X-ray Flares of GRBs in High-Energy Gamma Rays

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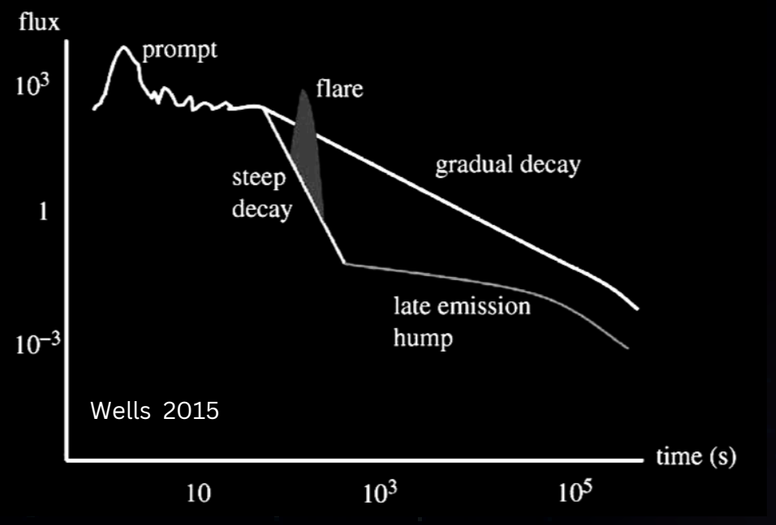
Gamma-Ray Bursts

Gamma-ray bursts (GRBs) are intense bursts of gamma-ray radiation lasting from subseconds to several minutes, believed to result from cataclysmic processes such as the collapse of massive stars or the merger of compact objects (for example neutron stars). GRB shows two main emission episodes:

- **Prompt emission is** produced by internal shocks within relativistic jets from the central engine.
- **Afterglow** is resulted from the interaction of these jets with the interstellar medium, producing radiation across wavelengths, from very high-energy gamma rays to radio bands.

Swift Canonical X-ray Light Curve



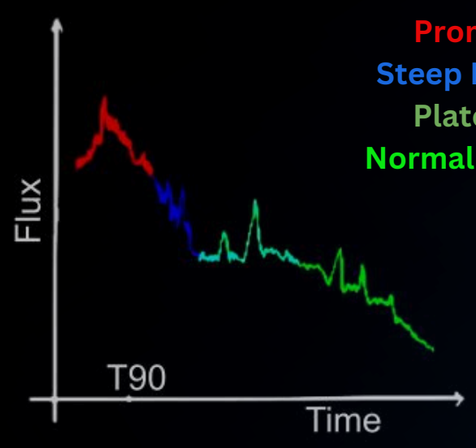
What are X-ray Flares?

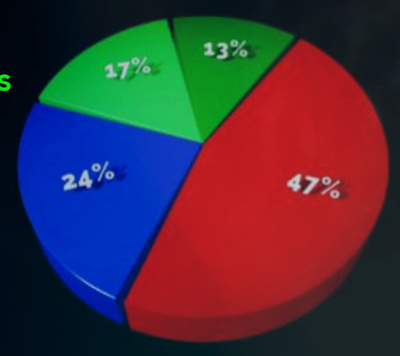
Sudden rebrightening of X-ray radiation during the afterglow phase in approximately 1/3 of GRBs [1]. These flares mostly occur within a thousand seconds after the initial burst (prompt emission). X-ray flares are believed to originate from various processes associated with the central engine of the burst. Proposed mechanisms include:

- Late-time central engine activity (prompt like)[2],
- Internal shocks within the jet of sub-relativistic velocity [3],
- Prompt Emission viewed off-axis [4]
- Magnetar activity in the central engine [3],
- Interactions with the clumpy surrounding medium (external origin) .

Flare Category:
Based on the position on XRT Light Curve

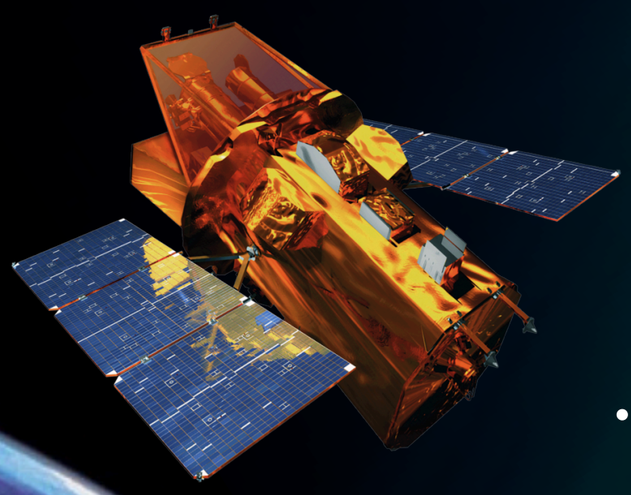
Prompt Flares
Steep Decay Flares
Plateau Flares
Normal Decay Flares





Neil Gehrels Swift Observatory

- Burst Alert Telescope (BAT; **15-150 keV**)
- X-Ray Telescope (XRT; **0.3-10.0 keV**)



Fermi Gamma-Ray Telescope

- Large Area Telescope (LAT; ~**30 MeV - 300 GeV**)

Why GeV?

GeV photons serve as effective probes for the reprocessing of low-energy photons generated by X-ray flares. A joint spectral analysis provides the unique possibility to explore the underlying emission mechanism, whether synchrotron self-Compton (SSC; [6]) or (delayed) external inverse Compton (EIC; [6]) .

Methodology

Goal: Investigate the temporal and spectral evolution of GRB (standard) afterglows, and flares using simultaneous data from Swift/XRT, Swift/BAT, and Fermi/LAT.

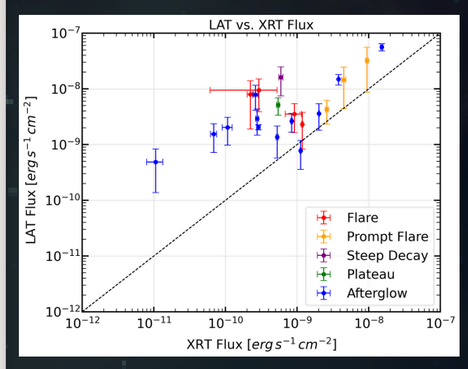
Data: Catalog based on GRBs with significant (>5σ) Fermi/LAT detection (2nd Fermi/LAT-GRB catalog: 2008-2018; [5]) and available simultaneous X-ray data (Swift/XRT, and Swift/BAT, if available)

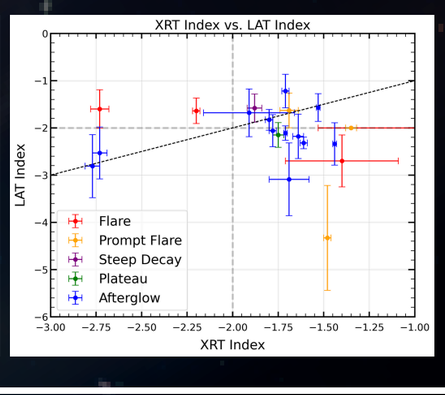
Analysis:

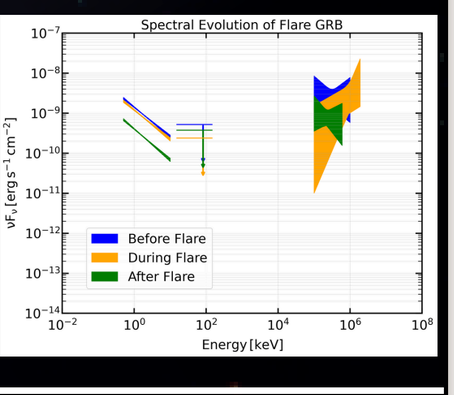
1. **Simultaneous Observations:** Identified simultaneous observations across Swift/XRT, Swift/BAT, and Fermi/LAT for afterglows and flares. We have **12** GRBs in our sample with joint XRT + BAT + LAT observation.
2. **Temporal and Spectral Evolution:** Studied the evolution of GRB properties over time and across different energy bands.
3. **Data Analysis:**
   - **High-Energy Photon (HEP) Search:** Determined the highest-energy photon detected (0.1-100 GeV) for each selected time interval.
   - **Spectral Analysis:** Conducted joint spectral analysis from 0.3 keV up to the HEP (detected by LAT) for each time interval.

Results

A joint spectral analysis with simultaneous data from Swift/ XRT, /BAT, and Fermi/ LAT reveals that **5 out of 12 GRBs show GeV excess**, while the remaining **7 cases align with the standard afterglow emission.**







Conclusion and Future Prospects

This study reveals a possible spectral hardening in the GeV energy band for certain flares and afterglow. Based on the findings, the theoretical implications of our joint X-ray (keV) to the GeV spectral properties of afterglow and flares. Also, the study of spectra evolution for pre-flare and post-flare is planned.

References

[1]Burrows et al. 2005; Falcone et al. 2007; Chincarini et al. 2010; Margutti et al. 2011
[2] Fan & Wei 2005; Zhang et al. 2006
[3] Beniamini & Kumar 2022
[4] Duque et al. 2022
[5] Fermi LAT Colloboration 2019
[6] Miceli and Nava 2022

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