ENERGY SPECTRA VARIABILITY OF NO-HIGH ENERGY GRBs

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Abstract

We report the results of a variability study of the averaged energy spectra of the Gamma-ray Bursts without photons with energy greater then 300 keV. In a previous statistical analysis this variability was not evident anywere within the errors. However the errors were large and only three energy channels were available, (those reported in the BATSE catalog). The present deeper study, with more details, is of interest to give constraints on the variability of these spectra.

1 Introduction

At present the GRB spectral behaviour is of great interest to investigate on the physical process producing gamma-ray flashes and relative afterglows and to have information on their sources. Numerous theoretical models have been proposed. A deeper knowledge of the spectral behaviour can help to select among them.

Some authors have looked for a theoretical law that fits the energy data most accurately (Band et al,1993, Tavani 1997 etc.) But this analysis is possible only for the event with a sufficiently large signal-to noise ratio.

An other approach is a statistical analysis using the data of GRB spectra reported in the BATSE catalog. This second way allows a less detailed analysis but feasible for all the events.

The two ways are complementarity. In a previous paper (Belli 1998) we analysed all the GRB spectra reported in the BATSE catalog, using the data provided by it, that is the fluences relative to the four channels in which the energy range has been divided. The aim of the research was to observe the global behaviour of the energy spectra and to put in evidence general characteristics and constraints. In this paper we limit our investigation only to those events with photons energy lower than 300 keV: the non high energy (NHE) events of Pendleton et al. (1997), for which any meaningful variability has been not previously found.

The analysis has been performed for the events of Class I and Class II, separately. The definition of the two classes is reported in the paper of Belli (1995). We remind here that the two classes have been obtained dividing the plot of the events in the plane duration-hardness ratio with the straight line HR = $2D^{0.5}$. Class I is the group at the right of the straight line and Class II the one at the left. It is necessary to perform this analysis separately to avoid the confusion due to the superimposition of the results different for the two classes.

2 Data Analysis

The previous analysis had suggested no variability for the values, normalized to the total fluence, of the partial fluences of the selected events, out of the errors. But the errors were large and the obtained results very rough (Belli 1998). Here we try to reduce the incertaincies dividing the events in subsets relative to different hardness-ratio ranges and averaging the fluences for each range. The hardness-ratio is the ratio of the fluences relative to the 100-300 keV and 50-100 kev, respectively. Besides the partial averaged fluences, normalized to the total fluence of the GRB, have been divided by the energy range width to obtain fluences per keV, and then divided by the energy corresponding to the half value point of the energy range to obtain photon energy spectra (Fig.1). The normalized fluences divided by the corresponding energy range and multiplied by the energy corresponding to the half value point give the percentage values of E^2 for keV^{-1} cm^{-2}, Fig. 2.

In Fig. 2a are reported the averaged values per keV of the photons relative to fl1, fl2, fl3, for the events of the 5 hardness-ratio intervals, from the softer to the harder ones, for Class I; in Fig 2b the same analysis for Class II. The events error bars are smaller than the dimensions of the marks. For this reason the obtained errors are sufficiently little to allows to observe some variabilities in the ordinate values. Fig. 1a and b clearly indicate that the GRB spectra vary with continuity, going from the softer to the harder ranges of HR. Fig. 2a and b show the results of the analysis of the percentage values of power E^2 keV^{-1} cm^{-2} for each energy.

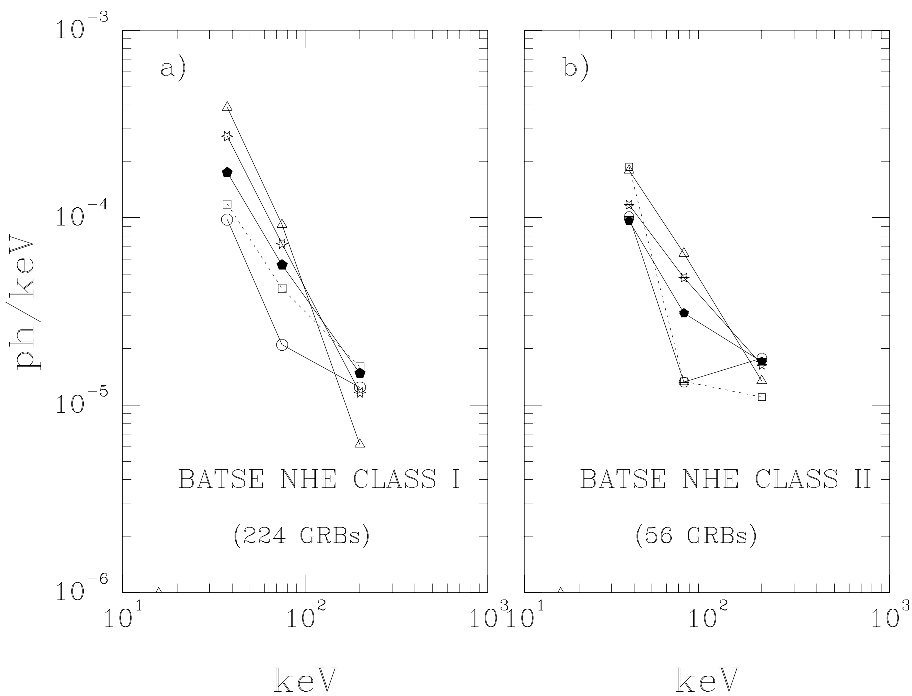

Figure 1: a) Percentage values of averaged photon energy spectra in logarithmic scale of Class I events, normalized with respect to the total fluence, relative to five ranges of HR: HR$<$1.0 (22 GRBs) mark $\triangleleft$, 1.0$<$HR$<$2.5 (160 GRBs) mark $*$, 2.5$<$HR$<$3.5 (18 GRBs) mark $\bullet$, 3.5$<$H$<$5.0 (11 GRBs) mark $\diamond$, 5.0$<$HR (3 GRBs) mark $\circ$. b) the same quantities of Class II events but relative to the HR ranges: HR$<$3.0 (19 GRBs) mark $\triangleleft$, 3.0$<$HR$<$4.5 (18 GRBs) mark $*$, 4.5$<$HR$<$8.0 (9 GRBs) mark $\bullet$, 8.0$<$HR$<$12. (3 GRBs) mark $\diamond$, 12.$<$HR (7 GRBs) mark $\circ$.

3 Results

It is very interesting to have a complete picture of the energy spectra variability for GRBs, even if we can only give a rough outline of it. The HR value determines, on average, the spectrum shape which changes as function of HR from a convex shape to a concave one. This behaviour continues to be present even if we divide the HR range in more than five intervals. Also for the emitted power spectra one found a similar evolution of the spectral shape with HR.

We used to fit the data for each HR range a comptonized thermal bremsstrahlung law, (the simplest law used at the beginning of GRBs study to fit GRBs spectra (Barat et al 1984 etc.)): $n = AE^{-\alpha}e^{E/E_o}$. In this law E_o is the temperature of the thermal bremsstrahlung and α the coefficient of comptonizetion. We pose A, the multiplicative coefficient, equal to 1. This corresponds to put β = 0 in the Band et al. law. We obtain E_0 and α for the different HR ranges. The fit results give α ranging between 3 and 2.3 and the relative temperatures between 40 and 300 keV. Only in one case the temperature is so high that suggests to fit with law a simple power law.

Fig. 2a and b suggest that there could be two different energy values for which the power energy emission

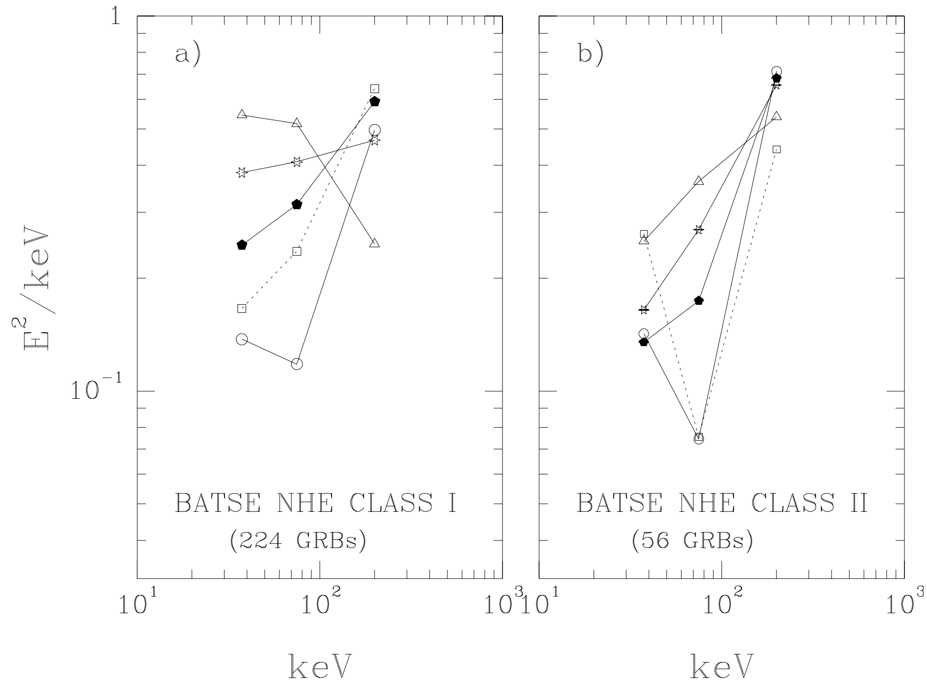

Figure 2: Percentage values of energy power density E^2 keV^{-1} cm^{-2}, in logarithmic scale, relative to the same HR intervals of Fig.1 a for Class I, b for Class II.

is maximum. This result is important to select the physical model for GRBs.

References

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