Observations of prompt optical emission of GRB 160625B with Mini-MegaTORTORA

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Abstract. Here we report our observations of bright optical flash coincident with Fermi GRB160625B using Mini-MegaTORTORA wide-field monitoring system. The prompt optical emission is correlated with gamma one and lags behind it for about 3 seconds, that suggests that optical and gamma emission are formed in different regions of the burst. The multiwavelength properties of this burst are very similar to ones of Naked-Eye Burst, GRB080319B, we detected earlier with TORTORA camera.

1. Introduction

Mini-MegaTORTORA is a novel robotic instrument developed according to the principles of MegaTORTORA multi-channel and transforming design formulated by us earlier (Beskin et al. 2010a; Biryukov et al. 2015) in order to detect and characterize fast optical transients of various origins, both cosmological, galactic and near-Earth. The importance of such instruments became evident after the discovery and detailed study of the brightest ever optical afterglow of a gamma-ray burst, GRB080319B (Beskin et al. 2010b).

It is a 9-channel wide-field (~900 square degrees) monitoring system with temporal resolution of 0.1 seconds and limit down to V~11 mag. Every channel of Mini-MegaTORTORA has 10x10 deg field of view and is equipped with installable photometric and polarimetric filters and coelostat mirror for a rapid repointing in a limited range. It allows to re-configure the system on the fly in order to rapidly follow-up the transients just detected.

Mini-MegaTORTORA started its operation in Jun 2014, and since then continuously monitors the sky looking for fast optical transients. Its real-time transient detection system routinely extracts various kinds of transient from the data stream – rapid flashes, meteors, satellites etc. Mini-MegaTORTORA also performs follow-up of Swift, Fermi and LIGO-Virgo triggers, including the ones with poor localization accuracy due to its large field of view allowing for simultaneous observations in 900 sq.deg. sky fields. For the triggers with better localizations, multicolor and/or polarimetric follow-up is performed. Since mid-2015, 4 of 89 Swift GRBs have been

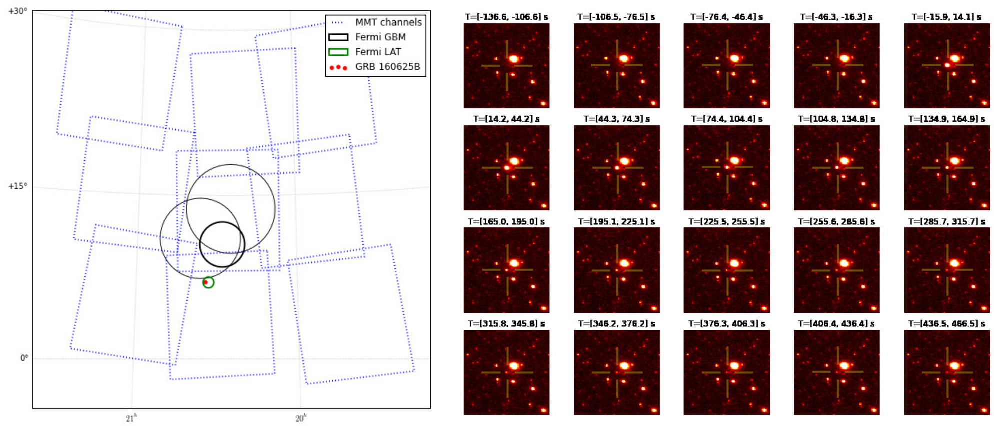

Figure 1. Left panel – lhe coverage of the GRB 160625B error box with Mini-MegaTORTORA channels during the follow-up. Three large circles represent the gradual improvement of GBM precursor 1-σ position constraints (the system initiated the follow-up using the largest one originally distributed through GCN network). The fourth, smallest circle is LAT error box for the main burst, and the inner dot is the optical transient position as reported by Troja et al. (2016). Right panel – the surroundings (20x20 arcmin) of the GRB 160625B optical localization as seen by Mini-MegaTORTORA during the event.

followed up in polarimetric mode in 30 to 60 seconds since trigger distribution through GCN network, with no optical emission detections. 9 of 250 Fermi GBM triggers have been also followed up in wide-field mode in 20 to 90 seconds from the trigger, with bright optical flash of GRB 160625B clearly detected during the gamma activity. All other events were either below the horizon or occurred in bad weather conditions.

2. Fermi GRB 160625B

The on-sky position of GRB 160625B has been observed before, during and just after the LAT trigger time (T_0 = 2016-06-25 22:43:24). Mini-MegaTORTORA reacted (Karpov et al. 2016) to precursor GBM event and started observing its error box 52 seconds after it and 136 seconds before LAT trigger. Due to large size of GBM error box (see Figure 1), the observations have been performed in "widefield+deep" regime, with channels simultaneously covering 30x30 deg field of view with 30 s exposures in white light to achieve deepest detection limit. The system acquired 20 frames in such regime, covering time interval from T_0-136 to T_0+466 s, and detected a bright optical flash on a frame coincident with LAT trigger time (T_0-15.9 - T_0+14.1 s), with a magnitude of about V=8.8 mag, which then brightened for about 0.1 mag, and then faded following nearly smooth power-law decay with slope of about - 1.6, down to V=12.2 at last acquired frame. The images acquired prior to LAT trigger do not display any object at that position down to about V=13.5 mag.

The system also observed the same location between T_0+1691 s and T_0+2264 s, acquiring 20 more 30-s exposure frames. These frames do not display any transient at the position of GRB 160625B brighter than V=13.5 mag.

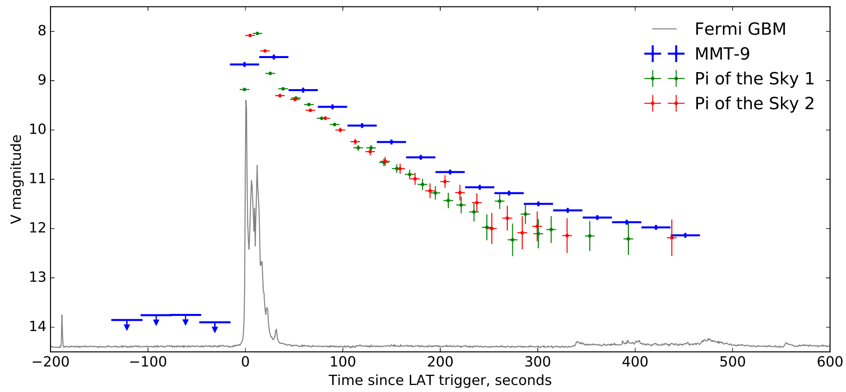

Figure 2. Lightcurve of GRB 160625B as seen by Mini-MegaTORTORA and Pi of the Sky (as published by Batsch et al. (2016)). For a reference, lower part of the figure displays the gamma-ray (GBM) light curve.

The optical light curve (see Figure 2) clearly displays the initial peak with duration of ∼40 s, close to the one of gamma-ray emission. This prompt emission then smoothly moves to the afterglow since ∼50 s. Such behavior – the absence of any gap between prompt and afterglow optical emission – is typical for several brightest gamma-ray bursts including GRB 080319B, the Naked-Eye Burst (Beskin et al. 2015). Moreover, the latter burst is similar to the present one in what the intensity of optical emission significantly exceeds the extrapolation of gamma-ray spectra, which suggests different emission mechanisms at work.

In GRB 080319B, the optical emission lagged behind gamma-ray one for ∼2 s (Beskin et al. 2010b). To study the possible lag in GRB 160625B, we combined our light curve with Pi of the Sky data published by Batsch et al. (2016), and built a statistical model for it. The results are shown in Figure 3. It is clear that, according to both data sets, the optical emission lags behind gamma-ray one for 2–4 seconds, which corresponds to 1–2 seconds at $z = 1.4$ redshift as measured for GRB 160625B (Xu et al. 2016). Such delay is nearly the same as rest-frame lag of Naked-Eye Burst, and corresponds to the optical emission being generated at 10–100 times greater radii from the central engine than gamma-ray ones (Beskin et al. 2010b). As a result, we may conclude that the optical emission is generated by electrons heated by residual collisions of ejecta shells (Li & Waxman 2008).

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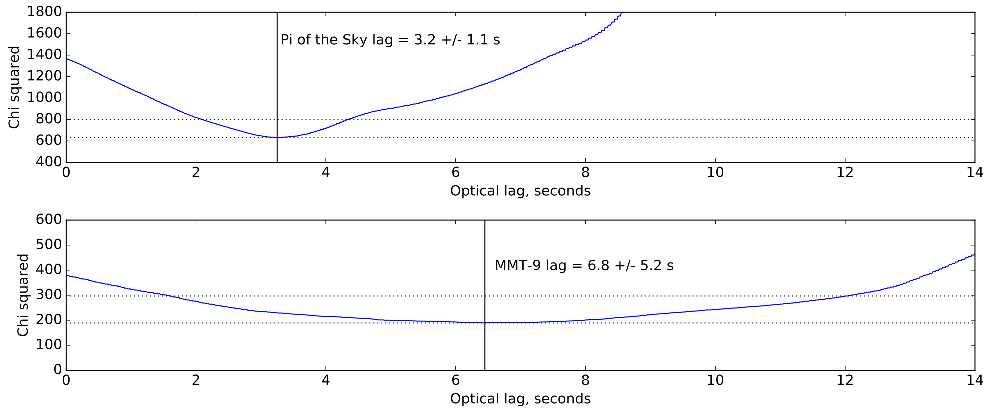

Figure 3. Lag analysis of optical (Mini-MegaTORTORA and Pi of the Sky as published by Batsch et al. (2016)) emission in respect to gamma-ray one. Both data sets show definitive several seconds lag of optical data.

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