Istituto Nazionale di Astrofisica

Osservatorio Astronomico di Brera

A complete sample of bright Swift short GRBs

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Selecting a complete sample: short GRBs

<u>Context</u>:

- About 10% of the *Swift* GRBs are short

- SGRBs are fainter than long duration GRBs

- About 2/3 of SGRBs are lacking a redshift measure.

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Criteria:

1) Short *Swift* GRB with favorable observing conditions from the ground ($A_V < 0.5$), promptly repointed by *Swift*-XRT (no need for an X-ray detection)

→ 36 SGRBs (up to June 2013), 15 (42%) with redshift ("*Total sample*")

2) Bright prompt (15-150 keV) emission (64ms peak flux > 3.5 ph/cm^2/s)

→16 SGRBs (up to June 2013), 11 (69%) with redshift ($0.12 < z < 1.30$; "*Complete sample*")

Note:

This sample is *complete* in terms of flux (it includes all the *Swift* SGRBs with $P_{64} > 3.5$ ph/cm^2/s) and, at the same time, has the highest fraction of events with measured redshift with respect to other SGRBs samples presented in the literature to date.

Selec … GRBs

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GRB	T_{90} s	PF_{64} ph cm^2 s^{-1}	EE	SL/LL	XRT err ″	OA	redshift
050509B	0.02	1.3	N	SL	3.8	N	N[a]
050813	0.45	2.1	N	SL	2.9	N	N
050906	0.153	1.7	N	–	–	N	N
051105A	0.06	2.7	N	–	–	N	N
051210	1.30	1.0	N	SL	1.6	N	1.3[b]
051221A	1.40	40.7	N	LL	1.4	Y	0.547
051227	115.40	1.5	Y	LL	3.6	Y	N
060313	0.74	30.9	N	LL	1.4	Y	N
060502B	0.14	3.4	N	SL	5.2	N	N[a]
060801	0.50	2.1	N	SL	1.5	N	1.13
061201	0.78	8.0	N	LL	1.4	Y	N
061217	0.24	2.0	N	SL	5.5	N	N[a]
070209	0.07	2.8	N	–	–	N	N
070714B	80.00	8.1	Y	LL	1.4	Y	0.92
070724A	0.43	1.5	N	LL	1.7	Y	0.457
070729	0.99	1.9	N	SL	2.5	N	N[a]
070809	1.28	1.9	N	LL	3.6	Y	N[a]
070810B	0.07	2.1	N	–	–	N	N
071227	144.98	2.9	Y	LL	1.7	Y	0.381
080123	115.18	6.1	Y	LL	1.7	Y	0.495
080503	159.78	4.0	Y	SL	1.6	Y	N
080905A	1.02	3.7	N	SL	1.6	Y	0.122[d]
090426[c]	1.24	4.7	N	LL	1.4	Y	2.609
090510	0.30	20.1	N	LL	1.4	Y	0.903
090515	0.04	5.2	N	SL	2.9	Y	N[a]
090607[c]	2.29	2.0	N	SL	3.6	N	N
100117A	0.30	4.4	N	SL	3.6	Y	0.92
100625A	0.33	9.3	N	SL	1.8	N	0.452
100816A[c]	2.90	12.9	N	LL	1.4	Y	0.805
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130603B	0.18	54.2	N	LL	1.4	Y	0.356

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0[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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Reliable redshift if: optical afterglow coincident with an HG or HG inside an X-ray circle with uncertainty < 2".

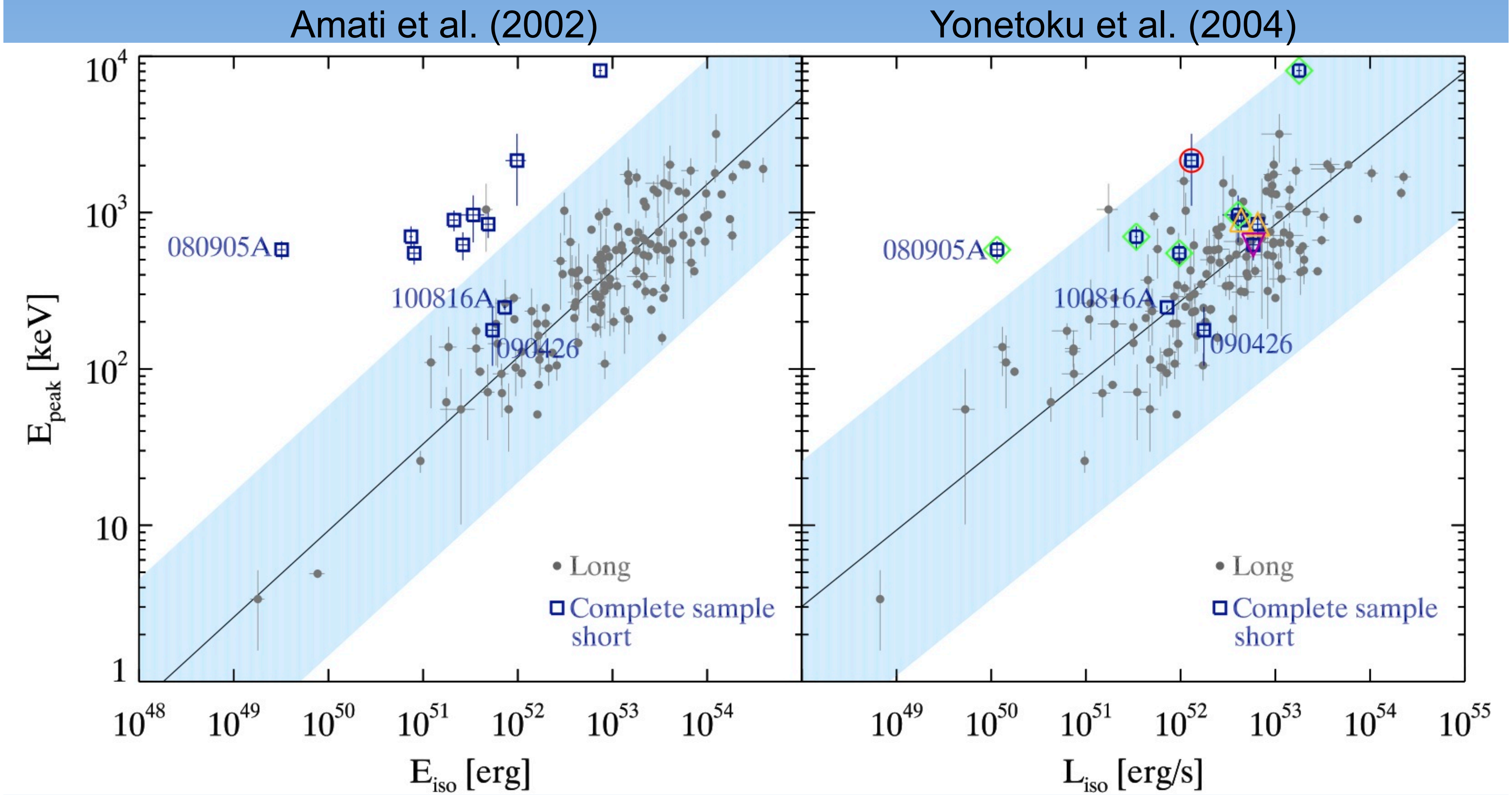
Uncertain long/short classification

Complete sample:

rest-frame properties

Prompt spectral energy correlations

Complete sample



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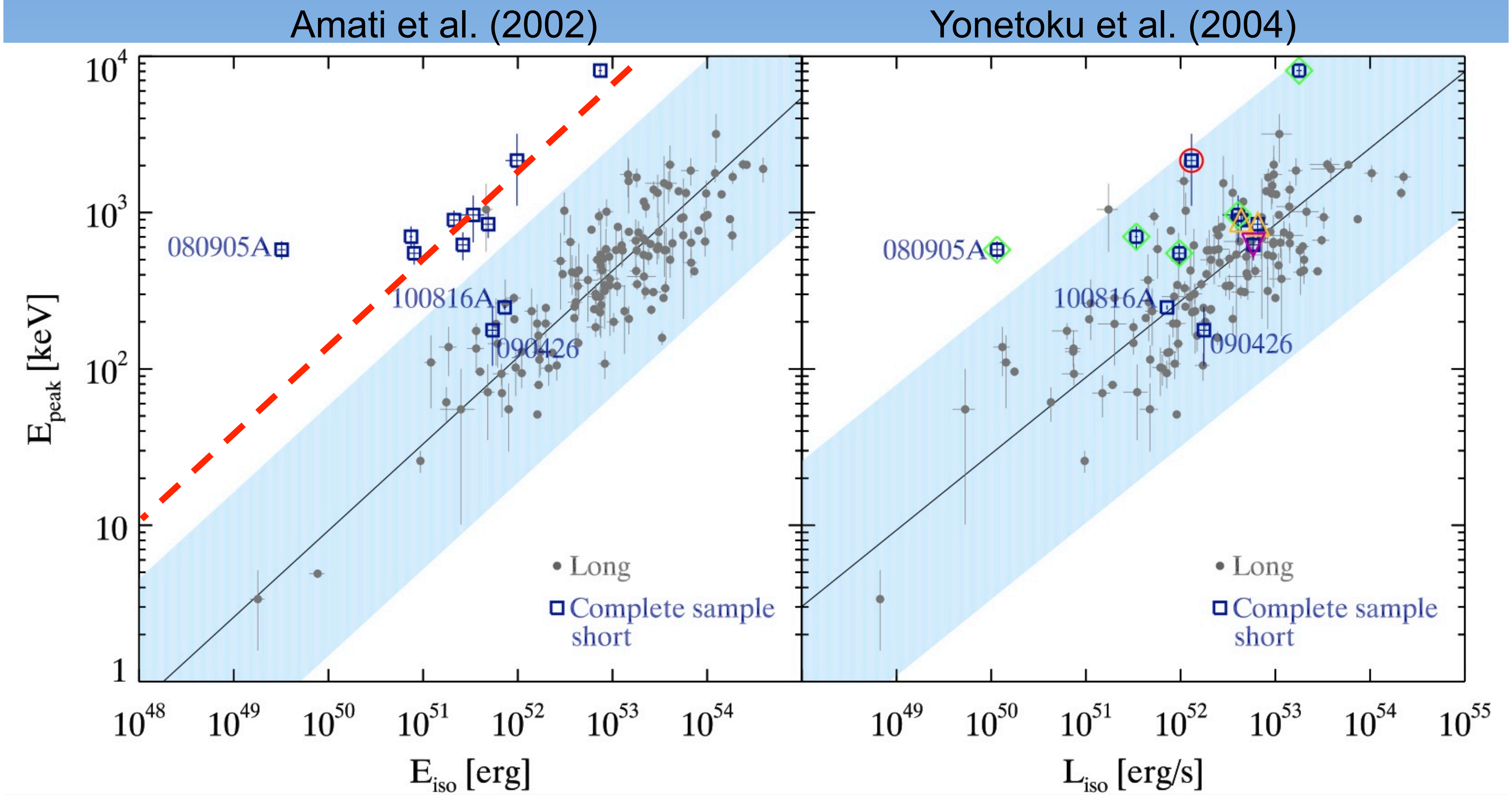


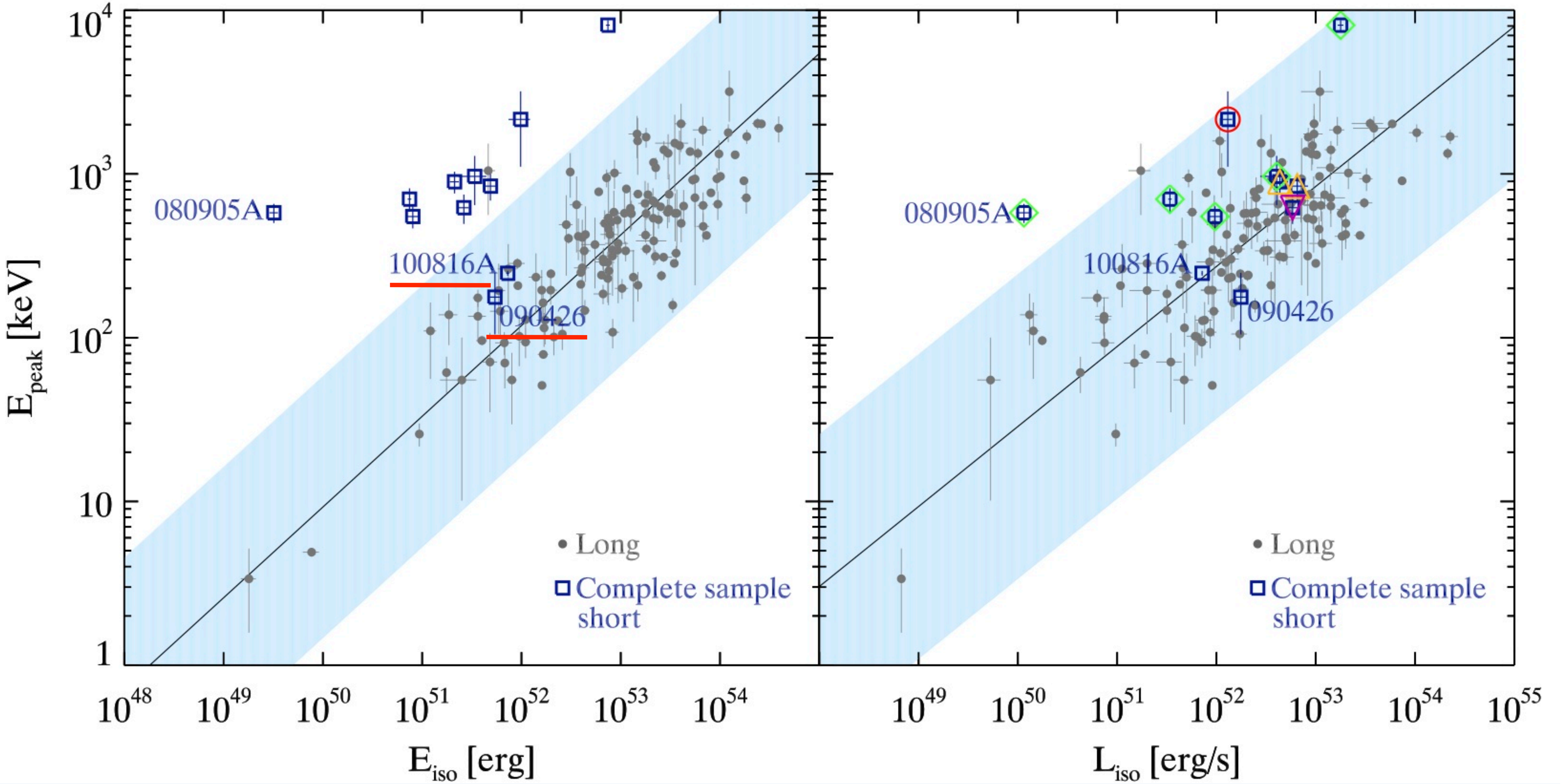
SGRBs E_p-E_{iso} correlation: $E_p = 10^{-28.0}\, E_{iso}^{0.6}$

See talk by G. Calderone

Prompt spectral energy correlations

Complete sample

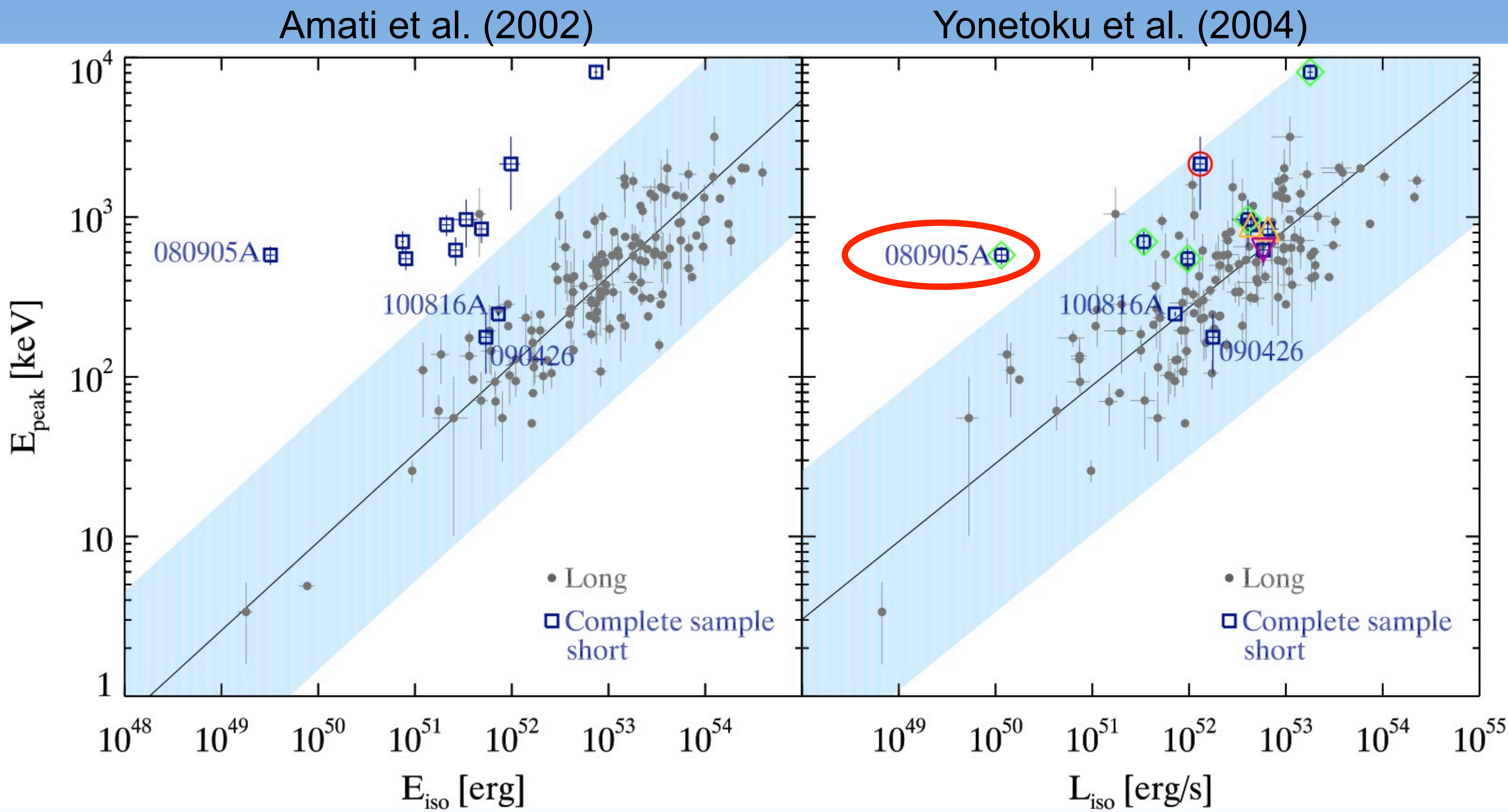
Amati et al. (2002) Yonetoku et al. (2004)



GRB 090426 and GRB 100816A are consistent with the E_p-E_{iso} correlation valid for LGRBs. Poor information on the GRB 090426 prompt spectrum (conservatively, we have just limits on E_p and E_{iso}). GRB 100816A has a T_{90} = 2.9s (probably long).

Prompt spectral energy correlations

Complete sample



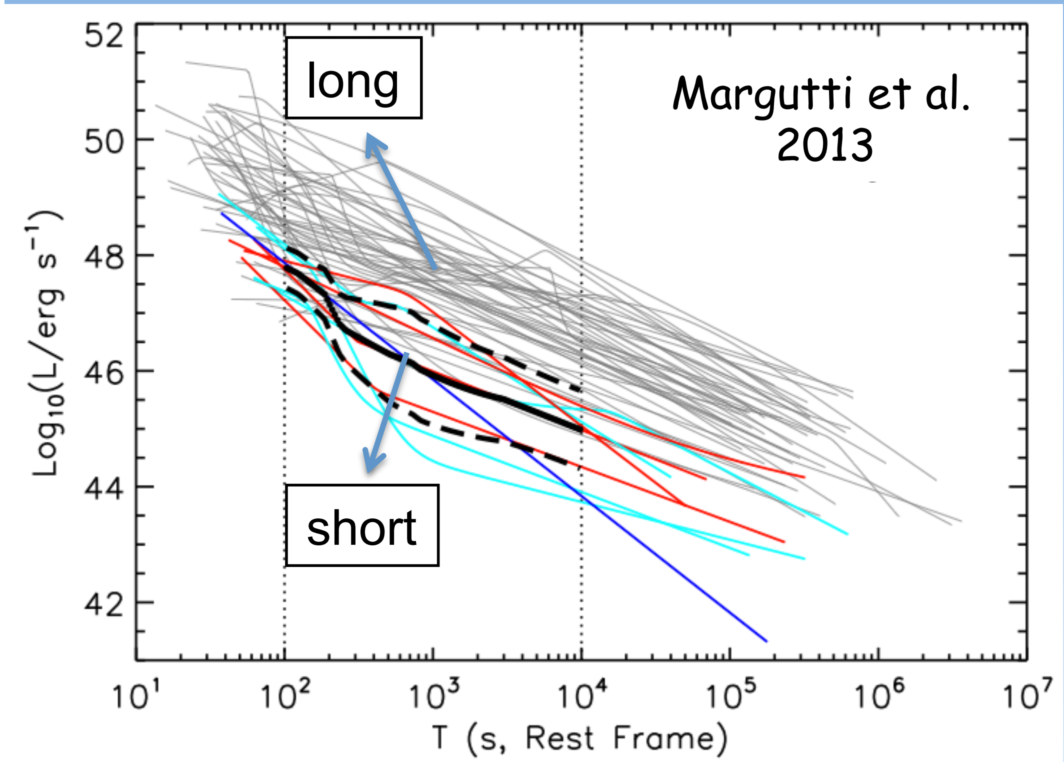
GRB 080905A is the event with the lowest *z* of the sample. It is associated to a face-on spiral galaxy at z=0.122, with a probability of chance alignment P < 1% (Rowlinson et al. 2010).

Either it is a peculiar sub-luminous SGRBs, or the association with the HG is spurius

Eiso normalized X-ray afterglow LCs

Complete sample

Rest frame X-ray luminosity



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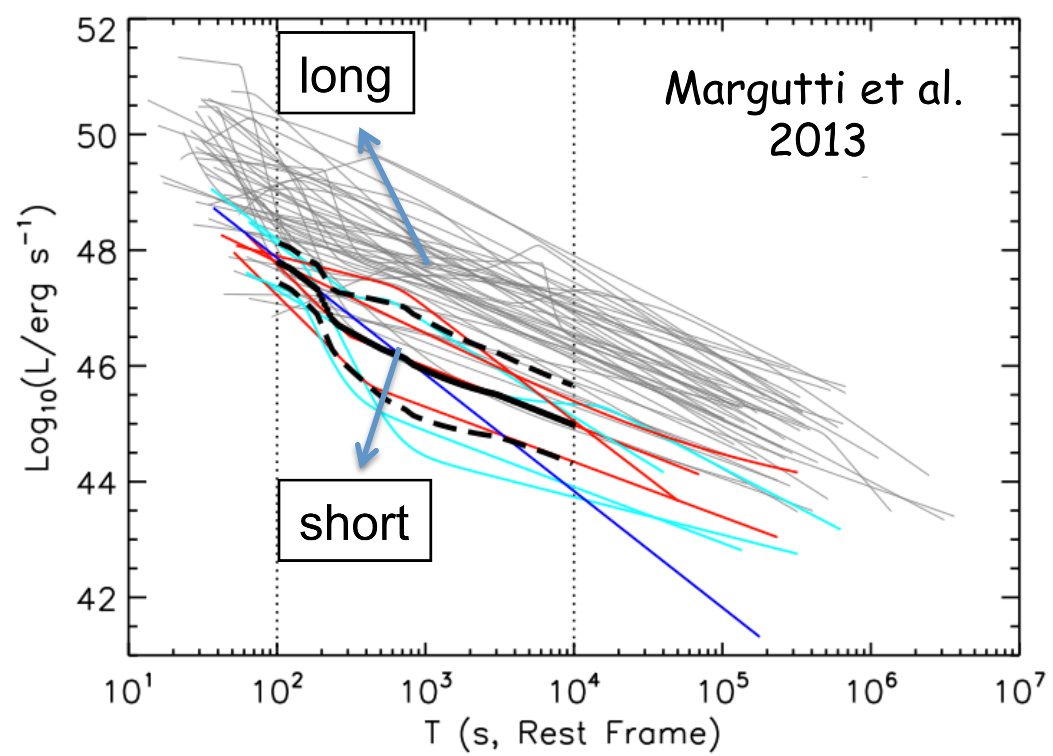
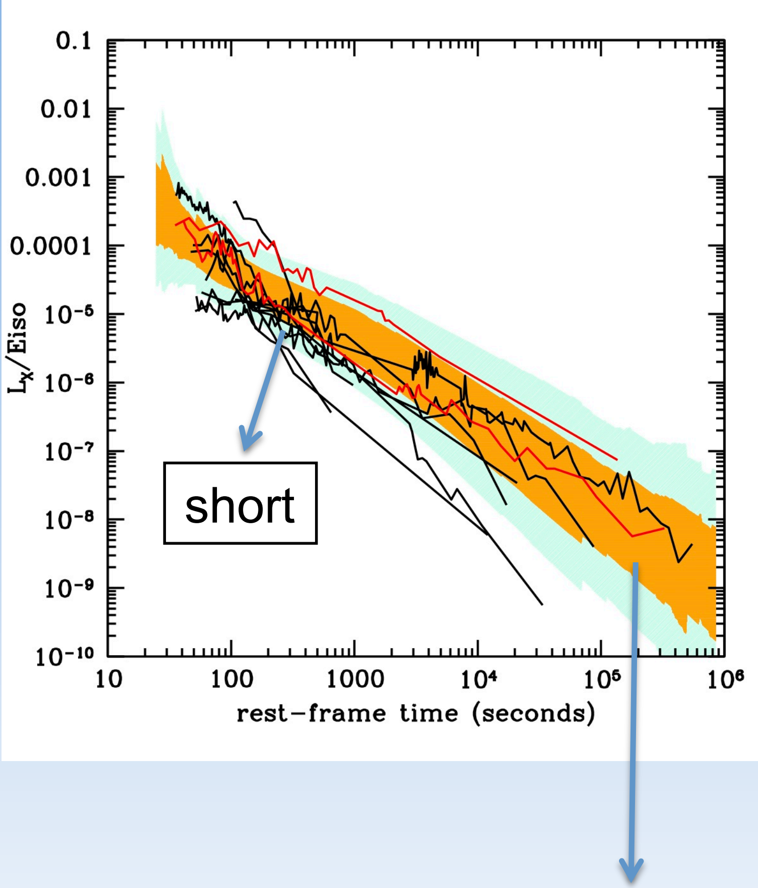


Rest frame X-ray luminosity normalized to Eiso



The afterglow X-ray luminosity is a good proxy of Eiso for both long and short GRBs

1sigma scatter for long GRBs (D'Avanzo et al. 2012)

Redshift distribution

Complete sample

Our sample has an average redshift <*z*> = 0.85

In the context of SGRBs originated by the coalescence of binary systems made by compact objects (NS-NS or NS-BH), this redshift value suggests for "primordial binary" progenitors (systems which were born as binaries), expected to have a redshift distribution peaking at $z \geq 0.8$ (Salvaterra et al. 2008).

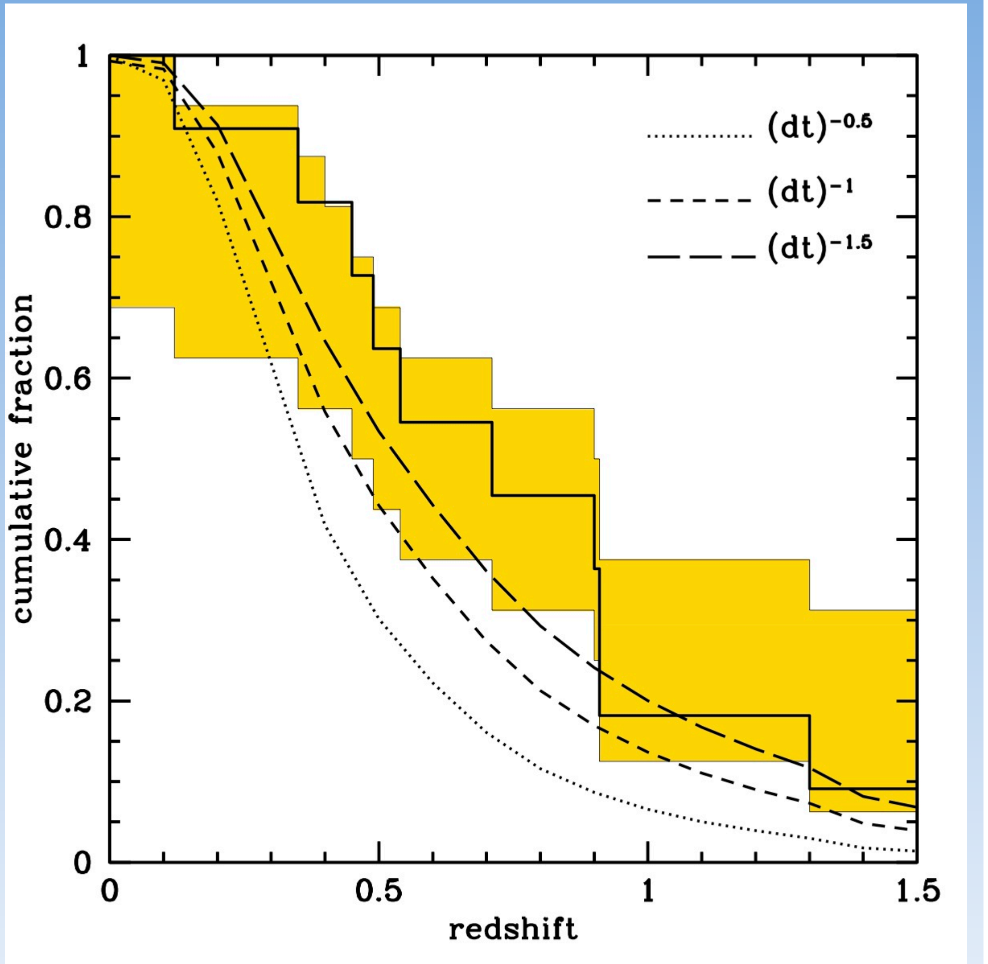
Binary systems formed through the "dynamical" channel (e.g. in globular clusters) are expected to be at lower z (Salvaterra et al. 2008; Guetta & Stella 2009).

Redshift distribution

Complete sample

Rate of bursts with peak flux $P_1 < P < P_2$

$$\frac{dN}{dt}(P_1 < P < P_2) = \int_0^\infty dz \frac{dV(z)}{dz} \frac{\Delta\Omega_s}{4\pi} \frac{k_{\rm SGRB}\Psi_{\rm SGRB}(z)}{1+z} \times \int_{L(P_1,z)}^{L(P_2,z)} dL' \phi(L'), \quad (5)$$



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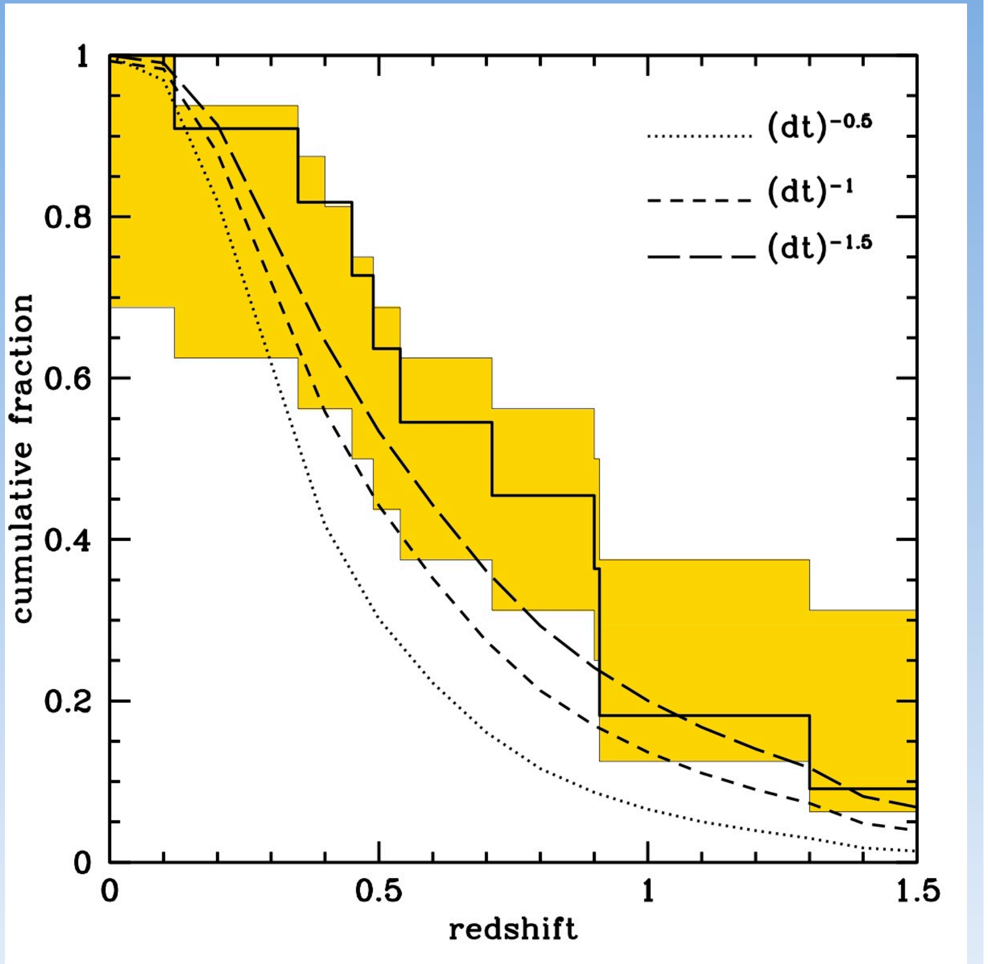
Formation rate (# of bursts per unit time and unit comoving volume at redshift *z*) proportional to massive star binary formation rate and the delay time (interval between binary formation and merging) distribution function:

$$f_{\rm F}(t) \propto t^n$$

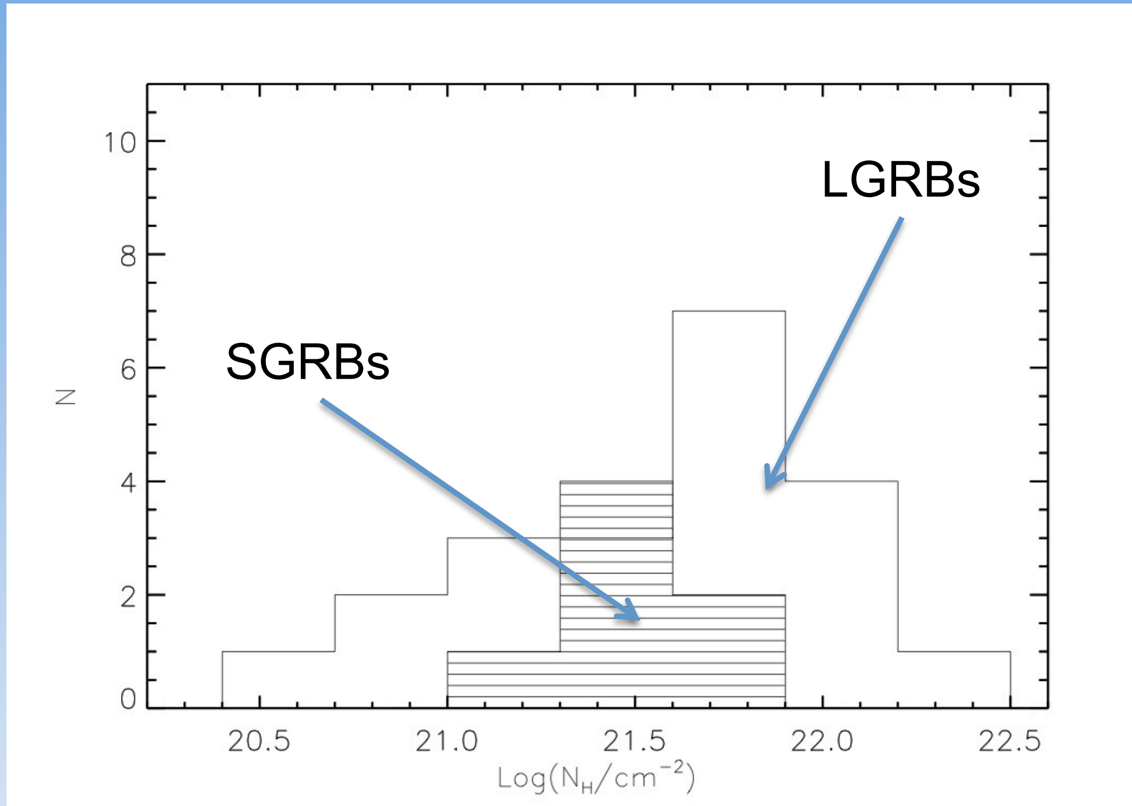
We compute the observed distribution of SGRBs for *n* = -1.5, -1, -0.5, delay times ranging from 20 Myr to ~10 Gyr (Behroozi, Ramirez-Ruiz & Fryer 2014)



Model with n=-1.5 favored in accounting for the observed z distribution of the SGRBs of our sample. Consistent with fast merging primordial binaries progenitors

Intrinsic X-ray absorbing column density of SGRBs

Complete sample



N_H distribution of our complete sample of short GRB (0.12 < z < 1.30)

N_H distribution of the BAT6 sample of bright long GRB presented in Campana et al. (2013), reduced to z < 1.3

K-S test -> P=34%

in agreement with Kopac et al. (2012); Margutti et al. (2013)

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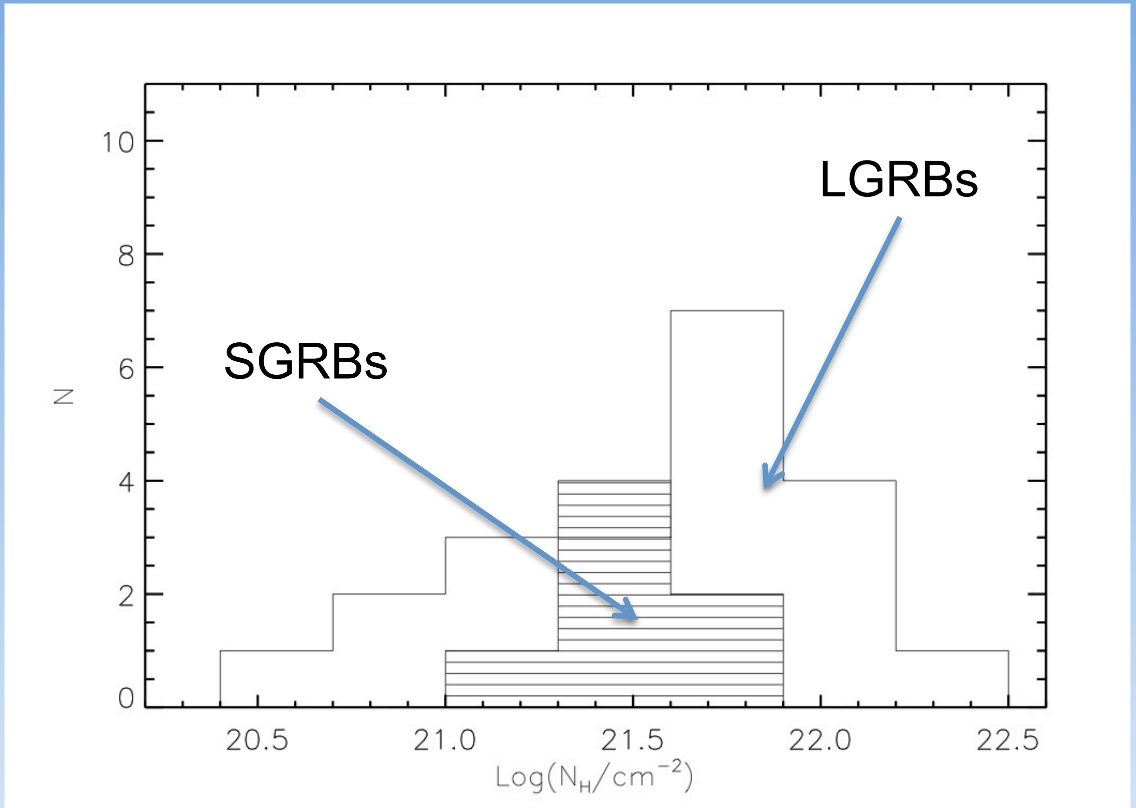

Fast merging "primordial" binaries are expected to merge near their star-forming birthplace (the environment for long and short GRBs may be similar in this case)

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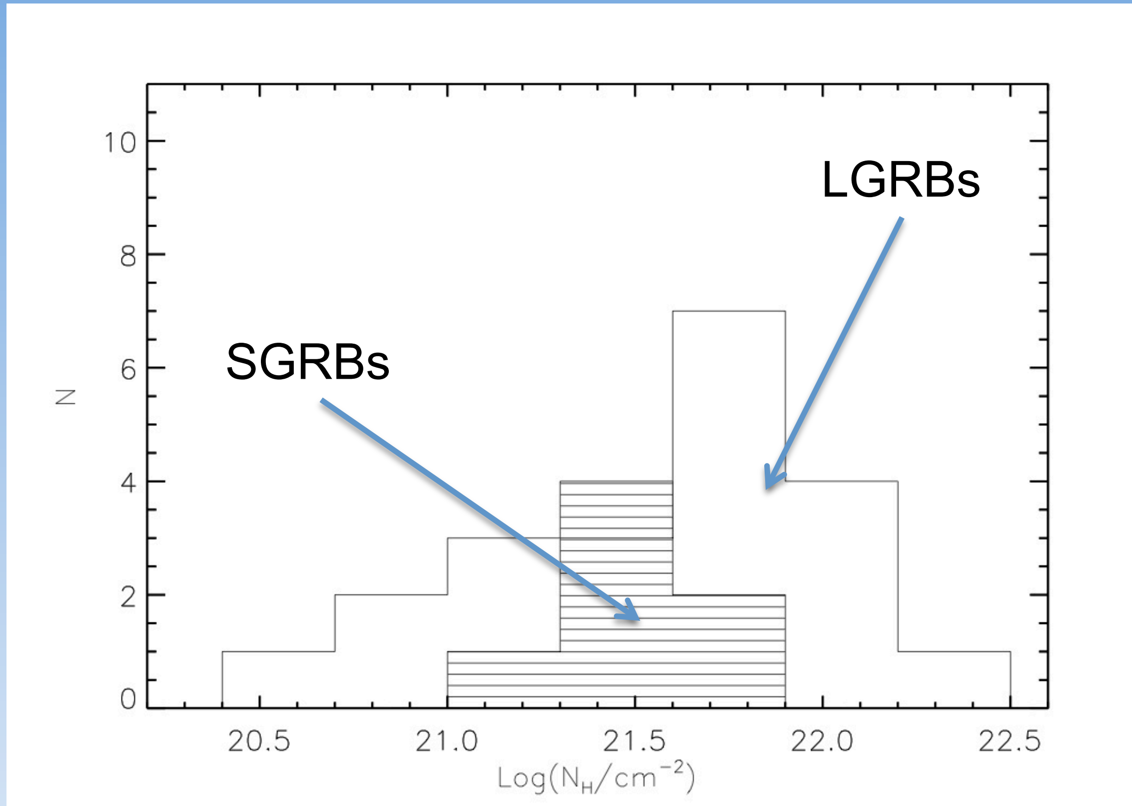

25% of the events of the sample have either a deep upper limit on the intrinsic N_H or are “hostless” SGRBs. This can hint for bursts occurred in low-density environments, originated by progenitors kicked out from their HG (e.g. primordial binaries with long coalescing times) or sited in outlying globular clusters (e.g. binaries formed via dynamically capture)

Conclusions

• A complete (in flux terms) sample of short GRB (~ 70% with redshift) for unbiased (except flux limit) statistical studies;

• SGRBs follow the E_p-L_{iso} correlation (exception for GRB 080905A?);

• On the E_p-E_{iso} plane SGRBs define a region with the same slope of the correlation holding for LGRBs, but different normalization;

• GRB 100816A is probably long (follows the E_p-E_{iso} relation). Classification of GRB 090426 still open;

• Comparison with LGRBs:
    • Comparable L_X/E_{iso}
    • Comparable N_H (in the same redshift bin)

• Redshift and N_H distribution consistent with "primordial binary" progenitors scenario with short merging times. Possible minor (25%) contribution of dynamically formed (or with large natal kicks) progenitors.

Details in D'Avanzo et al. 2014, MNRAS, in press (arXiv:1405.5131)