Determination of Pseudo-redshifts to Long GRBs by the Guiriec Method

Paula Yuc (IFIM, ECFM, USAC)
Rodrigo Sacahuí (IFIM, ECFM, USAC)
Magdalena González (IA-UNAM)
Yunior Pérez (IF-UNAM)

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Gamma Ray Bursts (GRBs)

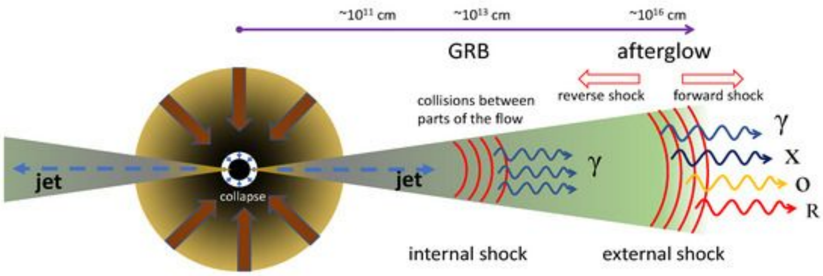


Figure 1: Visualization of the Fireball Model of GRBs (Dado S, Dar A, De Rújula A., 2022)

- **Isotropic Energy:** 10^{48} to 10^{55} erg
- **Peak energies:** keV-MeV (Zhang et al., 2020)
- **Non-Thermal Emission:**

  -Predominantly synchrotron and inverse Compton processes.

  -Characterized by the Band function spectrum.
- **Classification of GRBs according to their duration:**

  -Short GRBs: $T_{90} < 2s$

  -Long GRBs: $T_{90} \geq 2s$
- **Only about 11% of the redshifts of known GRBs have been recorded (Dainotti et al., 2024)**

Fermi Observatory Data

Instruments:

- ➢ LAT (Large Area Telescope)
- ➢ **GBM (Gamma-ray Burst Monitor)**
  - **Energy range:** 8 keV - 40 MeV
  - **Dead time per event:** 2.6 μs

Science Data Type used :

- ➢ **TTE Data:** Time-tagged events during bursts
  - Resolution of **0.064s** during bursts

GBM Tools Software (Goldstein et al., 2022):

- Data Processing
- Spectral Analysis
- Temporal Analysis

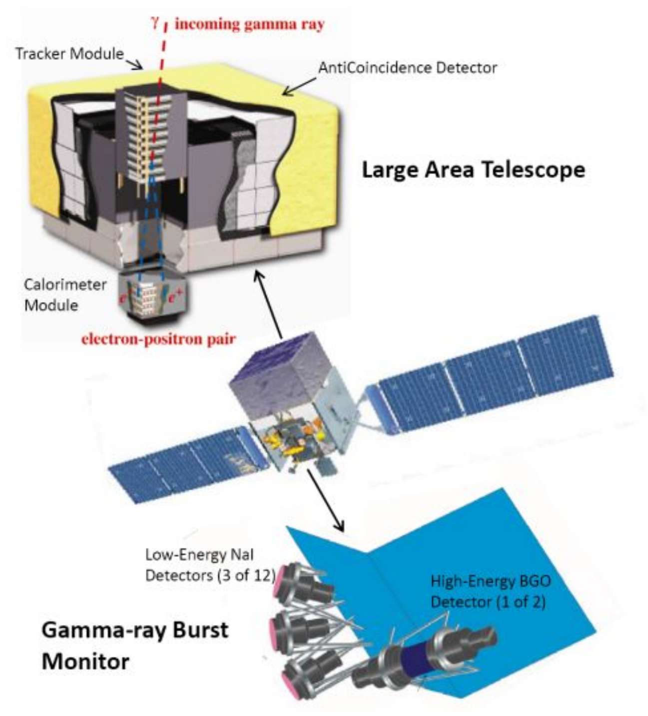


Figure 2: Fermi Observatory Instruments (Michelson et al., 2010)

Spectral Analysis Methodology

The implementation of a **Multicomponent Fitting in GRBs**, allows for the identification and characterization of different emission mechanisms contributing to the GRB prompt emission.

In this case we use three components:

- **Comptonized (C) Component:** Used instead of the Band model when the high-energy part of the spectrum is very steep.
- **Blackbody (BB) Component:** Thermal component representing photospheric emission.
- **Power Law (PL) Component:** Non-thermal component linked to high-energy emissions.

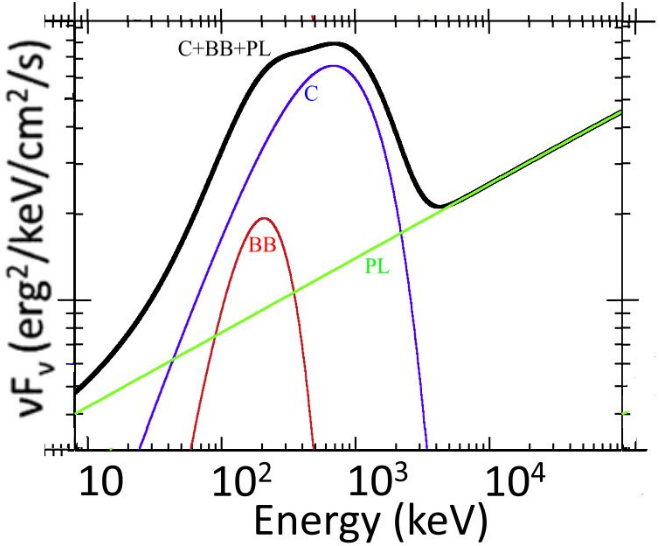


Figure 3: Sketch of the C+BB+PL model (Guiriec et al., 2015)

Multicomponent Model and Fine-Time Spectroscopy

Our three component model was reduced to have 5 free parameters whilst still maintaining the same quality for the fits. This makes it more statistically competitive with the simpler 4-parameter Band function (Guiriec et al., 2015).

Comptonized (C) Component:

$$F(E) = Ae^{-(2+\lambda)E/E_{peak}}\left(\frac{E}{E_{piv}}\right)^{\lambda}$$

→ fixed $\lambda = -0.7$

Power Law (PL) Component:

$$F(E) = A\left(\frac{E}{E_{piv}}\right)^{\lambda}$$

→ fixed $\lambda = -1.5$

Black Body (BB) Component:

$$F(E) = A\frac{E^2}{e^{E/kT}-1}$$

To better understand the behavior and temporal evolution of these spectral components, we conduct a fine-time spectral analysis, wherein we examine the data within very short time intervals (bins).

Guiriec Correlation

- The correlation specifically ties the non-thermal component's energy flux to its peak energy, using fine-time spectroscopy:

$$F_i^{\mathrm{NT}} - E_{\mathrm{peak},i}^{\mathrm{NT}}$$

  This relationship is observed to be quite strong when a multi-component spectral model is applied.
- Another strong correlation also appears between the luminosity and the rest-frame peak energy:

$$L_i^{\mathrm{NT}} = (9.6 \pm 1.1)10^{52} \left(\frac{E_{\mathrm{peak},i}^{\mathrm{rest,NT}}}{100\ \mathrm{keV}} \right)^{1.38\pm0.04} \mathrm{erg\ s^{-1}}$$

  (Guiriec et al., 2015)

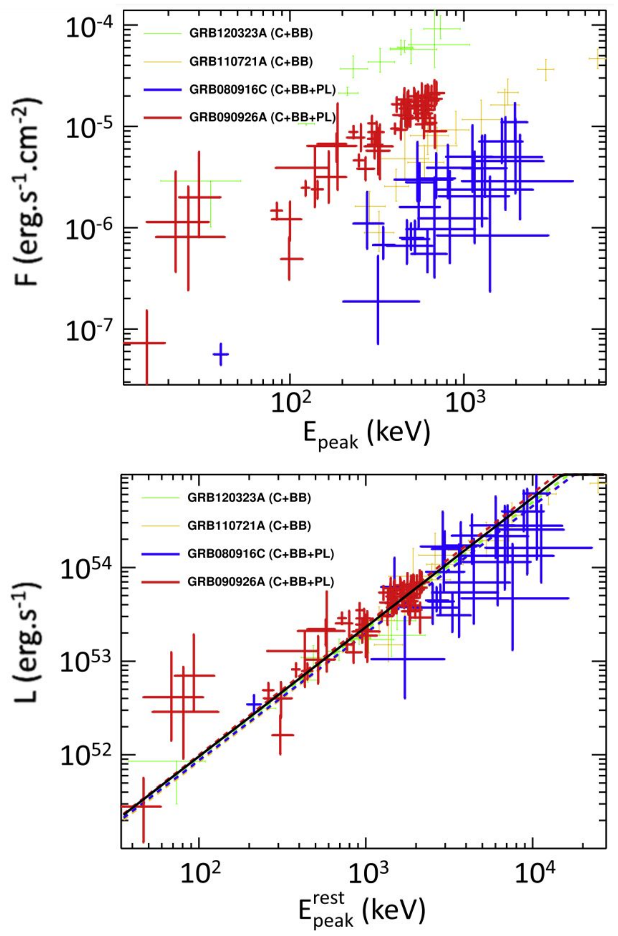


Figure 4: *(top)* Flux-Peak Energy relation *(bottom)* Luminosity-Rest Energy relation (Guiriec et al., 2015)

Sample Selection

24 GRBs were selected.

Criteria:

- Long GRBs
- High Luminosity (Fluence)
- Recorded redshift
- **Currently working on:** Fluence to T_{90} ratio > 0.12E-5

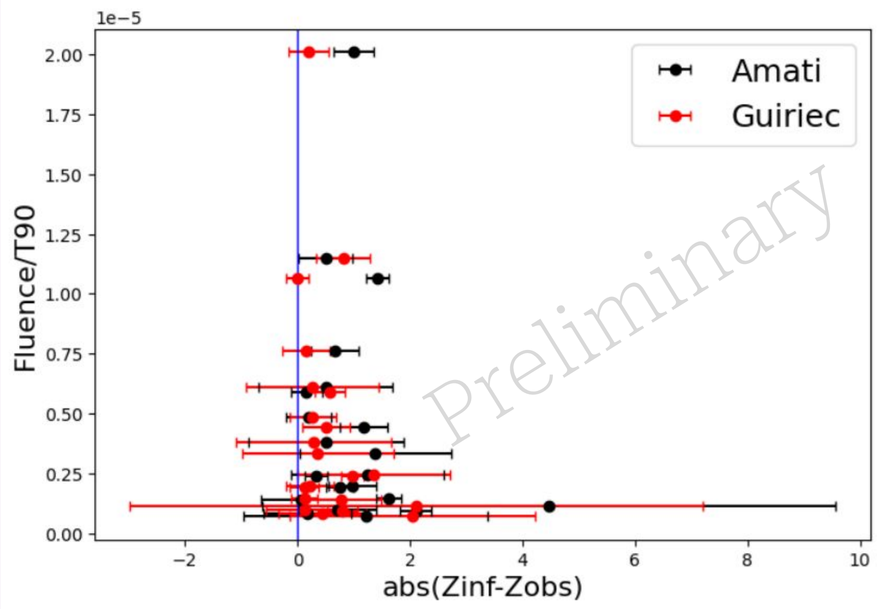


Figure 5: Analysis of the Fluence/T90 criteria for Long GRBs.

Estimated Pseudo-redshifts

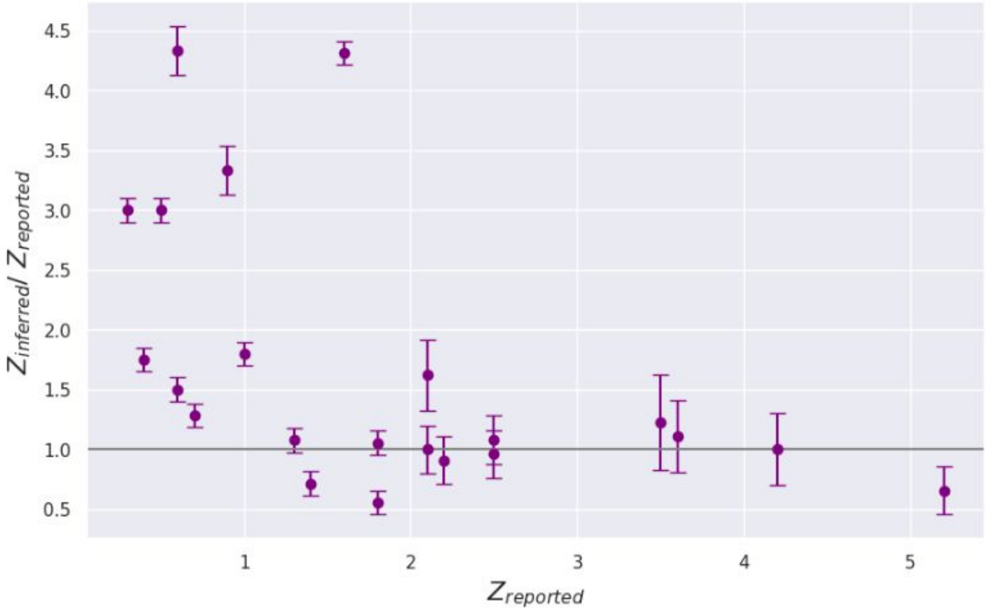
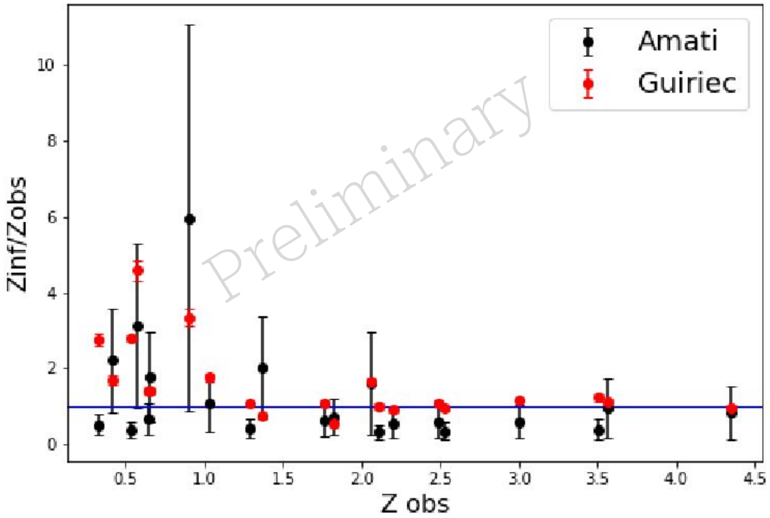


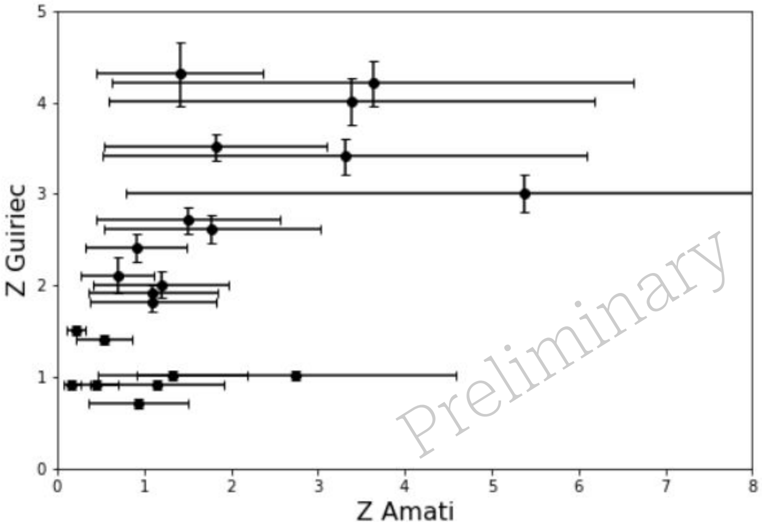
Figure 6: Estimated pseudo-redshifts obtained using the Guiriec Correlation

GRB	Reported redshift	inferred redshift $E_{peak,i}^{NT}$ - L_i^{NT} correlation
080916C	4.2 ± 0.2	4.2 ± 0.3
090323	3.6	4.0 ± 0.3
090618	0.5	1.5 ± 0.1
090902B	1.8	1.0 ± 0.1
090926A	2.1	2.1 ± 0.2
091003	0.9	3.0 ± 0.2
100414A	1.4	1.0 ± 0.1
100724B	1.3	1.4 ± 0.1
100728A	1.6	$6.9 \pm 0.$
120624B	0.6	2.6 ± 0.2
120711A	1.4^1 - 3^2	3.4 ± 0.2
130518A	2.5	2.7 ± 0.2
131231A	0.6	0.9 ± 0.1
140508A	1.0	1.8 ± 0.1
150314A	1.8	1.9 ± 0.1
150403A	2.1	3.4 ± 0.3
170214A	2.5	2.4 ± 0.2
170405A	3.5	4.3 ± 0.4
171010A	0.3	0.9 ± 0.1
180720B	0.7	0.9 ± 0.1
190114C	0.4	0.7 ± 0.1
190530A	<2.2	2.0 ± 0.2

Table 1: GRBs Sample with Reported Redshifts and Inferred Redshifts Obtained Using the Guiriec Correlation.

Comparison between the Guiriec Correlation and the Amati Correlation





Figures 7 and 8: Comparisons between the inferred pseudo-redshifts obtained with the Amati and Guiriec correlations.

Conclusions

- The obtained results align well with existing redshift data, showing that the Guiriec Correlation is an effective tool for estimating pseudo-redshifts to long GRBs.
- The calculated pseudo-redshifts provide a coherent view with cosmological observations.
- The results obtained from this sample are crucial for validating the empirical methods used and offer a valuable reference for future research in high-energy astrophysics.

Thank you for your attention!

Contact information:
pyuc@astro.unam.mx