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Constraints on an optical afterglow and on supernova light following the short burst GRB 050813[1]

P. Ferrero[1], S. F. Sanchez[2], D. A. Kann[1], S. Klose[1], J. Greiner[3], J. Gorosabel[4], D. H. Hartmann[5], A. A. Henden[6], P. Møller[7], E. Palazzi[8], A. Rau[9], B. Stecklum[1], A. J. Castro-Tirado[4], J. P. U. Fynbo[10], J. Hjorth[10], P. Jakobsson[11], C. Kouveliotou[12], N. Masetti[8], E. Pian[13], N. R. Tanvir[14], R. A. M. J. Wijers[15]

ABSTRACT

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[1]Thüringer Landessternwarte Tautenburg, Sternwarte 5, D–07778 Tautenburg, Germany

[2]Centro Astronómico Hispano Alemán de Calar Alto, Calle Jesus Durban Remon 2-2, E–04004 Almería, Spain

[3]Max-Planck-Institut für Extraterrestische Physik, Giessenbachstraße, D–85741 Garching, Germany

[4]Instituto de Astrofísica de Andalucía (IAA-CSIC), Apartado de Correos, 3.004, E–18.080 Granada, Spain

[5]Clemson University, Department of Physics and Astronomy, Clemson, SC 29634-0978, USA

[6]U. S. Naval Observatory/Universities Space Research Association, Flagstaff Station, Flagstaff, AZ 86001, USA

[7]European Southern Observatory, Karl Schwarzschild-Strasse 2, D–85748 Garching bei München, Germany

[8]INAF – Istituto di Astrofisica Spaziale e Fisica Cosmica di Bologna, via Gobetti 101, I-40129 Bologna, Italy

[9]Division of Physics, Mathematics and Astronomy, 105-24, California Institute of Technology, Pasadena, CA 91125

[10]Dark Cosmology Centre, Niels Bohr Insitute, University of Copenhagen, Juliane Maries Vej 30, 2100 Copenhagen, Denmark

[11]Centre for Astrophysics Research, University of Hertfordshire, College Lane, Hatfield, Herts, AL10 9AB, UK

[12]NSSTC, SD-50, 320 Sparkman Drive, Huntsville, AL 35805, USA

[13]INAF – Osservatorio Astronomico di Trieste, Via Tiepolo 11, I-34143 Trieste, Italy

[14]Department of Physical and Astronomy, University of Leicester, Leicester, LE1 7RH, UK

[15]University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands

We report early follow-up observations of the error box of the short burst 050813 using the telescopes at Calar Alto and at Observatorio Sierra Nevada (OSN), followed by deep VLT/FORS2 I-band observations obtained under very good seeing conditions 5.7 and 11.7 days after the event. No evidence for a GRB afterglow was found in our Calar Alto and OSN data, no rising supernova component was detected in our FORS2 images. A potential host galaxy can be identified in our FORS2 images, even though we cannot state with certainty its association with GRB 050813. In any case, the optical afterglow of GRB 050813 was very faint, well in agreement with what is known so far about the optical properties of afterglows of short bursts. We conclude that all optical data are not in conflict with the interpretation that GRB 050813 was a short burst.

Subject headings: Gamma rays: bursts: individual: GRB 050813 — Supernovae: general

1. Introduction

1.1. Short Bursts

Much progress is currently being made toward understanding the nature of the progenitors responsible for the class of short-duration, hard gamma-ray bursts (Kouveliotou et al. 1993, see also Appendix B). While the physical link between long-duration, soft gamma-ray bursts and the core collapse of massive stars (e.g., Paczyński 1998) has been conclusively confirmed by the spectroscopic detection of supernova (SN) light following some bursts (Stanek et al. 2003; Hjorth et al. 2003; Pian et al. 2006; Woosley & Bloom 2006, for a review), the nature of the sources responsible for short bursts remains to be revealed in full. Although there is a developing consensus in the community that at least some short bursts are due to merging compact stellar objects (cf. Fryer, Woosley & Hartmann 1999; Aloy, Janka & Müller 2005; Rosswog 2005; Oechslin & Janka 2006; Faber et al. 2006), an unambiguous observational verification of this model is not an easy task and has not yet been accomplished. Furthermore, the origin of a certain fraction of short bursts as giant flares of magnetars in nearby galaxies seems to be possible as well (cf. Tanvir et al. 2005). Indeed, the short-hard

[1]Based on observations collected at the European Southern Observatory, La Silla and Paranal, Chile (ESO Programme 075.D-0415) and on observations taken at the German-Spanish Calar Alto Observatory and at IAA's Observatorio de Sierra Nevada in Spain.

burst 051103 detected by the Interplanetary Network (Golenetskii et al. 2005) might be the first well-localized member of this class (Frederiks et al. 2006; Ofek et al. 2006).

Within the context of the merger model, the stellar populations underlying short bursts could be associated either with an old stellar population or even with a young one (Belczynski et al. 2006). Short bursts might therefore occur in quiescent ellipticals or star-forming galaxies. Indeed, the first short burst well-localized by *Swift*, GRB 050509B (Gehrels et al. 2005), was associated with a giant elliptical galaxy located in a cluster of galaxies at $z = 0.225$ (Bloom et al. 2006; Pedersen et al. 2005), while the *HETE-2* short burst GRB 050709 (Hjorth et al. 2005b) occurred in an isolated, star-forming dwarf galaxy. Shortly thereafter GRB 050724 was found in association with a lone early-type galaxy (Bloom et al. 2005; Prochaska et al. 2005; Berger et al. 2005a; Gorosabel et al. 2006). Assuming as a working definition that a short burst should have $T_{90} < 2$ s, then since GRB 050813 six further short bursts have been accurately localized by *HETE-2* or *Swift* via their X-ray afterglows by the end of September (see also table 8 in Donaghy et al. 2006). Among them GRB 051210 (La Parola et al. 2006), GRB 060502B (Bloom et al. 2007) and GRB 060801 (Racusin et al. 2006) had only X-ray afterglows, while GRB 051221A (Soderberg et al. 2006), GRB 060121 (Malesani et al. 2006; Levan et al. 2006; de Ugarte Postigo et al. 2006) and GRB 060313 (Roming et al. 2006, Hjorth et al. 2007, in preparation) have detected optical afterglows as well. A broad range of morphological types of host galaxies was derived for this set. For example, Bloom et al. (2007) postulated an association between GRB 060502B and a bright elliptical galaxy at a large offset at $z = 0.287$, while GRB 051221A is associated with an isolated star-forming dwarf galaxy (Soderberg et al. 2006), and the host of GRB 060121 might be a dusty edge-on irregular or spiral galaxy (Levan et al. 2006). This "mixed-bag" of host types is consistent with the idea that merging compact binaries will sample all types of galaxies, even those in which star formation turned off a long time ago. The short burst GRB 050813 belongs to the small set of short bursts for which up to date it has not been possible to define precisely the host galaxy.

1.2. GRB 050813

According to its observed duration (T_{90}, see below), GRB 050813 can be associated with the class of short bursts with very high (99.9%) probability (Donaghy et al. 2006). In addition, its measured spectral lag is consistent with zero, another important property of short bursts (Norris & Bonnell 2006; Donaghy et al. 2006). Furthermore, the small original *Swift* XRT error circle encompasses parts of an anonymous cluster of galaxies with ellipticals inside and close to the error circle (Gladders et al. 2005; Gorosabel et al. 2005; Prochaska et al. 2006). Taken together, these observations suggest that GRB 050813 should be considered as a typical short burst.

GRB 050813 was detected by the *Swift* satellite on 2005 August 13, 6:45:09.76 UT (Retter et al. 2005). Its duration in the 15-350 keV band was 0.6 ± 0.1 seconds (Sato et al. 2005), making it after GRB 050509B and 050724 the third short burst that *Swift* localized quickly and precisely. It is reminiscent of GRB 050509B, which had a very faint X-ray afterglow (Gehrels et al. 2005). Ground analysis of the X-ray data revealed a faint, uncatalogued source at coordinates RA, DEC (J2000) = $16^{\mathrm{h}}\ 07^{\mathrm{m}}\ 57\overset{\mathrm{s}}{.}0$, $+11^\circ\ 14'\ 52''$ with an uncertainty of 10 arcsec radius (Morris et al. 2005). This position was later refined by Moretti et al. (2006) to RA, DEC (J2000) = $16^{\mathrm{h}}\ 07^{\mathrm{m}}\ 57\overset{\mathrm{s}}{.}07$, $+11^\circ\ 14'\ 54\overset{''}{.}2$ with an uncertainty of 6.5 arcsec radius; an even smaller error region was reported by Prochaska et al. (2006). No optical or near-infrared afterglow candidate was found. Li (2005) reported an unfiltered upper limit of magnitude 18.6 at 49.2 seconds after the burst. UVOT observations started 102 seconds after the trigger and a 3-sigma upper limit of $V = 19.1$ was derived from a 188 seconds exposure (Blustin et al. 2005). Sharapov et al. (2005) found a limiting I-band magnitude of $\sim$21 at 10.52 hours after the burst, while Bikmaev et al. (2005) reported an R-band upper limit of $\sim$23 at 12.75 hours after the event.

Spectroscopy of galaxies close to and inside the XRT error circle revealed a mean redshift of $z = 0.72$ (Berger 2005b; Foley, Bloom & Chen 2005; Prochaska et al. 2006), indicating the possibility that this may also be the redshift of the GRB. This was later refuted by Berger (2006), who argued that the host is a background galaxy at a (photometric) redshift of about 1.8, possibly related to a background cluster of galaxies. This would make GRB 050813 the second most distant (after GRB 060121, de Ugarte Postigo et al. 2006; Levan et al. 2006) short burst for which a redshift could be estimated.

Here we report on a deep follow-up observing campaign of GRB 050813 with telescopes at Paranal, Chile, as well as at Calar Alto and at the Observatorio Sierra Nevada (OSN), Spain. The constraints we can set on any SN component following this burst as well as the faintness of its optical afterglow match well into what is known so far about the properties of short bursts. Throughout this paper we adopt a world model with $H_0 = 71$ km s^{-1} Mpc^{-1}, $\Omega_{\mathrm{M}} = 0.27$, $\Omega_\Lambda = 0.73$ (Spergel et al. 2003), which for z=0.72 yields a distance modulus of 43.22 mag. The luminosity distance is 1.36×10^{28} cm and 1 arcsec corresponds to 7.23 kpc. If z=1.8, the corresponding numbers are 45.7 mag, 4.26×10^{28} cm, and 8.55 kpc.

2. Observations and data reduction

A first imaging of the GRB error box was performed with the 1.5-m OSN telescope at Observatorio Sierra Nevada and the Calar Alto 2.2-m telescope equipped with CAFOS starting already 0.5 days after the burst (Gorosabel et al. 2005). Unfortunately, these observations resulted only in upper limits for the magnitude of any optical transient (Table 1). In order to set constraints on a rising SN component, we have then carried out deep follow-up observations using VLT/FORS2 in standard resolution (SR) imaging mode with a scale of 0.25 arcsec per pixel (field of view 6.′8 × 6.′8). Observations were performed in the Bessel I band in order to minimize the potential influence of host extinction on the discovery of a fading (afterglow) or a rising (supernova) source. A first run was performed on August 19.061 to 19.088 UT, 5.8 days after the burst. Ten frames were obtained, 200 seconds exposure time each. Seeing conditions were very good, $\sim$ 0.5 arcsec. A second run using the same instrumental setup was performed on August 24.990 to 25.017 UT, 11.7 days after the burst. Atmospheric seeing conditions were even better than during the first observing run, approaching 0.35 arcsec. Both nights were photometric.

The FORS2 images were bias-subtracted and flat-fielded with standard reduction procedures provided within IRAF.[2] Frames obtained on the same night and in the same band were summed together in order to increase the signal-to-noise ratio. Photometry was performed with standard Point Spread Function (PSF) fitting using the DAOPHOT II image data analysis package "PSF-fitting[3] algorithm" (Stetson 1987) within the MIDAS platform.[4] In addition, we performed aperture photometry using the IRAF Aperture Photometry Package Apphot.

Additional spectroscopic observations covering the entire original r=10 arcsec XRT error circle (Morris et al. 2005) were performed with the Integral Field Unit VIMOS/IFU at the ESO-VLT starting 20 hours after the burst. Unfortunately, these observations could not be implemented into this study due to technical problems with the data.

Figure 1 shows the *Swift* XRT 90% containment radius reported by Morris et al. (2005) (large circle), the refined error circle by Moretti et al. (2006) (small circle) and, as a small ellipse, the re-analyzed X-ray error box (68% containment radius) given by Prochaska et al.

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[2] http://iraf.noao.edu

[3] The PSF-fitting photometry is accomplished by modeling a two-dimensional Gaussian profile with two free parameters (the half width at half maxima along x and y coordinates of each frame) on at least five unsaturated bright stars in each image.

[4] http://www.eso.org/projects/esomidas

(2006). In the original r=10 arcsec XRT error circle we identify 11 sources, designated by the letters C, D, E, F and the numbers from 1 to 7. Note that B = X, C = B, 4 = B* and E = C in the nomenclature of Prochaska et al. (2006). The X-ray error box published by Prochaska et al. (2006) contains only two sources, of which #6 is the one identified by Berger (2006) as the possible host galaxy possibly related to a cluster of galaxies[5] at z=1.8. Nothing can be said at this stage about the redshift of source #7, however. Here, we assume that it is a member of the cluster of galaxies at z=0.72 (Berger 2005b; Foley, Bloom & Chen 2005; Prochaska et al. 2006).

3. Results

Our two FORS2 observing runs were arranged such that they would allow us to search for a fading (afterglow) as well as for a rising (supernova) component following GRB 050813, supposing z=0.72. Initially we searched for a transient isolated point source in the original 10 arcsec XRT error circle, but we did not find one. The fact that the sources #2, #5 and #6 (Fig. 1; Table 3) are not detected in the combined image of the first VLT/FORS2 observing run might be due to the presence of the Moon, causing an enhanced sky background level. During the second FORS2 run the sky background was much lower and the seeing even better than during the first observing run. We conclude that any well-isolated afterglow or supernova in this field was fainter than the magnitude limits at the time of the two FORS2 observing runs, I=25.1 and 25.5, respectively.

3.1. Search for an afterglow component

Based on our deep FORS2 observing runs, we searched for a potential fading afterglow superimposed on the brightest extended sources (galaxies) in the field (Table 2). No evidence for variability due to an underlying transient source was found. Prochaska et al. (2006) identified object C and E as elliptical galaxies (Fig. 1), with C being the most likely host candidate based on its location relative to their revised elliptical error circle. In our images source E appears to have an irregular halo which does not support its classification as an elliptical. Image subtraction did not reveal any transient source superimposed on this galaxy. Detailed analysis shows that we would have been able to detect (at 3 σ) a fading afterglow superimposed on this galaxy if its I-band magnitude had been 23.5 at the time of the first

[5]E. Berger, talk given at "Swift and GRBs: Unveiling the Relativistic Universe", San Servolo, Venice (Italy), 2006 June 5-9

FORS2 observation.

Among all seven clearly detected sources in the original 10 arcsec XRT error circle on our second FORS2 run (Fig. 1) we find tentative evidence for a fading of source #7 (Table 3). However, the derived magnitudes agree within 1.5σ. Unfortunately, in our first FORS2 images MIDAS daophot was unable to perform photometry of this galaxy, so that we had to estimate its magnitude in comparison to neighboring galaxies as well as in comparison to the deduced limiting magnitude of the first FORS2 run. Image subtraction (via the second FORS2 run) fails to identify a fading point source superimposed on this object. Source #7 is clearly extended in our images ($0\farcs7$ semi-major axis) and might be a late-type galaxy seen nearly edge-on. Its presence in the small XRT error ellipse derived by Prochaska et al. (2006) might favor its identification as the GRB host galaxy. Our data imply that the angular distance between the afterglow and the host was rather small, less than about 0.6 arcsec (corresponding the angular radius of the aperture). If z=0.72 then this corresponds to a projected distance from the center of this galaxy of less than 4 kpc.

3.2. Upper limits on a supernova

One of the main observational characteristics of a short burst should be the absence of a SN component in the late-time afterglow (Hjorth et al. 2005a), as the merger is not expected to result in the kind of radioactivity-powered optical display typical for thermonuclear (Type Ia) and core-collapse (Types II and Ib/c) supernovae. However, mergers may have sub-relativistic explosions with low amount of ejected mass (Li & Paczyński 1998; Kulkarni 2005), which are powered by the decay of free neutrons. But they should have a very small luminosity. In agreement with these expectations, strong upper limits could be set so far on any potential SN component accompanying short bursts (cf. Hjorth et al. 2005a; Fox et al. 2005).

The constraints we can place on a rising SN component for GRB 050813 are less severe, given the potentially relatively high redshift of this burst. For the cosmological parameters employed here, SN 1998bw (Galama et al. 1998) redshifted to z=0.72 would have magnitudes of I=24.7 and I=23.9 during our first and second VLT/FORS observing run, respectively, after taking into account a Galactic reddening of $E(B-V)$=0.056 mag (Schlegel, Finkbeiner & Davis 1998) in the direction of GRB 050813. At that brightness level we would have detected the SN if not superimposed on a much brighter host or strongly extinguished by dust. More precisely, we conclude that at the time of our second FORS2 observation any supernova following GRB 050813 was at least about 1.5 mag less luminous than SN 1998bw. While constraints placed on any SN component underlying the afterglow of e.g. GRB 050509B (Hjorth et al. 2005a) and GRB 050709 (Fox et al. 2005; Covino et al. 2006) are much stronger, this makes a potential SN component following GRB 050813 already fainter than any of the 11 GRB-SNe of long bursts known to date (Ferrero et al. 2006,their Figure 6).

On the other hand, we would have been able to detect (at 3 σ) a rising SN component superimposed on the bright galaxy E (Fig. 1) only if its I-band magnitude had been 23.5 at the time of the second FORS2 observation. In other words, a SN 1998bw-like component would be missed in this case. The same holds for a typical type Ia supernova (Krisciunas et al. 2003), which would have had I=26.9 and I=25.4 at the time of our first and second FORS2 observing run, respectively.

4. Discussion

One of the main goals of our observing runs was the localization of the afterglow and hence the identification of the GRB host galaxy. Basically, there are two possibilities: (1) Source #7 is the sum of the GRB host galaxy and a faint afterglow, as indicated by its marginally significant variability. (2) This variability is an artifact in our data (close to the detection limit, variable seeing conditions). So, the host cannot be identified and we have to consider other arguments that favor or disfavor any galaxy visible on the deep FORS2 I-band images of the XRT error circle as the potential host.

If the afterglow was located in the galaxy designated #7, then we can constrain its light curve parameters based on our I-band upper limits reported in Table 1. Assuming that the afterglow light curve had a break before our first FORS2 observation, then between our two FORS2 runs the flux density of the afterglow followed a single power-law decay with a slope α_2. Writing down the measured flux density for the two FORS2 epochs (Table 3) as a sum of the afterglow light and the light from the underlying host galaxy, we can then solve for both unknowns as a function of α_2. Afterglows (of long bursts) observed in the pre-*Swift*-era imply that in most cases $\alpha_2 > 2$ (Zeh, Klose & Kann 2006). If α_2 was between 2.0 and 2.5, then the magnitude of the afterglow at the time of the first and second FORS2 observing run was around I=25.7 and between I=27.2 and 27.7, respectively, while I=19.4 to 20.6 at the time of our OSN observations. Given our magnitude limit of I >22.8 at this time (Table 1), a break in the light curve must have occurred before the first FORS2 run, in agreement with our assumption. Depending on the break time t_b and the value of α_2, the value implied in this way for the pre-break decay slope α_1 is between 0.03 and 0.83 if t_b = 2.4 and 5.7 days, respectively (shorter break times would imply $\alpha_1 < 0$). These values are not unusual for GRB afterglows, even for short bursts (Watson et al. 2006).

Given the fact that we cannot state with certainty that the fading of source #7 is an artifact of the data or not, we cannot exclude that indeed no afterglow is visible in our images. GRB 050813 then joins the increasing list of short bursts with no detected optical afterglow, starting with GRB 050509B (Bloom et al. 2006; Castro-Tirado et al. 2005; Gehrels et al. 2005; Hjorth et al. 2005a). Using the upper limits on the afterglow of GRB 050813 (Table 1) we can follow Kann, Klose & Zeh (2006) and place the properties of this afterglow in the context of other known GRB afterglows (Fig. 2). The long burst afterglows shown in Fig. 2 by solid lines are those from the "Golden Sample" of Kann, Klose & Zeh (2006), i.e., those that have sufficient I-band data. In addition, we analyzed the available afterglow data on the short bursts GRB 050709 (Hjorth et al. 2005b; Fox et al. 2005; Covino et al. 2006), GRB 050724 (Berger 2005b), GRB 051221A (Soderberg et al. 2006) and GRB 060121 (Levan et al. 2006; de Ugarte Postigo et al. 2006) in an analogous way and also included them in Fig. 2 (see the Appendix B for details). As can be seen, short burst optical afterglows are intrinsically very faint, with the afterglows of GRB 050724 and GRB 051221A being about 3 magnitudes fainter than any long burst afterglow in the sample, and GRB 050709 being 4 magnitudes fainter at one day after the burst and assuming $z = 0.72$ (in agreement with the predictions for short burst afterglows; Panaitescu, Kumar & Narayan 2001). They are also significantly fainter than intrinsically faint afterglows of some long GRBs, such as GRB 021211. Only the afterglow of GRB 060121 is comparable with the typical afterglows of long GRBs. The upper limits on the optical afterglow of GRB 050813 show that its luminosity was also far below typical luminosities of (extinction-corrected) afterglows of long bursts. On the other hand, it matches the luminosity region occupied so far by afterglows of the short bursts (with GRB 060121 being the only exception).

Naturally, if source #7 is not the host, then the richness of galaxies in the XRT error circle does not allow us to identify the host galaxy. Figure 1 shows that there are only two sources in the error ellipse (Prochaska et al. 2006), while there are at least three additional sources in the refined error circle (Moretti et al. 2006). The former might favor a burst related to the very faint sources #6 and #7 (source #6 appears point-like in our images) but it does not even exclude an event in the outer halo of source C, an elliptical galaxy at a redshift of 0.719 (Prochaska et al. 2006). The minimum distance between the border of the error ellipse and the center of this galaxy is 3.2 arcsec, corresponding to a projected distance of 23 kpc. This is less than the projected distance of the error circle of GRB 050509B from the center of its suspected host, an elliptical galaxy at a redshift of z=0.225 (Gehrels et al. 2005). In addition, the minimum angular distance between source E and the border of the error ellipse is 7.1 arcsec, corresponding to a projected distance of 51 kpc. Even this is within the range predicted by recent models of merging compact objects (see Belczynski, Bulik & Kalogera 2002; Perna & Belczynski 2002). The error circle determined by Moretti et al.

(2006) is much larger, and thus allows not only source C but also galaxy E at $z = 0.73 \pm 0.01$ (Prochaska et al. 2006) to be the potential host of GRB 050813. This galaxy was classified by Prochaska et al. (2006) as an elliptical galaxy, while our images show morphology that point either to a spiral or to an irregular galaxy. The nature of the fifth, point-like source in the refined error circle, #4, remains undetermined.

While this paper was submitted, a new revised XRT error circle was reported by Butler (2006). This revised error circle is 3.8 arcsec in radius and centered close to the edge-on galaxy which we found to be the potential host galaxy (source #7, see Figure 1). While this does not prove that the source #7 is the host, it is in favorable agreement with this possibility.

To summarize, our optical data support the interpretation that GRB 050813 was a short burst giving rise to a faint optical afterglow and a faint SN component (if at all). If it was occurring in a cluster of galaxies at a redshift of z=0.72, as it might be indicated by the surrounding galaxy population, then its projected distance from its potential host galaxy could have been of the order of less than 4 to some dozen kpc, depending on the chosen potential host galaxy, in any case not atypical for what is known about short bursts so far. On the other hand, if the burster would had been at z=1.8 (Berger 2006), no SN 1998bw-like component would have been detectable in our images and any afterglow component would have been correspondingly fainter than in the former case (Figure 3).

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A. What is a short GRB?

Short bursts, by phenomenological classification introduced by Kouveliotou et al. (1993), are bursts whose T_{90} duration measured with *BATSE* was less than 2 sec. Even though it has already been known in the 1990s that T_{90} is a function of energy (and of detector properties), this definition, because of its simplicity, has been widely used even in the *HETE-2* and in the *Swift* era. In principle, having now much more observational data at hand for individual bursts than in the *BATSE* era, this phenomenological definition/classification scheme calls for a more accurate, namely a physical classification scheme. This, however, is a difficult task that is not yet solved in a satisfactory manner.

The observed bimodality in the T_{90} distribution of all *BATSE* bursts clearly showed that there are two kinds of bursters. It can be fitted very well by two overlapping Gaussian functions, suggesting that there are two different populations of progenitors responsible for the emission of GRBs (for the potential existence of a third group see, e.g., Horvath et al. 2004). This statement however refers to the GRB ensemble as a whole. Difficulties arise if one wants to classify an individual burst, because both Gaussian functions overlap.

In the *Swift* era, the observational situation has improved a lot. First at all, given that this is a different satellite/detector, any statistics of the GRB duration distribution has to be established again based on *Swift* bursts alone and it has to be checked at which duration T_{90} the two fitted Gaussians overlap.

However, *Swift* has shown that the observational situation is much more complex, too. For example, some bursts have long soft tails extending over several hundred seconds after the trigger while starting with a short spike (e.g., GRB 061006; Krimm et al. 2006). The question is, can we find any observational parameters that tell us exactly for any individual burst whether it was a member of the long or of the short burst class? In a more accurate and much more physical way, the question is (see also Zhang 2006): Which criteria apply for the GRBs and their follow-up phenomena if the burster was a collapsing single star or a compact merger event? Fortunately, the former does indeed provide us with a clear signal, namely the appearance of a SN 1998bw-like component in the GRB afterglow. Any such bright component rules out a merger event according to our present understanding of mergers of compact stars. Similarly, any GRB originating in an early-type galaxy cannot, according to our present understanding of ellipticals, be related to the collapse of a single massive star because there is no ongoing star-formation in elliptical galaxies anymore (at least at low redshifts). Unfortunately, these two criteria are the only clearly observationally founded criteria so far that can help to classify an individual burst unambiguously with respect to the nature of its progenitor. If no SN is seen following a GRB then the burst can still be due to the collapse of a single star, but then for sure something was very different in the collapse compared to the progenitors of the other GRB-SNe known so far (e.g., GRB 060614; Gehrels et al. 2006; Fynbo et al. 2006; Della Valle et al. 2006; Gal-Yam et al. 2006). On the other hand, the non-detectability of a SN component does not automatically imply that the burst was due to a merger event. In a same way, merger events can also occur in late-type spirals. So, if any GRB originates in a late-type spiral it cannot be classified based on the nature of the underlying host galaxy alone.

It is clear that the classification of individual bursts with respect to the nature of their progenitor is difficult. Recent investigations tackle this problem and have led to the suggestion of much more then just one criterium in order to classify a GRB (Donaghy et al. 2006; Norris & Bonnell 2006). As long as no consensus has been reached in the literature what the ultimate criteria are for a burst to be classified as being due to a merger event, in several cases only arguments can be provided that favor one scenario for the other (merger vs. collapse). The detection or non-detection of a SN signal plays a key role in this approach but has come into question recently (see Gehrels et al. 2006; Fynbo et al. 2006; Della Valle et al. 2006; Gal-Yam et al. 2006; Zhang 2006). This leaves the nature of the host galaxy as the strongest argument to detect a GRB due to a merger event, namely if the host is an elliptical galaxy. But the potentially broad range in merger times and hence distances of the merger events from their host galaxies (cf. Belczynski et al. 2006) might also call into question the application of this criterium. GRB 050813 belongs to those bursts that demonstrate all these problems in detail.

B. The light curves of the short burst afterglows

In Fig. 2 we included those four GRBs that have both an optical afterglow and a redshift derived either from host galaxy spectroscopy or photometry (GRB 060121; de Ugarte Postigo et al. 2006).

For GRB 050709, we derive a decay slope of $\alpha = 1.68 \pm 0.15$ from the R_C-band light curve. Fox et al. (2005) noted that the late *Hubble Space Telescope (HST)* data indicate a steepening of the light curve decay, possibly due to a jet break. Using the R_C-band decay index, we find a rebrightening (significant at the 5 σ level) in the HST data, but only marginal evidence that the afterglow is fainter than expected from the early decay in the last HST detection. This result is in accordance with Watson et al. (2006). The light curve shown in Fig. 2 is composed of the R_C data shifted to the HST F814W zero point, plus the HST data. From the $V, R_C, F8, K'$ spectral energy distribution (SED), we derive a steep uncorrected spectral slope $\beta_0 = 1.71 \pm 0.17$. This is indicative of additional source frame extinction. As the host is a blue dwarf galaxy (Fox et al. 2005), we assumed SMC-type dust (Pei 1992). A free fit implies $\beta = 0.26 \pm 1.16$ and a host extinction of A_V(host)$= 1.46 \pm 1.07$ mag, a very high value indeed. As the single K'-data point has a very large error (0.7 mag), this value may not be trustworthy. For a progenitor that has traveled far from its birthplace, an unstratified surrounding medium is expected (density $\rho \propto r^0$). We fixed β to the value derived from the pre-break decay slope α_1, and find $\beta = 1.12$ and A_V(host)$= 0.67 \pm 0.19$ mag. We used these parameters to correct and shift the light curve.

For GRB 050724, we derive, after correcting for the high Galactic extinction, $K - I = 1.81$ mag and a spectral slope of $\beta = 0.3$. This low value may imply an overcorrection for extinction. No source frame extinction was assumed. The light curve consists of the two I-data points (showing a rising behavior) and the K-band upper limit shifted to the I band.

In the case of GRB 051221A, we find that the light curve decays as a single power-law with a slope $\alpha = 0.94 \pm 0.03$, in accordance with Soderberg et al. (2006). We derive a flat spectral slope ($\beta = -0.16 \pm 0.84$) from the $r'i'z'$ spectral energy distribution, but caution that the errors of the i' and z' data are very large. Assuming an unstratified surrounding medium and a cooling frequency blueward of the optical bands, we derive $\beta = 0.62$ (coupled with a typical power-law index of the electron distribution function of $p = 2.25$; cf. Kann, Klose & Zeh 2006). We used this spectral slope and assume no additional extinction to shift the light curve.

Combining the data from Levan et al. (2006) and de Ugarte Postigo et al. (2006) of GRB 060121, we find that the zero points of the two data sets differ. We shifted the data from de Ugarte Postigo et al. (2006) to the fainter zero point of Levan et al. (2006). The light curve has a complex shape and seems to include several rebrightenings (Fig. 2). It is composed of I_C data and R_C data shifted to the I_C zero point. We used the redshift and host galaxy extinction derived by de Ugarte Postigo et al. (2006), assuming the more probable redshift of $z = 4.6$, and a spectral slope in the optical of $\beta = 0.6$, as derived by the authors cited above.

In all cases, except for GRB 060121, the afterglow data do not contain any host contribution. For GRB 060121, we used a host galaxy magnitude derived from the HST measurements (Levan et al. 2006). To correct for Galactic extinction, we used the value derived from the maps of Schlegel, Finkbeiner & Davis (1998) for GRB 050709, 051221A and 060121, and $E_{B-V} = 0.87$ mag for GRB 050724 (as suggested by Berger et al. 2005a).

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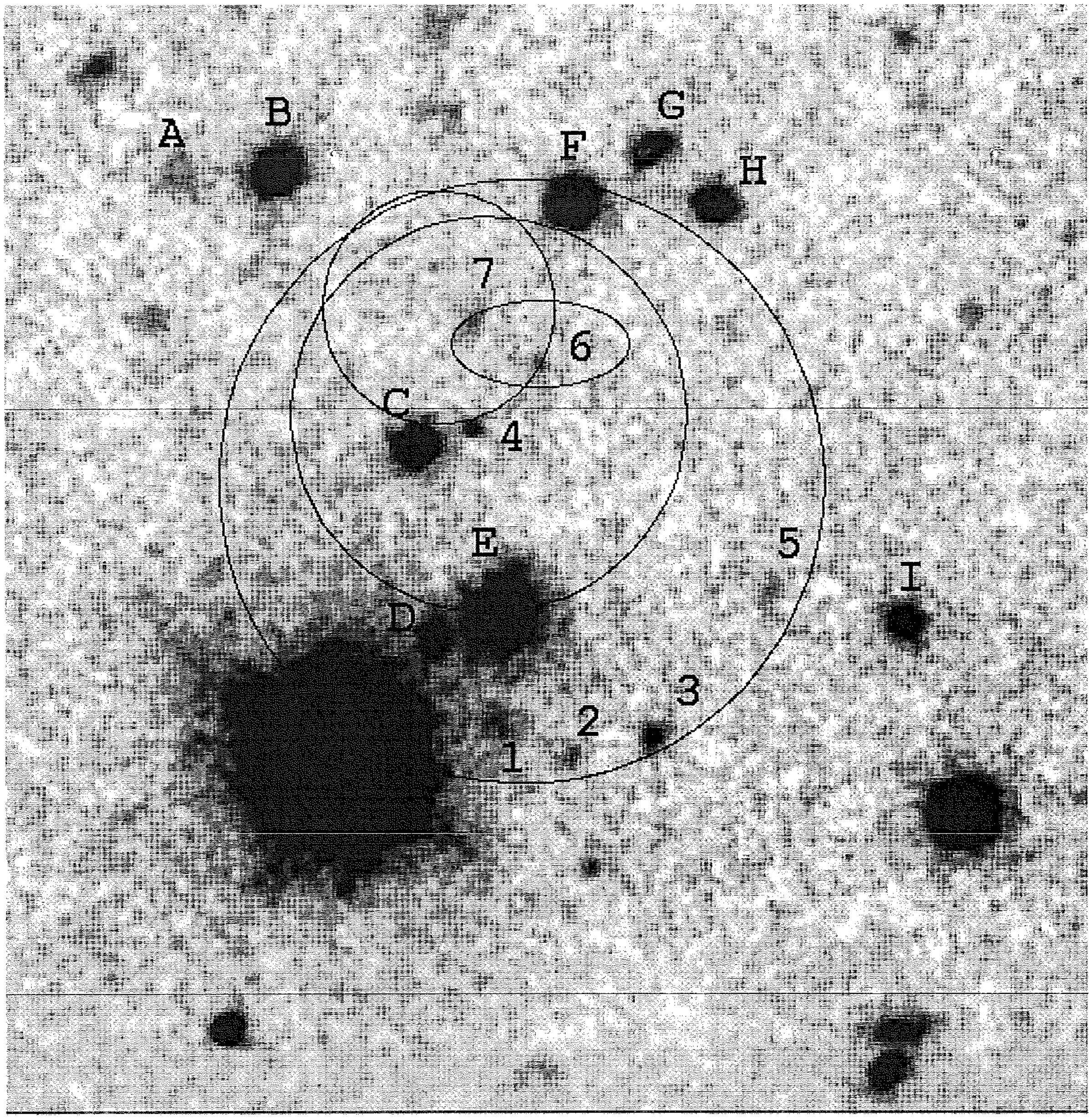

Fig. 1.— VLT I-band image of the GRB field obtained 11 days after the burst, showing the original 10 arcsec (radius) XRT error circle of GRB 050813 (Morris et al. 2005) (large circle), the refined error circle by Moretti et al. (2006) (small circle, center around source #4), the revised error ellipse (Prochaska et al. 2006), the refined error circle by Butler (2006) (small circle, center around source #7) and the objects listed in Tables 2 and 3.

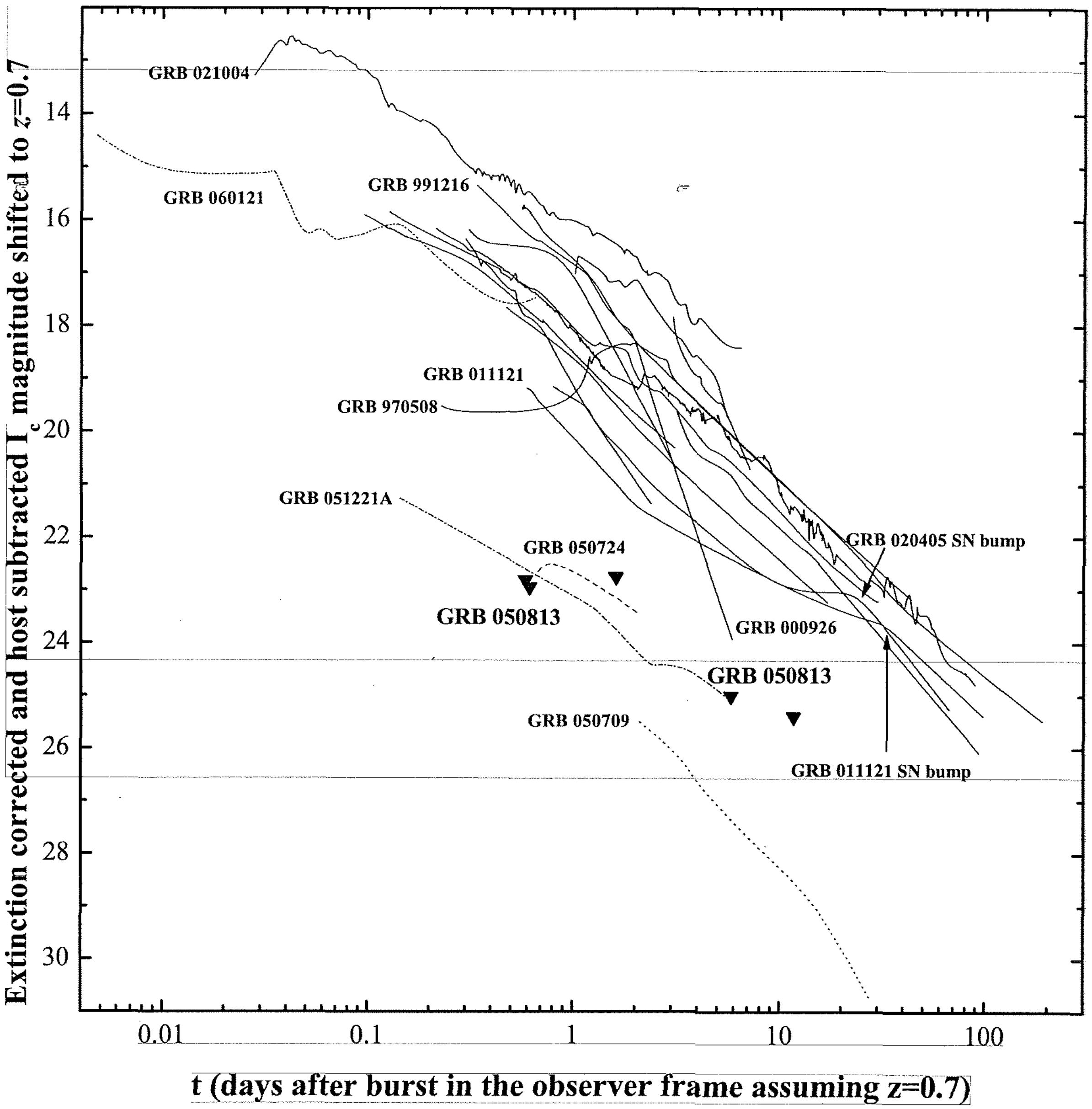

Fig. 2.— The I-band light curves of all afterglows from the "Golden Sample" of Kann, Klose & Zeh (2006) after correction for Galactic and for host extinction and after shifting them to a common redshift of z=0.722, the potential redshift of GRB 050813. Two long GRB supernova rebrightenings are indicated. Also shown are the I-band afterglows of the short bursts GRB 050709, 050724, 051221A and 060121 shifted in a similar way, and our upper limits on any afterglow or supernova from GRB 050813 (upside-down triangles). For GRB 060121 a redshift of z = 4.6 (de Ugarte Postigo et al. 2006) is assumed here. If z=1.7 is assumed instead (de Ugarte Postigo et al. 2006), then the light curve of this afterglow falls much closer to the light curves of the other short bursts.

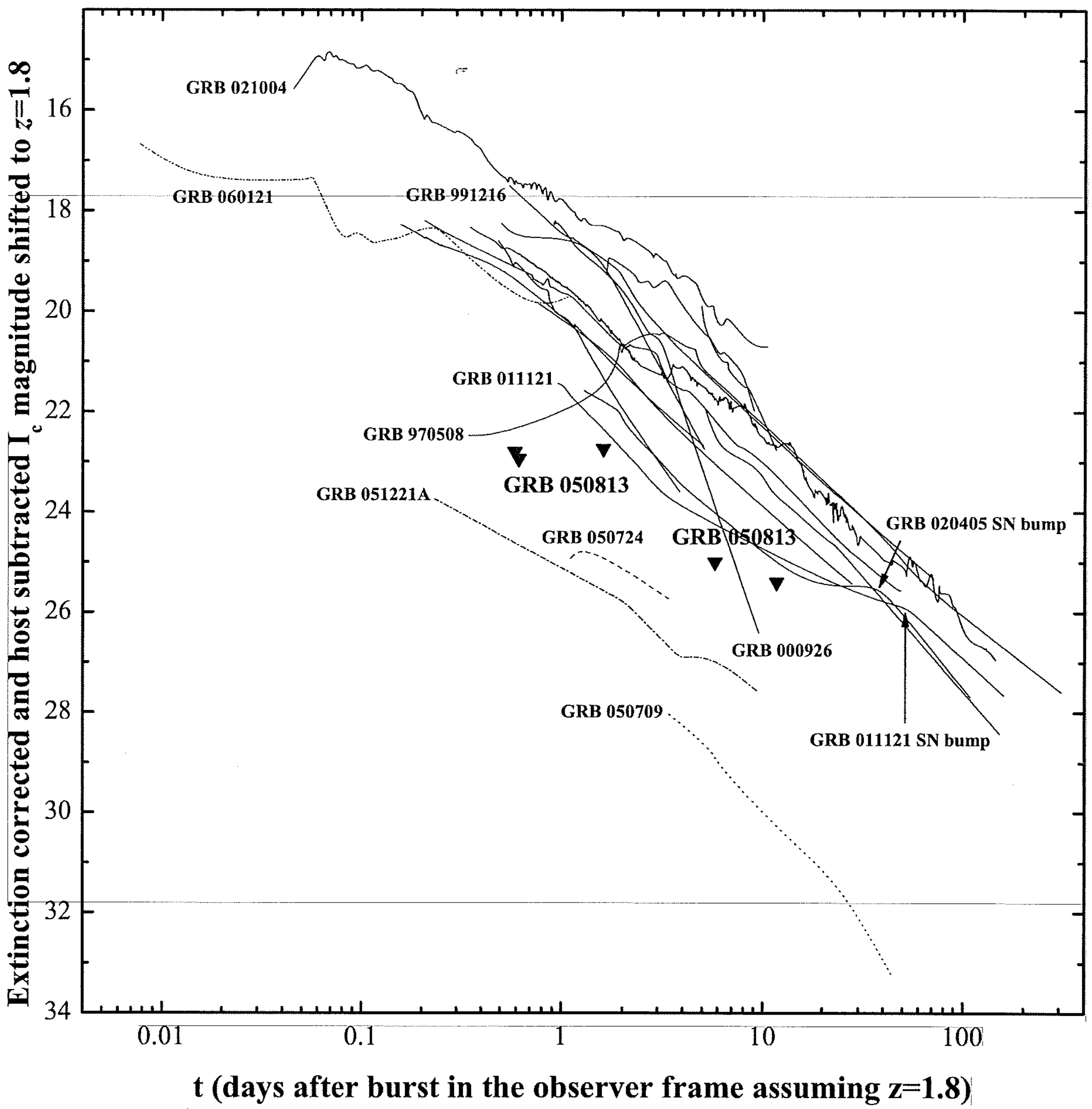

Fig. 3.— The same as Fig.2, but for a redshift of 1.8

Table 1. Observing log of the GRB 050813 field

Date [days]	$t - t_0$[a] [days]	Mag[b]	Exposure [s]	Filter	Telescope
13.8333	0.5519	22.8	10×600	I	1.5m OSN
13.8708	0.5894	23.3	23×180	R	2.2m, CAFOS
14.8475	1.5661	23.1	24×300	R	2.2m, CAFOS
19.0606	5.7792	25.1	10×200	I	8.2m, FORS2
24.9901	11.7087	25.5	10×200	I	8.2m, FORS2

[a]t_0 = 2005 August 13.2814, the time of the burst. All dates refer to August 2005 and give the time of the start of the first exposure.

[b]The limiting magnitude of the combined image.

Table 2. The objects used for the calibration of the photometry (A,B,F,G,H,I) and the brightest galaxies in the XRT error circle (C,D,E).

#[a]	RA[b]	DEC[b]	I
A	16:07:57.72	+11:15:02.24	24.68 ± 0.35
B	16:07:57.50	+11:15:02.13	21.83 ± 0.09
C	16:07:57.19	+11:14:53.15	22.43 ± 0.12
D	16:07:57.16	+11:14:46.86	23.38 ± 0.22
E	16:07:57.01	+11:14:47.61	22.74 ± 0.28
F	16:07:56.85	+11:15:01.80	20.88 ± 0.03
G	16:07:56.66	+11:15:02.87	23.61 ± 0.19
H	16:07:56.53	+11:15:01.11	22.85 ± 0.14
I	16:07:56.10	+11:14:47.34	23.50 ± 0.17

[a]The numbering follows Fig. 1

[b]Epoch J2000

Table 3. The photometry of the fainter sources in the XRT error circle.

#[a]	RA[b]	DEC[b]	I run 1[c]	I run 2[c]
1	16:07:57.00	+11:14:43.83	$24.7 < I < 24.9$	$24.4 < I < 25.4$
2	16:07:56.85	+11:14:42.91	> 25.1	$24.4 < I < 25.5$
3	16:07:56.66	+11:14:43.58	24.69 ± 0.24	24.44 ± 0.10
4	16:07:57.07	+11:14:53.65	24.63 ± 0.30	24.67 ± 0.13
5	16:07:56.40	+11:14:48.35	> 25.1	25.47 ± 0.25
6	16:07:56.91	+11:14:55.91	> 25.1	25.64 ± 0.28
7	16:07:57.07	+11.14.57.43	$24.7 < I < 25.1$	25.41 ± 0.25

[a]The numbering follows Fig. 1.

[b]Epoch J2000

[c]Run 1 and run 2 refer to the first and second VLT/FORS observations, respectively.