GRB 240219A:

First Einstein Probe-Detected Gamma-Ray Burst and Its Implications

Yi-Han Iris Yin

Nanjing University

2024.5.21

EP240219a

Einstein Probe's successful launch

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19 May 2024; 07:43 UT

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Detection of a bright X-ray flare by Einstein Probe in its commissioning phase

ATel #16463; *Chen Zhang (NAOC, CAS), Z. X. Ling (NAOC, CAS), Y. Liu (NAOC, CAS), X. Pan (NAOC, CAS), C. C. Jin (NAOC, CAS), H. Q. Cheng (NAOC, CAS), C. Z. Cui (NAOC, CAS), D. W. Fan (NAOC, CAS), H. B. Hu (NAOC, CAS), J. W. Hu (NAOC, CAS), M. H. Huang (NAOC, CAS), D. Y. Li (NAOC, CAS), H. Y. Liu (NAOC, CAS), H. W. Pan (NAOC, CAS), H. Sun (NAOC, CAS), W. X. Wang (NAOC, CAS), Y. F. Xu (NAOC, CAS), M. Zhang (NAOC, CAS), W. D. Zhang (NAOC, CAS), W. J. Zhang (NAOC, CAS), Z. Zhang (NAOC, CAS), D. H. Zhao (NAOC, CAS), E. Kuulkers (ESA), P. O'Brien (Univ. of Leicester) and W. Yuan (NAOC, CAS), on behalf of the Einstein Probe team*

*on **21 Feb 2024; 02:51 UT***

Credential Certification: Yuan Liu (liuyuan@bao.ac.cn)

Subjects: X-ray, Transient

Referred to by ATel #: 16472, 16473

Related
16473 EPW20240219aa is Likely a GRB Event
16472 Erratum of ATel #16463: Detection of a bright X-ray flare by Einstein Probe in its commissioning phase
16463 Detection of a bright X-ray flare by Einstein Probe in its commissioning phase

Atel report on EP240219a

GCN Circular 35773

Subject
EPW20240219aa is Likely a GRB Event
Date
2024-02-22T16:29:47Z (3 months ago)
From
Binbin Zhang at Nanjing U <bbzhang@nju.edu.cn>
Via
Web form

Binbin Zhang (NJU), Hui Sun (NAOC), Yi-Han Iris Yin (NJU), Jun Yang (NJU), Bing Zhang (UNLV), Xuefeng Wu (PMO) report on behalf of large collaboration:

Our team has followed up on EP's initial X-ray flare detection (EPW20240219aa; ATel 16463; ATel 16472) and discovered a weak, untriggered gamma-ray transient in the Fermi/GBM data at 2024-02-19T06:21:42 UTC. This transient lasted approximately 50 seconds and its location aligns with that of EPW20240219aa.

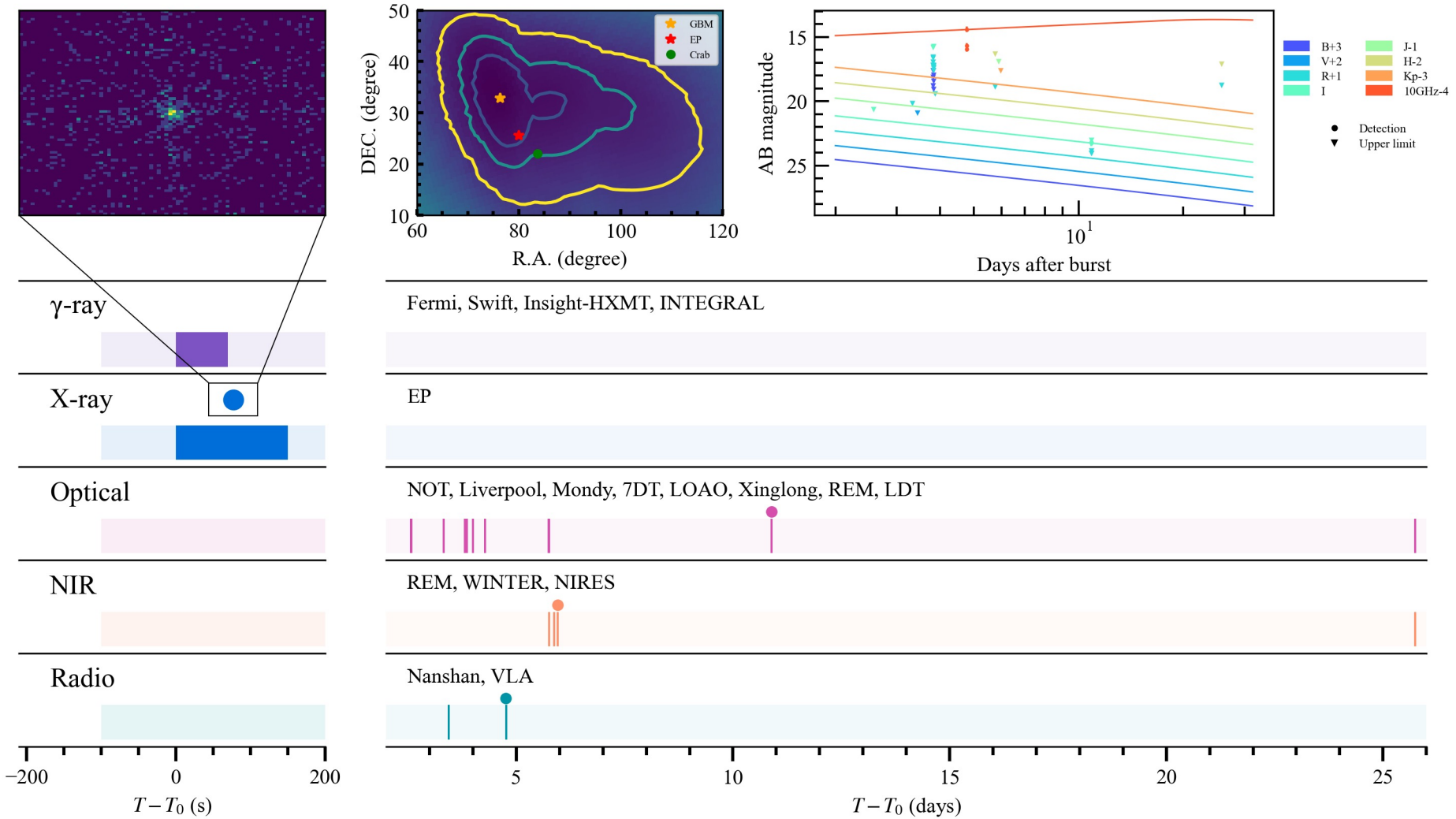
GCN report on GRB 240219A

2024.1.9 → 2024.2.21 → 2024.2.22

Content

- The discovery of GRB 240219A and follow up observations
- Classification of GRB 240219A
- Light curves of GRB 240219A
- Spectral fit and SED plot
- Discussion

EP240219a - GRB 240219A

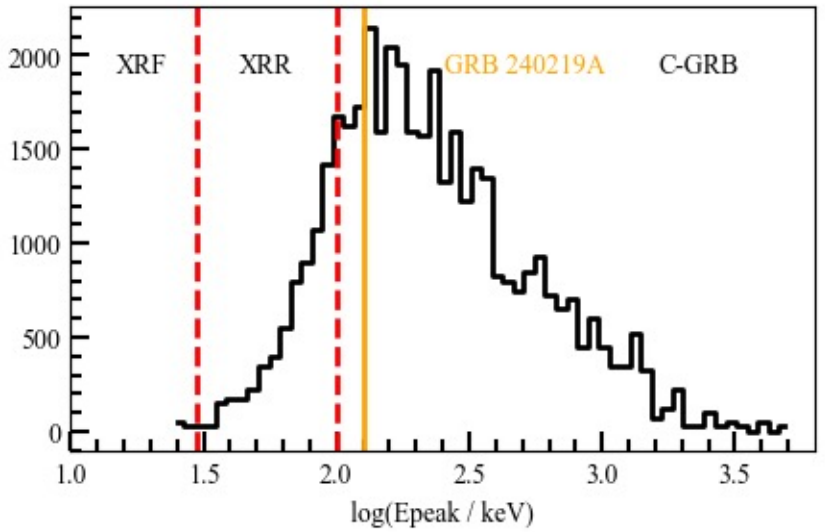


Multiwavelength Observations of EP240219a

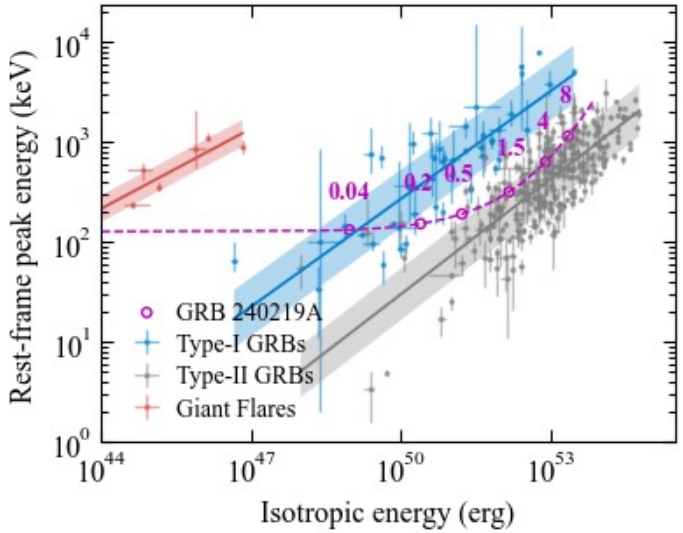
EP240219a - GRB 240219A

Observed properties of EP240219a

Observed Properties	GRB 240219A
$T_{90,\gamma}$ (s)	$54.83^{+6.17}_{-4.24}$
$T_{90,\mathrm{X}}$ (s)	$130.19^{+0.16}_{-4.14}$
Minimum variability timescale (s)	~ 2.19
Spectral index α	$-1.40^{+0.16}_{-0.29}$
Peak energy (keV)	$127.10^{+303.55}_{-31.91}$
γ-ray fluence ($\mathrm{erg\,cm^{-2}}$)	$2.44^{+0.69}_{-0.34} \times 10^{-6}$
X-ray fluence ($\mathrm{erg\,cm^{-2}}$)	$7.85^{+4.06}_{-1.51} \times 10^{-7}$
Fluence ratio	~ 0.78



E_{peak} distribution of Fermi/GBM samples



E_{pz} - E_{iso} diagram

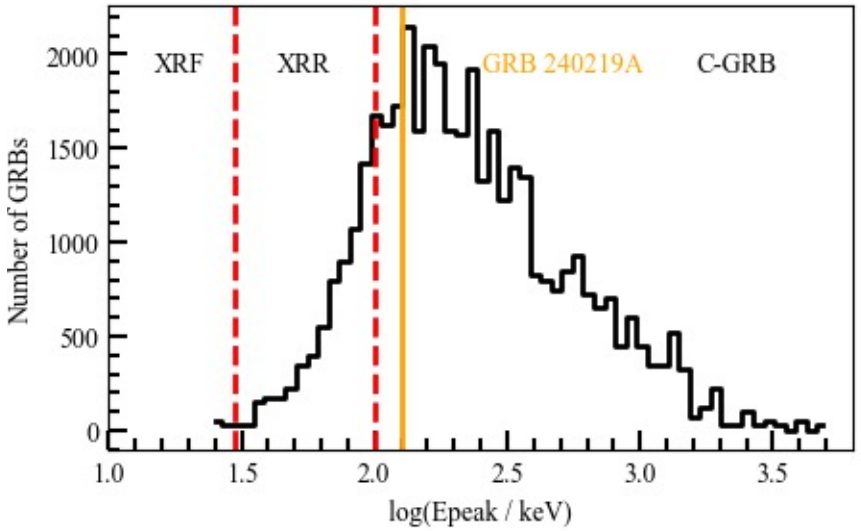
With **E_{peak} ~ 130 keV**, **alpha ~ -1.4** and T_{90} ~ 55 s,

EP240219a is most likely a GRB with redshift > 0.5.

GRB 240219A: classification

Conventional definition 1*:

E_{peak} as the border

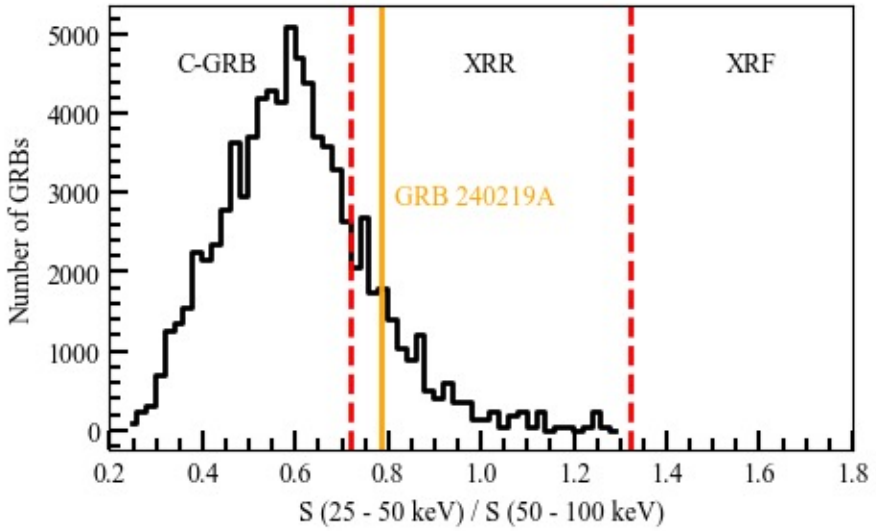


E_{peak} distribution of Fermi/GBM samples

Conventional definition 2:**

Fluence ratio r = S (25 - 50 keV) / S (50 - 100 keV)

as the border



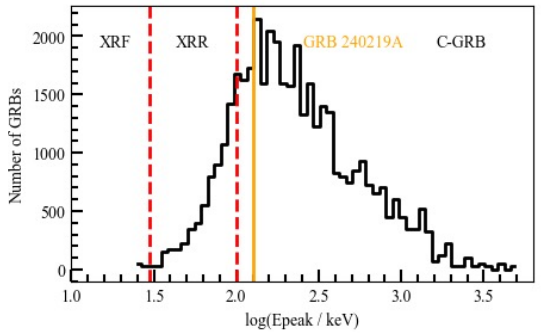
Fluence ratio distribution of Fermi/GBM samples

*reference:
T. Sakamoto et al 2005 ApJ 629 311
B. Zhang 2018, The Physics of Gamma-Ray Bursts

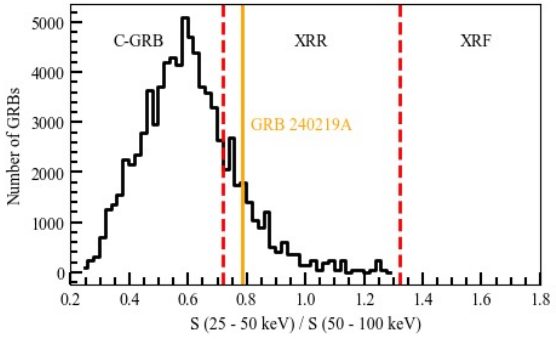
**reference: T. Sakamoto et al 2008 ApJ 679 570

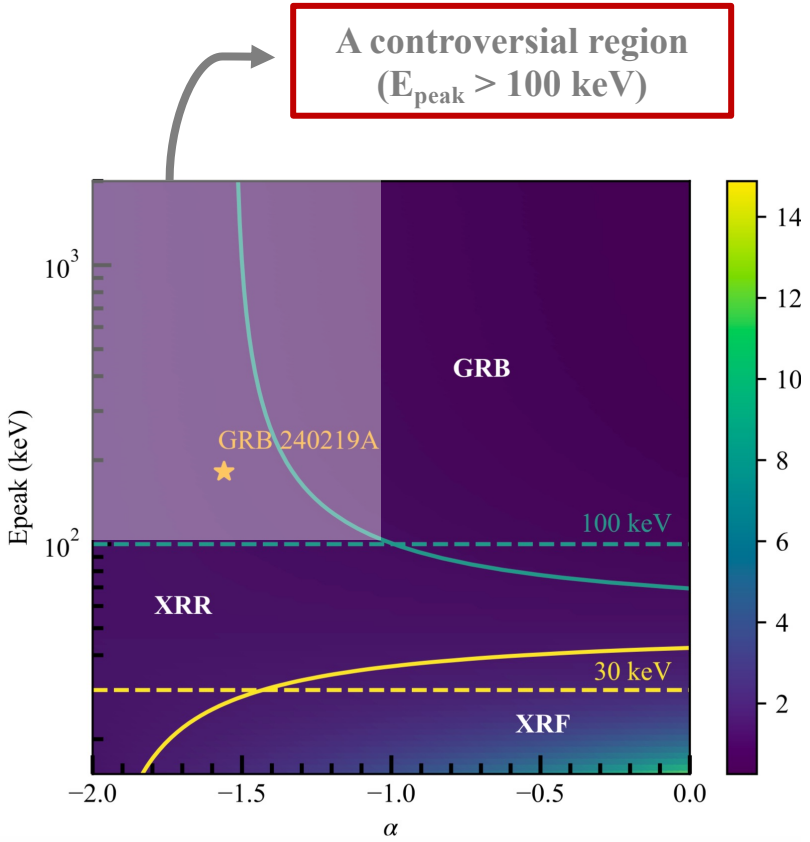
GRB 240219A: classification

E_{peak} as the border: Classical GRB



Fluence ratio as the border: X-ray rich GRB





projected fluence ratio on CPL parameters

EP's future detection of GRB 240219A-like events could extend subclass GRB samples, and may unveil the relationship of XRFs, XRRs and classical GRBs.

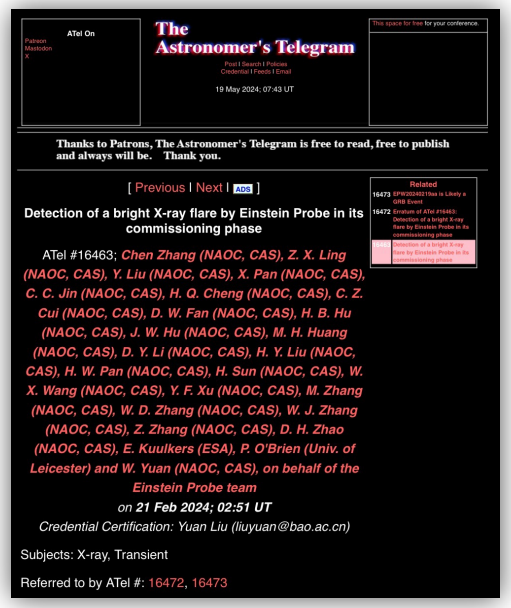
EP / LEIA detected GRBs

GCN Circular 33466

Subject
GRB 230307A: soft X-ray detection with LEIA
Date
2023-03-13T11:24:55Z (a year ago)
From
LEIA Team at NAOC/CAS <ep_ta@bao.ac.cn>

M.J. Liu, Y.L. Wang, Y. Liu, C. Zhang, Z.X. Ling, H.Q. Cheng, C.Z. Cui, D.W. Fan,
H.B. Hu, J.W. Hu, M.H. Huang, C.C. Jin, D.Y. Li, J.Q. Li, H.Y. Liu, H. Sun, H.W. Pan,
W.X. Wang, Q.Y. Wu, X.P. Xu, Y.F. Xu, H.N. Yang, M. Zhang, W.D. Zhang, Z. Zhang,
D.H. Zhao, and W. Yuan (NAOC, CAS), report on behalf of the LEIA and Einstein Probe team:

GRB 230307A



GRB 240219A

GCN Circular 35931

Subject
Einstein Probe detected of a fast X-ray transient EP240315a
Date
2024-03-16T15:49:37Z (2 months ago)
From
EP Team at NAOC/CAS <ep_ta@bao.ac.cn>
Via
legacy email

W. J. Zhang (NAOC, CAS), X. Mao (NAOC, CAS), W. D. Zhang (NAOC, CAS), H. Y. Liu (NAOC, CAS), Y. Liu (NAOC, CAS), C. Zhang (NAOC, CAS),

Z. X. Ling (NAOC, CAS), C. C. Jin (NAOC, CAS), H. Q. Cheng (NAOC, CAS), W. Chen (NAOC, CAS), C. Z. Cui (NAOC, CAS), D. W. Fan (NAOC, CAS),

H. B. Hu (NAOC, CAS), J. W. Hu (NAOC, CAS), M. H. Huang (NAOC, CAS), D. Y. Li (NAOC, CAS), T. Y. Lian (NAOC, CAS), M. J. Liu (NAOC, CAS),

GRB 240315A

GCN Circular 36016

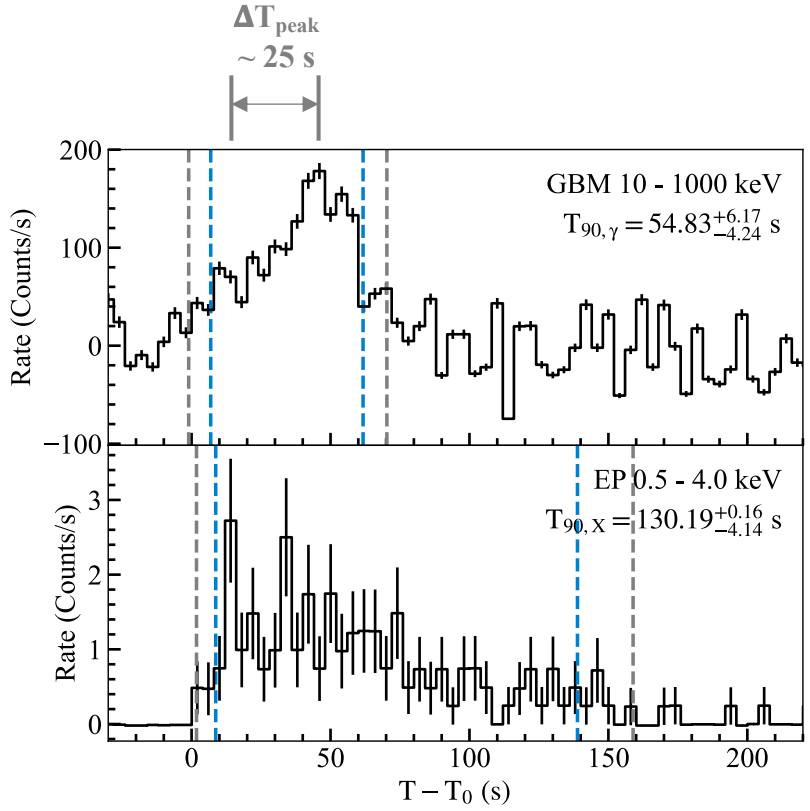
Subject
X-ray transient LXT 240402A: LEIA detection
Date
2024-04-03T16:20:48Z (2 months ago)
From
EP Team at NAOC/CAS <ep_ta@bao.ac.cn>
Via
Web form

X. P. Xu , Z. X. Ling , Y. Liu , C. Zhang , W. Chen , H. Q. Cheng , C. Z. Cui , D. W. Fan , H. B. Hu , J. W. Hu , M. H. Huang , C. C. Jin , D. Y. Li , T. Y. Lian , H. Y. Liu , M. J. Liu , Z. Z. Lv, X. Mao , H. W. Pan , X. Pan , H. Sun , W. X. Wang , Y. L. Wang , Q. Y. Wu , Y. F. Xu , H. N. Yang , M. Zhang , W. D. Zhang , W. J. Zhang , , D. H. Zhao (NAOC, CAS), D. M. Li, Q. X. Li (BNU), C. Y. Wang, Y. J. Zhang (THU), and W. Yuan (NAOC, CAS) on behalf of the LEIA and Einstein Probe team

GRB 240402B

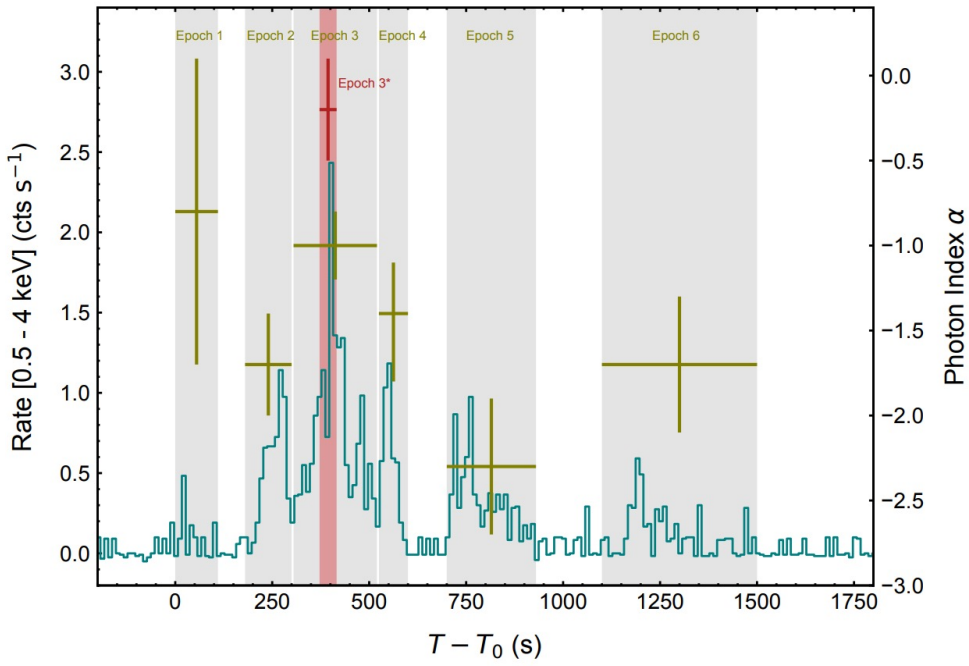
EP launch

GRB 240219A: light curves



light curves of GRB 240219A

(Y. Liu 2024 arxiv: 2404.16425)



light curve of GRB 240315A

GRB 240219A:

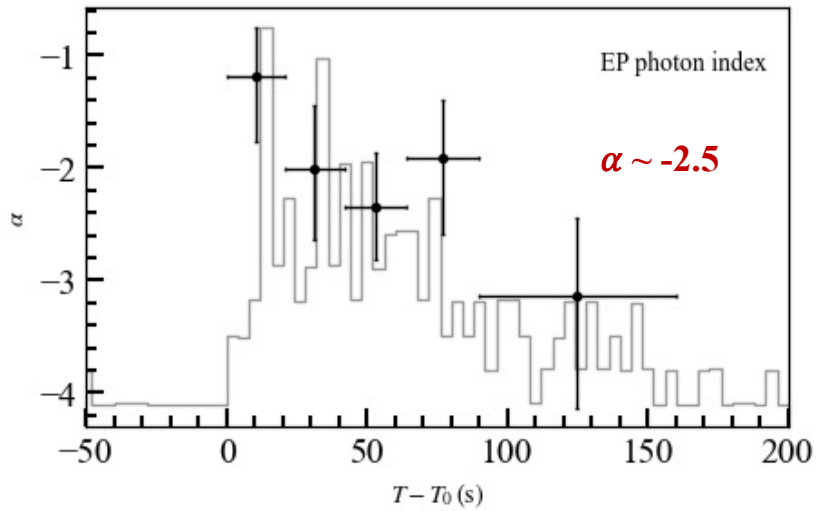
same trigger time, different peaks

GRB 240315A and GRB 240402B:

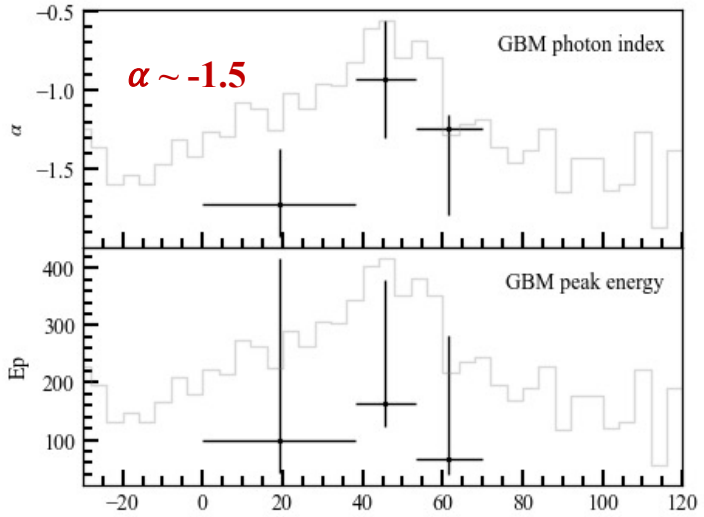
different trigger times, consistent peaks

GRB 240219A: individual spectral fit

EP/WXT



Fermi/GBM



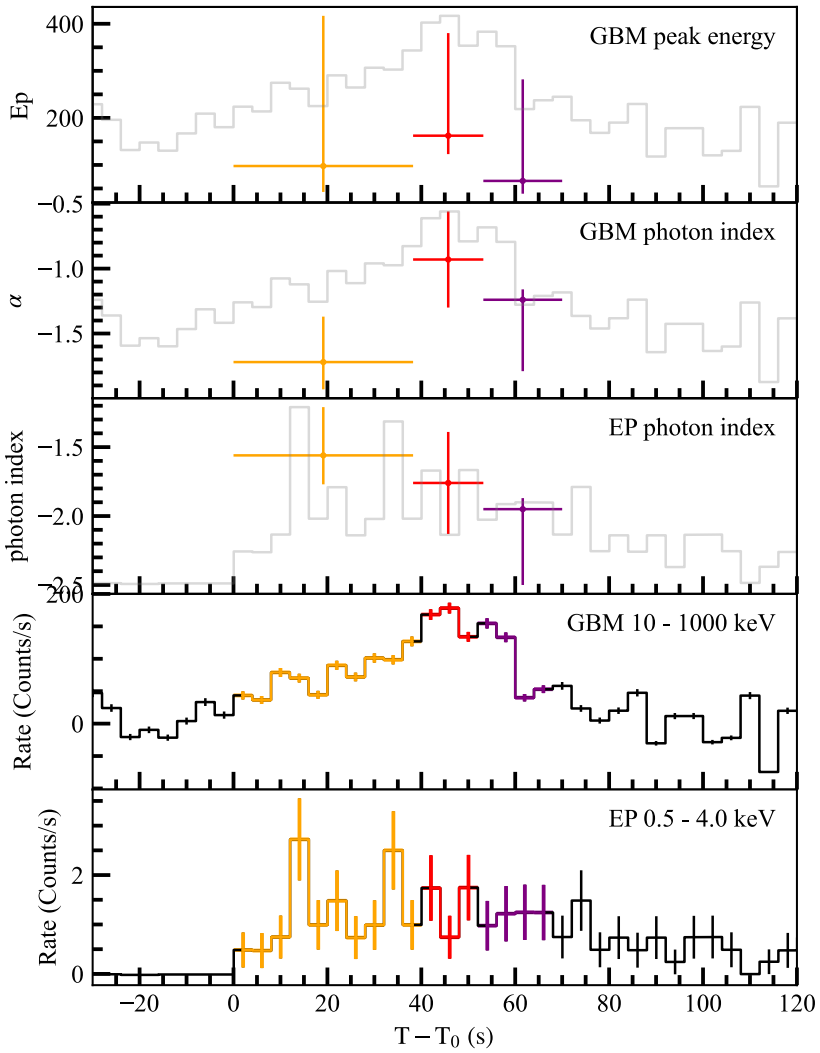
Spectral fitting results and corresponding fitting statistics for EP/WXT.

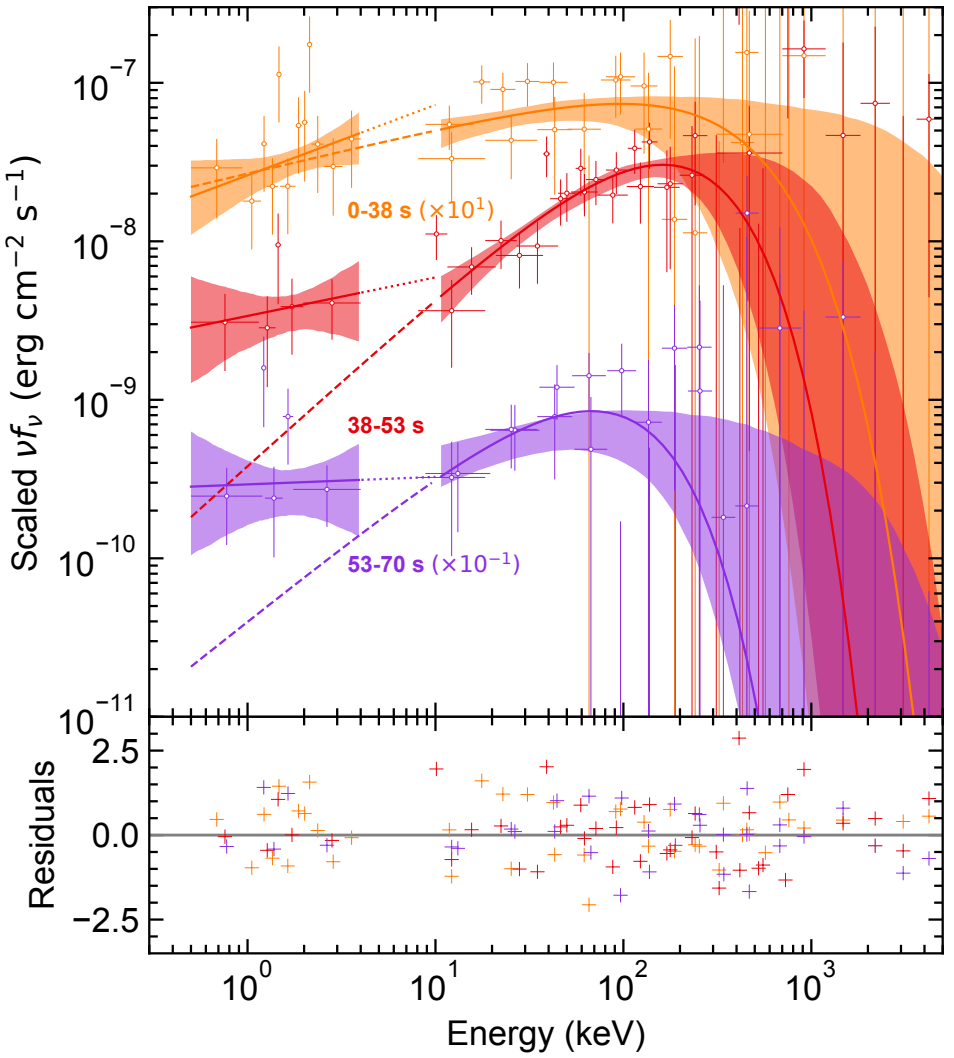
t1	t2	PL model			
		α	log$A$	cstat/dof	BIC
0.00	21.00	$-1.19^{+0.45}_{-0.58}$	$-2.25^{+0.77}_{-1.05}$	2.74/4	6.32
21.00	42.00	$-2.01^{+0.56}_{-0.63}$	$-3.70^{+0.96}_{-1.15}$	4.13/4	7.71
42.00	64.00	$-2.35^{+0.50}_{-0.46}$	$-4.26^{+0.88}_{-0.87}$	5.36/4	9.25
64.00	90.0	$-1.92^{+0.52}_{-0.67}$	$-3.63^{+0.91}_{-1.22}$	0.51/4	4.10
90.00	160.0	$-3.14^{+0.69}_{-0.99}$	$-6.25^{+1.24}_{-1.91}$	5.78/4	9.67

Spectral fitting results and corresponding fitting statistics for Fermi/GBM.

t1	t2	CPL model				
		α	logE_p	log$A$	pgstat/dof	BIC
0.00	38.25	$-1.72^{+0.35}_{-0.21}$	$1.99^{+0.63}_{-0.36}$	$-3.21^{+0.31}_{-0.18}$	308.42/352	326.03
38.25	53.21	$-0.93^{+0.37}_{-0.37}$	$2.21^{+0.37}_{-0.12}$	$-2.48^{+0.23}_{-0.27}$	326.73/352	344.35
53.21	70.00	$-1.24^{+0.08}_{-0.55}$	$1.82^{+0.63}_{-0.23}$	$-2.84^{+0.04}_{-0.51}$	317.37/352	334.99
0.00	70.00	$-1.40^{+0.17}_{-0.28}$	$2.11^{+0.52}_{-0.14}$	$-2.95^{+0.13}_{-0.22}$	281.40/352	299.02

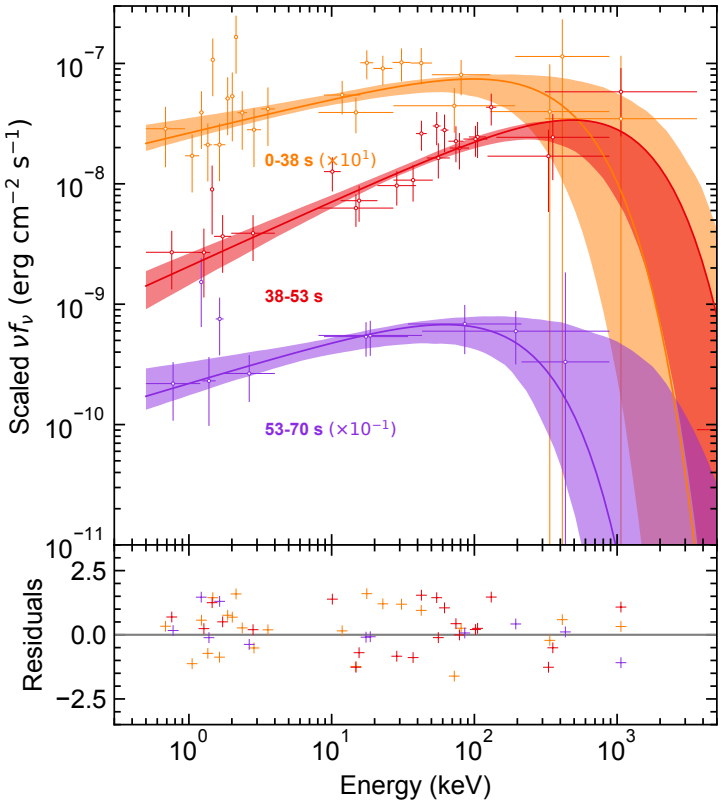
GRB 240219A: SED





different spectral evolution after the first time slice

GRB 240219A: joint fit



one cpl with 10% uncertainty

t1	t2	cpl			pl-cpl		
		stat	BIC	AIC	stat	BIC	AIC
0.00	38.25	319.51	343.13	327.51	319.42	348.95	329.42
38.25	53.21	333.56	357.11	341.56	328.86	358.29	338.86
53.21	70.00	324.20	347.74	332.20	323.08	352.51	333.08

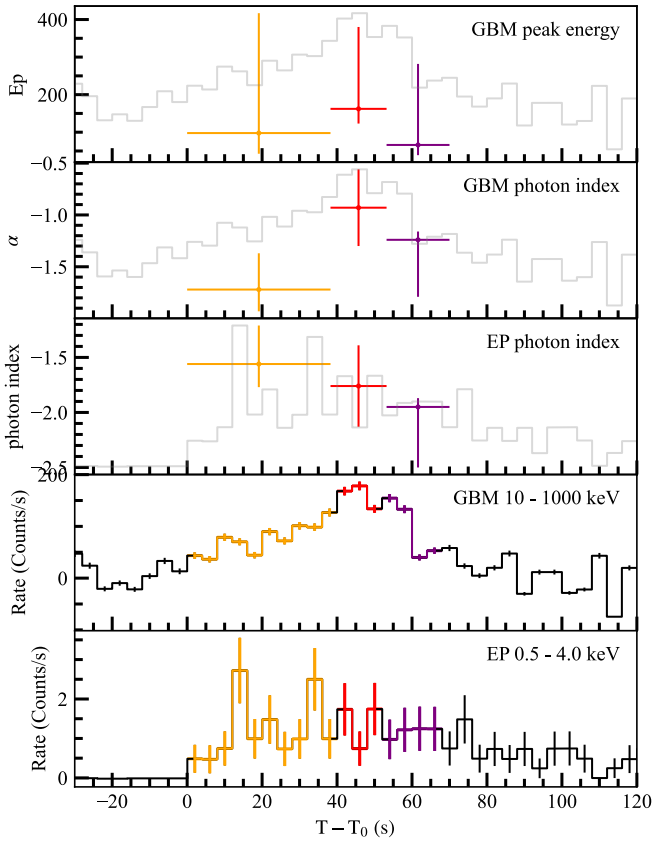
t1	t2	sync+cpl			bb+cpl		
		stat	BIC	AIC	stat	BIC	AIC
0.00	38.25	321.56	339.28	327.56	319.59	349.12	329.59
38.25	53.21	329.10	346.76	335.10	331.89	361.33	341.89
53.21	70.00	323.83	341.49	329.83	324.22	353.65	334.22

other physical model fit is ongoing…

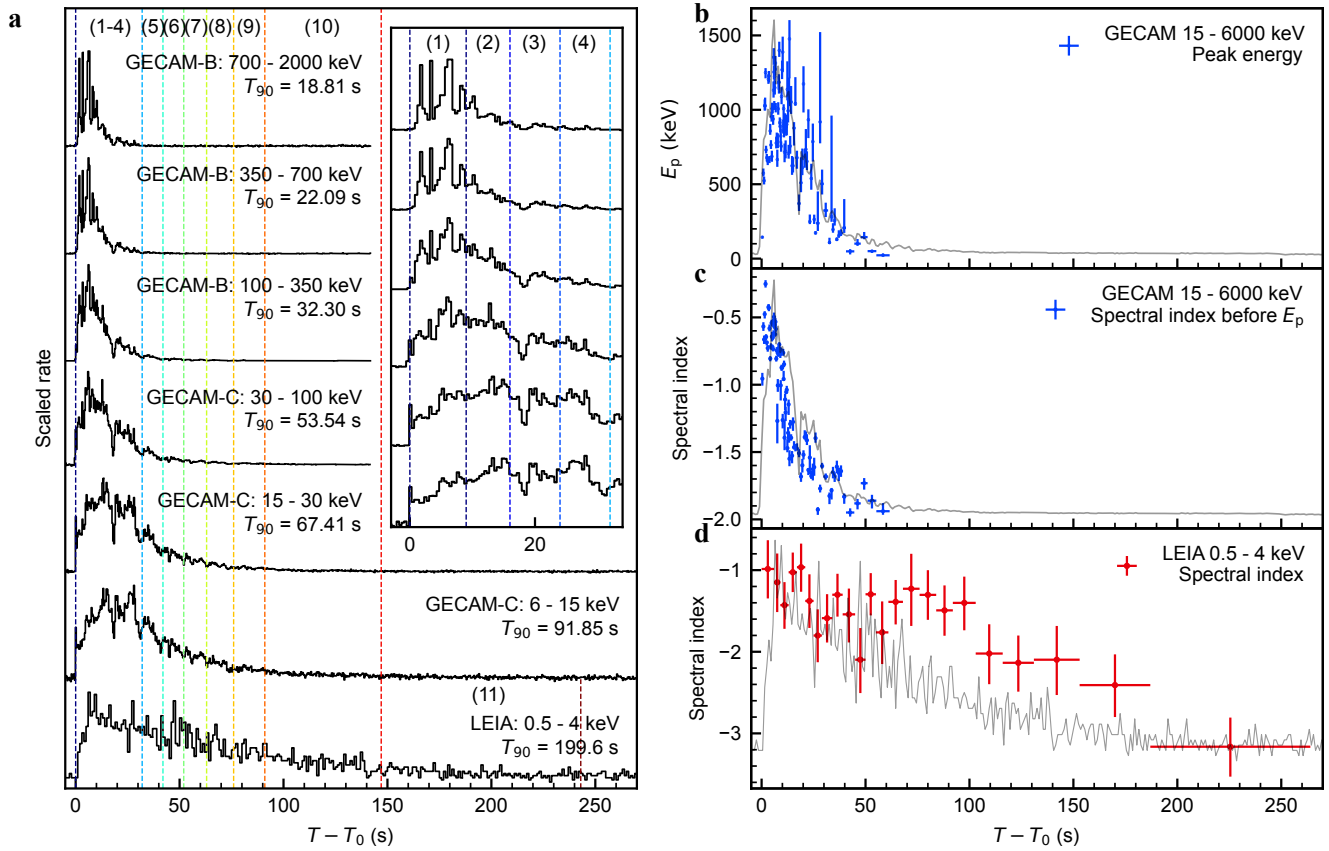
Due to limited photons and uncertainties, joint fit model is not exclusive!

GRB 240219A: discussion

(H. Sun 2023 arxiv: 2307.05689)



GRB 240219A



GRB 230307A

certain temporal similarities between GRB 240219A and GRB 230307A
suggest possible two-component emission

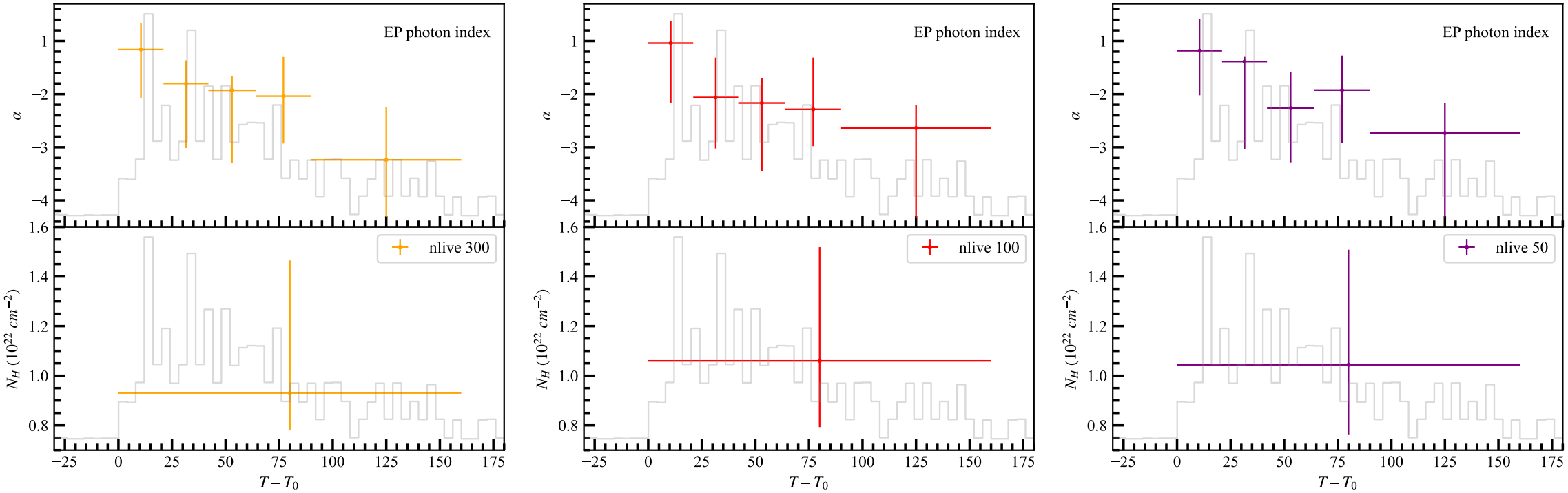
Conclusions

- We discovered GRB 240219A following up EP's first detection of EP240219a.
- GRB 240219A is most likely an X-ray rich GRB with E_{peak} ~ 130 keV.
- EP's future detection of GRB 240219A-like events could extend subclass GRB samples and may unveil the relationship of XRFs, XRRs and classical GRBs.
- While the trigger time is consistent, the profiles differ in X-rays and gamma-rays. Two components are implied, yet physical model fit is still ongoing.
- Upon spectral fit and SED, the origin of GRB 240219A is unclear.

Thank you.

EP/WXT Spectral Fit

Before spectral fit: N_H determination



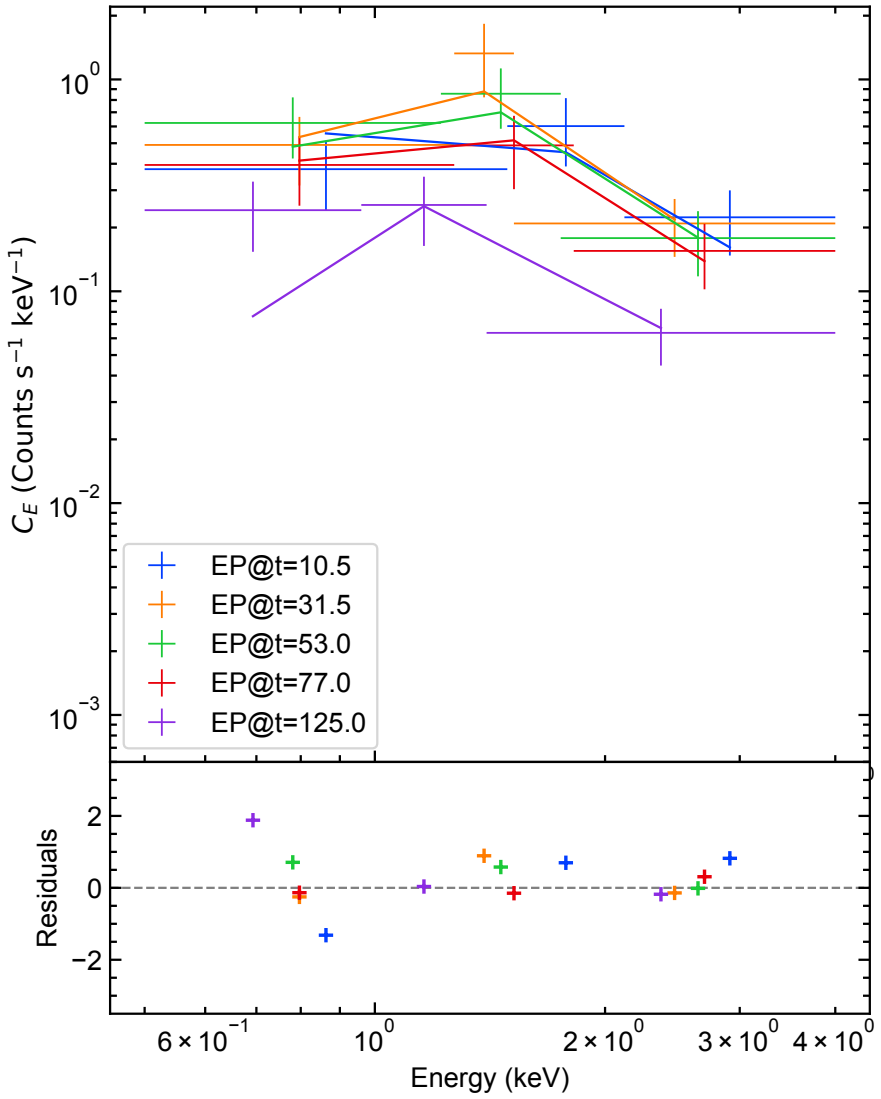
nlive = 300 nlive = 100 nlive = 50

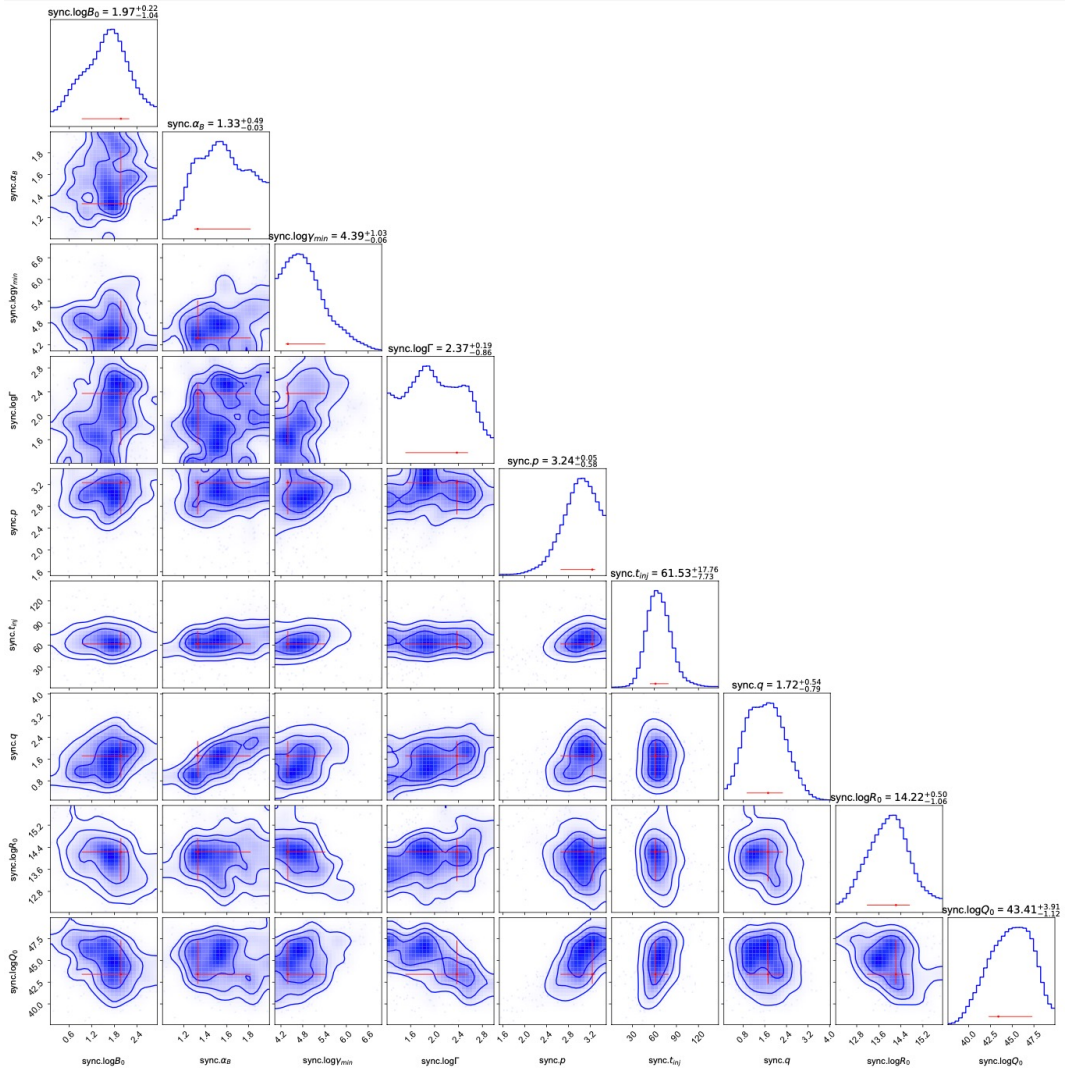
examined by time-resolved spectral fit with linked N_H,

N_H is ~ 10^{22} cm^{-2}, determined to be 1.03×10^{22} cm^{-2}

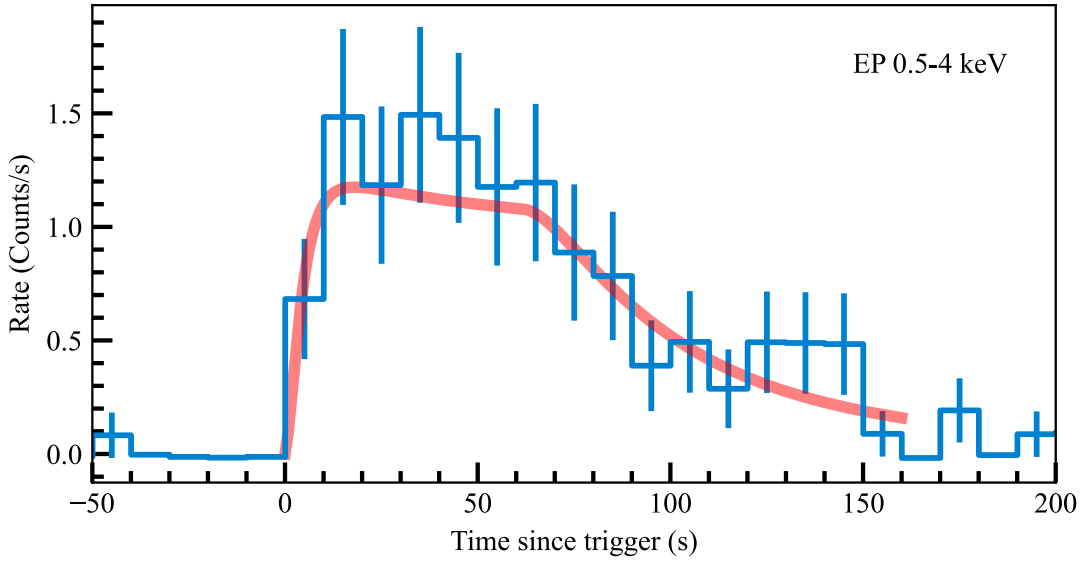
Spectral models

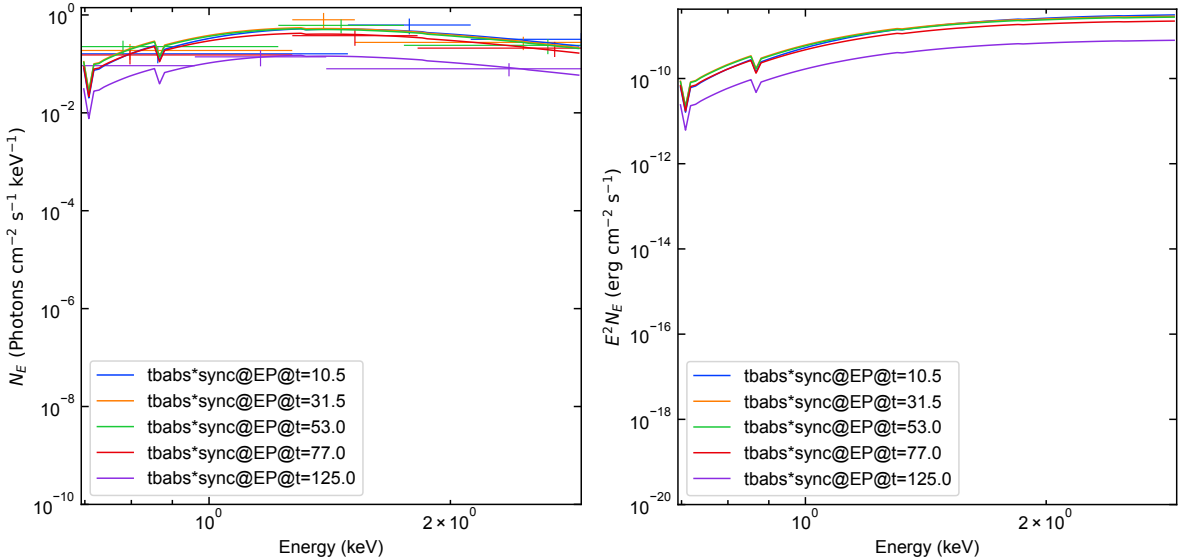
Unified Synchrotron Model



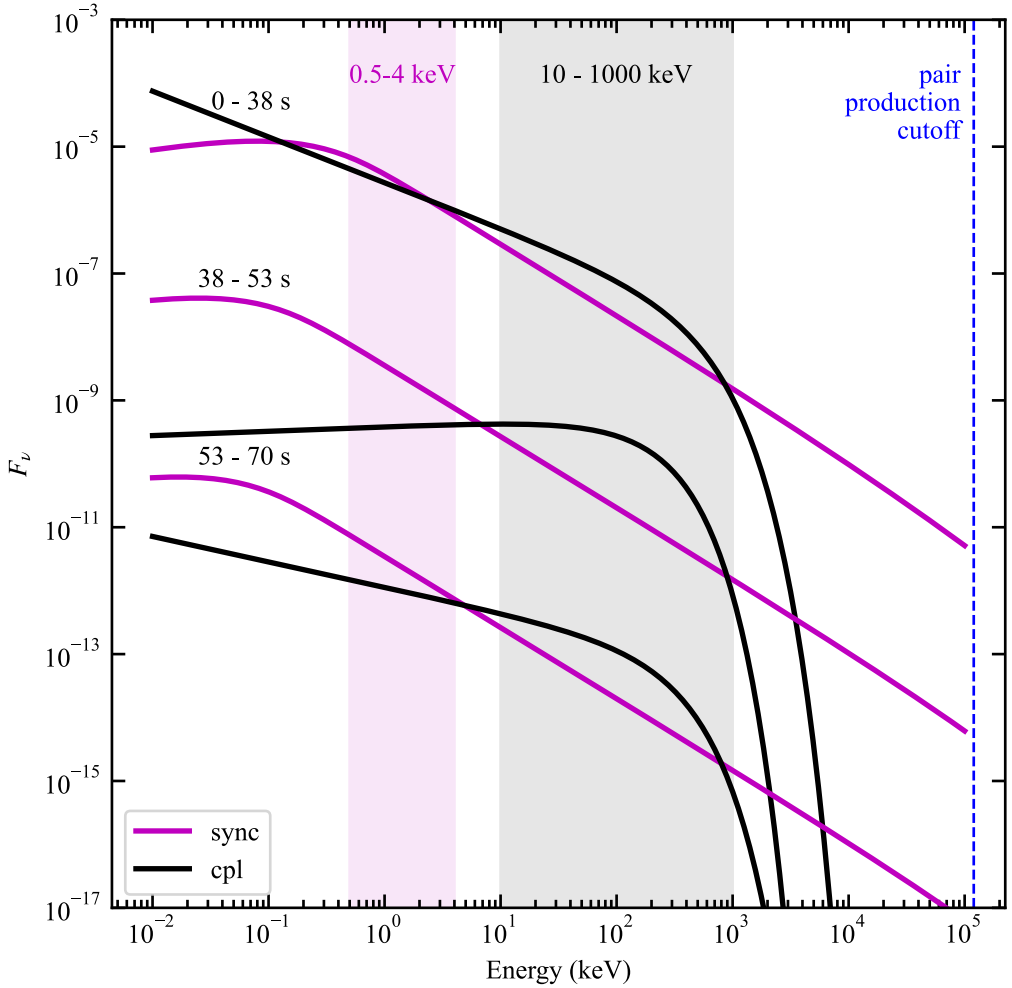


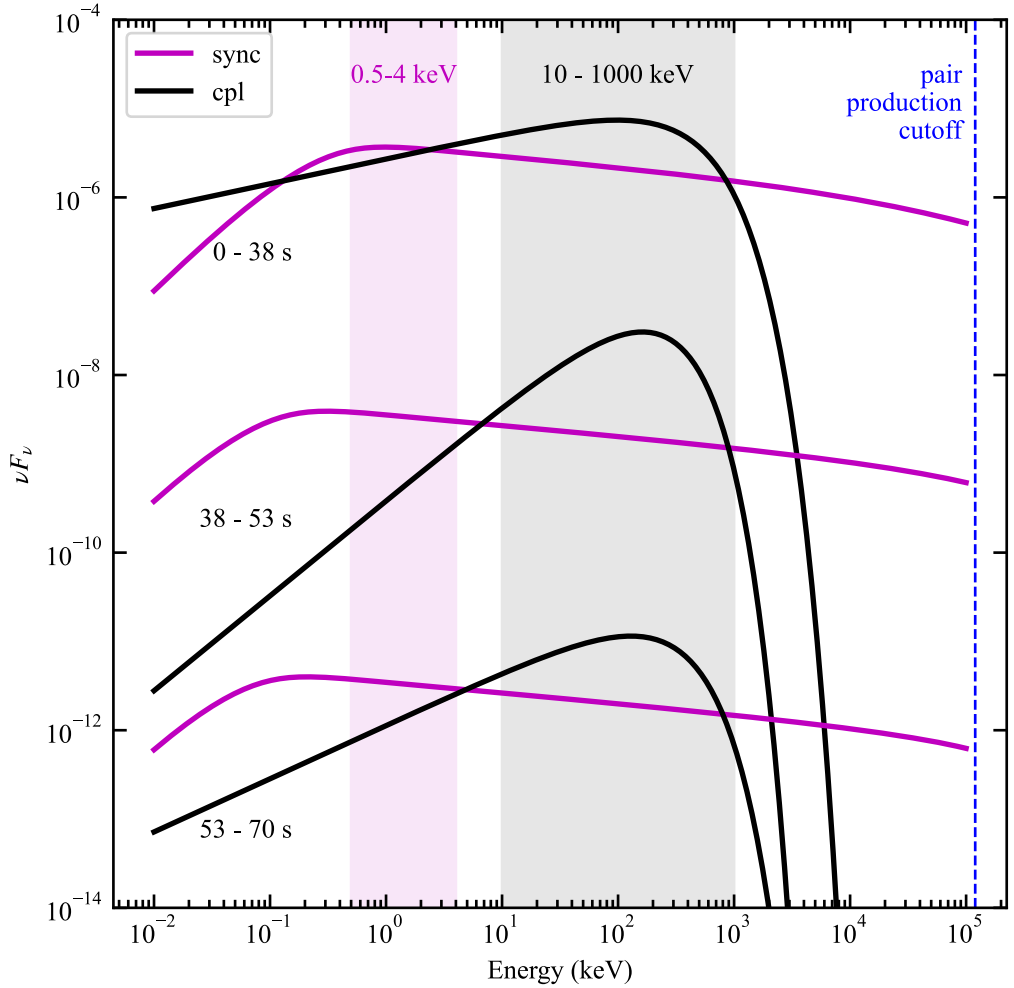
Unified Synchrotron Model



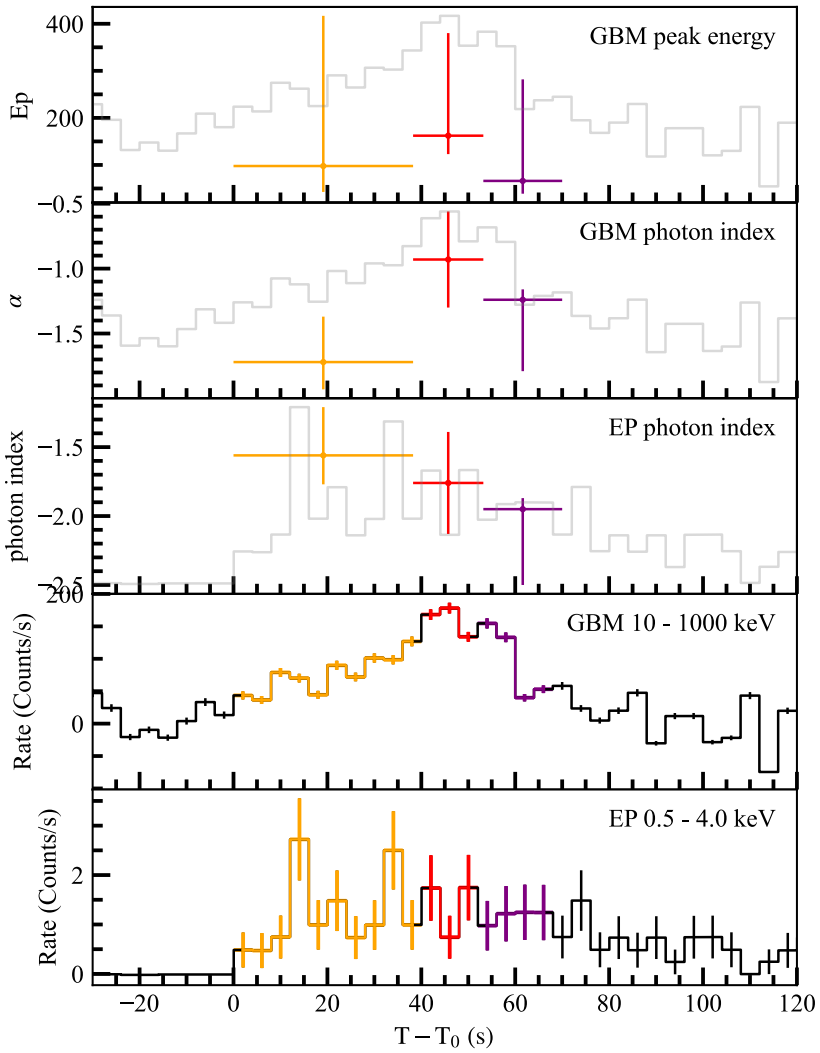


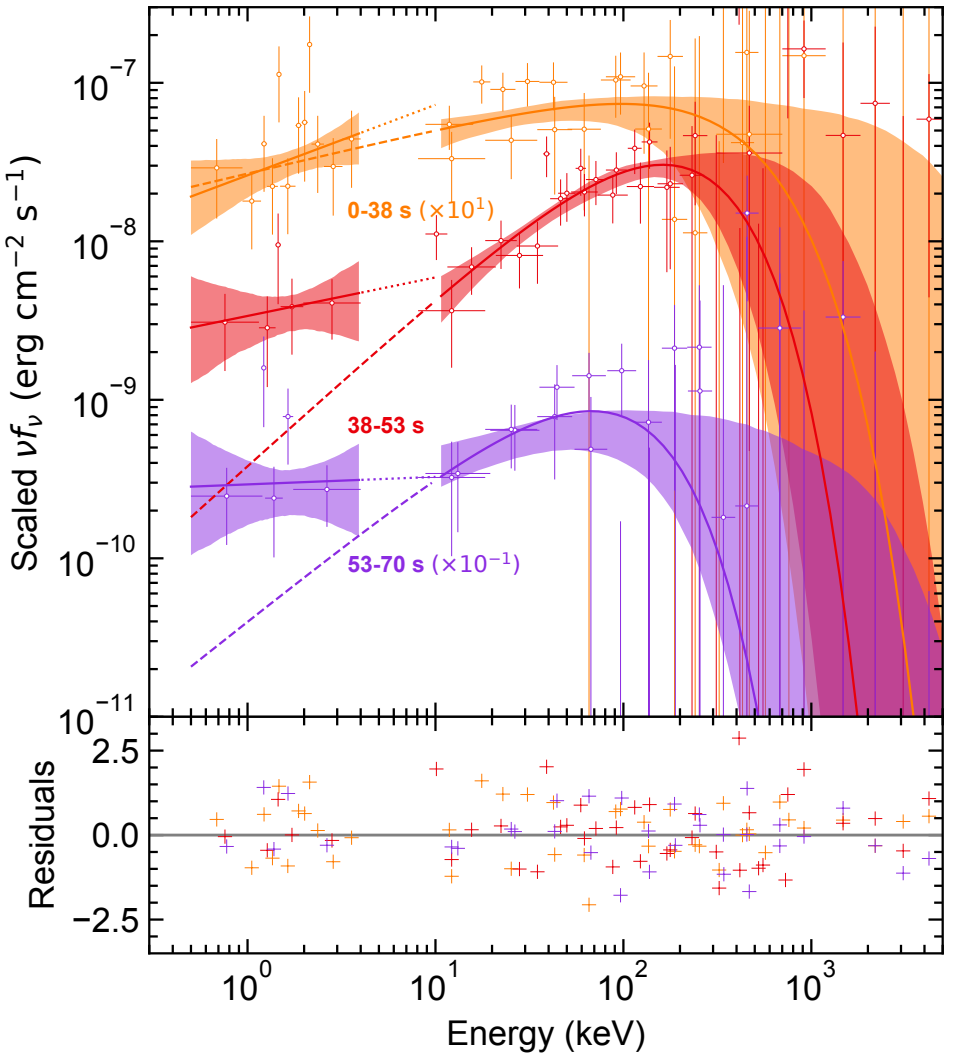
SSC ?


0 - 38 s
38 - 53 s
53 - 70 s
0.5-4 keV
10 - 1000 keV
pair production cutoff
sync
cpl
F_ν
Energy (keV)


sync
cpl
0.5-4 keV
10 - 1000 keV
pair production cutoff
0 - 38 s
38 - 53 s
53 - 70 s
νF_ν
Energy (keV)

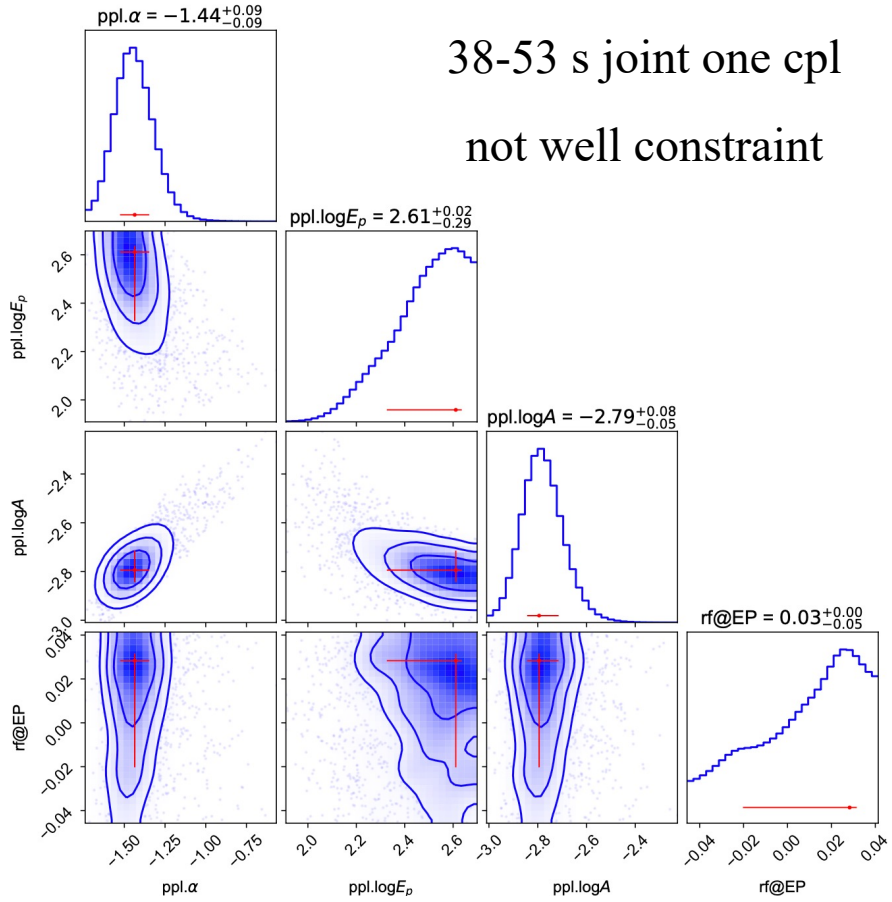
GRB 240219A: SED





different spectral evolution after the first time slice

GRB 240219A: models



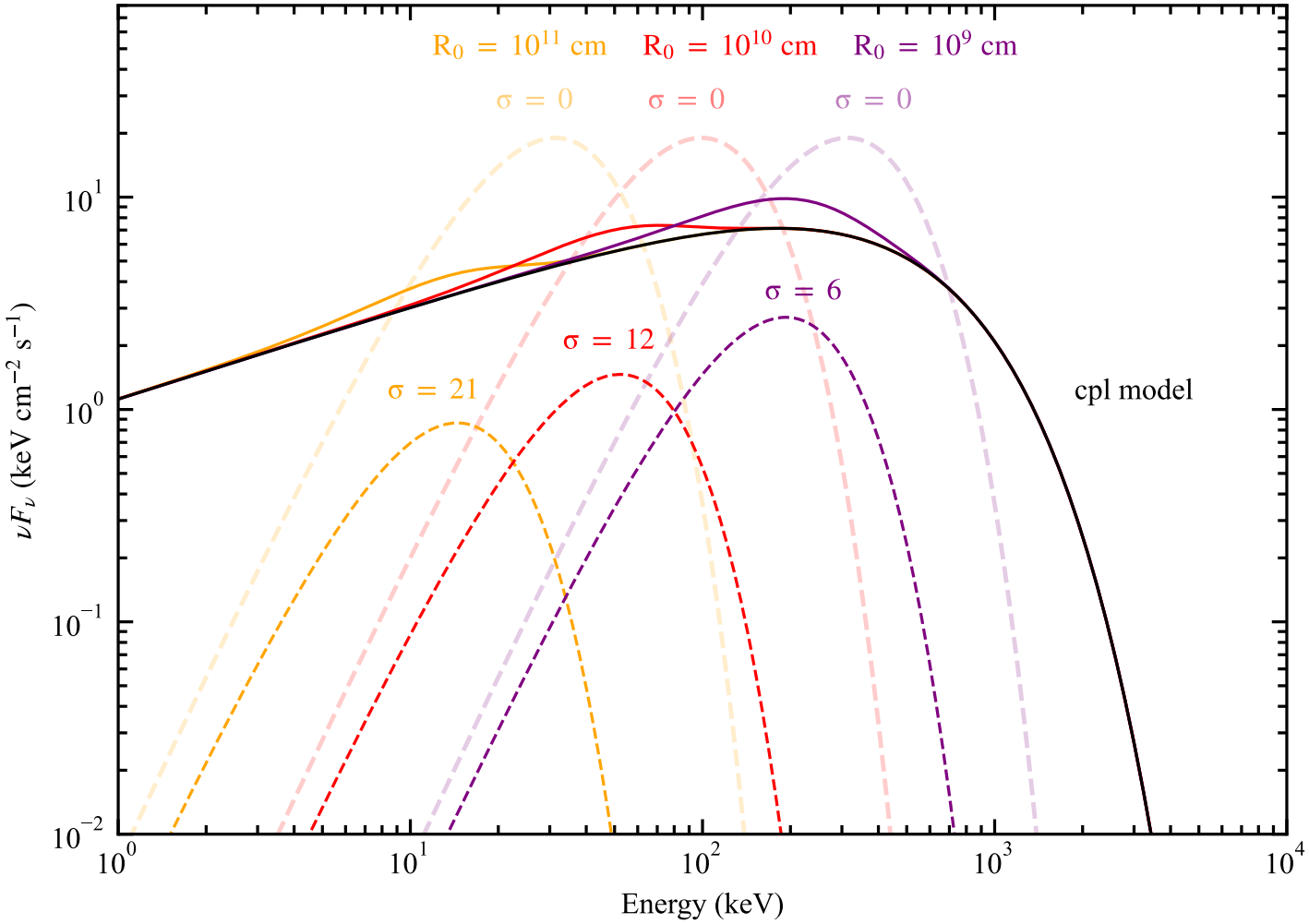
38-53 s joint one cpl

not well constraint

t1	t2	cpl			pl-cpl		
		stat	BIC	AIC	stat	BIC	AIC
0.00	38.25	319.51	343.13	327.51	319.42	348.95	329.42
38.25	53.21	333.56	357.11	341.56	328.86	358.29	338.86
53.21	70.00	324.20	347.74	332.20	323.08	352.51	333.08

GBM component

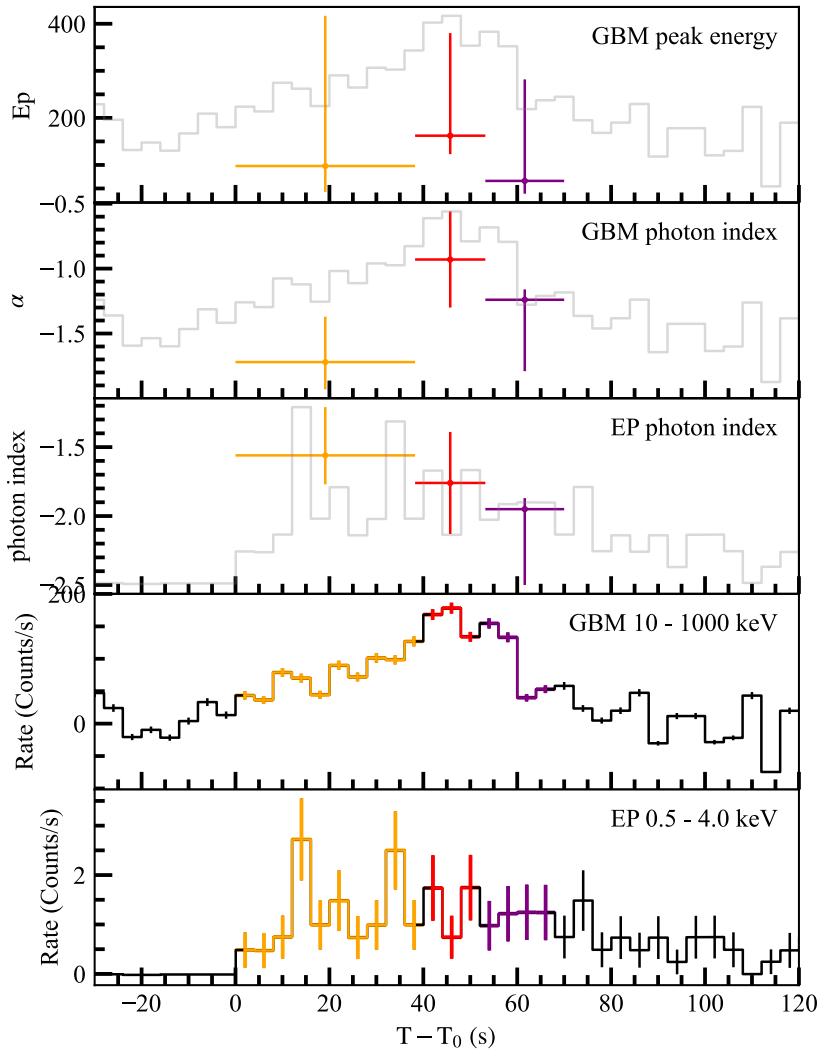
GBM constraint on σ



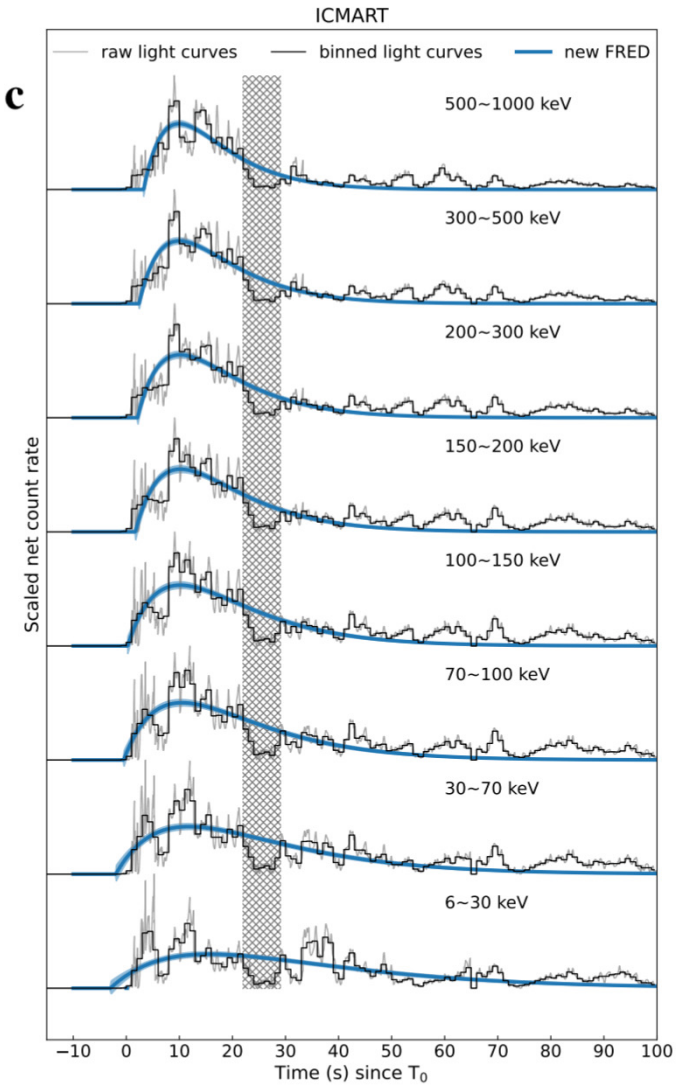
a global minimum σ >= 6

light curve difference

Similarities in light curves



GRB 240219A



simulated multi-band lightcurves for ICMART model

GRB 230307A Yi. et al 2024