11TH INTERNATIONAL FERMI SYMPOSIUM

09-13 SEP' 24

The Spectro-Polarimetry Study of the second BOAT burst -GRB 230307A

SOUMYA GUPTA

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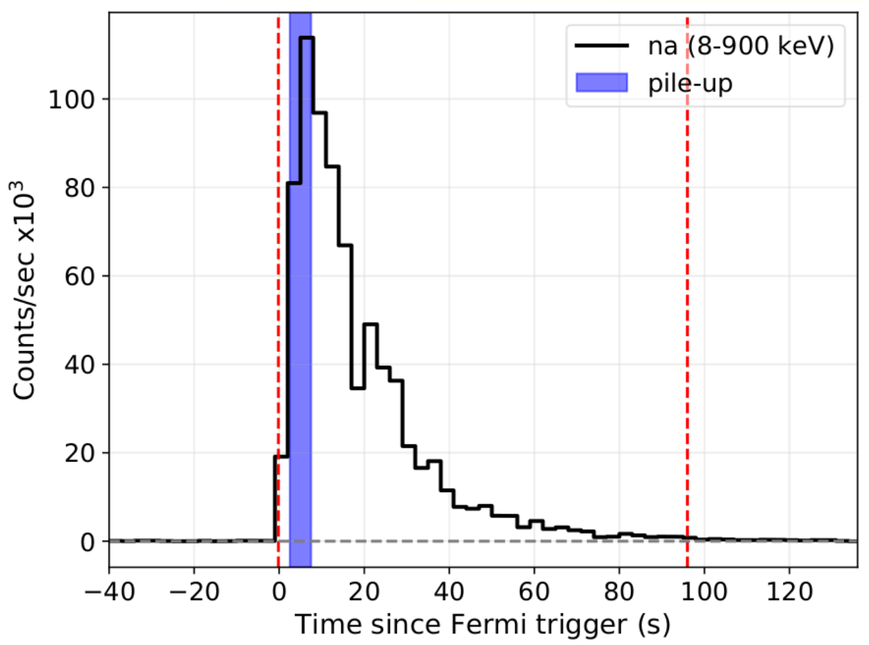
SEPTEMBER 10TH, MARYLAND, USA

GRB 230307A: OUTLINE

- Possible progenitor: Classification
- Spectral Analysis using Fermi GBM
- Polarisation Study using AstroSat CZTI
  - Saturation Correction
  - Corrected Results

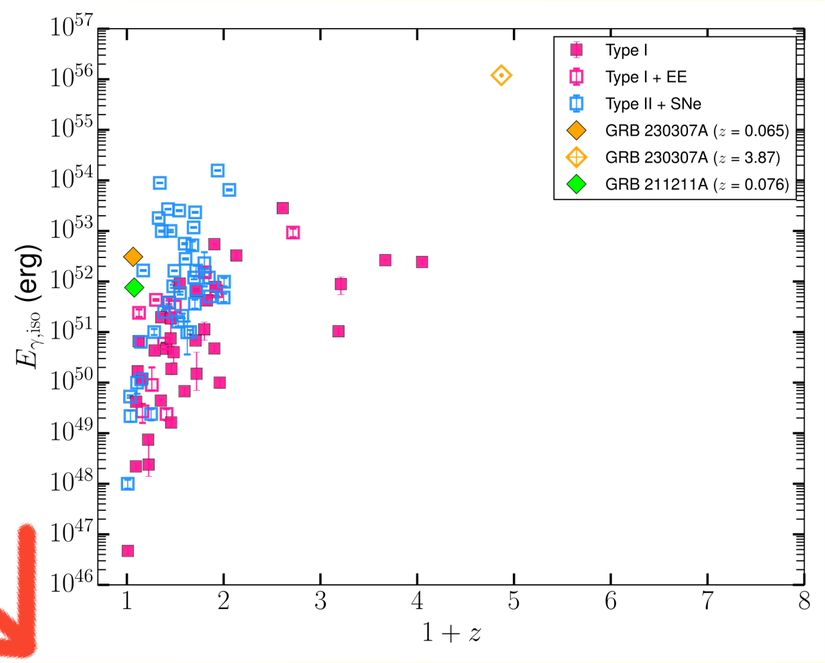
WHY THIS GRB???

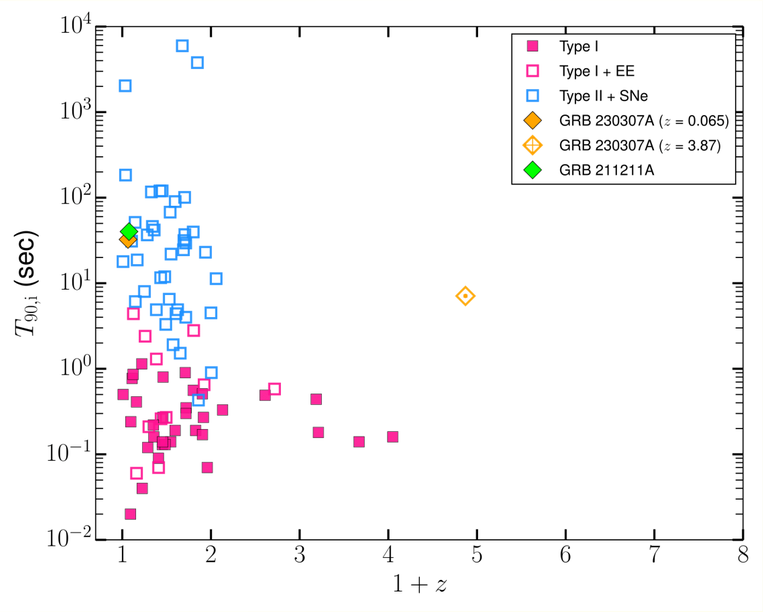
- **Second Brightest** Burst
- **Brightest GRB** detected by AstroSat **CZTI**
- Show the signature of **thermal to non-thermal evolution** with time
- **Time-resolved polarisation** study can be used to further inspect such spectral evolution

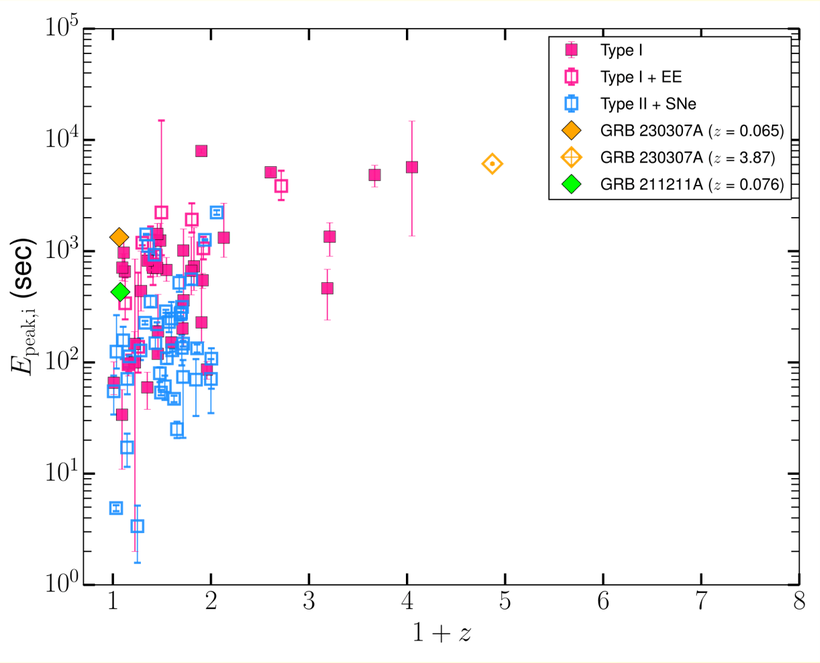


CLASSIFICATION

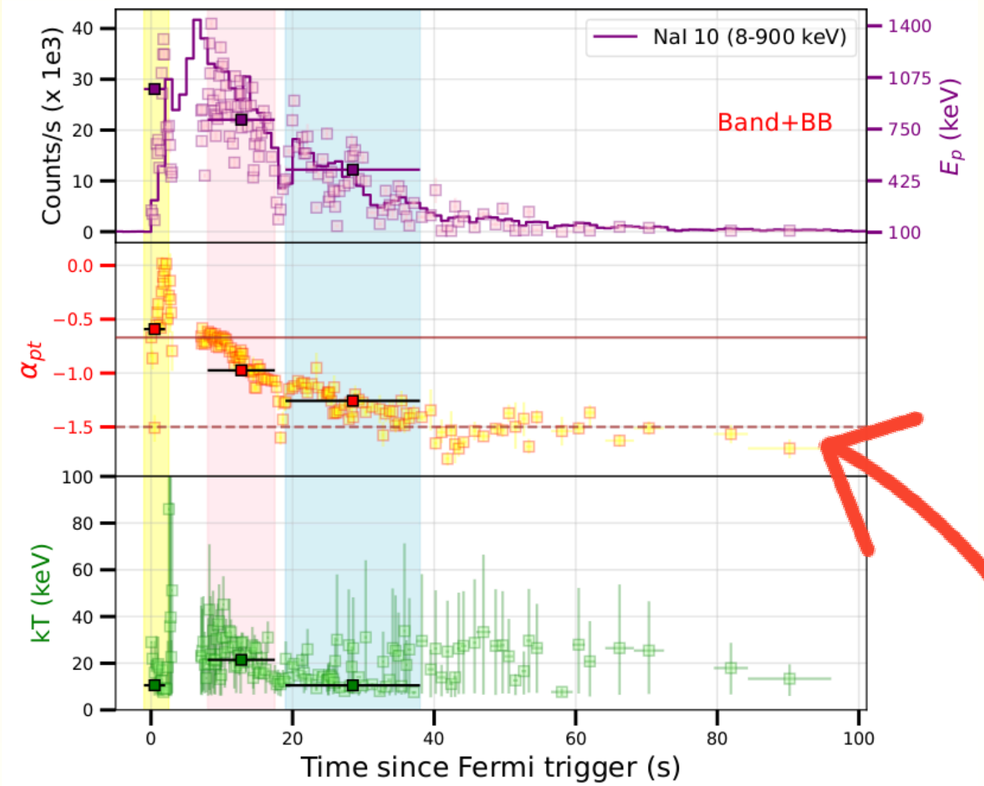
- Supports the case of **z=0.065**
- Resembles with the long burst, **GRB211211A**
- Association of **Kilonovae being a long burst**



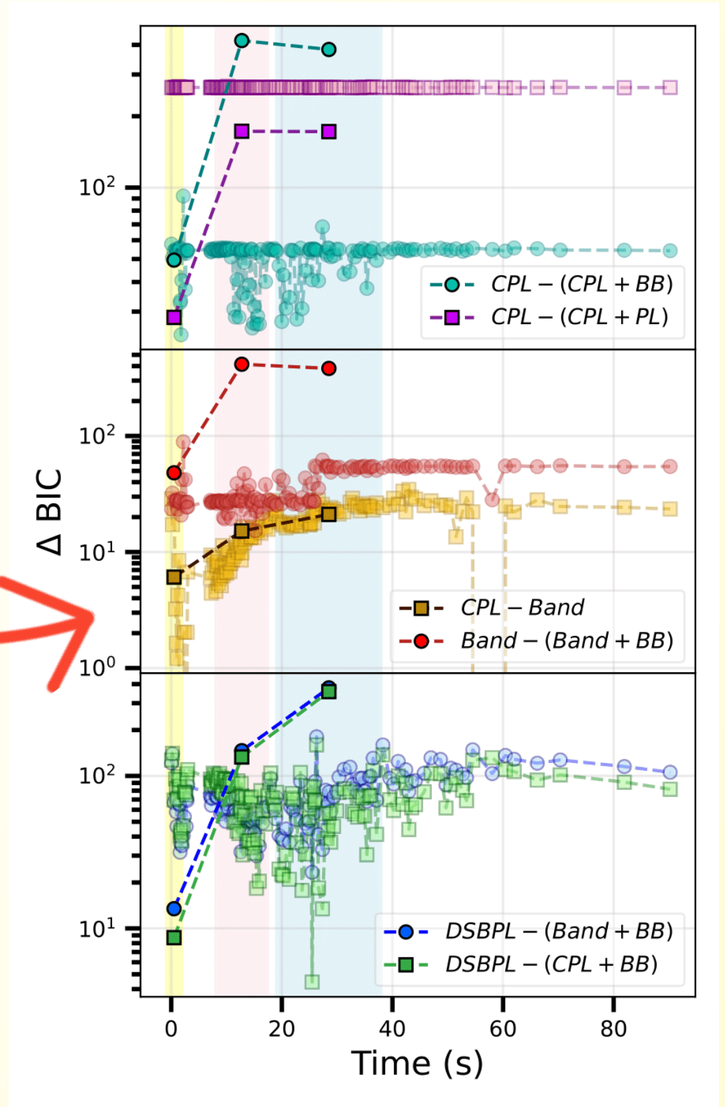




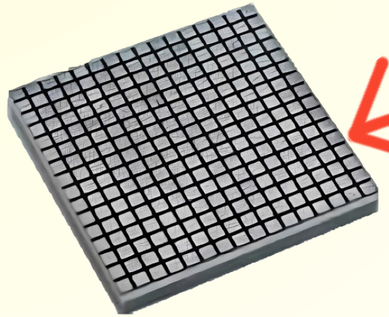
SPECTRAL ANALYSIS



- **Omitted the pile-up data** of Fermi GBM from spectral analysis
- The statistics suggested the **hybrid model Band + BB** is the best-fit model among all.
- Observed the evolution of low-energy spectral index from **hard(>-2/3) to softer** (**~-2/3 to -3/2**)

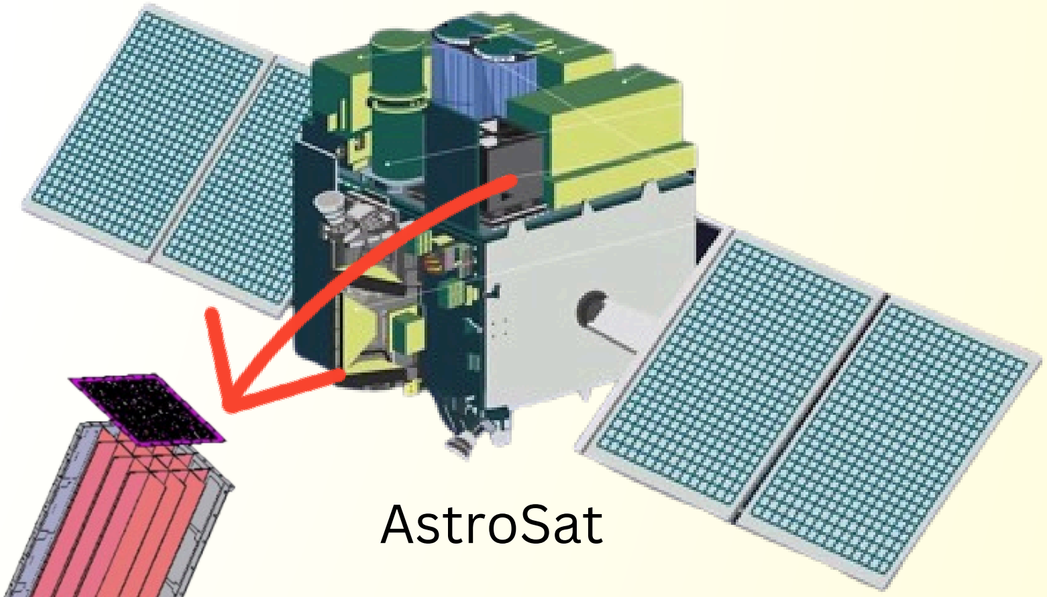


POLARISATION STUDY

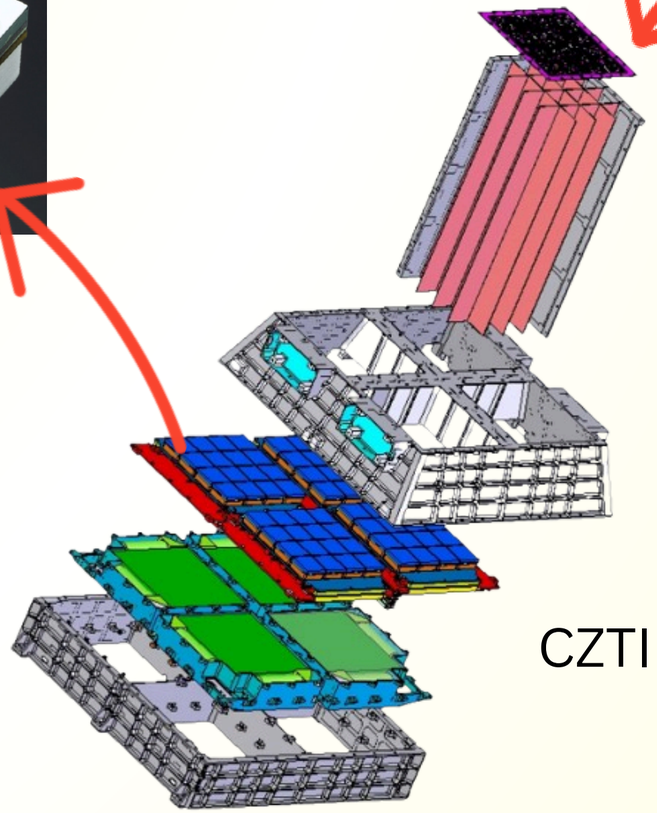


- Each module has **256** pixels (16x16)
- **~2.5mm** size
- **~20 us** time resolution

- Total **64** module
- **~1000 cm2** collecting area
- **5mm** thick



AstroSat



CZTI

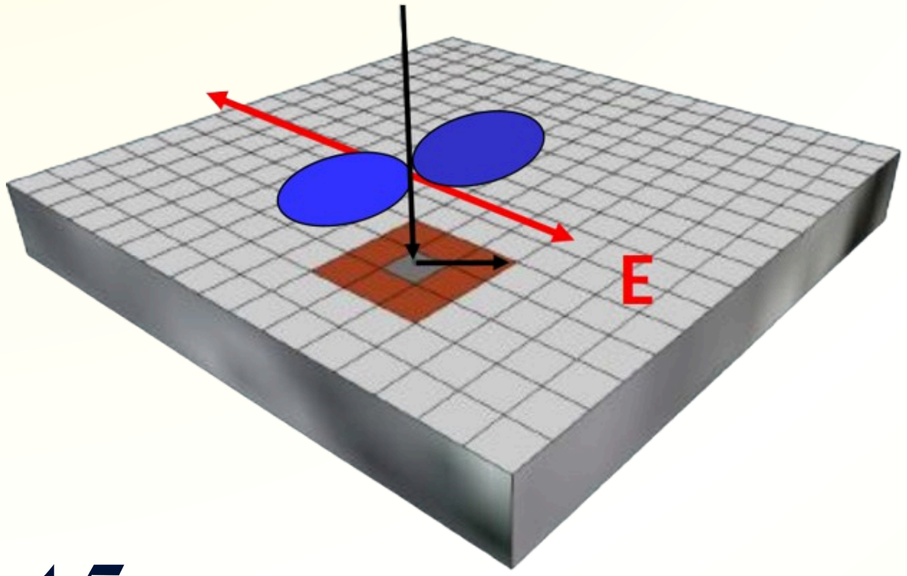
Bhalerao et al(2017)

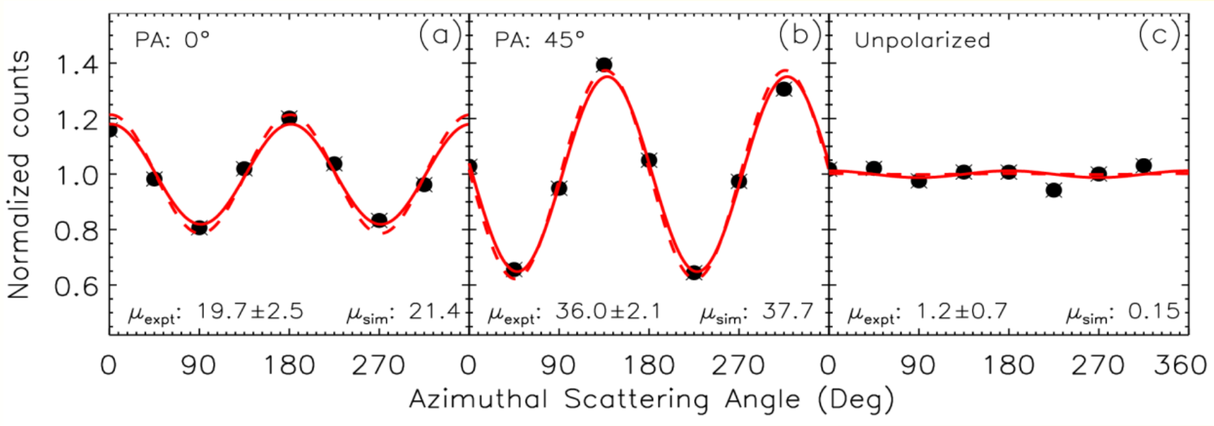
POLARISATION STUDY

5 mm thick CZT has a finite probability of **Compton Scattering** above **100 keV**

Polarisation Range ~100-600 keV

Possible **scattering in perpendicular to polarisation direction** -> Asymmetry in the azimuthal angle distribution





- The polarimetry technique was verified in the lab before the launch (Chattopadhyay et al 2014; Vadawale et al 2015)
- For GRBs, we **developed a mass model and verified it** against lab data (Vaishnava et al 2022)

The cookbook and pipeline going public soon!

Explore the GRB polarisation with AstroSat CZTI

The Astrophysical Journal, 936:12 (13pp), 2022 September 1 https://doi.org/10.3847/1538-4357/ac82ef

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OPEN ACCESS

Hard X-Ray Polarization Catalog for a Five-year Sample of Gamma-Ray Bursts Using AstroSat CZT Imager

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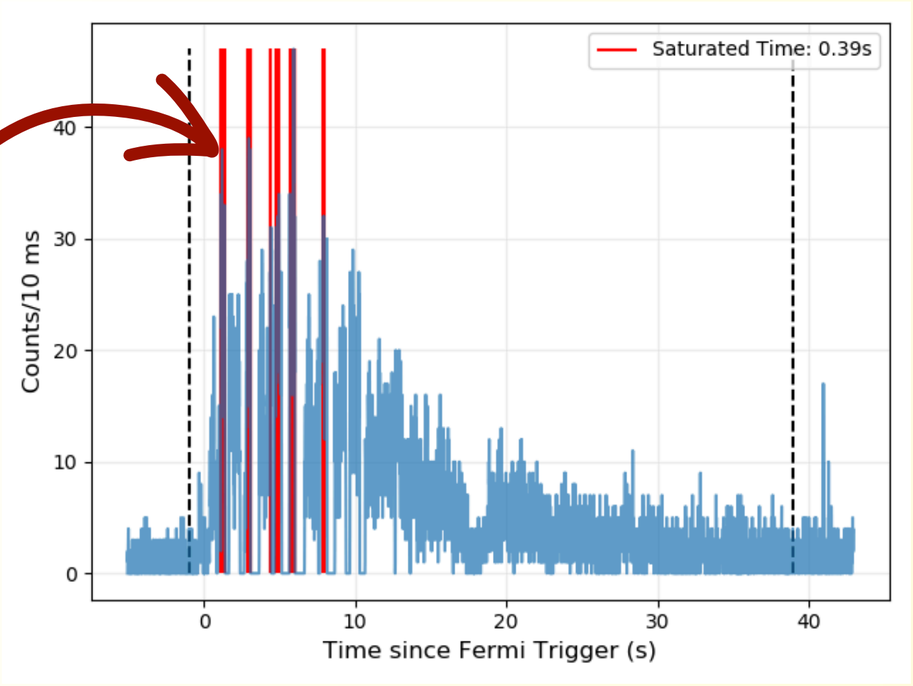
POLARISATION STUDY

- Above the detector threshold, **~10% of the Compton events** will be tagged **as triple bunches** while **~10-20% of single events** as **double events.**
- Data **above the detector threshold omitted**
- **Corrected for the livetime** to obtain the correct GRB duration
- Performed analysis for individual quadrants to check consistency



POLARISATION STUDY

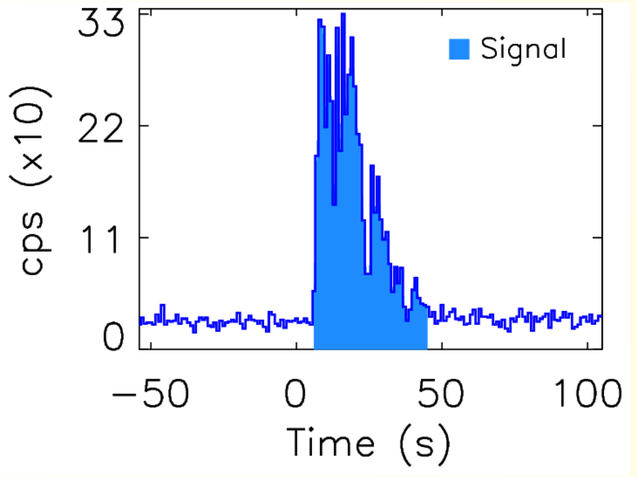
It is **consistent with most GRBs** that are unpolarised reported by **POLAR and AstroSAT** observations.

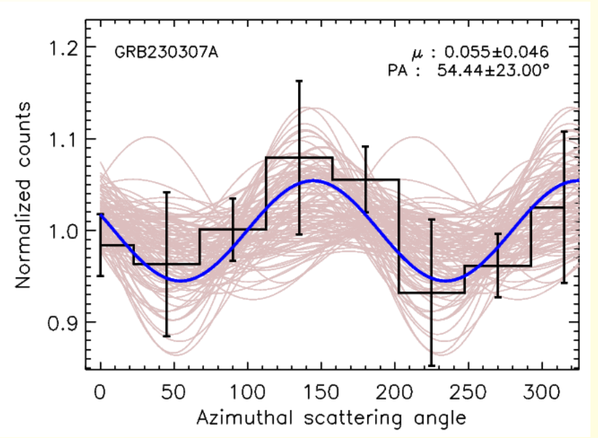
The Bayes Factor is the deciding criterion in the analysis for the burst to be polarised/unpolarised
BF >3 POLARISED

TIME-AVERAGED RESULT

UNPOLARISED

BF 0.97

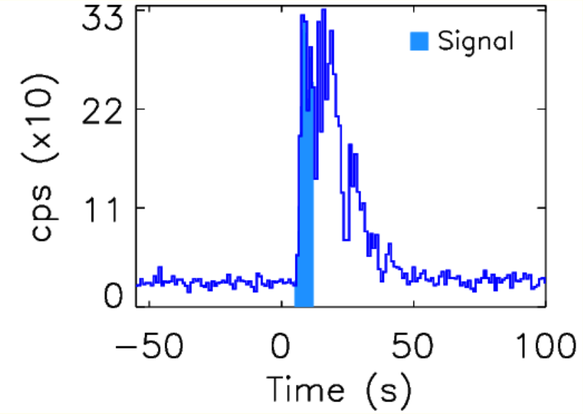


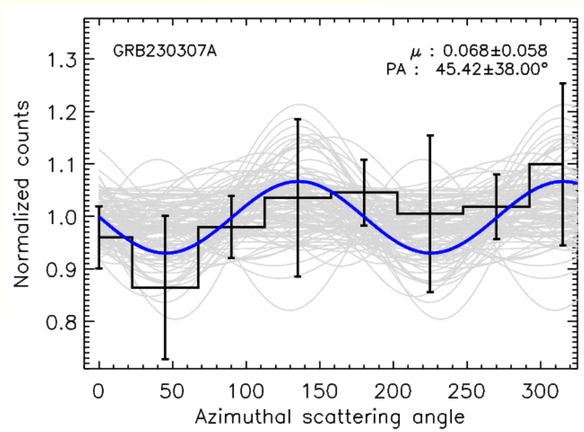


POLARISATION STUDY

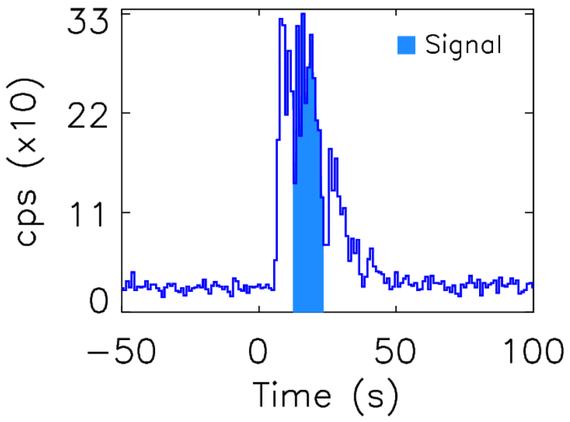
UNPOLARISED

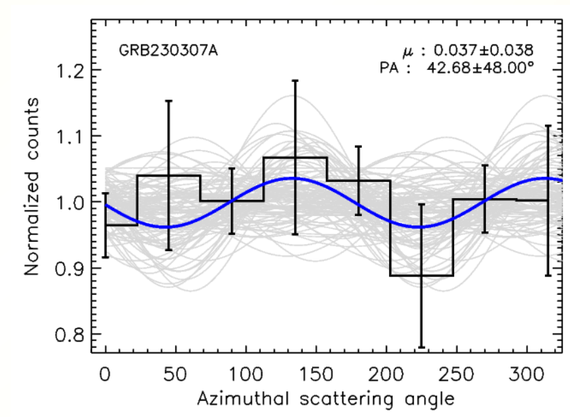
BF: 0.72





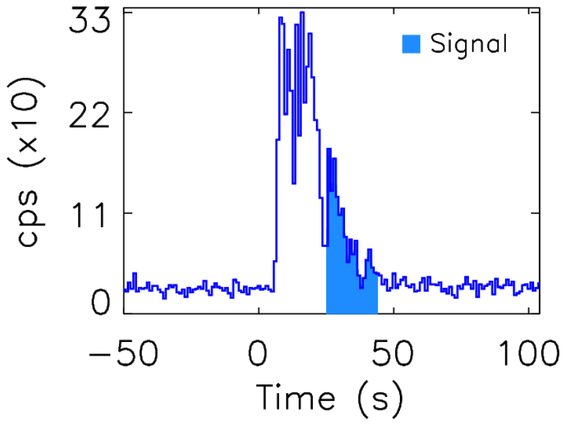
BF: 0.70

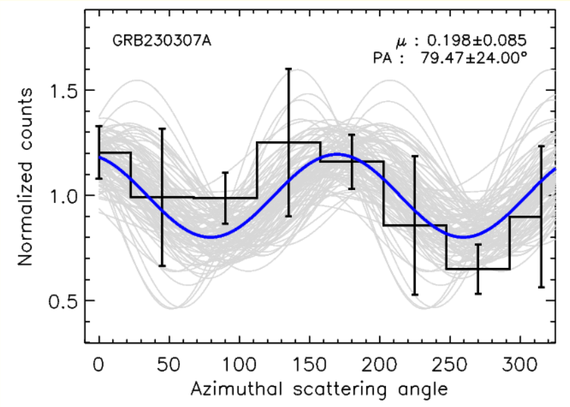




POLARISED

BF: 4.47

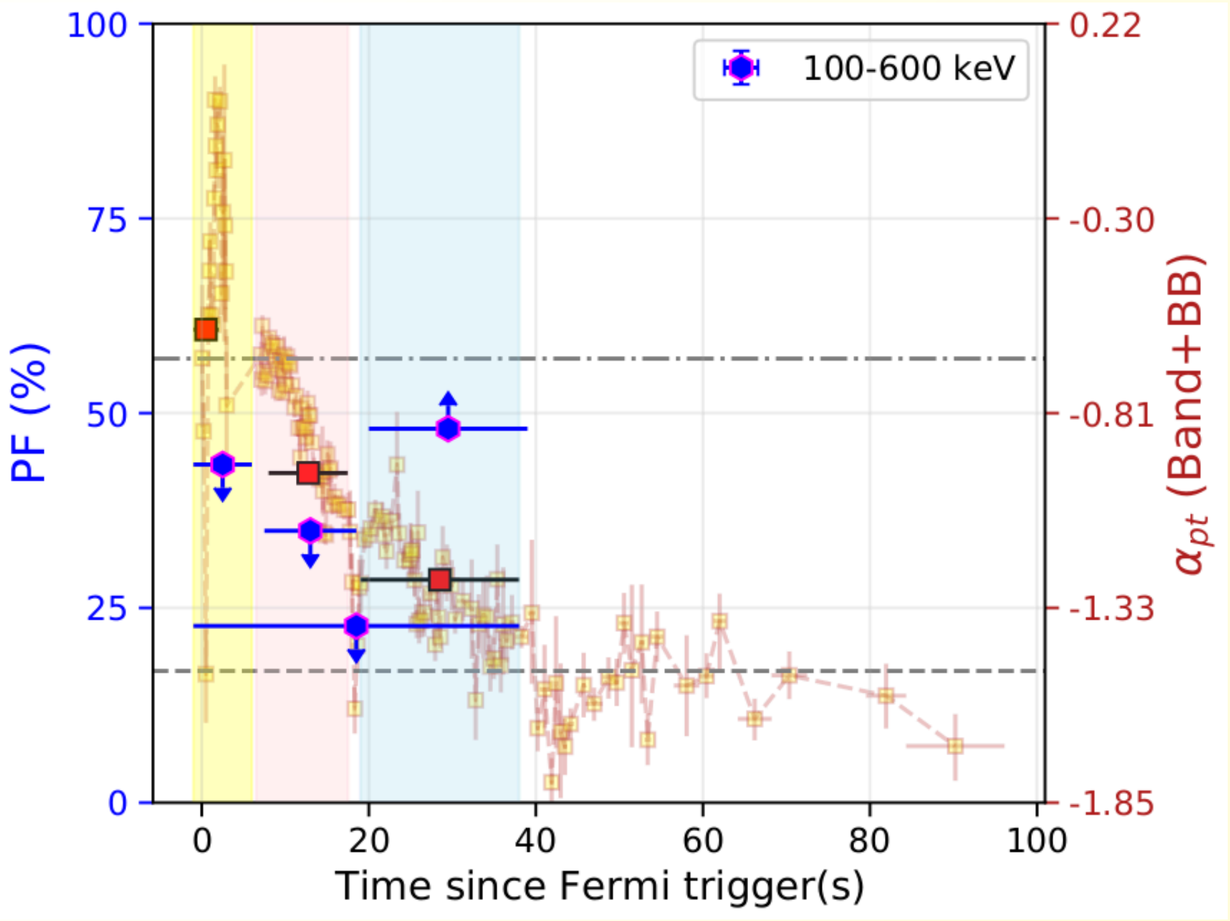




POLARISATION STUDY

The Polarisation Observation supports the Spectral Results

Thermal to Non-Thermal Evolution of Burst



CONCLUSIONS

- **GRB 230307A is a hybrid burst, long GRB with kilonovae association**

- **This is the brightest burst for which Spectro-polarimetry analysis has been attempted ever.**

- **Spectro-polarimetry study shows a matter-dominated to pointing flux-dominated nature.**
  - **harder to softer evolution** of the spectral index.
  - **unpolarised to polarised signatures**.

Investigating GRB 171227A Prompt Phase under the Relativistically Expanding Fireball Scenario

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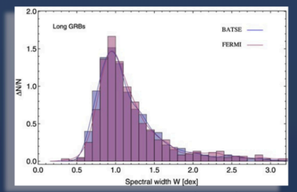
Fermi Gamma-ray Space Telescope

11TH INTERNATIONAL FERMI SYMPOSIUM

Motivation

- In the study by Axelsson et al (2015), it has been shown the FWHM for the distribution of ~1800 GRBs peaks at ~1 which is broader than a Planck Function while narrower than the typical synchrotron spectrum. In an attempt to explain the unusual FWHM of GRBs, we considered the thermal spectra under the relativistically expanding fireball model with its temperature evolving as a function of its radius.



Axelsson et al 2015

- The emission process of the prompt phase of the GRB is still an open question. Observations from the GBM onboard the Fermi Gamma-Ray space telescope suggest the presence of a thermal component along with the non-thermal, whose origin is unintelligible. The thermal radiation from the GRB is modelled using the evolving fireball scenario to study the dynamics of the early phase of the burst.

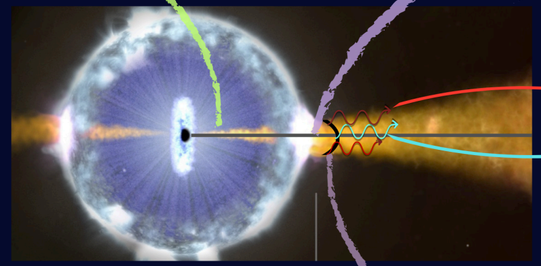
A numerical code developed and coupled with XSpec, under this scenario is employed to reproduce the spectrum of one of the bright Fermi GRB detected GRB 171227A.

Optical Depth

$$\tau(r,\theta) = \frac{r_d}{\pi r}(\theta - \beta\sin\theta)$$

Photospheric Radius

$$R_{ph}(\theta) = \frac{R_{ph0}}{(1-\beta)}\left(\frac{\theta}{\sin\theta} - \beta\right)$$



Picture Credits: NASA

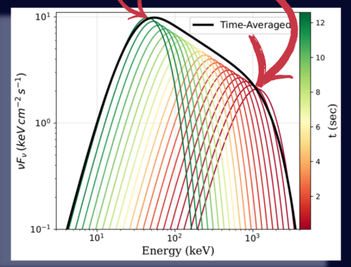
Temperature-Variation with expansion

$$\frac{T_\theta}{T_0} = \left[\frac{R(0)}{R(\theta)}\right]^\alpha = \left(\frac{1-\beta\cos\theta}{1-\beta}\right)^\alpha$$

Ranges from 0 to 2/3 depending on the dynamics of the fireball (Piran et al 1993)

Radially (Time)-Averaged Spectrum

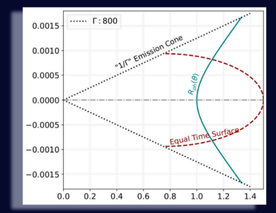
$$\mathcal{F}_\nu = \frac{\int_{R_1}^{R_2} F_\nu(x)\,dx}{R_2 - R_1}$$



Instantaneous Flux

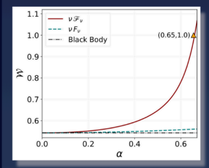
$$F_\nu = 4\pi h\nu^3\left[\frac{(1-\beta)R(0)}{cD_L}\right]^2 \times \int_{\cos\phi}^{1} \frac{\mu}{(1-\beta\mu)^2}\,\frac{\zeta(\theta)\,d\mu}{\left\{\exp\left[\frac{h\nu}{kT_{ph0}}\left(\frac{R(0)}{R_{ph0}}\frac{1-\beta}{1-\beta\mu}\right)^\alpha\right] - 1\right\}}$$

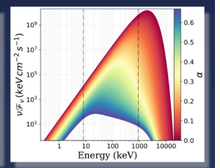
Initially the Opening angle will be smaller than 1/ Γ



Key Findings

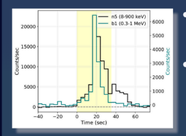
- The modified thermal spectra have a strong dependence on the α.
- Observed widths ranging from ~0.54 to 1.15 by varying α between 0 to 2/3.
- The FWHM ~1 was obtained for the α of 0.653.
- Most GRBs are in the Matter-dominated phase of fireball (Piran et al 1993)



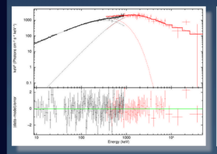


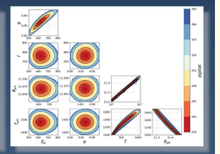
- These results are published in ApJL (Soumya et al 2024)

GRB 171227A (Preliminary Results)



- Single Pulse with T90 of 38 s.
- Fluence of (305.3 +/- 1.3) E-06 erg/cm^2 in 10-1000 keV energy range.
- Best Fit model: CPL + mBB.
- Degeneracy in parameters of mBB.





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