Prompt spectral properties of a complete sample of Swift Gamma-Ray Bursts

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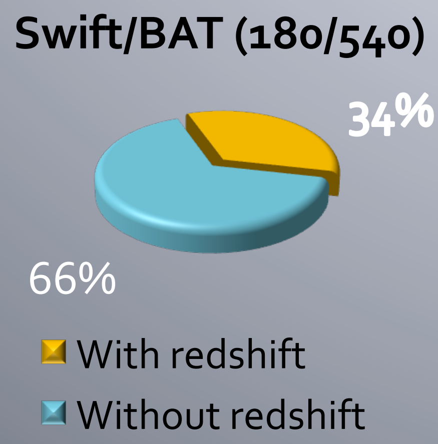
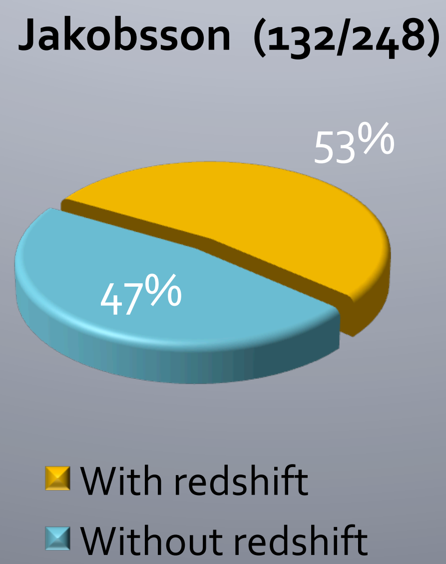
Redshift completness

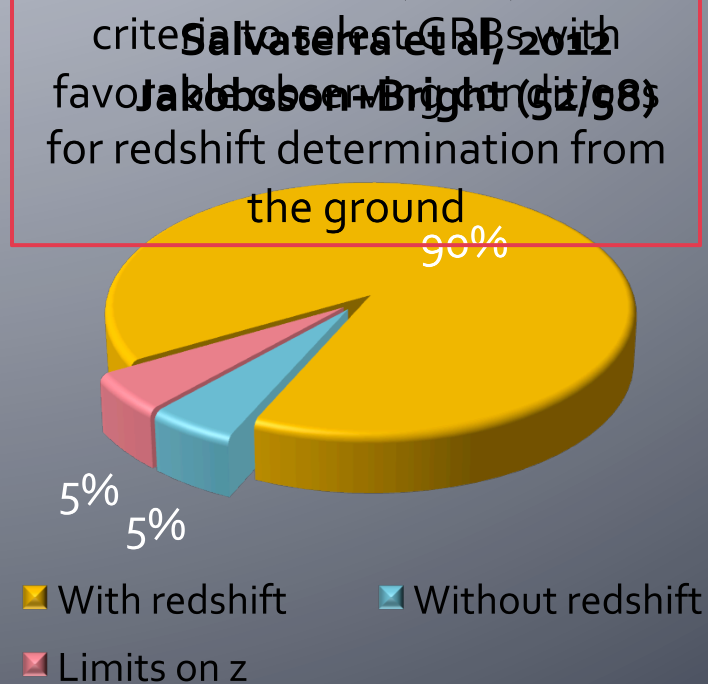




z of 1/3 of all GRBs detected by BAT has been measured

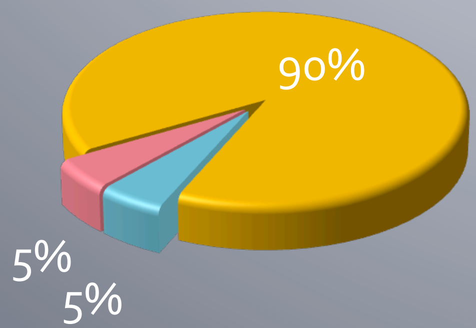
P≥2.6 ph s^{-1} cm^{-2}
Up to may, 2011: 58 GRBs
(52 with measured redshift)

Jakobsson et al. (2006) list of criteria to select GRBs with favorable observing conditions for redshift determination from the ground



Complete Sample

Salvaterra et al. 2012 (52/58)



See poster by Tagliaferri et al. P-III-7

Published / Submitted papers

Salvaterra et al.
Luminosity function and evolution

Nava et al.
Spectral properties and correlations

Campana et al.
X-ray absorbing column density

Melandri et al.
Dark bursts population

D'Avanzo et al. (submitted)
Correlations of prompt and X–ray afterglow emission

Redshift distribution & Luminosity evolution

redshift distribution:
mean (median) redshift= 1.84 (1.64)

luminosity evolution:

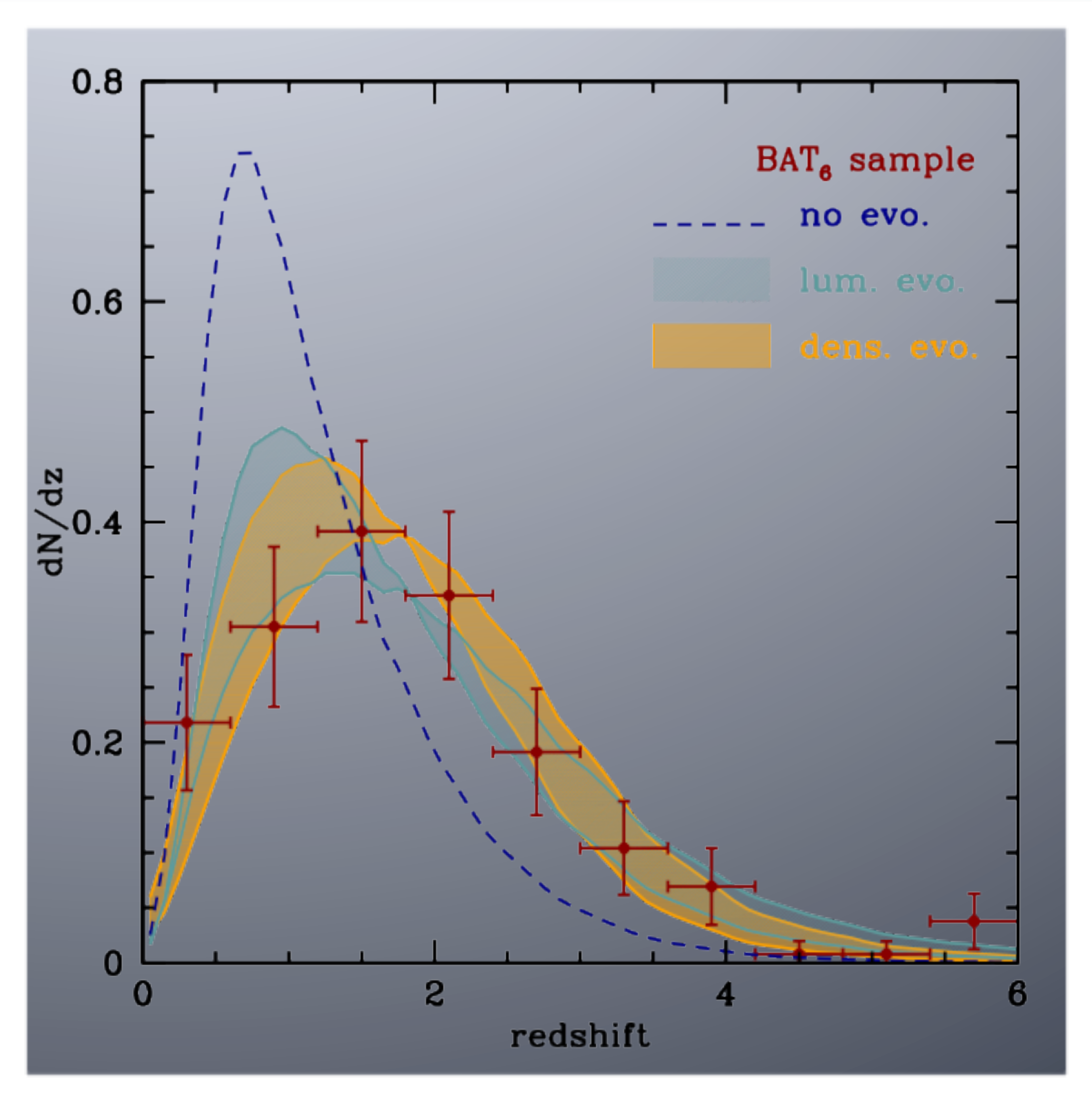
$$L_{\mathrm{cut}} \propto (1+z)^{\delta_l} \quad \text{with } \delta_l = 2.3 \pm 0.6$$

density evolution:

$$\eta \propto (1+z)^{\delta_n} \quad \text{with } \delta_n = 1.7 \pm 0.5$$

or

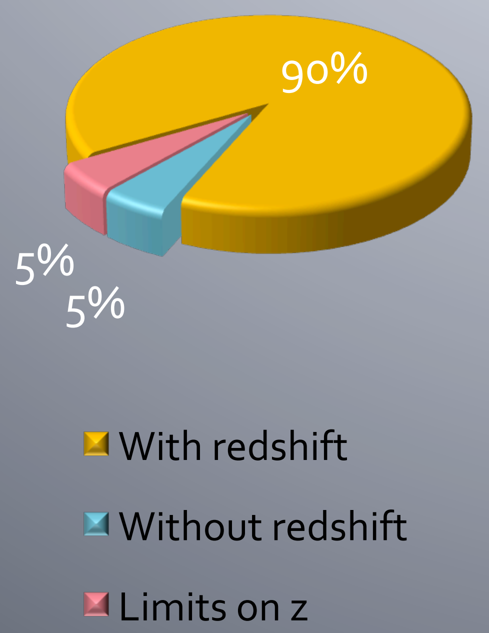
$$Z_{\mathrm{th}} < 0.3 Z_{\mathrm{sun}}$$



Salvaterra et al. 2012, ApJ, 749, 68

Spectral properties

Complete sample



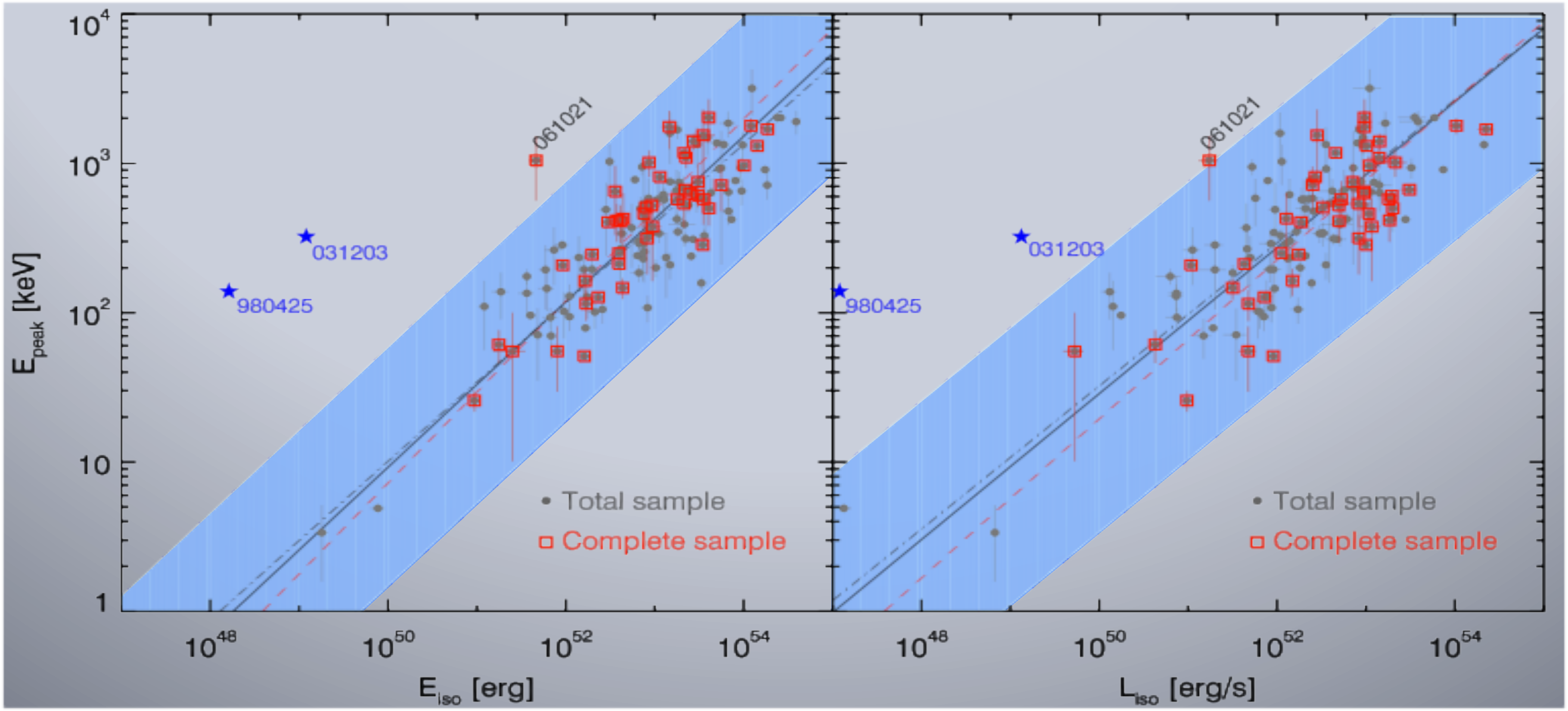
52 GRBs measured redshift
- 46: Epeak has been measured
- 3: lower limit on Epeak
- 3: no Epeak estimate

3 GRBs redshift upper limit → Epeak has been measured

3 GRBs without redshift → Epeak has been measured

Total sample: all bursts with known redshift and spectral properties (136 GRBs)

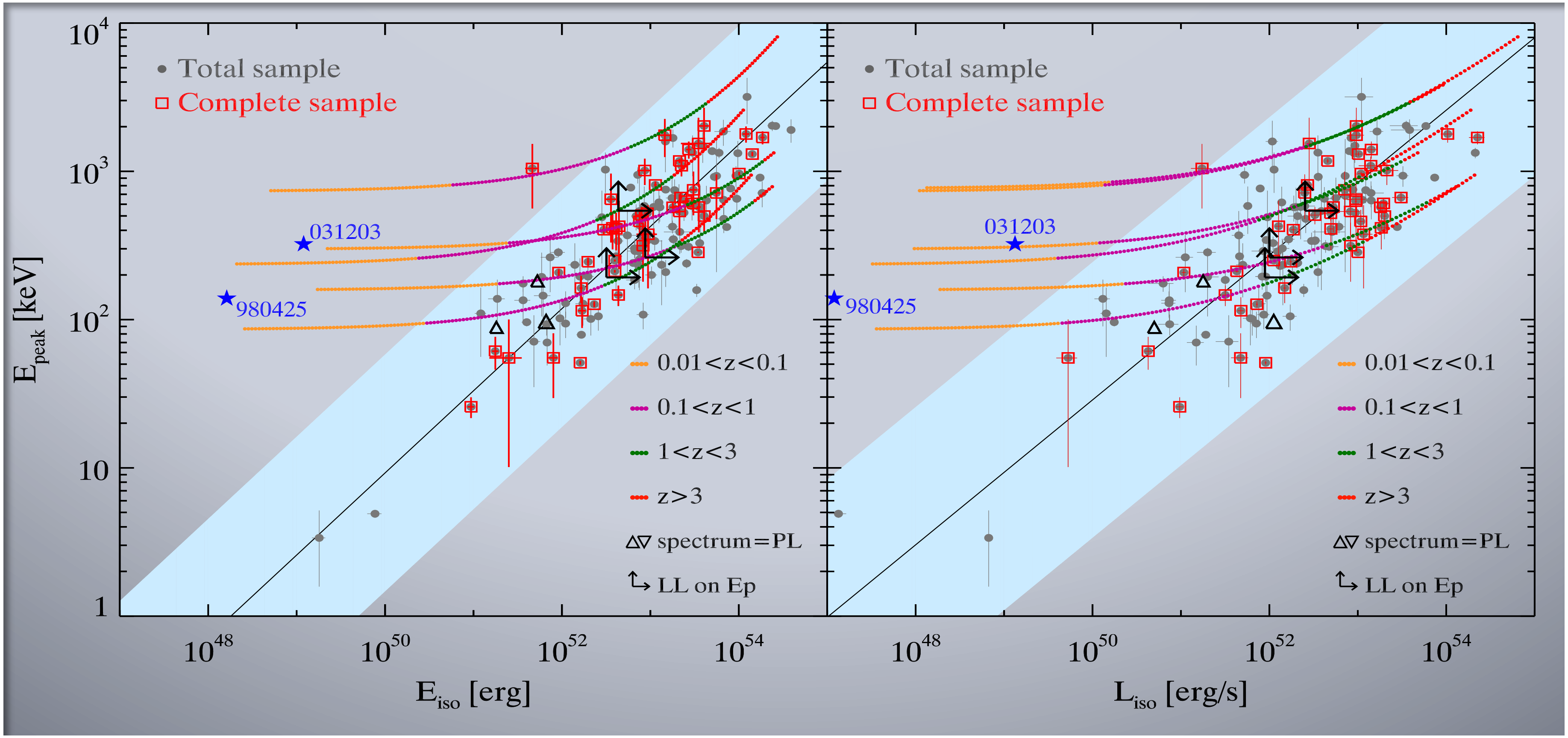
Amati & Yonetoku correlations



Nava et al. 2012, MNRAS 421, 1256

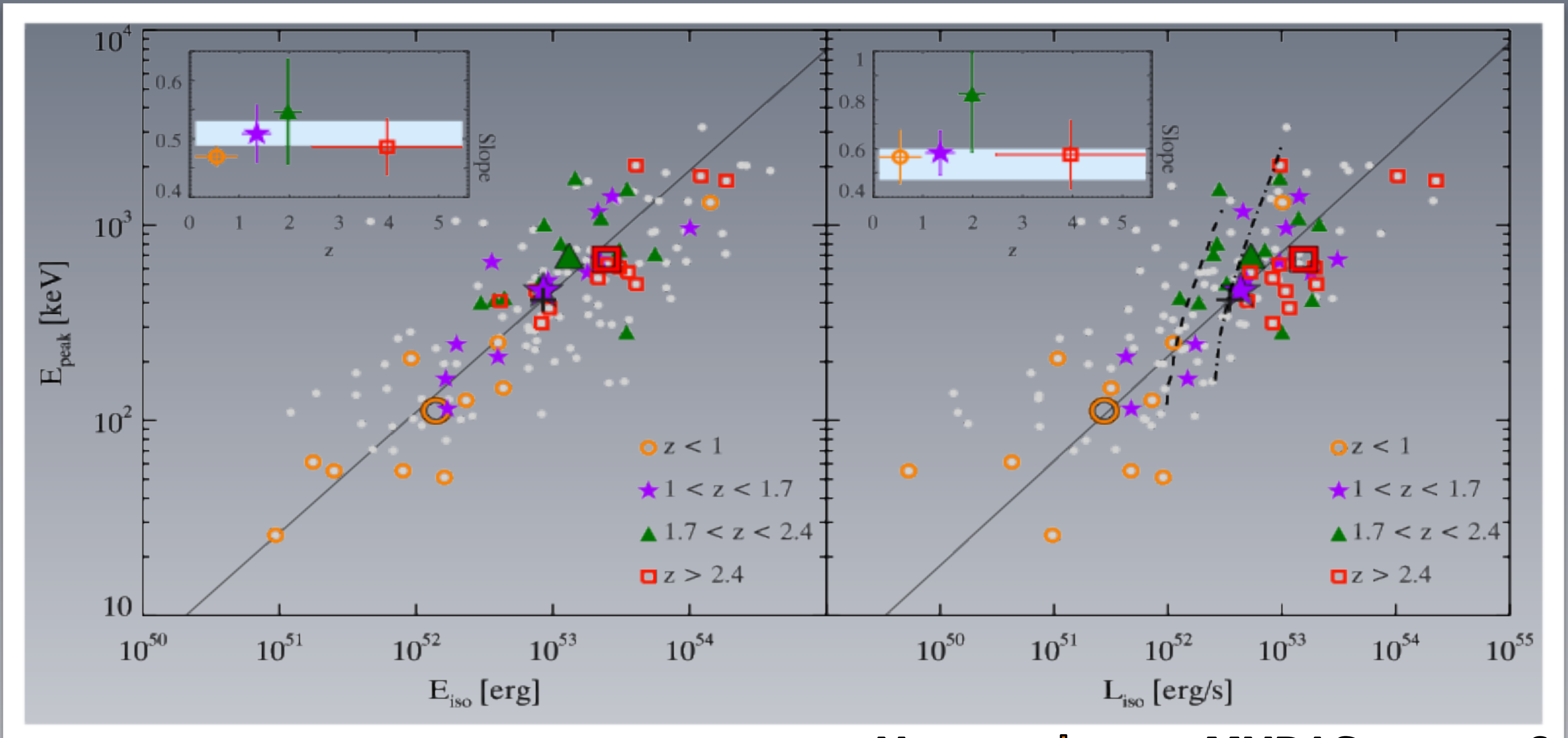
- ✓ Correlations are confirmed
- ✓ 1 outlier is found (~2% see Nava et al. 2008)
- ✓ Total and Complete sample: normalization, slope and dispersion are consistent

Amati & Yonetoku correlations



- ✓ consistency check on GRBs without redshift and/or without measured E_{peak}
- ✓ all bursts are consistent with both the correlations

Redshift evolution



Nava et al. 2012, MNRAS 421, 1256

Another important issue: possible evolution of correlations with z

✓ no evolution of the slopes is found

might the Epeak – Liso correlation be produced by the threshold of a flux-limited sample of bursts?

Monte Carlo simulations

- pick up a z (from GRB formation rate, Li 2008)
- we assign a peak luminosity adopting a luminosity function
- we assign to each simulated burst E_{peak} (independent on L_{iso})
- we extract a sub-sample of bursts with $P > 2.6$ ph cm^{-2}s^{-1}
- we then study the correlation Epeak-Liso: a correlation has been introduced by the introduction of a flux limit?

We compute:

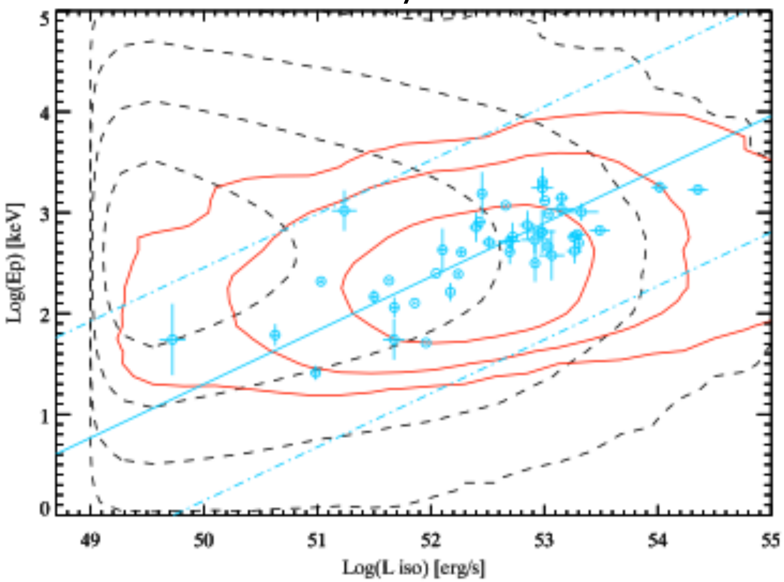
1- the percentage P_p of simulations *giving* a significant correlation (i.e. with chance prob. >10^{-3})

2- the percentage P_c of simulations *giving* a significant correlation that matches the observed slope, normalization and scatter

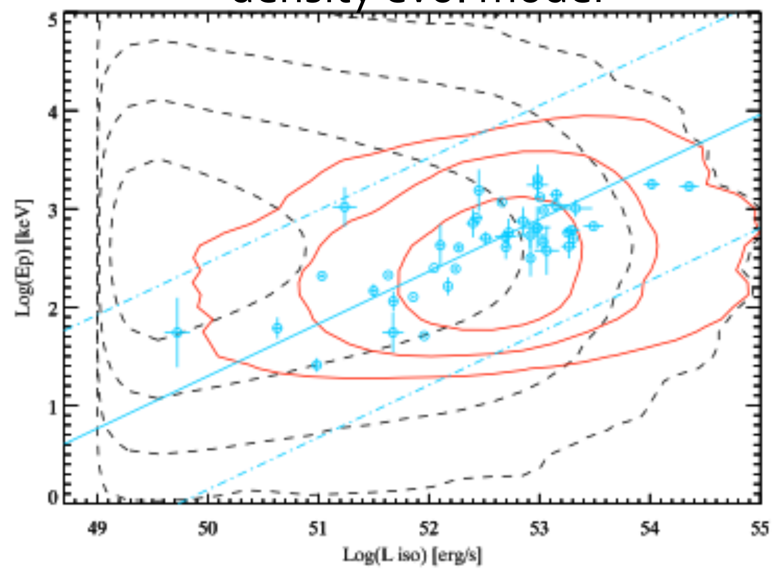
Ghirlanda et al. 2012, MNRAS in press, arXiv:1203.0003

Results from simulations

luminosity evo. model



density evo. model



P_p~8.3% P_c~0.6%

P_p~7.3% P_c~0.7%

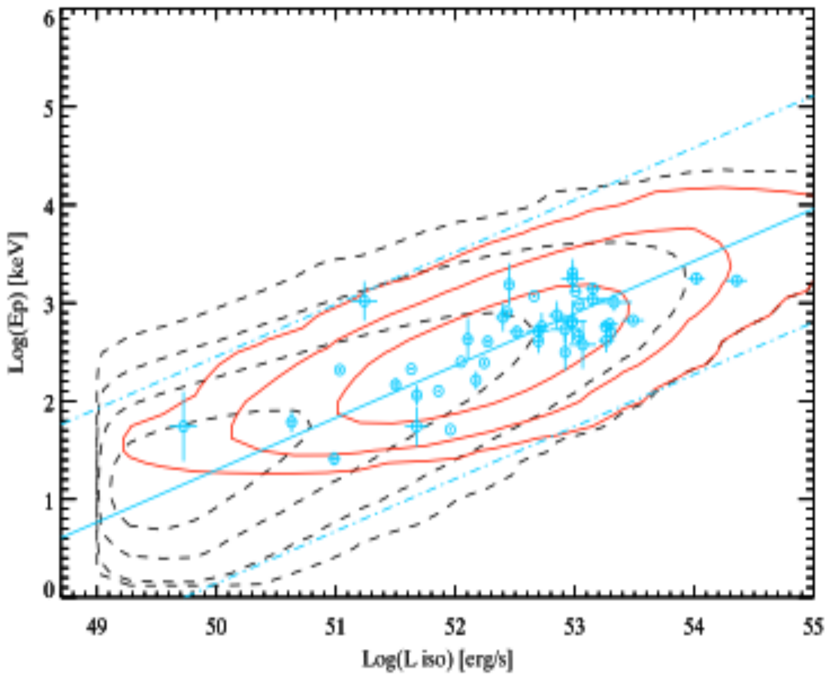
92.7% (91.7%) of simulations do not produce a significant correlation. If we also require that the obtained correlation is consistent (in terms of its slope, normalization and scatter) with that observed in the Swift complete sample, the percentage drops to P = 0.7%

<u>Yonetoku correlation is not due to the flux limit of the sample</u>

Ghirlanda et al. 2012, MNRAS in press, arXiv:1203.0003

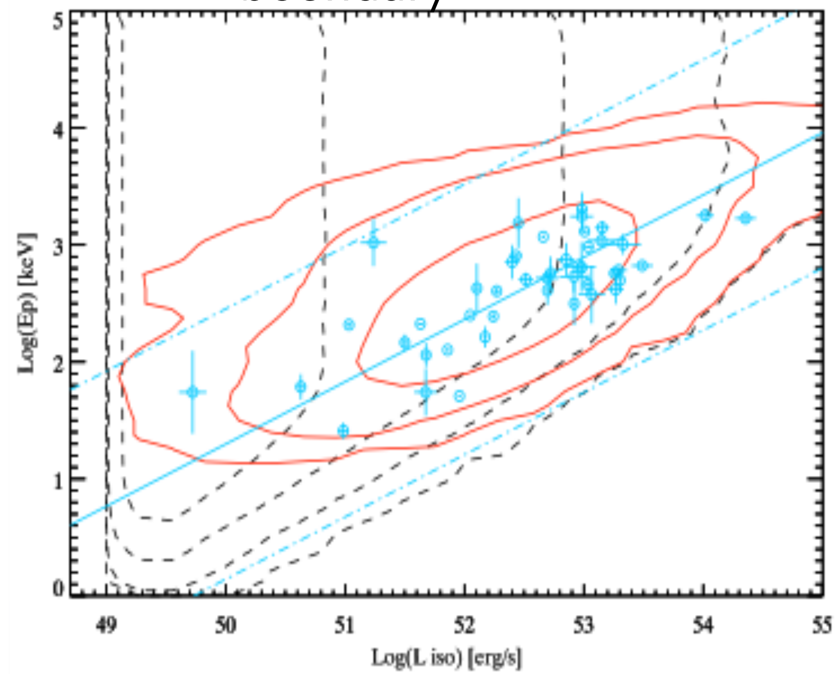
correlation or boundary?

correlation



P_p~100% P_c~66%

boundary



P_p~87% P_c~12%

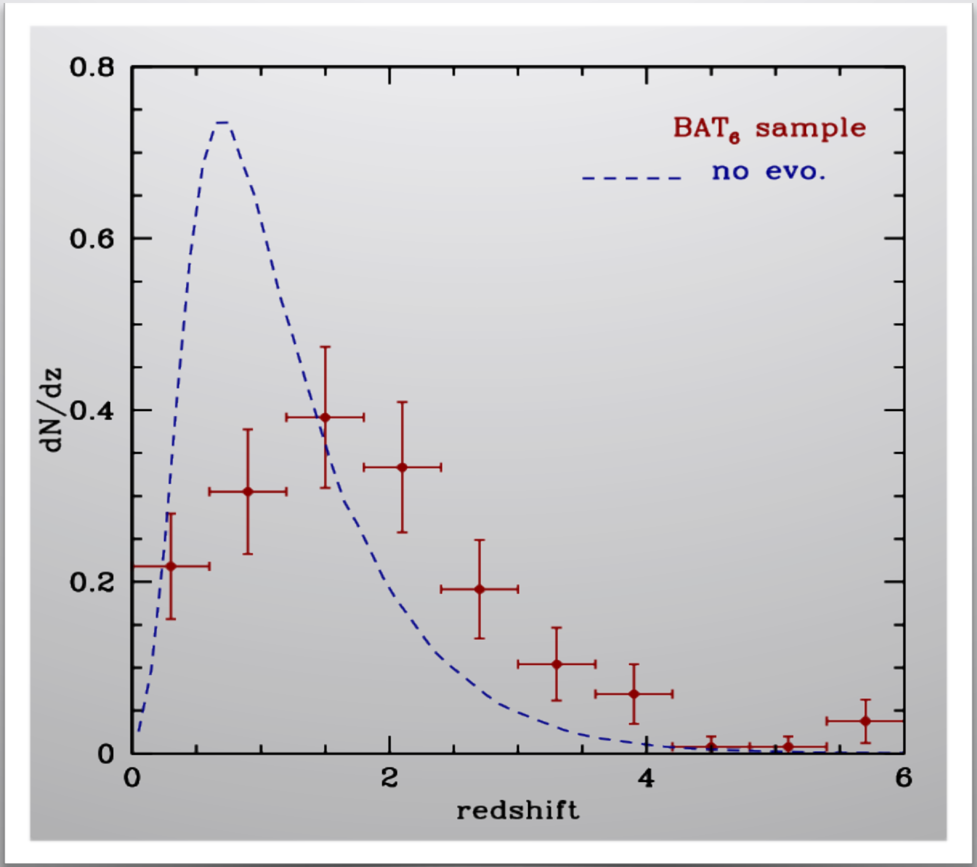
assuming the correlation or a boundary give reasonable results

Ghirlanda et al. 2012, MNRAS in press, arXiv:1203.0003

Conclusions

- GRB luminosity function
  - strong evolution (luminosity and/or density) is required
  - observed z-distribution does not allow to distinguish among evolutionary models
- Prompt emission properties and correlations
  - Amati & Yonetoku correlations are confirmed with 1 outlier
  - Slope, normalization and dispersion are consistent with those found from the Total (incomplete) sample
  - no redshift evolution of the slope is found
  - Yonetoku correlation is not due to the flux limit of the sample

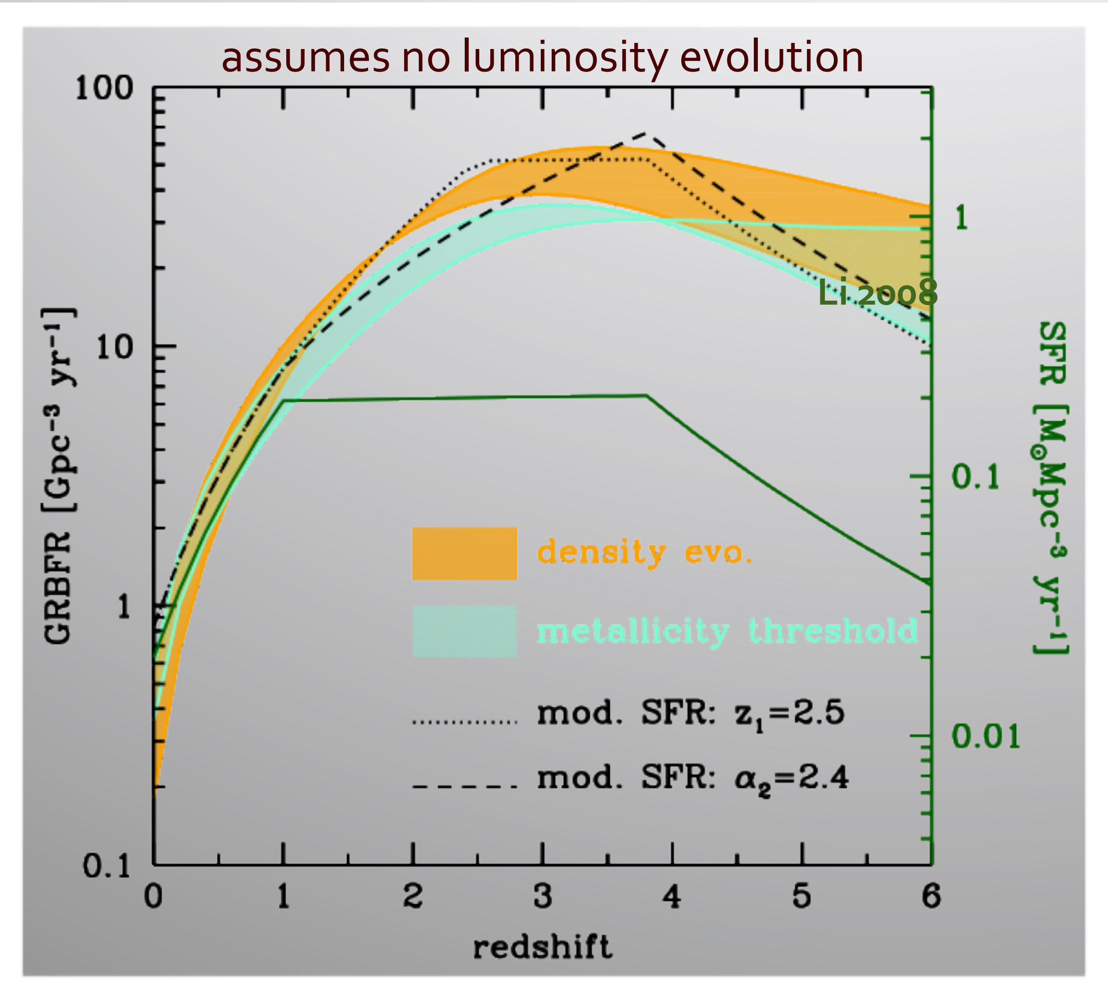
no evolution model



no evolution model provides a poor fit of the data (KS~5×10^{-5})

Salvaterra et al. 2012, ApJ 749, 68

GRB intrinsic z-distribution



GRB intrinsic distribution peaks at higher redshift with respect to stars, requiring:

- higher z for the first break
  $z_1=1 \rightarrow z_1=2.5$

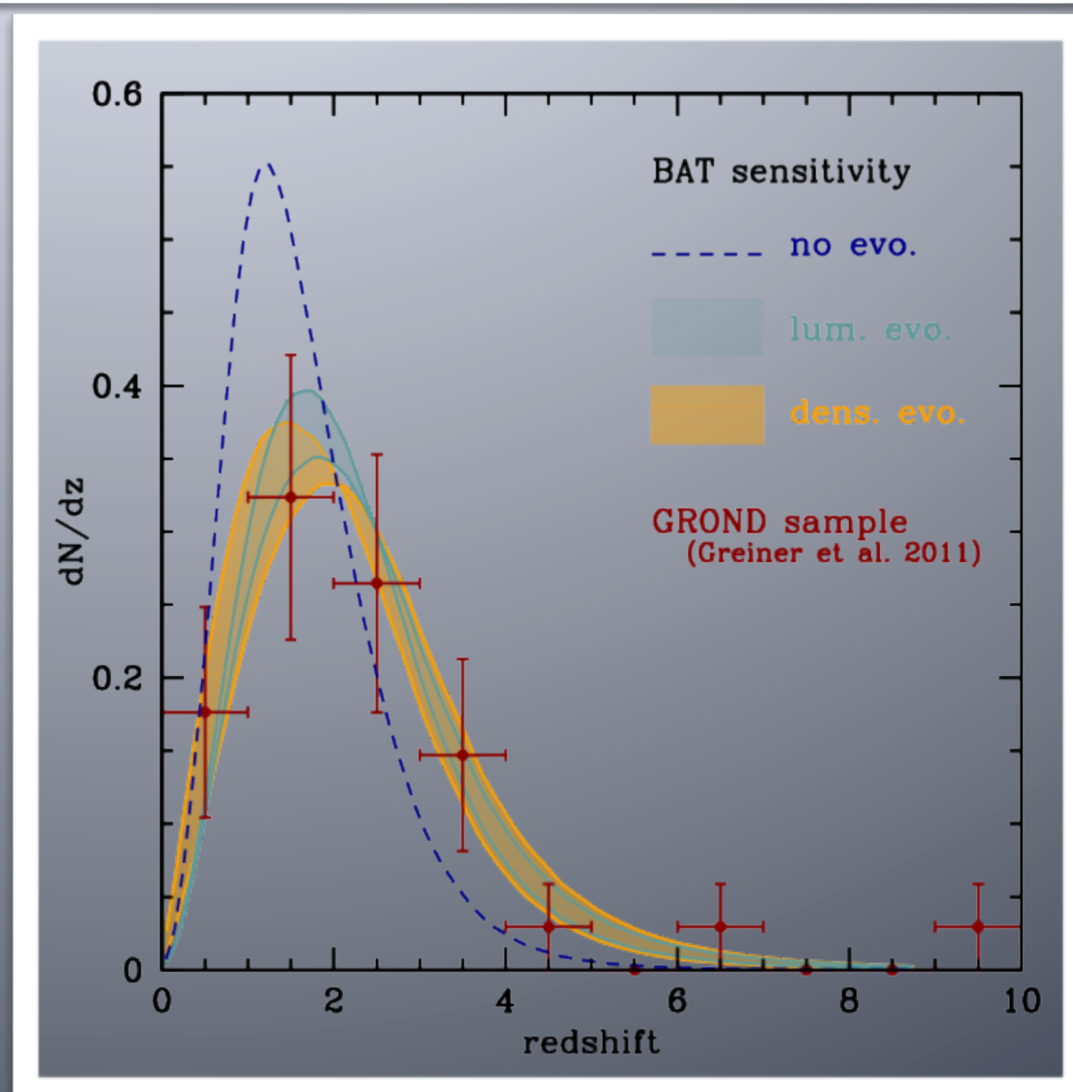
or

- harder second power-law
  $\alpha_2=0.055 \longrightarrow \alpha_2=2.4$

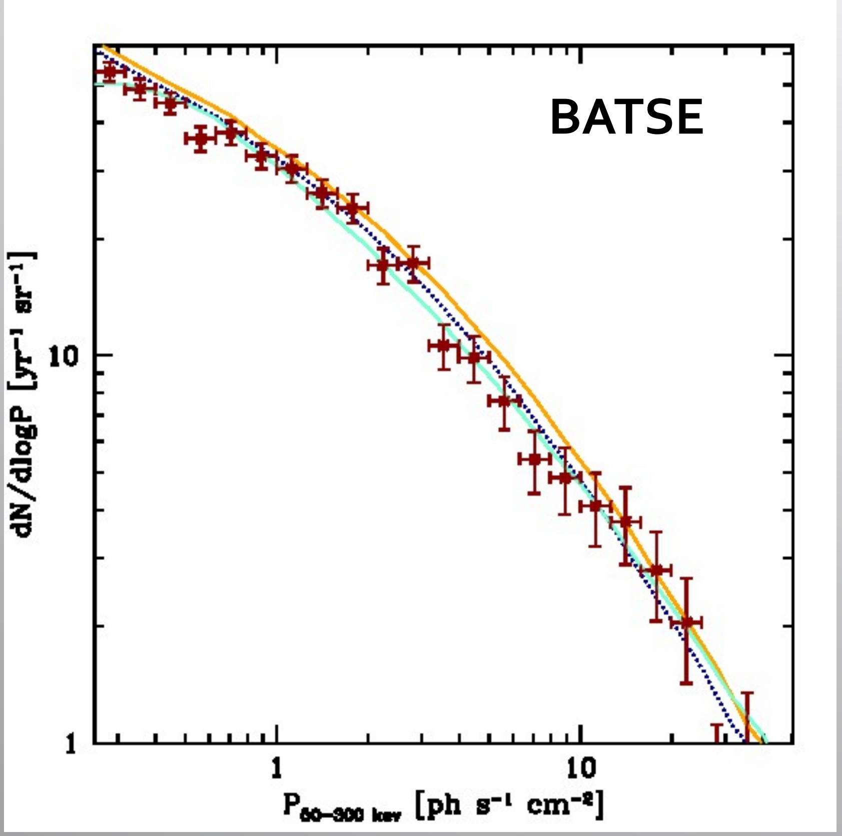
Salvaterra et al. 2012, ApJ 749, 68

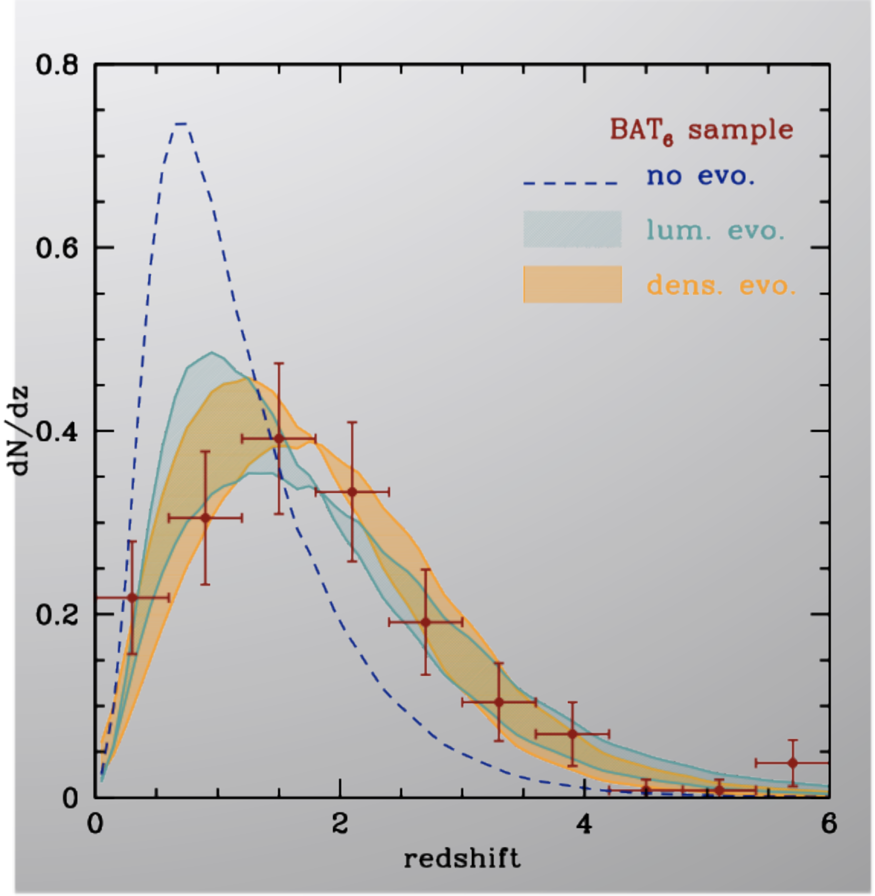
comparison with a deeper sample

- ✓ Mean predicted redshift <z>=2.05±0.15
- ✓ 3-5% at z>5 consistent with observations (Greiner et al. 2011; Perley et al. 2009)
- ✓ luminosity and density evolution predict similar observed redshift distributions



grb luminosity function



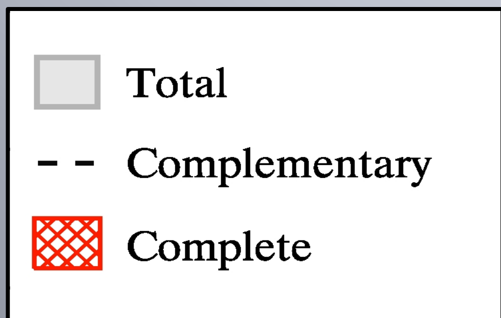


jointly fit the BATSE logN-logP and the z-distribution of the complete sample

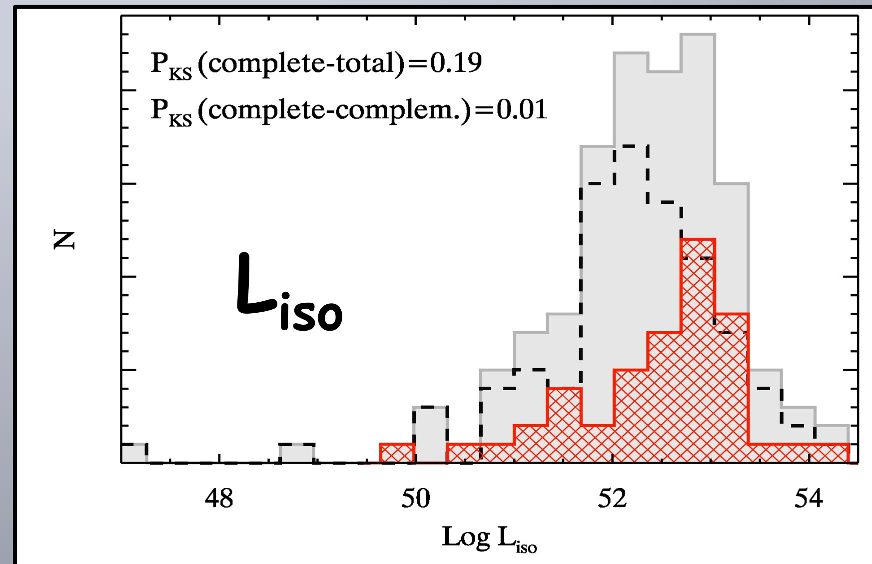
Salvaterra et al. 2012, ApJ 749, 68

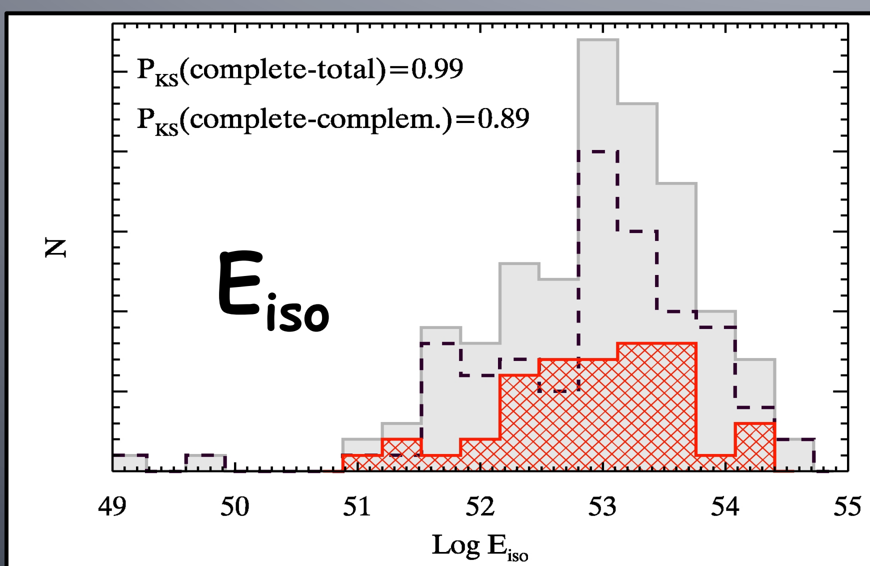
Spectral properties

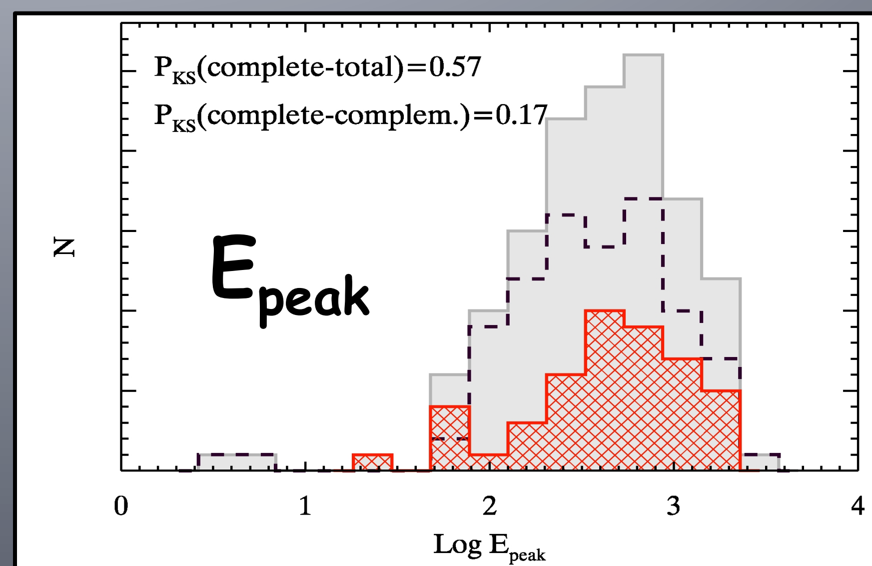
Comparison between different samples:



Nava et al. 2012, MNRAS 421, 1256





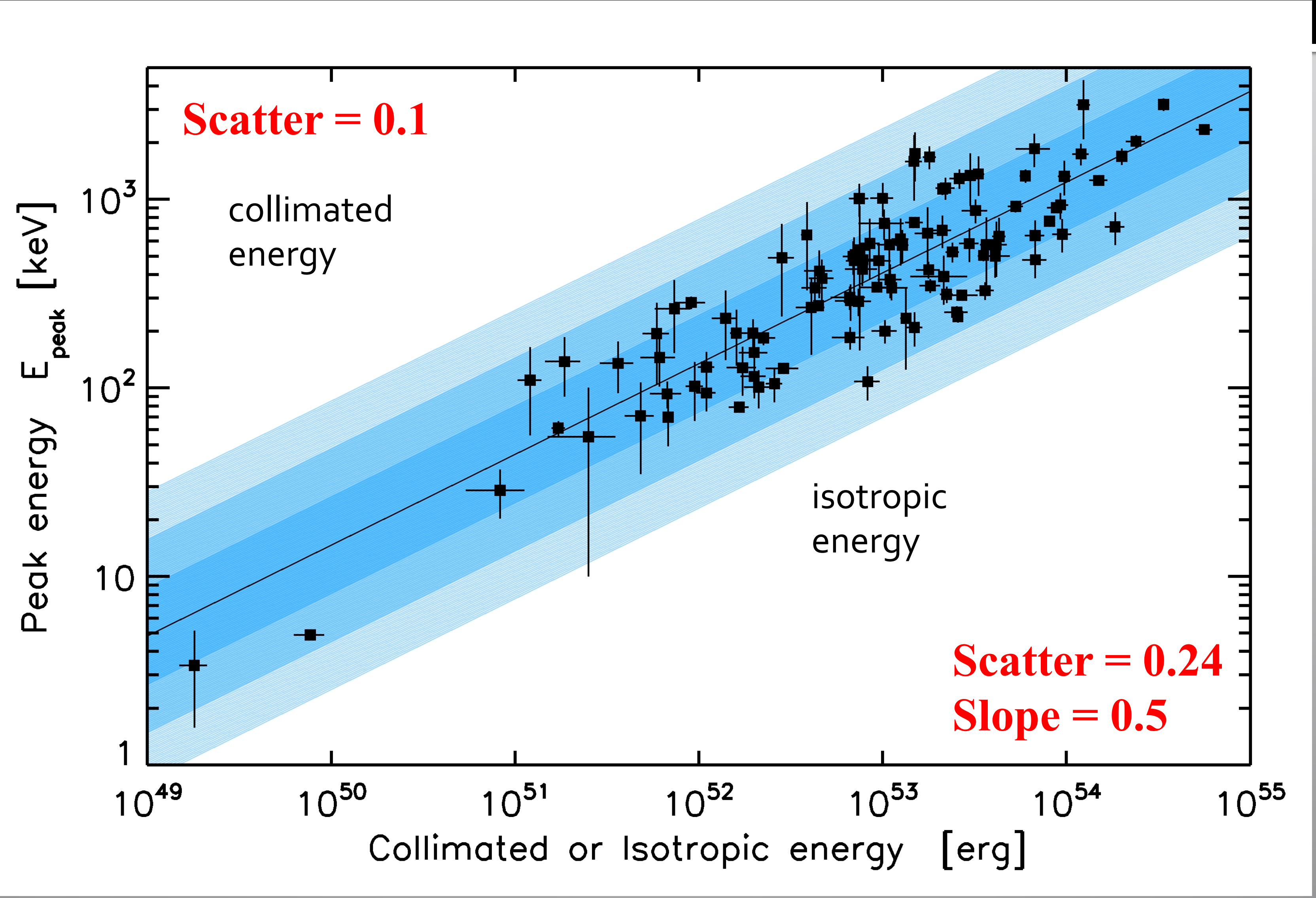


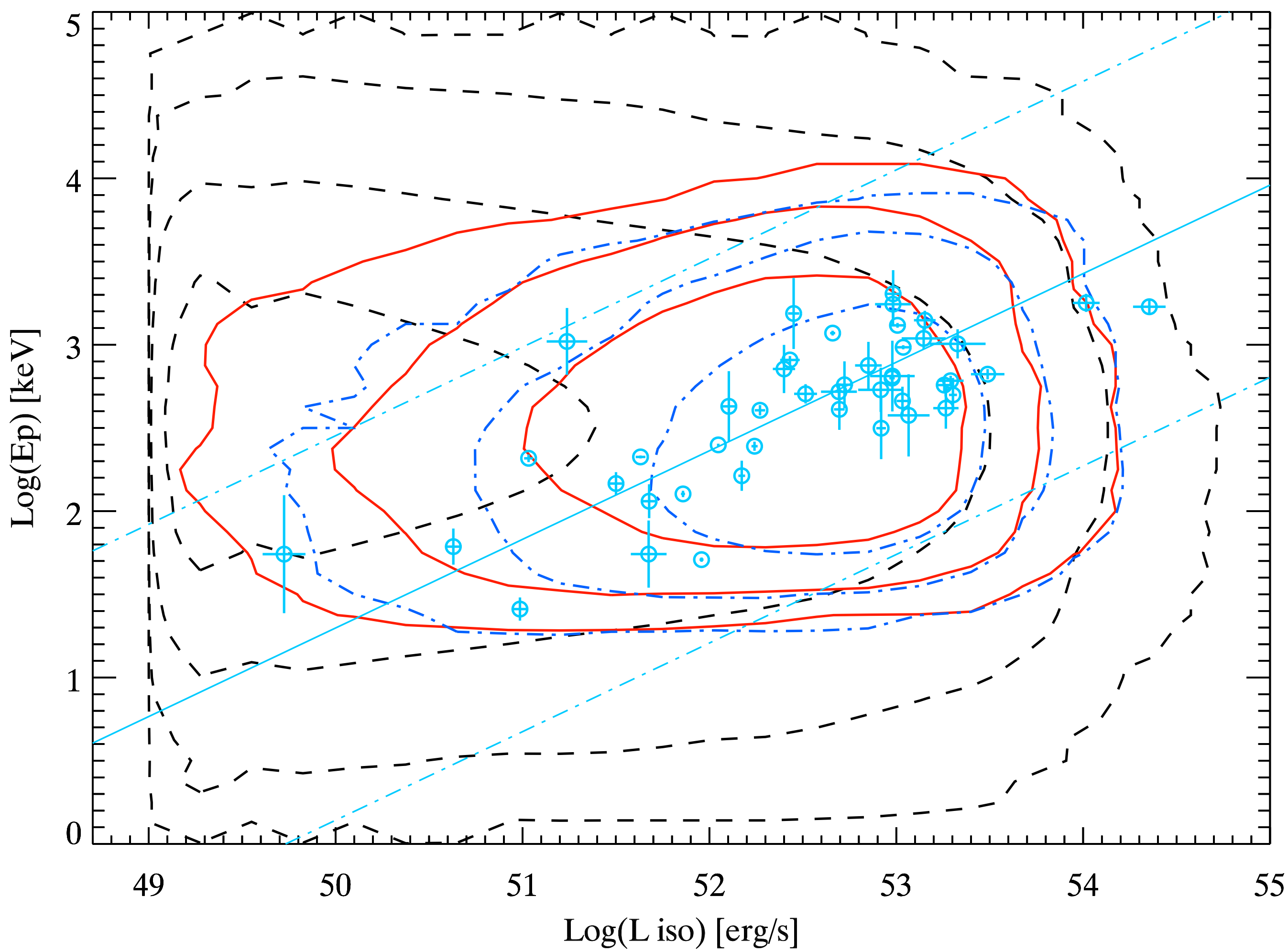
Correlation analysis

Correlation	Sample	#GRBs	ρ	P_{chance}	Slope	Norm.	σ_{sc}
$E_{peak} - E_{iso}$	Total	136	0.77	4×10^{-28}	0.55±0.02	-26.74±1.13	0.23
	Complete	46	0.76	7×10^{-10}	0.61±0.04	-29.60±2.23	0.25
	Complementary	90	0.78	3×10^{-19}	0.53±0.02	-25.55±1.35	0.25
$E_{peak} - L_{iso}$	Total	135	0.74	8×10^{-25}	0.49±0.03	-22.98±1.81	0.30
	Complete	46	0.65	1×10^{-6}	0.53±0.06	-25.33±3.26	0.29
	Complementary	89	0.75	3×10^{-17}	0.48±0.04	-22.44±2.12	0.30

E_{peak} - E_{γ} E_{peak} - E_{iso}

"GHIRLANDA" and "AMATI" correlation





5
4
3
2
1
0
Log(Ep) [keV]
49
50
51
52
53
54
55
Log(L iso) [erg/s]

Correlation analysis simulated sample

$\Phi(L)$	a	$L_{\rm cut}$ erg s^{-1}	b	δ	$\mathcal{P}_\rho$	$\mathcal{P}$	%Out.$\uparrow$	%Out.$\downarrow$
Density	-1.37	3.8×10^{52}	-2.37	1.22	7.3%	0.7%	0.7%	2.0%
Luminosity	-1.4	10^{51}	-2.13	2.67	8.3%	0.6%	1.0%	2.2%
Assume $E_{\rm peak}-L_{\rm iso}$	-1.4	10^{51}	-2.13	2.67	100%	66%	0.07%	0.2%
$E_{\rm peak}-L_{\rm iso}$ boundary	-1.4	10^{51}	-2.13	2.67	87%	12%	1.4%	0.1%
K12 (BATSE)	-1.22	10^{53}	-3.89		0.5%	0.0%	2.6%	0.7%
K12 (Swift)	-1.22	10^{53}	-3.89		0.7%	0.0%	0.4%	1.3%

Comoving frame properties:

an explanation for correlations?

Beaming effects

rest frame properties are affected by the relativistic motion of the emitting matter

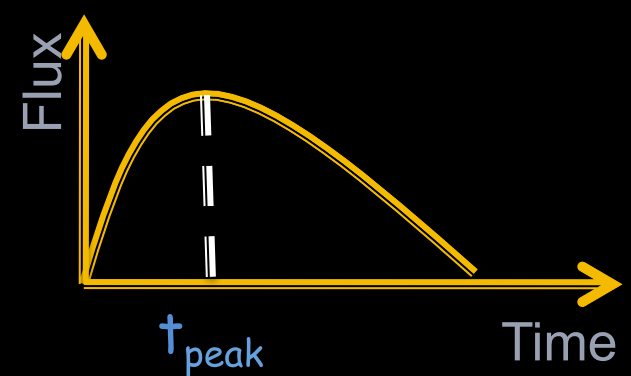
During prompt → bulk Lorentz factor ~ Γ_0

$$E_{peak}^{comov} = \frac{3}{5}\frac{E_{peak}}{\Gamma_0} \qquad E_{iso}^{comov} = \frac{E_{iso}}{\Gamma_0} \qquad L_{iso}^{comov} = \frac{3}{4}\frac{L_{iso}}{\Gamma_0^2}$$

Methods to estimate Γ_0

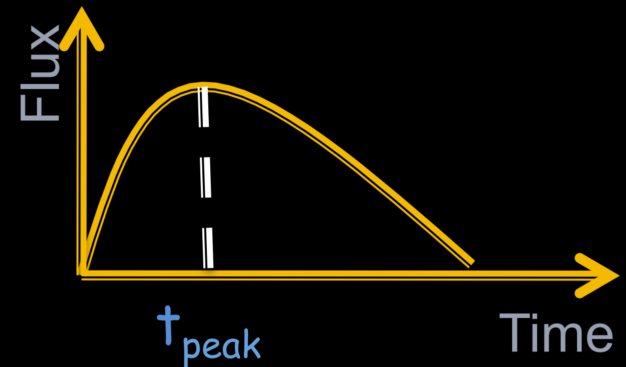
1. Lower limit from $\gamma\gamma$ opacity

2. Peak time of the afterglow lightcurves



Γ_0 from afterglow lightcurves

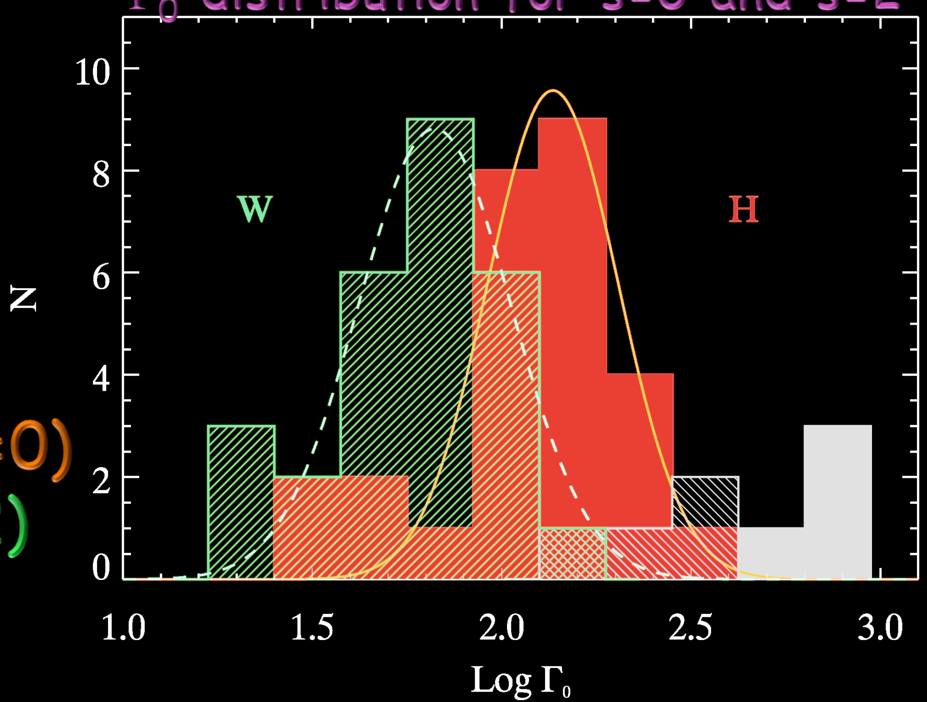
$$\Gamma_0 \propto \left[\frac{E_{iso}}{n_0 \eta t_{peak}}\right]^{1/(8-2s)} \qquad \left[n(r) = n_0 r^{-s}\right]$$



where:

η = prompt efficiency and $n(r)$ = ISM density

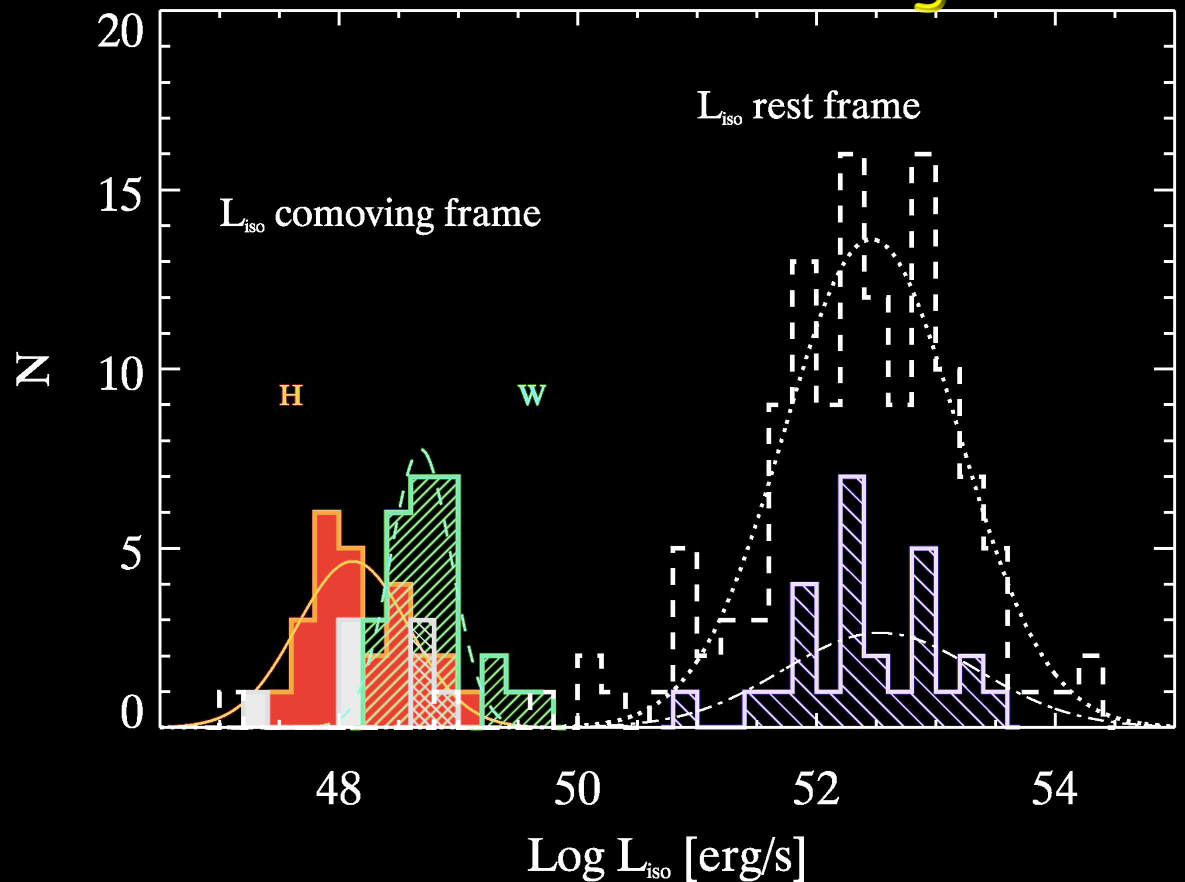
We selected all GRBs with a peak in the optical light curve (27 events)



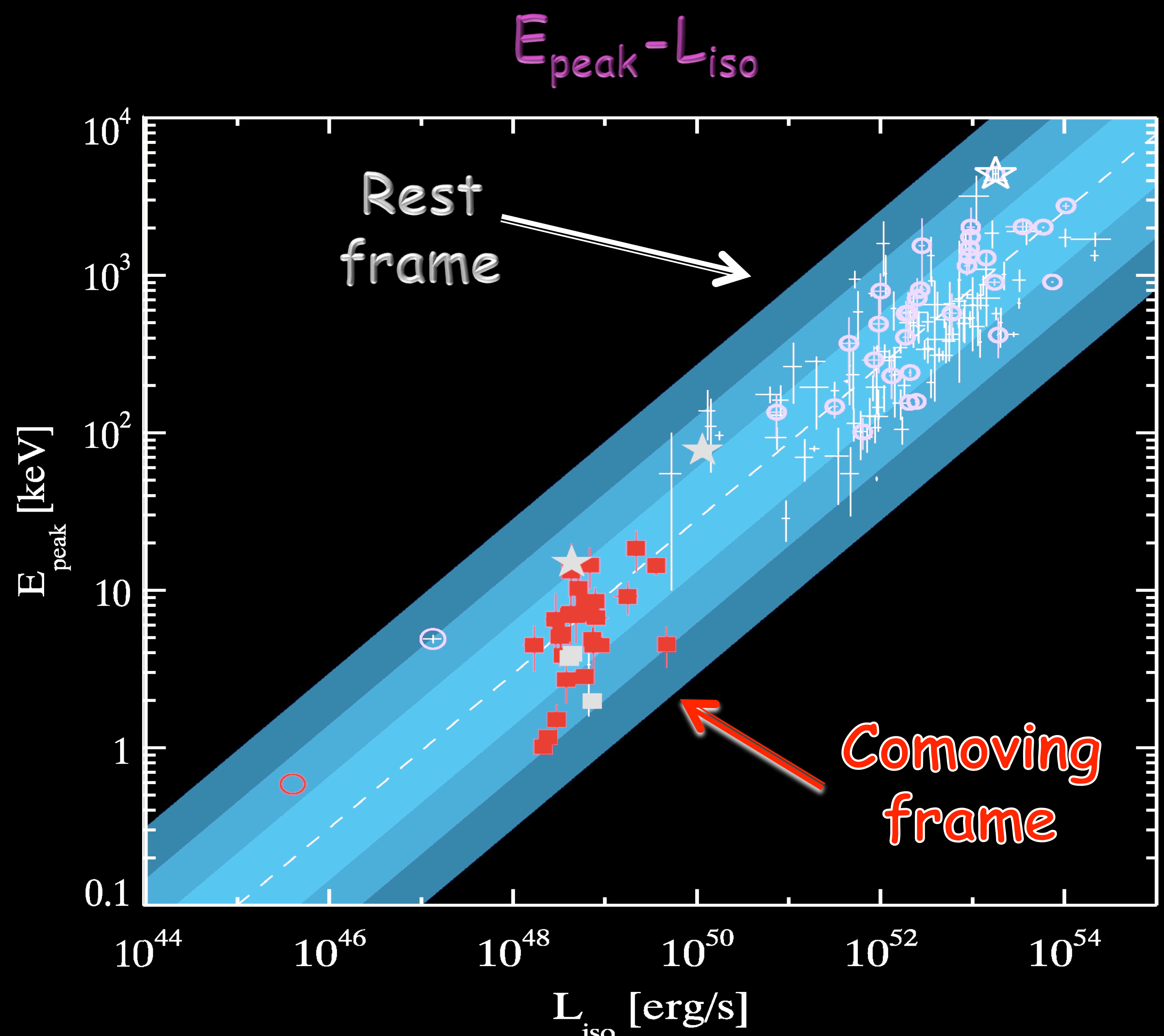
$<\Gamma_0>$ ~ 138 (Homog ISM s=0)

$<\Gamma_0>$ ~ 66 (Wind ISM s=2)

L_{iso} distribution: rest frame vs comoving frame

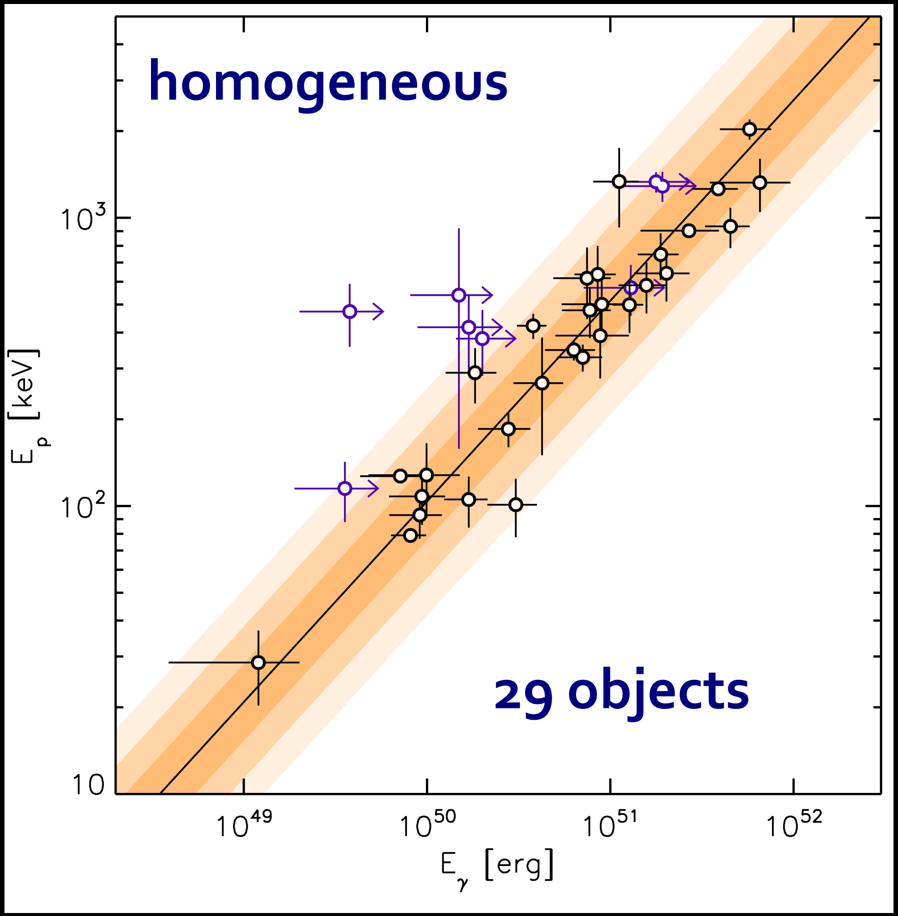


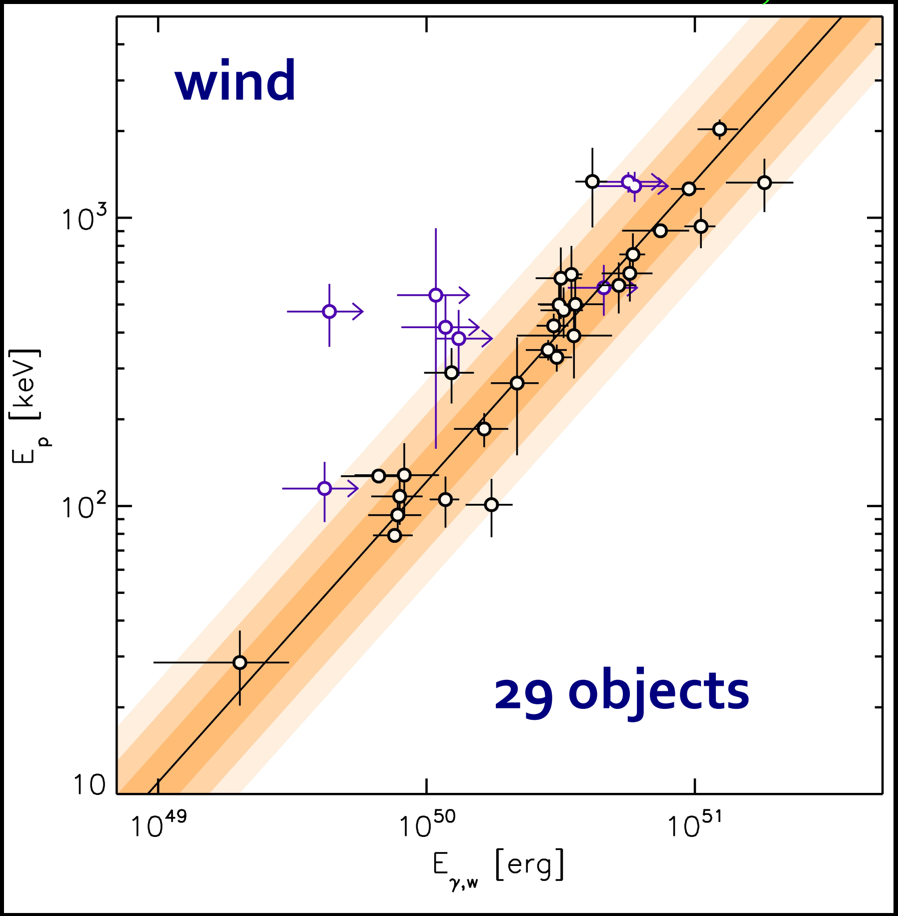
Comoving quantities have a smaller dispersion!
In particular, all bursts seem to have nearly the same comoving E_{peak} and L_{iso}



Epeak-Liso
Rest frame
Comoving frame
E_{peak} [keV]
L_{iso} [erg/s]
10^4
10^3
10^2
10
1
0.1
10^{44}
10^{46}
10^{48}
10^{50}
10^{52}
10^{54}

Nava et al., 2006





- slope = 0.70 ± 0.04
- scatter (1σ) = 0.11 dex
- $\chi^2_{red} \sim 1.5$ (27 dof)

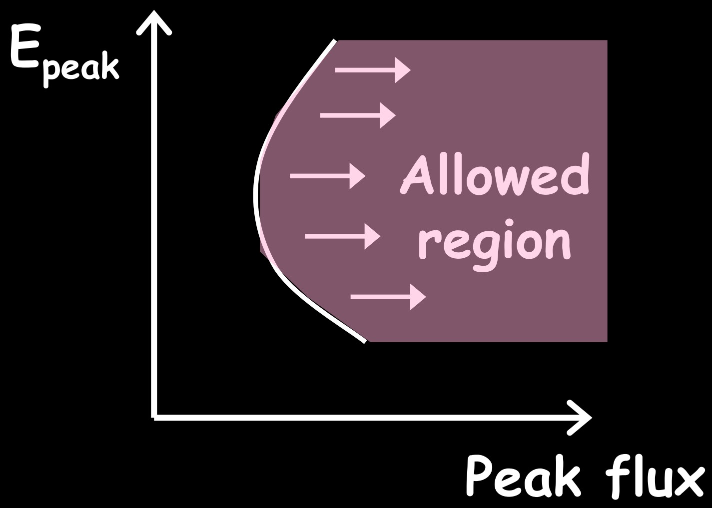
- slope = 1.04 ± 0.05
- scatter (1σ) = 0.09 dex
- $\chi^2_{red} \sim 1.4$ (27 dof)

Instrumental Selection Effects

TRIGGER THRESHOLD

Minimum Energy Peak Flux:

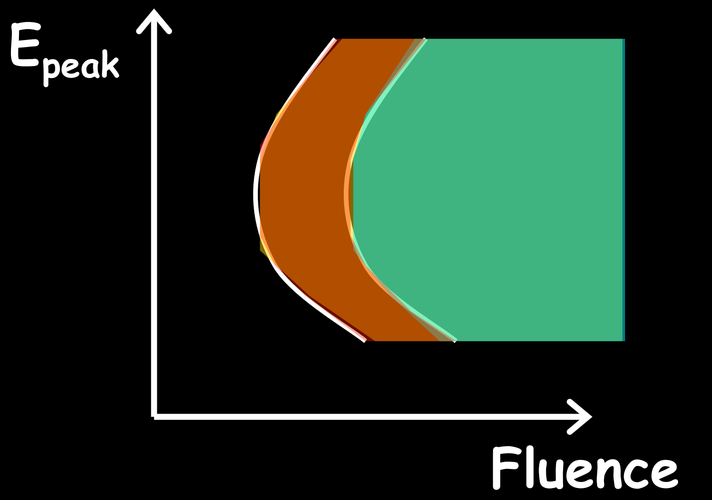
$P_{lim}\ (E_{peak,obs})$



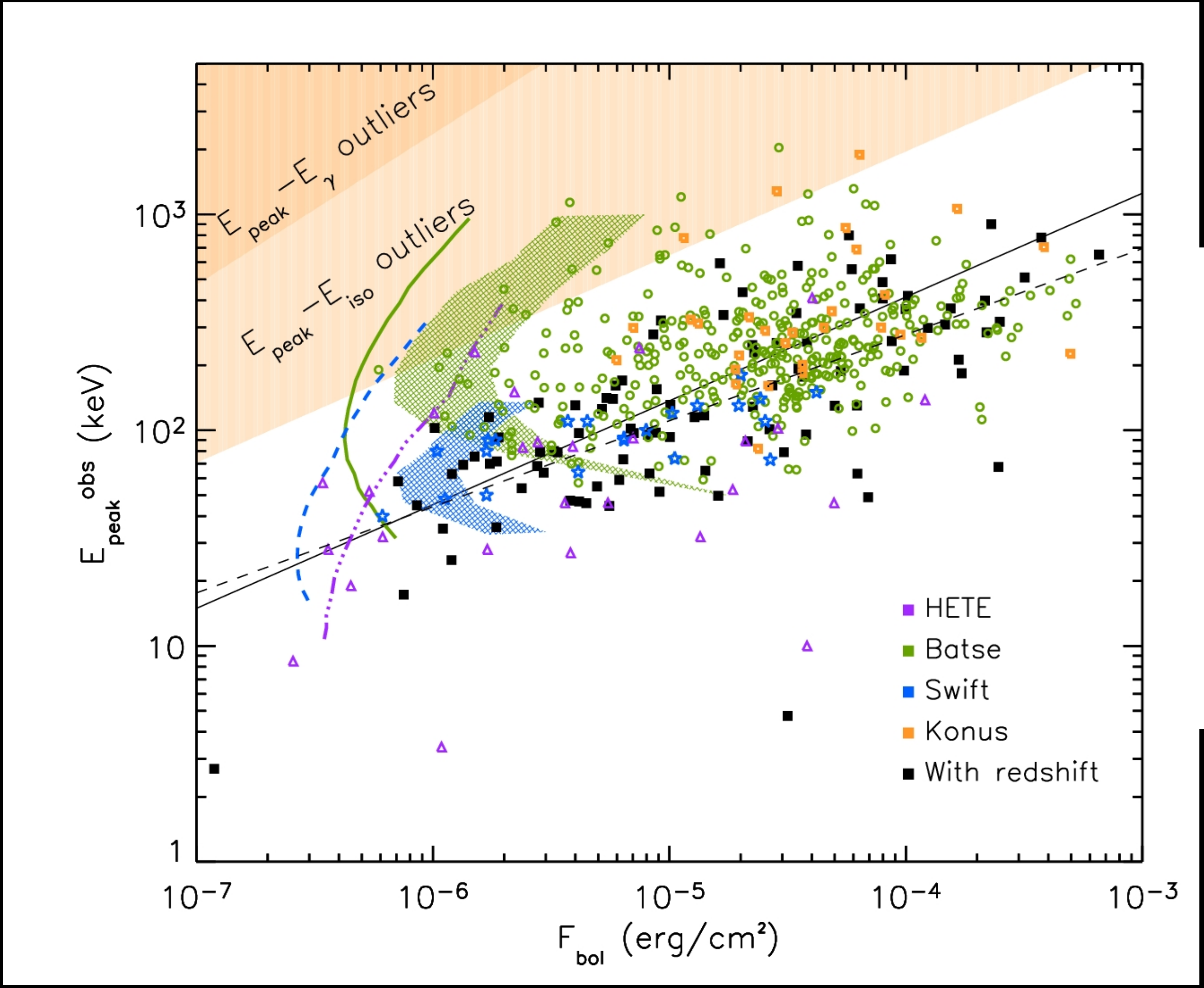
SPECTRAL ANALYSIS THRESHOLD

Minimum Fluence:

$F_{lim}\ (E_{peak,obs})$



Amati relation in the observational plane



All GRBs with published E_{peak} and Fluence

HETE: Sakamoto et al. 2005 **Swift/BAT:** Butler et al. 2007 (freq)

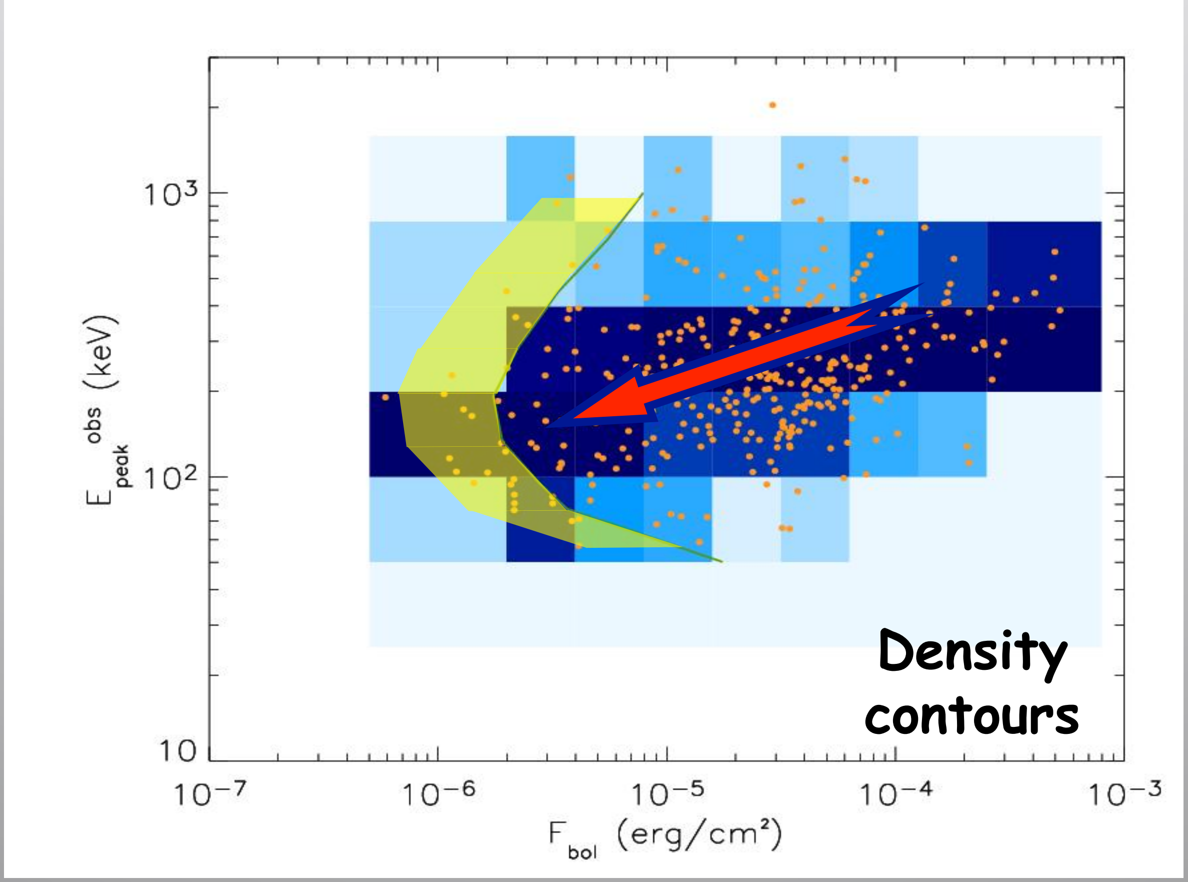
BATSE: Kaneko et al. 2006 **Konus/Wind:** Golenetskii et al. (GCNs)

Extend the Bright BATSE GRB sample (Kaneko et al. 2006) to lower fluences

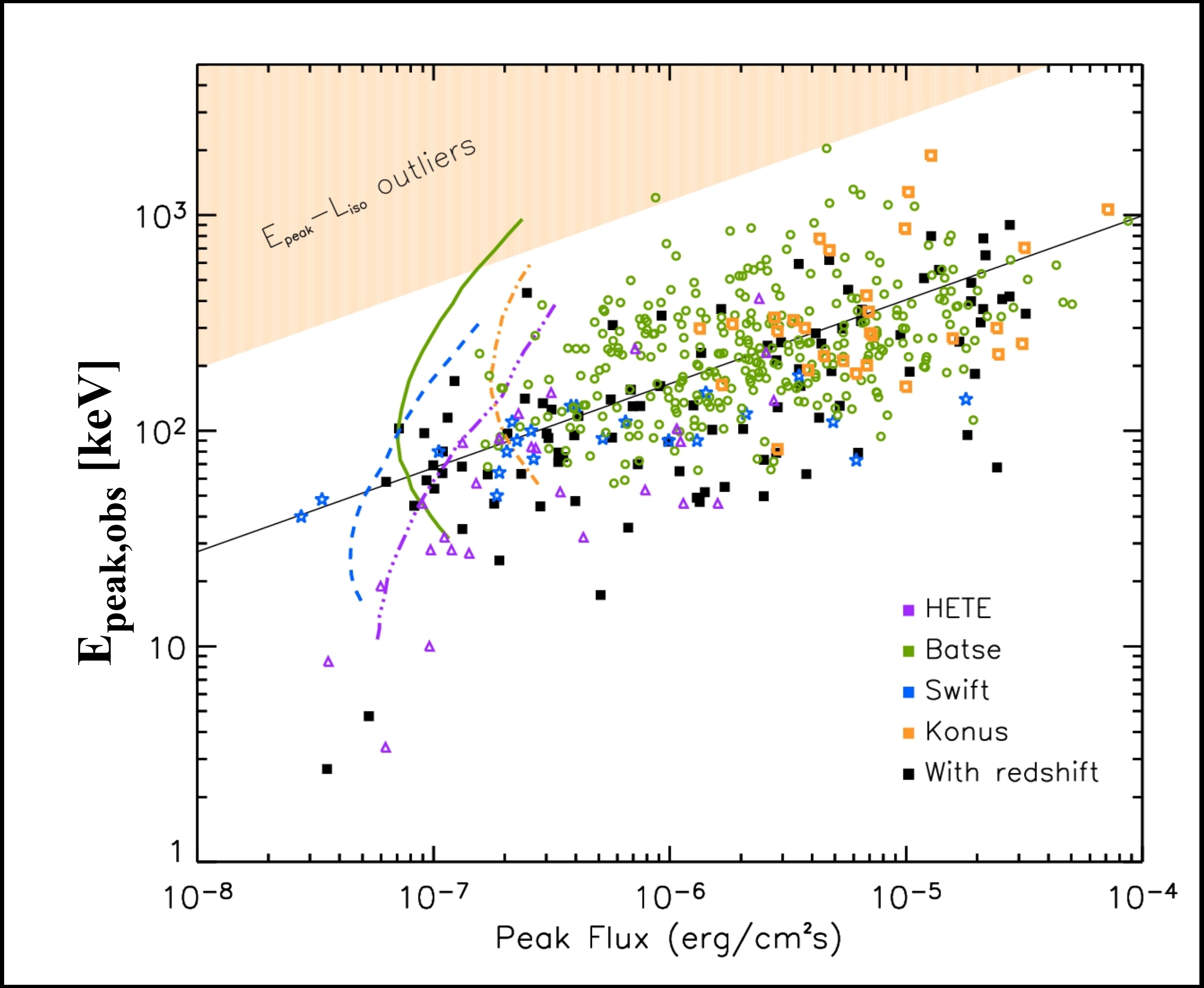
⟹

Build a complete spectral sample of BATSE bursts down to ~ 10^{-6} erg/cm^2

Nava et al., 2008, MNRAS

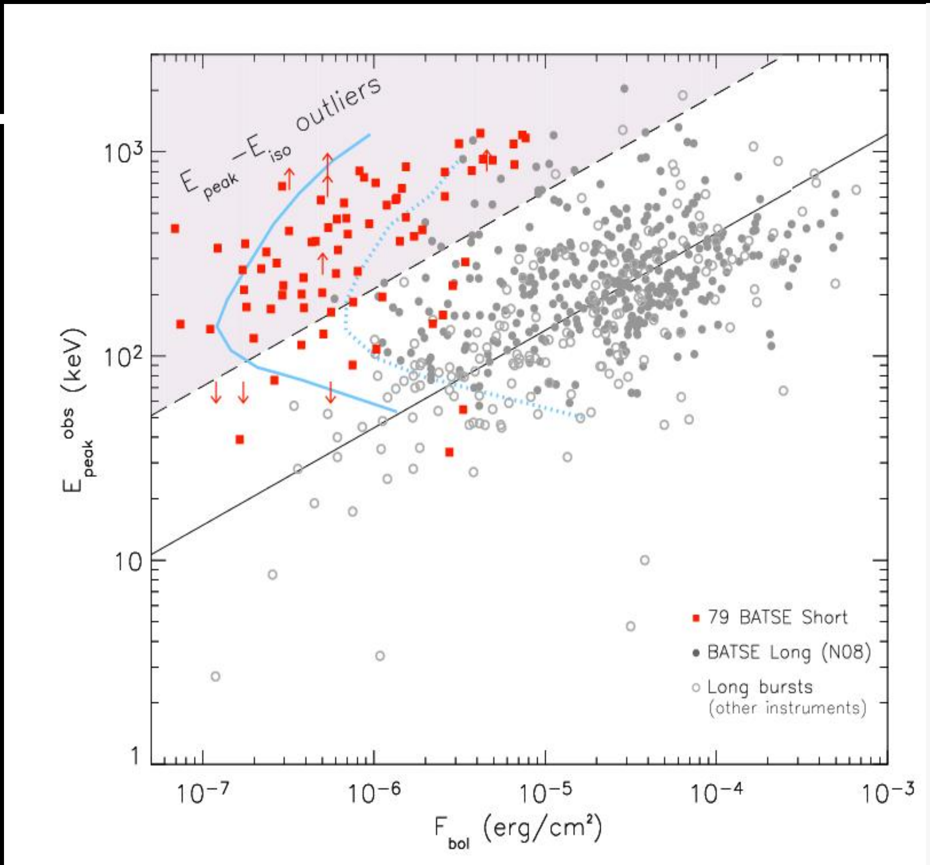


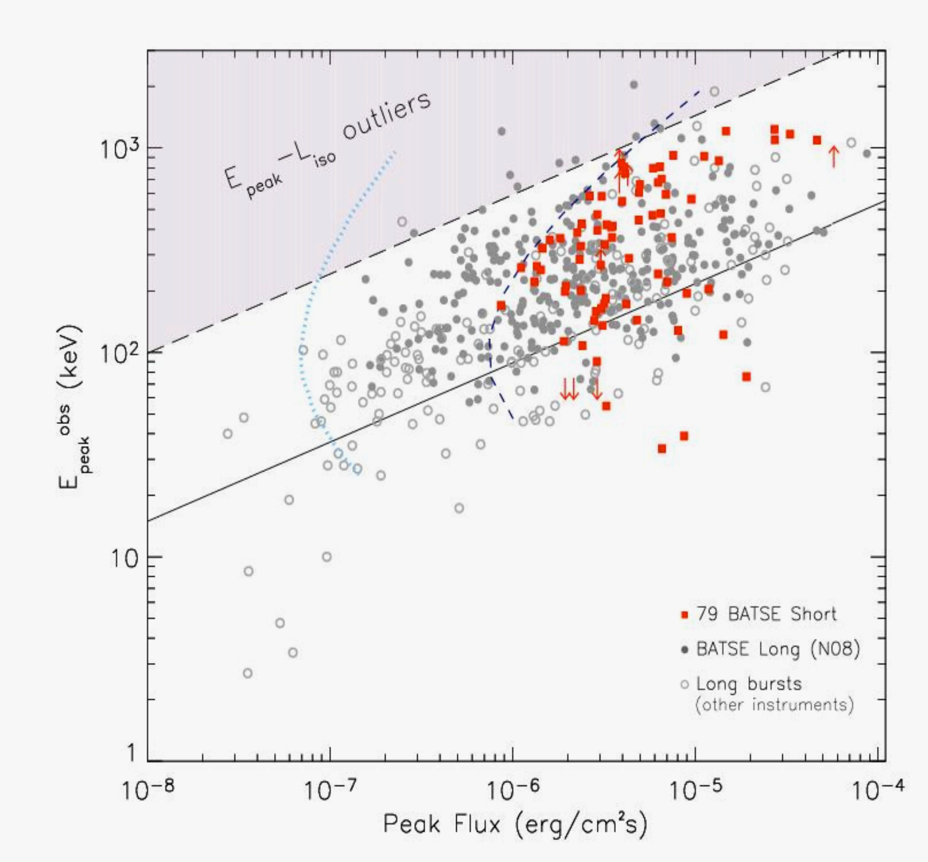
Yonetoku relation in the observational plane



HETE: Sakamoto et al. 2005 **Swift/BAT:** Butler et al. 2007 (freq)
BATSE: Kaneko et al. 2006 **Konus/Wind:** Golenetskii et al. (GCNs)

What about short bursts?





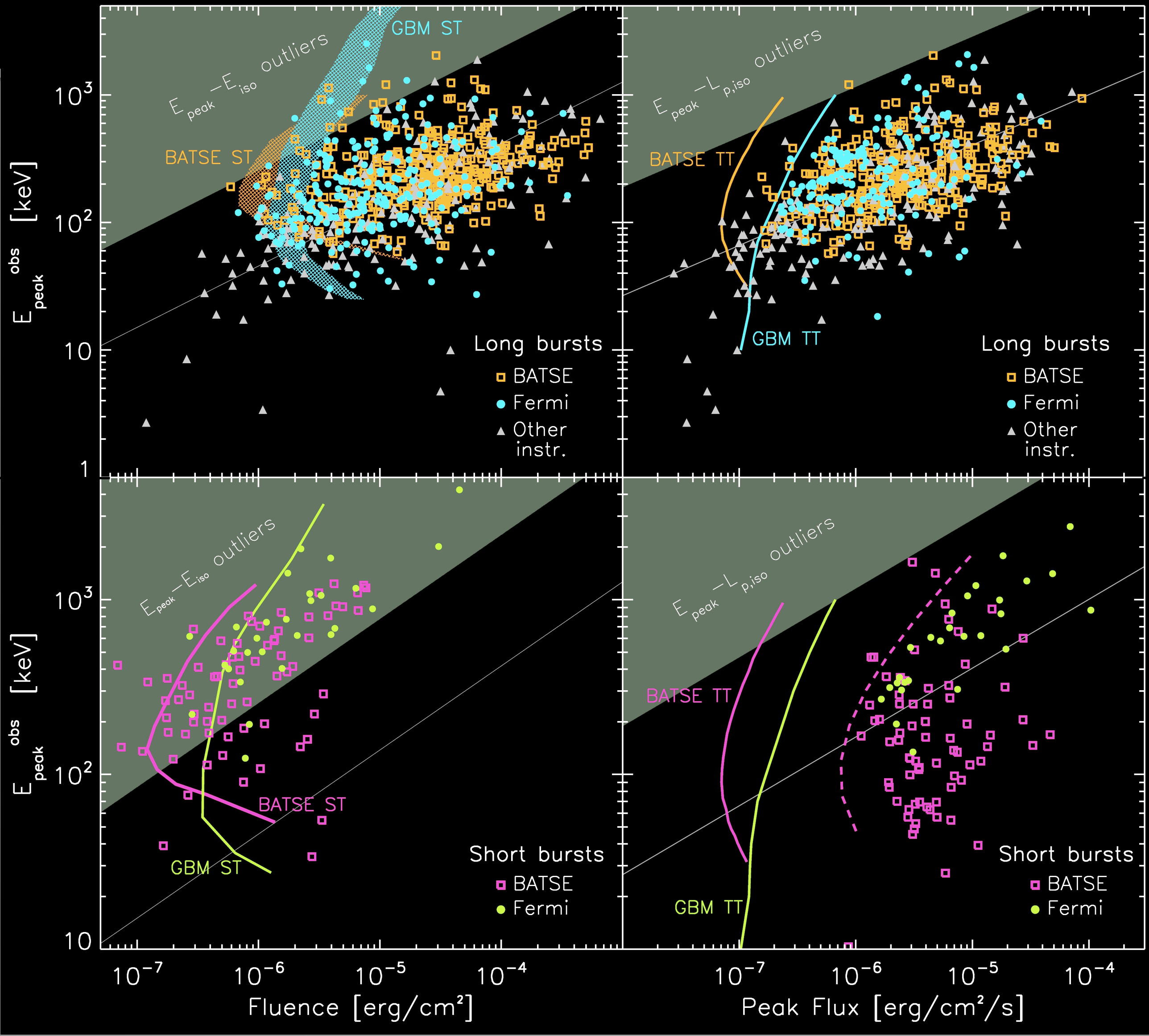
Short bursts populate the same region of long bursts in the $E_{peak,obs}$-Peak Flux plane. They can be consistent with the E_{peak}-L_{iso} correlation

Short bursts have similar Epeak but lower fluences in respect to Long bursts. They cannot be consistent with the E_{peak}-E_{iso} correlation

Fermi/GBM GRBs

LONG

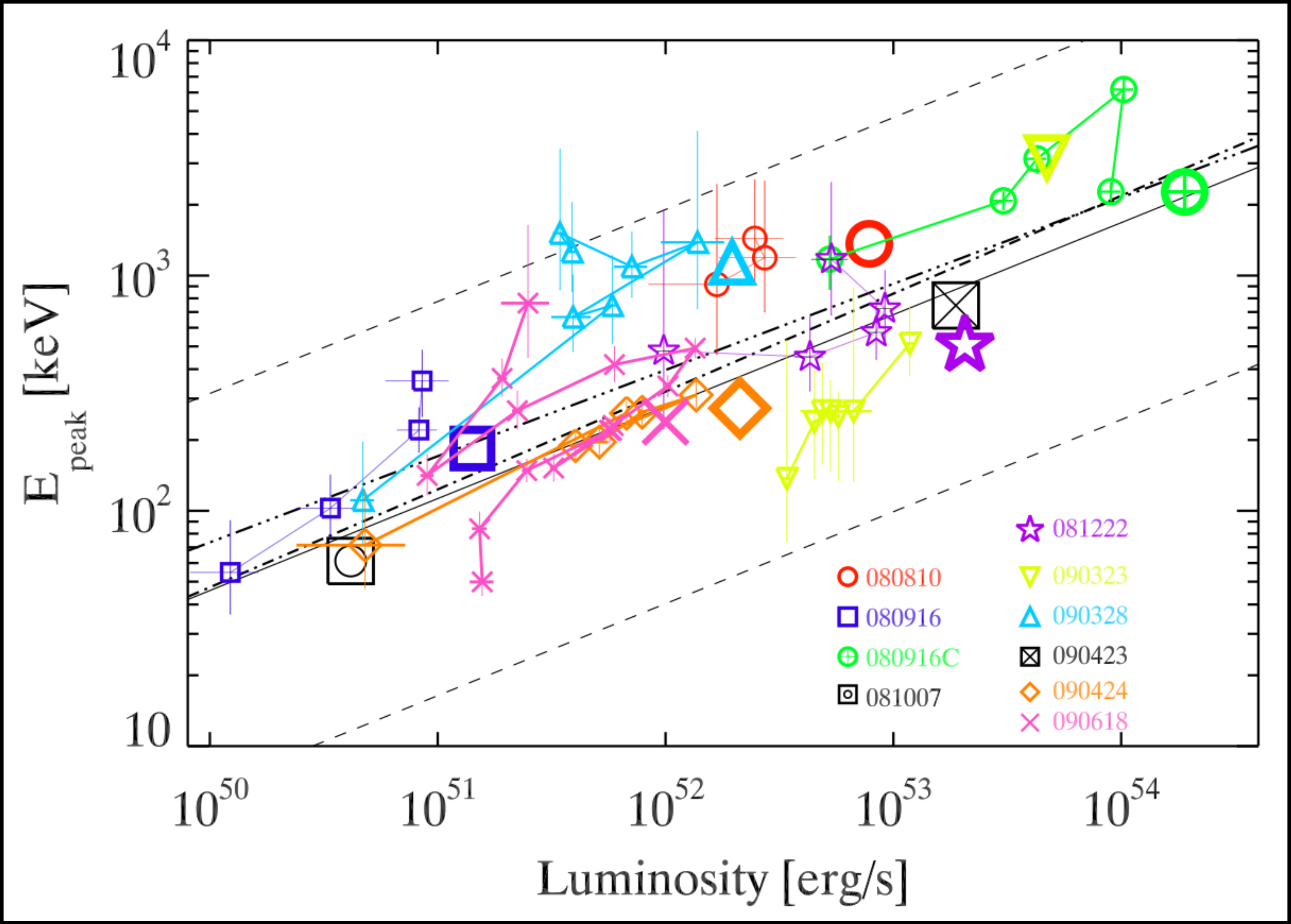
LONG



SHORT

SHORT

Selection effects ?



Ghirlanda, Nava & Ghisellini 2009