Abstract

The energy emission involved in a Gamma-Ray Burst evidently can be estimated only provided that we know the distance to the source. The same is true for the peak energy of the event in the source rest frame. Redshifts have been actually measured only for about 40 events. In order to check if it is possible to extend the \( E^{\text{rest}}_{\text{peak}} - E_{\text{rad}} \) relation originally found by Amati et al. (2002) to a larger number of events, we make use of the pseudo-redshift estimate proposed by Atteia (2003) and of the spectra published by Band et al. (1993). We thus obtain a completely independent set of events which indeed follows the same \( E^{\text{rest}}_{\text{peak}} - E_{\text{rad}} \) relation and confirms it.

Key words: gamma rays:bursts
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1 Introduction

Estimates of the energy released by Gamma-Ray Bursts, henceforth GRBs, and knowledge of their intrinsic, that is in the source rest frame, spectral parameters can be obtained only provided that their redshift is known.

Amati et al. (2002), later updated and/or integrated by Amati (2004), Barraud et al. (2003), Barraud et al. (2004) and Lamb, Donaghy & Graziani (2005), have shown that there is a correlation between the isotropic equivalent GRB energy \( E_{\text{rad}} \) and \( E^{\text{rest}}_{\text{peak}} \), the peak energy of the \( \nu F_\nu \) spectrum in the source rest frame. Those results have been derived from GRBs detected either by BeppoSAX,
BATSE, HETE or INTEGRAL, provided that for each of them it was possible to measure the redshift of the source or of the host galaxy. Indirect redshift indicators have been suggested by Jimenez, Band & Piran (2001), Bagoly et al. (2004), Band, Norris & Bonnell (2004), Friedman & Bloom (2004) and Band & Preece (2005).

Our approach is to use the empirical redshift indicator, or pseudo-redshift \( \hat{z} \), first proposed by Atteia (2003) and further discussed in Atteia et al. (2004), which has been tested to be accurate to a factor of two.

2 Data and procedure used

Following Atteia (2003), in order to estimate \( \hat{z} \) we need to compute

\[
X = \frac{n_\gamma}{e_p/\sqrt{t_{90}}},
\]

where \( e_p \) is the observed peak energy, \( n_\gamma \) the observed number of photons between \( e_p/100 \) and \( e_p/2 \) and \( t_{90} \) the observed duration. In this preliminary work we obtain the burst spectral parameters from Band et al. (1993), \( t_{90} \) and the burst fluence for normalization from the 3B and 4B BATSE catalogs (Meegan et al., 1996; Paciesas et al., 1999).

After deriving \( \hat{z} \) from \( X \), we obtain the total radiated energy \( E_{\text{rad}} (1 - 10^4 \text{ keV}) \) and \( E_{\text{rest,peak}} \), the peak energy in the rest frame, by using the formula given by Amati et al. (2002). For lack of all the necessary data, only 43 of the 54 events in table 1 of Band et al. (1993) could be used, practically the same number of measured redshifts at this time. None of them are “short” events \(^1\). The \( \hat{z} \) estimate calculation of Atteia (2003) goes as far as \( \hat{z} \sim 9 \) but it can be tested only between \( z = 0.0085 \) and \( z = 4.5 \), the smallest and largest GRB redshifts measured until now. As we already mentioned, it has been proved good within a factor of 2.

We recall that “Band model” spectra are given by

\[
N(E) = A \left( \frac{E}{100 \text{ keV}} \right)^{\alpha} \cdot \exp \left( -\frac{E}{E_0} \right)
\]

\[
N(E) = A \left[ (\alpha - \beta) \cdot E_0 \right]^{\alpha - \beta} \cdot \exp \left( \beta - \alpha \right) \cdot \left( \frac{E}{100 \text{ keV}} \right)^{\beta}
\]

\( ^1 \) The 11 events which we could not use, in the notation of Band et al. (1993), are: 1B910502, 1B910803, 1B911106, 1B911126, 1B920130, 920311_08426, 920315_15569, 920320_44340, 920325_02257, 920404_47506 and 920530_82797, corresponding to BATSE trigger numbers 142, 612, 1008, 1121, 1321, 1473, 1484, 1503, 1519, 1538 and 1630 respectively.
for \( E \leq (\alpha - \beta) \cdot E_0 \) and for \( E \geq (\alpha - \beta) \cdot E_0 \) respectively.

Band et al. [1993] fit GRB spectra either by leaving all parameters free or by keeping \( \alpha = -1 \) and \( \beta = -2 \), values which are often, but not always, a good approximation to the free ones.

By using the “all free” parameters of Band et al. [1993] we find 14 events with \( \hat{z} > 4.5 \), of which 8 with \( \hat{z} > 9 \). Taking into account the indetermination in the parameters, in the conversion from \( X \) to \( \hat{z} \), and in the correspondence between \( \hat{z} \) and actually measured redshifts, we interpret these large \( \hat{z} \) values only as an indication that a considerable fraction of BATSE GRBs, even the intense ones, might originate at cosmological distances. One event has \( \hat{z} < 0.015 \). If we use the “fixed \( \alpha, \beta \)” parameters we find a slightly more extended \( \hat{z} \) distribution: 19 events with \( \hat{z} > 4.5 \), of which nine with \( \hat{z} > 9 \). Two events have \( \hat{z} < 0.015 \). The \( \hat{z} \) histograms, compared to measured ones, are shown in Fig. 1.

![Histograms of the pseudo-redshift \( \hat{z} \) for GRBs in this paper](image)

Fig. 1. Histograms of the pseudo-redshift \( \hat{z} \) for GRBs in this paper (striped blocks), superimposed to the histogram of measured GRBs redshifts (dark blocks). Spectral parameters for \( \hat{z} \) computation from Band et al (1993). Left panel: free parameters; right panel: \( \alpha = -1, \beta = -2 \). Bursts with \( z > 9 \) are not shown.

Following Amati et al. [2002], we now proceed to derive energetics and spectral properties in the source rest frame of these “pseudo-redshifted” GRBs. The \( E_{\text{rad}} - \hat{z} \) and \( E_{\text{peak}} - E_{\text{rad}} \) distributions that we find are shown in Fig.s 2 and 3.

We find that we are in good qualitative agreement with Amati [2004], which includes 22 events, and Lamb, Donaghy & Graziani [2005] and references therein. However, considering the indetermination in our estimate of the redshift, we would not feel justified in giving an independent estimate of the \( E_{\text{peak}}^\text{rest} - E_{\text{rad}} \) correlation. The single burst with \( z < 0.015 \), GRB 910627, BATSE trigger 451, in the “all free parameters” case and also GRB 910523, BATSE trigger
222, in the “fixed parameters” case owe their low \( \hat{z} \) values, which then result in quite low \( E_{\text{rest}}^{\text{peak}} \) and \( E_{\text{rad}} \) values, mostly to very low \( E_0 \) values in the spectral fits. But the case of GRB 910523, which has \( \hat{z} < 0.015 \) for \( \alpha = -1, \beta = -2, E_0 = 24.6 \) and \( \hat{z} = 1 \). for \( \alpha = -0.423, \beta = -5, E_0 = 48.7 \) keV, shows that \( \hat{z} \) is also very sensitive to the values of \( \alpha \) and \( \beta \). In the case of GRB 910627, the ”free parameters”, \( \alpha = -0.921, \beta = -2.028 \) and \( E_0 = 37.0 \) differ very little from the fixed ones. Thus we consider the low \( \hat{z} \) value much more reliable. We conclude that is likely that GRB 910627 was a nearby XRF, with \( E_{\text{rest}}^{\text{peak}} - E_{\text{rad}} \) similar to those of Sakamoto et al. (2004) for XRF 020903.

Fig. 2. \( E_{\text{rad}} \) in units of \( 10^{50} \) erg as a function of \( \hat{z} \). As in fig. 1, spectral parameters for \( \hat{z} \) computation from Band et al. (1993). Bursts with \( z > 9 \) are not shown. Left panel: free parameters; right panel: \( \alpha = -1, \beta = -2 \).

Fig. 3. \( E_{\text{peak}}^{\text{rest}} \) vs \( E_{\text{rad}} \) in units of keV and \( 10^{50} \) erg, respectively. As in figs. 1 and 2, spectral parameters for \( \hat{z} \) computation from Band et al. (1993). Bursts with \( z > 9 \) are not shown. Left panel: free parameters; right panel: \( \alpha = -1, \beta = -2 \).

Since values of \( \hat{z} \) are good only within a factor of 2 (Atteia, 2003), we tested
the agreement of the $E_{\text{peak}}^\text{rest}$-$E_{\text{rad}}$ correlation with the one by Amati (2004)
by either multiplying or dividing all the $\hat{z}$ values by 2. While the absolute
values of $E_{\text{peak}}^\text{rest}$ and $E_{\text{rad}}$ obviously changed, the correlation was still valid
with approximately the same slope.

3 Discussion and conclusions

In absence of actual measurements of GRB redshifts, the $\hat{z}$ estimate by Atteia (2003),
in conjunction with observed spectral data, can provide a very useful
estimate of the source distance and thus of the burst intrinsic spectral parameters
and energetics. It is evident that this method can be particularly useful
for “dark bursts”, which now are still a large fraction of all detected GRBs.

We conclude that our findings are in agreement with the results of Amati (2004),
even when we take into account the indetermination in the estimate
of $\hat{z}$. The present sample certainly suffers from a selection effect in favour of
bright BATSE events, since the lowest fluence in our sample is $1.1 \cdot 10^{-6}$ erg
$\text{cm}^{-2} > 20 \text{ keV}$ (Meegan et al., 1996) and there is no doubt that in our case
the $\hat{z}$ estimate takes advantage of spectral parameters which can be expected
to be better determined for high count numbers.

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