THE REDSHIFT OF LONG GRBS’

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Abstract. The low energy spectra of some gamma-ray bursts’ show excess components beside the power-law dependence. The consequences of such a feature allows to estimate the gamma photometric redshift of the long gamma-ray bursts in the BATSE Catalog. There is good correlation between the measured optical and the estimated gamma photometric redshifts. The estimated redshift values for the long bright gamma-ray bursts are up to $z = 4$, while for the the faint long bursts - which should be up to $z = 20$ - the redshifts cannot be determined unambiguously with this method. The redshift distribution of all the gamma-ray bursts with known optical redshift agrees quite well with the BATSE based gamma photometric redshift distribution.

Key words: Cosmology - Gamma-ray burst

1. INTRODUCTION

In this article we present a new method called gamma photometric redshift (GPZ) estimation of the estimation of the redshifts for the
long GRBs. We utilize the fact that broadband fluxes change systematically, as characteristic spectral features redshift into, or out of the observational bands. The situation is in some sense similar to the optical observations of galaxies, where for galaxies and quasars the photometric redshift estimation (Csabai et. al (2000), Budavári et. al (2001)) achieved a great success in estimating redshifts from photometry only.

We construct our template spectrum that will be used in the GPZ process in the following manner: let the spectrum be a sum of the Band’s function and of a low energy soft excess power-law function, observed in several cases (Preece et. al (2000)). The low energy cross-over is at \( E_{cr} = 90\) keV, \( E_o = 500\) keV, and the spectral indices are \( \alpha = 3.2, \beta = 0.5 \) and \( \gamma = 3.0 \).

Let us introduce the peak flux ratio (PFR hereafter) in the following way:

\[
PFR = \frac{l_{34} - l_{12}}{l_{34} + l_{12}}
\]

where \( l_{ij} \) is the BATSE DISCSC flux in energy channel \( E_i < E < E_j \), here \( E_1 = 25\) keV, \( E_2 = E_3 = 55\) keV, \( E_4 = 100\) keV.

The spectra are changing quite rapidly with time; the typical timescale for the time variation is \( \simeq (0.5 - 2.5)\) s (Ryde & Svensson (1999, 2000)). Therefore, we will consider the spectra in the 320 ms time interval centered around the peak-flux. If we redshift the template spectrum and use the detector response matrix of the given burst, we can get for any redshift the observed flux and the PFR value.

On Fig. 1. we plot the theoretical PFR curves calculated from the above defined template spectrum using the average detector response matrices for the 8 bursts that have both BATSE data and measured redshifts (Klose (2000)). In the used range of \( z \) (i.e. for \( z \leq 4 \)) the relation between \( z \) and PFR is invertible, hence we can use it to estimate the gamma photometric
redshift (GPZ) from a measured PFR. For the 7 considered GRBs (leaving out GRB associated with the supernova and GRB having upper redshift limit only) the estimation error between the real $z$ and the GPZ is $\Delta z \approx 0.33$.

2. ESTIMATION OF THE REDSHIFTS

Here restrict ourselves to long and not very faint GRBs with $T_{90} > 10$ s and $F_{256} < 0.65$ photon/(cm$^2$s) to avoid the problems with the instrumental threshold (Pendleton et. al (1997), Hakkila et. al, (2000)). Introducing an another cut at $F_{256} > 2.00$ photon/(cm$^2$s) we can investigate roughly the brighter half of this sample.

As the soft-excess range redshifts out from the BATSE DISCSC energy channels around $z \approx 4$, the theoretical curves converge to a constant value. For higher $z$ it starts to decrease. This means that the method is ambiguous: for the given value of PFR one may have two redshifts - below and above $z \approx 4$. Because for the bright GRBs the values above $z \approx 4$ are practically excluded, for them the method is usable. Using only the 25 – 55 keV and 55 – 100 keV BATSE energy channels, this method can be used to estimate GPZ only in the redshift range $z \lesssim 4$.

Let us assume for a moment that all observed long bursts, we have selected above, have $z < 4$. Then we can simply calculate the $z_{GPZ}$ redshift for any GRB, which has PFR from the DISCSC data. Fig. 2. shows the distribution of the estimated derived redshifts under the assumption that all GRBs are below $z \approx 4$. The distribution has a clear peak value around PFR $\approx 0.2$, which corresponds to $z \approx (1.5 - 2.0)$.

Although there is a problem with the degeneracy (e.g. two possible redshift values) we think that the great majority of values of $z$ obtained for the bright half are correct. This opinion may be supported by the following arguments: the obtained distribution of GRBs in $z$ for the bright half is very similar to the obtained distribution of Schmidt (2001) and Schaefer
An another problem for $z$ as it moves into $z \geq 4$ regime for the bright GRB is the extremely high GRB luminosities, $\sim 10^{53}$ ergs/s (Mészáros & Mészáros, 1996).

As an additional statistical test we compared the redshift distribution of the 17 GRB with observed redshift with our reconstructed GRB $z$ distributions (limited to the $z < 4$ range). For the $F_{256} > 0.65$ photon/(cm$^2$s) group the KS test suggests a 38% probability, i.e. the observed $N(<z)$ probability distribution agrees quite well with the GPZ reconstructed function.

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