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GRB follow-up observations in the East-Asian region(*)

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Summary. — In 2004, we established a Japan-Taiwan-China collaboration for GRB study in the East-Asian region. This serves as a valuable addition to the world-wide optical and infrared follow-up network, because the East-Asia region would otherwise be blank. We have been carrying out imaging and spectroscopic follow-up observations at Lulin (Taiwan), Kiso (Japan), WIDGET (Japan) and Xinglong (China). From Xinglong and Kiso, we can locate candidates and obtain early time spectra for afterglows. While WIDGET provides early time observations before the burst, the high-time resolution for multi-band light curves can be obtained at Lulin. With the data from these sites, we can obtain detailed information about the light curve and redshift of GRBs, which are important to understand the mechanism of the afterglows. Up to March 2005, ten follow-up observations have been provided by this East-Asia cooperation. Two optical afterglows were detected, GRB 040924 and GRB 041006. The results of the two detected afterglows are reported in this paper.

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PACS 98.70.Rz – γ-ray source; γ-ray bursts.
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1. – Introduction

In East-Asia, since 2004, GRB optical follow-up observations have been carried out by the cooperation at Japan, Taiwan and China. Due to the nature of the GRB detection, the Target of Opportunity (TOO) programs have been provided by the Lulin (Taiwan),

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Kiso (Japan) and Xinglong (China) observatories. Since there was a blank in the east Asia region, the follow-up observations are expected to provide valuable observations for GRB fields. The position and different advantages of each site, reduce the risk of bad weather, allowing us to cover an observational range to up Dec $\sim$ 40 degrees, and provide a complete light curve in multi-wavelengths. Moreover, the 2.16 m telescope at Xinglong Observatory is able to perform spectral observations quickly, as soon as the optical afterglows have been located. By monitoring the observational ranges of *HETE-2* and *Swift*, *WIDGET* is capable of detecting the early optical emission of GRBs.

2. – Site information

2˙1. *Kiso observatory.* – The TOO system has been prepared for prompt GRB follow-up observations at Kiso observatory since 2001 [1]. The Kiso observatory is located in Nagano-Prefecture, Japan, and has a 105 cm Schmidt telescope and two other instruments. One is an optical 2k×2k CCD camera, the other is a near-infrared camera named KONIC (Kiso Observatory Near-Infrared Camera). The 2k×2k camera's FOV is 50 ×50 arcmin and its limited magnitudes are 22.0 mag, 22.5 mag, 21.0 mag, 21.0 mag. (for each B, V, R, I band, 10 σ, 900 s exposure). The KONIC's FOV is 20 arcmin. There are also two objective prisms, which allow low-dispersion slit less spectroscopy with 2k $\times$ 2k CCD with the FOV. 50×50 arcmin. For GRB021004, we could obtain the early afterglow spectrum using the low-dispersion slitless spectrograph with an objective prism, well before an optical transient position was reported [2].

2˙2. *WIDGET.* – WIDGET is a robotic telescope that monitor the *HETE-2* and large part of the *Swift* field of view, to detect optical flashes or possible optical precursors [3]. Since WIDGET has a $62^\circ \times 62^\circ$ FOV, we would uniformly obtain optical light curves before GRBs.

2˙3. *Lulin Observatory.* – The Lulin GRB program based on the Kiso GRB optical observation system [1], started in July 2003 using the Lulin One-meter Telescope (LOT) in Taiwan. The advantage of the LOT that it is able to perform small cadence $BVRI$-band time series photometry. The position of Lulin allows for further the observations of the southern sky. Moreover, with its better seeing and weather conditions, Lulin is capable of performing more GRB observations than Kiso either or Xinglong [4].

2˙4. *Xinglong station of Beijing observatory.* – Bejing observatory's Xinglong station is located in Xinglong County, Hebei Province, China. The brightness of the sky background on a moon-less night is $B = 22.2$, $V = 21.0$, $R = 20.3$, $I = 18.8$ mag arcsec^{-2}, respectively. Two telescopes participate in the East-Asia GRBs cooperation. One is a 2.16 m telescope, which is able to perform optical and near-infrared low-dispersion spectral observations for GRB afterglows by using the Optic-Metrics Research spectrograph with Tektronix 1024×1024 CCD. Typically there are about 210 spectroscopic night per year. The other is the 80 cm Cassegrain telescope, which is capable of automatically response to gamma-ray burst alerts to perform $BVRI$-band follow-up observations. The FOV is about $10' \times 10'$.

3. – Current results

Up to March 2005, ten follow-up observations have been provided by the East-Asia GRB observations in response to the alerts from *HETE-2*, *INTEGRAL* and *Swift*. We

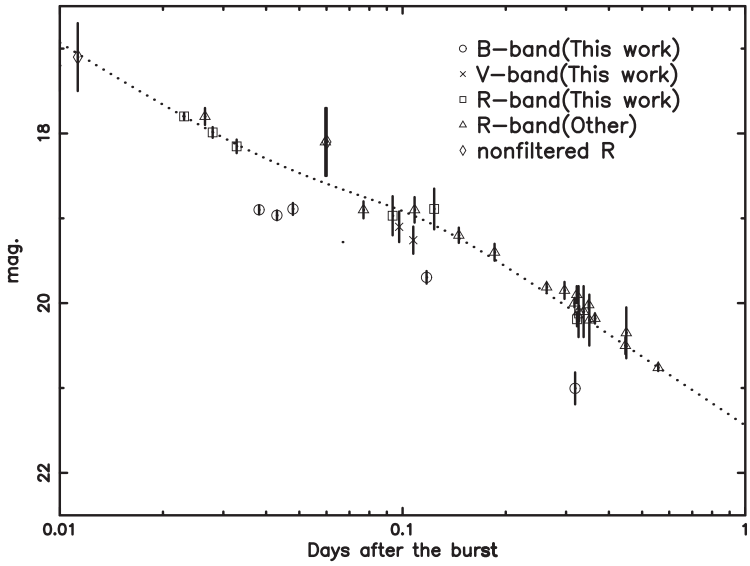

Fig. 1. – B, V and Rc band light curves based on the result at Kiso, Lulin and Beijing together with several points reported to GCN circulars.

could provide the upper limits of magnitude for eight events. Two optical afterglows were detected, GRB 040924 and GRB 041006. The results for the two detected afterglows will be described in the following.

3·1. *GRB 040924*. – The optical afterglows of short GRBs were elusive until the detection [5] of GRB 040924 by *HETE-2* on 2004 Sep. 24, at 11:52:11 UT. This event lasted about 1.2 s and was X-ray rich according to the *HETE-2* flux in the 7–30 keV and 30–400 keV bands. The Konus-Wind satellite also detected this event with 1.5 s duration in the 20–300 keV band [6]. Since the high-energy spectrum of GRB 040924 is soft [5], the object might actually be near the short-duration end of the long GRBs. The R_c-band and V-band measurements were made at the Lulin observatory between 3 and 9 hours after the burst. Our optical afterglow observations show that the temporal evolution, power-law index, and V-R color of GRB 040924 are also consistent with those of well-observed long GRBs. The signature of a break in the light curve, as suggested by our present data, can be explained by the afterglow model, by invoking an early cooling break [7].

3·2. *GRB 041006*. – Since it was night time in Japan when the burst occurred, the follow-up started at Kiso, 0.56 hours after the burst. Since the report by Costa *et al.*(2004) [8] had not yet reached us, we attended to cover the entire *HETE-2* error region. We made 300 s B, V, and Rc band imaging observations with exposure. In all bands, the afterglow was detected clearly. An example of the Rc band image is shown in fig. 1 [9]. As shown in fig. 1, the position of the optical afterglow is close to the standard star field of SA92 reported by Landolt (1992) [10]. To image optical afterglow and several standard stars from SA92 simultaneously, we pointed the telescope 5 arcmin to the east.

Since the weather conditions at Lulin were cloudy at the time of the burst, we had to wait for the weather to improve before retrieve. Meantime, we noticed, from our preliminary Kiso results that the afterglow evolution in the B and Rc bands was significantly different. Accordingly, we decided to focus on monitoring in these two particular bands. We were finally able to start the afterglow observation at the Lulin observatory at 7.65 hours after the burst. As planned in advance, we took 300 s B and Rc band image exposure. From 2.25 hours, we also performed Rc band imaging observations at the Beijing observatory, China. Based on the preliminary B and Rc band photometry results form Kiso, the afterglow was estimated te be slightly too faint to conduct multi color observations using the Beijing 60 cm telescope. Therefore, we focused on Rc band monitoring. Thus, thanks to our east Asian network, we were able to obtain multi-band information in an early phase with least interruptions, in spite of rather unstable weather conditions at the individual sites.

The multi-band light curve of the GRB 041006 afterglow is shown in fig. 1. There, we plot our B, V and Rc band points together with several unfiltered and Rc band points reported to GCN [11-14]. The B-band light curve shows a clear plateau around 0.03 days after the burst, although its behavior in earlier epochs remains unknown. The Rc band light curve shows a hint of plateau, or a possible slope change, around 0.1 days after the burst. Thus, the B, V and Rc band photometric points obtained by our east Asian cooperation plays an important role in characterizing the temporal evolution of the afterglow.

As is obvious in fig. 1, the Rc band light curve is poorly described by a single power-law ($\alpha = 0.82$, $\chi^2/\nu = 8.1$ with $\nu = 7$). However, the data subsets for $t < 0.04$ days and $t > 0.15$ days can be successfully described by separate single power-law models. We obtained $\alpha = -0.915 \pm 0.006$ with $\chi^2/\nu = 0.0011$ for $\nu = 1$, before 0.04 days, and $\alpha = -1.102 \pm 0.022$ with $\chi^2/\nu = 0.65$ for $\nu = 4$, after 0.15 days. Thus, the overall behavior of these multi band light curves may be understood as the sum of two separate components, one showing a monotonic decay while the other having rising and falling phases.

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REFERENCES

[1] Urata Y. *et al.*, *ApJL*, **595** (2003) 21.
[2] Urata Y. *et al.*, *Frontiers Sci.*, *Ser.* 41, Vol. **5** (2003) 2749.
[3] Tamagawa T. *et al.*, these proceedings (2005).
[4] Huang K. Y. *et al.*, these proceedings (2005).
[5] Fenimore E. E. *et al.*, *GCN Cir.*, **2735** (2004).
[6] Golenetskii S. *et al.*, *GCN Cir.*, **2754** (2004).
[7] Huang K. Y. *et al.*, *ApJL*, **628** (2005) 93.
[8] Costa G. *et al.*, *GCN Circ.*, **2765** (2004).
[9] Urata *et al.*, submitted to *ApJL*.
[10] Landolt A. U. *et al.*, *AJ*, **104** (1992) 340.
[11] Yost S. A. *et al.*, *GCN Circ.*, **2776** (2004).
[12] Ayani K. and Yamaoka H., *GCN Circ.*, **2779** (2004).
[13] Fugazza D., *GCN Circ.*, **2782** (2004).
[14] Monfardini A. *et al.*, *GCN Circ.*, **2790** (2004).