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Observations of GRB afterglows from Nainital: Evidence in favour of jet model

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Abstract. Broad band optical photometric observations of five Gamma-ray burst (GRB) afterglows (GRB 990123, GRB 991208, GRB 991216, GRB 000301c and GRB 000926) are taken from Nainital during 1999 and 2000. These in combination with the published observations including at other wavelengths are used to study their flux decays, broad spectral energy distributions and energetics in the light of fireball plus blast wave synchrotron emission models. Their early time flux decay constant is ~ 1.1 which becomes ≥ 2 at later times. All are having a relatively flat spectral index with values ranging from 0.73 to 0.95. Observations of these afterglows support the model of non-isotropic synchrotron emission from the centre of these GRBs which reduces the budget of isotropic energy emission from $> 10^{53}$ erg to $\leq 10^{52}$ erg. This, as well as the other observations indicate that GRBs originate most likely from the collapse of massive stars rather than the merging of compact objects.

Key words : Photometry – GRB afterglow – flux decay – spectral index

1. Introduction

GRBs are short and intense transient flashes of cosmic high energy ($\sim$ 10 keV$-$10 GeV) photons. Most of the burst energy is released in the 0.1 $-$ 1 MeV range. The duration of the bursts ranges from about few millisec to $\sim$ 1 ksec. The afterglow of a GRB appears after the GRB event, generally observed first in $X-$rays. The afterglow emission, unlike GRB emission, is long-lived and can be observed for much longer duration than that of a GRB.

One of the key issues regarding GRBs is the nature of the INNER ENGINE that releases relativistic ejecta generating the high energy emission of the burst and the lower frequency

Table 1. List of GRB afterglows observed from Nainital.

GRB burst	α_{20000}	δ_{2000}	Filters	Reference
GRB 990123	$15^h25^m29^s$	$+44°45'$	B, V, R	Sagar et al. (1999)
GRB 991208	16 33 55	+46 26	I	Sagar et al. (2000a)
GRB 991216	05 19 31	+11 11	R	Sagar et al. (2000a)
GRB 000301c	16 20 21	+29 25	V, R, I	Sagar et al. (2000b)
GRB 000926	17 04 10	+51 47	R	Sagar et al. (2001)

afterglow emission. A knowledge of the total amount of energy released in the event is therefore essential for understanding the origin of GRBs. For this, one would like to know whether emission from GRBs is isotropic or not. Optical observations have provided valuable information in this direction by setting the distance scale through measurement of redshift, and by determining the degree of collimation of the initial emission through detailed study of the afterglow light curve. Presence of steepening in the light curves of several GRB afterglows within few days of the event is considered as an evidence of an originally collimated outflow expanding laterally. Early and dense temporal coverage of the light curves of the GRB afterglows are therefore extremely important. Since the optical transient (OT) of a long duration GRB has generally R magnitude between 18 to 22, if it is detected within a few days or so after the burst, the 1-m class optical telescopes equipped with CCD detector are capable of observing them. We, at Nainital, have therefore started observing them since 1999. Out of the 14 GRB fields observed during 1999 and 2000 (Sagar 2001), broad band optical photometric data are obtained successfully only for GRB 990123, GRB 991208, GRB 991216, GRB 000301c and GRB 000926 afterglows. Modern CCD detectors mounted at the f/13 Cassegrain focus of 104-cm Sampurnanand telescope were used for carrying out the observations. We used 2048 × 2048 pixel^2 size CCD camera except in the case of GRB 990123 where the CCD camera size was 1024 × 1024 pixel^2. One CCD pixel corresponds to $\sim 0.''38$ square on the sky for both cameras. As the quantum efficiency of both CCD detectors peaks in the R passband and GRB afterglows are relatively faint for 1-m class optical telescopes, most of the observations were taken in R. Whenever possible, observations were also taken in B, V and I passbands (see Table 1). Further details of observations, data reductions and photometric calibrations are given in Sagar (2001). The flux decays, broad spectral energy distributions and energetics of the GRB OTs under study are discussed below.

2. Optical light curves and spectral indices

In order to define the light curves properly of the very fast evolving GRB afterglows, present observations are combined with the published data. Fig. 1 shows, as a sample, the optical flux decays of GRB 991208, GRB 000301c and GRB 000926 afterglows in R passband since it contains the densely observed data which are borrowed from Sagar et al. (2000a), Sagar et al. (2000b) and Sagar et al. (2001) respectively. The X-axis is log $(t - t_0)$ where t is the time of observation and t_0 is the time of GRB trigger which is 1999 December 8.192 UT for GRB 991208; 2000 March 1.411 UT for GRB 000301c and 2000 September 26.9927 UT for GRB 000926. All times are measured in unit of day. The optical emission from all GRB afterglows is overall fading. However, the pattern of their flux decays differs. The light curve of GRB 991208 OT is well characterized by a single power law $F(t) \propto (t - t_0)^{-\alpha}$, where $F(t)$ is the flux of the afterglow at time t and α is the decay constant. The light curves of both GRB 000301c and GRB 000926 afterglows steepen after a period of few days. This can be attributed to the lateral expansion of ejected material, which was initially confined to a small cone. Overall the flux decay, as expected in GRB OTs having jet-like relativistic ejecta (Sari, Piran & Halpern 1999; Rhoads 1999), seems to be described by a broken power-law of the form $F(t) = F_0[\frac{2}{(t/t_b)^{\alpha_1 s} + (t/t_b)^{\alpha_2 s}}]^{1/s} + F_g$, where F_g is the constant flux from the underlying host galaxy or other non-varying contaminants, α_1 and α_2 are asymptotic power-law slopes at early and late times with $\alpha_1 < \alpha_2$. The parameter $s(> 0)$ controls the sharpness of the break, a larger s implying a sharper break. F_0 is the flux of afterglow at the cross-over time t_b. The early and late time flux decay constants for the GRB events observed from Nainital are listed in Table 2.

The spectra of GRB 000301c and GRB 000926 afterglows $\sim$ 4.8 and 2.3 days after the burst are shown in Fig. 2, as a sample. The corresponding data are borrowed from Sagar et al. (2000b) and Sagar et al. (2001) respectively. It is observed that as the frequency decreases the flux increases. However, in the case of GRB 000301c, it turns over after millimeter wavelengths. The spectral energy distribution is generally well fit by the power-law $F(\nu, t) \propto \nu^{-\beta}$ for a range of frequencies that contain no spectral breaks. The value of β is 0.95 in $X-$ray to near-IR spectral region in the case GRB 000926 while it is 0.73 for GRB 000301c in the optical to millimeter region. Table 2 lists the values of β along with other parameters of the GRB afterglows observed from Nainital. This indicates that their β values, in the slow cooling phase, range from 0.7 to 0.95. The spectral energy distributions are thus relatively flat.

A brief description of multi-wavelength studies of the GRB afterglows under discussion is given in the following subsections.

2.1 GRB 990123

A very bright GRB with a peak fluence of $(5.09\pm0.02)10^{-4}$ erg cm^{-2} (Kippen 1999) was detected by the Burst and Transient Source Experiment (BATSE) on board the *Compton Gamma Ray Observatory* on 23 January 1999 at 09:46:56.12 UT in the constellation Boötes. The high energy emission of the burst was fairly typical of GRBs (Briggs et al. 1999). X-ray observations from the Dutch-Italian satellite BeppoSAX localized the position of the burst to within $5'$ (Piro 1999) and the Robotic Optical Transient Search Experiment (Akerlof et al., 1999) detected an OT that reached a peak magnitude of V = 8.86±0.02 mag just about 50 seconds after the burst. Further optical observations ob-

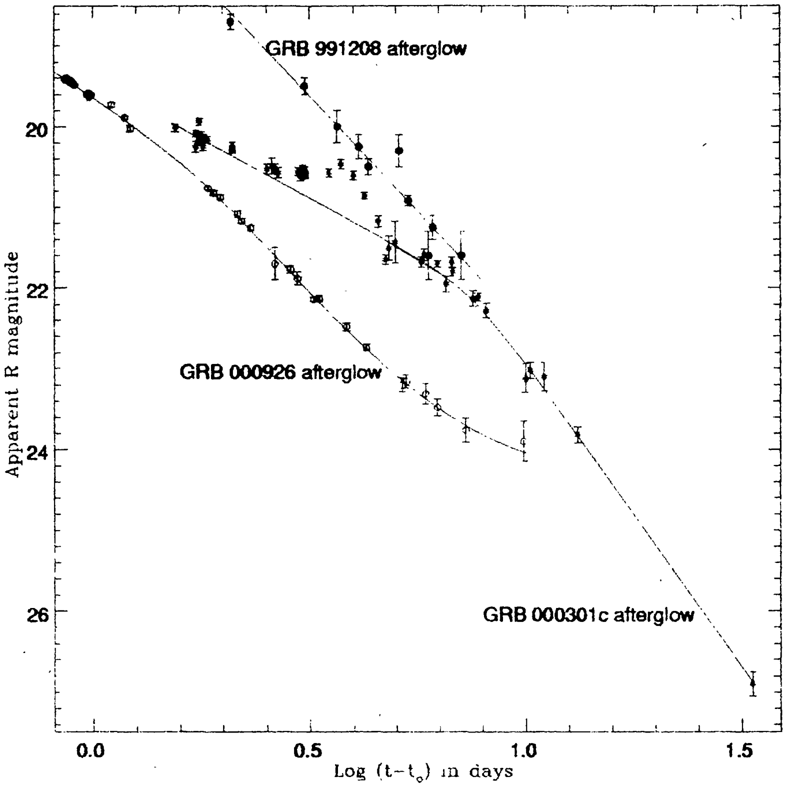

Figure 1. Light curves of GRB 991208 (•), GRB 000301c (∗) and GRB 000926 (o) afterglows in optical *R* passband. In the case of GRB 991208, solid line represents the linear least squares fit to the data points, while the continuous dotted and solid curves represent the non-linear least squares fit to the observed data of GRB 000301c and GRB 000926 respectively for a jet model with the value of sharpness parameter as 5 in both cases (see text). In the case of GRB 000301c, observed short term variability has been excluded, while in the case of GRB 000926, the constant flux from the underlying host galaxy has been included in the model fitting (see text).

tained the redshift, light curve and discussed the broad band spectral energy distribution (Andersen et al. 1999; Castro-Tirado et al. 1999; Galama et al. 1999; Kulkarni et al. 1999a; Sagar et al. 1999 and Holland et al. 2000). A host galaxy with $V = 24.25$ mag was detected by Holland & Hjorth (1999) using CCD images taken with Hubble Space Telescope (HST). The light curve of the OT is best fitted by a broken power law with t_b = 1.68±0.19 day, $\alpha_1 = 1.12\pm0.08$ and $\alpha_2 = 1.69\pm0.06$ (Holland et al. 2000). An upper limit of 2.3 % on the linear polarization of the OT was put by Hjorth et al. (1999).

This is the first GRB afterglow whose optical light curves exhibit a break (Kulkarni et al. 1999a; Fruchter et al. 1999; Castro-Tirado et al. 1999 and Holland et al. 2000)

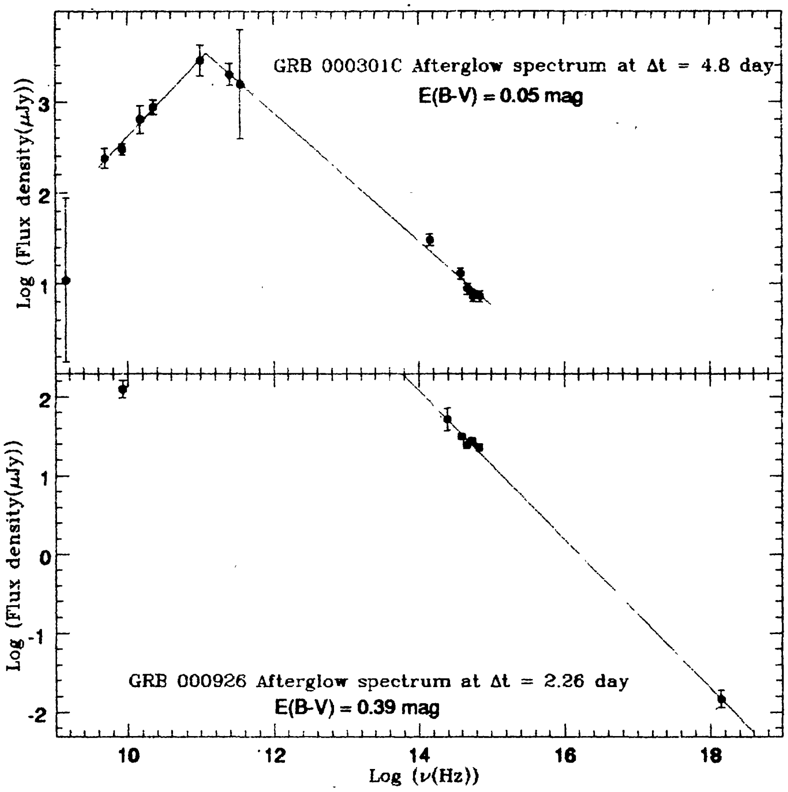

Figure 2. Spectral energy distribution of GRB 000301c and GRB 000926 afterglows at the epochs marked in the figure. In the case of GRB 000301c only galactic extinction amounting to $E(B-V) = 0.05$ mag is applied, while in the case of GRB 000926 extinctions due to both galactic and host galaxy amounting to $E(B-V) = 0.03$ and 0.36 mag respectively, are applied.

indicating presence of non-isotropic emission from the burst. The relative faintness of the observed late time radio emission from the afterglow also provides an independent indication of a jet-like geometry in this GRB (Kulkarni et al. 1999b, Frail et al. 1999). Peak frequency of the afterglow spectrum after a few days of the burst has been indicated in the radio region by Galama et al. (1999) while it has been indicated in the infrared region by Kulkarni et al. (1999b).

2.2 GRB 991208

The burst was detected at 04:36:52 UT on 8 December 1999 with Ulysses, Russian Gamma Ray Experiment (KONUS) and the Near Earth Asteroid Rendezvous (NEAR) detectors

Table 2. Parameters of the GRB afterglows observed from Nainital. α_1 and α_2 are the early and late times optical flux decay constants; t_b is the cross-over time when α_1 changes to α_2; β is the spectral index in slow cooling regime generally between X−ray to optical regions at epoch Δt; E_{52} is the energy in units of 10^{52} erg; θ is opening angle of the jet while α_1^p and α_2^p are the values predicted by the adiabatic jet synchrotron model from the observed value of β (see text).

Parameter	GRB 990123	GRB 991208	GRB 991216	GRB 000301c	GRB 000926
α_1	1.1 ± 0.1		1.2 ± 0.04	1.2 ± 0.14	$1.4 \pm .0.1$
α_2	1.7 ± 0.1	2.3 ± 0.1	1.5 ± 0.1	3.0 ± 0.5	2.6 ± 0.1
t_b(day)	1.68 ± 0.19	~ 2	~ 2	7.5 ± 0.6	1.7 ± 0.1
β at (Δt day)	$0.75 \pm 0.1(0.8)$	$0.75 \pm 0.1(8.5)$	$0.74 \pm 0.1(1.6)$	$0.73 \pm 0.1(4.8)$	$0.95 \pm 0.1(2.3)$
Redshift	1.6004 ± 0.0008	0.7063 ± 0.0017	1.00 ± 0.02	2.0404 ± 0.0008	2.0369 ± 0.0007
Distance (Gpc)	11	4.2	6.2	16.6	16.6
E_{52} (isotropic)	338	13	67	34	25
θ (deg)	5.0	8.7	6.0	8.6	8.0
E_{52}(non-isotropic)	1.1	0.13	0.3	0.4	0.2
α_1^p (jet model)	1.13 ± 0.15	1.13 ± 0.15	1.11 ± 0.15	1.1 ± 0.15	1.43 ± 0.15
α_2^p (jet model)	2.5 ± 0.2	2.5 ± 0.2	2.5 ± 0.2	2.5 ± 0.2	2.9 ± 0.3

with a fluence above 25 keV of $\sim 10^{-4}$ erg cm^{-2} and considerable flux above 100 keV. The γ−ray properties, the localization and the subsequent discovery of the radio counterpart to the burst are presented by Hurley et al. (2000). Galama et al. (2000) present the radio observations and also discuss the spectra and light curves over more than two decades in frequency for a two week period. They also studied the evolution of the characteristic synchrotron self-absorption frequency, peak frequency and the peak flux density. Optical light curve and spectral energy distribution of the afterglow have been studied earlier by Sagar et al. (2000a) and recently by Castro-Tirado et al. (2001). The flux decay is one of the steepest observed so far in a GRB OT with $\alpha = 2.3 \pm 0.1$. Other such GRB afterglows are GRB 980326 ($\alpha = 2.1 \pm 0.13$; Groot et al. 1998) and GRB 980519 ($\alpha = 2.05 \pm 0.04$; Halpern et al. 1999). Most probably, it is due to presence of jet which steepened the flux decay even before the start of their optical observations (cf. Sagar et al. 2000a). The jet model also gets support from the radio observations of GRB 991208 aftetglow (Galama et al. 2000) and the study by Huang, Dai & Lu (2000a). Castro-Tirado et al. (2001) derive a value of peak frequency about 100 GHz and self absorption frequency $\sim$ 13 GHz. They also estimate brightness of the host galaxy as $M_B = -18.2$ mag.

2.3 GRB 991216

The extremely bright burst was detected by BATSE by Kippen, Preece & Giblin (1999) on 16 December 1999 at 16:07:01 UT with its fluence above 20 keV $\sim$ 0.26 millierg cm^{-2} ranking it as the second brightest of all BATSE bursts detected so far. The Rossi X-Ray Timing Explorer (RXTE) Proportional Counter Array observations detected a strong, decaying X-ray afterglow (Takeshima et al. 1999). The first Chandra X-Ray Observatory observation of a GRB afterglow was performed on the afterglow (Piro et al. 2000) at $\sim \Delta t = 37$ hours. The two emission features discovered in the X-ray spectrum are indentified with the Lyman alpha line and the narrow recombination continuum by hydrogenic ions of iron at a redshift $z = 1.00 \pm 0.02$. Line width and intensity provide first direct evidence that the GRB progenitor is likely to be a massive star system that ejected, before the burst, about 0.01 $M_\odot$ of iron at a velocity of about 0.1c (Piro et al. 2000) providing strong support for the Supernova model (Vietri et al. 2001). Frail et al. (2000) present wide-band radio observations of the OT, ranging from 1.4 GHz to 350 GHz, taken from 1 to 80 days after the burst. In contrast to Garnavich et al. (2000) where the flux decay is described by a single power law with $\alpha = 1.36 \pm 0.04$ in optical R and near-IR J and K passbands, both Halpern et al. (2000) and Sagar et al. (2000a) indicate early time flux decay with $\alpha_1 \sim 1.2$ which steepens by about 0.3 dex around 2 days after the burst. The brightness of the host or intervening galaxy has been estimated as $R = 24.56 \pm 0.14$ mag by Halpern et al. (2000). Both optical and X-ray light curves seem to support the presence of jet rather than a simple spherical shock. In contrast, the light curve at the radio wavelength is unusual (Frail et al. 2000). The spectral index between X-ray and optical/near-IR is 0.8 ± 0.1 in the synchrotron cooling regime. The peak frequency of the fireball is $(2.1 \pm 0.6)\ 10^{14}$ Hz in near-IR region while the cooling frequency appears to lie between optical and X-ray at ~ 20 MGHz.

2.4 GRB 000301c

Smith, Hurley & Cline (2000) reported All Sky Monitor on the RXTE, Ulysses and NEAR detection of a burst at 09:51:37 UT on 1 March 2000. Multi-wavelength observations of the afterglow show peculiar light curves. It has been studied at optical by Bhargavi & Cowsik (2000), Masetti et al. (2000b), Sagar et al. (2000b), Jensen et al. (2001) and Rhoads & Fruchter (2001) and at radio by Berger et al. (2000). Stecklum et al. (2001) estimate the degree of linear polarization < 30 % using near-infrared observations taken at $\Delta t = 1.8$ day. The redshift is measured as $z = 2.0404 \pm 0.0008$ (Jensen et al. 2001). The light curve exhibits flux decay superposed with a short-lived achromatic variability during 3-5 days with $\alpha_1 = 1.2 \pm 0.1$ and $\alpha_2 = 3.0 \pm 0.5$. The value of t_b is 7.6 ± 0.5 day. The break in the light curve is attributed to the presence of jet. However, the cause of short-lived variability is debatable. Bhargavi & Cowsik (2000) argue that it could be due to a major burst followed after a short interval by a minor burst, each being represented by different flux decay constants. On the other hand, Garnavich, Loeb & Stanek (2000) and Gaudi, Granot & Loeb (2001) interpret it as microlensing event superposed on power-law flux decays typical for jet model. Dai & Lu (2001) propose a non-standard model in which an initial ultra-relativistic shock in a dense medium rapidly evolved to the non-relativistic phase in a day after the burst and in the process the shock was refreshed by strongly magnetized millisecond pulsar through magnetic dipole radiation which caused the observed peculiarity in the light cuve of the afterglow. Panaitescu (2001) found that the power-law distribution of the shock-energized electrons of the afterglow is hard, with index $p \sim 1.5$; the cooling frequency is below optical; the peak frequency seems to lie in millimeter region and the properties of the light curve and spectral index are best understood by a sideways expanding jet in an ambient medium of number density (n) ~ 25 cm^{-3}.

2.5 GRB 000926

This burst with a fluence of ~ 22 μerg cm^{-2} above 20 keV was detected on 26 September 2000 at 23:49:33 UT by the Ulysses, KONUS and NEAR (Hurley, Mazets & Golenetskii 2000). Multicolour optical light curves of the afterglow are presented by Fynbo et al. (2001), Price et al. (2001) and Sagar et al. (2001) while radio, HST and Chandra X-Ray Observatory observations of the OT are studied by Harrison et al. (2001). The afterglow is thus one of the best studied to date and provide valuable opportunity for understanding the GRB events. The optical light curves show a steepening of the flux decay as expected for an anisotropic fireball losing collimation with the fall of the bulk Lorentz factor. The early and late time flux decay constants are 1.4±0.1 and 2.6±0.06 respectively with $t_b \sim 1.7$ day. The light curve flattens $\sim$ 6 day after the burst which is due to the contribution of relatively bright host galaxy with $R = 23.87\pm0.15$ mag estimated by Fynbo et al. (2001). The spectral energy distribution indicates intrinsic extinction amounting to $E(B-V) = 0.36\pm0.02$ mag. In order to explain the observed broad spectral energy distribution, Harrison et al. (2001) invoke inverse Compton scattering. The excess X-ray emission detected for the first time in a GRB afterglow imply that the GRB exploded in a reasonably dense (n ~ 30 cm^{-3}) medium, consistent with a diffuse interstellar cloud environment.

3. Comparison with the Fireball model and Energetics

The current understanding of the GRBs events is that they arise when a massive explosion, known as a fireball, releases a large ($\sim M_{\odot}c^2$) amount of kinetic energy into a volume of $\leq$ 1 light millisecond across. When this ultra-relativistic (Lorentz factor $\Gamma \geq 300$) outflow of particles interacts with surrounding material, both forward (external) and reverse (internal) shocks are formed. The GRB itself is considered to be the result of a series of internal shocks within a relativistic flow while the afterglows are due to the external shocks driven in the ambient medium surrounding the GRB. The afterglow emissions are most likely synchrotron radiation (Sari, Piran & Narayan 1998; Piran 1999). If the GRB emission is not spherical but collimated, like jets, into a small solid angle, an achromatic break accompanied with a marked steepening are expected in the afterglow light curves when the jet makes the transition to sideways expansion after the relativistic Lorentz factor drops below the inverse of the opening angle of the initial beam (Mészáros & Rees 1999; Rhoads 1999; Sari et al. 1999; Huang et al. 2000b). The time of occurrence of the break in the light curve depends upon the opening angle of the collimated outflow. At late times, when the evolution is dominated by the lateral spreading of the jet, the value of α is expected to approach p while the value of β is expected to be $\alpha/2$ if the cooling frequency is below the observing frequency and $(\alpha-1)/2$ otherwise (Sari et al. 1999). The slope of the light curve before the break is then expected to be $3\beta/2$ (Sari et al. 1998). The values of early (α_1^p) and late (α_2^p) time flux decay constants can thus be predicted from observed values of β for the adiabatic jet synchrotron model. The values thus derived for the GRBs under discussions are listed in Table 2. A comparison of the predicted values with the corresponding observed values of flux decay constants (see Table 2) indicates that the afterglow emission from all of them except GRB 991208 is of jet type and not spherical, and that the cooling frequency is above the range of observed frequencies. In the case of GRB 991208, rapid decay with flat spectral energy distribution indicates that most probably break in the light curve occurred even before the first optical observations. We therefore conclude that the effects of beaming are present in the light curves of all 5 GRB afterglows observed from Nainital.

The anisotropy of the initial ejection needs to be incorporated into the derived energetics of the burst. The known redshifts for the GRB afterglows yield a minimum luminosity distance (see Table 2) for standard Friedmann cosmology with Hubble constant $H_0 = 65$ km s^{-1} Mpc^{-1}, cosmological density parameter $\Omega_0 = 0.2$ and cosmological constant $\Lambda_0 = 0$ (if $\Lambda_0 > 0$ then the inferred distance would increase). If the original emission were isotropic, the observed fluences above 20 keV yield the total γ–ray energy release which are always $> 10^{53}$ erg. However, the t_b values estimated for them imply, using the expression in Sari et al. (1999), a jet opening angle (θ) of few degrees. This means that the actual energy released from the GRBs is reduced by a factor depending upon the value of θ relative to the isotropic value and becomes $\leq 10^{52}$ erg (see Table 2).

4. Discussions and Conclusions

During 1999 and 2000, successful optical observations have been obtained for GRB 990123, GRB 991208, GRB 991216, GRB 000301c and GRB 000926 afterglows from Nainital. In the case of GRB 000301c, the earliest optical observations are obtained by us. From the point of view of the flux decay there are mainly three types of GRB afterglows:-

1. Shallow flux decay with $\alpha \sim 1.2$; like the first two and up to now the longest and best observed light curves from GRB 970228 and GRB 970508 afterglows. The emissions from such GRBs are probably spherical or at least have large opening angle. None of the GRB afterglows observed from Nainital belongs to this group.
2. Fast flux decay with $\alpha \geq 2$; like GRB 980326, GRB 980519 and GRB 991208 OTs. The emissions from such GRBs are most probably with narrow jets in which break in the light curve occurred very early even before the first optical observations could be taken.
3. In addition to GRB 990123, GRB 991216, GRB 000301c and GRB 000926 afterglows discussed here, breaks in the optical light curves of GRB 990510 (Stanek et al. 1999),

and GRB 990705 (Masetti et al. 2000a) afterglows are also observed. In these cases, early time flux decay constant is shallow while late time flux decay is fast. These are the best candidates for the presence of jets in GRB emissions. The steepening in the light curves occurred generally within 2 to 2.5 day after the burst, except for GRB 000301c. The difference ($\Delta\alpha = \alpha_2 - \alpha_1$) between early and late time flux decay constants ranges from ~ 0.3 (for GRB 991216) to ~ 1.8 (for GRB 000301c). The cause of such differences and the absence of break in the light curves of some GRB afterglows needs further investigations.

The overall flux decays observed in the light curves of all GRB afterglows discussed here are well understood in terms of a jet model. However, in the case of GRB 000926, a much steeper late decay of X-ray flux with $\alpha > 4$ and the flat spectral index (~ 0.8) is not consistent with the simple jet model which predicts similar late flux decay in both optical and X-ray regions (Sagar et al. 2001). Similarly, the flux decays of GRB 991216 afterglow (cf. Frail et al. 2000) are also different at X-ray, optical and radio wavelengths. The near-IR bump observed in the spectrum of GRB 991216 afterglow also can not be understood in terms of standard fireball model (Frail et al. 2000). The peculiarity in the light curves of GRB 000301c seems to be not due to synchrotron emission of the fireball. Another area of possible disagreement with the standard fireball model is the sharpness of the break in the light curve. While the expected sharpness of the transition could depend on the density profile of the ambient medium (Kumar & Panaitescu 2000), the very sharp transitions seen in GRB 000301c and GRB 000926 would be difficult to quantitatively explain in the standard fireball model. This is an area that deserves a detailed theoretical study.

Multi-wavelength observations of GRB afterglows obtained so far, though they are mostly after few hours of the burst, and energetics clearly indicate that long duration GRBs are produced from stellar-like systems e.g. merging remnants or explosions of massive stars. The line width and intensity of the two emission features discovered in the $X-$ray spectrum of the GRB 991216 (Piro et al. 2000) taken with the Chandra $X-$Ray Observatory imply that the GRB progenitor was a massive star system that ejected, before the burst, $\sim 0.01 M_\odot$ of iron at a velocity $\sim 0.1c$. The Chandra $X-$Ray Observatory observations reported by Harrison et al. (2001) for the GRB 000926 afterglow imply that the GRB exploded in a reasonably dense ($n \sim 30$ cm^{-3}) medium, consistent with a diffuse interstellar cloud environment. The presence of dust extinction amounting to $A_v \sim 1$ mag in the host galaxies of GRB 971214 (Ramaprakash et al. 1998); GRB 980329 (Palazzi et al. 1998); GRB 980703 (Vreeswijk et al. 1999); GRB 000418 (Klose et al. 2000) and GRB 000926 (Sagar et al. 2001) afterglows also broadly supports the proposal that GRBs could be associated with massive stars embedded in star-forming regions of the GRB host galaxies (Paczyński 1998). However, there is no clue about the origin of short duration, hard GRBs. Also, follow-up observations within few minutes to few hours of the burst are generally not available even for long duration GRBs. The High Energy Transient Explorer launched last year is expected to make the desired observations possible as it will provide accurate positions of both short and long duration GRBs within a few minutes of the burst.

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