GRB 050505: A HIGH REDSHIFT BURST DISCOVERED BY *SWIFT*

C.P. Hurkett, J.P. Osborne, K.L. Page, E. Rol, M.R. Goad, P.T. O'Brien, A. Beardmore, and O. Godet, on behalf of the *Swift* team.

XROA Group, Dept. of Physics & Astronomy, University of Leicester, Leicester LE1 7RH, UK.

ABSTRACT

We report the discovery by the *Swift* satellite, and subsequent multi-wavelength afterglow behaviour, of the high redshift (z = 4.27) Gamma Ray Burst GRB 050505. This burst is the third most distant burst discovered after GRB 000131 (z = 4.50) and GRB 050904 (z = 6.29). GRB 050505 is a long GRB with a multipeaked γ-ray light curve of T_{90} = 63±2 s and an inferred isotropic release in γ-rays of $\sim$1.45$\times$10^{53} ergs, placing it at the lower end of the long burst E_{iso} distribution. The *Swift* X-Ray Telescope followed the afterglow for 14 days, detecting two breaks in the light curve at $7.4^{+1.5}_{-1.5}$ ks and $58.0^{+9.9}_{-15.4}$ ks after the burst trigger. The powerlaw decay slopes before, between and after these breaks were $0.25^{+0.16}_{-0.17}$, $1.17^{+0.08}_{-0.09}$ and $1.97^{+0.27}_{-0.28}$ respectively. The X-ray afterglow shows no spectral variation over the course of the *Swift* observations, being well fit with a single powerlaw of photon index $\sim$1.90. This behaviour is expected for the cessation of continued energisation of the ISM shock followed by either a jet break or a break caused by the presence of a structured jet. Neither break is consistent with a cooling break. There is significant absorption in excess of that due to our Galaxy.

Key words: gamma-rays: bursts; gamma-rays: observations; galaxies: high redshift; galaxies: ISM.

1. INTRODUCTION

Gamma Ray Bursts (GRBs) are expected to be visible over a large range of redshifts with a potential upper limit of z $\sim$15-20 (Lamb & Reichart 2000). The lowest recorded GRB redshift to date is GRB 980425 with z = 0.0085±0.0002 (Tinney et al. 1998), whilst the highest is GRB 050904 at z=6.29±0.01 (Kawai et al. 2005). Bursts at high redshift are potentially important since they can be powerful probes of the early Universe. They allow us to probe the intervening matter between the observer and GRB, and particularly the conditions of their host galaxies (e.g. Vreeswijk et al. 2004).

So far, only $\sim$50 bursts have a firm redshift determination, mostly obtained through spectroscopy of their optical afterglow. The record holder is GRB 050904, but this is so recent that data on it are still being collected. Previously the highest redshift burst was GRB 000131 (Andersen et al. 2000). Unfortunately *BATSE* detected GRB 000131 during a partial data gap (Kippen 2000) so its position was not localised until 56 hours after the trigger, thus its early time behaviour is unknown. No breaks were directly observed in the light curve for GRB 000131 but, based on the spectral index, an upper limit on the jet break time of <3.5 days has been hypothesised (Andersen et al. 2000). In contrast, the rapid position dissemination for GRB 050505 allowed a rapid redshift determination, and its automated follow-up program provided a well-covered X-ray afterglow light curve. Here we present the results from *Swift* (Gehrels et al. 2004) on GRB 050505, which is shown to be a relatively weak burst.

2. *SWIFT* OBSERVATIONS OF GRB 050505.

At 23:22:21 UT on the 5^{th} of May 2005, the *Swift* Burst Alert Telescope (BAT; Barthelmy 2005) triggered and located GRB 050505 on-board (trigger ID 117504; Hurkett et al. 2005a). The BAT mask-weighted light curve (see Fig 1) shows a multi-peaked structure with a T_{90} (15-350 keV) of 63 ± 2 seconds.

The T_{90} 15-150 keV BAT spectrum was adequately fit by a single powerlaw with a photon index = 1.56 ± 0.12 (with χ^2/DOF = 48/56) and a mean flux over T_{90} of (6.44$^{+0.42}_{-1.54}$)$\times$10^{-8} ergs cm^{-2} s^{-1} in the 15-350 keV range and (3.76$^{+0.21}_{-0.69}$)$\times$10^{-8} ergs cm^{-2} s^{-1} in the 15-150 keV range. All errors in this paper are quoted at 90% confidence unless otherwise stated. Whilst fitting a cutoff powerlaw does not give a significantly better fit (χ^2/DOF = 45/55) it does provide us with an indication of the $E_{\rm peak}$ for this burst. We find a photon index = $1.02^{+0.51}_{-0.57}$ and a lower limit of $E_{\rm peak} > 52$ keV.

Swift executed an automated slew to the BAT position and the X-Ray Telescope (XRT; Burrows et al. 2005) began taking data $\sim$47 minutes after the burst trigger. The delay

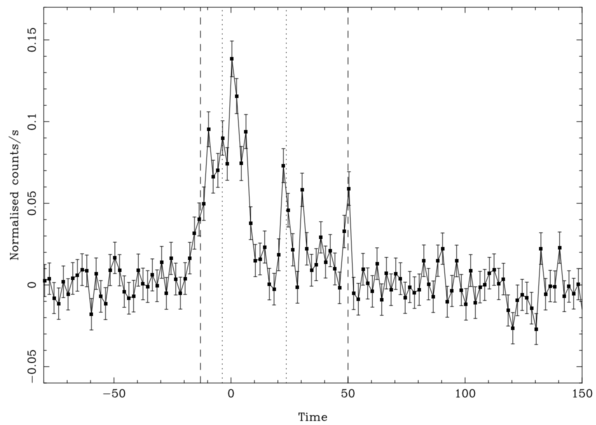

Figure 1. The BAT mask weighted light curve (15-350 keV), where T=0 is the trigger time. Vertical lines indicate the T_{90} (dashed) and T_{50} (dotted) intervals.

in the spacecraft slew was due to an Earth limb observing constraint. Ground processing revealed an uncatalogued X-ray source within the BAT error circle located at RA, Dec = 09:27:03.2, +30:16:21.5 (J2000) with an estimated uncertainty of 6 arcseconds radius (90% containment; Kennea et al. 2005).

Observations continued over the next 14 days, though the X-ray afterglow was not detected after the 6^{th} day. Co-adding the final 8 days of observations produced a total of 58ks of data providing an upper limit of 3.5×10^{-4} counts s^{-1}, consistent with the extrapolated decay (see § 2.1).

The *Swift* Ultra-Violet/Optical Telescope (UVOT; Roming et al. 2005) observed the field starting at ∼47 minutes after the burst trigger. The initial data were limited to one 100 second exposure in each of the four filters. No new sources were found in the XRT error circle to limiting magnitudes (5σ in 6 arcsecond radius apertures) of $V > 17.7$, $U > 18.4$, $UVW1 > 18.9$ and $UVM2 > 19.7$. Additional co-added, deeper exposures (∼2000 s) with the UVOT also failed to detect an optical counterpart at the location of the GRB (Rosen et al. 2005). The deeper exposure in V placed a limiting magnitude for the source at > 20.35 (3σ confidence level) for a total exposure of 2527 s coadded from a series of short exposures over T+2807 s to T+28543 s.

2.1. X-ray Light curve and Spectral Analysis.

In PC mode the XRT suffers from pile-up when the count-rate is $\geq$ 0.8 counts/s (Vaughan et al. 2005). See Hurkett et al. (2005b) for details of the pile-up correction method.

The X-ray light curve of GRB 050505 is shown in Fig 2. We characterise the behaviour of the XRT flux in terms of the standard powerlaw indices $f \propto \nu^{-\beta} t^{-\alpha}$. A single powerlaw was rejected since it gave an unacceptable value of χ^2/DOF = 122.5/46.

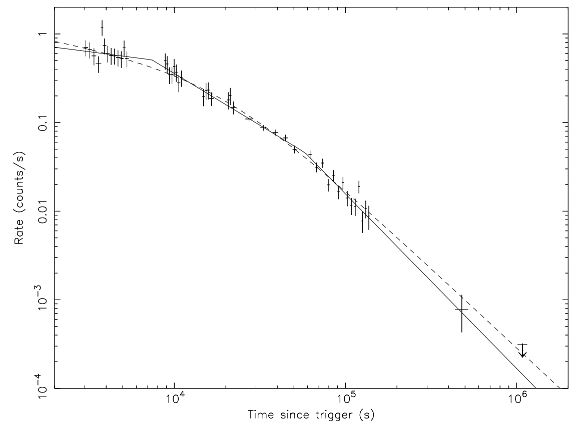

Figure 2. Light curve of GRB 050505 fit to a doubly broken powerlaw (solid line) and smoothly broken powerlaw (dashed line). Doubly broken powerlaw parameters (see §2.1): $\alpha_1 = 0.25^{+0.16}_{-0.17}$, $\alpha_2 = 1.17^{+0.08}_{-0.09}$ and $\alpha_3 = 1.97^{+0.27}_{-0.28}$, with breaks at $t_1 = 7.4^{+1.5}_{-1.5}$ ks (observer's frame) and $t_2 = 58^{+9.9}_{-15.4}$ ks. Smoothly broken powerlaw parameters: $\alpha_1 = 0.37^{+0.13}_{-0.15}$ and $\alpha_2 = 1.80^{+0.16}_{-0.16}$, which breaks at $t = 18.5^{+4.4}_{-3.2}$ ks (observer's frame), with a smoothing parameter = 1.0. It should be noted that the final point on the light curve is the upper limit to the detection of the afterglow at that time.

'Broken' and 'doubly broken' powerlaws were also fitted to the data. These models consist of two or three (respectively) powerlaw sections whose slopes join but change instantaneously from α_i to α_{i+1} at the break times. A 'broken' powerlaw model is also a poor description of the lightcurve with χ^2/DOF = 58.0/44. A 'doubly broken' powerlaw provides a much better statistical fit to the data with χ^2/DOF = 38.7/42 ($>$ 99.9% improvement over both the simple and the broken powerlaw). The model consists of $\alpha_1 = 0.25^{+0.16}_{-0.17}$, $\alpha_2 = 1.17^{+0.08}_{-0.09}$ and $\alpha_3 = 1.97^{+0.27}_{-0.28}$ with breaks at $t_1 = 7.4^{+1.5}_{-1.5}$ ks and $t_2 = 58^{+9.9}_{-15.4}$ ks.

The 'smoothly broken' powerlaw also consists of two powerlaw sections; however, the transition between these slopes is not instantaneous, but is spread out over several decades in time. This produces a smooth break rather than a sharp break as in the previous models. Typically the values of the smoothing parameter, S, reported in the literature range between 0.5-10, with a value of ∼1 being favoured both observationally and theoretically (Stanek et al. 2005; Beuerman et al. 1990). A larger value of the smoothing parameter gives a sharper break. The light curve of GRB 050505 is well fit by a smoothly broken powerlaw with χ^2/DOF of ∼1.0. Unfortunately there is degeneracy between the smoothing factor and the initial decay index, with any value between 0.5 and 3 producing a good fit to the data (limit of χ^2/DOF = 1.16). However, if we constrain the model parameters so that the intital emission must be decaying and that α_2 equals p, the electron spectral index [calculated from our spectral index, β, (Zhang & Meszaros 2004)], then we find that a smoothing

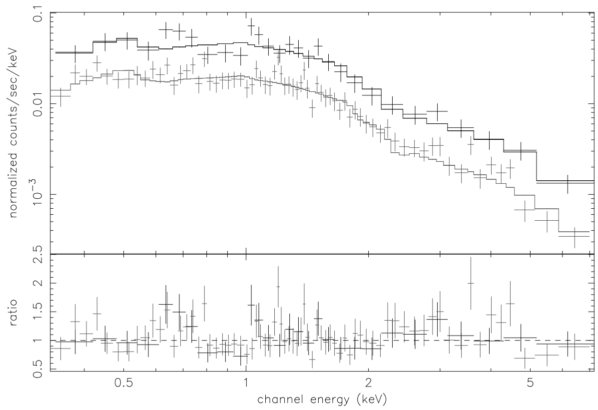

Figure 3. The summed 0.3-10.0 keV (observer's frame) spectrum of GRB 050505 from 'piled up' (black) and 'non piled up' (grey) data, which are consistent with a photon index of ∼1.90, Galactic absorption (2.1×10^{20} cm^{-2}) plus an excess absorption component from the host galaxy (128×10^{20} cm^{-2}).

parameter in the range of 0.5-2 is favoured. This range of smoothing factors produces $\alpha_1 \sim 0.5$; however, these values should be treated with caution. Restricting S to 1.0 we find $\alpha_1 = 0.37^{+0.13}_{-0.15}$, $\alpha_2 = 1.80^{+0.16}_{-0.16}$, $t_{break} = 18.5^{+4.4}_{-3.2}$ ks and χ^2/DOF = 46.9/45 (see Fig 2).

Spectral fits were performed over 0.3-10.0 keV using grade 0-12 events (see Table 1). The spectra were fit with a power law model (see Fig 3) with the absorption, N_H, set at the Galactic column density, and with power law models with excess absorption (either in our Galaxy or the GRB host galaxy).

It is clear from Table 1 that there is no evidence for spectral change over the duration of the observations. It is also clear from the fit to the total data-set that there is significant excess absorption in this spectrum at >99.99% confidence. Statistically both Galactic and extra-galactic absorption fits appear equally likely, however, if the excess absorption were to be due to gas in our Galaxy alone then the value of the excess absorption is almost twice the column density quoted by Dickey and Lockman (1990). Therefore, we conclude that the bulk component of excess absorption must come from the host galaxy with a value of $N_H = 1.28^{+0.61}_{-0.58} \times 10^{22}$cm^{-2} assuming local ISM abundances in the GRB rest frame.

The photon index = $\beta + 1 = 1.90^{+0.08}_{-0.08}$, is typical of the photon indices seen in other GRBs (Preece et al. 2000). With a redshift of 4.27 (Berger et al. 2005) we are measuring the spectrum over a rest-frame range of 1.6-53 keV. The spectrum is well modelled up to such high energies in the rest frame of the GRB, and the photon index is comparable to the values found from low redshift bursts.

3. FOLLOW-UP DETECTIONS OF GRB 050505.

The first reported detection of an optical counterpart for GRB 050505 was made by Cenko et al. (2005a) observing from the Keck I telescope, quickly followed by a measurement of the redshift by the same collaboration (Berger et al. 2005). See Hurkett et al. (2005b) for a summary of all of the optical observations reported on the GCN network as well as data from Faulkes Telescope North, reported there for the first time.

Unfortunately the majority of robotic follow-up missions did not observe GRB 050505 promptly. The sparse nature of this combined data-set naturally limits the knowledge that can be obtained.

4. DISCUSSION

4.1. Physical Origin of the Light curve Break

A 'doubly broken' powerlaw fit contains breaks at $7.4^{+1.5}_{-1.5}$ ks and $58.0^{+9.9}_{-15.4}$ ks in the observer's frame, which translate to T+$1.4^{+0.3}_{-0.3}$ ks and T+$11.0^{+1.9}_{-2.9}$ ks in the rest frame of the burst. The amplitudes of these temporal breaks are $\Delta\alpha_{1-2} = 0.92 \pm 0.19$ and $\Delta\alpha_{2-3} = 0.80 \pm 0.29$.

Light curve breaks can be caused by the passage through the X-ray band of the cooling frequency, the ending of continued shock energization, the presence of a structured jet or jet deceleration causing the relativistic beaming to become broader than the jet angle. We examine these possibilities here.

We can immediately rule out the presence of a cooling break for either break as this would result in $\Delta\alpha$ = 0.5 and a change in spectral index (Sari et al. 1998).

The combined BAT and XRT light curve (shown in Fig 4) is consistent with the schematic diagram (fig 3 of Nousek. et al. 2005) of the canonical behaviour of *Swift* XRT early light curves. For GRB 050505 the decay of the BAT emission would comprise the first powerlaw segment identified by Nousek et al. (2005; hereafter N05), the early flat slope of the XRT decay (α_1) would comprise the second segment of canonical decay and the second slope of the doubly broken powerlaw fit (α_2) would comprise the third canonical segment. The BAT and XRT light curves are consistent with joining in the ∼47 minute gap that separates them (see O'Brien et al. 2005), though this behaviour cannot be confirmed with the data we have available.

It might be considered that either of the X-ray light curve breaks represent the end of the energy injection into the forward shock of the relativistic outflow (N05; Zhang et al. 2000), given the lack of spectral variation (and presuming the emission before the break was dominated by the forward shock). However, the temporal placement of

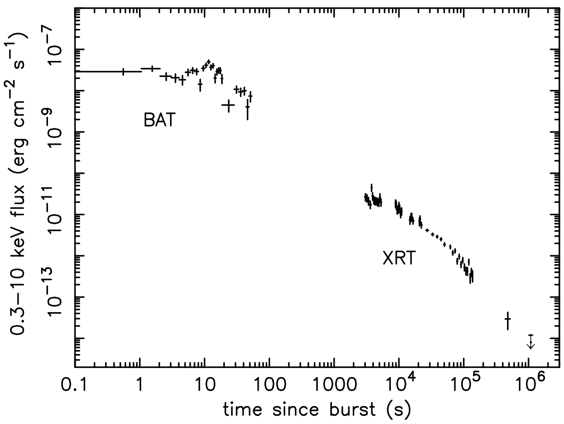

Figure 4. The combined BAT-XRT flux light curve, extrapolated into the 0.3-10.0 keV range. For the XRT section of the flux light curve, the countrate was converted into an unabsorbed flux using the best fit powerlaw model. The BAT data were extrapolated into the XRT band using the best fit powerlaw model derived from the BAT data alone.

the first break makes it the more favourable of the two for this interpretation.

N05 consider that a shallow flux decay is either caused by continous energy injection into the forward shock due to a decrease in the Lorentz factor of the outflow towards the end of the prompt emission or by long lasting central engine activity. The decreasing Lorentz factor (Γ) scenario requires that E(>Γ) $\propto \Gamma^{1-s}$ with s > 1, but N05 find, when modelling the light curve with a single broken powerlaw, that s = -16.7 ± 4.6 for this burst (see their table 3), thus disallowing this interpretation. However, our analysis shows that this scenario is valid for either of our breaks except when $\nu_{\rm c} < \nu_{\rm x} < \nu_{\rm m}$ for a wind medium.

The long-lasting central engine activity scenario requires that the source luminosity decays slowly with time, $L \propto t_{\rm lab}^{q}$ with q > -1. Our analysis shows that the long-lasting central engine activity scenario is valid, again for either of our breaks, as long as the X-ray frequency, $\nu_{\rm x}$, is above the cooling frequency, $\nu_{\rm c}$. We are unable to distinguish, in this case, whether a wind or homogenous cirumburst medium is favoured.

Another possible cause of either of the breaks in the light curve of GRB 050505 could be a structured jet outflow. In this case the ejecta energy over solid angle, $dE/d\Omega$, is not constant, but varies with the angle θ measured from the outflow symmetry axis (Meszaros et al. 1998). Panaitescu (2005) suggests that since afterglow light curves are power laws in time that $dE/d\Omega$ can be approximated as a power law in θ (see their eqn 13), with a power law index[1] of q. We assume a typical value of p (the electron spectral index) to be 2.2 and use the observed values of $\Delta\alpha$ to calculate q from eqns 14 and 15 of Panaitescu (2005). This relation only applies when q $<$ q̃, where q̃ = 8/(p+4) or 8/(p+3). For GRB 050505 the observed values of $\Delta\alpha$ give q significantly greater than q̃ for both wind and uniform environments and for ν_x above or below ν_c.

For q $>$ q̃, where $dE/d\Omega$ falls off sufficiently fast that the afterglow emission is dominated by the core of the jet, Panaitescu (2005) calculates $\Delta\alpha$ = 0.75 (homogenous environment) or 0.5 (wind environment). Thus a structured jet does not appear to be the origin of the first break but it appears to be consistent with the second break as long as the burst is surrounded by a homogenous environment.

The signatures of a jet break, where the relativistic outflow from the GRB slows sufficiently that $\Gamma \sim 1/\theta_j$ and the jet spreads laterally, are an achromatic temporal break with a typical amplitude of $\sim$1 (eg. see Rhoads 1999), no spectral variation (Piran 2005) and a post-break decay index equal to p (Rhoads 1999). There is no evidence for spectral variation during our observations (see Table 1). Unfortunately there were insuffcient optical detections of this GRB pre- and post-break to confirm the presence of a jet break in other wavelengths at either epoch.

The temporal index of an X-ray light curve post-jet break should equal p. We calculate from our measured spectral index, β, that p = 1.8 and 2.8, assuming that $\nu_{\rm x}$ is above and below the cooling frequency, $\nu_{\rm c}$, respectively (Zhang & Meszaros 2004). We measure a value of $\alpha_2 = 1.17^{+0.08}_{-0.09}$, which is not compatable with either value of p, which rules out the first break being due to a jet break. However, $\alpha_3 = 1.97^{+0.27}_{-0.28}$ which agrees, within the limits, to the $\nu_{\rm x} > \nu_{\rm c}$ case (p = 1.8). With this value of p we can constrain the jet break parameters further and conclude that the amplitude of the second break is consistent with a jet break.

Having considered the various potential origins for the breaks in the light curve of GRB 050505 for the doubly broken model we conclude that the first break is due to the end of energy injection into the forward shock, i.e. that GRB 050505 fits with the canonical light curve model proposed by N05, and that the second break is either due to a structured jet or is a jet break.

The 'smoothly broken' powerlaw provides a good fit to the XRT light curve data; however, the large degree of smoothing involved produces a degeneracy between the smoothing parameter, the first decay index and the break time. If we take the example case for S = 1 (see Fig 2), then a break is observed at T+18.5$^{+4.4}_{-3.2}$ ks in the observer's frame. This translates to T+3.5$^{+0.8}_{-0.6}$ ks in the rest frame of the burst, with $\Delta\alpha$ = 1.43$^{+0.21}_{-0.22}$.

The magnitude of this break allows use to rule out a cooling break, the presence of a structured jet or the end of continued energy injection into the forward shock. It is compatable with a jet break from optically thick synchrotron emission ($\Delta\alpha$ = 1.25, Rhoads 1999). However, a break this early requires an unreasonably large circumburst density to produce a value of E_γ, the true γ-ray energy released, that is comparable with the typical value seen thus far (Bloom et al. 2003). Thus the parameters of

[1]The q in this formulation is not the same as the q discussed by N05

Table 1. Spectral fits for GRB 050505. [a] Spectral models: power-law (PL), Galactic absorption (Gal), which has been assumed to be 2.1×10^{20} cm^{-2} (Dickey & Lockman 1990), excess Galactic absorption (Abs) and excess absorption in the host galaxy (ZAbs). ∗ z fixed at 4.27.

	Model[a]		
	PL+Gal	PL+Gal+Abs	PL+Gal+ZAbs*
Co-added data for T+3ks - T+17ks			
Photon index	$1.76^{+0.09}_{-0.09}$	$1.91^{+0.19}_{-0.18}$	$1.87^{+0.15}_{-0.14}$
Excess N_H (10^{20} cm^{-2})	-	< 7.74	113^{+123}_{-107}
χ^2/DOF	26.9 (27)	24.2 (26)	23.9 (26)
Co-added data for T+26ks - T+138 ks			
Photon index	$1.77^{+0.06}_{-0.06}$	$1.94^{+0.12}_{-0.11}$	$1.91^{+0.10}_{-0.09}$
Excess N_H (10^{20} cm^{-2})	-	$3.91^{+2.43}_{-2.14}$	133^{+73}_{-65}
χ^2/DOF	86.2 (69)	77.3 (68)	74.7 (68)
All data co-added			
Photon index	$1.76^{+0.05}_{-0.05}$	$1.93^{+0.10}_{-0.10}$	$1.90^{+0.08}_{-0.08}$
Excess N_H (10^{20} cm^{-2})	-	$3.81^{+2.09}_{-1.93}$	128^{+61}_{-58}
χ^2/DOF	133 (97)	102 (96)	99 (96)

the smoothly broken powerlaw model are not compatable with any theoretical framework put forward thus far.

4.2. Burst Properties

From the redshift of GRB 050505 (z = 4.27) we calculate an isotropic equivalent radiated energy, $E_{\rm iso}$, in the observed 15-350 keV energy range to be (1.45±0.14)×10^{53} ergs, using the standard cosmology: H$_o$ = 71 km s^{-1} Mpc^{-1}, (Ω_M, Ω_Λ) = (0.27, 0.73).

If we take the second break in the light curve to be a jet break we are then able to calculate the properties of GRB 050505. Using the formulation of Frail et al. (2001), and assuming that the efficiency of the fireball in converting the energy of the ejecta into γ-rays is ∼0.2, we obtain a range in $\theta_{\rm j}$ from 2.5^o (n = 1 cm^{-3}) to 4.4^o (n = 100 cm^{-3}).

From this we can calculate the beaming fraction, f_b, (Sari et al. 1999) to be between 9.4×10^{-4} (n = 1 cm^{-3}) and 3.0×10^{-3} (n = 100 cm^{-3}) and E_γ to be in the range of 1.37×10^{50} (n = 1 cm^{-3}) to 4.33×10^{50} ergs (n = 100 cm^{-3}). We note that the typical E_γ of bursts thus far is 1.33×10$^{51}h_{65}^{-2}$ ergs (Bloom et al. 2003) with a burst-to-burst variance about this value of ∼ 0.35 dex (or a factor of 2.2), thus this burst appears to be slightly weak in comparison.

Given that these values for E_γ are low compared to the mean value discovered so far we calculated $E_{\rm peak}$ from these values of E_γ via the Ghirlanda relation (Ghirlanda et al. 2004) and compared them to the observed lower limit of $E_{\rm peak,obs} > 52$ keV. We calculated that the Ghirlanda relation gave $E_{\rm peak}$ = 153^{+65}_{-63} keV (for n=1 cm^{-3}) and 341^{+138}_{-134} keV (for n=100 cm^{-3}), which both agree with the lower observed limit. We also calculated $E_{\rm peak}$ via the Amati correlation (Amati et al. 2002). Using equation 6 of Ghirlanda et al. (2005) for GRBs of known redshift gives $E_{\rm peak}$ = 112±6 keV, consistent with our observed limit.

5. CONCLUSIONS

We have presented multi-wavelength data for GRB 050505. The X-ray light curve of GRB 050505 (see Fig 2) can be adequately fit with either a ‘smoothly broken’ or ‘doubly broken’ powerlaw model.

The ‘smoothly broken’ powerlaw model favours a smoothing factor of 0.5-2 (highly smoothed transition). This produces an initially shallow decay with $\alpha_1 \sim 0.5$, which breaks over several decades in time to a steeper slope, α_2, of ∼1.8 (χ^2/DOF ∼ 1.04). However, the parameters of this fit are not compatable with any theoretical framework put forward thus far.

A ‘doubly broken’ powerlaw model consists of α_1) = $0.25^{+0.16}_{-0.17}$ (first detected at T+3 ks), $\alpha_2 = 1.17^{+0.08}_{-0.09}$ and α_3 = $1.97^{+0.27}_{-0.28}$ (which continues to at least T+1.05×10^3 ks) with breaks at $t_1 = 7.4^{+1.5}_{-1.5}$ ks and $t_2 = 58^{+9.9}_{-15.4}$ ks (χ^2/DOF = 38.7/42).

We see no change in the X-ray spectral properties during *Swift's* observations of this GRB. The best fit model parameters for the X-ray spectrum indicates that this burst has a typical photon index of $1.90^{+0.08}_{-0.08}$ and an excess absorption component from the host galaxy of ($1.28^{+0.61}_{-0.58}$)×10^{22}cm^{-2} (χ^2/DOF = 99/96).

Having considered the temporal position and amplitude of the two breaks in the doubly broken light curve we conclude that the first break is due to end of energy injection into the forward shock (N05; Zhang et al. 2005), i.e. that GRB 050505 fits with the canonical light curve model proposed by N05, and that the second break is either a jet break or a break caused by the presence of a structured jet.

The redshift of 4.27 allowed us to calculate the intrinsic parameters for this GRB, in conjunction with the second light curve break time observed in *Swift's* X-ray observations. Whilst the identification of this break with a jet break provides a value for E_γ that is slightly low with respect to previous GRBs, it is consistent with the Ghirlanda relation (Ghirlanda et al. 2004; 2005). It also suggests that GRB 050505 has a narrow beaming angle; however, this degree of beaming is not unexpected for GRBs at high redshift since GRBs with wider jets could potentially be too faint to be detected by any of the current γ-ray missions.

ACKNOWLEDGMENTS

This work is supported at the University of Leicester by the Particle Physics and Astronomy Research Council (PPARC). CPH gratefully acknowledges support from a PPARC studentship

REFERENCES

Amati L., et al., 2002, A&A, 390, 81.

Anders E. & Grevesse N. 1989, Geochim. Cosmochim. Acta. 53, 197.

Andersen M. I., et al. 2000, A&A, 364, L54.

Barthelmy S. D. 2005, Space Sci. Rev., in press (astro-ph/0507410).

Berger E., et al. 2005, GCN Circ. 3368.

Beuerman K., et al. 1990, A&A, 352, L26.

Bloom J. S., Frail D. A. & Kulkarni S. R. 2003, ApJ, 594, 674.

Burrows D. N., et al. 2005, Space Sci. Rev., in press (astro-ph/0508071).

Cenko S. B., et al. 2005a, GCN Circ. 3366.

Cenko S. B., et al. 2005b, GCN Circ. 3377.

Dickey & Lockman. 1990, ARAA, 28, 215.

Frail D. A. 2001, ApJ, 562, L55

Gehrels, N.; et al. 2004, ApJ, 611, 1005.

Ghirlanda G., Ghisellini G. & Lazzati D. 2004, ApJ, 616, 331.

Ghirlanda G., Ghisellini G. & Firmani C. 2005, MNRAS, 361, L10.

Hohman D., Henden A. & Price A. 2005, GCN Circ. 3370.

Homewood A., Hartmann D. H., & Wood M. 2005, GCN Circ. 3398.

Hurkett C. P., et al. 2005a, GCN Circ. 3360.

Hurkett C. P., et al. 2005b, in preparation.

Jelinek A. J. et al. 2005, GCN Circ. 3373.

Kawai, et al. 2005, GCN Circ. 3937.

Kennea J. A., et al. 2005, GCN Circ 3365.

Kippen R. M. 2000, GCN Circ. 530.

Klotz A., Boer M. & Atteia J. L. 2005, GCN Circ. 3403.

Lamb D. Q. & Reichart D. E. 2000, ApJ, 536, 1.

Meszaros P., Rees M. J. & Wijers R. 1998, ApJ, 499, 301.

Nousek J. A., et. al. 2005, ApJ, submitted.

O'Brien P. T. et al. 2005, in preparation.

Panaitescu A. 2005, MNRAS, 362, 921.

Piran T. 2005, Rev. Mod. Phys. 76, 1143.

Preece R. D, et al. 2000, ApJ, 126, 19.

Rhoads J. E. 1999, ApJ, 525, 737.

Rol E., et al. 2005, GCN Circ. 3372.

Roming P. W. A., et al. 2005, Space Sci. Rev., in press (astro-ph/0507413).

Rosen S., et al. 2005, GCN Circ. 3371.

Sari R., Piran T. & Narayan R. 1998, ApJ, 497, L17.

Sari R., Piran T. & Halpern J. P. 1999, ApJ, 519, L17.

Stanek K. Z., et al. 2005, ApJ, 626, 45.

Tinney C., et al. 1998, IAU Circ. 6896.

de Ugarte Postigo A., et al. 2005, GCN Circ. 3376.

Vaughan S., et al. 2005, ApJ in press (astro-ph/0510677).

Vreeswijk P. M., et al. 2004, A&A 419, 927.

Wilms J., Allen A., & McCray R. 2000, ApJ, 542, 914.

Zhang B. & Meszaros P. 2004, IJMPA, 19, 2385.

Zhang B., et al. 2005, in preparation.