The luminosity and redshift distributions of LGRBs.

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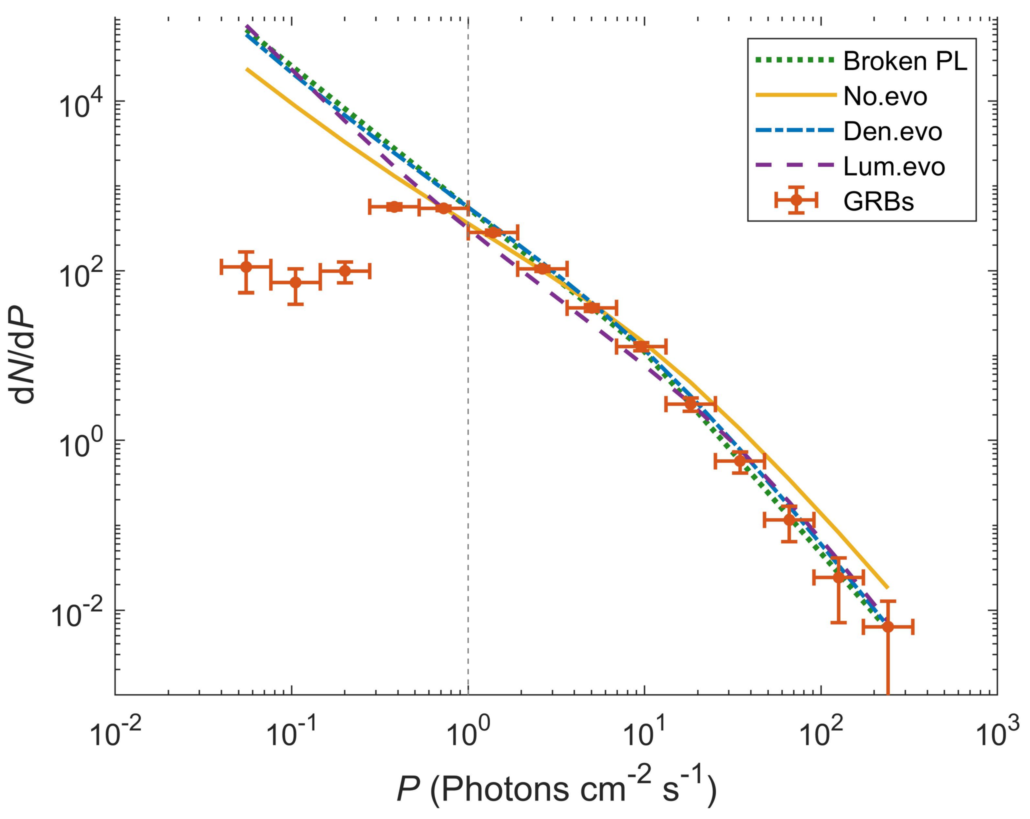
MNRAS, 508, 52-68 (2021)

1. Introduction

Gamma-ray bursts (GRBs) are the most luminous explosive transients in the cosmos. Generally, long GRBs (LGRBs) with durations T_{90}>2s are believed to be powered by the core collapse of massive stars then thus suggested to be excellent tools to probe the star formation rate (SFR) at high redshifts. However, base on the studies over the last two decades, there is a general agreement on the fact that GRBs may have experienced some kind of evolution with redshift[1]. However, as is well known, the observational samples inevitably subject to various instrumental selection effects and observational biases[2] e.g. trigger problems of faint bursts and redshift-measurement problems for hard location and limited ability of instrument. It is difficult to reveal the intrinsic distributions of long GRBs and their evolution features from these samples. Though some complete samples[3] can provide a solid basis for the statistical study of the long-GRB population, their current sample size is admittedly small. In this work, we update and enlarge the GRB sample observed by Swift/BAT and use it to revisit the GRB luminosity function (LF) and redshift distribution by carefully considering the incomplete sampling of the faint bursts and the probability of redshift measurement.

2. Sub-sample of bright bursts

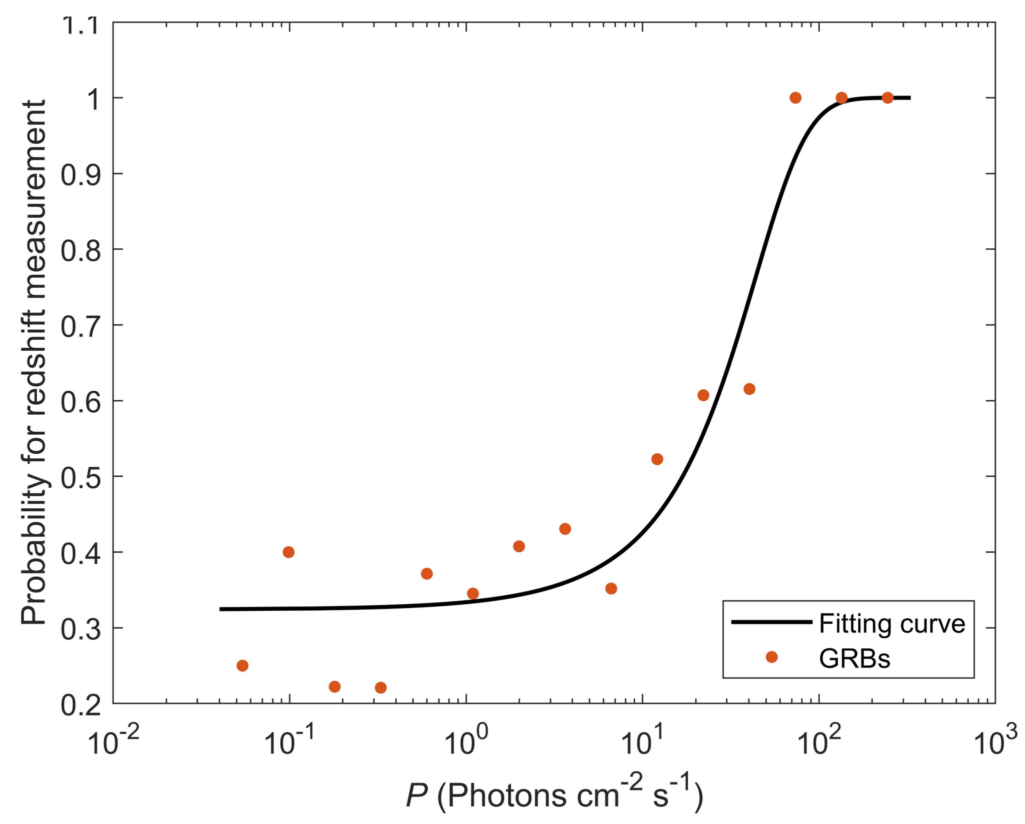
We firstly select a sub-sample with P≥1 Photons cm^{-2} s^{-1} where the instrumental selection effect is nearly negligible.



3. Redshift measurement probability

We define the redshift measurement probability θ_z as a function of the peak flux P, in which the probabilities are estimated by the fraction of the number of bursts with redshift measurement in each bin to the overall number of detected bursts in the corresponding bin. Here we use an empirical function to model the redshift measurement probability like

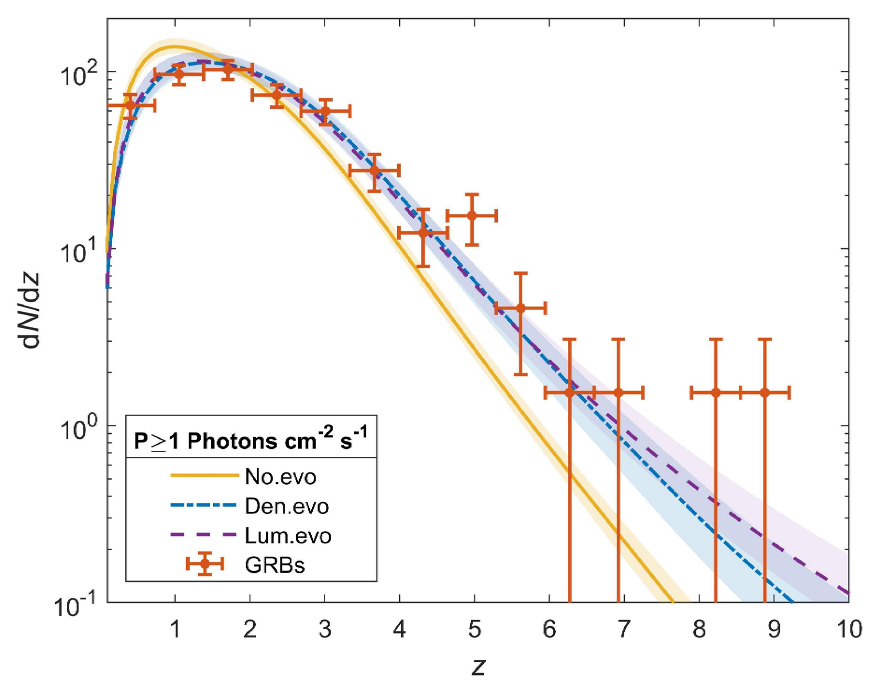
$$\theta_z(P) = \frac{1}{1+\xi_z \kappa_z^P} \, . \qquad (1)$$

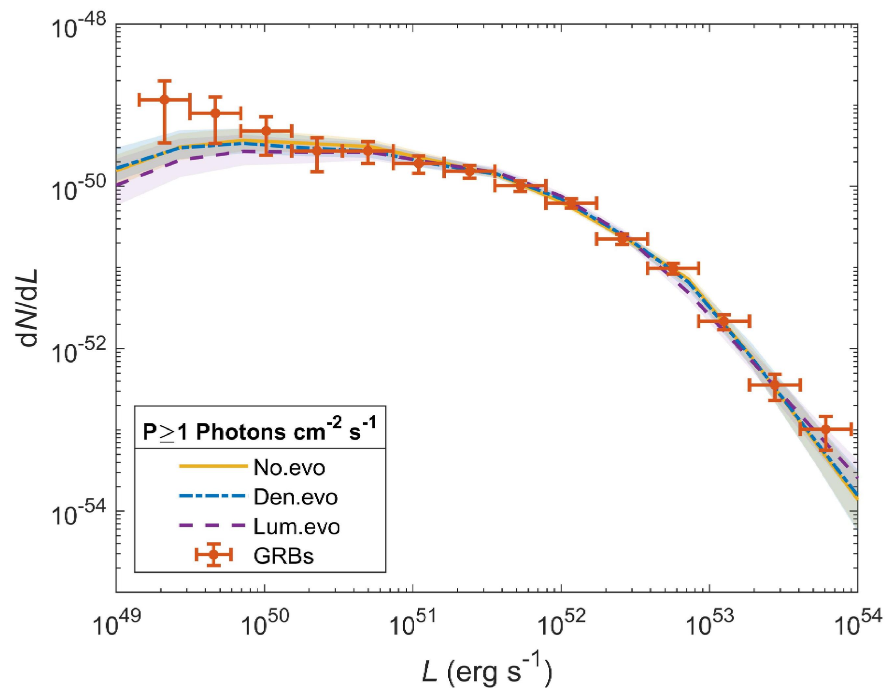


4. Results for bursts with P $\geq$ 1 Photons cm^{-2} s^{-1}

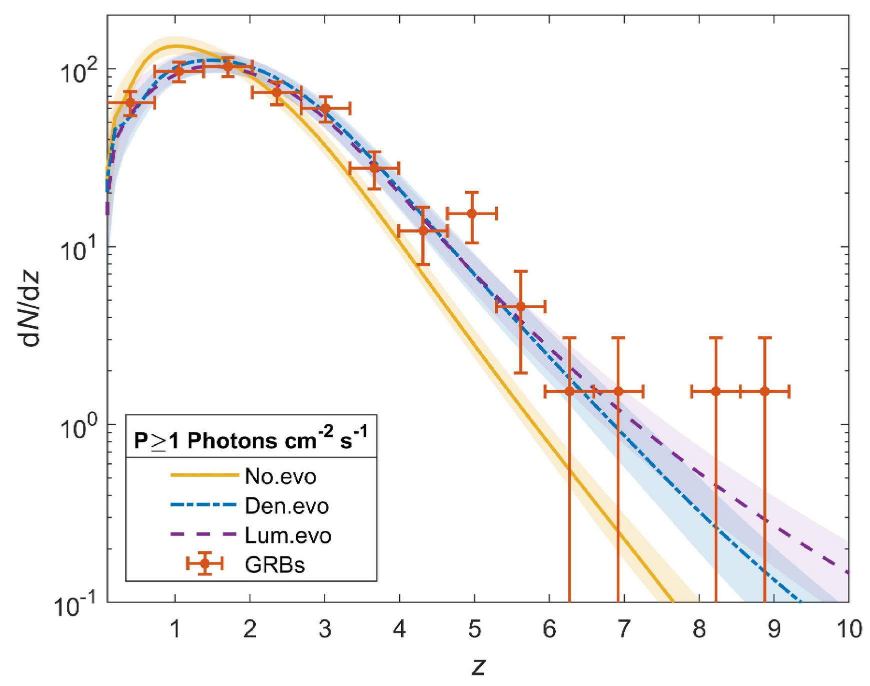
Adopt the probability of redshift measurement, we can calculate the expected distributions of redshift and luminosity for our bright sub-sample.

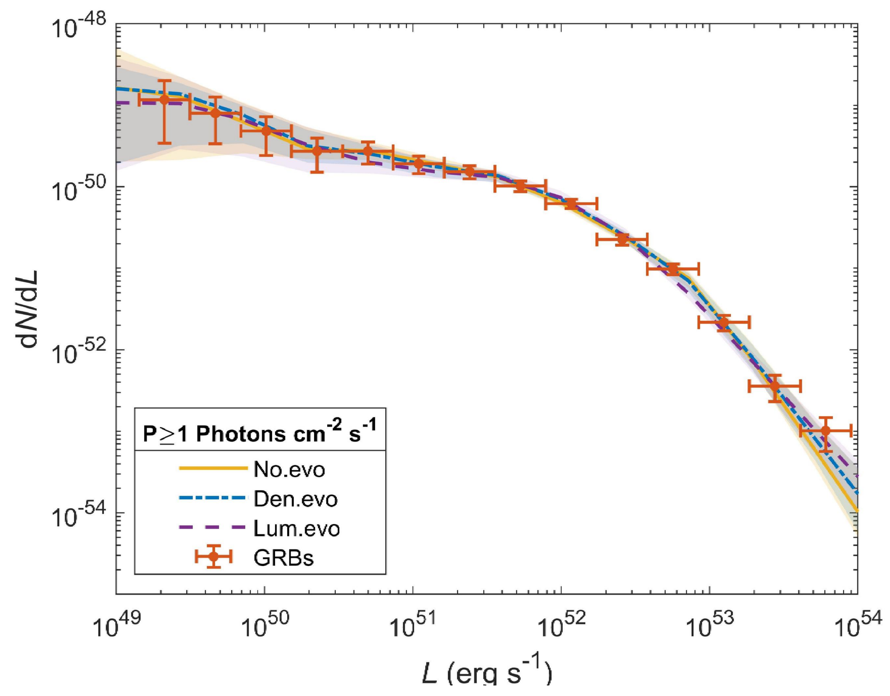
(The luminosity distribution is described by a broken power-law function.)





(The luminosity distribution is described by a triple power-law function.)





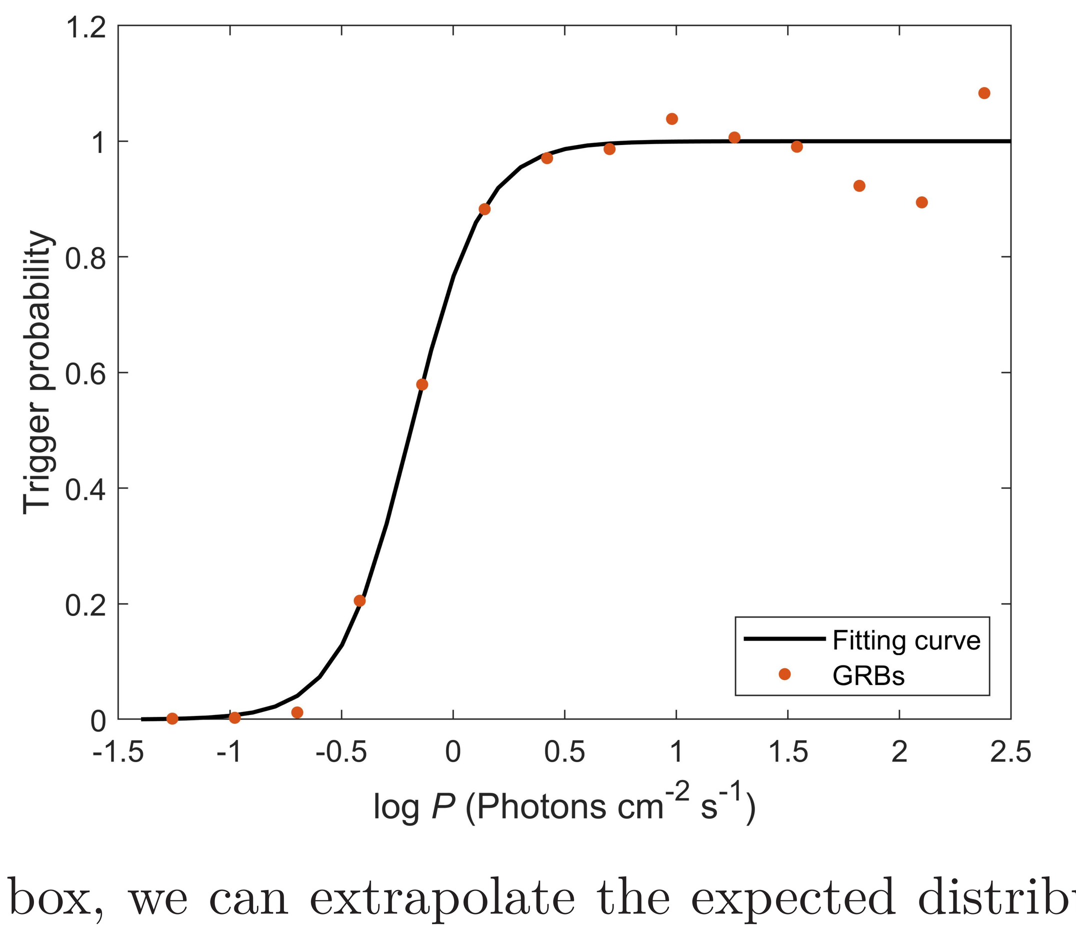
5. Extrapolate to whole sample with trigger probability

Assume that the P distribution follows a broken power law like

$$\frac{dN}{dP} \propto \begin{cases} P^{\beta_1}; & P \leq P_c \, , \\ P_c^{\beta_1-\beta_2} P^{\beta_2}; & P > P_c \, , \end{cases} \qquad (2)$$

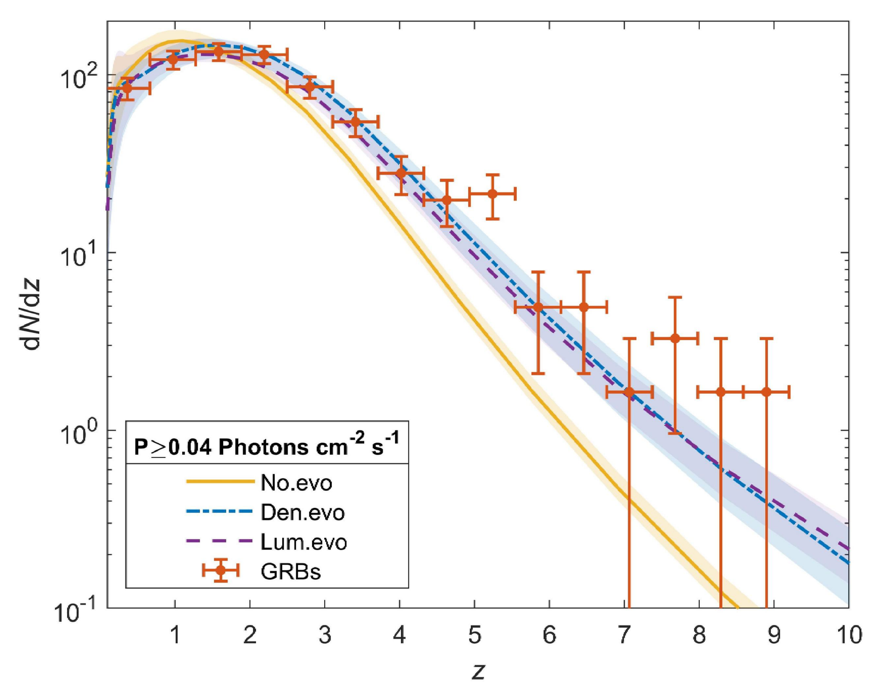
then we can have the intrinsic P distribution (green dotted line in box 2) of faint bursts by extrapolating the expected P distribution from bright end to faint end. The trigger probability can be subsequently calculated through the function:

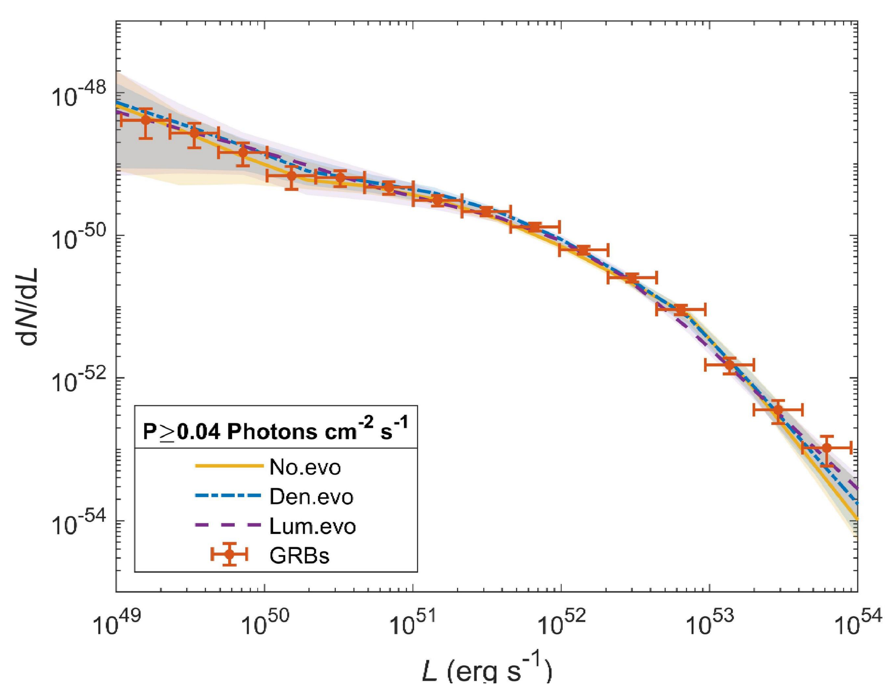
$$\theta_\gamma(P) = \frac{(dN/dP)_{\rm obs}}{(dN/dP)_{\rm int}} = \frac{1}{1+\exp(\xi_P \log P + \kappa_P)} \, . \qquad (3)$$



Combine the trigger probability with results of last box, we can extrapolate the expected distributions of GRBs to the faintest end.

(The luminosity distribution is described by a triple power-law function.)





6. Conclusions

1. The redshift evolution has to be considered when using GRBs to track SFR.
2. With the support of the trigger probability, our best-fitting models can reflect the distributions of whole sample without any adjustment of free parameters.
3. A triple power-law model is better in the description of the luminosity distribution. This is quite different from the previous studies which applied a complete sample with little bursts at low-z.

7. References

[1] Guang-Xuan Lan, Hou-Dun Zeng, Jun-Jie Wei, and Xue-Feng Wu. The luminosity function and formation rate of a complete sample of long gamma-ray bursts. , 488(4):4607–4613, October 2019.

[2] J. S. Bloom. Is the Redshift Clustering of Long-Duration Gamma-Ray Bursts Significant? , 125(6):2865–2875, June 2003.

[3] R. Salvaterra, S. Campana, S. D. Vergani, S. Covino, P. D'Avanzo, D. Fugazza, G. Ghirlanda, G. Ghisellini, A. Melandri, L. Nava, B. Sbarufatti, H. Flores, S. Piranomonte, and G. Tagliaferri. A Complete Sample of Bright Swift Long Gamma-Ray Bursts. I. Sample Presentation, Luminosity Function and Evolution. , 749:68, April 2012.