RECENT RESULTS OF THE FIGARO COLLABORATION

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Abstract. The FIGARO collaboration aims are to study the early phase of the gamma ray burst afterglows and the prompt-to-afterglow transition phase, using multi-wavelength observations (mostly from Swift and TAROT). Here, we review the recent results of the collaboration, including the discovery of a rising part of the optical light curve and its theoretical interpretation.

Keywords: gamma-ray: bursts

1 Introduction

Gamma-Ray Bursts (GRBs, see e.g. Piran 2005, for a review) were discovered in the late 1960's (Klebesadel et al. 1973). For about three decades, their exact nature remained elusive. The effort to provide a fast re-pointing of the BeppoSAX satellite allowed for the first detection of their afterglows at all wavelengths (e.g. Costa et al. 1997; van Paradijs et al. 1997). Since then, the specification of each generation of instrumentation devoted to GRB studies included the need to point to the GRB afterglows quickly. Now, with Swift, we have reached the point where we can collect data from X-rays to optical within seconds after the start of the event, thanks to fast moving telescopes triggered by GCN notices (Barthelmy 1998). This run toward fast re-pointing has allowed for prompt optical emission observations by small autonomous telescopes for several GRBs (e.g. Klotz et al. 2009b), and produced a huge set of data available to study the prompt, the prompt-to-afterglow transition, and the early afterglow phases. Here we present the FIGARO collaboration and the results this collaboration has obtained within the last years.

2 The FIGARO collaboration

The France-Italy GAmma Ray burst afterglow Observation collaboration (FIGARO) has been set in 2005 in order to increase the scientific return of the huge set of data made available by this observational strategy. It consists of several experts in data reduction and analysis, experts in the field of GRB theories, and experts in data modelization. The data are provided by the instruments available to the collaboration (the two TAROT robotic telescopes, the public data of Fermi and Swift) and by several observation on competitive facilities (such as XMM-Newton). The collaboration works either on a burst-by-burst basis (when data are important enough to deserve a specific publication) or on a sample basis for statistical studies of the GRB properties. The burst selection main criterion is an observation by one of the TAROT telescopes during the Swift era. As such, we used bursts listed in Klotz et al. (2009b), and reported in Fig. 1. In brief, we have a sample of 13 burst detections, and of 59 observations of GRB field (with a good constraint on the position). About one third of the sample was observed/detected during the prompt phase.

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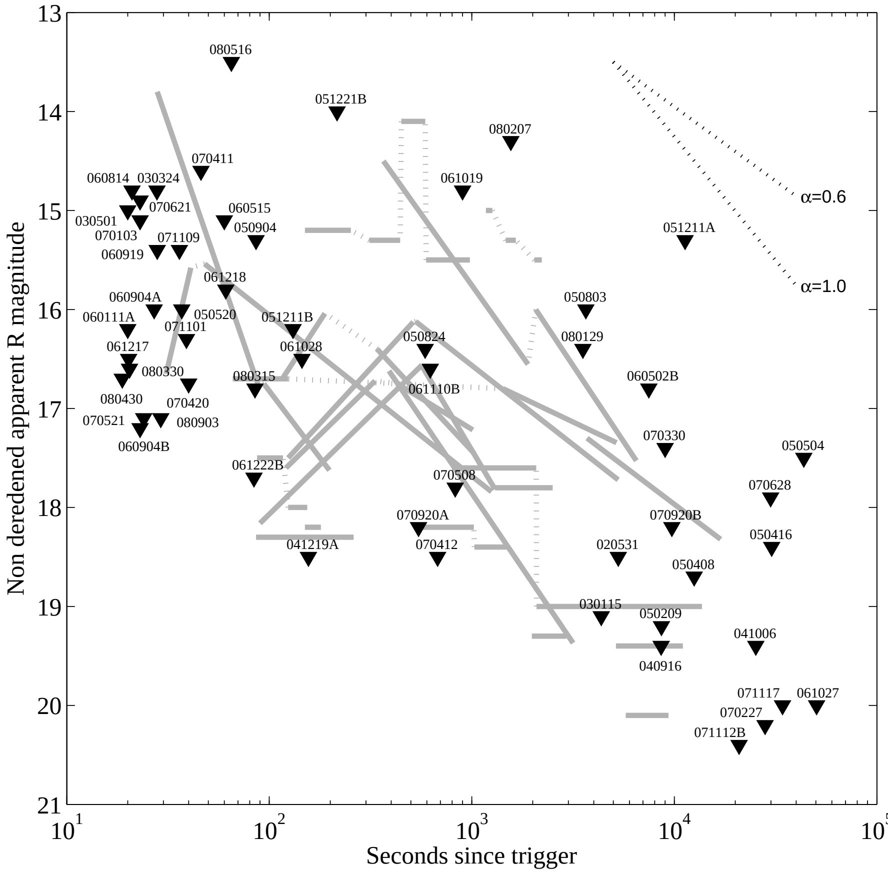

Fig. 1. Light curves of bursts used by the FIGARO collaboration. Triangle are upper limits. Figure extracted from Klotz et al. (2009b).

3 Rising afterglows

An optical rising has been observed for several GRBs (GRB 060904B, GRB 070420, GRB 080330, 080430, see Fig. 1). A similar rise was observed in the near infrared light curves of GRB 060418 and GRB 060607A (Molinari et al. 2007), together with a simultaneous X-ray emission characterized by the presence of various flares. As already noticed, in the Swift era, GRB optical light curves are complex and rarely track the X-ray flux behavior, suggesting a possible different origin. We thus aim at testing whether the global properties of the TAROT GRB sample do favor the hypothesis that we observe a reverse shock signature in optical, without considering the X-ray properties.

We first worked under the hypothesis that, for each GRB in the sample, the optical emission was due to the internal shock model. As this emission is not correlated with the high energy one, this can be ruled out (Klotz et al. 2008). An external shock has been proposed by (Molinari et al. 2007) for those bursts observed by REM (GRB 060418 and GRB 060607A). However, in the TAROT cases the increase and decay indexes are not consistent with the expected values (Klotz et al. 2008).

We then worked under the hypothesis that, for each GRB in the sample, the emissions observed before and after the first temporal break by TAROT both originate from the same physical region (i.e. forward or reverse shocks) (see Corsi et al. 2010, for more details). In this hypothesis, the observed breaks could be due to the RS crossing, i.e. to the onset of the afterglow deceleration phase, or else to the passage of the synchrotron peak frequency into the observed band.

In Corsi et al. (2010), we derived and/or recalled the temporal laws of the reverse shock in various cases: relativistic vs non-relativistic ejecta, thin vs thick shock, constant density profile vs variable density profile (to account for a possible stellar wind from the progenitor), and slow vs fast cooling mode. We then tested these laws on the observed light curves.

Our preliminary results seem to indicate that the best agreement between data and model predictions (allowing for a 3σ scatter of the data) is obtained for the case in which the emission is dominated by a slow cooling forward shock, the optical band is above the synchrotron peak frequency ν_m, and the temporal break is associated with the reverse shock crossing. Else, comparable level of agreement is found for the case in which the emission comes from a slow cooling FS after the RS crossing, with the temporal break being associated to the passage of ν_m in the optical band. The TAROT data alone do not allow us to distinguish between the relativistic and Newtonian hypotheses (Corsi et al. 2010).

As for GRB 060904B, TAROT found the presence of a plateau following the first break. This break in the optical light curve may be explained as forward shock emission in the slow cooling phase from a reverse shock, with the break possibly due to the reverse shock crossing or to the passage of ν_m in the optical band. Under this hypothesis, the observed plateau could be associated with an episode of energy injection into the forward shock, as discussed in more detail in Klotz et al. (2008).

Last, despite all the hypotheses tested, GRB 090102 data cannot be explained with the reverse shock model, and in this case an alternative model needs to be tested.

4 The peculiar GRB 090102

GRB 090102 triggered *Swift*-BAT (trigger 338895, Mangano et al. 2009a) on Jan. 2009, 2^{nd} at 02:55:45 UT (hereafter, T_0). It was also recorded by Konus Wind (Golenetskii et al. 2009), and by INTEGRAL/SPI-ACS (Mangano et al. 2009b). The duration of this event, as observed by *Swift* was $T_{90} = 27.0 \pm 2.2$ s. Due to an observational constraint (Earth limb too close), *Swift* slewed to the position of the afterglow with a delay, and XRT and UVOT observations began only at $T_0 + 395$ s, observing a bright fading source in both the XRT and the UVOT fields of view (Mangano et al. 2009a). The earliest ground search of the optical afterglow was performed by TAROT, starting at T_0+40.8 s (Klotz et al. 2009a).

The X-ray light curve can be adequately fit using a single power law with a decay index $\alpha_X = 1.34 \pm 0.02$. On the other hand, the fit of the optical light curve implies the use of a broken power law model, with a break time on the order of 1000 s. Using other data from GROND, REM and other facilities, it was possible to show that the multi-wavelength observations of this burst cannot be explained by the standard model, and that an alternative model (such as the cannonbal model) should be preferred (Gendre et al. 2010).

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References

Barthelmy, S., 1998, in AIP Conf. Proc. 428, Gamma–Ray bursts, ed. C. Meegan & R. Preece (Berlin: Springer), 99

Corsi, A., et al., 2010, in preparation

Costa, E., Frontera, F., Heise, J., et al., 1997, Nature, 387, 783

Gendre, B., Klotz, A., Palazzi, E., Krühler, T., Covino, S., et al., 2010, MNRAS, 405, 2372

Golenetskii, S., Aptekar, R., Mazets, E., et al., 2009, GCN # 8776

Klebesadel, R., Strong, I., & Olson, R., 1973, ApJ 182, L85

Klotz, A., Gendre, B., Stratta, G., et al., 2008, A&A, 483, 847

Klotz, A., Gendre, B., Boër, M., & Atteia, J.L., 2009a, GCN # 8761

Klotz, A., Boër, M., Atteia, J.L., & Gendre, B., 2009b, AJ 137, 4100

Mangano, V., Barthelmy, S.D., Burrows, D.N., et al., 2009a, GCN # 8762

Mangano, V., Markwardt, C.B., Barthelmy, S.D., et al., 2009b, GCN Report 192.1

Molinari, E., Vergani, S.D., Malesani, D., et al., 2007, A&A, 469, L13

Piran, T, 2005, RvMP, 76, 1143

van Paradijs, J., et al., 1997, Nature, 386, 686