LIGHT CURVES IN X-RAYS AND GAMMA-RAYS

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OBJECTIVES

Using Willingale non-linear model fits of GRB light curves we will;

1. Check the temporal and spectral index 'Closure Relations' predicted by the Fireball Model of GRB emission.
2. Examine the Dainotti correlation with our expanded sample
3. Determine the existence of the 'plateau' in gamma-ray light

INTRODUCTION

Gamma-Ray Bursts are the most energetic and luminous events in the universe.
The Fireball Model describes GRBs as as two anti-parallel jets of photons and charged particles emitted from the central engine.
The phenomenological Willingale model allows us to quantify aspects of these emissions by using non-linear regression methods to fit the light curve for each swift GRB with a detectable plateau in X-ray.

METHODS

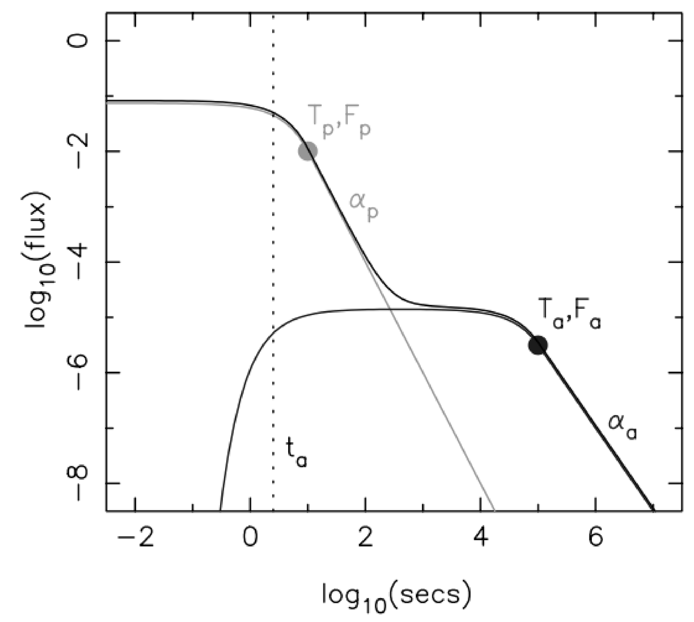


Figure 1: A 'typical' GRB light curve

1. t_a - afterglow curve start time
2. T_a - time at the end of the plateau
3. F_a - flux at the end of the plateau
4. α_a - afterglow temporal decay index

$$f_c(t) = \begin{cases} F_c \exp\left(\alpha_c - \frac{t\alpha_c}{T_c}\right) \exp\left(\frac{-t_c}{t}\right), & t < T_c, \\ F_c \left(\frac{t}{T_c}\right)^{-\alpha_c} \exp\left(\frac{-t_c}{t}\right), & t \geq T_c. \end{cases}$$

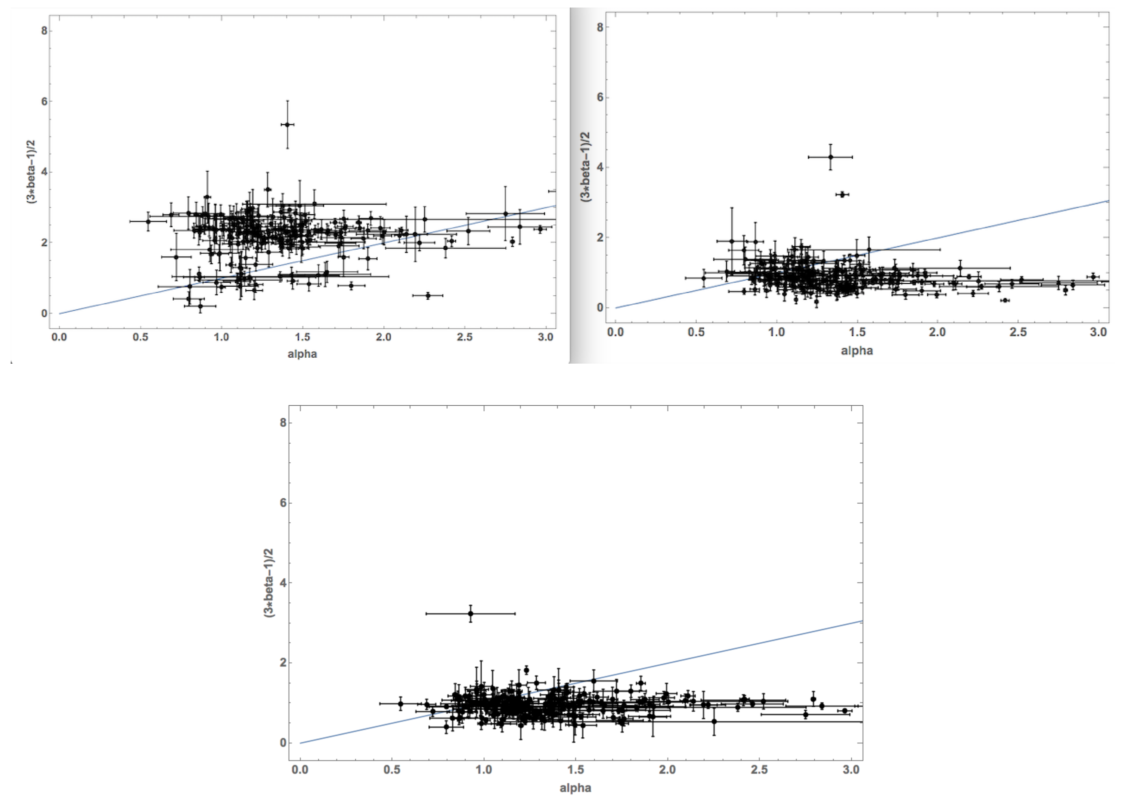
Figure 2: Piecewise Willingale Function

Our sample for this project was built by fitting light curves to this piecewise function (Willingale et al. 2007). We investigated only GRBs which had a plateau in the light curve and whose redshifts were known. A total of 235 GRBs were successfully fit.
This is an 8-parameter model, however we were primarily concerned with the 4 parameters describing the 'afterglow' portion of the light curves. These parameters are,

All data was collected from repositories for the Swift and Fermi space telescopes. The non-linear model fits were performed using computer software, primarily Mathematica.
In this poster we focus on those GRBs with known redshifts and detectable plateaus. Most of the analysis described here was also performed on a similar sample without known redshift values.
All errors recorded at 1 σ

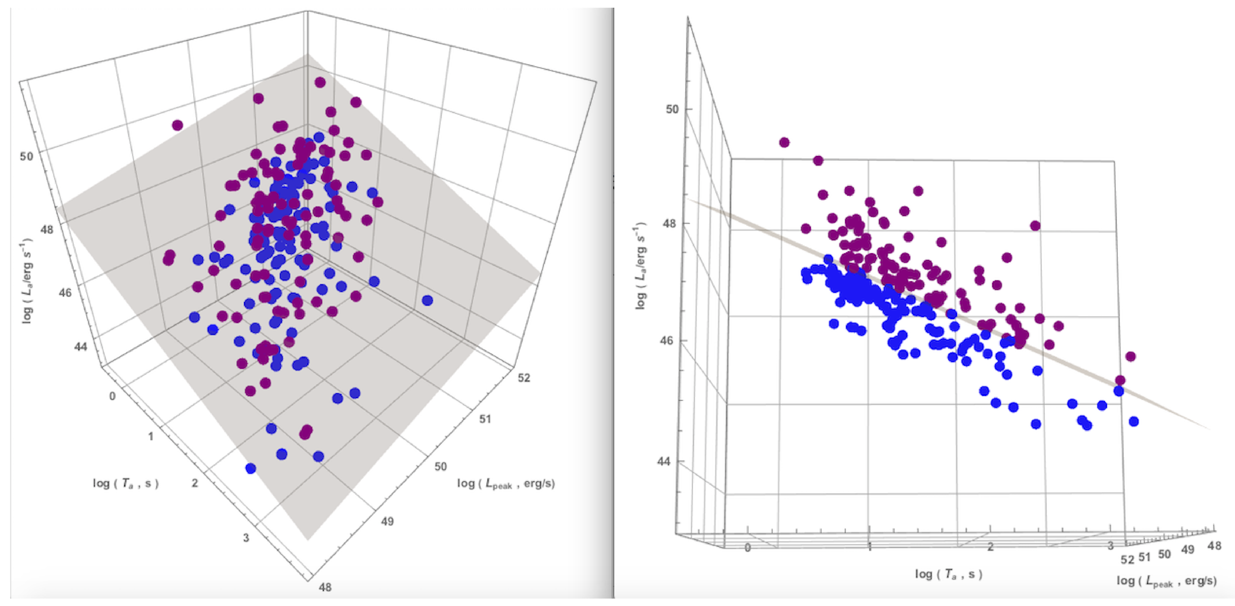
RESULTS

Closure Relations: Our predicted closure relation is given by $\alpha = \frac{3\beta - 1}{2}$ where α is the temporal decay index and β is the time-dependent spectral index (Willingale et al. 2007).
The β values for three different sections of the afterglow light curve are shown; the portion covering the plateau, the portion including the time T_a and it's associated error, and the afterglow decline.



Above: Left: 57 out of 235 GRBs are consistent with the predicted relation using the spectral index near T_a. Right: 48 out of 235 are consistent using the plateau spectral index. Bottom: 58 out of 235 are consistent using afterglow decline spectral index.

Dainotti Correlation: The previously established Dainotti Correlation (Dainotti et al. 2016) is examined using our expanded sample of 235 GRBs. The time T_a is anti-correlated with both the luminosity of the plateau and the peak luminosity. The two luminosity values are correlated with one another.



Plane of Best Fit:

$$L_a = 29.1 - 0.95 T_a + 0.40 L_{peak}$$

CONCLUSION

We find that around 25% or less of GRBs in our sample are consistent with the predicted α-β relationship. Previous studies (Willingale, 2007) found that around 50% of their sample fulfilled this relation.

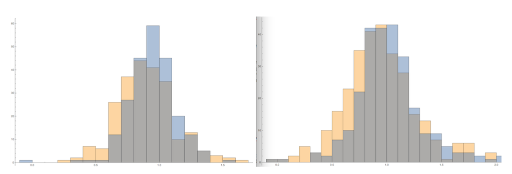


Figure 3: β distribution with and without known redshift

The similarity of the index distributions like the one shown suggests that we should expect similar closure relation results in the sample without known redshift.
As shown in the 3-D plots, our sample confirms the Dainotti Correlation, at least qualitatively. This expanded sample shows a clear anti-correlation between plateau time and both luminosity values (plateau and peak). At this stage our plane equation needs to be more closely compared to previous studies to determine if the specific correlation coefficients are confirmed.
We have tested the existence of the plateau in 11 light curves observed by Fermi and found that in 4 of them the plateau does exist.

REFERENCES

- Willingale et al., *Testing the standard fireball model of gamma-ray bursts using late x-ray afterglows measured by SWIFT*, 2007
- Dainotti et al., *A fundamental plane for long gamma-ray bursts with x-ray plateaus*, 2016.
- Evans et al., *SWIFT Burst Analyzer, www.swift.ac.uk*, Accessed 2018.

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