Characterization of LIGO O1data around GW150914

Feb. 16, 2016

DetChar Meeting

Osaka City University

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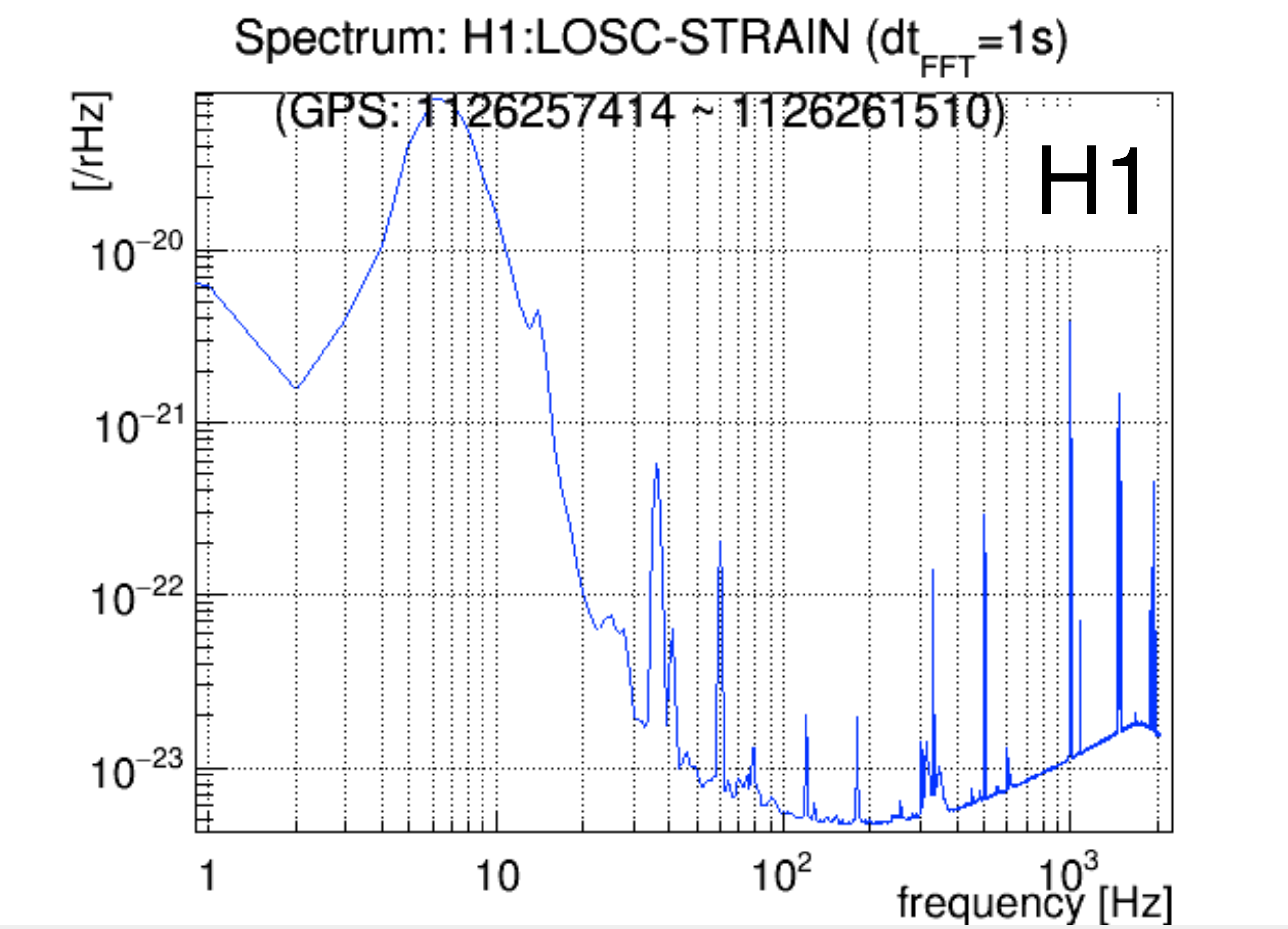
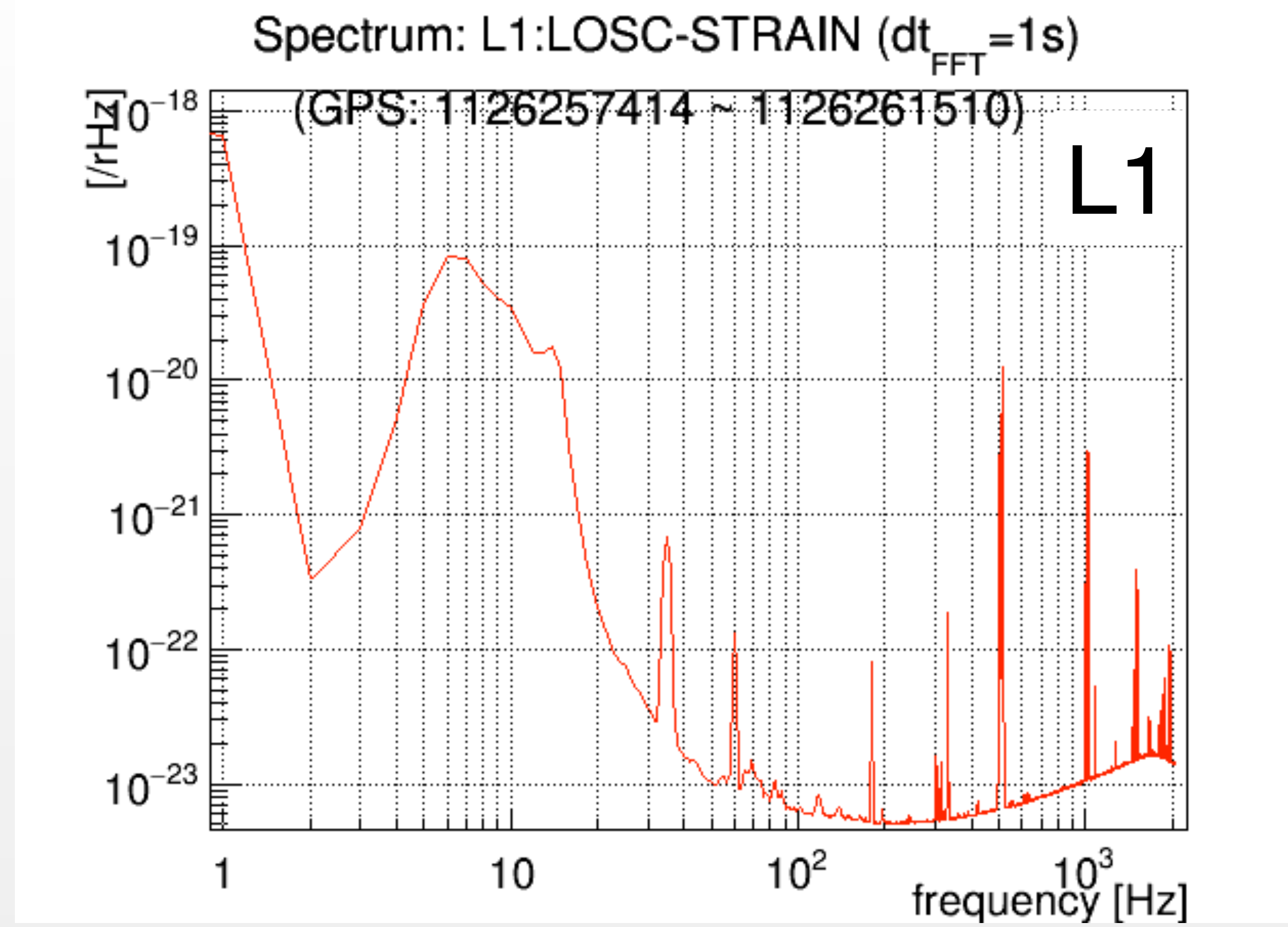
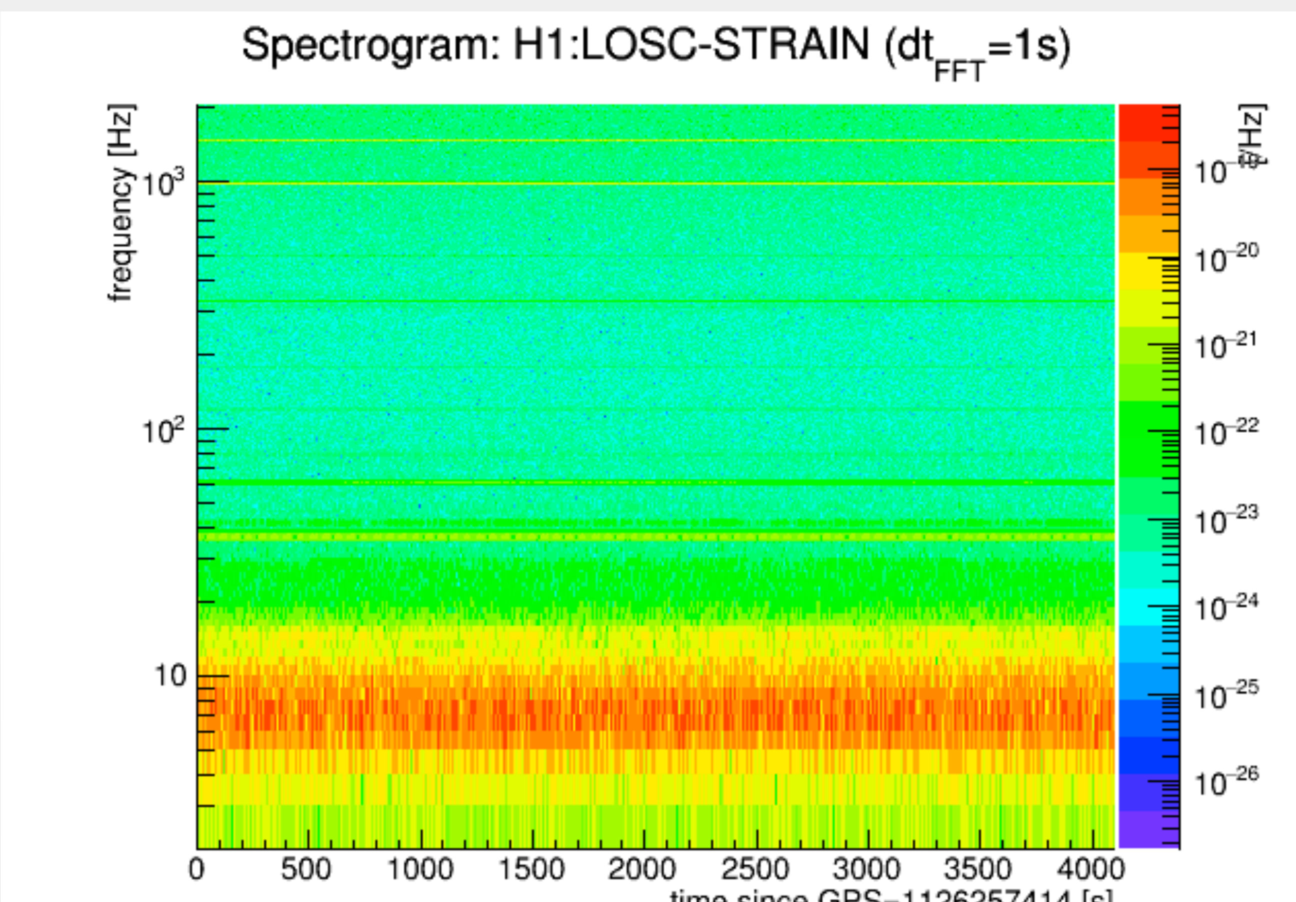
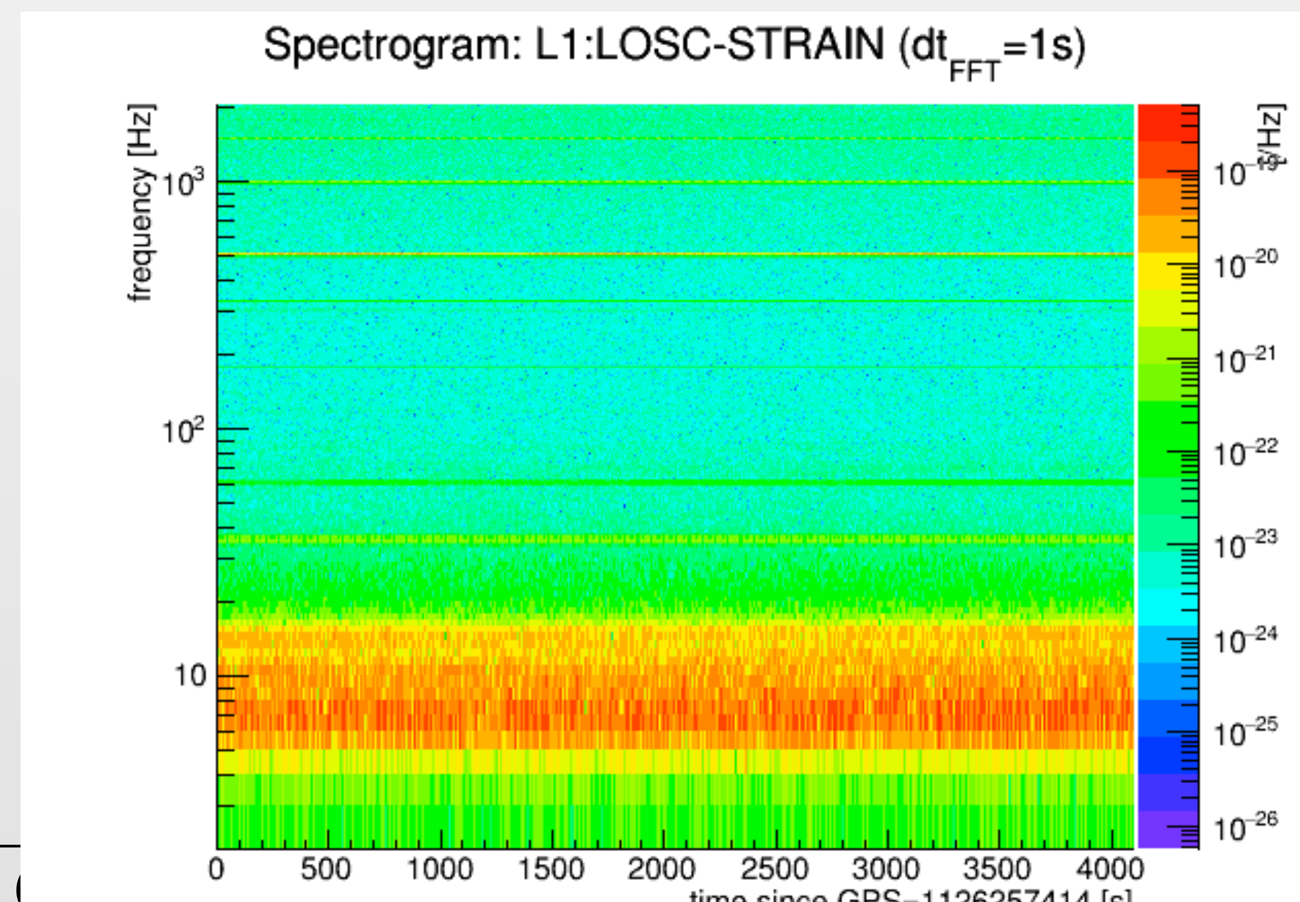
spectrum and spectrogram of H1 and L1









about RayleighMon

Spectrogram of data: **(short time Fourier transform)**

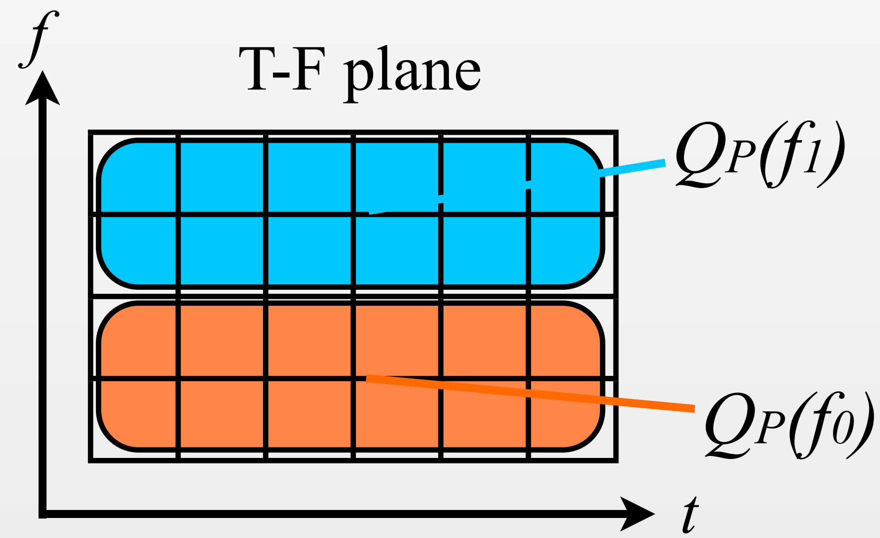
$S(t_i,\ f_j)\ \ (1 \leq i \leq N,\ \ 1 \leq j \leq M)$

Quantiles of data:

$Q_P(f_l)$ is P-percentile of $S(t_i, f_j)$

$(1 \leq i \leq N,\ \ 1 \leq l \leq M/m,$

$ml \leq j \leq m(l+1),\ \ m = \mathrm{d}f/\mathrm{d}f_{\mathrm{fft}} = \mathrm{d}f\ \mathrm{d}t_{\mathrm{fft}})$

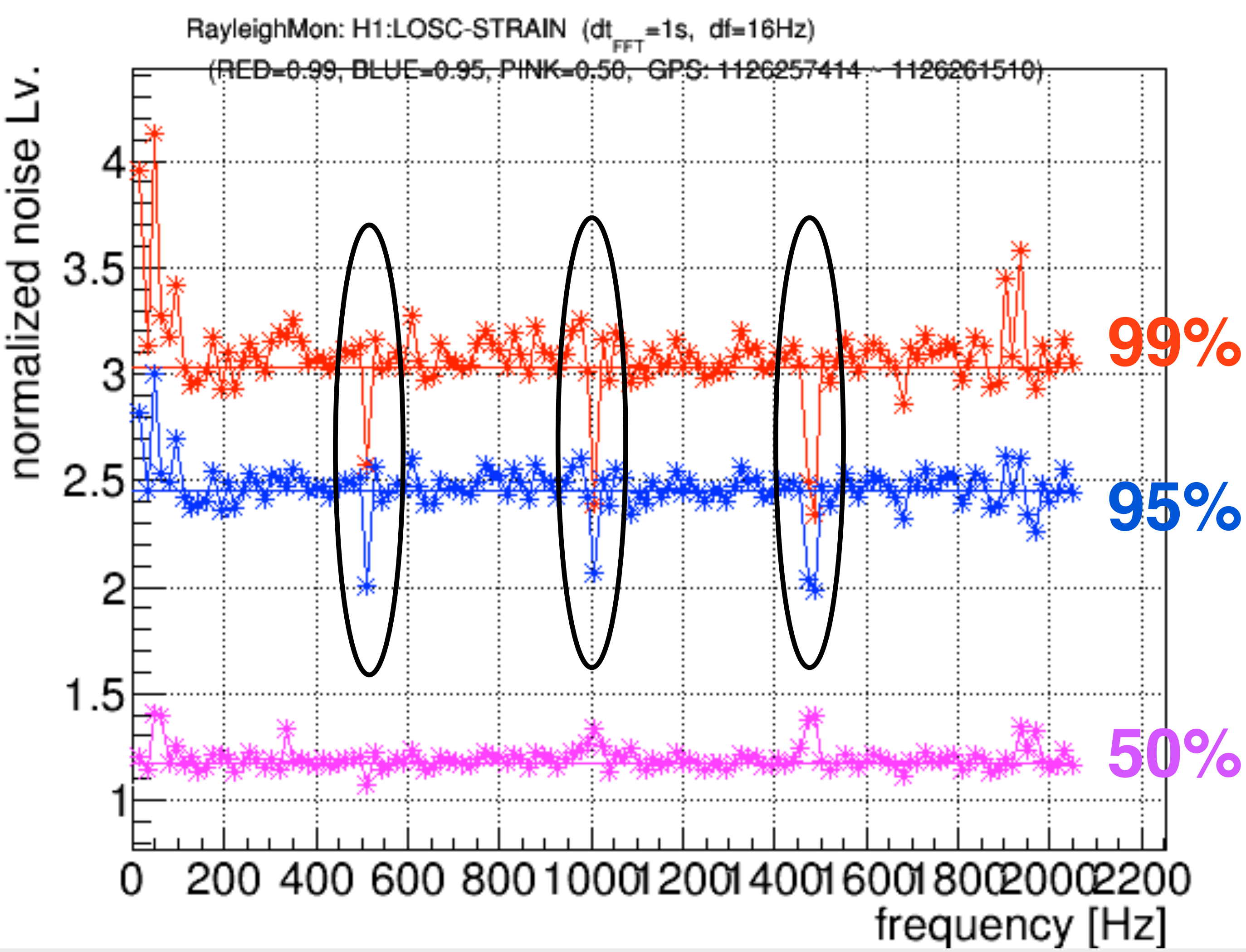


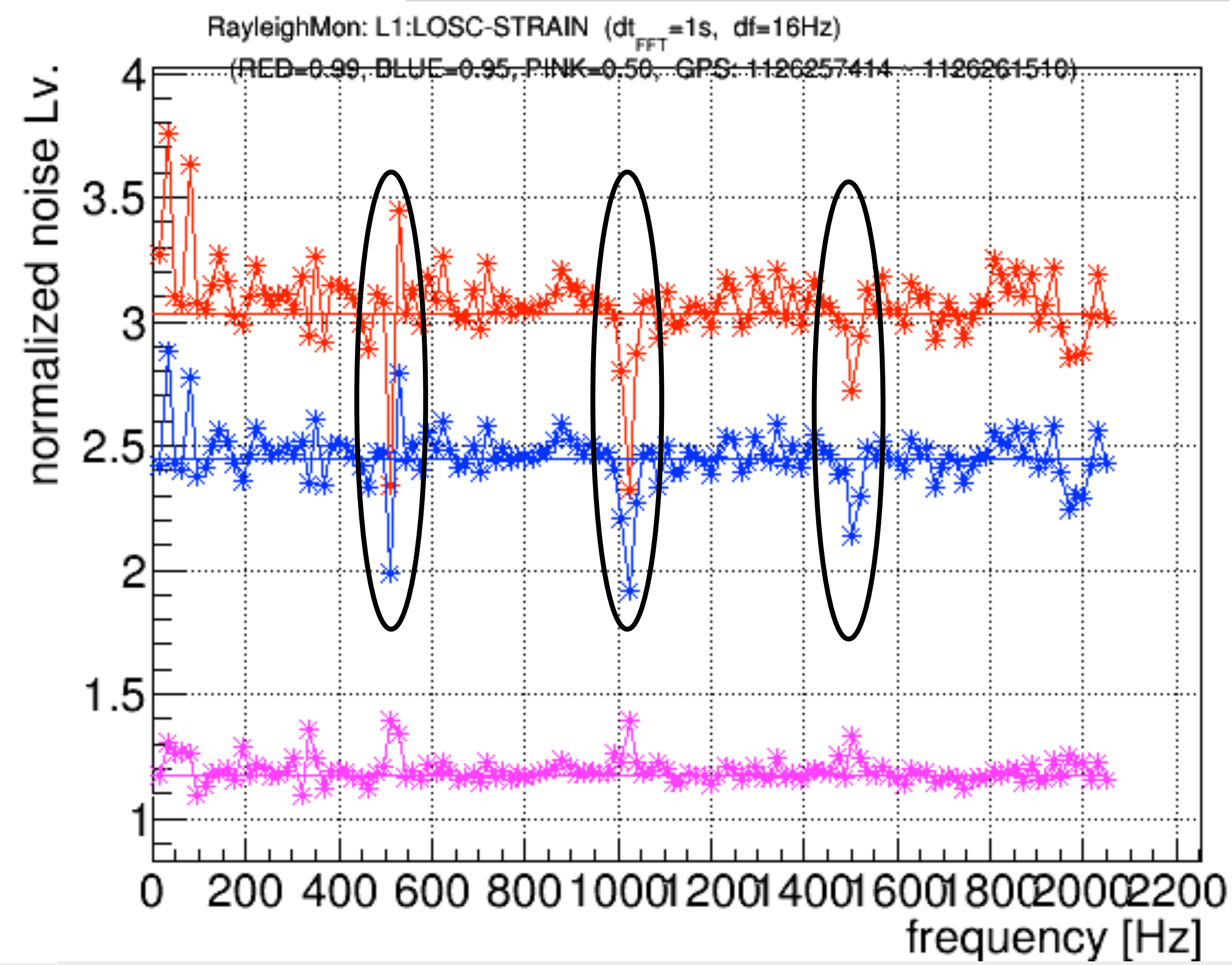
In daily monitor, parameter is fixed.

$\mathrm{d}t_{\mathrm{fft}} = 1\ \mathrm{s},\quad P = 0.5,\ 0.95,\ 0.99,\quad \mathrm{d}f = 16\ \mathrm{Hz}$

Results of Rayleigh Monitor

Parameters:
frequency resolution : 16Hz
data length of FFT : 1s





Gaussianity in low frequency seems worse than one in high frequency.

Line noises at 500, 1000 and 1500Hz are stable.

Averaged spectrum, Sn(f), is estimated
from the begining of 64s of the data.

Normalized noise level, n(f)/√Sn(f), may be estimated small.

about Student-RayleighMon

Noise distribution:

$$\Re[\tilde{n}(f)],\ \Im[\tilde{n}(f)] : \text{Gaussian dist.} \quad \Longrightarrow \quad \text{Student-t dist.}$$

$$|\tilde{n}(f)| : \text{Rayleigh dist.} \quad \Longrightarrow \quad \text{Student-Rayleihg dist.}$$

Probability density function:

$$p_{\mathrm{sr}}(\sigma, \nu; x) = \frac{x}{\sigma^2}\left(1 + \frac{1}{\nu}\left(\frac{x}{\sigma}\right)^2\right)^{-(1+\nu/2)} \xrightarrow[\nu\to\infty]{} p_{\mathrm{rayleigh}}(\sigma; x)$$

σ: scale factor, ν: degree of non-Gaussianity (weight of tail of distribution)

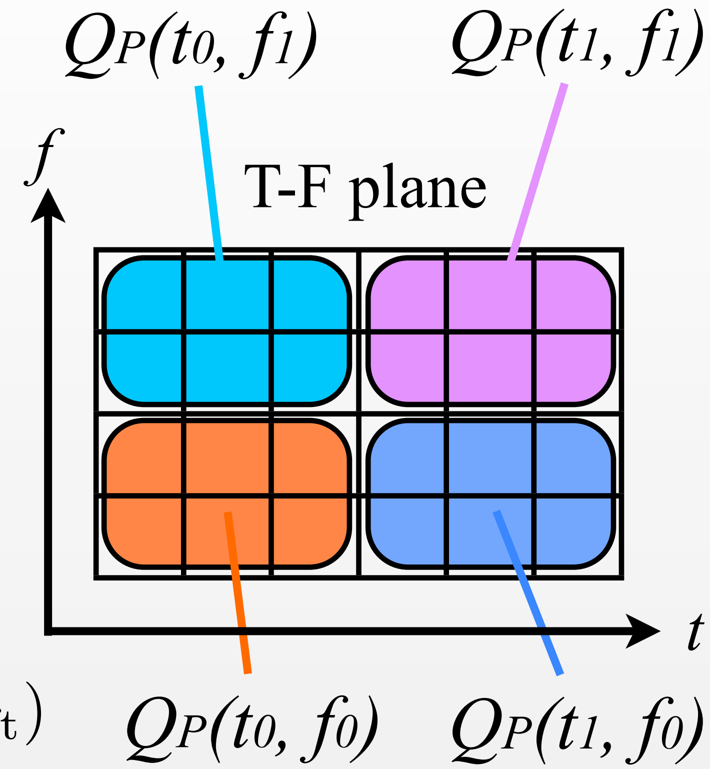
Cumulative distribution function:

$$P_{\mathrm{sr}}(\sigma, \nu; x) = 1 - \left(1 - \frac{x^2}{\nu\sigma^2 + x^2}\right)^{\nu/2} \xrightarrow[\nu\to\infty]{} P_{\mathrm{rayleigh}}(\sigma; x)$$

Quantile function:

$$Q_{\mathrm{sr}}(\sigma, \nu; P) = \sigma\sqrt{\frac{\nu(1-(1-P)^{2/\nu})}{(1-P)^{2/\nu}}} \xrightarrow[\nu\to\infty]{} Q_{\mathrm{rayleigh}}(\sigma; x)$$

about Student-RayleighMon



Spectrogram of data: **(short time Fourier transform)**

$$S(t_i,\ f_j)\ \ (1 \le i \le N,\ \ 1 \le j \le M)$$

Quantiles of data:

$Q_P(t_k, f_l)$ is P-percentile of $S(t_i, f_j)$

$$(1 \le k \le N/n,\ \ 1 \le l \le M/m,\ \ n(k-1)+1 \le i \le nk,$$
$$m(l-1)-1 \le j \le ml,\ \ n = \mathrm{d}t/\mathrm{d}t_{\mathrm{fft}},\ \ m = \mathrm{d}f/\mathrm{d}f_{\mathrm{fft}} = \mathrm{d}f\ \mathrm{d}t_{\mathrm{fft}})$$

Theoretical Quantile:

$Q_{\mathrm{sr}}(\sigma, \nu; P)$ $\quad\cdots\quad$ (shown in previous slide)

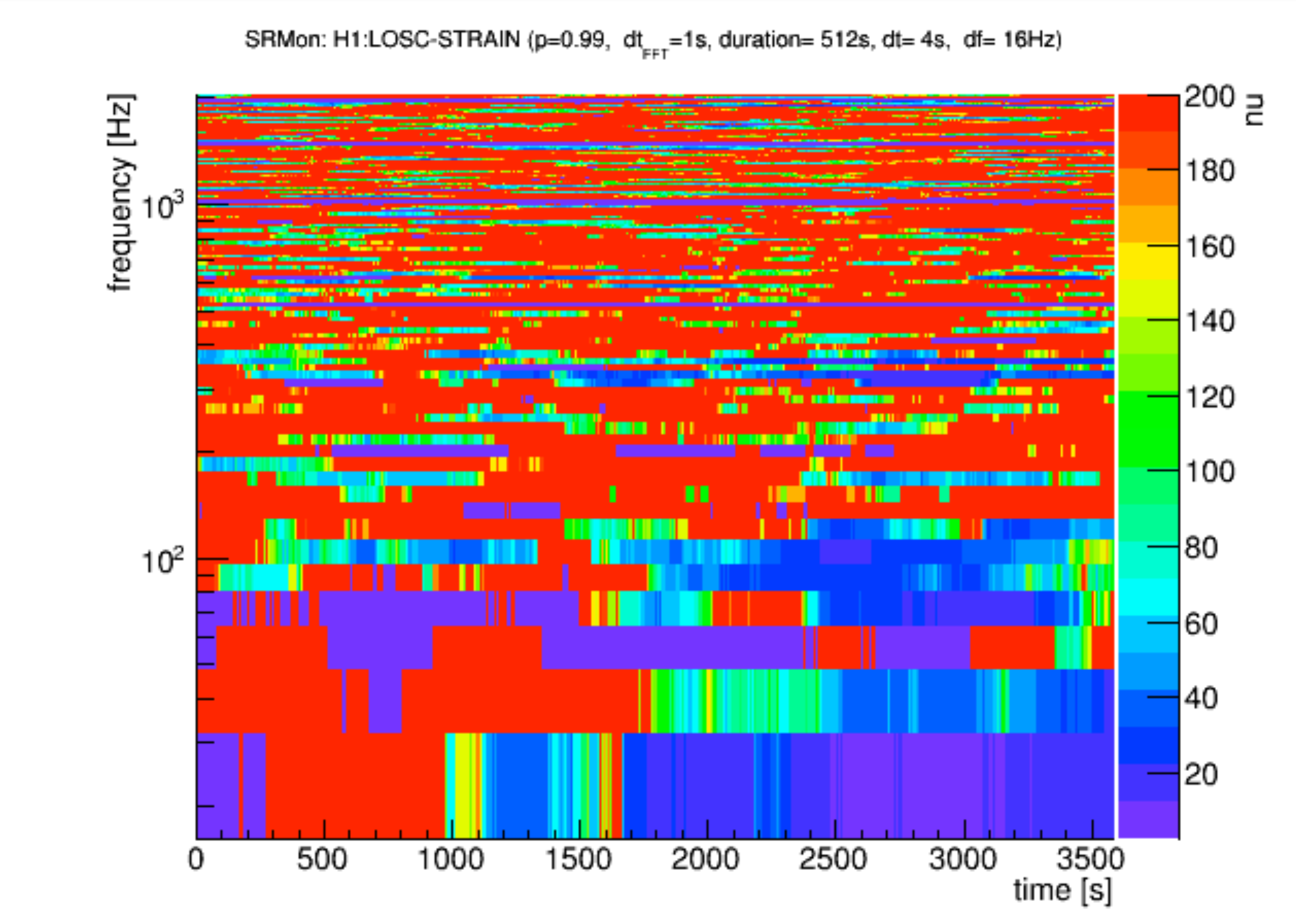
Degree of Non-Gaussianity:

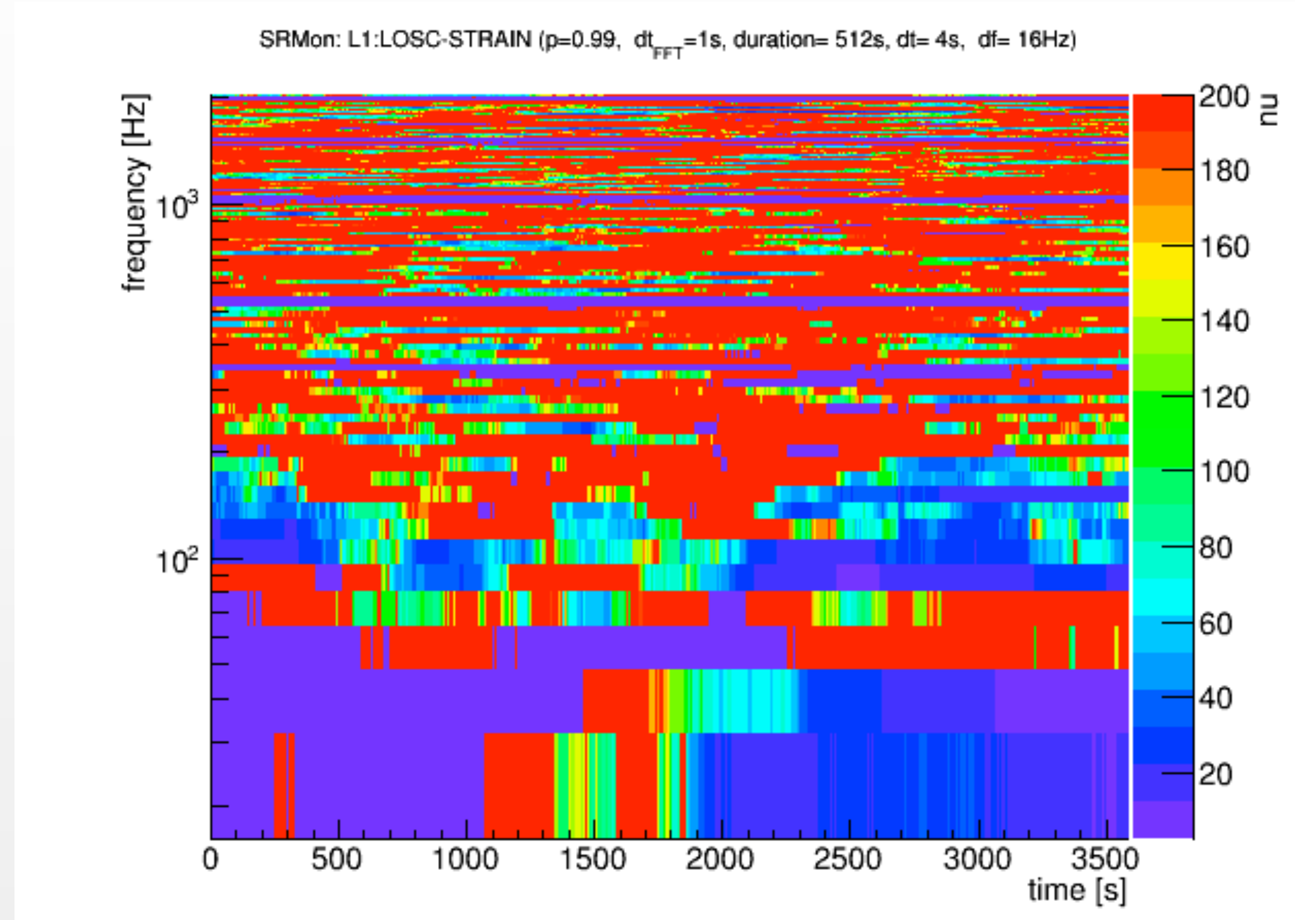
$$\nu(t_k, f_l) = \arg\min_{\nu} |Q_{P=P_0}(t_k, f_l) - Q_{\mathrm{sr}}(\sigma, \nu; P = P_0)|$$

In daily monitor, parameter is fixed.

$$\mathrm{d}t_{\mathrm{fft}} = 1\ \mathrm{s},\quad P = 0.99,\quad \mathrm{d}t = 3600\ \mathrm{s},\quad \mathrm{d}f = 16\ \mathrm{Hz}$$

Results of Student-Rayleigh monitor





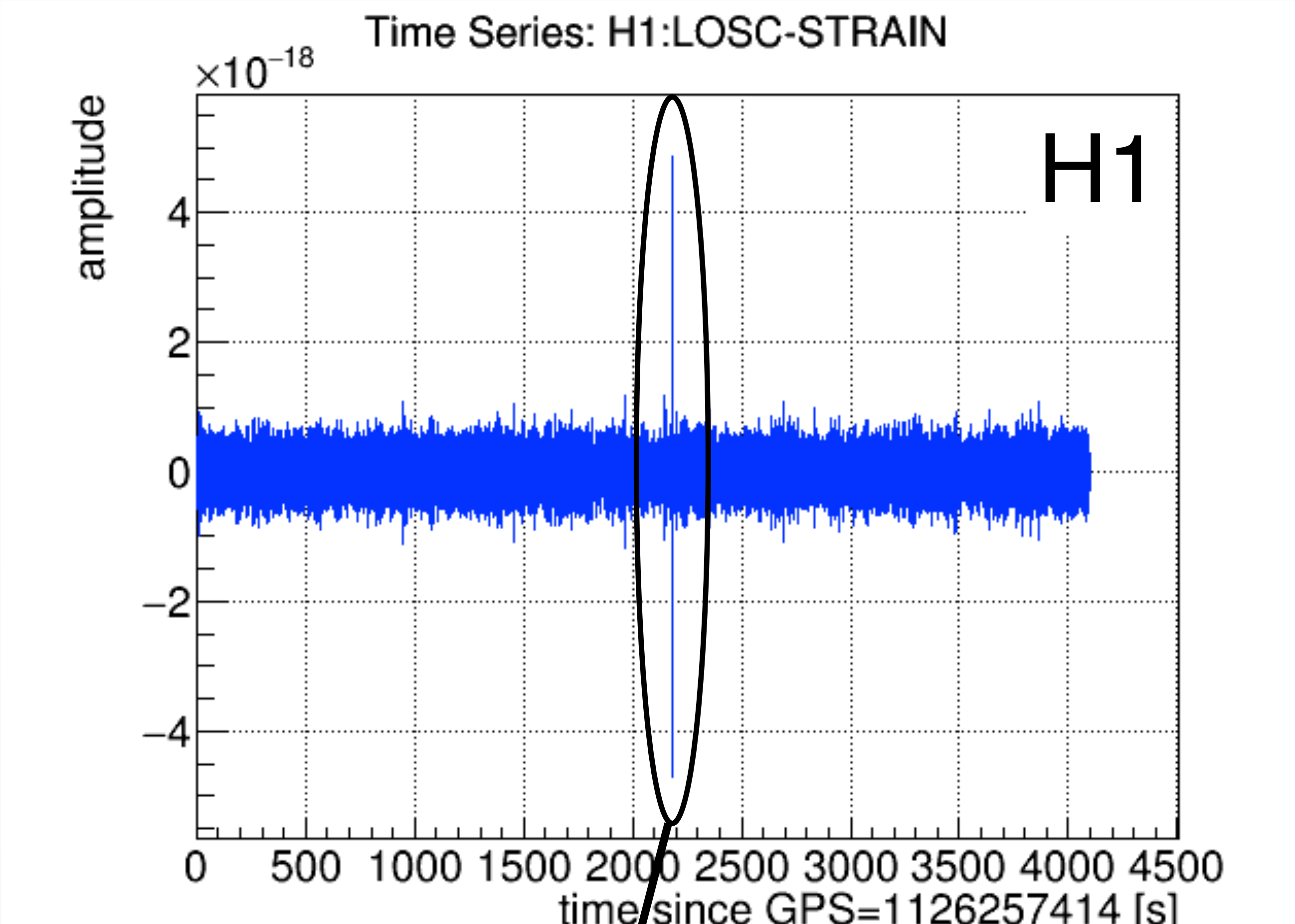
Non-Gaussianity can be seen in low frequency band.

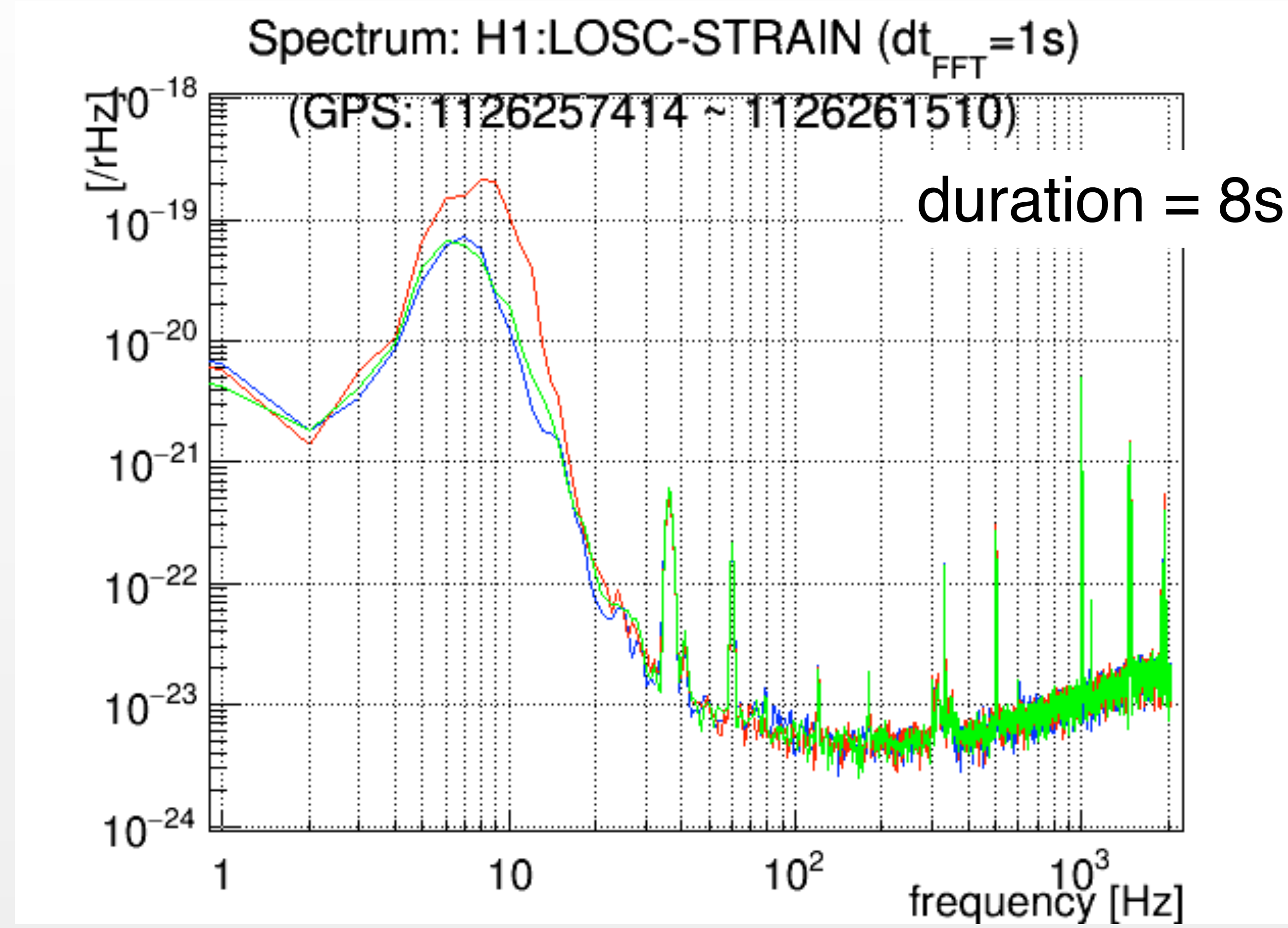
Gaussian hypothesis is rejected in $\nu \leqq 45$

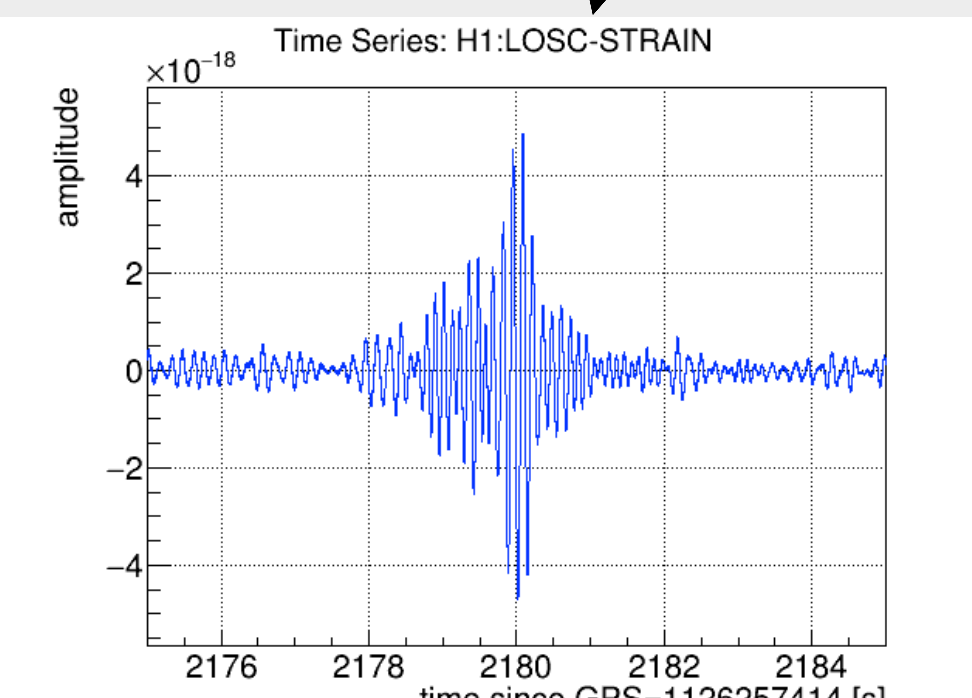
Above 200Hz, noise can be regarded Gaussian
in many time-frequency regions
except for line noises.

Parameters:
- data length of FFT : 1s
- duration : 512s
- data overlap : 508s
- time resolution : 4s
- frequency resolution : 16Hz

Strain signal h(t) of H1







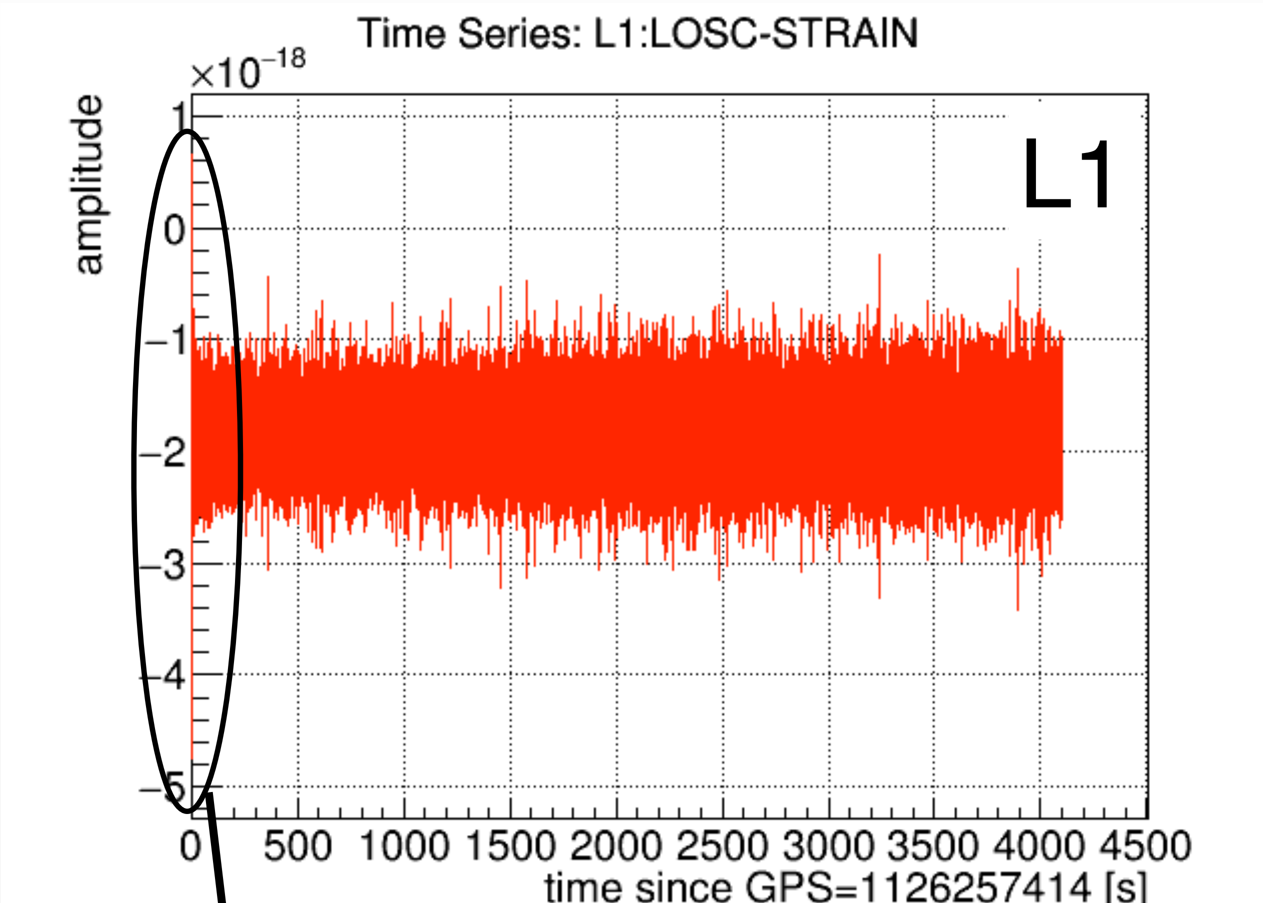
There is a loud signal at 2180s

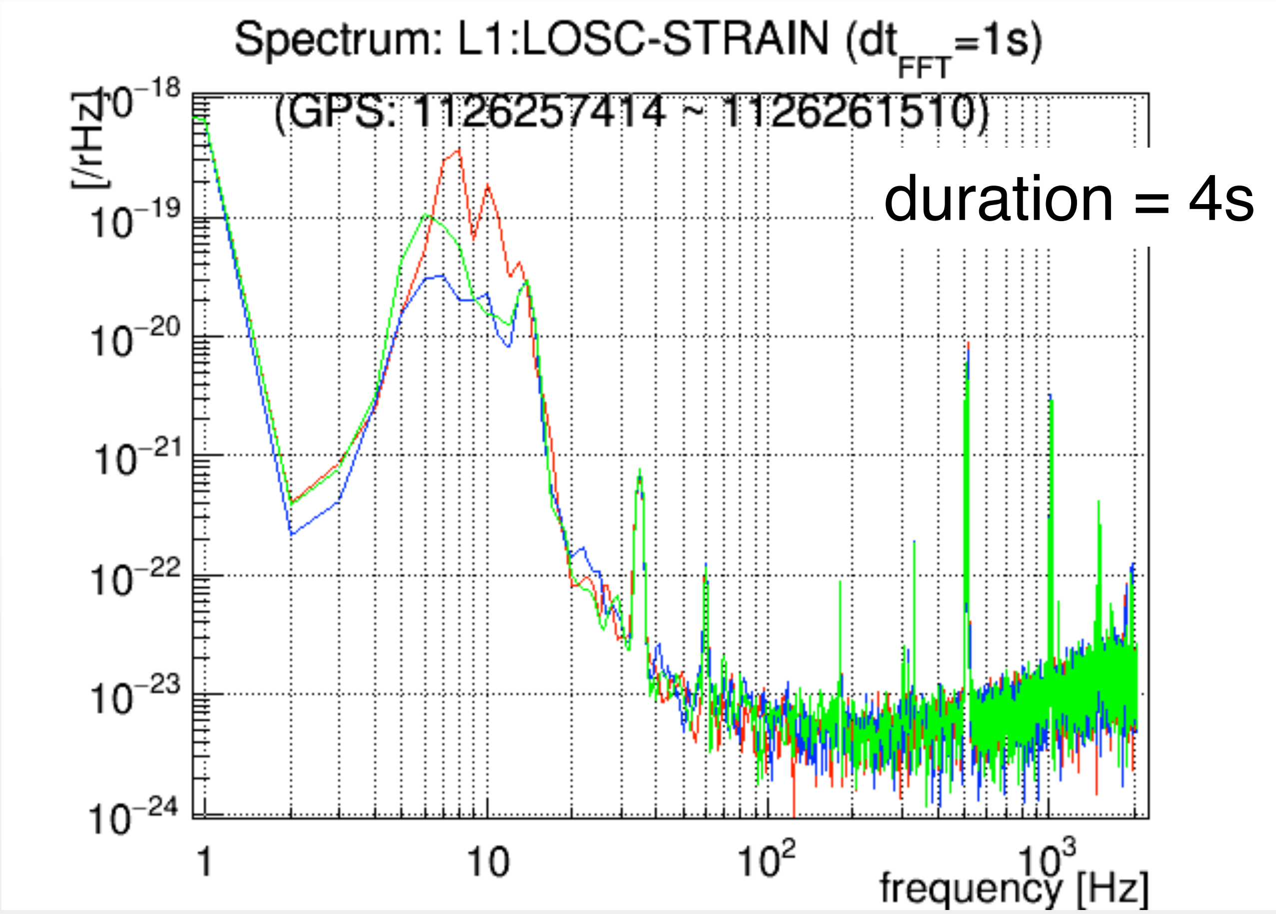
This may be a transient noise
whose characteristic frequency is 8~9Hz.

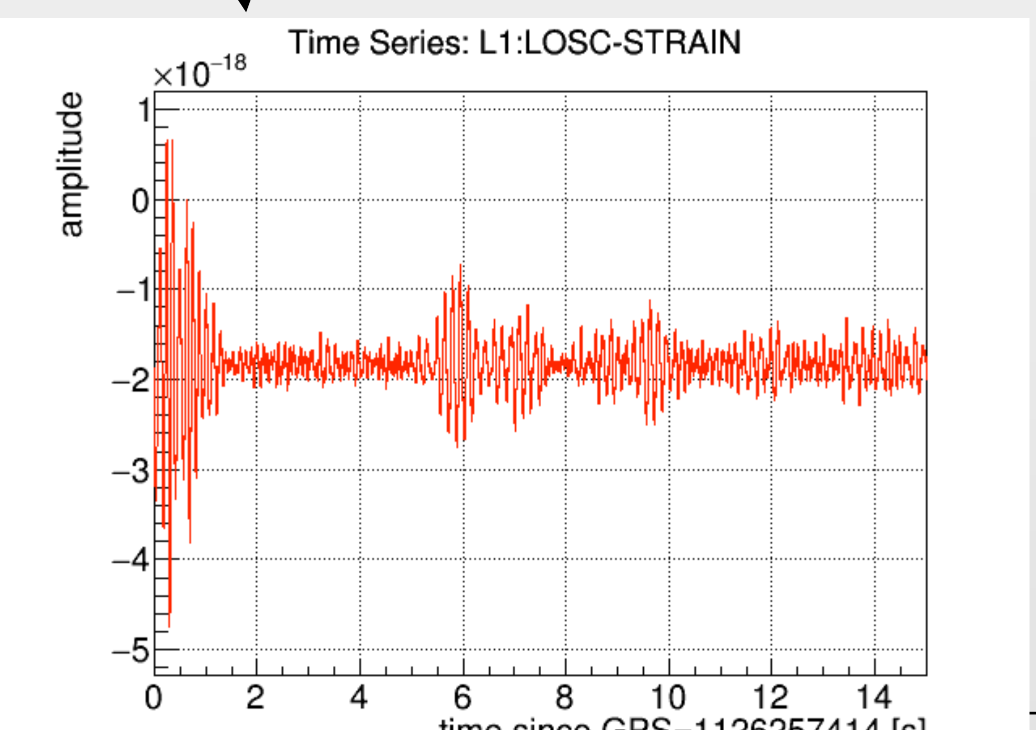
Red spectrum contains a transient noise.

Blue and green show spectrums of
before and after a transient noise.

Strain signal h(t) of L1







There is a loud signal at 0s

This is also a transient noise
whose characteristic frequency is 8~9Hz.

Red spectrum contains a transient noise.

Blue and green show spectrums of
4s and 8s after a transient noise.