Search for prompt optical radiation in coincidence with Gamma Ray Bursts using **WIDGET**

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1 Introduction

Gamma-Ray Bursts (GRBs) are the most violent explosions in the universe. The detection of GRB 030329 by the GRB satellite *High Energy Transient Exploere (HETE-2)* led to a dramatic confirmation of the GRB-supernova (SN) connection. However the difference between GRB and SN or central engine are still unknown. The ground-based telescope network is getting growth. For example, a follow-up observation of GRB 050502a was carried out 7 seconds after the trigger. However no detection was recorded in an optical band on and before the GRB trigger. To observe the optical emission from GRBs in prompt before the trigger, we have developed *WIDeField telescope for Gamma-ray burst Early Timing (WIDGET)* [1][2][3].

2 WIDGET

*WIDGET* is able to obtain the optical data in prompt of the GRB trigger, because the telescope tracks the field of view (FOV) of *HETE-2* or *Swift* automatically. *WIDGET* has the widest FOV, 44 deg × 44 deg × 3 cameras, in the world in optical telescopes waiting for GRB. The standard exposure in our operation is 5 seconds, so that we obtain sky images every 10 seconds including the readout time. As of December 2006, the limiting magnitude is evaluated to be 12th magnitude at S/N=1. *WIDGET* will observe;

1) bursts with bright afterglow (e.g. 030329),
2) the bright optical flash (e.g. 990123),
3) optical radiation before the GRBs.

*WIDGET* has observed 15 GRBs in two and half years. Four of them occurred in coincident with *HETE-2* or *Swift* trigger.

3 Analysis and results

3.1 The data analysis of **WIDGET**

We carried out the collection of dark- and flat-field. The dark-frame data was obtained before and after the observation period. In each period, 50 frames were taken and averaged. We took several pictures and averaged them for obtaining flat-frame. We extracted 10 deg × 10 deg regions around the GRB position.

For the dark- and flat-field corrected data, the GRB position based on the central coordinate of the polar mount pointing direction. In the region, astrometric calibrations were carried out...
using 10 standard stars from Thcho-2 catalog. The data reduction was carried out by using the APHOT package of IRAF that is standard program for analyzing optical data. Since the precision of the astrometry is well below a size of one pixel, we can identify the position of the GRB on the chip without any ambiguity.

We derived the GRB flux by subtracting background \( \text{bg} \) from a source region. The source was extracted as a ring region with radius of 4 to 5.5 pixels. If the signal from the GRB exceeds \( 3\sigma \) of bg fluctuation, it was regarded as the signal detection. If we were not able to detect the signal at \( 3\sigma \) level we derive the limiting magnitude. Because of the Galactic extinction, the limiting magnitude may be affected. To correct it, we use the NED information \(^1\). Table 3.1 shows the results of our analyses about four GRBs.

\[
\begin{array}{|c|c|c|c|c|c|}
\hline
\text{GRB} & \text{before burst(s)} & \text{after burst(s)} & \text{Satellite} & V^a (1 \sigma) & \text{Gal(V-band)} & f(\text{mm})^b \\
\hline
050408 & 300 & 240 & \text{HETE} & 10.9 & 0.076 & 25 \\
060413 & 26 & 335 & \text{Swift} & 10.0 & 6.305 & 35 \\
060211A & 792 & 321 & \text{Swift} & 10.8 & 0.587 & 35 \\
060323 & 750 & 82 & \text{Swift} & 12.0 & 0.046 & 35 \\
\hline
\end{array}
\]

\( a \) : Limiting magnitude
\( b \) : focal length

### 3.2 The data analysis of HETE-2

\( HETE-2 \) is the international satellite mission collaboration among USA, Japan, France, and Italy, headed by the Center for Space Research at MIT. It was successfully launched with a Pegasus launcher, on October 9 2000. The primary goals of the \( HETE-2 \) mission are the multi-wavelength observation of GRBs and the prompt distribution of precise GRB coordinates to the astronomical community for immediate follow-up observations. \( HETE-2 \) carries three science instruments. In this work, we used Wide-field X-ray Monitor(WXM) and FREnch GAmmatelescope(FREGATE) data. WXM and FREGATE are sensitive to photons in the energy range of 2-25 keV and 6-400 KeV, respectively\[^4\].

On this data analysis, we plot the light curve around the burst time for extracting the foreground and background regions. We obtain the GRB spectrum by subtracting the bg spectrum from the foreground one with the time regions. The left panel of Fig.2 shows the light curve of GRB 050408. We made the time resolved spectra with the time intervals which WIDGET observed. In Table 2, we show the spectral fitting parameters of the time intervals 1 and 3. The right panel of Fig.2 shows the extrapolation of the synchrotron power-law spectrum measured by \( HETE-2 \) lower than that of the extrapolation. It means some breaks were between optical and X-ray regions.

\[
\begin{array}{|c|c|c|c|c|c|}
\hline
\text{Time region} & \text{model} & \text{alpha} & \text{beta} & \text{Ebreak} & \text{norm[photons/keV/cm}^2/\text{s}]^b \\
\hline
1 & \text{grbm} & -1.26 & -2.44 & 32.51 & 12.51 \\
3 & \text{grbm} & -1.75 & -2.81 & 12.56 & 19.48 \\
\hline
\end{array}
\]

\( b \) : the normalization at \( 1\text{[KeV]} \)

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\(^1\)http://nedwww.ipac.caltech.edu/forms/calculator.html
4 summary

We have developed the robotic telescope \textit{WIDGET} for monitoring the \textit{HETE-2} and \textit{Swift} FOV to detect GRB optical flashes or possible optical precursors. The system has 44 deg × 44 deg × 3 cameras. \textit{WIDGET} has observed 15 GRBs in two and half years.

In this work, four of them occurred in coincident with \textit{HETE-2} or \textit{Swift} triggers were analyzed. In GRB 050408 and GRB 060323, the limiting magnitude measured by \textit{WIDGET} had lower flux than the extrapolation from the X-ray and gamma-ray spectra. On the other hand, in the cases of GRB 060211A and GRB 060413, the limiting magnitude were brighter than that of the extrapolation of X-ray and gamma-ray spectra.

References


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Abstract

To study the light curve and the spectrum of the visible light originating from gamma-ray bursts (GRBs), we have developed the wide-field telescope WIDGET, which tracks the field-of-view of a GRB satellite HETE-2 or Swift. This system is located at the Akeno campus of the Institute for Cosmic Ray Research University of Tokyo, and has been observing automatically since June 2004; we observed seven GRBs within two years. The standard GRB model predicts a power-law spectrum. However, we have found that the energy flux deduced from WIDGET data of GRB060323 is one order of magnitude lower than the extrapolated value from Swift data according to the GRB model. In this report, possible explanations will be discussed.

1. Introduction

Gamma-ray bursts (GRBs) are known as the most luminous events in the universe. Recently, the relation between GRB and supernova became clear, but its mechanism has not been understood. We especially aim to study the following:

1) Bursts with bright afterglow
2) The bright optical flash of bursts
3) Optical radiation before the GRBs.

We attempt to reveal the mechanism of GRBs.

2. WIDGET

We have developed WIDGET (WDe Field telescope for Gamma-ray burst Early Timing) for observing GRBs in a very early phase, even before the trigger onset since June 2004 (Fig3). The telescope tracks the field of views of HETE-2 or Swift automatically.

WIDGET can acquire optical data in prompt or the GRB trigger. In January 2006, we added more CCD cameras, so WIDGET has wider field-of-view (Fig4), 44 deg, 3 cameras (Fig2).

3. Simultaneously Analysis of WIDGET and satellite data

The standard exposure in our operation is 5 sec, so that we obtain sky images every 10 seconds including the readout time. We set time interval of the satellite data observation as same as the WIDGET one. We extrapolated the spectrum.

4. Summary and Discussion

• We analyzed in 4 GRBs triggered by GRB satellites and observed by WIDGET simultaneously.
• In GRB050408 and GRB060323, the limiting magnitude measured by WIDGET had lower flux than the extrapolation from the X and gamma-ray spectra.
• On the other hand, in the cases of GRB060211A and GRB060413, the limiting magnitude were brighter than that of the extrapolation of X and gamma-ray spectra.
• The GRB we observed with WIDGET did not have bright optical flash, which is observed only for GRB990123. When we extrapolate the X and gamma-ray spectrum of GRB990123 into the optical region, it should be as dark as 16 magnitude. However, GRB990123 has 8.9 magnitude optical emission around 50 seconds after the trigger. Therefore, optical flash might be emitted by different mechanism from X and gamma-ray emission.
• We expect that it will become actual to catch an unusual phenomenon like GRB990123 with our continuous observation.

Table 1: The spec of the WIDGET

- Site: Akeno-Yamagishi, Japan, Institute for cosmic ray research, University of Tokyo
- CCDcamera: Apogee Alta U-10
- Optics: Canon EF 55mm F1.4
- Limiting magnitude: V = 11 - 12 mag
- Integration time: 5 sec (reading 5 sec)
- Field of view: 44 deg 2
- Mount: Takahashi EM-200 Temma-2

Figure 3: poster