Critical tests of γ-ray burst emission models

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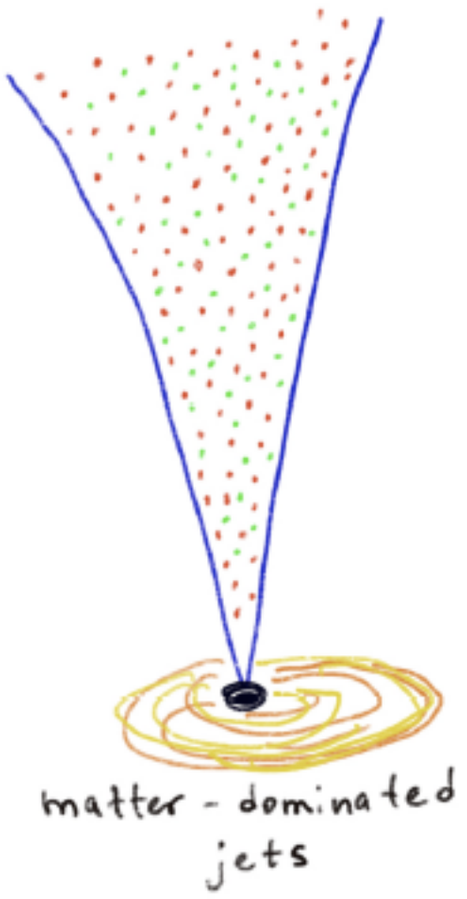
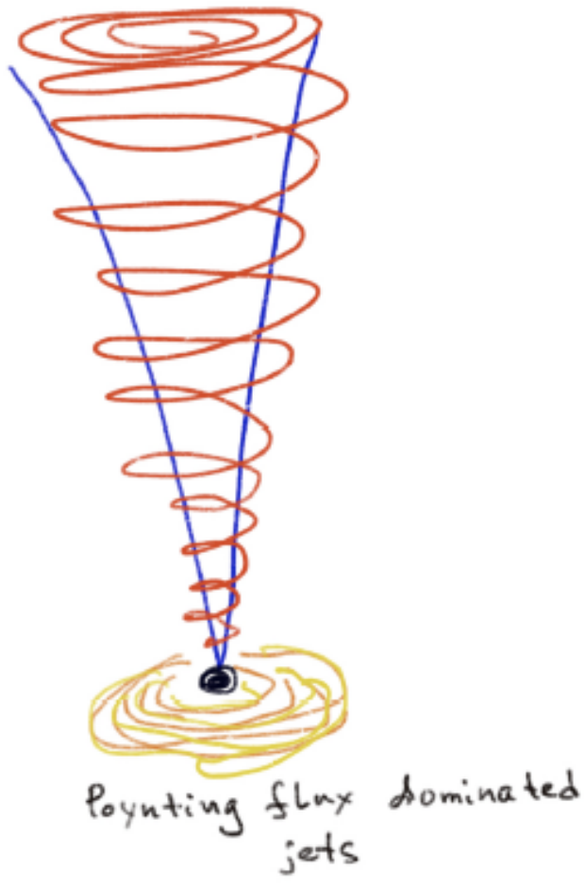
Ninth International Fermi Symposium

GRB prompt emission: open problems

jet composition



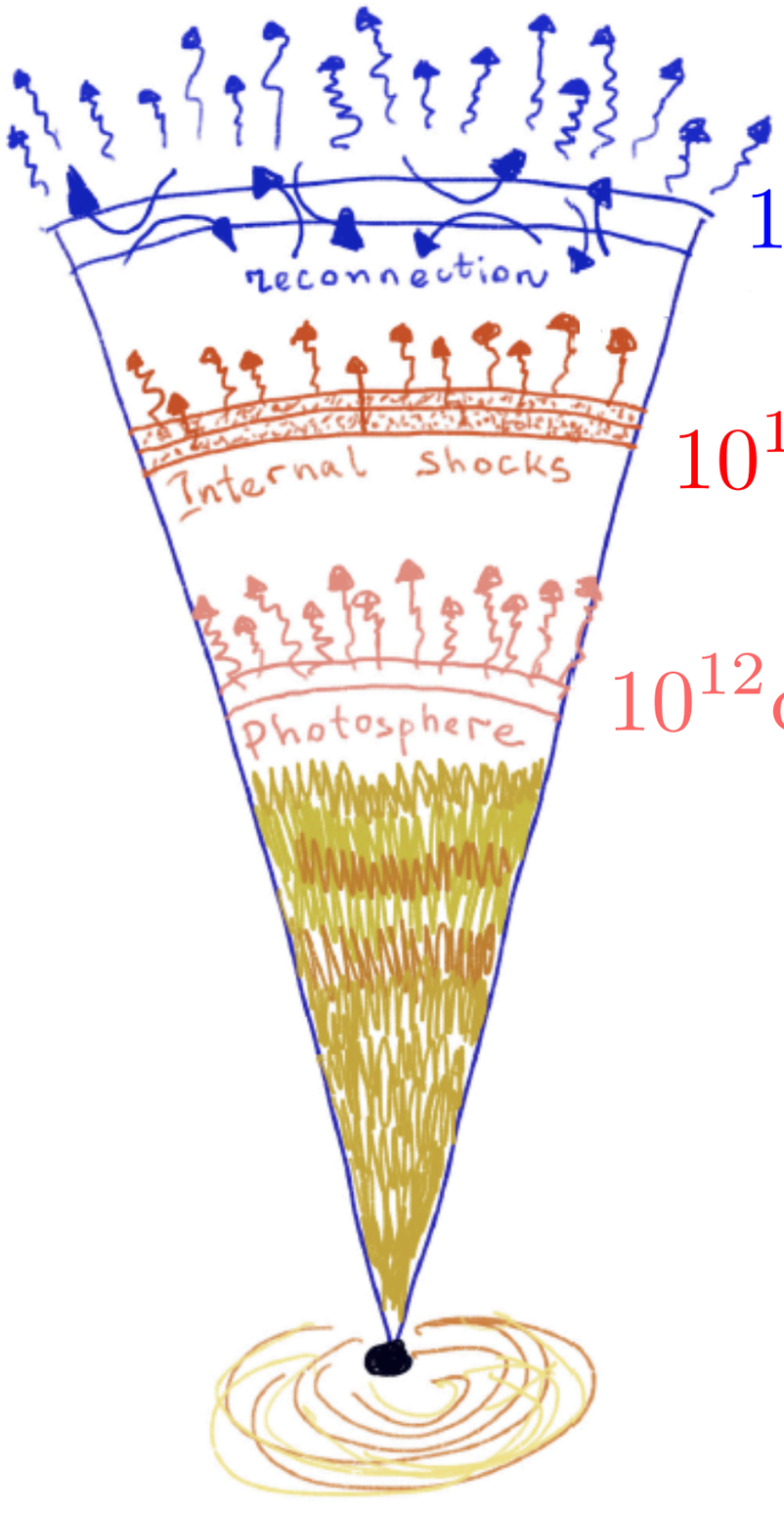
Cavallo & Rees 1978
Paczýnski 1986
Goodman 1986
Shemi & Piran 1990



Usov 1992
Thompson 1994
Mészáros & Rees 1997
Lyutikov & Blandford 2003

GRB prompt emission: open problems

dissipation and radiation mechanisms



10^{16}cm

10^{14}cm

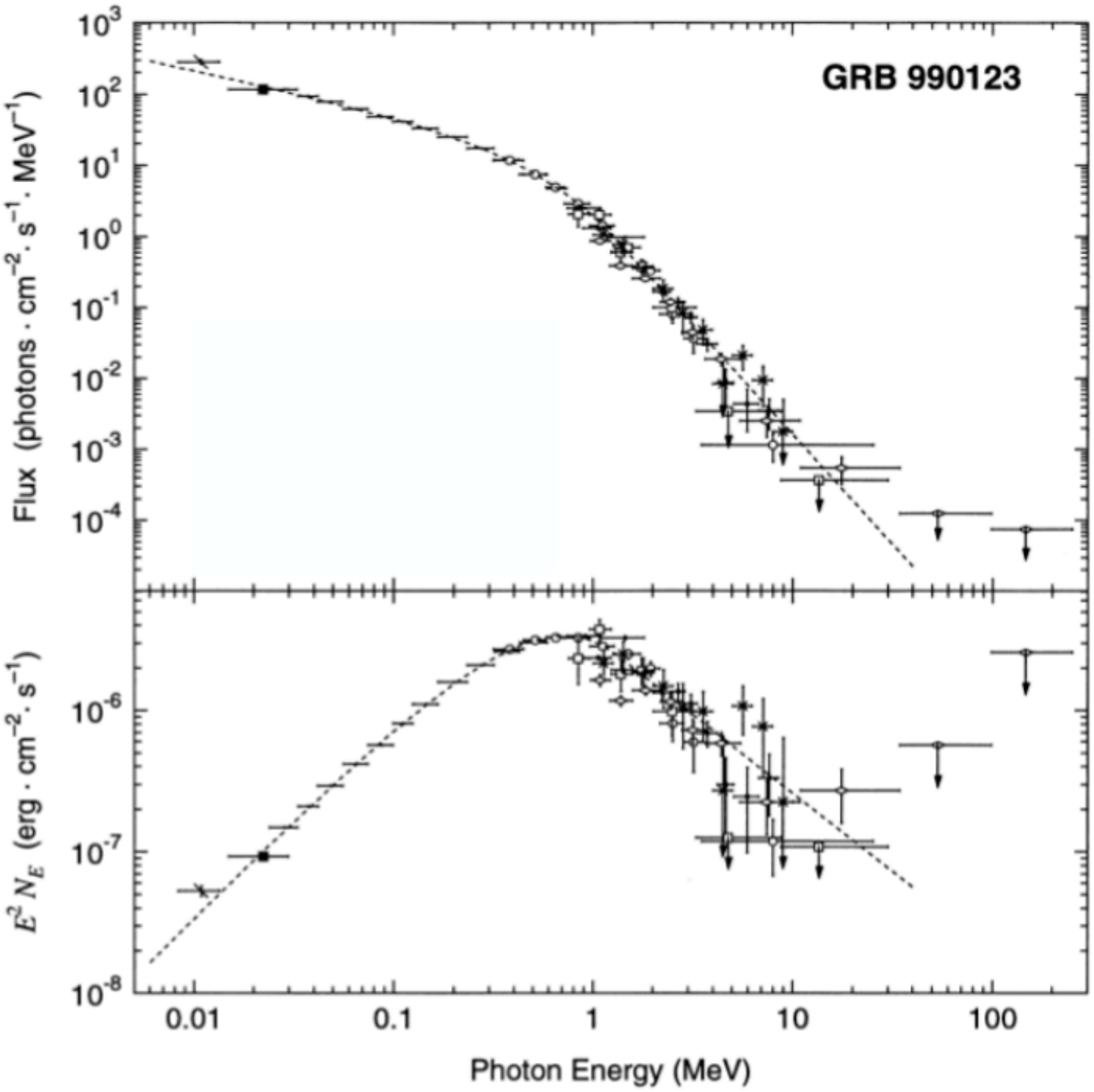
10^{12}cm

Drenkhahn & Spruit 2002,
Lyutikov & Blandford 2003,
Zhang & Yan 2011

Narayan et al. 1992, Rees & Mészáros 1994

Thomson 1994, Ghisellini & Celotti 1999,
Mészáros & Rees 2000, Pe'er et al. 2006

the mystery of the prompt emission spectra



Briggs et al. 1999

observed non-thermal spectra

what is it?

accelerated electrons
in
magnetic field

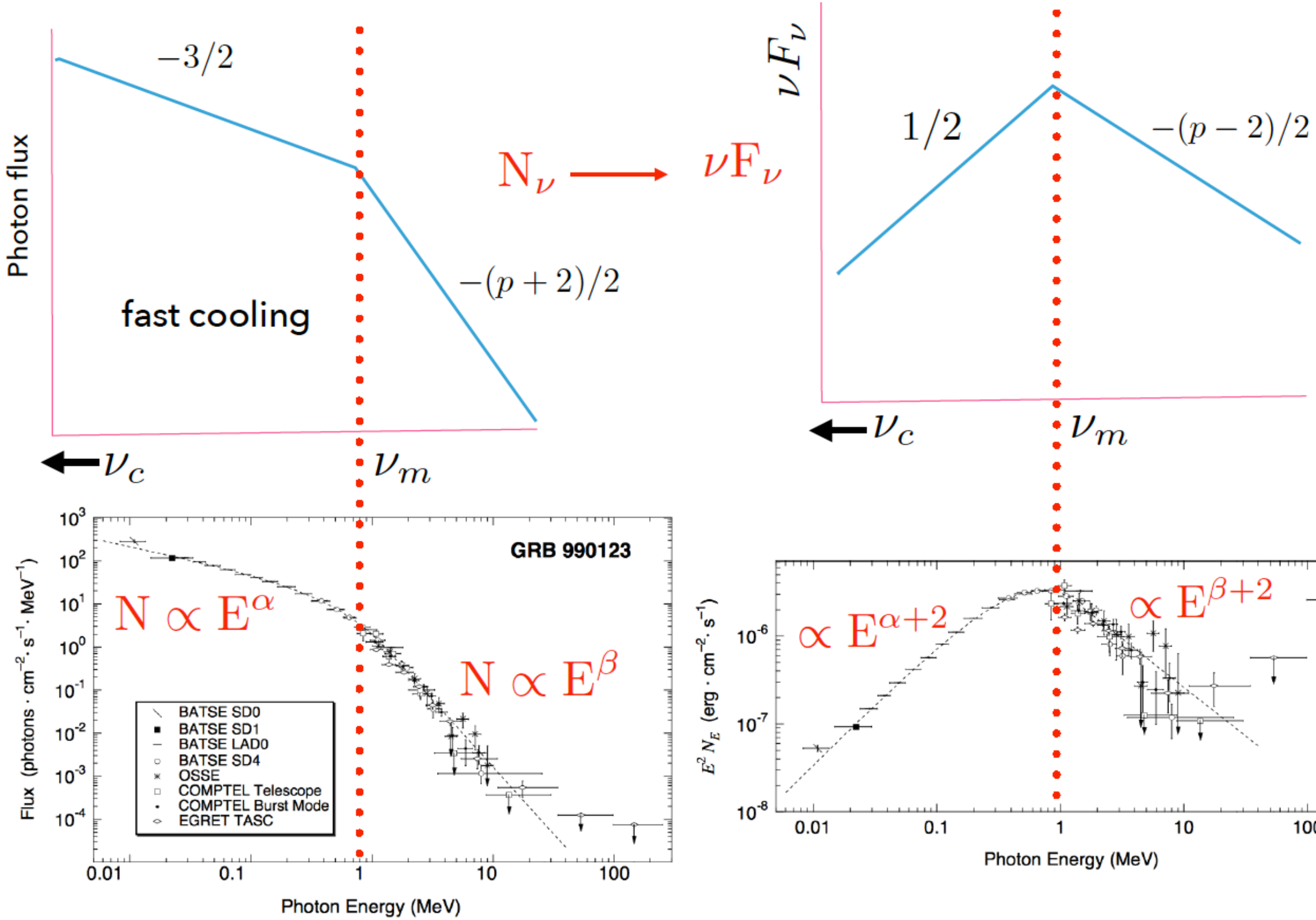
synchrotron?

Rees & Mészáros 1994
Sari et al. 1996, 1998

fast cooling regime

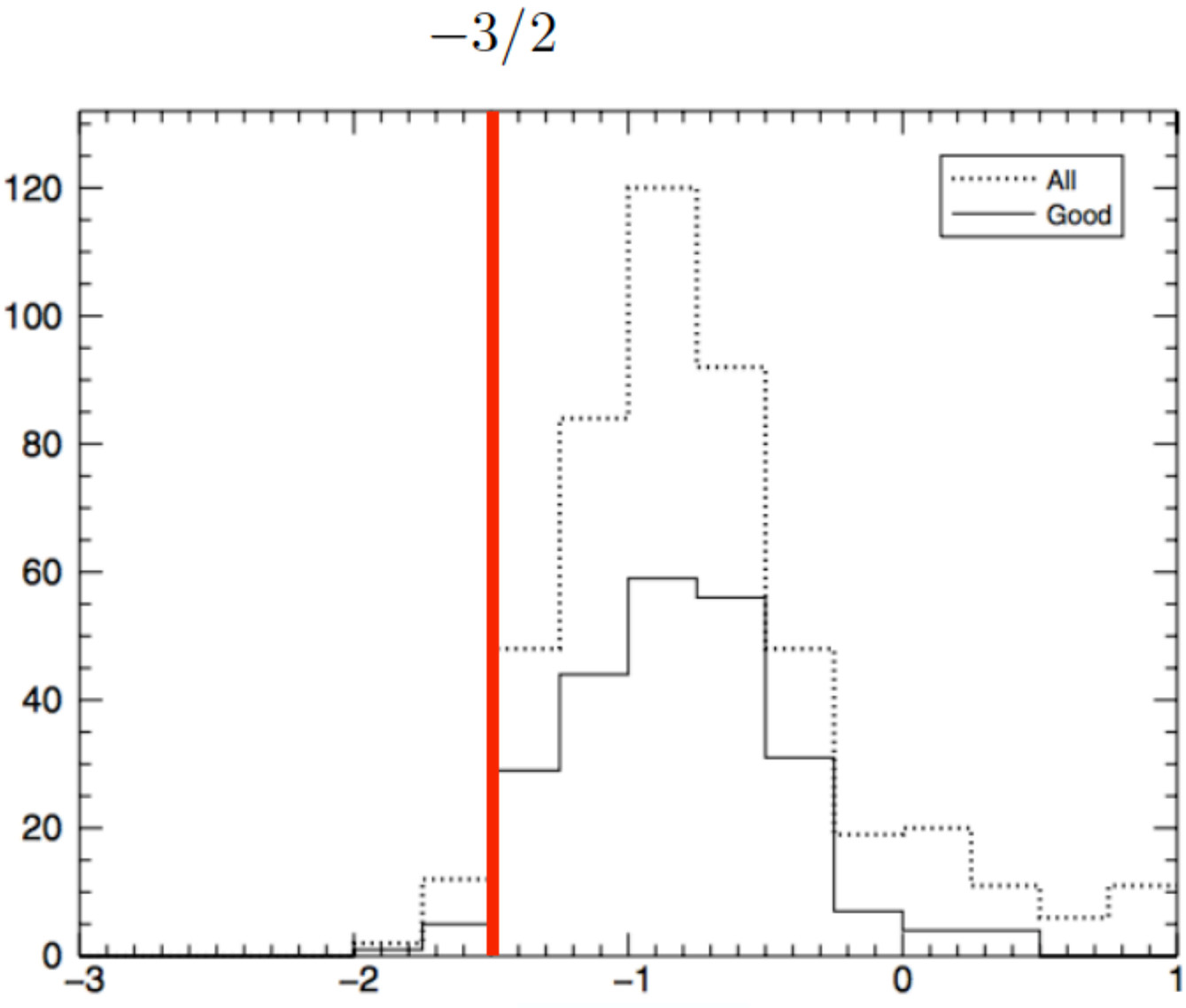
Preece et al. 1998
Ghisellini et al. 2000

the expectations



the reality

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



2nd Fermi catalog

$\alpha \sim -1$

Preece et al. 1998
Ghisellini et al. 2000
Frontera et al. 2000
Ghirlanda et al. 2002
Kaneko et al. 2006
Nava et al. 2011

Solutions [synchrotron based]

prevent electrons from fast cooling via synchrotron [marginally fast cooling]

Kumar & McMahon 2008, Daigne 2011, Beniamini & Piran 2013

how?

- decay of the magnetic field within the emitting region

  Pe'er & Zhang 2006, Derishev 2007, Zhao 2014 + more

- continuous acceleration/heating/re-acceleration

  Asano & Terasawa 2009, Xu et al. 2018, Beniamini et al. 2018

electrons cool via IC in KN regime

Derishev et al. 2001, Nakar et al. 2009, Daigne et al. 2011

self-absorption/anisotropy of electrons' pitch angles

Lloyd & Petrosian 2000, Medvedev 2000

synchrotron self-Compton model

Piran et al. 2009 for the criticism

Solutions [alternatives]

photospheric models

Thompson 1994, Liang et al. 1997, Ghisellini & Celotti 1999, Meszaros & Rees 2000, +

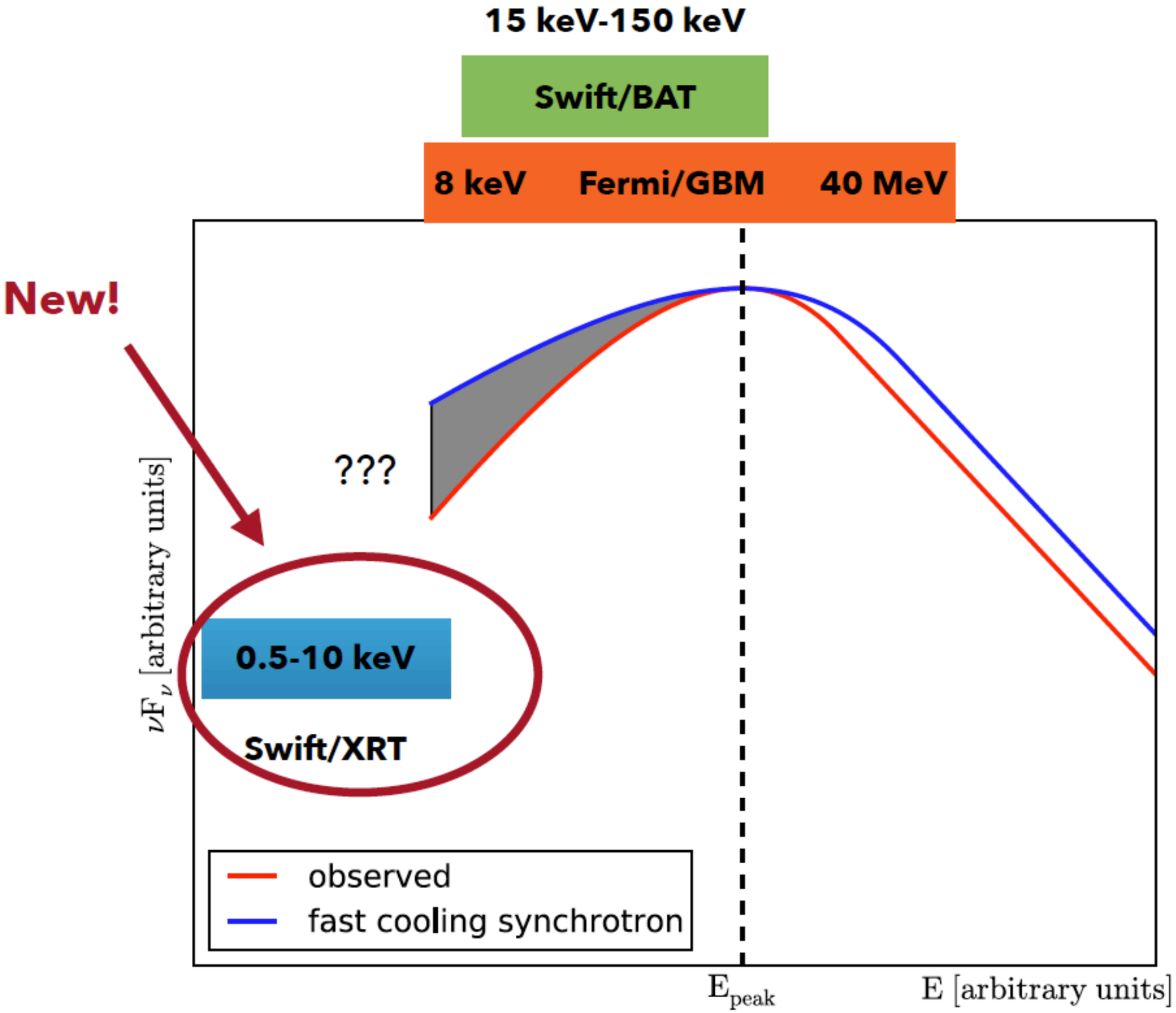
+

many claims of the BB components in the prompt emission spectra

Ryde & Pe’er 2009, Guiriec 2011, Ghirlanda et al. 2013 +

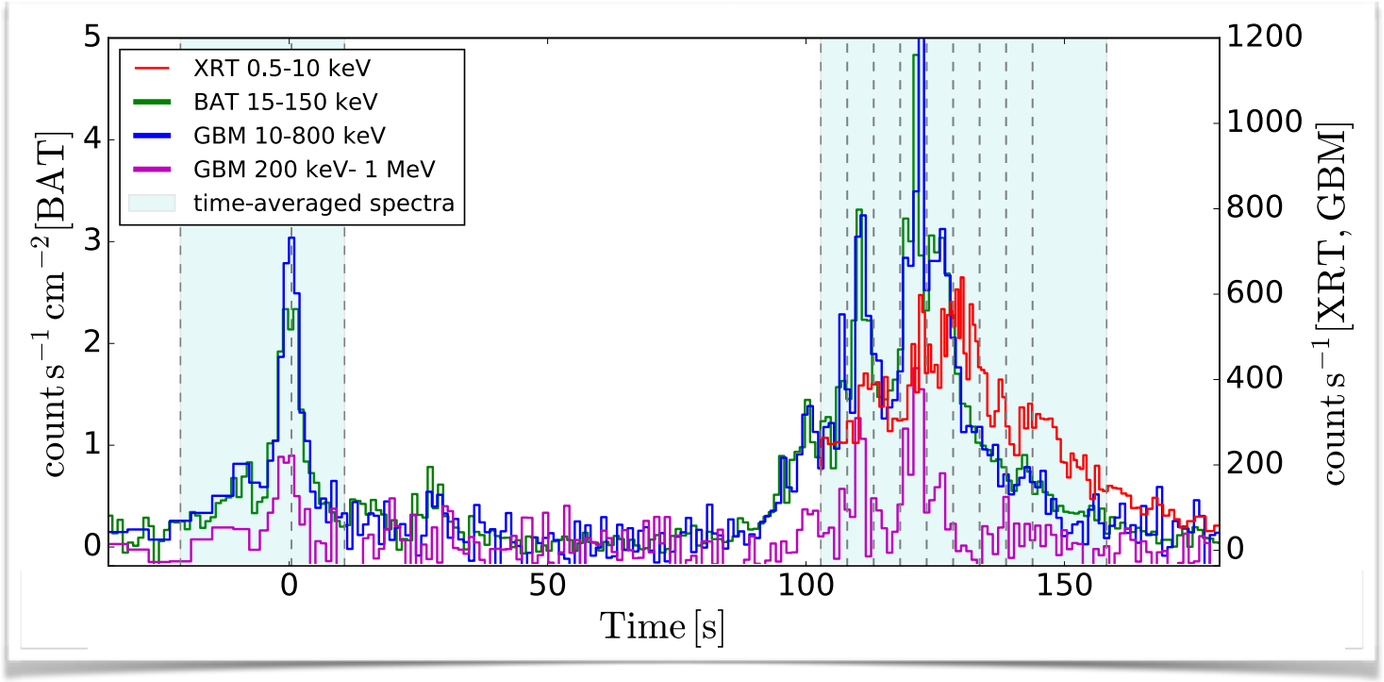
too many options! what can we do?

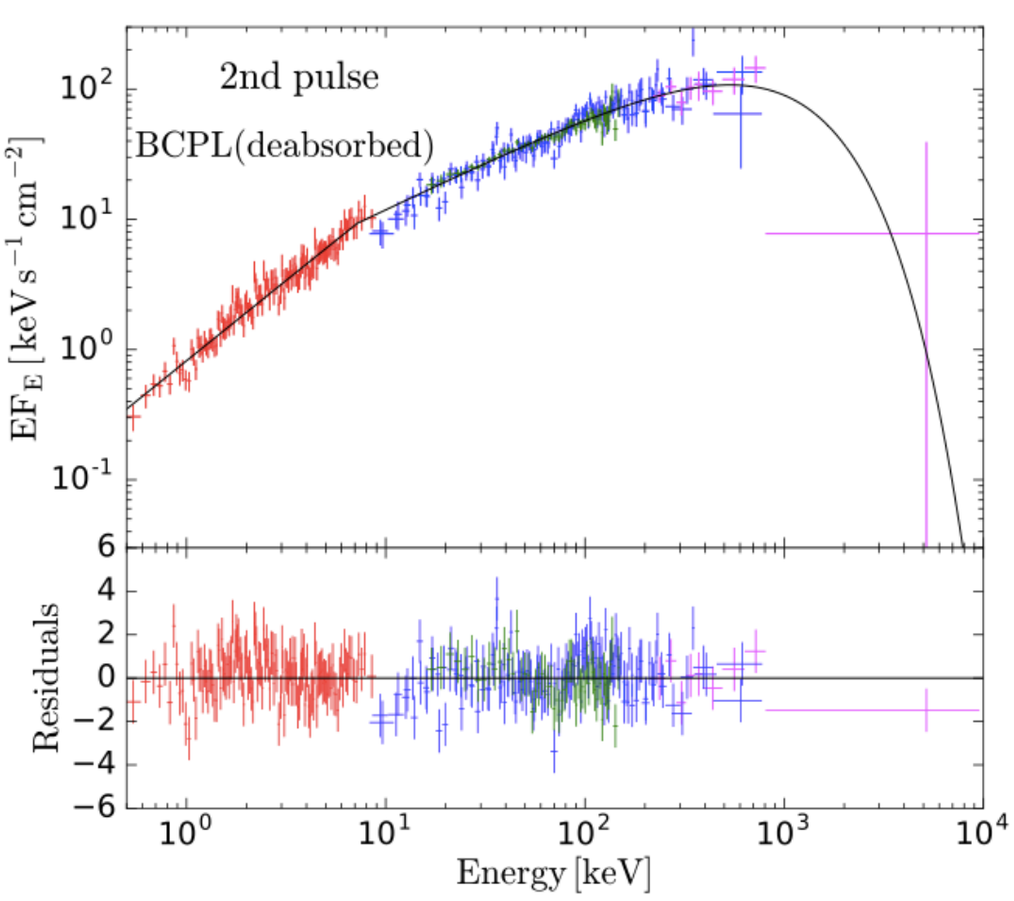
Low-energy look at the problem

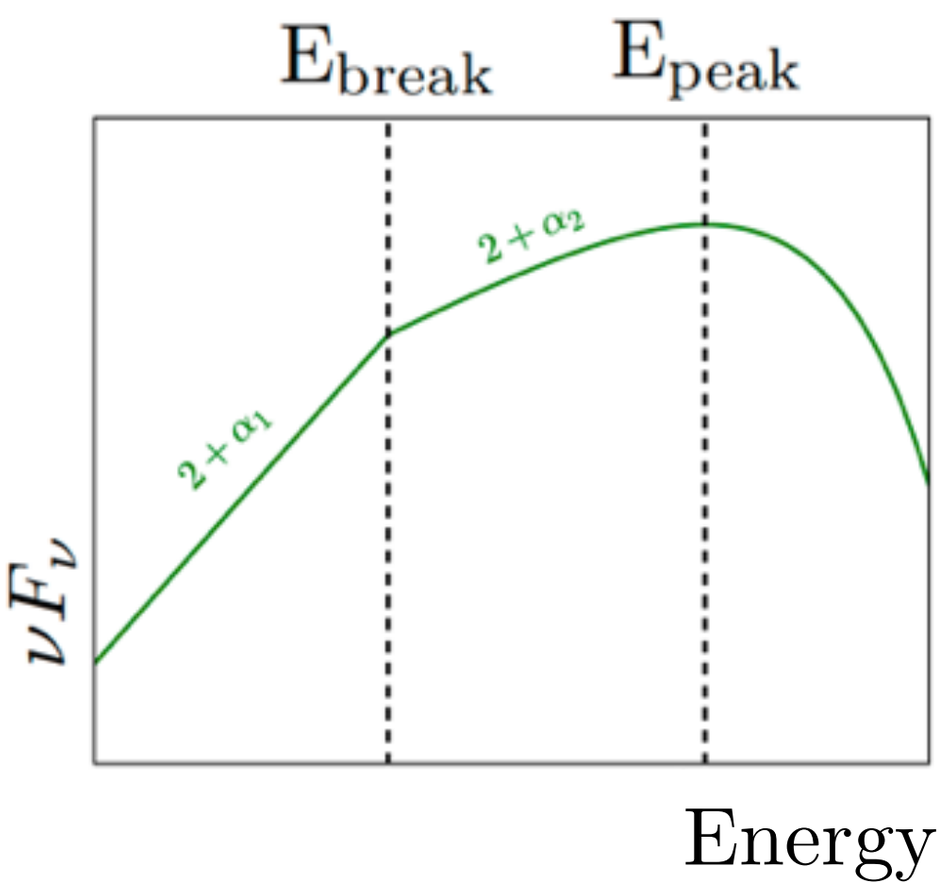


Oganesyan et al. 2017,2018

Low-energy look at the problem

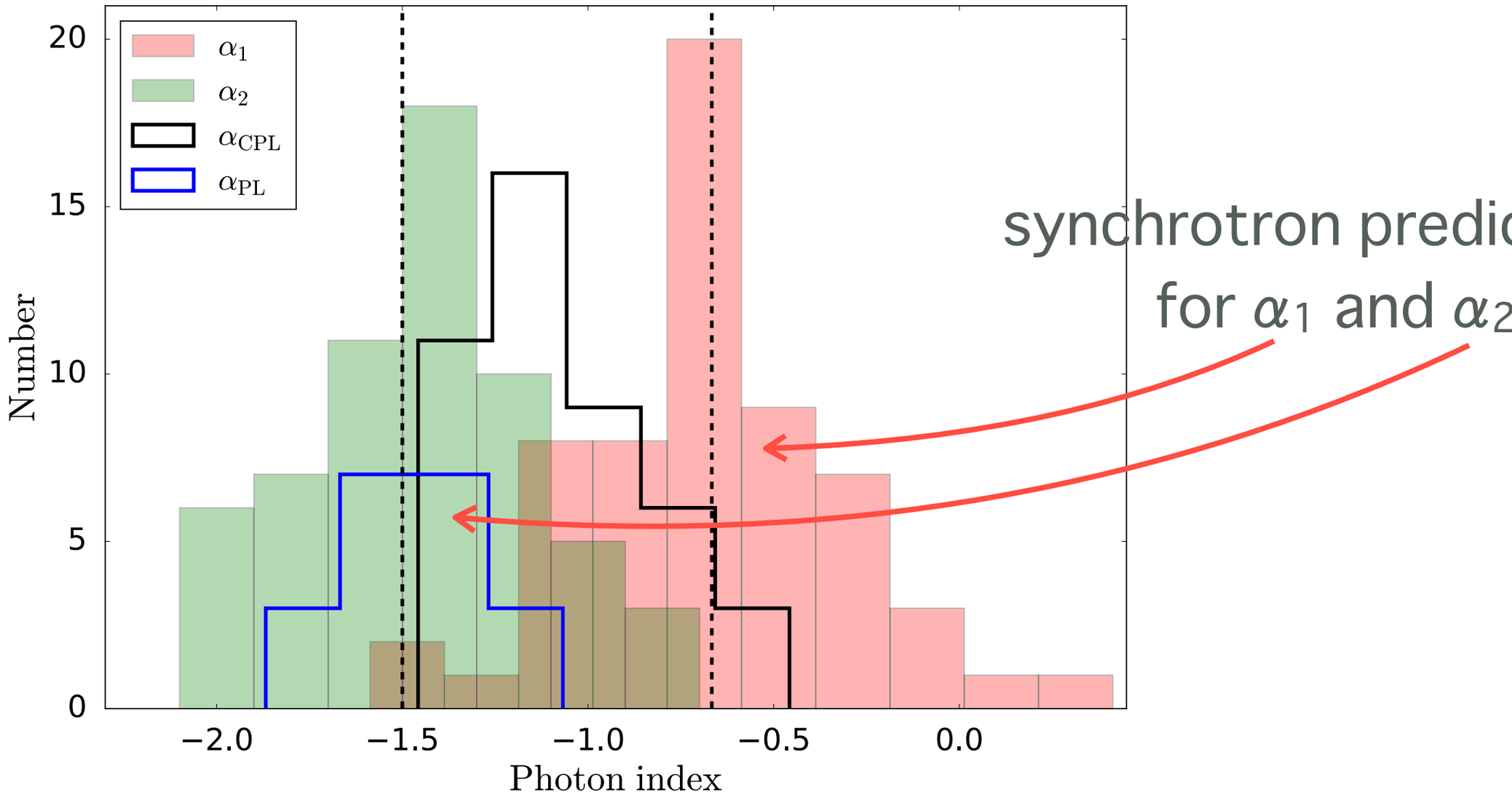






Low-energy look at the problem

synchrotron origin is suggested from the empirical fits



synchrotron predictions for α_1 and α_2

Oganesyan et al. 2017,2018

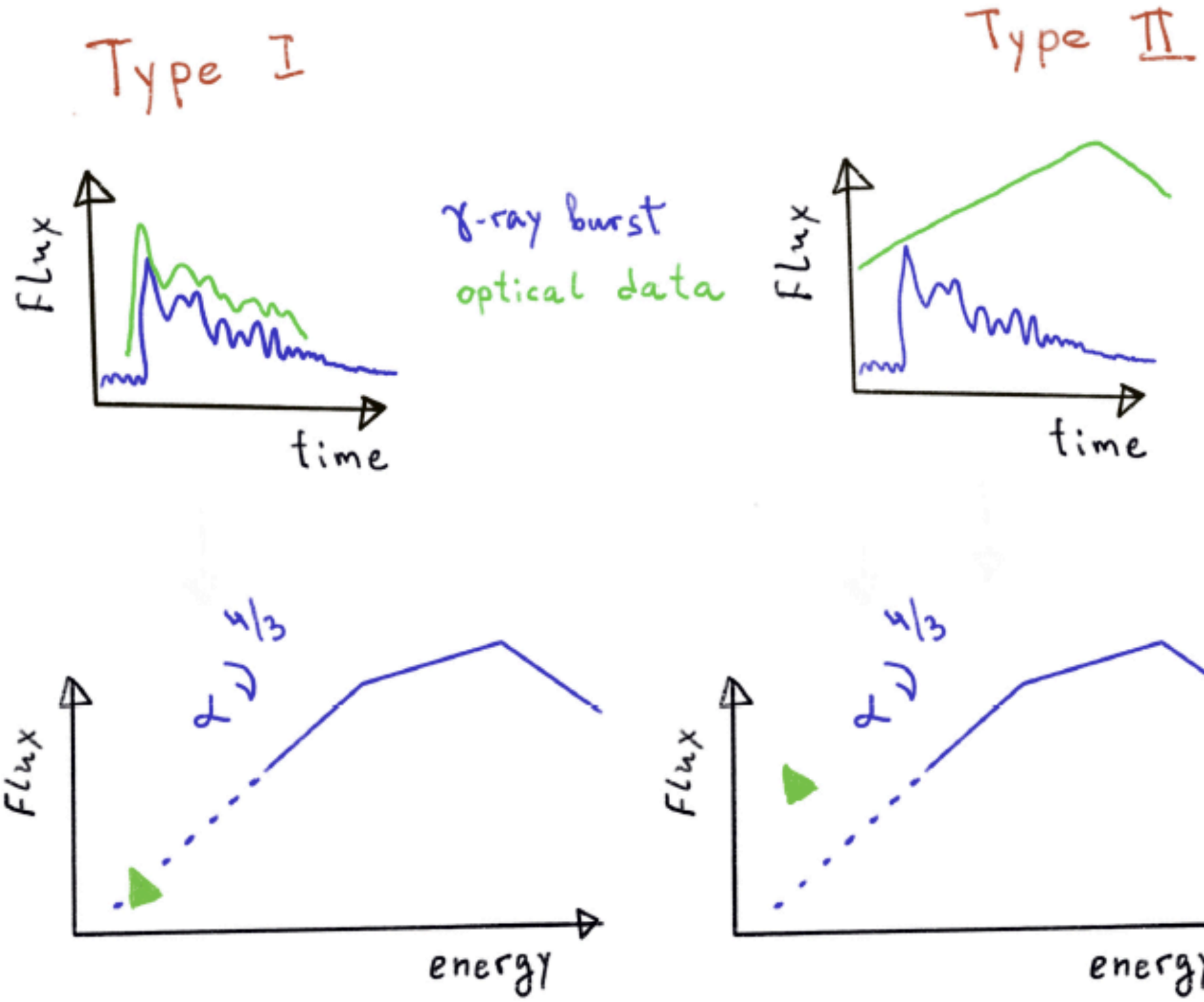
Another strategy

PHYSICAL MODELLING
[synchrotron radiation]

+

CRITICAL TEST BY OPTICAL DATA

Optical Emission



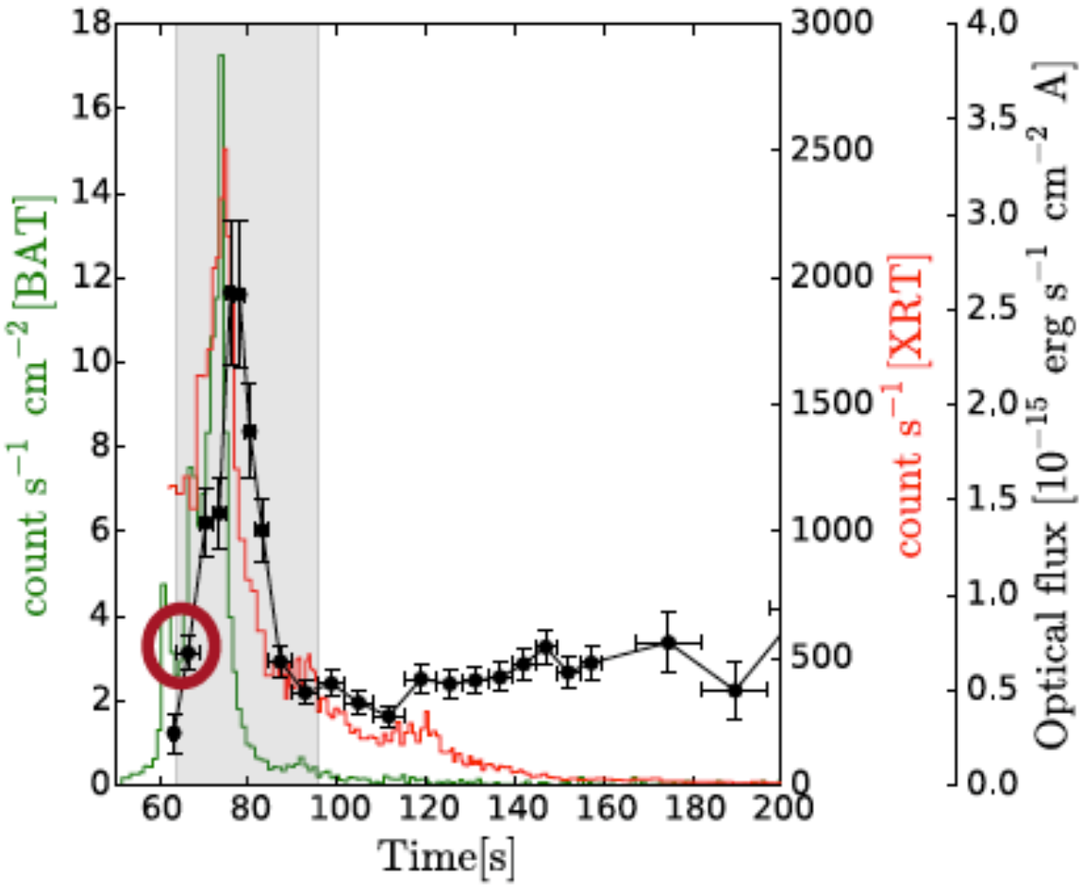
Oganesyan et al. 2019

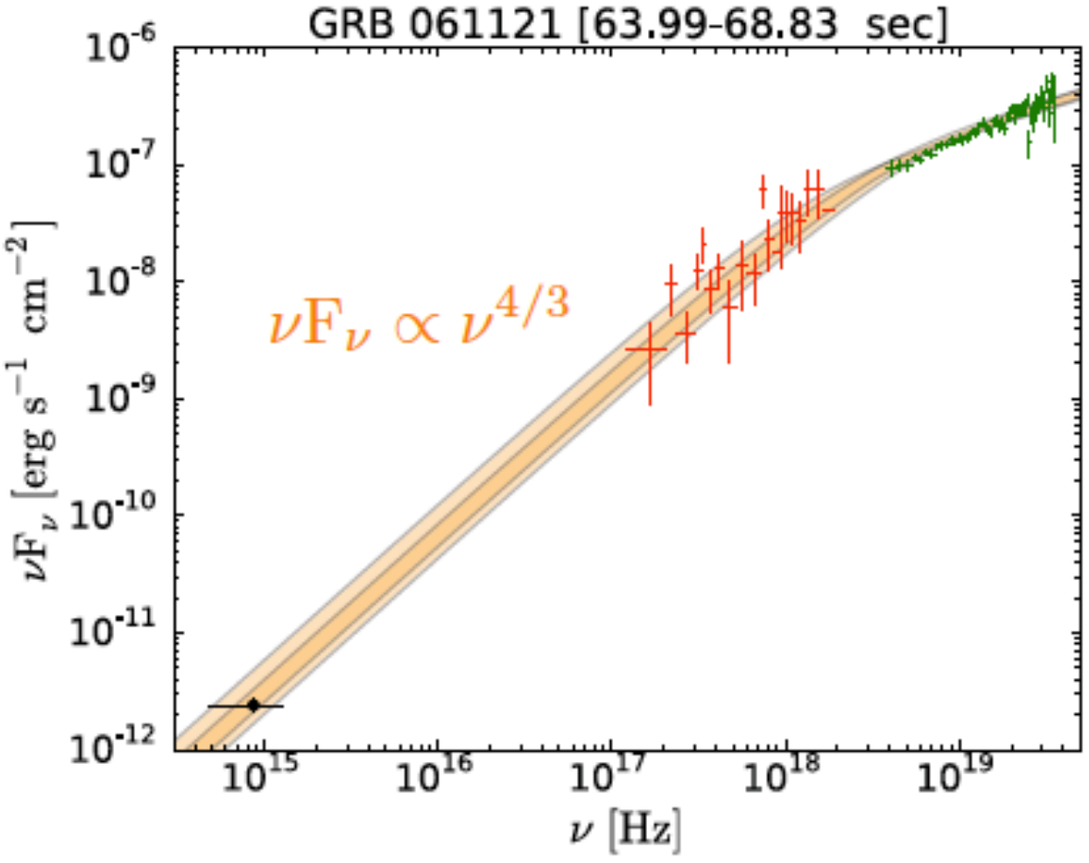
Optical observations during the prompt phase

RESULTS - SYNCHROTRON MODEL

Case I (3 GRBs, 26 spectra)

TEMPORAL BEHAVIOUR OF OPTICAL EMISSION IS CORRELATED WITH PROMPT





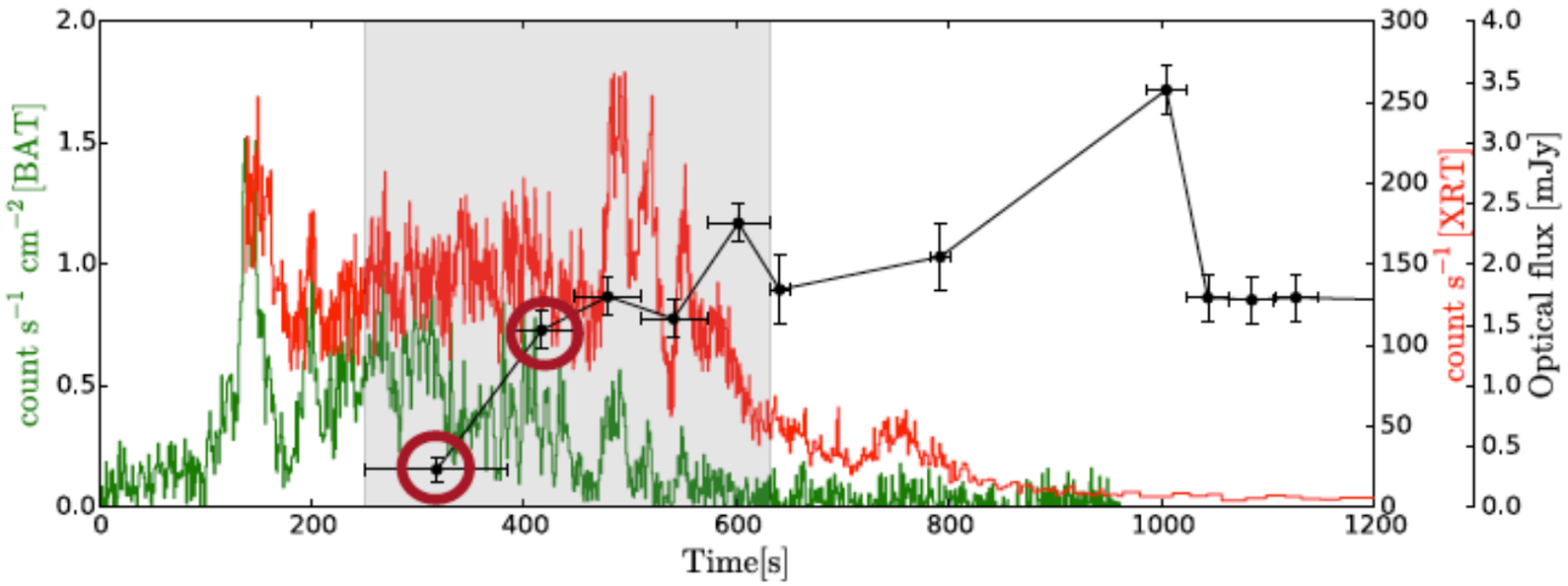
Oganesyan et al. 2019

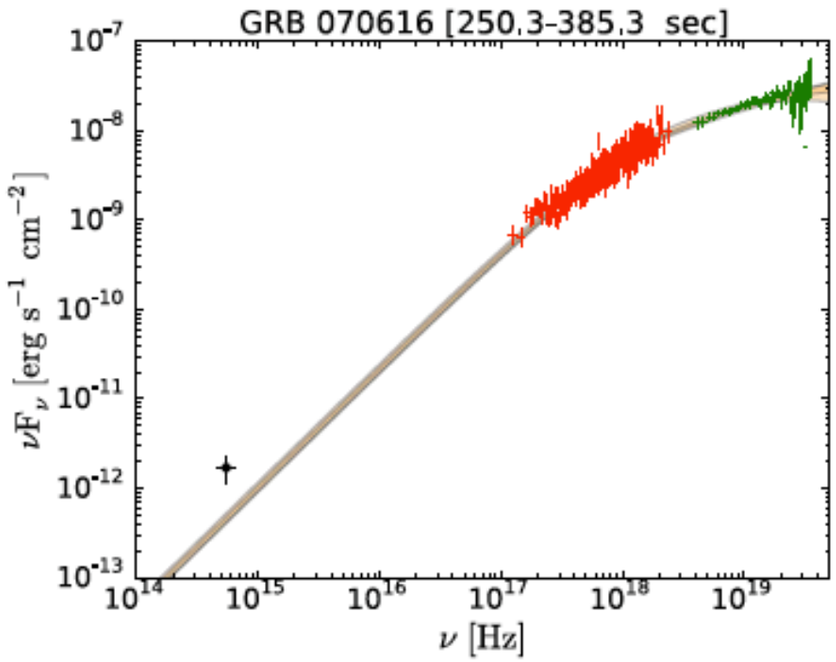
Optical observations during the prompt phase

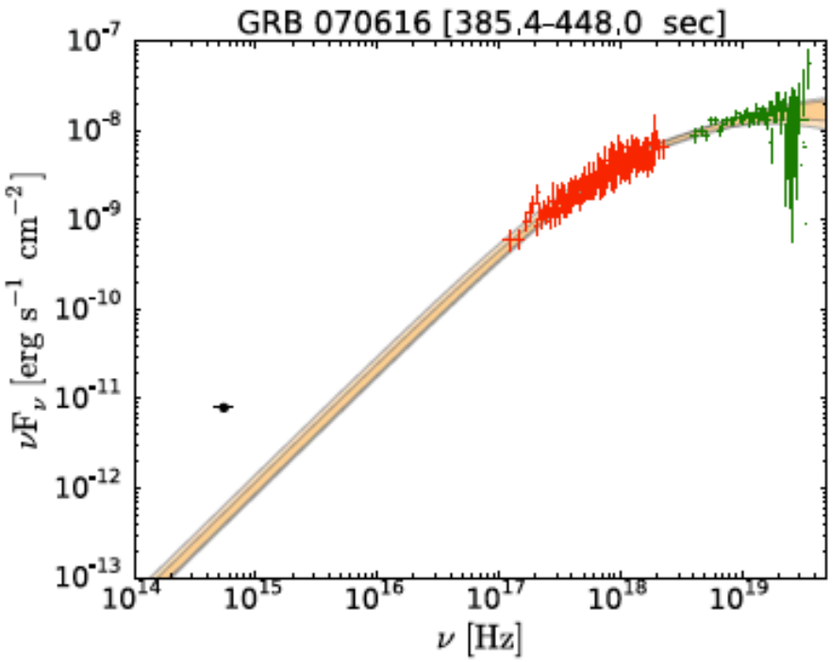
RESULTS - SYNCHROTRON MODEL

Case II (4 GRBs, 11 spectra)

TEMPORAL BEHAVIOUR OF OPTICAL EMISSION IS NOT CORRELATED WITH PROMPT







Oganesyan et al. 2019

What we have learnt

- **There is a low-energy break in the GRB spectra**

- **The break could be the synchrotron cooling frequency**
  Oganesyan et al. 2017,2018; Ravasio et al. 2018,2019

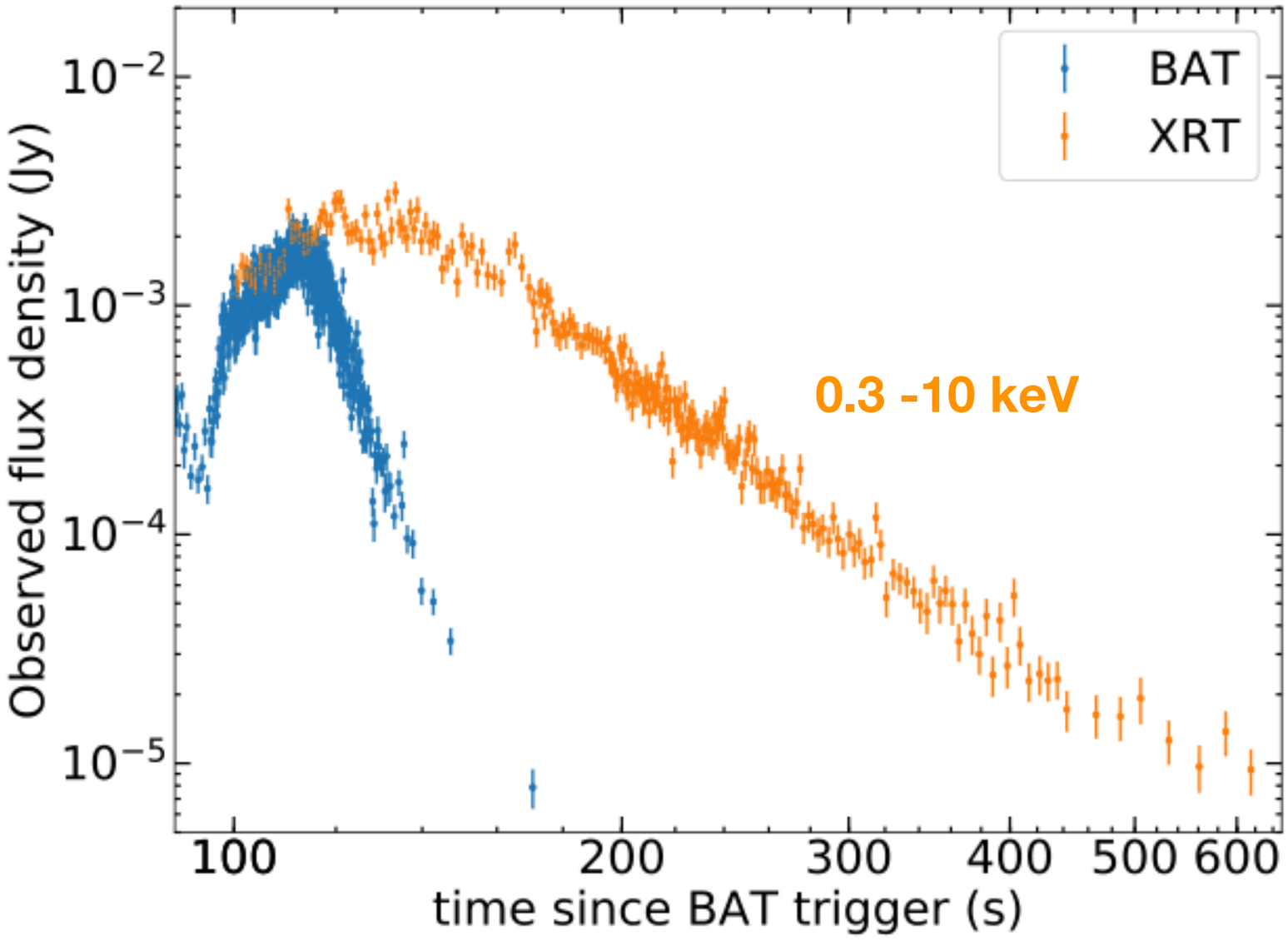
- **Synchrotron model fits the (considered) data**
  Oganesyan et al. 2019; Burgess et al. 2020

see B. Zhang 2020, Nature Astronomy, for a brief discussion

Models that could work

- re-acceleration/heating of electrons
  Kumar & McMahon 2008; Asano & Terasawa 2009; Beniamini & Piran 2014; Beniamini et al. 2018;
- noticeable decay of the magnetic field
  Pe'er & Zhang 2006; Derishev 2007; Zhao et al. 2014; Uhm & Zhang 2014; Zhang et al. 2016
- ICMART
  Zhang & Yan 2011
- proton synchrotron model
  Ghisellini et al. 2020

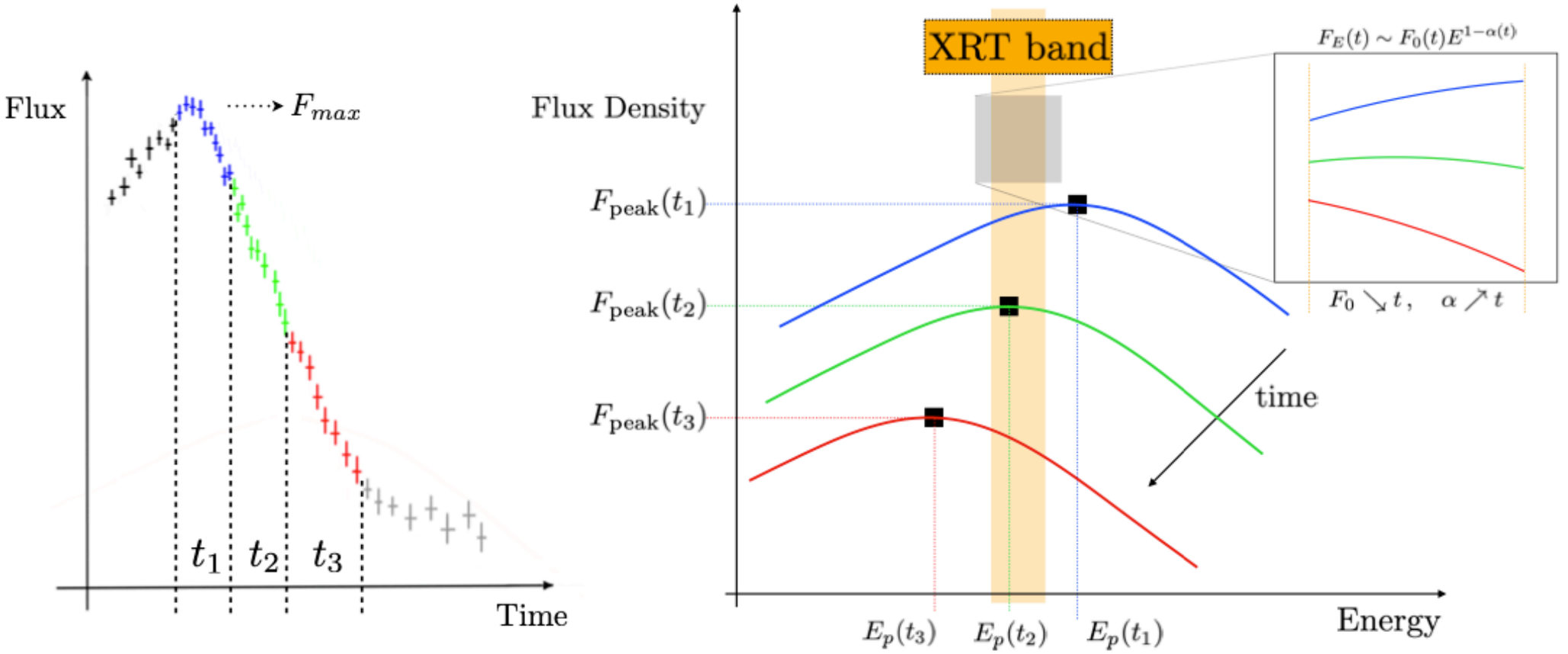
X-ray steep decay as diagnostics of the GRB emission side



Ronchini, Oganesyan, Branchesi et al. 2020 ⟶ **see the poster!**

X-ray steep decay as diagnostics of the GRB emission side

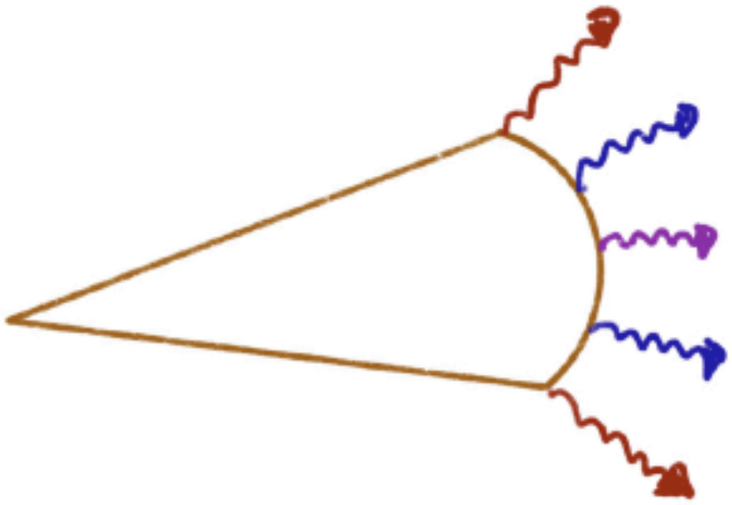
0.3 -10 keV

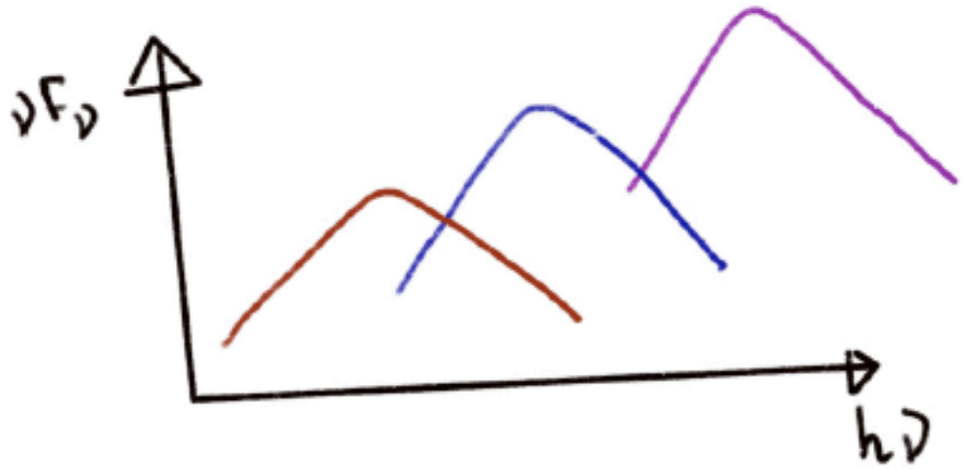


Ronchini, Oganesyan, Branchesi et al. 2020 ⟶ **see the poster!**

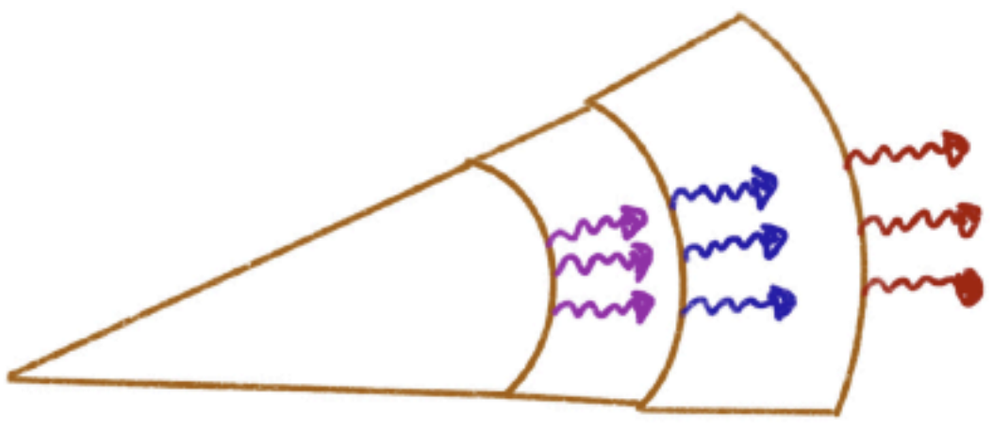
X-ray steep decay as diagnostics of the GRB emission side

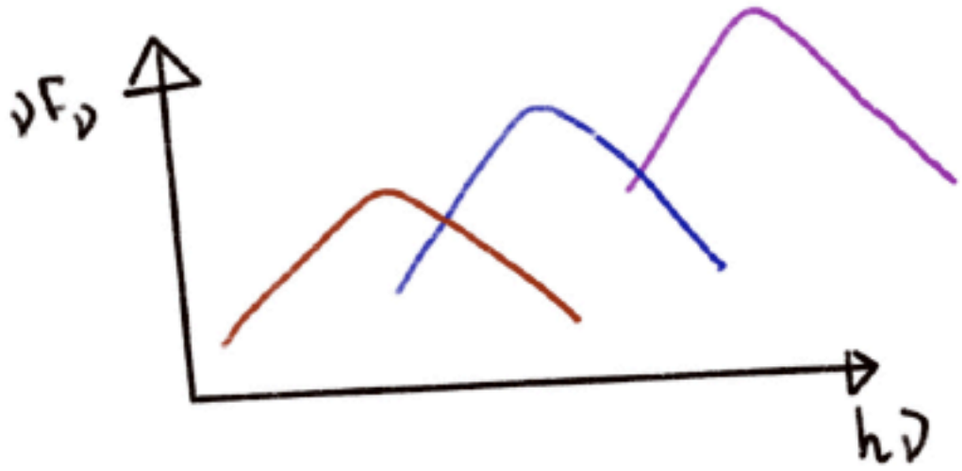
Efficient cooling —> we observe the high latitude emission





Inefficient cooling —> we observe the adiabatic cooling





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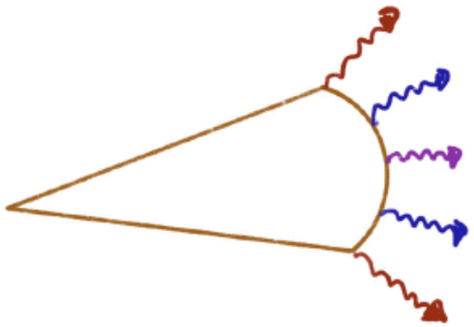

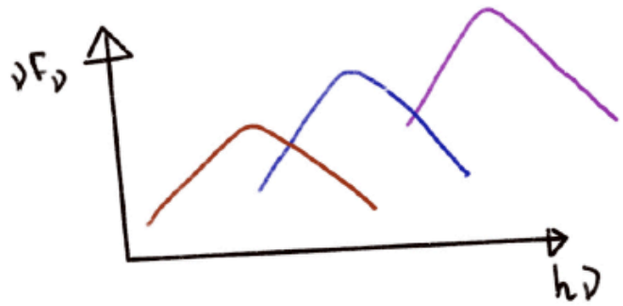

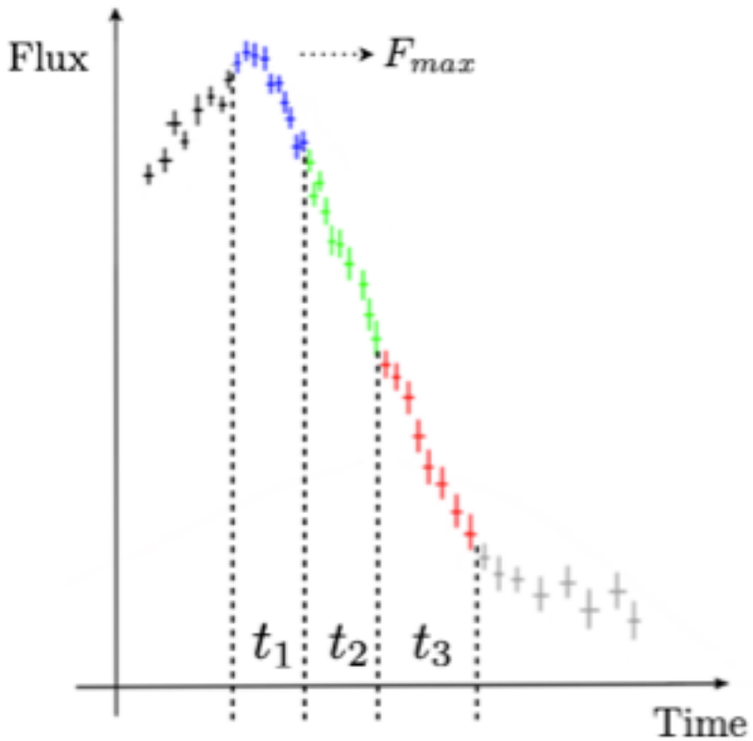

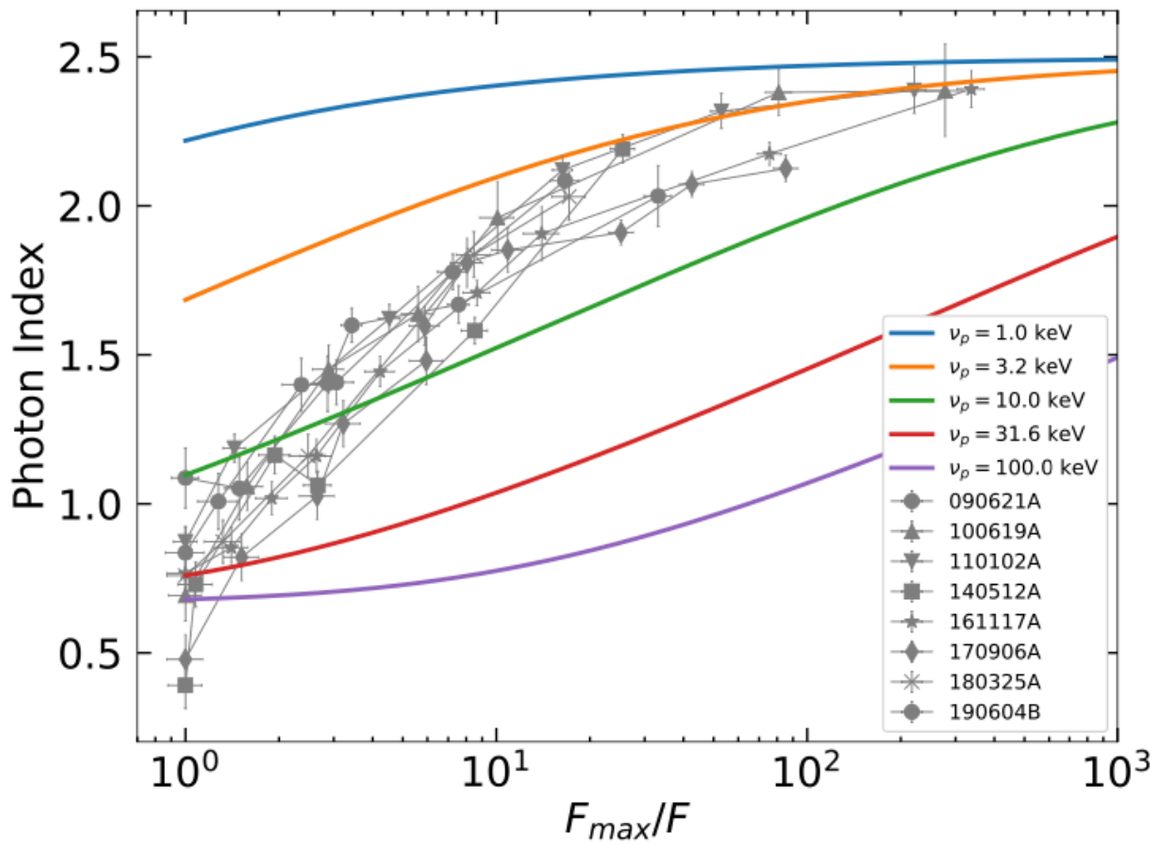

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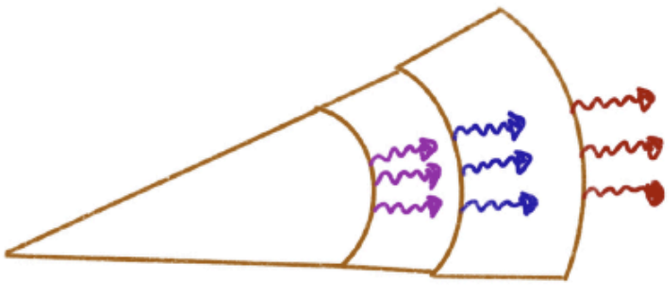

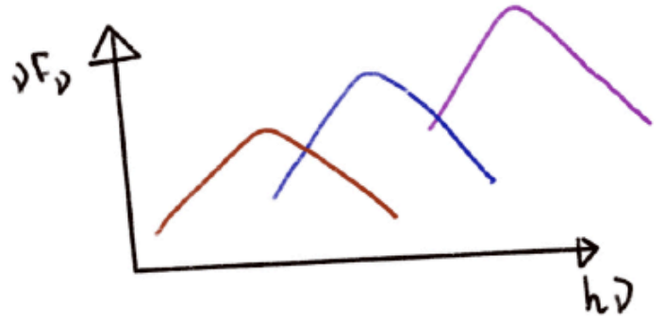

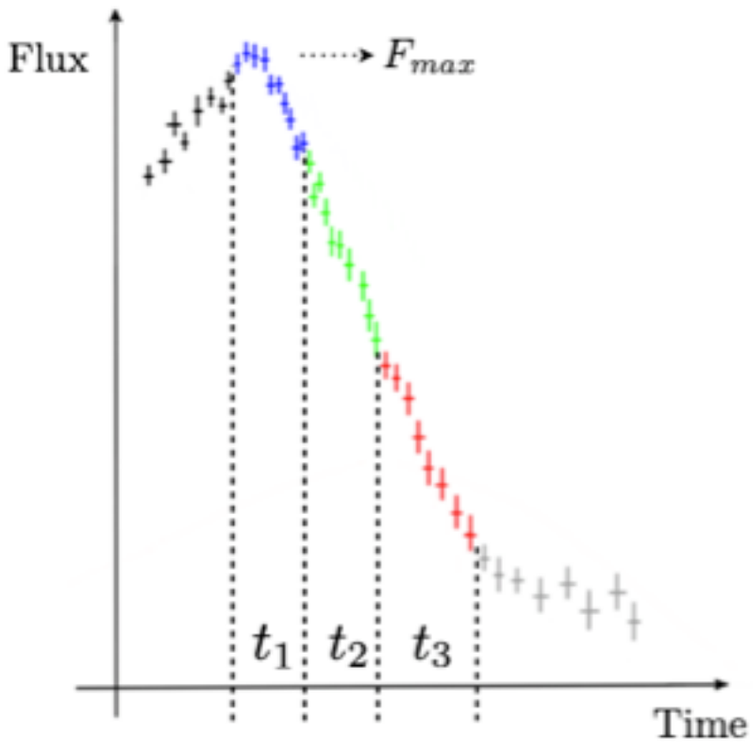

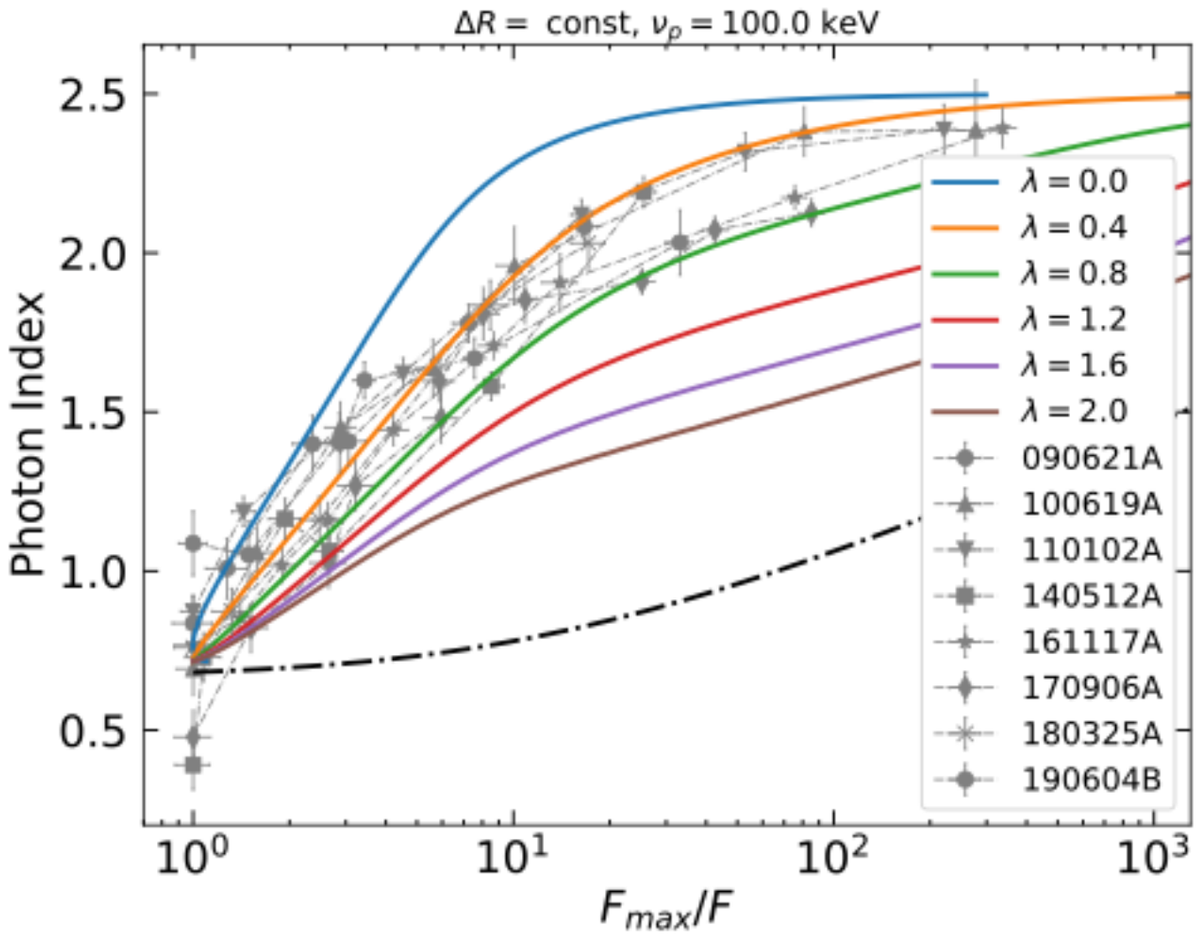

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