

Report of Brief Glitch Search for K1_DQ_Channels

Machine Learning Meeting, 30 November 2018

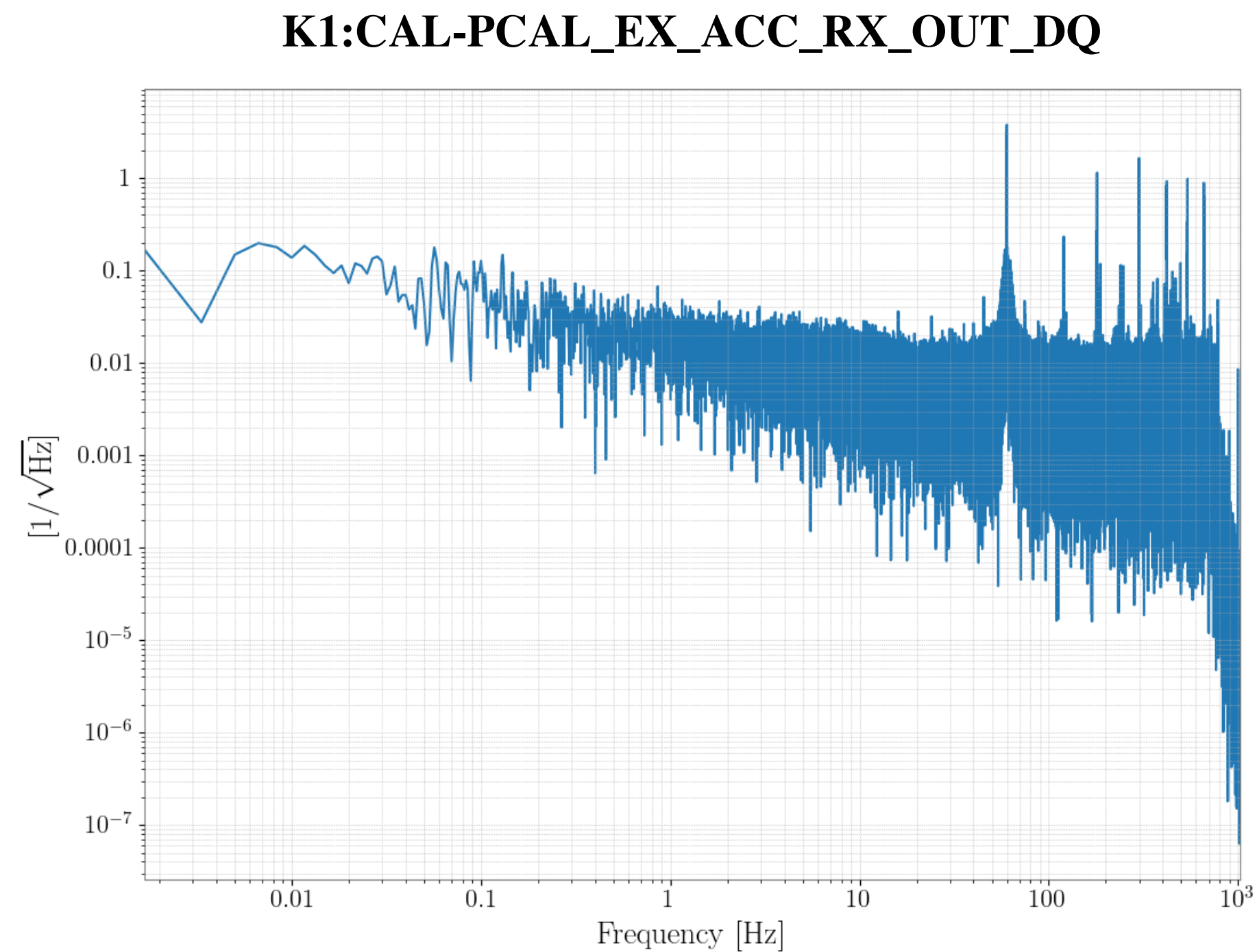
Pil-Jong, Jung

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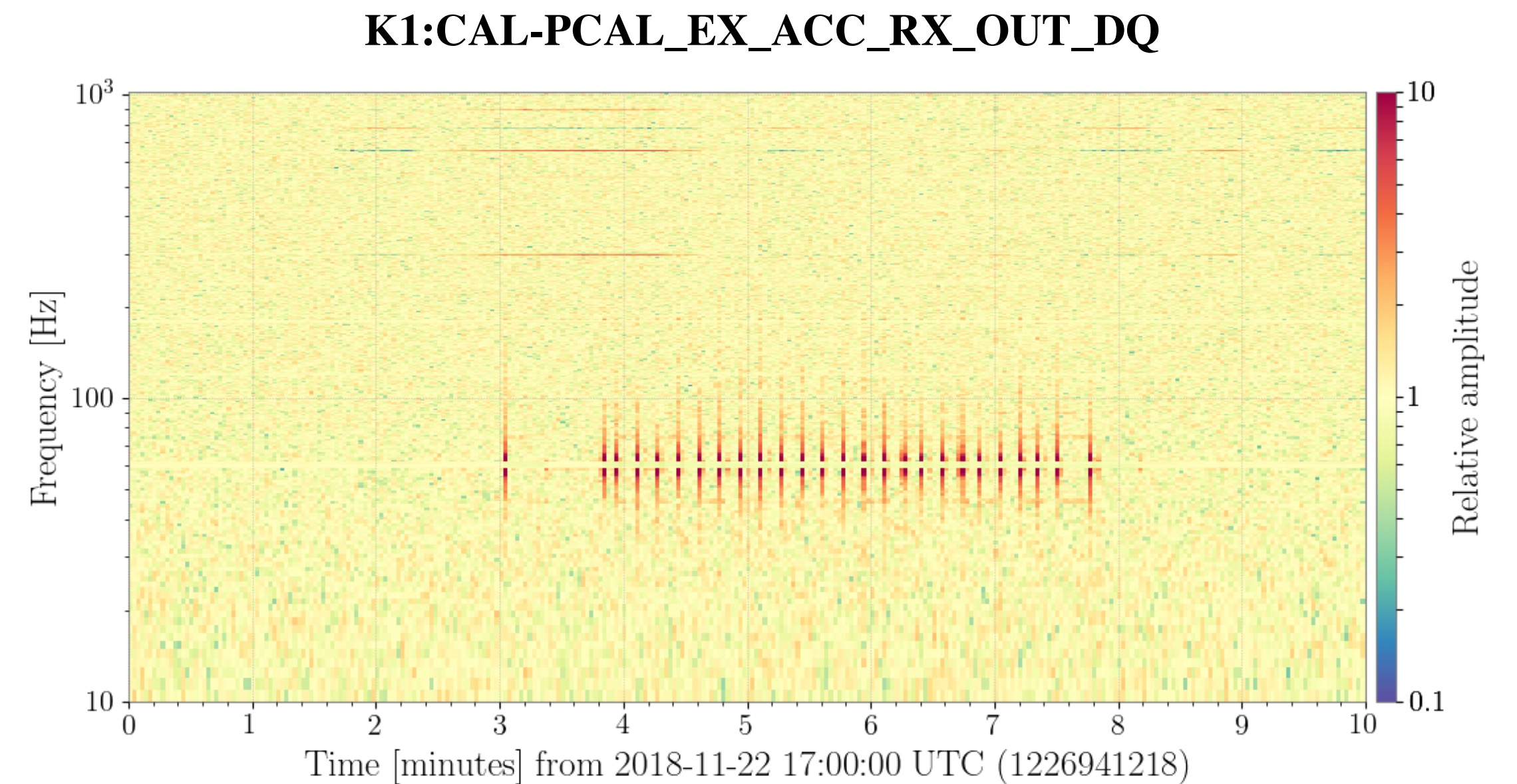
#1 Used Plots

⇒ Power Spectral Density, PSD



: This describes **the power** present in the signal as a function of frequency,

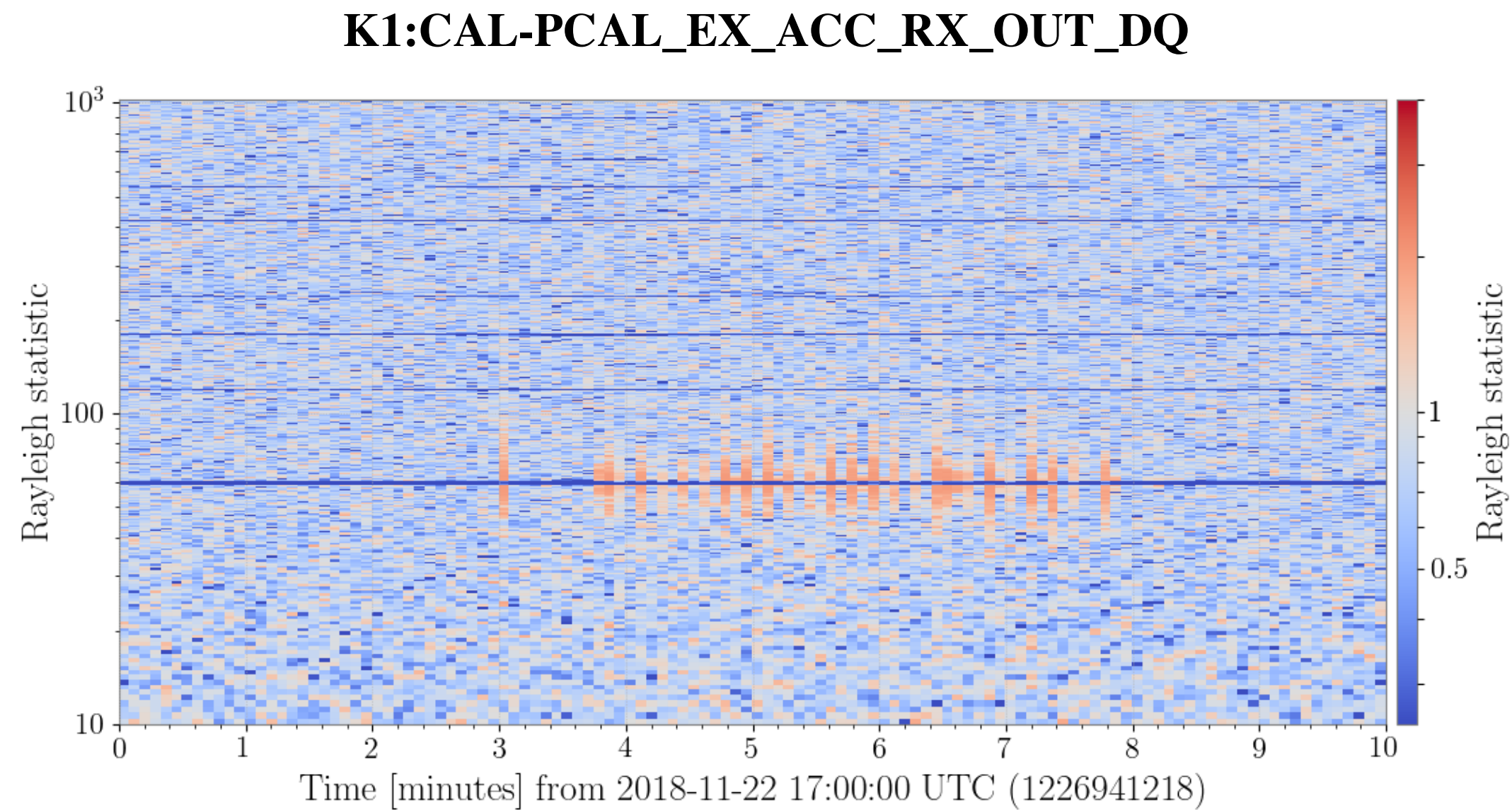
⇒ Spectrogram



: This is **a visual representation of the spectrum** of frequencies of sound or other signal as they vary with time.

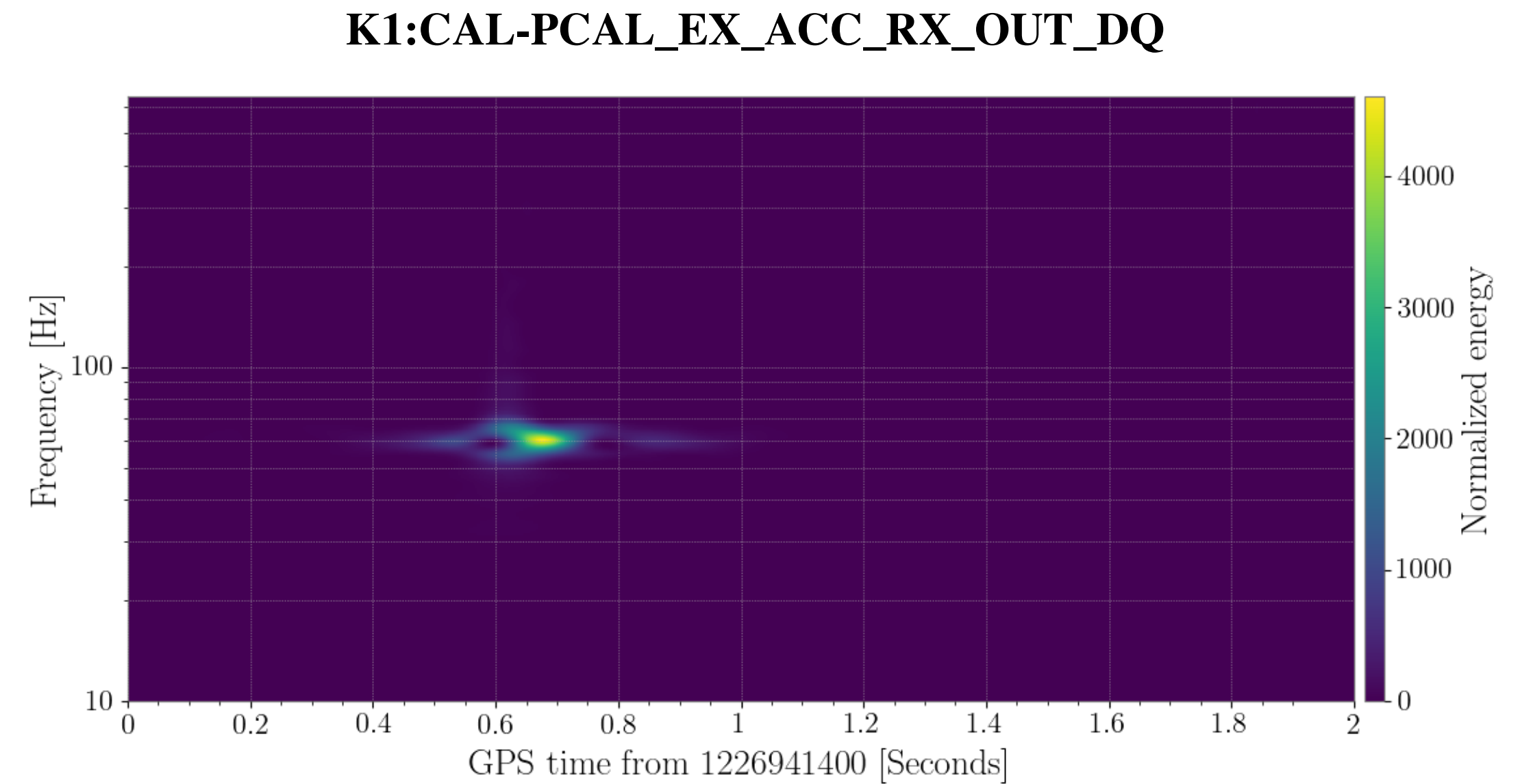
#1 Used Plots

⇒ Rayleigh-Stochastic



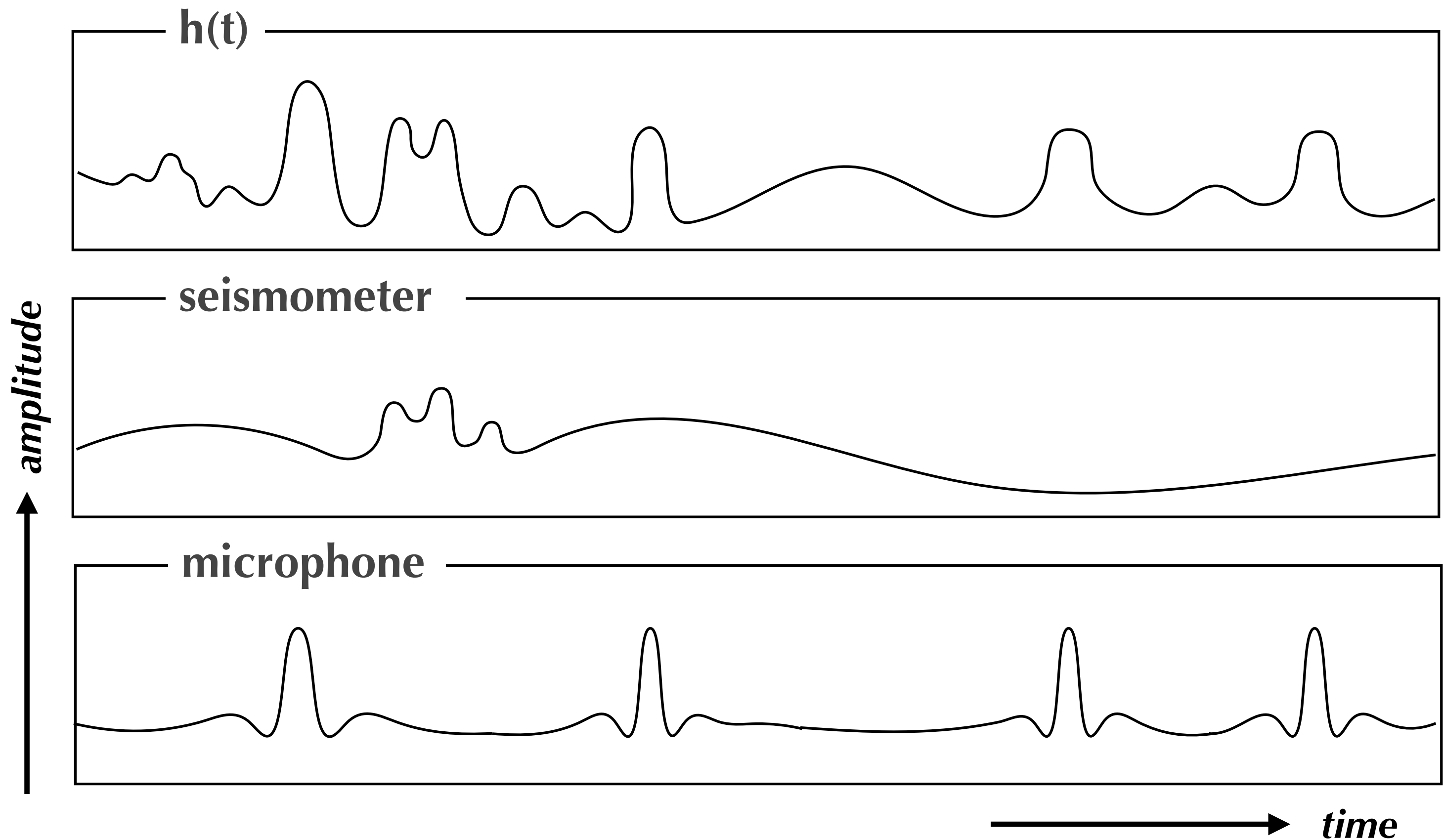
: It is used to measure **the 'Gaussianity'** of those data, where a value of 1 indicates Gaussian behavior, less than 1 indicates coherent variations, and greater than 1 indicates incoherent variation. It is a useful measure of the quality of the strain data being generated and recorded.

⇒ Omega-scan



: This is regularly used to produce **high-resolution time-frequency maps of transient noise (glitches)** and potential gravitational-wave signals.

#2 Trigger and Omega-scan



TimeSeries Data

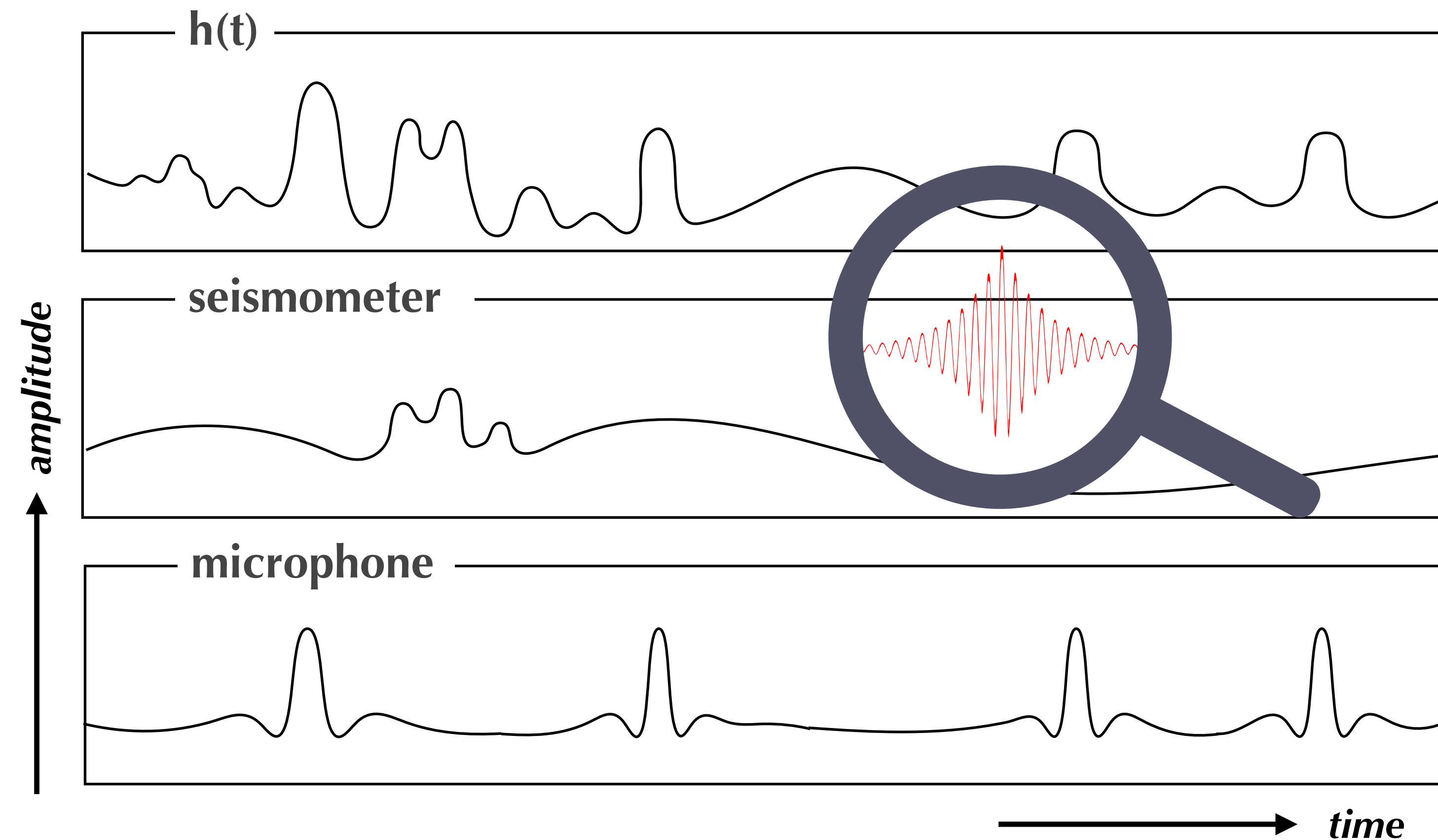


Event Trigger Generator
(Kleine-welle, Omicron)



Fine Triggers

#2 Trigger and Omega-scan



TimeSeries Data

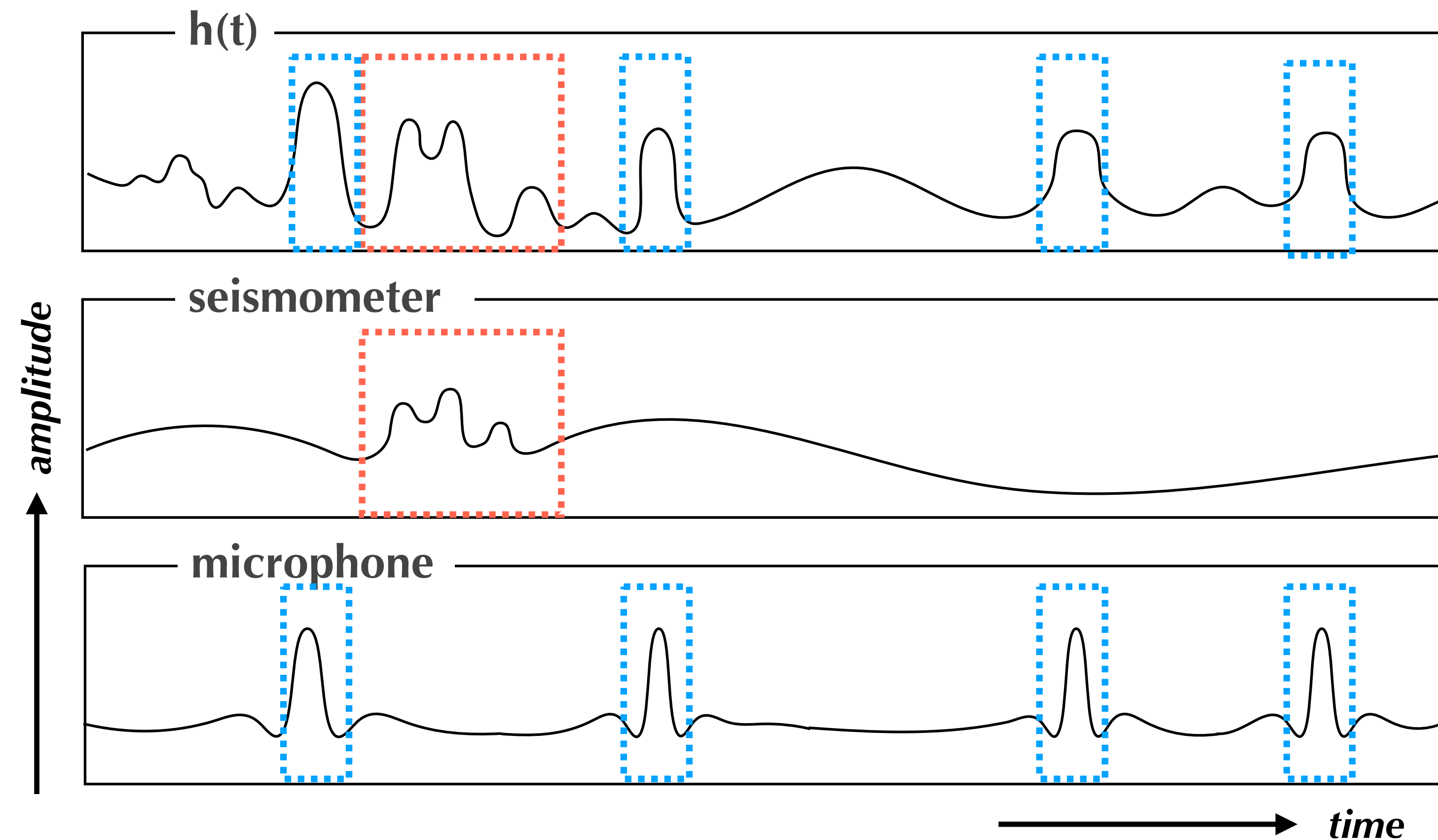


Event Trigger Generator
(Kleine-welle, Omicron)



Fine Triggers

#2 Trigger and Omega-scan



TimeSeries Data

∨

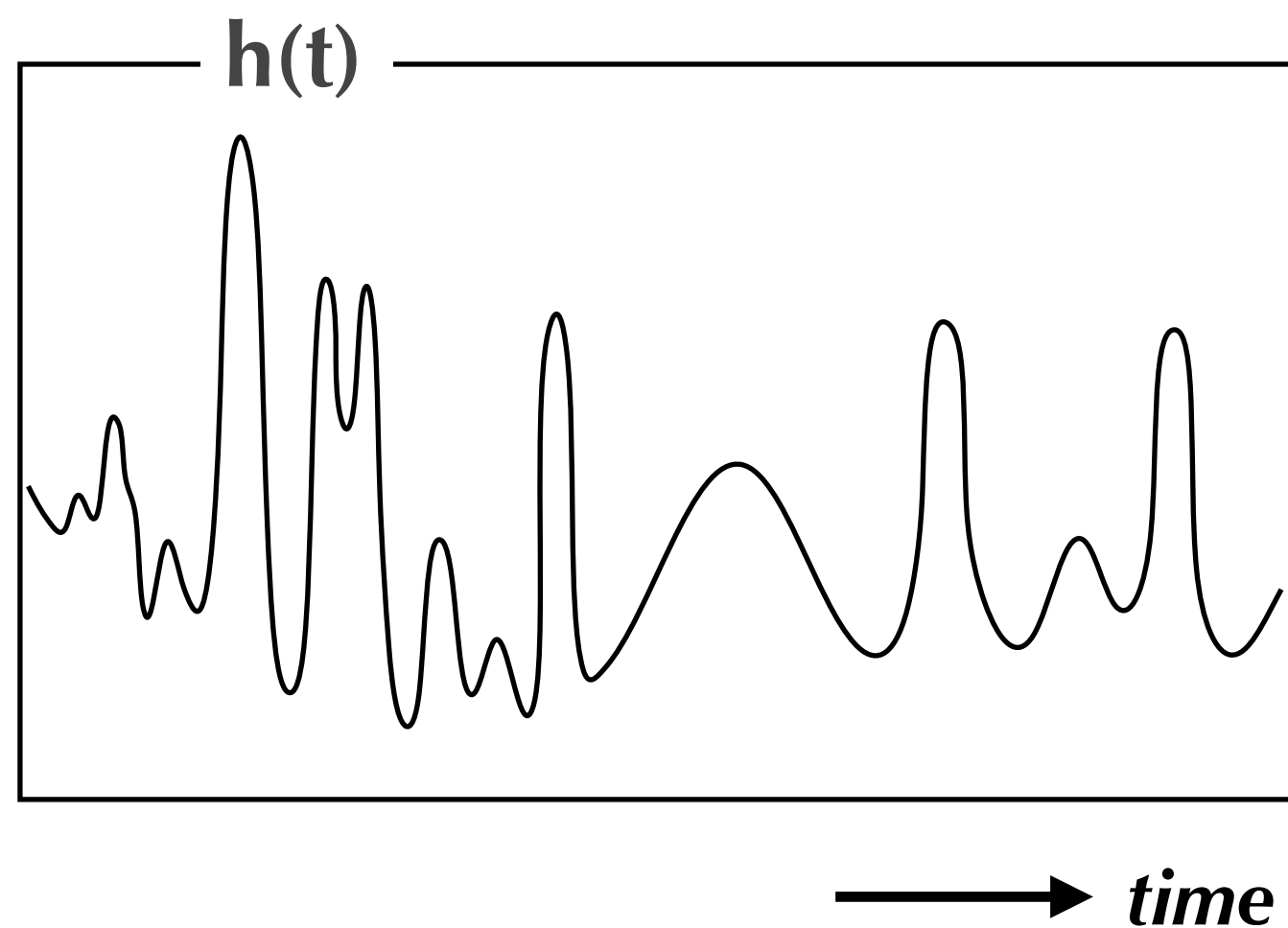
Event Trigger Generator
(Kleine-welle, Omicron)

∨

Fine Triggers

#2 Trigger and Omega-scan

⇒ Omega-Scan; Q-transformation



>

the central time :

$$t_c = \int_{-\infty}^{+\infty} t \frac{|h(t)|^2}{\langle h^2 \rangle} dt.$$

the time duration :

$$\sigma_t^2 = \int_{-\infty}^{+\infty} (t - t_c)^2 \frac{|h(t)|^2}{\langle h^2 \rangle} dt.$$

the central frequency :

$$f_c = \int_{-\infty}^{+\infty} f \frac{|\tilde{f}(f)|^2}{\langle h^2 \rangle} df$$

the bandwidth :

$$\sigma_f^2 = \int_{-\infty}^{+\infty} (f - f_c)^2 \frac{|\tilde{f}(f)|^2}{\langle h^2 \rangle} df$$

the squared amplitude of detected signal in time and frequency domain :

$$\langle h^2 \rangle = \int_{-\infty}^{+\infty} |h(t)|^2 dt = \int_{-\infty}^{+\infty} |\tilde{h}(f)|^2 df$$

#2 Trigger and Omega-scan

⇒ Omega-Scan; Q-transformation

the quality factor Q : $Q = \sqrt{2}f_c/\sigma_f$

> the uncertainty relationship : $\sigma_t\sigma_f \geq 1/4\pi$.

a finite region of parameter space

> $[t_c^{\min}; t_c^{\max}] \times [f_c^{\min}; f_c^{\max}] \times [Q^{\min}; Q^{\max}]$



tiles : $\delta_s^2 = \frac{4\pi^2 f_c^2}{Q^2} \delta t_c^2 + \frac{2 + Q^2}{4f_c^2} \delta f_c^2 + \frac{1}{2Q^2} \delta Q^2$

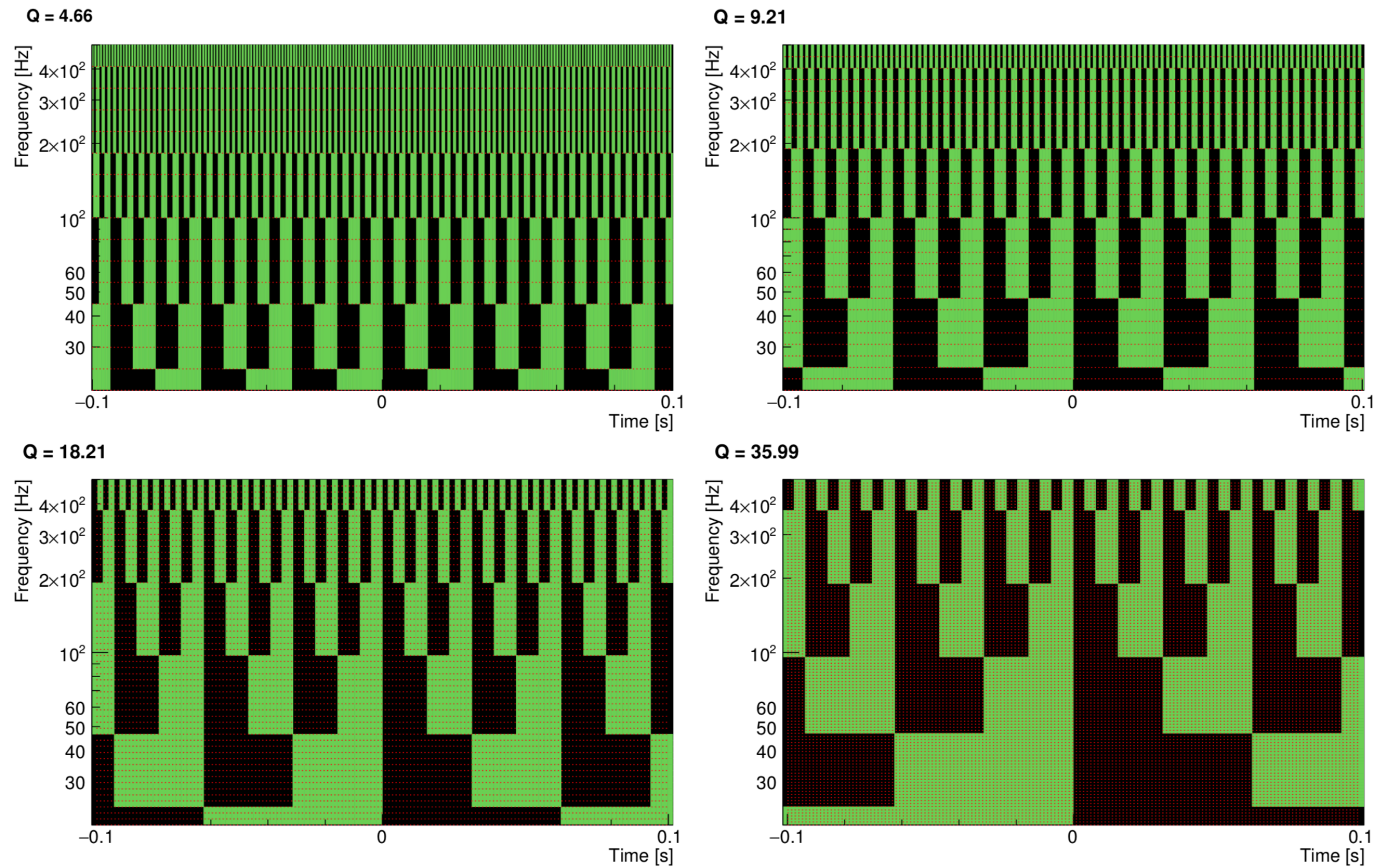
Q-transform :

$$\begin{aligned} X(t_c, f_c, Q) &= \int_{-\infty}^{+\infty} dt h(t) \omega(t - t_c, f_c, Q) e^{-2i\pi f_c t} \\ &= \int_{-\infty}^{+\infty} df \tilde{h}(f + f_c) \tilde{\omega}^*(f, f_c, Q) e^{2i\pi f t_c} \end{aligned}$$

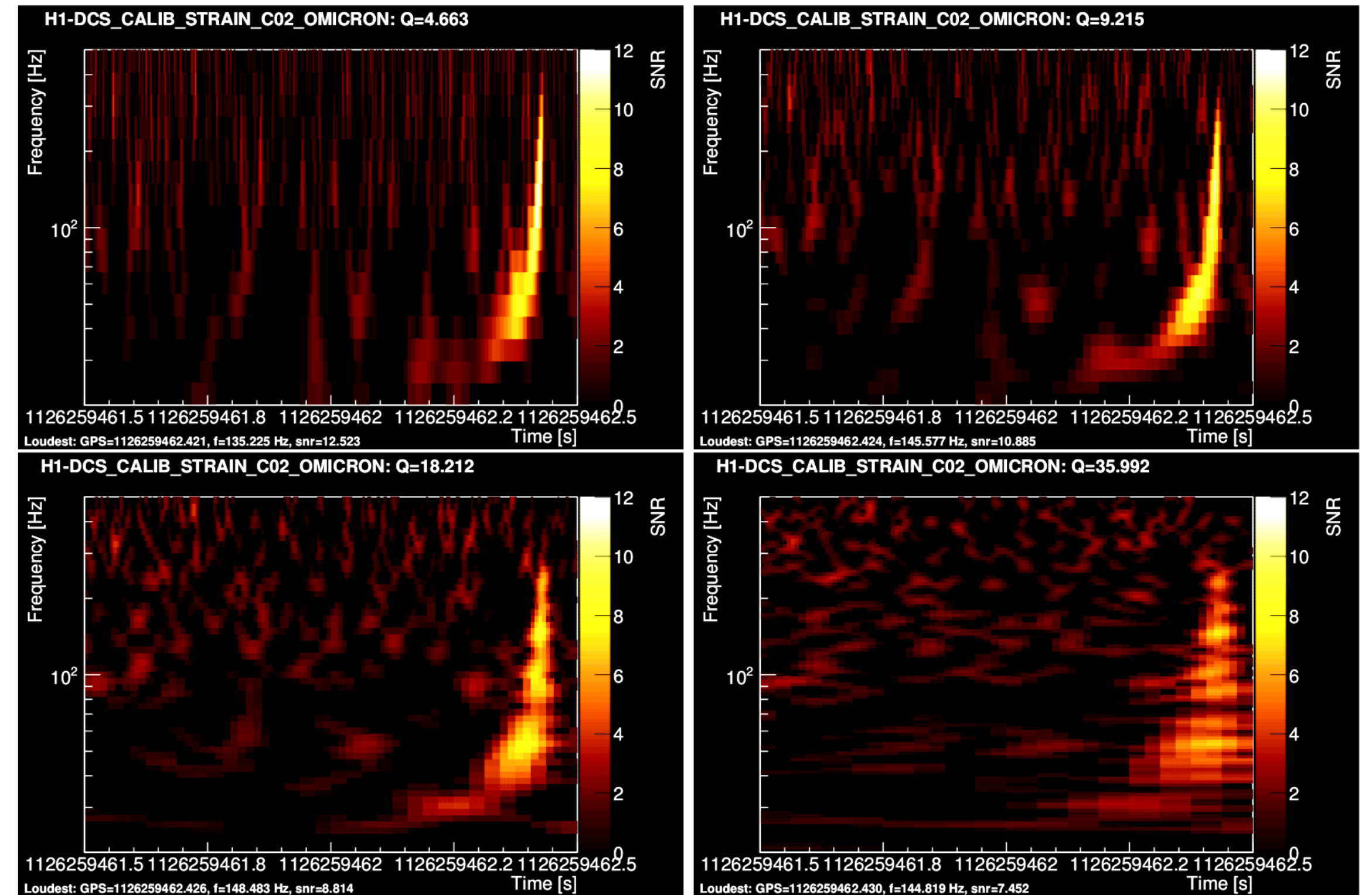
is a modified short-time Fourier transform re-defined on the parameter space tiles of a constant quality factor Q with optimized resolutions

#2 Trigger and Omega-scan

on the parameter space tiles



mapping



#2 Trigger and Omega-scan

⇒ Omega-Scan; Q-transformation

the minimum number of tiles :

$$\begin{aligned} N_{t_c} &\geq \frac{s_{t_c}}{2\sqrt{\mu_{\max}/3}}, & s_{t_c} &= \frac{2\pi f_c}{Q}(t_c^{\max} - t_c^{\min}), \\ N_{f_c} &\geq \frac{s_{f_c}}{2\sqrt{\mu_{\max}/3}}, & s_{f_c} &= \frac{\sqrt{2+Q^2}}{2} \ln(f_c^{\max}/f_c^{\min}), \\ N_Q &\geq \frac{s_Q}{2\sqrt{\mu_{\max}/3}}, & s_Q &= \frac{1}{\sqrt{2}} \ln(Q^{\max}/Q^{\min}), \end{aligned}$$

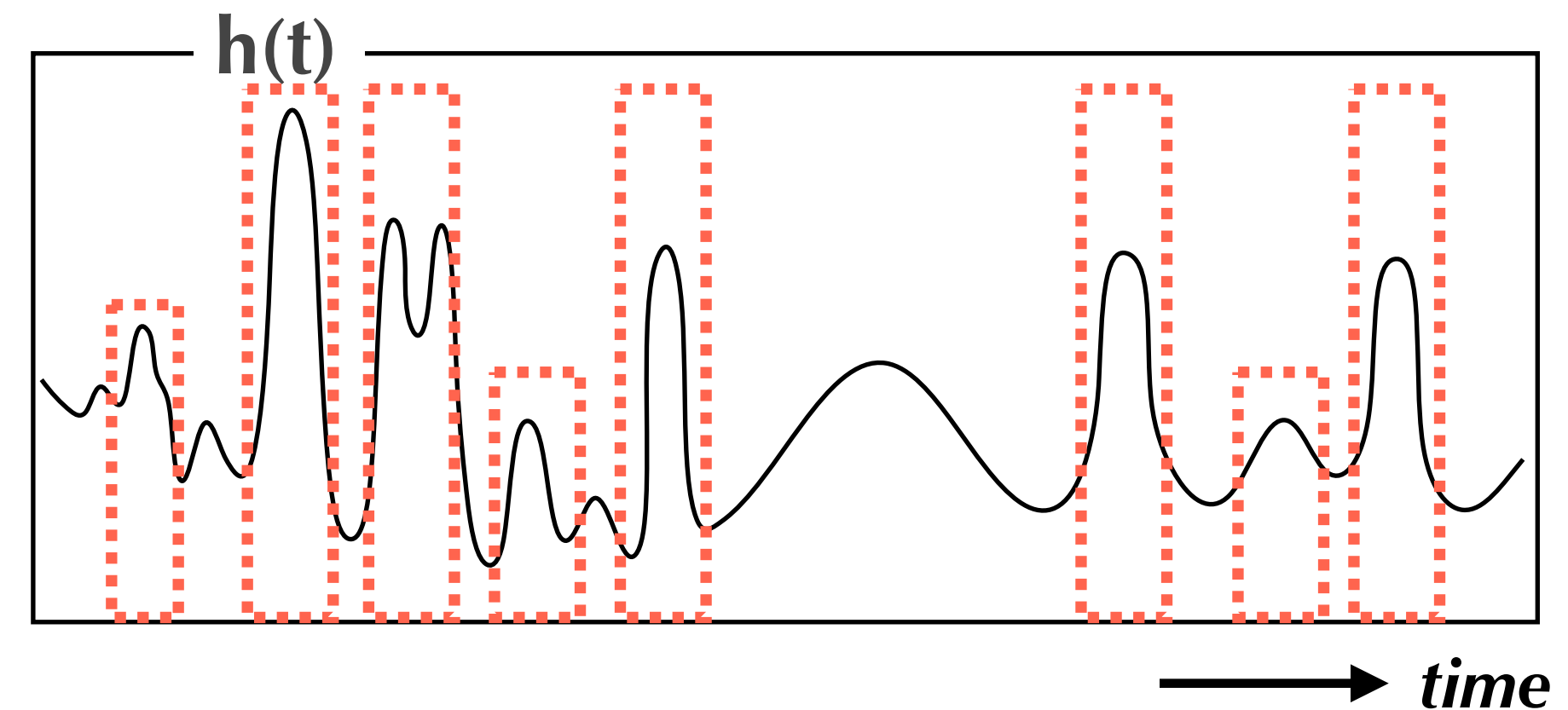
the resolution of the optimized tile :

$$\begin{aligned} Q^q &= Q^{\min} \left[\frac{Q^{\max}}{Q^{\min}} \right]^{(0.5+q)/N_Q} & (0 \leq q < N_Q), \\ f_c^{ql} &= f_c^{\min} \left[\frac{f_c^{\max}}{f_c^{\min}} \right]^{(0.5+l)/N_{f_c}(Q^q)} & (0 \leq l < N_{f_c}(Q^q)), \\ t_c^{qlm} &= t_c^{\min} + \frac{(m+0.5)(t_c^{\max} - t_c^{\min})}{N_{t_c}(Q^q, f_c^{ql})} & (0 \leq m < N_{t_c}(Q^q, f_c^{ql})). \end{aligned}$$

Find Triggers :

a set of (q,l,m) tiles with SNR :

$$\rho_{qlm}^2 = \frac{|X_h(t_c^{qlm}, f_c^{ql}, Q^q)|^2}{\langle |X_n(t_c^{qlm}, f_c^{ql}, Q^q)|^2 \rangle / 2}$$



⇒ Q-transformation data

Channel : K1:CAL-PCAL_EX_ACC_RX_OUT_DQ -s 1226941218 duration 37s

```
<Spectrogram([[ 0.09265488, 0.00821098, 0.06883343, ...,
                0.02522794, 0.02522794, 0.02522794],
              [ 0.0927586 , 0.00841609, 0.0690567 , ...,
                0.02192003, 0.02192003, 0.02192003],
              [ 0.09286829, 0.00862691, 0.06928917, ...,
                0.01934536, 0.01934536, 0.01934536],
              ...,
              [ 0.07389838, -0.11229309, -0.10057292, ...,
                0.03171151, 0.03171151, 0.03171151],
              [ 0.07382319, -0.1138508 , -0.10259651, ...,
                0.03031545, 0.03031545, 0.03031545],
              [ 0.07375078, -0.11541509, -0.10462873, ...,
                0.02608719, 0.02608719, 0.02608719]])
unit=Unit(dimensionless),
name=None,
epoch=<Time object: scale='utc' format='gps' value=1226941218.0>,
channel=None,
x0=<Quantity 1.22694122e+09 s>,
dx=<Quantity 0.001 s>,
xindex=<Index [1.22694122e+09, 1.22694122e+09, 1.22694122e+09, ...,
              1.22694125e+09, 1.22694125e+09, 1.22694125e+09] s>,
y0=<Quantity 9.73314936 Hz>,
dy=<Quantity 0.5 Hz>,
yindex=<Index [ 9.73314936, 10.23314936, 10.73314936, ...,
              644.23314936, 644.73314936, 645.23314936] Hz>>
```

the quality factor Q : $Q = \sqrt{2}f_c/\sigma_f$
the uncertainty relationship : $\sigma_t\sigma_f \geq 1/4\pi$

$y_0 \approx 10$ Hz \Leftarrow duration 37 seconds

#3 Time duration and Channels

⇒ Time duration

date : 11/23~25
time : 2 ~ 5 AM

> time duration : 10 minute > total 54 segments

⇒ Channels

total channels
: 85,114

> sampling rate \geq 2048Hz
and DQ Channels : 1087

>

ALS Channels : 37
AOS Channels : 61
CAL Channels : 33
IMC Channels : 124
ISS Channels : 20
LAS Channels : 16

LSC Channels : 15
MZM Channels : 7
OMC Channels : 27
PEM Channels : 152
PSL Channels : 44
VIS Channels : 551

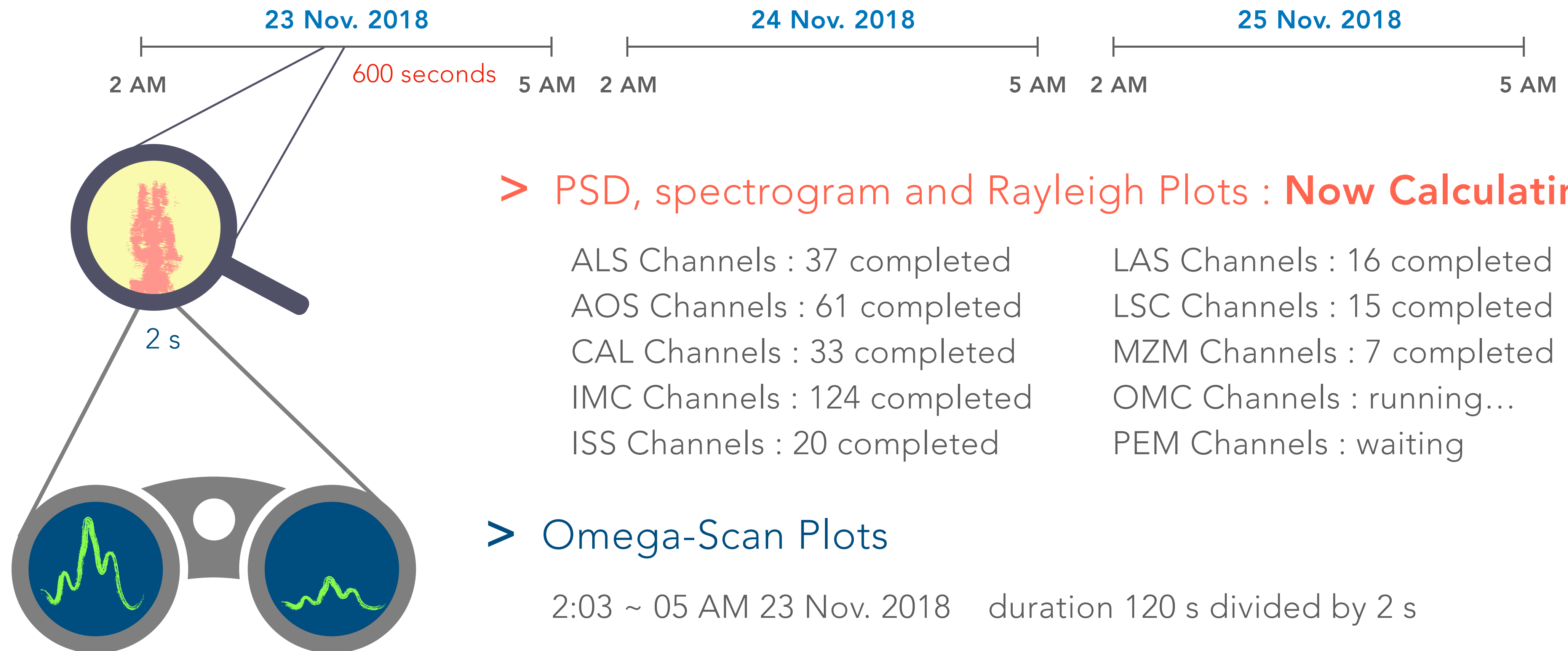
⇒ Number of **PSD, spectrogram and Rayleigh** plots

: $54 \times 3 \times 950 = 153,900$ (40Gb)

#4 Results

⇒ All results : [Googledrive Link](#)

⇒ Current status



> PSD, spectrogram and Rayleigh Plots : **Now Calculating...**

ALS Channels : 37 completed
AOS Channels : 61 completed
CAL Channels : 33 completed
IMC Channels : 124 completed
ISS Channels : 20 completed

LAS Channels : 16 completed
LSC Channels : 15 completed
MZM Channels : 7 completed
OMC Channels : running...
PEM Channels : waiting

> Omega-Scan Plots

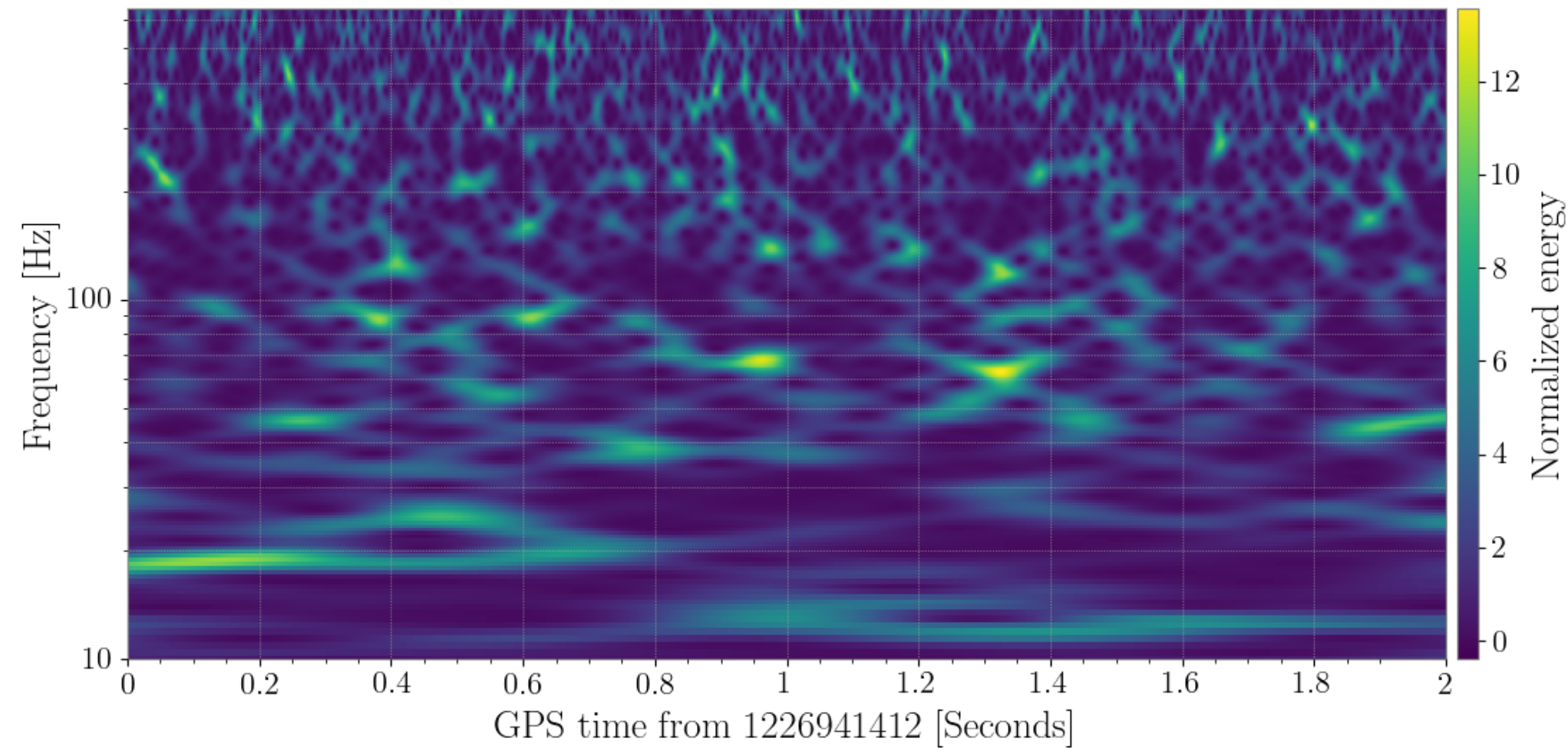
2:03 ~ 05 AM 23 Nov. 2018 duration 120 s divided by 2 s

K1:CAL-PCAL_EX_ACC_RX_OUT_DQ

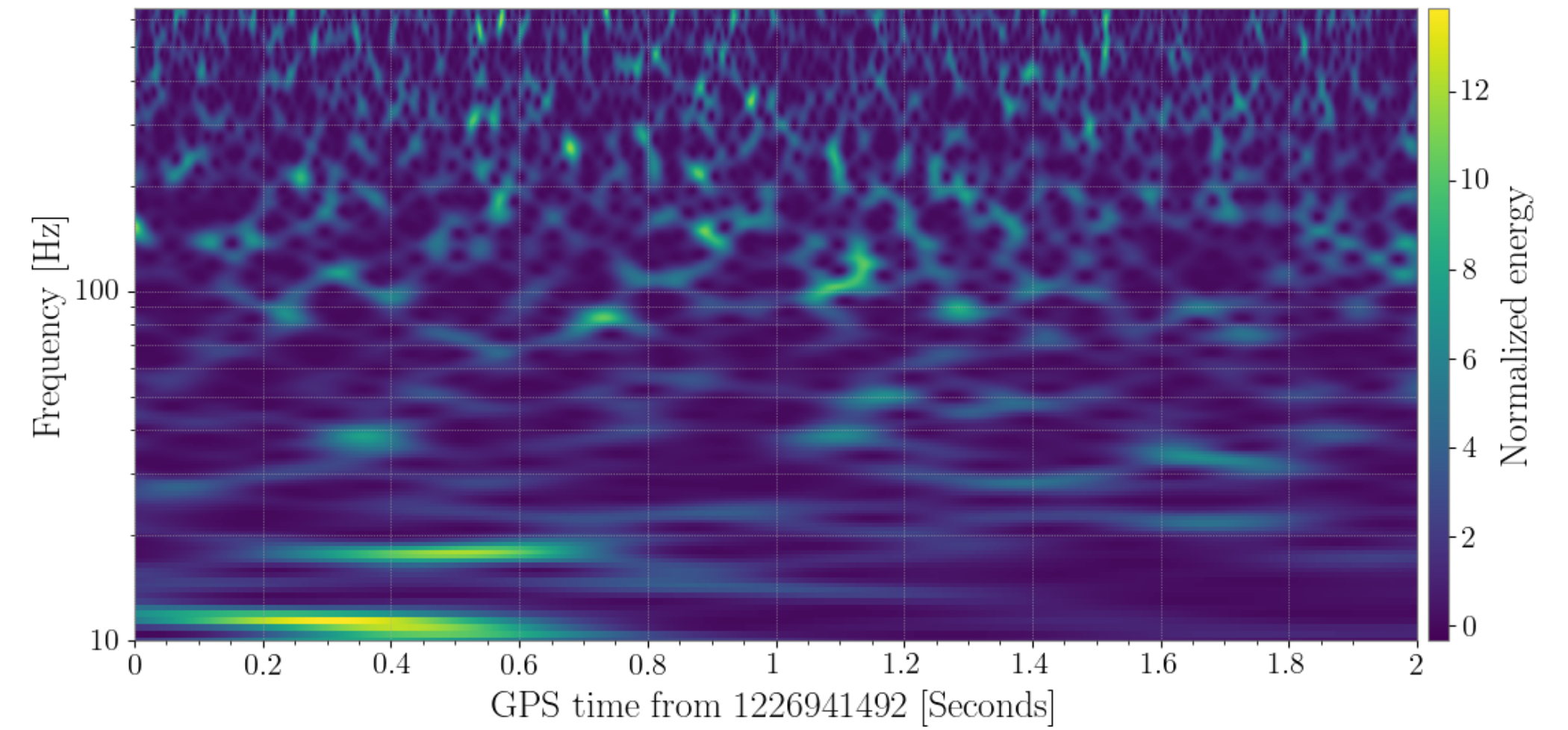
#4 Results

⇒ All results : [Googledrive Link](#)

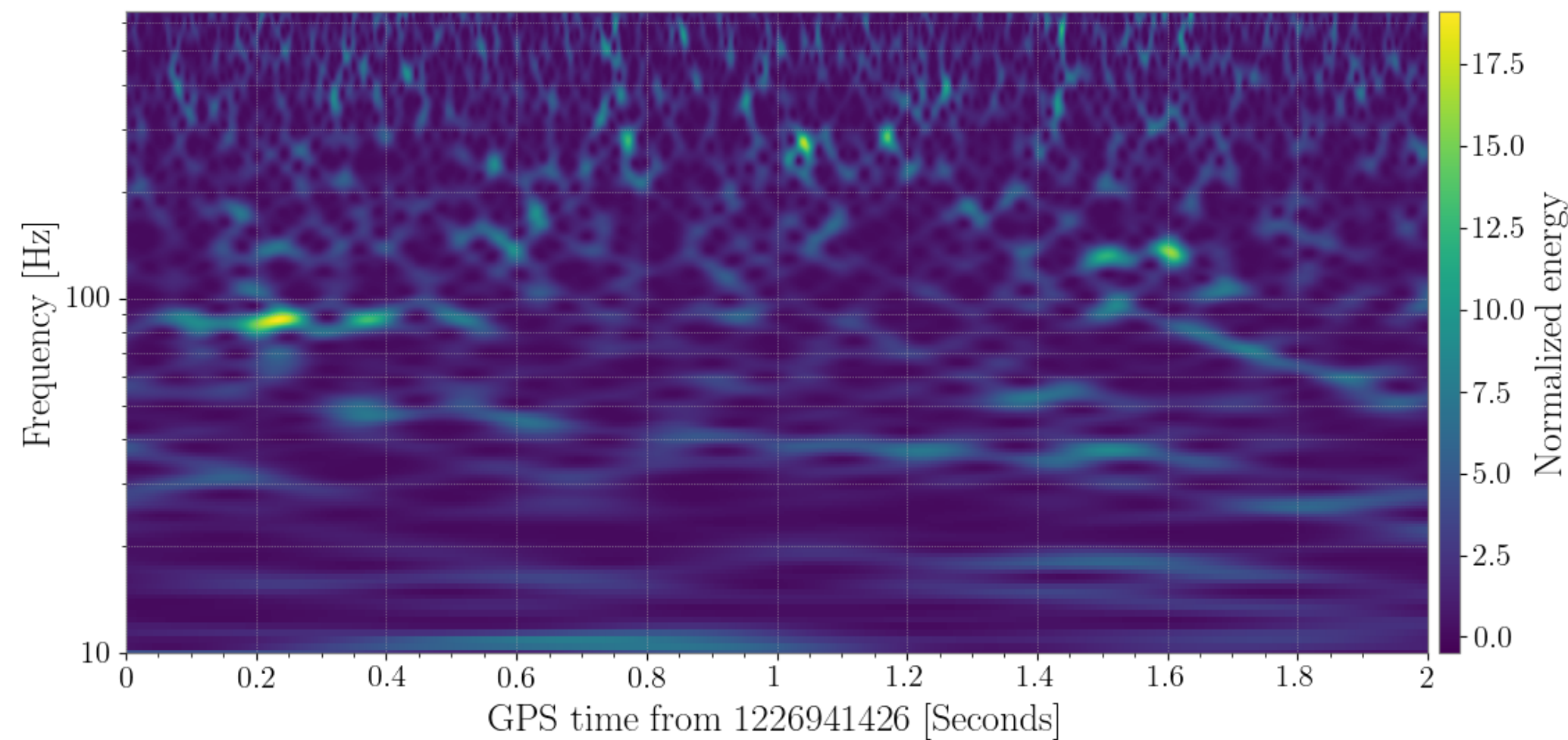
K1:CAL-PCAL_EX_ACC_RX_OUT_DQ



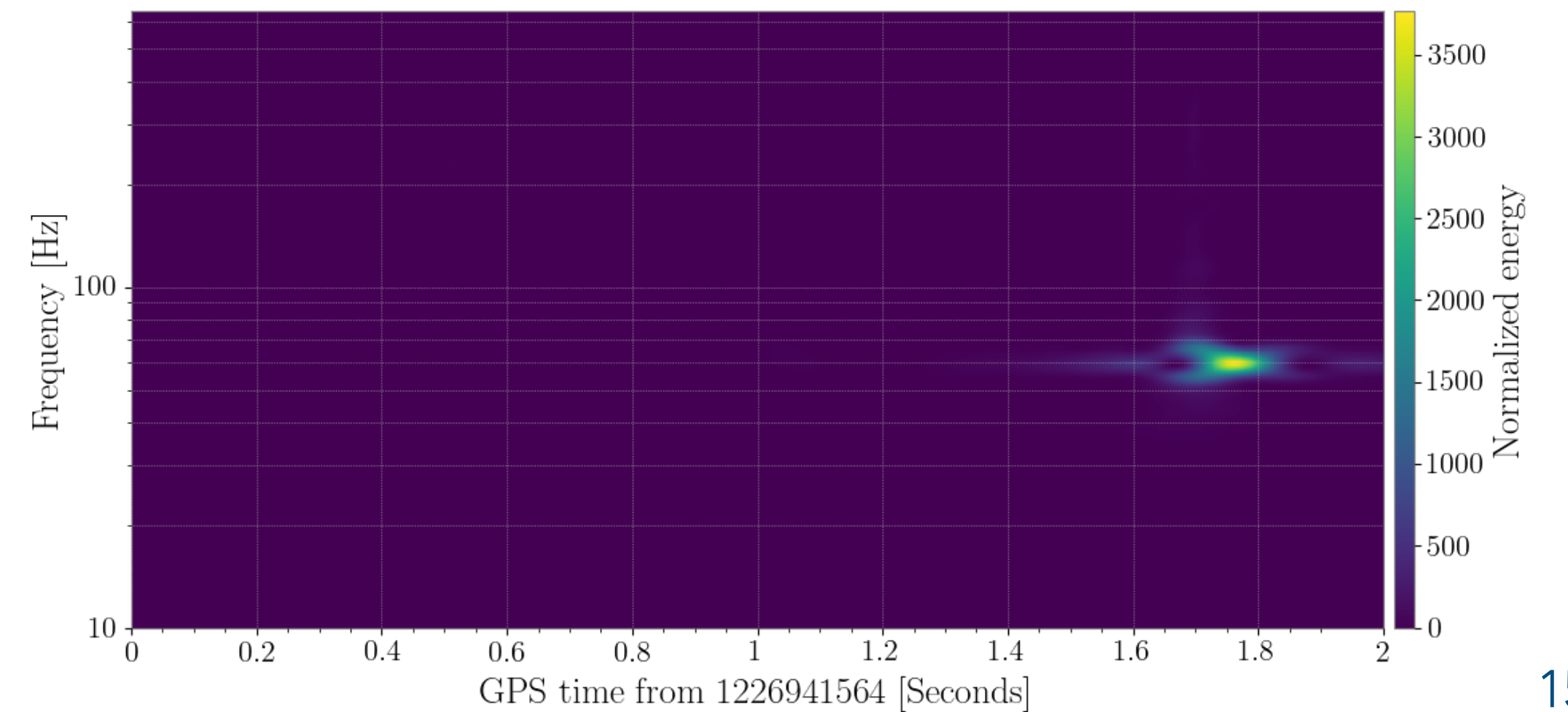
K1:CAL-PCAL_EX_ACC_RX_OUT_DQ



K1:CAL-PCAL_EX_ACC_RX_OUT_DQ



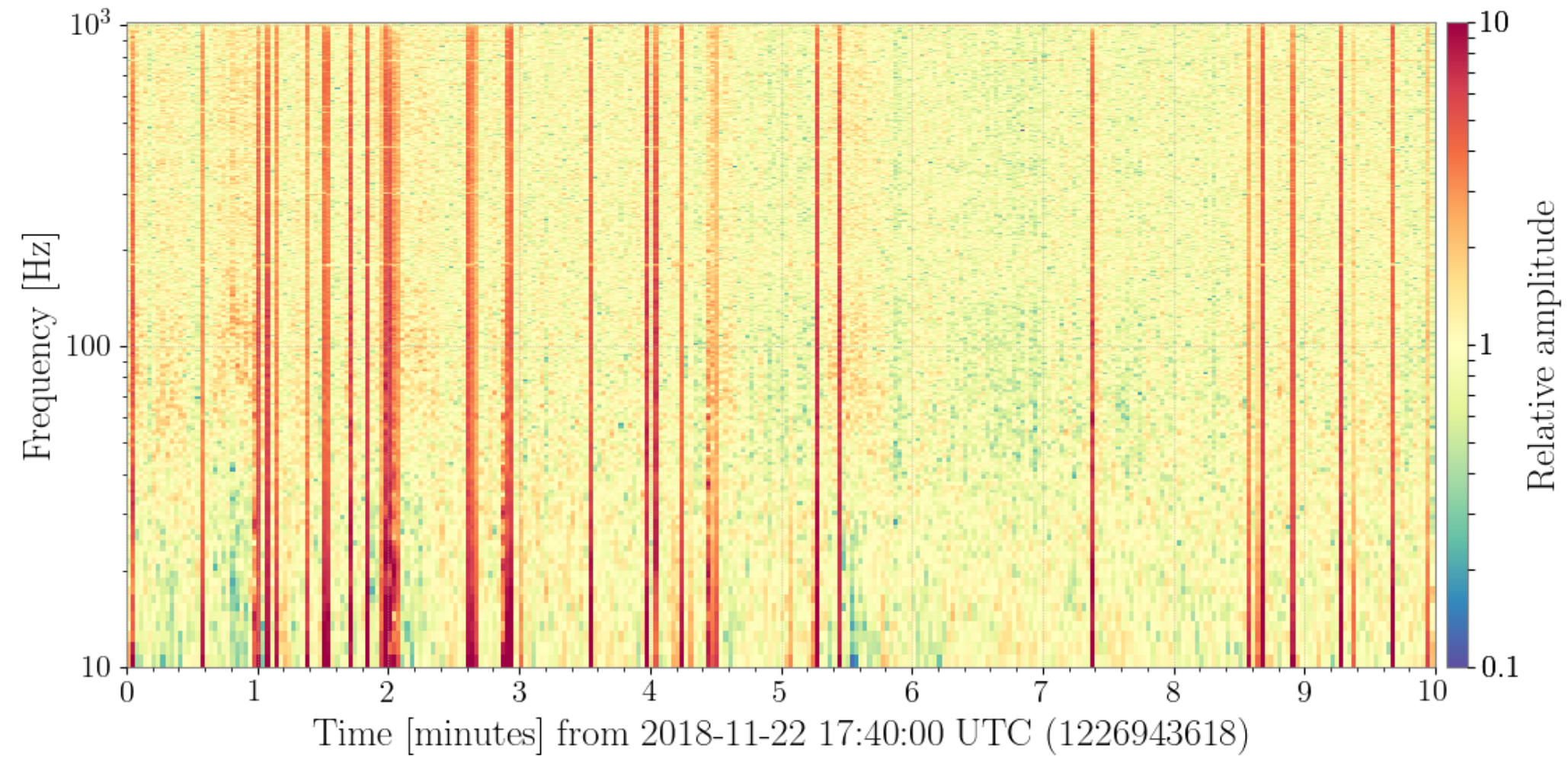
K1:CAL-PCAL_EX_ACC_RX_OUT_DQ



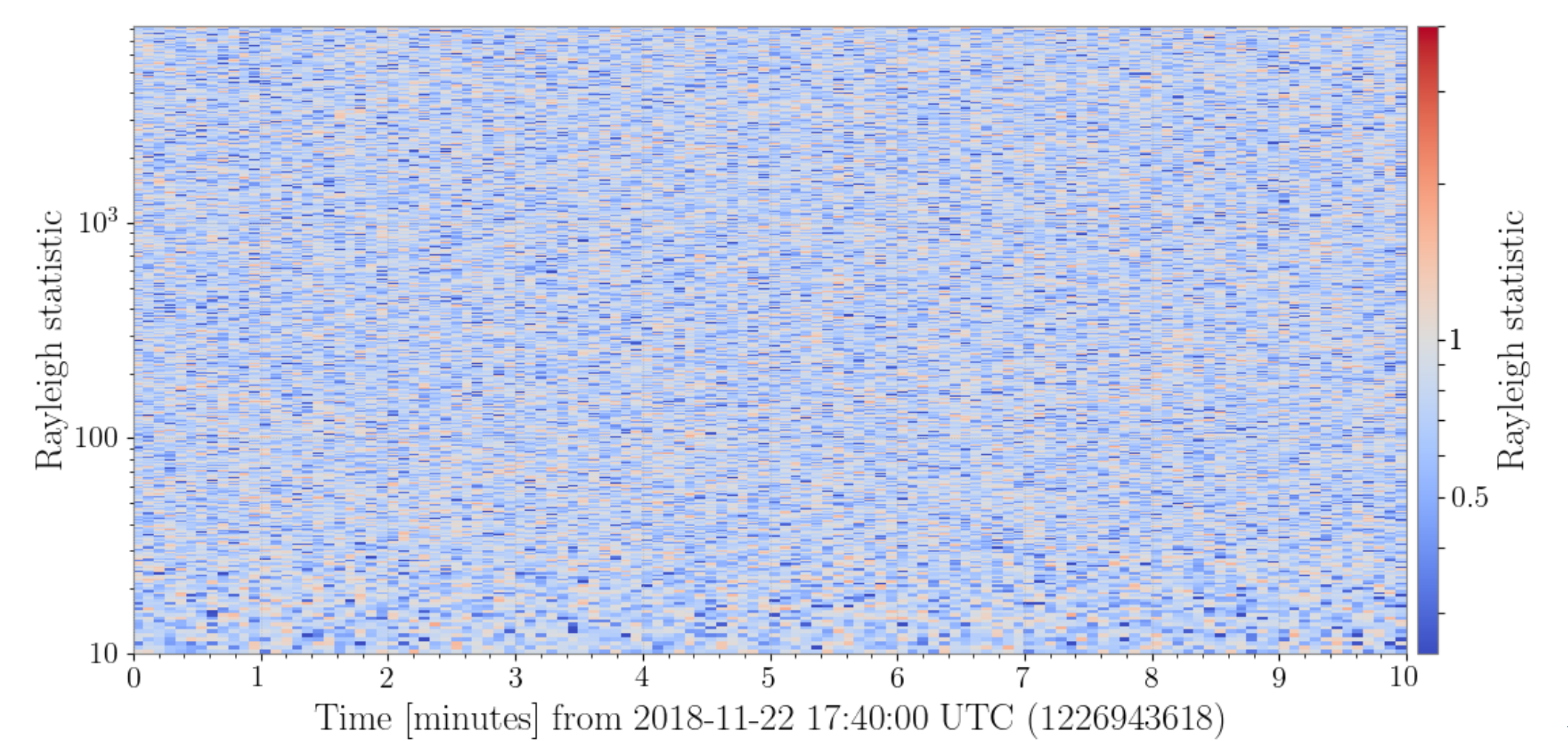
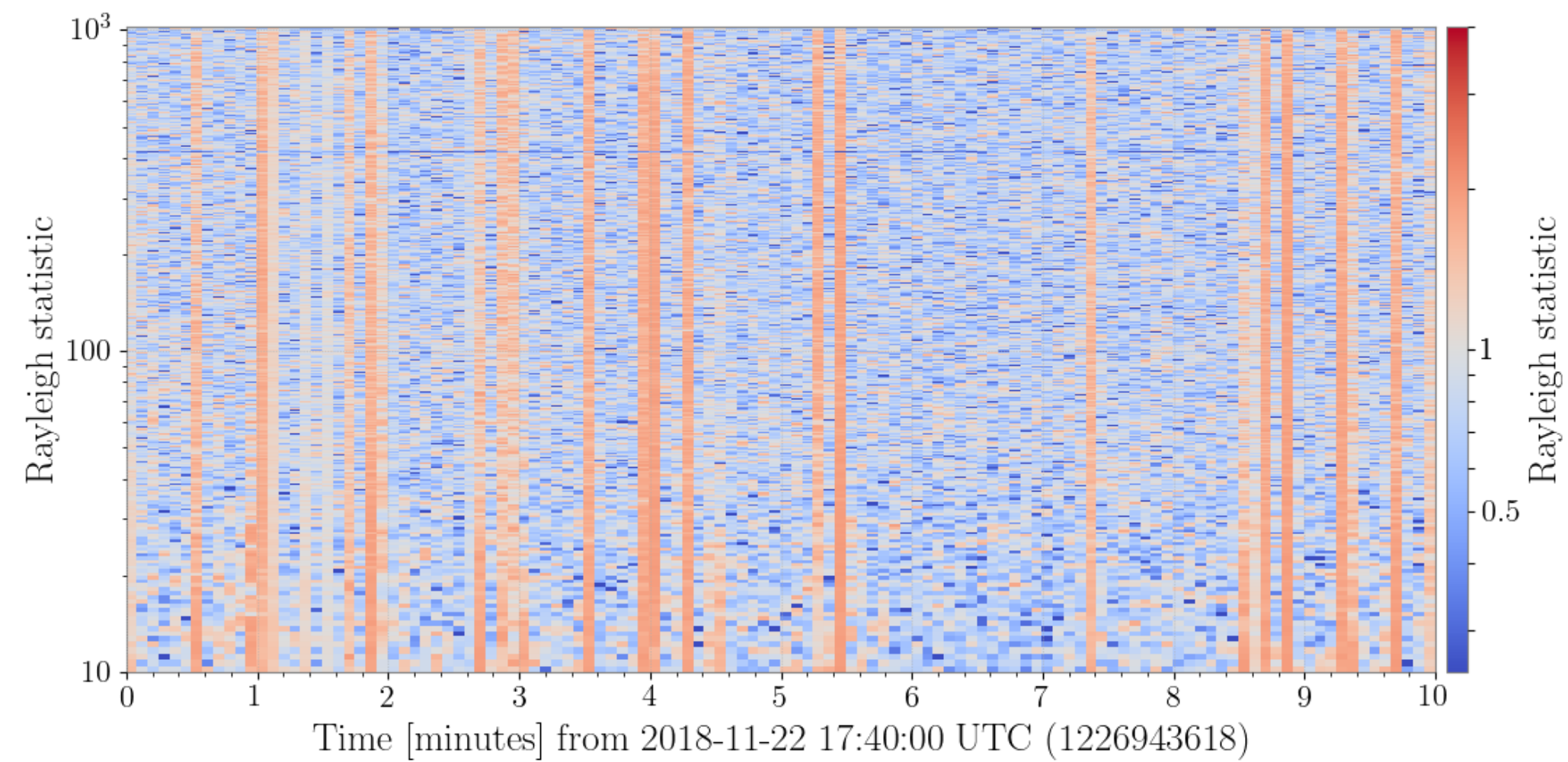
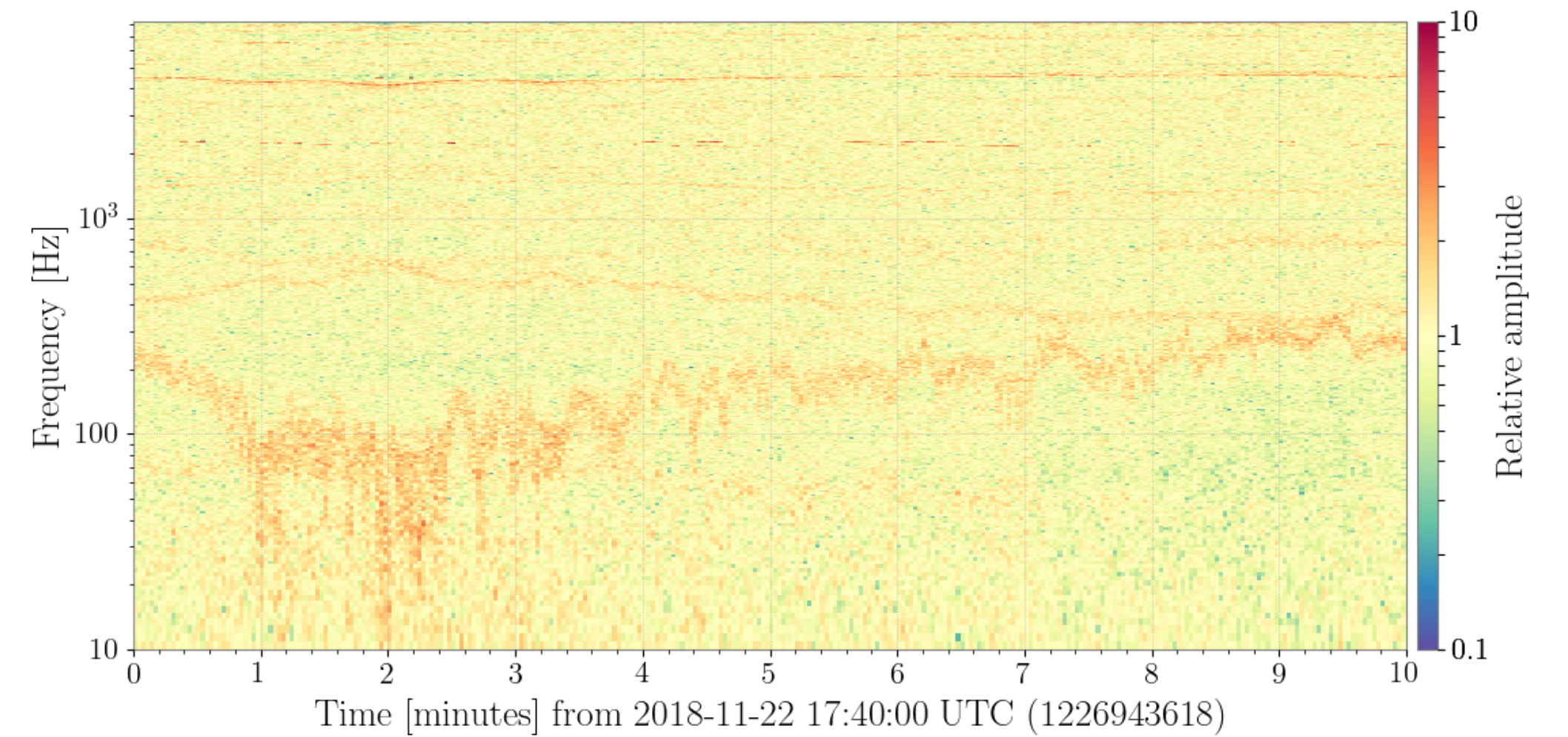
#4 Results

⇒ All results : [Googledrive Link](#)

K1:ALS-DRIFTX_SERVO_OUT_DQ



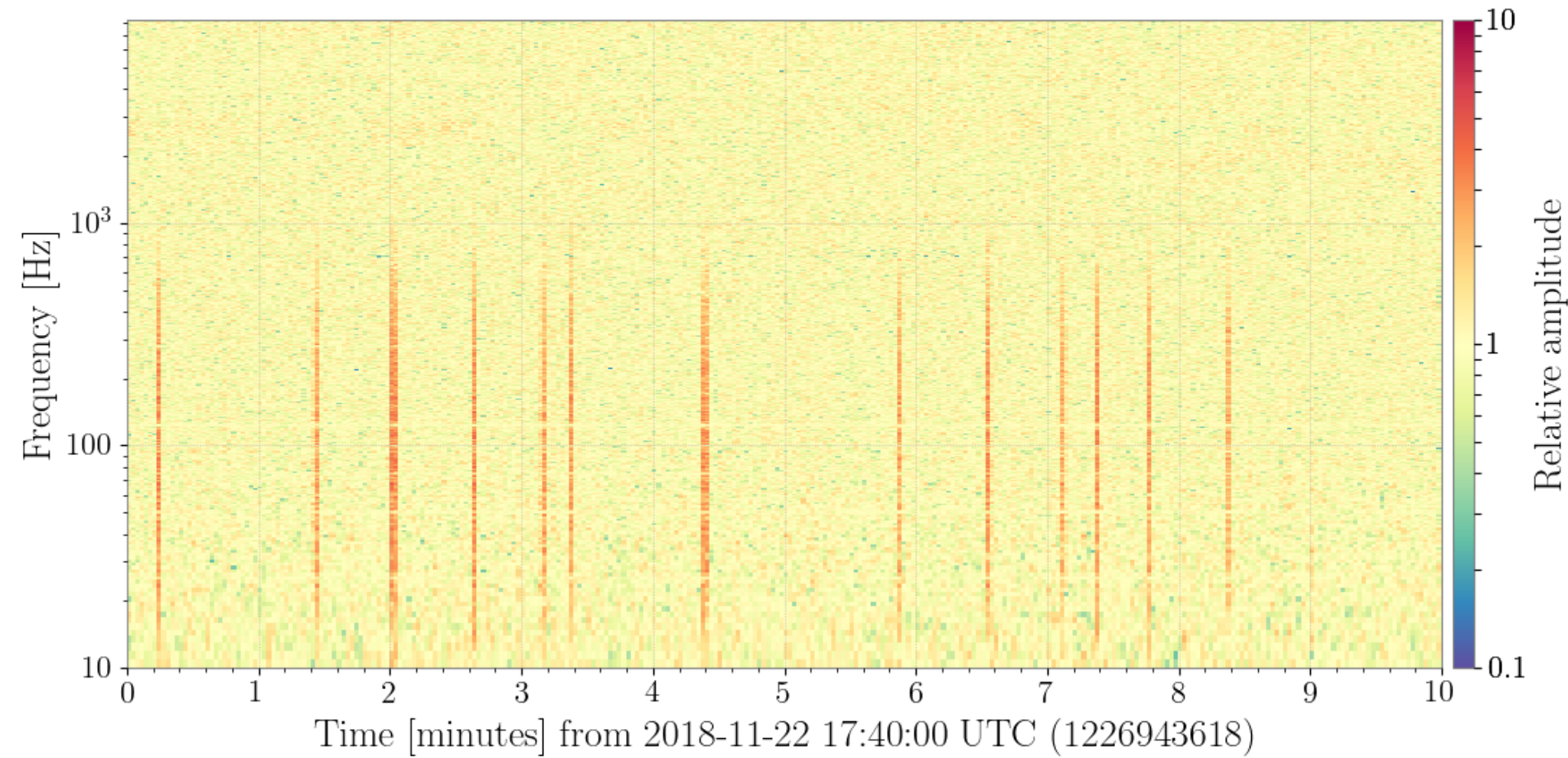
K1:CAL-PCAL_EX_1_PD_OFS_V_DQ



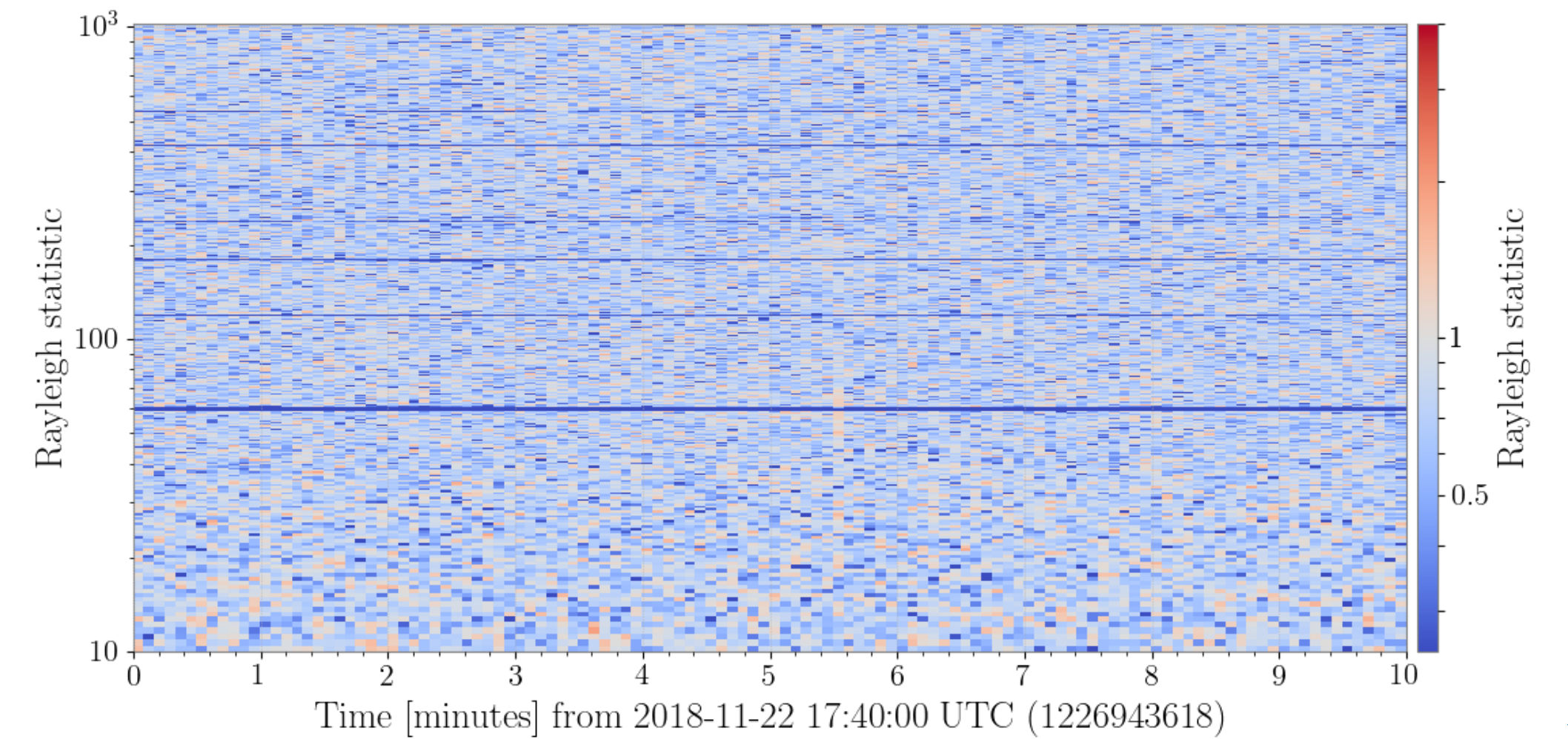
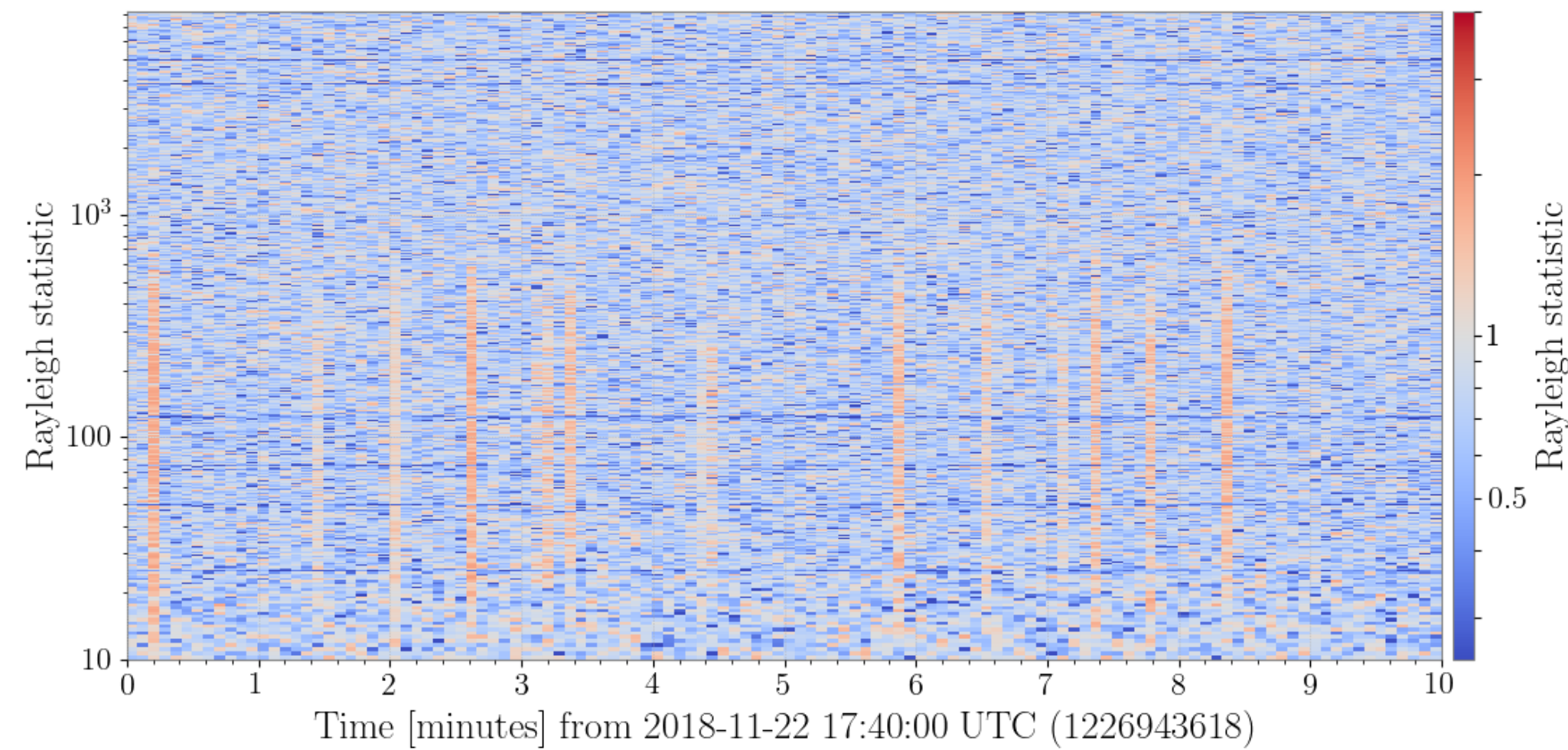
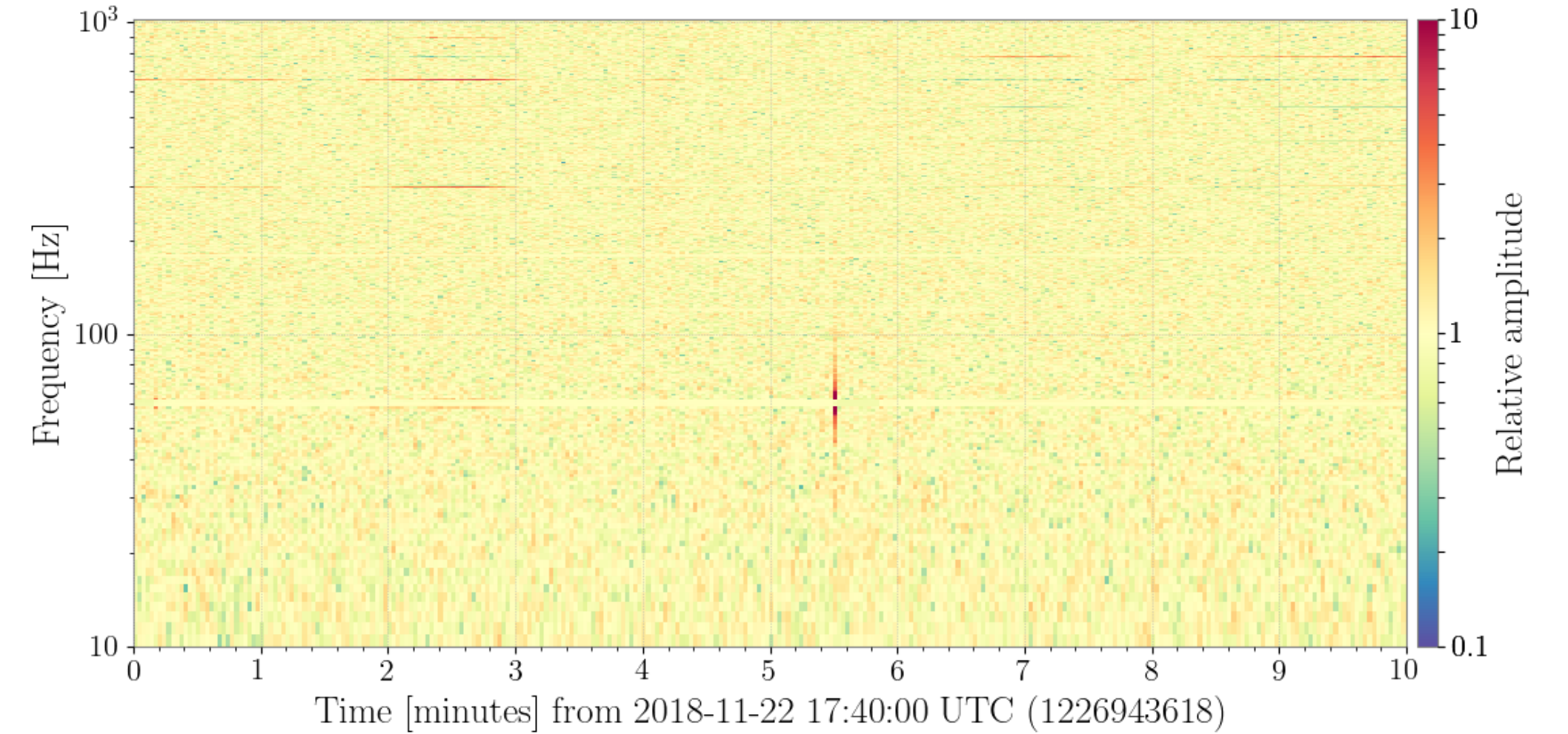
#4 Results

⇒ All results : [Googledrive Link](#)

K1:CAL-PCAL_EX_2_PD_RX_V_DQ



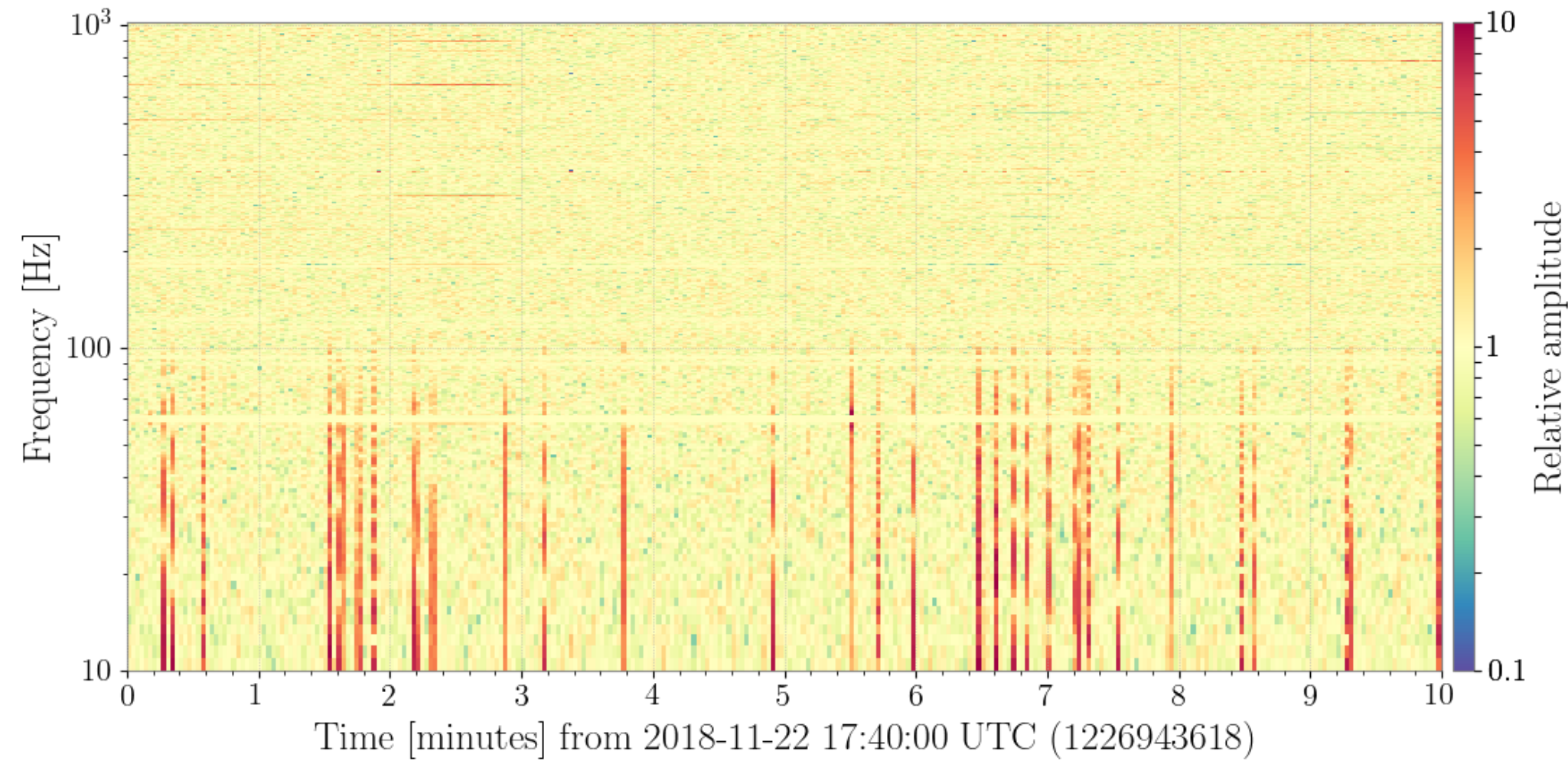
K1:CAL-PCAL_EX_ACC_RX_OUT_DQ



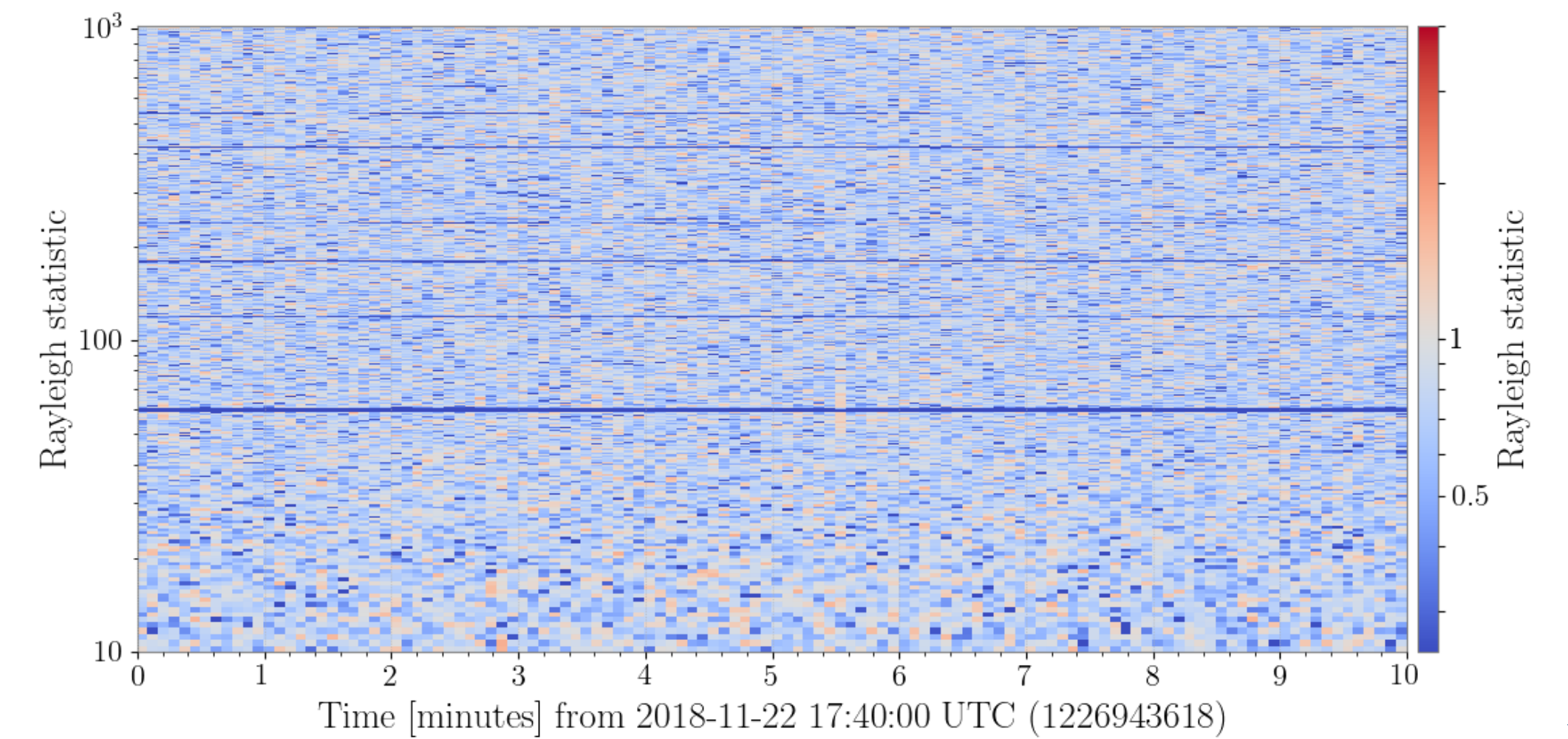
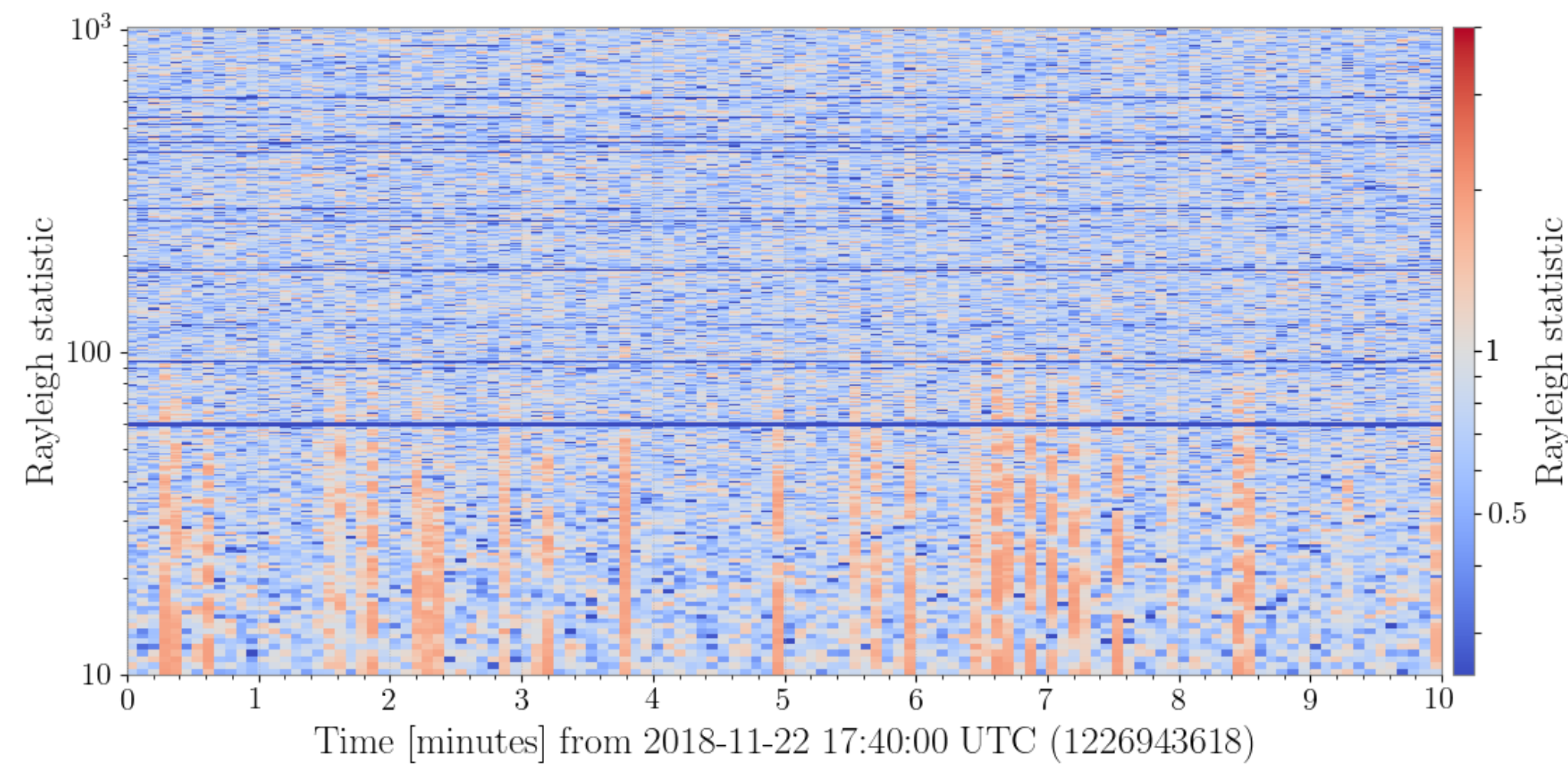
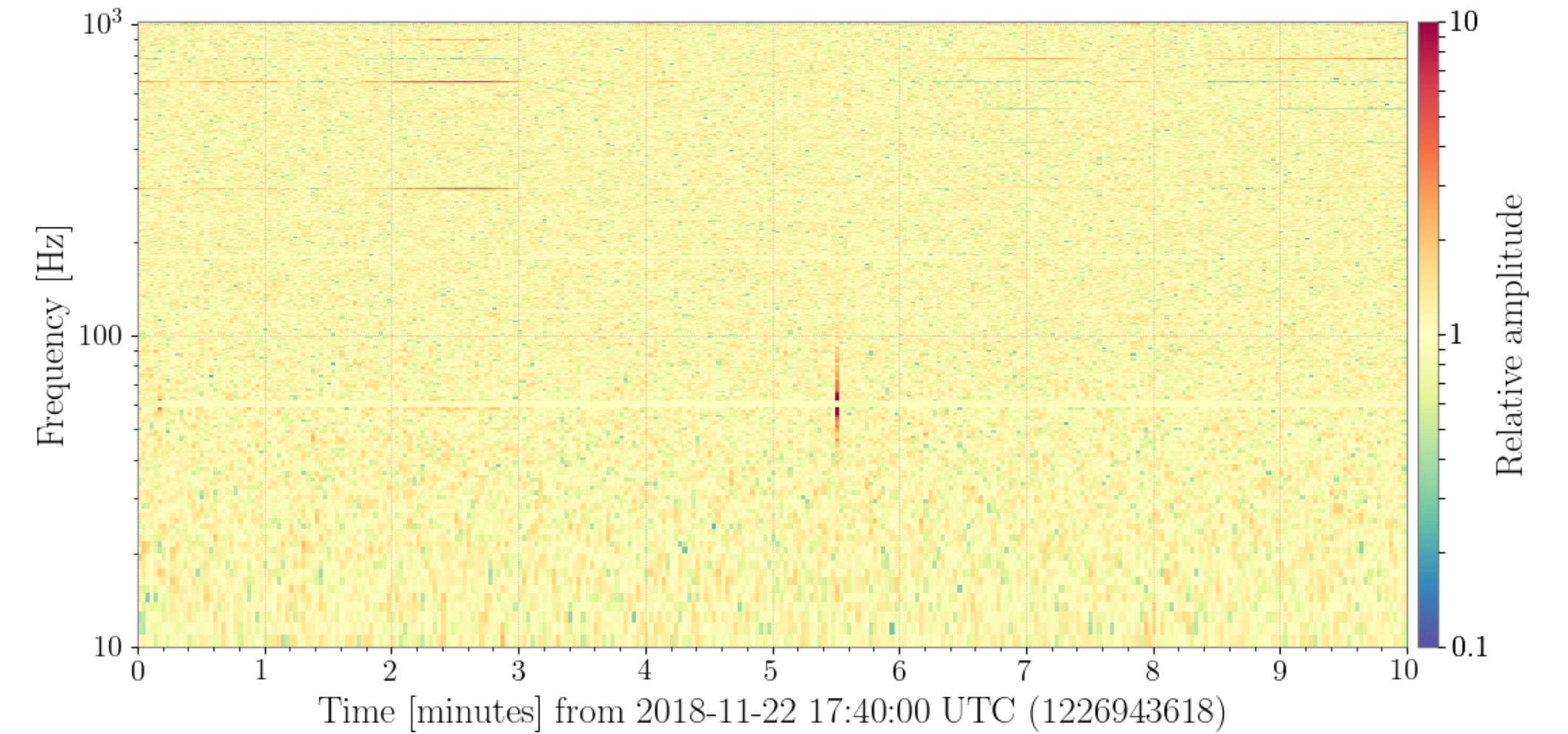
#4 Results

⇒ All results : [Googledrive Link](#)

K1:CAL-PCAL_EX_ACC_TX_OUT_DQ



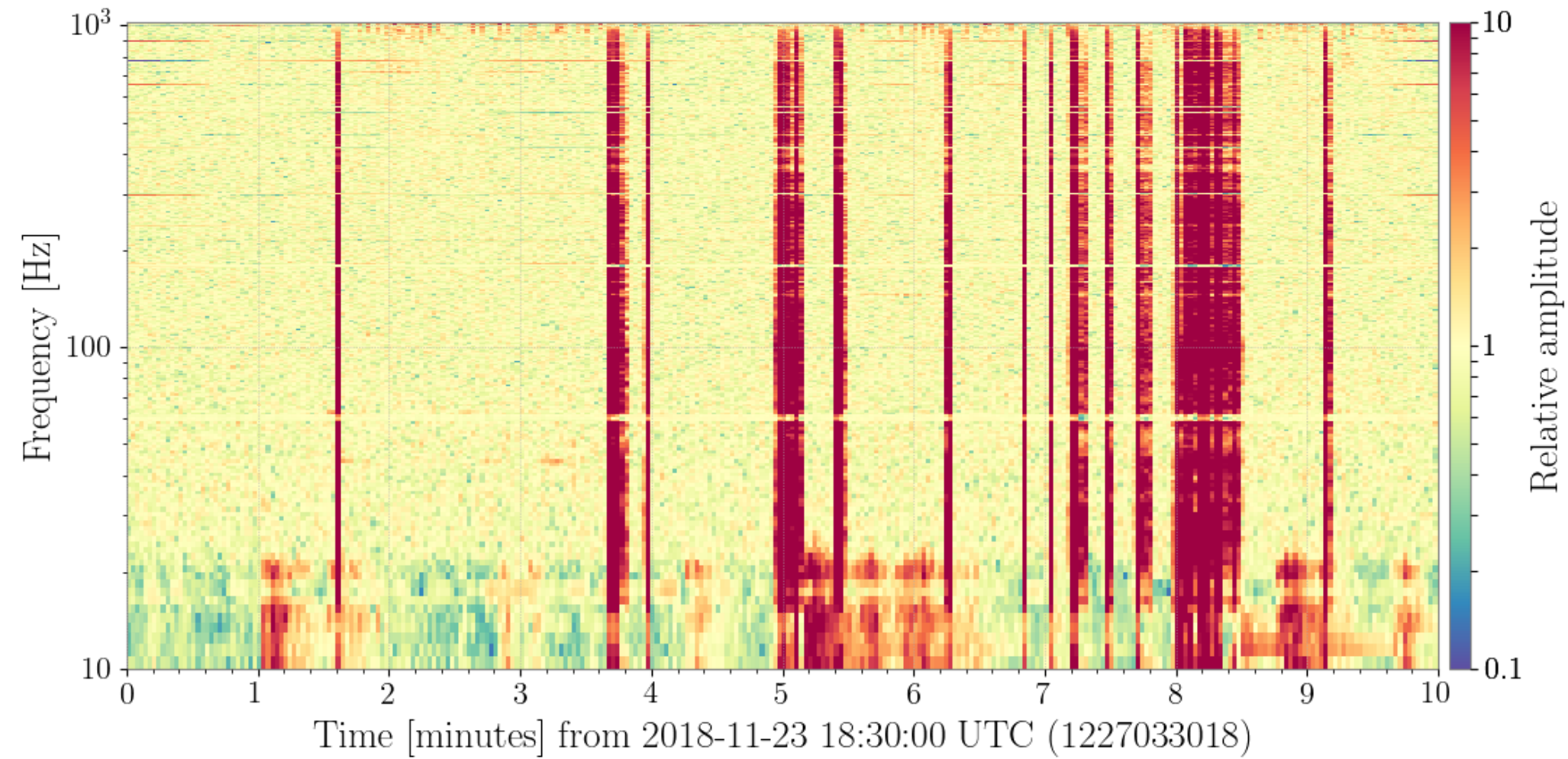
K1:CAL-PCAL_EX_MIC_OUT_DQ



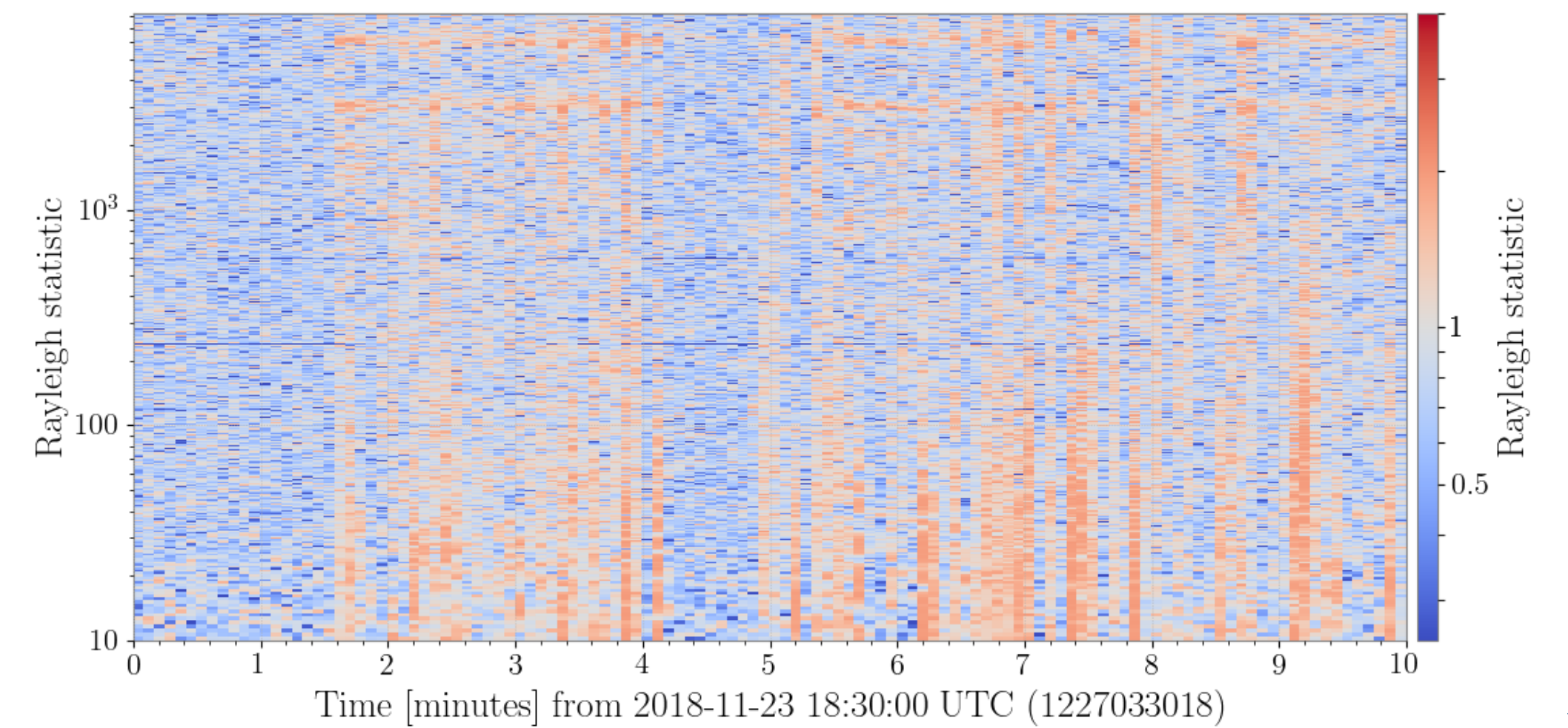
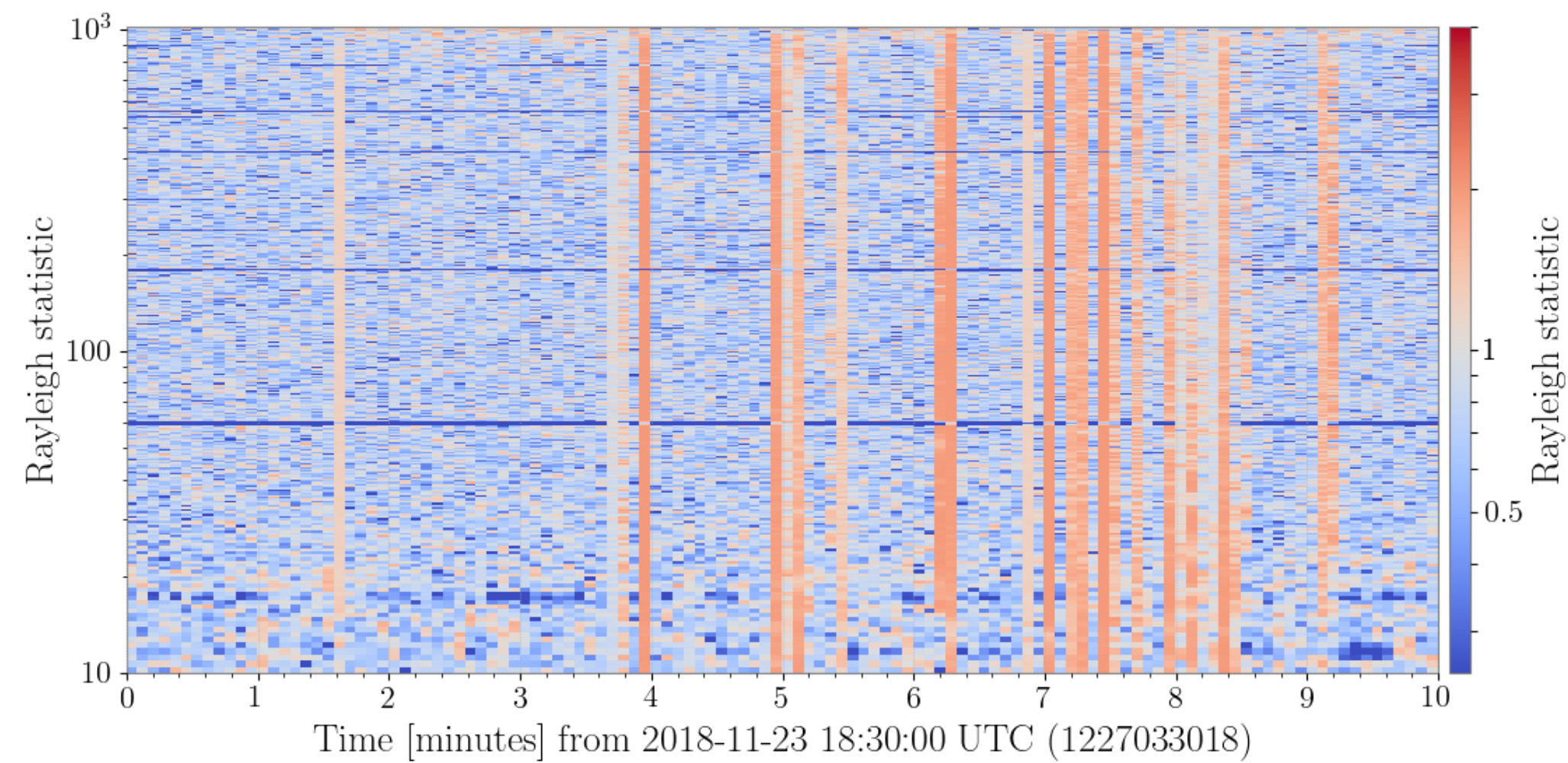
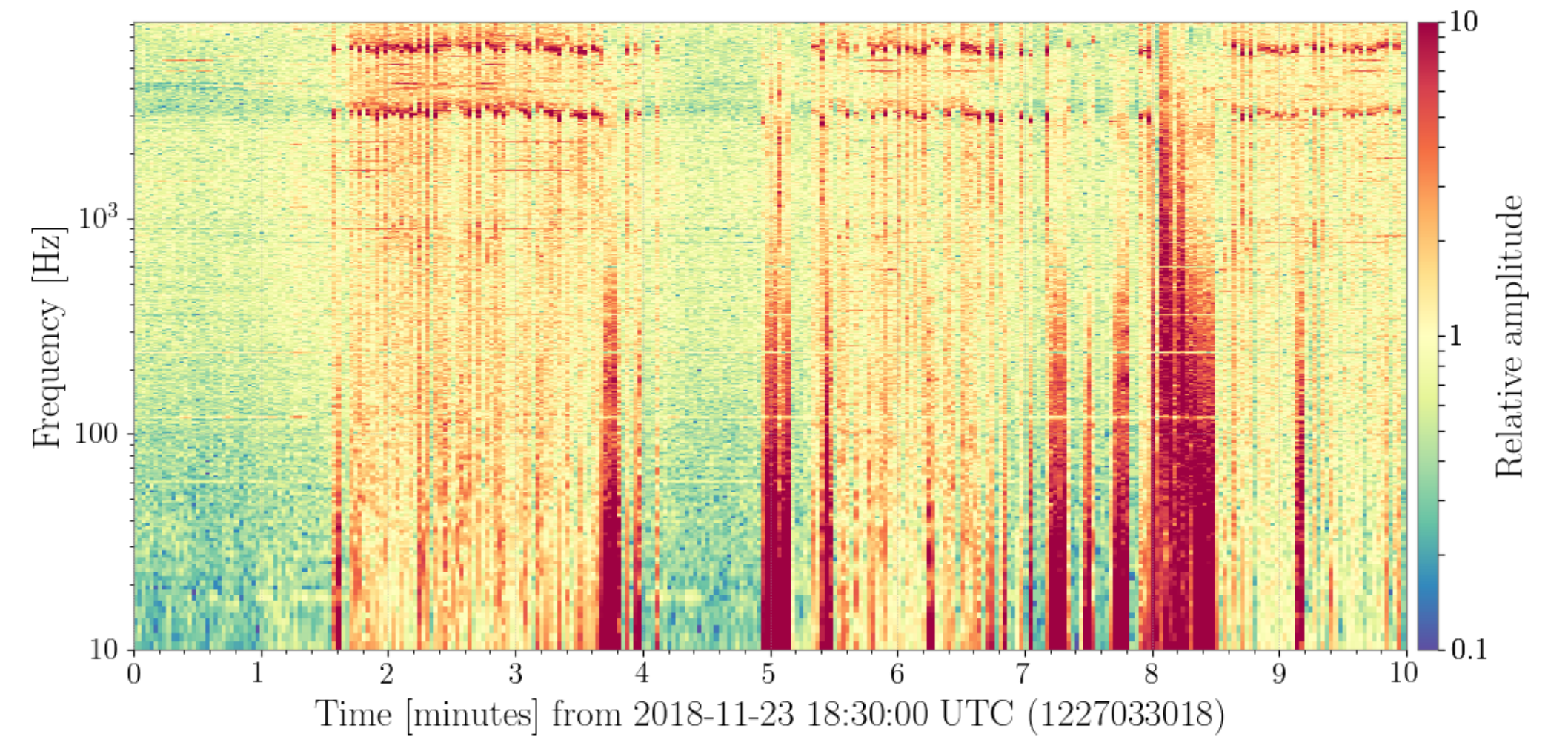
#4 Results

⇒ All results : [Googledrive Link](#)

K1:ALS-DRIFTX_SERVO_IN2_DQ



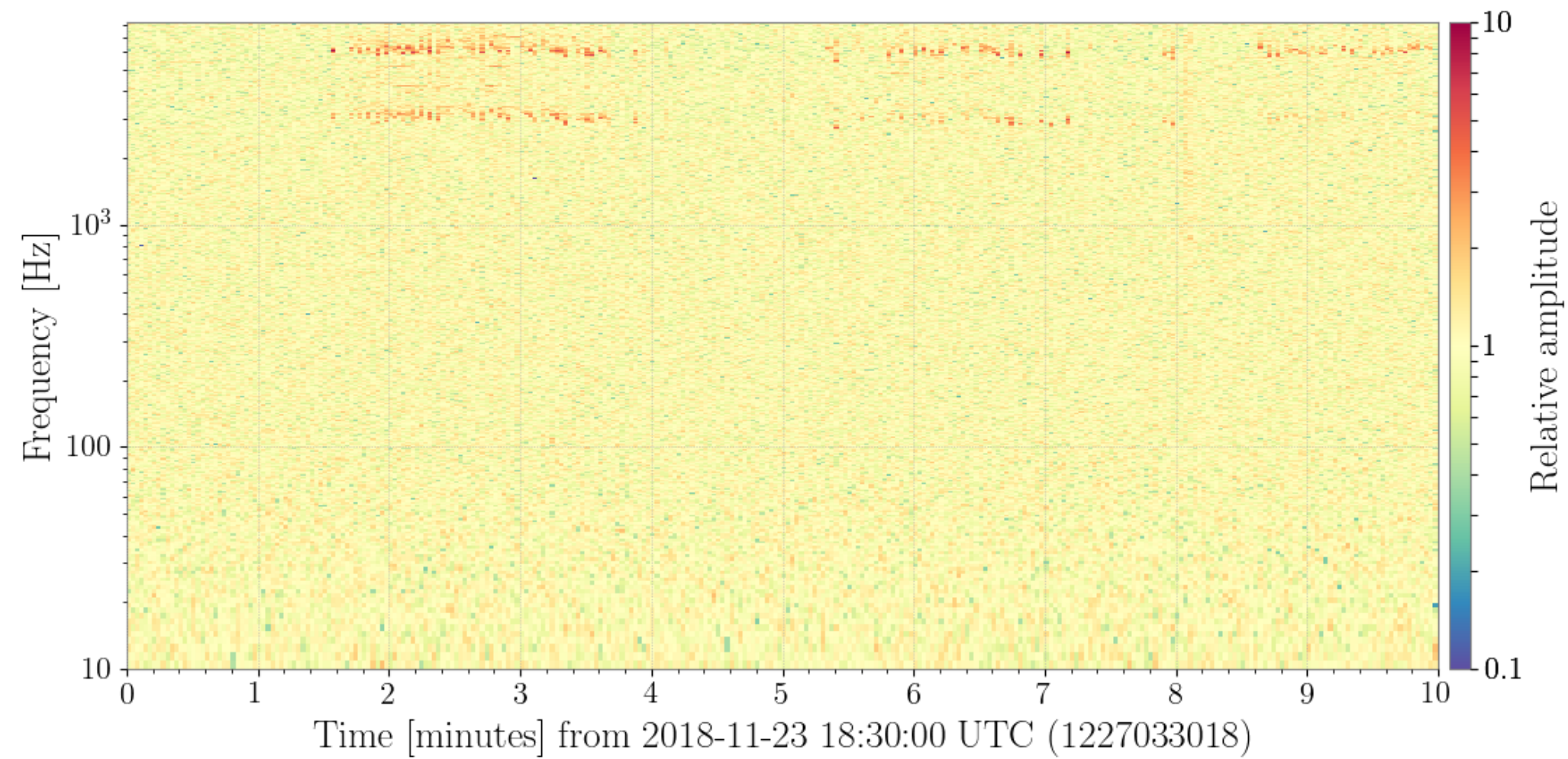
K1:ALS-XARM_REFL_OUT_DQ



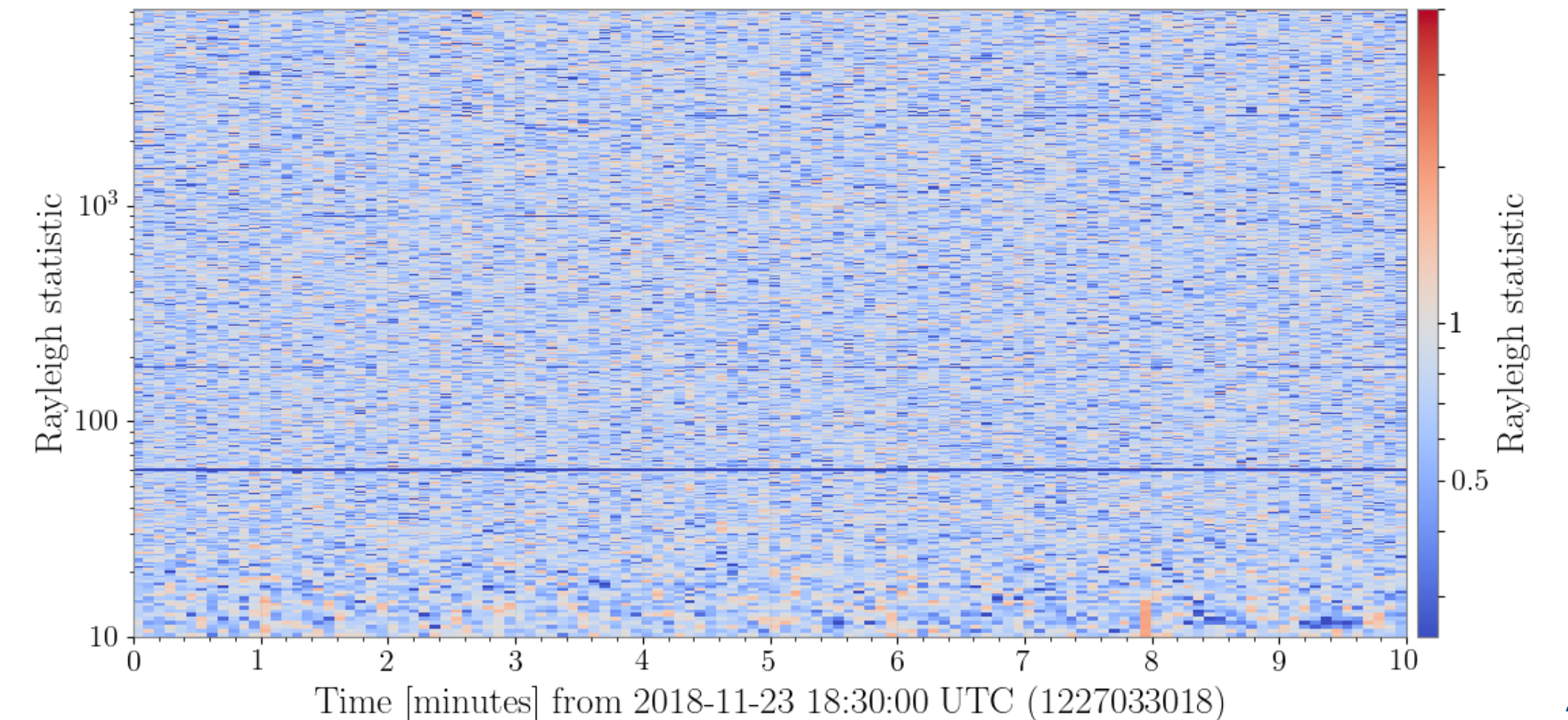
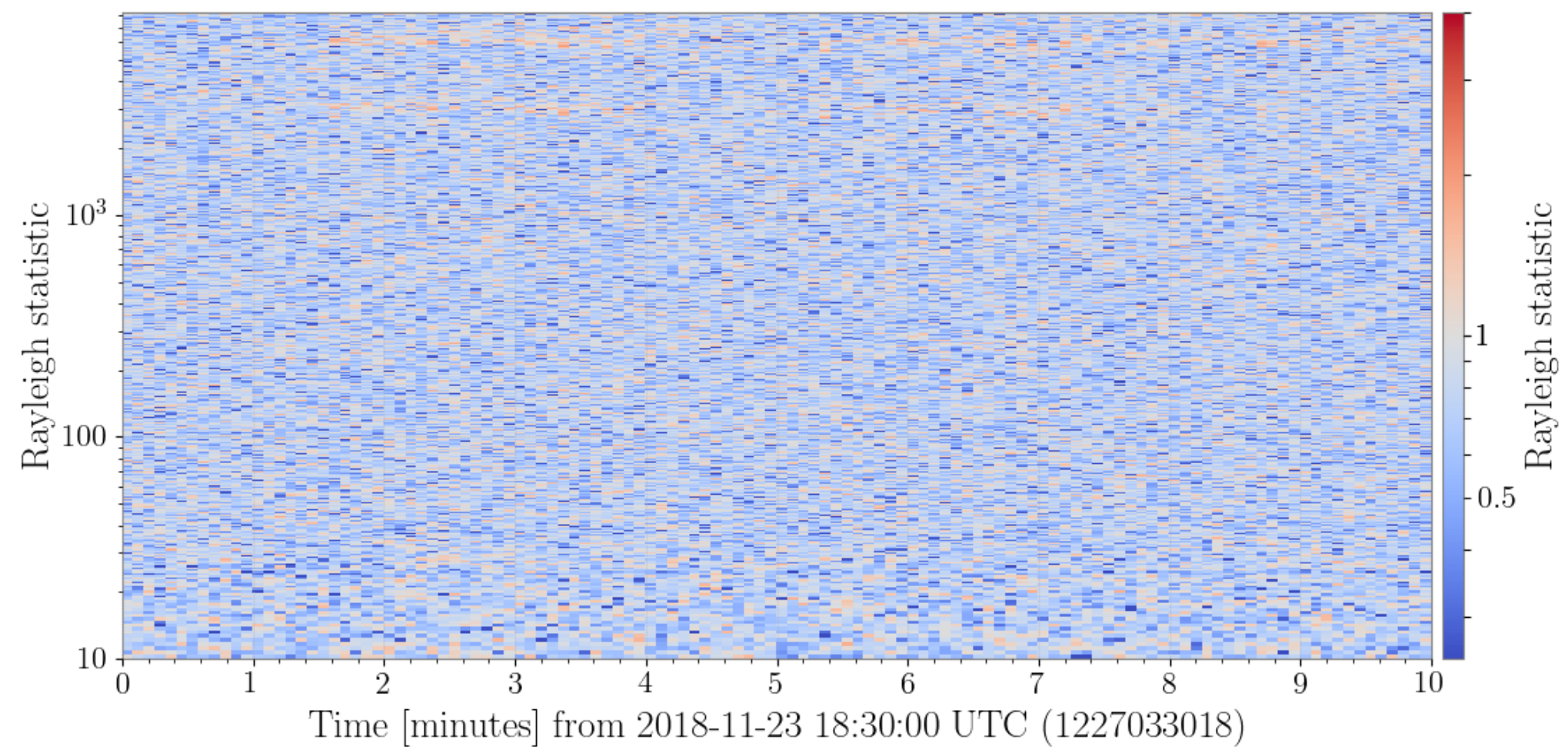
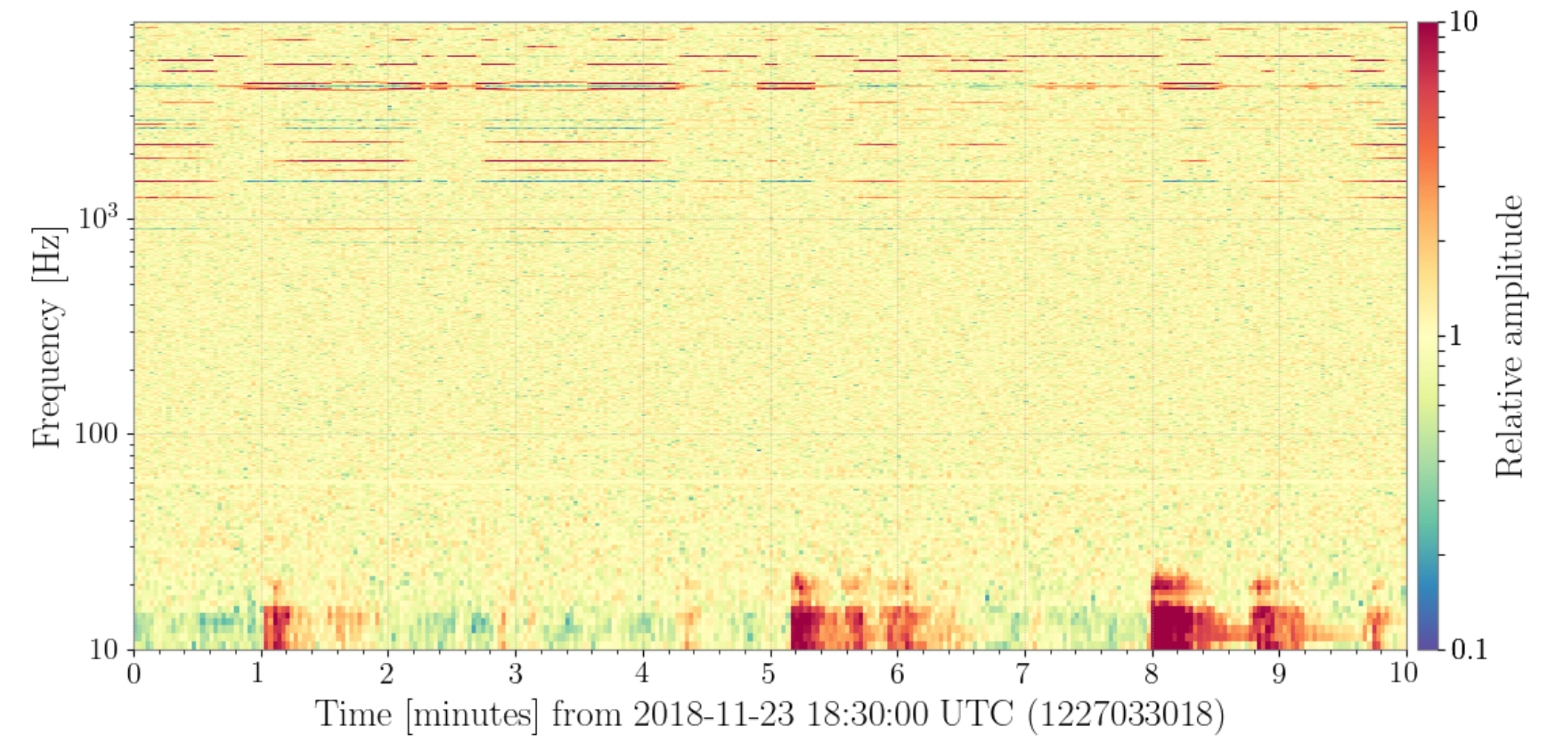
#4 Results

⇒ All results : [Googledrive Link](#)

K1:ALS-YARM_REFL_OUT_DQ



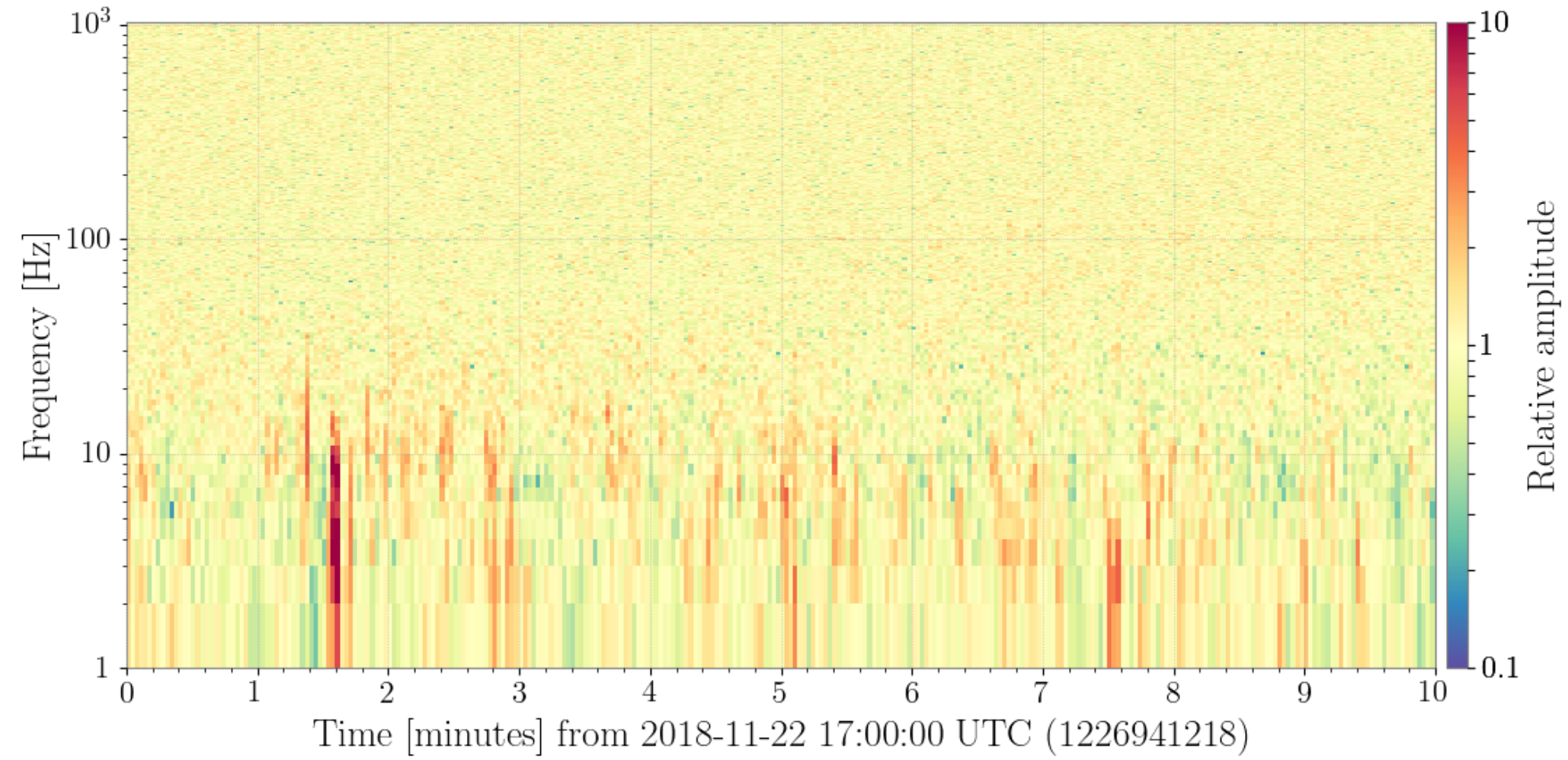
K1:CAL-CS_PROC_XARM_RESIDUAL_DQ



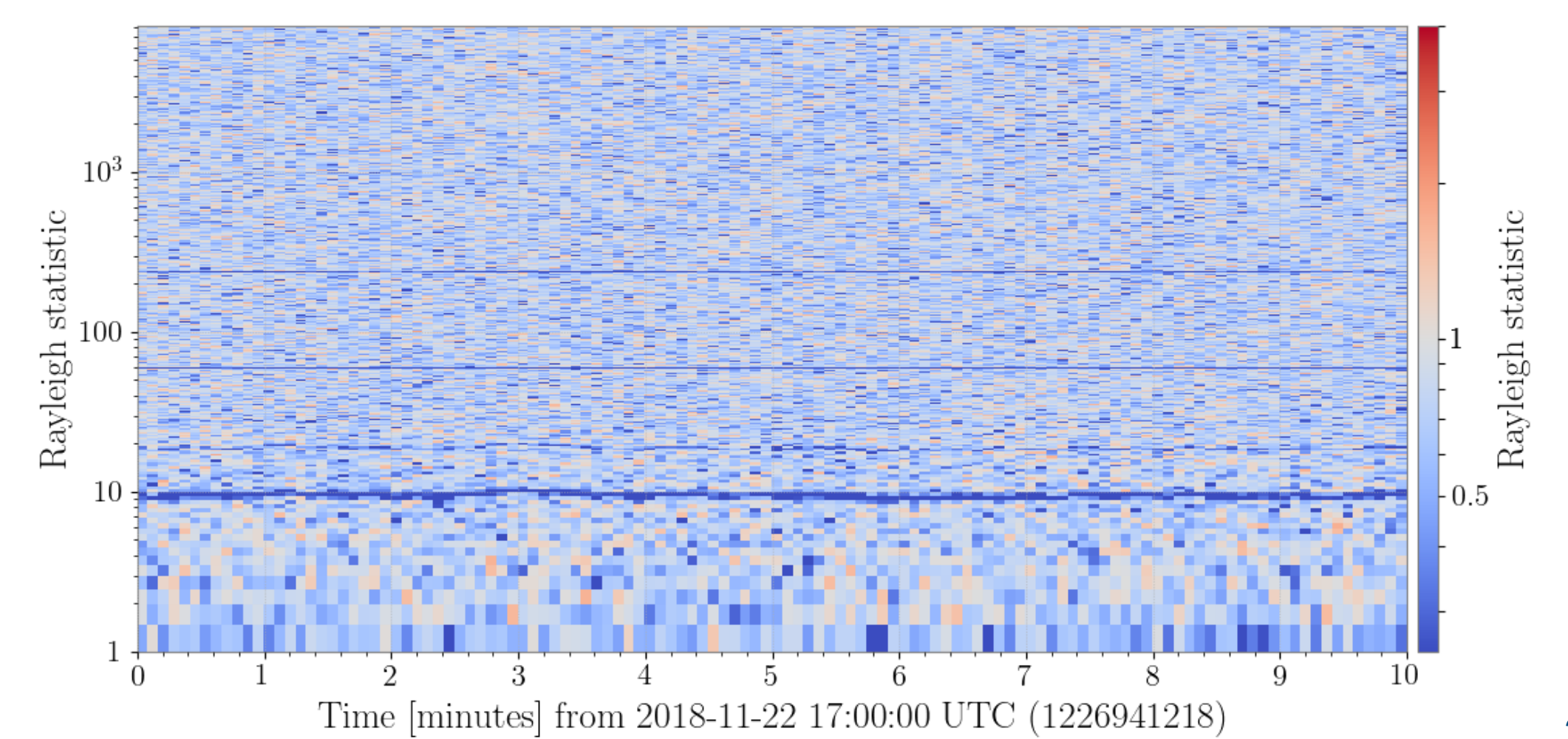
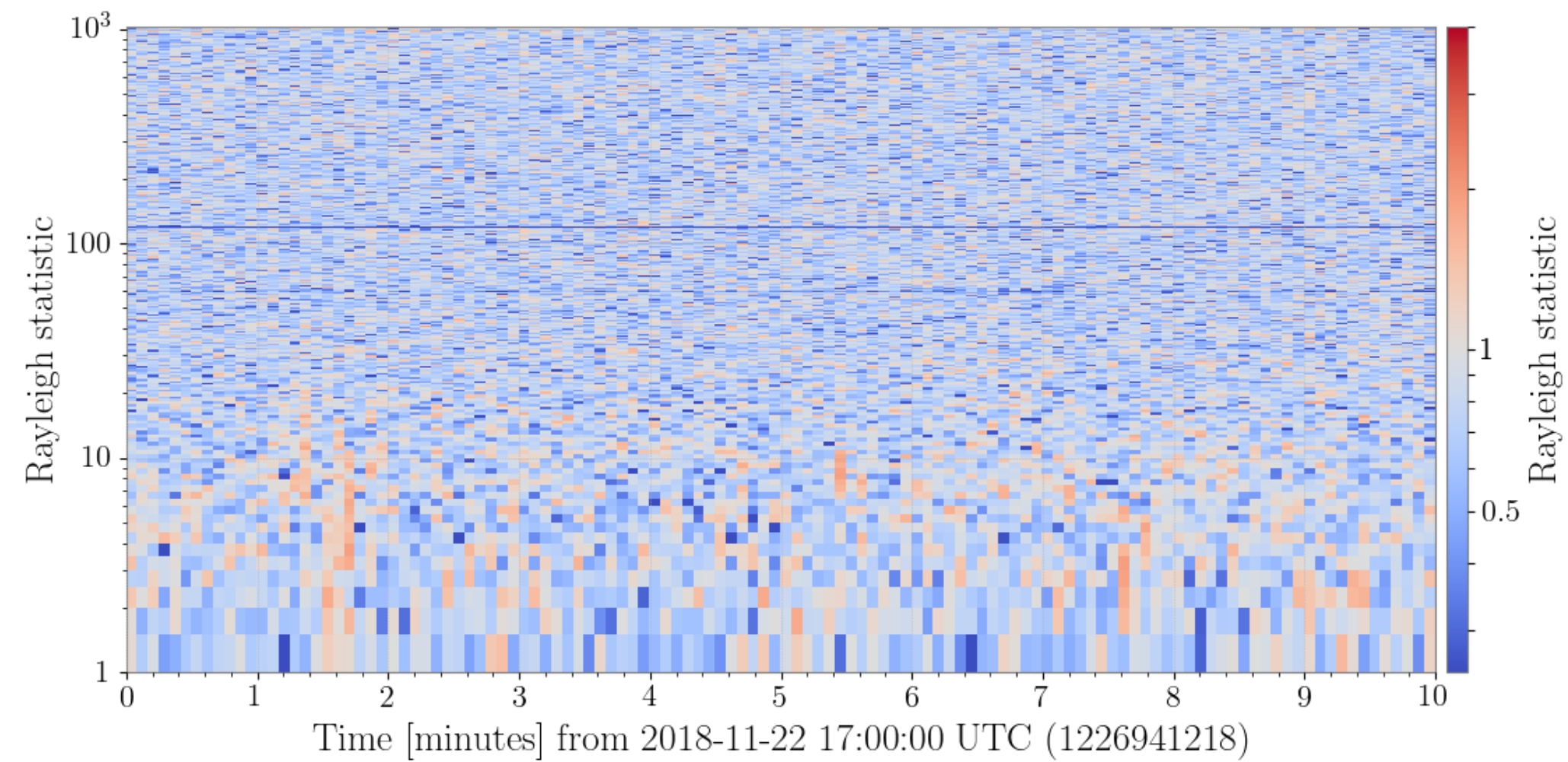
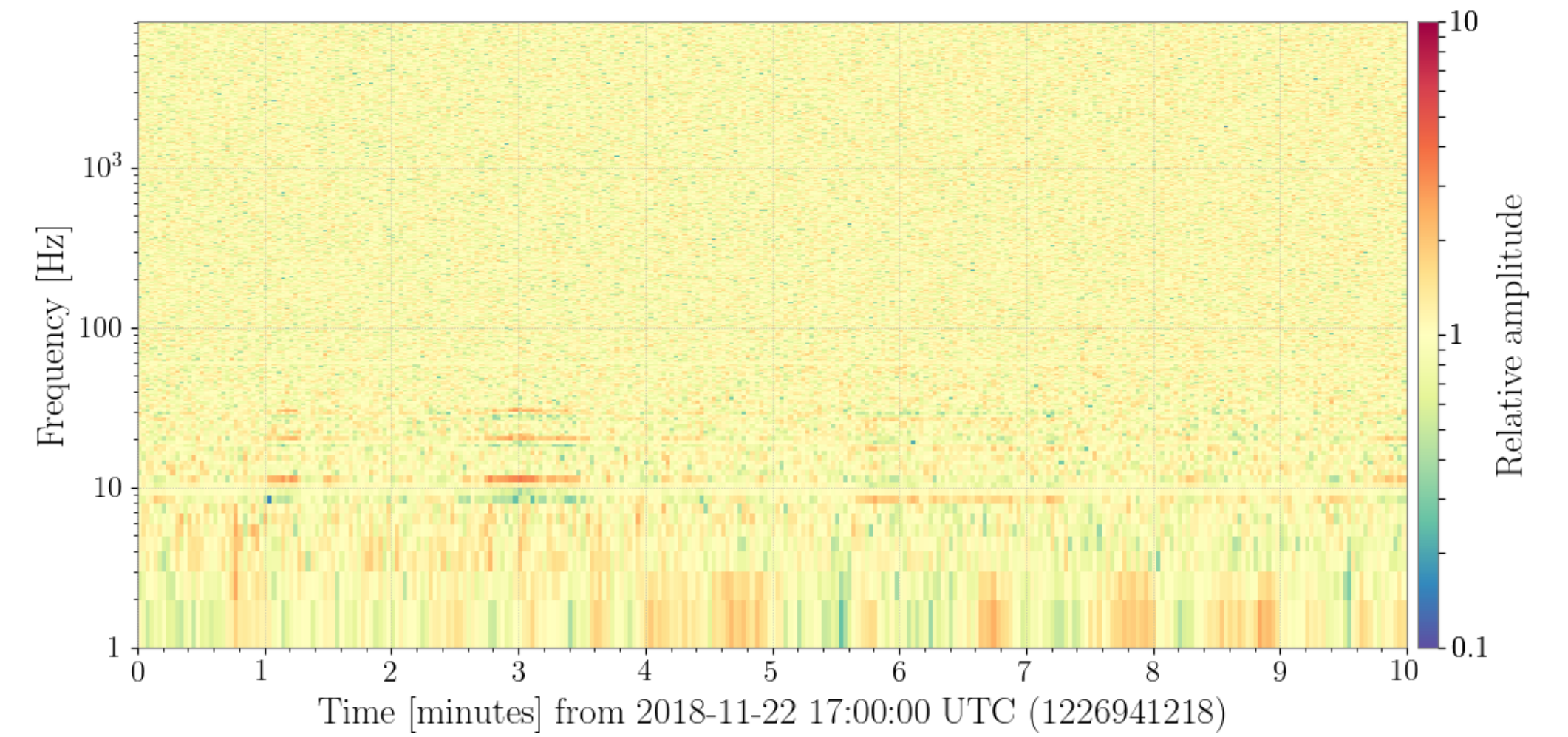
#4 Results

⇒ All results : [Googledrive Link](#)

K1:IMC-MCE_TRANS_QPDA1_DC_YAW_OUT_DQ



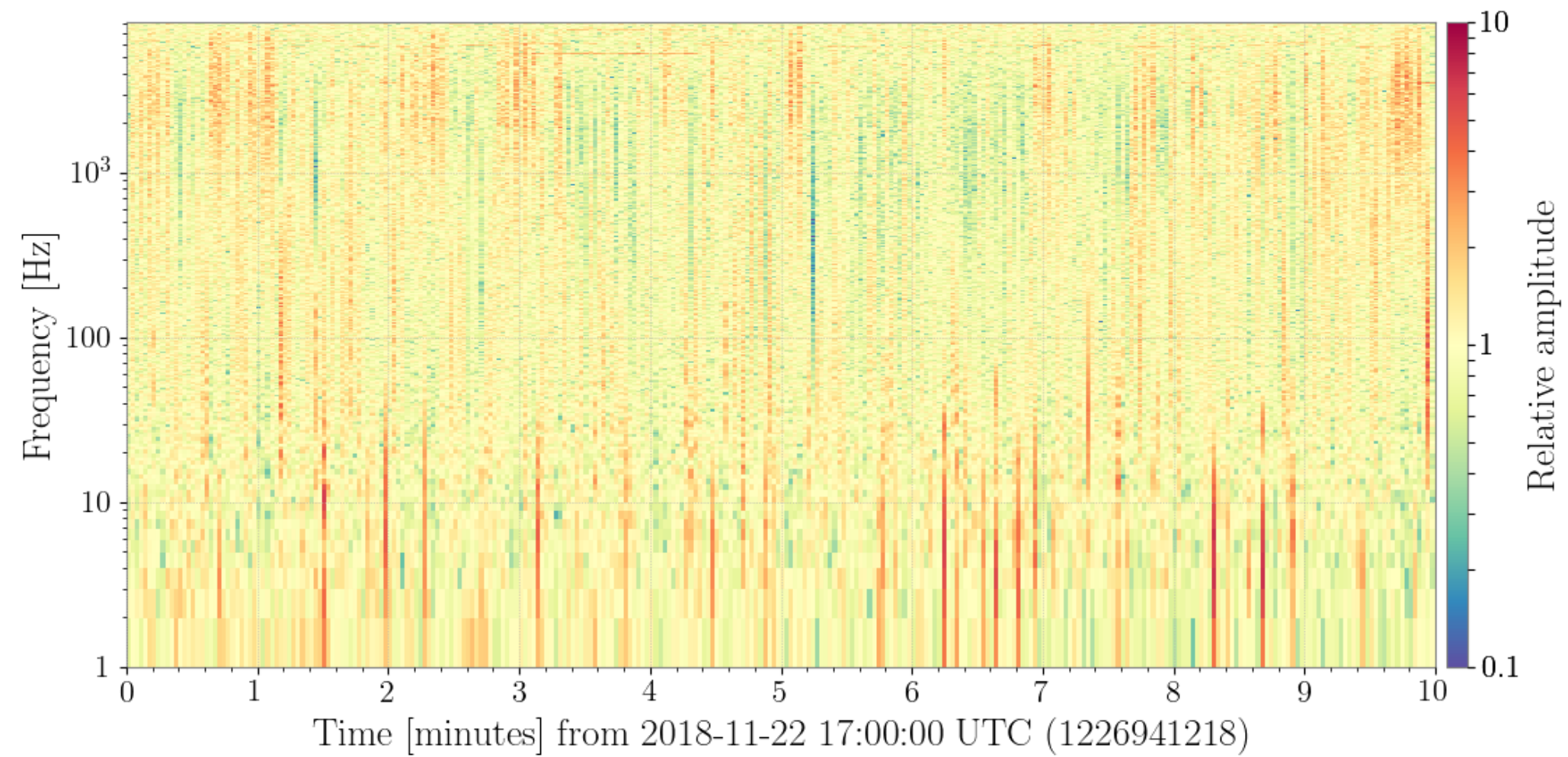
K1:LAS-POW_PMC_OUT_DQ



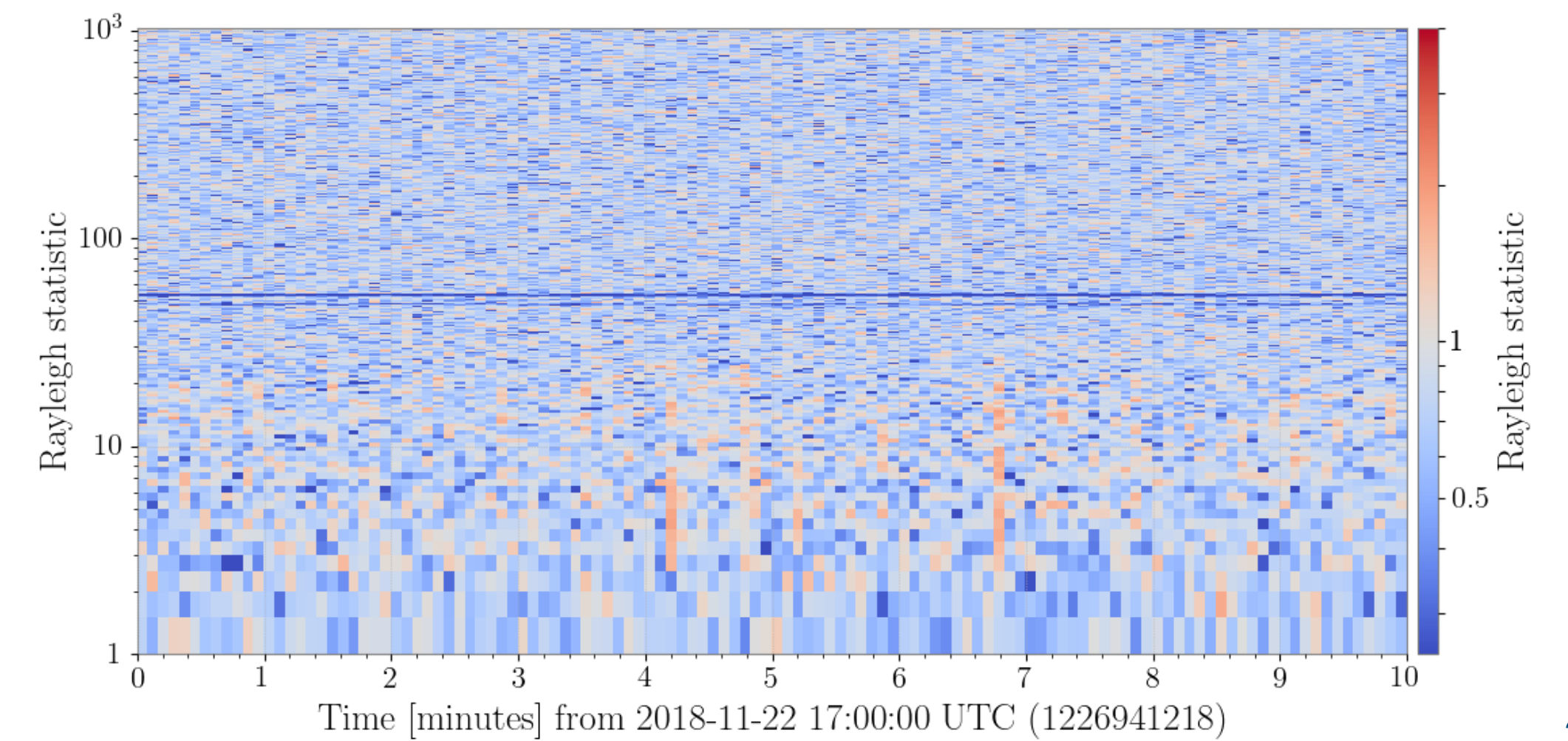
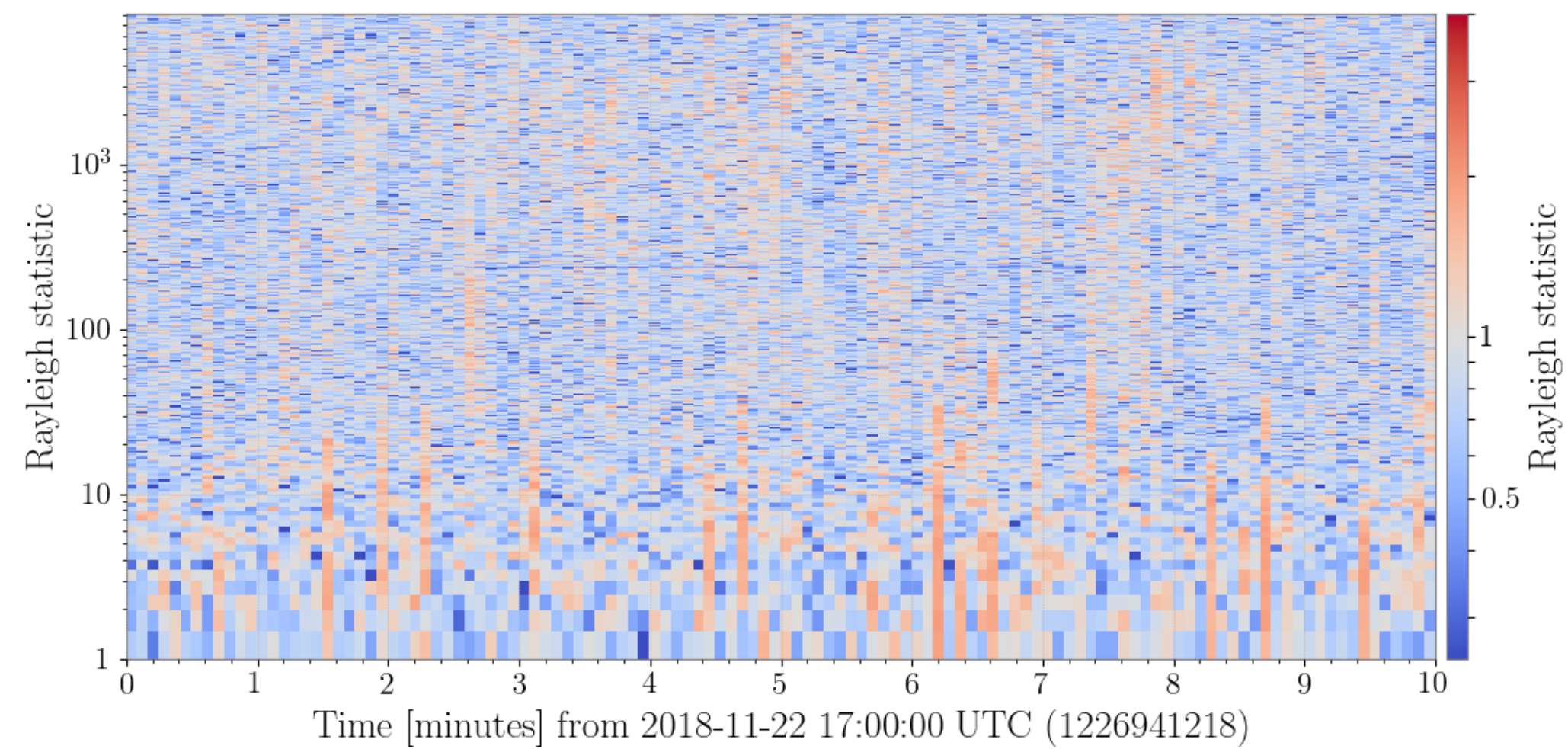
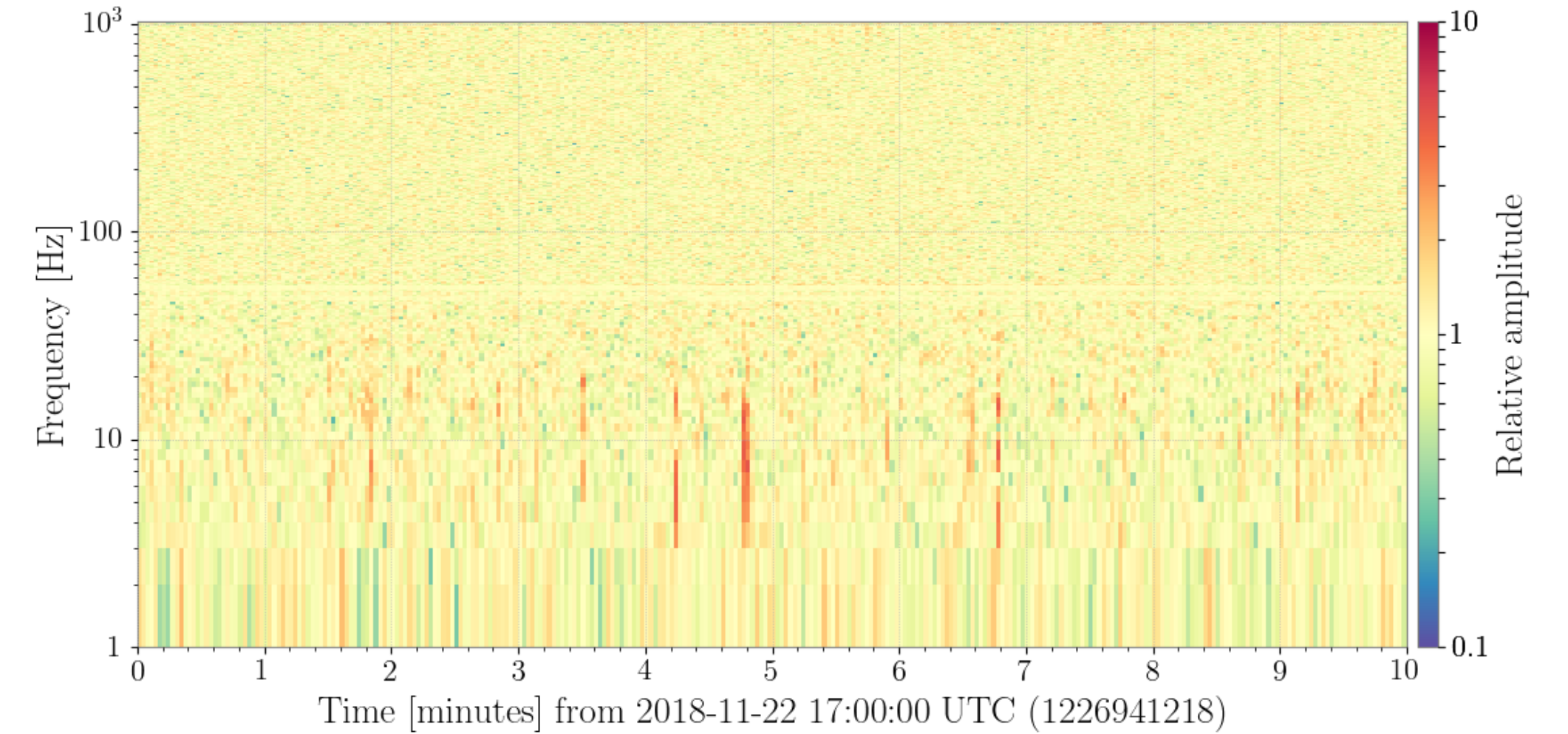
#4 Results

⇒ All results : [Googledrive Link](#)

K1:LSC-REFLAIR_A_LF_OUT_DQ



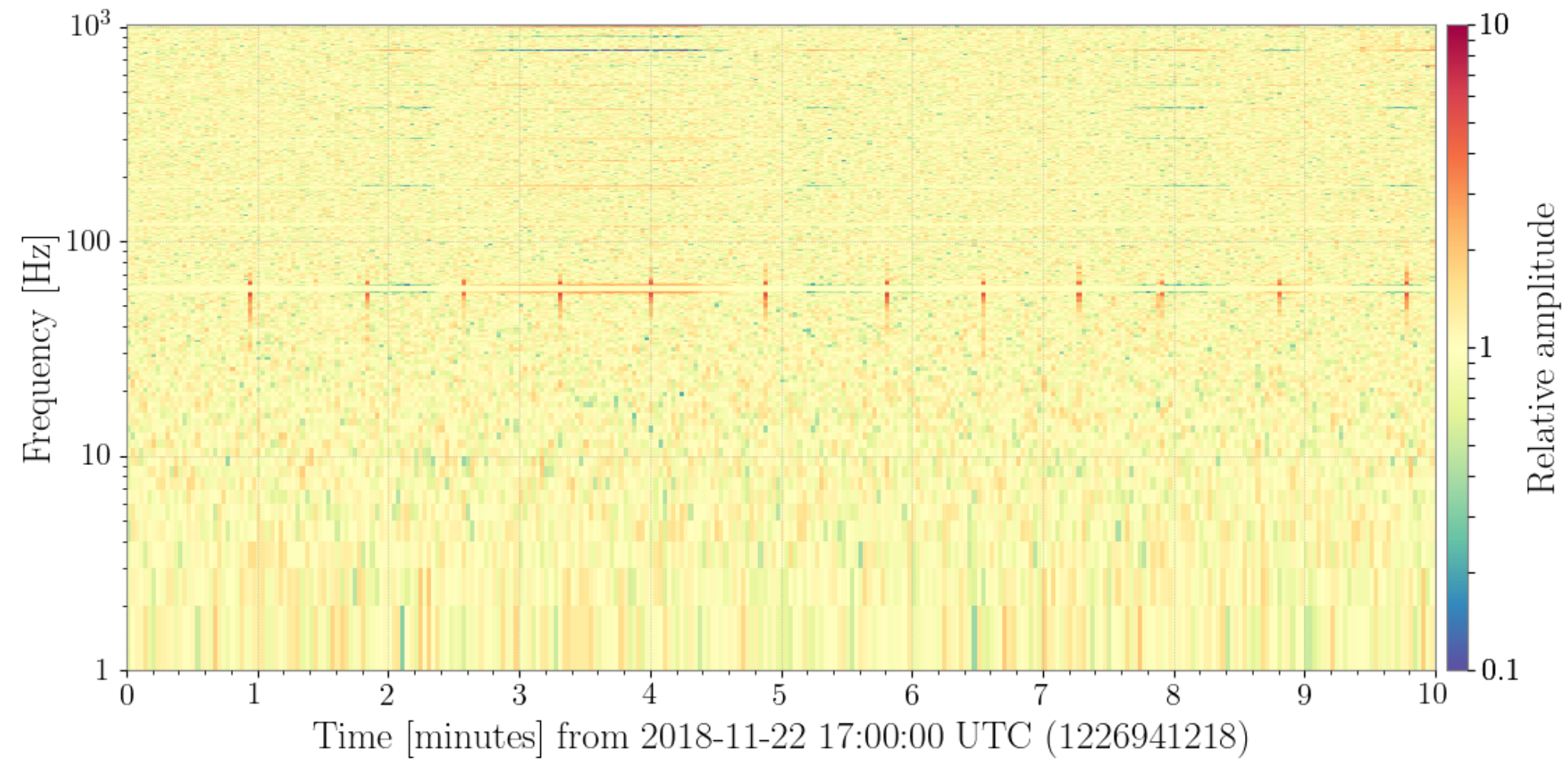
K1:PEM-EXV_SEIS_WE_BLRMS_MID_OUT_DQ



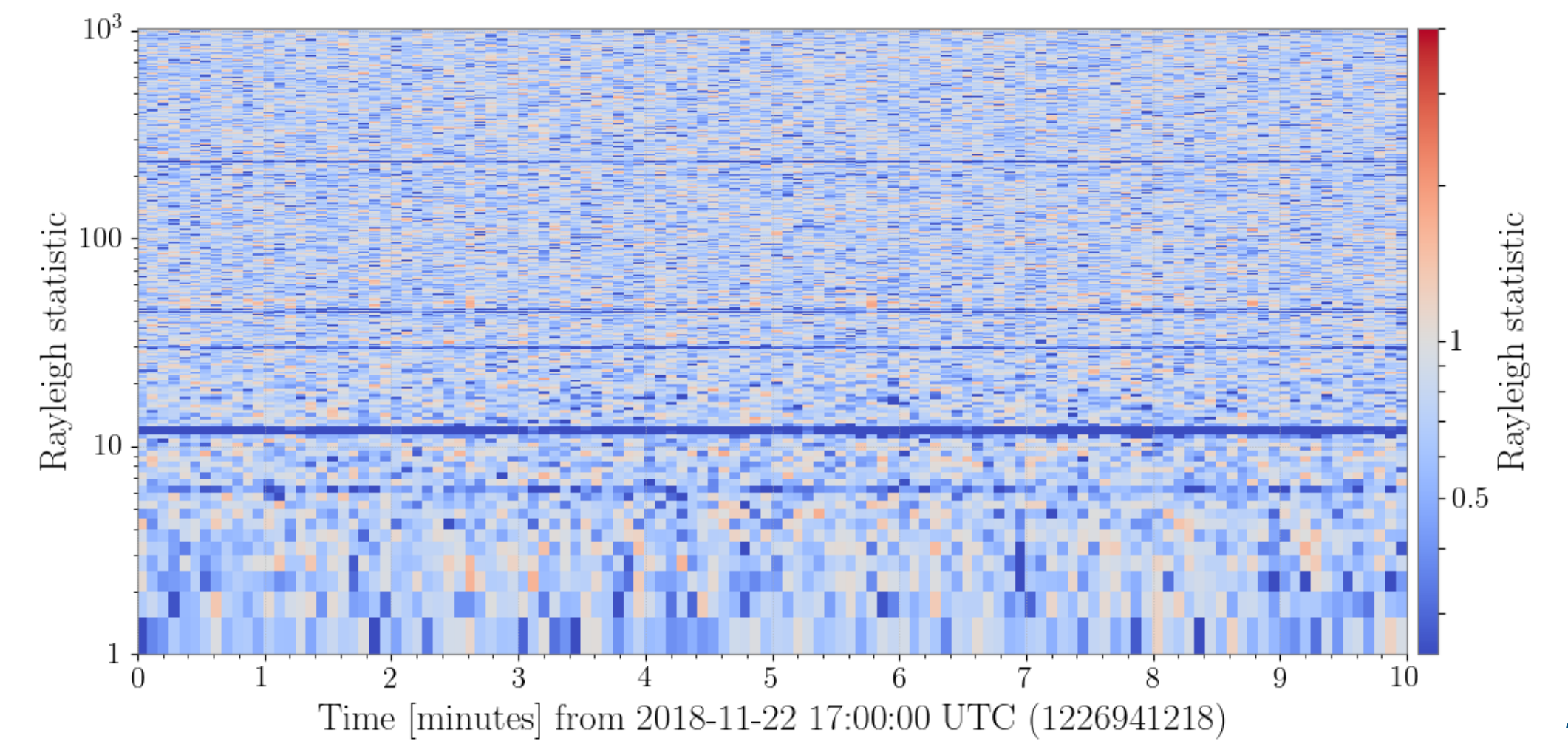
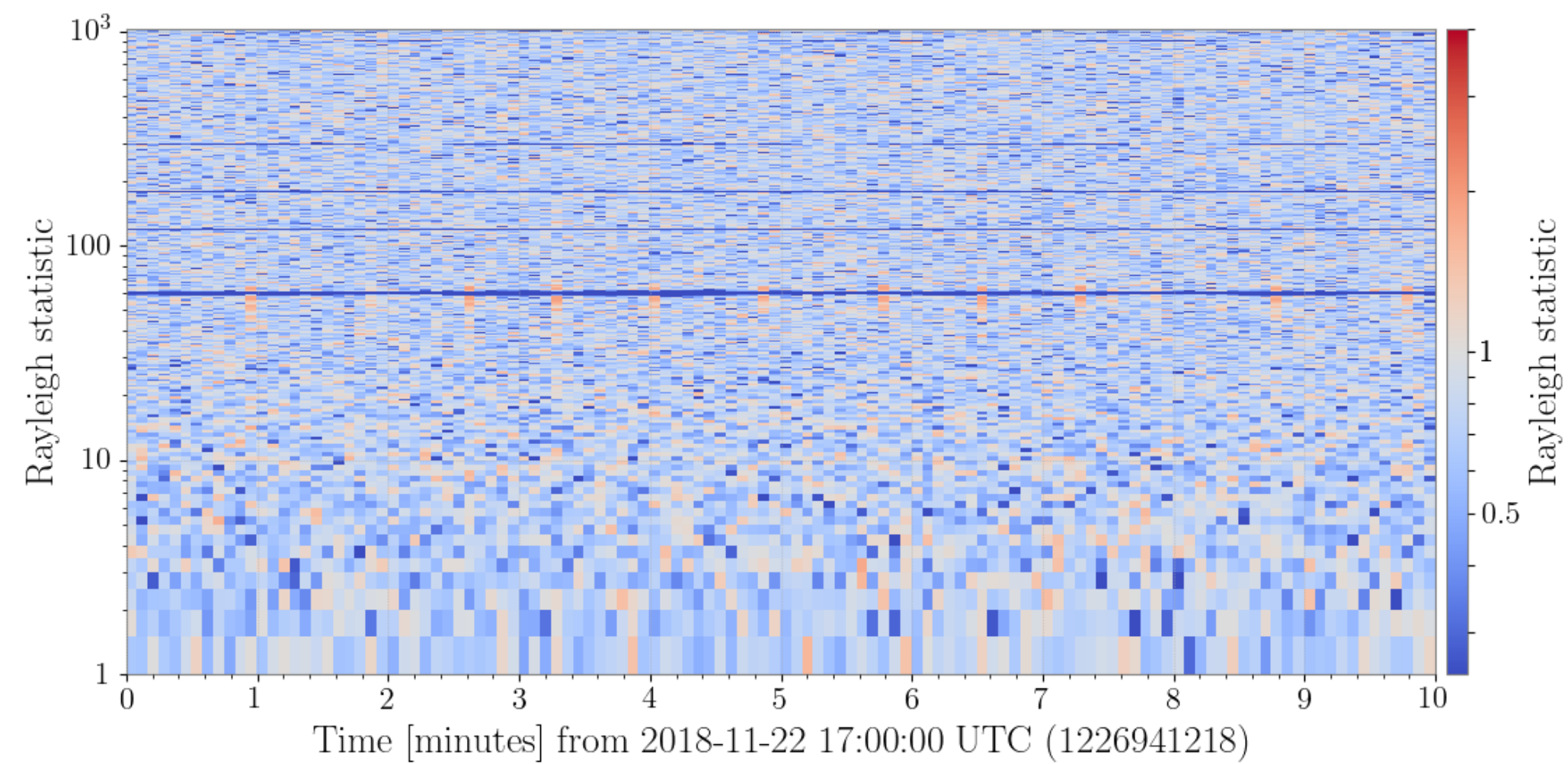
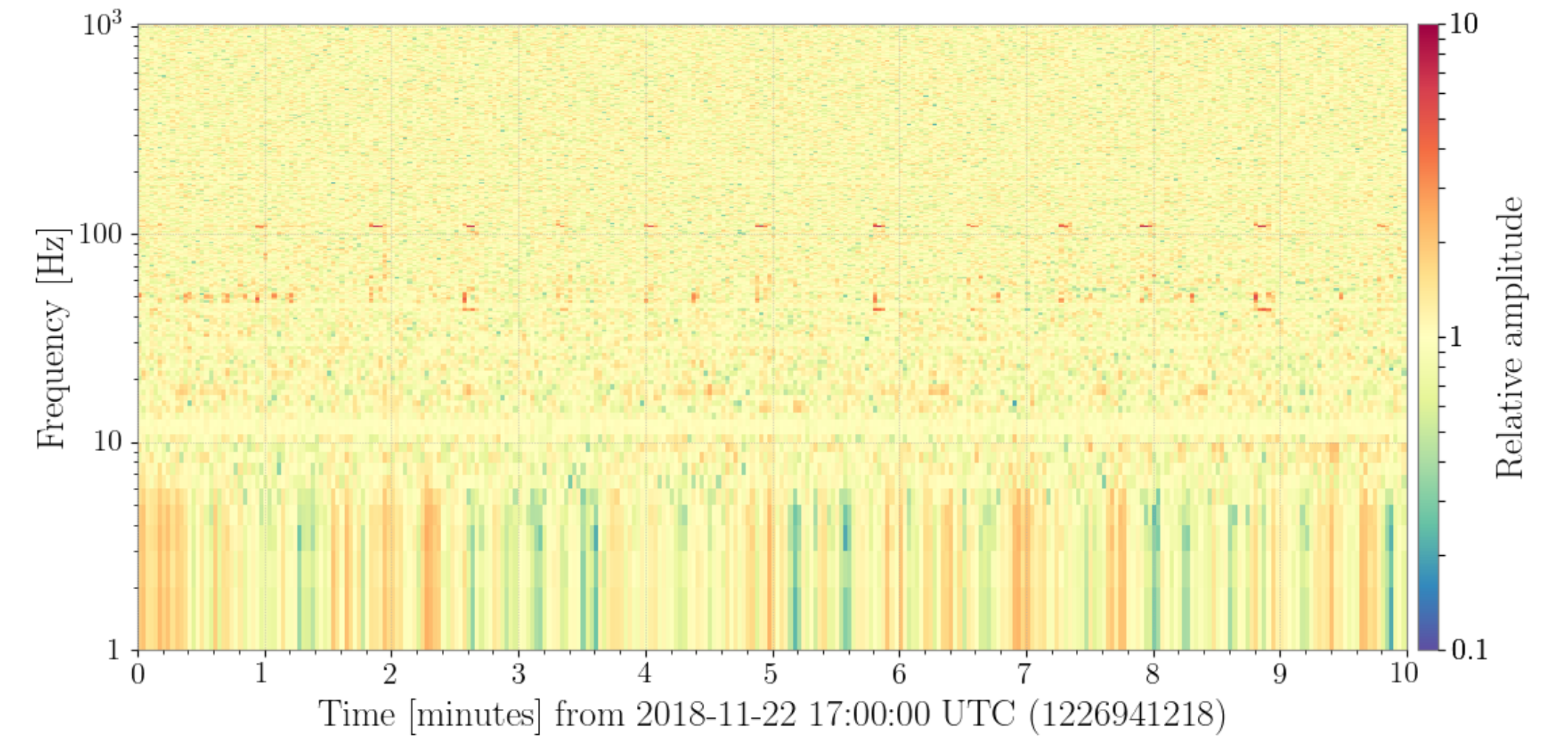
#4 Results

⇒ All results : [Googledrive Link](#)

K1:PEM-IFI_ACC_REFL_TABLE_OUT_DQ



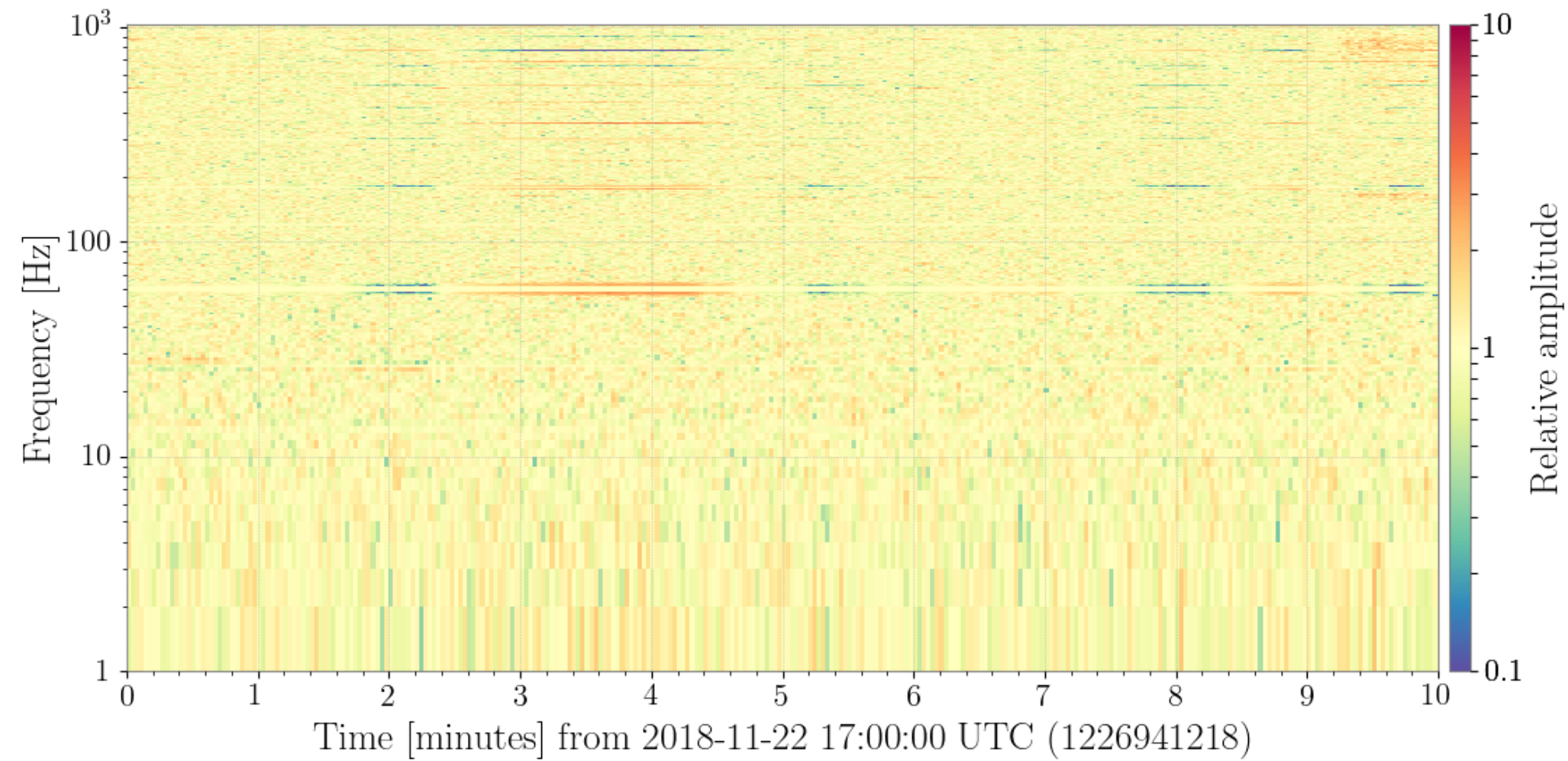
K1:PEM-IMC_SEIS_MCI_WE_SENSINF_OUT_DQ



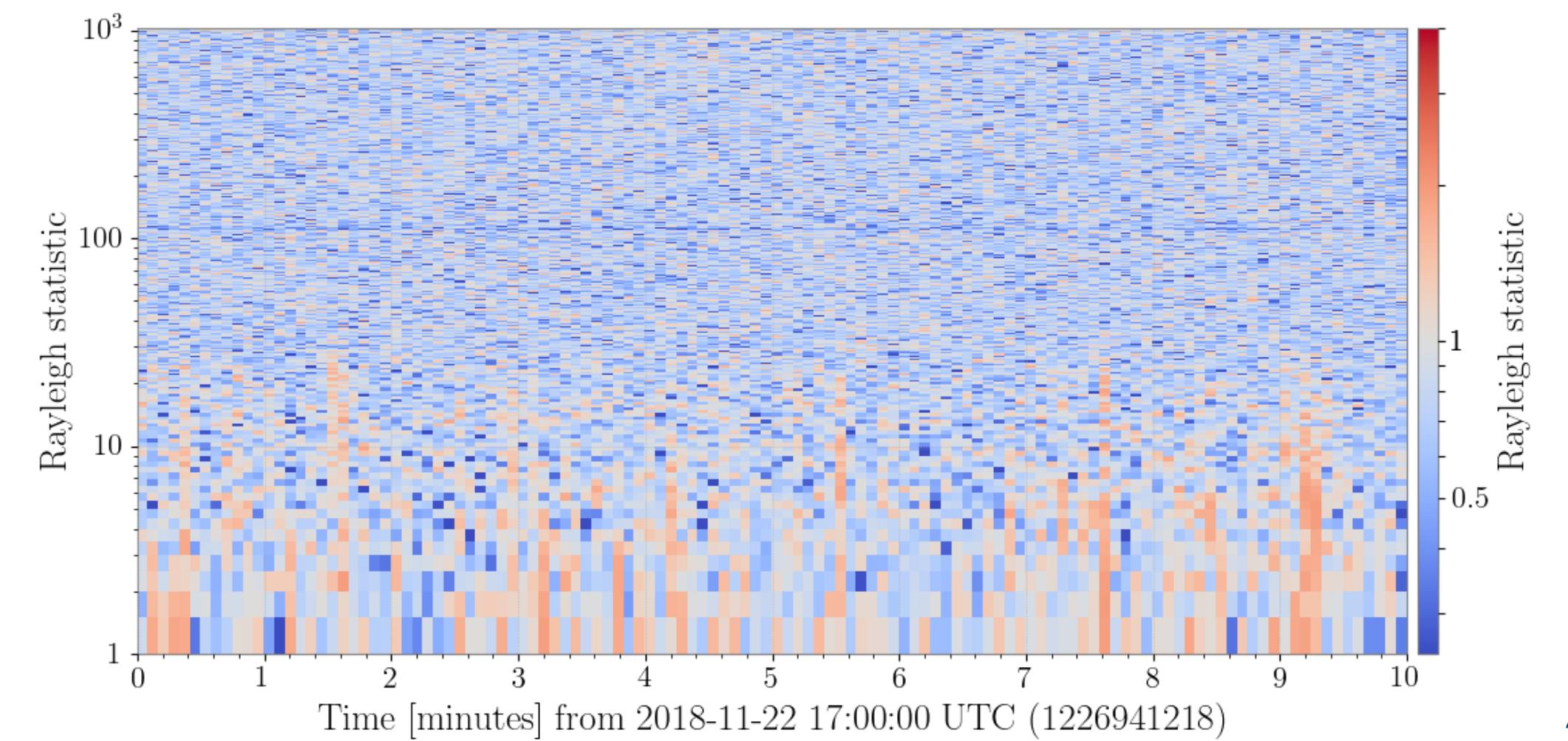
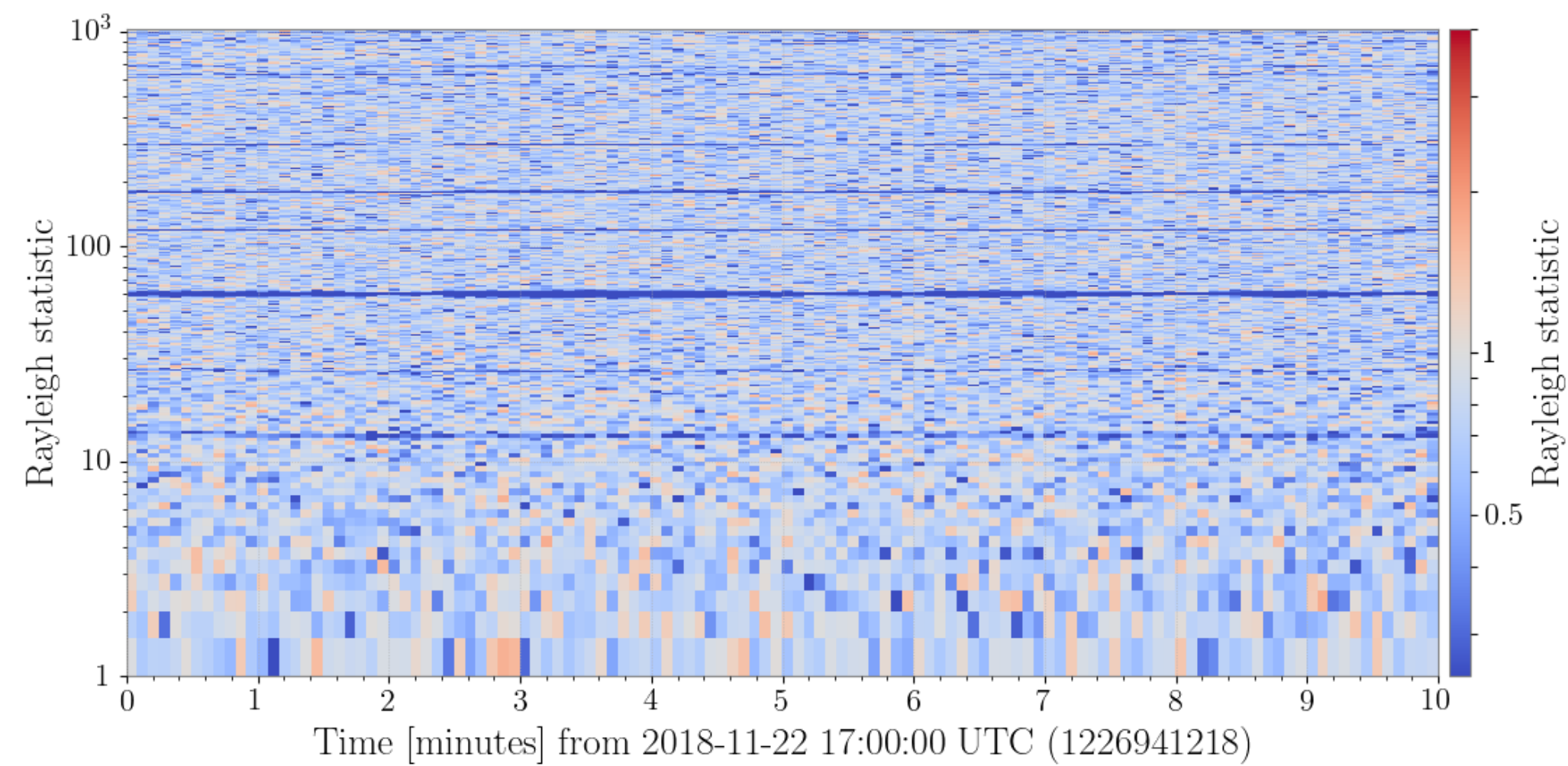
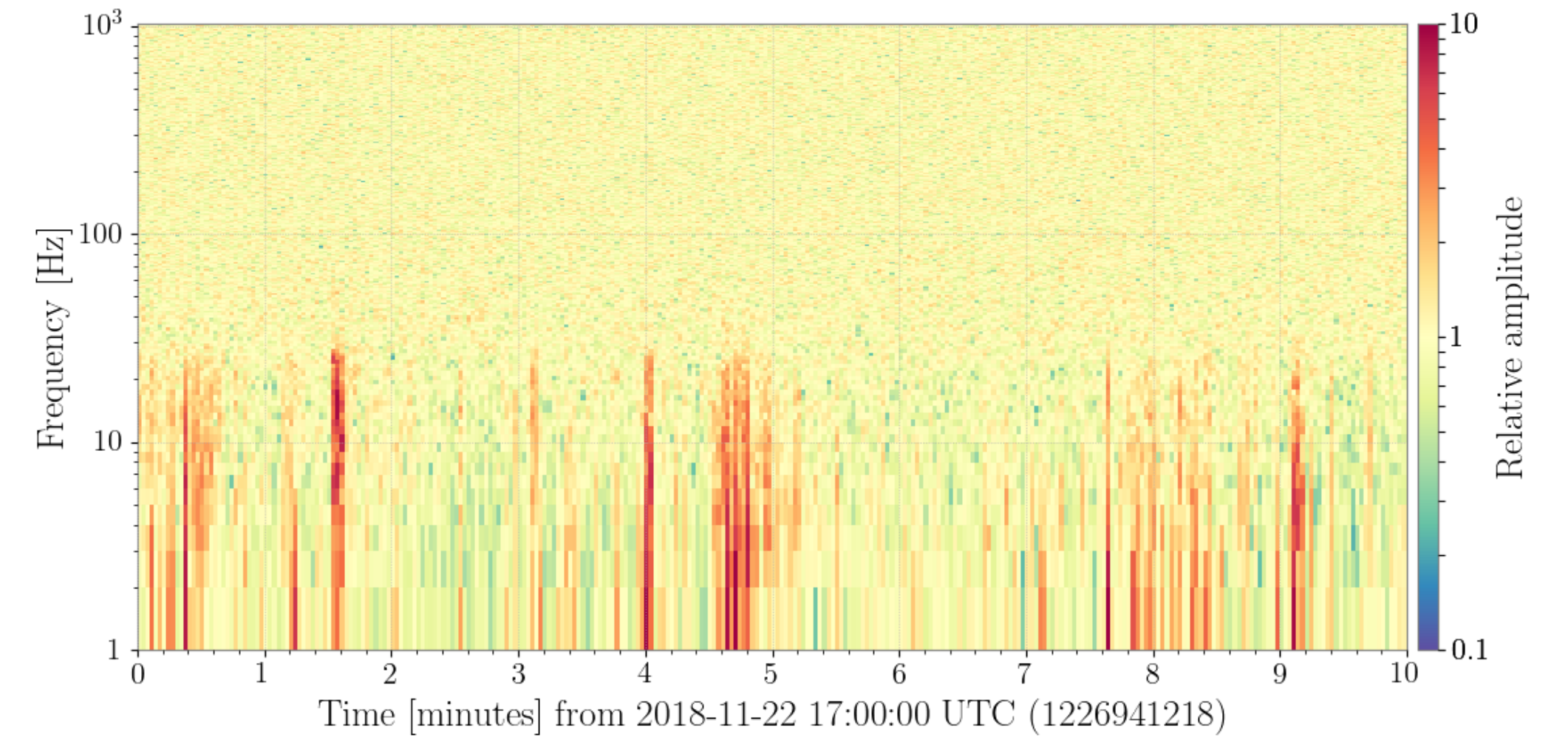
#4 Results

⇒ All results : [Googledrive Link](#)

K1:PEM-POP_MIC_OUT_DQ



K1:PEM-PSL_ACC_TABLE1_Z_OUT_DQ



#5 Progress toward the MLA application

⇒ First assignment

Basically, Q-Scan data is **three-dimensional data** of time-frequency-energy.

```
[[ 0.09265488, 0.00821098, 0.06883343, ..., 0.02522794, 0.02522794, 0.02522794],  
 [ 0.0927586 , 0.00841609, 0.0690567 , ..., 0.02192003, 0.02192003, 0.02192003],  
 [ 0.09286829, 0.00862691, 0.06928917, ..., 0.01934536, 0.01934536, 0.01934536],  
                                     ...,  
 [ 0.07389838, -0.11229309, -0.10057292, ..., 0.03171151, 0.03171151, 0.03171151],  
 [ 0.07382319, -0.1138508 , -0.10259651, ..., 0.03031545, 0.03031545, 0.03031545],  
 [ 0.07375078, -0.11541509, -0.10462873, ..., 0.02608719, 0.02608719, 0.02608719]]
```

So, How do we **labeling** this?

#5 Progress toward the MLA application

⇒ **Second assignment**

> Glitch types

: **Burst** types , **Periodic** types, **Harmonics** types and Others

>> Need more detailed List for Glitch types

: Air compressor, Chirp, Blip, Whistle and so on...

>>> Measure the frequency of glitches with Machine Learning

- Whether One glitch appears in another channel at the same time.
- Whether One glitch appears at different times in the same channel.

Appendix

⇒ **Used cluster**

k1det1/detchar

CPU core : 20

CPU unit : 2

Process thread : 40

models : Intel(R) Xeon(R) CPU E5-2680 v2 @ 2.80GHz (3rd Gen. Ivy Bridge / 22nm / 2013)