

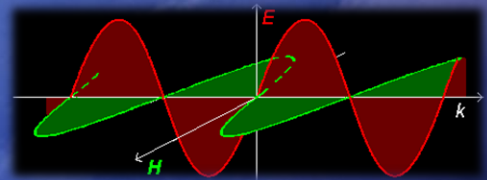
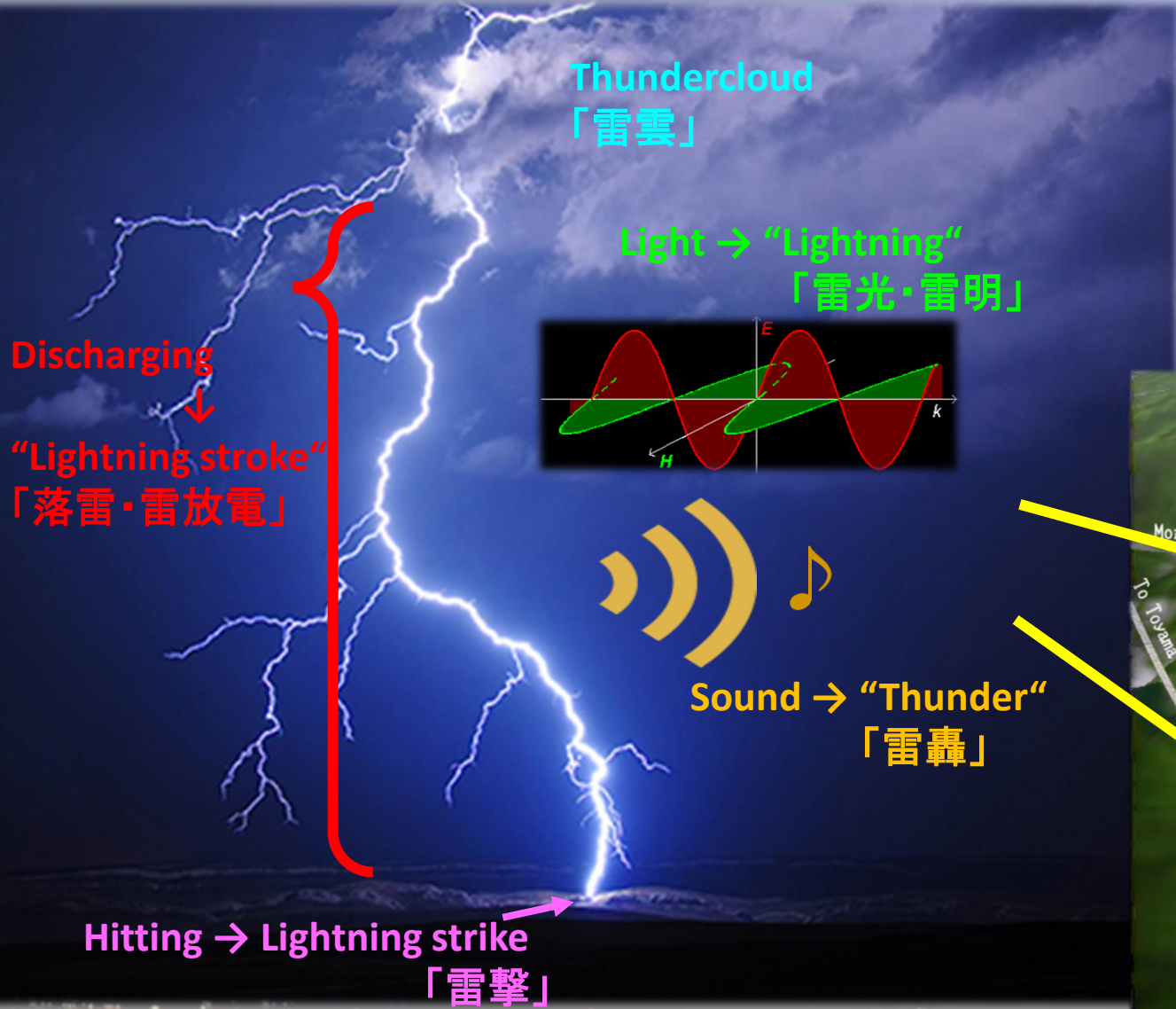
Kamioka Lightning & Thundercloud observation and its application for the astroparticle experiments

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Lightning and Thunder

Lightnings and thunders are familiar natural high-energy phenomena.

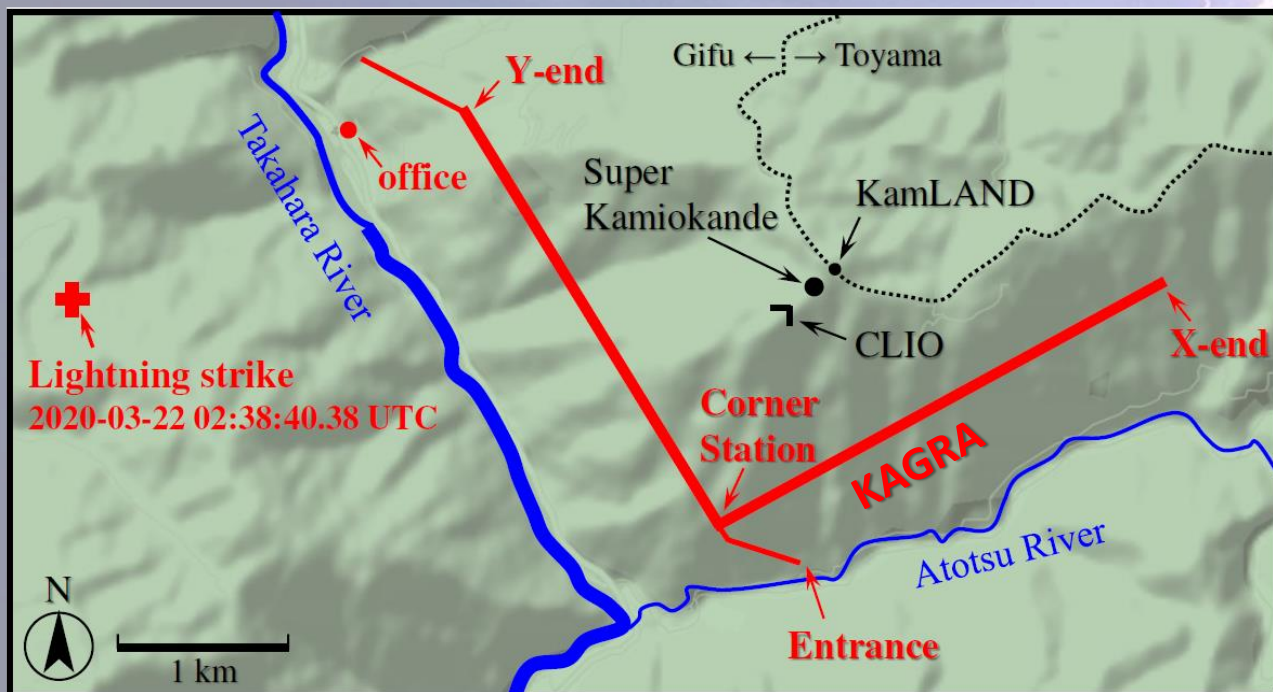
- They can be noises or backgrounds for the underground experiments.



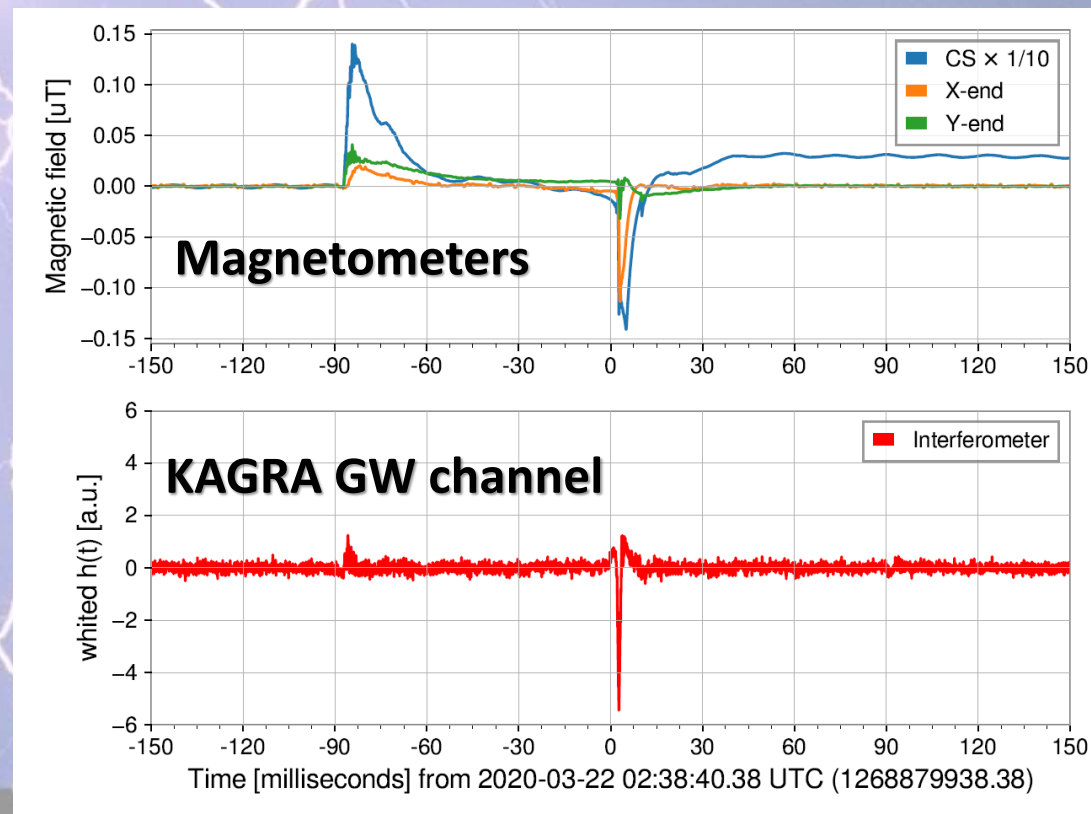
Example : Lightning signal in the KAGRA interferometer

A lightning stroke happened very close to Mt. Ikenoyama.

- ✓ Detected by magnetometers and KAGRA, simultaneously.
- Lightnings will be background events of burst-GW search.

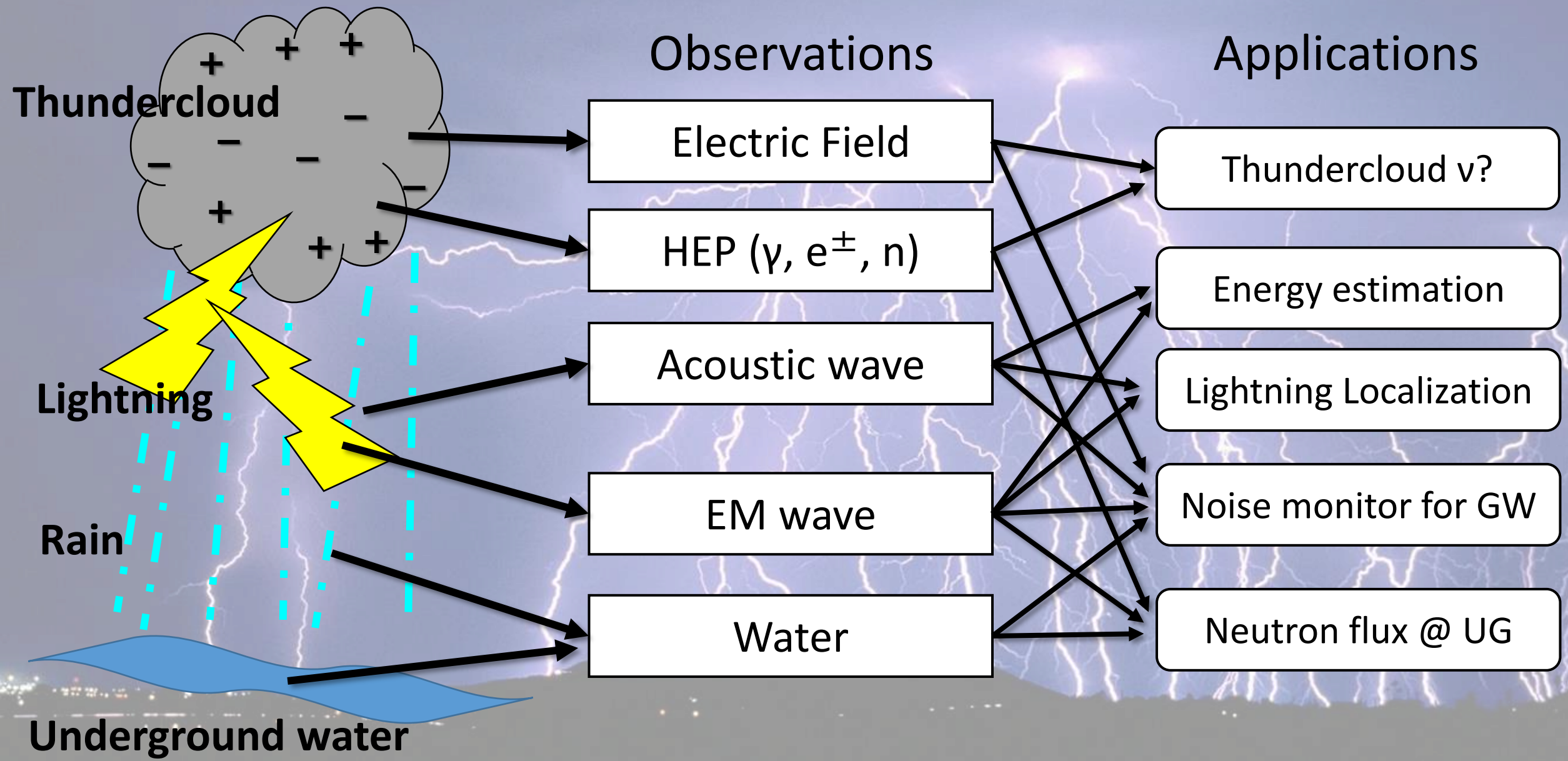


[T. Washimi et al., JINST 16 P07033 \(2021\)](#)

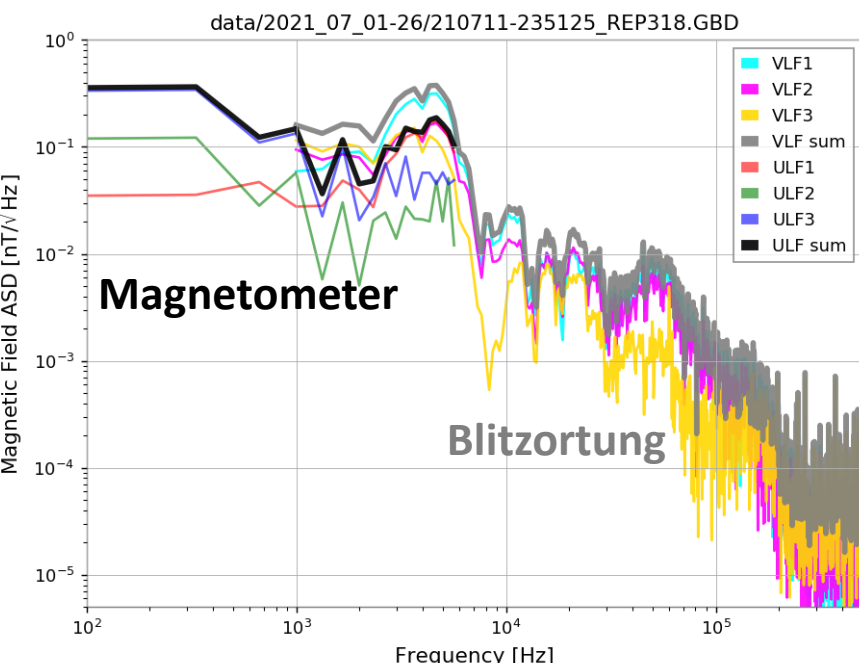
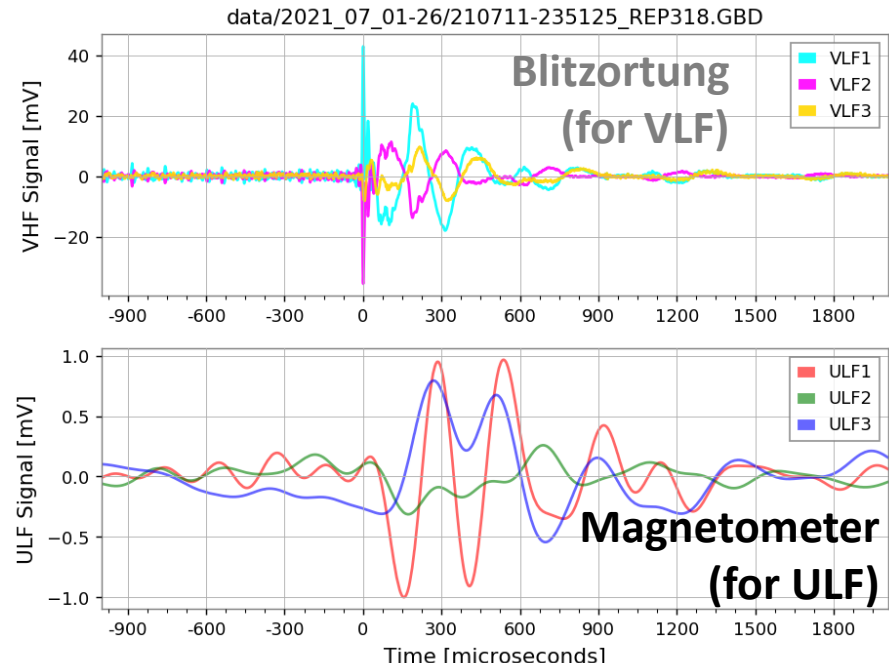
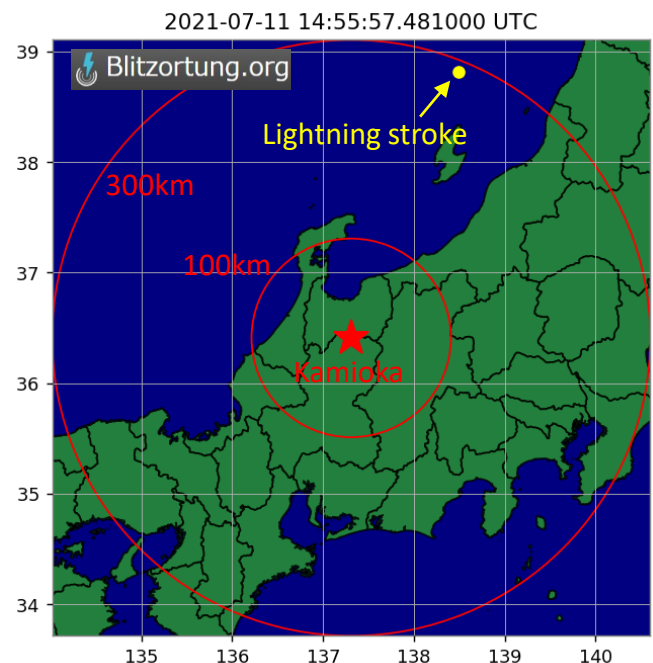
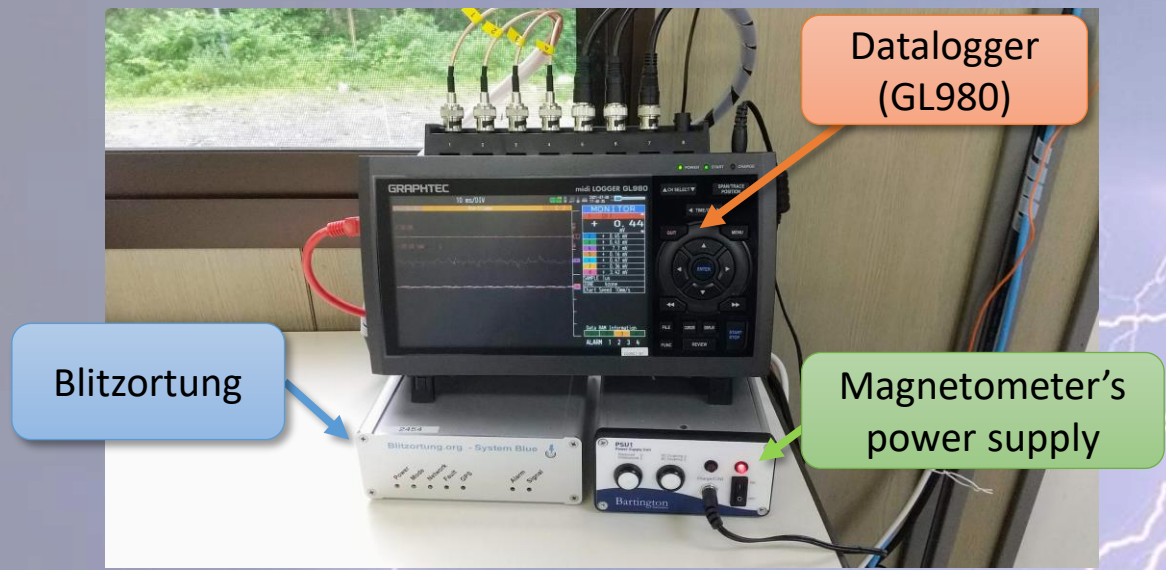


- Monitoring of lightnings & thunders at Kamioka is worth for the astroparticle physics.
- These data also might be useful for the atmospheric physics.

Observations and Applications



EM wave (VLF, ULF) measurement @ KAGRA entrance

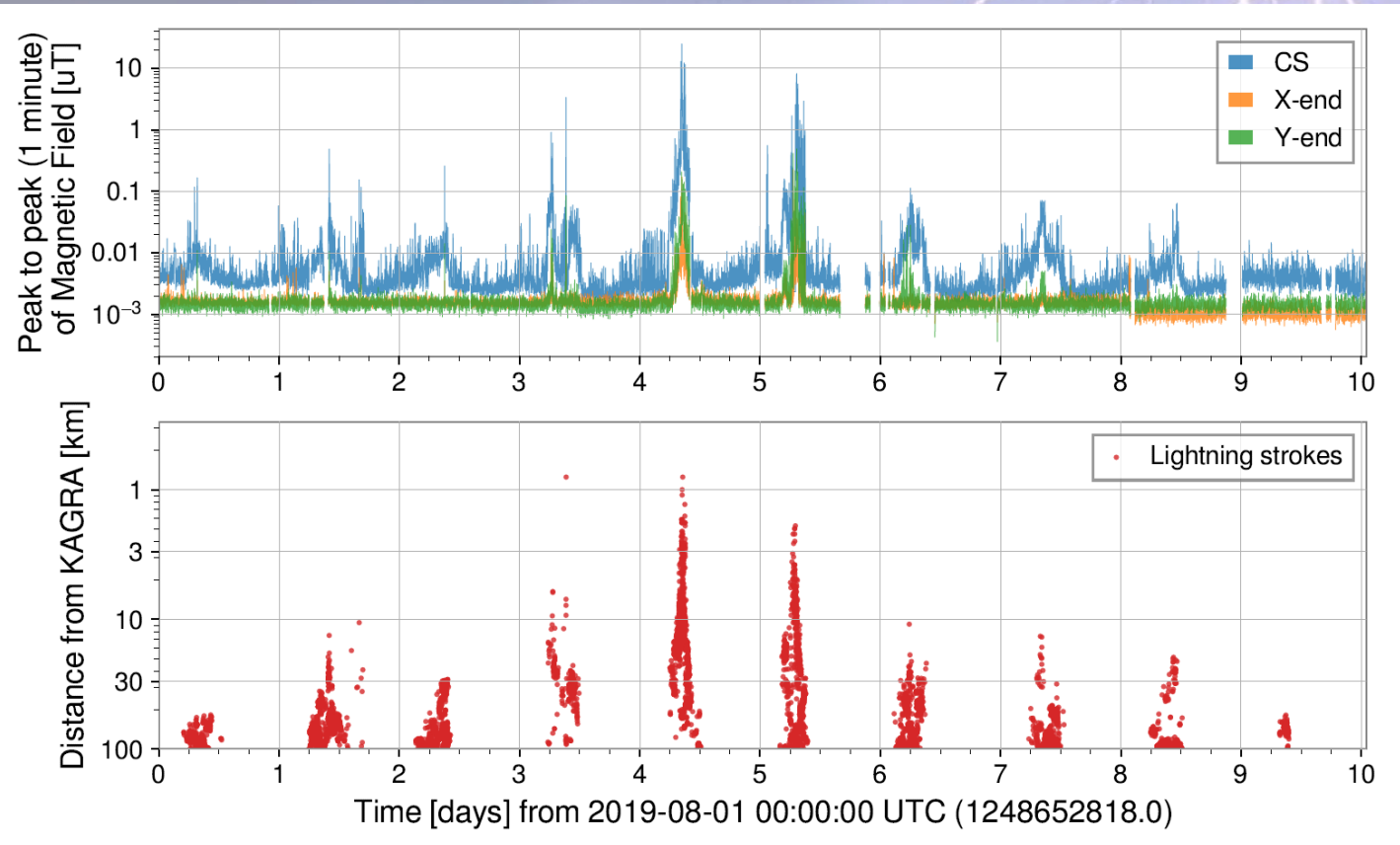


EM wave (ULF) measurement @ Underground

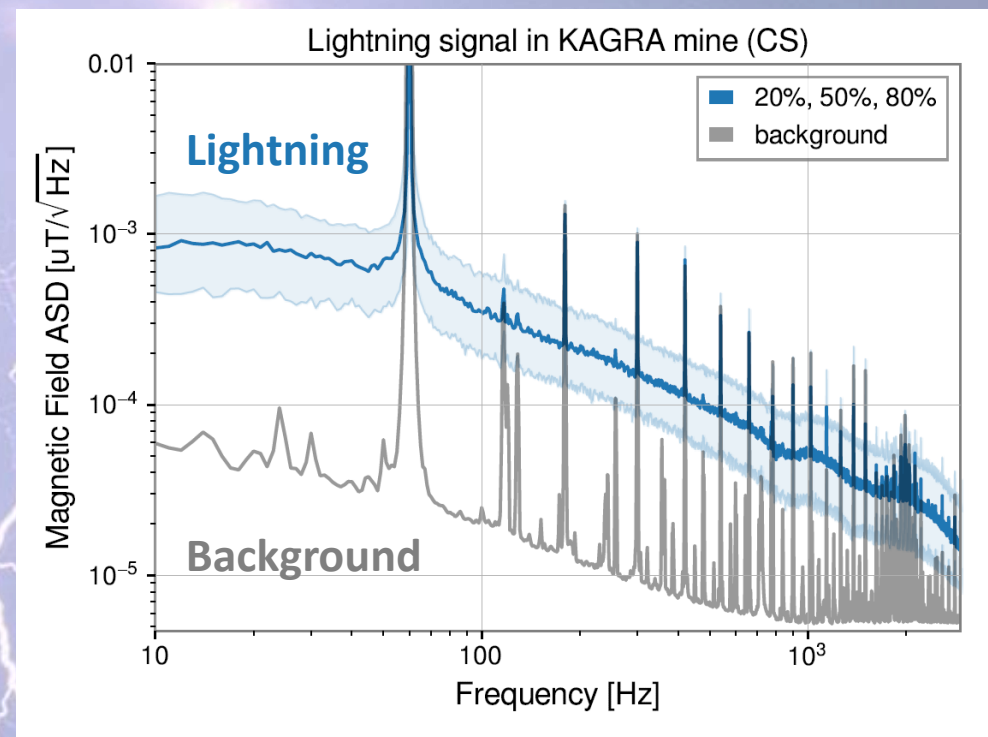
Magnetometers in the KAGRA site.

- 3-axial fluxgate (Bartington Mag-13 MCL100) : DC - 3 kHz
- corner station (CS), X-end, Y-end

They detect pulses when nearby lightning strokes happen.
Such behavior is not seen in the other kinds of sensors.



[T. Washimi et al., JINST 16 P07033 \(2021\)](#)



The skin-depth should be dependent on the amount of UG water.

➤ Its analysis is ongoing.

Schumann resonance (ELF)

Resonance of the Earth electromagnetic field (ELF)

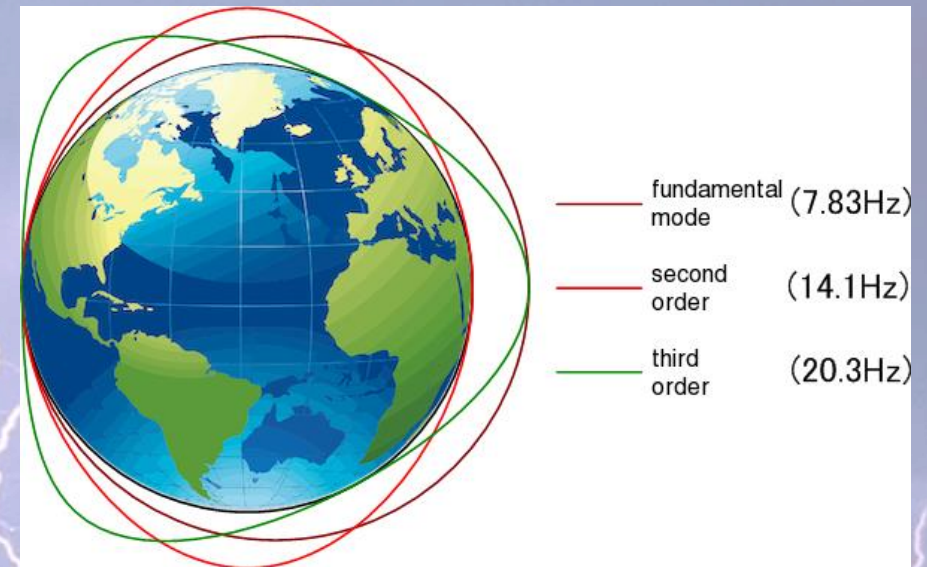
- Excited by lightnings, solar wind, etc.
- $f_n = \frac{c}{2\pi R_\oplus} \sqrt{n(n+1)} = 7.8 \text{ Hz}, 14.1 \text{ Hz}, 20.3 \text{ Hz}, \dots$

- Amplitude $\sim 1 \text{ pT}/\sqrt{\text{Hz}}$

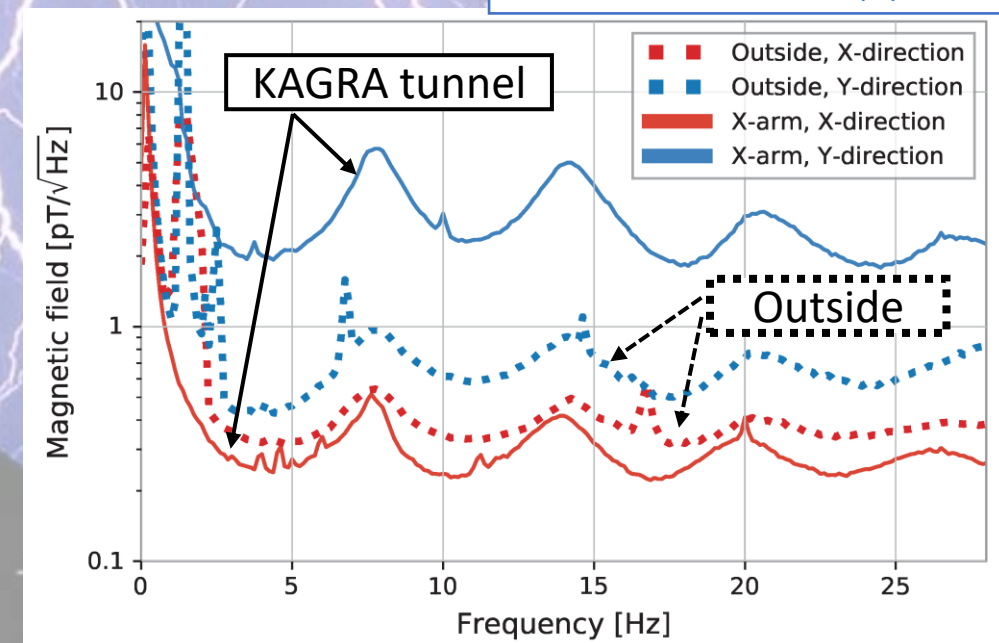
- Coherent in the Earth -> It can fake a Stochastic GW signal

Study at Kamioka:

- Short time measurements at many places were performed.
- Preparation for the long-term monitoring is ongoing.



Galaxies 2022, 10(3), 63



Schumann resonance excited by Volcanic lightning

On January 15th, 2022, at 04:14:45 (UTC), the undersea volcano of Tonga erupted, and its signals were observed at Kamioka.

- Press release : <https://gwcenter.icrr.u-tokyo.ac.jp/en/tonga-20220115>
- A paper is in-preparation.

This eruption triggered so many lightning strokes ->

- <https://wildfiretoday.com/2022/01/17/hunga-tonga-volcano-triggered-nearly-400000-lightning-strikes/>
- Just after (without delay) the eruption, excitation of the Schumann resonance was observed at KAGRA site.

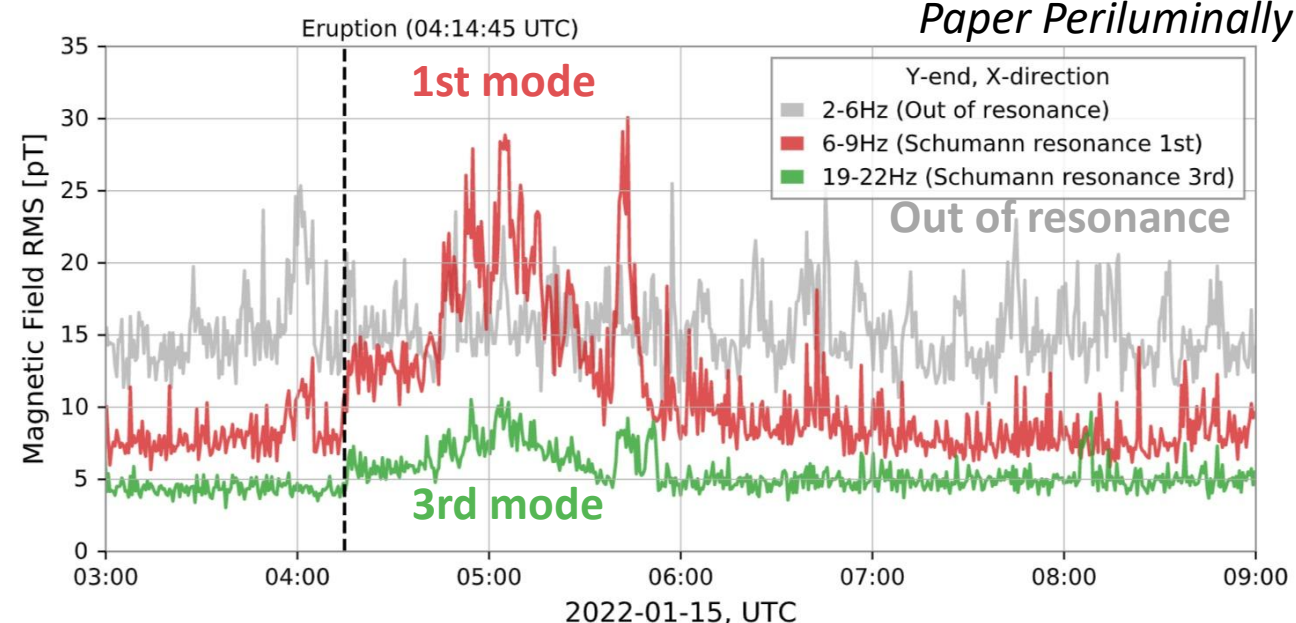
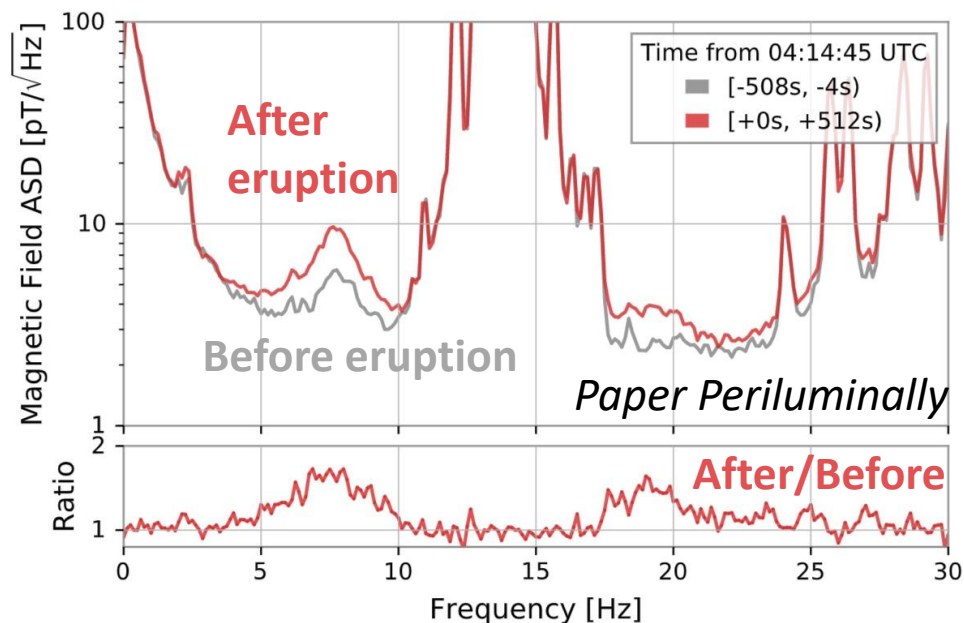
Hunga Tonga volcano triggered nearly 400,000 lightning strikes

Bill Gabbert January 17, 2022 Uncategorized volcano

C-130 aircraft to parachute drop drinking water and other emergency supplies for Tonga residents



Lightning at the Hunga Tonga volcano. Still image from video by Potungae Koloa Fakaenatula / Servicio Geológico de #Tonga.



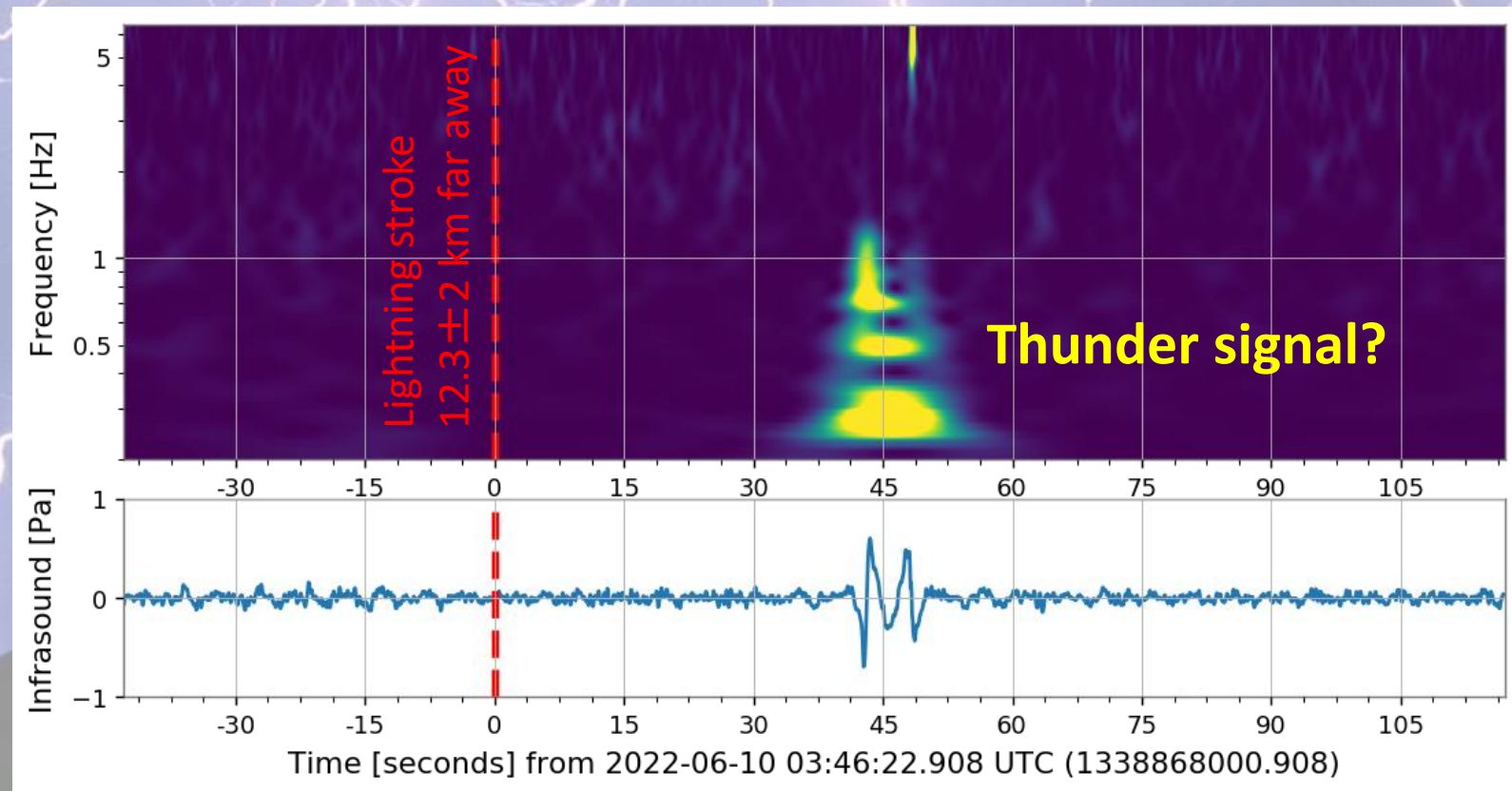
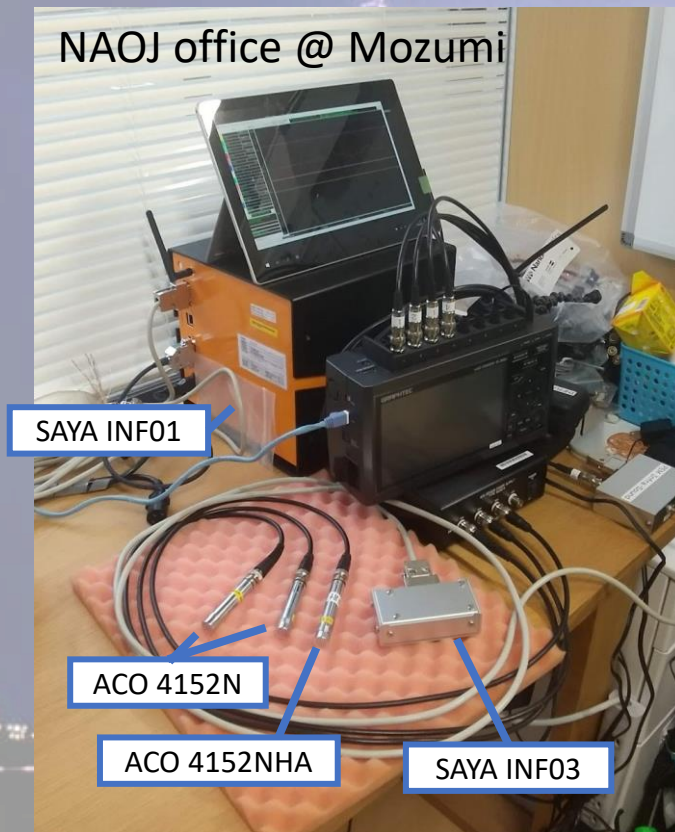
Infrasound (Low frequency sound)

Low frequency sound below human ear's sensitivity (< 20 Hz).

- Attenuation length of sound is proportional to f^2 . -> Infrasound can propagate very long distance.
- Sound velocity is much slower than light. -> Better position resolution is expected.

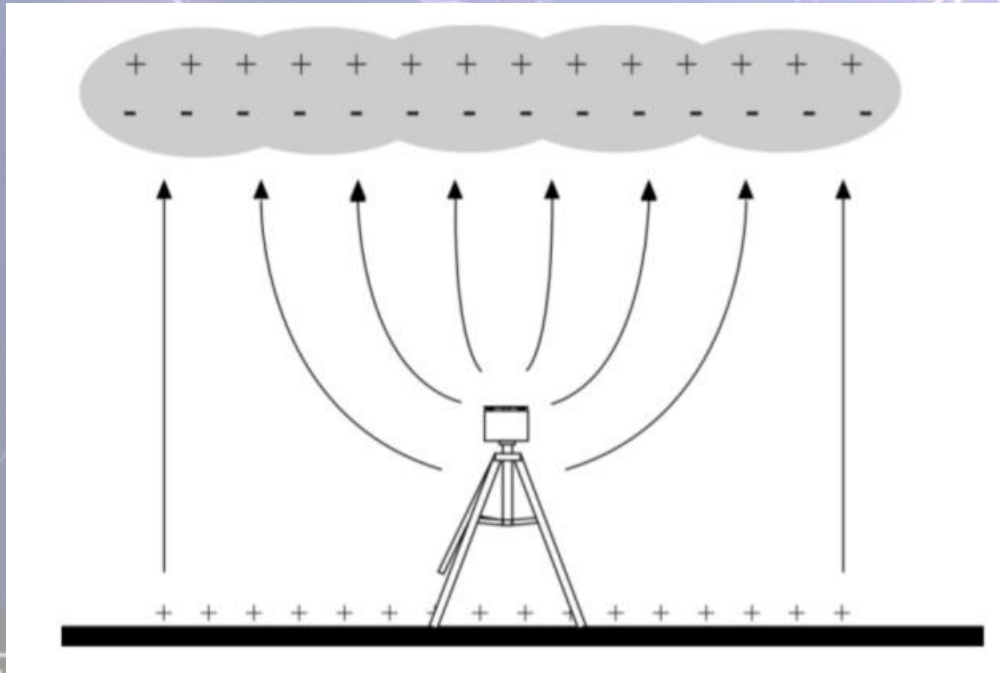
Infrasound monitoring is being performed at Mozumi.

- Thunder-like events were detected, but not confirmed.
 - Increasing the number of monitoring locations is planned.



Thundercloud Electric Field

- Electric field induced by thundercloud can be electrical noises, even without discharging.
- Electric Field Mill has been purchased.
 - BOLTEK EFM-100
 - Not operate yet



Thundercloud Gamma-ray

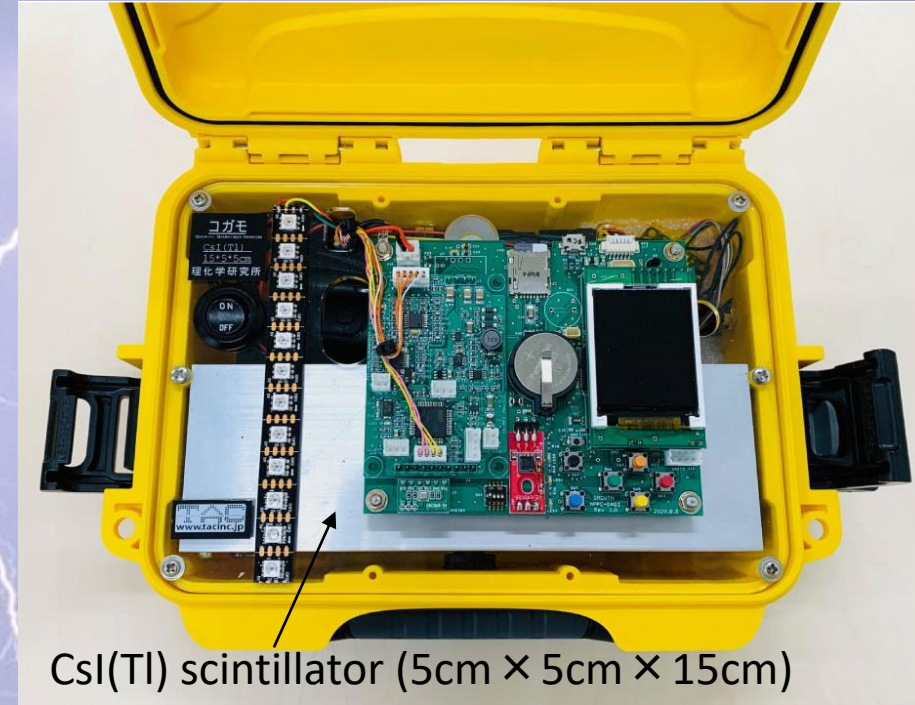
<https://fabcafe.com/jp/labs/kyoto/thunderstorm/>

Thundercloud emits high energy particles.

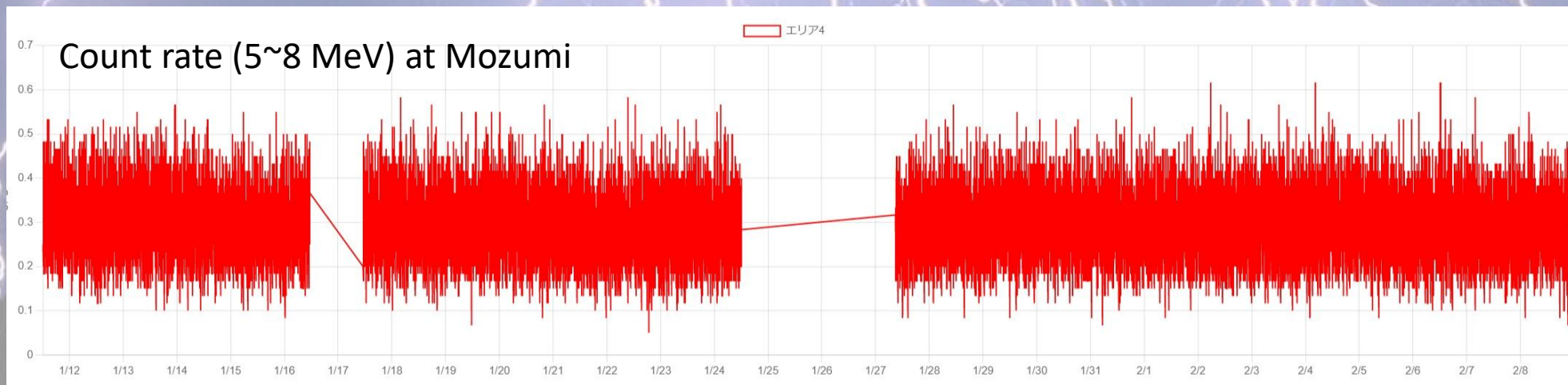
- Gamma (TGF, γ -ray glow)
- e^{\pm} , n
- Neutrino?

“CoGaMo” (compact gamma-ray monitor) developed by RIKEN (Enoto *et al.*) has been installed and working at Mozumi.

- No significant signals in this winter



CsI(Tl) scintillator (5cm × 5cm × 15cm)

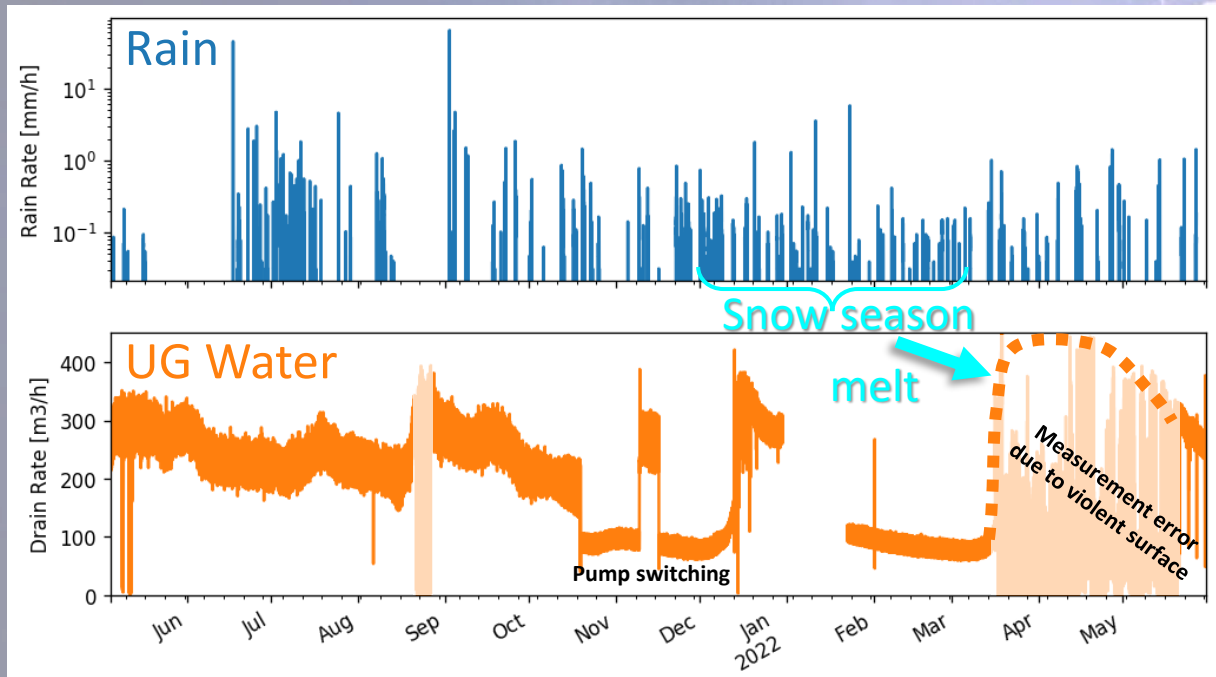


Rain Fall and Underground Water

Amount of the underground water is an important issue.

- For low-BG exp. : Neutron flux
- For GW exp. : Newtonian noise

Rain fall monitor and Water fluid monitors are working.



The ground resistivity corresponds to the amount of water contained in the ground

Archie's formula : $\frac{1}{\sigma} = \rho = a\phi^{-m}S^{-n}\rho_w$



Summary

- ◆ Lightnings & thunders are interested phenomena for the underground astroparticle experiments.
- ◆ Lightning & thunder monitoring is developed in Kamioka.
 - VLF wave : Lightning localization
 - ULF wave : Glitch noise monitor
 - ELF wave : Schumann resonance monitor
 - Infrasound : Thunder localization
 - Electric field : Electrical noise (ground level) monitor
 - Gamma-ray : high-energy atmospheric physics
 - Weather (rain, wind, temperature, pressure, humidity)
 - Underground water : Neutron flux, Newtonian noise
- ◆ Something new study can be expected with these sensors!