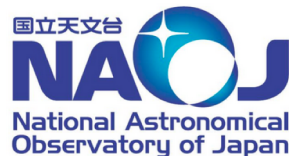


Development of the new Detchar tool GlitchPlot

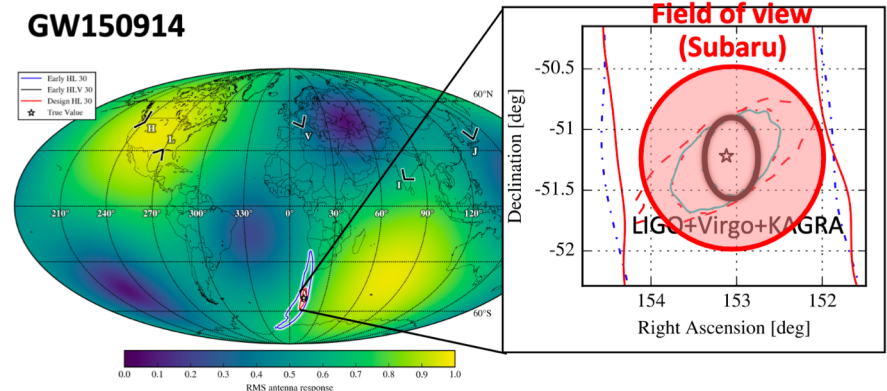
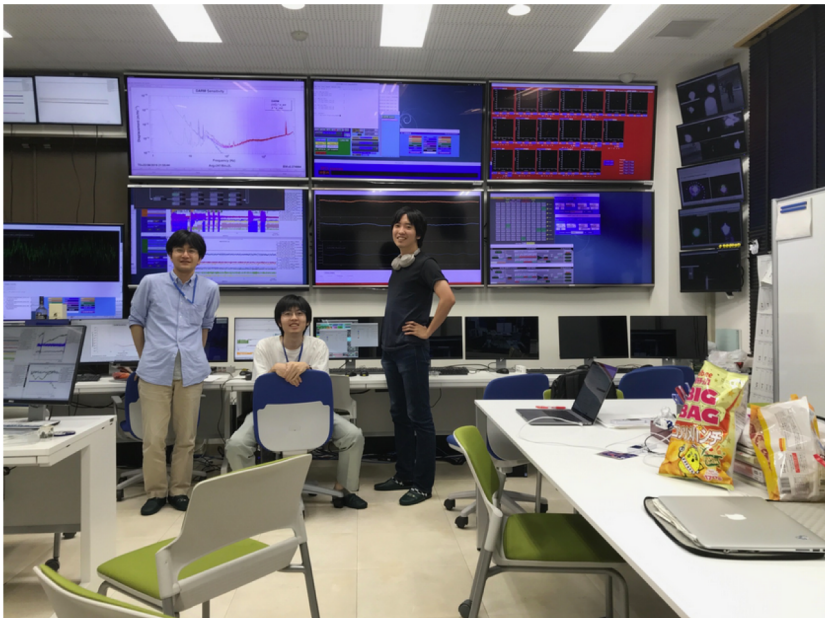
Chihiro Kozakai (NAOJ), KAGRA collaboration

2019/10/14 GWPAAW@RESCEU



KAGRA

- We are on hard working to join the GW observation network within 2019 !
 - FPMI lock is achieved in August. Sensitivity improvement is ongoing.
 - When KAGRA join the observation, significant improvement of GW source direction resolution is expected.



Localization area (realtime analysis)

LIGO: 600 deg² => 300 deg²

LIGO + Virgo: 5.5 deg²

LIGO + Virgo + KAGRA: 1.2 deg²

<https://arxiv.org/pdf/1703.08988.pdf>

TAUP2019 talk by M. Tanaka

GW Interferometer noise

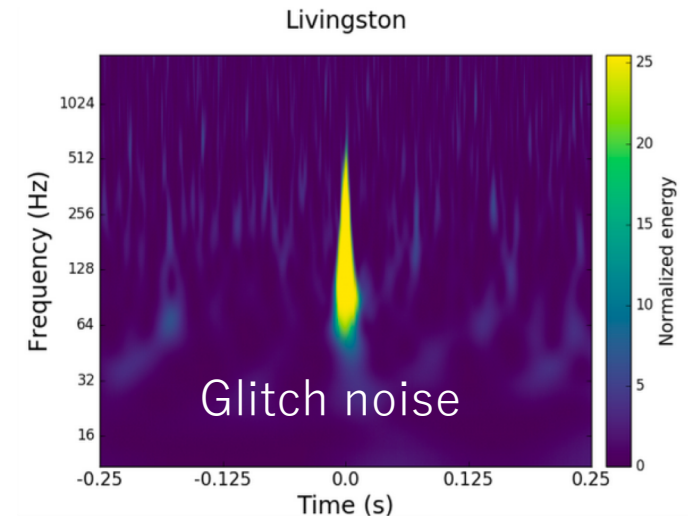
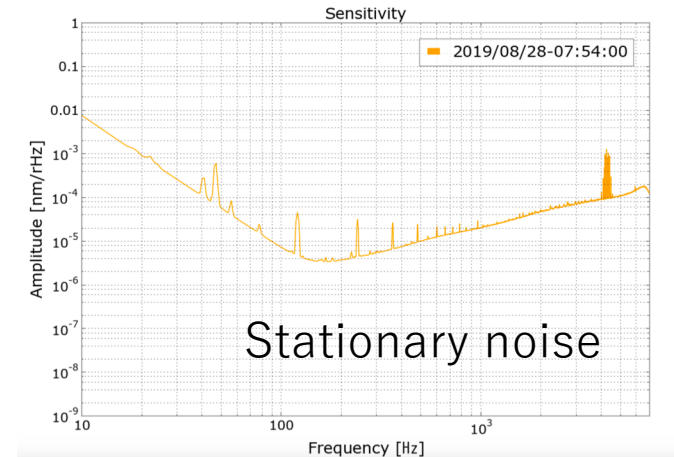
- Noise can be classified in 2 categories.

1. Stationary noise

- Noise which is not local in time.
- It affects how small $h(t)$ is detectable.

2. Glitch noise

- Due to problem in hardware side, the GW signal is sometimes contaminated by large signal.
- It affects false alarm rate.
- **It is important to distinguish glitch from true GW events like CBC and burst events.**



Investigation of the glitch noise

- By investigating the cause of noise and eliminating them, we want to lower the threshold to detect the GW signal and improve the reliability to identify the event as GW origin.
→ It is necessary to check if the detector is working well.
- As a simple method, a tool for easy visual inspection of the detector state, “GlitchPot” was developed.
 1. To search glitch noise, external tool is used.
 - Omicron (Q-transform based search, developed by F.Robinet)
 - Preparation for combination with data analysis pipeline is ongoing.
 2. According to the result of 1, plots of each auxiliary channels are provided.
 3. With the cooperation of Yuzurihara-san(ICRR), the result is easily accessible on website and collaborators can vote their opinion about the glitch origin.
- ✓ It is also useful for detector sanity check for GW event candidate.
- ✓ It can be applied to lock loss event investigation too.

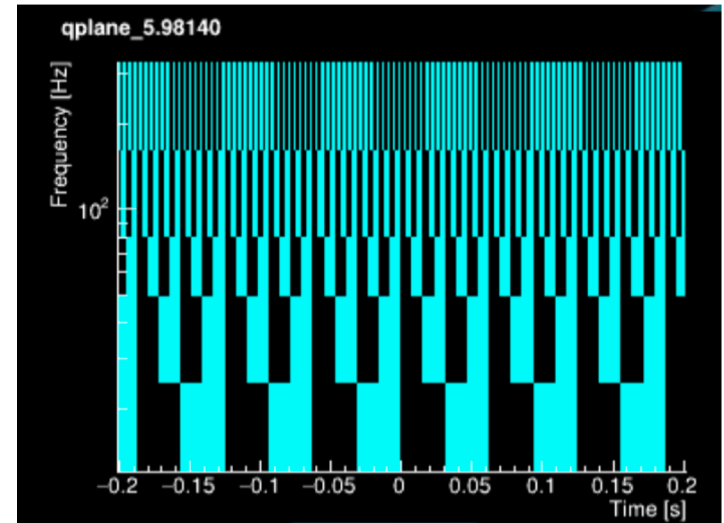
search for glitch noise

- Software library developed by F. Robinet : Omicron is used.
 - **Search for time-frequency bin with large SNR using Q-transform.**
 - Q-transform : Spectrogram with variable time window depending on frequency.

$$X(\tau, \phi, Q) = \int_{-\infty}^{+\infty} x(t)w(t - \tau, \phi, Q)e^{-2i\pi\phi t} dt.$$

$$w(t - \tau, \phi, Q) = \frac{W_g}{\sigma_t \sqrt{2\pi}} \exp \left[-\frac{1}{2\sigma_t^2} (t - \tau)^2 \right], \quad \sigma_t^2 = \frac{Q^2}{8\pi^2 \phi^2}$$

- It is performed for several Q value. The list of large SNR bin in each Q is output.
- Omicron provides time, frequency, band width, duration, SNR and so on. ○



- Omicron usually provides multiple output for 1 event from several Q value or several frequency/time. Here, continuous or overlapping time output is counted as 1 event.

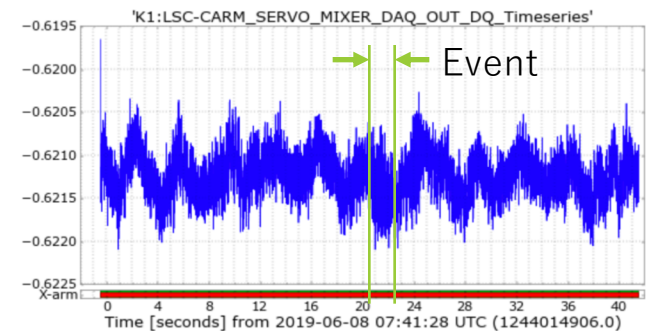
Making plots

- Several basic plots are provided for all channels which may affect to the main channel.
 - Time series
 - Spectrum
 - Spectrogram
 - Q-transform
 - Coherencegram
 - Main (trigger) channel
 - Upstream channel
 - Channels used for interferometer control
 - Suspension channel
 - Physical environmental monitor channel etc.
- There is many types of glitches. The parameters for plot should be optimized depending on the property of each glitch.
 - Using Omicron information, the plot parameter is automatically determined.

Plot parameter determination

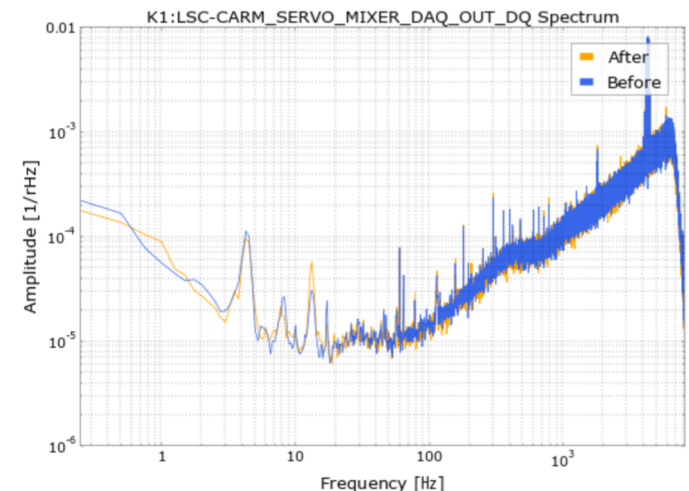
● Time series

- To see immediately before and after the event, 10 times long time as event duration is plotted before and after the event. If too short, the time is extended to 2 sec.
- ✓ The glitch event comes to the center of the plot.
- ✓ Fine tuning according to the spectrogram setting (described later)



● Spectrum

- Taking 2 sec margin, check spectra of immediately before and after the glitch. (Spectrum of the event itself will be provided in spectrogram.)
- ✓ Check if glitch cause state change.
- Enough frequency resolution is given according to the band width of the event.



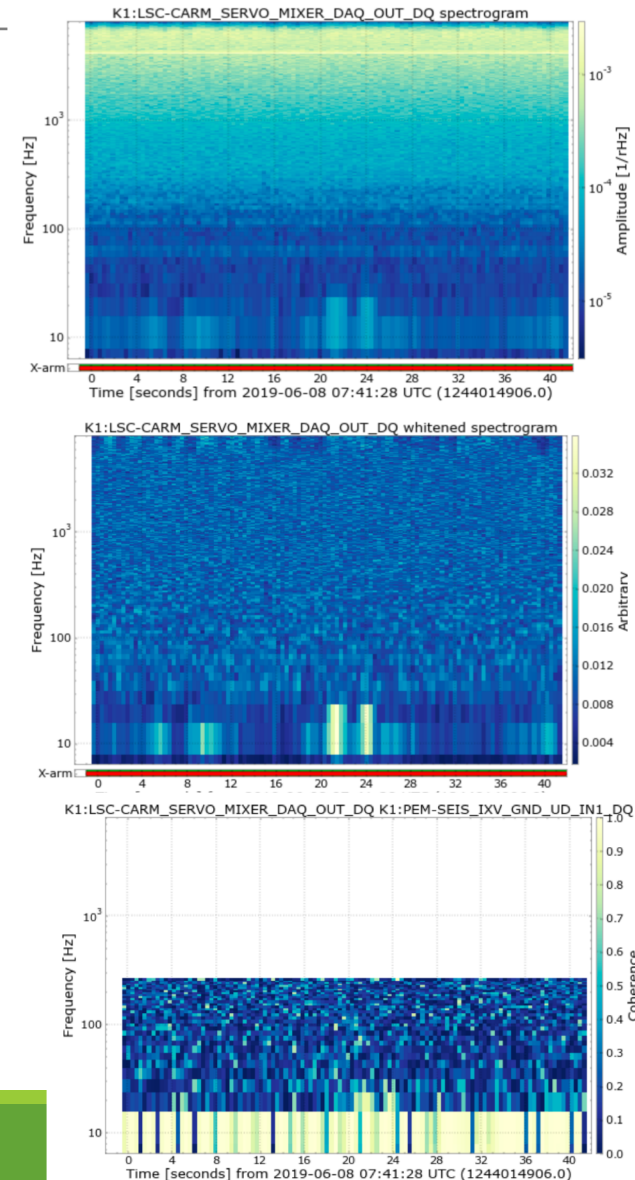
Plot parameter determination

- Spectrogram :

$$X(\omega, t) = \int_{-T}^T x(\tau) w(t - \tau) e^{-i\omega t} d\tau$$

- Time bin width is determined to be shorter than event duration.
 - Trade off with frequency resolution. If event duration is short, the time bin width is half of the event duration. Else it is determined according to the Omicron information.
 - Fine tuning to contain 2^n data point.
- Whitened plot is also provided.
 - Whitening : By normalizing the amplitude of each frequency, time depending component is clarified.

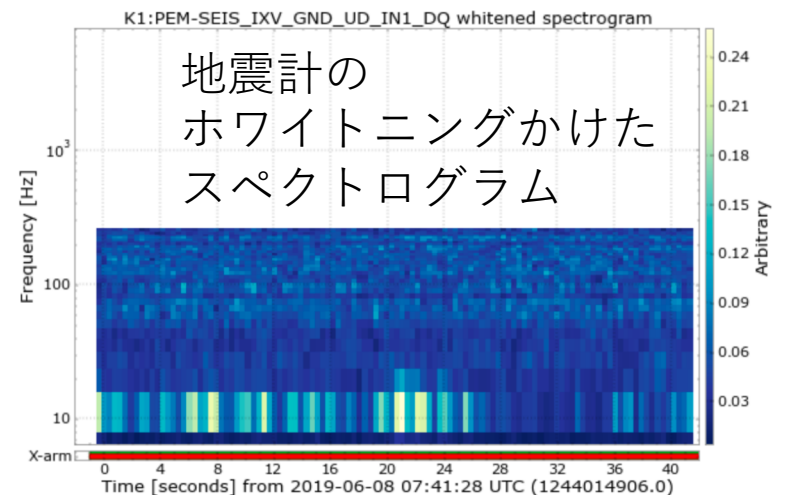
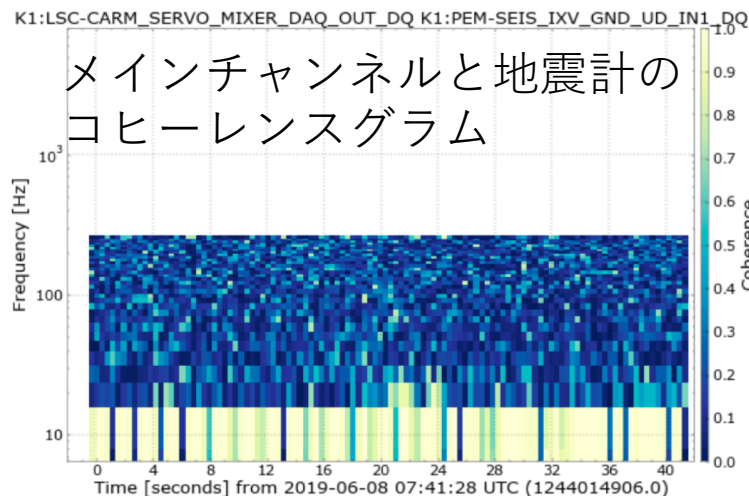
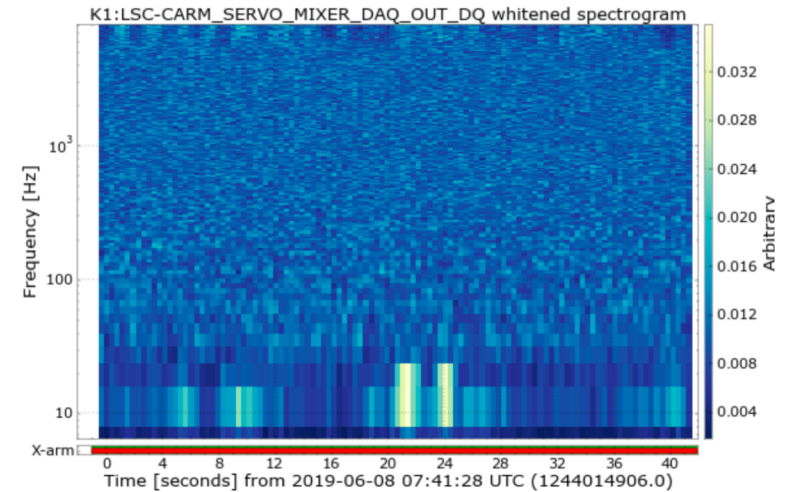
- Coherencegram : $\text{coh}^2(\omega) = \frac{|S_{xy}(\omega)|^2}{S_{xx}(\omega)S_{yy}(\omega)}$
 - Use same parameter as spectrogram.



Example of the glitch noise

メインチャンネル

- In this event, main channel and seismometer shows significantly large amplitude in the same time-frequency bin. The correlation is also confirmed by coherencegram.



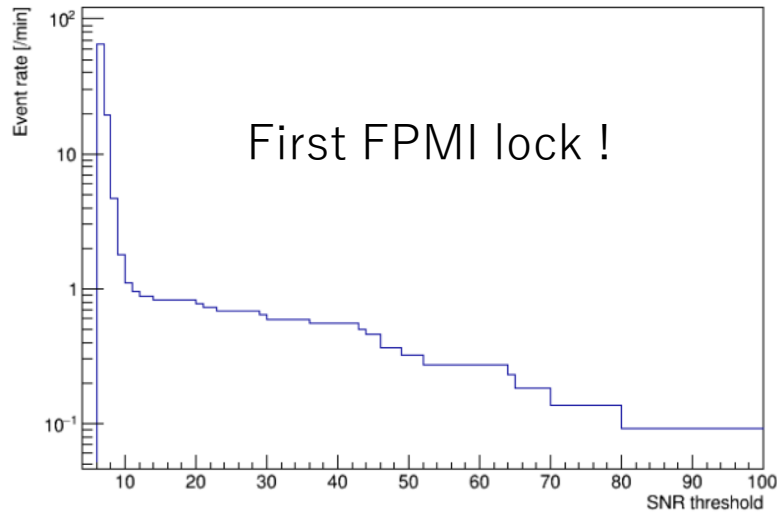
Conclusion

- Interferometer noise can be categorized into stationary noise and glitch noise. Glitch noise has to be distinguished from true GW event and we need to understand them well.
- To investigate glitch noise, a new tool “GlitchPlot” is developed.
- GlitchPlot is a tool which provides glitch related plots with optimized parameter using event information given by external tool.
- By investigating various information related to the interferometer using GlitchPlot, it will be easy to identify glitch noise from instrumental cause.
- GlitchPlot will be used for noise hunting in KAGRA and it will contribute to identify the cause of glitch noise.

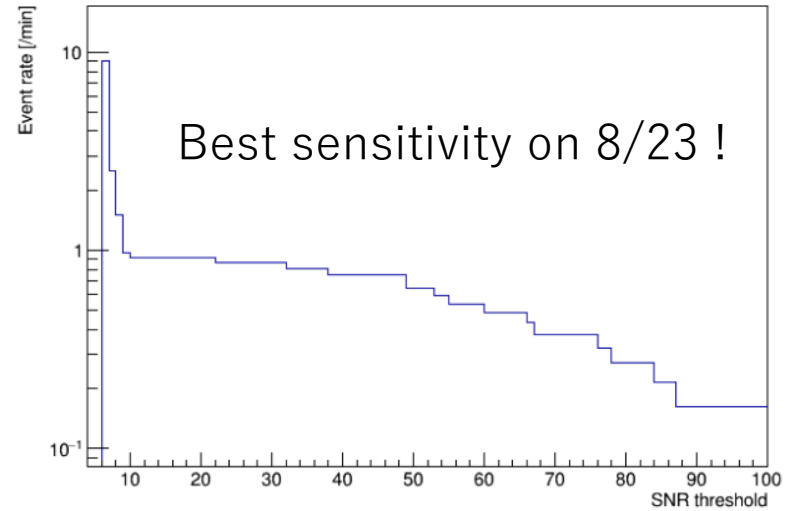
Backup

Trigger rate quick report

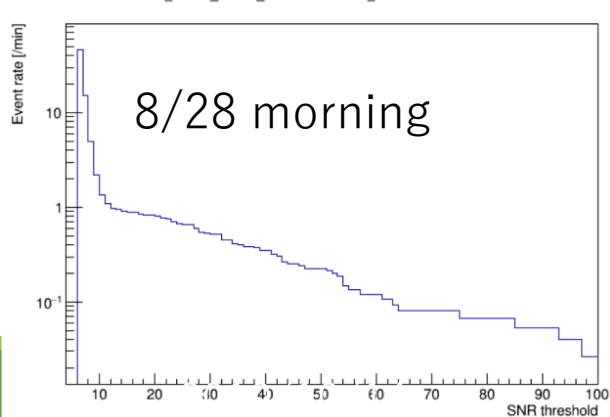
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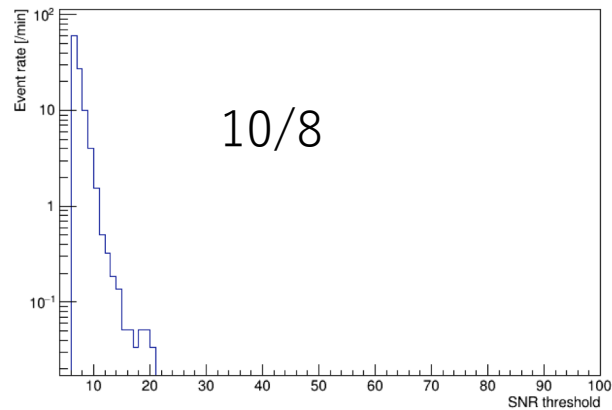
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