Feeding Compact Objects: Accretion on All Scales
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Instrumental Selection Effect on the Bimodal T_{90} Distribution of Gamma-Ray Bursts†

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Abstract. The durations (T_{90}) of 315 GRBs detected with *Fermi*/GBM (8-1000 keV) by 2011 September are calculated using the Bayesian Block method. We compare the T_{90} distributions between this sample and that observed with previous/current GRB missions. We show that T_{90} is energy-band dependent and the observed bimodal T_{90} distribution would be due to the instrumental selection effect.

Keywords. Gamma-rays: bursts – methods: statistics

1. Introduction

The gamma-ray burst (GRB) survey with Burst And Transient Source Experiment (BATSE) on board Compton Gamma-Ray Observatory (CGRO) reveals a clear bimodal distribution of burst duration (T_{90}), which is measured with the time interval from 5% (t_5) to 95% (t_{95}) accumulative counts, and two groups of GRBs, i.e., long vs short GRBs with a division at $T_{90} = 2$ seconds, was identified (Kouveliotou *et al.* (1993)). It is also found that long GRBs may originate from the deaths of massive stars and short GRBs are from mergers of compact stars (Zhang & Mészaros (2004); Woosley & Bloom (2006); Nakar (2007)). However, several lines of evidence have show that the long-short GRB classification does not always match the physical classification scheme (e.g., Zhang (2006), Zhang *et al.* (2007), Zhang *et al.* (2009); Lv *et al.* (2010); Xin *et al.* (2011). It is unclear that if the bimodal T_{90} distribution is an intrinsic property or just only due to instrumental selection effect. This paper focuses on this issue with the observations by Gamma-Ray Burst Monitor onboard *Fermi* satellite.

2. Data Reduction and Calculation of T_{90}

We include all 315 GRBs with GBM detection reported by GBM team in GCN circulars up to Sep. 2011. We download the data from *Fermi* Archive. The time tagged event (TTE) data of the most illuminated NaI detector for each GRB is used for our analysis. The Rmfit(v3.7) package is used for the data reduction. We extract the 64-ms binned light curve from the data in different energy bands and subtract the background data for each energy band, and then calculate the T_{90} with the Beyasian Block method (Scargle *et al.* (1998)). With the method we derive the times of t_5 and t_{95}. The t_5 and t_{95} values as

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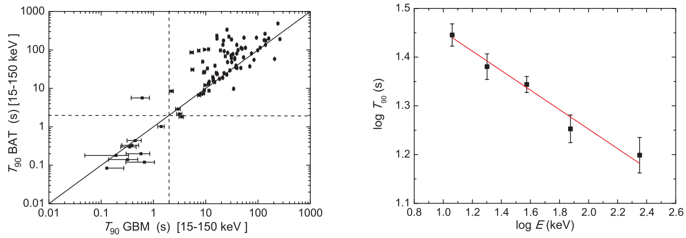

Figure 1. Left: Comparison of T_{90}s measured with Swift/BAT and Fermi/GBM. The dotted line marks $T_{90} = 2$ seconds. Right: Energy dependence of T_{90} for long GRBs.

well as their errors (1σ) are obtained from a Gaussian fit to their distributions from the mock lightcurve sample. The T_{90} and its error are calculated with $T_{90} = t_{95} - t_5$ and $\delta T_{90} = (\delta t_{95}^2 + \delta t_5^2)^{1/2}$.

3. T_{90} measured with *Swift*/BAT and *Fermi*/GBM for a Joint BAT and GBM sample

We first select a sub-sample of GRBs (75 GRBs) that were detected by both GBM and BAT. We calculated the T_{90}s in the whole energy band of GBM, and compare the results with Swift teams, as shown in Fig. 1(Left). We find that long GRBs are much longer in BAT detector; however, short GRBs are less shorter in BAT detector. Since BAT is more sensitive to softer emission than GBM. It is generally consistent with the soft/hard nature of long/short GRBs.

4. Comparison of the T_{90} Distribution to Other GRB Missions

GRB survey observations in different energy bands have been done with *CGRO*/BATSE (50-300 keV), *HETE-2*/FREGATE (6-80 keV), *BeppoSAX*/GRBM (40-700 keV), *Swift*/BAT (15-150 keV), and *INTEGRAL*/SPI-ACS (20 keV-8 MeV). We compare the T_{90} distribution of our GBM sample in the 8-1000 keV band with those derived from the data collected by these missions. The data of *HETE-2*/FREGATE, *BeppoSAX*/GRBM, CGRO/BATSE, *Swift*/BAT, *INTEGRAL*/SPI-ACS, are taken from Pelangeon *et al.* (2008), Frontera *et al.* (2009), Paciesas *et al.* (1999), Sakamoto *et al.* (2011), and Savchenko *et al.* (2012) respectively. As shown in Fig. 2(Left), the T_{90} distributions of the LGRB groups observed with different missions are generally consistent, but those of the SGRBs are dramatically different, even no GRB with $T_{90} < 2$ seconds in the *HETE*-2 sample. We fit the T_{90} distribution with a model of two log-normal functions and find that the bimodal distribution feature is confidently confirmed in the BATSE, GBM, *BeppoSAX* and *INTEGRAL* samples.

5. Energy Dependence of T_{90}

As shown above, the T_{90} distribution is instrument-dependent. The deficit of SGRBs in samples observed with instruments in a lower energy band may be due to a lower trigger probability of SGRBs with instruments in a lower energy band since SGRBs tend to have a harder spectrum and/or larger T_{90} in a lower energy band that results in some SGRBs moving into the LGRB group. As seen in GRB 050724 and 050709, their T_{90} are highly energy-dependent. We investigate the energy dependence of T_{90} with the GBM data. We derive the T_{90} values in the energy bands of 8-15 keV, 15-25 keV, 25-50

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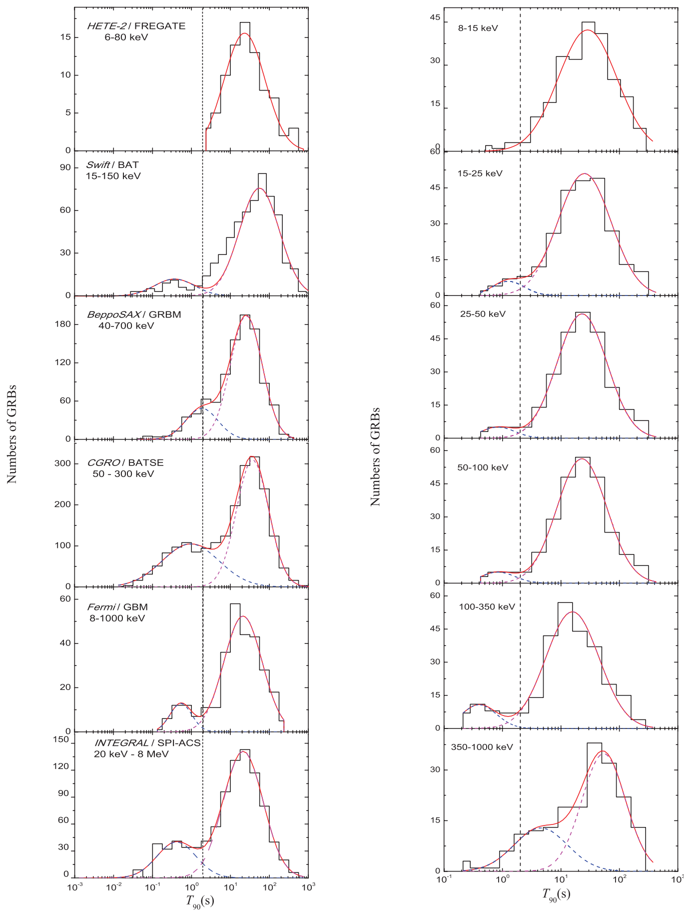

Figure 2. Left: Comparison of the T_{90} distributions observed with different instruments. Right: T_{90} distributions in different energy bands. The vertical dotted line marks $T_{90} = 2$ seconds. The fits to the distributions with two Gaussian functions or one Gaussian function are also shown.

keV, 50-100 keV, 100-350 keV and 350-1000 keV, respectively. The T_{90} distributions are shown in Fig. 2(Right). Comparing the T_{90} distributions with those observed by other instruments in similar bands, it is found that they are roughly consistent, i.e., 8-15 keV band vs. *HETE-2*/FREGATE (6-80 keV), 15-25 and 25-50 keV bands vs. *Swift*/BAT (15-150 keV), 50-100 KeV band vs. *BeppoSAX*/GRBM (40-700 keV), and 100-350 band vs. *CGRO*/BATSE (25-2000 keV). The most significant bimodal T_{90} distribution is seen in the 100-350 keV band. We still adopt $T_{90} = 2$ seconds in the 8-1000 keV band as the division line to classify the LGRBs and SGRBs. One can find that some SGRBs in the 8-1000 keV band move to the LGRB group in soft sub-bands. We investigate the energy dependence of T_{90} for the LGRBs only since the sub-sample of SGRBs is too small to present robustly statistical result. The typical value ($\bar{T}_{90}$) and its error of $\log T_{90}$ for a given energy band are derived from the Gaussian fit to the $\log T_{90}$ distribution. Fig. 1(Right) shows $\bar{T}_{90}$ as a function of the central value of the energy band. A clear correlation is found, and the best linear fit gives $\bar{T}_{90} \propto E^{-0.20\pm0.02}$. This may be due to a sample selection effect.

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6. Conclusions and Discussion

We have calculated T_{90} of *Fermi*/GBM GRBs in various energy bands and compared the T_{90} distribution with those obtained from previous/current GRB survey missions. We measure the T_{90} in several sub-bands, i.e., 8-15, 15-25, 25-50, 50-100, 100-350, and 350-1000 keV bands to investigate the energy band selection effect on the bimodal T_{90} distribution. It is found that the bimodal feature is well recognized in the 50-100 and 100-350 keV bands and only marginally accepted in the 25-50 keV and 350-1000 keV energy bands. The hypothesis of the bimodality is confidently rejected for the T_{90} distributions in 8-15 and 15-25 keV bands. We compare the T_{90} distributions in these sub-energy bands with that observed by other instruments in similar bands and find they are roughly consistent. The T_{90} as a function of energy band follows $\bar{T}_{90} > \propto E^{-0.20\pm0.02}$ for LGRBs. Some GRBs fall into the short category in a high energy band, but move to the long category in a lower energy band. Considering the erratic optical and X-ray flares that may have the same physical origin as the prompt gamma-rays, the duration of burst would be even much longer for most GRBs. These results indicate that the T_{90} is energy dependent and the bimodal T_{90} distribution is due to energy band selection effect.

Burst duration is critical for both GRB classification and understanding the behavior of the GRB central engine. It is an indicator of the lifetime of the GRB central engine. Popular central engine models of GRBs are related to the accretion onto a central compact object that is formed from collapses of massive stars or mergers of compact star binaries. It is theoretically expected that the timescale of the central engine from mergers of compact stars would be shorter than 1 s based on both analytic and simulation analysis (Narayan *et al.* (2001). The T_{90} distribution observed with *CGRO*/BATSE is seemly well consistent with the speculation of the two types of GRB from collapse of massive stars and mergers of compact objects. However, as we shown here that the bimodal T_{90} distribution would be due to instrument selection effect.

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