Gamma-ray Observation of Winter Thunderclouds: Long-distance tracking of long burst with monitoring posts

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Lightning activity emitting MeV gamma-rays has been observed on the coast of the Sea of Japan in winter season. Those gamma rays are due to bremsstrahlung from electrons accelerated by the electrostatic field in thundercloud. This is an interesting phenomenon related to electron acceleration via static electric field, which is hardly observed in other locations, i.e. in the universe. The gamma-ray emission observed from the thundercloud itself for a few minutes is called a long burst. Many of its properties are unknown such as the position of the accelerator in the cloud, the electron amplification factor, and its stability in both time duration and distance.

We have been observing gamma-rays from lightning and thunderclouds in the coast of the Sea of Japan in winter since 2006. The project is named GROWTH (Gamma-ray Observation of Winter Thunderclouds). Particularly in FY2014, 6 long bursts were detected at the Kashiwazaki-Kariwa Nuclear Power Plant in Niigata within five months. This is equivalent to ~ 6 times more frequent than average. The long bursts were also observed at monitoring posts inside the nuclear power plant in addition to the GROWTH detector. These showed that the emission area was about 1 km in diameter. It was also suggested that multiple accelerators existed at the same time, because the positional profile of the emission region do not always show a simple single peak [Umemoto dissertation. 2017, Umemoto et al. in prep.].

In order to track these long bursts on a larger scale, we analyzed them using 8 monitoring posts operated by Niigata prefecture that extend about 5 km outside the nuclear power plant. It was confirmed that three long bursts were detected at 2-3 downwind monitoring posts. These events were on December 2nd, 2014, December 30th, 2014, and January 25th, 2015. The moving direction and time difference coincided with the movement of the thundercloud obtained from the Japan Meteorological Agency radar. As a result, it is understood that the long burst accelerator moved on a west wind of 10 m/s to 24 m/s.

In the December 30th event, the time drift of GROWTH detection and the monitoring post 4 km downwind matches very well with the wind speed. We interpreted that the same accelerator continuously existed for 9 minutes and 30 seconds. This is comparable to the longest time of long burst tracking in near-sea level observed by Torii et al. (2011). The moving distance is about three times longer.

From previous analysis using the detectors located within the power plant, it was strongly suggested that a few accelerators were these at least in December 2nd and January 25th. Looking at the profile of the radiant intensity, although very sparse, in the vertical direction of the wind, the emission region’s size and shape are not simple, indicating that they were made of a few compact regions (or accelerators), or very time variable. It was also confirmed that the event on December 2nd was detected at a monitoring post 4 km downwind, and that one accelerator continued to exist for 4-5 km.

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