Time Resolved Spectral Fit of the Exceptionally Luminous GRB 130427A

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Abstract

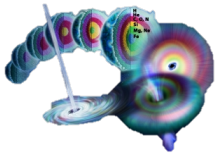
To more accurately understand the intense astronomical events known as Gamma-ray Bursts (GRBs) we spectrographically analyzed GRB 130427A. GRB 130427A Is the brightest GRB ever observed due to its close proximity to our galactic region, thus making it an ideal candidate for analysis of GRB gamma emission. We show here that this gamma ray burst is well fitted with a combination of two components. A thermal component which most likely originates from the GRB jet photosphere and the non-thermal component compatible with synchrotron emission.

Introduction

- Gamma-ray Bursts represent the most energetic electromagnetic events to be observed in the universe.
- One of the most important astrophysical aspects of a GRB is the central engine and its progenitor.
- GRB central engines are believed to be a stellar-mass black hole or rapidly rotating neutron stars with a strong magnetic field (magnetars).
- GRB central engines would result from the collapse of a massive star or the merger of two compact objects (two neutron stars).
  - The latter case was recently observed simultaneously with a gravitational wave signal

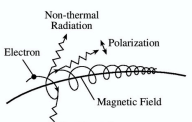
b.) Artist's illustration of one model of the bright gamma-ray burst GRB 08039B

a.) Artist's illustration showing the life of a massive star



Technical Overview and Challenges

- Although GRBs have been known within the mainstream scientific community for nearly half a century, many GRB phenomena are still unknown.
- The most fundamental questions surrounding GRBs are primarily focused on the emission mechanism that generates the gamma-rays.
- One of the most accepted explanations of the nature of the physical processes at play in creating the observed photons is that of synchrotron radiation.
- The jet of GRBs have very strong local magnetic fields and the surrounding electroı accelerated and radiate as synchrotron emission.

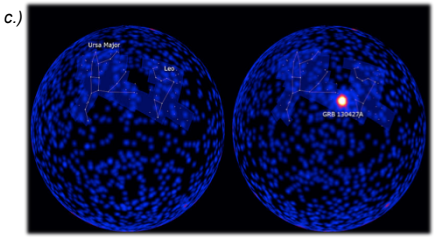


c.) Visualization of synchrotron radiation

Dynamics of the Gamma Ray Burst 130427A (*Monster in the Garden*)

- Observed in April, 2013, GRB 130427A is one of the most energetic GRBs ever recorded.
- GRB 130427A had an extremely high-energy photon range (95 GeV), or nearly 35 billion times the energy of visible light, and an extremely large fluence.
- The light curve has multiple peaks with the first peak occurring from 0 s to 1 s along with a recorded luminosity greater than most observed GRBs.
- A reason for the high luminosity of this GRB is because of its close proximity to our galactic region.
- *Figure c.* shows the gamma-ray energies of the observable region in comparison to GRB 130427A.

c.)



Analysis: Procedure

- We collected the spectral-temporal data of GRB 130427A--observed with Fermi Gamma-ray Space Telescope--from the NASA archives.
- The spectral analysis was completed with the RMfit software package (background fit, source selection, time and energy source selection, and fit of a spectral model).
- The burst emission was captured by three sodium iodide (NaI) scintillators (6, 9, 10) and one cylindrical bismuth germanate (BGO1) scintillator of the *Fermi*/Gamma-ray Burst Monitor (*Fermi*/GBM).
  - The NaI detectors are sensitive from 8 keV to about 1 MeV and provide burst triggers and locations
  - The BGO detectors covers ~200 keV to ~40 MeV, providing a good overlap with the NaI detectors
- We fitted 2 different models (Band & Band + Black Body) with a combination of components to 16 separate time intervals using the maximum likelihood approach (Cstat).
- We estimated the background for each detector by fitting a polynomial function before and after the burst, and extrapolating it during the burst onset.

Analysis: Result

- Instead of providing all 16 separate fits below, we have chosen a specific time interval that effectively represents the data as a whole.
  - Noted by the yellow hatch marks in *figure 1* the burst selected was observed at the time interval of 3.520 s to 4.200 s
- From this fit we recorded the following parameters:
  - Alpha (*α*) is the index of low energy power laws of the band function.
  - Beta (*β*) is the index of high energy power laws of the band function.
  - Epeak (keV) is the maximum of the NuFu spectrum as seen in *figure 2.*
  - Cstat is a measure of the the goodness of fit for binary outcomes in a maximum likelihood model.
  - Reduced χ^2 is a measure of model convergence, model comparison, and error estimation.

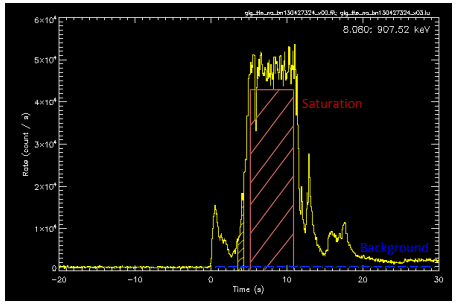


Figure 1.

Model \ Component	Band			Black Body	Cstat/dof	Reduced χ^2
	α	β	Epeak (keV)	kT (keV)		
Band	*-0.635 +/- 0.0186*	*-2.589 +/- 0.0667*	*319.1 +/- 8.11*	-	*639.12/467*	*1.28*
Band + Black Body	*-0.728 +/- 0.0279*	*-3.034 +/- 0.172*	*413.6 +/- 17.2*	*25.30 +/- 2.07*	*600.25/465*	*1.22*

Spectral Fits

Thermal Spectral Display (Band)

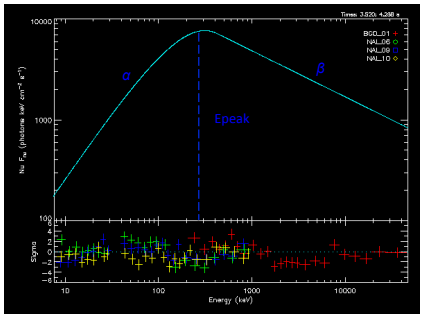


Figure 2.

Thermal & Non-Thermal Spectral Display (Band + Black Body)

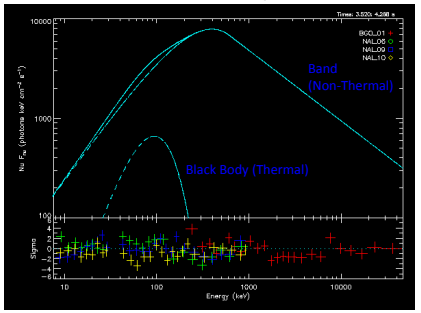


Figure 3.

Conclusion

- As observed in the table and spectral fits provided the two component model supports lower Cstat and reduced χ^2 values, thus indicting that the two component model (Band + Black Body) is the best fit.
- Additionally, the observed *α and β* values accurately support our spectral analysis as similar values have been observed in existing scientific literature for GRB 130427A.
- Due to this analysis the following observations can be made:
  1. The thermal component (Black Body) is believed to originate from the jet photosphere.
  2. The non-thermal component (Band) is compatible with synchrotron emission.

Bibliography

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