Luminosity function of GRBs dominated by extended afterglow

Rangel Lemos, Luis Juracy

University of Rome “La Sapienza”
ICRA - International Center of Relativistic Astrophysics

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1 Introduction

2 Extracting informations from DISCLA BATSE data
   - Euclidean value of $V/V_{max}$
   - Sample selection
   - Spectral classes, $E_{pk}^{rp}$ and $<V/V_{max}>$

3 Luminosity function and GRB rate density
   - Luminosity function at $z = 0$
   - GRB rate density

4 Source count and calibration
   - k-correction
   - Source count
   - Calibration and results
Introduction

- We applied the statistical approach of Schmidt (2009) in a DISCLA BATSE GRB sample selected by us.
- Classification of the GRBs in 5 spectral classes.
- The statistical analysis is based on the luminosity function (LF) of GRB, where Schmidt assumed LF Gaussian-like.
- The LF used has a dependence of the: 1 - luminosity (L), 2 - spectral class (sp) and 3 - redshift (z).
- If we know the intrinsic LF of a kind of source, we can extract many informations about that kind of source, but the difficulty is to find the correct intrinsic LF.
- The LF is calibrated using the Swift data and $< V/V_{max} >$, which is an indicator of cosmological distance.
- The goal is to obtain the effects of Malmquist bias and the distribution of sources conform: L, sp and z.
Euclidean value of $V/V_{max}$

$$
\frac{V}{V_{max}} = \left( \frac{C_{max}}{C_{min}} \right)^{-3/2}
$$

where $C_{max}$ and $C_{min}$ are the rate count, respectively, maximum and minimum.
The GUSBAD is a catalog, organized by Schmidt (2004), with data of 2207 GRBs measured by DISCLA BATSE detector, which it was made two selections:

1\textsuperscript{st} selection: reduced GUSBAD

Schmidt took out the GRBs with peak photon flux less than \(0.5 \text{ ph cm}^{-2}\text{s}^{-1}\), where limiting flux is chosen due the break seen on the histogram of the source count versus peak flux, from 2207 GRBs it was left 1319. In the case of the BAT/Swift the break is around \(1.0 \text{ ph cm}^{-2}\text{s}^{-1}\).
**2nd selection: GUSBAD “sanitized”**

We took out the sources in which the P-GRB contribute to the $F_{ph}^{pk}$; in this case we want to study only the GRBs whose peak fluxes was located in the **extended afterglow**. Thus we excluded the sources:

1) with duration smaller than 2 seconds.
2) *disguised short* candidates, GRBs that have duration greater than 10 seconds and peak flux occurring in the first two seconds.

With this selection we were left 888 GRBs.
DISCLA BATSE detector has four spectral channels:  
1ch : 20 − 50 keV, 2ch : 50 − 100 keV, 3ch : 100 − 300 keV,  
4ch : > 300 keV.

The representative peak spectral energy $E_{rk}^{rp}$ of each spectral class are obtained by geometric means or statistical weight of the $E_{rk}^{rp}$ of the spectral channels.

Schmidt computed the $V/V_{max}$ of each GRB.

<table>
<thead>
<tr>
<th>sp</th>
<th>ch</th>
<th>$N_{grb}$</th>
<th>$E_{rk}^{rp}$ (keV)</th>
<th>$&lt;V/V_{max}&gt;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,2</td>
<td>153</td>
<td>66</td>
<td>0.452 ± 0.024</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>114</td>
<td>117</td>
<td>0.407 ± 0.027</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>154</td>
<td>178</td>
<td>0.312 ± 0.022</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>145</td>
<td>247</td>
<td>0.295 ± 0.023</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>322</td>
<td>420</td>
<td>0.332 ± 0.017</td>
</tr>
</tbody>
</table>
Luminosity function and GRB rate density

\[ \Phi(sp, L, z) = \Phi_0(sp, L)GR(z) \]

\( \Phi_0(sp, L) \rightarrow \) luminosity function at \( z = 0 \)

\( GR(z) \rightarrow \) GRB rate density
We used the LF adopted by Schmidt (2009), where he assumed Gaussian-like

\[ \Phi_0(L, sp) = \frac{R_0(sp)}{\sigma_{\log L} \sqrt{2\pi}} \exp \left\{ -\frac{1}{2} \left[ \log \left( \frac{L}{L_c(sp)} \right) / \sigma_{\log L} \right]^2 \right\} \]
We adopted the GRB rate density suggested by Wanderman & Piran (2010), which they calibrated with the data of Swift.

\[ GR_{WP}^{ob}(z) = \begin{cases} (1 + z)^{2.1} & \text{if } z \leq 3.1 \\ 139.55(1 + z)^{-1.4} & \text{if } z > 3.1 \end{cases} \]
Relation flux-luminosity

\[
F_{\text{en}}^{ob} = \frac{L_{\text{ob}}^{b} k(z)}{4\pi [D_L(z)]^2}
\]

\[
k^2(z) = \frac{\int_{E_1(1+z)}^{E_2(1+z)} EN_B(E, E_{p_k}^R) dE}{\int_{E_1}^{E_2} EN_B(E, E_{p_k}^R) dE}
\]

The k-term is a spectral adjustment to obtain the emitted flux/luminosity of a known non bolometric observed flux/luminosity.
Source count

The source count is obtained integrating the luminosity function, as

\[ N(sp) = \int_{L_1(sensitivity)}^{\infty} \int_{0}^{V_{max}(sensitivity)} \Phi_0(sp, L)GR(z)dLdV \]

thus

\[ \text{flux} \to N(F > F_{lim}, sp) = \int_{0}^{\infty} \phi_0(L, sp)dL \int_{0}^{z(L,F,sp)} \xi(z')dz' \]

\[ \text{luminosity} \to N(L, sp) = \phi(L, sp) \int_{0}^{z(L,F_{lim},sp)} \xi(z')dz' \]

\[ \text{redshift} \to N(z, sp) = \xi(z) \int_{L(z,F_{lim},sp)}^{\infty} \phi(L', sp)dL' \]

where

\[ \xi(z) = GR^{intrinsic}(z) \frac{dV_{com}(z)}{dz} = 4\pi \frac{GR^{ob}(z)}{1 + z} [D_{com}(z)]^2 \frac{dD_{com}(z)}{dz} \]
The obtaining of the parameters is by trial and error. We make the iteration of $L_c$ and $E_0^R$, obtaining in each step, respectively, $\left\langle \frac{V}{V_{\text{max}}} \right\rangle$ and $<E_{pk}^{rp}>$. This procedure is done until we obtain the data of the table below.

<table>
<thead>
<tr>
<th>sp</th>
<th>$N_{\text{grb}}$</th>
<th>$E_{pk}^{rp}$ (keV)</th>
<th>$&lt;V/V_{\text{max}}&gt; \pm$</th>
<th>$\log_{10}(L_c)$</th>
<th>$E_0^R$ (keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>153</td>
<td>66</td>
<td>0.452 ± 0.024</td>
<td>49.03</td>
<td>82</td>
</tr>
<tr>
<td>2</td>
<td>114</td>
<td>117</td>
<td>0.407 ± 0.027</td>
<td>50.18</td>
<td>206</td>
</tr>
<tr>
<td>3</td>
<td>154</td>
<td>178</td>
<td>0.312 ± 0.022</td>
<td>51.47</td>
<td>500</td>
</tr>
<tr>
<td>4</td>
<td>145</td>
<td>247</td>
<td>0.295 ± 0.023</td>
<td>51.68</td>
<td>725</td>
</tr>
<tr>
<td>5</td>
<td>322</td>
<td>420</td>
<td>0.332 ± 0.017</td>
<td>51.29</td>
<td>1199</td>
</tr>
</tbody>
</table>
Iteration of $L_c$ (1) until obtain $\langle \frac{V}{V_{\text{max}}} \rangle$.

Iteration of $E_R^0$ until obtain $E_{pk}^{rp}$. 
Results: observations versus predictions

Source count vs Peak photon flux

Source Count, $N(F_{pk})$ vs Peak photon flux, $F_{pk}\,(ph\,cm^{-2}\,s^{-1})$

- spectral class = 1
- spectral class = 2
- spectral class = 3
- spectral class = 4
- spectral class = 5
- sum of spectral classes

525 GRBs of SWIFT - total
173 GRBs of SWIFT - with $z$

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Luminosity function of GRBs dominated by extended afterglow
Source count vs Redshift

![Source Count vs Redshift Diagram](image)

- 217 GRBs
- sp=1
- sp=2
- sp=3
- sp=4
- sp=5
- sum of spectral classes

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Source count vs Luminosity
The goal in this work was to apply the statistical approach of Schimdt (2009) to a GRB sample without contamination by the P-GRBs. We have also used a different GRB rate density from the one used by Schmidt (2009), namely that obtained by Wanderman & Piran (2010). We can see the effect of this choice in the statistics, looking at the figures $N \ vs \ F_{pk}$ and $N \ vs \ z$, where a reasonable agreement with the observation data is obtained. The next goal is to obtain an Amati-like relation, between the isotropic luminosity and peak spectral energy in the rest frame.
GRAZIE
THANK YOU
DANKE SCHÖN
SPASIBO
GRACIAS
OBRIGADO
XIE XIE