Timing Properties of GRBs Detected by HETE-2

M. Suzuki[1], N. Kawai[1,2], T. Sakamoto[1,2,6], R. Sato[1], Y. Urata[1,2], A. Yoshida[3,2], Y. Nakagawa[3], D. Takahashi[3], Y. Shirasaki[2,4], T. Tamagawa[2], K. Torii[2], M. Matsuoka[5], E. Fenimore[6], M. Galassi[6], D.Q. Lamb[7], C. Graziani[7], T. Donaghy[7], J-L Atteia[8], C. Barraud[8], J-F Olive[9], J-P Dezalay[9], M. Boer[9], K. Hurley[10], G. Ricker[11], J. Doty[11], J. Villasenor[11], R. Vanderspek[11], G. Crew[11], G. Monnelly[11], N. Butler[11], and HETE-2 Science Team
(1) Department of Physics, Tokyo Institute of Technology (2) RIKEN (The Institute of Physical and Chemical Research) (3) Department of Physics, Aoyama Gakuin University (4) National Astronomical Observatory of Japan (5) NASDA (6) Los Alamos National Laboratory (7) Department of Astronomy and Astrophysics, University of Chicago (8) Laboratoire d'Astrophysique, Observatoire Midi-Pyrenees (9) C.E.S.R (10) UC Berkeley Space Sciences Laboratory (11) Center for Space Research, MIT

Abstract

We studied timing properties of six gamma-ray bursts (GRBs) detected by HETE-2 (High Energy Transient Explorer 2) satellite. The properties we studied are (a) durations of bursts, (b) hardness ratio, (c) spectral lags.

We examine the empirical relations found by earlier observations: (1) Shorter durations in higher energy bands. (2) GRBs tend to have hard-to-soft spectral evolution, i.e. soft lags.

We could not find clear relation between duration and energy band, but found soft lags.

1. Introduction

It is important that HETE-2 can detect "X-ray rich" GRBs (or X-ray flashes) and that this class of bursts are as numerous as "(well-known) classical" GRBs.

Though X-ray rich GRBs had been detected by Ginga [5], they have started to be widely discussed based on BeppoSAX observations [3]. We distinguish X-ray rich bursts from classical ones according to fluence ratio. Fluence ratio is defined as ratio of fluence in X-ray band to that in gamma-ray band.

We know classical GRBs lie at cosmological distance and may be related with star forming region based on the observations of afterglows in longer wavelength, and this afterglows fade on a time-scale of days. In addition, recent prompt

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and detailed observations of gamma-ray burst afterglows suggest there is a close connection between GRBs and SNe.

On the other hand, afterglows of X-ray rich GRBs have not been firmly detected. GRBs accompanied by bright and well observed afterglows belong to "classical class". The afterglows of X-ray rich GRBs are not as bright as classical ones. However, we may be able to derive some indication from empirical laws similar to classical GRBs. In fact, the HETE-2 satellite reveals that fluence ratio, which is primary distinctive property, of X-ray rich GRBs distributes continuously toward classical class. This fact suggests classical and X-ray rich GRBs are essentially not separable. In this paper, We show properties of GRBs from timing analysis and produce further similarity between X-ray rich GRBs and classical ones.

2. Methods

The properties we studied are (a) durations of bursts, (b) hardness ratio and (c) spectral lags. We used, for these studies, the data of 6 bright bursts observed with the Wide-field X-ray Monitor (WXM) on board HETE-2 satellite. The data consist of three energy bands (1: 2-5 keV, 2: 5-10 keV, 3: 10-25 keV). The time resolution for this data is 0.1 s (triggered bursts) or (untriggered bursts).

For calculating spectral lags, we used a cross-correlation function (CCF) which is defined in reference [1]. To decide lags, We fitted CCF for band 1 to 2 (lag_{12}), band 1 to 3 (lag_{13}) and band 2 to 3 (lag_{23}) with quadratic curve. The fit range was adjusted so as to lower enough the residuals. We also calculated hardness ratio, which is defined as the ratio of photon counts in 2-10 keV to 10-25 keV.

3. Results

The durations, spectral lags and hardness ratios are listed in Table 1. Typical error of T_{90} and T_{50} are ~ 1 sec. The relation between energy band and duration is not clear in some case. On the other hand, there is definite evidence of soft lag. It is also remarkable that lag_{12} may relate to lag_{13} or lag_{23} (Fig. 1).

4. Discussion

In our analysis, we cannot see clear relation between energy and duration. A possible reason is that we did not use the duration of individual peaks (peak duration) but used duration T_{90} or T_{50}. In fact, the reference [2] discussed the relation between energy and peak duration which is derived from auto-correlation function. For the bursts with extremely soft spectra, such as GRB010213, the events in hard band is weak and then the error of duration must be large. The

Table 1. Table of durations, spectral lags and hardness ratios.

GRB name	resolution	T^1_{90}	T^2_{90}	T^3_{90}	T^1_{50}	T^2_{50}	T^3_{50}
010213	1.2	23.4	23.3	23.4	8.6	9.8	13.5
020331	1.2	72.5	84.8	81.1	38.1	34.4	34.4
020819	0.1	30.4	24.2	20.6	12.6	10.5	9.3
021211	0.1	23.0	5.4	3.9	4.8	2.3	1.9
030115	0.1	14.5	12.6	19.8	7.4	6.1	7.6
030329	0.1	42.7	32.6	27.5	13.2	11.7	11.3

GRB name	lag_{12}	lag_{13}	lag_{23}	hardness ratio (2-10keV/10-25keV)
010213	-2.32	-4.35	-1.46	14.6
020331	-4.88	-9.28	-2.34	1.93
020819	-0.37	-1.40	-0.84	2.31
021211	-0.65	-1.24	-0.55	2.64
030115	-0.91	-1.56	-1.25	2.66
030329	-1.04	-1.74	-0.63	2.32

method we adopted to evaluate the error may give systematically small error for these weak events.

We could see spectral lags in X-ray band. The bursts we selected consist of one X-ray flash (010213) and five classical or modestly X-ray rich GRBs. We can conclude that X-ray rich GRBs have spectral lag the same as classical GRBs. It is known that spectral lag relate to peak luminosity of the bursts [4]. This relation derived from BATSE observation, which consist of 4 energy band of 25 - 1000keV. Although the energy range differ from our observation, there may be similar relation between spectral lags and peak luminosity in X-ray band. This is important because there is a possibility that we can estimate source distance only from X-ray light curves, not only for classical GRBs but also for X-ray rich GRBs. Unfortunately there are few X-ray rich bursts whose distance is known. However if the relation is confirmed, it will be very useful.

As shown in Fig. 1, there are relations between lags of different energy bands. The burst GRB020819 does not follow this relation. It is interesting that from the spectral analysis, the absorption of GRB020819 is much larger ($n_H \sim 10^{22}$) than that of the Galactic value ($n_H \sim 5 \times 10^{20}$). Therefore soft tail of the burst may be not seen, and the lags of this burst may be shortened.

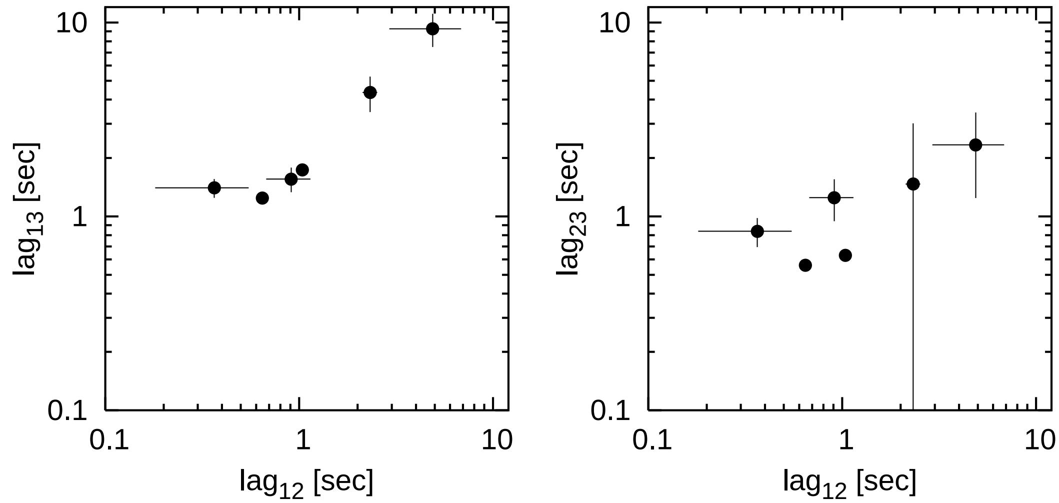

Fig. 1. The relation between lag_{12} and lag_{13} (lag_{23}).

5. Conclusions

We studied a) energy - duration relation and b) spectral lags for 6 bright GRBs observed with WXM on board HETE-2. The energy - duration relation was not clearly seen, but this might be due to poor statistics in the high energy band of the WXM. Spectral lags are observed in X-ray band whether the burst is X-ray rich or not. We do not know if the spectral lags are related to the peak luminosities of the bursts since the red shifts of X-ray rich GRBs are poorly known. Further observations and studies may confirm a relation similar to classical GRB's.

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