Development of line removal methods

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Outline

- **Introduction**
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  - Motivation
- **Line removal method->MBLT**
  - Method
  - implementation
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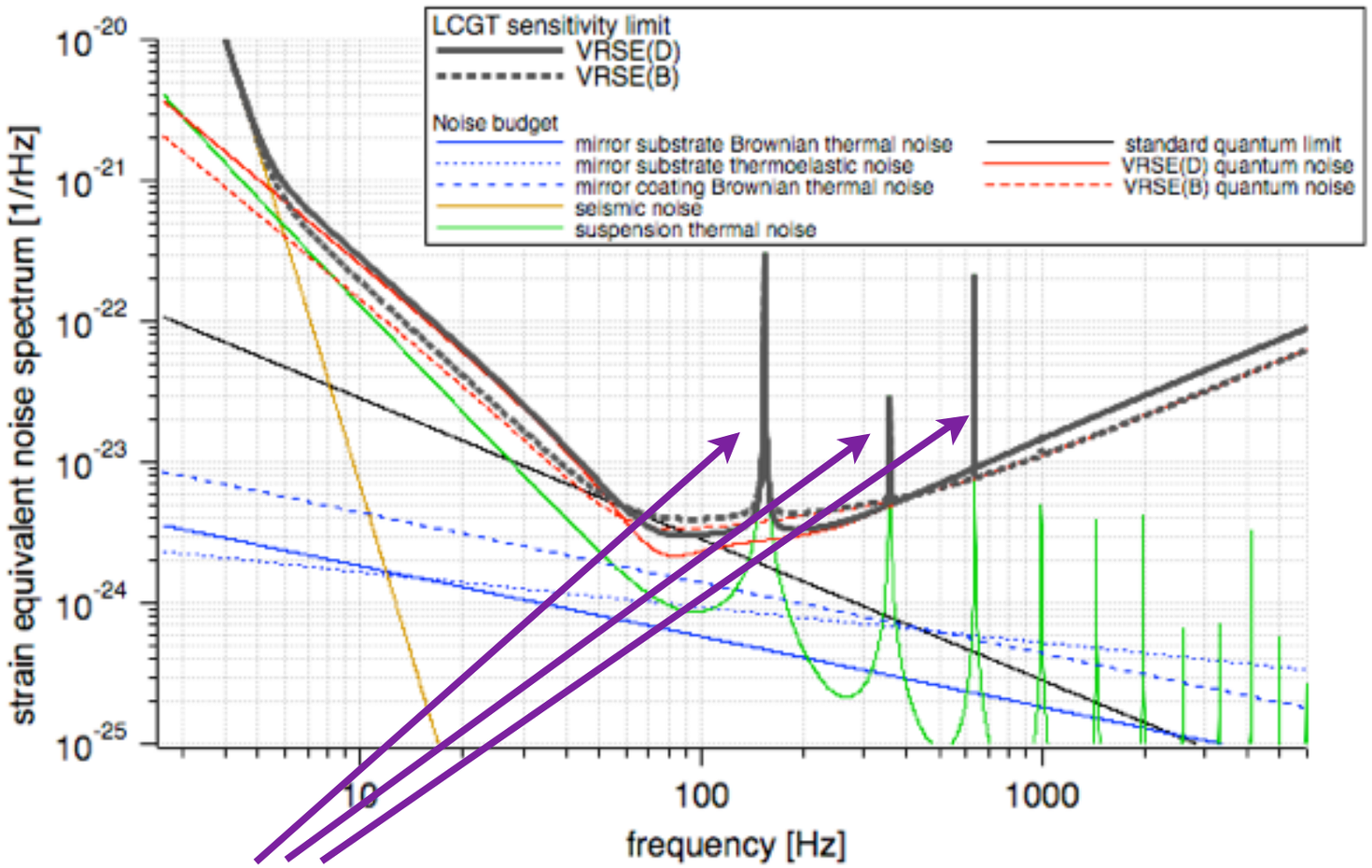
  - various Q values
  - effect to the detection of GW burst signal
  - apply to real data(LIGO S5)
- **Summary and future plan**

Introduction

◆**What's narrow band noise**

KAGRA's design sensitivity curve



<u>Narrow band noise of GW detector (called line)</u>

-> Caused by the elastic vibration of the wire of the noise and the suspension system of power

Motivation

- **Problem of Lines**
  - The detection of GW signal becomes difficult when the overlap in terms of frequency narrow band noise
  - Lines in high sensitivity area

⇩

- **Important to remove the lines with leaving GW signal**
- **Clarify what kind of lines can be removed**
- **Clarify the benefits of the detection by line removal**

Line removal methods

- **LIGO's past observations**
  When the line affecting the signals, signals was inhibited with lines

- **Line Removal method that was used this time**

Soumya D Mohanty (2002)stacks.iop.org/ CQG/19/1513

MBLT(Median Based Line Tracker)

< Feature >

- small effect on the transient signal
- possible to follow the frequency variation of lines
- remove lines in time domain
- depends on the center frequency and Q value of lines

MBLT Algorithm

Assume that center frequency and Q values of lines are known

step1

x :time series before MBLT

apply Heterodyne,
apply low path filter

$$X + iY = \mathcal{L}(x * Z)$$
$$Z = exp(-2\pi i f_c t)$$
$\mathcal{L}$: cutoff frequency = f_c LPF

X : Real part
Y : Imaginary part

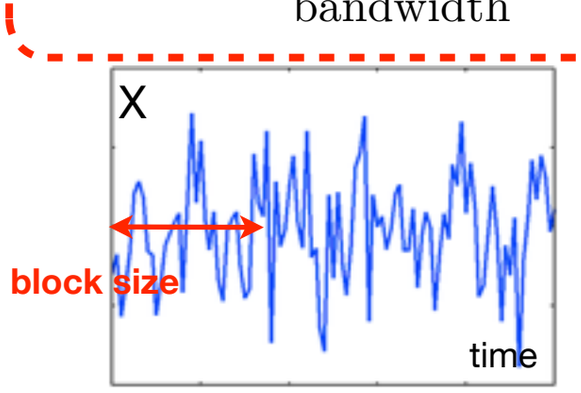
step2

calculate median X,Y

$$\mathcal{X} = median(X), \mathcal{Y} = median(Y)$$

block size of calculating madian

$$\text{blocksize} = \frac{1}{\text{bandwidth}} = \frac{Q}{f_c}$$



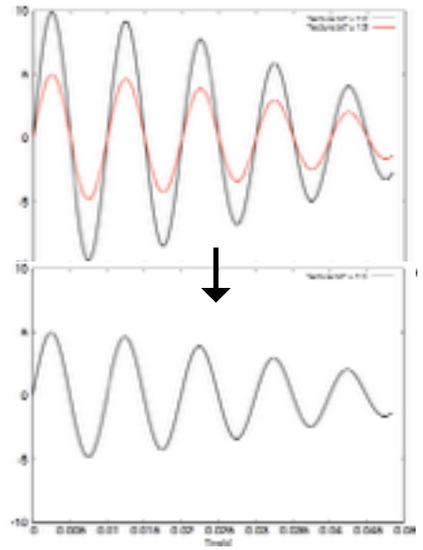
e : estimated time series

$$e = Re\left((\mathcal{X} + i\mathcal{Y}) * Z^*\right)$$

step3

$$x - e$$

example
black:time series of line
red:estimated time series in step2



can reduce the line

Repeat this steps until removing lines

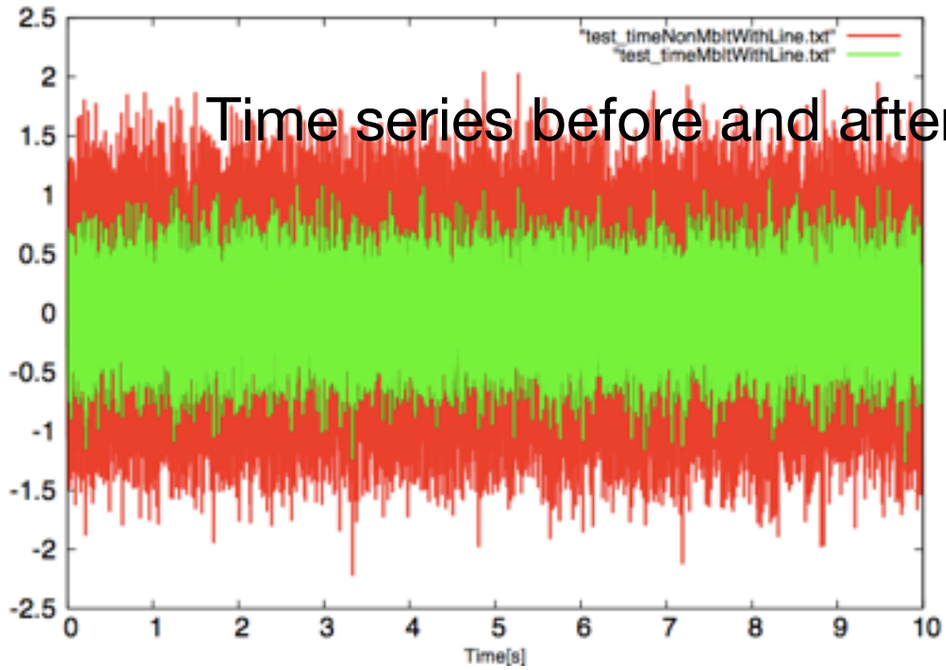
Center frequency and Q value are important
(ex：change the accuracy of the median estimated by block size)

MBLT operation check

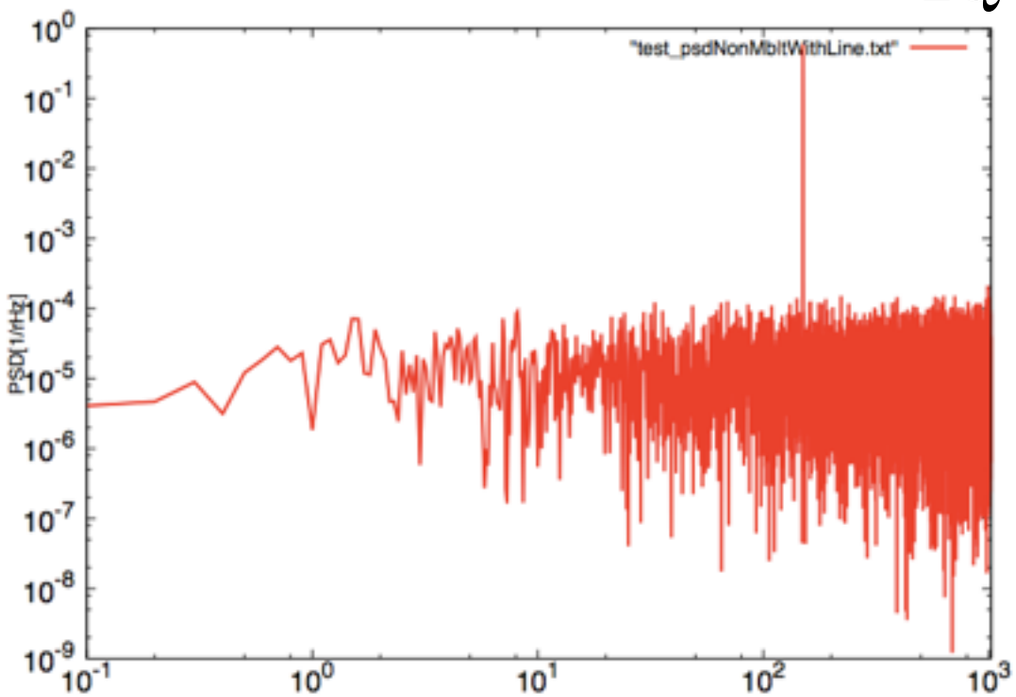
operation check data

- gauss noise
  - sampling rate = 2048 [Hz]
  - time = 10 [s]
- dumped sine signal
  - center freq=150[Hz]
  - Q value=10^6

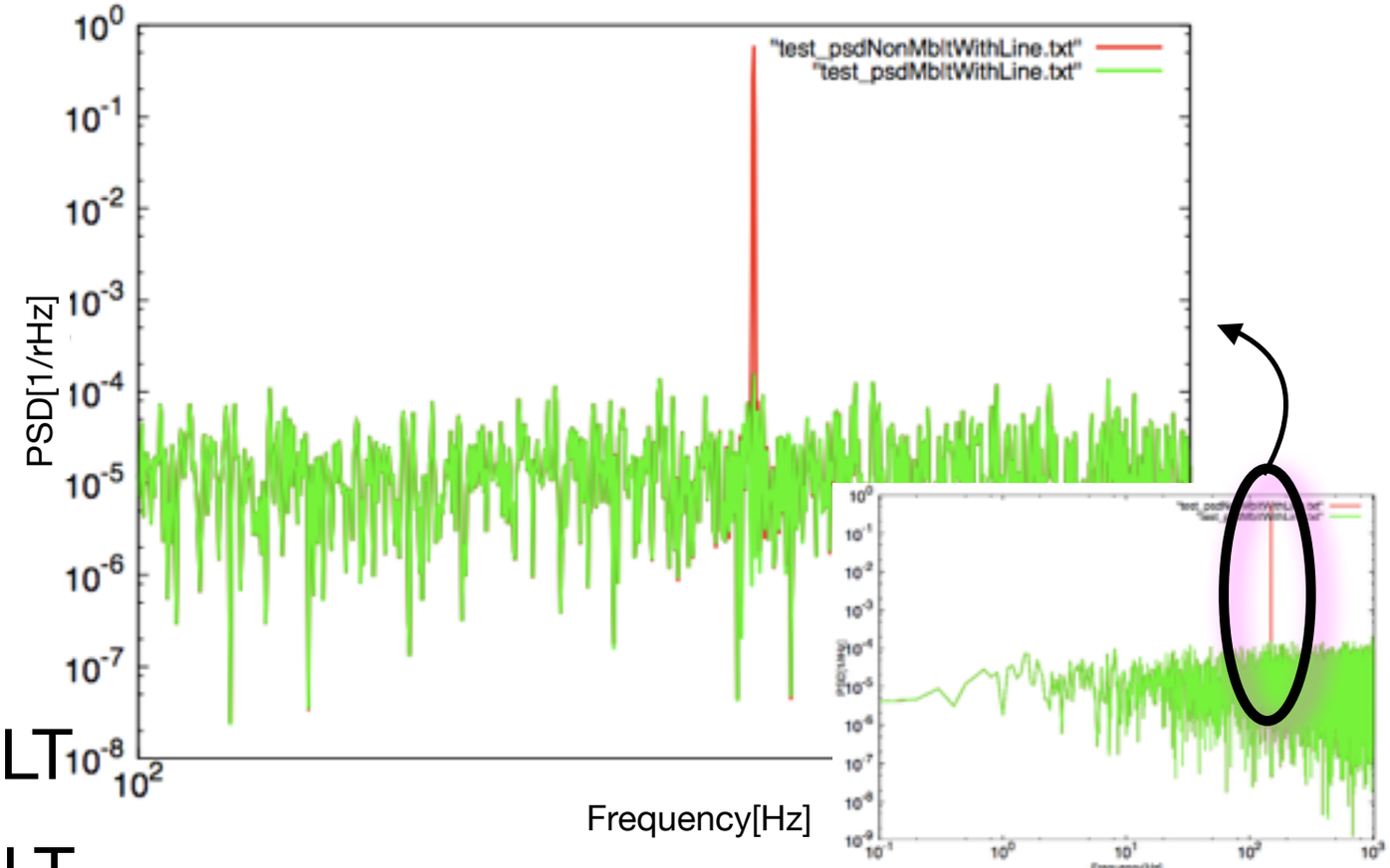
$$A\sin(2\pi f_0 t)\exp[-\frac{2\pi f_0 t}{2Q}]$$



Time series before and after MBLT



MBLT

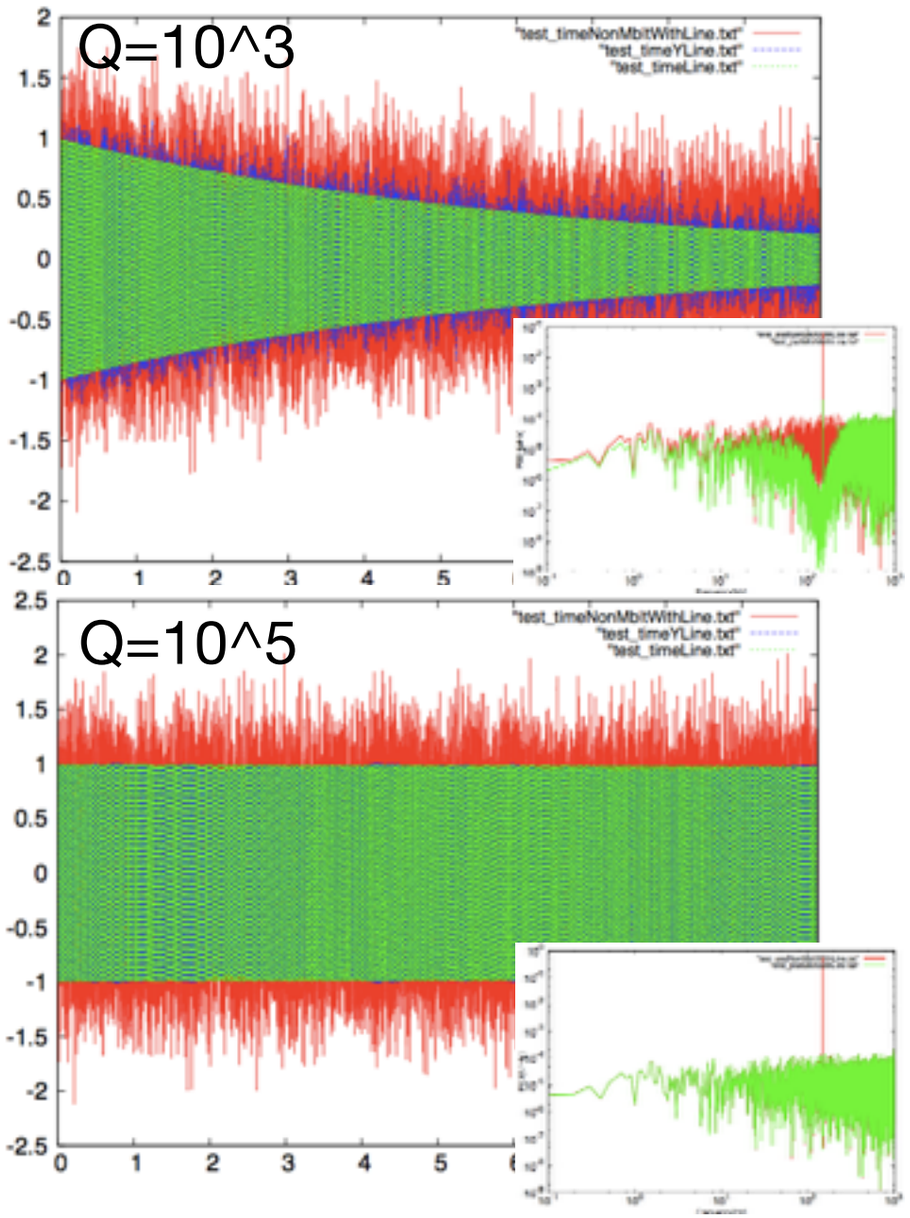


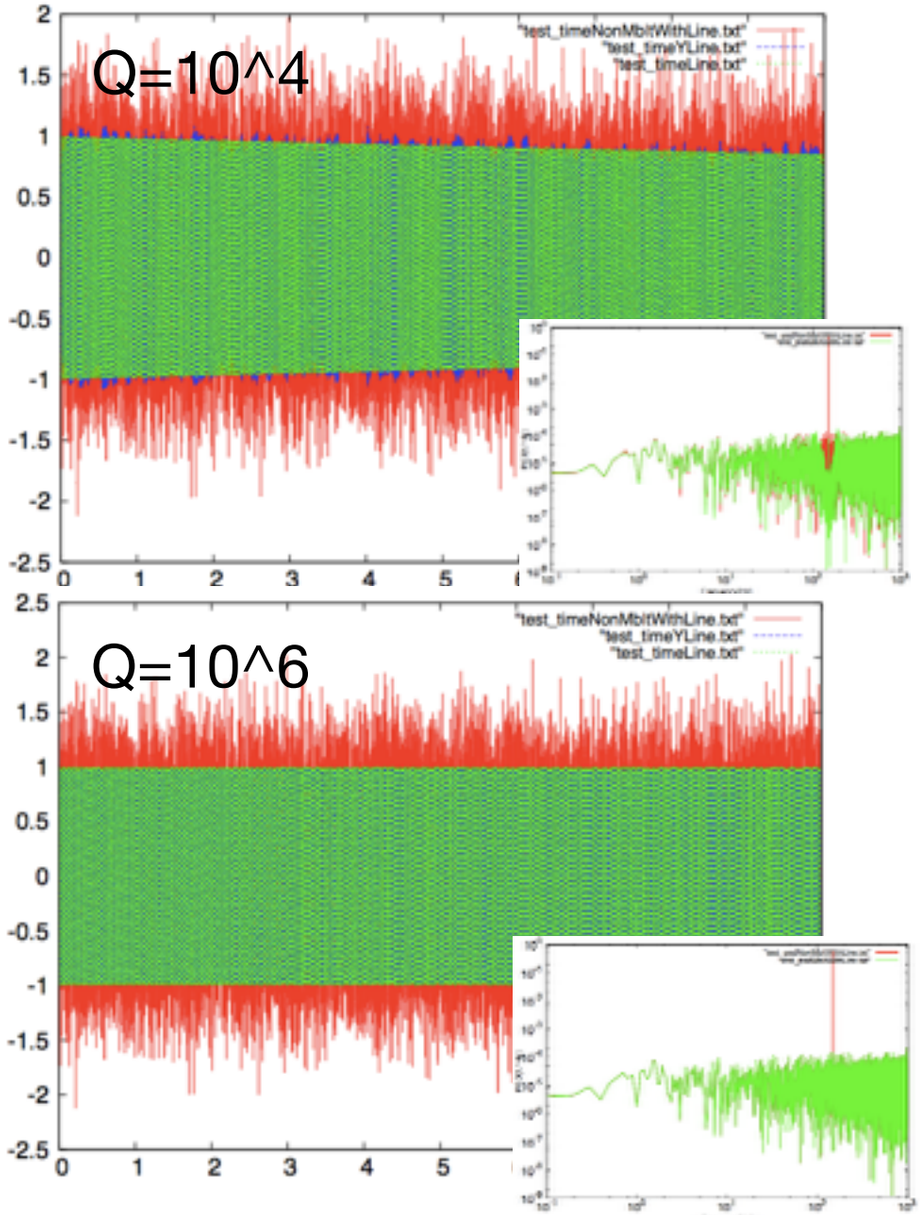
Red：before MBLT

Green：after MBLT

MBLT operation check

for example,inject
center freq=150[Hz], various Q value dumped sine signal
to
sampling rate =2048[Hz], time=10[s] Gauss noise





time series
red：before MBLT
green：line
blue：estimated time series

spectrum
red：before MBLT
green：after MBLT

Motivation

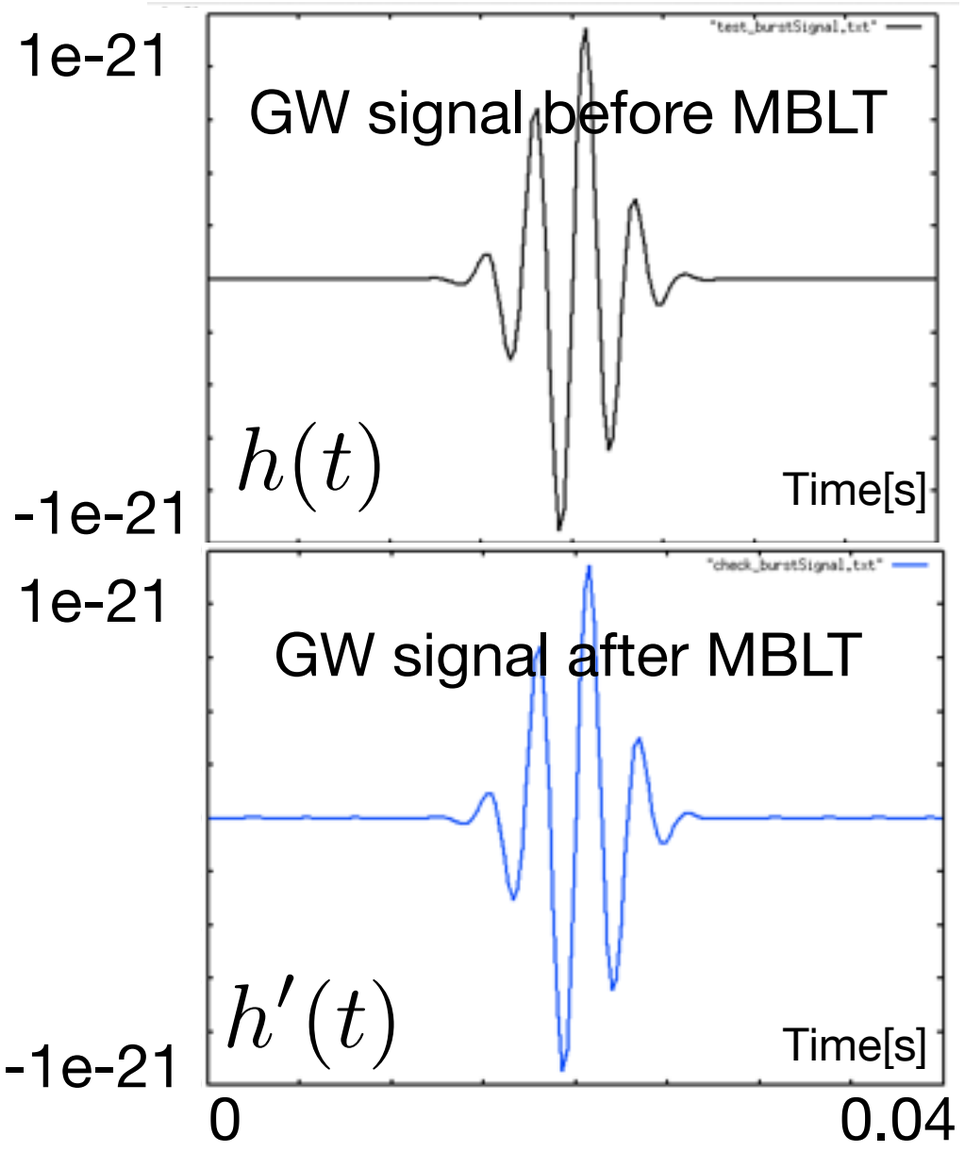
- Important to remove the lines with leaving GW signal
- Clarify what kind of lines can be removed
- Clarify the benefits of the detection by line removal

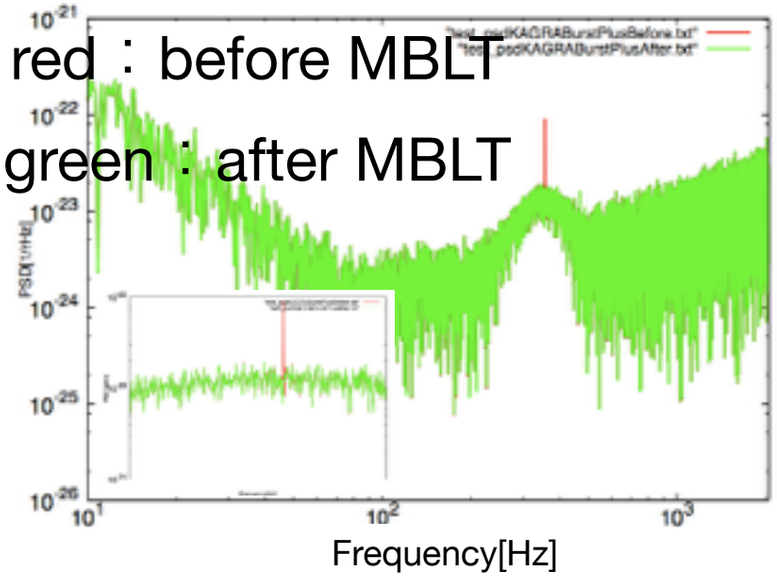
Is it possible to remove the line while leaving GW burst signal ?

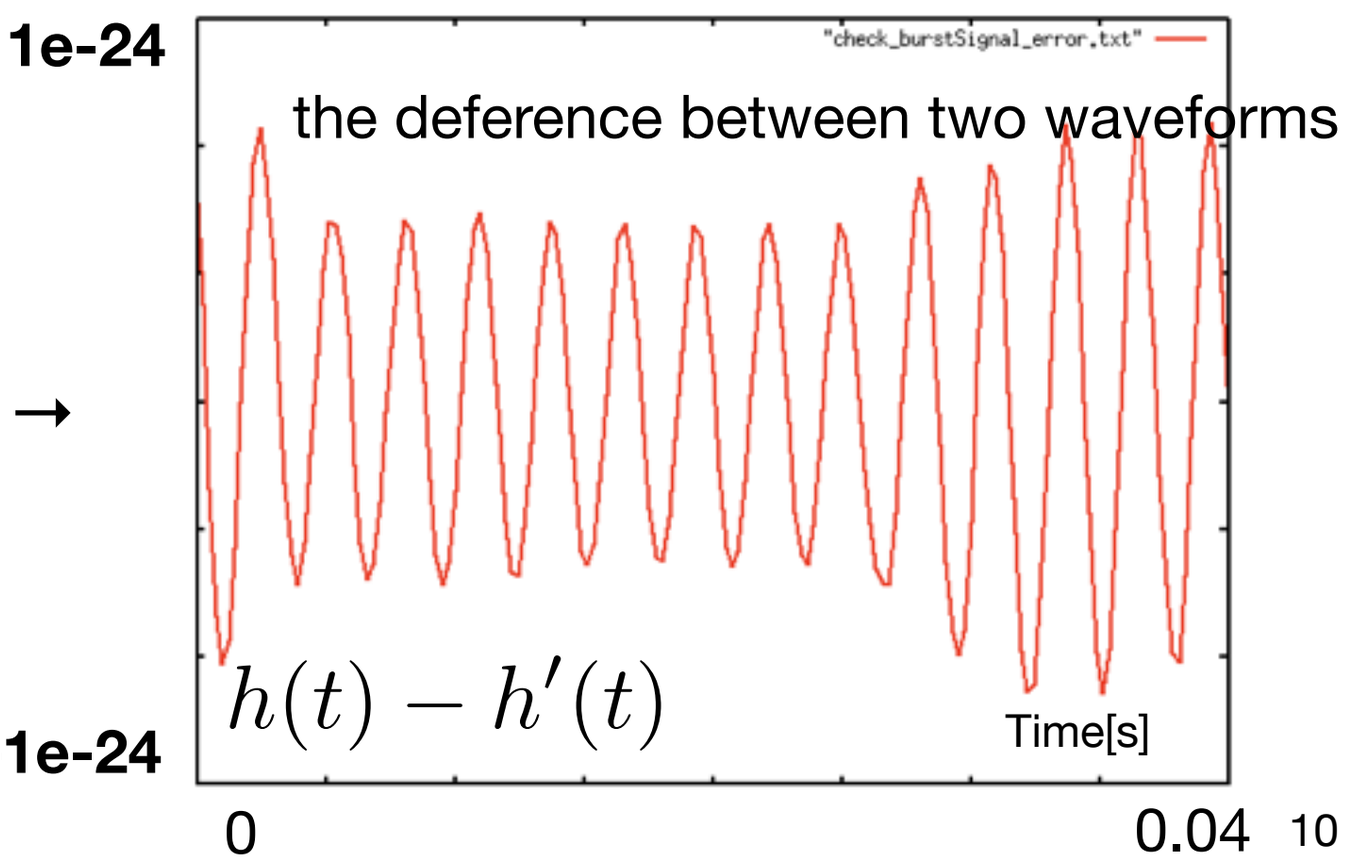
Effect on GW burst analysis

◆**Injection GW signal and line to KAGRA's simulation data**

- •GW signal : sine gaussian
- •center frequency of line and GW signal is the same
- •confirm signals not removed together





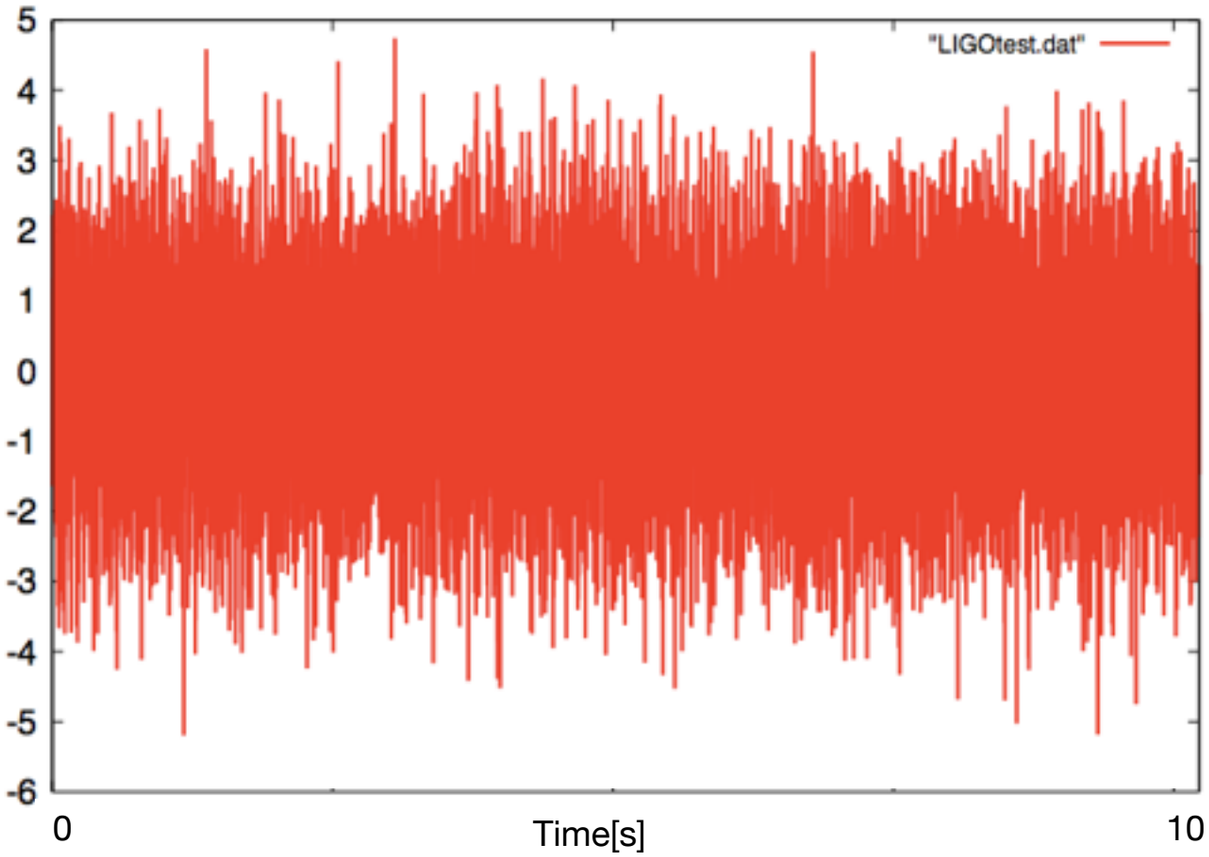


For real data

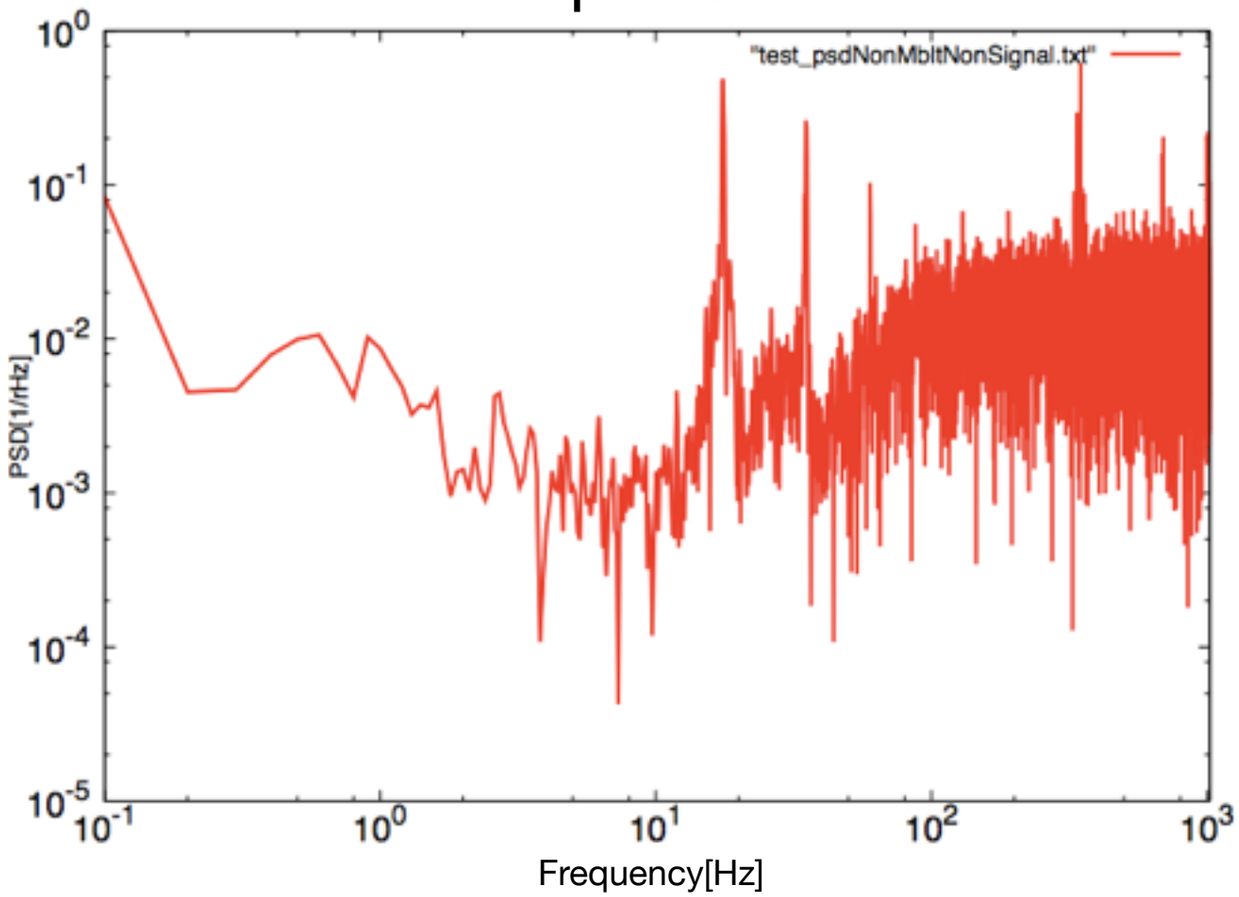
◆**LIGO's data (LIGO S5(H1) data)** T=10[s],fs=2048[Hz]

LIGO data which was conditioned other than line

time series



spectrum



the lines in 17,35,60,337,345,695Hz

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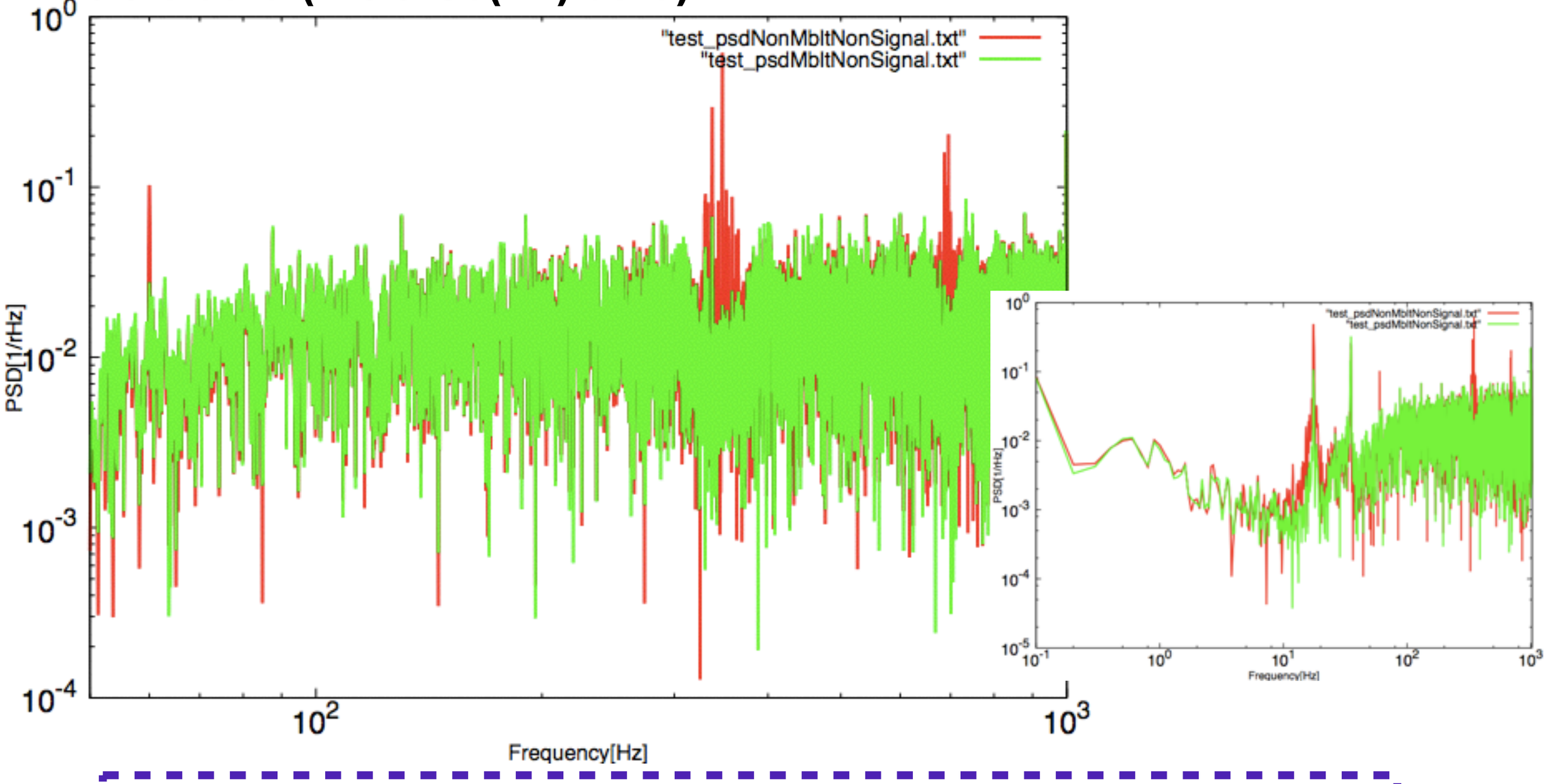
For real data

◆LIGO’s data (LIGO S5(H1) data)



Also operates on real data, is likely to be removed or reduced to some extent lines

summary and future plan

summary

- We have implemented MBLT
- High Q lines are advantageous when removing with MBLT
- Success to remove line with leaving signal
- Operation check by real data(LIGO S5)

-> 100Hz~ lines can be removed successfully

-> ~100Hz lines cannot be removed -> need more detail checks

future plan

- Measures in the case where there is more than one line at a frequency close
- Understand what type of lines can remove or can't remove
  - -> Q value dependence
  - -> frequency dependence
  - -> noise level dependence
- Reduce the lines that cannot be removed

END