Confronting GRB prompt emission with a model for subphotospheric dissipation

Why should we, and how do we, move to physical models?

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Outline

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Credit: ESO/A. Roquette
Introduction
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- Prompt emission still an unsolved problem in GRB physics
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- Band function has no physical meaning
- Physical models needed
Based on fireball model, using numerical code by Pe’er and Waxman (2005)

- $L_{0.52}$ is released at $r_0$
- Fraction $\varepsilon_d$ dissipates at $r_d$
- Follow the photon and electron distribution until last interaction
- No dynamics included
- Code is 1D
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: $\tau, \Gamma, L_{0.52}, \varepsilon_d$
- 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, \( \tau \)

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**
- $z = 0.54$
- $L = 2.8 \times 10^{51}$ erg s$^{-1}$
- “Typical” Band function

**GRB 100724B**
- $z = \text{unknown}$
- Double peaked spectrum (Guiriec et al. 2011)

Time resolved analysis with signal-to-noise binning and pgstat statistics in XSPEC
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, $\tau$
Parameter evolution

GRB 090618

Bulk Lorentz factor, $\Gamma$
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)

$\tau = 4.9$
$\Gamma = 443$
$L_{0.52} = 42$
$\varepsilon_d = 0.12$
$\text{pgstat/dof} = 406/383$
z = 1

$\alpha = -1.06$
$\beta = -2.4$
$E_{\text{peak}} = 712\text{keV}$
$kT = 32\text{keV}$
$\text{pgstat/dof} = 401/381$
Parameter evolution

GRB 100724B

Fireball luminosity, $L_{0.52}$

Optical depth, $\tau$

Bulk Lorentz factor, $\Gamma$
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 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

For more details, please see Ahlgren et al. (2015)
Thank you!

Questions?