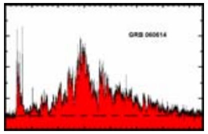
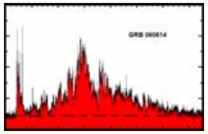


The Mysterious Burst
After the Short Burst

Jay Norris

- Brief History, Overview, Central Questions
- Spectral lag distributions (long & short GRBs)
- Pulse width distributions (long & short GRBs)
- Canonical morphology of short GRBs
- Dynamic Range of $R_{intensity} = I_{EE} / I_{IPC}$
- Prompt Extended Emission ≠ Onset of X-ray afterglow
- Summary



Brief History of Short GRBs

- **Ancient History (1973-1983)** — KONUS*, ISSE-3
  There is a small hint of bimodality. SGRs discovered.

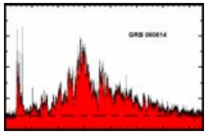
- **Dark/Middle Ages (1984-1990)** — IPN, SMM
  SGRs consistent with Galactic Plane, LMC (A/A_{max}).

- **BATSE Renaissance (1991-2000)** — BATSE
  Bimodality is clear. Shorts separately isotropic.
  Shorts appear slightly spectrally harder, but dynamic ranges of Longs' & Shorts' spectra largely overlap.
  Shorts tend to have much narrower temporal structures.
  (Short bursts with Extended Emission secretly postulated.)

- **Statistical Interlude (2000-2004)** — HETE-2

- **Modern Age (2004 →)** — Swift, HETE-2
  Afterglows lead to Redshifts, and no SN.
  Extended Emission evident in ~ 33% of Swift Short GRBs.

(*Konus lives)



Nature of Problem: Duration Distributions Overlap

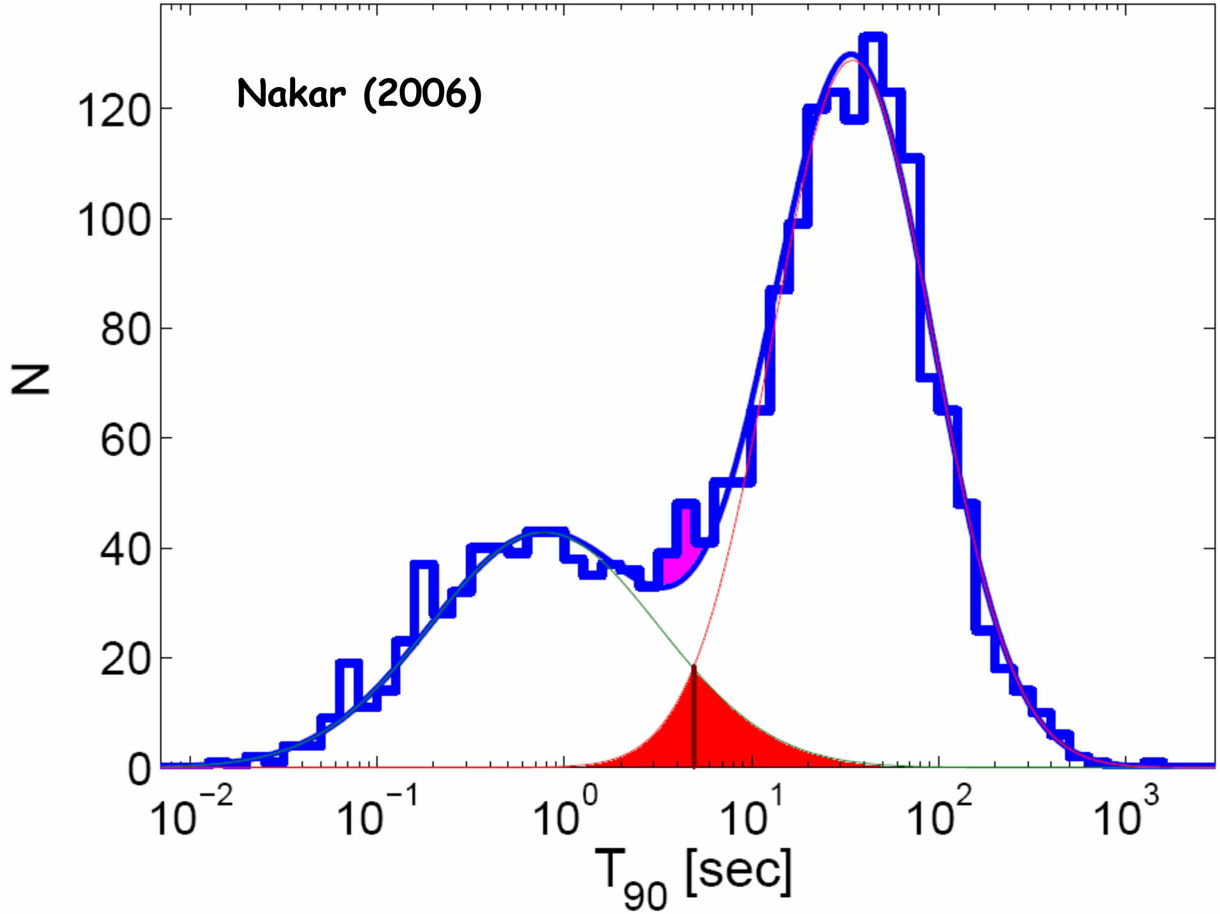
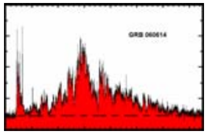
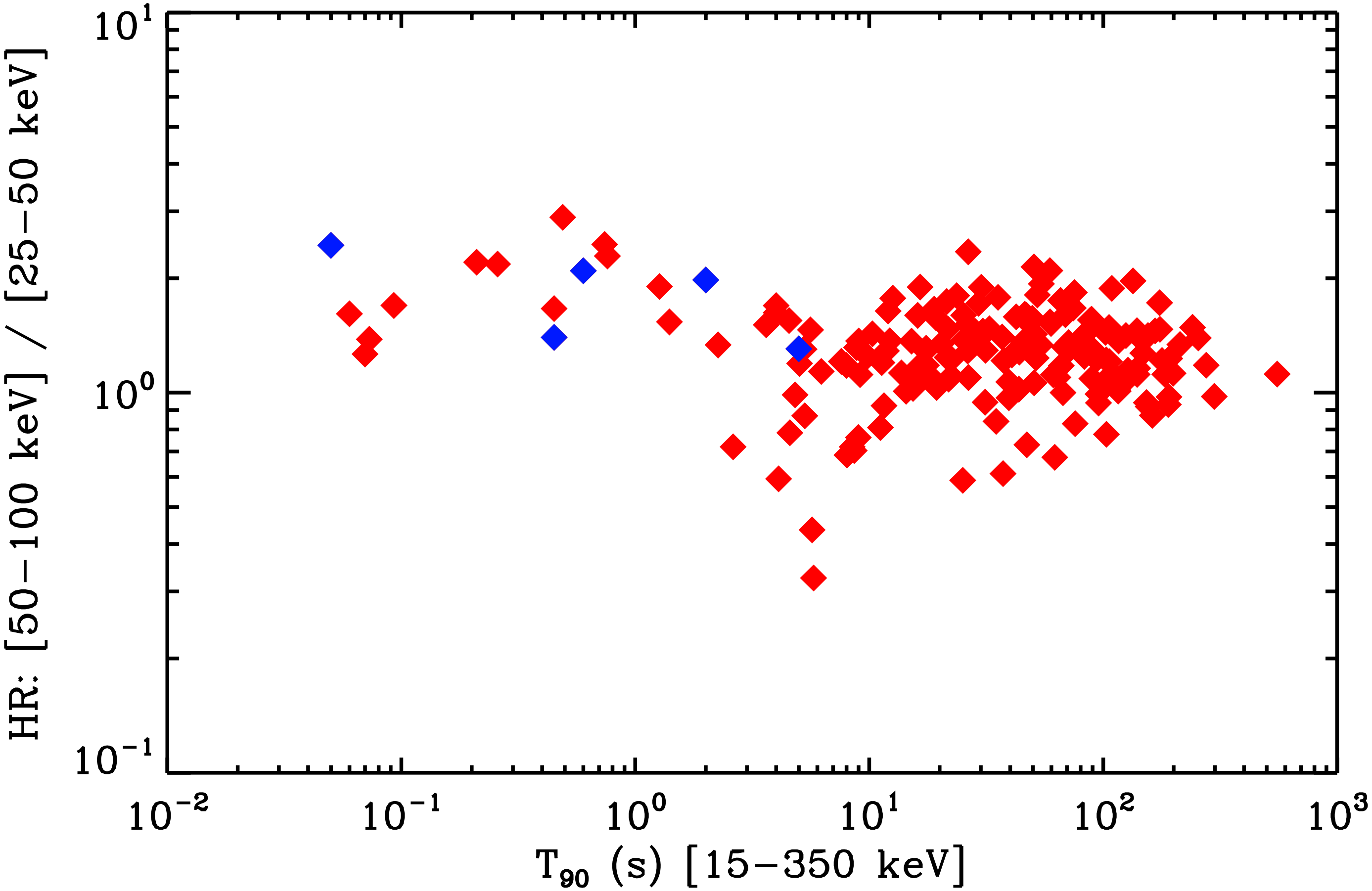
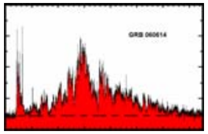


Fig. 1. The bimodal duration distribution of GRBs. The observations (2041 bursts in the current *BATSE* catalog) are marked by the thick stairs. The decomposition of the distribution into two lognormal distributions, as determined by Horváth (2002), (*thin solid lines*) and the sum of these components (*thick solid line*) are superposed.



Swift/BAT: T90 vs. Spectral Hardness





Statistical Interlude: Hard X-ray Afterglows of Short GRBs

Lazzati et al. 2001 (co-addition, 76 shorts)

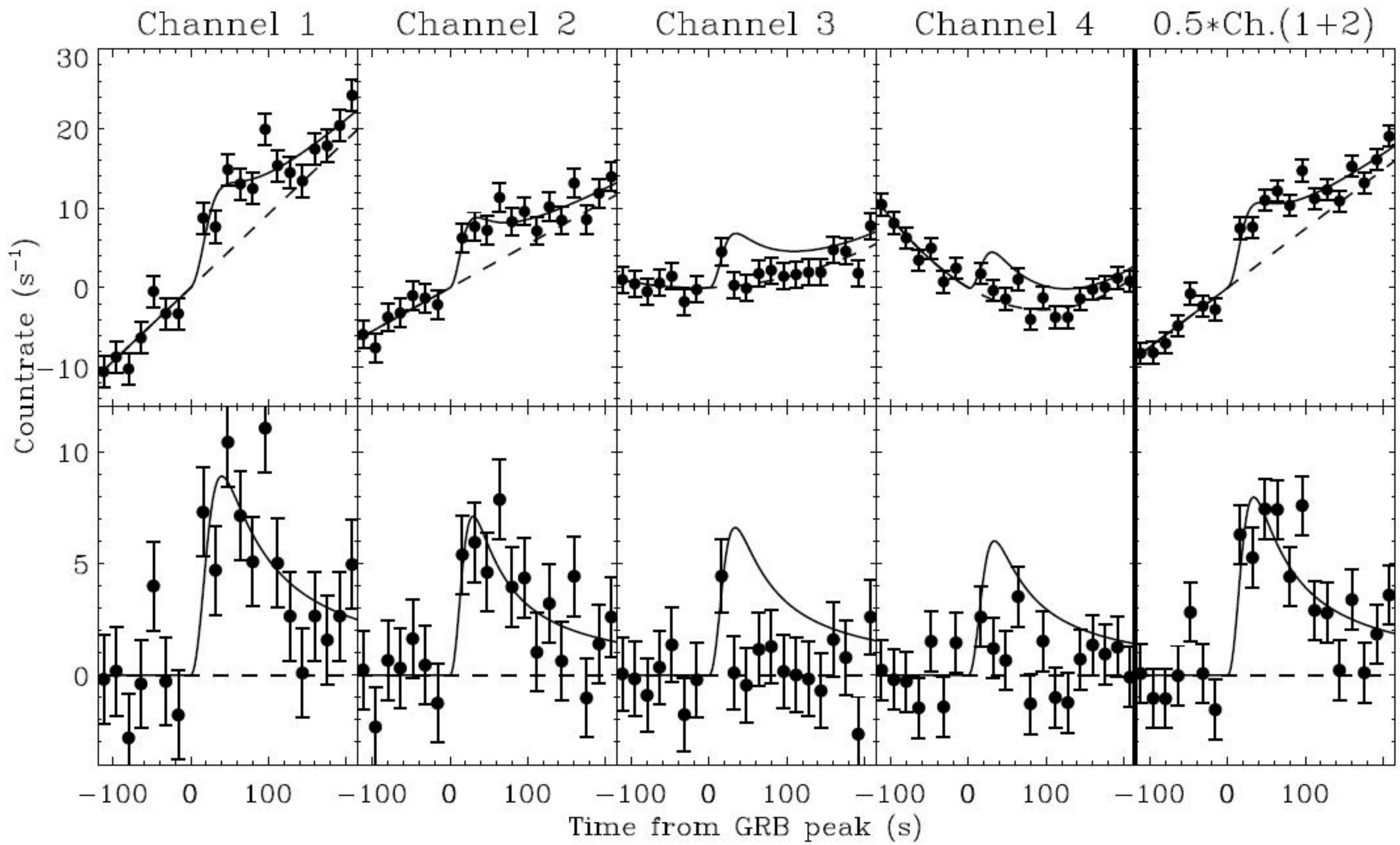
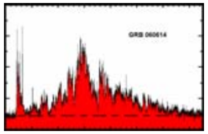


Fig. 2. Overall lightcurves in the 4 BATSE channels (from left to right) of the sample of short bursts (see text). The rightmost panels show the average signal in the first and second channels. The time interval of the burst emission has been excluded. The upper panels show the lightcurves without background subtraction (a constant has been subtracted in all panels for viewing purposes in order to have zero counts at $t = 0$). The solid line is the best fit background plus afterglow model (in the channel 3 and 4 panels the 3σ upper limit afterglow is shown). The dashed line shows the background contribution in all channels. The lower panels show the same data and fit after background subtraction.



Statistical Interlude: Hard X-ray Afterglows of Short GRBs

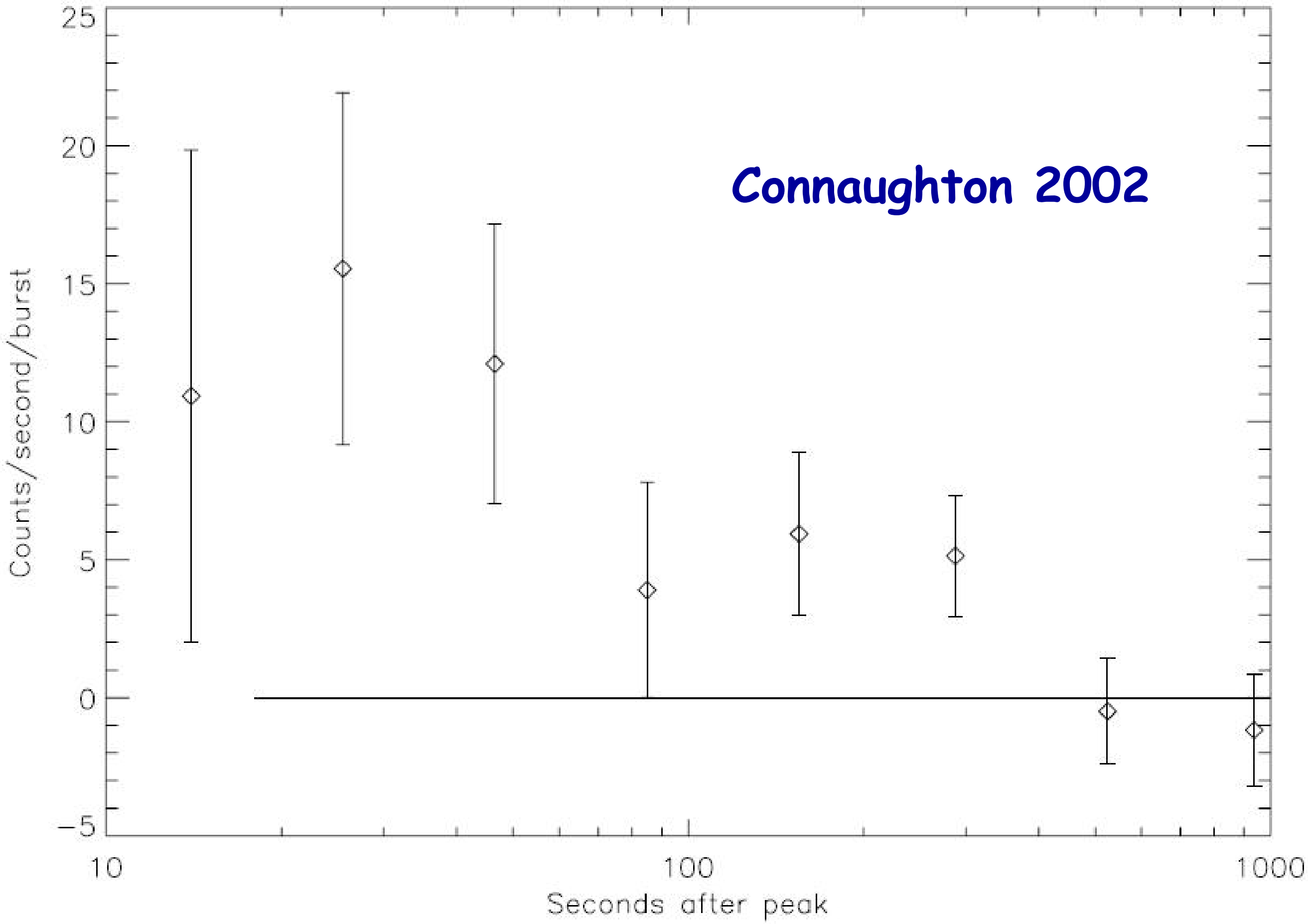
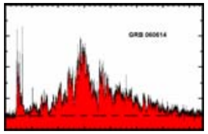
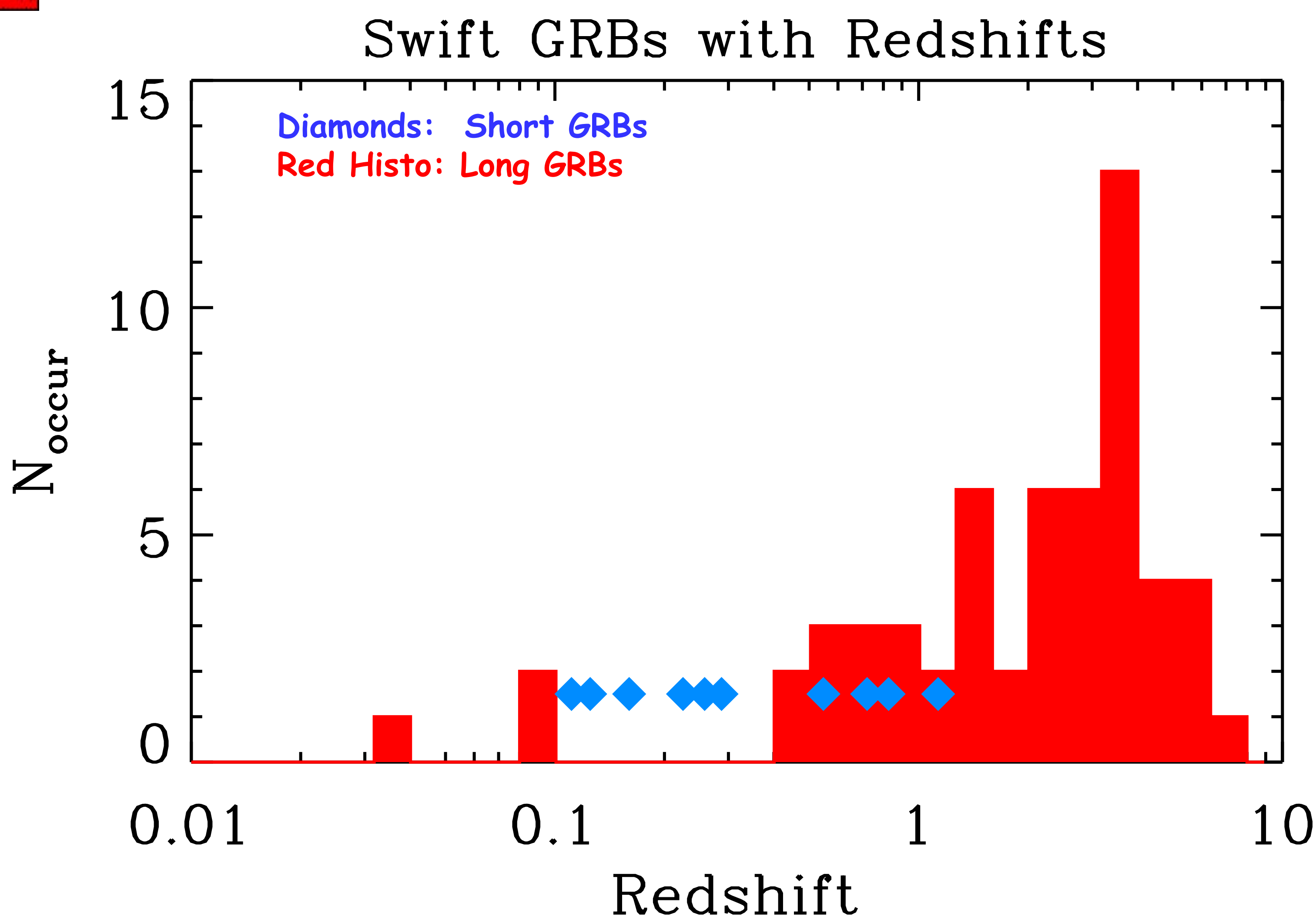


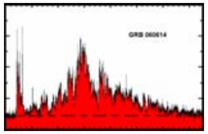
FIG. 7.—Light curve for 100 short (<1 s), summed, background-subtracted, BATSE bursts after peak alignment, with peak time suppressed.

Several central questions remain on short GRBs, especially concerning extended emission …

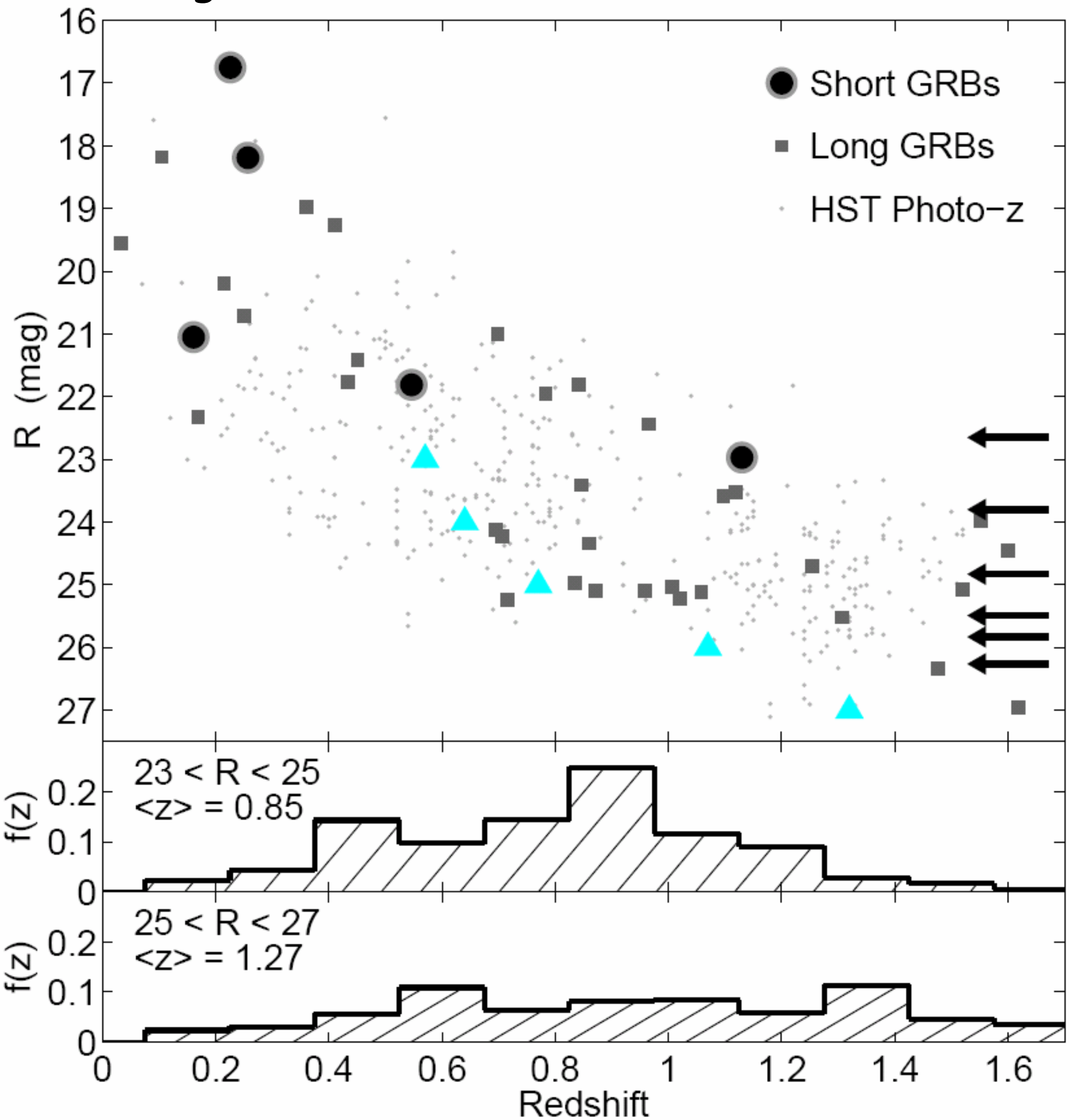




Swift GRBs with Redshifts
Diamonds: Short GRBs
Red Histo: Long GRBs
15
10
5
0
Noccur
0.01
0.1
1
10
Redshift



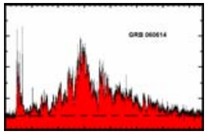
Berger et al. 2006

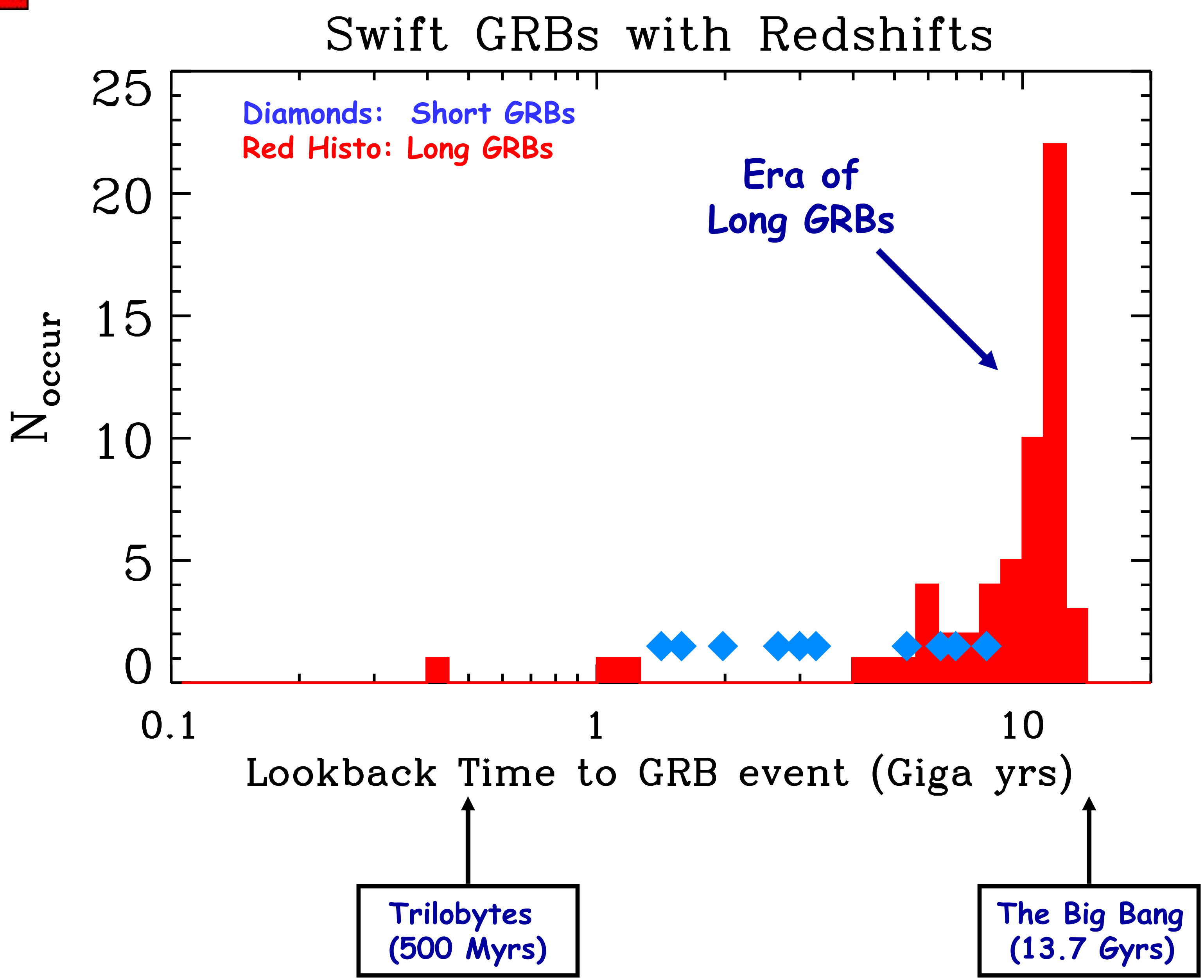


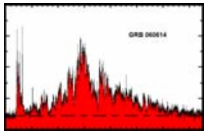
Six Probable Short GRB Host Galaxy R magnitudes, 22.6→26.3

z_{median_shorts}

~ 0.75




Swift GRBs with Redshifts
Diamonds: Short GRBs
Red Histo: Long GRBs
Era of Long GRBs
25
20
15
10
5
0
N_{occur}
0.1
1
10
Lookback Time to GRB event (Giga yrs)
Trilobytes (500 Myrs)
The Big Bang (13.7 Gyrs)

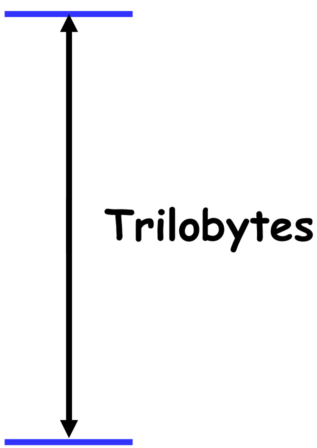


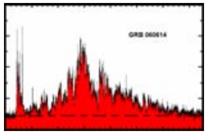
Geologic Time Scale

Era	Period	Epoch	Years Before The Present
Cenozoic	Quaternary	Holocene (Recent)	11,000
		Pleistocene (Glacial)	500,000 to 2,000,000
	Tertiary	Pliocene	13,000,000
		Miocene	25,000,000
		Oligocene	36,000,000
		Eocene	58,000,000
		Paleocene	63,000,000
Mesozoic	Cretaceous		135,000,000
	Jurassic		180,000,000
	Triassic		230,000,000
Paleozoic	Permian		280,000,000
	Pennsylvanian (Upper Carboniferous)		310,000,000
	Mississipian (Lower Carboniferous)		345,000,000
	Devonian		405,000,000
	Silurian		425,000,000
	Ordovician		500,000,000
	Cambrian		600,000,000
Precambrian			

Us

20 x before the age when the first Trilobytes appeared, Gamma-Ray Bursts had their big heyday.





Questions on Short GRBs' Extended Emission

- (Usual) morphology of Short GRBs
- Dynamic range in $R_{int} = I_{EE} / I_{IPC}$
- Temporal structure of Extended Emission
- Spectra of Extended Emission (vs. R_{int})

Fraction of *individual* short bursts (reported) with Extended Emission:

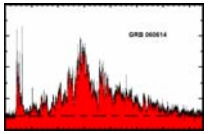
BATSE ~ 1.5%

Swift/BAT ~ 33%

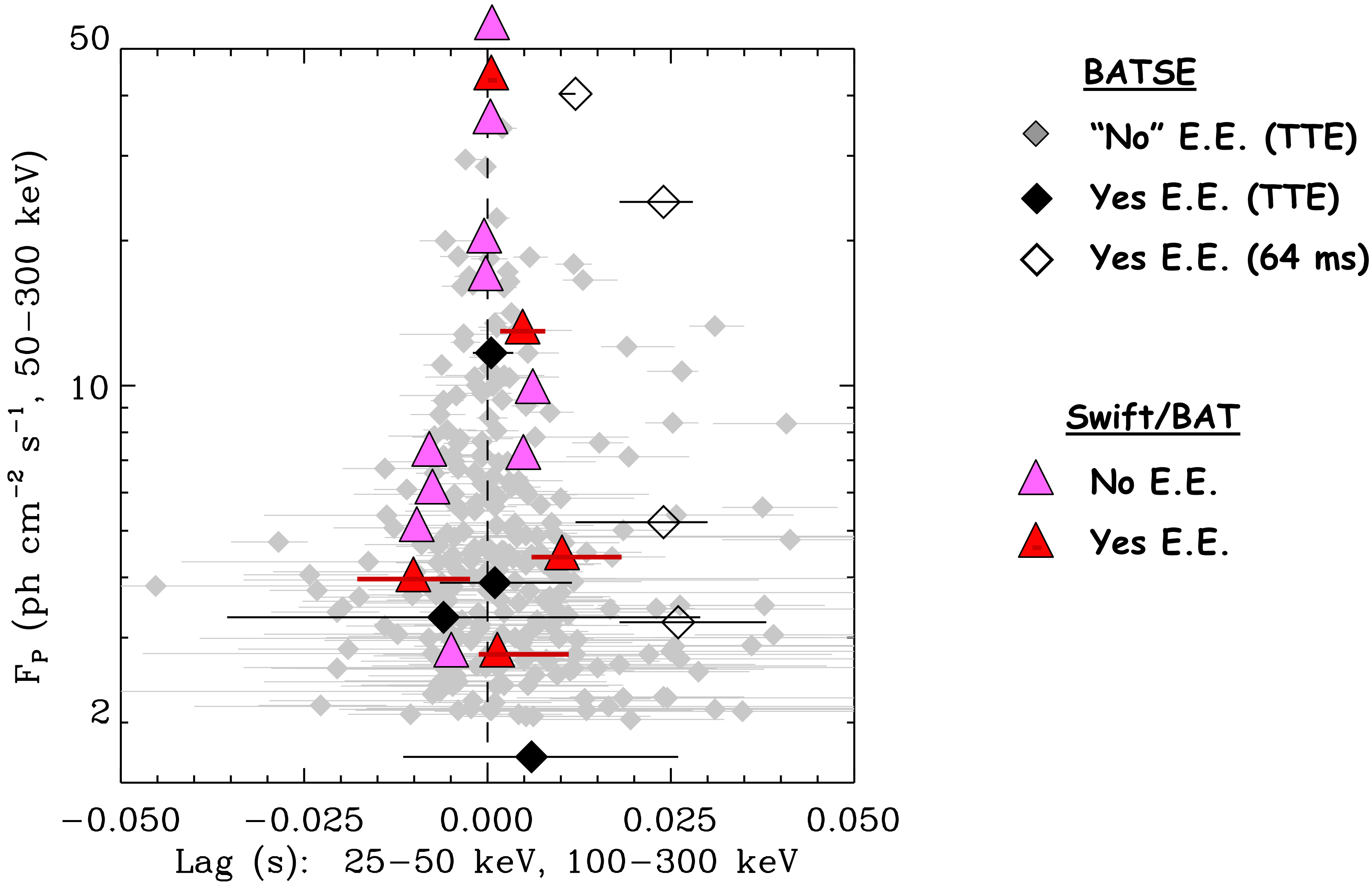
Two instrumental effects increase BAT percentage:

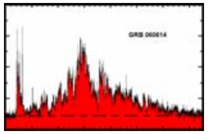
(1) BAT has A_{eff} to ~ 15 keV, and
(2) uses mask-tagged background estimation

{ NOT that: BAT less sensitive && $I_{EE} \propto I_{IPC}$ }

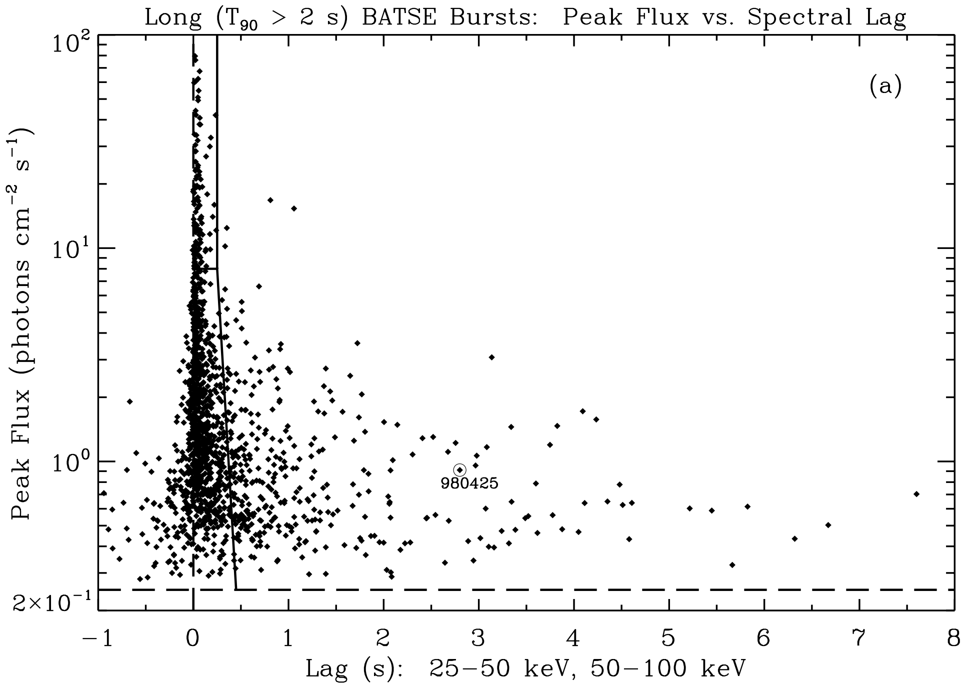


Spectral Lags: Short GRBs, w/ & w/o E.E.





Spectral Lags: Short & Long GRBs

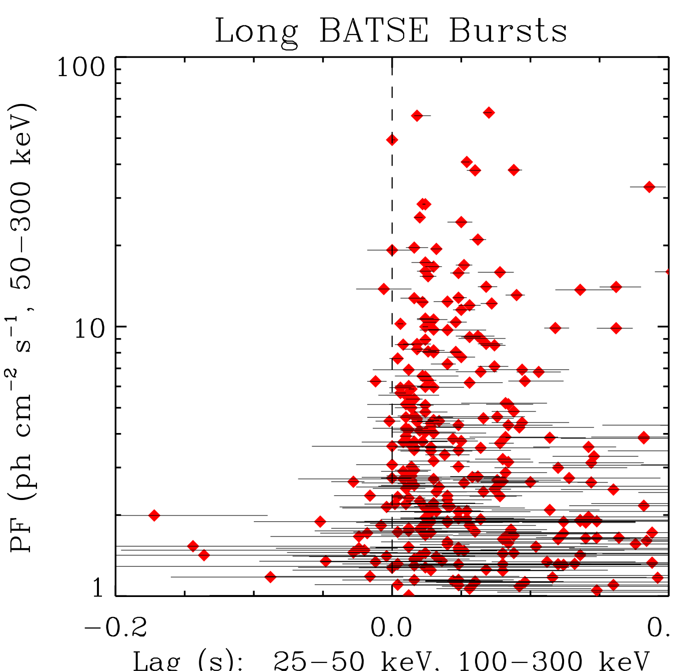


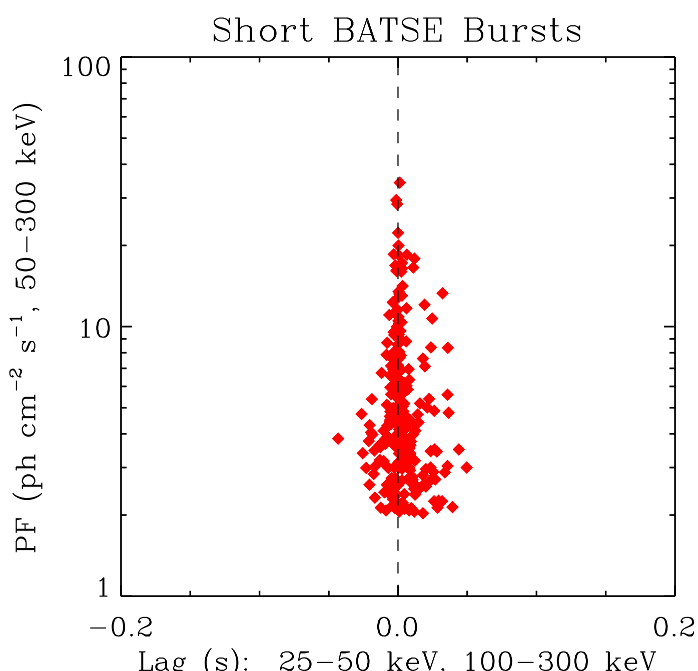
__Generalities__

(1) When good S/N, *shorts* have measured lags 0-few ms — fairly uniform picture.

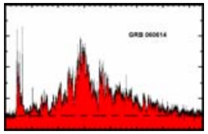
(2) Median lag for *bright long bursts* is ~ 55 ms, with a few % extending to shorts' domain

Lags for *dimmer long bursts* extend to several seconds.

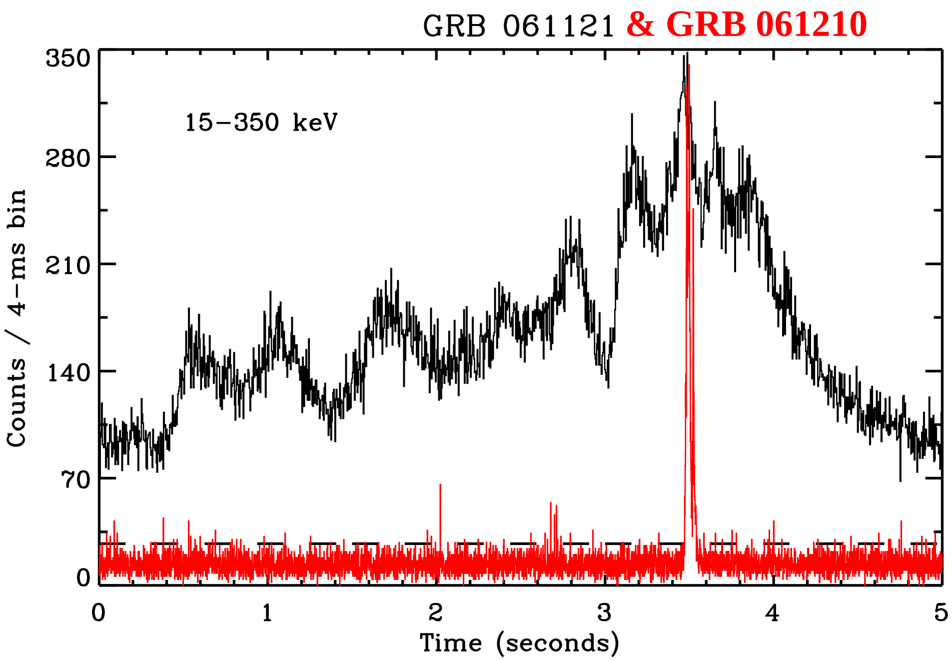




Spectral Lag is a good discriminant — but by itself, not the "silver bullet"



Pulse Widths: Brightest Short & Long GRBs

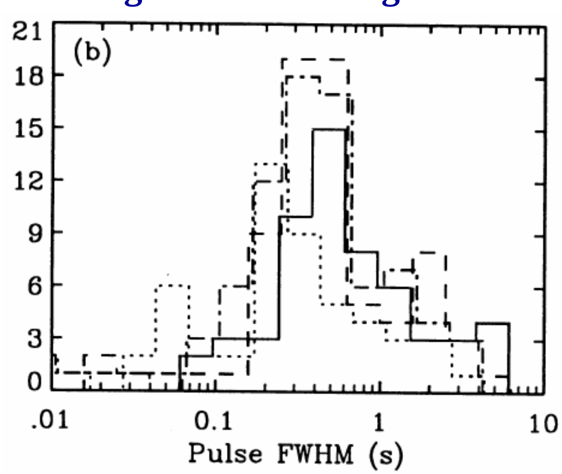


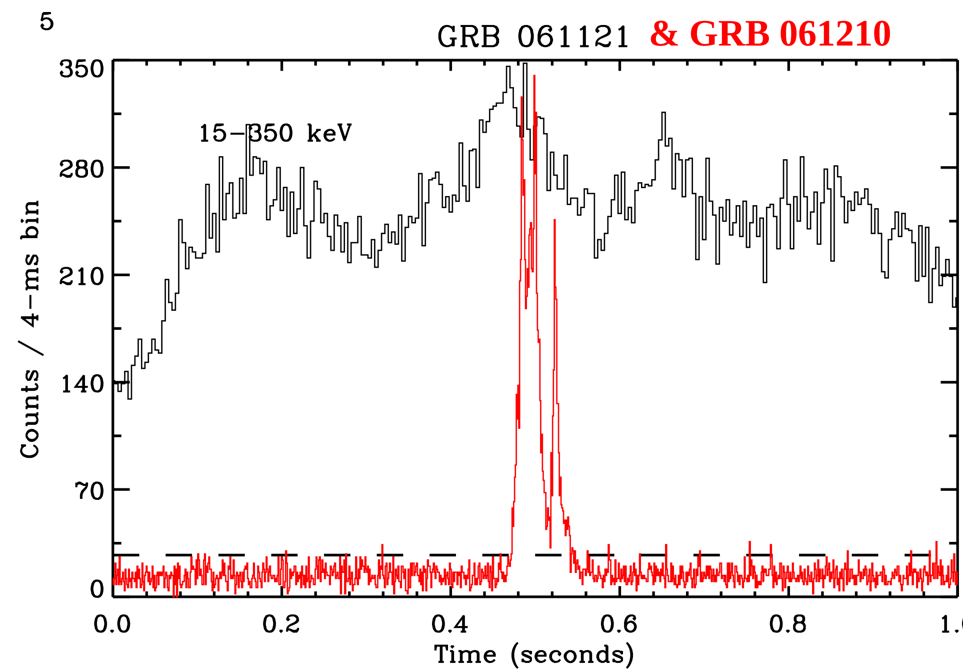
<u>*Generalities*</u> (when good S/N)

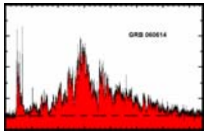
(1) Long bursts *nearly* always have pulse FWHM > 100 ms, event when lag is very short.

(2) Short bursts usually have pulse FWHM ~ 5-30 ms.

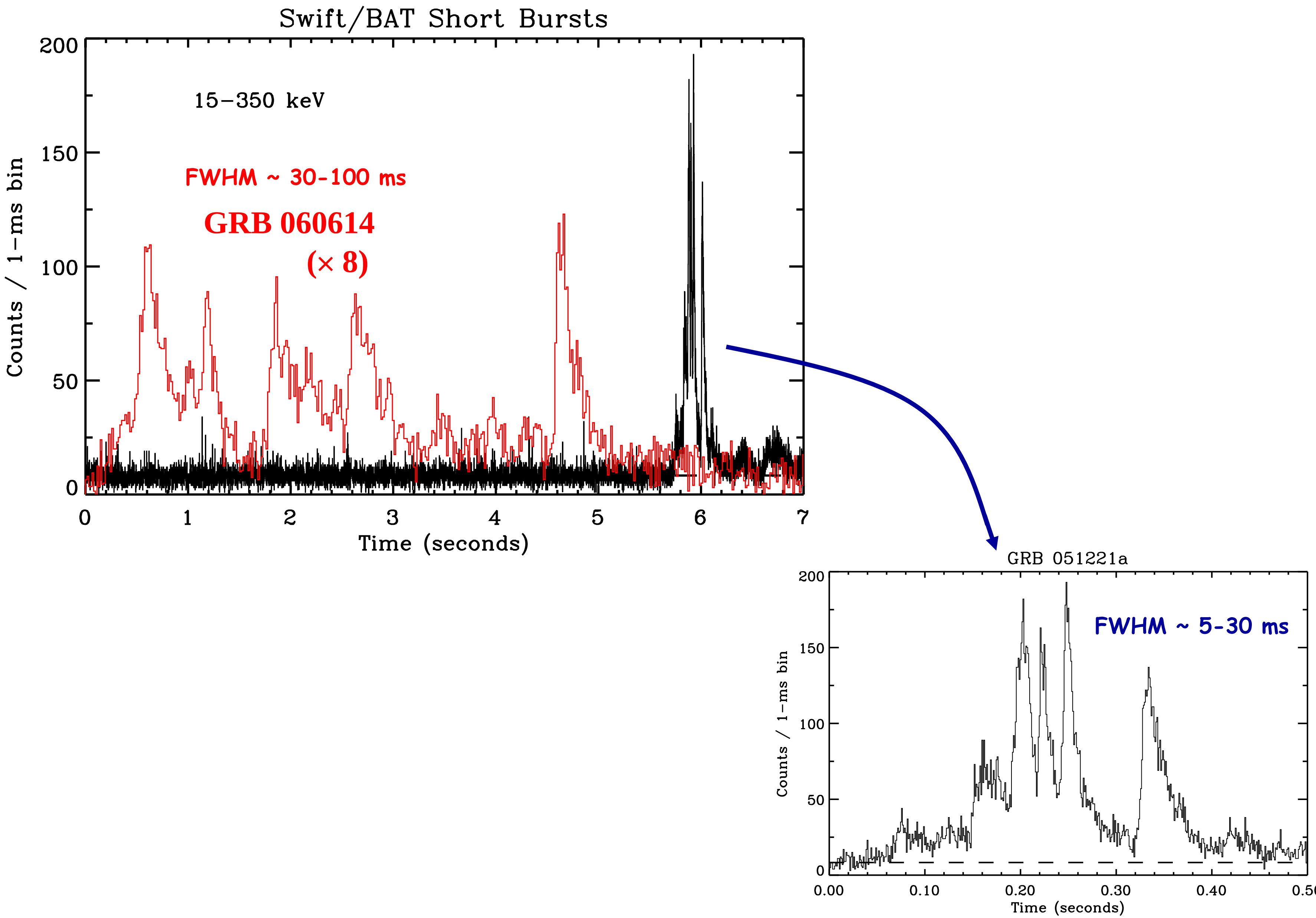
Bright BATSE Long Bursts

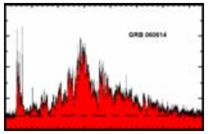




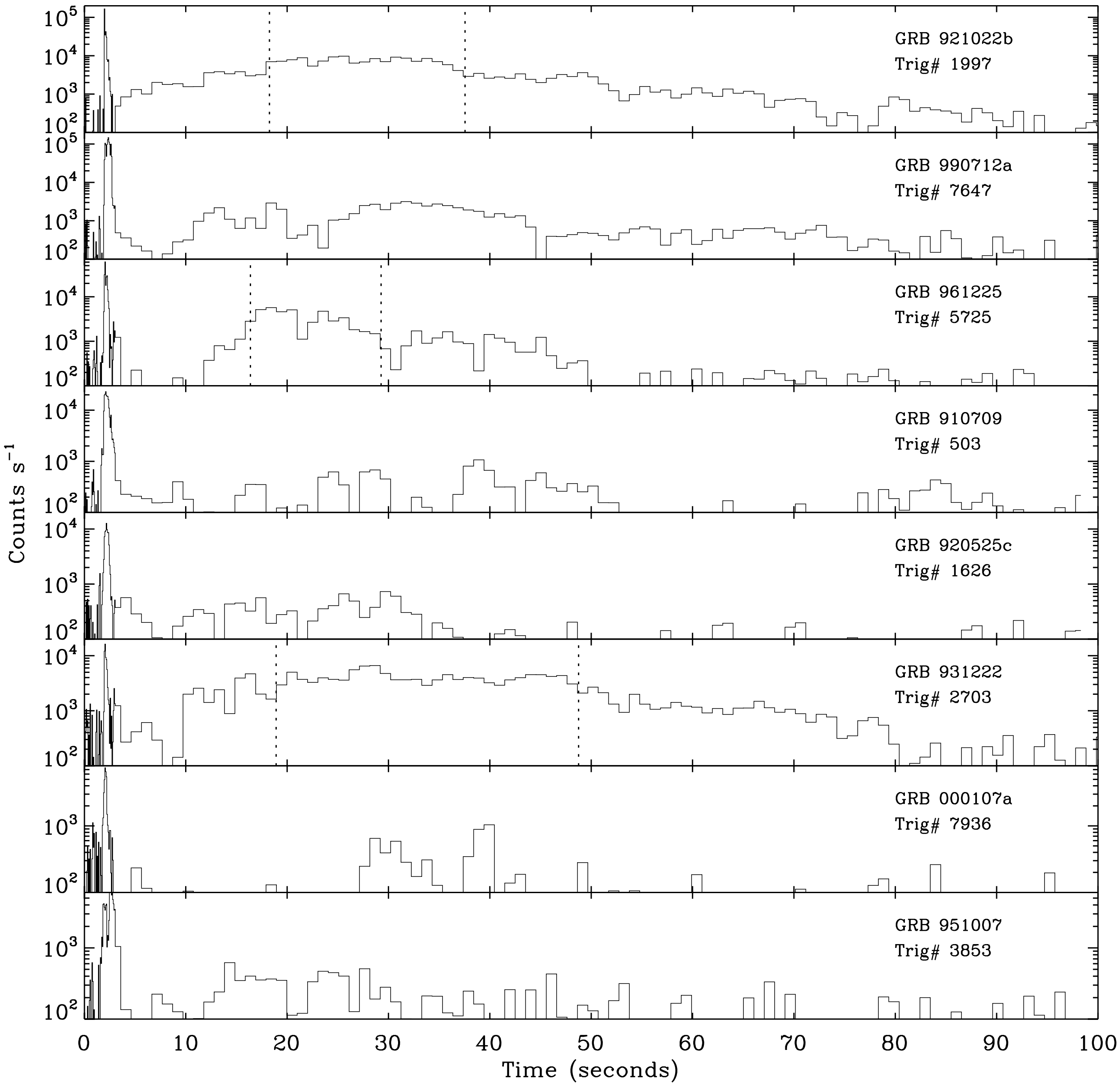


Pulse Widths: GRB 060614 and 051221a





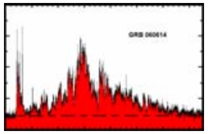
Short GRBs' Canonical Morphology: 3 phases



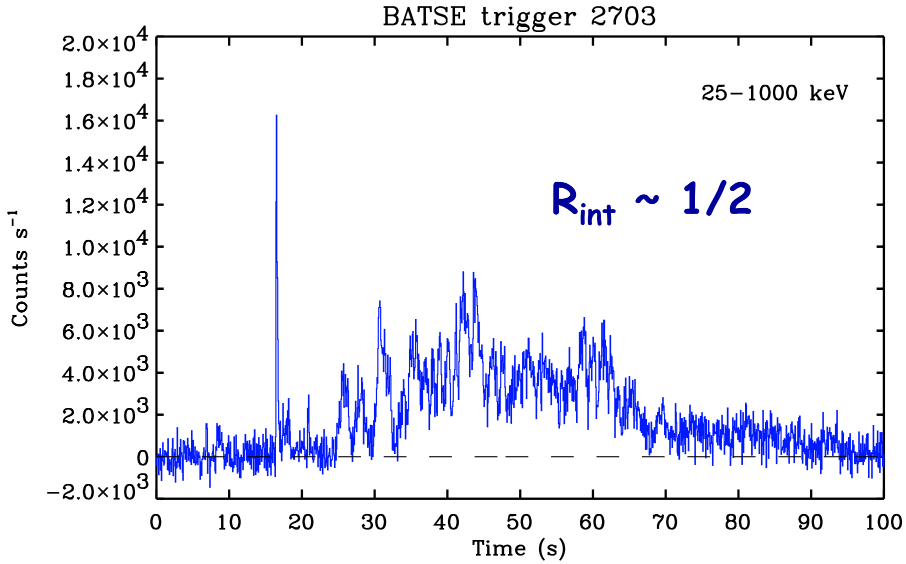
Initial short pulses complex ~ 0.1-3 s

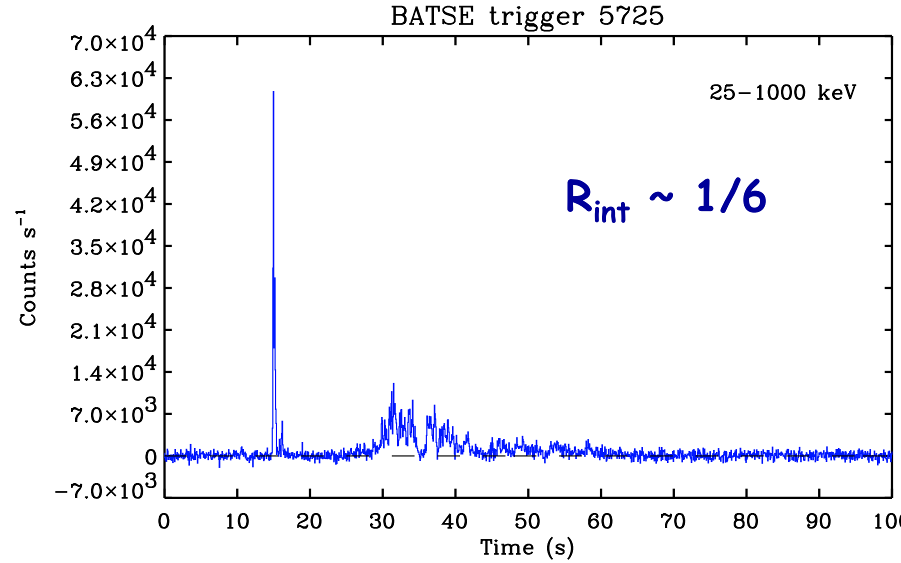
~ 5-10 s hiatus

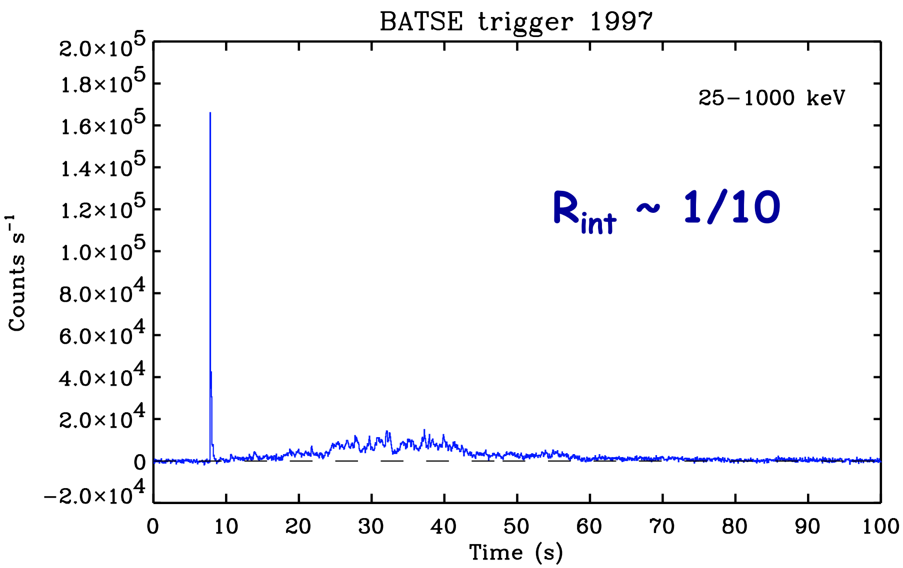
Extended Emission ~ 30 - 100 s

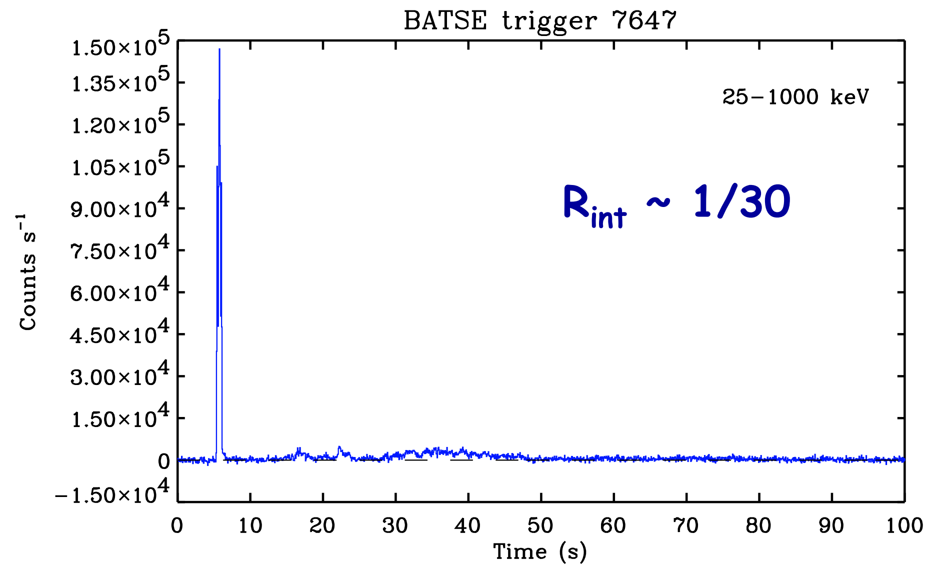


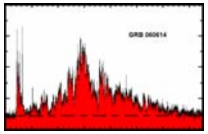
Short GRBs' Canonical Morphology: Intensity Ratio



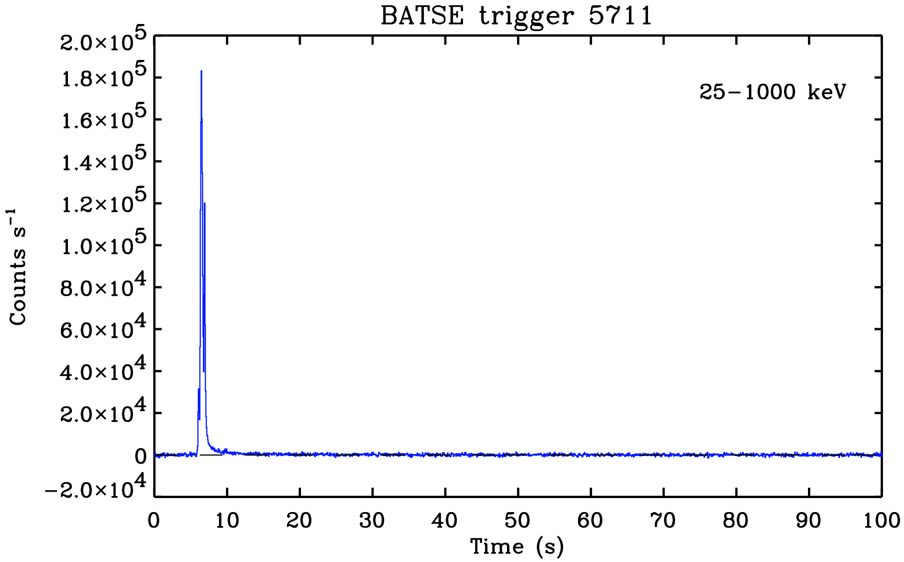






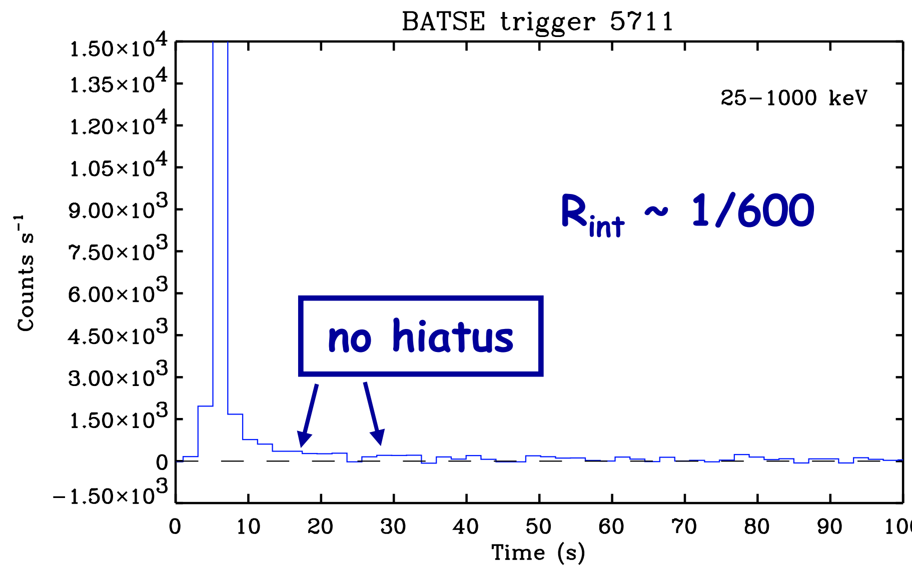


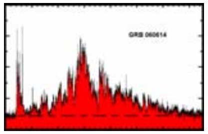
Short GRBs' Canonical Morphology



R_{int} shrinks …

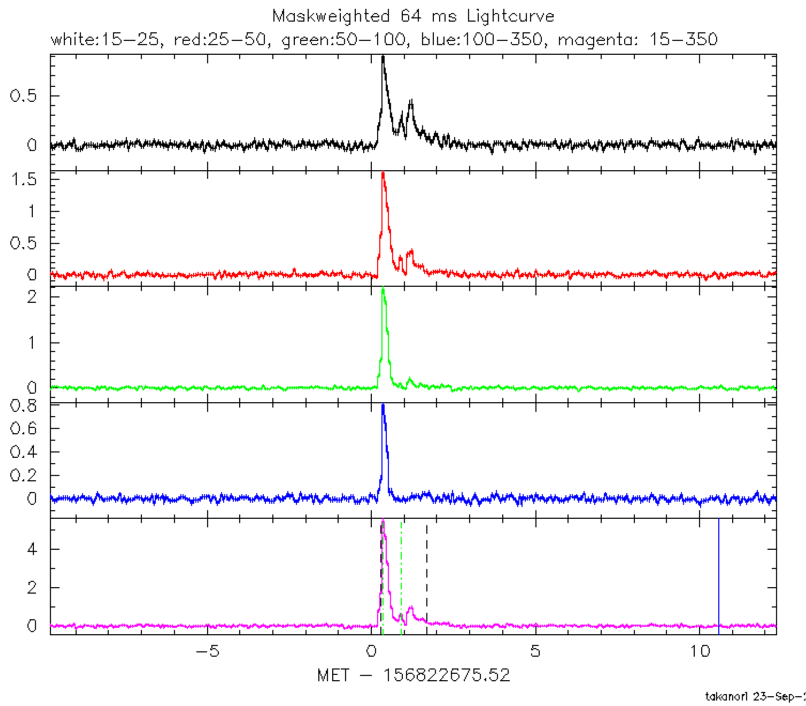
X 13 →



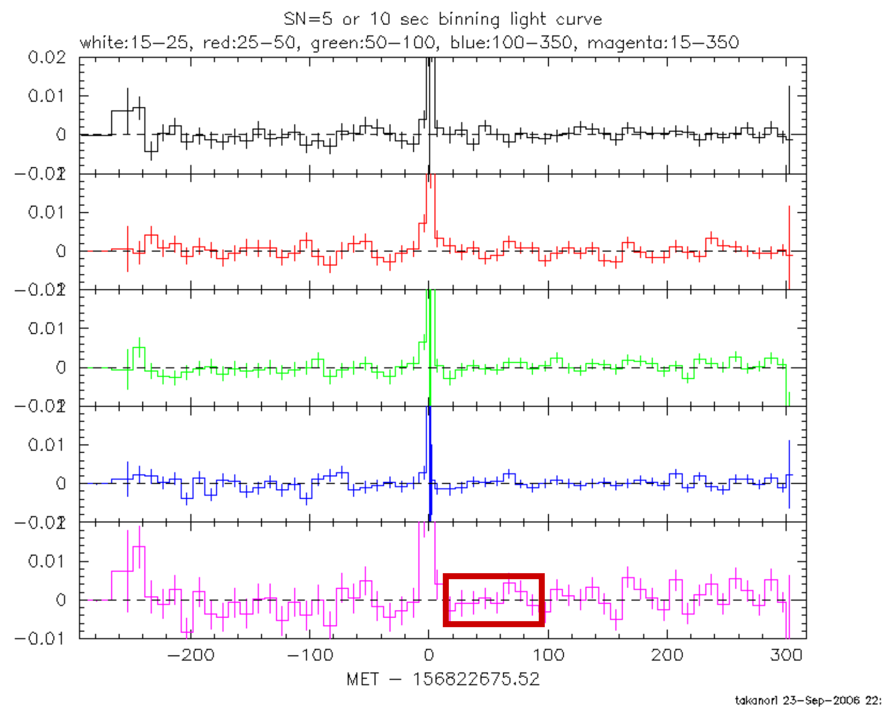


Short GRBs' Canonical Morphology

R_{int} shrinks more

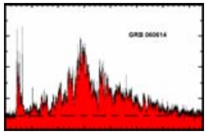


GRB 051221a — Momentarily, Brightest Swift/BAT burst !!!

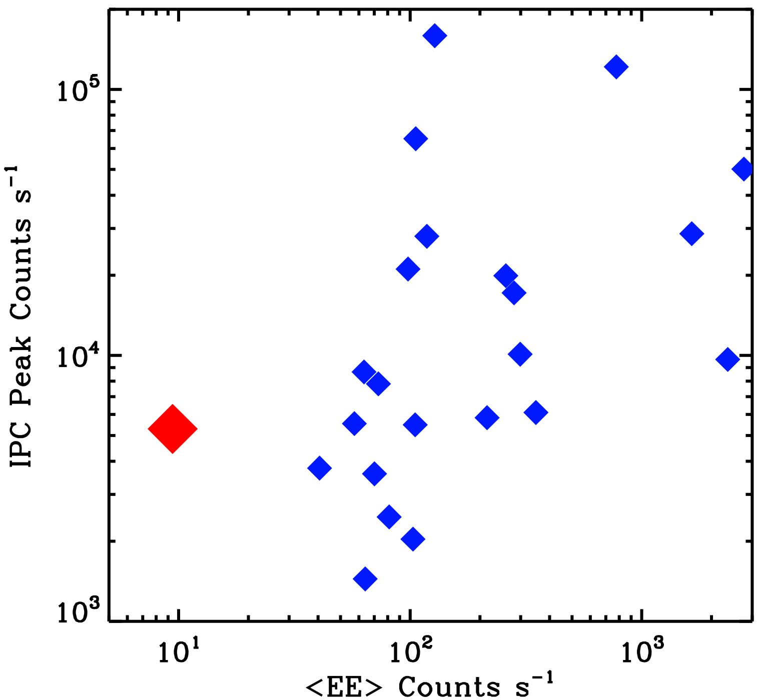


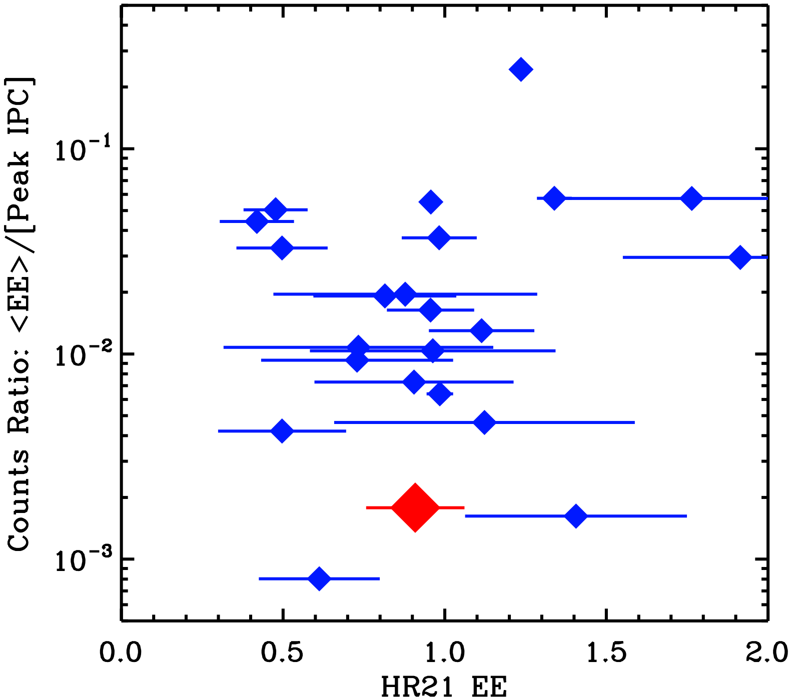
R_{int} < 1/3000

So, what's the "normal" Intensity Ratio?



Short GRBs' Canonical Morphology

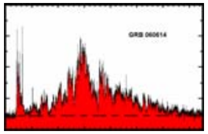




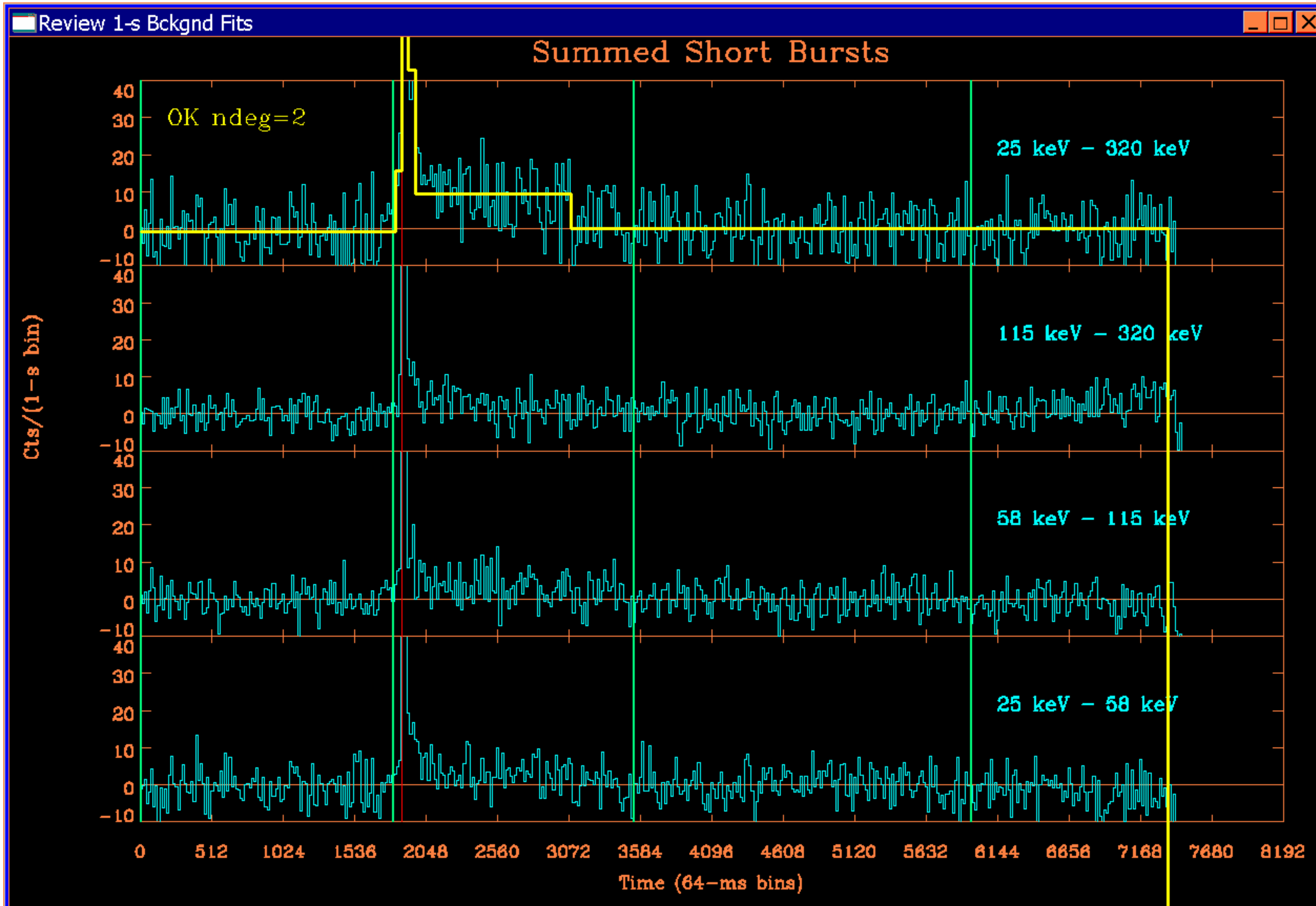
In most short bursts the E.E. component is present, but weak.

There is no obvious relation between IPC and EE intensities.

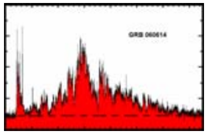
The average spectral hardness for bursts with weak EE is near the middle of the HR21 distribution.



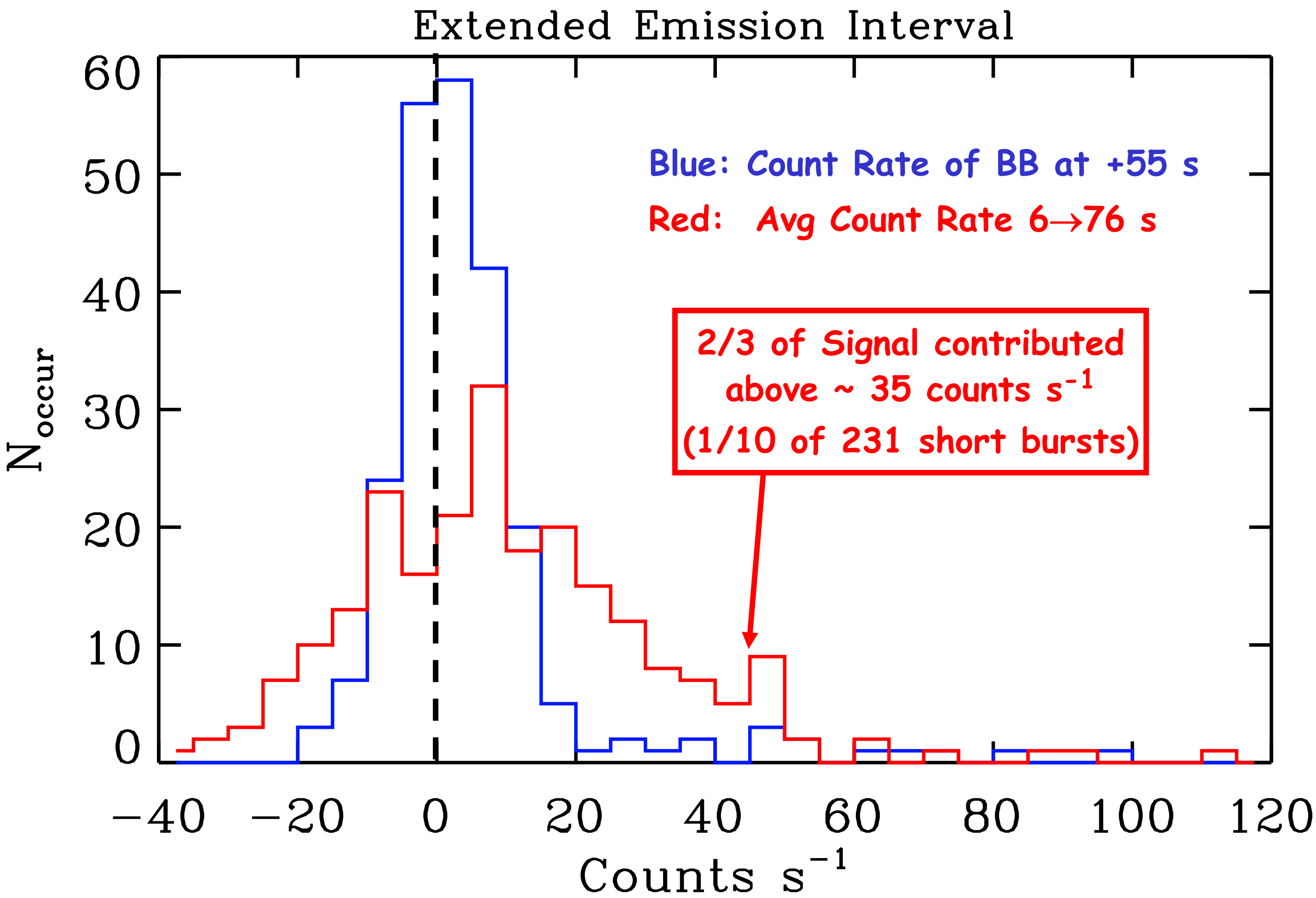
231 Co-added BATSE bursts (where EE “indiscernible”):

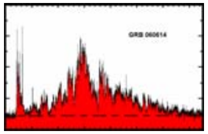


EE ≈ 9.4 cts s^{-1} IPC ≈ 5290 cts s^{-1} : R_{int} ≈ 0.0018

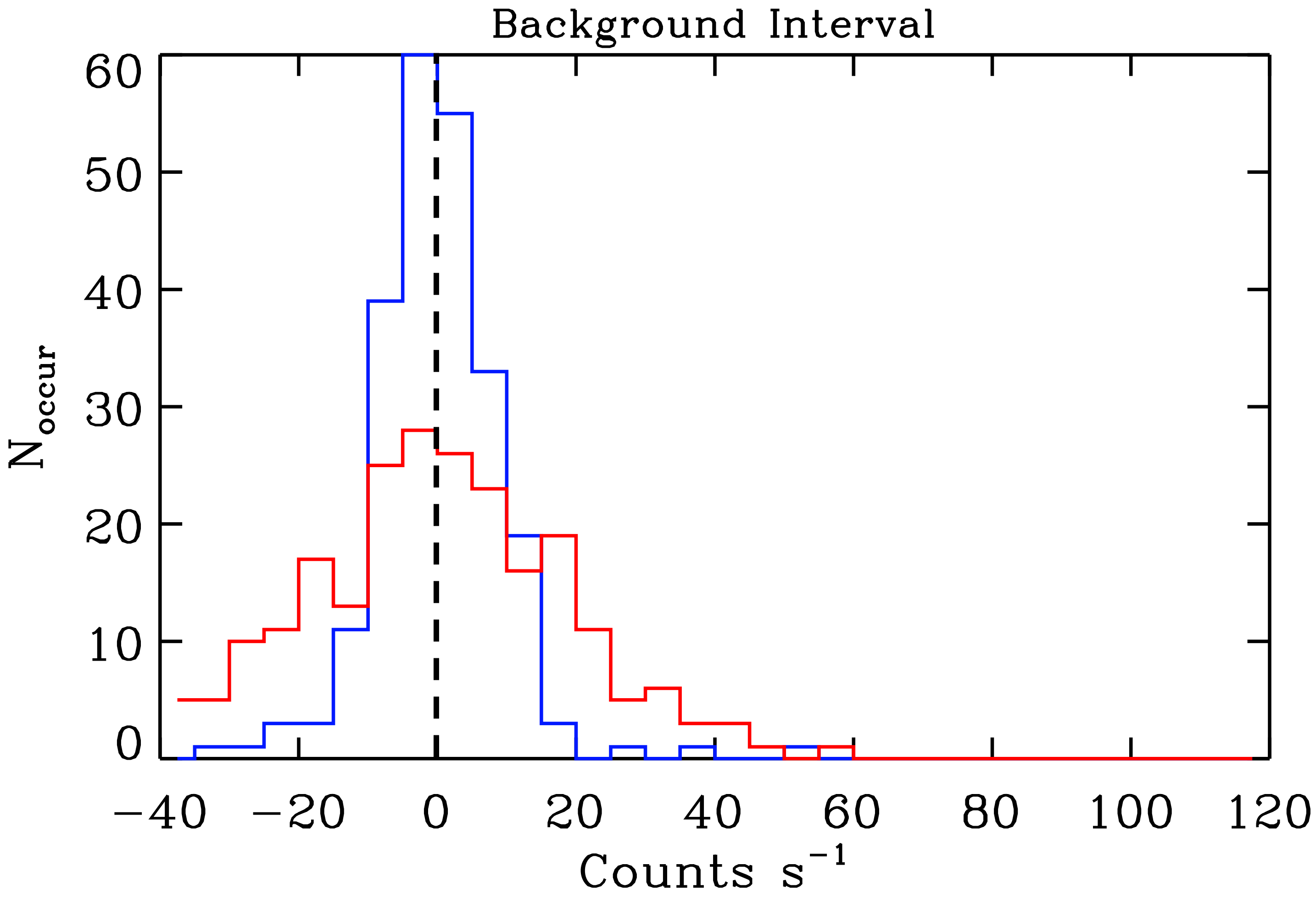


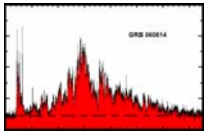
Short GRBs' Canonical Morphology



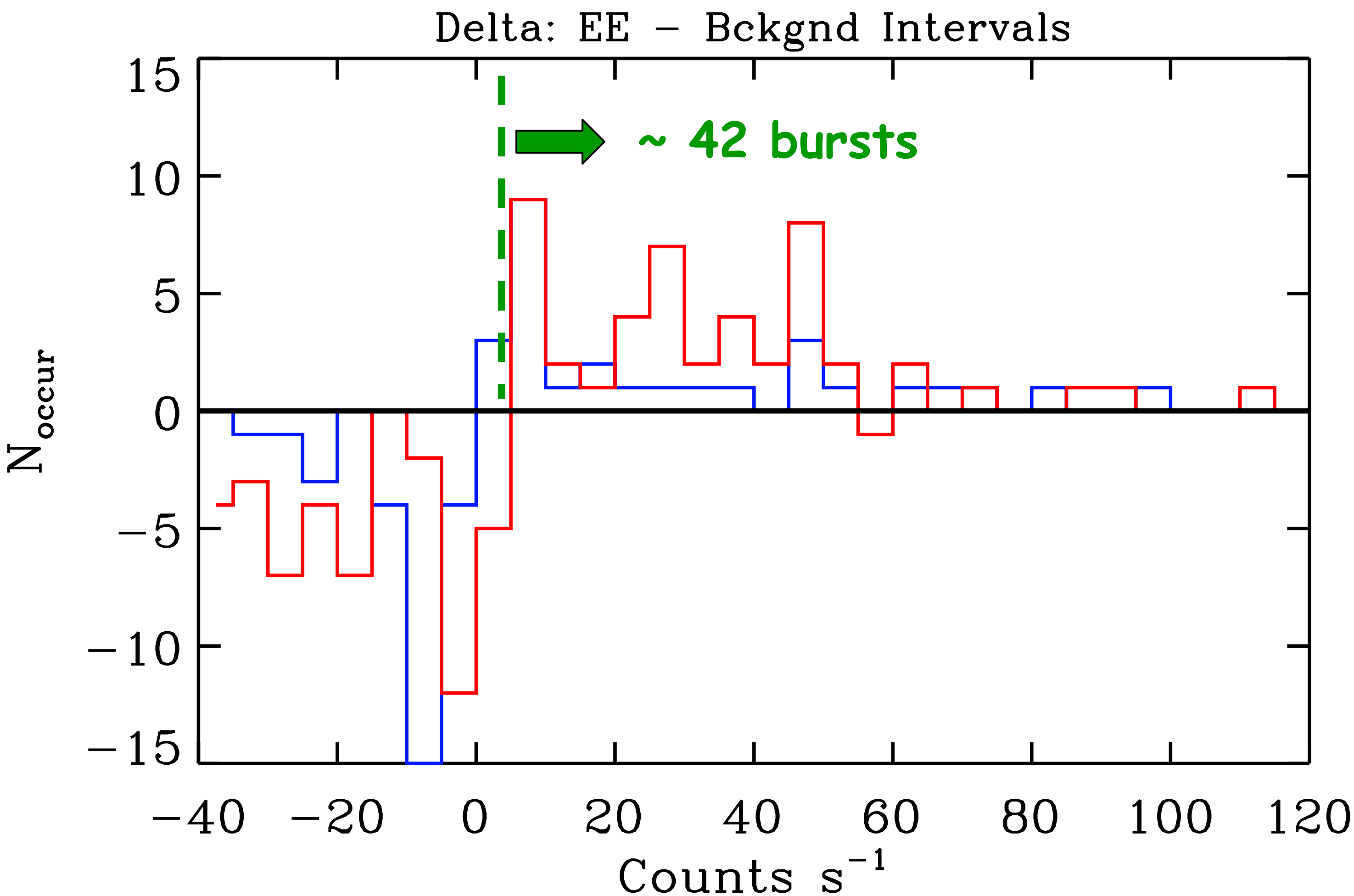


Short GRBs' Canonical Morphology

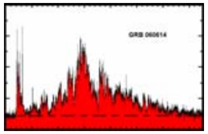




Short GRBs' Canonical Morphology

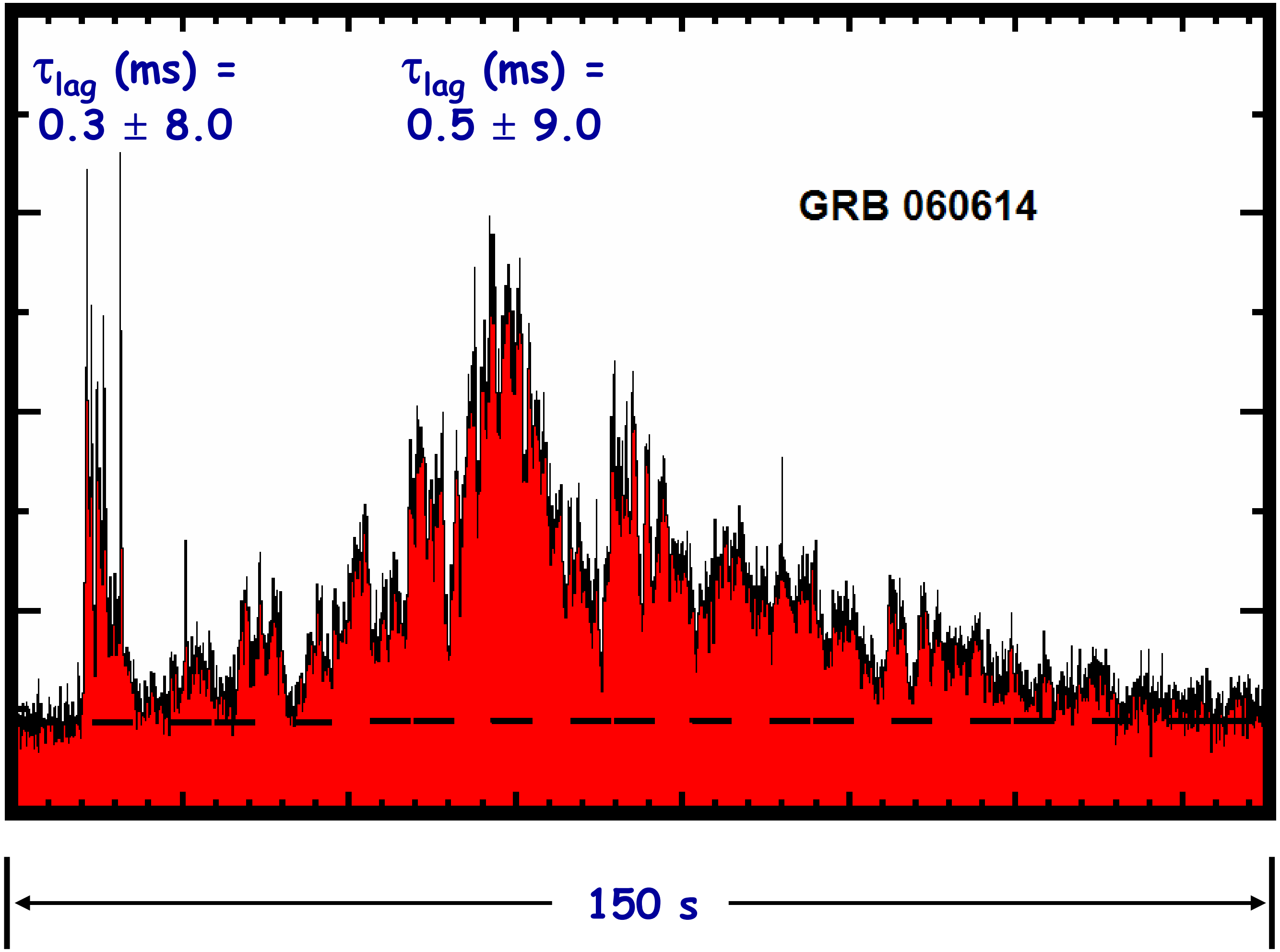


~ (42+22) / (231+22) → 25% have R_{int} >~ 0.001



"The Mysterious Burst After the Short Burst"

"New Gamma-Ray Burst Classification Scheme from GRB 060614" Gerhels et al. (Nature 2007)



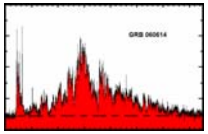
R_{int} ~< 1/1

Initial short pulses complex ~ 0.1-3 s (6 s)

~ 5-10 s hiatus (5 s)

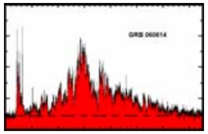
Extended Emission ~ 30 - 100 s (130 s)

(z = 0.125 and no SN)



Conclusions: Short GRB Morphology

- EE component is present in ~ 33% (25%) of BAT (BATSE) bursts at levels ranging over $R_{int} = I_{EE}/I_{IPC} \sim 0.001 - 0.6$, the large majority with $R_{int} \sim 0.001 - 0.01$.
- Over the range of R_{int} the EE components of individual bursts are spectrally similar, and no correlation with $F_p\{IPC\}$.
- Some of the brightest short bursts have no EE component, to $R_{int} < 0.0003$.
- Vast dynamic range in R_{int} is the clue to short bursts.



Prompt EE component spectrally different from X-ray afterglow

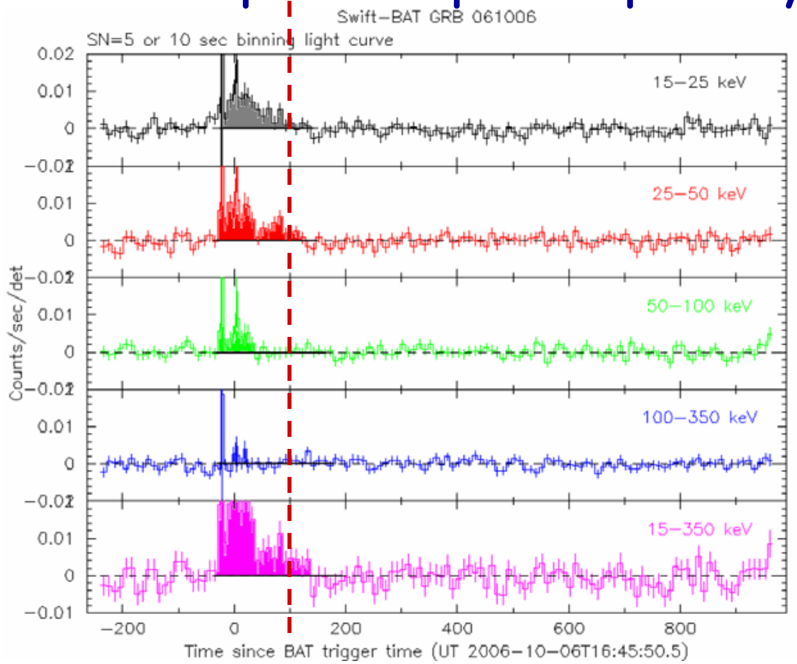
15-25 keV

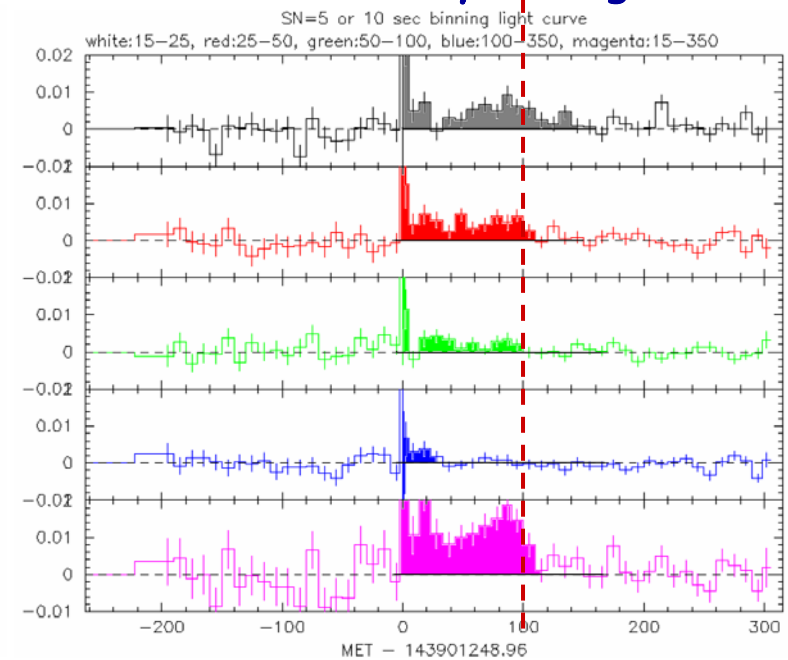
25-50 keV

50-100 keV

100-350 keV

15-350 keV





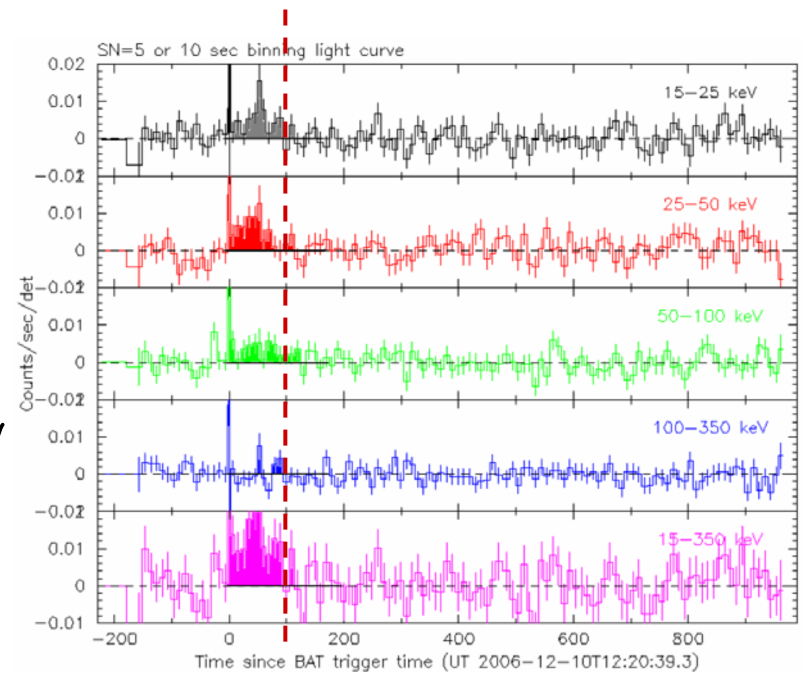
15-25 keV

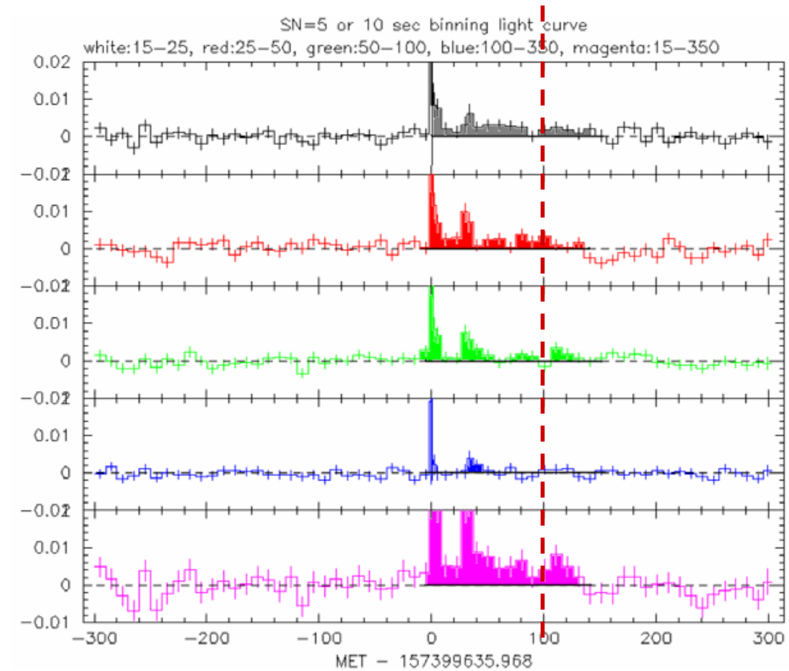
25-50 keV

50-100 keV

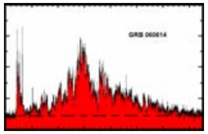
100-350 keV

15-350 keV

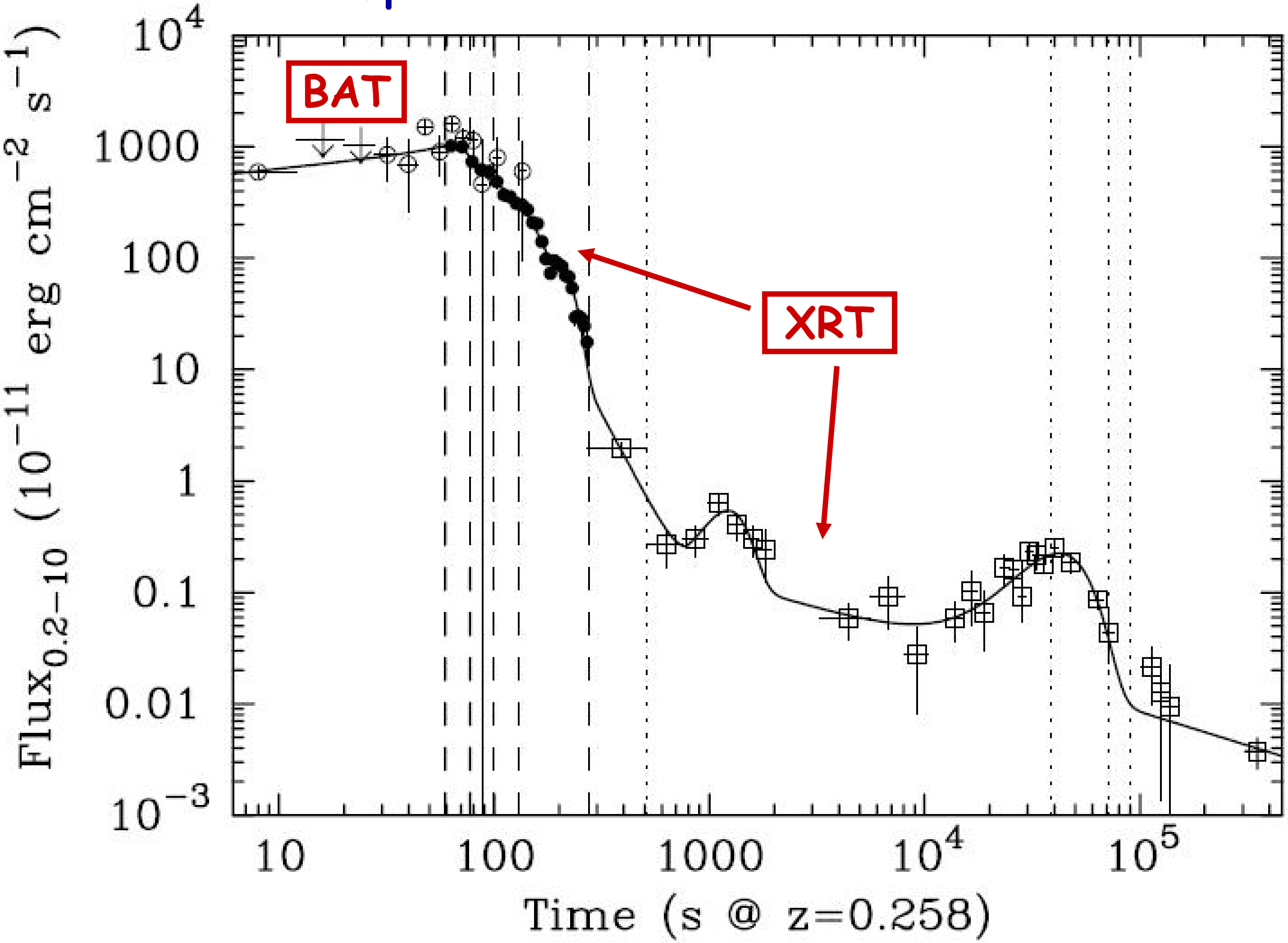




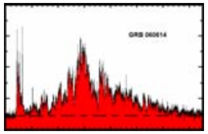
Prompt EE component temporally different from X-ray afterglow



Campana et al. — GRB 050724



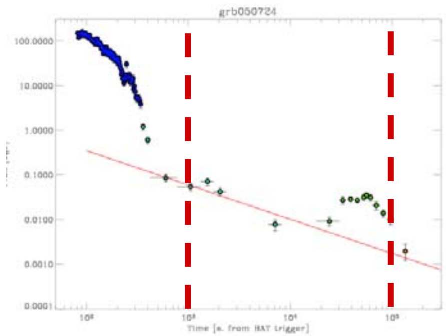
Model fit: 4 Gaussians + triple power-law

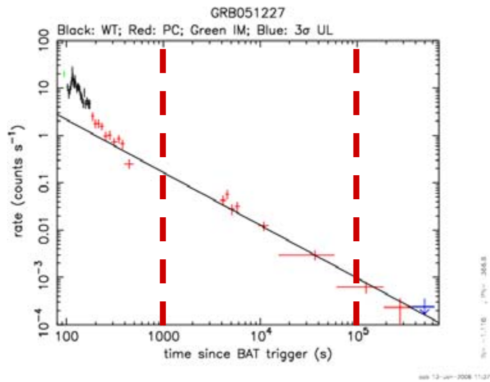


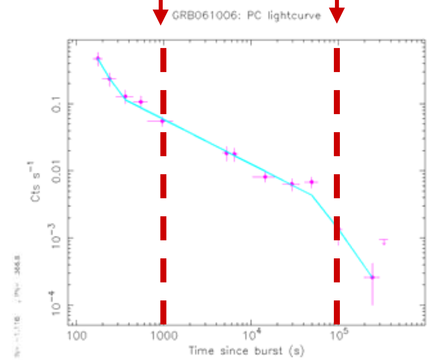
Diverse X-ray Afterglows of Short GRBs, not correlated with presence/absence of EE component

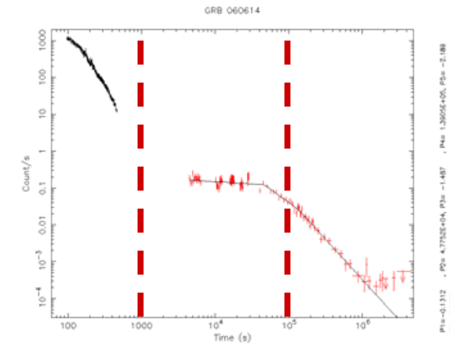
10^3 s 10^5 s

Extended Prompt Emission:

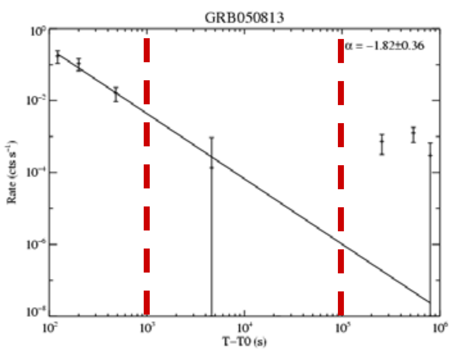


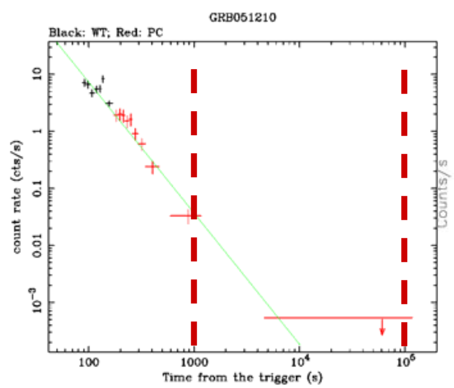


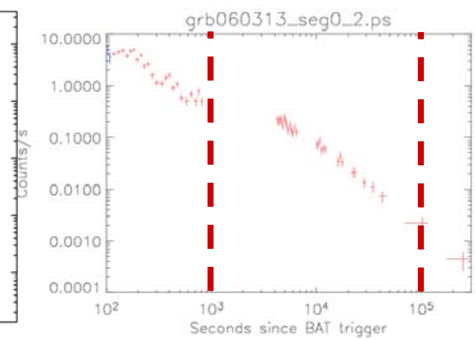


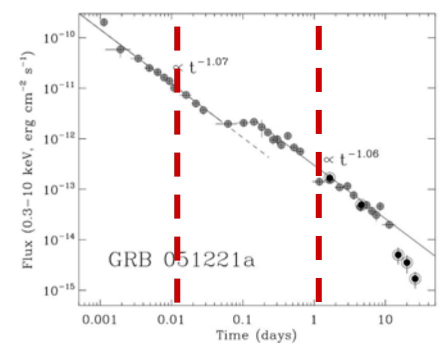


No Extended Prompt Emission:

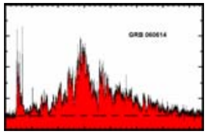








Late "flares" Early "flares" Three phases Three phases



Summary

- No one attribute is a silver bullet indicating short vs. long. However, Long GRBs manifest a large range in temporal attributes {pulse width, duration} — Short GRBs less so.
- EE component is present in ~ 33% (25%) of BAT (BATSE) bursts, to levels $R_{int} > 0.001$. Much below this level, neither BAT nor BATSE have the sensitivity to comment.
- Infrequent bursts with R_{int} ~> 0.1 appear phenomenal, but just represent the tail of the distribution.
- A few of the very brightest short bursts have no EE component, to $R_{int} = I_{EE}/I_{IPC} < 0.0003$.
- Vast dynamic range in R_{int} is the real mystery.