

Properties of the host galaxy of the gamma-ray burst 970508 and local star-forming galaxies

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Abstract. Recent observations of GRB970508 with the SAO–RAS 6-m telescope in July–August 1998 show that the optical transient (OT) has varied very little since November 1997. Here we report on the behaviour of the BVR_cI_c light-curves for up to 470 days from the date of the GRB occurrence. After $\simeq 200$ days any power-law decay has ceased and the OT contamination of the host galaxy flux is already less than the observational errors. We derive the broad band spectrum of the host galaxy, without OT, and compare it with the average continuum spectra of galaxies of different Hubble types. The spectral distribution of normal galaxies with types earlier than Sbc is confidently excluded. For $H_0 = 60 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and three Friedmann models with matter density and cosmological constant parameters $(\Omega_m, \Omega_\Lambda) = (1,0); (0,0); (0,1)$ the derived host galaxy absolute magnitudes ($M_{B_{rest}}$) are -18.0 ± 0.3 , -18.5 ± 0.3 and -19.0 ± 0.3 respectively. The absolute B magnitude ≈ -18.5 corresponds to the luminosity $L_B \approx 0.1L_{\text{gen}}^*$ where L_{gen}^* is the knee of the local general Schechter luminosity function. However, the luminosity of the GRB host is roughly at the knee of the local luminosity function L_{late}^* for late type galaxies Sd–Sm–Irr (Binggeli et al. 1988). Comparison of the BVR_cI_c spectral energy distribution of the GRB host with local starburst galaxies leads to best fits for the Scd starburst H II galaxy NGC7793 and the blue compact galaxy Mrk 1267. The position of the host galaxy in the M_B vs. $\log D_{25}$ diagram for local late-type LEDA (Lyon-Meudon Extragalactic database) galaxies allows us to attribute the GRB970508 host galaxy to the blue compact galaxies.

Key words: galaxies: starburst – galaxies: photometry – cosmology: observations – gamma rays: bursts

1. Introduction

At the present time, eight optical counterparts for gamma-ray bursts (GRB) are known, all of them after detection with the Wide Field Cameras on board the Italian-Dutch BeppoSAX

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observatory. They are: GRB 970228 (Groot et al. 1997; Van Paradijs et al. 1997), GRB 970508 (Bond 1997), GRB 971214 (Halpern et al. 1997), GRB 980326 (Groot et al. 1998; Eichelberger et al. 1998), GRB 980329 (Djorgovski et al. 1998), GRB 980519 (Jaunsen et al. 1998), GRB 980613 (Hjorth et al. 1998), GRB 980703 (Frail et al. 1998; Zapatero-Osorio et al. 1998). Galama et al. (1998a,b) reported about a possible supernova optical candidate for GRB 980425. But a connection between type-Ib SN and the GRB (Pian et al. 1998) is still unclear. In all but GRB 980613 it is possible to speak about the detection of an underlying host galaxy (Hogg & Fruchter 1998).

This paper is dedicated to a detailed analysis and interpretation of new BVR_cI_c photometrical data of the GRB970508 host galaxy. Since our BVR_cI_c observations in November 1997 of the optical source related to GRB970508, we have continued them in January, July and August 1998. These observations were undertaken with the main purpose to check how constant this faint ($R_c \approx 25$) source is up to 470 days after the gamma-ray burst, i.e. when the contribution of the OT can be considered to be comparable with or even less than the observational errors of brightness estimates in all BVR_cI_c photometrical bands. These observations do show that the optical counterpart has varied very little since November 1997 and allow us to determine the apparent magnitude of the host galaxy. In this paper we compare the BVR_cI_c spectrum of the GRB970508 host galaxy with spectral energy distributions of normal galaxies of different Hubble types and extend the comparison to include local star-forming galaxies.

2. The GRB970508 host galaxy – recent BVR_cI_c observations

Table 1 presents the results of our observations with the 6-m telescope of SAO–RAS in November (I_c band) and in December 1997 (B band), in January, July and August 1998 (BVR_cI_c bands) in one photometric system. The photometrical analysis and details are reported in Sokolov et al. (1998). The B point in Dec. 1997 and B , R_c points in Aug. 1998 were obtained by A. I. Kopylov.

Table 1. Observations summary ($t_o = 8.904$ May 1997).

Date UT	$t - t_o$ (days)	Band	Time _{exp} (s)	Magnitude
25.00 Nov. 1997	201.09	I_c	4800	23.90 ± 0.14
01.00 Dec.	206.01	B	2400	25.75 ± 0.30
24.87 Jan. 1998	260.96	R_c	2580	24.96 ± 0.17
24.87 Jan.	260.96	V	2400	25.44 ± 0.25
22.99 Jul.	440.08	R_c	3000	24.90 ± 0.16
23.95 Jul.	441.05	B	2400	25.80 ± 0.30
23.95 Jul.	441.05	V	2000	25.25 ± 0.22
23.95 Jul.	441.05	I_c	2000	24.07 ± 0.25
21.74 Aug.	469.84	B	4200	25.77 ± 0.19
21.74 Aug	469.84	R_c	3000	24.99 ± 0.17

If BVR_cI_c magnitudes of the optical counterpart did not change during the last half-year we can conclude that we observe a pure host galaxy without the optical remnant of GRB970508. Corresponding stellar magnitudes and fluxes are given in Table 2, case (1). On the other hand, the brightness may have changed within the errors, and it may still be possible to describe the brightness decay of the optical remnant by a power-law relation during about a year after the burst occurrence. In that case the flux can be determined by fitting the observed BVR_cI_c light curves with a two-component model, a sum of the optical remnant of GRB970508, fading according to a power-law, and a constant brightness host galaxy (see Zharikov et al. (1998) for details): $F = F_o \times t^\alpha + F_c$.

To investigate the possible variability of a faint source we must avoid any systematic shifts in the observational data due to different photometric systems in various instruments. That is why for these χ^2 fits (Table 2.) we used the data from the 6-m telescope only (from 10.77 May 1977 UT to 21.74 Aug 1988 UT) unlike what was shown in the paper by Zharikov et al. (1998) for R_c and B filters. So, the four independent BVR_cI_c power-law fits with different slopes (Fig. 1) give magnitudes for the host galaxy reported in Table 2 case (2). In comparison, an average power-law slope with $\langle \alpha \rangle = -1.25 \pm 0.05$ gives the magnitudes for the constant source given in Table 2, case (3).

Additionally, observational spectra in Fig. 2 are presented for the 3 cases: the recent observations (case (1)) and the two fits described above. In cases (2) and (3) we indicate not observed, but “theoretical” values and fluxes corresponding to t tending to infinity. As can be seen from Table 1, the magnitude values in each individual band are almost constant during the period Nov. 97 – Aug. 98, the last observations giving the **upper** estimates of the host brightness (spectrum 1 in Fig. 2). However if we force-fit a power-law brightness change then **lower** estimates are derived by fitting each observed band (spectrum 2 in Fig. 2). Fig. 2 shows the broad-band spectrum of the GRB970508 host galaxy compared with the typical spectra (Pence 1976) of different Hubble types of galaxies normalized to the average value of the I_c flux as measured for the host galaxy.

So, we choose the BVR_cI_c spectrum of the host galaxy as given in Table 2 (case (2)) for interpretation in the following

Table 2. Magnitudes and fluxes for the host galaxy of GRB970508. (1) The recent observational magnitudes from Table 1. (2) χ^2 fits: $F = F_o \times t^\alpha + F_c$. (3) The same χ^2 fit for $\langle \alpha \rangle = -1.25 \pm 0.05$. The photometry with the BTA was reported by Sokolov et al. (1998) and Zharikov et al. (1998).

Band	Magnitude	$\log F_{\lambda,obs}$ $\left(\frac{\text{erg}}{\text{cm}^2 \text{ s } \text{\AA}}\right)$	χ^2 (d.o.f)
(1)			
B	25.77 ± 0.19	-18.52 ± 0.07	
V	25.25 ± 0.22	-18.54 ± 0.09	
R_c	24.99 ± 0.17	-18.66 ± 0.07	
I_c	24.07 ± 0.25	-18.58 ± 0.10	
(2)			
B ($\alpha = -1.32 \pm 0.05$)	25.99 ± 0.11	-18.60 ± 0.05	14.2/11
V ($\alpha = -1.24 \pm 0.07$)	25.65 ± 0.17	-18.70 ± 0.07	36.6/14
R_c ($\alpha = -1.25 \pm 0.04$)	25.16 ± 0.09	-18.73 ± 0.04	52.7/19
I_c ($\alpha = -1.18 \pm 0.07$)	24.17 ± 0.28	-18.62 ± 0.11	44.3/12
(3)			
B	26.15 ± 0.16	-18.67 ± 0.06	18.9/12
V	25.61 ± 0.16	-18.69 ± 0.07	36.1/15
R_c	25.16 ± 0.09	-18.73 ± 0.04	52.7/18
I_c	23.99 ± 0.25	-18.55 ± 0.10	47.1/13

sections. However, all other cases in Table 2 should be also kept in mind (as well as the observational errors) when comparing the results with the spectra of local galaxies.

Zharikov et al. (1998) report a photometric study of the field of GRB970508. They performed BVR_cI_c observations of the OT and of 3 nearby galaxies (named G1, G2 and G3, see their paper for more details). They conclude that only G2 may be responsible for the observed absorption system at redshift 0.767 (Metzger et al. 1997a). G1 and G3 are very blue galaxies with z probably greater than 1, maybe in the range 1.5–2.5. There are no optical lines for identifying redshifts in that z range. So it is not surprising that the spectrum of the nearby galaxy G1 shows a relatively featureless, blue continuum (Bloom et al. 1998). Fig. 3 shows the broad-band spectrum of the field galaxy G2 (G1 and G3) compared with those of typical galaxies of different Hubble types at $z = 0.767$.

3. Absolute magnitudes of the GRB970508 host galaxy

In order to compare the properties of the host galaxy with those of the local galaxy population, one needs to derive possible intervals for absolute magnitude, linear size, and spectral energy distribution. To do this a cosmological model, redshift, and K-correction are required.

The estimate of intrinsic physical parameters of extragalactic objects with redshifts approaching 1 depends rather sensitively on the adopted cosmological model. The standard Friedmann model contains three parameters: Hubble constant H_0 ,

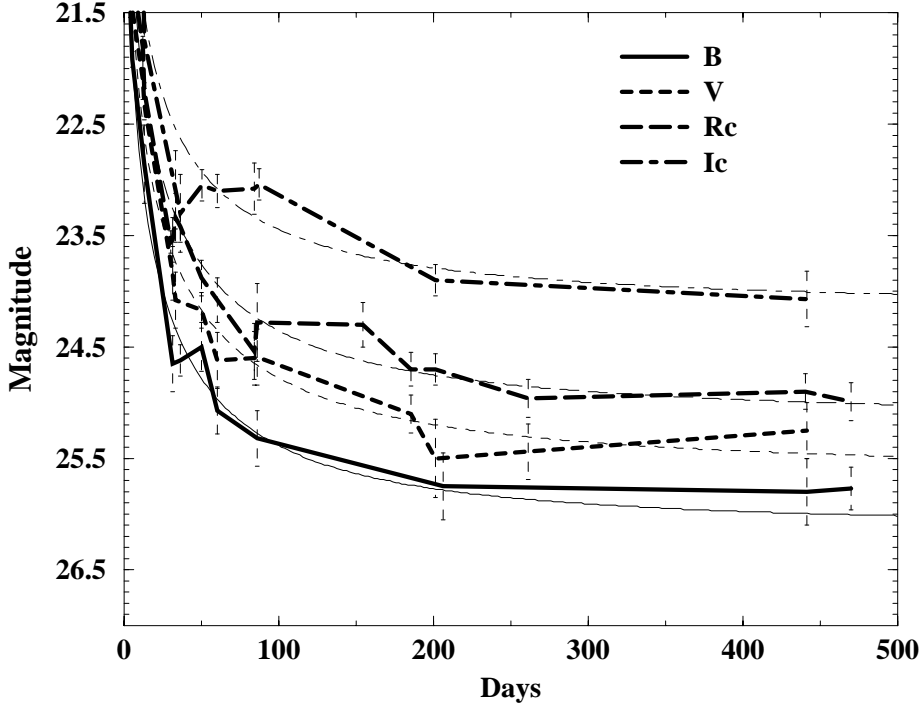


Fig. 1. The recent BVR_cI_c light-curve behavior of the OT + host galaxy of GRB970508 up to $\simeq 470$ days from the time of the GRB. Four independent BVR_cI_c power-law fits ($F = F_o \times t^\alpha + F_c$, see Table 2) with different α are indicated by the thin lines.

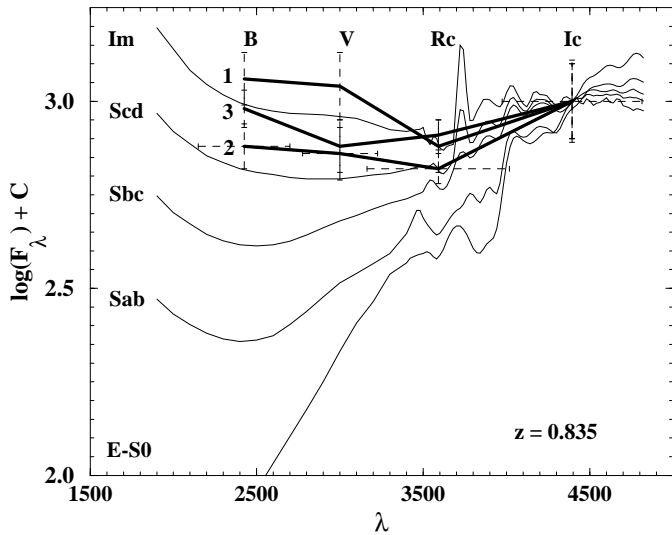


Fig. 2. A comparison of GRB970508 broad-band rest-frame ($z = 0.835$) spectrum $\log(F_\lambda) = \log F_\lambda(\text{obs}) + C$ to average continuum spectra of galaxies of different Hubble types. No. 1, 2, 3 correspond to the three cases reported in Table 2. The spectra were shifted by some arbitrary constants for the best fits. F_λ is in $\text{erg cm}^{-2} \text{s}^{-1} \text{\AA}^{-1}$ and λ is in \AA . FWHM of each filter for λ_{eff} with the account for $z = 0.835$ are denoted by dashed horizontal lines with bars.

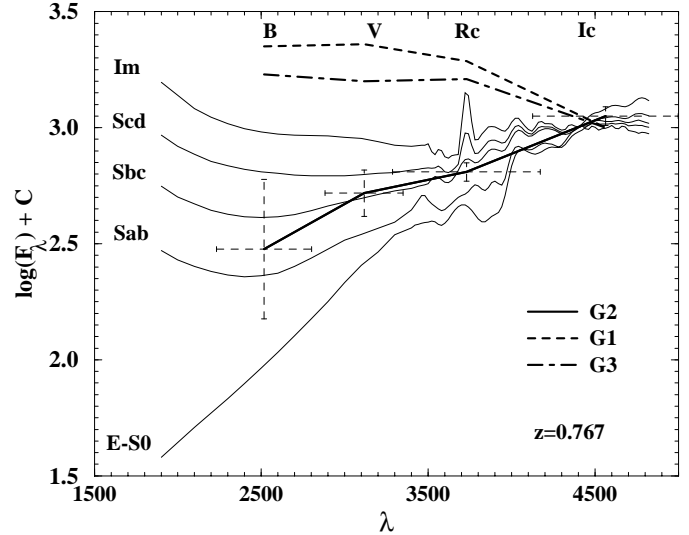


Fig. 3. Comparison of G2 (G1 and G3) broad-band rest-frame spectra ($z = 0.767$) to typical average continuum spectra of galaxies. F_λ is in $\text{erg cm}^{-2} \text{s}^{-1} \text{\AA}^{-1}$ and λ is in \AA . See also the caption of Fig. 2. Magnitudes and fluxes for GRB host field objects were taken from Zharikov et al. (1998).

matter density parameter Ω_m , and cosmological constant parameter Ω_Λ . Recent studies of the Hubble constant put it within the range $50\text{--}70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ (see Theureau et al. 1997). In this paper we adopt $H_0 = 60 \text{ km s}^{-1} \text{ Mpc}^{-1}$. The values of Ω_m and Ω_Λ are observationally less constrained. The recent work on the $m - z$ test with supernovae of type Ia at redshifts up to 1 by Garnavich et al. (1998) makes it imperative to consider in

addition to the standard inflationary model also an empty universe with cosmological constant. For a review of modern cosmological models and the needed mathematical relations, see Baryshev et al. (1994). Here we use three Friedmann models which conveniently limit reasonable possibilities:

$$H_0 = 60 \text{ km s}^{-1} \text{ Mpc}^{-1}, \Omega_m = 1, \Omega_\Lambda = 0 \text{ (A)}$$

$$H_0 = 60 \text{ km s}^{-1} \text{ Mpc}^{-1}, \Omega_m = 0, \Omega_\Lambda = 0 \text{ (B)}$$

$$H_0 = 60 \text{ km s}^{-1} \text{ Mpc}^{-1}, \Omega_m = 0, \Omega_\Lambda = 1 \text{ (C)}$$

For these models the relation $\Omega_m + \Omega_\Lambda + \Omega_k = 1$ is valid, where $\Omega_m = \rho_0 8\pi G / 3H_0^2$, $\Omega_\Lambda = \Lambda c^2 / 3H_0^2$, and $\Omega_k = -kc^2 / R_0^2 H_0^2$. Here ρ , Λ , k , and R are density, cosmological constant, curvature constant, and radius of curvature, respectively, and “0” denotes the present epoch. The luminosity distance R_{lum} , the angular size distance R_{ang} and the proper metric distance R_p are connected by the relation:

$$R_{\text{lum}} = R_{\text{ang}}(1+z)^2 = R_p(1+z) \quad (1)$$

where the proper distances for the adopted models are given by

$$R_p = \begin{cases} R_H \frac{2(z - \sqrt{1+z} + 1)}{1+z} & \text{for model A,} \\ R_H \frac{z(1+0.5z)}{1+z} & \text{for model B,} \\ R_H z & \text{for model C.} \end{cases} \quad (2)$$

Here $R_H = c/H_0$ is the present value of the Hubble radius. The absolute magnitude $M_{(i)}$ of the source observed in filter (i) can be calculated from the magnitude-redshift relation

$$M_{(i)} = m_{(i)} - K_{(i)}(z) - 5 \log(R_{\text{lum}}/\text{Mpc}) - 25 \quad (3)$$

where $m_{(i)}$ is the observed magnitude of the object in the photometric band system (i) and $K_{(i)}(z)$ is the K-correction at redshift z , calculated from the rest-frame spectral energy distribution.

The linear size l of an object having an angular size θ is given by

$$l = \theta R_{\text{ang}} = \theta R_p / (1+z) \quad (4)$$

For $z = 0.835$, we get from Eq. (4) the linear sizes as normalized to $\theta = 1''$:

$$l \approx 6.9 \text{ kpc} (\theta/1'')$$

$$l \approx 8.5 \text{ kpc} (\theta/1'')$$

$$\text{and } l \approx 11.1 \text{ kpc} (\theta/1'')$$

A detailed discussion on the possible range of GRB970508 linear size is given in Sect. 5, after the discussion of the spectral energy distribution from our broad band photometry data, which can restrict the possible type of the host galaxy.

The first spectral observations of the GRB970508 optical transient were obtained with the Keck-II 10-m telescope on 11 May 1997 (Metzger et al. 1997a). Two absorption line systems were detected: 1) $z = 0.835$ for the elements Fe II, Mg II and Mg I, 2) $z = 0.767$ for Mg II doublet. Such absorption features are commonly seen in the spectra of QSOs and are usually associated with galaxies along the line of sight to the QSO. This gives rise to two possibilities: 1) we have detected the host galaxy with $z = 0.835$, or 2) we have detected a foreground galaxy on the line of sight, and the true host has $z > 0.835$. Further optical follow-up observations, both imaging and spectroscopy, performed again with the Keck-II in June and November 1997 and February 1998, revealed an emission line [O II] corresponding to $z = 0.835$. The faint host galaxy of GRB970508 seems to be responsible for this line (Metzger et al. 1997b; Bloom et al. 1998).

For the calculation of the intrinsic parameters of the GRB host galaxy we adopt BVR_cI_c magnitudes which correspond

to case 2 with none or minimal OT contamination (see Table 2). The central $\lambda_{\text{obs}} = \lambda_{\text{eff}}$ for our photometric system are equal correspondingly to: $\lambda_B = 4448 \text{ \AA}$, $\lambda_V = 5505 \text{ \AA}$, $\lambda_R = 6588 \text{ \AA}$, $\lambda_I = 8060 \text{ \AA}$. (Corresponding FWHMs are equal to: $\Delta\lambda_B = 1008 \text{ \AA}$, $\Delta\lambda_V = 827 \text{ \AA}$, $\Delta\lambda_R = 1568 \text{ \AA}$, $\Delta\lambda_I = 1542 \text{ \AA}$.) It is a useful coincidence that for $z = 0.835$ the observed wavelength of the R_c filter corresponds to the rest band U_{rest} ($\lambda_U = 3652 \text{ \AA}$), and I_c filter corresponds to the rest band B_{rest} ($\lambda_B = 4448 \text{ \AA}$). By a simple shift λ_{obs} to $\lambda_{\text{emit}} = \lambda_{\text{obs}}/(1+z)$, in the $\log(F(\lambda_{\text{obs}}))$ vs. λ_{obs} diagram, we have four points of the rest frame continuum spectral distribution, which allow us to make a comparison with the available spectral distributions measured for local galaxies (see also Figs. 2 and 3).

The K-correction in Eq. (3) can be calculated from the standard formula (Oke & Sandage 1968):

$$K_{(i)}(z) = 2.5 \log(1+z) + 2.5 \log \frac{\int_0^\infty F_\lambda S_{(i)}(\lambda) d\lambda}{\int_0^\infty F_{\lambda/(1+z)} S_{(i)}(\lambda) d\lambda} \quad (5)$$

In this formula F_λ is the rest-frame spectral energy distribution and $S_{(i)}(\lambda)$ is the transmission curve for filter (i). As we mentioned above, the effective wavelength of the I_c band for $z = 0.835$ happens to correspond to the B_{rest} band. This allows us to calculate directly from Eq. (5) the value of the K-correction for the B -magnitude, replacing the second term with $2.5 \log(F_{B_{\text{rest}}}/F_{\lambda_B/(1+z)}) \approx 2.5 \log(F_{I_{\text{obs}}}/F_{B_{\text{obs}}})$. The calculation yields

$$K_B = +0.6 \pm 0.3$$

The absolute B_{rest} magnitudes from Eq. (3), (with K-correction $+0.6$ for $z = 0.835$) are: $M_{B_{\text{rest}}} = -18.0 \pm 0.3$ for model A, $M_{B_{\text{rest}}} = -18.5 \pm 0.3$ for model B, and $M_{B_{\text{rest}}} = -19.0 \pm 0.3$ for model C.

We also estimate that the K-correction for the field G2 galaxy at $z = 0.767$ is $K_B \approx 2.1$. (Only an upper limit exists for the flux at B , see Fig. 2.). This allows us to derive $M_{B_{\text{rest}}} \lesssim -18.4, -18.9, -19.4$ for the cosmological models A, B and C, respectively. Following Natarajan et al. (1997) we can now calculate a lower limit to the maximum radius R_{max} of the gaseous halo of the galaxy G2 which can produce the observed Mg II absorption line system: $R_{\text{max}} \gtrsim 38, 42$ and 46 kpc (models A, B and C). The angular distance between the GRB host and G2 is about $4''$ which corresponds to a linear projected radius of 29, 35 and 45 kpc, so we may conclude that the G2 galaxy could really be responsible for the observed absorption line Mg II at $z = 0.767$ in the spectrum of the GRB970508 OT (Metzger et al. 1997a).

4. Comparison with ultraviolet spectra of local galaxies

In Fig. 2 we compared the BVR_cI_c spectrum of the GRB970508 host galaxy with the spectral energy distributions of normal galaxies of different Hubble types. It appears difficult to match the observed spectrum with any single Hubble type. However, for the GRB970508 host galaxy one may confidently

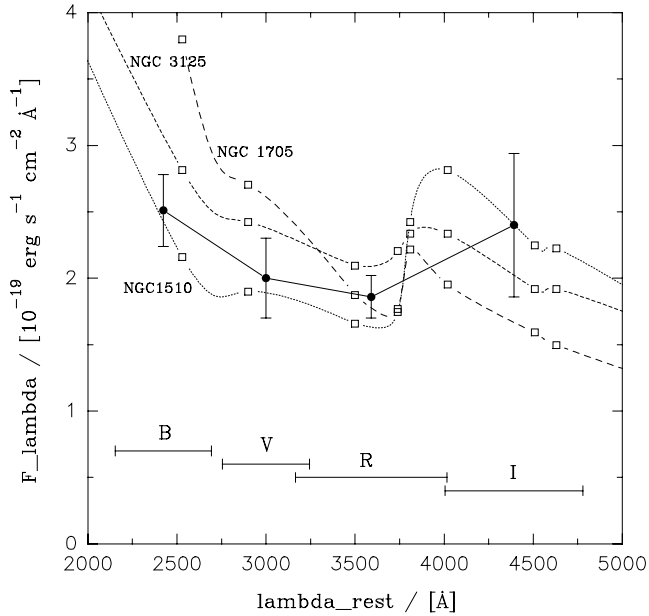


Fig. 4. A comparison of the GRB970508 broad-band $BVRcIc$ spectrum with continuum spectra F_λ of some blue compact dwarf galaxies in Kinney et al. (1993). The fluxes from Table 2 (case (2)) have been scaled arbitrarily to the best fit. The observing bands have been shifted to the rest frame ($z = 0.835$) of GRB970508. Filled symbols indicate the observations and the smooth curves connect the selected continuum points, marked with open boxes. See text for details.

reject early type galaxies from E to Sb. Here we extend the comparison to include local star-forming galaxies.

Figs. 4 and 5 show a comparison between the continuum fluxes of the GRB970508 host (shifted to the rest frame) and continuum spectra of some star-forming galaxies selected from the ultraviolet atlas of Kinney et al. (1993). We restricted the search to the absolute magnitude interval $-21 < M_B < -17$ and looked for spectra that resemble the observed broadband spectrum of the GRB970508 host galaxy. For the latter task we used the tables in McQuade et al. (1995) and Storchi-Bergmann et al. (1995) who list continuum fluxes at selected wavelengths in the interval 1355–7525 Å. The catalog fluxes have been marked with open boxes in Figs. 4 and 5. The fluxes have been scaled arbitrarily and smooth lines connect the points for better comparison with observed points. The observed continuum points are reported with the associated error bars (a galactic extinction of $A_V = 0.08$ was assumed (Djorgovski et al. 1997; Sokolov et al. 1998)). We have checked that changing the galactic extinction from a low value of 0.01 to a higher value of 0.15 does not essentially alter the spectrum.

All galaxies in Figs. 4 and 5 display also fairly strong emission lines, most notably at $\lambda = 3727$ Å [O II], $\lambda = 4861$ Å H_β , $\lambda = 4959$, 5007 Å [O III] and $\lambda = 6563$ Å H_α , which are caused by their star-forming activity. Of these strong lines only $\lambda = 3727$ Å [O II] falls within the range of our continuum observations, close to the R_c band.

We conclude that the best fits to the observed spectrum of the host galaxy are displayed by blue compact S0 dwarf

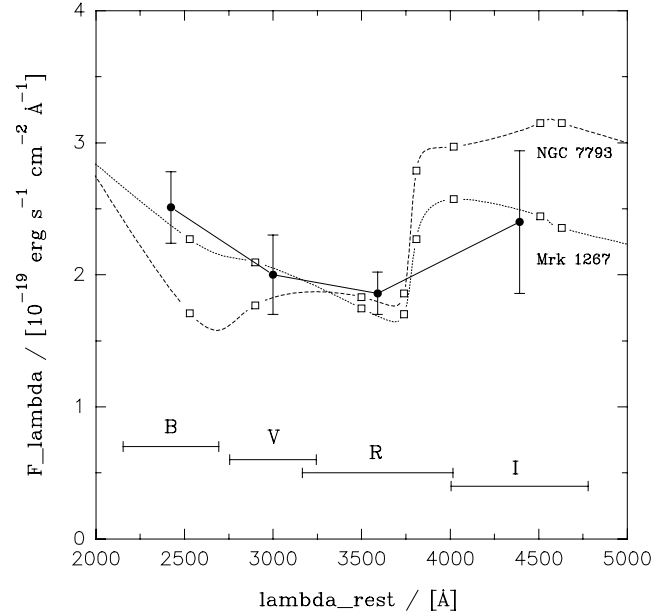


Fig. 5. A comparison of the GRB970508 broad-band spectrum from Table 2 (case (2)) with continuum spectra F_λ of a blue compact galaxy (Mrk 1267) and an Scd H II galaxy (NGC 7793). See also the caption of Fig. 4 and text for details.

galaxy NGC 1510, the star-forming H II galaxy NGC 7793 and the blue compact galaxy Mrk 1267. The absolute B magnitude of NGC 7793 (-18.0), which has Hubble type Scd, is practically the same as that of the host, while Mrk 1267 is much brighter (-20.8) and its Hubble type is not well defined.

5. Discussion

The presence of absorption lines as characteristic of star formation regions like Mg II, Mg I and Fe II (Metzger et al. 1997a), evidence for emission line $\lambda = 3727$ Å [O II], and the similarity of the observed GRB host spectrum to the spectral energy distribution in a Scd galaxy prompts us to inquire how the host galaxy might be related to the class of late-type spiral and irregular galaxies. The first step in such a study is to compare the properties of the GRB host galaxy with the galaxies in the local Universe, of which we have good knowledge. The second step is to understand possible deviation from the local galaxy population (normal, starburst, irregular) as an effect of evolution and/or selection.

The studies of the local luminosity function of types Sd - Sm - Irr (see e.g. Binggeli et al. 1988) indicate that these form a subclass among all galaxies with a knee in the luminosity function at about $M_B \approx -18$, -19 . So, the luminosity of the GRB host is roughly at the knee of the local luminosity function L_{late}^* . Though one should note that here the primary selection is not optical but comes from the gamma-ray burst, this may explain why overluminous galaxies do not dominate among detected GRB hosts.

In order to make a further comparison between the GRB970508 host and local galaxies, especially to utilize the

Table 3. Parameters of the galaxies used in the comparison of the UV spectra, extracted from LEDA. Distances r (with dispersions σ_r) are calculated using radial velocities corrected to Virgo infall and $H_0 = 60 \text{ km s}^{-1} \text{ Mpc}^{-1}$, except for NGC1705 (O’Connell et al. 1994) and NGC7793 (Puche & Carignan 1988). B_T are total apparent B-magnitudes, $\log d_{25}$ are log of 25 B-mag/arcsec² angular isophote diameters in units of 0.1 arcmin, D_{25} are linear 25 B-mag/arcsec² isophote diameters with dispersions $\sigma_{D_{25}}$.

PGC/LEDA id.	Alt. id.	Type	$\log d_{25}$	B_T	D_{25} (kpc)	$\sigma_{D_{25}}$ (kpc)	M_B	σ_{M_B}	r (Mpc)	σ_r (Mpc)
PGC 0014375	NGC 1510	S0	1.429	13.51	9.37	10.12	-16.77	0.63	11.41	0.14
PGC 0016282	NGC 1705	E-S0	1.270	12.76	2.71	1.11	-15.73	0.87	5.0 ¹	2.0 ¹
PGC 0029366	NGC 3125	E	1.047	13.47	5.59	0.85	-17.38	0.31	14.81	1.51
PGC 0032672	MK 1267		0.644	14.16	12.31	1.74	-20.75	0.59	96.04	0.72
PGC 0073049	NGC 7793	Scd	1.982	9.70	9.43	1.44	-17.95	0.24	3.38 ²	0.30 ²

absolute magnitude–linear size relation (M_B vs. $\log D_{25}$) we used the Lyon-Meudon Extragalactic database (LEDA) which currently lists the main astrophysical parameters for more than 165 000 galaxies. The data are collected from the major published galaxy surveys, and complemented with individual measurements. The parameters have been carefully reduced to a common system (of de Vaucouleurs et al. 1991) and corrected for any instrumental or observational imperfections (Paturel et al. 1997). The latest information on the status of LEDA and the data itself are available at <http://www-obs.univ-lyon1.fr/leda/>. Extracted from LEDA, parameters of the galaxies used in the comparison (Figs. 4 and 5) with the GRB970508 host UV spectra are shown in Table 3.

Fig. 6 shows the M_B vs. $\log D_{25}$ diagrams for four ranges of galaxy types from LEDA (Sbc-Sc, Scd-Sd, Sm, Irr). Different types have a well known relation, roughly following the dependence $M \approx 5 \log D + \text{const}$. The slope reflects what is expected from discs of different diameters with a constant average surface brightness. M_B and D_{25} are calculated as

$$M_B = B_T - 5 \cdot \log \frac{v}{H_0} - 25$$

$$D_{25} = \frac{\pi}{108} \frac{v}{H_0} \cdot 10^{\log d_{25}}$$

where B_T (total apparent B-magnitude), $\log d_{25}$ (log of 25 B-mag/arcsec² isophote diameter in units of 0.1 arcmin), and v (radial velocity in km s^{-1}) are from LEDA. Isophotal diameters were corrected for inclination and galactic absorption, and radial velocities for Virgo infall. The horizontal dotted lines in Fig. 6 indicate the allowed region of the present GRB host galaxy, as based on the absolute magnitudes derived from the models A, B and C.

In order to derive restrictions to the linear size, we use the result from HST measurements of Fruchter et al. (1998): the GRB970508 host galaxy has an exponential disk with a scale length r_0 of about 0.07 arcsec.

For a model disk with an exponential distribution of surface brightness from the center of the galaxy to its periphery a simple relation between the central surface brightness μ_0 , the 25 mag/arcsec² isophotal angular radius r_{25} (in arcsec), and the scale length r_0 (r_{25}/r_0) can be determined as:

$$25 - \mu_0 = \frac{r_{25}}{r_0} 2.5 \log(e).$$

If for an exponential (model) disk one chooses as observational central surface brightness a value $\mu_0 = 20.4 \text{ mag/arcsec}^2$, then the fraction r_{25}/r_0 is 4.24. For the angular scale length $r_0 = 0.07 \text{ arcsec}$, the corresponding angular diameter $2r_{25}$ turns out to be equal to $\sim 0.6 \text{ arcsec}$. The latter angular size of the GRB host galaxy corresponds to the isophote of 25 mag/arcsec² and is in good agreement with the upper limit of $\sim 0.4 \text{ arcsec}$ of the observable size of the GRB host obtained in previous HST/NICMOS observations (Pian et al. 1997). So, the linear diameter D_{25} would be in the range of $\sim 4\text{--}7 \text{ kpc}$ for the A, B, C cosmological models (4) and the allowed region for D_{25} is shown by vertical dotted lines in Fig. 6.

But in that case the GRB970508 host galaxy turns out to be in the region of blue compact galaxies with heightened central surface brightness. In other words the galaxy is on the same line in Fig. 6 (Scd–Sd) $M_B \approx -5 \log D_{25} + \text{const}$ where the blue compact Mrk 1267 with the continuum spectra (see Fig. 5) is located. There is a good correspondence (mentioned above, see Fig. 4) between the continuum UV spectrum and the BVR_cI_c broad-band GRB host spectrum.

6. Conclusions

The recent observations of the optical counterpart GRB970508 allow us to think that 470 days after the GRB the observed BVR_cI_c fluxes can be attributed only to the GRB host galaxy. Any contribution of OT is already less than observational errors. This allows us to calculate the intrinsic parameters of the GRB970508 host galaxy and to make the first step in the study of the properties of the GRB host galaxy by the comparison with the properties of galaxies in the local Universe, on which we have good knowledge.

But for the GRB redshift $z = 0.835$, the derived absolute magnitude and diameter, needed for comparison with local galaxies, depend on the adopted cosmological model. A change in the model parameters easily produces a change of 1 mag in the absolute magnitude of the host galaxy and a change of $\sim 50\%$ in diameter. We have measured the K_B corrections for the GRB970508 host galaxy and the neighbouring G2 galaxy, which are +0.6 and +2.1, respectively. Such corrections make absolute magnitudes brighter and shift them away from dwarf galaxies. The position and luminosity of one of the neighbouring

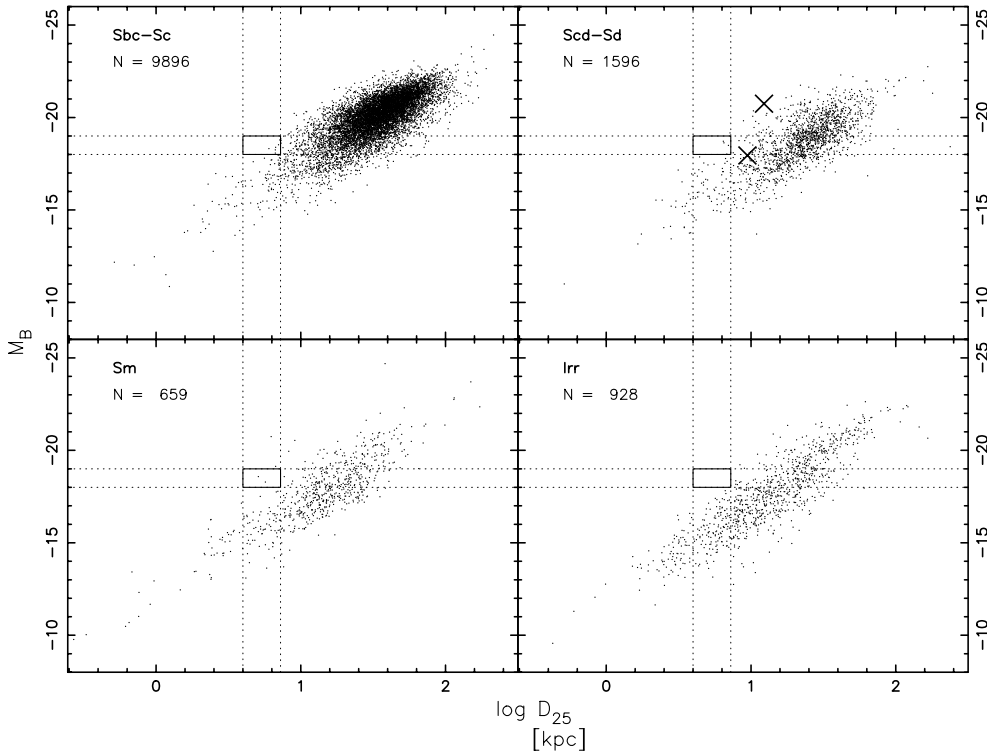


Fig. 6. Absolute magnitude M_B vs. linear diameter $\log D_{25}$ diagrams for galaxy types Sbc-Sc, Scd-Sd, Sm, and Irr, as extracted from LEDA. The region formed by the dotted lines, $-19.0 < M_B < -18.0$ and $4 < D_{25} < 7$ gives the derived location for the GRB host galaxy in this diagram. Crosses denote galaxies Mrk 1267 and NGC 7793 from Table 3. Their continuum spectra are similar to that of the GRB host.

G2 allows it to produce the $z = 0.767$ absorption line system in the spectrum of the GRB970508 OT on 11 May 1997.

The intrinsic physical properties of the possible host galaxy for GRB970508 correspond to a late-type galaxy, with its $M_B \approx -18.0, -19.0$ (depending on the cosmological model) clearly fainter than the knee of the general Schechter luminosity function at about -20.8 mag. However as demonstrated by Binggeli et al. (1988), the luminosity function essentially depends on the type of galaxies and their environment (field and clusters). For Sd + Sm galaxies the knee of the luminosity function is at $M_B \approx -18$ and hence the detected host of GRB970508 would be from the bright end of the range for this galaxy type. In terms of the classification by Binggeli (1994), the host belongs to his Sequence 3 and lies well away from the border between normal and dwarf galaxies traditionally taken to be around $M_B = -16$.

The spectral distributions of normal galaxies with types earlier than Sbc are confidently excluded for GRB970508 host galaxy. The comparison of the spectral distribution of the host galaxy with local starburst galaxies revealed that the best fits were given by the H II galaxy NGC7793 and the blue compact galaxy Mrk 1267. The position of the host galaxy in the M_B vs. $\log D_{25}$ diagram for local late-type LEDA galaxies and an analysis of the angular diameter of its disc using the scale length of about 0.07 arcsec from Fruchter et al. (1998) give evidence for a higher than normal surface brightness. The latter, together with the closeness of the spectral distribution for Mrk 1267 in the UV range of spectrum, allows us to attribute the GRB970508 host galaxy to the blue compact galaxies.

Taking everything together, the observed absorption lines Mg II, Mg I and Fe II, the evidence for emission line [O II] and

evidence for a high surface brightness are consistent with a starburst process going on in the present GRB host galaxy.

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References

- Baryshev Yu.V., Sylos Labini F., Montuori M., Pietronero L., 1994, *Vist. Astron.* 38, 419
- Binggeli B., Sandage A., Tammann G., 1988, *ARA&A* 26, 509
- Binggeli B., 1994, In: Meylan G., Prugniel P.(eds.) *Proceedings of ESO/OHP Workshop, Dwarf Galaxies.* p. 13
- Bloom J.S., Djorgovski S.G., Kulkarni S.R., 1998, *astro-ph/9807315*
- Bond H.E., 1997, *IAUC* 6654
- Djorgovski S.G., Metzger M. R., Kulkarni S. R., et al., 1997, *Nat* 387, 876
- Djorgovski S.G., Kulkarni S.R., Sievers J., Frail D., Taylor D., 1998, *GCN circ.* # 41
- Eichelberger A.C., Kulkarni S.R., Djorgovski S. G., et al., 1998, *GCN circ.* # 33
- Frail D.A., Halpern J.P., Bloom J.S., Kulkarni S.R., Djorgovski S.G., 1998, *GCN circ.* # 128
- Fruchter A., Pian E., et al., 1998, *GCN circ.* # 151
- Galama T.J., Vreeswijk P.M., Pian E., et al., 1998a, *IAUC* 6895
- Galama T.J., Vreeswijk P.M., van Paradijs J., et al., 1998b, *Nat.* in press
- Garnavich P.M., Kirshner R.P., Challis P., et al., 1998, *ApJ* 493, L53

- Groot P.J., Galama T.J., van Paradijs J., et al., 1997, IAUC 6584
Groot P.J., Vreeswijk P.M., Galama T.J., et al., 1998, GCN circ. # 32
Halpern J., Thorstensen J., Helfand D., Costa E., 1997, IAUC 6788
Hjorth J., Andersen M.I., Pedersen H., et al., 1998, GCN circ. # 109
Hogg D.W., Fruchter A.S., 1998, astro-ph/9807262
Jaunsen A.O., Hjorth J., Andersen M.I., et al., 1998, GCN circ. # 78
Kinney A.L., Bohlin R.C., Calzetti D., Panagia N., Wyse R.F.G., 1993, ApJS 86, 5
McQuade K., Calzetti D., Kinney A.L., 1995, ApJS 97, 331
Metzger M.R., Cohen J.G., Chaffe F.H., 1997a, IAUC 6676
Metzger M.R., Djorgovski S.G., Kulkarni S.R., et al., 1997b, Nat 387, 878
Natarajan P., Bloom J.S., Sigurdsson S., et al., 1997, New Astronomy 2, 471
O'Connell R.W., Callagher J.S., Hunter D.A., 1994, ApJ 433, 65
Oke J.B., Sandage A., 1968, ApJ 154, 21
Paturel G., Bottinelli L., di Nella H., et al., 1997, A&AS 124, 109
Pence W., 1976, ApJ, 203, 39
Pian E., Fruchter A.S., Bergeron L.E., et al., 1997, ApJ., 492, L103
Pian E., Antonelli L. A., Daniele M.R., et al., 1998, GCN circ # 61.
Puche D., Carignan A., 1988, AJ 95, 1025
Sokolov V.V., Kopylov A.I., Zharikov S.V., et al., 1998, A&A 334, 117
Storchi-Bergmann T., Kinney A.L., Challis P., 1995, ApJS 98, 103
Theureau G., Hanski M., Ekholm T., et al., 1997, A&A 322, 730
van Paradijs J., Groot P., Galama T., et al., 1997, Nat 386, 686
Vaucouleurs G. de, Vaucouleurs A. de, Corwin H.G., et al., 1991, Third Reference Catalog of Bright Galaxies. Springer-Verlag (RC3)
Zapatero-Osorio M.R., Castro-Tirado A., Corosabel J., et al., 1998, GCN circ. # 130
Zharikov S.V., Sokolov V.V., Baryshev Yu.V., 1998, A&A 337, 356