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Comparison between *Swift* and pre-*Swift* gamma-ray bursts

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Abstract The gamma-ray burst (GRB) mission *Swift* has made a much deeper GRB survey than any previous one. I present a systematical comparison between GRB samples detected with pre-*Swift* missions and those from *Swift*, in order to investigate whether they show any statistical difference. Our *Swift* GRB sample includes the bursts detected by *Swift*/BAT before 2007 September. With both flux-limited surveys and redshift-known GRB samples, I show that, apparently, the observed distributions of the redshifts, T_{90}, and $\log N - \log P$ are significantly different, but not for the spectral hardness ratio, fluence and $E_{\rm iso}$. The redshifts of the *Swift* GRB sample are statistically larger than those of pre-*Swift* GRBs, with a mean of 1.95 ± 0.17 compared to ~ 1 for pre-*Swift* GRBs. The cosmological effect on the observables is thus considerable. This effect on the spectral hardness ratio, fluence and $E_{\rm iso}$ is cancelled out, and the distributions of these quantities indeed do not show significant differences between the *Swift* and pre-*Swift* GRBs. Taking this effect into account, I found that the corrected distributions of T_{90} for long GRBs and $\log N - \log P$ observed with *Swift*/BAT are also consistent with those observed with CGRO/BATSE. These results indicate that the *Swift* and pre-*Swift* GRBs are from the same population.

Key words: gamma-rays: bursts

1 INTRODUCTION

The launch of NASA's dedicated gamma-ray burst (GRB) mission, *Swift* (Gehrels et al. 2004), has achieved many breakthroughs and opened a new era of GRB research (see reviews by Mészáros 2006; Zhang 2007). It is a multi-wavelength observatory that can "swiftly" catch early X-ray and UV-optical afterglows of GRBs with the on board X-ray Telescope (XRT; Burrows et al. 2005a) and UV-Optical Telescope (UVOT; Roming et al. 2005). The XRT has revealed some unexpected features of X-ray emission promptly after the gamma-ray observations, including late X-ray flares (Burrows et al. 2005b), a steep decay and a shallow decay segment in the XRT lightcurves (Zhang et al. 2006; Nousek et al. 2006). Their physical origins are uncertain (see review by Zhang 2007), and systematical tests for the conventional models against the data are presented by some authors (Liang et al. 2006; Willingale et al. 2007; Zhang et al. 2007; Liang et al. 2007a,b, 2008).

It has been suggested that GRBs originate in the deep universe (Bromm & Leob 2002; Lin et al. 2004). The Bursts Alert Telescope (BAT) is much more sensitive than previous GRB missions (Barthelmy et al. 2005), offering an opportunity to detect the events at higher redshift. The quick and accurate localization with XRT and UVOT aid ground-based telescopes to follow up the optical transients and measure redshifts of the bursts. Looking at the samples in the first *Swift* operation year, Jakosson et al. (2006) found that the mean redshift of *Swift* GRBs is around 2.8, much higher than the pre-*Swift* GRB sample (~ 1.0). The *Swift* GRB sample with redshift measurement has been dramatically enlarged

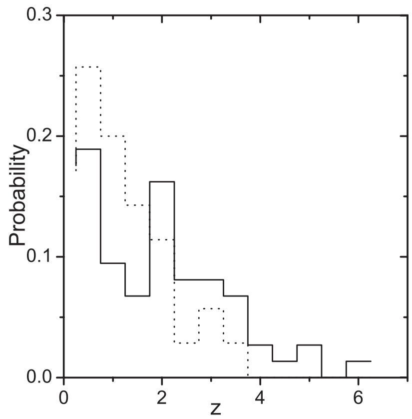

Fig. 1 Redshift distributions of the BATSE GRBs (dotted line) and the *Swift* GRBs (solid line) in our sample.

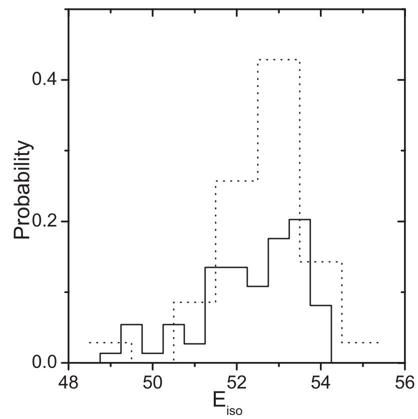

Fig. 2 Distribution of $E_{\rm iso}$ for both the BATSE GRBs (dotted line) and *Swift* GRBs (solid line) in our sample.

during the last two years, and it places more constraints on the GRB luminosity function (Liang et al. 2007b; Francisco et al. 2008).

In this paper, we present a global comparison of the GRB samples observed with *Swift* and pre-*Swift* missions. The data description is presented in Section 2, and our results are shown in Section 3 to Section 7. A discussion and conclusions are presented in Section 8.

2 DATA DESCRIPTION

We compile two kinds of samples for our analysis. One is a uniform flux-limited sample obtained by GRB surveys, including the CGRO/BATSE triggered GRBs and the *Swift*/BAT triggered GRBs. The BATSE GRBs are taken from *http://www.batse.msfc.nasa.gov/batse/*. I select only those bursts with duration measurements, and 1599 bursts are included. Among them, 1213 are long GRBs, and 386 are short ones. The *Swift* GRB sample is taken from the first GRB Catalog (Sakamoto et al. 2008), including 223 bursts observed between 2004 December 17 and 2007 September 20. The ratio of long to short bursts in the *Swift* sample is 204/19. The other GRB samples that I use are redshift-known samples complied from the literature. We collect the data of these bursts from published papers or GCN reports, and 109 events are included. Among them, 35 were detected with pre-*Swift* GRB missions (most of them are detected by BeppoSAX and HETE-2), and 74 were detected by *Swift*.

3 REDSHIFT AND ISOTROPIC GAMMA-RAY ENERGY

I first compare the redshift distributions of the pre-*Swift* and *Swift* GRBs in Figure 1. The redshift of *Swift* GRB sample is statistically larger than that of pre-*Swift* GRBs, with a mean of 1.95 ± 0.17. The difference could be due to the sensitivities of instruments. *Swift*/BAT operates in an image trigger model, and is much more sensitive than pre-*Swift* GRB missions (Sakamoto et al. 2008). Swift/BAT can trigger events deeper in the universe more easily than pre-swift GRB missions. Assuming that the GRB rate as a function of redshift follows the star formation rate, Liang et al. (2007b) showed that the detection rate of a typical GRB with *Swift*/BAT should peak at around $2 \sim 3$, which is very consistent with our result. Comparison of isotropic gamma-ray energy $E_{\rm iso}$ is shown in Figure 2. Statistically, no significant difference is observed. We measure the difference with the K-S test, which yields $p_{\rm k-s} = 0.48$, indicating that the two distributions are statistically identical.

4 BURST DURATION

The comparison of T_{90} distributions between BATSE and BAT GRBs is shown in Figure 3. It is found that the distribution of T_{90} observed with BAT is systematically longer than that observed with BATSE, and the bimodal feature in the BAT sample is much weaker than that observed in the BATSE sample. Observational selection effects may account for these differences.

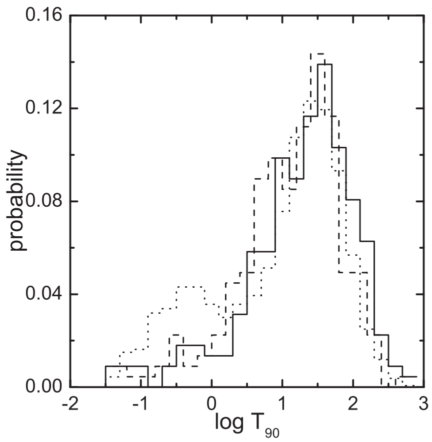

Fig. 3 Distribution of T_{90} for both the BATSE (dotted line) and *Swift* (solid line) GRBs in our sample. The dashed line is for the corrected distribution of the BAT GRB sample.

First, BAT is more sensitive than BATSE, so it can trigger bursts at higher redshifts than previous GRB missions, as mentioned above. The means of the redshifts are 1 and 2 for pre-*Swift* GRBs and *Swift* GRBs, respectively. Considering the time dilation effect, we suggest a universal correction factor of 2/3 for the *Swift* GRBs. We multiply this factor by the T_{90} observed by *Swift* and compare it with that observed with BATSE (the dashed line in Fig. 3). It is found that the corrected T_{90} distribution of the BAT long GRBs is roughly consistent with the BATSE sample.

Second, the energy band of BAT is slightly lower than BATSE, and the soft extension emission of some short GRBs have been detected by BAT. This effect blurs the division of T_{90} observed with BATSE for the long and short GRBs. Some short GRBs, such as GRB 060614 (Zhang et al. 2007; Zhang 2006), may be classified into the long group due to its soft extension emission. In addition, the BAT energy band is not high enough to efficiently catch short-hard events. Generally speaking, the spectrum of the short GRBs tends to be hard, with a peak energy of the νf_ν spectrum much higher than the BAT band. These effects make the ratio of short-to-long events in the BAT sample much lower than the BATSE sample, i.e., 1213/386 for BATSE and 204/19 for BAT.

5 SPECTRAL HARDNESS RATIO

It is well known that the GRB spectrum generally fits with the Band function (Band et al. 1993). The E_p of the νf_ν spectrum of a typical GRB is ~ 250 keV. The E_p is far beyond the BAT energy band. Therefore, the spectrum observed with BAT is only a small part of a typical GRB spectral domain. In order to compare spectral properties of the BAT sample with the BATSE sample, we show the gamma-ray fluences in 50–100 keV band as a function of fluences in 25–50 keV band in Figure 4. The reason for our selection is that both BAT and BATSE cover two energy ranges. We find that the spectral hardness ratio of BAT GRBs in the two energy bands is similar to that of BATSE bursts for both long and short GRBs.

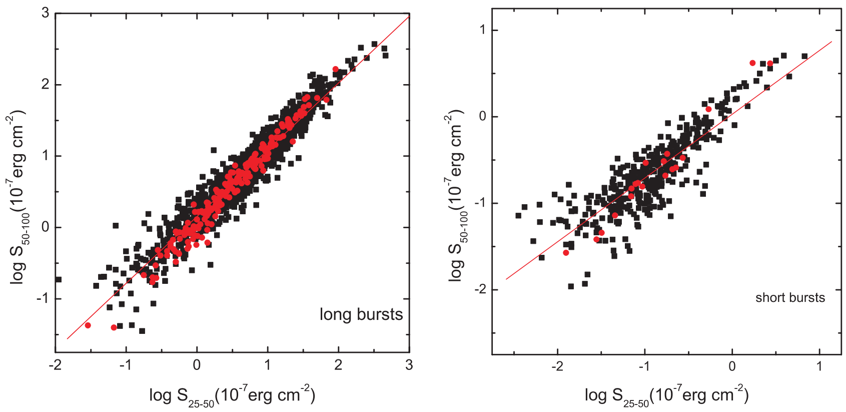

Fig. 4 Gamma-ray fluences in the 25–50 keV versus fluences in the 50–100 keV band for *Swift* (circles) and BATSE (squares) for both long (left) and short (right) GRBs.

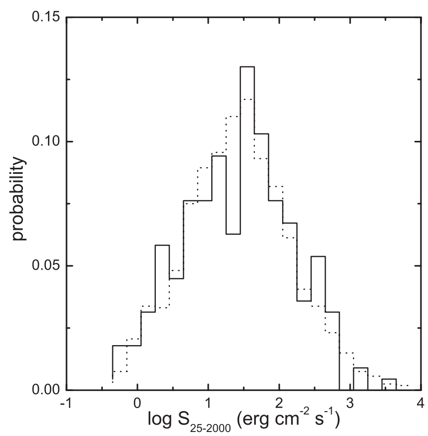

Fig. 5 Distribution of fluence in the 25–2000 keV for *Swift* (solid line) and pre-*Swift* (dotted line) for both long and short bursts.

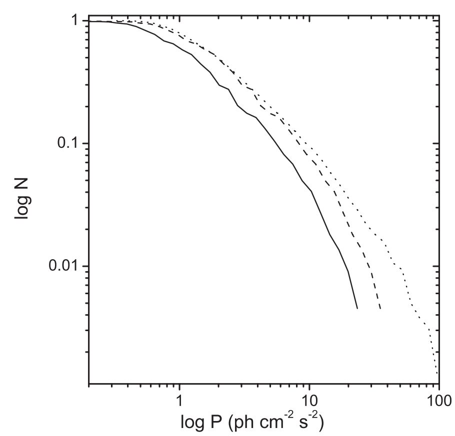

Fig. 6 $\log N - \log P$ distribution plots for BATSE (dotted line) and *Swift* (solid line) bursts. The dashed line represents the corrected distribution of the *Swift* sample.

6 FLUENCES

In order to compare the fluence distributions for the BATSE and BAT GRB samples, I take the fluences of BATSE GRBs in the BATSE energy band and correct the fluences of BAT GRBs to the same energy band with the spectral information mentioned above. The result is shown in Figure 5. Please note that the cosmological effect on observed fluence is cancelled out since $f^{'} = f * (1 + z)$ and $T^{'}_{90} = T_{90}/(1 + z)$, where f is the observed flux and prime denotes observables in the burst rest frame. It is found that the two distributions are almost the same. The K-S test derives $p_{\rm k-s} = 0.83$, suggesting that there is no statistical difference between the two distributions.

7 DISTRIBUTION OF $\log N - \log P$

In order to make a comparison between the $\log N - \log P$ distributions observed with Swift/BAT and CGRO/BATSE, we pick the peak flux observed in the 50–300 keV band for the BATSE GRB sample, and correct the observed peak flux in the 15–150 keV band observed by BAT GRBs to the same energy band with spectral information presented by Sakamoto et al. (2008). Since the BAT spectrum is generally fit with a simple power law (Zhang et al. 2007; Sakamoto et al. 2008), $F \propto \nu^{-\Gamma}$, and Γ is strongly correlated with E_p if E_p is not much beyond the BAT energy band (Zhang et al. 2007; Sakamoto et al. 2008), i.e.,

$$\log E_p = (2.76 \pm 0.07) - (3.61 \pm 0.26) \log \Gamma. \tag{1}$$

We use this empirical relation to derive E_p for all *Swift* GRBs and make the k-correction for an energy band of $1 - 10^4$ keV by assuming the Band function parameters of $\alpha = -1$, $\beta = -2.3$. The comparison of $\log N - \log P$ distributions observed with BATSE and BAT is shown in Figure 6. The two distributions are significantly different, with a $p_{\rm k-s} = 1.25 \times 10^{-9}$ derived from the K-S test. The difference could be explained by the instrumental selection effect. I make a systematical correction by multiplying a factor of 3/2 to the peak flux of each BAT GRB. The corrected $\log N - \log P$ distribution of the BAT GRB samples is also shown in Figure 6 (dashed line). It is very consistent with that of the BATSE samples.

8 CONCLUSIONS

With both flux-limited GRB survey samples and redshift-known GRB samples, I have made a systematical comparison between the *Swift* and pre-*Swift* GRB samples. Apparently, the observed distributions of the redshifts, T_{90} and $\log N - \log P$ are significantly different, but not for the spectral hardness ratio, fluence and $E_{\rm iso}$.

The redshift of the *Swift* GRB sample is statistically larger than that of pre-*Swift* GRBs, with a mean of 1.95 ± 0.17 compared to ~ 1 for pre-*Swift* GRBs. When we consider the cosmological effect on observables, this effect on the spectral hardness ratio, fluence and $E_{\rm iso}$ is cancelled out, and the distributions of these quantities indeed do not show a significant difference between the *Swift* and pre-*Swift* GRBs. Taking this effect into account, I found that the corrected distributions of T_{90} for long GRBs and $\log N - \log P$ observed with *Swift*/BAT are also consistent with those observed with CGRO/BATSE. These results indicate that *Swift* and pre-*Swift* GRBs are from the same population.

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References

Band, D., Matteson, J., Ford, L., et al. 1993, ApJ, 413, 281
Barthelmy, S. D., Scott, D., Barbier, L. M., et al. 2005, Space Science Reviews, 120, 143
Bromm, V., & Leob, A. 2002, ApJ, 575, 111
Burrows, D. N., David, N., Hill, J. E., et al. 2005a, Space Science Reviews, 120, 165
Burrows, D. N., Romano, P., Falcone, A., et al. 2005b, Science, 309, 1833
Francisco, V., Liang, E. W., & Zhang, B. 2008, arXiv: 0801.0751
Gehrels, N., Chincarini, G., Giommi, P., et al. 2004, ApJ, 611, 1005
Jakobsson, P., Levan, A., Fynbo, J. P. U., et al. 2006, A&A, 447, 897
Liang, E. W., Zhang, B., O'Brien, P. T., et al. 2006, ApJ, 646, 351
Liang, E. W., Zhang, B. B., & Zhang, B. 2007a, ApJ, 670, 565
Liang, E. W., Zhang, B., Virgili, F., & Dai, Z. G. 2007b, ApJ, 662, 1111
Liang, E. W., Racusin, J. L., Zhang, B., et al. 2008, ApJ, 675, 528
Lin, J. R., Zhang, S. N., & Li, T. P. 2004, ApJ, 605, 819
Meszaros, P. 2006, Rev. Prog. Phys., 69, 2259
Nousek, J. A., Kouveliotou, C., Grupe, D., et al. 2006, ApJ, 642, 389
Roming, P. W. A., Kennedy, T. E., Mason, K. O., et al. 2005, Space Science Reviews, 120, 95
Sakamoto, T., Barthelmy, S. D., Barbier, L., et al. 2008, ApJS, 175, 179
Willingale, R., O'Brien, P. T., Osborne, J. P., et al. 2007, ApJ, 662, 1093
Zhang, B. 2006, Nature, 444, 1010
Zhang, B. 2007, ChJAA (Chin. J. Astron. Astrophys.), 7, 1
Zhang, B., Fan, Y. Z., Dyks, J., et al. 2006, ApJ, 642, 354
Zhang, B., Liang, E. W., Page, K. L., et al. 2007, ApJ, 655, 989