Prompt Emission Properties of Swift GRBs

T. Sakamoto
(CRESST/UMBC/GSFC)
On behalf of Swift/BAT team

101029

101029

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Weight: 5 lbs 8 oz (2490g)
Length: 19” (48cm)

Content

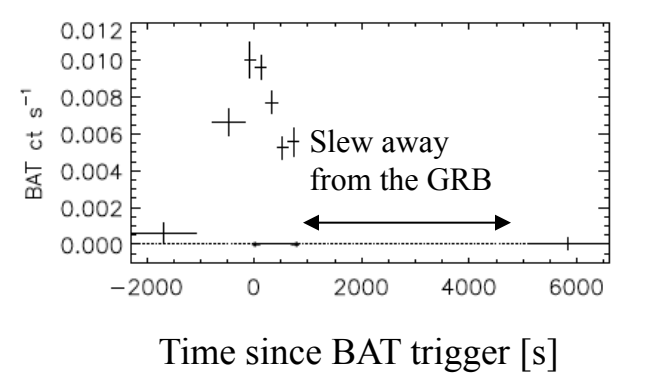
- Highlight on Swift's discovery on 2010
- BAT2 GRB catalog
  - Duration distribution (short GRBs)
  - E_{peak} distribution
  - Line of Death Problem
  - Extra power-law component in the BAT data?
- Pre-/post-burst hard X-ray emission

Discovery on 2010

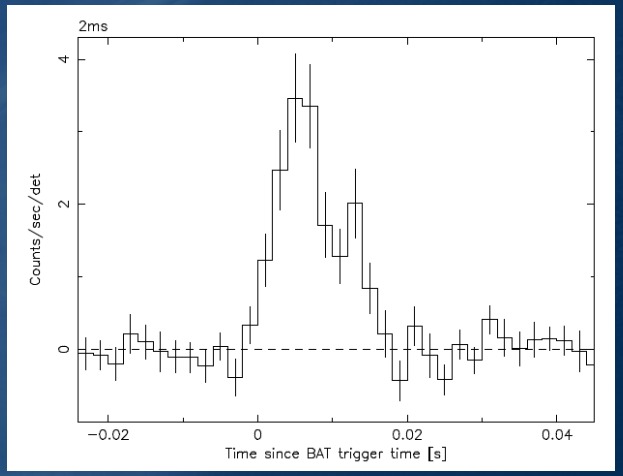
GRB 100316D/SN 2010bh: SN-GRB Association

New SGR 1833-0832

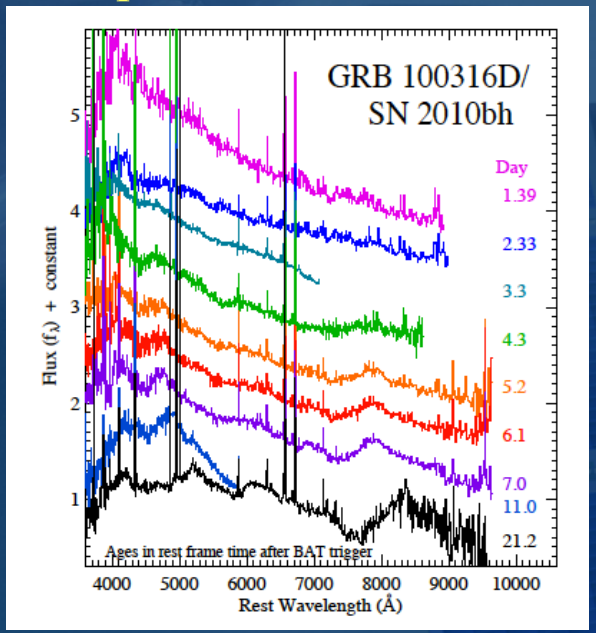
Prompt emission (Starling et al. 2010)



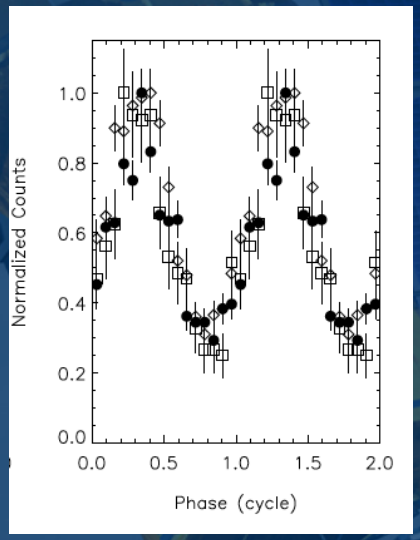
BAT light curve



Optical spectrum (Chornock et al. 2010)



X-ray pulse profile (XRT and RXTE)



- BAT Position
  (l, b) = (23.325^d, 0.009^d)
- Pulsating new X-ray source:
  P=7.56 s, Pdot = 4 x 10^{-12} s/s
  (XRT and RXTE)
- B = 1.8 x 10^{14} G (lower end)

(Gogus et al. 2010)

BAT2 GRB Catalog

(Submitted to ApJS, under the revision…)

BAT2 GRB Catalog

- 476 GRBs (from GRB 041219 to GRB 091221)
  - including 25 GRBs found in ground processing
- 3323 time-resolved spectra
- 146 known-z GRBs

476 GRBs

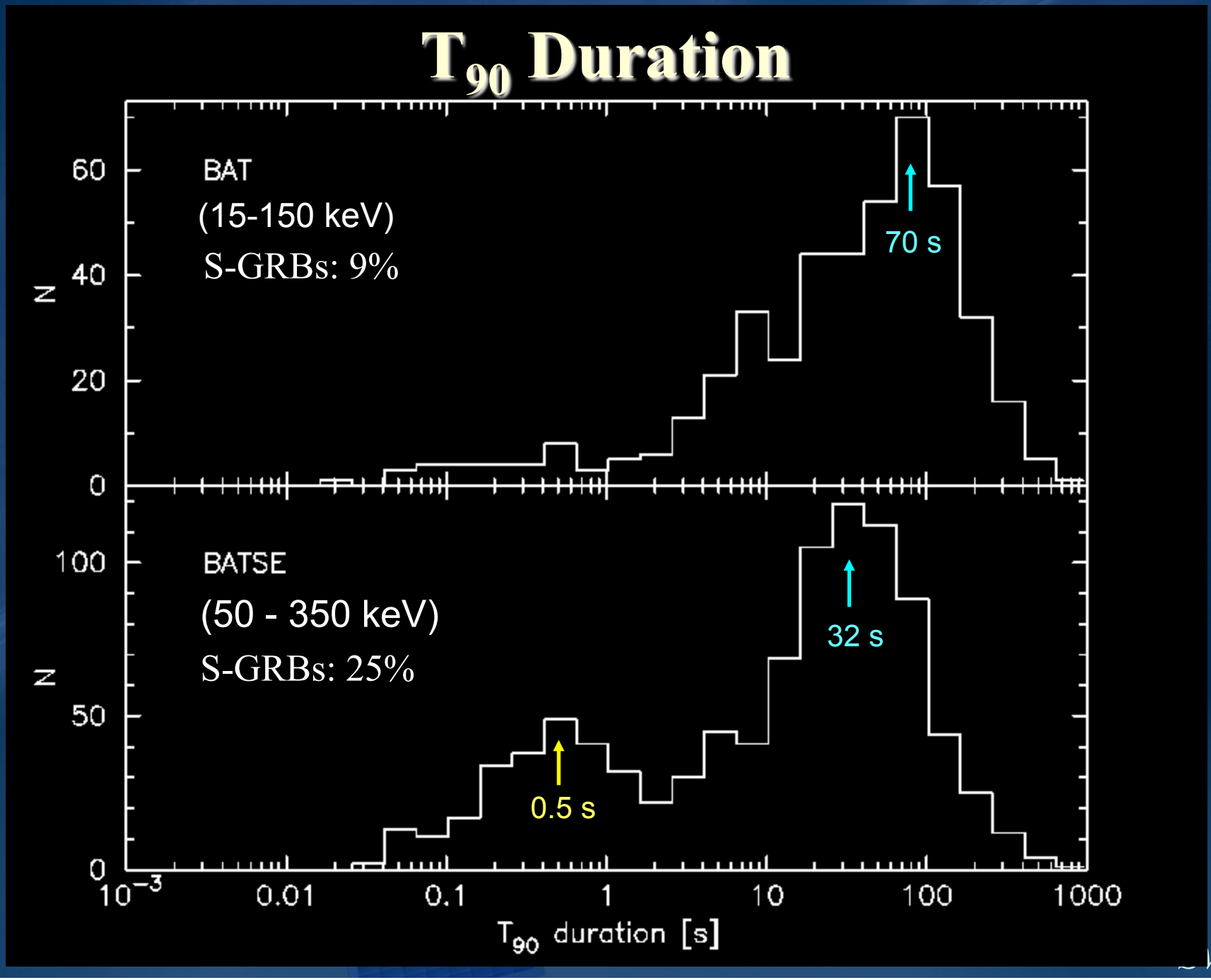
- 426 Long-duration GRBs (L-GRBs) (89%)
- 41 Short-duration GRBs (S-GRBs) (9%)
- 9 Short-duration GRBs with extended emissions (S-GRBs w/ E.E.) (2%)

Working definition of L-GRB vs. S-GRB:

L-GRB: $T_{90} \geq 2$ s

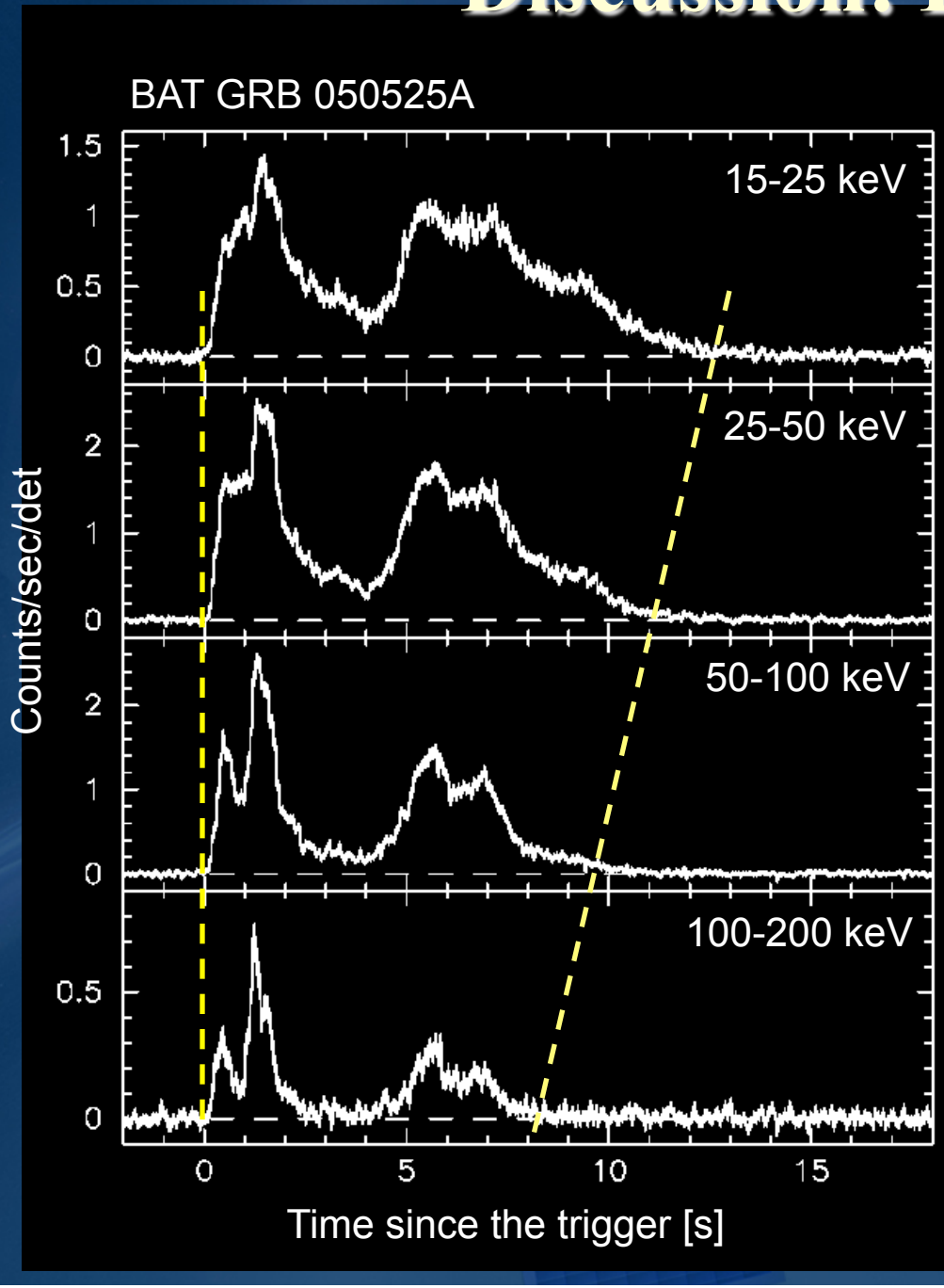
S-GRB: $T_{90} < 2$ s

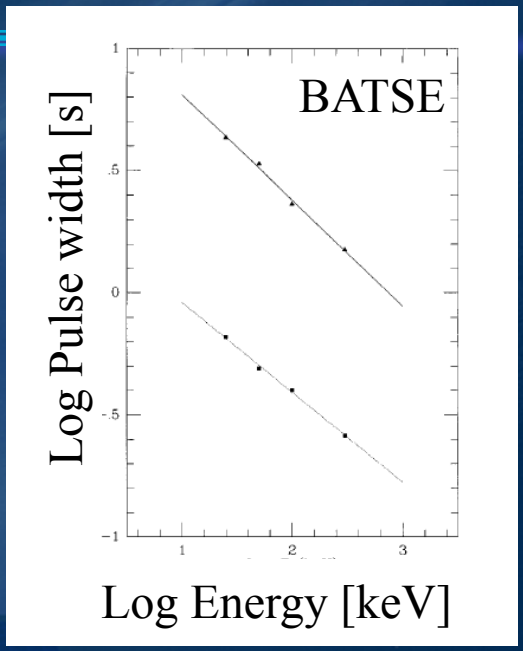
T_{90} Duration



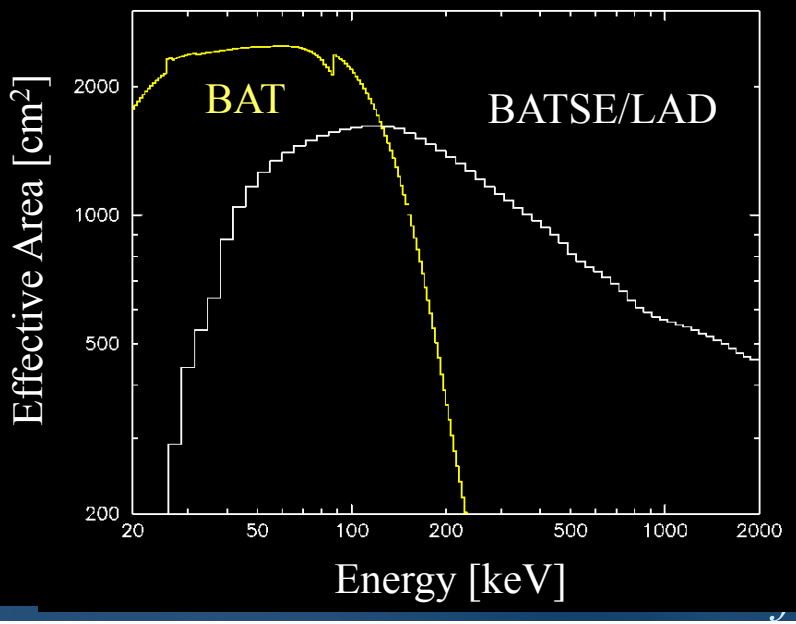
Swift

Discussion: Duration





(Fenimore et al. 1995)



Discussion: Short on S-GRBs in BAT

BAT: 10% S-GRBs (90% L-GRBs)

BATSE: 25% S-GRBs (75% L-GRBs)

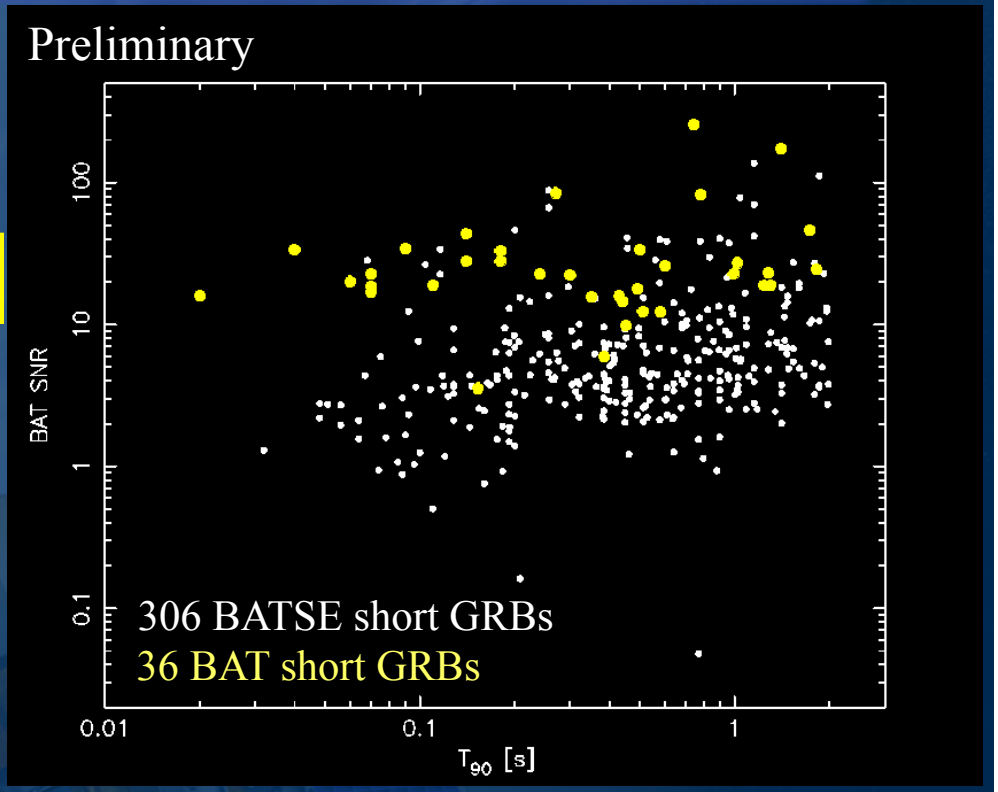
Factor of 2.5 small # on S-GRBs in BAT

BATSE
- Rate trigger

vs.

BAT
- Rate trigger
- Imaging

BATSE complete spectral catalog
(Goldstein, Preece & Mallozzi)



BATSE short GRBs Band spectral parameters

↓

BAT energy response (30^d) + background

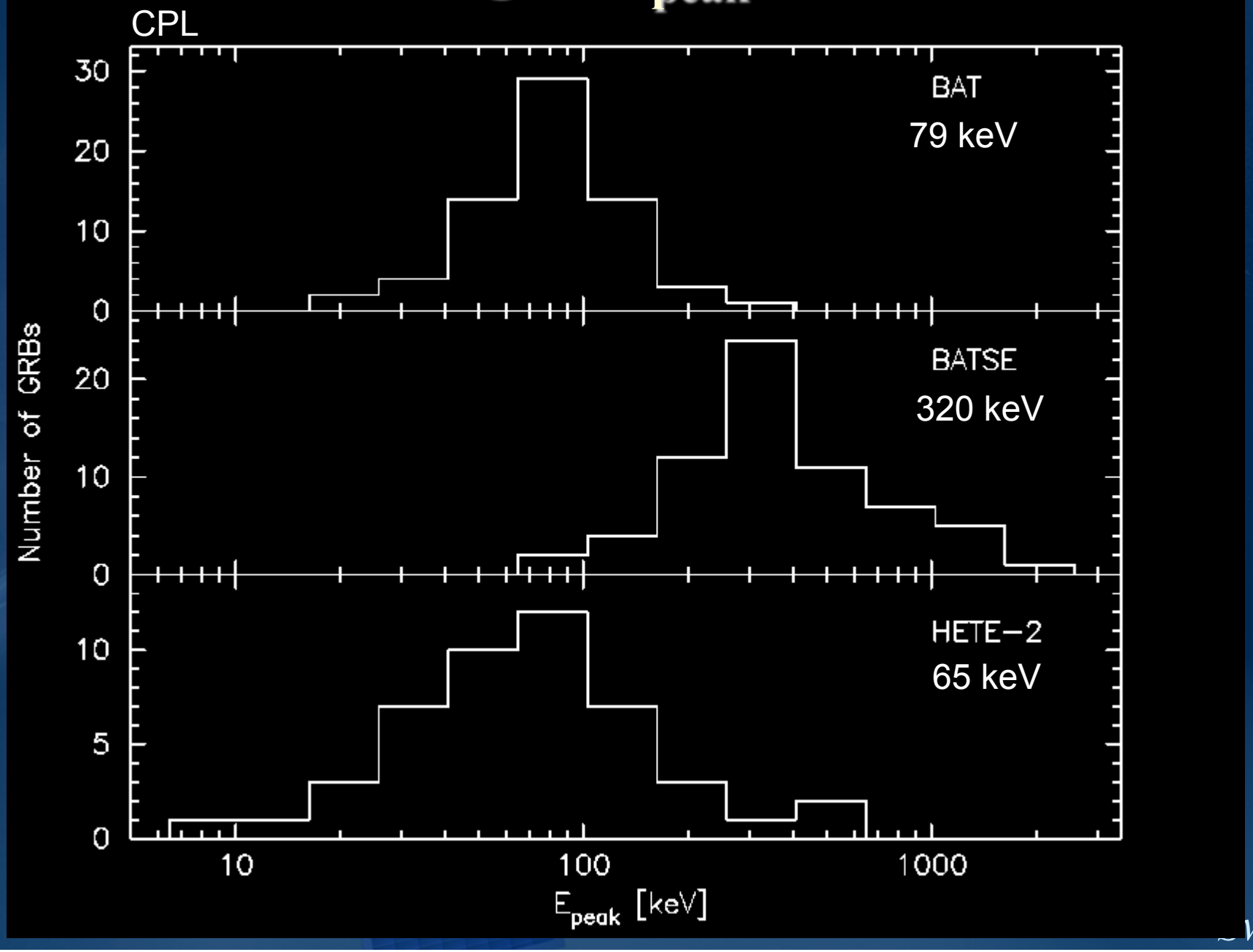
↓

Simulate BAT fg/bg spectrum → SNR

SNR > 10: 62 BATSE short GRBs
4% of total BATSE GRBs
20% of BATSE short GRBs

Majority of the BATSE short GRBs is too faint in BAT

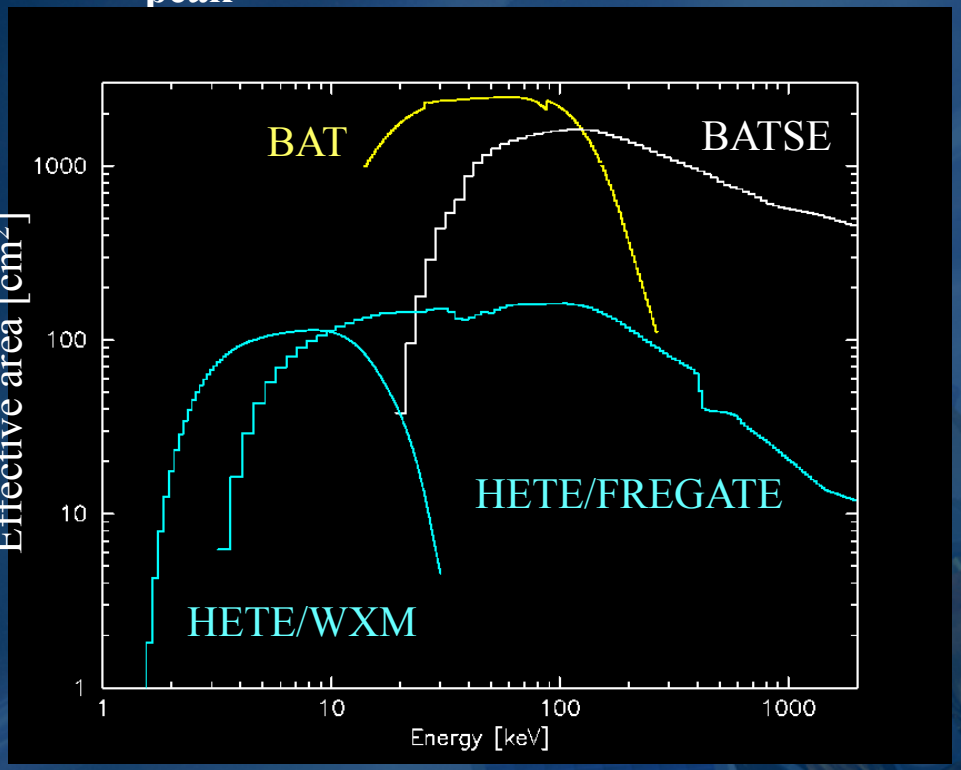
Time-averaged E_{peak} distribution



Swift

Discussion: E_{peak}

(1) E_{peak} distribution



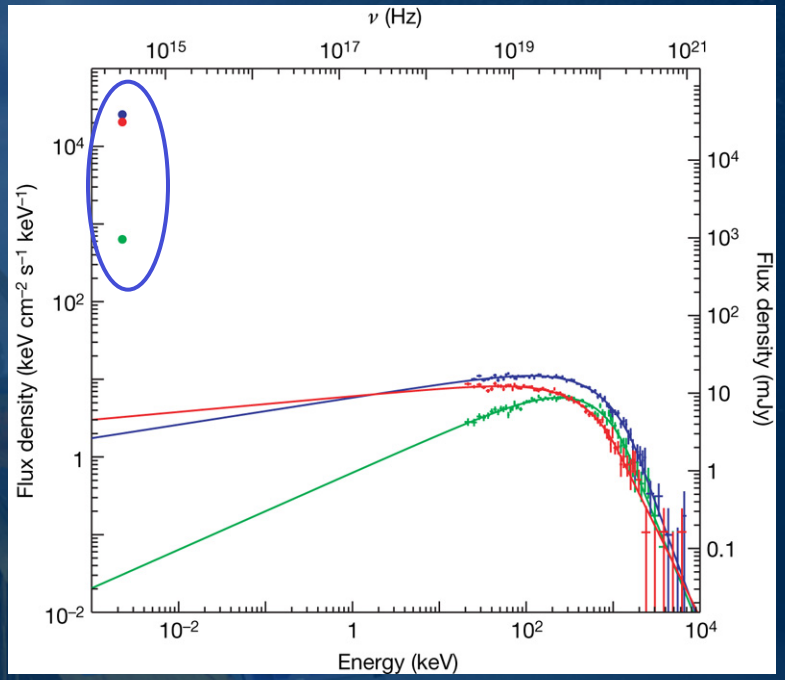
- Broad single E_{peak} distribution

Open questions:

- Where is a lower/upper limit of E_{peak}?

(2) What is E_{peak}?

E_{peak} : Peak of the Synchrotron spectrum



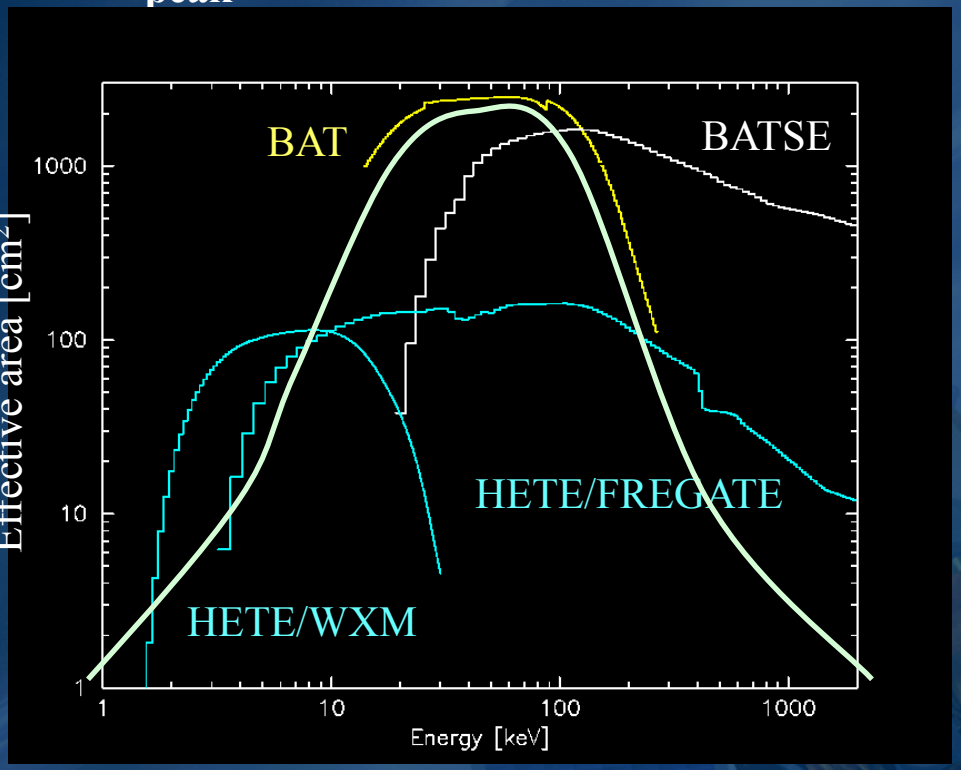
(Racusin et al. 2008)

E_{peak} : Inverse Compton peak?

Broad-band observation (from radio to gamma-ray) of the prompt emission is a key!

Discussion: E_{peak}

(1) E_{peak} distribution



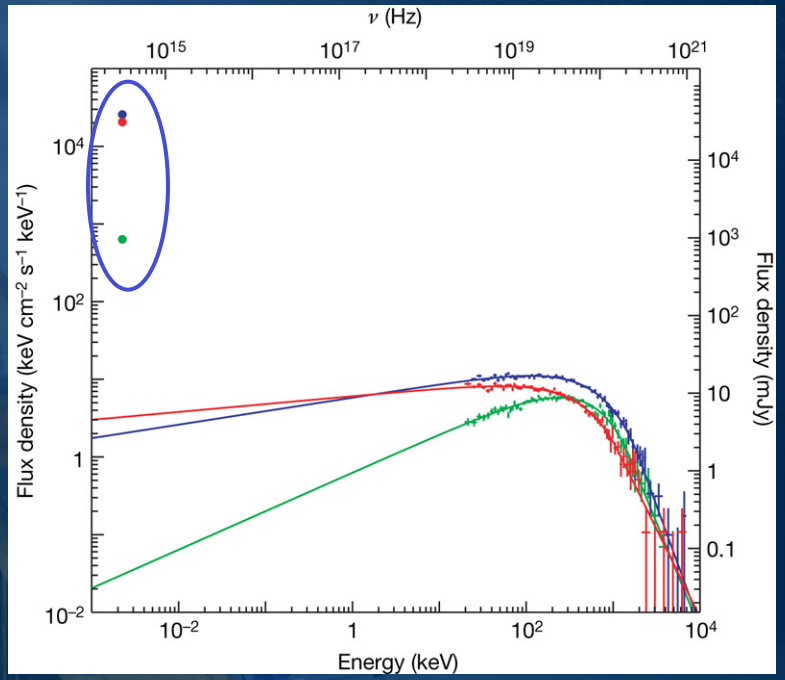
- Broad single E_{peak} distribution

Open questions:

- What is the intrinsic distribution of E_{peak}?

(2) What is E_{peak}?

E_{peak} : Peak of the Synchrotron spectrum



(Racusin et al. 2008)

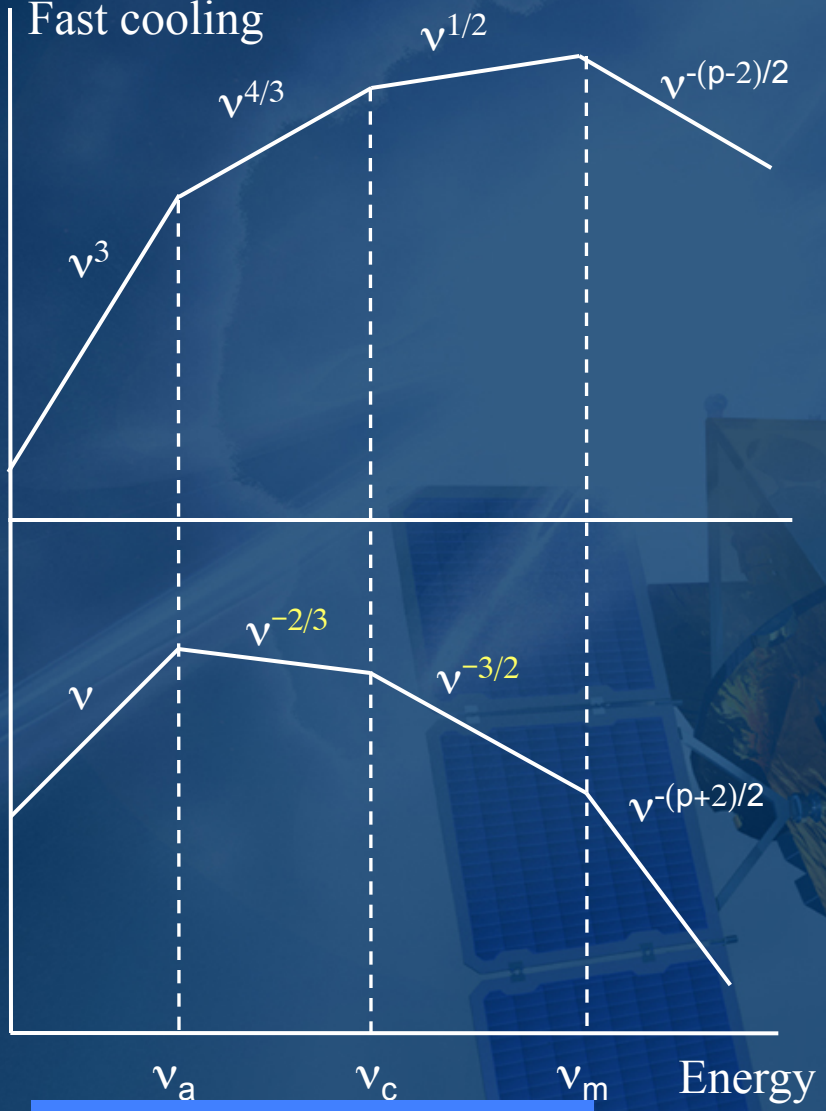
E_{peak} : Inverse Compton peak?

Broad-band observation (from radio to gamma-ray) of the prompt emission is a key!

Line of Death Problem

Synchrotron Shock Model (SSM)

Fast cooling



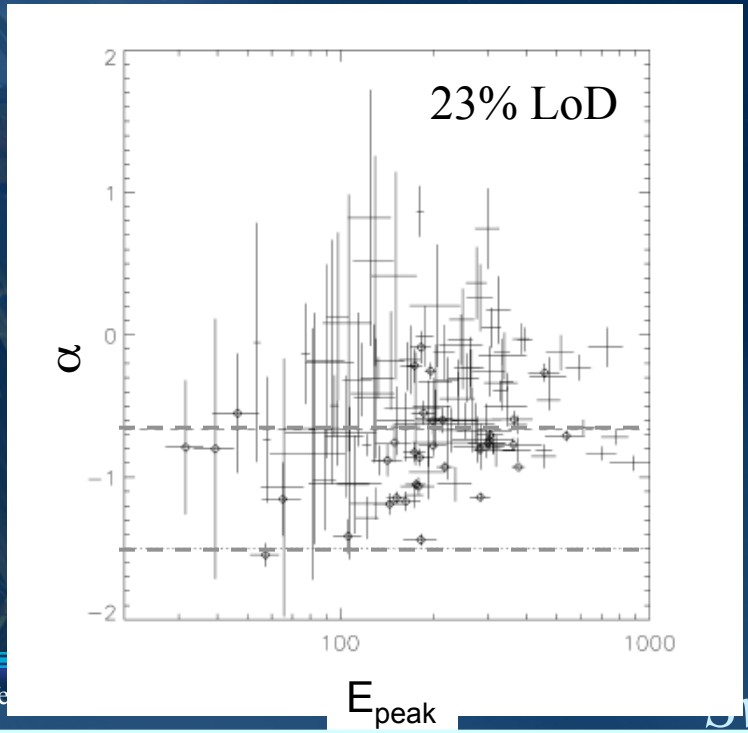
(e.g. Sari et al. 1996, 1998)

$N(\gamma_e)\, d\gamma_e \sim \gamma_e^{-p}\, d\gamma_e \quad (\gamma_e \geq \gamma_m)$

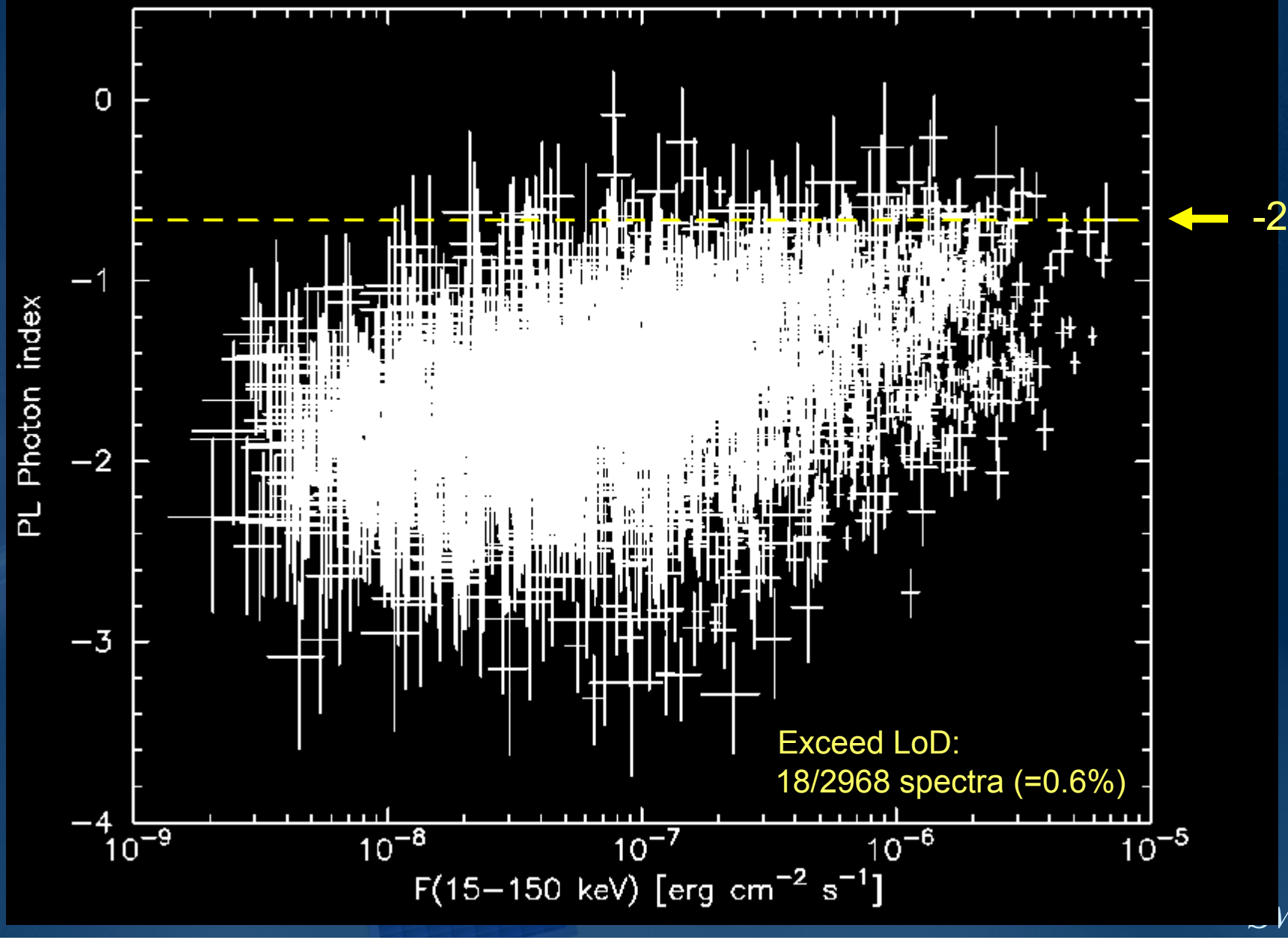
ν_a : self-absorption frequency
ν_c : cooling frequency
ν_m : synchrotron frequency of the minimum-energy electrons

BATSE time-resolved spectra

(Preece et al. 1998)

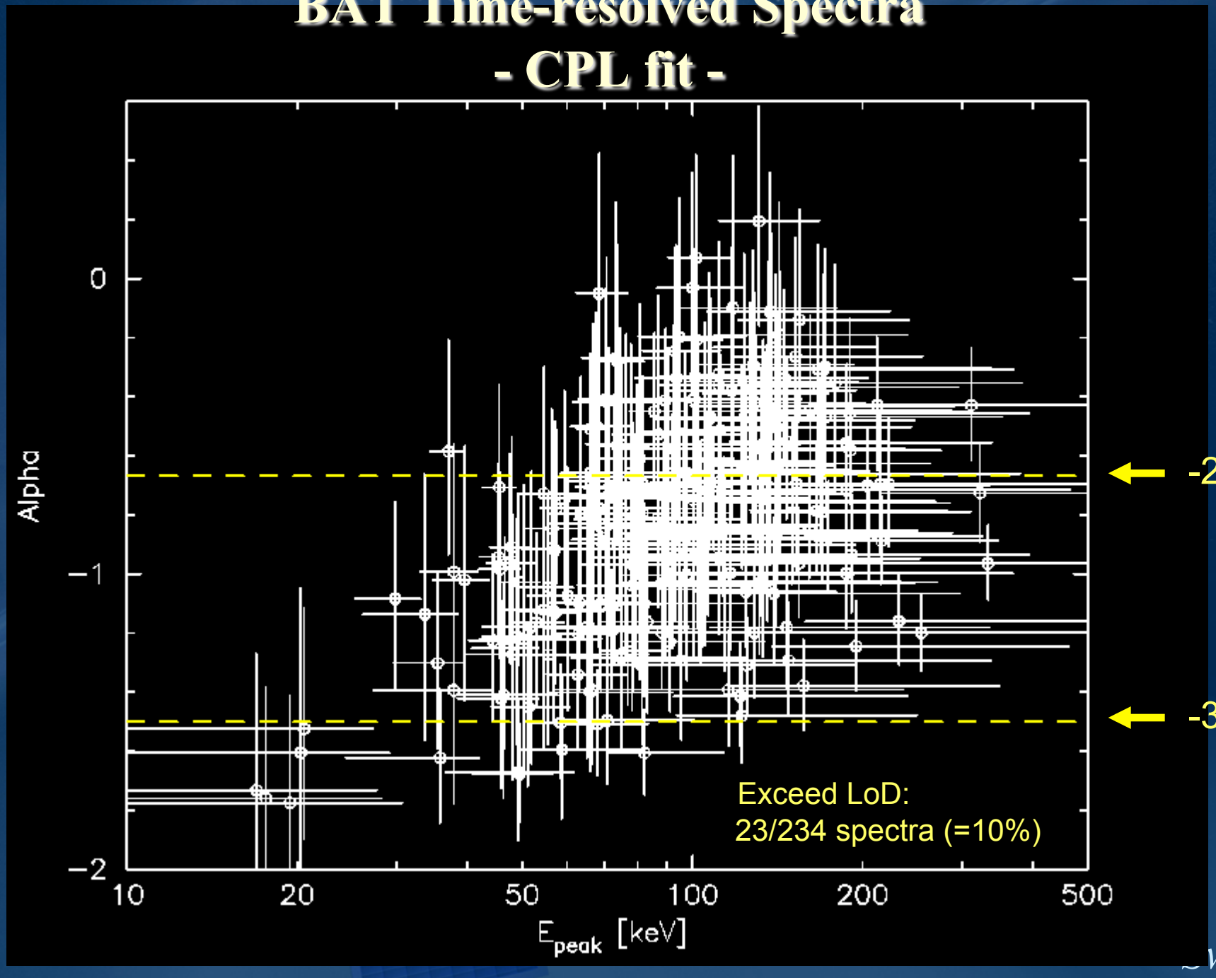


BAT Time-resolved Spectra
- PL fit -



Swift

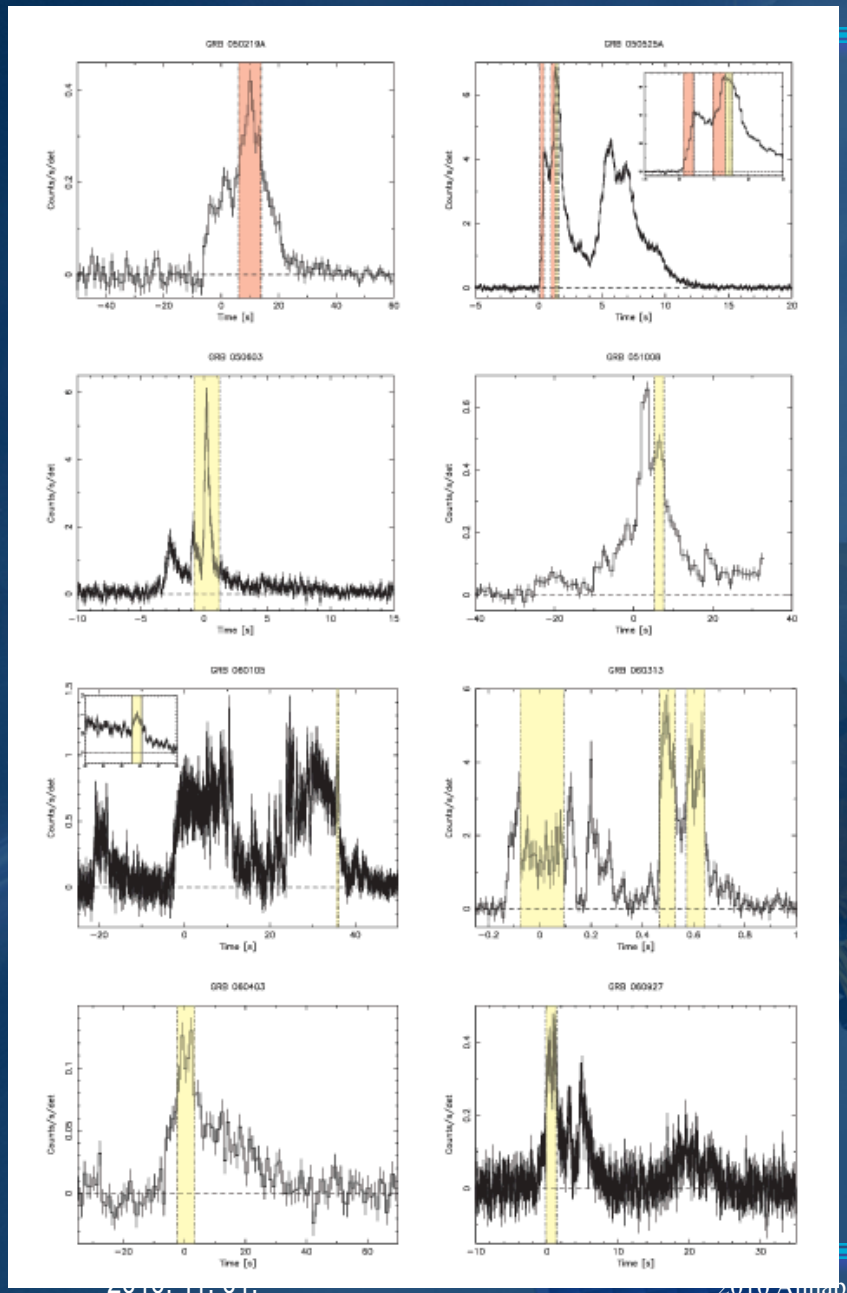
BAT Time-resolved Spectra
- CPL fit -

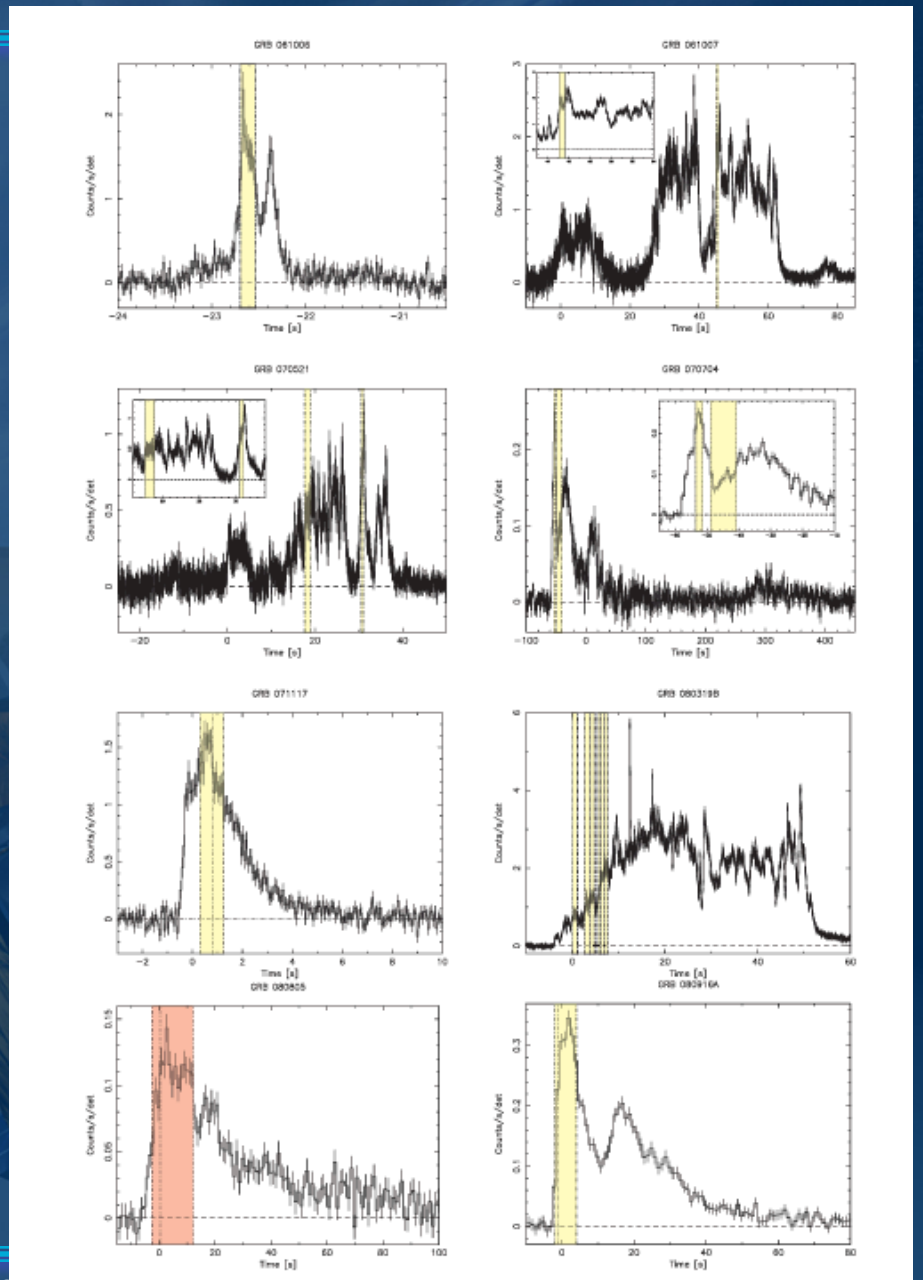


Swift

Examples of LoD intervals

>1.6σ
>3.2σ





Swift

Examples of LoD intervals

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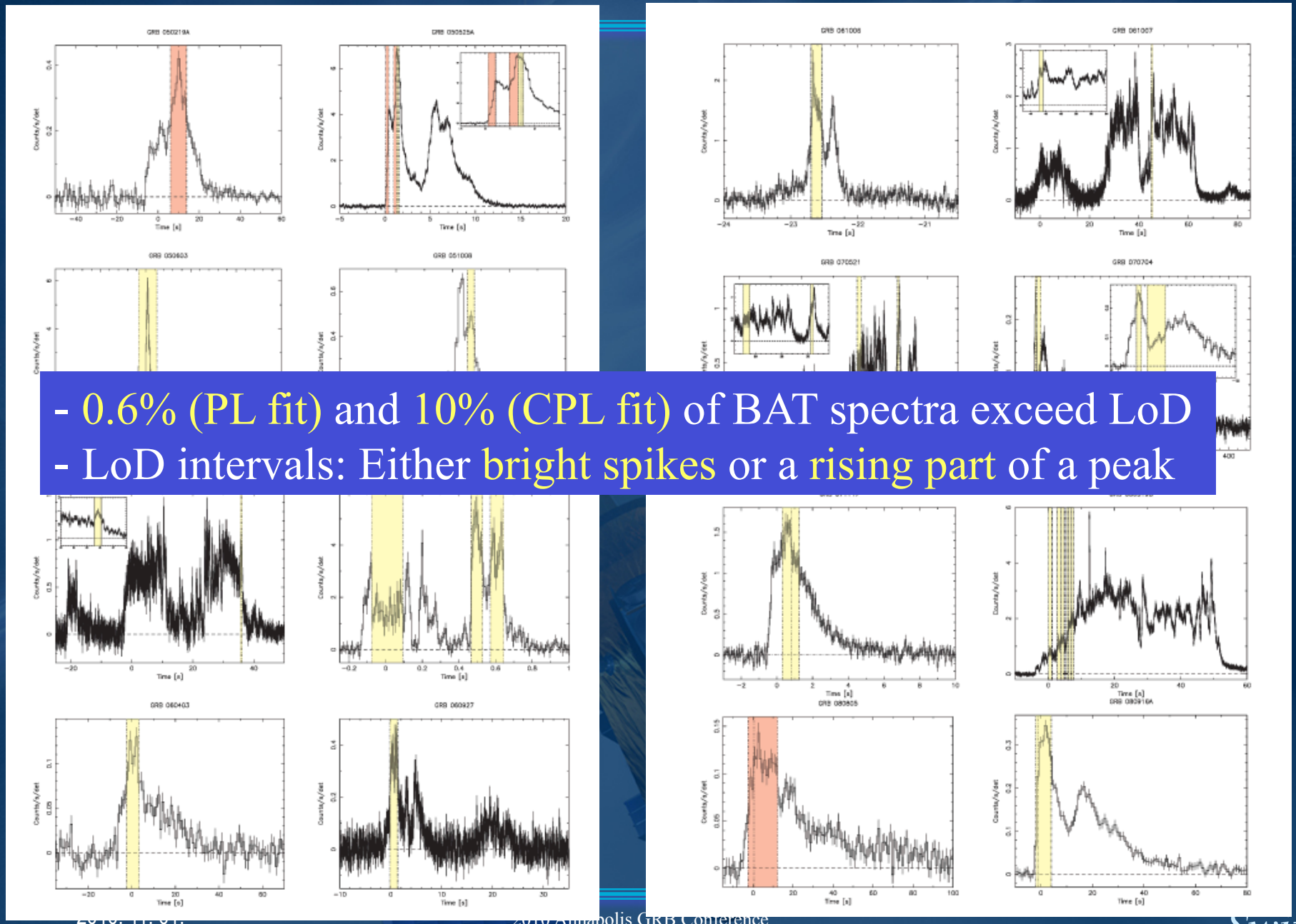
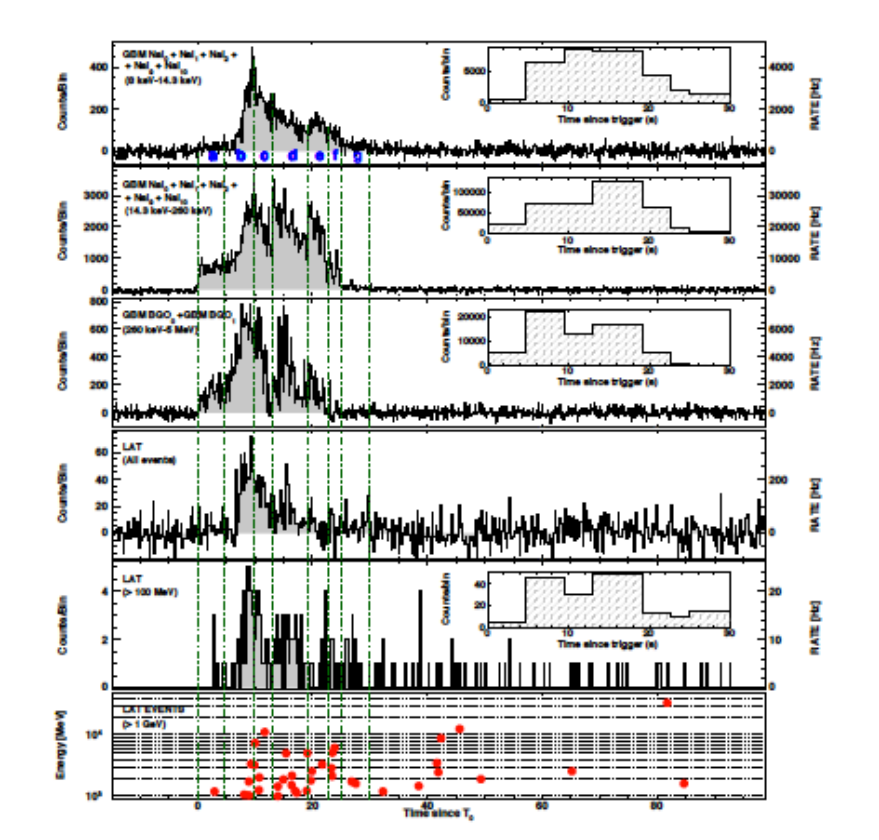


- 0.6% (PL fit) and 10% (CPL fit) of BAT spectra exceed LoD
- LoD intervals: Either bright spikes or a rising part of a peak

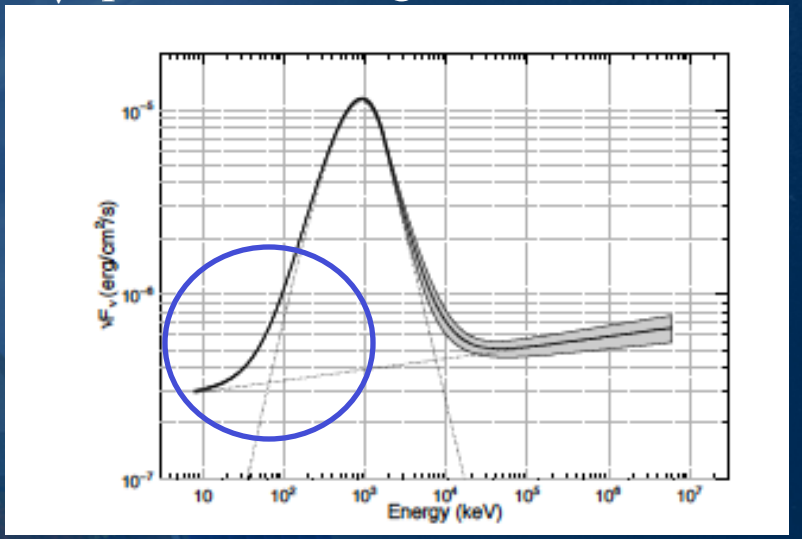
Swift

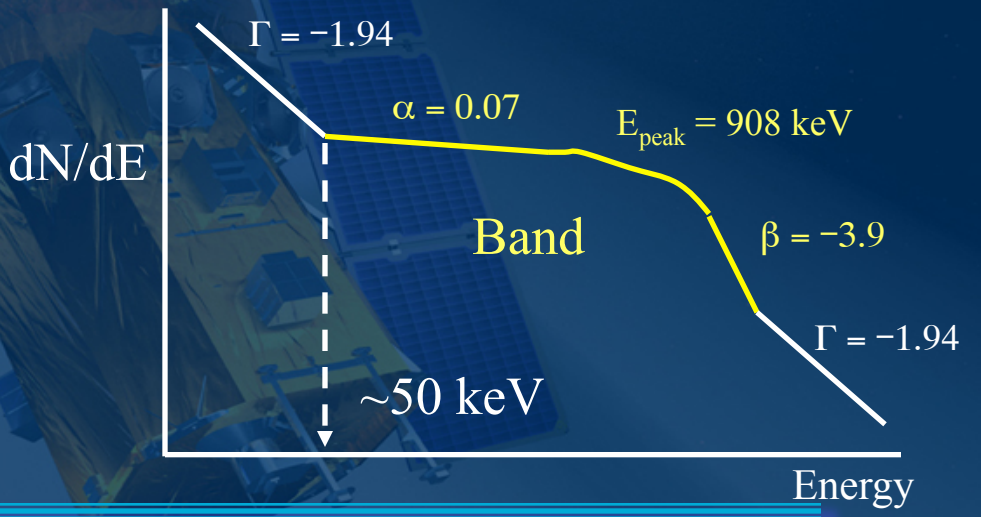
Extra power-law component in the BAT spectra?

Fermi GRB 090902B (Abdo et al. 2009)



νF_ν spectrum of region b



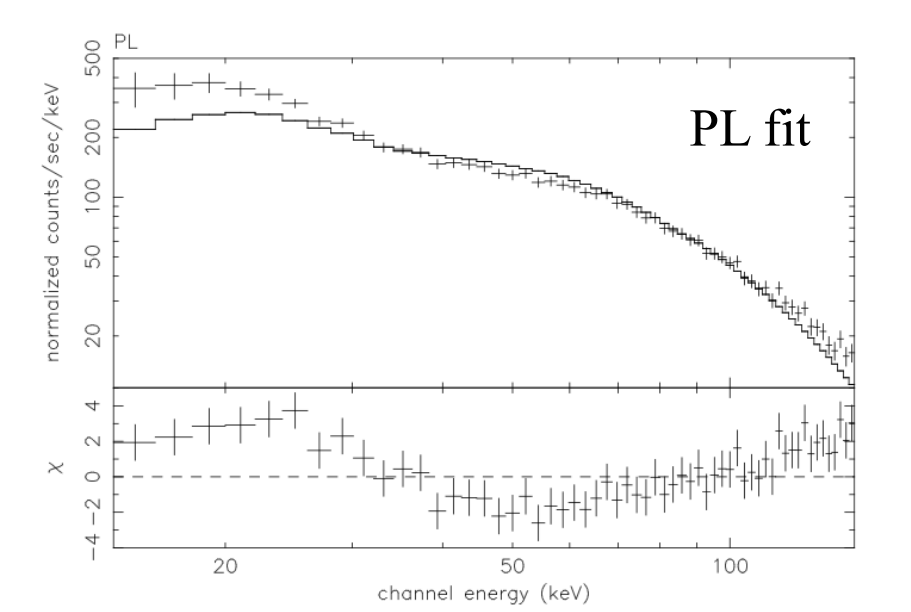


Extra power-law component in the BAT spectra?

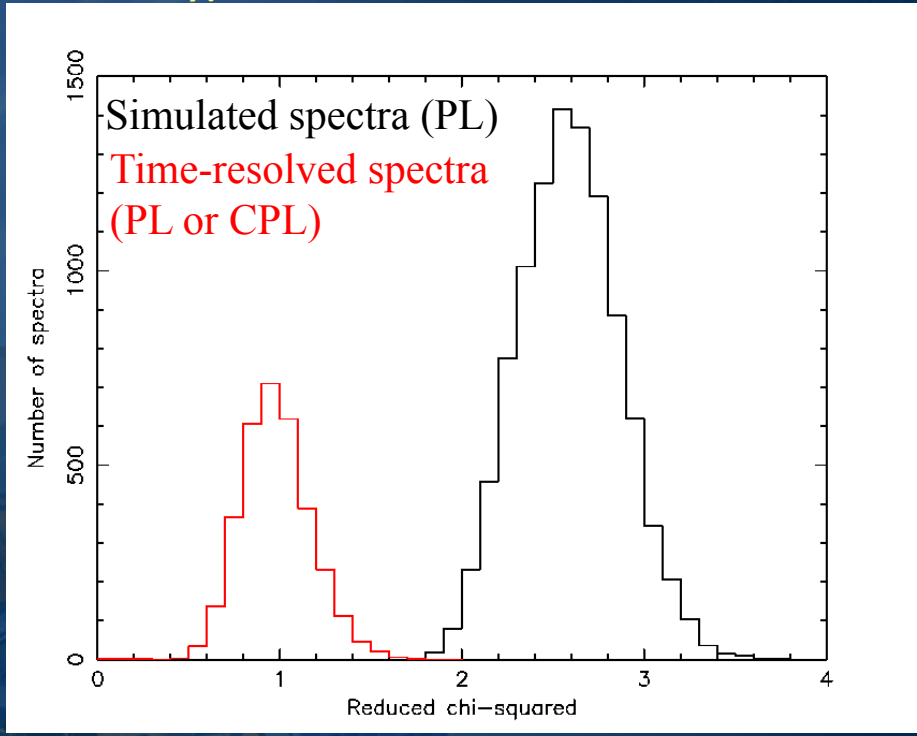
BAT spectral simulation of region b

- 30 deg off-axis BAT energy response
- including real background data
- xspec fakeit 10,000 simulations
- fit by PL and CPL

Example of BAT simulated spectrum of reg b



Reduced χ^2 distribution



- 99.97% of the simulated spectra $\chi^2_\nu > 1.7$
- 2/3284 (0.06%) of the BAT time-resolved spectra $\chi^2_\nu > 1.7$

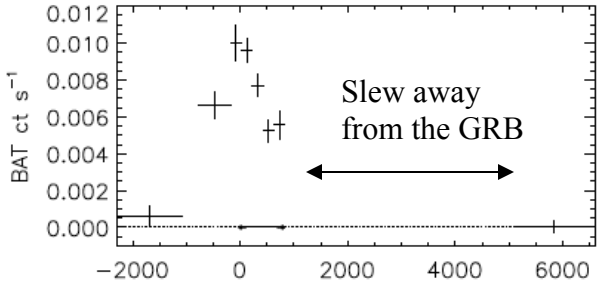
BAT hasn't seen such a spectral feature…

Summary

- Duration: long GRB T_{90} ~ 70 s
  - ➔ longer duration at softer energy band
  - : lack of short GRBs
  - ➔ localizing bright end of BATSE short GRBs
- E_{peak}: Strong instrumental selection bias
  - ➔ broad-band observation of the prompt emission
- Line of Death: ~1% (PL) and ~10% (CPL) violate LoD limit
  - ➔ Either bright or rising part of the peak
- Extra power-law component: No

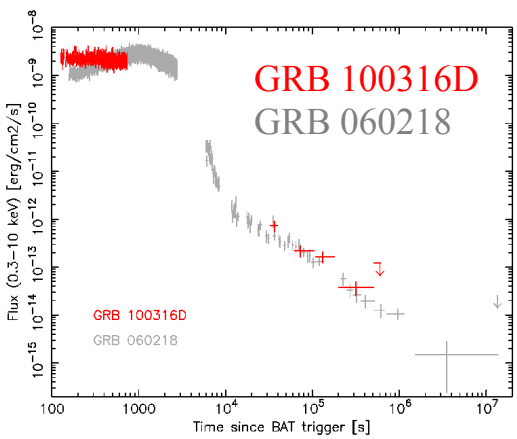
GRB 100316D/SN 2010bh: SN-GRB Association

Prompt emission

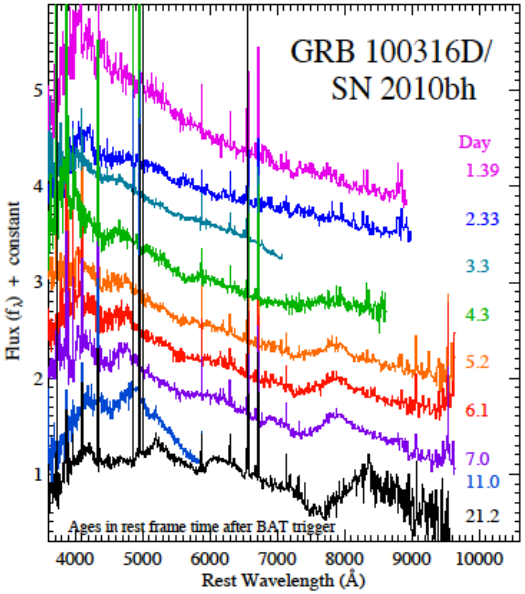


(Starling et al. 2010)

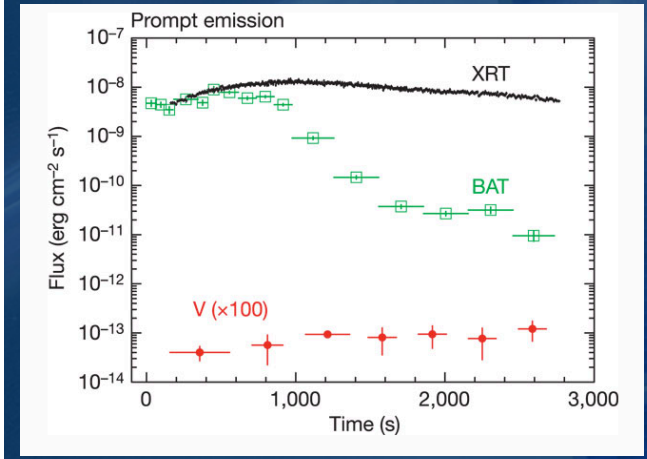
X-ray afterglow



Optical spectrum

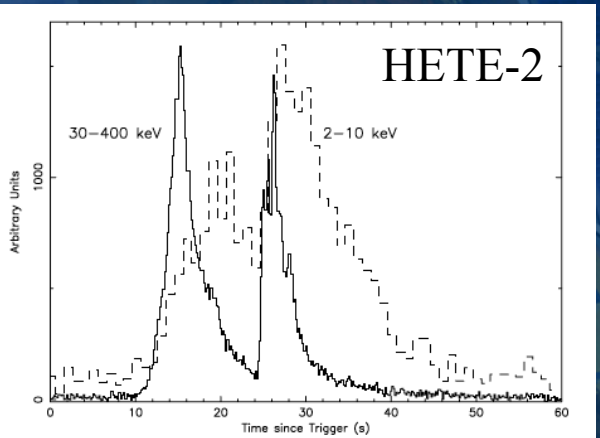


c.f. GRB 060218



(Campana et al. 2006)

c.f. GRB 030329/SN 2003dh



(Vanderspek et al. 2004)

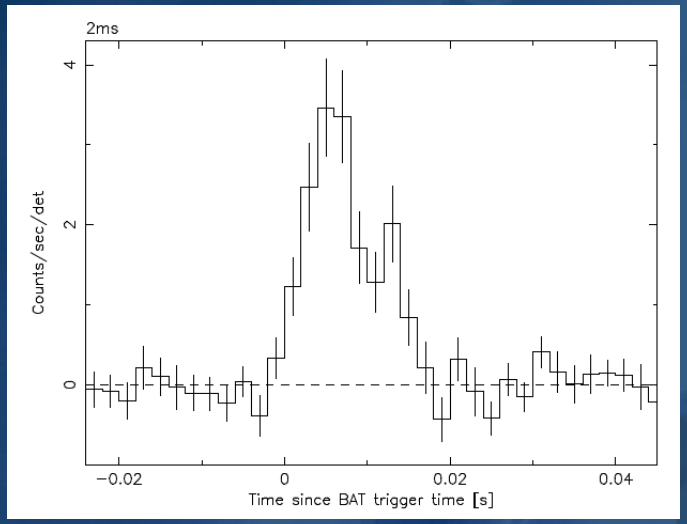
- z = 0.0593
- Type Ic
- v ~ 26,000 km/s@21 days (2x SN 1998bw)
- No evidence of helium
- Low metallicity host

(Chornock et al. 2010)

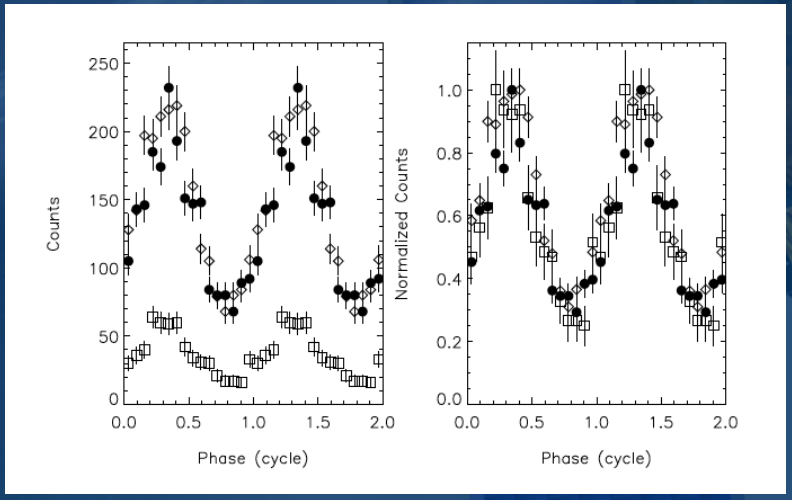
New SGR 1833-0832

(Gogus et al. 2010)

BAT light curve



X-ray pulse profile (XRT)

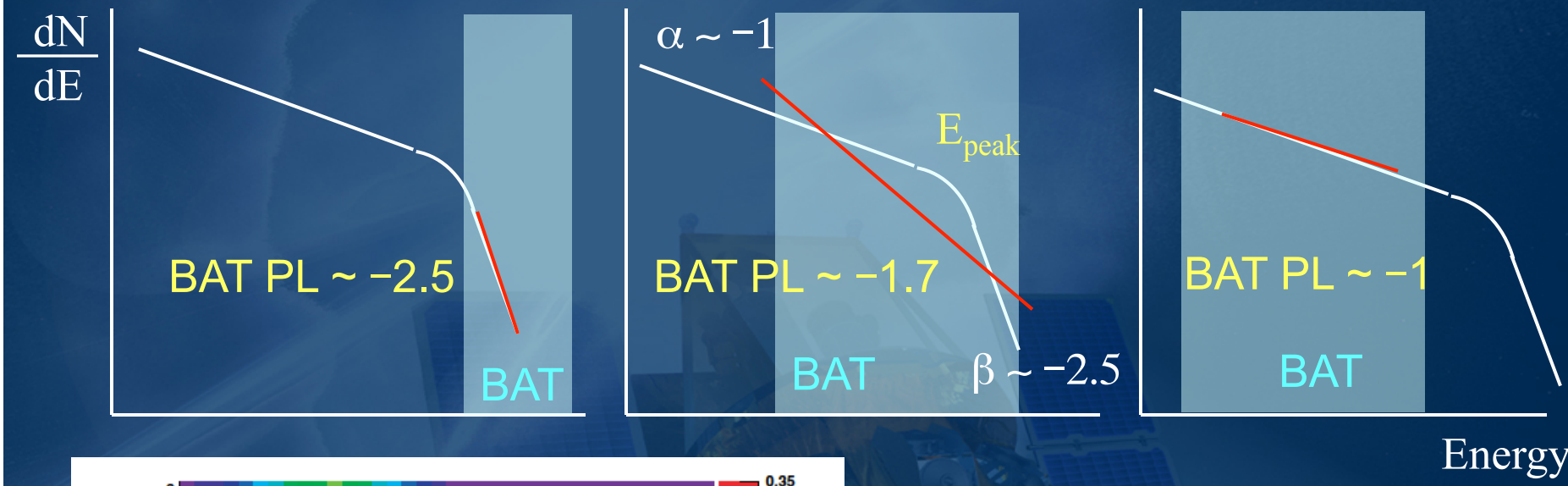


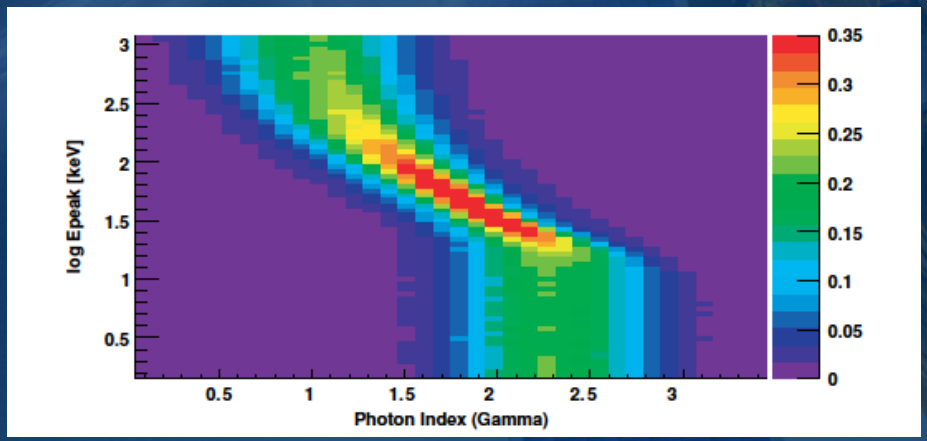
- March 19, 2010 18:34:50.78 UT
- BAT Position ($18^h33^m46^s$, $-8^d32^m13^s$)
  (l, b) = (23.325^d, 0.009^d)
- BAT spectrum fit well with BB (kT=10 keV) instead of PL
- Very faint X-ray source by XRT (Issue GCN Circ. "Possible new SGR")

- Pulsating new X-ray source: P=7.56 s, Pdot = 4×10^{-12} s/s (XRT and RXTE)
- Sub-arcsec position by Chandra
- No burst detection by Fermi/GBM; four weak bursts detected by RXTE/PCA
- No obvious IR (UKIRT) and radio (WSRT) counterpart
- B = 1.8×10^{14} G (lower end)

Interpretation of BAT PL index

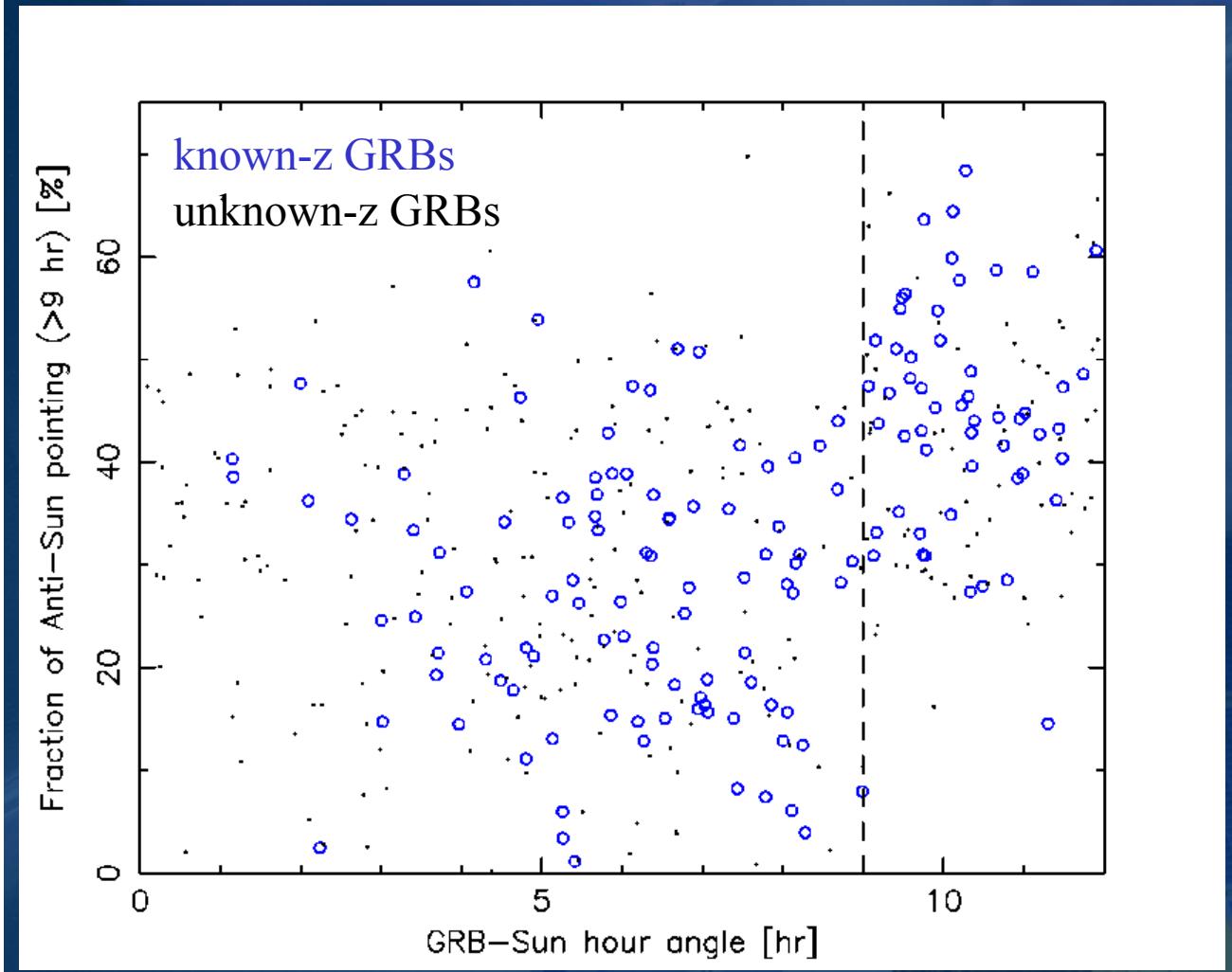
(1) $E_{BAT} < E_{peak}$ (2) $E_{BAT} < E_{peak} < E_{BAT}$ (3) $E_{peak} > E_{BAT}$





- BAT PL photon index does inform about E_{peak}.
- ~75 % of BAT GRBs: E_{peak} is very likely located inside the BAT energy range (Sakamoto et al. 2009).

Anti-Sun Pointing Matters!



Redshift determination rate by different Sun hour angle (GRB_{Sun}) of GRBs

GRB_{Sun} > 9 hr: 45%
6 hr < GRB_{Sun} ≤ 9 hr: 47%
3 hr < GRB_{Sun} ≤ 6 hr: 34%
0 hr < GRB_{Sun} ≤ 3 hr: 10%

Anti-Sun pointing has a strong effect in redshift determination of Swift GRBs