Suzaku/WAM and Swift/BAT Joint Spectral Studies of Gamma-ray Bursts

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Abstract

We report on results from joint spectral studies using 96 gamma-ray bursts (GRBs) which were simultaneously detected with the Suzaku/WAM and Swift/BAT. This sample contains 5 short GRBs and 36 GRBs with a wide range of known redshifts (z=0.089 to 6.3). For most of these bursts, Suzaku/WAM or Swift/BAT cannot determine the peak energy of the νF_{ν} spectrum ($E_{\rm peak}$) solely, but a combination of Suzaku/WAM and Swift/BAT could determine the $E_{\rm peak}$ for 80% of all the sample, owing to their broad band coverage of 15–5000 keV. The derived $E_{\rm peak}$ concentrated on around 250 keV, although the distribution is slightly broader than the CGRO/BATSE distribution. We also verified the peak energy - isotropic radiation energy ($E_{\rm peak}$-$E_{\rm iso}$) relation for long GRBs including the high redshift GRB 050904 (z=6.3). One exception is the sub-luminous nearby GRB 060505. All the 5 short GRBs are outliers for this relation, suggesting that the radiation mechanisms are difference in short and long duration GRBs.

Key words: gamma rays: bursts

1. Introduction

The Swift gamma-ray burst explorer (Gehrels et al. 2004) has been detecting 120 GRBs per year since its launch in 2004. It has led to many discoveries such as X-ray flares and plateau phase in X-ray afterglows. However, a study of GRB prompt emission was limited due to the narrow energy range (15–150 keV) of the Burst Alert Telescope (BAT; Barthelmy et al. 2005). The Suzaku wide-band all-sky monitor (WAM; Yamaoka et al. 2009) is the anti-coincidence shield of the Hard X-ray Detector (HXD; Takahashi et al. 2007). It has been operating since Aug. 2005, and is sensitive to gamma-rays in 50–5000 keV, beyond the BAT energy range. So a combination of Swift/BAT and Suzaku/WAM could result in precise determination of the peak energy ($E_{\rm peak}$) of prompt emission due to its broad energy coverage (15–5000 keV). Thus we have started a project of joint spectral studies (Krimm et al. 2009) with cross-calibration among the three instruments (Konus-Wind, BAT, and WAM) (Sakamoto et al. 2009) since Aug. 2006 based on the Japanese-US collaboration. Here we describe the sample used, analysis, and the first results in this project.

2. Analysis and Results

We have 98 simultaneous bursts up to April 2009, consisting of 48 WAM triggered, 48 WAM untriggered, and 2 Swift untriggered events. Table 1 shows a summary of events. This sample contains 36 GRBs with known redshifts with a wide range from 0.089 (GRB 060505) to 6.3 (GRB 050904; Sugita et al. 2009) and 5 short GRBs. Spectral analysis was done using the standard HEADAS package. The Swift/BAT and Suzaku/WAM data are jointly fitted with a single power-law, a power law with an exponential cutoff, and the GRB Band function (Band et al. 1993). The consistency of the normalization between the two instruments has been checked within 15–20 %. The spectral parameters are a low energy photon index α, a high energy photon index β, and a peak energy in the νF_ν spectrum E_{peak}. 7 events were rejected because of their bad incident directions to the WAM. For 67 of remaining 91 events (73.6 %), the E_{peak} was succesfully determined. In general, triggered events are more intense than untriggered events, so the ratio of the E_{peak} determined events to total events for triggered events is rather high (89.6 %).

Table 1. Summary of the fitting status of BAT-WAM bursts. The number in parentheses indicate GRBs with known redshifts.

	E_p determin.	E_p non-determin.	Not used	Total
WAM trig.	43(21)	3(1)	2(0)	48(22)
WAM untrig.	22(8)	21(5)	5(1)	48(14)
BAT untrig.	2(0)	0(0)	0(0)	2(0)
Total	67(29)	24(6)	7(1)	98(36)

Figure 1 shows the BAT-WAM E_{peak} distribution for 67 GRBs. It is compared with CGRO/BATSE (Kaneko et al. 2006), HETE2 (Pelangeon et al. 2008), and Swift (Sakamoto et al. 2008) results. The E_{peak} distribution is very different among missions maybe due to a difference of the sensitivity of each experiment. The median value of the BAT-WAM E_{peak} is 291^{+283}_{-119} keV, which is consistent with BATSE results (265^{+256}_{-111} keV), although the BAT-WAM distribution has slightly wider tail than BATSE. Other parameters (α:–1.23±0.28 and β:–$2.23^{+0.12}_{-2.00}$) are also coincide within errors, so we can conclude that the parameter distribution of prompt emissions has almost similar distributions for BAT-WAM and BATSE.

We have also verified the validity of the relationship between the E_{peak} and the isotropic radiated energy E_{iso} (so-called "Amati relation") for 29 GRBs. Figure 2 shows the comparison of our sample to the recent Amati relationship (Amati 2006). The current BAT-WAM sample shows a clear correlation between E_{peak} and E_{iso} for long bursts. The best-fit equation is found as $E_{peak} = (182\pm22)E_{iso}^{0.50\pm0.04}$. The slope is very similar to the previously published relation (0.47±0.02), but we can see that there is a bias toward higher E_{peak} and lower E_{iso}. 5 short bursts with known redshifts (GRB 051221A, 060801, 061006, 070714B, and 071227) lie on the high E_{peak} and low E_{iso} branch apart from the distribution as a long GRB. Another outlier is the nearby sub-luminous GRB 060505 with z=0.089, categorized in long GRBs. Such rare events are keys to understanding radiation mechanisms and geometry of the GRB jets.

BAT-WAM simultaneous events will continue to increase by about 26 events (13 for both triggered and untriggered events) per year. We have a plan to announce results as GCN circulars, and make the data publicly available. This project will also expand to verification of the time-resolved E_{peak} and L_{iso} relation and construction of the BAT-WAM spectral catalog in the future.

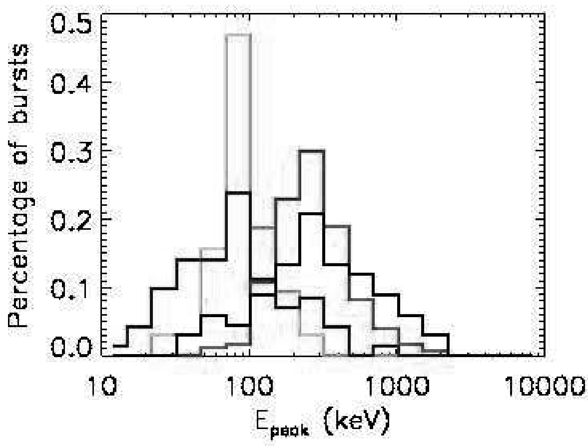

Fig. 1. BAT/WAM E_{peak} distribution (black) in comparison with CGRO/BATSE (red; Kaneko et al. 2006), HETE2 (blue; Pelangeon et al. 2008), and Swift/BAT (green; Sakamoto et al. 2008)

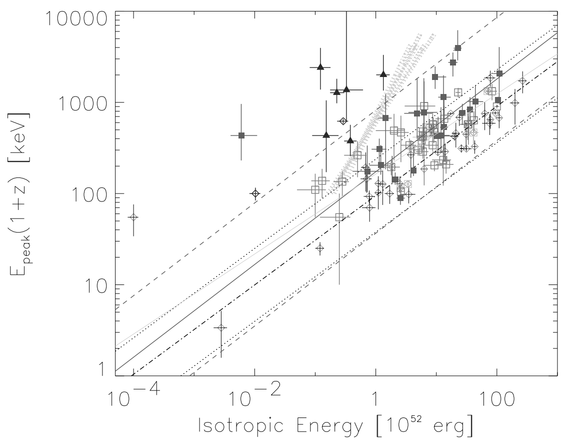

Fig. 2. Comparison to the Amati relationship (Amati 2006). Filled points are from this work (blue: short bursts and red: long bursts). The green hashed lines represent the selection effects due to the sensitivities.

References

Amati, L. 2006, MNRAS, 372, 233
Band, D. et al. 1993, 413, 281
Barthelmy, S.D. et al. 2005, Space Sci. Rev. 120, 143
Gehrels, N. et al. 2004, ApJ, 611, 1005
Kaneko Y. et al. 2006, ApJS, 166, 298
Krimm H.A. et al. 2009, ApJ., 704, 1405
Pelangeon, A. et al. 2008, A&A, 491, 157
Sakamoto T. et al. 2008, ApJS, 175, 179
Sakamoto T. et al. 2009, PASJ, submitted
Sugita, S. et al. 2009, PASJ, 61, 521
Takahashi T. et al. 2007, PASJ, 59, S35
Yamaoka, K. et al. 2009, PASJ, 61, S35