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This is Dr. Eman Moneer, Im working in Princess Noura University in Riyadh Saudi Arabia. I am currently looking for a collaboration in researches concerning my field of expertise.

My Ph.D thesis was on the topic of Spectral Analysis of GRBs Observed by *Swift* and *Fermi* Satellites using Gtburst - rmfit - xspec. under Dr. Paul O'Brien supervision at Leicester University.

I was a previous Masters graduate at UAH/ USA in 2011 under Dr. Rob Preese's supervision.

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# Detecting the High-energy Cutoffs for a Sample of Bright *Fermi* (GBM+LLE) GRBs

**By Dr. Eman Moneer**

# Introduction

- Gamma-ray bursts (GRBs) are extremely energetic explosions that are powered by ultra-relativistic jets. A variety of experimental studies have been undertaken to investigate the properties of the electromagnetic radiation arising from GRBs. Each experimental study in this field has different explanations, and therefore various different theoretical models to describe GRB prompt emission exist; each has its own characteristics that explain observed GRB signatures.

- At a very high energy in the prompt emission phase, detection of a high-energy cutoff becomes possible in some cases (only at high energies >130 MeV), hence the estimation of $\Gamma$ become possible. One of the scenarios that can be used to estimate $\Gamma$ from the high energy spectral cutoff $E_C$ of the prompt GRB spectrum is due to the deceleration of the fireball emission in the medium [1].

- In this poster, we will attempt to jointly fit the spectra of a sample of 36 bight/long GRBs detected via Fermi (GBM+LLE). Our attempts to constrain the high-energy cutoff was achieved by choosing the BandCut model to obtain a detectable high-energy cutoff $E_C$, suggesting that the shape of the GRB spectrum in the high-energy spectral cutoff region is relevant to the cutoff region of the primary particles within the prompt emission [2].

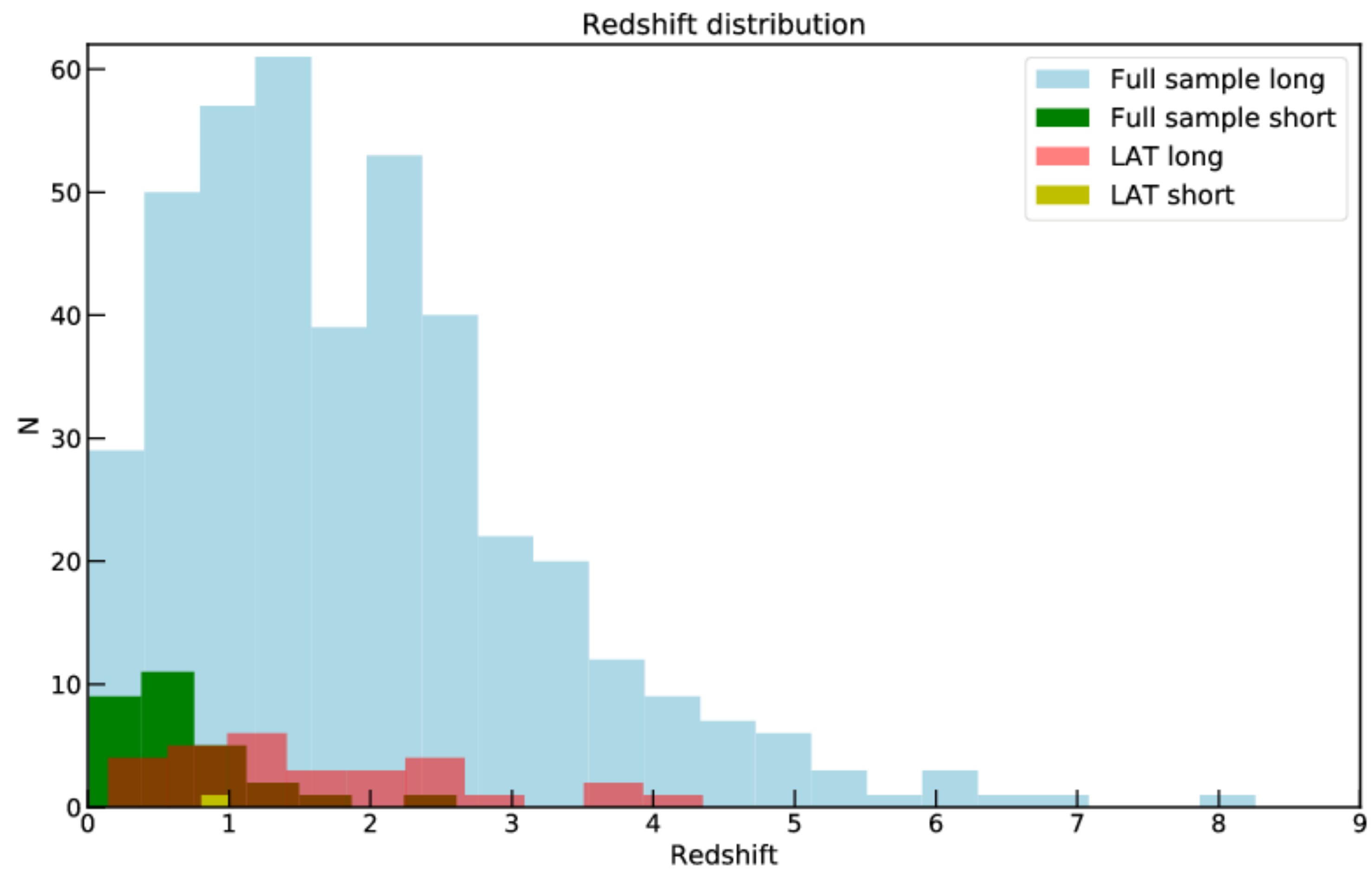
# Data Reduction and analysis

- The data (GBM+LLE) were collected and downloaded from the *GTburst* software.
- The time interval before and after the burst was carefully selected in order to allow the background to be extracted.
- In 2010, Pelassa et al 2010 [3] presented a new method which suggests combining the energies determined by both Fermi instruments and generating the so-called LAT Low- Energy (LLE).
- Improving the quality of the photon statistics covering energies >> 30 MeV appears to be a very promising capability offered by the LLE. The LLE also gives a better understanding of the spectral properties of prompt emission.

**Table 1** The measured GRB redshifts; the remainder of the sample with no redshifts are assumed to have z = 1.

| GRB name | z | Ref |
|---|---|---|
| 090902B | 1.822 | (Cucchiara et al., 2009) (GCN 9873) |
| 090323A | 3.57 | (Chornock et al., 2009) (GCN 9028) |
| 090328A | 0.73 | (Cenko et al., 2009) (GCN 9053) |
| 090926A | 2.1062 | (Malesani et al., 2009) GCN 9942) |
| 130518A | 2.488 | (Sanchez-Ramirez et al., 2013) (GCN 14685) |
| 131108A | 2.4 | (de Ugarte Postigo et al., 2013) (GCN 15470) and (Xu et al., 2013) (GCN 15471) |
| 131231A | 0.642 | (Sonbas et al., 2013) (GCN 15640) |
| 150403A | 2.06 | (Pugliese et al., 2015) (GCN 17672) |
| 170214A | 2.53 | (Kruehler et al., 2017) (GCN 20686) |

The redshift distribution of a GRB sample (LGRBs/SGRBs) detected via *Fermi* (LAT) up to December 2017. The pink histogram is the LAT LGRBs and the yellow histogram is the LAT SGRBs compared to the full sample (long/short), adapted from Nava (2018). [4]



- The Band- Cut model, however, is used to study the change of the spectral slopes, where this model is a modified form of the simple Band model with an additional high-energy exponential cutoff component with a two-break energy spectrum, as introduced in Zheng et al. (2012) [5]. BandCut model can be simply expressed as:

$$N_{BandCut}(E) = \begin{cases} E^{\alpha}\, e^{\frac{E}{E_0}} \quad , \\ if \quad E \leq E_b \\ \\ \left(\frac{E_0\, E_c}{E_c - E_0}(\alpha - \beta)\right)^{\alpha-\beta} \quad e^{\alpha-\beta}\, E^{\beta}\, e^{\frac{E}{E_c}} \\ if \quad E > E_b \end{cases}$$

Where,

$$E_b = \frac{E_0\, E_c}{E_c - E_0}(\alpha - \beta)$$

Where, $E_0$ is the characteristic Band energy and $E_c$ characterizes the position of the cutoff energy. α and β are the low-energy indices above and below the break, respectively.

# Bulk Lorentz factor estimation $\Gamma$

- When $\gamma\gamma$ absorption (only for photon energies that are larger than the highest photon energy in the LAT detection) takes place, the spectral energy cutoff $E_c$ can be interpreted within the source due to which an estimation of the bulk Lorentz factor,$\Gamma$ , of the emitting region is made possible by satisfying the condition: $\tau_{\gamma\gamma}(E_c) = 1$, where $\tau_{\gamma\gamma}$ is the optical depth [5].

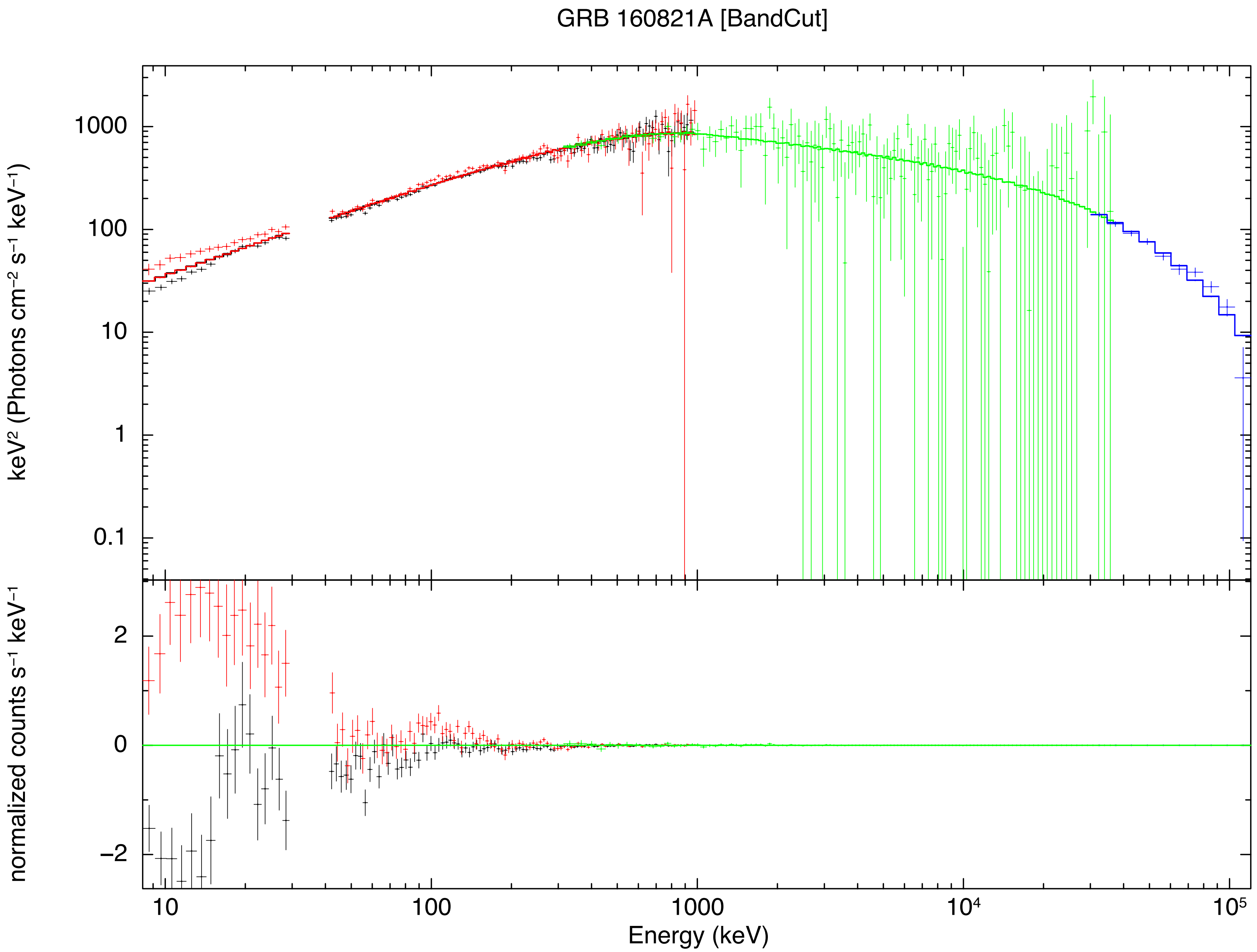
- One assumes that all bursts are produced by synchrotron radiation and only consider the photons produced in a single region (e.g., the one-zone model where the photons are isotropic, uniform and time-independent in the comoving frame) (see [6]) in order to compute the bulk Lorentz factor, $\Gamma_c$ . $\Gamma \sim \frac{E_c}{m_e c^2}(1+z)$

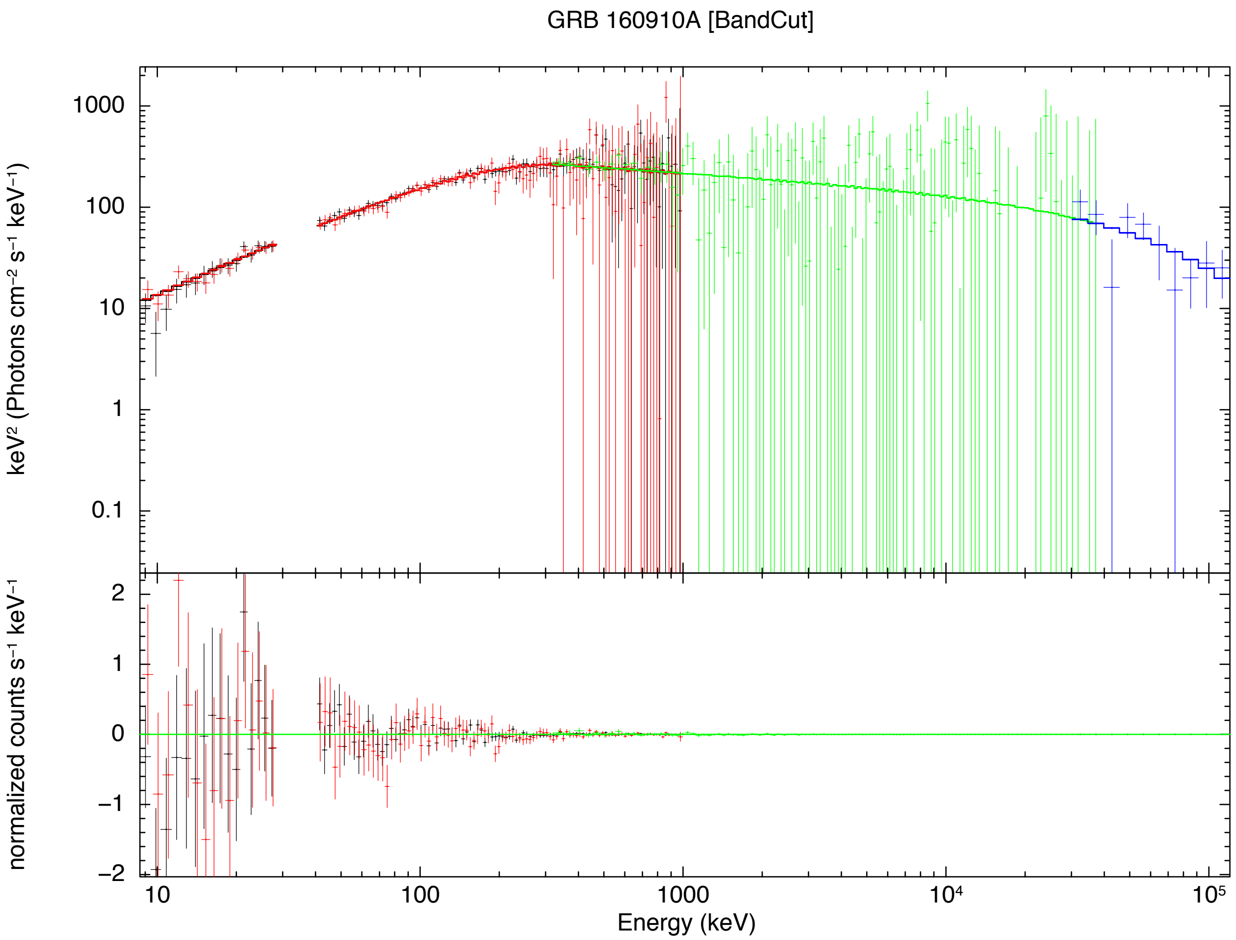
- Recently, it has been suggested by *Fermi* (LAT) with regards to GeV emission, that there is a possibility that the high energy emission MeV might offer some evidence as to how the emission occurs from different origins, and hence using the two- zone model where the high energy has a large radius, as compared to the MeV-range emission, can result in a very high $\Gamma$ >1000 being measured.

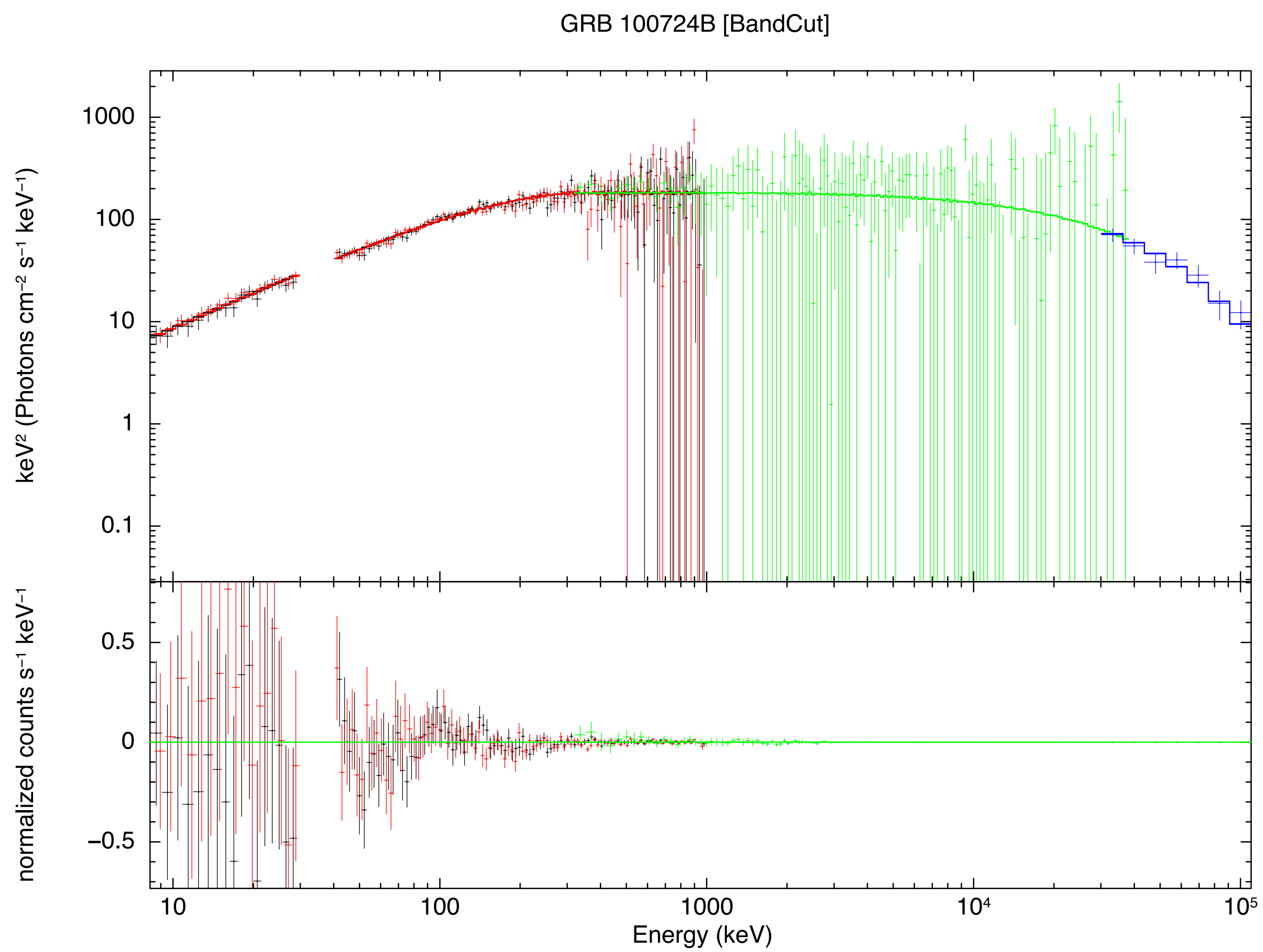
# Results and Discussion

## GRB with a constraining high-energy spectral cutoff, $E_c$

- One of the three GRBs that showed high-energy spectral cutoff features are graphically represented in the Figure below.




GRB 160910A [BandCut]
keV² (Photons cm⁻² s⁻¹ keV⁻¹)
normalized counts s⁻¹ keV⁻¹
Energy (keV)


GRB 100724B [BandCut]
keV² (Photons cm⁻² s⁻¹ keV⁻¹)
normalized counts s⁻¹ keV⁻¹
Energy (keV)

- The distribution of Lorentz factor Γ0 verses luminosity taken from other studies, the three GRBs from this study pointed in red.

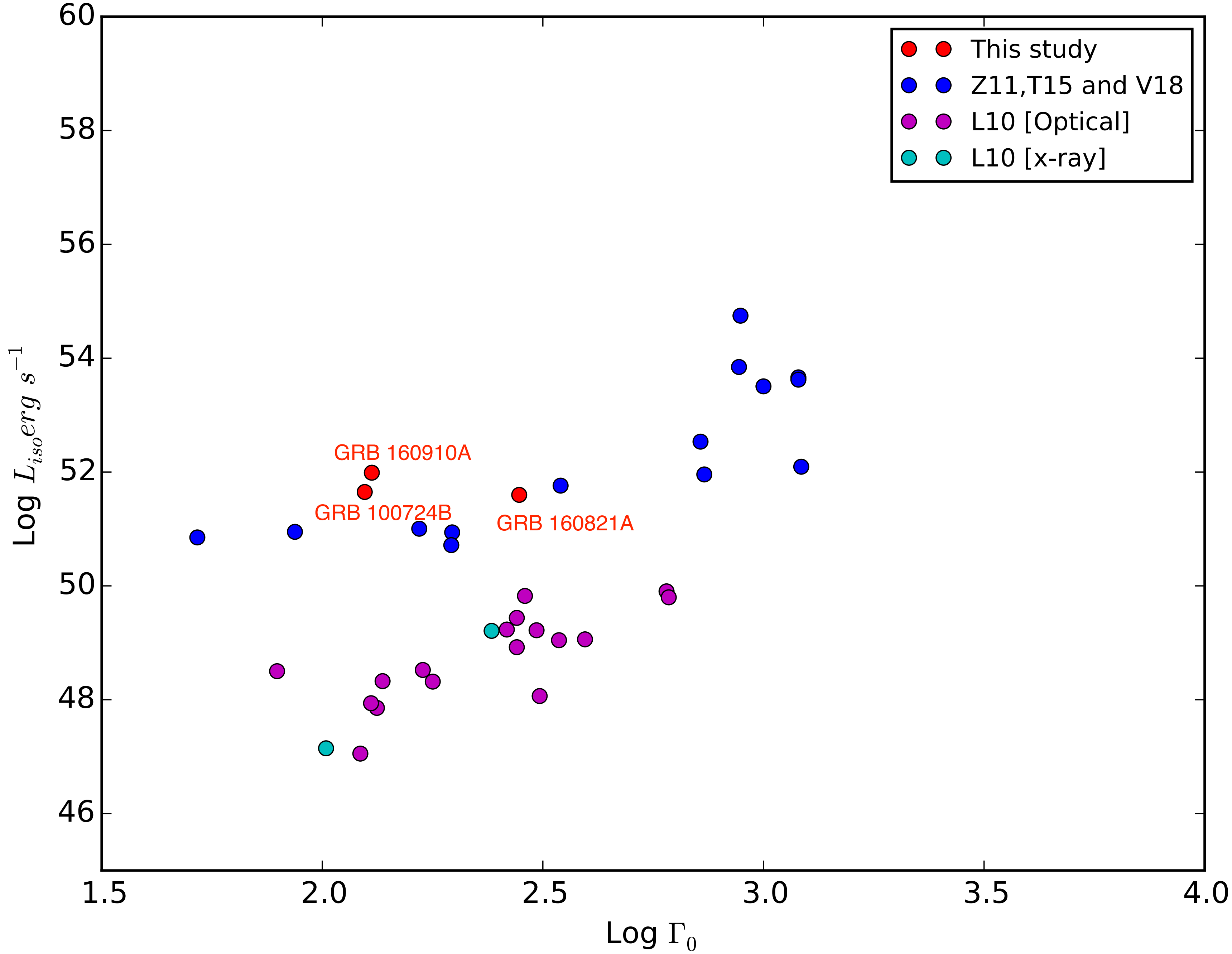


**Table 2** The GBM+LLE joint-fit spectral analysis of the three GRBs that were best fitted with the BandCut model. $T_s$ is the start time interval, $T_e$ is the end time-interval, $\alpha$ is the low-energy index, $\beta$ is the high-energy index, $E_{peak}$ is the peak energy in keV, $E_c$ is the high energy spectral cutoff in MeV and $\Gamma$ is the Lorentz factor.

| GRB name | $T_s$ | $T_s$ | $\alpha$ | $\beta$ | $E_{peak}$ [keV] | $E_c$ [Mev] | $\Gamma$ | $Cstat$/dof |
|---|---|---|---|---|---|---|---|---|
| 100724B | -62.465 | 244.74 | $-0.81 \pm 0.0.3$ | $-1.97 \pm 0.07$ | $346.58^{+33.13}_{-30.26}$ | $31.89^{+10.06}_{-6.10}$ | $124.81^{+39.86}_{-24.36}$ | 523.65/354 |
| 160821A | -2.048 | 220.16 | $-1.01 \pm 0.01$ | $-2.25^{+0.05}_{-0.05}$ | $881.10^{+41.15}_{-39.79}$ | $33.09^{+5.49}_{-4.48}$ | $129.51^{+21.99}_{-18.04}$ | 1620.1/354 |
| 160910A | -1.02 | 77.82 | $-0.81^{+0.05}_{-0.04}$ | $-2.18^{+0.13}_{-0.11}$ | $315.59^{+37.63}_{-35.55}$ | $71.42^{+157.01}_{-30.25}$ | $279.53^{+615.61}_{-119.49}$ | 432.7/355 |

**Table 4** The spectral joint-fit analysis LAT+LLE+GBM obtained from A13, T15, which showed the high energy spectral cut-off $E_c$ detection and estimations of the Lorentz factor $\Gamma$ for some GRBs. All errors are in the 90% confidence band.

| GRB | Model | $T_s$ [s] | $T_e$ [s] | $\alpha$ | $\beta$ | $E_{peak}$ [keV] | $E_c$ [MeV] | $\Gamma$ | $Cstat$ $(dof)$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | A13 | | | | | |
| 080825C | Band | - | - | $-065 \pm 0.02$ | $-2.40^{+0.03}_{-0.04}$ | $141 \pm 5$ | - | - | 1002.(821) |
| 100116A | Band | - | - | $-1.02 \pm 0.01$ | $-3.00^{+0.10}_{-0.13}$ | $1133^{+91}_{-82}$ | - | - | 381.2(356) |
| 100724B | BandCut | - | - | $-0.73^{+0.01}_{-0.00}$ | $-2.00 \pm 0.01$ | $263 \pm 4$ | $40 \pm 3$ | - | 734.7(468) |
| | | | | T15 | | | | | |
| 100724B | BandCut | - | - | $-0.71 \pm 0.01$ | $-2.08 \pm 0.01$ | $354.5 \pm 1.5$ | $42.4 \pm 4.0$ | $165.9 \pm 15.6$ | 1202.3(389) |
| 131014A | Band | - | - | $-0.21 \pm 0.01$ | $-2.62 \pm 0.02$ | $308.5 \pm 2.7$ | - | | 990(487) |
| 131108A | Band | - | - | $-0.88 \pm 0.03$ | $-2.16 \pm 0.01$ | $308.5 \pm 14.6$ | - | - | 440.9(388) |
| 140102A | Band | - | - | $-0.75 \pm 0.02$ | $-2.58 \pm 0.04$ | $182.1 \pm 4.3$ | - | - | 808(632) |
| | | | | This study | | | | | |
| 100724B | BandCut | -62.46 | 244.74 | $-0.81 \pm 0.0.3$ | $-1.97 \pm 0.07$ | $346.58^{+33.13}_{-30.26}$ | $31.89^{+10.06}_{-6.10}$ | $124.81^{+39.86}_{-24.36}$ | 523.65(354) |
| 160821A | BandCut | -2.05 | 220.16 | $-1.01 \pm 0.01$ | $-2.25^{+0.05}_{-0.05}$ | $881.10^{+41.15}_{-39.79}$ | $33.09^{+5.49}_{-4.48}$ | $129.51^{+21.99}_{-18.04}$ | 1620.1(354) |
| 160910A | BandCut | -1.02 | 77.82 | $-0.81^{+0.05}_{-0.04}$ | $-2.18^{+0.13}_{-0.11}$ | $315.59^{+37.63}_{-35.55}$ | $71.42^{+157.01}_{-30.25}$ | $279.53^{+615.61}_{-119.49}$ | 432.7(355) |

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