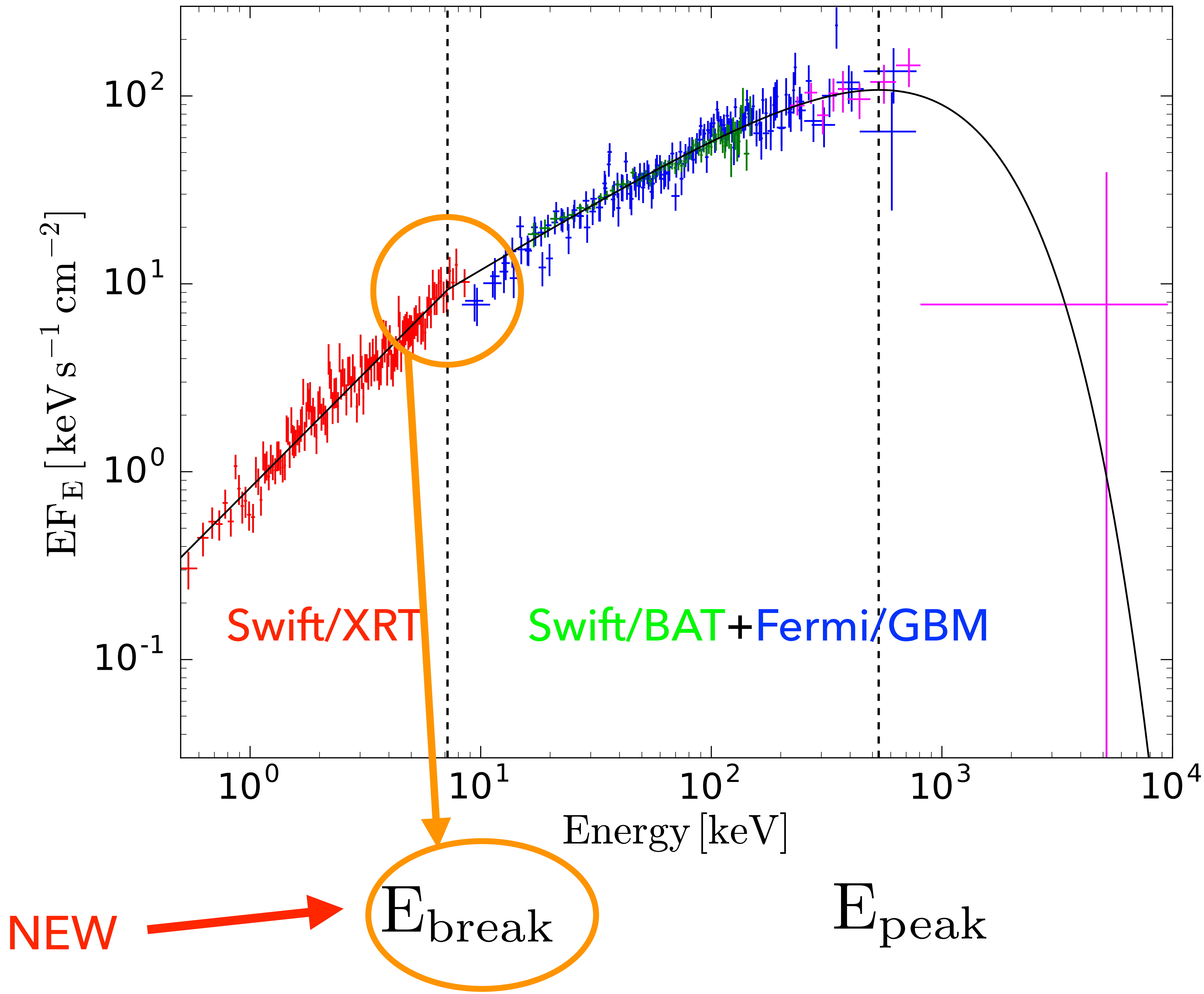
Discovery of a low-energy spectral breaks in prompt GRB spectra

GOR OGANESYAN
SISSA, Trieste, Italy

LARA NAVA
INAF - Osservatorio Astronomico di Brera, Merate, Italy

GIANCARLO GHIRLANDA
INAF - Osservatorio Astronomico di Brera, Merate, Italy

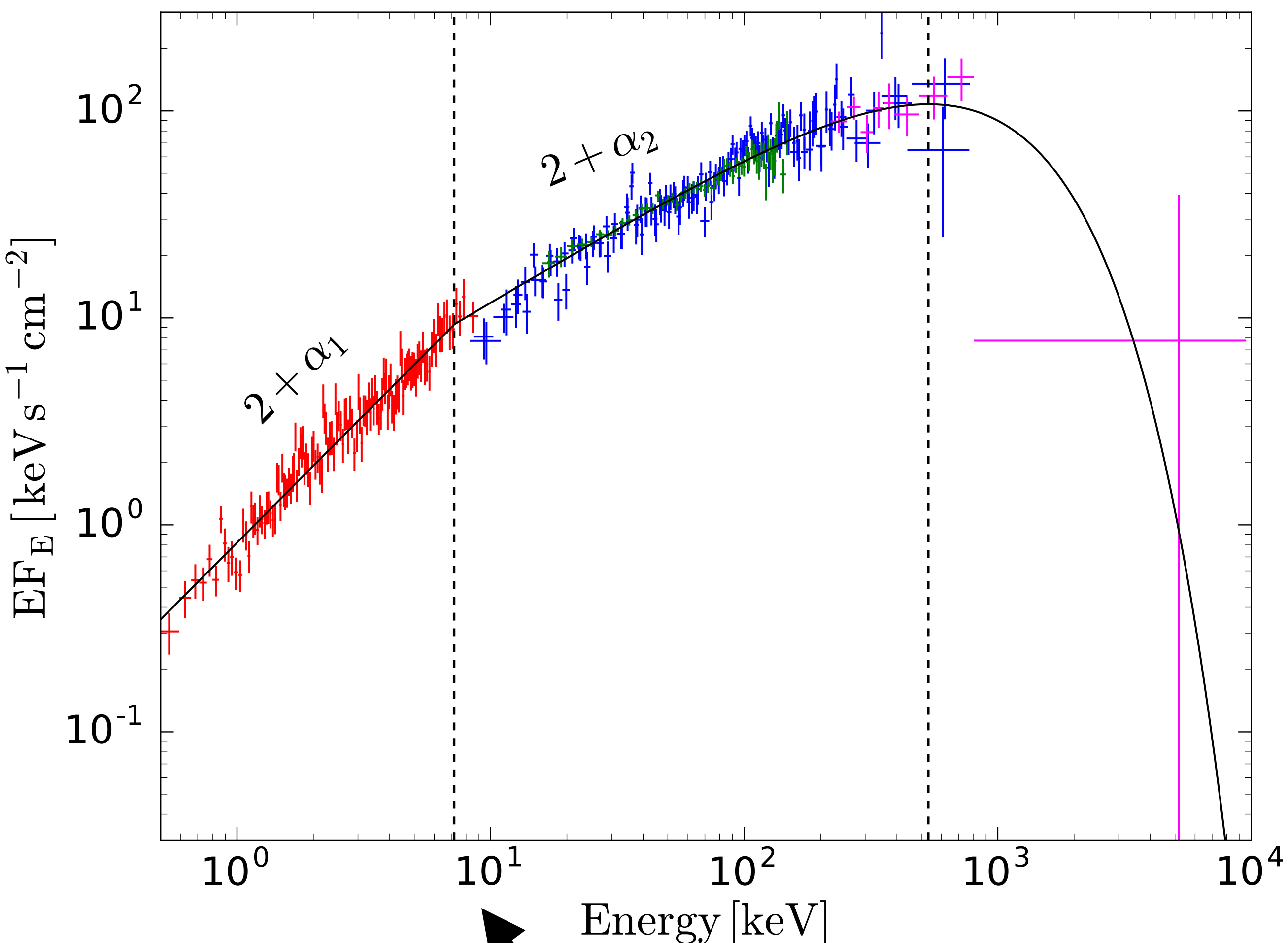
ANNALISA CELOTTI
SISSA, Trieste, Italy

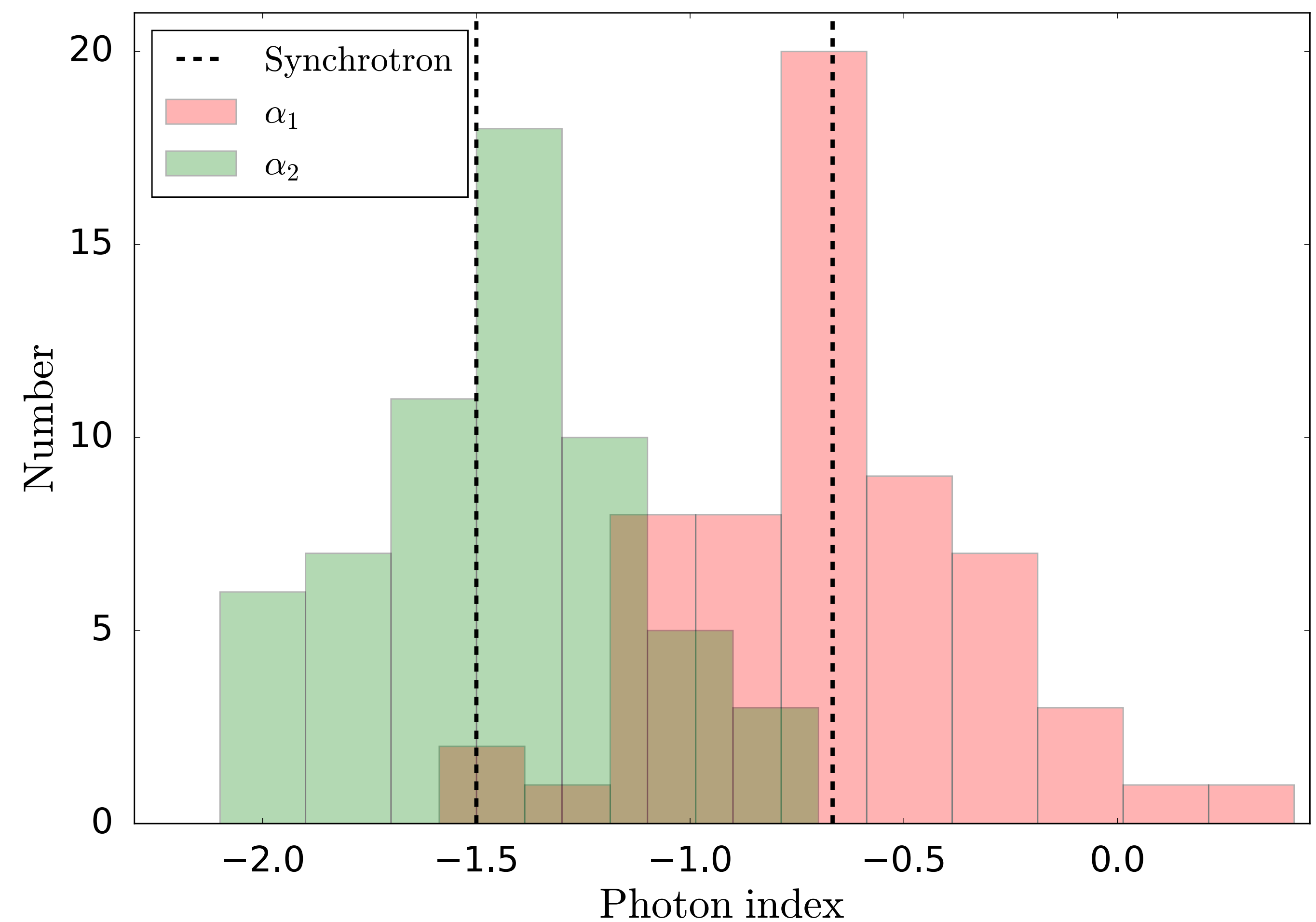


$EF_E\,[\mathrm{keV\,s^{-1}\,cm^{-2}}]$
10^{2}
10^{1}
10^{0}
10^{-1}
Swift/XRT
Swift/BAT+Fermi/GBM
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Energy [keV]
NEW
E_{break}
E_{peak}

SWIFT/XRT + SWIFT/BAT + Fermi/GBM

0.5-10 keV 15-150 keV 8 keV-40 MeV





$\mathrm{E_{break}}$

cooling frequency?

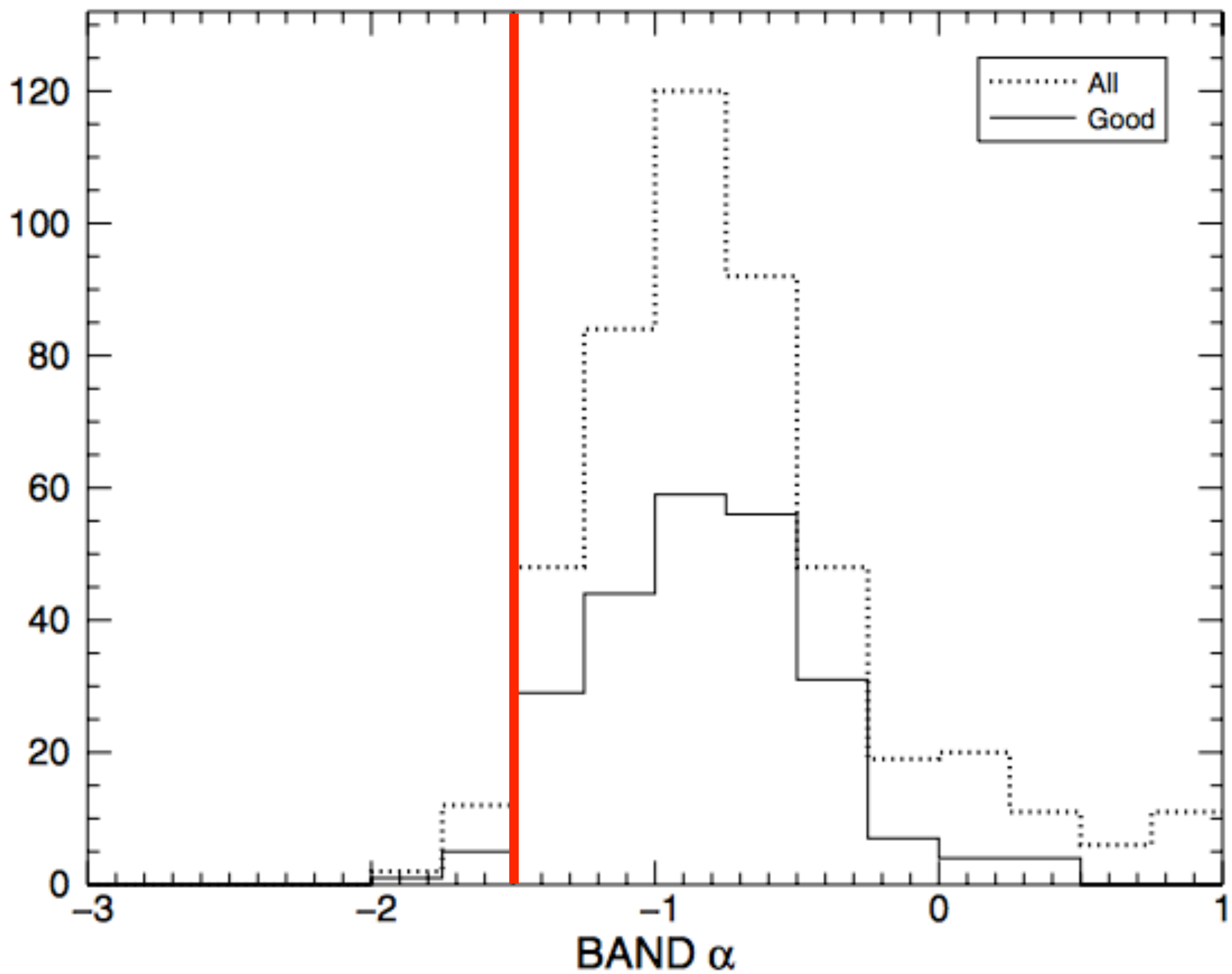
mean values are in agreement with synchrotron spectrum

SYNCHROTRON LINE OF DEATH

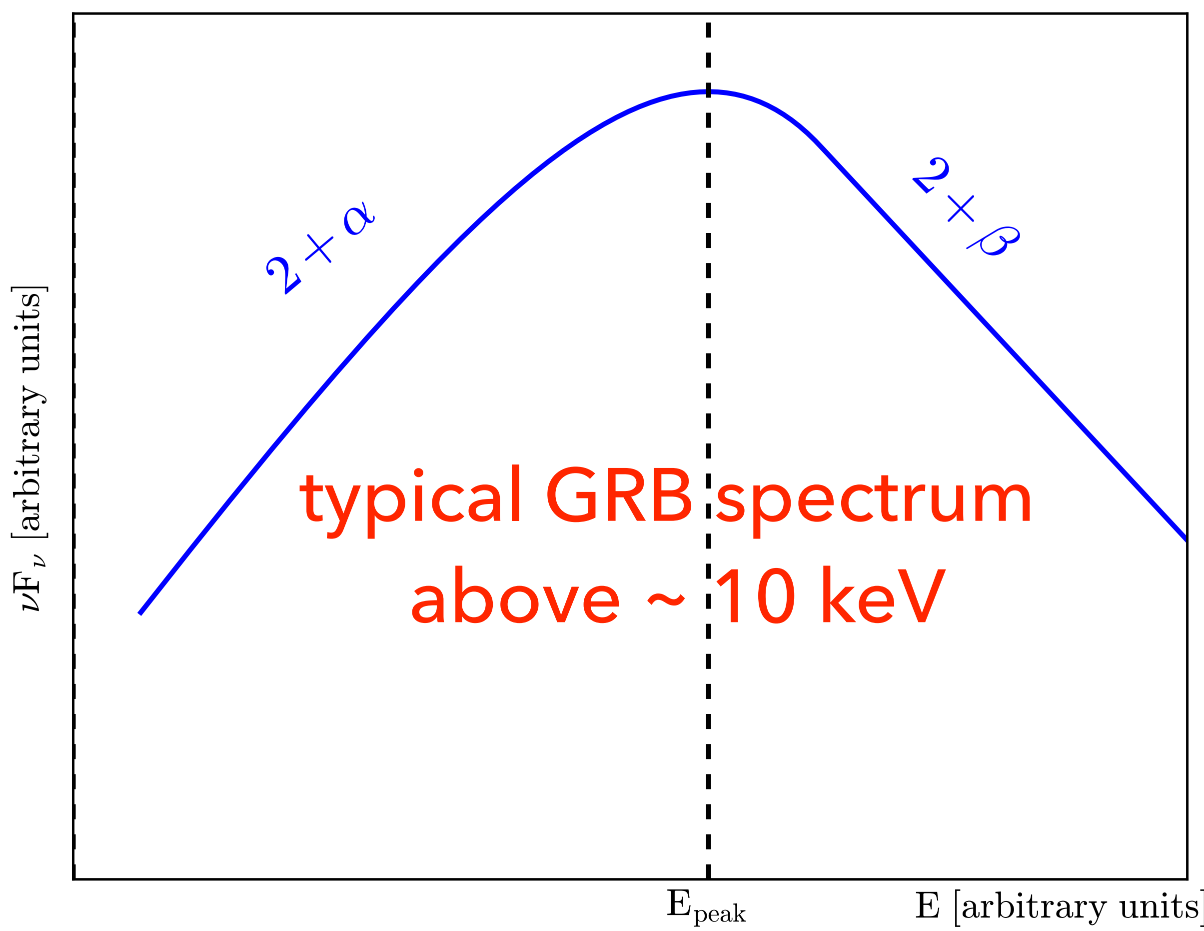
most prompt spectra, in the literature, are not consistent with fast cooling synchrotron spectrum

$\alpha \sim -1 \qquad \beta \sim -2.5$

$-3/2$

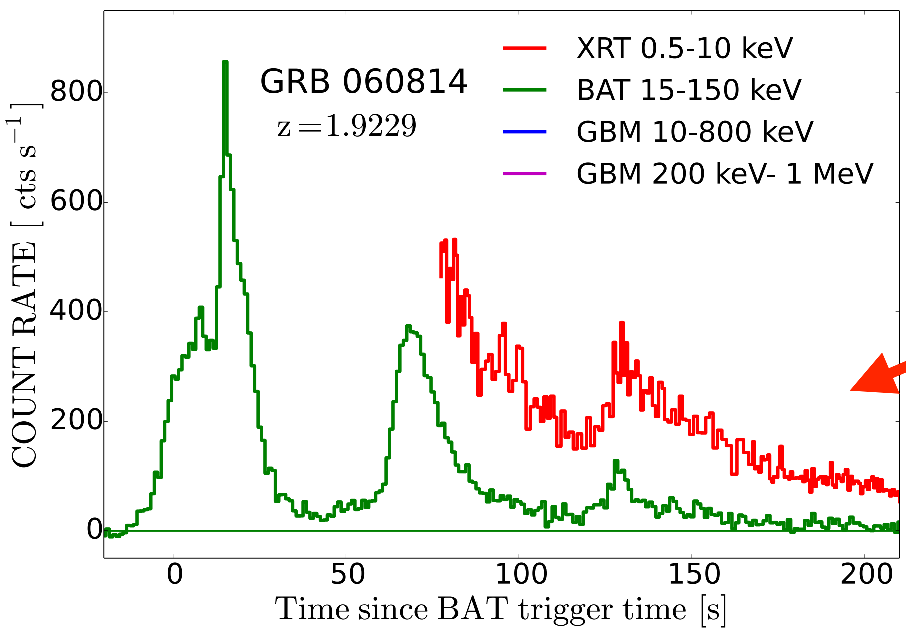


2nd Fermi catalog

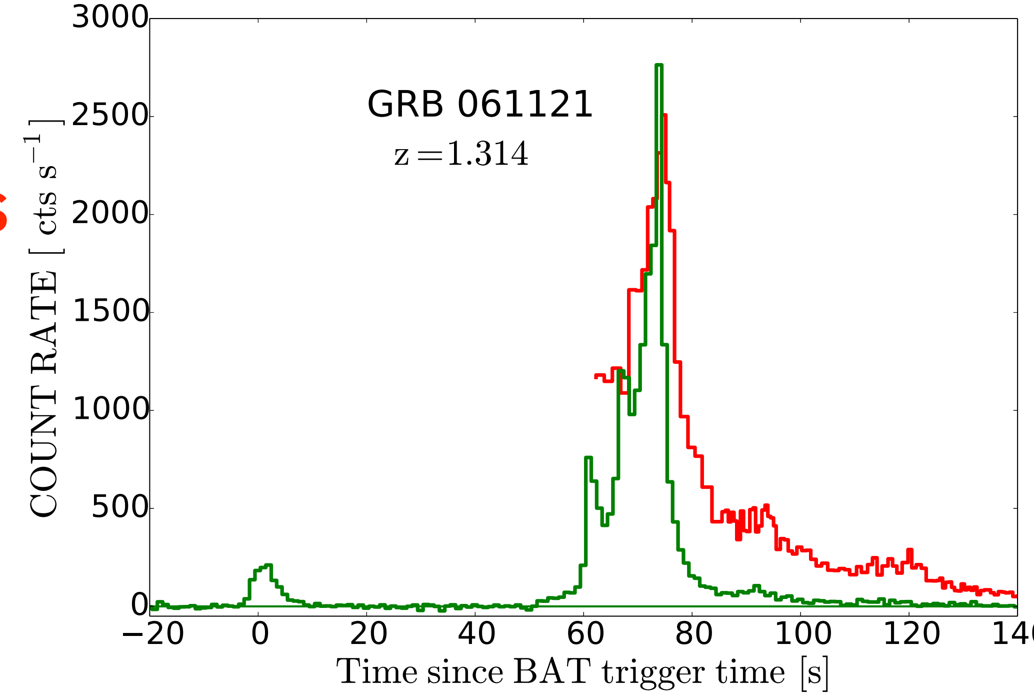


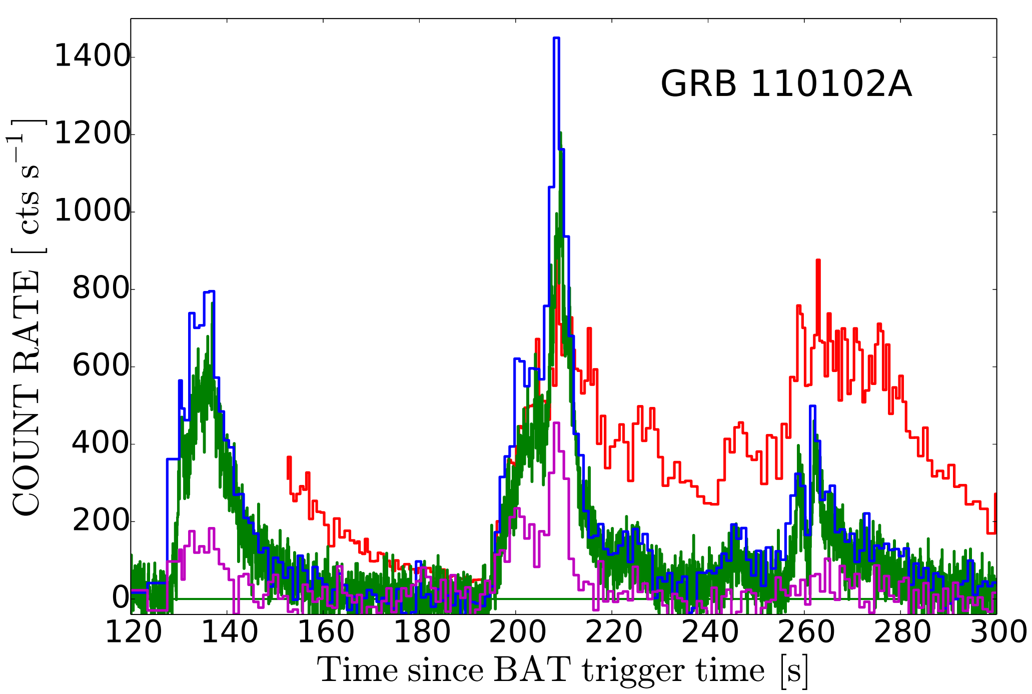
XRT + BAT + GBM SAMPLE   14 GRBs with 128 TIME-RESOLVED SPECTRA

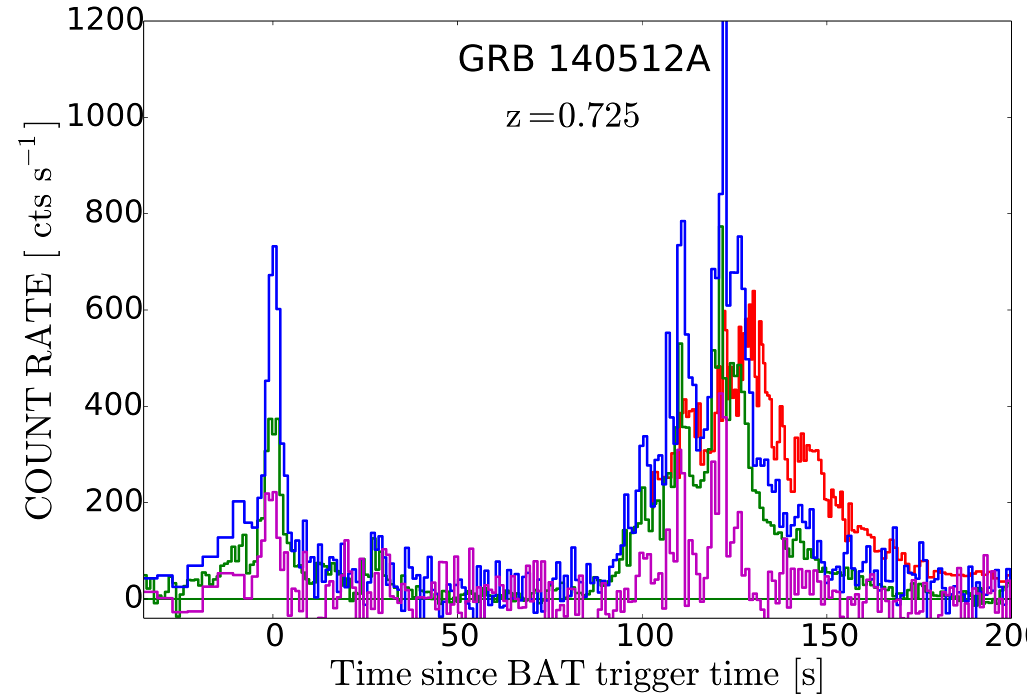
Light curve examples



Swift/XRT observations during the prompt!

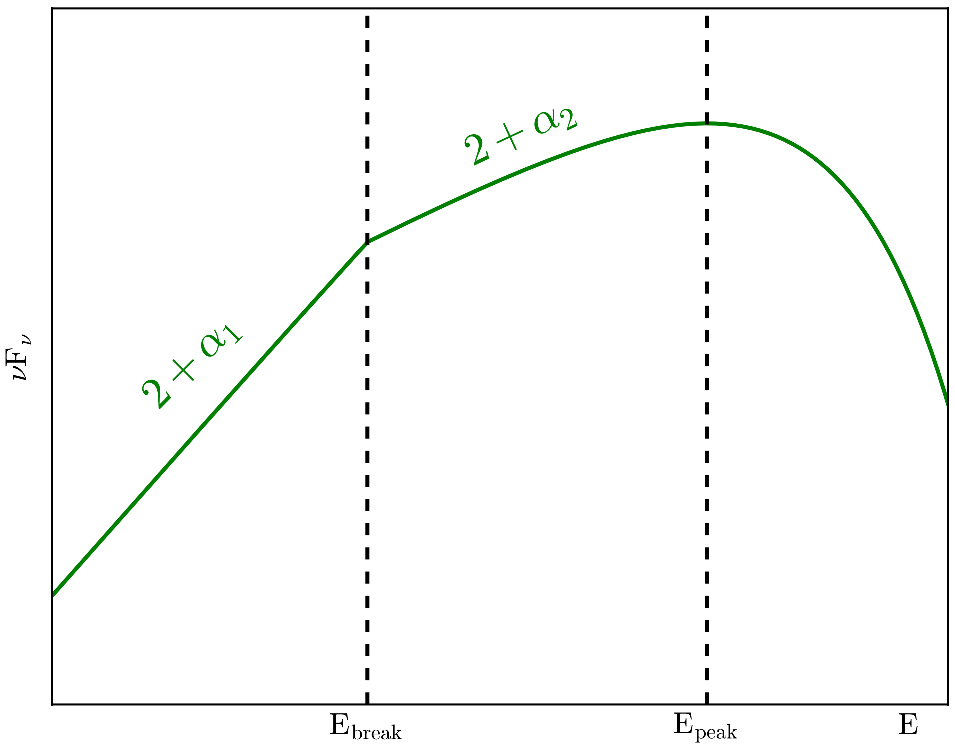


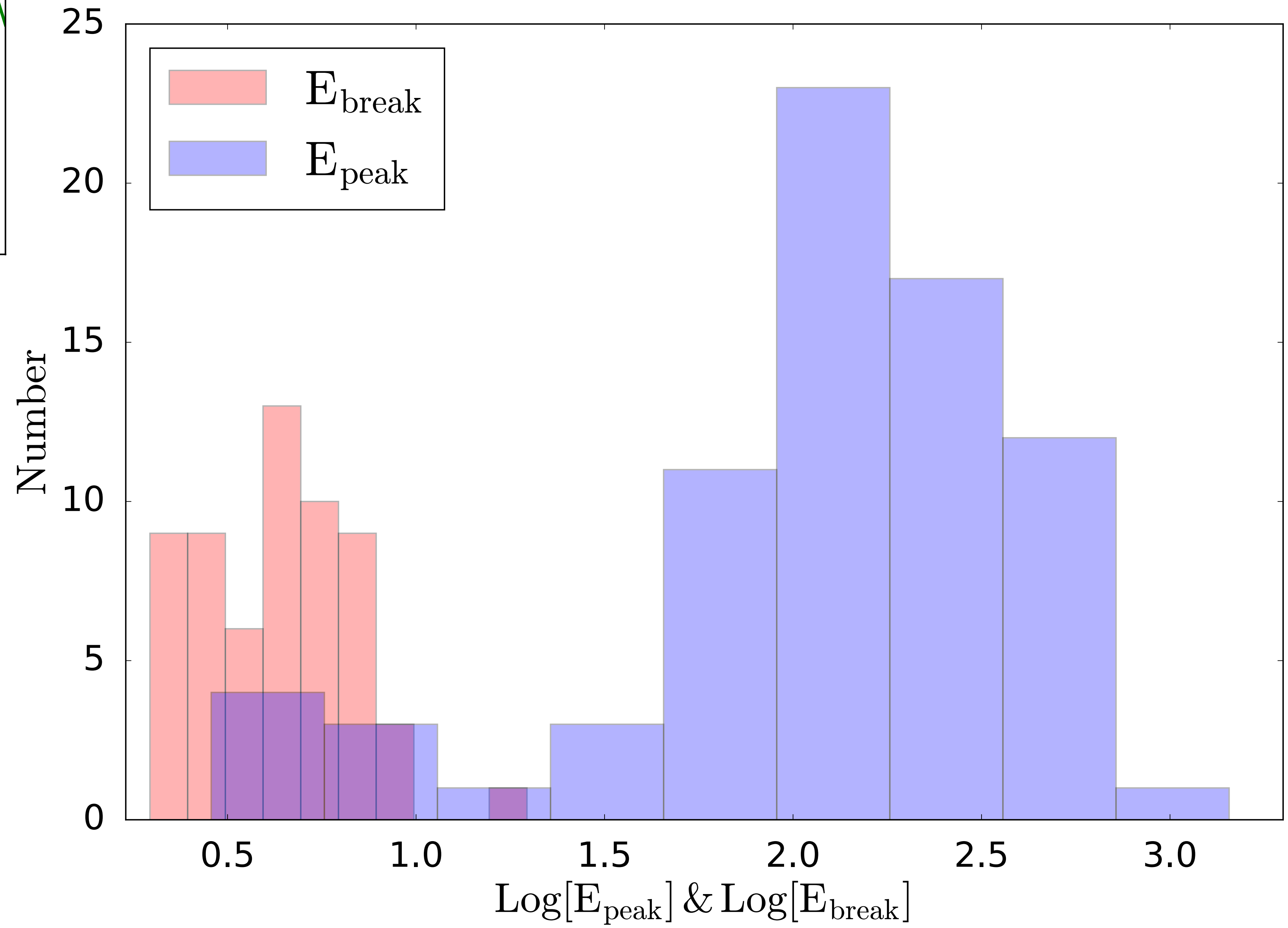




DISTRIBUTION OF PEAK/BREAK ENERGIES

A spectral break is found for 67% of time-resolved spectra





$$\langle E_{break} \rangle = 4.3\ \mathrm{keV}$$

$$\langle E_{peak} \rangle = 126\ \mathrm{keV}$$

$$E_{peak}/E_{break} \sim 30$$

MAIN FINDINGS OF THE TIME-RESOLVED SPECTROSCOPY

- Large sample (34 GRBs): presence of breaks is confirmed, analysis in progress
- A spectral break at soft X-rays is found for more than 50% of spectra
- Photon indices are consistent with synchrotron radiation scenario
- The typical ratio is $\frac{\mathrm{E_{peak}}}{\mathrm{E_{break}}} \sim 30$. This regime ('moderately fast cooling') has been considered before as a solution for the synchrotron line of death problem.
- We gave the first time observational evidence in support of this scenario

Submitted to ApJ

DISCOVERY OF LOW-ENERGY BREAKS IN GAMMA-RAY BURST PROMPT EMISSION SPECTRA

Gor Oganesyan,[1] Lara Nava,[2,3,4,5] Giancarlo Ghirlanda,[4] and Annalisa Celotti[1,3,4]

[1] *SISSA, via Bonomea 265, I–34136 Trieste, Italy*
[2] *Dipartimento di Fisica, Università di Trieste, via Valerio 2, I–34127 Trieste, Italy*
[3] *INFN - Sezione di Trieste, via Valerio 2, I–34127 Trieste, Italy*
[4] *INAF – Osservatorio Astronomico di Brera, via Bianchi 46, I–23807 Merate (LC), Italy*
[5] *INAF – Osservatorio Astronomico di Trieste, via G.B. Tiepolo 11, I–34143 Trieste, Italy*

Thank you!

THE MICROPHYSICAL PARAMETERS OF MARGINALLY FAST COOLING SYNCHROTRON REGIME

$$\nu_c \sim \nu_m$$

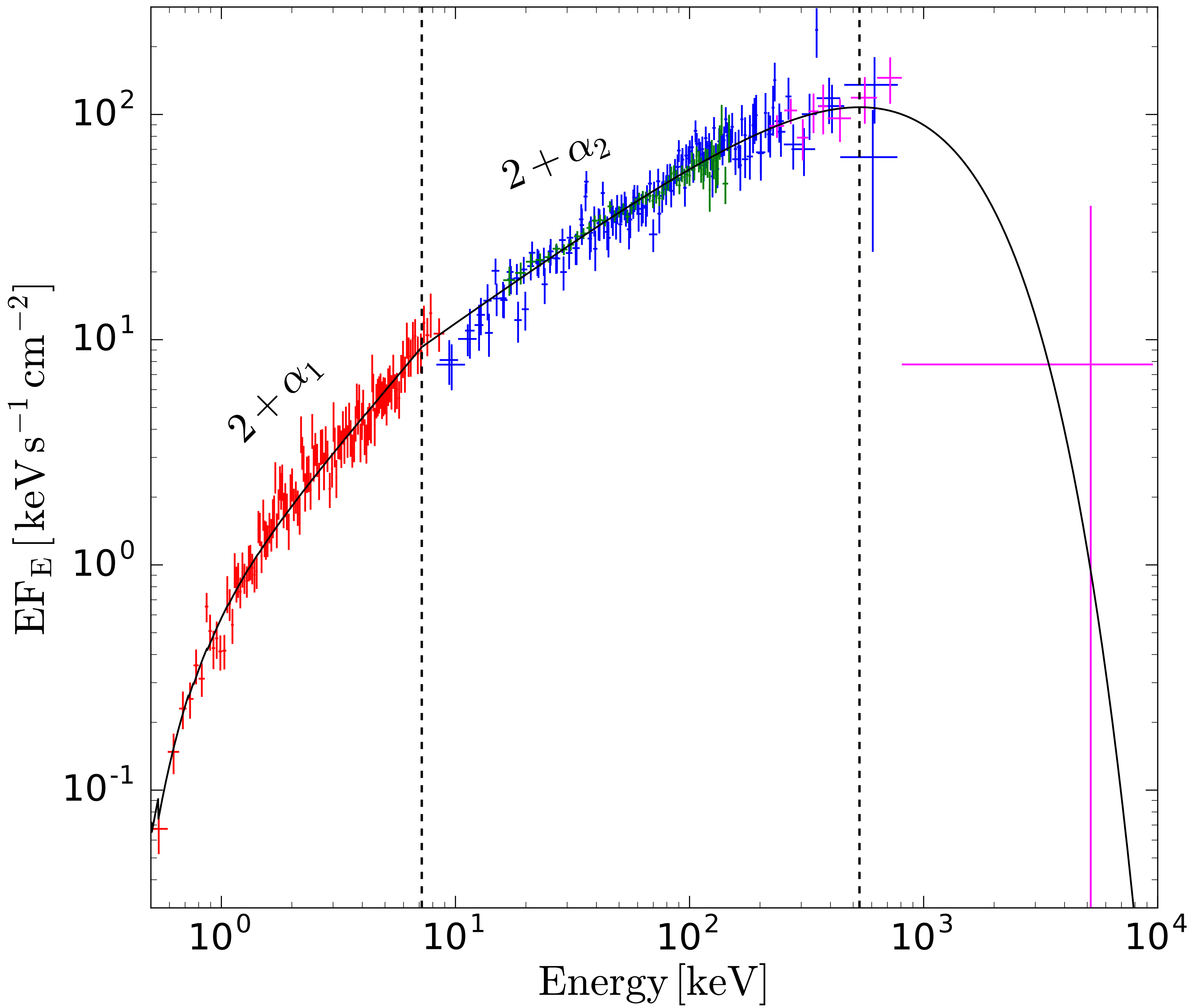
$\Gamma \geq 300$ large bulk Lorentz factors

$B \sim 10\ G$ weak magnetic fields

$R \geq 3 \times 10^{16}\ cm$ large radii (excludes wind-like solutions for the ISM)

$\gamma_m \sim 10^5$ only small fraction of electrons should be accelerated

Beniamini & Piran (2013) F. Daigne et al (2011)



$2+\alpha_1$
$2+\alpha_2$
$\mathrm{EF_E}\,[\mathrm{keV\,s^{-1}\,cm^{-2}}]$
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
$\mathrm{Energy}\,[\mathrm{keV}]$

SAMPLE SELECTION

I Searching for X-ray emission episodes

II Searching for signal in BAT

X-RAY LIGHT CURVE WITH EMISSION EPISODES

+

BAT/SWIFT DATA SHOULD HAVE SIGNIFICANT SIGNAL WITHIN WT/XRT/SWIFT OBSERVATIONS

=

77/1000 SWIFT GRBs

III Time-binning

S/N in BAT 15-150 keV light curve >30

+

at least 4 time-bins

=

$\boxed{\text{14 GRBs (1000)}}$

FINAL SAMPLE

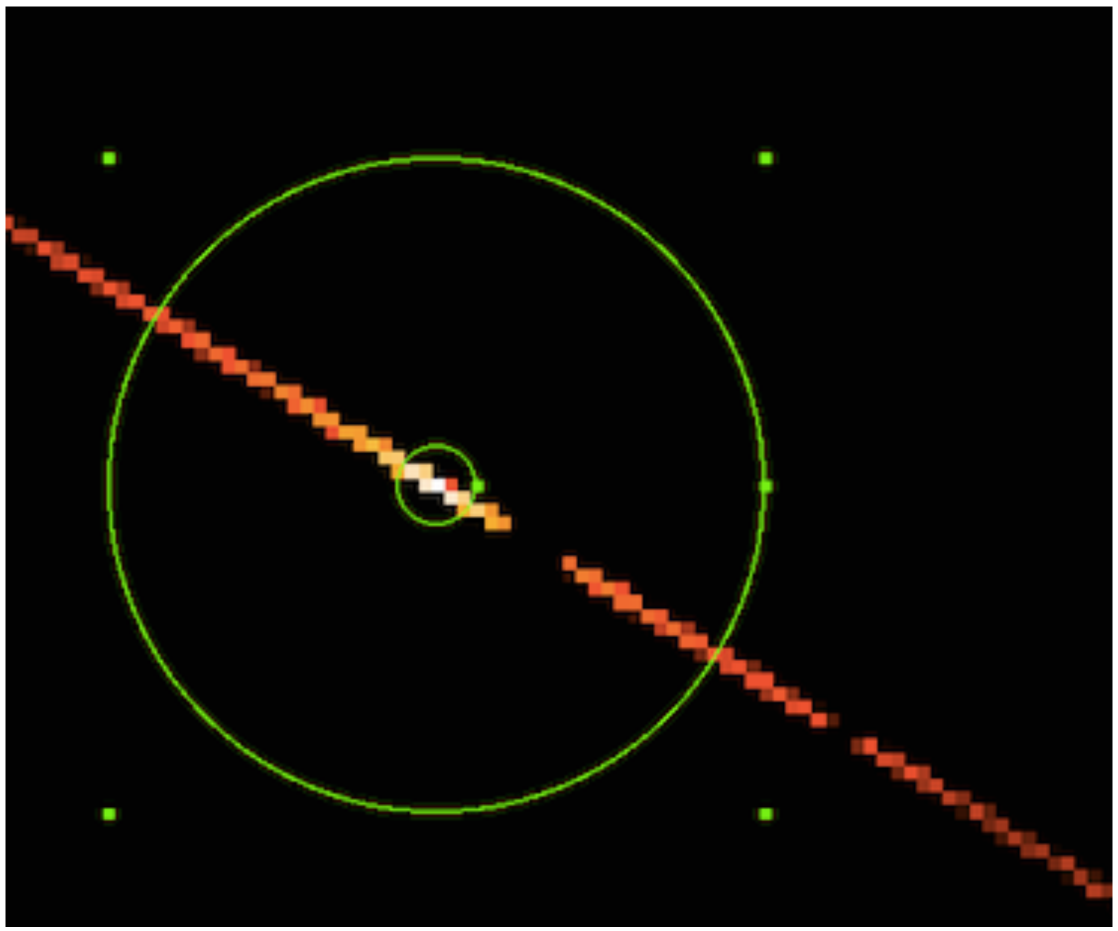
Fermi/GBM data in 7 GRBs

Redshift in 8 cases (0.73-2.73)

SPECTRAL ANALYSIS - SWIFT/XRT

Pile-up correction

< 150 cts/s



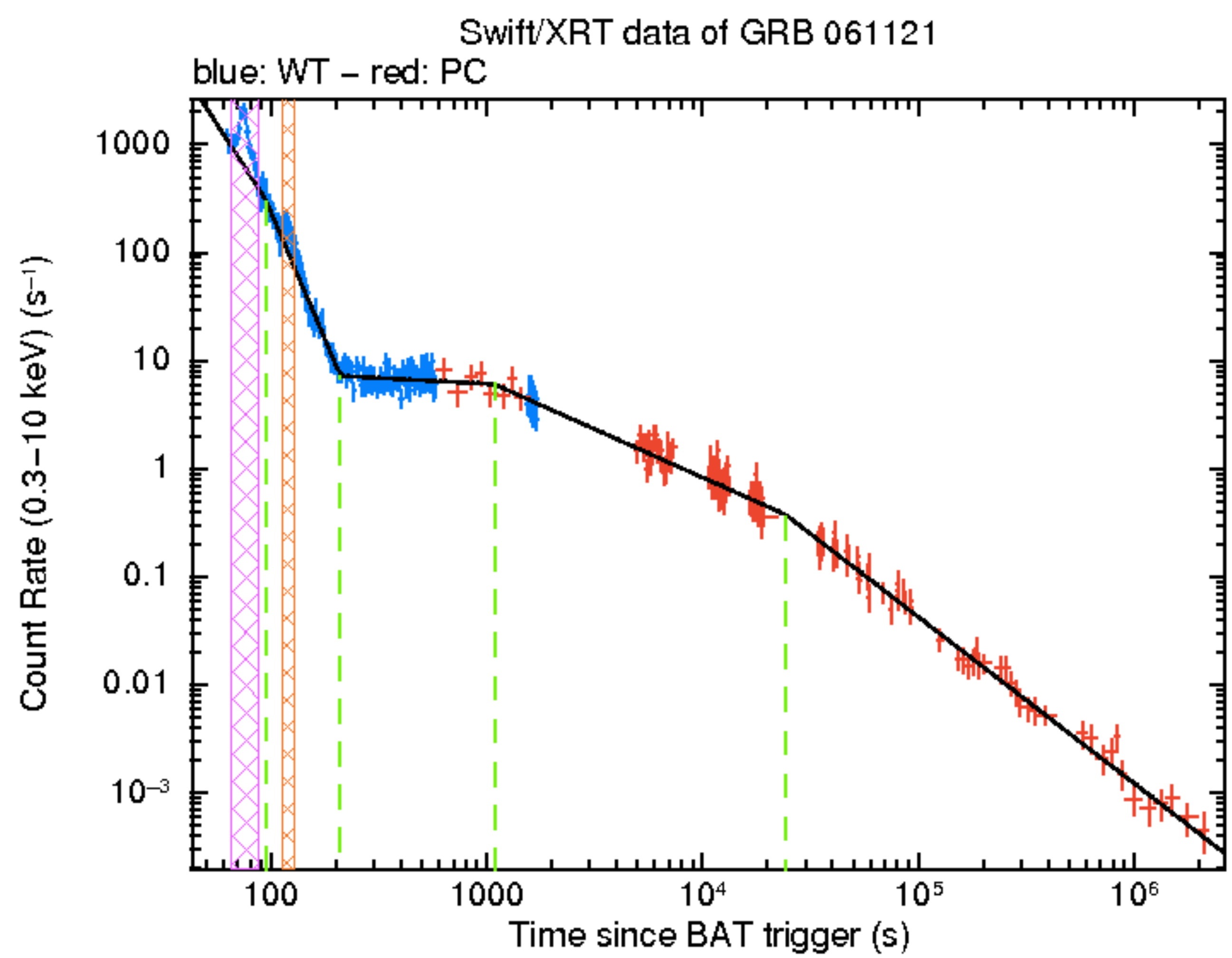
N_H

The Tuebingen-Boulder ISM absorption model

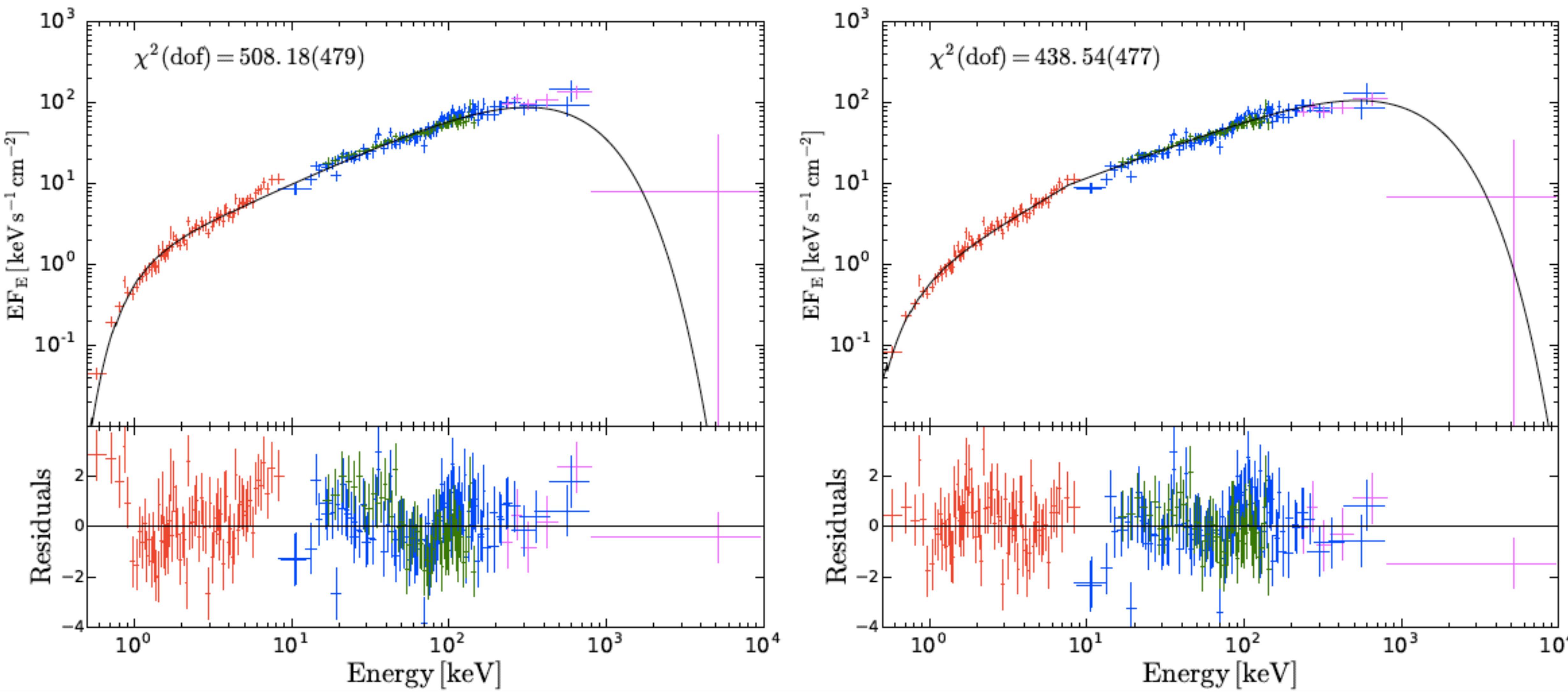
the photoionization cross-section Verneret. al. (1996 Ap.J.)

ISM abundances Wilms, Allen and McCray (2000, ApJ 542, 914)

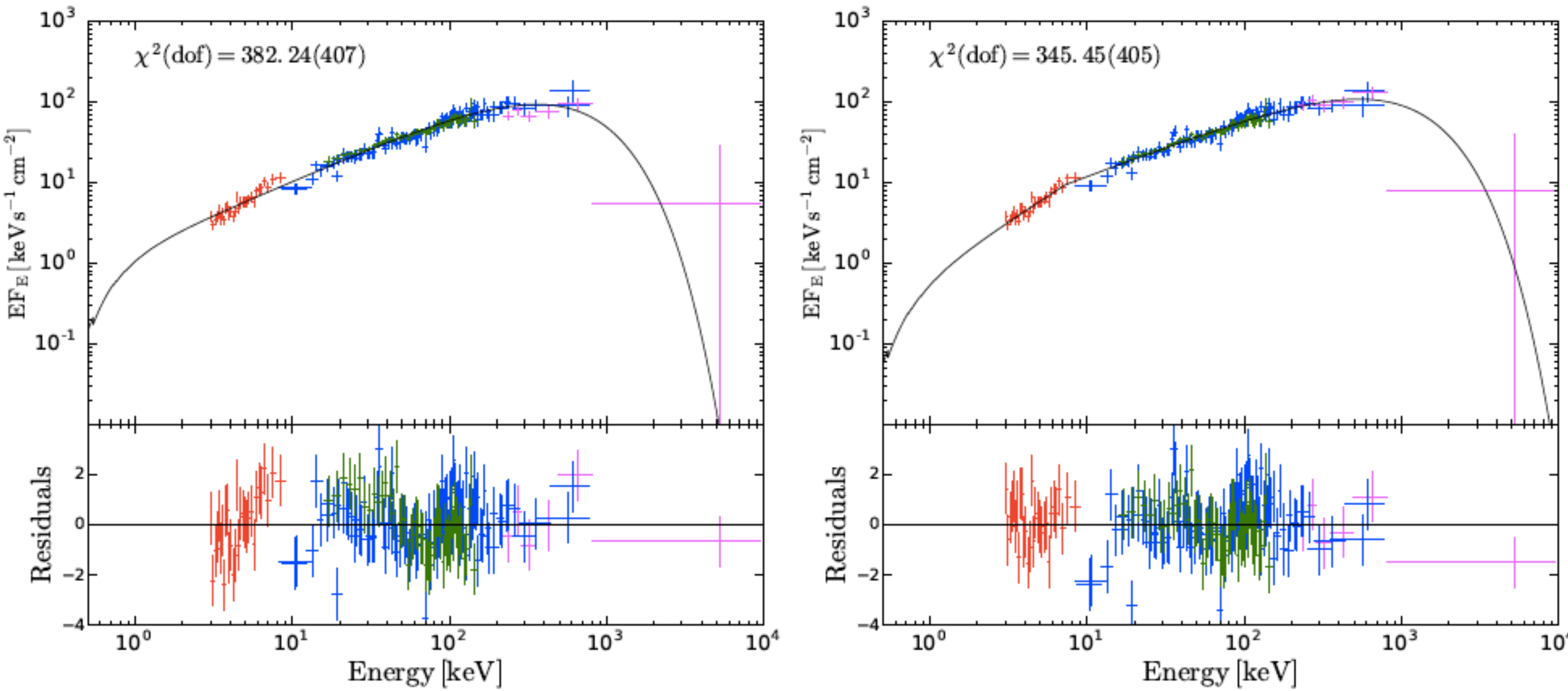
found by spectra of late-time X-ray emission



N_H


$\chi^2(\mathrm{dof}) = 508.18(479)$
$\chi^2(\mathrm{dof}) = 438.54(477)$
EF_E [keV s^{-1} cm^{-2}]
Residuals
Energy [keV]

N_H

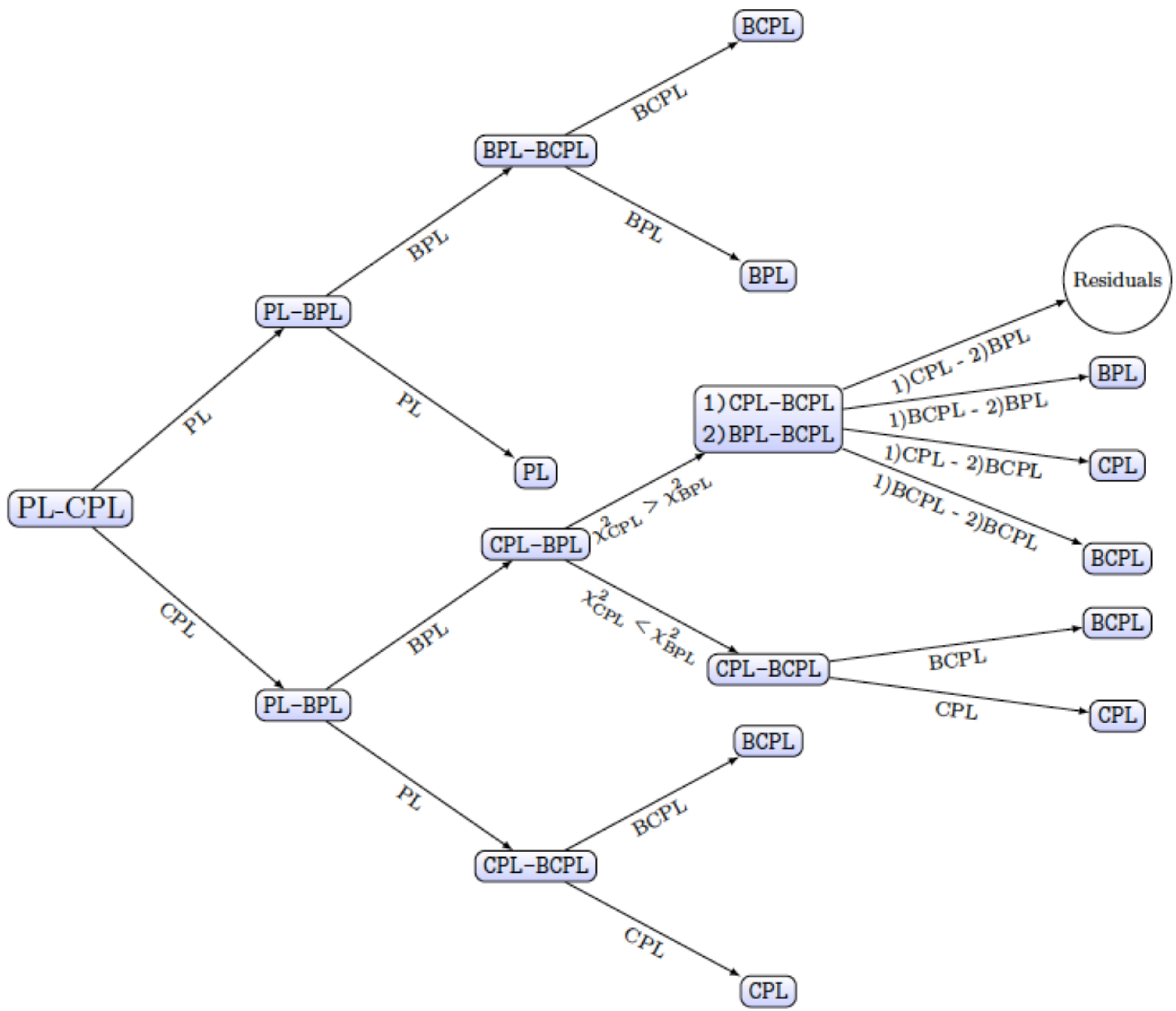


$\chi^2(\mathrm{dof}) = 382.24(407)$
$\chi^2(\mathrm{dof}) = 345.45(405)$
$EF_E\,[\mathrm{keV\,s^{-1}\,cm^{-2}}]$
Residuals
Energy [keV]

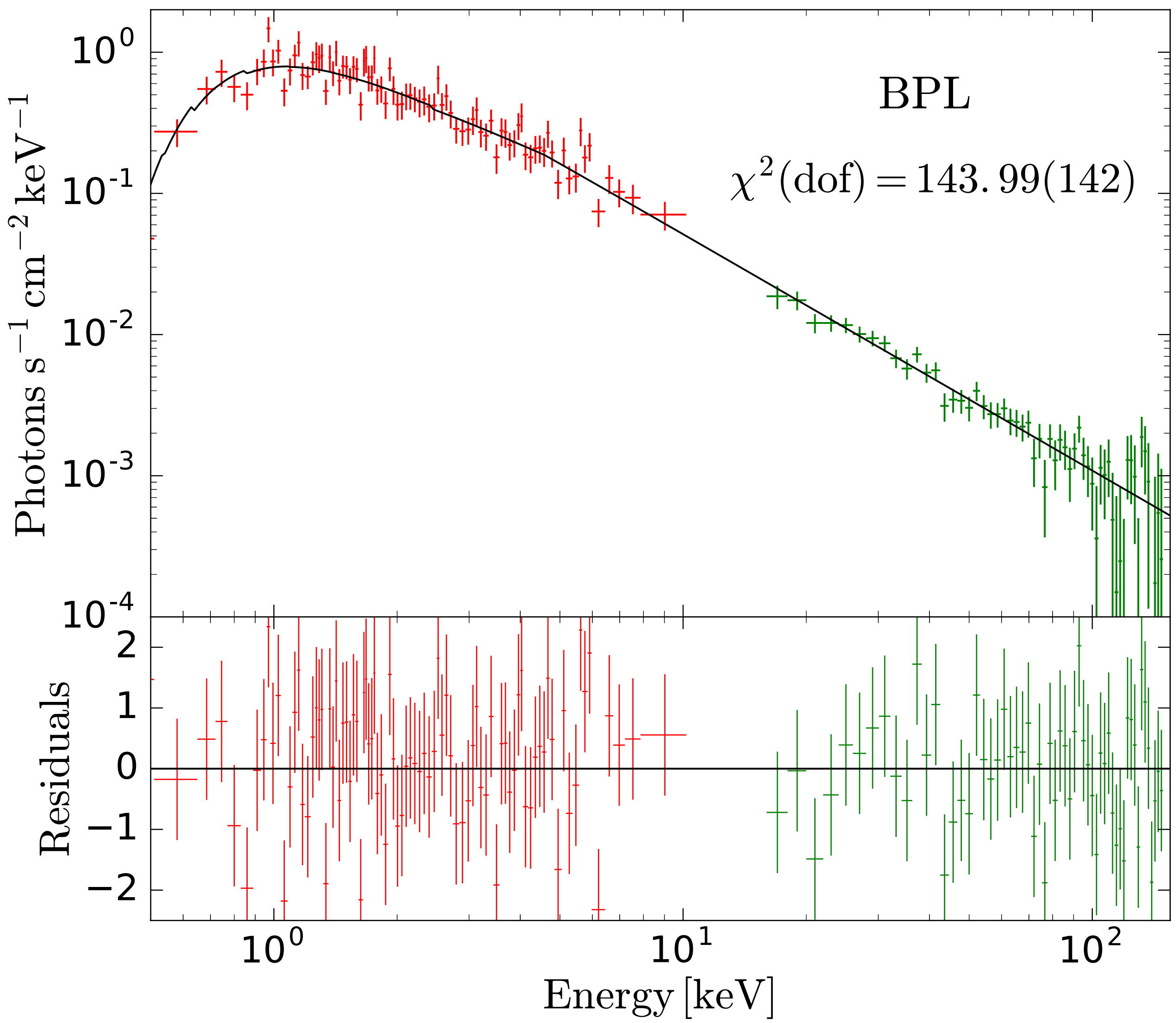
PILE-UP

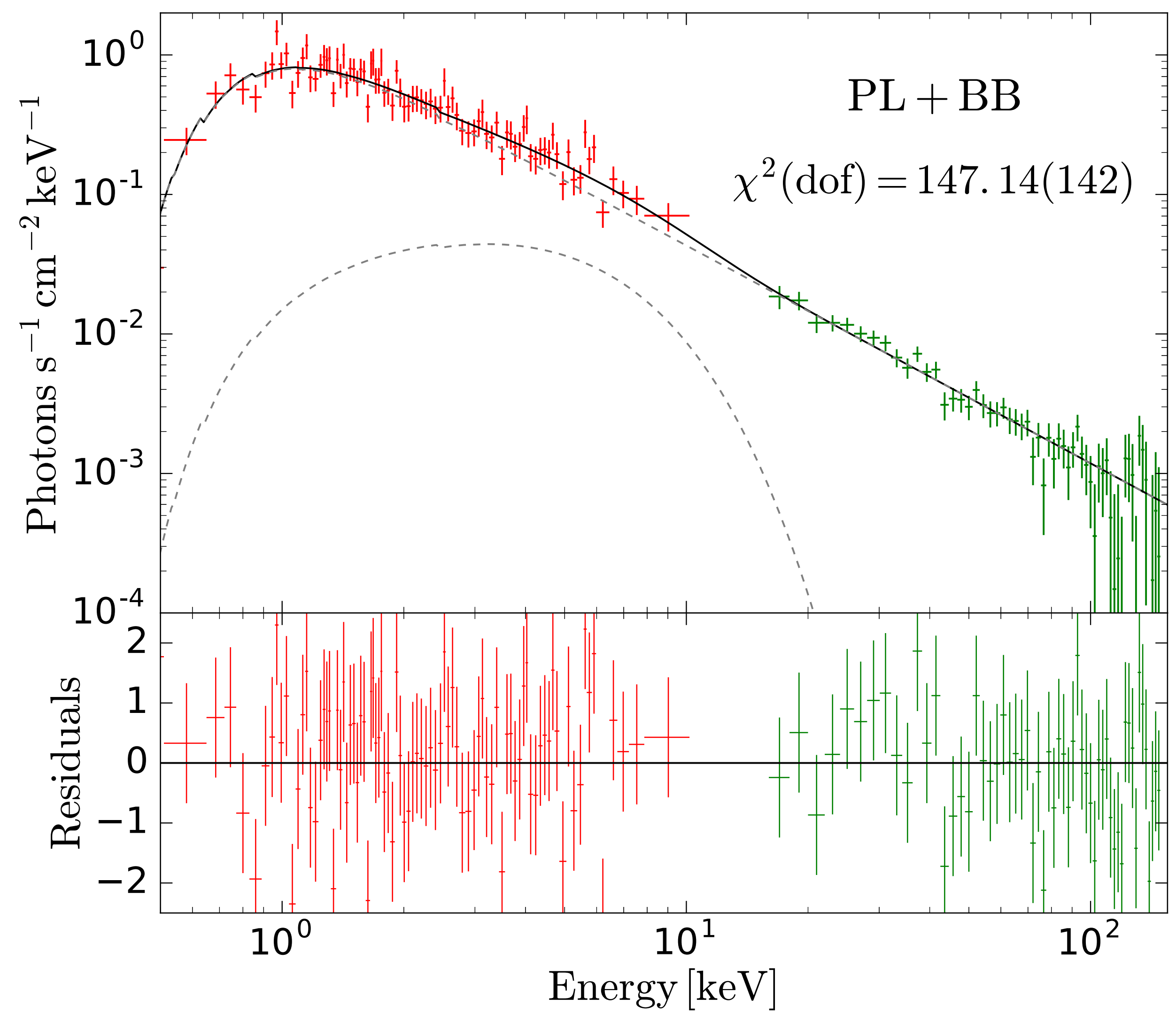
Rate [cts/s]	PL	CPL	BPL	BCPL	F_{PL-BPL}	$F_{CPL-BCPL}$
120	412.97 (228)	243.89 (227)	217.09 (226)	210.95 (225)	1.11e-16 (8.4)	8.14e-08 (5.4)
90	264.89 (220)	224.17 (219)	216.90 (218)	211.05 (217)	3.45e-10 (6.3)	1.44e-03 (3.2)
70	253.40 (218)	218.80 (217)	213.14 (216)	207.45 (215)	7.67e-09 (5.8)	3.26e-03 (2.9)

THE BEST FIT MODEL SEARCH



WHAT ABOUT BB COMPONENTS?





CAN WE GO TO EVEN HARDER SPECTRA?

2nd Fermi catalog

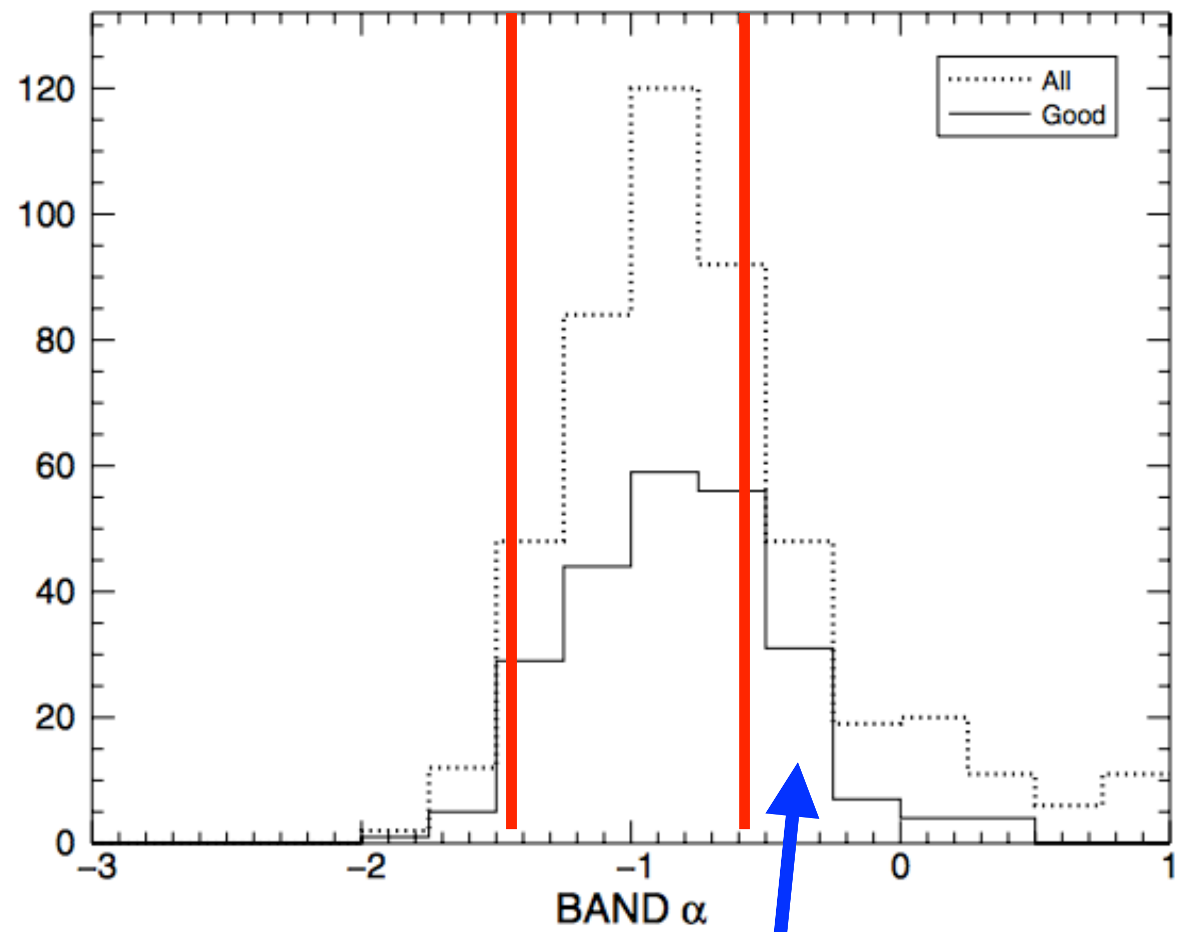
$$N_\nu \propto \nu^0, \nu < \nu_{ssa}$$

$$\frac{\nu_{ssa}}{\nu_p} \propto \Gamma^{-4/3}\epsilon^{1/12}\nu_p^{-3/4}t_{var}^{-5/6}$$

$$\downarrow$$

$$\frac{\nu_{ssa}}{\nu_p} \sim 10^{-4}$$

(for typical parameters)



What is it?

An observational effect?

WHAT ABOUT BB COMPONENTS?