INAF – TIME ALLOCATION COMMITTEE

Application for observing time **Category: A**

Period AOT39 (April 2019 – September 2019) **Submit using: www.tng.iac.es/submit.html**

1. Title

Prompt emission and early afterglows of gamma-ray bursts

2. Abstract

Robotic telescopes provide a unique tool to observe the prompt emission and early afterglows of gamma-ray bursts (GRBs) in the optical and near-infrared (NIR). The required rapid reaction time does not allow human-driven observations to be carried out effectively. REM has been implemented for this purpose coupling a rapid all-sky pointing together with an effective wavelength coverage from about 0.5 μm up to 2.2 μm. Our goal is therefore to study the very early emission for all GRBs promptly visible from La Silla and follow their evolution down to the telescope sensitivity limits. Early photometry can reveal short time-scale deviations from the expected power-law temporal behaviour, which are due to inhomogeneities in the density of the environment and/or delayed activity of the inner engine. It is also possible to observe the afterglow onset allowing a determination of the bulk Lorentz factor of the expanding fireball. Finally, the REM capability to simultaneously observe at optical and NIR wavelengths and its broad band coverage allow us to possibly detect very high redshift GRBs, whose signature would be an optical drop-out, and measure their photometric redshifts. Rapid robotic observations of GRB emission are therefore a powerful tool to study the structure of the local environment, the mechanism of the GRB energy release and, possibly, the GRB redshift.

3a. Number of requested hours per telescope and instrument

TNG					REM	
DOLORES	DOLOR.+MOS	NICS	HARPS-N	GIANO-B	ROSS	REMIR
					100	100

3b. Observing modes

TNG:		Visitor		Service		ToO
REM:	X	Rapid Response		Queuing		ToO

4a. Preferred months

first choice: second choice:

4b. Other scheduling constraints (use also box 14)

5a. Past and future of the project

a) Hours already awarded to the project: 1800

b) Hours foreseen to complete the project:
(not including this request)

6. Principal investigator

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7. Co-investigators (name and institution)

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8. Status of the project

Telescope	Instrument	Date	Hours	Notes
REM	ROS	May18	100	AOT38
REM	REMIR	May18	100	AOT38
REM	ROS	Nov17	100	AOT37
REM	REMIR	Nov17	100	AOT37
REM	ROS	May17	100	AOT36
REM	REMIR	May17	100	AOT36
REM	ROS	Nov16	100	AOT35
REM	REMIR	Nov16	100	AOT35
REM	ROS	May16	100	AOT34
REM	REMIR	May16	100	AOT34
REM	ROS	Nov15	100	AOT33
REM	REMIR	Nov15	100	AOT33
REM	ROS	May15	100	AOT32
REM	REMIR	May15	100	AOT32
REM	ROS	Nov14	100	AOT31
REM	REMIR	Nov14	100	AOT31
REM	ROS	May14	100	AOT30
REM	REMIR	May14	100	AOT30

Description

Since June 2003, we have been seeking GRB afterglows with REM and monitoring in multiple bands their light curves. This allowed us to discover and study several optical and near-infrared GRB afterglows and also to derive stringent upper-limits on the detection of many others. Since 2006, we observed about 300 GRBs with REM, detecting 58 afterglows and 9 of them were discovered by REM. Unfortunately, many GRBs go off during daytime at La Silla thus the REM observations were performed hours after the event when the afterglow magnitude was already below the instrument detection limits.

Publications

Molinari et al., 2007, A&A, 469, L13
Covino et al. 2008, MNRAS, 388, 347
Guidorzi et al., 2009, A&A, 499, 439
Covino et al., 2010, A&A, 521, 53
Filgas et al., 2011, A&A, 526, 113
Littlejohns et al. 2013, MNRAS, 421, 2692
Martin-Carrillo et al. 2014, A&A, 567, 84
Melandri et al. 2017, A&A, 607, 29
Guidorzi et al. 2007, A&A, 474, 793
Racusin et al., 2008, Nature, 455, 183
Gendre et al., 2010, MNRAS, 405, 2372
Marshall et al., 2011, ApJ, 727, 132
Holland et al., 2012, ApJ, 745, 41
Jin et al. 2013, ApJ, 774, 114
D'Elia et al. 2015, A&A, 577, 116
Bolmer et al. 2018, in prep.

In addition, since 2004, $\sim$ **120 GCN circulars** have been published by our team reporting on GRBs observed by REM: the complete list of these GCN circulars can be found in: http://www.rem.inaf.it/GRB.php

A comprehensive catalog of all GRBs observed by REM will also be produced.

9a. If this proposal is a part of a PhD thesis, write here the name of the student, the thesis title and briefly describe the relevance of these observations for the thesis goals.

9b. Is this, or a similar application submitted to other time allocation committees (e.g. ESO, TNG-CAT, ITP)? If yes, please specify which and explain if and why the proposals should be considered complementary.

10. Description of the programme (max. 3 pages, including references, tables, and figures.)

A) Scientific rationale Since its launch (November 2004), the USA/Italy/UK mission *Swift* (Gehrels et al. 2004, ApJ, 611, 1005) revolutionised the understanding of GRBs and their afterglows. This satellite has detected more than 1100 GRBs (~ 2/week), providing, for 90% of them, their X-ray arcsecond positions within ~ 3 min after the GRB explosion. In the last years, thanks to the optical and NIR follow-up of the *Swift* GRBs, several important results have been achieved. Among them, we can list: the discovery of **powerful late-time flares** during the afterglows (Burrows et al. 2005, Science, 309, 1833); the discovery of the afterglows and host galaxies of **short GRBs** (SGRBs) (Barthelmy et al. 2005, Nature, 438, 994; Covino et al. 2005, A&A, 447, L5), i.e. those lasting less than 2 s (Kouveliotou et al. 1993, 413, L101); the detection of several long GRBs (LGRBs) at large redshift ($\langle z \rangle = 2.2$, up to $z = 9.4$). Most of LGRBs are possibly produced by a peculiar class of core-collapse supernovae (Galama et al. 1998, Nature, 395, 670; Malesani et al. 2004, ApJ, 609, L5), and are thus strictly connected with the cosmic star formation, although the quantitative link is still under investigation (e.g. Kistler et al. 2008, ApJ, 673, L119; Salvaterra et al. 2009, MNRAS, 396, 299; Salvaterra et al. 2012, ApJ, 749, 68). Whereas, the SGRBs are found to originate in the coalescence of a binary compact objects system (Goldstein et al. 2017, ApJ, 848, L14; Savchenko et al. 2017, ApJ, 848, L15). However, our knowledge on these GRBs is based on a small sample which needs to be enlarged (e.g. D'Avanzo et al. 2014, MNRAS, 442, 2342).

GRB physics. GRB afterglow emission is believed to originate (Piran 1999, Phys. Rep., 314, 575) inside a relativistic shell impacting on the surrounding medium ("external" shocks). In contrast, the prompt GRB emission is likely produced inside the flow itself ("internal" shocks). This model predicts well-defined afterglow light curves and spectra (power-law segments). However, optical and X-ray observations have revealed unexpected features like time-scale deviations from the expected power-law temporal behaviour (e.g., flares, plateaus), which may be due to inhomogeneities in the density of the environment and/or delayed activity of the inner engine. These features cannot be easily explained within the standard model and require to be studied further. In spite of its limited size, REM offers immediate simultaneous coverage in the optical-NIR. Collecting well-sampled optical-NIR light curves (see Figs. 1 and 2), and comparing them with the γ, X-ray, optical and UV data provided by other facilities, is an effective way to fully characterise the models and to disentangle different contributions (e.g. the SN contribution for nearby GRBs; D'Elia et al. 2015, A&A, 577,116).

High redshift or dust obscured GRBs. REM has detected so far many GRBs, but has not yet fulfilled its main task: the detection of the counterpart of a very high-z GRB as a result of its capability to cover the whole optical-NIR wavelength range. Part of the difficulty is related to the fact that high-z GRBs are fainter, although GRB 050904, one of the GRBs with the largest z so far measured (Tagliaferri et al. 2005, A&A, 443, 1; $z \sim 6.3$), would have been well within the reach of REM. Unfortunately this event was already below the observational altitude limit of the telescope when it exploded. A prompt NIR follow-up allows us to study also the afterglow when it is strongly affected by dust extinction. In this case the burst could even be not visible by optical facilities, and therefore NIR observations are of unique importance. Several authors (e.g., Melandri et al. 2008, ApJ, 686, 1209; Greiner et al. 2011, A&A, 526, A30; Melandri et al. 2012, MNRAS, 421, 1265) showed that up to 40% of all burst may be part of a population with strong dust extinction along the line of sight.

Short GRBs. The first SGRB afterglows and host galaxies were discovered during 2005, indicating smaller redshifts ($z \sim 0.5$), lower energies ($E \sim 10^{49}$ erg), and different host galaxies (both early and late type) compared to LGRBs. However, surprisingly, other events (e.g. GRB 090426; Antonelli et al., 2009, A&A, 507, 45) displayed markedly different properties again, being farther away and much more energetic than previously observed SGRBs. Although such objects are fainter than LGRBs at optical and NIR wavelengths, there are already cases that would have been observable with REM.

B) Scientific aim Currently there are four high energy satellite missions (*Swift*, INTEGRAL, AGILE and *Fermi*) which can rapidly deliver (a few seconds after the trigger) GRB positions with arcmin down to arcsec error. The rapid decay of the afterglow makes it difficult for REM to observe events later than a few hours after the high-energy detection, although some events do keep bright at later times (e.g. the naked-eye GRB 080319B). Our main goal, therefore, is to observe the GRB fields as soon as possible after detection to locate the optical and/or NIR counterpart and then to follow their light curves down to the detection limits. The optical camera ROS2, with the capability to observe simultaneously in the four Sloan/SDSS filters g',r',i',z', will allow us to to detect more GRBs, given its improved sensitivity. In addition, we will obtain simultaneous optical SEDs, without the need of interpolations/extrapolations which are dangerous especially in the early part of the GRB light curves. Finally, we will be able to sample the GRB light curves and SEDs with a higher time resolution, since there will be no time losses in cycling through the optical filters. Prompt observations are also useful to the GRB community so as to optimise their strategies with larger telescopes. Past experience shows that about 1 event per month is promptly visible from La Silla, although a much lower percentage of them shows a bright enough afterglow to be effectively monitored by REM (as for GRB 060418 and GRB 090102; see Fig. 1). However, prompt optical-NIR limits still constitute a valuable result of robotic observations (Fig. 2, left panel). We plan to observe all GRBs visible from La Silla through simultaneous optical and NIR photometry (multi-time, repeated imaging in different filters) with different strategies depending on the delay from the actual GRB discovery to detect breaks, flares, and any irregularities in the early light curve and broad-band spectra with great precision. In some cases photometric redshift and information about local dust absorption will also be derived from simultaneous REM and XRT broad band energy spectra.

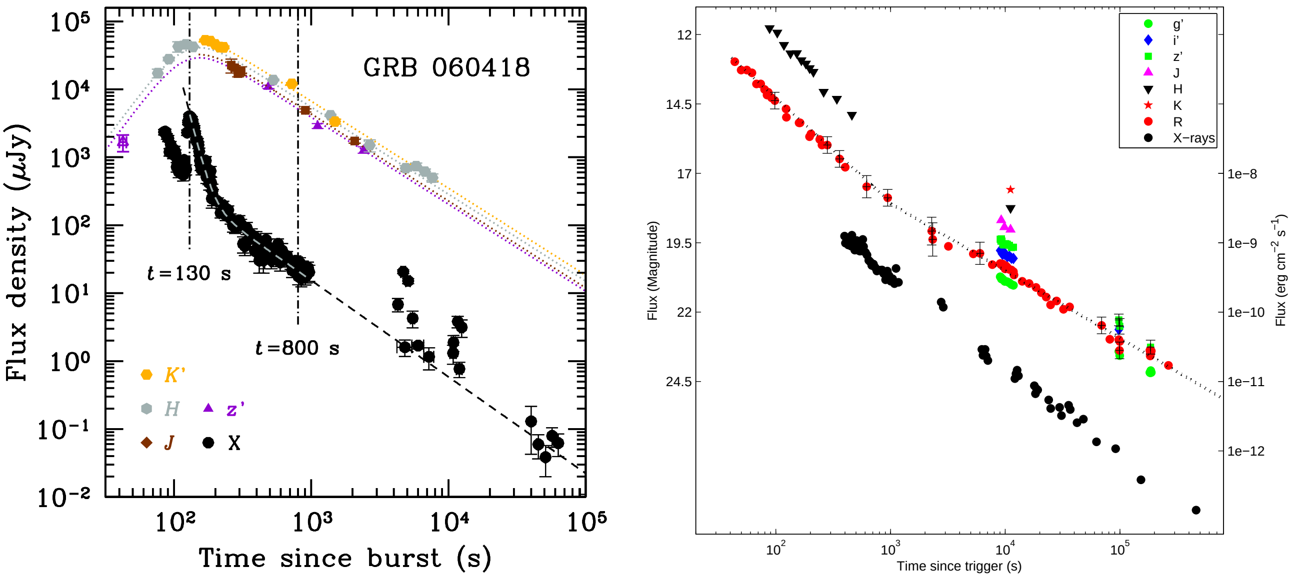

Figure 1: *Left*: near-infrared and Swift-XRT prompt light-curves for GRB 060418. The time of the maximum in the NIR emission allowed the first direct and firm determination of the fireball Lorentz factor of $\Gamma_0 \sim 400$, confirming the highly relativistic nature of GRB fireballs (Molinari et al., 2007, A&A, 469, L13). *Right*: light curve of the afterglow of GRB 090102 in many different bands. All the H data and 1/3 of the R data, up to 2400 s, come from REM. The X-ray light curve is extracted in the 0.5 to 10.0 keV band. The dotted line is the best fit decay law. The left axis applies to optical/infrared data, the right axis to X-ray data. The well sampled broad band afterglow light curve at early time allowed testing different emission models (fireball, cannonball, two component model), which all require a fine tuning of the parameters to reproduce the observed data (Gendre at al., 2010, MNRAS, 405, 2372).

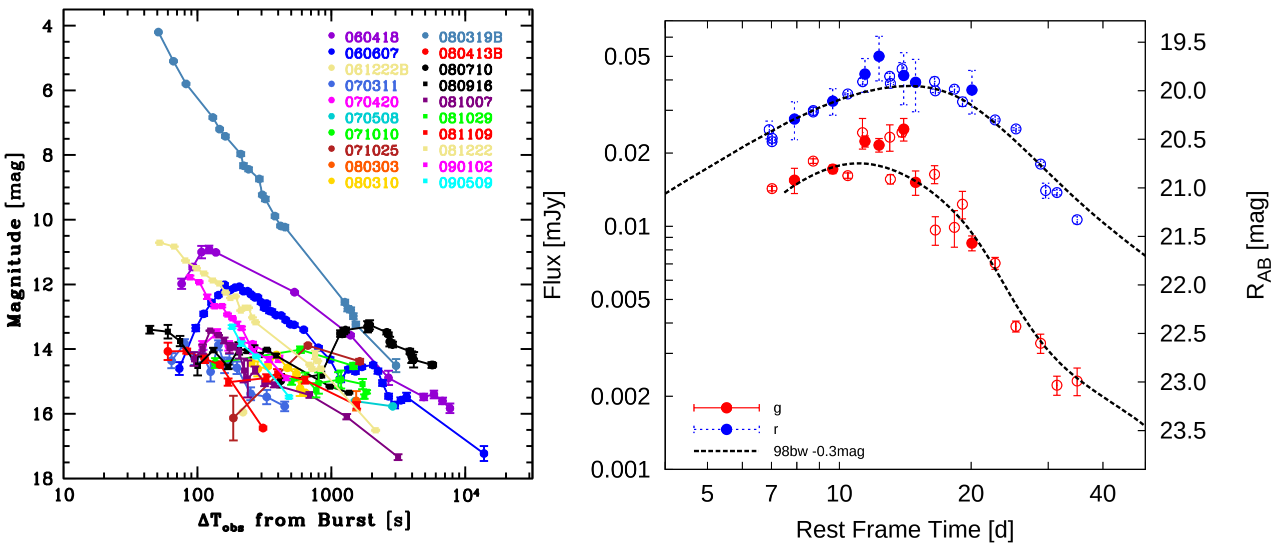

Figure 2: *Left*: Representative sample of the GRB H band light curves promptly observed by REM between 2006 and 2009 (20 events). The three typical patterns of GRB early afterglow (i.e. power law decay, afterglow onset and plateau) identified in the optical band (e.g. Panaitescu & Vestrand, 2008, MNRAS, 387, 497 and 2011, MNRAS, 414, 3537) can be easily recognised also in the NIR bands. *Right*: g and r light curves of SN 2013dx associated with the nearby ($z = 0.145$) GRB 130702A. We monitored the SN light curve for several epochs with REM (filled points), joining a monitoring campaign together with TNG and VLT telescopes (D'Elia et al. 2015, A&A, 577, 116). For exceptional cases like GRB 130702A/SN 2013dx REM observations can effectively help to disentangle different contributions of the GRB emission (early time prompt/afterglow emission and/or late time supernova/host galaxy contribution).

11. List of targets (note that the absence of a proper object list and information may weaken the proposal)

Name	α	δ	Epoch	Mag.	Time	Additional Information
GRB	00 00 00	00 00 00	J2000		ToO	

12. Observational strategy and justification of requested time, including overheads.

We ask for repeated observations with increasing exposure times in all the REM available filters. The specific strategy depends on the delay between the burst itself and the start of the observations.

Less than 1 hour from the high energy trigger: Initially we will perform repeated observations with ROS2 (simultaneous g',r',i',z' filters) and the REMIR H filter, to better sample the light curve of the afterglow possibly detected. After about half an hour we begin to observe cycling all the available REMIR filters (always together with the optical ones), to obtain broad-band spectral information for a total of one hour of observations.

Between 1 and 3 hours: We begin cycling all the available REMIR filters and then again we will observe using the REMIR H filter only (always simultaneously with ROS2). If necessary, we complete the sequence with one more full cycle of the available REMIR filters. Again we plan one hour of observations, possibly repeated twice if the brightness of the event is adequate.

More than 3 hours: Only the REMIR H filter is used simultaneously with ROS2 in this last phase. Observations are carried out until the source is not detectable anymore.

As stated above, using ROS2+REMIR we will be able to sample the afterglow light curves and SEDs with a higher temporal resolution with respect the previous ROSS+REMIR observations, given the capability of ROS2 to simultaneously observed in 4 optical filters at once.

The resulting SEDs can possibly also give indication on high redshift ($z > 5$) candidates since in this case we should observe a very sharp break in the optical produced by the Lyman α forest.
Moreover the higher ROS2 sensitivity with respect to the ROSS camera will increase our chances to detect fainter afterglows ($r' \sim 20$) like the ones associated to SGRBs.

With an event promptly visible from La Silla every month and, possibly, one more per week visible with some delay, **we plan to use for this project (including late-time calibrations, etc.) at most 4 hours/week**.

13. Requested instrument(s) setup

Id	Instrument	Binning	Filter(s)	Slit	Grism	Time	Additional Information
1	ROS2	1x1	g', r', i', z'	none	none	100hr	
2	REMIR	1x1	z, J, H, K	none	none	100hr	

14a. Moonlight constraints

Max. # of days from new moon ☐

14b. Scheduling constraints, special requirements and other remarks

(please include justification of constraints in 14a)

15. Observational background of the applicants

Name of the observer(s) at TNG:

Experience of the observer(s) with the requested TNG instrument(s)

Experience of the observer(s) with other telescopes/instruments

Most of us are also deeply involved in GRB follow-up activities, within the STARGATE consortium, with the ESO-VLT.