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Performance evaluation of the MoMoTarO gamma-ray detector and future GRB observations in near-Earth and lunar orbits

The Moon Moisture Targeting Observatory (MoMoTarO), a compact and scalable neutron and gamma-ray detector aimed at exploring lunar water resources, also aims to observe gamma-ray bursts (GRBs).
MoMoTarO has a GAGG scintillator (7cm × 7cm × 1cm) for gamma-ray spectroscopy, with high energy resolution, fast decay time, and no hygroscopic nature.
This detector can contribute to multi-messenger astronomy.
A binary star merger occurred in 2017, where the GRB and gravitational wave were detected simultaneously, combined measurements with gravitational wave and multi-wavelength electromagnetic waves from gamma rays to radio waves, allowed us to identify not only the parent galaxy but also the details of the merger. With the discovery of this event, multi-messenger astronomy started gaining attention.
We want to resolve the discrepancy in the Hubble constant by measuring the cosmological distance by gravitational waves and redshift by optical.
Since the field of view of the optical telescope is small, it is necessary to determine the arrival direction of GRBs with high positional accuracy of less than a few degrees and immediately alert the ground-based telescope in order to link gravitational wave observations and optical follow-up observations.
The method of the GRB direction determination is to use the difference in arrival times of GRBs observed at multiple locations. This method is used in the Interplanetary network (IPN), a network for determining the arrival direction of GRBs using Earth-orbiting and interplanetary satellites. MoMoTarO operated around the Moon, can improve its accuracy of direction determination by taking advantage of the long distance between the Earth and the Moon.
In a previous study, the accuracy of direction determination was estimated when GRB observation points were placed at three points: the earth orbit, the Lagrangian point, and the lunar north pole. The results showed that to determine the position with an accuracy of a few degrees, the arrival time difference must be determined with an uncertainty of less than a few ms. However, this study assumed an ideal detector and didn't consider the actual detector size and performance.
Therefore, we present two topics in this talk.
First, we evaluated the performance of the MoMotarO gamma-ray detector. The GAGG scintillator in the MoMotarO detector was irradiated with 137Cs, 60Co, 22Na sources and gamma-ray beam of 6 MeV. The results showed that MoMoTarO has an energy range of about 0.1–20 MeV considering the number of ADC channels, an energy resolution of about 8% at 1 MeV, and linearity between energy and channel up to 6 MeV.
Next, We investigate the performance of determining the arrival time difference using MoMoTarO and an earth-orbiting satellite. We simulated GRB lightcurves detected by the MoMoTarO using Geant4. We exposed the GRB emission characterized by a typical GRB spectrum observed by Fermi satellites to the GAGG scintillator. We estimated the accuracy of the arrival time difference by cross-correlating the light curves detected by the Earth-orbiting satellite and MoMoTarO. The results showed that it was possible to determine the arrival time difference with an accuracy of a few ms.

Collaboration(s)

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