Konus-Wind observations of GRBs with measured redshifts

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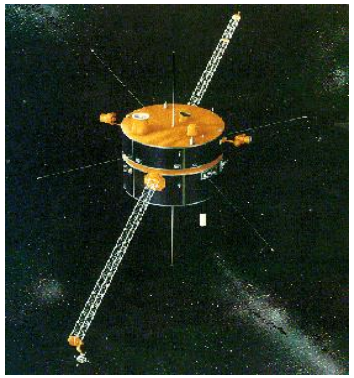
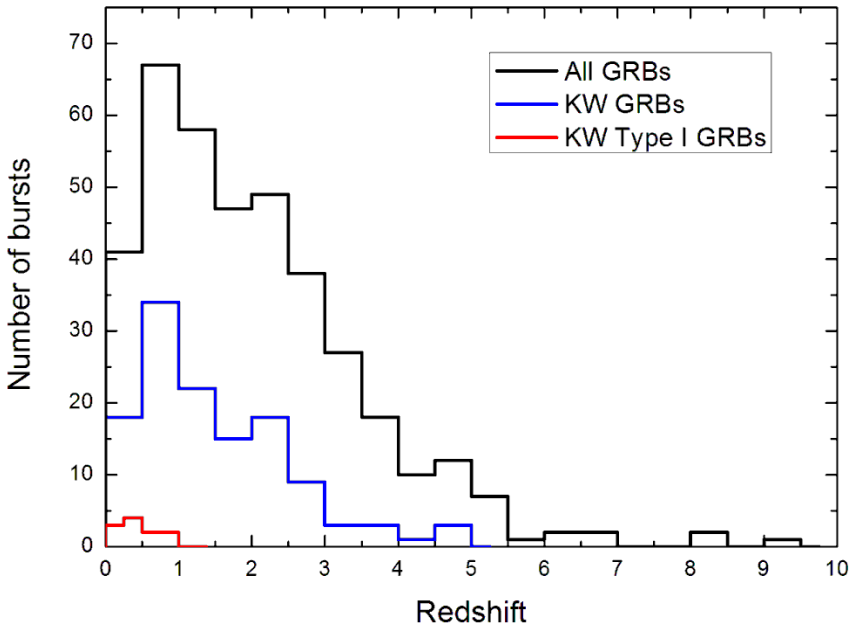
Joint Russian-US Konus-Wind experiment

- Launched on November 1, 1994
- Two detectors (S1 and S2) are located on opposite faces of spacecraft, observing correspondingly the southern and northern celestial hemispheres
- Continuous observations of all sky
- ~100-160 cm^2 effective area
- Sensitivity ~(1-3)x10^{-7} erg cm^{-2}
- The orbit of s/c excepts interferences from radiation belts and the Earth shadowing.
- Now around L1 at ~5 light seconds from Earth
- Exceptionally stable background
- Spectral data: ~20 keV – 15 MeV energy range (present time)
- Time history: ~20 keV – 1 MeV

  Two modes: waiting (resolution 2.944 s) and triggered (2 ms –256 ms, from T_0-0.512 s to T_0+230 s)



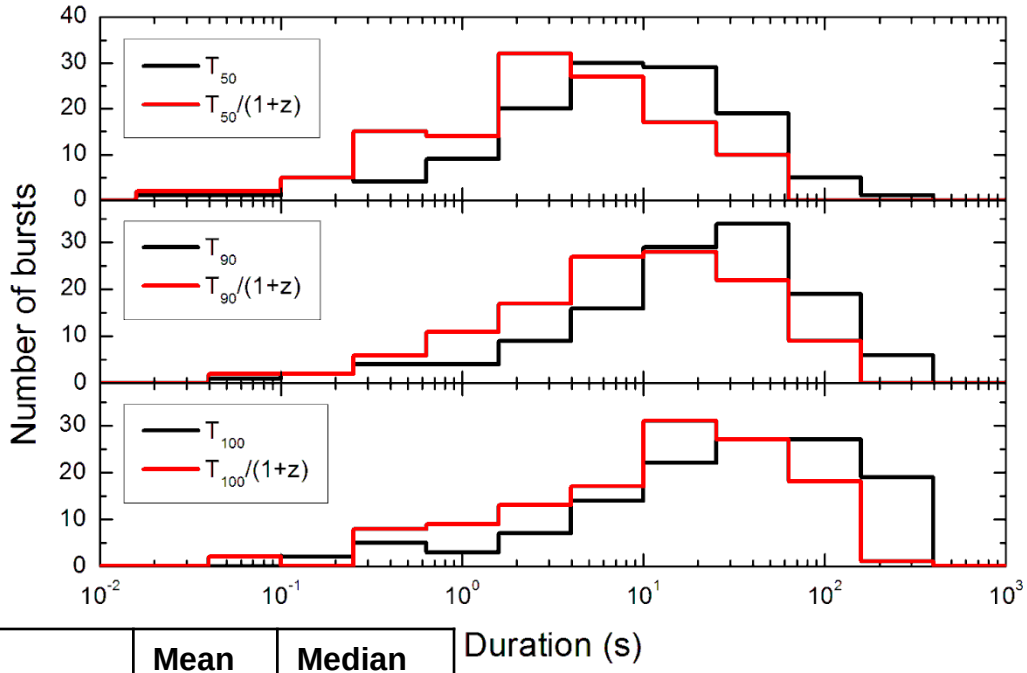
Redshift distribution



Data set	Number of bursts	Min z	Max z	Mean z	Median z
All GRBs	401	0.00649 (GRB080109)	9.4 (GRB090429B)	2.0	1.7
KW GRBs	126	0.096 (GRB091117A)	5.0 (GRB111008A)	1.5	1.2
Type I KW GRBs	11	0.096 (GRB091117A)	0.92 (GRB070714B)	0.5	0.4

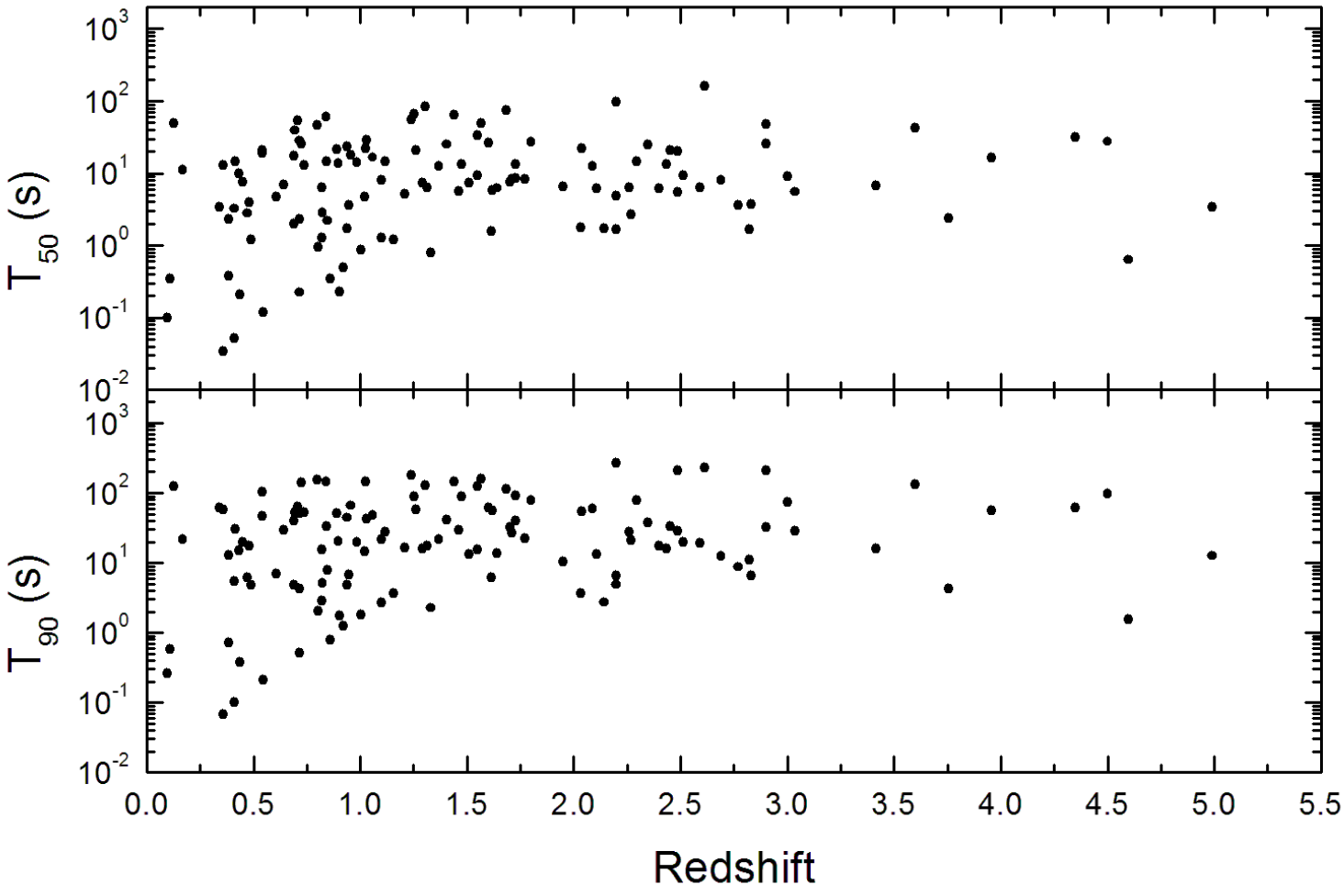
Durations

Durations are calculated
in the 75 keV – 1 MeV range



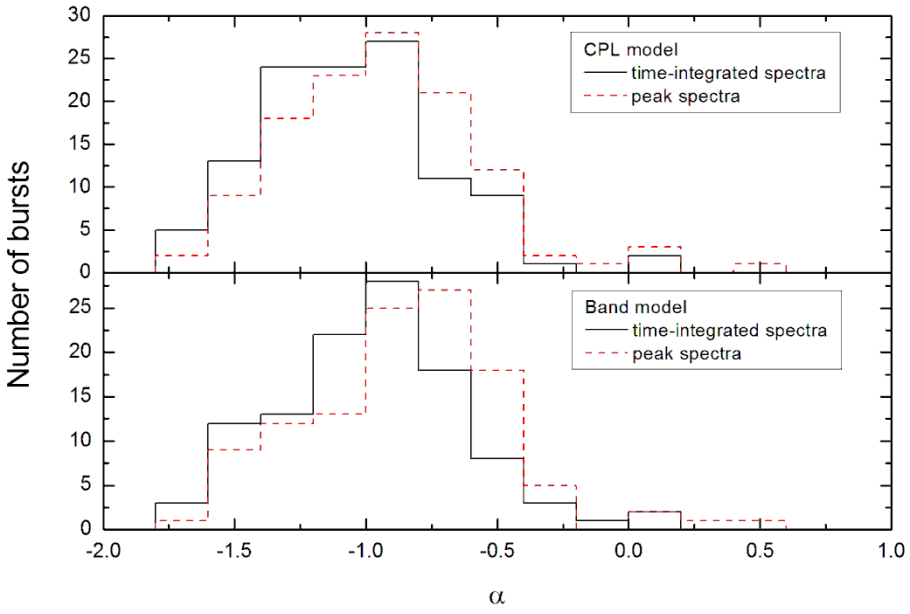
Parameter	Min	Max	Mean	Median
Observer frame T_{50} (s)	0.03 (GRB130603B)	160.76 (GRB050820A)	16.30	7.73
Observer frame T_{90} (s)	0.07 (GRB130603B)	267.904 (GRB120624B)	44.26	21.68
Observer frame T_{100} (s)	0.11 (GRB130603B)	288.51 (GRB120624B)	63.84	34.93
Rest frame T_{50} (s)	0.02 (GRB130603B)	44.51 (GRB050820A)	6.94	3.08
Rest frame T_{90} (s)	0.05 (GRB130603B)	109.91 (GRB060614)	18.73	9.42
Rest frame T_{100} (s)	0.08 (GRB130603B)	170.88 (GRB130427A)	28.04	13.66

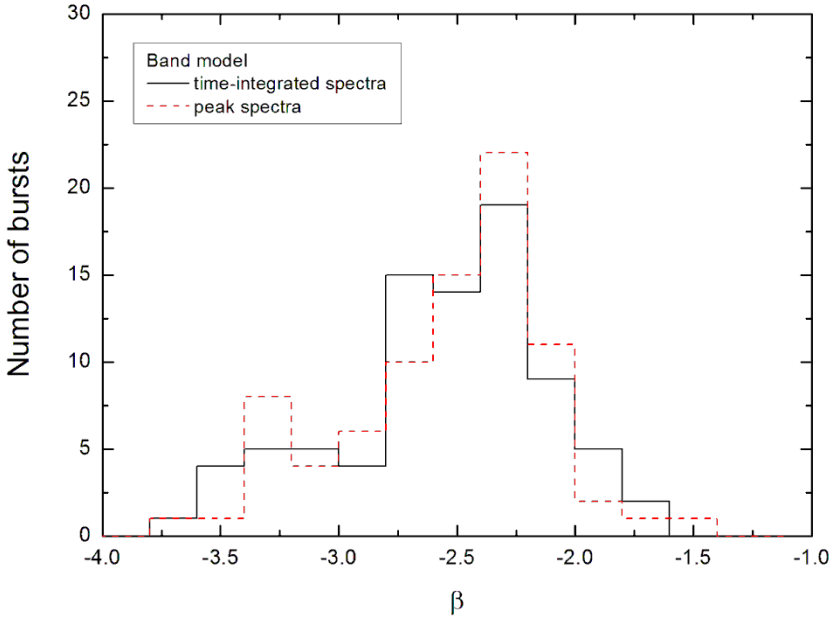
Temporal parameters



Spectral parameters: PL indices

Spectral analysis: time-integrated and peak spectra,
CPL and Band models.





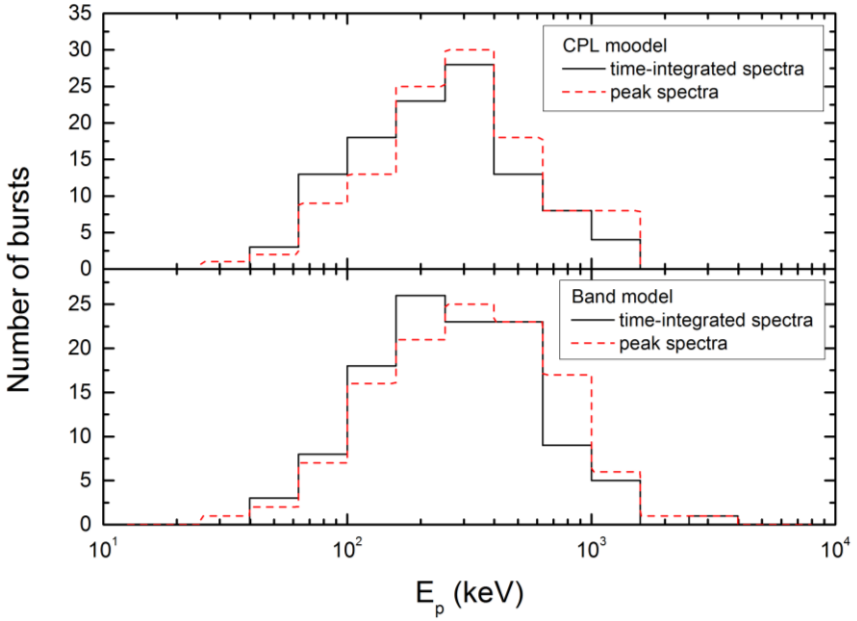
The GRBs outside the synchrotron “line-of-death” and the synchrotron cooling limit:

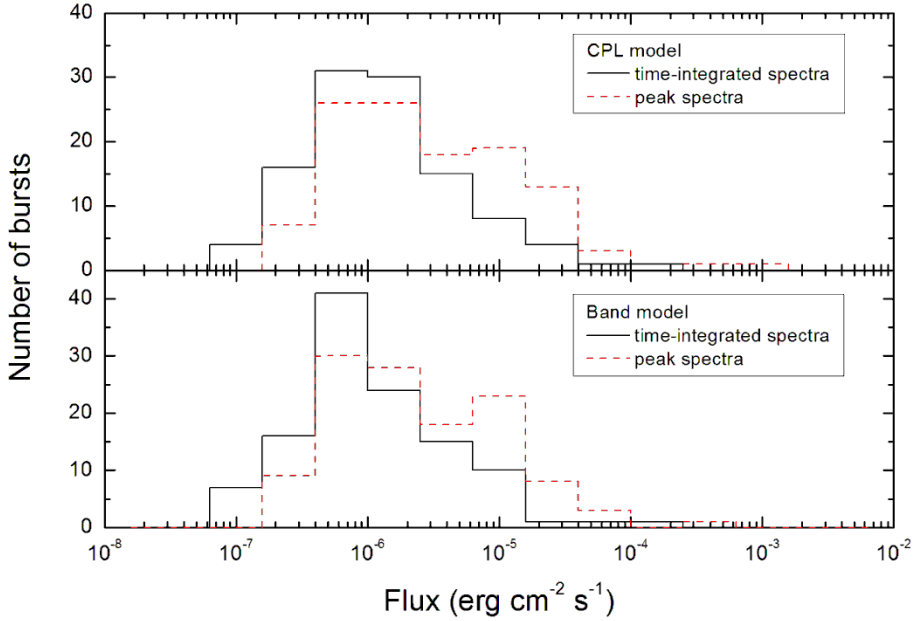
α>-2/3: 15% of time-int & 25% of peak spectra

α<-3/2: 10% of time-int & 5% of peak spectra

Parameter name	mean value	median value
α	-0.98	-0.97
β	-2.56	-2.48

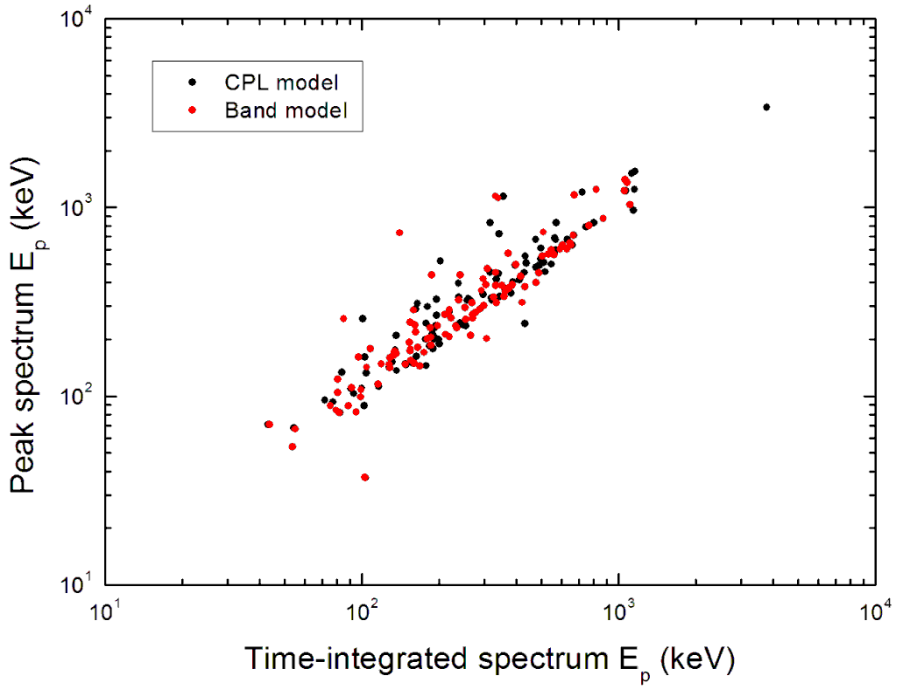
Spectral parameters: E_p and flux

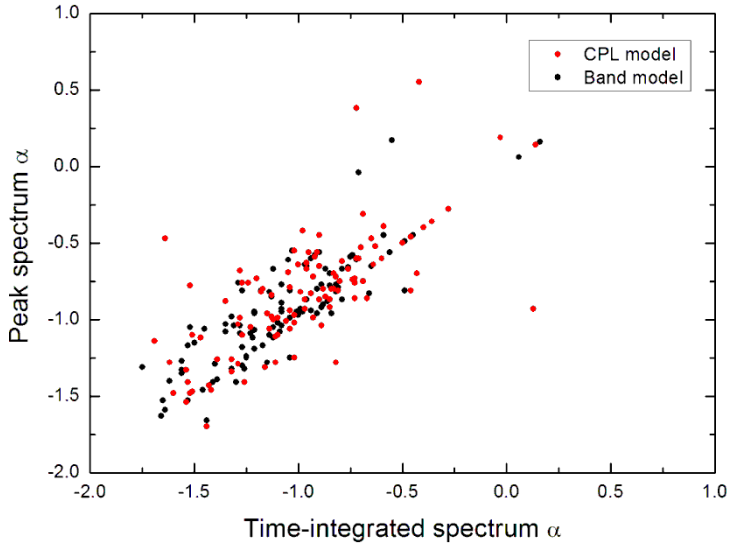


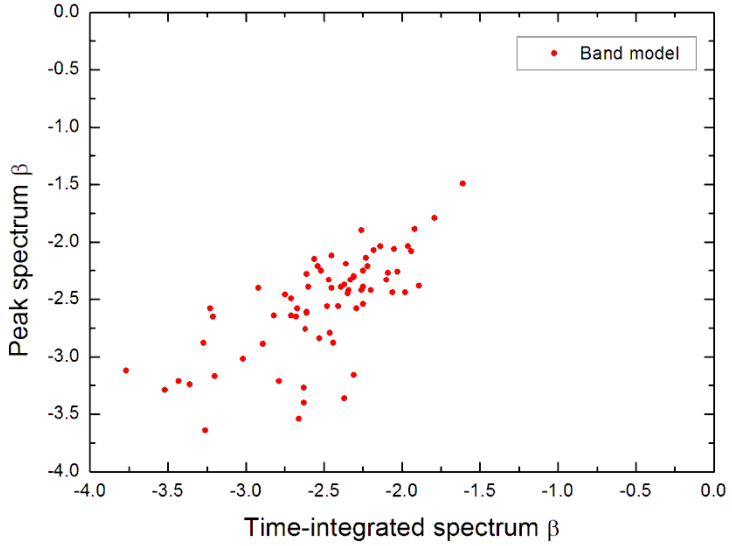


Parameter name	min value	max value	mean value	median value
E_p (keV)	37	3778	370	271
Flux (erg cm^{-2} s^{-1})	7.87×10^{-8}	7.75×10^{-4}	6.58×10^{-6}	1.37×10^{-6}

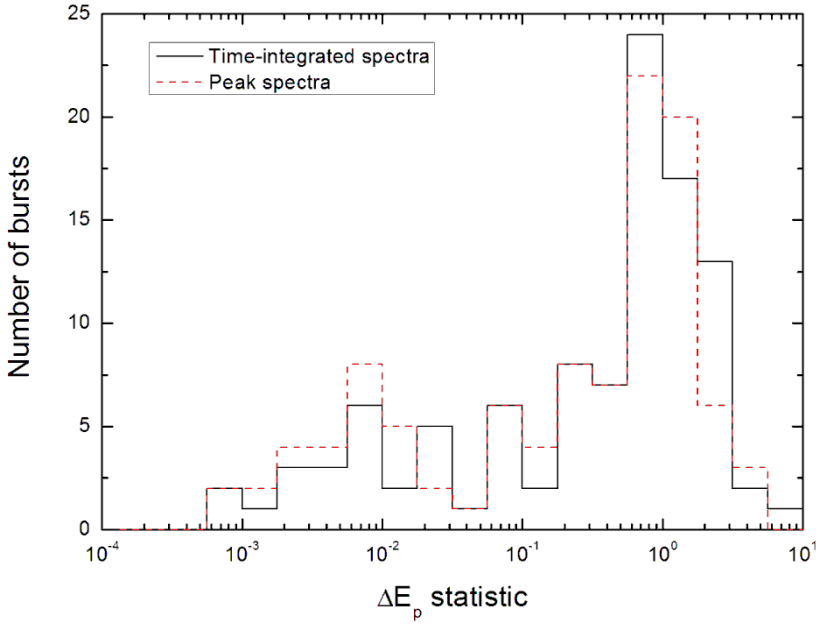
Peak spectral parameters as a function of the time-integrated spectral parameters

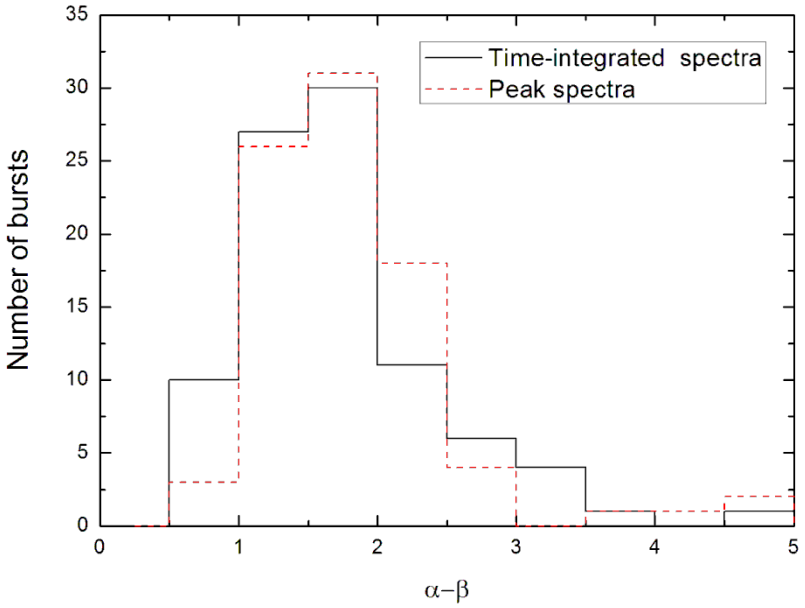






Spectral parameters: ΔE_p statistic and the difference between the low- and high-energy indices





$$\Delta E_p^{obs} = \frac{|E_p^{obs,CPL} - E_p^{obs,Band}|}{\sigma_{E_p^{obs,CPL}} + \sigma_{E_p^{obs,Band}}}$$

Prompt emission parameters overview

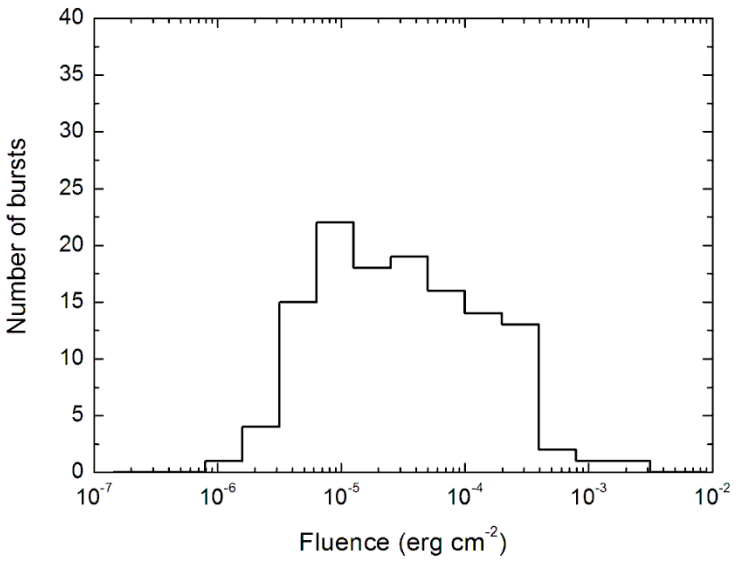
Data set	Low-energy index α	High-energy index β	Peak energy E_p (keV)
Time-integrated spectra			
This Catalog (CPL)	-1.05 ± 0.34	$\cdots$	371 ± 409
This Catalog (Band)	-0.97 ± 0.36	-2.55 ± 0.45	305 ± 235
Fermi GBM Goldstein et al. 2012 (CPL)	-0.90 ± 0.40	$\cdots$	224 ± 353
Fermi GBM Goldstein et al. 2012 (Band)	-0.82 ± 0.40	-2.17 ± 0.42	186 ± 309
BATSE Kaneko et al. 2006 (CPL)	-1.18 ± 0.22	$\cdots$	321 ± 161
BATSE Kaneko et al. 2006 (Band)	-1.08 ± 0.20	-2.33 ± 0.27	262 ± 101
Peak spectra			
This Catalog (CPL model)	-0.93 ± 0.38	$\cdots$	442 ± 449
This Catalog (Band model)	-0.84 ± 0.38	-2.55 ± 0.43	365 ± 296
Fermi GBM Goldstein et al. 2012 (CPL)	-0.81 ± 0.44	$\cdots$	215 ± 253
Fermi GBM Goldstein et al. 2012 (Band)	-0.75 ± 0.41	-2.16 ± 0.45	194 ± 232

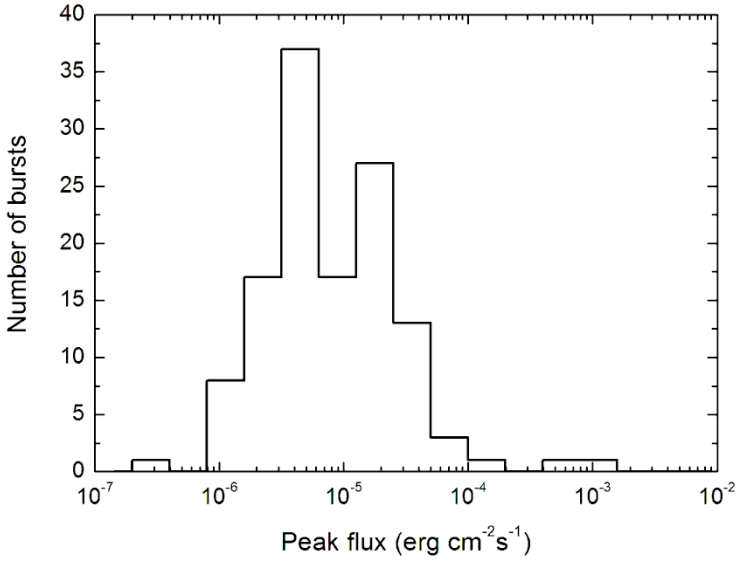
Observer frame energetics

Standard energy range
in the observer frame: 1 keV – 10 MeV

Best fit model: $\chi^2_{CPL}-\chi^2_{Band}>6$ ➡ Band
$\chi^2_{CPL}-\chi^2_{Band}<6$ ➡ CPL

The highest fluence: GRB130427A
The highest peak flux: GRB110918A





Parameter name	min value	max value	mean value	median value
Fluence (erg cm^{-2})	9.57×10^{-7}	2.87×10^{-3}	1.60×10^{-4}	2.62×10^{-5}
Peak flux (erg cm^{-2} s^{-1})	3.27×10^{-7}	9.32×10^{-4}	2.62×10^{-5}	6.38×10^{-6}

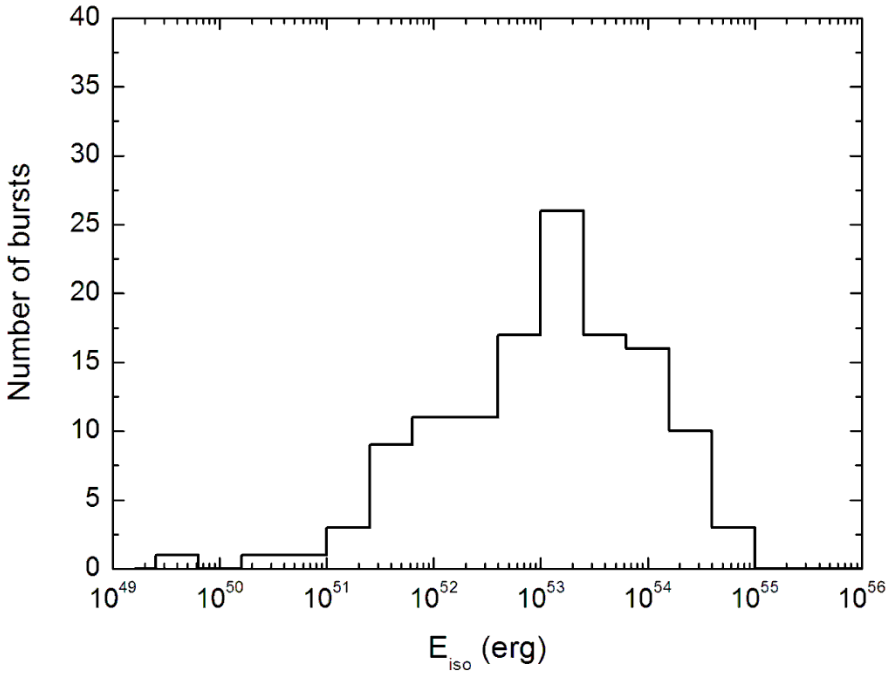
Rest frame energetics

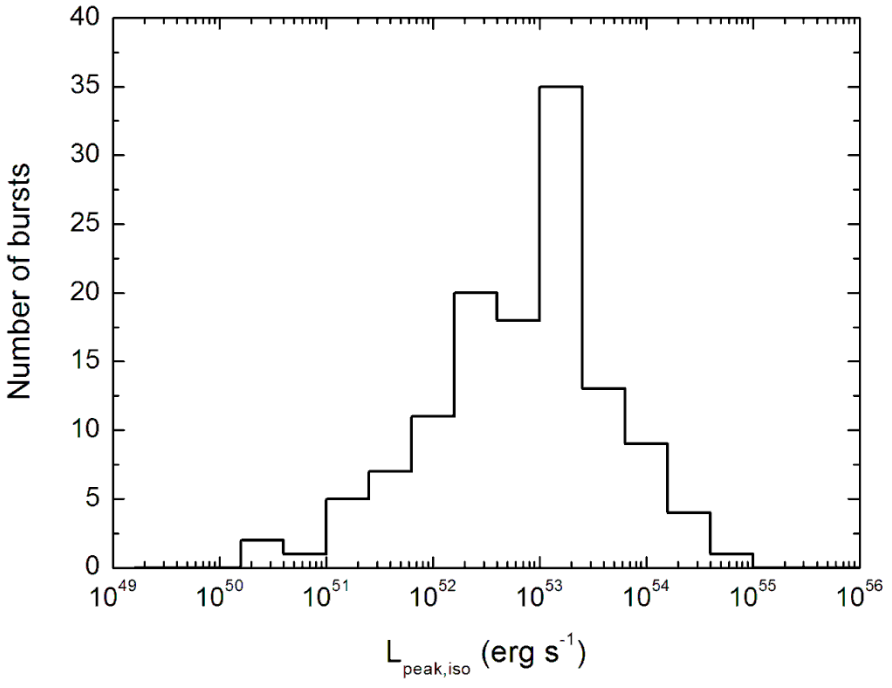
$\Omega_M = 0.315,\ h = 0.673$

(The Planck Collaboration, 2013)

The highest E_{iso}: GRB090323

The highest $L_{peak,iso}$: GRB110918A



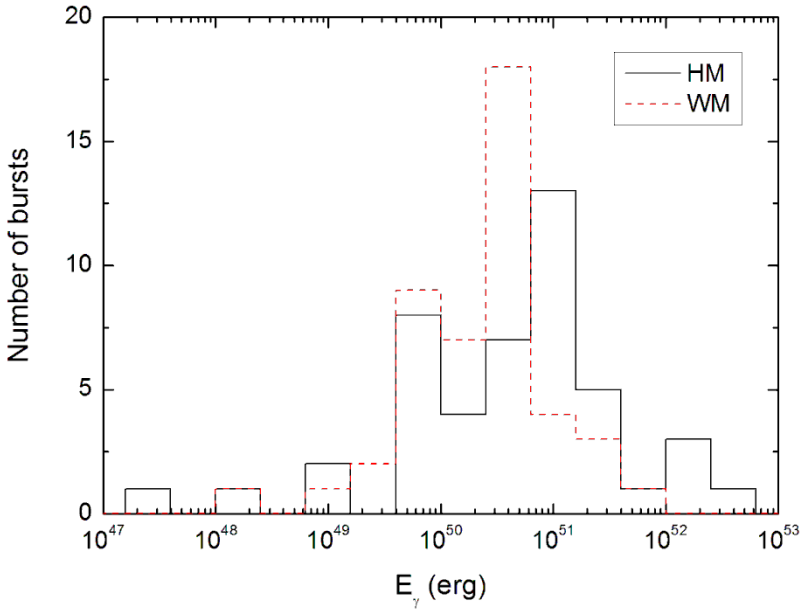


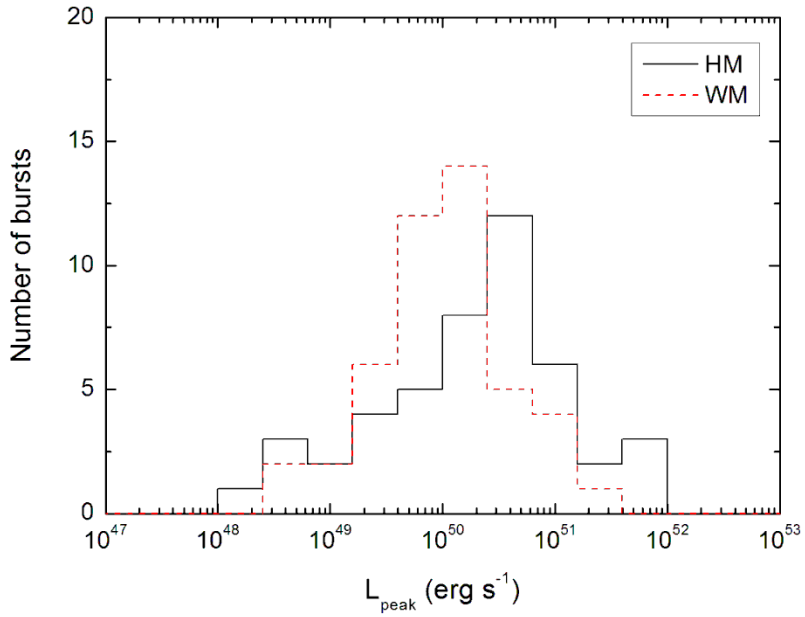
Parameter name	min value	max value	mean value	median value
$E_{\gamma,iso}$ (erg)	4.18×10^{49}	5.78×10^{54}	5.34×10^{53}	1.63×10^{53}
$L_{peak,iso}$ (erg s^{-1})	2.90×10^{50}	4.97×10^{54}	2.99×10^{53}	9.27×10^{52}

Collimation-corrected energetics

Homogeneous (HM) Sari et al. 1999: $n \propto r^0$
Wind (WM) Li & Chevalier 2003: $n \propto r^{-2}$

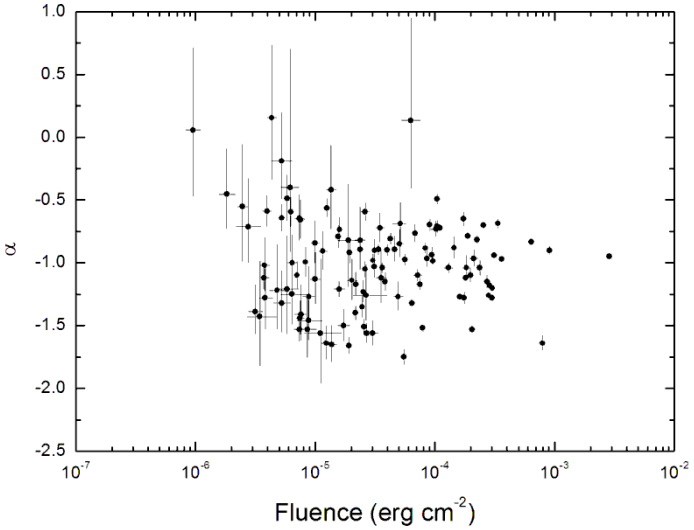
The highest E_γ: GRB090323
The highest L_{peak}: GRB090926A (HM), GRB060112(WM)



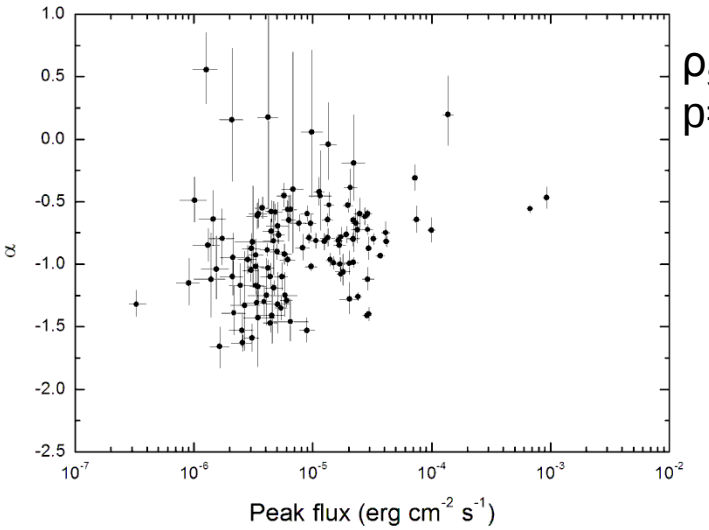


Parameter name	min value	max value	mean value	median value
$E_{\gamma,HM}$ (erg)	3.44×10^{47}	3.66×10^{52}	2.69×10^{51}	6.14×10^{50}
$E_{\gamma,WM}$ (erg)	1.90×10^{48}	4.27×10^{51}	5.28×10^{50}	2.80×10^{50}
$L_{\gamma,peak,HM}$ (erg s^{-1})	1.60×10^{48}	6.79×10^{51}	7.94×10^{50}	2.50×10^{50}
$L_{\gamma,peak,WM}$ (erg s^{-1})	3.28×10^{48}	2.36×10^{51}	2.38×10^{50}	1.07×10^{50}

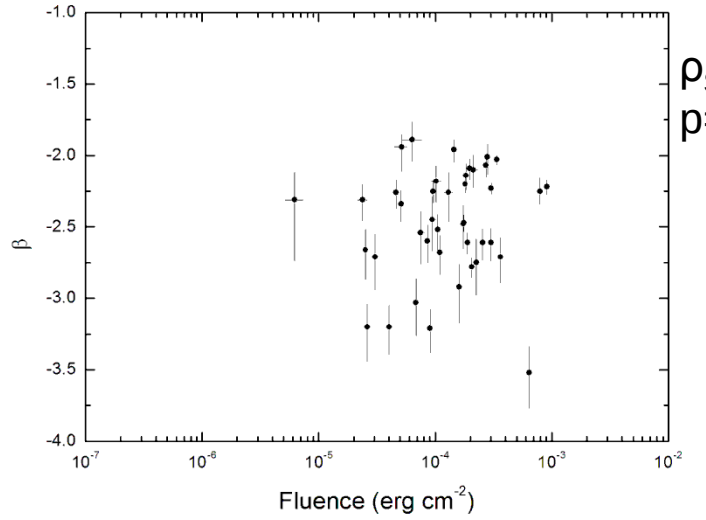
Energetics



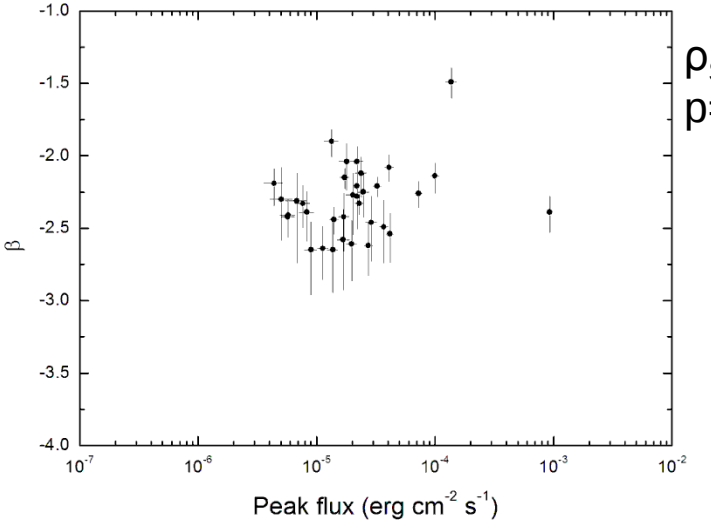
ρ_S=-0.032,
p=0.73



ρ_S=0.31,
p=0.00067



ρ_S=0.086,
p=0.59



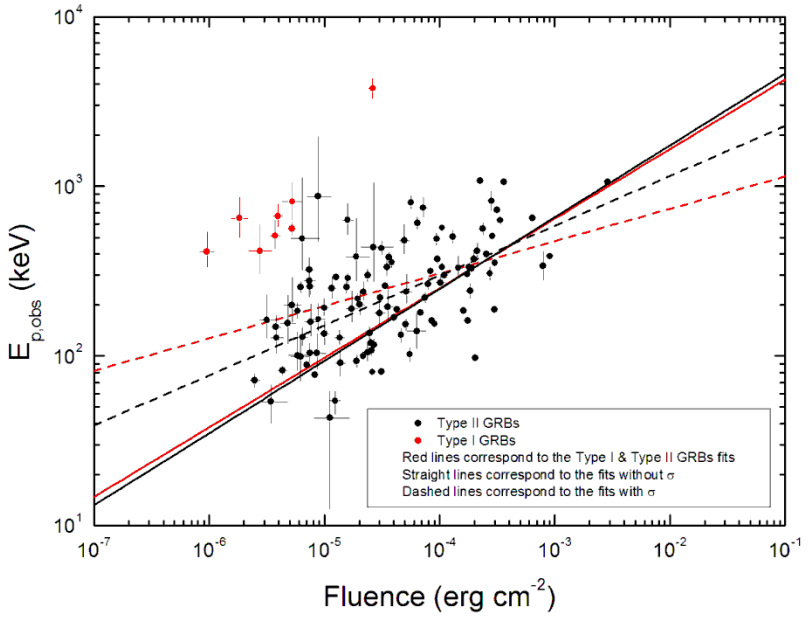
ρ_S =0.35,
p=0.038

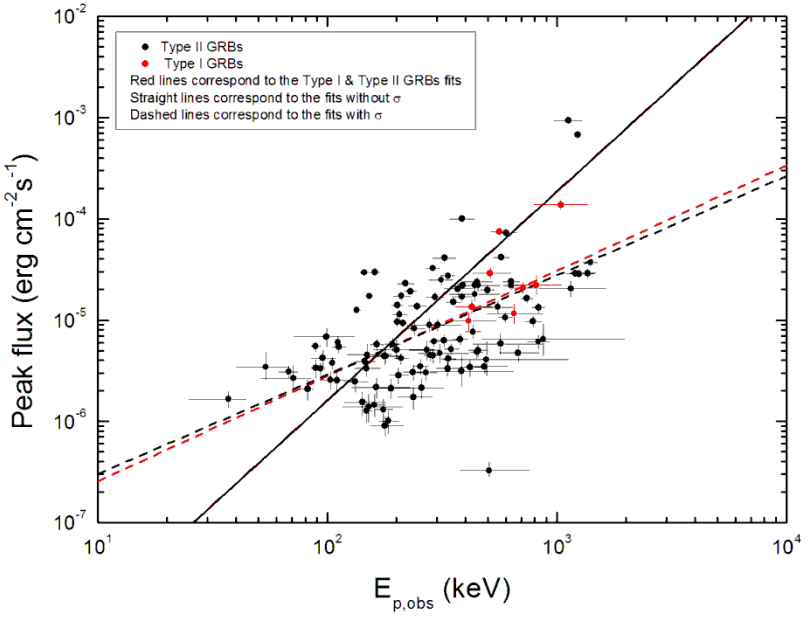
Observer frame correlations

Correlations: with and without scatter

(Williams et al. 2010)

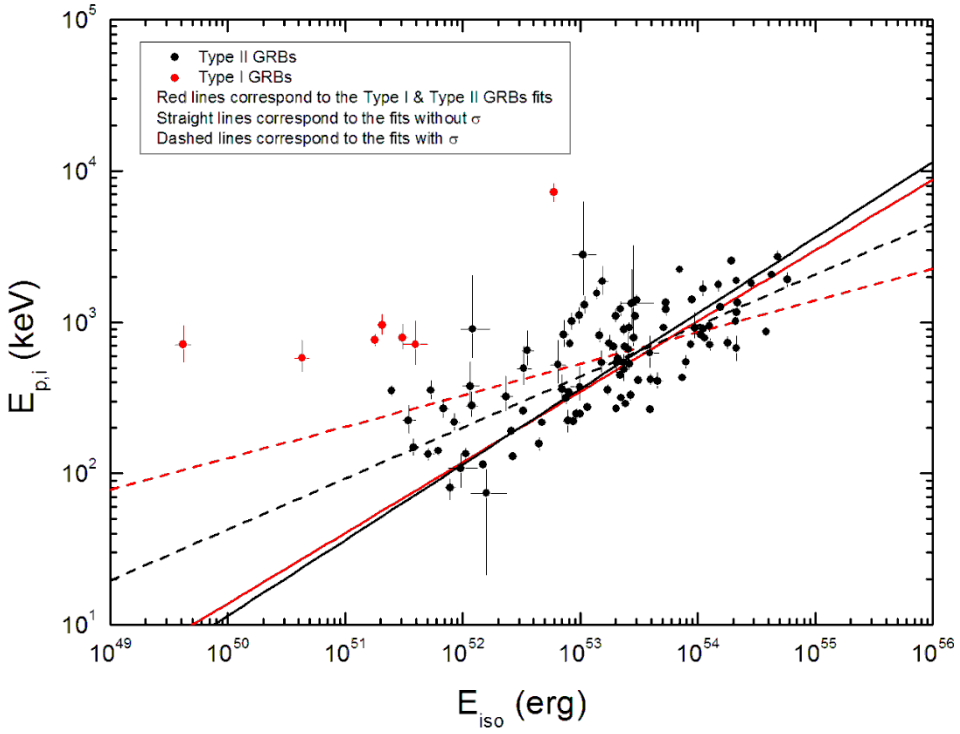
$$\chi^2_r = \frac{1}{DoF}\sum_{i=1}^{N}\frac{(y_i - ax_i - b)^2}{\sigma^2_{xi} + \sigma^2_{yi}/a^2 + \sigma^2_{ext}}$$





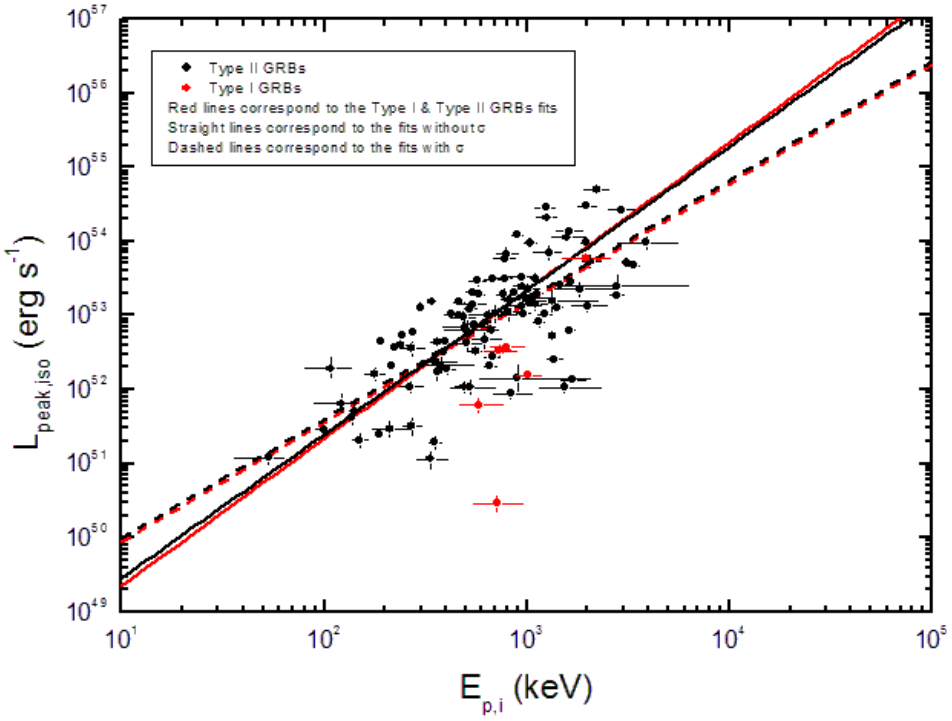
Correlation and data sample	N	ρ_S	P-value	a	b	$a_{\sigma_{ext}}$	$b_{\sigma_{ext}}$	σ_{ext}
$E_{p,int} - S$ "I+II"	116	0.37	3.9×10^{-05}	0.410 ± 0.002	4.04 ± 0.01	0.191 ± 0.042	3.25 ± 0.19	0.296
$E_{p,int} - S$ "II"	108	0.57	1.4×10^{-10}	0.424 ± 0.003	4.09 ± 0.01	0.294 ± 0.036	3.65 ± 0.16	0.231
$F_p - E_{p,peak}$ "I+II"	116	0.59	2.9×10^{-12}	2.063 ± 0.026	-9.92 ± 0.07	1.039 ± 0.127	-7.63 ± 0.31	0.430
$F_p - E_{p,peak}$ "II"	108	0.56	4.4×10^{-10}	2.064 ± 0.026	-9.92 ± 0.07	0.981 ± 0.135	-7.50 ± 0.33	0.437

Amati relation



Correlation and data sample	N	ρ_S	P-value	a	b	$a_{\sigma_{ext}}$	$b_{\sigma_{ext}}$	σ_{ext}
Amati "I+II"	110	0.58	2.0×10^{-11}	0.467 ± 0.003	-22.21 ± 0.16	0.209 ± 0.032	-8.35 ± 1.70	0.303
Amati "II"	103	0.70	2.0×10^{-16}	0.500 ± 0.003	-23.94 ± 0.17	0.337 ± 0.030	-15.22 ± 1.59	0.229

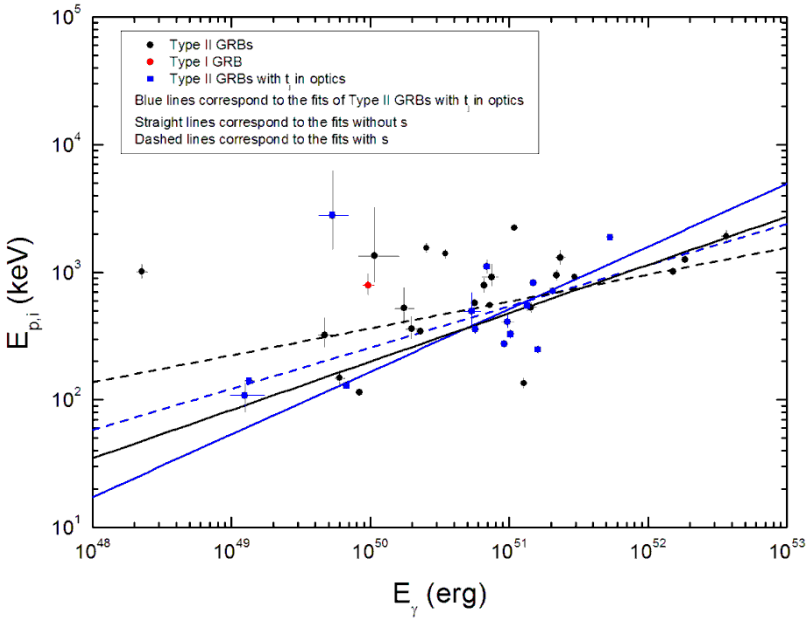
Yonetoku relation



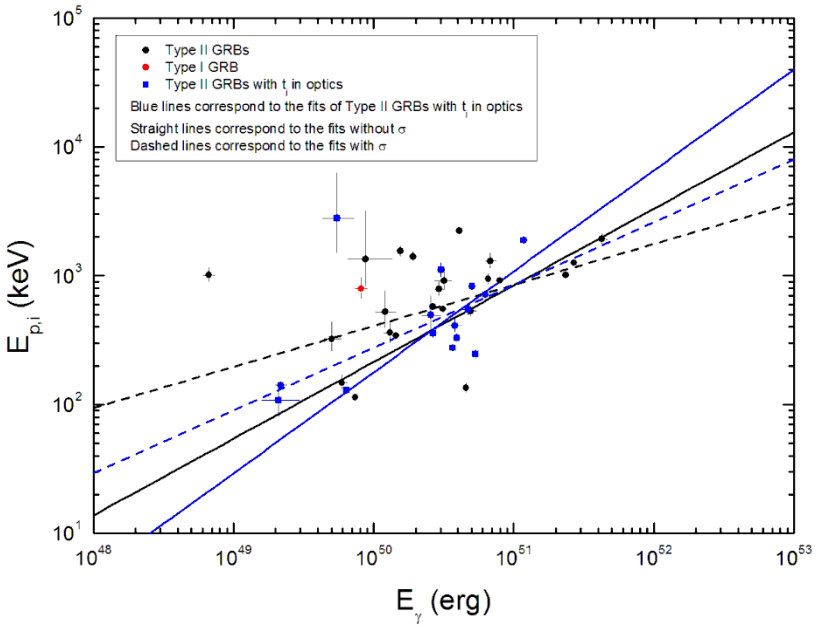
Correlation and data sample	N	ρ_S	P-value	a	b	$a_{\sigma_{ext}}$	$b_{\sigma_{ext}}$	σ_{ext}
Yonetoku "I+II"	110	0.68	2.8×10^{-16}	1.995 ± 0.025	47.35 ± 0.07	1.613 ± 0.157	48.33 ± 0.44	0.577
Yonetoku "II"	103	0.71	4.6×10^{-17}	1.942 ± 0.024	47.51 ± 0.07	1.611 ± 0.146	48.38 ± 0.41	0.530

Ghirlanda relation

HM



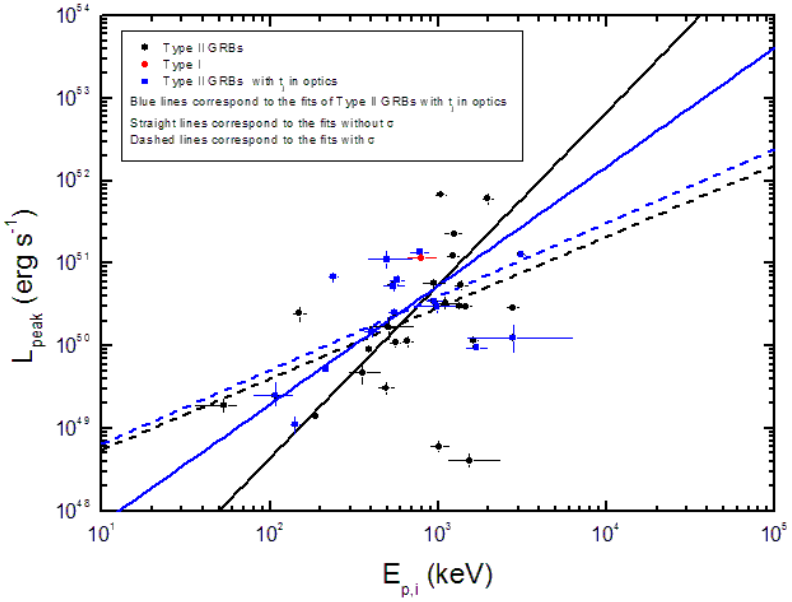
WM



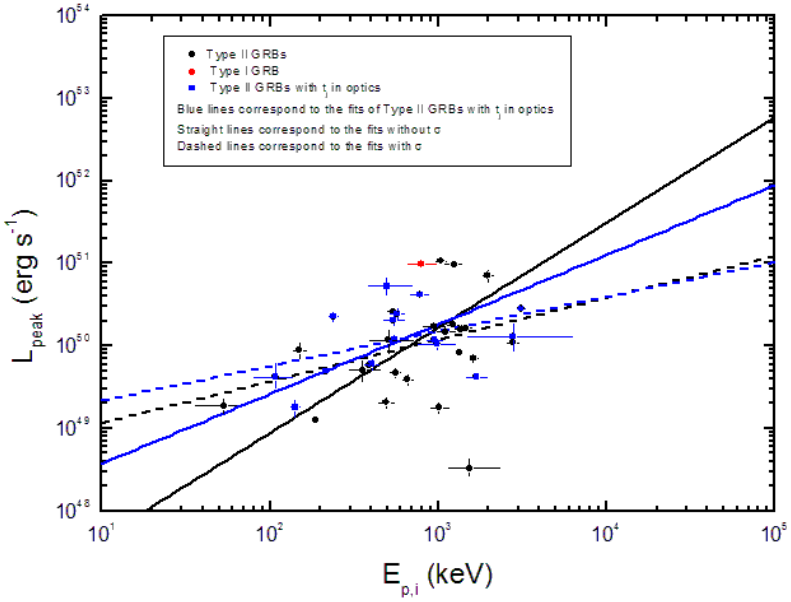
Correlation and data sample	N	ρ_S	P-value	a	b	$a_{\sigma_{ext}}$	$b_{\sigma_{ext}}$	σ_{ext}
Ghirlanda "I+II" (HM)	39	0.38	0.017	0.378 ± 0.003	-16.59 ± 0.17	0.203 ± 0.063	-7.57 ± 3.20	0.329
Ghirlanda "II" (HM)	38	0.39	0.016	0.379 ± 0.003	-16.65 ± 0.17	0.211 ± 0.064	-7.99 ± 3.24	0.330
Ghirlanda "II^{OPT}" (HM)	15	0.43	0.11	0.491 ± 0.009	-22.33 ± 0.47	0.323 ± 0.098	-13.74 ± 4.97	0.278
Ghirlanda "I+II" (WM)	39	0.38	0.017	0.593 ± 0.006	-27.33 ± 0.29	0.306 ± 0.095	-12.66 ± 4.78	0.329
Ghirlanda "II" (WM)	38	0.39	0.016	0.595 ± 0.006	-27.42 ± 0.29	0.318 ± 0.096	-13.29 ± 4.84	0.330
Ghirlanda "II^{OPT}" (WM)	15	0.43	0.11	0.784 ± 0.016	-36.95 ± 0.81	0.487 ± 0.147	-21.91 ± 7.41	0.276

Collimation-corrected Yonetoku relation

HM



WM



Correlation and data sample	N	ρ_S	P-value	a	b	$a_{\sigma_{ext}}$	$b_{\sigma_{ext}}$	σ_{ext}
Yonetoku (coll. corr.) "I+II" (HM)	39	0.39	0.016	2.107 ± 0.042	44.42 ± 0.12	0.873 ± 0.285	47.86 ± 0.81	0.689
Yonetoku (coll. corr.) "II" (HM)	38	0.39	0.016	2.096 ± 0.042	44.45 ± 0.12	0.861 ± 0.285	47.88 ± 0.81	0.689
Yonetoku (coll. corr.) "II^{OPT}" (HM)	15	0.40	0.14	1.440 ± 0.048	46.41 ± 0.13	0.892 ± 0.369	47.92 ± 1.02	0.543
Yonetoku (coll. corr.) "I+II" (WM)	39	0.33	0.04	1.311 ± 0.030	46.30 ± 0.09	0.520 ± 0.213	48.55 ± 0.61	0.516
Yonetoku (coll. corr.) "II" (WM)	38	0.34	0.036	1.273 ± 0.030	46.40 ± 0.08	0.506 ± 0.206	48.56 ± 0.59	0.499
Yonetoku (coll. corr.) "II^{OPT}" (WM)	15	0.34	0.22	0.843 ± 0.039	47.73 ± 0.11	0.419 ± 0.257	48.92 ± 0.72	0.388

Relations overview

Paper	Relation	N	ρ_S	P-value	a
Amati et al. 2002	Amati	9	0.92	5.0×10^{-4}	0.52 ± 0.06
Amati 2003	Amati	20	0.92	1.1×10^{-8}	0.35 ± 0.06
Ghirlanda et al. 2004	Amati	27	0.80	7.6×10^{-7}	0.40 ± 0.05
Ghirlanda et al. 2004	Ghirlanda	15	0.94	1.4×10^{-7}	0.706 ± 0.047
Yonetoku et al. 2004	Yonetoku	16	0.96	5.3×10^{-9}	2.0 ± 0.2
Ghirlanda et al. 2005	$E_{p,i}$–L_{iso}	25	0.83	2.4×10^{-7}	0.50 ± 0.02
Ghirlanda et al. 2005	$E_{p,i}$–L_{γ}	16	0.83	5.6×10^{-5}	0.56 ± 0.03
Ghirlanda et al. 2005	Ghirlanda	17	0.93	3.2×10^{-8}	0.69 ± 0.04
Friedman & Bloom 2005	Amati	29	0.88	4.9×10^{-10}	0.496 ± 0.037
Friedman & Bloom 2005	Ghirlanda	19	0.86	2.9×10^{-6}	0.669 ± 0.34
Amati 2006	Amati	39	0.89	3.1×10^{-14}	0.57 ± 0.02
Ghirlanda et al. 2006	Amati	19	...	...	0.57 ± 0.02
Ghirlanda et al. 2006	Ghirlanda (HM)	19	...	...	0.67 ± 0.04
Ghirlanda et al. 2006	Ghirlanda (WM)	19	...	...	1.00 ± 0.06
Nava et al. 2006	Amati	18	0.82	3.1×10^{-5}	0.57 ± 0.02
Nava et al. 2006	Ghirlanda (HM)	18	0.93	2.3×10^{-8}	0.69 ± 0.04
Nava et al. 2006	Ghirlanda (WM)	18	0.92	6.9×10^{-8}	1.03 ± 0.06
Ghirlanda et al. 2007	Amati	62	...	...	0.57 ± 0.01
Ghirlanda et al. 2007	Ghirlanda (HM)	25	...	...	0.70 ± 0.04
Ghirlanda et al. 2007	Ghirlanda (WM)	25	...	...	1.05 ± 0.06
Amati et al. 2008	Amati	70	0.872	2.6×10^{-30}	0.57 ± 0.01
Amati et al. 2008	Amati$^{\sigma_{ext}}$	70	0.872	2.6×10^{-30}	0.54 ± 0.03
Amati et al. 2009	Amati	95	...	...	0.57 ± 0.01
Amati et al. 2009	Amati$^{\sigma_{ext}}$	95	...	...	0.54 ± 0.03
Amati 2010	Amati	67	...	0.88	0.57 ± 0.01
Gruber et al. 2011	Amati (Types I+II)	30	0.74	1.7×10^{-5}	0.52 ± 0.06
Gruber et al. 2011	Yonetoku* (Types I+II)	30	0.7	2.3×10^{-5}	0.58 ± 0.08
Zhang et al. 2012	Amati	110	0.85	1.2×10^{-31}	0.51 ± 0.03

Summary

- 126 GRBs with known redshifts were analyzed.
- The relation coefficients (*a* and *b*) strongly depend on the approximation method.
- The coefficients of collimated-corrected relations depend on the circumburst medium type.
- The Type I GRBs affect only the relations between the time-integrated parameters.
- No obvious correlations between $E_{p,i}$ and the collimation-corrected energetics is seen.

Thank you!