THE BRIGHT AND THE SLOW

GRBS 100724B & 160509A WITH HIGH-ENERGY CUTOFFS AT <~ 100 MEV

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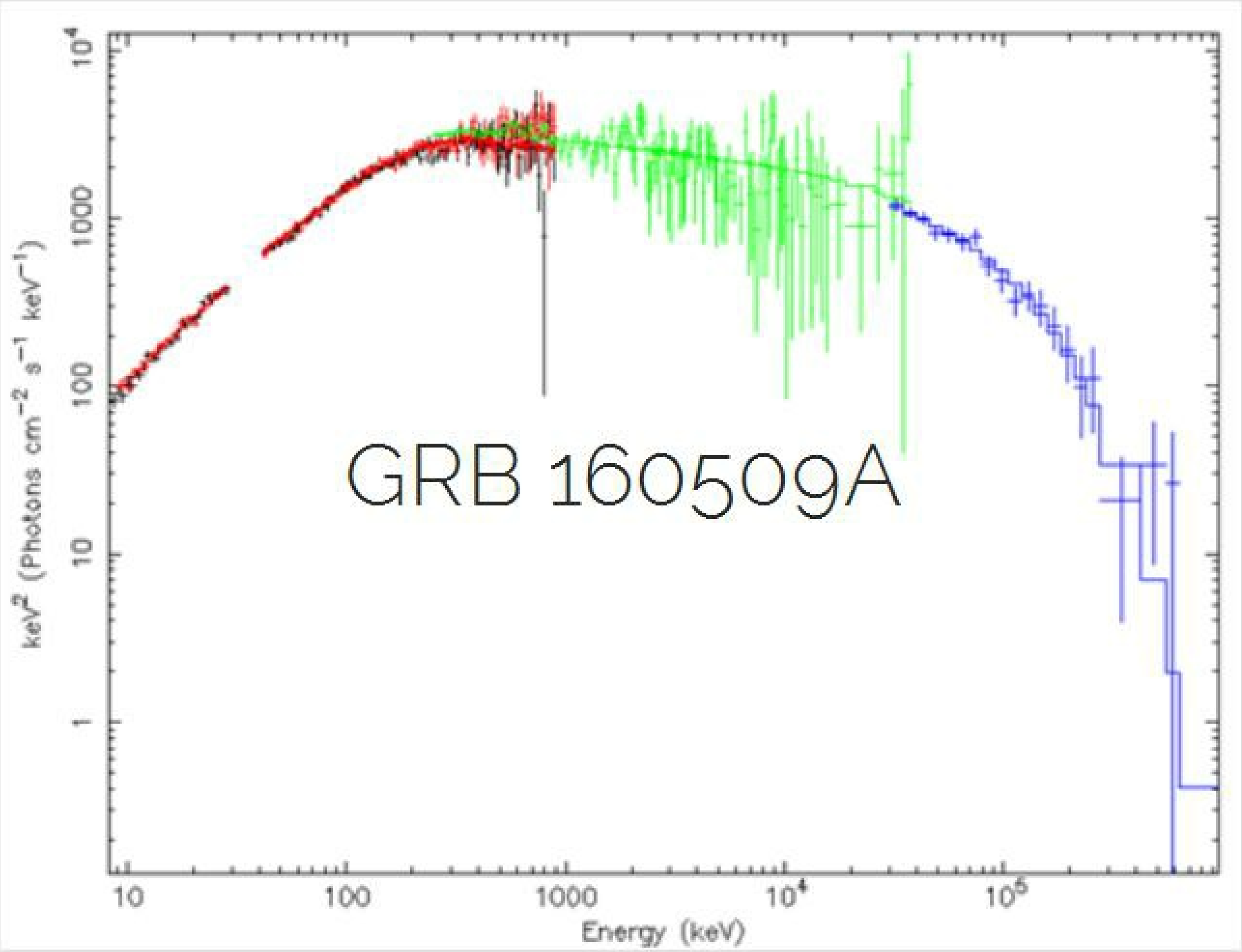
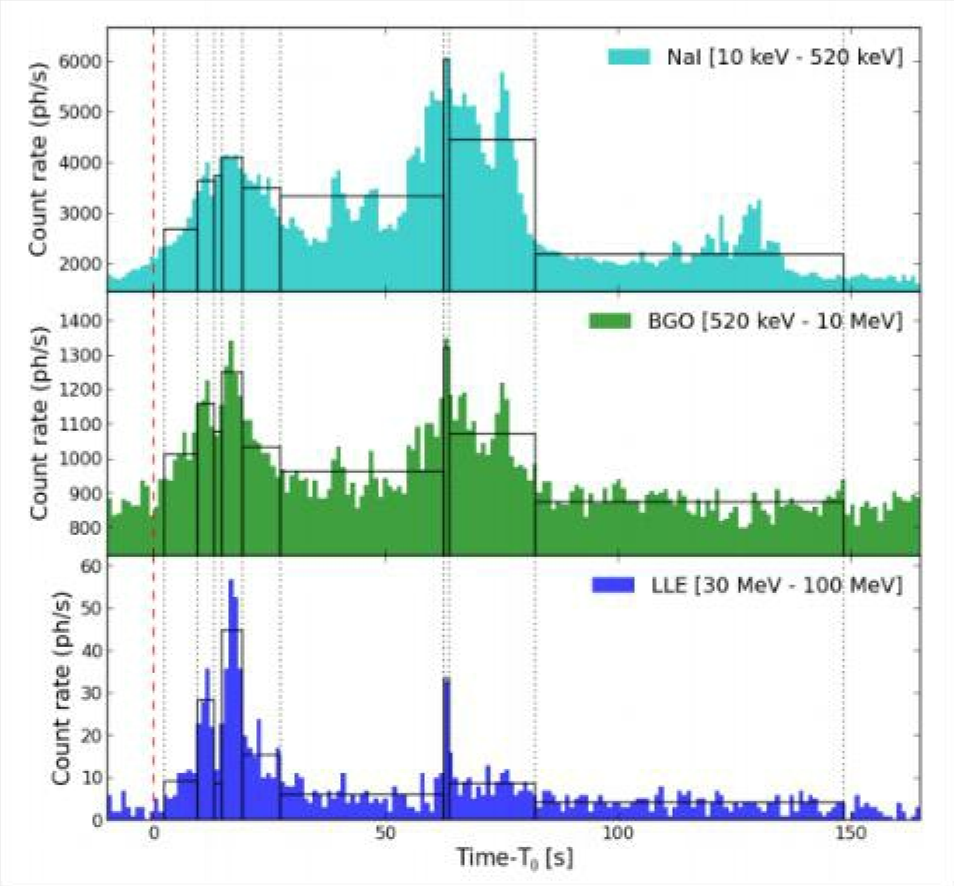
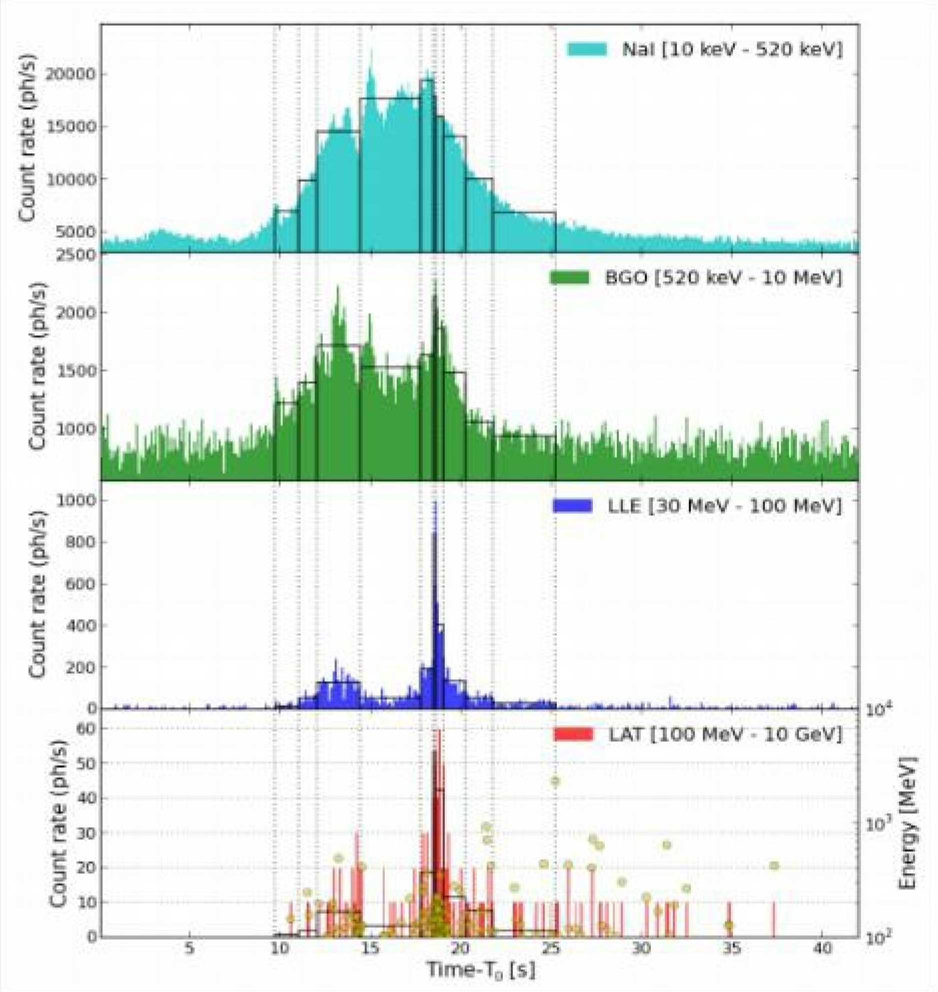






WHY THESE TWO GRBS

- very bright < 100 MeV, faint above
  - evident spectral cutoff in time-integrated spectrum
  - gamma-gamma opacity or something else?
- > 100 MeV emission picks up after the end of the prompt emission
  - "naked prompt" (high-energy afterglow emission starts after the prompt)
  - opportunity to study in detail the prompt emission without contamination from the long lived, high-energy component

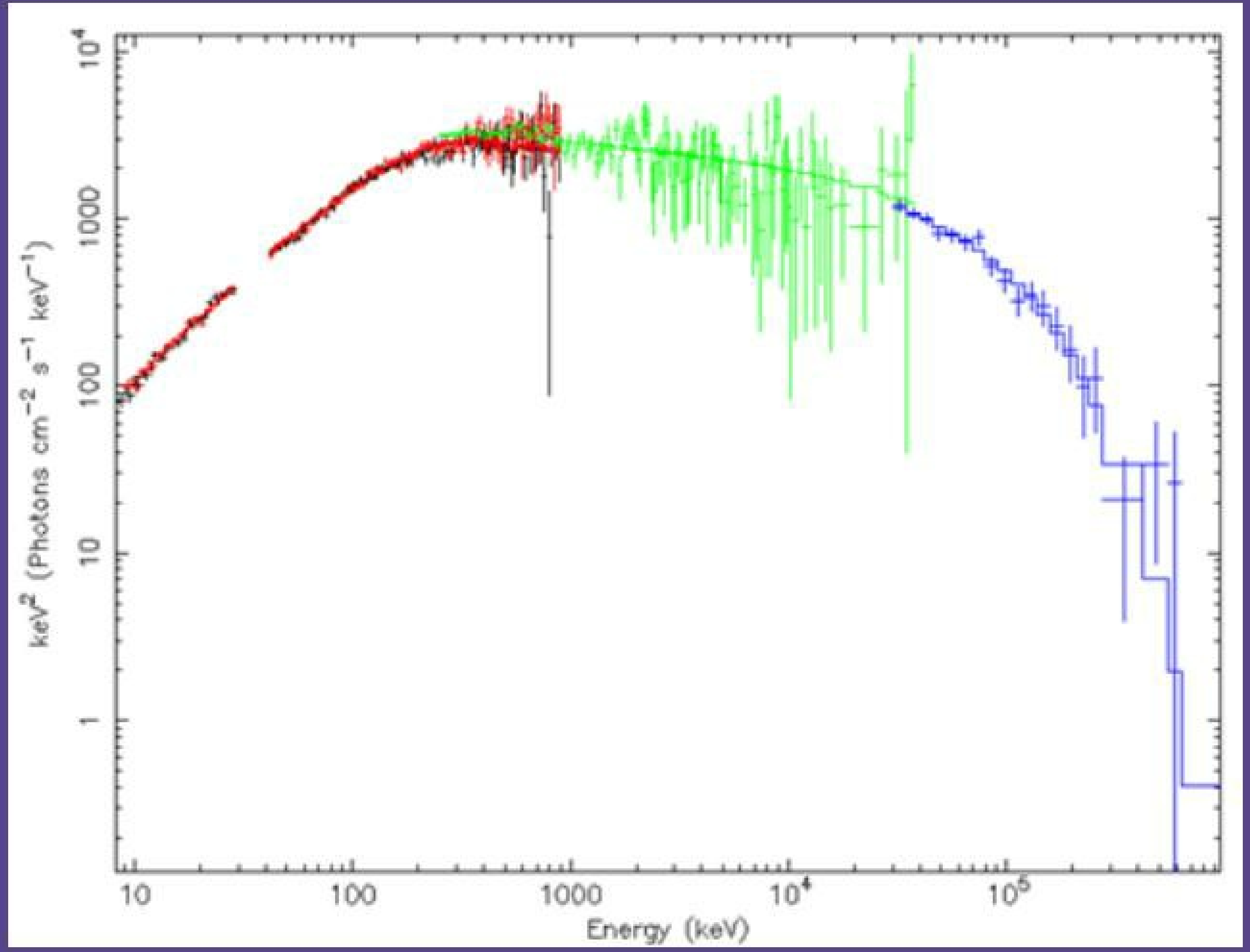
OUTLINE

- Phenomenological study:
  - look for a phenomenological function describing well the data in time-resolved spectroscopy
  - independent from physical model
- Physical modeling with two models (among many possibilities):
  - A semi-phenomenological model with pair production opacity (Granot et al., 2008)
  - a photospheric model (Gill & Thompson, 2014)

Vianello et al., 2018 (under review)
ARXIV: 1706.01481

PHENOMENOLOGICAL MODELS

- Band w. exponential cutoff describes well the data (g.o.f. ~0.1 - 1) with the minimum number of parameters among the model we tried (Band, Band with black body, Comptonized...)
- Band with black body overshoots greatly LLE data
- Analyzed using 3ML (Vianello et al., 2015)



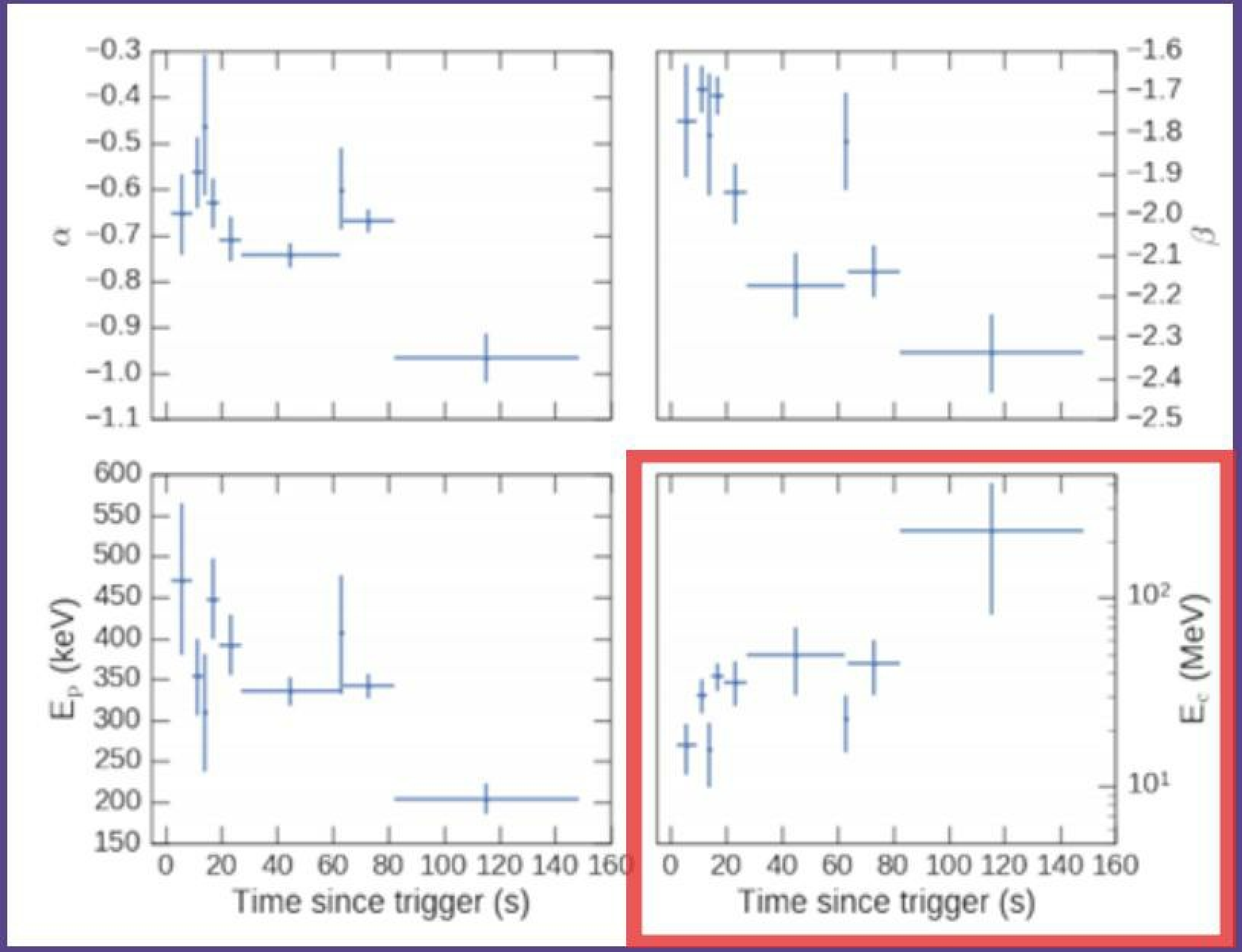
100724B

#	Time interval	S of f_{Band}	p_{null}	TS of f_{BB}	p_{null}	TS of f_{BHec}	p_{null}
1	2.11 - 9.39	1374.3	$< 10^{-3}$	16.8 (3.5 σ)	0.002	27.0 (5.2 σ)	0.23
2	9.39 - 13.11	1079.6	$< 10^{-3}$	74.6 (8.3 σ)	$< 10^{-3}$	74.2 (8.6 σ)	0.52
3	13.11 - 14.61	604.9	0.002	12.8 (2.9 σ)	0.004	16.4 (4 σ)	0.05
4	14.61 - 19.14	1227.2	$< 10^{-3}$	97.6 (9.5 σ)	$< 10^{-3}$	127.2 (11.2 σ)	0.61
5	19.14 - 27.23	1448.3	$< 10^{-3}$	12.0 (2.8 σ)	$< 10^{-3}$	57.3 (7.6 σ)	0.17
6	27.23 - 62.52	2174.9	0.001	50.8 (6.7 σ)	$< 10^{-3}$	27.1 (5.2 σ)	0.09
7	62.52 - 63.65	544.7	0.03	3.8 (3.1 σ)	0.001	7.8 (2.8 σ)	0.82
8	63.65 - 82.23	1888.2	$< 10^{-3}$	51.8 (6.8 σ)	$< 10^{-3}$	40.6 (6.4 σ)	0.36
9	82.23 - 148.41	2393.0	0.12	7.2 (1.9 σ)	0.15	3.2 (1.8 σ)	0.32

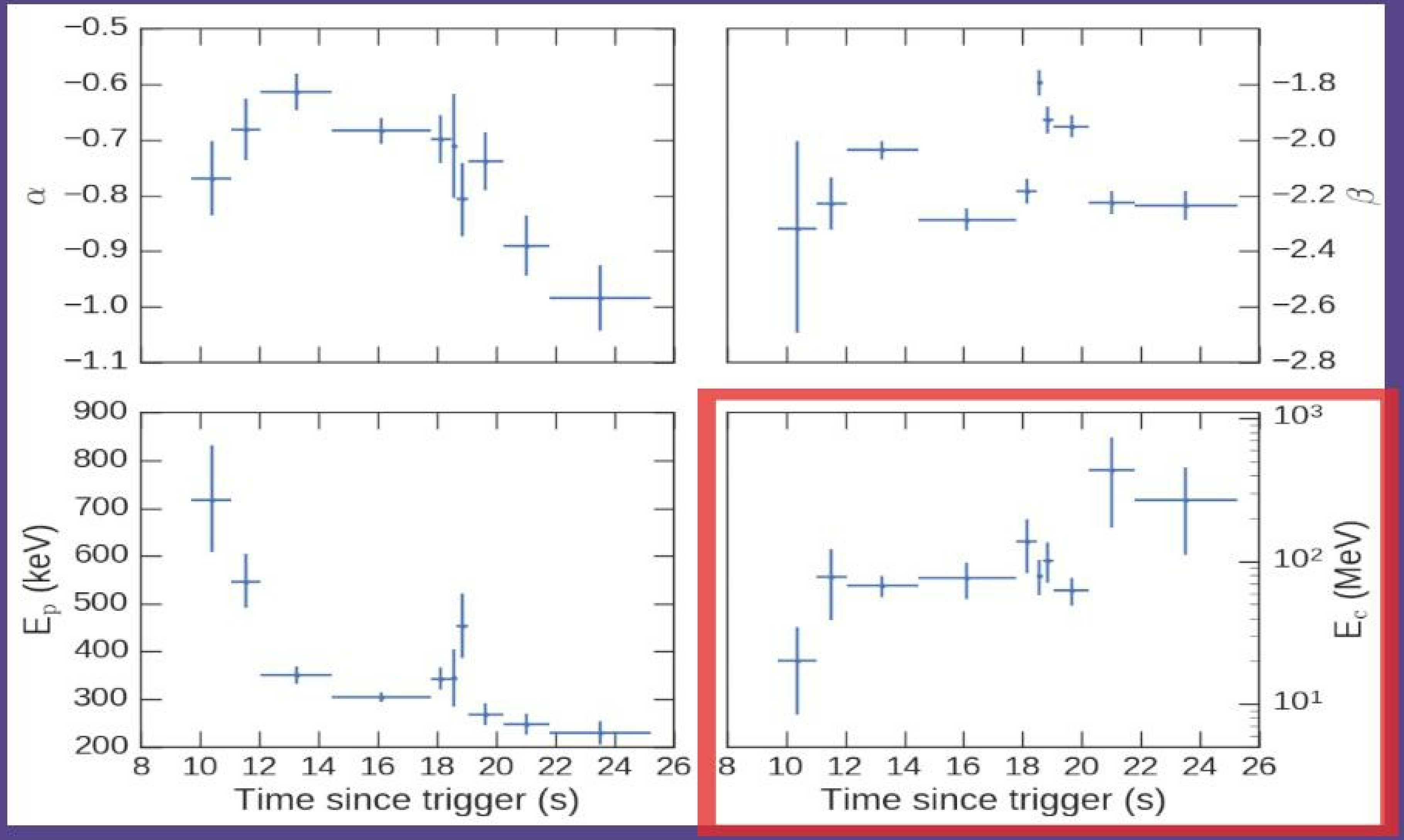
160509A

#	Time interval	S of f_{Band}	p_{null}	TS of f_{BHec}	p_{null}
1	9.712-11.045	970.5	0.12	7.07 (2.4 σ)	0.15
2	11.045-12.042	894.07	0.05	7.63 (2.5 σ)	0.31
3	12.042-14.449	1516.65	$< 10^{-3}$	93.83 (9.6 σ)	0.33
4	14.449-17.783	1620.88	$< 10^{-3}$	42.07 (6.4 σ)	0.48
5	17.783-18.480	847.16	0.003	21.19 (4.5 σ)	0.23
6	18.480-18.667	233.18	$< 10^{-3}$	67.54 (8.1 σ)	0.77
7	18.667-19.044	527.27	$< 10^{-3}$	43.89 (6.5 σ)	0.24
8	19.044-20.249	1105.23	$< 10^{-3}$	63.11 (7.8 σ)	0.89
9	20.249-21.787	1124.36	0.09	5.09 (2.0 σ)	0.35
10	21.787-25.254	1460.61	0.23	6.30 (2.2 σ)	0.22

100724B



160509A

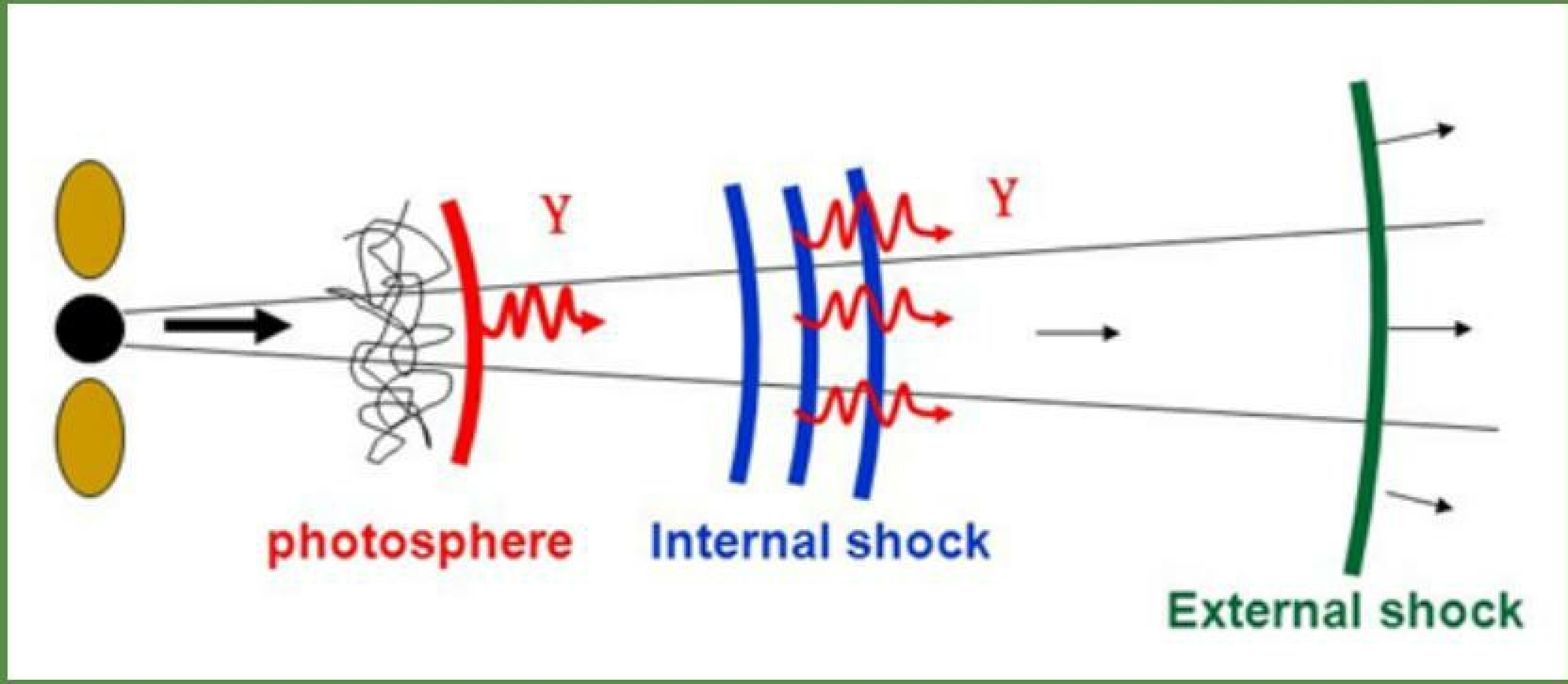


PHENOMENOLOGICAL RESULTS

- Band with cutoff is the simplest model providing a good description of the data
- Cutoff statistically required in intervals with good signal to noise
- Models with a black body or a power-law cutoff provide a worse fit (despite having one more parameter)

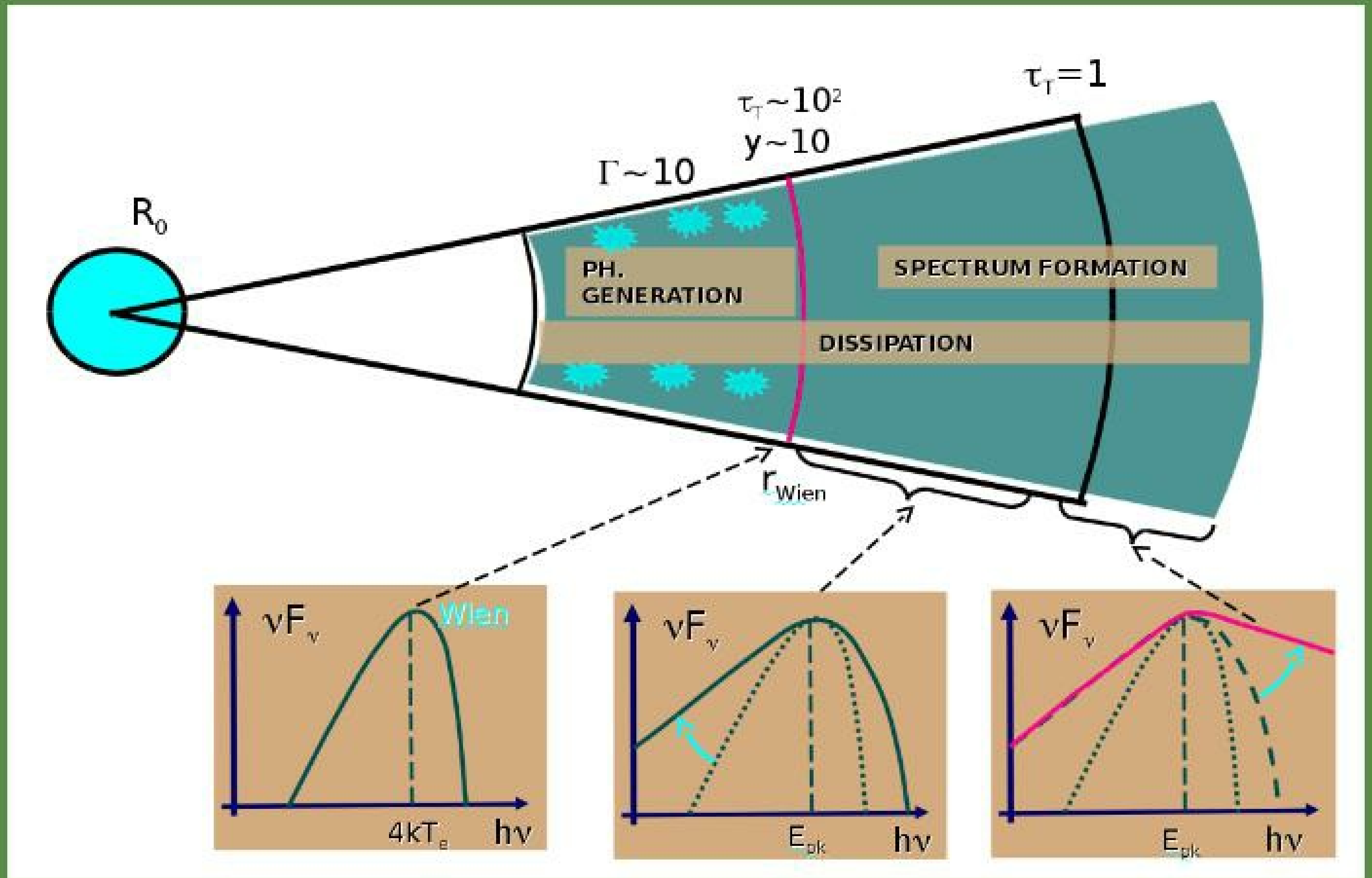
FIREBALL MODEL

INTERNAL SHOCKS



- Problems:
  - efficiency
  - sync. radiation cannot explain some of the spectra

PHOTOSPHERIC MODELS



(Vurm et al. 2013, 2nd EUL GRB workshop, www.exul.ru/workshop2013)

- Many different diss. mechanisms proposed, requiring different features in the jet (composition, magnetization…)

Combinations of the two are possible as well

PHYSICAL MODELING

- we consider 2 scenarios (among many possibilities):
  - a photospheric model: development of an electron-positron pair cascade in a highly magnetized, dissipative and baryon-poor outflow (Gill & Thompson 2014)
  - "classical" explanation: pair-production opacity attenuating a non-thermal spectrum (produced for example by synchrotron emission during internal shocks) (Granot et al. 2008)
- spectra are computed numerically from "first principles" as function of physical parameters, then fitted directly on the data using 3ML (models and templates will be publicly available after the paper is accepted)

100724B

160509A

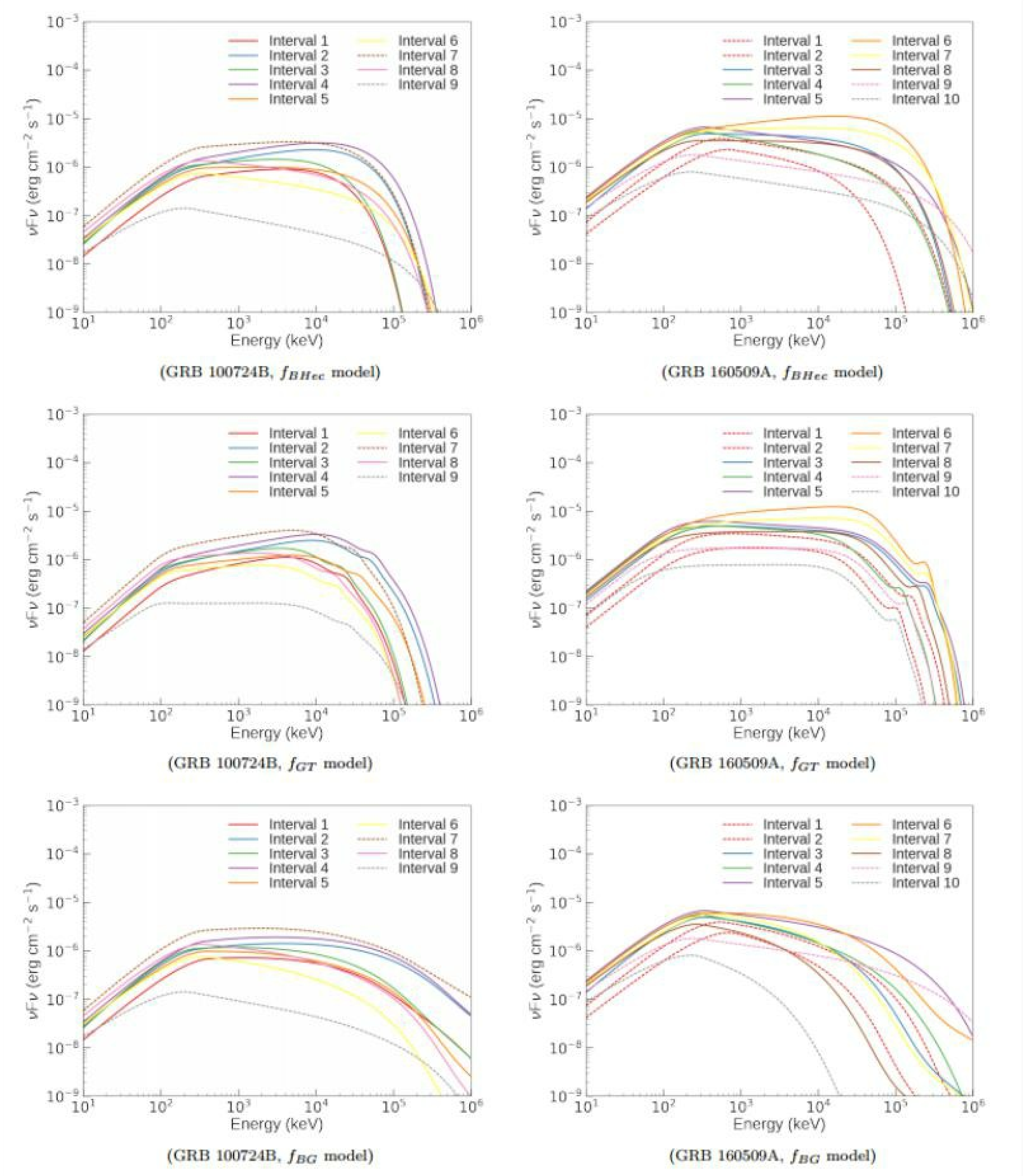
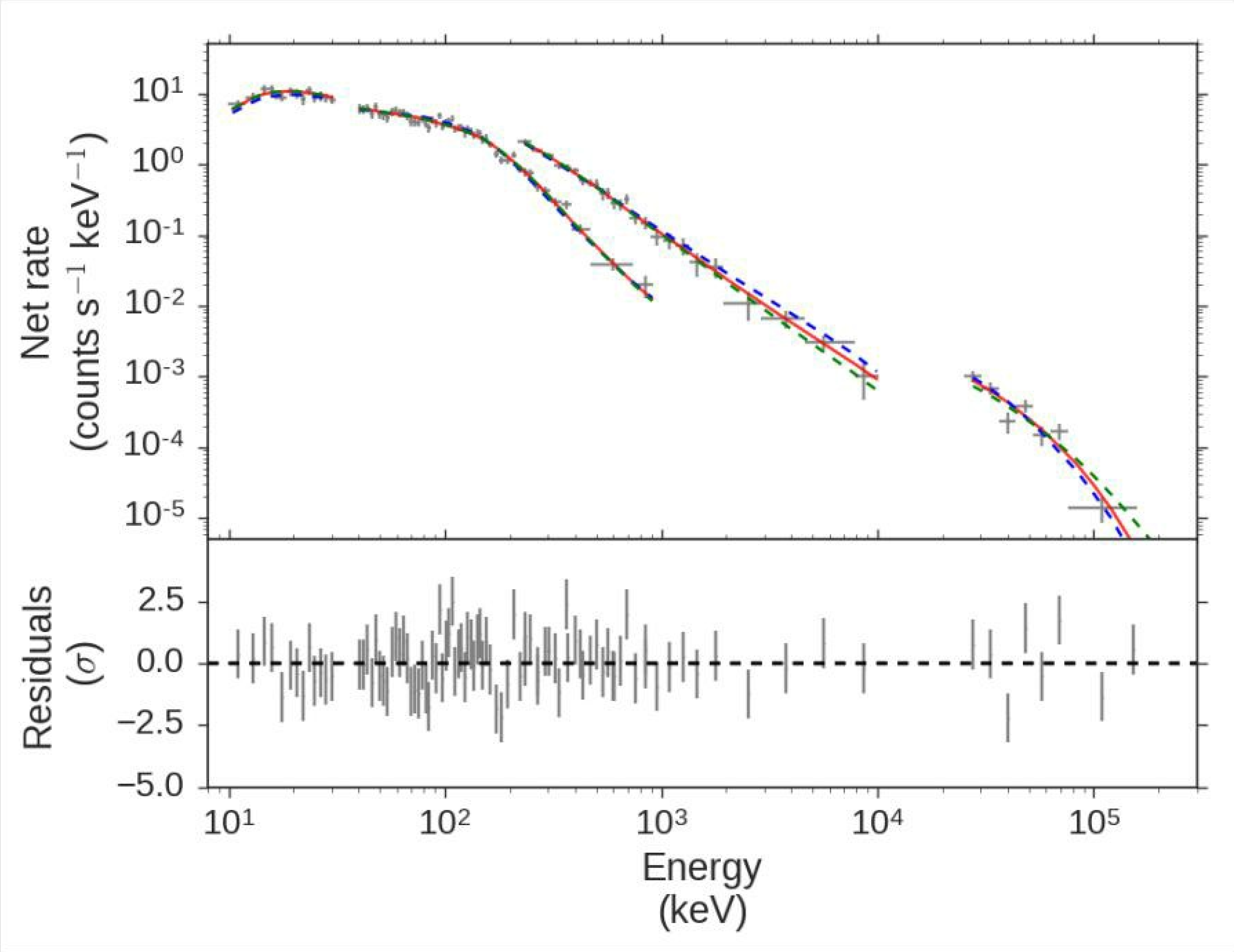


Figure 7: Best fit spectra for GRB 100724B (left) and for GRB 160509A (right), for the f_{BHec}, f_{GT} and f_{BG} models. The dashed lines mark intervals where the improvement given by the addition of the cutoff is lower than 3 σ.

BOTH MODELS WORK WELL

- despite their differences in nuFnu, the folded spectra look very similar (due to the energy dispersion)
  - cannot distinguish between them
  - both work well and are viable models for these two GRBS



Example: interval 5 for GRB 100724B (the paper figures with all the spectra for all the intervals)

PHYSICAL PARAMETERS

"Internal-shock" model

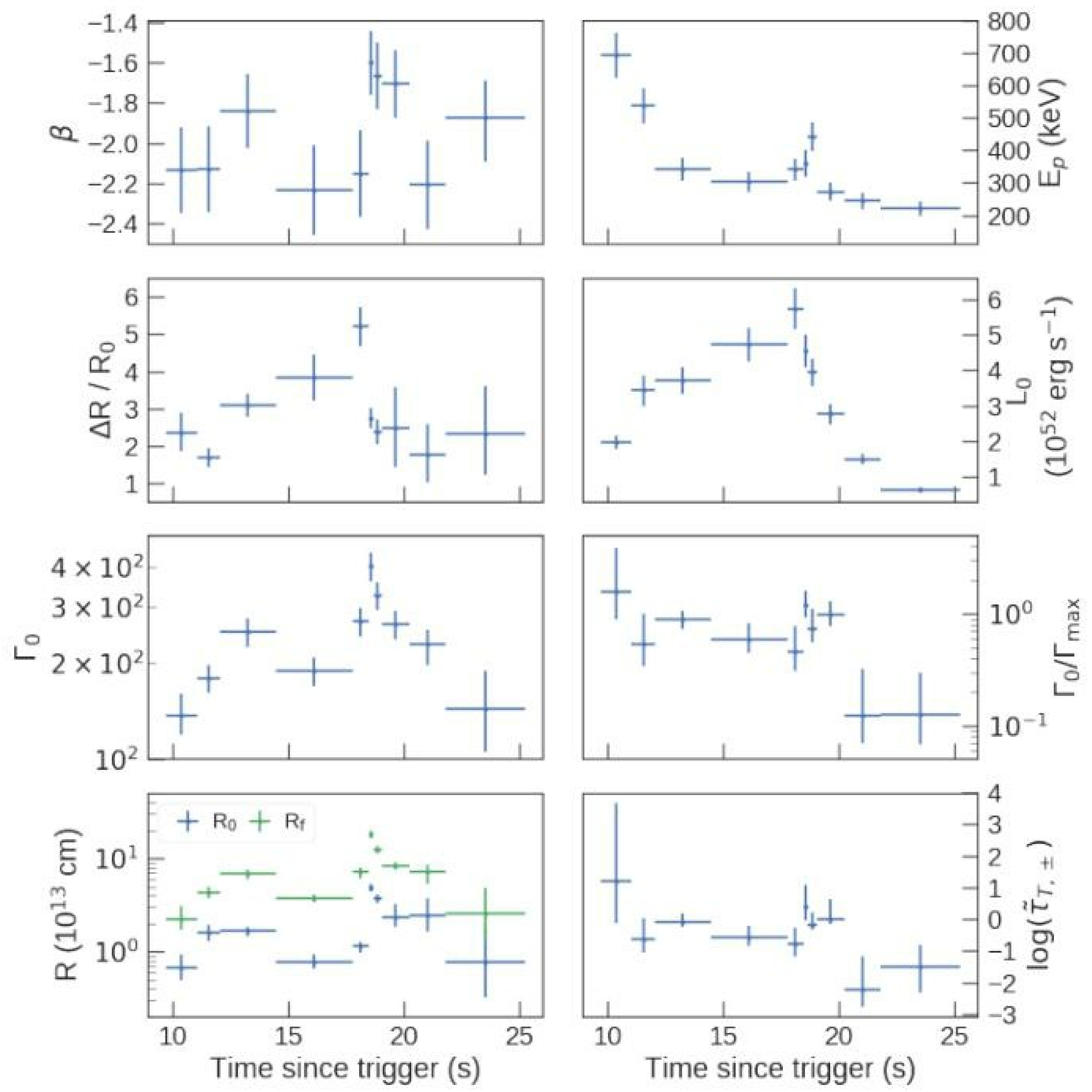
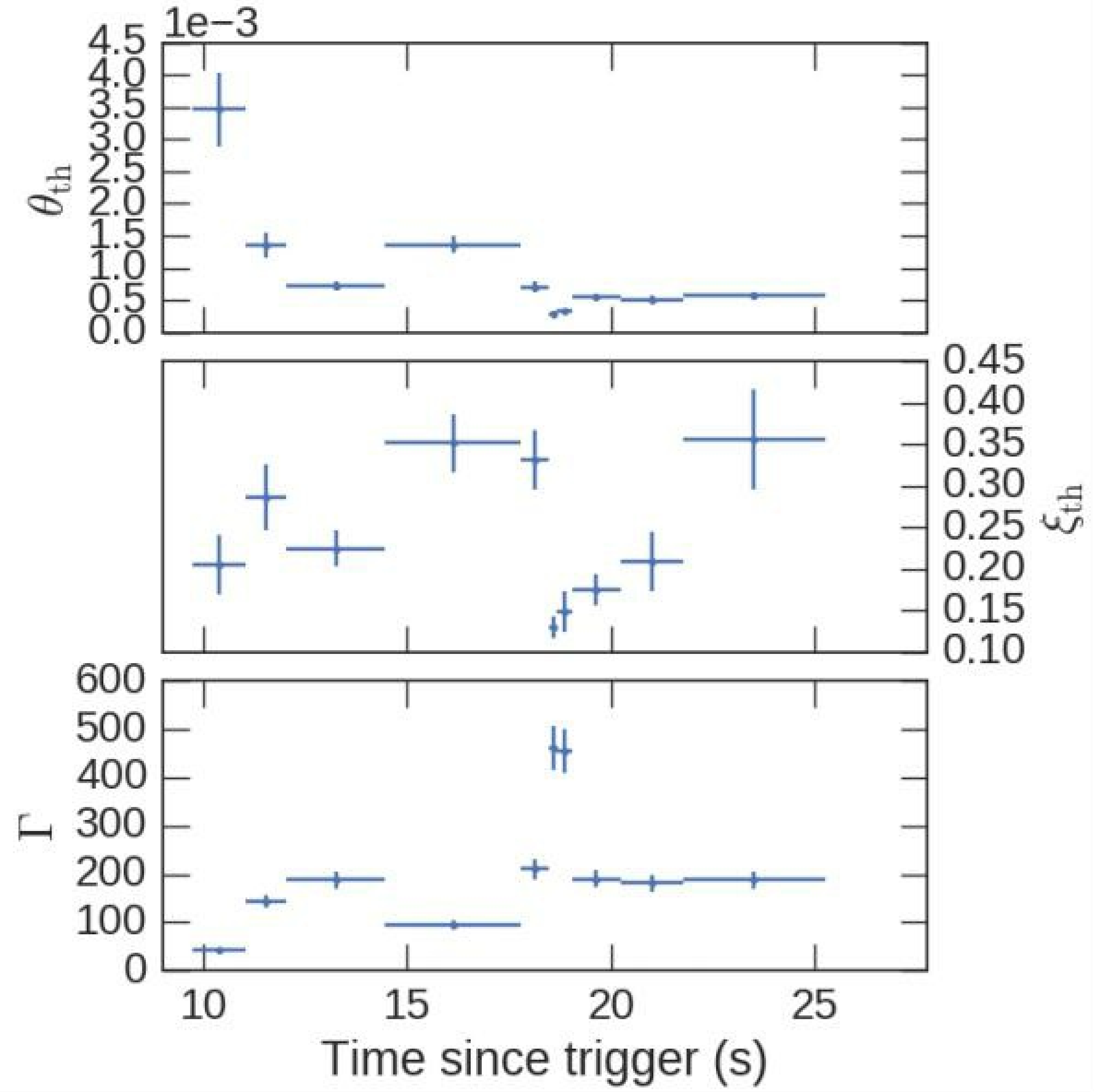


Figure 11: Similar to Figure 10, but for GRB 160509A, which occurred at $z = 1.17$.

Parameters compatible with IS model

photospheric model



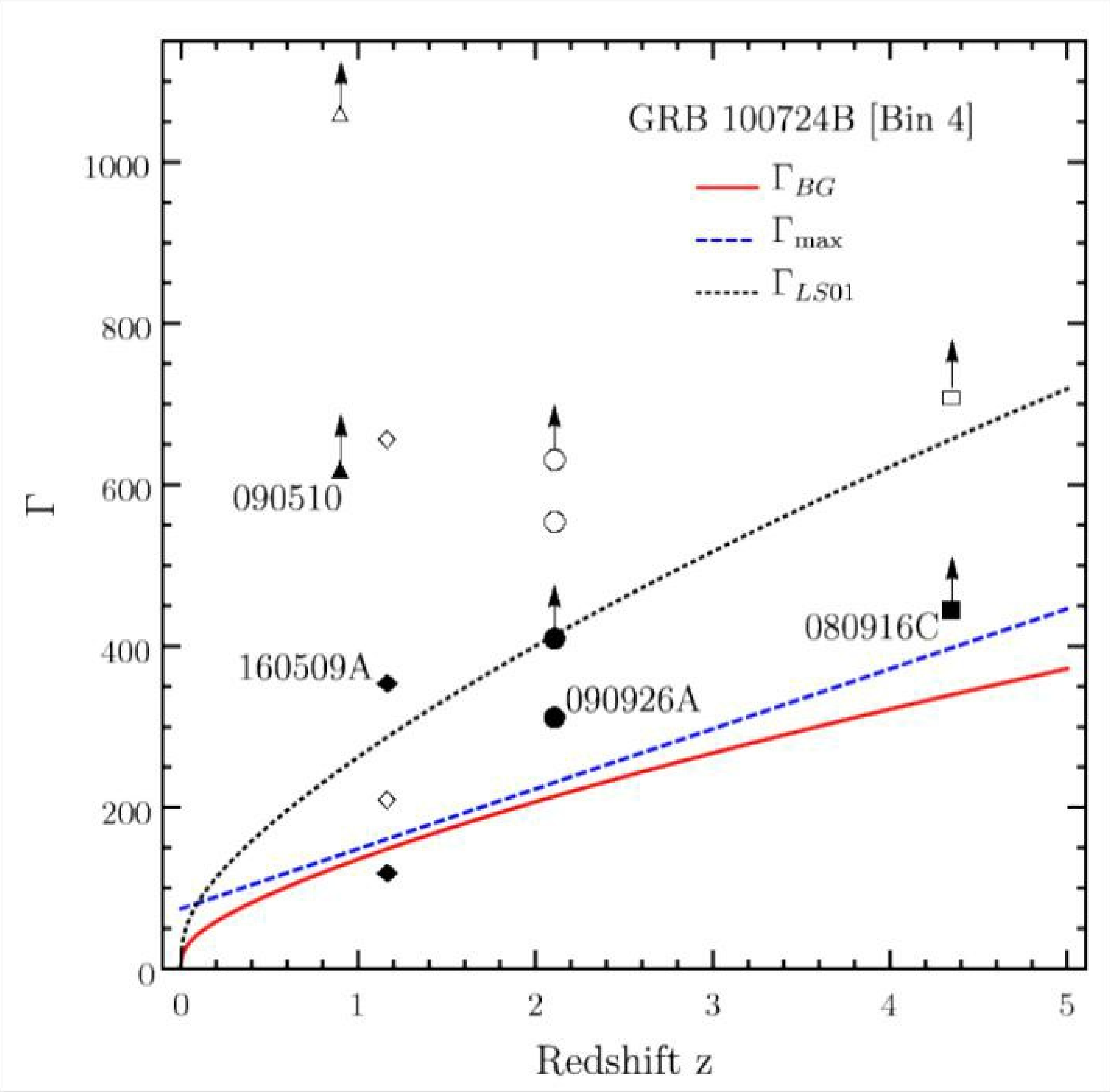
Realistic values for parameters

(these are for GRB 160509A, the paper contains similar plots for GRB 100724B)

COMPARISON WITH OTHER LAT GRBS

	080916C	090926A	090510	160509A
z	4.35	2.1062	0.903	1.17
E_c^* (GeV)	3.0*	0.4	30.5*	0.08
$\Gamma_{\rm min}^{**}$	887 ± 21^a	720 ± 76^b	1218 ± 61^c	-
Γ_{BG}	451	319	628	363
β	−2.21	−1.71	−1.85	−1.60
$L_{0,52}$ (erg/s)	55.78	3.42	1.24	6.18
$t_{v,z}$ (ms)	374	48	6.3	23
$\psi_{(1+z)}$	−0.20	−0.18	0.02	
ψ_Γ	0.41	−0.58	0.81	
ψ_β	0.58	0.41	0.26	
$\psi_{L_{0,52}}$	−0.81	0.50	0.46	
$\psi_{t_{v,z}}$	1.03	0.63	−0.37	

Table 4: Ratio of intrinsic parameters as described in eq. (12) with GRB 160509A as the reference system. In systems where no spectral cutoff was observed (marked with *), the maximum observed photon energy is quoted. ** Minimum bulk-Γ (or the actual inferred Γ when a cutoff is observed) calculated using a one-zone analytical model employing a more elaborate radiation field spectrum as compared to a simple power-law used in LS01. In all three cases, the inferred $\Gamma_{\rm min} \sim 2\Gamma_{BG}$: [a]Abdo et al. (2009b), [b]Ackermann et al. (2011), [c]Ackermann et al. (2010)



CONCLUSIONS

- Two bright GRBs at low energies with cutoffs < 150 MeV
- Well described by opacity effects, either in an internal-shock scenario or in a photospheric scenario
    - alternative explanations (for example cutoff in the electron's energy distribution) appear to be less natural
- Both models provide a good fit to the data with reasonable parameters
    - direct estimate of bulk Lorentz factors
    - $\Gamma \sim$ 100–400, on the lower end of what is generally inferred from Fermi GRBs
    - variability times, luminosity, and high-energy photon index all contribute to low Ec
    - low Ec values may prevent detection by Fermi-LAT, thus introducing a bias in the Fermi-LAT GRB sample against GRBs with low Lorentz factors or variability times.