The Viability of the Synchrotron Shock Model as a Prompt Emission Mechanism in the Era of Fermi

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Overview

• Synchrotron Shock Model
  • Electron Distributions
  • Synchrotron Emmissivity
  • Past Results

• Observations
  • Case Study: GRB 090820A

• Conclusions and Future Work
Synchrotron Shock Model

e- distribution

\[ n_e(\gamma, \theta) = n_\theta \left[ \left( \frac{\gamma}{\gamma_{th}} \right)^2 e^{-(\frac{\gamma}{\gamma_{th}})} + \epsilon \left( \frac{\gamma}{\gamma_{th}} \right)^{-\delta} \Theta \left( \frac{\gamma}{\eta \gamma_{th}} \right) \right] \]


- The electron distribution is parameterized into two terms: a relativistic Maxwell-Juettner distribution and supra-thermal power law tail.

- The power-law tail would be the result of an acceleration process e.g. the Fermi mechanism.

\[ n_e(\gamma, \theta) = \text{Thermal} + \text{Non-Thermal} \]

\( \epsilon \): efficiency
\( \delta \): power-law index
\( \eta \): non-thermal minimum energy

\[ n_e(\gamma, \theta) \approx 10^{-4} \text{ for } n_\theta = 1 \]
Synchrotron Shock Model

Single particle synchrotron emissivity

\[ n_s(\gamma, \epsilon) \propto \int_{\epsilon/c}^{\infty} K_{5/3}(x) \, dx \]

Total synchrotron emissivity

\[ \int \int n_e(\gamma, \theta)n_s(\gamma, \epsilon)d\gamma d\theta \]

\[ F_\nu \propto B_{ps} n_{tot}(\epsilon) \]

\[ \epsilon_c \propto \Gamma B_{ps} \gamma_{th} \]

- The single particle emissivity is convolved with the electron distribution to produce a photon model.
- The resulting spectrum can be fit in the GBM data allowing a determination of \( \epsilon_c \), \( \delta \), \( n_\theta \), and \( \epsilon \). This allows for us to measure the underlying electron distribution.
Synchrotron radiation (preferred paradigm) fits most burst spectra - index below 100 keV is key ("line of death": Preece et al. 1998, 2000) issue;

But, underlying electron distribution is predominantly non-thermal, i.e. unlike a variety of shock acceleration predictions (e.g. PIC codes, hybrid codes, Monte Carlo simulations): see Baring & Braby (2004).
• Black body radiation at the same temperature as thermal synchrotron peaks lower in energy. The two photon models are coupled by the underlying electron distribution’s thermal energy.

• For more on the recent observations of thermal emission in GRBs see Guiriec et al. (2010) [arXiv:1010.4601v1](http://arxiv.org/abs/1010.4601v1)
Observations

GRB 090820A (V. Connaughton, GCN 9829)

- **Why this burst?**
  - One of the brightest GBM bursts
  - FRED like structure
  - Bright in a BGO detector

- **Features**
  - One main peak plus and additional weak peak at $T_0 + 45$ s
  - Out of LAT FOV

The goal is to examine 4 bins (A, B, C, and D) in order to demonstrate the feasibility of the model and examine the time evolution of the parameters.
Observations

**Thermal Synchrotron**

- **Amplitude**: $0.2750 \pm 0.0499$ p/s-cm$^2$-keV
- **Critical Energy**: $12.16 \pm 1.44$ keV

**Bin A**: 28.672 - 30.72 s
Observations

Best Fit Parameters

**PL Synchrotron + Black Body**

- Amplitude PL: 3212. ± 242 p/s-cm²-keV
- Critical Energy: 12.16 ± 1.44 keV
- PL Index: 5.2
- Eta: 3.000
- Amplitude: 2.04E-4 ± 3.71E-5 p/s-cm²-keV
- kT: 34.70 ± 1.49 keV

**Bin B:** 31.744 - 32.768 s
Observations

Best Fit Parameters

PL Synchrotron + Black Body
- Amplitude PL: 6340 +/- 301 p/s-cm²-keV
- Critical Energy: 15.61 +/- 0.42 keV
- PL Index: 5.2
- Eta: 3.000
- Amplitude: 8.42E-5 +/- 2.55E-5 p/s-cm²-keV
- kT: 41.11 +/- 3.22 keV

Bin C: 33.792 - 34.817 s
**Observations**

**Best Fit Parameters**

**Thermal Synchrotron + Black Body**
- Amplitude Th: 1.454 ± 0.216 p/s-cm²-keV
- Critical Energy: 6.530 ± 0.676 keV
- Amplitude: 3.8E-5 ± 1.21E-5 p/s-cm²-keV
- \( kT \): 39.99 ± 3.80 keV

**Bin D**: 40.961 - 41.99 s
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<th>C-STAT/DOF</th>
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<td></td>
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<tr>
<td>Bin A</td>
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<td>Bin D</td>
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Observations

Best Fit
Conclusions and Future Work

• Identified physical components with distinct curvatures that are able to accurately fit GRB spectra.

• Identified interesting time evolution of parameters. Further investigations are necessary.

• Through the introduction of a black body component, this model naturally explains the line of death. (c.f. Guiriec et al 2010)

• Future studies may be extended to the LAT to aid in constraining the power law indices.