

**EtaGen** (an ETG based on HHT)

Triggers in **iKAGRA** data

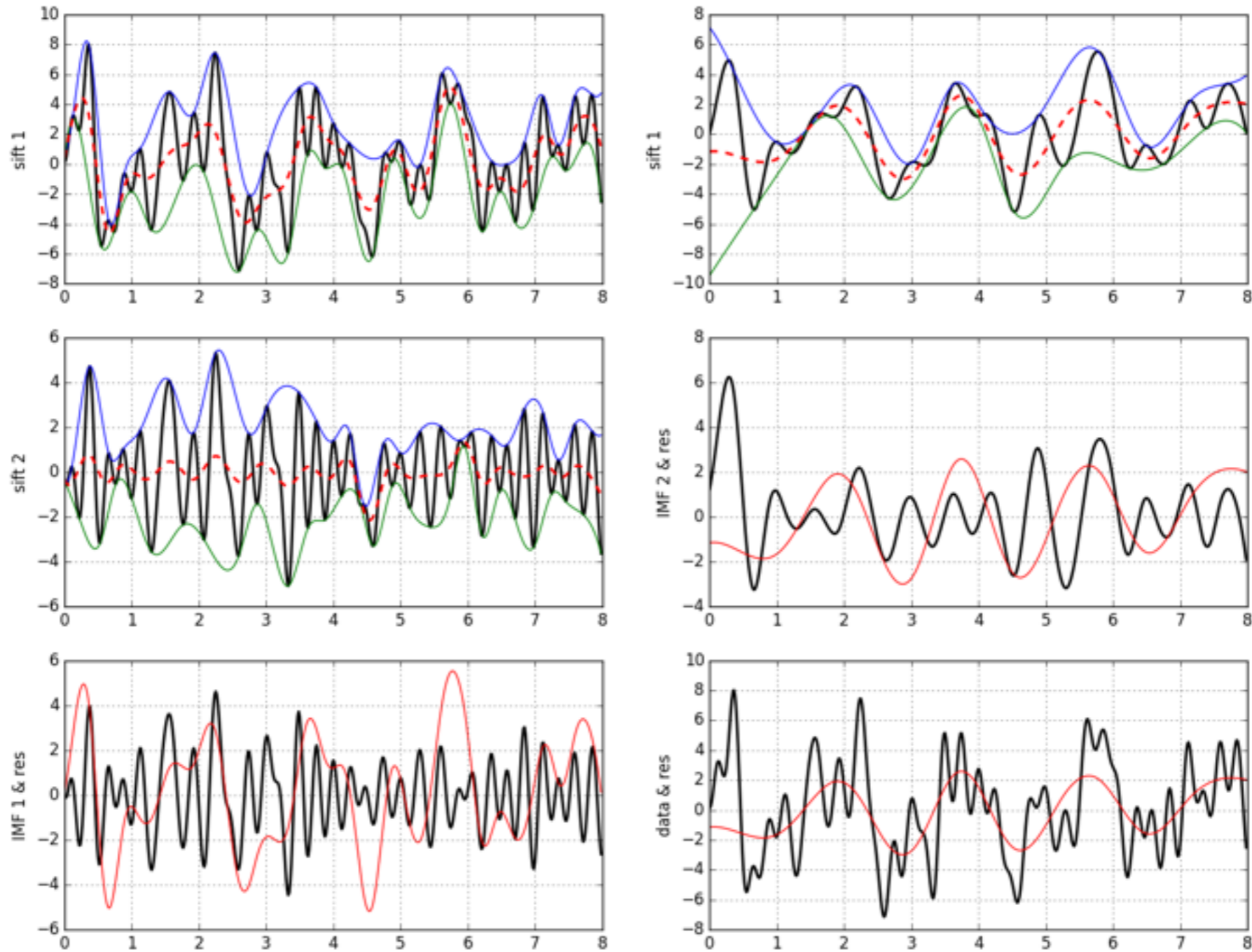
Edwin J. Son (NIMS)  
on behalf of KGWG-DetChar

# Hilbert–Huang Transform

- **HHT** is composed of the **Empirical Mode Decomposition (EMD)** and the **Hilbert Spectral Analysis (HSA)**.
- The **EMD** decomposes the given time-series data into adaptive basis modes, and the **HSA** finds the instantaneous amplitude and frequency of each mode.
- In mathematics and in signal processing, **the Hilbert transform** is **a linear operator** which takes a function,  $u(t)$ , and produces a function,  $\mathcal{H}[u](t)$ , with the same domain. [[wikipedia.org](http://wikipedia.org)]

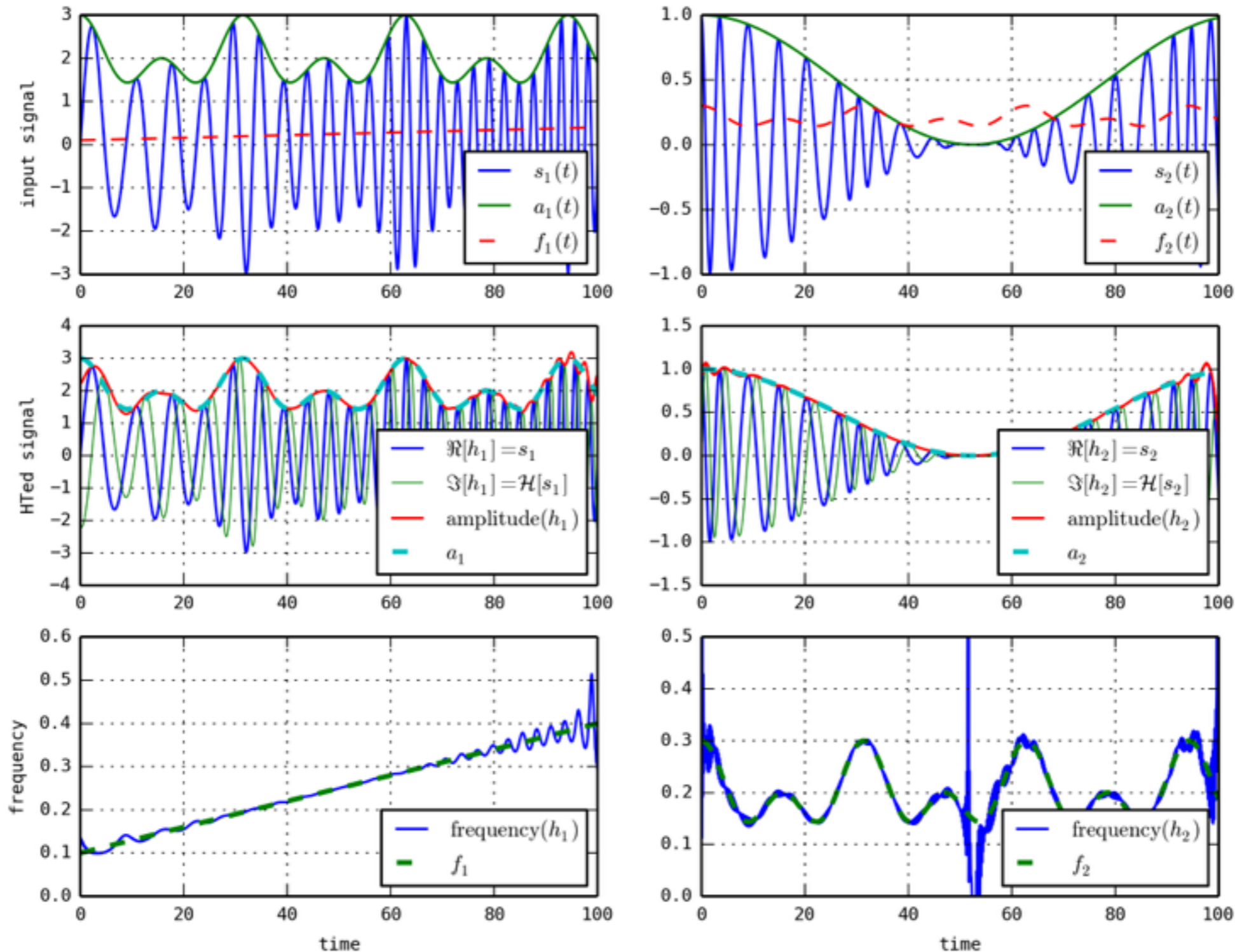
$$\mathcal{H}[u](t) = \frac{1}{\pi} \mathcal{P} \int_{-\infty}^{\infty} \frac{u(\tau)}{t - \tau} d\tau$$

# Empirical Mode Decomposition (EMD)

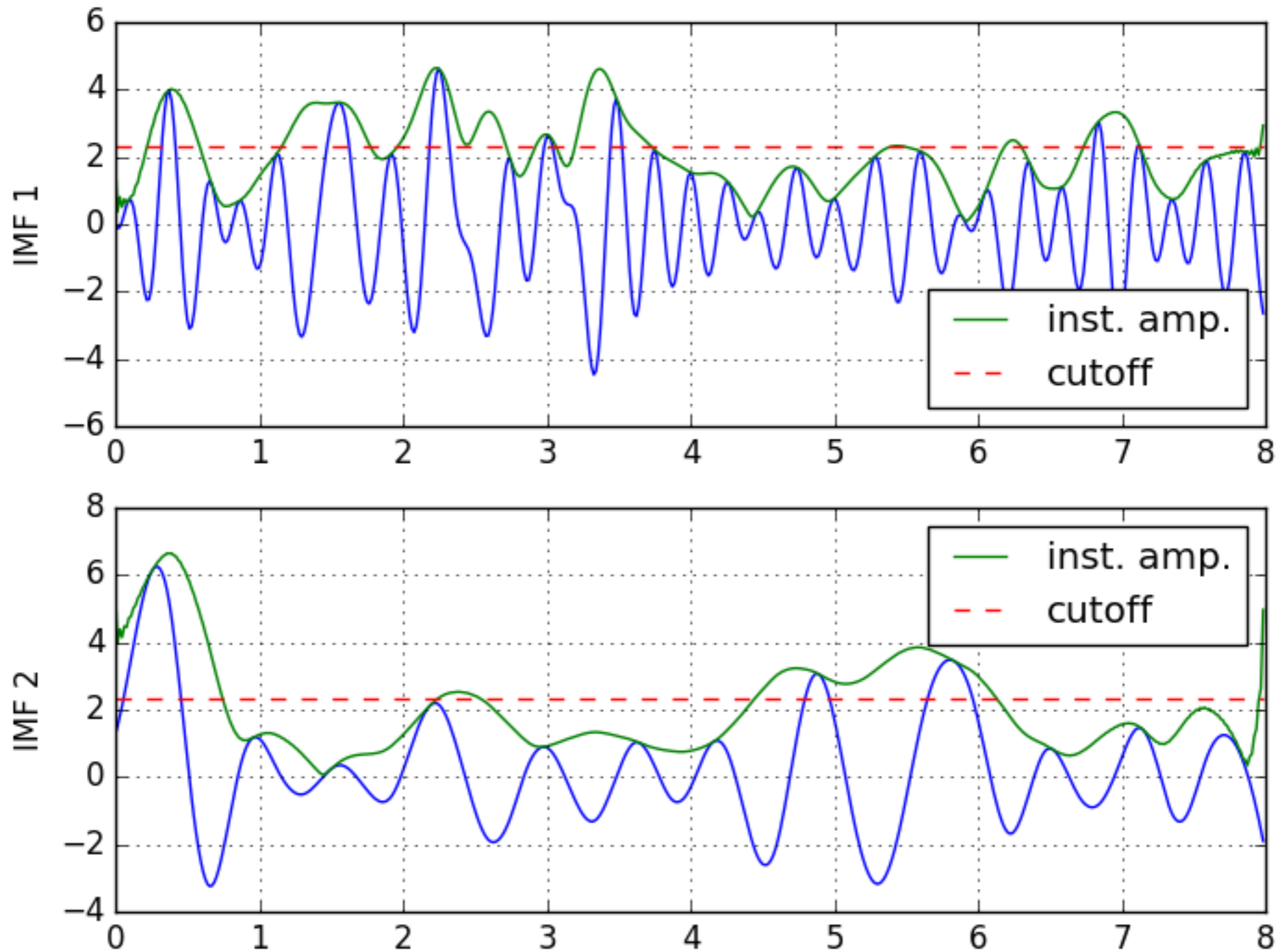


# Hilbert transform examples

$$s(t) = a(t)\sin\theta(t), \theta(t) = 2\pi \int_0^t f(\tau) d\tau$$

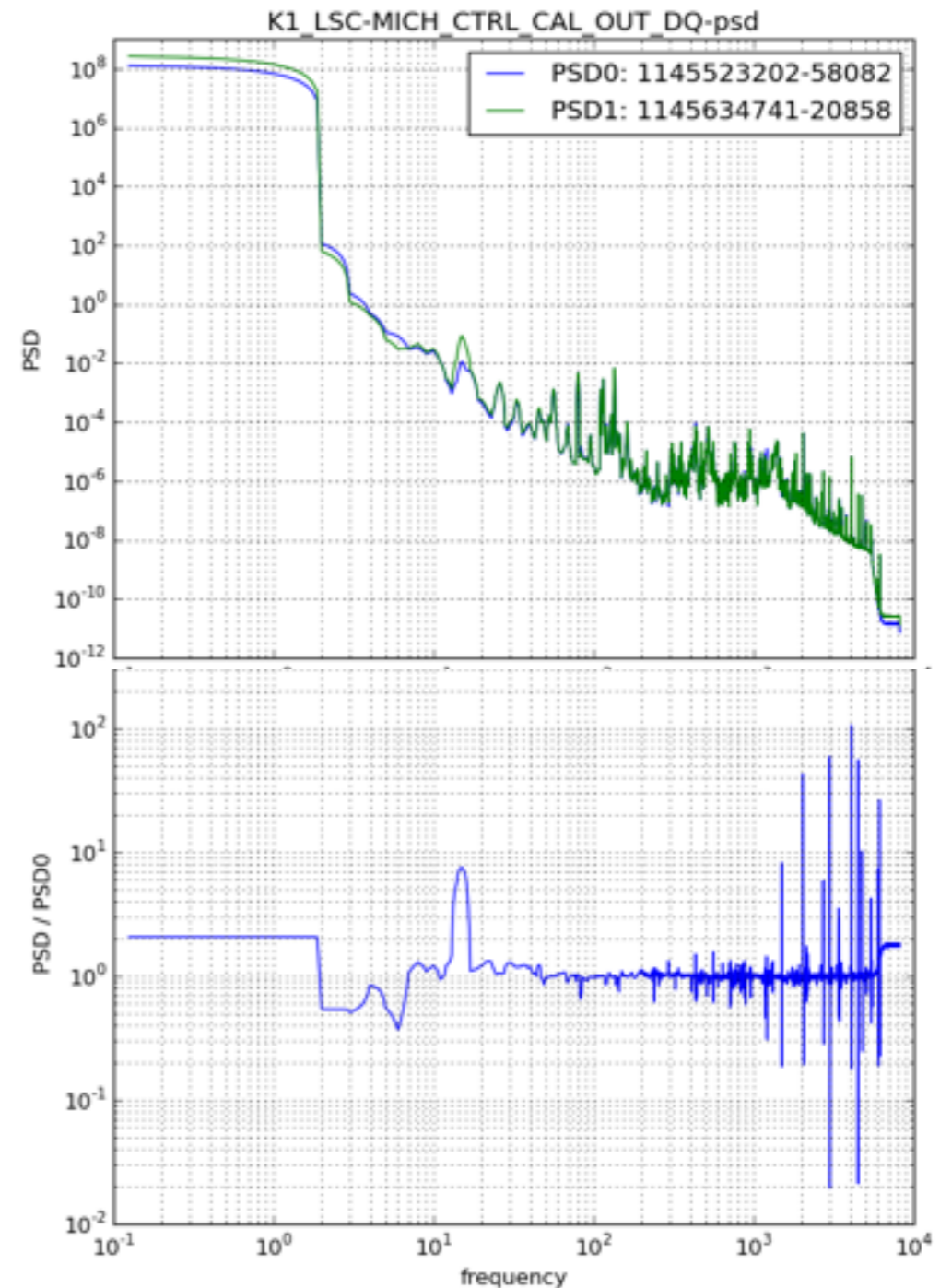


# Trigger Generation

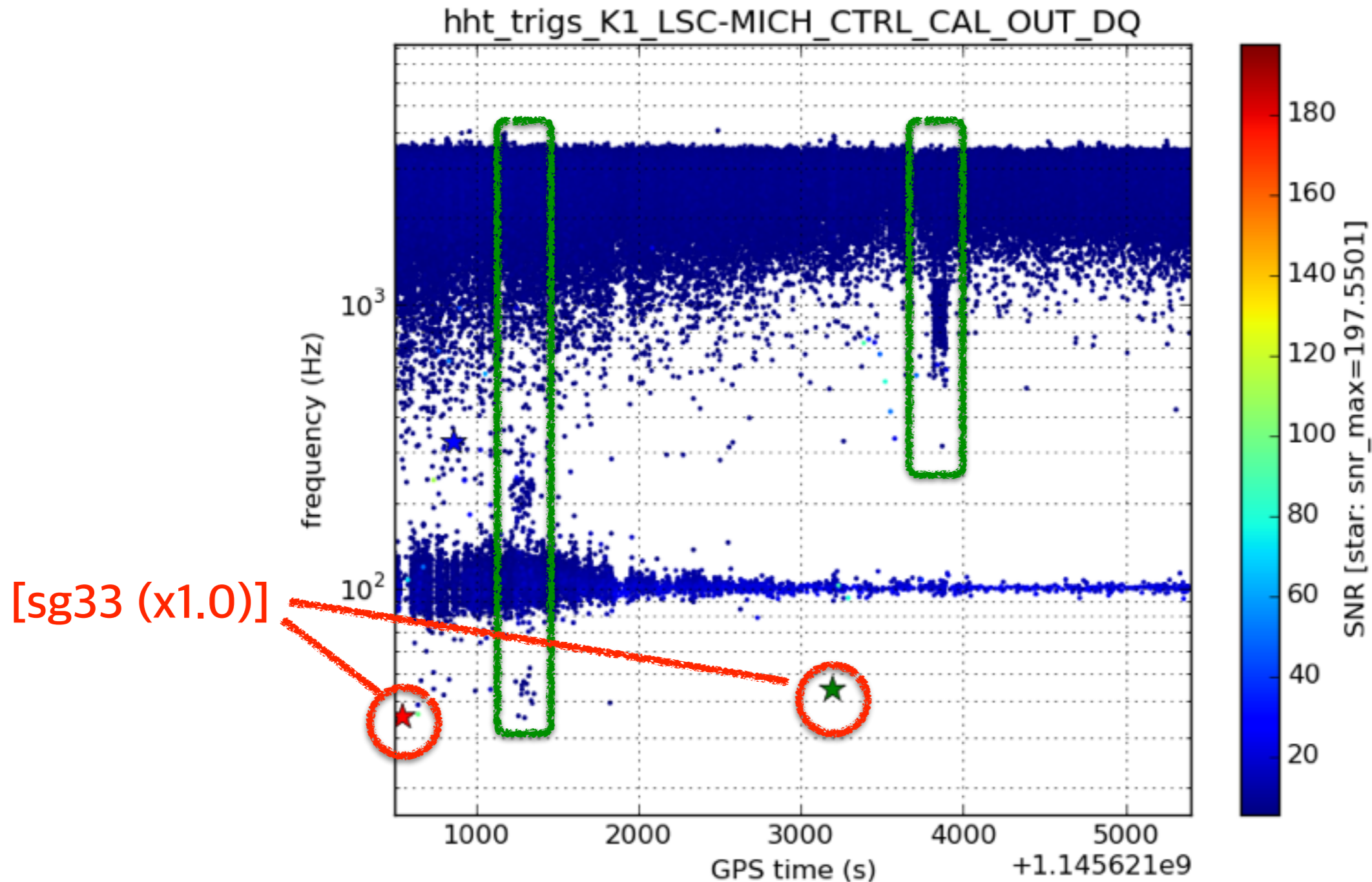


# EtaGen triggers of iKAGRA data

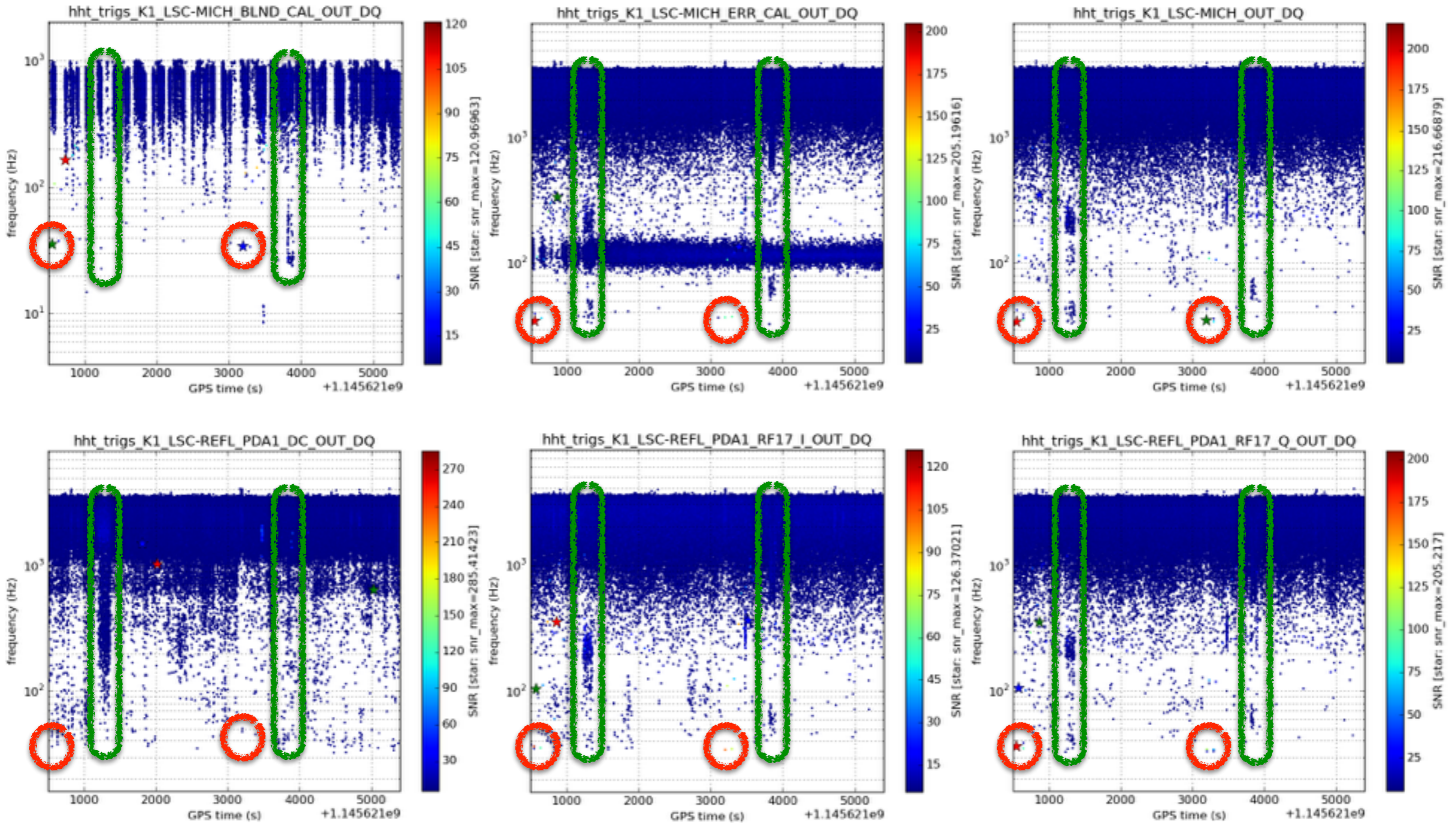
- We select data segments containing H/W injections:
  - 1145621500 - 1145626400
  - 1145665600 - 1145671040
- PSD used for whitening is extracted from data during
  - 1145523202 - 1145581284
  - 1145634741 - 1145655599
- A LIGO tool is used for clustering



EtaGen triggers of h(t) channel for GPS time  
1145621500 - 1145626400  
(Red, green and blue stars shows top 3 SNR)

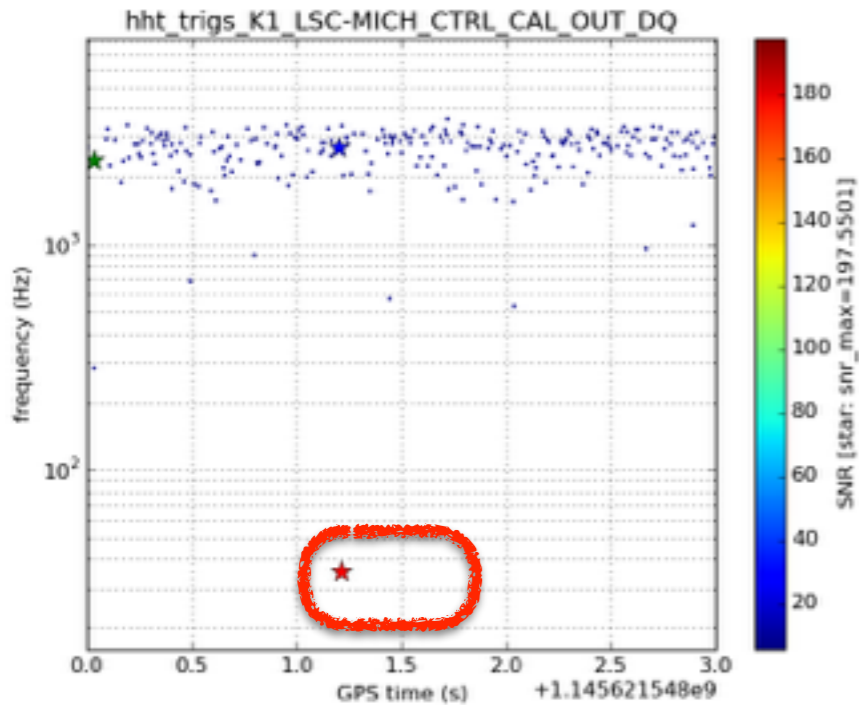


# Unsafe Channels?

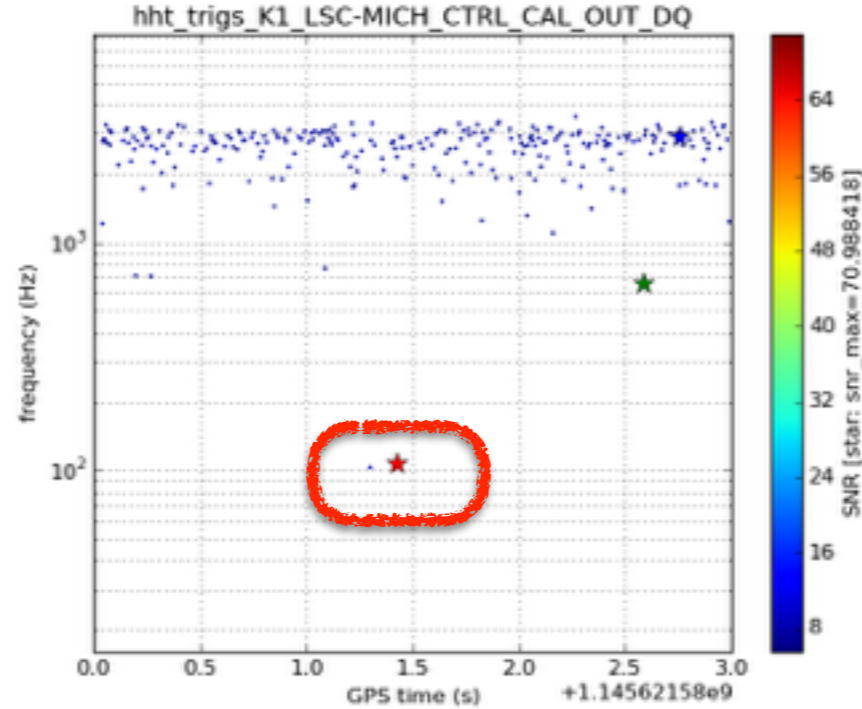




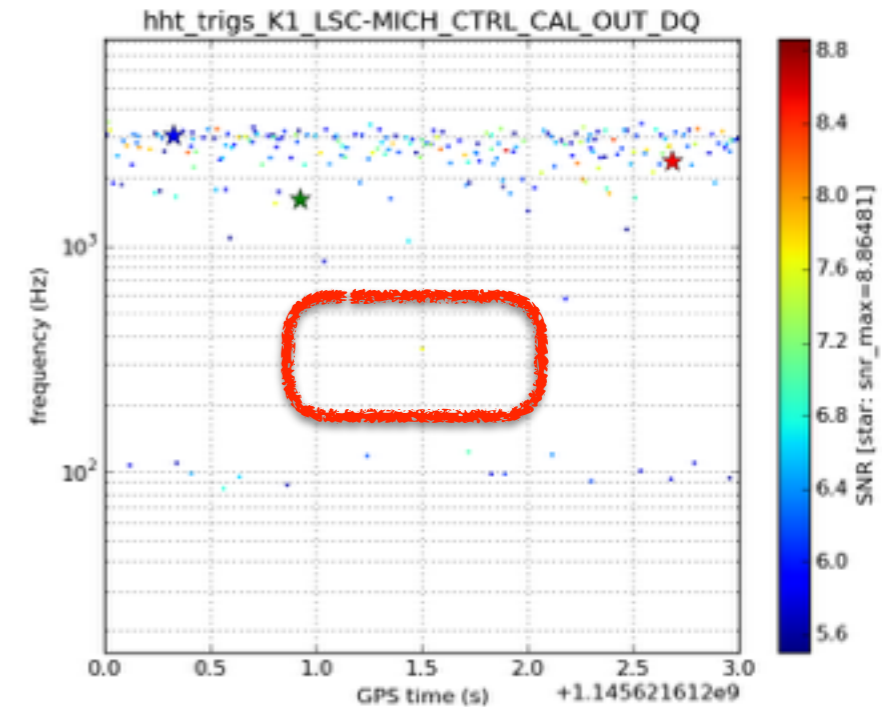
[sg33 (x1.0)]



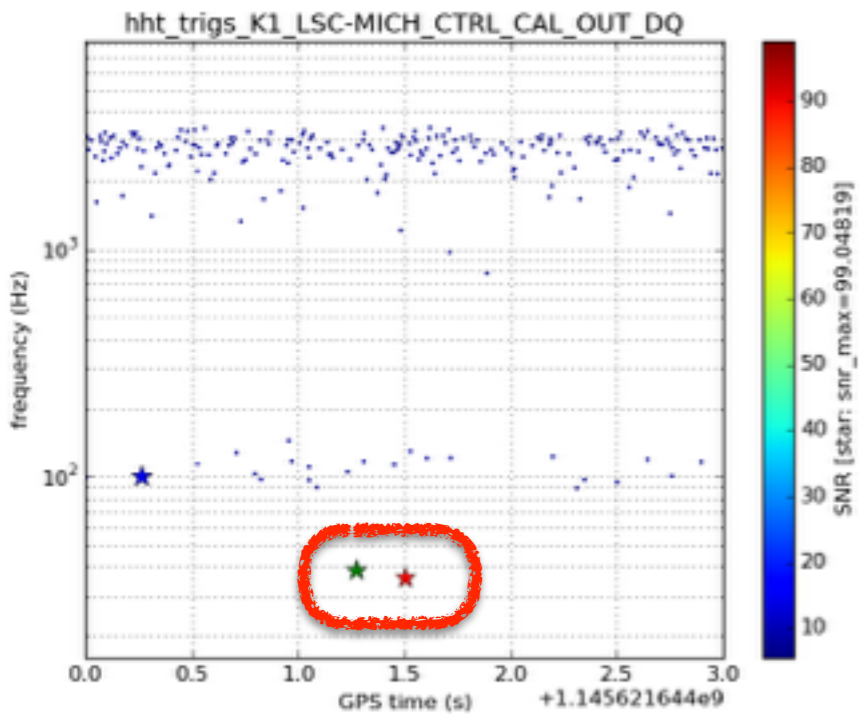
[sg100 (x1.0)]



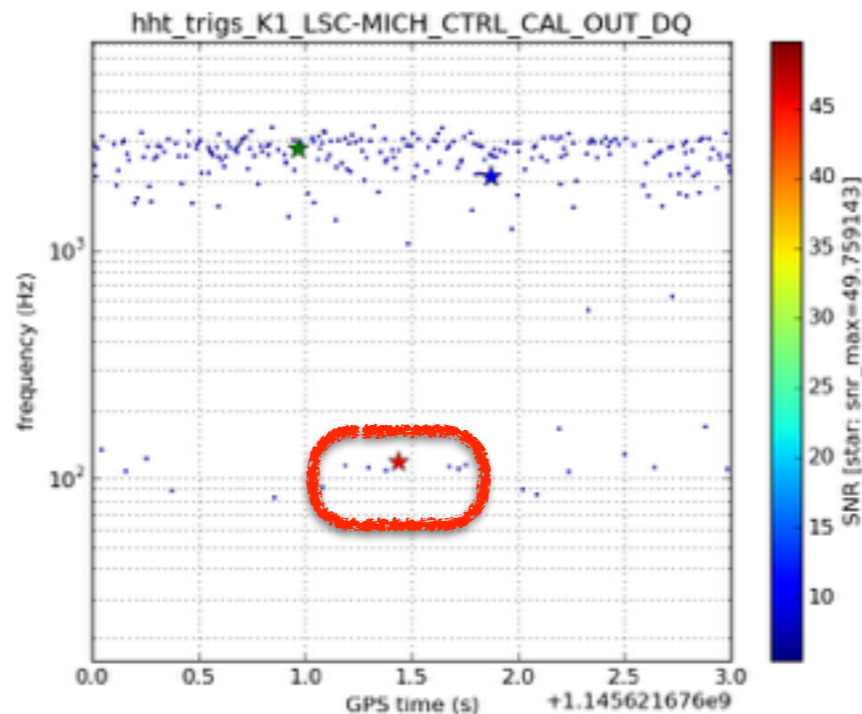
[sg333 (x1.0)]



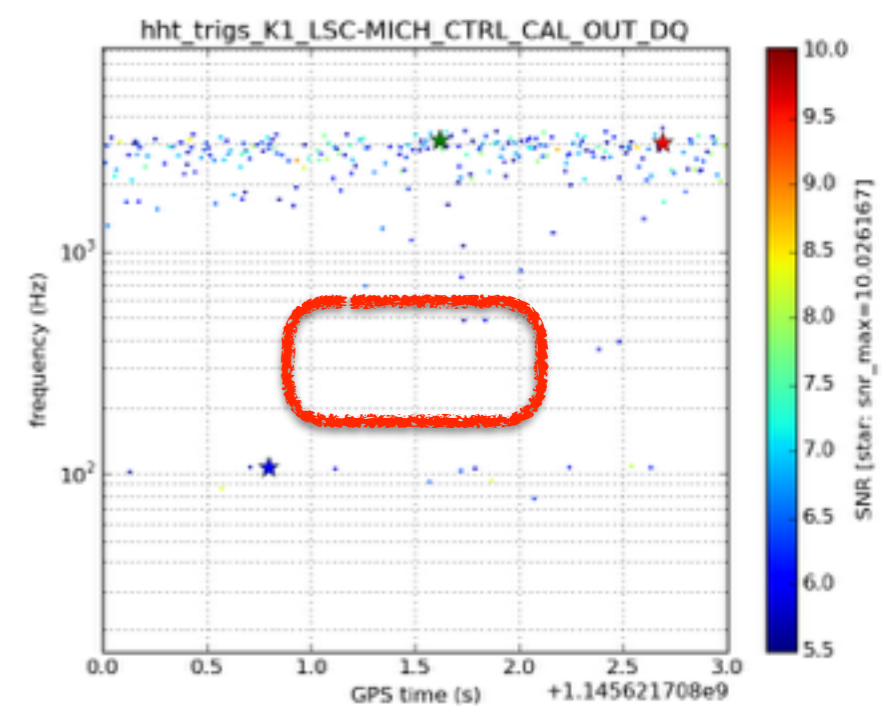
[sg33 (x0.5)]



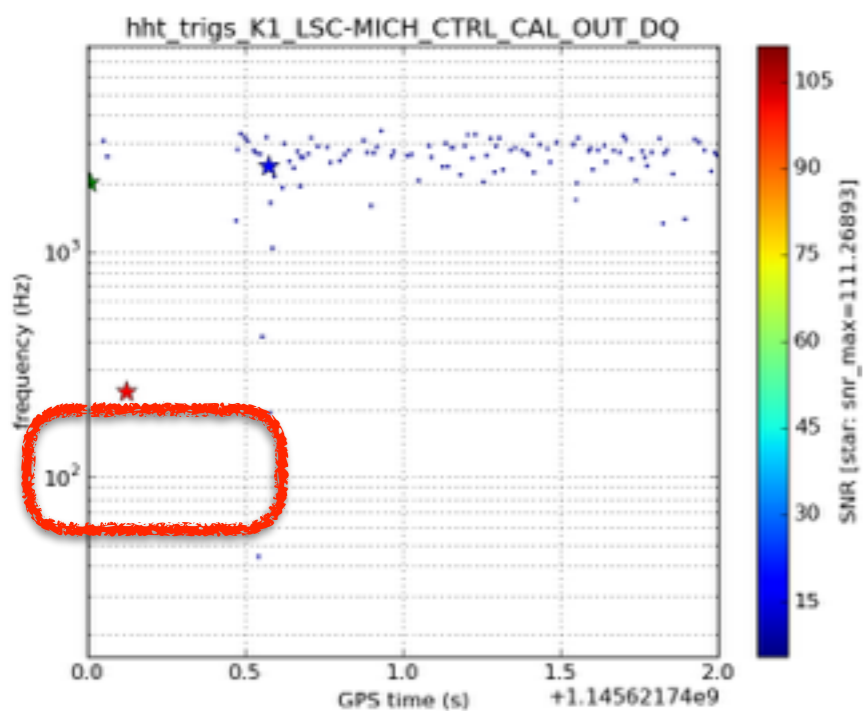
[sg100 (x0.5)]



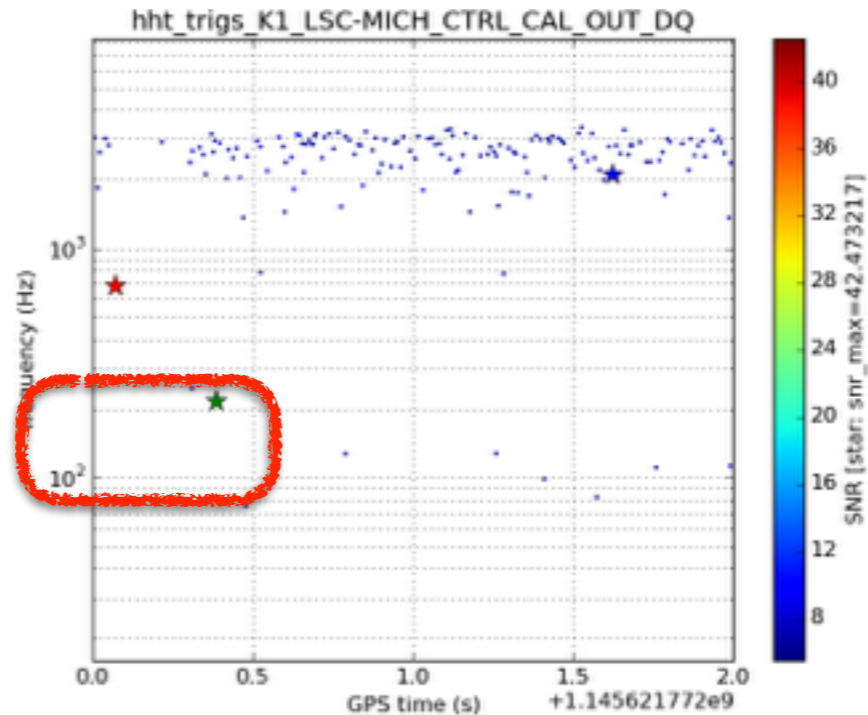
[sg333 (x0.5)]



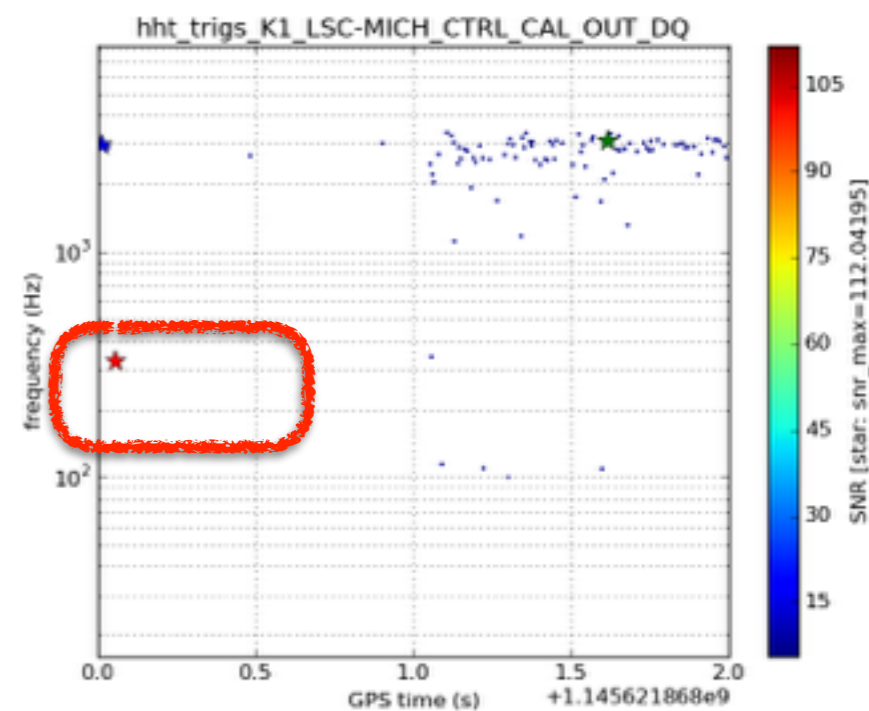
[sw11\_00 (x1000.0)]



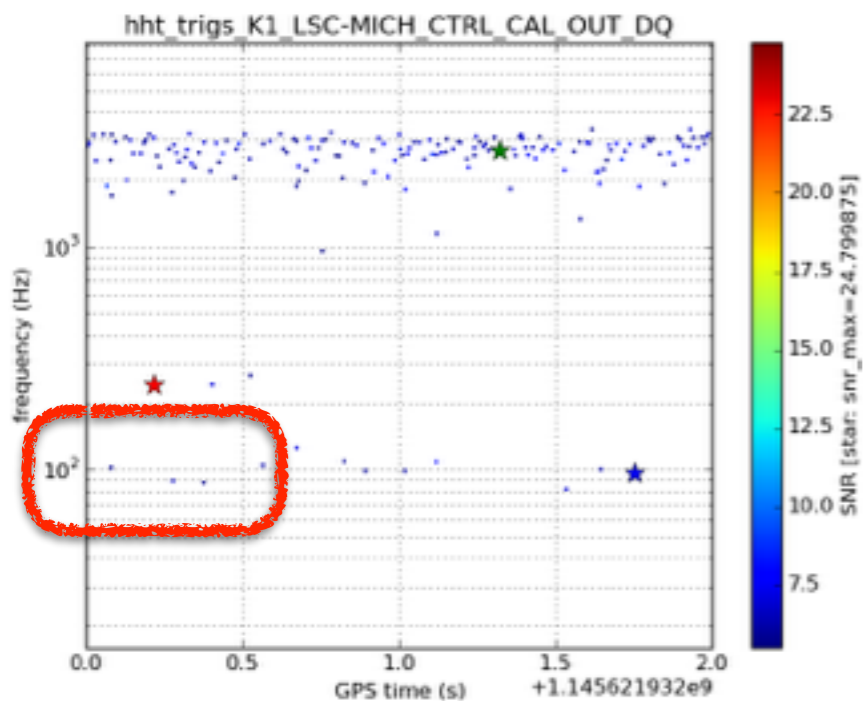
[sw11\_02 (x1000.0)]



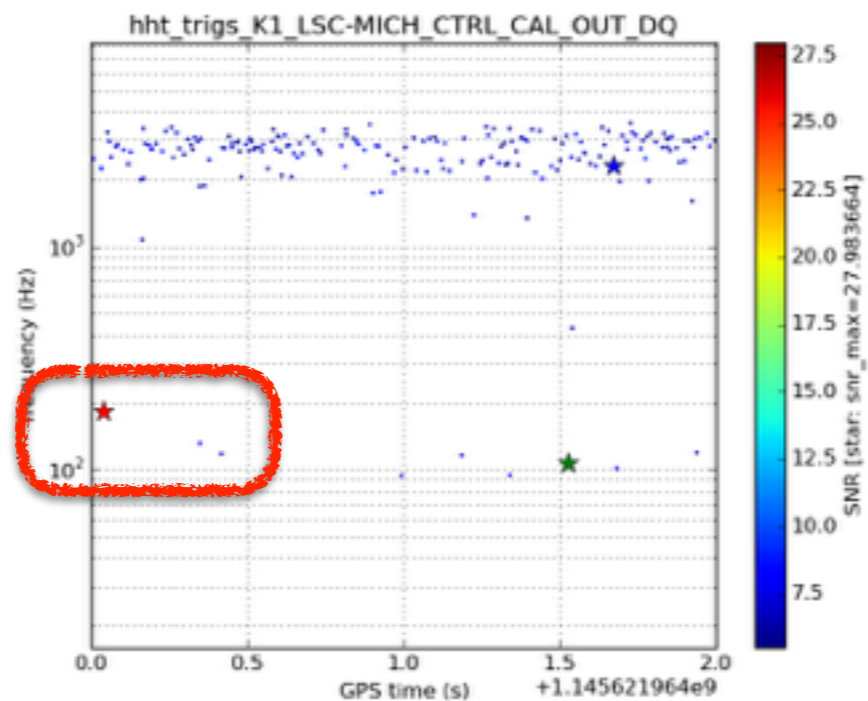
[sw50 (x1000.0)]



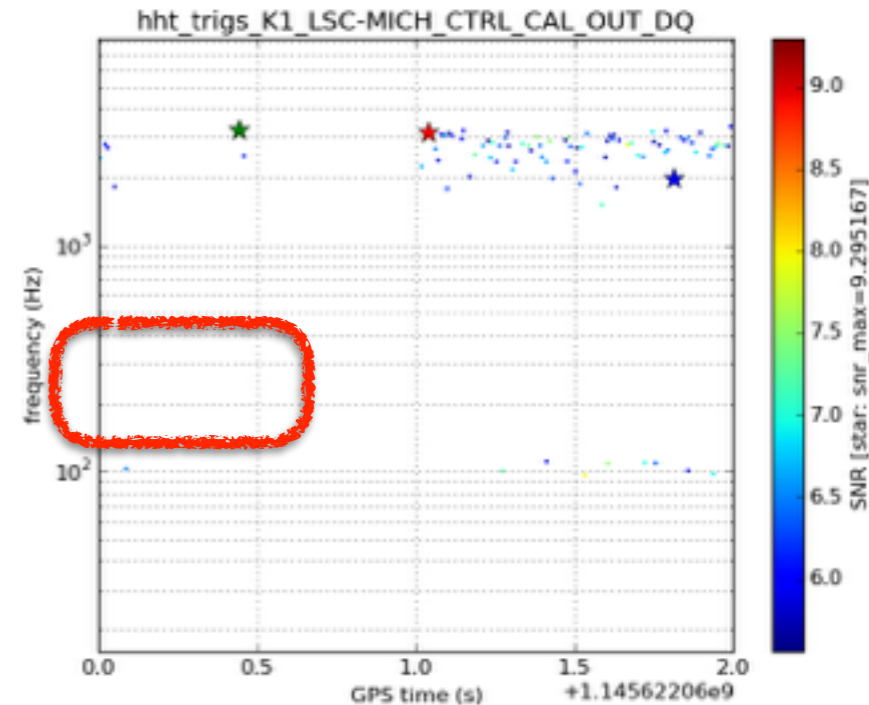
[sw11\_00 (x500.0)]



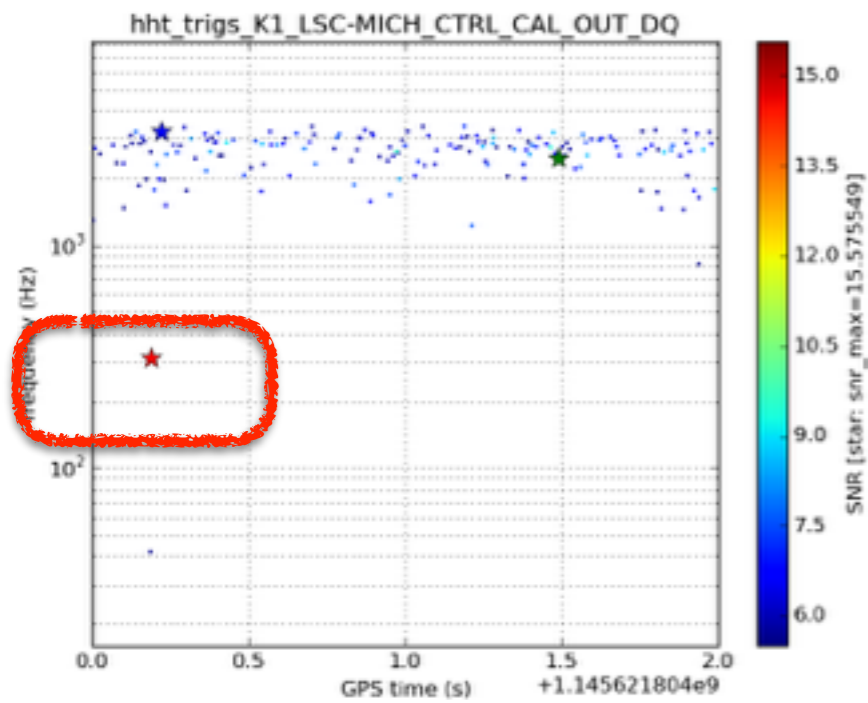
[sw11\_02 (x500.0)]



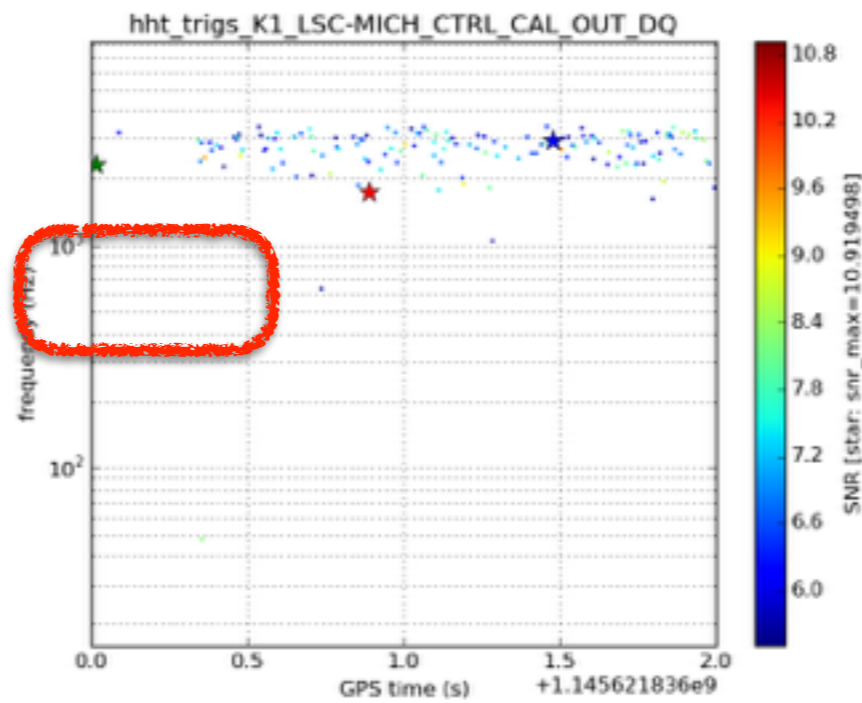
[sw50 (x500.0)]



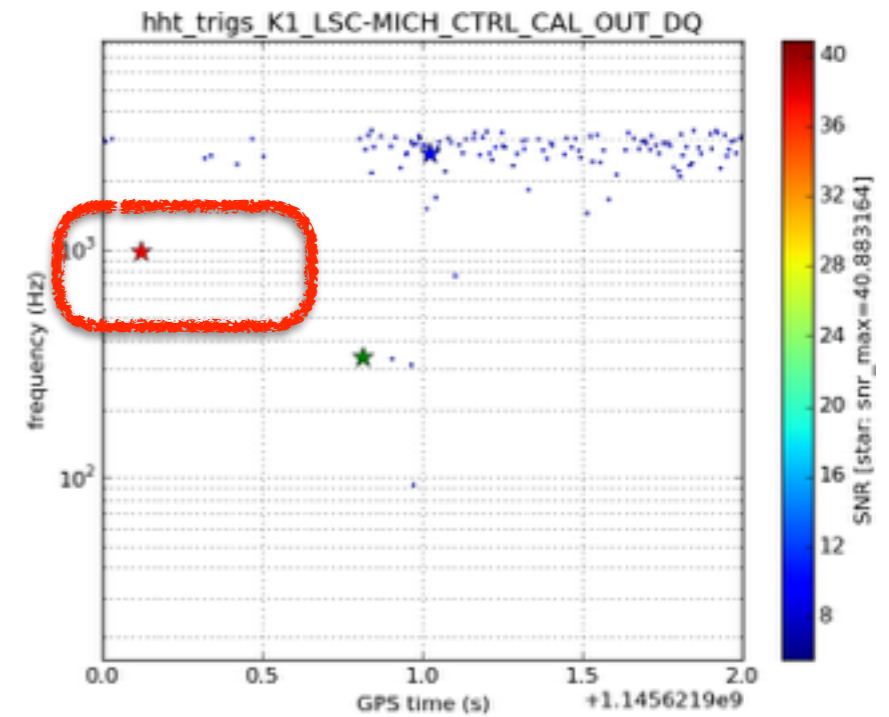
[sw11\_05 (x100.0)]



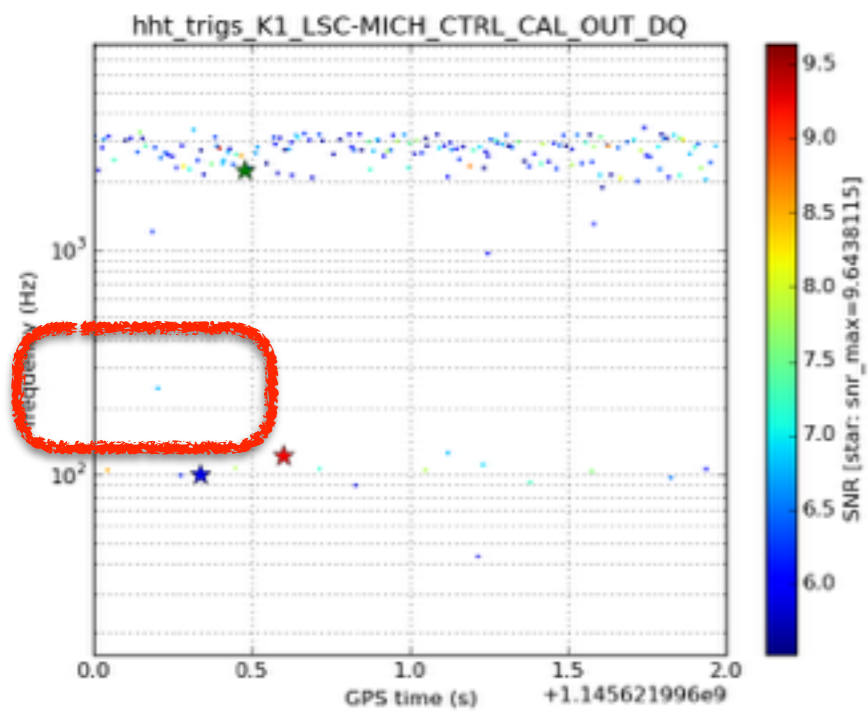
[sw11\_10 (x100.0)]



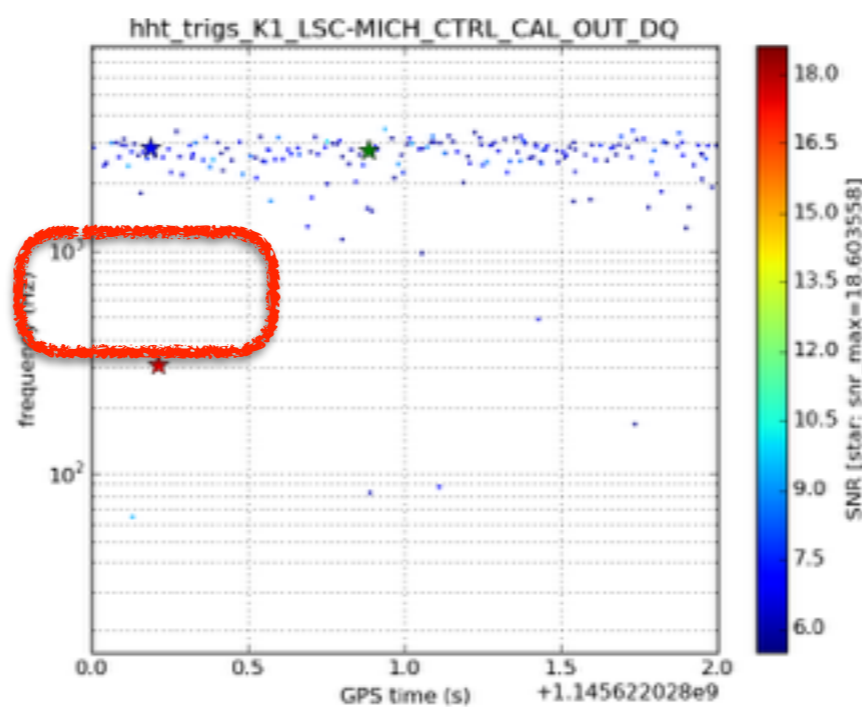
[sw80 (x100.0)]



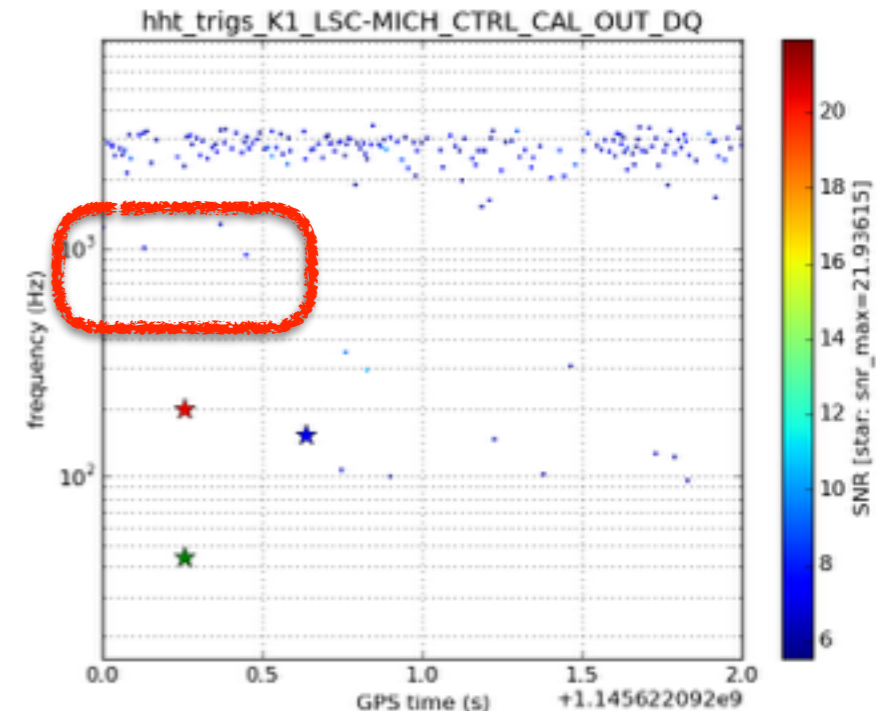
[sw11\_05 (x50.0)]



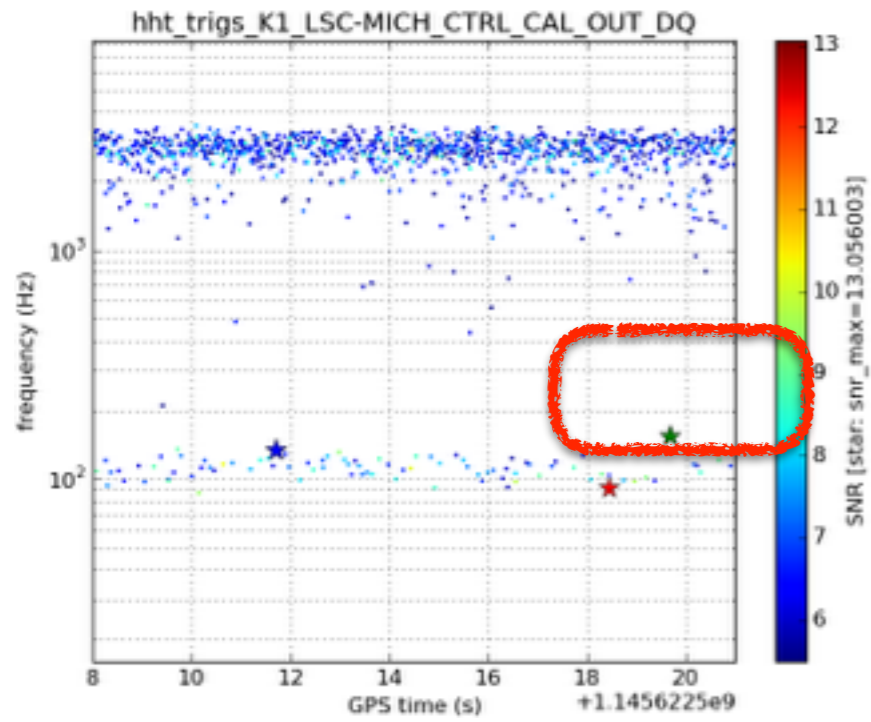
[sw11\_10 (x50.0)]



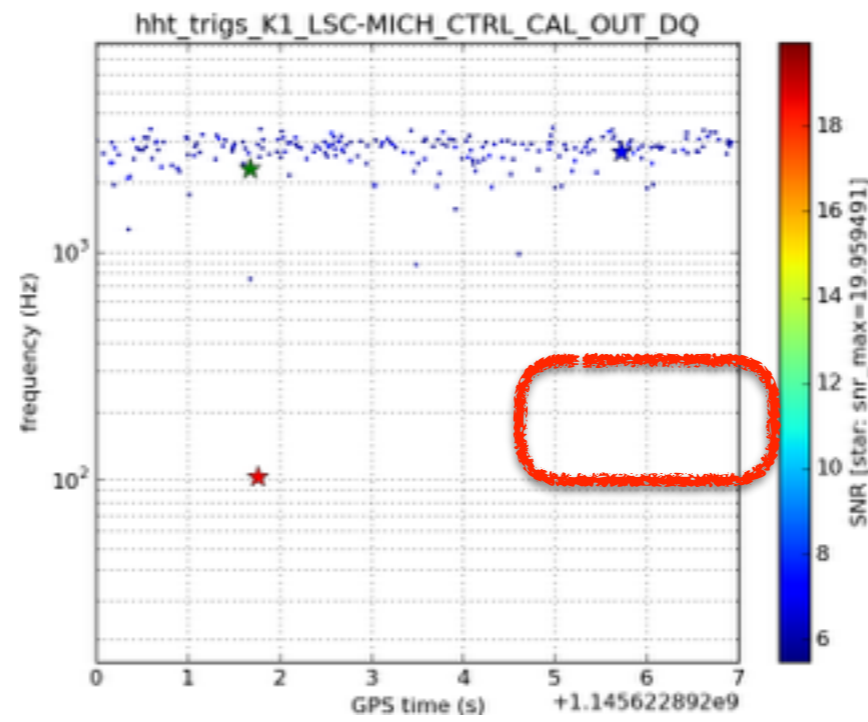
[sw80 (x50.0)]



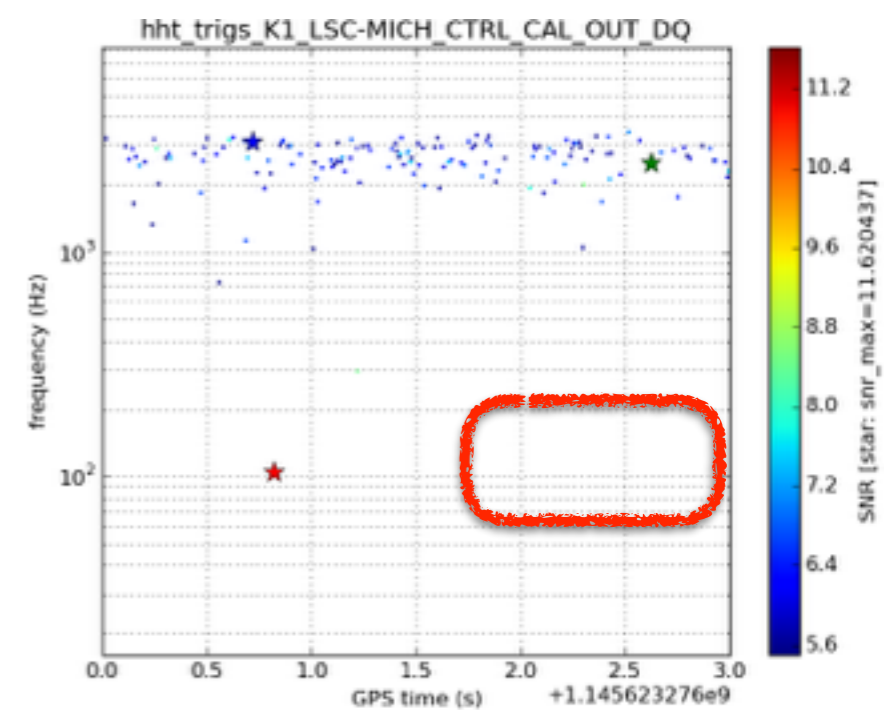
[cbc\_2020\_20]



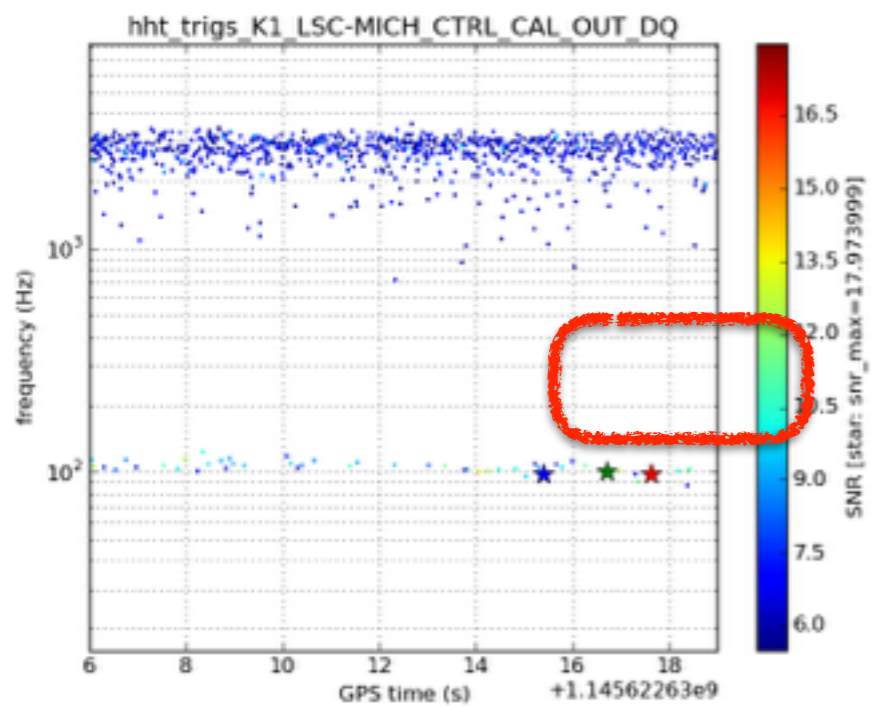
[cbc\_3030\_20]



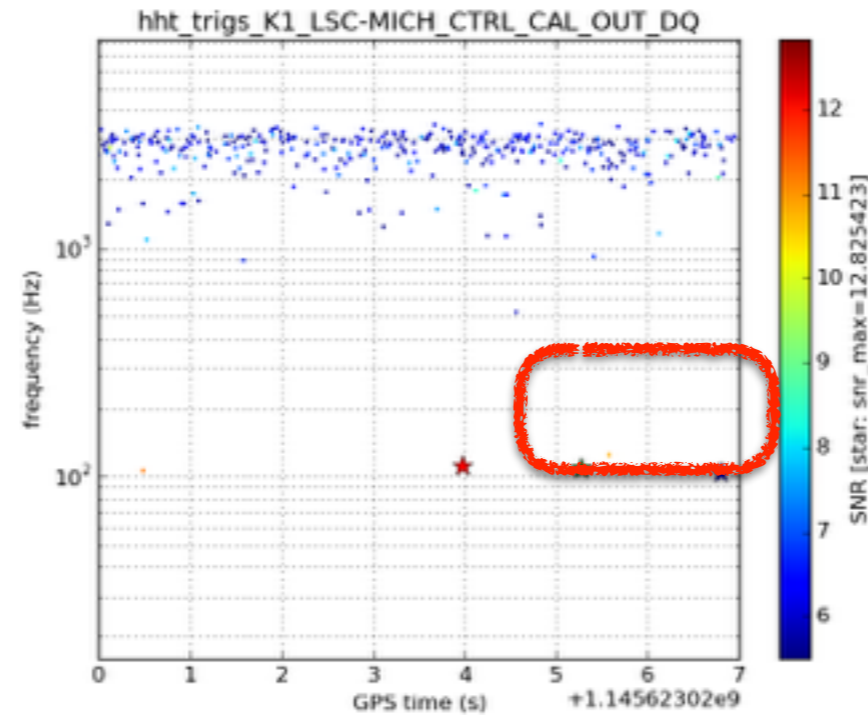
[cbc\_5050\_20]



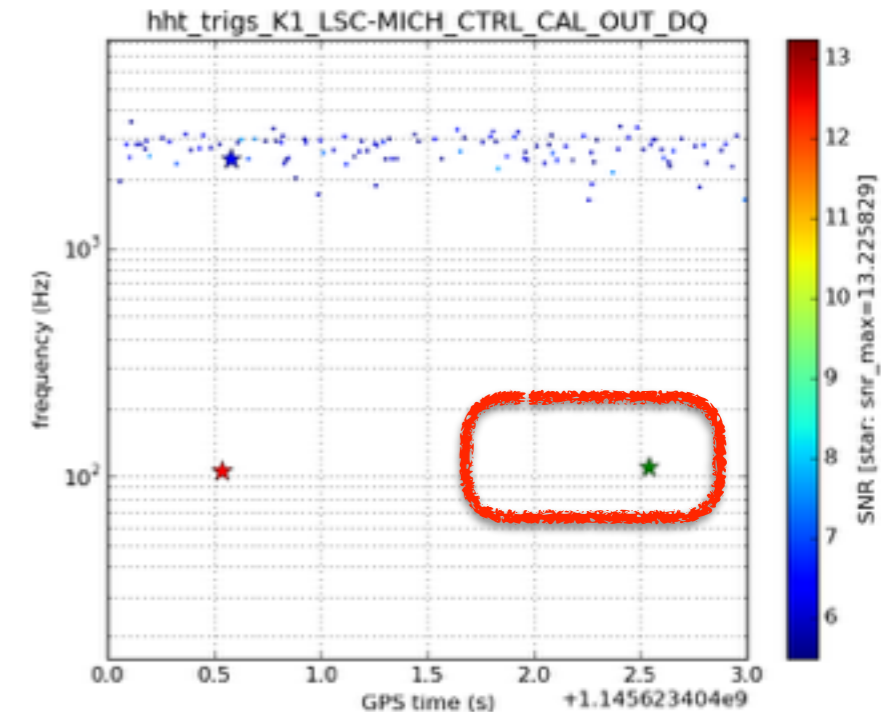
[cbc\_2020\_10]



[cbc\_3030\_10]

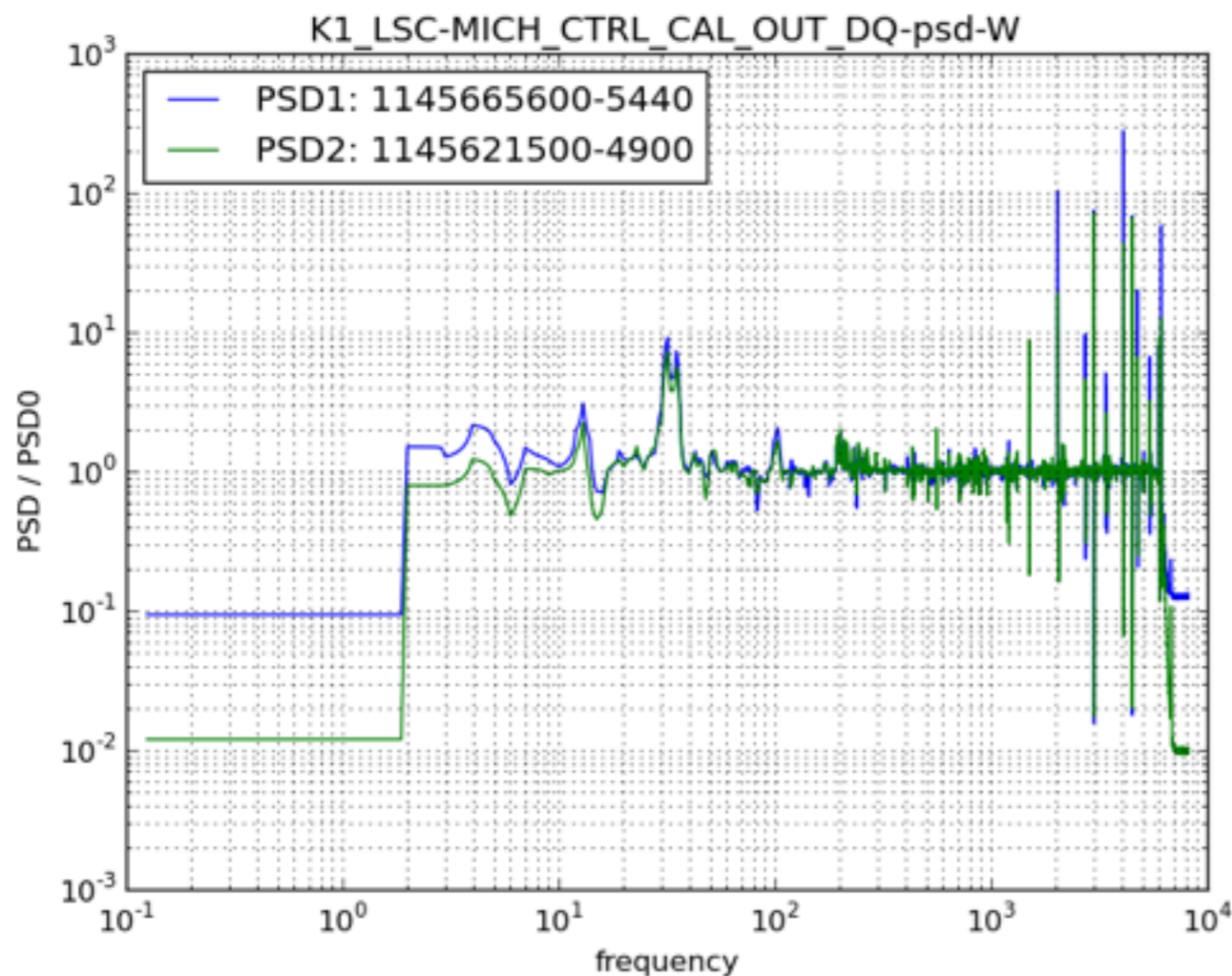


[cbc\_5050\_10]

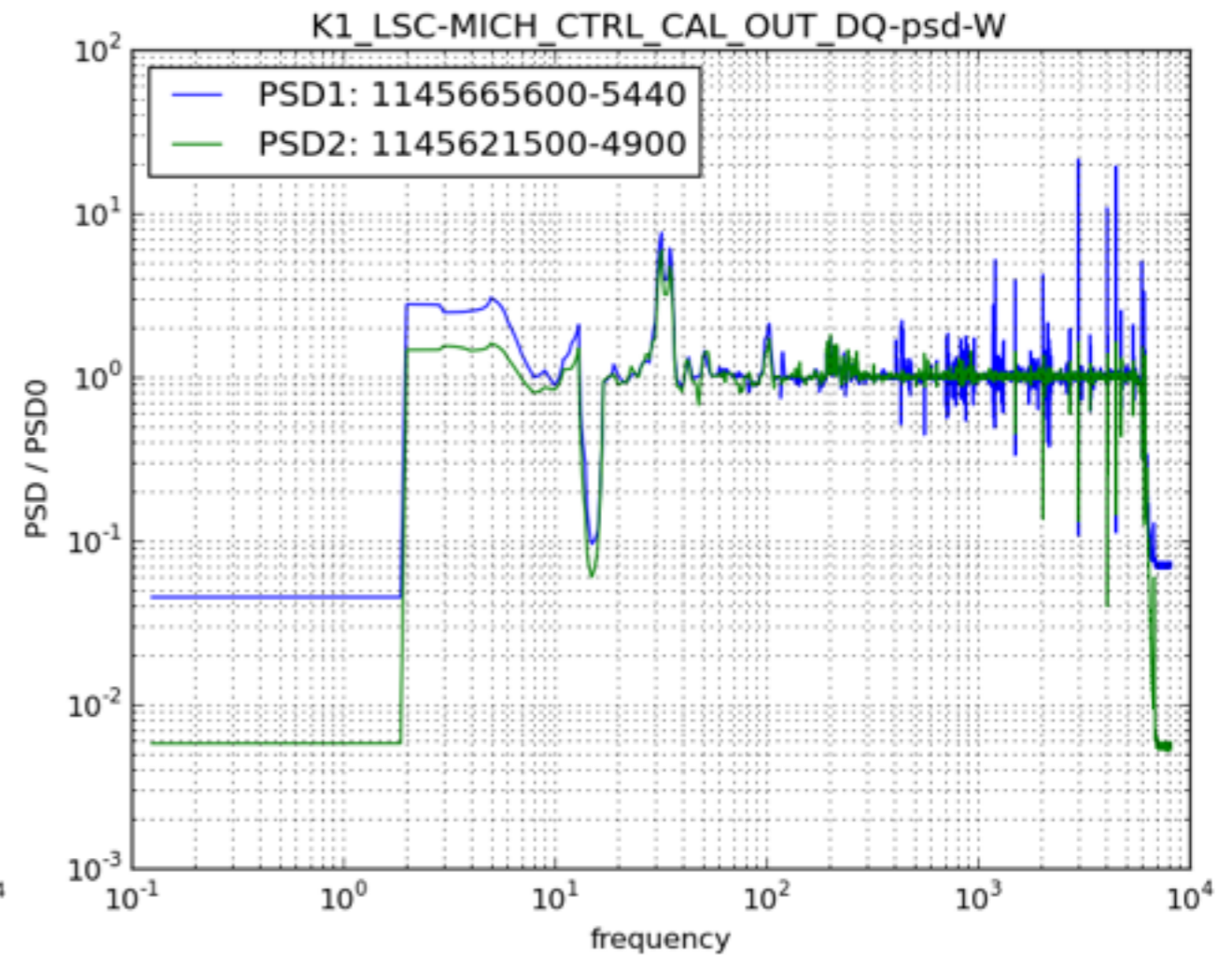


# Whitening issue on EtaGen triggers

whitened by PSD generated for  
1145523202 - 1145581284

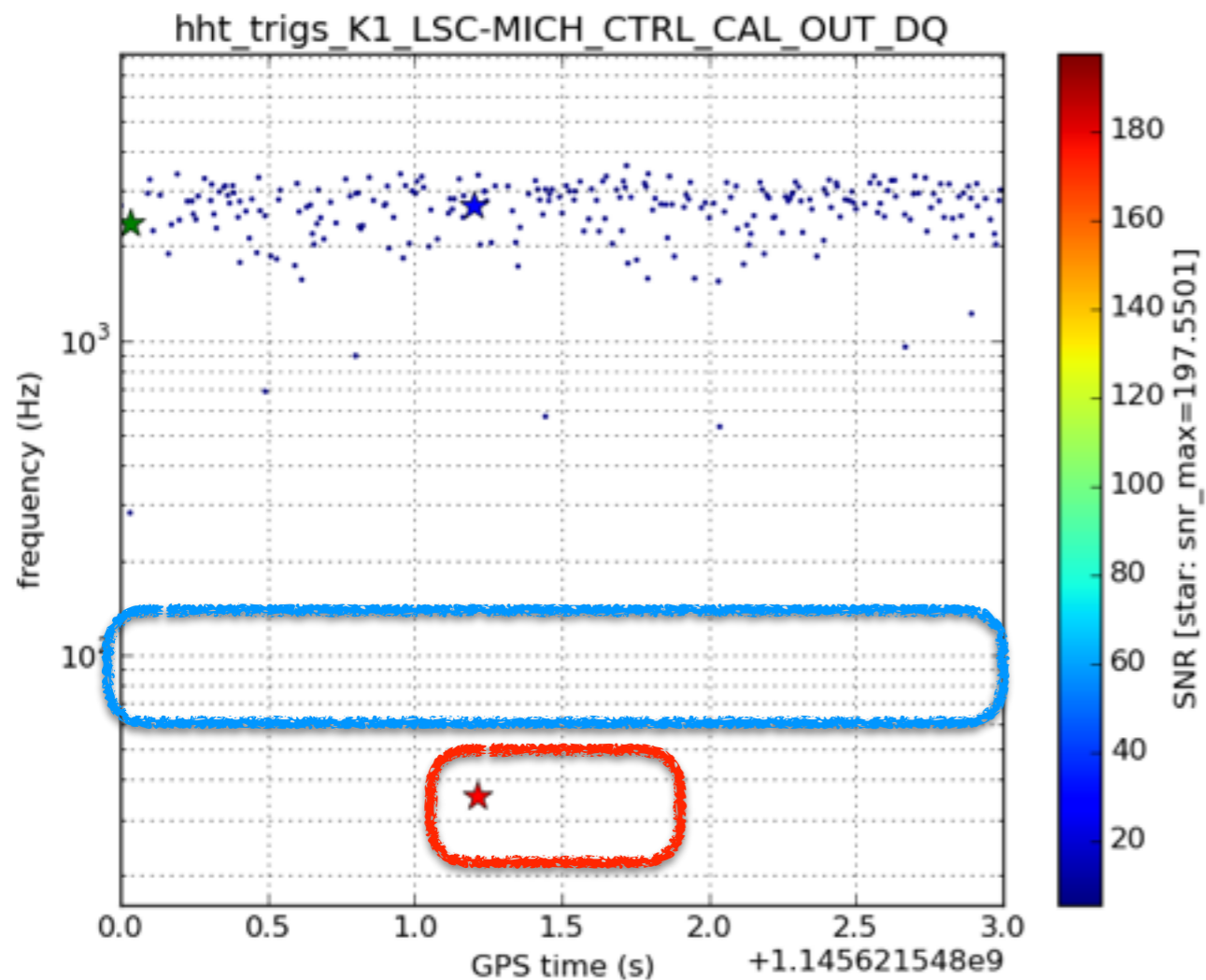


whitened by PSD generated for  
1145634741 - 1145655599

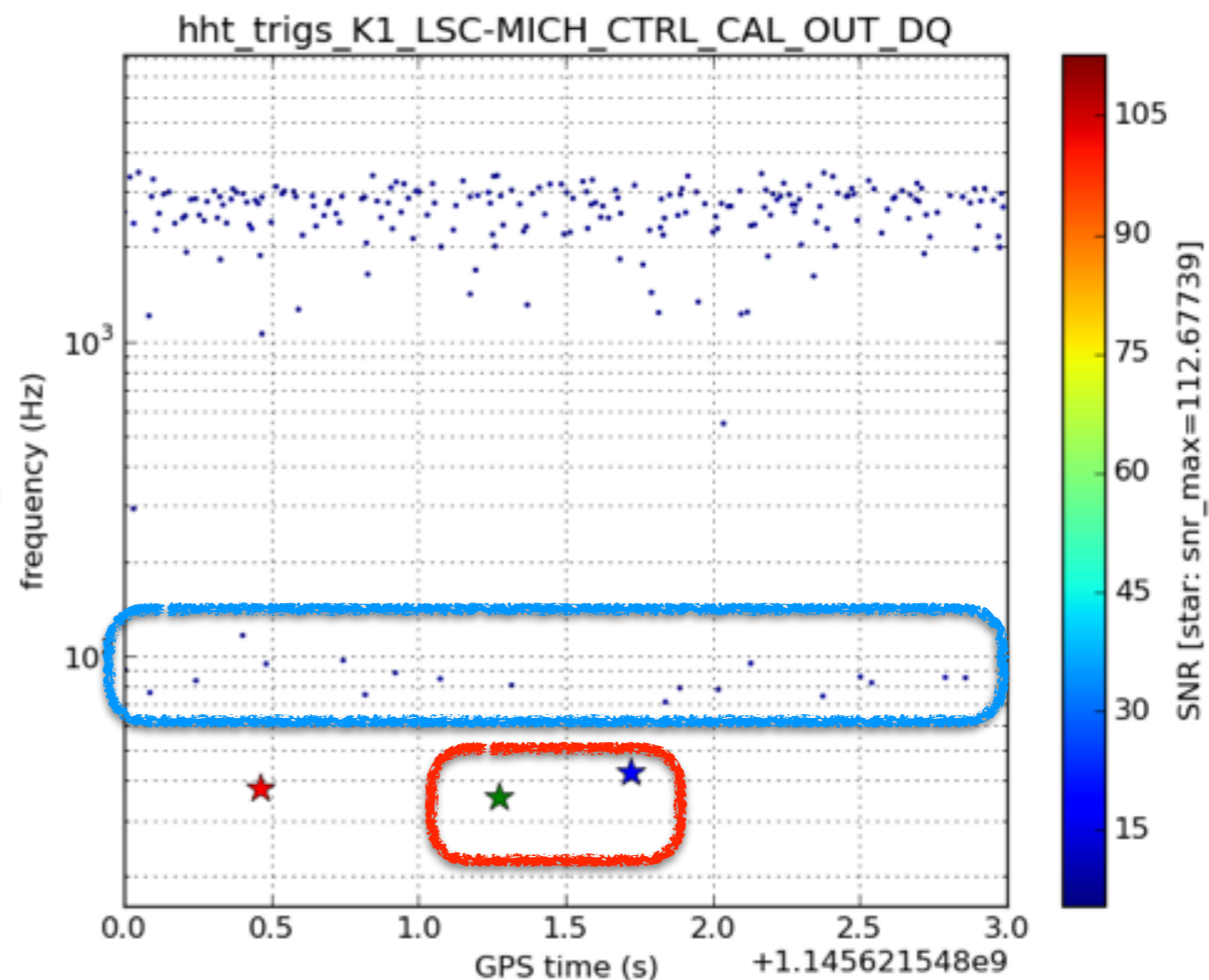


# Whitening issue on EtaGen triggers

whitened by PSD generated for  
1145523202 - 1145581284

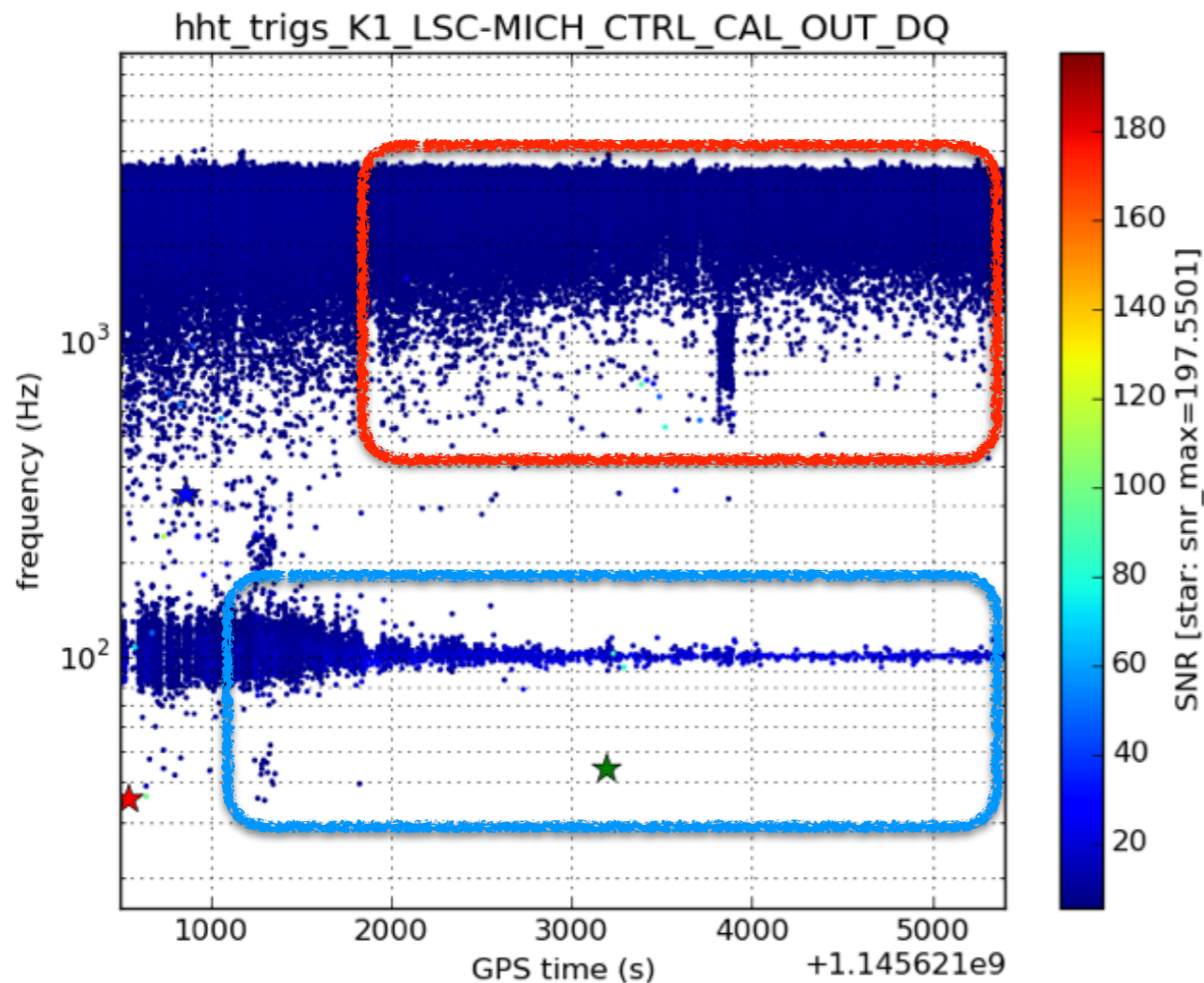


whitened by PSD generated for  
1145634741 - 1145655599

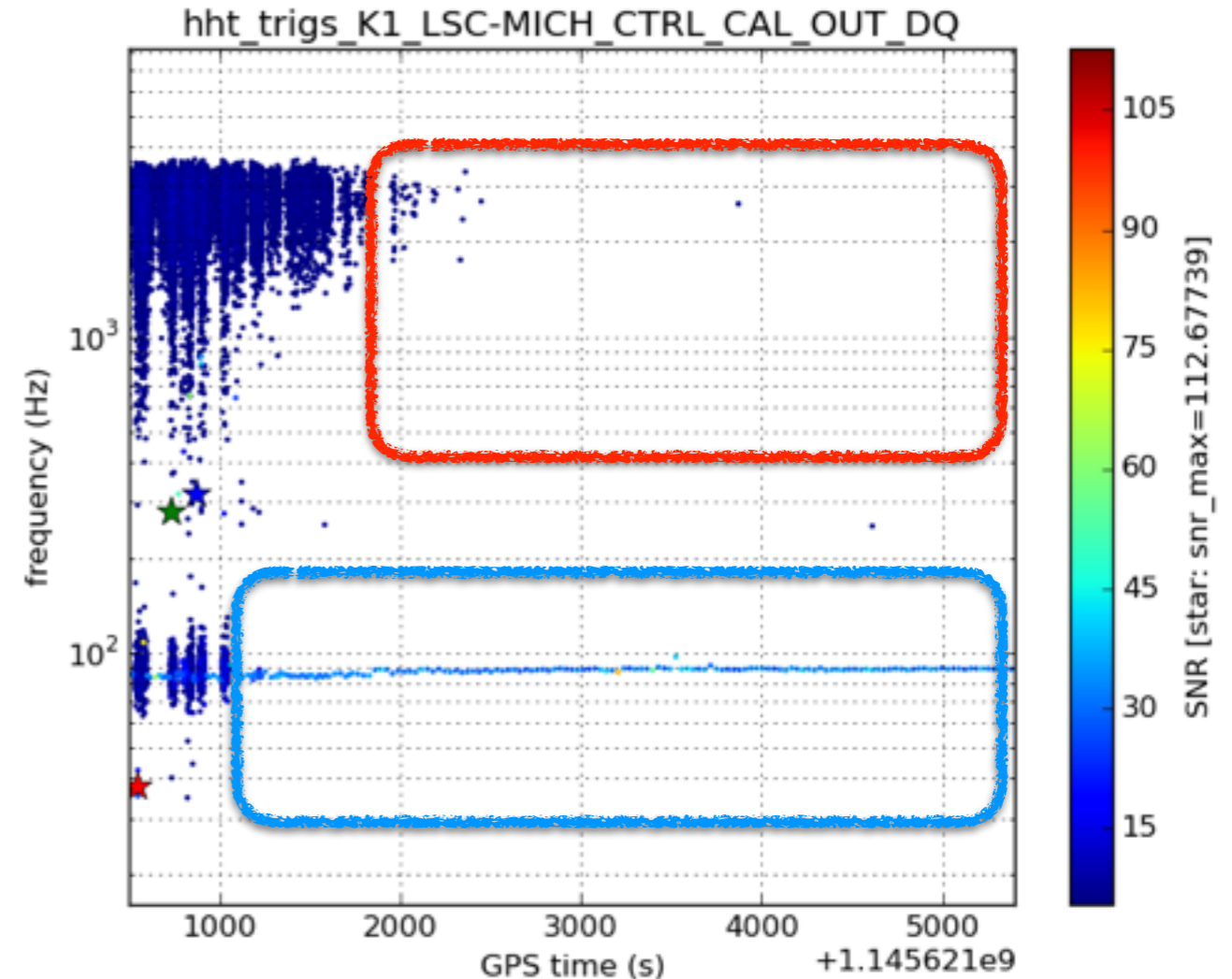


# Whitening issue on EtaGen triggers (& clustering issue)

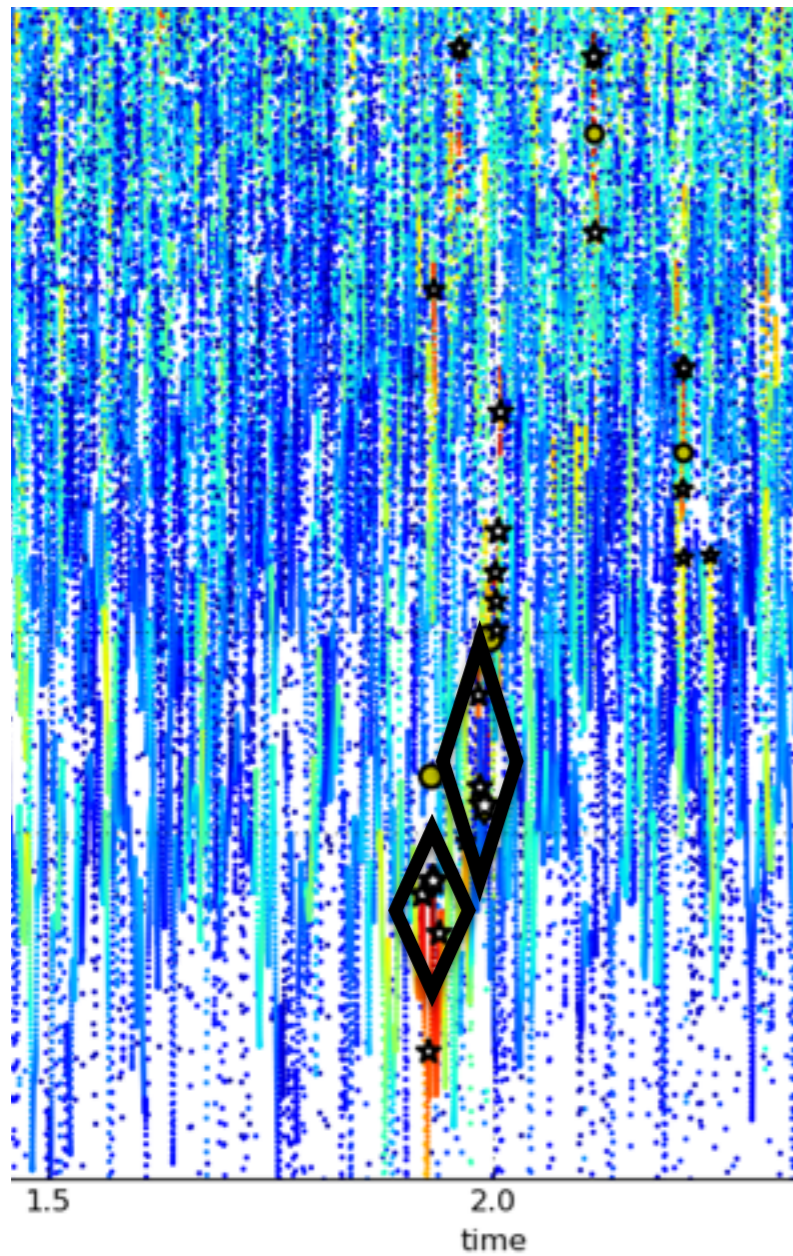
whitened by PSD generated for  
1145523202 - 1145581284



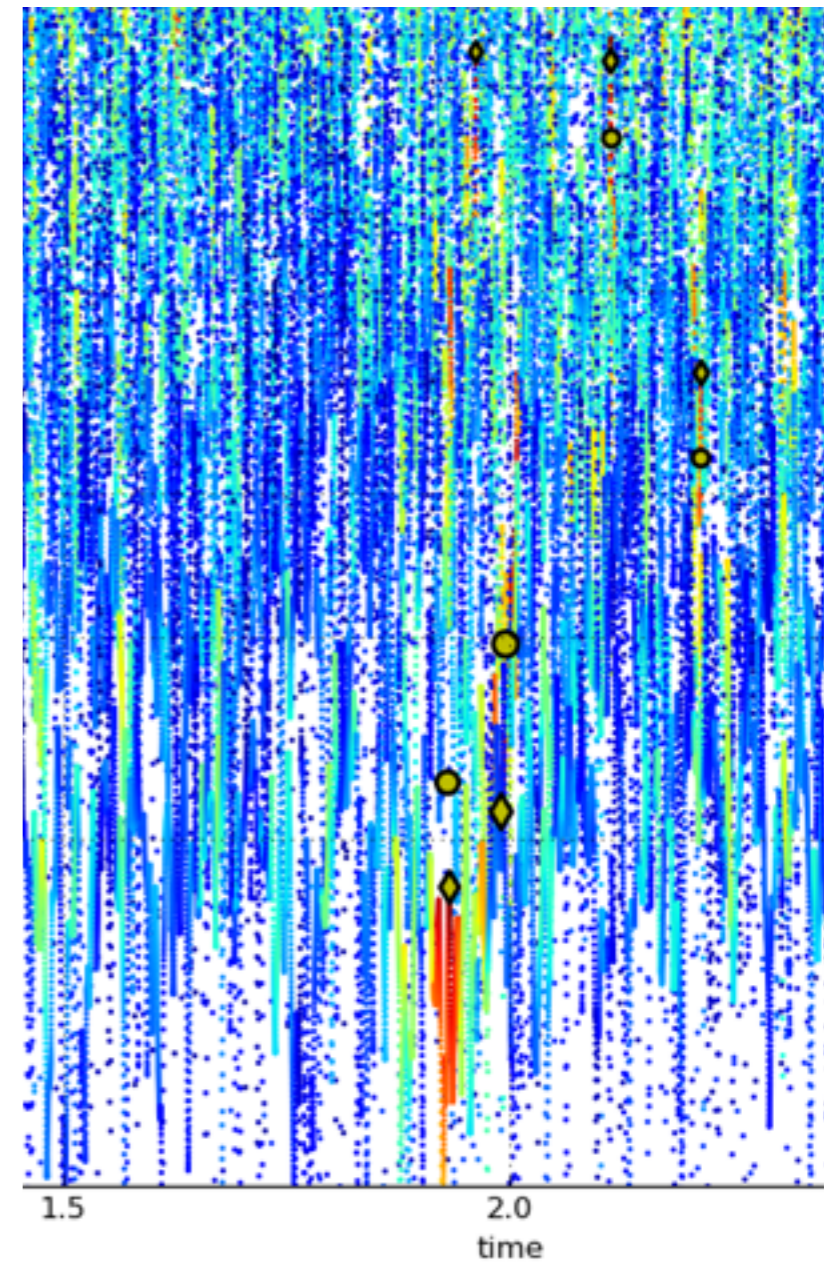
whitened by PSD generated for  
1145634741 - 1145655599



# Clustering in PyHHT

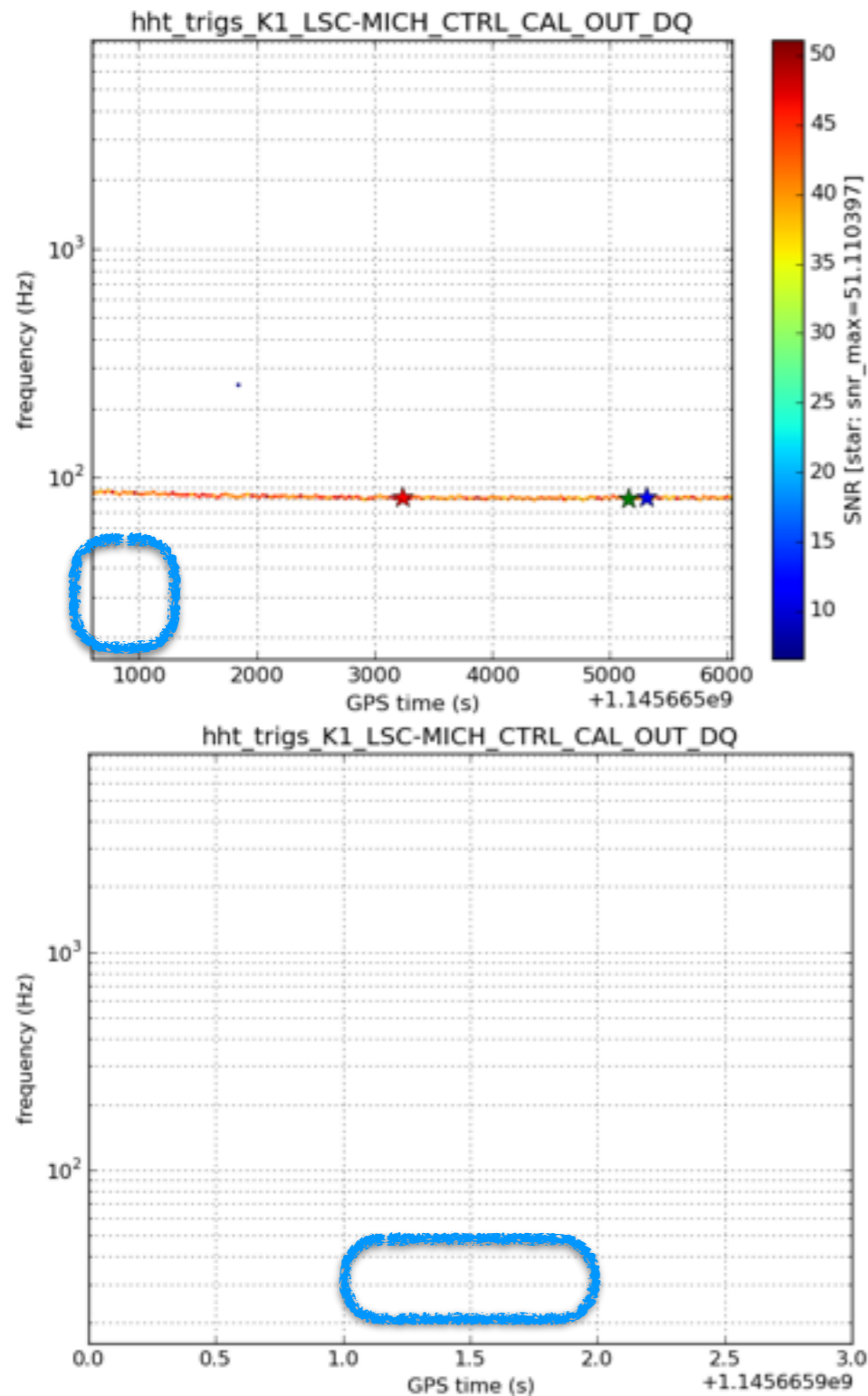


- EtaGen produces numerous data points with respect to time and frequency as well as IMFs.
- A simple recursive routine make those data be clustered.
- Kleine-Welle trigger uses L1-norm since it generates data at the specific frequency band.
- PyHHT (a Python implementation of EtaGen) uses L2-norm to cluster the data points because PyHHT does not restricted to a specific frequency band.

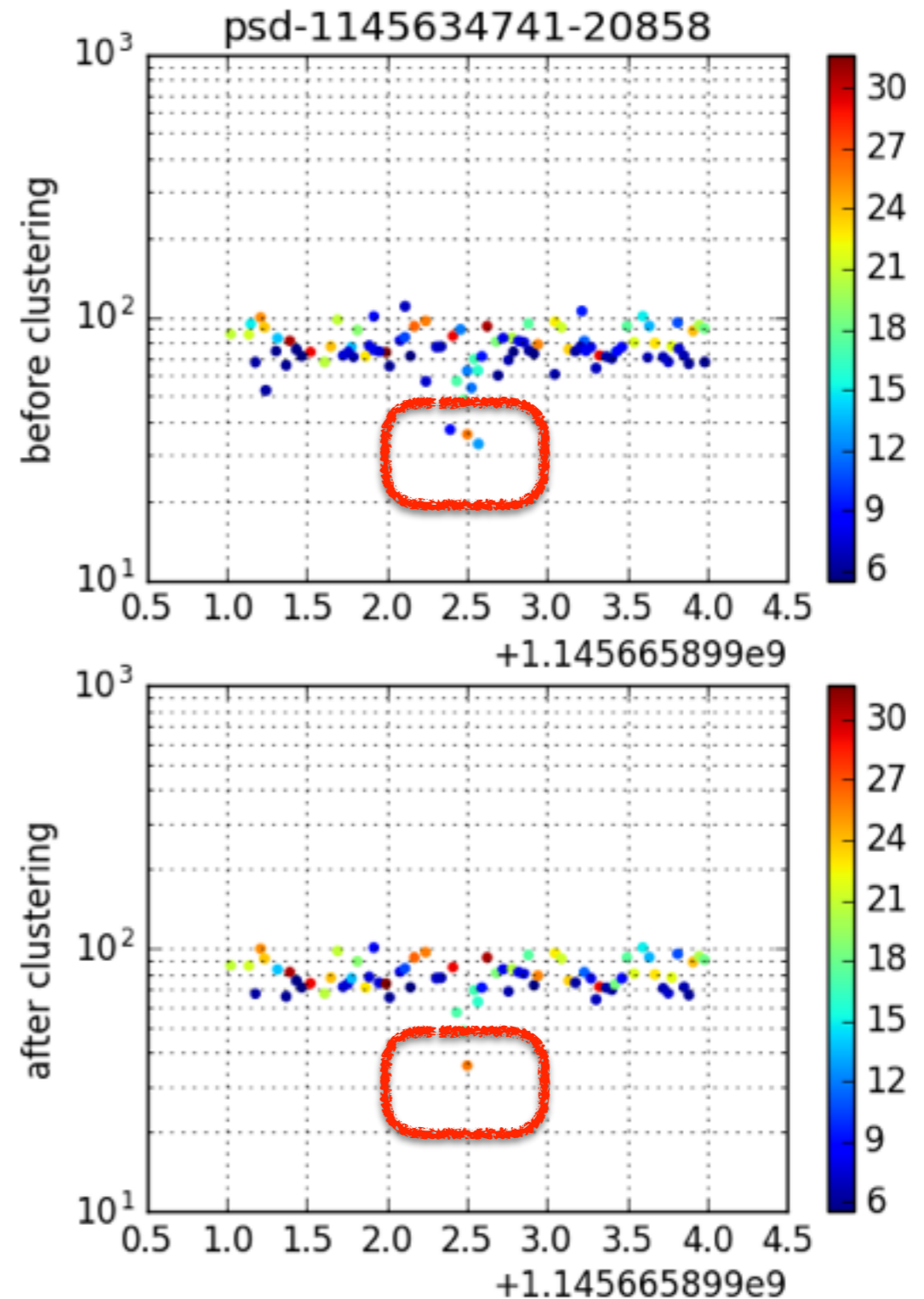




# Clustering issue on EtaGen triggers



[Clustered by a LIGO tool]



[Clustered by PyHHT]

# Remarks

- The LIGO clustering tool used in this study is a requirement for **ETG performance test** in LSC.
- We should review the algorithm and suggest a suitable one for EtaGen.
- It maybe includes upgrading of the clustering algorithm of PyHHT, a Python implementation of EtaGen.
- Also, we are **upgrading EtaGen algorithm** to narrow down the errors in SNR of triggers.

# Links to figures

- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621500-4900.html> # 1st HIs
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621548-3.html> # sg33 (x1.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621580-3.html> # sg100 (x1.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621612-3.html> # sg333 (x1.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621644-3.html> # sg33 (x0.5)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621676-3.html> # sg100 (x0.5)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621708-3.html> # sg333 (x0.5)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621740-2.html> # sw11\_00 (x1000.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621772-2.html> # sw11\_02 (x1000.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621804-2.html> # sw11\_05 (x100.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621836-2.html> # sw11\_10 (x100.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621868-2.html> # sw50 (x1000.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621900-2.html> # sw80 (x100.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621932-2.html> # sw11\_00 (x500.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621964-2.html> # sw11\_02 (x500.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145621996-2.html> # sw11\_05 (x50.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145622028-2.html> # sw11\_10 (x50.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145622060-2.html> # sw50 (x500.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145622092-2.html> # sw80 (x50.0)
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145622508-13.html> # cbc\_2020\_20
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145622572-13.html> # cbc\_2020\_15
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145622636-13.html> # cbc\_2020\_10
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145622700-9.html> # cbc\_2525\_20
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- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145622892-7.html> # cbc\_3030\_20
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145622956-7.html> # cbc\_3030\_15
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145623020-7.html> # cbc\_3030\_10
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- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145623404-3.html> # cbc\_5050\_10
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145623468-64.html> # BNS135DD2SNR3
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145623588-64.html> # BNS135DD2SNR5
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145665600-5440.html> # 2nd HIs
- <http://seikai.icrr.u-tokyo.ac.jp/~eddy/etagen-1145665900-3.html> # sg33 (x1.0)

Thank you!