

# High precision spectroscopic observation of gamma rays from thundercloud

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**Abstract:** Thunderclouds are known to emit minute-long gamma-ray bursts, commonly referred to as gamma-ray glows. These emissions are believed to originate from bremsstrahlung produced by high-energy electrons accelerated within the clouds. We conducted winter lightning observations in a mountainous area of Niigata, Japan, where thunderclouds are easily observable. Our detection system comprises various scintillation detectors, including BGO, CsI(Tl), Srl2(Eu), and a high-purity germanium (HPGe) detector, to search for line gamma-ray emissions such as nuclear gamma rays and pair annihilation lines (511 keV). On December 24, 2024, we observed a gamma-ray glow event lasting approximately three minutes. Radar data indicated the presence of rain clouds over the observation site during this period. Each detector recorded an increase in gamma-ray count rates. In addition to the enhancement of continuum emissions, we detected tentative line emissions between 200 and 600 keV. Although the event was relatively weak as a gamma-ray glow, the presence of line-like features suggests that future, more intense events may reveal clearer spectral structures.

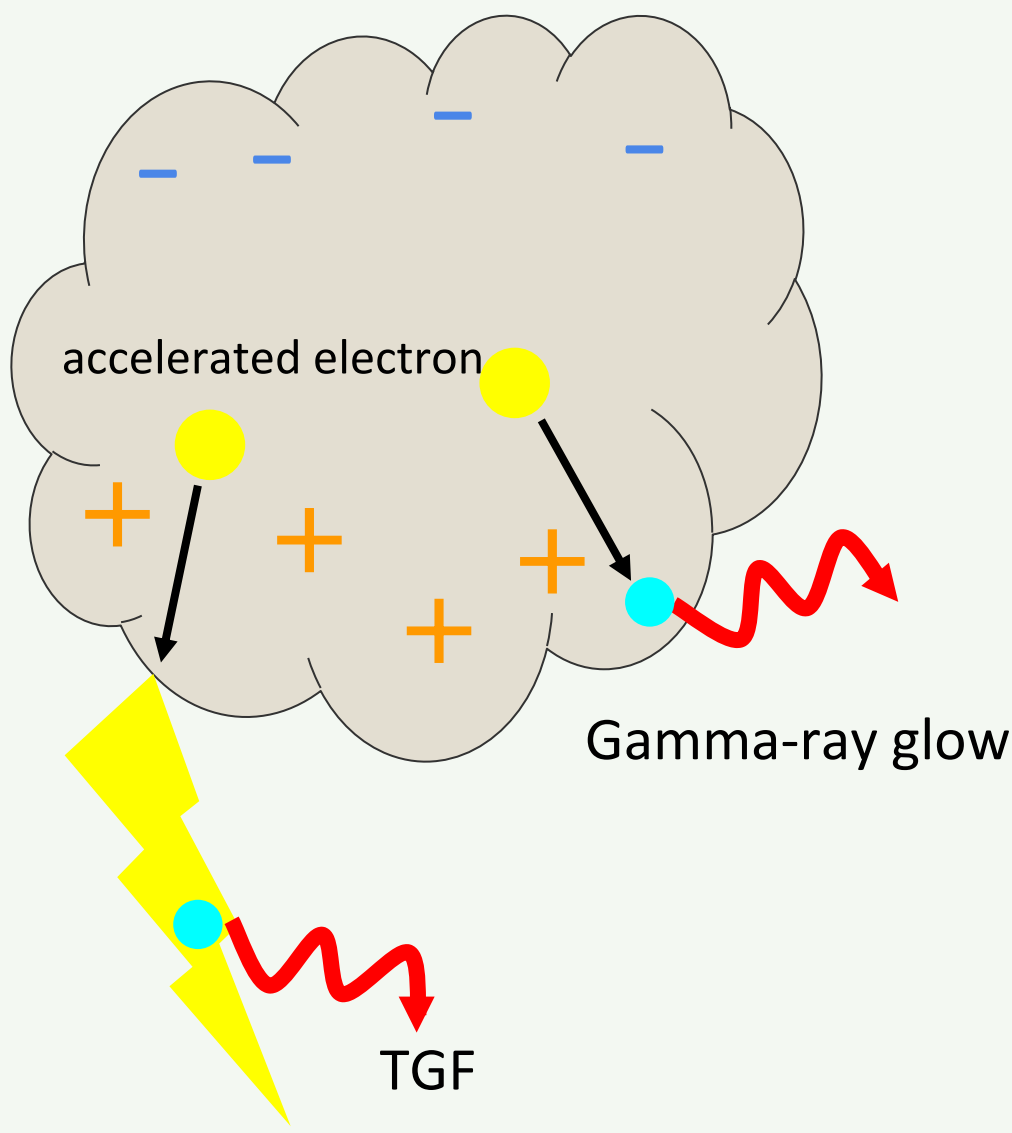
## Introduction

### Gamma-ray Glow

- tens second ~ minute-long gamma-ray burst
- bremsstrahlung by accelerated electron within thundercloud.

### TGF (Terrestrial Gamma-ray Flash)

- submillisecond ~ several millisecond gamma-ray burst from lightning
- bremsstrahlung with air molecule
- observed 511keV gamma-ray



### Our Motivation

- Observe gamma-ray burst emitted by winter lightning & thundercloud
- search for line gamma-ray emission expected from nuclear reactions and/or pair annihilation in the atmosphere

## Detector

### HPGe (High Purity Germanium) detector

- High energy resolution ( $\sigma \sim 3\text{keV}$ )
- $\phi = 63\text{mm}$ ,  $h = 64.6\text{mm}$  cylinder
- Energy Range :  $15\text{keV} \sim 20\text{MeV}$

### Scintillation detector

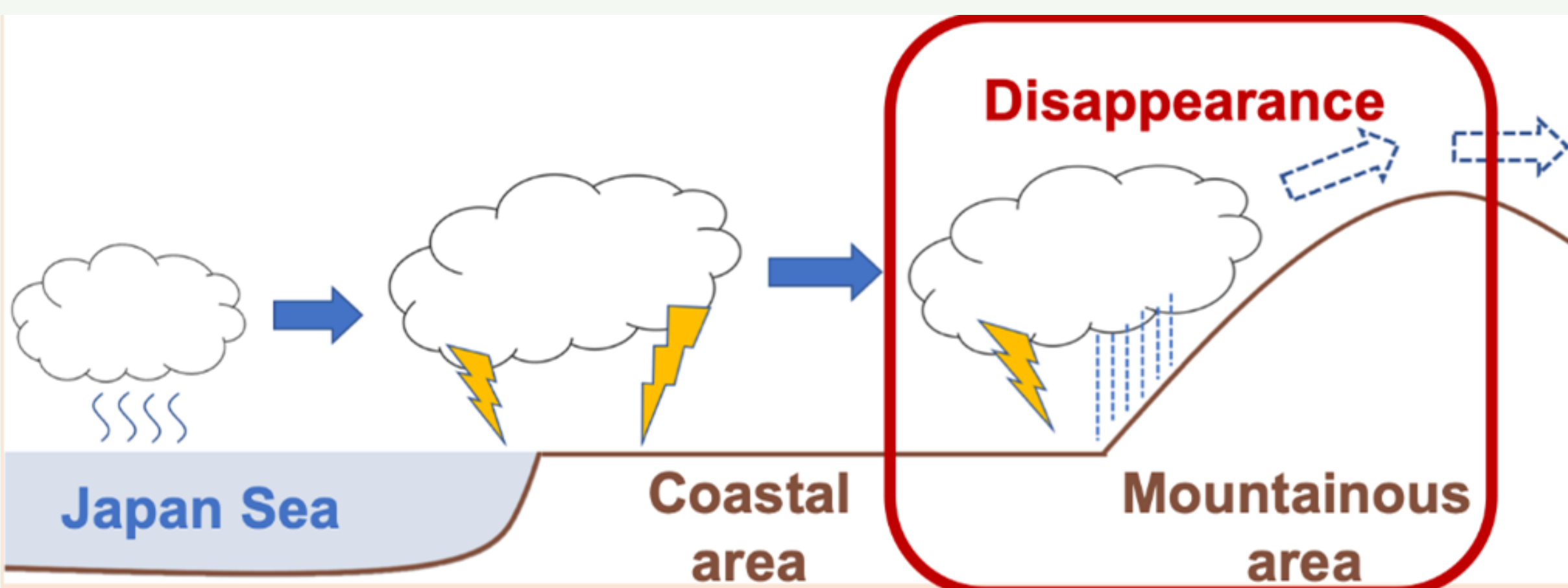
- BGO (30mm  $\times$  50mm  $\times$  120mm)
- CsI(Tl) (40mm  $\times$  40mm  $\times$  100mm)
- Srl2(Eu) ( $\phi = 1\text{inch}$ ,  $h = 2\text{inch}$  cylinder) +PMT
- Energy Range :  $25\text{keV} \sim 5\text{MeV}$



## Observation Location

### Ground observation of gamma-ray burst

- the mountainous area near the Japan Sea
- observe clouds closely from the ground
- thunderclouds are easily observable in winter

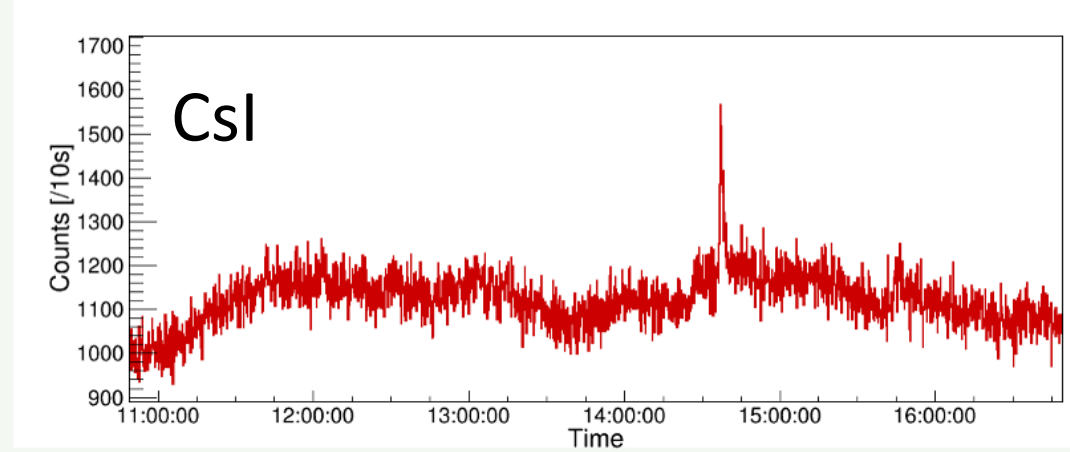
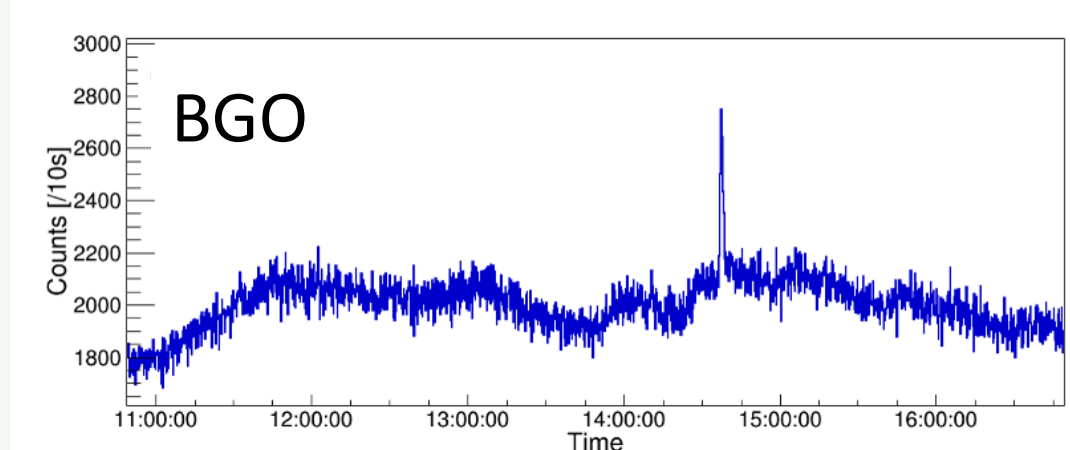
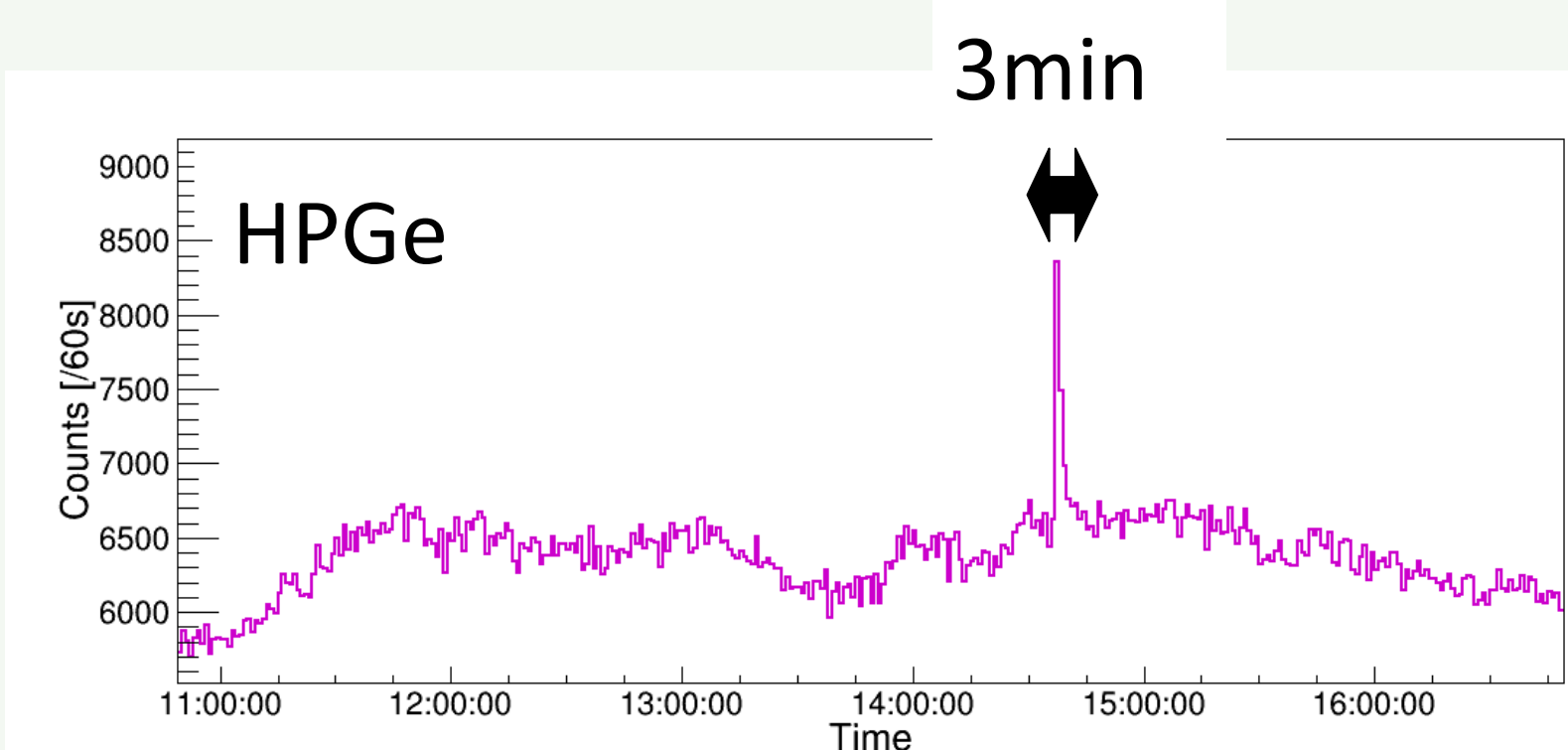
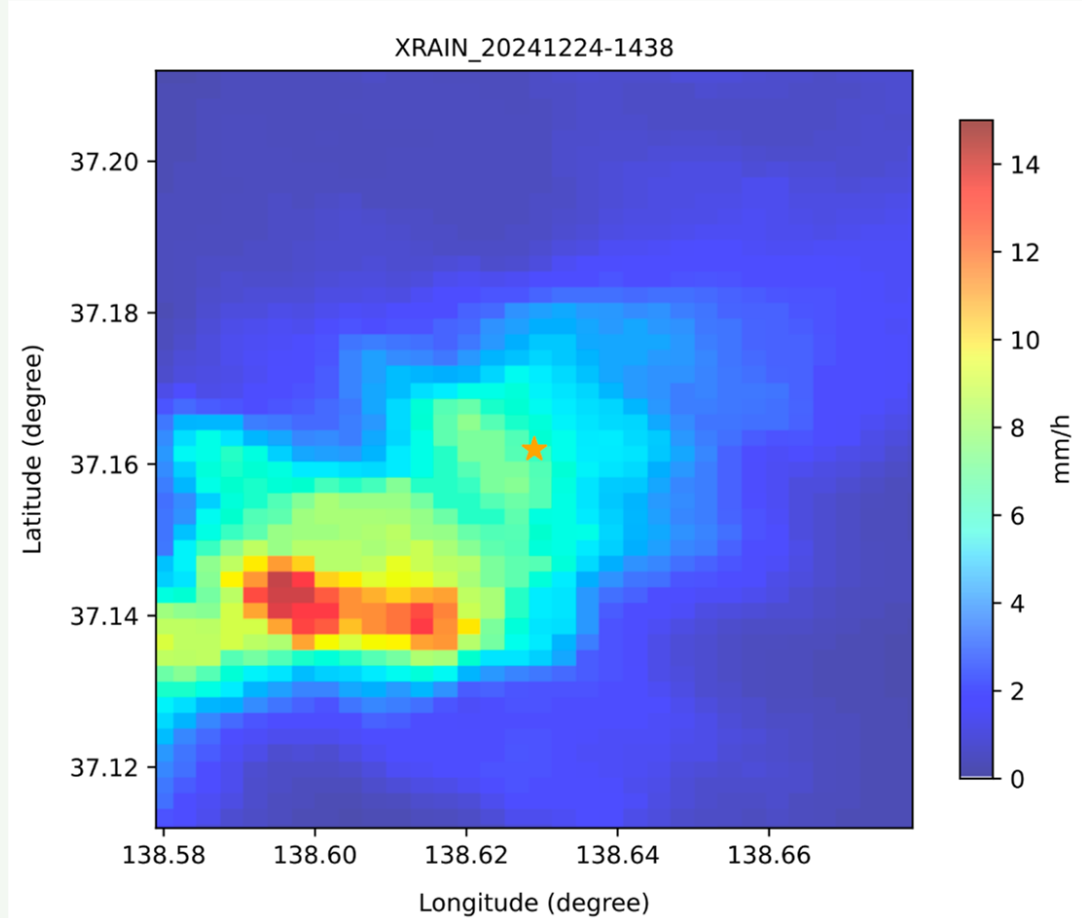


## Observation Result

### Gamma-ray Glow

2024/12/24 14:36~14:39  
detected Gamma-ray glow

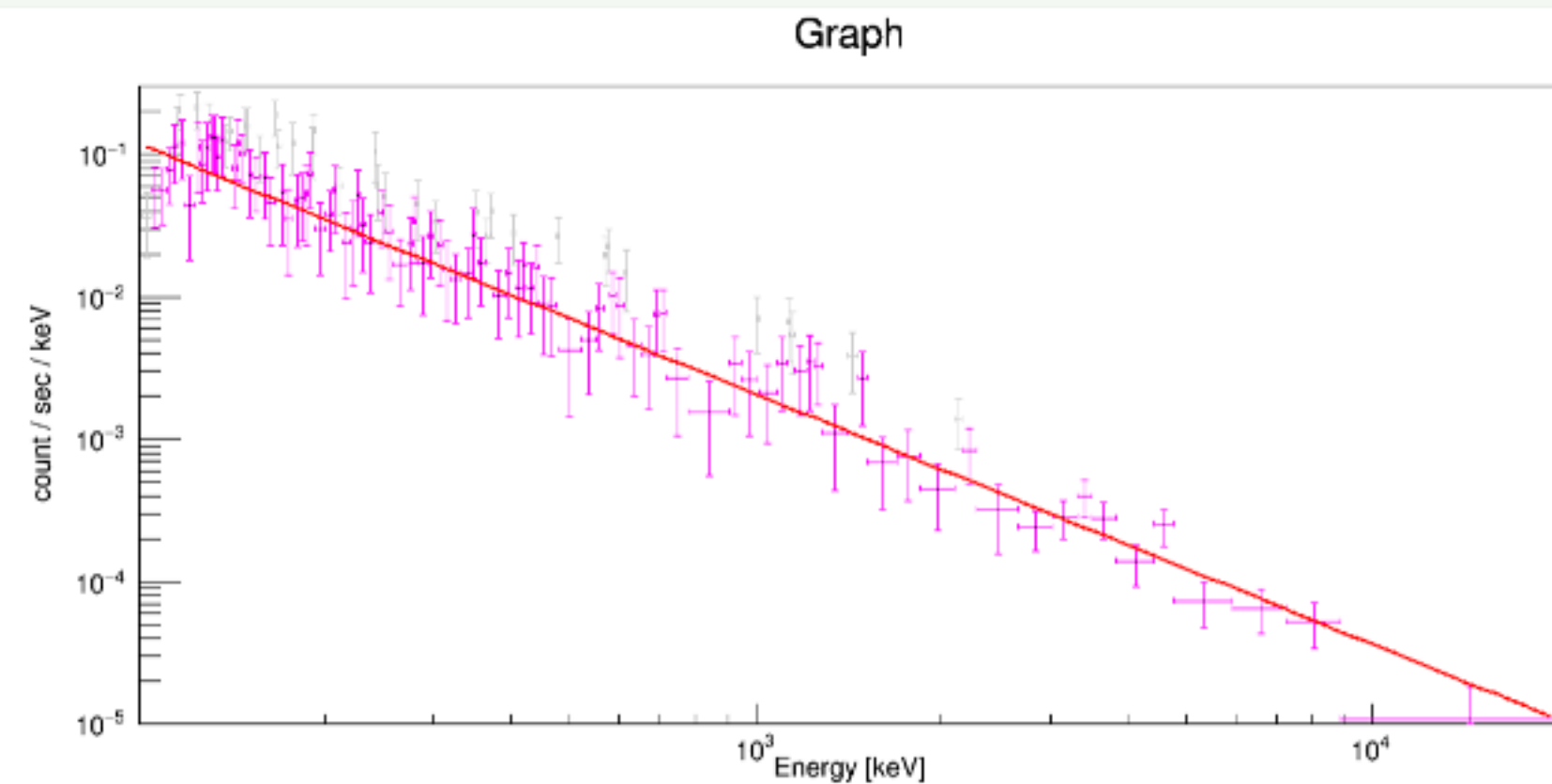
- 3 minutes enhancement
- all scintillator detected
- rain cloud in the sky(Radar data)



### Spectrum Analysis (HPGe)

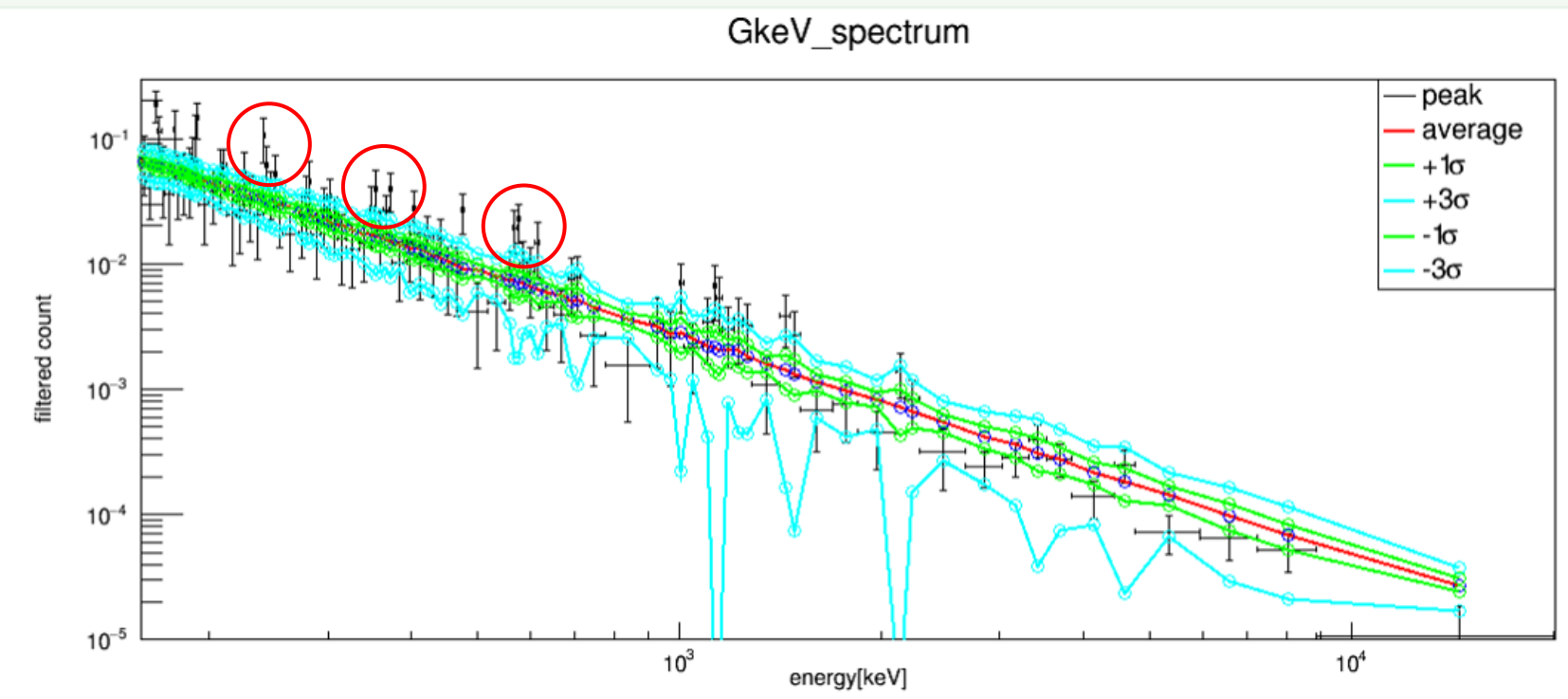
- Power-law fit & get detection count
- Veto outlier  $\rightarrow$  avoid noise & peak when get power-law index
- Power-law fit (get power-law index)
- Make random spectrum by ①count & ③index
- ④ $\times 10000$  cycle
- Calculate count/bin  $\sigma \rightarrow$  Evaluate peak significance

① ~ ③  
continuum energy  
& some line peak  
enhancement  
Fit power-law & veto $\rightarrow$   
power-law index : 1.7



④ ~ ⑥

peak energy(keV)	Significance ( $\sigma$ )
242	6.97
372	6.00
568	2.81



$\rightarrow$ Hint of multiple line emissions between 200 keV ~ 600 keV  
but its significance is yet to be confirmed ,,,  
We expect more intense event to be come to confirm possible  
detection of gamma-ray lines

## Conclusion:

- Searched for gamma-ray glow and TGF from thundercloud
- We used HPGe detector to search for line gamma-ray emission for the first time
- Winter observation in the mountainous area near Japan Sea
- Detected 3 minutes long gamma-ray glow by multi detector
- First detection of multiple line emissions, although its significance is still under debate  $\rightarrow$  more intense event may reveal clearer spectral structures.