Progress Report: Noise Storms and Beam Splitter Oscillations

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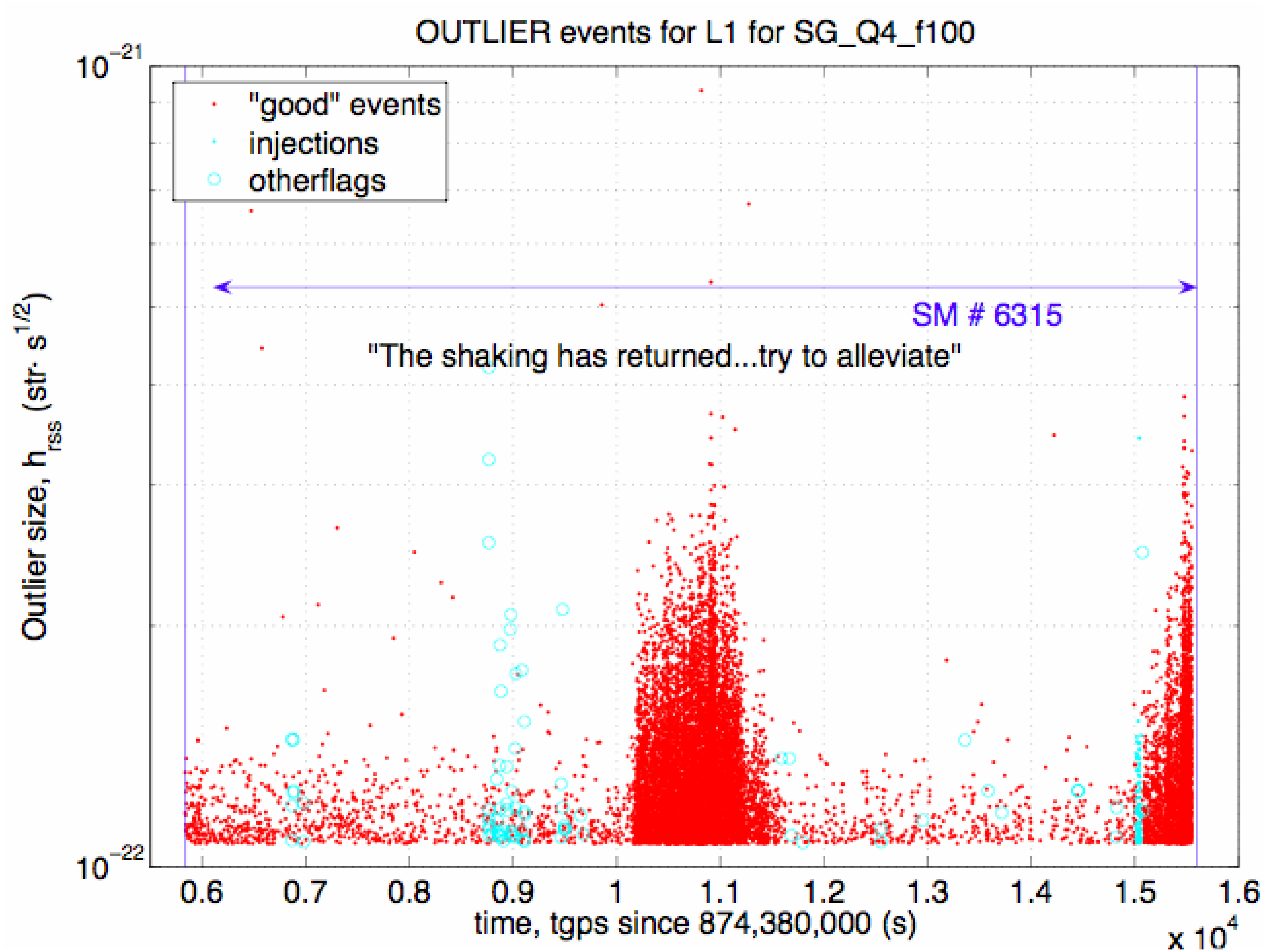
- Operators at L1 noticed a problem near autumnal equinox 2007. After a few days, Valery Frolov fixed it.
- Problem, as understood at the time: “gain peaking” oscillations in BS OPTLEV pitch servo, at 3.6 Hz.
- Gabi noticed large variance in SensMon range at those times; suggested vetos for those times.
- Myungkee’s SG-CG filter bank showed “noise storms” at those times.
- Cristina has preliminary evidence that this problem has came and gone throughout S5 run.

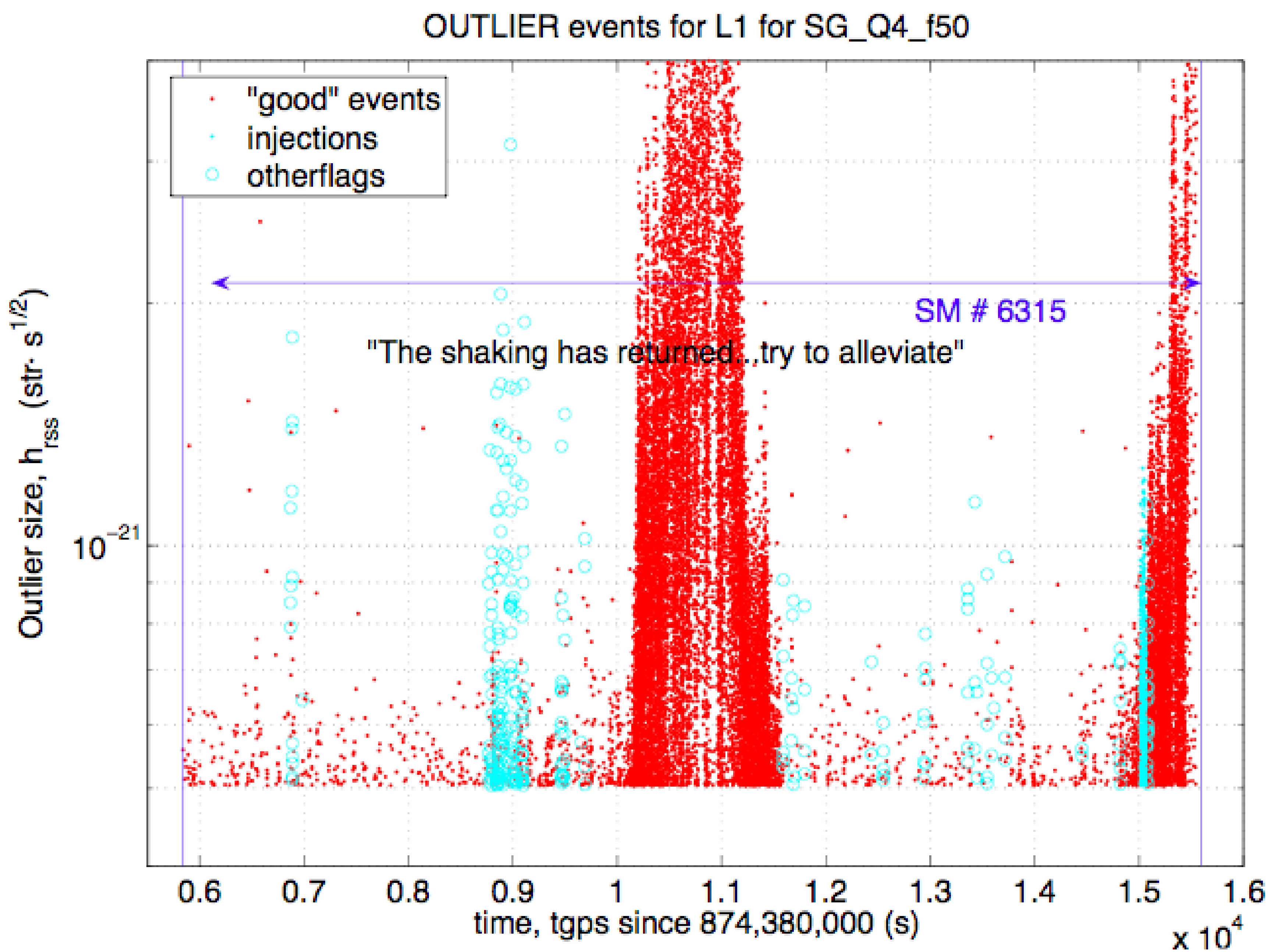
Follow-up, or detailed look, at the phenomena:

- Start with “noise storms”
  - Optimal Filter protopipeline uses a template bank of sine-gaussians and cosine-gaussians, classified by center frequency f ($50<f<150$ Hz), and fractional inverse bandwidth Q (2.5, 4, 6.3, 10).
  - it produces *event lists* for each interferometer, or times when a filtered data stream is above a threshold.

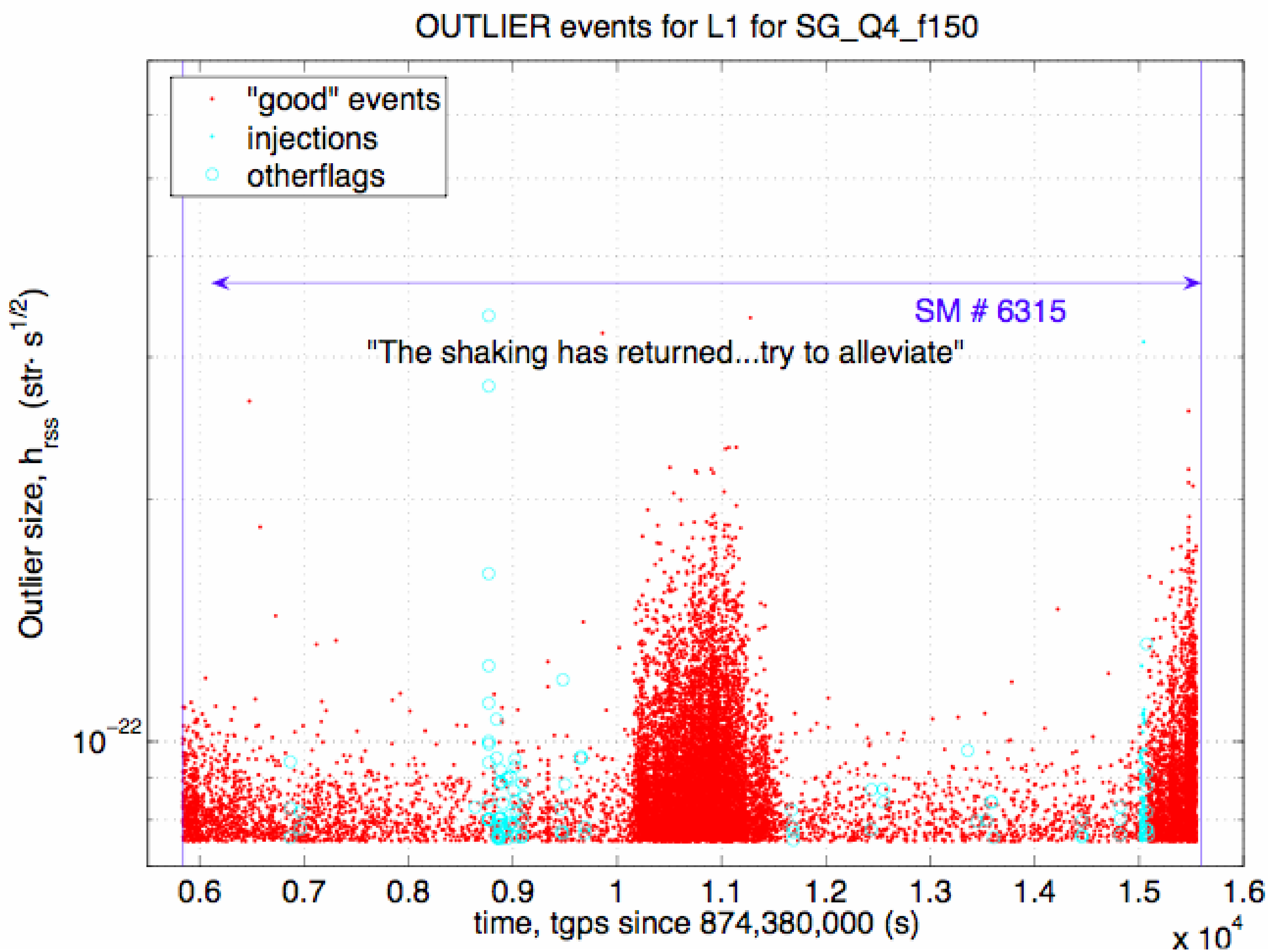
- We call an event that is over-threshold event is an *outlier*, characterized by
  - The “shape” of the template, (e.g. SG_Q4_f100)
  - the strength of the event’s component in that shape, in h_{rss}, or units of strain.sec$^{1/2}$
  - the arrival time (time at max of filtered strain)
    - And also record start and end times
- History-plot shows strength of outlier vs arrival time.
- Summary: An outlier is a single detector burst-like event,
  - or (?) “single detector trigger” or “glitch in gw channel”

- 20 minutes of history, with two noise storms, or all of SM # 6315 at L1.
- 3 views of same time interval, using 3 different filters


OUTLIER events for L1 for SG_Q4_f100
"good" events
injections
otherflags
SM # 6315
"The shaking has returned...try to alleviate"
Outlier size, h_{rss} (str· $s^{1/2}$)
10^{-21}
10^{-22}
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
time, tgps since 874,380,000 (s)
x 10^4

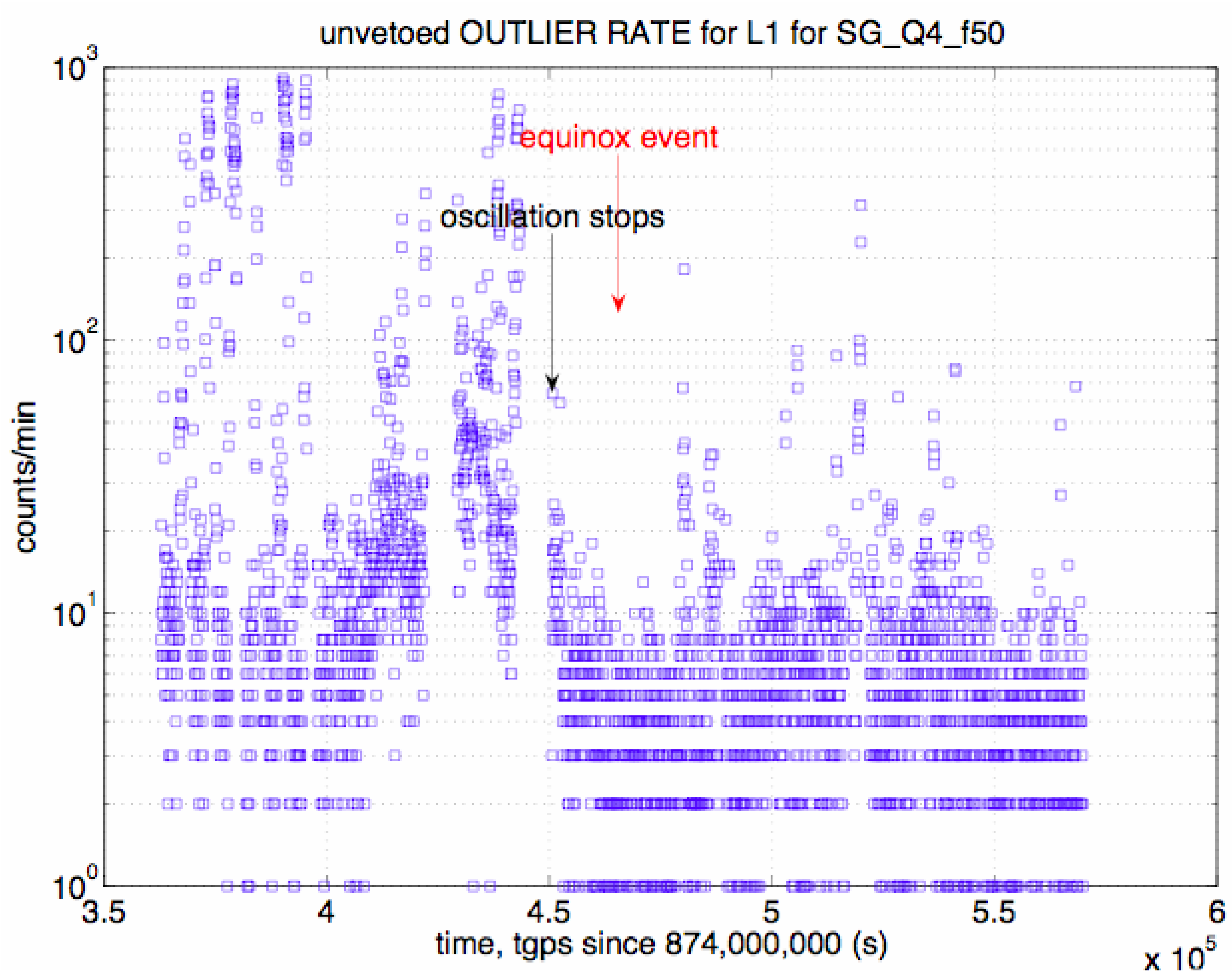


OUTLIER events for L1 for SG_Q4_f50
"good" events
injections
otherflags
SM # 6315
"The shaking has returned...try to alleviate"
Outlier size, h_{rss} (str· $s^{1/2}$)
10^{-21}
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
time, tgps since 874,380,000 (s)
x 10^4



OUTLIER events for L1 for SG_Q4_f150
"good" events
injections
otherflags
SM # 6315
"The shaking has returned...try to alleviate"
Outlier size, h_{rss} (str· $s^{1/2}$)
10^{-22}
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
time, tgps since 874,380,000 (s)
x 10^4

- Now, look at rate of outliers in one filter for a two day period.



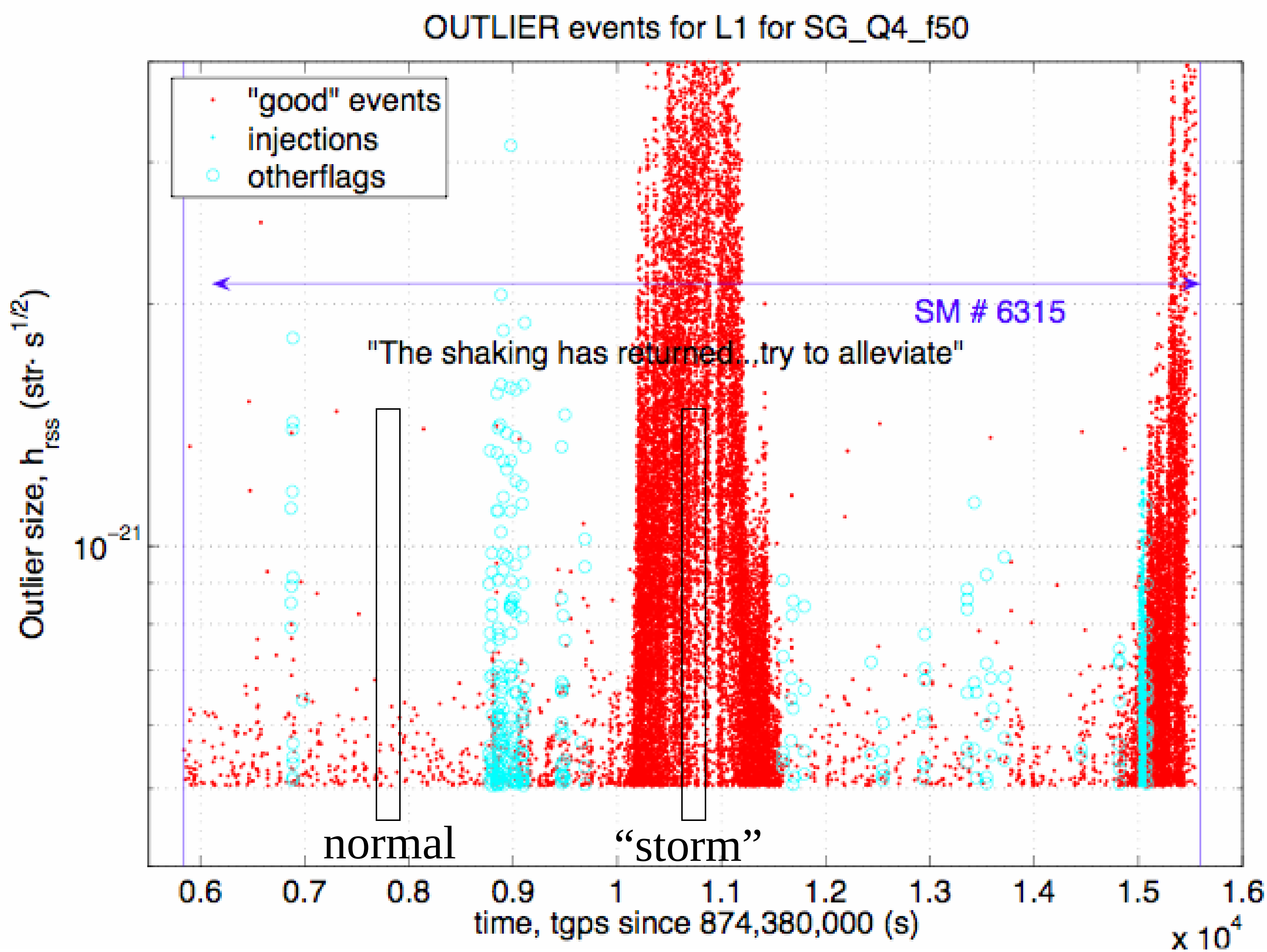
unvetoed OUTLIER RATE for L1 for SG_Q4_f50
equinox event
oscillation stops
counts/min
10^0
10^1
10^2
10^3
3.5
4
4.5
5
5.5
6
time, tgps since 874,000,000 (s)
x 10^5

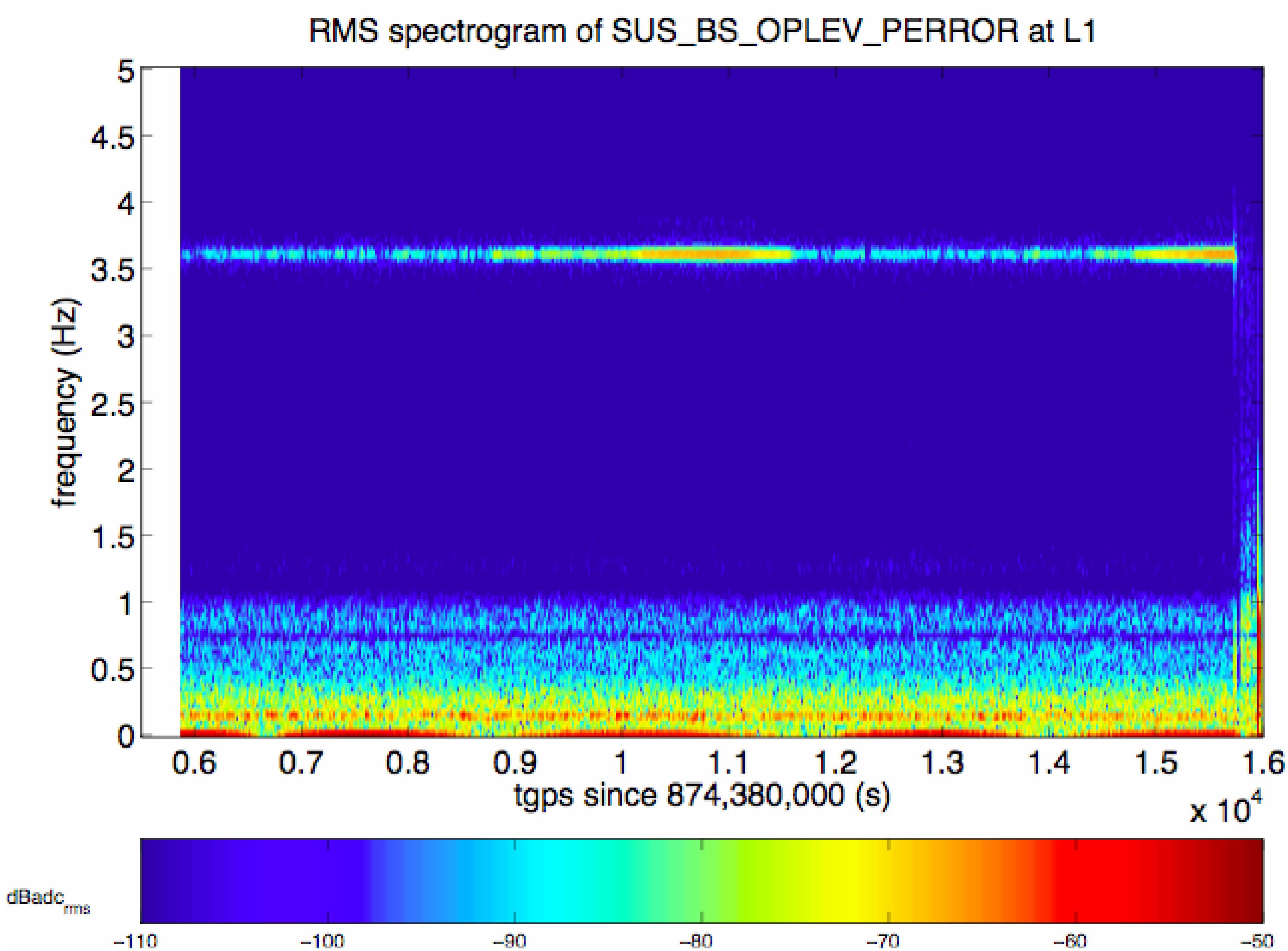
Observations

- *Rate* and *strength* of outliers went way up during a “storm”.
- This *appears* to be a storm of *bursts*, not a rise in continuous noise.
- these outliers have mostly low-frequency content.
  - accounts for large reduction in SensMon range
- Are BS oscillations really the cause?

Flip Test

- Compare Outlier History plot (next page)
- To Spectrogram covering same time (page following).

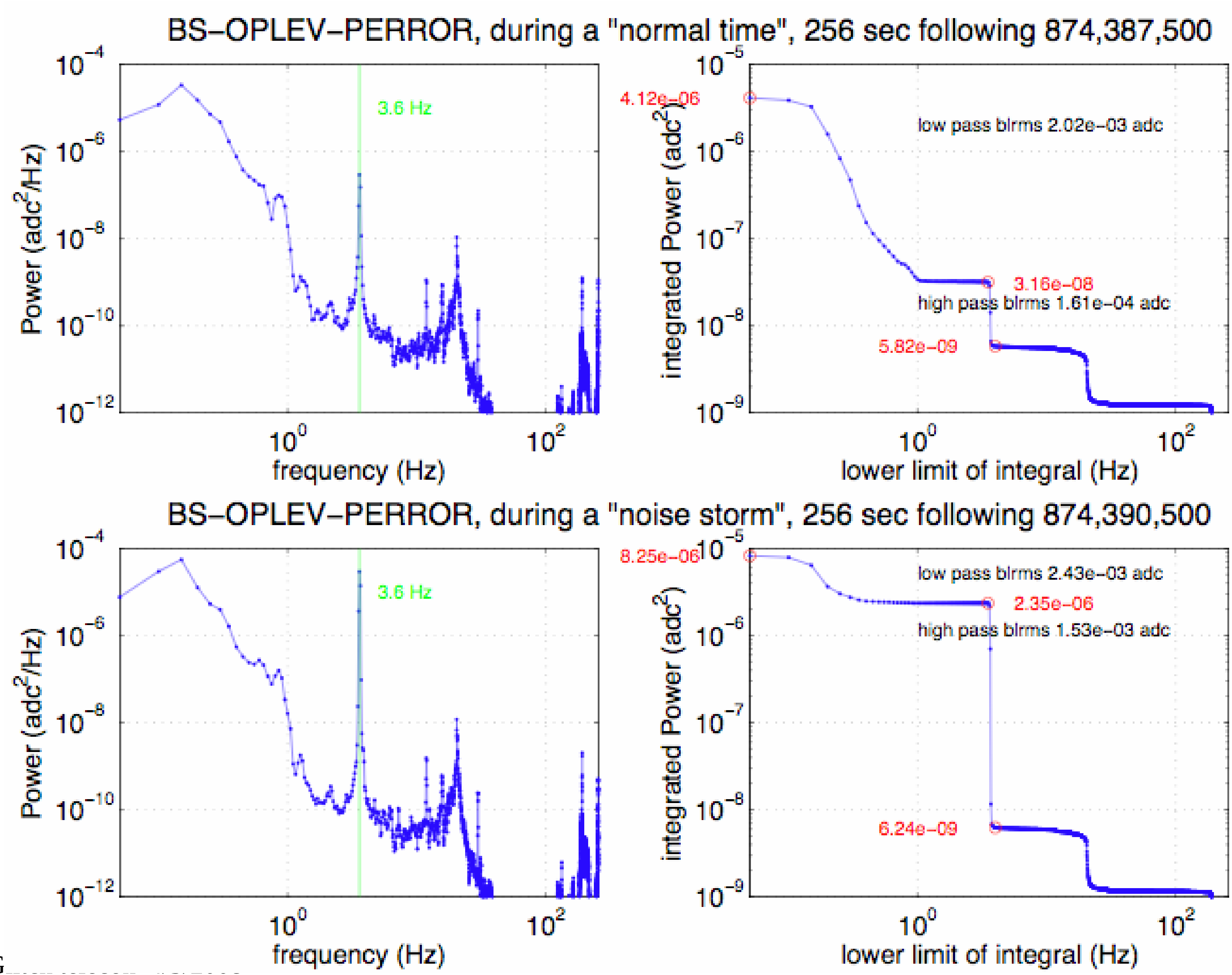

OUTLIER events for L1 for SG_Q4_f50
"good" events
injections
otherflags
SM # 6315
"The shaking has returned..,try to alleviate"
normal
“storm”
Outlier size, h_{rss} (str· $s^{1/2}$)
10^{-21}
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
time, tgps since 874,380,000 (s)
x 10^4

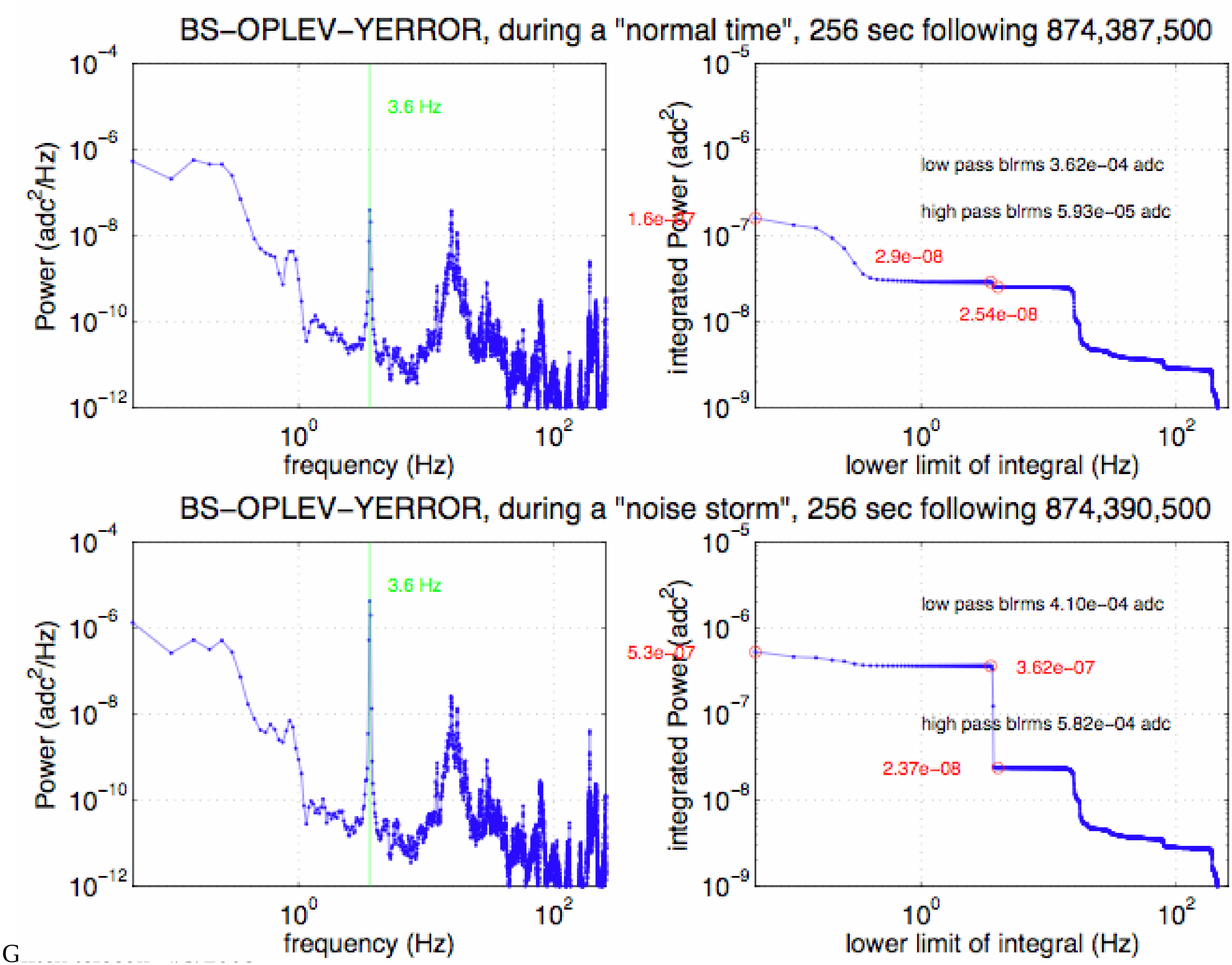


RMS spectrogram of SUS_BS_OPLEV_PERROR at L1
frequency (Hz)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
tgps since 874,380,000 (s)
x 10^4
dBadc_rms
−110
−100
−90
−80
−70
−60
−50

Next, look closer at spectrum of BS_OPTLEV_PERROR during this same time interval

- Compare the “normal” spectrum (top row) (when lowfreq burst rate low)
  - Starts at 874,387,500
- to the “noise-storm” spectrum (bottom row) (when burst rate is high).
  - Starts at 874,390,500


BS–OPLEV–PERROR, during a "normal time", 256 sec following 874,387,500
Power (adc²/Hz)
frequency (Hz)
3.6 Hz
integrated Power (adc²)
lower limit of integral (Hz)
4.12e−06
low pass blrms 2.02e−03 adc
3.16e−08
high pass blrms 1.61e−04 adc
5.82e−09
BS–OPLEV–PERROR, during a "noise storm", 256 sec following 874,390,500
Power (adc²/Hz)
frequency (Hz)
3.6 Hz
integrated Power (adc²)
lower limit of integral (Hz)
8.25e−06
low pass blrms 2.43e−03 adc
2.35e−06
high pass blrms 1.53e−03 adc
6.24e−09


BS–OPLEV–YERROR, during a "normal time", 256 sec following 874,387,500
Power (adc²/Hz)
3.6 Hz
frequency (Hz)
integrated Power (adc²)
low pass blrms 3.62e–04 adc
high pass blrms 5.93e–05 adc
1.6e–07
2.9e–08
2.54e–08
lower limit of integral (Hz)
BS–OPLEV–YERROR, during a "noise storm", 256 sec following 874,390,500
Power (adc²/Hz)
3.6 Hz
frequency (Hz)
integrated Power (adc²)
low pass blrms 4.10e–04 adc
high pass blrms 5.82e–04 adc
5.3e–07
3.62e–07
2.37e–08
lower limit of integral (Hz)

(Mean was subtracted before fft)

The AC power can be compared in two bands:

Low-Frequency (~.05 - 3.5 Hz)

High-Frequency (3.5 - 4.0 Hz)

by reading the integrated power at the band boundaries (red text on graph), subtracting, and then taking root to find the blrms (black text on graph):

$$\sqrt{\int_{f_1}^{\infty} P_x(f)df - \int_{f_2}^{\infty} P_x(f)df} = \sqrt{\int_{f_1}^{f_2} P_x(f)df} = \sqrt{\overline{x^2}|_{f_1}^{f_2}}$$

Observations
compare "normal" to "storm"

- small change in seismic < 1 Hz

  2.0×10^{-3} ---> 2.4×10^{-3} adc_{rms}
- large change in the peak at 3.6 Hz

  0.16×10^{-3} ---> 1.5×10^{-3} adc_{rms}
- moderate change in the total rms

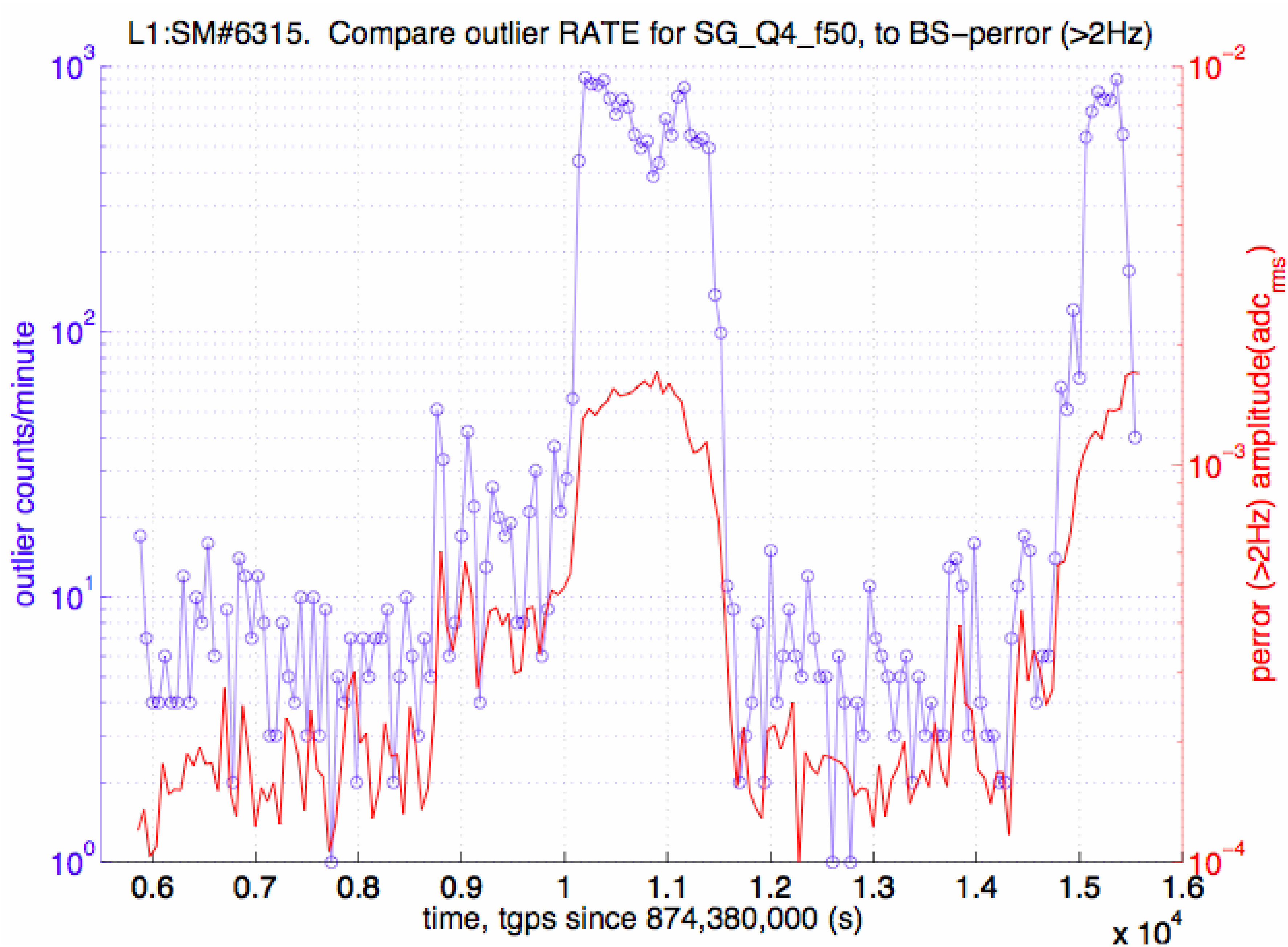
  2.0×10^{-3} ---> 2.9×10^{-3} adc_{rms}
- Yerror always ~ 3 times smaller than Perror

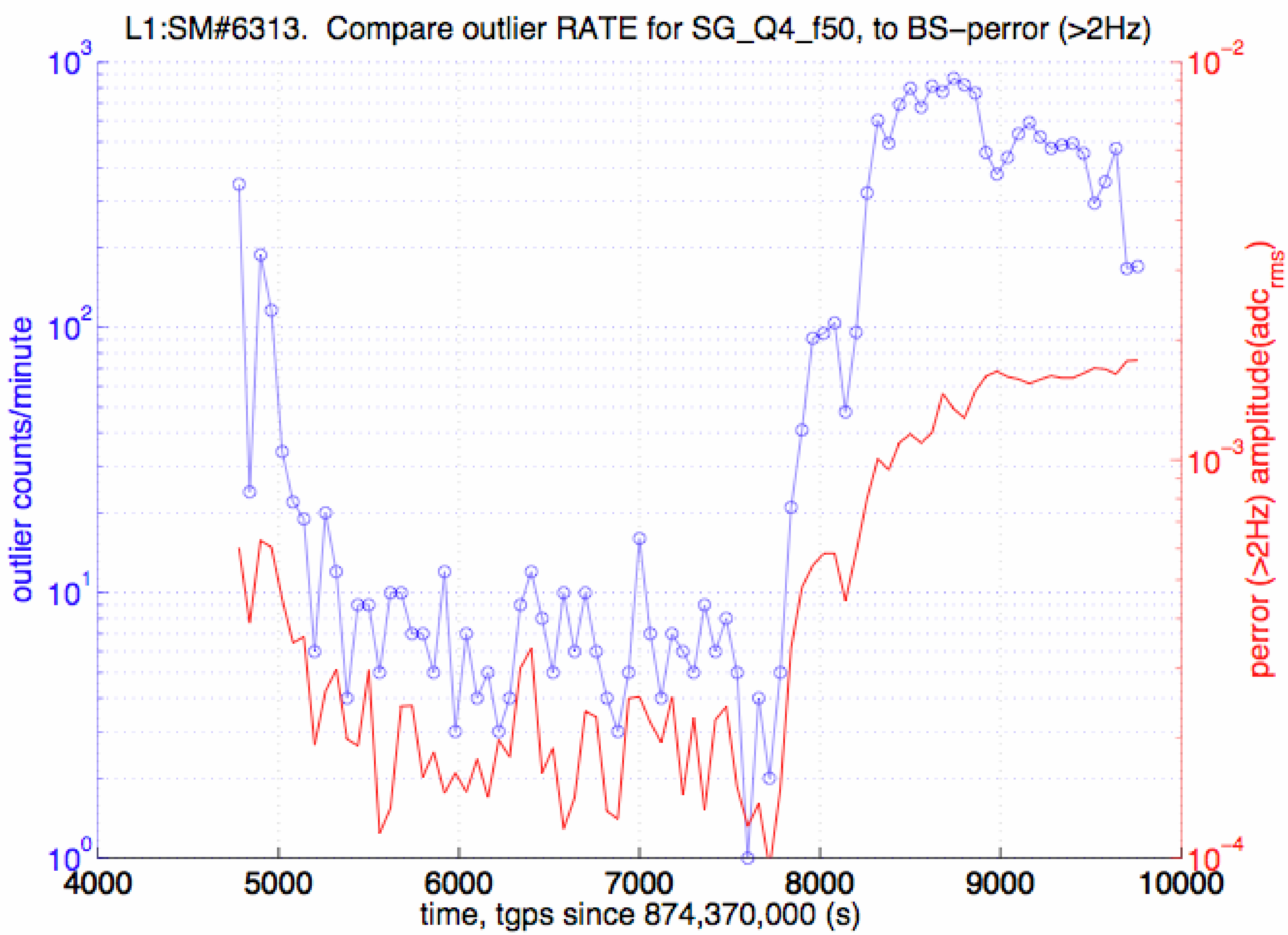
Next: compare

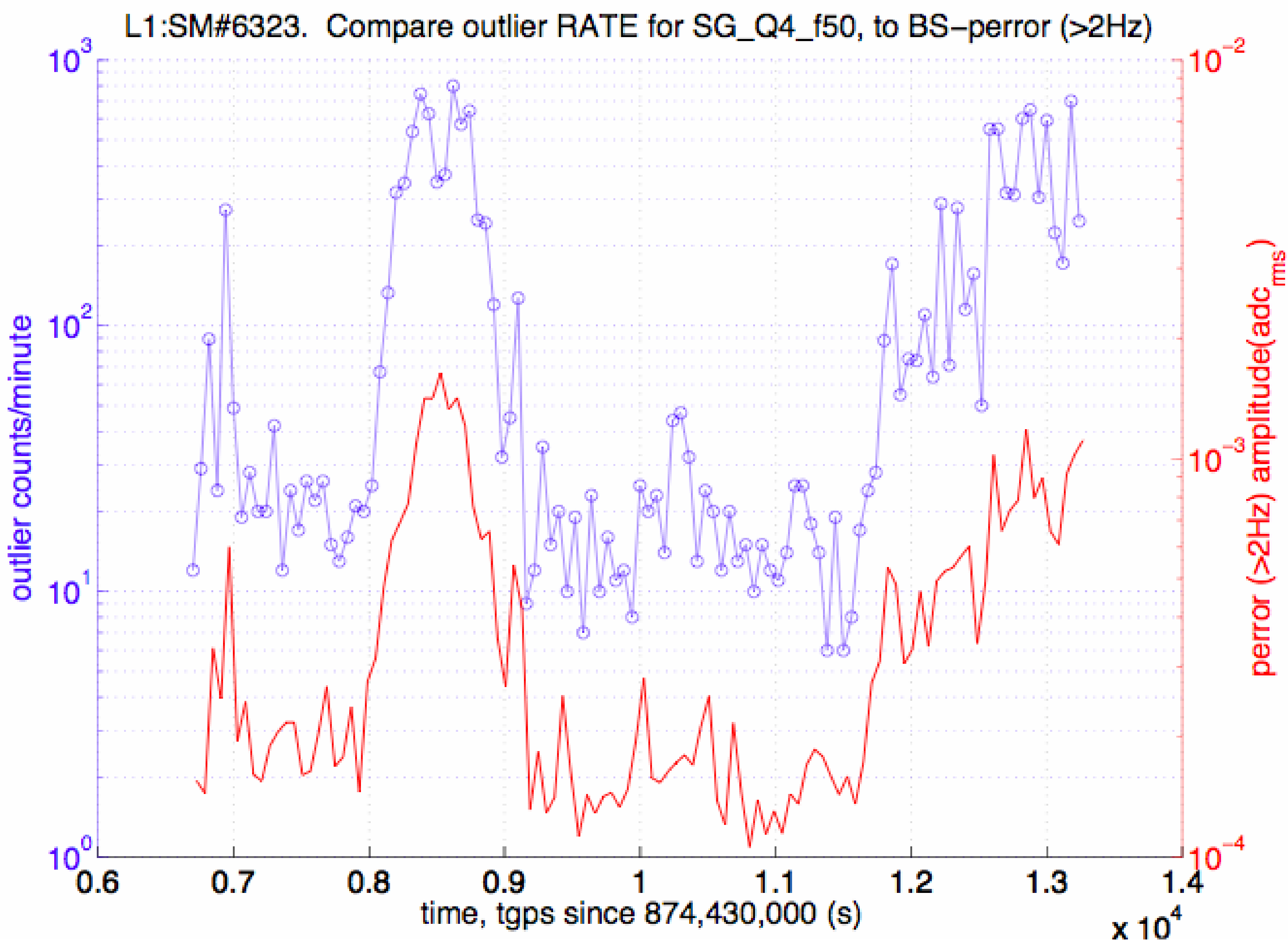
outlier rate vs time (left axis and blue trace)

to

perror peak vs time (right axis and red trace)


L1:SM#6315. Compare outlier RATE for SG_Q4_f50, to BS−perror (>2Hz)
outlier counts/minute
perror (>2Hz) amplitude(adc_rms)
time, tgps since 874,380,000 (s)
x 10^4
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
10^0
10^1
10^2
10^3
10^−4
10^−3
10^−2


L1:SM#6313. Compare outlier RATE for SG_Q4_f50, to BS−perror (>2Hz)
outlier counts/minute
10^3
10^2
10^1
10^0
perror (>2Hz) amplitude(adc_rms)
10^−2
10^−3
10^−4
4000
5000
6000
7000
8000
9000
10000
time, tgps since 874,370,000 (s)


L1:SM#6323. Compare outlier RATE for SG_Q4_f50, to BS−perror (>2Hz)
outlier counts/minute
perror (>2Hz) amplitude(adc_rms)
10^3
10^2
10^1
10^0
10^−2
10^−3
10^−4
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
time, tgps since 874,430,000 (s)
x 10^4

Tentative Conclusions

- Monotonic correlation of oscillation amplitude and burst rate suggests cause and effect relation.
- This implies quasi-steady 3.6 Hz oscillations in the BS servo cause ~50 Hz bursts.
- Notice that a popular veto search would fail here. (kleinewelle triggers (burst events) are apparently not happening in BS_OPLEV)
- Hints that this problem existed earlier in S5 run.

Next ?

- Survey some fraction of S5, to find other episodes?
- What happens at higher frequency?
- Explore possible mechanisms, and look for evidence pro and con. [“RF Saturation”, “Barkhausen upconversion”]
- Does vetoing these intervals change the background for burst searches? Especially near equinox time?
- Look at other noise “storms”, searching for new noise mechanisms (and vetos)?