# 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

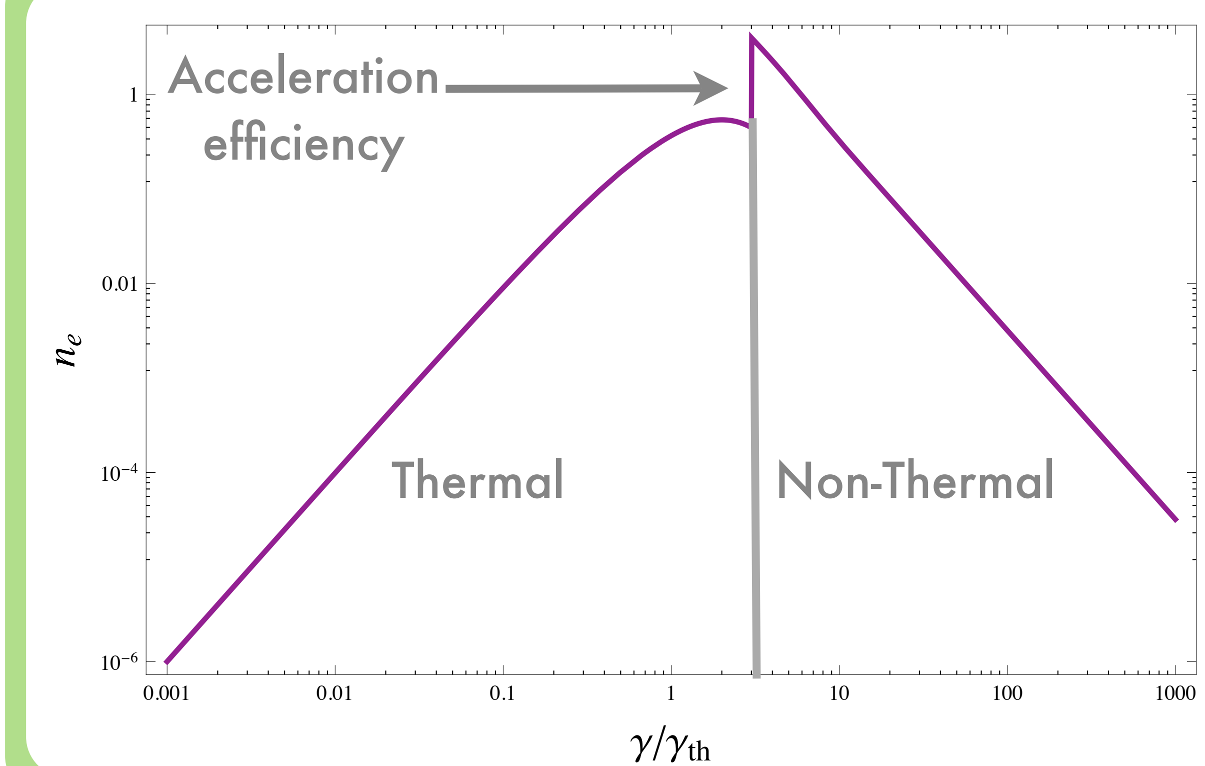
# Synchrotron Shock Model

## e⁻ distribution

$$n_e(\gamma,\theta) = n_\theta\left[\underbrace{\left(\frac{\gamma}{\gamma_{\rm th}}\right)^2 e^{-\left(\frac{\gamma}{\gamma_{\rm th}}\right)}}_{\text{Thermal}} + \epsilon \underbrace{\left(\frac{\gamma}{\gamma_{\rm th}}\right)^{-\delta}\Theta\left(\frac{\gamma}{\eta\gamma_{\rm th}}\right)}_{\text{Non-Thermal}}\right]$$

Baring & Braby (2004)

ε: efficiency
δ: power-law index
η: non-thermal minimum energy




- 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

# Synchrotron Shock Model

## Single particle synchrotron emissivity

$$n_s(\gamma,\epsilon) \propto \int_{\frac{\epsilon}{\epsilon_c}}^{\infty} K_{\frac{5}{3}}(x)\,dx$$

## Total synchrotron emissivity

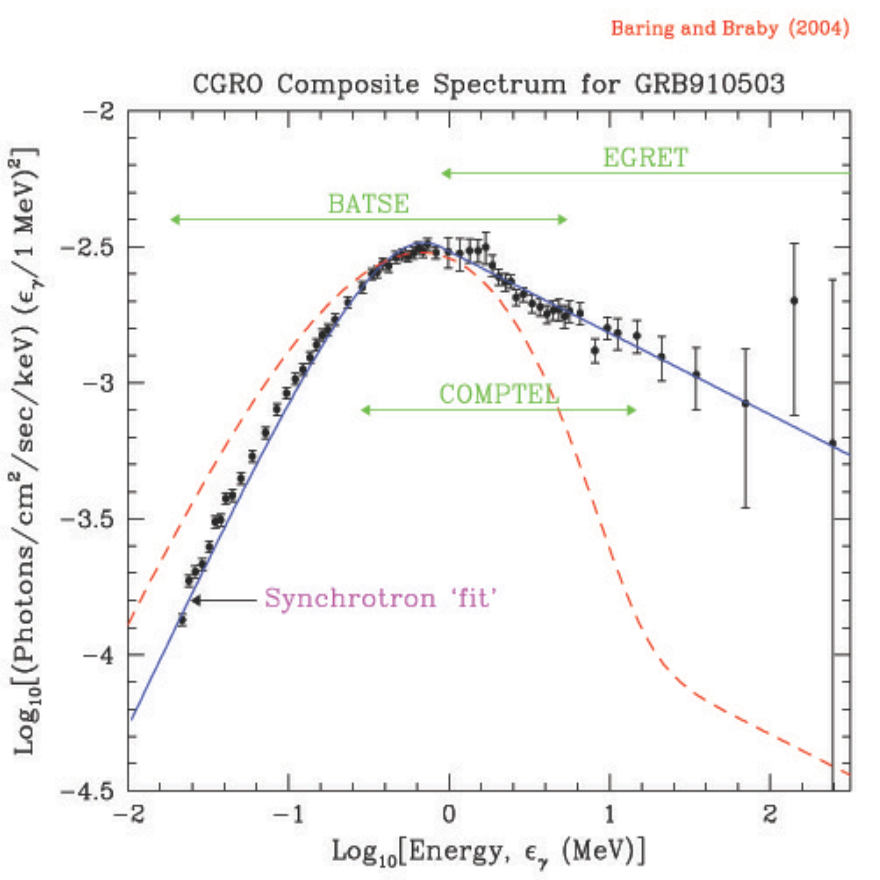
$$\int\int n_e(\gamma,\theta) n_s(\gamma,\epsilon) d\gamma d\theta$$

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

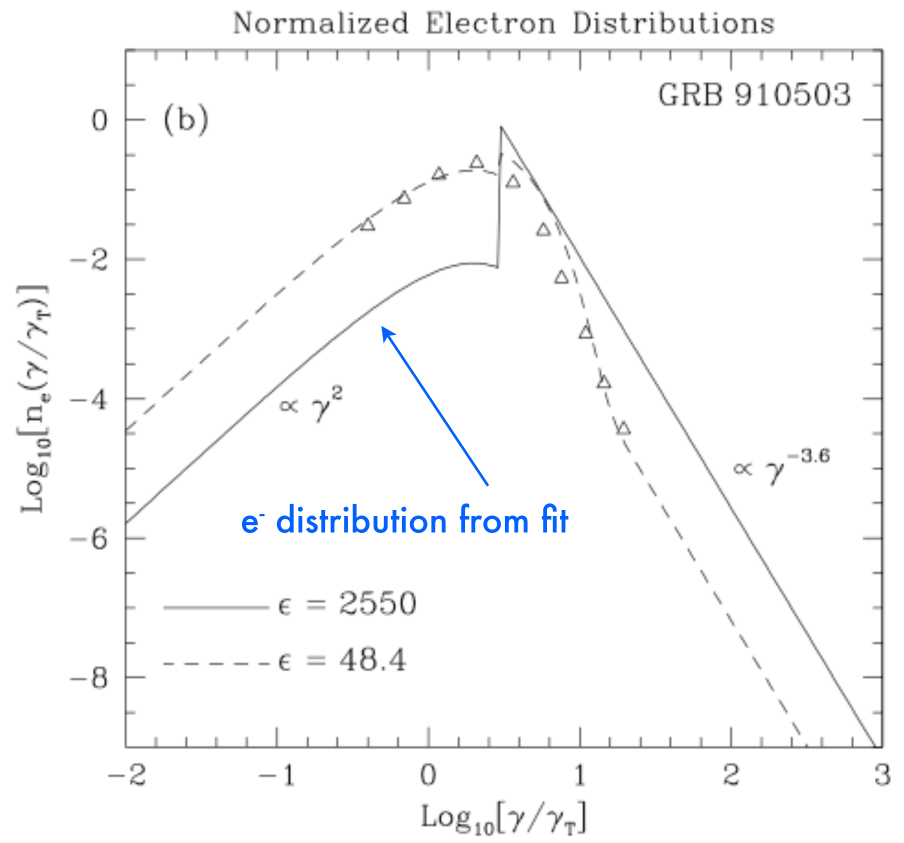
$$\epsilon_c \propto \Gamma B_{ps} \gamma_{th}$$

- 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 $\varepsilon_c$ , $\delta$, $n_\theta$ , and $\in$. This allows for us to measure the underlying $e^-$ distribution

# Synchrotron Shock Model



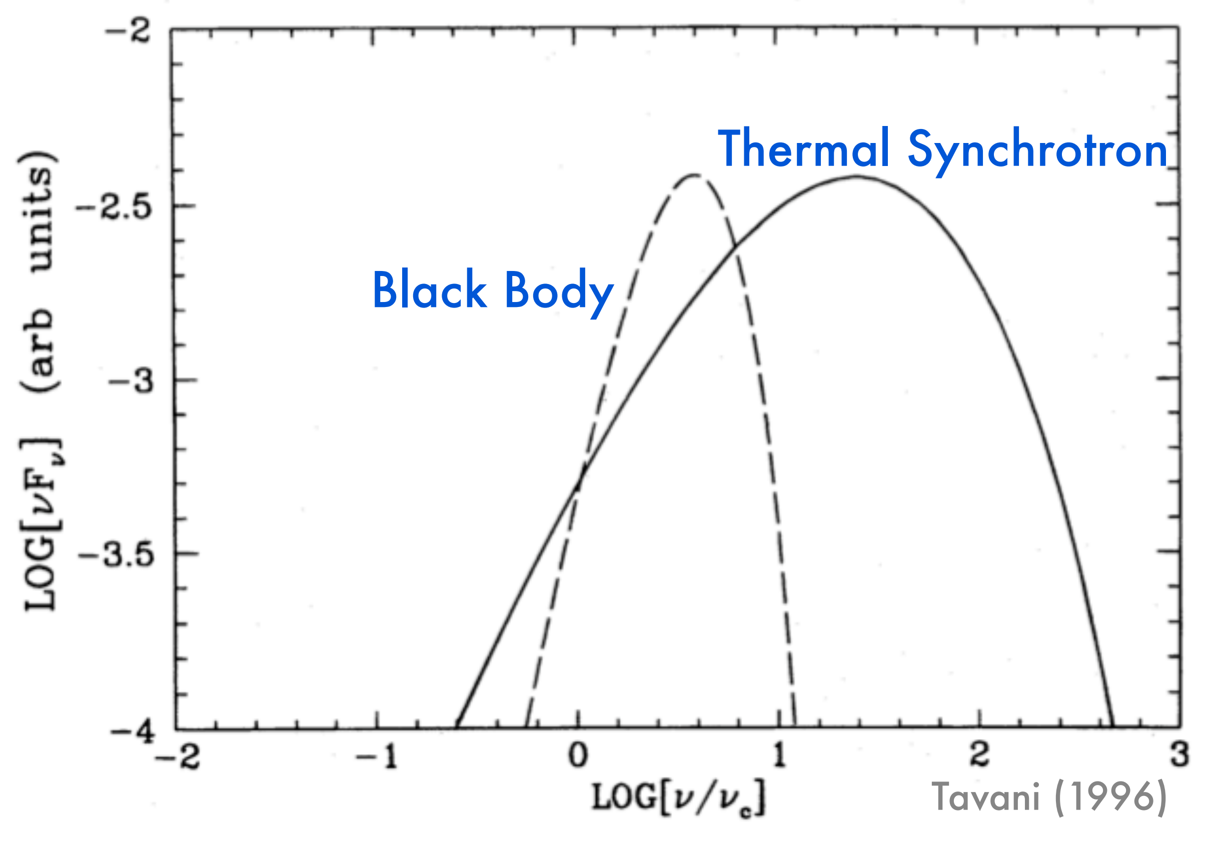

Photon spectrum




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).

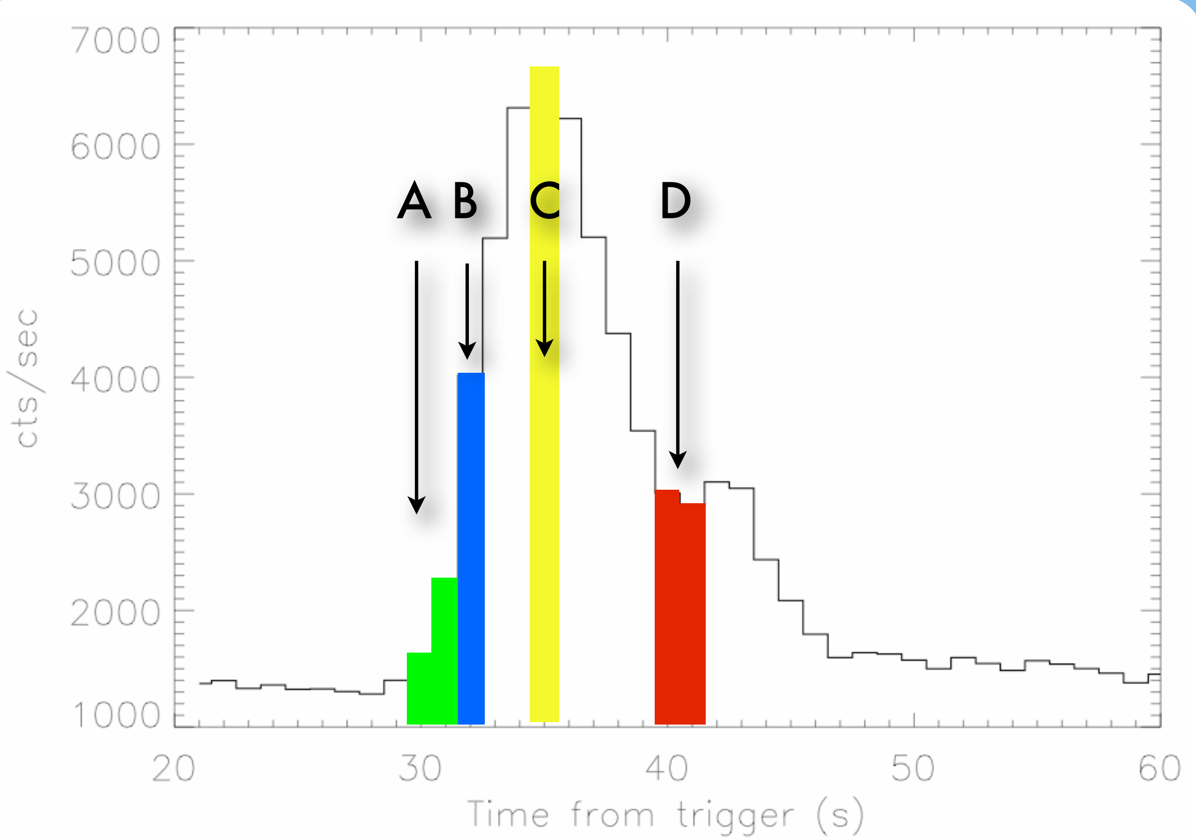
# Synchrotron Shock Model




- 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

# Observations

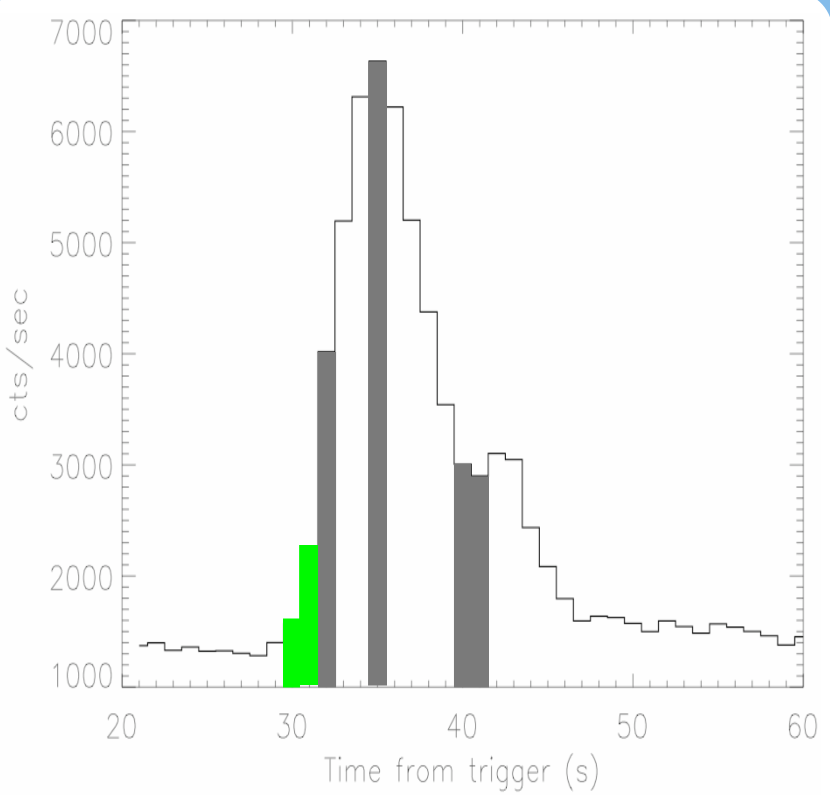
## GRB 090820A (V. Connaughton, GCN 9829)

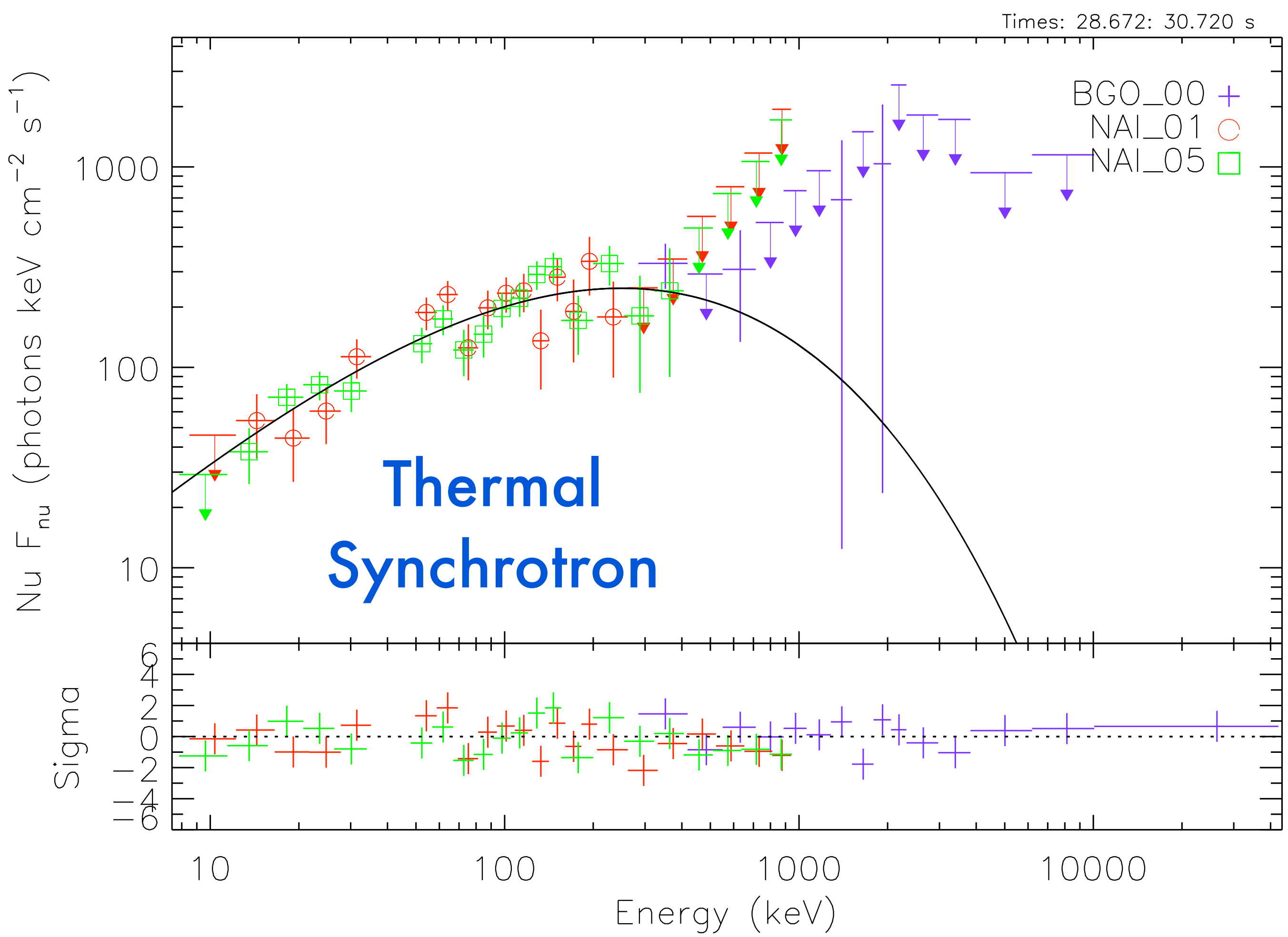



- Why this burst?
  - One of the brightest GBM bursts
  - FRED like structure
  - Bright in a BGO detector
- Features
  - One main peak plus and additional weak peak at $T_0 + 45$ s
  - Out of LAT FOV

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



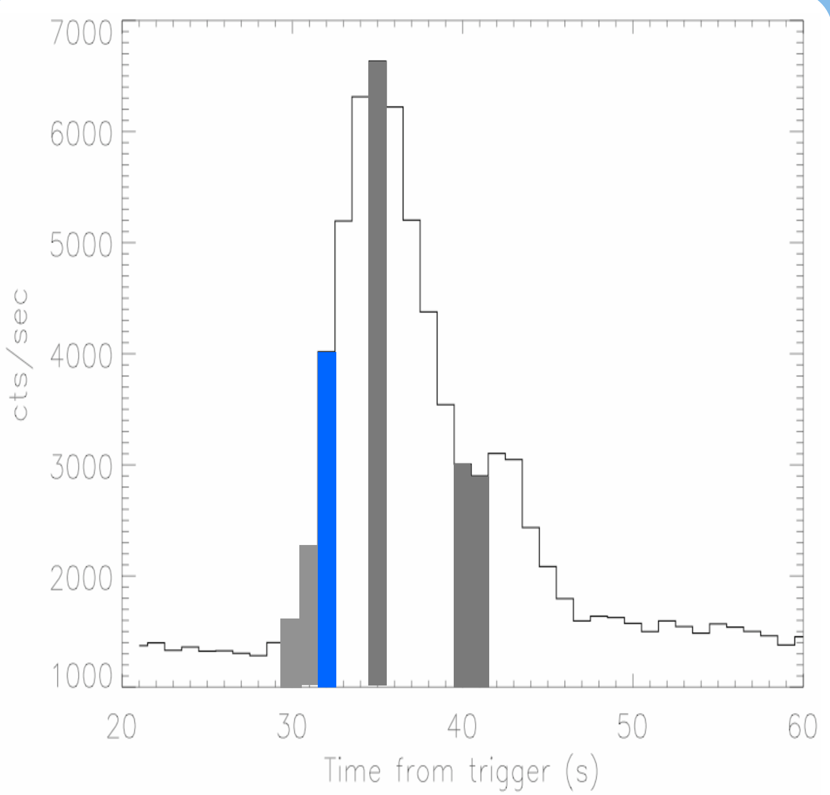



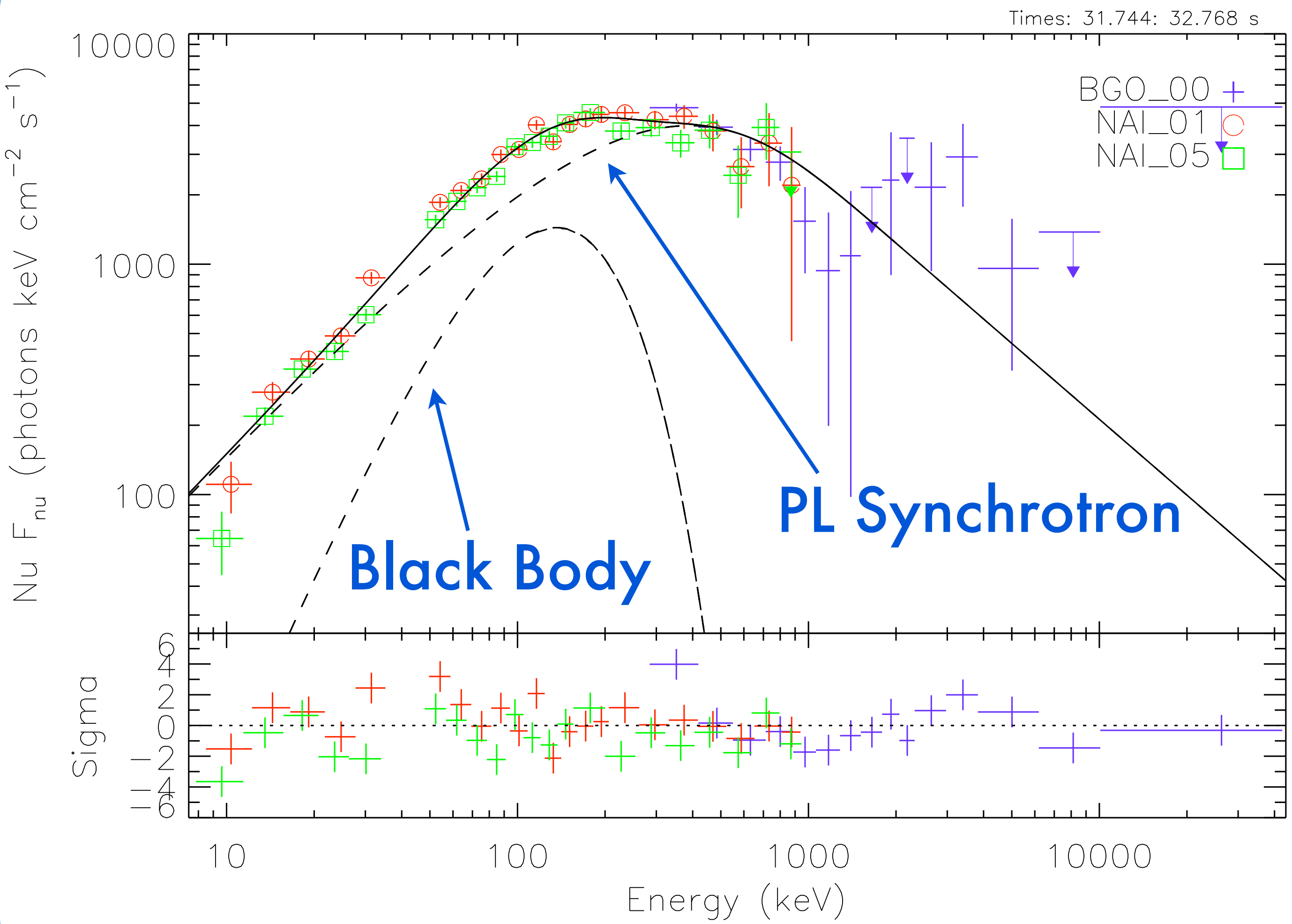

<u>Thermal Synchrotron</u>

| | | | | |
|---|---|---|---|---|
| Amplitude | 0.2750 | +/- | 0.0499 | p/s-cm2-keV |
| Critical Energy | 12.16 | +/- | 1.44 | keV |

<u>Bin A</u>: 28.672 - 30.72 s

# Observations



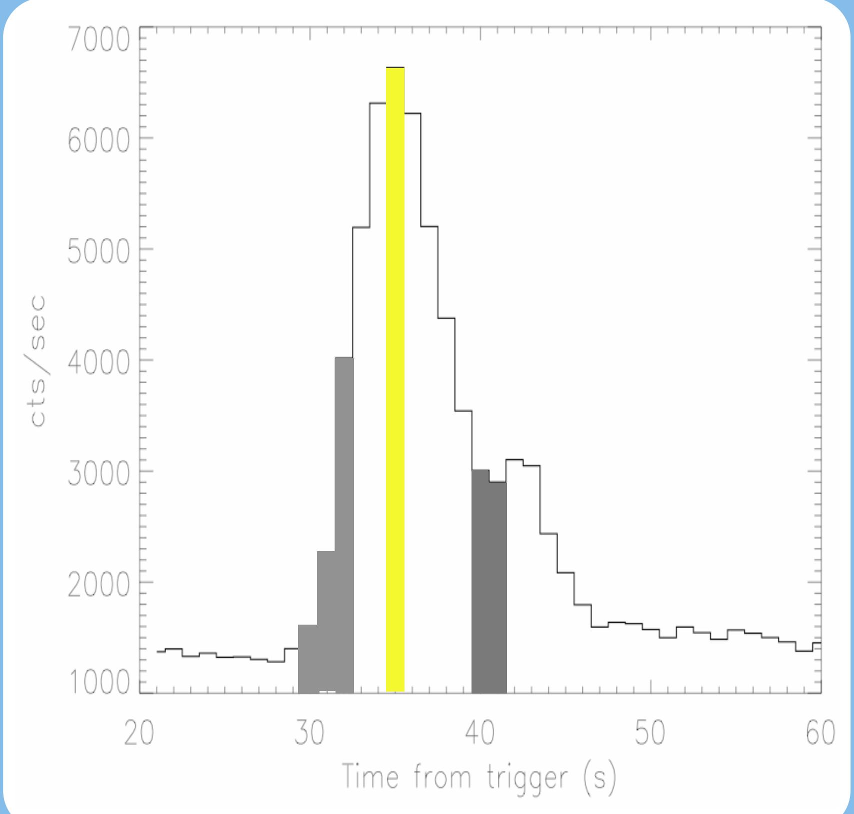

## Best Fit Parameters

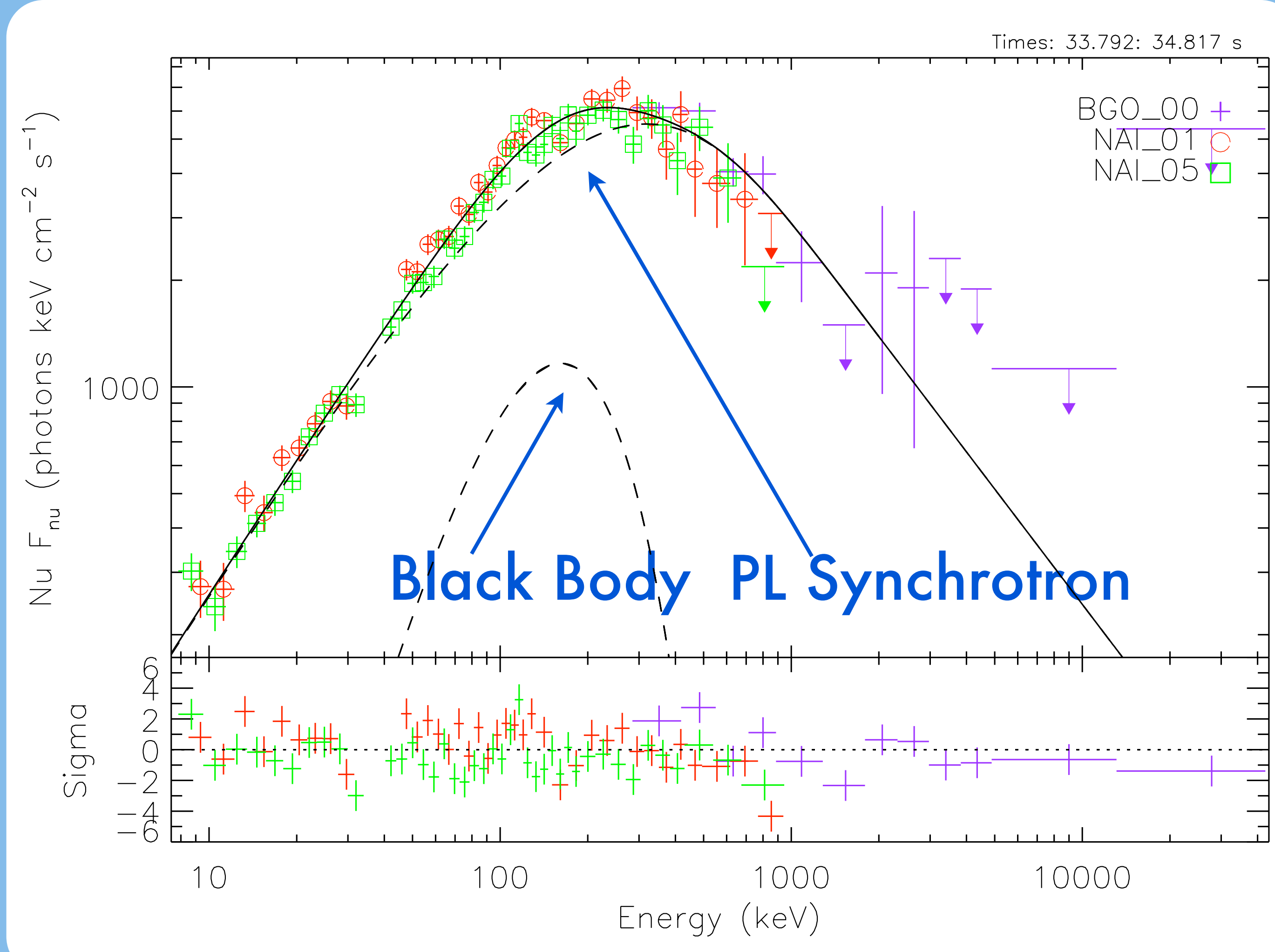
PL Synchrotron + Black Body

| | | | | |
|---|---|---|---|---|
| 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



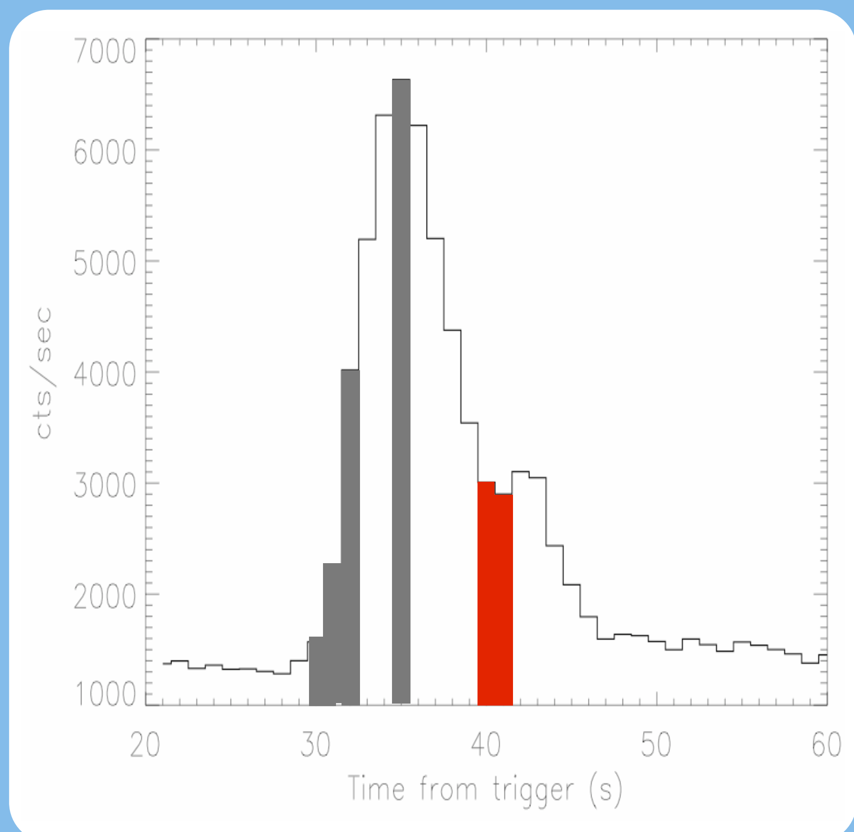

## Best Fit Parameters

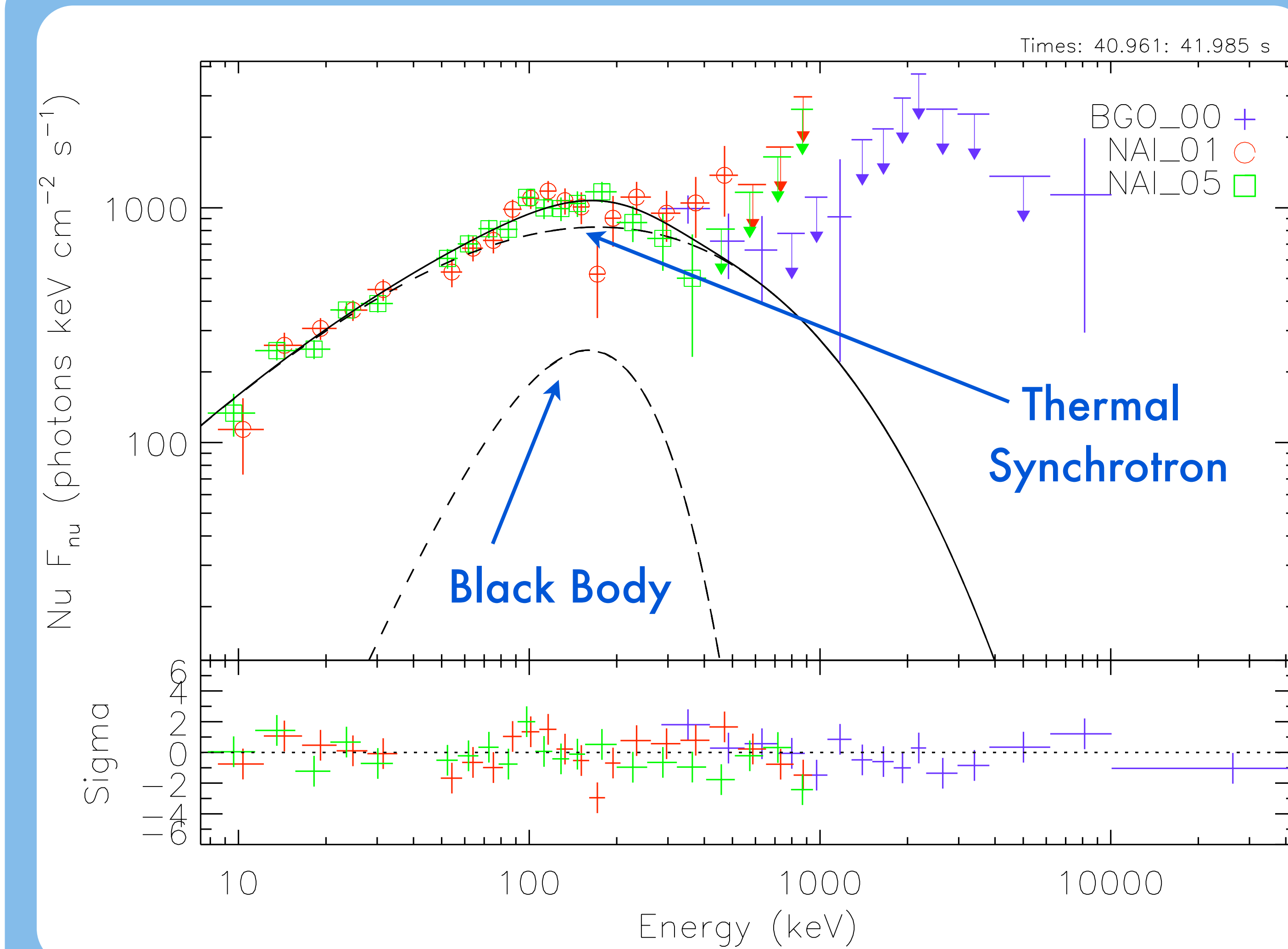
PL Synchrotron + Black Body

| | | | | |
|---|---|---|---|---|
| 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 | +/- | .216 | p/s-cm2-keV |
| Critical Energy | 6.530 | +/- | .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

# Observations

Best Fit (red box)

| C-STAT/DOF | Model: Band | Band +BB | TS | TS+BB | PLS | PLS +BB |
|---|---|---|---|---|---|---|
| Bin A | 398/350 | 397/348 | **400/352** | 398/350 | 402/351 | 398/349 |
| Bin B | 443/350 | 437/348 | 706/352 | 456/350 | 526/351 | **440/349** |
| Bin C | 452/3502 | 427/348 | 888/352 | 477/350 | 492/351 | **441/349** |
| Bin D | 380/350 | 376/348 | 392/352 | **382/350** | 395/351 | 389/349 |

# 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.