Tenth International Fermi Symposium

9th-15th October 2022

Pulse fitting of SGRBs with known redshift detected by Fermi-GBM

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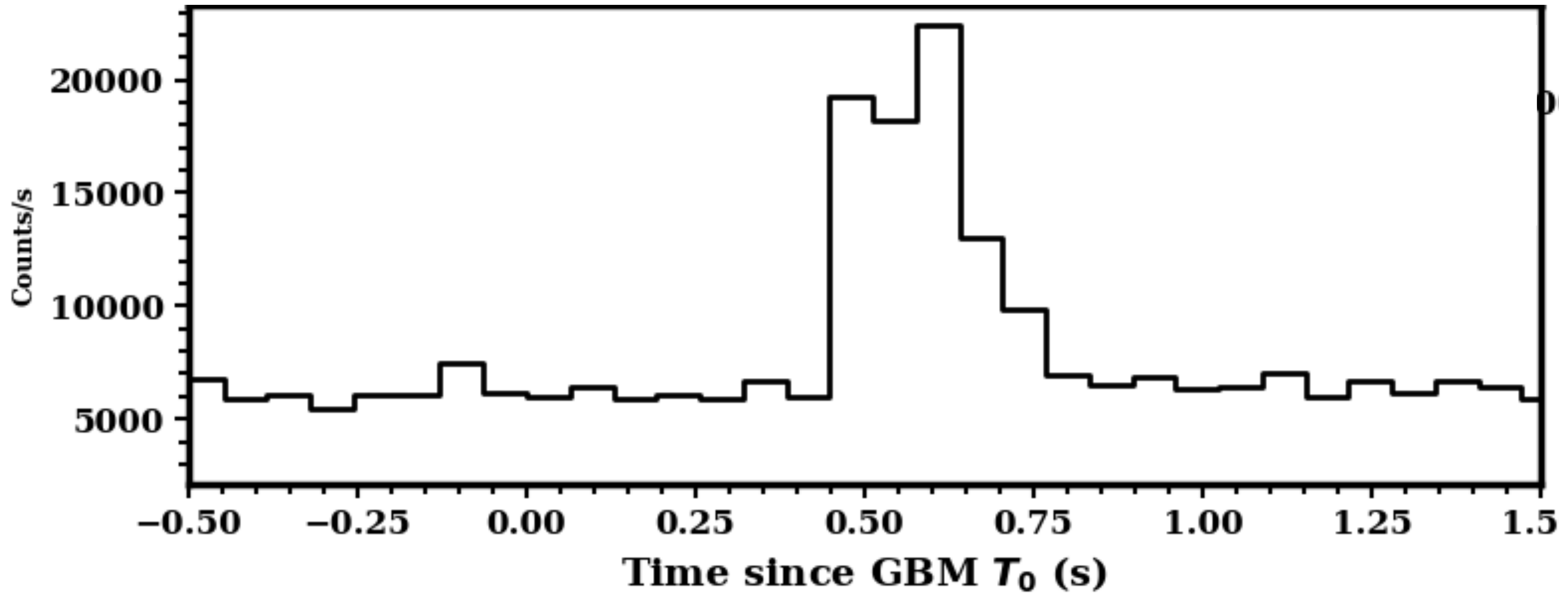
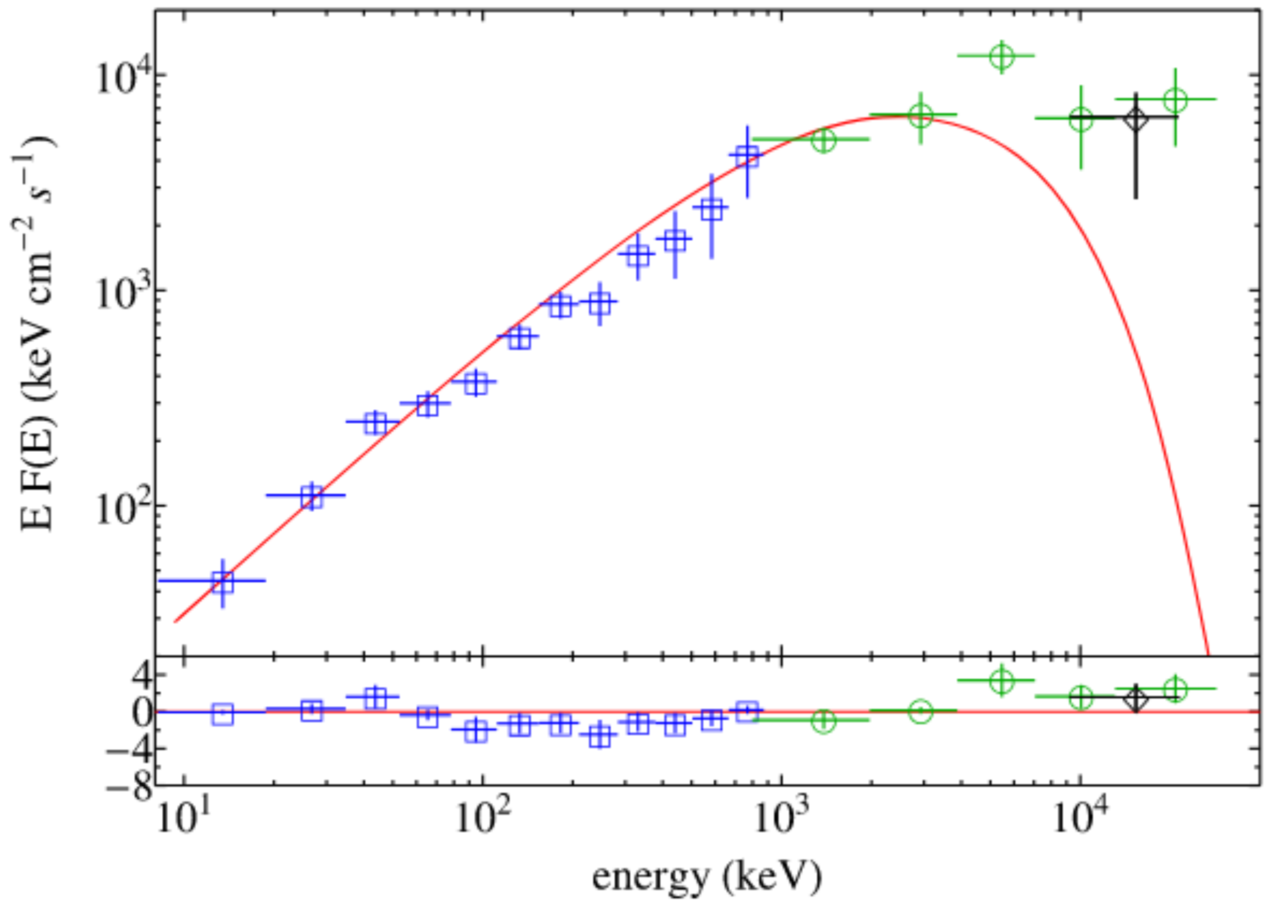
Short Gamma-Ray Bursts (SGRBs)

- The interval between the times when the burst reaches 5% and 95% of its maximum fluence is less than 2 seconds i.e $T_{90} < 2s$
- Originate from compact binary mergers like NS - NS, NS - blackhole
- They occur at cosmological distances
- Can help study the properties of NS mergers
- NS mergers are sources of GWs (i.e GRB170817/GW170817) and electromagnetic radiation

GRB090510



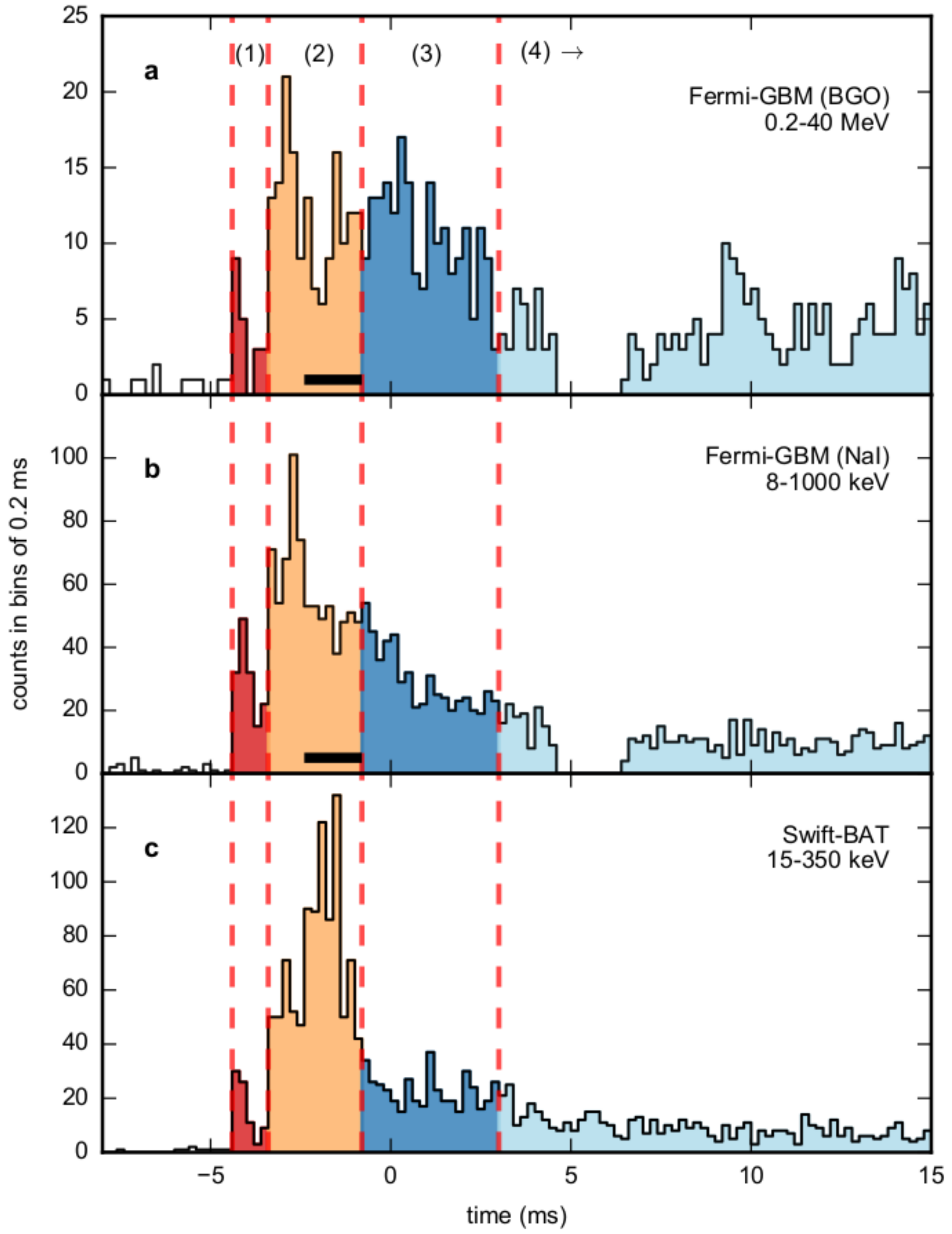


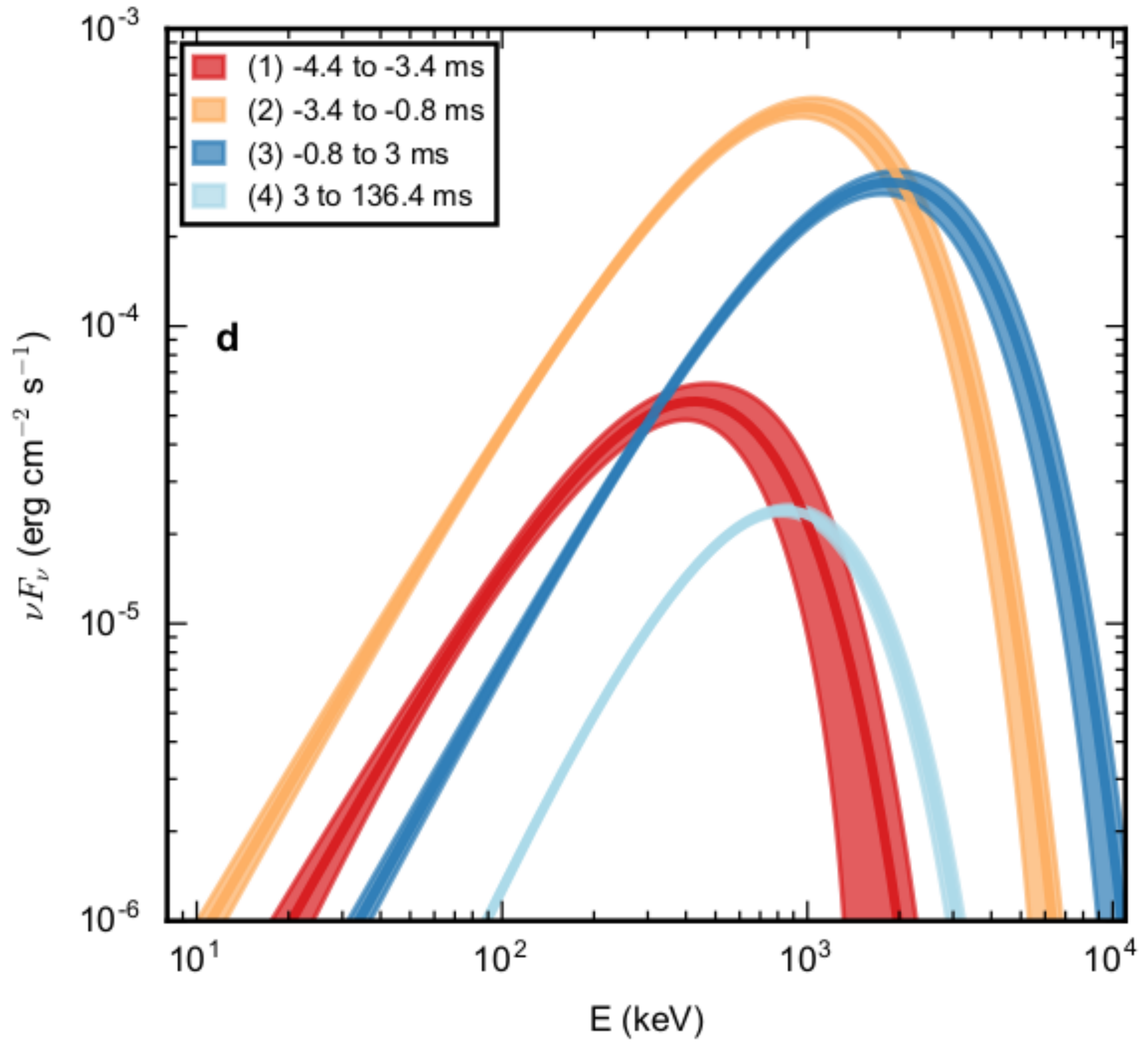
R. Ruffini et al 2016 ApJ **831** 178

Magnetar Giant Flares (MGFs)

- Magnetars are highly magnetised NSs and they produce short energetic gamma-ray transients similar to SGRBs called Magnetar giant flares
- Originate from our galaxy and nearby galaxies and are not cosmological entities, hence fake SGRBs
- MGFs that are close to our galaxy show a single prominent peak, which can be mistaken as that of a SGRB

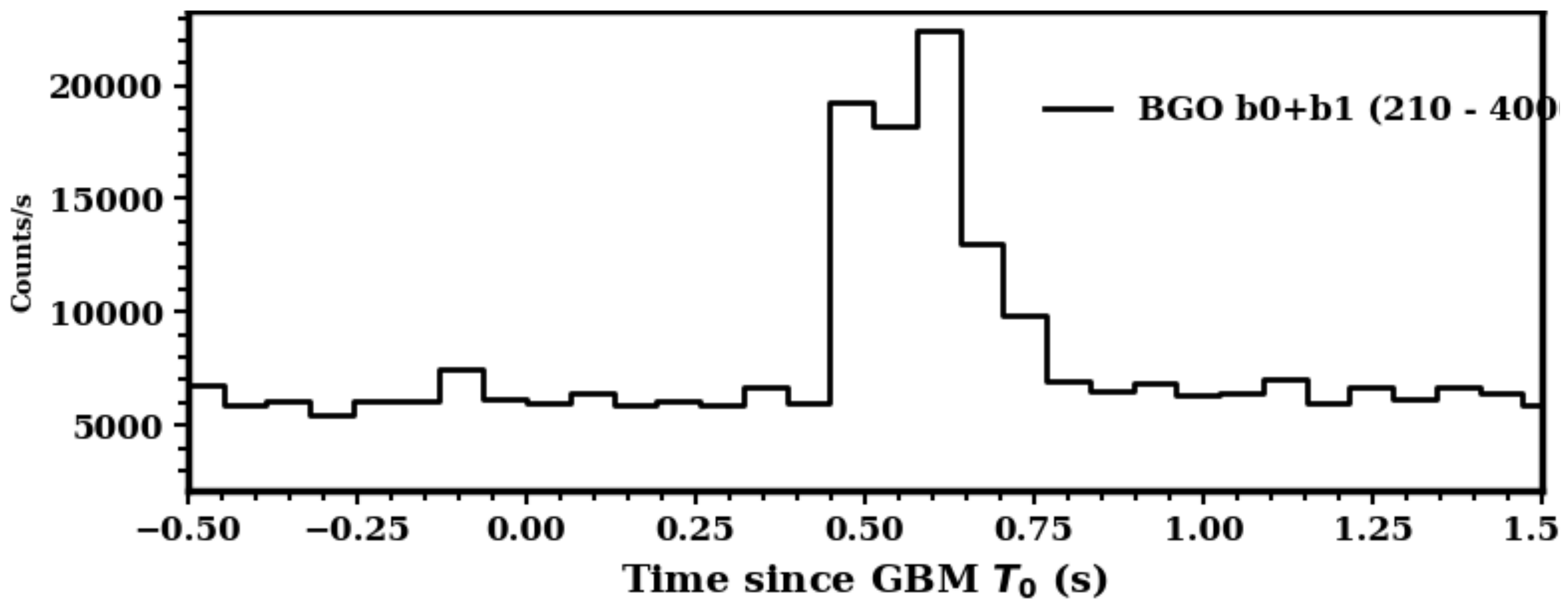
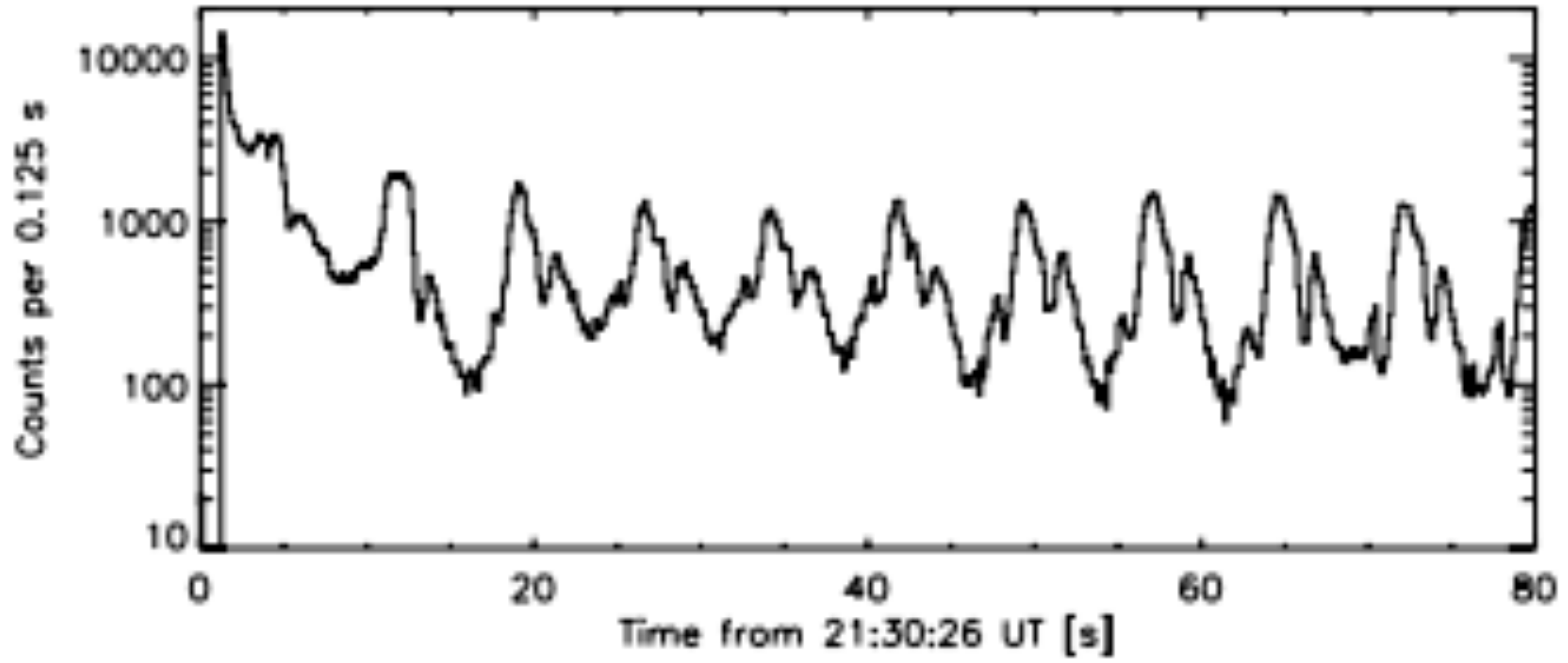
GRB200415A





https://arxiv.org/pdf/2101.05146.pdf

SGRBs and MGFs

Property	SGRBs	MGFs
Origin	Cosmological origin	Nearby star forming galaxies
Prompt emission isotropic energy	~ 10^{53} erg	~ 10^{43} - 10^{46} erg
Light curve peak(s)	typically 1 peaked spectra	Multi-peaked spectra with a fading oscillating phase
Light curve	**GRB090510** 	**2004/12/27 MGF** 

Objective

- Problems

1. Both fake and real SGRBs show a single prominent when they are detected
2. The multi-peaked oscillating phase of MGFs cannot be detected for sources that are nearby hence these sources can be mistaken as SGRBs
3. Without the redshift, one cannot tell if the gamma-ray source is a MGF or SGRB

- Solution

4. The objective is to create a method that can easily distinguish the two
5. This is achieved with pulse fitting using the Norris function
6. The MGF pulse rise time will be compared to that of SGRBs

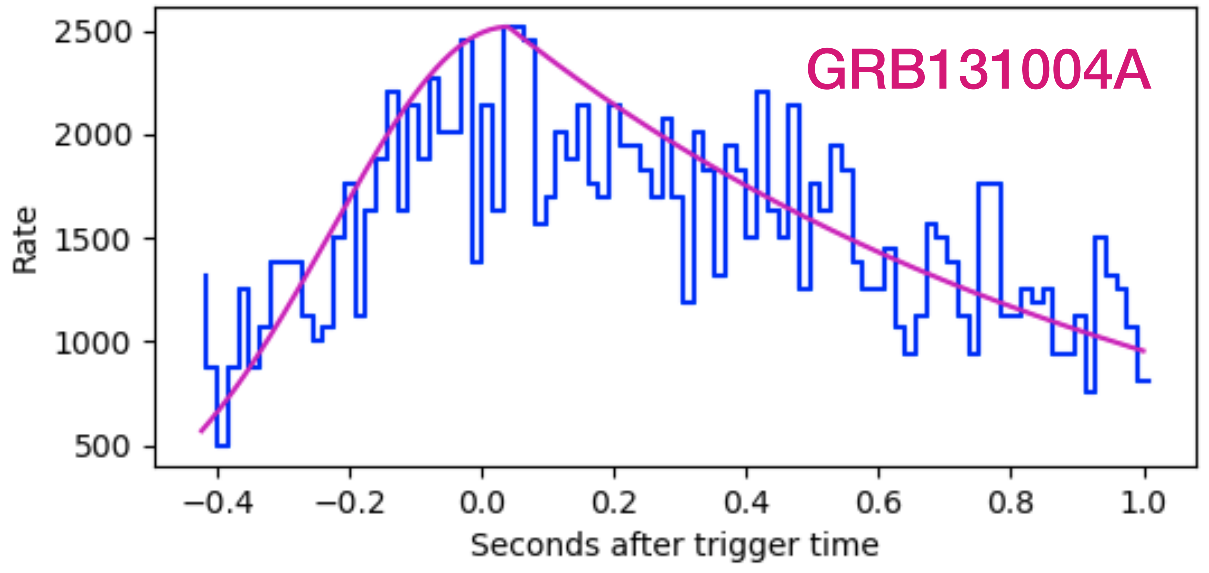
SGRB Data (2008-2022) and Analysis

Fermi GBM HEASARC browse interface

367 SGRBs → 20 of them had redshift, z → Only 10 had prominent peaks

↓

The *gtburst* tool is used to select a detector whose incoming signal has incident angle < 50^o → Background selection and data refinement was achieved with the *RMFIT* package from the *Fermi* Science Center using tte data → Pulse fitting within the energy band 10 - 900 keV

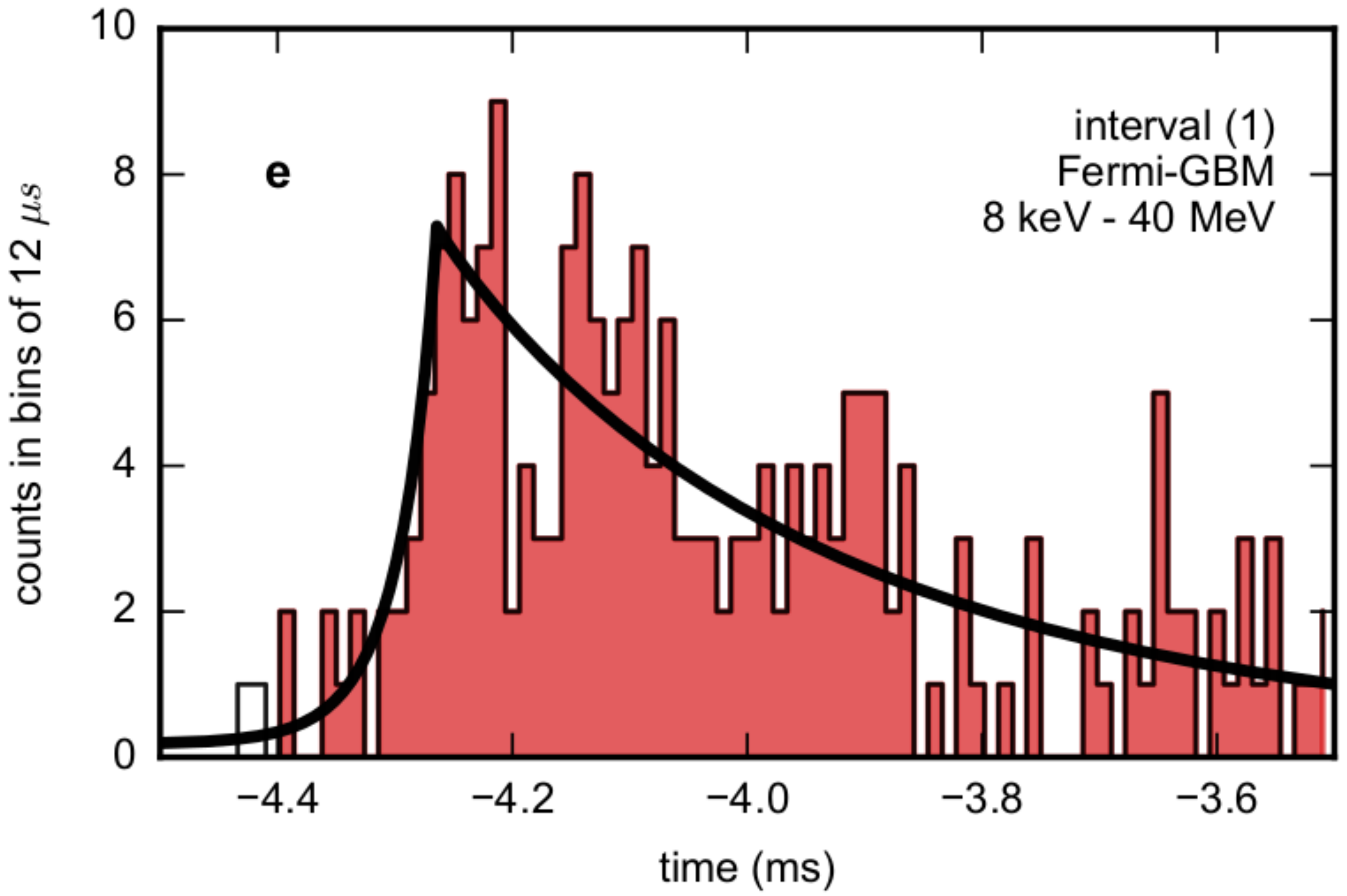


Source	NaI triggered detectors	NaI detector with highest rate counts
GRB090510	n0, n3, n6, n7 and n9	n6
GRB201221D	n7 and n8	n7
GRB200415A	n0, n1, n3, n5 and n9	n3

Pulse fitting - Norris function

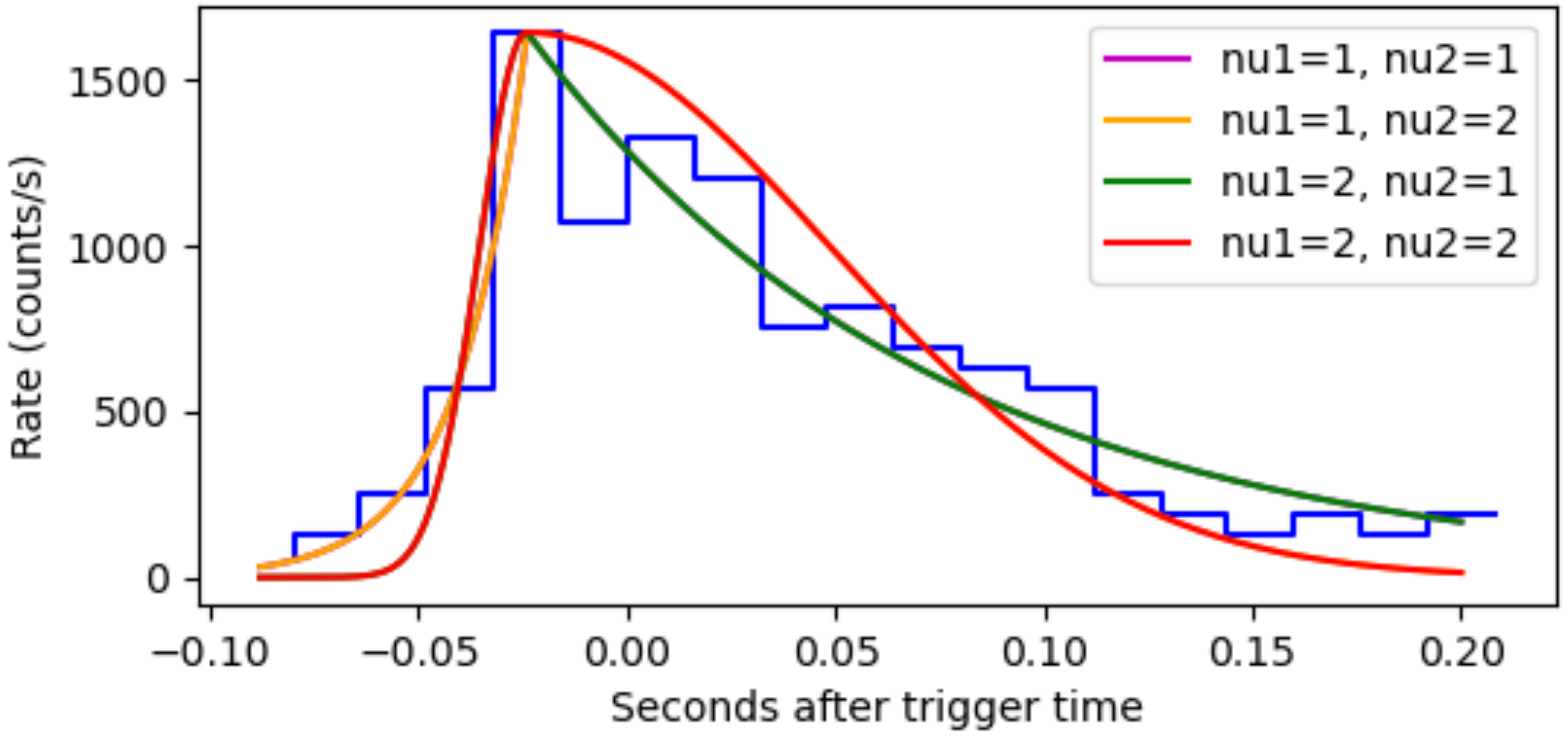
$$I(t) = \begin{cases} A\exp\left[-\left(\frac{|t-t_{peak}|}{t_{rise}}\right)^{\nu_1}\right]; & t < t_{peak} \\ A\exp\left[-\left(\frac{|t-t_{peak}|}{t_{fall}}\right)^{\nu_2}\right]; & t > t_{peak} \end{cases}$$

GRB200415A



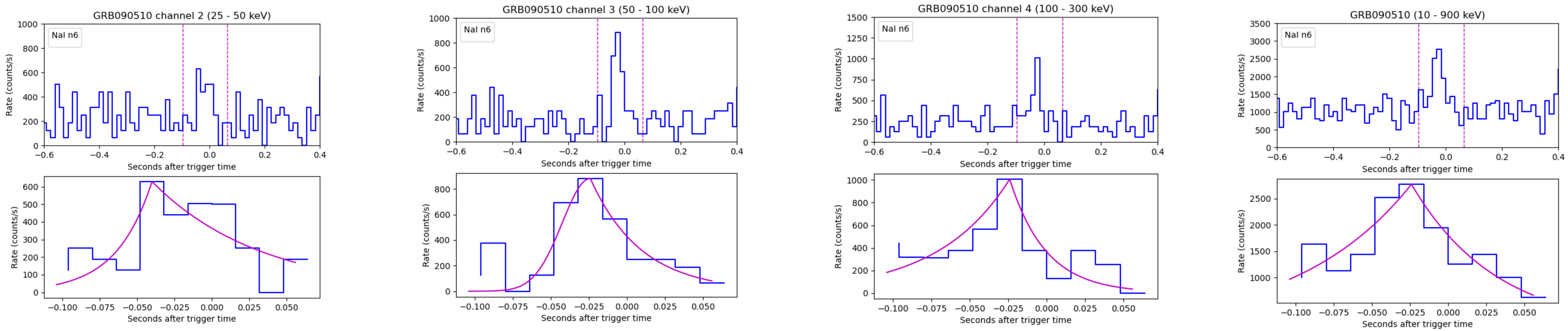
https://arxiv.org/pdf/2101.05146.pdf

GRB201221D



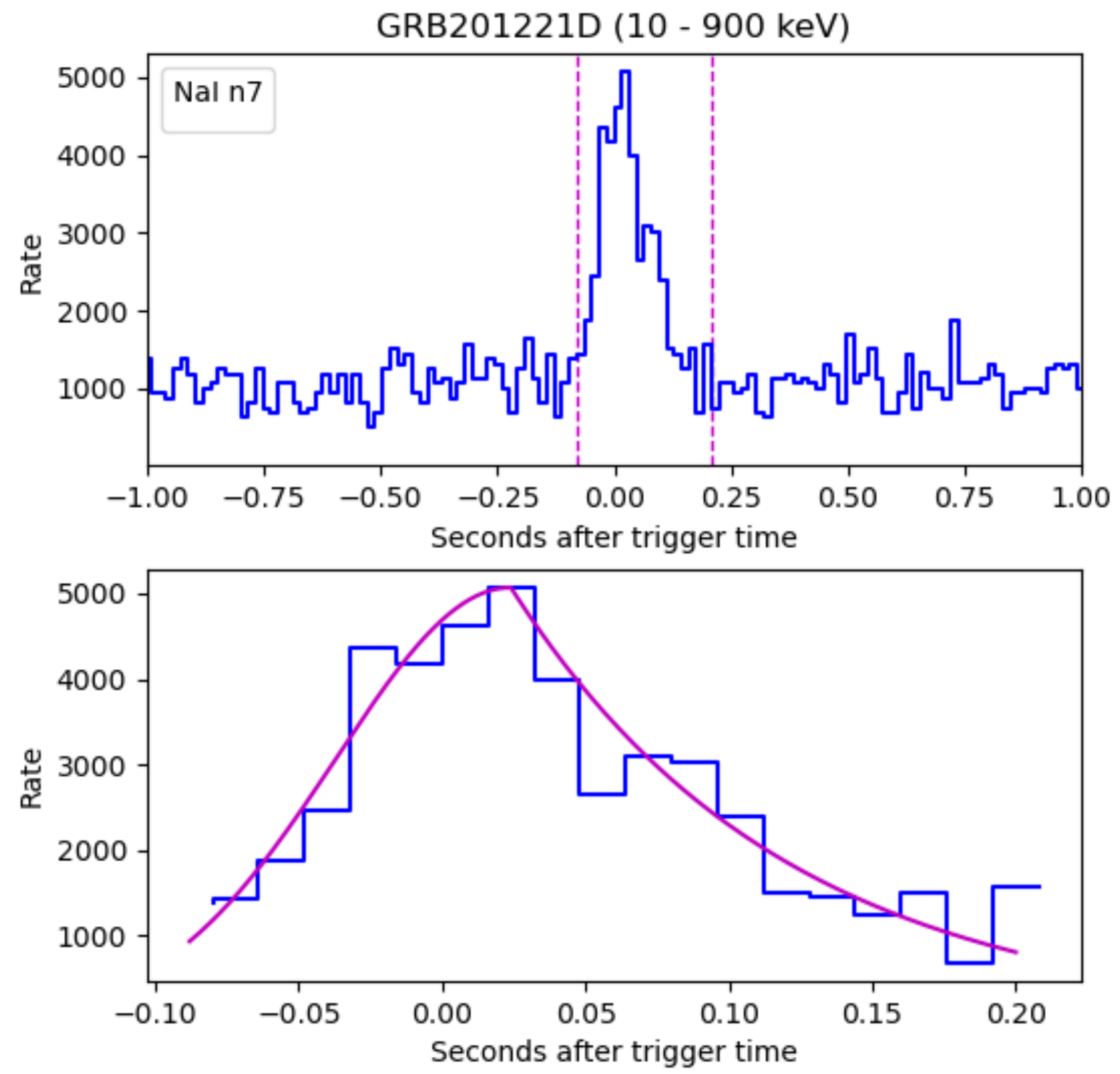
GRB090510 (-0.096 - 0.064 s)

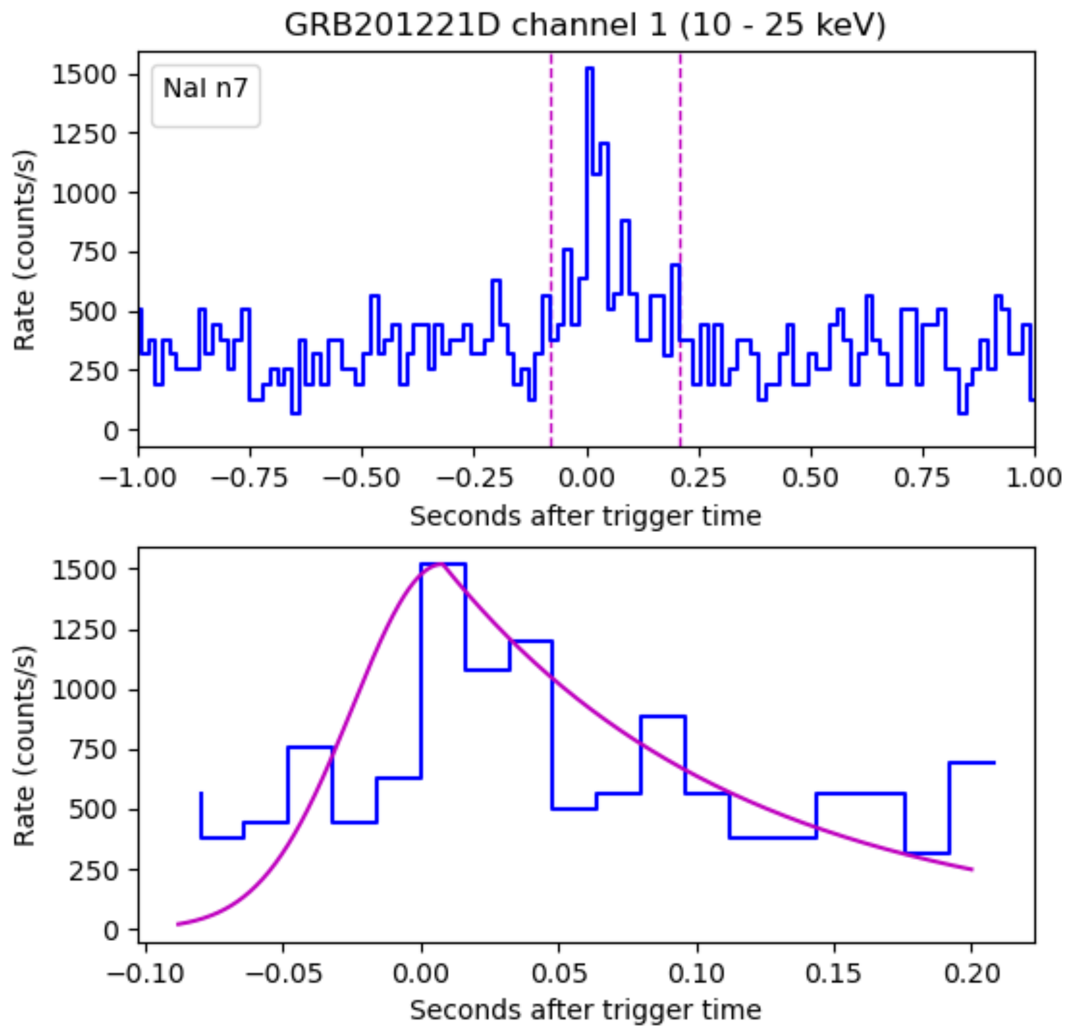
Parameter	Channel number 1 (10 - 25 keV)	2 (25 - 50 keV)	3 (50 - 100 keV)	4 (100 - 300 keV)	5 (> 300 keV)	All channels (10 - 900 keV)
A (counts/s)	- -	629.19	881.73	1007.69	- -	2771.1
ν_1, ν_2	- -	1,1	2,1	1,1	- -	1,1
Peak time (ms)	- -	-32.00	-16.00	-16.00	- -	-16.00
Rise time (ms)	- -	24.06 ± 8.71	26.17 ± 4.83	46.79 ± 10.46	- -	75.98 ± 11.21
Fall time (ms)	- -	73.31 ± 19.94	33.44 ± 7.91	23.72 ± 6.45	- -	55.96 ± 7.88
χ^2/dof	- -	52.69/9	57.50/9	63.57/9	- -	47.41/9

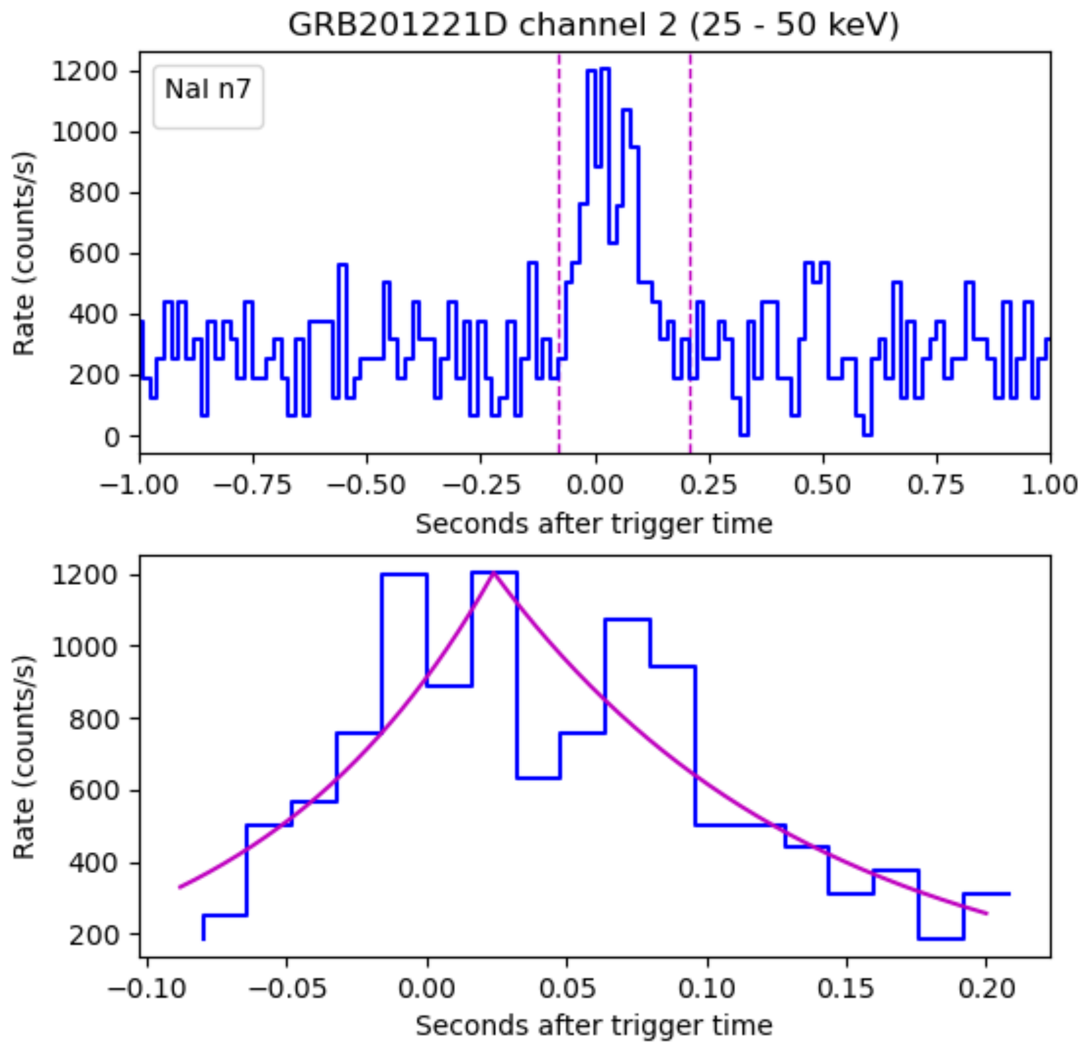


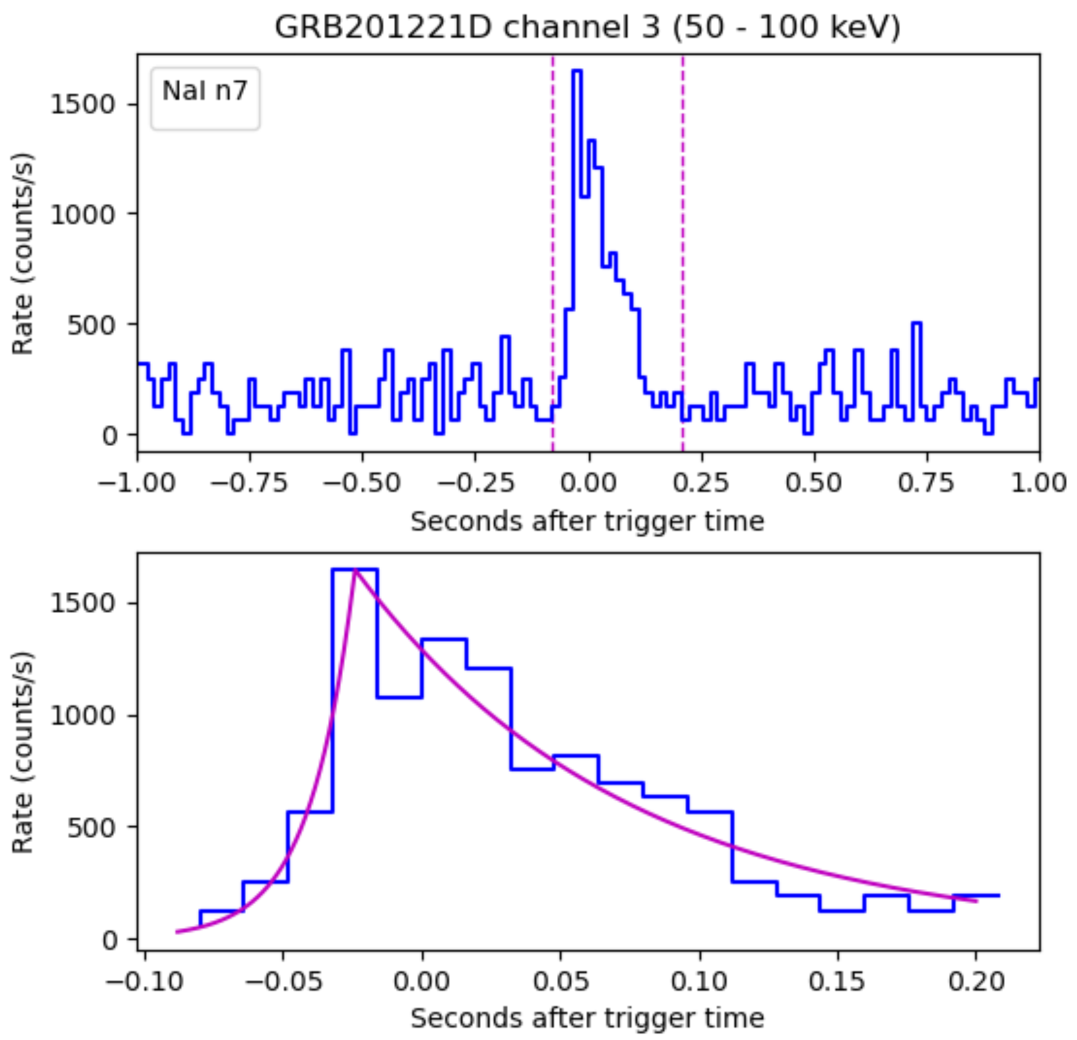
GRB201221D (-0.080 - 0.208 s)

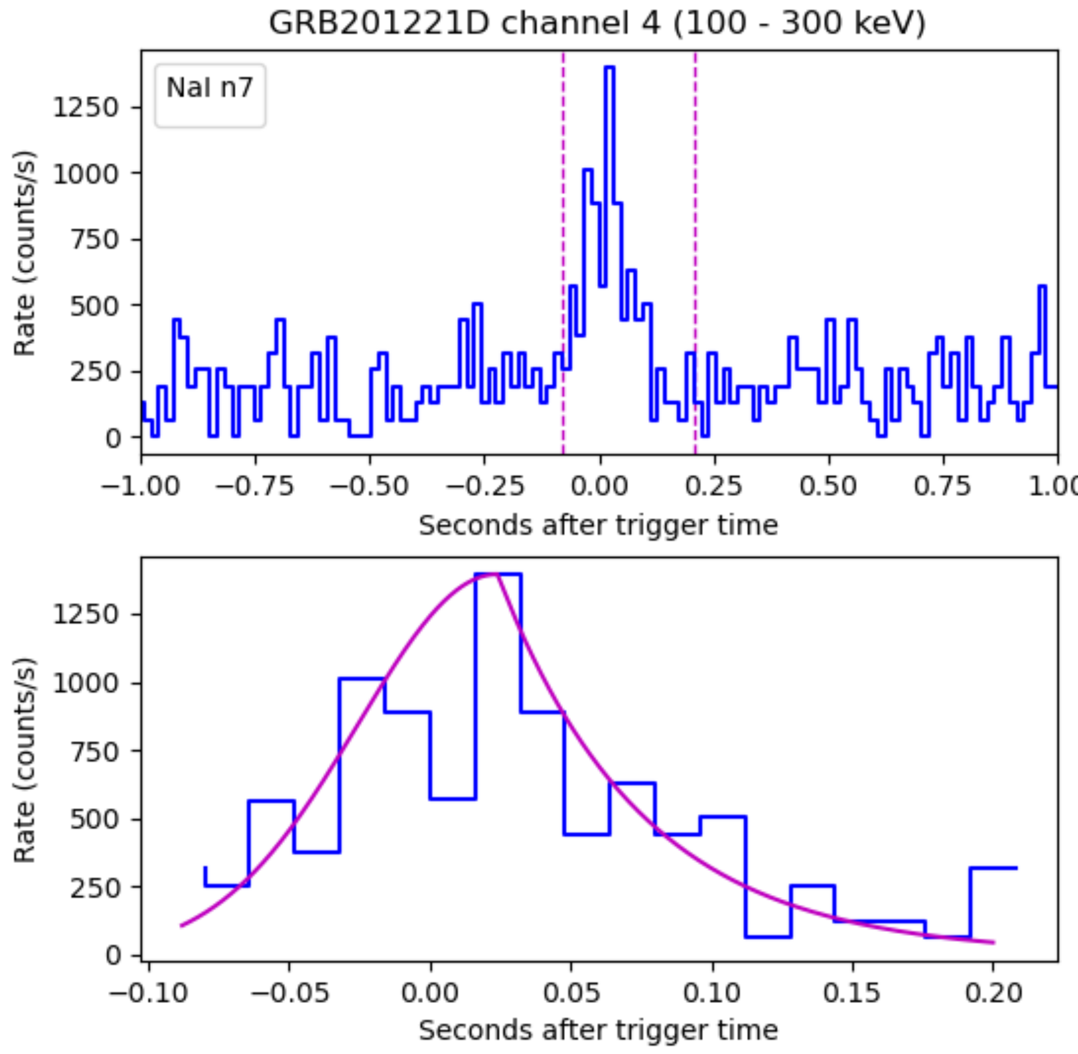
Parameter	Channel number					
	1 (10 - 25 keV)	2 (25 - 50 keV)	3 (50 - 100 keV)	4 (100 - 300 keV)	5 (> 300 keV)	All channels (10 - 900 keV)
A (counts/s)	1518.99	1203.42	1643.98	1393.80	- -	5068.36
ν_1, ν_2	1,1	1,1	1,1	2,1	- -	2,1
Peak time (ms)	16.00	32.00	16.00	32.00	- -	32.00
Rise time (ms)	46.45 ± 8.83	86.62 ± 15.63	16.11 ± 2.58	69.90 ± 8.86	- -	86.15 ± 5.13
Fall time (ms)	106.14 ± 21.45	114.08 ± 16.41	98.13 ± 6.71	51.27 ± 10.35	- -	95.87 ± 7.88
χ^2/dof	206.48/17	62.46/17	32.18/17	128.34/17	- -	83.50/17





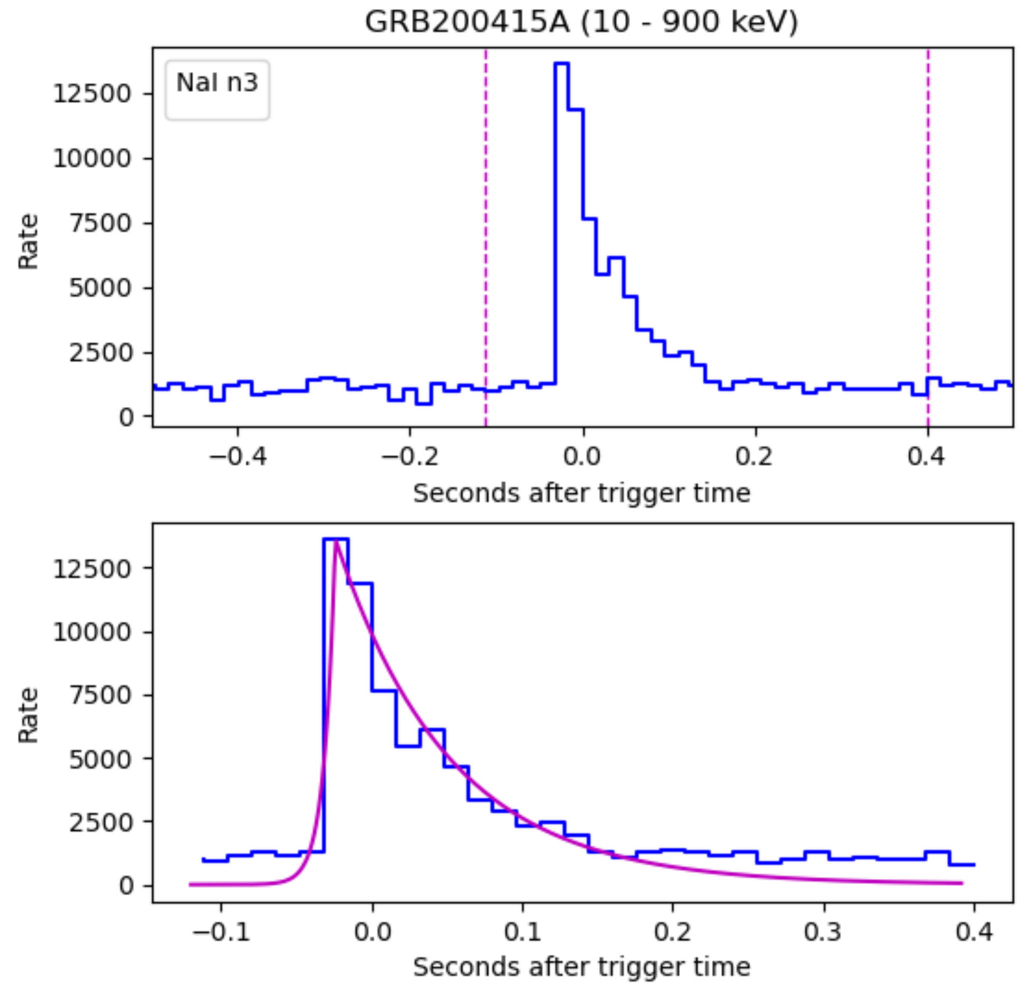


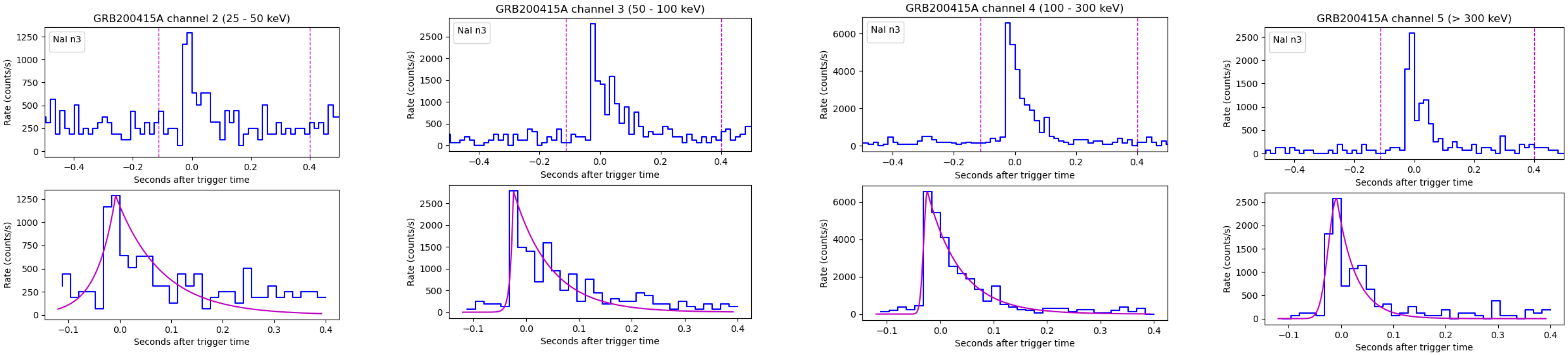




GRB200415A (-0.096 - 0.384 s)

Parameter	Channel number 1 (10 - 25 keV)	2 (25 - 50 keV)	3 (50 - 100 keV)	4 (100 - 300 keV)	5 (> 300 keV)	All channels (10 - 900 keV)
A (counts/s)	- -	1290.29	2788.55	6549.85	2580.54	13618.50
ν_1, ν_2	- -	1,1	1,1	2,1	2,1	1,1
Peak time (ms)	- -	0.00	16.00	16.00	0.00	16.00
Rise time (ms)	- -	37.09 ± 8.96	5.42 ± 3.44	9.73 ± 1.00	22.71 ± 2.52	7.31 ± 1.78
Fall time (ms)	- -	87.77 ± 13.50	69.82 ± 6.59	61.28 ± 2.32	36.08 ± 4.39	75.38 ± 4.25
χ^2/dof	- -	168.92/31	181.98/31	80.45/31	179.03/31	310.18/31





Conclusion

- For gamma-ray sources that have redshift, one can tell if we have a SGRB or a MGF.
- The Norris function gives the pulse rise time which is usually small for MGFs compared to SGRBs
- MGFs usually have fast rising pulse rising times
- **Work in progress:** Apply the proposed fitting method to a sample of gamma-ray bursts with unknown redshift and identify MGFs

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Thank you for your attention!

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