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GRBs Optical follow-up observation at Lulin observatory, Taiwan(*)

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Summary. — The Lulin GRB program, using the Lulin One-meter Telescope (LOT) in Taiwan started in July 2003. Its scientific aims are to discover optical counterparts of XRFs and short and long GRBs, then to quickly observe them in multiple bands. Thirteen follow-up observations were provided by LOT between July 2003 and Feb. 2005. One host galaxy was found at GRB 031203. Two optical afterglows were detected for GRB 040924 and GRB 041006. In addition, the optical observations of GRB 031203 and a discussion of the non-detection of the optical afterglow of GRB 031203 are also reported in this article.

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1. – Introduction

A parallel effort based on the Kiso GRB optical observation system [1,2], was started in July 2003 using the Lulin One-meter Telescope (LOT) at Taiwan. The scientific aims of our Lulin GRB program are: 1) to discover optical counterparts of XRFs, and short- and long-duration GRBs; 2) to perform multi-band observations that will unlock the temporal and spectral evolution of the corresponding optical afterglows. The Lulin observatory is located in Nantou County, Taiwan, at $120°52'25''E$, $23°28'07''N$, on a 2862-m high peak. The sky background levels in the $UBVRI$ bands are: $U = 21.8$; $B = 22.0$; $V = 21.3$; $R = 20.9$; $I = 19.5$ mag arcsec^{-2}, respectively. From statistical

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TABLE I. – *Basic characteristics of LOT with PI1300B and AP8 CCD*

Filter	PI1300B CCD			AP8 CCD		
	Zero point[a]	Color term	Extinction	Zero point	Color term	Extinction
B	22.34±0.02	0.199±0.018	0.19±0.02	21.99±0.03	0.035±0.005	0.28±0.02
V	22.68±0.02	−0.058±0.017	0.11±0.01	21.97±0.02	0.069±0.004	0.20±0.02
R	22.66±0.01	−0.049±0.021	0.09±0.01	21.87±0.02	0.113±0.007	0.15±0.02
I	21.99±0.04	0.040±0.029	0.06±0.01	21.27±0.03	0.043±0.005	0.12±0.02

[a]Units: Zero point (mag), Color term (mag), Extinction (mag/airmass)

measurements at Lulin site, it was found that the typical accumulative observation time is 1700 hours per year and the typical seeing is 1.5 arcsec. The LOT is a Cassegrain telescope ($f/8$) with an ACE filter system and a main CCD camera— PI1300B (1340×1300, F.O.V.$\sim 11.5' \times 11.2'$) as well as a spare CCD camera—Ap8 ($1k \times 1k$, F.O.V. $\sim 10.6' \times 10.6'$). Table I shows the characteristics of LOT with AP8 and PI1300B CCD [3].

Due to the fact that there are only a very few telescopes for GRB follow-up observations in East Asia, and that the observational range can reach up to Dec. −40 degree, Lulin enjoys a unique position for GRB study. The fast PI1300B read out time that allows small cadence multi-band time series photometry is another distinct advantage. Due to the nature of GRBs detection, the Lulin GRB project is included as a part of the Target of Opportunity (TOO) program. We have developed two approaches to search for GRB optical afterglows, according to the dimensions of the burst error box provided by such satellites as *HETE-2*, INTEGRAL, and SWIFT. First, if the error range is larger than the FOV of the LOT, we can dither the field and search for the optical counterpart in the B or R band. Second, if the error range is smaller than the FOV, we can quickly locate the counterpart and monitor the temporal variation of the brightness of the optical afterglow in several wavelengths.

During the analysis procedure, the positions and coordinates of the detected objects in our images are compared with the USNO stellar coordinates. These physical coordinates are then transformed to equatorial coordinates using the WCS (World Coordinate System). After this, our images compared with DSS2 images, to look for likely candidates.

2. – Summary of observed events

Between July 2003 and Feb. 2005 (table II), thirteen follow-up observations were provided by LOT. We could provide upper limits to the magnitude for ten events. Two optical afterglows were detected for GRB 040924 and GRB 041006 and the host galaxy of GRB 031203 was identified. We will focus on the GRB 031203 case in the following.

GRB 031203 was detected by the IBIS instrument on *INTEGRAL* on December 3, 2003 at 22:01:28 UT as a single peaked burst with a duration of 30s [4]. Newton-XMM detected two sources named S1 and S2 within the INTEGRAL error circle. The brightest source S1, which faded throughout the observation period, was interpreted to be the afterglow [5]. Its position coincided with that of a fading radio source [6].

A new source was detected by Lulin I-band observations [7]; see fig. 1. Bloom *et al.* [8] have pointed out that this new source could either be a galaxy in the foreground or the

TABLE II. – *Log of Lulin GRB follow-up observations.*

GRB	Delay time (hr)	Triggered Spacecraft	Limit mag. (3σ)	Results	Publications
GRB 030823	3.3	*HETE-2*	$R \sim 19$	Upper limit	GCN 2360
GRB 031026	6.0	*HETE-2*	$R \sim 21$	Upper limit	GCN 2436
GRB 031203	19.6	*INTEGRAL*	$I \sim 20$	Host Galaxy	GCN 2470
GRB 031220	8.0	*HETE-2*	$R \sim 20$	Upper limit	GCN 2494
GRB 040422	9.6	*INTEGRAL*	$R \sim 20$	Upper limit	GCN 2577
GRB 040916	16.3	*HETE-2*	$I \sim 20$	Upper limit	GCN 2721
GRB 040924	2.3	*HETE-2*	–	OT	GCN 2744
GRB 041006	9.0	*HETE-2*	–	OT	GCN 2785
GRB 041211	3.4	*HETE-2*	$R \sim 20$	Upper limit	GCN 2840
GRB 041219	9.6	*SWIFT*	$R \sim 21$	Upper limit	GCN 2891
GRB 050123	5.5	*HETE-2*	$I \sim 19$	Upper limit	GCN 2971
GRB 050124	4.4	*SWIFT*	$R \sim 20$	Upper limit	GCN 2976
GRB 050215B	13.1	*SWIFT*	$V \sim 19$	Upper limit	GCN 3030
			$I \sim 20$	Upper limit	GCN 3030

host of GRB 031203. A radio afterglow was detected at the same position. From spectroscopic observations, Prochaska *et al.* [9] found this to be an active star-forming galaxy, with $z = 0.105$ and that should be the host galaxy of GRB 031203, designated HG 031203.

The LOT follow-up observations in combination with other I-band data [10-12], indicated that the source did not show variability in terms of its brightness (fig. 2). Thus, the optical source detected was the host galaxy, HG 031203, and no variable source brighter than $I = 20.0$ was found during our observations. The astrometry of the GRB 031203 field was corrected by matching with stars in the USNO A2 catalog. This resulted in the following astrometric position of HG 031203: R.A. $= 08^{\rm h}02^{\rm m}30^{\rm s}.177 \pm 0.175$ arcsec, Dec. $= -39°51'03''.960 \pm 0.164$ arcsec (J2000.0). It is important to note that optical and spectroscopic observations made by several groups have revealed that SN 2003lw was associated with GRB 031203. It had a brightness peak between 26 and 34 days after the gamma-ray burst [10-13].

In order to explore the reason behind the absence of optical afterglow, we have analyzed the X-ray Newton-XMM afterglow data. Using the power law plus absorption model, we found that the best fit of the photon index is 1.8 ± 0.1 ($\chi^2 = 14.07$ with 22 dof) with $N_H = 7.73 \pm 0.04 \times 10^{21}\,{\rm cm}^{-2}$ for the energy between 0.6 keV to 10 keV. Our results are consistent with those found by Watson *et al.* [14]. Assuming no break in the lightcurve, the spectral flux distribution follows $F_\nu \propto \nu^{-\beta} (\beta = 0.8 \pm 0.1)$ and the

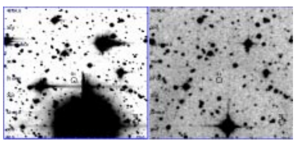

Fig. 1. – LOT I-band image of XMM-Source: S1 and S2. By comparing this with the DSS I-band image, we found a source near S1.

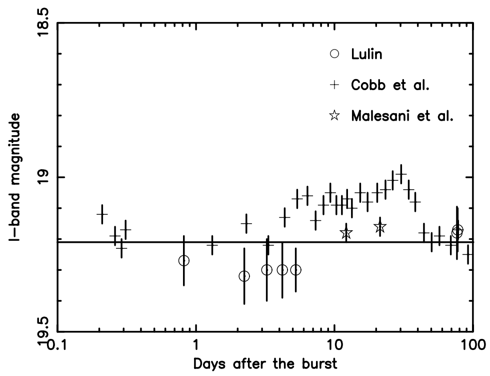

Fig. 2. – Lightcurve of HG 031203 at the I-band. The solid line shows the magnitude of the host galaxy ($I = 19.21$).

extrapolation of the X-ray flux to the optical range yields $I = 20.65$ and $R = 21.13$, at 0.26 days after the burst.

In comparison with the value of $N_H = 7.73 \pm 0.04 \times 10^{21}\,\mathrm{cm}^{-2}$, the neutral hydrogen column density along the line-of-sight to GRB 031203, is on the order of $N_H = 6.21 \times 10^{21}\,\mathrm{cm}^{-2}$ within the Galaxy [15]. This means that most of the extinction of the optical emission of this gamma-ray burst should have come from the Galactic interstellar medium. This effect alone is enough to reduce the optical brightness by 2 magnitudes from 20.65 to about 22.65 at the I-band [15]. This might explain why GRB 031203 shows no optical afterglow.

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