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GRB optical and IR rapid follow-up with the 2 m Liverpool Robotic Telescope

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The Liverpool Telescope, owned and operated by Liverpool John Moores University and situated at Roque de los Muchachos, La Palma, is the first 2-m, fully instrumented robotic telescope. We plan to use the LT in conjunction with Gamma Ray Observatories (HETE-2, INTEGRAL, Swift) to study GRB physics. A special over-ride mode will enable observations commencing less than a minute after the GRB alert, including optical and near infrared imaging and spectroscopy. These observations, together with systematic monitoring of the burst through the afterglow, will help to unravel the nature of prompt optical flashes, short bursts, optically dark bursts, redshift distribution, GRB - supernova connection and other questions related to the GRB phenomenon. In particular, the combination of aperture, instrumentation and rapid automated response makes the Liverpool Telescope excellently suited to the investigation of optically dark bursts and currently optically unstudied short bursts.

1 Introduction

Early acquisition of multi-wavelength light curves for many GRBs is essential to further our understanding of the nature and origin of these objects, the relationship between the prompt and afterglow emission and to distinguish between different afterglow models. On the other hand, systematic observation of the afterglows for weeks following the GRB will help determine the connection between GRB and supernovae.

Robotic operation of a telescope has the advantages of providing rapid reaction to short and unpredictable phenomena and their systematic follow-up, simultaneous or coordinated with other ground facilities or satellites. This makes such facilities invaluable in the study of GRBs.

The Liverpool Telescope (LT), with a primary mirror diameter of 2 m, is the largest fully robotic telescope (Fig. 1). It is located on the excellent astronomical site of La Palma in the Canaries and is housed in a unique fully-opening enclosure. It can have 5 permanently mounted instruments, which are selected automatically by a deployable, rotating mirror in the A&G box within 30s.

The LT instrumentation currently comprises

RATCam Optical CCD Camera with 2048×2048 pixels, FoV 4.6'×4.6' and 8 filter selections (u', g', r', i', z', B, V, ND2.0)

and will be complemented with:

SupIRCam 1-2.5 micron Camera with 256× 256 pixels, FoV 1.7'×1.7' and Z, J, H, K' filters - in Autumn 2003,

Prototype Spectrograph with 49, 1.7" fibres, 512×512 pixels, R=1000; $3500<\lambda<7000$ Å- in Autumn 2003, and

FRODOSpec Integral field double beam spectrograph with R=4000, 8000; $4000<\lambda<9500$ Å- in Summer 2004.

Fig. 1. The Liverpool Telescope at Roque de los Muchachos, La Palma, Canaries is a 2-m fully robotic altitude-azimuth design telescope. Fully openable enclosure and the slew rate $> 2^o$/s enable the start of observations in less than a minute after the GRB alert.

First light on the LT was successfully achieved at the end of July 2003 and currently, the LT is still in the commissioning phase. For updated information please see http://telescope.livjm.ac.uk/.

2 GRB follow-up with the LT

GRB follow-up observations have been assigned high priority in the LT observing programme. Following the GRB alert from the GCN network and HETE-2, INTEGRAL and Swift, we will employ the Over-Ride mode and commence the search for and observation of GRB counterparts. The initial LT strategy for responding to Swift alerts is presented in Table 1. With this routine as the starting point, the automated procedures can be optimised with experience and adapted regarding scientific imperatives.

Table 1. Initial LT strategy for responding to Swift alerts.

Time (s)	Swift instrument and the error box of GRB position	Alert progress and simultaneous LT activity
0		GRB alert
15	BAT (γ-ray) $\sim$ 4'	Release of GCN alert
20		GCN alert arrives at LT - Automatic override starts slew
50		Commence multiband optical imaging (FOV=4.6')
140	XRT (X-ray) $\sim$ 5"	Re-point and select SupIRCam (FOV=1.7')
160		Commence near infrared imaging
320	UVOT (opt.) $\sim$ 0.3"	Re-point and select spectrograph (FOV=10")
340		Commence optical spectroscopy

3 GRB science with the LT

3.1 Short bursts

Of all the GRB afterglows so far observed, only one single epoch observation [2] of a possible optical counterpart to a short GRB was reported. As it may be expected that short GRB afterglows will be 3-4 magnitudes fainter than long GRB afterglows [8], a 2-m or even larger telescope is required for their rapid follow-up, or, in the case of no detection, to place even more stringent limits on the afterglow immediately following the short burst.

3.2 Spectroscopy and redshift

Redshift information is currently available for about 40 long bursts [5] with the selection likely to be extremely biased towards the brightest events, those with the slowest optical decay curves or those with the brightest host galaxies. In the search for high-redshift GRBs, infra-red imaging is particularly important. Lyman limit absorption will heavily extinguish the optical emission from objects with $z>10$. In the near infrared however, Lyα emission would still be clearly detected. A near-infrared detection of an optically dark GRB is the signature of either a very high redshift or highly dust enshrouded event.

Spectroscopy also has the potential to probe the evolution of the circumstellar and interstellar environment of the burst. Currently, due to lack of spectra obtained in the crucial early phases of the bursts, this is largely unexplored territory.

3.3 Prompt flashes

Currently there are only 3 GRBs (GRB990123, GRB021004 and GRB021211) with optical afterglows detected within the first ten minutes after the GRB initial event, of which GRB021004 has only a poorly sampled light curve. The prompt flashes following GRB990123 and GRB021211 have been extensively analyzed [1], [7] and show similar rapid decay rates (3-5 magnitudes in 10 min) despite GRB990123 being about four magnitudes brighter at peak ($R_{peak} \sim 9$) than GRB021211 ($R_{peak} < 14$). Given this rapid decline, it is easy to imagine that the roughly 50% of the bursts currently considered optically 'dark', may be detected by a larger rapid reaction telescope such as the LT. Furthermore, in both the above cases, interpretation is hindered by there only being white-light unfiltered observations. On the basis of these though, evidence has been cited for rapid colour changes during the first minute [7], underlining the need on these time scales for multicolour filtered photometry. The limiting magnitude ($V=22$) and photometric accuracy of the LT will allow direct and detailed measurement of prompt optical and infrared flashes.

3.4 Burst physics

Existing afterglow observations are broadly consistent with fireball models, but more complex models involving beaming, jets and disks are not well constrained by existing data [3], [9], [10]. High quality light curves and spectra, which track the source evolution from initial burst stages through to late afterglow probing both the energetics of the progenitor and its interaction with its surrounding will help to determine several important parameters. These include the identity of the progenitors, the nature of triggering mechanism, the physics of the energy transport during burst and afterglow, the timescales involved and the interaction between the ejected material and the surrounding medium.

3.5 Supernova connection

The first evidence of a possible association of GRBs with supernovae was reported for the GRB 980425 and SN1998bw [4]. The recent discovery of temporal and spatial coincidence of GRB 030329 and SN2003dh together with the spectral evolution [6] gives significant support to the GRB-supernova connection and hence the model that long duration GRBs originate in the death (core collapse) of massive stars. Systematic observations of afterglows also at later stages, 10-30 days after the GRB, are therefore essential to reveal more about the GRB phenomena and their link to supernovae.

4 Conclusions

Rapid response time, moderate aperture, excellent site and range of instrumentation make the LT especially suitable for study of afterglows of short GRBs, afterglows of optically dark GRBs, prompt optical flashes, early afterglow spectrometry and statistical properties of GRBs and their afterglows. With approximately 25% of GRBs occuring at night over La Palma and 70^o maximal zenith distance observable by the LT, we expect to observe 1 in 6 GRBs immediately following the alert. We plan to monitor GRB afterglows also at later stages depending on their scientific significance and in collaboration with other facilities, including the Faulkes Telescopes (clones of LT sited in Australia and Hawaii).

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