南京大學
NANJING UNIVERSITY

天文與空間科學學院
School of Astronomy and Space Science

多信使天文学时代
新型和特殊伽马射线暴的研究

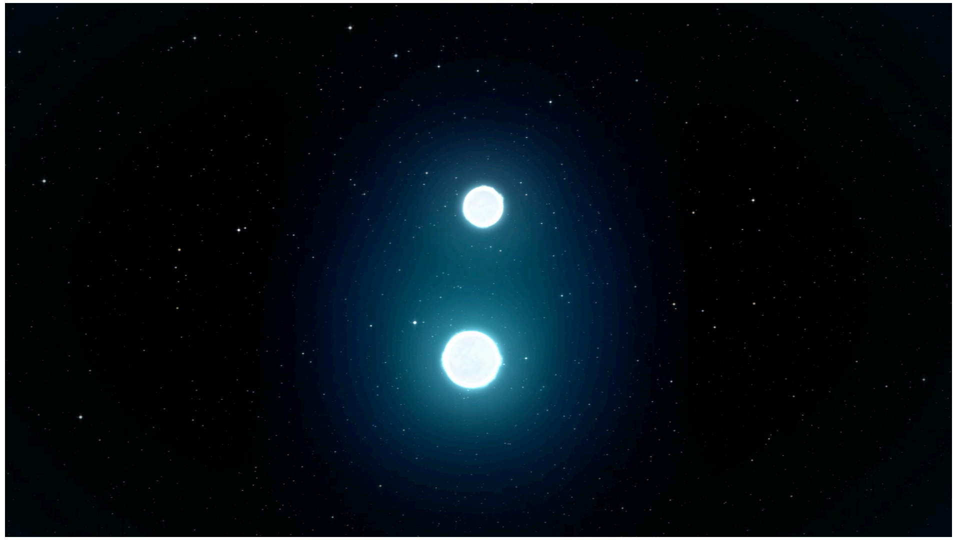
Binbin Zhang

Nanjing University

Online
08/24/2021

Old-Type GRBs

"Expected"



- Collapsar or Merger Hints
- Central Engine (Compact Star + Disk + Jet)
- Prompt Emission: γ -ray , X-ray (sometimes), GeV, EE (seconds ~ hours)
- Afterglow : X-ray, optical, radio, GeV (mintutes ~ hours ~ years)
- SN: optical (~ weeks)
- Kilonova: optical, UV (~ hours)
- Host: optical , radio, other wavelength (~ always)

Unusal & New-Type GRBs

“Old” Type short & long GRBs

- Precursors: all-wavelength
- Prompt Emission: optical, radio, (early) X-ray, γ -ray , GeV, TeV
- Afterglow : (early) X-ray, (early) optical, (deep) optical, radio, GeV
- SN
- Kilonova: optical, UV, (large sample)
- Host: optical , radio , (large sample)
- Neutrinos
- Gravitational Waves
- VHE (e.g., LHAASO observations of GRB 190829A)

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"New-Type" GRBs

- Ultra-Long GRBs (~ hours, all wavelength, all time frames)
- Ultra-Soft GRBs (~ low Ep, thermal spectrum, all wavelength, all time frames)
- X-ray only GRBs (a.k.a. X-ray transient, Xue et al. 2019, Nature)
- GRB related to other unusual sources (e.g., FRBs ? Dai et al.; GWs ;)
- Sub-TeV GRBs
- Sub-threshold GRBs (more interesting if coincidence w/ other messengers/wavelength)
- Temporally or spectrally peculiar GRBs (LL, extra component, etc)
- SGR GF GRB;
- Unknown-Origin GRBs (trouble makers)

Unusal & New-Type GRBs

"Old" Type short & long GRBs

- Precursors: all-wavelength **<==**
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- SN
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- **Gravitational Wave GRBs — 短暴起源的多新使研究、中子星物理**
- **Precursors of GRBs — GRB 的早期物理**
- **Sub-threshold GRBs — 短暴前身星、引力波源的样本全面性**
- **SGR-GF GRBs — 全新物理起源**
- **Unknown-Origin GRBs — 未知新物理**

- **Gravitational Wave GRBs — 短暴起源的多新使研究、中子星物理**
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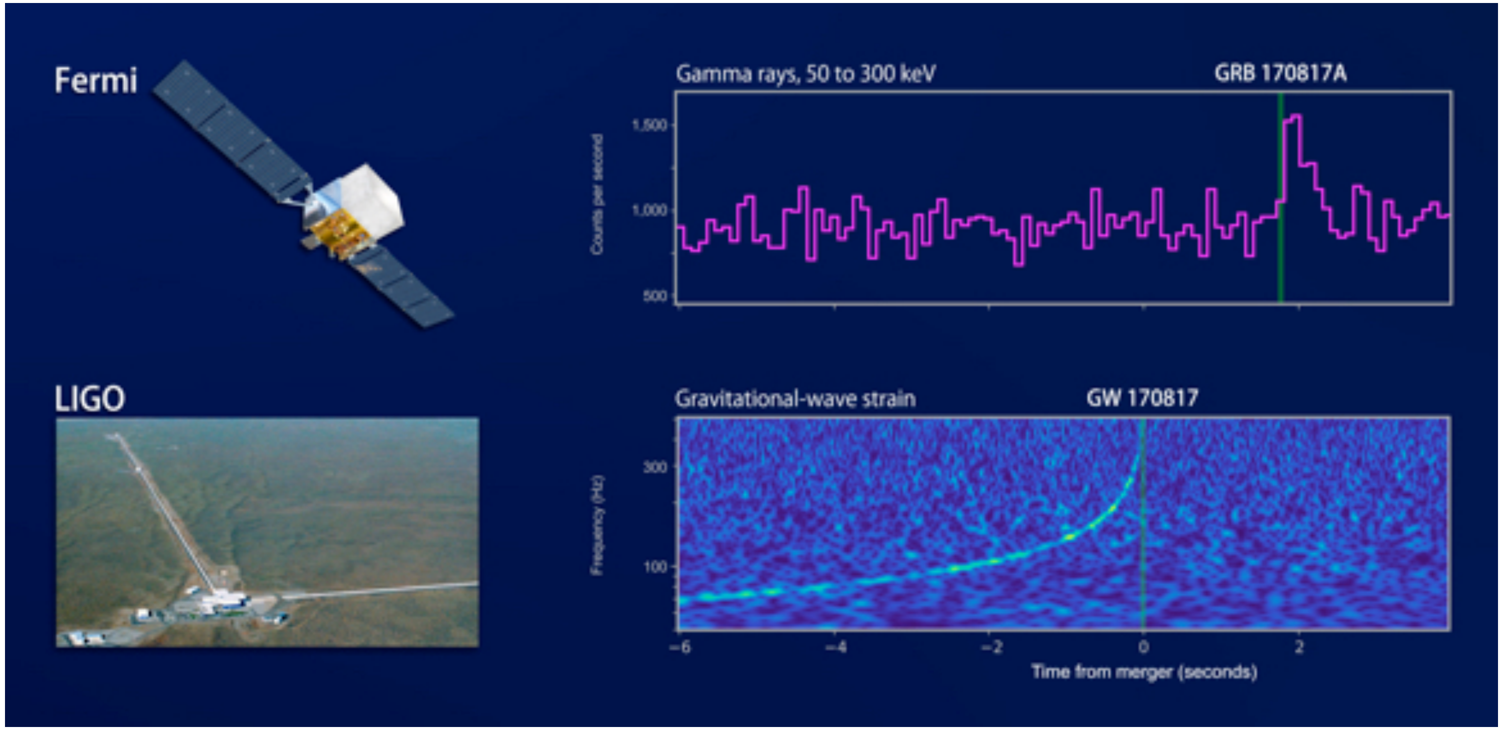
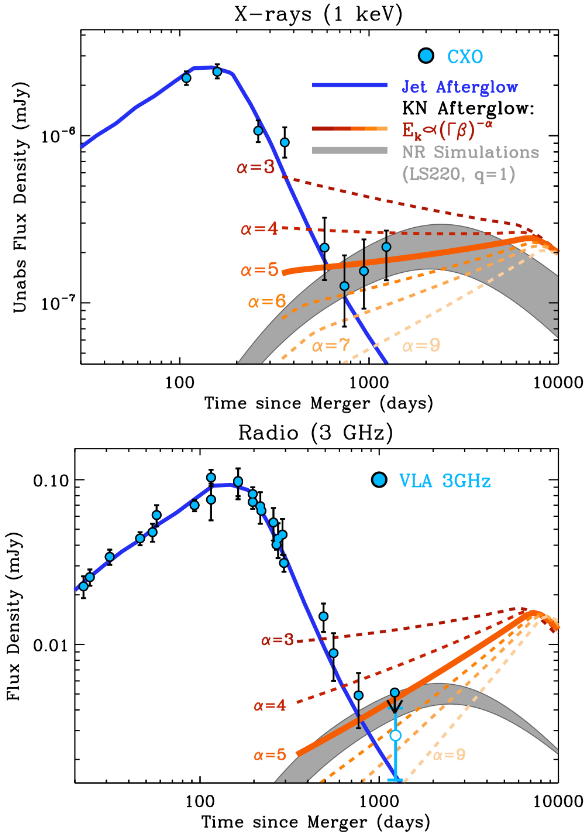
New-Type GRBs

GW GRBs (e.g., **GRB 170817A**)





Fermi, LIGO Team, 2017, PRL
Zhang, B.-B. et al, 2018, Nature Comm, 9, 447

Hajela, et al, 2021, arxiv 2104.02070

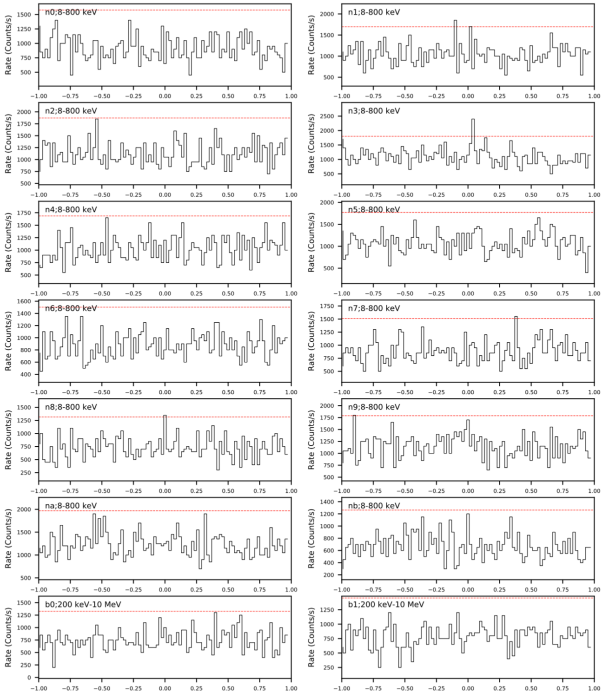
More GW GRBs?

Case	Type	EM	Ref.
GW150914-GBM/ GW150914	BH-BH	very unlikely EM	Connaughton+15
GRB170817A/ GW170817/AT 2017gfo	NS-NS	Definitely Beautiful!	Abbott+17
S190510g	NS-NS	13 optical EM candidtes, NONE confirmed	Andreoni+19a
S190814bv	BH-NS	Deep search yeild nothing confirmed in EM	Andreoni+19b Dobie+19, etc
GW190425z	NS-NS	13 optical candiates, nothing confirmed	Coughlin+19a Antier+19
S190426c, S190510g, S190901ap, S190910h	NS-?	deep search, some candiates, nothing confirmed	Coughlin+19b Goldstein+19
"I-OGC 151030"	NS-NS	found by 3rd party, sub-threshold, high FAR, GW NOT confirmed by LIGO	Nitz+19
GBM-190816	BH-?	Both GW and EM are identified as sub-threshod by LVC/Fermi	GCN Circulars

New-Type GRBs

Sub-threshold GRBs

(dig out a needle in a haystack)

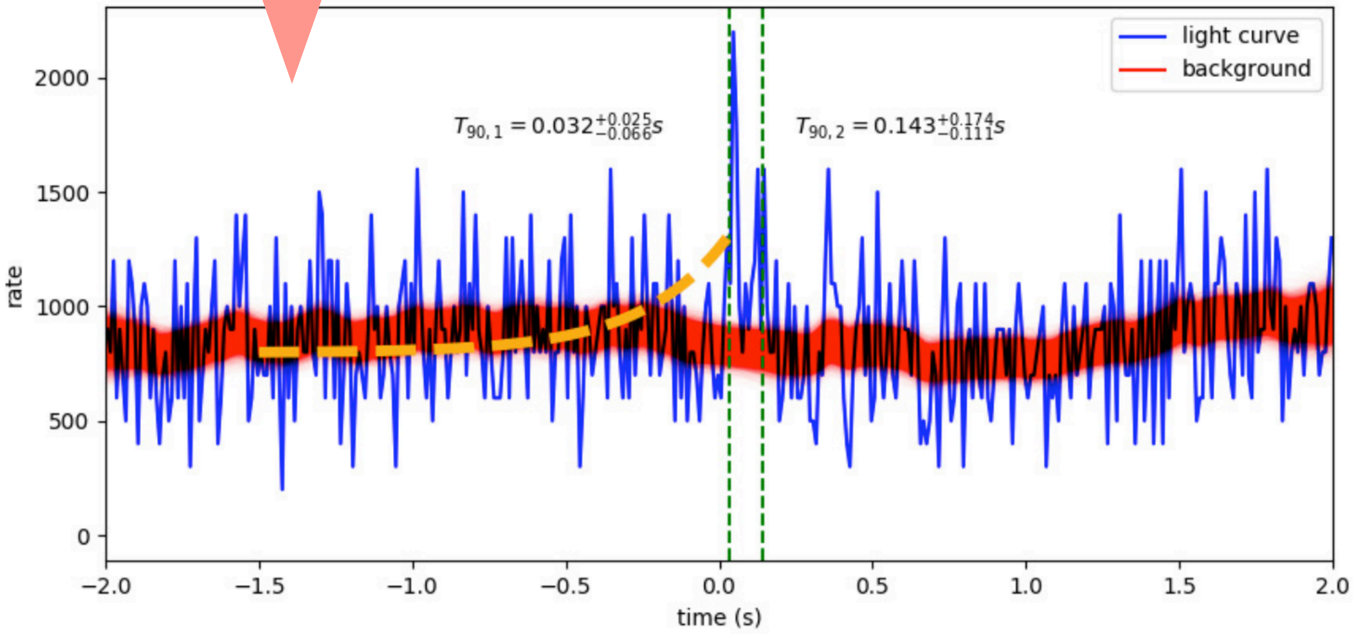


Subthreshold GRBs More interesting w/ GW

GW

可能为第一例中子星-黑洞并合GRB事件

(NS-BH event, 2nd GW-EM association
subject to LIGO/Fermi official confirmation)



Yang, Y.-S, Chand, BBZ et al, 2020, ApJ, 899, 60

How can dig it?

- ✓Prove it is a GRB.
- ✓Assume the GW signal is real (LIGO says so).
- ✓Find what can make it .

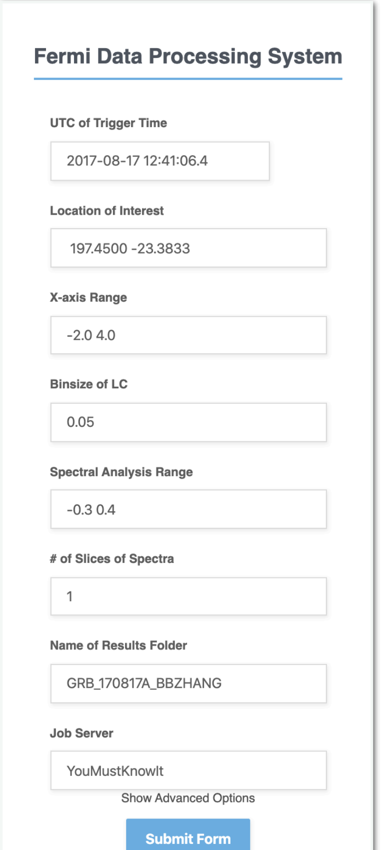
Burst Confirmation

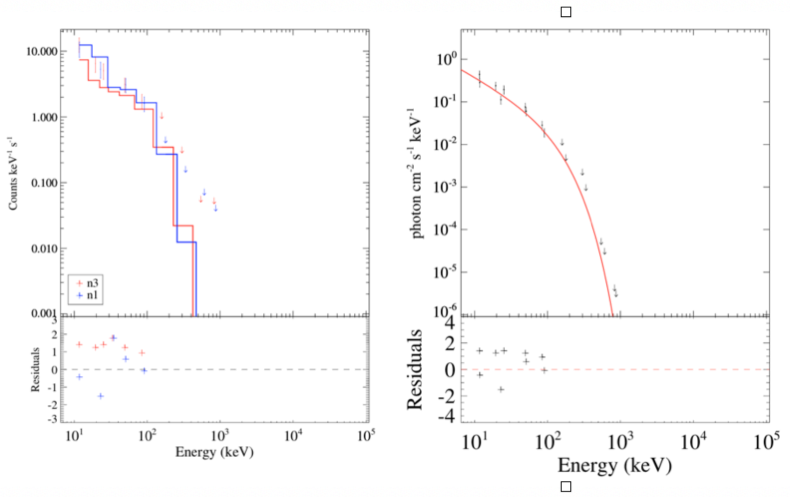
Spectral Analysis

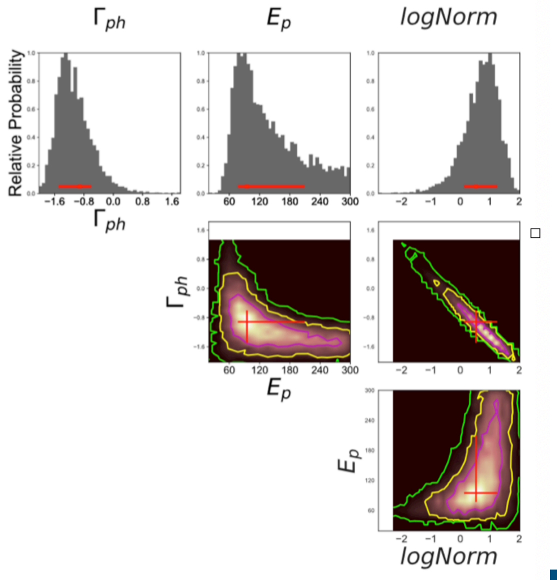
Time Interval		CPL			
t_1	t_2	$\Gamma_{\rm ph}$	$E_{\rm p}$	$logNorm$	PGSTAT/dof
0.032	0.143	$-0.92^{+0.32}_{-0.58}$	$94.84^{+114.64}_{-17.94}$	$0.53^{+0.72}_{-0.41}$	130.1/227

Advanced mission-independent data analysis tools:

Input: Time & Location
Output: All you need
Things Considered: Geometry, Detector Rsp, S/N
Counts Statistics, BKG Modeling, Noise Uncertainties …



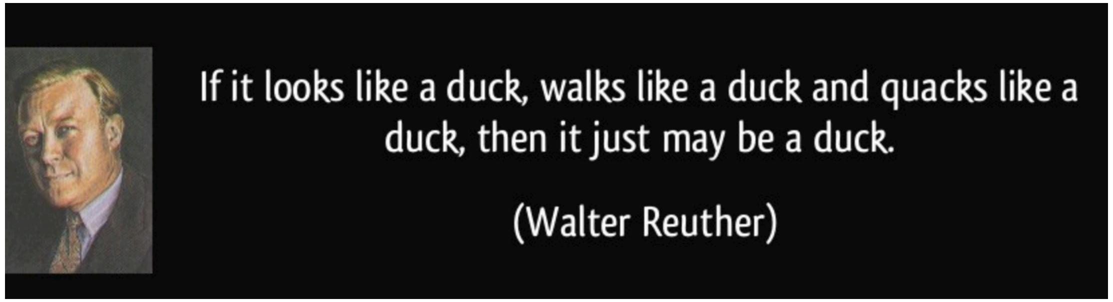


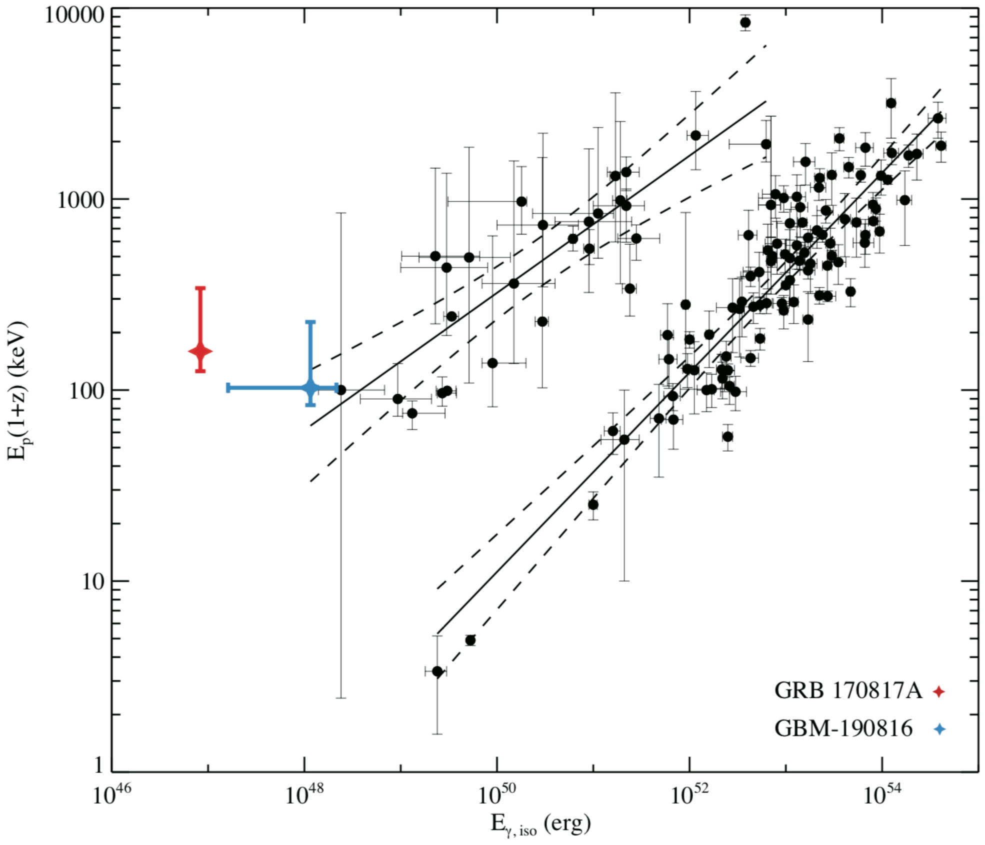


Burst Confirmation

GBM-190816 as a short GRB

Observed Properties	
T_{90} (s)	$0.112^{+0.185}_{-0.085}$
Peak energy E_p (keV)	$94.84^{+114.64}_{-17.94}$
Total fluence($erg\,cm^{-2}$)	$7.38^{+6.35}_{-2.51} \times 10^{-8}$
Distance (Mpc)	$362 +/- 151$
Isotropic energy $E_{\gamma,\mathrm{iso}}$ (erg)	$1.14^{+3.18}_{-0.89} \times 10^{48}$
Luminosity $L_{\gamma,\mathrm{iso}}$ ($erg\,s^{-1}$)	$1.02^{+2.84}_{-0.80} \times 10^{49}$
f parameter	$2.58 +/- 0.37$





POSSIBLE SUB-THRESHOLD GRAVITATIONAL WAVE SIGNAL

Information:

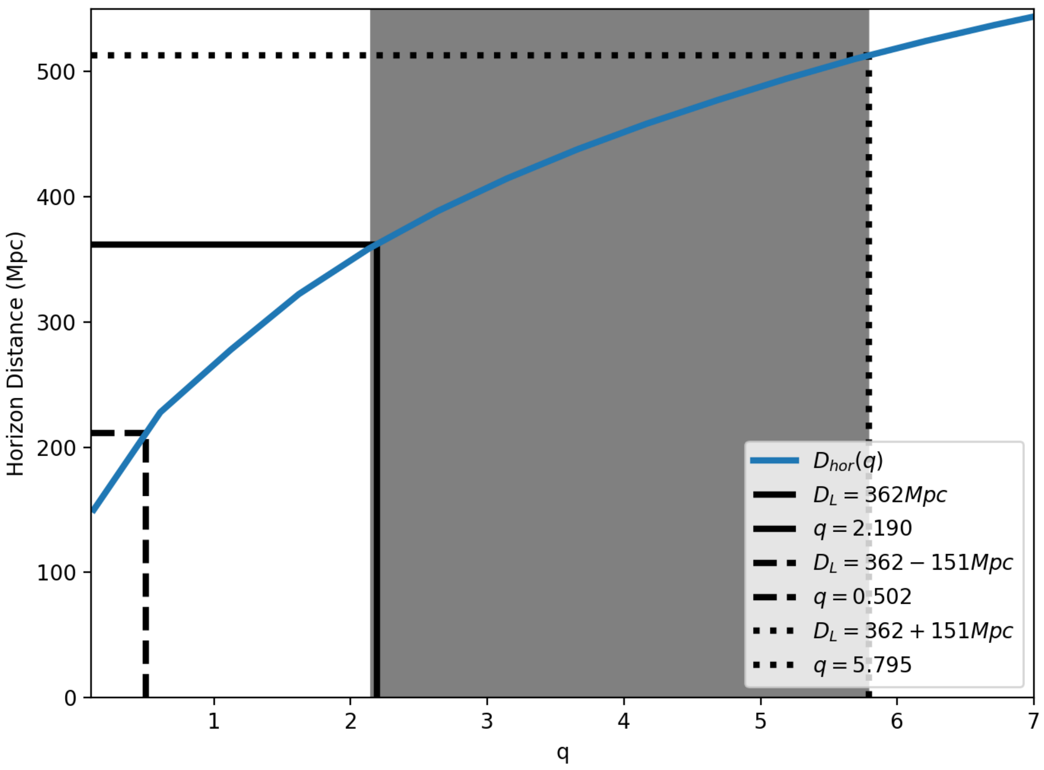
1. L1 and V1 data are available at that time.
2. LVC identified a possible CBC candidate at 2019-08-16 21:22:13.027 UTC.
3. The network S/N of this sub-threshold event is below the threshold of GW analysis pipelines, which is 12.
4. The luminosity distance of the event is constrained to 362±151 Mpc
5. The lighter compact object of this CBC event may have a mass < 3 $M_\odot$

Assumptions:

1. One compact object of this CBC event is an NS with a mass of **1.4 $M_\odot$**
2. The sensitivity of the L1 detector in O3 is twice of that in O1.
3. The **S/N of the event is 8** and mostly contributed by L1.

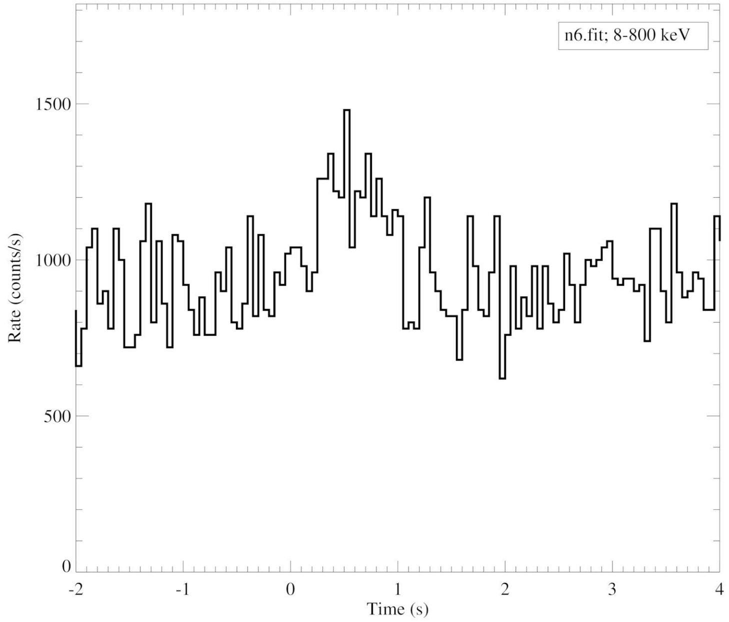
Constraints:

Follow the FINDCHIRP pipeline (Allen et al. 2012). The mass ratio lies in **q ~ [2.142, 5.795]**



GW

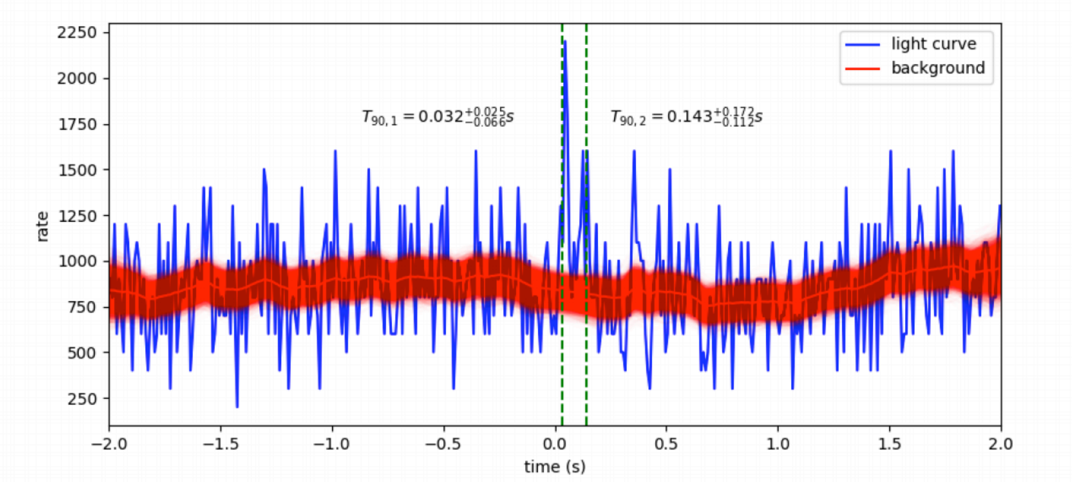
GRB 170817A
Duration: 2 s
Delay: 1.7s



GW

GBM-190816

Duration: 0.1 s
Delay: 1.57s



What can cause the delay?

(1) **Δt_{jet},**

delay time to launch a clean relativistic jet. Includes three parts :

①.The waiting time Δt_{wait} for a central object (BH) to form,

②. The accretion time scale Δt_{acc},

③. time Δt_{clean} for the jet to become clean.

In the case GBM-180916, at least one BH exists in the pre-merger system so Δt_{wait} is 0.

$\Delta t_{clean} \sim 0$ (BH)

Δt_{acc} is typically ~ 10 ms.

So Δt_{jet} is at most 0.01 s.

(2) **Δt_{bo}**

delay time for the jet to break out from the surrounding medium.

For an NS-BH central engine, **Δt_{bo}** is typically **10 ms to 100 ms.**

(3) **Δt_{GRB},**

delay time for the jet to reach the energy dissipation and GRB emission site.

$\Delta t_{GRB} = R/2c\Gamma^2$. <— should mostly account for the delay

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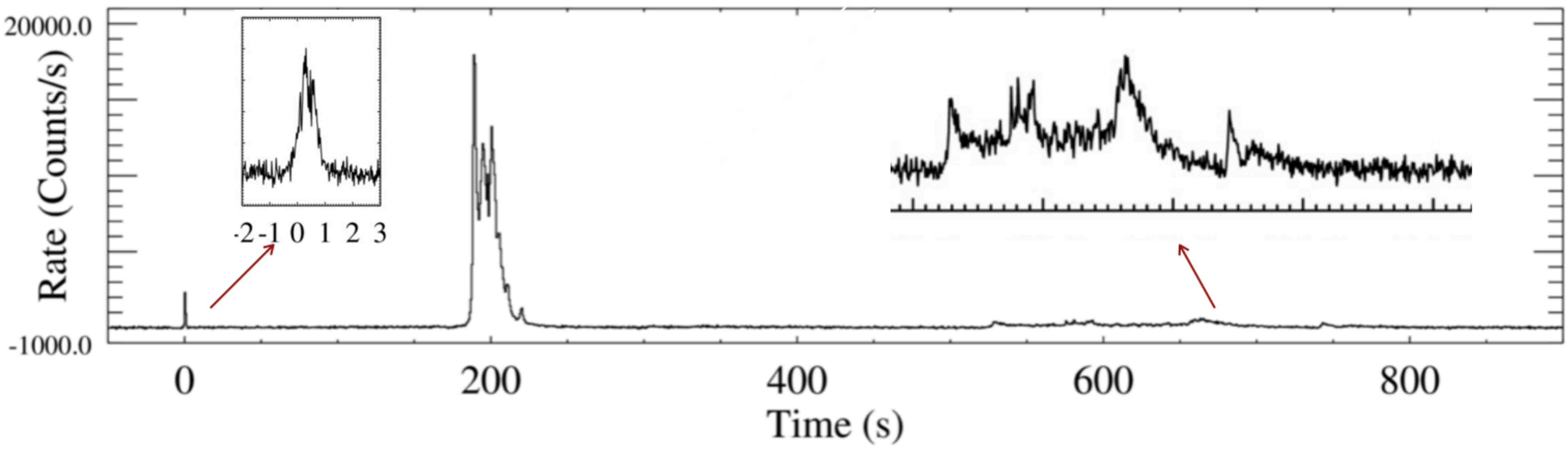
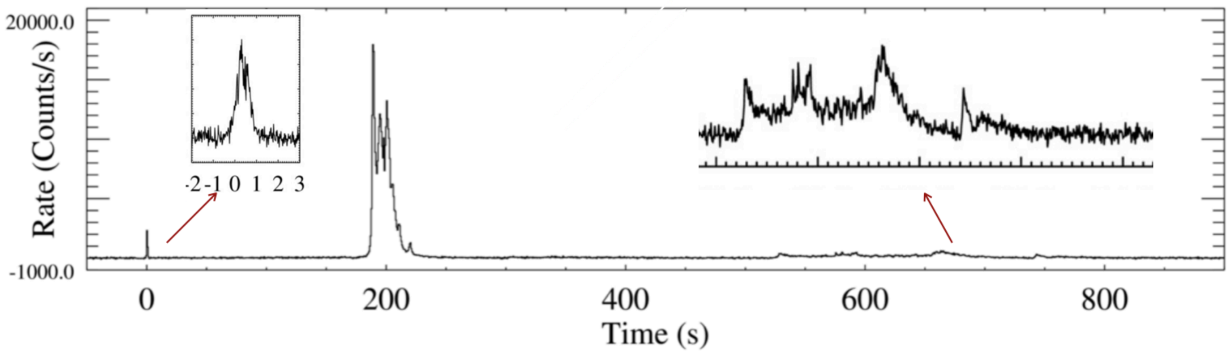
Precursors of GRBs

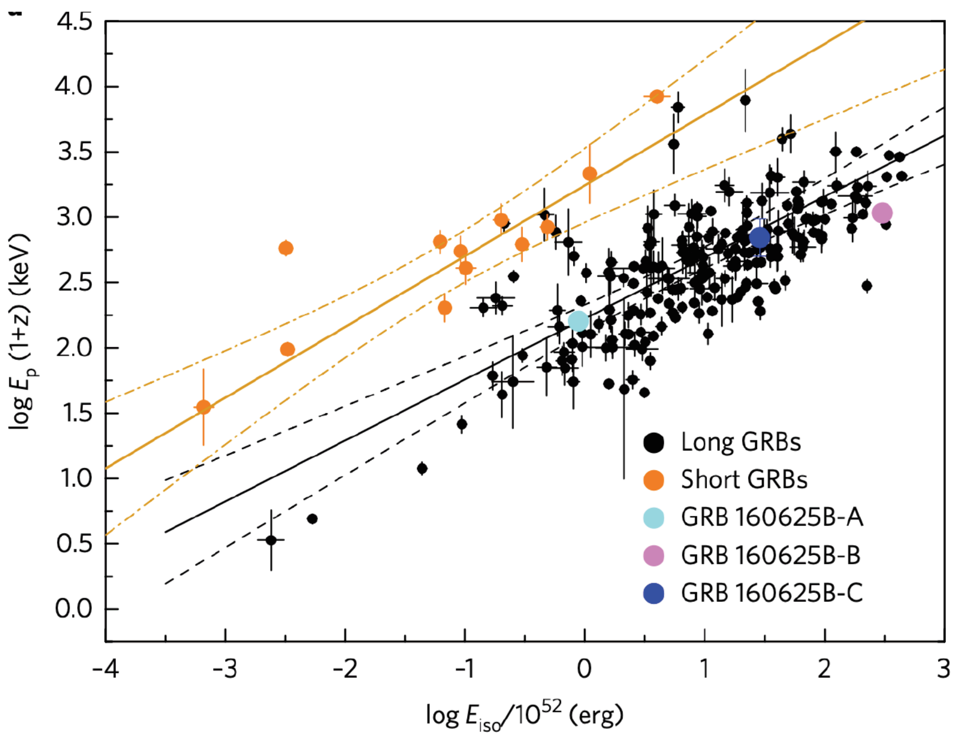


Zhang B.-B. et al 2018 Nature Astronomy

Precursors can be common: photosphere emission is always there….

Precursors of GRBs

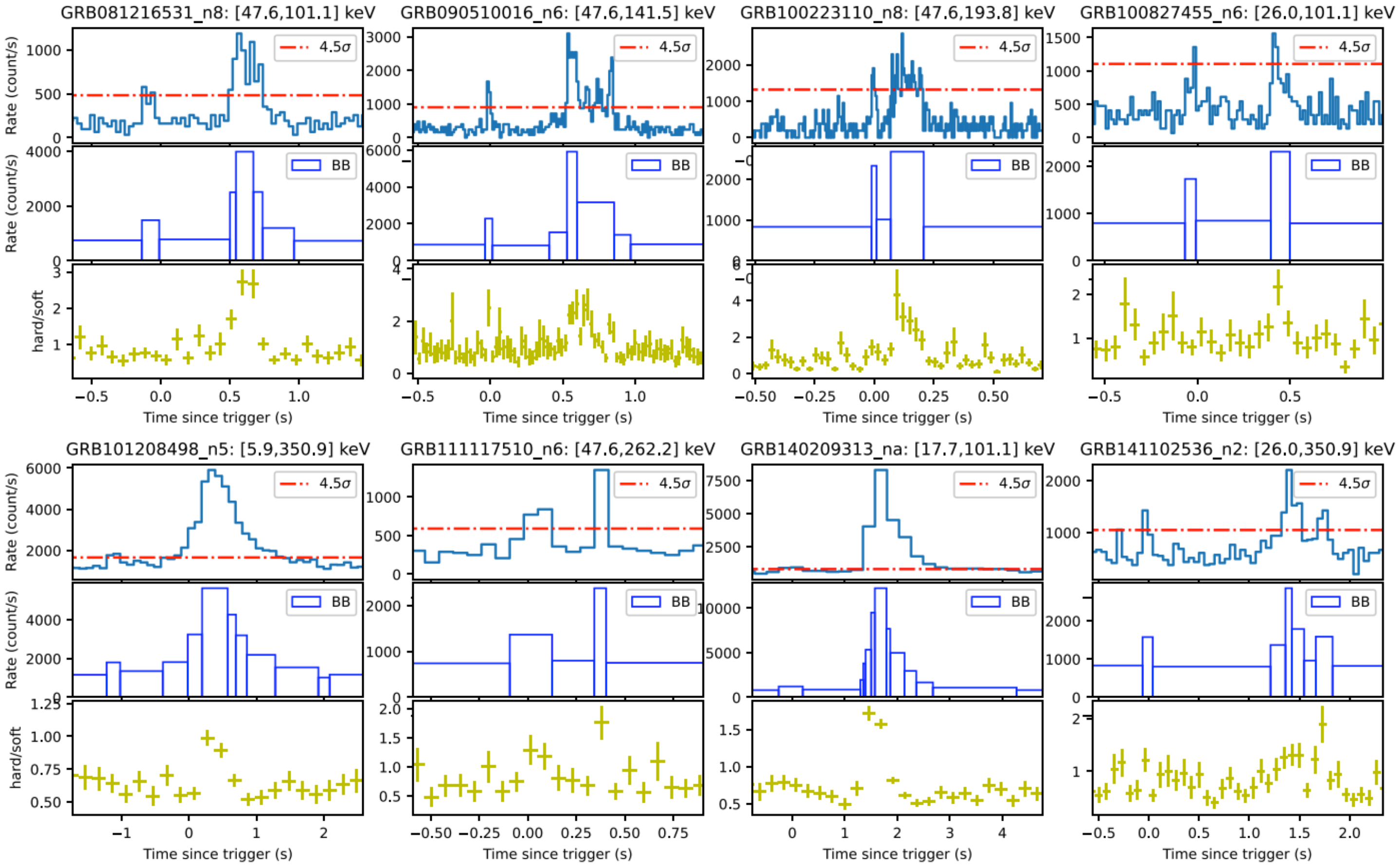




Zhang B.-B. et al 2018 Nature Astronomy

Precursors can be common: photosphere emission is always there….

Precursors in short GRBs



- Found 16 out of 529 sGRB (3%).
- Thermal or Non-Thermal
- Shock breakout, photospheric, magnetospheric
- $\Gamma \sim 30$

Wang, J.-S. … BBZ, …et al. 2020, ApJL

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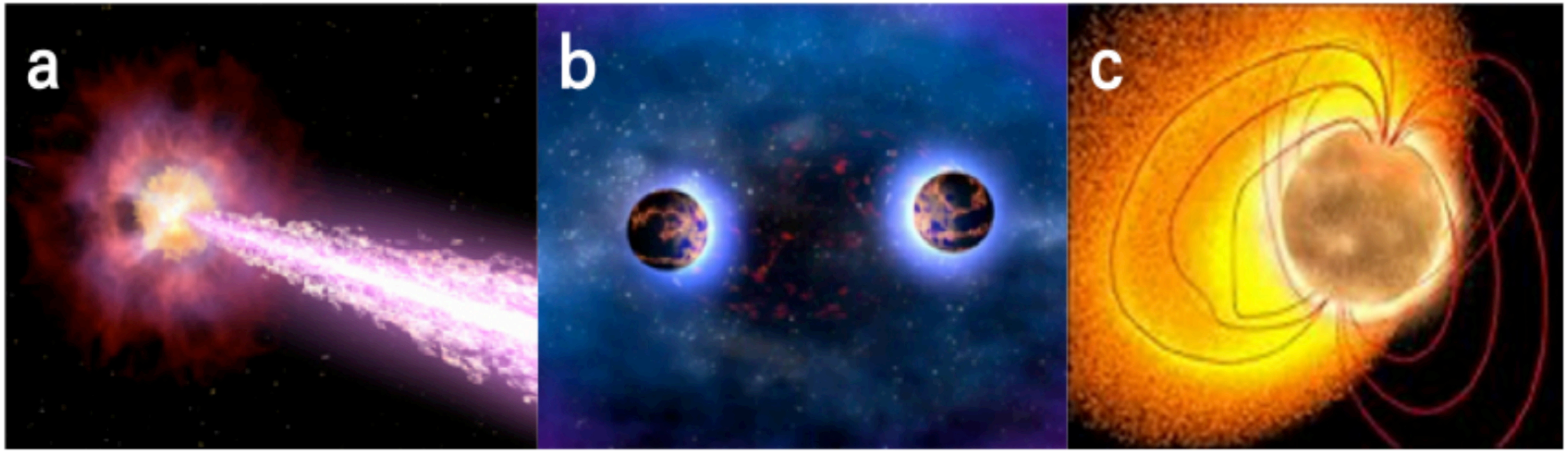
SGR GF GRB 200415A

1st confirmed short GRB that comes from magnetar giant flare

(Not a sGRB from NS-NS, NS-BH merger)



Yang, Jun, Chand, BBZ et al 2020, ApJ, 899,166

SGR GF GRB 200415A

磁星超级耀发的新型伽马射线暴

GRB领域内重要事件（2021年多篇Nature文章；NASA Press Release）

THE ASTROPHYSICAL JOURNAL, 899:106 (11pp), 2020 August 20
https://doi.org/10.3847/1538-4357/aba745

CrossMark

GRB 200415A: A Short Gamma-Ray Burst from a Magnetar Giant Flare?

Jun Yang[1,2], Vikas Chand[1,2], Bin-Bin Zhang[1,2,3], Yu-Han Yang[1,2], Jin-Hang Zou[4], Yi-Si Yang[1,2], Xiao-Hong Zhao[5,6,7], Lang Shao[4], Shao-Lin Xiong[8], Qi Luo[8,9], Xiao-Bo Li[8], Shuo Xiao[8], Cheng-Kui Li[8], Cong-Zhan Liu[8], Jagdish C. Joshi[1,2], Vidushi Sharma[10], Manoneeta Chakraborty[11], Ye Li[12,13], and Bing Zhang[3]

[1] School of Astronomy and Space Science, Nanjing University, Nanjing 210093, People's Republic of China; bbzhang@nju.edu.cn, vikasK2@nju.edu.cn
[2] Key Laboratory of Modern Astronomy and Astrophysics (Nanjing University), Ministry of Education, People's Republic of China
[3] Department of Physics and Astronomy, University of Nevada Las Vegas, NV 89154, USA
[4] College of Physics, Hebei Normal University, Shijiazhuang 050024, People's Republic of China
[5] Yunnan Observatories, Chinese Academy of Sciences, Kunming, People's Republic of China
[6] Center for Astronomical Mega-Science, Chinese Academy of Sciences, Beijing, People's Republic of China
[7] Key Laboratory for the Structure and Evolution of Celestial Objects, Chinese Academy of Sciences, Kunming, People's Republic of China
[8] Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, 19B Yuquan Road, Beijing 100049, People's Republic of China
[9] University of Chinese Academy of Sciences, Chinese Academy of Sciences, Beijing 100049, People's Republic of China
[10] Inter University Centre for Astronomy and Astrophysics, Pune, India
[11] DAASE, Indian Institute of Technology Indore, Khandwa Road, Simrol, Indore 453552, India
[12] Kavli Institute for Astronomy and Astrophysics, Peking University, Beijing 100871, People's Republic of China
[13] Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008, People's Republic of China

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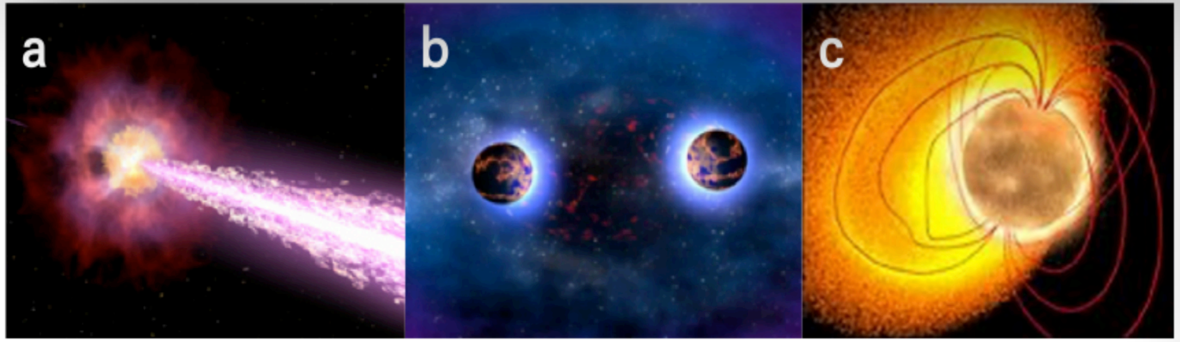

Article

Rapid spectral variability of a giant flare from a magnetar in NGC 253

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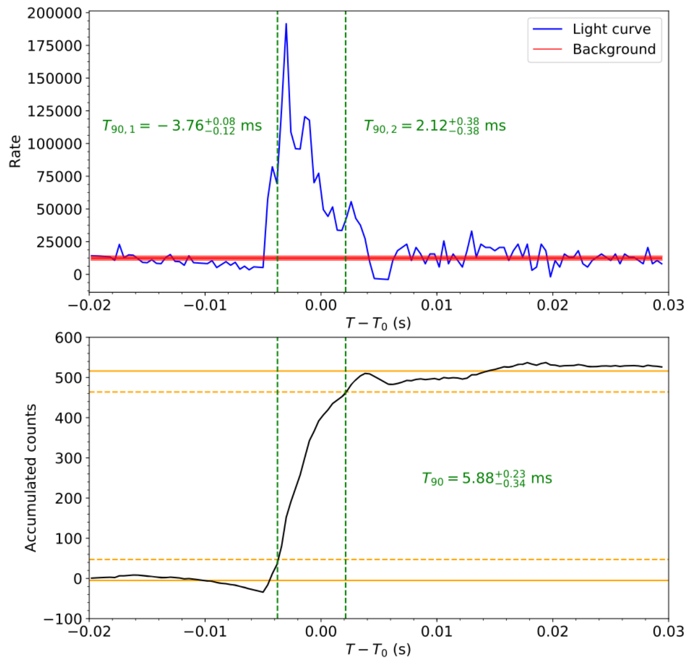
Check for updates

O. J. Roberts[1]✉, P. Veres[2]✉, M. G. Baring[3]✉, M. S. Briggs[2,4], C. Kouveliotou[5,6], E. Bissaldi[7,8]✉, G. Younes[5,6], S. I. Chastain[5,6], J. J. DeLaunay[9], D. Huppenkothen[10], A. Tohuvavohu[11], P. N. Bhat[2,4], E. Göğüş[12], A. J. van der Horst[5,6], J. A. Kennea[13], D. Kocevski[14], J. D. Linford[15], S. Guiriec[5,6,16], R. Hamburg[2,4], C. A. Wilson-Hodge[14] & E. Burns[17]

Magnetars are neutron stars with extremely strong magnetic fields (10^{13} to 10^{15} gauss)[1,2], which episodically emit X-ray bursts approximately 100 milliseconds long and with energies of 10^{40} to 10^{41} erg. Occasionally, they also produce extremely bright and energetic giant flares, which begin with a short (roughly 0.2 seconds), intense flash, followed by fainter, longer-lasting emission that is modulated by the spin period of the magnetar[3,4] (typically 2 to 12 seconds). Over the past 40 years, only three such flares have been observed in our local group of galaxies[3–6], and in all cases the extreme intensity of the flares caused the detectors to saturate. It has been proposed that extragalactic giant flares are probably a subset[7–11] of short γ-ray bursts, given that the sensitivity of current instrumentation prevents us from detecting the pulsating tail, whereas the initial bright flash is readily observable out to distances of around 10 to 20 million parsecs. Here we report X-ray and γ-ray observations of the γ-ray burst GRB 200415A, which has a rapid onset, very fast time variability, flat spectra and substantial sub-millisecond spectral evolution. These attributes match well with those expected for a giant flare from an extragalactic magnetar[12], given that GRB 200415A is directionally associated[13] with the galaxy NGC 253 (roughly 3.5 million parsecs away). The detection of three-megaelectronvolt photons provides evidence for the relativistic motion of the emitting plasma. Radiation from such rapidly moving gas around a rotating magnetar may have generated the rapid spectral evolution that we observe.

Yang. J, Vikas Chanda, Zhang, B.-B. et al. , 2020，ApJ, .899, 106

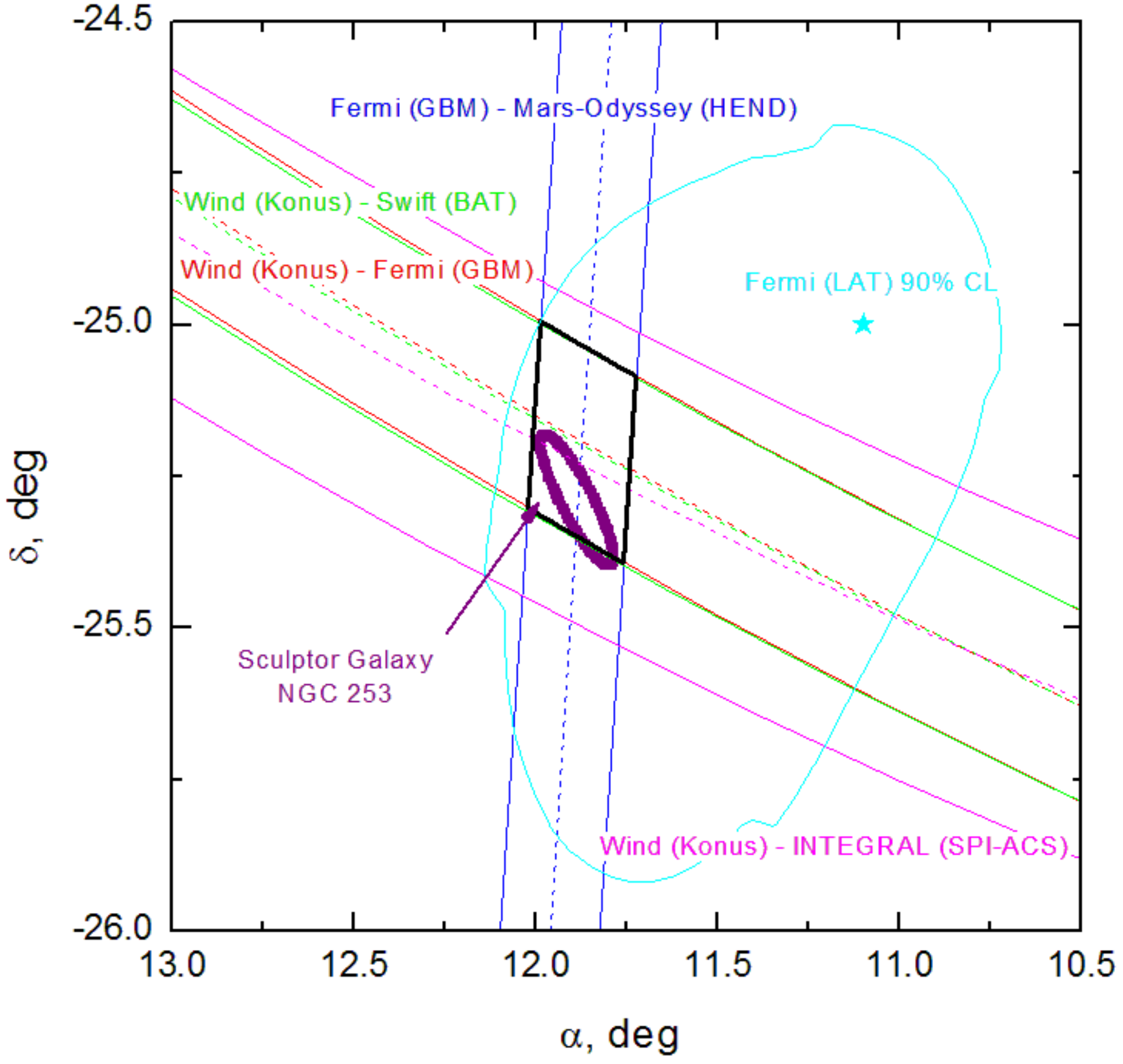
Direct Hint



✓Spatially associated with a nearby galaxy @ 3.5 Mpc

✓Short, Bright, High E_{peak} , LAT detection

Localization



IPN location to the Sculptor galaxy : 5.7 arcmin

Chance probability: 1.3×10^{-5} **(Bloom et al 2002)**

Distance of Sculptor galaxy (NGC 253): 3.5 Mpc

Giant Flare GRBs : Previous Attempts

Vol 438|15 December 2005|doi:10.1038/nature04310 nature

LETTERS

An origin in the local Universe for some short γ-ray bursts

N. R. Tanvir[1], R. Chapman[1], A. J. Levan[1] & R. S. Priddey[1]

GRB 070201: A POSSIBLE SOFT GAMMA-RAY REPEATER IN M31[1]

E. O. Ofek,[2] M. Muno,[2] R. Quimby,[2] S. R. Kulkarni,[2] H. Stiele,[3] W. Pietsch,[3] E. Nakar,[2] A. Gal-Yam,[4] A. Rau,[2] P. B. Cameron,[2] S. B. Cenko,[2] M. M. Kasliwal,[2] D. B. Fox,[5] P. Chandra,[6,7] A. K. H. Kong,[8,9] and R. Barnard[10]

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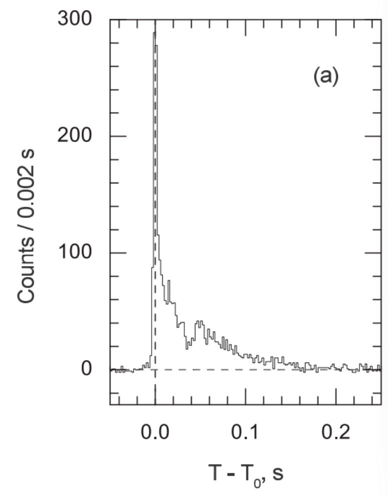
Published: January 2007

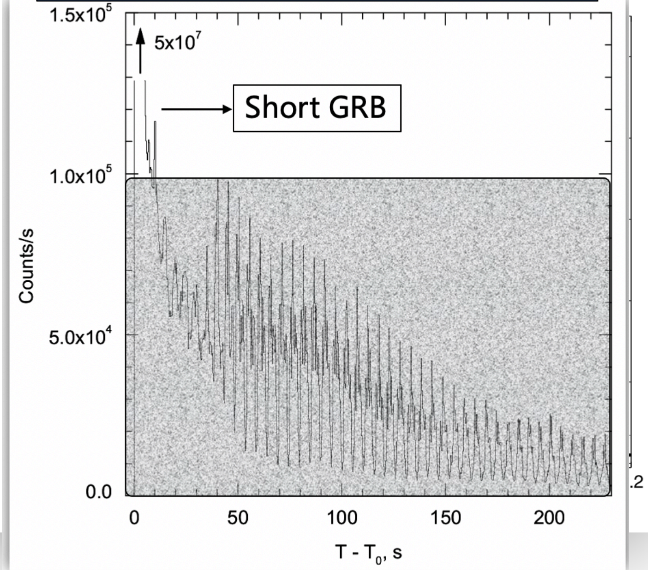
On the possibility of identifying the short hard burst GRB 051103 with a giant flare from a soft gamma repeater in the M81 group of galaxies

D. D. Frederiks, V. D. Palshin, R. L. Aptekar, S. V. Golenetskii, T. L. Cline & E. P. Mazets

Astronomy Letters **33**, 19–24(2007) | Cite this article



GF of SGR 1900+14, Mazets et al. 1999



NO Smoking Gun!

GRB 200415A: unprecedented data and smoking guns!

The Astrophysical Journal, 899:106 (11pp), 2020 August 20 https://doi.org/10.3847/1538-4357/aba745

CrossMark

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[1] School of Astronomy and Space Science, Nanjing University, Nanjing 210093, People's Republic of China; bbzhang@nju.edu.cn, vikasK2@nju.edu.cn

[2] Key Laboratory of Modern Astronomy and Astrophysics (Nanjing University), Ministry of Education, People's Republic of China

[3] Department of Physics and Astronomy, University of Nevada Las Vegas, NV 89154, USA

[4] College of Physics, Hebei Normal University, Shijiazhuang 050024, People's Republic of China

[5] Yunnan Observatories, Chinese Academy of Sciences, Kunming, People's Republic of China

[6] Center for Astronomical Mega-Science, Chinese Academy of Sciences, Beijing, People's Republic of China

[7] Key Laboratory for the Structure and Evolution of Celestial Objects, Chinese Academy of Sciences, Kunming, People's Republic of China

[8] Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, 19B Yuquan Road, Beijing 100049, People's Republic of China

[9] University of Chinese Academy of Sciences, Chinese Academy of Sciences, Beijing 100049, People's Republic of China

[10] Inter University Centre for Astronomy and Astrophysics, Pune, India

[11] DAASE, Indian Institute of Technology Indore, Khandwa Road, Simrol, Indore 453552, India

[12] Kavli Institute for Astronomy and Astrophysics, Peking University, Beijing 100871, People's Republic of China

[13] Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008, People's Republic of China

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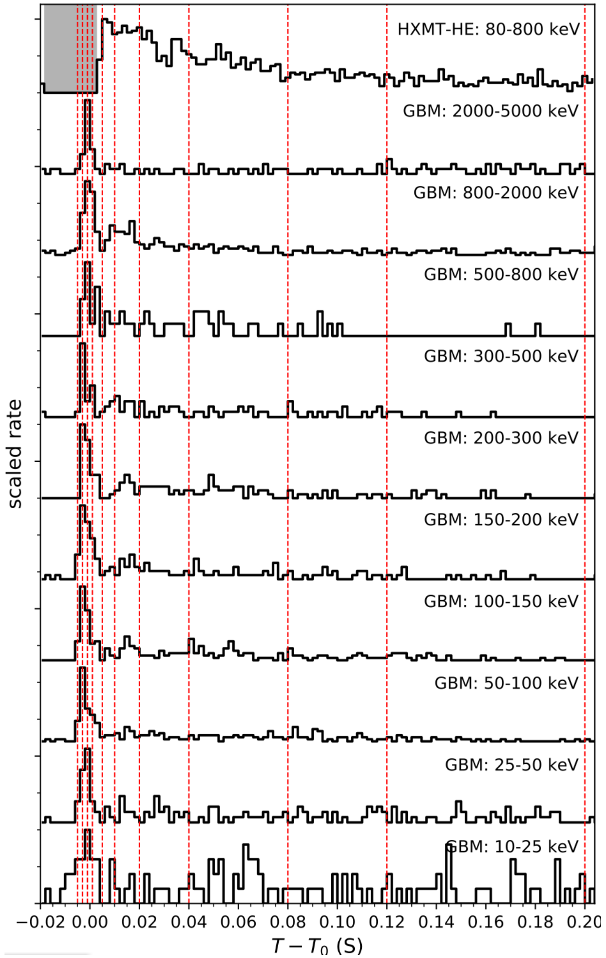
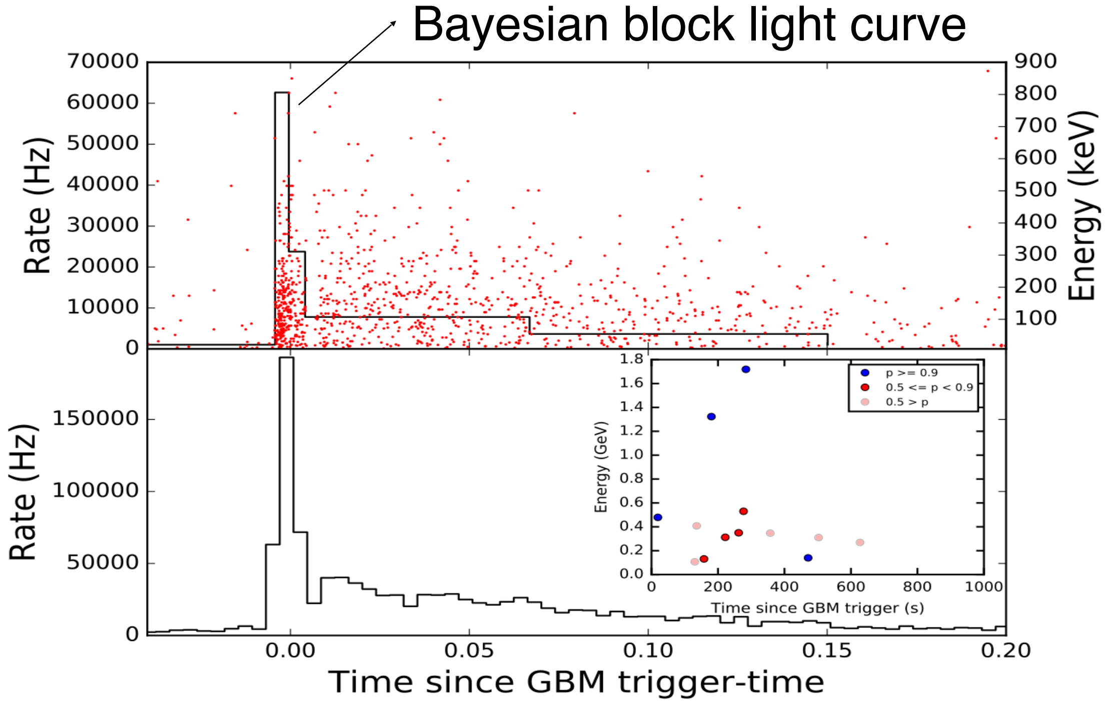
GRB 200415A: Light Curve





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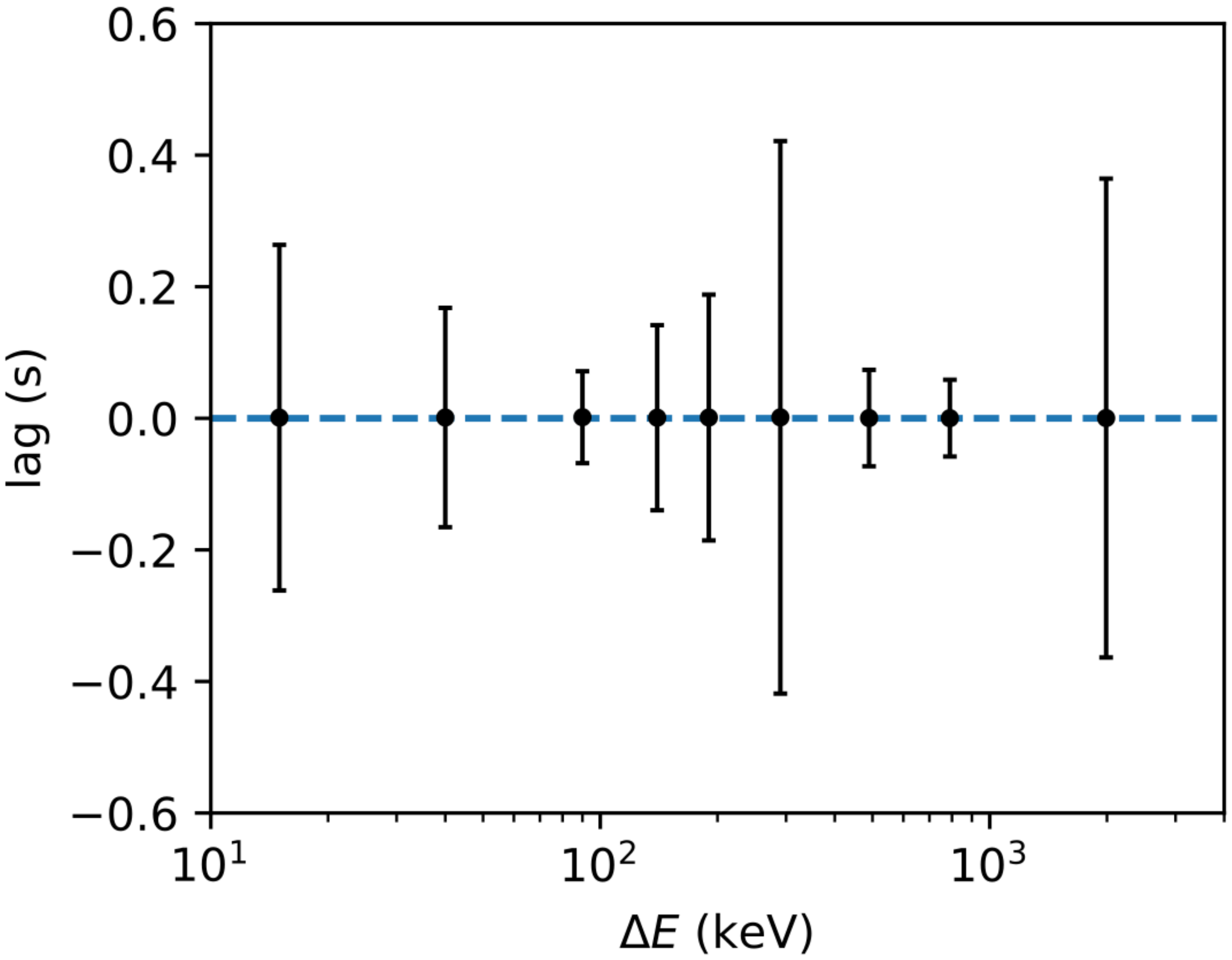
GRB 200415A: Tiny Lags



Emission Region should be one-time fireball-like.

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GRB 200415A: Time-Dependent Spectral Analysis

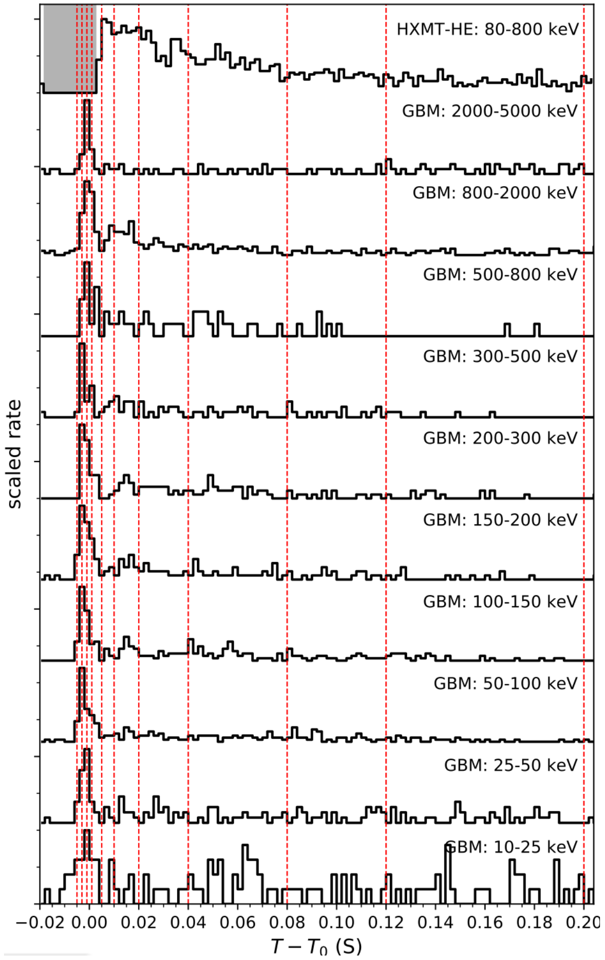

Table 1
Both Time-integrated and Time-dependent Spectral Fittings of GRB 200415A

Time Intervals (t_1, t_2) (s)	Best Model	Flux (erg cm^{-2} s^{-1})	mBB Parameters kT_{min} (keV)	kT_{max} (keV)	m	pgstat/dof	BIC
(−0.005, 0.005)	mBB	$4.32^{+0.66}_{-0.62} \times 10^{-4}$	$39.40^{+6.25}_{-6.15}$	$807.00^{+123.29}_{-113.78}$	$-0.33^{+0.17}_{-0.15}$	278.5/350	302.01
(0.005, 0.200)	CPL	$2.79^{+0.32}_{-0.27} \times 10^{-5}$	$27.75^{+15.31}_{-5.48}$	$399.87^{+81.42}_{-43.70}$	$0.38^{+0.17}_{-0.40}$	277.8/350	301.28
(−0.005, 0.200)	mBB	$4.53^{+0.45}_{-0.44} \times 10^{-5}$	$34.29^{+8.88}_{-4.79}$	$542.61^{+71.79}_{-54.22}$	$-0.00^{+0.15}_{-0.23}$	279.9/350	303.34
(−0.005, −0.003)	CPL	$1.99^{+0.50}_{-0.39} \times 10^{-4}$	$43.32^{+11.64}_{-3.98}$	$402.21^{+814.98}_{-102.98}$	$-1.18^{+0.31}_{-0.58}$	192.1/350	215.55
(−0.003, −0.001)	mBB	$4.10^{+1.58}_{-0.93} \times 10^{-4}$	$47.96^{+13.75}_{-5.94}$	$539.31^{+501.25}_{-84.08}$	$-0.85^{+0.22}_{-0.57}$	208.5/350	231.98
(−0.001, 0.001)	CPL	$6.61^{+2.19}_{-1.66} \times 10^{-4}$	$42.29^{+44.52}_{-4.45}$	$789.59^{+343.87}_{-118.46}$	$0.45^{+0.20}_{-0.67}$	221.1/350	244.58
(0.001, 0.005)	BB	$1.79^{+0.46}_{-0.38} \times 10^{-4}$	$94.05^{+1.31}_{-29.75}$	$533.12^{+257.78}_{-162.44}$	$-0.76^{+1.25}_{-0.30}$	206.2/350	229.64
(0.005, 0.010)	BB	$1.17^{+0.37}_{-0.32} \times 10^{-4}$	$68.85^{+26.53}_{-19.77}$	$298.35^{+281.16}_{-60.56}$	$1.64^{+0.00}_{-1.81}$	177.1/350	200.60
(0.010, 0.020)	CPL	$1.16^{+0.26}_{-0.20} \times 10^{-4}$	$77.42^{+16.68}_{-18.98}$	$375.41^{+225.17}_{-19.63}$	$0.63^{+0.18}_{-1.22}$	218.4/350	241.91
(0.020, 0.040)	BB	$5.07^{+0.86}_{-0.75} \times 10^{-5}$	$98.56^{+1.44}_{-38.76}$	$273.80^{+198.59}_{-1.52}$	$0.81^{+0.18}_{-1.68}$	194.2/350	217.66
(0.040, 0.080)	CPL	$3.76^{+0.66}_{-0.54} \times 10^{-5}$	$34.33^{+43.53}_{-18.48}$	$269.64^{+187.74}_{-1.92}$	$0.81^{+0.43}_{-1.65}$	257.4/350	280.83
(0.080, 0.120)	BB	$8.38^{+1.80}_{-1.48} \times 10^{-6}$	$48.89^{+16.36}_{-5.89}$	$221.49^{+697.44}_{-61.68}$	$-0.83^{+0.95}_{-0.96}$	195.2/350	218.67
(0.120, 0.200)	PL	$3.78^{+2.93}_{-2.48} \times 10^{-6}$			Unconstrained		

Time Intervals (t_1, t_2) (s)	CPL Parameters Γ_{ph}	E_p (keV)	pgstat/dof	BIC	BB Parameters kT (keV)	pgstat/dof	BIC
(−0.005, 0.005)	$-0.28^{+0.06}_{-0.08}$	$1118.09^{+113.39}_{-75.49}$	300.2/351	317.79	$140.45^{+8.48}_{-6.83}$	458.4/352	470.10
(0.005, 0.200)	$-0.01^{+0.09}_{-0.08}$	$826.43^{+59.65}_{-52.00}$	279.1/351	296.68	$143.09^{+5.27}_{-5.38}$	385.3/352	397.05
(−0.005, 0.200)	$-0.14^{+0.06}_{-0.06}$	$926.68^{+51.78}_{-52.33}$	292.3/351	309.92	$142.12^{+4.36}_{-4.03}$	533.5/352	545.27
(−0.005, −0.003)	$0.36^{+0.29}_{-0.31}$	$393.53^{+72.77}_{-38.06}$	196.6/351	214.18	$82.27^{+9.69}_{-6.53}$	205.5/352	217.19
(−0.003, −0.001)	$0.03^{+0.22}_{-0.18}$	$607.43^{+109.26}_{-75.55}$	217.7/351	235.26	$97.81^{+10.26}_{-6.84}$	237.5/352	249.27
(−0.001, 0.001)	$-0.00^{+0.26}_{-0.16}$	$1688.27^{+304.76}_{-224.37}$	222.6/351	240.22	$299.57^{+0.40}_{-42.39}$	241.2/352	252.97
(0.001, 0.005)	$0.60^{+0.46}_{-0.26}$	$857.35^{+134.64}_{-132.59}$	208.6/351	226.25	$182.53^{+27.82}_{-18.18}$	212.4/352	224.10
(0.005, 0.010)	$1.67^{+0.88}_{-0.68}$	$847.03^{+198.13}_{-121.32}$	176.4/351	194.05	$233.18^{+32.22}_{-29.92}$	177.0/352	188.73
(0.010, 0.020)	$0.53^{+0.30}_{-0.20}$	$907.19^{+99.54}_{-89.61}$	220.4/351	238.05	$202.23^{+21.71}_{-14.30}$	227.9/352	239.66
(0.020, 0.040)	$0.63^{+0.38}_{-0.20}$	$743.53^{+74.67}_{-75.94}$	194.6/351	212.19	$168.98^{+15.06}_{-12.12}$	198.8/352	210.55
(0.040, 0.080)	$0.31^{+0.23}_{-0.16}$	$676.90^{+66.68}_{-58.29}$	257.9/351	275.50	$139.89^{+10.02}_{-7.78}$	273.9/352	285.62
(0.080, 0.120)	$0.65^{+0.52}_{-0.35}$	$374.23^{+63.24}_{-46.83}$	196.4/351	214.00	$85.80^{+10.20}_{-7.34}$	199.0/352	210.70
(0.120, 0.200)		Unconstrained				Unconstrained	

Note. The CPL model can be expressed as $N(E) = AE^{\Gamma_{ph}} \exp[-E(2 + \Gamma_{ph})/E_p]$. The PL model gives an acceptable fit in the time slice between $T_0 + 0.12$ and $T_0 + 0.20$ s: $\Gamma_{ph} = -1.44^{+0.11}_{-0.28}$, pgstat/dof = 179.2/352, BIC = 190.96. Flux is derived based on the best model within 10–10,000 keV for each slice. Here the errors correspond to the 1σ credible intervals.

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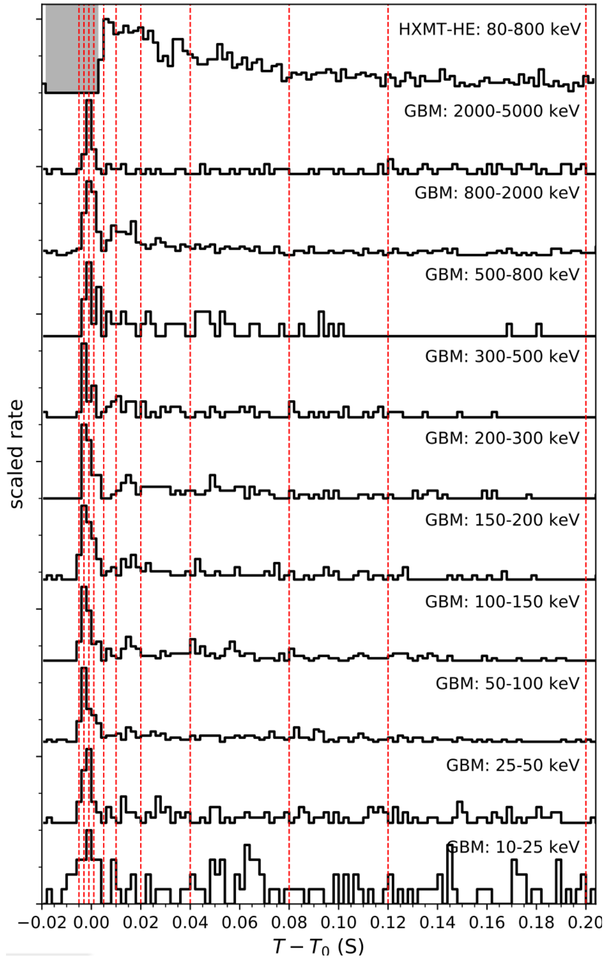
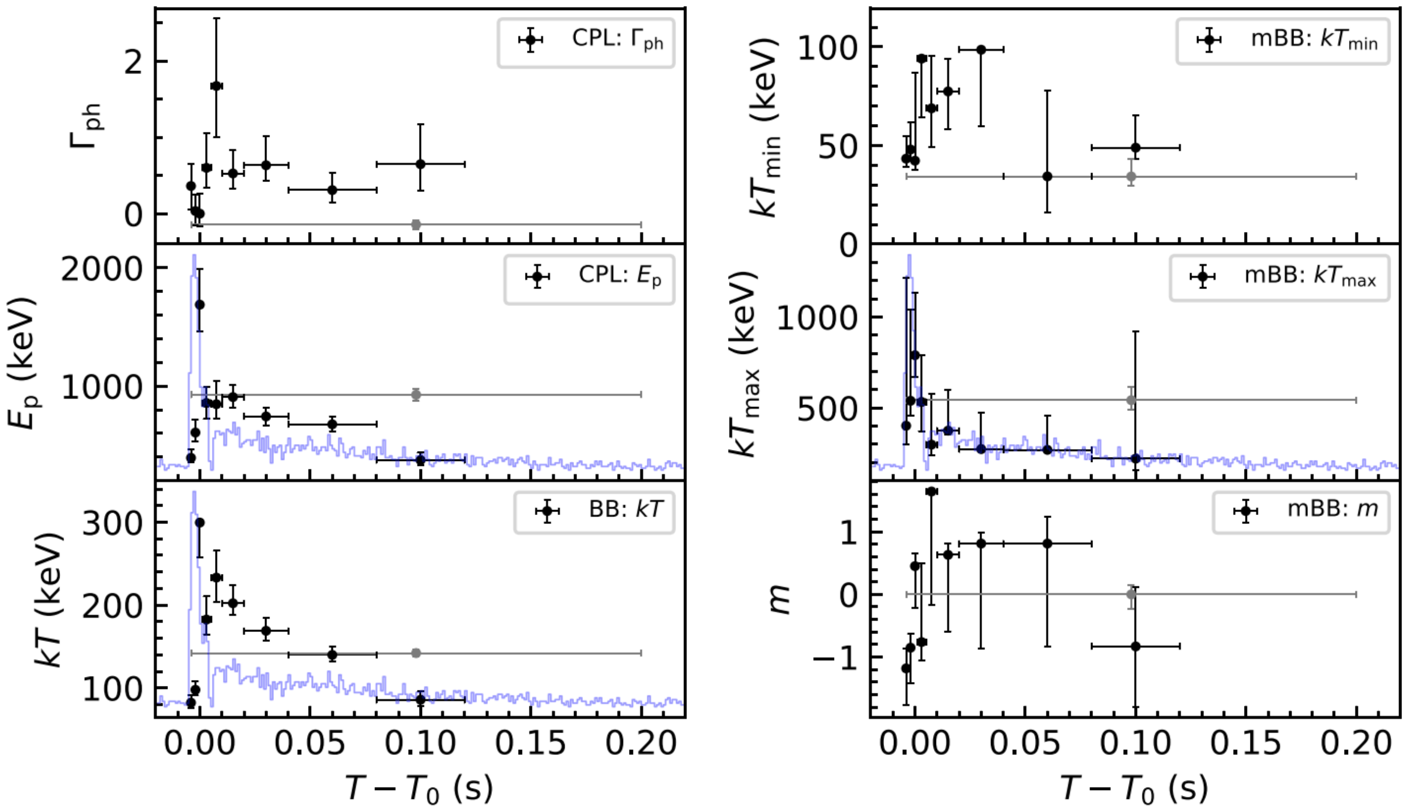
GRB 200415A: Time-Dependent Spectral Evolution





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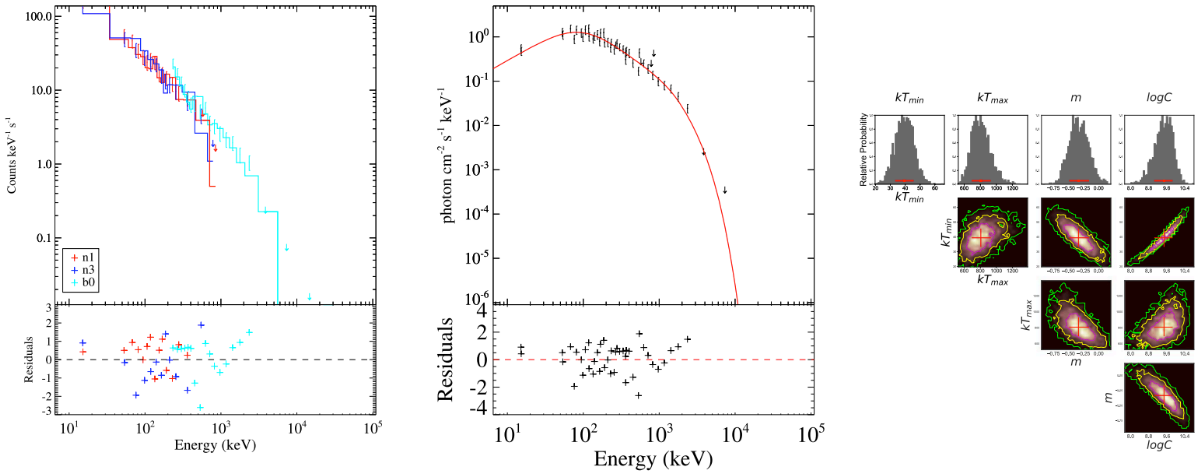
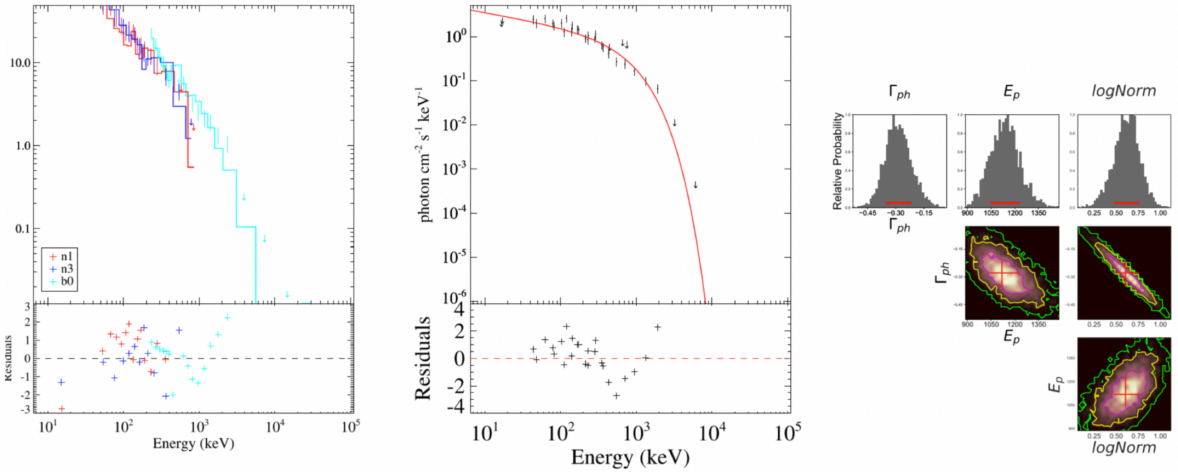
GRB 200415A: Time-Dependent Spectral Constraints



mBB



CPL

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GRB 200415A: Summary of Properties

Observed Properties	GRB 200415A
Abrupt rise time	$\sim$2 ms
Steep decay time	$\sim$8 ms
T_{90} (sharp peak only)	$5.88^{+0.23}_{-0.34}$ ms
Total duration	$\sim$200 ms
$\Gamma_{\rm ph}$ at peak	$-0.00^{+0.26}_{-0.16}$
$E_{\rm p}$ at peak	$1688.27^{+304.76}_{-224.37}$ keV
Time-integrated $\Gamma_{\rm ph}$	$-0.14^{+0.06}_{-0.06}$
Time-integrated $E_{\rm p}$	$926.68^{+51.78}_{-52.33}$ keV
Total fluence	$9.29^{+0.92}_{-0.90} \times 10^{-6}$ erg cm^{-2}
Peak flux	$1.11^{+0.15}_{-0.11} \times 10^{-3}$ erg cm^{-2} s^{-1}
Possible host galaxy	Sculptor galaxy (NGC 253)
Distance	3.5 Mpc
Isotropic energy $E_{\gamma,\rm iso}$	$1.36^{+0.14}_{-0.13} \times 10^{46}$ erg
Peak luminosity $L_{\gamma,\rm p,iso}$	$1.62^{+0.21}_{-0.16} \times 10^{48}$ erg s^{-1}

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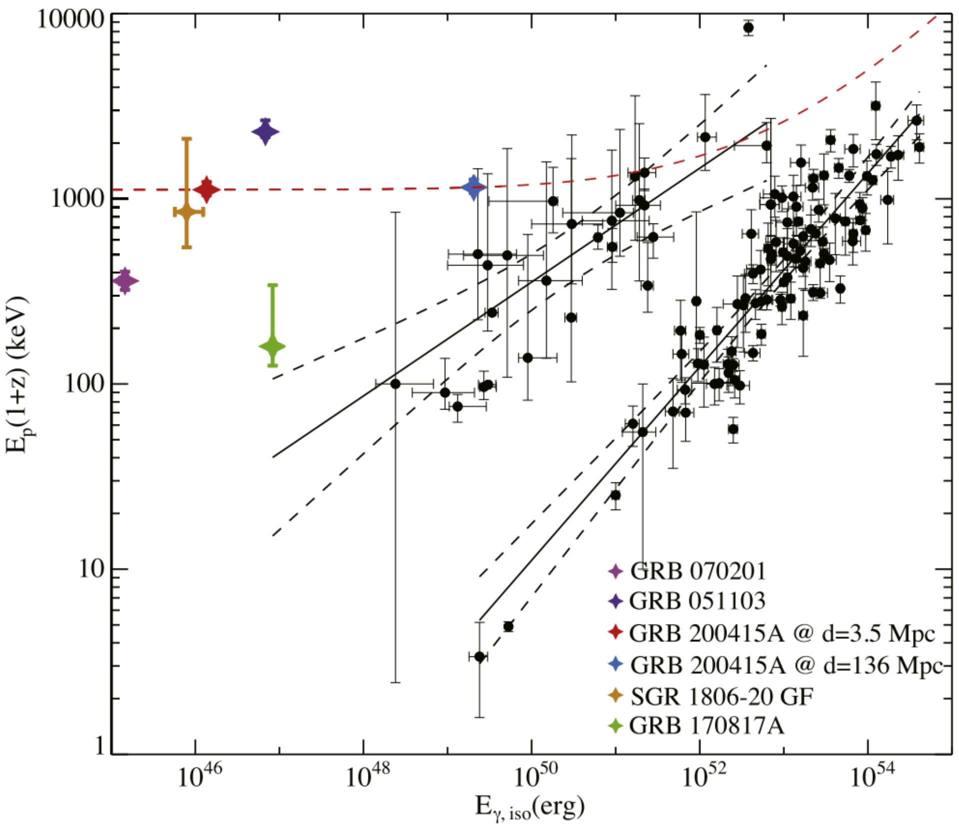
GRB 200415A: Comparison with Other GF GRB Candidates

Properties	GRB 200415A	SGR 1806–20 GF	GRB 051103	GRB 070201
Location	NGC 253	Massive star cluster	M81	M31
Distance	3.5 Mpc	8.7 kpc	3.6 Mpc	0.78 Mpc
Initial Pulse				
Steep rise, ms	$\sim$2	$\sim$1	$\leqslant$6	$\sim$20
Decay, ms	$\sim$8	$\sim$200	$\sim$40	$\sim$160
Rapid spectral evolution	✓	✓	✓	✓
CPL photon index Γ_{ph}	$-0.28^{+0.06}_{-0.08}$	$-0.73^{+0.64}_{-0.47}$	$0.16^{+0.19}_{-0.15}$	$-0.52^{+0.15}_{-0.13}$
CPL peak energy, keV	$1118.09^{+113.39}_{-75.49}$	850^{+1259}_{-303}	2300^{+350}_{-150}	360^{+44}_{-38}
BB temperature, keV	$140.45^{+8.48}_{-6.83}$	175 ± 25, 116	…	…
Peak flux, erg cm^{-2} s^{-1}	$1.11^{+0.15}_{-0.11} \times 10^{-3}$	$\sim$5.0, $13.1^{+8.0}_{-4.4}$	$(2.8 \pm 0.3) \times 10^{-3}$	$1.61^{+0.29}_{-0.50} \times 10^{-3}$
Peak luminosity, erg s^{-1}	$1.62^{+0.21}_{-0.16} \times 10^{48}$	$0.45(1.19) \times 10^{47}$	$(4.34 \pm 0.46) \times 10^{48}$	1.2×10^{47}
Tail				
Tail duration	$\sim$150 ms	$\sim$380 s	$\sim$130 ms	$\sim$100 ms
Period, s	…	7.56	…	…
QPO	Yes, Nature paper accetped	✓	…	…
BB temperature, keV	$143.09^{+5.27}_{-5.38}$	$\sim$30	…	…
CPL photon index Γ_{ph}	$-0.01^{+0.09}_{-0.08}$	…	$0.43^{+0.34}_{-0.40}$	$\sim(-1)$
CPL peak energy, keV	$826.43^{+59.65}_{-52.00}$	…	530 ± 80	$\sim$125
Fluence, erg cm^{-2}	$5.44^{+0.63}_{-0.52} \times 10^{-6}$	8×10^{-3}	$(2 \pm 0.3) \times 10^{-6}$	$\sim 10^{-6}$
Total fluence, erg cm^{-2}	$9.29^{+0.92}_{-0.90} \times 10^{-6}$	$0.87^{+0.50}_{-0.24}$	$(4.4 \pm 0.5) \times 10^{-5}$	$2^{+0.10}_{-0.26} \times 10^{-5}$
Total energy, erg	$1.36^{+0.14}_{-0.13} \times 10^{46}$	$7.88^{+4.53}_{-2.17} \times 10^{45}$	$(6.82 \pm 0.78) \times 10^{46}$	$1.5^{+0.07}_{-0.19} \times 10^{45}$
References		Hurley et al. (2005) Frederiks et al. (2007a)	Frederiks et al. (2007b) Ofek et al. (2006)	Mazets et al. (2008) Ofek et al. (2008)

GRB 200415A: Amati Relation



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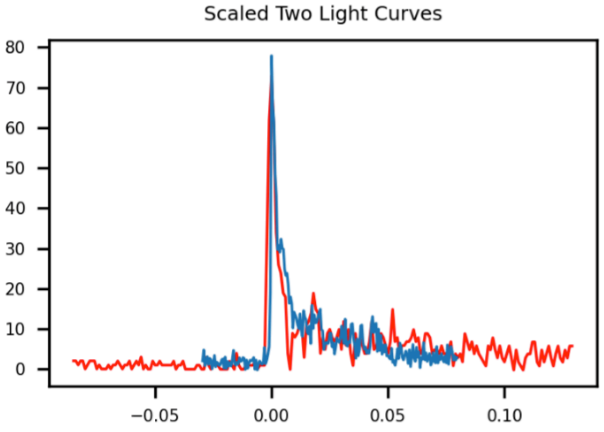
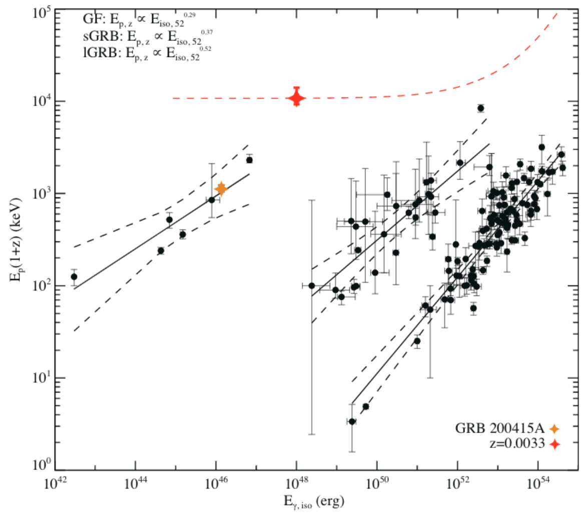
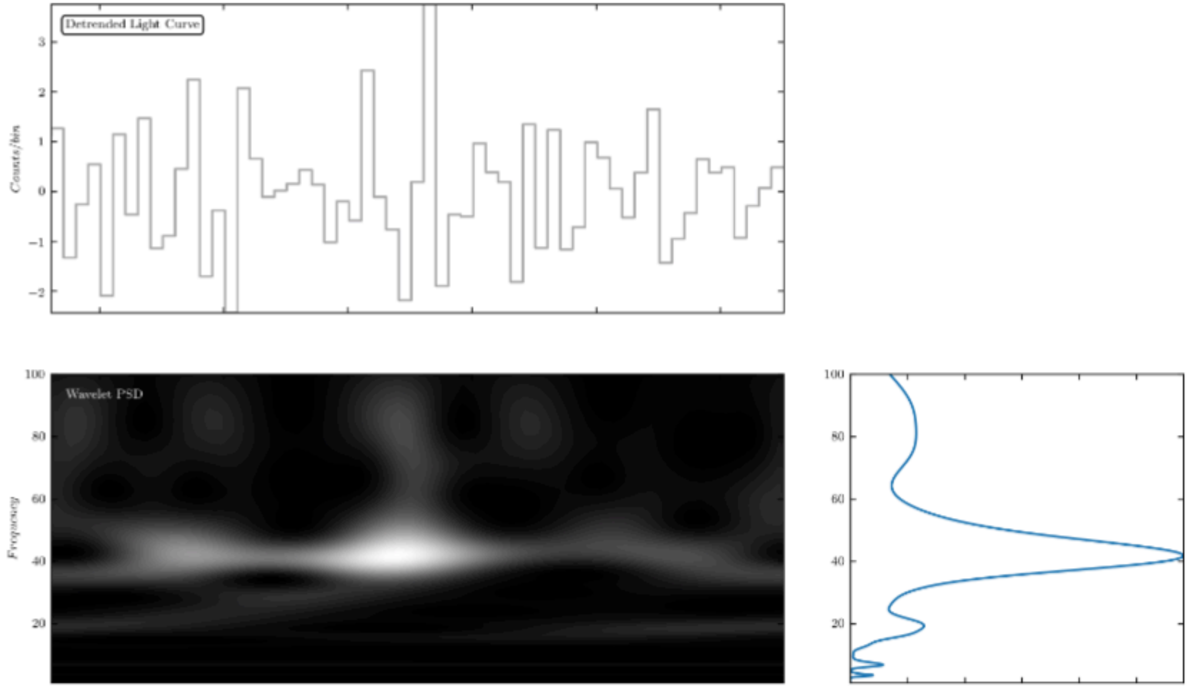
Additional Cases?

Additional Cases?

Yes!







Zhang,B.-B. et al in prep.

- **Gravitational Wave GRBs — 短暴起源的多新使研究、中子星物理**
- **Sub-threshold GRBs — 短暴前身星、引力波源的样本全面性**
- **Precursors of GRBs — GRB 的早期物理**
- **SGR-GF GRBs — 全新物理起源**
- **Unknown-Origin GRBs — 未知新物理**

New Type Unusual GRBs

A peculiarly short-duration gamma-ray burst from massive star core collapse

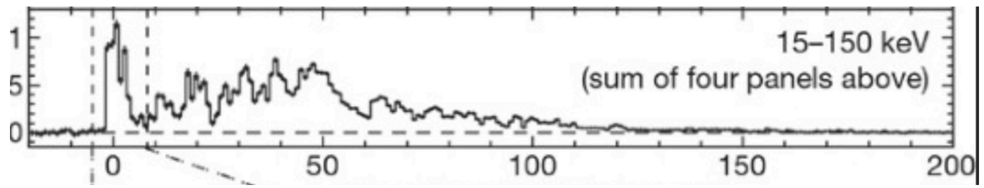
B.-B. Zhang[1,2,3,13] ✉, Z.-K. Liu[1,2,13], Z.-K. Peng[1,2,13], Y. Li[4,5], H.-J. Lü[6], J. Yang[1,2], Y.-S. Yang[1,2], Y.-H. Yang[1,2], Y.-Z. Meng[1,2], J.-H. Zou[1,2,7], H.-Y. Ye[1], X.-G. Wang[6], J.-R. Mao[8], X.-H. Zhao[8], J.-M. Bai[8], A. J. Castro-Tirado[9,10], Y.-D. Hu[9,11], Z.-G. Dai[1,2,12], E.-W. Liang[6] and B. Zhang[3] ✉

Bottom Lines about short and long

- Short GRBs can be apparently long (because of extended emission/tails)

(so we can ignore the tail, and make a short GRB from a long one)

THE ASTROPHYSICAL JOURNAL, 655: L25–L28, 2007 January 20



MAKING A SHORT GAMMA-RAY BURST FROM A LONG ONE: IMPLICATIONS FOR THE NATURE OF GRB 060614

BING ZHANG,[1] BIN-BIN ZHANG,[1,2,3] EN-WEI LIANG,[1,4] NEIL GEHRELS,[5] DAVID N. BURROWS,[6] AND PETER MÉSZÁROS[6,7]
Received 2006 October 22; accepted 2006 December 13; published 2007 January 4

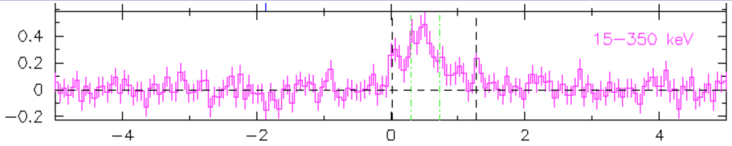
ABSTRACT

Bottom Lines about short and long

- Short GRBs can be apparently long (because of extended emission/tails)
- Long GRBs can be apparently (fat-)short (because of tip of iceberg effect)

Monthly Notices
of the
ROYAL ASTRONOMICAL SOCIETY

Mon. Not. R. Astron. Soc. **401,** 963–972 (2010)



GRB 090426: the environment of a rest-frame 0.35-s gamma-ray burst at a redshift of 2.609

Emily M. Levesque,[1,2★] Joshua S. Bloom,[3] Nathaniel R. Butler,[3†] Daniel A. Perley,[3] S. Bradley Cenko,[3] J. Xavier Prochaska,[4] Lisa J. Kewley,[1] Andrew Bunker,[5] Hsiao-Wen Chen,[6] Ryan Chornock,[3] Alexei V. Filippenko,[3] Karl Glazebrook,[7] Sebastian Lopez,[8] Joseph Masiero,[1] Maryam Modjaz,[3‡] Adam Morgan[3] and Dovi Poznanski[3]

Plus, recent GRB 201015A (short+tails)

Bottom Lines about short and long

- Short GRBs can be apparently long (because of extended emission/tails)
- Long GRBs can be apparently short (because of tip of iceberg effect)

- But:

Long GRBs can **NOT** be genuinely short
if it is really an accretion powered massive star collapsar

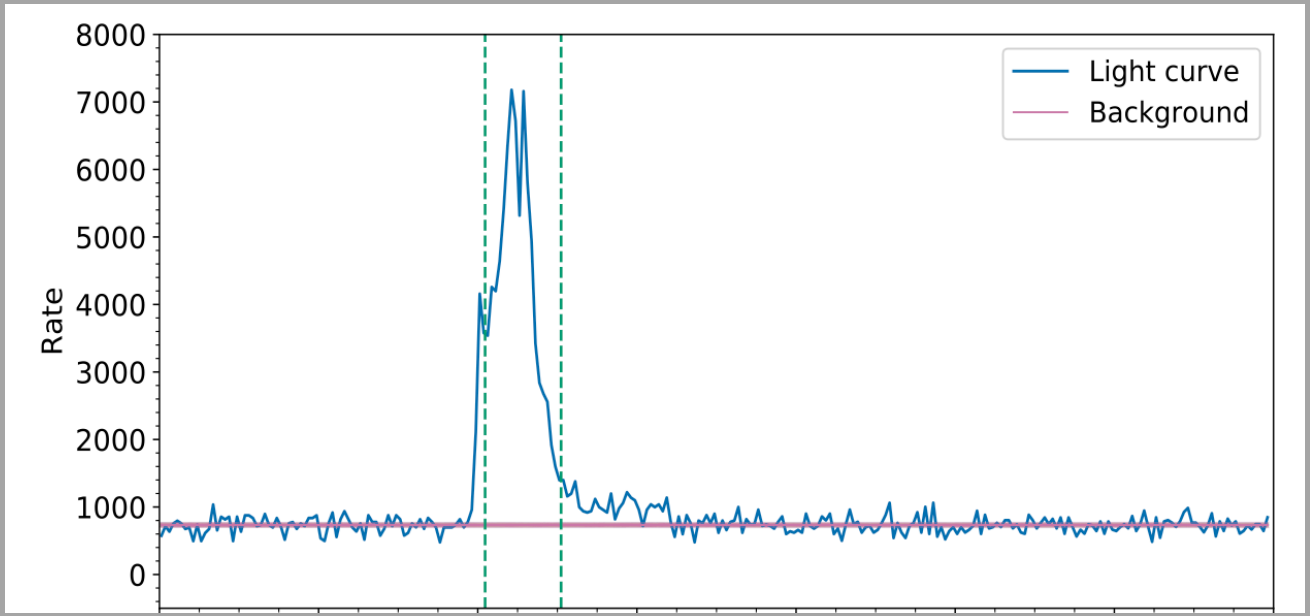
$$t_{\rm ff} \sim \left(\frac{3\pi}{32G\bar{\rho}}\right)^{1/2} \sim 210{\rm s}\left(\frac{\bar{\rho}}{100{\rm gcm^{-3}}}\right)^{-1/2}$$

Zhang, B.-B. et al 2021, Nature Astronomy

GRB 200826A !

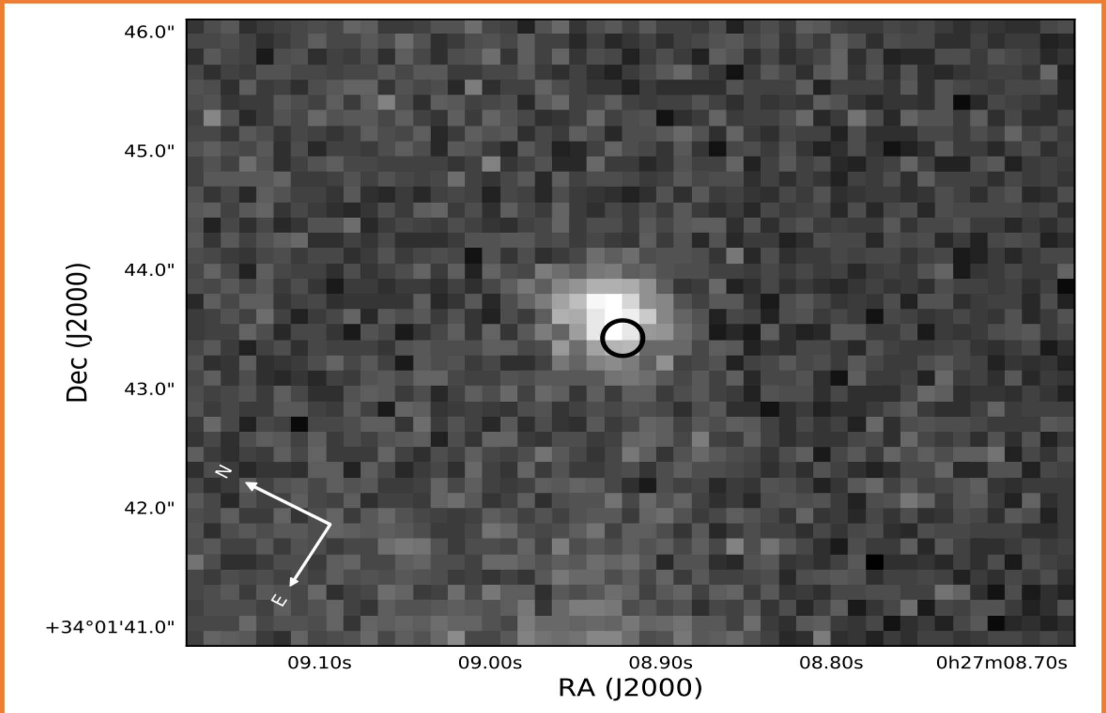
Zhang, B.-B. et al 2021, Nature Astronomy

GRB 200826A : A Bright GRB



Zhang, B.-B. et al 2021, Nature Astronomy

GRB 200826A : Host Galaxy



Typical LGRB Host

Redshift = 0.75

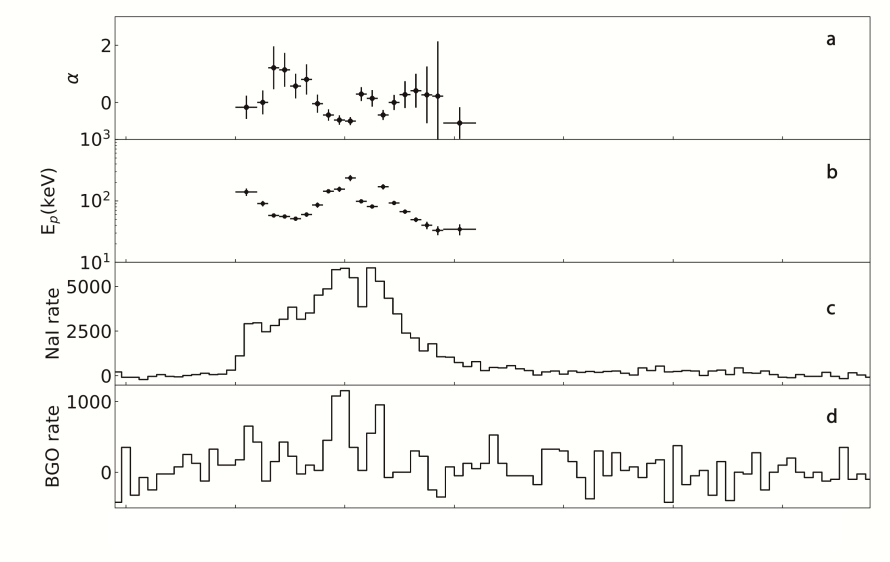
Offset = 2.6 kpc

SFR > 1.44 $M_{\odot} yr^{-1}$

SSFR > 0.35 Gyr^{-1}

Zhang, B.-B. et al 2021, Nature Astronomy

GRB 200826A : Spectra & Energy



$\alpha = -0.68$

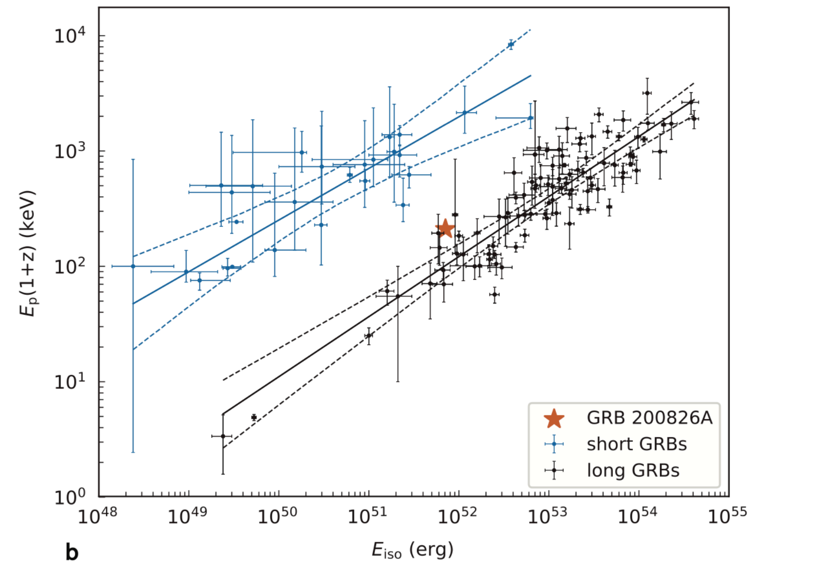
$E_p = 120keV$

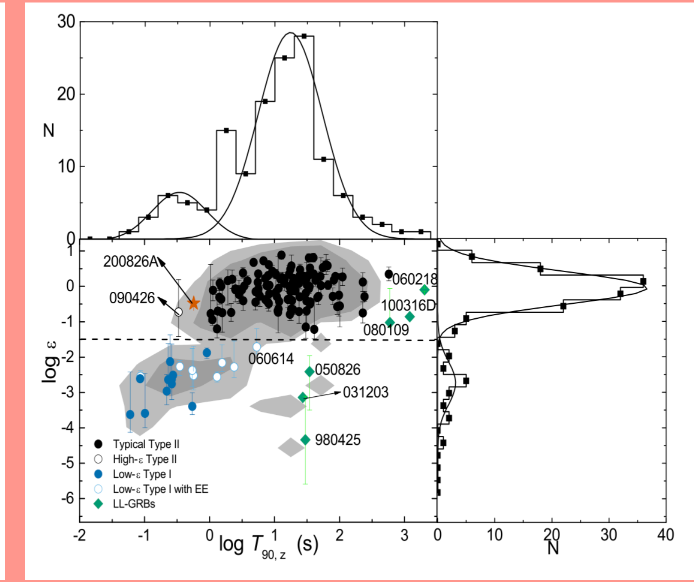
$F \sim 4.9 \times 10^{-6} erg\ cm^{-2}$

$E_{iso} = 7.1 \times 10^{51} erg$

Zhang, B.-B. et al 2021, Nature Astronomy

GRB 200826A : Correlation

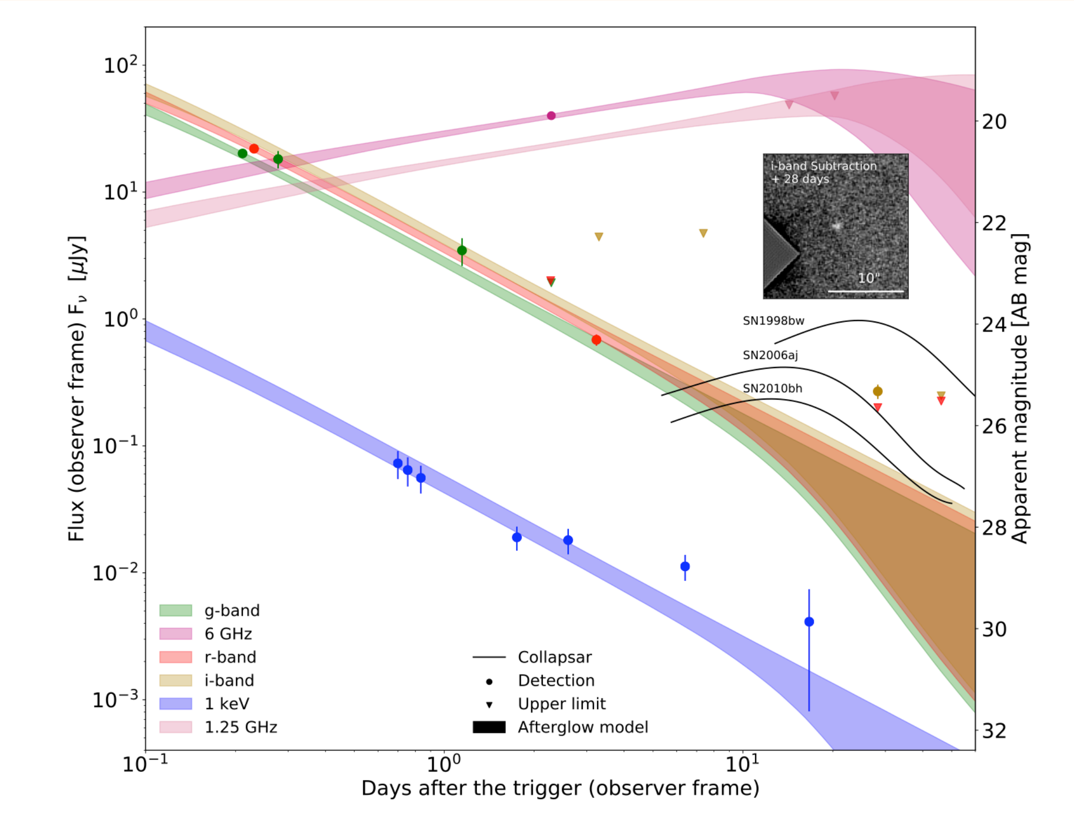




$$\epsilon = E_{\gamma,\mathrm{iso},52} / E_{\mathrm{p,z},2}^{5/3},$$

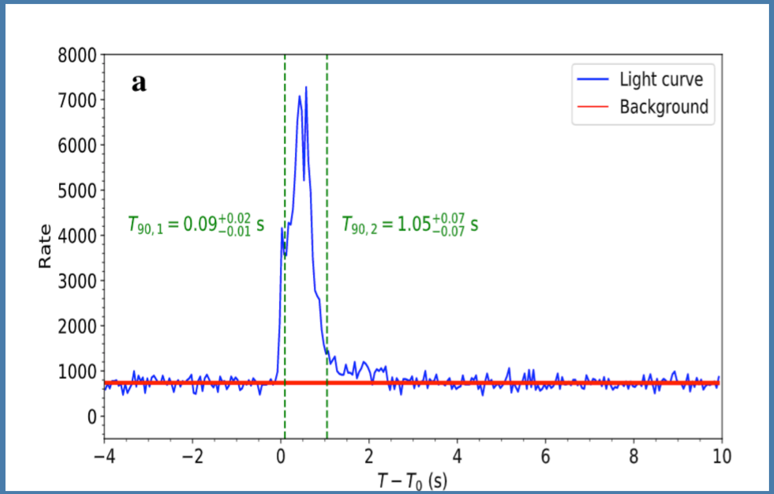
Zhang, B.-B. et al 2021, Nature Astronomy

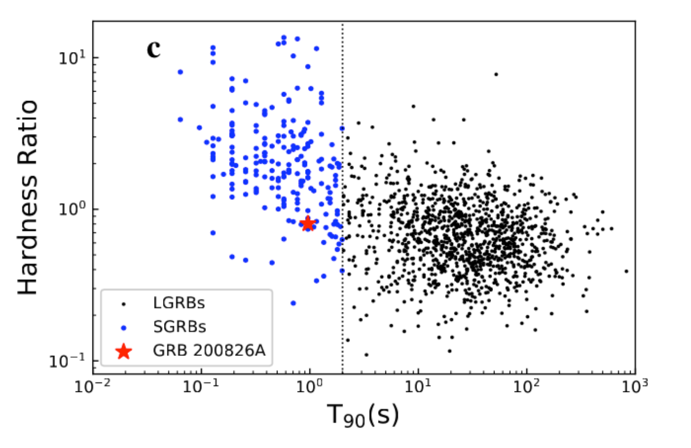
GRB 200826A : A Supernova!

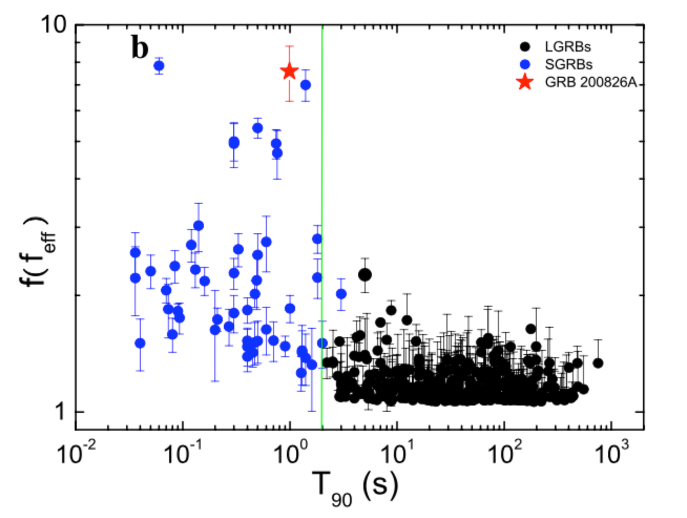


Zhang, B.-B. et al 2021, Nature Astronomy; Ahumada et al. 2021, Nature Astronomy

GRB 200826A : But it is definitely short !



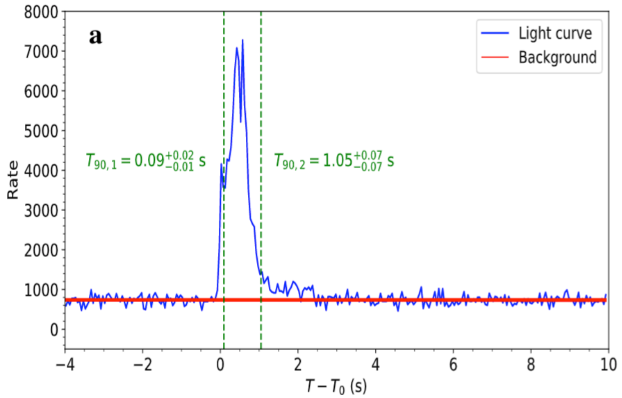


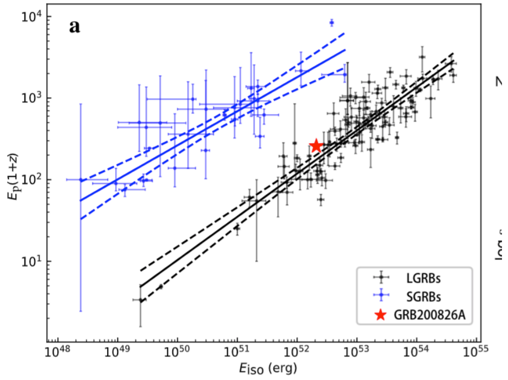


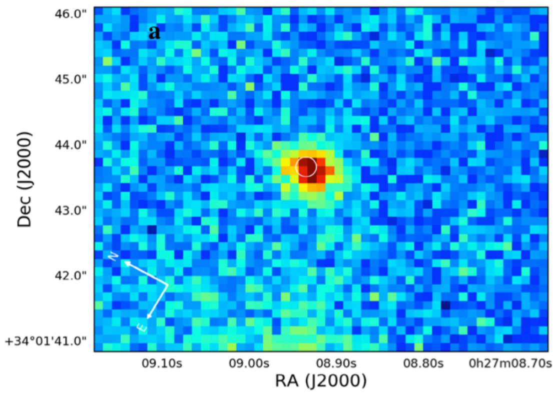
NO Tail and NOT fat

Zhang, B.-B. et al 2021, Nature Astronomy

GRB 200826A: “shortest-long gamma ray burst”







Time duration
f-parameters
hardness
Spectral photon index
Spectral peak energy
Isotropic energy
Total fluence
ϵ - parameter
Time lag(10-20 keV $\sim$ 250-300 keV)
Redshift
Offset $R_{\rm off}$
Half light radius R_{50}
$R_{\rm off}/R_{50}$
Cumulatve light fraction $F_{\rm light}$
Log OII/OI
Peak flux
Peak luminosity
SFR
SSFR
SN-association

Everything looks like a long GRB, except for its definitely short duration!

(f, HR, spectra, energy, epsilon, lag, offset, log O, SN)

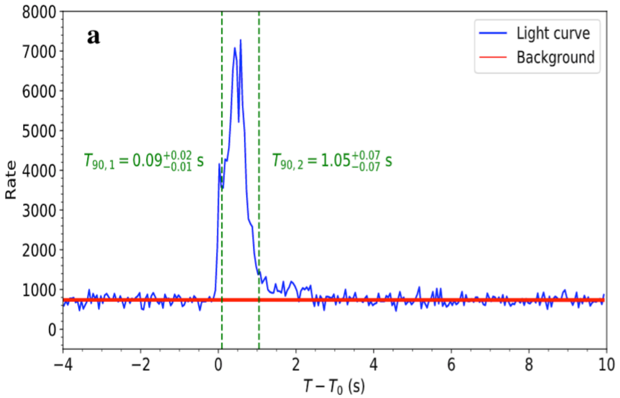
$$t_{\rm ff} \sim \left(\frac{3\pi}{32 G\bar{\rho}}\right)^{1/2} \sim 210\ {\rm s}\left(\frac{\bar{\rho}}{100\ {\rm g\ cm^{-3}}}\right)^{-1/2},$$

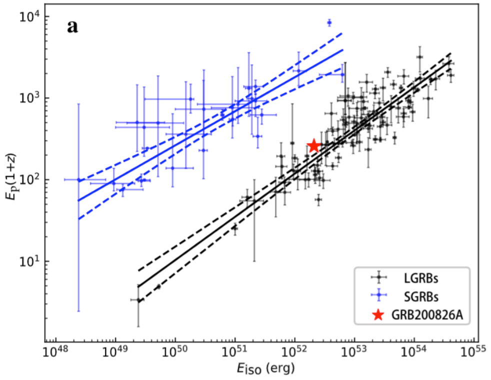
NO Tail and NOT fat

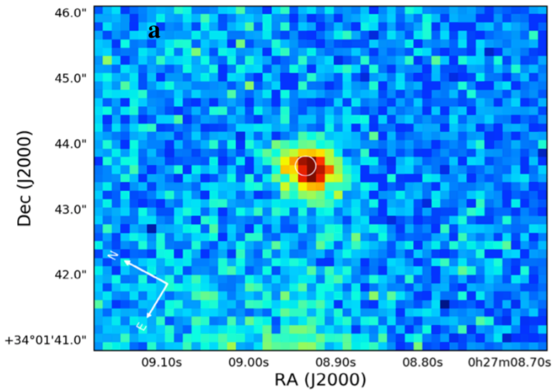
Zhang, B.-B. et al 2021, Nature Astronomy

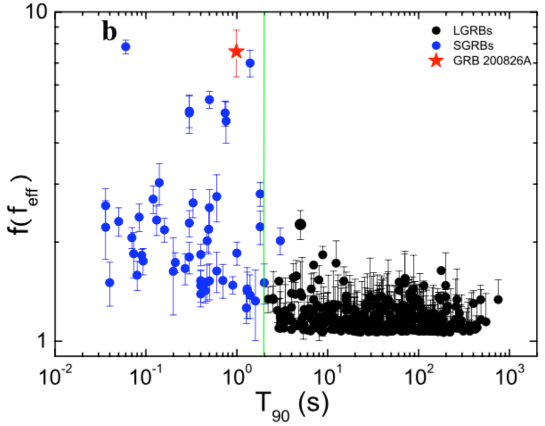
(Collaborators: PKU, HEBNU, YNAO, GXU., USTC , IAA, UNLV,)

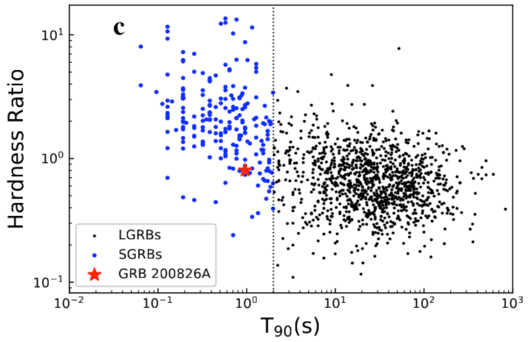
GRB 200826A: "shortest-long gamma ray burst"

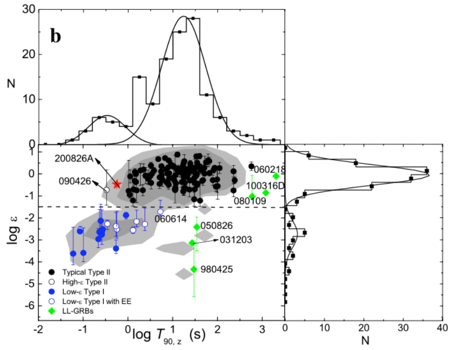












Time duration
f-parameters
hardness
Spectral photon index
Spectral peak energy
Isotropic energy
Total fluence
ϵ - parameter
Time lag(10-20 keV $\sim$ 250-300 keV)
Redshift
Offset $R_{\rm off}$
Half light radius R_{50}
$R_{\rm off}/R_{50}$
Cumulatve light fraction $F_{\rm light}$
Log OII/OI
Peak flux
Peak luminosity
SFR
SSFR
SN-association

Everything looks like a long GRB, except for its definitely short duration!

Zhang, B.-B. et al 2021, Nature Astronomy

A successfully theory on GRB 200826A should:

1. reproduce its short duration.
2. not evolve with the tip-of-iceberg effect.
3. explain its all other properties consistently with long GRBs
4. explain why it is rare (1/10000)

Trouble Maker GRB 200826A

How to make it? We don't know (yet)!

Hints : (1) large density? —> WD —> WD-involved merger? (NS-WD?)

Short

$$t_{\rm ff} \sim (\frac{3\pi}{32G\bar{\rho}})^{1/2} \sim 210{\rm s}(\frac{\bar{\rho}}{100{\rm gcm^{-3}}})^{-1/2}$$

(2) Delay between the collapse (“supranova”) and NS-powered short-duration GRB ?

(3) Not accretion powered: NS diff. rotation?

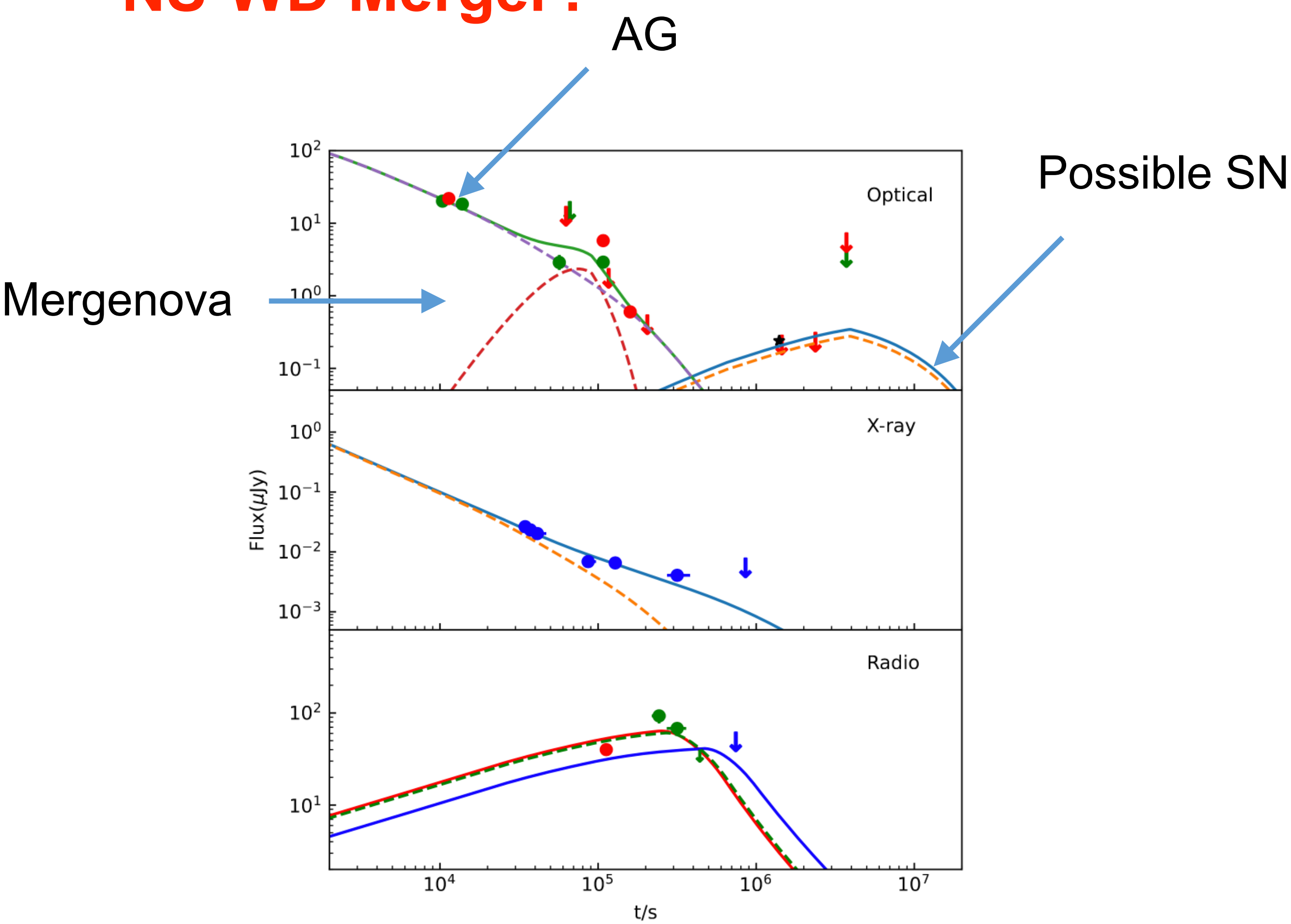
(4) Needs time to breaking stellar envelope : $\Delta t_{GRB} = \Delta t_{engine} - \Delta t_{jet} \simeq 1s$

Long

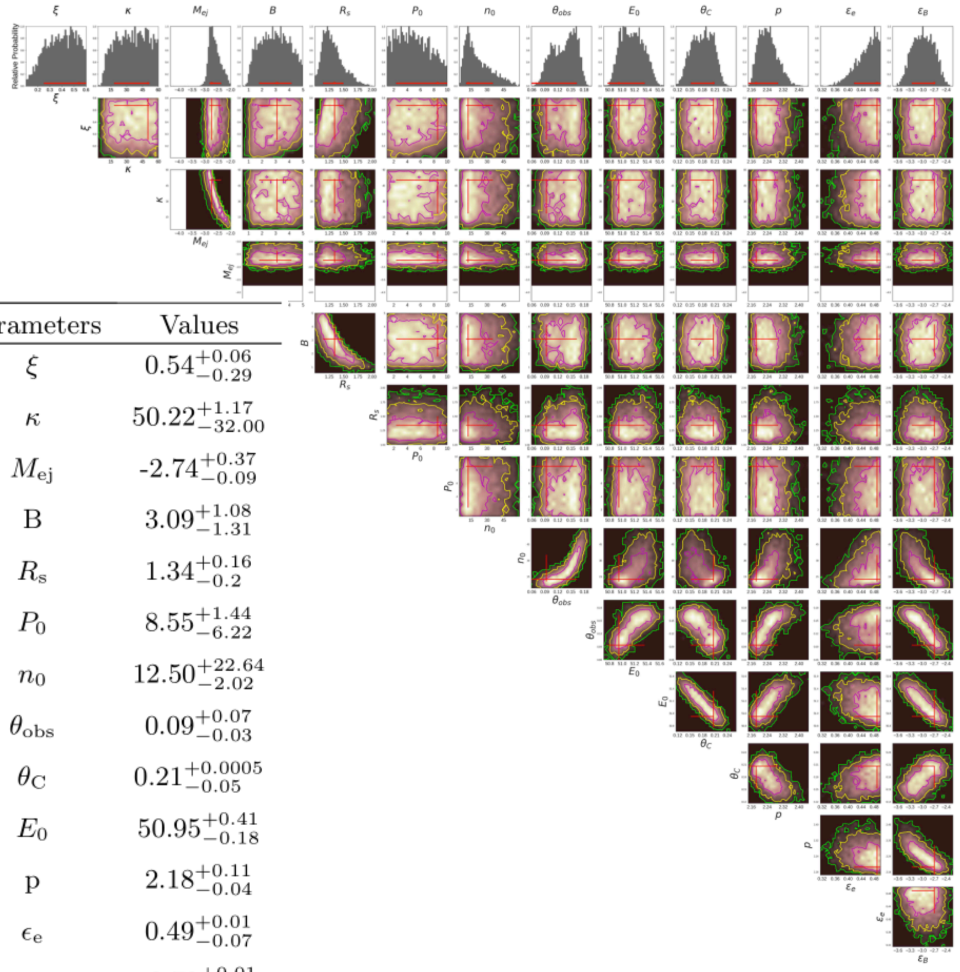
(5) Dirty engine: new-born magnetar with heavy baryon loading and mild-relativistic jet

Trouble Maker GRB 200826A

NS-WD Merger?



Peng, Z.-K. , BBZ, et al., 2021, in prep.



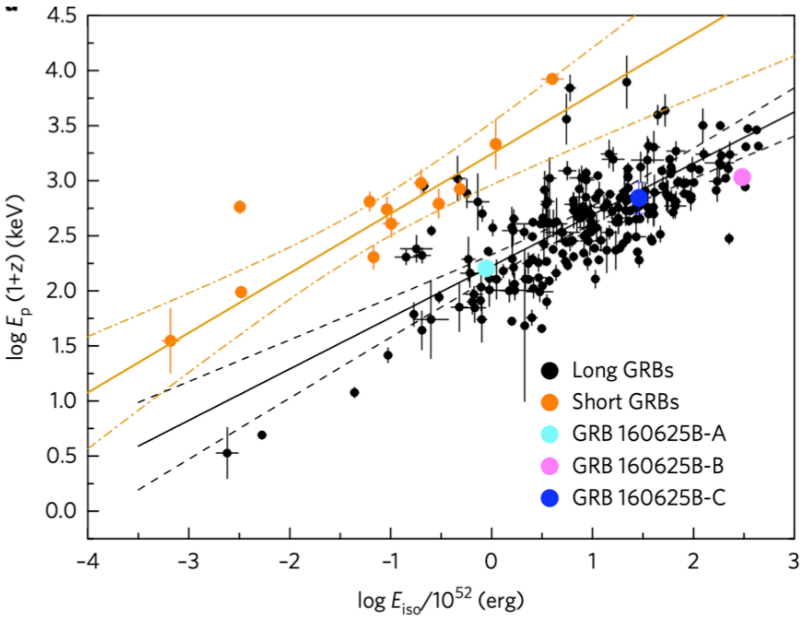
Parameters	Values
ξ	$0.54^{+0.06}_{-0.29}$
κ	$50.22^{+1.17}_{-32.00}$
$M_{\rm ej}$	$-2.74^{+0.37}_{-0.09}$
B	$3.09^{+1.08}_{-1.31}$
$R_{\rm s}$	$1.34^{+0.16}_{-0.2}$
P_0	$8.55^{+1.44}_{-6.22}$
n_0	$12.50^{+22.64}_{-2.02}$
$\theta_{\rm obs}$	$0.09^{+0.07}_{-0.03}$
$\theta_{\rm C}$	$0.21^{+0.0005}_{-0.05}$
E_0	$50.95^{+0.41}_{-0.18}$
p	$2.18^{+0.11}_{-0.04}$
$\epsilon_{\rm e}$	$0.49^{+0.01}_{-0.07}$
$\epsilon_{\rm B}$	$-2.70^{+0.01}_{-0.56}$

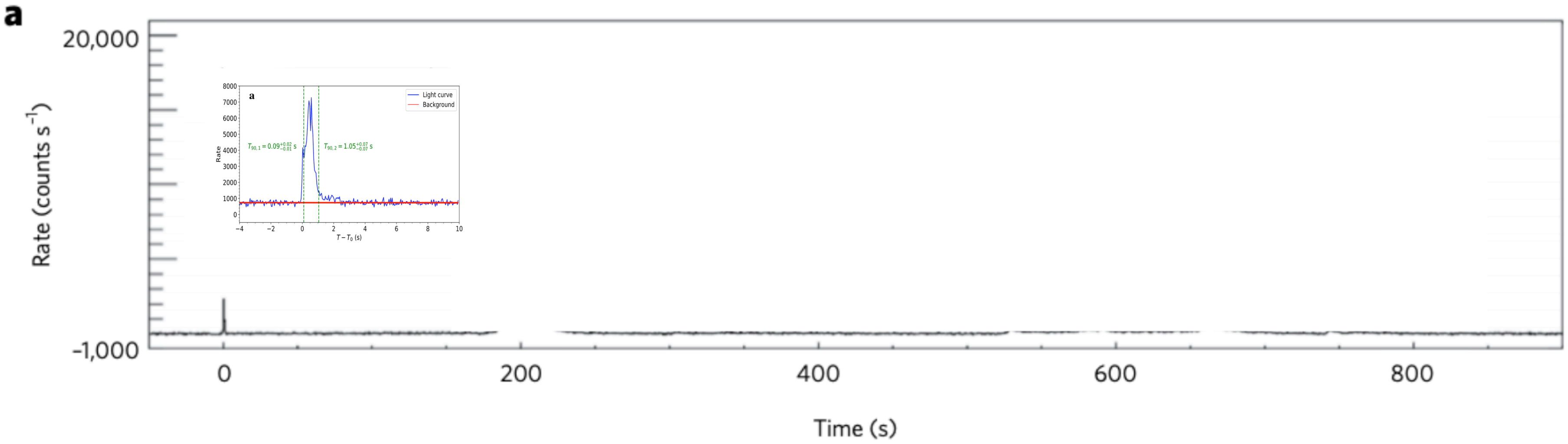
What if it is not peculiar at all?

nature astronomy
LETTERS
https://doi.org/10.1038/s41550-017-0309-8

Transition from fireball to Poynting-flux-dominated outflow in the three-episode GRB 160625B

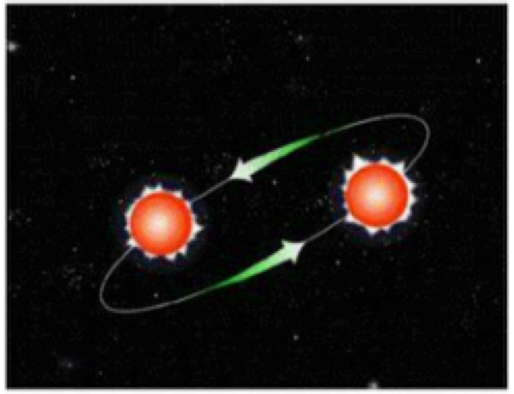
B.-B. Zhang, B. Zhang, A. J. Castro-Tirado, Z. G. Dai, P.-H. T. Tam, X.-Y. Wang, Y.-D. Hu, S. Karpov, A. Pozanenko, F.-W. Zhang, E. Mazaeva, P. Minaev, A. Volnova, S. Oates, H. Gao, X.-F. Wu, L. Shao, Q.-W. Tang, G. Beskin, A. Biryukov, S. Bondar, E. Ivanov, E. Katkova, N. Orekhova, A. Perkov, V. Sasyuk, L. Mankiewicz, A. F. Żarnecki, A. Cwiek, R. Opiela, A. Zadrożny, R. Aptekar, D. Frederiks, D. Svinkin, A. Kusakin, R. Inasaridze, O. Burhonov, V. Rumyantsev, E. Klunko, A. Moskvitin, T. Fatkhullin, V. V. Sokolov, A. F. Valeev, S. Jeong, I. H. Park, M. D. Caballero-García, R. Cunniffe, J. C. Tello, P. Ferrero, S. B. Pandey, M. Jelínek, F. K. Peng, R. Sánchez-Ramírez and A. Castellón





Time to be open-minded about GRB origins

Type I



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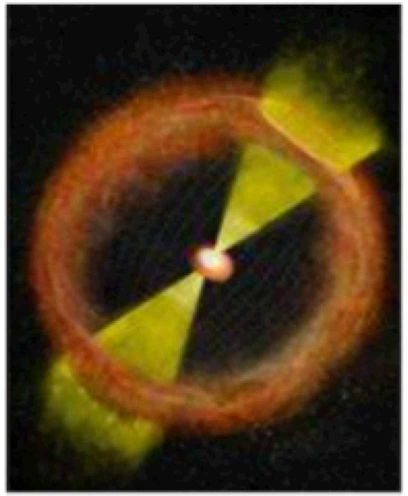

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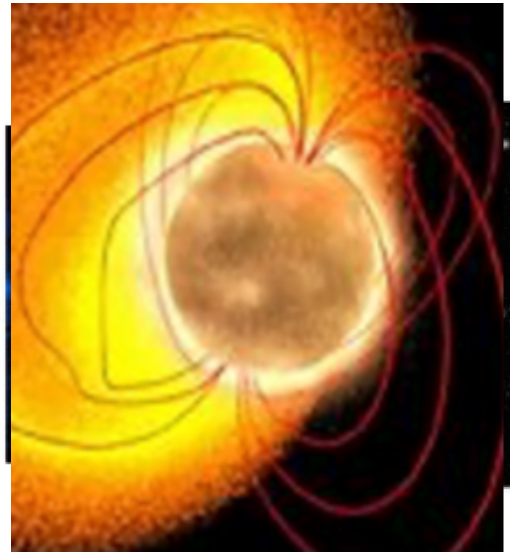
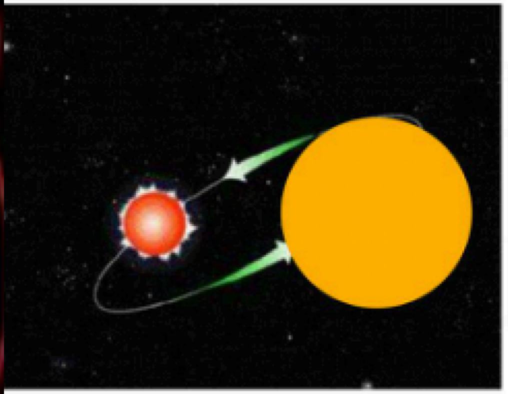


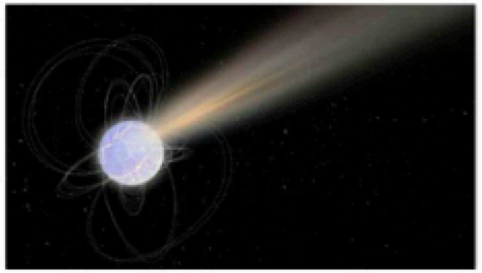
GRB 200415A
Yang, J. BBZ et al 2020

Type IV



GRB 200826A
(Maybe; Zhang et al)

Type V



FRB-related