Probing Gamma-Ray Burst Prompt Emission Mechanisms through Spectro-Polarimetric Observations with *Fermi* and *AstroSat*

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Abstract

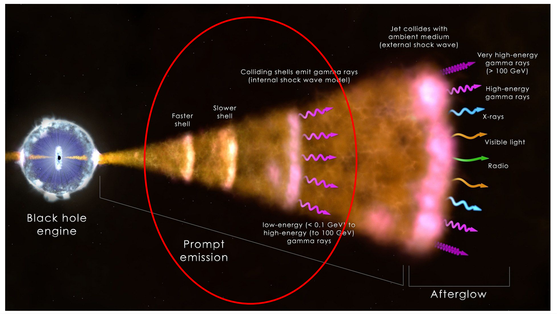
The radiation mechanism of the prompt emission is still an open issue and can be resolved using a systematic and uniform time-resolved spectro-polarimetric study. In this work, we performed a comprehensive investigation of the spectral, temporal, and polarimetric characteristics of bright GRBs observed using the *AstroSat* CZTI, *Fermi* GBM, and *Swift*-BAT to provide insight into the prompt emission radiation mechanisms. We investigated the time-resolved (in 100-600 keV) and energy-resolved polarization measurements of these GRBs with an improved polarimetric technique. In addition, we also carried out detailed time-resolved spectral analyses of these GRBs using empirical and physical synchrotron models. By these improved time-resolved and energy-resolved spectro-polarimetric studies, we could pin down the elusive prompt emission mechanism of these GRBs. Our spectro-polarimetric analysis reveals that GRB 160821A has a Poynting flux-dominated jet. On the other hand, GRB 160325A and GRB 160802A have a baryonic-dominated jet with mild magnetization. Furthermore, we observe a rapid change in polarization angle by ~ 90 degrees within the main pulse of very bright GRB 160821A. Additionally, we also discuss the spectro-polarimetric analysis of the second brightest burst, GRB 230307A, using data from Fermi, Konus-Wind, and AstroSat. In this analysis, we discovered evidence of a transition from a Baryonic to a Poynting flux-dominated jet composition within the burst's duration. Our study suggests that the jet composition of GRBs may exhibit a wide range of magnetization, which can be revealed by utilizing spectro-polarimetric investigations of the bright GRBs.

Gamma-Ray Burst: Radiation mechanisms?

1. Some authors explain the observed prompt emission spectrum using the synchrotron radiation model, while on the other hand, photospheric models similarly can equally describe the observed prompt emission spectrum.

2. Emission mechanism of prompt emission is still unknown! Spectro-polarimetry is a powerful tool that can provide a clear view of the long-debated mystery of the emission mechanisms.

3. In this poster, we present the time-integrated and time-resolved spectro-polarimetric results for GRB 160802A and GRB 230307A as examples.



Open problem

What is the radiative process responsible for the prompt emission?

Improvements in the Polarimetric analysis

1. Extending the energy range to sub-MeV
2. Improvement in noise rejection
3. Improvements and validation of the mass model

Spectral analysis of *Fermi* data

Use of 3ML

Physical as well as empirical modelling

3ML Multi-Mission Maximum Likelihood Framework

Polarization depends on the jet viewing geometry

On axis viewing

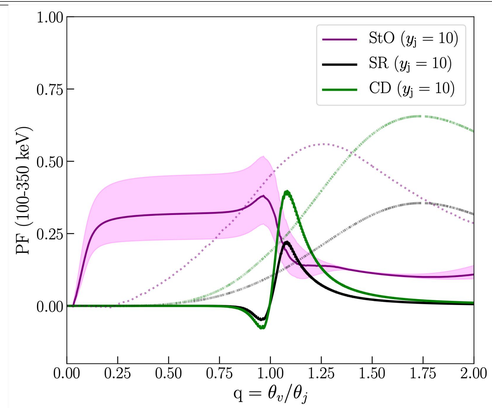
High Polarisation fraction:

Synchrotron emission in ordered magnetic field.

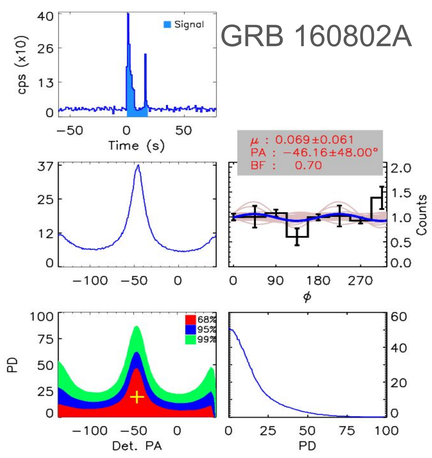
Nearly, null Polarisation fraction:

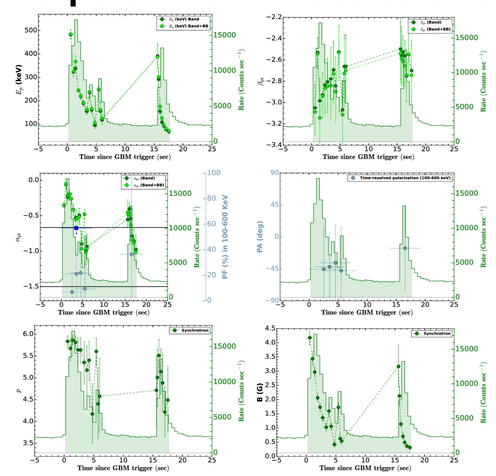
Synchrotron emission in random magnetic field.

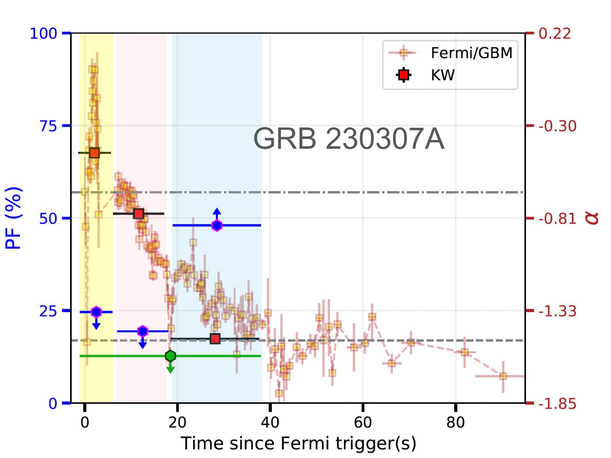
Photospheric emission: Compton scattering



Time-resolved spectro-polarimetric results of GRB 160802A and GRB 230307A







Summary & Conclusion

1. Detailed spectro-polarimetric observations and analysis of bright GRBs using Fermi and AstroSat provide a valuable approach to constraining the radiation mechanisms of GRBs.

2. GRB 230307A is the brightest burst for which Spectro-polarimetry analysis has been attempted ever.

3. Time-resolved spectro-polarimetry of the bright GRBs give hint of time-dependent nature of polarization properties.

4. We conclude that the prompt emission polarization analysis, along with spectral and temporal information, has a unique capability to solve the long debatable topic of the emission mechanisms of GRBs. *AstroSat* will be the only GRB polarimeter till 2027 at least. GRB Polarization analysis: https://astrosat.iucaa.in/czti/node/14

References: Chattopadhyay et al. 2022, Sharma et al. 2019, Gupta et al. 2022, Gupta et al. 2024, S. Gupta et al. 2025 **Thank you!**

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