Gamma Ray Bursts: Short vs Long

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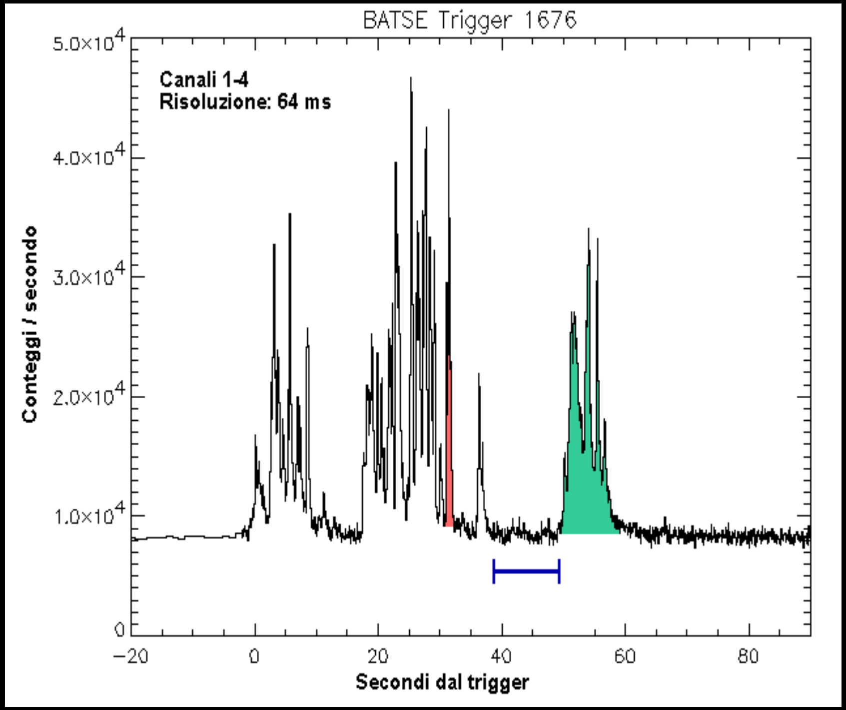
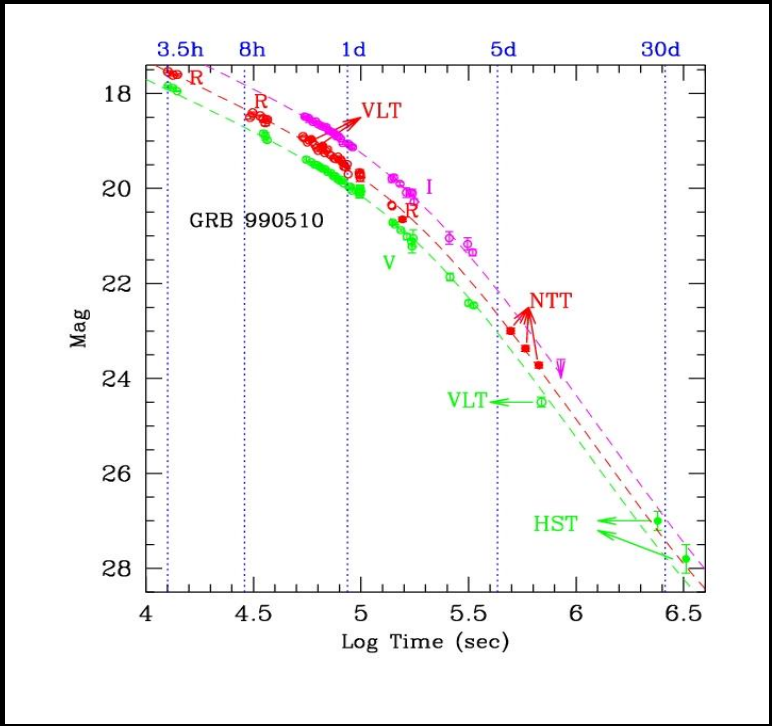
What is a GRB

Prompt emission (<1997)



- energies > 10 keV
- 1 ms to 1 ks
- high variability

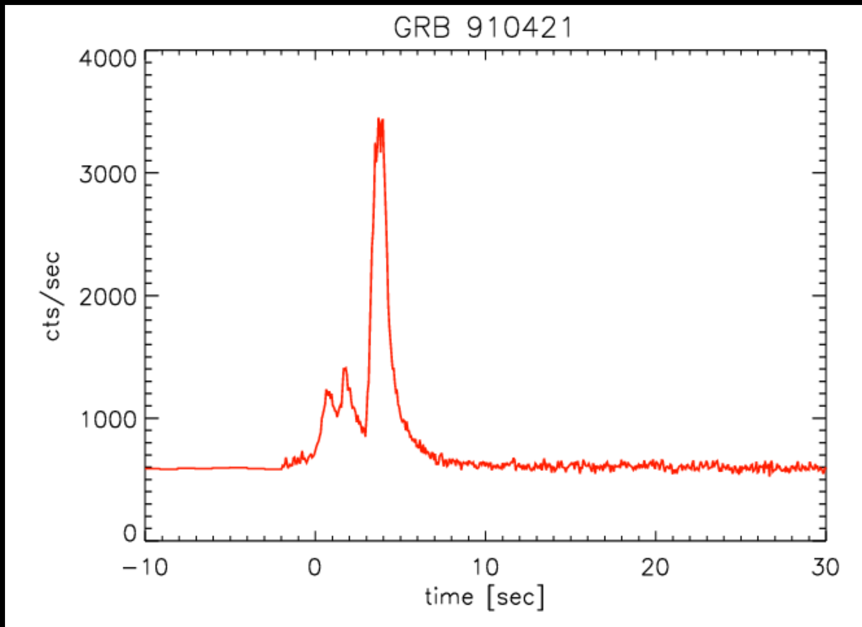
Afterglow emission (>1997)

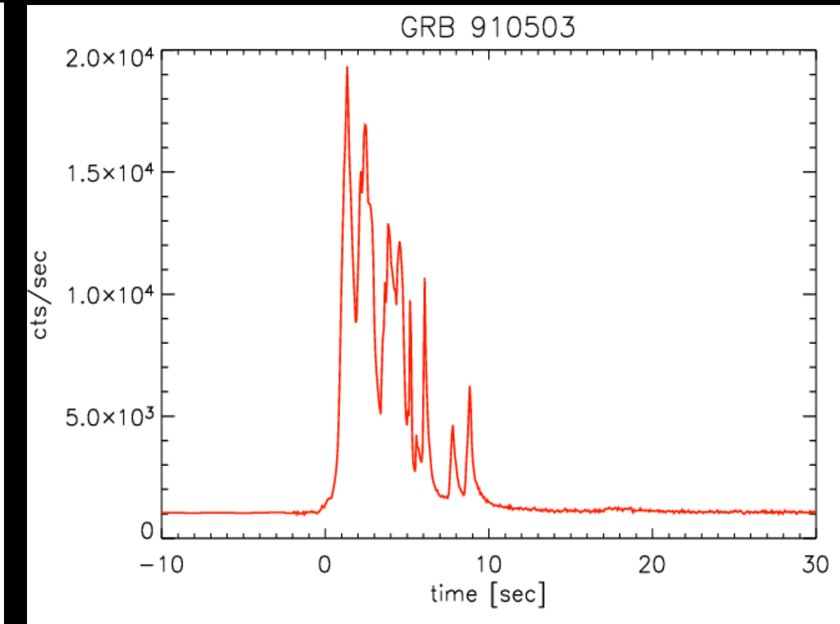


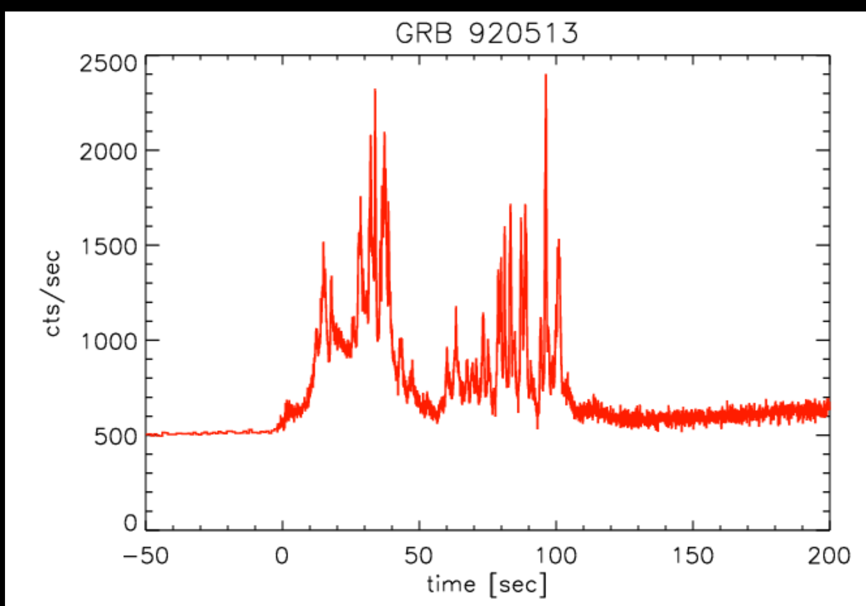
- energies Opt, IR, Radio
- hours, days, months
- smooth

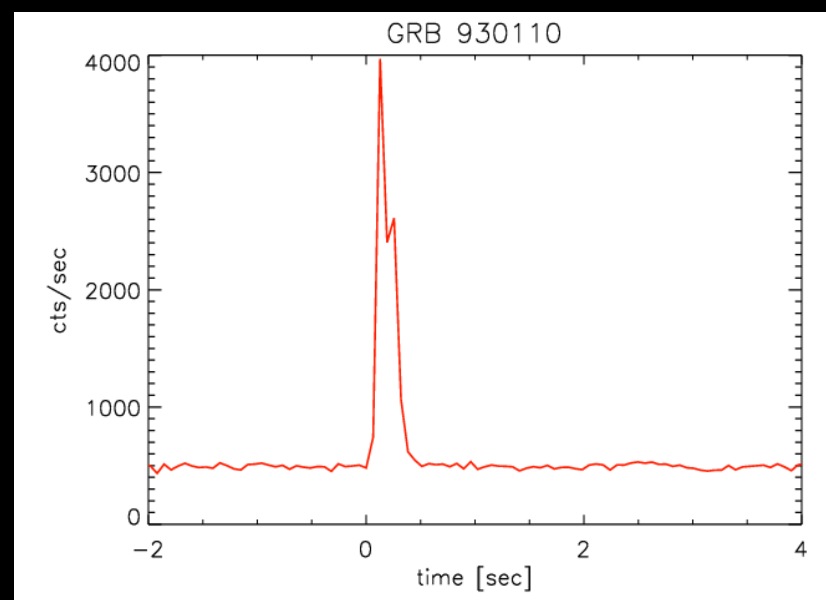
GRB – Temporal Properties

Photons E>30 keV





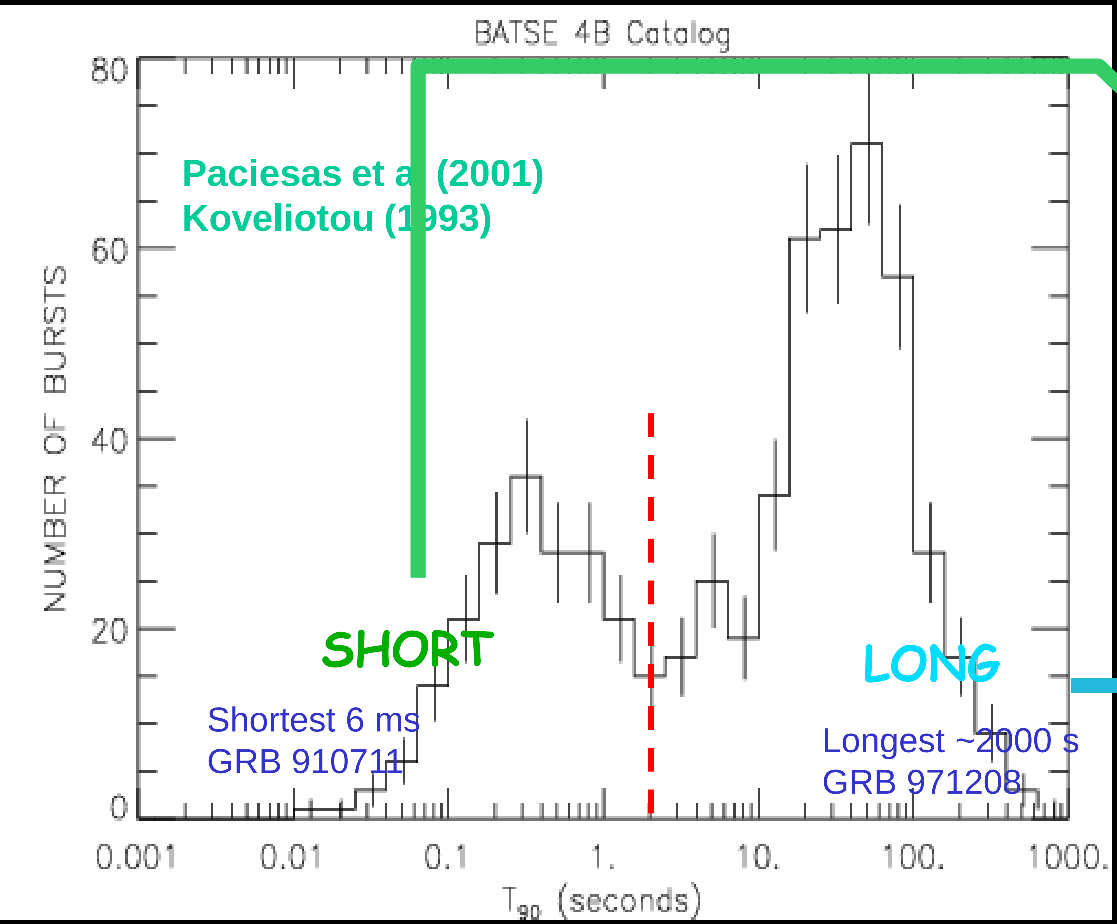




GRB - Temporal Properties

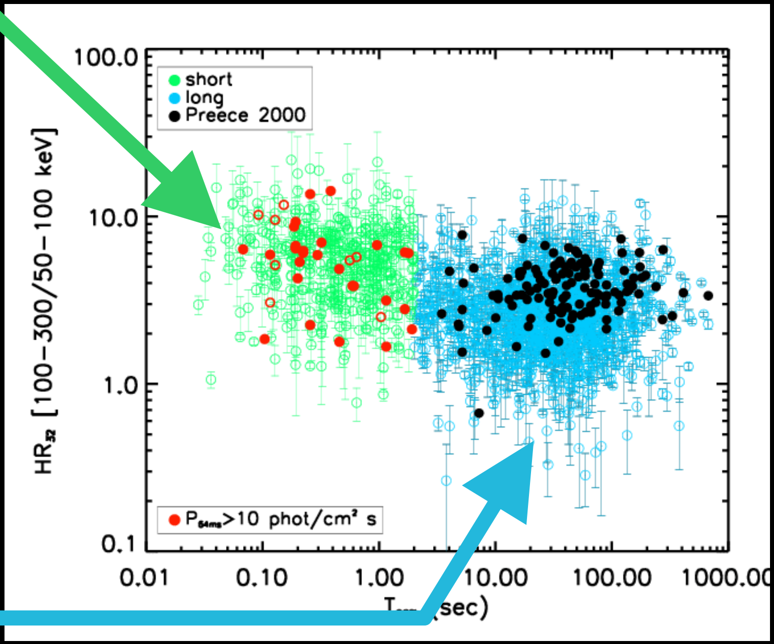
Photons E>30 keV

GRB duration distribution is bimodal



Hardness ratio vs duration

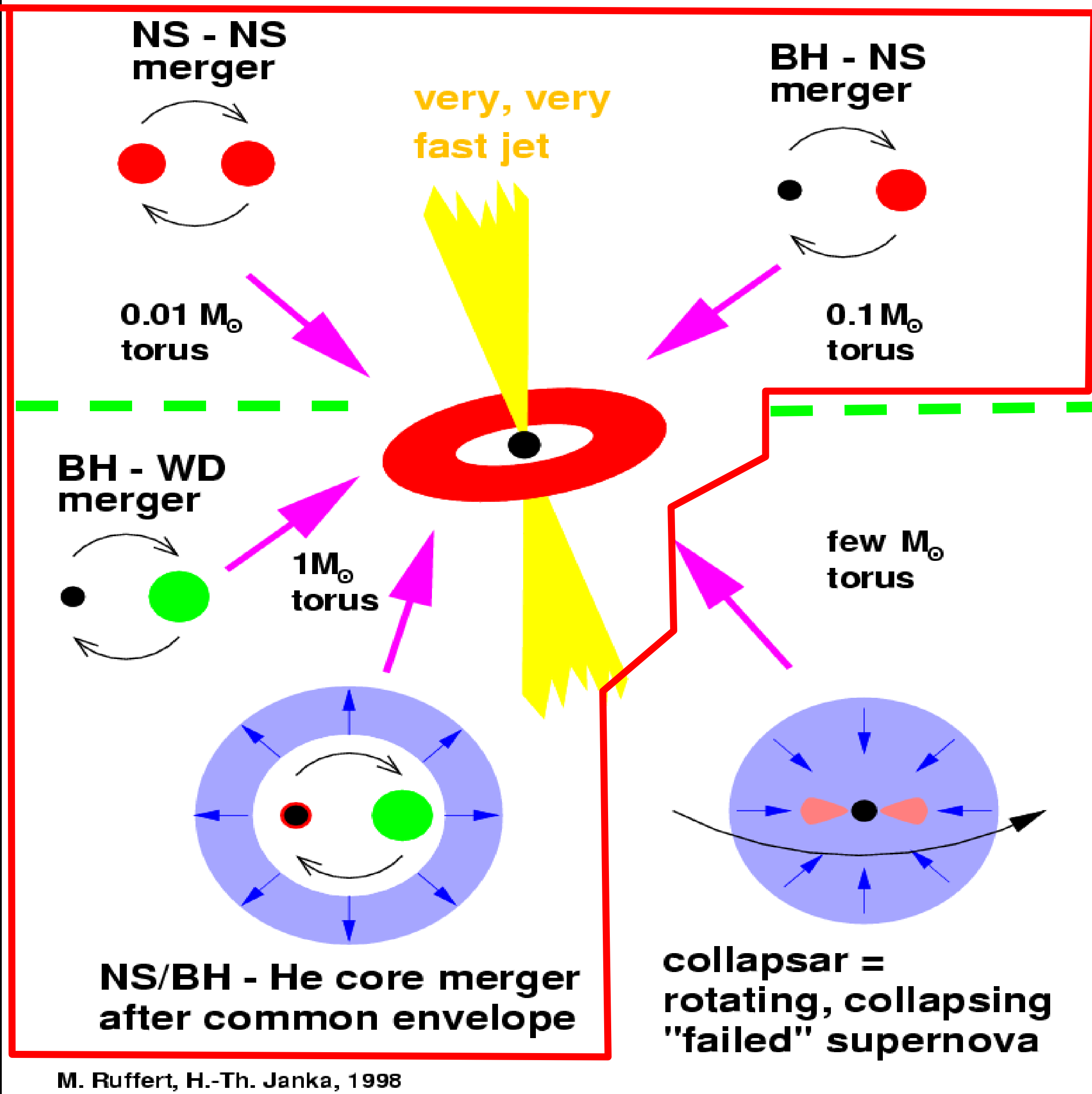
(e.g. Tavani et al. 1996)



Short - Hard
Long - Soft

Hardness-duration paradigm

GRB: → Hyperaccreting Black Holes

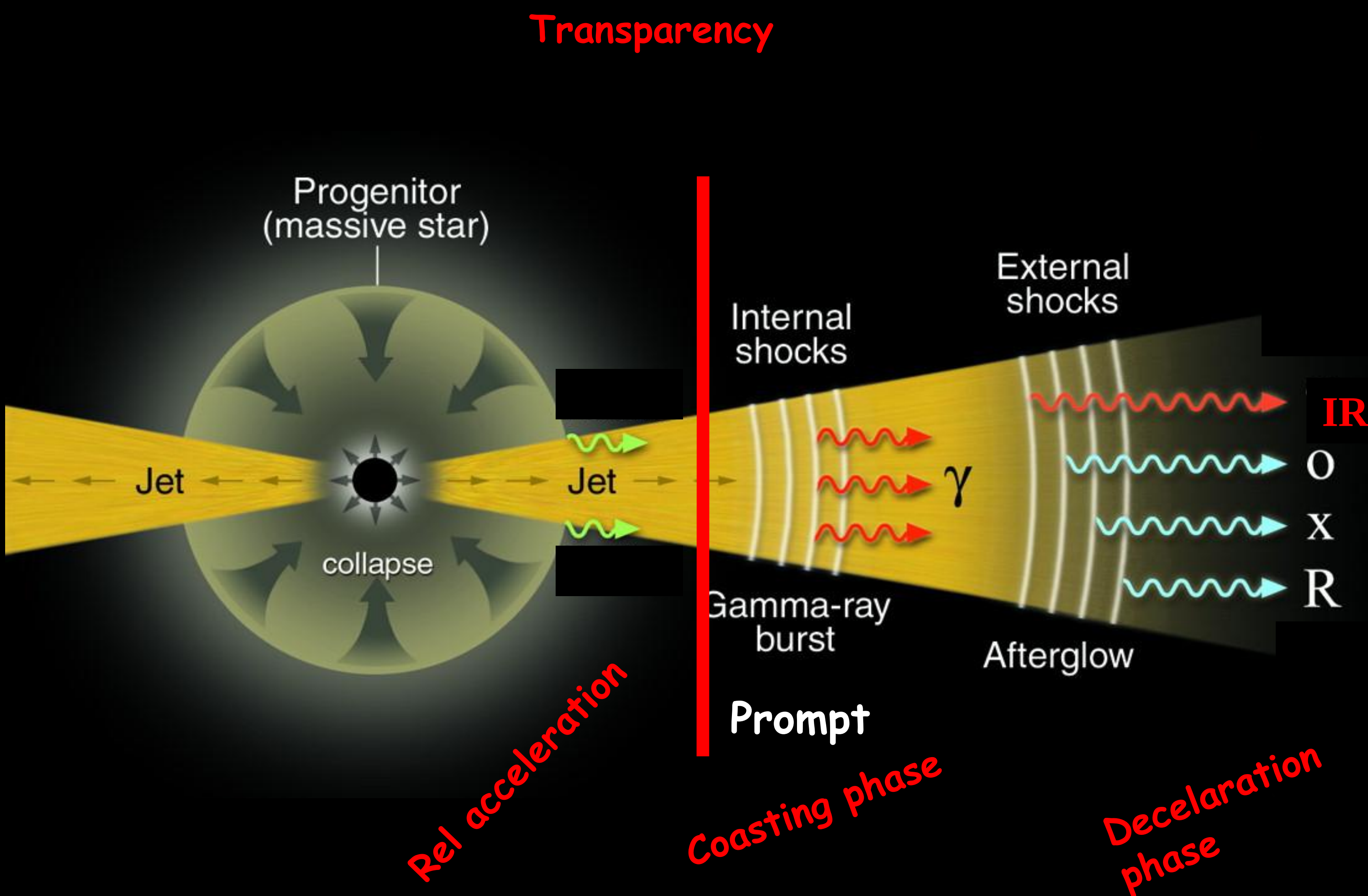


SHORT

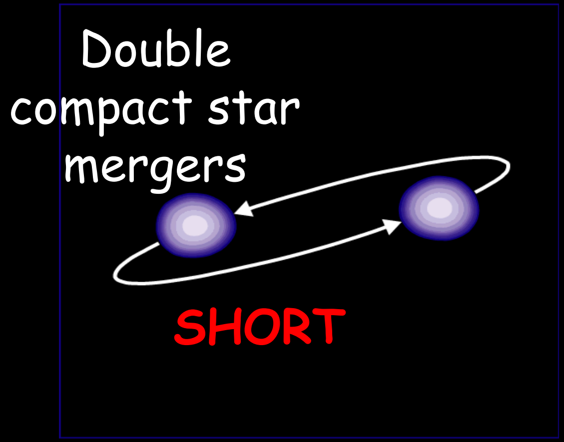
LONG

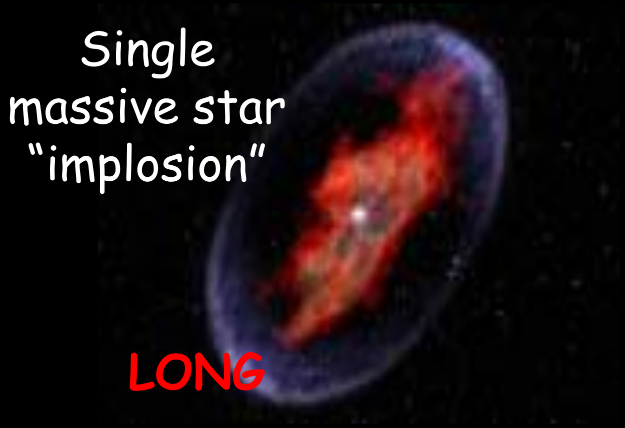
(e.g. Woosley & McFadyen 1999; Heger et al. 2001)

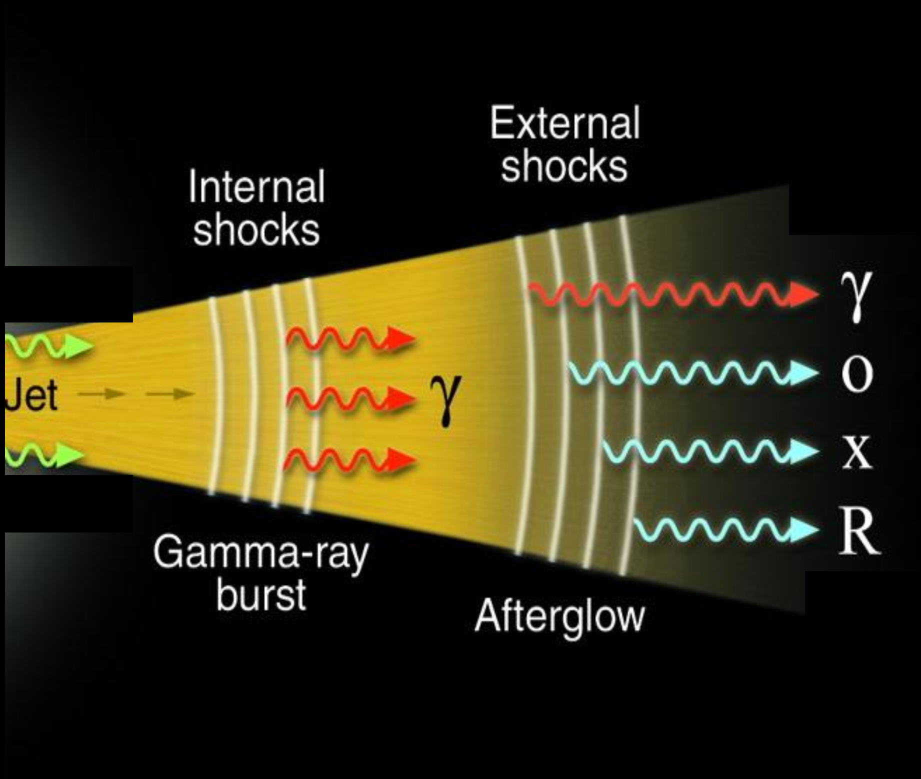
The Fireball model



Predictions







If Internal/External shocks → **similar** prompt and afterglow properties

Different hosts, distance scale, environment

some questions

Q1: how do short GRB spectra look like?

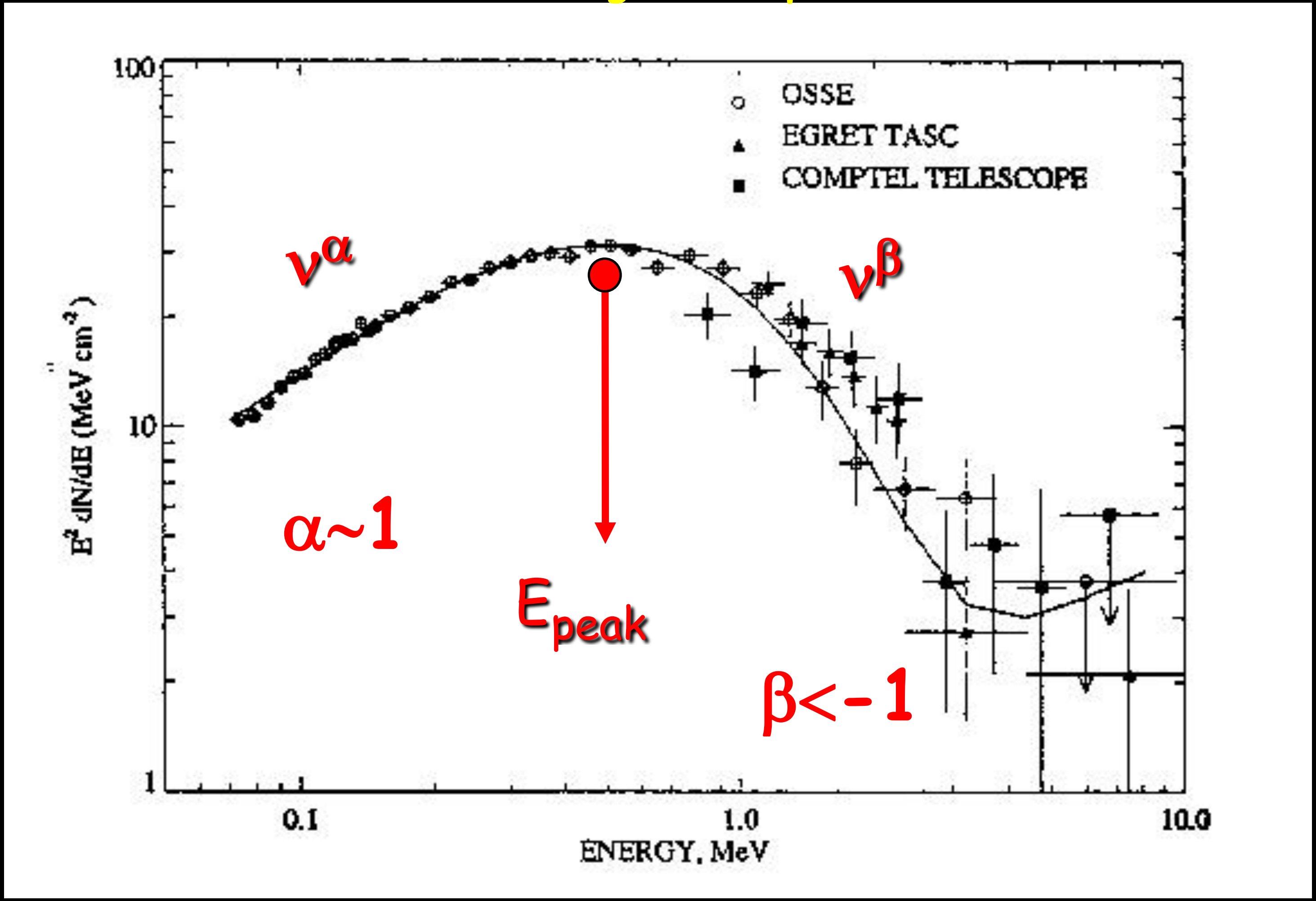
Q2: Are (some) short GRBs the extragal. counterpart of SGR giant flares?

Q3: which is the distance scale to short GRBs?

Q4: what about the prompt and afterglow energetics?

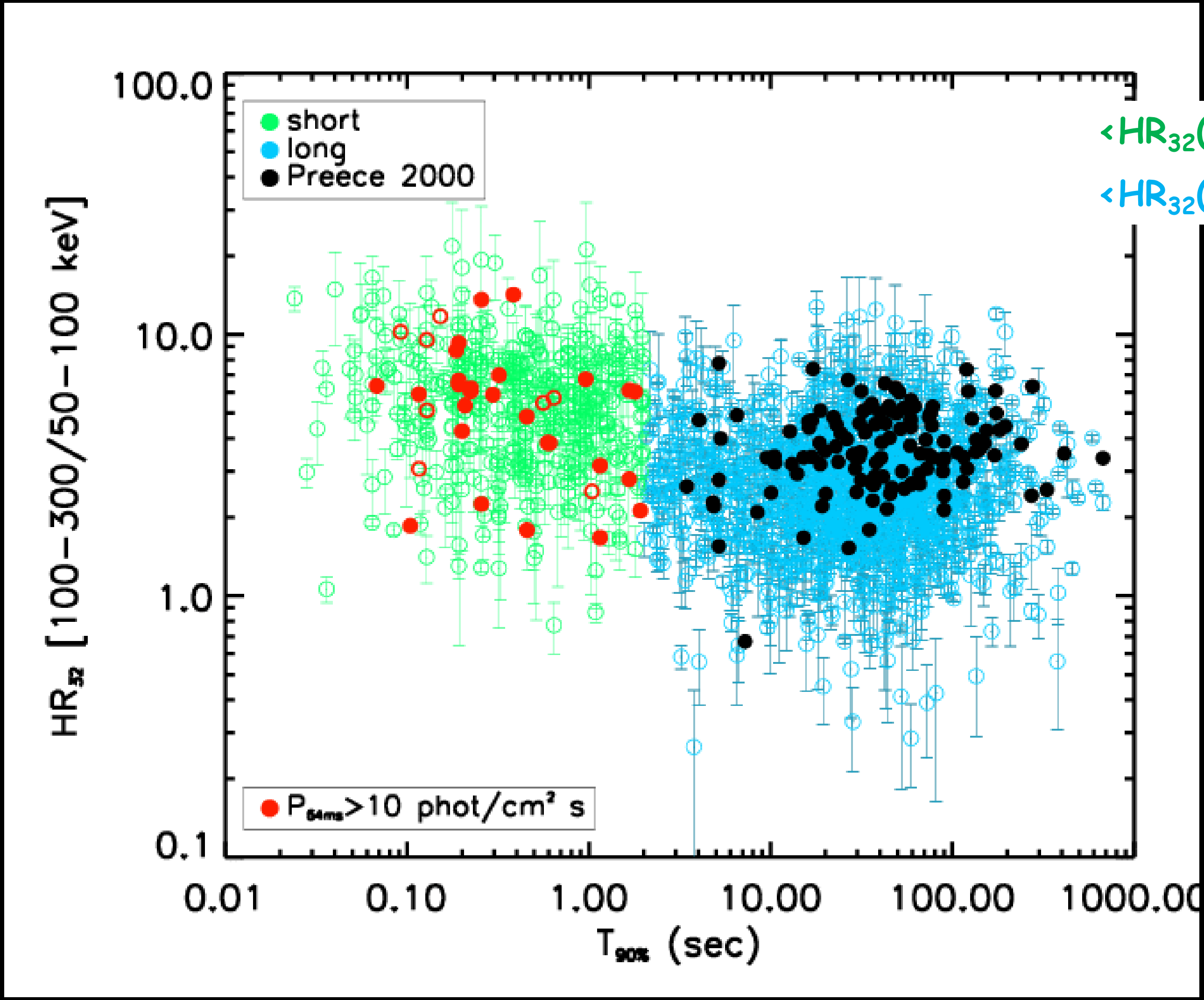
Long GRB (prompt) spectrum

Time integrated spectrum



Fishman & Meegan 1995, Band et al. 1993,
Preece et al. 2000, GG et al. 2002

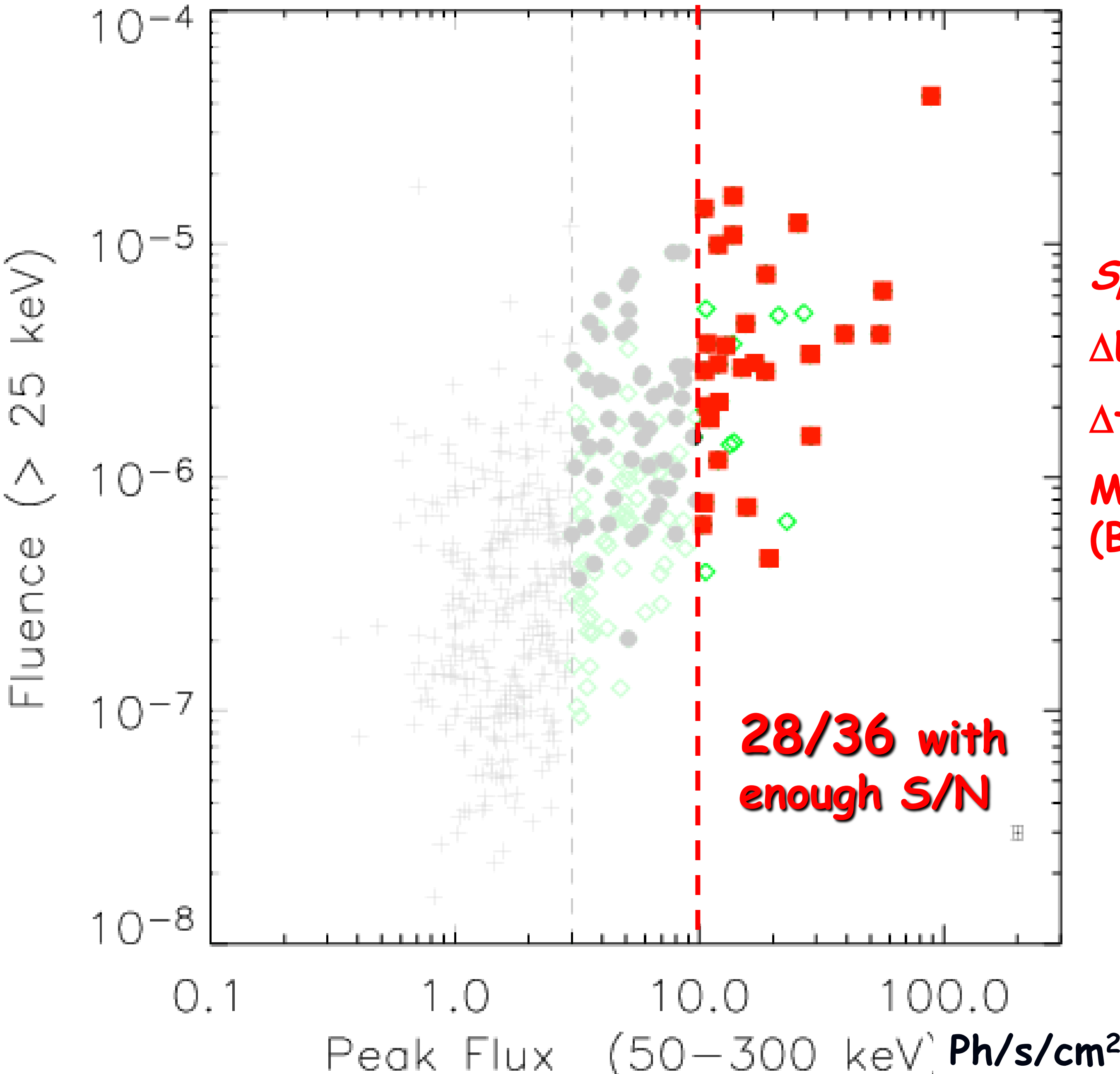
What about Short GRBs?



$<HR_{32}(\text{short})>\sim 5$

$<HR_{32}(\text{long})>\sim 2.3$

500 Short GRBs from BATSE



Spectral analysis:

$\Delta E \sim 0.03-1.8 MeV$

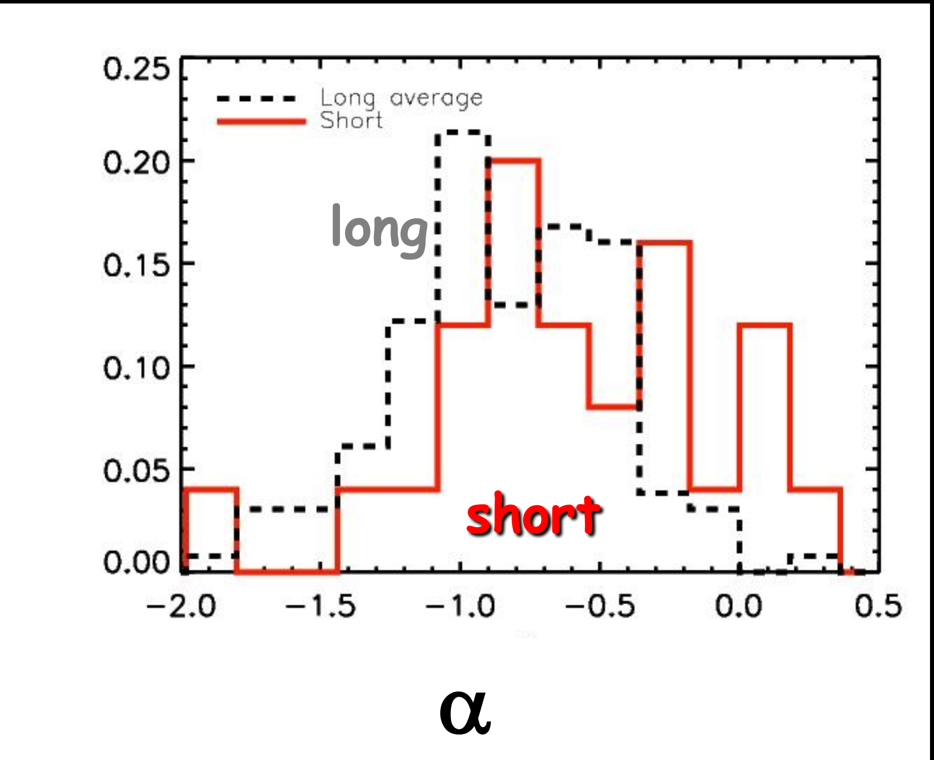
$\Delta t \sim 0.2$ sec

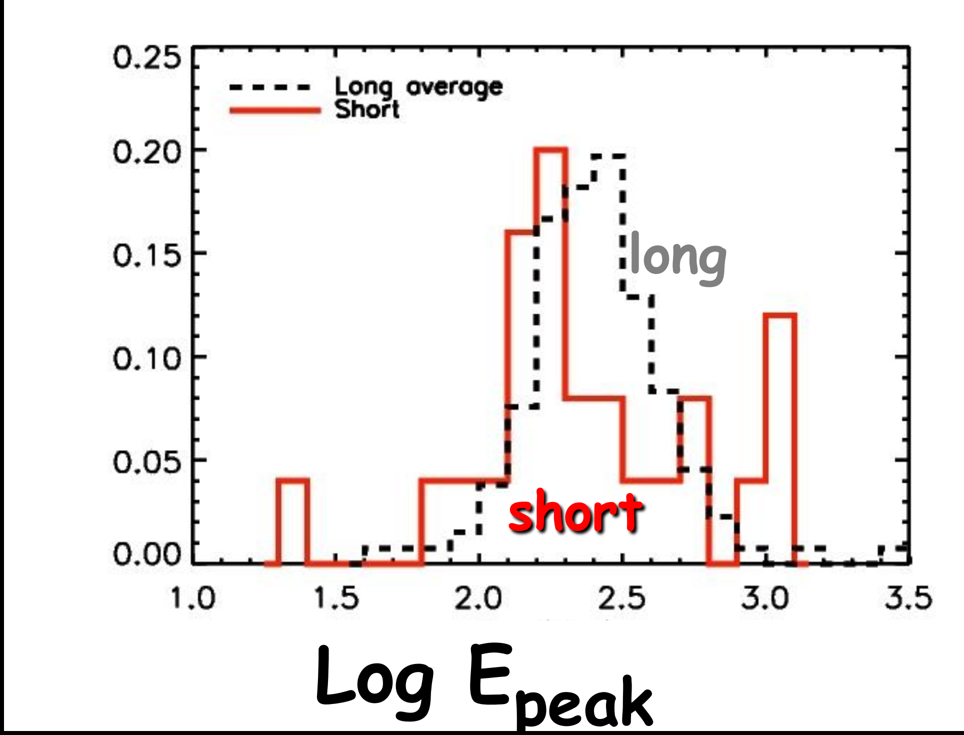
Model: *CPL*
(Band, BKNPL)

GG, Ghisellini, Celotti 2004

Short vs Long: average spectra

GG, Ghisellini, Celotti 2004





Short <α>~-0.58+-0.10

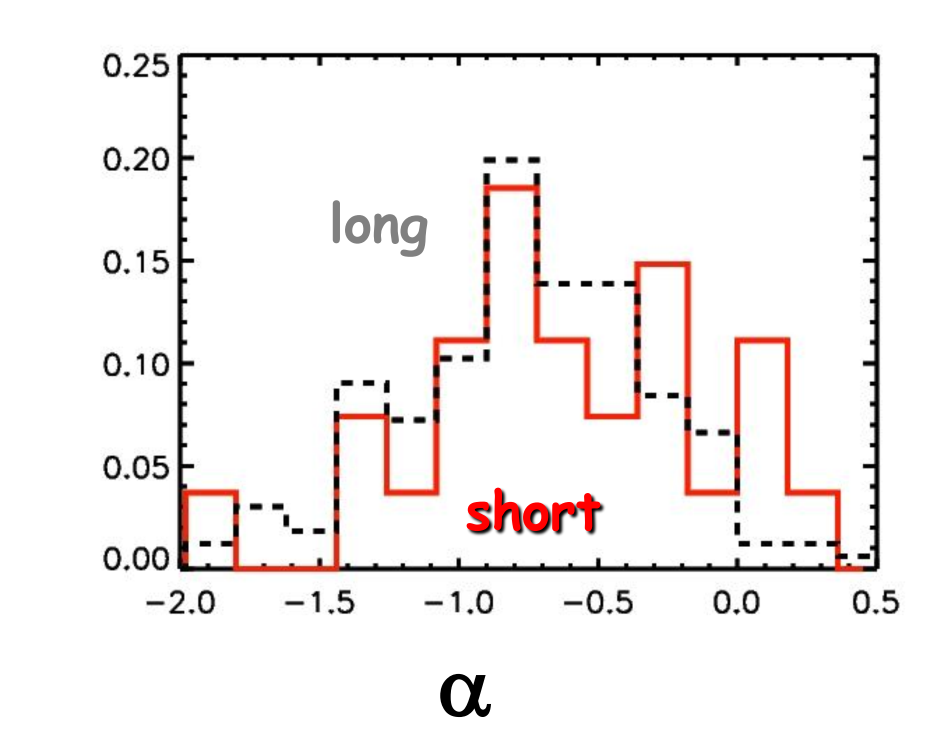
Long <α>~-1.05+-0.14

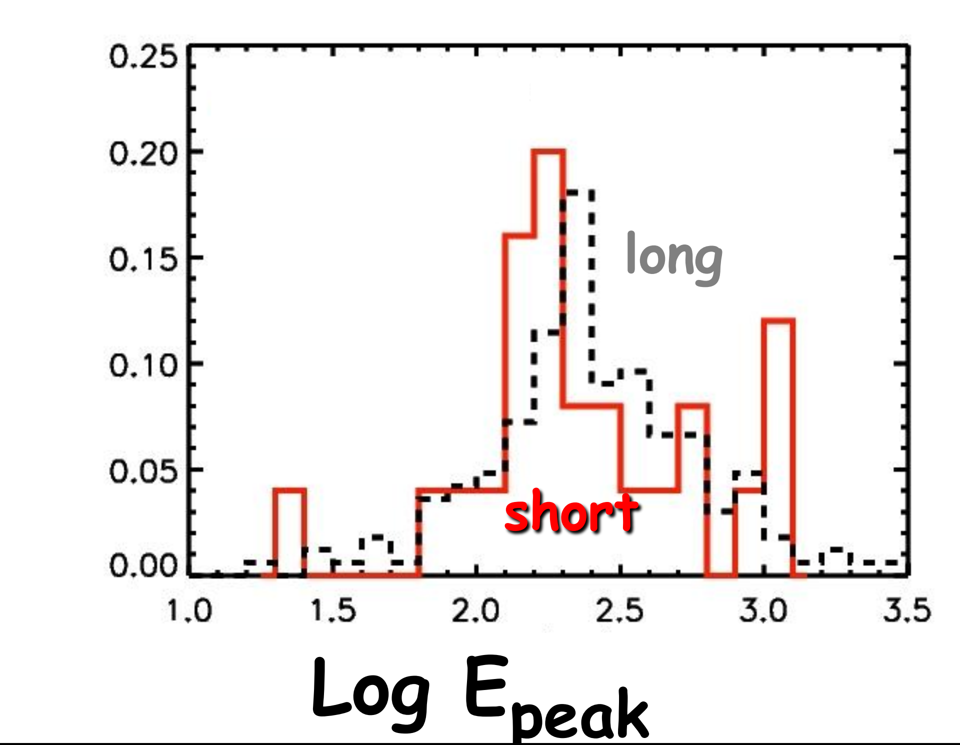
K-S → P=0.04%

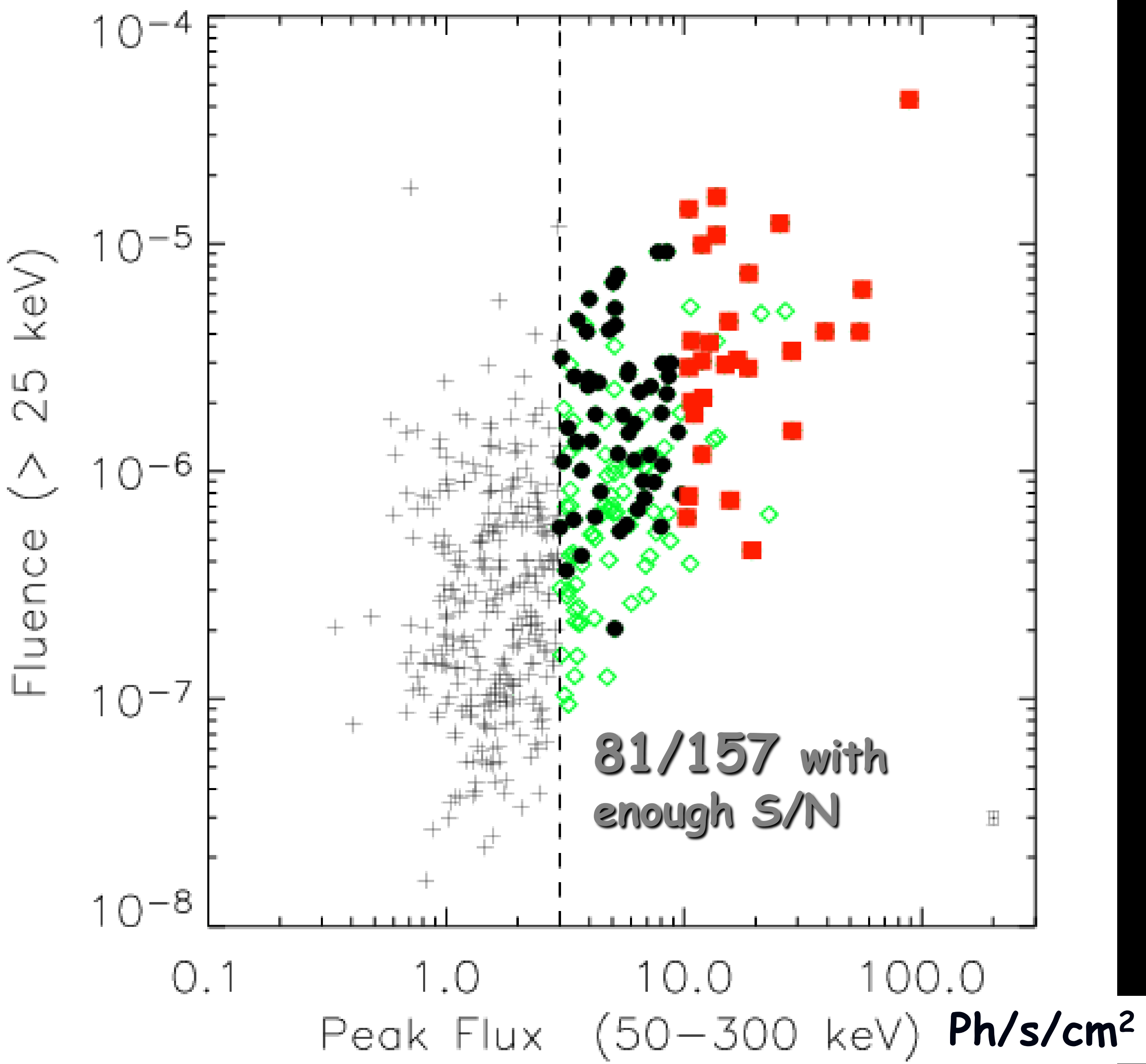
Long bursts comparison sample from Preece et al. 2000 and GG, Celotti, Ghisellini 2002

Short vs First 2 s of Long

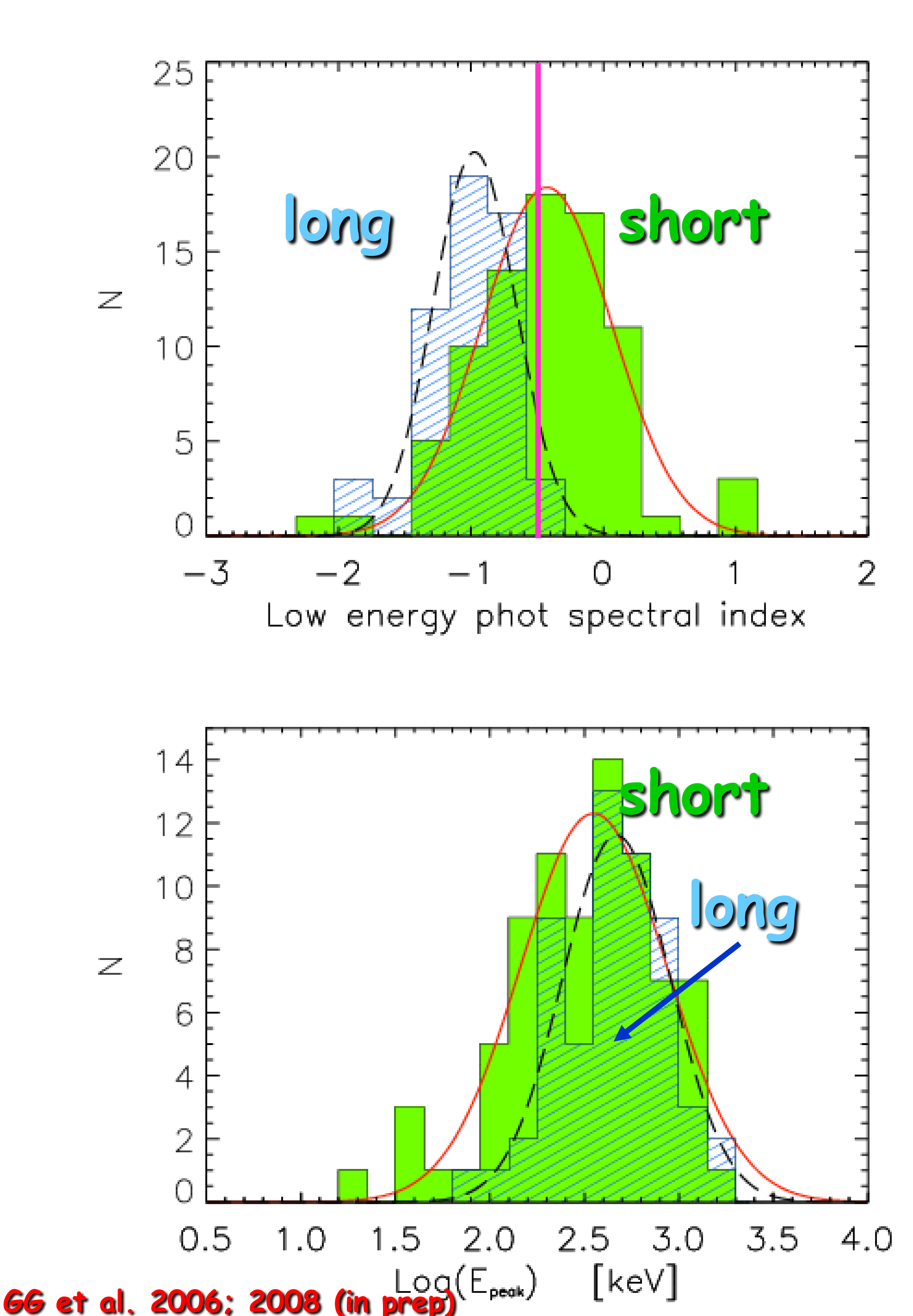
GG, Ghisellini, Celotti 2004





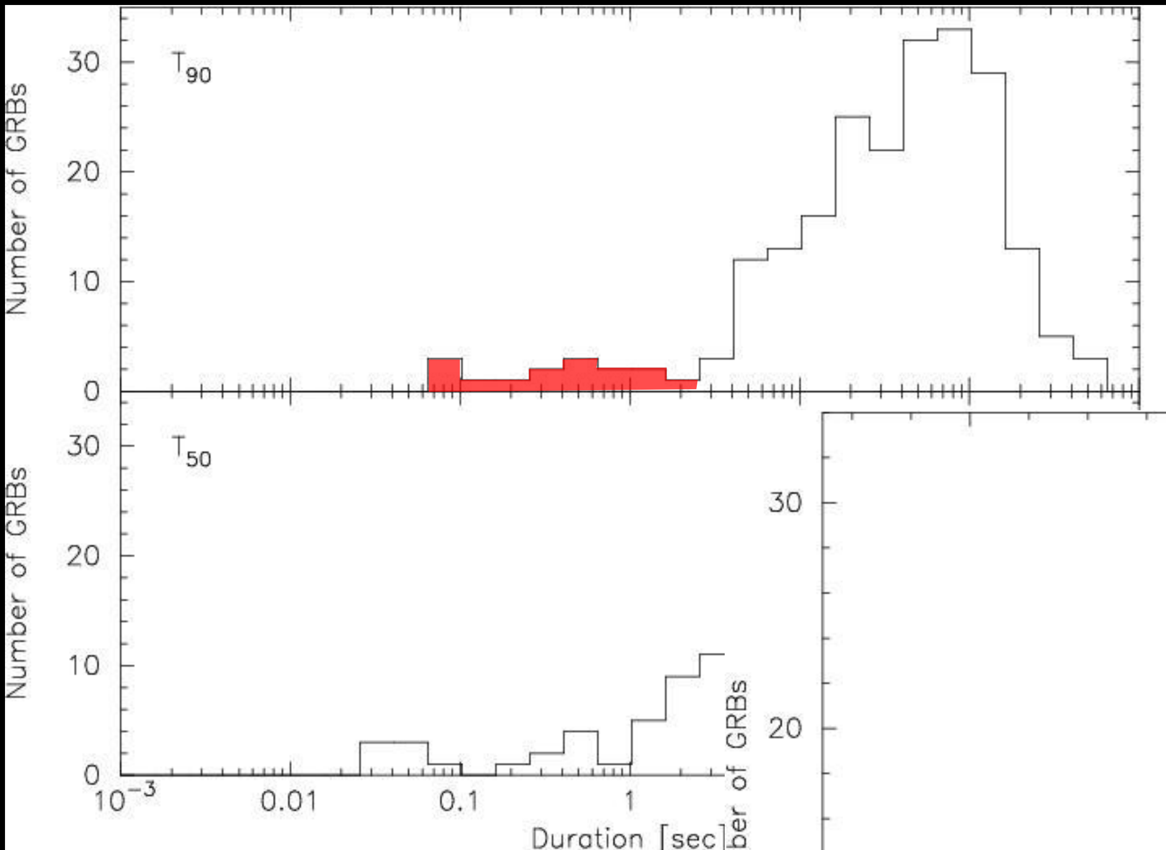


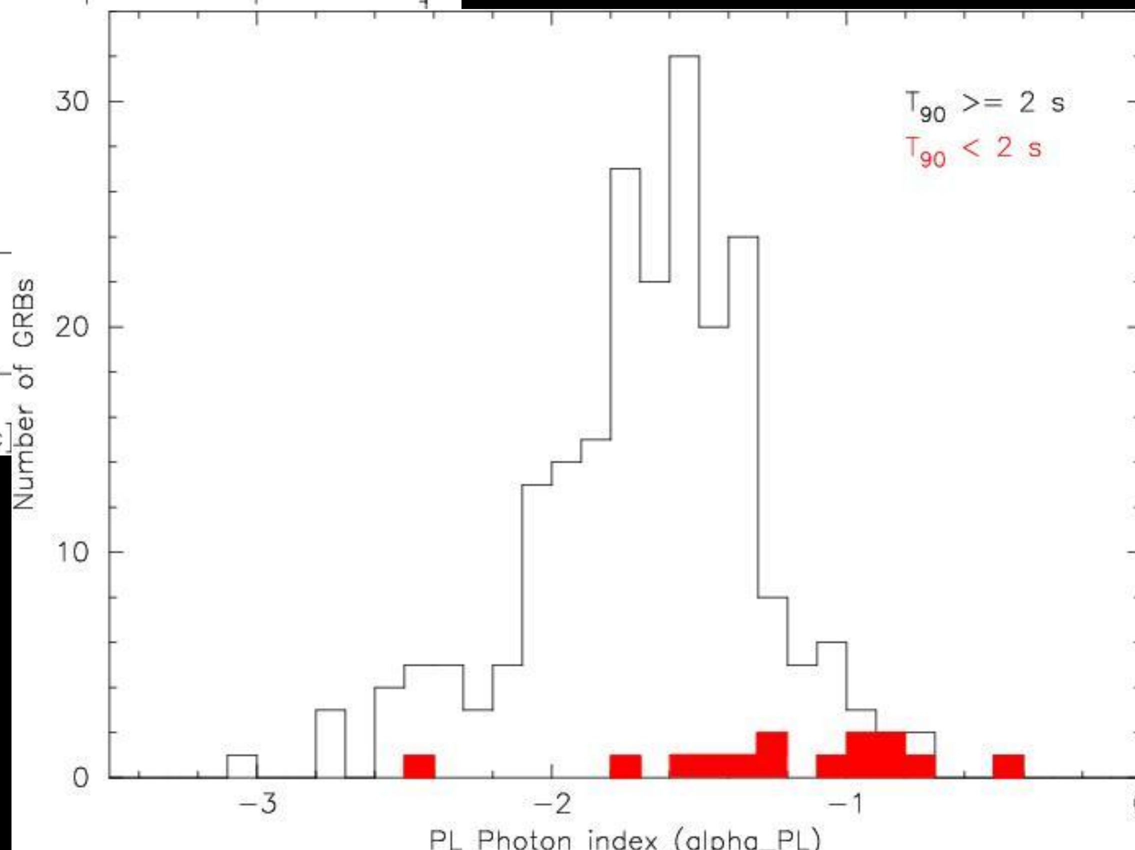
Fluence (> 25 keV)
10−4
10−5
10−6
10−7
10−8
0.1
1.0
10.0
100.0
Peak Flux (50−300 keV)
Ph/s/cm²
81/157 with
enough S/N


25
20
15
10
5
0
N
long
short
−3
−2
−1
0
1
2
Low energy phot spectral index
14
12
10
8
6
4
2
0
N
short
long
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Log(Epeak) [keV]
GG et al. 2006; 2008 (in prep)

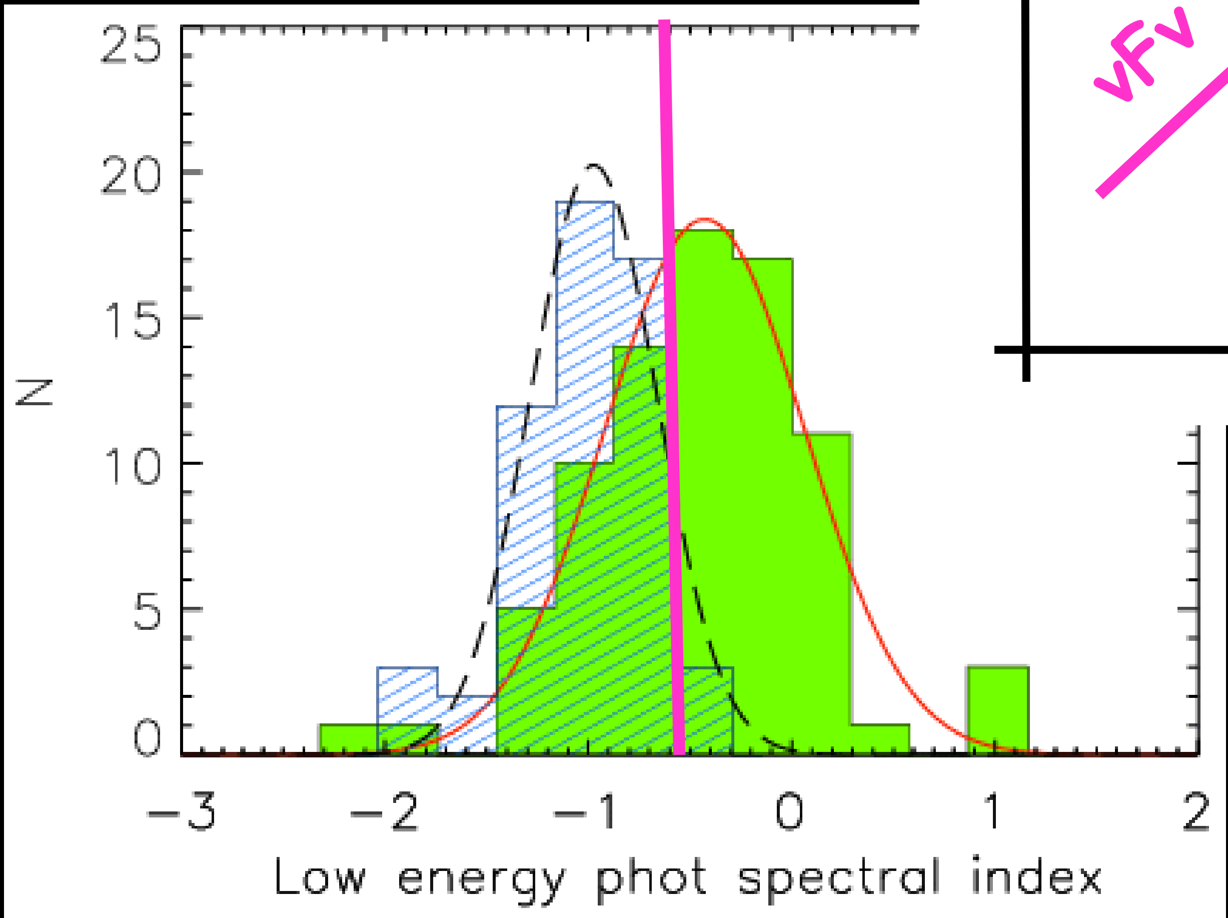
Swift confirms

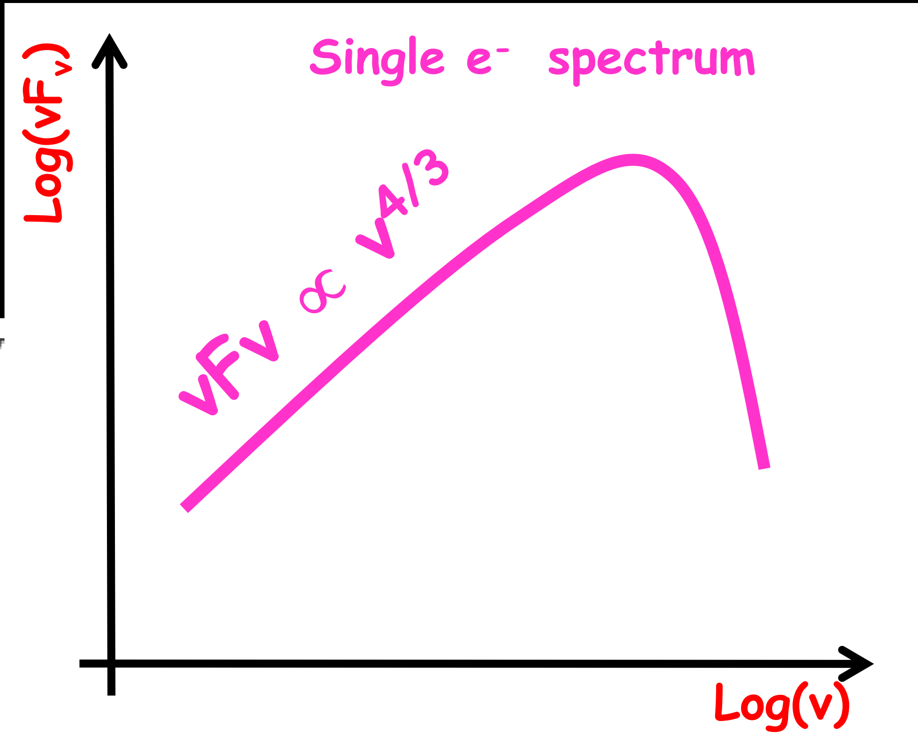
Sakamoto et al. 2008





Short GRB spectra: a challange for the (standard) emission mechanism

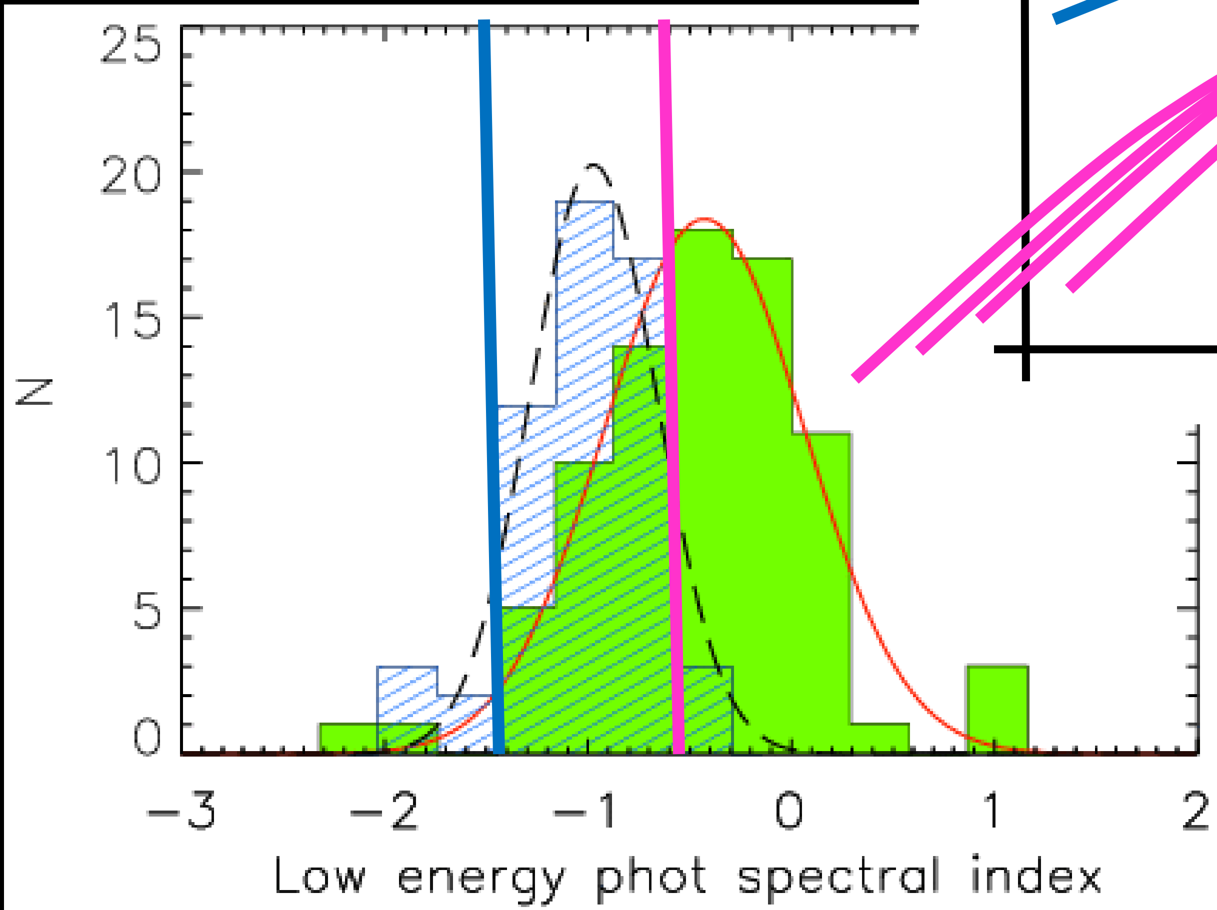


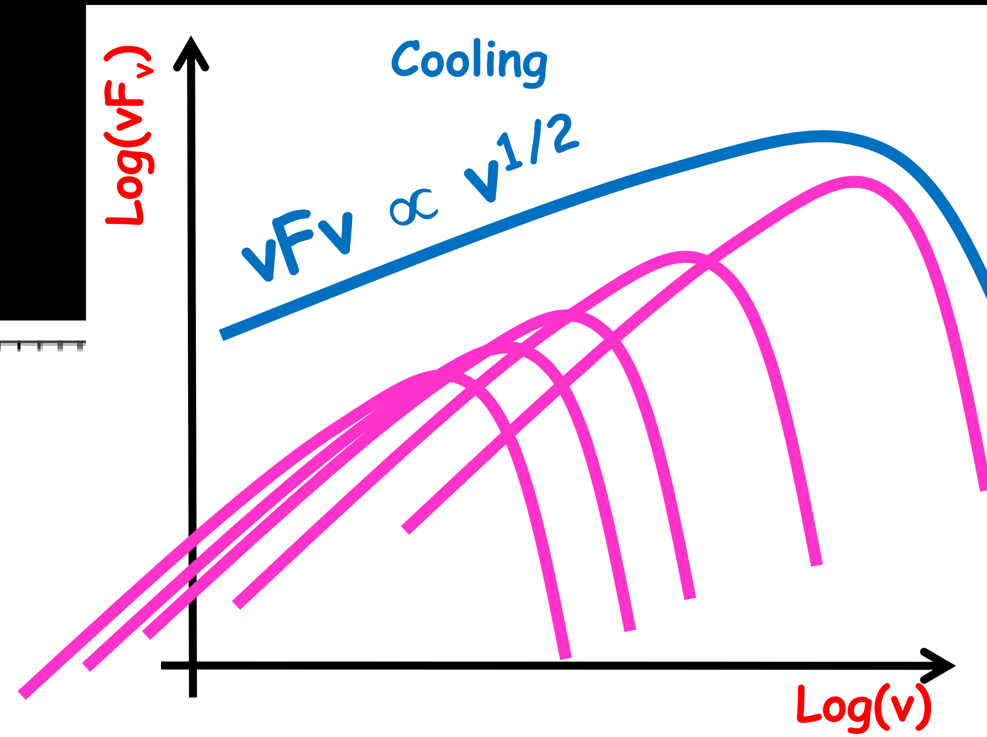


$\nu F\nu \propto \nu^{4/3}$

$N(\nu) \propto \nu^{-2/3}$

Short GRB spectra: a challange for the (standard) emission mechanism





$\nu F\nu \propto \nu^{1/2}$

$N(\nu) \propto \nu^{-3/2}$

Short GRBs: spectra

Q1: how do short GRB spectra look like?

Short/Hard – Long/Soft paradigm (based on the HR) revisited:

Short GRBs are harder because their low energy spectral component (α) is harder while their peak energy E_{peak} is similar wrt Long GRBs

A larger fraction (wrt to long) of short GRBs violate the OTSSM limit and a larger fraction of short bursts are consistent with Th-BB (or modified BBPL).

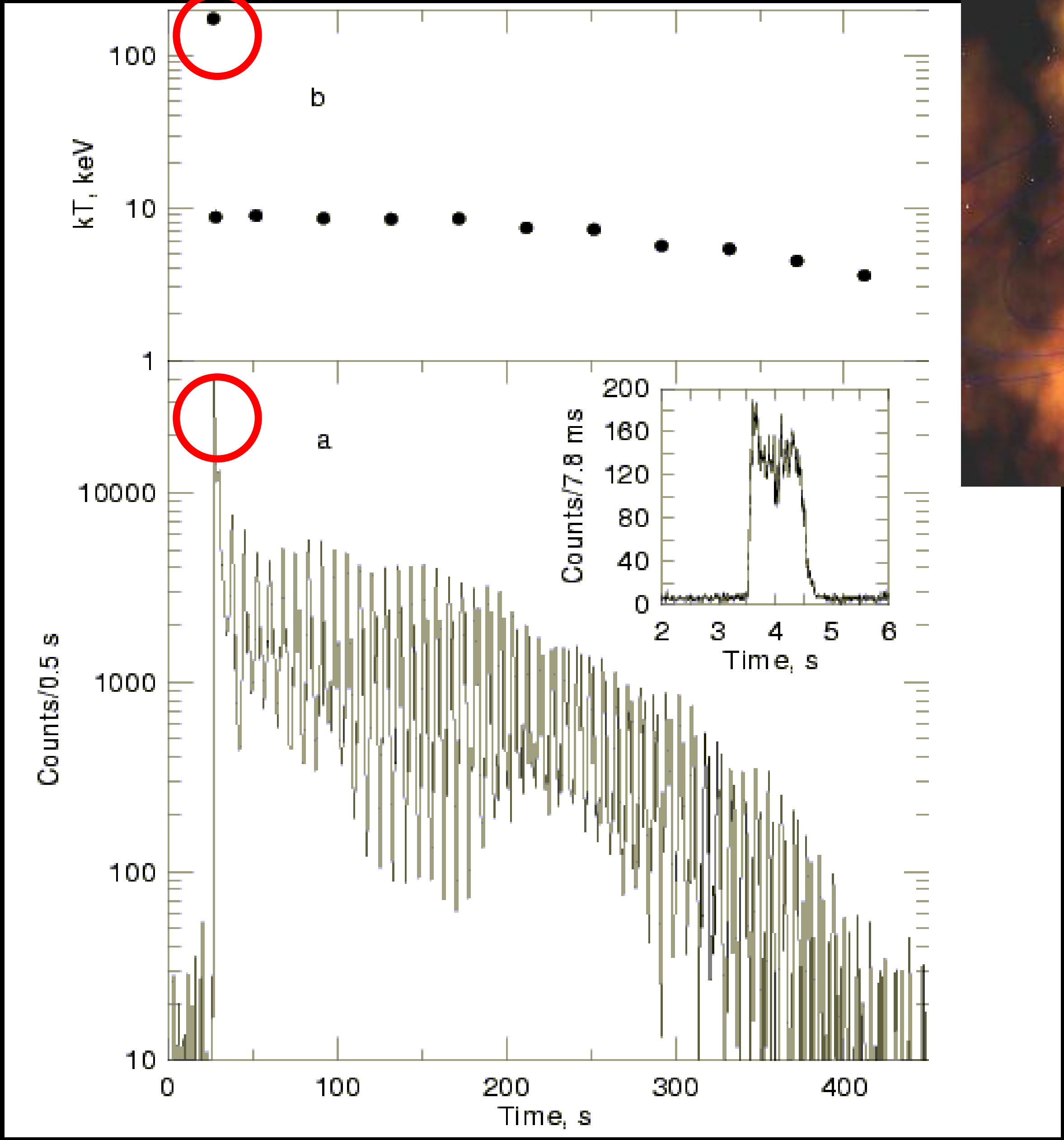
Short GRB spectra → no high energy tail ?

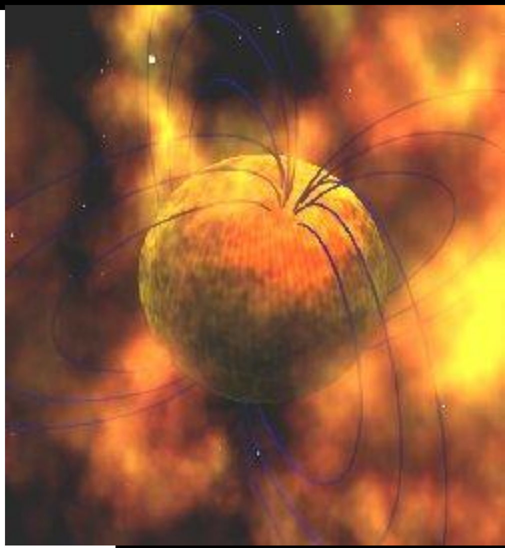
Short GRB spectra are similar to the first 2 sec of long GRB

Soft Gamma ray Repeaters (SGR) and short bursts

Dec. 26 2004 a giant flare form SGR 1806-20

$L \sim 10^{47}$ erg/s





Hurley et al. 2005

Shorts as giant flares of SGR?

SGR giant flares (SGRgf):

1. T <= 2 sec (single peaked low variability)
2. L = 10^{47} erg/s
3. Hard spectrum → Black Body KT=150 keV

If short GRBs are the extragal counterpart of SGRgf

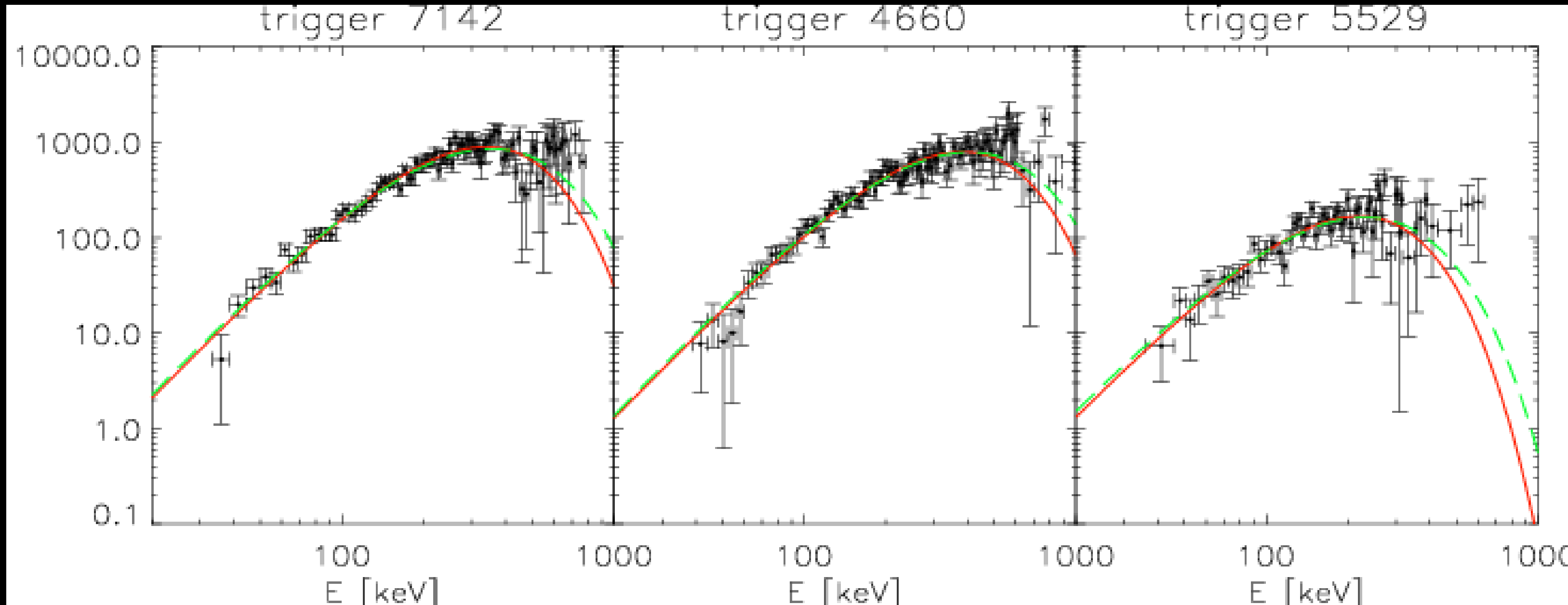
SGRgf should be detected by BATSE

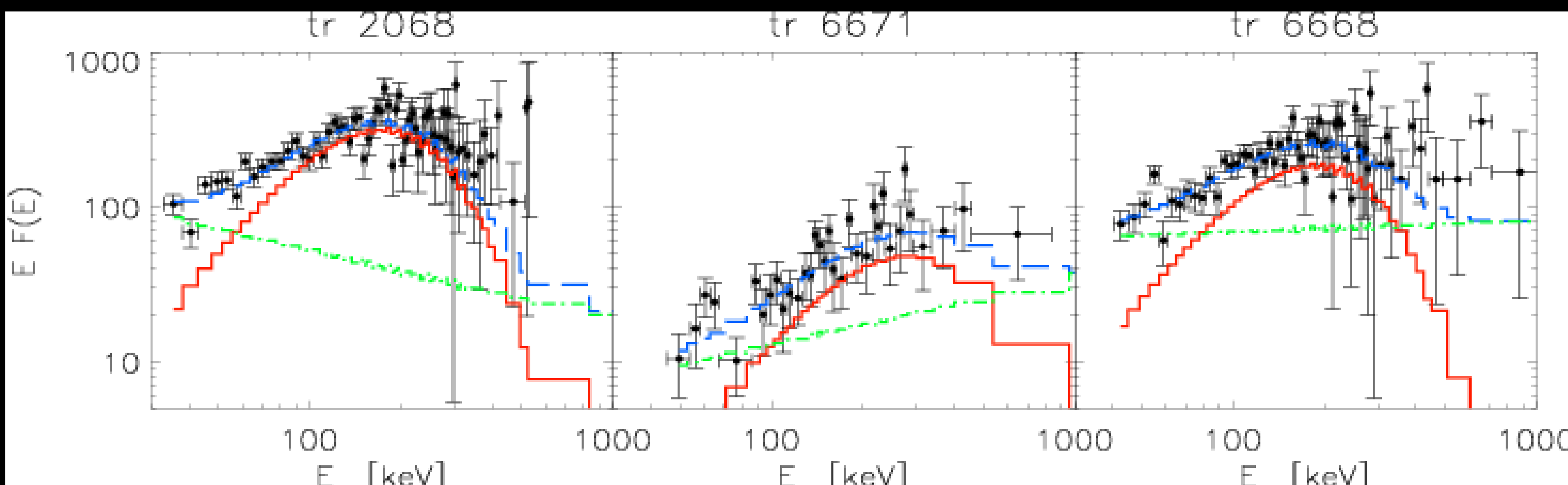
1. up to 35 Mpc (z<0.008)
2. N=30 yr^{-1} (60%)

TEST:

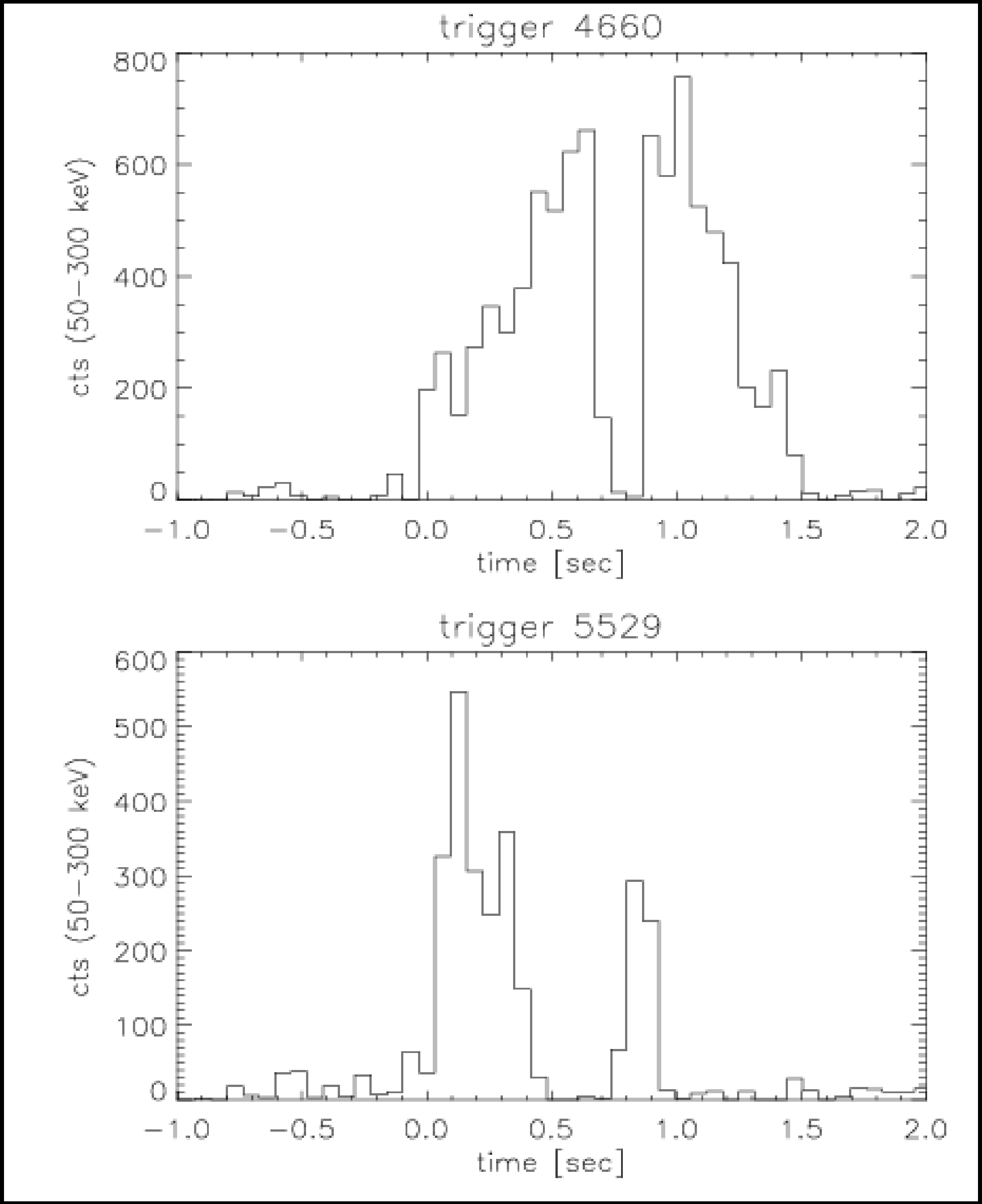
1. Association with nearby galaxies (<30-50 Mpc)
   (Nakar 2005 → 50%; Popov 2005 → N<10^{-3} yr^{-1})
2. spectra + light curves of Short GRBs

BB in Short (15/81)





Lazzati, GG, Ghisellini, 2005, GG et al. 2008



... but light curves are not single peaked

Short GRBs: spectra

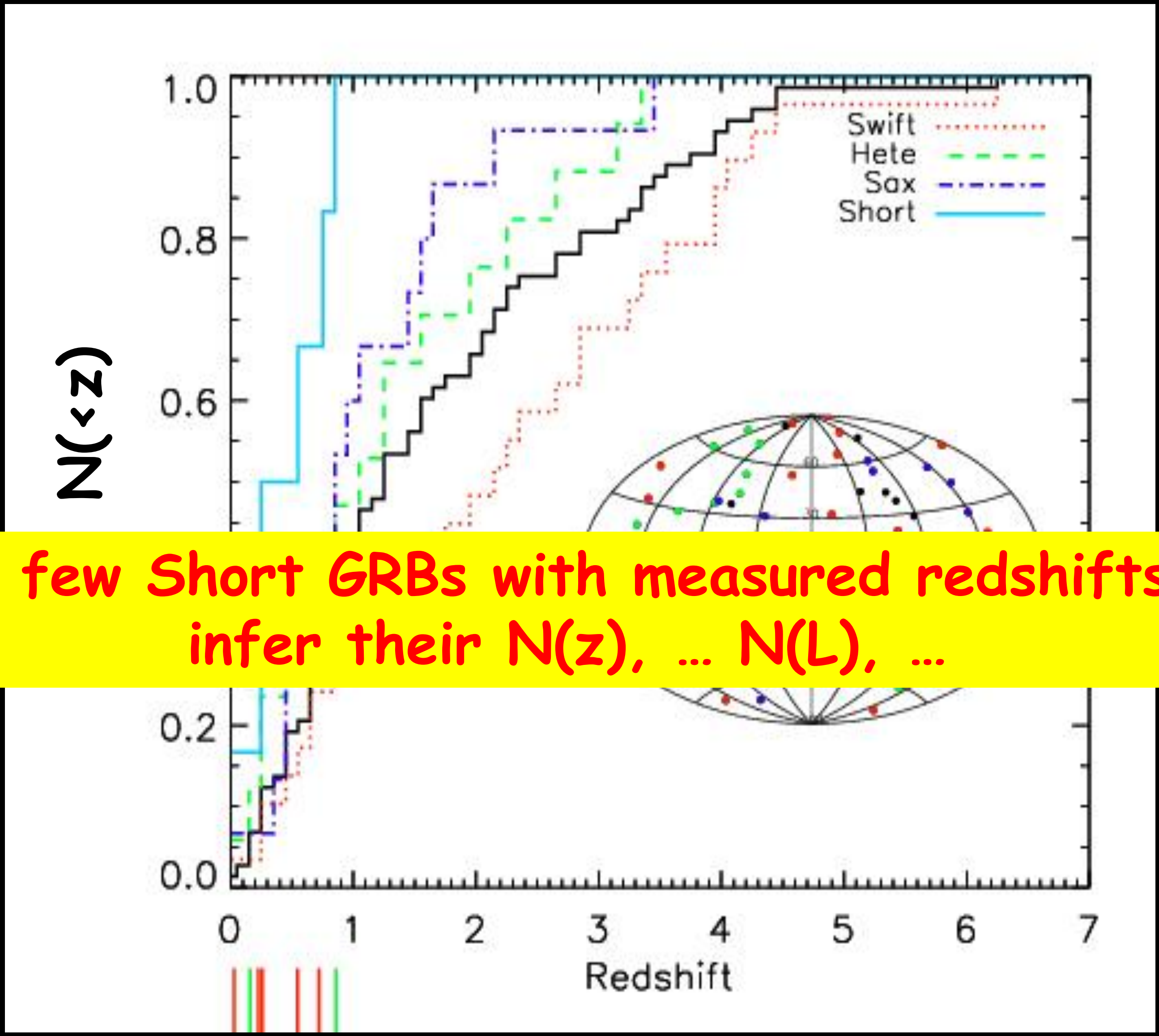
Q2: Are (some) short GRBs the extragal. counterpart of SGR giant flares?

3 short GRB candidates in the BATSE bright sample of 81 short bursts (GG et al. 2006) → BB spectrum with KT<100 keV but light curve is multipeaked.

If $L \propto (KT)^4$ (and similar to 1806-20) then D~2-5 Mpc but no host candidate within the error box at the same distance.

We can exclude at 4σ Q2 (but there are some caveats).

Redshift



73 Long

29 Swift

15 Sax

17 Hete

… 12 other

Still few Short GRBs with measured redshifts to infer their N(z), … N(L), …

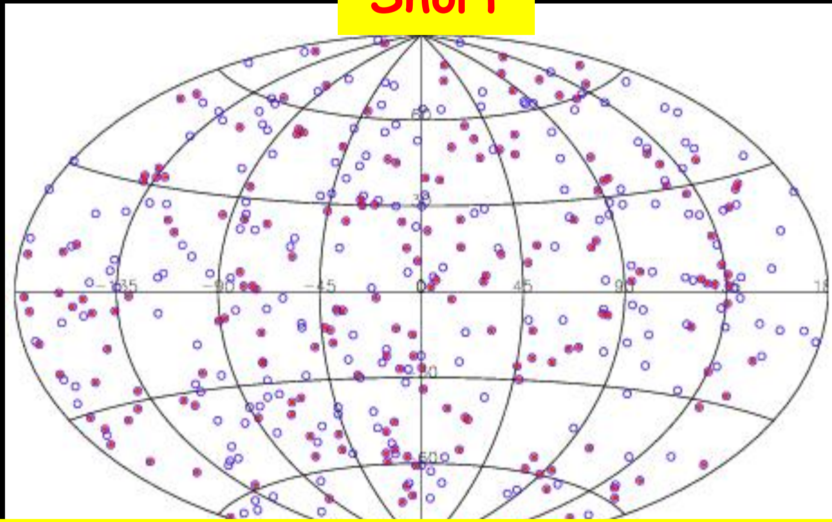
GG 2006

Short GRB

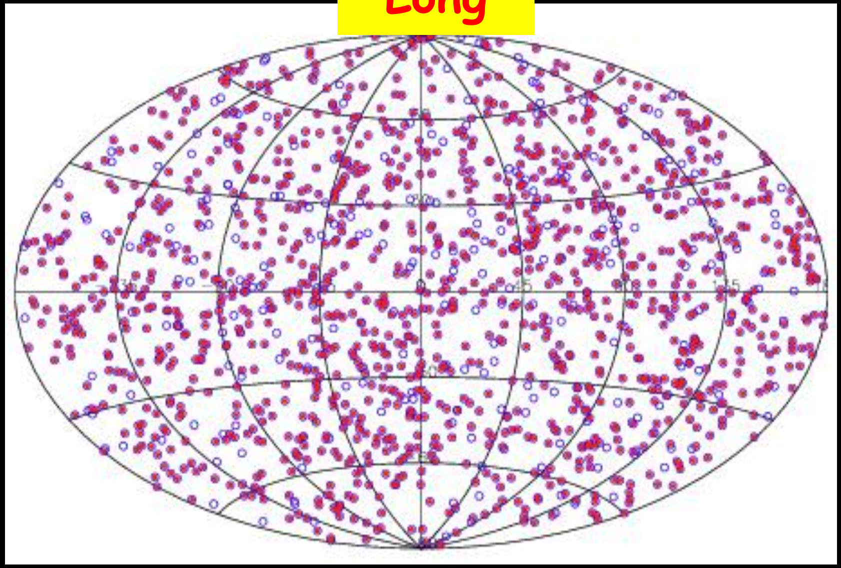
050925 050709 050509B 050724 051221 050813 040924

Swift 5/7 with redshift

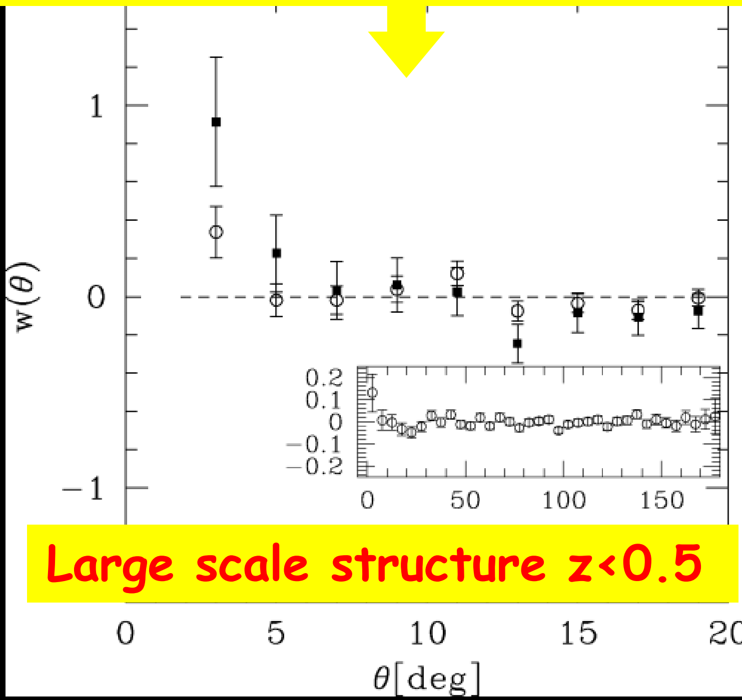
Short



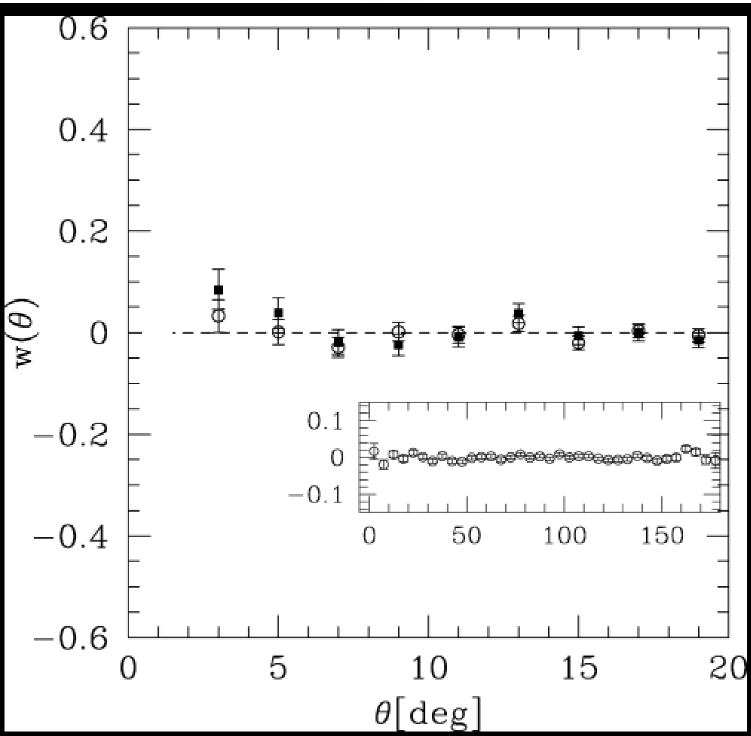
Long



Anisotropic distribution of short GRBs

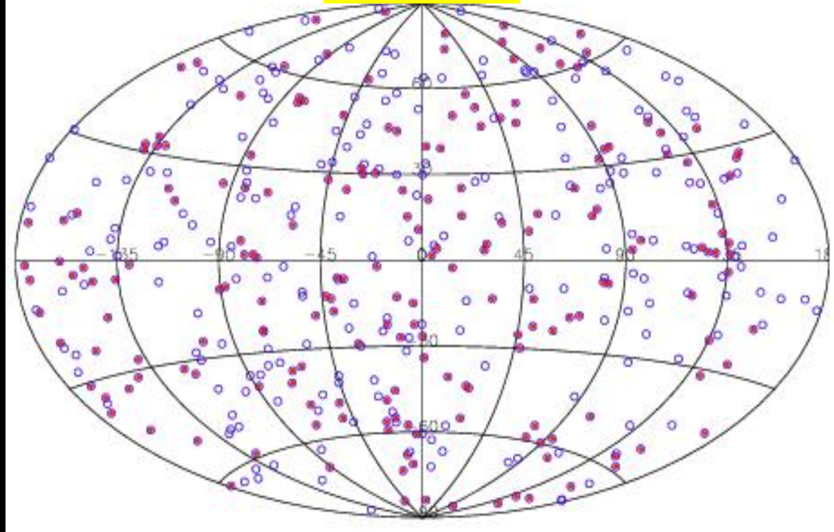


Large scale structure z<0.5

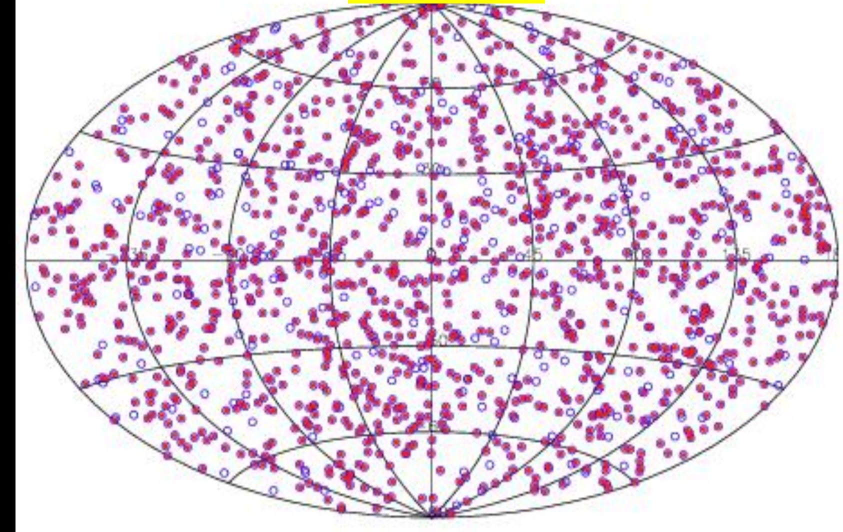


Magliocchetti, GG, Celotti 2004

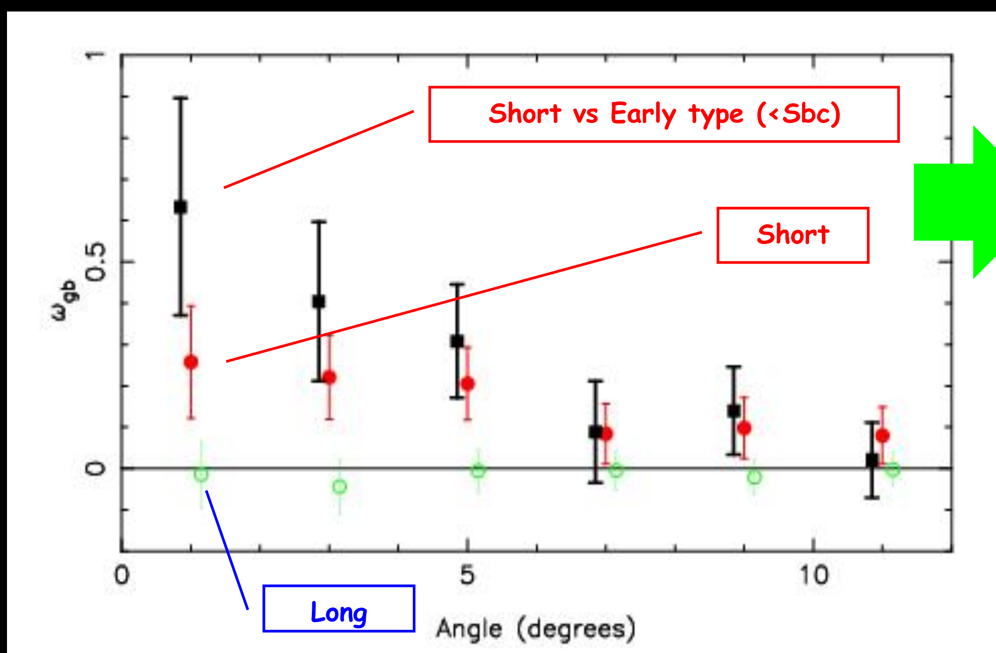
Short



Long



RC3 galaxy (2300) z<0.007

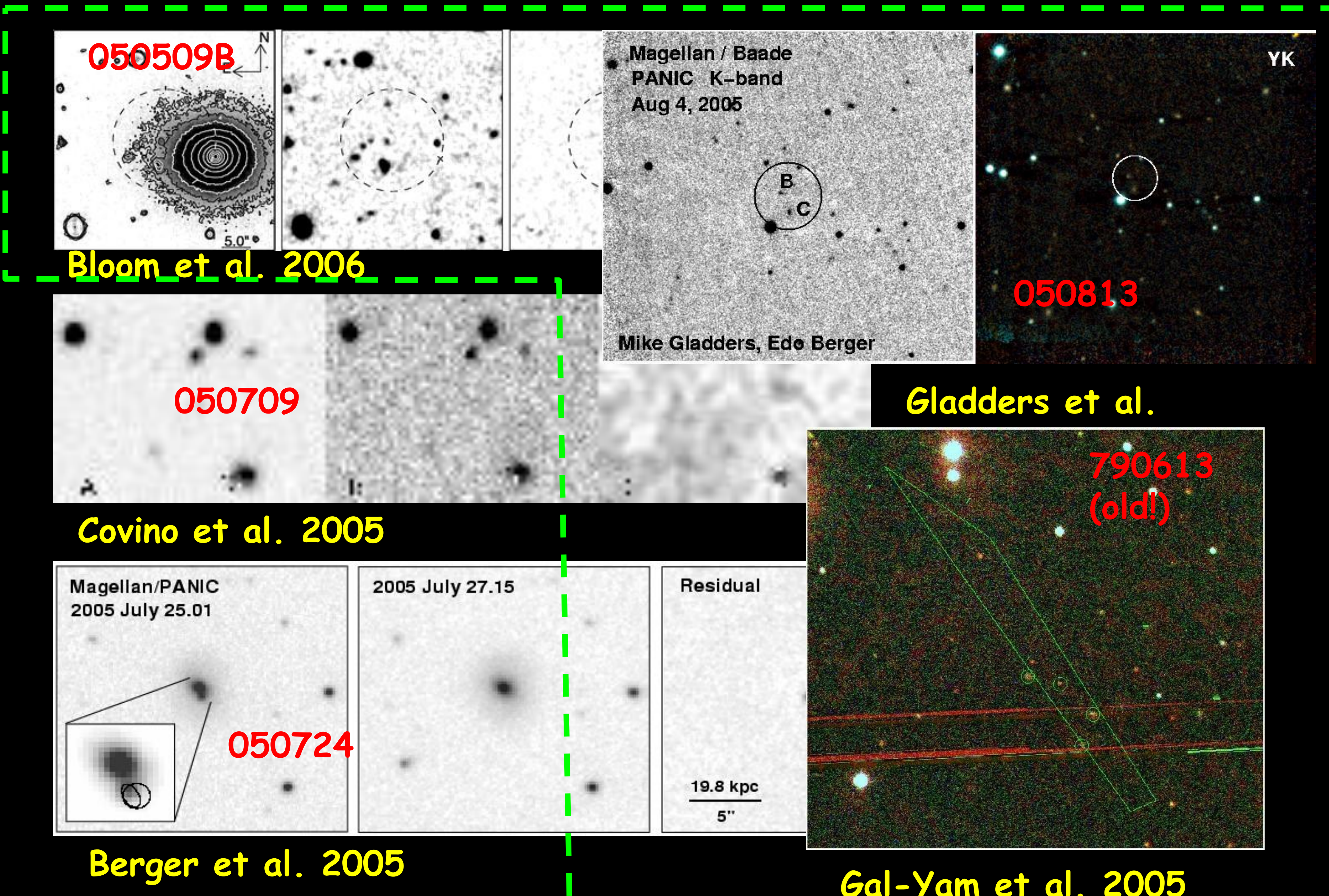


Short correlate with local galaxies and + with local early type gal.

~10-20% of Batse Short GRBs originate within 100 Mpc

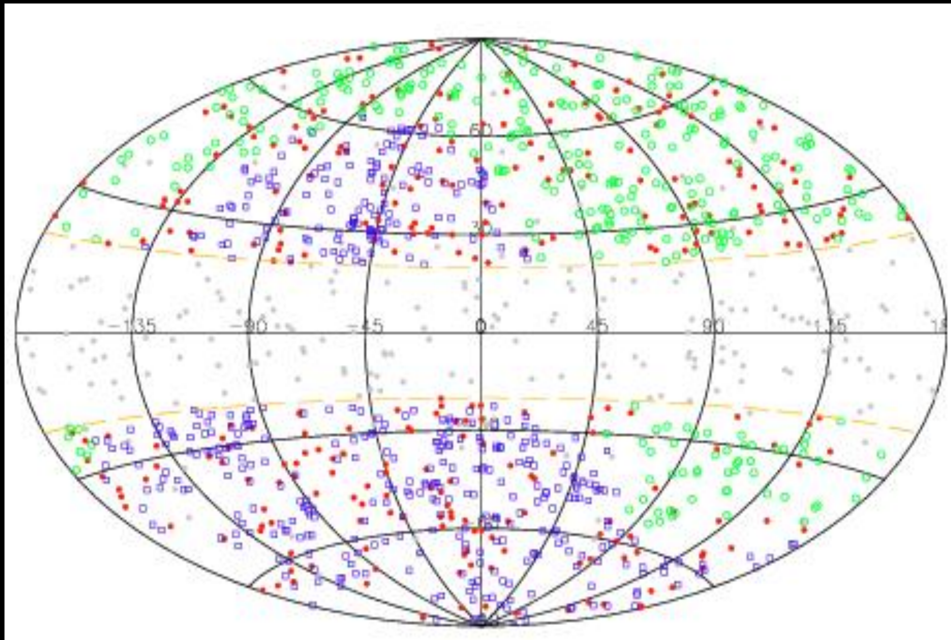
Tanvir et al. 2005

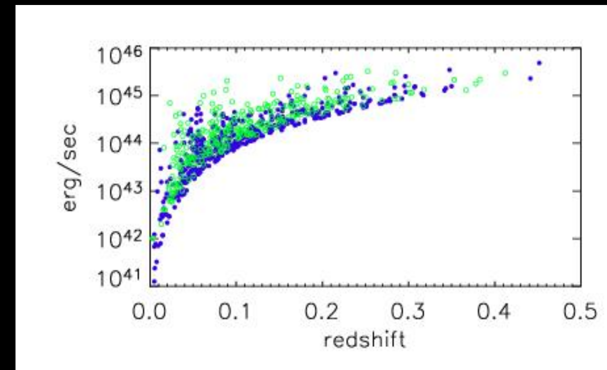
Short GRB hosts



… let's try with clusters …

(previous evidences of cluster-GRB correlation e.g. Kolatt & Piran 1996, Struble & Rood 1997 and discussion by Hurley et al. 1999; Gorosabel et al 1997)





497 short GRBs

448 REFLEX (Boeringher et al. 2004)

484 NORAS (391) (Boeringher et al. 2000)

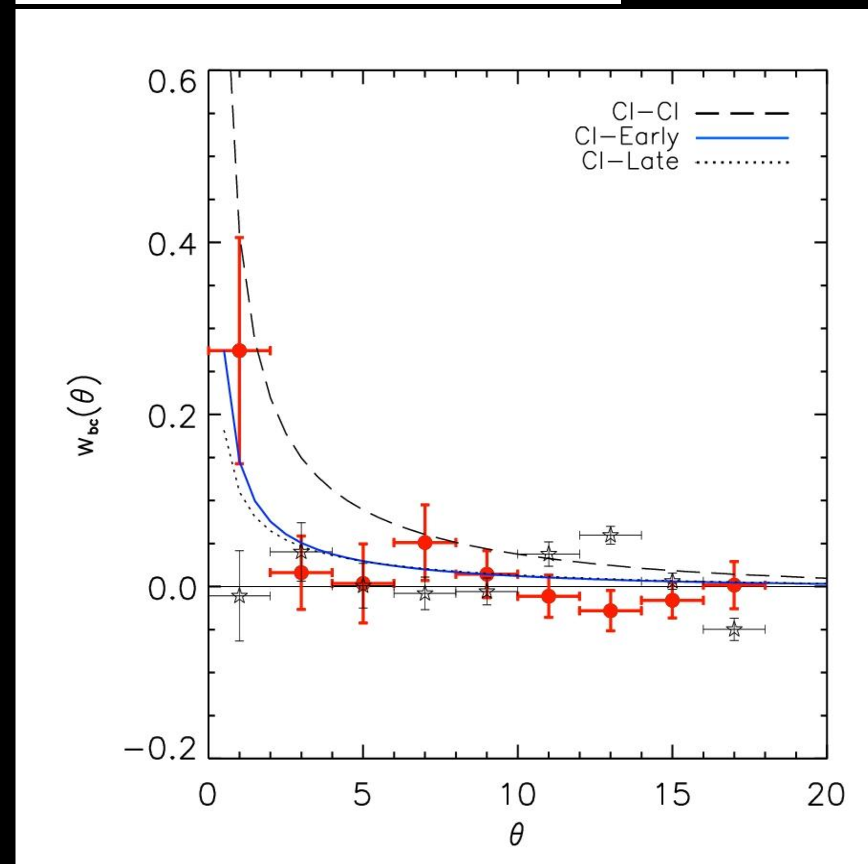
Z<0.459

•Short GRB-Cluster positive correlation signal

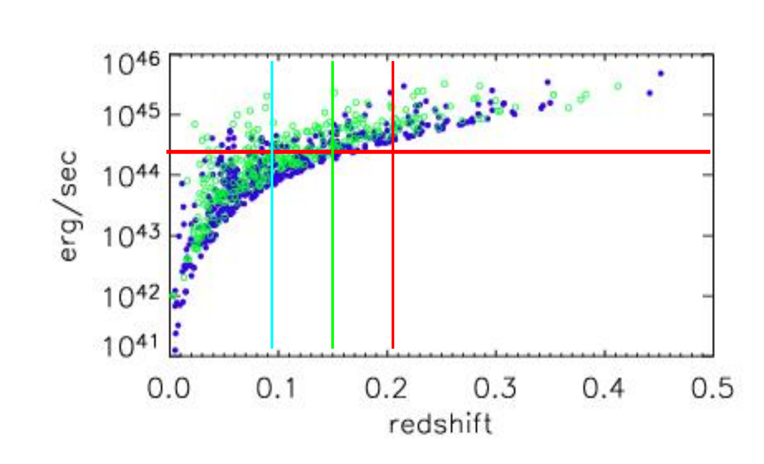
•No corr signal with long

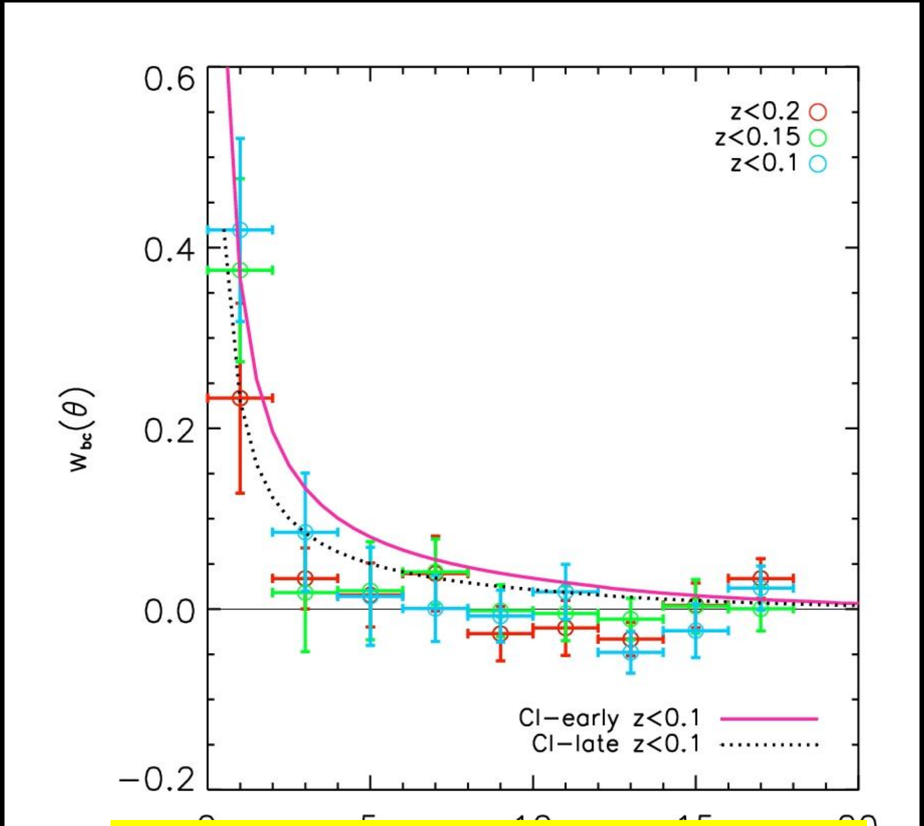
•Short do not trace exactly clusters

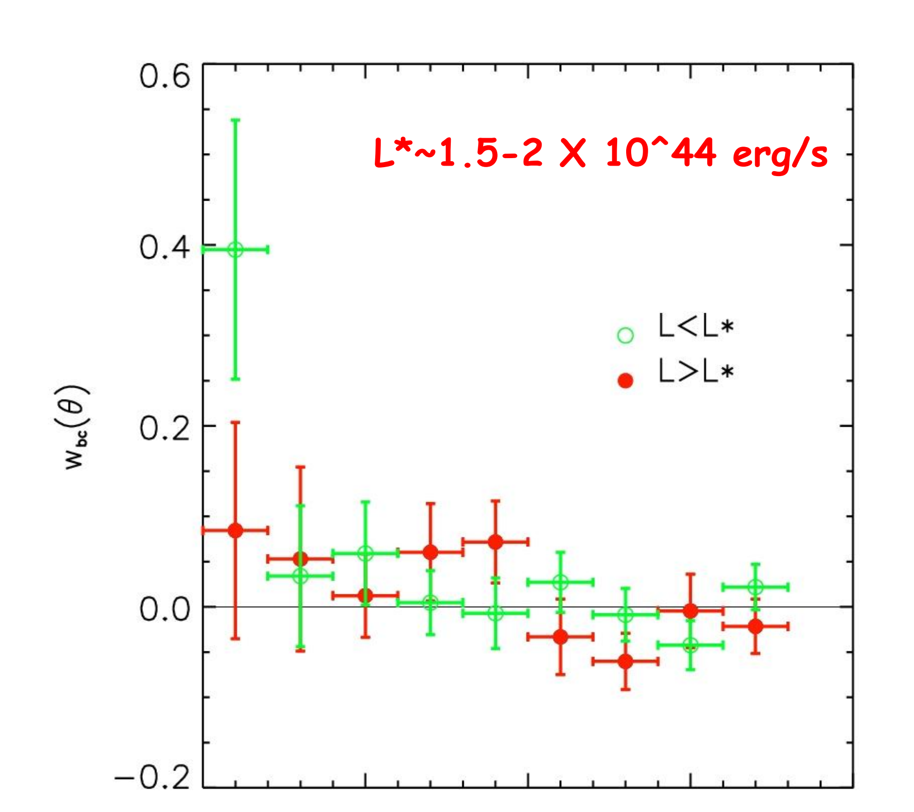
•No preference for early types



Ghirlanda, Magliocchetti, Ghisellini, Guzzo, 2006, MNRAS







Stronger correlation signal with lower redshift cuts

Stronger correlation signal with sub-luminous cl.

Short GRBs: distance scale

Q3: which is the distance scale to short GRBs?

Direct (spectroscopic) redshift measures of ~ 5(swift)+2(Hete) short bursts	➡	Z~0.1-1.0
Statistical analysis of BATSE GRB sample with local galaxies or clusters	➡	Z<0.1
if Short GRBs are at z<0.1	➡	Eiso~10^48 erg

Possible solutions to be searched in any (or a combination of)

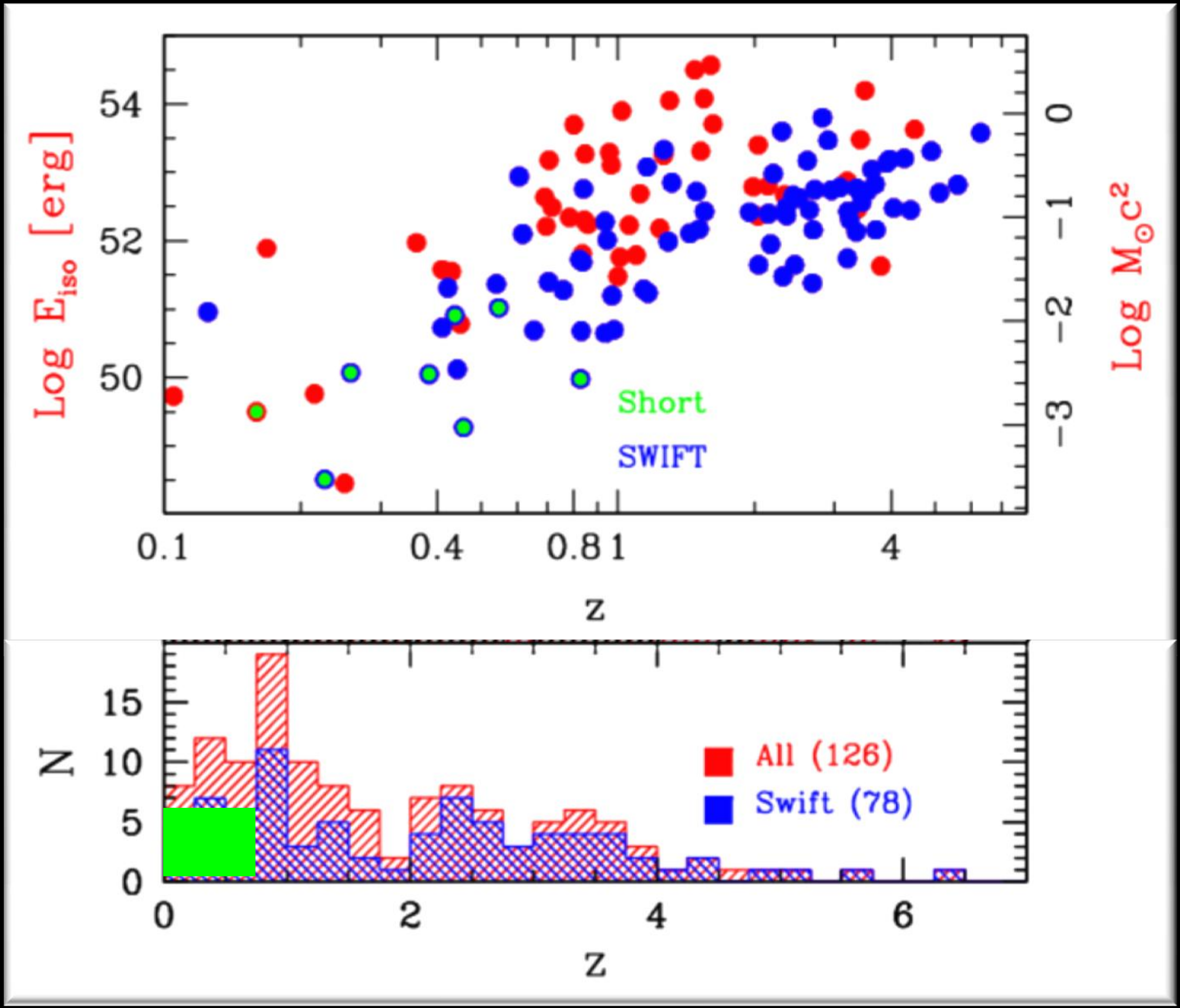
(i) swift preference to detect larger z bursts (as also seen for the long GRB population, e.g. Berger et al. 2005)

(ii) Possible contamination of the S-grb pop by extra-gal SGR (Hurley et al. 2005, but Nakar et al. 2005, Lazzati et al. 2005) (??)

(iii) complex N(L) (e.g. Guetta & Piran 2005, Nakar et al. 2005, Gal-Yam et al. 2005)

PROMPT ENERGETICS
and
LUMINOSITIES

ENERGETICS: Short vs Long



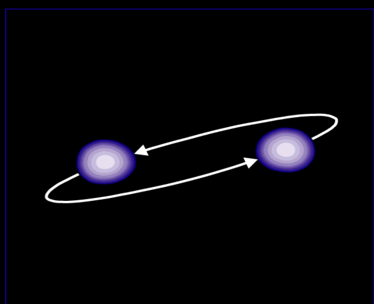
… in brief …

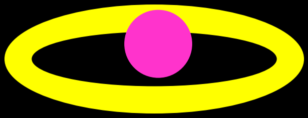
1) Short GRBs are spectrally similar to the first 2 sec of long GRBs

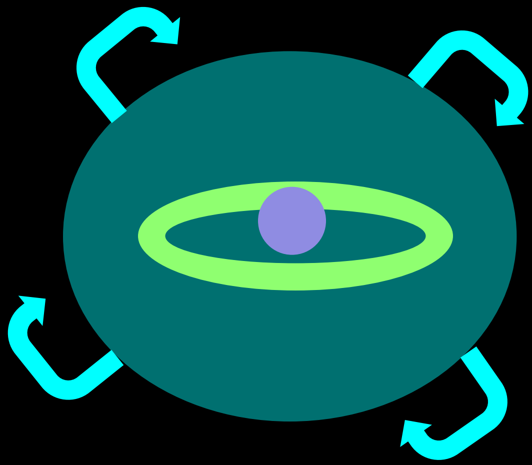
2) Long GRBs energetics are 100 > energetics of short GRBs, i.e.

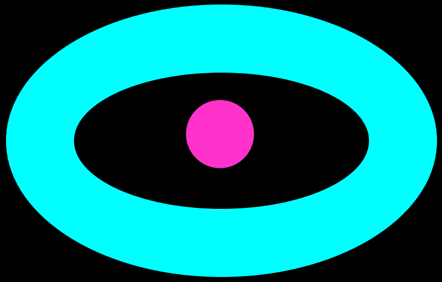
Long → $0.1\text{-}1 M_{eq,sun}$

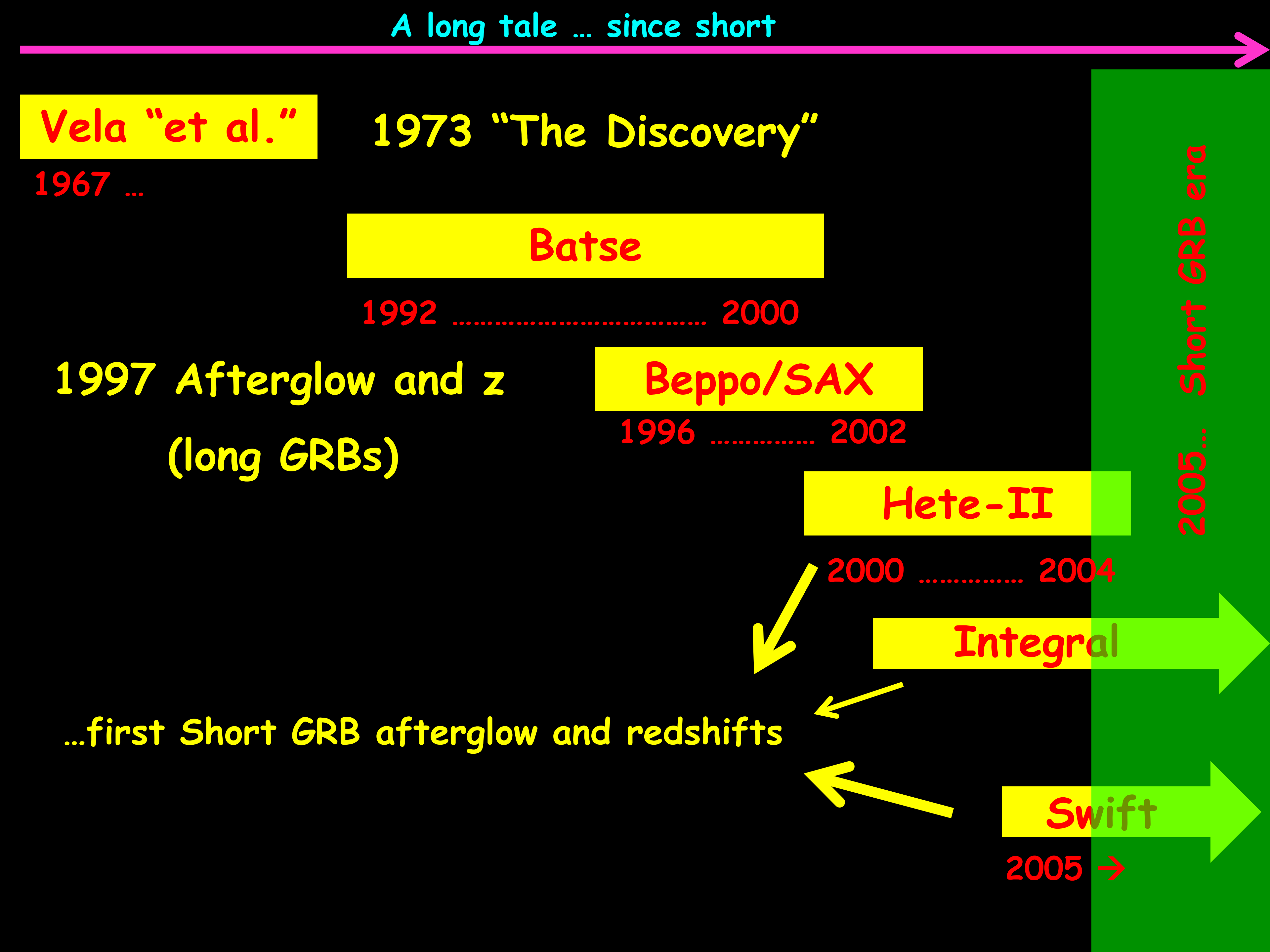
Short → $0.001\text{-}0.01 M_{eq,sun}$










A long tale … since short
Vela "et al."
1967 …
1973 "The Discovery"
Batse
1992 ………………………………… 2000
1997 Afterglow and z
(long GRBs)
Beppo/SAX
1996 …………… 2002
Hete-II
2000 …………… 2004
Integral
…first Short GRB afterglow and redshifts
Swift
2005 →
2005… Short GRB era

Thanks