Sudden termination of high-energy γ rays detected from thunderclouds before lightning†

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Observations of prolonged γ rays emitted from thunderclouds are important for understanding how relativistic electrons are produced there. Recently, the Gamma Ray Observation of Winter Thunderclouds (GROWTH) experiment, successfully operated mainly by RIKEN and the University of Tokyo at the Kashiwazaki-Kariwa nuclear power plant since December 2006, has been conducting an increasing the number of prolonged γ-ray observations. Here we report one particular event wherein γ-ray emission suddenly terminated immediately before a lightning flash.

At ∼13:30 universal time (UT) on December 30, 2010 (22:30 local time), the GROWTH system of daq0 and daq1, consisting mainly of NaI counters, detected γ-ray increases lasting for ∼3 min. Figure 1 shows the enhancements, together with those obtained by radiation monitoring posts (MPs) operated by the Tokyo Electric Power Company. The observed duration is consistent with previous GROWTH events[1,2]. Importantly, only three MPs located within ∼1 km of the GROWTH system clearly detected the radiation bursts, while the remaining MPs (1−6) observed no increases with statistical significance $>2\sigma$. This means that the horizontal extent of γ-ray emission on the ground was within ∼1 km at most.

A lightning event was recorded by our optical sensor and electric field mill at 13:35:55 UT (dashed line in Fig. 1). It is noted that a γ-ray termination seemingly coincided with the lightning occurrence. Interestingly, the Japan Lightning Detection Network system (Franklin Japan Co. Ltd.) registered no lightning within 5 km of our site between 13:05 and 14:05 UT. Thus, the termination is thought to be related to lightning that occurred >5 km away from the site.

As shown in Fig. 2, a notable feature of this event is that the γ-ray termination occurred not in an exact coincidence with the lightning, but 800 ms prior to it. In addition, it is obvious that only >3 MeV γ-ray radiation ceased before the lightning. This finding indicates that production of relativistic electrons to emit >3 MeV γ rays would stop 800 ms before the lightning.

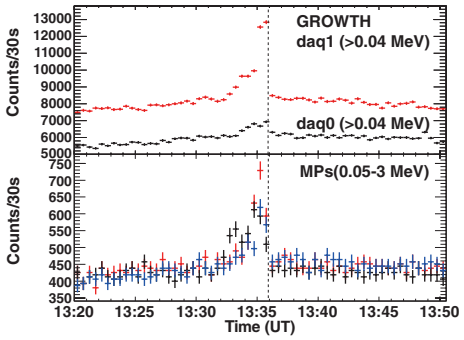

Fig. 1. Count histories per 30 s of the present event, obtained during 13:20−13:50 UT. (Top) The NaI count rates of daq0 and daq1. (Bottom) The NaI count rates of MPs 9 (black), 8 (red), and 7 (blue). The vertical dashed line indicates the lightning occurrence time.

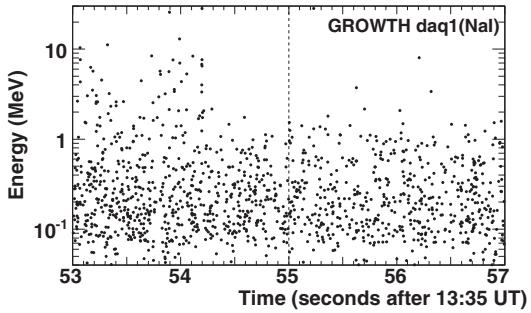

Fig. 2. Photon energies recorded during 13:35:53-13:35:57 UT. The time resolution is 0.1 ms.

Using an aircraft-onboard detector, Mcarthy and Parks[3] observed a similar termination event that follows an x-ray (5−110 keV) increase lasting for ∼10 s, and estimated a source length of ∼1 km by considering the duration, the aircraft velocity, and an attenuation length of 150 m for 100 keV x rays. It is certain from the present and these results that a local electric field in thunderclouds is enhanced, in a few seconds to minutes, to accelerate electrons and initiate lightning.

In summary, the present event shows that relativistic electrons were continuously produced in a limited acceleration region 800 ms before lightning.

References

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