A Comptonized Fireball Bubble

Fits the Second Extragalactic Magnetar Giant Flare GRB 231115A

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Discovery

GCN Circular 35035

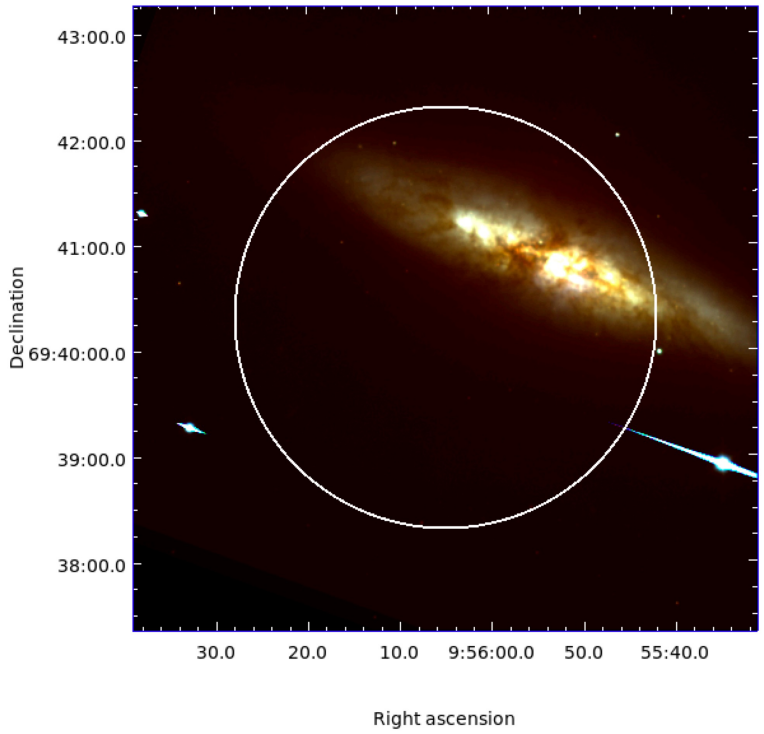
Subject
GRB 231115A: Fermi GBM Final Real-time Localization
Date
2023-11-15T15:46:53Z (8 months ago)
From
Fermi GBM Team at MSFC/Fermi-GBM
<do_not_reply@GIOC.nsstc.nasa.gov>
Via
email

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

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

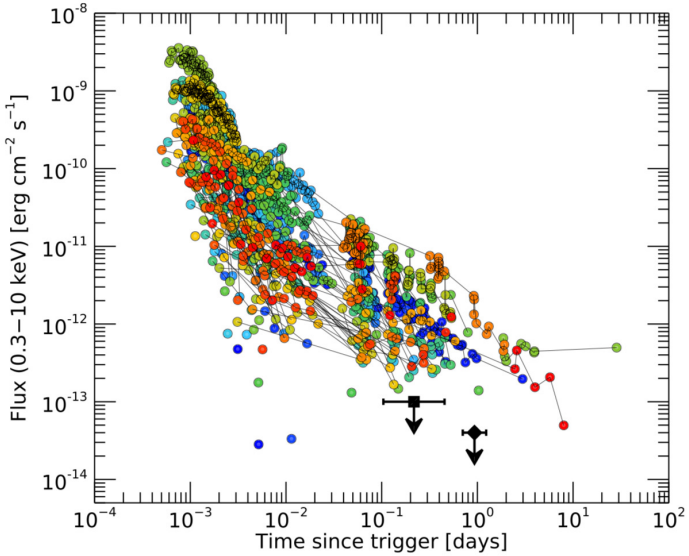
The on-ground calculated location, using the Fermi GBM trigger data, is RA = 131.0, Dec = 73.5 (J2000 degrees, equivalent to J2000 08h 43m, 73d 30'), with a statistical uncertainty of 8.7 degrees.

The angle from the Fermi LAT boresight is 38.0 degrees.



The position of GRB 231115A coincides with the nearby starburst galaxy M82.*

- length of the burst
- spectral properties
- limits on X-ray and optical counterparts*



- lack of a gravitational wave signal
- …

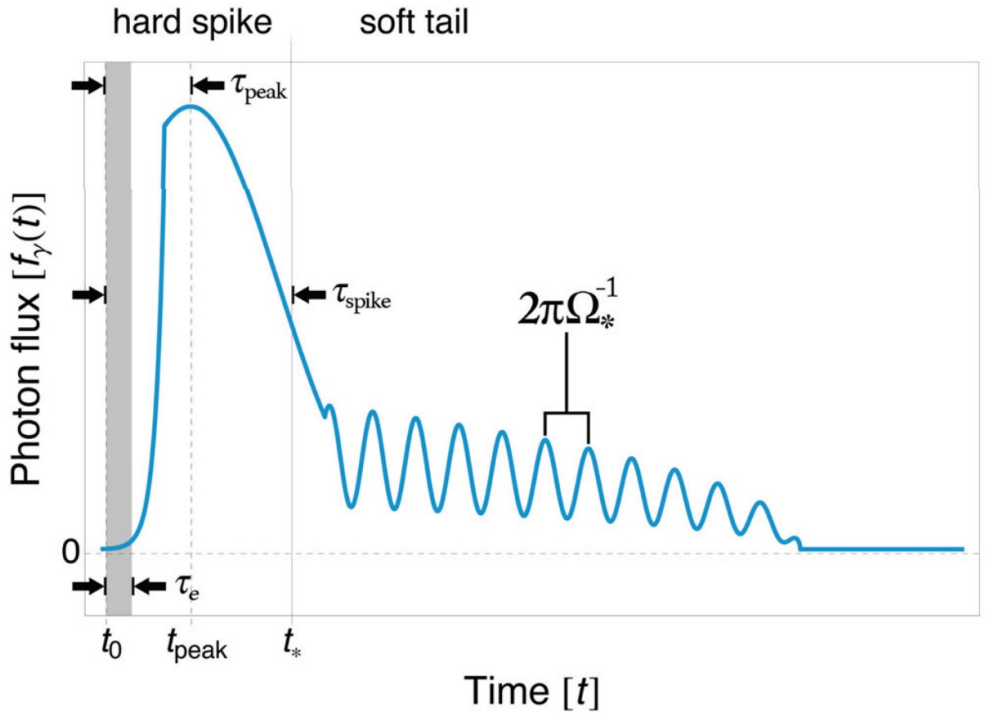
likely-short-GRB trigger → **position consistency** → **further evidences**

*reference: Mereghetti et al., 2024, Nature, doi:10.1038/s41586-024-07285-4

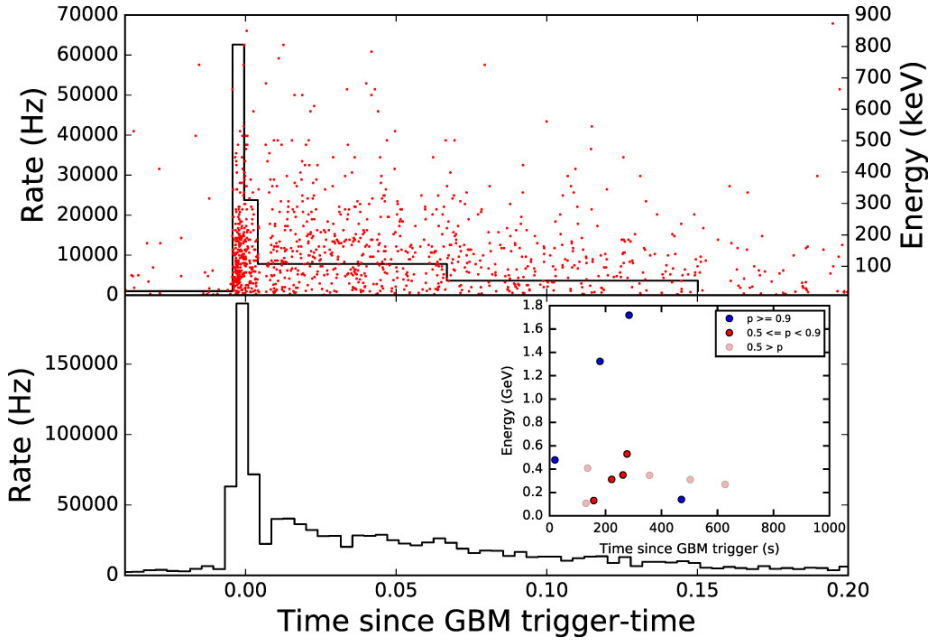
Content

- Magnetar giant flare (MGF)
- Similarities to MGF GRB 200415A
- The Comptonized fireball bubble model
- Spectral fits and implications
- Conclusion

Magnetar Giant Flare (MGF)



Schematic representation of MGF light curve*



Light curves of GRB 200415A**

Three Galactic MGF saturated

Extragalactic MGF tail invisible

The first confirmed extragalactic MGF
GRB 200415A

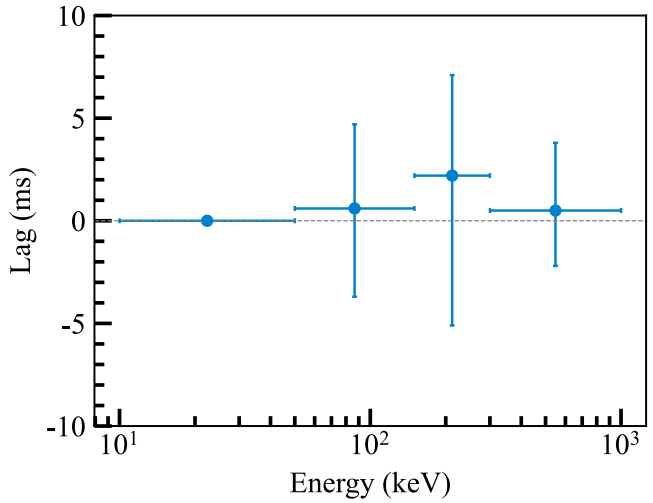
*reference: Elenbaas et al., 2016, MNRAS, doi: 10.1093/mnras/stv2860

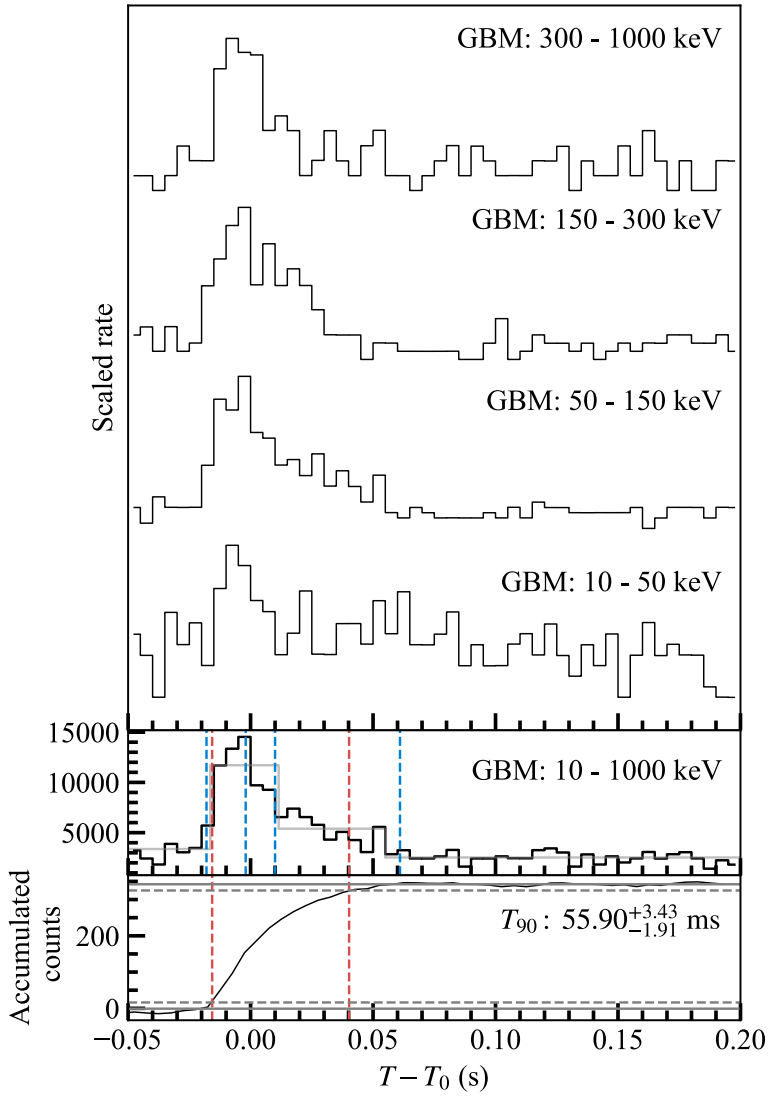
**reference: Yang et al., 2021, ApJ, doi: 10.3847/1538-4357/aba745

MGF GRB 231115A

Observed properties of MGF GRB 231115A*

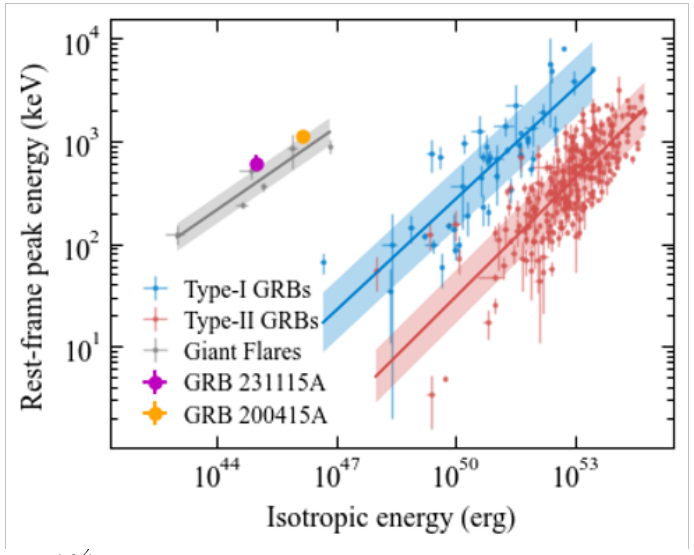
Observed Properties	GRB 231115A
T_{90} (ms)	$55.90^{+3.43}_{-1.91}$
Total spanning time (ms)	$\sim$ 79
Minimum variability timescale (ms)	$\sim$ 13.95
Effective amplitude	4.24 ± 1.29
Spectral index α (CPL)	$0.16^{+0.21}_{-0.19}$
Peak energy (keV) (CPL)	$605.54^{+84.72}_{-67.84}$
Peak energy (keV)	$606.15^{+113.94}_{-30.47}$
Peak flux (erg cm^{-2} s^{-1})	$1.85^{+0.31}_{-0.13} \times 10^{-5}$
Total fluence (erg cm^{-2})	$6.20^{+0.54}_{-0.40} \times 10^{-7}$
Peak luminosity (erg s^{-1})	$2.71^{+0.46}_{-0.18} \times 10^{46}$
Isotropic energy (erg)	$9.08^{+0.80}_{-0.58} \times 10^{44}$
Possible host galaxy	Cigar galaxy (NGC 3034)
Distance (Mpc)	3.5
Event rate density (Gpc^{-3} yr^{-1})	...

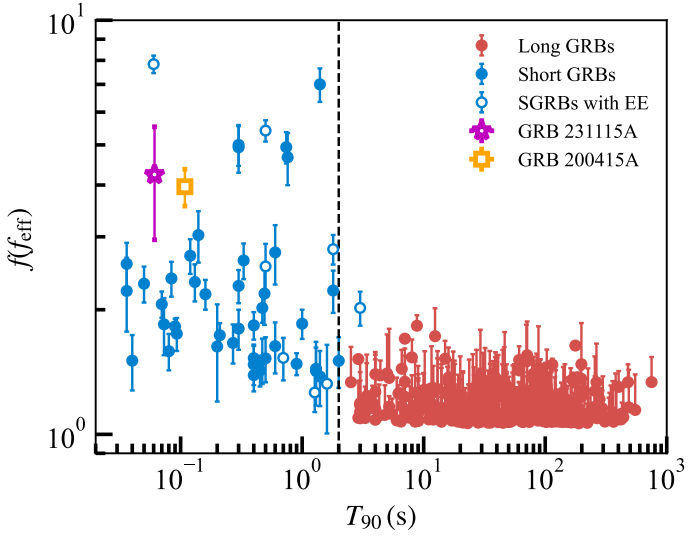


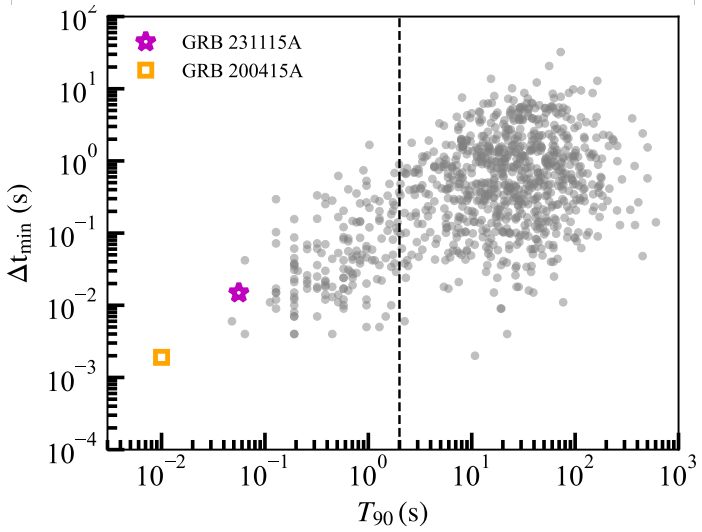


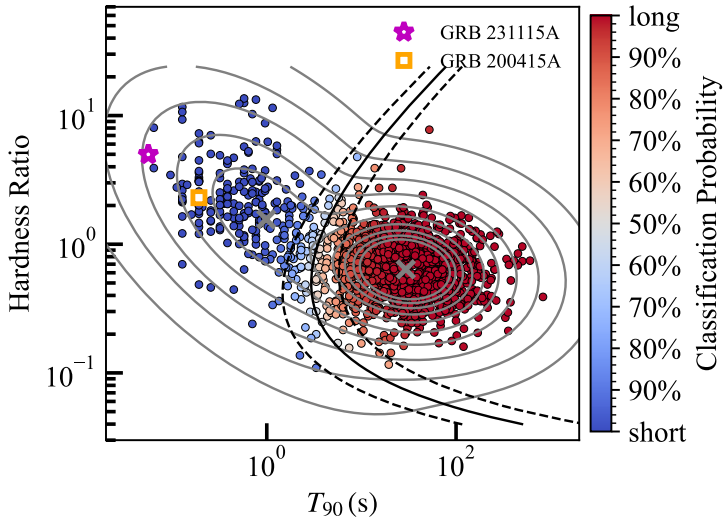
*reference: Yin et al., 2024, ApJL, doi: 10.3847/2041-8213/ad2839

MGF GRB 231115A



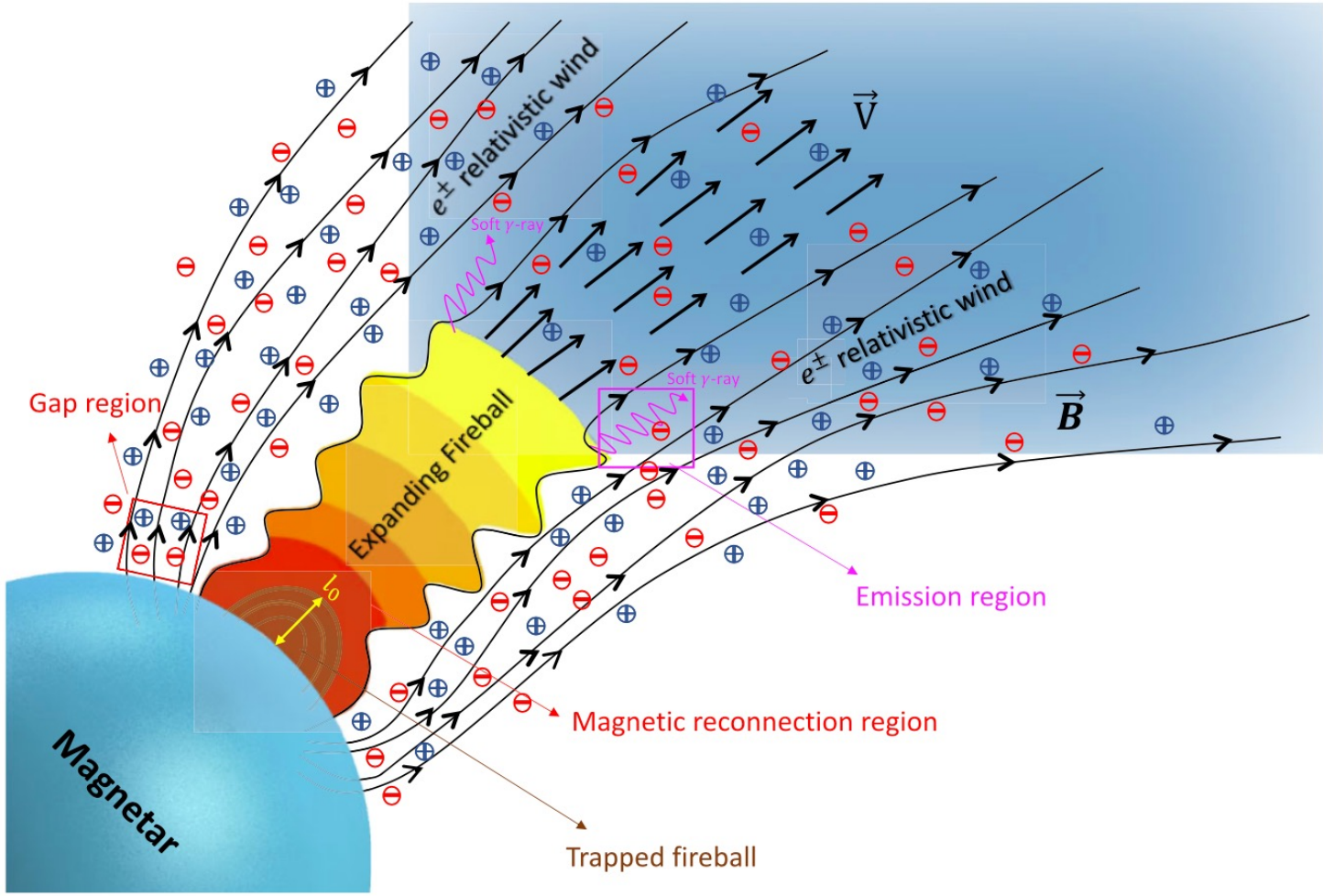






Property diagrams of GRBs

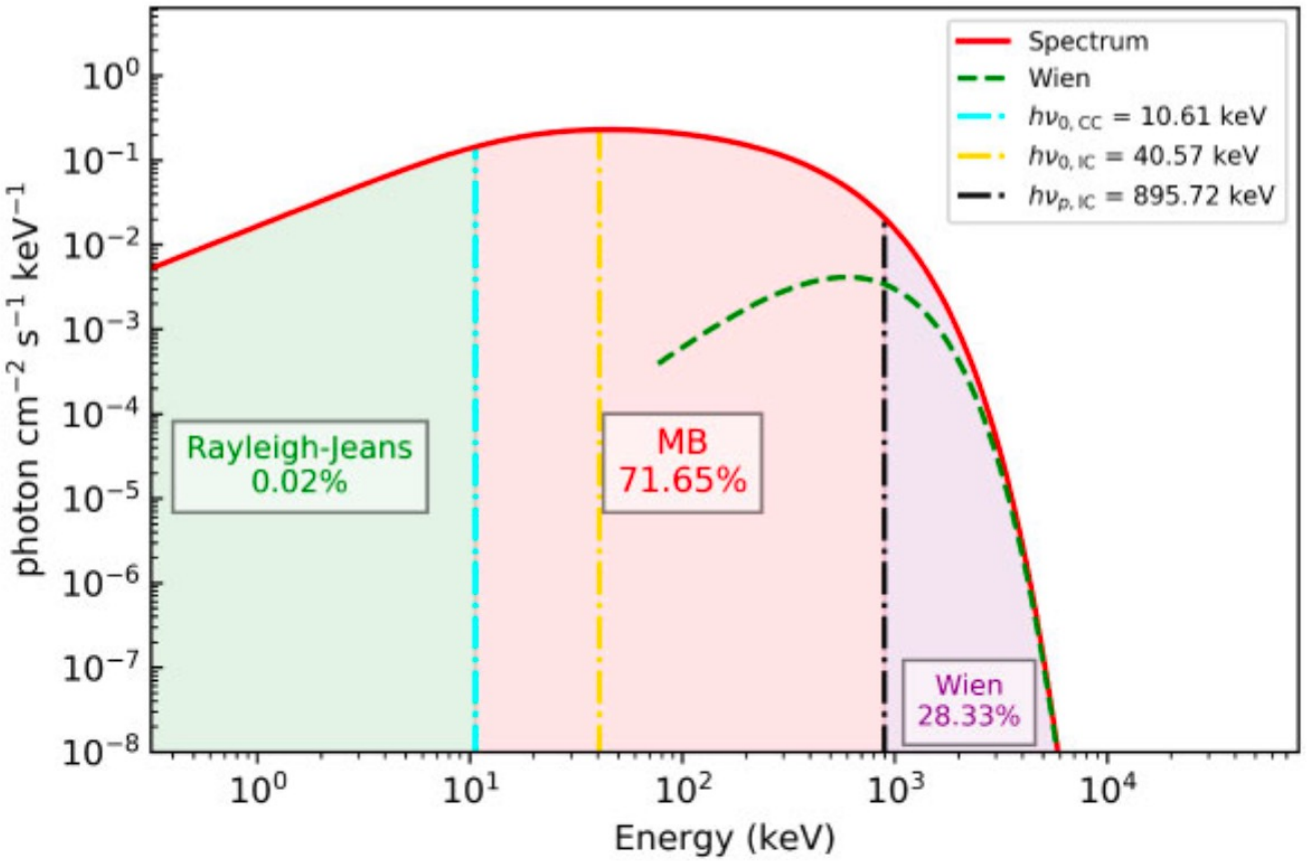
The Comptonized Fireball Model



A schematic diagram of the Comptonized fireball bubble model*

*reference: Zhang et al., 2023, MNRAS, doi: 10.1093/mnras/stad443

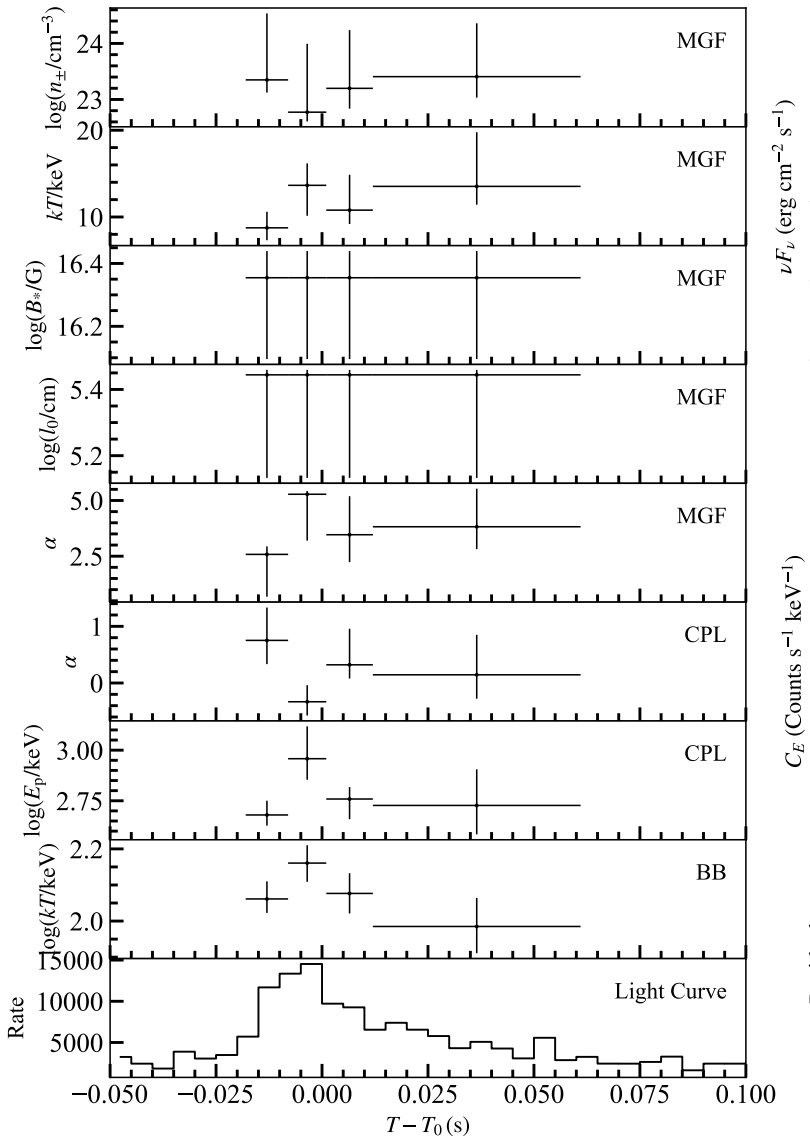
The Comptonized Fireball Model

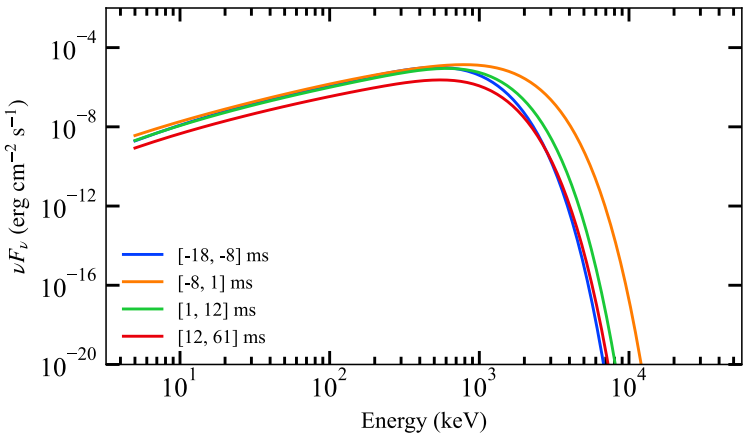


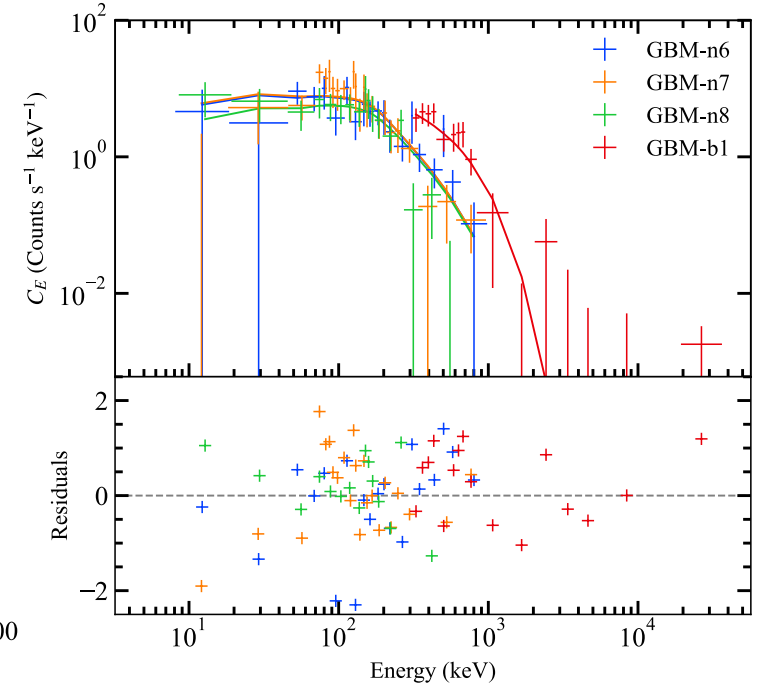
Schematic diagram for energy fractions of different components*

*reference: Zhang et al., 2023, MNRAS, doi: 10.1093/mnras/stad443

Spectral fits







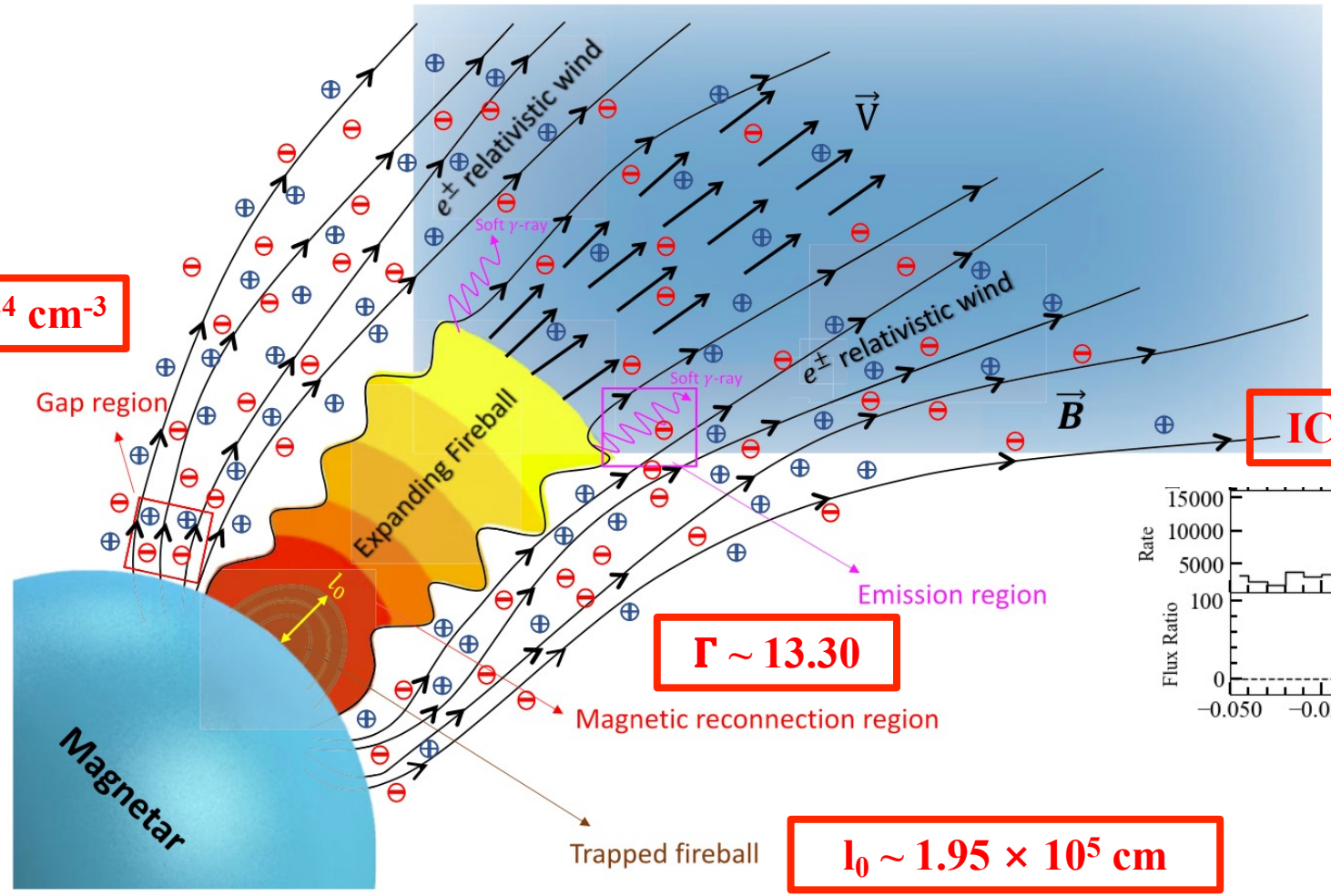
Spectral fits

Spectral fitting results and corresponding statistics

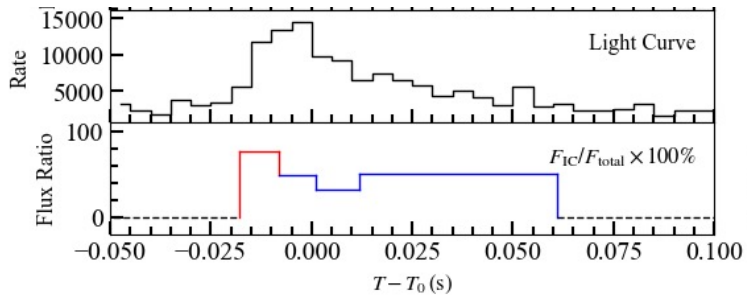
Time Intervals	CPL Parameters				BB Parameters		
(t_1,t_2) (s)	α	$E_{\rm p}$ (keV)	PGSTAT/d.o.f	BIC	kT (keV)	PGSTAT/d.o.f	BIC
(-0.018, 0.061)	$0.16^{+0.21}_{-0.19}$	$605.54^{+84.72}_{-67.84}$	468.89/463	487.32	$119.66^{+8.32}_{-8.12}$	487.51/464	499.79
(-0.018, -0.008)	$0.75^{+0.58}_{-0.42}$	$478.50^{+84.43}_{-54.65}$	321.99/463	340.42	$115.16^{+13.69}_{-9.85}$	322.62/464	334.91
(-0.008, 0.001)	$-0.33^{+0.29}_{-0.24}$	$907.55^{+404.02}_{-193.04}$	336.11/463	354.54	$144.77^{+17.53}_{-16.32}$	349.98/464	362.27
(0.001, 0.012)	$0.32^{+0.64}_{-0.24}$	$573.73^{+83.60}_{-117.56}$	313.13/463	331.56	$119.28^{+16.46}_{-14.31}$	316.62/464	328.91
(0.012, 0.061)	$0.14^{+0.71}_{-0.42}$	$533.27^{+271.80}_{-149.56}$	387.60/463	406.03	$96.61^{+19.32}_{-15.14}$	391.03/464	403.32
Time Intervals	MGF Parameters						
(t_1,t_2) (s)	$\log(n_\pm)$	kT	$\log(B_*)$	$\log(l_0)$	α	PGSTAT/d.o.f	BIC
(-0.018, 0.061)	$23.24^{+0.08}_{-0.27}$	$12.22^{+3.21}_{-0.67}$	16.35 (fixed)	5.44 (fixed)	$3.67^{+1.65}_{-0.41}$	467.56/463	485.99
(-0.018, -0.008)	$23.35^{+1.19}_{-0.23}$	$8.75^{+1.85}_{-1.43}$	$16.35^{+0.08}_{-0.26}$	$5.44^{+0.01}_{-0.31}$	$2.58^{+0.36}_{-1.90}$	321.94/461	335.28
(-0.008, 0.001)	$22.77^{+1.22}_{-0.17}$	$13.65^{+2.53}_{-3.50}$			$5.28^{+0.14}_{-2.08}$	336.69/461	350.03
(0.001, 0.012)	$23.20^{+1.04}_{-0.36}$	$10.79^{+4.08}_{-1.60}$			$3.46^{+1.73}_{-1.23}$	313.96/461	327.30
(0.012, 0.061)	$23.41^{+0.95}_{-0.37}$	$13.53^{+6.24}_{-2.11}$			$3.82^{+1.71}_{-1.00}$	388.17/461	401.52

Implications

density ~ 1.07×10^{24} cm^{-3}



IC- ➡ CC-dominated



$\Gamma \sim 13.30$

$l_0 \sim 1.95 \times 10^5$ cm

B* ~ 2.51×10^{16} G

Conclusions

- We found that the second observed extragalactic MGF, GRB 231115A, is similar to GRB 200415A with respect to the temporal and spectral properties.

- We further employed the Comptonized fireball model to successfully infer the radiation origin of the burst, establishing a clear and self-consistent scenario to explain these peculiar bursts.

- The fits indicate relatively higher local magnetic fields (2.5×10^{16} G), increasing the likelihood of detecting gravitational waves generated by magnetar oscillations, making MGF GRBs promising candidates for kilohertz GW sources, especially if they can occur within our Galaxy.

Thank you.