

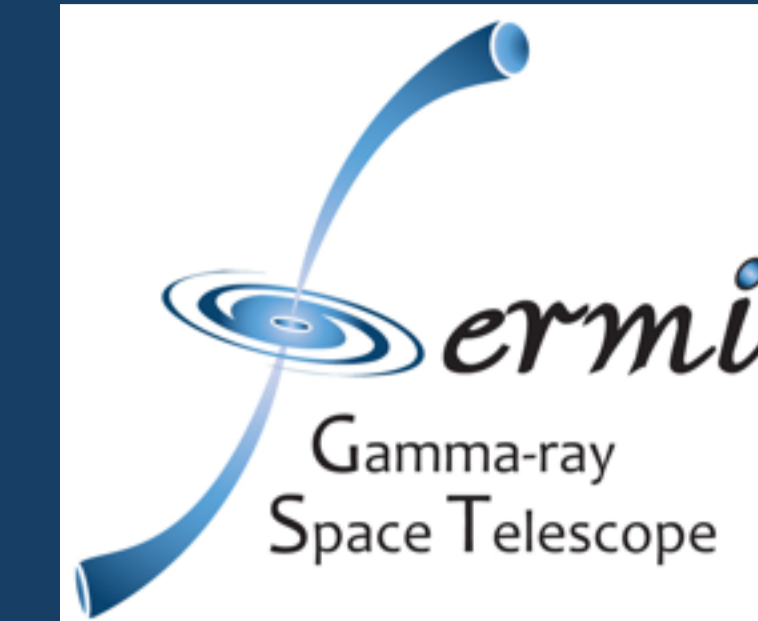
Suphotospheric Dissipation in Fermi GRBs

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Introduction

The prompt emission mechanism of gamma-ray-bursts (GRBs) is still an unsolved problem with several interesting aspects begging an answer. While GRB spectra are usually well fitted with the so called Band function [1], this gives little understanding of the underlying radiation mechanism, which has prompted several new approaches to the problem. For this poster we present a physically motivated model for prompt gamma-ray burst emission containing the relevant emission mechanisms for subphotospheric dissipation. We show that this model can describe different kinds of GRB spectra, and discuss some of the implications.

The Model

The subphotospheric dissipation model based on [2,3] can produce spectra resulting from dissipation below the photosphere in a relativistically expanding fireball, following the schematics of the fireball model.

A progenitor releases an energy L_0 through a jet traveling towards the observer. Due to thermal pressure the bulk flow accelerates up to some saturation radius, where the bulk Lorentz factor, Γ , becomes equal to the dimensionless entropy, η (see Fig. 1). At this stage the bulk flow contains photons and electrons in thermal equilibrium. At some dissipation radius, r_d , an unspecified process dissipates a fraction of the kinetic energy, $\varepsilon_d L_0$, to the electrons. The ejecta continues outward while the heated electrons and the thermal seed photons interact by

- Compton- and inverse Compton scattering
- Pair production
- Pair annihilation
- Synchrotron radiation
- Synchrotron self-absorption

which, as the ejecta reaches the photosphere and the photons are released, has produced the observed spectrum.

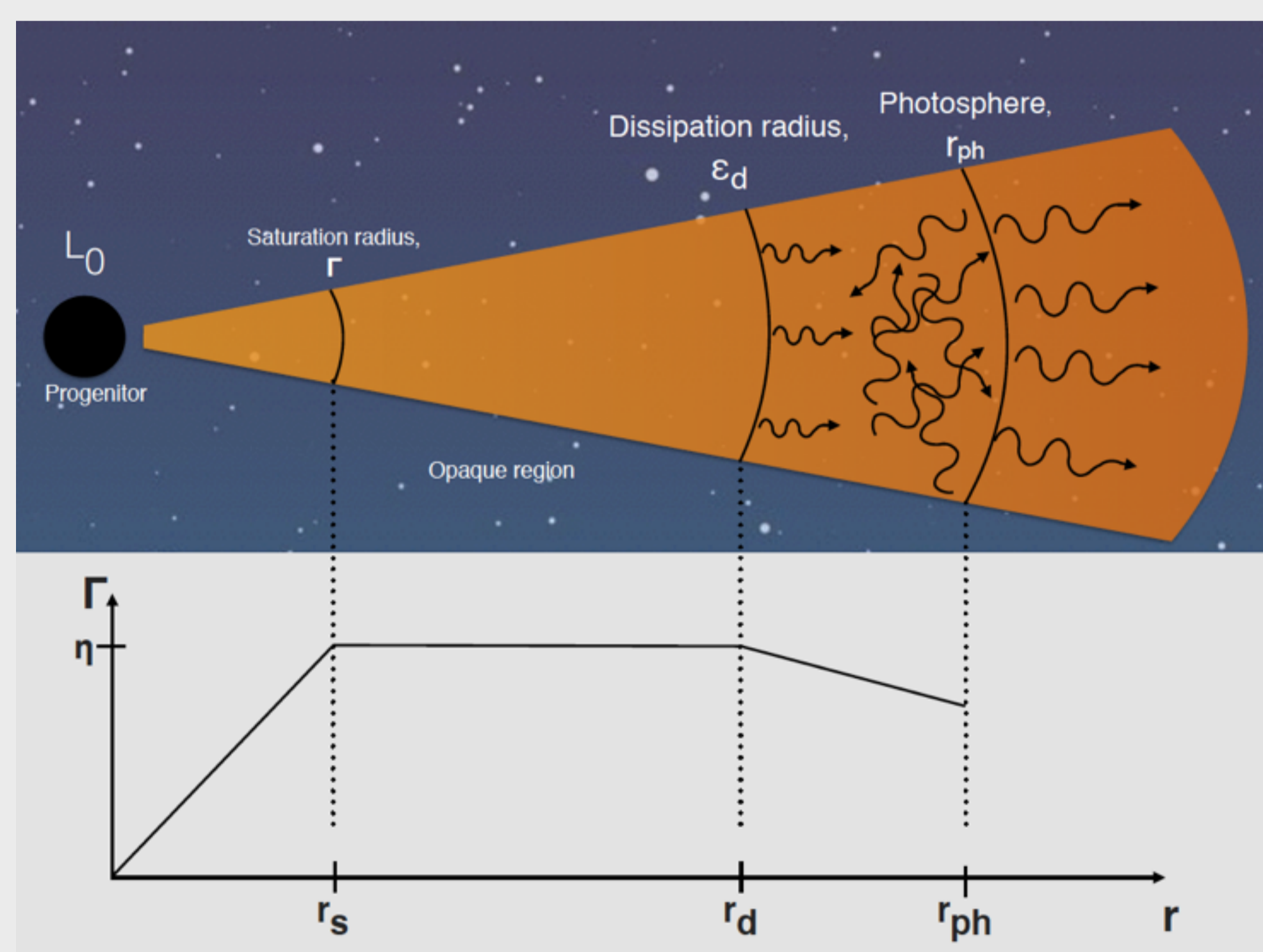


Figure 1: Schematics of a GRB

The figure shows the schematics of a GRB in the framework of the discussed model. 4 of the free parameters are shown in the figure as L_0 , r_d , ε_d and Γ . The bottom half of the figure depicts the evolution of the bulk flow Lorentz factor, Γ , as a function of the outflow radius.

The numerical code simulating the model allows for 7 free input parameters, governing the luminosity of the burst, the fraction dissipated energy, the fraction of this energy going into the electrons and the magnetic field, respectively, the bulk Lorentz factor, the electron energy distribution and the dissipation radius.

The current version of the model used assumes a very low magnetic field and so the model has very low synchrotron radiation and synchrotron self-absorption. The electrons are assumed to have a Maxwellian energy distribution.

Fitting the Model

• The numerical code

To simulate GRBs in accordance with the model, we have used the numerical code by Pe'er et al. [2,3]. A parameter grid is spanned over a relevant parameter space, using 4 of the model's free parameters; the luminosity, L_0 , the dissipation radius, r_d , the dissipation factor, ε_d , and the bulk Lorentz factor, Γ . For this study a grid of 500 spectra was created and condensed into a table model for XSPEC.

• Performing fits

With the table model we can perform fits to data using XSPEC. The model is fitted with the aforementioned 4 free parameters, keeping the redshift dependent normalization constant. We make qualitative comparisons of these fits with Band model fits and Band+black body fits to demonstrate the characteristics of the model. The analysis is time resolved and binned with a signal-to-noise ratio of 40. Below we show two examples of different bursts; GRB100724B and GRB120711.

Example 1: GRB100724B

Time interval: 9.7-11.4 s after trigger.

$T_{90} = 114.6$ s

Redshift is unknown.

Fluence $2.17e-04$ erg cm^2

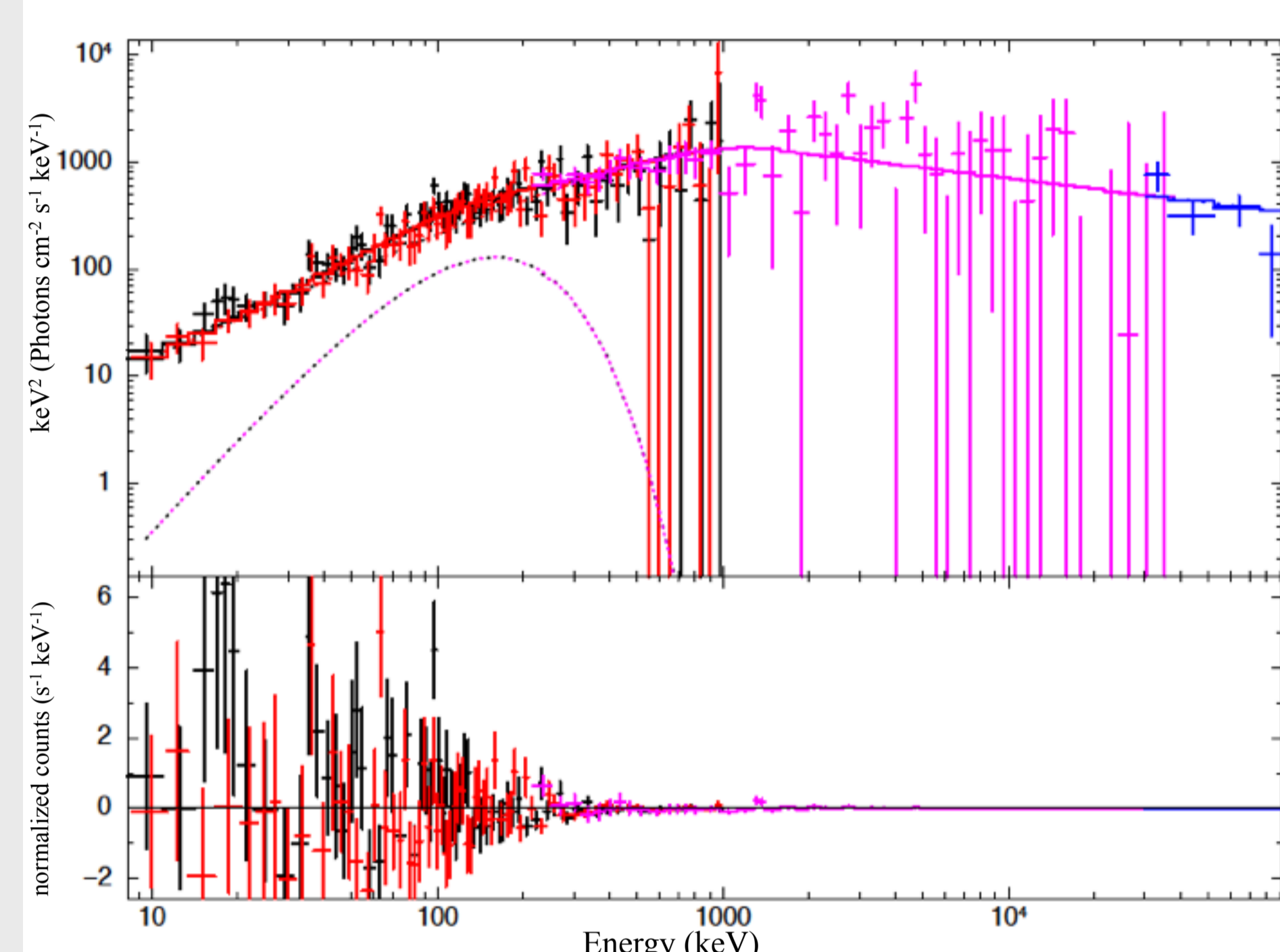


Figure 2: GRB100724B fitted with a Band+black body

The data contains GBM and LAT-LLE data. NaI 0 and NaI 1 (red and black 8-1000 keV, respectively), BGO 0 (magenta 200-60 000 keV), LAT-LLE (blue 30-1000 MeV)

Parameter values

- $\alpha = -0.90^{0.02}_{-0.03}$
- $\beta = -3.46^{0.04}_{-0.05}$
- $E_{peak} = 1050^{166}_{-78}$ keV
- $kT = 39.3^{2.6}_{-2.7}$ keV

The spectrum of GRB100724B has a dubbel peaked structure which may be fitted with a Band function plus a significant black body, as shown in [4].

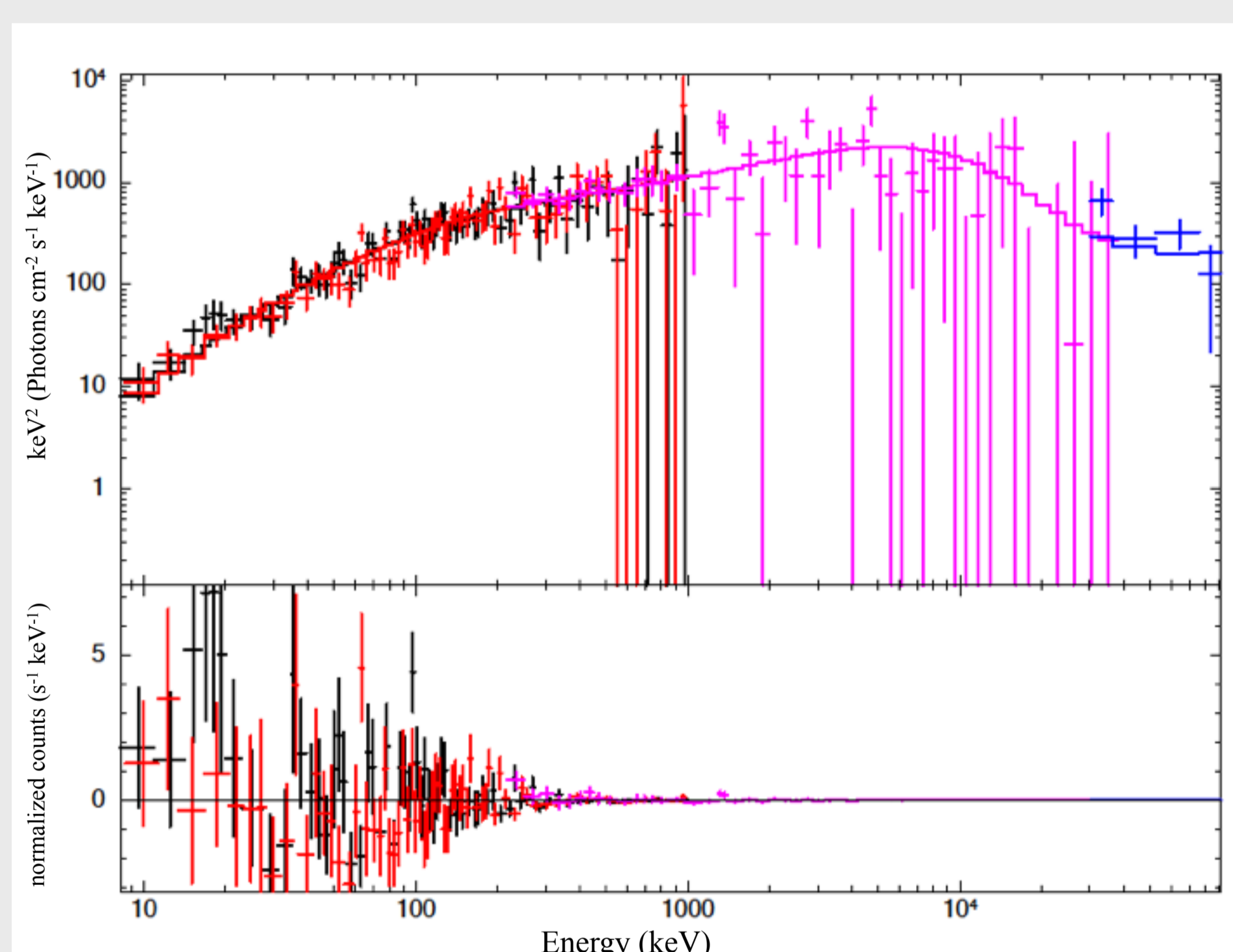


Figure 3: GRB100724B fitted with subphotospheric dissipation model

The data is the same as in Fig. 2.

Parameter values

- $r_d = 1.68e12^{1.44e11}_{-1.00e11}$ cm
- $\Gamma = 478.2^{5.1}_{-4.1}$
- $\varepsilon_d = 0.123^{0.008}_{-0.012}$
- $L_{0,52} = 157.3^{9.1}_{-4.6}$ erg
- $z = 1.00$ frozen

To keep the fit conservative and keeping 4 free parameters we have fixed the redshift and the normalisation.

The same data as in Fig. 2 can be fitted with the subphotospheric dissipation model, which here exhibits a clear dubbel peaked structure.

The first peak corresponds to the seed thermal component while the second peak is due to Inverse Compton scattering.

Example 2: GRB120711A

Time interval: 69.2 - 70.8 s after the precursor.

$T_{90} = 44.0$ s

$z = 1.405$

Fluence $1.94e-04$ erg cm^2

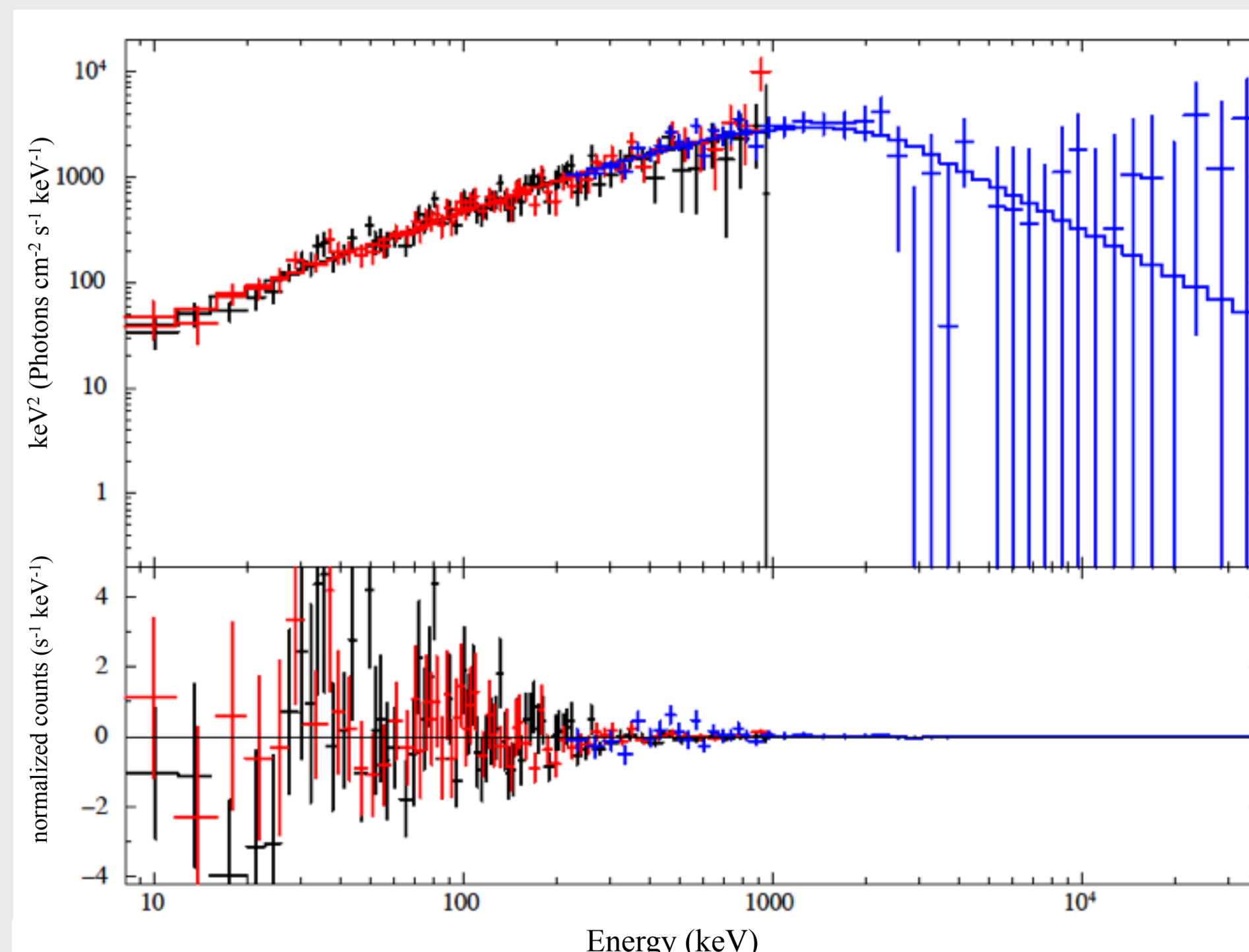


Figure 4: GRB120711A fitted with a band function.

The data contains GBM and LAT-LLE data. NaI 2 and NaI a (red and black 8-1000 keV, respectively), BGO 0 (blue 200-60 000 keV).

Parameter values

- $\alpha = -0.90^{0.02}_{-0.03}$
- $\beta = -3.46^{0.49}_{-1.85}$
- $E_{peak} = 1230^{108}_{-97}$ keV

The spectrum of GRB120711 is single peaked and when fitted with a Band function we find typical values for the parameters.

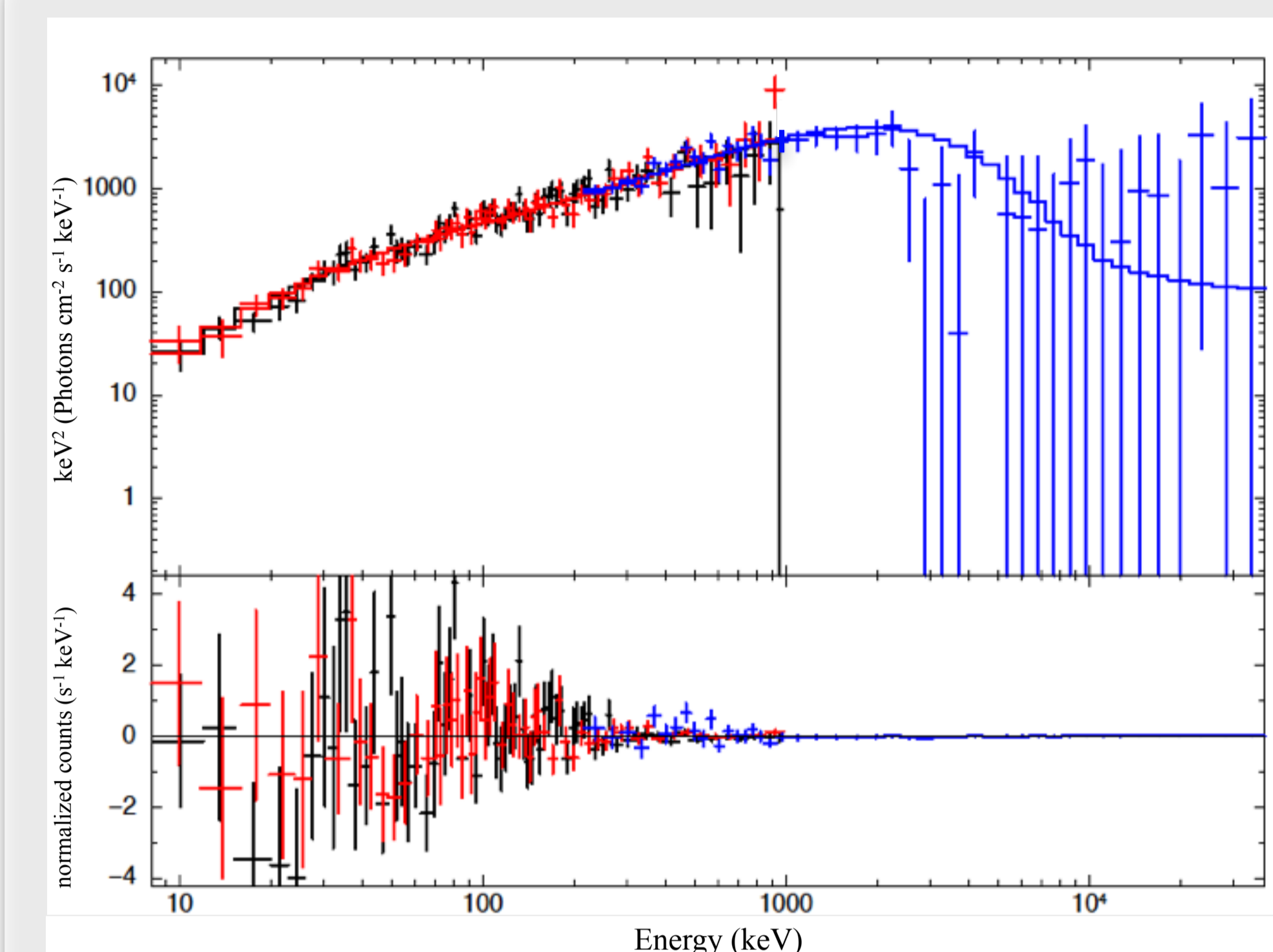


Figure 5: GRB100724A fitted with subphotospheric dissipation model

The data is the same as in Fig. 4.

Parameter values

- $r_d = 1.11e13^{3.88e12}_{-0.17e12}$ cm
- $\Gamma = 250.6^{1.3}_{-1.8}$
- $\varepsilon_d = 0.362^{0.013}_{-0.010}$
- $L_{0,52} = 300.0^{4.5}_{-4.5}$ erg
- $z = 1.405$ frozen

The fit is comparable to that of the Band function, but with the peak at higher energies.

Summary and Conclusion

We have shown examples of fitting a subphotospheric emission model to real data, giving fits of comparable quality as fits with Band's function or Band+black body. The model is physically motivated and can thus constrain physical parameters.

The fit to GRB120711A shows that the model can mimic a typical Band function. Additionally, the fit to GRB100724B demonstrates how we, with the same model and free parameters, can obtain a dubbel peaked structure, where one can otherwise fit a Band+black body.

The lower fraction of dissipated energy in GRB100724B, helps give rise to the dubbel peaked structure and the high Lorentz factor of the same burst yields the energy at the main peak.

Note that the main peak of the spectra are shifted to higher energies in our model as compared to the Band function. Noticeably these fits has been performed with a low dependence on synchrotron radiation.

The next step is to fit a larger sample of bursts with the model and to explore more of the relevant parameter space. A more comprehensive and thorough presentation of the work and the details of the model will be available in Ahlgren et al. (in preparation).

References

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