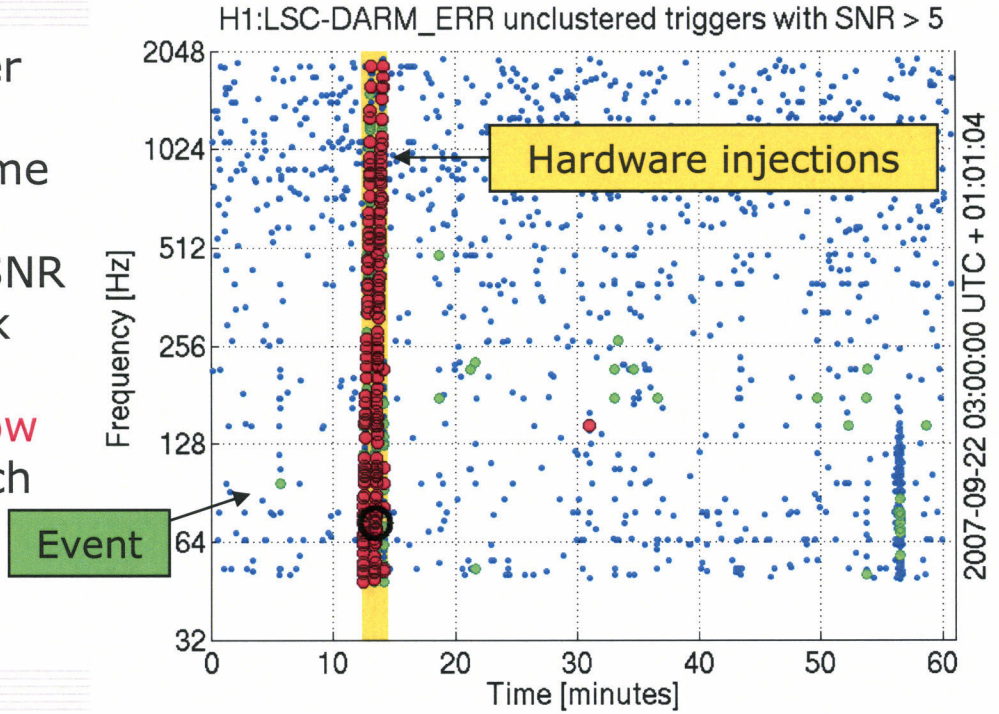

H1H2:SIGNAL-INCOHERENT at 874465554.718 with Q of 4.2
512
256
128
64
32
Frequency [Hz]
-50
0
50
Time [milliseconds]
0
10
20
30
40
50
60
Normalized tile energy

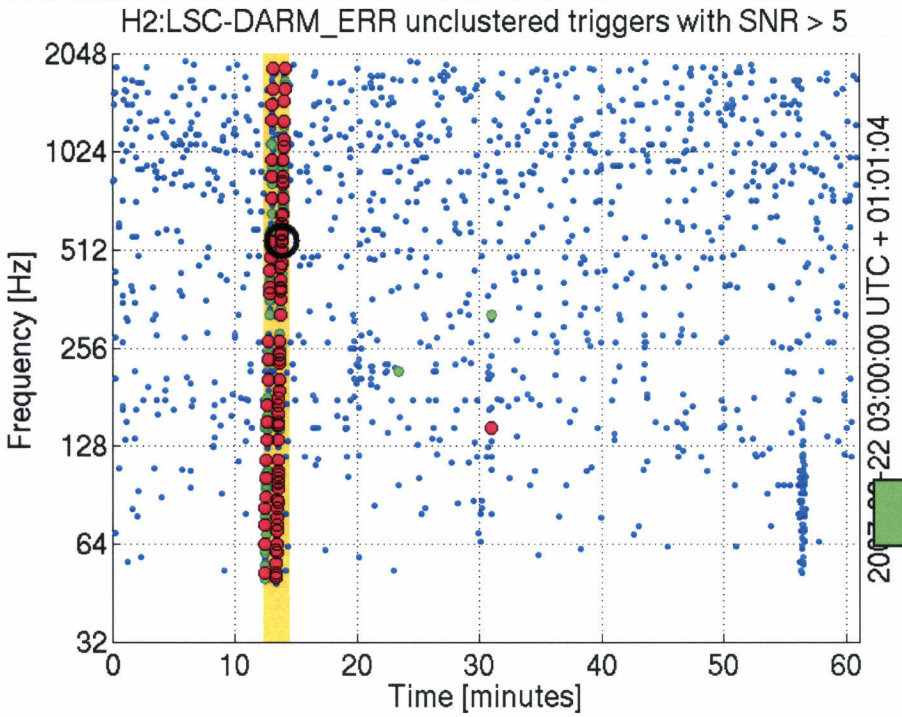

H1H2:SIGNAL-COHERENT at 874465554.718 with Q of 4.2
512
256
128
64
32
Frequency [Hz]
-50
0
50
Time [milliseconds]
0
10
20
30
40
50
60
70
Normalized tile energy

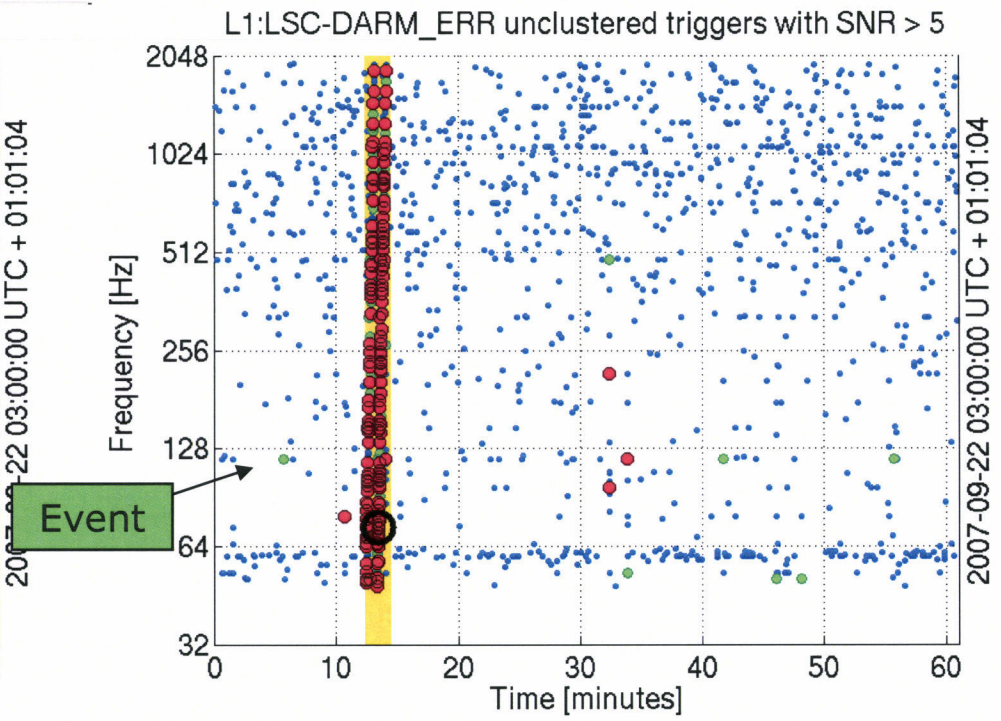

H1H2:NULL-INCOHERENT at 874465554.718 with Q of 4.2
512
256
128
64
32
Frequency [Hz]
-50
0
50
Time [milliseconds]
0
2
4
6
8
10
Normalized tile energy


H1H2:NULL-COHERENT at 874465554.718 with Q of 4.2
512
256
128
64
32
Frequency [Hz]
-50
0
50
Time [milliseconds]
0
1
2
3
4
5
6
Normalized tile energy

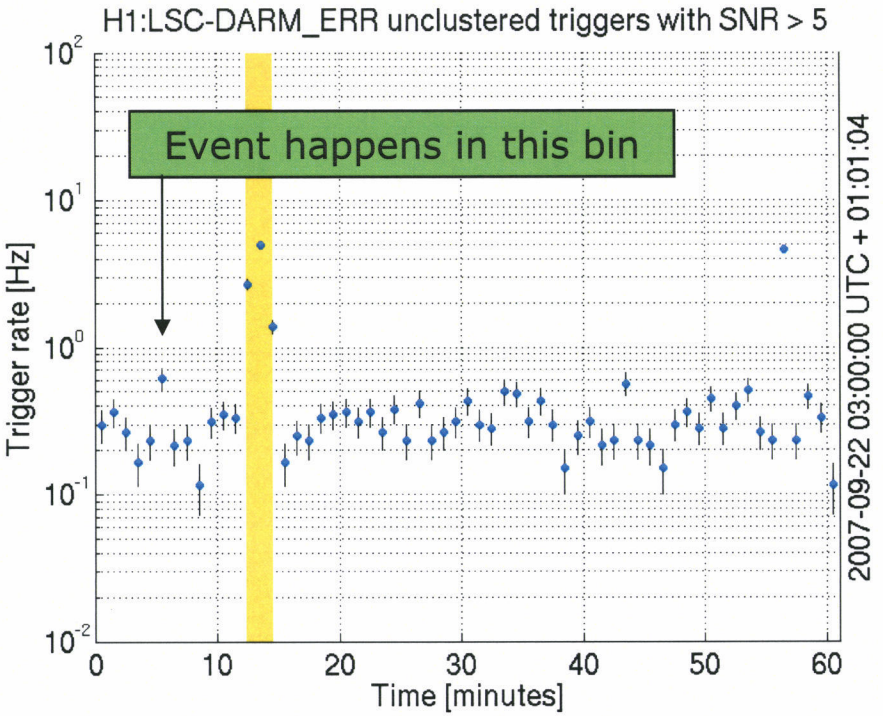
- Here we see time-frequency scatter plots of single-detector Q pipeline triggers which happened in the same hour as the event
- Red/green/blue dots indicate the SNR of the triggers from strong to weak
- The event, in green for H1 and L1, occurs six minutes before the yellow bar filled with strong triggers, which are burst hardware injections
- The 100 Hz glitches do not seem uncommon in L1

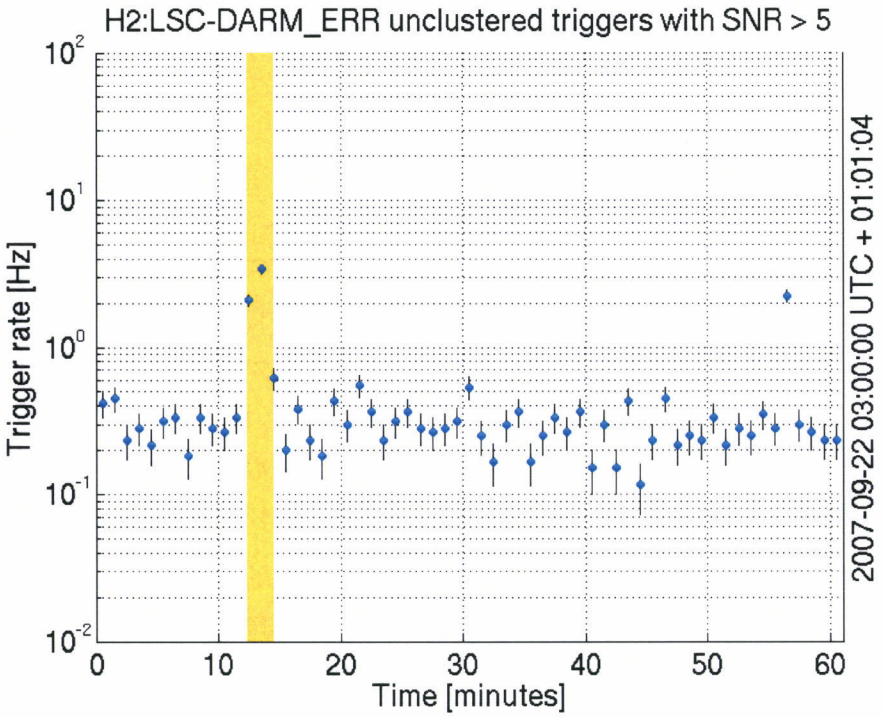


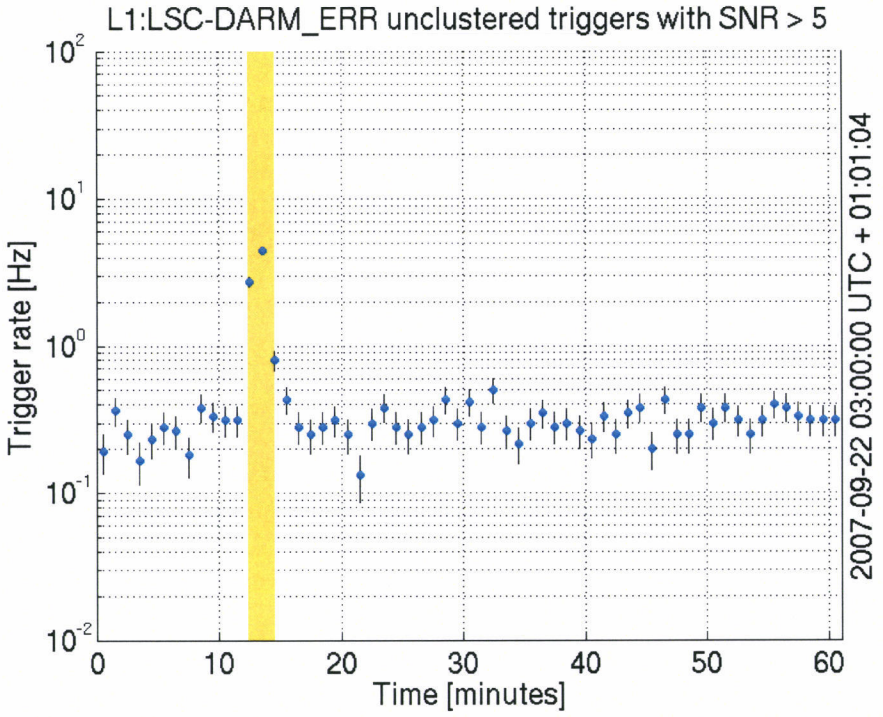




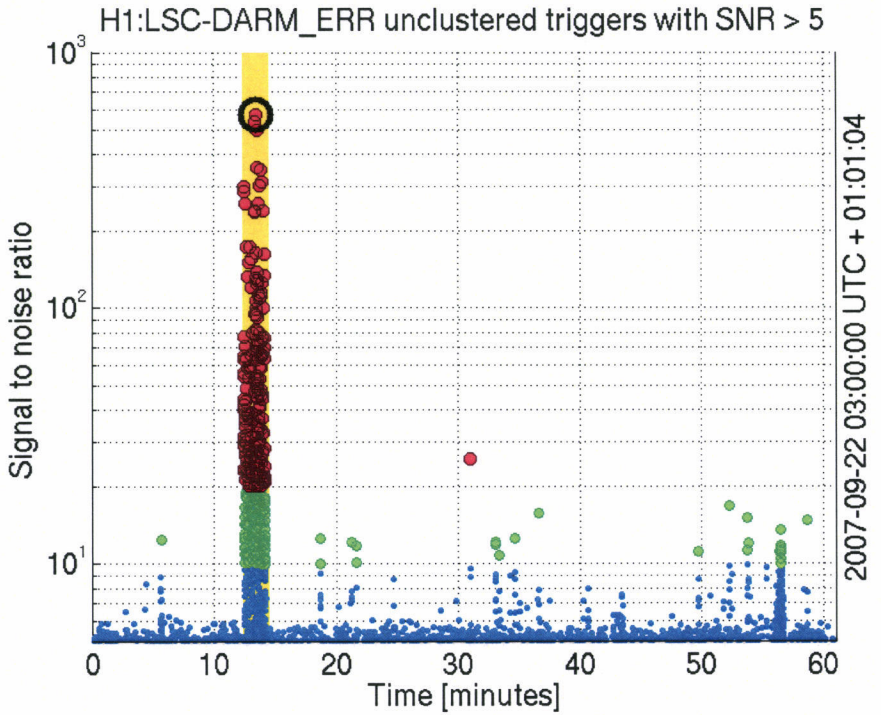
- Here we see rates of low-threshold unclustered single-detector Q pipeline triggers which happened in the same hour as the event
- H1 shows a 3-fold increase in low-threshold event rates during the time of the event (depends on bin size)
- H1 rarely shows such a large rate again throughout the hour
- H2 and L1 are quiet

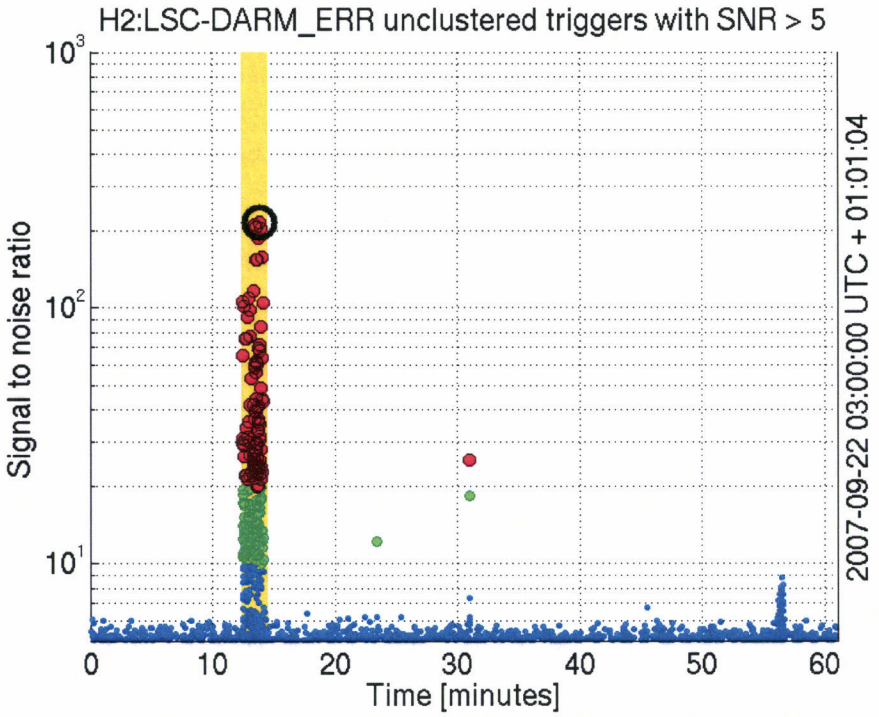


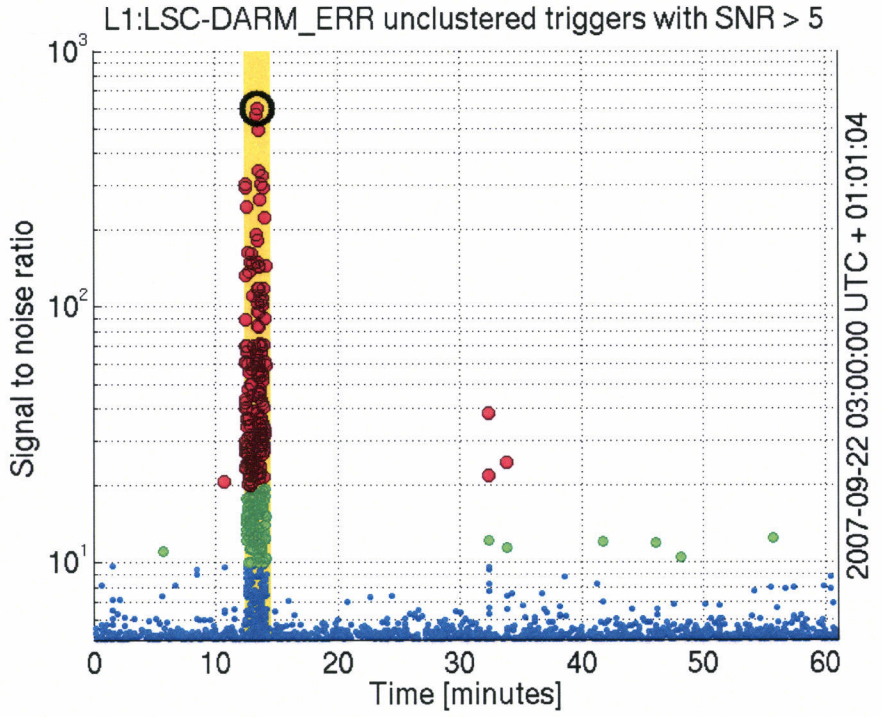


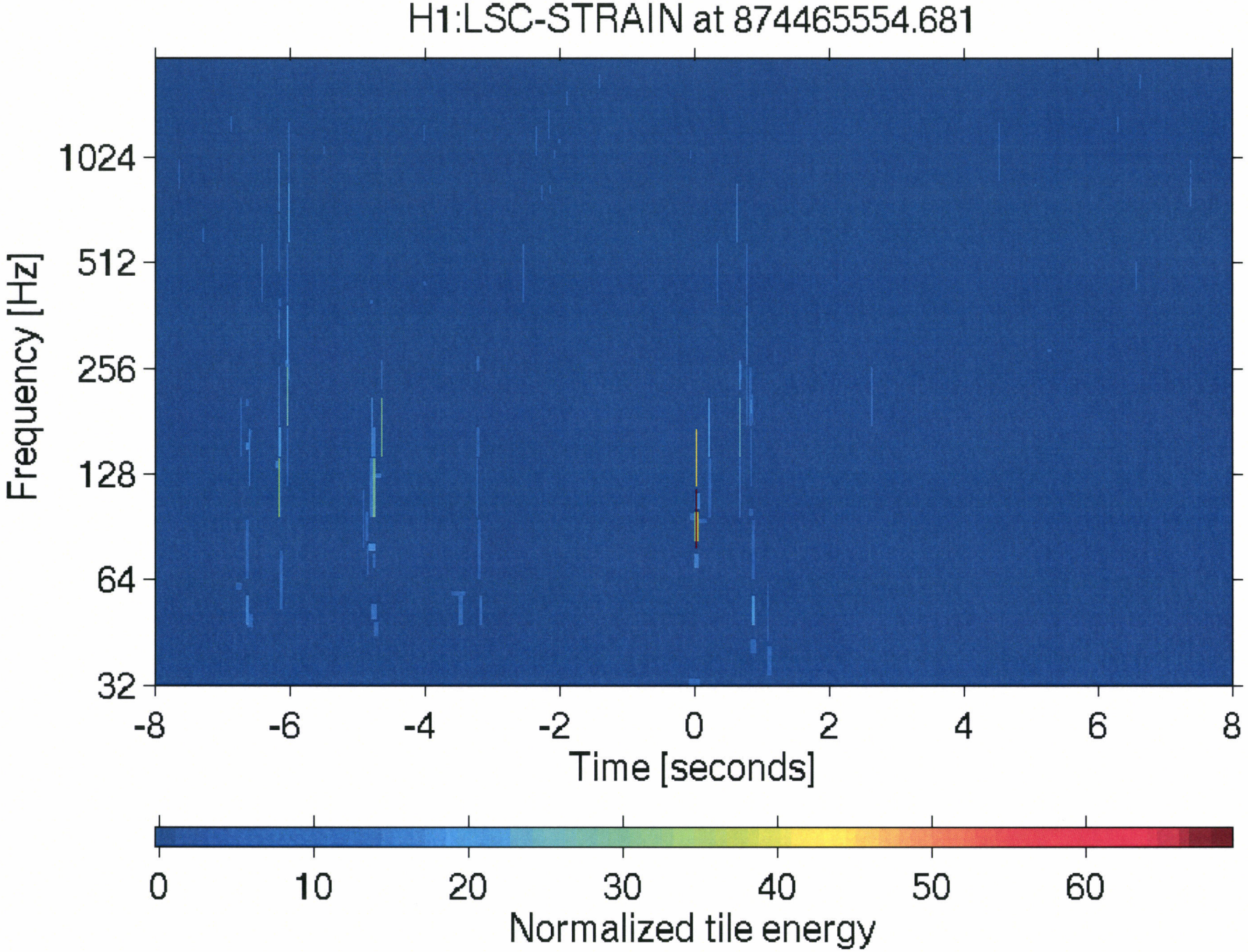


- Here we see time-SNR scatter plots of single-detector Q pipeline triggers which happened in the same hour as the event
- Red/green/blue dots indicate the SNR of the triggers from strong to weak
- We see in H1 that the event falls along with a series of weaker glitches
- This pattern seems to be the same for other green events, though the others do not happen at 100 Hz so it is not the exact same behavior

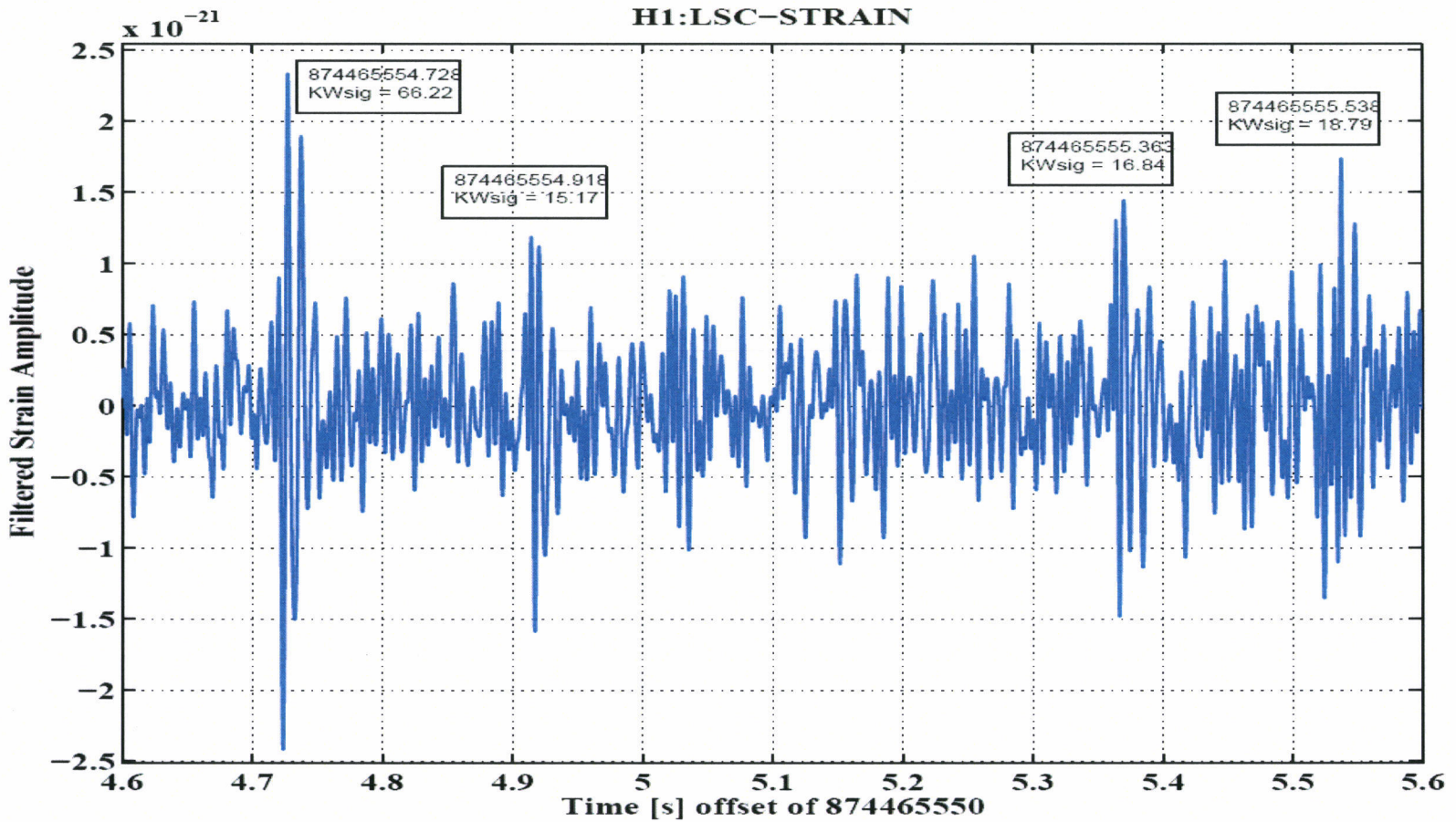




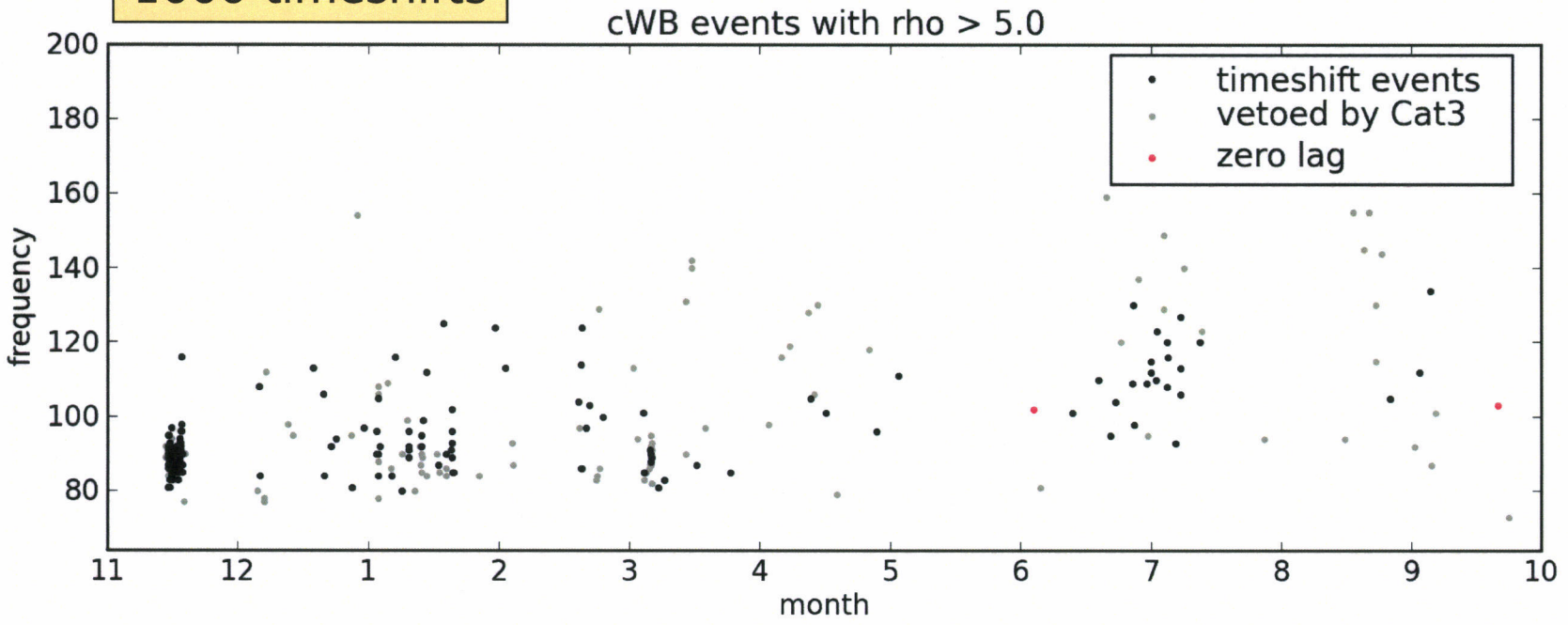


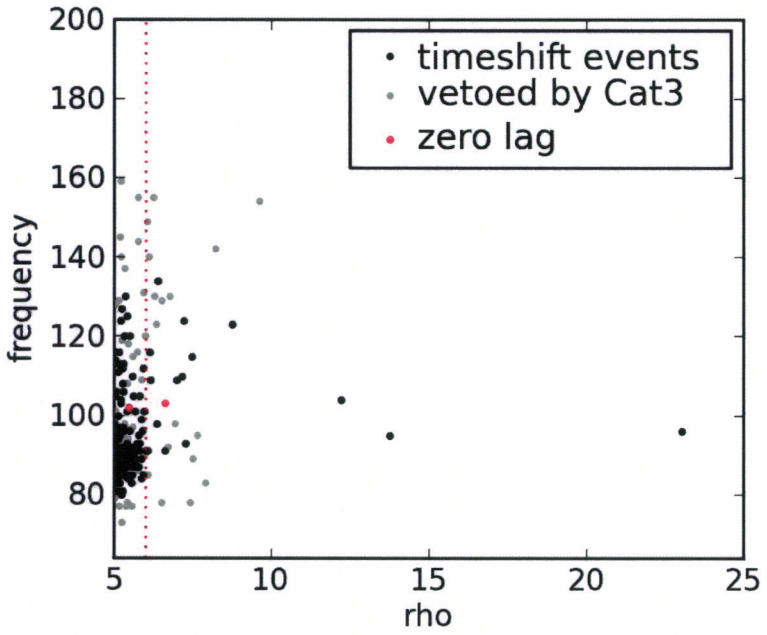

H1:LSC-STRAIN at 874465554.681
Frequency [Hz]
1024
512
256
128
64
32
-8
-6
-4
-2
0
2
4
6
8
Time [seconds]
0
10
20
30
40
50
60
Normalized tile energy

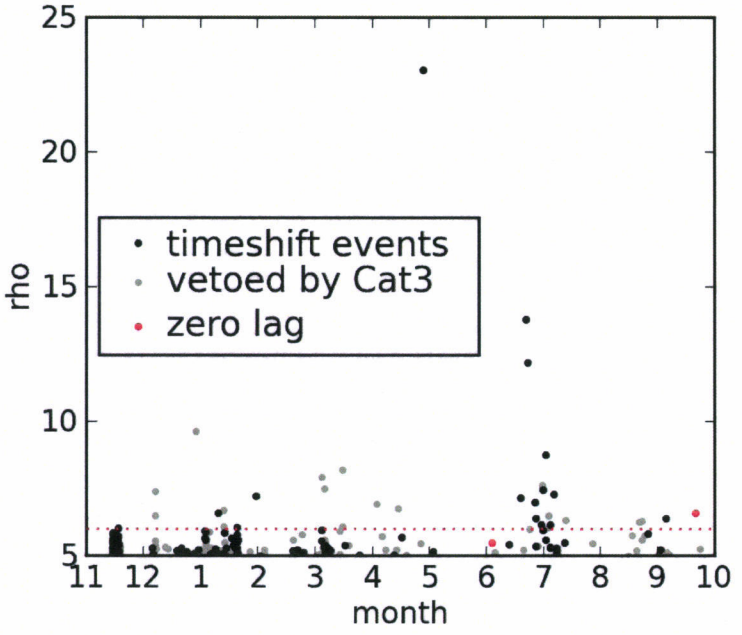
In the same second as the event..



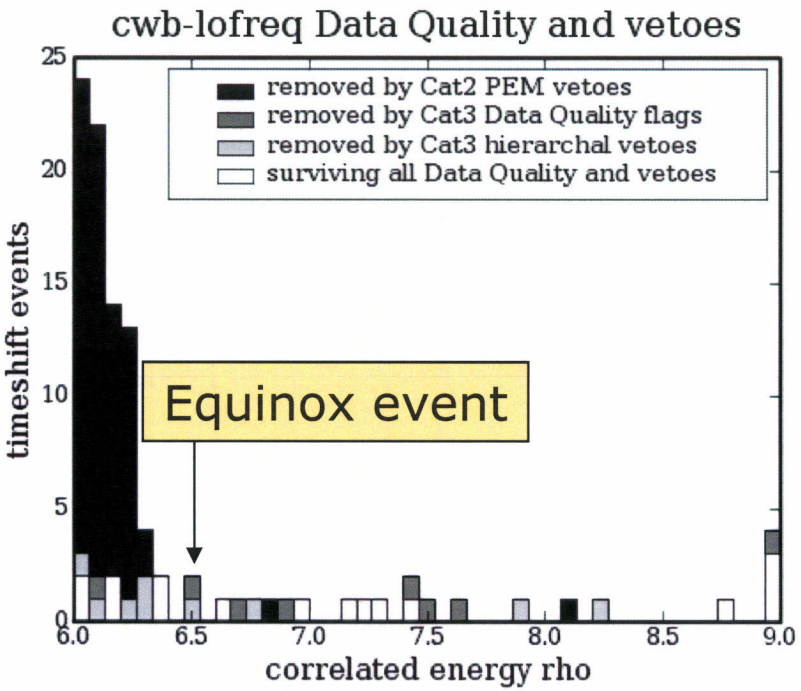
1000 timeshifts

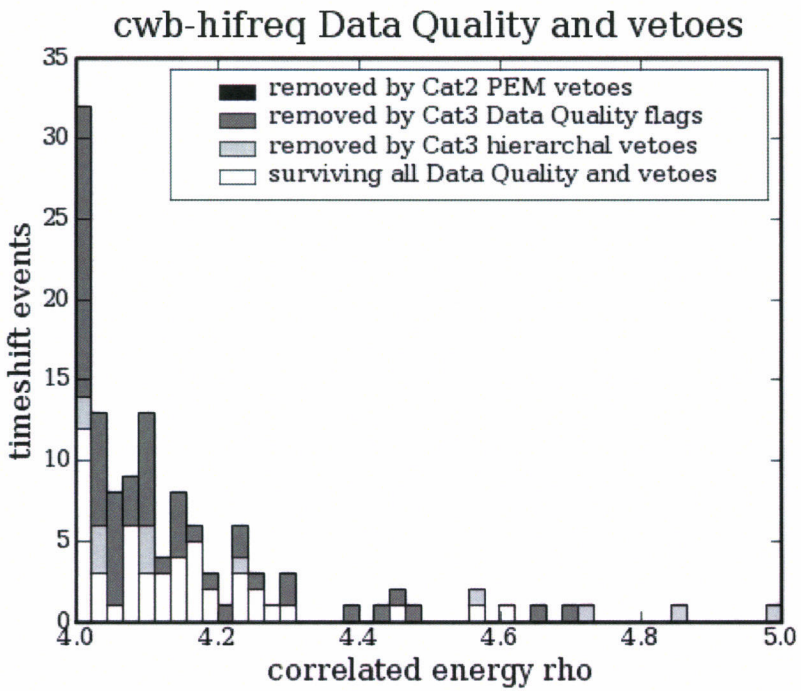






Coherent Waveburst Background





Below 200 Hz ***only***:

- 19 events at or stronger than equinox event, 2% chance, 1/26 years
- 10 events after Cat3 DQ+vetoes, 1% chance, 1/43 years

What does this statement mean?

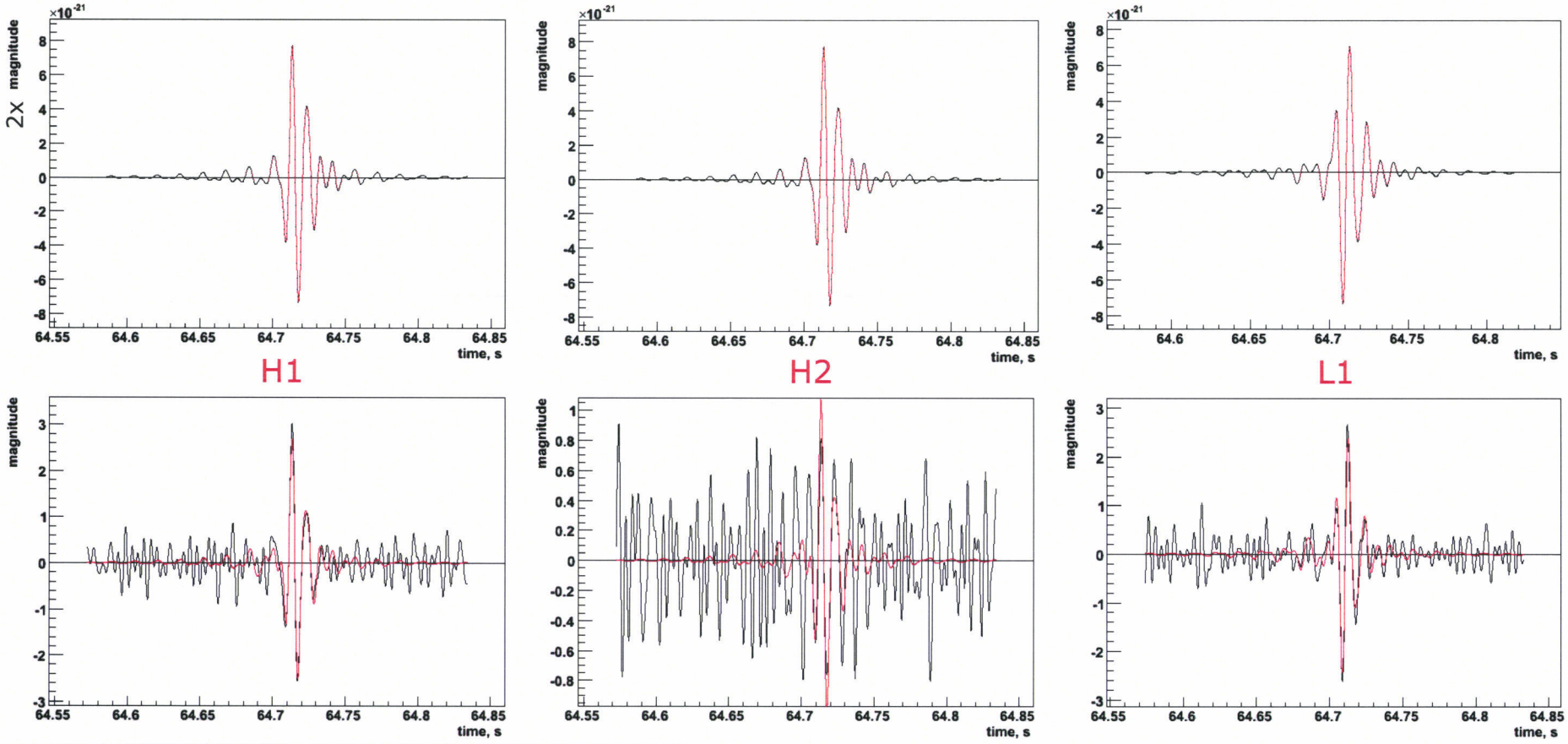
We have a 2% probability of observing a background event of equal or greater ρ in the S5 2yr 64-200 Hz analysis on H1H2L1 data with cWB if Category 3 vetoes and DQ are not applied

~~We expect our search to yield a more convincing gravitational-wave candidate event 2% of the time~~

Making use of a likelihood statistic to rank our events according to how likely they are to be gravitational waves instead of background will go a long way toward automating many (not all) of the additional considerations which can now only be applied after the fact (not blind)

So what if it's real, what would it look like?

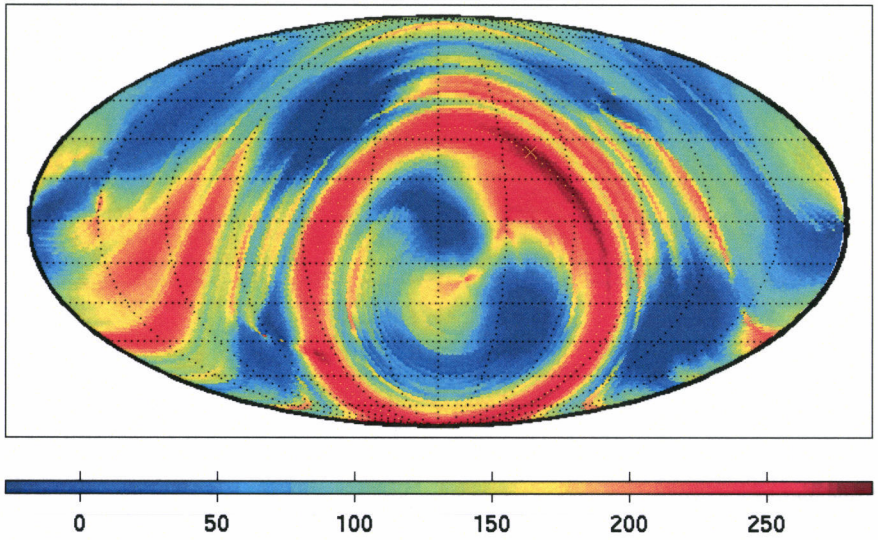
cWB most likely coherent waveform (above), whitened waveform+noise (below)



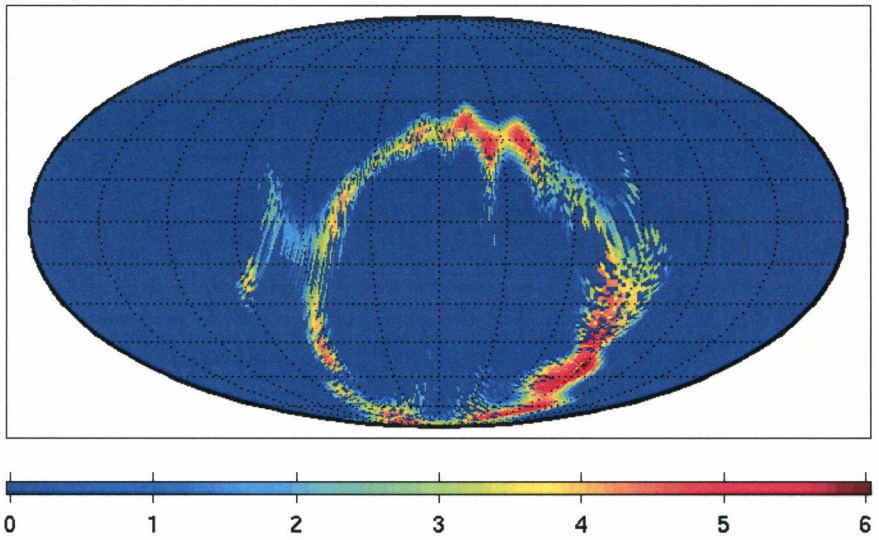
$h_{peak} = 4 \times 10^{-21}$ $h_{rss} = 3 \times 10^{-22}$

Skymaps

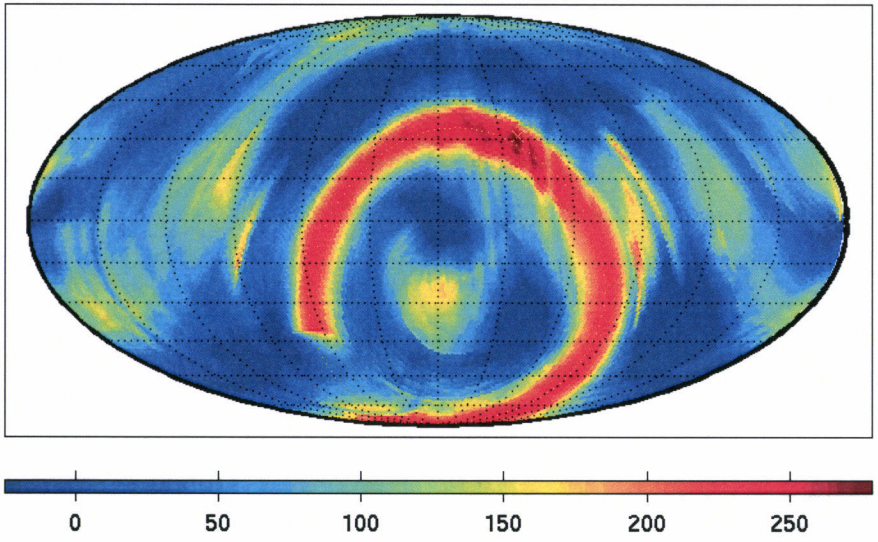
CWB HL sky statistic



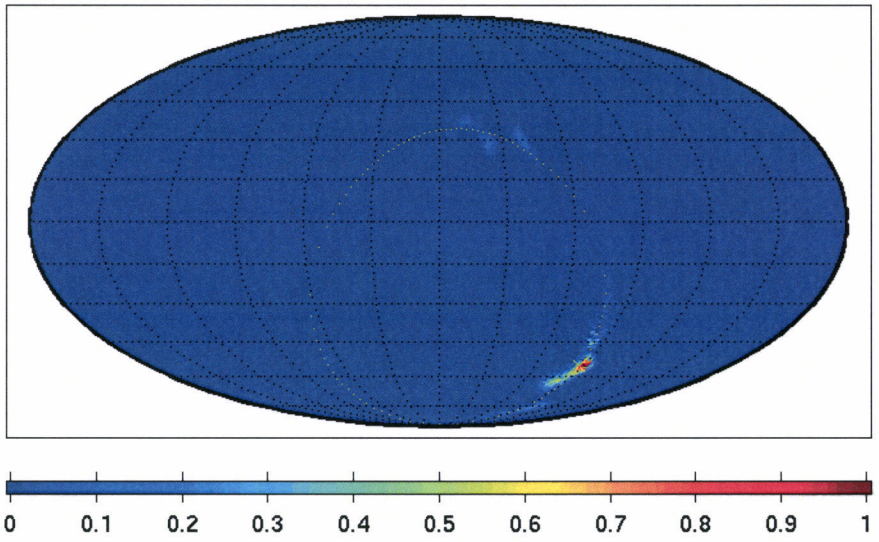
Omega HLV log10 posterior



CWB HLV sky statistic

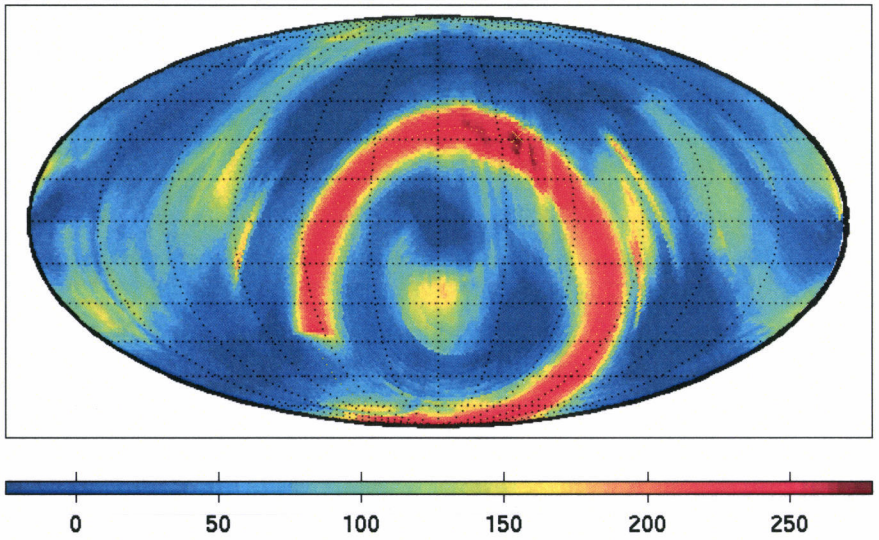


Omega HLV unnormalized posterior

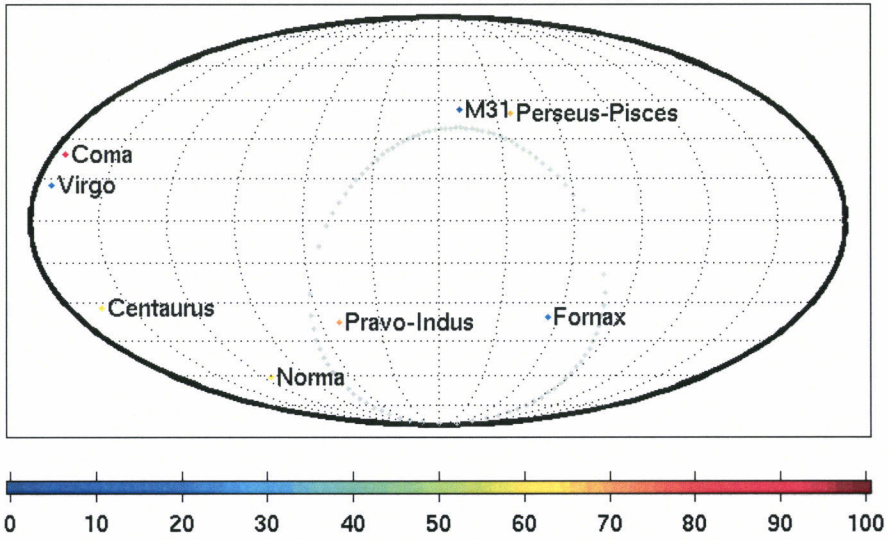


What's there?

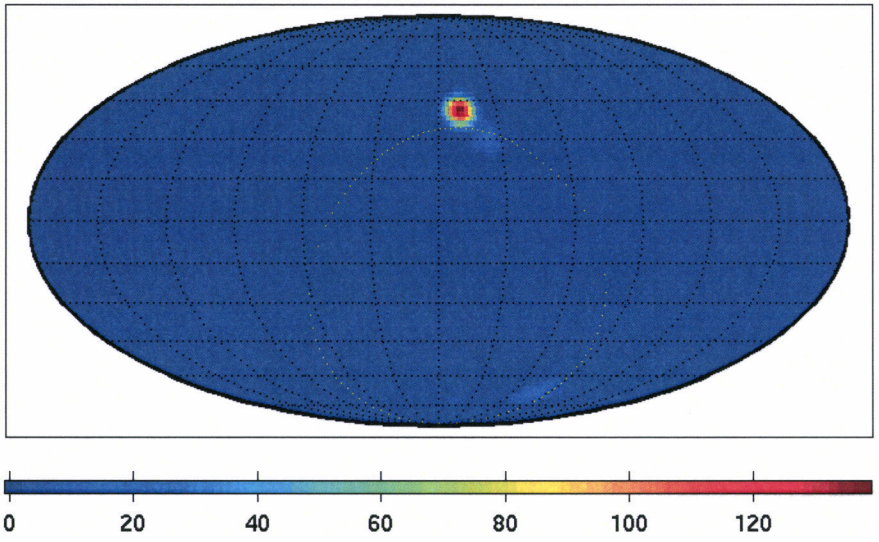
CWB HLV sky statistic



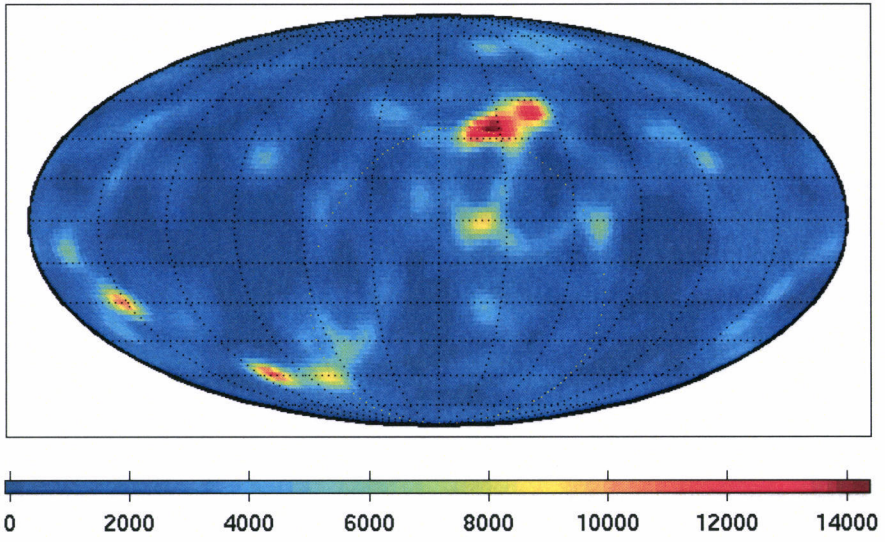
some galaxies, clusters, and superclusters within 100 Mpc



cumulative L10 luminosity per solid angle between 0 Mpc and 1 Mpc

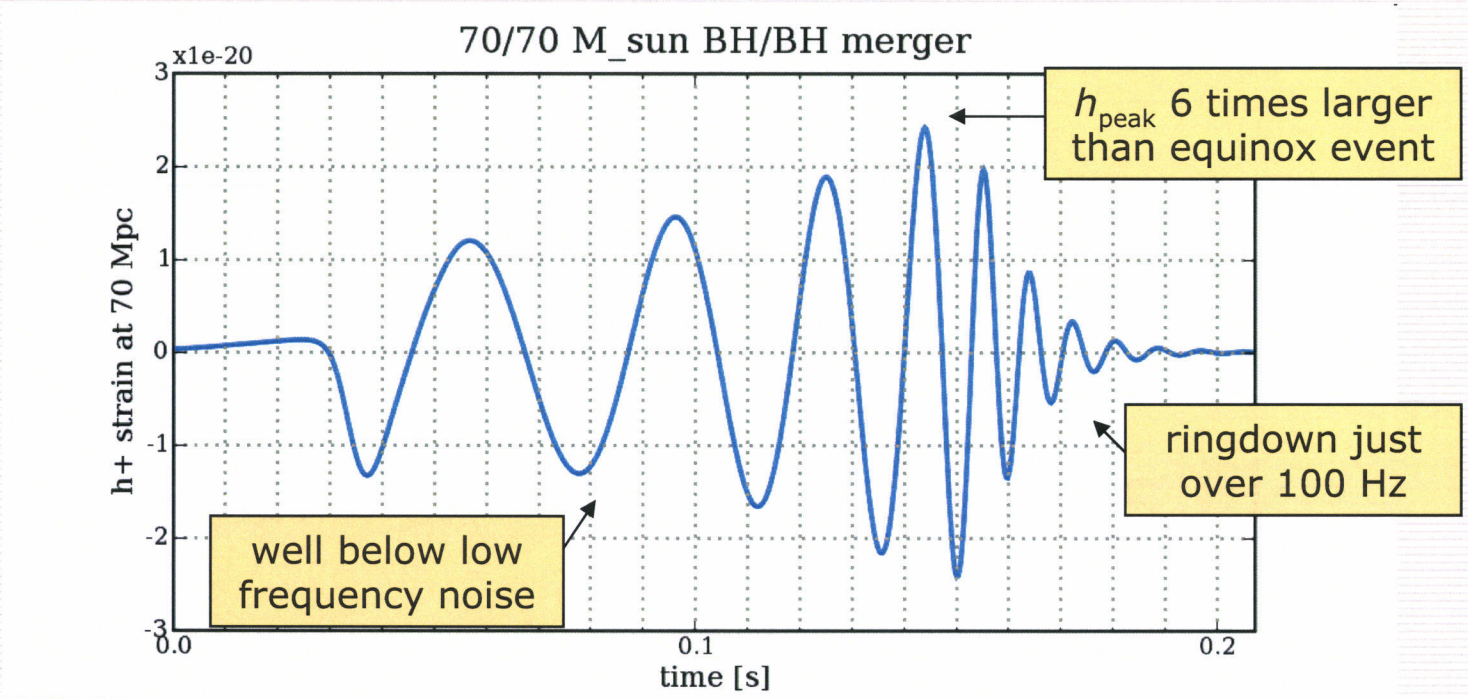


cumulative L10 luminosity per solid angle between 50 Mpc and 80 Mpc



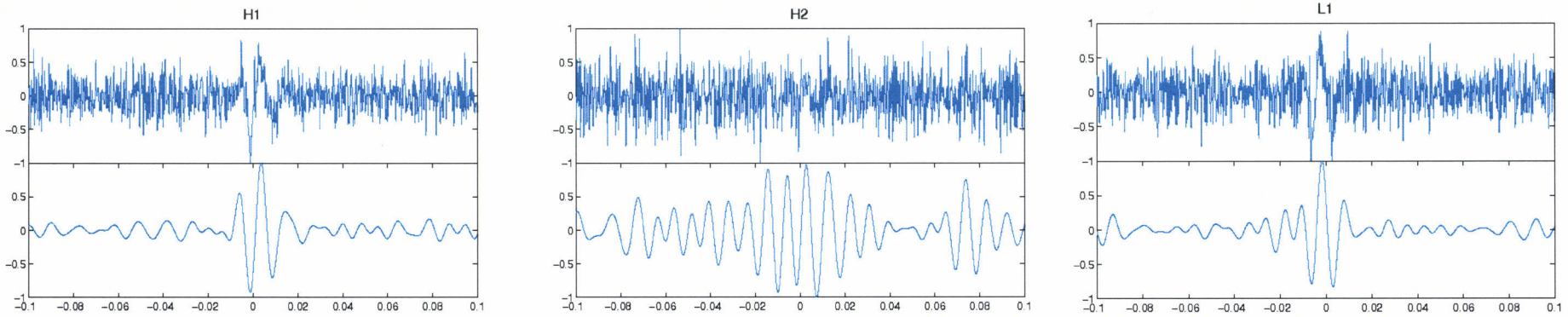
What a BH/BH merger looks like

- Equal mass, no spin:
  - http://astrogravs.nasa.gov/docs/waveforms/NRmergers/
- At 70 Mpc (distance to Perseus-Pisces), optimal orientation

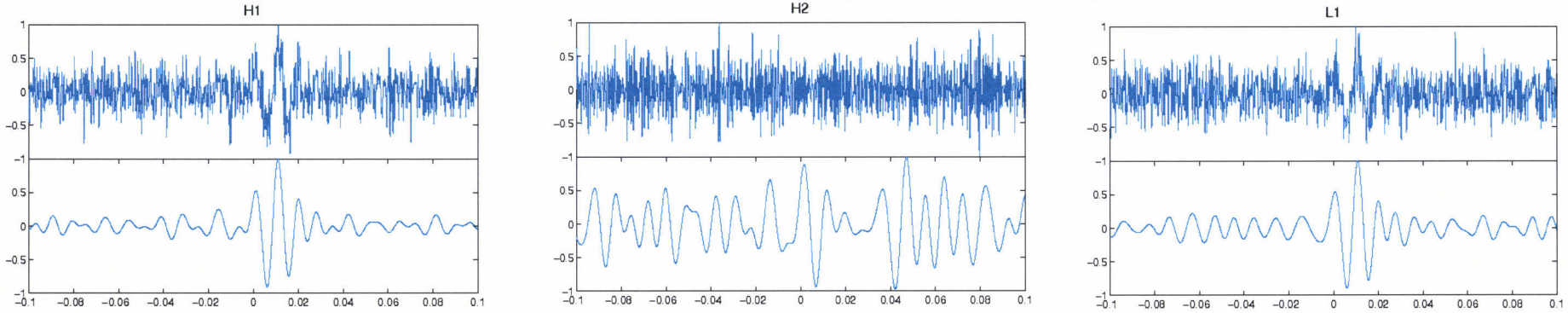


Timeseries comparison

Equinox event

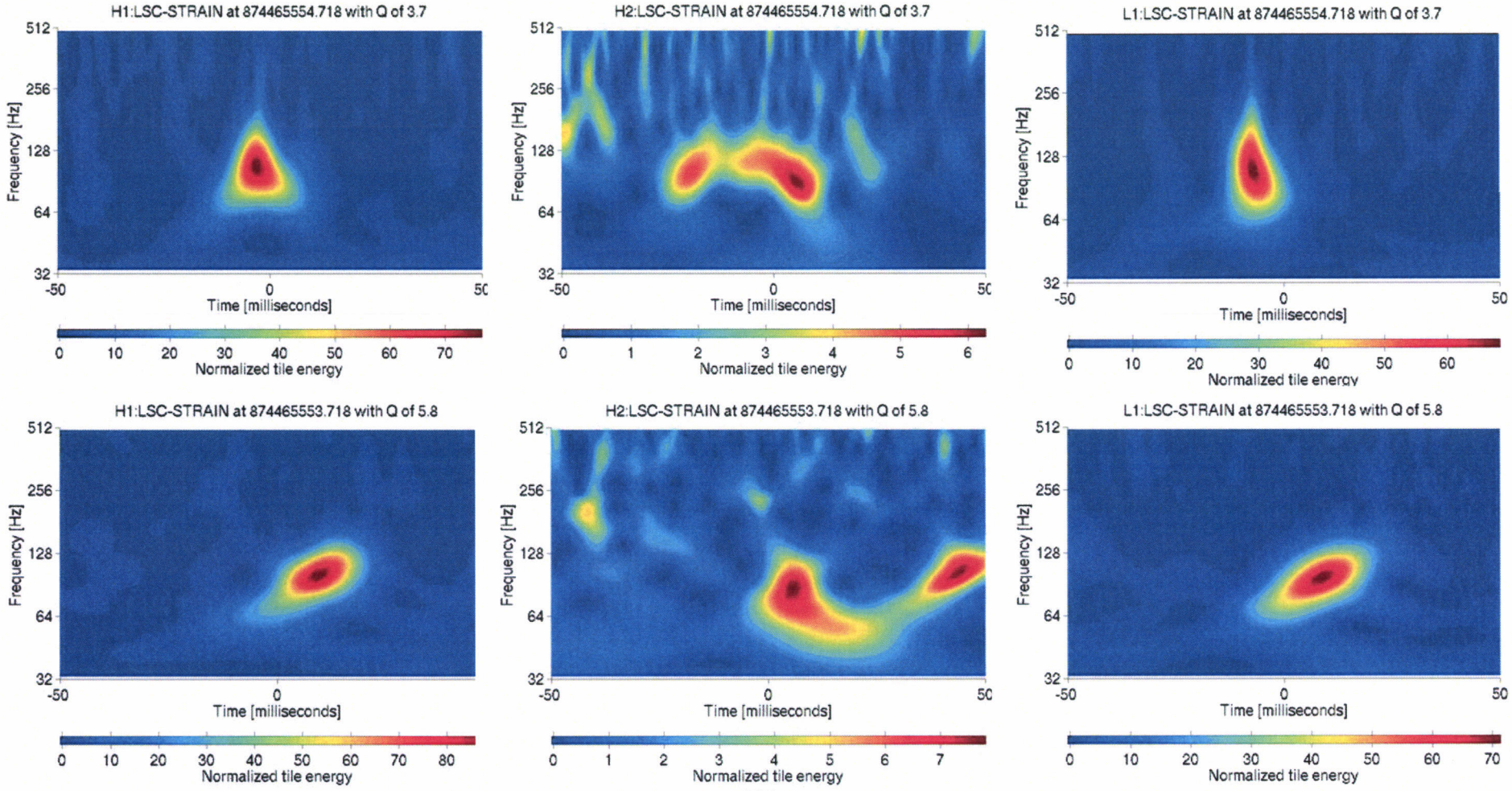


Equal mass, no spin, 70/70 merger



Top: 60-1024 Hz Bottom: 60-140 Hz

Q-scan comparison



Summary

- The obvious
  - The event, at low *f* and *Q*, shares the same morphology as our background
  - 1-2% chance of a stronger event originating from background is marginal given the number of burst searches we do (several)
- The good
  - Looked hard and did not find any evidence of an instrumental cause or glitch
  - Did not happen during noisy times in the run (see cWB rho vs time)
  - The impressive consistency between H1L1 and H1H2 is very unusual
  - Passed a very extensive checklist, probably on deep inspection is a more convincing candidate than our expected background at the same threshold
- The bad
  - If we were unlucky (2% chance) as to get a random background event, it would probably look like this!
  - The excess weak glitchiness of H1 just around the event is disconcerting
- The interesting
  - Match filter analysis using only SG100Q4 during September 2007 data gives a FAR from this very restrictive parameter space of 1/300 years (Preliminary)
  - The frequency seems to decrease after the peak signal
  - Many interesting sources intersecting sky ring
- Conclusion
  - This event is very interesting, but does not qualify as a gold-plated detection. A claim that the event is a gravitational wave ***is not*** beyond reasonable doubt.

links

- Detection checklist and document:
  - http://www.gravity.phys.uwm.edu/cgi-bin/pcvs/viewcvs.cgi/bursts/projects/detection/
- Q-scans (GW, RDS, RAW):
  - http://ldas-jobs.ligo.caltech.edu/~qonline/qscans/874465554.680700000/
  - http://ldas-jobs.ligo.caltech.edu/~qonline/qscans/874465554.680700001/
  - http://ldas-jobs.ligo.caltech.edu/~qonline/qscans/874465554.718000000/
- Coherent Event Display (LIGO, LIGO/Virgo)
  - http://ldas-jobs.ligo.caltech.edu/~ram/ced/874465554a
  - http://ldas-jobs.ligo.caltech.edu/~ram/ced/874465554-LV
- Astrophysical sources
  - http://lancelot.mit.edu/~lindy/s5/catalog/summary.html
- Q Event Display
  - http://ldas-jobs.ligo.caltech.edu/~shourov/GWB070922/qevents_H1H2/874465554.718/
- Q Online
  - http://ldas-jobs.ligo-wa.caltech.edu/~qonline/H1/index.html?2007/09/22/03/
  - http://ldas-jobs.ligo-wa.caltech.edu/~qonline/H2/index.html?2007/09/22/03/
  - http://ldas-jobs.ligo-la.caltech.edu/~qonline/L1/index.html?2007/09/22/03/
- Audio analysis
  - http://phy.syr.edu/research/relativity/ligo/restricted/mciver/Newandimprovedlowpass.html