Early Optical Follow-up Observations of Gamma Ray Bursts with the Robotic Liverpool Telescope

A. Gomboc1,2 (andreja.gomboc@fmf.uni-lj.si), C. Guidorzi1 (crg@astro.livjm.ac.uk), A. Monfardini1,3, C. G. Mundell1, M. F. Bode1, D. Carter1, S. N. Fraser1, C. J. Mottram1, R. J. Smith1, I. A. Steele1

1 Astrophysics Research Institute, Liverpool John Moores University, Twelve Quays House, Egerton Wharf, Birkenhead, CH41 1LD, UK
2 Department of Physics, University in Ljubljana, Jadranska 19, 1000 Ljubljana, Slovenia
3 ITC-IRST and INFN, Trento, via Sommarive, 18 38050 Povo (TN), Italy

Abstract

Robotic telescopes are new tools in Astronomy to study astronomical objects, which vary in their brightness and spectral properties on timescales from seconds to years, and therefore contribute essentially to areas of astronomy, which were not sufficiently covered by conventional telescopes. One of the crucial advantages of robotic telescopes is the rapid reaction to Targets of Opportunity, including short and unpredictable phenomena, such as Gamma Ray Bursts (GRBs). These flashes (lasting at most a few minutes) of high energy photons occur approximately once per day in random directions in the sky. Subsequently, at their positions, longer lasting afterglows are detected in X-rays, optical and radio wavelengths. Study of early afterglow emission is crucial since it holds important information about the origin and environment of GRBs. To-date the number of GRBs with well-sampled optical light curves obtained only minutes after the burst remains small; understanding the early blast wave evolution and solving the enigma of “missing” optical counterparts requires both rapid and deep observations. Here we discuss the 2-m robotic Liverpool Telescope GRB optical follow-up programme and present some recent results.

1. GAMMA RAY BURSTS

Gamma-ray bursts (GRBs) were first detected in the late 1960’s by military satellites monitoring compliance with the nuclear test ban treaties. With the publication of results from the Vela and Konus satellites several years later [1], this became public information and it triggered an avalanche of theoretical models for their explanation - in 1994 there were more than a hundred models [2]. However their nature remained a complete mystery for more than two decades, mainly because they remained detectable only for tens of seconds and exclusively at gamma-ray energies [3].

The important question of distance to GRB sources has been under debate for a long time and was not settled even by the 2nd Great Debate1 in 1995 between Lamb, who argued that GRB sources lie in our Galaxy [4] and Paczynski, who put them at cosmological distances [5]. Results from the Compton Gamma-Ray Observatory (launched in 1991), and its Burst and Transient Experiment, which recorded over 2700 bursts, however showed that GRBs are isotropically distributed across the sky, therefore suggesting the cosmological origin of GRBs [6].

A great breakthrough happened in the last years of the 20th century with the discovery of GRB afterglows and their host galaxies. The Italian-Dutch satellite BeppoSAX was able to produce the first rapid and small error boxes of GRB positions in the sky. This was a crucial breakthrough because when these small (arcmin) error boxes of GRB were observed in other wavelengths, longer-lived fading afterglows were found. On 1997 February 28, BeppoSAX detected the first X-ray afterglow coinciding with the position in the sky of GRB 9702282 [7]. This was also the first GRB with an optical counterpart detected [8], which lay in a host galaxy at redshift $z \approx 0.7$ [9]. Another important burst was GRB 970508, which was the first with a detected radio-afterglow [10]. Detection of redshifted absorption lines in its spectrum ([11]) was crucial indication that this burst lies at cosmological distances. This was further supported by observations with Hubble Space Telescope, which revealed its optical counterpart to be in a blue, actively star-forming dwarf galaxy and it was concluded [12] that this establishes a cosmological origin at least for some GRBs.

The discovery that GRBs are occurring in distant galaxies, together with their observed luminosity, led to the realization that these immense explosions are the most luminous ($E_{iso}^{\gamma} \sim 10^{51–54}$ erg), transient objects known in the Universe and represent the most significant new astrophysical phenomenon since the discovery of quasars and pulsars. Although bursts exhibit a variety of complex and irregular flux curves, they can be separated into two main categories depending on their duration (in $\gamma$-rays): short GRBs ($t < 2s$) and long GRBs ($t > 2s$). Almost all of the GRBs with measured redshift belong to the long class. Only recently it has been possible to measure the distance to a few short GRBs ([13], [14], [15]), because of the faint-
ness of their optical and X-ray afterglow.

Current consensus on the processes occurring in the GRB explosion is that, given the huge release of energy in gamma-rays in a few seconds, the compactness problem (the huge pair-production optical depth could not be reconciled with the observed gamma-rays) can be solved only by invoking relativistic bulk motion, i.e. an emitting region moving toward us with an ultra-relativistic Lorentz factor ($\Gamma \sim 10^2$). According to the so-called "fireball" model [16], the gamma-ray pulses observed during the prompt emission are thought to be the result of interactions between different relativistic shells with different Lorentz factors (internal shocks), while the afterglow emission at longer wavelengths is interpreted as the result of the late interaction between these expanding shells and the surrounding interstellar medium (external shocks). Alternative interpretations of the gamma-ray pulses as due to external shocks are not definitively ruled out, although it seems more problematic to explain some properties of the evolution of the pulses within the same GRB.

The spectra of GRBs as well as those of afterglows are non-thermal. While the afterglow spectrum is interpreted as due to synchrotron emission of relativistic electrons in random magnetic fields, the issue for the prompt emission is still debated.

The nature and origin of these explosions is at present still an open question. There are observations indicating that (at least some) long GRBs are connected to highly energetic supernovae and with that supporting the "collapsar" model (in this model GRBs are produced in the process of core-collapse of a rapidly rotating massive star, which produces a black hole and launches an ultra relativistic explosion). The first evidence of a possible association of GRBs with supernovae was reported for the GRB 980425 and SN1998bw [17]. The discovery of temporal and spatial coincidence of GRB 030329 and SN2003dh together with their spectral evolution [18] gives significant support to the GRB-supernova connection.

Among current models for short GRBs the most accepted is that they occur in the merging of two compact objects (neutron stars or black holes) as suggested for GRB 050509B [19] and for GRB 050724 [15], although other models invoking the collapse of young stars cannot be ruled out in some cases, like for GRB 050709 ([14]).

1.1. "Missing" optical afterglows

Optical afterglows of short GRBs were until recently one class of so-called "missing" optical afterglows. It has been predicted that the afterglows of short GRBs may be 3-4 magnitudes fainter than the afterglows of long GRB [20]. To-date (Nov 2005), afterglows of three short GRBs were detected, all at later times ($t > 8$ hr after the GRB), with only upper limits at earlier times. While it seems that their magnitudes indicate that afterglows of short GRBs are indeed fainter, rapid follow-up observations with a 2-m or larger telescope, are needed to learn more about properties of afterglows of short GRBs and their origin.

In the case of long GRBs, X-ray counterparts are now observed for essentially all of them, while optical afterglows are not always detected. Whether this second class of "missing" optical afterglows is inherently dark, dust absorbed, highly redshifted or just observationally overlooked (not deep and early enough observed) is still an open question. So far, there is only a handful of optical afterglows detected within the first 10 minutes after the GRB initial event. Given the rapid afterglow decline, it is possible that for some bursts currently considered optically "dark", afterglows may be detected in these early moments by a larger rapid response telescope. To establish the fraction of truly dark bursts, routine rapid follow-up observations are therefore critical.

2. GRB FOLLOW-UP WITH THE LIVERPOOL TELESCOPE

The Liverpool Telescope (LT, see Fig.1), operated by Liverpool John Moores University, has a 2-m primary mirror
diameter and is situated at Roque de los Muchachos Observatory on Canary Island La Palma. Thanks to its robotic control and automated scheduling, the LT is especially suitable for rapid response to GRB alerts issued by gamma-ray detecting satellites (HETE-2, INTEGRAL and Swift), which makes the LT, together with two Faulkes Telescopes (see Section 3) the largest rapid response telescope. This, together with the range of its instrumentation (optical and infrared cameras with a selection of filters, two spectrographs and polarimeter under development, see Table 1), enables the study of prompt optical and infra-red emission and afterglows of GRBs to much fainter magnitudes than smaller robotic telescopes can reach, while early spectroscopy and polarimetry will provide additional tool to test current models of GRBs and their environment.

A vital component of a successful rapid follow-up strategy is obtaining observations without any human intervention. We describe here the sophisticated and fully-automated procedure that we have implemented on the LT to ensure that no human input is required throughout, from the initial receipt of a satellite GRB alert at the LT, through observation, GRB identification and subsequent selection and execution of the most suitable follow-up observations based on the identified optical transient properties.

### Table 1:

<table>
<thead>
<tr>
<th>Instrumentation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RATCam Optical CCD Camera</td>
<td>2048×2048 pixels, 0.135′′/pixel, FOV 4.6′×4.6′, 8 filter selections (u′, g′, r′, i′, z′, B, V, ND2.0)</td>
</tr>
<tr>
<td>SupIRCam 1 - 2.5 micron Camera (with Imperial College)</td>
<td>256×256 pixels, 0.4′′/pixel, FOV 1.7′×1.7′, Z, J, H, K′ filters - from late 2005</td>
</tr>
<tr>
<td>Prototype Spectrograph (with University of Manchester)</td>
<td>49, 1.7′ fibres, 512×512 pixels, R=1000; 3500 &lt; λ &lt; 7000 Å - from 2006</td>
</tr>
<tr>
<td>RINGO optical polarimeter - Ring Polarimeter based on the design of [21]</td>
<td>- from 2006</td>
</tr>
<tr>
<td>FRODOSpec Integral field double beam spectrograph (with University of Southampton)</td>
<td>R=4000, 8000; 4000 &lt; λ &lt; 9500 Å - from 2007</td>
</tr>
</tbody>
</table>

#### 2.1. LT GRB follow-up strategy

The basic observing strategy, following the GRB alert issued by HETE-2, INTEGRAL and Swift and received from the Gamma ray bursts Coordinates Network (GCN) via socket connection, is triggered when the special Over-Ride mode is automatically started (interrupting any currently on-going observations). This points the telescope to the location of the GRB in the sky in about 1–3 min after the initial event and starts the first sequence of observations, called "Detection Mode" (DM). DM consists of two sets of three 10-sec exposure images in the Sloan r′ filter. As soon as these initial images are acquired, the GRB pipeline is invoked in order to process them and to look for possible optical transient (OT) candidates. In the following paragraphs, we give a description of the GRB pipeline. For more details, we address the reader to the paper devoted to it [22].

If the GRB pipeline finds a high confidence level OT, the so called "Multi-Colour Imaging Mode" (MCIM) is triggered: this consists of a multi-colour sequence of exposures: before 2005 May 16th it consisted of BVr′i′z′ images of increasing exposure times: 30-sec, 60-sec and then repeatedly switching between 120-sec and 180-sec exposures until the end of observations. After this date, the multi-colour sequence has been changed to g′r′i′ repeated twice with 30-sec exposure times and it continues with 60-sec exposure cycles up to 18 times.

After successful commissioning of spectrographs (expected in 2006-07), the "Spectroscopy Mode" (SM) will be invoked if the best OT candidate is found to be brighter than a given value (r′=15 for Prototype Spectrograph and r′=19 for FRODOSpec). A high significance detection of an OT with r′=15 can also trigger the "Polarimetry Mode" (PM), which consists of an automatic series of polarimetric exposures taken with RINGO (expected 2006). These exposures will not be reduced and analyzed in real-time.

Alternatively, when no high confidence OT candidate is found in the DM, the sequence of longer, deeper exposures in the optical and infrared, called "RIZ Mode" (RIZM) is triggered: this is a sequence of 2-min exposure r′, i′ and z′ images repeated in the following order: first one image per filter, then two, followed by three exposures per filter and so on. This is meant to detect the possible afterglow, when it is faint or at least to provide constraining upper limits. Prior to November 2005, this mode consisted of r′, i′ cycles only; we inserted the additional z′ exposures to enable the identification of possible higher redshift bursts (with z > 6). Under average conditions, i.e. seeing ~ 1 arcsec, 2-min exposure limiting magnitudes are around r′ ∼ 21–22 and i′ ∼ 20–21.

In order to quickly analyse the images obtained and detect a new source (i.e. a GRB afterglow) an automatic data reduction pipeline is crucial. This pipeline must reliably identify GRB afterglow in real-time and according to the results of initial observations in first few minutes, select the most suitable follow-up strategy (MCIM or RIZM at the moment, later also SM and PM). Rapid detection of a GRB afterglow (i.e. coordinates and brightness) is disseminated through GCN to the astronomical community and other observing facilities, which enables follow-up of the detected afterglow with more complicated observations (e.g. high resolution spectroscopy, polarimetry, study of host galaxies, etc.).

#### 2.2. LT GRB pipeline

For the real-time automatic pipeline for GRB afterglow detection, we used the method of comparison of two lists of objects: we compare a list of objects from the new image taken by the LT with the object lists of the same part of the sky from other epochs (i.e. existing catalogues such as USNO-B1). In general, this approach can identify an afterglow from a single image and gives good results for af—
The GRB pipeline analysis proceeds in two major steps: first, the GRB Pipeline Astrometric Script fits the astrometry to images obtained (i.e. assigns accurate sky-coordinates to objects in the image), compares them with objects from the catalogues and finds possible OT candidates. In the second step, the GRB Pipeline Variability Script looks for luminosity variations by any of the OT candidates. In these processes, each OT candidate is assigned a confidence level, and the highest one determines the subsequent observing strategy, as described above.

- The GRB Pipeline Astrometric Script
This script extracts sources from the images and compares them with the USNO-B1.0 catalogue. The sources which match catalogue stars are used to fit the astrometry, and when this is successful, the unmatched image sources are first filtered from false objects, e.g. due to cosmic rays, various CCD defects and effects, such as saturation spikes, bad CCD columns and edge defects. Finally, it selects the good OT candidates, each of which is assigned a confidence level according to its features (see [22] for details).

- The GRB Pipeline Variability Script
After the GRB pipeline script described above has run on the first three images (once for each set of three images), the three resulting OT candidates’ lists are cross-checked through so-called ”variability script”. This script aims at identifying the same objects in the different OT candidates lists and evaluating possible significant variations in magnitude. Each OT candidate confidence level is finally adjusted on the basis of the variability results (for details see [22]). To test the sensitivity of the script, we simulated an OT fading according to a power law, \( F \propto (t - t_0)^{-\alpha} \) (\( t_0 \) is the GRB onset time; see footnote on next page). The script detected significant variability for \( \alpha \sim 1-2 \), for objects at least as bright as \( t' \sim 16-17 \), provided that DM is triggered quickly enough, at \( (t - t_0) < 200 \) sec.

3. GRBS AND ROBONET-1.0
The same strategy and automatic pipeline (although slightly adapted) is used also in the RoboNet-1.0\(^5\) project, of which the LT is an essential part. RoboNet-1.0 is a network of 2-m robotic telescopes, which at present includes three telescopes around the globe. Added to the LT on the Canary Islands are the two Faulkes Telescopes, which are almost exact clones of the LT: Faulkes Telescope North (FTN) is situated in Maui, Hawaii and has been operating since the end of 2003, and the Faulkes Telescope South (FTS) in Sidings Spring, Australia, which achieved first light in September 2004. The Faulkes Telescopes were built by Telescope Technologies Ltd, adjacent to the LJMU Astrophysics Research Institute in Birkenhead, and were initially funded by the Dill Faulkes Educational Trust. Currently they are financed by Las Cumbres Observatory and are mainly intended for use by UK schools. The FTs are usually operated in a remote control mode (through the Telescope Management Centre in Liverpool or from schools), but can also operate in a fully robotic mode, identical to the LT’s. Although most of the observing time is intended for educational use, some time is also available to the research community.

Access to research time on all three large robots is the core of the RoboNet-1.0 project, which is led by Liverpool JMU, funded by the UK PPARC and includes members of 9 other UK university teams in Cardiff, Exeter, Hertfordshire, Leicester, Manchester, MSSL, QUB, St. Andrews and Southampton. The primary technological aim of the RoboNet-1.0 project is to integrate LT, FTN and FTS into a global network optimised for round-the-clock rapid-response and continuous monitoring science, such as exoplanet searches and GRB follow-up. As each telescope can observe approximately 1 in 10 GRBs immediately following the alert (taking into account night/day, south/north hemisphere, zenith distance, < 70°, weather and technical restrictions), the capabilities of the telescope network, particularly in its increased sky and time coverage, greatly benefit GRB detectability, and also facilitate continuous observations of longer-term light-curve decay.

The strategy of GRB observation on the Faulkes Telescopes is similar to the strategy at the LT with some difference regarding the available instrumentation (the FT’s have a somewhat different optical filter set and no infra-red camera).

4. RESULTS
Since the LT and FTs became operational, to-date (Nov 2005) we followed-up 3 GRBs detected by HETE-2 (GRB 041006, GRB 041211, GRB 050408), 5 GRBs detected by INTEGRAL (GRB 040223, GRB 041218, GRB 050502a, GRB 050504, GRB 050520) and 12 GRBs detected by Swift (GRB 050128, GRB 050215b, GRB 050412, GRB 050505, GRB 050528, GRB 050713a, GRB 050716, GRB 050730, GRB 050904, GRB 050925, GRB 051111) and we published our results in 21 GCN Circulars.

Out of 20 GRBs that we followed, the LT reacted robotically to 6 GRBs and FTN to 6 more. Times of robotic start

\(^{5}\) see www.astro.livjm.ac.uk/RoboNet
of observations range between 2.4 and 4.5 min after the GRB trigger time (see Table 4 of [22]).

The best followed GRB afterglow observed by the LT so far is that of GRB 050502a (GCN Circ. 3325 [23]) followed by the acquisition of the first early (<1 hr) multicolour light curve [24] and is described in detail in 4.2. The other cases of prompt detection plus longer-term follow-up using RoboNet-1.0, are GRB050713A (GCN Circ. 3588 [23]) and GRB 051111 (GCN Circ. 4250 [23]). In the first case, the afterglow was not identified automatically because of the poor quality of images affected by the presence of a bright 6-mag star in the field. Instead it was identified afterwards by visual inspection. In the second case, the afterglow of the GRB 051111 was identified by the automatic pipeline in images taken 4 minutes after the burst. Unfortunately, observations were interrupted shortly after due to a technical problem and were re-started manually; data obtained are currently being analyzed. We also followed-up GRB 050730: since this burst occurred before twilight at the LT site, the observations were triggered manually. Because of the high sky background due to sky not being completely dark, the OT was not recognized in the DM images, but it was automatically identified in the subsequent RIM (GCN Circ. 3706 [23]).

In other cases, the combination of sensitivity and rapid response allowed us to derive constraining upper limits on optical afterglow, as in the cases of GRB 050504 with R>19 (GCN Circ. 3351 [23]) and GRB 050716 with R>19.8 (GCN Circ. 3625 [23]) at 3-4 min after the GRB trigger time.

4.1. GRB 041006A

The first GRB we followed up (manually) with the LT was GRB 041006. It was detected by HETE-2 satellite on 2004 Oct 06 at UT 12:18:08 and located at the position \( \alpha = 00:54:53 \) and \( \delta = +01:12:04 \) (J2000) with an error radius of 5 arcmin (90% confidence level) (GCN Circ. 2770 [23]). Observations with the LT started as soon as this area of the sky became visible to the LT, i.e. 8.2 hours after the GRB. The first GRB we followed up (manually) with the LT was

The first GRB we followed up (manually) with the LT was GRB 041006. It was detected by HETE-2 satellite on 2004 Oct 06 at UT 12:18:08 and located at the position \( \alpha = 00:54:53 \) and \( \delta = +01:12:04 \) (J2000) with an error radius of 5 arcmin (90% confidence level) (GCN Circ. 2770 [23]). Observations with the LT started as soon as this area of the sky became visible to the LT, i.e. 8.2 hours after the GRB.

The light curve of the optical afterglow of GRB 041006 is shown in Fig. 2. In the case of this burst, from the knowledge of the gamma-ray spectrum from HETE-2 and of the redshift \( z = 0.712 \) (GCN Circ. 2782 [23]), we made use of the Ghirlanda et al. [25] relation to predict the time of the break in the optical afterglow light curve \(^6\). Notably, the predicted break time turned out to be in agreement with observations (for details see [26]).

4.2. GRB 050502A

GRB 050502a is the first example of rapid robotic reaction of the LT to a GRB alert and automatic detection of the optical afterglow by the GRB pipeline.

On 2005 May 02 INTEGRAL detected the long duration (20 s) GRB 050502a at 02:13:57 UT and determined its position as \( \alpha = 13:29:45.4 \) and \( \delta = +42:40:26.6 \) (J2000) with an error radius of 2 arcmin (90% confidence level) (GCN Circ. 3323 [23]). ROTSE-IIIb\(^7\) started observing at 23.3 s after the GRB and detected a 14.3 mag (unfiltered) unknown fading source at \( \alpha = 13:29:46.3 \) and \( \delta = +42:40:27.7 \) (J2000) (GCN Circ. 3322 [23]).

The LT responded robotically to the INTEGRAL alert and started observing 3 min after the GRB trigger time (2.5 min after the notice time). Independently of ROTSE-IIIb, it detected a fading source not present in the USNO-B1.0, 2MASS and GSC 2.3 catalogues, with a position consistent with that of the optical transient (OT) identified by ROTSE-IIIb (GCN Circ. 3322 [23]).

The automatic identification of the bright and fading OT (see Fig. 3) by the LT GRB robotic pipeline resulted in the automatic triggering of a technical afterglow light curve \( F \sim t^{-\alpha} \), with power-law index \( \alpha \) between 0.6 and 2.3. In some GRB afterglow light curves a “break” is observed in the power-law index \( \alpha \) which becomes steeper at some time after the burst. When the break is achromatic, it is interpreted as evidence of collimated emission.

\(^6\)In general, GRB afterglows fade according to a power-law \( F \sim t^{-\alpha} \), with power-law index \( \alpha \) between 0.6 and 2.3. In some GRB afterglow light curves a “break” is observed in the power-law index \( \alpha \) which becomes steeper at some time after the burst. When the break is achromatic, it is interpreted as evidence of collimated emission.

\(^7\)ROTSE-IIIb is a 0.45-m robotic telescope at McDonald Observatory, Texas, USA.
multi-colour imaging sequence that provided light curves in $BVR'i'i'$ filters from 3 min to 1 hr after the GRB onset. The robotic follow-up with the LT ended after the first hour, subsequent follow-up observations were triggered manually both on the LT and FTN as part of RoboNet-1.0.

Figure 4 shows the multi-colour light curve acquired by the LT during the first hour and later points with both LT and FTN. A multi-colour bump rising at $t \sim 0.02$ d is evident. Fitting each light curve with a power-law of the form $F \propto t^{-\alpha}$ and excluding points $0.02 < t < 0.2$ d (the latter corresponding approximately to the bump rise time), we obtain power-law indices consistent across all bands: $\alpha_B = 1.20 \pm 0.04$, $\alpha_V = 1.16 \pm 0.06$, $\alpha_r = 1.20 \pm 0.04$, $\alpha_i = 1.16 \pm 0.03$.

Combining the power-law index of the temporal decay of the light curve with spectrum properties and taking into account the upper limit in the X-ray provided by Swift (GCN Circ. 3374 [23]), we found (see [24]) that the scenario which accounts better for the data is that of a uniform medium with clumps in density in the case of GRB 021004 [27]. According to this interpretation, the bump would be the result of the impact of the expanding fireball on over-dense clumps, which produce a rapid flux increase relaxing asymptotically. Alternative interpretations for the GRB 050502a data, as discussed in [24], concern a wind environment, or energy injections due to the interaction of late refreshed shocks which catch up with slower shells. Those models have been proposed for GRB 021004 and, although they cannot be ruled out in the case of GRB 050502a, it seems that they can less adequately explain our data.

5. CONCLUSIONS

The GRB early afterglow emission allows us to uniquely probe the medium surrounding the progenitor and potentially the nature of the progenitor itself. As the GRB afterglows rapidly fade, multi-wavelength observations starting as soon as possible after the GRB are essential to shed light on the nature and origin of these events. In particular, the combination of rapidity (minutes) and sensitivity (down to magnitude $V=21$) in the optical and infrared can be crucial to solve the problem of the “missing” afterglows. Early observations are important also for the use of GRBs as cosmological tools; in measuring the redshift of distant GRBs (for which the host galaxy is too faint to enable the detection of emission lines in its spectrum), that can only be achieved with the detection of absorption lines in the early afterglow and the spectroscopy of early afterglows, which enables the probe of the host and the intergalactic medium.

After the launch of the USA/UK/Italian satellite Swift in November 2004, and the beginning of its science operation in early 2005, more GRBs with good localization are provided (5-10 per month compared to 1-2 per month from HETE-2 and INTEGRAL). Robotic telescopes (including the LT and the FT’s) have been playing a crucial role in the rapid detection of GRB afterglows. As early observations of afterglows could provide decisive clues to prove or disprove current GRB models, observations like those obtained by the LT and FT’s in recent months are contributing to the solution of one of the biggest mysteries in Astrophysics in recent decades.

6. ACKNOWLEDGEMENTS

AG and CG acknowledge the receipt of Marie Curie Fellowships (Contract No. HPMD-CT-200100071). AG acknowledges also the receipt of Marie Curie European Re-integration Grant (Contract No. MERS-CT-2004-012842). AM acknowledges financial support from the UK PPARC and CGM from the Royal Society. MFB is supported by a UK PPARC Senior Fellowship. The Liverpool Telescope is funded via EU, UK PPARC, Liverpool John Moores University grants and the benefaction of Mr. A. E. Robarts.

7. REFERENCES