Development of the new Detchar tool GlitchPlot

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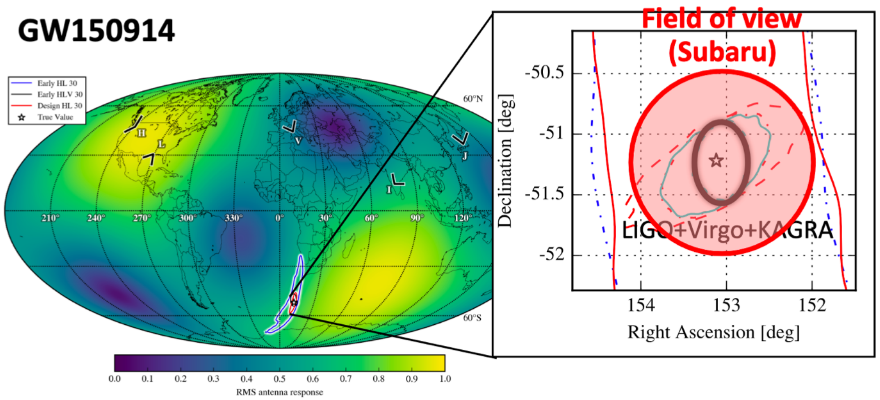
KAGRA

- 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.



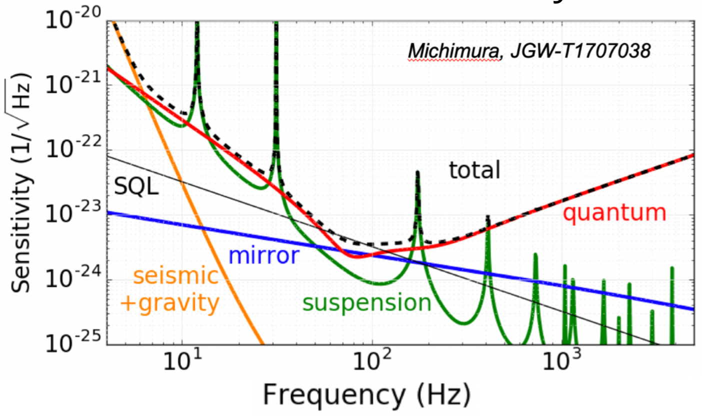
Localization area (realtime analysis)
LIGO: 600 deg^2 => 300 deg^2
LIGO + Virgo: 5.5 deg^2
LIGO + Virgo + KAGRA: 1.2 deg^2

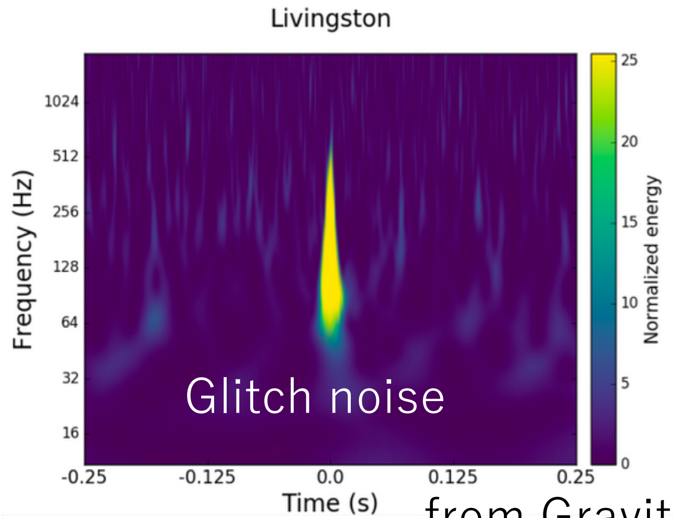
https://arxiv.org/pdf/1703.08988.pdf
TAUP2019 talk by M. Tanaka

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 or external disturbance like earthquake, the GW signal is sometimes contaminated by large signal.
     - It affects false alarm rate.
     - <u>**It is important to distinguish glitch from true GW events like CBC and burst events.**</u>

Stationary noise





from Gravity Spy (LIGO)

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.

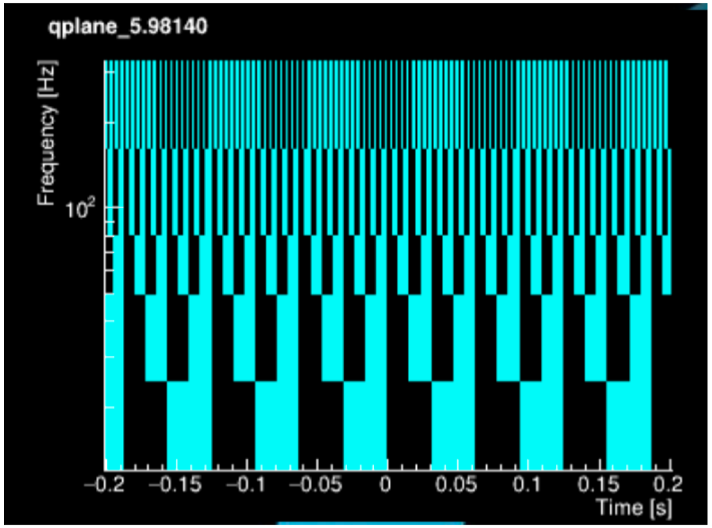
search for glitch noise

- 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

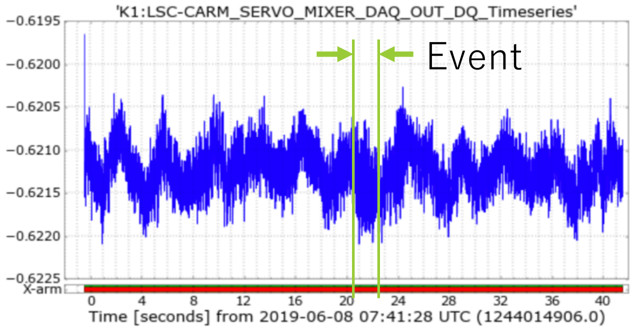
  - Main (trigger) channel
  - Upstream channel
  - Channels used for interferometer control
  - Suspension channel
  - Physical environmental monitor channel etc.

- There is many types of glitches. The parameters for plot should be optimized depending on the property of each glitch.

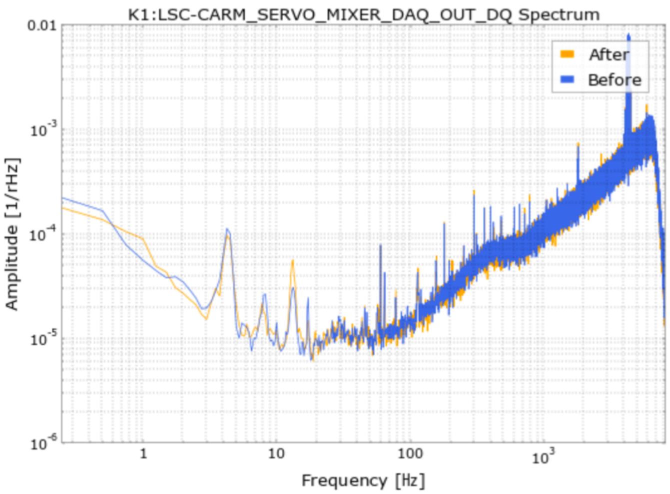
→ Using Omicron information, the plot parameter is automatically determined.

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.

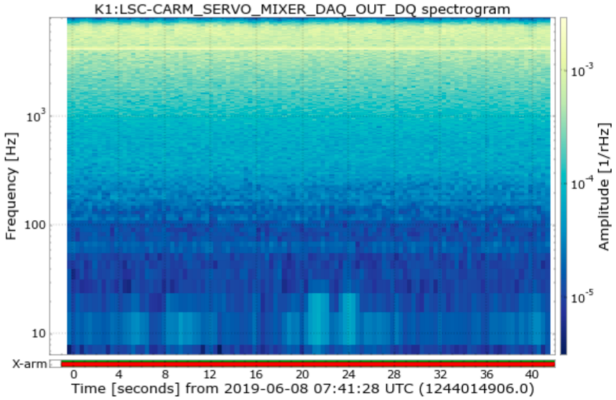


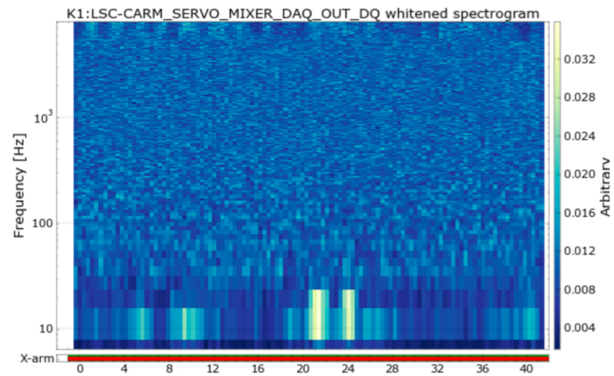
Plot parameter determination

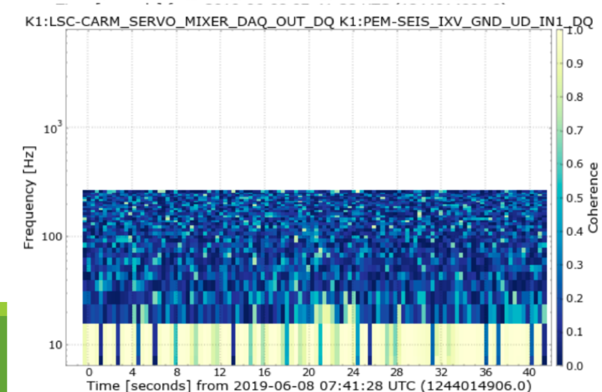
- Spectrogram：

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

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



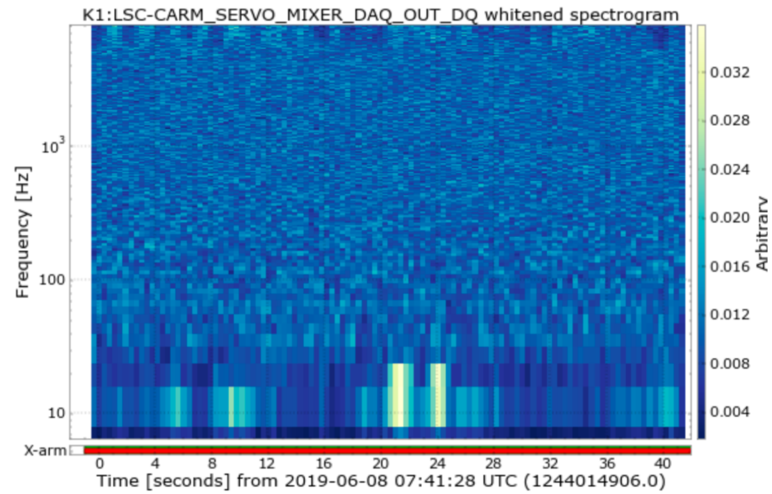


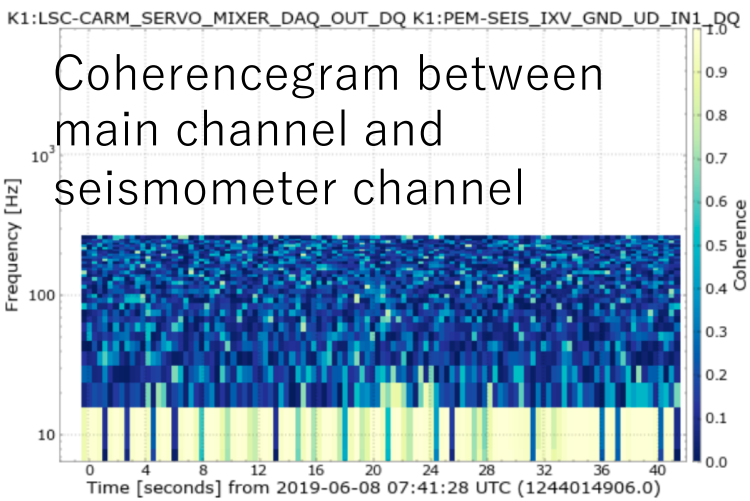


Example of the glitch noise in KAGRA

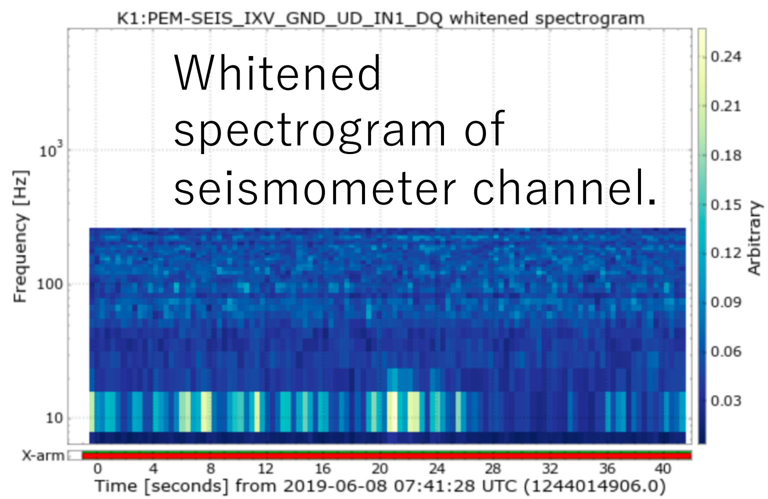
- In this event, main channel and seismometer shows significantly large amplitude in the same time-frequency bin. The correlation is also confirmed by coherencegram.

Main channel





Coherencegram between main channel and seismometer channel



Whitened spectrogram of seismometer channel.

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