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Light extinction in GRB host galaxies

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Abstract. Measurements and analysis of spectral energy distribution (SED) of afterglows provide a mean to determine some properties of the GRB local environment, i.e. light extinction and equivalent hydrogen column density of the surrounding material in the line of sight. Until now, several statistical analyses on a significantly large SED sample have been carried out. Here we present the results of the analysis of a sample of 11 GRB afterglows, observed by robotic telescopes: Liverpool Telescope (LT), Faulkes Telescope North (FTN) and Faulkes Telescope South (FTS). Our results confirm some of the properties presented in previous studies, i.e. low host galaxy extinction and high average gas-to-dust ratio.

Key words. gamma-rays: bursts - dust extinction - galaxies: ISM

1. Introduction

The light of GRB afterglows, emitted from X-ray to infrared part of the spectrum, carries information on the material lying in the line of sight between the origin of the burst and the Earth. Observed SED deviates from expected power-law/broken power-law decay due to light absorption and scattering. The strength of those effects depends on chemical composition and amount of intervening gas and dust, size distribution of dust grains, etc. By analysing afterglow SED we can get information on GRB host galaxy intrinsic properties (e.g., Kann et al., 2010; Schady et al., 2010; Zafar et al., 2011). We analysed a sample of 11 GRB afterglows in order to obtain host galaxy equivalent hydrogen column density N_{H} and extinction A_{V}. The results are compared to similar studies made on larger GRB samples.

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2. Data and Analysis

The GRBs in our sample have to meet a few selection criteria, the first one being the detection and observation by at least one of the three telescopes: LT, FTN or FTS. In order to obtain good fitting parameter values, observations in at least three UV/optical/IR filters are required. Where possible, data from previously published papers and GCN Circulars (Barthelmy et al., 1995) have been added. In order to perform a broadband fit at a certain epoch, X-ray data at that epoch should also be available. Since the data from different filters were usually obtained at different times, the epoch of observation was chosen to be the one closest to observations at all wavelengths, which were then interpolated to the epoch of interest. X-ray data were taken from Swift online repository of X-ray afterglow spectra (Evans et al., 2009) and binned to

Table 1. Table of analysed GRBs with their redshift, Galactic hydrogen column density and reddening in the line-of-sight, epoch of observation and photometric obseravations used in the analysis.

GRB	z	$N_{\mathrm{H,G}}{}^{a}$ $\left(10^{21}\ \mathrm{cm}^{-2}\right)$	$E_{\mathrm{B-V,G}}{}^{b}$	$T - T_0$ (s)	UV/optical/IR data^{c}
050408	$1.236^{(1)}$	0.18	0.026	52000	$^{(1)}$ K_s, H, J, $^{(2)}$B, U, $^{(*)}$R
051111	$1.55^{(2)}$	0.58	0.158	4800	$^{(3)}$ K_s, H, J, $^{(*4)}$i', $^{+}$R, V, B
060210	$3.91^{(3)}$	0.85	0.094	2000	$^{(5)}$ K_s, $^{(*6)}$I, $^{+}$R
060418	$1.489^{(4)}$	0.88	0.225	5000	$^{(7)}$ K_s, H, J, $^{(*)}$z', i', $^{+}$r', g'
060512	$0.4428^{(5)}$	0.15	0.016	10000	$^{(8)}$ K_s, $^{(*)}$ i', $^{+}$r', $^{(9)}$ v
061007	$1.261^{(6)}$	0.18	0.019	300	$^{(*10)}$i', $^{+}$R, V, B
061121	$1.316^{(7)}$	0.51	0.045	10000	$^{(*11)}$ $^{+}$R, $^{(12)}$i', $^{(13)}$w1, m2, w2
061126	$1.1588^{(8)}$	0.10	0.194	1700	$^{(14)}$ K_s, H, J, $^{(*15)}$i', $^{+}$R, V, B
080330	$1.51^{(9)}$	0.12	0.017	1000	$^{(*16)}$ K_s, H, J, z', i', r', V, g', B, U, uvw1
080810	$3.355^{(10)}$	0.33	0.029	5000	$^{(17)}$ v, b, $^{(*)}$ R, i'
090618	$0.54^{(11)}$	0.58	0.088	10000	$^{(*18)}$ i', R, V, B

Redshift references: (1) Prochaska et al. (2005), (2) Hill et al. (2005), (3) Cucchiara et al. (2006), (4) Vreeswijk & Jaunsen (2006), (5) Bloom et al. (2006a), (6) Osip et al. (2006), (7) Bloom et al. (2006b), (8) Perley et al. (2008), (9) Malesani et al. (2008), (10) Page et al. (2009), (11) Cenko et al. (2009)

References: (1) Foley et al. (2006), (2) Postigo et al. (2007), (3) Bloom (2005), (4) Guidorzi et al. (2007), (5) Hearty et al. (2006a), (6) Curran et al. (2007), (7) Molinari et al. (2007), (8) Hearty et al. (2006b), (9) Pasquale & Cummings (2006), (10) Mundell et al. (2007), (11) Page et al. (2007), (12) Cobb (2006), (13) Marshall et al. (2006), (14) Perley et al. (2008), (15) Gomboc et al. (2008), (16) Guidorzi et al. (2009), (17) Page et al. (2009), (18) Cano et al. (2011)

[a] Data from Schlegel et al. 1998.

[b] Data from Kalberla et al. 2005.

[c] Data marked with (*) were obtained with at least one of the three telescopes (LT, FTN, FTS). Data marked with + were also published in Melandri et al. (2008).

a minimum of 20 counts per channel. Finally, spectroscopically measured redshift of a given burst is required. In order to prevent possible contamination by Lyman alpha forest, we exclude bursts with large redshift values (or, in the case of a good long-wavelength coverage, only magnitudes that could be affected by Lyman alpha forest are excluded). UV-to-NIR data were corrected for Galactic extinction using maps by Schlegel et al. (1998). Galactic contribution to X-ray absorption was taken into account using data from Kalberla et al. (2005). Our sample contains 11 GRBs detected between April 2005 and July 2009. List of GRBs in our sample is given in Table 1, together with the epoch of observation, redshift, Galactic column density and reddening in the line-of-sight for each burst. Broadband fit was performed with spectral fitting package XSPECv12.6. SED is expected to be described by a power-law of spectral index β_{o} or a broken power-law with β_{o} and $\beta_{\mathrm{x}} = \beta_{\mathrm{o}} + 0.5$ (Sari, Piran & Narayan, 1998), where the frequency of the break ν_{br} lies somewhere between X-ray and NIR frequencies.We describe the effects of dust on each afterglow by one of the three observed average extinction laws measured for Milky Way (MW), Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC), with parametrisation given in Pei (1992). X-ray spectra were modelled using photoelectric absorption, adopting cross-section of Morrison & McCammon (1983).

3. Results

The best-fit results are given in Table 2. The values are in agreement within errors with other analyses already done (references in Table 1). In the cases where a broken power-law turned out to be the best fit we used F-test to determine whether the use of the broken power-law is sensible. We find that SMC extinction profile fits SED best in most cases,

Table 2. The results of the best broadband fit for each burst: optical spectral index, energy of the cooling break (if there is one), equivalent hydrogen column density and extinction in the host galaxy in the line-of-sight and the best fitted extinction profile.

GRB	β_o	E_{br}[a] (keV)	N_H $\left(10^{21}\ \mathrm{cm}^{-2}\right)$	A_V	Extinction curve
050408	$0.40^{+0.02}_{-0.04}$	1.18	$6.25^{+1.28}_{-1.45}$	$0.71^{+0.09}_{-0.08}$	SMC
051111	$0.93^{+0.17}_{-0.08}$	0.03	$7.61^{+3.58}_{-2.74}$	$0.13^{+0.08}_{-0.10}$	SMC
060210	$0.65^{+0.03}_{-0.04}$	1.11	$6.98^{+2.56}_{-2.73}$	$0.63^{+0.07}_{-0.08}$	SMC
060418	$0.57^{+0.05}_{-0.01}$	0.01	$6.41^{+4.12}_{-2.65}$	$0.15^{+0.03}_{-0.05}$	MW
060512	$0.94^{+0.03}_{-0.03}$	-	< 0.5	< 0.12	SMC
061007	$0.86^{+0.04}_{-0.04}$	-	$5.37^{+0.52}_{-0.49}$	$0.38^{+0.15}_{-0.14}$	SMC
061121	$0.40^{+0.03}_{-0.03}$	1.02	$5.83^{+2.20}_{-2.19}$	$0.58^{+0.08}_{-0.10}$	LMC
061126	$0.36^{+0.05}_{-0.03}$	0.46	$6.71^{+1.85}_{-2.21}$	$0.28^{+0.12}_{-0.08}$	SMC
080330	$0.80^{+0.02}_{-0.02}$	-	< 1.80	< 0.03	SMC
080810[b]	$1.00^{+0.03}_{-0.03}$	-	0	$0.18^{+0.02}_{-0.01}$	SMC
090618	$0.49^{+0.05}_{-0.05}$	0.22	$2.57^{+0.37}_{-0.34}$	$0.18^{+0.07}_{-0.08}$	SMC

[a] This value is blank in case of a single power-law.
[b] Best fit when there is negligible host absorption.

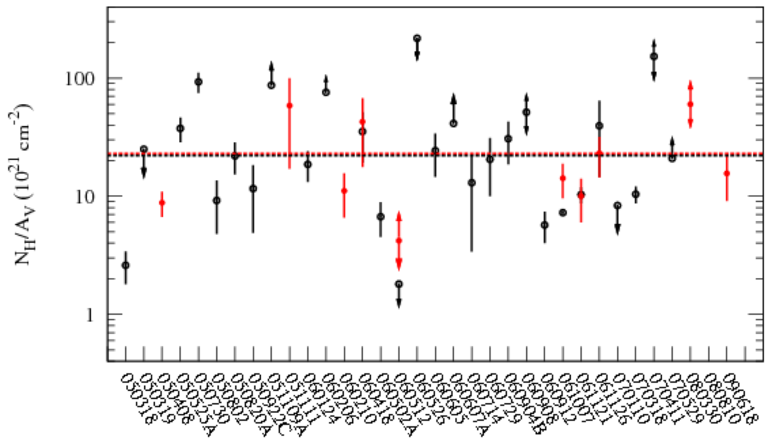

Fig. 1. Gas-to-dust ratios for a number of bursts. Red data were obtained in our analysis (we exluded GRB 080810, where no host absorption was found). Black data are best fit values from Schady et al. (2010). Arrows denote 3σ upper limits on N_H or A_V (or both) values. Black and red horizontal lines represent the average ratios, where only data without upper limits were taken into account.

which is in agreement with the results obtained in other studies (Schady et al., 2007, 2010; Zafar et al., 2011; Greiner et al., 2011). Extinction values (where found) are given with 90 percent confidence and are low, ranging from $0.15 \leq A_V \leq 0.71$. The SMC profile usually results in lesser extinction than MW, since the latter has a shallower slope (Pei, 1992). Thus it has been suggested (e.g., Zafar et al., 2011) that the observational bias against fainter bursts (larger A_V) is responsible for the dominance of SMC profile. Although gas-to-dust ratios for different galaxies differ substantially (Figure 1), their average value is of the order of ten larger than the ratios measured in SMC, LMC and MW. Large scattering around the average value could be due to different internal composition of hosts. The high average ratio implies a lack of dust, which could be explained by a dust destruction (Perna & Lazzati, 2002).

4. Conclusion

Our results on 11 GRBs observed by LT, FTN and FTS confirm some of the host galaxy properties seen in analyses done on larger GRB samples (e.g. Schady et al., 2010; Zafar et al., 2011; Greiner et al., 2011).

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