Postprint of the Peak Energy Distribution of Gamma-Ray Burst vFv Spectra from Different Satellites

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Abstract

Gamma-ray bursts are among the most violent explosive phenomena in the universe. Observations from the Compton Gamma-Ray Observatory/Bursts and Transient Source Experiment (BATSE), the High Energy Transient Explorer (HETE), and Fermi have provided a large sample of gamma-ray bursts. It is necessary to analyze these data and employ statistical methods to search for the physical information of gamma-ray burst radiation contained therein. The peak energy Ep of the gamma-ray burst energy spectrum vFv is a very important physical quantity for gamma-ray bursts, and each burst has a different peak energy. Studies comparing the peak energy Ep distribution of gamma-ray burst vFv spectra observed by different instruments have found that the peak energy Ep distribution of gamma-ray bursts is very broad, the distributions from different instruments are similar, and the peak of the BATSE sample distribution is somewhat larger than the Ep peak of the HETE-2 and Fermi samples, which may be due to the selection of bright bursts in the BATSE sample. The LogN-LogP distribution observed by the three instruments also shows no significant differences. That is, from a statistical point of view, the Ep distributions of the three types of bursts are not essentially different, and the radiation physical information of gamma-ray bursts observed by different instruments should be consistent.

Full Text

Peak Energy Distribution of F Spectra of Gamma-Ray Bursts Observed by Different Satellites

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Abstract

Gamma-ray bursts (GRBs) are among the most violent explosive phenomena in the universe. The Compton Gamma-Ray Observatory' s Burst and Transient Source Experiment (CGRO/BATSE) has provided a large sample of GRBs, and analyzing these data using statistical methods to uncover the underlying radiation physics is essential. The GRB spectrum, particularly its peak energy E_p in the F spectrum, is a crucial physical parameter that varies dramatically from burst to burst. By comparing the E_p distributions from different instruments, we find that the peak energy distribution is broad. The E_p distribution from Fermi shows a higher peak than that from HETE-2, likely because the BATSE sample consists exclusively of bright bursts. The E_p distributions observed by the three instruments (BATSE, HETE-2, and Fermi) are similar, with no significant differences. From a statistical perspective, the radiation physics information obtained from GRBs observed by different instruments should be consistent.

Keywords: Gamma-ray bursts; Peak energy; Observations

1. Introduction

Gamma-ray bursts (GRBs) are extremely energetic explosive phenomena observed from cosmological distances, characterized by sudden, short-duration enhancements of gamma-ray emission. Since their discovery, observations from various satellites and follow-up observations of afterglows by ground-based telescopes have provided essential insights into the nature of GRBs. Studies of the prompt emission spectra and their temporal evolution have offered valuable evidence for investigating GRB radiation mechanisms.

The peak energy E_p of the F spectrum is a critical physical quantity for GRBs. Correlations exist between E_p and the burst luminosity or isotropic energy [1]. In addition to the typical non-thermal radiation component, some spectra exhibit a thermal component believed to originate from thermal emission. While early models overestimated the gamma-ray flux for most bursts, it is now widely accepted that if an instrument has a sufficiently broad energy band, the prompt emission spectrum of a typical GRB can be approximated by two smoothly connected power-law segments, most of which are well-fitted by the Band function [3]. The high-energy and low-energy segments are power laws that connect smoothly at E_p. Some bursts show a single power-law spectrum, likely due to the narrow energy band of certain instruments; this single power-law may represent only the low-energy portion of the Band function [4].

Comprehensive GRB spectral properties have been obtained primarily by the Compton Gamma-Ray Observatory' s Burst and Transient Source Experiment (BATSE; 1991-2000) with its energy coverage of 20 keV to 2 MeV, which detected over 2,700 GRBs [6]. The High Energy Transient Explorer 2 (HETE-2), launched in 2000, was the first satellite dedicated entirely to GRB detection and study. Its French Gamma Telescope (FREGATE) is sensitive to photons in the 10-400 keV band, extending sensitivity to low energies and enabling exploration of hard X-ray emission and X-ray flashes (XRFs), which extends the E_p distribution down to a few keV.

The Fermi Gamma-ray Space Telescope, launched in 2004, carries the Gamma-ray Burst Monitor (GBM) with an energy range of 8 keV to 25 MeV and the Large Area Telescope (LAT) covering 20 MeV to 300 GeV. Fermi' s broad energy coverage allows for complete, broadband spectral recording of GRBs [7]. Although GBM' s energy range fully encompasses BATSE' s range, its sensitivity differs from BATSE' s. Given these differences in energy coverage, sensitivity, and observational characteristics among satellites, we compare the peak energies E_p of GRB F spectra observed by different instruments.

2. Observations and Data Samples

To ensure reliable results, we consider only bright bursts, as Swift/BAT' s narrow energy band (15-150 keV) often captures only a small portion of the GRB spectrum, and most bursts have E_p values exceeding this range. The data for our three samples were collected as follows:

BATSE Sample: We selected 156 bright bursts from the BATSE catalog observed between 1991-2000, requiring a peak flux exceeding 10 photons cm ^{2} s ^{1} in the 50-300 keV trigger band. The E_p values for these bursts were obtained from spectral fits using the Band function or smoothly broken power-law models.

HETE-2 Sample: Our HETE-2/FREGATE sample contains 57 bursts with E_p values derived from spectral hardness ratios or estimated using the empirical relation between the spectral index Γ and E_p [5]. The energy range of 1 keV to 1 MeV was used for analysis.

Fermi Sample: We compiled a sample of 1,407 bursts observed by Fermi/GBM. For each burst, the spectrum was fitted with a Band function or cutoff power-law model to determine E_p.

3. Results

Figure 1(a) shows the E_p distributions for the three samples. The BATSE distribution exhibits a broad peak around 200-400 keV, concentrated near 250 keV, with an additional component at 100-200 keV. The HETE-2 distribution shows a single prominent peak at approximately 125 keV. The Fermi distribution displays multiple peaks at roughly 25 keV, 125 keV, and 360 keV, with the highest peak at 125 keV.

The apparent differences in peak positions can be attributed to sample selection effects. The BATSE sample, consisting exclusively of bright bursts, shows a statistically higher E_p than the HETE-2 and Fermi samples. According to the Amati relation [9], brighter bursts with higher fluxes tend to have larger E_p values. Therefore, the elevated BATSE peak is expected. When selection effects are accounted for, the E_p distributions from the three instruments are fundamentally consistent.

Figure 1(b) presents the Log E_p distributions, showing that the three samples have consistent distribution profiles. The solid line represents all Fermi bursts, the dashed line represents bright Fermi bursts, and the dotted line represents the BATSE sample. The similarity among these distributions demonstrates that the observed GRB radiation physics is consistent across different observational platforms.

4. Discussion and Conclusion

We have compared the E_p distributions of GRBs observed by BATSE, HETE-2/FREGATE, and Fermi/GBM. While the distributions show some variations, they are consistent within a relatively narrow range. The results from INTEGRAL (International Gamma-Ray Astrophysics Laboratory) appear continuous within this range, further supporting the consistency across missions.

The BATSE distribution peaks at 250 keV, higher than the HETE-2 peak at 125 keV and the Fermi peak at 125 keV. This difference likely arises from sample selection bias, as BATSE only included bright bursts, whereas HETE-2 and Fermi samples contain both bright and faint bursts. When bright bursts are selected from the Fermi sample, its E_p distribution shifts to higher energies, consistent with the BATSE results.

In conclusion, the E_p distributions observed by different satellites are fundamentally similar, indicating that the radiation physics of GRBs is consistent across different observational instruments. From a statistical standpoint, GRBs observed by different satellites provide consistent physical information about GRB emission mechanisms.

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Note: Figure translations are in progress. See original paper for figures.