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Constraints on the optical afterglow emission of the short/hard burst GRB 010119*

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Abstract. We report optical observations of the short/hard burst GRB 010119 error box, one of the smallest error boxes reported to date for short/hard GRBs. Limits of R > 22.3 and I > 21.2 are imposed by observations carried out 20.31 and 20.58 hours after the gamma-ray event, respectively. They represent the most constraining limits imposed to date on the optical emission from a short/hard gamma-ray burst afterglow.

Key words. gamma rays: bursts

1. Introduction

Before the Beppo-SAX era it was noticed that the high-energy properties of gamma-ray bursts (GRBs) could be distributed following a bi-modal duration distribution (Hurley 1992; Kouveliotou et al. 1993), constituted by short-duration ($T < 2$s) and long-duration bursts ($T > 2$s). It was also noted that the short-duration bursts tend to have harder spectra than the long ones (Kouveliotou et al. 1993; Dezalay et al. 1996). Hence, in the present paper the short and long GRBs will be hereafter named as “short/hard” and “long/soft” bursts, respectively. Several years later, an analysis of the Third BATSE Catalog indicated that, in addition to these two classes of bursts, there may exist a third, intermediate soft-spectrum class of GRBs with durations 2s $< T <$ 5s (Mukherjee et al. 1998).

Although the existence of this third intermediate duration class of GRBs is still under debate, in this paper we have considered them as a separate class. Thus, we consider a tri-modal distribution of GRBs; short/hard ($T < 2$s), intermediate (2s $< T <$ 5s) and long/soft ($T >$ 5s) bursts.

In the simplest scenario, the short/hard bursts may be explained by the merging of the two compact components of a binary system (Lattimer & Schramm 1974, Eichler et al. 1989), although other more exotic theories like the evaporation of primordial black-holes could also explain the observed properties of short/hard bursts (Hawking 1974). According to the merging model, GRBs would occur in very-low density environments, with very faint or even no afterglows at all. The observed properties of long/soft bursts can be better accommodated in the context of the collapsar model (MacFadyen & Woosley 1999).

Castro-Tirado et al. (2001) have recently reported the possible detection of the prompt optical flash 4 min after the short/hard burst GRB 000313, suggesting that short/hard GRBs only show optical emission shortly after the gamma-ray event, with no afterglows at all. This fact would favour the models that relate short/hard GRBs to binary mergers in low-density environments.

All the GRBs for which optical, X-ray, and radio afterglows have been discovered to date belong to the long/soft GRB class, with the exception of a couple of potential intermediate duration GRBs (GRB 000301C, Jensen et al. 2001; GRB 991014, in't Zand et al. 2000). GRB 991106 was preliminarily classified as a possible short/hard GRB (Gandolfi et al., 1999a), a more detailed analysis noted that it belongs to the long/soft or intermediate class (Gandolfi et al., 1999b). Hereafter the optical upper limits reported for GRB 991106 (Castro-Tirado et al.

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* Based on observations made with the Nordic Optical Telescope, operated on the island of La Palma jointly by Denmark, Finland, Iceland, Norway, and Sweden, in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias.

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1999a, Williams et al. 1999, Jensen et al. 1999, Gorosabel et al. 1999b) will not be considered as constraints on short/hard GRB afterglows. Thus, no afterglows have been detected to date for short/hard GRBs, so their origin as well as their distance scale remain unknown. The detection of a short/hard GRB optical afterglow similar to the ones seen for long/soft bursts would be against the low-density environment hypothesis.

Upper limits for the prompt optical emission (response times $<$ 5 min, R$<$ 15), as well as for the afterglow emission (response times $>$ 5 min, R$<$ 16) have been reported by Kehoe et al. (2001). Hurley et al. (2001a) has recently reported improved positions of four short/hard GRBs determined by the Interplanetary Network (IPN) as well as several constraining upper limits on their afterglow optical and radio emission.

Fynbo et al. (2001) have recently argued that $\sim 75\%$ of the upper limits reported to date for long/soft GRBs are compatible with faint afterglows as the one of GRB 000630, which are unreachable with most of the current long response times and shallow detection limits. However, Reichart & Yost (2001) suggest that the majority of rapidly, well-localized GRBs with undetected optical afterglows are most likely the result of extinction by dust in the circumburst medium. This idea is supported by Lazzati, Covino & Ghisellini (2000) who claim that the low detection rate can not be explained by adverse observing conditions or delay in performing the observations. Thus, the existence of intrinsically dark bursts would imply that the UV flash and the X-ray afterglow do not destroy the dust responsible of the optical extinction (Reichart 2001). Panaitescu, Kumar & Narayan (2001) predict for short/hard GRBs faint optical afterglows, exhibiting typically R$\gtrsim$ 23 a few hours after the gamma-ray event.

Upper limits imposed on short/hard burst afterglows could be very helpful to clarify the main open questions on short/hard GRBs; do they exhibit optical afterglows? and if so, is the fraction of short/hard GRBs with optical afterglows similar to the one of long/soft GRBs?

In the present paper we intend to discuss the above mentioned open questions reporting constraining R and I-band upper limits on the afterglow optical emission from GRB 010119. In Sec. 2 the high-energy properties as well as the localisation of GRB 010119 are reported. Sec. 3 describes the optical observations obtained at the Nordic Optical Telescope (NOT). In Sec. 4 our upper limits are compared to other constraints given in the literature for long/soft, intermediate, and especially short/hard GRB afterglows. Finally, Sec. 5 summarizes the conclusions of our study.

2. Localisation of the GRB

GRB 010119 was detected by the IPN composed by Ulysses, NEAR, WIND and Beppo-SAX spacecraft on January 19.430306 UT 2001 (Hurley et al. 2001a). As observed by Ulysses, it had a duration of approximately 0.2 seconds (Hurley et al. 2001b).

Integrating the analytic expression of the spectral fit of GRB 010119 given by Hurley et al. (2001a) the hardness-ratio between the BATSE channels 2 and 3 (H_{32}; the 100-300 keV fluence divided by the 50-100 keV fluence) $H_{32} = 4.14$ is obtained.

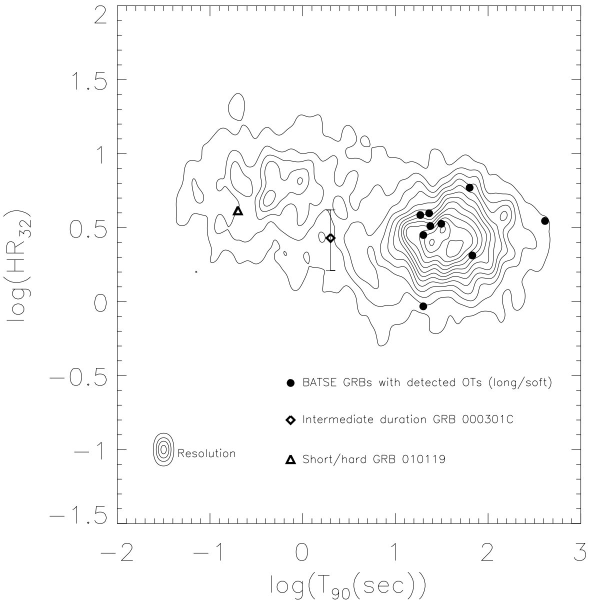

Fig. 1. A contour plot showing the duration-hardness ($log(T_{90})$-$log(H_{32})$) distribution of BATSE bursts. The filled circles represent the 9 BATSE bursts with identified counterparts for which data on fluence and duration are available. All of them belong to the long/soft class of GRBs. The open diamond located in the centre of the figure represents the intermediate duration burst GRB 000301C (Jensen et al. 2001). The open triangle to the left of the plot represents GRB 010119. As can be seen, GRB 010119 belongs to the short/hard class of GRBs. Errors in the BATSE data are smaller than the symbol size. Contour levels scale linearly. The centroid in the lower left corner indicates the resolution.

In Fig. 1 the duration distribution of 2115 BATSE GRBs, from the revised Fourth BATSE GRB Catalogue (Paciesas et al. 1999 and the Current BATSE GRB Catalogue at `http://www.batse.msfc.nasa.gov/-batse/grb/catalog/current`) is displayed. The bimodal distribution composed by long/soft and short/hard classes of bursts can easily be seen.

Additionally, we have overplotted 9 long/soft BATSE bursts with identified afterglows for which data on fluence and duration are available (filled circles). The error in the data points is smaller than the size of the circles. The diamond represents the short-intermediate GRB 000301C (Jensen et al. 2001) and the triangle shows GRB 010119. As can be seen, GRB 010119 belongs to the short/hard class of gamma-ray bursts.

The coordinates of the centre of the improved GRB 010119 IPN error box are $\alpha_{2000} = 18^h53^m46.17^s$, $\delta_{2000} = 11^\circ59'47''.04$ (Hurley et al. 2001a). The size of the error box is 3.3 arcmin^2, significantly smaller than the preliminary 11.0 arcmin^2 box first reported by Hurley et al. (2001b). In fact, the error box of GRB 010119 is one of the smallest IPN error boxes reported so far for short/hard GRBs. This fact, as well

Table 1. Journal of the GRB 010119 optical observations

Telescope	Date (UT)	Seeing arcsec	Airmass	Effective Airmass	filter	Exp. time (sec)	Lim. Mag.†† (3σ)
NOT	20.2703–20.2829/01/2001	$1.1 \times 1.8^{\star}$	$5.34 - 3.84$	4.45	R	3×300	22.3
NOT	20.2840–20.2920/01/2001	$1.2 \times 1.5^{\star}$	$3.84 - 3.25$	3.57	I	2×300	21.2
NOT	21.2689–21.2831/01/2001	$3.0^{\dagger}$	$5.15 - 3.59$	4.27	R	3×300	20.9
NOT	21.2848–21.2977/01/2001	$1.7^{\dagger}$	$3.59 - 3.05$	3.36	I	3×300	20.2
NOT	29.2035–29.2257/05/2001	0.75	$1.10 - 1.13$	1.11	R	2×900	24.5
NOT	14.0390–14.0261/08/2001	1.0	$1.19 - 1.23$	1.21	I	3×300	23.0

$\star$ Elongated profiles due to the chromatic refraction of the atmosphere.

† Through clouds.

†† Not corrected for Galactic extinction.