Current new progress of gamma-ray burst physics and its possible connection to mHz GWs

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NANJING UNIVERSITY
1902 – 2022

GW/GRB Coincidence

- Only 1 case since 2015 in aLIGO/Virgo Operations

  GRB 170817A/GW170817

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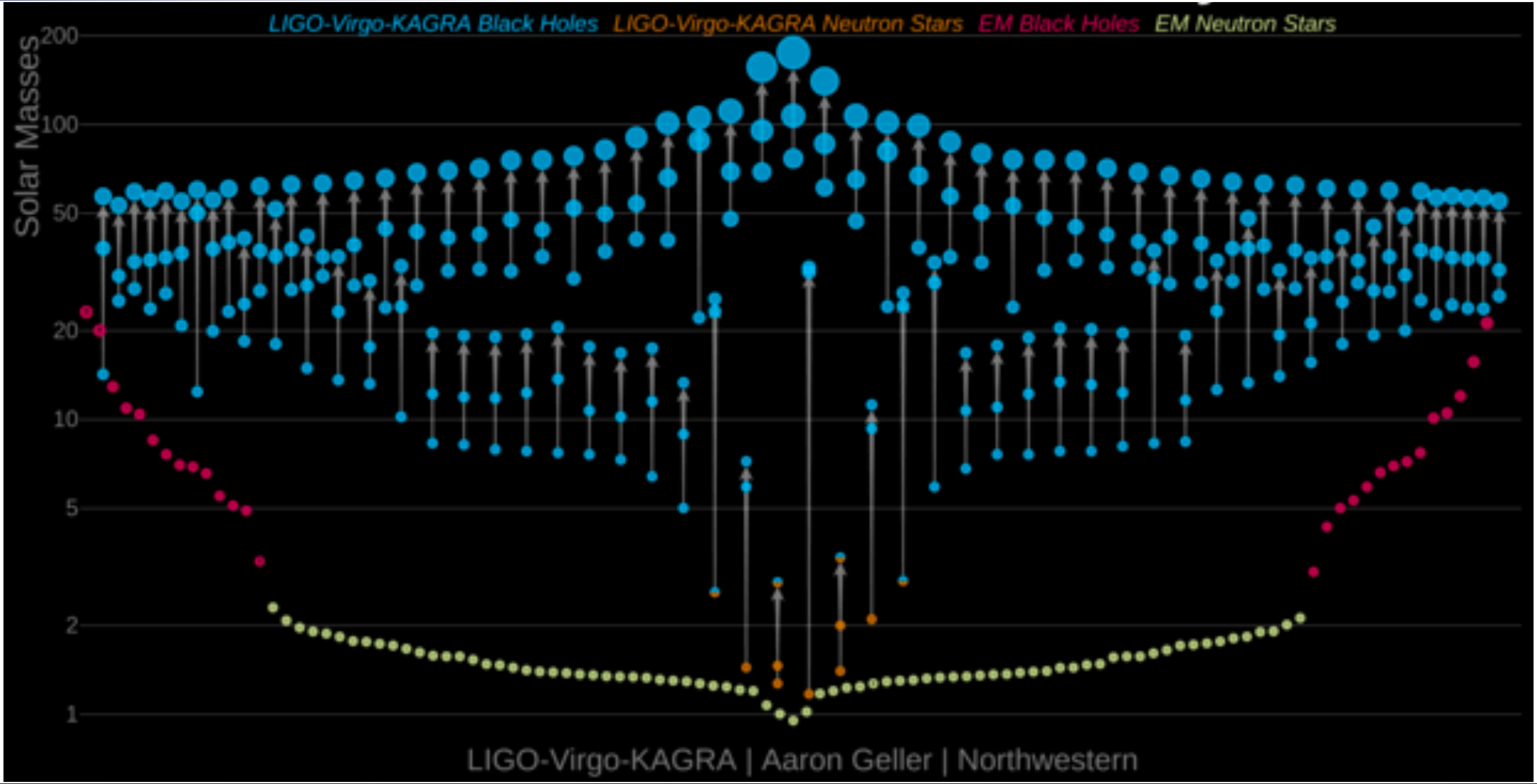
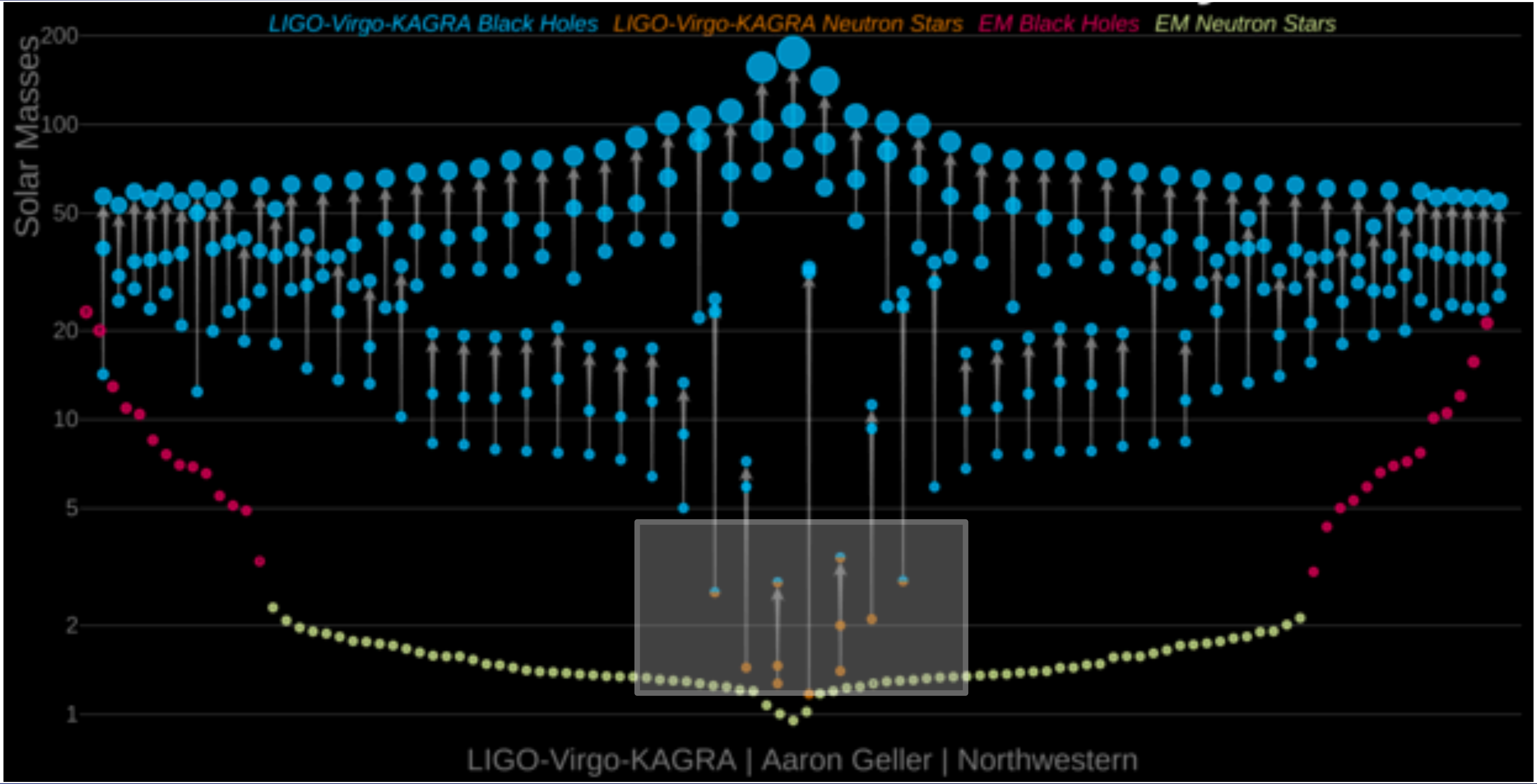
- Do we expect more?

  event rate: 0.1 - 10 /yr
  NS-BH mergers

GW/GRB Coincidence



GW/GRB Coincidence



More GW-GRBs in LIGO/Virgo archive?

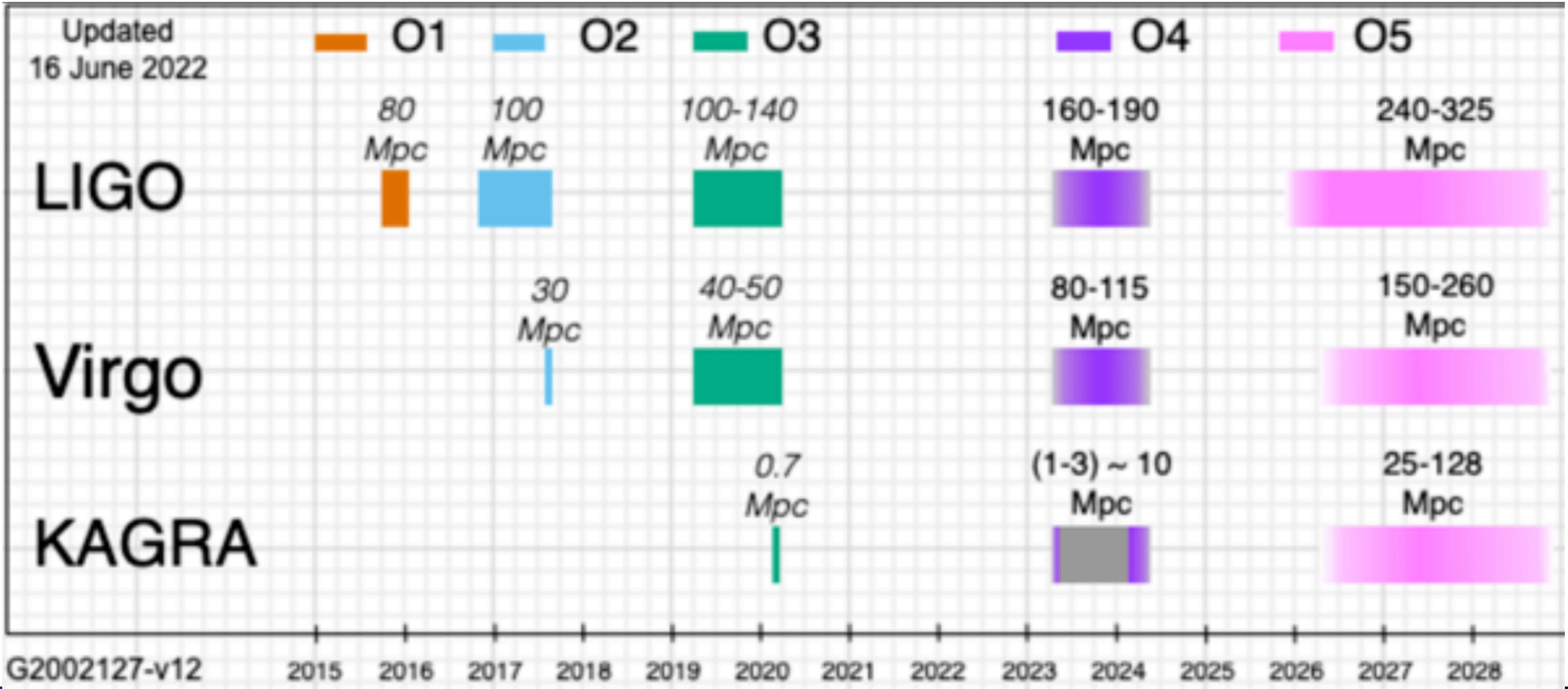
Case	Type	EM	Ref.
GW150914-GBM/ GW150914	BH-BH	very unlikely EM	Connaughton+15
GRB170817A/ GW170817/AT 2017gfo	NS-NS	Definitely Beautiful!	Abbott+17
S190510g	NS-NS	13 optical EM candidtes, NONE confirmed	Andreoni+19a
S190814bv	BH-NS	Deep search yeild nothing confirmed in EM	Andreoni+19b Dobie+19, etc
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 Yang et al, 2020 EM is like a real GRB

More GRB/sub-GW paris in LIGO/Virgo archive?

	GW candidate	$\mathcal{M}_c/M_\odot$	long GRB	$t_{\rm GRB}$	$\lambda_{\rm gw}$	$\lambda_{\rm gw+grb}$	IFAR/yr	GWobs	$d_{\rm ex}$/Mpc
1	200205_201716	1.01	GRB 200205845	2020-02-05 20:17:23.32	4.2	5.5	2.20	HL	281
2	170330_222948	1.05	GRB 170330A	2017-03-30 22:29:51.34	6.9	6.7	1.99	HL	191
3	191213_060532	1.01	GRB 191213254	2019-12-13 06:05:33.02	4.1	4.1	0.91	HLV	286
4	151001_082025	1.12	GRB 151001348	2015-10-01 08:20:35.16	3.2	5.2	0.73	HL	156
5	190404_070114	1.03	GRB 190404293	2019-04-04 07:01:21.92	1.7	3.9	0.67	HLV	341
6	191110_140525	1.20	GRB 191110587	2019-11-10 14:05:34.99	0.3	3.2	0.54	HLV	231
7	191213_040623	1.53	GRB 191213A	2019-12-13 04:06:23.92	2.7	1.8	0.29	HLV	363
8	190701_094513	1.03	GRB 190701A	2019-07-01 09:45:20.83	3.4	1.9	0.27	HLV	295
9	170723_161524	0.97	GRB 170723677	2017-07-23 16:15:27.85	1.8	2.2	0.21	HL	176
10	170409_024157	0.88	GRB 170409112	2017-04-09 02:42:00.49	1.9	2.1	0.20	HL	194
11	190613_040717	1.19	GRB 190613A	2019-06-13 04:07:18.31	1.7	0.6	0.16	HLV	343
12	200216_090724	0.88	GRB 200216380	2020-02-16 09:07:25.03	0.6	-0.0	0.14	HLV	274
13	190827_111245	1.57	GRB 190827467	2019-08-27 11:12:48.54	1.3	-0.5	0.11	HL	76
14	190508_234118	1.24	GRB 190508987	2019-05-08 23:41:24.14	0.6	-0.5	0.11	HLV	389
15	190628_123052	1.55	GRB 190628521	2019-06-28 12:30:55.31	0.4	-0.8	0.10	HL	313
16	170402_065048	2.42	GRB 170402285	2017-04-02 06:50:54.39	1.1	-0.7	0.09	HL	184
17	190726_152445	0.87	GRB 190726642	2019-07-26 15:24:53.60	0.7	-1.3	0.09	HLV	183
18	151029_074936	1.40	GRB 151029A	2015-10-29 07:49:38.96	4.2	-0.5	0.09	HL	65
19	191119_061605	1.27	GRB 191119261	2019-11-19 06:16:07.17	5.1	-2.4	0.07	HL	192
20	170424_101224	1.03	GRB 170424425	2017-04-24 10:12:30.75	1.7	-1.7	0.07	HL	129
21	190623_110326	1.46	GRB 190623461	2019-06-23 11:03:27.09	0.7	-2.7	0.07	HLV	238
22	170626_093721	1.17	GRB 170626A	2017-06-26 09:37:23.12	0.4	-2.6	0.06	HL	137
23	200317_004025	0.91	GRB 200317028	2020-03-17 00:40:30.48	0.6	-4.4	0.06	HLV	131
24	200117_122400	1.05	GRB 200117517	2020-01-17 12:24:06.53	2.9	-4.9	0.06	HLV	213
25	190919_181958	1.34	GRB 190919764	2019-09-19 18:20:02.65	0.7	-6.7	0.05	HLV	394
26	190805_044554	1.84	GRB 190805199	2019-08-05 04:46:00.97	3.2	-10.8	0.04	HLV	204
27	190422_160459	2.95	GRB 190422670	2019-04-22 16:05:04.52	4.2	-11.1	0.04	HLV	370
28	170825_120003	1.12	GRB 170825500	2017-08-25 12:00:05.99	0.2	-6.7	0.04	HLV	186
29	170323_012316	2.04	GRB 170323058	2017-03-23 01:23:23.26	4.6	-9.5	0.04	HL	121
30	190824_144634	1.19	GRB 190824A	2019-08-24 14:46:39.57	0.8	-inf	0.04	HLV	292
31	151027_224040	1.90	GRB 151027B	2015-10-27 22:40:40.66	7.4	-inf	0.03	HL	182
32	170629_125329	2.17	GRB 170629A	2017-06-29 12:53:33.15	3.6	-inf	0.03	HL	195

Motivated by GRB 211211A
Wang et al, 2022, [arXiv:2208.03279]

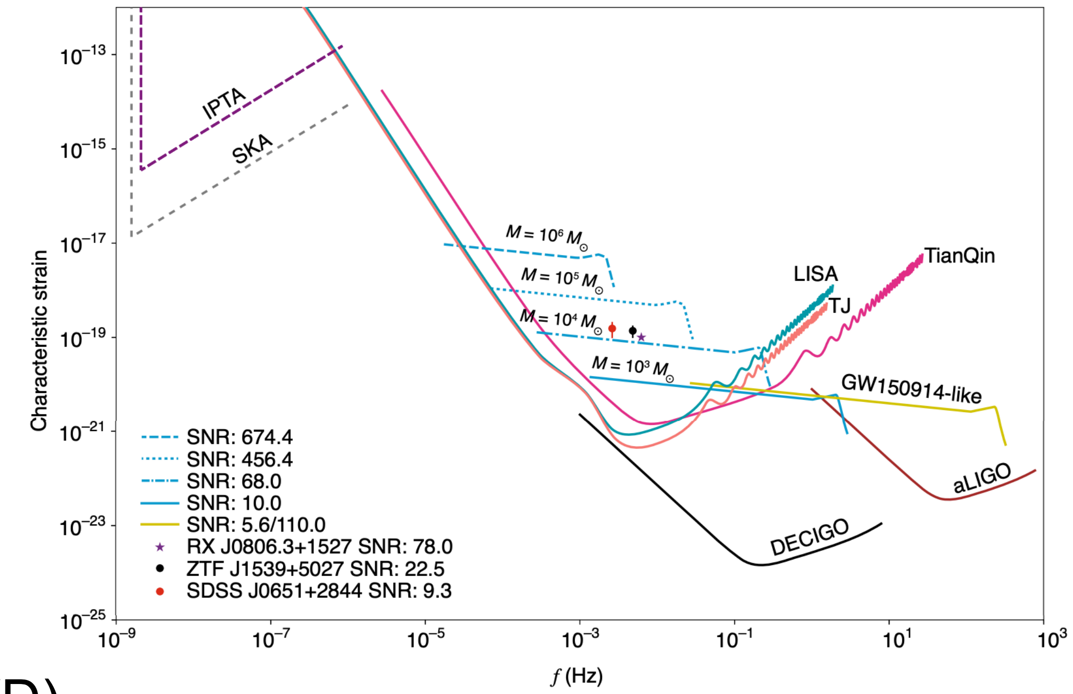
What do we expect in the next few 10-20 years ?



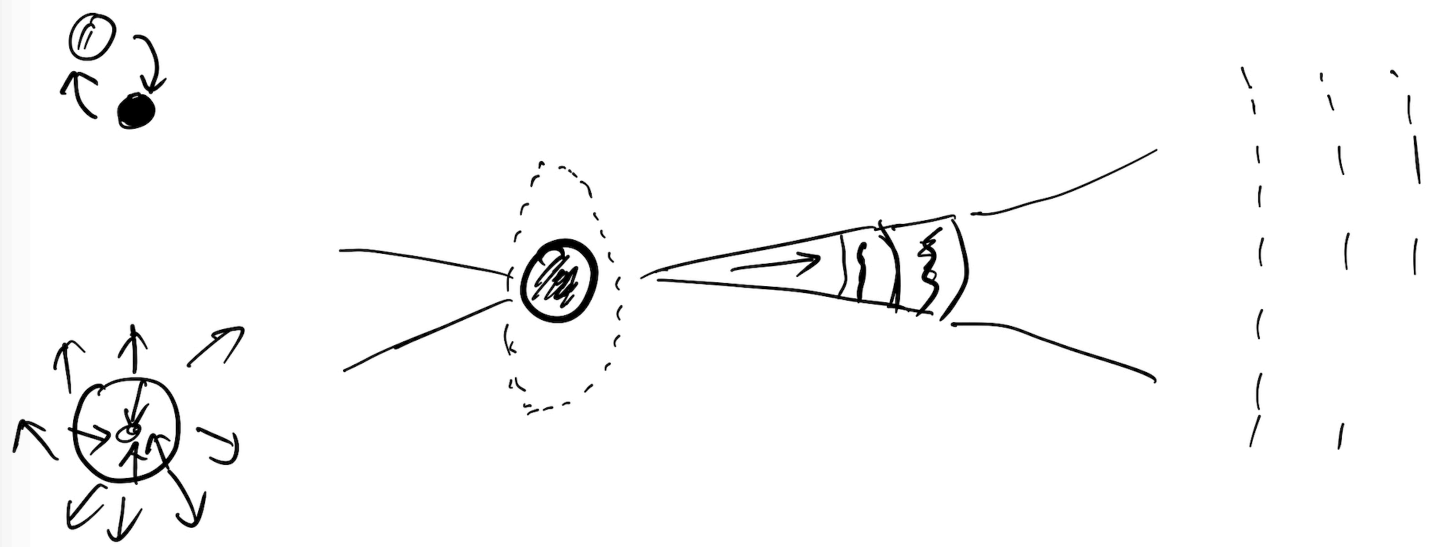
GRB (HE transients) prospect for in the next few 10-20 years ?

1. ON-axis NS-NS GRBs
2. Off-axis NS-NS Kilonova (orphan GRBs)
3. First detection of NS-BH GRBs
4. Non-detection helps to confirm
   (1) special origin of some short GRBs
   (2) special origin of some long GRBs
5. Detection of high-freq GW in long-duration GRBs
   May still be NS-NS or NS-BH
6. Non-detection of high-freq GW in
   apparent merger-origin GRBs

   merger-origin : host, kilonova, lack of SN, etc.
   —> new physical configurations , new origins (NS-WD)
7. Tianqin can help:
   (1) constrain the lower freq of a LIGO GW event.
   (2) confirms the new origins of GRBs (NS-WD, magnetar giant flares etc)



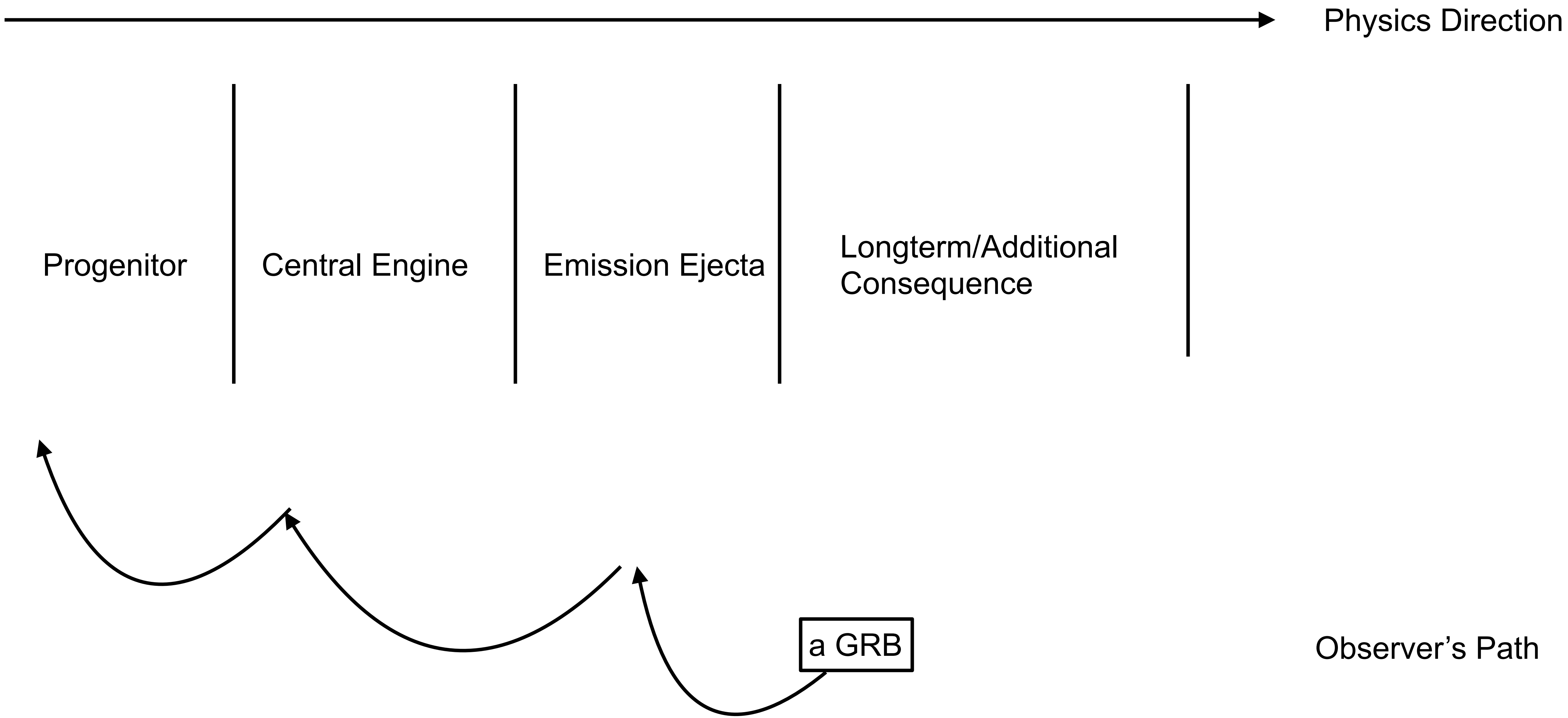
The "standard" GRB Model



Progenitor	Central Engine	Emission Ejecta	Longterm/Additional Consequence

Physics Direction

How do we know the GRB physics?



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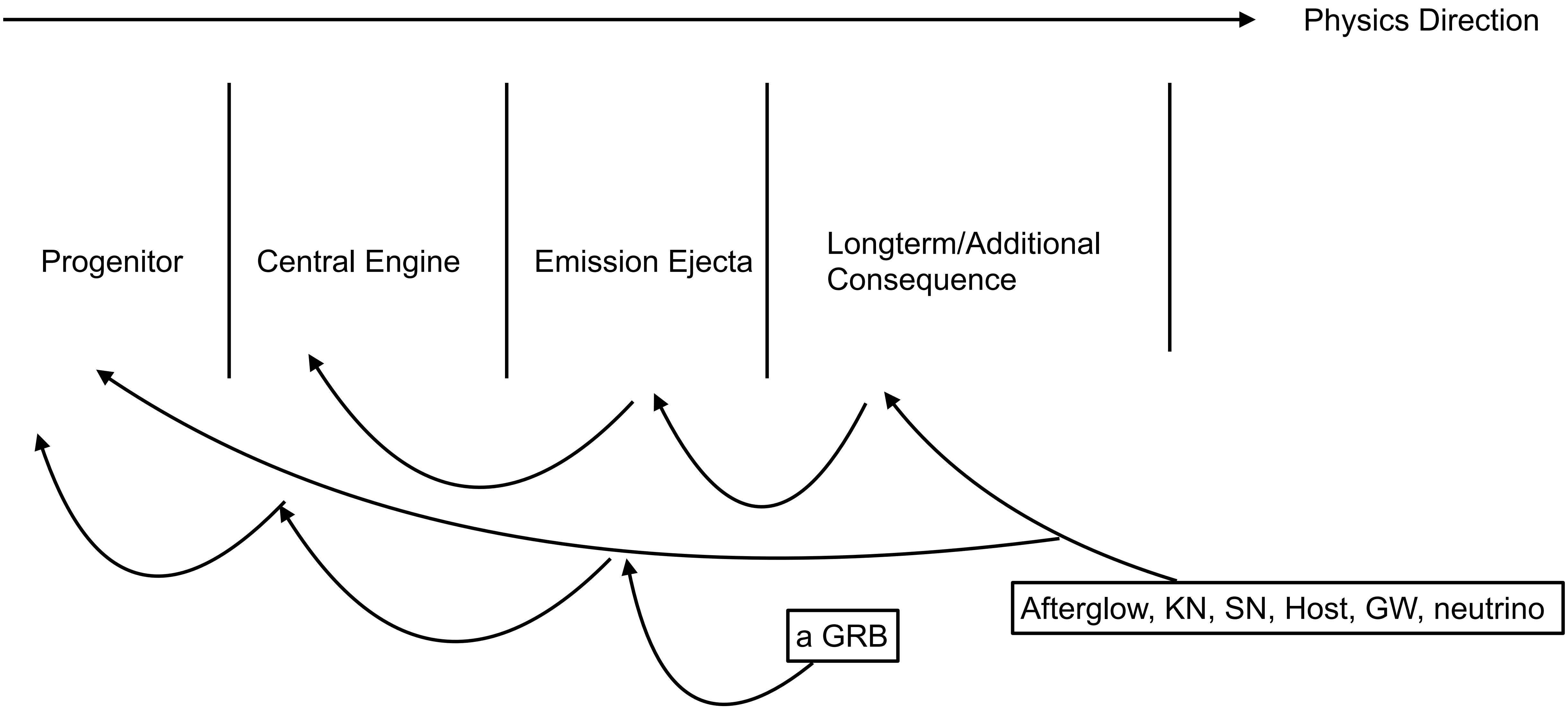
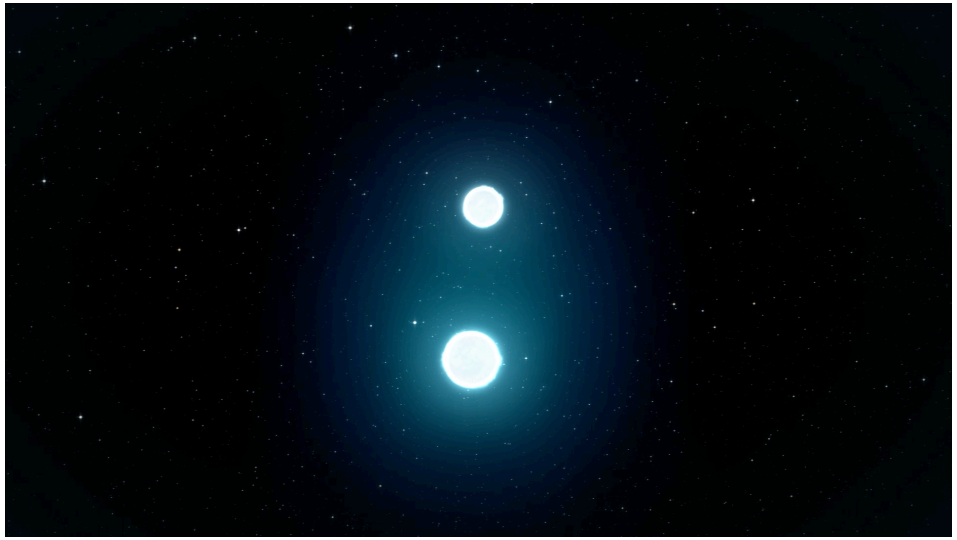


A “Standard” Understanding of GRBs

“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 (minutes ~ hours ~ years)
- SN: optical (~ weeks)
- Kilonova: optical, UV (~ hours)
- Host: optical , radio, other wavelength (~ always)

Standard, yet with growing new types

Typical 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, Orphan AG
- SN
- Kilonova: optical, UV, (large sample)
- Host: optical , radio , (large sample)
- Neutrinos
- Gravitational Waves （～100 HZ）

"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 coincident w/ other messengers/wavelength)
- Temporally or spectrally peculiar GRBs (LL, extra component, etc)
- SGR GF GRB;
- Unknown-Origin GRBs (trouble makers, e.g, GRB 200826A, GRB 211211A —> WD —> mHZ GW).

Standard, yet with growing new types

Typical 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)
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⇒

new radiation mechanisms
new physical origins

Topics on “new”

1. **Transition**: central engine can transform

2. **Different**: central object can be nonstandard

3. **New**: progenitor can be new

Topics on “new”

1. **Transition**: central engine can transform
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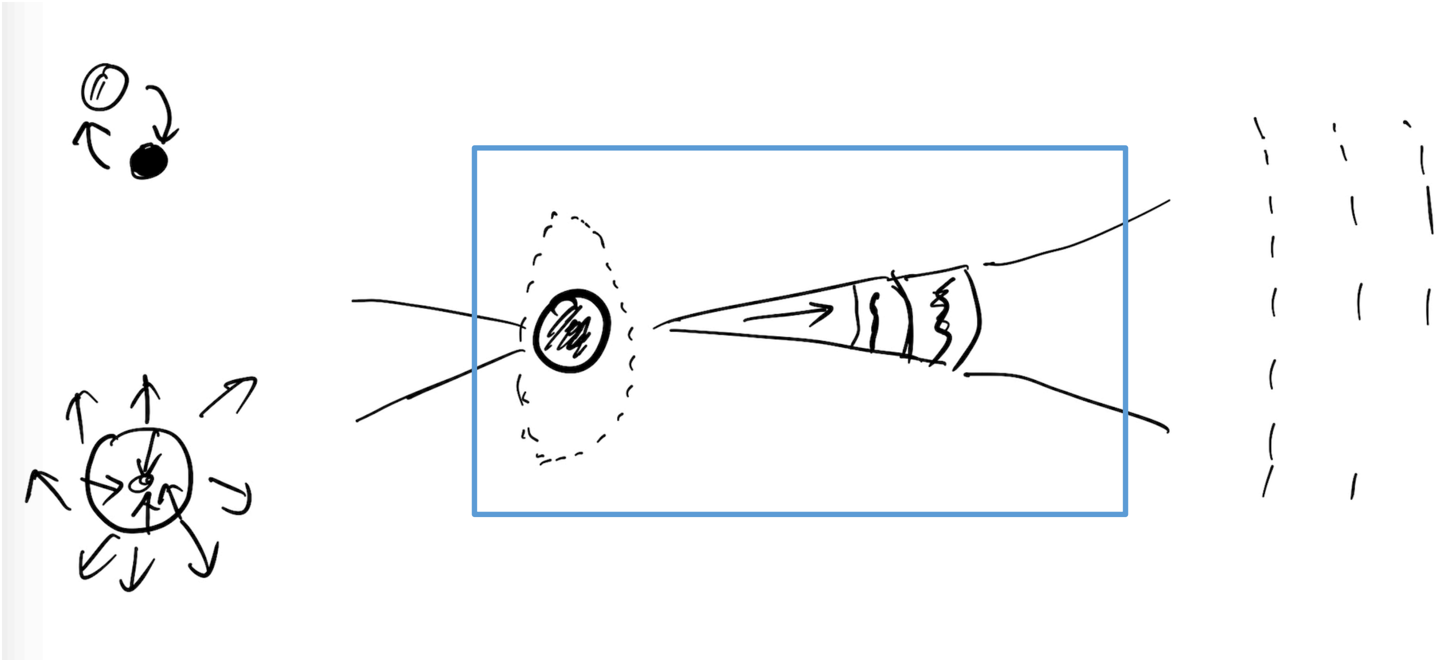
Transition of the Central Engine

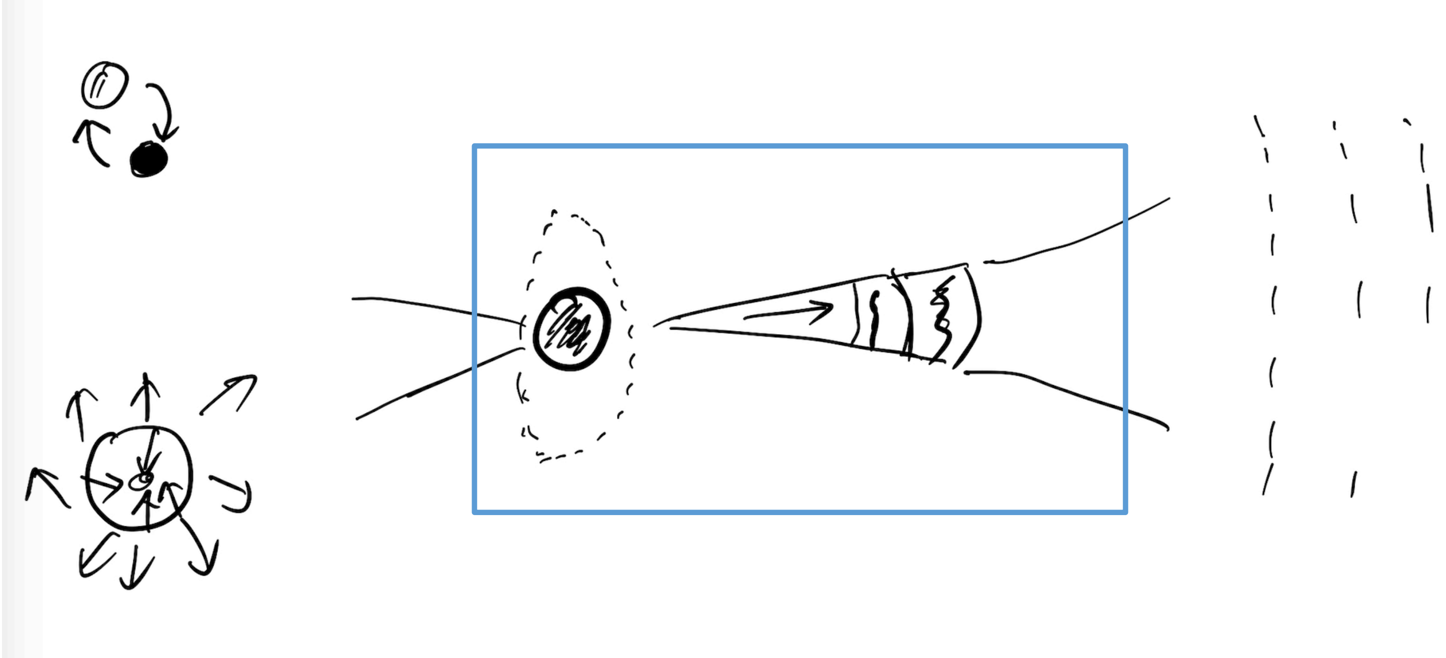


Why?

1. Ejecta radiation condition transition

2. Further collapse of the central object

Transition of the Central Engine



What do we expect?

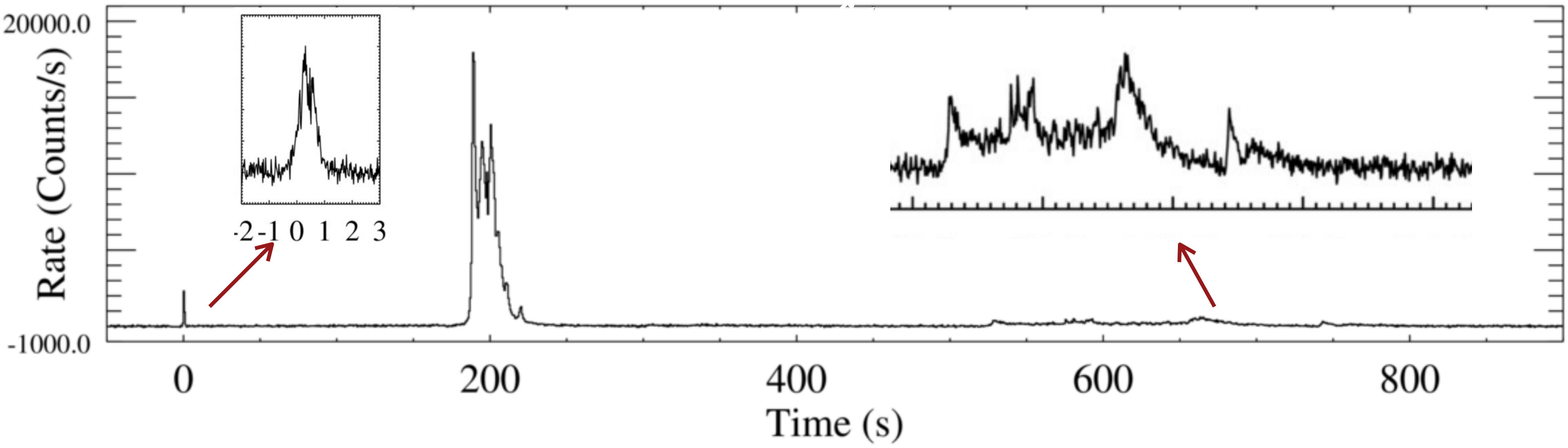
1. Ejecta radiation condition transition

   —> spectral change, energy change

2. Further collapse of the NS to a BH

   —> multiple episode

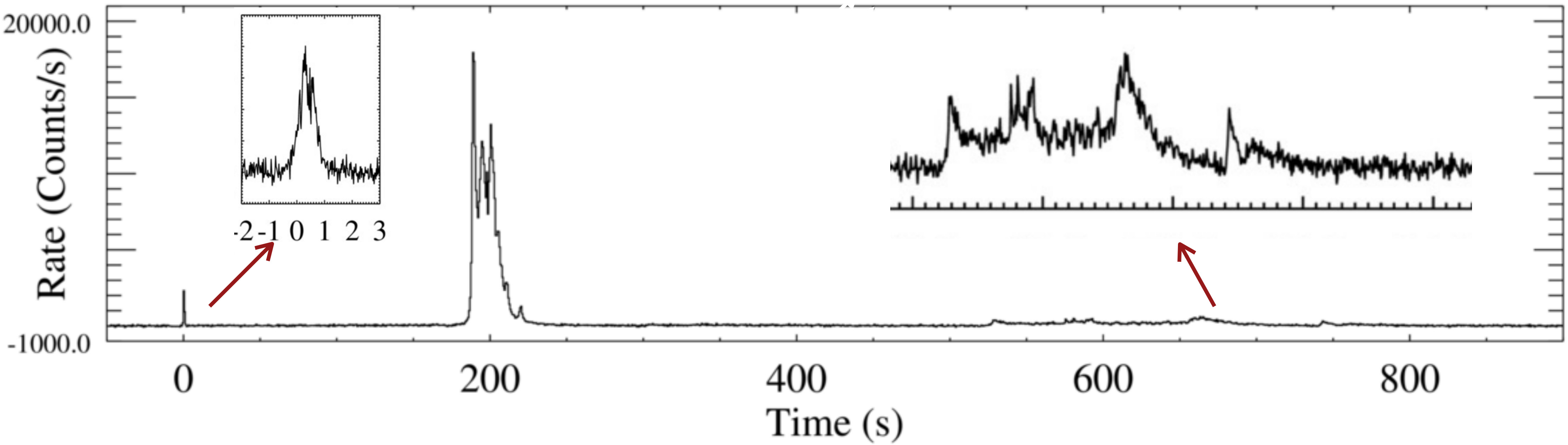
A textbook-version transition



short + long + long tail

GRB 160625B, **BBZ** et al. 2018, Nature Astronomy, 2, 69

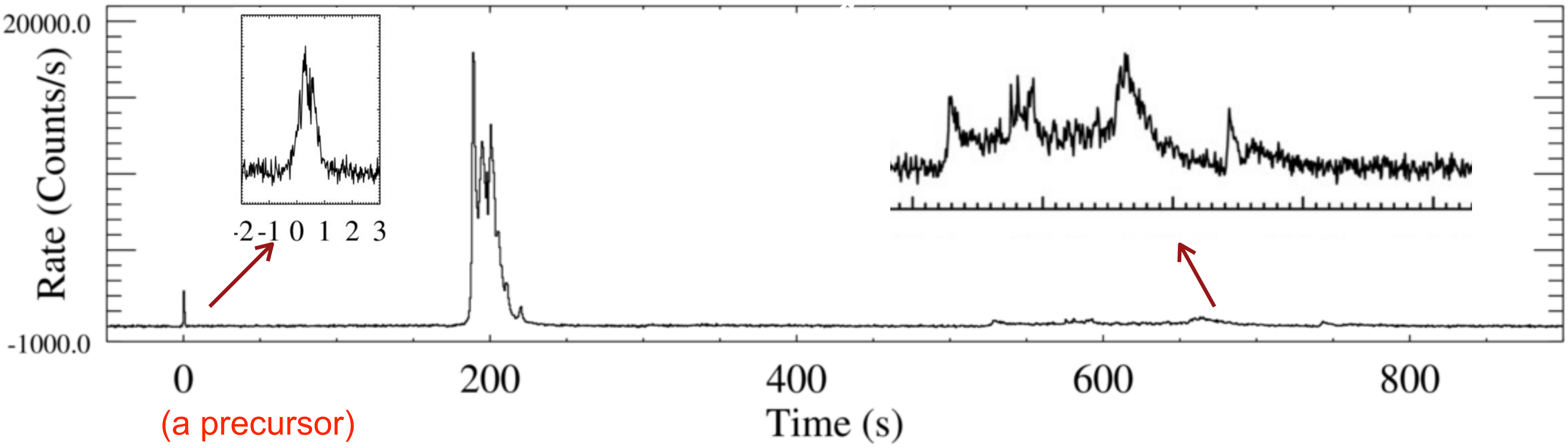
A textbook-version transition



short	+ long	+ long tail
thermal	+ non-thermal	+ soft non-thermal

GRB 160625B, **BBZ** et al. 2018, Nature Astronomy, 2, 69

A textbook-version transition



short	+ long	+ long tail
thermal	+ non-thermal	+ soft non-thermal

Matter-dominated fireball —> Poynting-flux-dominated Outflow

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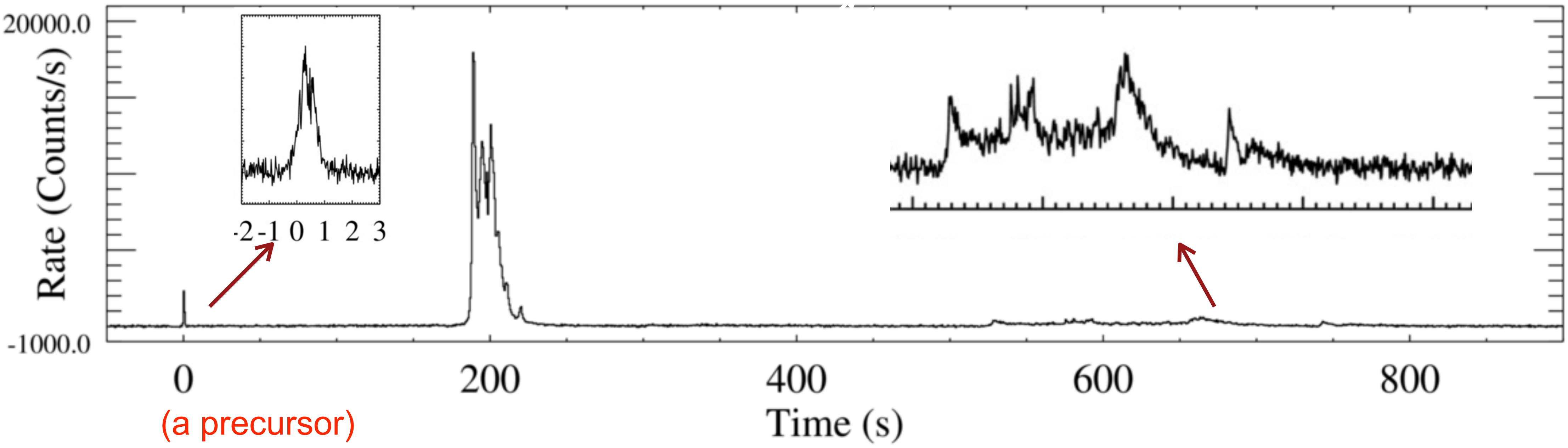
A textbook-version transition



(a precursor)

short	+ long	+ long tail
thermal	+ non-thermal	+ soft non-thermal

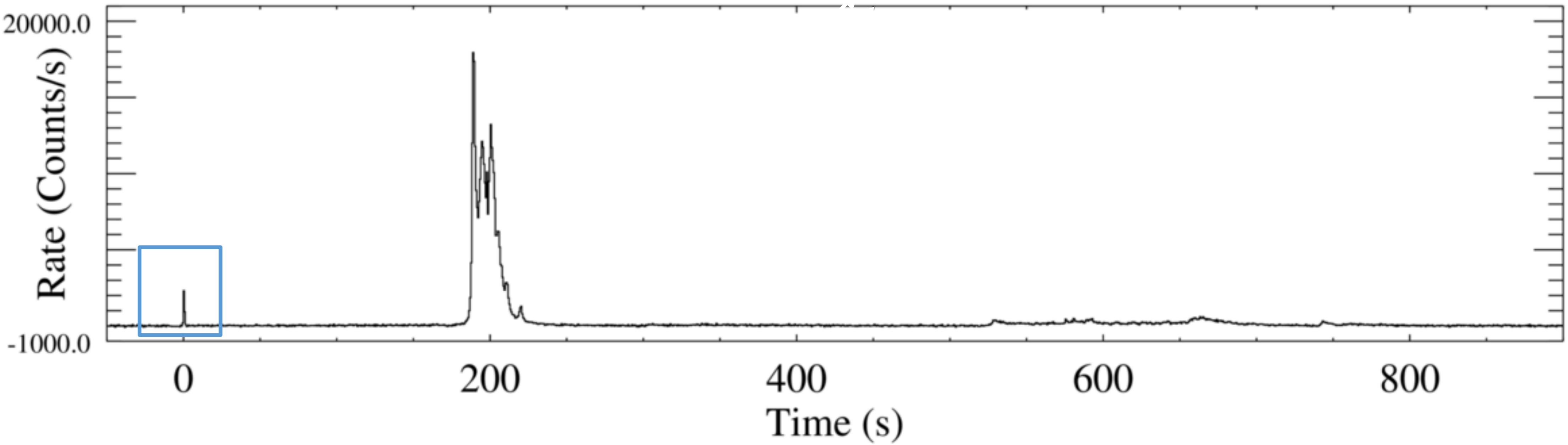
Matter-dominated fireball (thermal breakout) —> Poynting-flux-dominated Outflow

Strongly magnetized Centra Engine with central object being a magnetar-collapsing BH

Topics

1. **Transition**: central engine can transform
2. **Different**: central object can be nonstandard
3. **New**: progenitor can be new

What about if we only see the first “burst”?



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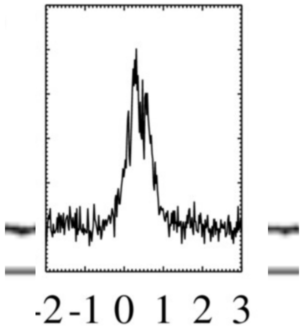
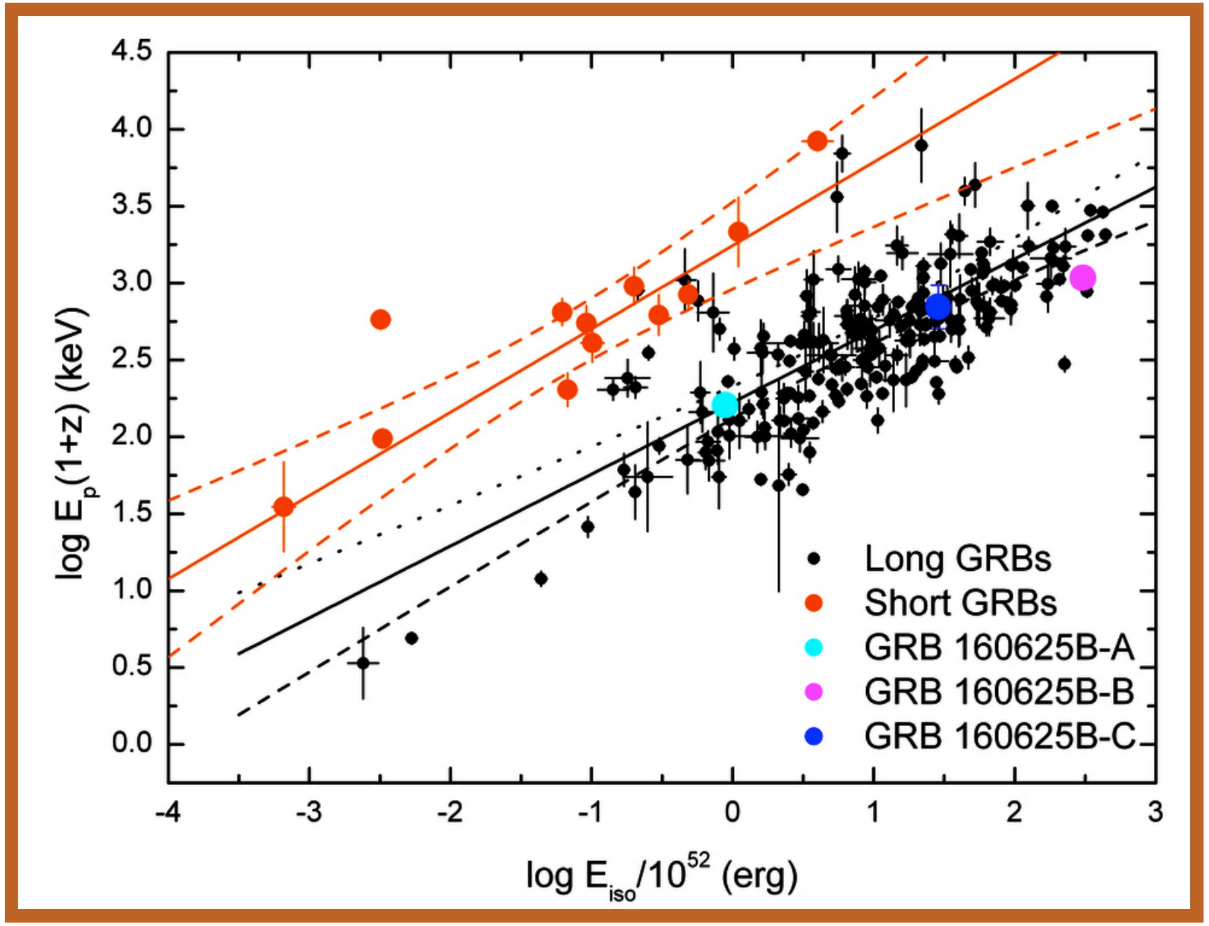


GRB 160625B-A



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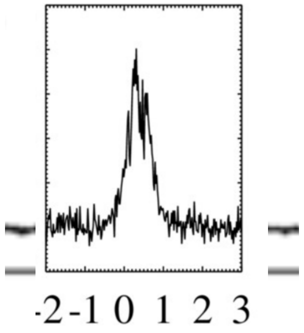

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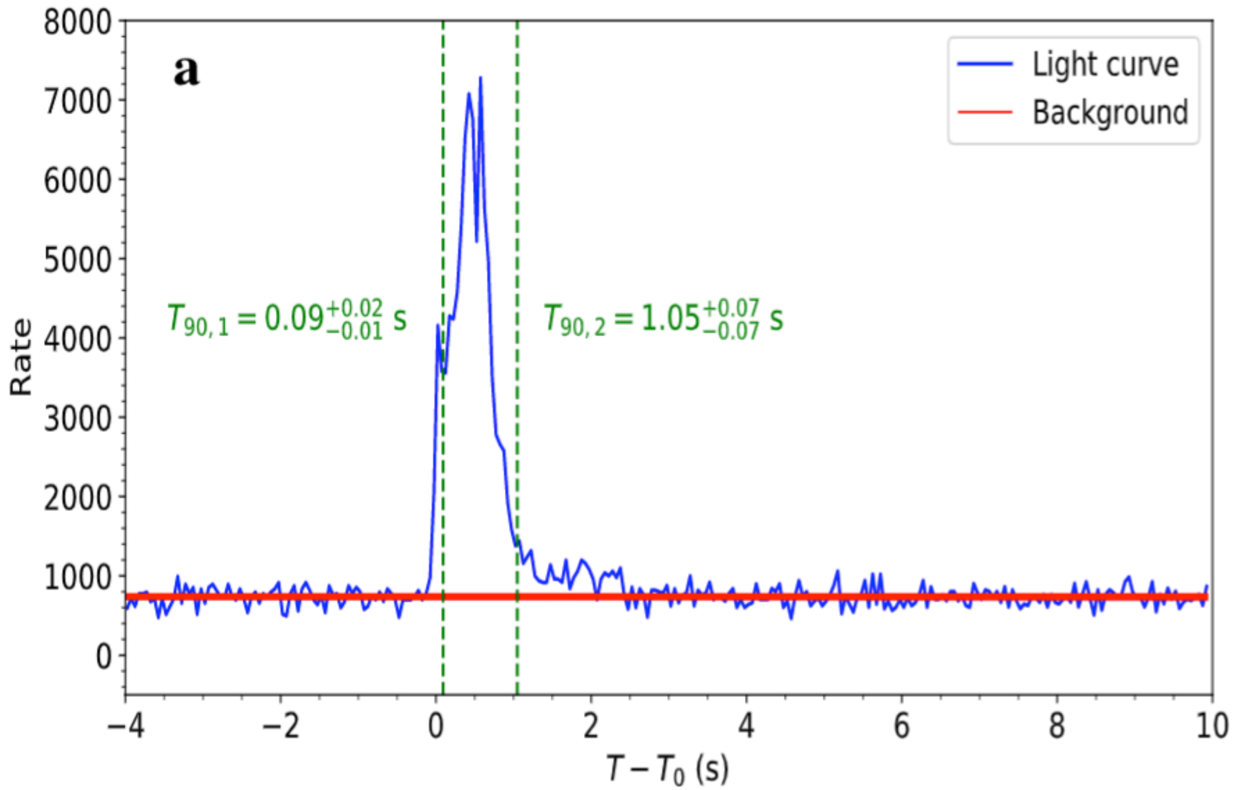
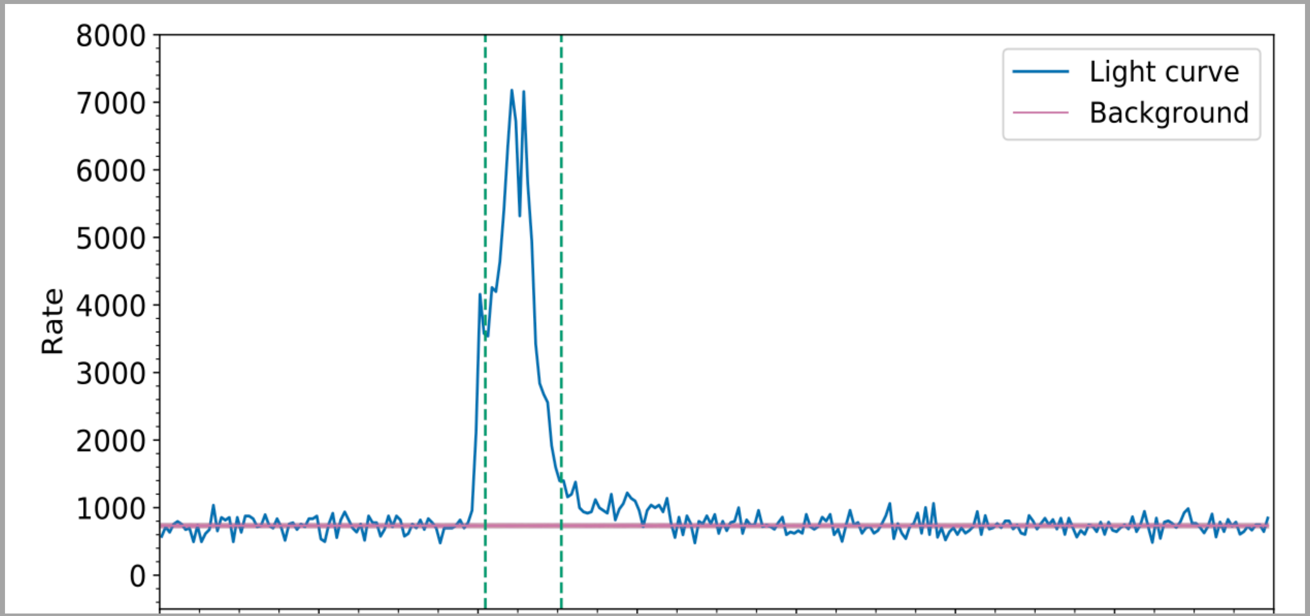


GRB 200826A

GRB 200826A !

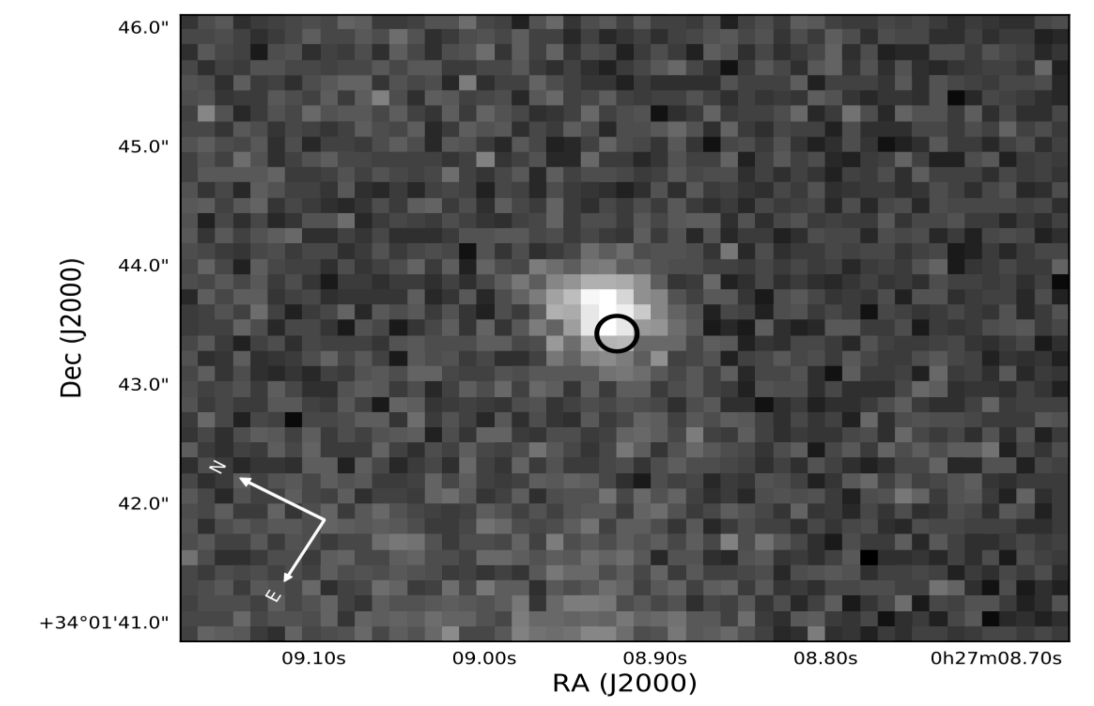
Zhang, B.-B. et al 2021, Nature Astronomy,5, 911

GRB 200826A : A Bright GRB



Zhang, B.-B. et al 2021, Nature Astronomy, 5, 911

GRB 200826A : Host Galaxy



Redshift = 0.75

Offset = 2.6 kpc

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

SSFR > 0.35 Gyr^{-1}

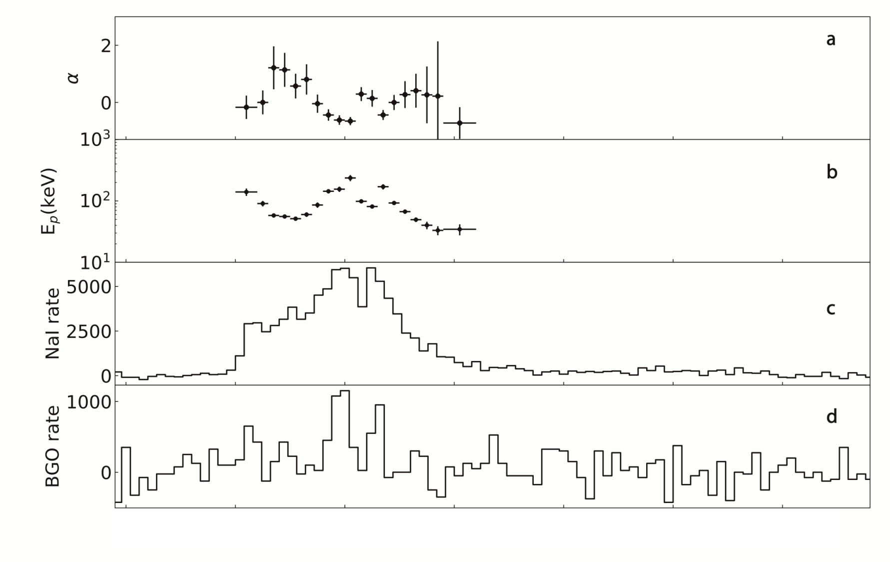
—>

Typical star-forming host

Type II GRB

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

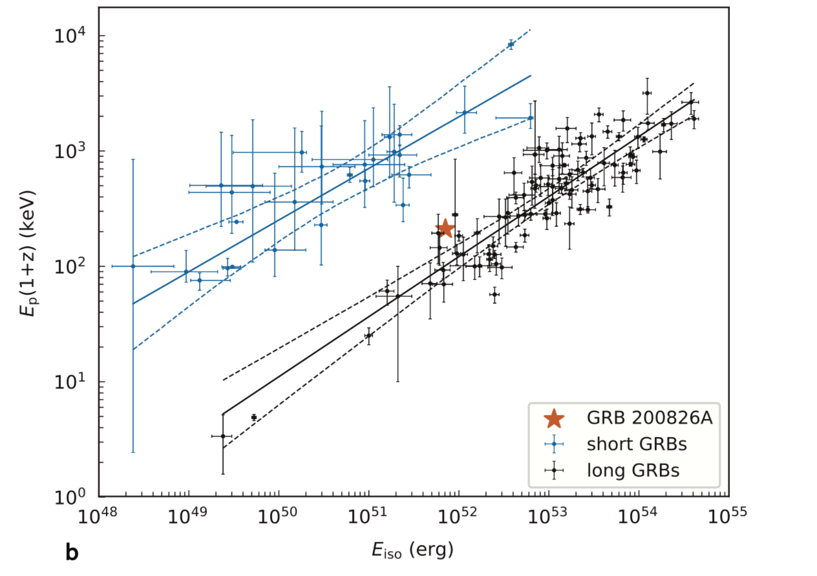
GRB 200826A : Spectra & Energy

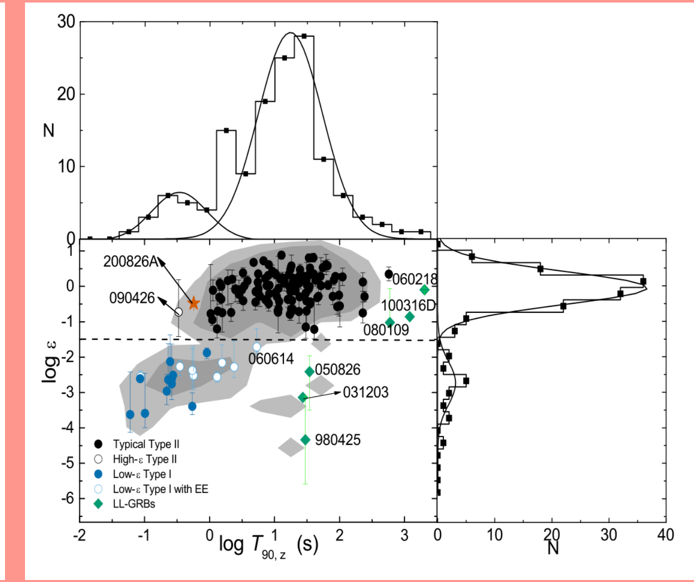


$\alpha = -0.68$
$E_p = 120keV$
F ~ $4.9 \times 10^{-6} erg\ cm^{-2}$
$E_{iso} = 7.1 \times 10^{51} erg$

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

GRB 200826A : Correlation

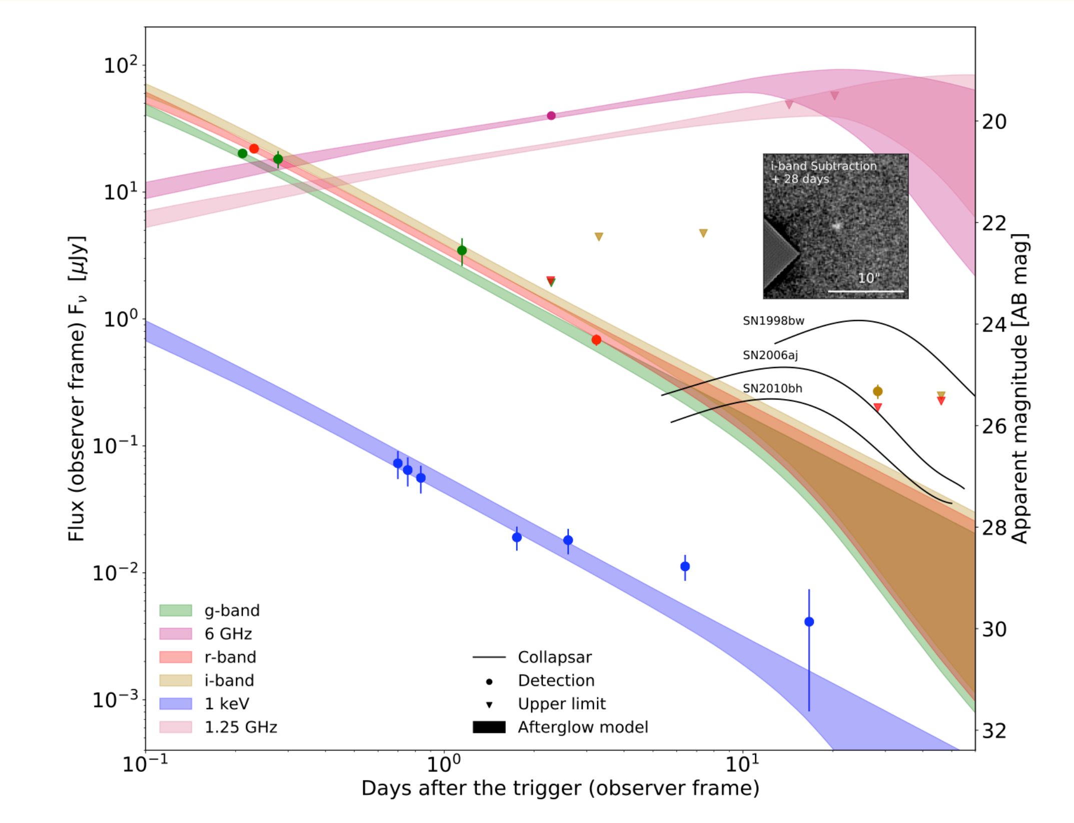




$$\epsilon = E_{\gamma,\mathrm{iso},52}/E_{\mathrm{p,z},2}^{5/3},$$

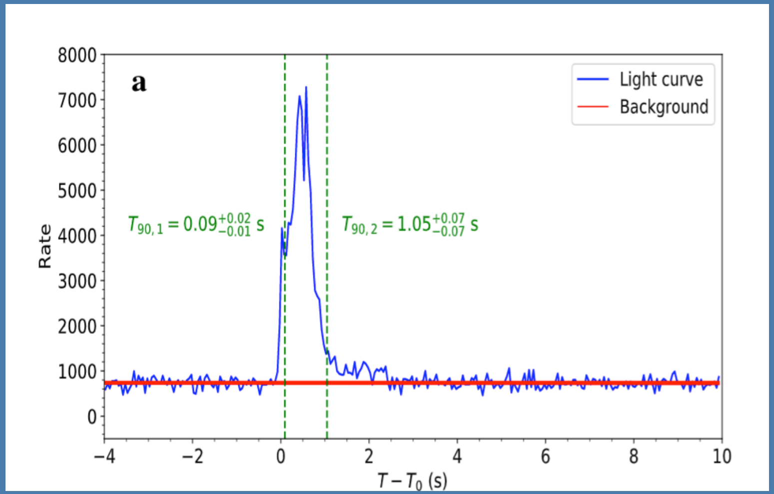
Zhang, B.-B. et al 2021, Nature Astronomy, 5, 911

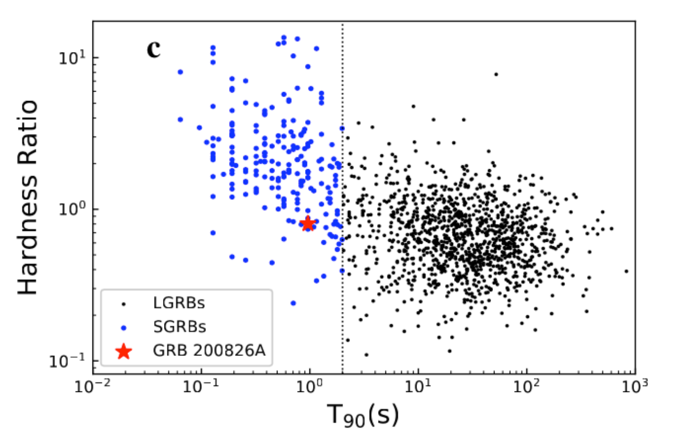
GRB 200826A : A Supernova!



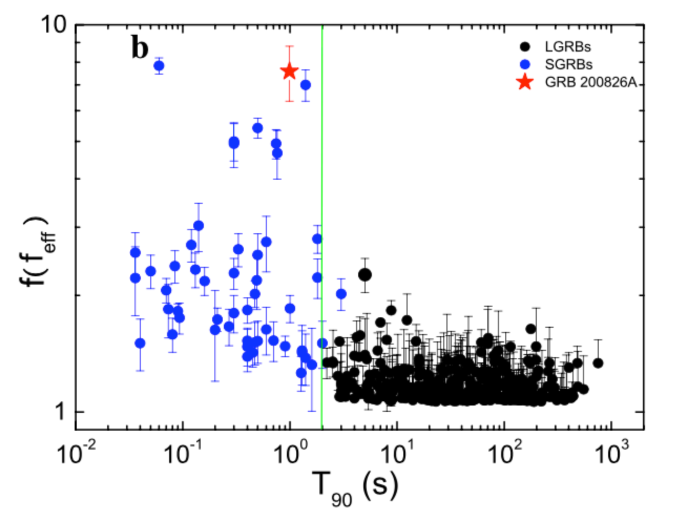
Zhang, B.-B. et al 2021, Nature Astronomy; Ahumada et al. 2021, Nature Astronomy

GRB 200826A : But it is definitely short !



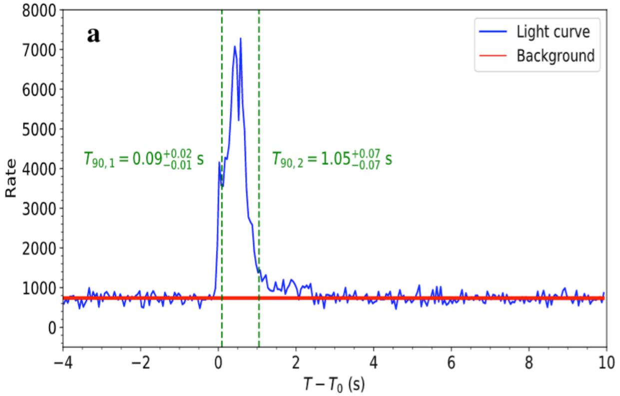


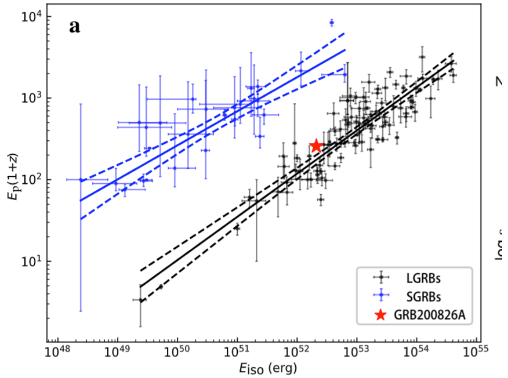
NO Tail and NOT fat

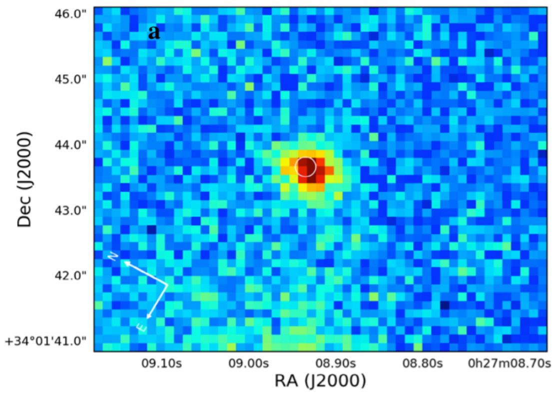


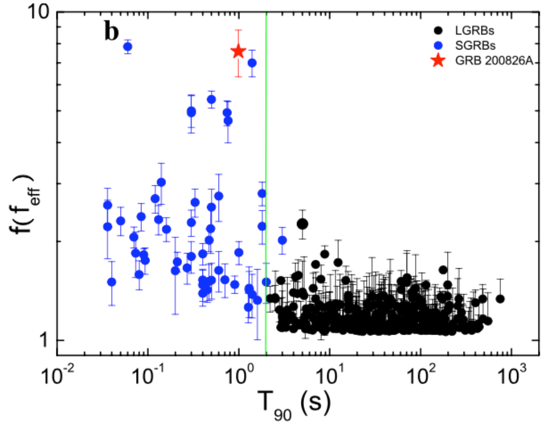
Zhang, B.-B. et al 2021, Nature Astronomy

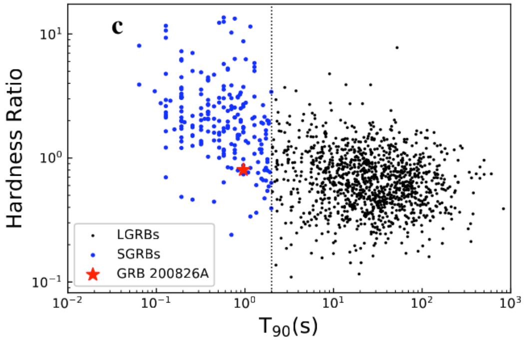
GRB 200826A: “shortest-long gamma ray burst”

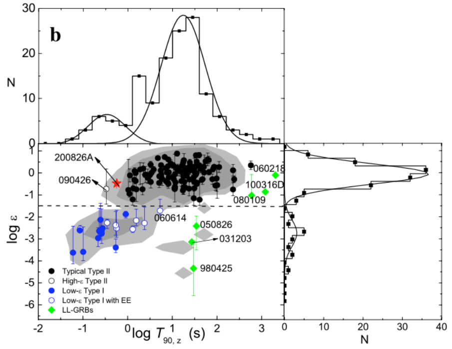










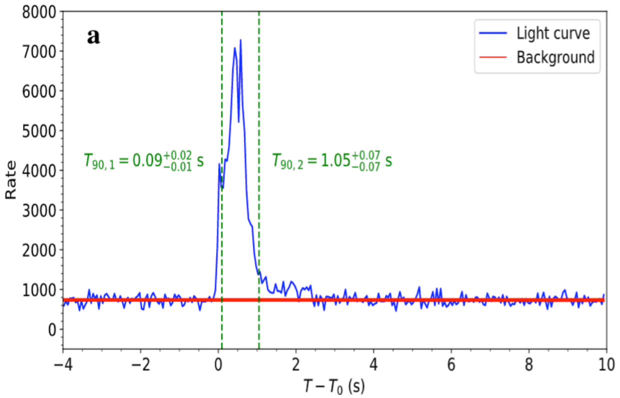


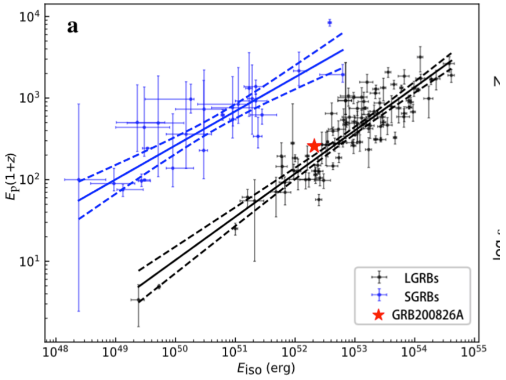
Everything looks like a long GRB, except for its definitely short duration!

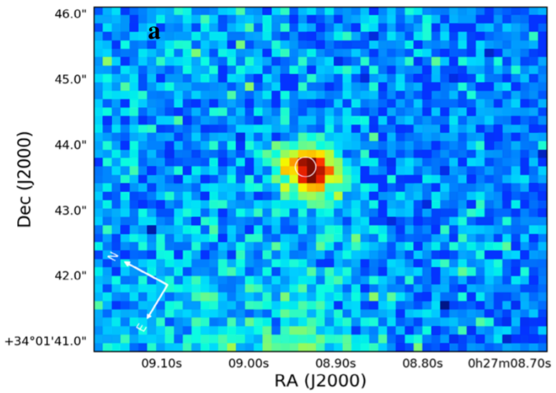
Time duration
f-parameters
hardness
Spectral photon index
Spectral peak energy
Isotropic energy
Total fluence
ϵ - parameter
Time lag(10-20 keV $\sim$ 250-300 keV)
Redshift
Offset $R_{\rm off}$
Half light radius R_{50}
$R_{\rm off}/R_{50}$
Cumulatve light fraction $F_{\rm light}$
Log OII/OI
Peak flux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

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)

NO Tail and NOT fat

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

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

Fightings between Short & Long Since 2006

Vol 437|6 October 2005|**doi:10.1038/nature04142** nature

LETTERS

A short γ-ray burst apparently associated with an elliptical galaxy at redshift $z = 0.225$

N. Gehrels[1], C. L. Sarazin[2], P. T. O'Brien[3], B. Zhang[4], L. Barbier[1], S. D. Barthelmy[1], A. Blustin[5], D. N. Burrows[6], J. Cannizzo[1,7], J. R. Cummings[1,8], M. Goad[3], S. T. Holland[1,9], C. P. Hurkett[3], J. A. Kennea[6], A. Levan[3], C. B. Markwardt[1,10], K. O. Mason[5], P. Meszaros[6], M. Page[5], D. M. Palmer[11], E. Rol[3], T. Sakamoto[1,8], R. Willingale[3], L. Angelini[1,7], A. Beardmore[3], P. T. Boyd[1,7], A. Breeveld[5], S. Campana[12], M. M. Chester[6], G. Chincarini[12,13], L. R. Cominsky[14], G. Cusumano[15], M. de Pasquale[5], E. E. Fenimore[11], P. Giommi[16], C. Gronwall[6], D. Grupe[6], J. E. Hill[6], D. Hinshaw[1,17], J. Hjorth[18], D. Hullinger[1,10], K. C. Hurley[19], S. Klose[20], S. Kobayashi[6], C. Kouveliotou[21], H. A. Krimm[1,9], V. Mangano[12], F. E. Marshall[1], K. McGowan[5], A. Moretti[12], R. F. Mushotzky[1], K. Nakazawa[22], J. P. Norris[1], J. A. Nousek[6], J. P. Osborne[3], K. Page[3], A. M. Parsons[1], S. Patel[23], M. Perri[16], T. Poole[5], P. Romano[12], P. W. A. Roming[6], S. Rosen[5], G. Sato[22], P. Schady[5], A. P. Smale[24], J. Sollerman[25], R. Starling[26], M. Still[1,9], M. Suzuki[27], G. Tagliaferri[12], T. Takahashi[22], M. Tashiro[27], J. Tueller[1], A. A. Wells[3], N. E. White[1] & R. A. M. J. Wijers[26]

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

Mon. Not. R. Astron. Soc. **401,** 963–972 (2010) doi:10.1111/j.1365-2966.2009.15733.x

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]

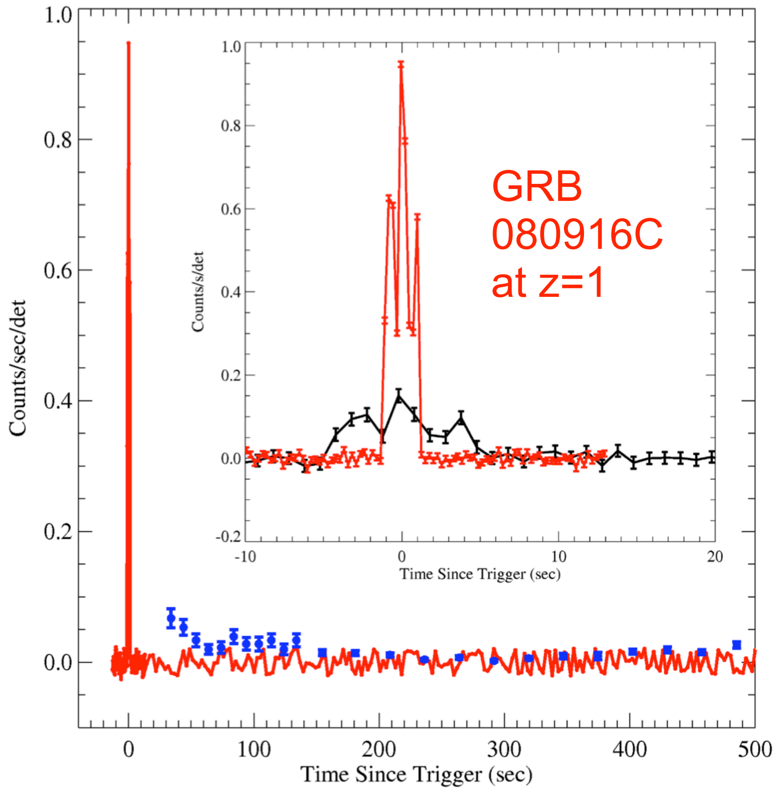
Physically Short (merger type), but it is long.

Physically long (collapsar type), but it is short.

Fightings between Short & Long Since 2006

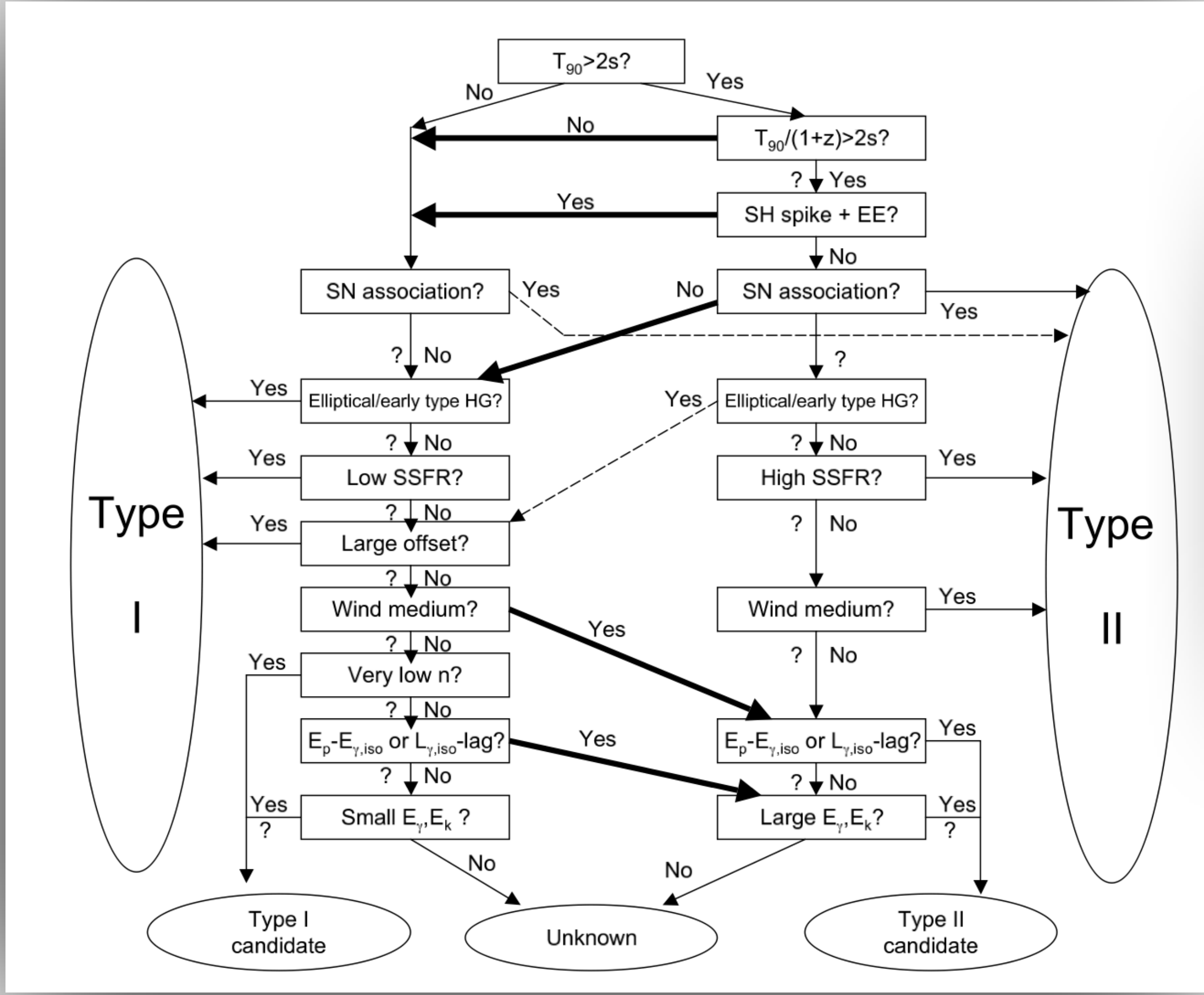
A GRB can be (physically) **long** (300 s),
Nature can shows it as **short** (~ 10 s).
But it can never be **intrinsically short** (~ 1 s)
(At least we believed so.)

A GRB can be (physically) **short** (2 s),
Nature can shows it as **long** (~ 100 s).
But it can never be **intrinsically long** (> 2 s)
(At least we believed so.)

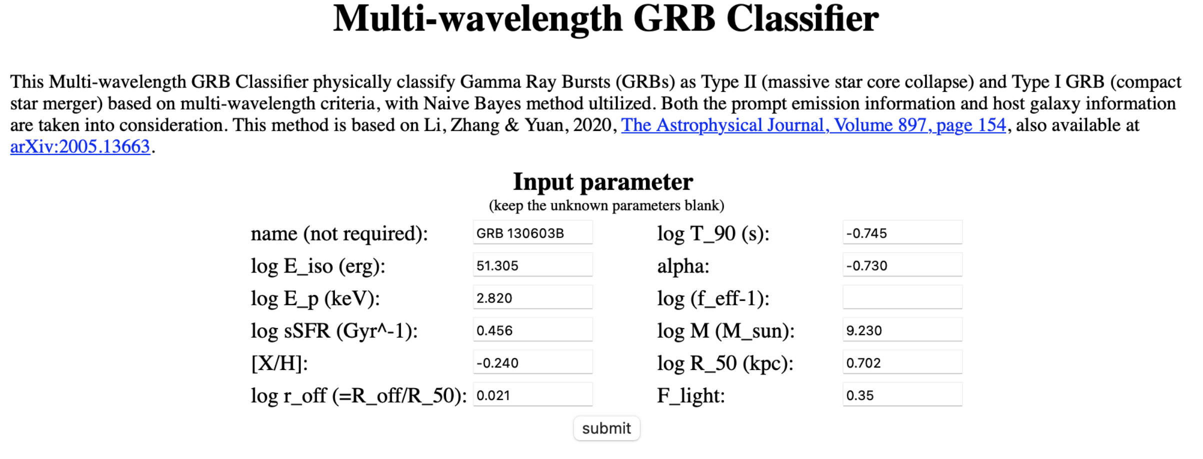


Zhang, B. ,BBZ, et al. 2009

Fightings between Short & Long Since 2006



Zhang, B. ,BBZ, et al. 2009



Multi-wavelength GRB Classifier

This Multi-wavelength GRB Classifier physically classify Gamma Ray Bursts (GRBs) as Type II (massive star core collapse) and Type I GRB (compact star merger) based on multi-wavelength criteria, with Naive Bayes method ultilized. Both the prompt emission information and host galaxy information are taken into consideration. This method is based on Li, Zhang & Yuan, 2020, The Astrophysical Journal, Volume 897, page 154, also available at arXiv:2005.13663.

Input parameter

(keep the unknown parameters blank)

name (not required):	GRB 130603B	log T_90 (s):	-0.745
log E_iso (erg):	51.305	alpha:	-0.730
log E_p (keV):	2.820	log (f_eff-1):	
log sSFR (Gyr^-1):	0.456	log M (M_sun):	9.230
[X/H]:	-0.240	log R_50 (kpc):	0.702
log r_off (=R_off/R_50):	0.021	F_light:	0.35

submit

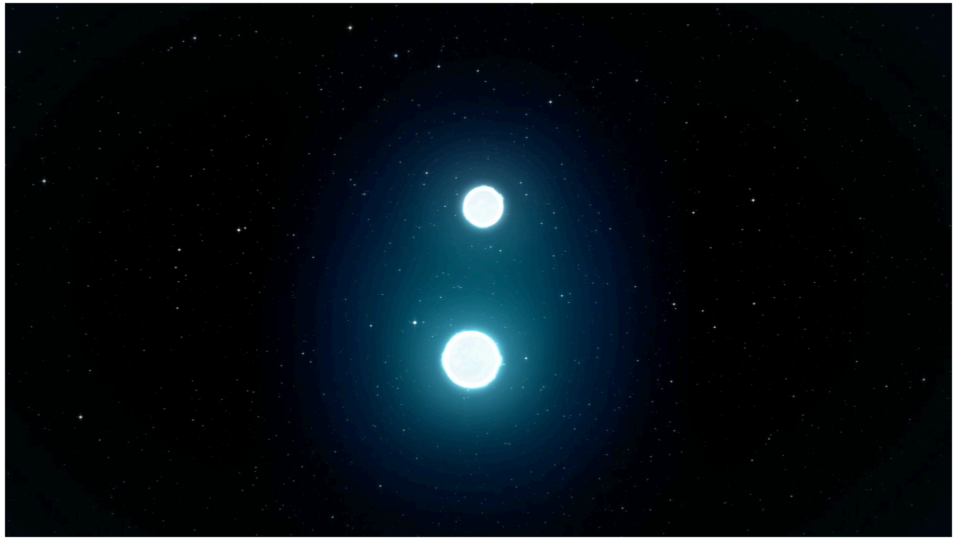
Li, Zhang & Yuan, 2020

HOW TO?

- make a short GRB long
- make a long GRB short

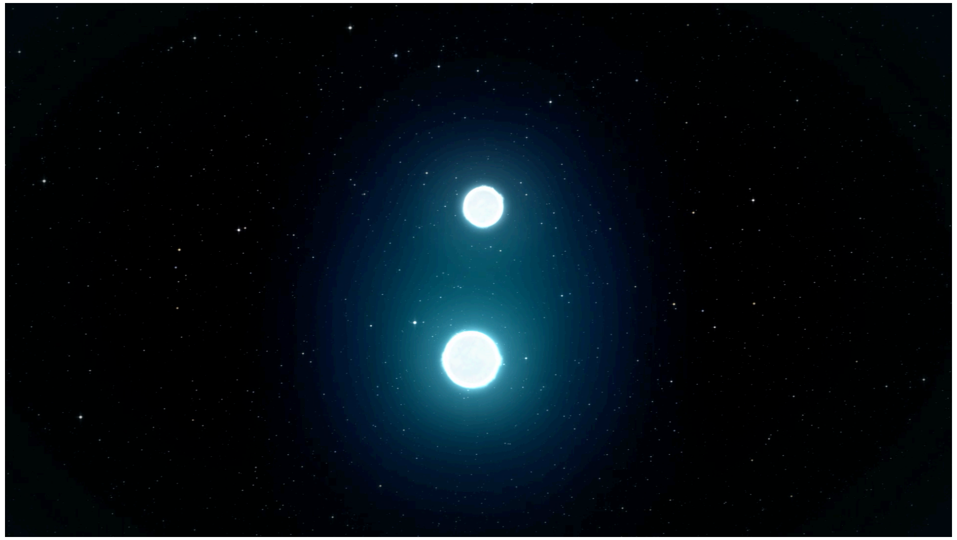
HOW TO?

- make a (physically) short GRB (apparently) long
- make a (physically) long GRB (apparently) short



HOW TO?

- make a Type I GRB (apparently) long
- make a Type II GRB (apparently) short

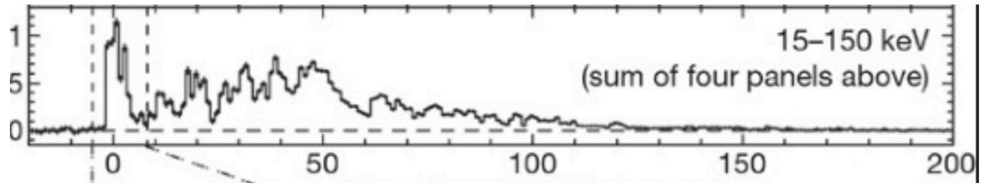


Bottom Lines

- 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

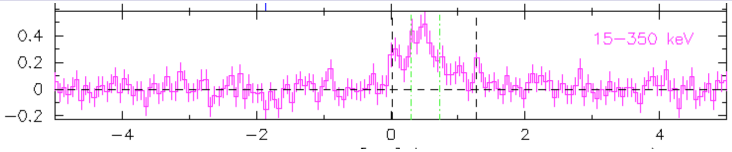
ABSTRACT

Bottom Lines

- 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

- 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,

A successfully theory on GRB 200826A should:

1. reproduce its short duration,
2. not involve 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

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

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

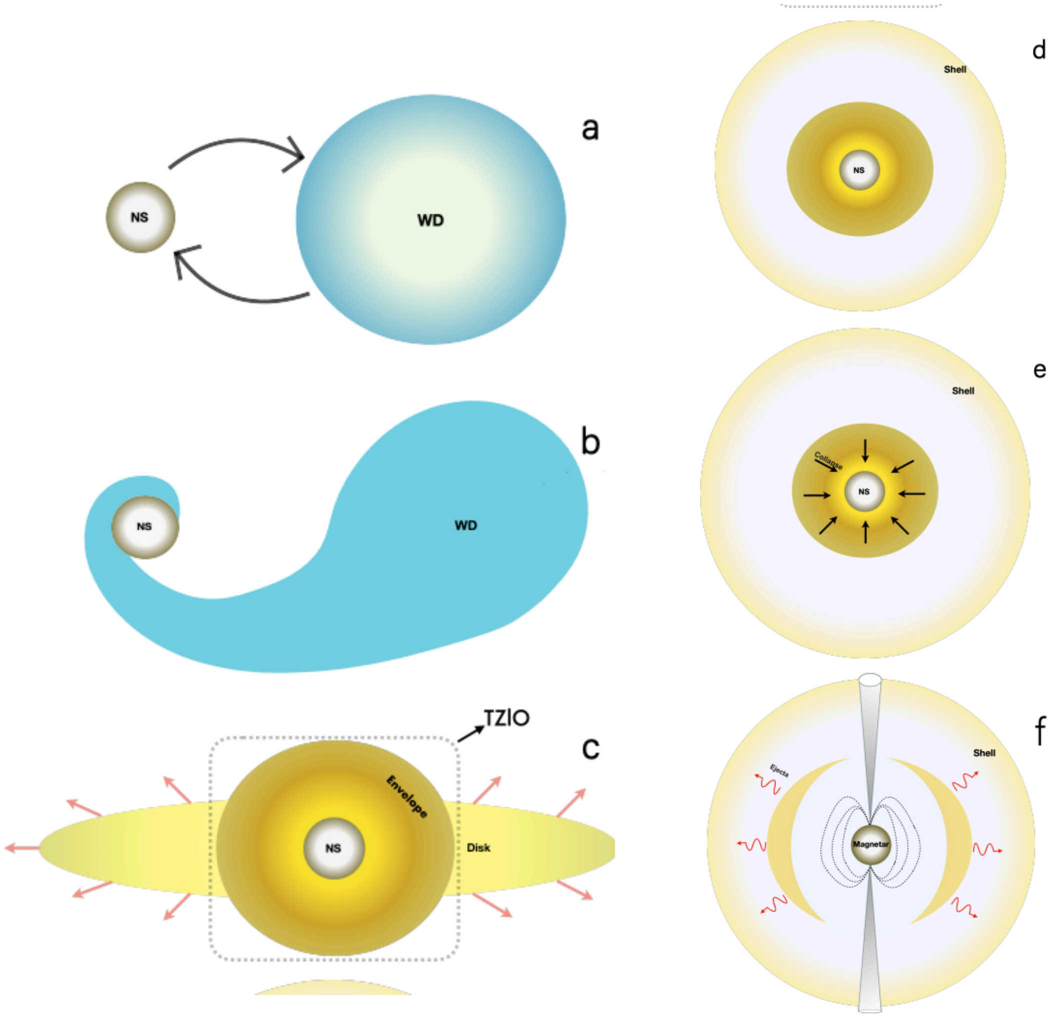
(3) Not accretion powered: NS diff. rotation?

(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

Collapse of a Thorne-Zytkow-like Object as the Aftermath of a WD-NS Merger



A. WD capture
B. WD disrupted, and UMT (unstable mass transfer)
C. TZIO (w/ disk) formed, T > 10^9 k
D. (~ hours) Disk accreted —> more massive TZIO and a shell

$$t_{\rm A} \simeq 5\times10^{6}\ {\rm s}\ (\frac{\beta}{10^{-12}})^{-1/2}(\frac{\rm H/R}{1.0})^{-2}(\frac{\rm R}{10^{4}\ {\rm km}})^{3/2} \times(\frac{M_{\rm TZ}}{1.8M_{\odot}})^{1/2}$$

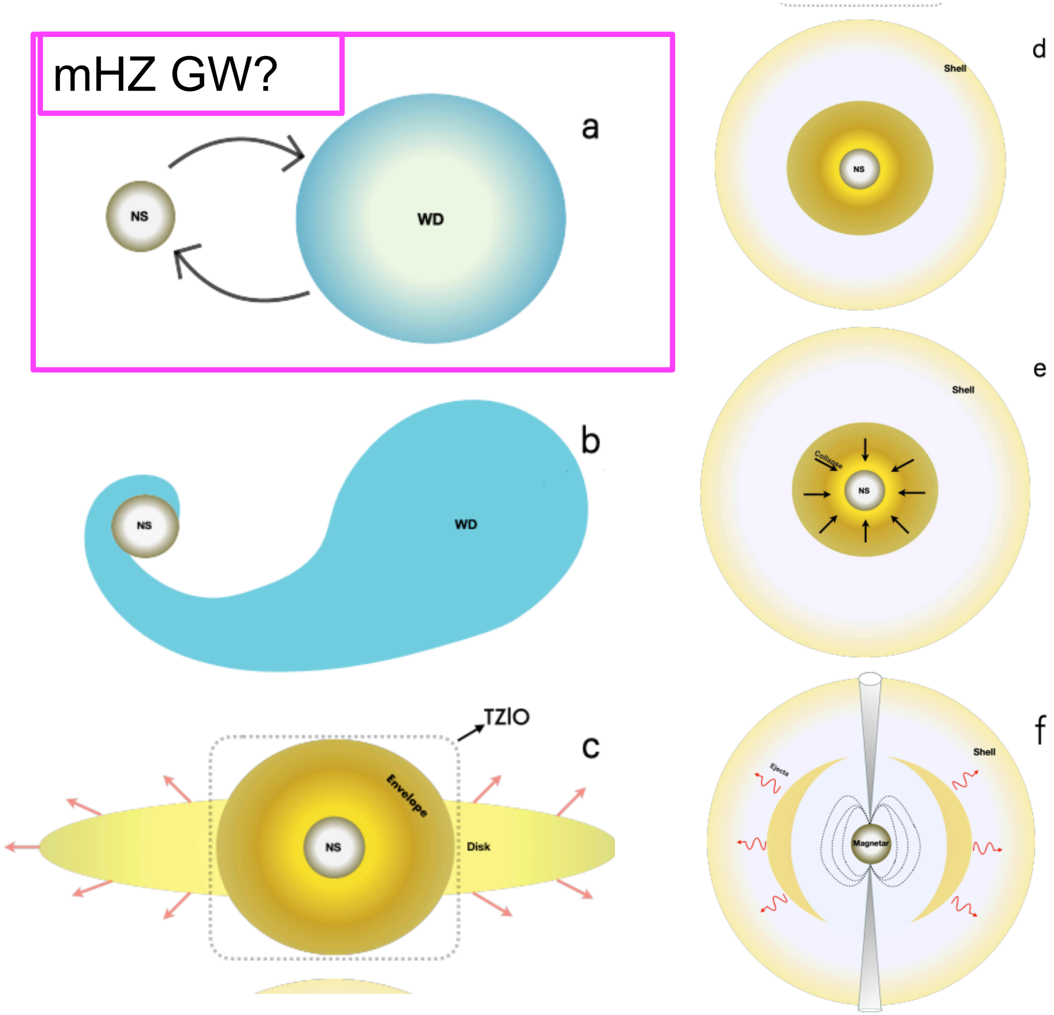
E. (~ 1 year) Cooling down and collapse

$$t_{\rm ff,TZ} \sim (\frac{\rm R_{TZ}^3}{GM_{\rm TZ}})^{1/2} = 0.52\ {\rm s}\ (\frac{\rm R_{TZ}}{5\times10^{8}\ {\rm cm}})^{3/2}(\frac{\rm M_{TZ}}{1.8\ {\rm M}_{\odot}})^{-1/2},$$

F. Heated ejected material —> merger-nova
disk wind shell + heated ejected material —> late-time bump

Peng, Z.-K. , **BBZ**, et al., 2022, ApJL, under review

Collapse of a Thorne-Zytkow-like Object as the Aftermath of a WD-NS Merger



A. WD capture
B. WD disrupted, and UMT (unstable mass transfer)
C. TZIO (w/ disk) formed, T > 10^9 k
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$$t_A \simeq 5\times10^6\ \mathrm{s}\left(\frac{\beta}{10^{-12}}\right)^{-1/2}\left(\frac{\mathrm{H/R}}{1.0}\right)^{-2}\left(\frac{\mathrm{R}}{10^4\ \mathrm{km}}\right)^{3/2}\times\left(\frac{M_{\mathrm{TZ}}}{1.8M_\odot}\right)^{1/2}$$

E. (~ 1 year) Cooling down and collapse

$$t_{\mathrm{ff,TZ}} \sim \left(\frac{\mathrm{R}^3_{\mathrm{TZ}}}{GM_{\mathrm{TZ}}}\right)^{1/2} = 0.52\ \mathrm{s}\left(\frac{\mathrm{R_{TZ}}}{5\times10^8\ \mathrm{cm}}\right)^{3/2}\left(\frac{\mathrm{M_{TZ}}}{1.8\ \mathrm{M}_\odot}\right)^{-1/2},$$

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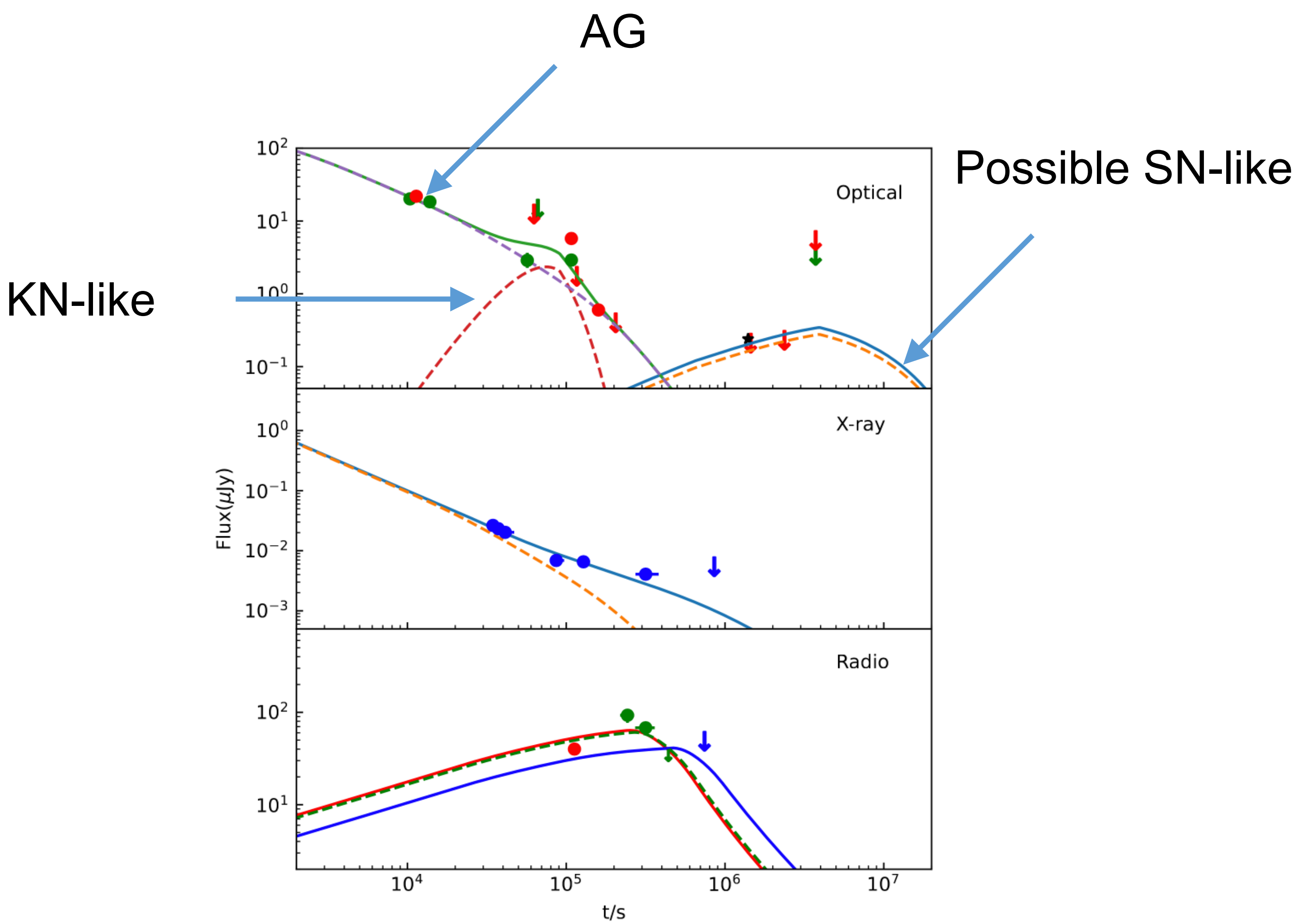
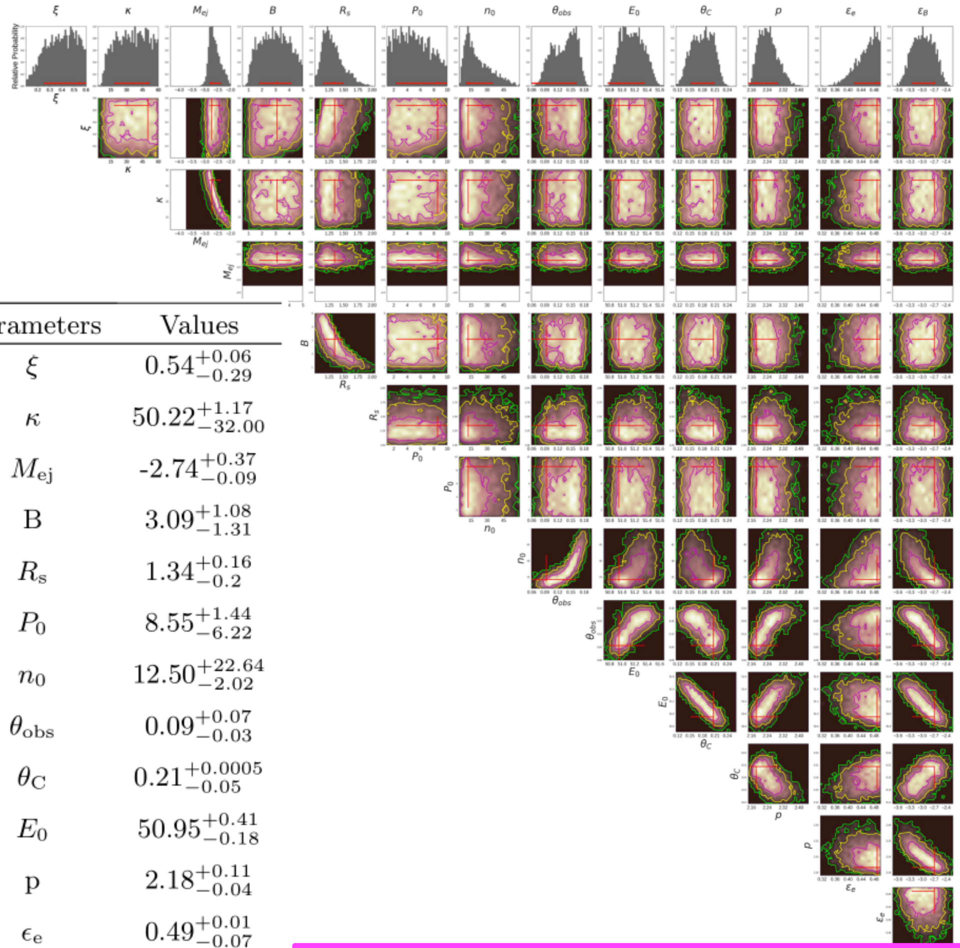


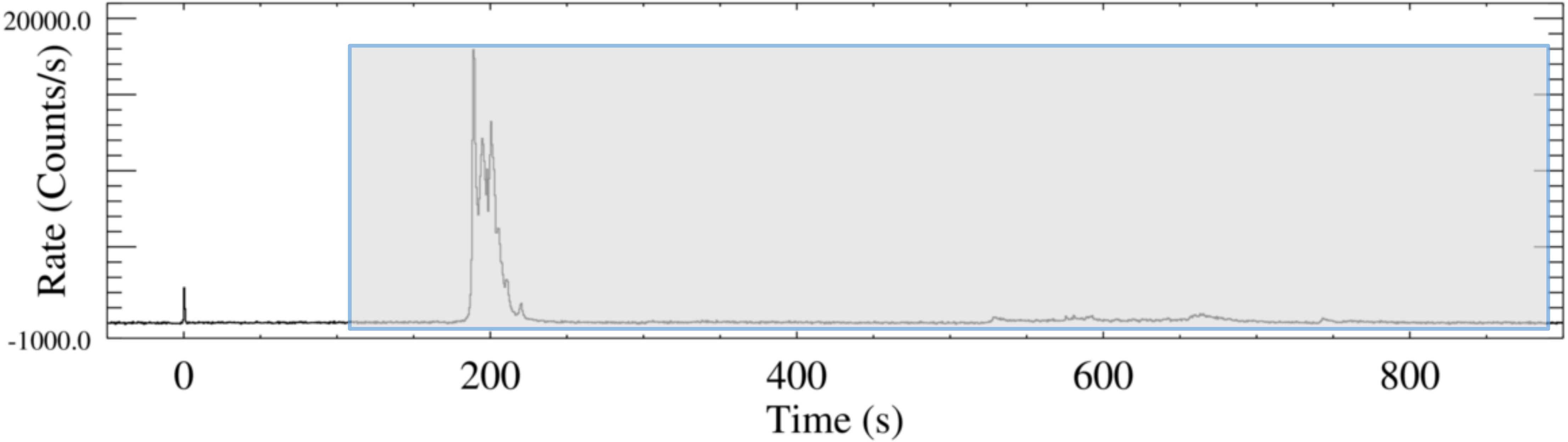
Peng, Z.-K. , BBZ, et al., 2022, ApJL, under review



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	$2.18^{+0.11}_{-0.04}$
$\epsilon_{\rm e}$	$0.49^{+0.01}_{-0.07}$
$\epsilon_{\rm B}$	$-2.70^{+0.01}_{-0.56}$

Further numerical simulations needed

Alternatively, what about if we really missed the main burst?



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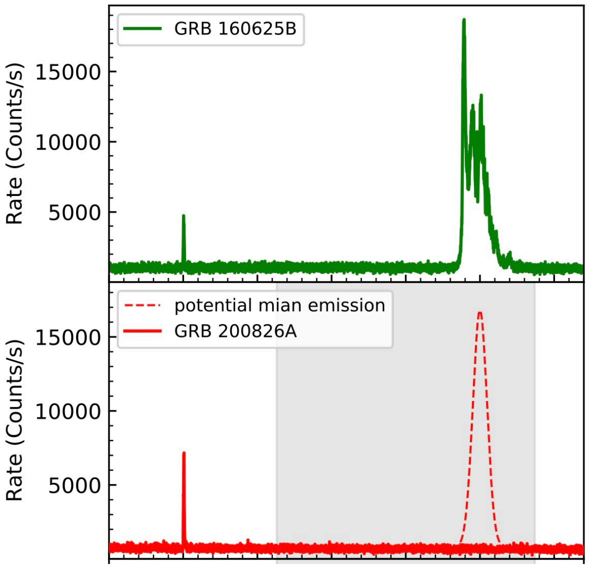
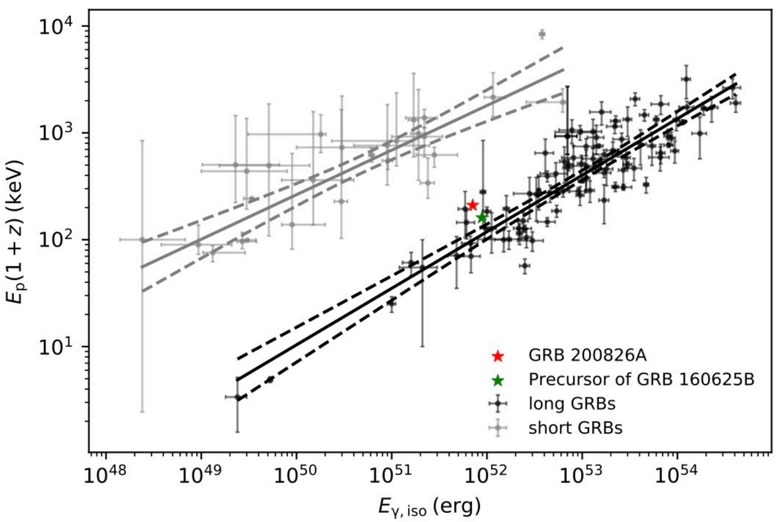
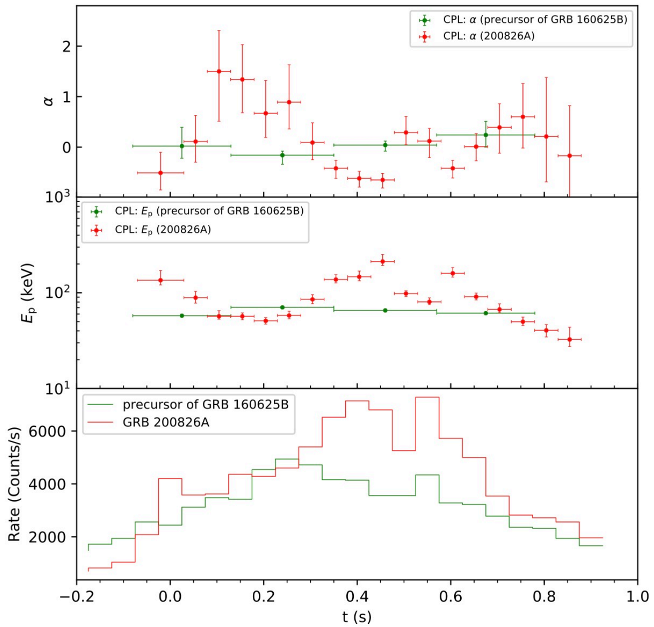


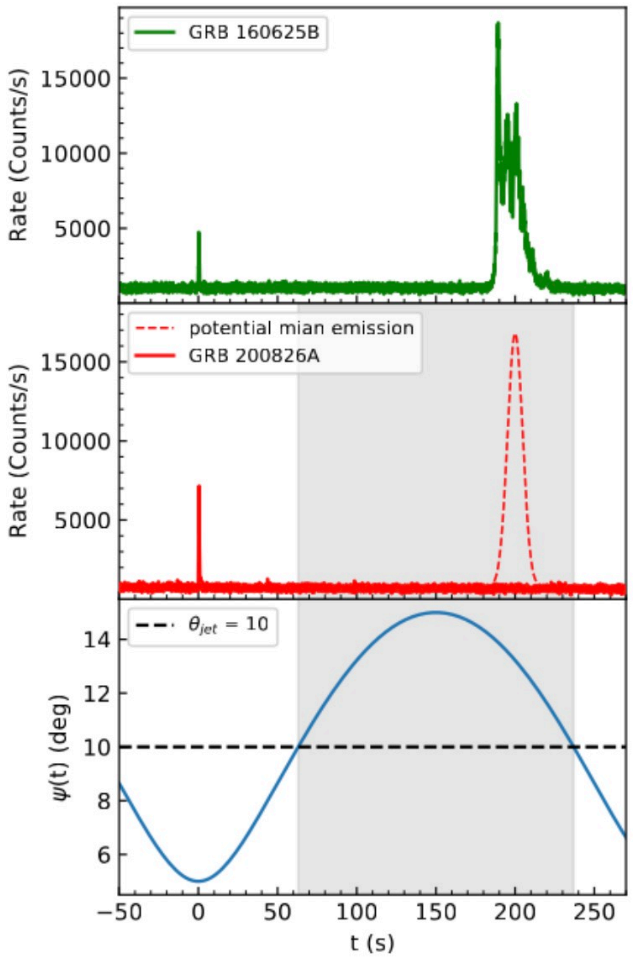




We appear to have some observational evidence; but how?

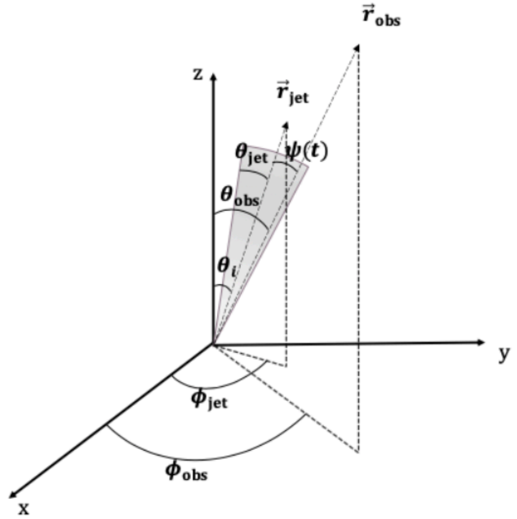
Wang, X. I., **BBZ**, Lei, W.-H., 2022, ApJL, 931, 2

GRB 200826A: A Precursor of a Long GRB with Missing Main Emission



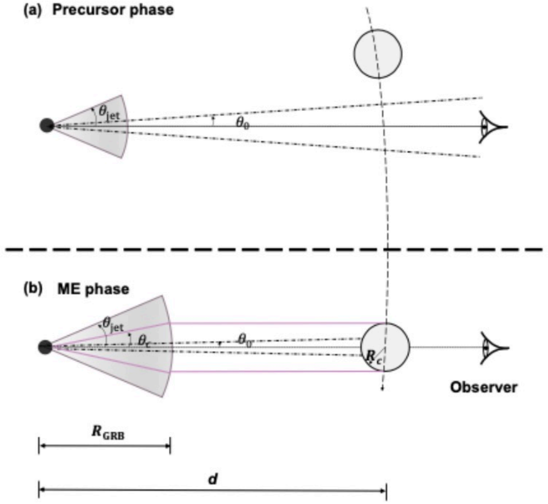
Option 1: Jet Precession

θ_{obs} = $10°$, θ_i = $5°$, β_0 = 0,
θ_{jet} = $10°$, and $\tau = 300$s



Option 2: Companion Star Blockage

M_{total} = 50$M_{\odot}$, Γ = 800, R_{GRB} = 10^{11} cm,
R_c = 3$R_{\odot}$, and d ≤ 3.3 ×10^{12} cm



Wang, X. I., **BBZ**, Lei, W.-H., 2022, ApJL, 931, 2

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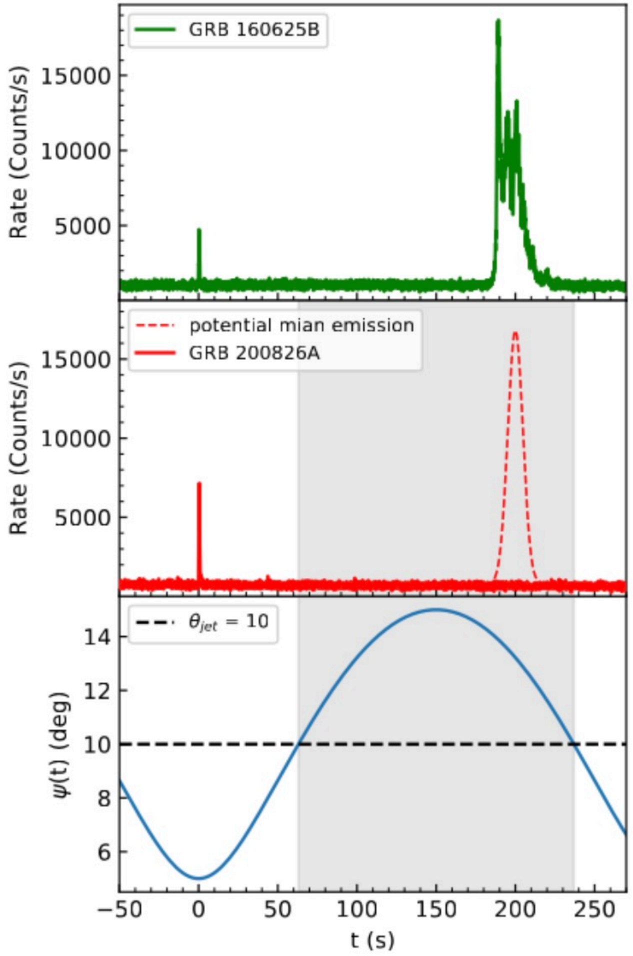

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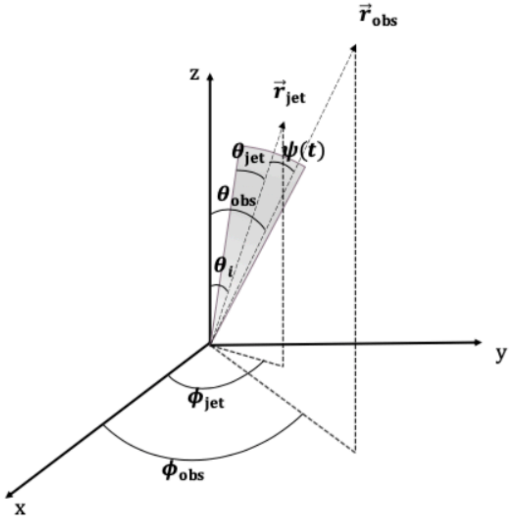

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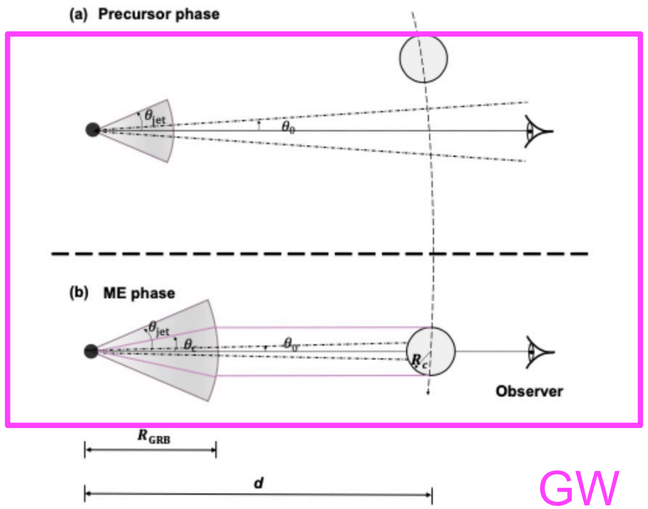


GW

Wang, X. I., **BBZ**, Lei, W.-H., 2022, ApJL, 931, 2

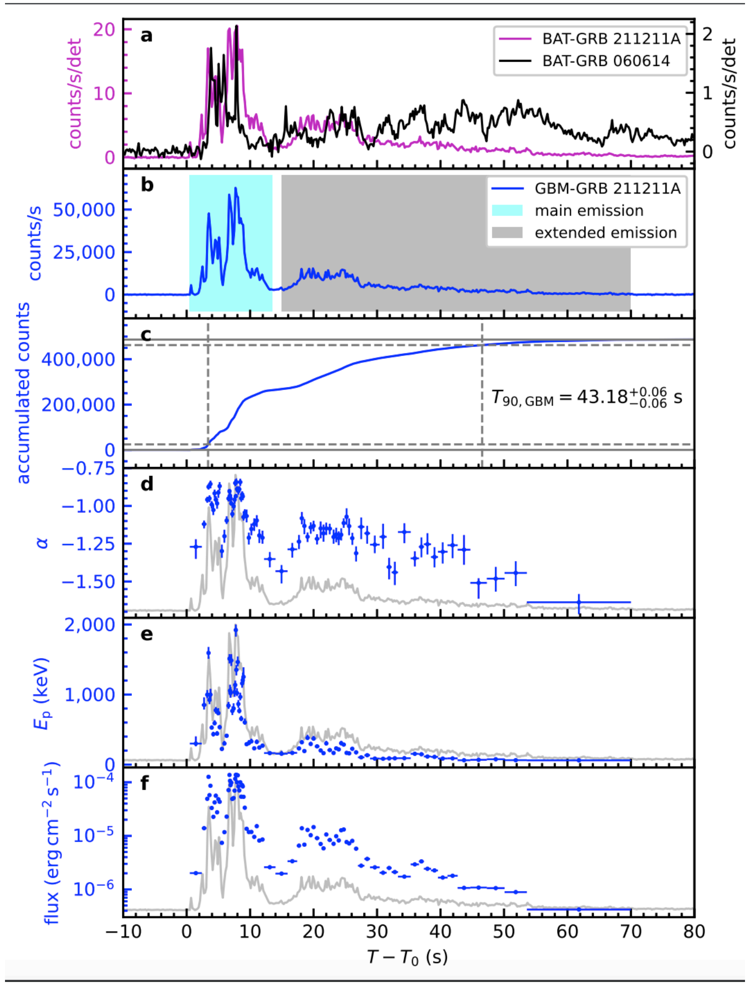
An opposite case?

GRB 200826A: A peculiarly short-duration gamma-ray burst from massive star core collapse

GRB 211211A: A peculiarly long-duration gamma-ray burst from a binary merger

Jun Yang, Shunke Ai, **BBZ** , et al. 2022, Nature, under revision, arXiv:2204.12771

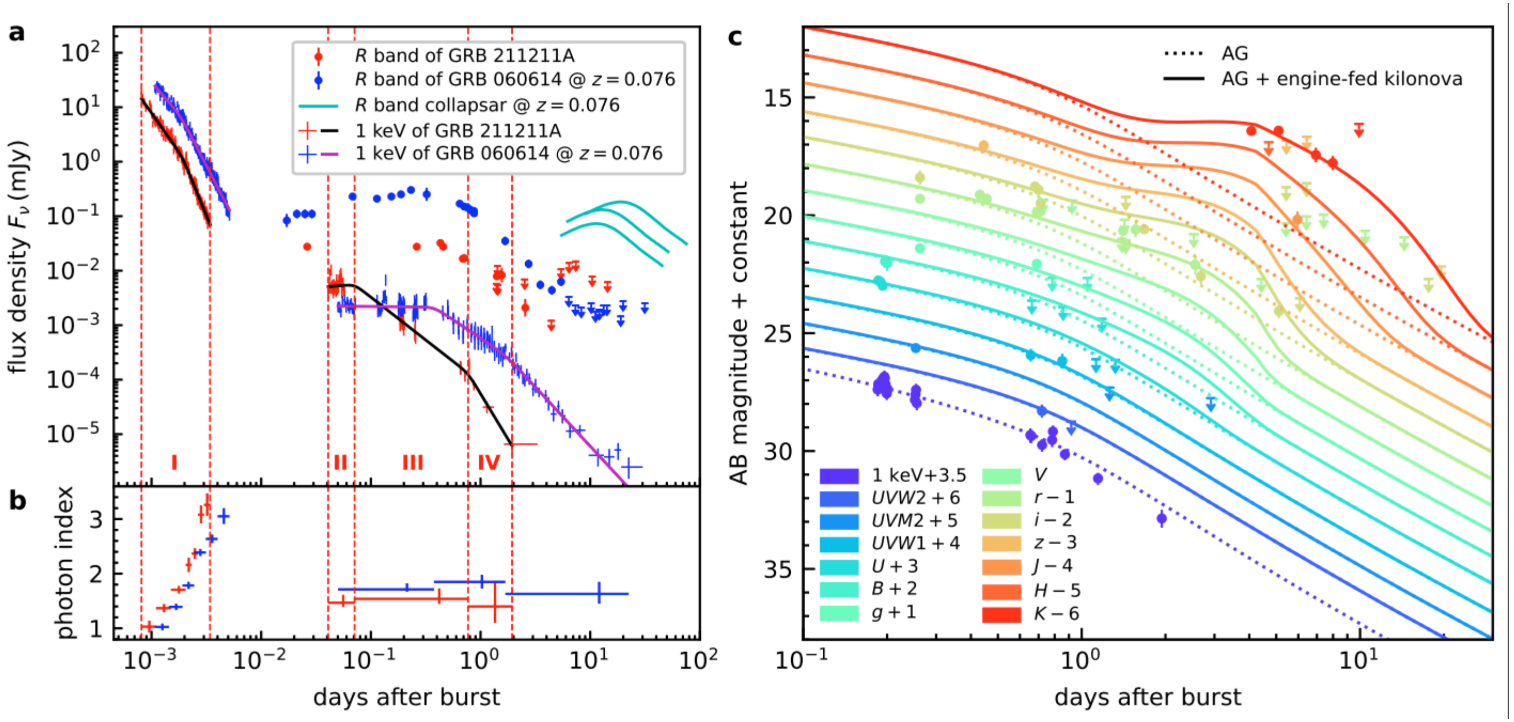
GRB 211211A: a Genuinely Long GRB from Merger



- Definitely long (not like GRB 060614 with a long soft tail)
- NO SN, old host galaxy,
- Possible KN excess

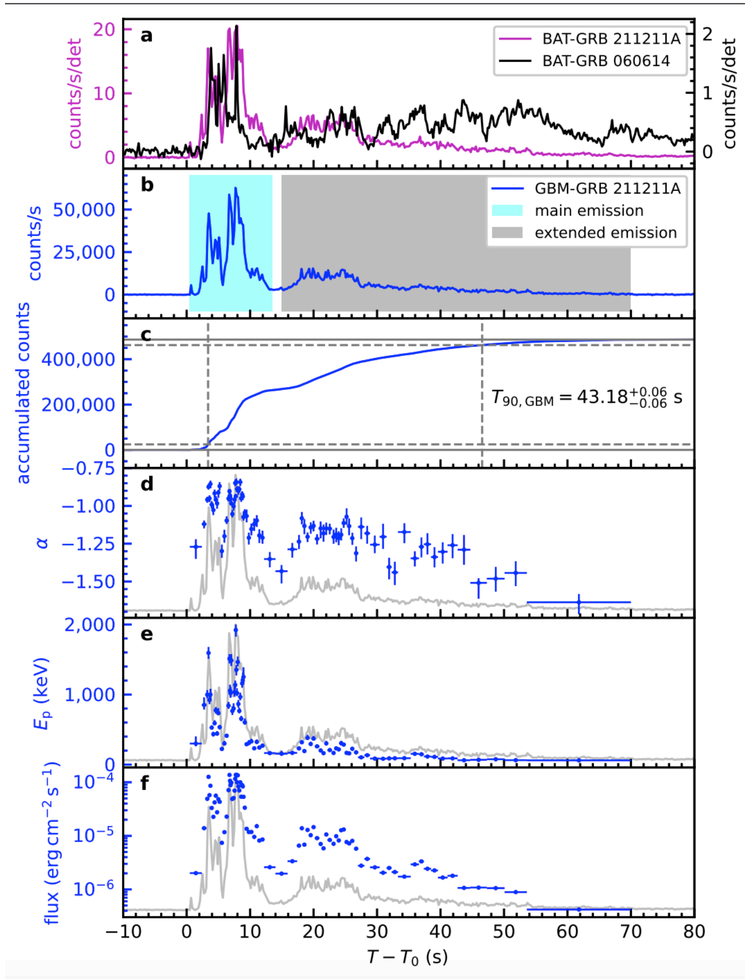
==> **Special Merger**

+ Special & Continuous CE?



Jun Yang, Shunke Ai, **BBZ** , 2022, Nature, under revision, arXiv:2204.12771

GRB 211211A: a Genuinely Long GRB from Merger



- Definitely long (not like GRB 060614 with a long soft tail)
- NO SN, old host galaxy,
- Possible KN excess

==> **Special Merger +   Special & Continuous CE?**

(1) NS+BH Merger   (high-freq GW)

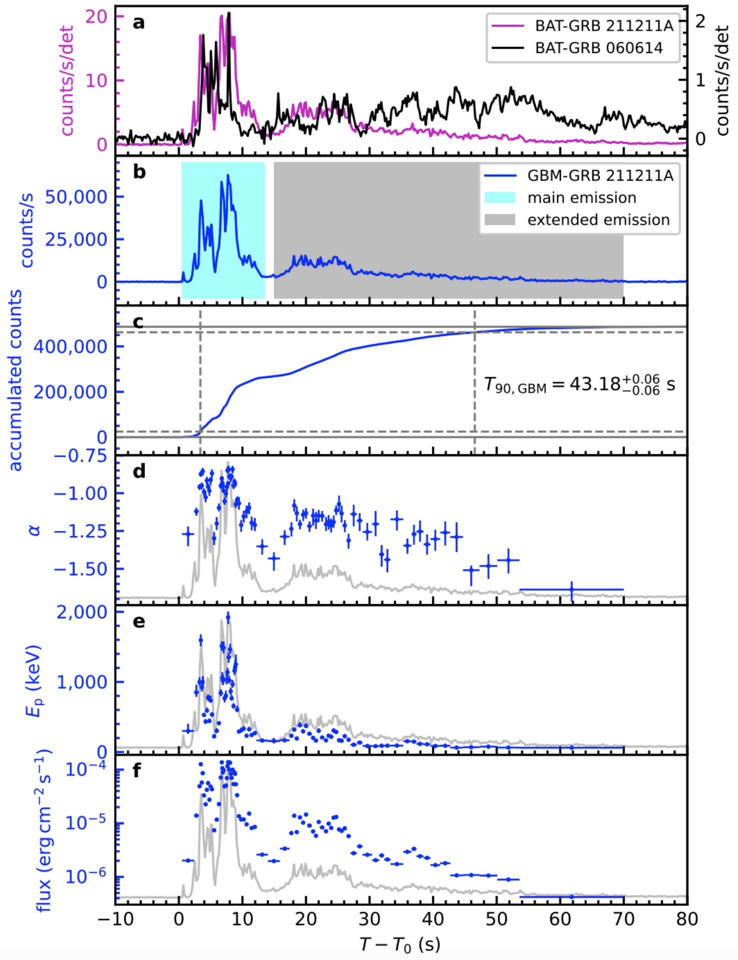
Zhu, J.-P. et al., 2022 , ApJL in press,
Gompertz et al, 2022, Science submitted,

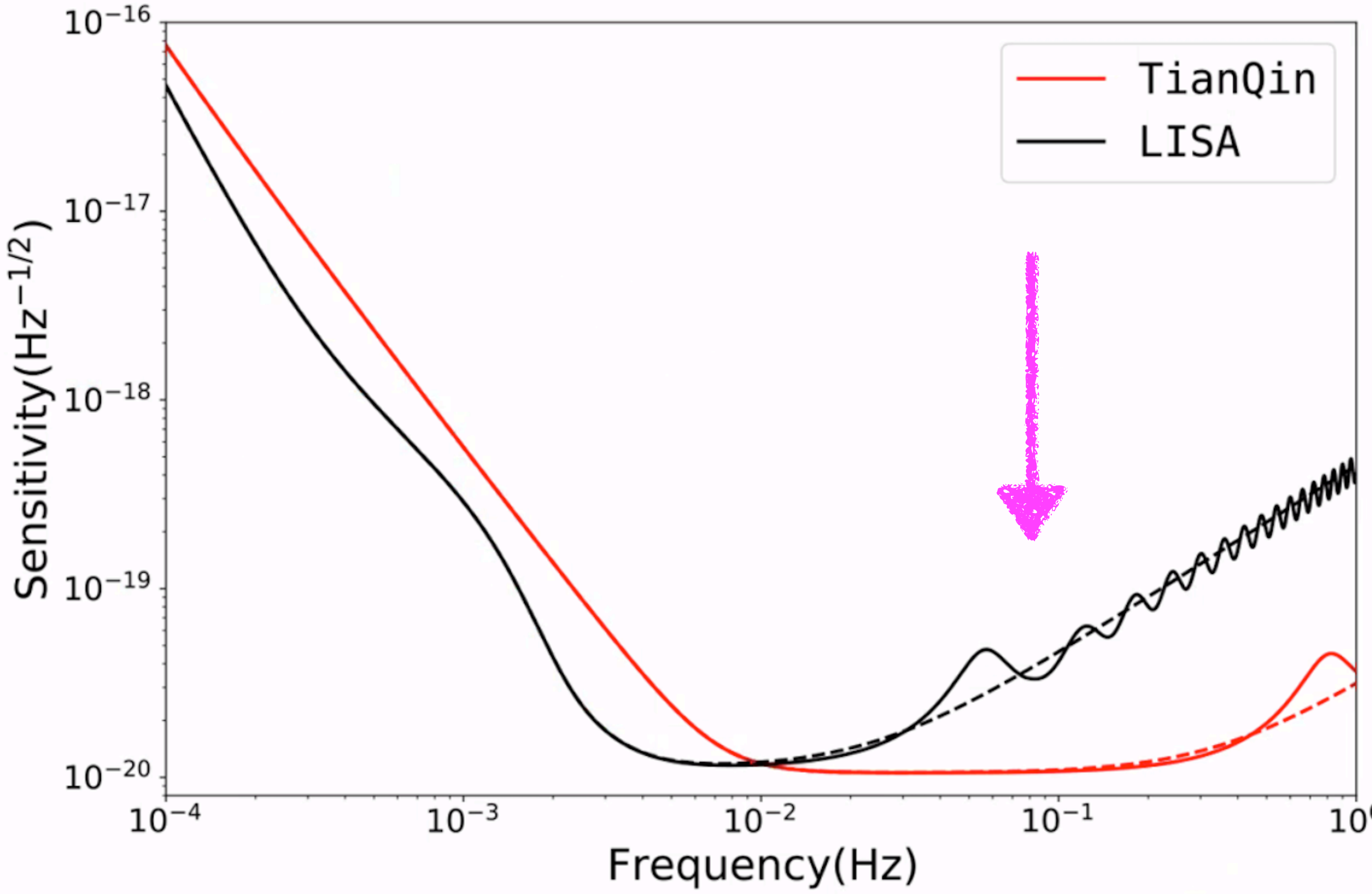
(2) NS+WD Merger (0.1 HZ GW)

Yang, J. et al., 2022, Nature, under review

Jun Yang, Shunke Ai, **BBZ** , 2022, Nature, under revision, arXiv:2204.12771

GRB 211211A: a Genuinely Long GRB from Merger





Zhu et al., Phys.Rev.Res. 4 (2022) 1, 013247

Jun Yang, Shunke Ai, B

Topics

1. **Transition**: central engine can transform

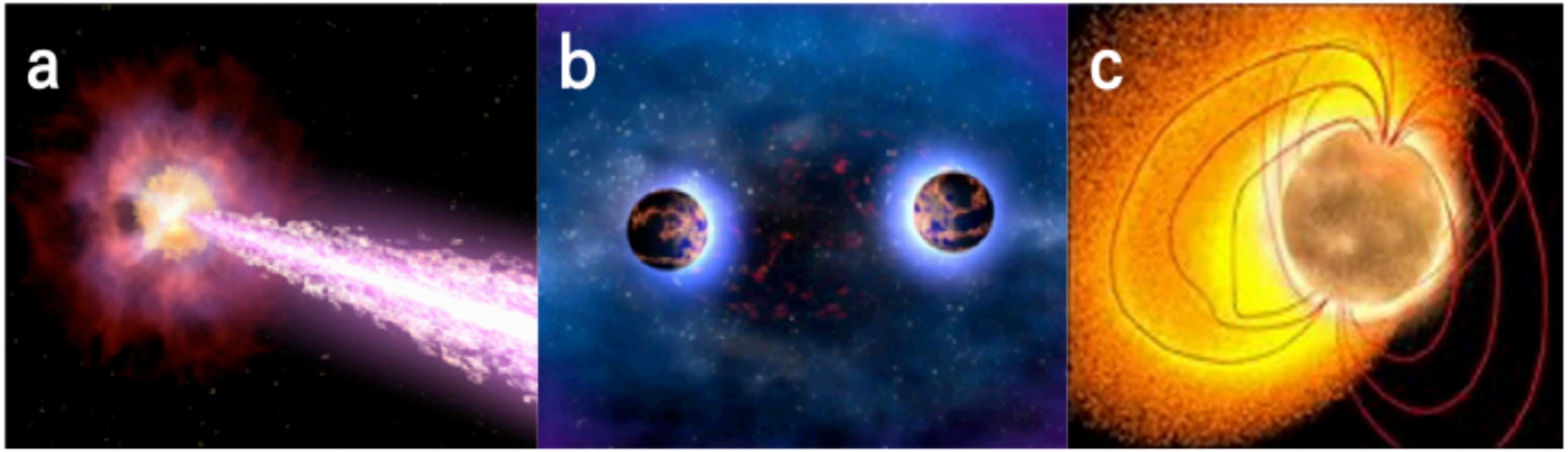
2. **Different**: central object can be nonstandard

3. **New**: progenitor can be new

MGF GRB 200415A

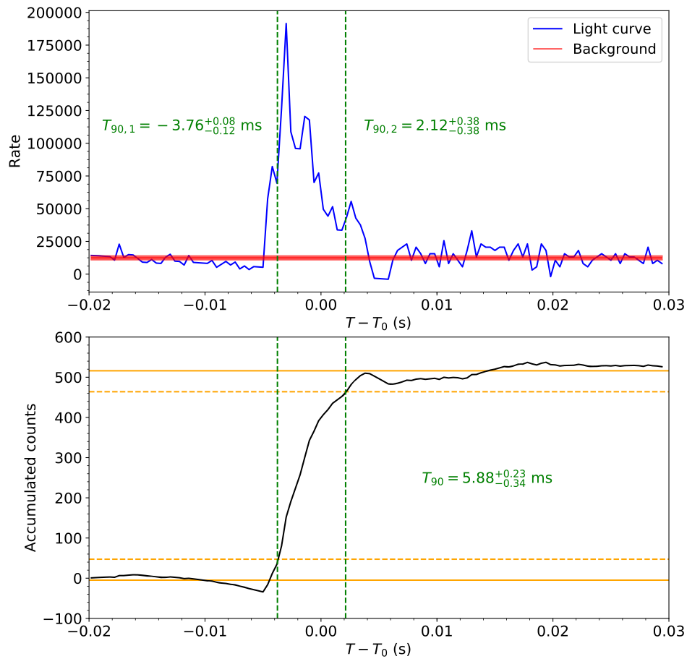
1st spectrally confirmed short GRB from magnetar giant flare

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



Yang, Jun, Chand, **BBZ** et al 2020, ApJ, 899,166;
Roberts et al., 2021, Nature
Svinkin et al., 2021, Nature
Castro-Tirado et al, 2021, Nature
Burn et al., 2021, ApJL

Direct Hint



✓Spatially associated with a nearby galaxy @ 3.5 Mpc

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

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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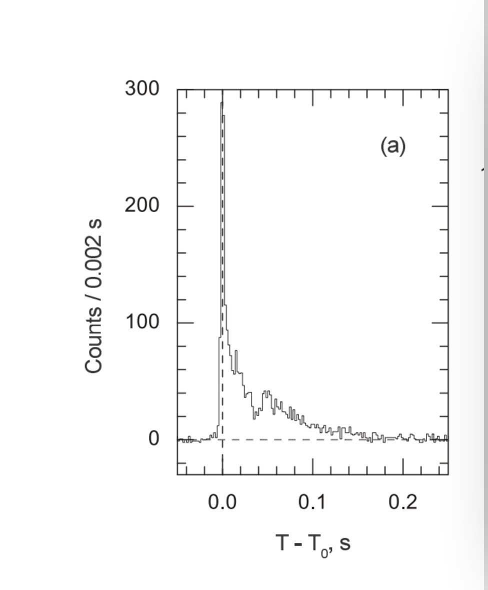
Published: January 2007

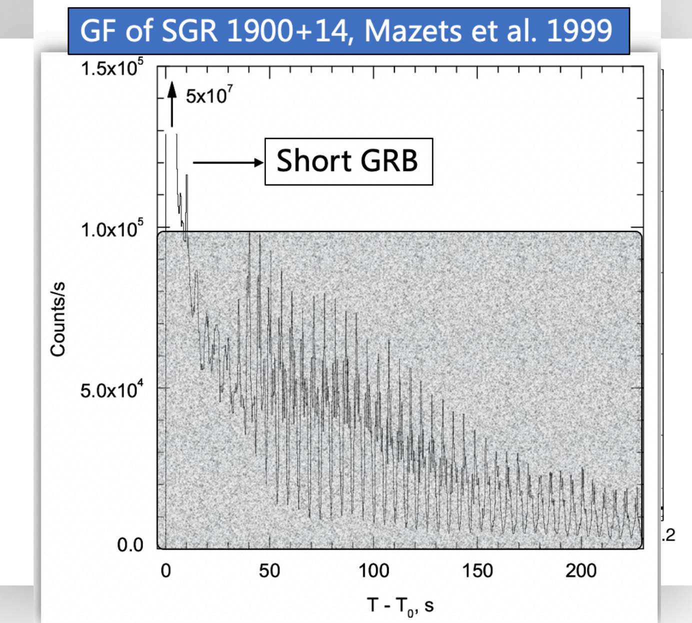
On the possibility of identifying the short hard burst GRB 051103 with a giant flare from a soft gamma repeater in the M81 group of galaxies

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

46 Accesses | **38** Citations | Metrics





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

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]

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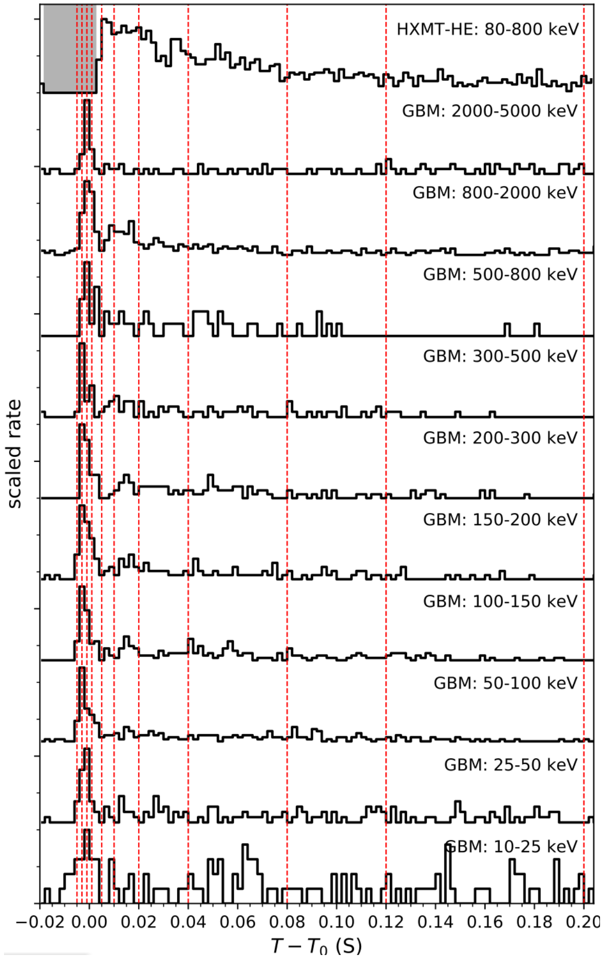
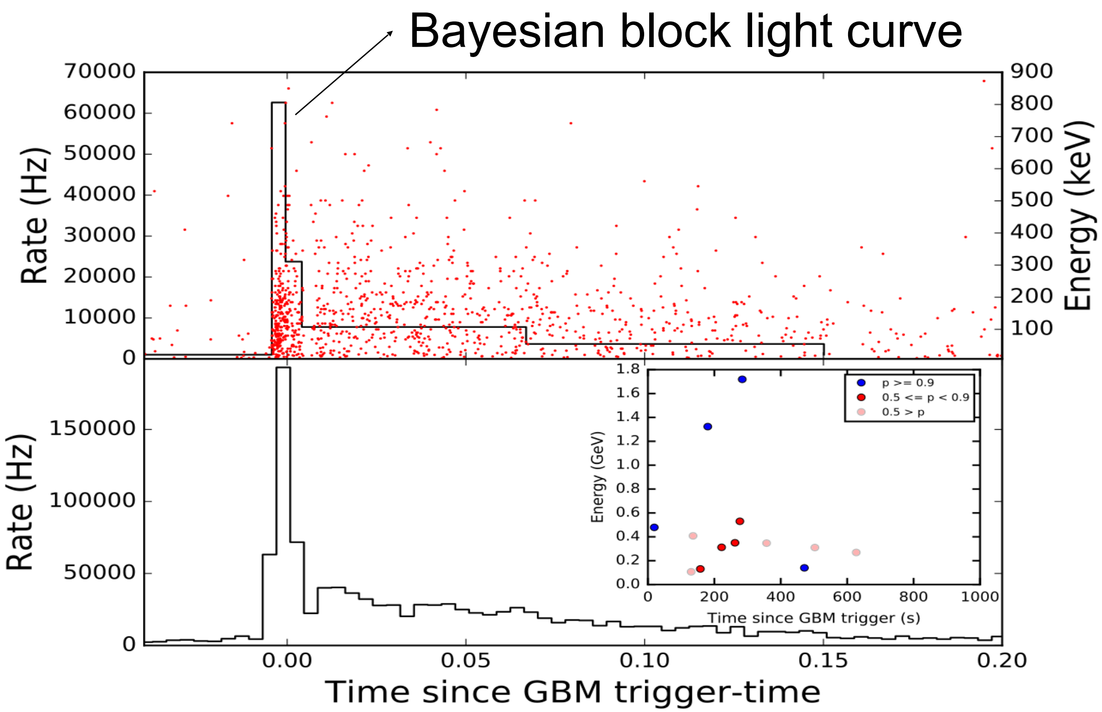
Yang, Jun, Vikas Chanda, BBZ et al. 2020 ApJ, 899, 106

Also seen in :

Roberts et al., 2021, Nature
Svinkin et al., 2021, Nature
Castro-Tirado et al, 2021, Nature
Burn et al., 2021, ApJL

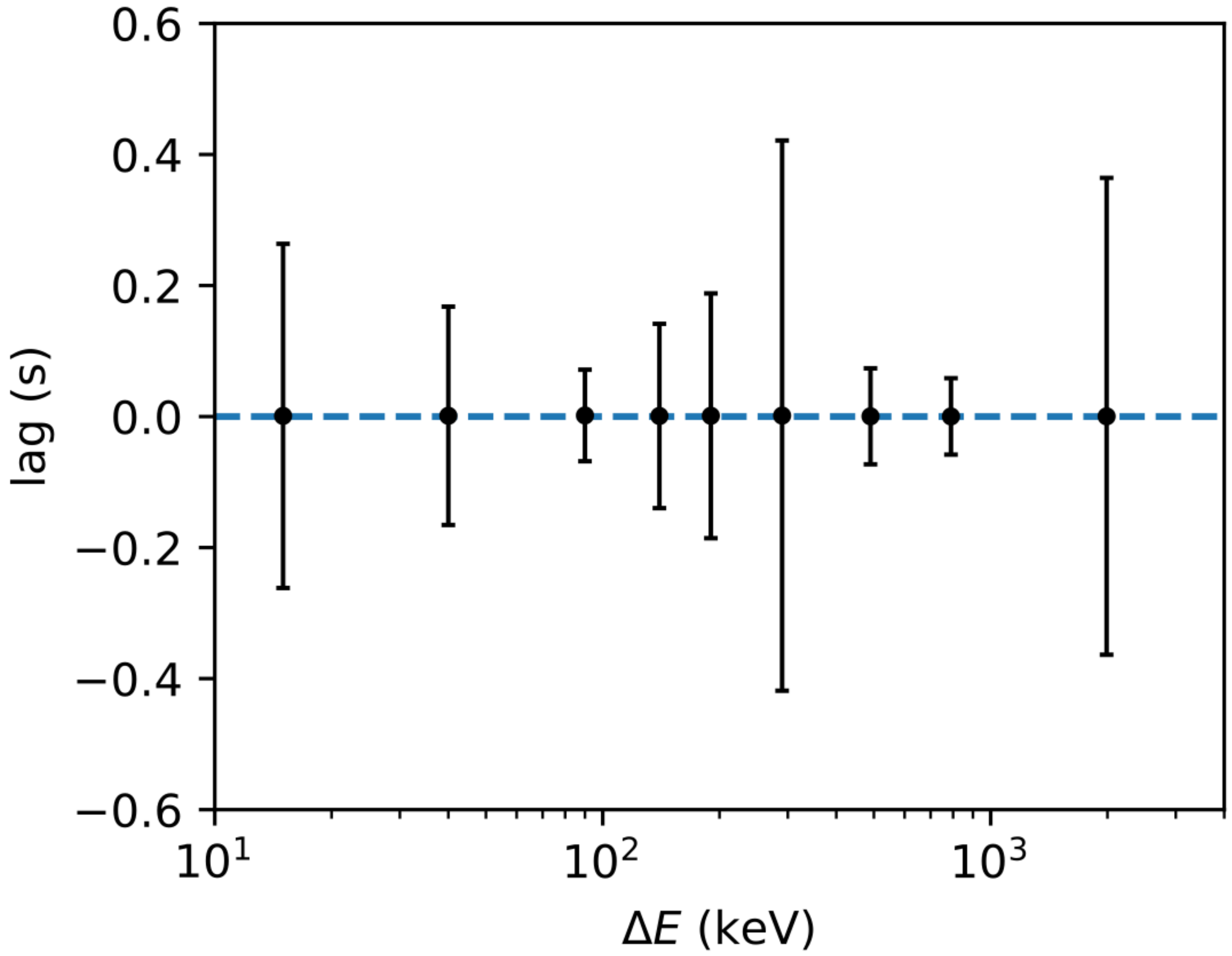
GRB 200415A: Light Curve





Yang, Jun, Vikas Chanda, BBZ et al. 2020 ApJ, 899, 106

GRB 200415A: Tiny Lags



Emission Region should be one-time fireball-like.

Yang, Jun, Vikas Chanda, BBZ et al. 2020 ApJ, 899, 106

GRB 200415A: Time-Dependent Spectral Analysis

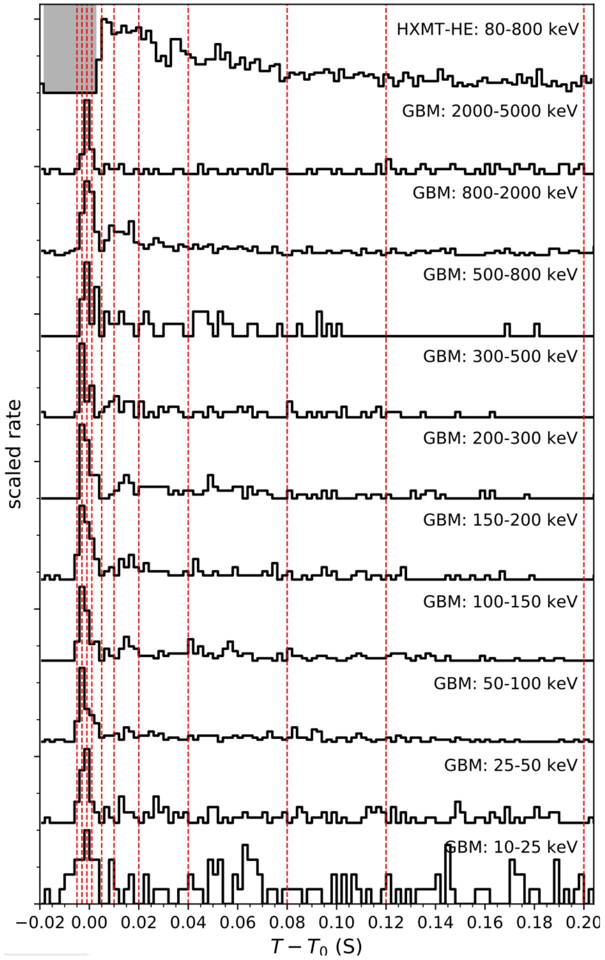


Table 1
Both Time-integrated and Time-dependent Spectral Fittings of GRB 200415A

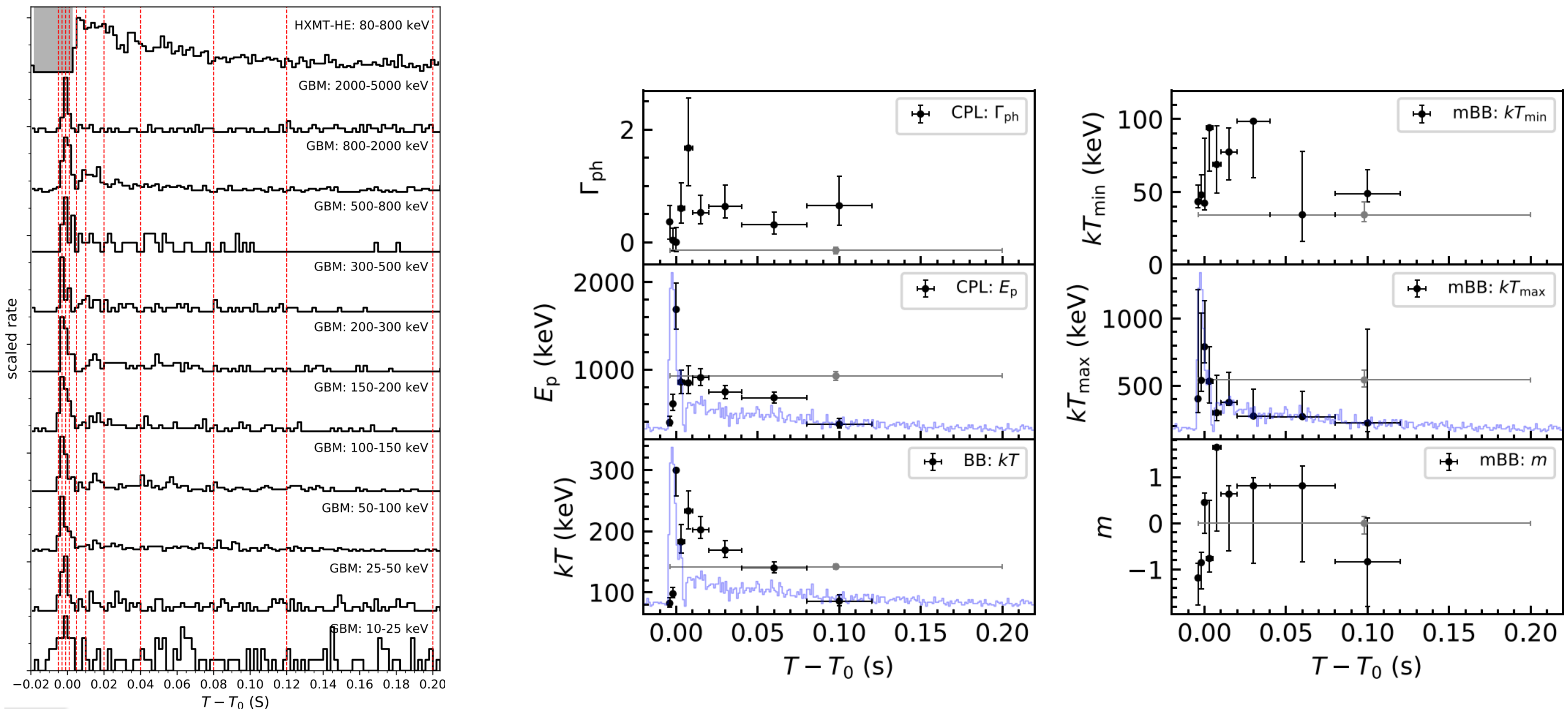
Time Intervals (t_1, t_2) (s)	Best Model	Flux (erg cm^{-2} s^{-1})	mBB Parameters $kT_{\rm min}$ (keV)	$kT_{\rm max}$ (keV)	m	pgstat/dof	BIC
(−0.005, 0.005)	mBB	$4.32^{+0.66}_{-0.62} \times 10^{-4}$	$39.40^{+6.25}_{-6.15}$	$807.00^{+123.29}_{-113.78}$	$-0.33^{+0.17}_{-0.15}$	278.5/350	302.01
(0.005, 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 $\Gamma_{\rm ph}$	$E_{\rm p}$ (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 $N(E) = AE^{\Gamma_{\rm ph}} \exp[-E(2 + \Gamma_{\rm ph})/E_{\rm p}]$. The PL model gives an acceptable fit in the time slice between $T_0 + 0.12$ and $T_0 + 0.20$ s: $\Gamma_{\rm ph} = -1.44^{+0.11}_{-0.28}$, 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.

Yang, Jun, Vikas Chanda, BBZ et al. 2020 ApJ, 899, 106

GRB 200415A: Time-Dependent Spectral Evolution

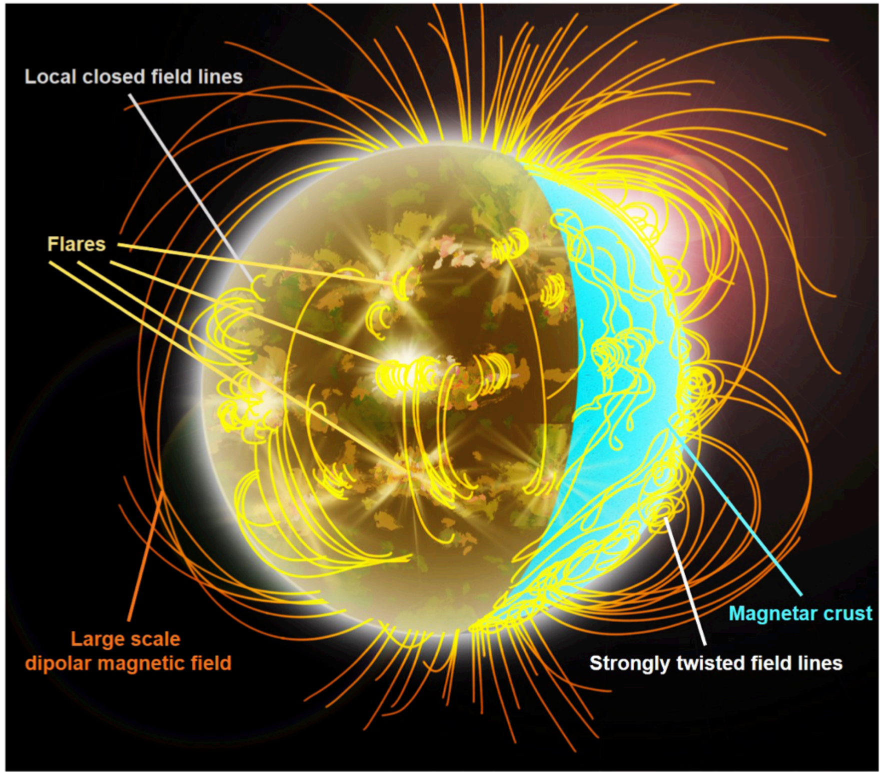


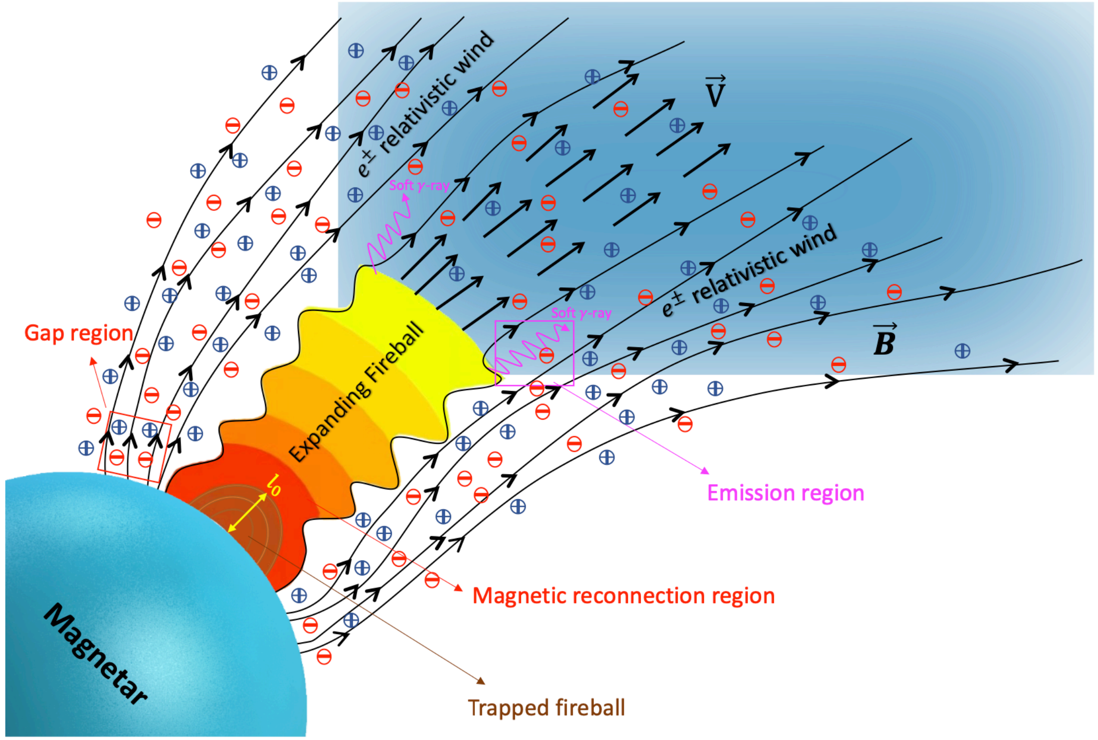
Yang, Jun, Vikas Chanda, BBZ et al. 2020 ApJ, 899, 106

Directly Physical Spectral model fit

A Comptonized Fireball Bubble

radiation caused by the interaction between the expanding fireball and the wind

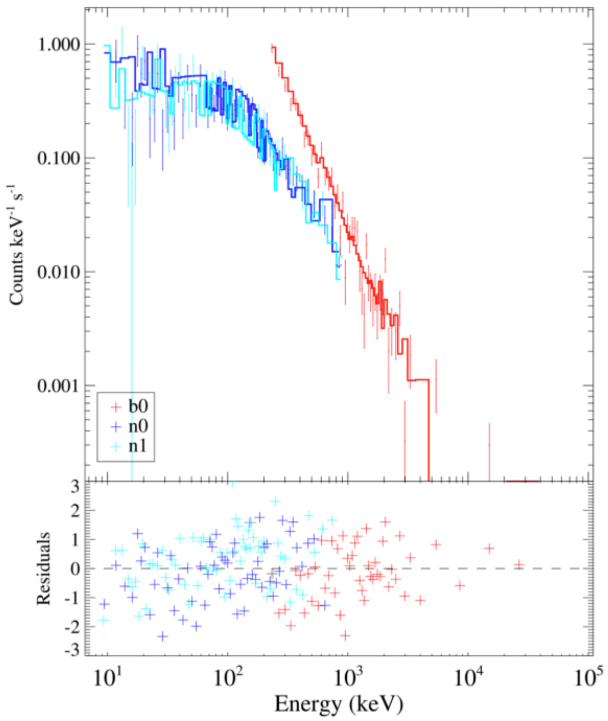


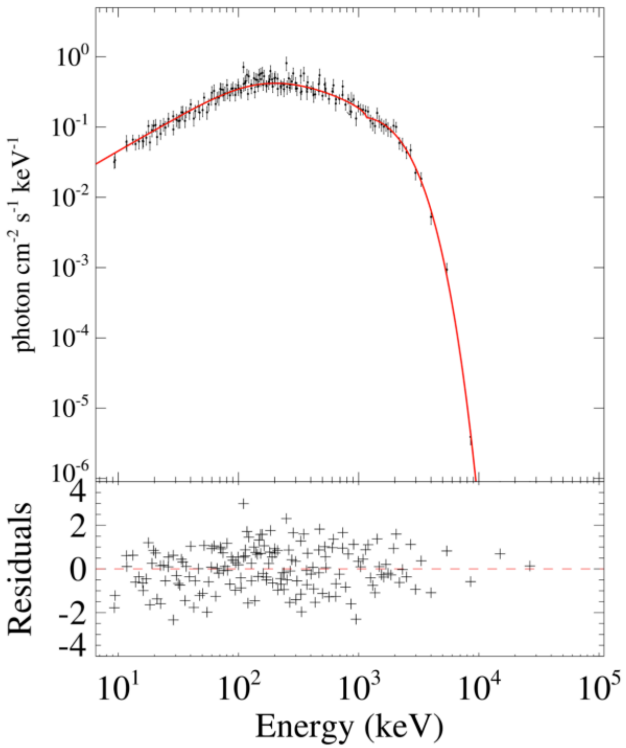


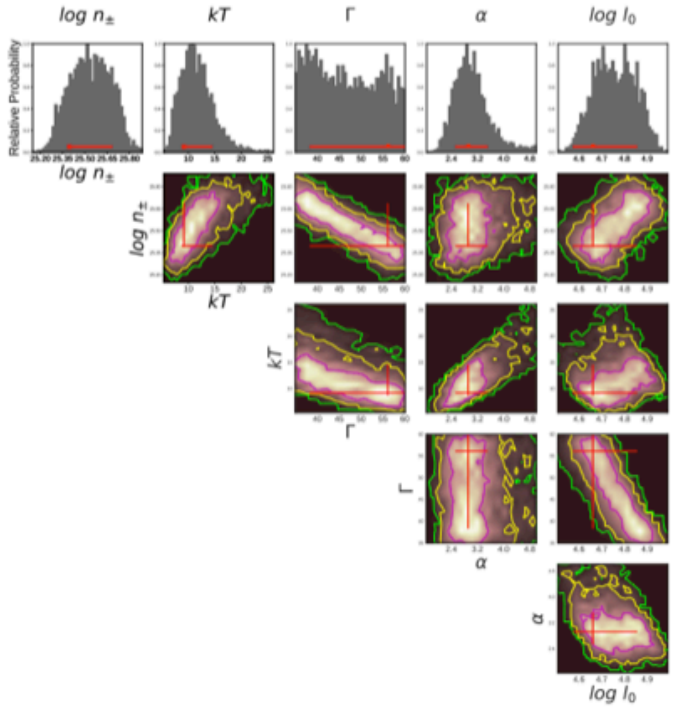
Zhao Zhang, **BBZ**, Meng, Y et al. 2021 ApJ Under review

Directly Physical Spectral model fit

A Comptonized Fireball Bubble

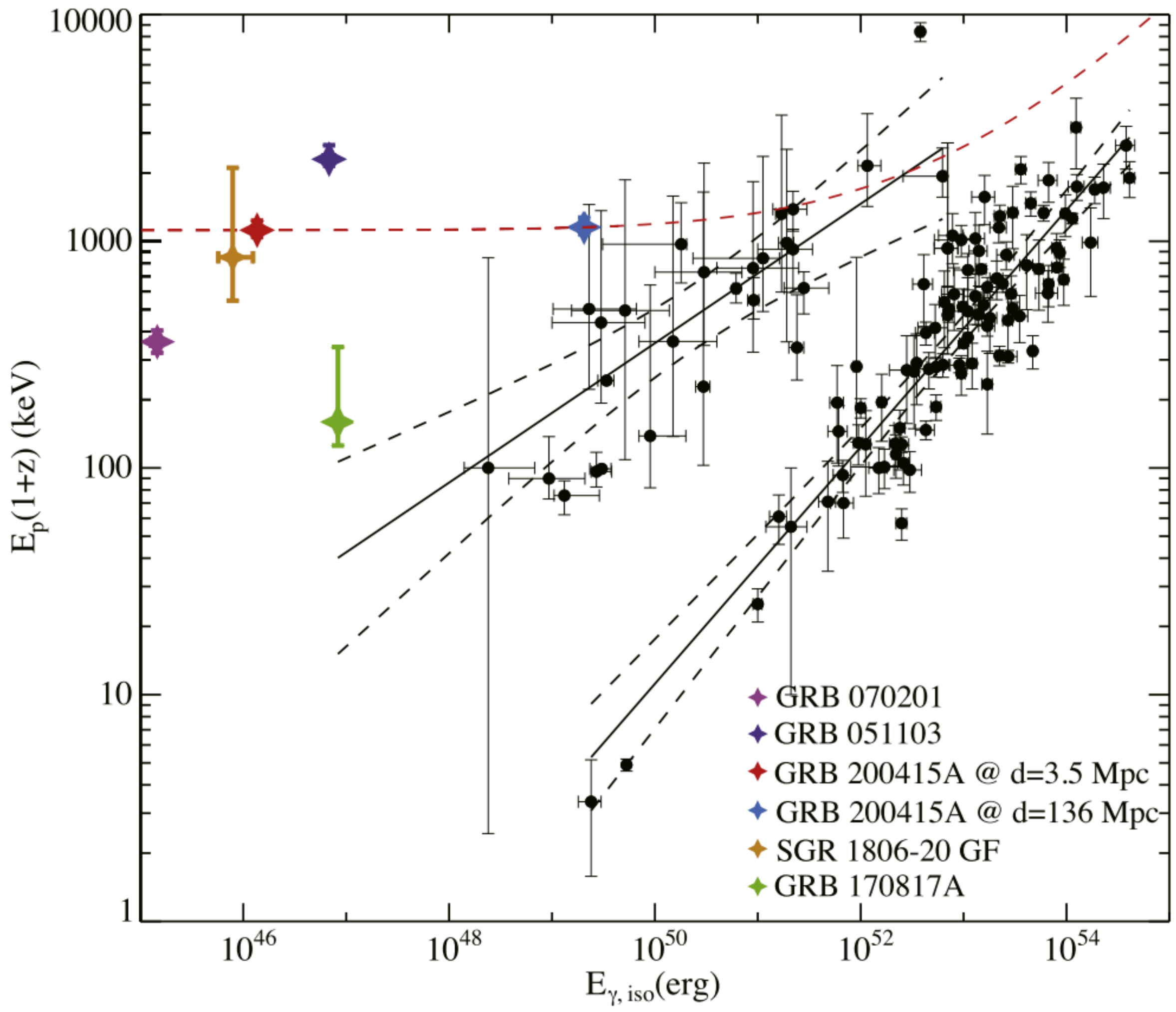






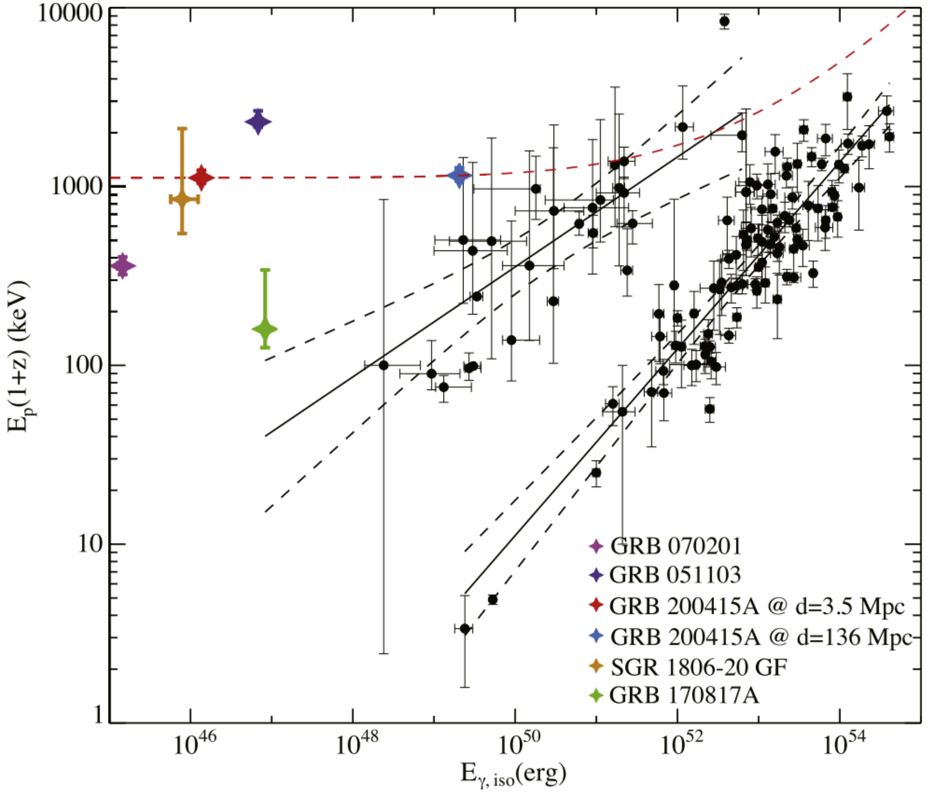
Zhao Zhang, **BBZ**, Meng, Y et al. 2021 ApJ Under review

GRB 200415A: Amati Relation

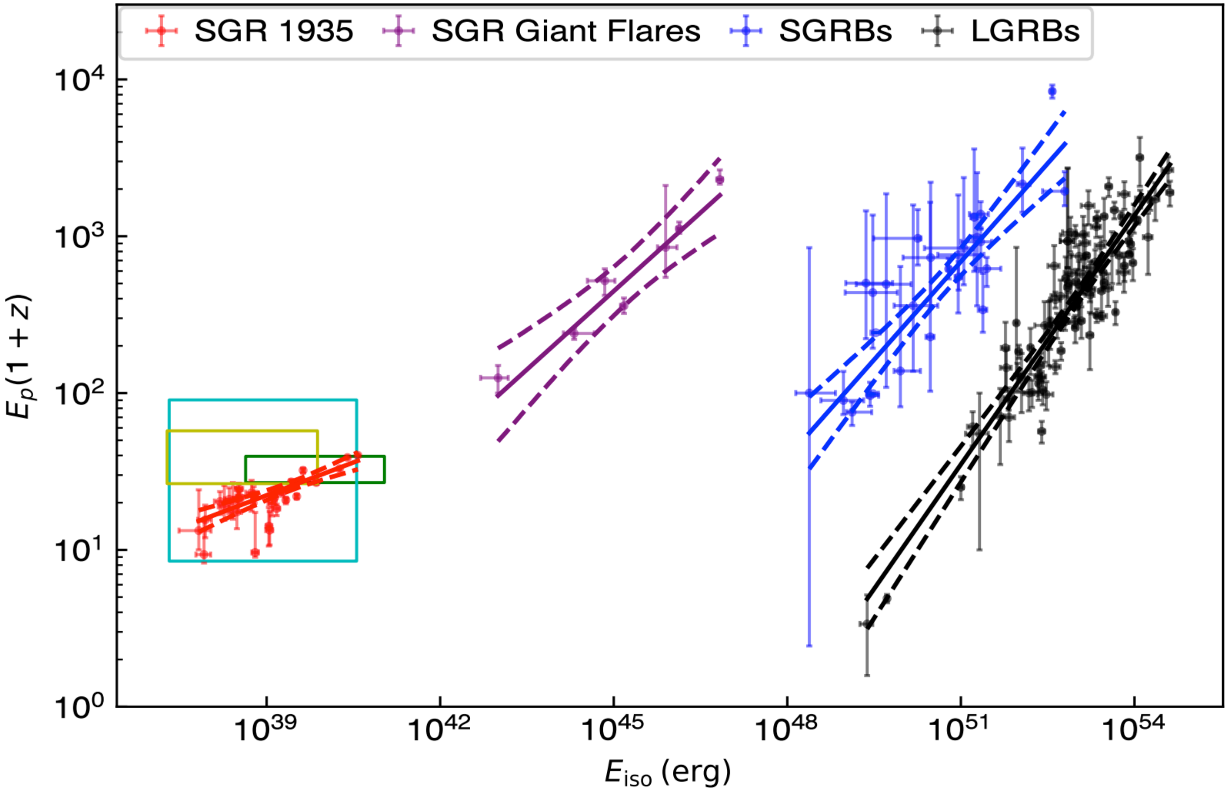


Yang, Jun, Vikas Chanda, BBZ et al. 2020 ApJ, 899, 106

GRB 200415A: Amati Relation



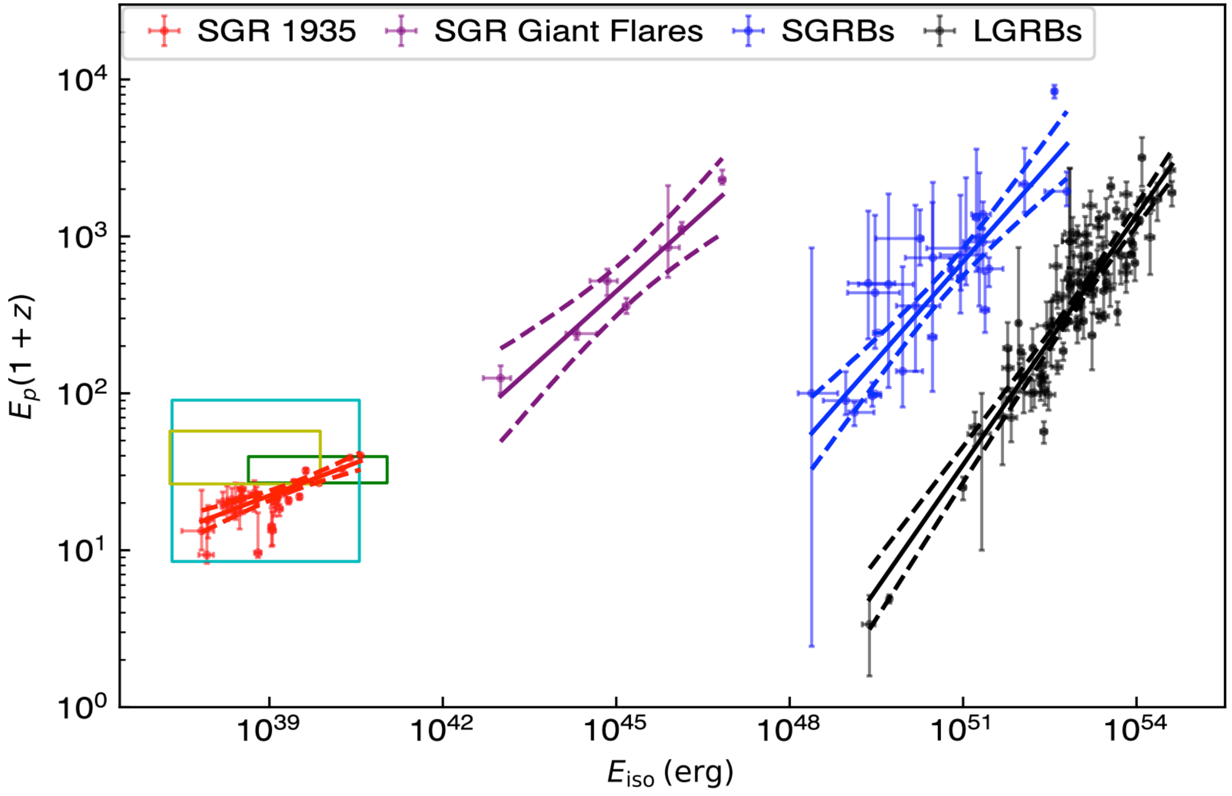
Yang, Jun, et al . 2020 ApJ,



Yang, Y.-H., BBZ et al. , 2020 ApJL

Magnetars seem to be related to all of them!

GWs from magnetars



Yang, Y.-H., BBZ et al. , 2020 ApJL

Magnetars seem to be related to all of them!

e. g, , ~300 Hz due to the deformation of non-barotropic magnetar

can be as low as 0.1 Hz

can be detected in giant flares by aLIGO, maybe Tianqin

Mastrano, A. et al. 2011, MNRAS

Magnetars

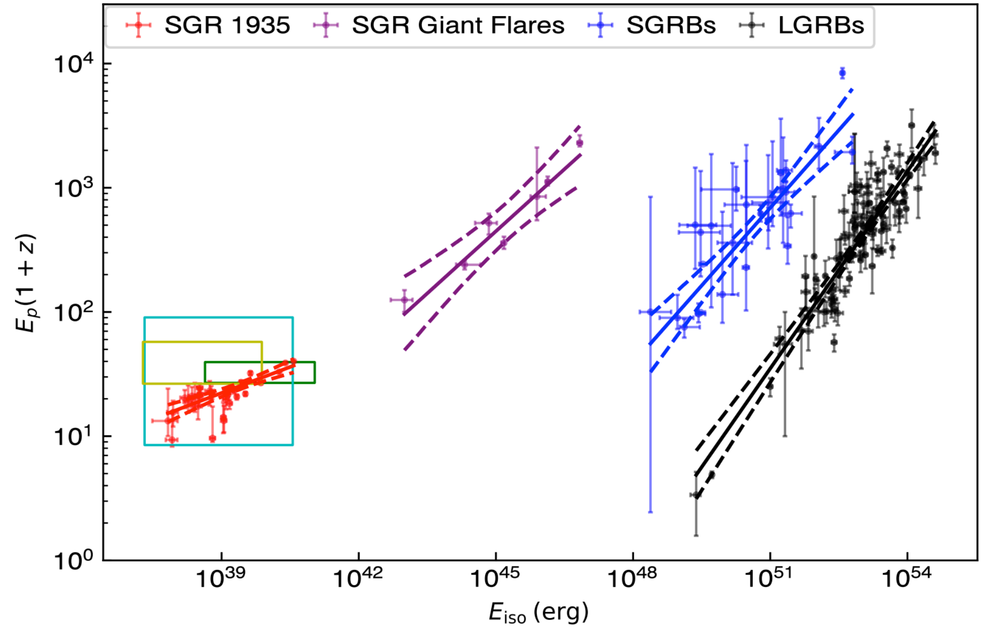
✓GRB/SN —> [hypothetic] newborn magnetars

✓ Pulsars/SGRs/FRBs —> older ($10^{3\text{-}4}$ years) magnetars

✓ Giant Flare —> younger magnetars

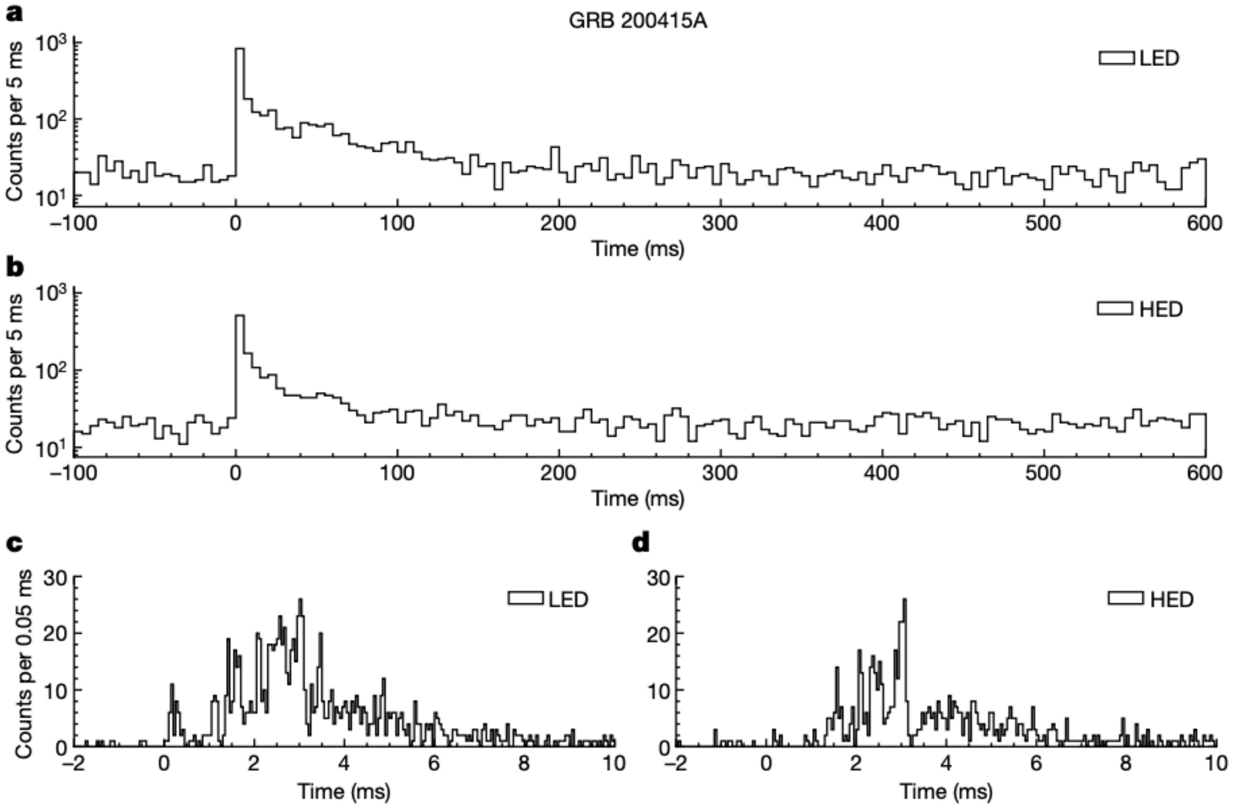
But how young are they?

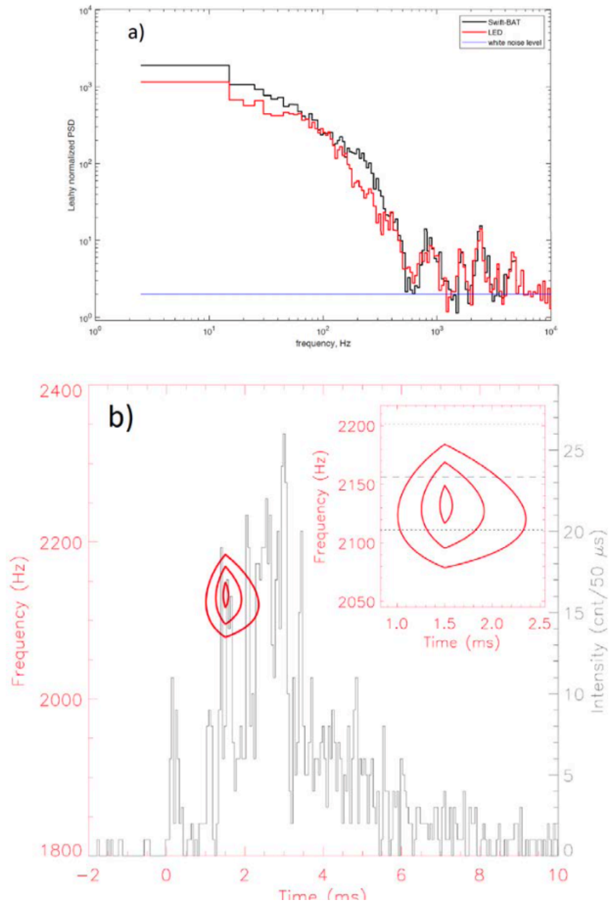
$P, \dot{P}$



Do we have a P measured for GRB 200415A?

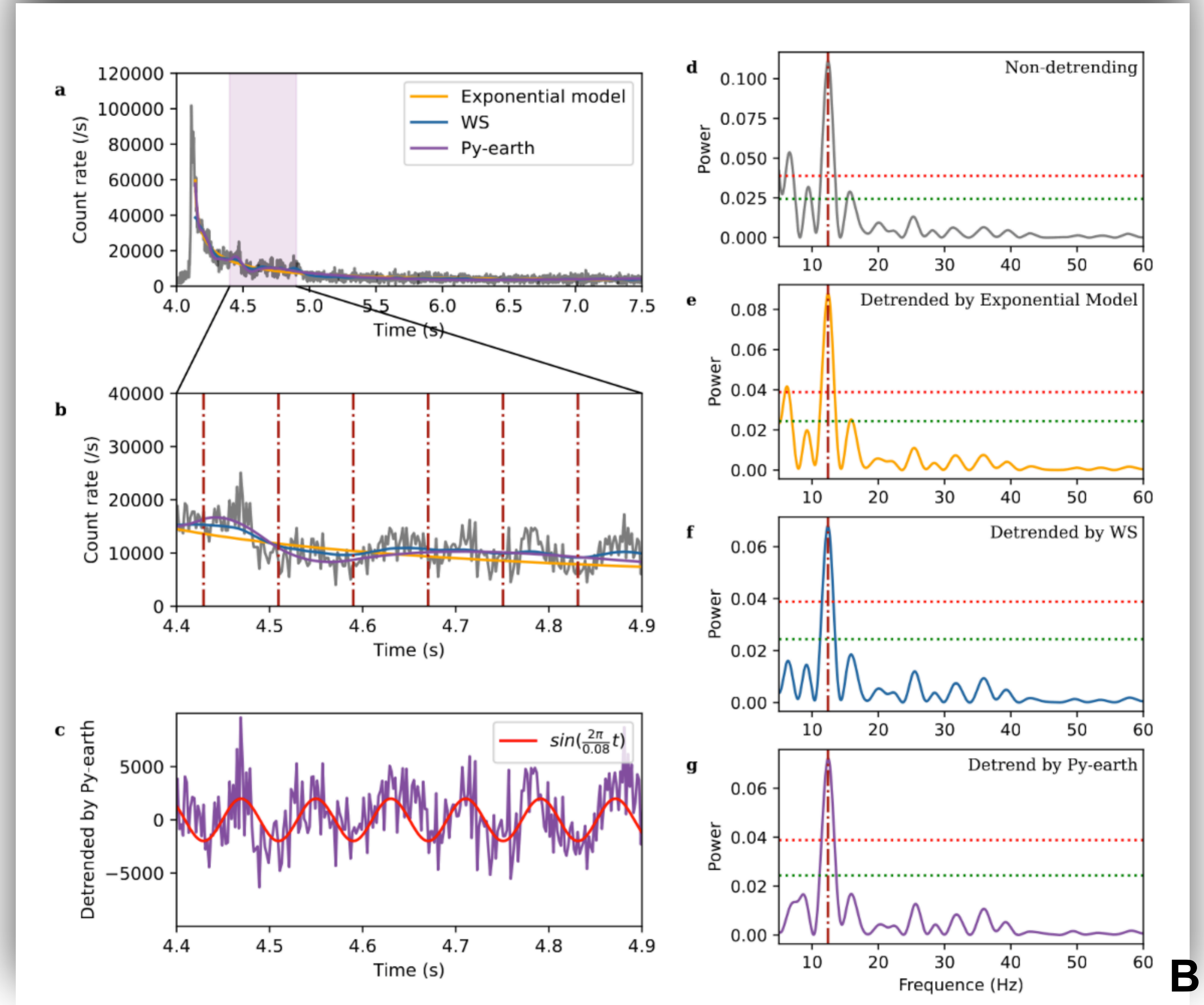
2k HZ & 4k HZ QPOs (not a rotation period)





Castro-Tirado, …**BBZ**, … et al. 2021, Nature

But we may have found one!



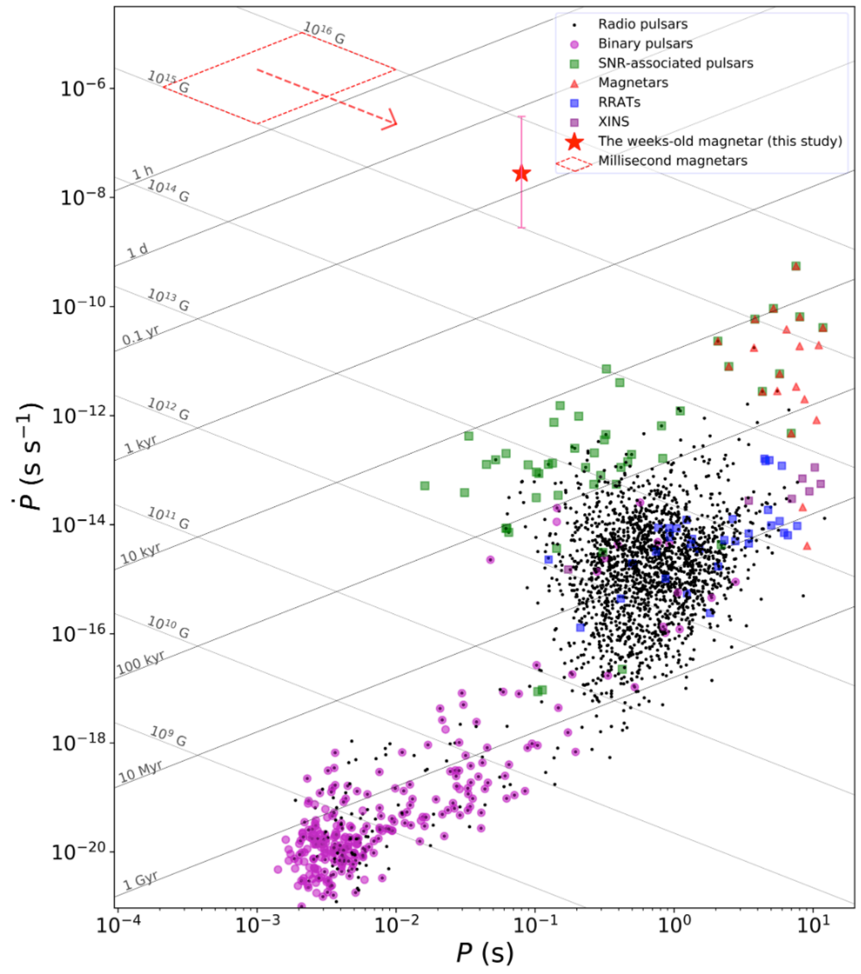
12 Hz —> P = 80 ms

$$\dot{P} \simeq \frac{2\pi^2 R_s^6 B_*^2}{3c^3 IP}$$
$$= 1.94 \times 10^{-8}\ \mathrm{s\ s^{-1}} \left(\frac{P}{80\ \mathrm{ms}}\right)^{-1} \left(\frac{M}{2M_\odot}\right)^{-1} \left(\frac{B_*}{10^{15.5}\ \mathrm{G}}\right)^{2} \left(\frac{R_s}{10^6\ \mathrm{cm}}\right)^{6},$$

—> NS age ~ a few weeks!

BBZ et al., 2022, under revision, [arXiv:2205.07670]

But we may have found one!



12 Hz —> P = 80 ms

—> NS age = a few weeks!

GW (non-)detection could be a key to confirm!

BBZ et al., 2022, under revision, arXiv:2205.07670

Topics

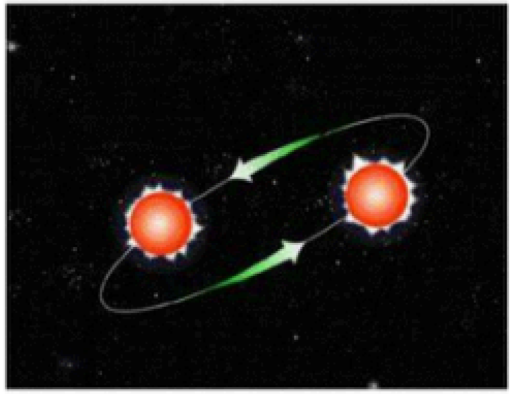
1. **Transition**: central engine can transform

2. **Different**: central object can be nonstandard

3. **New**: progenitor can be new

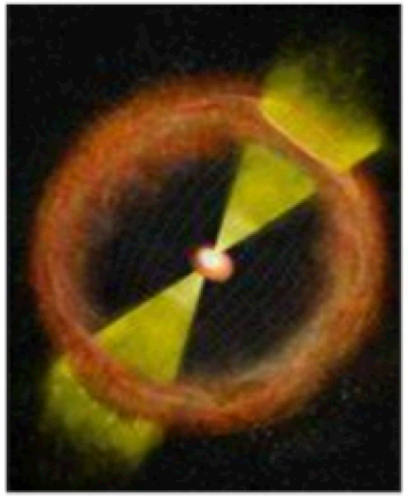
Time to be open-minded about GRB origins

Type I



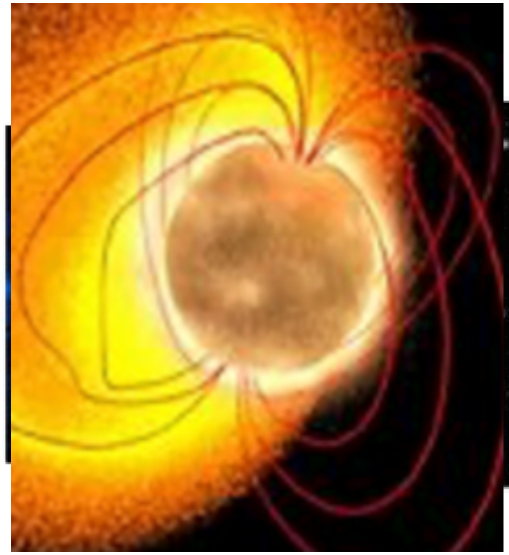
GW

Type II



GW (?)

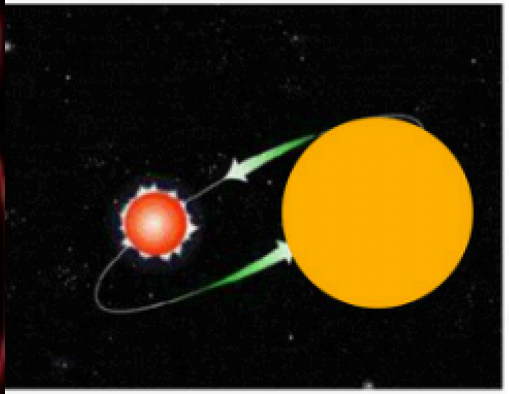
Type III



GRB 200415A

GW

Type IV



GRB 200826A
GRB 211211A

GW

Type V

GBM-190816
GRB 211211A

GW

New progress of gamma-ray burst physics

1. **Transition**: central engine can transform

2. **Different**: central object can be nonstandard

3. **New**: progenitor can be new

New progress of gamma-ray burst physics

1. **Transition**: central engine can transform
2. **Different**: central object can be nonstandard
3. **New**: progenitor can be new

As Tianqin's sources:

1. Low-freq part of the NS-NS/NS-BH Merger GRBs
2. New Mergers: NS-WD, WD-BH GRBs
3. MGF-GRBs (magnetars)
4. Binary "progenitors" of the GRB progenitors (e.g., NS, BH)
5. Surprising coincidence with high-E transients.

Thanks!