Pulse fitting and spectral analysis of short gamma-ray bursts and the magnetar giant flare, GRB200415A

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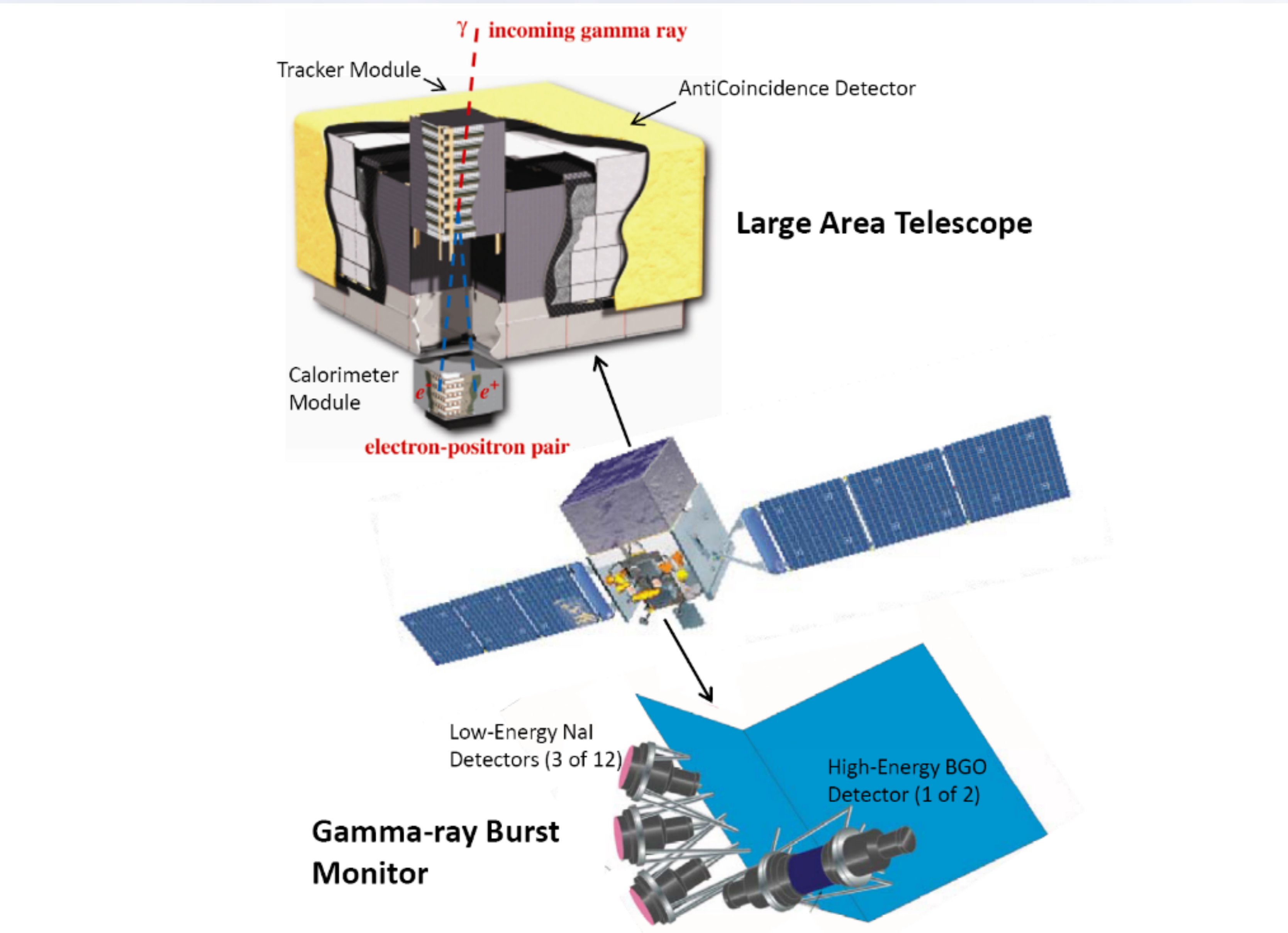
Introduction

Short gamma-ray bursts (SGRBs) are gamma-ray sources with the interval between their 5% and 95% of maximum photon flux being less than 2 seconds i.e $T_{90} < 2s$ [1, 2]. SGRBs and magnetar giant flares (MGFs) are both short gamma-ray transients and both of them have hard spectra. The former originates from compact binary mergers [3] hence they occur at cosmological distances whilst the latter originates from magnetars [4] in star forming galaxies. MGFs progenitor and energies vary from those of the SGRB however only their initial peak is detected without the fading oscillating phase, hence these sources can be mistaken to be SGRBs. In this work we compare temporal and temporal results of the GRB200816A and the MGF, GRB200415A.

Observations and analysis

Fermi Gamma-ray Space Telescope



Pulse fitting - Norris function

- The Norris function [6] is a mathematical function that is used to fit the pulses of the sources.

$$I(t) = \begin{cases} A\exp\left[-\left(\frac{|t-t_{peak}|}{t_{rise}}\right)^{\nu_1}\right]; & t < t_{peak} \\ A\exp\left[-\left(\frac{|t-t_{peak}|}{t_{fall}}\right)^{\nu_2}\right]; & t > t_{peak} \end{cases}$$

- where A is the rate, t_{peak} is the time where the maximum rate is observed with t_{rise} and t_{fall} being the pulses rise and fall times respectively.
- The spectra below are reported for the energy range 0 - 900 keV.
- The SGRB and MGF pulse rise times are 144.86 ms and 7.31 ms respectively
- Typically MGFs have pulse rise times that is only a few milliseconds and SGRBs pulse rise time ranges from tens to hundreds of milliseconds

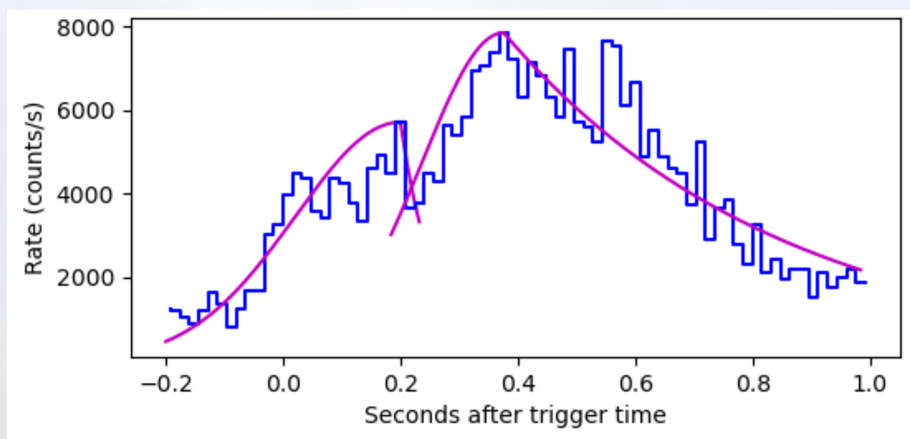


Figure 1: GRB200816A light curve

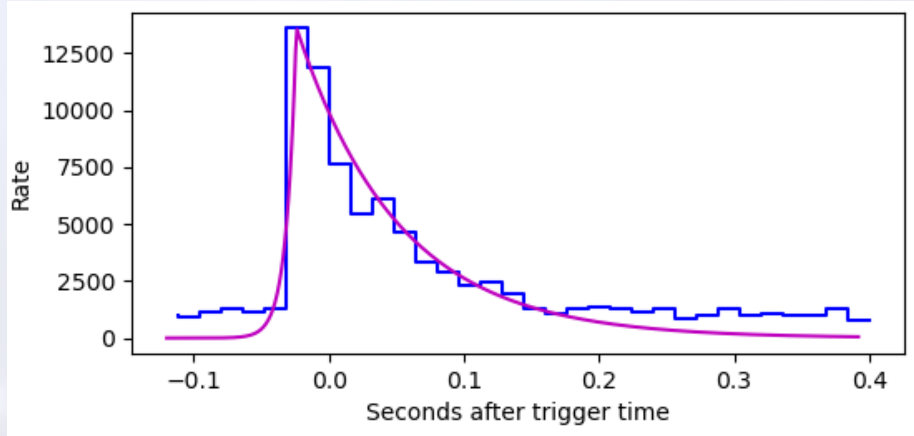


Figure 2: GRB200415A light curve

Spectral analysis - Comptonized model

$$COMP(E) = N\left(\frac{E}{E_0}\right)^{\Gamma}\exp\left(-\frac{E}{E_c}\right)$$

- where N is the prefactor, E_0 is the scaled energy at 100 Mev and E_c is the cutoff energy and the spectral index is given by gamma.
- The SGRB shows a rapid decrease in rate compared to the MGF

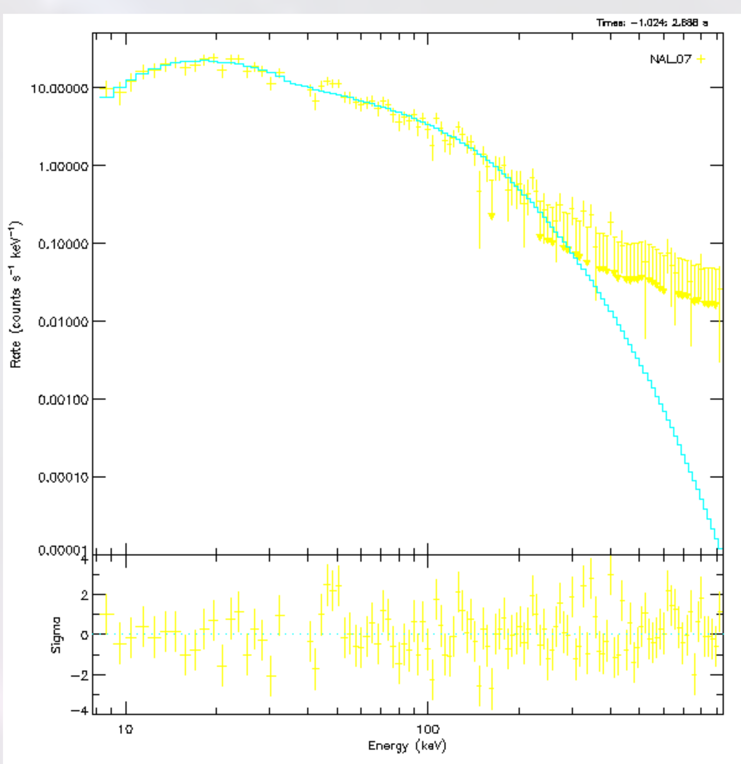


Figure 3: GRB200816A spectra

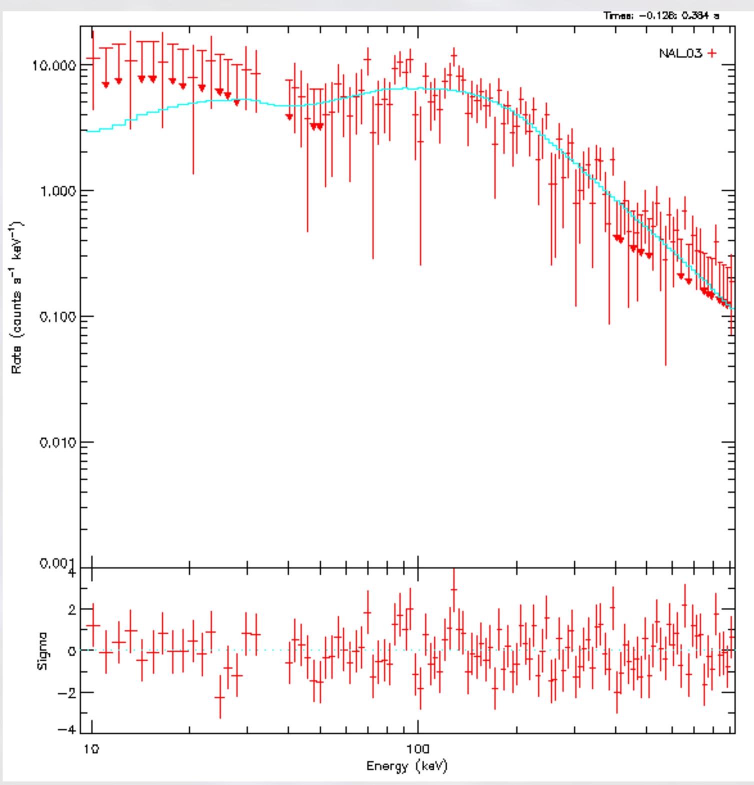


Figure 4: GRB200415A spectra

Results

- The MGFs spectral spectral index (Table 1) is approximately zero. Nonetheless, it is still a hard short gamma-ray transient

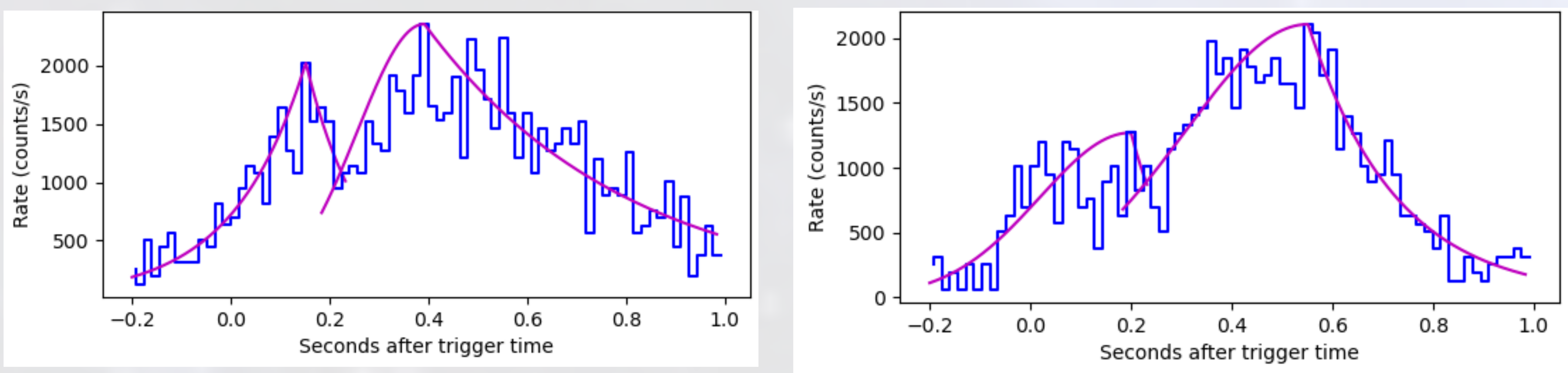


Figure 5: GRB200826A channel 2 (25 - 50 keV) and channel 3 (50 - 100) light curves respectively

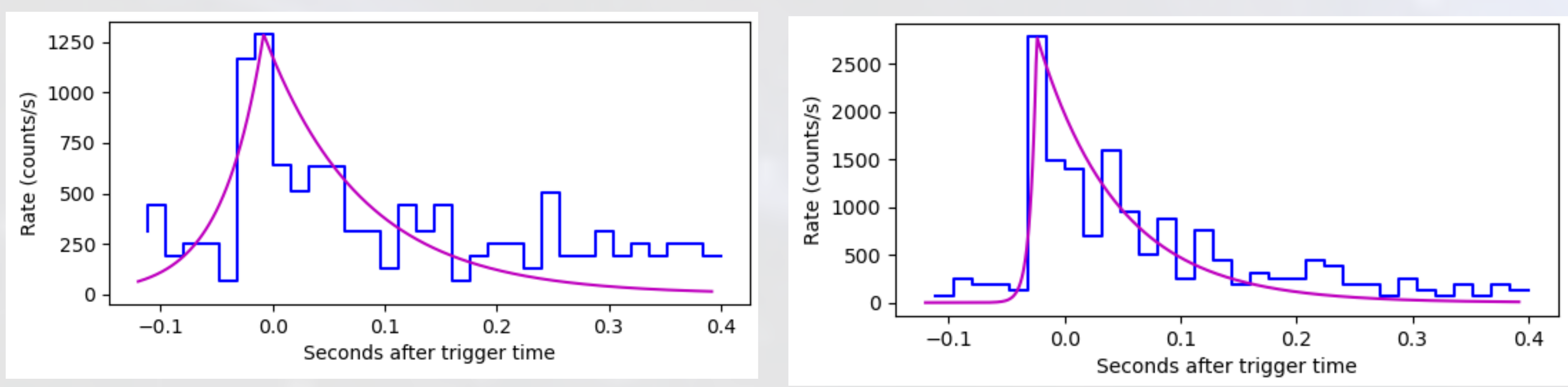


Figure 6: GRB20415A channel 2 (25 - 50 keV) and channel 3 (50 - 100) ight curves respectively

		Rise time in ms for varying energy channels					
GRB	Spectral index	1 (10 - 25 keV)	2 (25 - 50 keV)	3 (50 - 100 keV)	4 (100 - 300 keV)	5 (> 300 keV)	All channels (10 - 900 keV)
GRB200816A	-0.83 ± 0.08	252.73 ± 33.95	110.40 ± 9.69	197.98 ± 9.31	99.90 ± 7.61	- -	112.50 ± 8.04
GRB200415A	-0.02 ± 0.22	- -	37.09 ± 8.96	5.42 ± 3.44	9.73 ± 1.00	22.71 ± 2.52	7.31 ± 1.78

Table 1: Comptonized model fit parameters and pulse rising time of GRB200816A and the MGF, GRB200415A

Summary

The results presented in this work depicts that MGF have fast pulse rise times across all the energy channels compared to the cosmological GRB show which has tens to hundreds of milliseconds in pulse rise times. We have also shown that although the MGF is spectrally hard, its spectral index is approximately zero (Table 1) which makes it distinct from the SGRB.

References

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[2] Meszaros P 2006 *Reports on Progress in Physics* **69** 2259
[3] Dirirsa FF et al. 2019 *The Astrophysical Journal* **887** 13
[4] BUrns E et al. 2021 *The Astrophysical Journal Reviews* **907** L28
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