Discovery of a subclass of merger-origin GRBs from morphology

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On behalf of GECAM team

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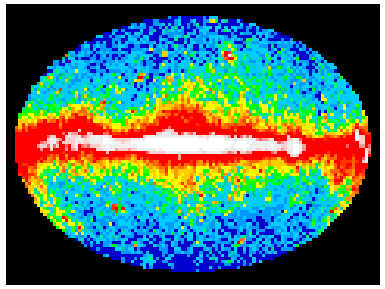
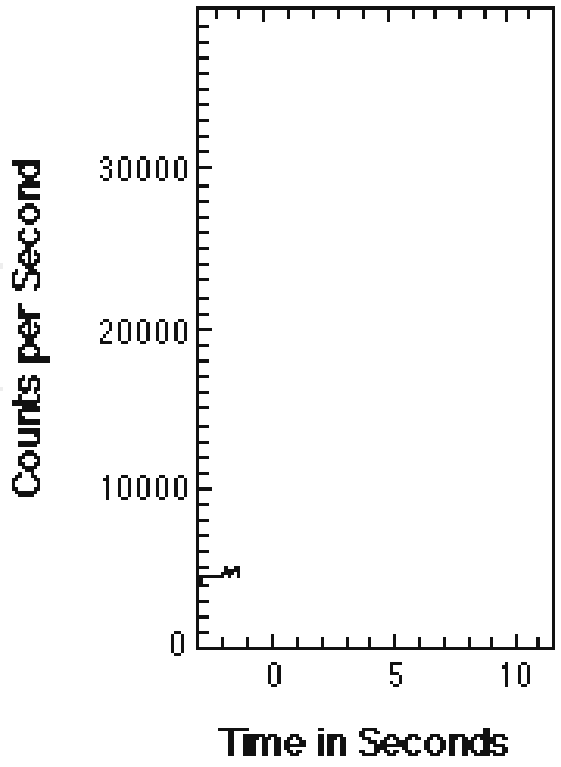
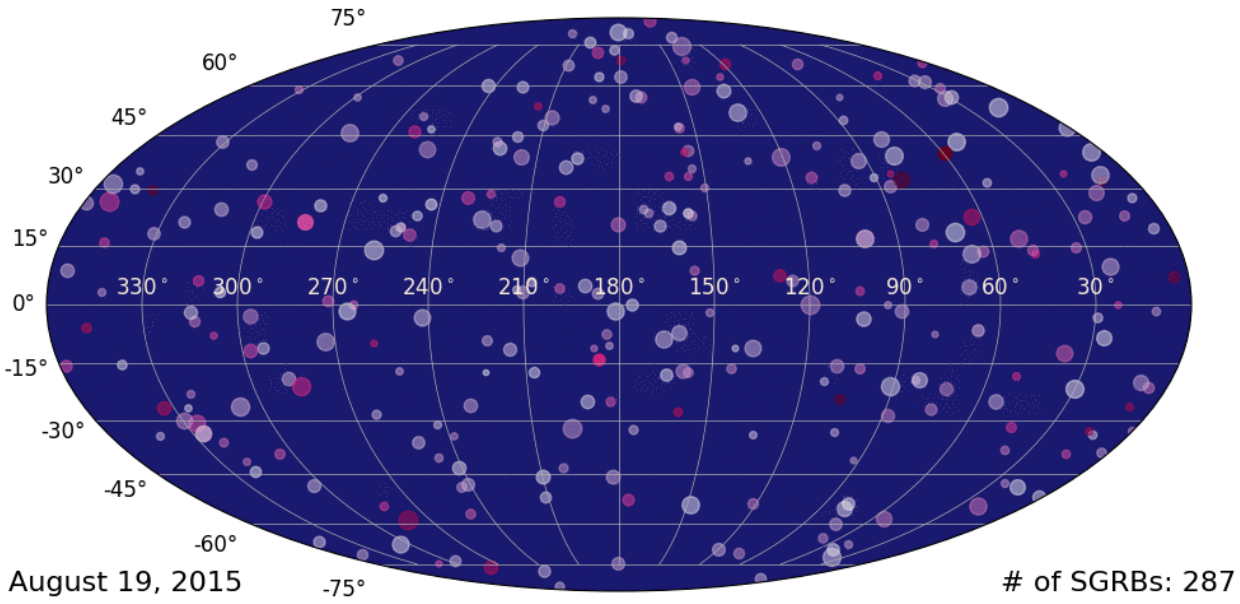
2025-07-10

Gamma Ray Bursts







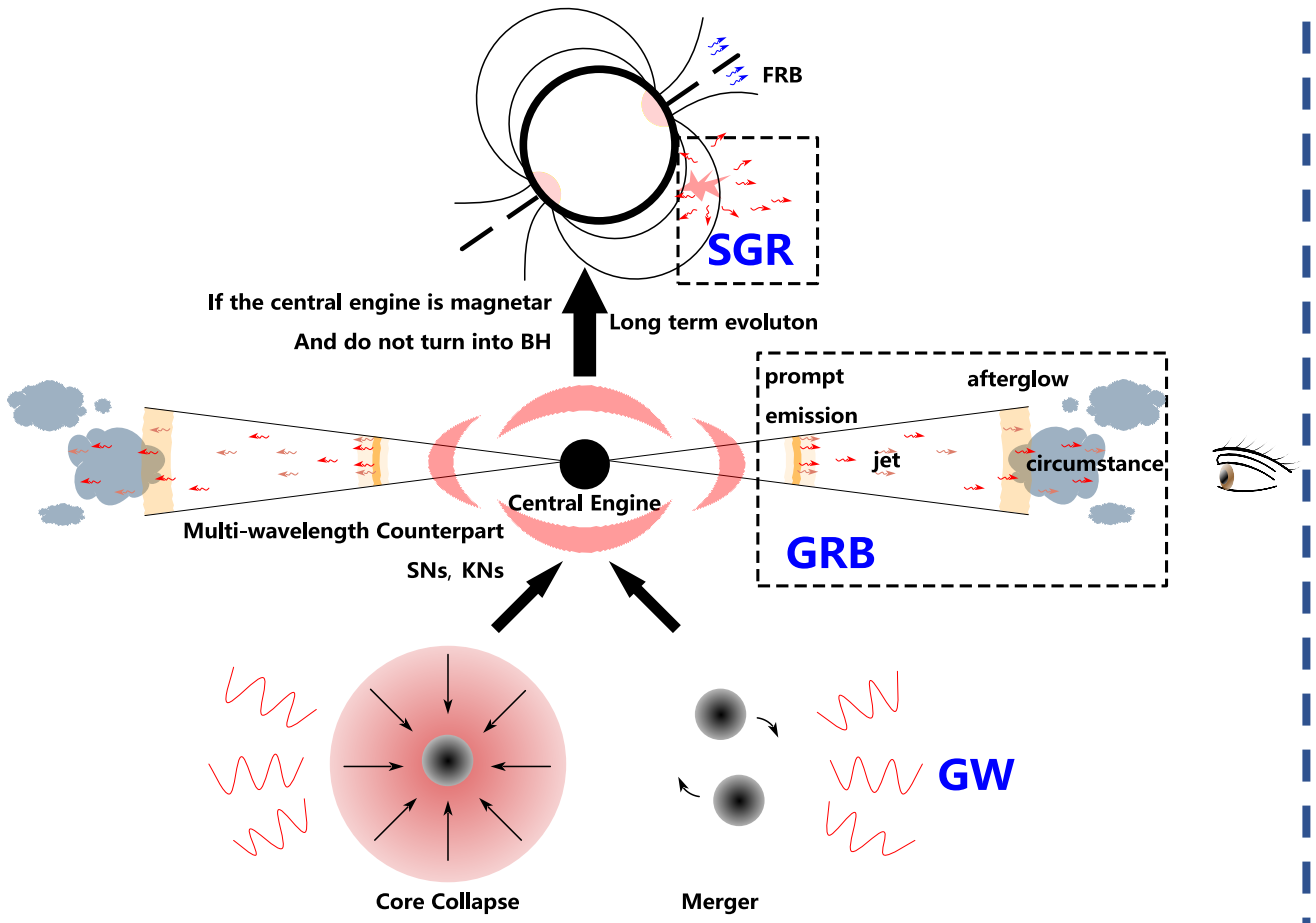
GRB, the most luminous explosion in the universe

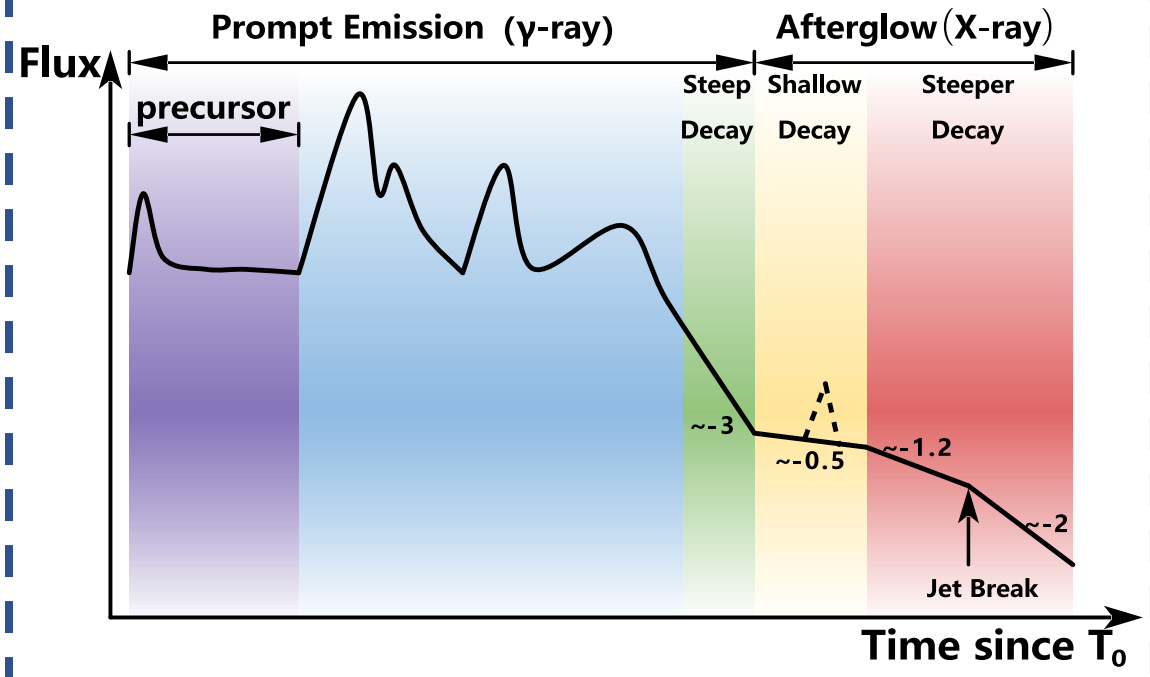
① appear randomly and fade rapidly in all the sky

② short duration (T_{90}) in γ-ray

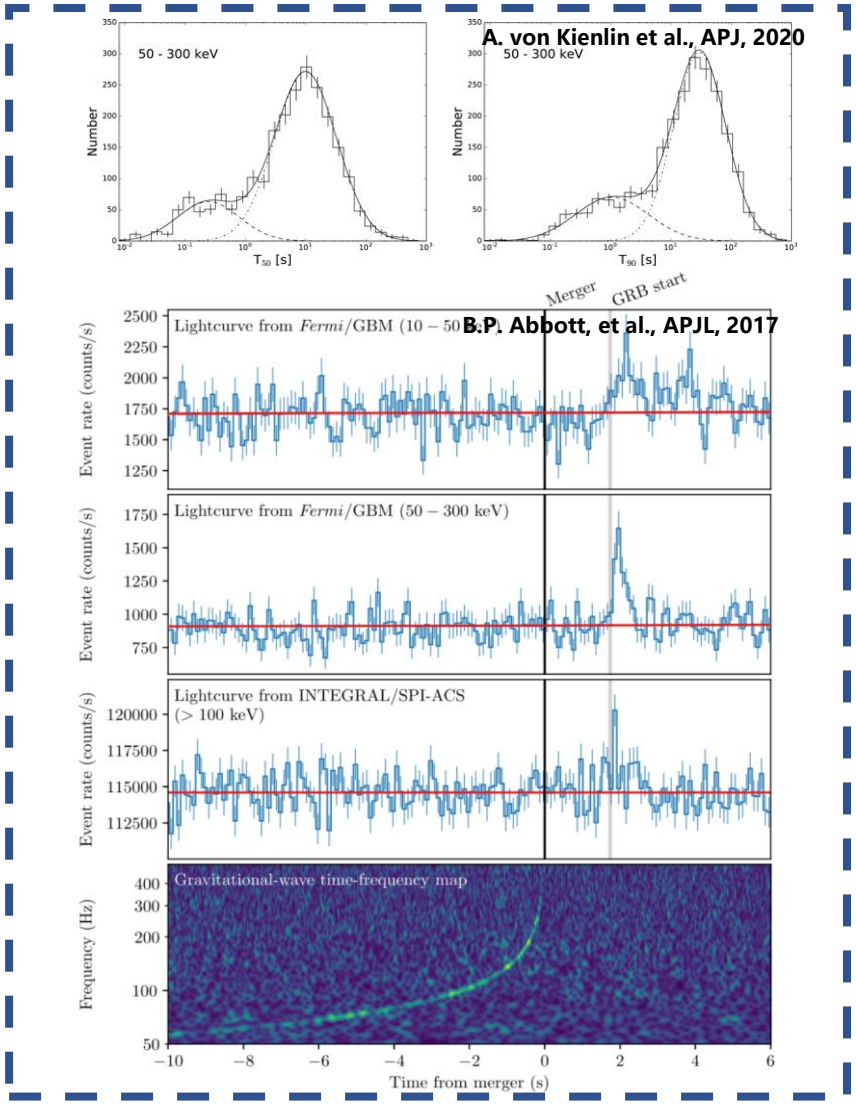
③ detection rate of 1~2 per day

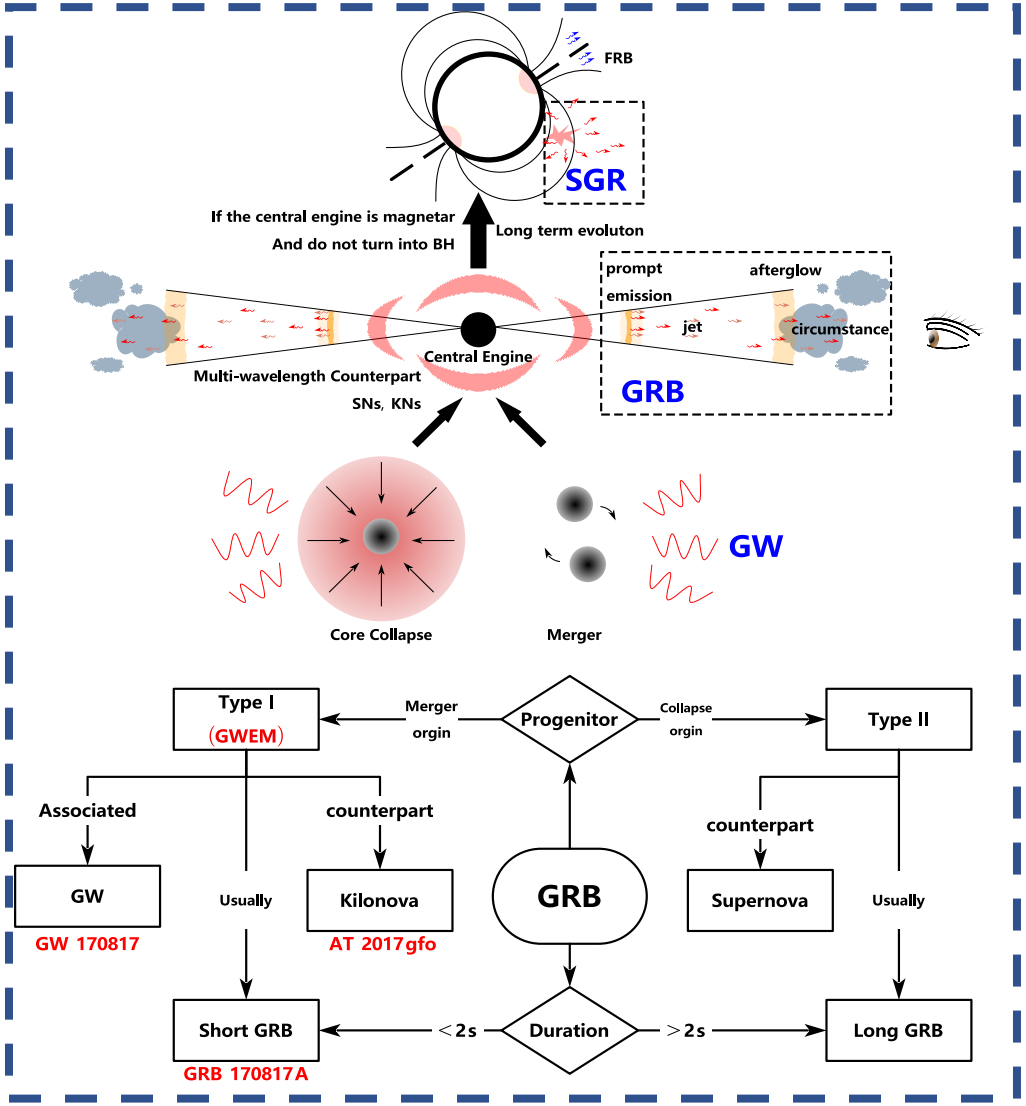
Gamma Ray Bursts





Gamma Ray Bursts



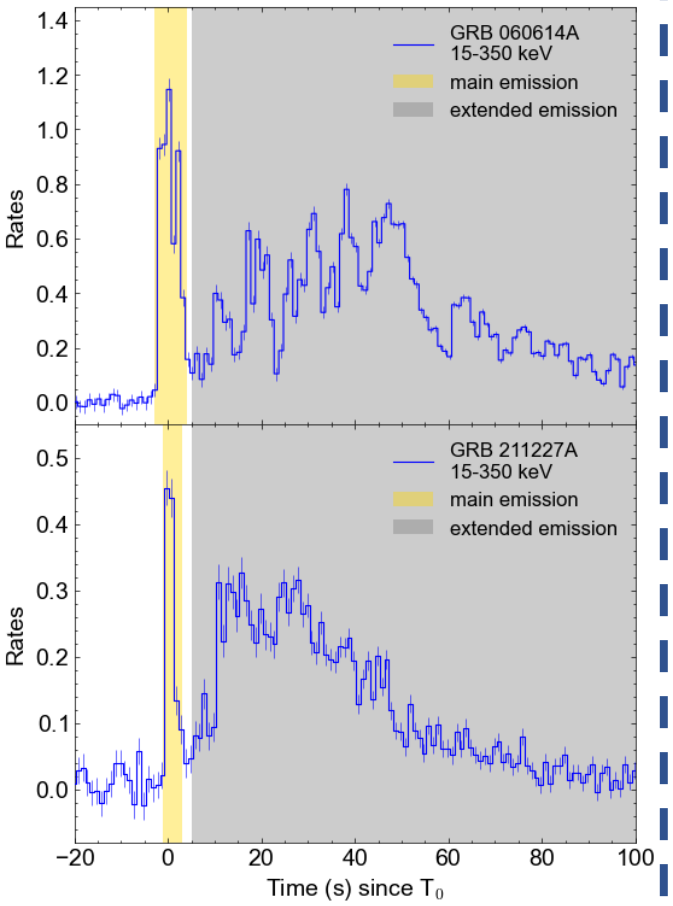


$$t_{ff} \simeq (0.02S)\left(\frac{\rho}{10^{10}\ \mathrm{g\ cm^{-3}}}\right)^{-\frac{1}{2}}$$

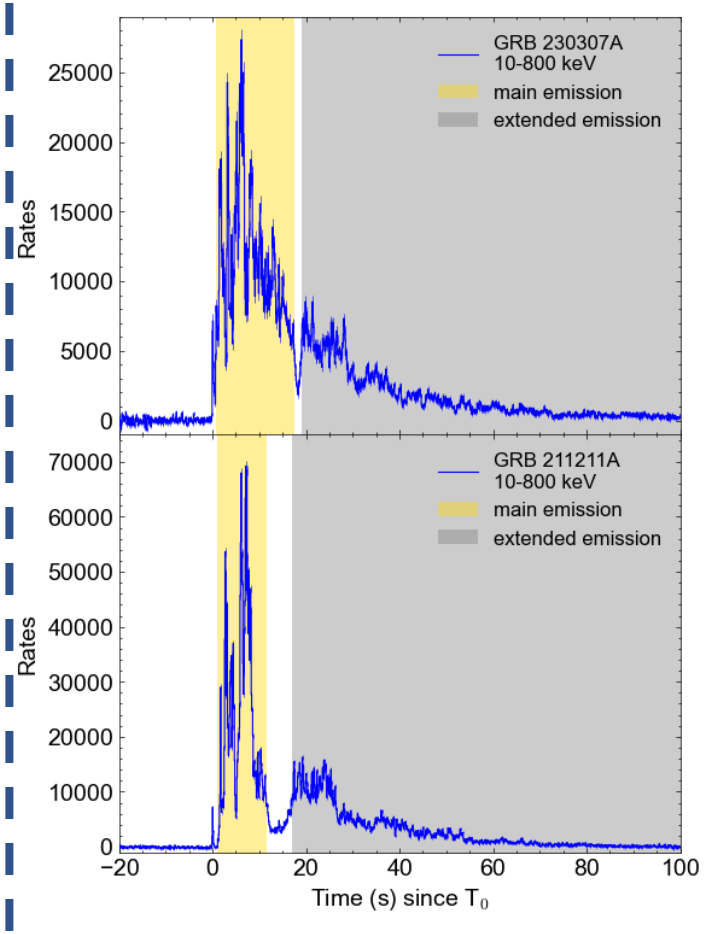
A general picture in the past 50 years

SGRB<->merger & LGRB<->collapse

“Long(duration)” short GRB

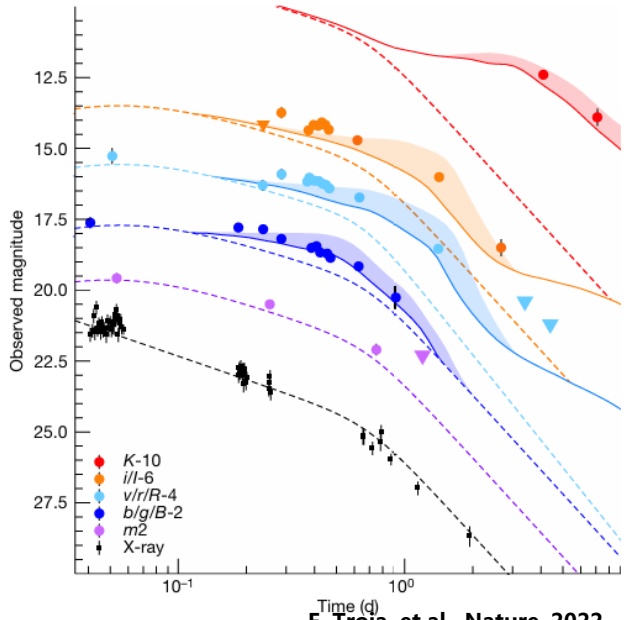


sGRBEE

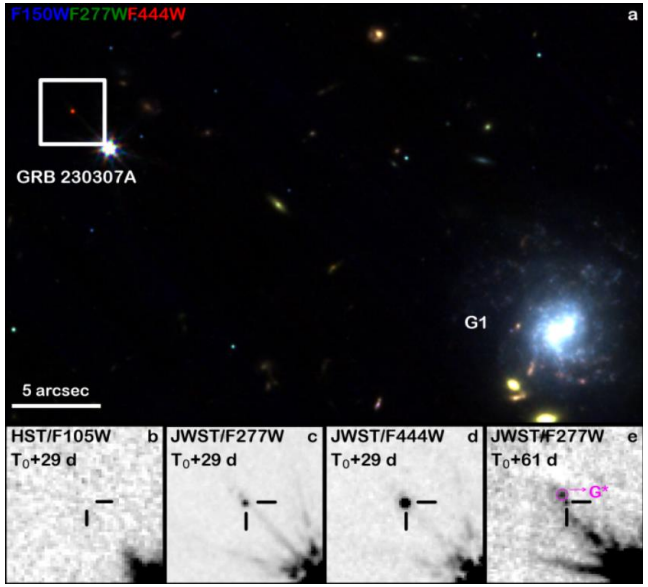


Type I L GRB

associated with KN



E. Troja, et al., Nature, 2022



Yuhan Yang, et al., Nature, 2024

Some observations suggest long GRBs can also have merger origin

Overview of GRB 230307A

15:54:06:650 UTC GECAM-B in-flight trigger

15:54:06:671 UTC Fermi/GBM in-flight trigger

16:53 the extremely brightness and preliminary flux is reported by GECAM (GCN #33406)

17:10 the extremely brightness is verified by GBM (GCN #33407)

23:33 IPN triangulation (GCN #33413)

12:57 tiled Swift observations

20:16 improved IPN localization (GCN #33425)

23:17 two X-ray counterpart candidates by Swift/XRT

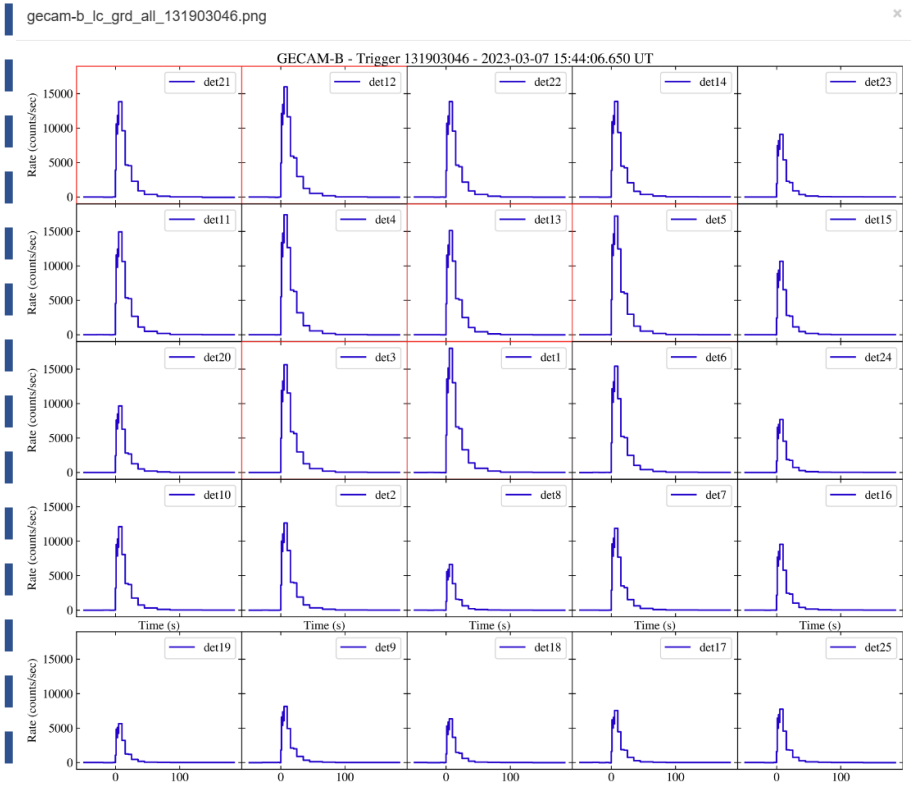
15:14 possible optical counterpart (GCN #33439)

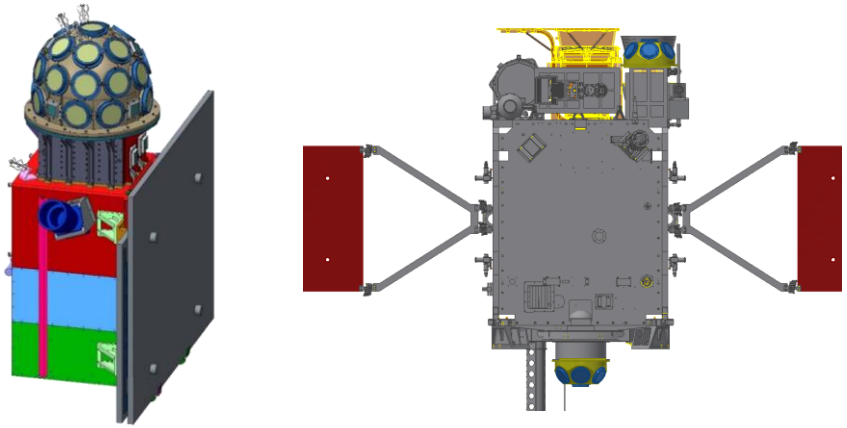
03:37 verify of the optical counterpart (GCN #33447)

measure of red-shift (GCN #33485)

discovery of KN by JWST (GCN #33569)

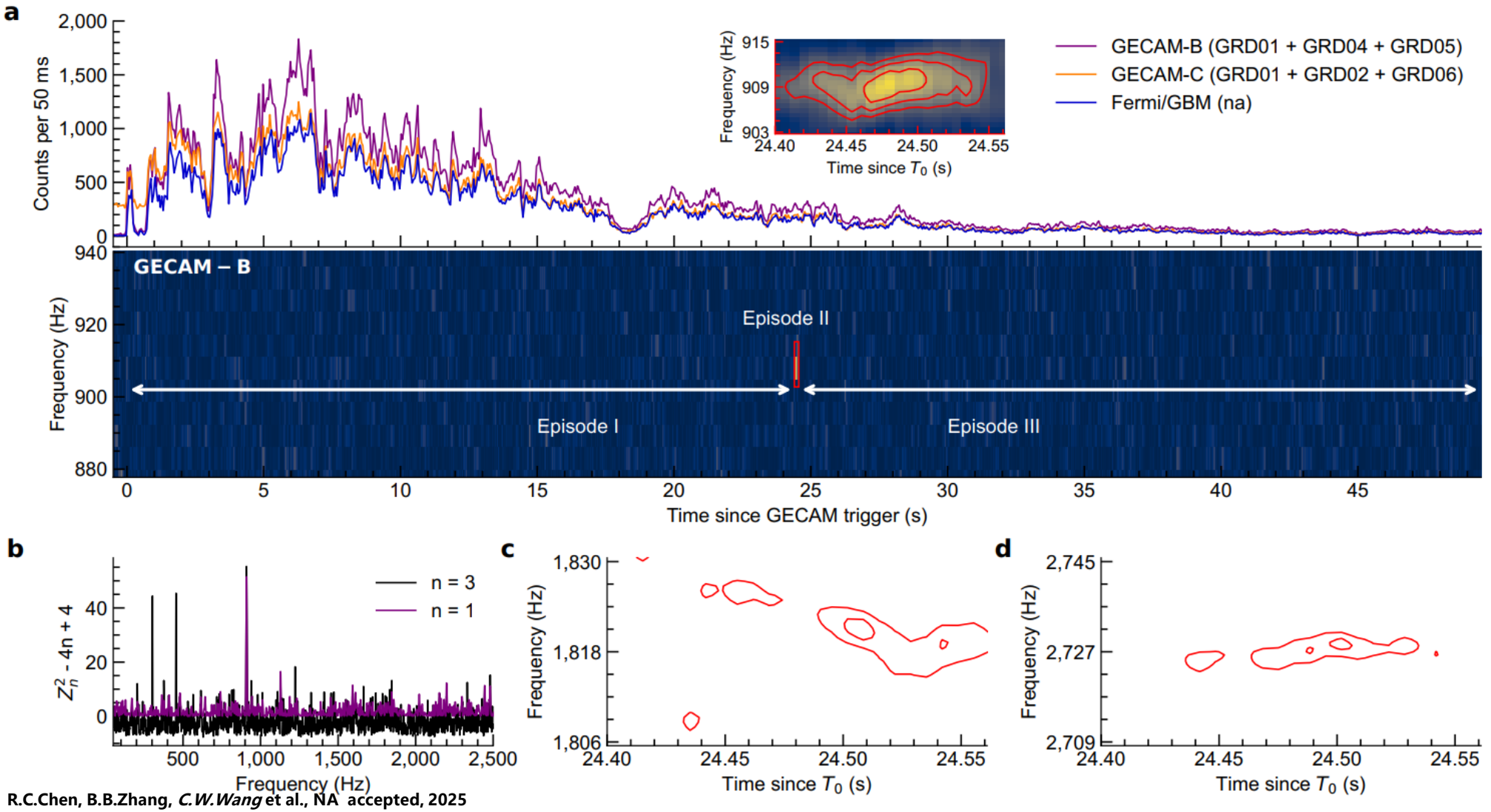
03-07 03-08 03-09 03-10 03-11 03-17 04-05





- GECAM-B firstly reported that this is an extremely bright GRB leading a global observation campaign to this event
- Both GECAM-B & GECAM-C have high quality observation data neither of them suffered from data saturation
- Both GECAM-B & GECAM-C have a time resolution as high as 0.1 μs

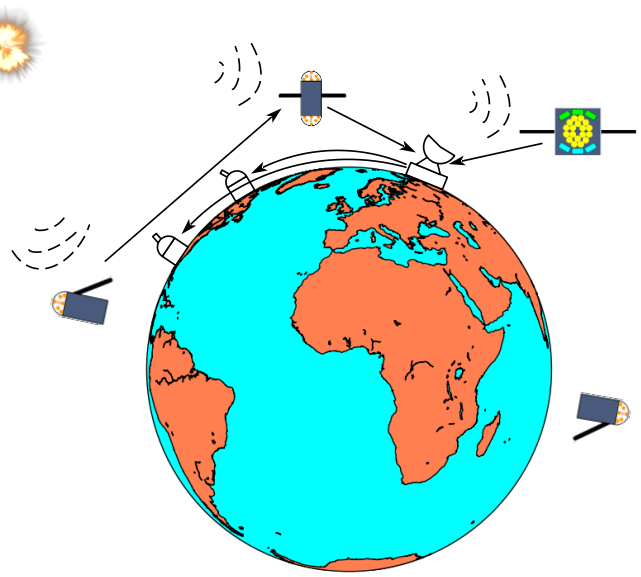
Overview of GRB 230307A

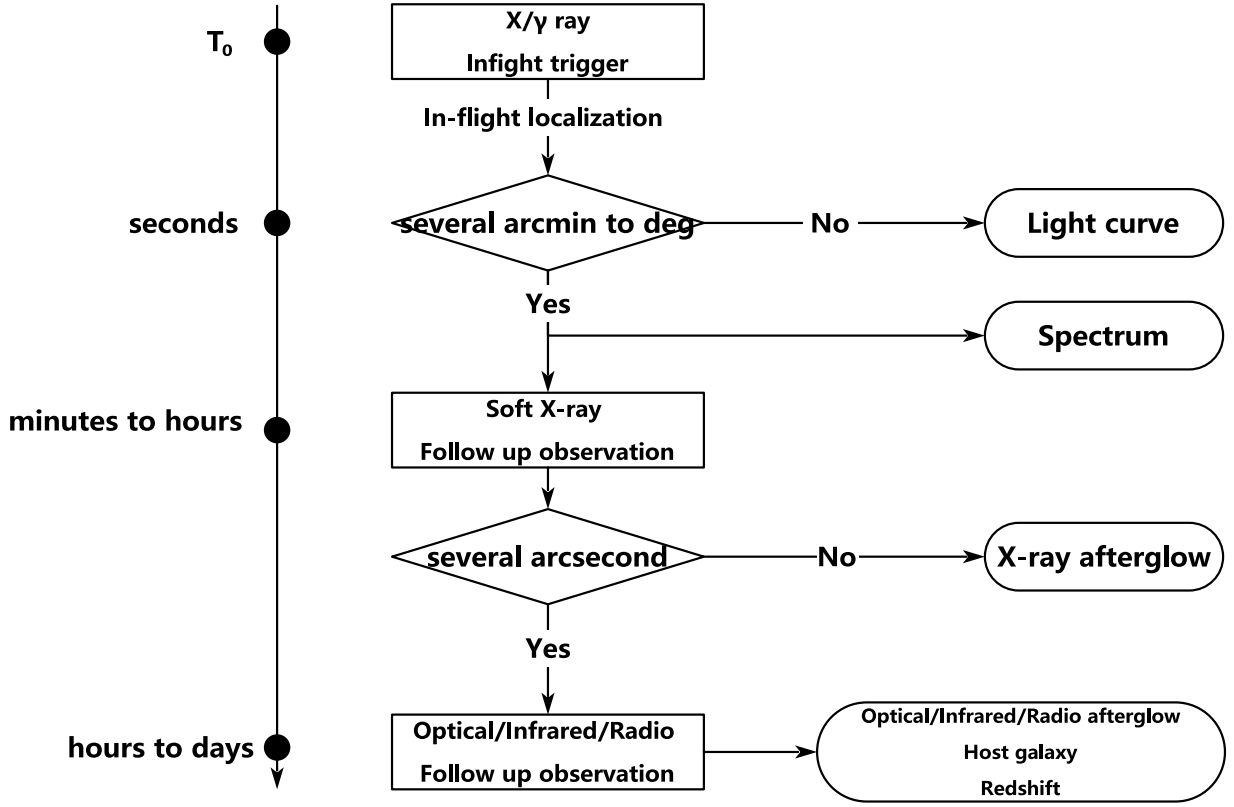


R.C.Chen, B.B.Zhang, *C.W.Wang* et al., NA accepted, 2025

A high significance 909-Hz gamma-ray periodic signal is detected in GRB 230307A

Typical observation campaign of GRB

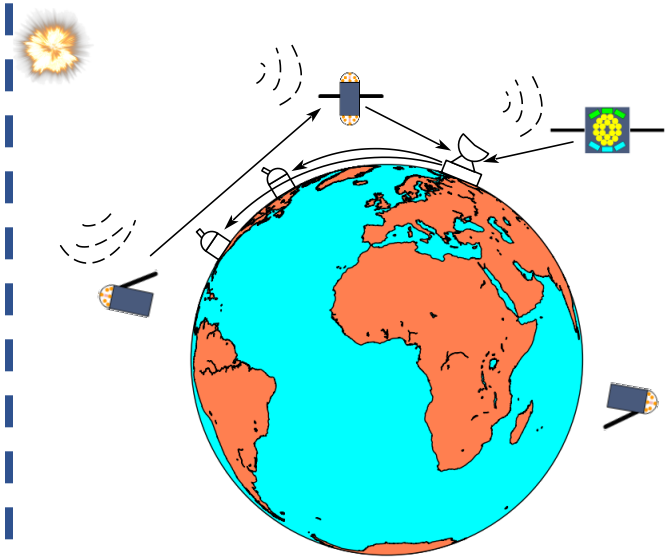


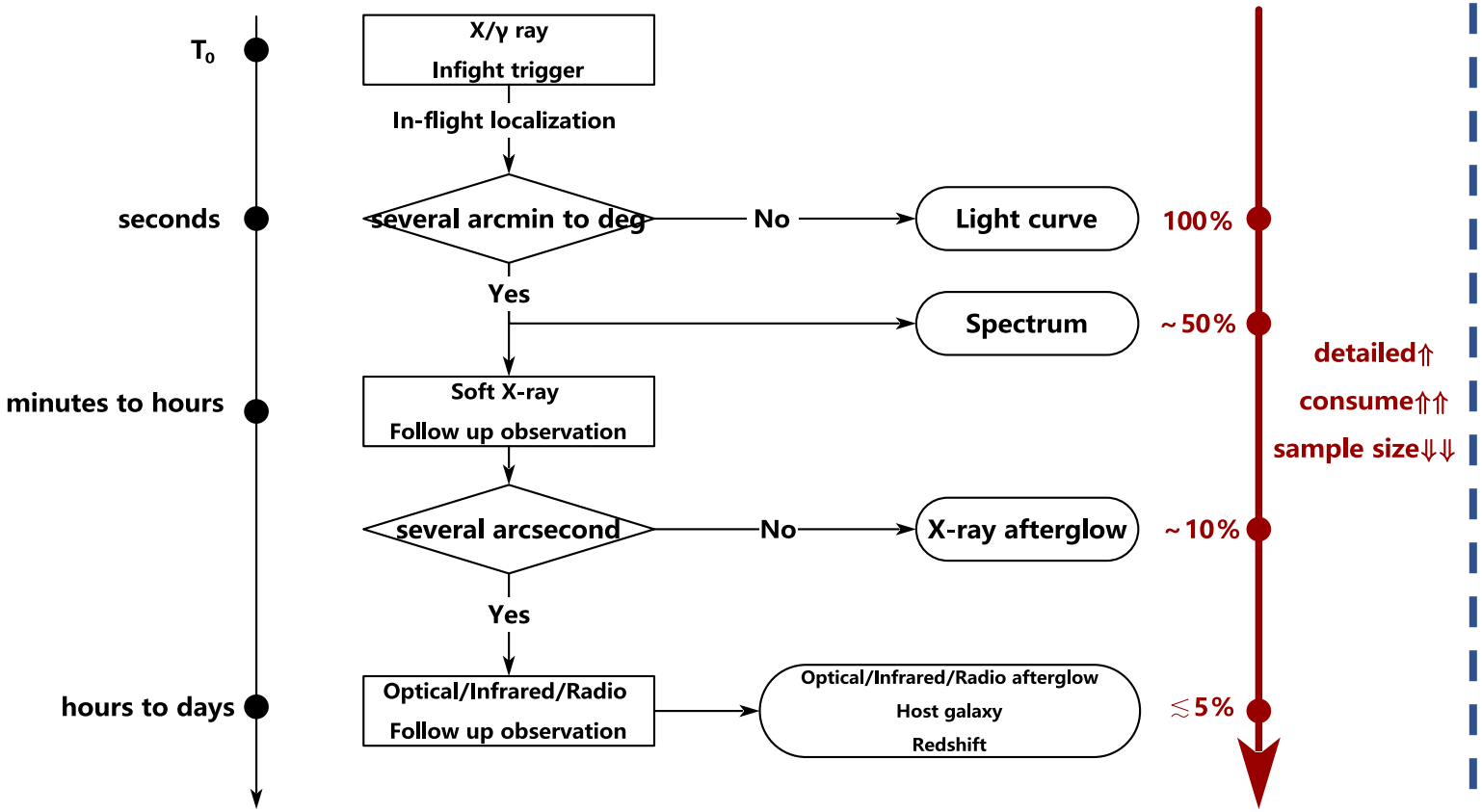


Majority GRB(-like) observation campaign starts with in-flight of wide FOV monitor

Although instruments like CHIME/EP/LSST have changed or will change this

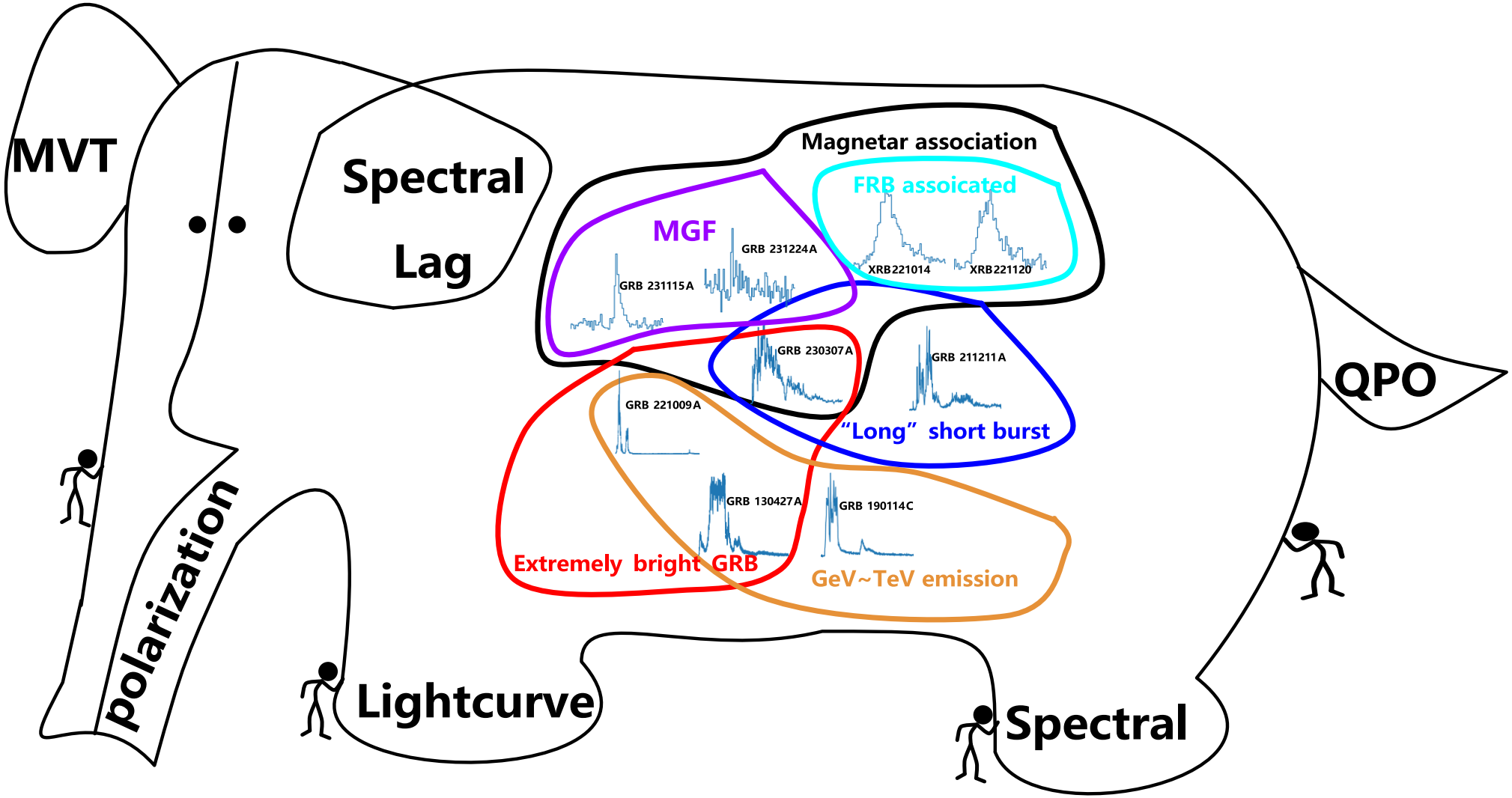
Typical observation campaign of GRB





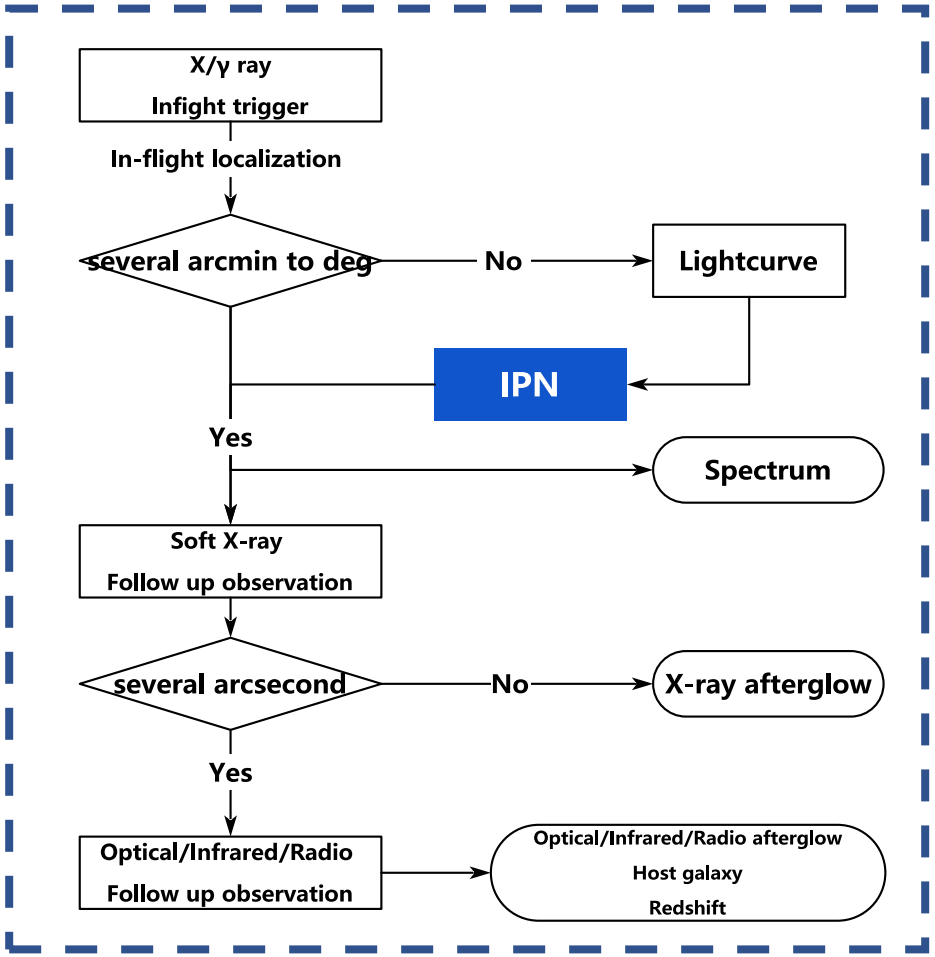
To get more information, more exposure time in multi-wavelength are needed

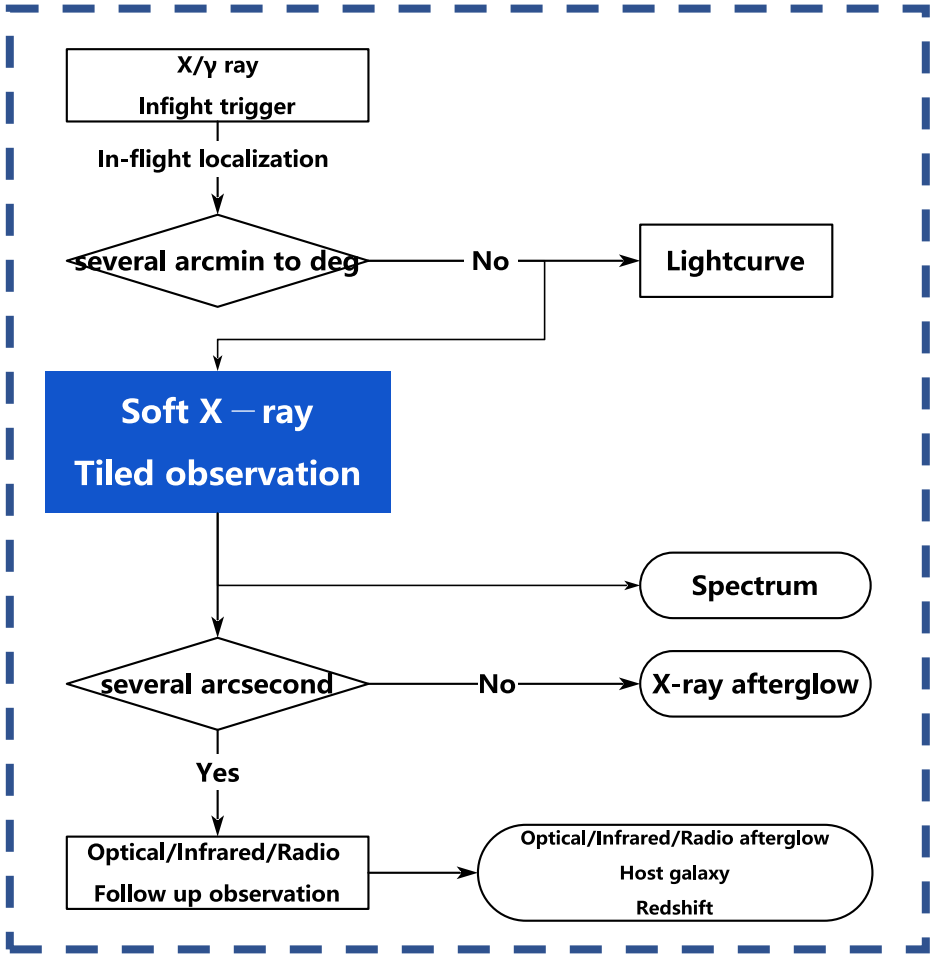
Peculiar GRBs



Limited exposure time should be prioritized for peculiar events

Typical observation campaign of GRB





In some cases, costs may further increase (e.g. GRB 170817A, GRB 230307A …)

It is necessary to weigh the costs against the benefits —— like gambling

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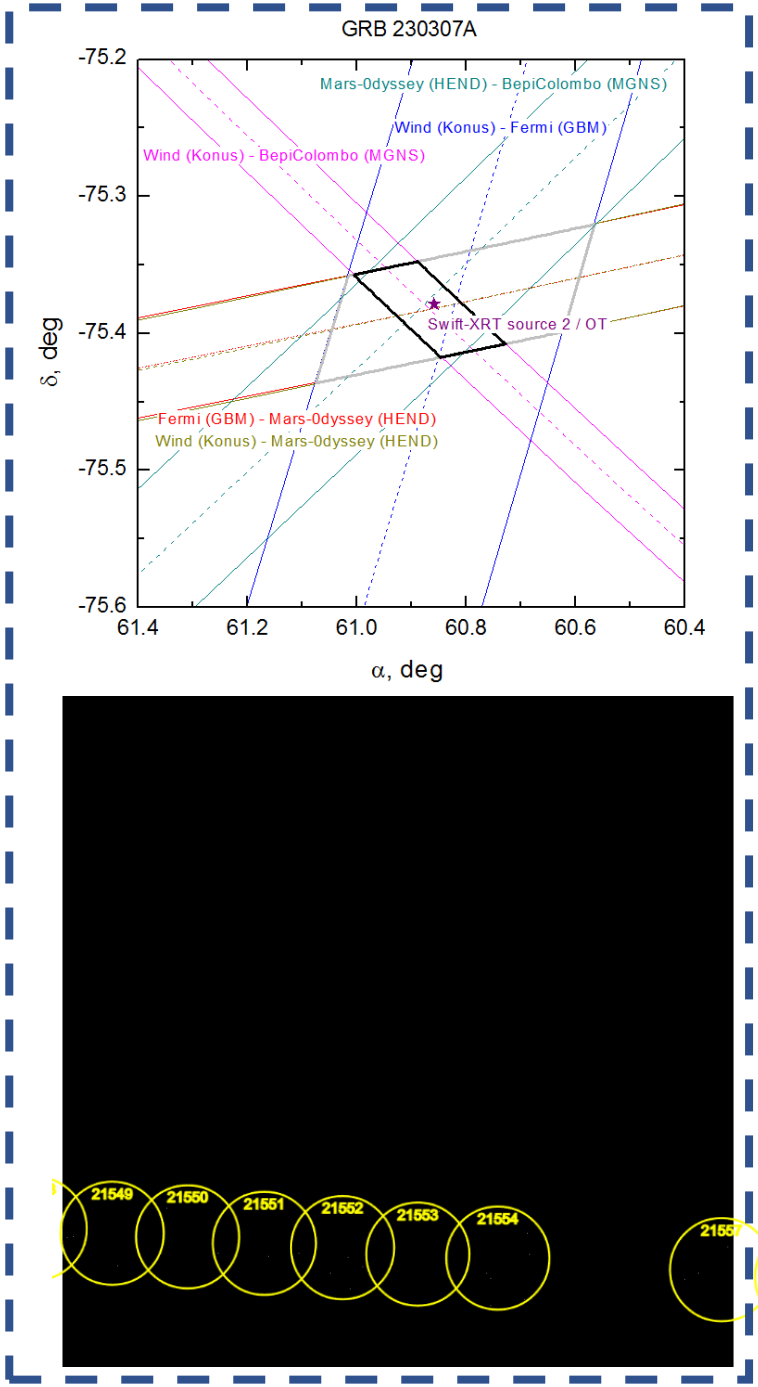
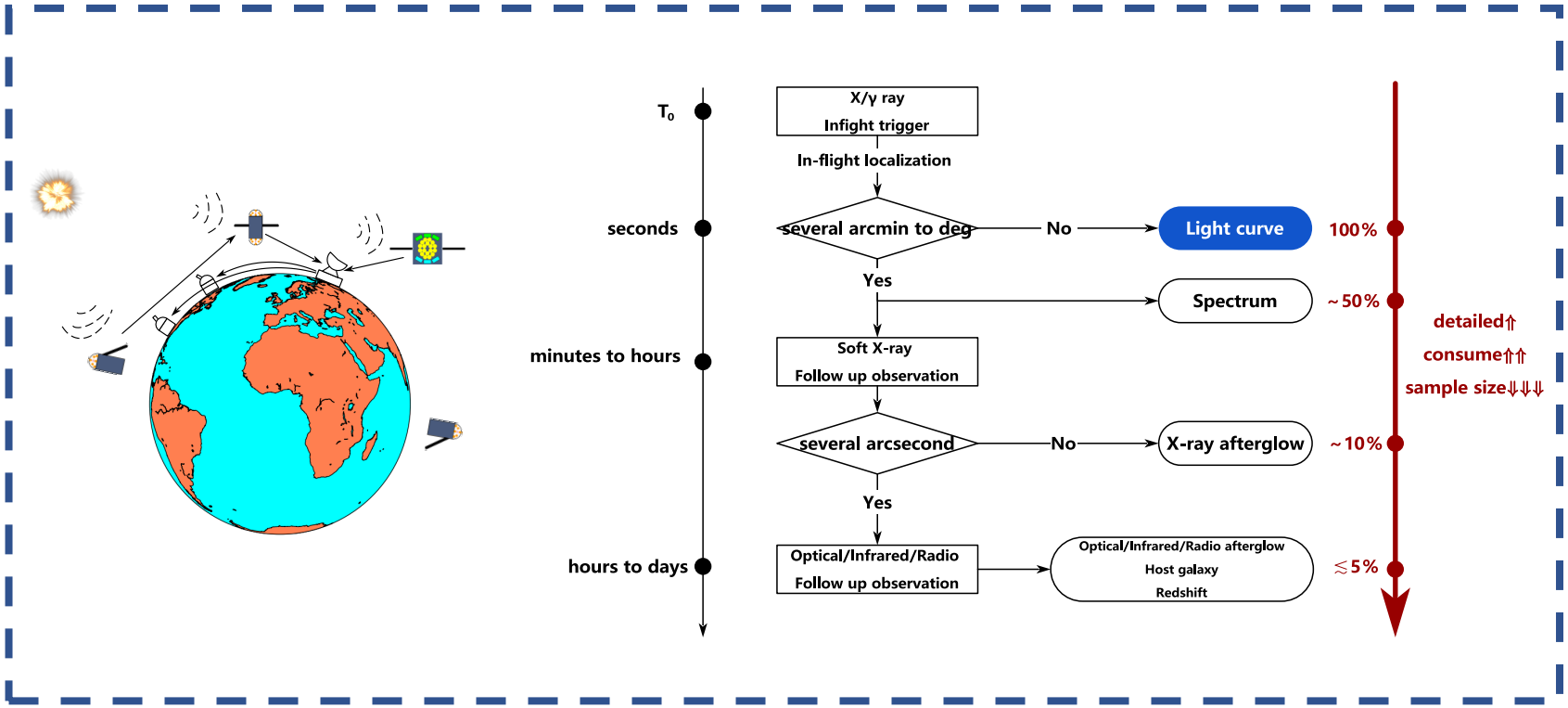


People were initially attracted by its high brightness without realizing that it is a "Long" short GRB

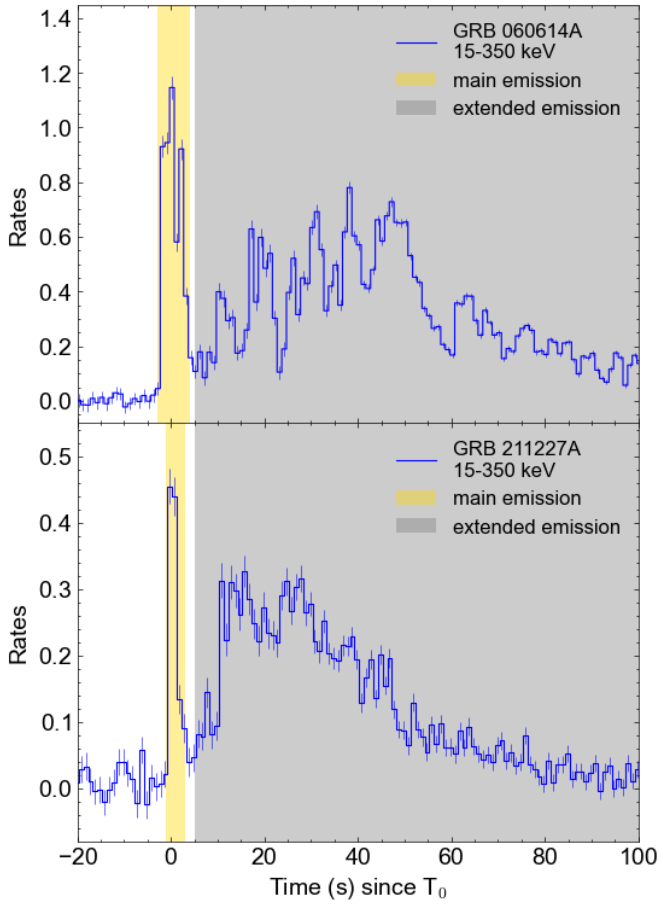
A logical bug



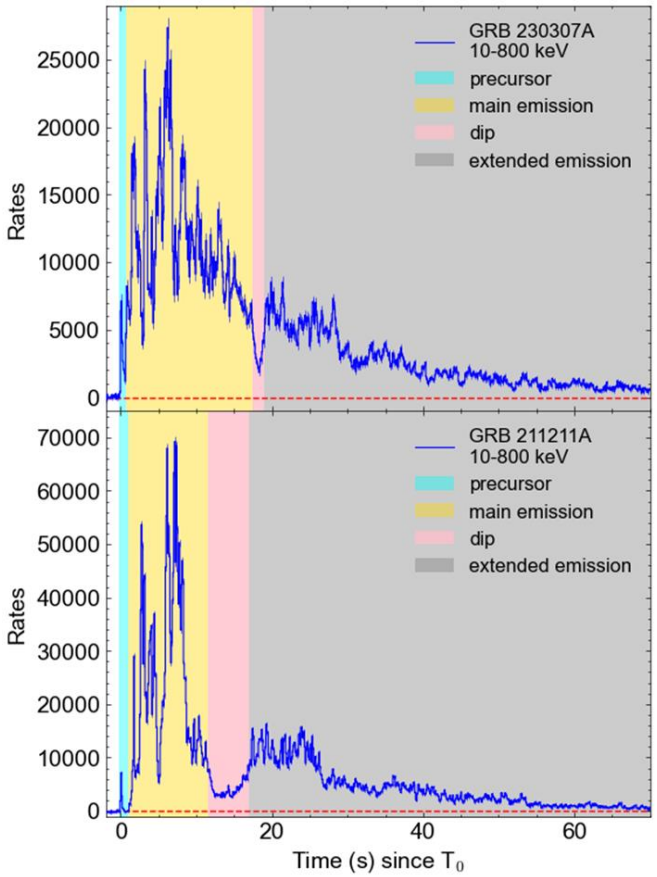
How to increase the sample size of “long” sGRB?

How to quickly identify such events from light curve?

Similarities?

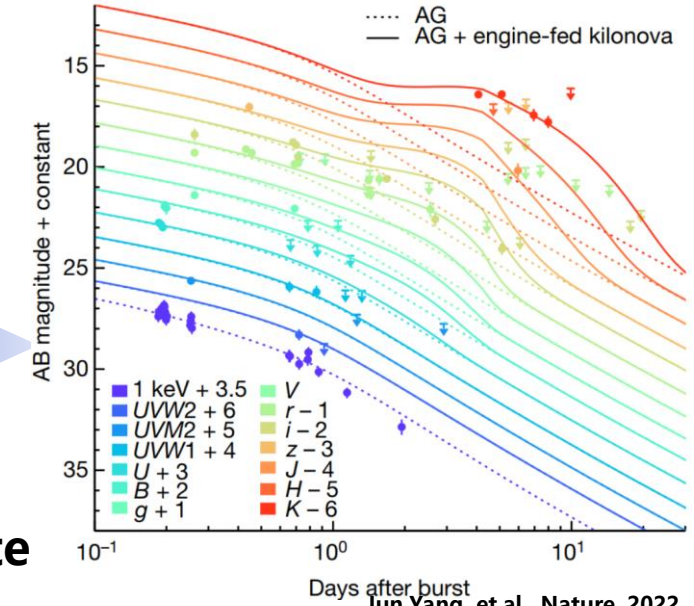


Short-Hard main emission
+
Long-Soft extended emission

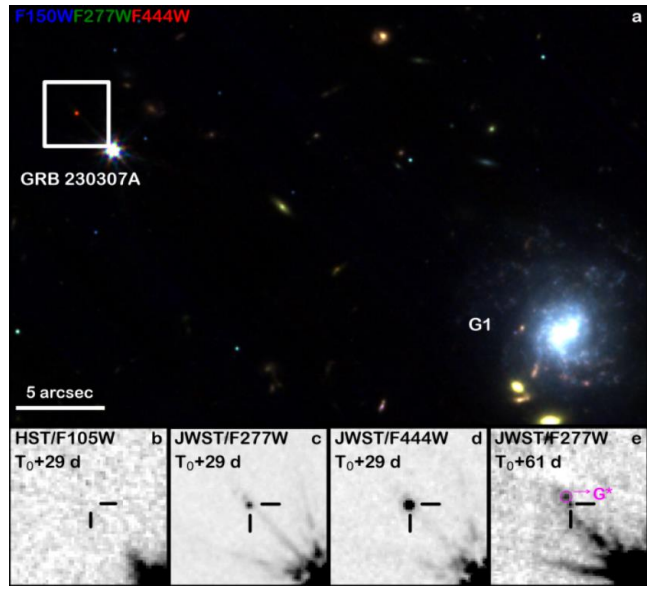


Precursor (?)
+
Long-Hard main emission
+
Long-Soft extended emission

associate with KN

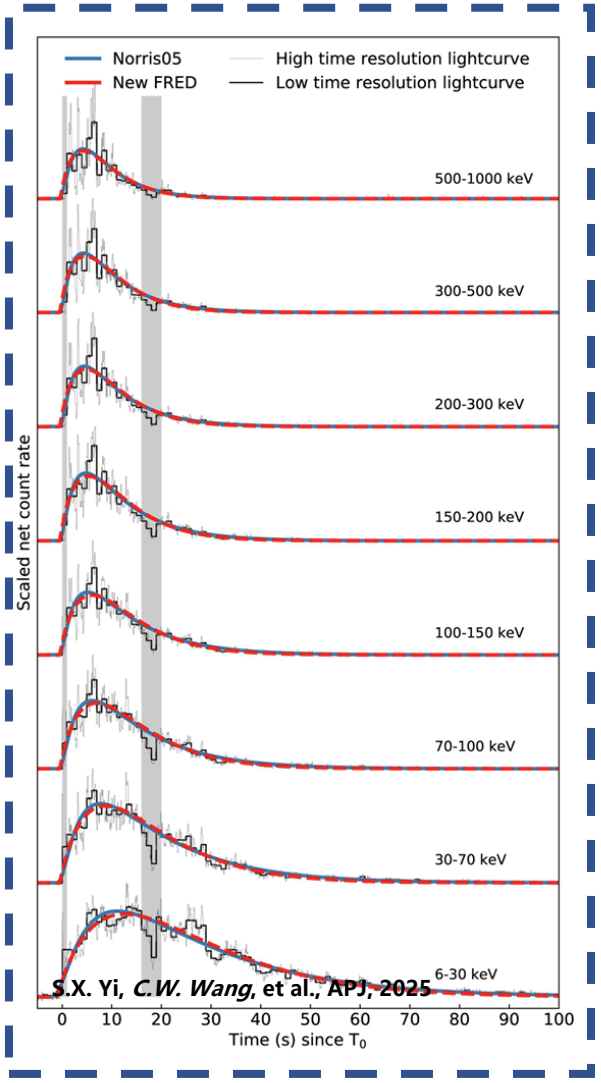


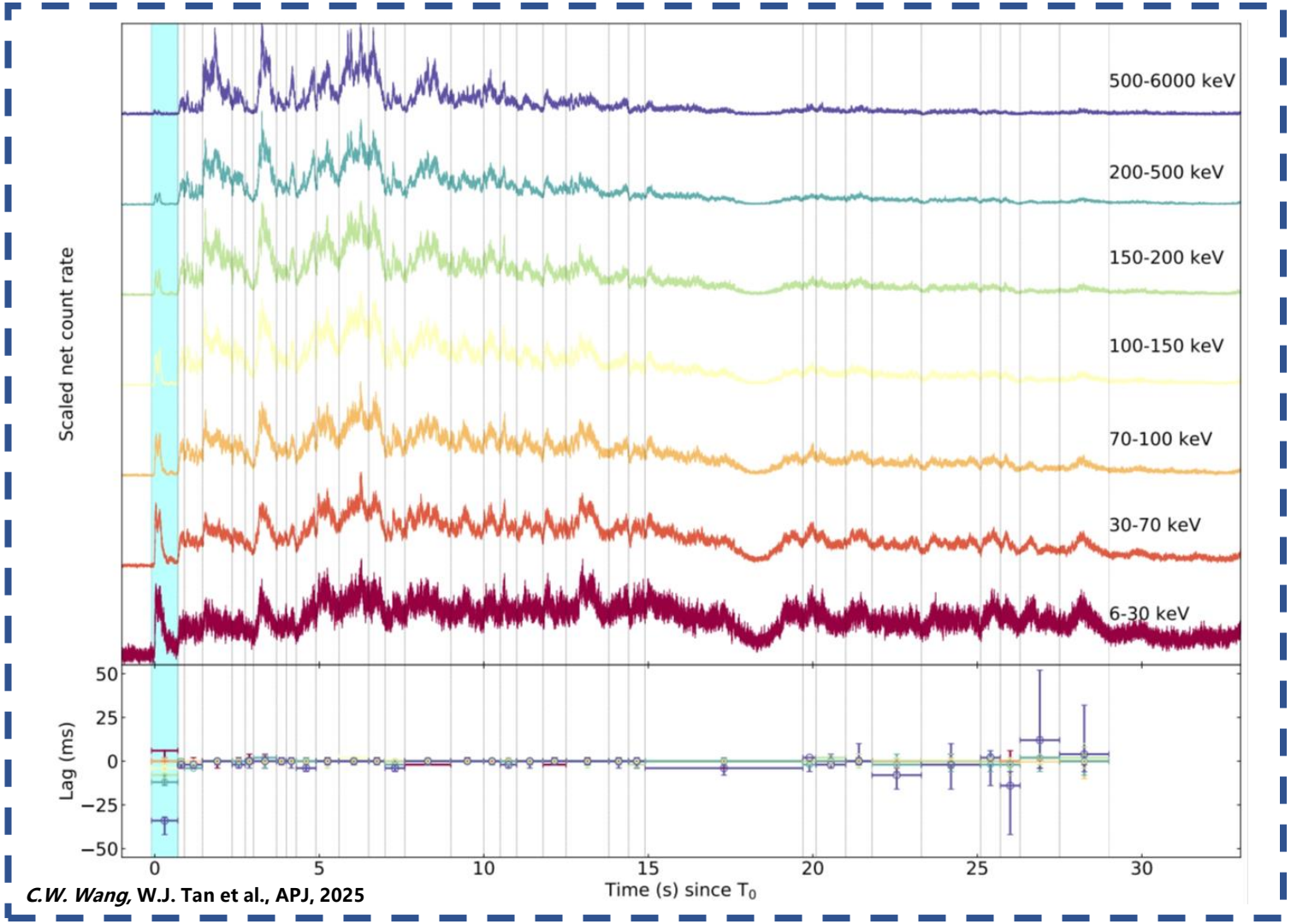
Jun Yang, et al., Nature, 2022



Yuhan Yang, et al., Nature, 2024

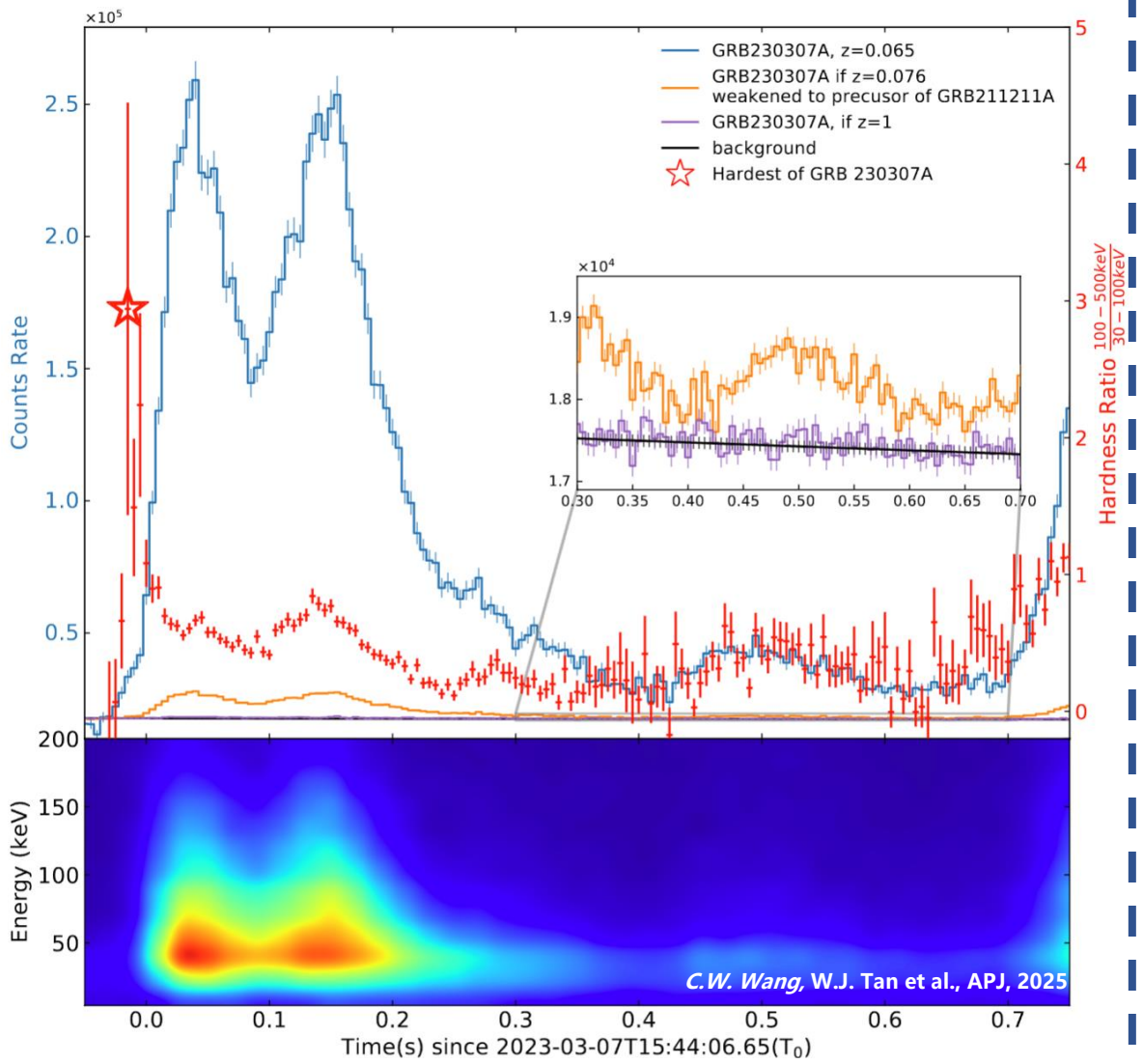
Identification of precursor in GRB 230307A

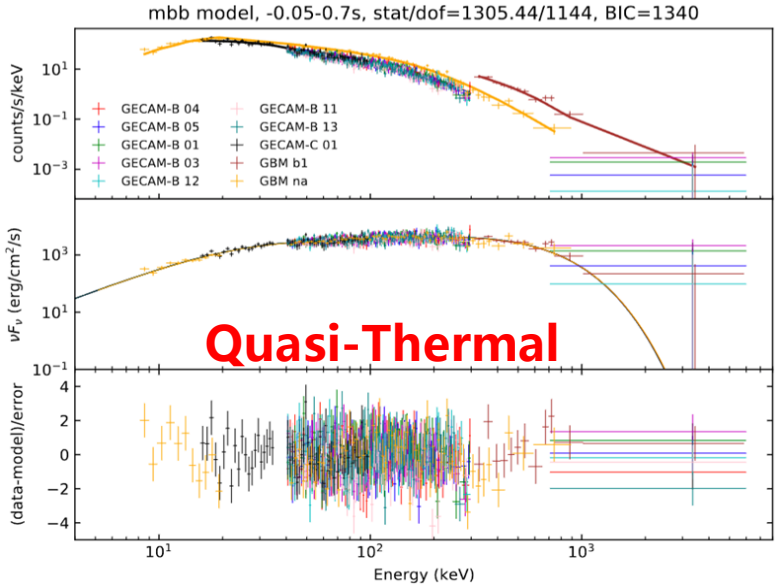




The first pulse show different temporal behavior from the other pulses

Identification of precursor in GRB 230307A





redshift	0.5	1
SNR of 1 GRD	0.73	0.13
SNR of 25 GRD	0.37	0.07
SNR of 1 NaI	0.62	0.11

If the burst is farther away, a quiescent period will exist

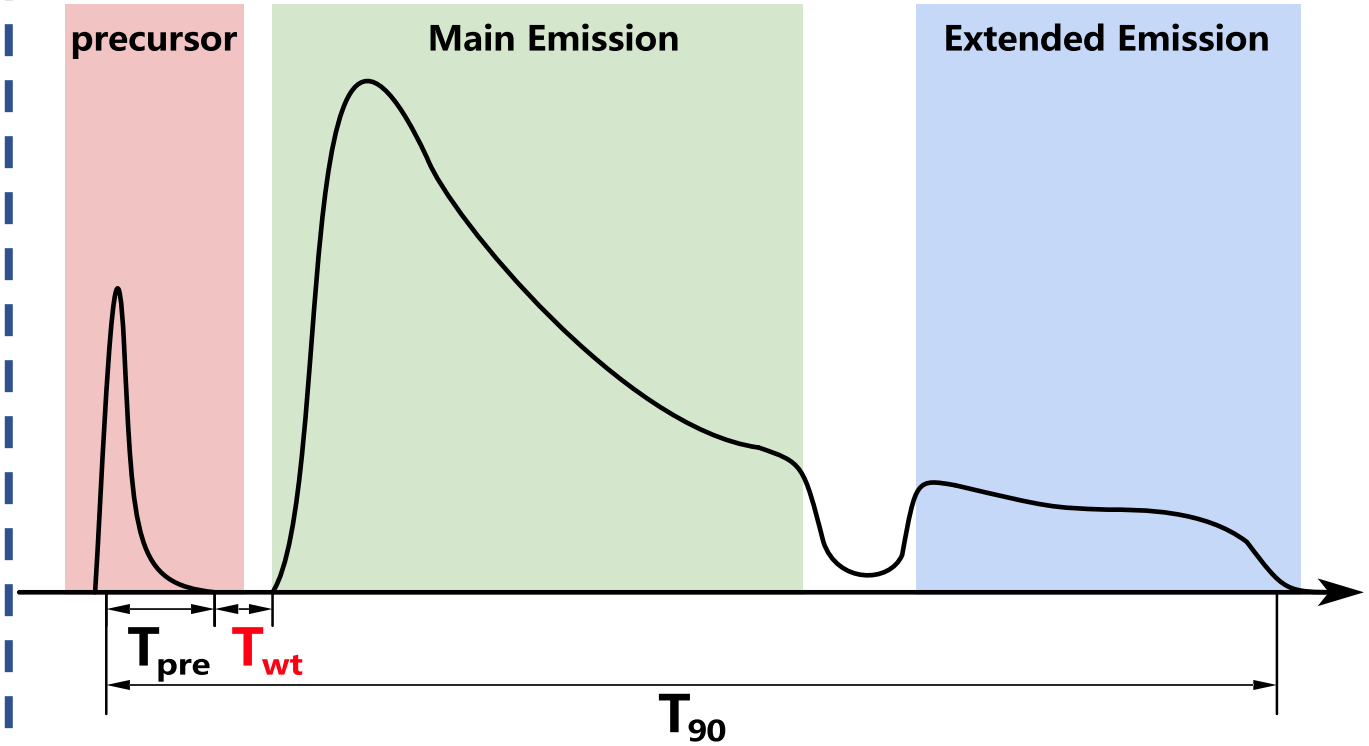
Type Ⅰ L GRB

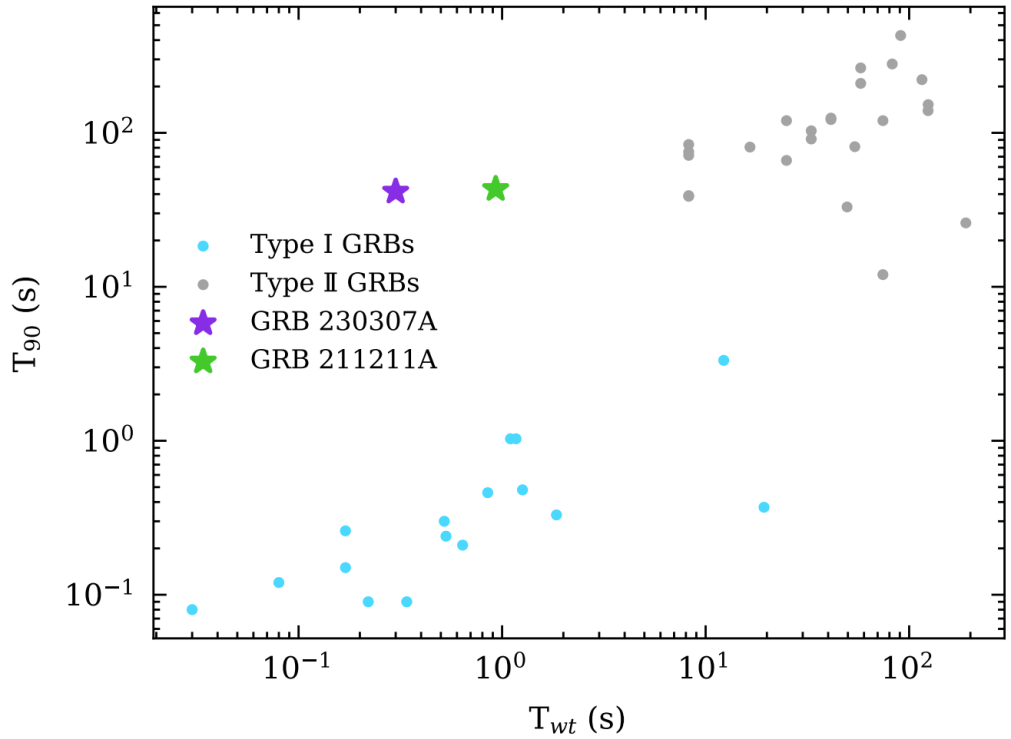
Three-episode burst pattern

① a precursor followed by a short quiescent (or weak emission) period

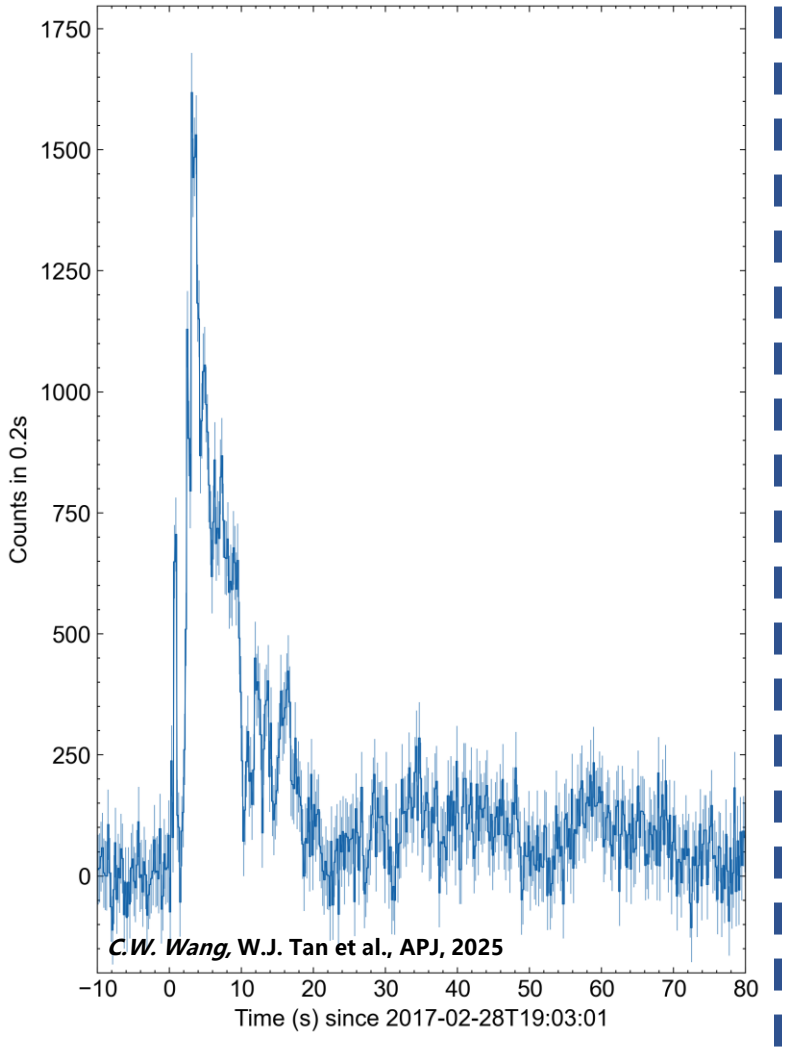
② a long-duration main emission

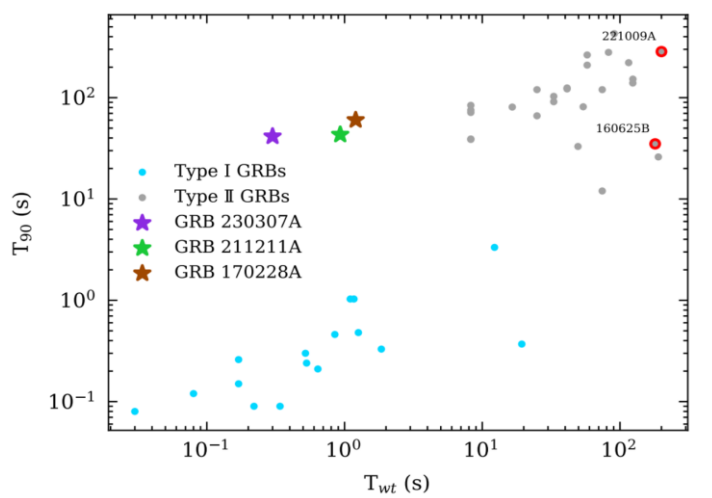
③ an extended emission

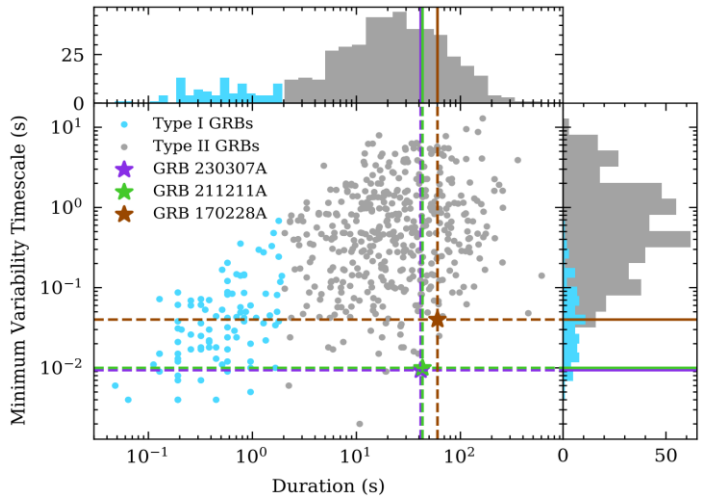


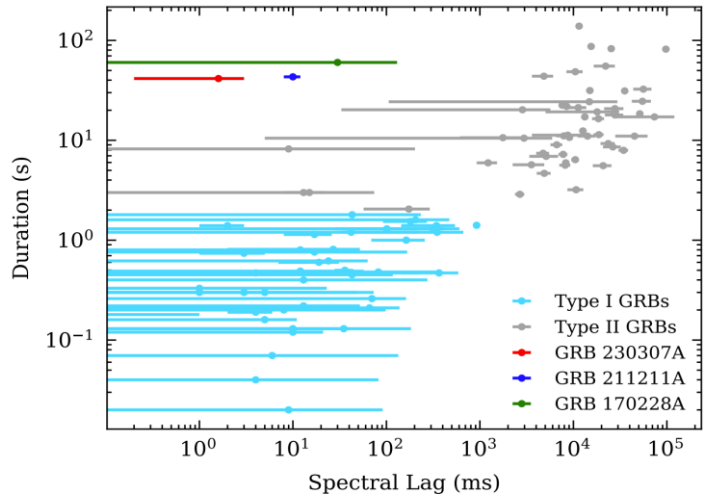


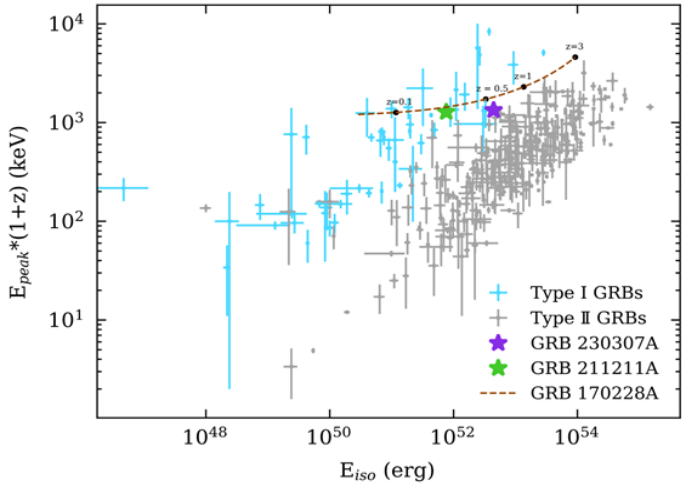
GRB 170228A





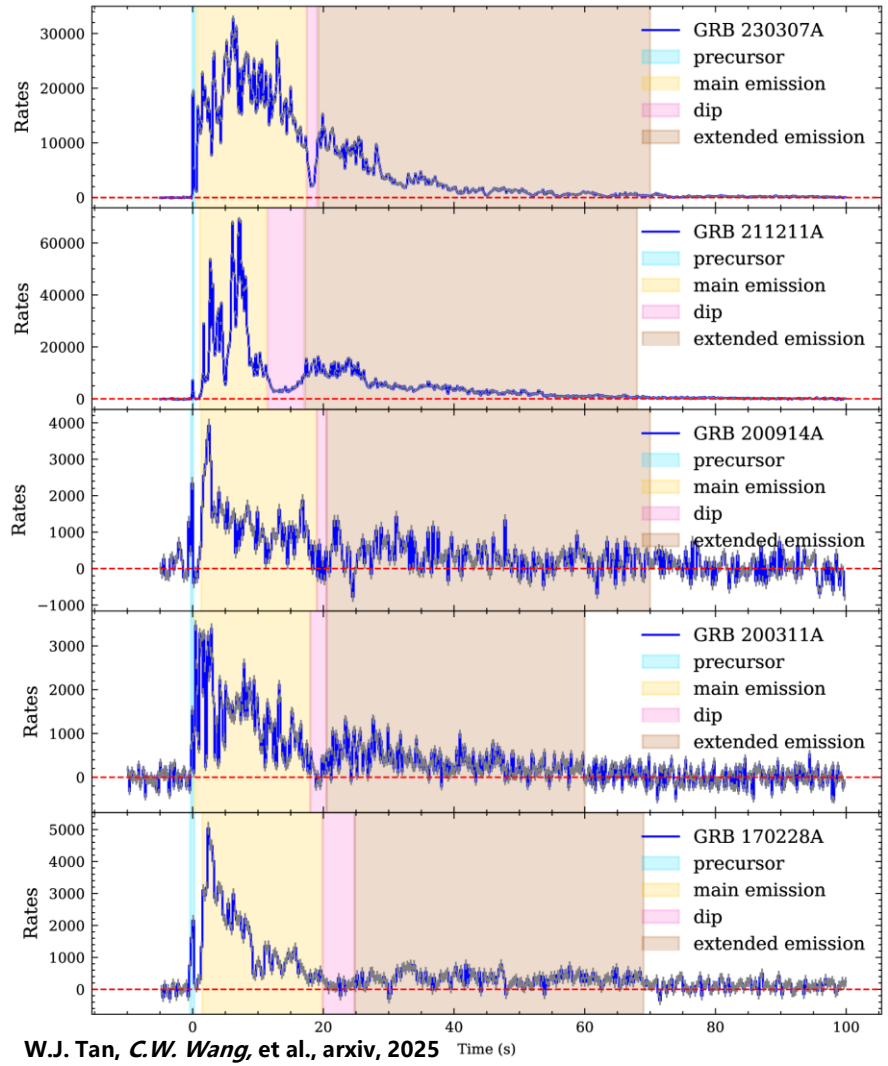




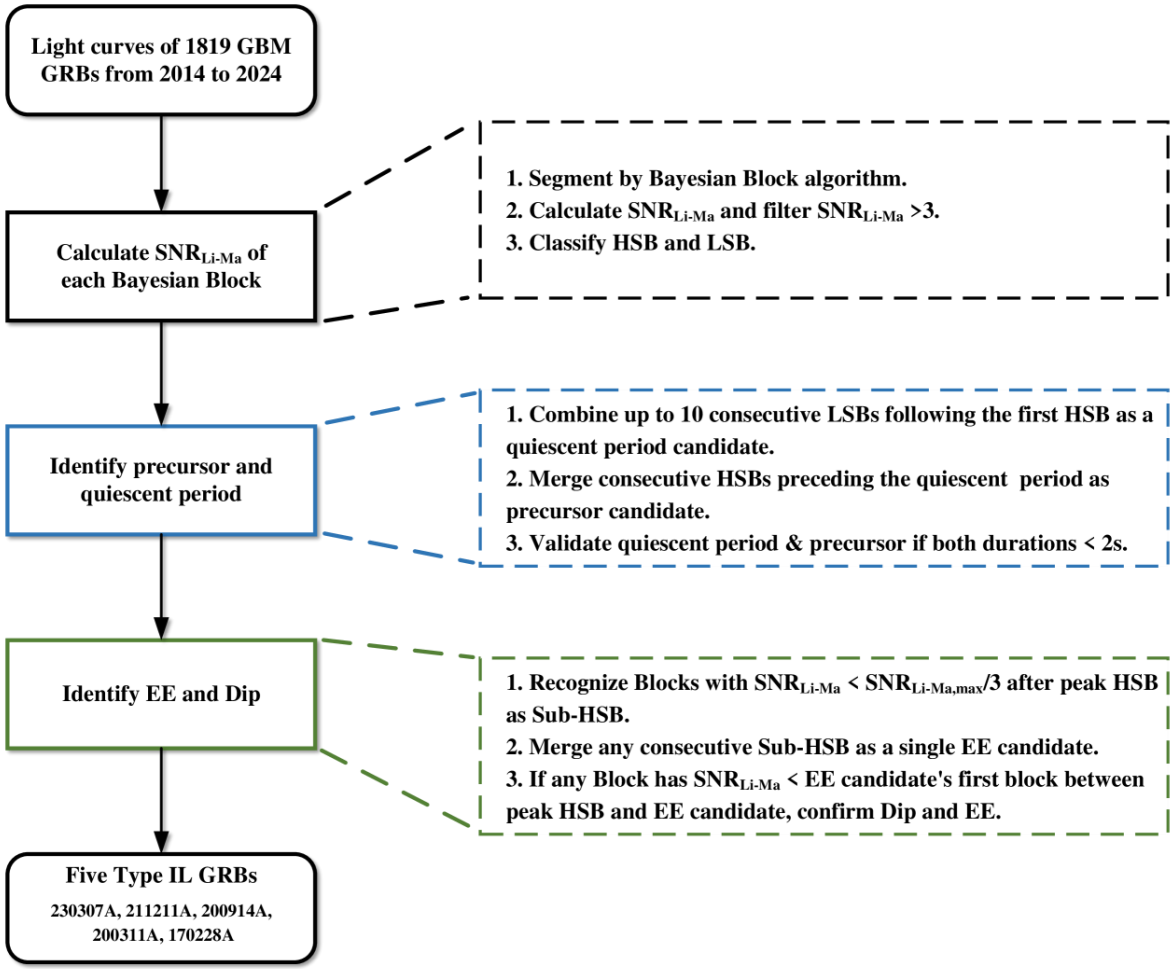


The prompt emission properties are consistent with a merger origin

More candidates from archive data



W.J. Tan, *C.W. Wang,* et al., arxiv, 2025



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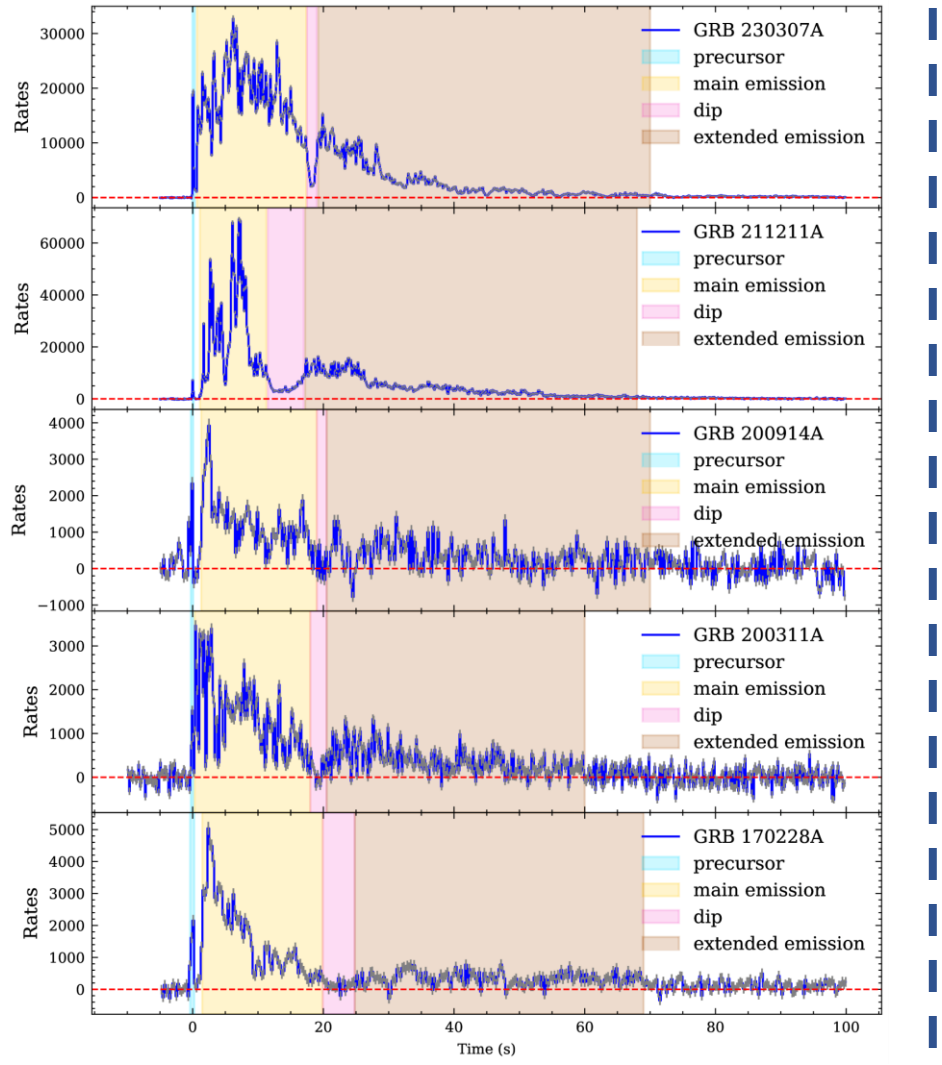

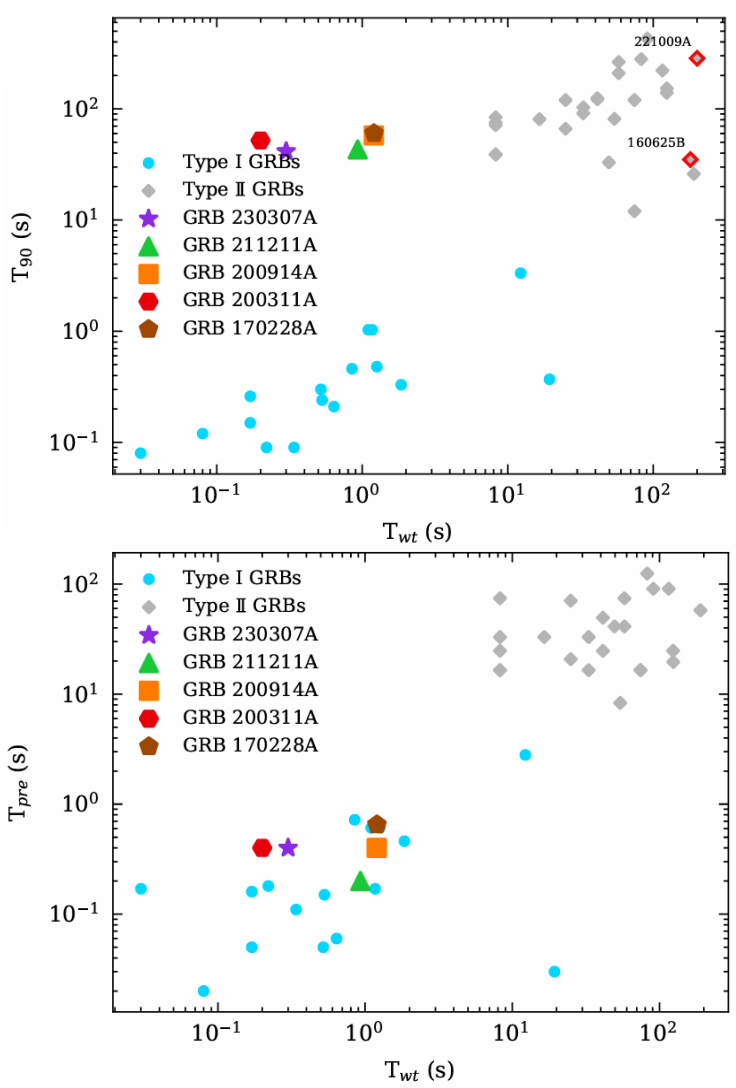

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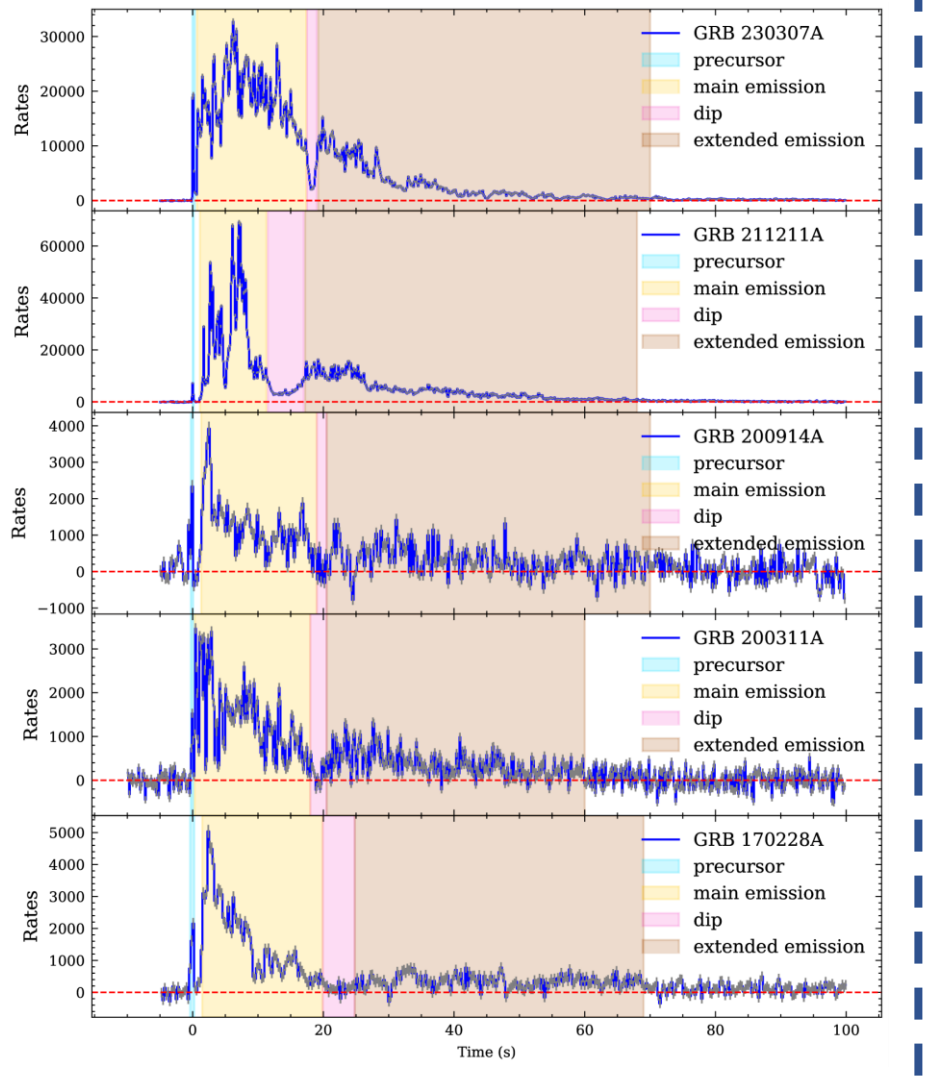
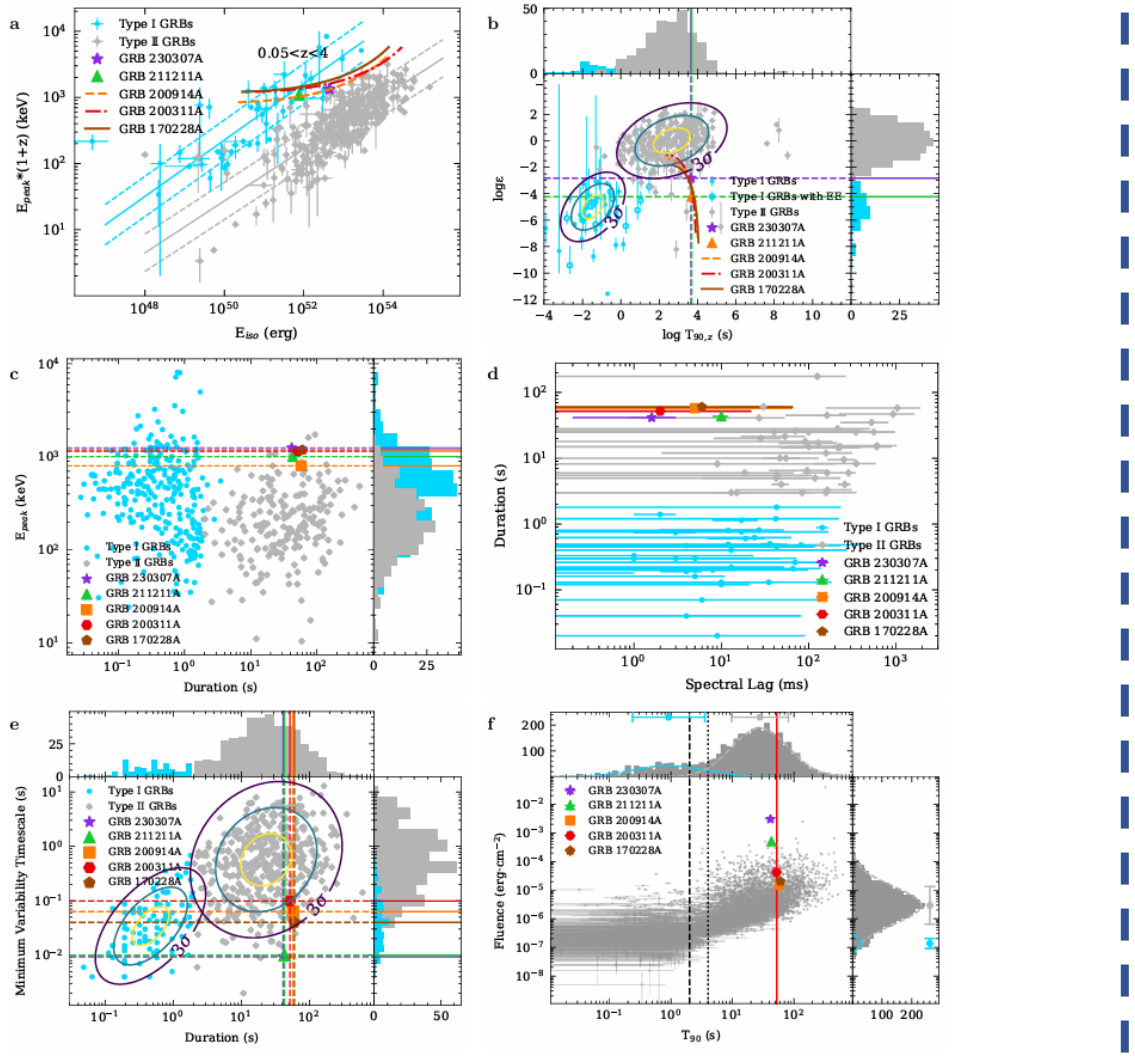
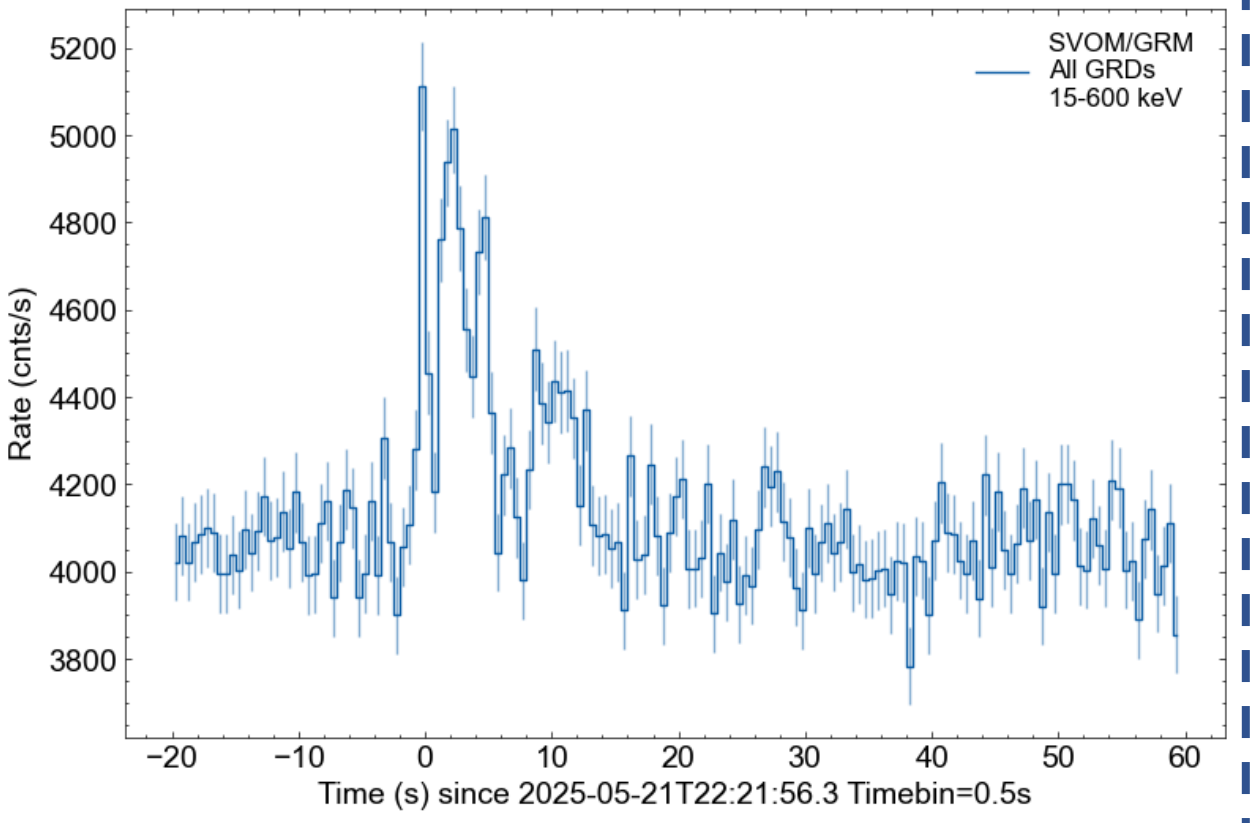
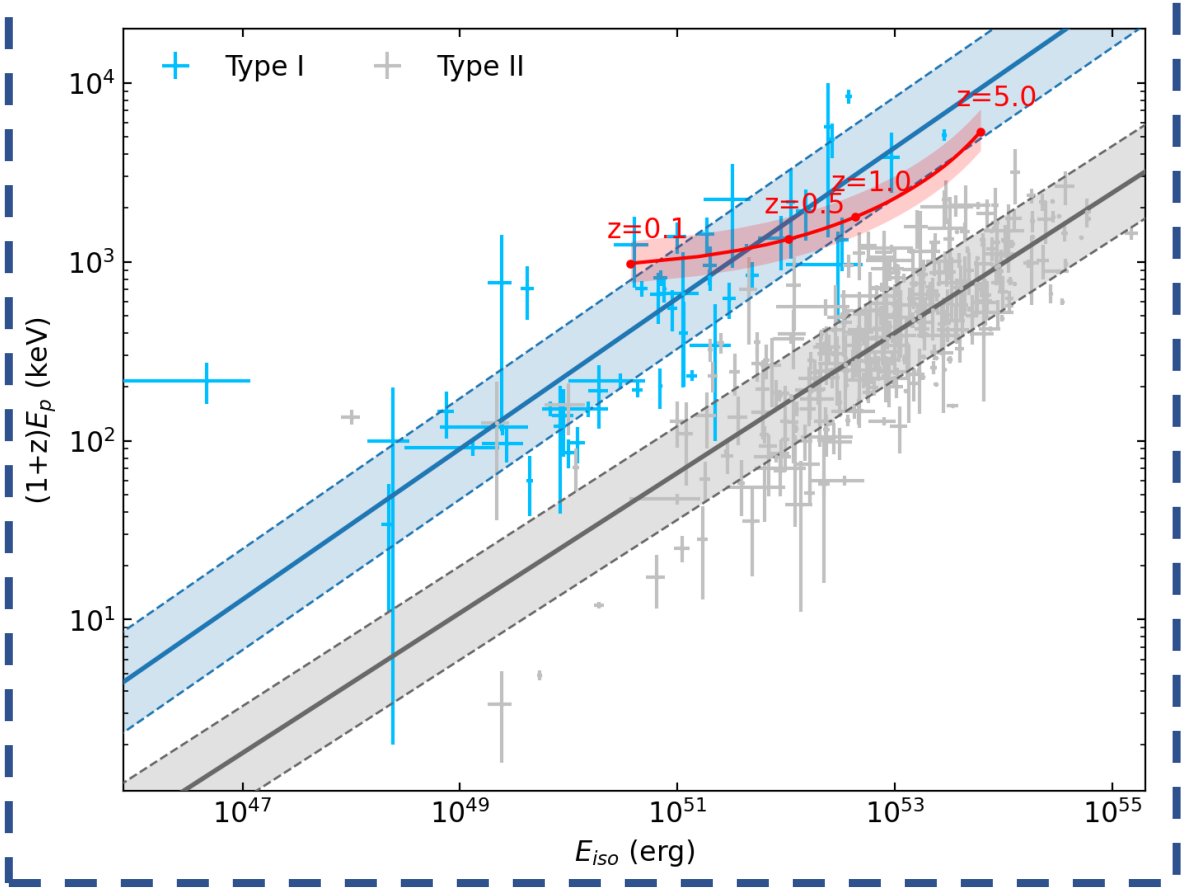




Application – GRB 250521D

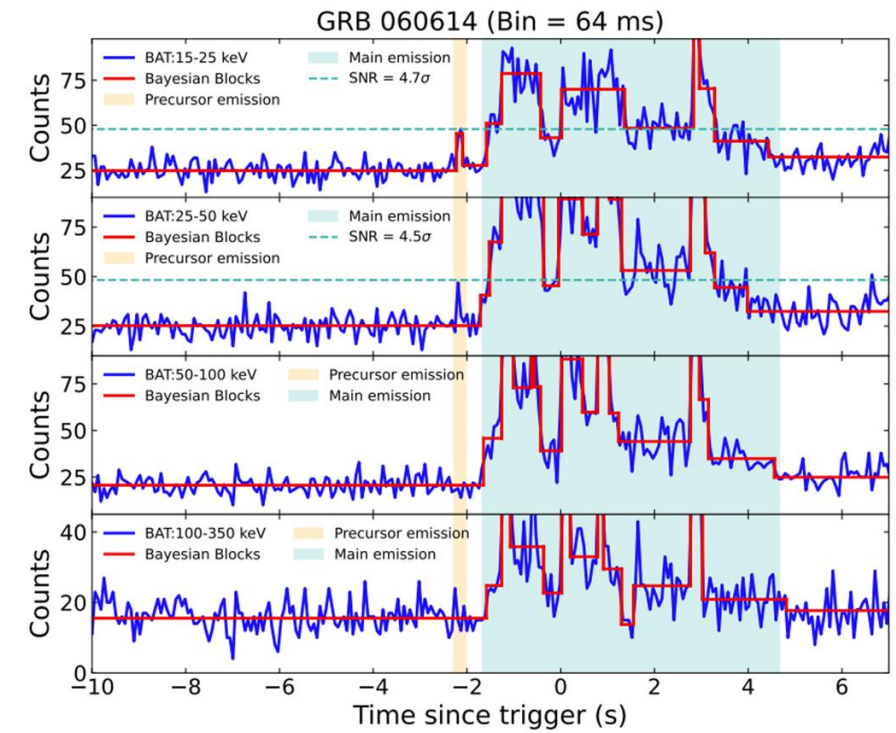




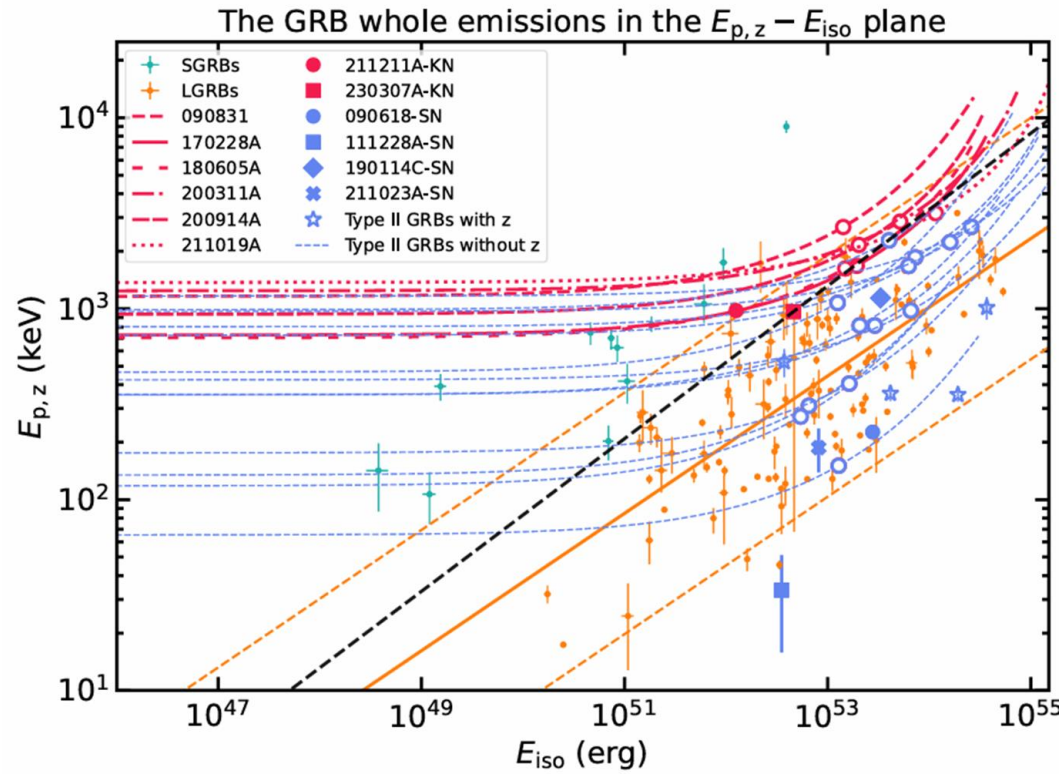
GCN Circular 40561

GRB 250521D: SVOM/GRM analysis suggests a possible "long" duration type I burst

Fundamentalism?

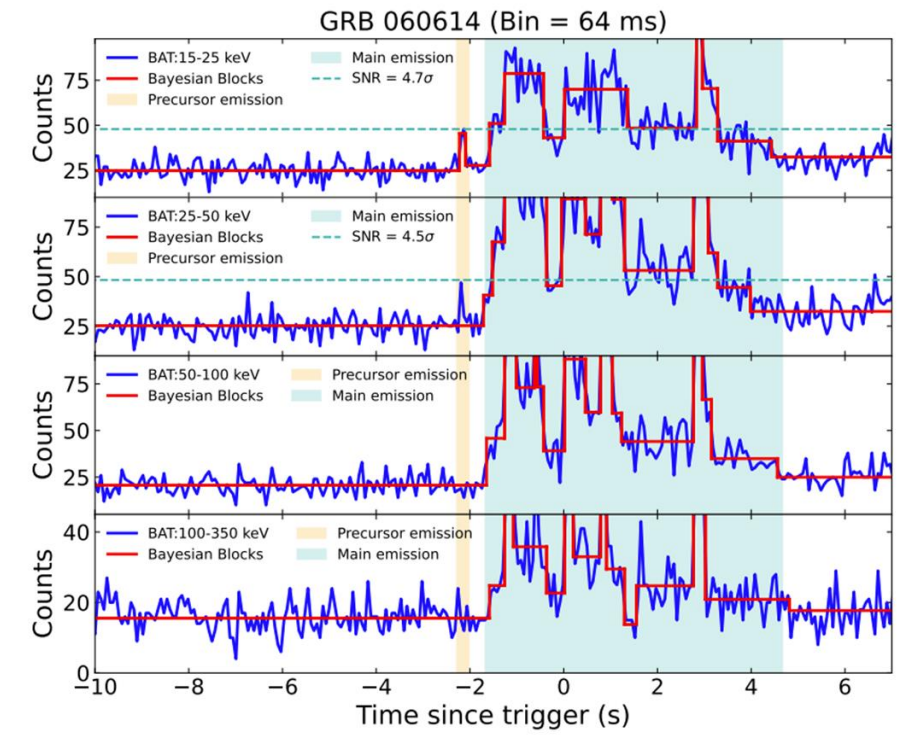


S.Y. Zhu, et al., arxiv, 2025



A precursor is identified in GRB 060614

Fundamentalism?



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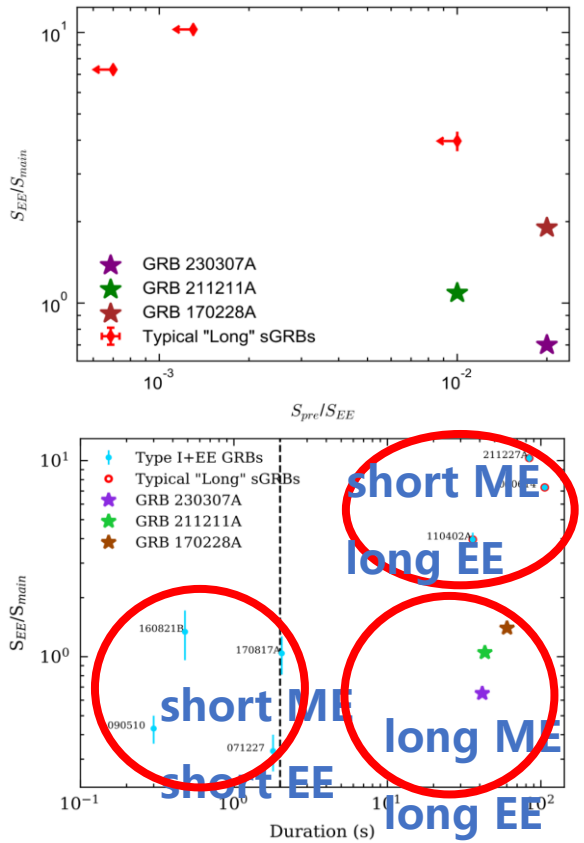
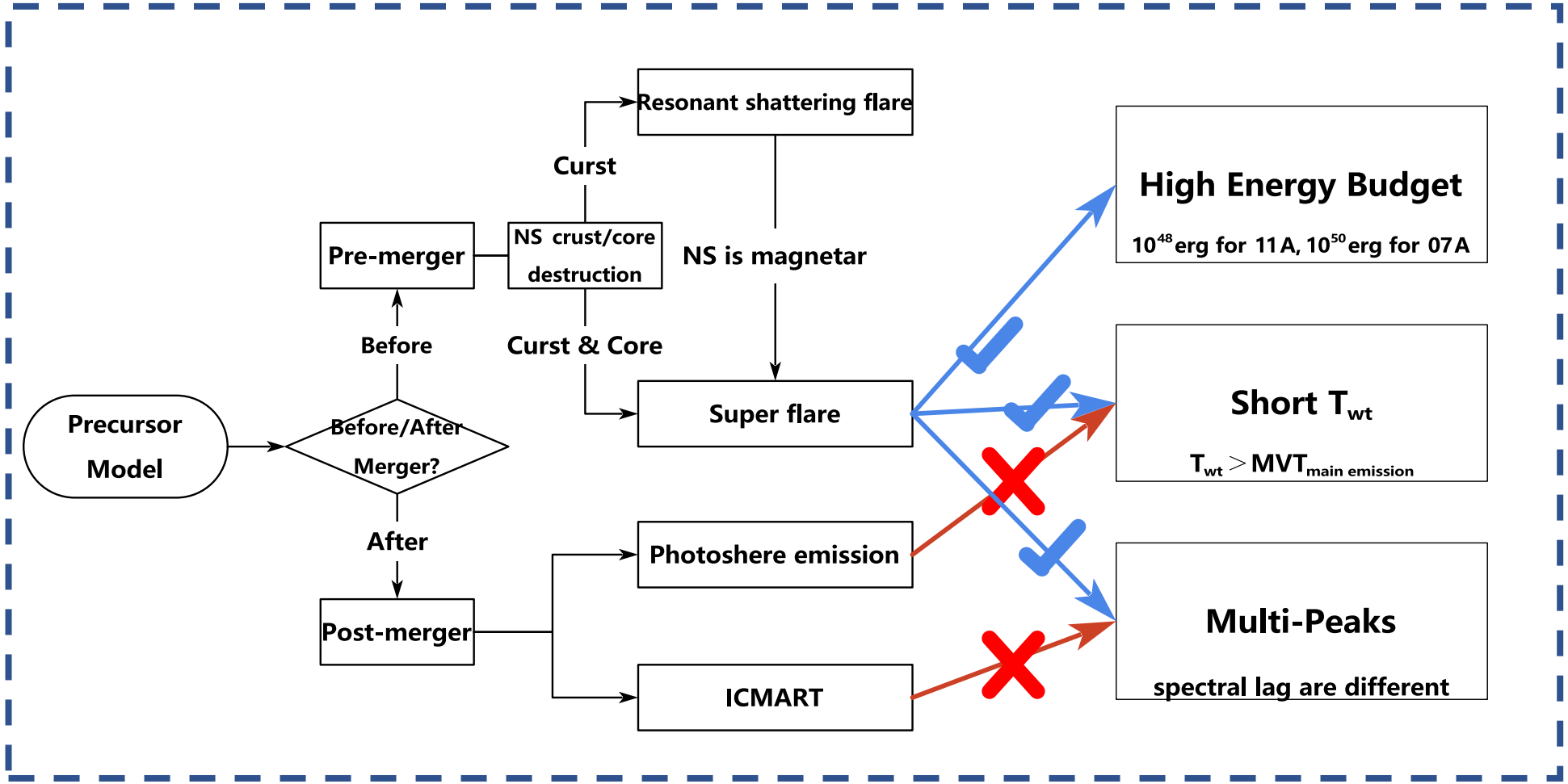


A precursor is identified in GRB 060614

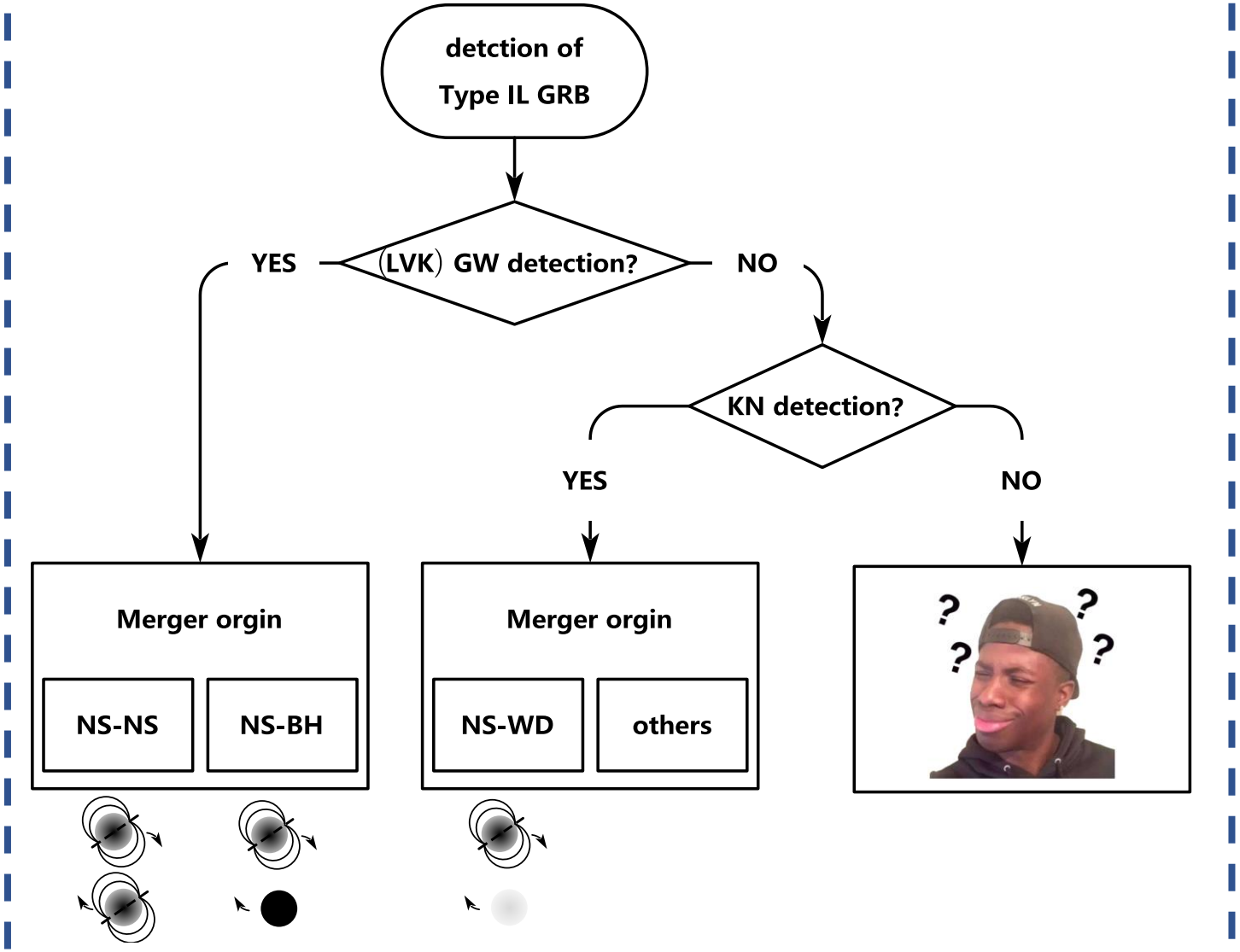
Anyway, precursor is still a crucial clue

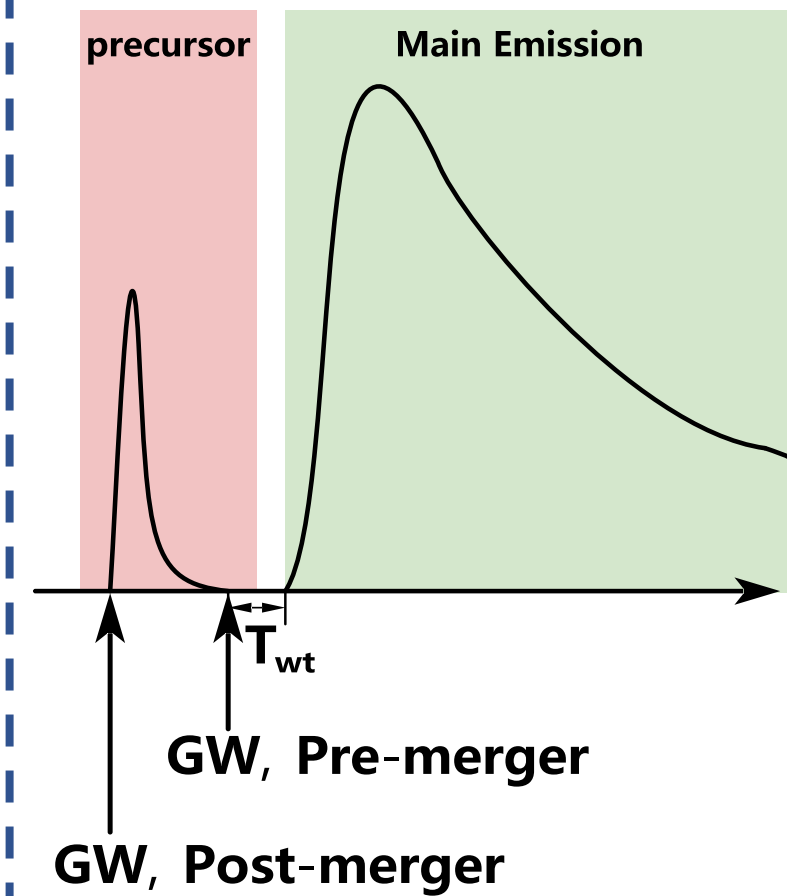


10 years, 3~5 type IL GRB in ~400 sGRB with an occurrence rate about 1%

same as the proportion of magnetars in NSs

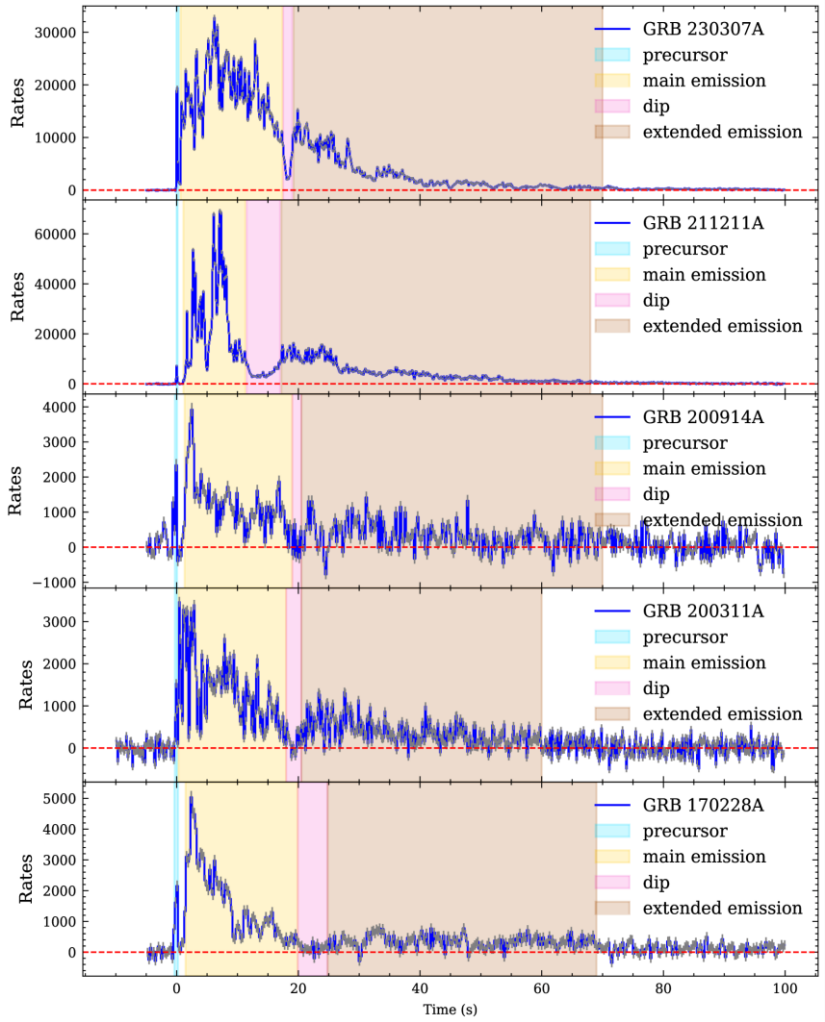
Anyway, precursor is still a crucial clue

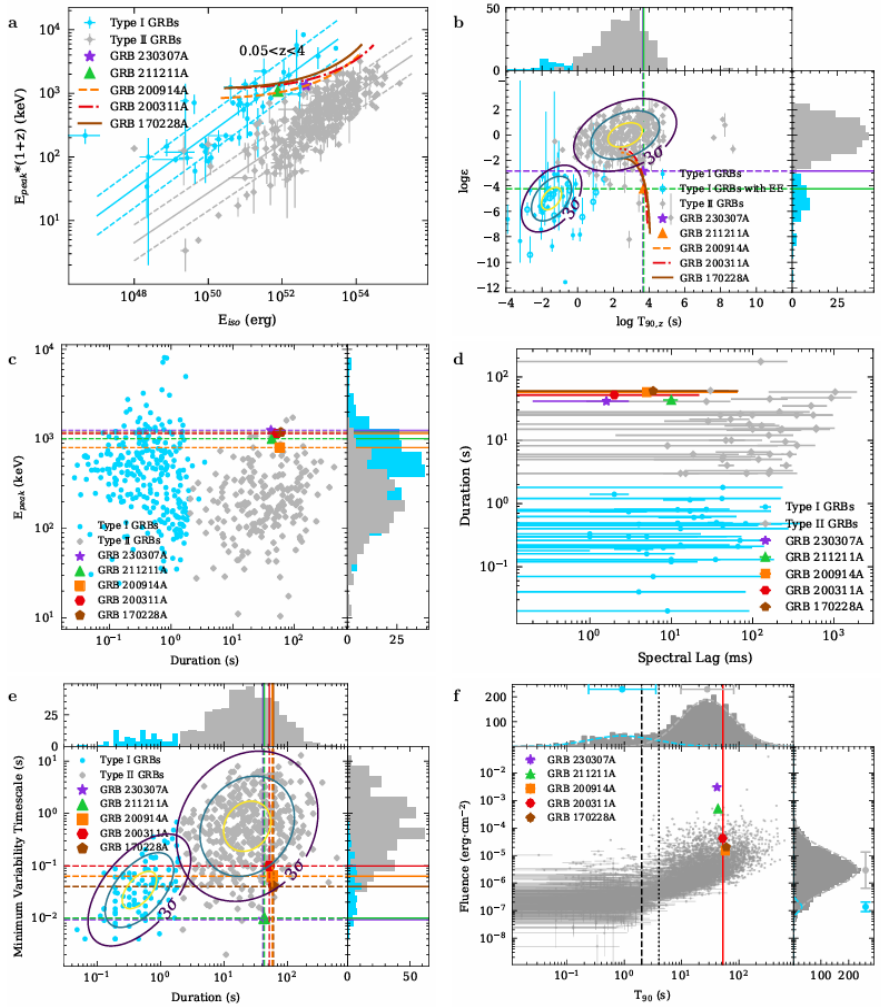




Jun Yang, et al., Nature, 2022
Zhen Zhang, et al., ApJL, 2022
Yanzhi Meng, et al., ApJ, 2024
Junping Chen, et al., APJL, 2024

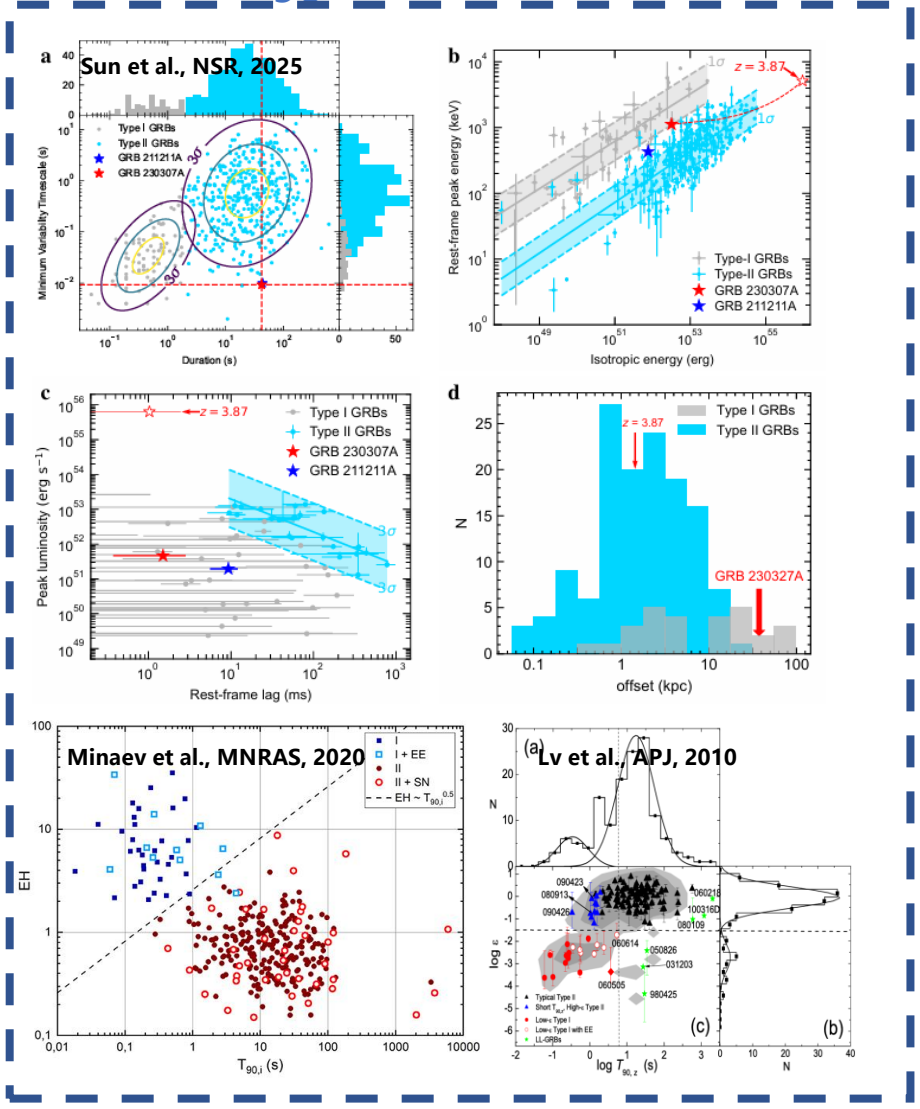
Two insights from Type Ⅰ L GRB

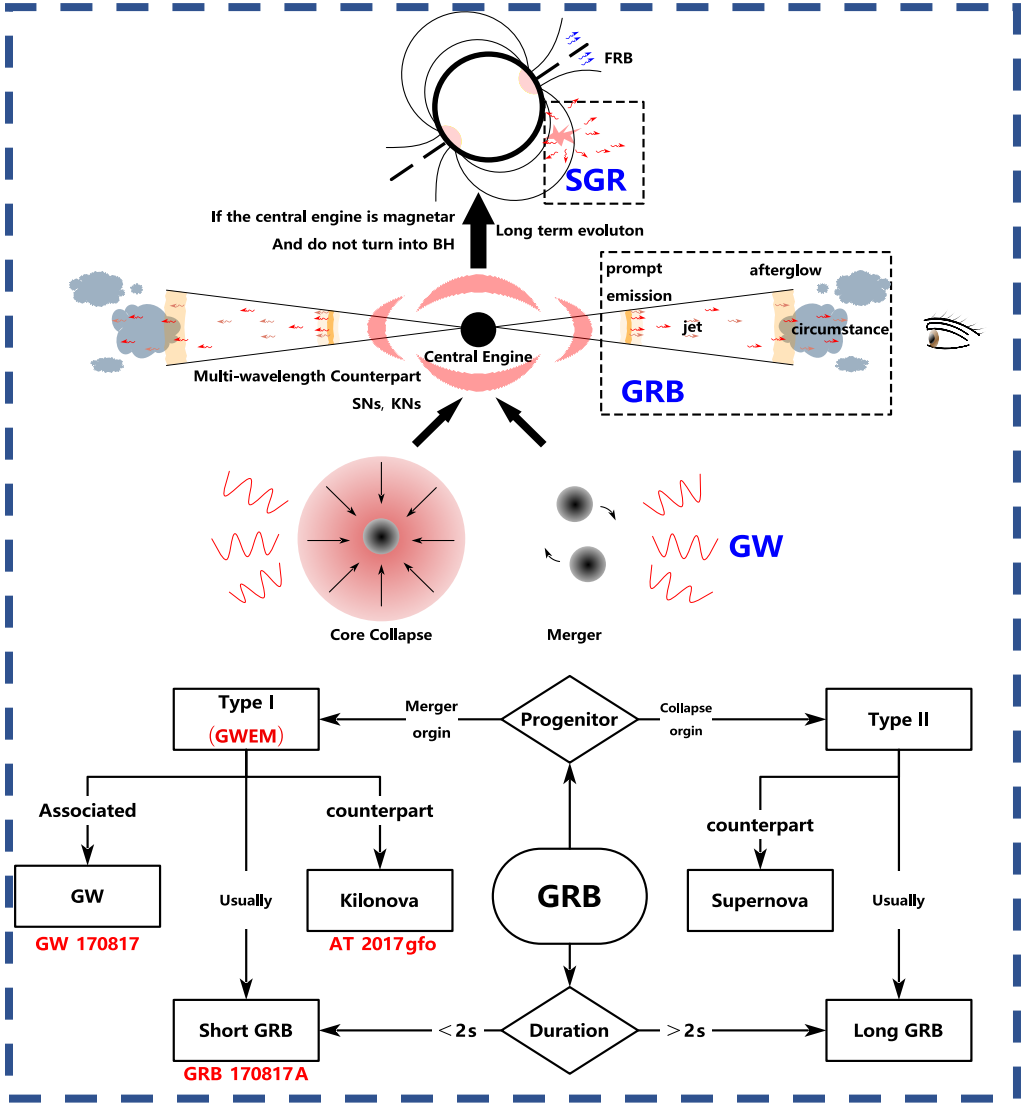




What can we get except the burst pattern?

1st : Does T_{90} follows a double Gaussian

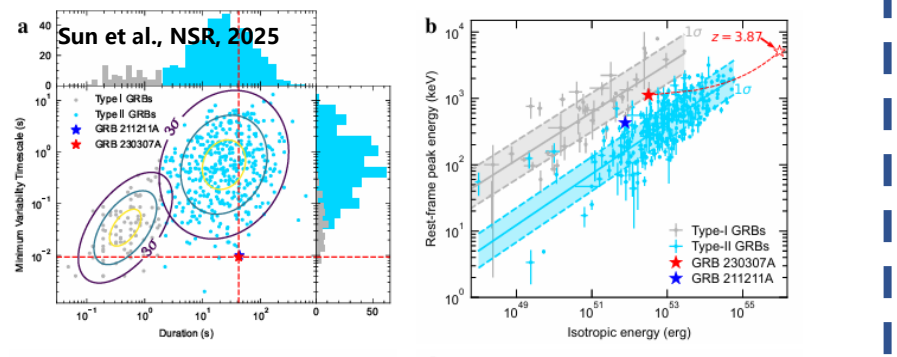


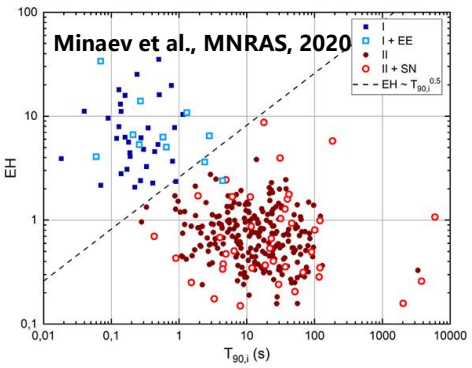


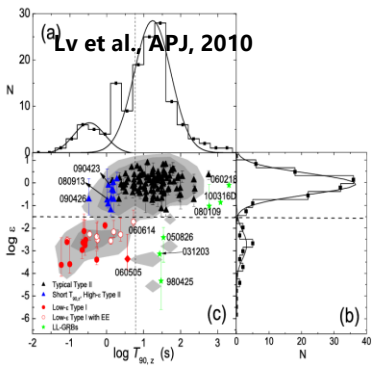
Lots of classification criteria are proposed to replace T_{90}

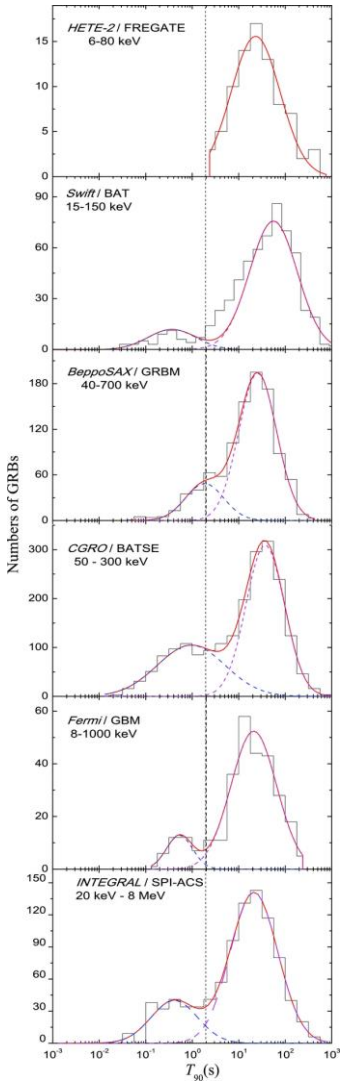
But……

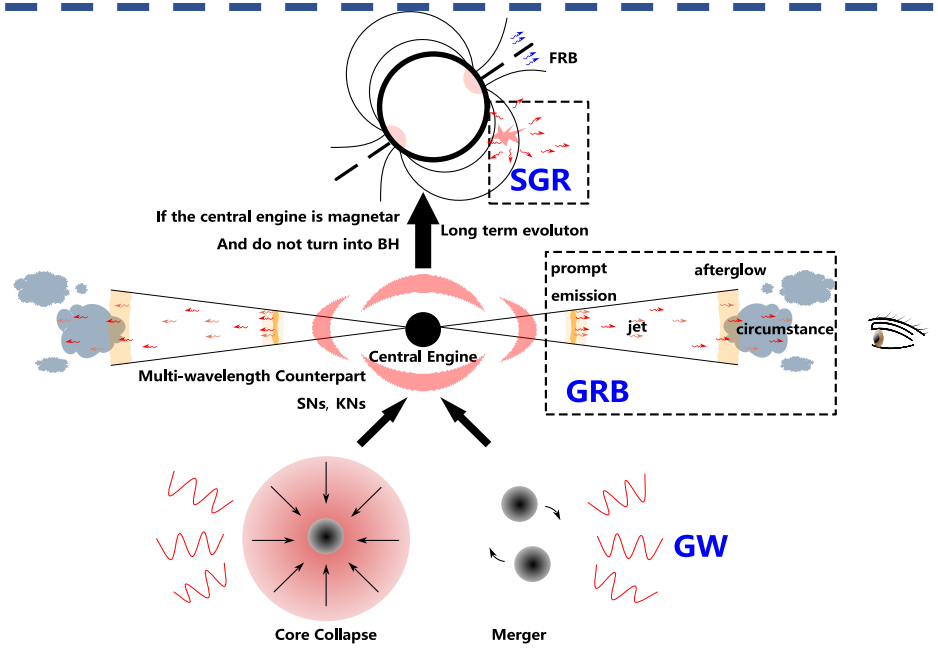
1st : Does T_{90} follows a double Gaussian

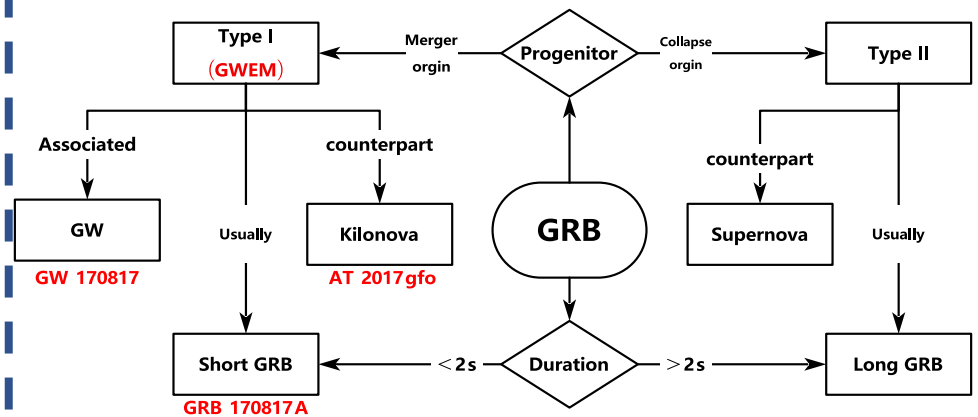






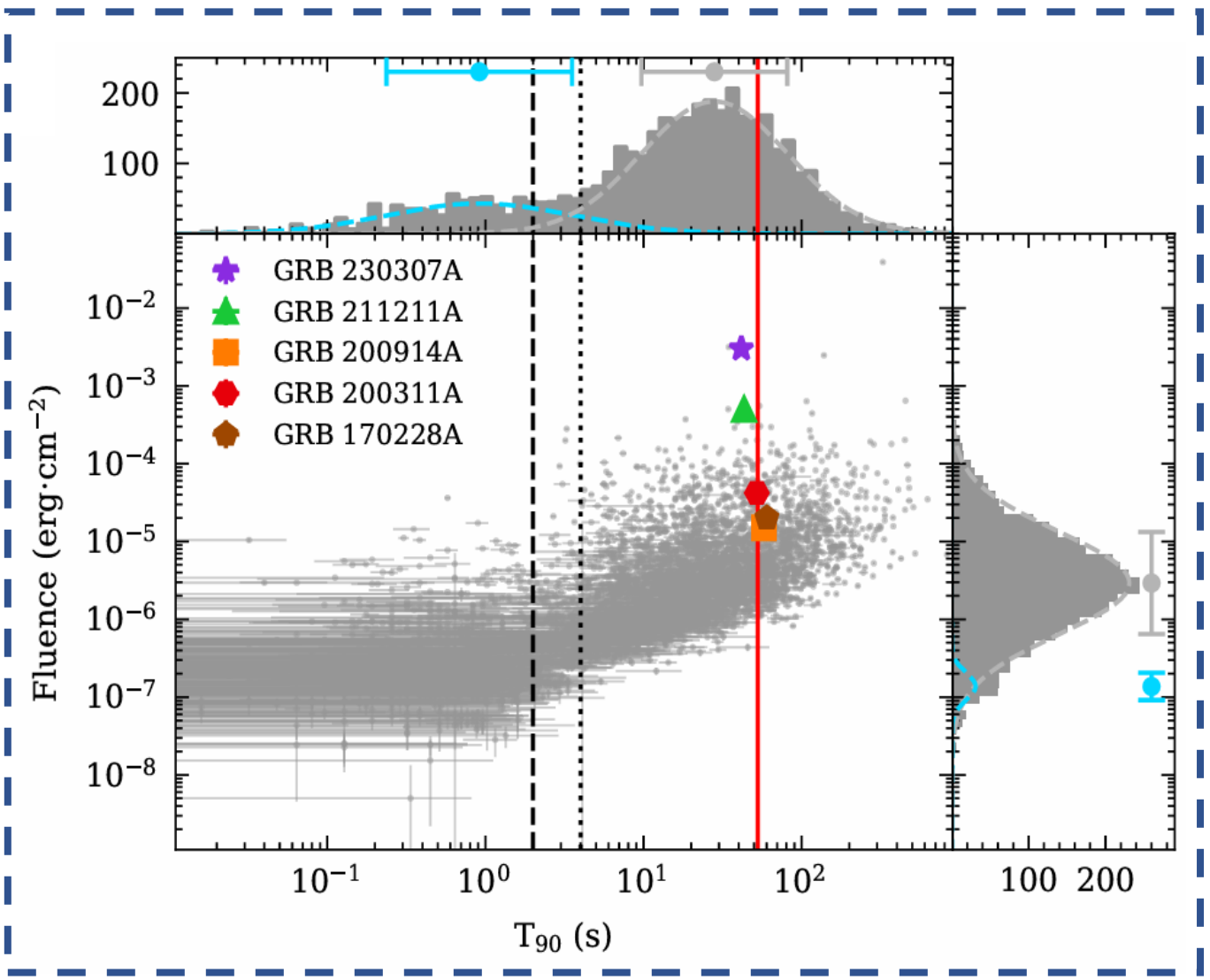


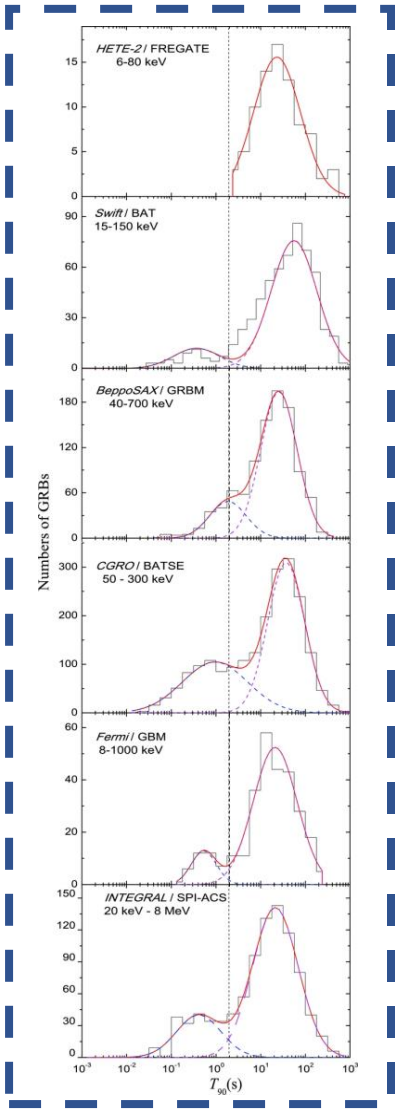




T_{90} is still the most effective & widely used criterion

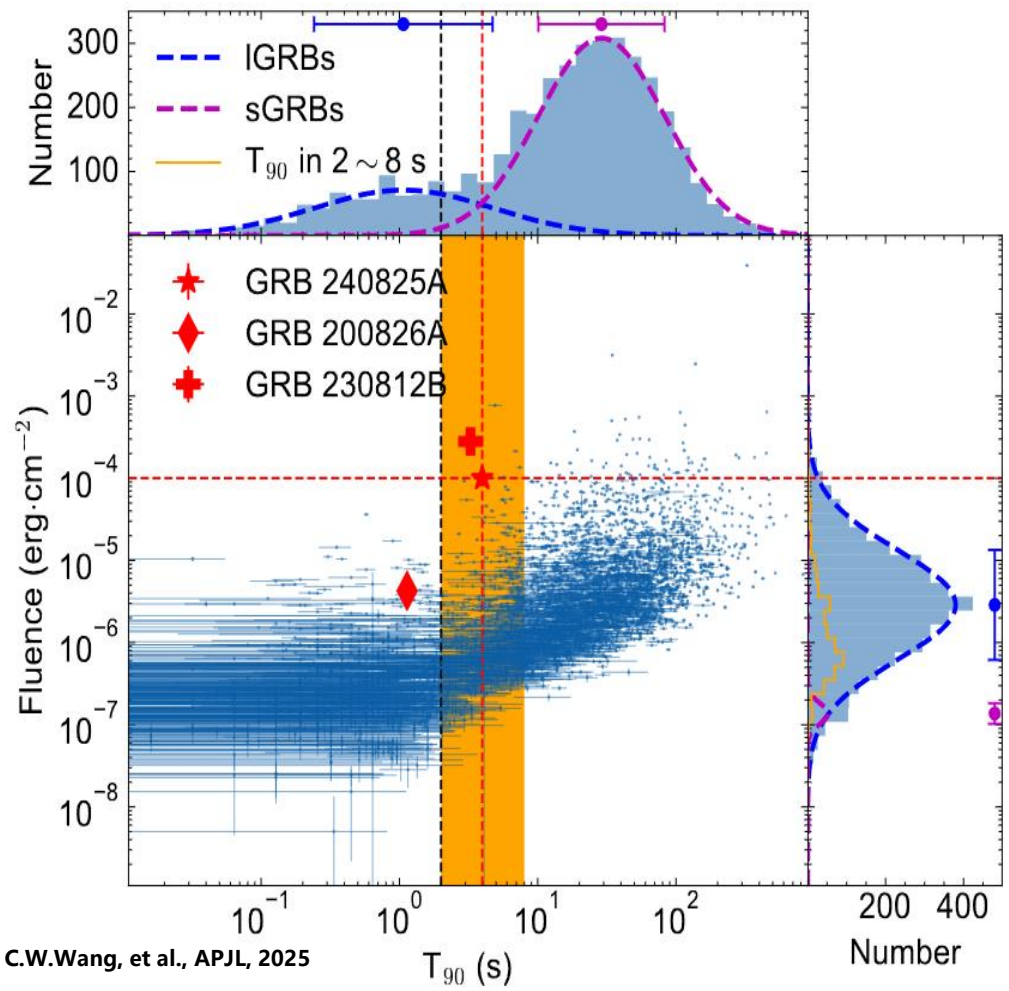
1st : Does T_{90} follows a double Gaussian



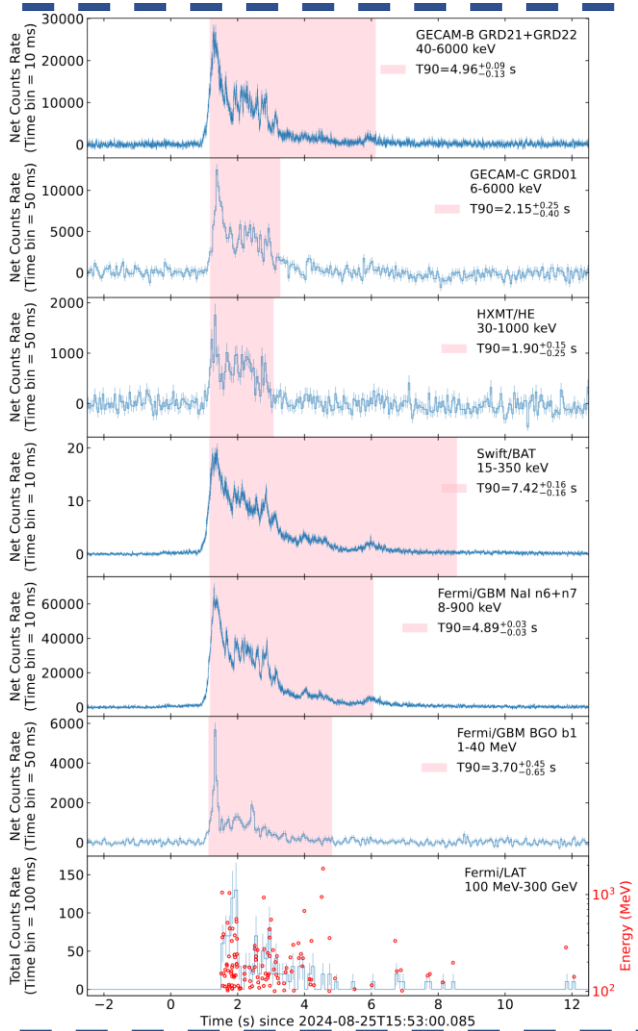


The number of type IL GRBs number is much higher than the prediction of Gaussian distrubation

1st : Does T_{90} follows a double Gaussian

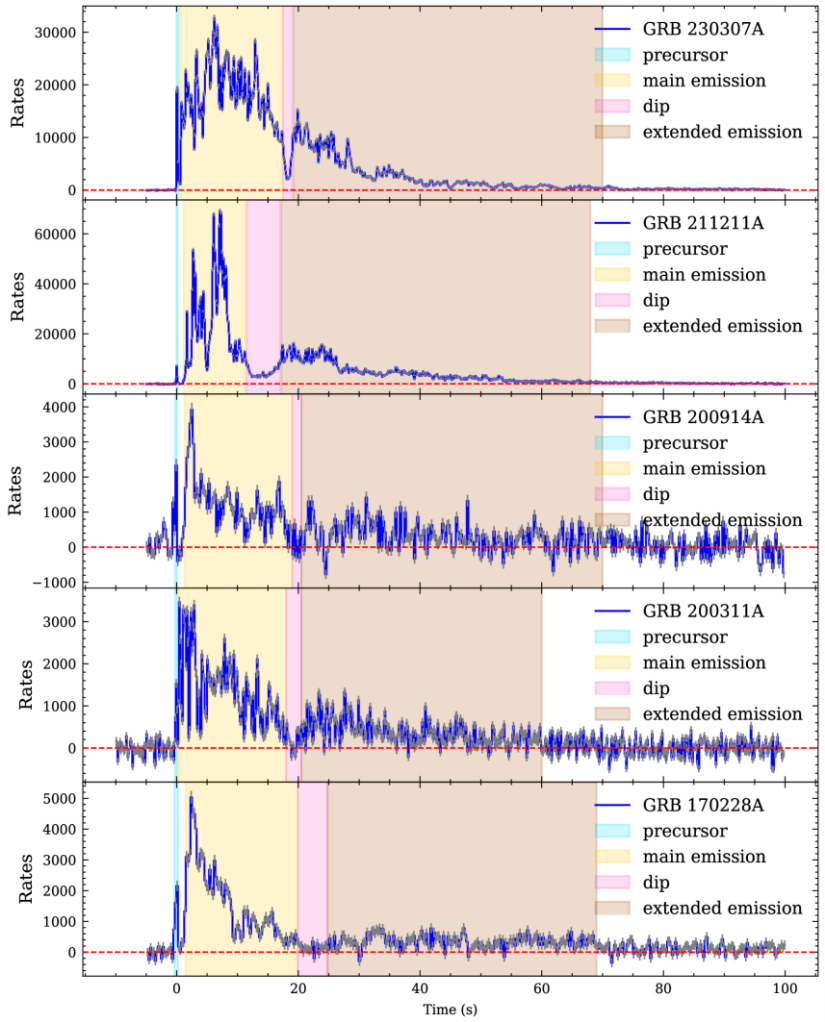


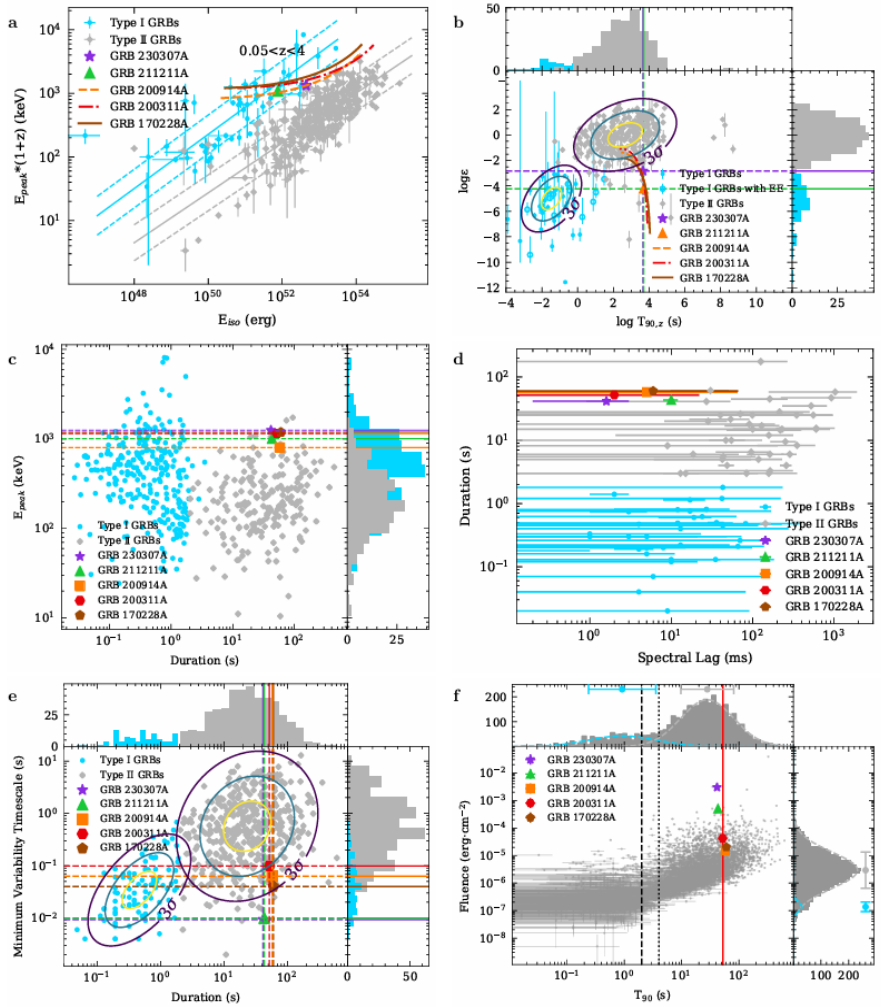
C.W.Wang, et al., APJL, 2025



Measurement of intermedium duration GRB will be an important topic

2nd hit: the association between pattern and physic





The clustering of parameters imply that similar GRBs have similar physical processes

Summary

- GRB 211211A and GRB 230307A would be a new subclass of type I GRB, named as type Ⅰ L GRBs
- A series of good candidates, e.g. GRB 170228A, are found by the burst pattern of type IL GRB
- This burst pattern will play an important role in identifying peculiar GRBs
- Precursor is one of the crucial clue of type Ⅰ L GRBs
- Summarize and generalize more burst patterns would be a meaningful topic

Thanks!

Your comments and suggestions are appreciated!