Prompt Emission Properties of Swift GRBs

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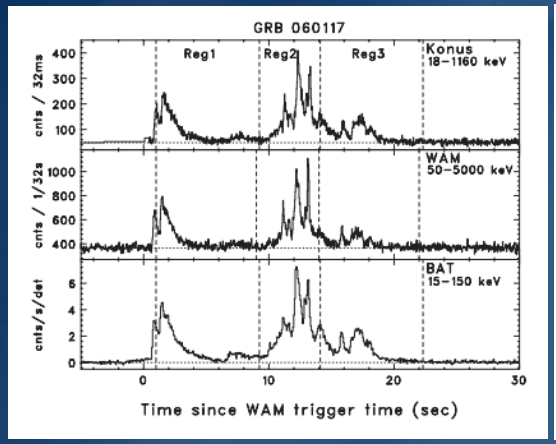
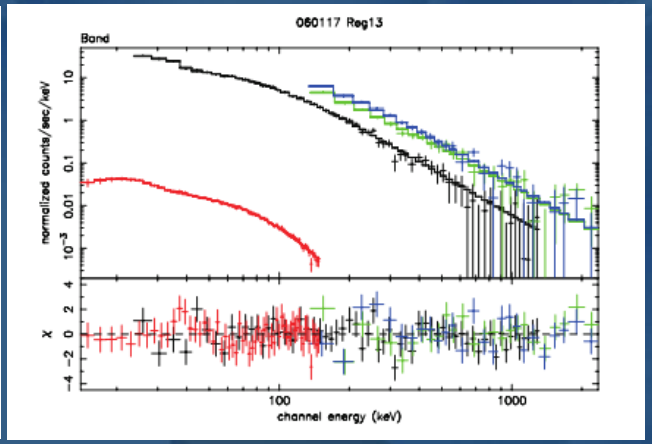
Outline

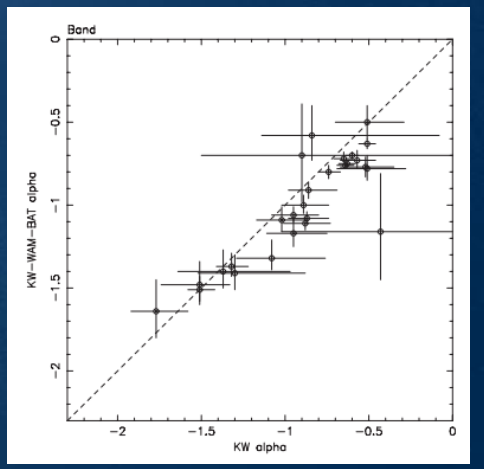
- Collaboration with KW team
- BAT 3rd GRB catalog
  - Duration and hardness
  - Global properties of BAT GRBs
  - Pre-/Post-GRB emission (survey data)

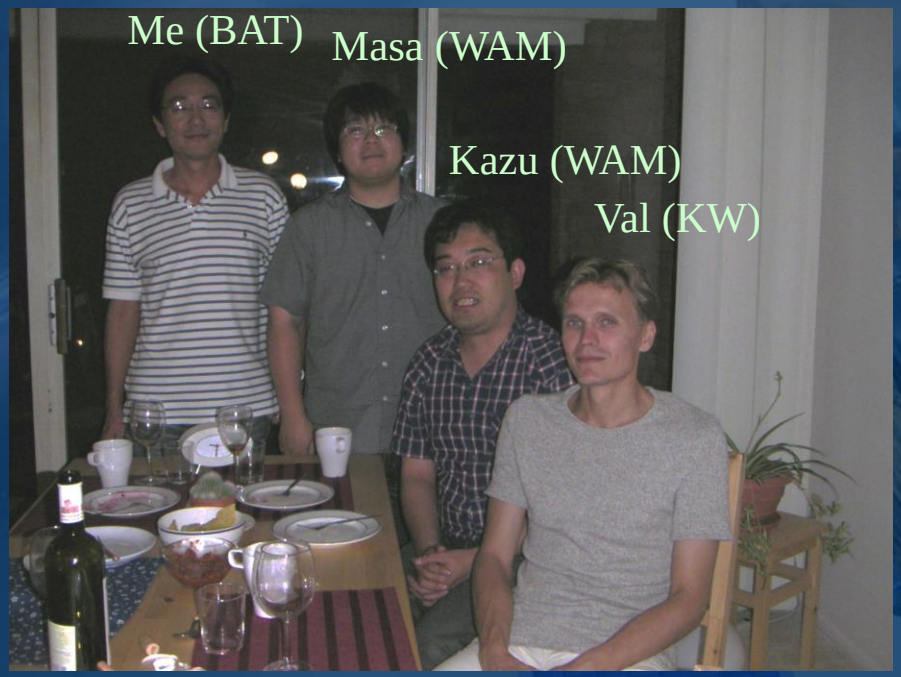
Collaboration with Konus-Wind

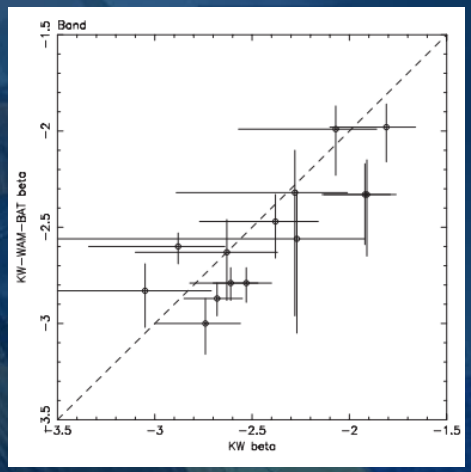
Spectral cross-calibration work (8/1/06-8/22/06 @ NASA/GSFC)

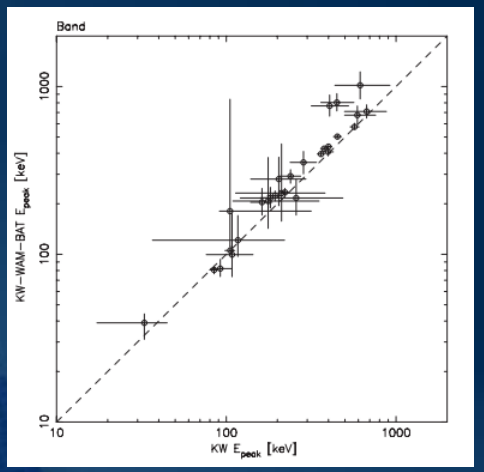












"Spectral Cross-Calibration of the Konus-Wind, the Suzaku/WAM, and the Swift/BAT Data Using Gamma-Ray Bursts," T. Sakamoto, V. Pal'shin, K. Yamaoka, M. Ohno et al., PASJ, 63, 215 (2011)

BAT 3rd GRB Catalog

Lien, Sakamoto et al. in prep.

BAT 3rd GRB Catalog

Lien et al. in prep.

- 833 GRBs (from GRB 041217 to GRB 140215A),
  778 GRBs are presented here (BAT2 cat: 476 GRBs)
- 331 known-z GRBs
- BAT survey data are also analyzed to search for pre/post GRB emission

778 GRBs

- 717 Long-duration GRBs (L-GRBs) (92%)
- 61 Short-duration GRBs (S-GRBs) (8%)
  (13 short GRBs with E.E.)

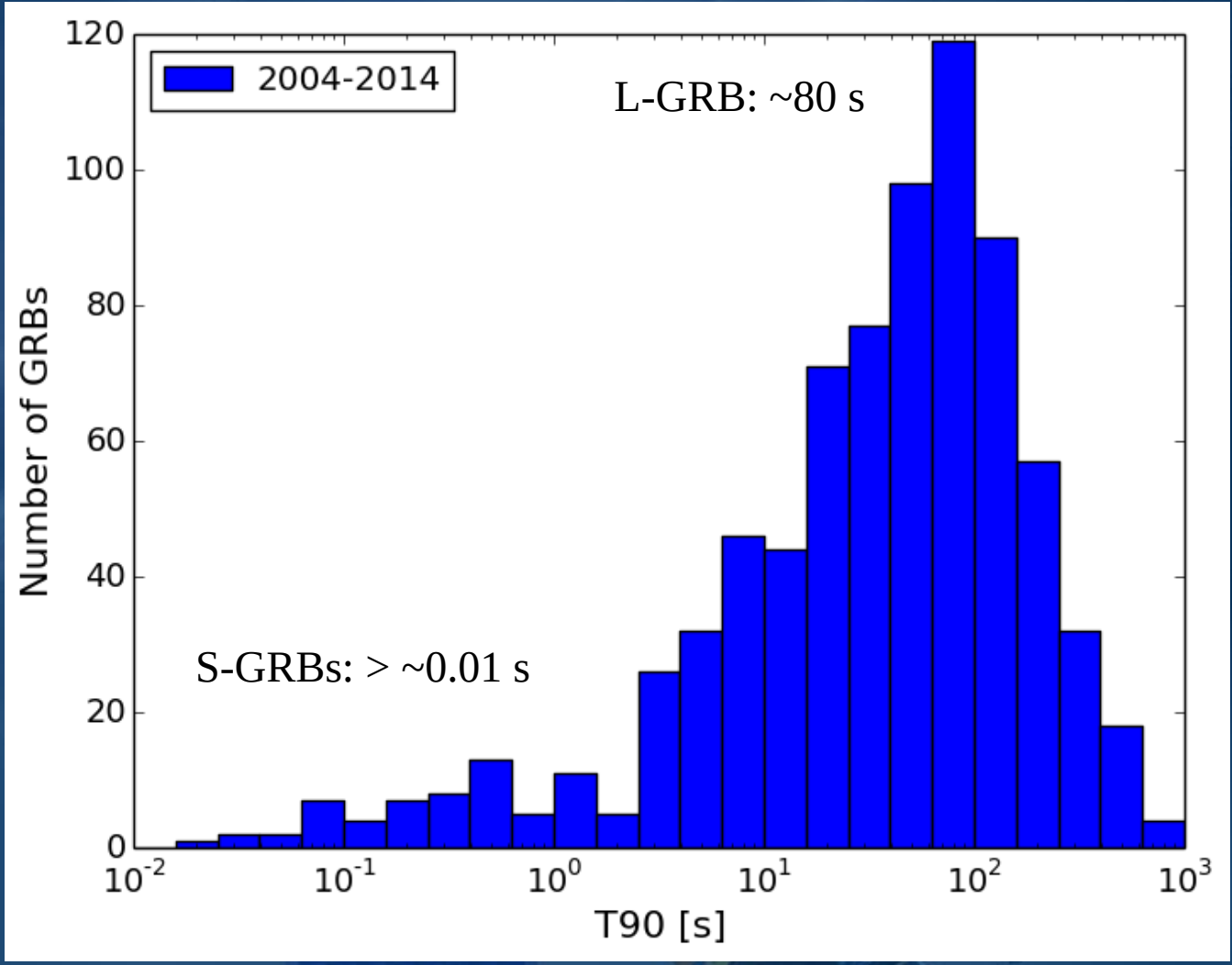
Working definition of L-GRB vs. S-GRB:

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

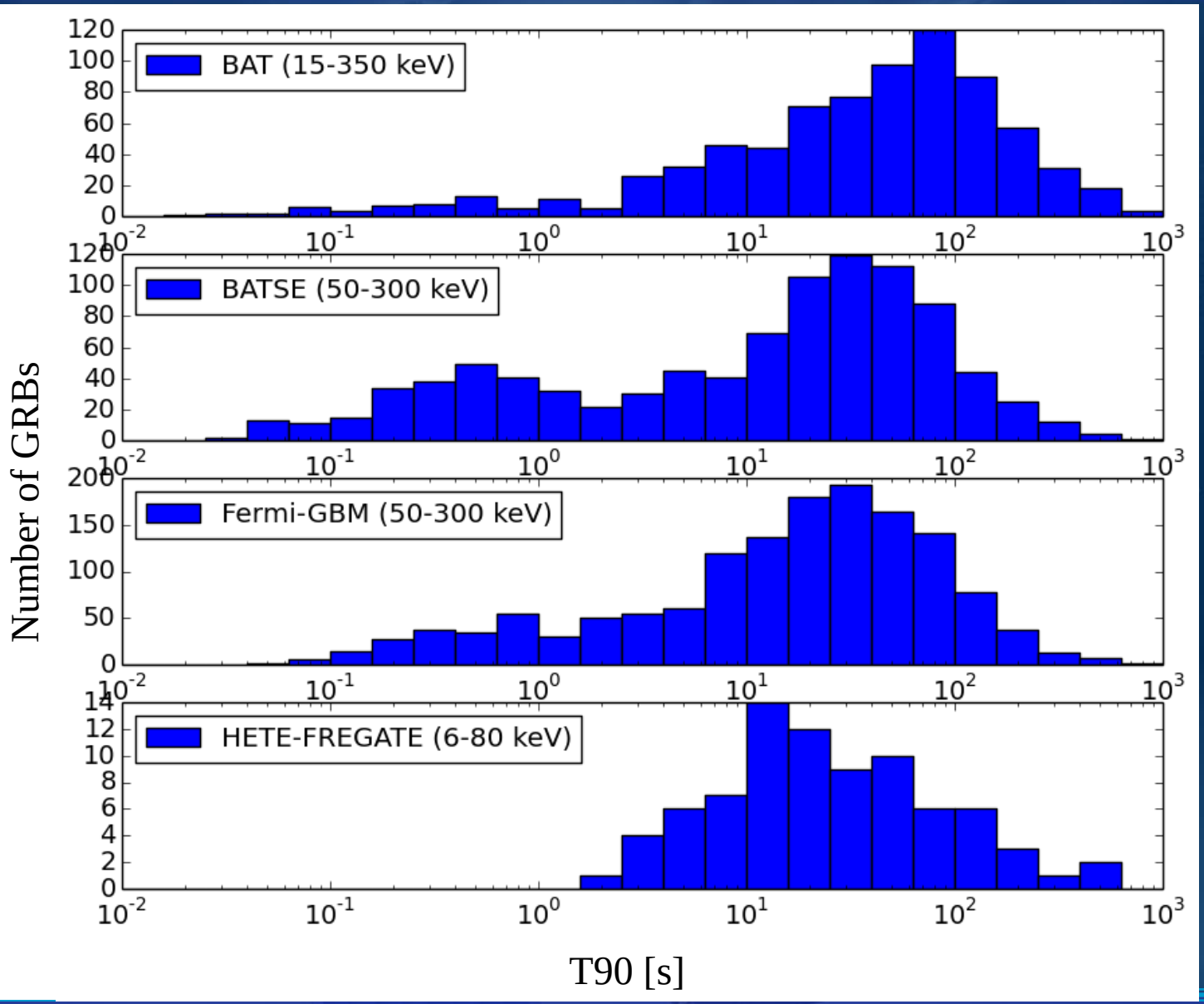
S-GRB: $T_{90} < 2$ s

Duration

BAT T_{90} distribution (15-350 keV)



Comparison of T_{90} distribution



Short on S-GRBs in BAT

(Sakamoto et al. 2010 @ Annapolis)

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)

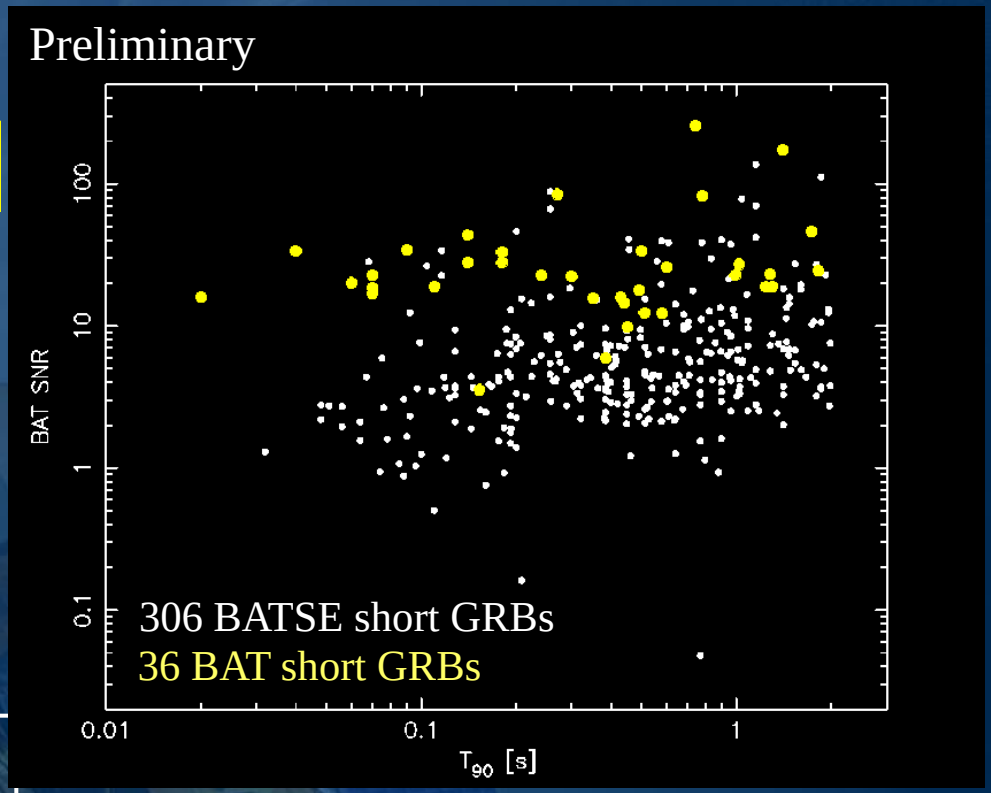
BATSE short GRBs Band spectral parameters

↓

BAT energy response (30^d) + background

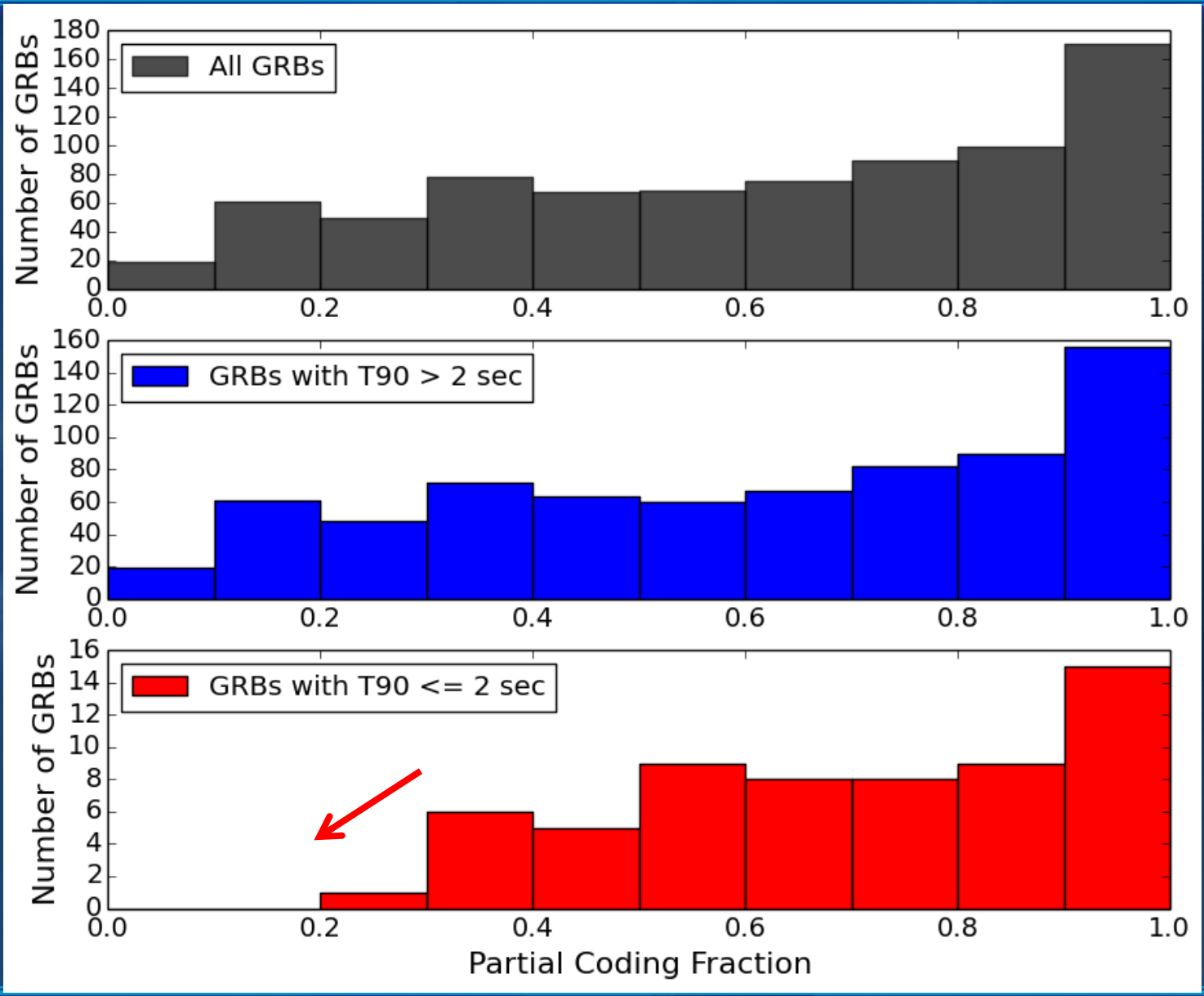
↓

Simulate BAT fg/bg spectrum → SNR

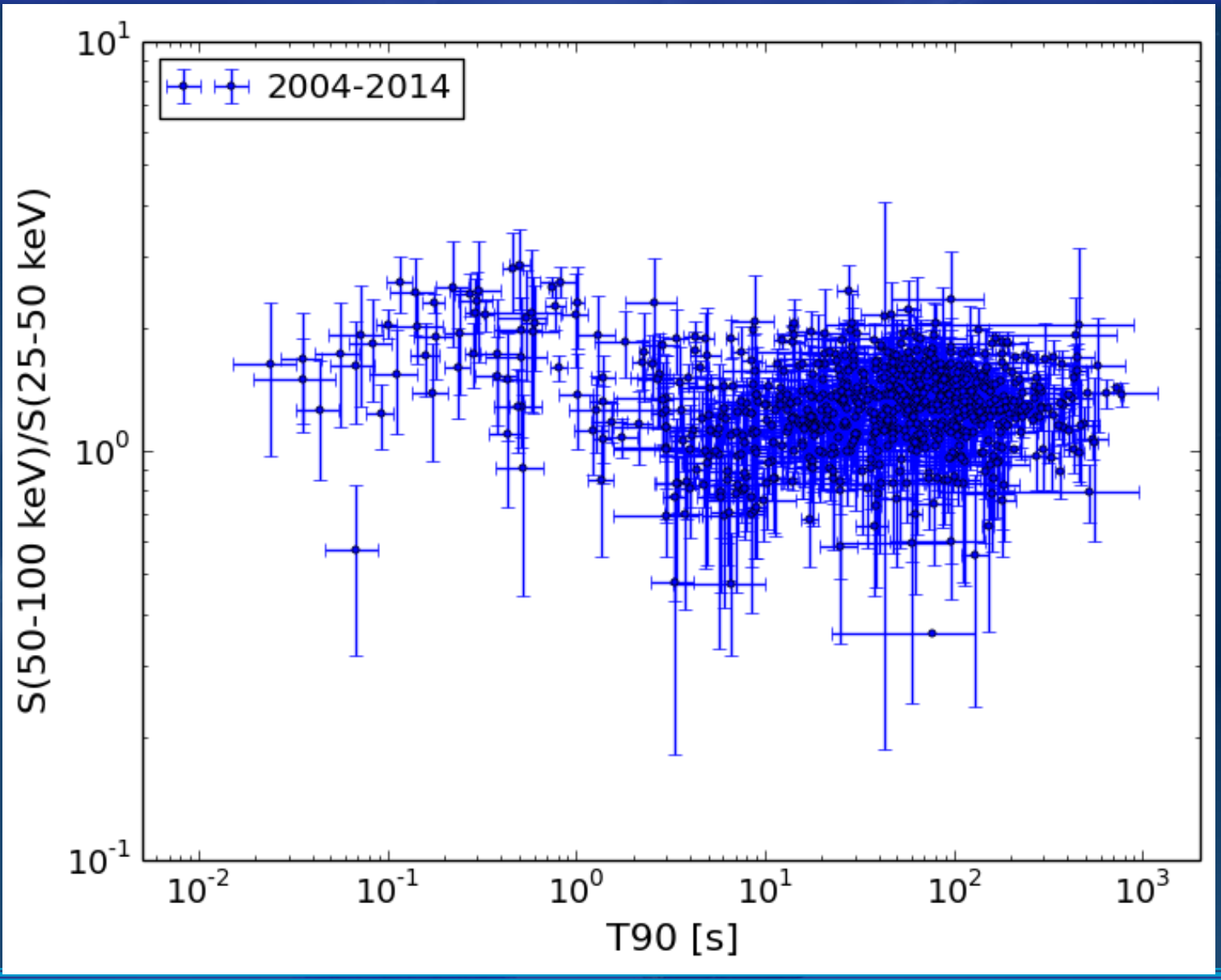


Majority of the BATSE short GRBs is too faint in BAT

BAT partial coding fraction between L-GRBs and S-GRBs

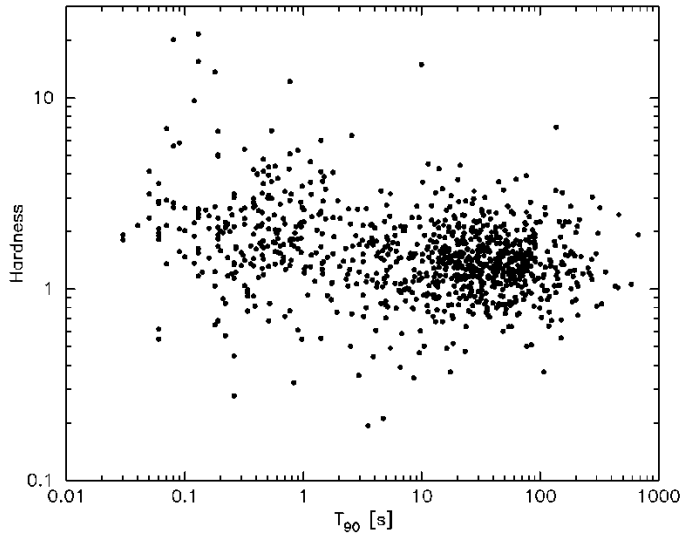


Fluence ratio (Hardness) vs. T_{90}

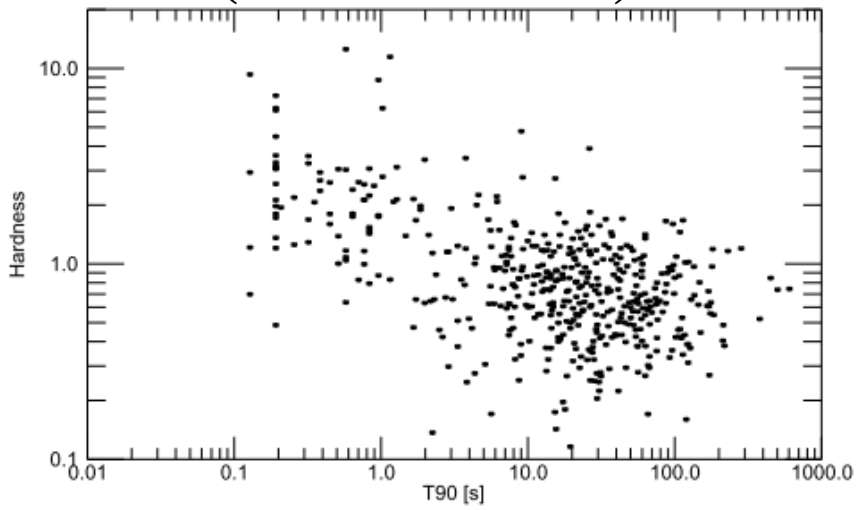


Hardness of S-GRBs

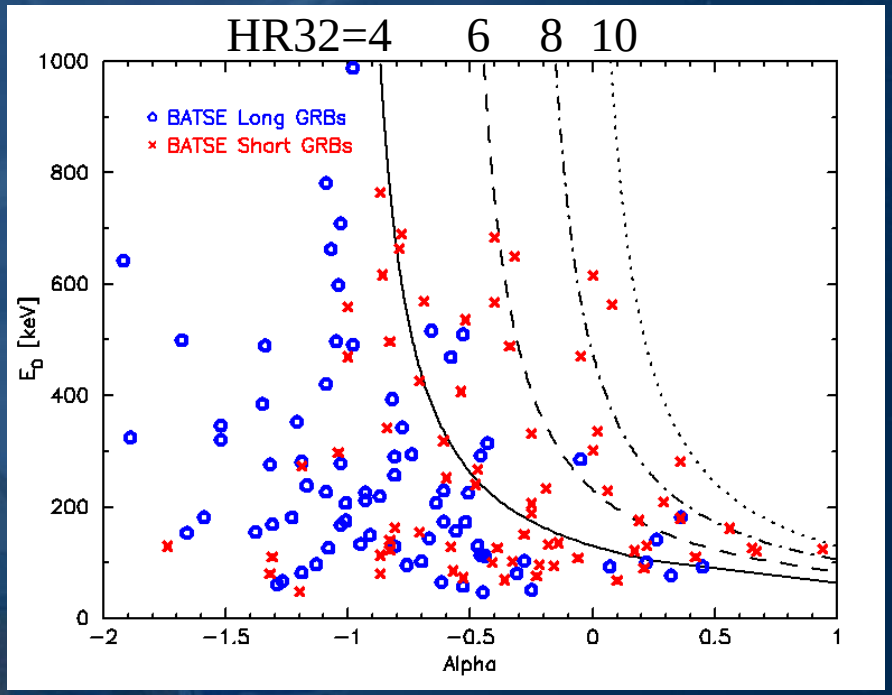
BATSE



Fermi GBM (Paciesas et al. 2012)



"Clear anti-correlation between hardness and T_{90}"

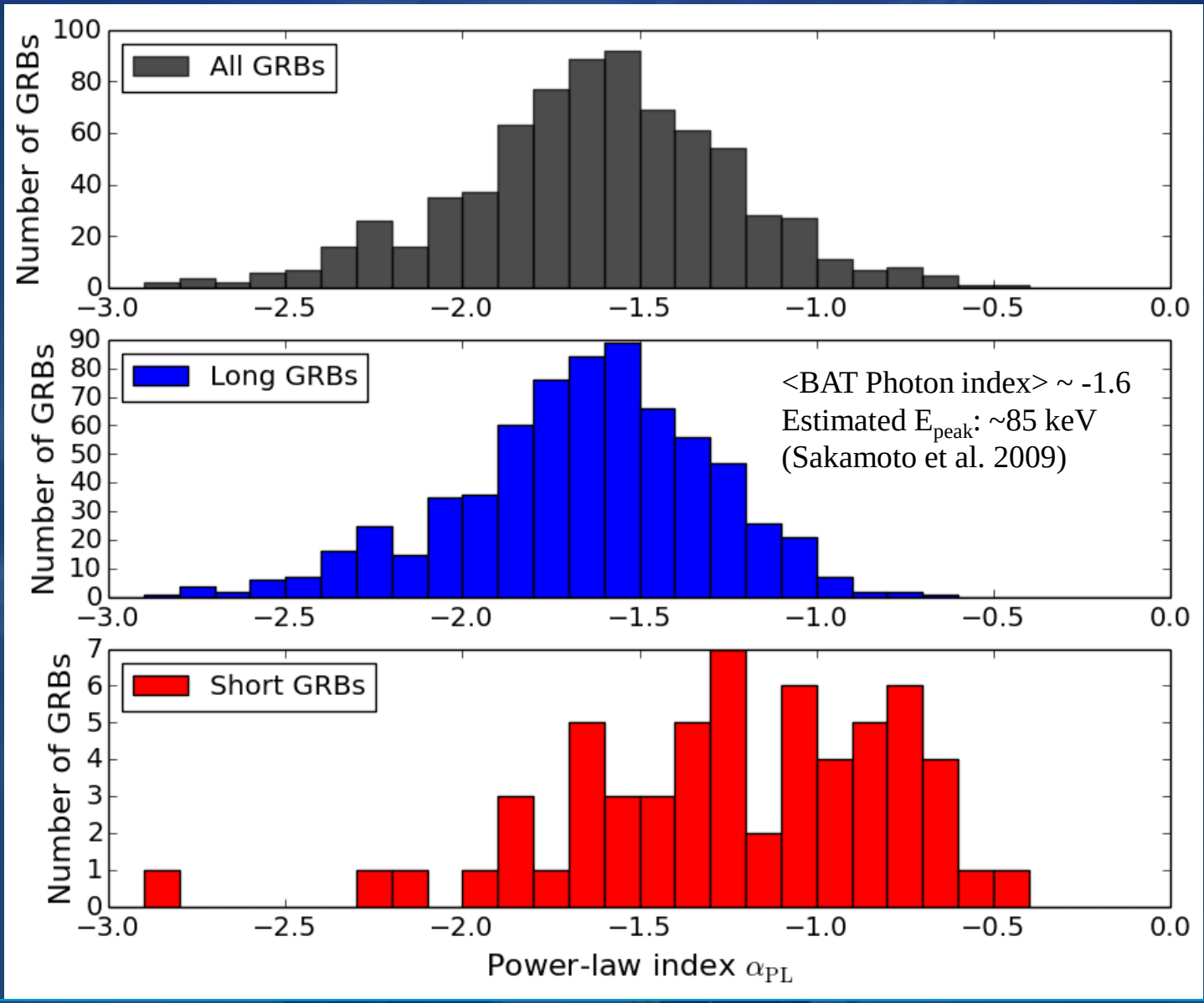


(Sakamoto et al. 2006)

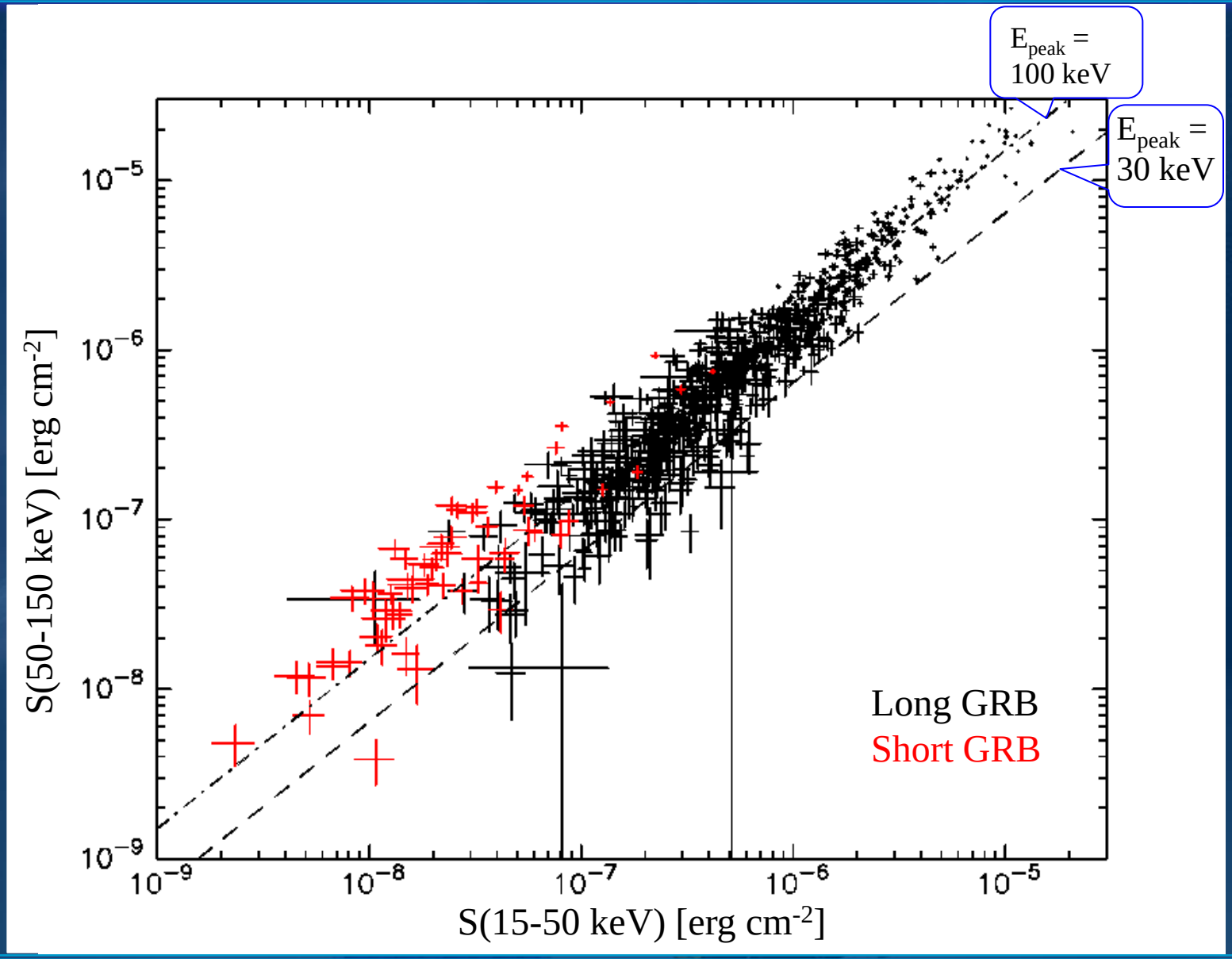
(*) $E_{peak} = (2+alpha)*E_0$

HR > 4 requires low-energy photon index to be extremely flat or positive

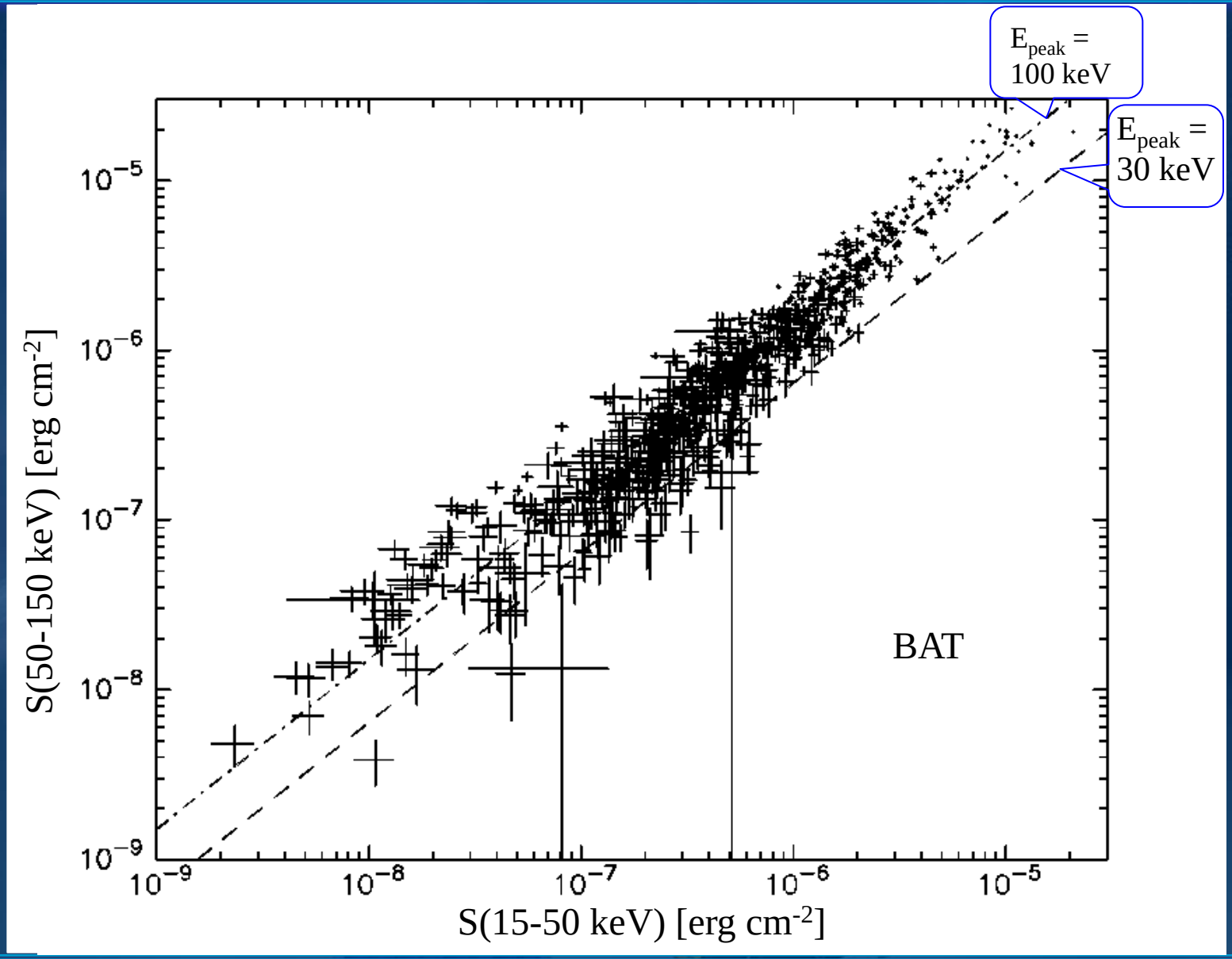
PL: Photon index distribution



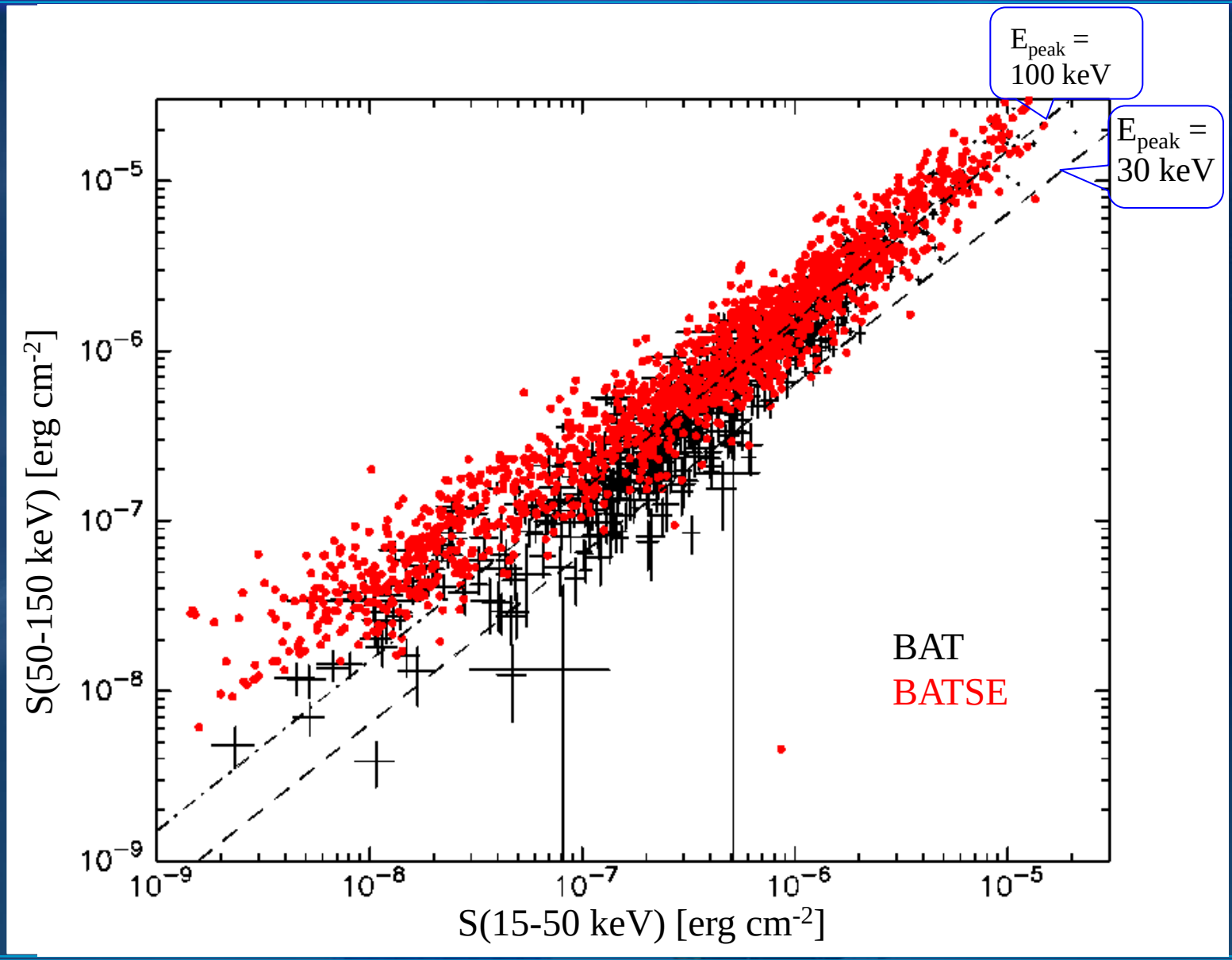
S(50-150 keV) vs. S(15-50 keV)



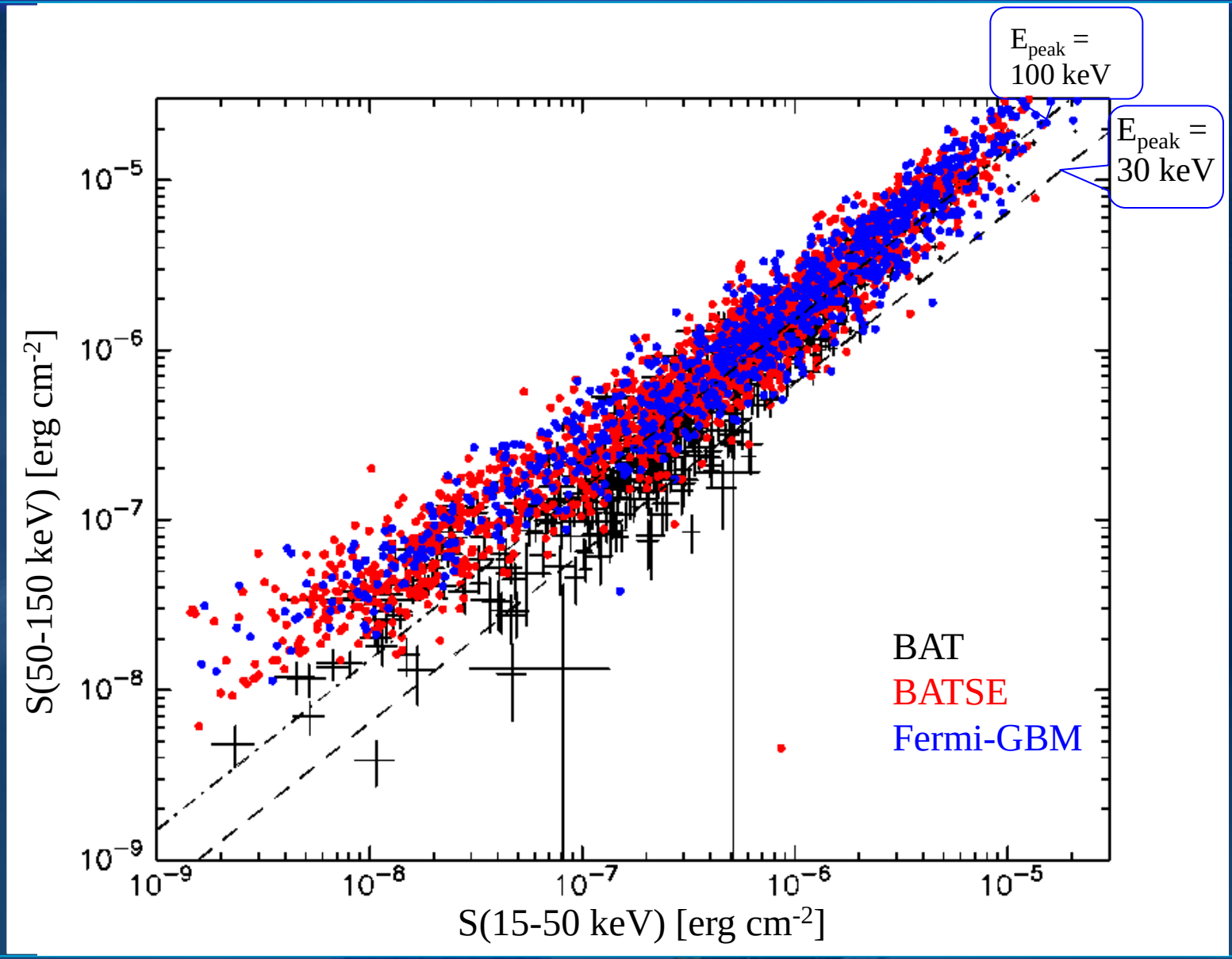
S(50-150 keV) vs. S(15-50 keV)



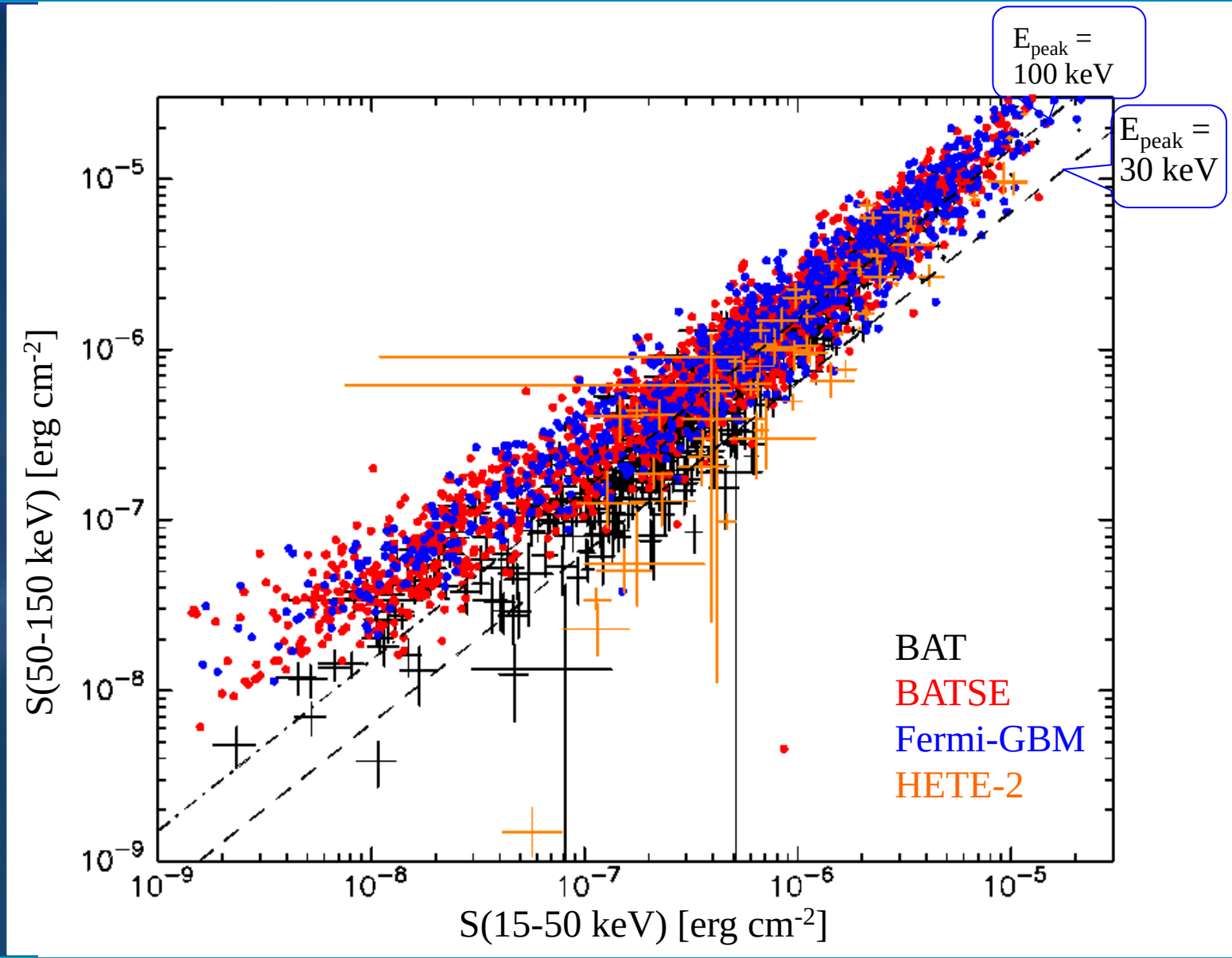
S(50-150 keV) vs. S(15-50 keV)



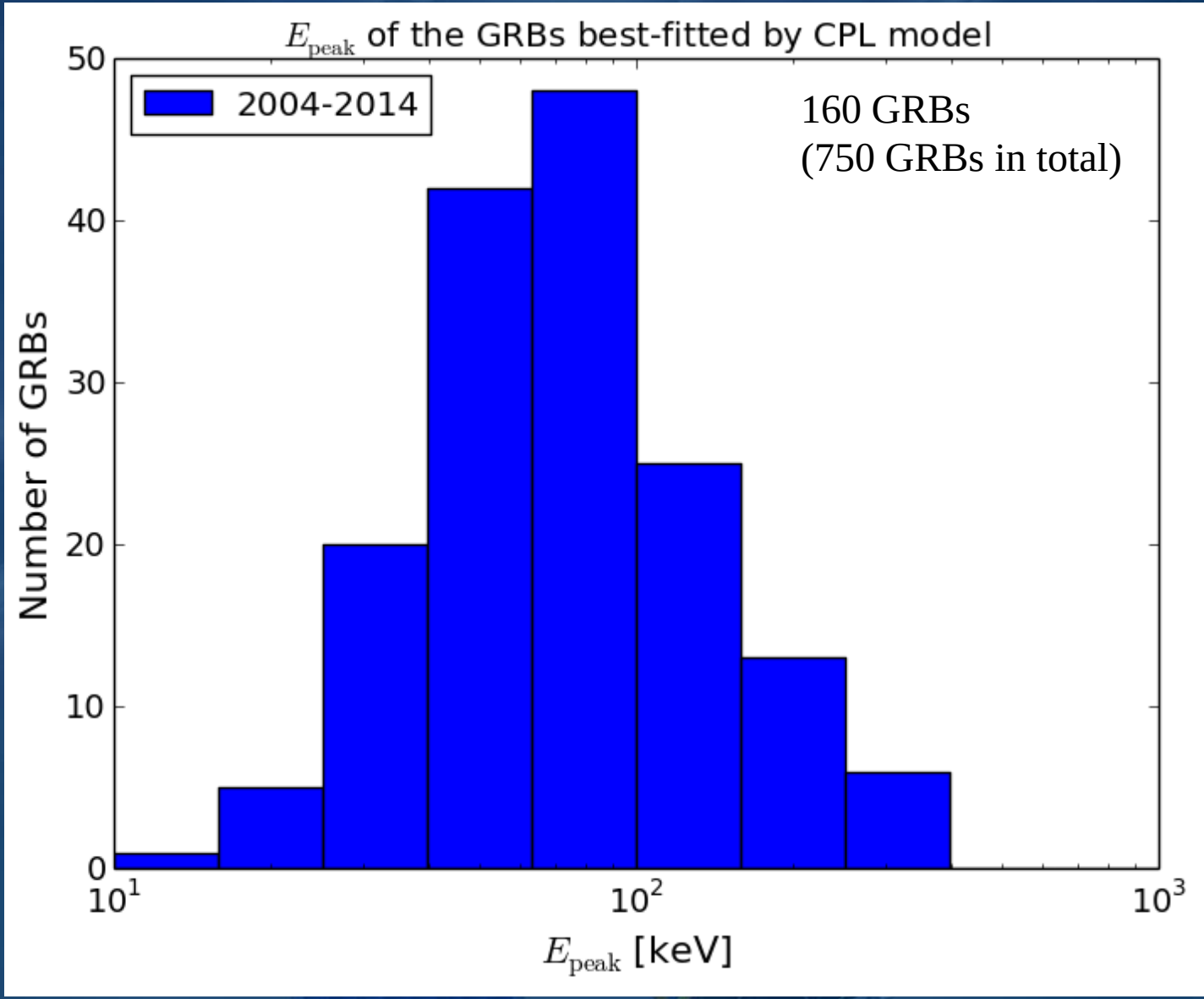
S(50-150 keV) vs. S(15-50 keV)



S(50-150 keV) vs. S(15-50 keV)

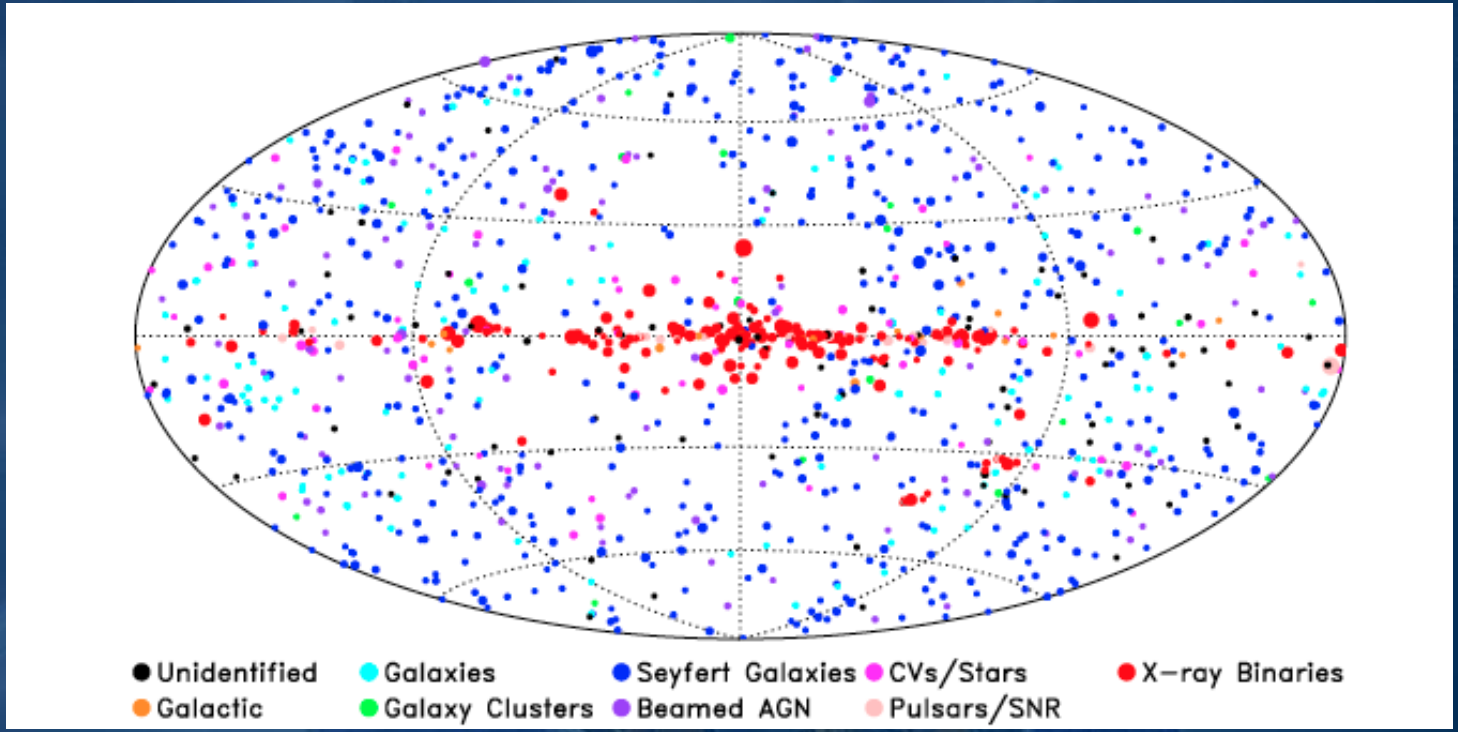


E_{peak} Distribution



BAT Survey data (DPH data)

Swift/BAT 70 months Hard X-ray Survey (Baumgartner et al. 2012)

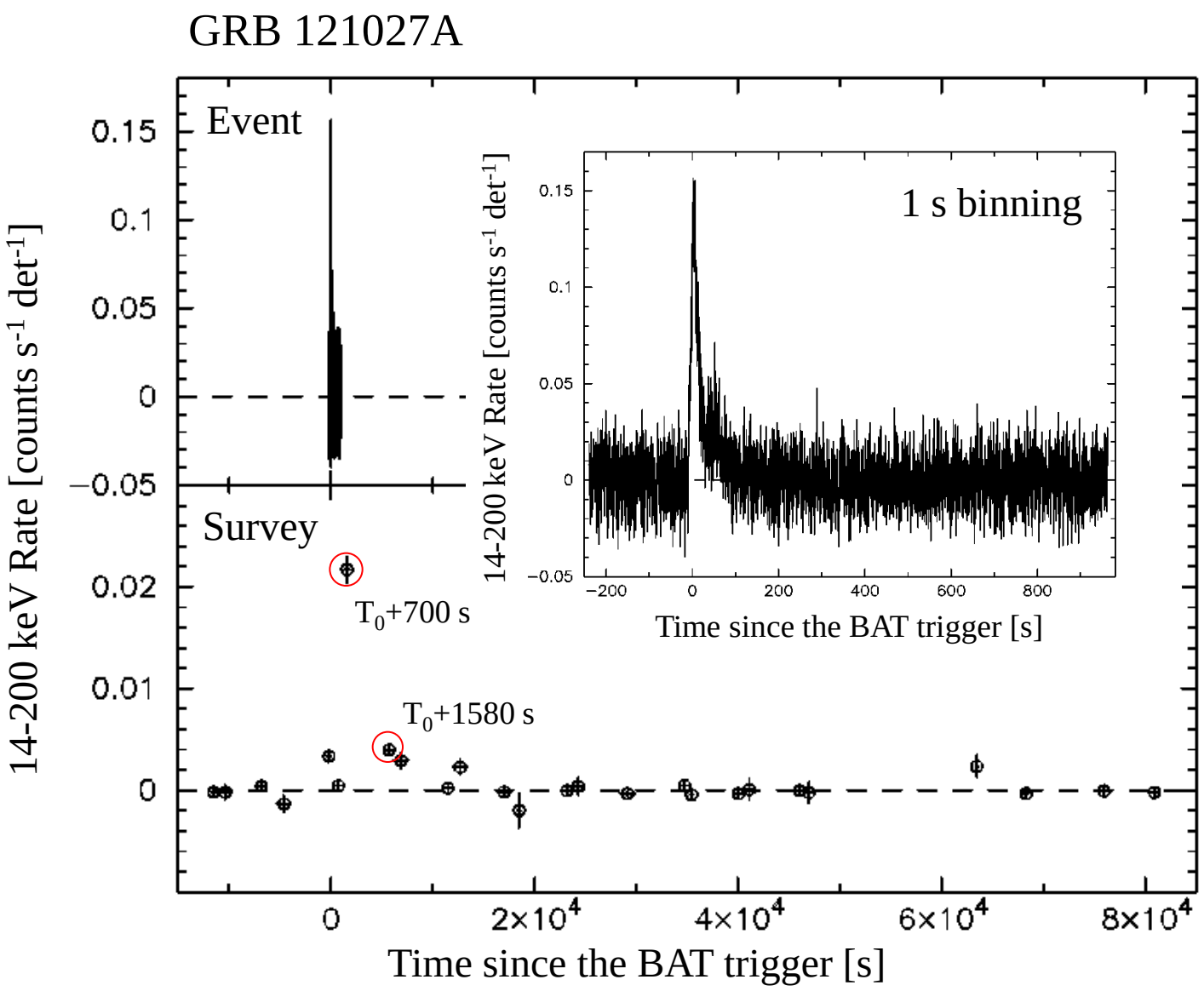


>1000 sources detected in this survey

Detector Plane Histogram (DHP data; survey data):

- 80 energy channel data (counts in each detector)
- Every 5 min.
- During the pointing observations

BAT Survey data on GRB analysis



Search for emission in the survey data

Processed data:

- Latest BAT cleaned sky images from the BAT hard X-ray survey process
  - Standard 8 energy bands (14-20, 20-24, 24-35, 35-50,5 0-75, 75-100, 100-150, 150-195 keV)
  - Exposure time of the image: a single pointing duration
  - 790 GRBs (GRB 041217 - GRB 130831B)

Search interval:

- Between T_0(BAT) – 0.2 days (4.8 hours) and T_0(BAT)+1 day
- Excluding periods that overlap with the event data
  - Excluding the period between T_0(BAT)-50 s and T_0(BAT)+500 s

Energy bands:

- Standard 8 energy bands plus 14-195 keV, 14-35 keV and 35-100 keV

Detection Search

Motivation:

- Search for a weak and extended emission before/after the GRB trigger time

Detection threshold: as low as possible, but also minimize a false rate

Approach to find the detection threshold:

1. Defined the background points around the GRB positions
2. Set the detection threshold (sigma)
3. Run the BAT detection software (batcelldetect) to the images and extract the significance of background points
4. Calculate the "detection" rate at the given threshold for the background points

Detection threshold: 4.3 sigma (14-195 keV image)

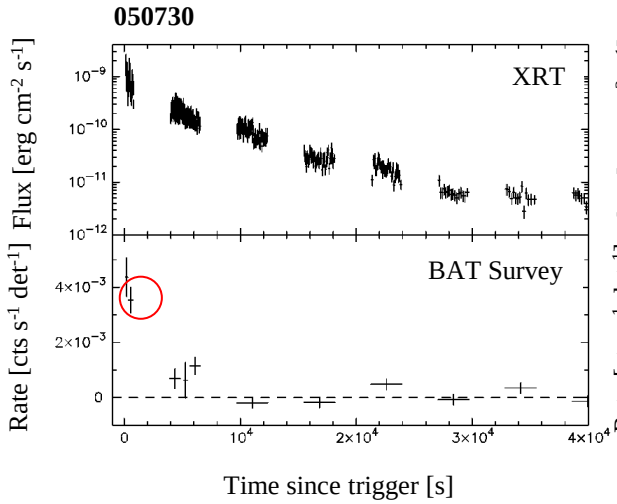
false positive rate: 5.206×10^{-5}

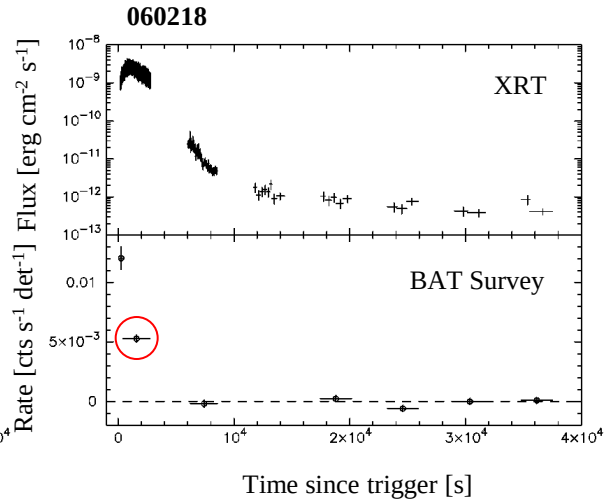
Results

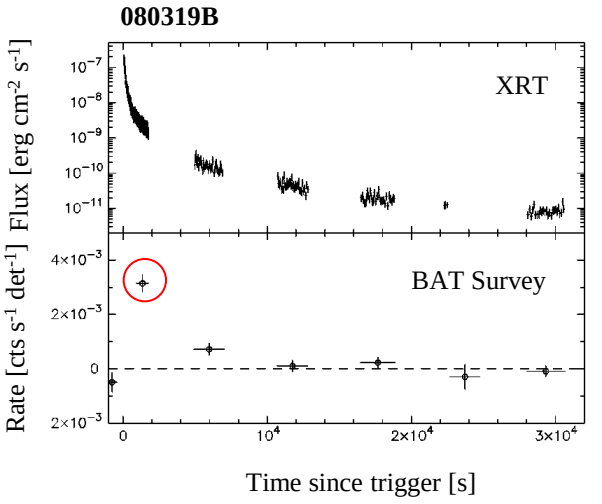
- Detection at the pre-trigger time interval:
  - GRB 101024A
  - GRB 100316D : SN associated GRB, duration ~1300 s (Starling et al.)

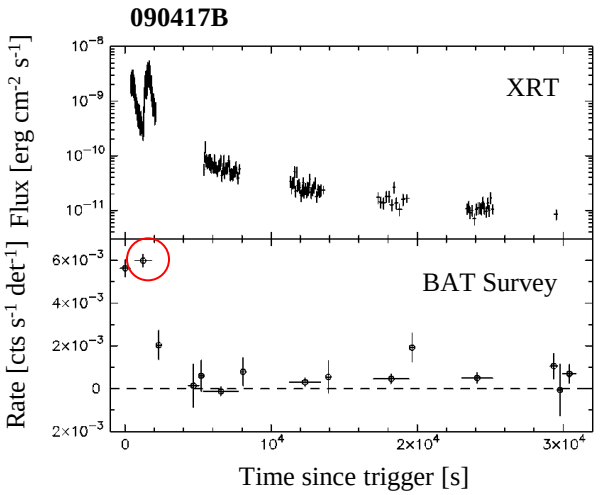
- Detection at the post trigger time for 15 GRBs
  - GRB 050730
  - GRB 060218 : SN associated GRB, duration > 1000 s (Campana et al.)
  - GRB 070419B
  - GRB 070518
  - GRB 080319B : Naked-eye burst (Racusin et al.)
  - GRB 090309
  - GRB 090404
  - GRB 090417B : duration > 2300 s (Holland et al.)
  - GRB 091127 : SN associated GRB
  - GRB 100728A
  - GRB 101225A : duration ~10,000 s (Levan et al.)
  - GRB 111209A : duration > 25,000 s (Gendre et al.)
  - GRB 111215A
  - GRB 121027A : duration ~6000 s (Levan et al.)

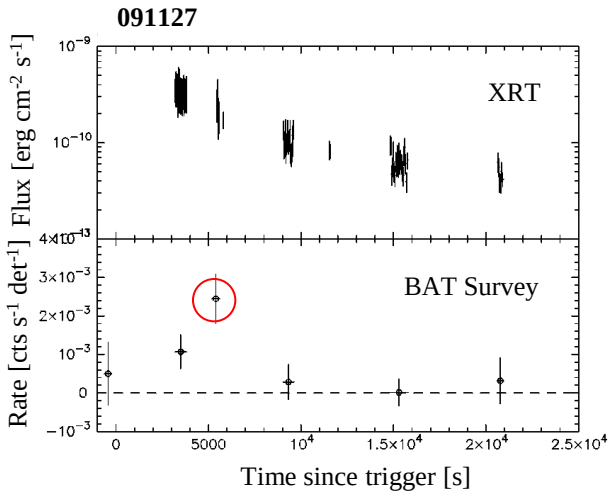
BAT detection at the epoch of bright XRT emission

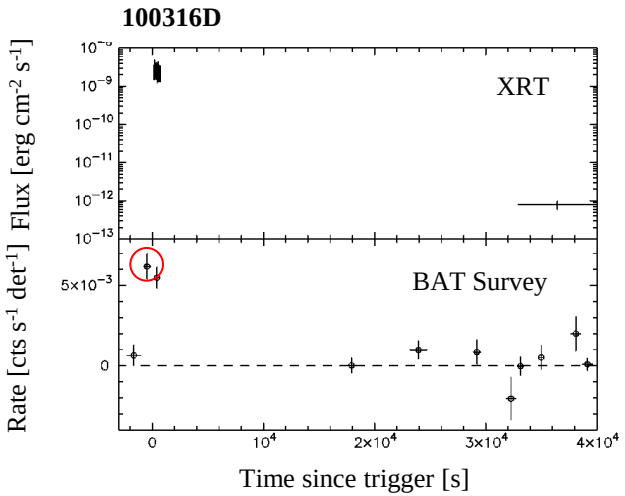




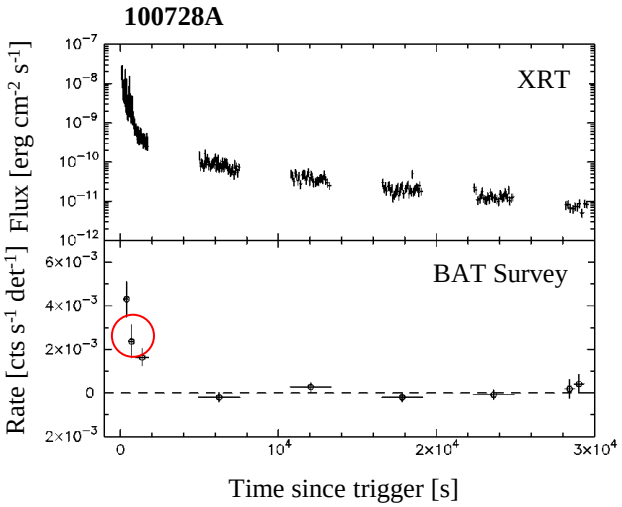


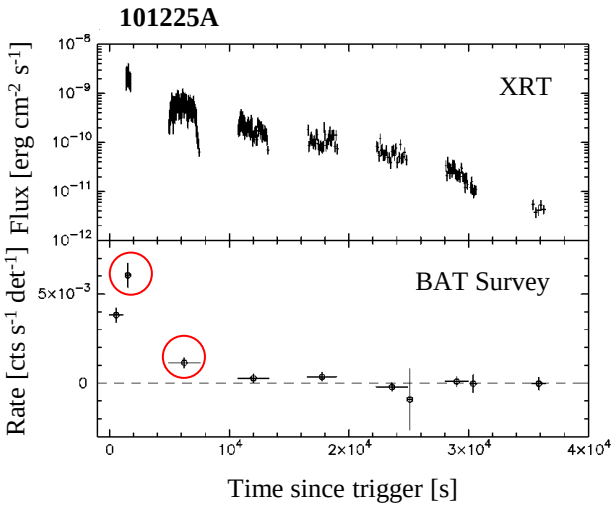


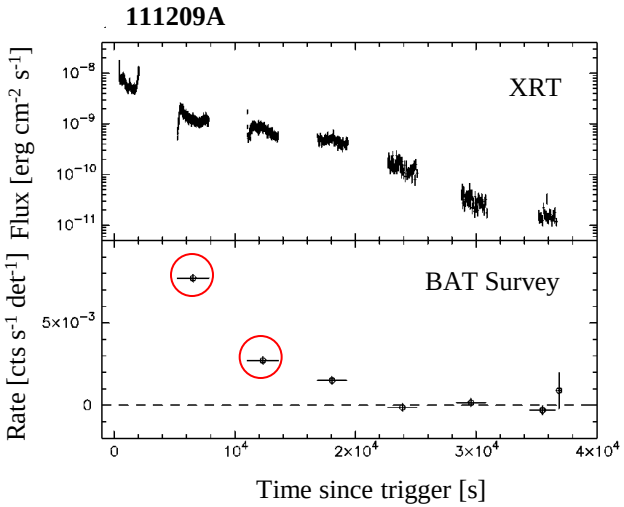


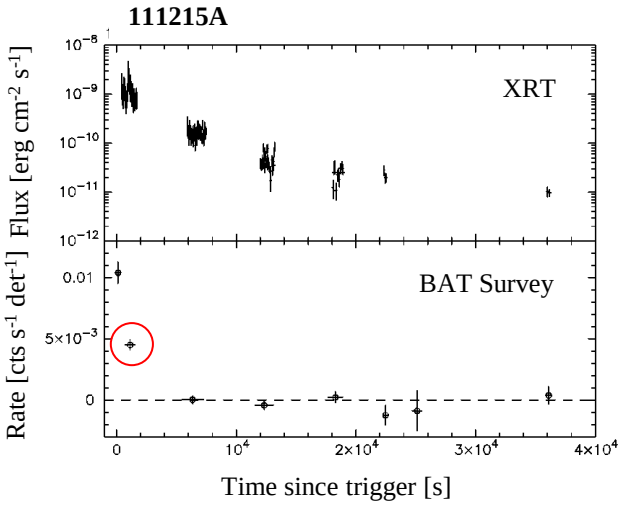


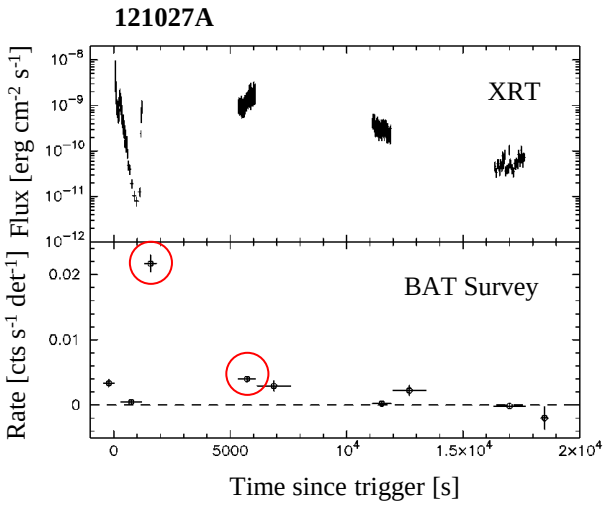
BAT detection at the epoch of bright XRT emission





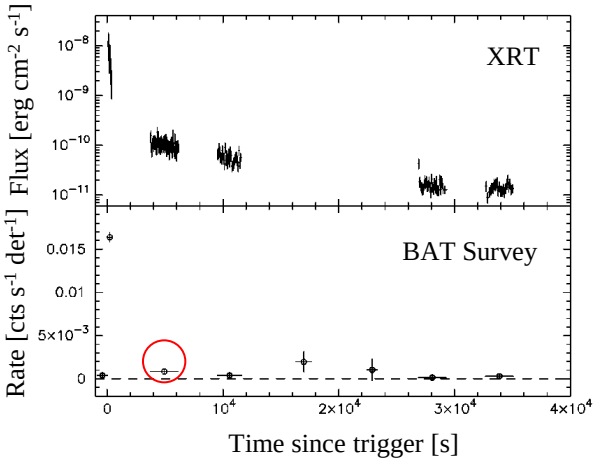




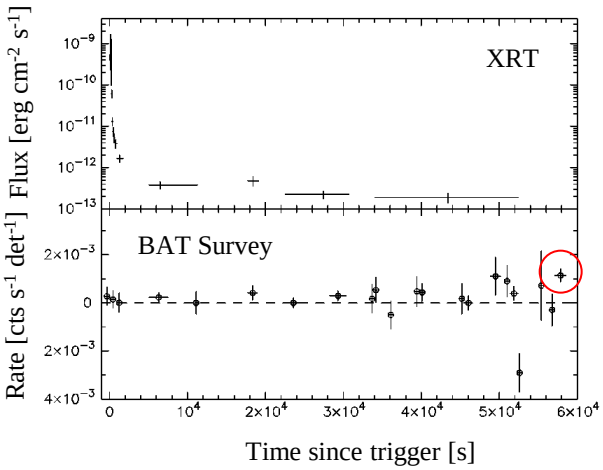


?

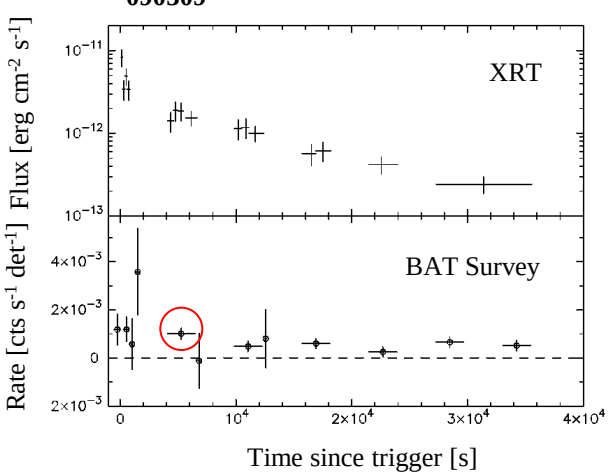
070419B



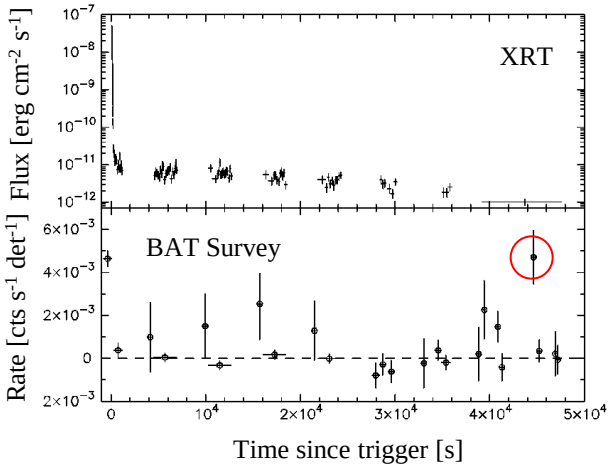
070518



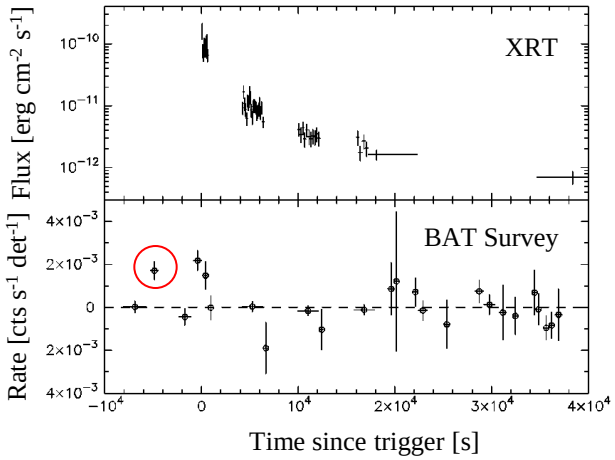
090309



090404



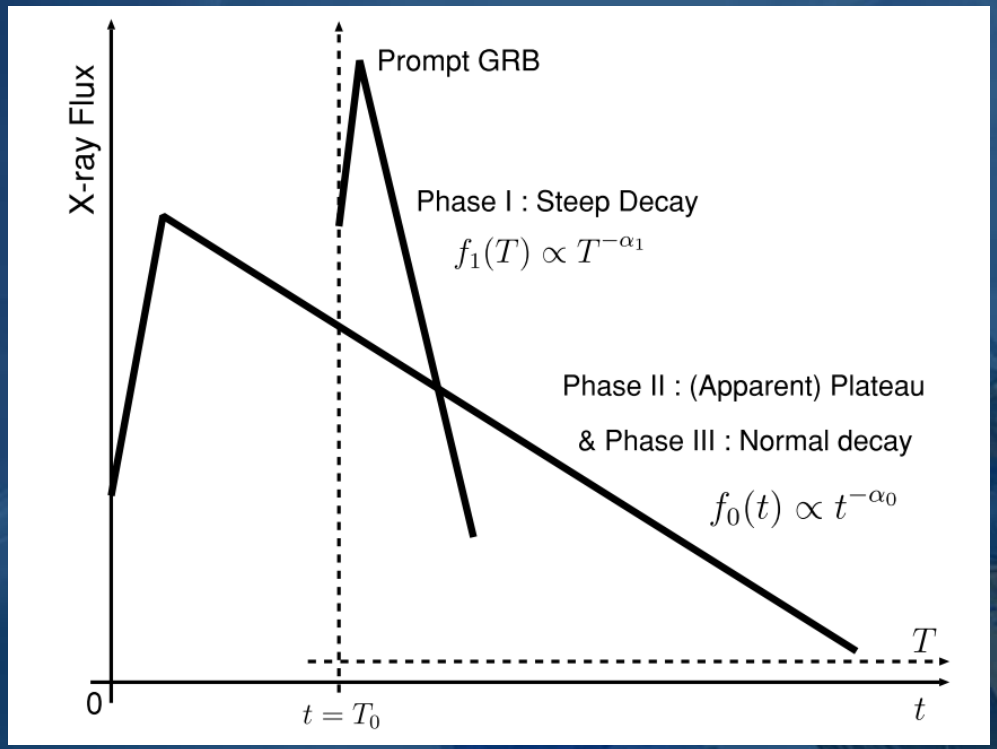
101024A



Prior GRB Emission

- Only two GRBs (GRB 101024A & GRB 100316D) have the detection prior to the trigger time.

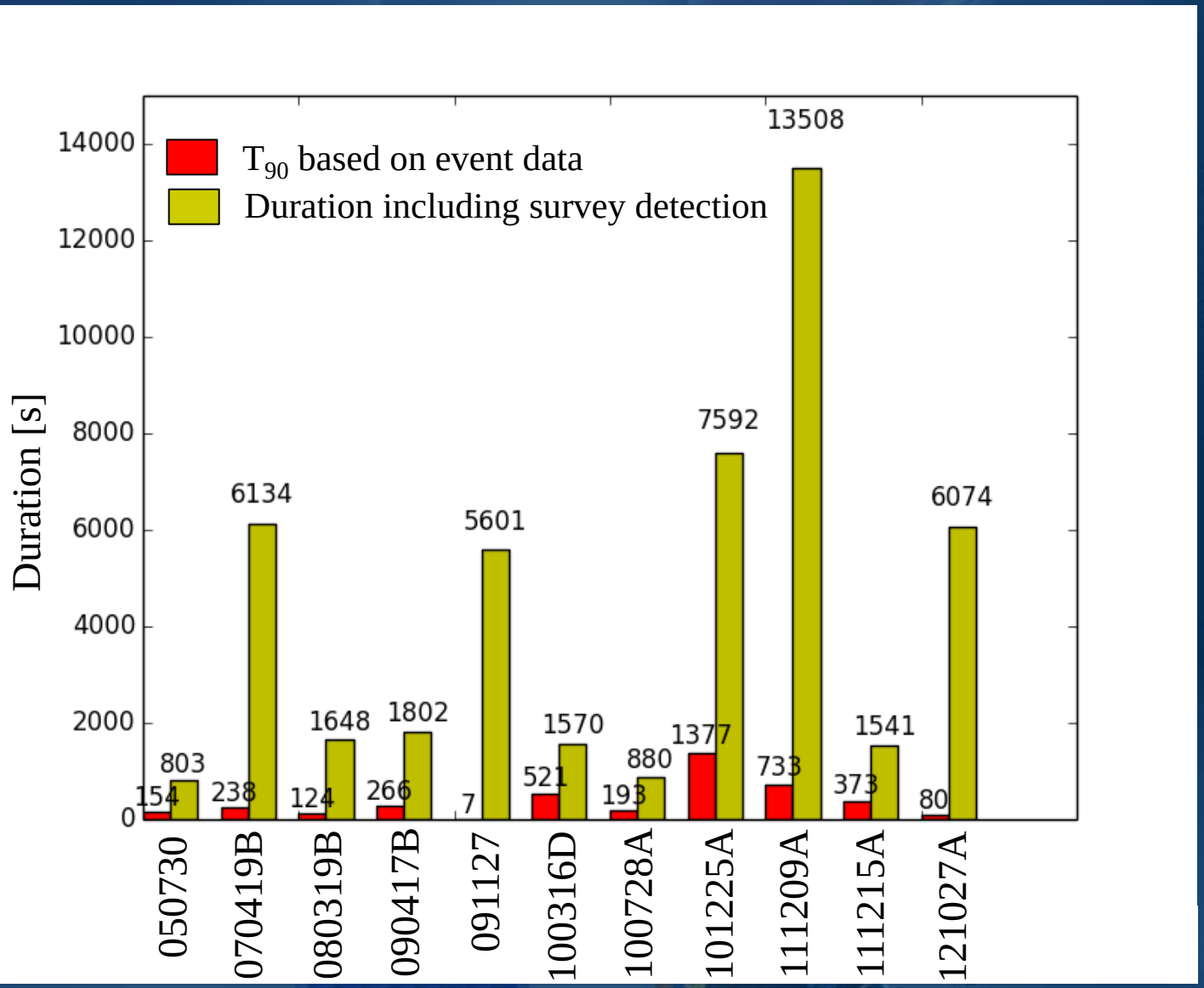
Most of GRBs do not have a bright emission prior to the trigger time.



Yamazaki 2009: By moving T_0 backward for 1-3 hrs, a temporal decay slope at a plateau phase in X-ray afterglow can go steeper (matches to a normal decay slope).

Future: Look the survey data in finer time binning, and/or wait for higher sensitivity instrument.

Post GRB Emission

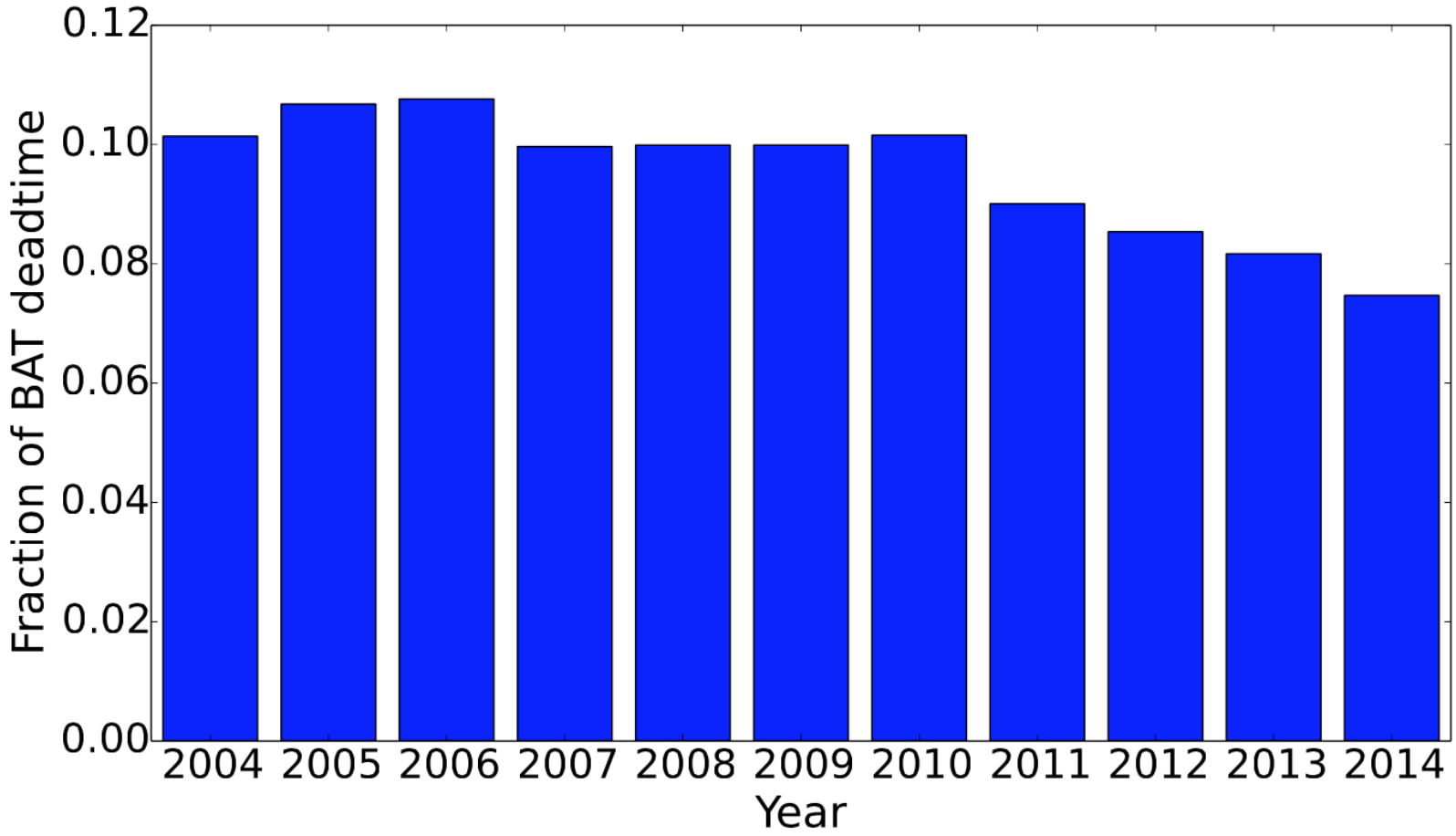


Summary

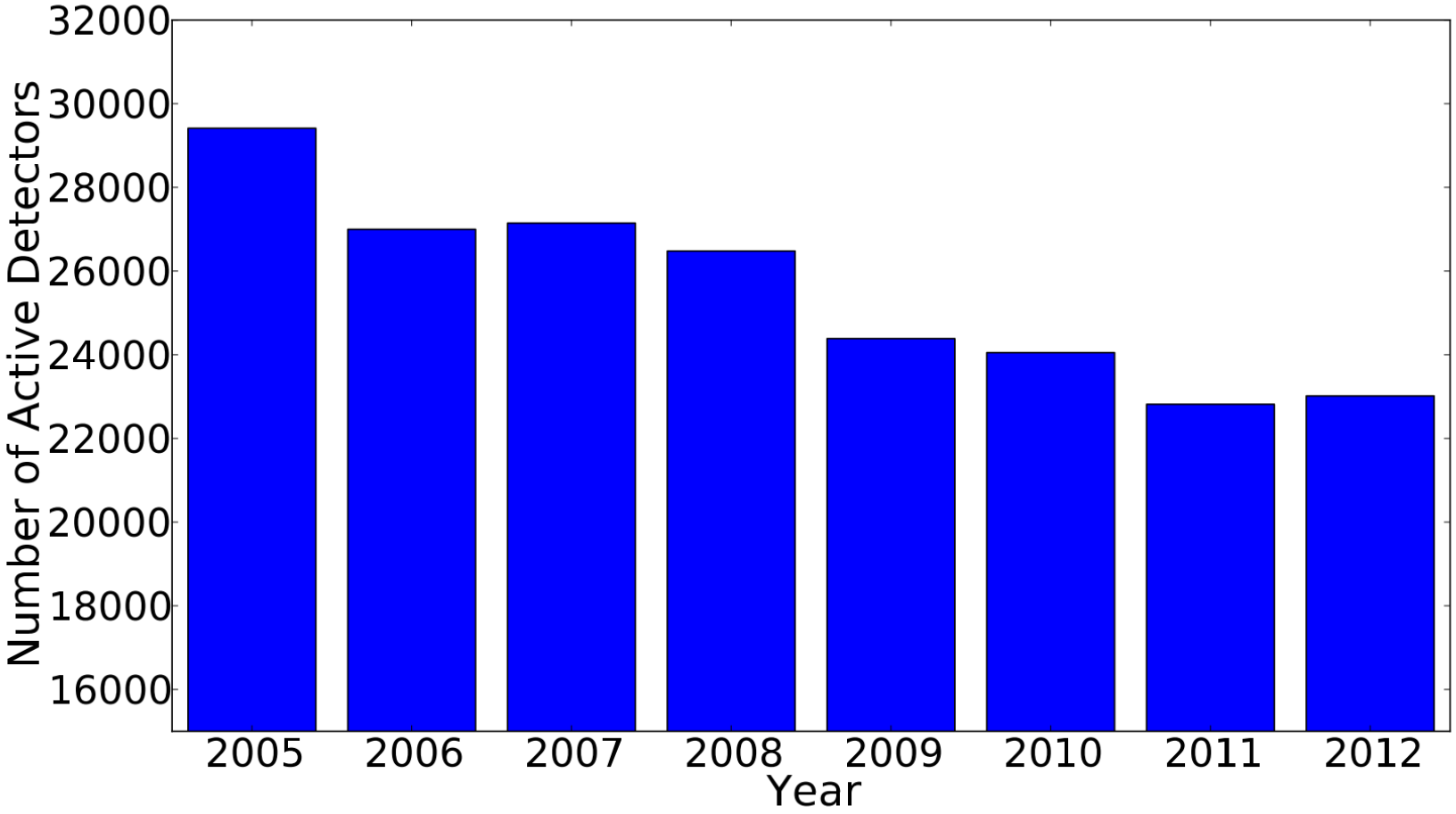
- Great collaboration with KW team enable us to present our scientific results in high confidence.
- BAT 3rd GRB catalog
  - Short on short GRBs:
    - Difficulty in localizing
  - Spectral hardness in short GRBs:
    - Mysterious hardness in BATSE and Fermi-GBM short GRBs.
  - Global BAT GRB population:
    - E_{peak} of 30-100 keV
  - Pre-/Post-GRB emission search:
    - only 1 pre-GRB emission and 15 post-GRB emissions (very few)

Backup slides

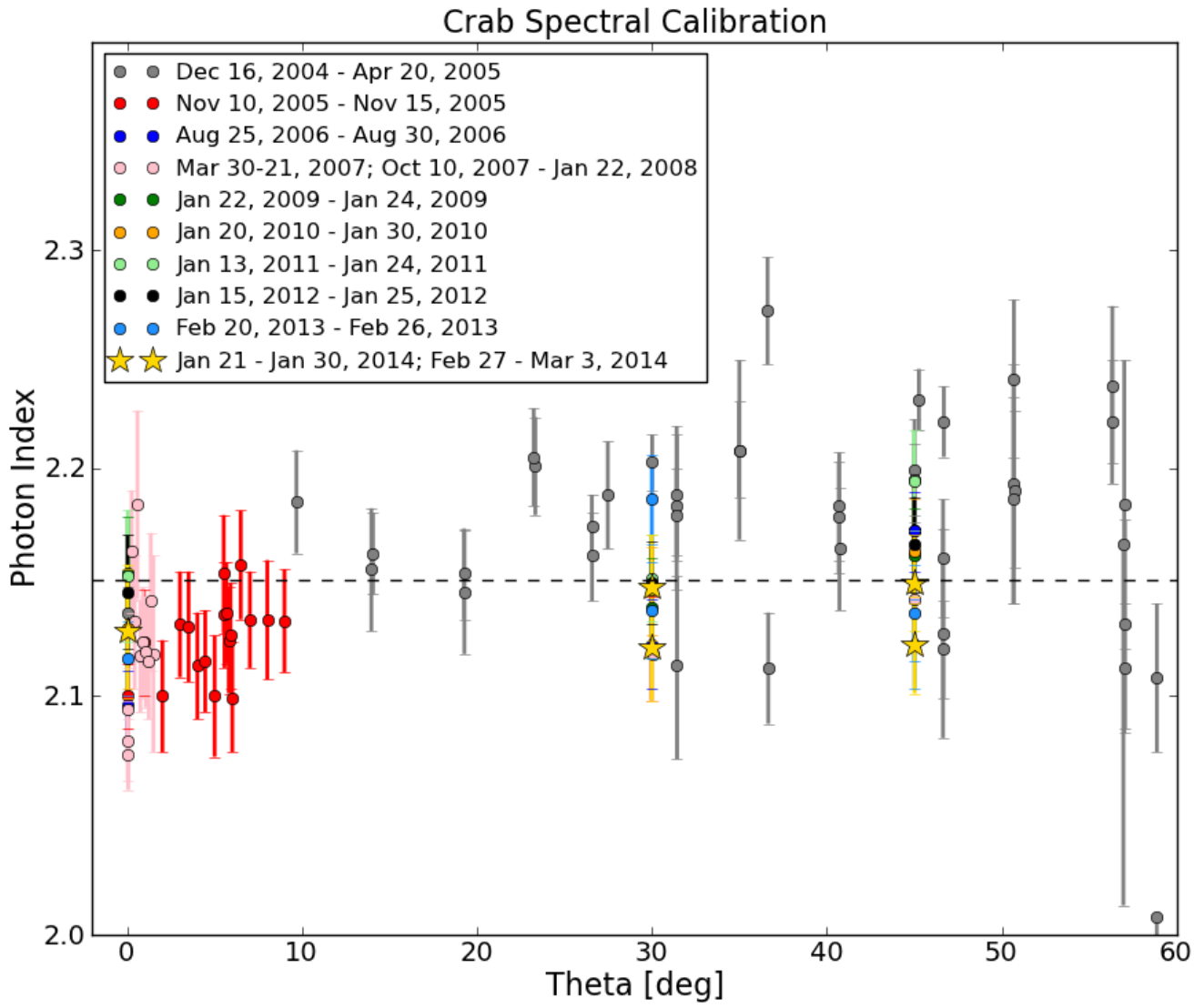
Fraction of BAT Deadtime



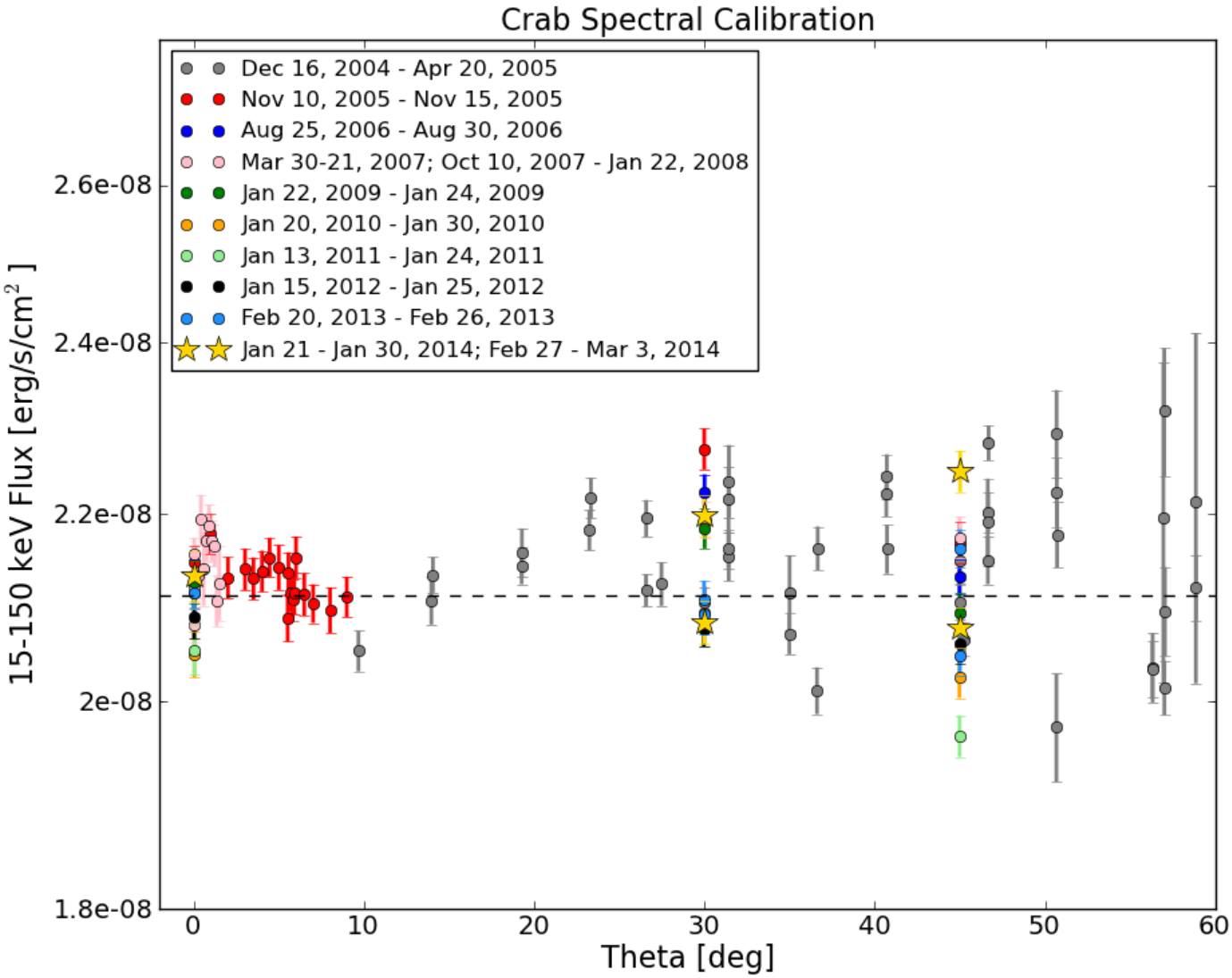
Number of Active Detectors



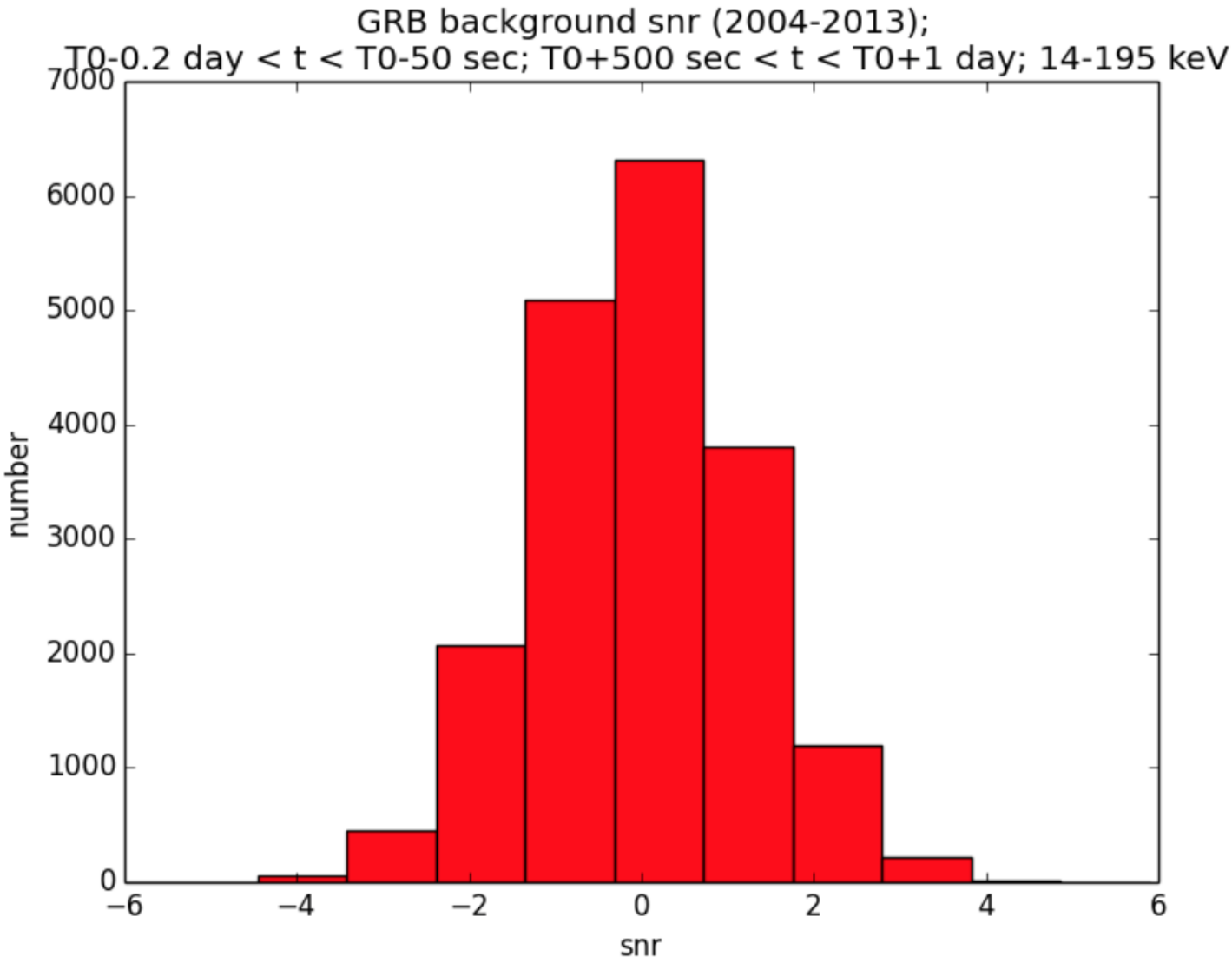
Crab Spectral Calibration: Photon Index



Crab Spectral Calibration: Flux



Background SNR in the survey images



BAT XRFs

~ 3% of Swift/BAT GRBs are XRFs (definition of Sakamoto et al. 2008)

GRB140103A	1.46183
GRB131120A	1.79914
GRB130608A	1.52637
GRB121212A	1.44384
GRB120816A	1.42633
GRB120724A	1.34119
GRB120403B	2.78896
GRB111229A	1.70954
GRB111129A	1.42947
GRB100425A	1.36026
GRB090417A	1.74747
GRB081007	1.32351
GRB080520	2.08715
GRB080330	1.68278
GRB080218B	1.41238
GRB070714A	1.44477
GRB060926	1.3988
GRB060923B	1.36895
GRB060428B	1.66514
GRB060219	1.42821
GRB050824	1.71409
GRB050819	1.51896
GRB050416A	2.11259

121027A zoom