On the role of extinction in failed gamma-ray burst optical/IR afterglows

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ABSTRACT

While all but one Gamma-Ray Bursts observed in the X-ray band showed an X-ray afterglow, about 60 per cent of them have not been detected in the optical band. We demonstrate that in many cases this is not due to adverse observing conditions, or delay in performing the observations. We also show that the optically non-detected afterglows are not affected by particularly large Galactic absorbing columns, since its distribution is similar for both the detected and non-detected burst subclasses. We then investigate the hypothesis that the failure of detecting the optical afterglow is due to absorption at the source location. We find that this is a marginally viable interpretation, but only if the X-ray burst and afterglow emission and the possible optical/UV flash do not destroy the dust responsible for absorption in the optical band. If dust is efficiently destroyed, we are led to conclude that bursts with no detected optical afterglow are intrinsically different. Prompt infrared observations are the key to solve this issue.

Key words: gamma rays: bursts — ISM: dust, extinction — radiation mechanisms: nonthermal

1 INTRODUCTION

The standard external shock synchrotron model (Meszaros & Rees 1997; Sari et al. 1998) has been very successful in describing the properties of observed optical afterglows (Wijers et al. 1997; Galama et al. 1998d; Covino et al. 1999). However, for more than half of the afterglows observed in the optical band we did not detect any emission. We will call these Failed Optical Afterglow (FOA) gamma-ray bursts. In all the gamma-ray burst error boxes promptly followed by narrow field X-ray instruments, an X-ray transient (afterglow) has been detected (with the only exception of GRB 990217), while only for \(\sim\) 40 per cent of them optical observations have revealed an afterglow at optical wavelengths. This despite the rough similarity of the X-ray afterglow fluxes and the prompt reaction of optical telescopes. Paczynski (1998) ascribes this failed detection to dust extinction pointing out how this interpretation requires the association of bursts with star forming regions. If this is the case, infrared observations should be better suited for the hunt of afterglows, where the extinction plays a reduced role. For this reason, the IR follow-up of GRBs has recently become quite common, and some afterglows (GRB 990705, Masetti et al. 2000; and GRB 000418, Klose et al. 2000a) have been detected in the infrared before being confirmed at optical wavelengths. Yet, we still miss the detection of an IR afterglow without an optical counterpart: such a detection would confirm the role of dust in FOAs. Adding confusion to this picture, observations of extinction in X-ray spectra seem to reveal a very low gas to dust ratio (Vreeswijk et al. 1999, Galama & Wijers 2000) which, if common in all GRB environments, would strongly limit the role of dust extinction in the absorption of afterglows in the optical band and, even more, in the NIR.

In this paper we show that upper limits derived for FOAs are indeed not consistent with an “average afterglow”, contrary to what recently claimed by Galama & Wijers (2000). We then analyze the properties of detected and non detected optical afterglows in order to check whether the absorption commonly seen in star forming regions can explain the large fraction of FOAs.

2 OBSERVATIONS

The first problem we face if we want to quantitatively describe the failed detection of afterglows is the extreme inhomogeneity of the sample. Different burst error boxes have been observed with different telescopes, with different depths, in different filters and at different times after the burst explosion. This situation makes extremely difficult even to understand whether FOAs are consistent with the brightness dispersion of the detected afterglows. We there-
Table 1. Properties of the bursts with associated optical transient. The first 13 bursts have been observed by the BeppoSAX-GRBM/WFC, while the remaining bursts (below the horizontal line) have been discovered by other instruments (see text).

| GRB      | $F_{X,NP}$ | $\Delta t_x$ | $\delta_x$ | Ref  | $R$ | $\Delta t_R$ | $z$ | Ref  |
|----------|------------|--------------|------------|------|-----|--------------|----|------|
| 970228.12362  | 28±4 | 8 | 1.32 | Co97 | 21.5±0.3 | 16.5 | 1.73±0.12 | Ma98, Ga00 | 0.695 | B98 |
| 970508.904     | 7±0.7 | 6 | 1.1 | Am98 | 19.77±0.1 | 52 | 1.2 | Pe98, Ga98a | 0.835 | Me97 |
| 971214.97272   | 4±0.4 | 6.7 | 0.9 | An97 | 22.06±0.06 | 13 | 1.20±0.02 | D98 | 3.418 | Ku98 |
| 98326.88812    | NP | --- | --- | --- | 21.25±0.03 | 11 | 2 | Bi09 | --- | --- |
| 98329.1559     | 7.8±0.9 | 7 | 1.35 | Za98a,b | 21.2±0.3 | 17 | 1.3±0.1 | Re99 | --- | --- |
| 98425.59915c   | 4±0.6 | 10 | 0.2 | Pi00a | 15.7±0.1 | 59.8 | --- | Ga98b | 0.0085 | T98 |
| 98519.51403     | 1.4±0.3 | 9.7 | 1.8 | N99 | 20.4±0.1 | 15.5 | 2.05±0.07 | Ha99 | --- | --- |
| 98613.20215     | 1.1±0.3 | 9 | 0.8 | Co99a | 22.9±0.2 | 16.3 | 1 | Hj98, Dj98a | 1.0964 | D98b |
| 990123.40780    | 110 | 5.8 | 1.35 | He99a | 18.26±0.04 | 3.8 | 1.12±0.03 | Od99, Ga99a | 1.6004 | Ku98 |
| 990510.36743    | 14.7±1.8 | 8 | 1.4 | Ku00 | 17.54±0.02 | 3.5 | 0.82±0.02 | Hr99 | 1.619 | Vr99a |
| 990703.66765    | 1.9 | 11 | 1.6 | Am00 | 18.7±0.05 | 5.5 | 1.68±0.10 | Ma00 | --- | --- |
| 990712.69655     | NP | --- | --- | --- | 19.4±0.1 | 4.16 | 0.97±0.02 | Sa00a | 0.4331 | Vr00 |
| 990110.66038    | NP | --- | --- | --- | 20.6±0.1 | 8.4 | 1.4 | Go00 | --- | --- |
| 980703.182468   | 7.5 | 22 | 1.3±0.25 | Ga98c | 21.00±0.09 | 22.6 | 1.39±0.3 | Ca99a | 0.9662 | D98c |
| 990308.21883     | --- | --- | --- | --- | 18.14±0.05 | 3.34 | 1.2±0.1 | Sc99 | --- | --- |
| 991208.192269    | --- | --- | --- | --- | 18.7±0.1 | 49.9 | 2.15 | Je98a | 0.7055 | D99 |
| 991216.671544    | 1240±40 | 4.03 | 1.64 | Ta99 | 18.49±0.05 | 19.8 | 1.22±0.04 | Ha00 | 1.02 | D99 |
| 990131.62446     | --- | --- | --- | --- | 23.26±0.04 | 84.3 | 2.25±0.19 | An00 | 4.50 | An00 |
| 990301.41084     | --- | --- | --- | --- | 20.42±0.06 | 36.5 | 1.18±0.14 | Sa00b | 2.0335 | Ca00a |
| 990418.41921     | --- | --- | --- | --- | 21.63±0.04 | 59.3 | 0.86±0.06 | Ki00 | 1.1854 | B100 |
| 990630.02145     | 23.04±0.8 | 21.6 | 1.1 | Je00 | --- | --- | --- | --- | --- |
| 990011.30237     | --- | --- | --- | --- | 20.26±0.17 | 34.3 | 1.5±0.14 | Pr00a, La00 | --- | --- |
| 990026.99274     | 2.1±0.6 | 54.2 | 4.3±1.0 | Pi00b | 19.37±0.02 | 20.7 | 1.36±0.11 | Sa00c, Fy00a | 2.066 | Fy00b |
| 991007.20749     | --- | --- | --- | --- | 20.3 | 83 | 09 | Ca00b, Pr00b | --- | --- |

Notes: $t_0$ is defined by $F_{\nu}(t) \propto t^{-\delta_0}$. X-ray fluxes in the 2–10 keV band. NP=repointing of BeppoSAX not possible. $a$: for $t > 2$ days; earliest detection time is 3 hours; $R = 21.1 \pm 0.1$. $b$: $R = 23.6 \pm 0.2$ after 20 hours. $c$: SN 1998bw, not used in the analysis. $d$: Converted from Gunn r-mag. $e$: $R$ mag derived from $I = 20.8 \pm 0.3$; $f$: $R$=23.6±0.2 after 20 hours. $g$: In SN 1998bw.

These data have been used to produce Figure 1, which shows the magnitudes of the optical afterglow detections and tating the search for an optical transient in the field of view. It is not appropriate to include the IPN-detected GRBs in the sample of FOAs, since some of the error boxes have been observed only partially, so that it is not possible to define a single limiting magnitude for each burst. It is possible, even though not required by the data (see the following statistical analysis), that the subsample of IPN OAs is intrinsically different from the sample of BeppoSAX OAs. For this reason, we will compare in the following the FOAs both with the sample of all OAs and with the subsample of BeppoSAX OAs. The results will be similar, but the larger sample of OAs will give higher statistical confidence, due to the larger number of elements.

In Table 2, we report the properties of the bursts with associated optical afterglow detected by the BeppoSAX network. The first 13 bursts have been observed by the BeppoSAX network and the IPN network with the SAX satellite. Instead, for FOAs, we have been more restrictive and have considered only those bursts detected by the WFC of BeppoSAX, which usually gives narrower error boxes, facilitating the search for an optical transient in the field of view.
Notes: NP = Repointing of BeppoSAX not possible; a: R mag derived from V > 23.2. b: R mag derived from V > 20.3. c: R mag derived from K > 18.15. d: R mag derived from V > 22.
An99a: Antonelli et al., 1999a; An99b: Antonelli et al., 1999b; An00: Antonelli et al., 2000; Ax99: Axelrod et al., 1999; BS00: BeppoSAX mail # 00/18 = GCN Circ. # 707; Ca99b: Castro-Tirado et al., 1999b; Co99b: Costa et al., 1999b; Fe99: Feroci et al., 1999; Fr99: Frontera et al., 1999; Fr99: Frontera et al., 1999; Fr00: Frontera et al., 2000; G80a: Gorosabel et al., 2000a; G80b: Gorosabel et al., 2000b; G60c: Gorosabel et al., 1999c; Gr97a: Groot et al., 1997a; Gr97b: Groot et al., 1997b; Li99: Lindgren et al., 1999; Je99b: Jensen et al., 1999b; Je99: Jensen et al., 1999; Je99b: Jensen et al., 1999b; Je99: Jensen et al., 1999b; Masetti et al., 1999; Mo99: Mohan et al., 1999; Ni98: Nicastro et al., 1998; Ni99b: Nicastro et al., 1998; Pa99a: Palazzii et al., 1999a; Pa99b: Palazzii et al., 1999b; Pa99c: Palazzii et al., 1999c; Pa00a: Palazzii et al., 2000a; Pa00b: Palazzii et al., 2000b; Pa99a: Piro et al., 1999a; Pa99b: Piro et al., 1999b; Pr00c: Price et al., 2000; Rh99: Rhoads et al., 1999; Ro99: Rol et al., 1999; St00: Stanek et al., 2000; Ug99: Ugeselsh et al., 1999; Ug00: Ugeselsh et al., 2000; Vr99: Vreeswijk et al., 1999c; Za00: in’t Zand et al., 2000.

Table 2. Properties of the bursts with BeppoSAX-WFC detection but without associated optical transient. The last three bursts below the horizontal line refer to the γ-ray poor GRBs (or X-ray transients) detected by BeppoSAX.

| GRB     | \( F_X \cdot NFI \times 10^{-13} \text{erg cm}^{-2} \text{s}^{-1} \text{arcsec}^{-2} \) | \( \Delta t_x \) | \( \delta_x \) | Ref | \( R \) | \( \Delta R \) | Ref |
|---------|----------------------------------------------------------------------------------|------------------|----------------|-----|--------|----------------|-----|
| 970402.930 | 2.2±0.6 8 1.6 N998 21 18.5 Gr97a | | | | | | |
| 971227.34938 | 2.6±0.6 14 1.12 An99a 22.8 21.3 Gr97b | | | | | | |
| 981226.40793 | 5±1 11 1.3 F698 23 10. Li99 | | | | | | |
| 990217.22462 | < 1 6 >1.6 P99a 23.5 19. Pa99a | | | | | | |
| 990627.20894 | 3.5 8 N99b 21. 23. Ro99 | | | | | | |
| 990704.7294 | 4.4±0.3 8 Fe99 22.5 4.6 Je99b | | | | | | |
| 990826.60286 | 5.5±1.5 7.8 Fr99 22. 3.8 Vr99c | | | | | | |
| 990907.7319 | 15±5 11 P99b 22.9 24.9 Pa99b | | | | | | |
| 990908.00125 | NP 20.8 11.5 Ax99 | | | | | | |
| 991014.9115 | 3.5±0.5 13 >0.4 Sa00 22.6 12.9 Ug99 | | | | | | |
| 991105.69495 | NP 23.5 16. Pa99c | | | | | | |
| 991106.4545 | 1.25±0.3 8 An99b 21. 9.1 Ca99b | | | | | | |
| 000210.36396 | 1.5 7.2 Co99b 23.3 16. Go00a,b | | | | | | |
| 000214.042 | 2.75±0.9 12 0.6 An00 21.1 32.4 Rh00 | | | | | | |
| 000424.76258 | NP 22.8 33. Ug00 | | | | | | |
| 000528.36568 | 1.7±0.3 8.3 1 Ku00 23.3 18. Pa00a | | | | | | |
| 000529.3361 | 2.8±0.7 7.5 Fr00 22.3 47 Pa00b | | | | | | |
| 000615.2625 | 10 BS00 21.5 4.2 St00 | | | | | | |
| 000620.2317 | NP 19.8 5.7 Go00c | | | | | | |
| 990520.08539 | NP 21.7 19.5 Ma99 | | | | | | |
| 991217.17496 | NP 22. 11. Mo99 | | | | | | |
| 000416.6062 | 20.7 50.3 Pr00c | | | | | | |

upper limits, all in the R band versus the time of observation. Filled and empty circles correspond to BeppoSAX and non-BeppoSAX bursts with detected optical afterglows, while arrows are upper limits. The three X-ray transients tentatively associated with bursts (γ-ray poor GRBs, non significantly detected in the GRBM) are included in the sample of upper limits (however, their exclusion does not significantly influence any of the following results).

We have checked that local Galactic extinction does not play a crucial role by comparing the hydrogen column densities in the direction of detected afterglows with those in the direction of FOAs. Figure 2 shows the comparison. Applying a Kolmogorov-Smirnov (KS) test (Press et al. 1992), we obtain that the two distributions are drawn from the same parent population at the 94 per cent confidence level.

The visual inspection of Figure 2 reveals a clear segregation of arrows from dots, the former being systematically fainter than the latter at comparable times. The eye impression can be tested through several statistical tests. If we consider the whole sample of OAs, a bidimensional KS test (Press et al. 1992) can be applied. The probability for the circles (empty + filled) and the arrows being derived from the same parent distribution is \( P \sim 0.2 \) per cent (\( \sim 3\sigma \)). This test, however, may be biased due to the systematic difference in the observing times between the OAs and FOAs samples. Since a correlation between the R magnitude and the detection time \( t \) is present in the data, a monodimensional test can be applied on the residual quantity:

\[
M = R - \{A + B[\log(t) - 1.2]\},
\]

where \( A \) and \( B \) are two parameters obtained by a linear fit of the OA sample and the value 1.2 is the logarithmic average observing time. Fitting Eq. 1 to the BeppoSAX OAs data, we obtain \( A = 20.84 \pm 0.44 \) and \( B = 2.86 \pm 1.2 \). Using non-BeppoSAX data only, we find \( A = 19.84 \pm 0.54 \) and \( B = 2.31 \pm 1.2 \). Since the two results are in agreement at the 1.5σ level, in the following we use the \( A \) and \( B \) parameters obtained in the cumulative fit of BeppoSAX and non-BeppoSAX OAs. This yields:

\[
A = 20.3 \pm 0.3 \quad B = 1.9 \pm 0.7
\]
(see also Eq. 3). It is however worth mentioning that, should the earliest photometric point of GRB970508 be used instead of the brightest one (see Tab. 1), the difference of the photometric residuals for BeppoSAX afterglows will be increased to \( \sim 2\sigma \).

We obtain the following results. The distribution of the \( M \) residuals (Eq. 2 with parameters from Eq. 3) for the BeppoSAX and non-BeppoSAX OAs is different from that of the FOAs at the 99.4 per cent (\( \sim 2.7\sigma \)) level. If we consider, instead, the distribution of the residuals for BeppoSAX OAs and FOAs only, these differ at the 95 per cent (\( \sim 2\sigma \)) level.

Alternatively, one can fix the value of the parameter \( B \) to the median decay slope of GRB afterglows (\( B = 2.5(\Delta \nu) = 3.25 \)) and derive \( A = 20.3\pm0.3 \). Using these values of \( A \) and \( B \), the two tests described above yield \( P = 99.5 \) and \( P = 94 \) per cent, respectively. These numbers are very similar to those obtained with the fitted slope \( B \).

All the statistical tests discussed above do not assume any particular shape for the probability distribution of OAs or FOAs but depend on the assumption that BeppoSAX OAs and non-BeppoSAX OAs are drawn from the same parent population. A more stringent test can be applied if we assume that the residual quantity \( M \) is gaussianly distributed around the mean value 0 for BeppoSAX OAs. We find that 4 FOAs out of 19 deviates more than 2\( \sigma \). The probability for this is \( P \sim 0.08 \) per cent (\( \sim 3\sigma \)).

This result shows that in many cases we failed to detect the optical afterglow not because the search was conducted without the necessary depth, but instead because the FOAs are indeed fainter than the detected ones. Yet, it is possible that FOAs are optically fainter because intrinsically less energetic at all wavelengths, or because they are more distant. In order to check this, we compared the X-ray and \( R \) band flux densities of bursts with and without optical detection 12 hours after the burst event. For bursts with optical detection, the magnitude at \( t = 12 \) h has been computed taking into account the measured flux decay with time while for FOAs an average \( \delta_R = 1 \) has been used.

The result is shown in Fig. 3, where dots correspond to detected afterglows while arrows indicate upper limits. In this figure, the number of points is smaller than in Fig. 1 because only those bursts with BeppoSAX NFI observations have been plotted, for consistency in the X-ray flux. We can see that the X-ray fluxes of FOAs are not systematically fainter than the fluxes of afterglows with optical detection, indicating that FOAs are indeed optically poor and define a different population with respect to optically detected afterglows.

Given this conclusion, we now explore the possibility that FOAs are intrinsically similar to bursts with detected optical afterglows, but suffer from dust extinction due to the propagation of their photons in a molecular cloud, where the burst explosion took place.

We here estimate a lower limit to the extinction that may cause the FOAs to go undetected. There are two ways of doing this. A first way is to consider the ensembles of detections and upper limits, add a constant magnitude shift to all upper limits and recompute the KS probability until a maximum value is reached. This will give the average value of the extinction required to have an undetectable afterglow. This procedure gives an average absorption in the \( R \) band of \( (A_R) \sim 2.0 \). Dereddening all FOAs by this amount maximizes the probability that all bursts belong to the same parent population \( (P \sim 35 \text{ per cent}) \).

To compute the fraction of FOAs with respect to all bursts we must use an homogeneous dataset. We then use only bursts detected by the WFC of BeppoSAX, excluding GRB 980425 and X-ray transients. We are left with 31 bursts, 19 of which are FOAs, yielding a fraction of 60 per cent. Therefore an average absorption of 2 magnitudes in the \( R \) band is needed for more than half of the bursts.

A different method to constrain the required absorption for FOAs is to estimate a burst-by-burst absorption by computing the lack of brightness with respect to an “average afterglow” \( R-t \) relation (see Eq. 1 and 3 above):

\[
R = 17.991 + 1.936 \log t
\]

where \( t \) is given in hours. This fit is shown in Figure 2 with a solid line.

The dotted line in Figure 2 shows the integrated distribution of the required \( A_R \) to bring each upper limit on the magnitude of FOAs to the magnitude given by Equation 1. X-ray transients have not been considered in this sample. Since it is not possible to quantify the local absorption that affects the detected bursts, we conservatively assume that their local absorption is negligible. The fact that the dotted line saturates for \( A_R \leq 0.6 \) is due to this assumption. If the optical afterglows of the detected bursts were locally absorbed, the dotted line would approach unity for \( A_R \) in the range shown in Fig. 4, making the discrepancy among

\[†\] The parameter \( \delta \) is defined through \( F_\nu(t) \propto t^{-\delta} \).
Absorption in GRB afterglows

Figure 2. Logarithmic distribution of the column densities of bursts with (solid line and line shaded) and without (dashed line and grey shaded) optical afterglow. The distribution of bursts with afterglow includes both BeppoSAX and non BeppoSAX bursts. The vertical lines show the median value of the column density for bursts with (solid line) and without optical afterglow (dashed line). The two distributions can belong to the same parent population (at 94 per cent level, according to the KS test).

Figure 3. Optical R band magnitudes vs X-ray flux for BeppoSAX afterglows. Dots are afterglows with both optical and X-ray detections while arrows are upper limits for afterglows with X-ray detection but without any optical detection.

3 ABSORPTION IN MOLECULAR CLOUDS

Absorption of several visual magnitudes in a molecular cloud is not uncommon, and hence the hypothesis that failed optical detections are due to absorption deserves a detailed analysis.

3.1 Average cloud absorption

As a first simple approach, we consider molecular clouds as uniform, with standard dust to gas ratios. A compilation of Galactic cloud masses and sizes is given in Leisawitz et al. (1989), who analyze with a systematic survey the CO emission around 34 young open clusters of the Galaxy. We have computed the column density

\[ N_H = \frac{3M}{4\pi \, m_p \, a_{maj} \, a_{min}} \]  

where \( M \) is the mass of the cloud and \( a_{maj} \) and \( a_{min} \) are the major and minor axis of the cloud. For simplicity we have assumed that all the matter is in pure atomic hydrogen. This assumption implies that the derived \( N_H \) is slightly overestimated, but correct up to factors of order unity.

Analyzing the data of the same molecular clouds, Leisawitz (1990) derives a maximum observed column density \( N_H \) of molecular hydrogen \( H_2 \) (note that a factor of two difference with \( N_H \) is expected for clouds with the same total mass) in each cloud. Clouds were observed through 3 to 144 lines of sight. Since the interstellar medium (ISM) in the clouds is not uniform, the maximum observed value is significantly larger than the derived average one (see Fig. 4) and may be a better statistical indicator of the column density where massive stars form.

3.2 The Orion molecular cloud

To better constrain the distribution of the expected extinctions within a single star-forming molecular cloud we have analyzed the observed extinction in O, B and A stars within the Orion molecular cloud. Data of \( E_{B-V} \) have been taken from Lee (1968), who gives the observed reddening for a sample of 196 stars. This reddening has been converted in absorption in the \( V \) band (\( A_V \)) by adopting the average shape parameter \( R_V \) appropriate for the environment close to hot, massive and young stars in the cloud (Lee 1968):

\[ R_V \equiv \frac{A_V}{E_{B-V}} = 5.5 \]  

from which \( A_V = 5.5 \, E_{B-V} \) (see also Sect. 4).

4 COMPARISON WITH AFTERGLOW (FAILED) OBSERVATIONS

In order to compare the absorption properties of (and in) the molecular clouds, as described above, with the \( R \) band absorption derived for FOAs, we must convert column densities and \( V \) band absorption in the \( R \) band.

To convert column densities into dust absorption, we adopt the dust to gas ratio given in Predhel & Schmitt (1995):

\[ A_V = \frac{N_H}{1.79 \times 10^{21} \text{cm}^{-2}} \]
Figure 4. Comparison between the estimated absorption in FOAs and the absorption expected from molecular clouds. Lines show the integral distribution of the R band absorption for the average column density in molecular clouds (dot-dashed); for the peak column density in molecular clouds (dashed) and for stars in Orion (solid). See text for the conversion of $N_H$ and $A_V$ in $z = 1$ R band absorption. The dotted line shows the integral distribution of the lower limits of $A_R$ for FOAs, while the shaded area is the 1 $\sigma$ confidence region.

To convert dust absorption values from a wavelength to a different one, we use the analytic approximation for the dust extinction curve given in Cardelli et al. (1989).

A final problem is represented by the fact that we do not know the redshift of FOAs. Therefore we do not know at which rest frame wavelength we have to compute the extinction in the afterglow. In fact, what we observe in the R filter effective wavelength $\lambda_R$ has been emitted (and dust extincted) at a rest frame wavelength $\lambda = \lambda_R/(1+z)$. As a zero-order assumption, we put all FOAs at a redshift $z = 1$, close to the average value of the detected afterglows. In this case we obtain $A_R(z=1) = 1.31 A_V$.

By adopting all the corrections described above, we can convert the average $N_H$, the peak $N_{H_2}$ and the $A_V$ values of molecular clouds into a distribution of expected R band extinctions for a burst at redshift $z = 1$. Figure 4 shows the result of this conversion: the dot-dashed line shows the integral distribution of $A_R$ values as derived from the average $N_H$ of Galactic molecular clouds. The dashed line shows the integral distribution of $A_R$ as derived from the distribution of the peak value of $N_{H_2}$ in the same clouds, while the solid line shows the integral distribution derived from $A_V$ absorption of hot stars in the Orion molecular cloud.

In order to compare the absorption required to obscure FOAs with the distributions in Figure 4 we consider first the average ($A_R$) inferred for the bursts as a sample. As detailed in Section 2 we need that 60 per cent of the lines of sight to bursts are affected by 2 magnitudes of absorption.

Fig. 4 shows that if we use the average value of $N_H$ of the clouds, $A_R > 2$ only in the ~0.8 per cent of the cases, while if we use the peak value of $N_H$ this fraction increases to ~15 per cent. We also have that ~18 per cent of the hot stars in Orion have $A_R > 2$. Note that all these values refer to the absorption estimated in the observed R band, but assuming that the sources are at $z = 1$.

These results imply that even if FOAs are located in the most absorbed regions of molecular clouds, in several cases the corresponding absorption is not enough to hide their optical afterglows. Given our assumptions, the statistical significance of this result is $\gtrsim 3\sigma$: admittedly not extremely compelling, but consider that we have used upper limits to measure the amount of $A_R$, which could then be much larger.

Besides the integral distributions of $A_R$ observed in molecular clouds, Fig. 4 shows (dotted line) the integral distribution of the lower limits on $A_R$ derived for FOAs, with the gray shaded area corresponding to the 1 $\sigma$ confidence region for the same distribution.

The large negative deviations of the high and low absorption tails are due to the intrinsic limitations of the lower limits sample, but the difference around $A_R \sim 2$ with respect to the solid line is real, even if significant at the $\gtrsim 2\sigma$ level only. This, again, shows that the required absorption is larger than the absorption associated on average to a molecular cloud at redshift $z = 1$.

5 DISCUSSION

By analyzing the properties of detected optical and X-ray afterglows and the upper limits for failed detections, we show that the subset of bursts without optical afterglow (FOAs) defines a different family. This conclusion relies on several assumptions, like the homogeneity of the BeppoSAX and non BeppoSAX detected afterglows, imposed by the paucity of the sample. Should some of these turn out to be wrong, the conclusion would become statistically less stringent (see §2 for further details). We have investigated if this can be due to dust extinction of optical radiation in a molecular cloud. We find that this hypothesis can only marginally account for the large fraction of FOAs, and therefore we cannot exclude the possibility that FOAs are intrinsically less luminous in the optical/UV band with respect to the detected ones, and with respect to their own X-ray luminosity.

Consider also that we have been very conservative in our procedure, because our results are based on considering upper limits on the optical flux, and peak absorption columns expected in giant molecular clouds. The latter assumptions may well be too conservative, if the dust is bound to evaporate when illuminated and heated by the powerful optical/UV flash of the gamma-ray burst (Waxman & Draine 2000) and by its X-ray radiation (Fruchter et al. 2000). This dust sublimation is suggested for a sample of burst afterglows (Vreeswijk et al. 1999c, Galama & Wijers 2000), in which a very large hydrogen column density $N_H \gtrsim 10^{22}$ cm$^{-2}$, as estimated by X-ray data, is associated with almost no optical extinction. The results can be understood only in terms of a dust to gas ratio $\sim 100$ times smaller than the Galactic average value. In turns, such low values of the dust to gas ratio can be explained only if the dust has been completely sublimated in the surroundings of the burst. Indeed the theoretical models mentioned above predict that dust can be destroyed by the burst emission out to a radius
comparable to the dimension of a typical molecular cloud (up to a few tens of parsecs). If this is the case, the material responsible for absorption in FOAs is not the overdense cocoon surrounding the star forming region, but the cloud as a whole (or even less), and the discrepancy between the observed and measured value (see dash-dotted line in Fig. 1) becomes extremely compelling.

An interesting way to assess whether dust is playing any role in FOAs is to perform near infrared (NIR) follow-up of their $\gamma$ or X-ray error boxes. For instance, in the $K$ filter, absorption is greatly reduced, so that only a very small fraction (less than 10 per cent) of afterglows should show more than 1 magnitude of absorption, in any of the adopted cloud models. This is therefore a crucial test to understand whether FOAs are due to dust absorption (less severe in the near infrared) or to an intrinsic difference in the emitted spectrum (that should be more severe in the NIR). Some FOAs have been indeed looked for in the NIR band, but the observations are still very sparse and we lack any statistics to draw any meaningful conclusion.

NIR observations are thus strongly recommended as the key test for the dust extinction hypothesis, especially after the launch of HETE II, which will rapidly distribute accurate enough locations of bursts to be promptly followed by ground based telescopes. A more homogeneous dataset, though, will have to await the launch of the Swift satellite, foreseen in 2003. The systematic follow-up with the on-board optical telescope will provide a multiband spectroscopic database of the first hours of optical afterglows. Data of even higher quality could be achieved if IR robotic telescopes (such as the one proposed by the consortium of Brera, Rome and Catania Observatories, called REM, for Rapid Eye Mount), will be in operation to complement Swift observations from the ground.

A possibility to increase the absorption in the observed $R$ band without invoking particularly dense molecular clouds is by allowing for a higher redshift of the bursts. This would make the afterglow undetectable, especially if the redshift of the burst is particularly high ($z \gg 4$), so that the redshifted Lyman $\alpha$ break falls in the $R$ filter. In this case, again, near infrared ($JHK$) observations should be unaffected by absorption and the optical transient easily detectable. Estimates of the fraction of high redshift GRBs (see, e.g., Porciani & Madau 2001) predict however a very small fraction of bursts (up to few per cent) at $z > 3$, if the GRB and star-formation rate are related. A more interesting way-out is that the property of clouds at high redshift are different from those of our Galaxy (see Ramirez-Ruiz Trentham & Blain 2001), or that the dust extinction curve changes its shape with redshift.

In conclusion, we have found that dust absorption due to a cloud with properties similar to Galactic clouds is not a completely satisfying explanation for bursts without a detected optical afterglow, and we cannot rule out the possibility that they are due to an intrinsic larger dispersion of optical fluxes with respect to the dispersion of the X-ray fluxes (see also Böer & Gendre 2000).

This, in turn, opens some exciting observational perspectives aiming to disclose the nature of the burst progenitor: if bursts are indeed associated with the final stages of stellar evolution and a supernova-like event is associated to all bursts, then the search for supernova signatures should be easier for bursts with an optical faint afterglow, for which the SN lightcurve would not be polluted by the flux of the afterglow. If we assume SN1998bw (Galama et al. 1998c) as a template supernova lightcurve, the expected magnitudes at maximum should be roughly $I = 24$ and $R = 25$, easily detectable with a signal to noise ratio of $\sim 10$ with an exposure time of only $\sim 10$ min with an 8 meter class telescope.

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