# Temporal and Spectral studies of GRBs detected by the Suzaku Wide-band All-sky Monitor (WAM)

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Abstract

We have performed temporal and spectral studies of 920 GRBs observed from 2005 Aug. to 2010 Dec. by the Suzaku Wide-band All-sky Monitor which covers an energy range of 50–5000 keV. The duration $T_{90}$ distribution for WAM GRBs clearly shows short/hard and long/soft categories, and the ratio of short GRBs is 25 %. This result is not consistent with the Swift/BAT but CGRO/BATSE. Similar results can be obtained using 51 GRBs simultaneously detected by Swift/BAT, then we found that the Swift/BAT is much more sensitive to extended emission in short GRBs. The spectral parameter distributions show that the average of the peak energy ($E_{\rm peak}$) is 645 keV for long GRBs and 1286 keV for short GRBs. This $E_{\rm peak}$ is much higher than previous measurements of 264 keV for CGRO/BATSE and 285 keV for Fermi/GBM. Simulating energy spectra using GRB parameters observed by Fermi/GBM, we found that the WAM can determine high $E_{\rm peak}$s only for bright GRBs. Based on these results, we suggest that the GRB intrinsic properties are almost the same, although the apparent differences in durations and spectral parameters among detectors have been observed due to their different energy bands and sensitivities.

Key words: workshop: proceedings — gamma-ray burst: general — methods: statistical

## 1. Introduction

Gamma-ray bursts (GRBs) are one of the most powerful explosion phenomena. The duration $T_{90}$ distribution for CGRO/BATSE GRBs clearly shows short/hard ($T_{90} \leq 2$ s) and long/soft ($T_{90} > 2$ s) categories (Kouveliotou et al. 1993), and the ratio of short GRBs is 25 % (Paciesas et al. 1999). However this result is not consistent with the Swift/BAT (Sakamoto et al. 2011). The spectral parameter distributions of CGRO/BATSE show that the average of the peak energy ($E_{\rm peak}$) is 264 keV for long GRBs and 584 keV for short GRBs (Goldstein et al. 2013). This $E_{\rm peak}$ is much higher than that of Swift/BAT (Lien et al. 2016). To clarify the these causes, we require confirmation by other instruments with high sensitivity.

## 2. Analysis

In this work, we analyzed 920 GRBs observed from 2005 Aug. to 2010 Dec. by the Suzaku Wide-band All-sky Monitor (WAM) which covers an energy range of 50–5000 keV (Yamaoka et al. 2009, 2017). The numbers of triggered and untriggered GRBs are 529 and 391. 302 GRBs out of 920 GRBs data are localized by other satellites such as Swift and Interplanetary Network (IPN). In analysis, we modeled background variation with 1–4th order polynominal functions and estimated the duration $T_{90}$ (5% to 95%) and $T_{100}$ (0% to 100%) utilizing the tool `battblocks`. To fit the $T_{100}$ time averaged spectra, we chose three models, which are power-law (PL), power-law with an exponential cutoff (CPL), and the Band function (GRB) models.

## 3. Results

### 3.1. Duration distributions

The $T_{90}$ distribution of the WAM shows clear bimodality. The WAM short:long event ratio in 50–250 keV range is 0.25:0.75 (Ohmori et al. 2016), which is not consistent with Swift/BAT but CGRO/BATSE. We discuss about the difference of trigger type, energy dependence of the duration, and the difference of detection sensitivities using 415 GRBs from the BAT second catalog. The BAT short:long event ratio of rate and image triggered GRBs are 0.09:0.91 and 0.02:0.98. These results show the short:long event ratios depend on the rate trigger.

To discuss about energy dependence of the duration, we used 51 GRBs detected simultaneously by WAM and BAT. Figure 1 shows correlation between the WAM $T_{90}$ and BAT $T_{90}$. This result shows the WAM $T_{90}$ is shoter than BAT one, because the WAM cannot detect weak components of short GRBs with extended emission (E.E.) or long GRBs with tails component or flare-like component, which is a very weak separated pulse following the main large pulse. So we fitted with a power law to the data except these GRBs with weak components. Using this result, the BAT $T_{90}$ values 15–350 keV range were converted to $T_{90}$ values in the WAM 50–250 keV range. The short:long event ratio of 279 GRBs out of 353 GRBs is 0.20:0.80. The 8 short GRBs with E.E. and 66 long GRBs with tails or flare-like components might be measured as short and long GRBs in WAM data, respectively. As a result, the short:long event ratio is extimated 0.18:0.82.

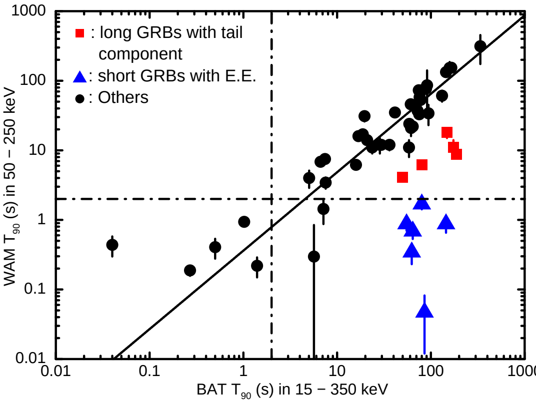


Fig. 1. Correlation between the WAM $T_{90}$ and BAT $T_{90}$

Using the trigger efficiencies of the WAM, we estimated the detection ratio of WAM for 353 events detected by BAT. The calculation conditions of the trigger efficiencies are assumed a 0.25 s peak flux with $\alpha = -0.6$, $\beta = -2.1$, and $E_{\rm peak} = 400$ keV for short GRBs, and 1-s peak flux with $\alpha = -1.1$, $\beta = -2.5$, and $E_{\rm peak} = 200$ keV for long GRBs. The short:long event ratio is approximately 0.24:0.76, which is consistent with that of all WAM data. From this result, the simulated detection ratio of WAM to the BAT is estimated to be about 52 % of short GRBs and about 35 % of long GRBs. For GRBs data simultaneously detected by WAM and BAT, the observed detection ratio of short and long GRBs are 54 % and 39 %. Thus, the results obtained from simulation are sonsistent with real data.

## 3.2. Spectral parameter distributions

Table 1 shows the average and median values of the three spectral parameters, which are the WAM $\alpha$, $\beta$ and $E_{\rm peak}$ (Ohmori et al. 2019). The WAM $\alpha$ and $\beta$ distributions are almost consistent with those of other detectors. But the WAM $E_{\rm peak}$ is higher than other detectors.

Table 1. Average and median for each observed spectral parameters

| | $\alpha$ | $\beta$ | $E_{\rm peak}$ (keV) |
|---|---|---|---|
| | Ave.(Med.) | Ave.(Med.) | Ave.(Med.) |
| Long GRB | –0.90(–0.98) | –2.65(–2.69) | 645(487) |
| Short GRB | –0.55(–0.61) | – | 1286(1053) |

To understand the WAM spectral properties, we simulated WAM spectra based on spectral parameters obtained from the Fermi/GBM database. The simulated WAM spectra were analyzed in the same way as real GRB data. As a result of fitting 1156 GRBs of Fermi/GBM, the number of CPL and GRB model are 234 and 11. The $E_{\rm peak}$ average values are estimated 610 keV and 930 keV for long and short GRBs, respectively. These values are consistent with observational results. Figure 2 shows 100–1000 keV energy fluence versus $E_{\rm peak}$. The WAM can constrain $E_{\rm peak}$ for GRBs with energy fluence larger than $10^{-5}$ erg cm$^{-2}$ for long GRBs and $10^{-6}$ erg cm$^{-2}$ for short GRBs. This shows that the GRBs with low $E_{\rm peak}$ and low fluence cannot be well constrained by the WAM. So the $E_{\rm peak}$ distributions of WAM present higher than other detectors.

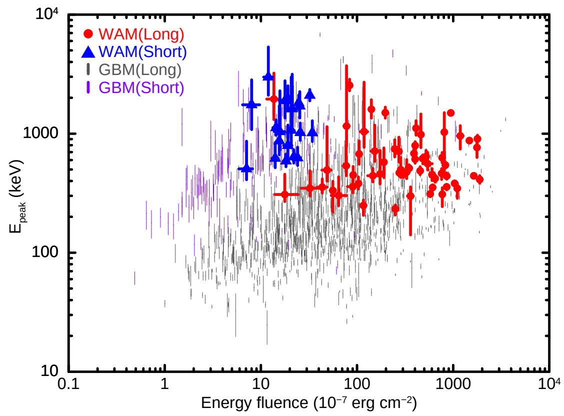


Fig. 2. $E_{\rm peak}$ as a function of energy fluence in 100–1000 keV.

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