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Swift GRB GRB071010B: outlier of the $E_{\text{src peak}}^\gamma - E_\gamma$ and $E_{\text{iso}} - E_{\text{src peak}}^\gamma - t_{\text{jet}}^\gamma$ correlations

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ABSTRACT

We present multi-band results for GRB071010B based on Swift, Suzaku, and ground-based optical observations. This burst is an ideal target to evaluate the robustness of the $E_{\text{src peak}}^\gamma - E_{\text{iso}}$ and $E_{\text{src peak}}^\gamma - E_\gamma$ relations, whose studies have been in stagnation due to the lack of the combined estimation of $E_{\text{src peak}}^\gamma$ and long-term optical monitoring. The joint prompt spectral fitting using Swift/Burst Alert Telescope and Suzaku/Wide-band All sky Monitor data yielded the spectral peak energy as $E_{\text{src peak}}^\gamma$ of $86.5^{+6.4}_{-6.3}$ keV and $E_{\text{iso}}$ of $2.25^{+0.19}_{-0.16} \times 10^{52}$ erg with $z = 0.947$. The optical afterglow light curve is well fitted by a simple power law with

\[E_{\text{src peak}}^\gamma = 86.5^{+6.4}_{-6.3}\text{ keV}\]
\[E_{\text{iso}} = 2.25^{+0.19}_{-0.16} \times 10^{52}\text{ erg}\]

\[\text{with } z = 0.947\]

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temporal index $\alpha = -0.60 \pm 0.02$. The lower limit of temporal break in the optical light curve is 9.8 days. Our multi-wavelength analysis reveals that GRB071010B follows $E_{\text{peak}}^{\text{src}} - E_{\text{iso}}$ but violates the $E_{\text{peak}}^{\text{src}} - E_{\gamma}$ and $E_{\text{iso}} - E_{\text{peak}}^{\text{src}} - t_{\text{jet}}^{\text{src}}$ at more than the $3\sigma$ level.

Subject headings: gamma rays: bursts — gamma rays: observation

1. Introduction

A few tight correlations linking several properties of gamma-ray bursts (GRBs), namely the spectral peak energy, the total radiated energy, and the afterglow break time, have been discovered with pre-Swift GRBs. Amati et al. (2002) found the empirical relation between the rest-frame spectral peak energy of prompt emission $E_{\text{peak}}^{\text{src}}$ (here, we use the $E_{\text{peak}}^{\text{src}}$, $E_{\text{peak}}^{\text{obs}}$ for the values in the rest and observer frames, respectively) and the isotropic-equivalent energy released during the prompt phase $E_{\text{iso}}$. Ghirlanda et al. (2004a) showed a tight empirical relation between the $E_{\text{peak}}^{\text{src}}$ and the collimation-corrected energy $E_{\gamma}$ based on a jet interpretation of the temporal break in the optical afterglow light curve. Liang & Zhang (2005) found the three-dimensional correlation in the $E_{\text{iso}} - E_{\text{peak}}^{\text{src}} - t_{\text{jet}}^{\text{src}}$ plane. The existence of these correlations could uncover crucial properties of GRB physics which are not yet fully understood. Recently, there have been studies of outliers to these relations (e.g., Campa et al 2007, Sato et al. 2007, Ghirlanda et al. 2007). Using Swift/XRT observations, Sato et al (2007) showed that there are cases with continuous X-ray afterglow light curves where no jet break is seen at the expected break time derived from the $E_{\text{peak}}^{\text{src}} - E_{\gamma}$ relation. However, some X-ray afterglow light curves may not show jet breaks together with the optical afterglow at the expected time, because there is a possibility that X-ray and optical emission come from different regions and mechanisms even in the normal decay phase (e.g., Urata et al. 2007a, Liang et al 2007, Huang et al. 2007, Ghisellini et al. 2009). Therefore, it is critical to check the aforementioned relations by combining prompt $\gamma$-ray wide-band spectroscopy and optical long-term monitoring.

In this Letter, we present joint spectral analysis of the prompt gamma-ray and systematic optical follow-up results for GRB 071010B. This event was detected and localized by Swift (Markwardt et al. 2007a). The Suzaku/Wide-band All sky Monitor (WAM; Yamaoka et al. 2009) and Konus/WIND (Golenetskii et al. 2007) also detected this main burst. Thanks to the wide energy band of the Suzaku/WAM (Yamaoka et al. 2009), the joint spectral fittings between the Swift/Burst Alert Telescope (BAT) and the Suzaku/WAM data yield better constraint for the determination of $E_{\text{peak}}$. The optical afterglow was discovered by Oksanen (2007) and observed by many telescopes from the early stage (e.g., Wang et al.}
The redshift was determined to be $z = 0.947$ by Cenko et al. (2007) using the Gemini North telescope. In the framework of EAFON (Urata et al. 2003, 2005), we have performed long term monitoring to determine the jet break time. Therefore, GRB071010B is one of the most suitable event to evaluate $E_{\text{src}}^{\text{peak}} - E_{\gamma}$ and $E_{\text{iso}} - E_{\text{src}}^{\text{peak}} - t_{\text{jet}}$ in Swift era. All the errors are quoted at the 90% statistical confidence level in this paper.

2. Observations

2.1. Swift/BAT

The Swift/BAT triggered and located GRB 071010B (trigger ID=293795) at 20:45:47 (T$_0$) UT on 2007 October 10. The on-board localization was distributed 13 sec after the trigger and its position was reported as RA= 10$^h$02$^m$07.5, Dec= +45$^\circ$44$'$0", with an uncertainty of 3". The spacecraft did not slew promptly to the burst position because automated slewing was disabled due to ongoing recovery from a gyro anomaly (Markwardt et al. 2007a). After 6800 s of the trigger, Swift/XRT started observing the field and detected a bright X-ray counterpart at R.A.= 10$^h$02$^m$09.2, decl. = +45$^\circ$43$'$52".2, with an uncertainty of 5". Markwardt et al. (2007b) reported the mask-weighted light curve which shows a pre-trigger pulse starting at T$_0$ $\sim$ −45 s, peaking at T$_0$ $\sim$ −20 s, and returning almost to background at T$_0$ $\sim$ −8 s. The main FRED pulse started at T$_0$ $\sim$ 2 s and ended around T$_0$ $\sim$ 60 s. A small third soft peak started at T$_0$ + 95 s and was terminated by the planned spacecraft slew (Markwardt et al. 2007b). The two peaks at T$_0$ − 45 s and T$_0$ + 95 s are much weaker than the main peak, thus they are not visible in Figure 1.

2.2. Suzaku/WAM

The Suzaku/WAM was triggered at 20:45:49 (T$_0 + 2$ s) UT on 2007 October 10. The Suzaku/WAM is the active shield of the Hard X-ray detector (Takahashi et al. 2007; Kokubun et al. 2007) onboard the 5th Japanese X-ray satellite Suzaku (Mitsuda et al. 2007). It consists of large area, thick BGO crystals and is also designed to monitor the all sky from 50 keV to 5 MeV by a large effective area. The large effective area from 300 keV to 5 MeV (400cm$^2$) surpasses those of other currently operating experiments with spectral capability, and enables us to perform wide-band spectroscopy of GRBs with high sensitivity.

As shown in Figure 1, the WAM light curve also shows a single FRED-like peak starting at T$_0$ − 1 s, ending at T$_0$ + 8 sec. The duration of the WAM signal is $T_{90} = 5$ s. This spike was also detected by both the Swift/BAT, and the Konus/WIND. There is no signif-
icant signal from the pre-cursor and the weak soft tail seen in the Swift/BAT light curve (Markwardt et al. 2007b) during the time coverage.

2.3. Optical Follow-ups

We carried out follow-up observations of the GRB071010B optical afterglow at the Mt. Lemmon, Arizona, USA and the Xinglong, China observatories within the framework of the EAFON (Urata et al. 2003, 2005). Using the robotic 1 m telescope and a 2k × 2k CCD camera at the Mt. Lemmon observatory operated by the Korea Astronomy Space Science Institute (I. Lee et al. in preparation; Han et al. 2005), we have made B-, V-, and R-band imaging observations with 300 s exposures, starting at 10:51:14.6 UT on 2007 October 11 (0.5871 days after the burst). In all the bands, we detected the afterglow clearly. We have also monitored the afterglow on October 12, 16, 19, 21, 25, and 26 in the Rc-band. Additional V-band observations were performed using the EST 1.0 m telescope at the Xinglong Observatory (Zheng et al. 2008), starting at 2007 October 11 (19:08 UT; 0.971 days after the burst). The filed of view is 11′.4 × 11′.1, and the pixel size is 0′′.51 square.

The i′- and z′-band observations were acquired with the 3.6-m CFHT using MegaCam on 2008 October 26, and November 6 (approximately one year after the burst), respectively. These deeper images show the host galaxy with i′ = 23.63 ± 0.14 AB mag, z′ = 22.73 ± 0.11 AB mag at R.A. = 10h02m09.274, decl. = +45°43′49″.69.

3. Analysis and Results

3.1. Swift/BAT Prompt Emission

The BAT data were analyzed using the standard BAT analysis software distributed within HEADAS v6.4. Using batgrbproduct v2.41, the mask-weighted BAT light curves were created in the standard four energy bands, 15 − 25, 25 − 50, 50 − 100, 100 − 350 keV, and the duration was determined as T_{90} = 36.0 ± 2.4 s. Figure 1 shows 15 − 50 keV and 50 − 150 keV light curves. Response matrices were generated with the task batdrmgen using the latest spectral redistribution matrices. The time-averaged spectrum (15 − 150 keV) from T_0 − 35.7 to T_0 + 24.2 s is well fitted by a power law with an exponential cutoff. This fit yields a photon index of 1.53 ± 0.22, and E_{obs,peak} of 52.0 ± 6.4 keV. A fit to a simple power law gives a photon index of 2.01 ± 0.05 (χ^2/ν = 0.82 for ν = 57).
3.2. Suzaku/WAM Prompt Emission

The WAM spectral and temporal data were extracted using hxdmkwamlc and hxdmkwamspec in the HEADAS version 6.4. The background was estimated using the fitting model described in Sugita et al. (2009). Response matrices were generated by the WAM response generator as described in Ohno et al. (2008). The time-averaged spectrum (150 – 1000 keV) from $T_0 - 0.78$ to $T_0 + 24.2$s was well fitted by a single power law with a photon index of $2.64^{+0.26}_{-0.22}$ ($\chi^2/\nu = 1.07$ for $\nu = 10$). This result is consistent with the Swift/BAT power law with an exponential cutoff fitting with the photon index $1.53 \pm 0.22$, and $E_{peak}^{obs}$ of $52.0 \pm 6.4$ keV.

3.3. BAT and WAM Joint Analysis

In order to better constrain the spectral peak energy, we perform joint fitting between Swift/BAT and Suzaku/WAM. Figure 1 shows the overlapping time regions (from $T_0 - 0.78$ to $T_0 + 24.2$s) for this fitting. As shown in Figure 2, the spectrum is well fitted with the Band function (Band et al 1993). The fitting yields a low-energy photon index of $1.19^{+0.29}_{-0.23}$, a high-energy photon index of $2.30^{+0.06}_{-0.07}$ and $E_{peak}^{src}$ of $86.5^{+6.4}_{-6.3}$ keV ($\chi^2/\nu = 0.59$ for $\nu = 87$). This result is consistent with that of Konus/WIND (Golenetskii et al. 2007). We have also estimated the $E_{iso}$ as $2.25^{+0.19}_{-0.16} \times 10^{52}$ erg, assuming cosmological parameters: $H_0 = 71 \text{km s}^{-1} \text{Mpc}^{-1}$, $\Omega_m = 0.27$, and $\Omega_{\Lambda} = 0.73$.

3.4. Optical Afterglow

A standard routine including bias subtraction and flat-fielding corrections was employed to process the data using the IRAF package. The DAOPHOT package was used to perform aperture photometry of the GRB images. For the photometric calibration of the afterglow, several calibration stars reported by Henden (2007) were chosen. In Figure 3, we plot the $Rc$-band light curve of the GRB071010B afterglow based on our photometry. The data contain our LOAO measurements, TAOS observations (Wang et al. 2008) with the re-calibrated GCN measurements (Oksanen 2007; Kann et al. 2007a,b,c; Kocevski et al. 2007; Klunko et al. 2007 ). The light curve between 0.02 and 10.6 day is well fitted by a single power law with index $\alpha = -0.60 \pm 0.02$ ($\chi^2/\nu = 0.89$ for $\nu = 37$), defined by $F(t) \propto t^{\alpha}$, where $F(t)$ is the flux in the $Rc$-band at time $t$ after the BAT trigger time $T_0$. The single power-law index is consistent with that of the TAOS measurement ($\alpha \sim -0.51$) reported by (Wang et al. 2008). This fitting also excludes the possible 3.4 days temporal break reported
by Kann et al (2007) and Im et al (2007) based on GCN data point measurements. We have also confirmed that the host-galaxy brightness ($i' = 23.63$ mag, $z' = 22.73$ mag) derived by the CFHT observations is insufficient to affect this fitting. We consider both red and typical host-galaxy colors to evaluate $R$-band brightness. Although the late-time light curve could be fitted by a single power-law, it is interesting to note that a possible temporal break occurred at around 9 days after the burst. We tried to fit the 0.02–10.6 days light curve with a broken power law function expressed as

$$F_{\nu}(t) = \frac{F_{\nu}^*}{\left[ (t/t_b)^{\alpha_1} + (t/t_b)^{\alpha_2} \right]},$$

where $\alpha_1$ and $\alpha_2$ are the power-law indices before and after the break, $F_{\nu}^*$ is the flux at the break, and $t_b$ is the break time. The fitting yields $\alpha_1 = -0.54 \pm 0.03$, $\alpha_2 = -3.03 \pm 1.15$ and $t_b = 9.81 \pm 1.00$ ($\chi^2/\nu=0.52$ for $\nu = 35$). When we fix $\alpha_2$ as -2, the fitting provides the break time of $t_b = 9.61 \pm 1.49$. Therefore, these results imply that the temporal break should be around or later than 9.8 days after the burst.

4. Discussion

Spectral parameters of the prompt emission of GRB071010B are well constrained by our joint fitting of Swift/BAT and Suzaku/WAM. The measured values of current event ($E_{\text{src} \, \text{peak}} = 86.5^{+6.4}_{-6.3}$ keV and $E_{\text{iso}} = 2.25^{+0.19}_{-0.16} \times 10^{52}$ erg) well follow the $E_{\text{src} \, \text{peak}} - E_{\gamma}$ relation. Furthermore, our systematic long term (10 days) optical monitoring observation suggests a possible jet break at later than $\sim 9.8$ days after the burst. The wealth of the multi-wavelength data with a good temporal coverage makes GRB071010B one of the best targets to evaluate the $E_{\text{src} \, \text{peak}} - E_{\text{iso}}$ and the $E_{\text{iso}} - E_{\text{src} \, \text{peak}} - t_{\text{jet}}$ relations which studies have been in stagnation due to the lack of the $E_{\text{src} \, \text{peak}}$ estimation and long term optical monitoring.

In order to evaluate the $E_{\text{src} \, \text{peak}} - E_{\gamma}$ relation for the optical light curve, we invert this relation to predict the jet break time as described in Sato et al. (2007). The expected jet break time is expressed as

$$t_{\text{jet}} = 389 \left(1 + \frac{n}{3 \text{cm}^{-3}} \right)^{-\frac{1}{3}} \left( \frac{\eta_{\gamma}}{0.2} \right)^{-\frac{1}{3}} E_{\text{iso}, 52}^{-1} \left( \frac{E_{\text{src \, peak}}}{A} \right)^{1.89} \text{day},$$

where $n$ and $\eta_{\gamma}$ are the number density of the ambient medium and the efficiency of the shock, respectively. Here, we use the Ghirlanda relation as $E_{\text{src \, peak}} = A E_{\gamma, 52}^{0.70}$, allowing $A$ to vary within the $3\sigma$ level. The value of $n$ is in general within $1 < n < 30$ cm$^{-2}$ (Panaitescu & Kumar 2001, 2002). Following the assumption made by Ghirlanda et al. (2004a) for most of their sample GRBs, we initially assume $n = 3$ cm$^{-2}$ and $\eta_{\gamma}=0.2$. As shown in Figure 3, the
optical light curve is well described with a single power law during the expected jet break time. We also tried to fit the optical light curve by fixing the jet break time as $t_j = 1.25$ days expected from Equation (2). The fitting yields $\alpha_1 = -0.30 \pm 0.06$ and $\alpha_2 = -0.91 \pm 0.04$ ($\chi^2/\nu = 0.72$ for $\nu = 36$). Although this fitting is acceptable in terms of the $\chi^2$-fitting, an $F$-test indicates that this broken power-law model with $t_j = 1.25$ days over the single power law is not significant at the 90% confidence level. These temporal decay indices are inconsistent with those of typical jet break events. The temporal ($\alpha_x = 0.67$) and spectral ($\beta_x = 1.10$) relation of X-ray afterglow also support the sphere phase ($\alpha = 3/2 \beta - 1 \sim 0.65$). These X-ray values come from UK’s X-ray afterglow repository (Evans et al 2009). Thus, these results imply that GRB071010B is an outlier of the tight $E_{\text{src}}^{\text{peak}} - E_\gamma$ relation.

In Figure 4, we also plotted the $E_{\text{src}}^{\text{peak}} - E_\gamma$ relation together with GRB041006, GRB050904 and others reported by Ghirlanda et al. (2007). According to the detailed optical analysis of the GRB041006 afterglow (Urata et al. 2007b), this pre-Swift era event shows a chromatic optical plateau phase around 0.1 $\sim$ 0.2 days after the burst. Since Ghirlanda et al. (2007) regarded this chromatic plateau in the GRB041006 optical light curve as the jet break, we updated $E_\gamma$ for this event. As shown in Figure 4 GRB071010B is a clear outlier of the tight correlation with more than 3$\sigma$ deviation. GRB041006 is also possible outlier at the 2$\sigma$ level. We have also tested the wind case. The estimated $E_{\gamma,\text{sw}} > 2.8 \times 10^{50}$ erg from the jet break limit is inconsistent with Ghirlanda et al (2007) by over 3$\sigma$ level. According to Sugita et al. (2009), GRB050904 is also an outlier of the $E_{\text{src}}^{\text{peak}} - E_\gamma$ relation, but it follows the $E_{\text{src}}^{\text{peak}} - E_{\text{iso}}$ relation.

These three events including a high-redshift GRB050904 imply the $E_{\text{src}}^{\text{peak}} - E_\gamma$ relation could have larger scatter than originally suggested. Since the $E_{\text{src}}^{\text{peak}} - E_\gamma$ correlation requires a small scatter to be used to standardize GRBs in a way similar to Type Ia supernovae (Ghirlanda et al. 2004b), these three events pose a problem to the cosmological application of the $E_{\text{src}}^{\text{peak}} - E_\gamma$ relation. Another implication is that these outliers have the relevant role of the circumburst environments for different origins (e.g., long and short bursts). In the GRB050904 case, the gap can be explained by a higher circumburst density which implies a massive stars origin. The required density is consistent with the estimations by optical and radio observations (Sugita et al. 2009). However, GRB071010B requires a 2 or 3 order smaller circumburst density ($n \sim 5.9 \times 10^{-3}$ cm$^{-3}$) to be consistent with the tight correlation. This lower density environment implies the origin of GRB071010B is of short GRB, where typical circumburst density is $n = 10^{-2}$ cm$^{-3}$ (e.g., Nakar 2007), even though the prompt duration of GRB071010B is longer than 2 s ($T_{90} = 36.0 \pm 2.3$ s).

We also tested the empirical $E_{\text{iso}} - E_{\text{src}}^{\text{peak}} - t_{\text{jet}}^{\text{src}}$ relation (Liang & Zhang 2005) expressed
as

\[
\frac{E_{\text{iso}}}{10^{52}} = (0.85 \pm 0.21) \left( \frac{E_{\text{peak}}}{100\text{keV}} \right)^{1.94\pm0.17} \left( \frac{t_{\text{src jet}}}{1\text{day}} \right)^{-1.24\pm0.23}
\]

where \( t_{\text{src jet}} \) is the jet break time in the rest frame. As shown in Figure 5, this relation yields the expected upper limit of isotropic total energy as \( E_{\text{iso}} < 0.11 \times 10^{52}\text{erg} \) with the jet break time \( t_{\text{jet}} > 9.8 \text{day} \). Therefore, GRB071010B is also an outlier of this model-independent relation at more than the 3\( \sigma \) level.

Since the tight correlations \( E_{\text{peak}} - E_{\gamma} \) and \( E_{\text{iso}} - E_{\text{peak}} - t_{\text{src jet}} \) might indicate a crucial property of GRB physics (e.g., Thompson, 2006 and Thompson, Meszaros & Rees, 2007 for the \( E_{\text{peak}} - E_{\gamma} \) relation), GRB071010B might be classified as a new category. However, there is also the possibility that these relations simply have larger dispersion than previous studies. Therefore, further study is required with large volume of good samples which can be built up by the joint analysis of Swift/BAT, Suzaku/WAM, Konus/WIND, Fermi/GBM and future missions such as the Space Variable Objects Monitor (SVOM) (Basa et al. 2008) with ground-based optical follow-ups.

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REFERENCES

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

Basa, S., et al. 2008, in proceedings of the SF2A conference, Paris, 2008 (arXiv:0811.1154)

Cenko, S. B., Cucchiara, A., Fox, D. B., Berger, E., & Price, P. A. 2007, GRB Coordinates Network, 6888, 1

Campana, S., Guidorzi, C., Tagliaferri, G., Chincarini, G., Moretti, A., Rizzuto, D., & Romano, P. 2007, A&A, 472, 395

Ghirlanda, G., Ghisellini, G., & Lazzati, D. 2004a, ApJ, 616, 331
Ghirlanda, G., Ghisellini, G., Lazzati, D., & Firmani, C. 2004b, ApJ, 613, L13
Ghirlanda, G., Nava, L., Ghisellini, G., and Firmani, G., 2007, å, 466, 127
Ghisellini, G., et al., 2009, MNRAS 393, 253
Golenetskii et al. 2007, GCN Circ., (2007) 6879
Han, W., et al. 2005, PASJ, 57, 821
Huang, K.Y., et al. 2007, ApJ, 654, L25
Im, M., I. Lee, & Urata, Y. 2007, GRB Coordinates Network, 6897, 1
Kann, D. A., Hoegner, C., & Filgas, R. 2007, GRB Coordinates Network, 6918, 1
Kann, D. A., Laux, U., & Filgas, R. 2007, GRB Coordinates Network, 6923, 1
Kann, D. A., et al. 2007, GRB Coordinates Network, 6935, 1
Klunko, E., Marchenkov, A., Eselevich, M., Shulga, A., Volnova, A., & Pozanenko, A. 2007, GRB Coordinates Network, 6945, 1
Kira, C., et al. 2007, GRB Coordinates Network, 6931, 1
Kocevski, D., Perley, D. A., Bloom, J. S., Modjaz, M., & Poznanski, D. 2007, GRB Coordinates Network, 6919, 1
Kokubun, M., et al. 2007, PASJ, 59, 53
Liang, E. W., Zhang, B. B, Zhang, B, 2007 ApJ, 670, 565
Liang, E. W., and Zhang, B, 2005 ApJ, 633, 611
Markwardt, C., 2007, GCN Circ., (2007) 6871
Markwardt, C., Kennea, J., Mangano, V., Barthelmy, S. D., Burrows, D. N., Roming, P., & Gehrels, N. 2007, GCNR, 92, 1 (2007), 92, 1
Mitsuda, K., et al. 2007, PASJ, 59, 1
Nakar, E. 2007, Phys. Rep., 442, 166
Oksanen, A. 2007, GRB Coordinates Network, 6873, 1
Ohno, M., et al. 2008, PASJ, 60, 361
Sato, G., et al. 2007, ApJ, 657, 359
Shirasaki, Y., et al. 2008, PASJ, 60, 919
Sugita, S., et al. 2009, PASJ, in press
Takahashi, T., et al. 2007, PASJ, 59, 35
Thompson, C., 2006, ApJ, 651, 333
Thompson, C., Meszaros, P., & Rees, M.J., 2007, ApJ, 666, 1012
Urata, Y., et al. 2003, ApJ, 595, L21
Urata, Y., et al. 2005, Nuovo Cimento C Geophysics Space Physics C, 28, 775
Urata, Y., et al. 2007a, ApJ, 668, L95
Urata, Y., et al. 2007b, ApJ, 655, L81
Yamaoka, K., et al. 2009, PASJ, 61, S35
Wang, J. H., Schwamb, M. & Huang K. Y. et al. 2008 ApJ, 679, L5
Zheng, W. K., et al. 2008 ChJAA, 8, 693

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Fig. 1.— Prompt X-ray and gamma-ray light curve of GRB071010B observed by *Swift*/BAT and *Suzaku*/WAM. The data in the time region between the dashed lines are used for the joint spectral analysis.
Fig. 2.— Broad band spectrum of GRB071010B prompt emission made by the joint analysis of the Swift/BAT and Suzaku/WAM data.
Fig. 3.— $R_c$-band afterglow light curve. The time region enclosed by the dashed ($3\sigma$) and the dash-dotted ($5\sigma$) lines indicates the expected jet break time from the $E_{\text{peak}}^\text{src} - E_\gamma$ relation.
Fig. 4.— \( E_{\text{src}}^{\text{peak}} - E_{\gamma} \) relation including the data for GRB071010B and GRB041006 corrected for a homogeneous circumburst medium. The solid line shows the best-fit correlation derived by Ghirlanda et al. (2007). The dashed and dash-dotted lines indicate the 1\( \sigma \) and 3\( \sigma \) scatter of the correlation, respectively.
Fig. 5.— Plot of log $\hat{E}_{\text{iso}}$ calculated by the empirical $E_{\text{iso}} - E_{\text{peak}}^{\text{src}} - t_{\text{jet}}^{\text{src}}$ relation (Liang & Zhang 2005) as compared with log $E_{\text{iso}}$ derived from the observed fluence. The arrow indicates the upper limit of GRB071010B.