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Confronting GRB prompt emission with a model for subphotospheric dissipation

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in collaboration with:
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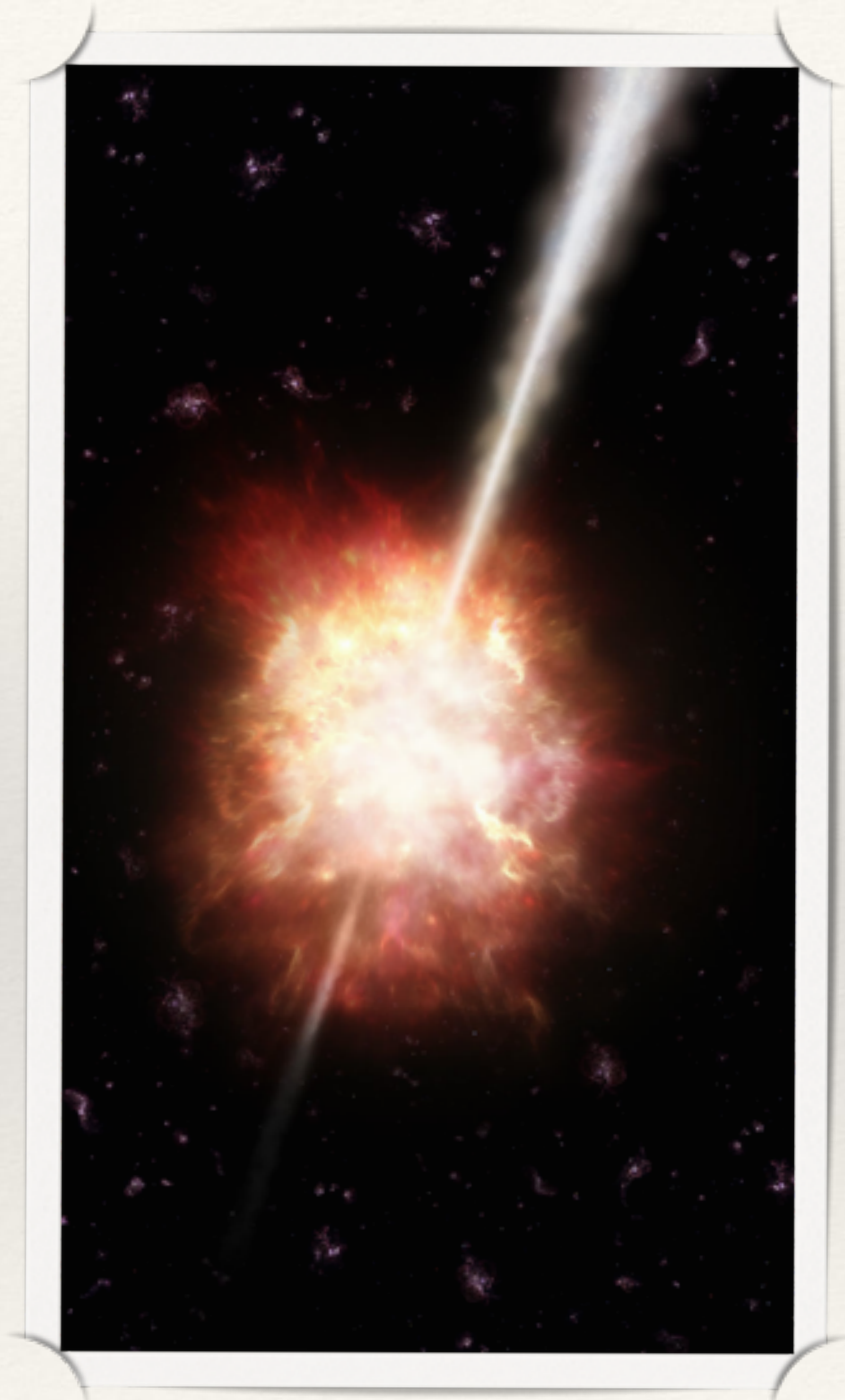
Why should we, and how do we, move to physical models?

Outline

- Introduction
- The model
  - Physics and numerical code
  - Creating DREAM
- Fitting the model to data
  - GRB 100724B
  - GRB 090618
- Conclusions
- Current and future work



Credit: ESO/A. Roquette

Introduction

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- Lack a clear smoking gun signal

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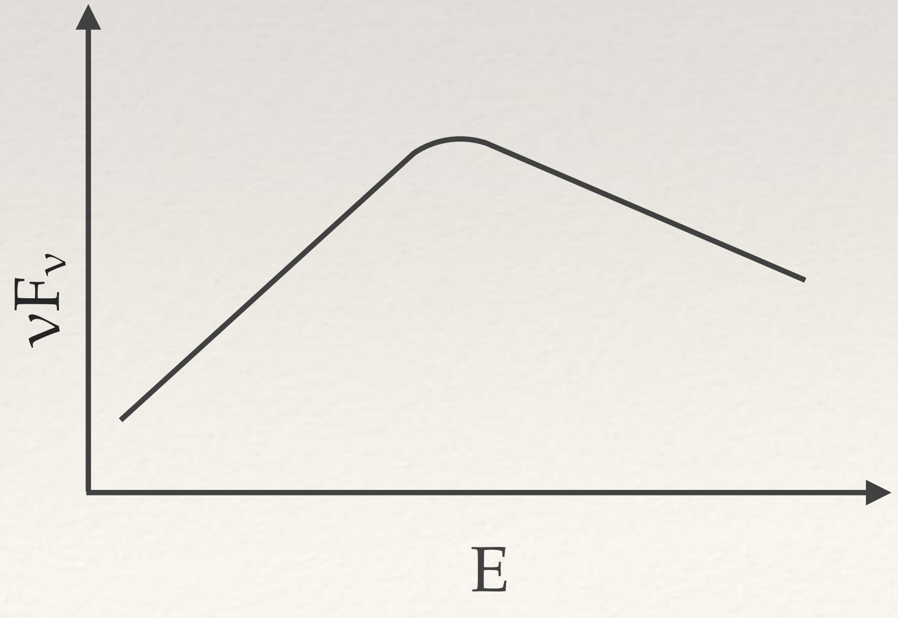
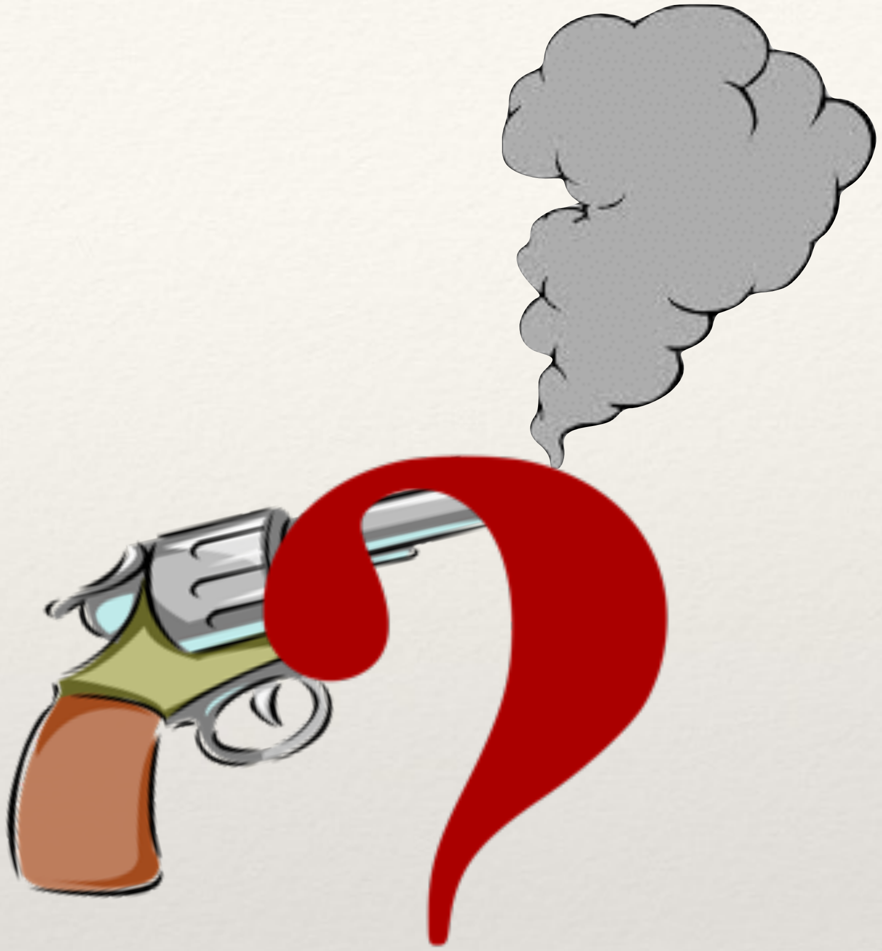
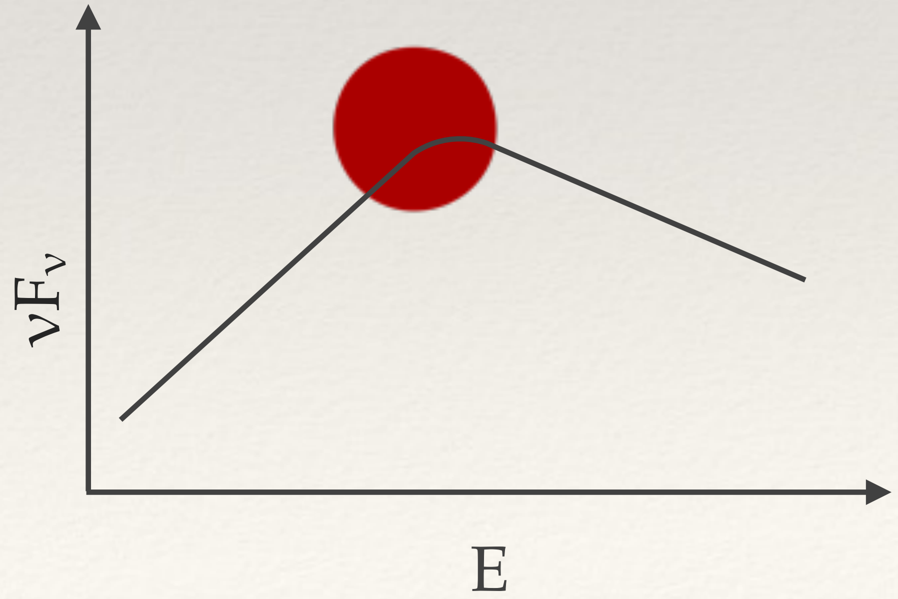


Introduction

- Prompt emission still an unsolved problem in GRB physics
- Lack a clear smoking gun signal
- Band function has no physical meaning
    - Physical models needed

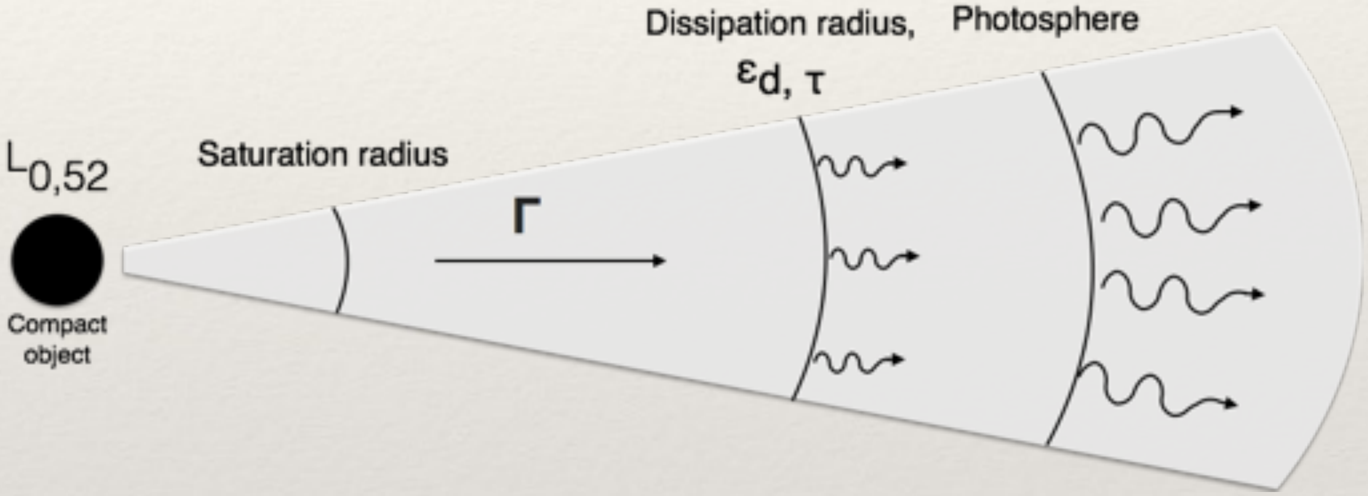




The model

Numerical code

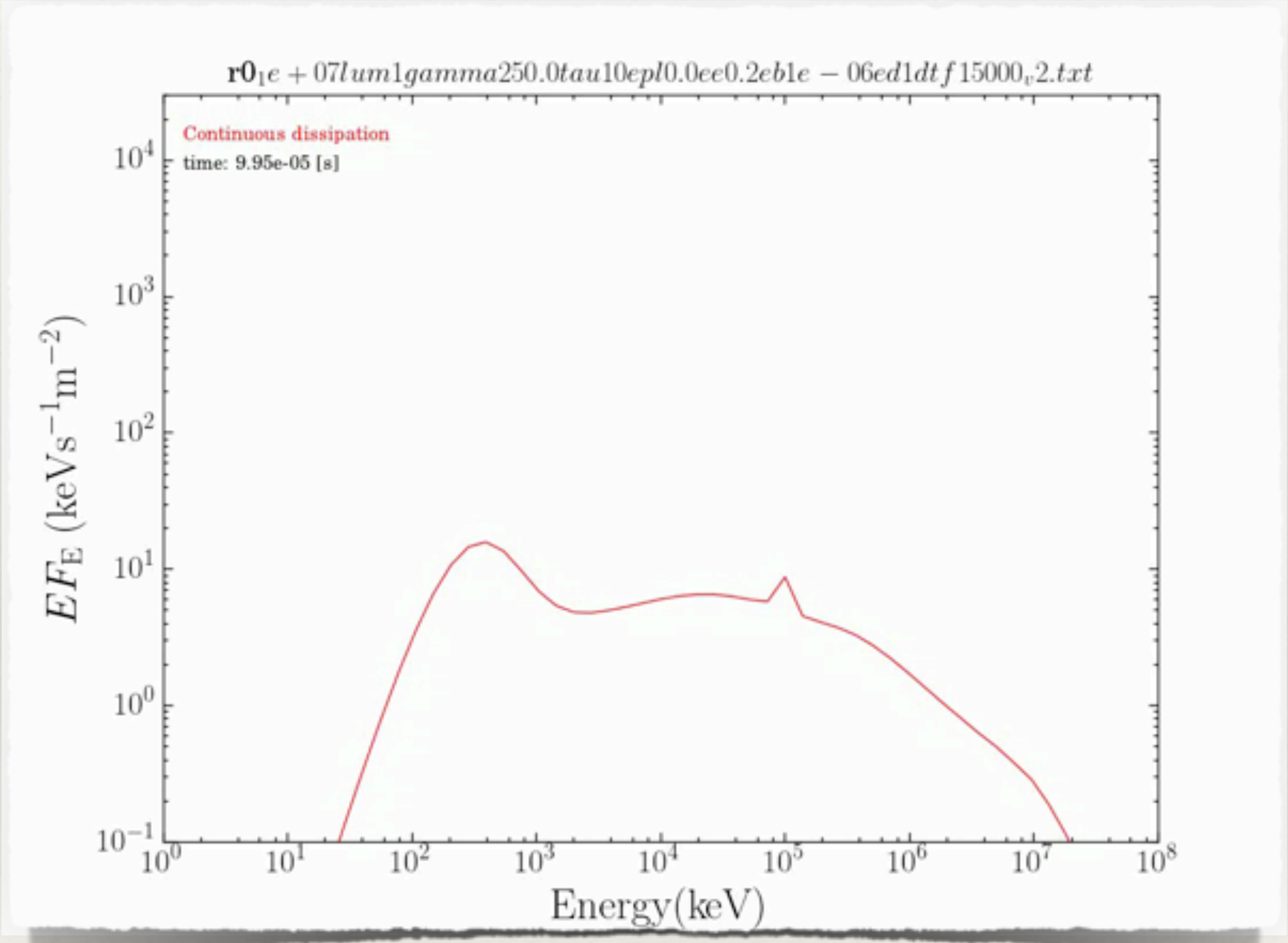
- Based on fireball model, using numerical code by Pe'er and Waxman (2005)
  - $L_{0,52}$ is released at r_0
  - Fraction ε_d dissipates at r_d
  - Follow the photon and electron distribution until last interaction
- No dynamics included
  - Code is 1D



Schematics of the subphotospheric model.

Formation of the spectrum

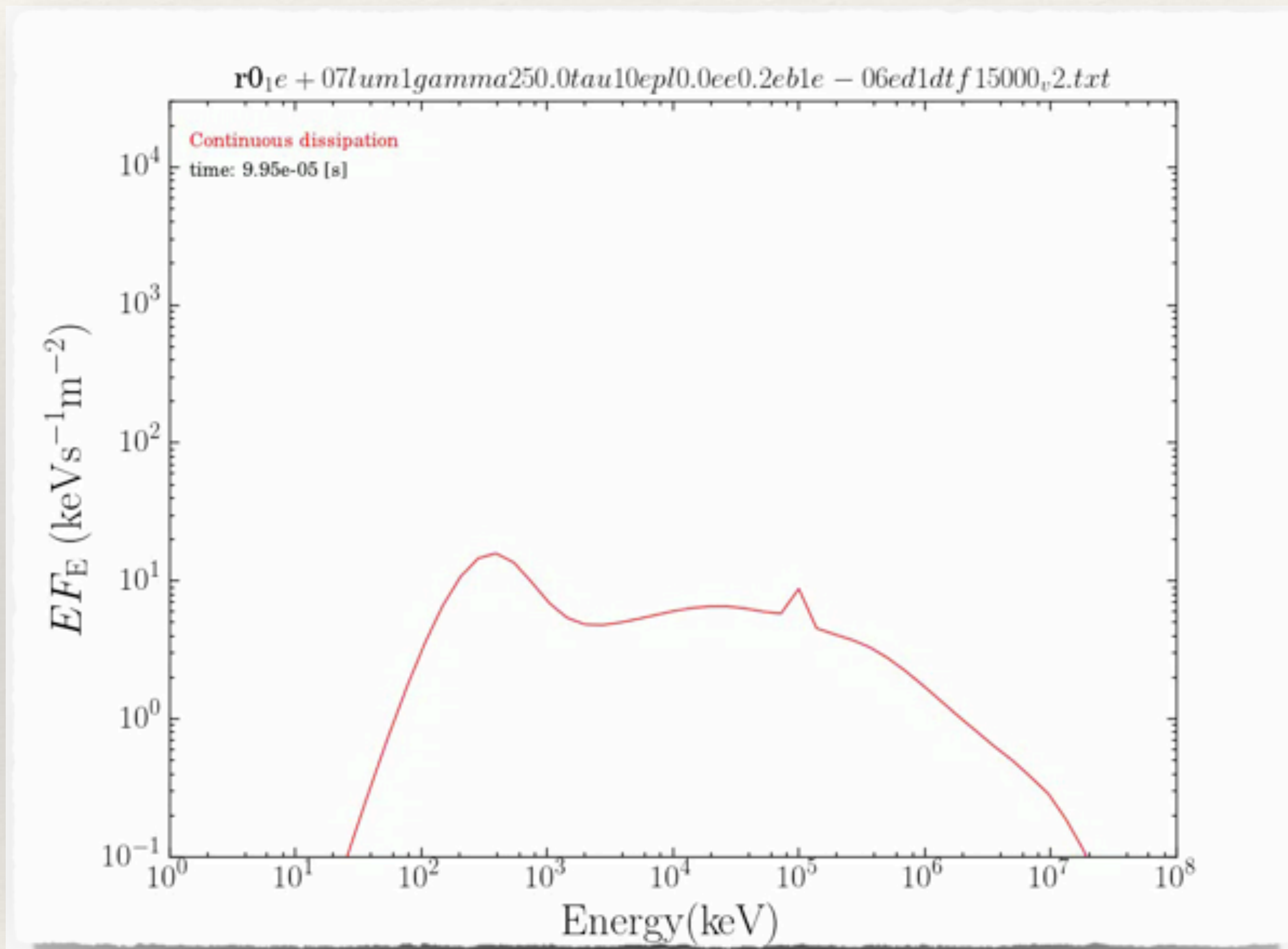
Running the code



Building the output in a specific simulation

Formation of the spectrum

Running the code



Building the output in a specific simulation

The model

Creating DREAM

- Table model for Xspec
  - DREAM - Dissipation with Radiative Emission As a table Model
- 4 free parameters: τ, Γ, $L_{0,52}$, ε_d
- Interpolation between spectra

Parameters:

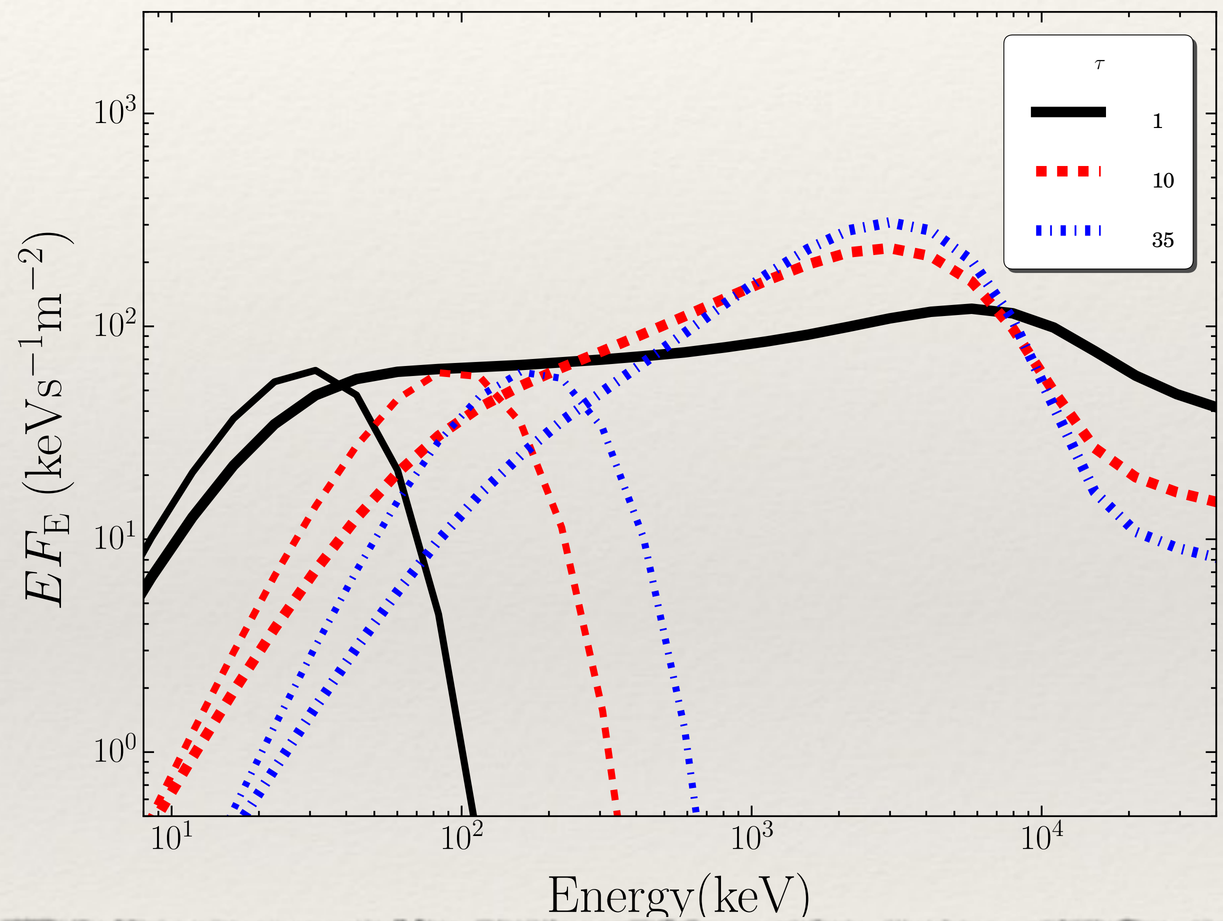
- $\tau = \{1,5,10,20,35\}$
- $\Gamma = \{50,100,250,500\}$
- $L_{0,52} = \{0.1,1,10,100,300\}$
- $\varepsilon_d = \{0.1,0.2,0.3,0.4,0.5\}$

All energy into electrons, none to magnetic fields. Electrons in Maxwellian distribution.

The model

Output, in GBM energy interval

- Soft slope due to comptonisation
- Increasingly peaked spectrum with increasing optical depth, τ



Example output from three runs of the code. $\Gamma = 250$, $L_{0,52} = 10$, $\varepsilon_d = 0.2$, *From Ahlgren et al. (2015)*

Fitting the model to data

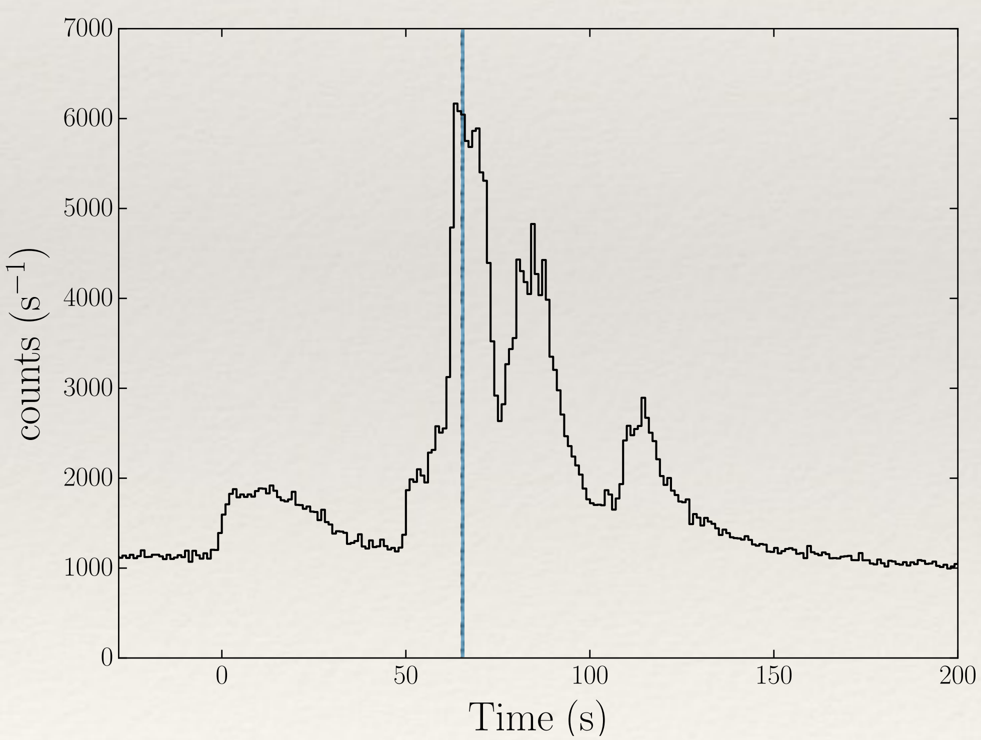
Data & analysis

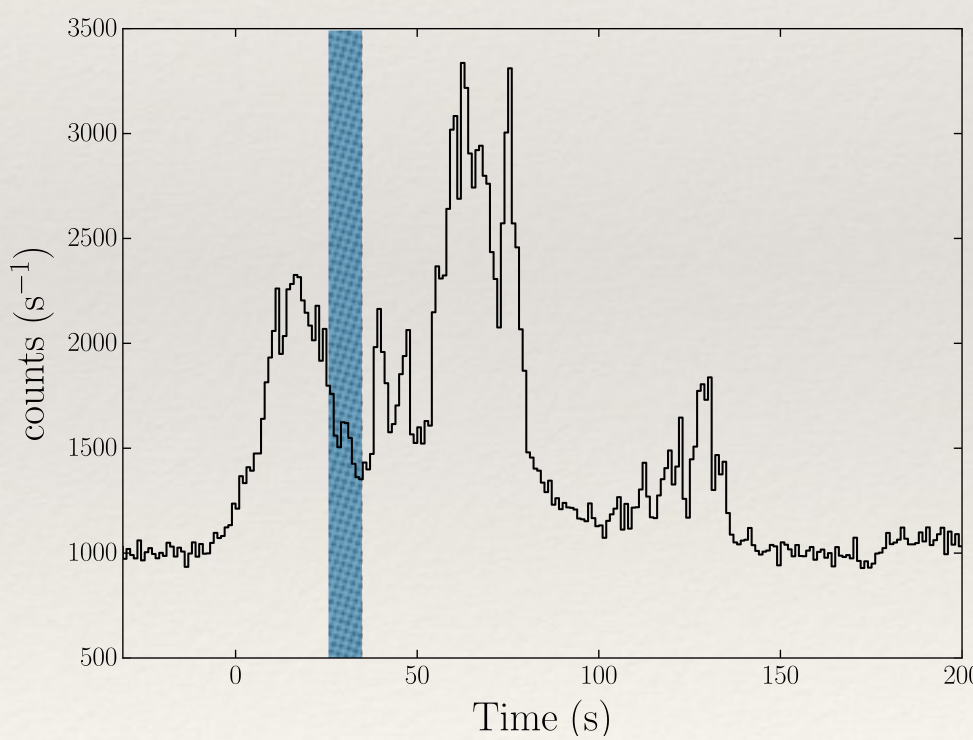
GRB 090618

- z = 0.54
- L = 2.8E51 erg s^{-1}
- “Typical” Band function

GRB 100724B

- z = unknown
- Double peaked spectrum (Guiriec et al. 2011)

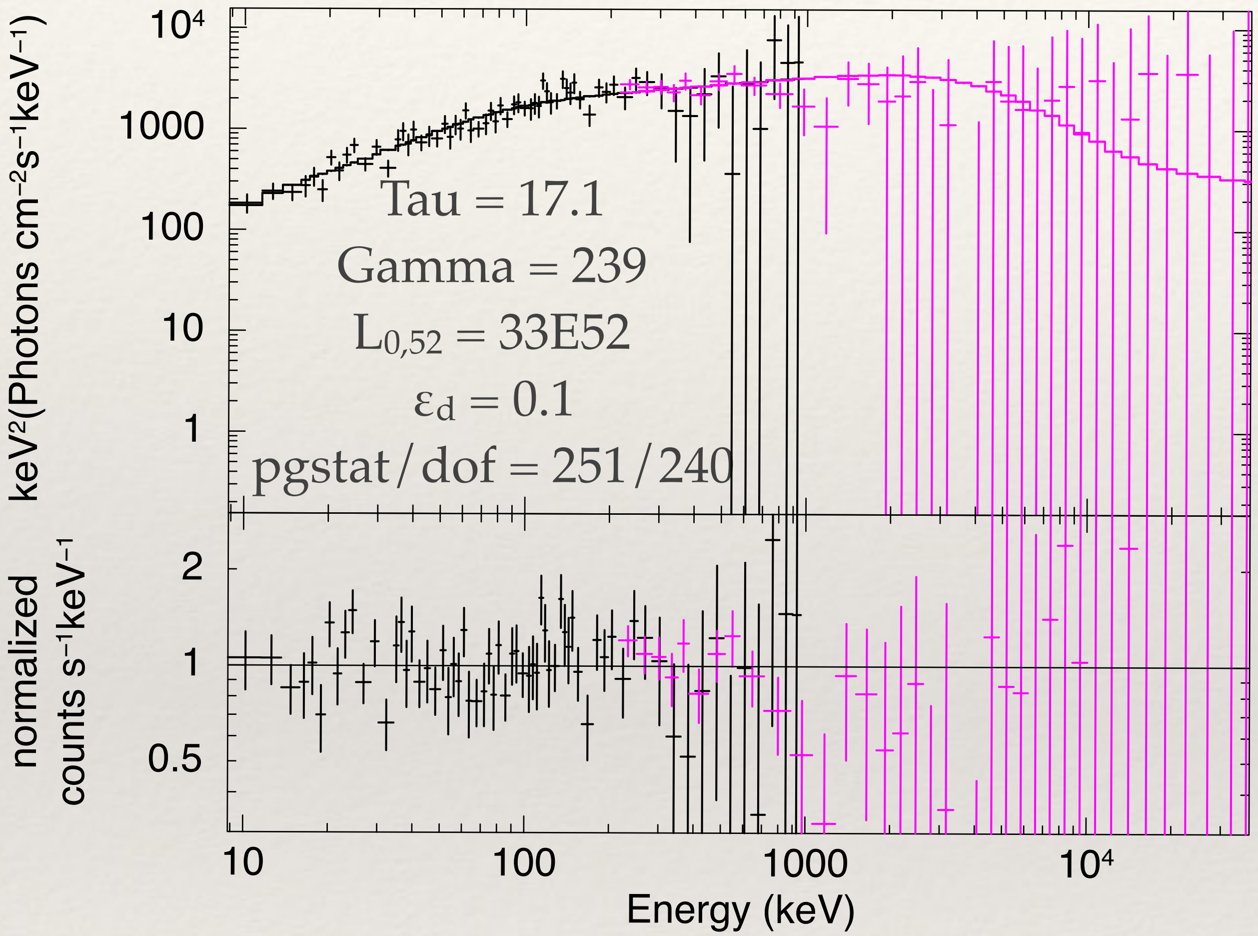




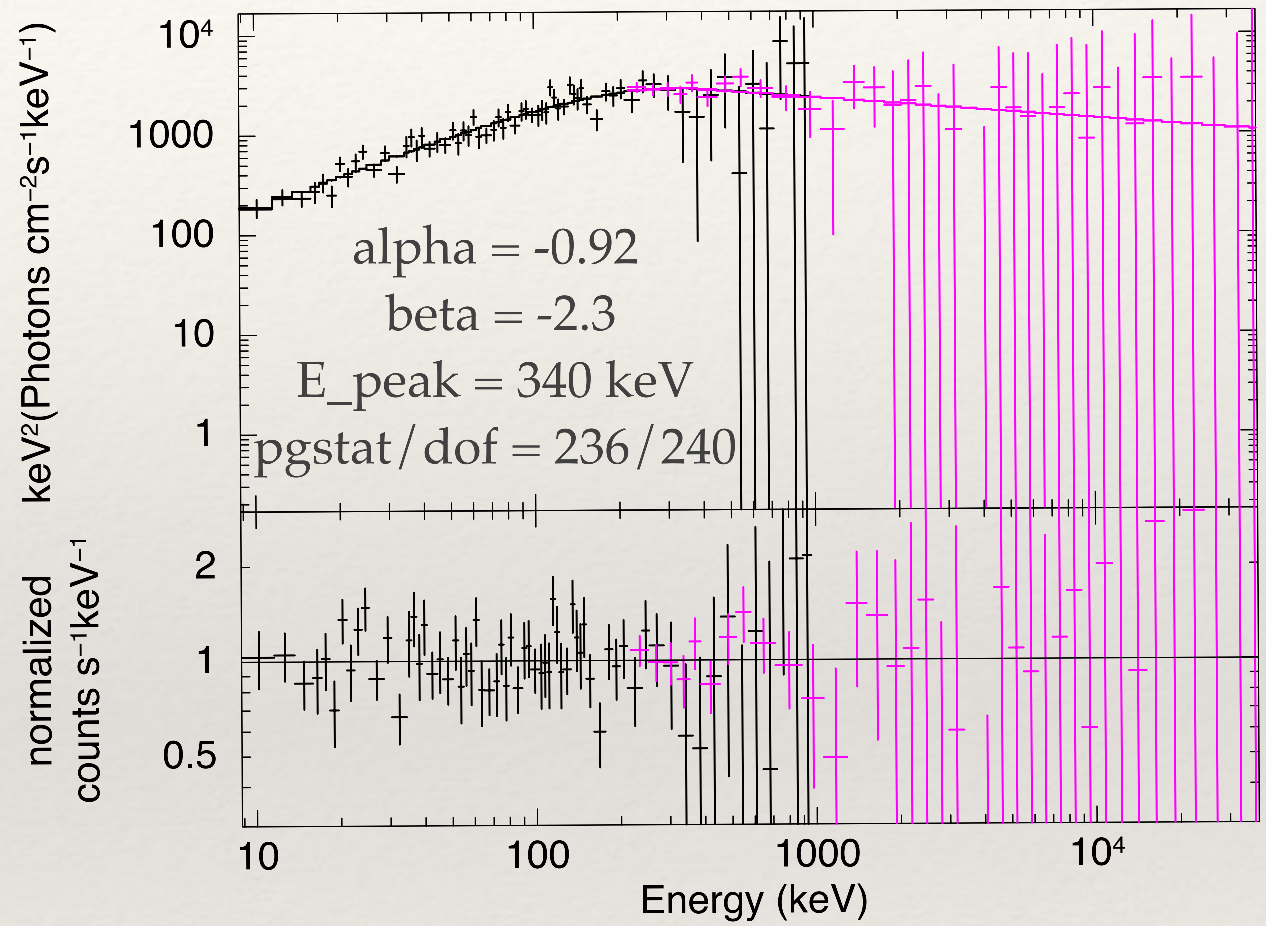
Time resolved analysis with signal-to-noise binning and pgstat statistics in XSPEC

GRB 090618 (65.3-65.7 s)

DREAM



Band



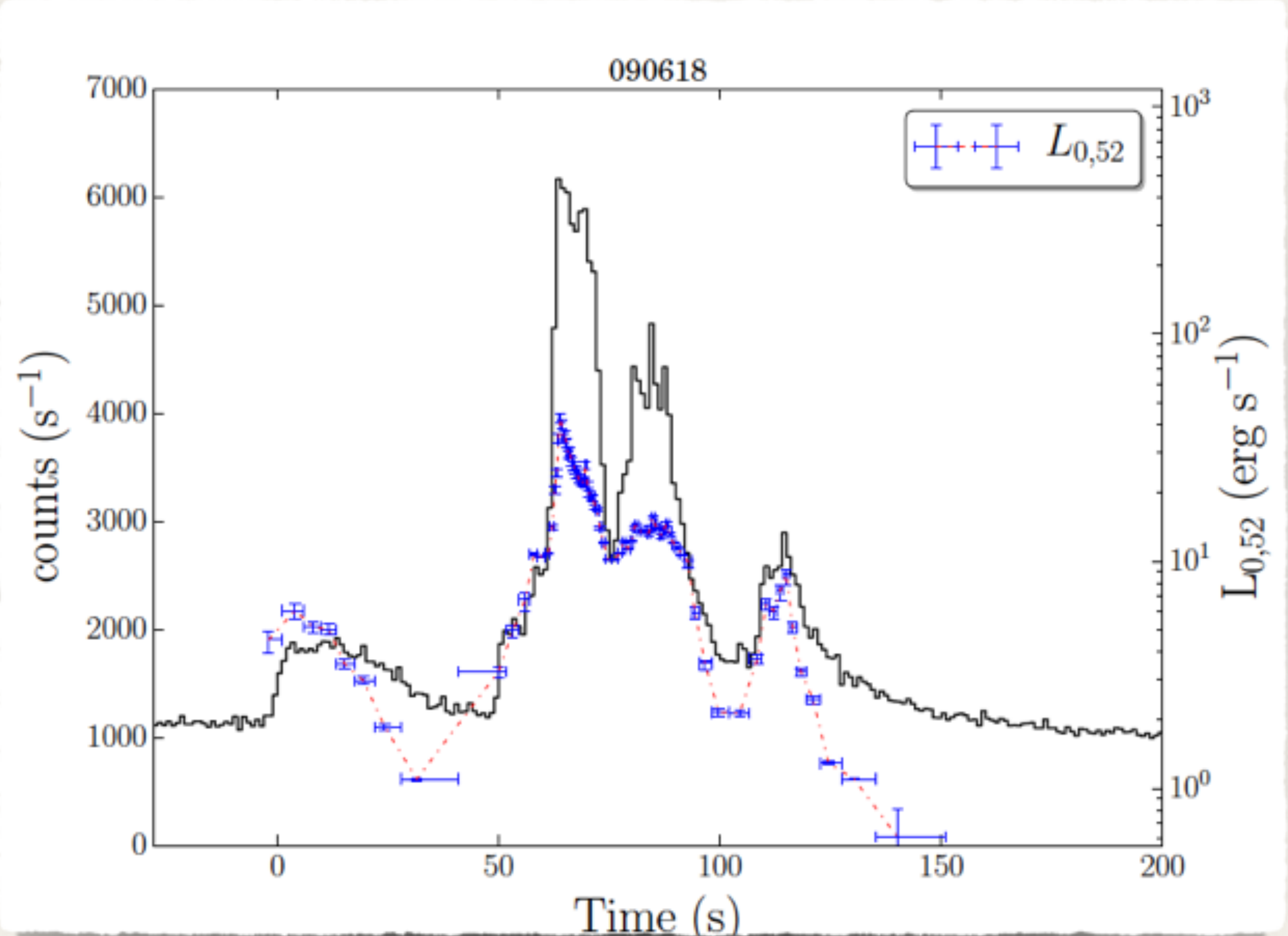
Example fits with the DREAM model to a specific time bin of GRB 090618. Band function fit for comparison. GBM data.

From Ahlgren et al. (2015)

Parameter evolution

GRB 090618

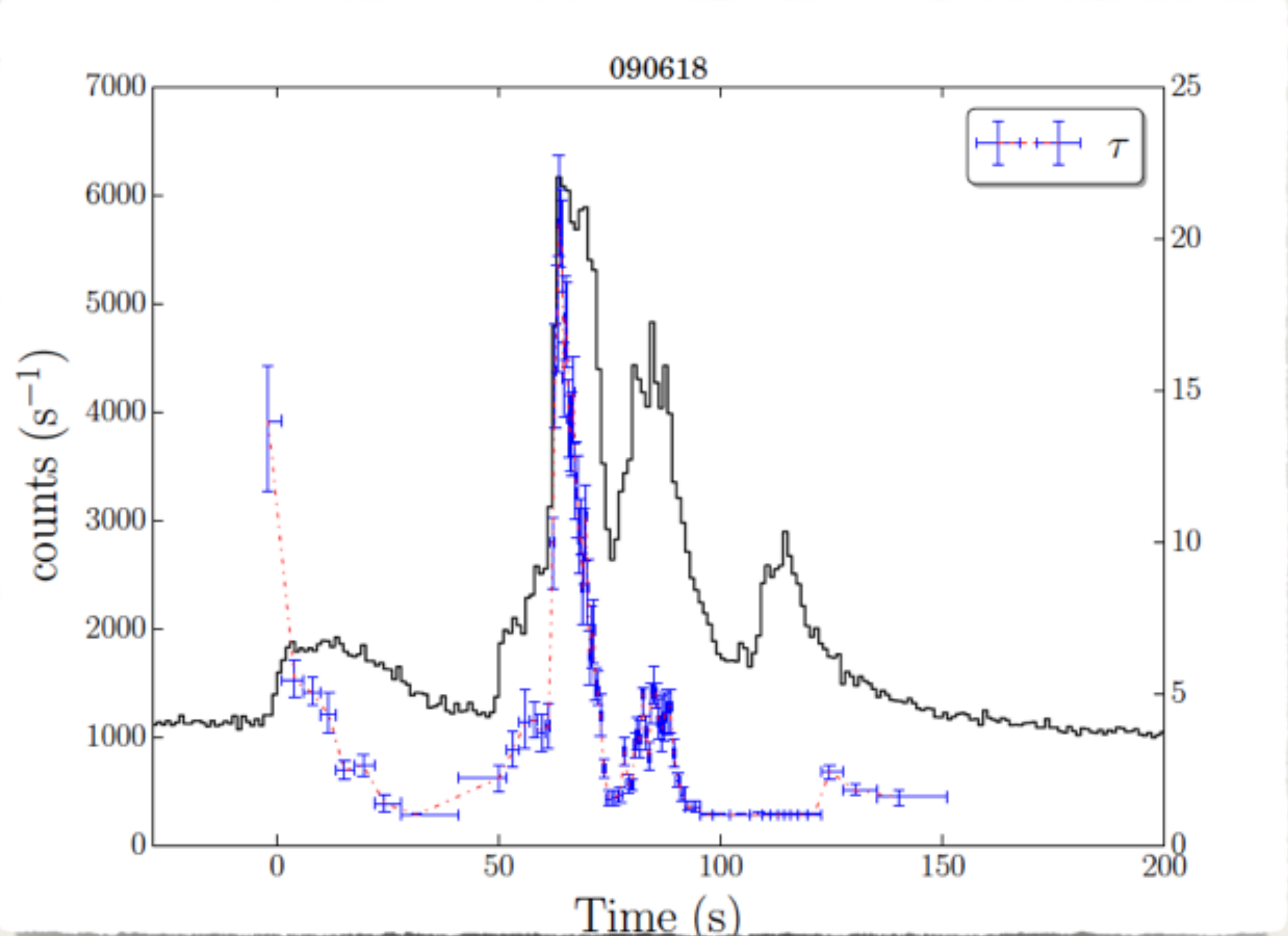
Fireball luminosity, $L_{0,52}$



Parameter evolution

GRB 090618

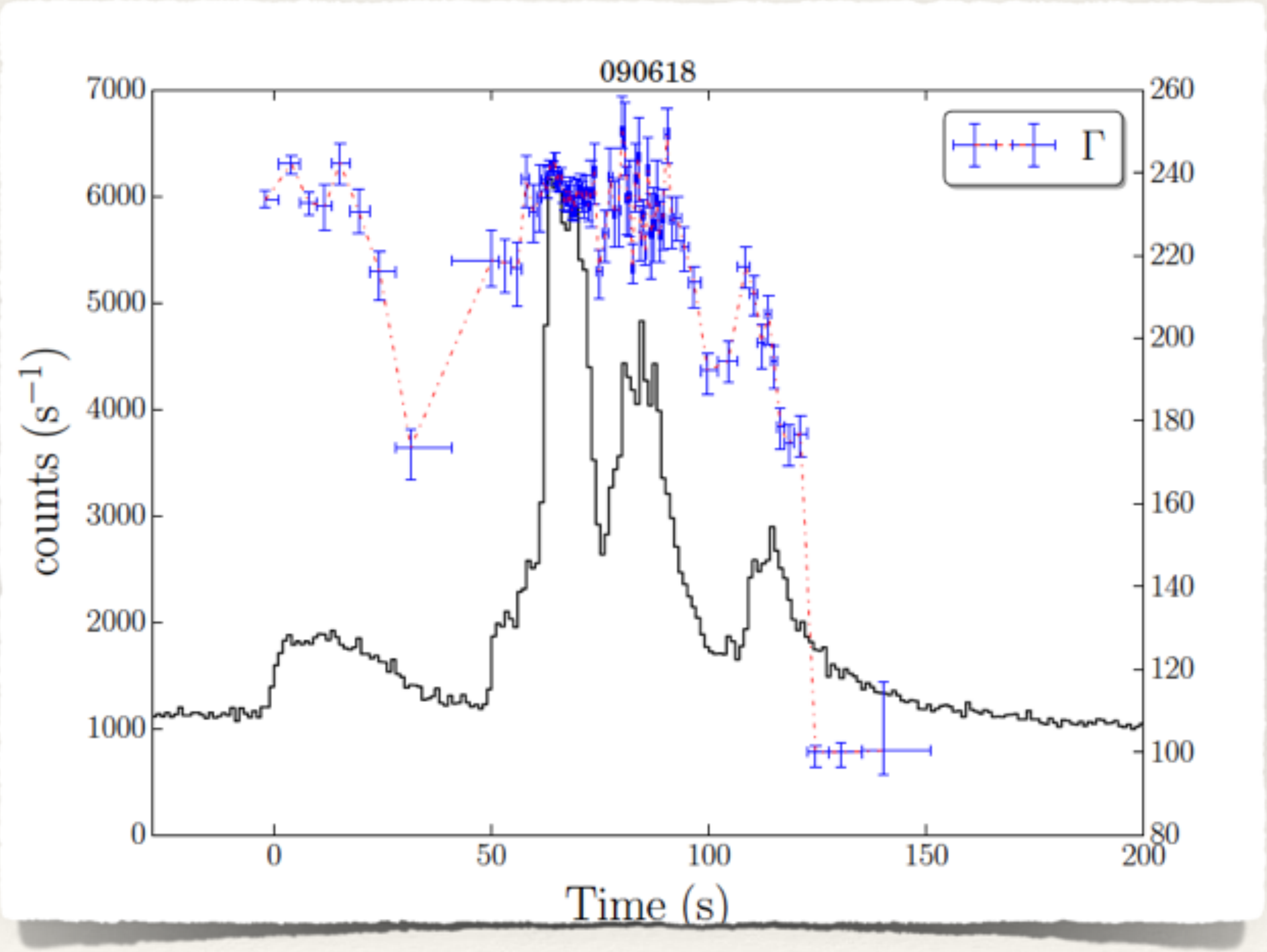
Optical depth, τ



Parameter evolution

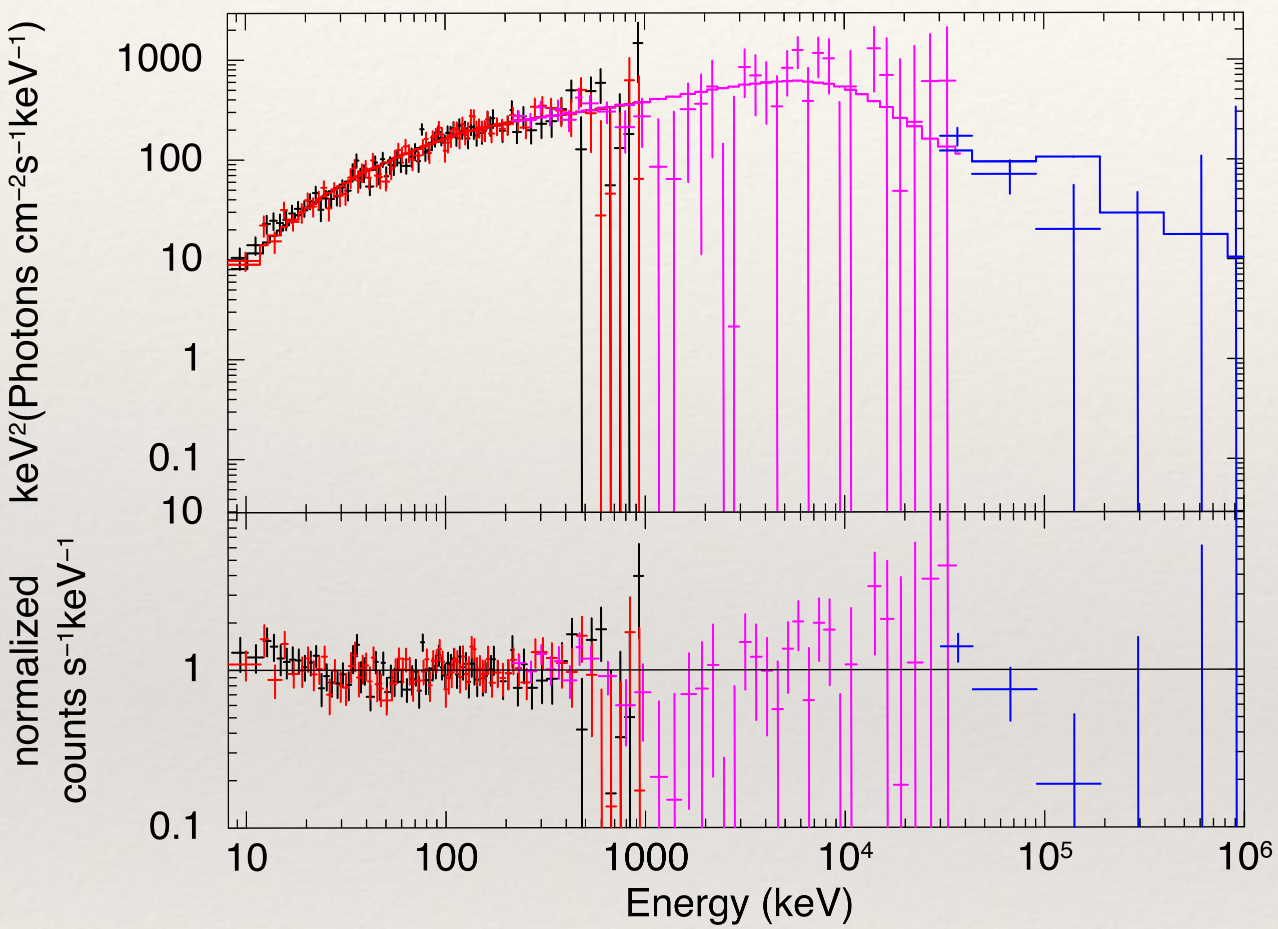
GRB 090618

Bulk Lorentz factor, Γ

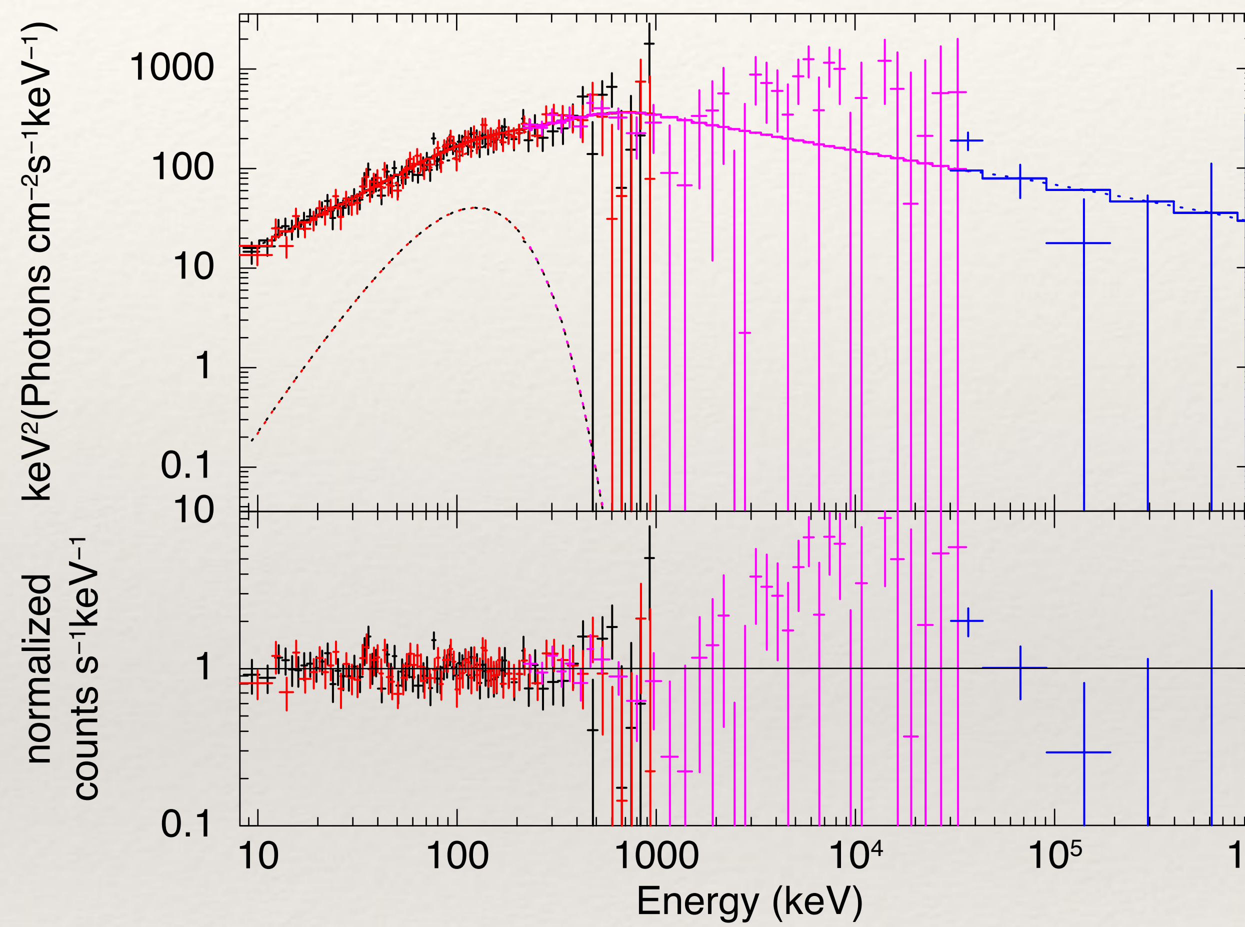


GRB 100724B (25.8-33.5 s)

DREAM



Band + black body



Tau = 4.9
Gamma = 443
$L_{0,52}$ = 42
ε_d = 0.12
pgstat/dof = 406/383
z = 1

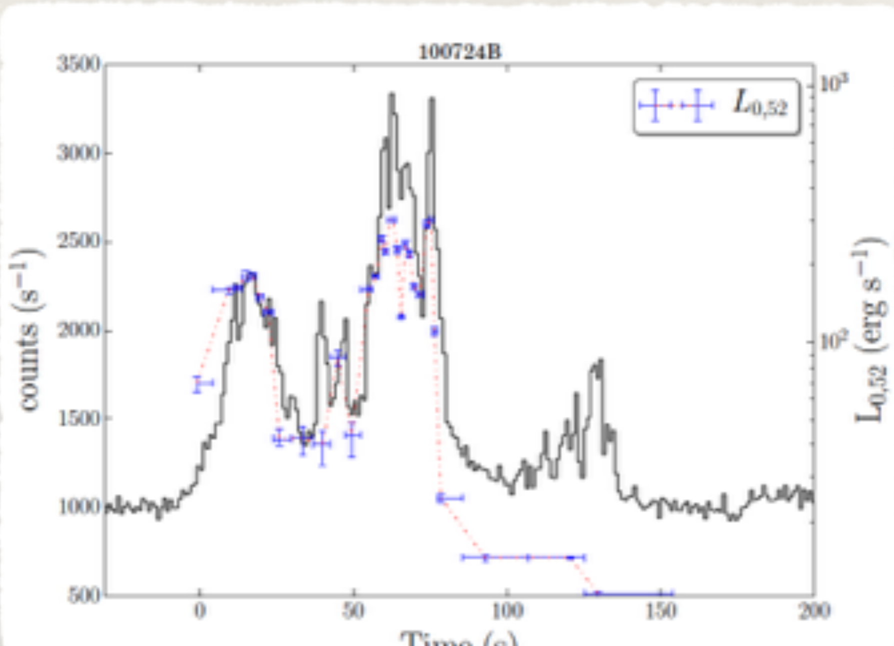
Example fits with the DREAM model to a specific time bin of GRB 100724B. Band function + black body fit for comparison. GBM data, and LAT-LLE data in blue.
From Ahlgren et al. (2015)

alpha = -1.06
beta = -2.4
E_peak = 712keV
kT = 32 keV
pgstat/dof = 401/381

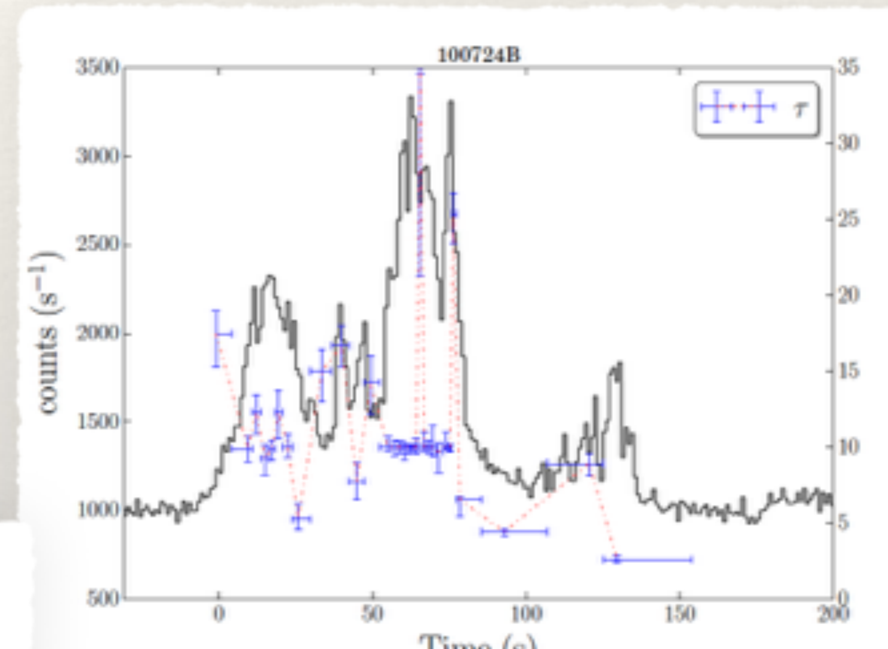
Parameter evolution

GRB 100724B

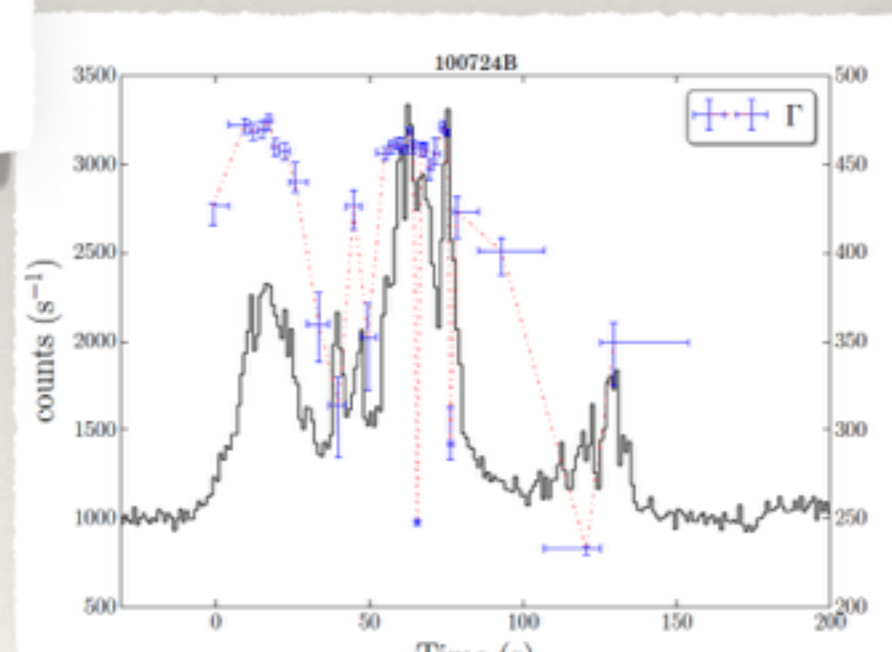
Fireball luminosity, $L_{0,52}$



Optical depth, τ

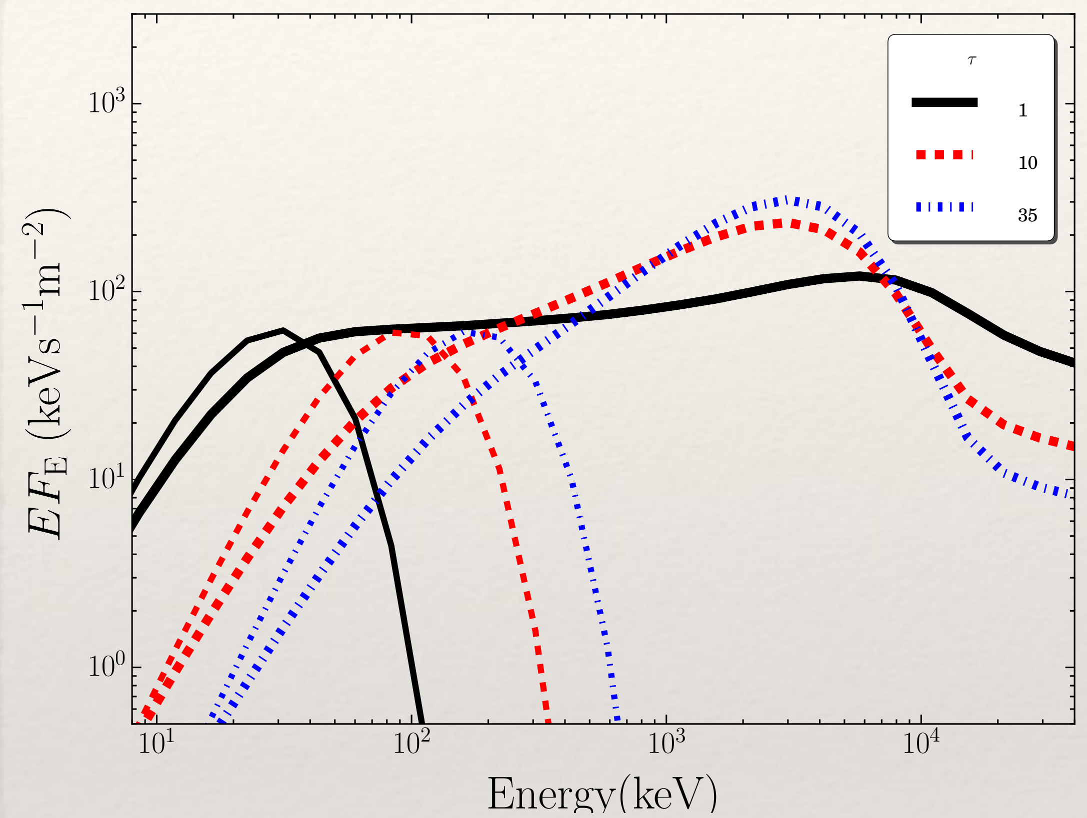


Bulk Lorentz factor, Γ



Summary and conclusions

- We show fits to data with a physical model for GRB prompt emission.
- We obtain good fits to different bursts, without synchrotron radiation.
- We suggest that there is no fundamental difference between a burst typically fitted with Band and one fitted with Band+BB.
  - If a spectrum is found to be single or double peaked by fitting with Band or Band+BB depends on of how close the thermal and comptonised peaks are.



Band-like spectrum produced from Comptonisation of thermal component

Current and future work

- Currently expanding the parameter space
  - Includes synchrotron radiation
  - Changed jet properties
- Fitting large sample of GRBs
  - What fraction of GRBs can be described by this model?
- Distribution of best-fitting parameters and temporal evolution

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ABSTRACT
The origin of the prompt emission in gamma-ray bursts (GRBs) is still an unsolved problem and several different mechanisms have been suggested. Here we fit Fermi GRB data with a photospheric emission model which includes dissipation of the jet kinetic energy below the photosphere. The resulting spectra are dominated by Comptonization and contain no significant contribution from synchrotron radiation. In order to fit to the data we span a physically motivated part of the model's parameter space and create DREAM (*Dissipation with Radiative Emission as A table Model*), a table model for xspec. We show that this model can describe different kinds of GRB spectra, including GRB 090618, representing a typical Band function spectrum, and GRB 100724B, illustrating a double peaked spectrum, previously fitted with a Band+blackbody model, suggesting they originate from a similar scenario. We suggest that the main difference between these two types of bursts is the optical depth at the dissipation site.

Key words: gamma-ray burst: general – radiation mechanisms: thermal – gamma-ray burst: individual: GRB 090618 – individual: GRB 100724B

1 INTRODUCTION

For more details, please see *Ahlgren et al. (2015)*

Thank you!

Questions?