Spectro-Polarimetry of GRB 160802A and GRB 171010A

Optical flash GRB 130427A (Source: NASA)

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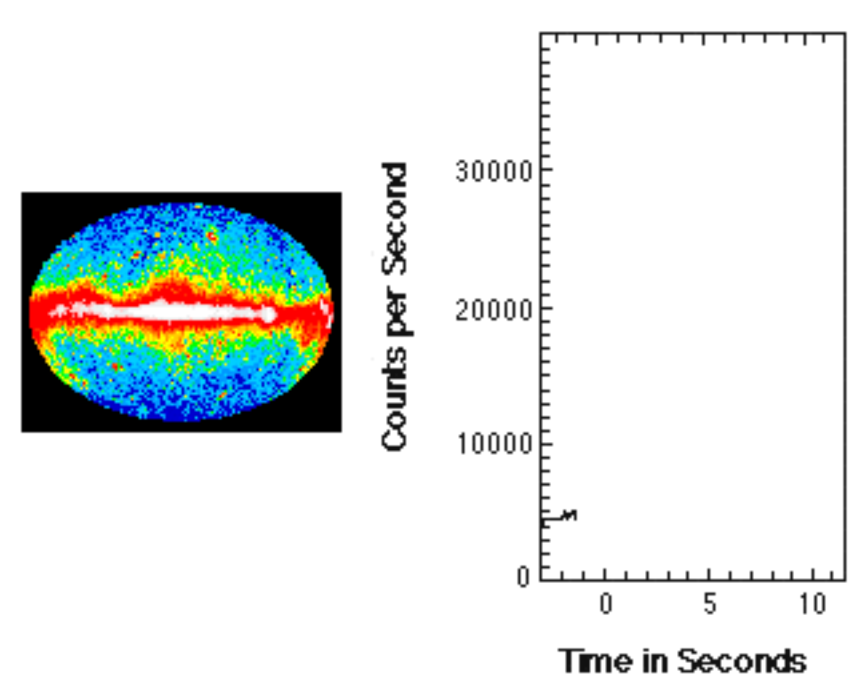
Anastasia Tesvetskova (Konus/Wind)

VHEPU, ICISE
Vietnam
14 Aug, 2018



GRB - Introduction

Prompt/ AG: importance of understanding prompt emission

Polarimetry: spectro-polarimetry

GRB polarisation - CZT Imager

GRB pol. as a class

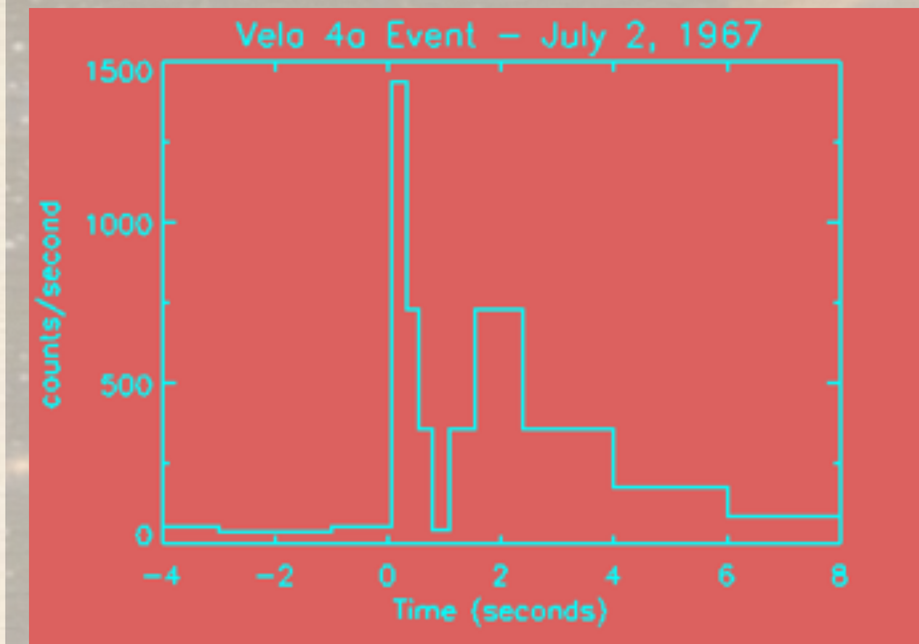
Individual: GRB 160802A and GRB 171010A

Needed: better spectroscopy and better polarimetry

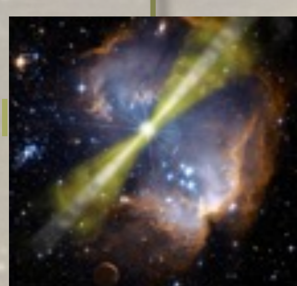
Other sources

Conclusions

Gamma ray bursts (GRBs) Observational Timeline



1973 First reported

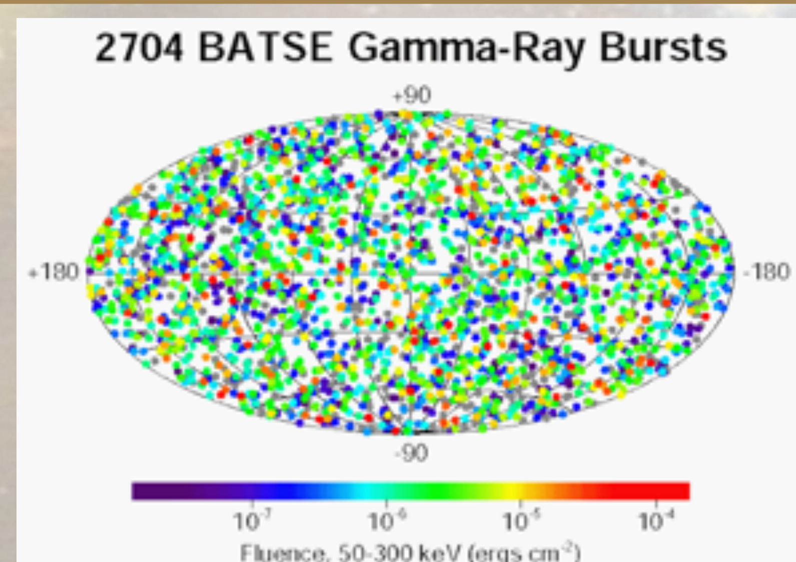


NASA

Vela Satellites on July 2, 1967

BATSE 1991-2000 Isotropic

key: Localization



NASA

Gamma ray bursts (GRBs) Observational Timeline

BeppoSAX

WHT, HST follow-up: z=0.695

1997

2002

INTEGRAL

IBIS and SPI

polarisation

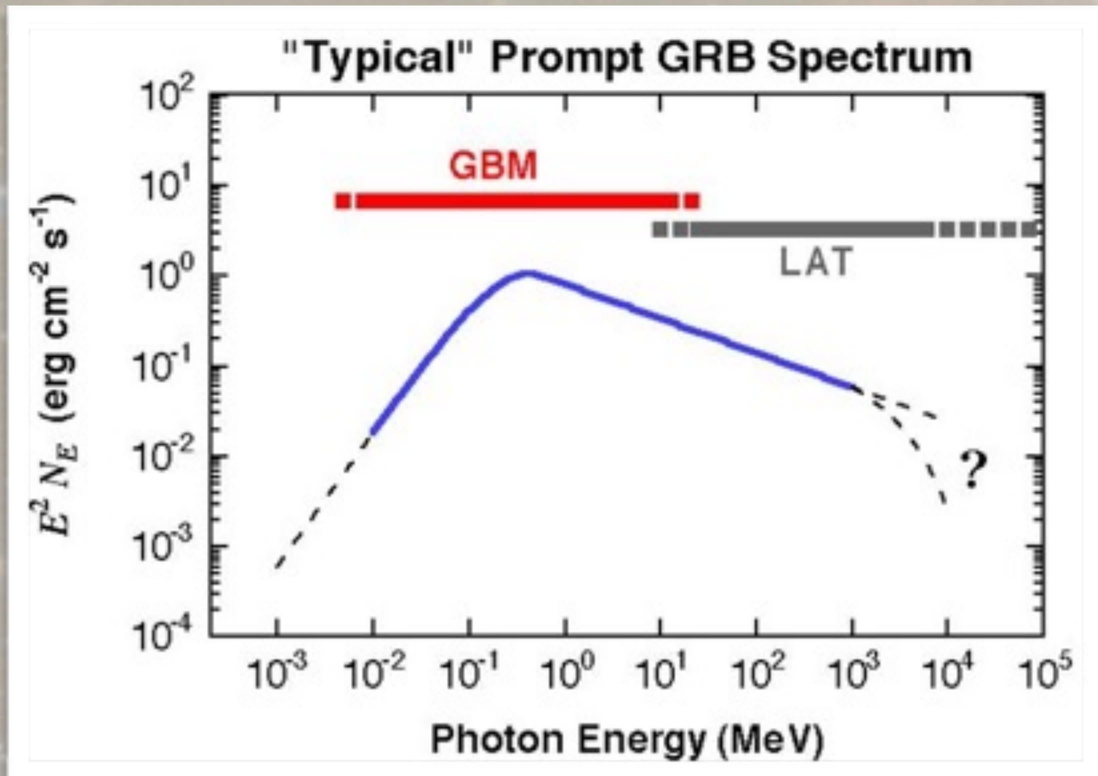
not tested on ground

2004

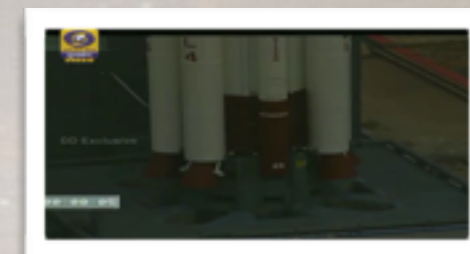
Swift

Slewing ability

XRT X-ray coverage



Gamma ray bursts (GRBs) Observational Timeline



Fermi

2008

2010

GAP

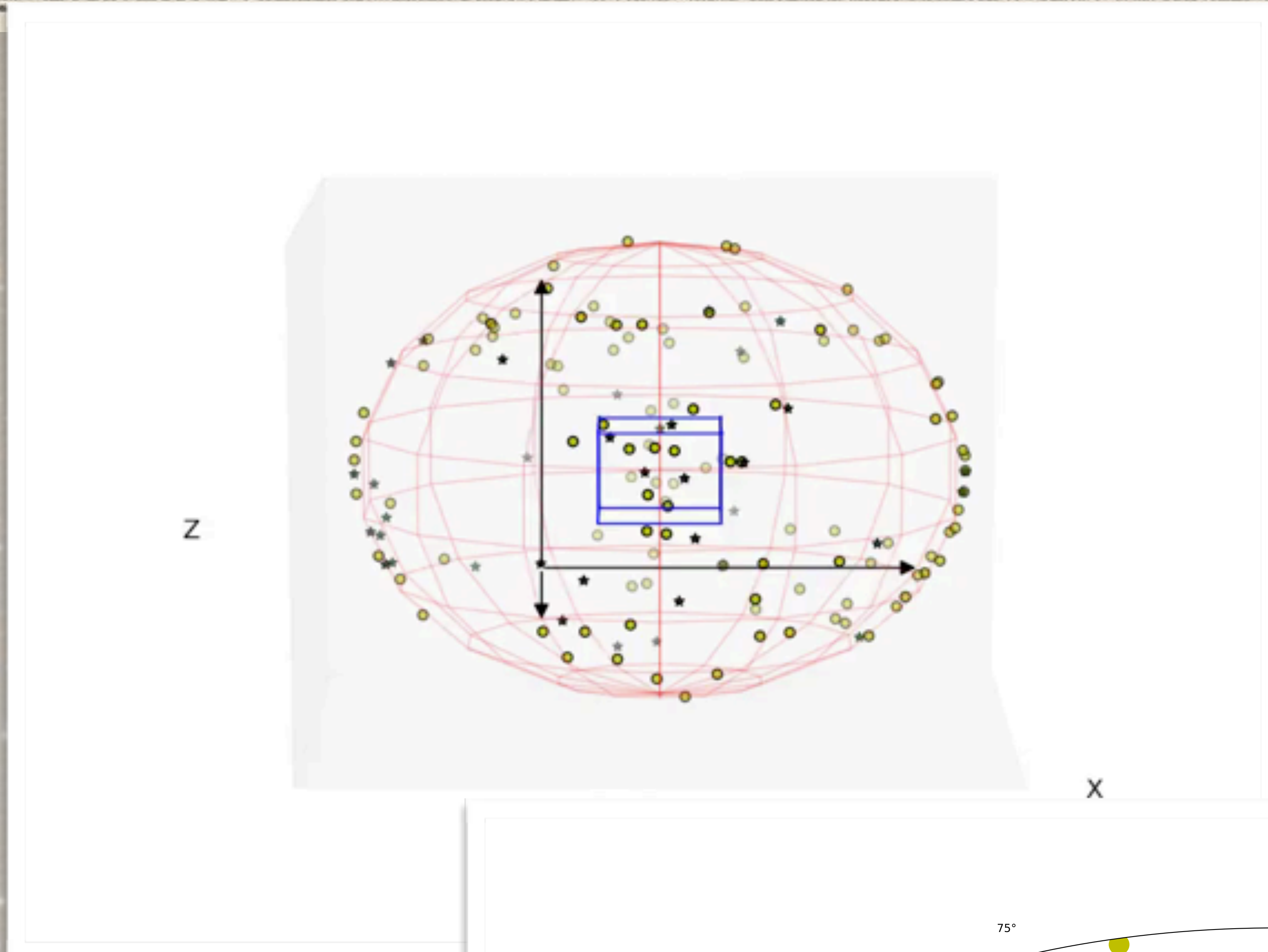
AstroSat

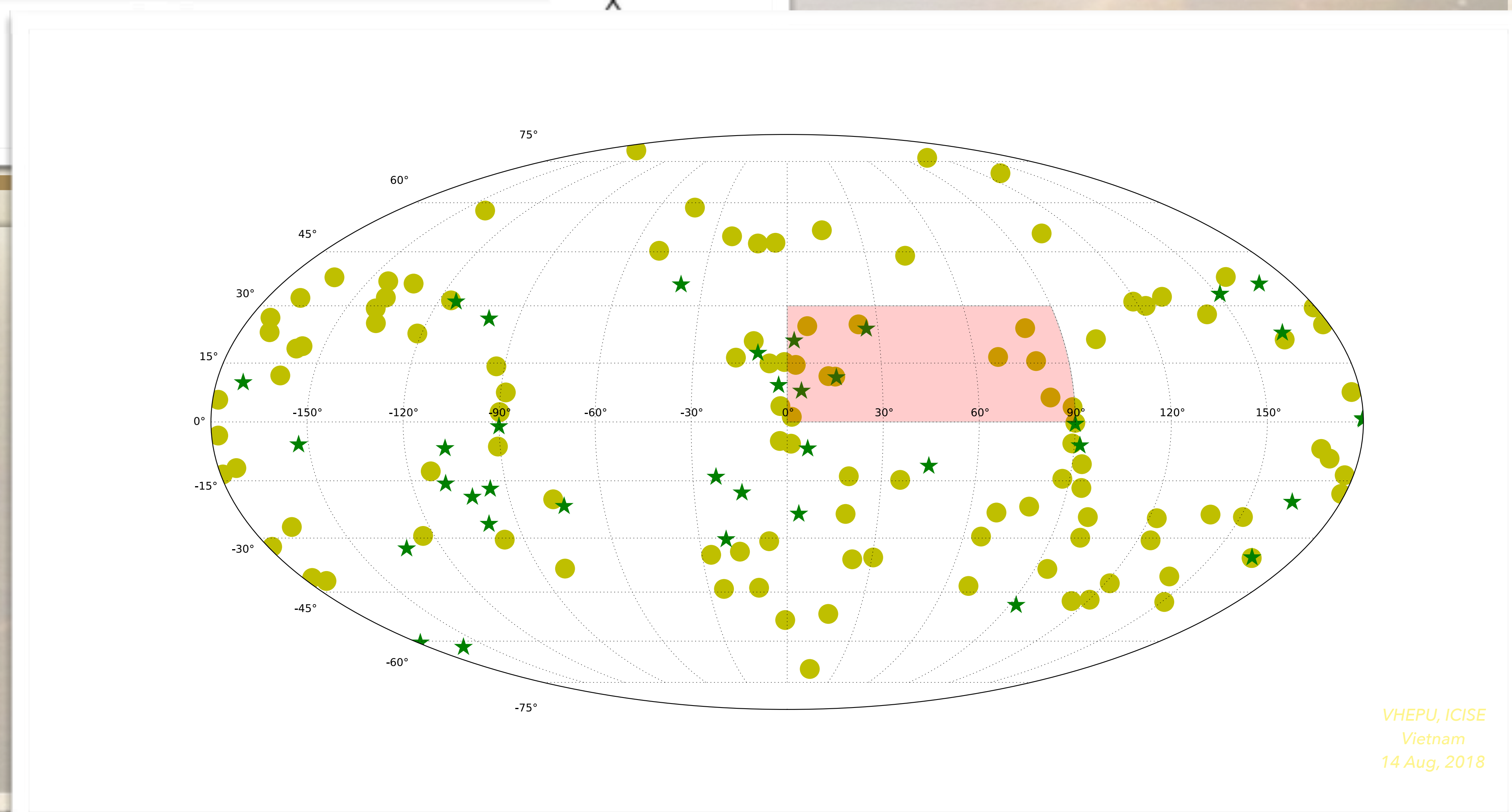
28 Sept, 2015

CZTI can measure polarisation in 100 - 400 keV

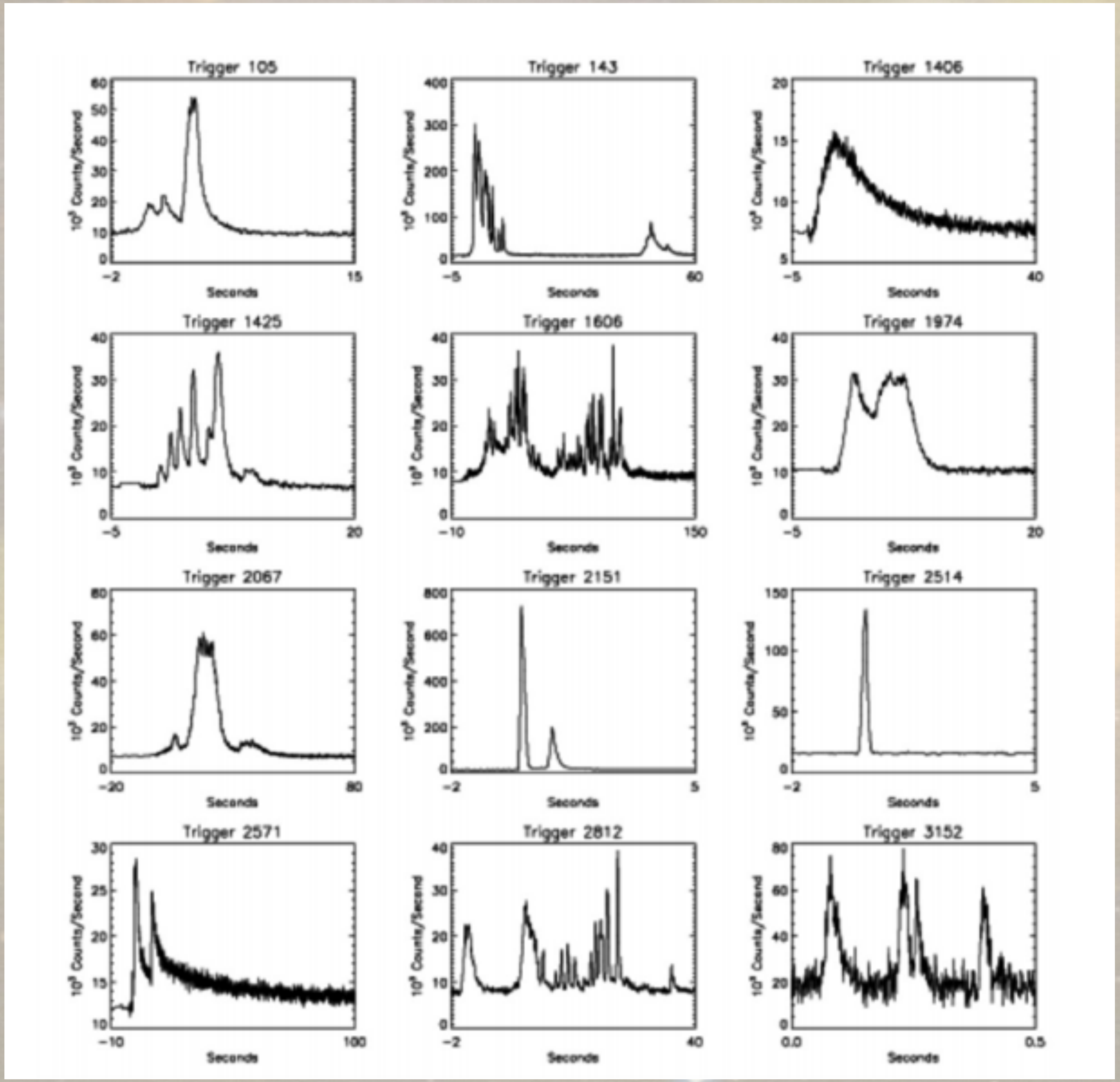
CZTI GRBs

- Observed more than 47 GRBs in First year





Light Curves



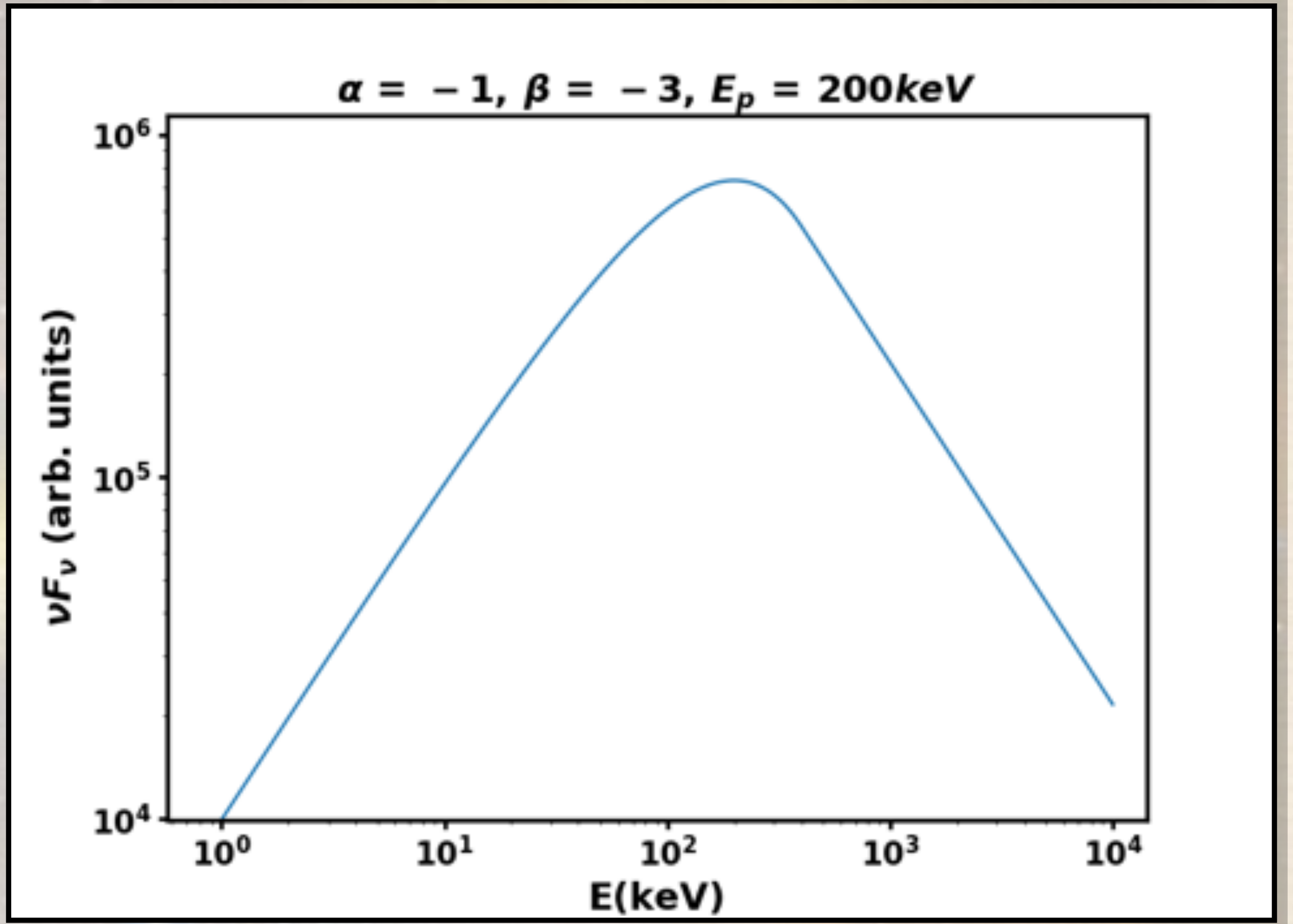
Spectral Properties-Simplest picture

✤ Non thermal

Band function

$$N(E) = \begin{cases} A\left(\frac{E}{100\ \mathrm{keV}}\right)^{\alpha} \exp\left(-\frac{E}{E_0}\right), & E < (\alpha-\beta)E_0\,, \\ A\left[\frac{(\alpha-\beta)E_0}{100\ \mathrm{keV}}\right]^{\alpha-\beta} \exp(\beta-\alpha)\left(\frac{E}{100\ \mathrm{keV}}\right)^{\beta}, & E \geq (\alpha-\beta)E_0\,, \end{cases}$$

$$<\alpha>= -1,\ <\beta>= -2 \text{ and } E_p = 200\ keV$$



Band function

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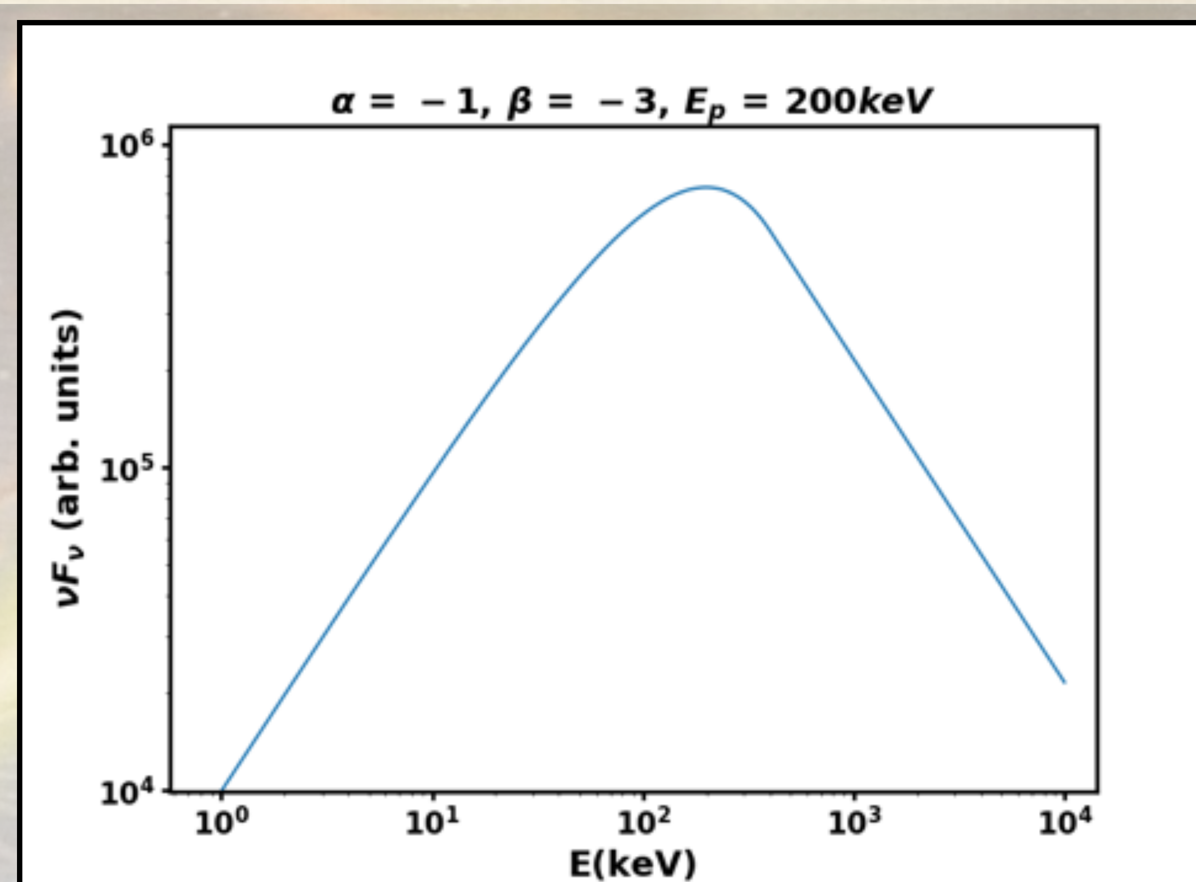
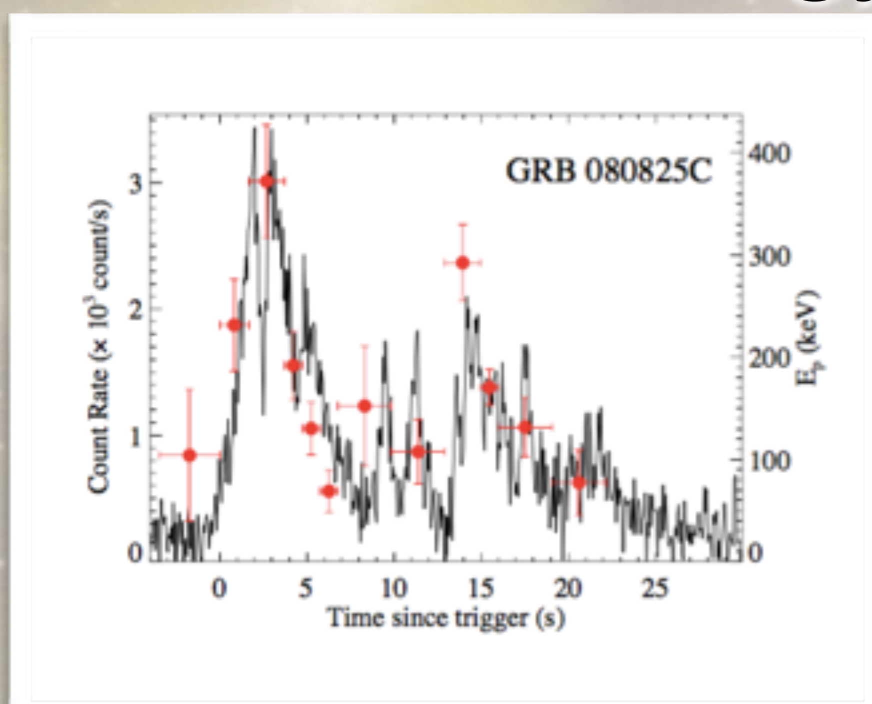
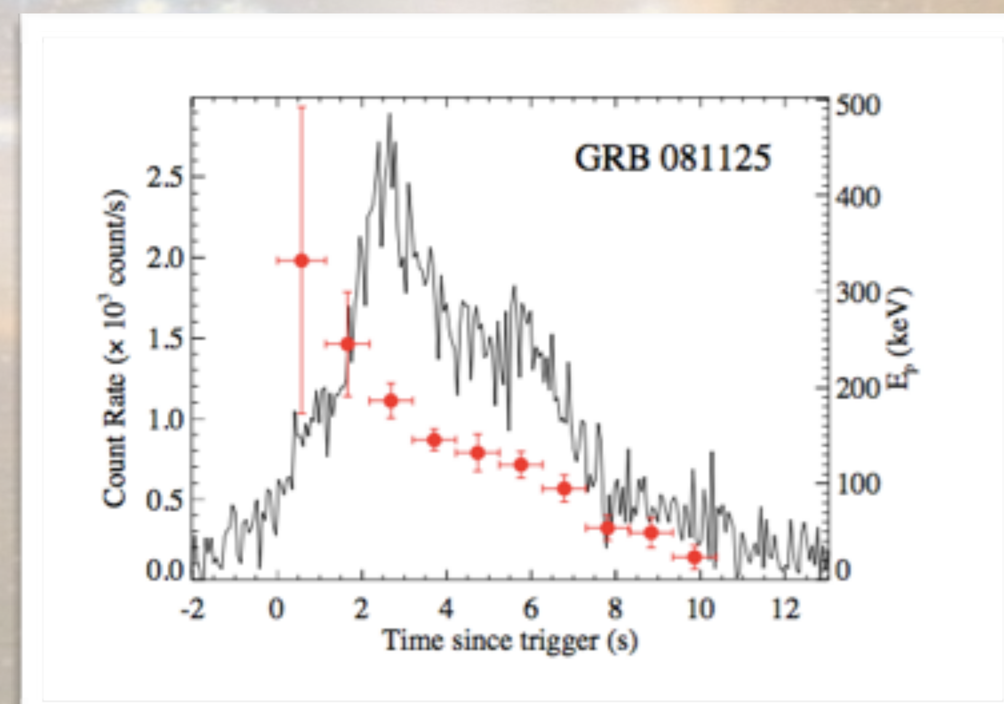


Peak Energy Evolution

IT

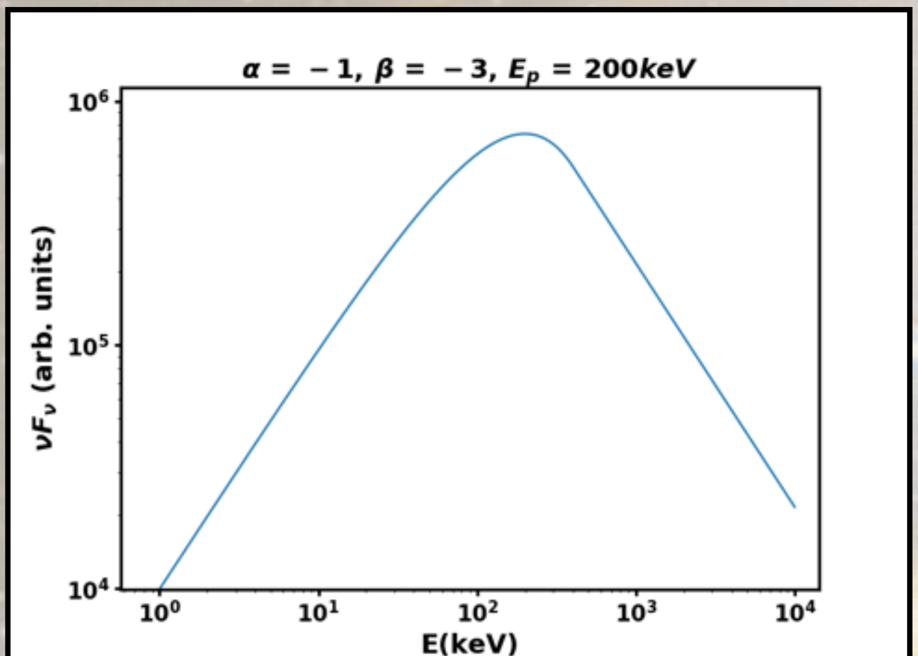
Lu et al. 2012



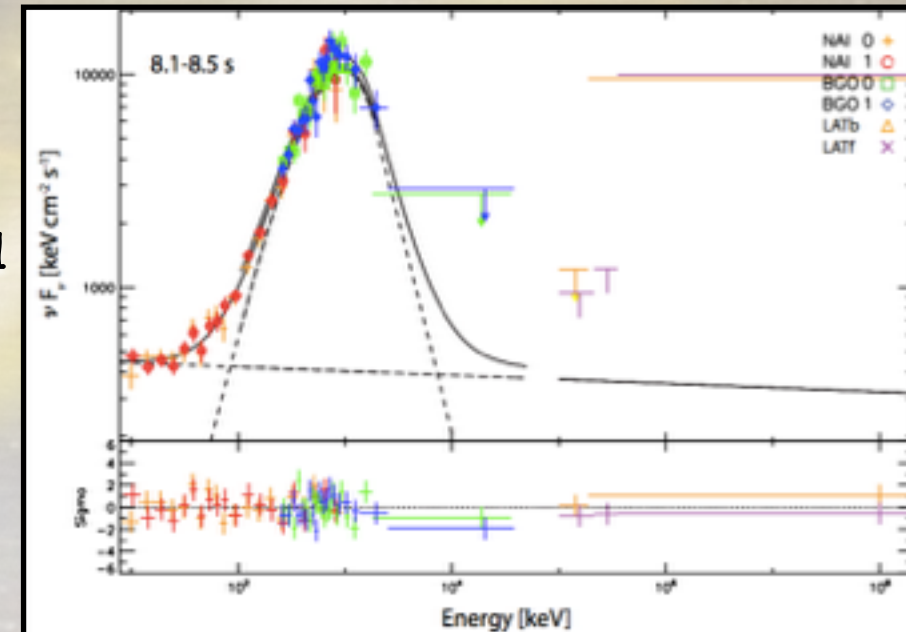


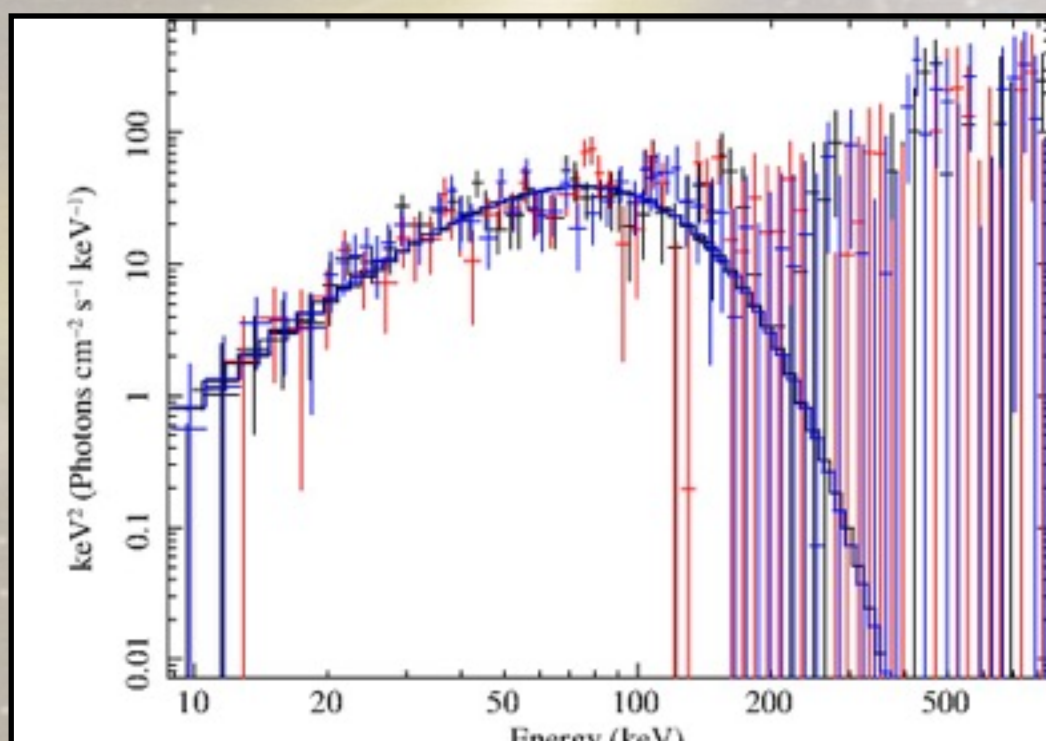
HTS

Observational properties of GRBs

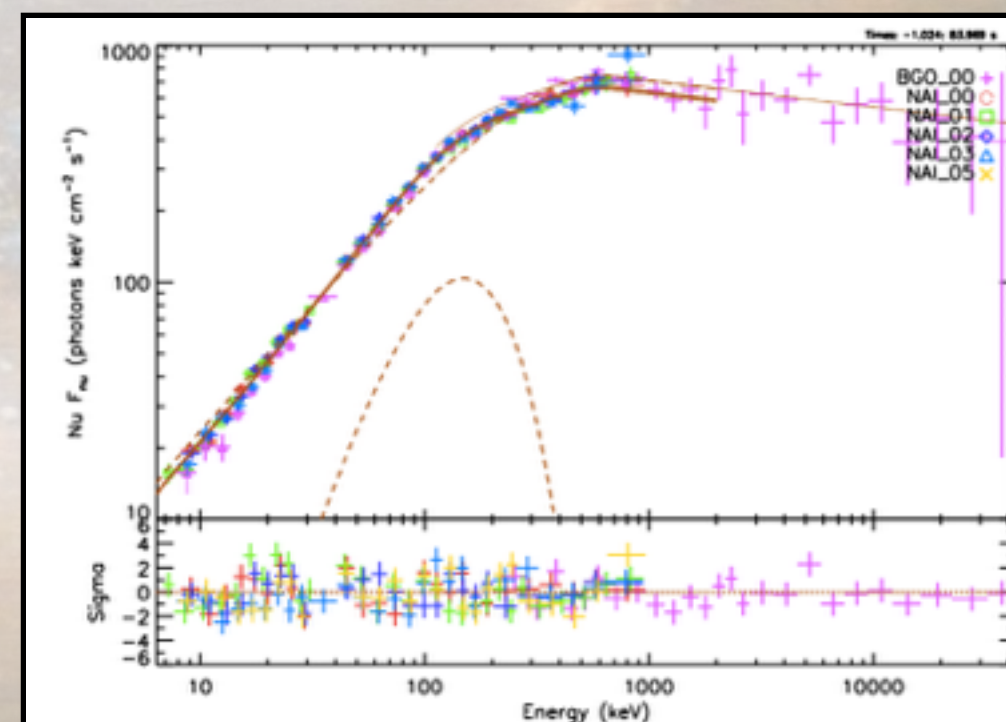


Ryde et al. 2011





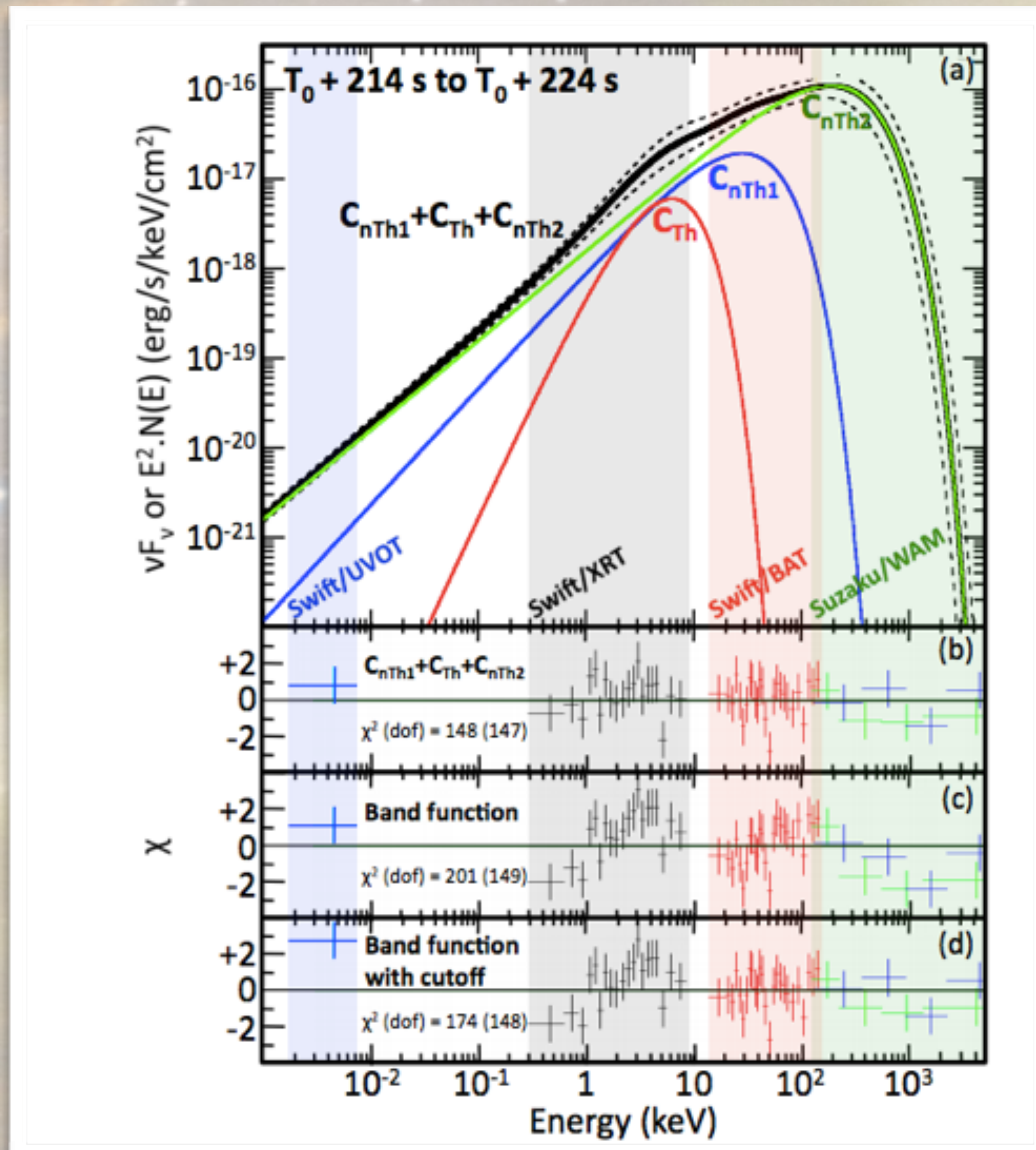
Larsson 2015



Guiriec et al. 2011

- Band Only, BB, BBPL, BB+Band, 2BBPL, BandC, GRBCOMP

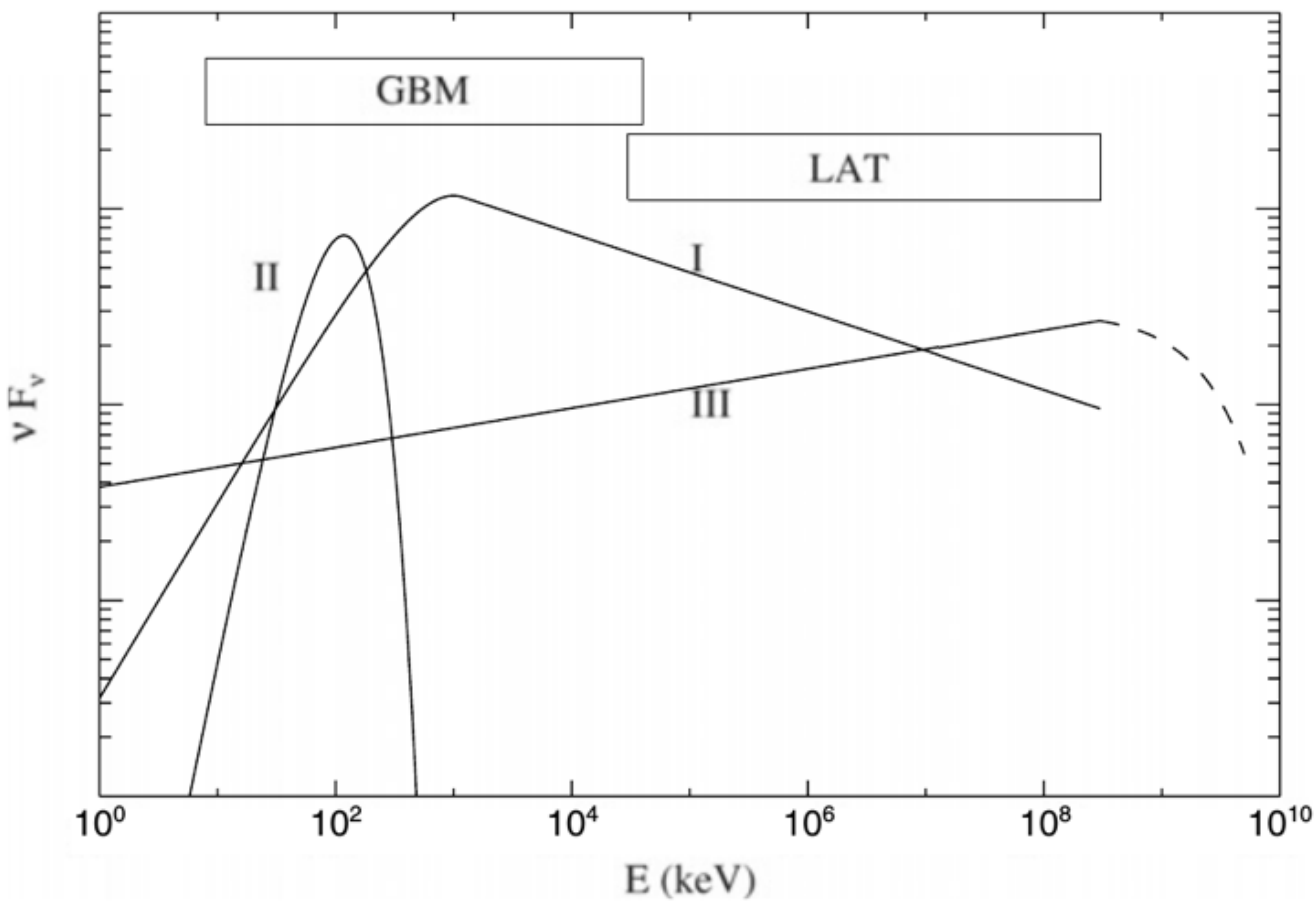
Observational properties of GRBs



Guiriec et al. 2017

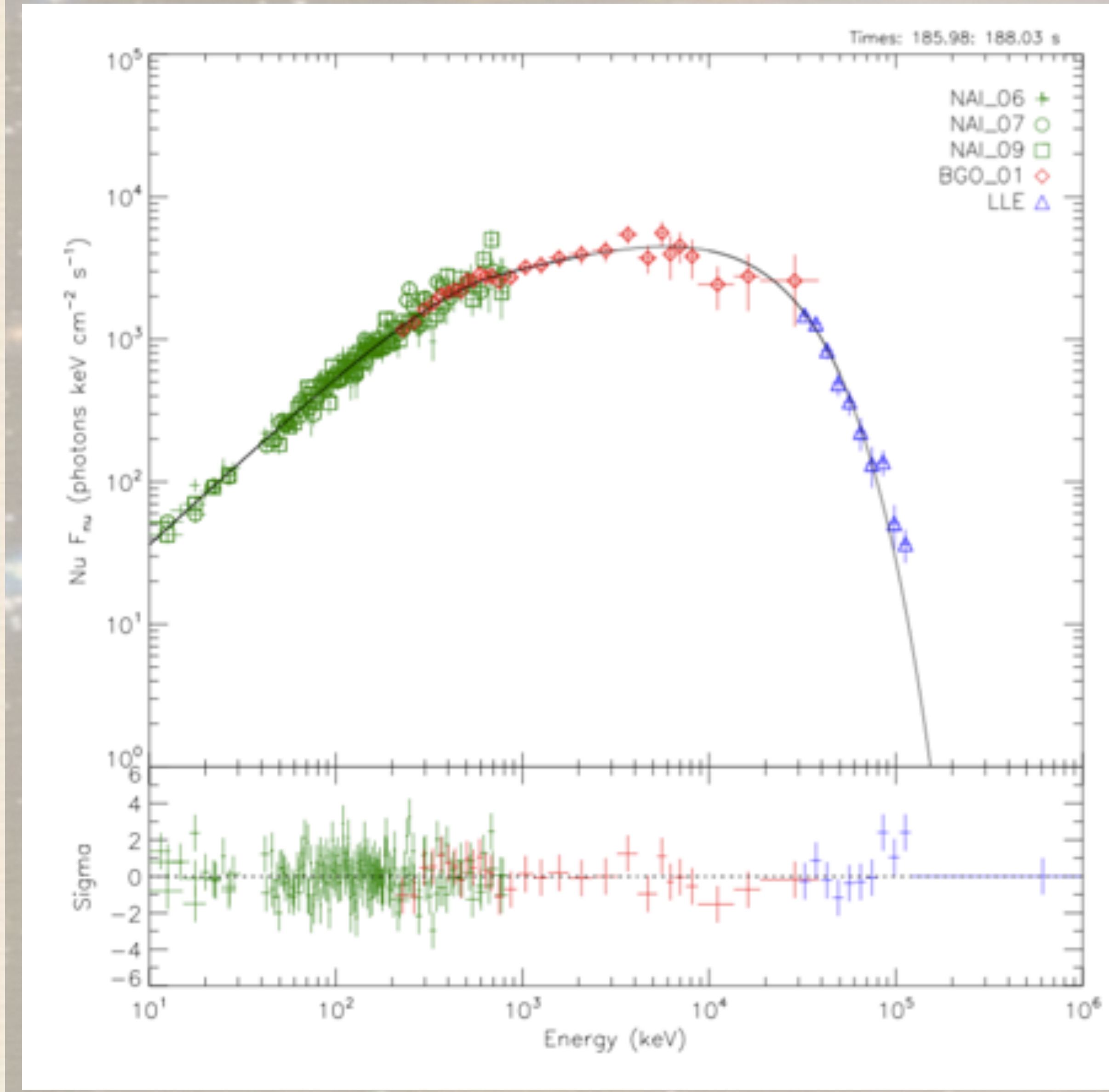
- *Band Only, BB, BBPL, BB+Band, 2BBPL, BandC, GRBCOMP*

Band + BB + High energy emission extending to GeVs

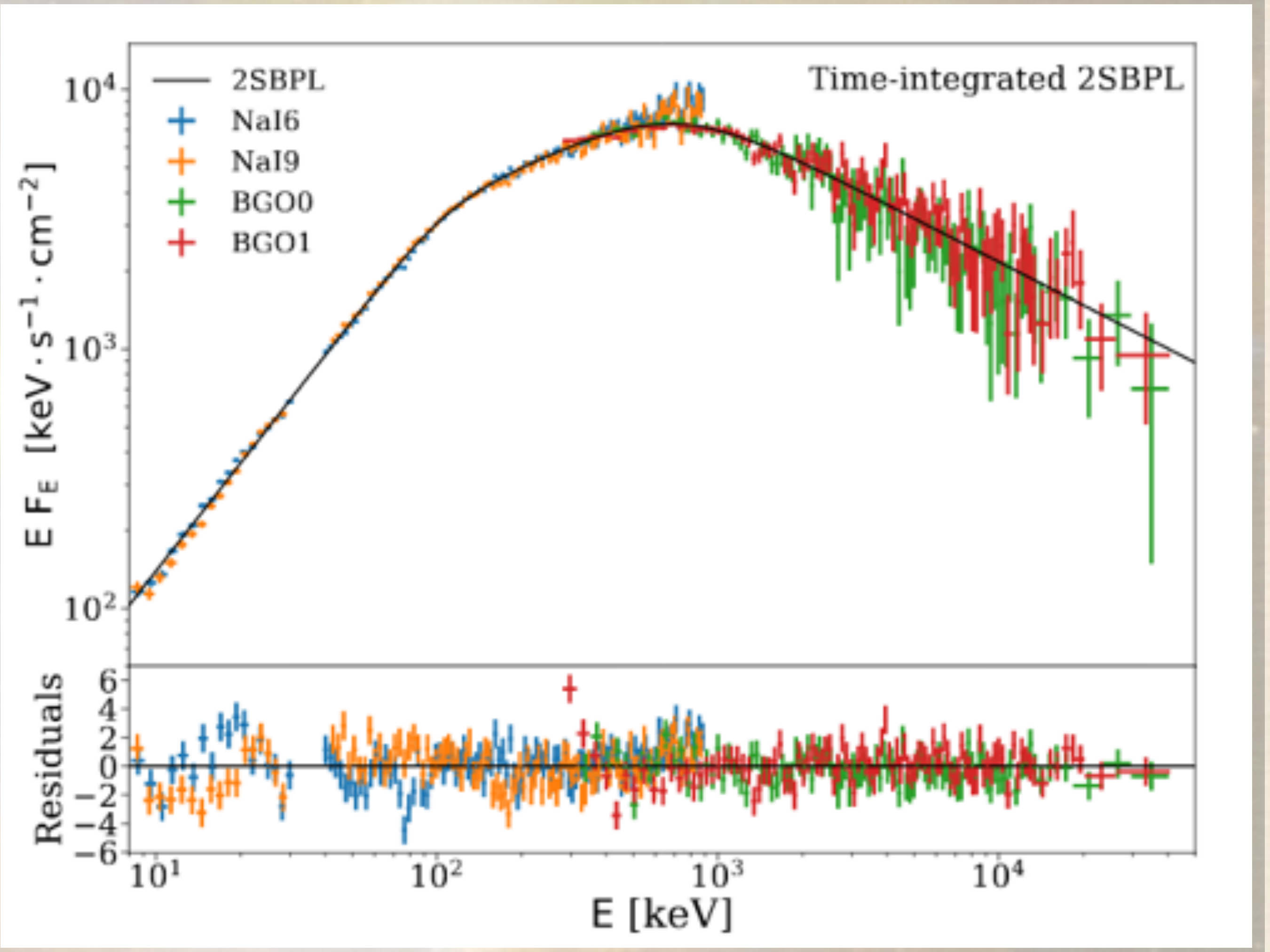


Pawan Kumar 2014

Observational properties of GRBs

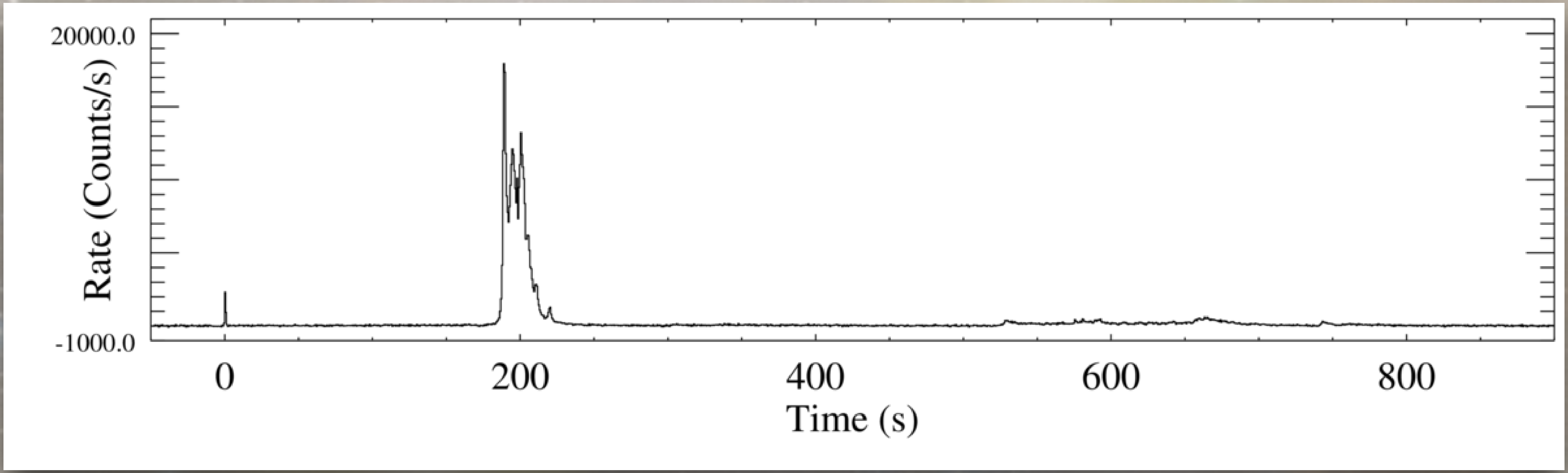


Wang et al., 2017; GRB160625B



Ravasio et al.; GRB160625B

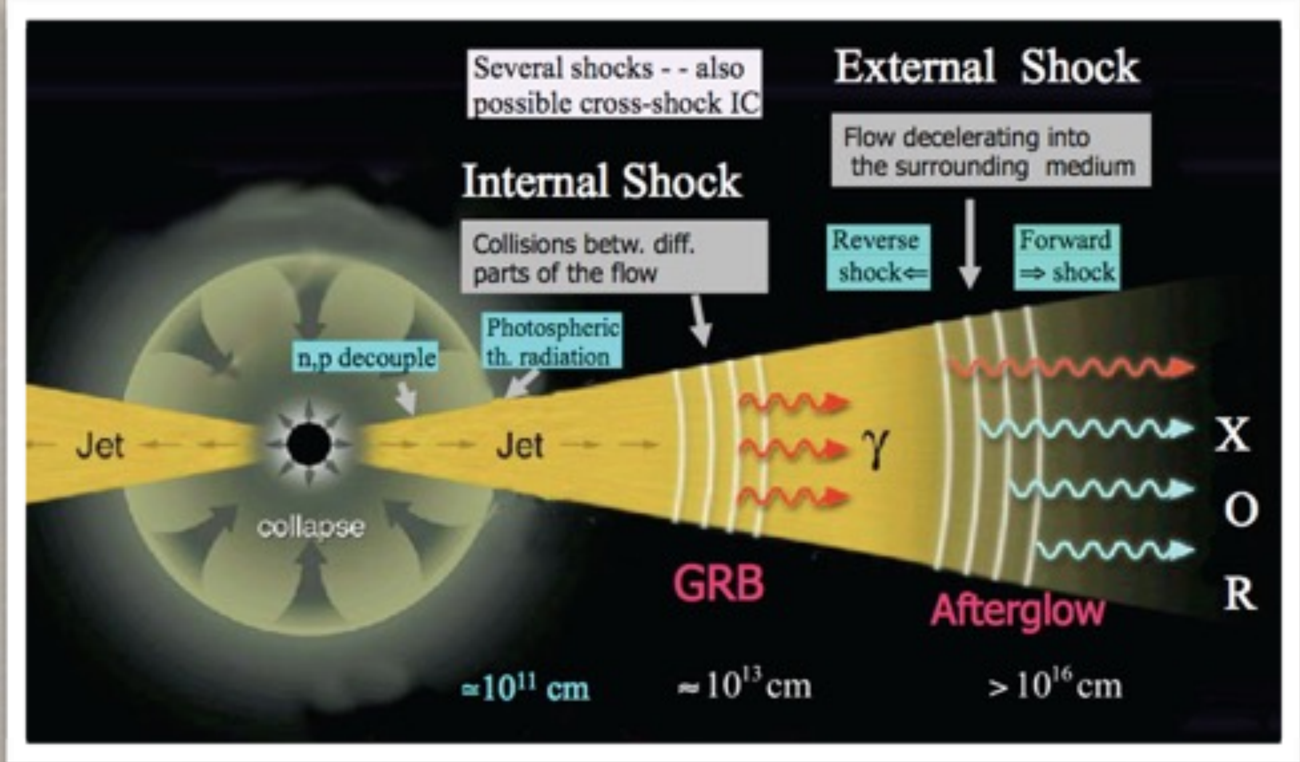
Transition from thermal to non-thermal mechanism



Zhang et al., 2018

GRB models

- *Synchrotron radiation*

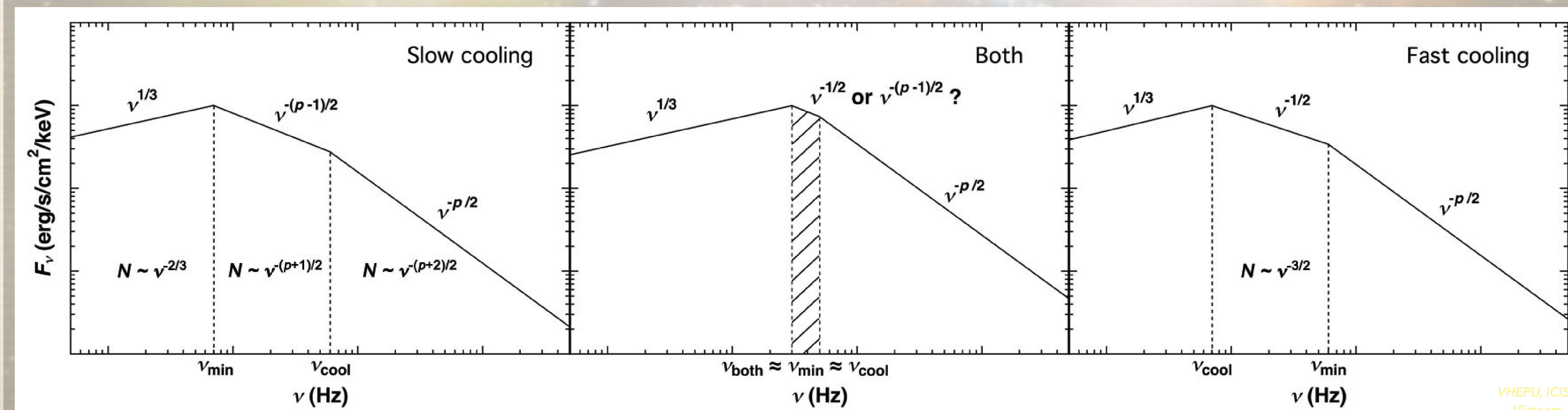


- *Fast cooling*
- *Slow cooling*

Meszaros et al. 1994

- *Line of Death*
- *Both*

Yu et al., 2015



GRB models

- *Photospheric models*

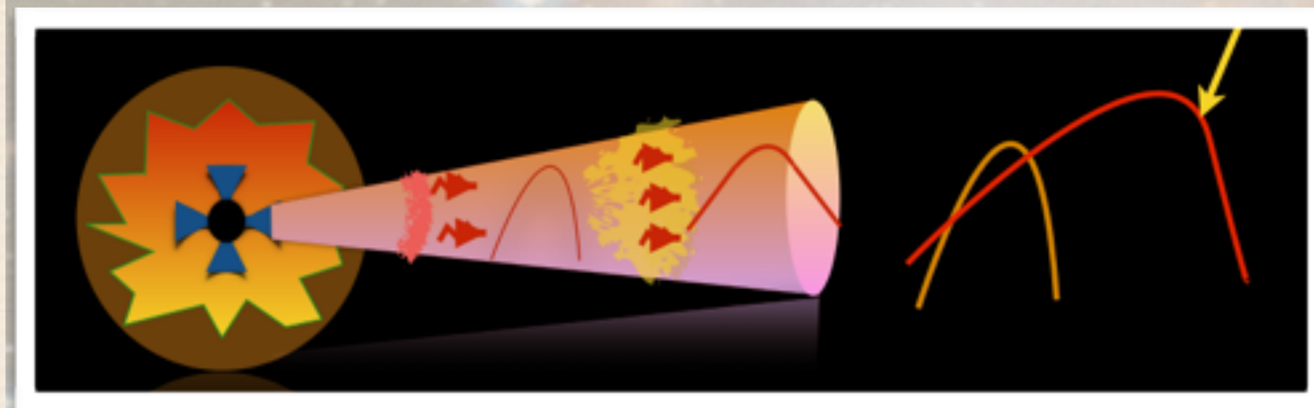
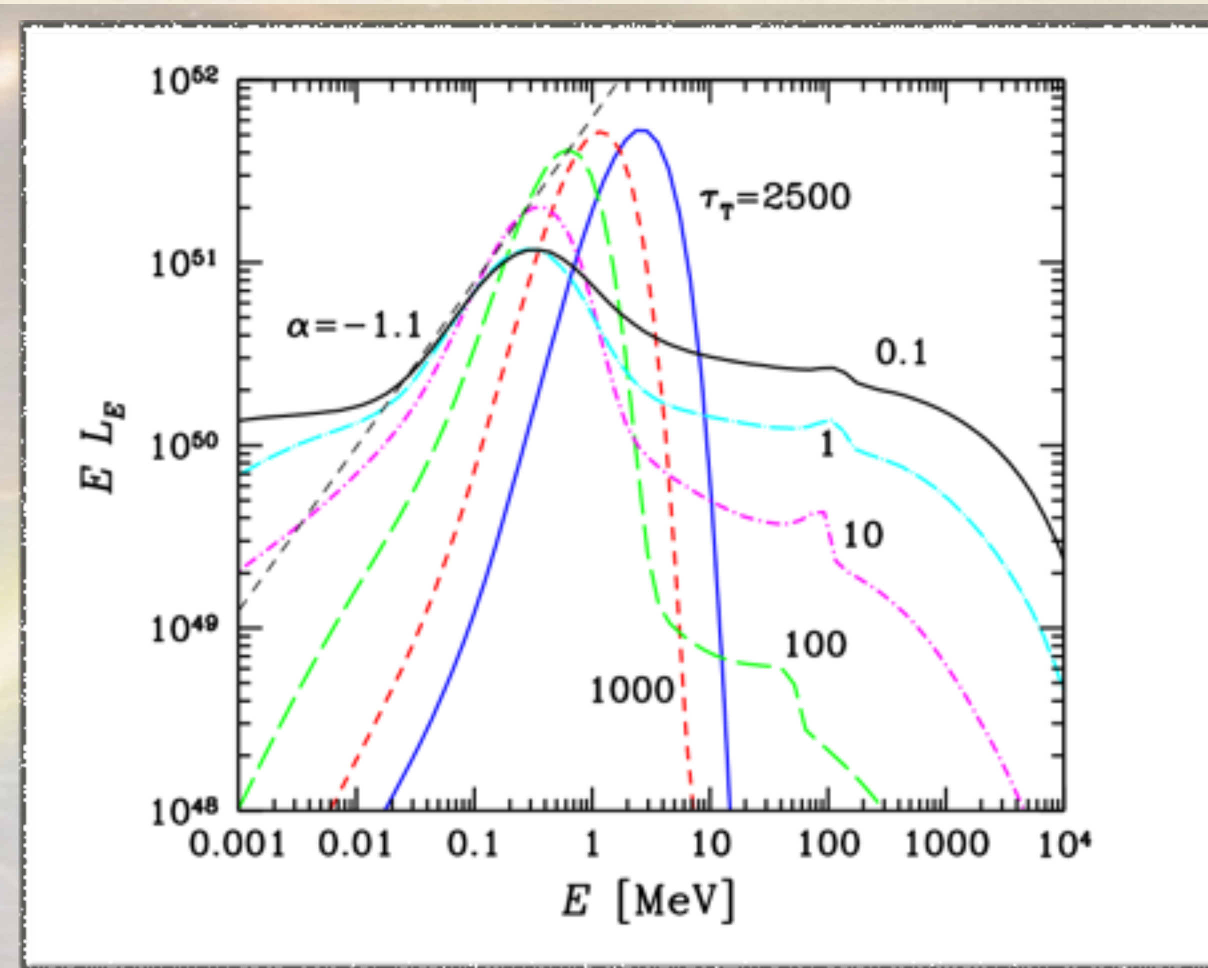
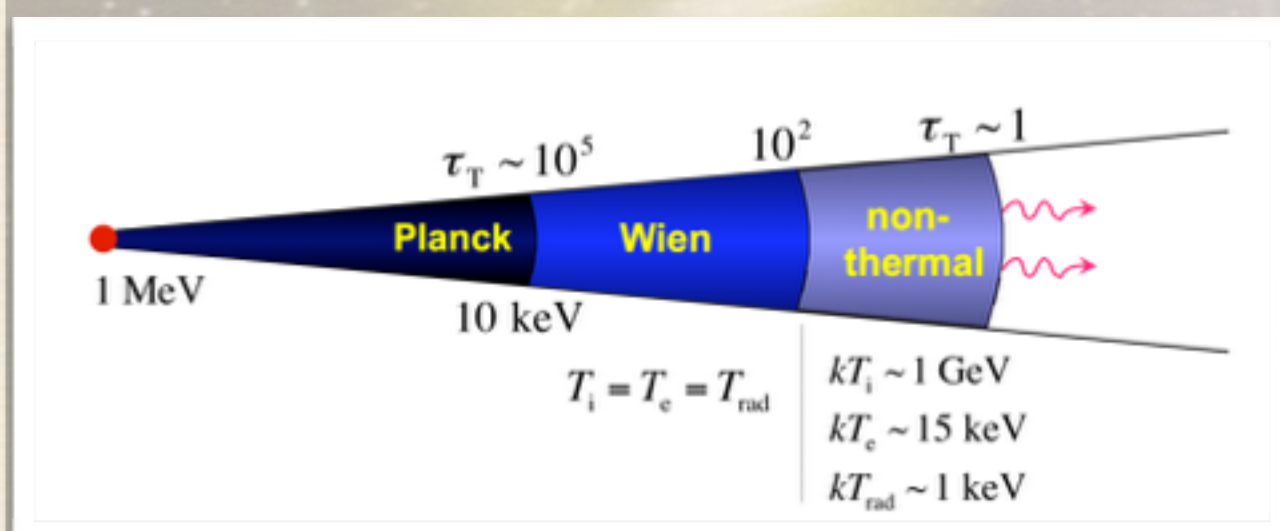


Image credit: S. Iyyani



Vurm and Beloborodov (2016)



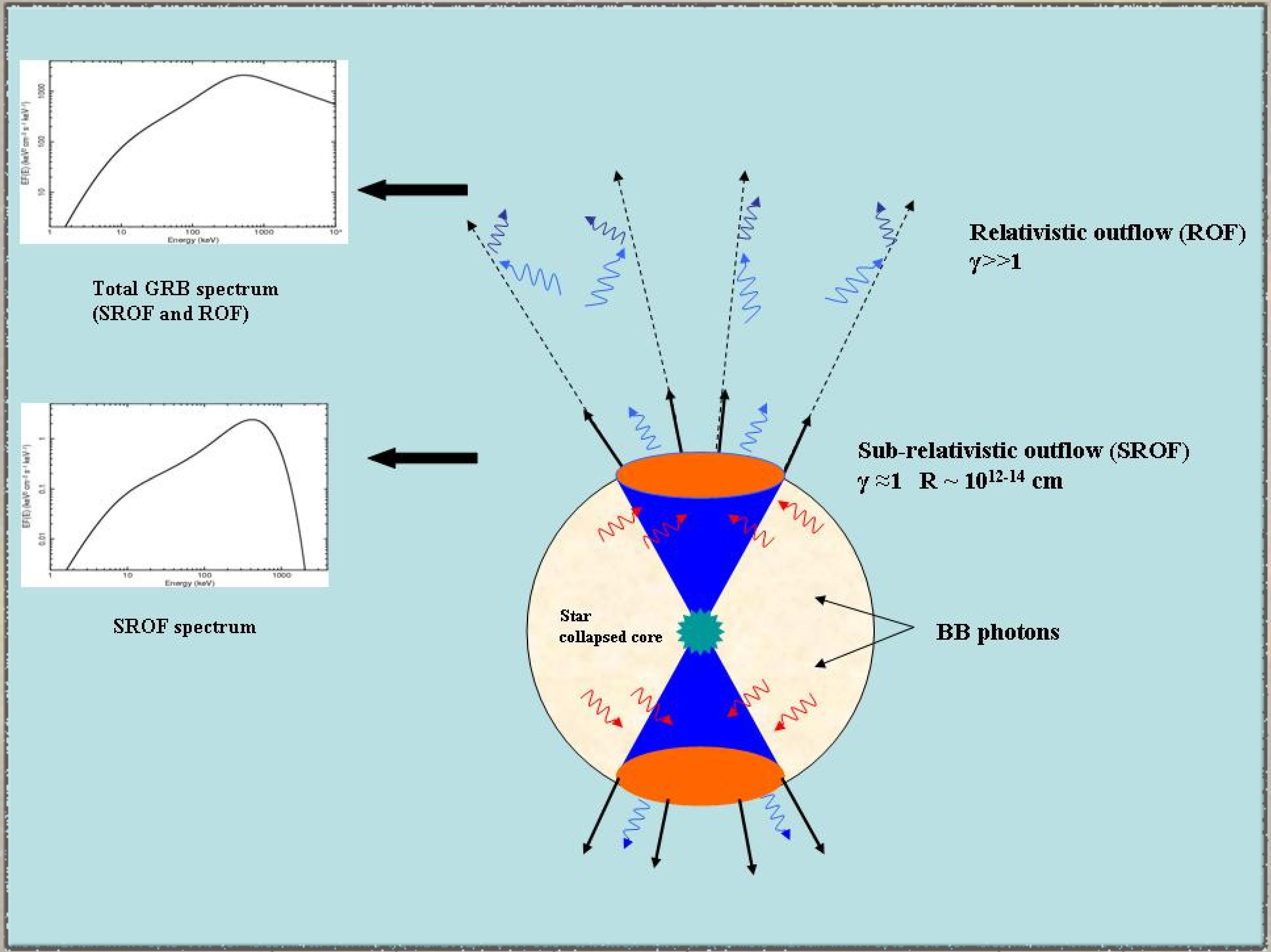
Beloborodov and Meszaros (2017)

- *Photosphere + shock*
- *Dissipation inside a fuzzy photosphere*

- *Magnetic dissipation (Beniamini and Giannios 2017)*

GRB models

- *Comptonization models*

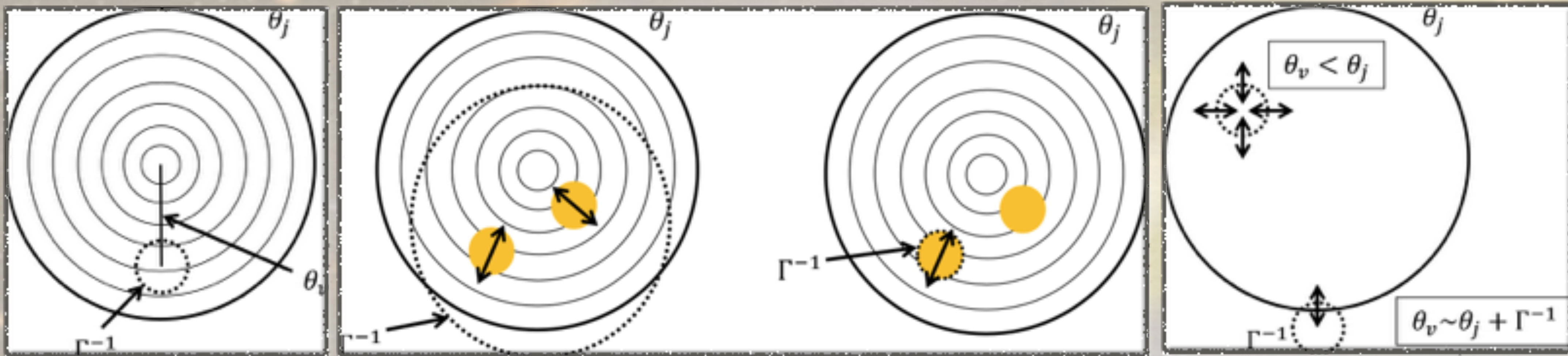


Titarchuk et al., 2012

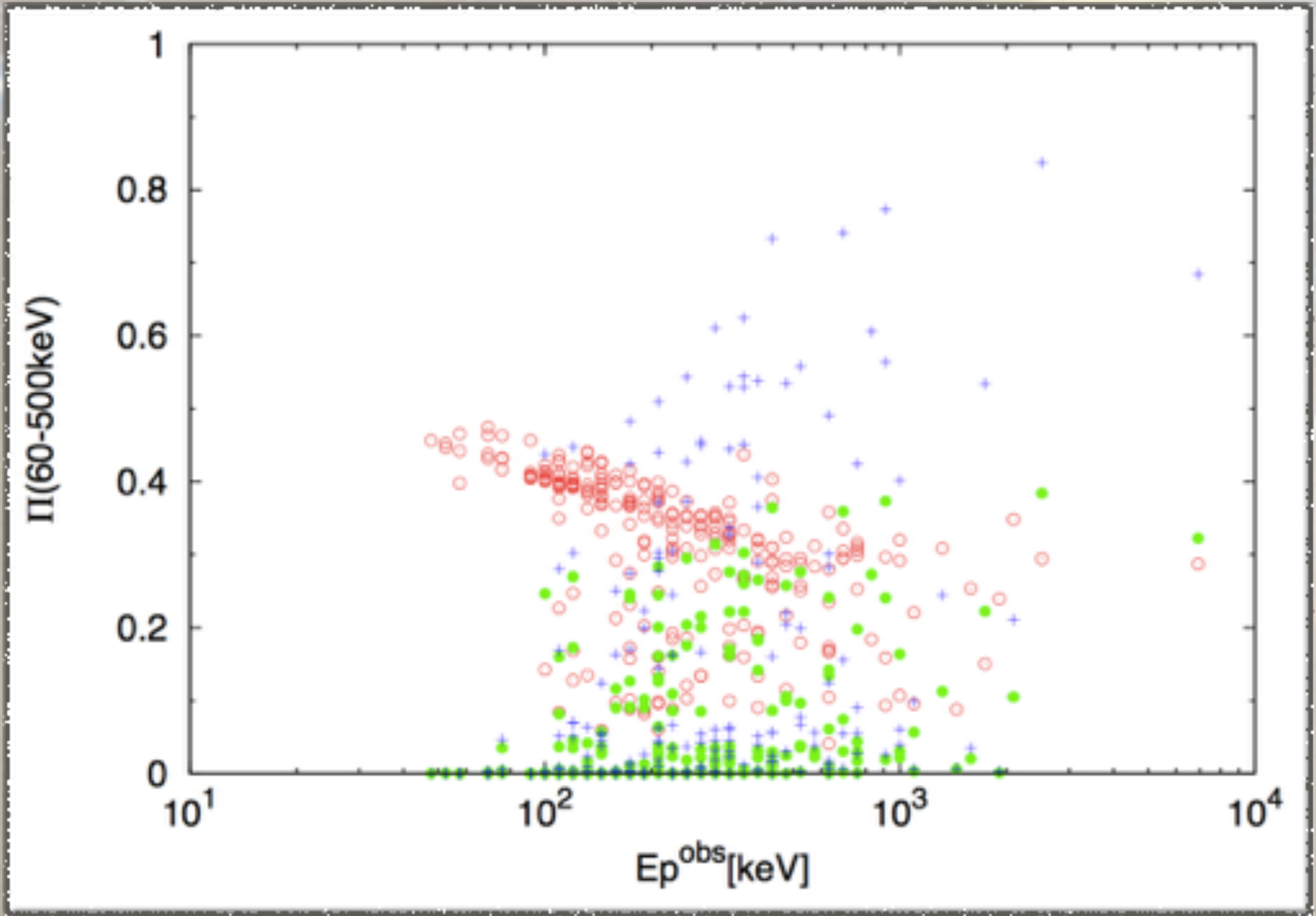
GRB Physics
What do we want to answer ?

- *What are the radiation mechanisms producing GRBs in prompt emission?*
- *How is the distribution of electron is non thermal with a low energy cutoff created?*
- *Jets or no jets (fragments)*
- *Geometry of jets*
- *What is the energy reservoir: Thermal, Kinetic or magnetic?*
- *Central engine of GRBs: Black holes or Magnetars?*

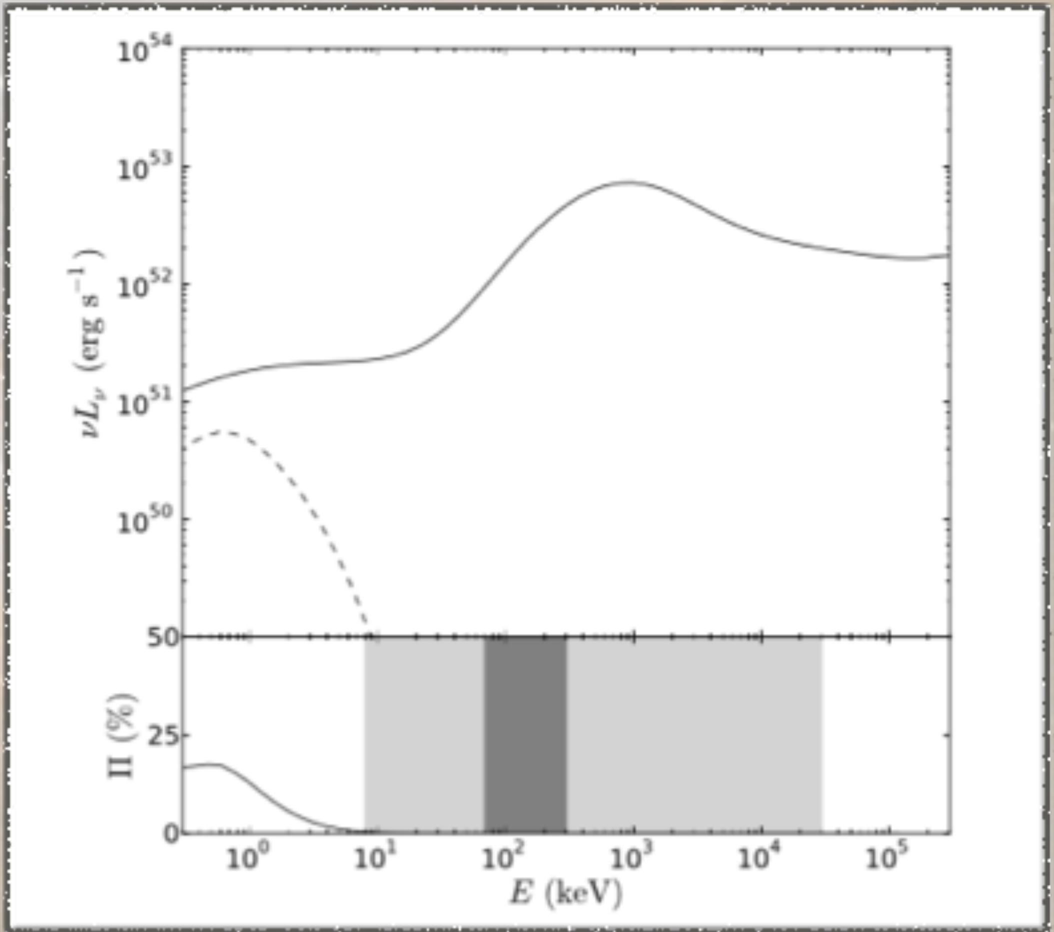
Polarisation in GRBs



Toma et al., 2009



Toma et al., 2009



Lundman 2017

Polarisation Measurements

RHESSI GRB 021206 Pi= 80+- 20 %

BATSE, INTEGRAL, GAP

Table 2: Summary of recent GRB polarization measurement by IBIS/SPI and GAP.

GRB	Π (68% c.l.)	Peak energy (keV)	Fluence (erg cm^{-2})	Energy Range	Redshift z	Instrument
041291A	65±26%	201^{+80}_{-41}	2.5×10^{-4}	20–200 keV	$0.31^{+0.54}_{-0.26}$	IBIS, SPI
06122	>60%	188±17	2.0×10^{-5}	20–200 keV	$1.33^{+0.77}_{-0.76}$	IBIS, SPI
100826A	27±11%	606^{+134}_{-109}	3.0×10^{-4}	20 keV–10 MeV	0.71–6.84[1]	GAP
110301A	70±22%	107±2	3.6×10^{-5}	10 keV–1 MeV	0.21–1.09[1]	GAP
110721	84^{+16}_{-28}%	393^{+199}_{-104}	3.5×10^{-4}	10 keV–1 MeV	0.45–3.12[1]	GAP
140206A	>48%	98±17	2.0×10^{-5}	15–350 keV	2.739±0.001	IBIS

[1] redshift based on empirical prompt emission correlations, not on afterglow observations.

Source: Covino and Diego, 2016

High polarisation measured for prompt emission

- *Synchrotron emission or Inverse Compton scattering*

AstroSat/CZTI Observations

Table 2. Table for polarization

GRB Name	Compton events	PF (%)	PA (°)
GRB 151006A	459	<62	-31.0±12.8°
GRB 160106A	950	68.5±24	-22.5±12.0°
GRB 160131A	724	94±31	41.2±5.0°
GRB 160325A	835	58.75±23.5	10.9±17.0°
GRB 160509A	460	96±40	-28.6±11.0°
GRB 160607A	447	<63	-42.0±24.0°
GRB 160623A	1400	<35	-4.0±27.0°
GRB 160703A	448	<45	-47.9±6.0°
GRB 160802A	901	85±29	-36.1±4.6°
GRB 160821A	2549	48.7±14.6	-34.0±5.0°
GRB 160910A	832	93.7±30.92	43.5±4.0°

Chattopadhyay et al., 2017

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GRB 160802A

VIOLATION OF SYNCHROTRON LINE OF DEATH BY THE HIGHLY POLARIZED GRB 160802A

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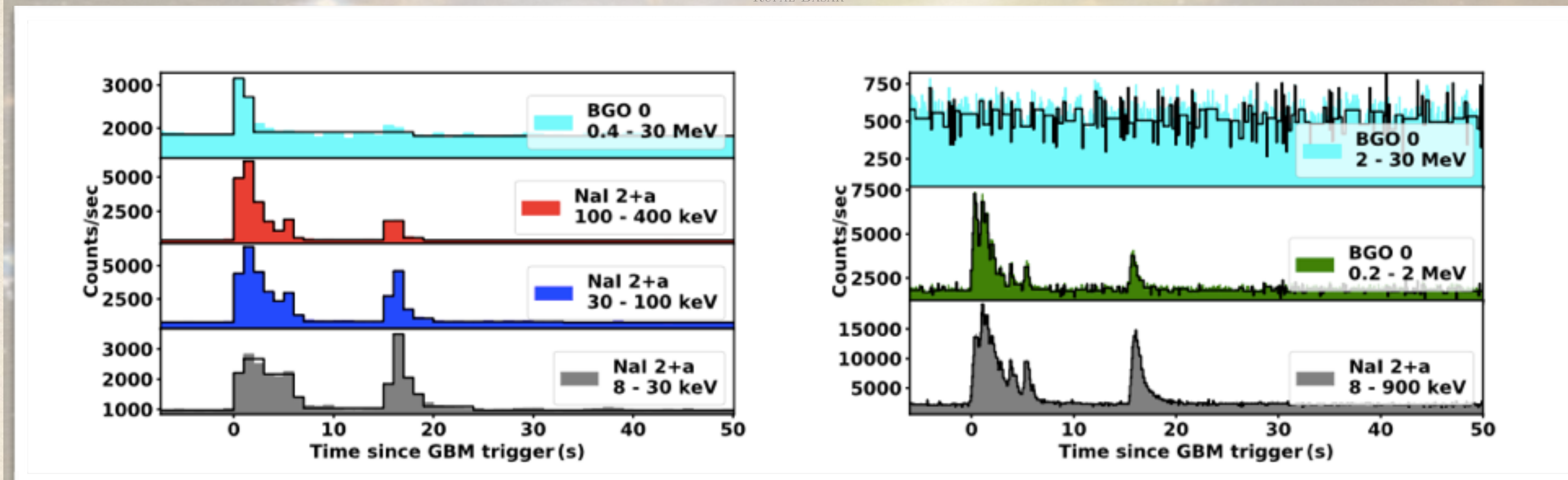


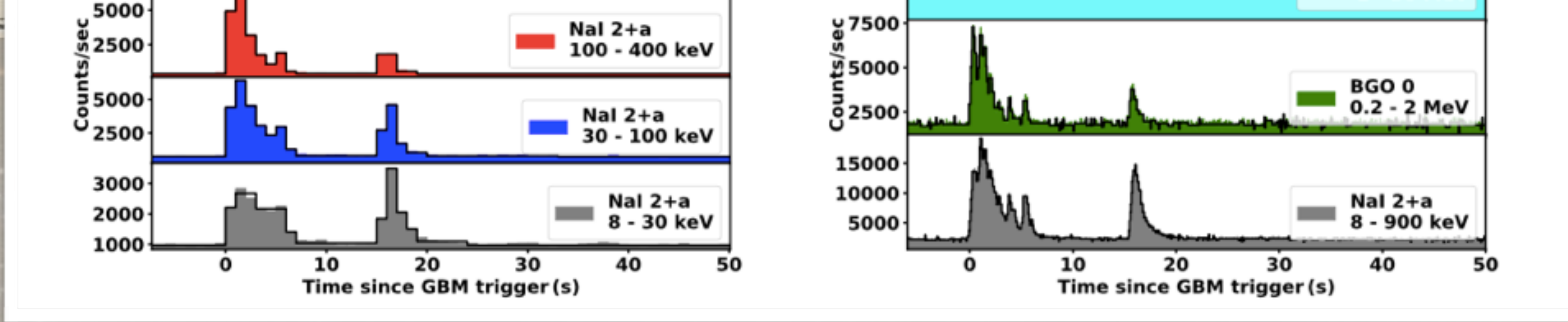
Vikas Chand, Chattopadhyay, T., S. Iyyani et. al. 2018

The spectrum in general shows a hard-to-soft evolution in both episodes. Only the later part of the first episode shows intensity tracking behaviour [illegible] to multiple pulses. The photon index [illegible] even the slow cooling limit ($\alpha = -2/3$) of an optically thin synchrotron shock model (SSM). Though such hard values are generally associated with a subdominant thermal emission, such a component is not statistically required in our analysis. In addition, the measured polarisation in 100–300 keV is too high, $\pi = 85 \pm 29\%$, to be accommodated in such a scenario. Jitter radiation, which allows a much harder index up to $\alpha = 0.5$, in principle can produce high polarisation but only beyond the spectral peak, which in our case lies close to 200–300 keV during the time when most of the polarisation signal is obtained. The spectre-polarimetric data seems to be consistent with a subphotospheric dissipation process occurring within a narrow jet with a sharp drop in emissivity beyond the jet edge, and viewed along its boundary.

Keywords: gamma-ray burst: general – gamma-ray burst: individual (GRB160802A) – polarization – radiation mechanisms: non-thermal

1. INTRODUCTION

One of the putative models invoked to explain the non-thermal spectral shape in the prompt emission of



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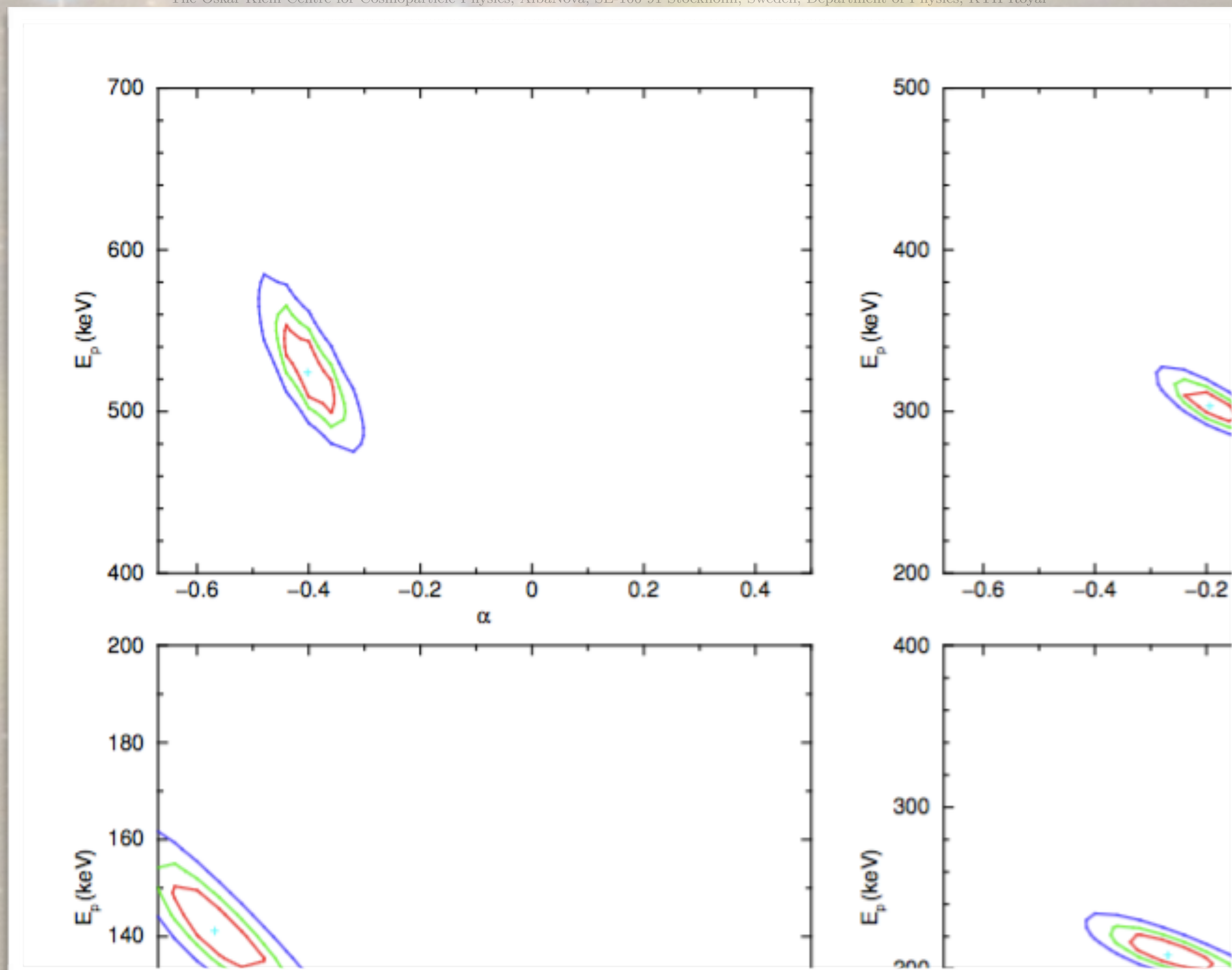

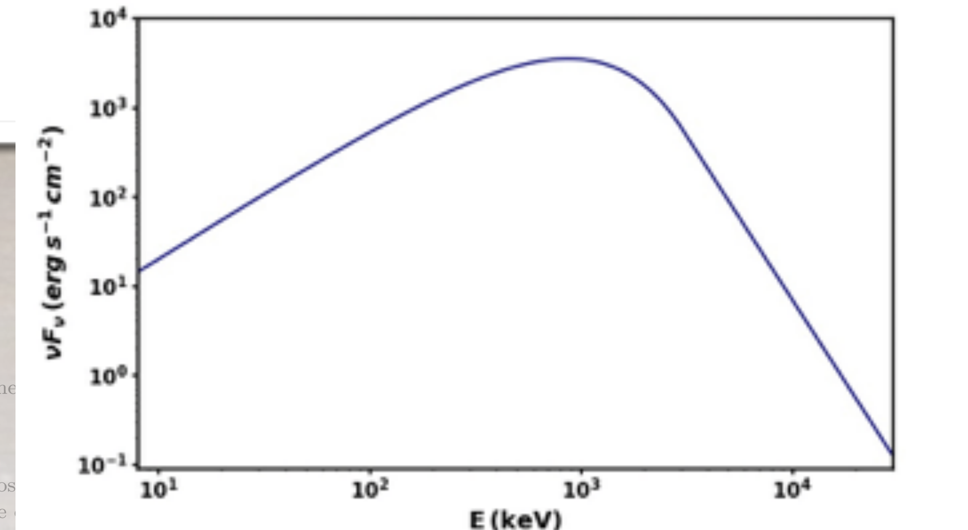

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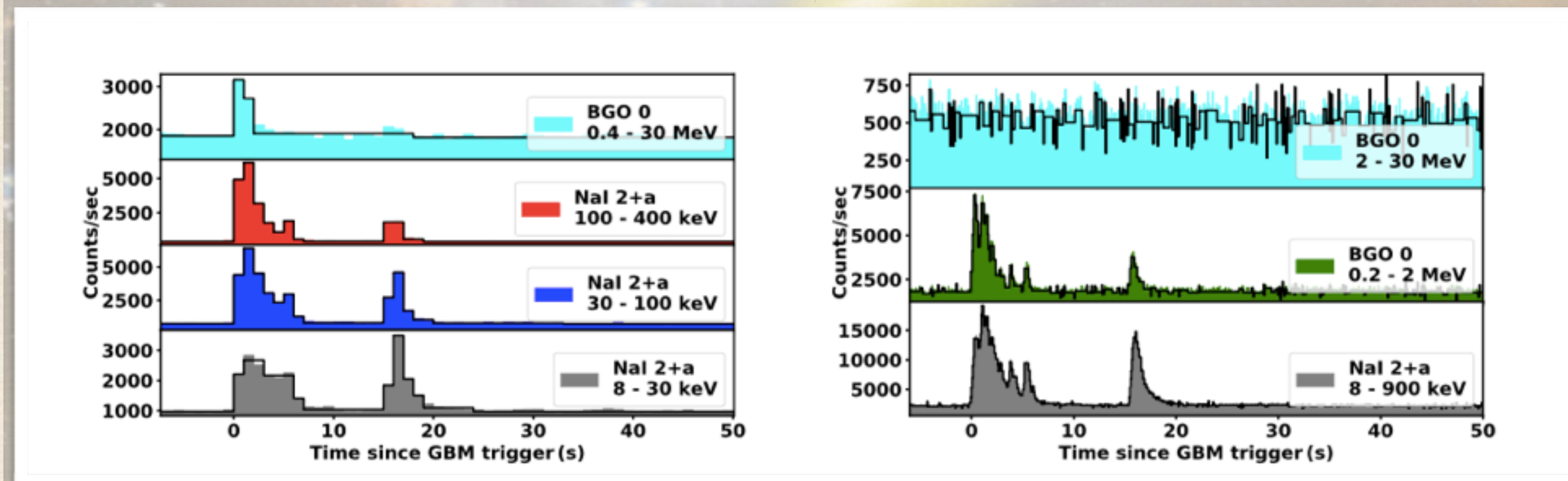
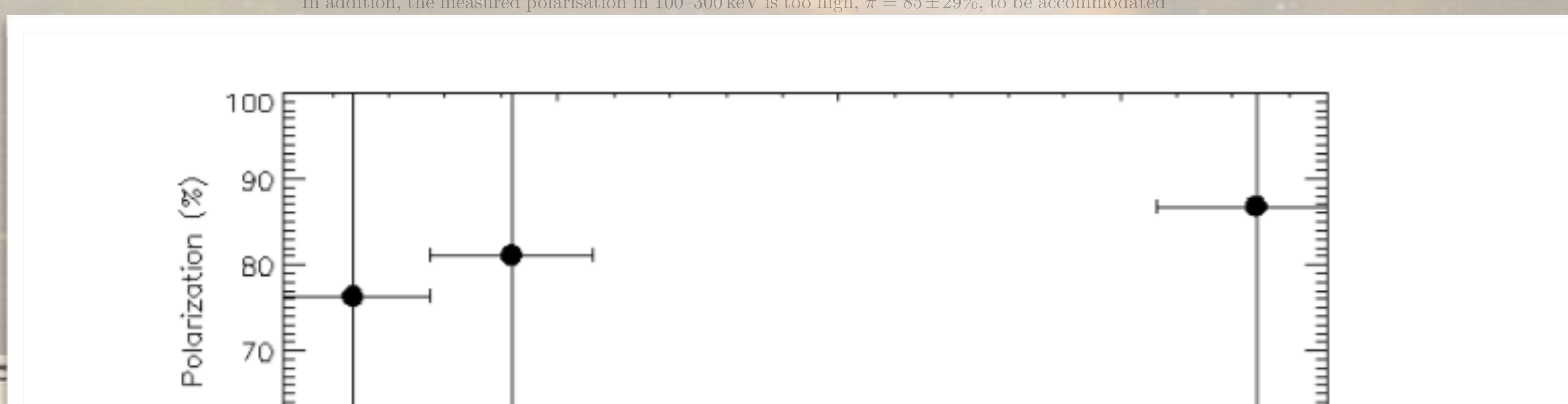
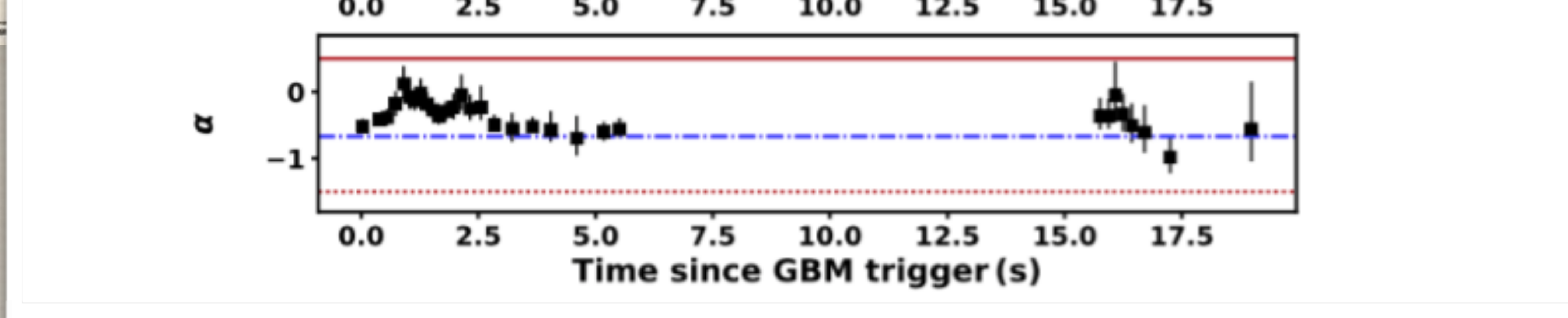
The Oskar Klein Centre for Cos
Institute

Aarthy, E.



with a subdominant thermal emission, such a component is not statistically required in our analysis. In addition, the measured polarisation in 100–300 keV is too high, $\pi = 85 \pm 29\%$, to be accommodated





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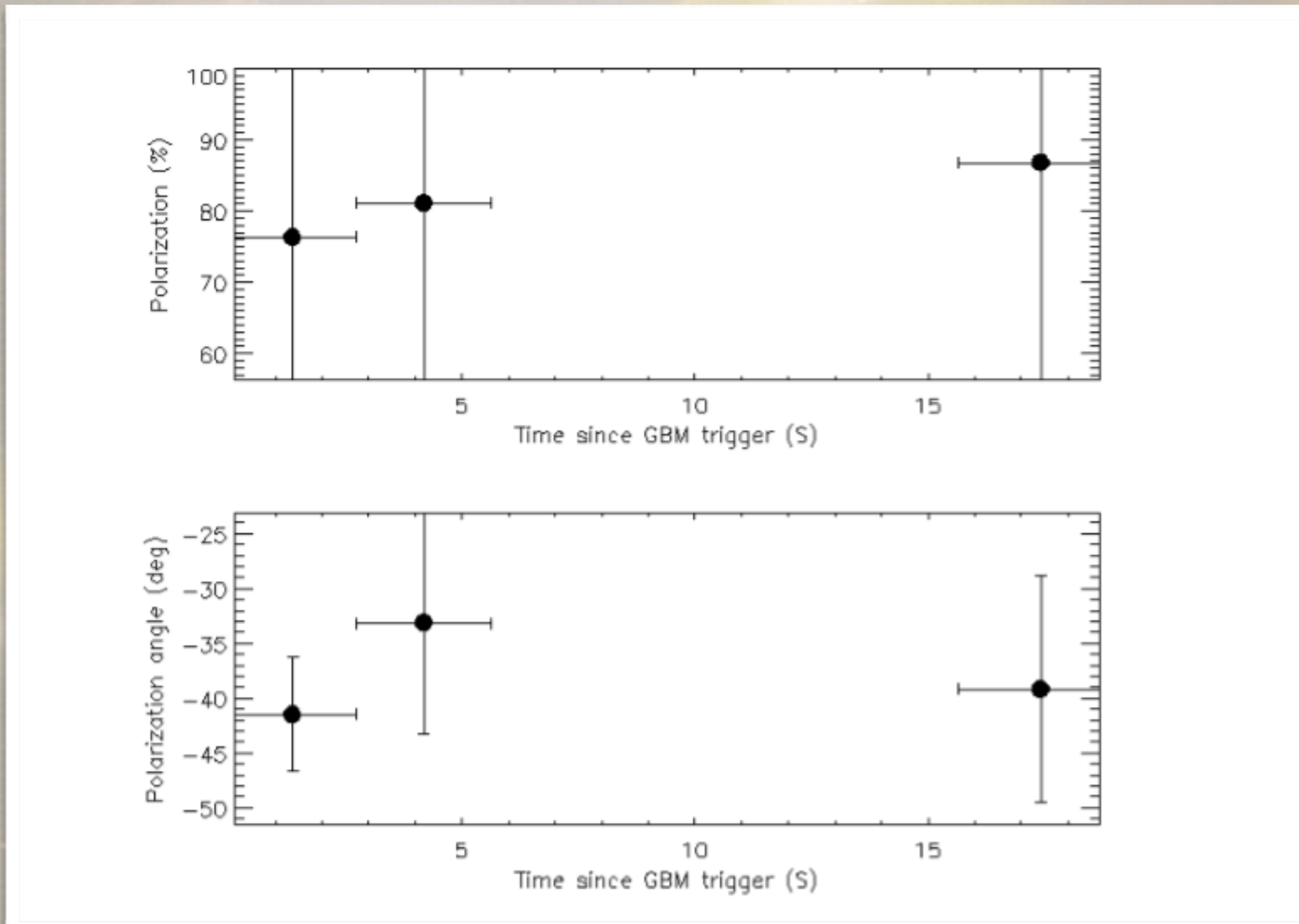

GRB 160802A conclusions

- Hard low energy index inconsistent with SSM
- Burst is not observed much off axis as then it should be dominated by high latitude radiation which is much softer
- Subphotospheric dissipation - low polarisation
- Jitter radiation can give larger polarisation, however at energies beyond Ep, around spectral peak polarisation <= 40%
- Viewing geometry
- Very narrow jet viewed along its edge
- Sharp drop in the jet edge otherwise high lattitude emission will soften the spectrum
- Cutoff in energy jet ~ 1 degree (lowest deduced from jet breaks)

GRB 171010A

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VARIABLE PROMPT EMISSION POLARIZATION OF GAMMA RAY BURST *GRB* 171010*A* DETECTED WITH *ASTROSAT*/CZTI

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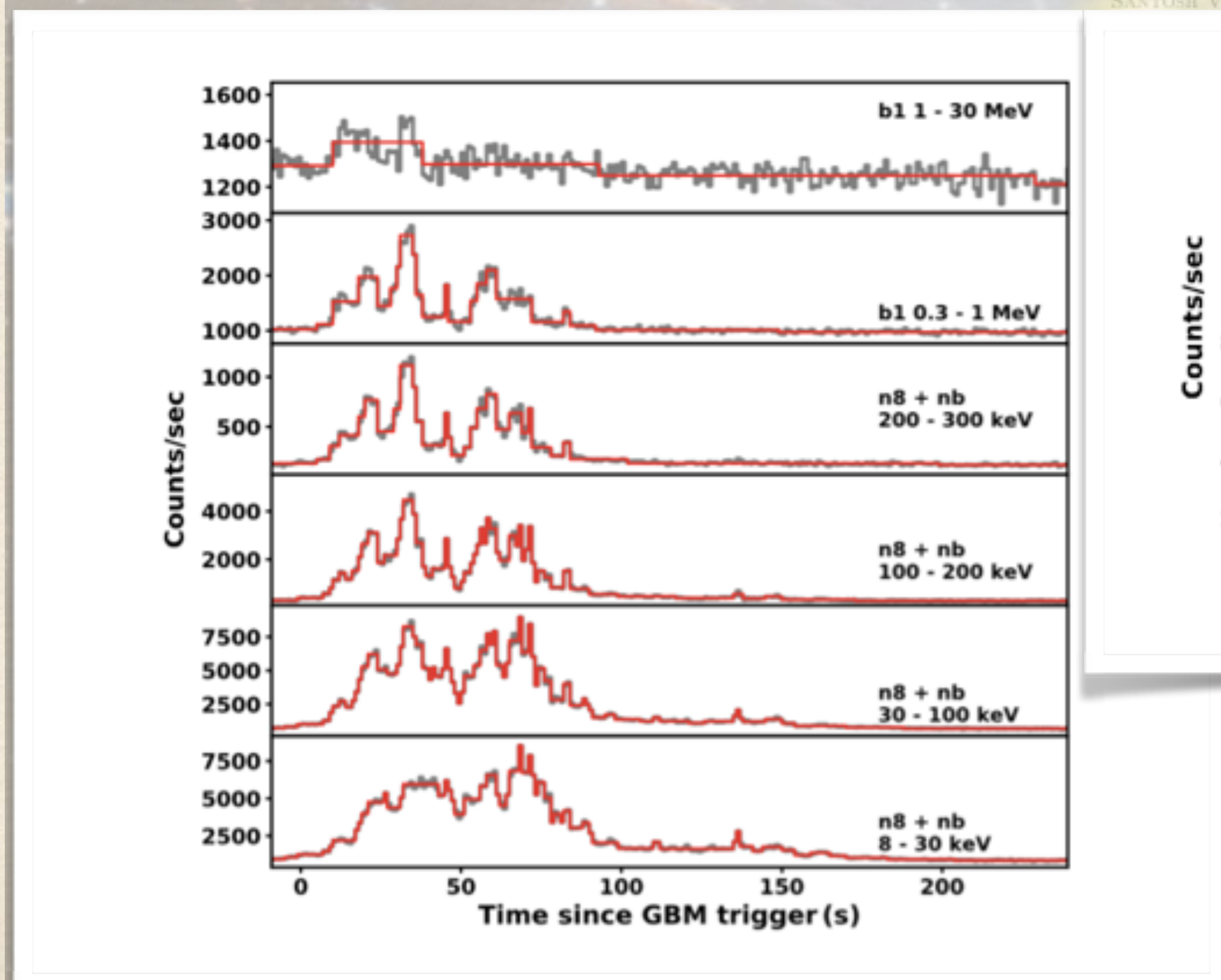
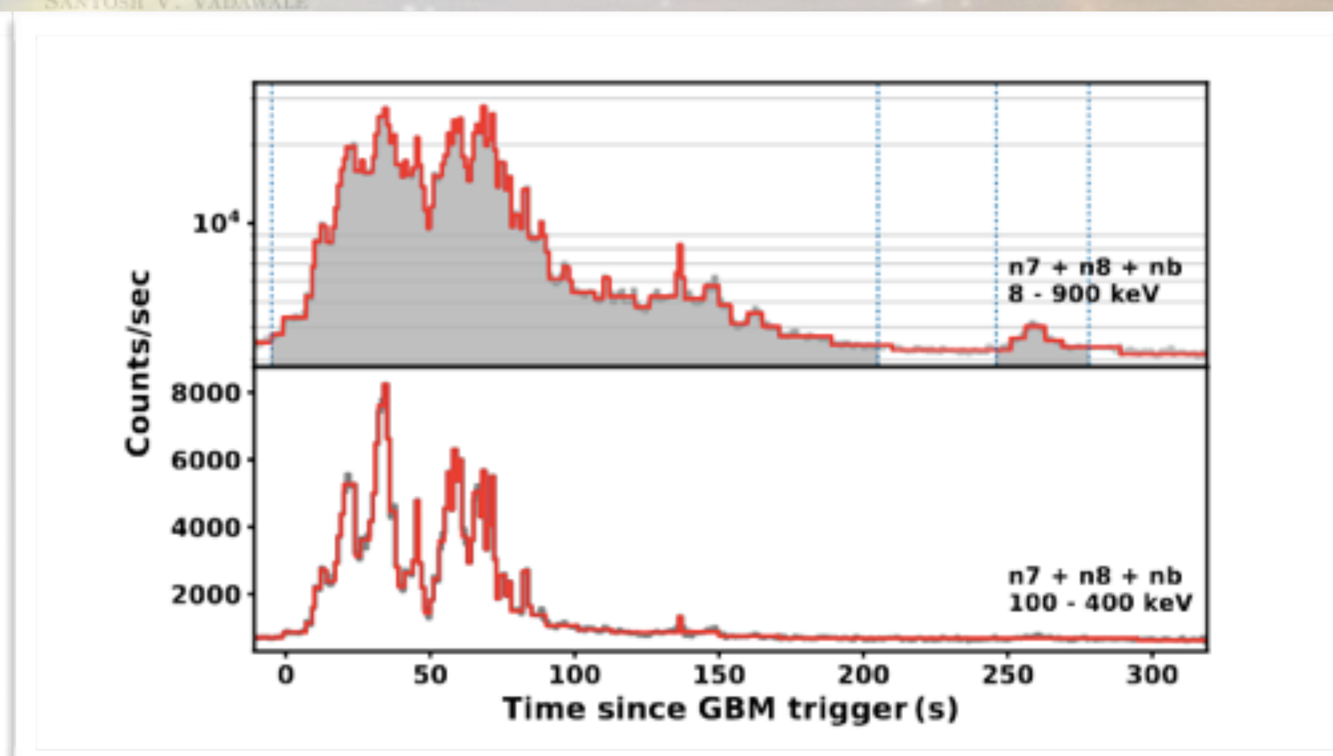
Santosh V. Vadawale





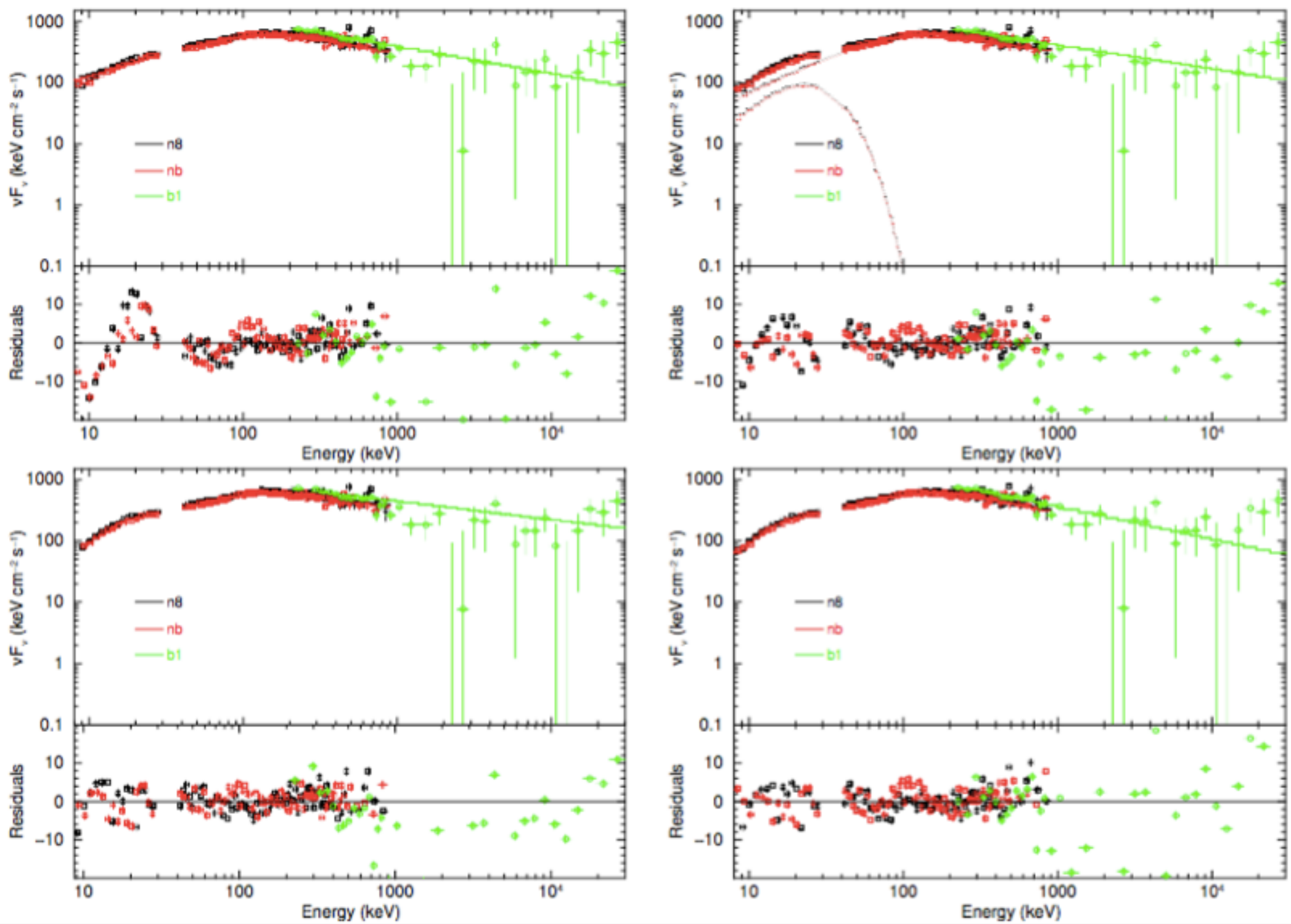
…nalyzing the Compton double scattering events. …ble scattering events among the GRBs detected by …isation. There is, however, a hint that the burst is … polarised at higher energies. The polarization is … to reconcile these diverse information by invoking …nission is produced in multiple shocks with random … example where a combined study of the prompt …emission polarization brings a new dawn in GRB

…burst: individual (GRB171010A) – polarization – radiation mechanisms: non-thermal

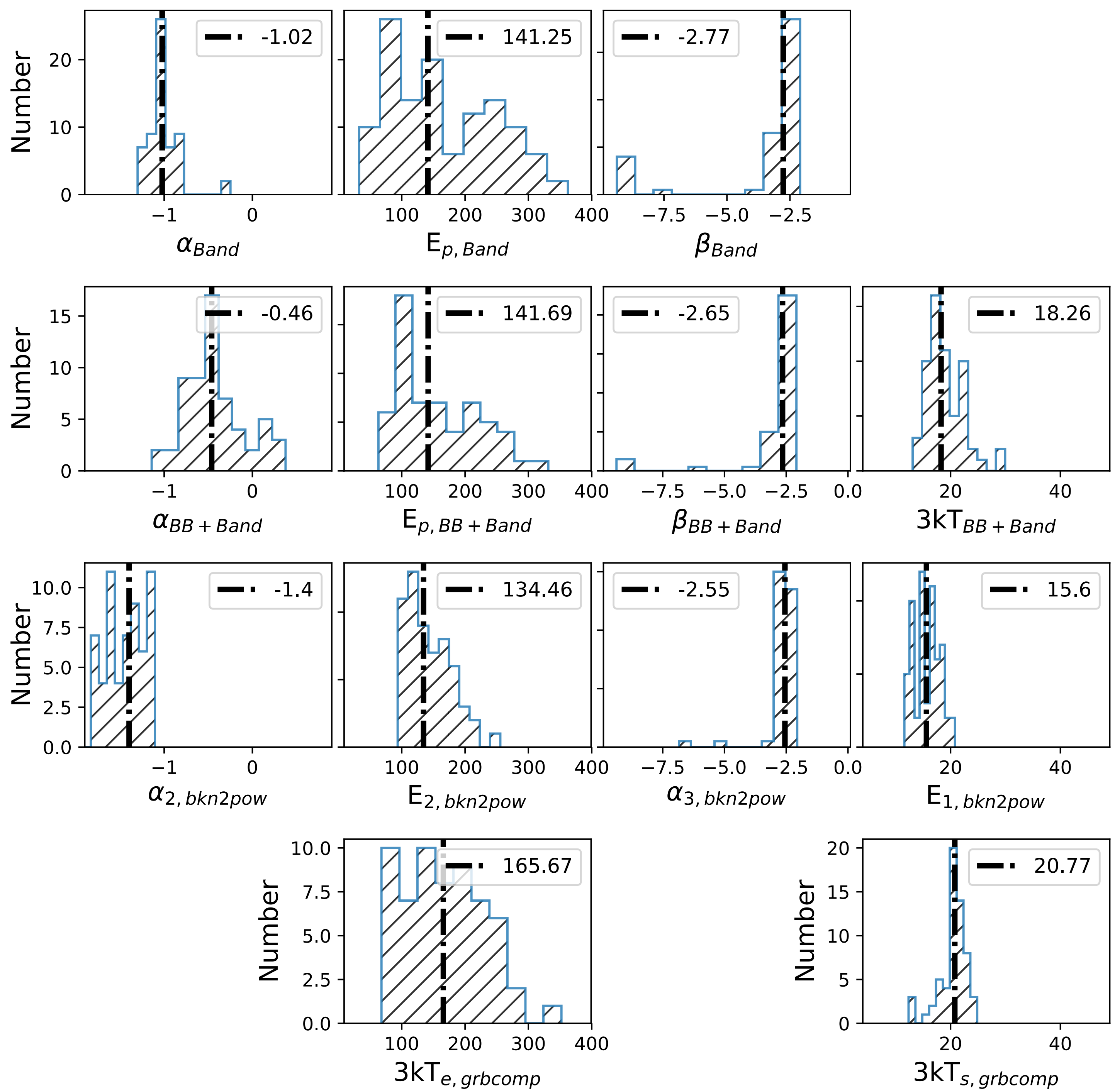
GRB 171010A

ABSTRACT

GRB 171010A is a very bright GRB (fluence $>10^{-4}$ ergs cm^{-2}) and its prompt emission is observed by Fermi/GBM and AstroSat/CZTI and the afterglow is observed by Fermi/LAT and Swift/XRT. We present here a detailed spectro-polarimetric study of this GRB to provide insights into the physical mechanisms of the prompt radiation and the jet geometry. The main episode of the burst has a complex structure with multiple pulses superimposed. The energy spectra deviate from the typical

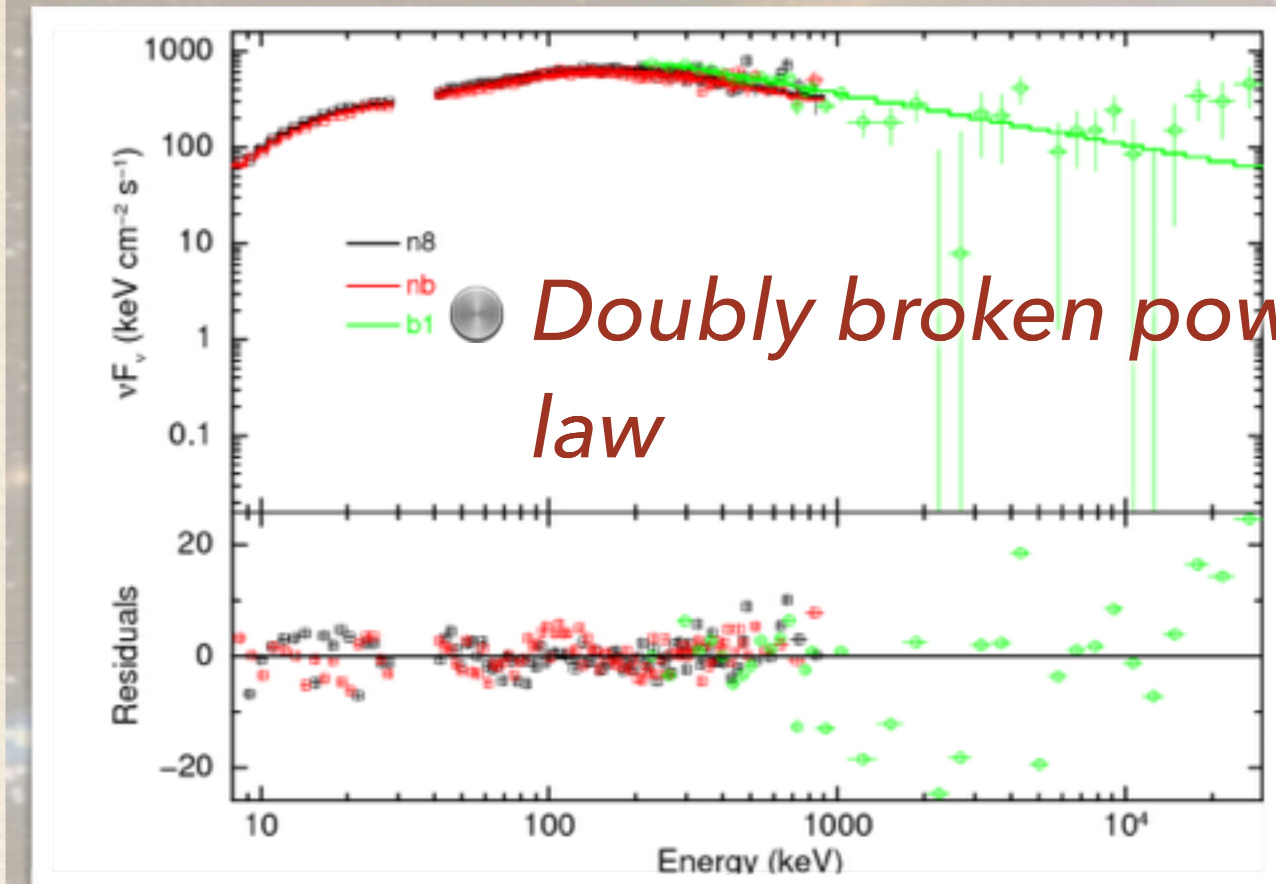


GRB 171010A

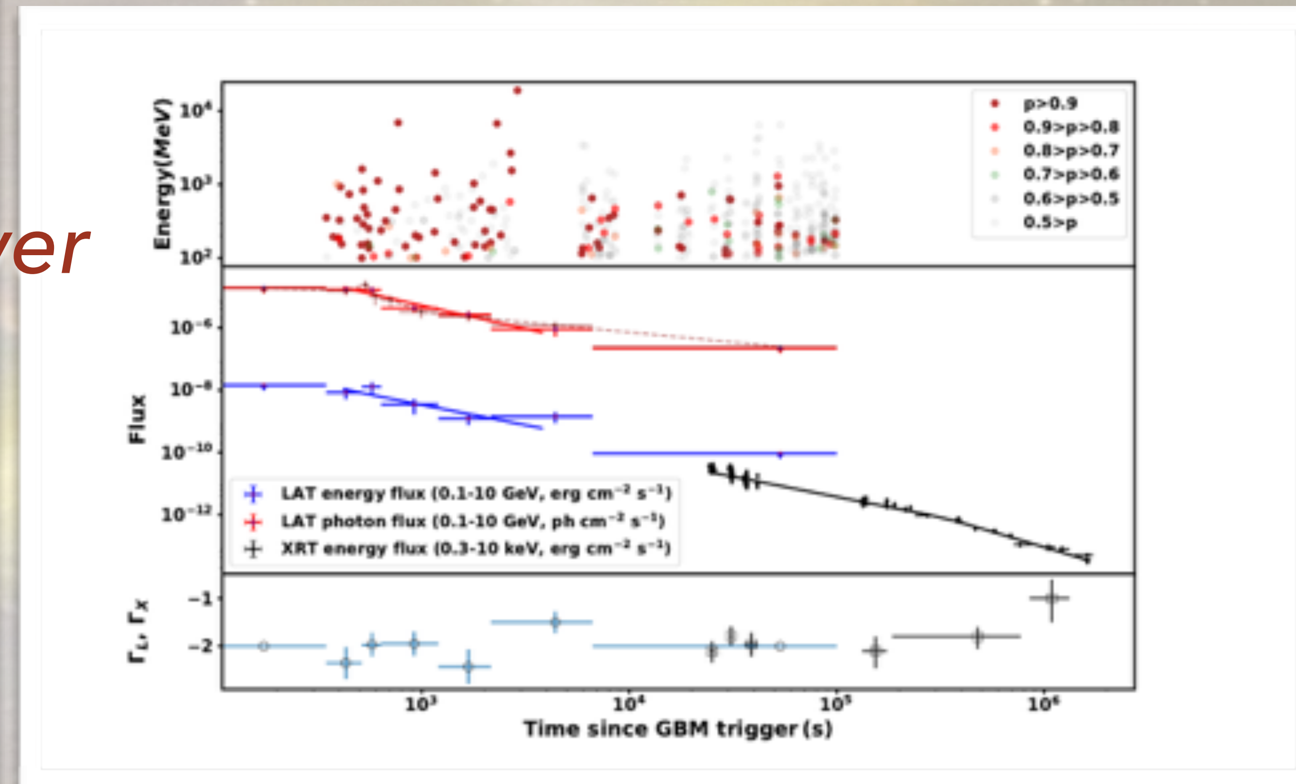


-1.02
141.25
-2.77
α_{Band}
$E_{p,Band}$
β_{Band}
-0.46
141.69
-2.65
18.26
$\alpha_{BB+Band}$
$E_{p,BB+Band}$
$\beta_{BB+Band}$
$3kT_{BB+Band}$
-1.4
134.46
-2.55
15.6
$\alpha_{2,bkn2pow}$
$E_{2,bkn2pow}$
$\alpha_{3,bkn2pow}$
$E_{1,bkn2pow}$
165.67
20.77
$3kT_{e,grbcomp}$
$3kT_{s,grbcomp}$
Number

GRB 171010A



- *Doubly broken power law*



$\alpha_L = -1.37 \pm 0.45$ and $\beta_L = -1.0 \pm 0.1$

- *Comptonization model*
- *LAT and XRT*

- *Detection of an associated SN*
- *Afterglows detection: Lorentz factor > 330 (beaming angle = 0.17 degree and*
  jet opening angle = 6.3 degree
  Polarisation measurements and variability in polarisation

GRB 171010A

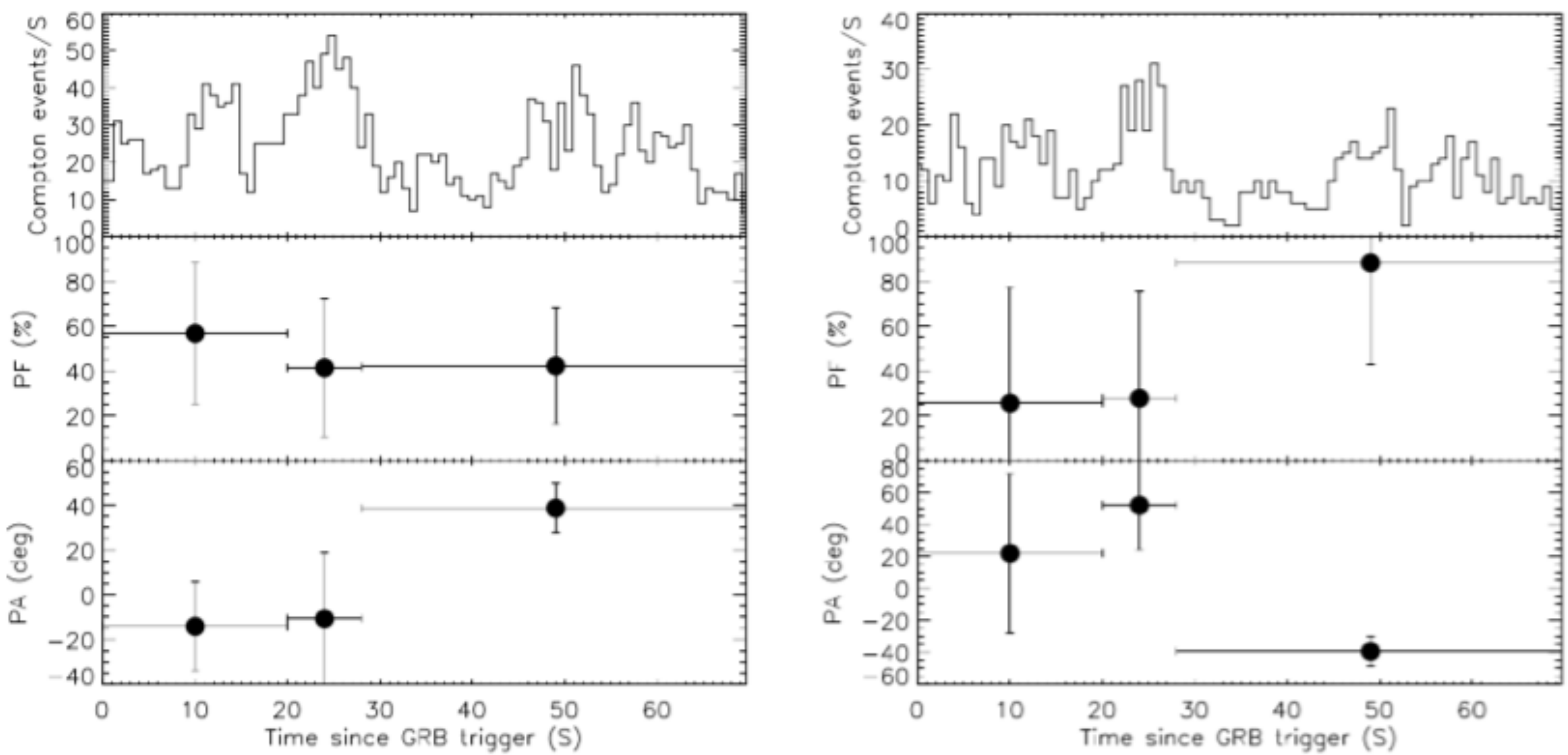


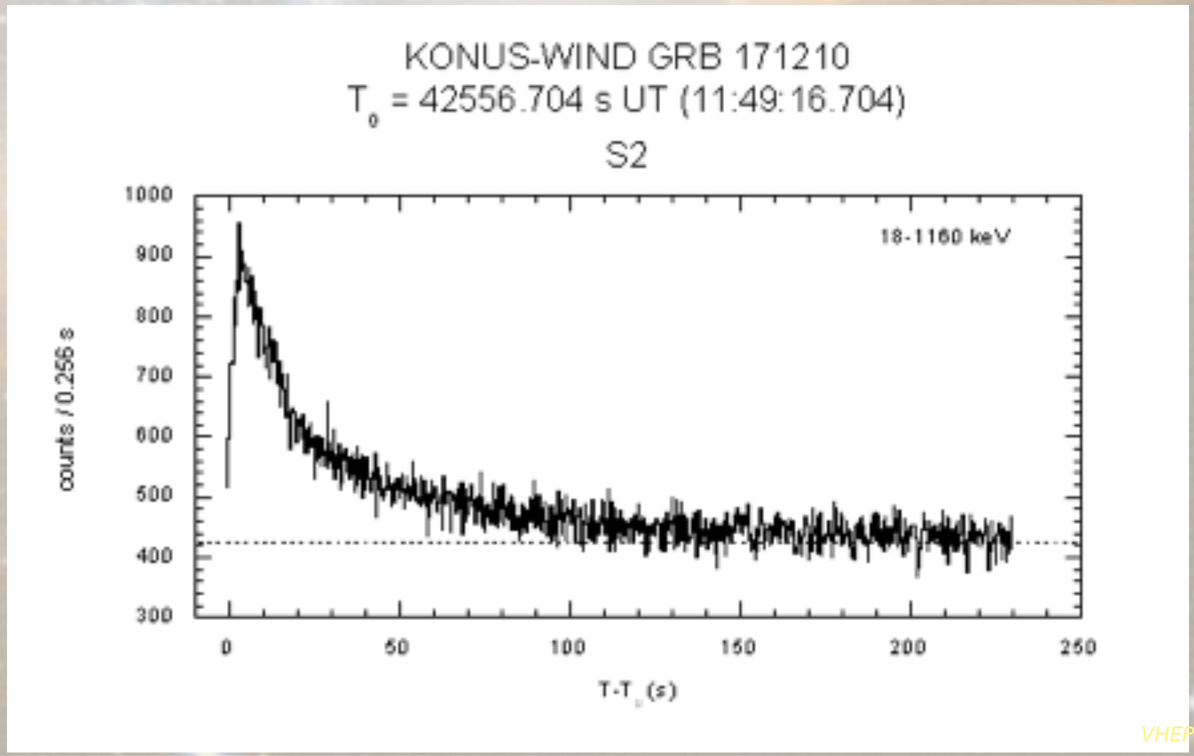
Figure 15. Compton light curve (top), polarization fraction (middle) and angle (bottom) for three different time intervals during the prompt emission of GRB 171010A in 100 — 200 keV (left) and 200 — 300 keV (right).

GRB 171010A conclusions

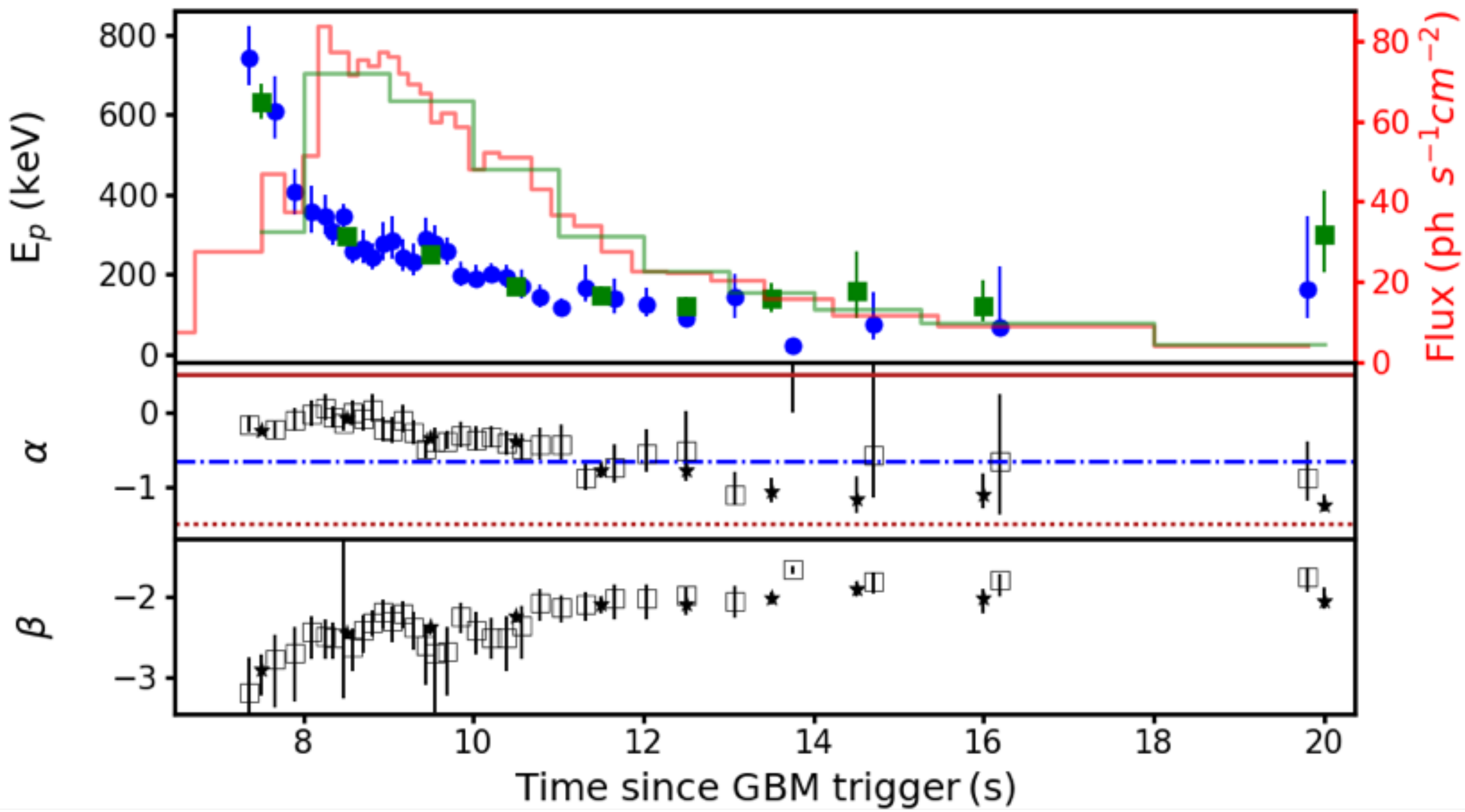
- Spectrum can be modelled by doubly broken power law, Synchrotron radiation
- Low Polarisation: high Lorentz factor: Random magnetic field at small scales (compared with beaming angle)
- Polarisation variation: multiple fragments of fireballs
- Polarisation variation with energy: angular effect and dominance of fragments at different energies
- Comptonization model can also explain low polarisation

Other Sources

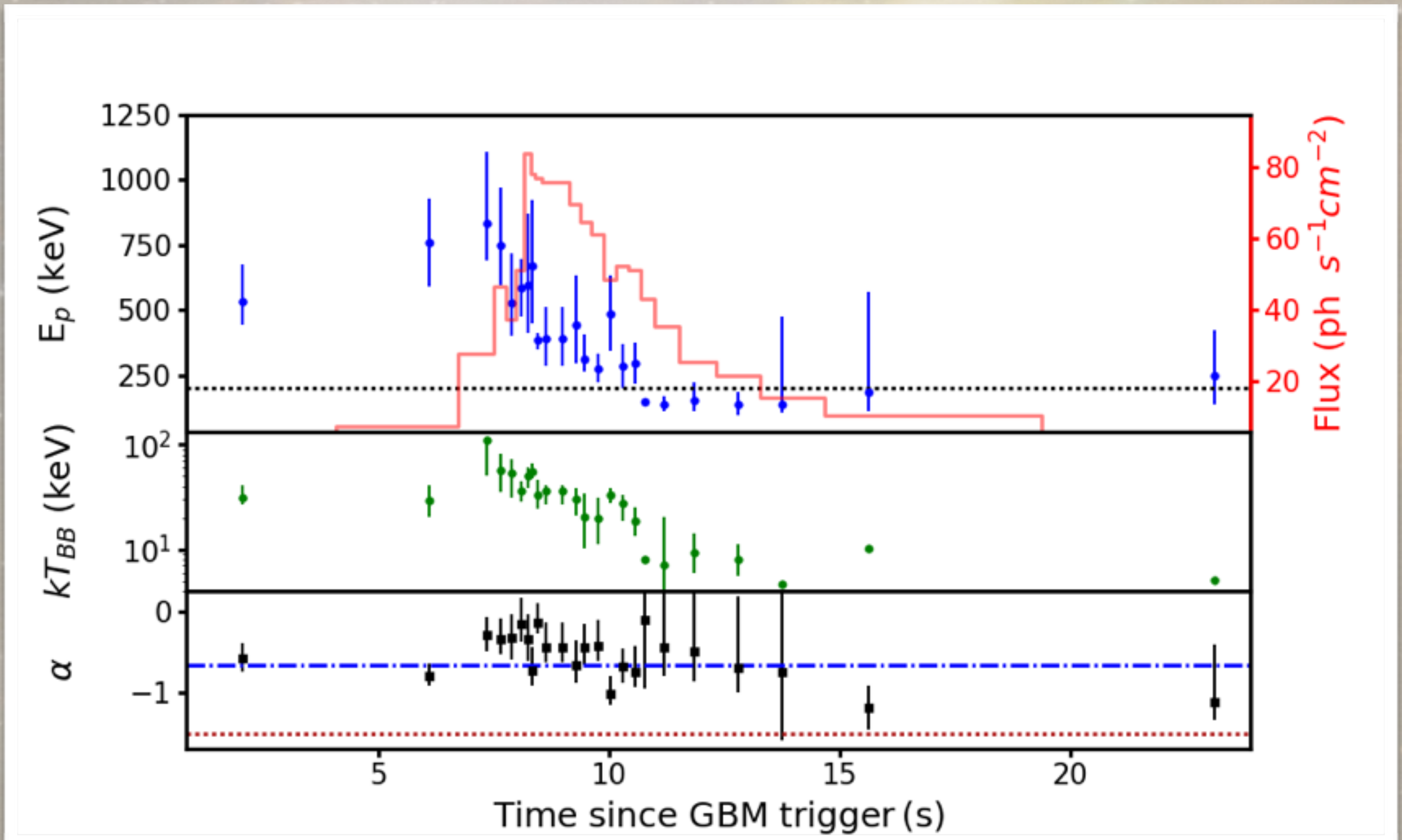
- *170304A*
- *170228A*
- *170115B*
- *170127C*
- *161218B*
- *161015A*



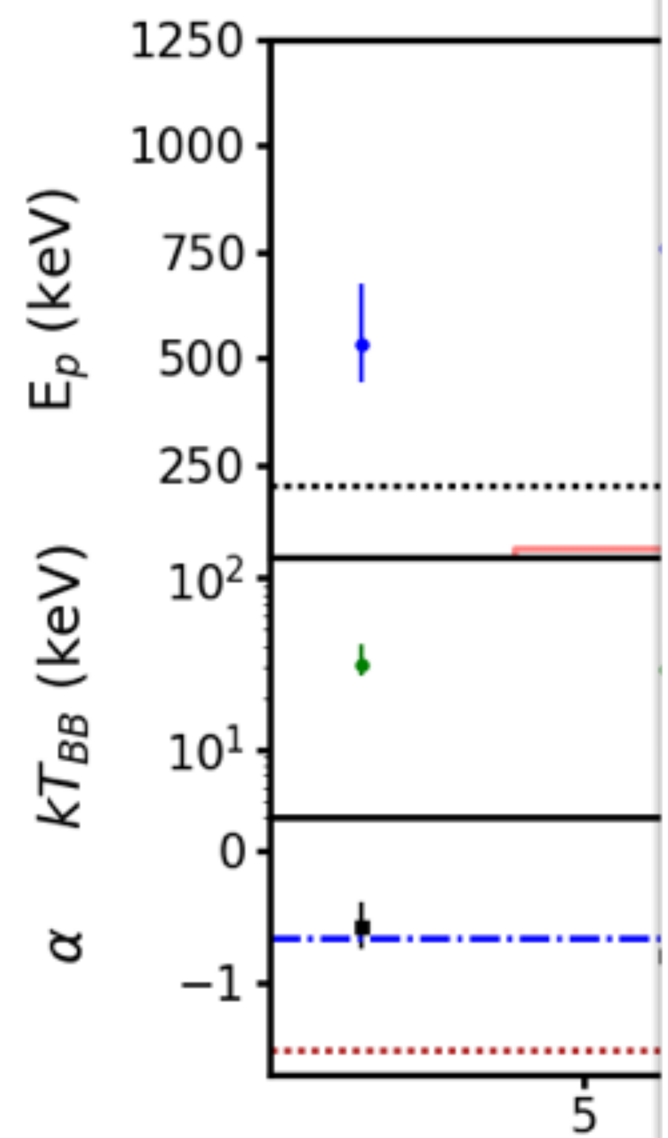
Bright Bursts: single pulse bursts:



Bright Bursts: single pulse bursts:



Bright Bursts: single pulse bursts:



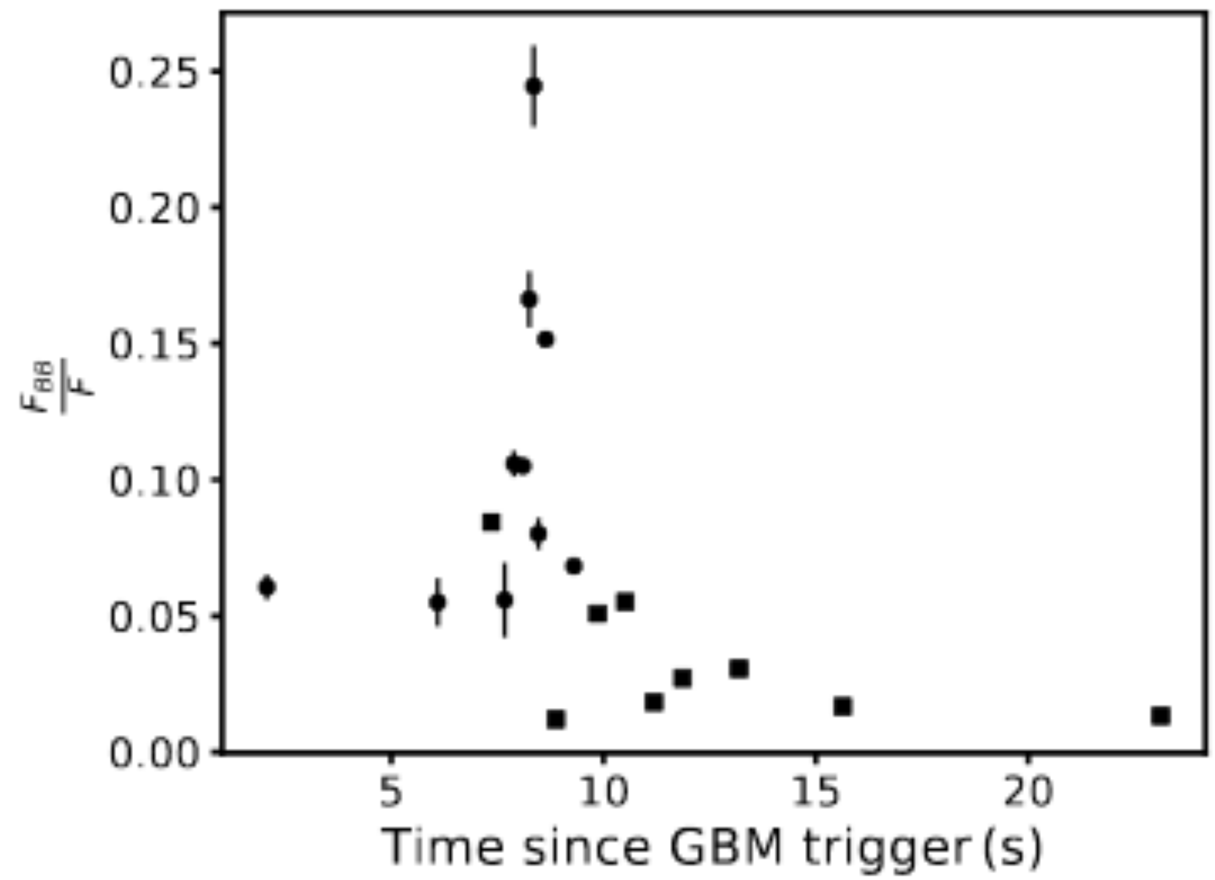
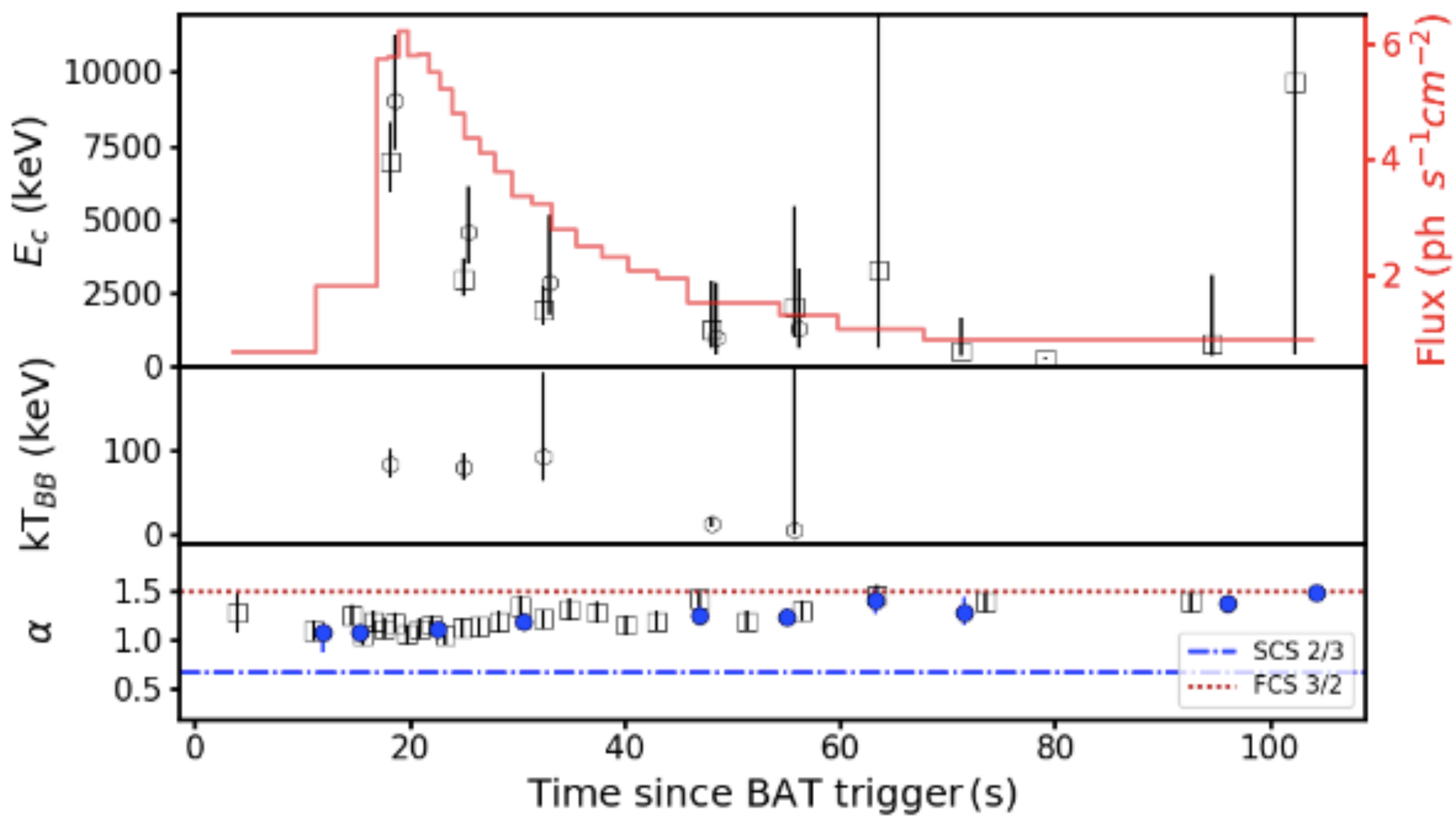
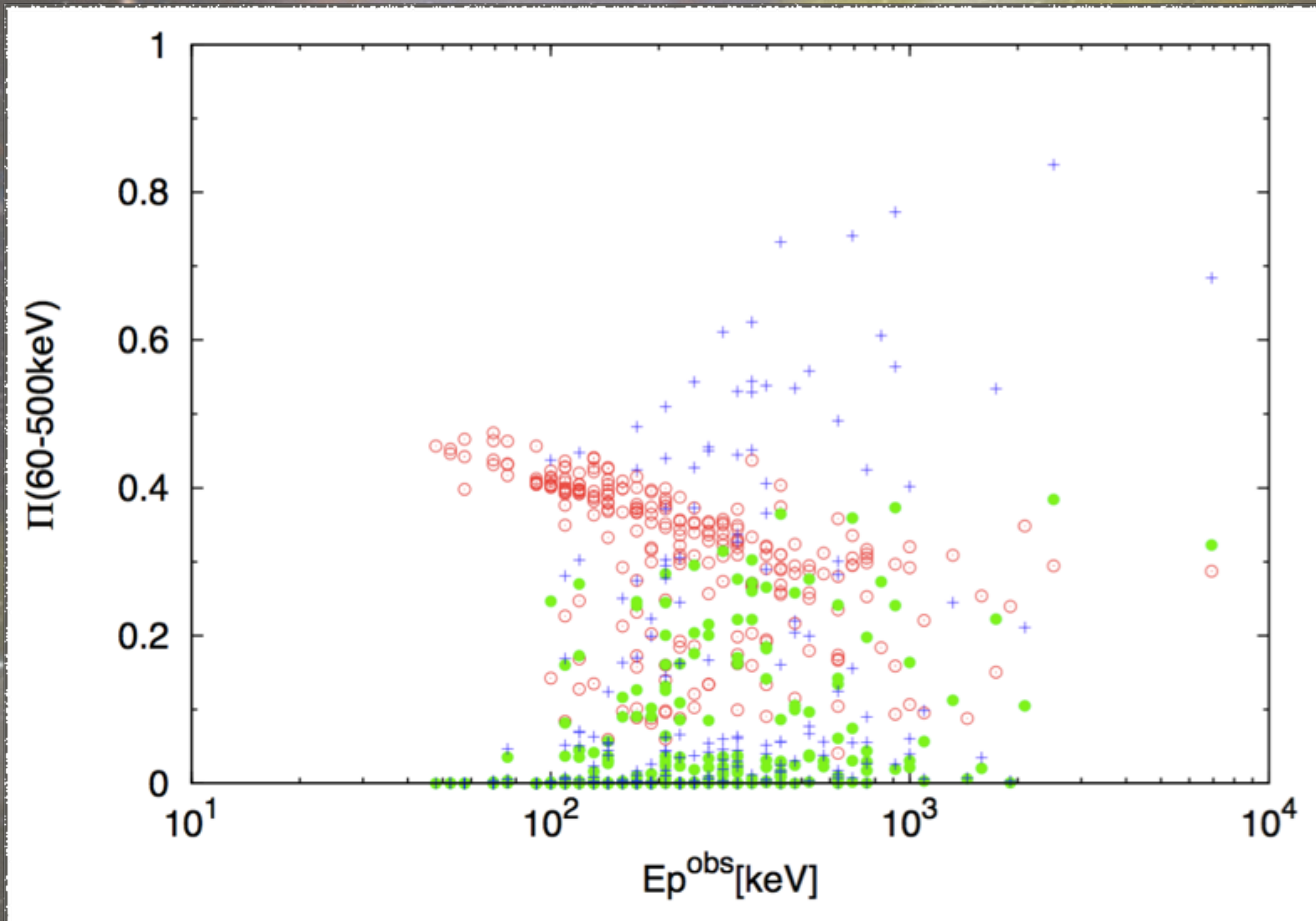


Figure 6. The ratio of the blackbody flux observed in 1 keV - 10 MeV and the total flux under the BB + Band model in the same energy range. The ratio is initially $\sim 5\%$ and increases to peak value of $\sim 25\%$.

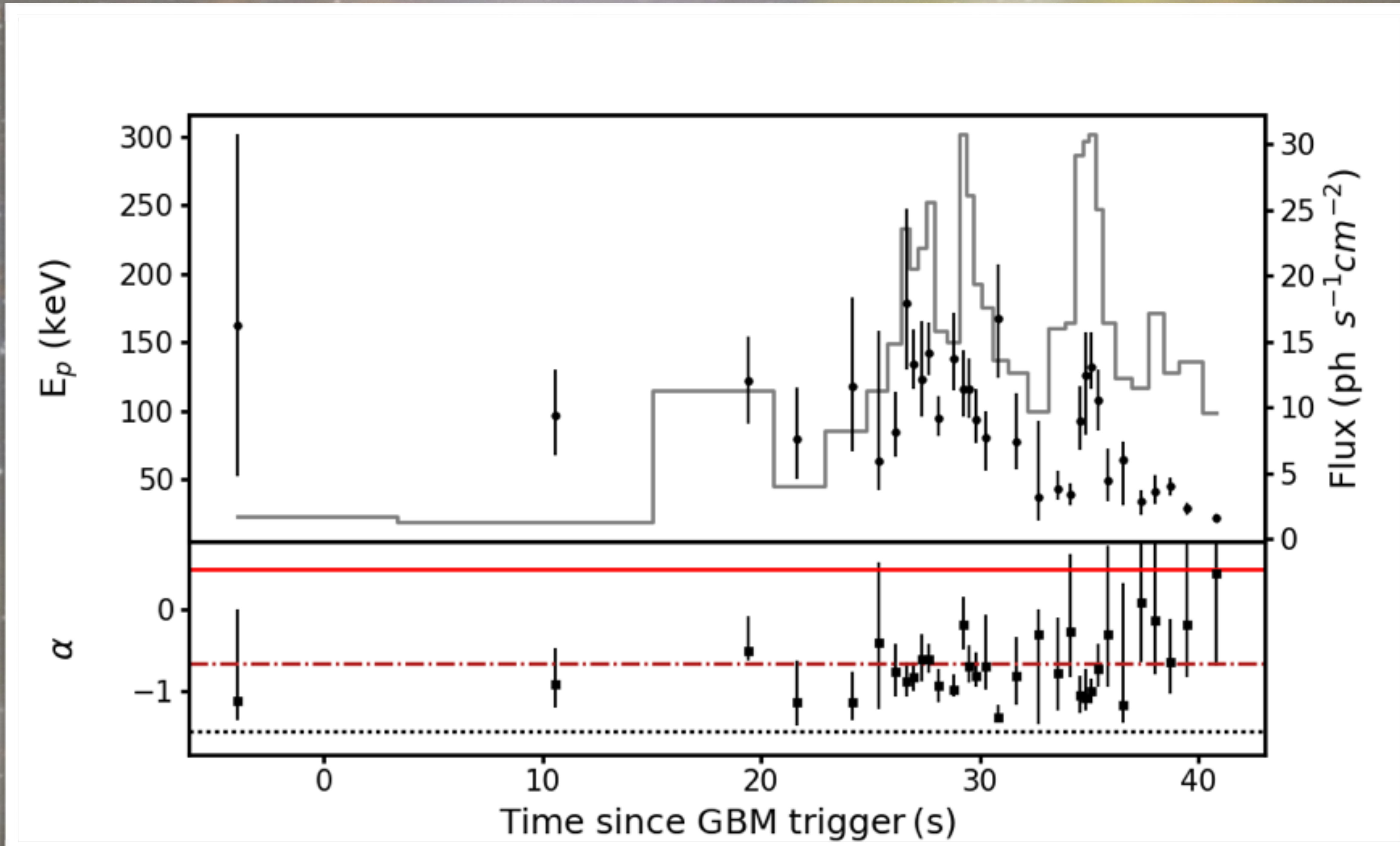
Bright Bursts: single pulse bursts



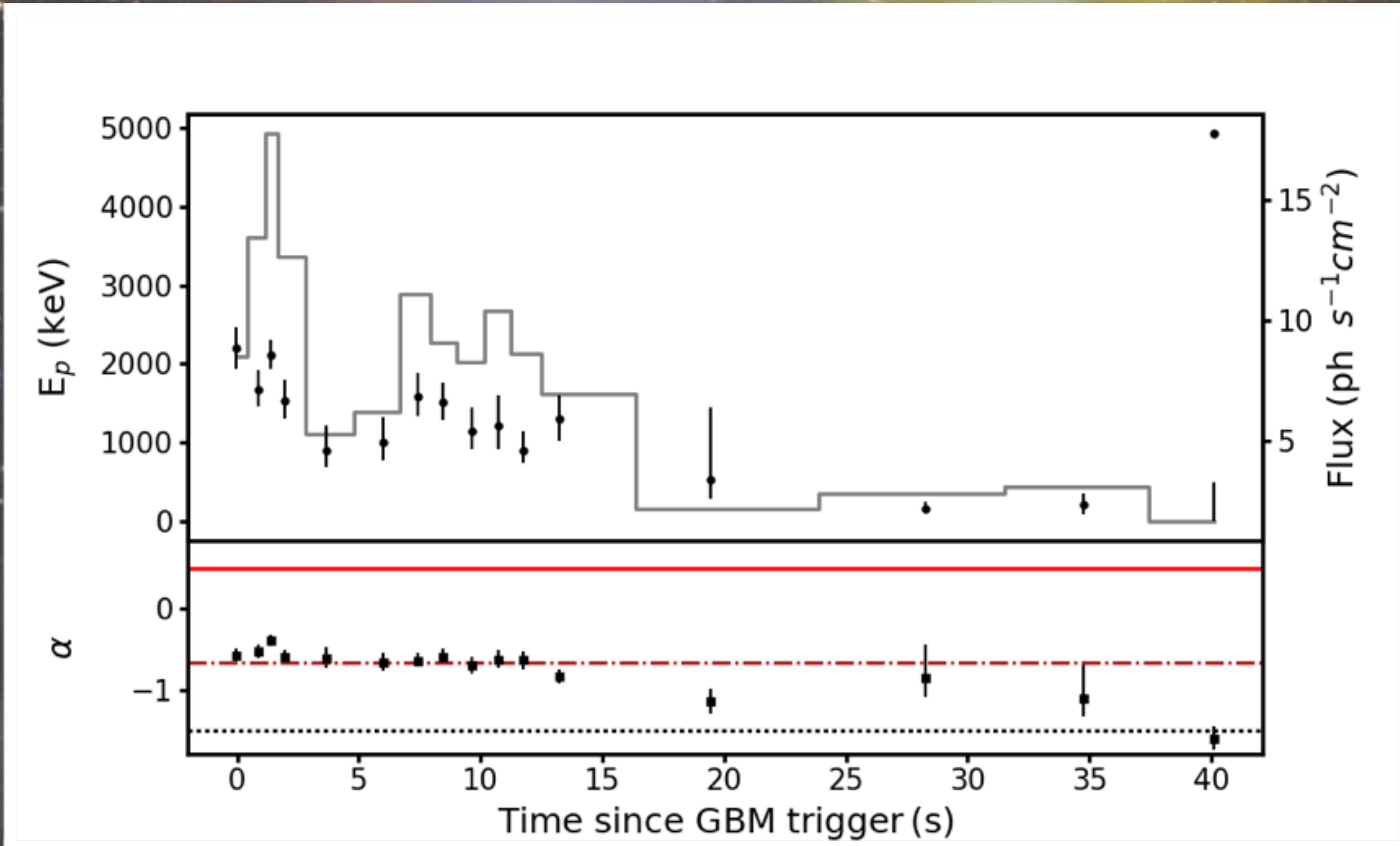
Extreme peaks (low and high Ep)



Bright Bursts: Fermi and Wind/Konus



Bright Bursts: Fermi and Wind/Konus




Questions ?
VHEPU, ICISE
Vietnam
14 Aug, 2018