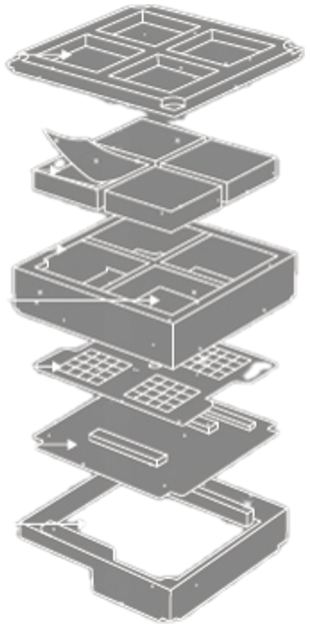
清华大学 2024“天格计划”夏令营

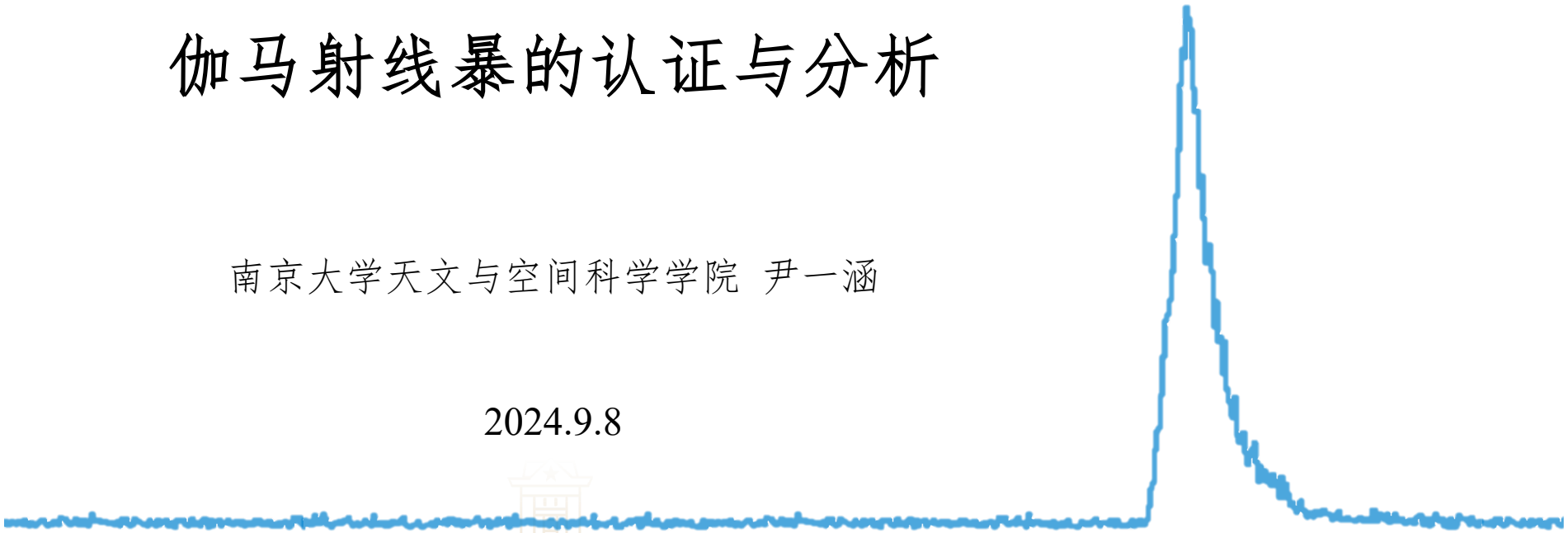
To Be GRB or Not to Be GRB:

伽马射线暴的认证与分析



南京大学天文与空间科学学院 尹一涵

2024.9.8



伽马射线暴

能量

时间

tens of keV
to
several MeV

milliseconds
to
thousands of s.

伽马暴探测器：

BATSE

Swift-BAT

Fermi-GBM

Konus-wind

GECAM

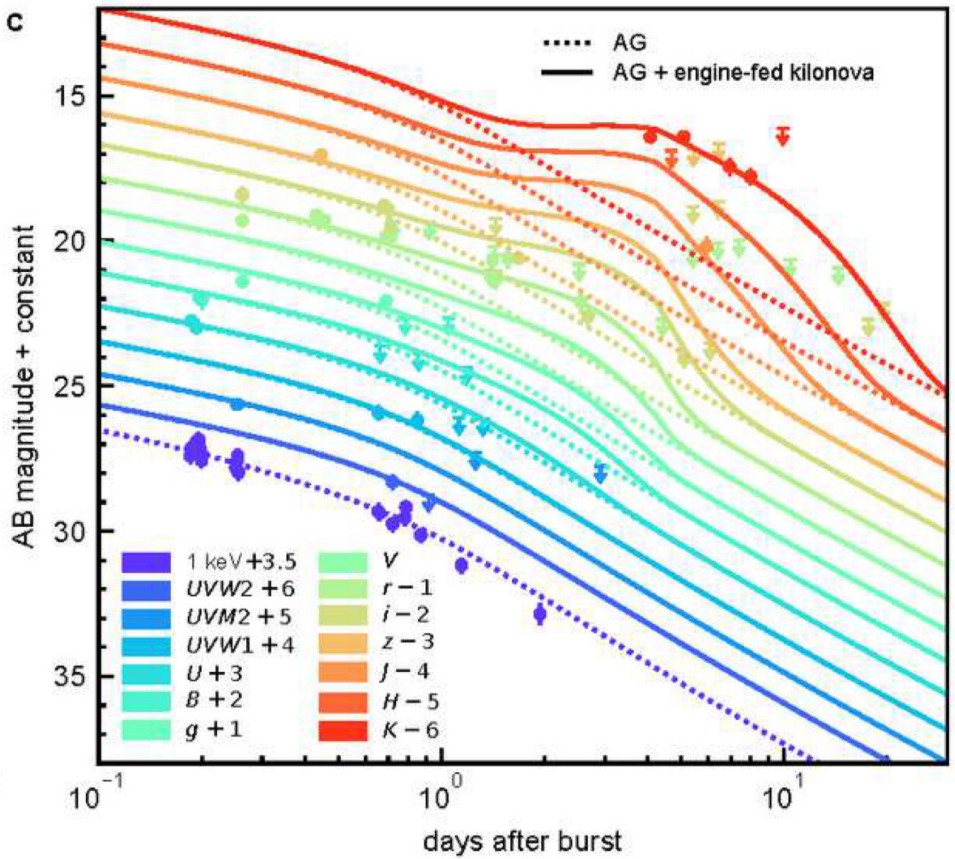
…

GRID

“瞬时辐射”阶段：

硬 X 射线/软伽马射线

余辉（Afterglow）



GRB 211211A 多波段余辉
(Yang et al., 2022, Nature)

SCIENCE ADVANCES | RESEARCH ARTICLE

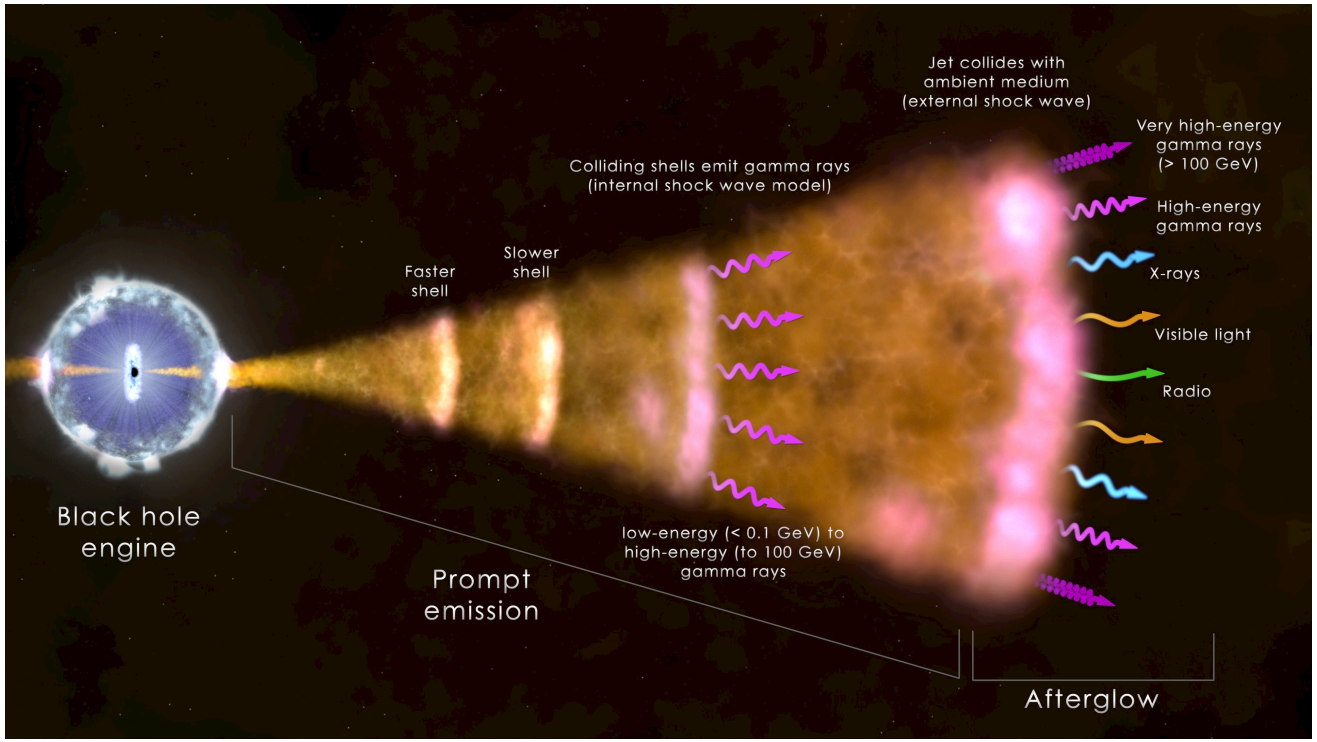
PHYSICS

Very high-energy gamma-ray emission beyond 10 TeV from GRB 221009A

The LHAASO Collaboration*†

The highest-energy gamma-rays from gamma-ray bursts (GRBs) have important implications for their radiation mechanism. Here we report the detection of gamma-rays up to 13 teraelectronvolts from the brightest GRB 221009A by the Large High Altitude Air-shower Observatory (LHAASO). The LHAASO-KM2A detector registered more than 140 gamma-rays with energies above 3 teraelectronvolts during 230 to 900 seconds after the trigger. The intrinsic energy spectrum of gamma-rays can be described by a power-law after correcting for extragalactic background light absorption. Such a hard spectrum challenges the synchrotron self-Compton scenario of relativistic electrons for the afterglow emission above several teraelectronvolts. Observations of gamma-rays up to 13 teraelectronvolts from a source with a measured redshift of $z = 0.151$ hints more transparency in intergalactic space than previously expected. Alternatively, one may invoke new physics such as Lorentz invariance violation or an axion origin of very high-energy signals.

GRB 221009A 拉索探测
(LHAASO Collaboration, 2023, Science Advances)



伽马暴 1 秒之内释放的能量

超过太阳毕生所释放的能量总和

伽马暴的典型能量 ~ 10^{51} – 10^{53} erg/s

太阳的典型光度 ~ 10^{33} erg/s

（“羲和号”全日面 Hα 线心图像）

伽马暴起源

$\Delta t_{obs} \sim 2$ s

$\Gamma \sim 100$

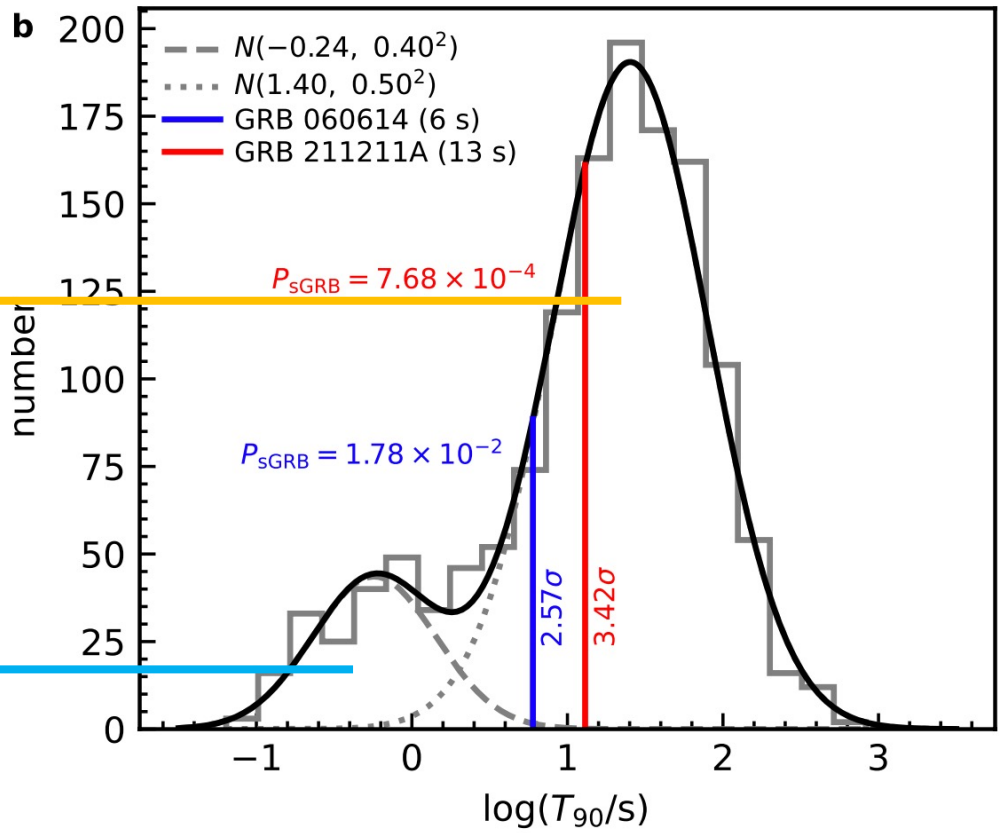
辐射区尺度 $R \sim c\,\Gamma^2\,\Delta t_{obs} \sim 10^{15}$ cm

↓

恒星尺度

大于 2 秒
大质量恒星坍缩

小于 2 秒
双致密星并合



伽马暴瞬时辐射时标分布
(Yang et al., 2022, Nature)

多信使天文学

四种“信使”：

电磁辐射

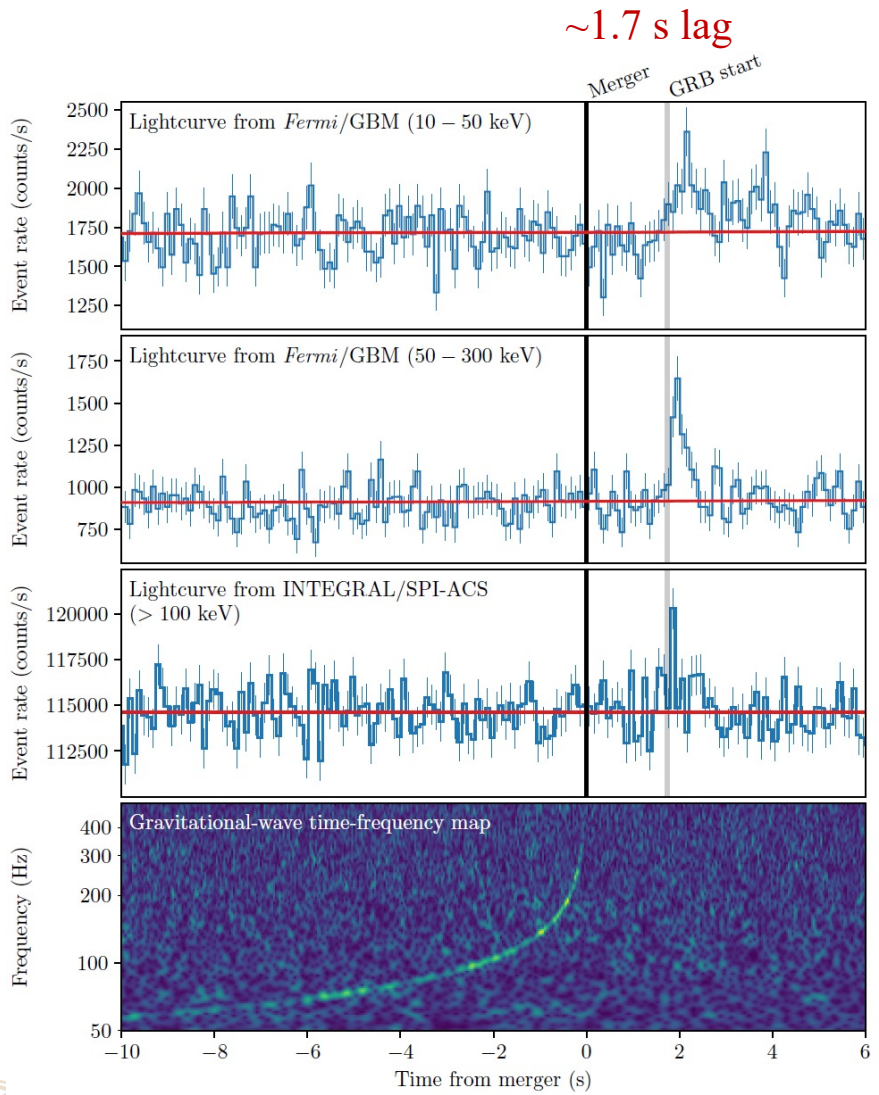
引力波

中微子

宇宙射线

电磁信号

引力波信号



GRB 170817A 和 GW170817
(Abbott et al., 2017, ApJL)

天格卫星数据准备

零级数据：原始卫星数据

一级数据：原始事例数据

二级数据：标定后事例数据等

三级数据：光变、能谱等

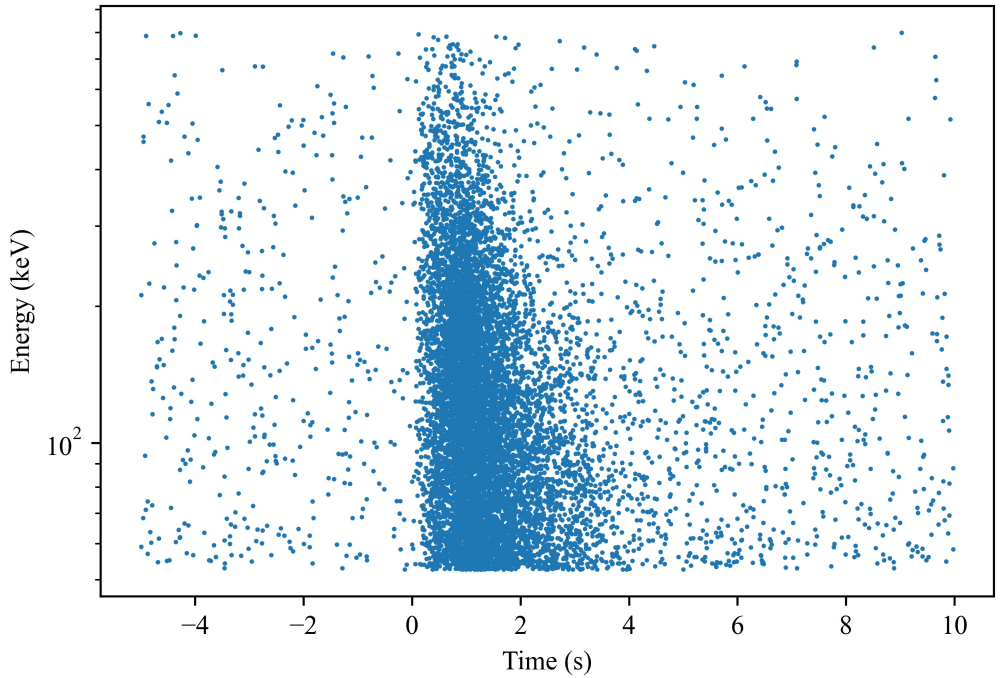
TOPCAT(3): Table Browser

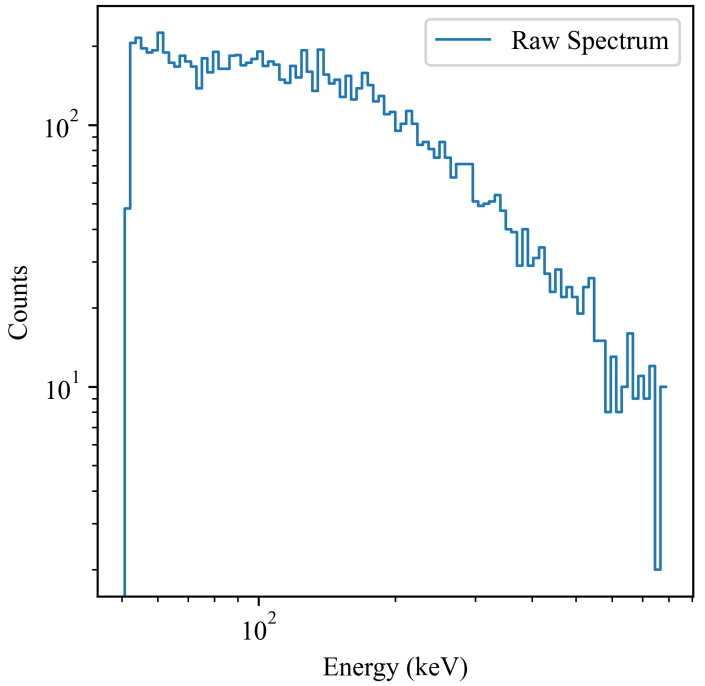
Table Browser for 3: G04_evt_2204080717_2204080736_v02_10.fits-3

	TIME	PI	DEAD_TIME	EVT_TYPE
1	1.346374E8	23	15	1
2	1.346374E8	8	15	1
3	1.346374E8	9	15	1
4	1.346374E8	181	15	1
5	1.346374E8	8	15	1
6	1.346374E8	10	15	1
7	1.346374E8	182	15	1
8	1.346374E8	23	15	1
9	1.346374E8	8	15	1
10	1.346374E8	25	15	3
11	1.346374E8	25	15	3
12	1.346374E8	26	15	1
13	1.346374E8	44	15	1
14	1.346374E8	9	15	1
15	1.346374E8	7	15	1
16	1.346374E8	8	15	1

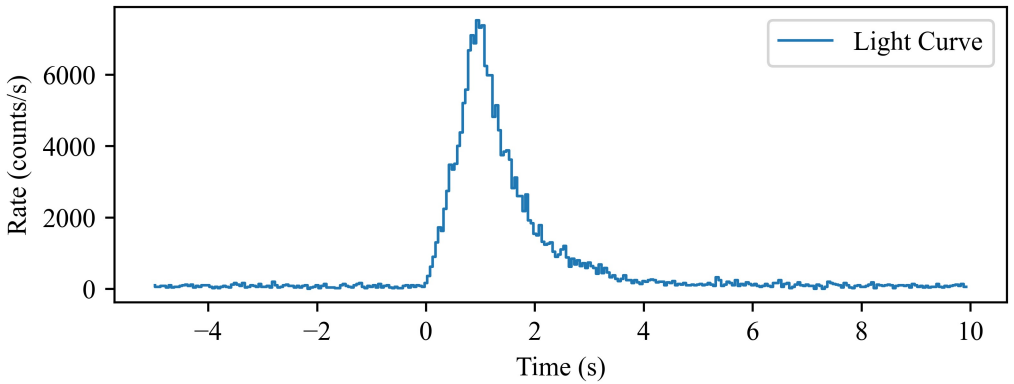
Total: 509,074 Visible: 509,074 Selected: 0

天格事例数据文件


Energy (keV)
10^2
−4
−2
0
2
4
6
8
10
Time (s)


Raw Spectrum
Counts
10^2
10^1
10^2
Energy (keV)

能谱


Light Curve
Rate (counts/s)
6000
4000
2000
0
−4
−2
0
2
4
6
8
10
Time (s)

光变曲线

过滤 和 去背景

filtering:

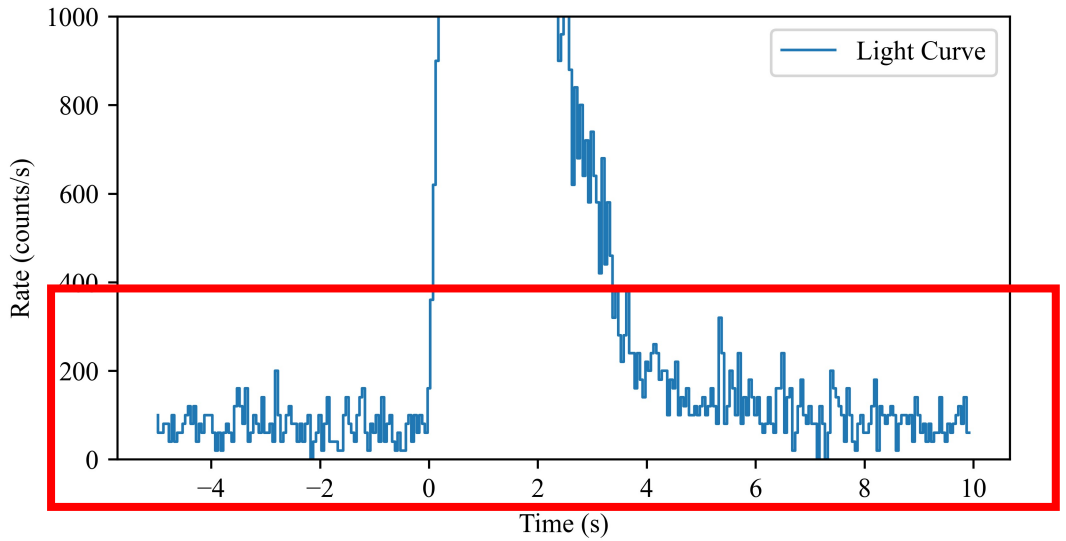
数据类型

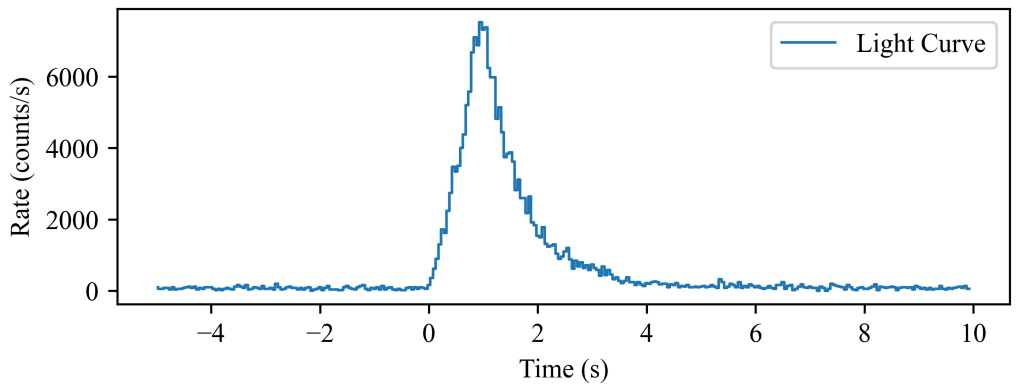
死时间修正

筛选时间范围

筛选能道

……





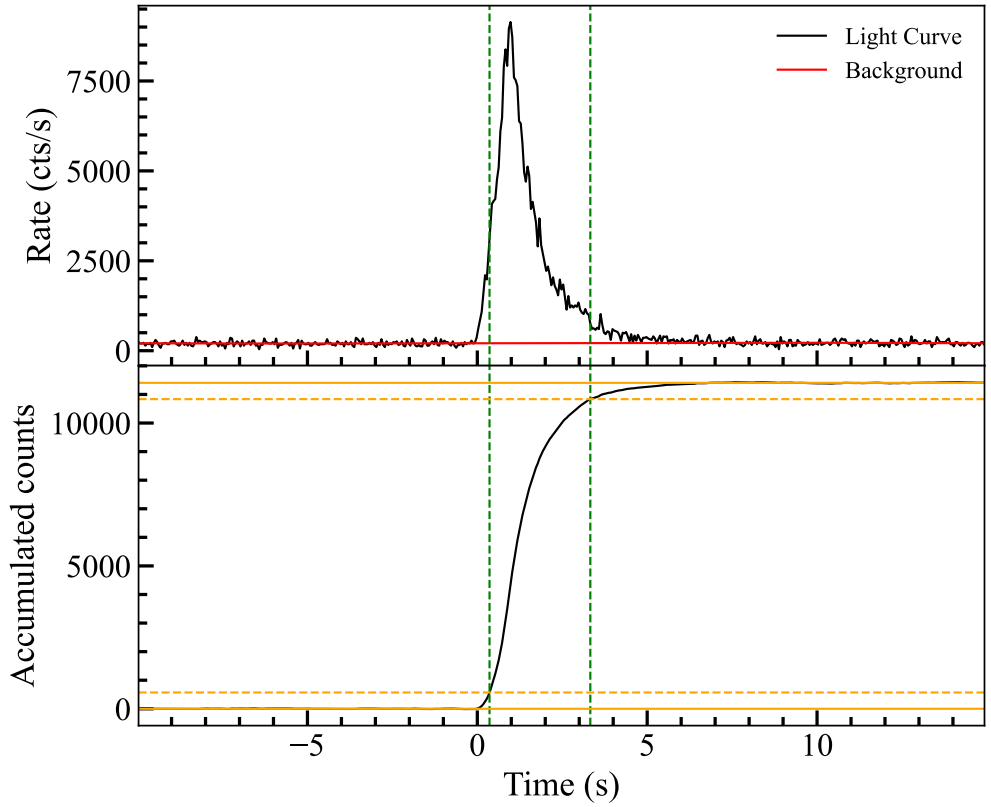
光变曲线

三级数据

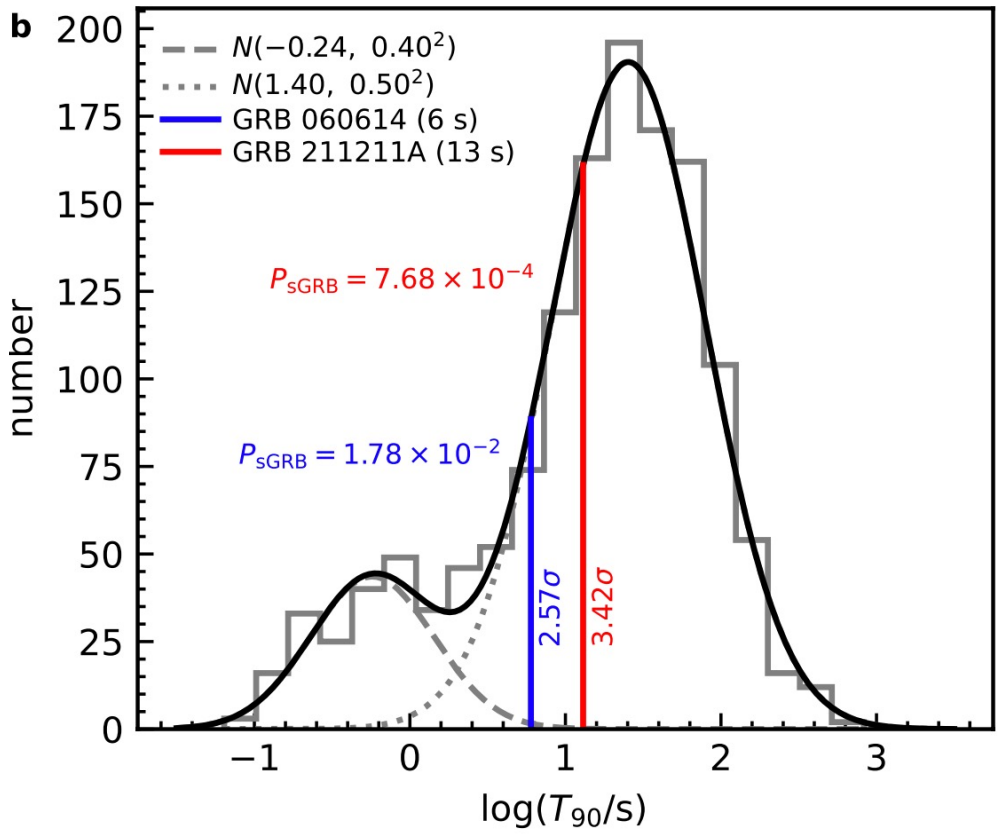
光变：	能谱：
source.lc	**source.pha**
back.lc	**back.pha**
	matrix.rsp

科学数据分析

时变性质

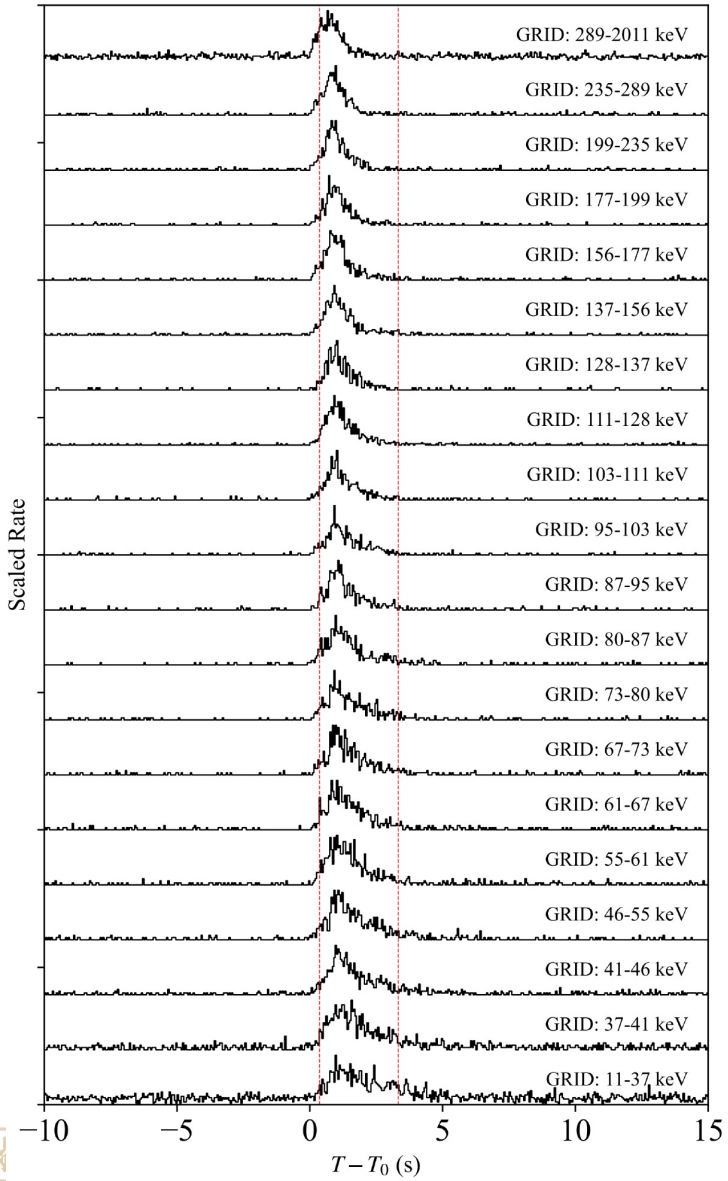


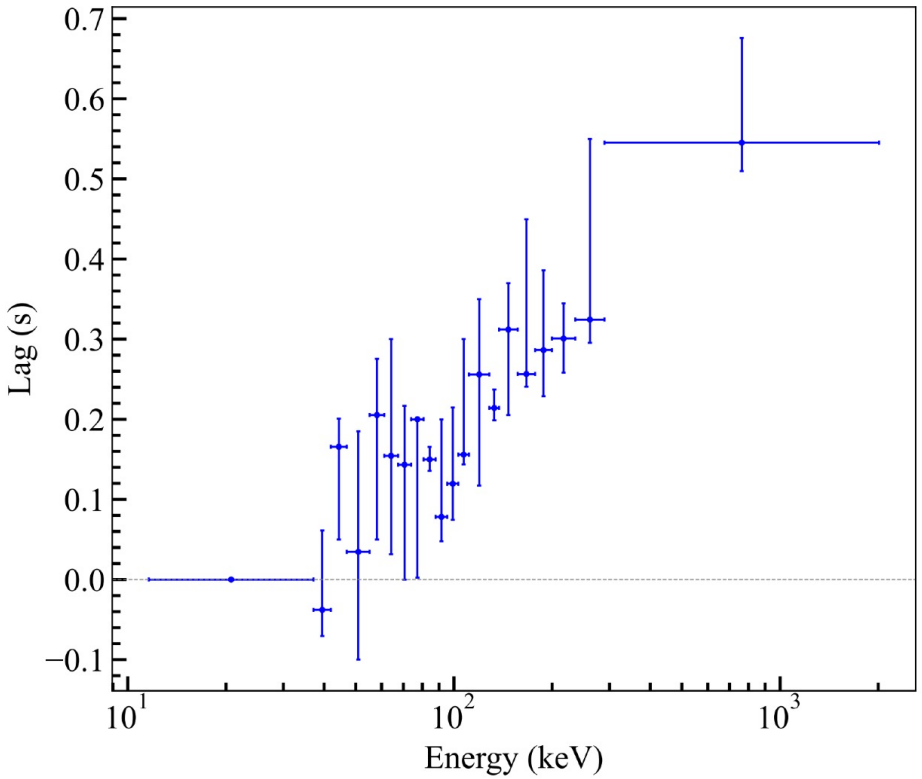
GRB 230812B 的 T_{90} 计算
(Wang et al., 2024, in prep)



伽马暴瞬时辐射时标分布
(Yang et al., 2022, Nature)

时变性质



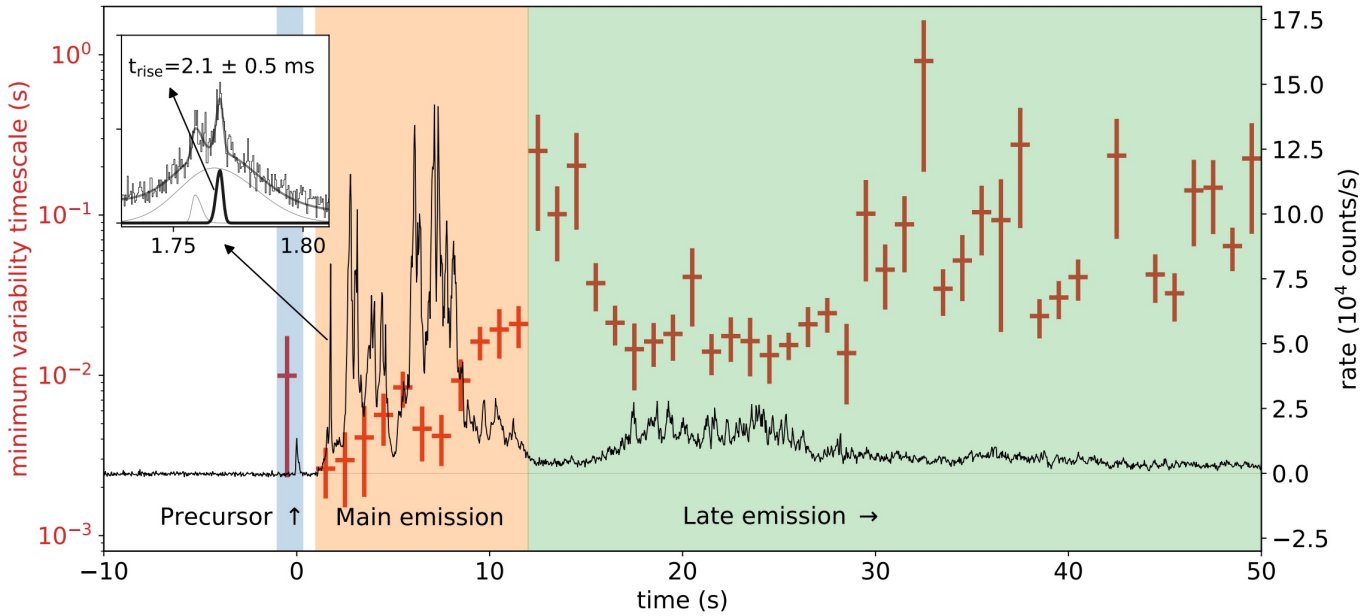


GRB 230812B 的能量时延
(Wang et al., 2024, in prep)

长暴的 **spectral lag** 较大

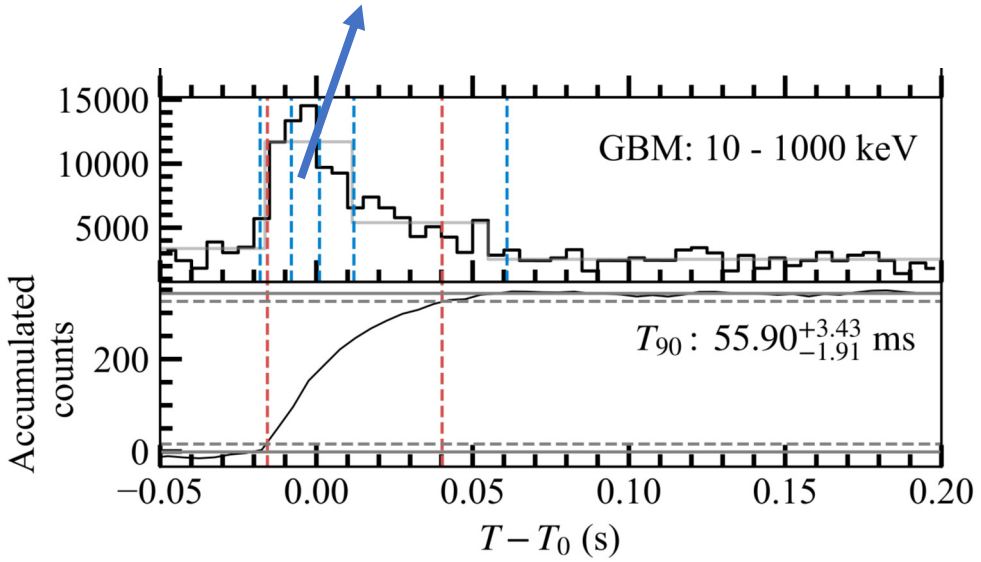
短暴的较小，甚至是负的

时变性质



GRB 211211A 的最小光变时标 (MVT)
(Veres et al., 2023, arxiv: 2305.12262)

最小贝叶斯块的一半



GRB 231115A 的最小光变时标 (MVT)
(Yin et al., 2024, ApJL)

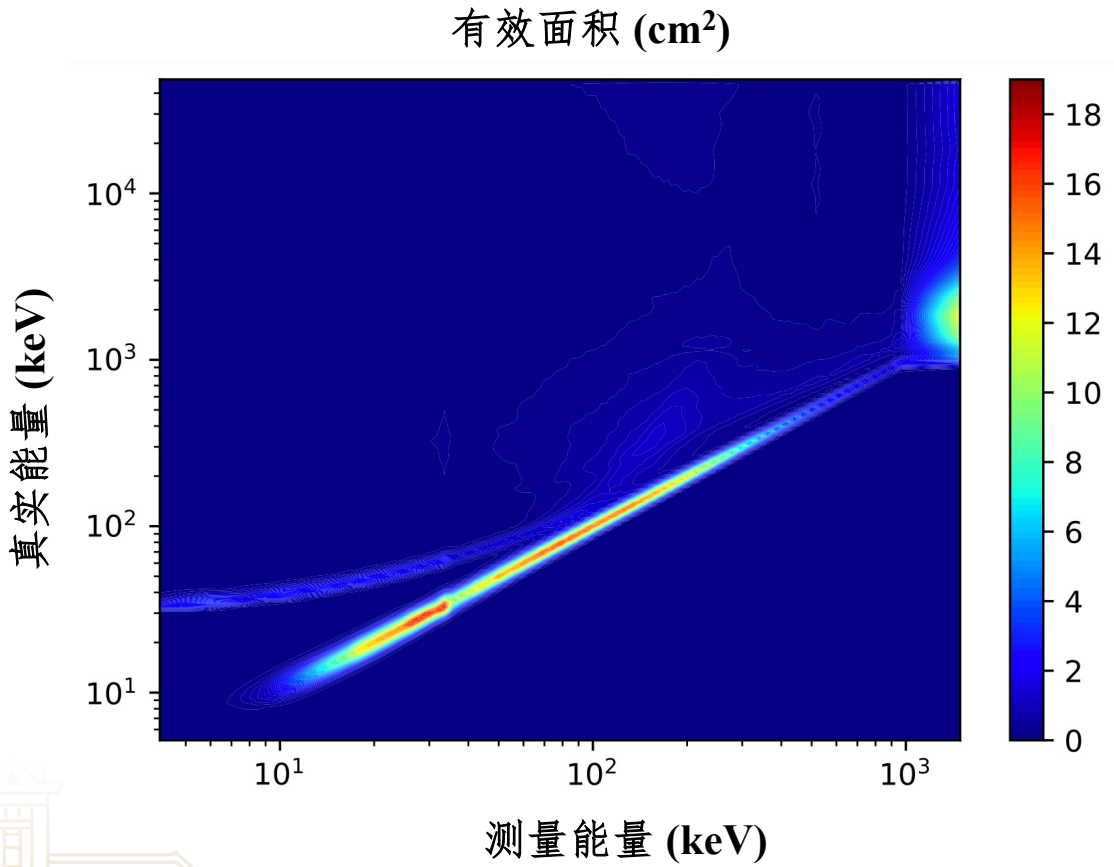
能谱性质

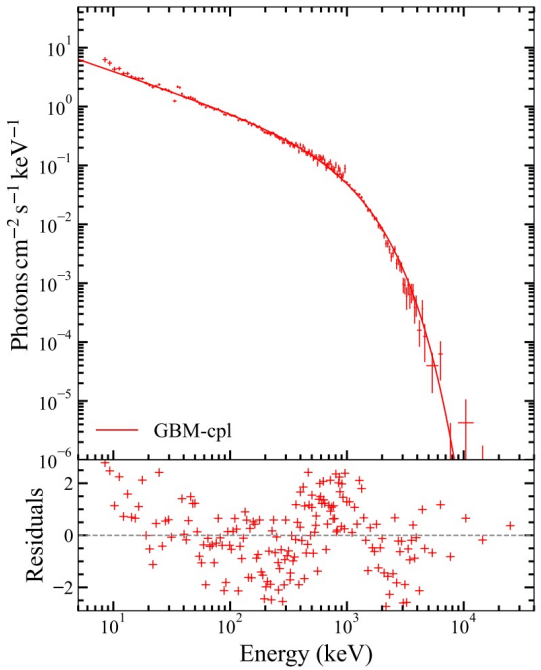
能谱：

source spectrum

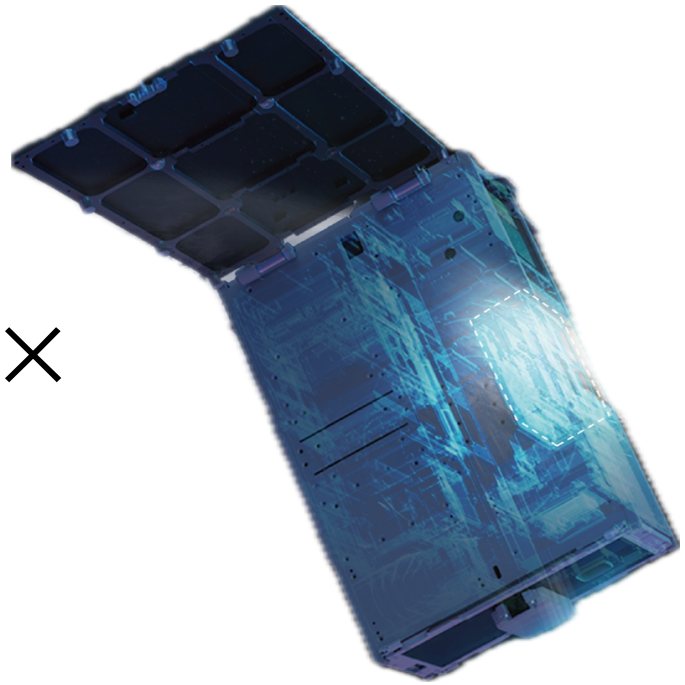
background spectrum

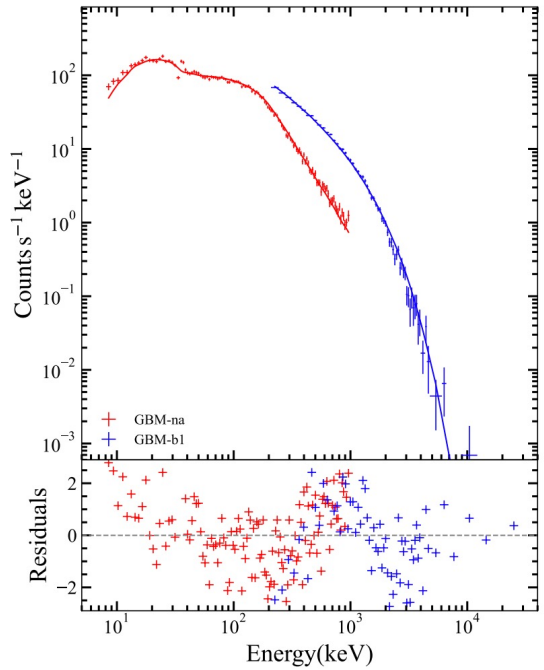
detector response matrix




Photons cm^{-2} s^{-1} keV^{-1}
GBM-cpl
Residuals
Energy (keV)

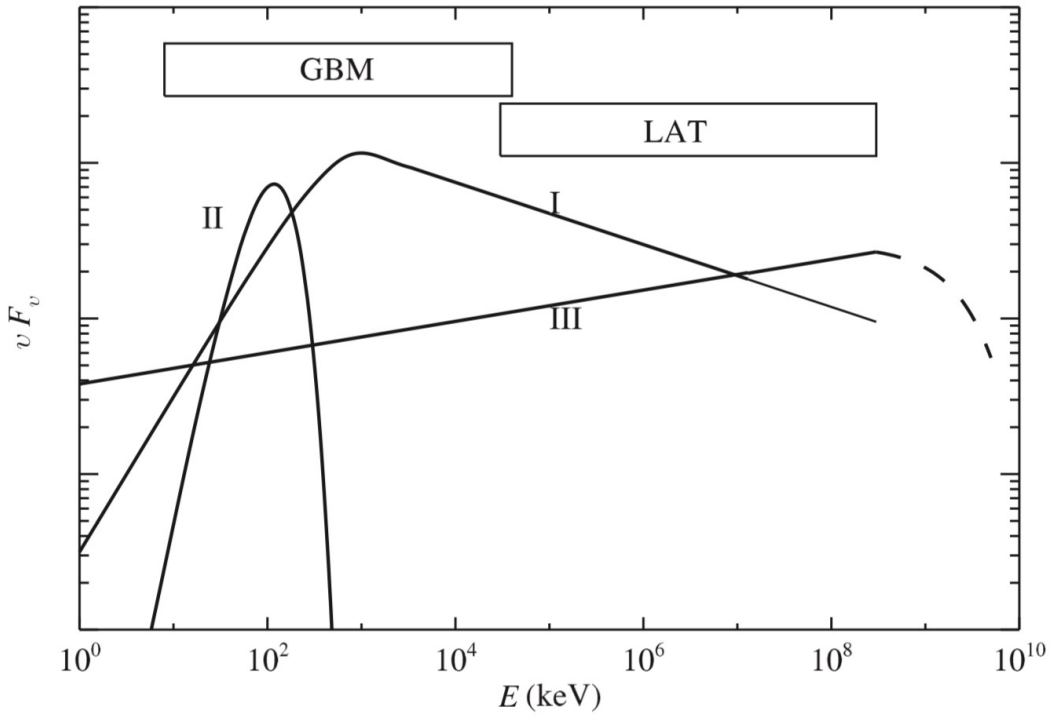
×




Counts s^{-1} keV^{-1}
GBM-na
GBM-b1
Residuals
Energy(keV)

反卷积 ❓

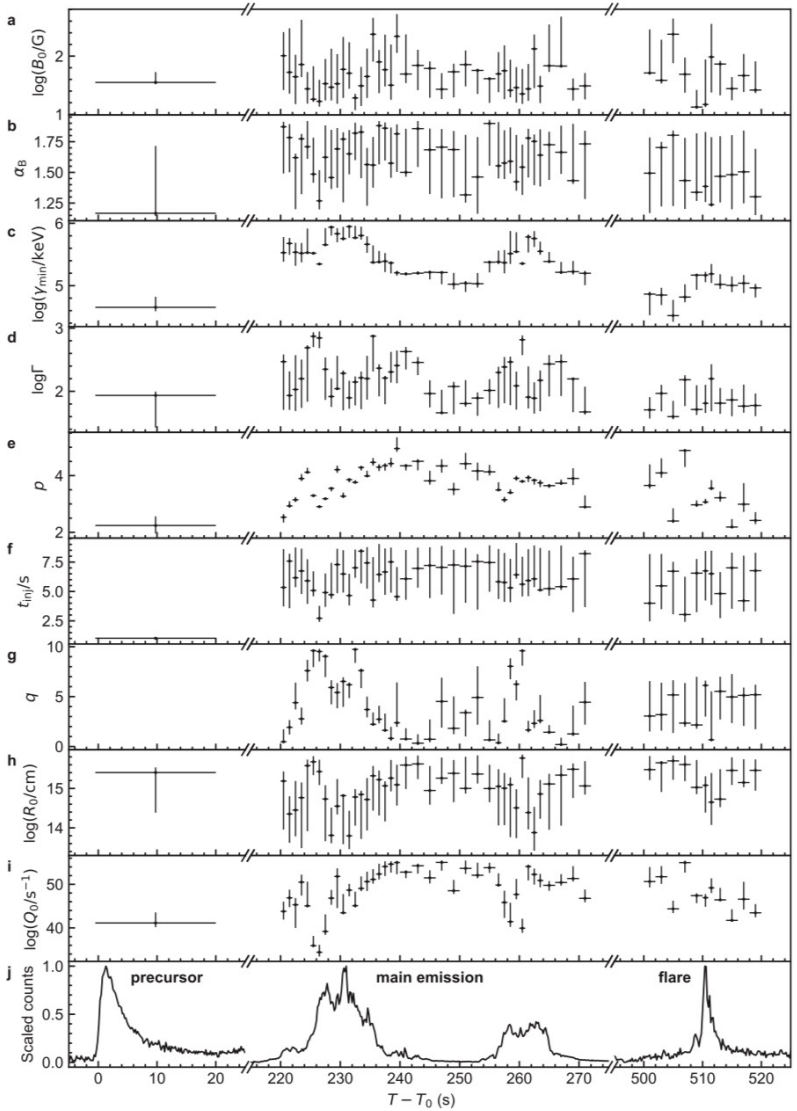
能谱拟合 ✅



经验模型拟合：

band, cutoff power law, black body,

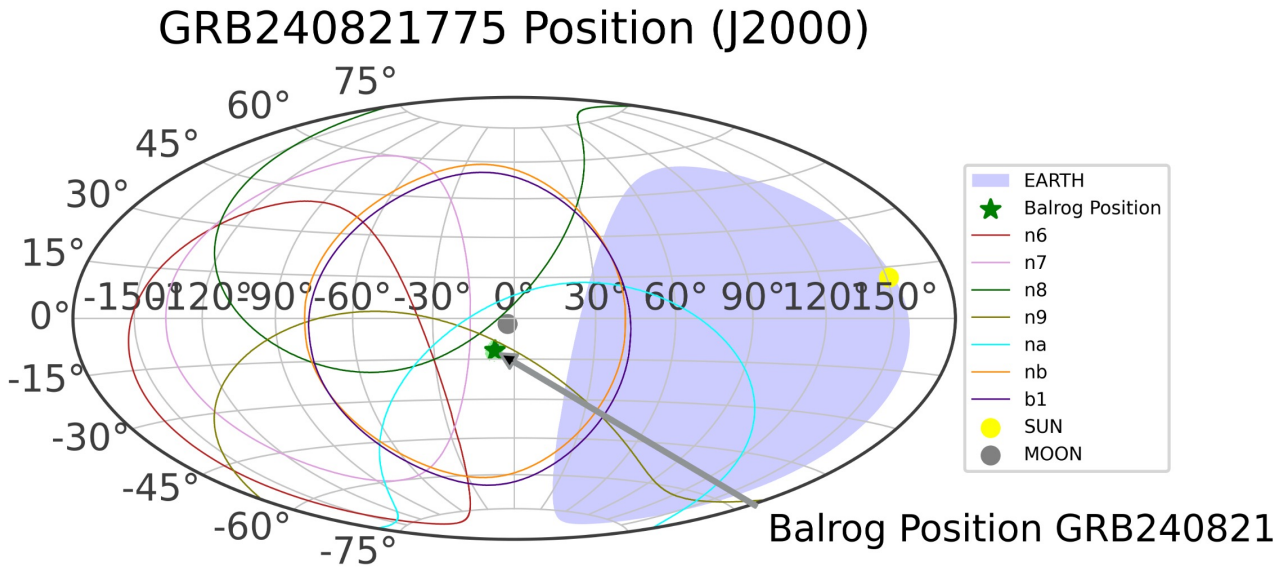
multicolor black body, power law…



物理模型拟合

(Yang et al., 2023, ApJL)

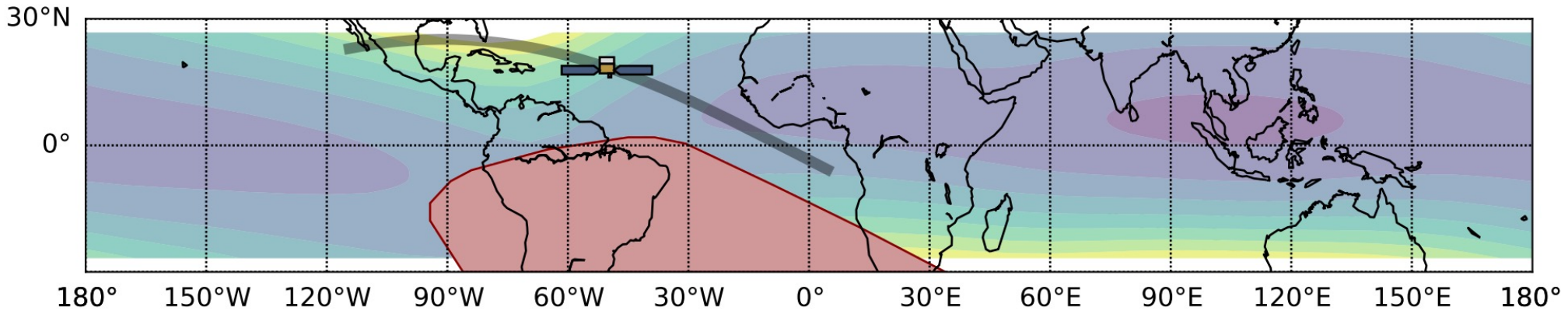
源定位



地球阴影遮挡？

来自太阳？

南大西洋异常区 (SAA)？



源定位

GCN Circular 35035

Subject
GRB 231115A: Fermi GBM Final Real-time Localization
Date
2023-11-15T15:46:53Z (8 months ago)
From
Fermi GBM Team at MSFC/Fermi-GBM
<do_not_reply@GIOC.nsstc.nasa.gov>
Via
email

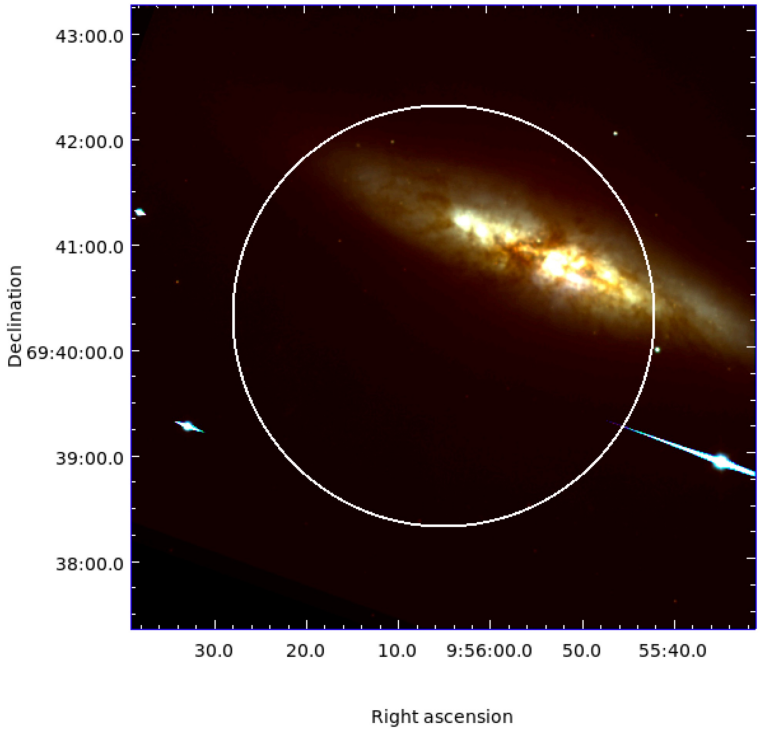
The Fermi GBM team reports the detection of a likely SHORT GRB

At 15:36:21 UT on 15 Nov 2023, the Fermi Gamma-ray Burst Monitor (GBM) triggered and located GRB 231115A (trigger 721755386.20138 / 231115650).

The on-ground calculated location, using the Fermi GBM trigger data, is RA = 131.0, Dec = 73.5 (J2000 degrees, equivalent to J2000 08h 43m, 73d 30'), with a statistical uncertainty of 8.7 degrees.

The angle from the Fermi LAT boresight is 38.0 degrees.

likely-short-GRB trigger



The position of GRB 231115A coincides with the nearby starburst galaxy M82. (Mereghetti et al., 2024, Nature)

借助定位：

确认来源

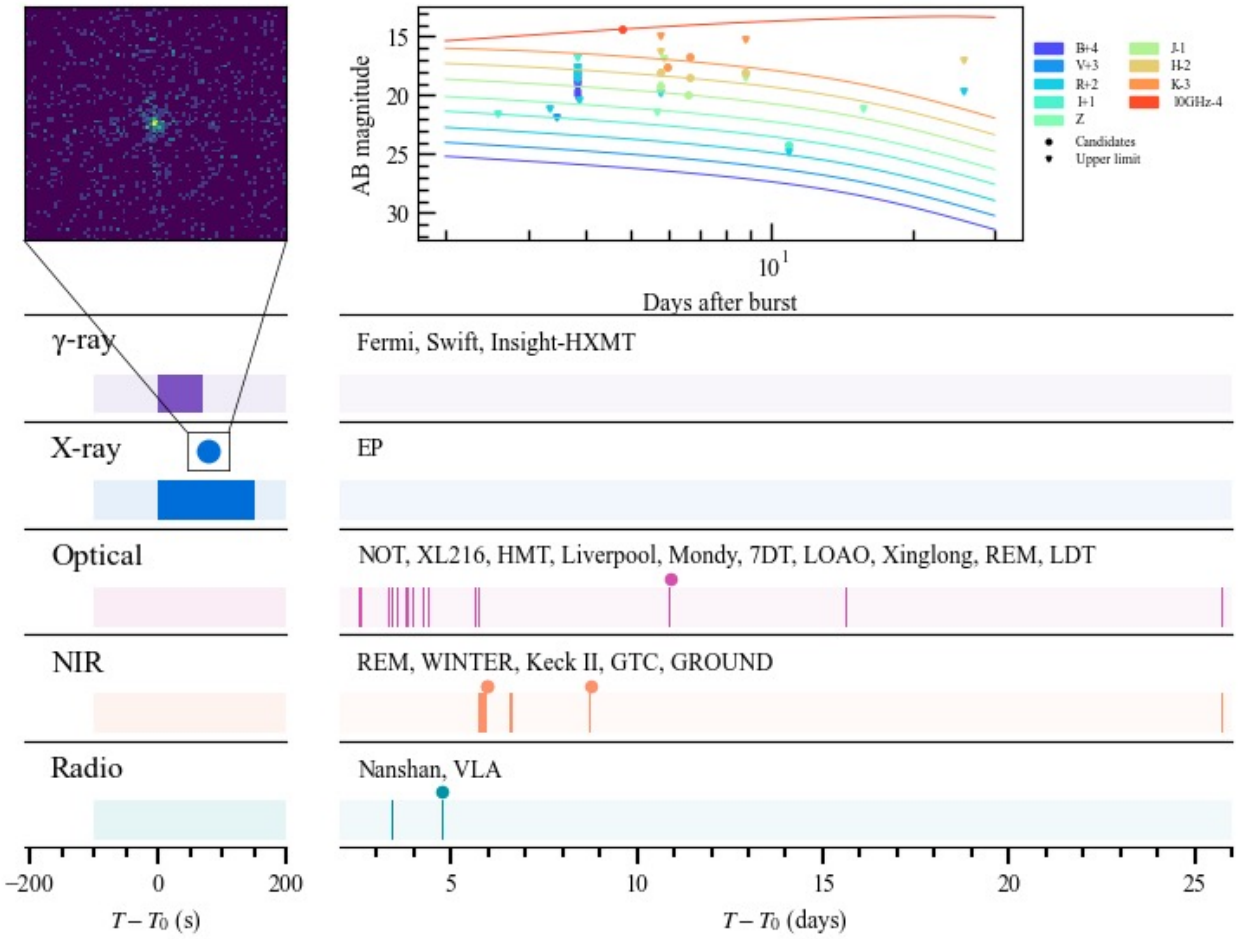
余辉

寄主星系

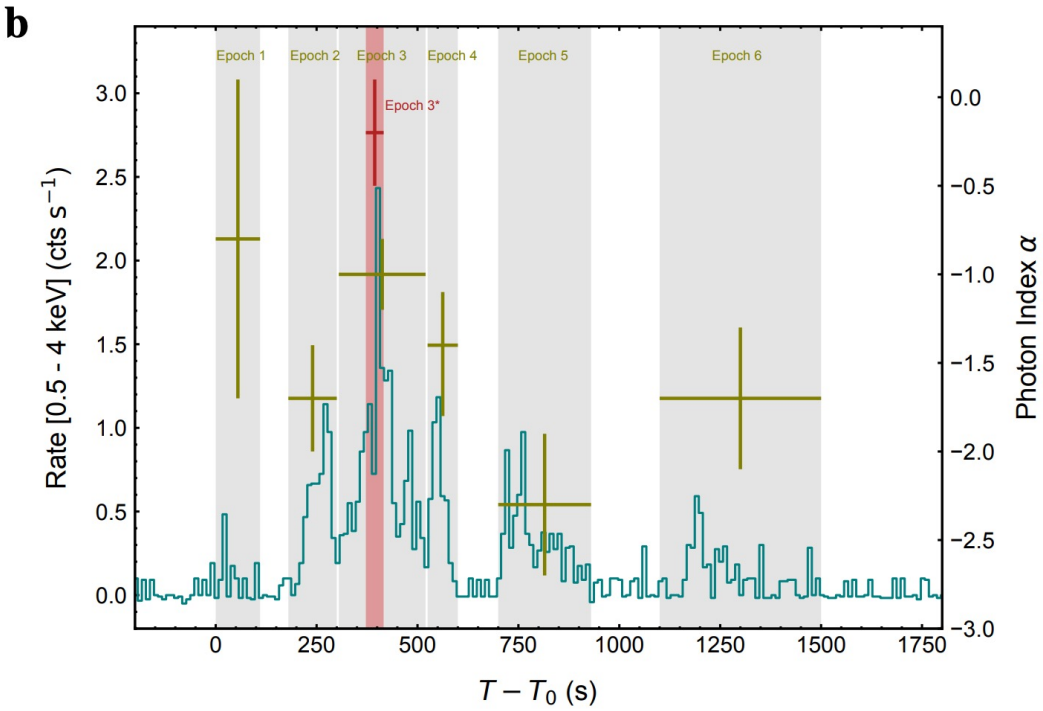
多波段观测

…

多波段观测



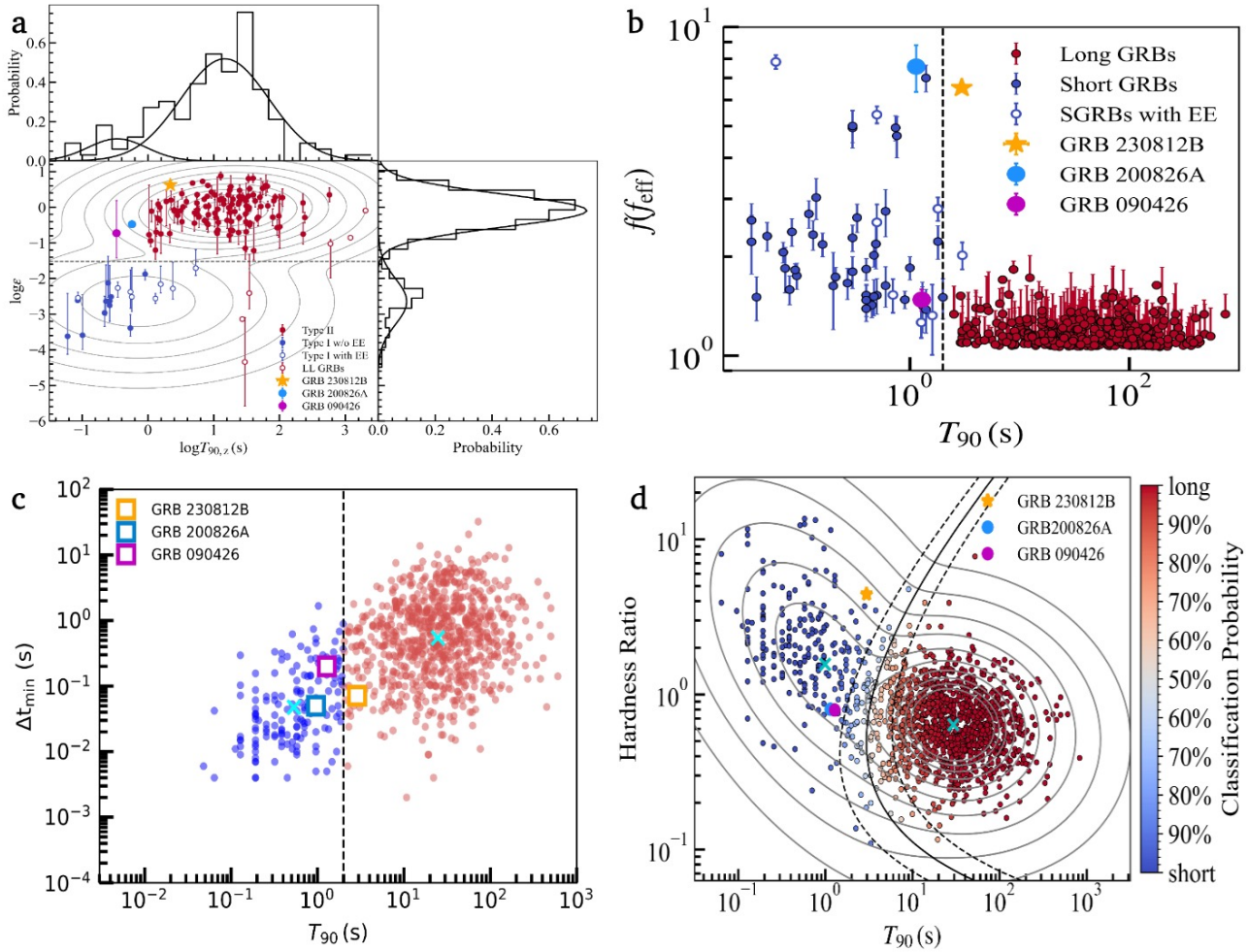
EP240219a/GRB 240219A (Yin et al., 2024, arxiv: 2407.10156)



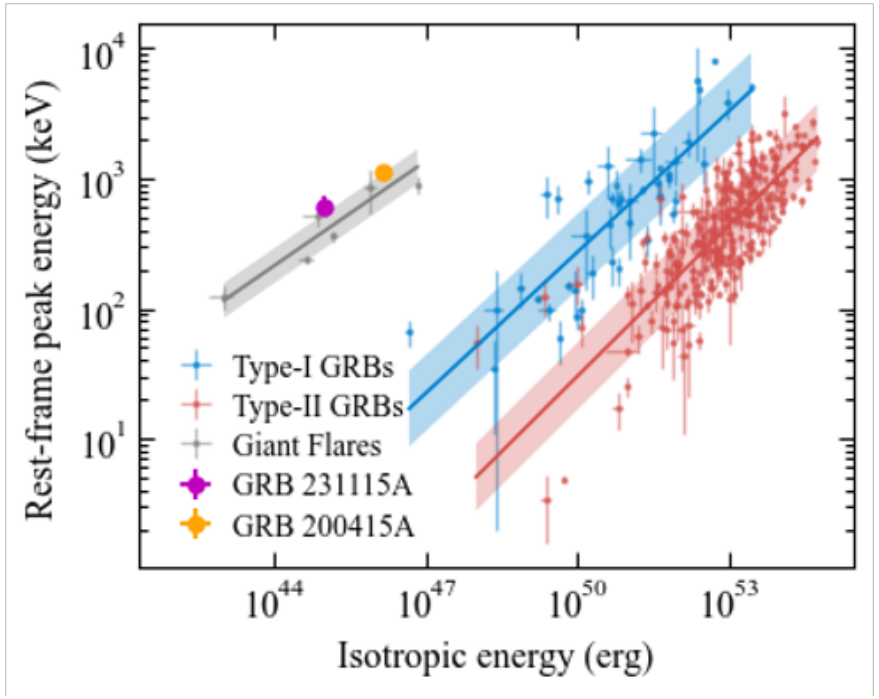
EP240315a/GRB 240315C
(Liu et al., 2024, arxiv: 2404.16425)

What about the GW-GRB lag?

伽马暴统计分类

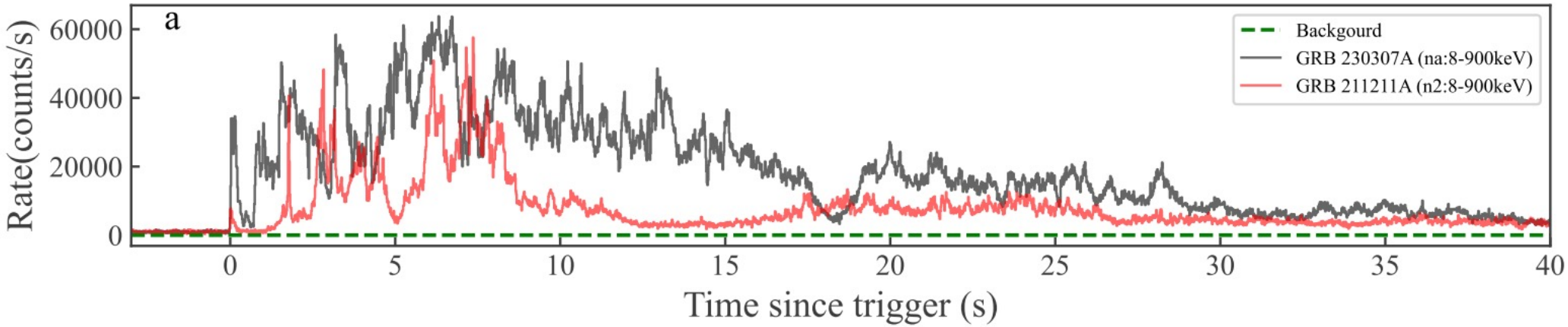


GRB 230812B in GRB samples (Wang et al., 2024, in prep)



The E_p-E_{iso} diagram (Yin et al., 2024, ApJL)

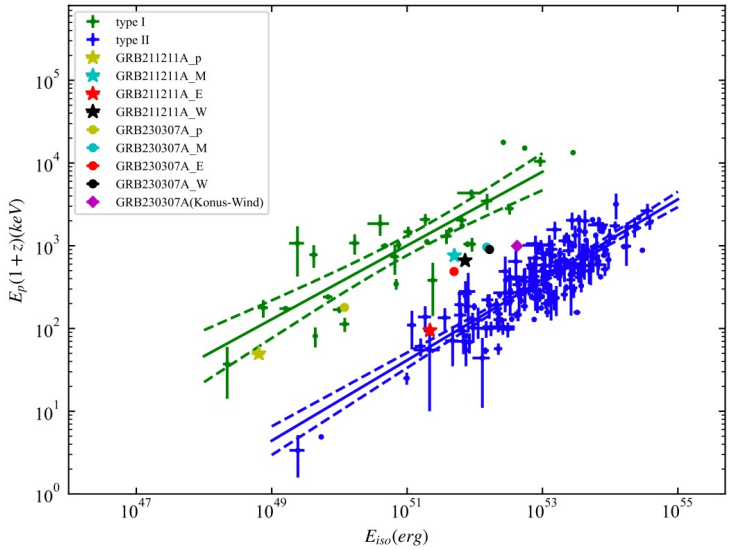
伽马暴统计分类



light curves of kilonova associated long GRB (Peng et al., 2024, ApJ)

Long or short?

Type I or Type II?



多波段
观测

时变性质

……

To be GRB or not to be GRB?

源定位

能谱性质

GCN Circular

GCN Circular 37341

Subject
GRB 240828A: Fermi GBM Observation
Date
2024-08-29T19:24:23Z (8 days ago)
From
Sarah Dalessi at UAH <sd0104@uah.edu>
Via
Web form

S. Dalessi (UAH) and C. Meegan (UAH) report on behalf of
the Fermi Gamma-ray Burst Monitor Team:

"At 14:55:06.83 UT on 28 August 2024, the Fermi Gamma-ray Burst Monitor (GBM)
triggered and located GRB 240828A (trigger 746549711/240828622).
which was also detected by AstroSat (S. Srijan et al. 2024, GCN 37328), Fermi-LAT (R.
Gupta et al. 2024, GCN 37331), Swift-XRT (A.P. Beardmore et al. 2024, GCN 37337), and
KAIT (W. Zheng et al. 2024 37339)
The Fermi GBM on-ground location is consistent with the AstroSat, Fermi-LAT, Swift-
XRT, and KAIT positions.

The angle from the Fermi LAT boresight is 97 degrees.

The GBM light curve multiple peaks with a duration (T90)
of about 41.2 s (50-300 keV). The time-averaged spectrum
from T0+0.002 to T0+44.225 s is best fit by
a power law function with an exponential high-energy cutoff.
The power law index is -0.96 +/- 0.01 and the cutoff energy,
parameterized as Epeak, is 850 +/- 30 keV.

The event fluence (10-1000 keV) in this time interval is
(8.05 +/- 0.07)E-05 erg/cm^2. The 1-sec peak photon flux measured
starting from T0+38.8 s in the 10-1000 keV band is 18.6 +/- 0.4 ph/s/cm^2.

A Band function fits the spectrum equally well
with Epeak= 820 +/- 30 keV, alpha = -0.96 +/- 0.01 and beta = -2.9 +/- 0.2.

触发时间

探测器

多波段观测

定位

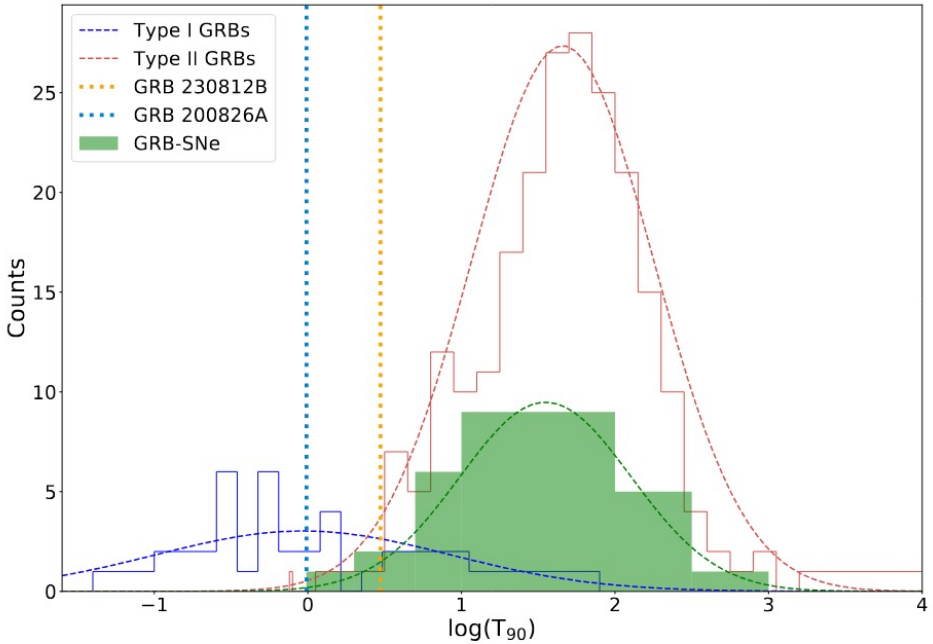
时变性质

能谱性质

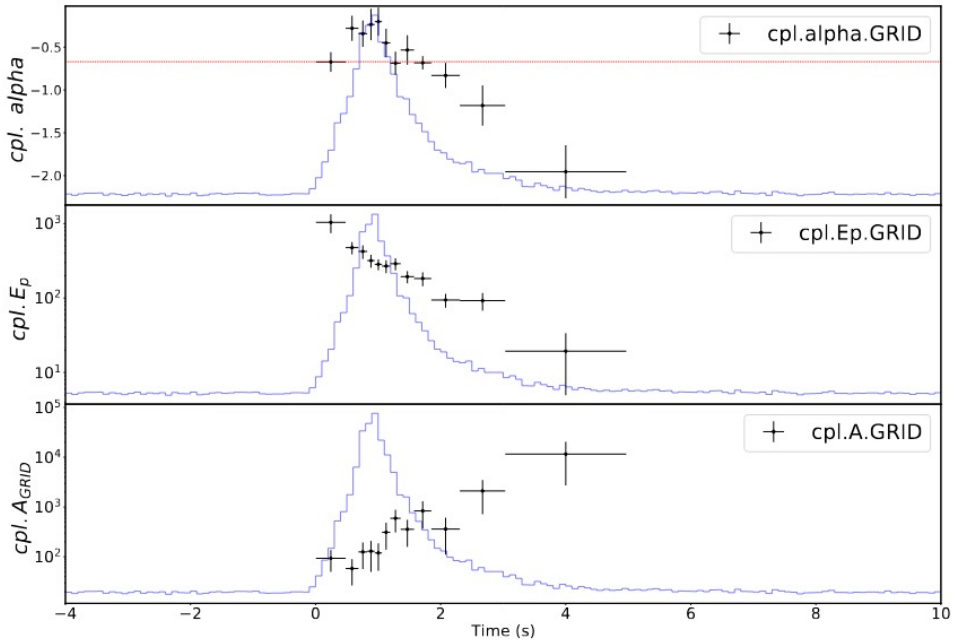
科学进展

GRB 230812B: A Three-Second Gamma-Ray Burst with Supernova Association Detected by the GRID Mission

Chenyu Wang et al., 2024, in prep



特殊的光变时长

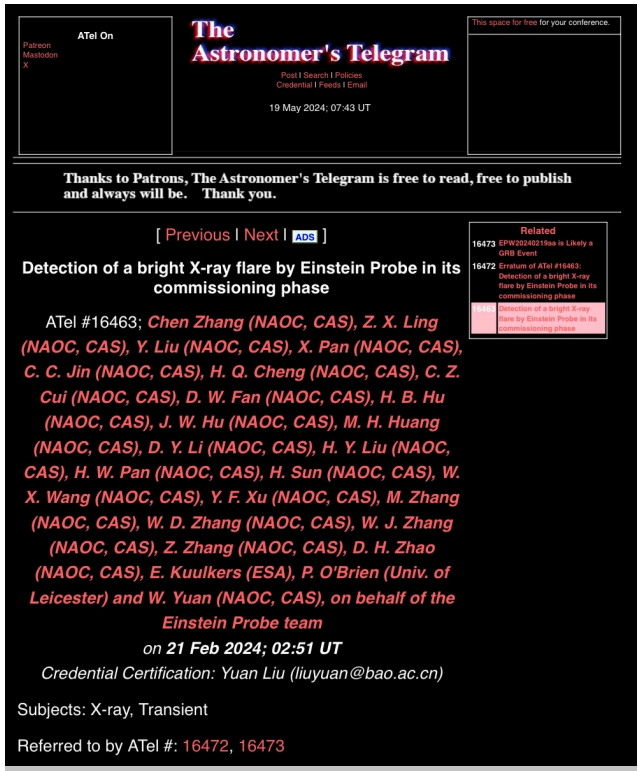


精细的能谱演化

由于此暴极高的亮度，费米卫星数据饱和部分丢失，极目卫星受到大气返照影响，天格卫星成功捕捉完整光变并进行精细的能谱分析。

GRID with Einstein Probe?

Einstein Probe’s successful launch



ATel On

Patreon
Mastodon
X

The Astronomer's Telegram

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Credential | Feeds | Email

19 May 2024; 07:43 UT

This space for free for your conference.

Thanks to Patrons, The Astronomer's Telegram is free to read, free to publish and always will be. Thank you.

[Previous | Next | ADS]

Related
16473 EPW20240219aa is Likely a GRB Event
16472 Errata 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

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

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

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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.
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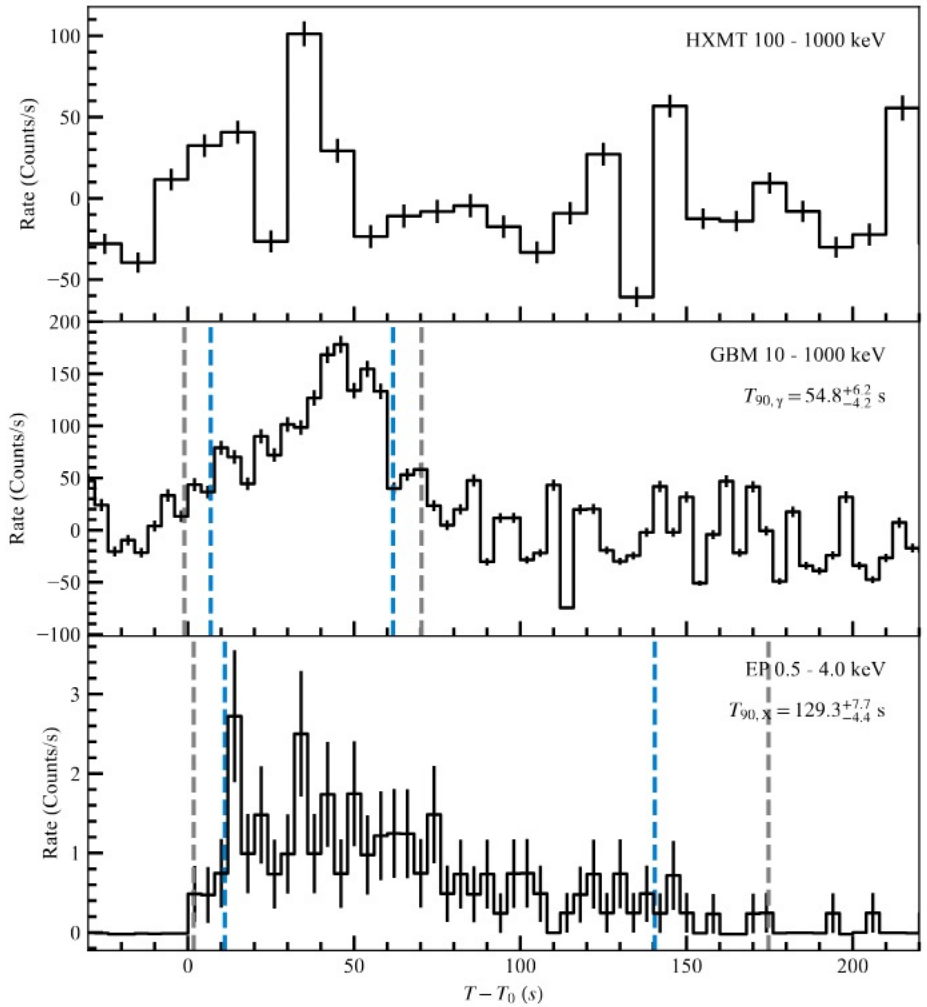
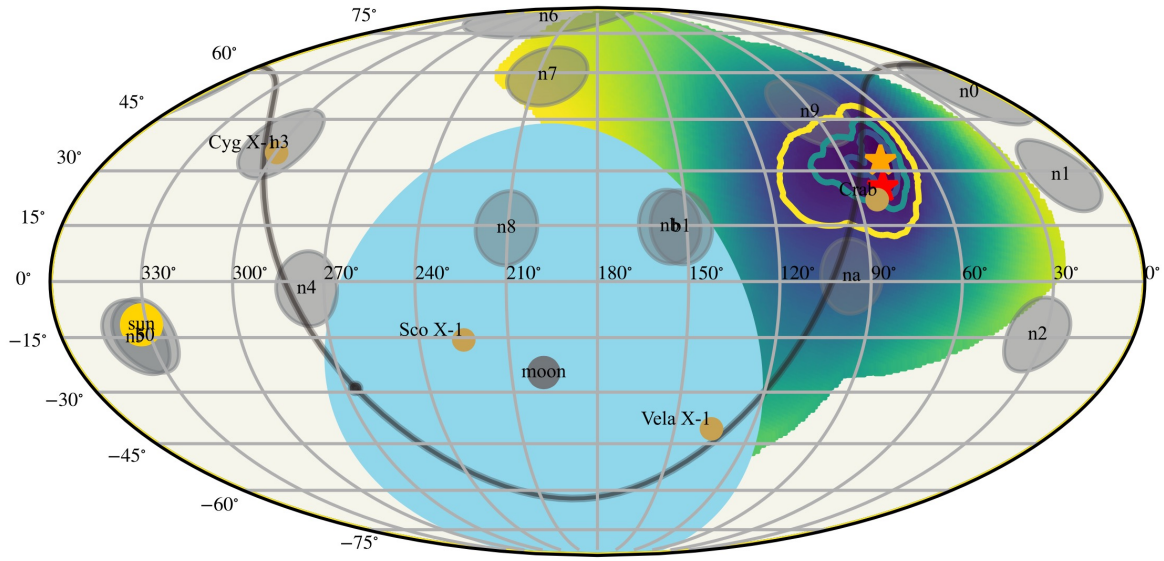
GCN report on GRB 240219A

2024.1.9 → **2024.2.21** → **2024.2.22**

GRID with Einstein Probe?



EP240219a/GRB 240219A (Yin et al., 2024, arxiv: 2407.10156)



如何证认未知的软 X 射线瞬变源？

GRID may help!

清华大学 2024“天格计划”夏令营

推荐阅读

《The Physics of Gamma-Ray Bursts》

Bing Zhang

谢谢！

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