Open questions in GRBs: the role of X-ray observations

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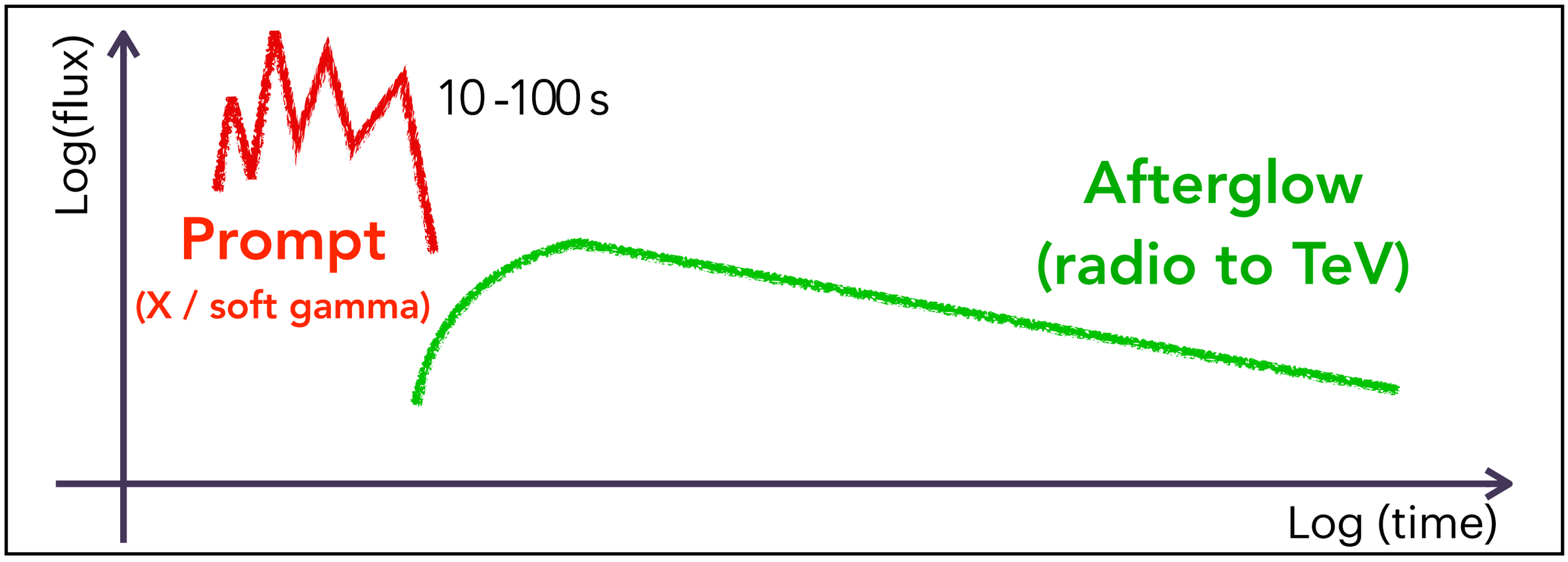
EMISSION FROM GRBS: AN OVERVIEW

TWO DISTINCT EMISSION PHASES



PROMPT

- from 10 keV to 10 MeV
- non-thermal spectra
- 0.1 seconds to 10^3 seconds
- highly variable flux

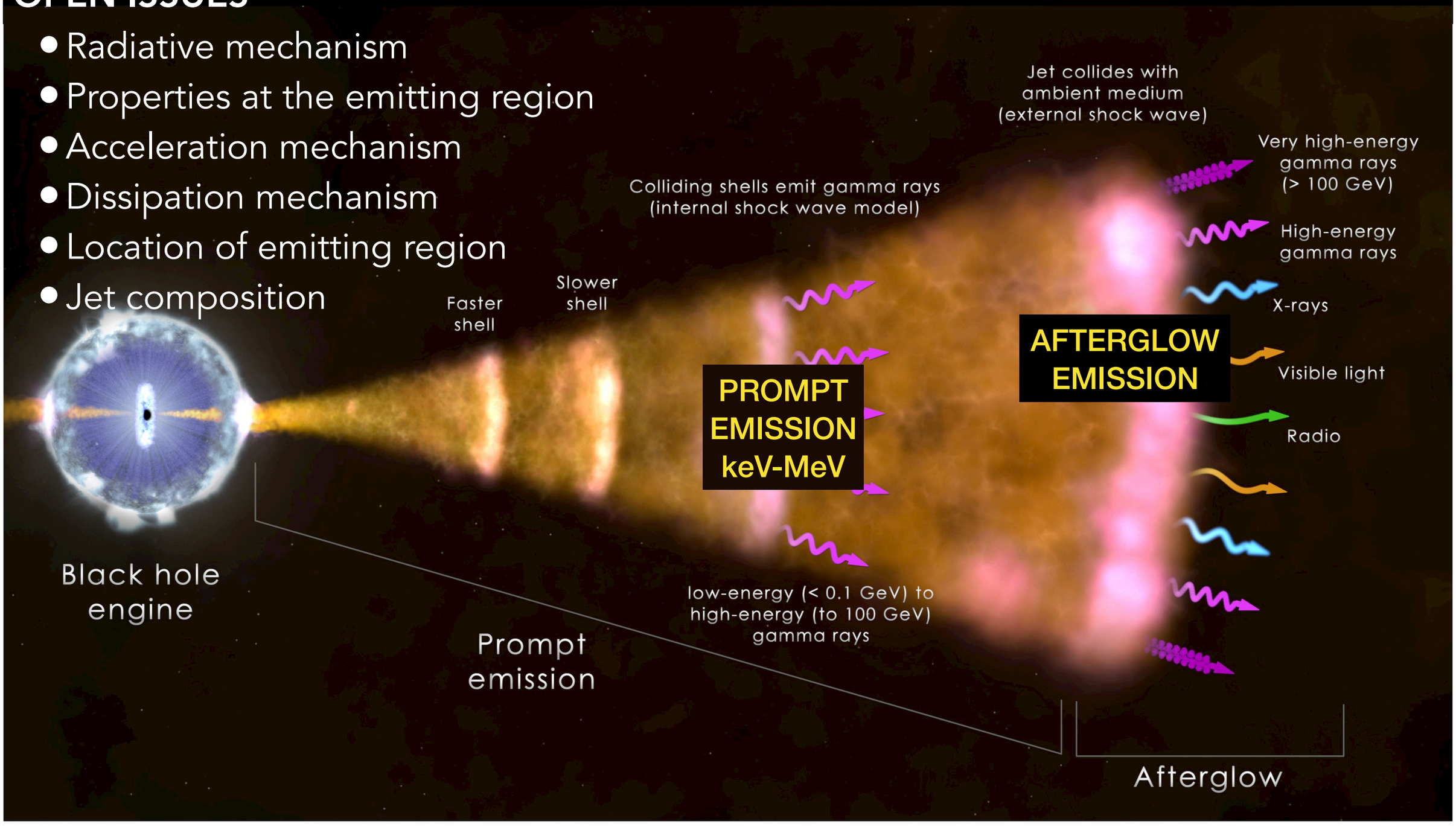
AFTERGLOW

- from radio to TeV
- non-thermal spectra
- days - weeks
- smooth (PL) lightcurve

GAMMA-RAY BURSTS - THE STANDARD MODEL

OPEN ISSUES

- Radiative mechanism
- Properties at the emitting region
- Acceleration mechanism
- Dissipation mechanism
- Location of emitting region
- Jet composition

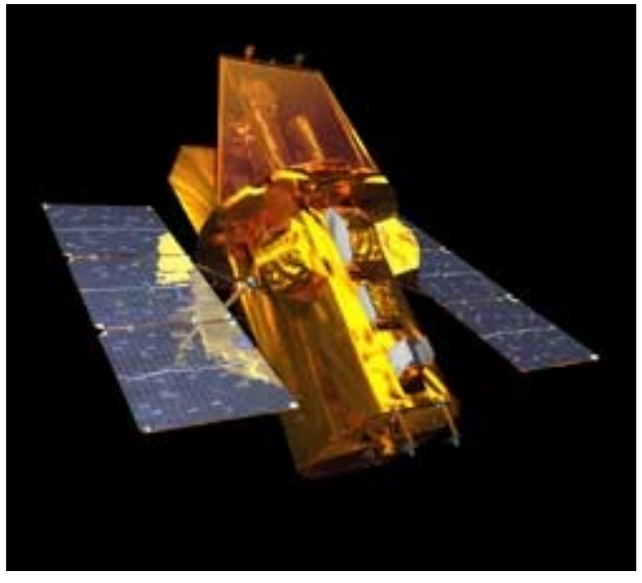


PROMPT EMISSION OBSERVATIONS FROM SATELLITES

*CGRO/***BATSE**: prompt emission in the range 20 keV - 2 MeV from **2700** GRBs

*Fermi/***GBM**: prompt emission in the range 8 keV- 40 MeV from **4100** GRBs

Fermi/**LAT**: emission 20 MeV-300 GeV from about **300** GRBs



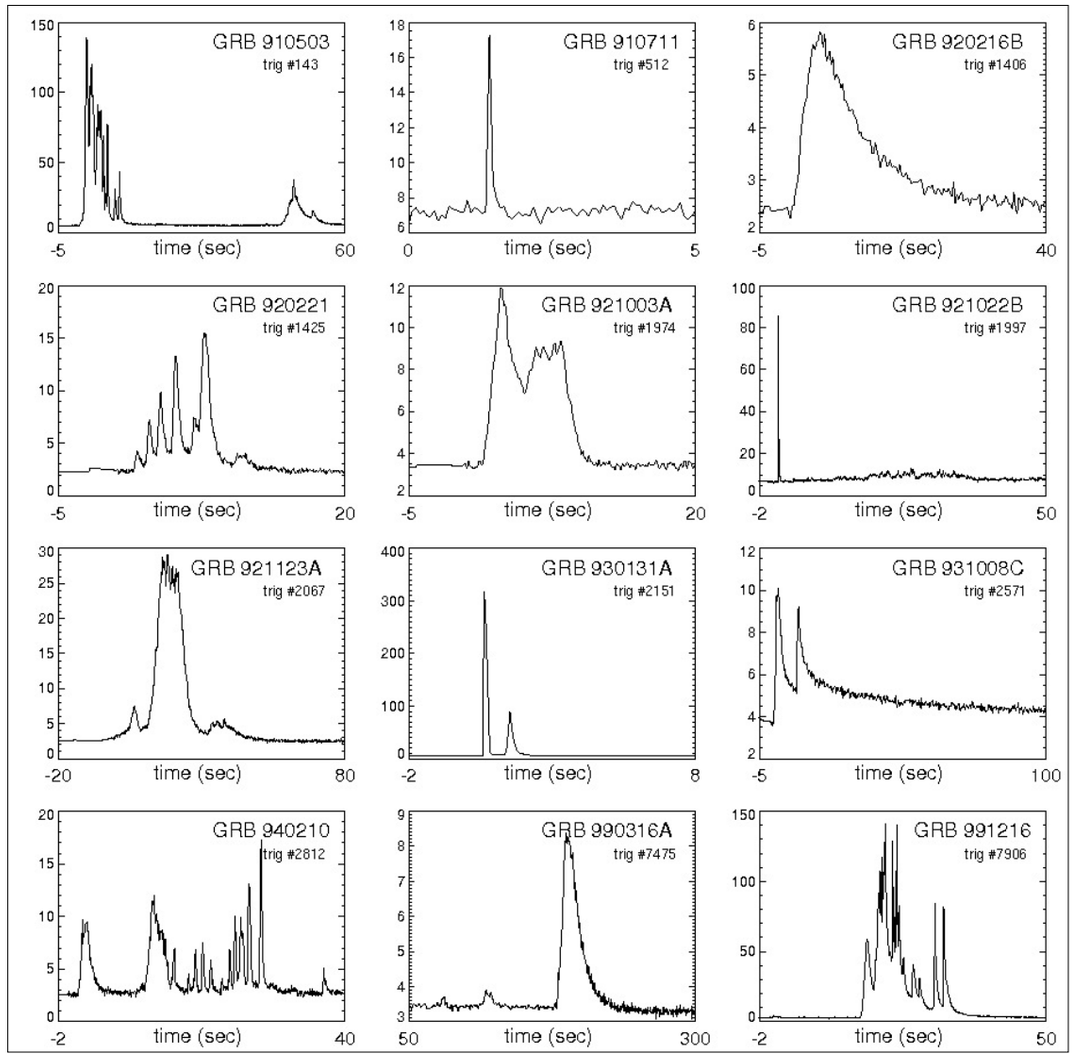
The Neil Gehrels Swift Observatory

*Swift/***BAT**: 15-150 keV from **1700** GRBs

PROMPT EMISSION

LIGHTCURVES

Examples of prompt emission light curves: flux (50-300 keV) vs time



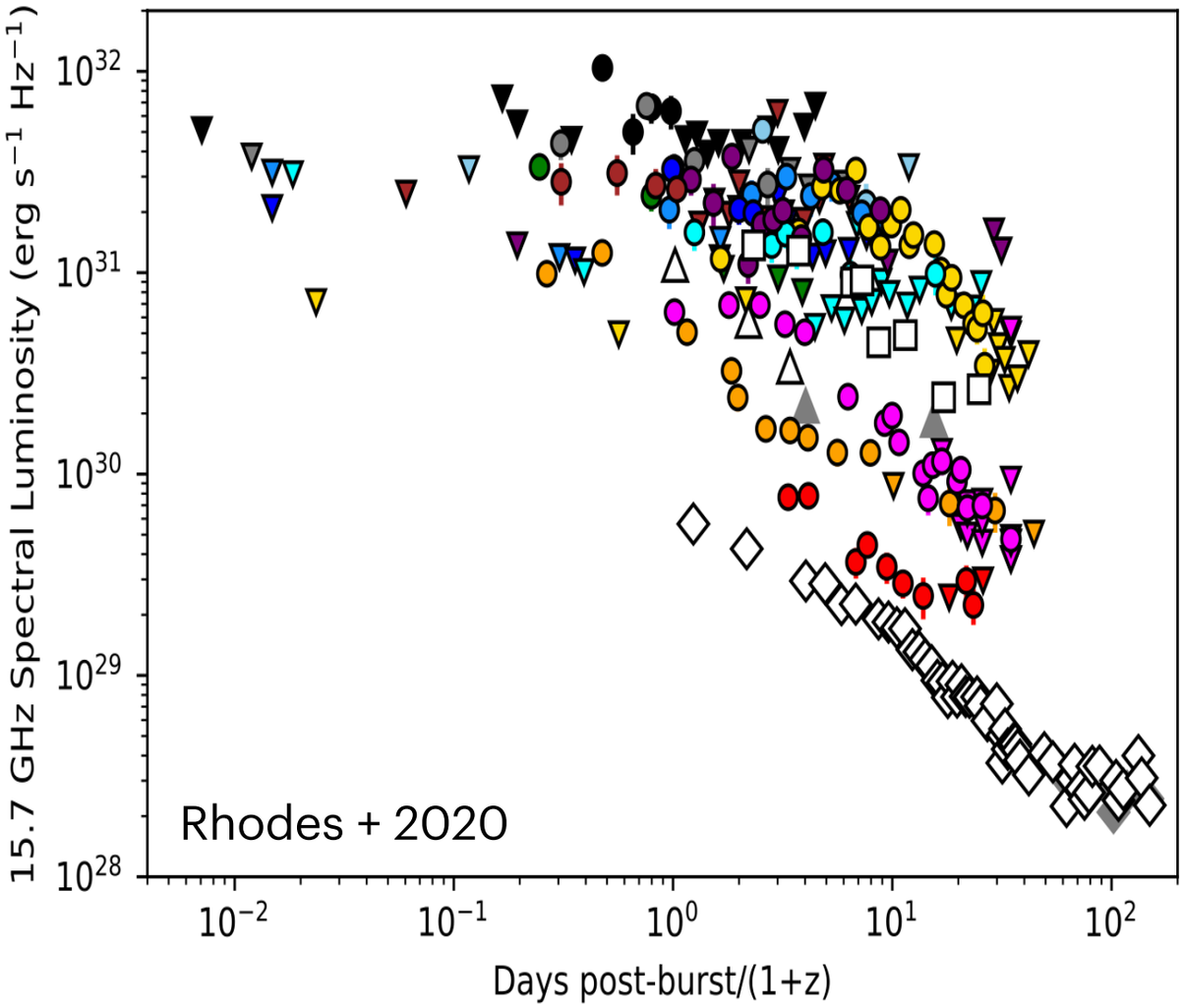
- Energy range: 1 keV to 10 MeV
- Variability: 0.01 - 1 s
- Duration: 0.1 to 10^3 seconds
- No typical morphology
- Quiescence times
- $E_{iso} = F \times 4\pi d_L^2 \sim 10^{51} - 10^{54}\, erg$
- $L_{iso} \sim 10^{50} - 10^{53} erg/s$

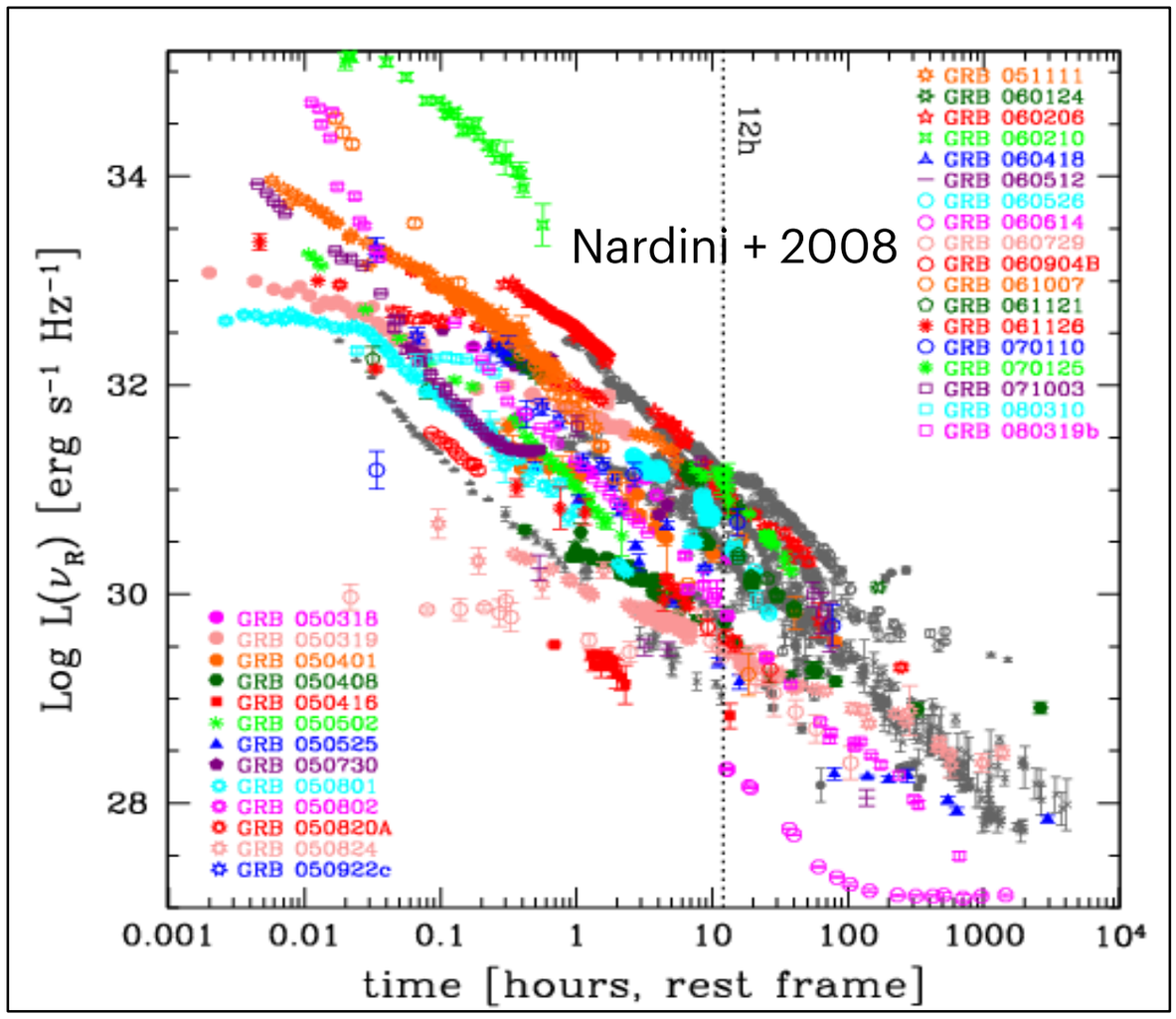
AFTERGLOW EMISSION LIGHTCURVES

OBSERVATIONS AT DIFFERENT FREQUENCIES

radio

optical

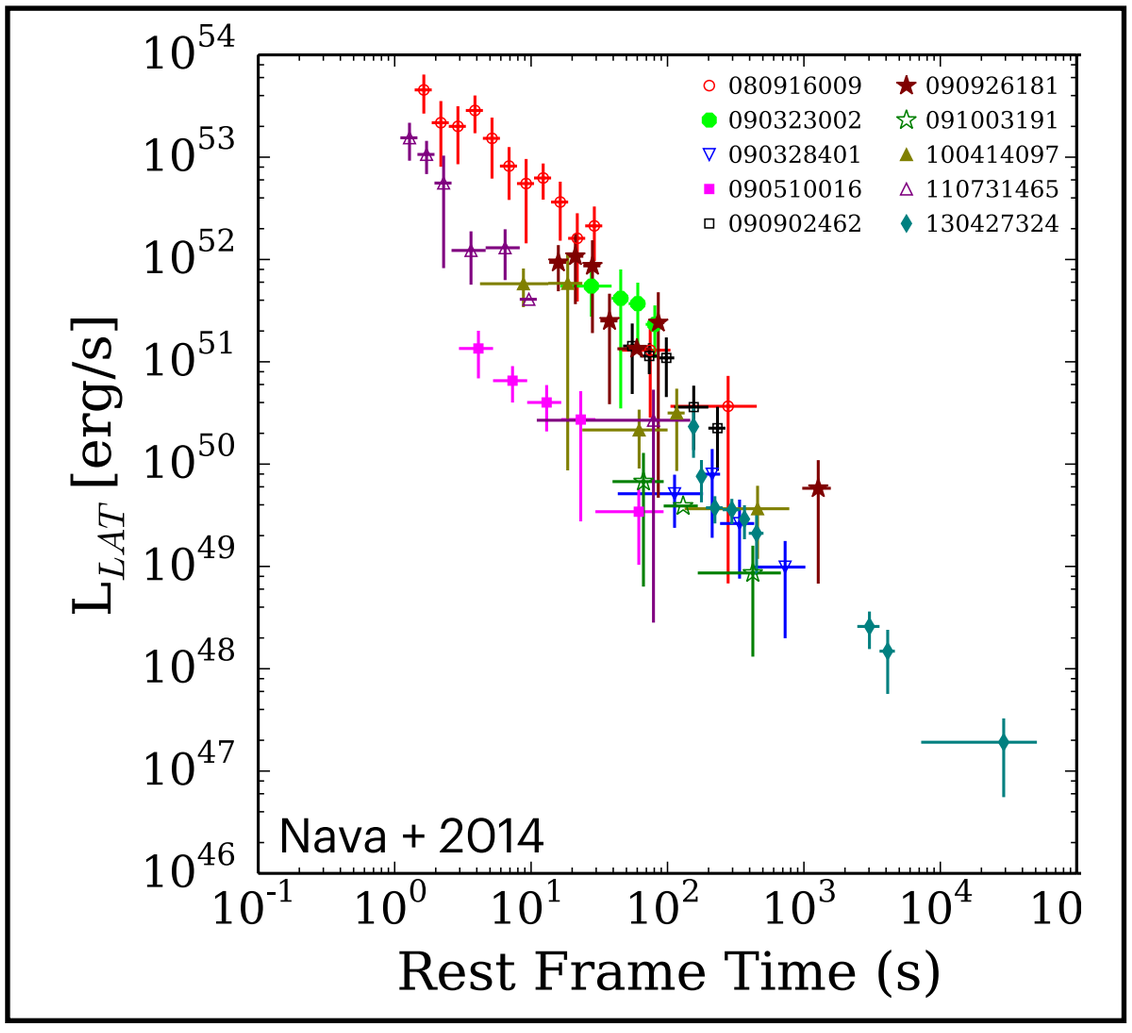




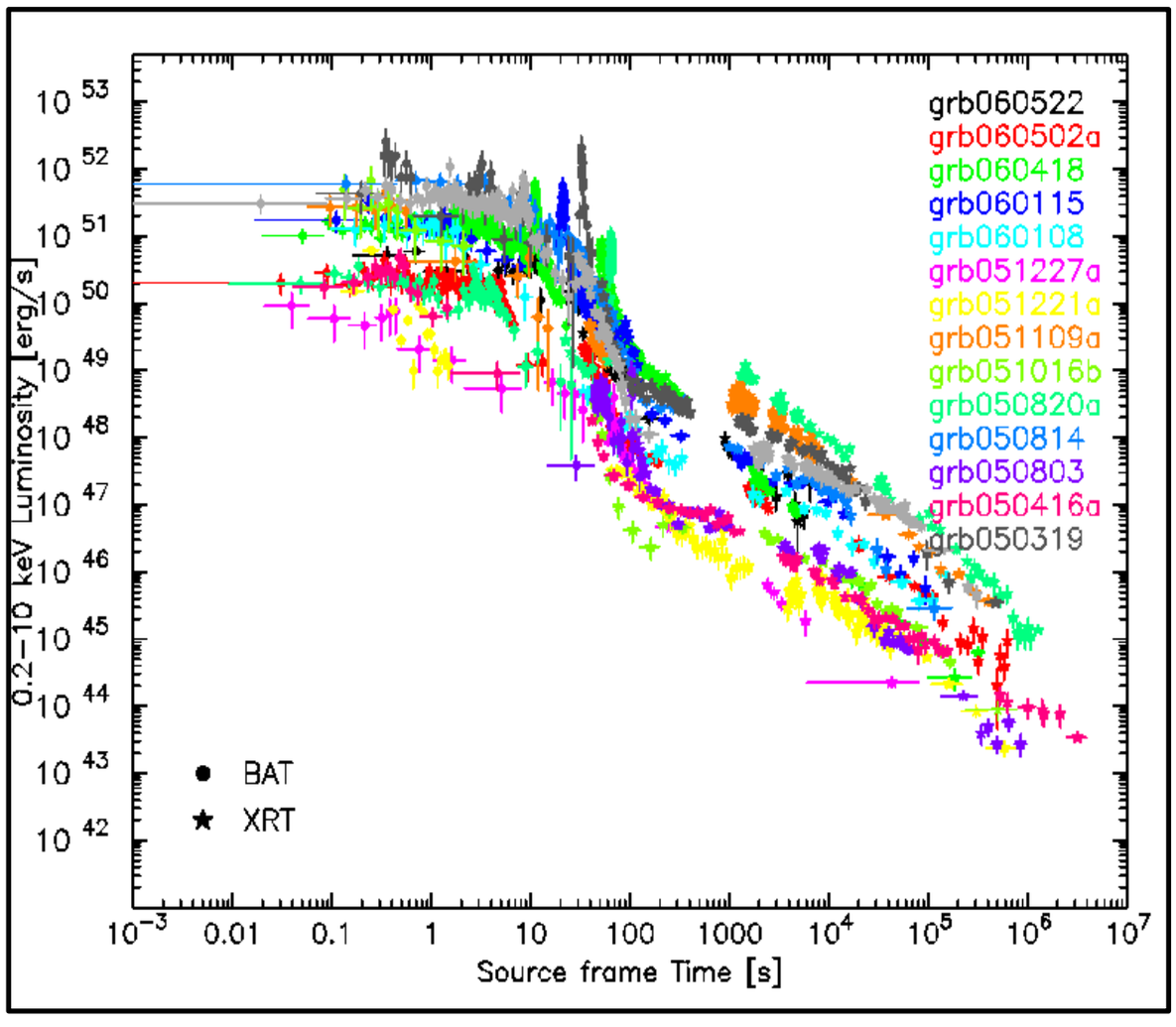
AFTERGLOW EMISSION LIGHTCURVES

OBSERVATIONS AT DIFFERENT FREQUENCIES

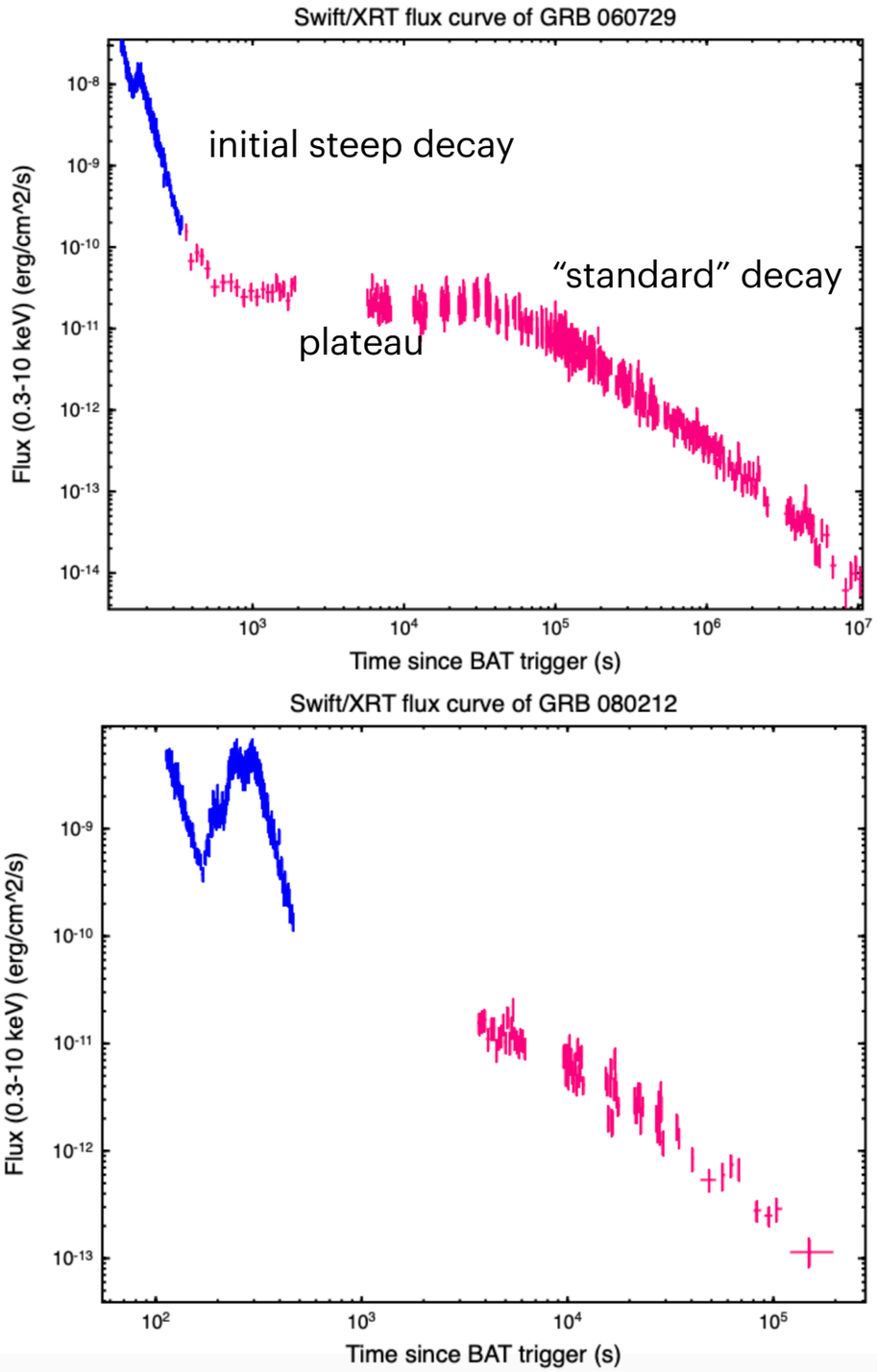
GeV (0.1-10 GeV)

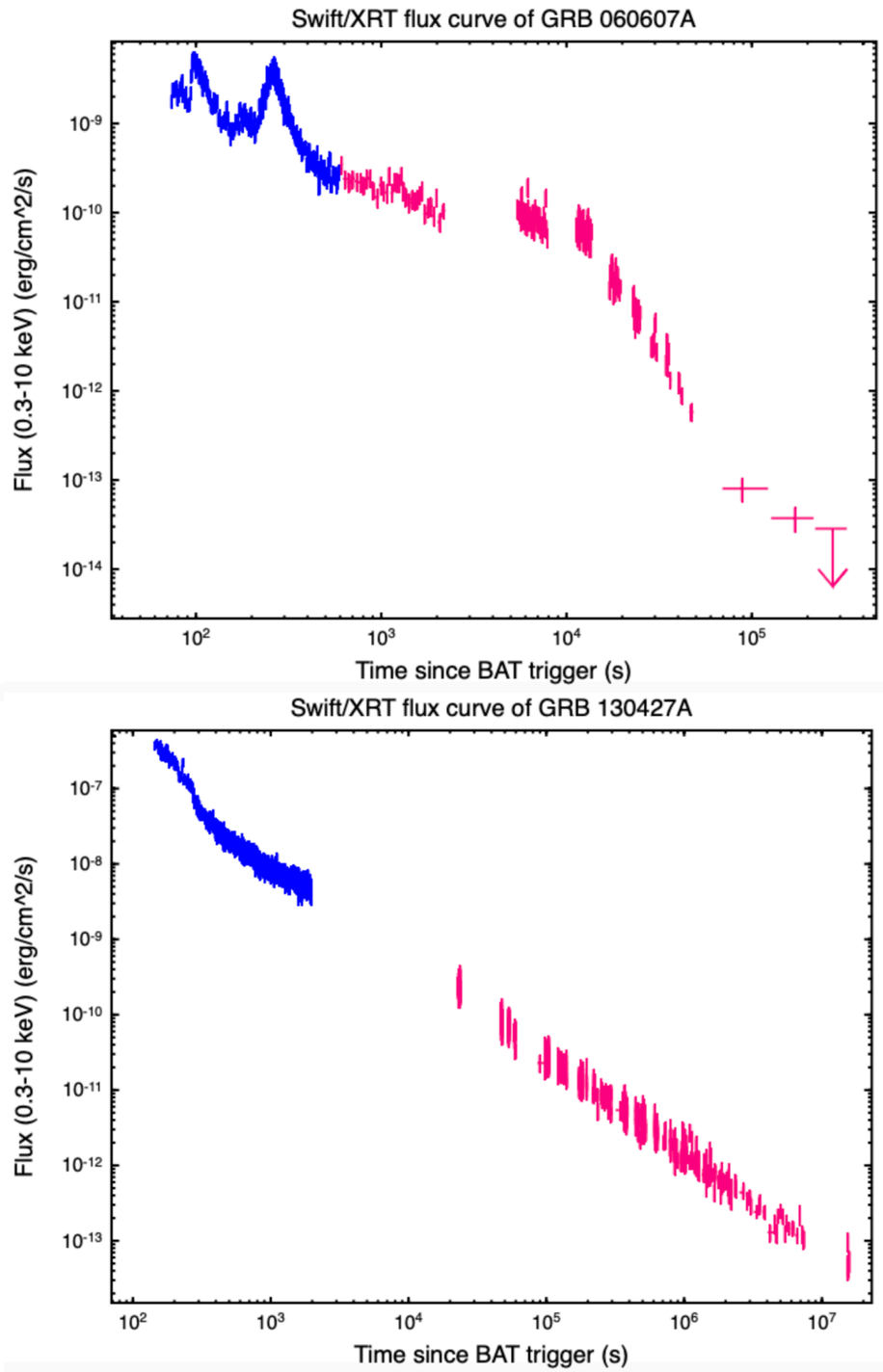


X-ray



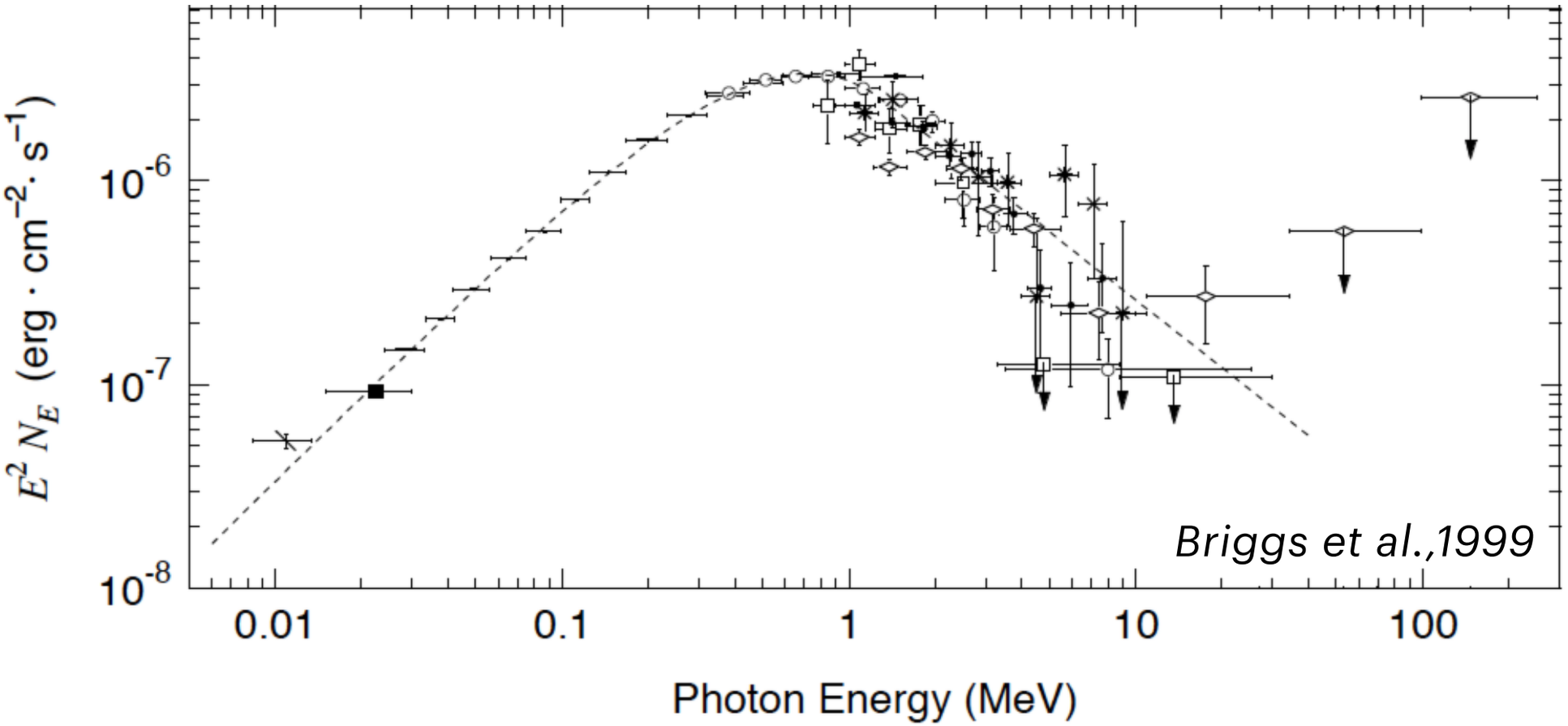
X-RAY TYPICAL LIGHTCURVE AND X-RAY FLARES



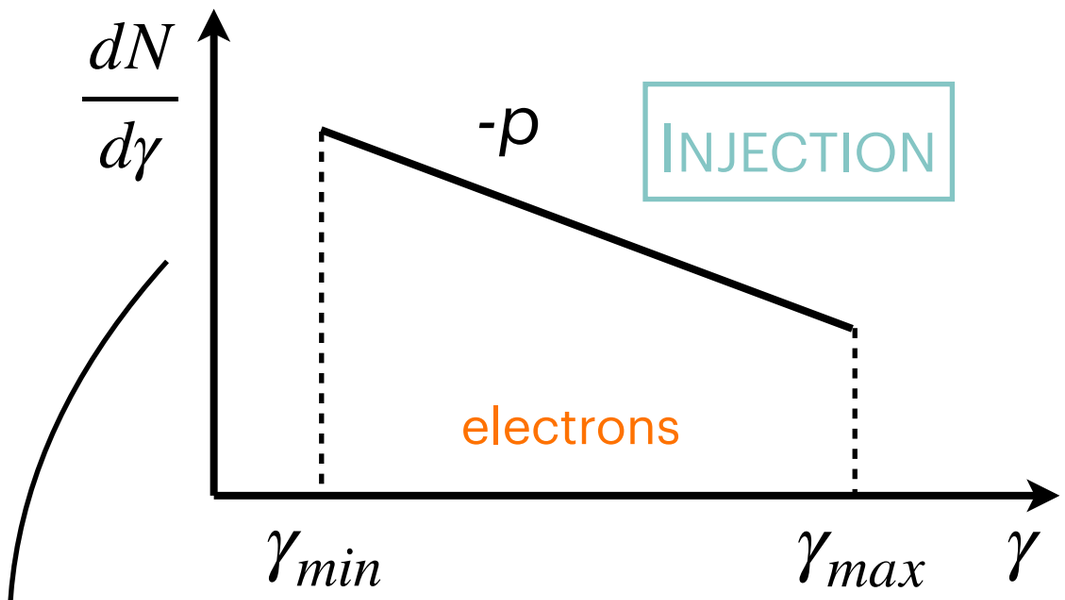


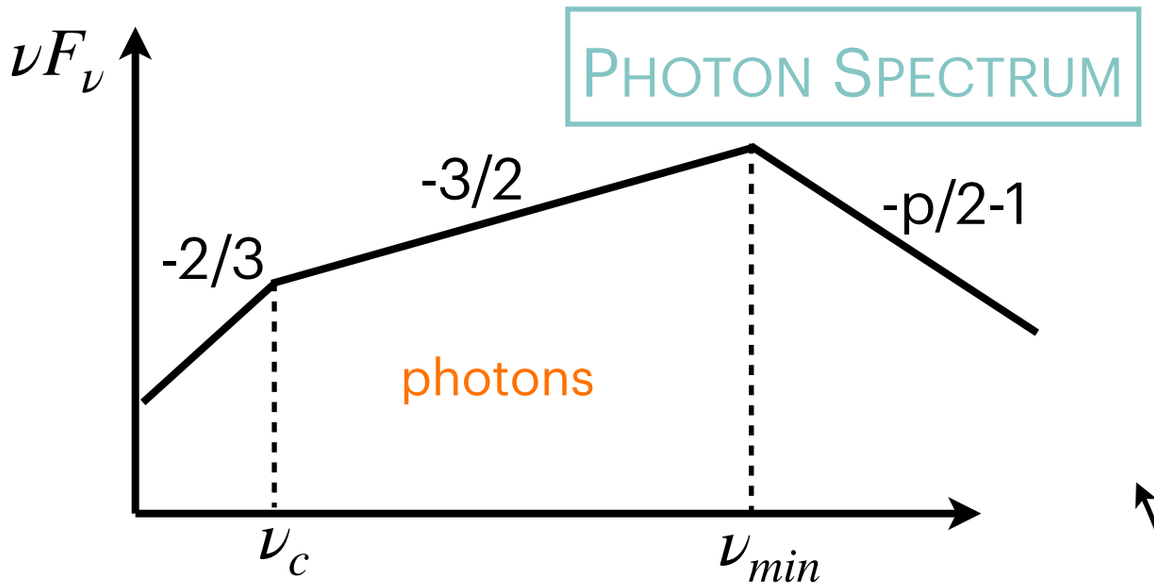
PROMPT EMISSION SPECTRUM

Example of typical prompt spectrum

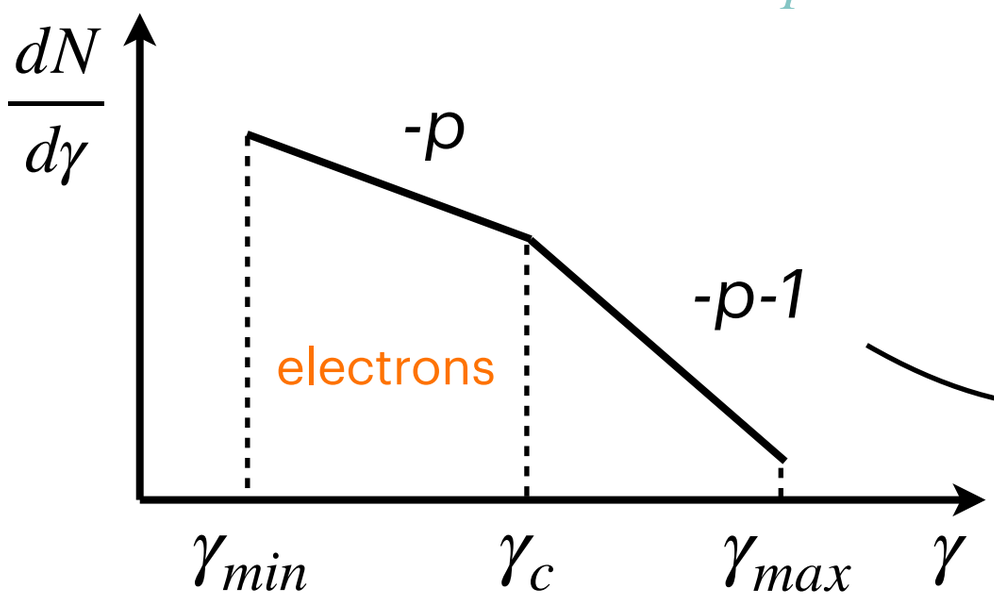


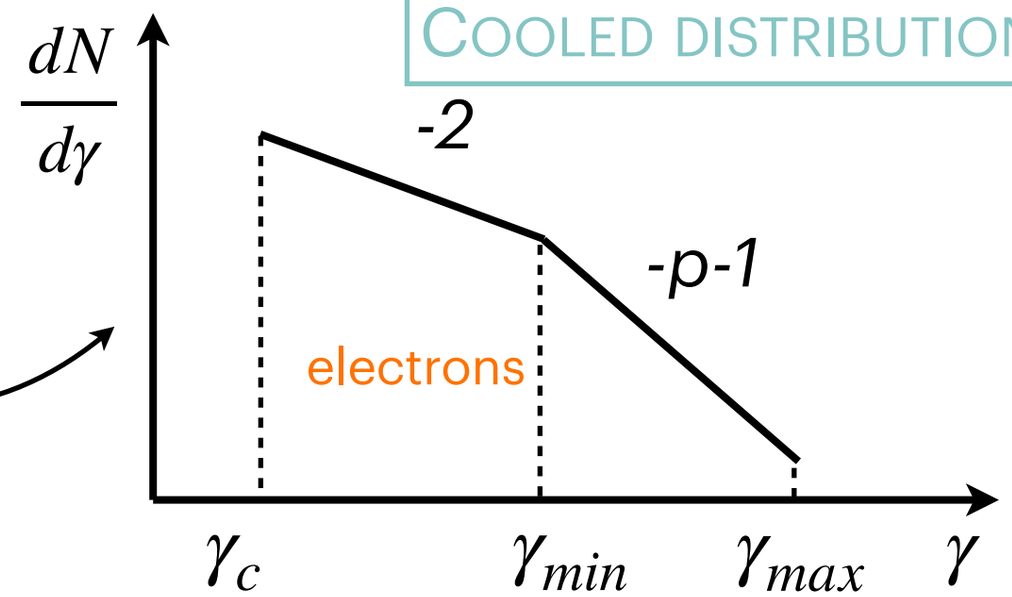
SYNCHROTRON EMISSION





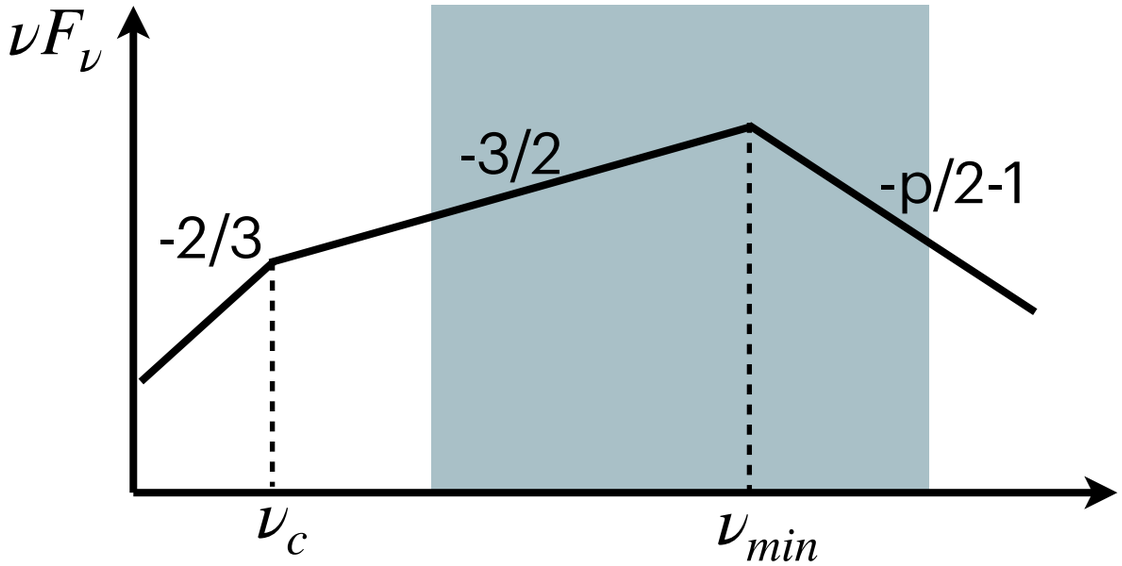
COOLING $\gamma_c = \frac{6\pi m_e c}{\sigma_T t' B'^2}$



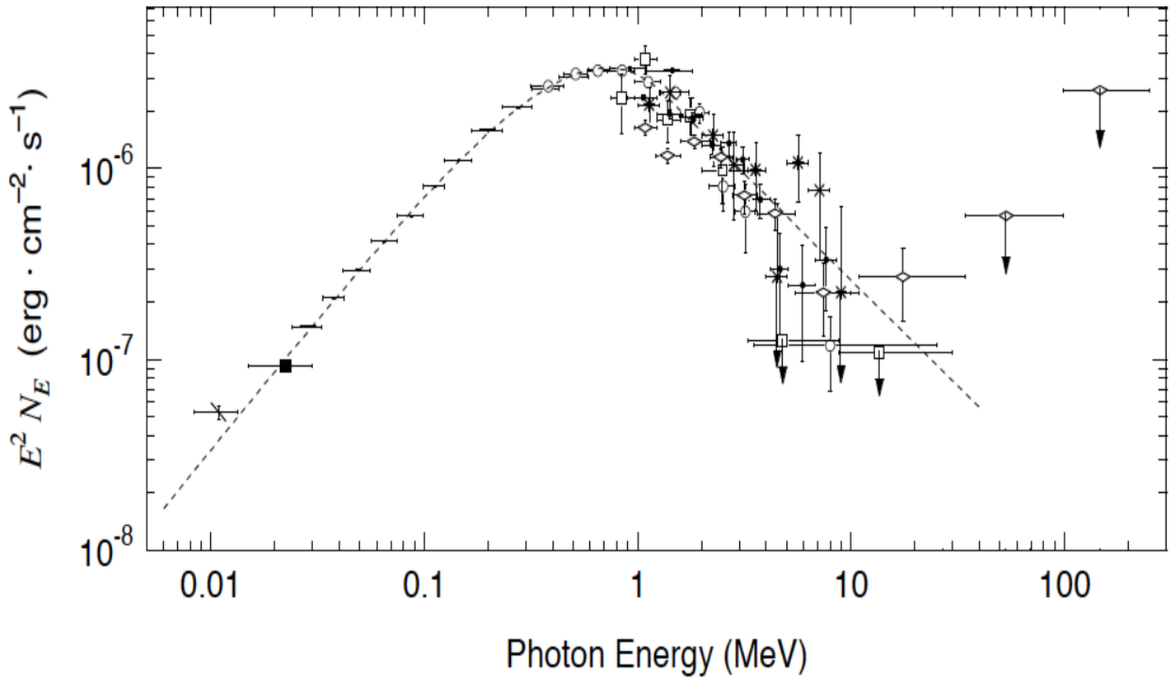


PROMPT EMISSION INTERPRETATION

PREDICTIONS
FROM SYNCHROTRON THEORY



OBSERVATIONS
OF PROMPT SPECTRA



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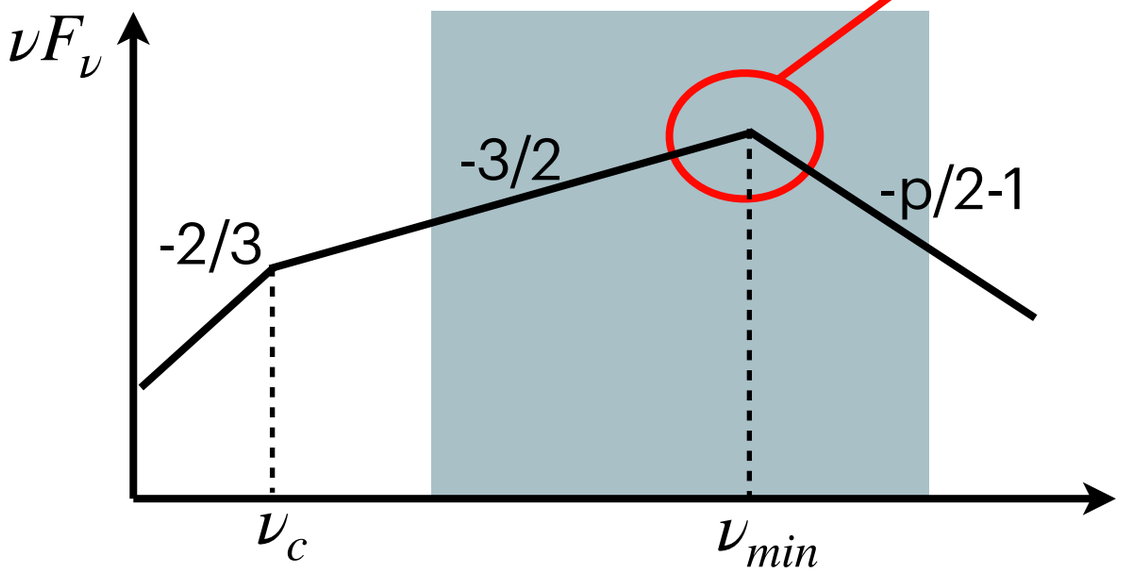

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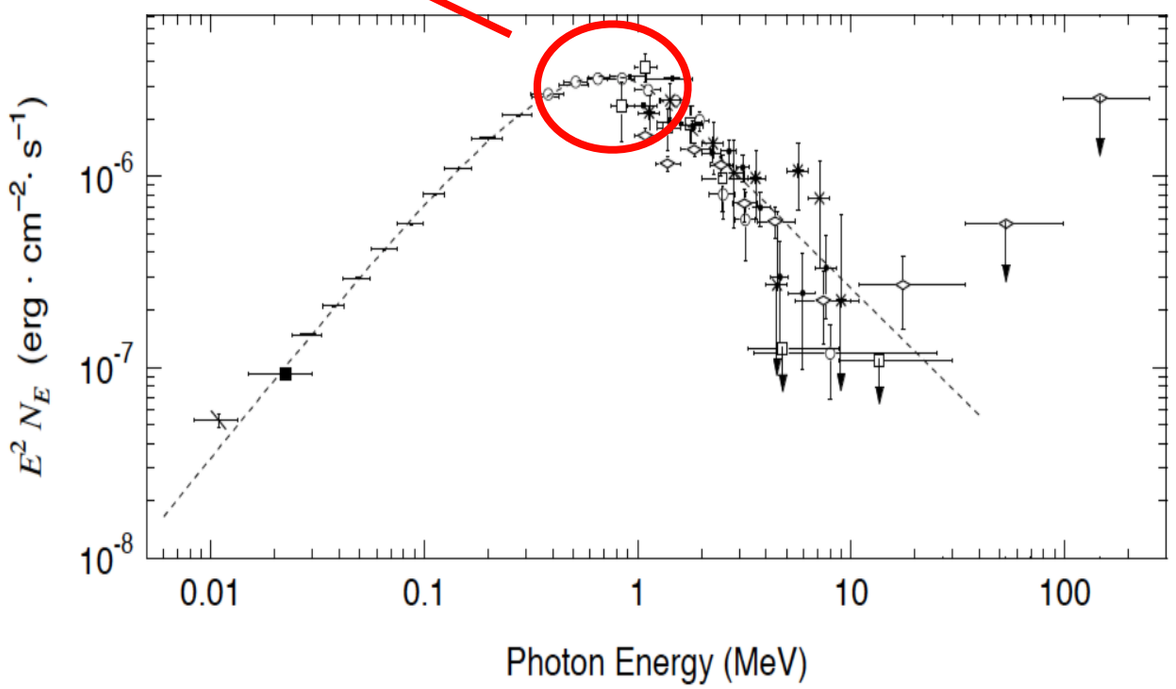

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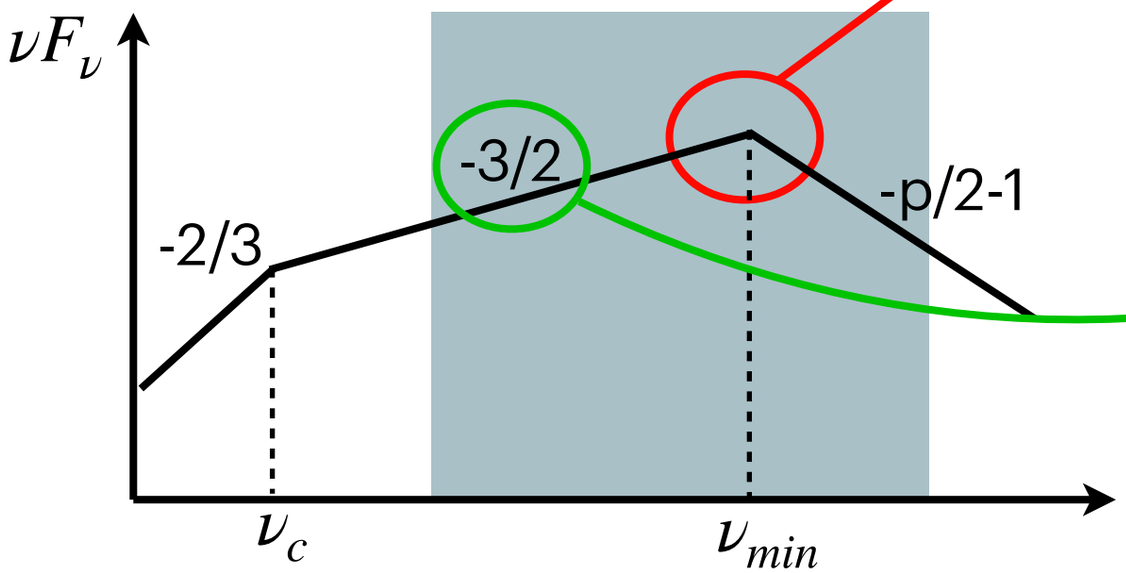

OBSERVATIONS
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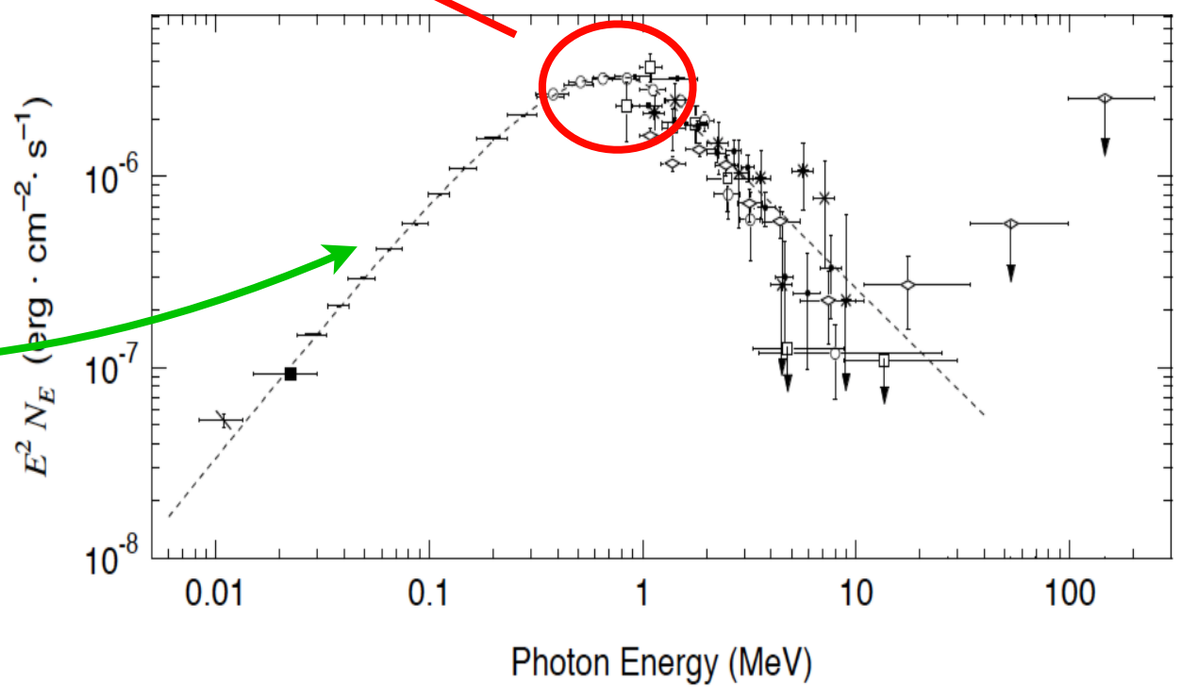
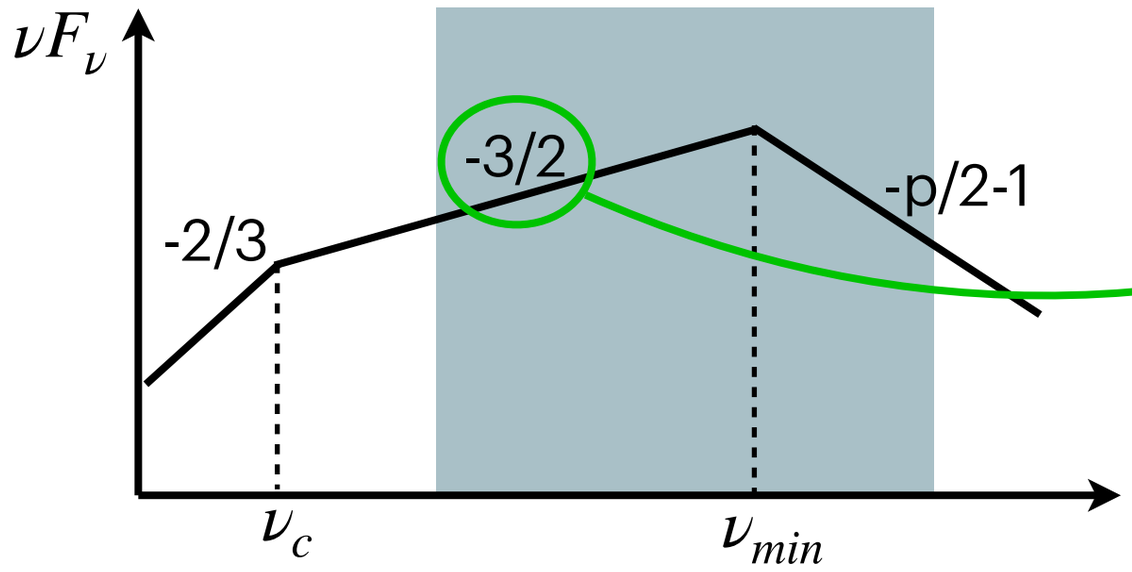


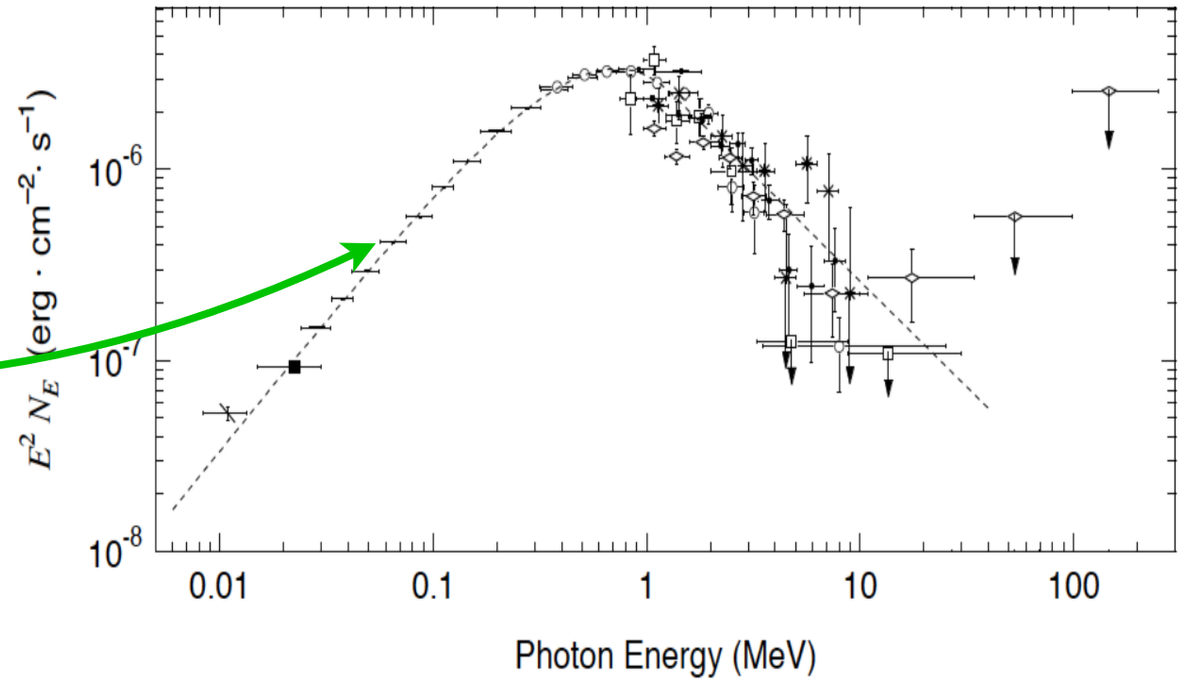
ISSUES WITH SYNCHROTRON INTERPRETATION

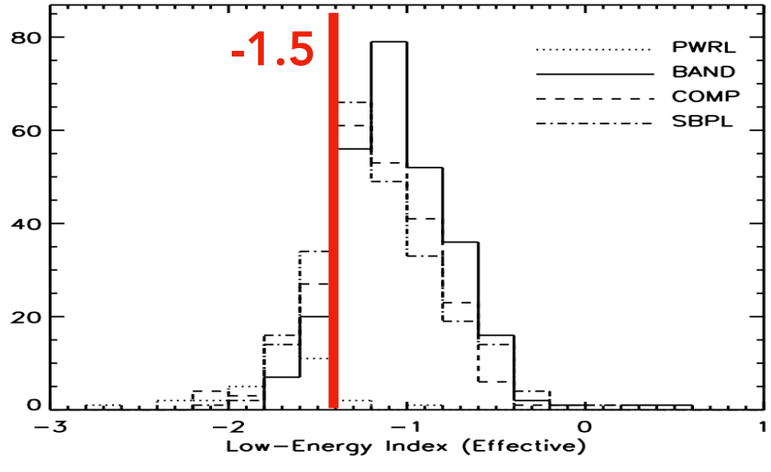
PREDICTIONS
FROM SYNCHROTRON THEORY



value predicted in case of synchrotron process

OBSERVATIONS
OF PROMPT SPECTRA

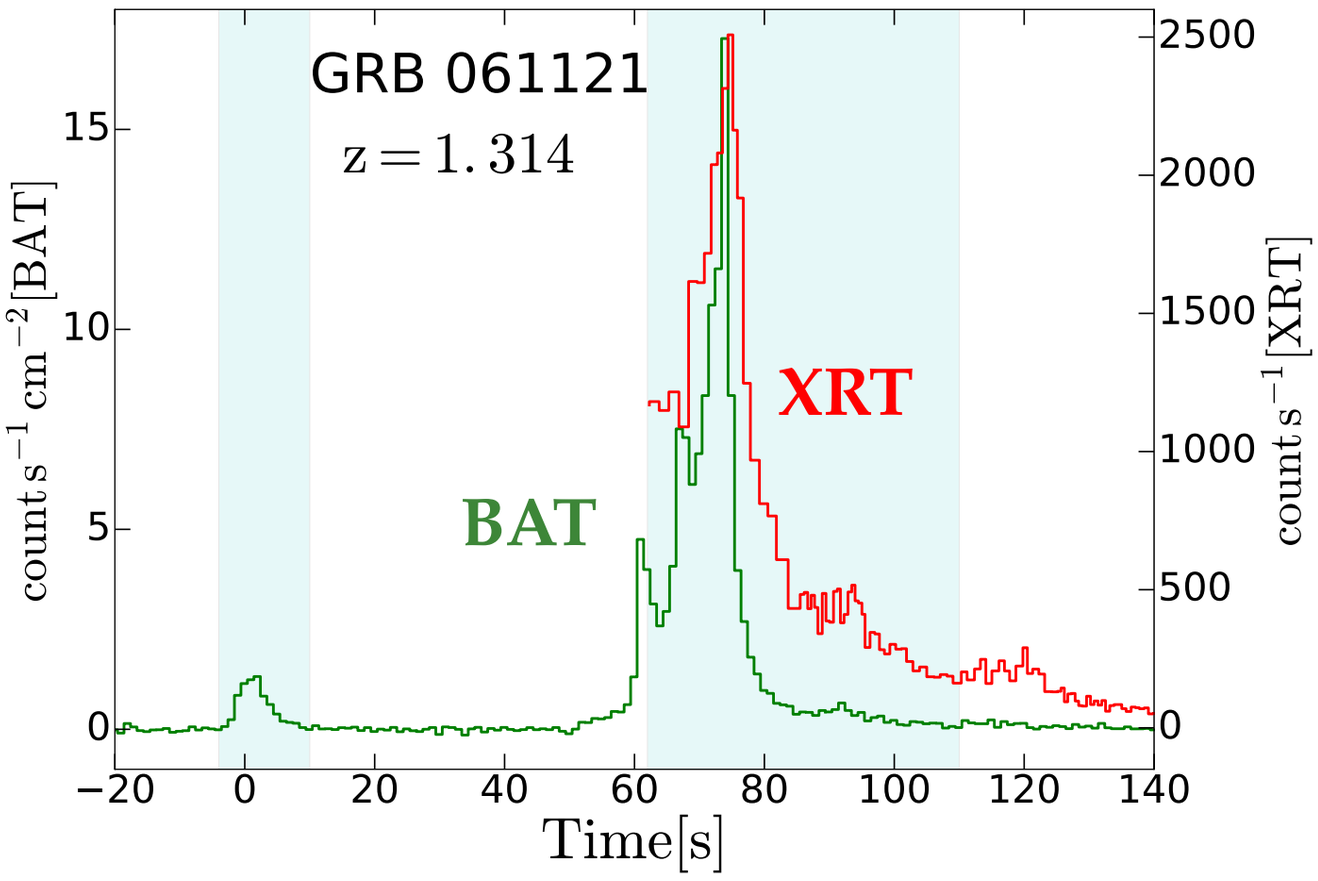




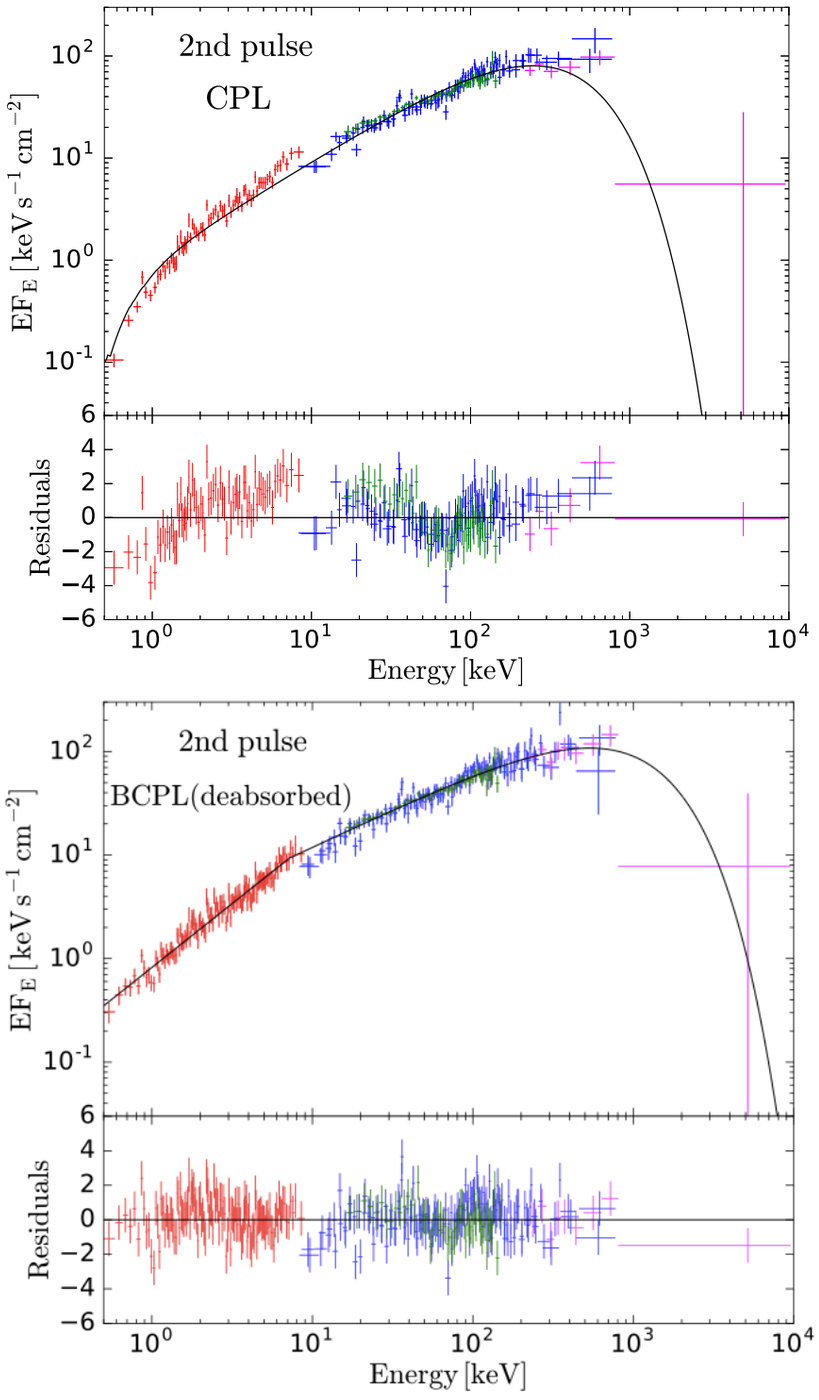
distribution of measured spectral index in a large sample of GRBs

CAN XRT HELP?

Swift GRBs with BAT+XRT simultaneous prompt observations



SPECTRAL BREAK AT LOW ENERGIES



Cutoff PL model

> 8σ improvement

CPL + break at low energy

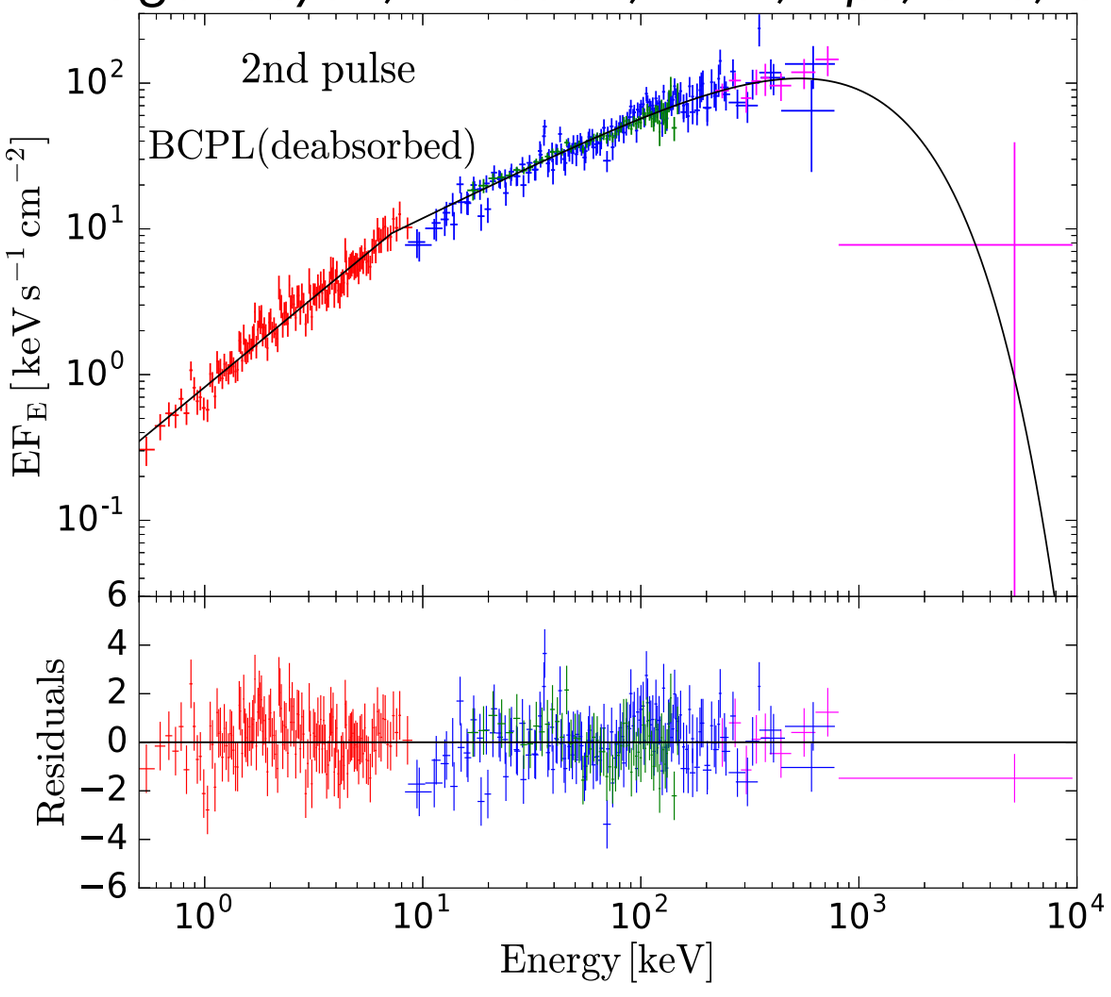
E_{break} = (7.2 ± 1) keV

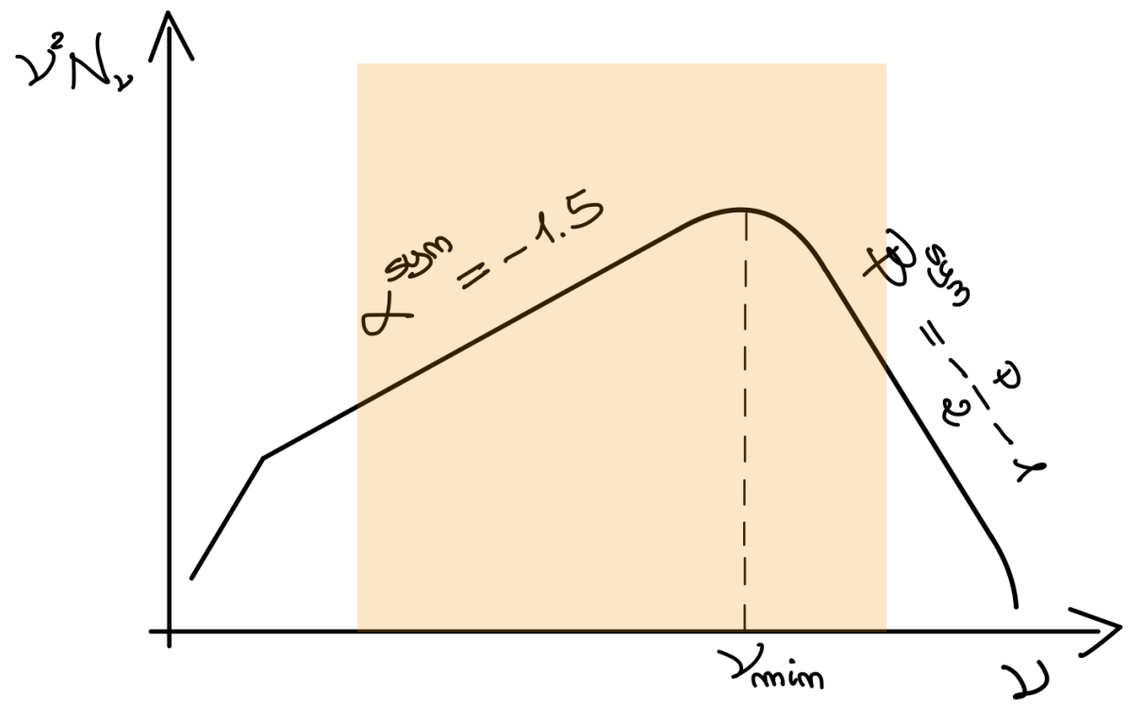
E_{peak} = (532 ± 150) keV

Oganesyan, LN et al., 2017, ApJ, 846,137

SPECTRAL BREAK: INTERPRETATION

Oganesyan, LN et al., 2017, ApJ, 846,137





SPECTRAL BREAK: INTERPRETATION

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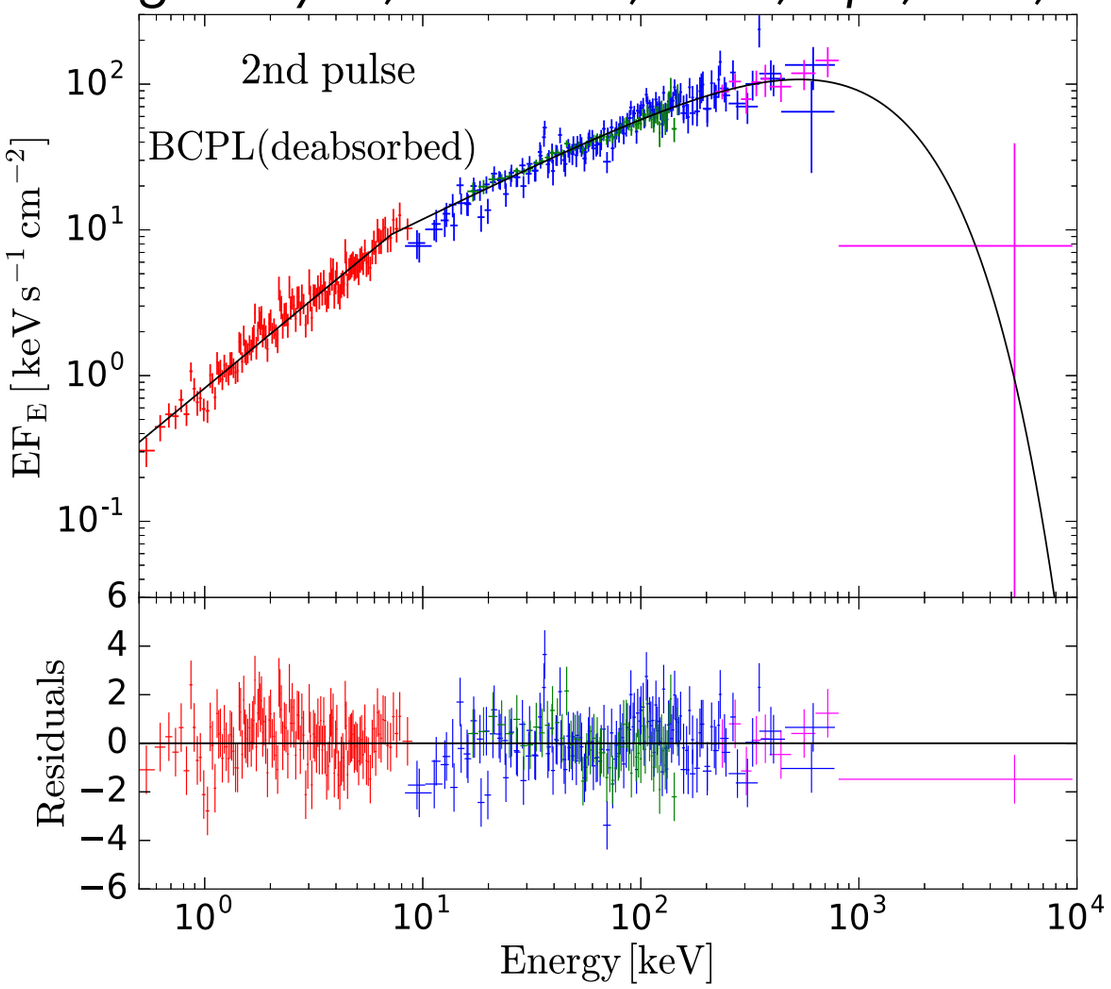
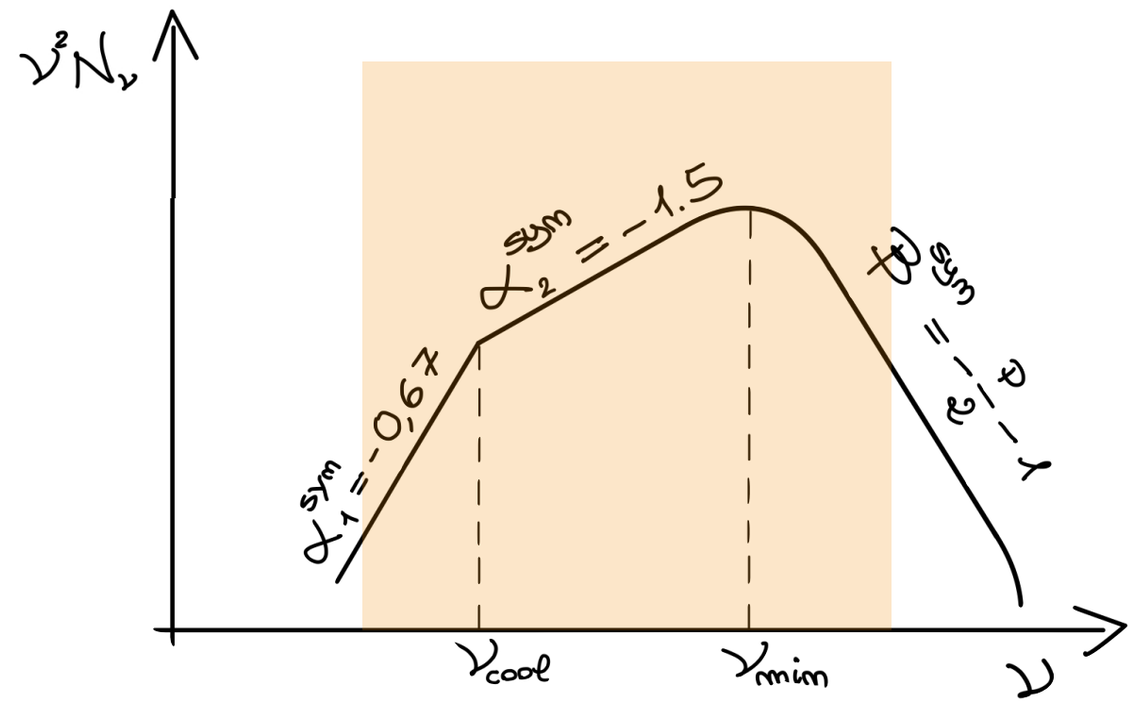
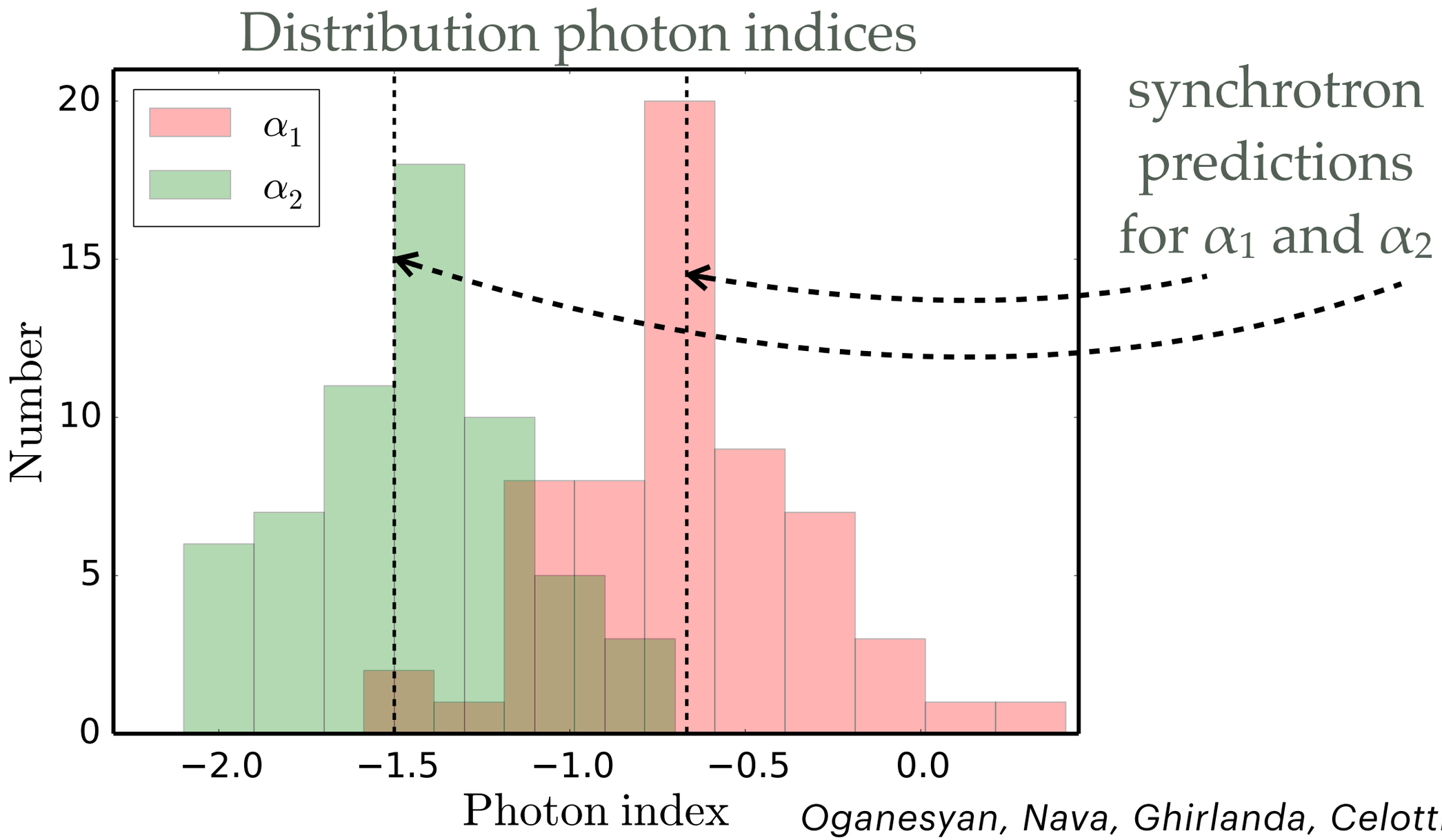




COMPARISON OF PHOTON INDICES



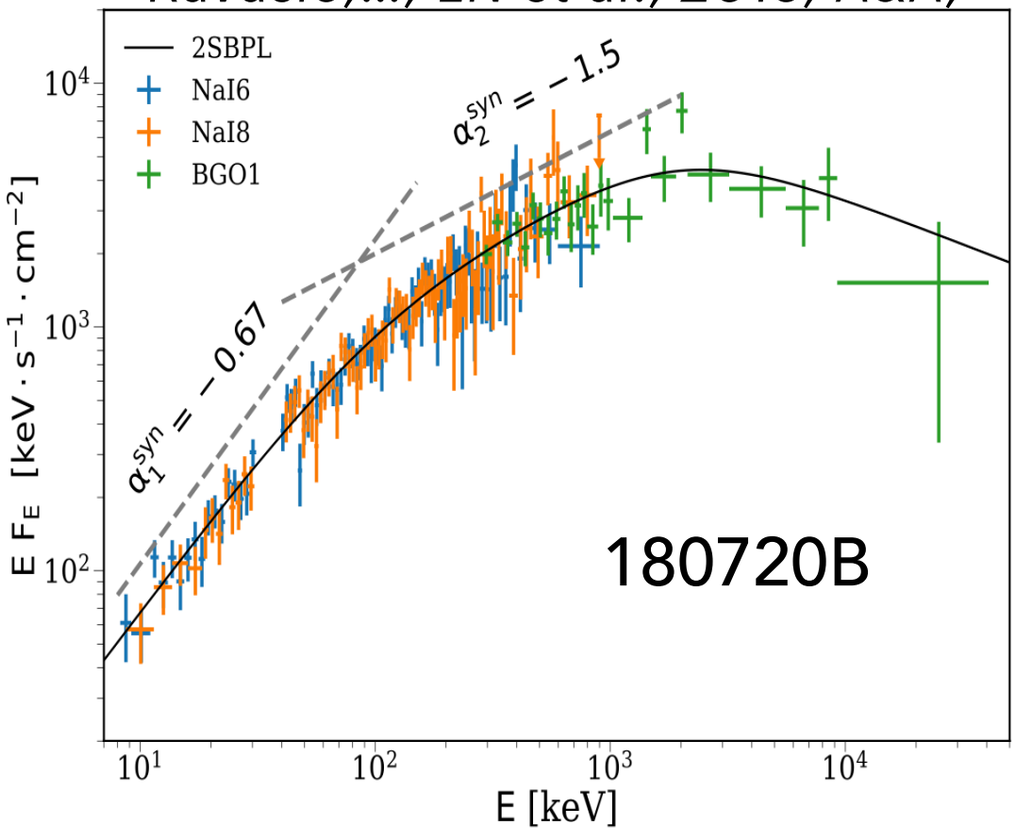
Oganesyan, Nava, Ghirlanda, Celotti, 2017, ApJ

LOW ENERGY BREAKS IN GBM GRBS?

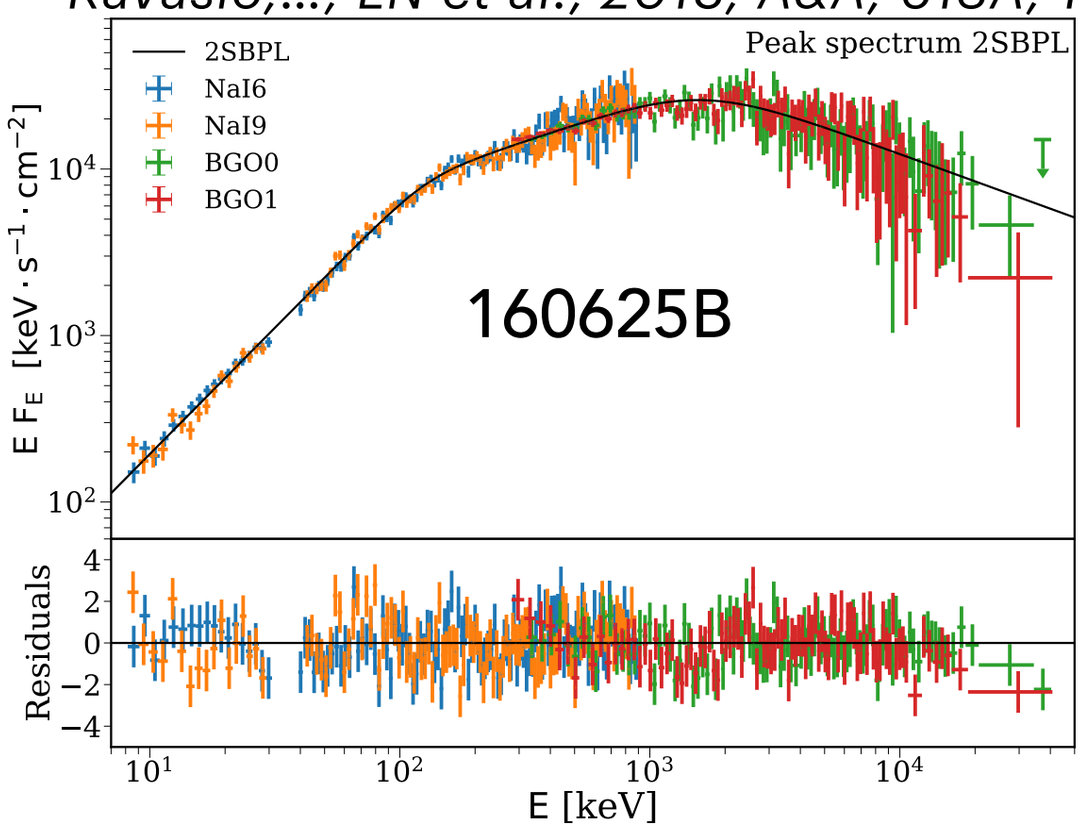
10 brightest long GRBs in the GBM catalog

- 8 have breaks in the low-energy part of the spectrum (20-100 keV)
- Photon indices have distributions centered around synchrotron values

Ravasio,..., LN et al., 2019, A&A,



Ravasio,..., LN et al., 2018, A&A, 613A, 16



LOW ENERGY BREAKS IN GBM GRBS?

10 brightest long GRBs in the GBM catalog

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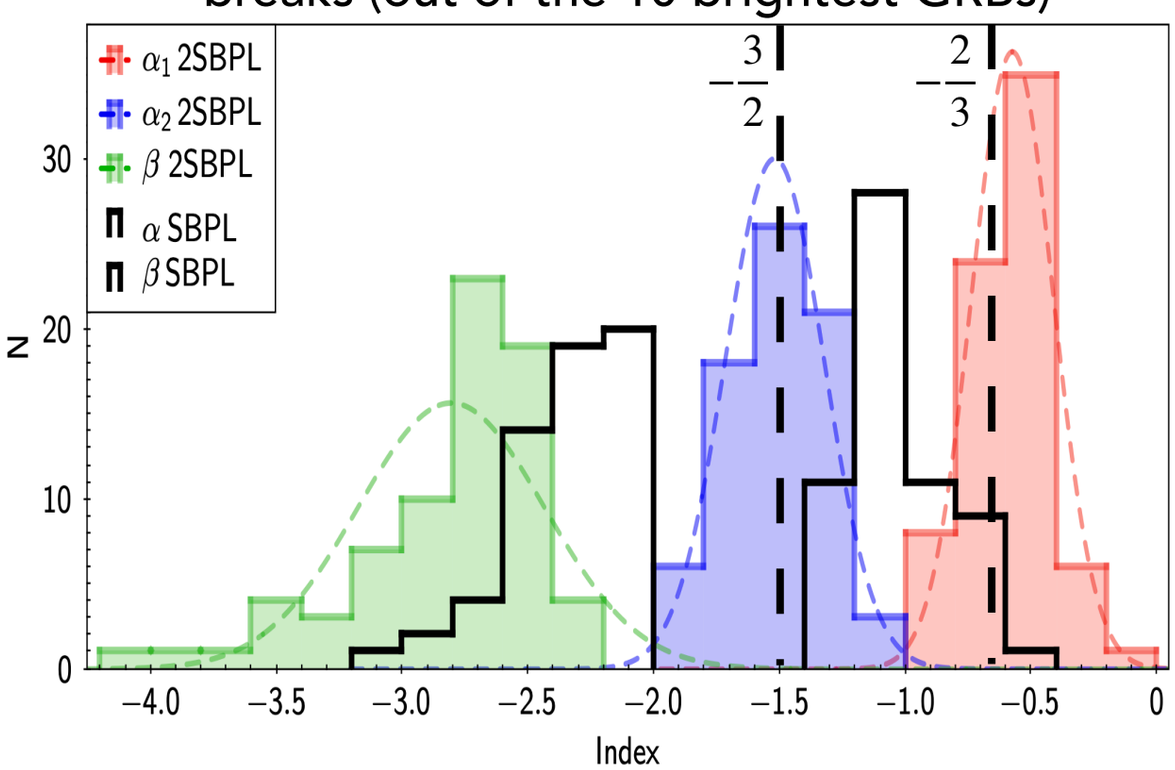
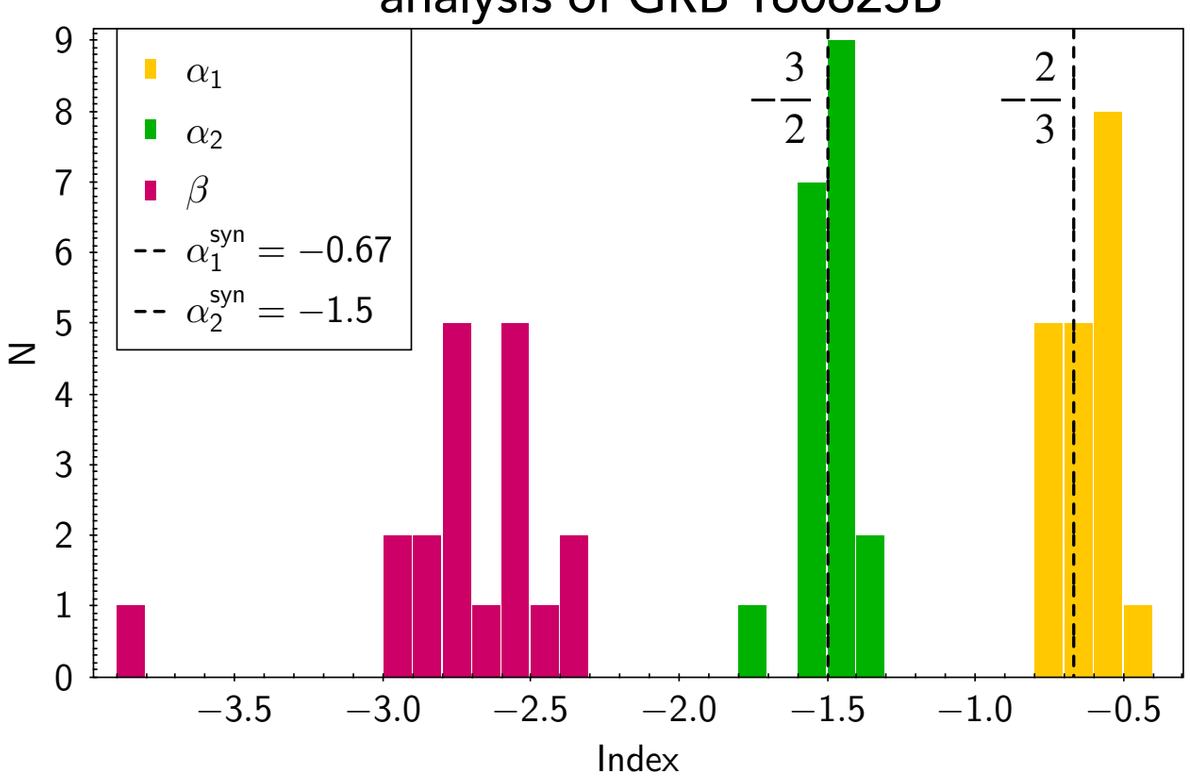
Photon index distribution of the 8 GRBs with breaks (out of the 10 brightest GRBs)

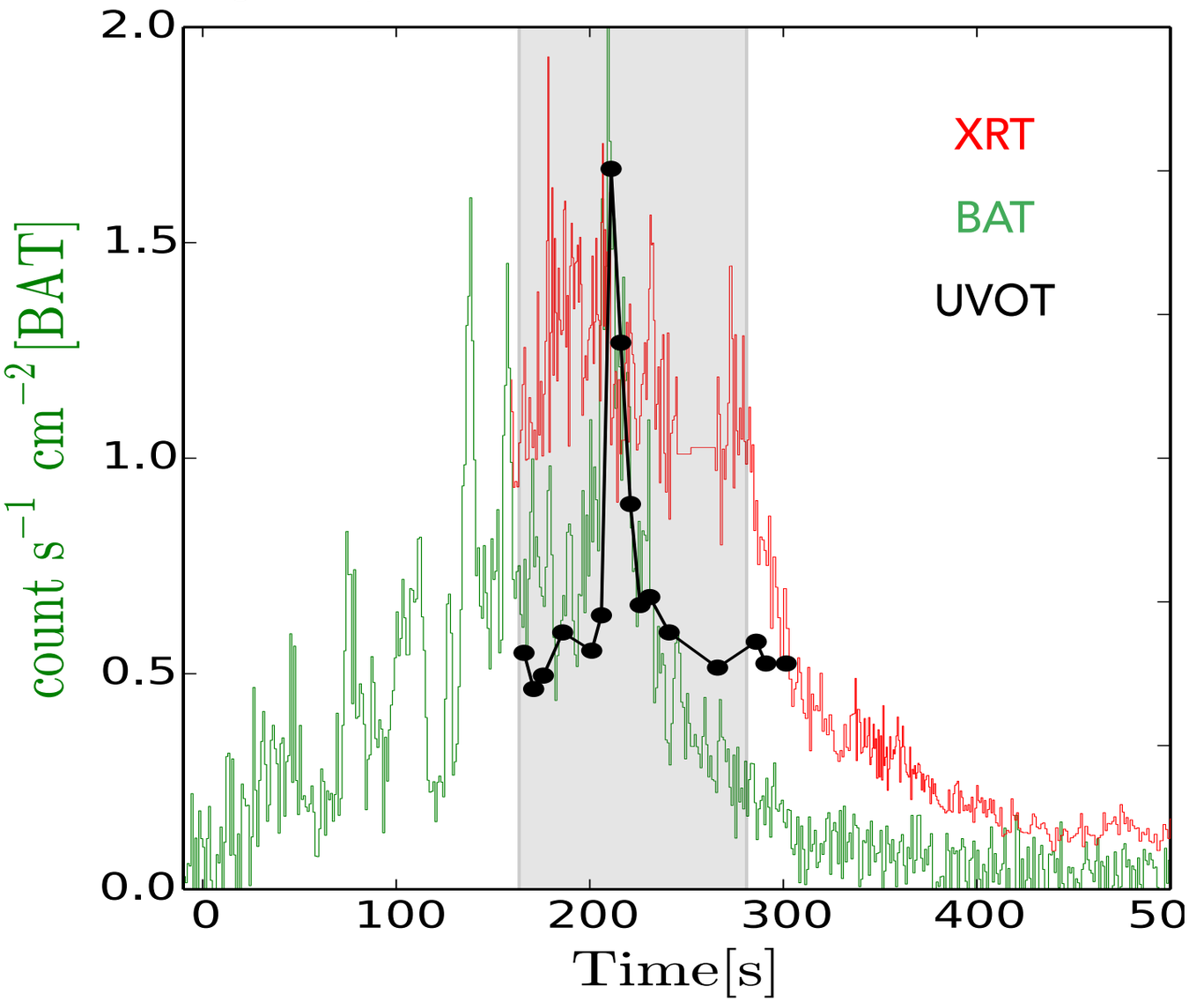


Photon index distribution time-resolved spactral analysis of GRB 160625B



PROMPT OPTICAL DATA

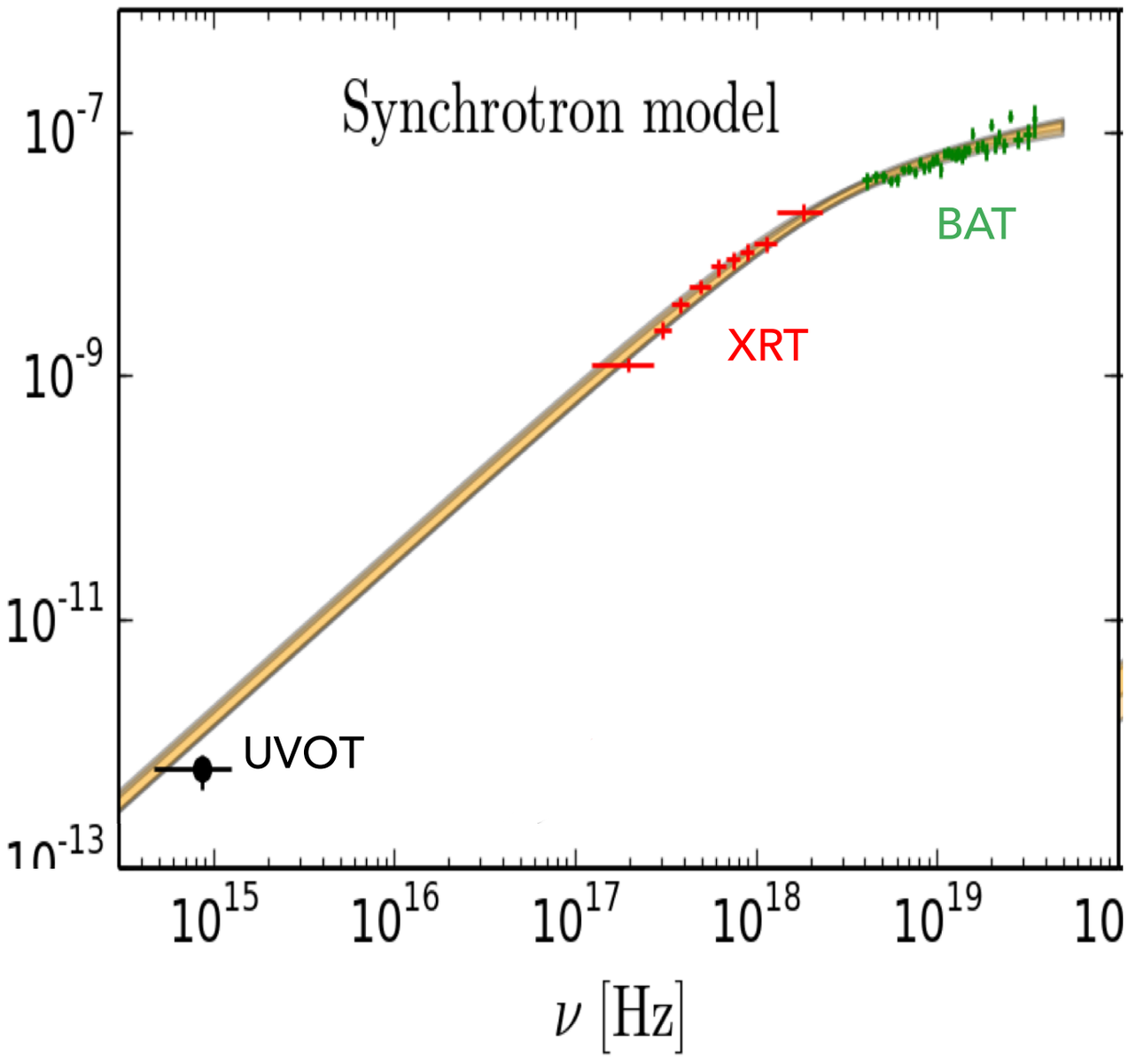
Oganesyan, LN, et al., 2019, A&A, 628, 59



Sample of 21 GRBs with simultaneous BAT, XRT and optical data:

PROMPT OPTICAL DATA

Oganesyan, LN, et al., 2019, A&A, 628, 59



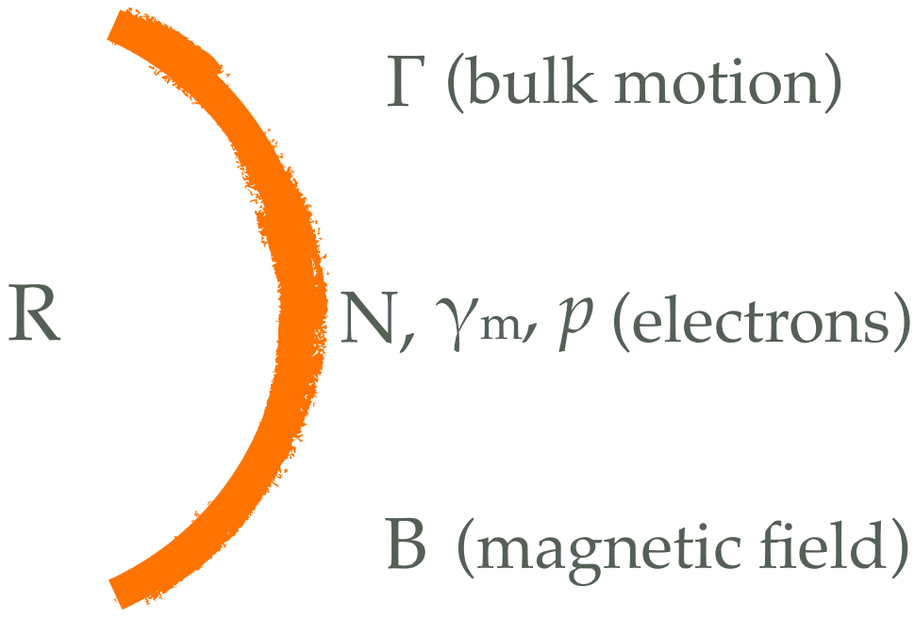
Sample of 21 GRBs with simultaneous BAT, XRT and optical data:

- In ~all cases we found a break in the low-energy part of the spectrum (between 0.4 and 30 keV)
- In all cases, sychrotron model provides a good fit

CONSTRAINTS ON EMISSION REGION

Unknowns

Observables



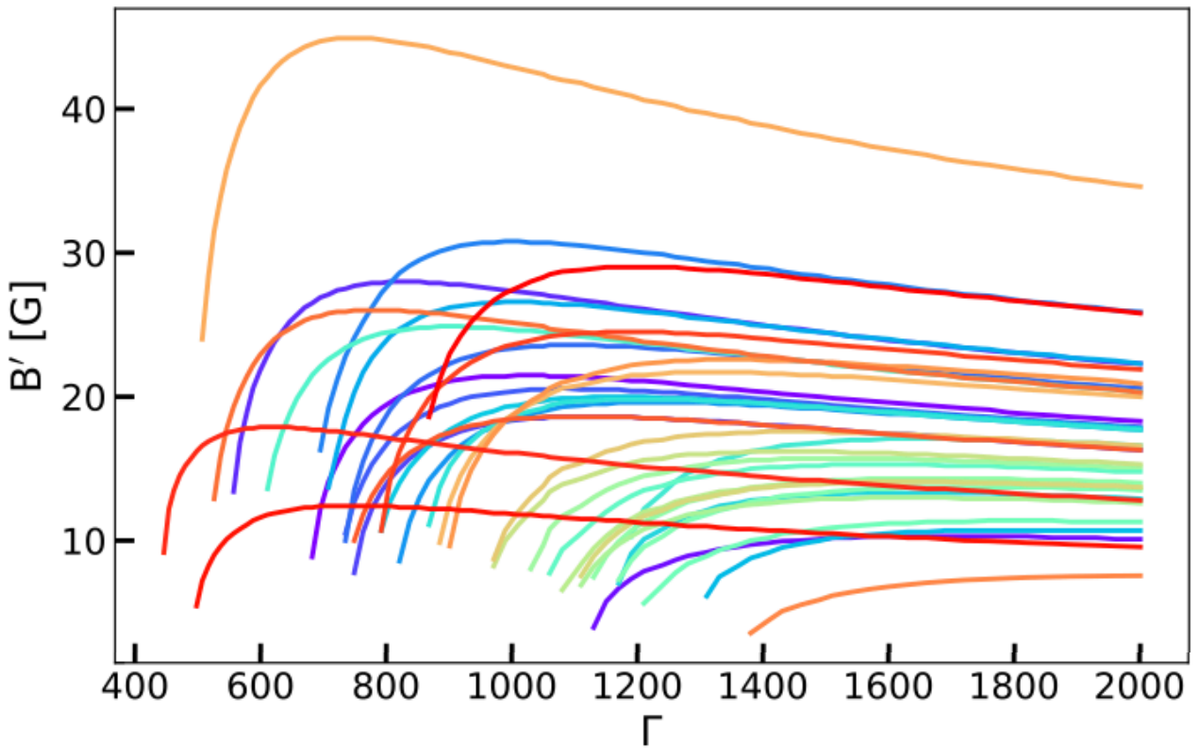
$$F_m, \nu_m, \beta, t_{var}$$

+

$$\boxed{\nu_c}$$

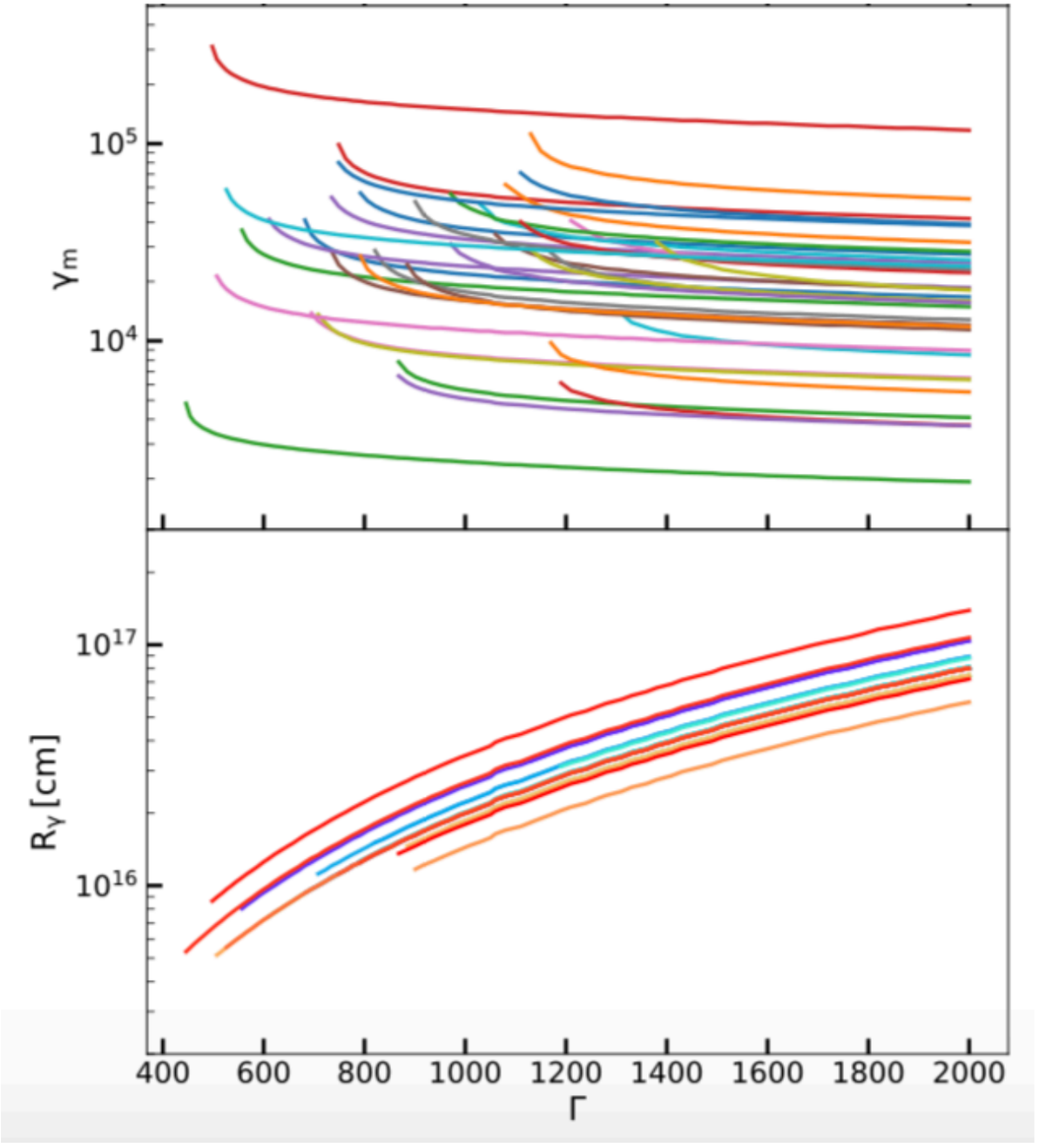
Derishev 2007; Kumar & McMahon 2008; Daigne et al. 2011; Beniamini & Piran 2013,2014; Uhm & Zhang 2014

CONSTRAINTS ON EMISSION REGION



A large cooling frequency (i.e., in the keV band) implies:

- a magnetic field lower than expected
- a large distance *R* of the emitting region
- a population of electrons accelerated to large Lorentz factors



Oganesyan, LN, et al., 2019, A&A, 628, 59