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Spectral Evolutions Study of Gamma-Ray Burst Exponential Decays with Suzaku-WAM

Makoto S. Tashiro[1], Kaori Onda[1], Kazutaka Yamaoka[2], Masahiro Ohno[3], Satoshi Sugita[4], Takeshi Uehara[5], and Hiromi Seta[6]

[1]Department of Physics, Saitama University, Sakura, Saitama, Japan,
email: tashiro@phy.saitama-u.ac.jp

[2]Research Institute for Science and Engineering, Waseda University, Shinjuku, Tokyo, Japan

[3]JAXA/Institute of Space and Astronautical Science, Sagamihara, Japan

[4]EcoTopia Science Institute, Nagoya University, Chikusa-ku, Nagoya, Japan

[5]Department of Physics, Hiroshima University, Kagami-Yama, Higashi-Hiroshima, Japan

[6]Research Center for Measurement in Advanced Science, Rikkyo University, Tokyo, Japan

Abstract. An observational study is presented of the spectral evolution of gamma-ray burst (GRB) prompt emissions with the Suzaku Wide-band All-sky Monitor (WAM). We selected 6 bright GRBs exhibiting 7 well-separated fast-rise-exponential-decay (FRED) shaped light curves to investigate spectral changes by evaluating exponential decay time constants of the energy-resolved light curves. In addition, we carried out time-resolved spectroscopy of two of them which were located with accuracy sufficient to evaluate the time-resolved spectra with precise energy response matrices. The two imply different emission mechanisms; the one is well reproduced with a cooling blackbody radiation model with a power-law component, while the other prefers non-thermal emission model with a decaying turn over energy.

Keywords. gamma rays: bursts, radiation mechanisms: nonthermal, thermal

1. Introduction

Gamma-ray burst (GRB) prompt emission spectra are often described with a power law, an exponentially cut-off power law, or a smoothly connected broken power law (GRBM; Band *et al.* (1993)). They are consistent with the energy spectral distributions from optically thin synchrotron or synchrotron self-Compton radiation produced by relativistic electrons accelerated through shock fronts in the outflows . Alternatively, an optically thick thermal (blackbody) component has been proposed in addition to the pure non-thermal (power-law) model (e.g. Meszaros & Rees (2000)).

In this paper, we study luminosity-spectrum evolution to investigate the emission mechanism by using data collected with the Suzaku Wide-band All-sky Monitor (WAM; Yamaoka *et al.* (2009)). The WAM has a good advantage in the effective area at the energy band in which we often observe turn-over frequency of the GRB prompt emission. To reduce the number of parameters affecting the time evolution, here we focus on fast-rise-and-exponential-decay (FRED) light curves, which are the most promising for investigating the radiation process separately from the geometrical effects of the emission regions. The relatively fast rise implies that the time scale of geometrical variation is sufficiently short not to dominate the longer decaying process. The exponential decay time scale is thus expected to reflect the state evolution of the emission region. Therefore, we selected from WAM archive those event which have: bright (>1000 c s^{-1} at peak, asymmetric (fast rise-slow decay), and no overlapped peak in decay phase. Consequently we study 7 FRED peaks from 6 GRBs in this paper. Detailed description of this study is seen in Tashiro *et al.* (2012).

2. Results

2.1. *Energy resolved lightcurve*

We evaluated each decaying portion in three bands of WAM lightcurve data (nominally 50-110keV, 110-240 keV, and 240-520 keV). We confirmed that every decay is exponential and no power-law decay model was accepted. In general, the shorter time constant is observed in the higher energy band light curve. In order to evaluate this trend quantitatively, we fitted the derived time constants of decays with a power-law function, $\tau(E) \propto E^{-\gamma}$. All of the peaks shows clear spectral variation ($\gamma < 0$) in the accuracy of 90 % confidence level, an the derived average $\tau_{\rm ave} = -0.34 \pm 0.12$. Five of 7 peaks accept simple synchrotron/IC cooling interpretation ($\gamma = -1/2$), though we cannot reject thermal interpretation only with this energy resolved lightcurve study.

2.2. *Time resolved spectrum*

The incident angle of gamma-rays only from GRB 081224 and GRB 100707A were determined with an accuracy sufficient to generate reliable energy response matrices.

We examined four overlaid 1-s time-resolved spectra from GRB 081224 in the decay phase. A blackbody radiation with a power-law model (BBPL) succeeded to describe the time resolved spectra with naturally lowering kT and decreasing normalization, which implies a relatively constant power-law component with a gradually cooling blackbody component. The derived behavior of kT is well reproduced by a power-law function of time with an index of $-(0.43^{+0.27}_{-0.28})$.

On the contrary, the four 1-s time-resolved spectra from the decay phase in GRB 100707A exhibit a statistically significant preference for GRBM (χ^2/d.o.f.= 64.7/57) over BBPL (χ^2/d.o.f. = 131.4/39). In order to evaluate the spectral softening in the best-fit value of the turn-over energy E_0, we tied the first and second spectral indices. The parameter of E_0 exhibits a power-law-type decrease in time with an index of $-(1.1^{+0.6}_{-0.8})$, which is consistent with the expected non-thermal (synchrotron/IC) cooling model.

3. Conclusion

We studied 7 well-separated bright FRED peaks with exponential decay but power-law decays are not accepted. They clearly show spectral evolution and the energy indices of the time constants are concentrated around −0.3. We also showed time resolved spectroscopy for GRB 081224 and GRB 100707A. These behaviors observed in the light curves and the spectral evolution analysis suggest that the emission mechanism in GRBs consists of at least two different components, such as the thermal and non-thermal processes.

References

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