香 港 大 學
THE UNIVERSITY OF HONG KONG

香港天文與天體物理研究所
THE HONG KONG INSTITUTE FOR ASTRONOMY AND ASTROPHYSICS

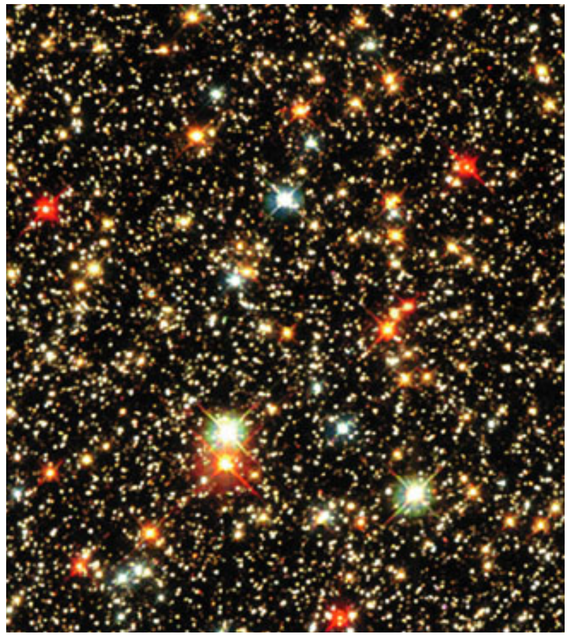
Gamma-Ray Bursts and Fast X-ray Transients

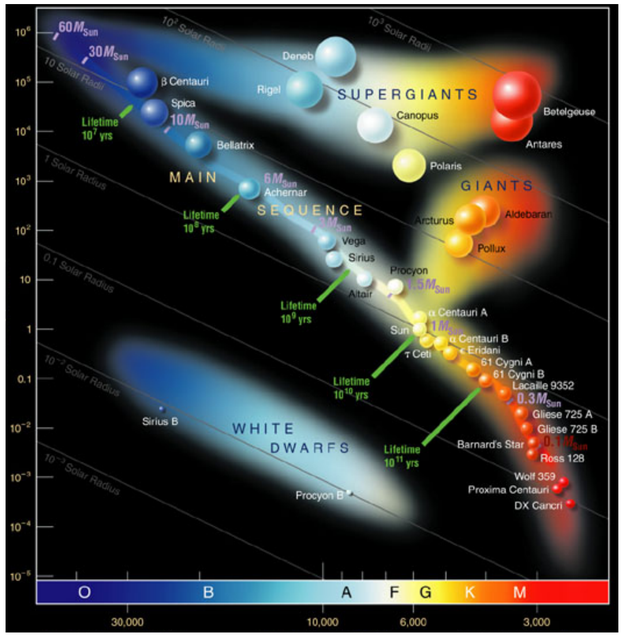
The LHAASO connection

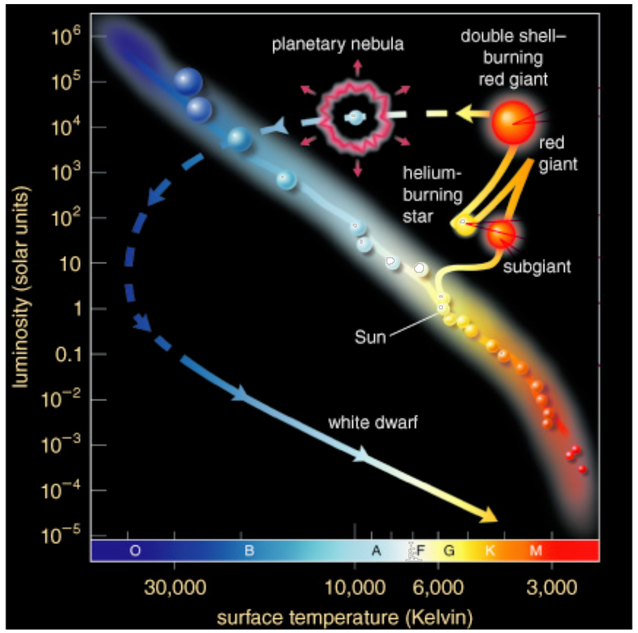
Bing Zhang

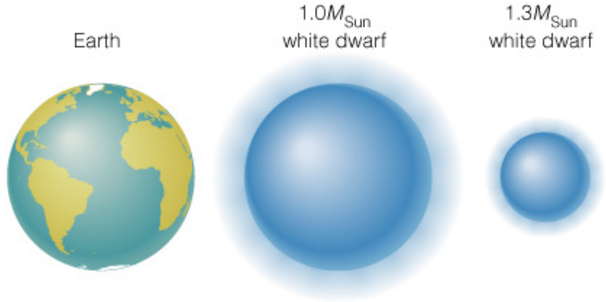
Oct. 26, 2026, Chengdu

An Evolving Universe

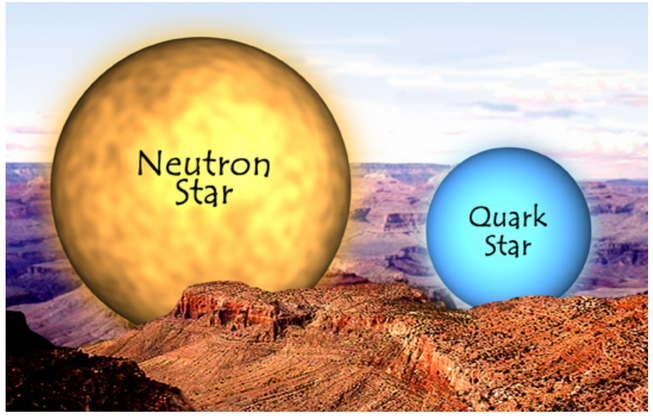








white dwarfs



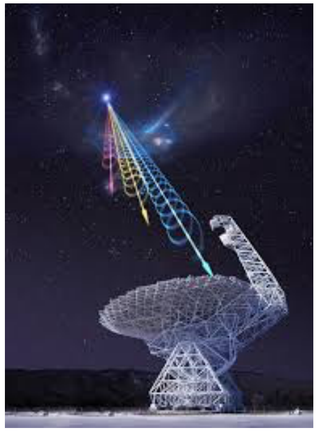
neutron stars



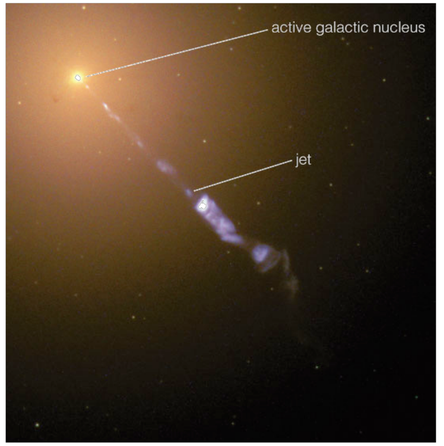
black holes

A Violent Universe
— Transient Astrophysics

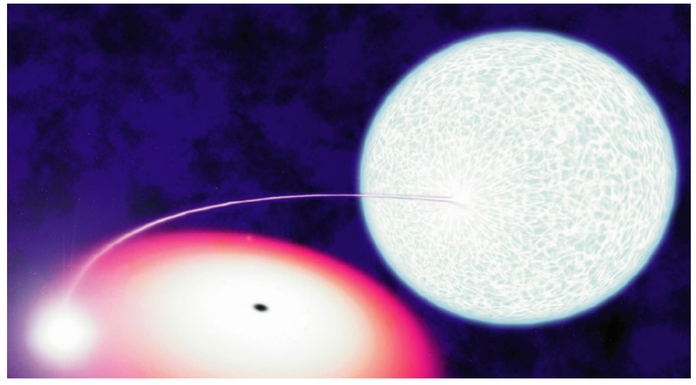


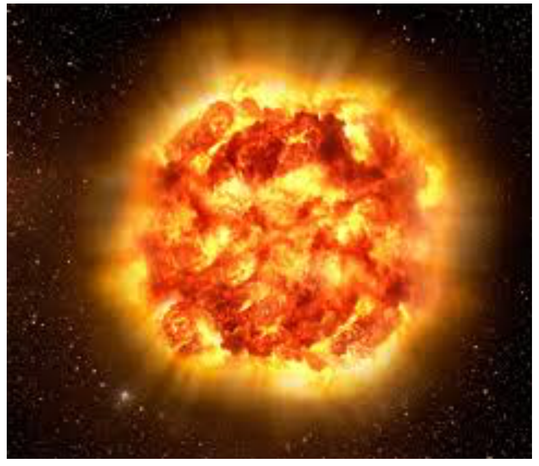




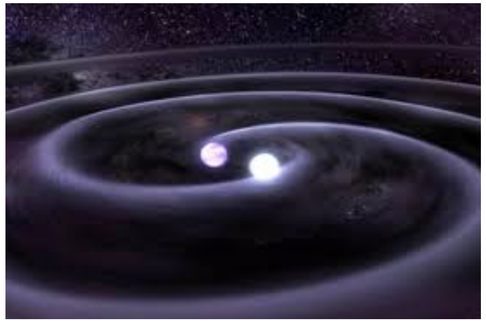


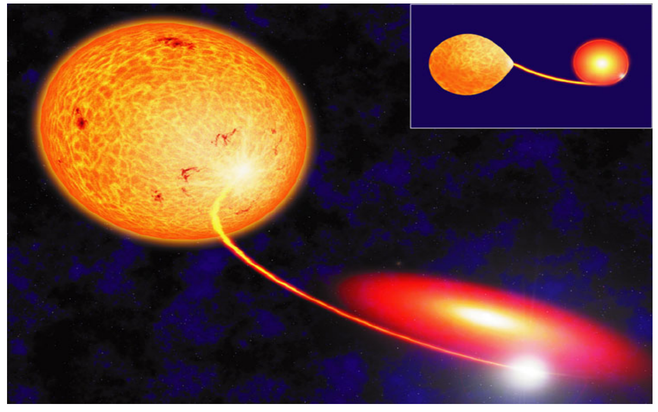




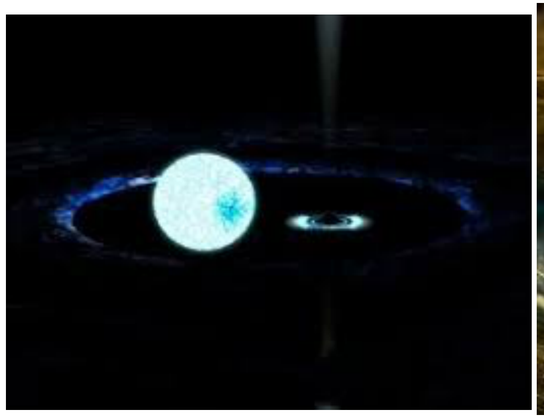














High-energy, transients (time domain) astrophysical objects:

I



Compact objects

Stellar BHs, NSs, WDs

II



Stars

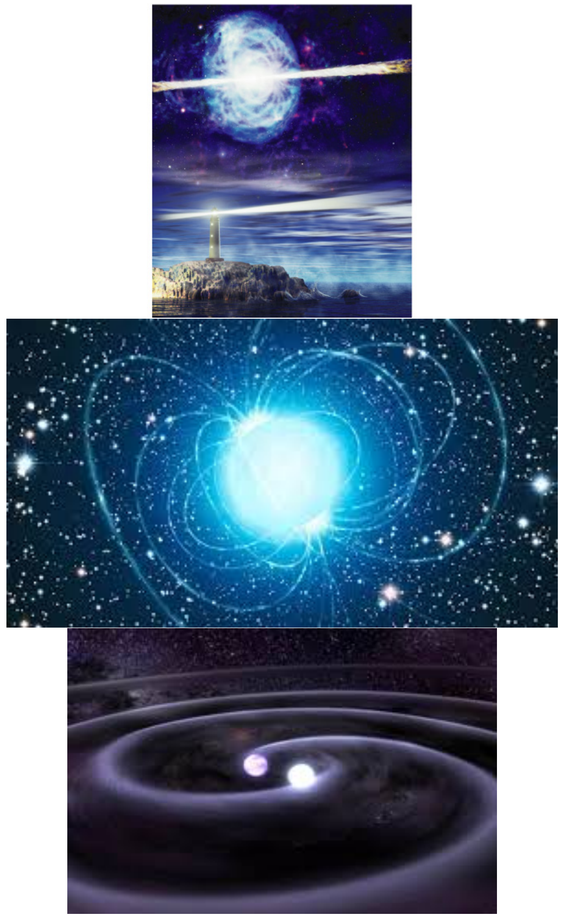
Massive stars, binaries

III

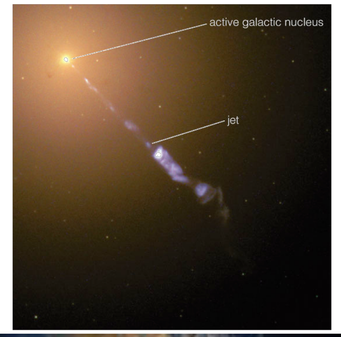


Supermassive BHs

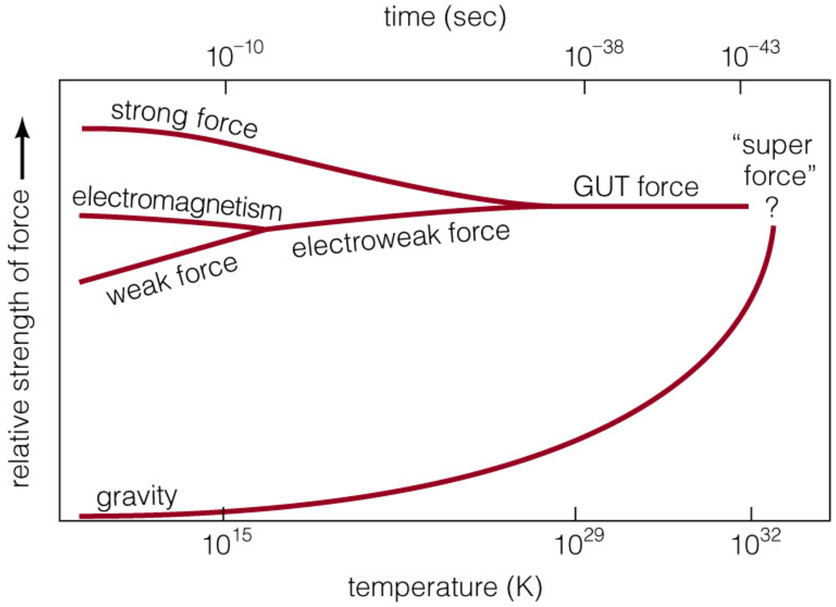
Non-catastropic (repeating):

	I	II	III
			
Radio:	Radio pulsars, repeating FRBs …	Radio flares	Radio jets, knots, lobes
Optical:	novae …	Optical flares	AGN variability
X-rays:	X-ray binaries, bursts …	X-ray flares	AGN X-ray outbursts
Gamma-rays:	Soft gamma-ray repeaters …	Gamma-ray flares (binaries)	Blazar gamma-ray variability

Catastrophic:

	I	II	III
			
			
			
Radio:	**Some non-repeating FRBs?**	**Radio afterglow, radio SNe**	**Radio TDEs …**
Optical:	**Type Ia SNe, kilonovae …**	**Type II, Ib, Ic SNe, FBOTs, SLSNe, SBOs …**	**Optical TDEs …**
X-rays:	**Type I fast X-ray transients (FXTs)**	**Type II FXTs (jets, shock breakouts)**	**X-ray TDEs, QPEs, Type III FXTs…**
Gamma-rays:	**Short or Type I GRBs (NS mergers)**	**Long or Type II GRBs**	**Gamma-ray (jetted) TDEs …**

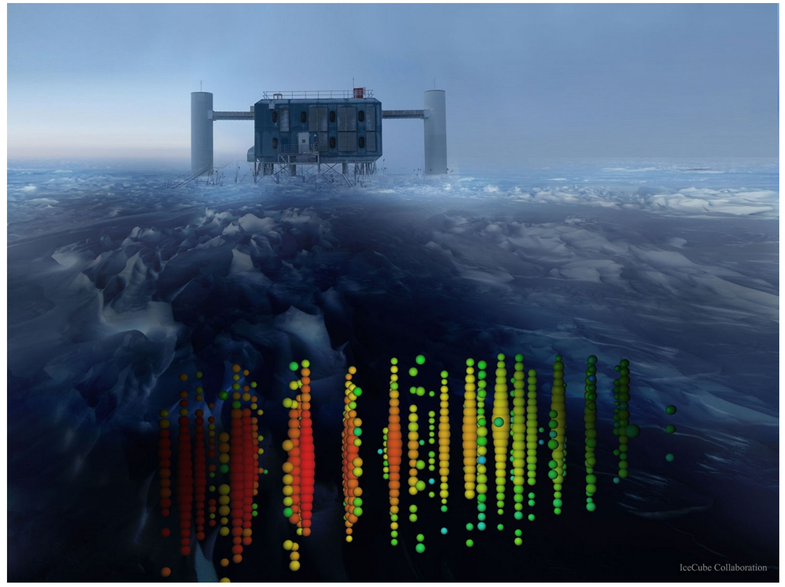
Four Fundamental Interactions





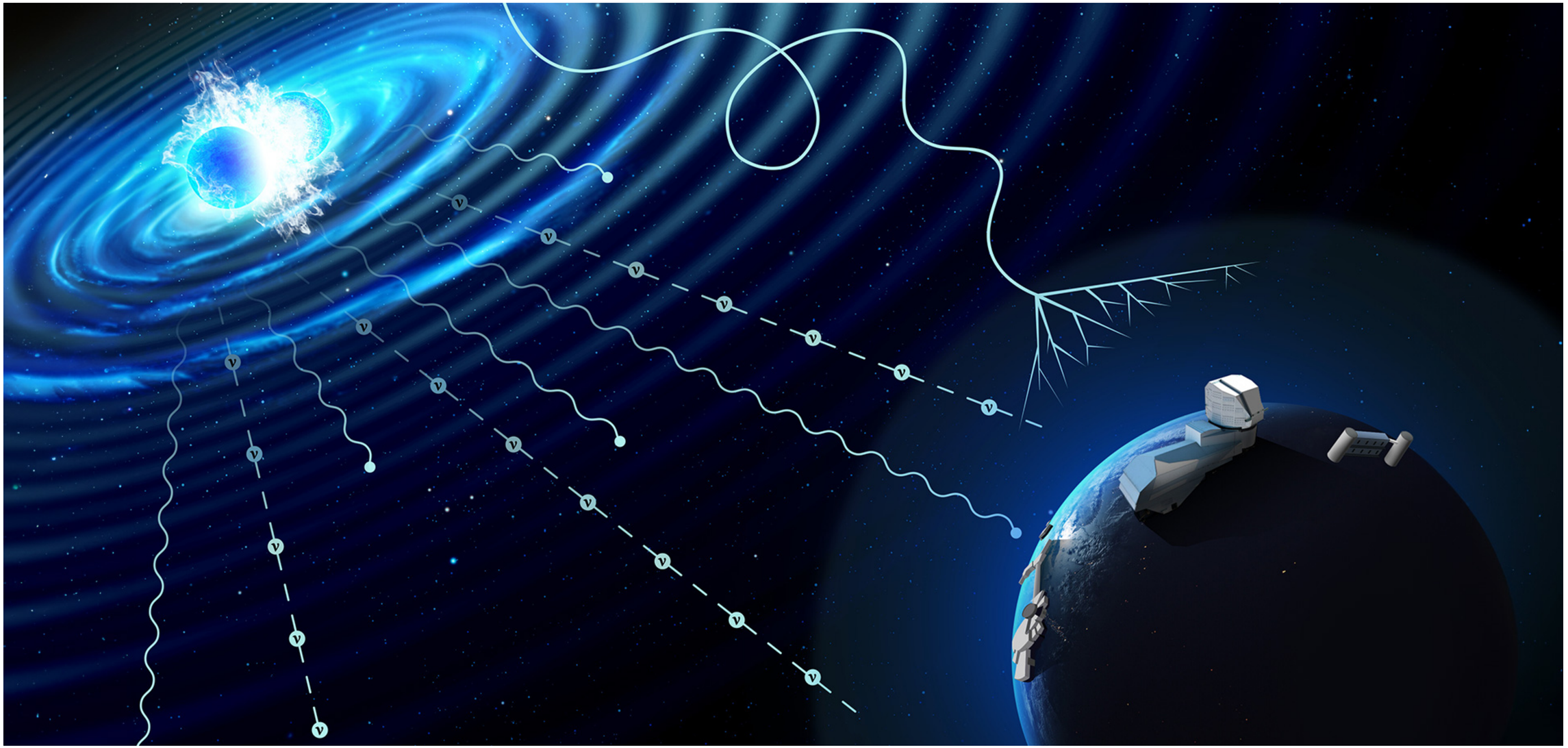
Multi-Messenger

- Electromagnetic: photons (seeing)
- Weak interaction: neutrinos (smelling)
- Strong interaction: cosmic rays (touching)
- Gravity: gravitational waves (hearing)

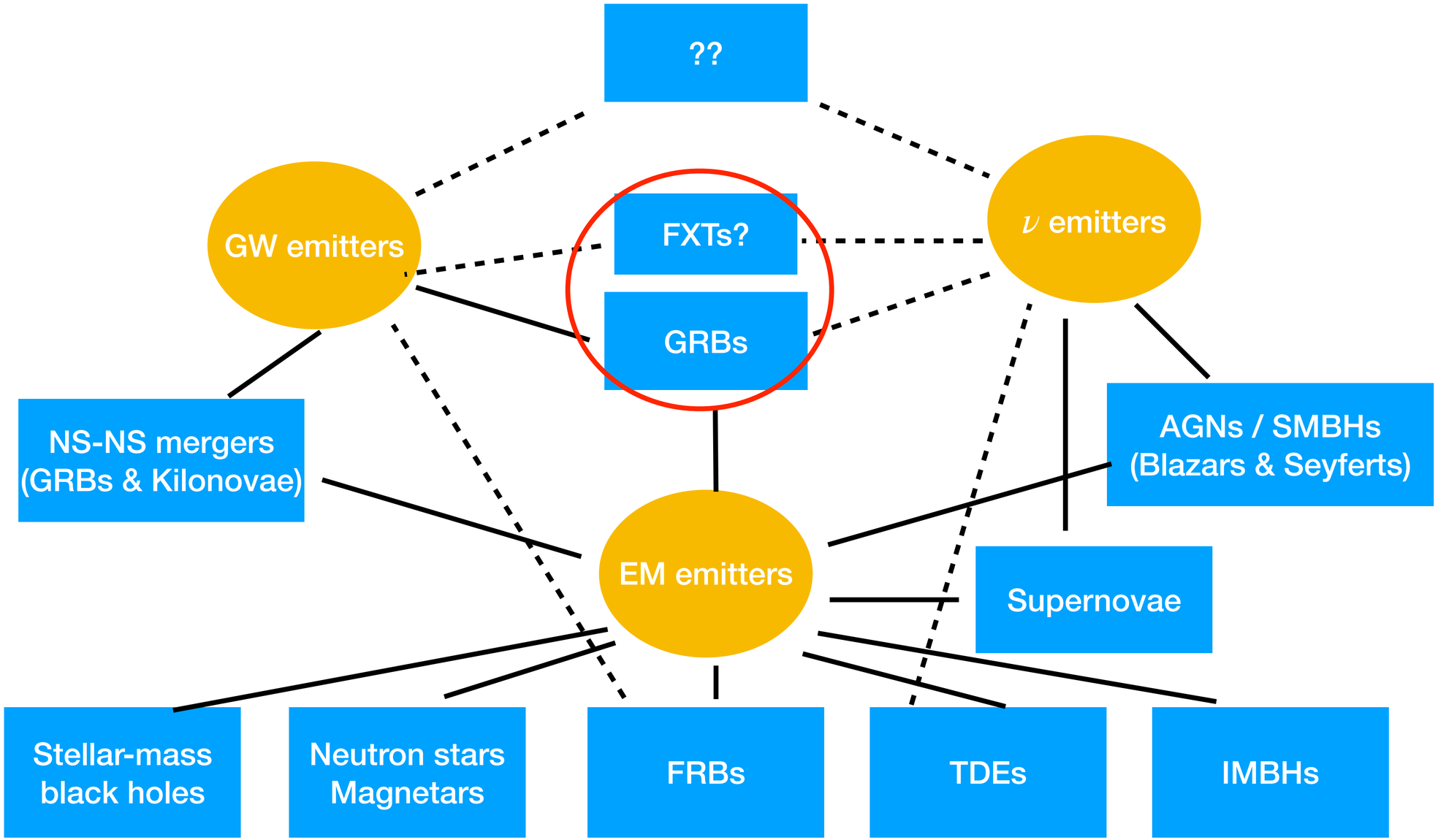




Multi-messenger emitters

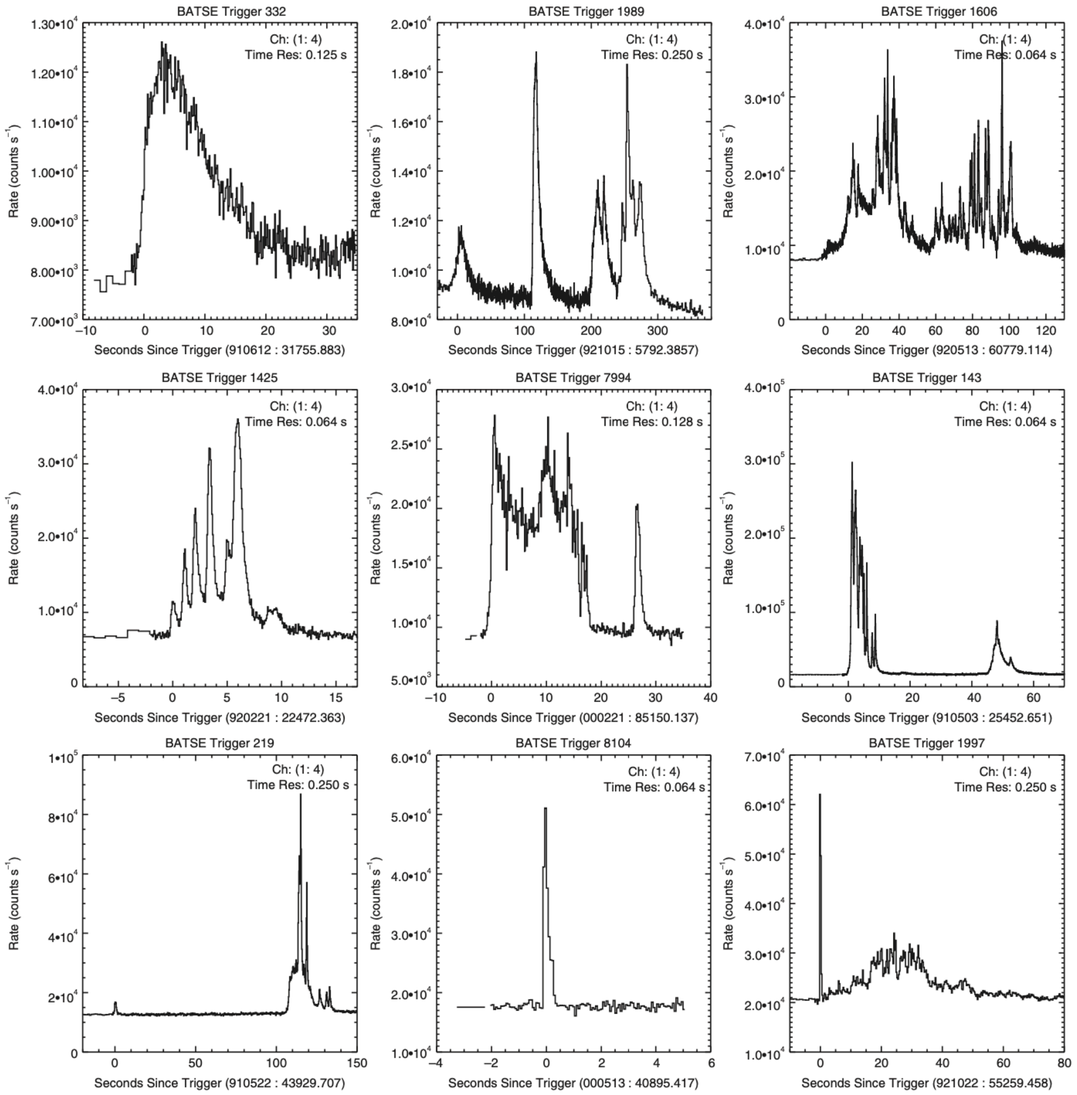


Multi-messenger emitters

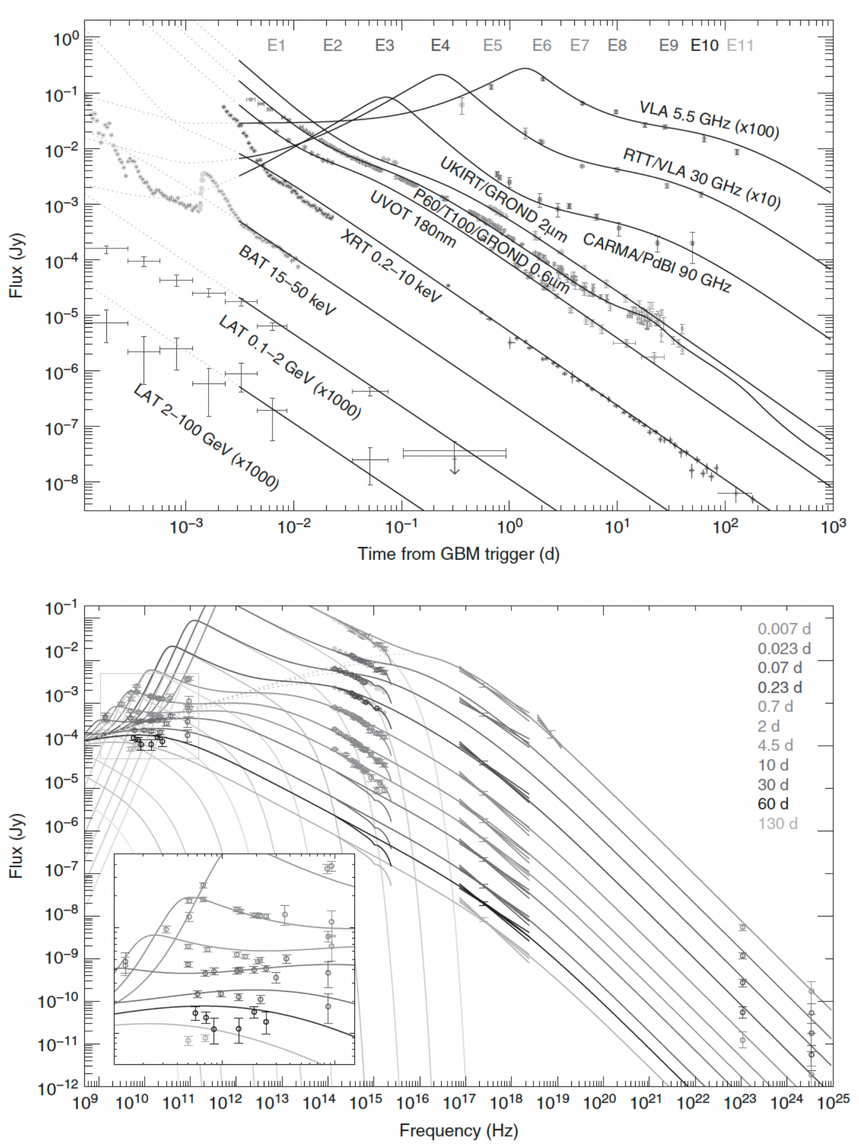


Gamma-ray Bursts

Prompt emission vs. afterglow

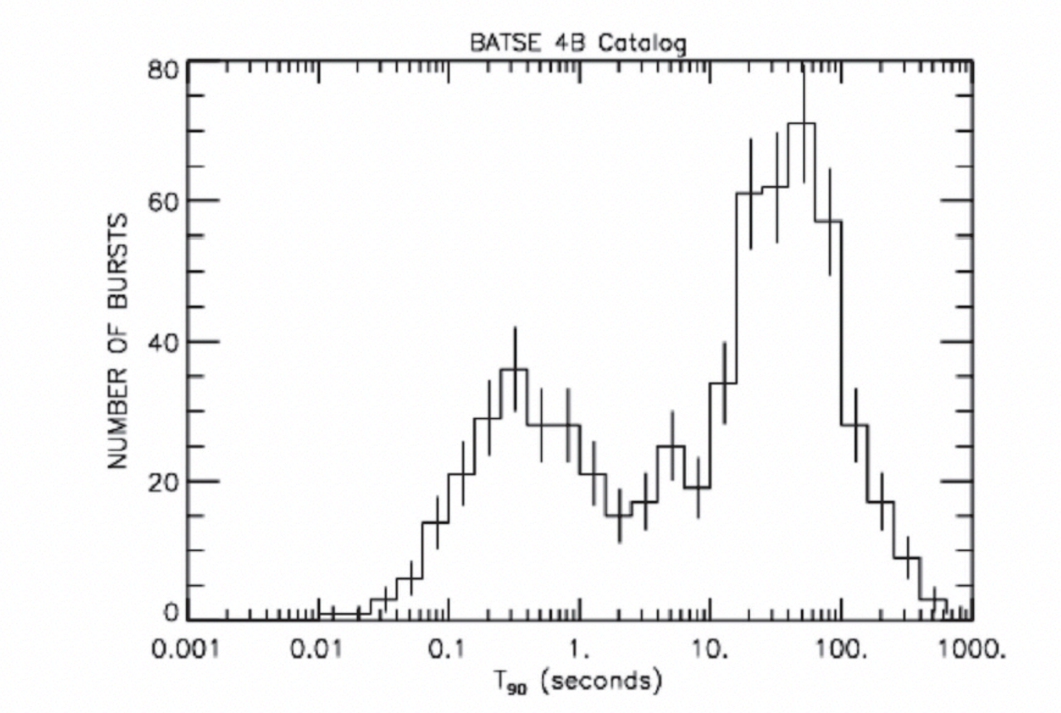


BATSE catalog



Perley et al. 2014

Long vs. short; Type II vs. Type I

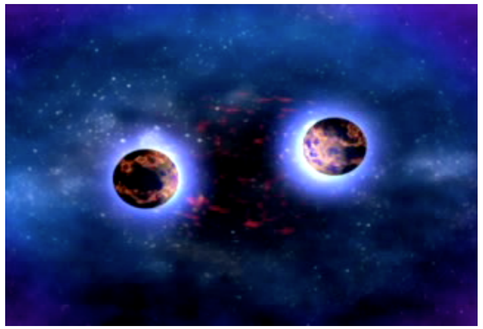


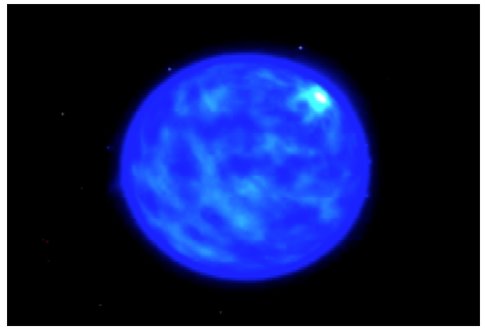
	Type Ia	Type II (Type Ib/c)
Stellar population	Old	Young
Host galaxy	All types of galaxy	Late-type galaxies
Progenitor	Binary systems (accretion-induced collapse of white dwarfs)	Single-star systems (core collapse of massive stars)

Figure 1 | The classification of supernovae[18].

	Type I (short-hard)	Type II (long-soft)
Duration	Usually short (may have a long tail?)	Usually long
Spectrum	Usually hard (tail is soft)	Usually soft
Spectral lag	Short	Long
Associated supernova	No	Yes
Stellar population	Old	Young
Host galaxy	All types of galaxies (predominantly in regions of low star formation rate)	Late-type galaxies (predominantly in irregular, dwarf galaxies)
Location in the host galaxy	Outskirts	Central
Progenitor	Mergers of compact objects in binary systems?	Single-star systems? (Core collapse of massive stars)

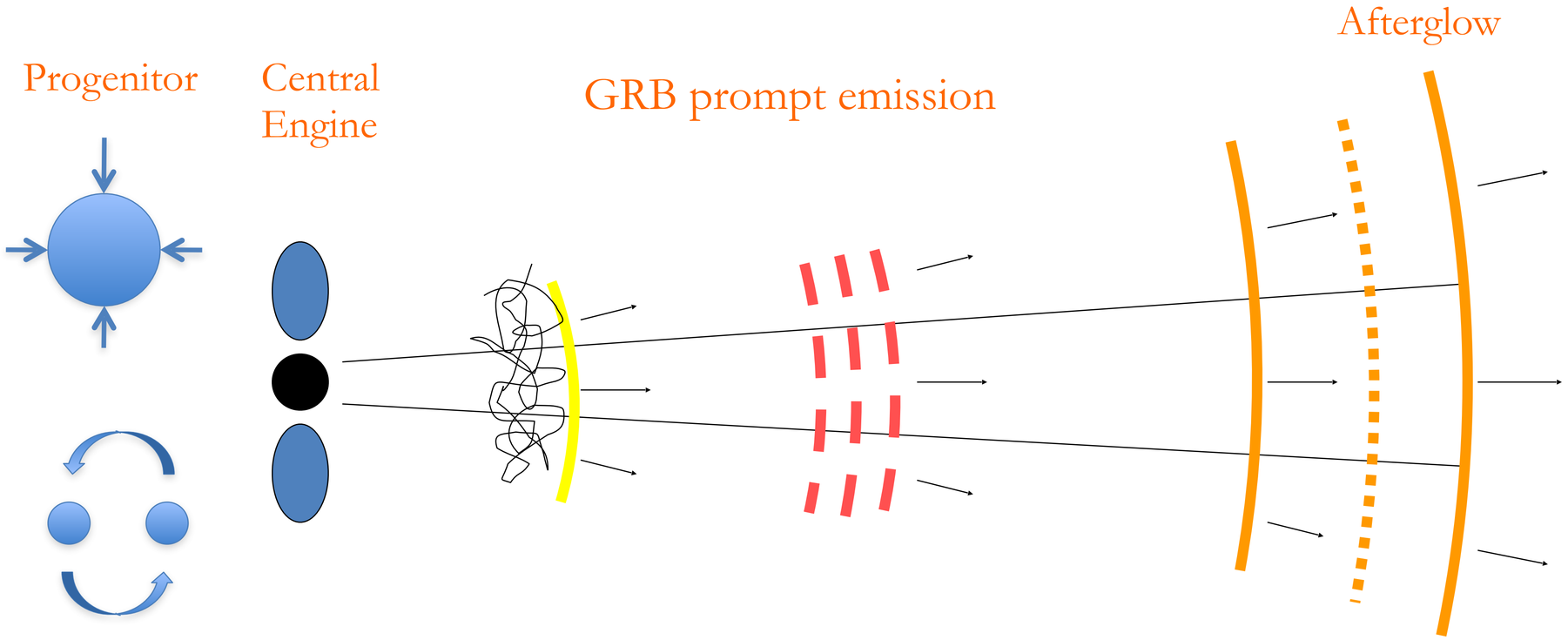
Figure 2 | A classification scheme for γ-ray bursts. The red rows show the analogy with the supernova classification scheme. Blue cells show the properties of GRB 060614 (refs 7–10).





Zhang, 2006, Nature

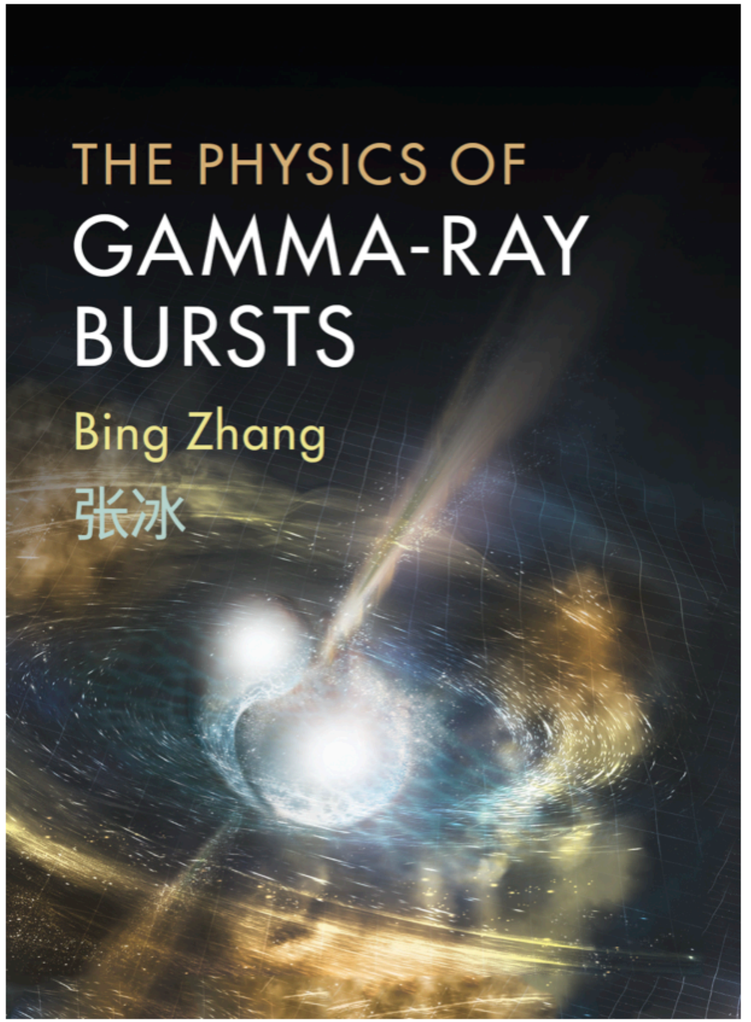
Physical picture of GRBs



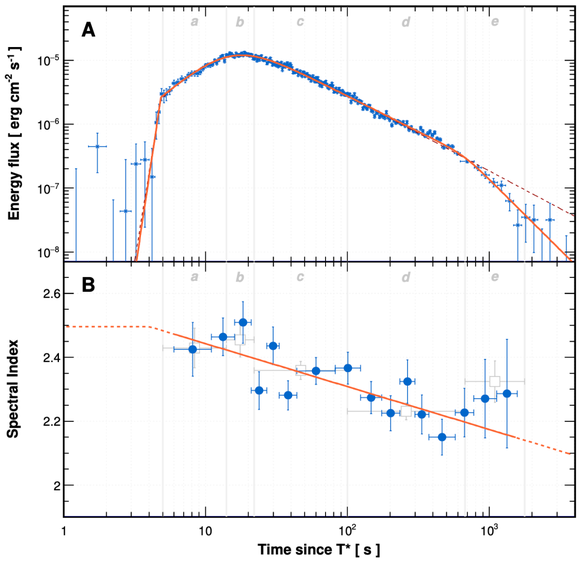
Increasingly difficult to diagnose with electromagnetic signals

Open Questions in GRB Physics

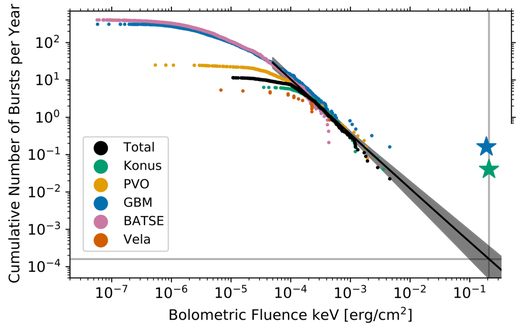
- **Progenitors & classification** (massive star core collapse vs. compact star mergers; others progenitor systems?)
- **Central engine** (black hole vs. millisecond magnetar)
- **Ejecta composition** (fireball vs. Poynting-flux-dominated outflow)
- **Energy dissipation mechanism** (shock vs. magnetic reconnection)
- **Particle acceleration & radiation mechanisms** (synchrotron, inverse Compton, vs. quasi-thermal)
- **Afterglow physics** (medium interaction, from radio to TeV, synchrotron vs. synchrotron self-Compton, jet break …)



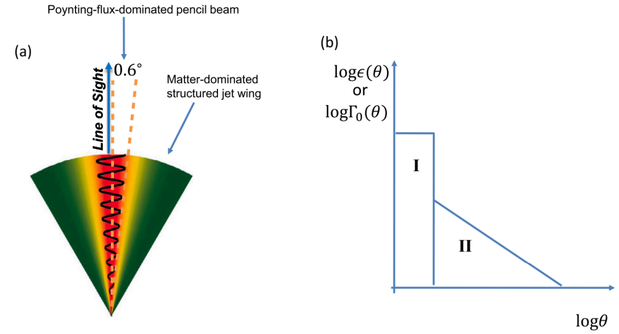
Highlight: GRB 221009A, the B.O.A.T

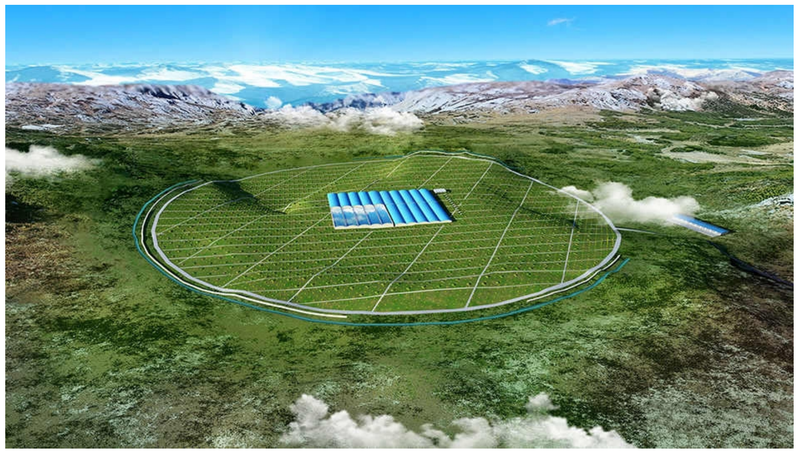


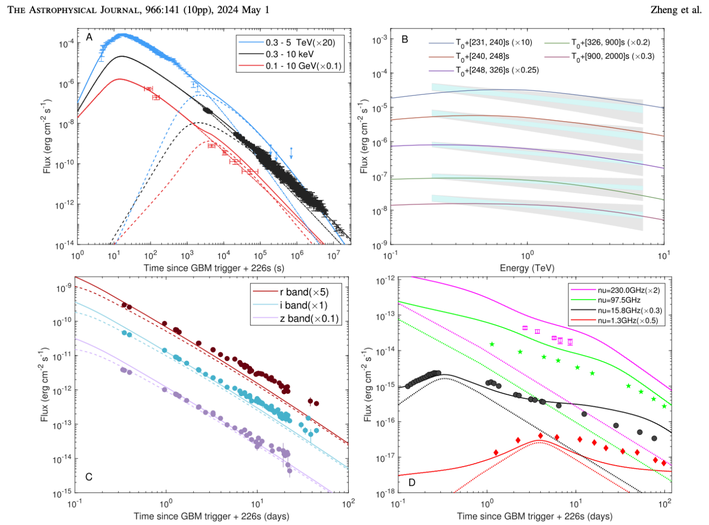
Cao et al. 2023, Science



Burns et al. 2023, ApJL



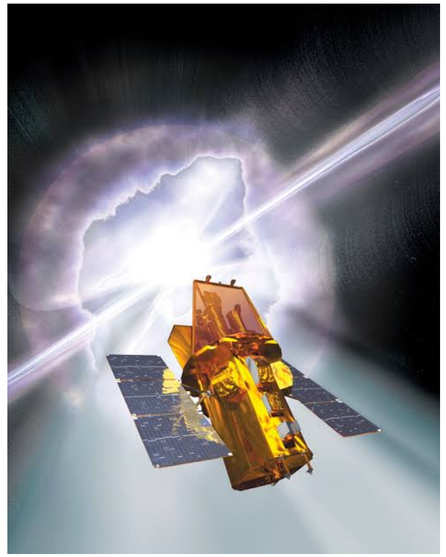




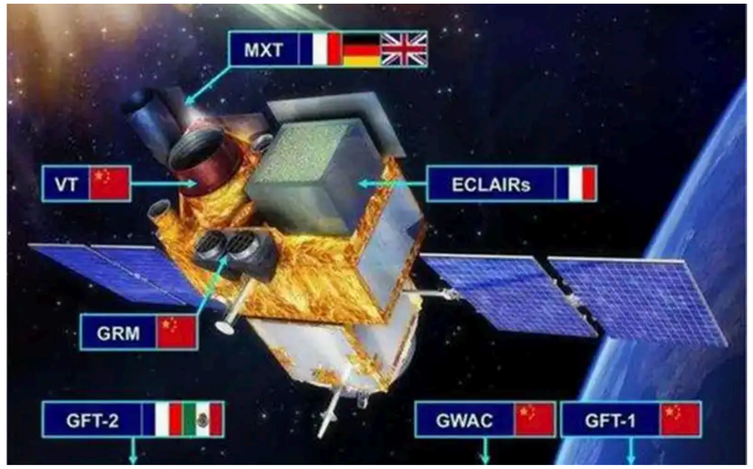
- Observed from radio all the way to the TeV energies
- Once in a thousand year event can happen in our lifetime
- At least some GRBs can have a very narrow jet; surrounded by a structured jet
- Afterglow is not only powered by electron synchrotron, but also in synchrotron self-Compton (SSC) in the high-E regime
- TeV emission from prompt emission? Associated with precursor?

Zhang, Wang, Zheng, 2024, JHEAp
Zheng, Wang, Liu, Zhang, 2024, ApJL
Zhang, Murase, Ioka & Zhang, 2025, JHEAp
…

Swift vs. SVOM

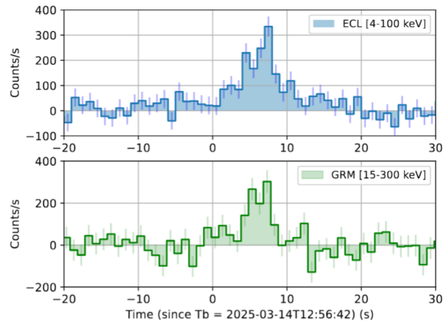


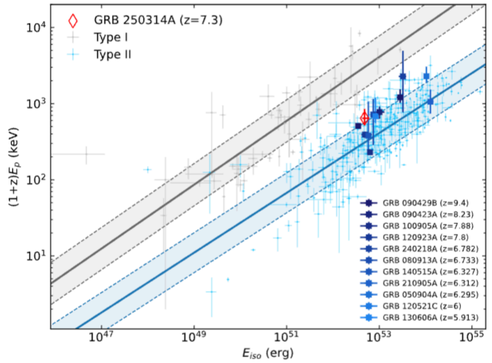
Neil Gehrels Swift Observatory
(Nov. 20 2004 - Oct. 20 2026)

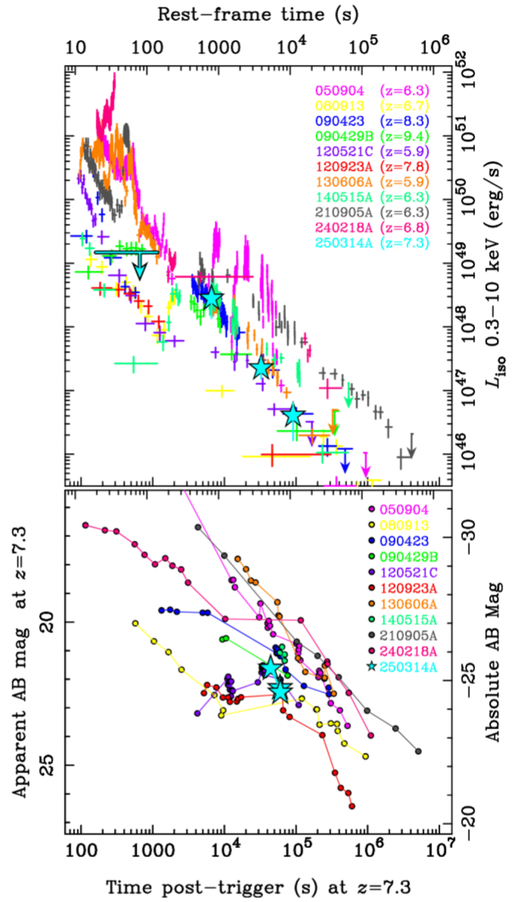


Space Variable Objects Monitor
(Jun. 22 2024 -)

Wei, Cordier et al.







GRB 250314A, Cordier et al. 2025

- GRBs of all types are regularly detected by SVOM
  - Short vs. long
  - High-z: 7.3
  - X-ray rich and X-ray flashes
  - Central engine activities in optical

Fast X-ray Transients

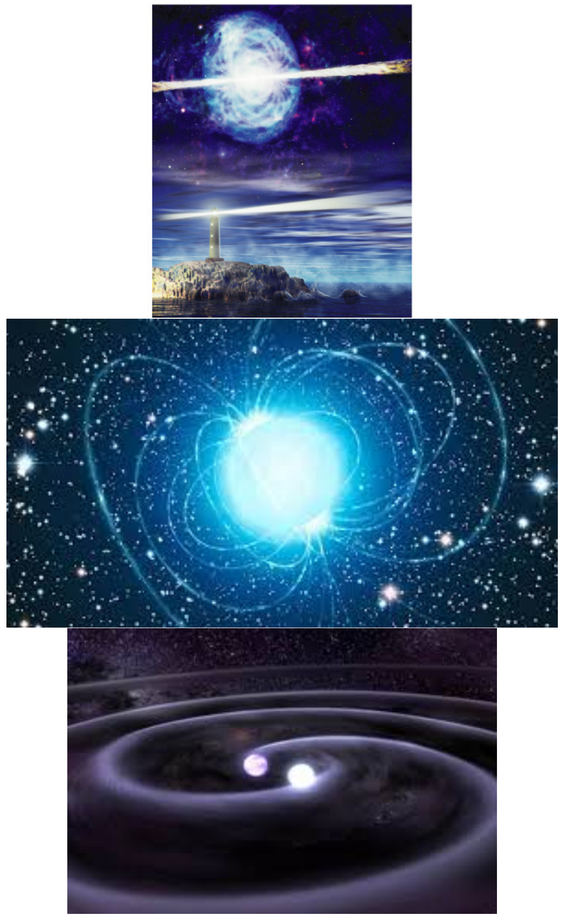
Fast X-ray Transients

The Einstein Probe breakthrough



Einstein Probe: a CAS / ESA / MPE mission, a wide field, high sensitivity, X-ray survey telescope

I



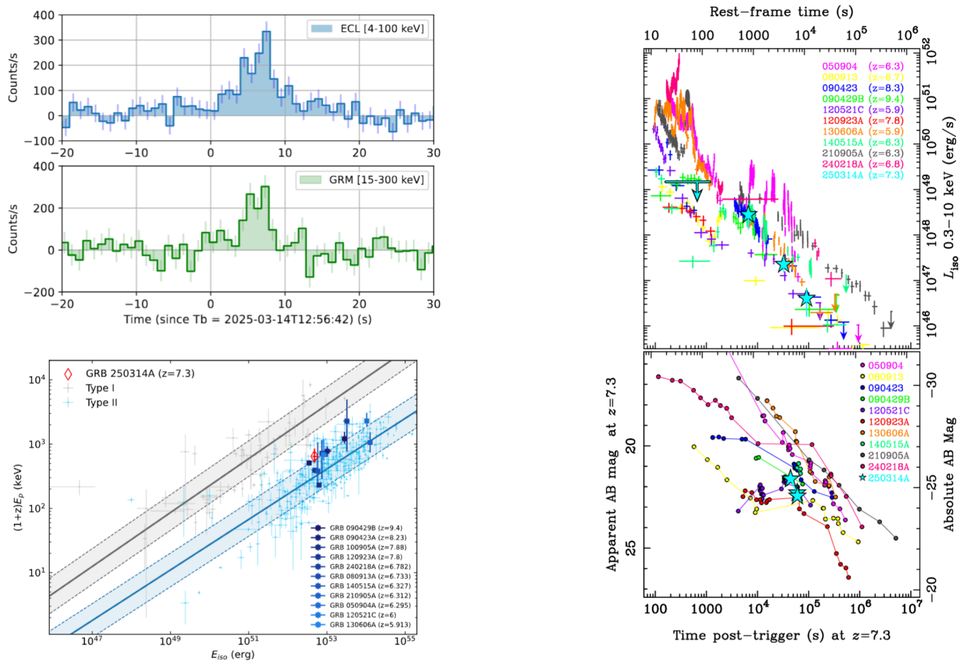
II



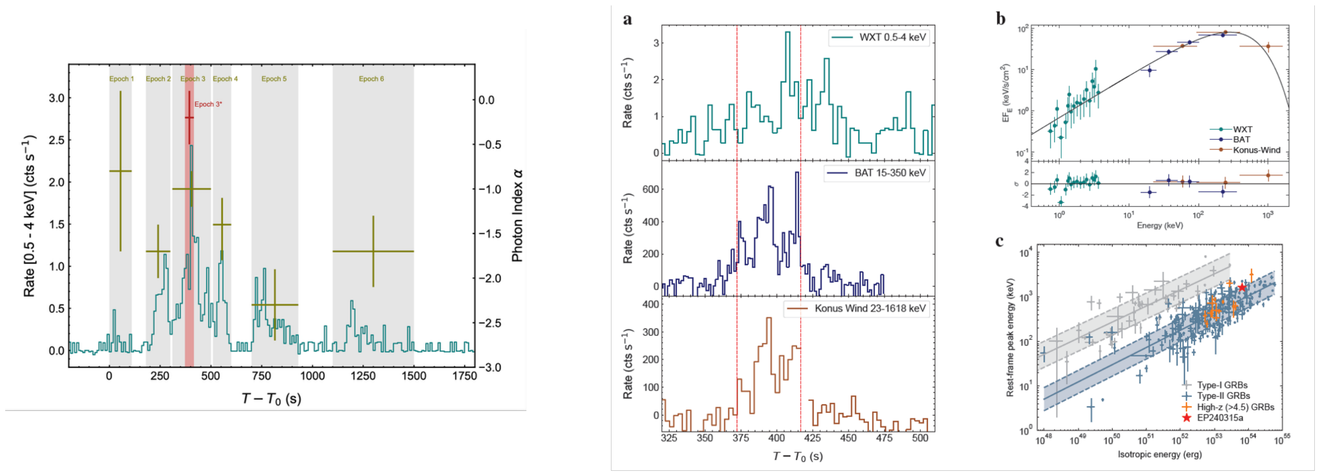
III



X-rays: **NS mergers** **Massive star core collapse** **SMBH triggered FXTs**



GRB 250314A: Cordier et al. 2025, A&A

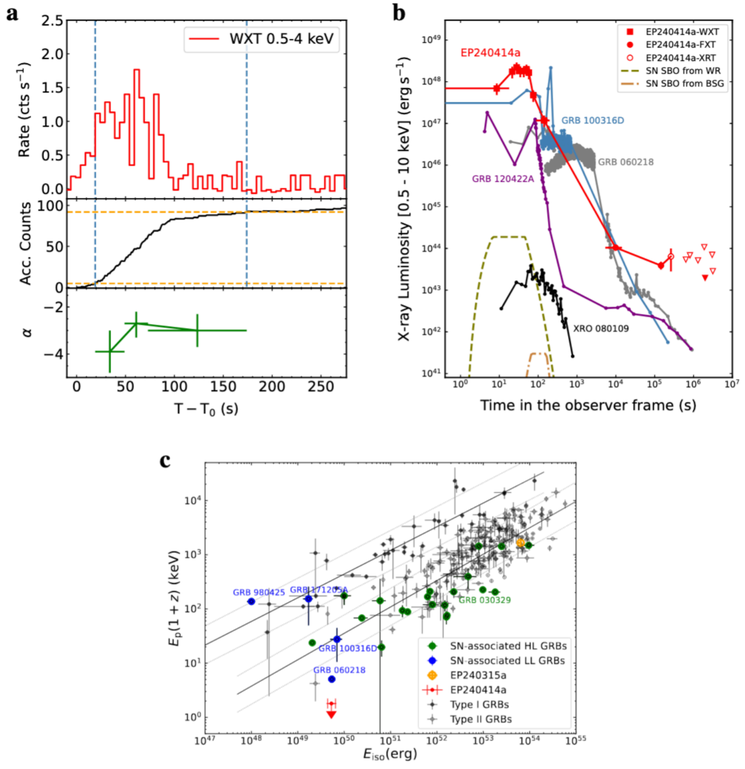


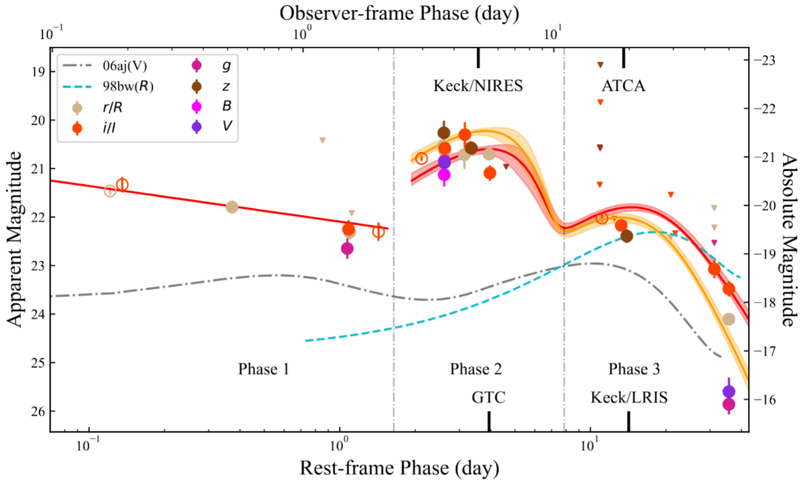
EP 240315a: Liu et al. 2024, Nature Astronomy

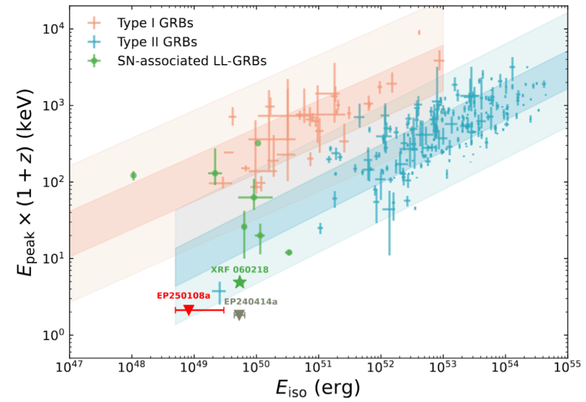
High-z explosions

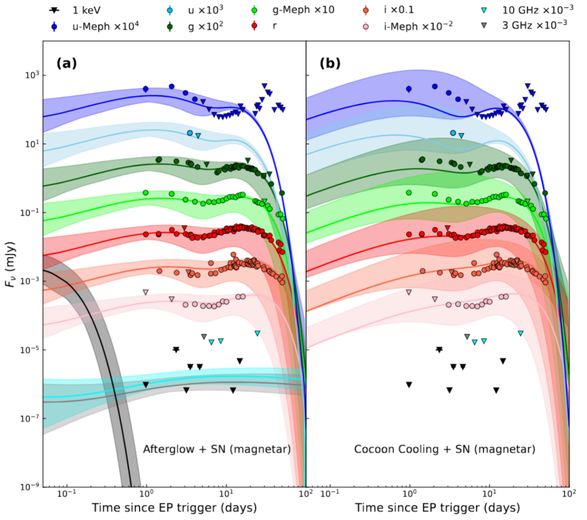
- SVOM GRB 250314A @ z=7.3
- EP240315a/GRB 240315 @ z=4.859
- Breaking record of z=9.4?

GRB-less, SN-Ic-BL-associated Type II EFXTs
Relativistic shock breakout or successful weak jets?





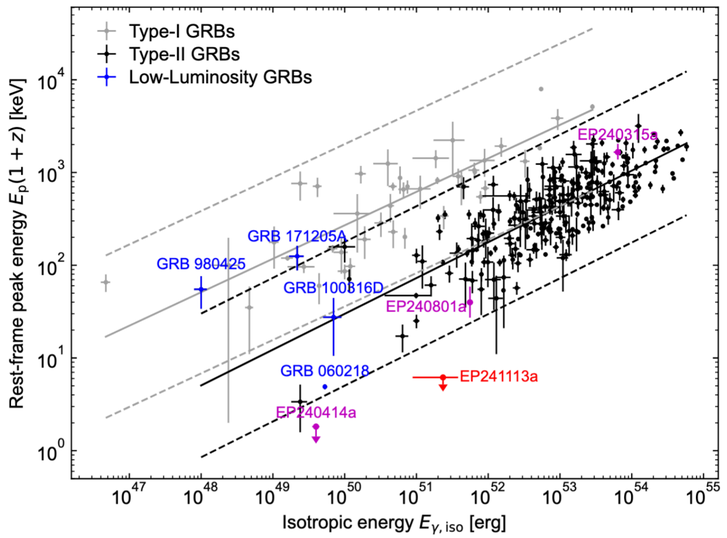


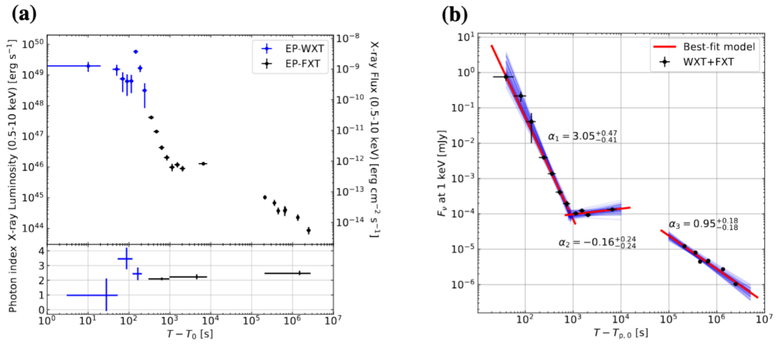


EP 240414A, H. Sun et al., 2025, Nature Astronomy
@ z = 0.401

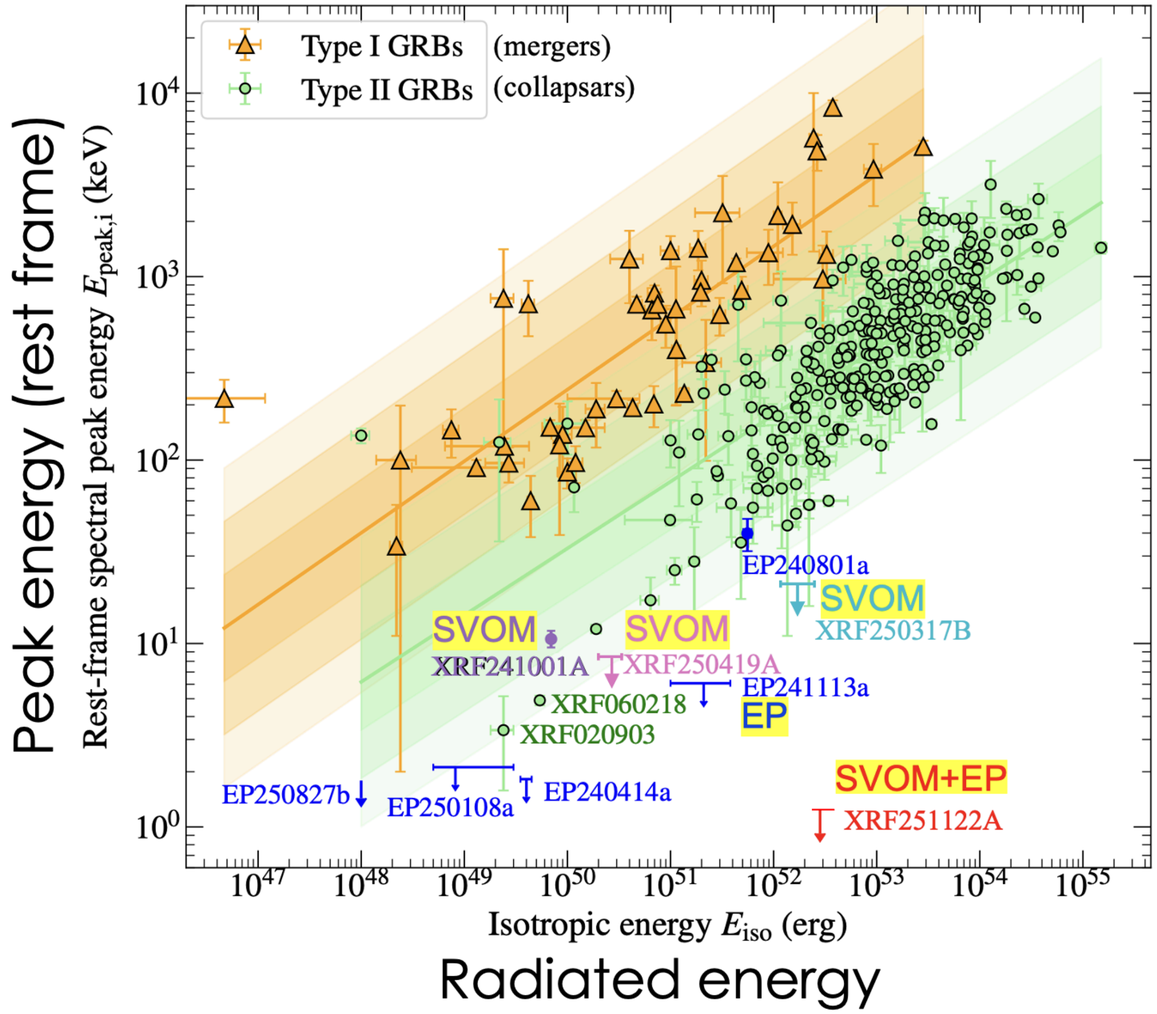
EP 240108A, W.-X. Li et al., 2025

GRB-less, energetic dirty fireball Type II EFXTs



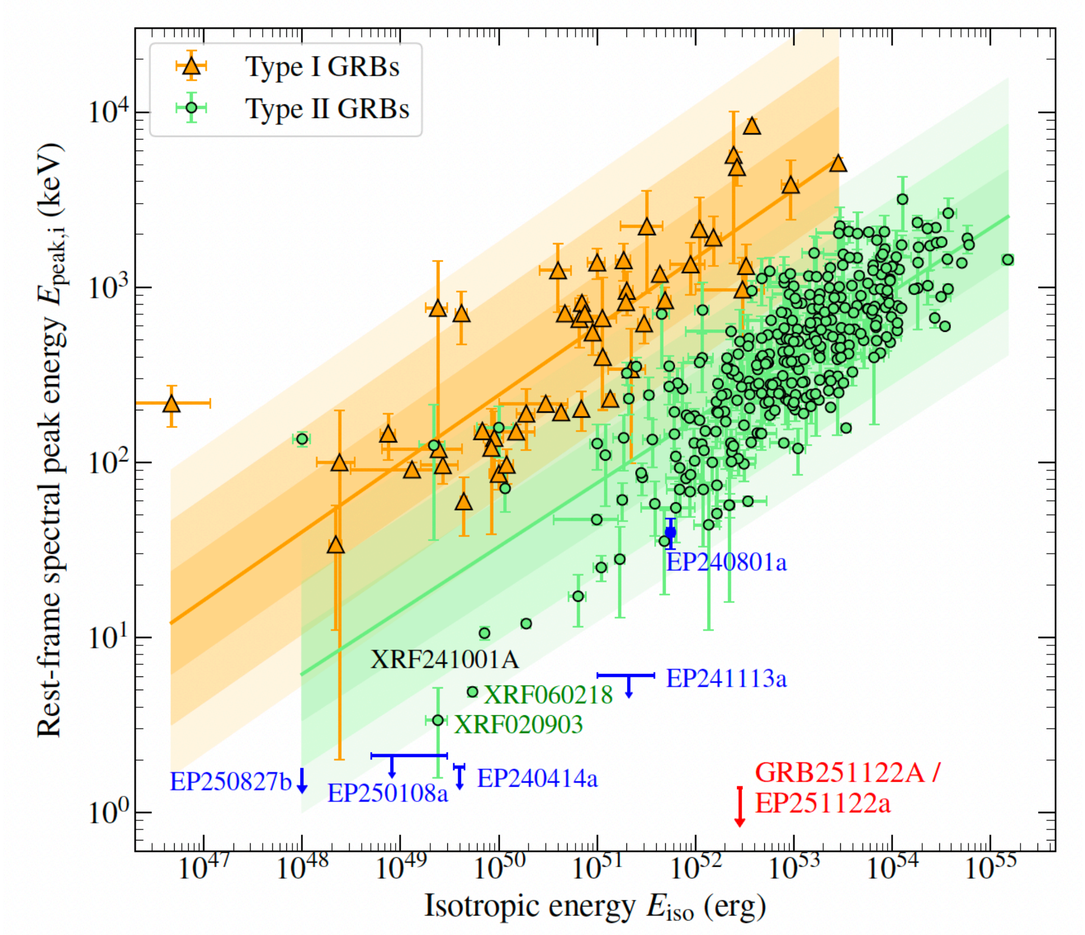


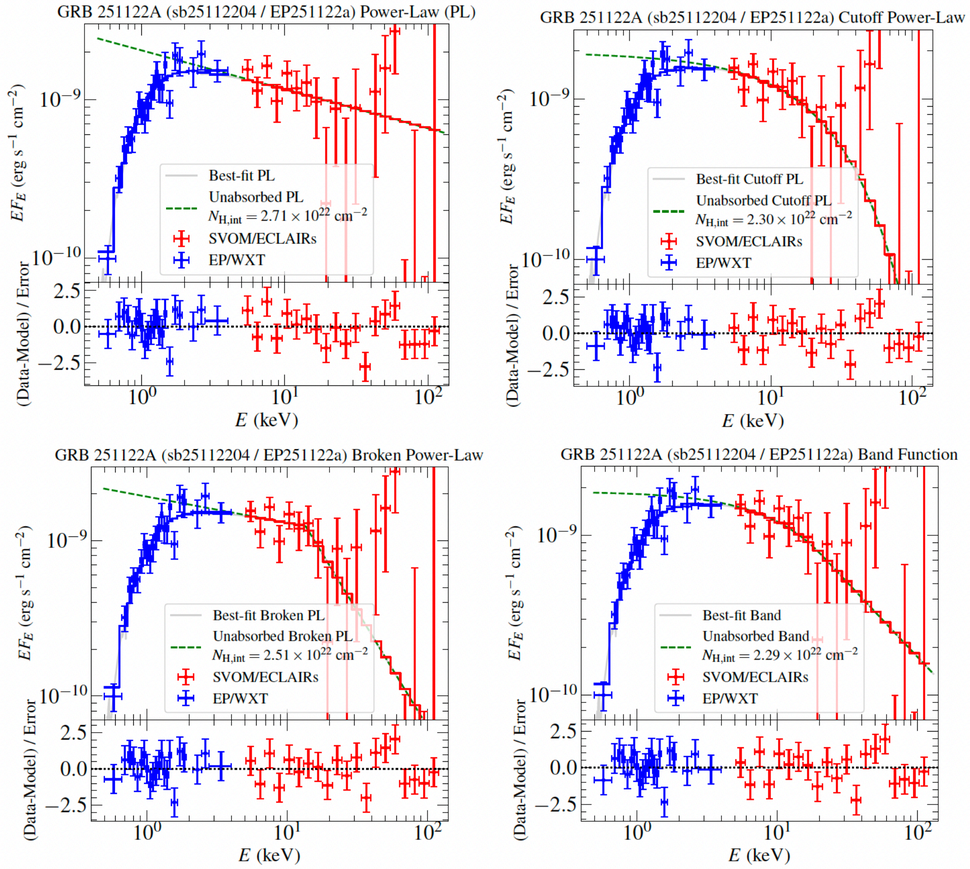
EP 241113A, C.-Y. Dai et al., 2026, Science



Credit: Frederic Daigne

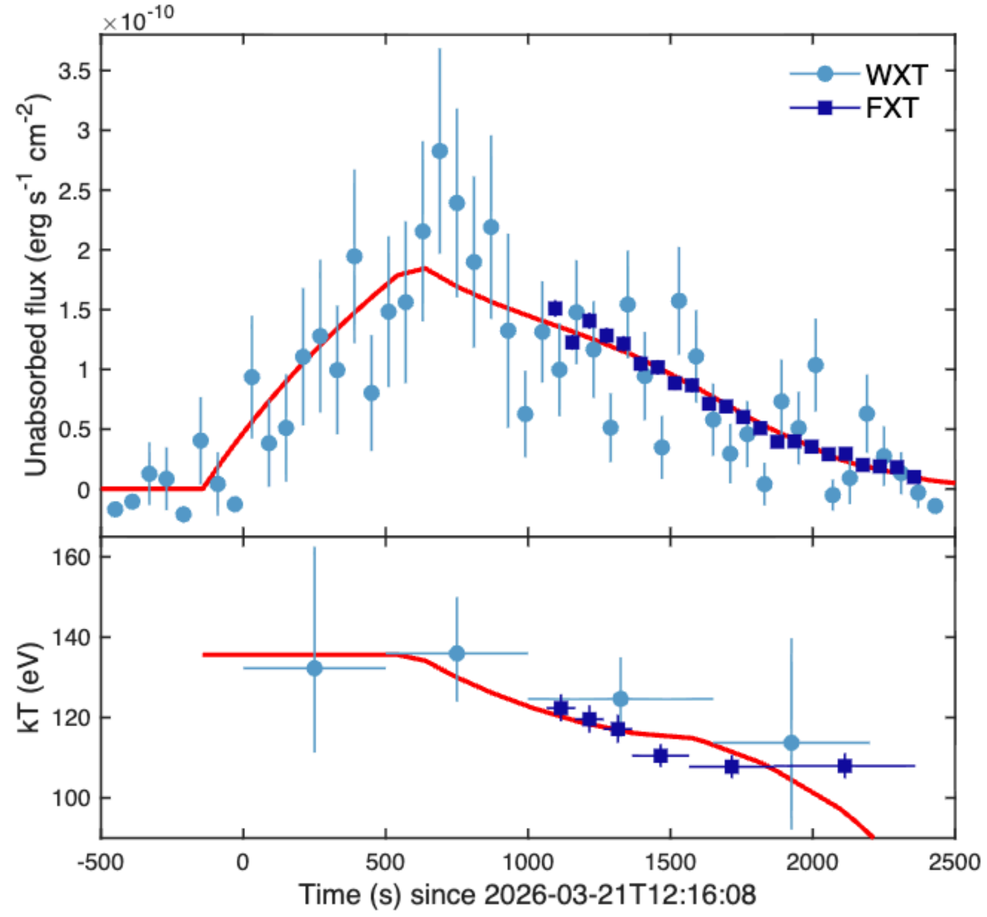
GRB 251122A / EP251122a: a new type of explosion?



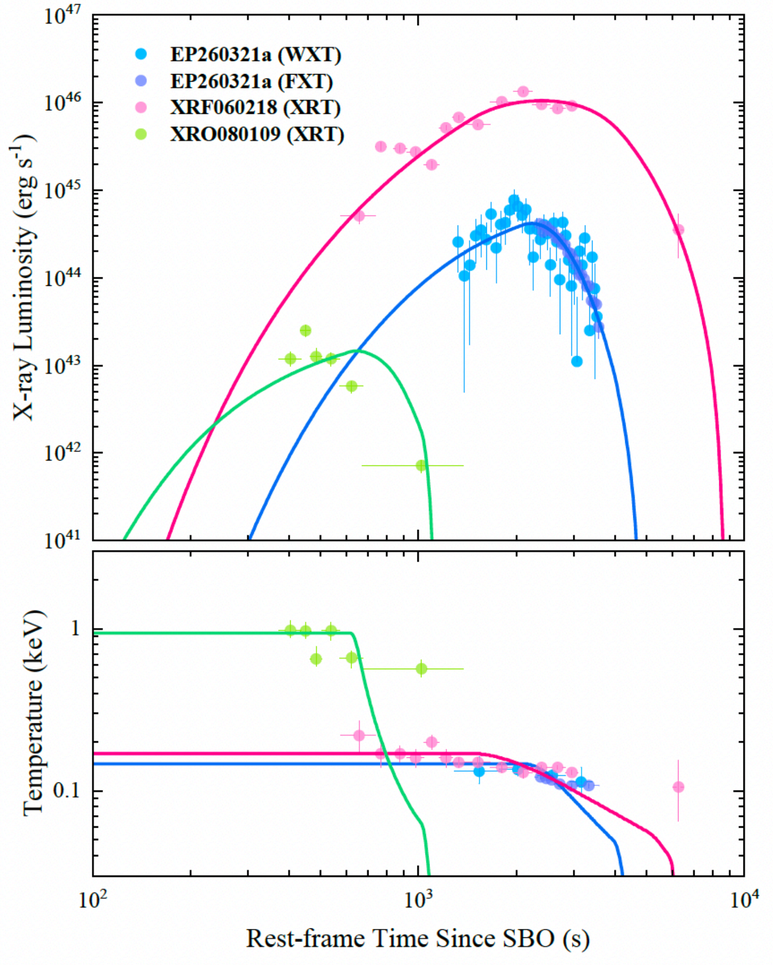


A joint ECLAIRs/WXT spectrum
Lin et al. 2026

Shock breakouts

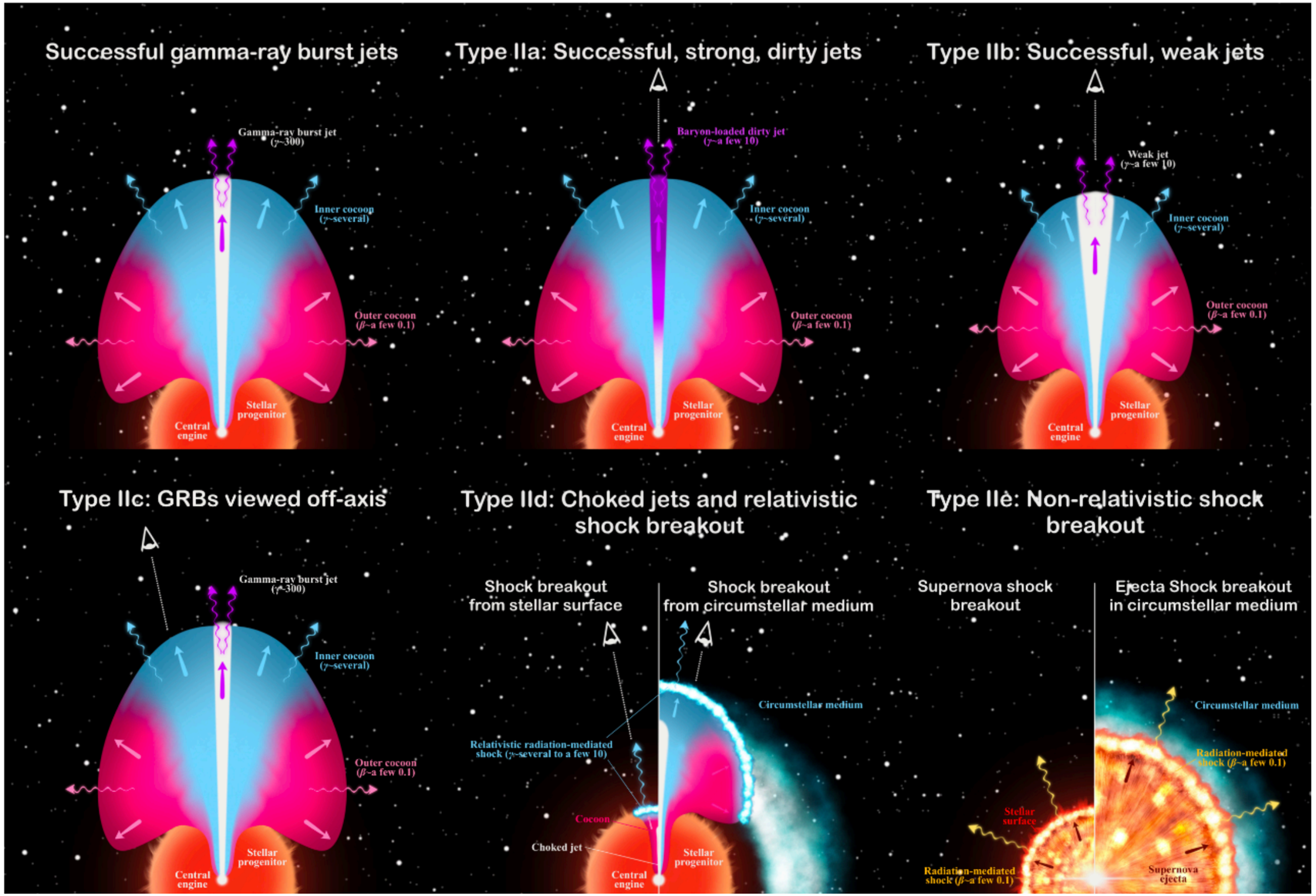


EP 260321a, Yuan et al., 2026, Science, submitted



Zhu et al. 2026

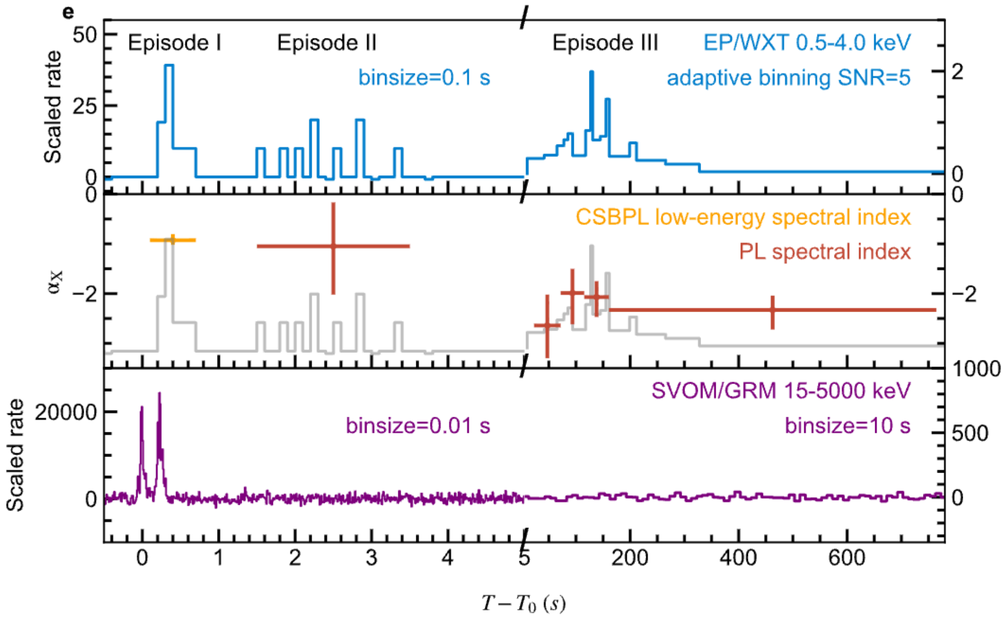
How to make Type II FXTs?



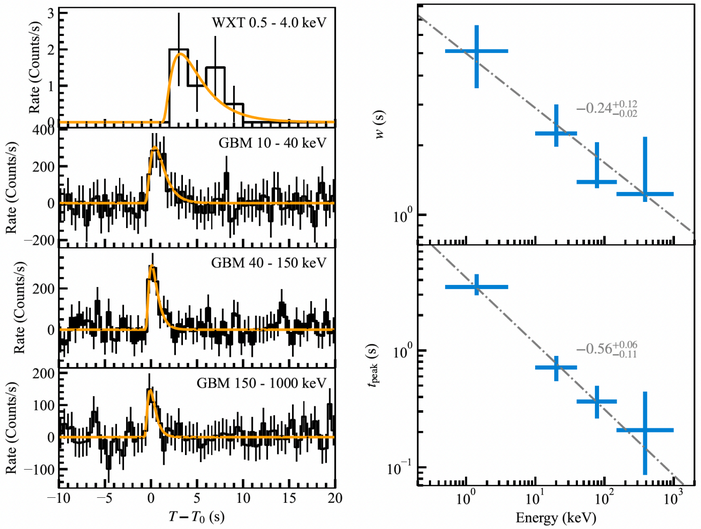
B. Zhang et al. 2026, in prep

Credit: Jin-Ping Zhu

Type I EFXT

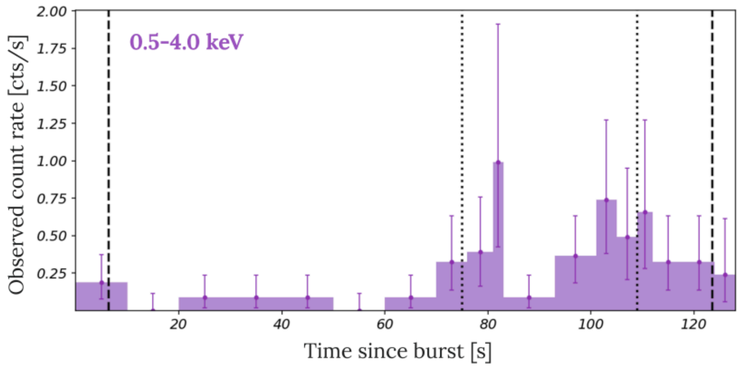


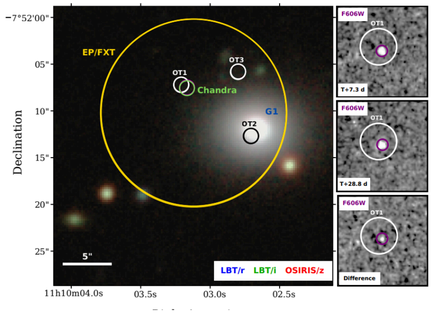
EP250704a, A. Li et al. 2026



EP260411a, Yin et al. 2026

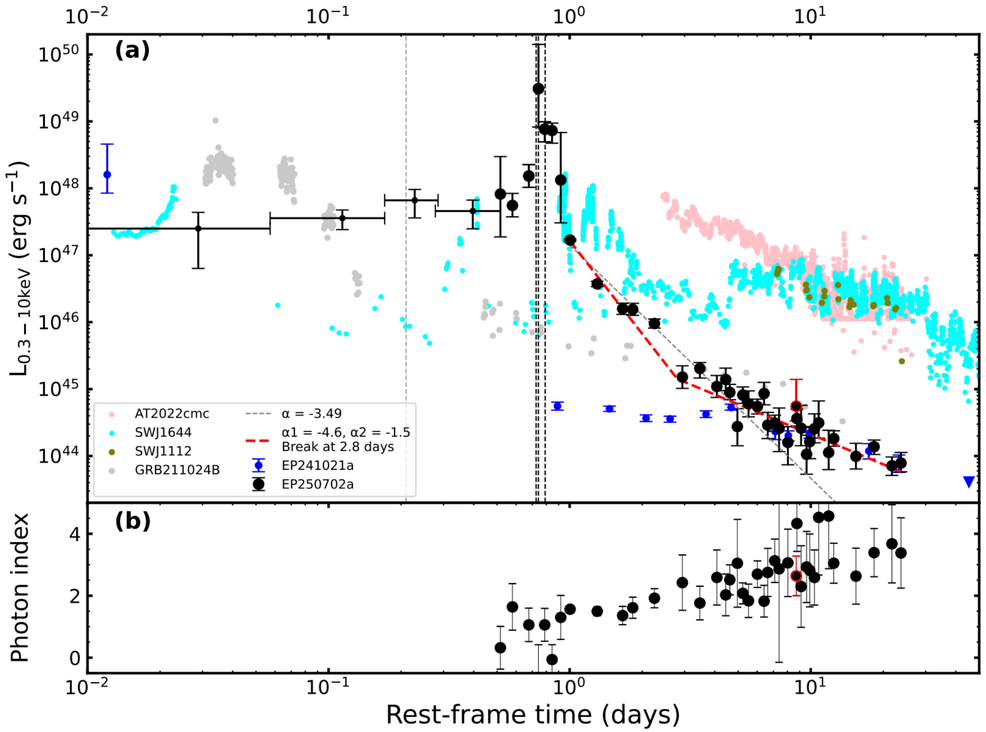
- EP250704a / GRB 250704B
  - sGRB: 0.37 s
  - FXT: 562 s
- EP260411a / GRB a60411A
  - sGRB: 1.3 s
  - FXT: 6.1 s
- Other candidates without GRBs
  - EP 250207b & LXT240402A

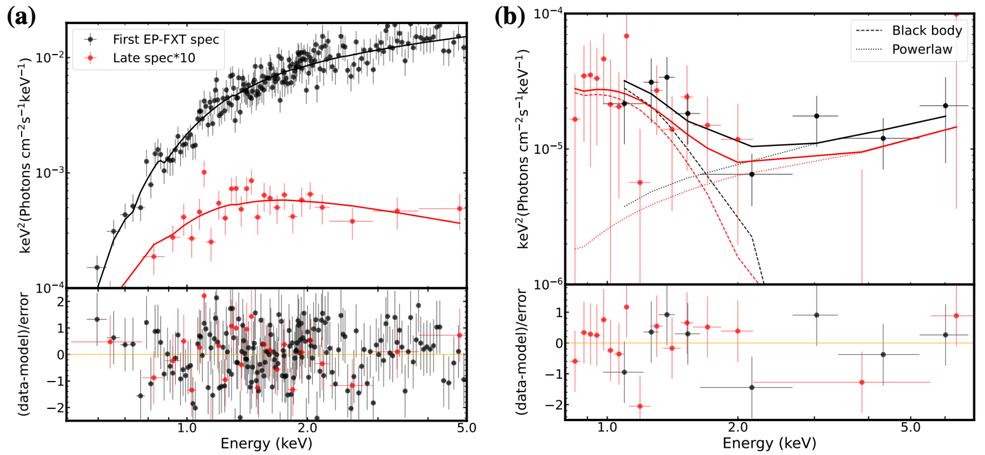


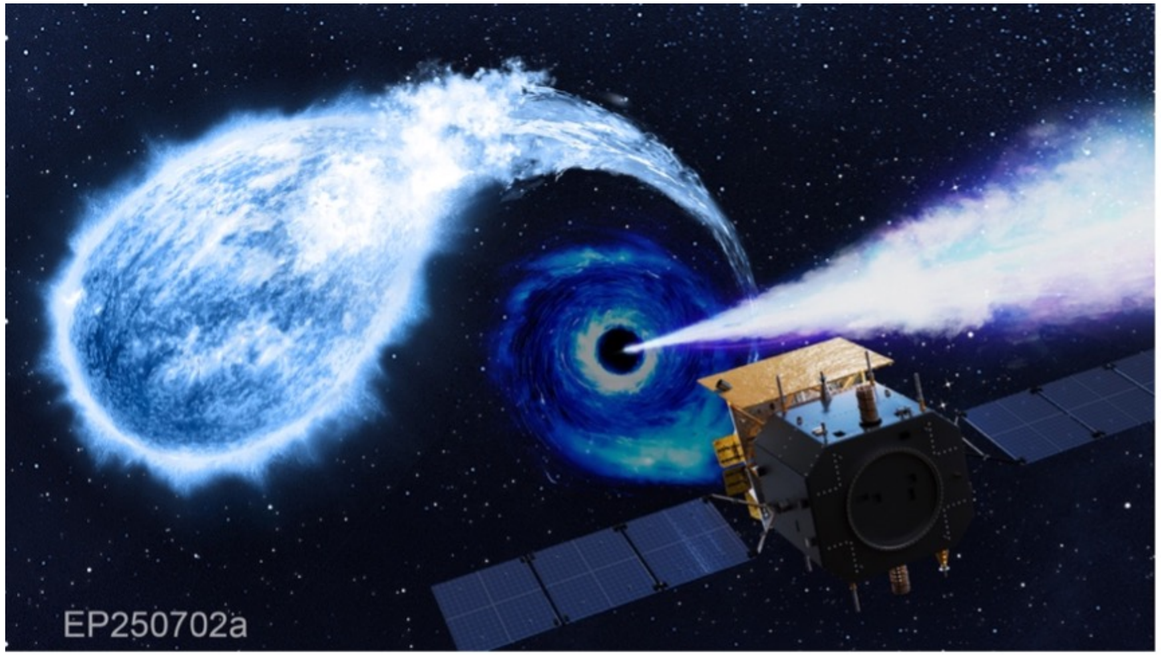


EP250207b & LXT240402A, Beccerra et al. 2026, A&A

Jetted TDE of a WD by an IMBH

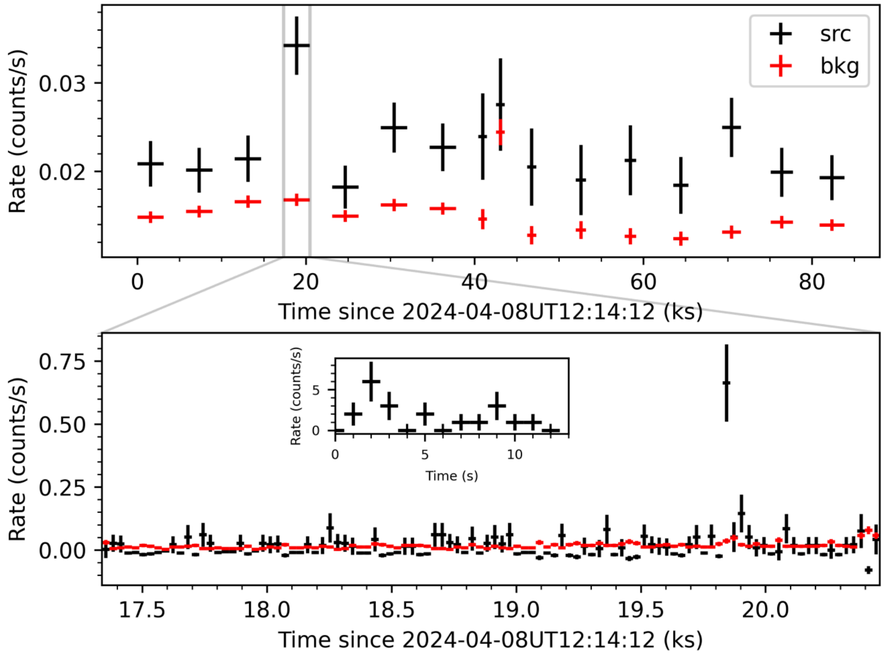






EP 250702a, D. Li et al. 2026, Science Bulletin, 71, 538

Type III events?



EP240408a
12 s X-ray flare
4-d X-ray plateau
Emission before flare

W. Zhang et al. 2025, SCPMA

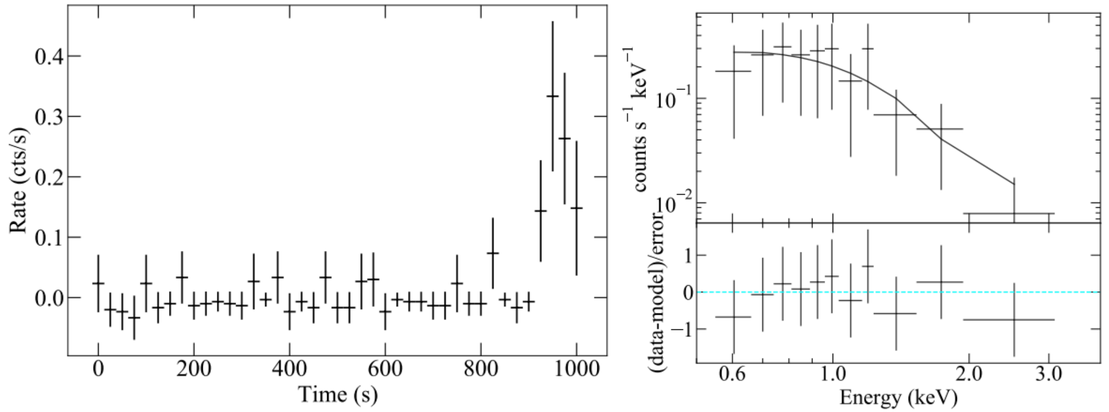


Figure 2. Left: the EP/WXT light curve of the count rate in the 0.5–4 keV band, in which an intense flare lasting ~91.9 s was observed. Right: the WXT X-ray spectrum during the flare period, which can be described by an absorbed single power-law model with photon index $\Gamma = 1.8^{+0.57}_{-0.54}$.

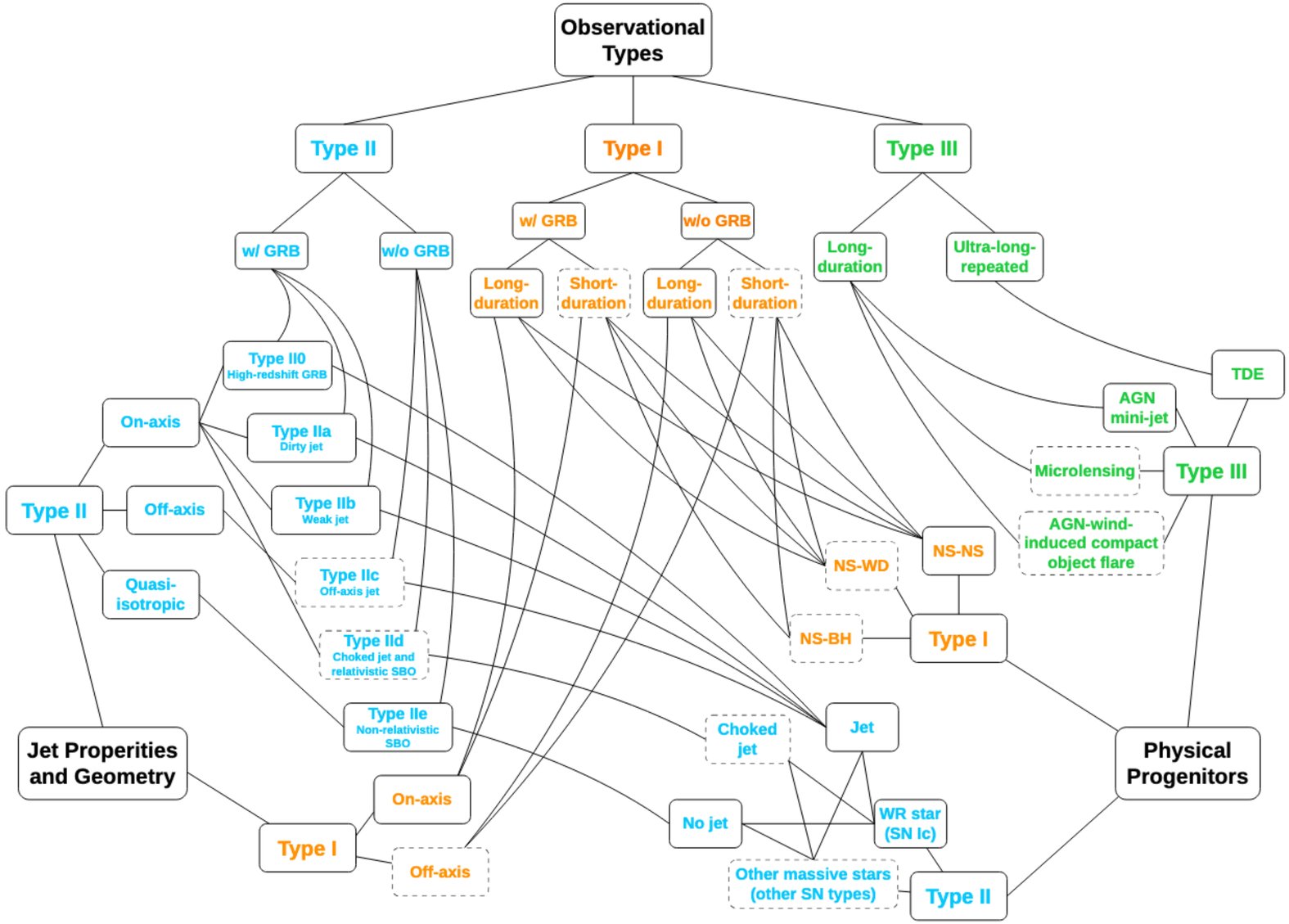
EP241021a
100 s X-ray flare
1.5-d X-ray plateau
Repeating TDE or magnetar?

X. Shu et al. 2025; G.-L. Wu et al. 2025

EP241206a
500 s X-ray flare
from an AGN
Flux contrast ~300 times

C.-Y. Wang et al. 2026, ApJ

FXT classification

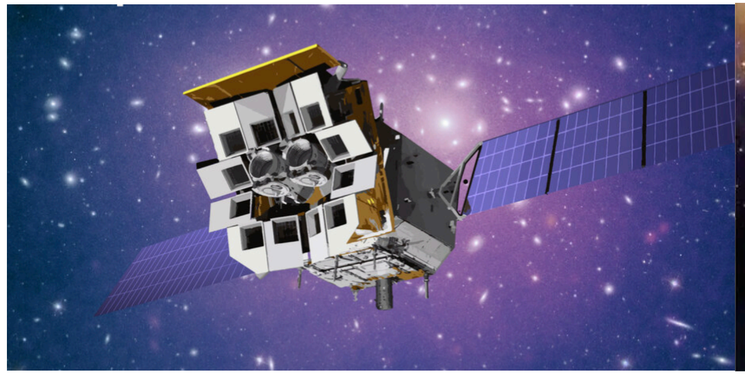


B. Zhang et al. 2026, in prep

Credit: Jin-Ping Zhu

GRBs vs. FXTs

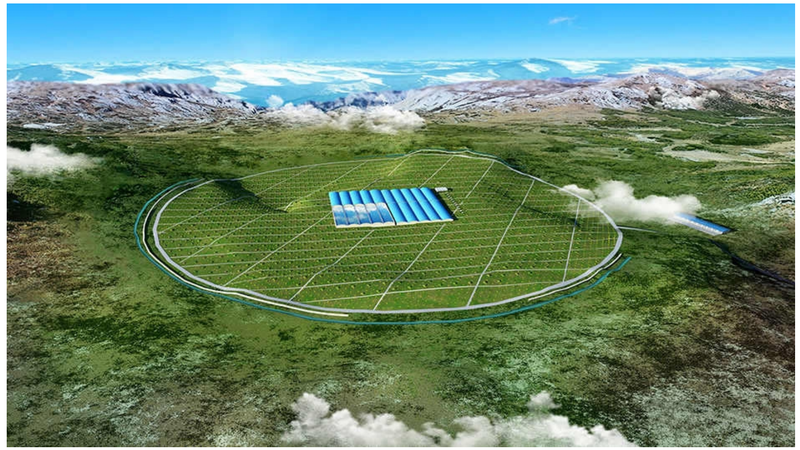
- At least some fast X-ray transients are GRBs extended to softer domain
- Others open up new parameter regimes for cosmic explosions
- Both Type I & II FXTs have been discovered, all with long duration
- Possible new type(s) discovered
- Some are quite nearby
- Searching for LHAASO counterparts for EP and SVOM sources are desirable. Upper limits potentially helpful to constrain the FXT physics.



Einstein Probe



SVOM



LHAASO