Short Gamma-Ray Bursts

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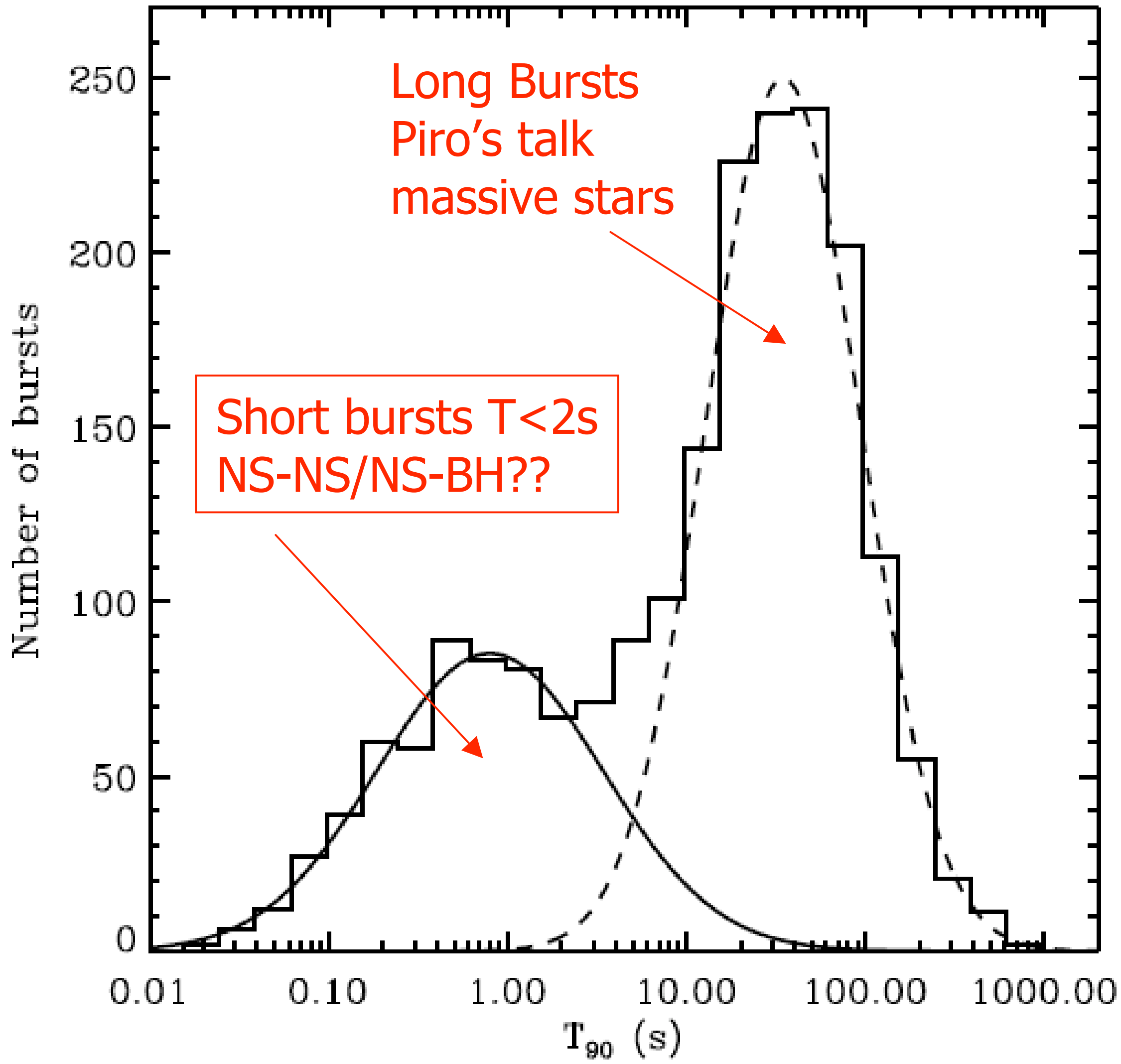
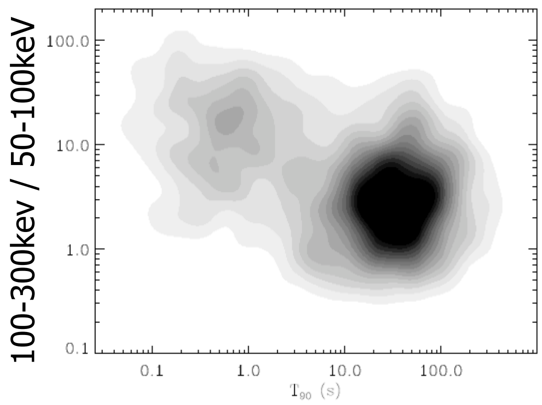
GRB duration distribution



Lazzati and Perna

Hardness ratio vs Duration



Duration

Mazets et al. 1981, Norris et al. 1984, Kouveliotou et al. 1993

Talk Outline

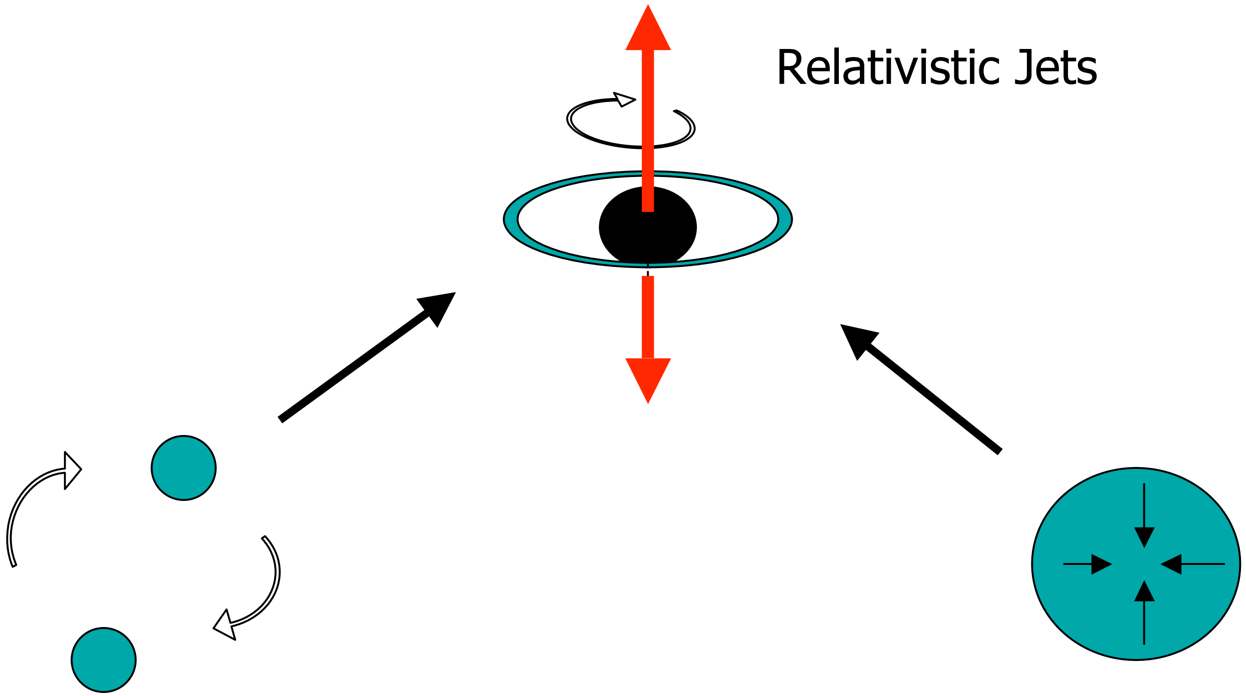
- How the EM radiation produced?
  - long lasting emission: afterglow
- Short bursts produced by NS-SN/NS-BH?
  - host galaxies, redshift distribution…
  - classification issue
- Short burst properties
  - requirements for the central engine

Afterglow: long lasting, low freq counterparts

Discovery of long burst afterglow by BeppoSAX in 1997 revolutionized our understanding of long bursts.

Discovery of short burst afterglow by Swift in 2005
~10 short burst afterglow per year
we begin to understand the physical origin

Leading central engine model
stellar mass BH + massive accretion disk



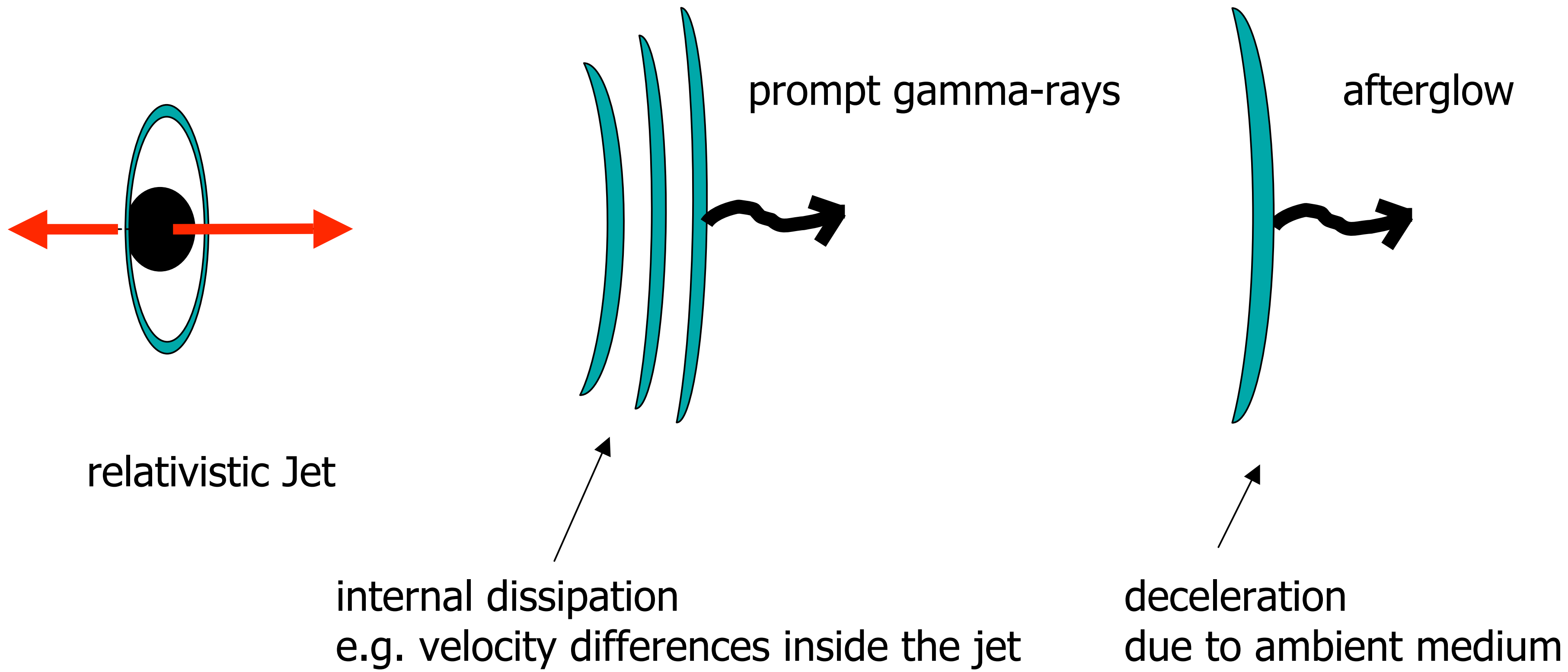
Short Bursts
NS-NS/NS-BH

Eichler et al. 1989, Narayan et al. 1992

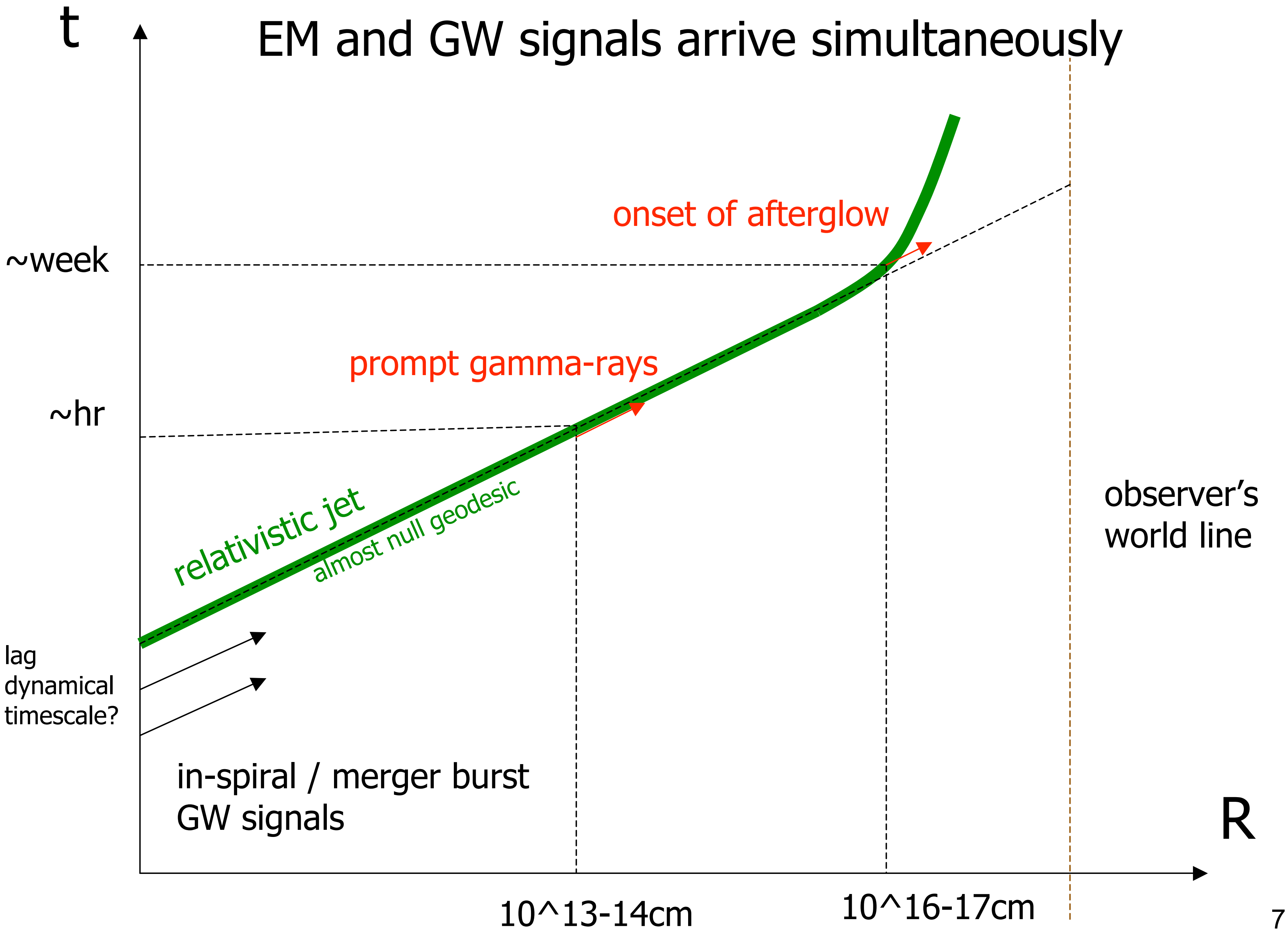
Long Bursts
Massive Stellar Collapses
Woosley 1993, Hojorth et al. 2003, Stanek et al. 2003

Strong gravitational wave sources?

Fireball Model (Synchrotron Shock Model)



EM and GW signals arrive simultaneously

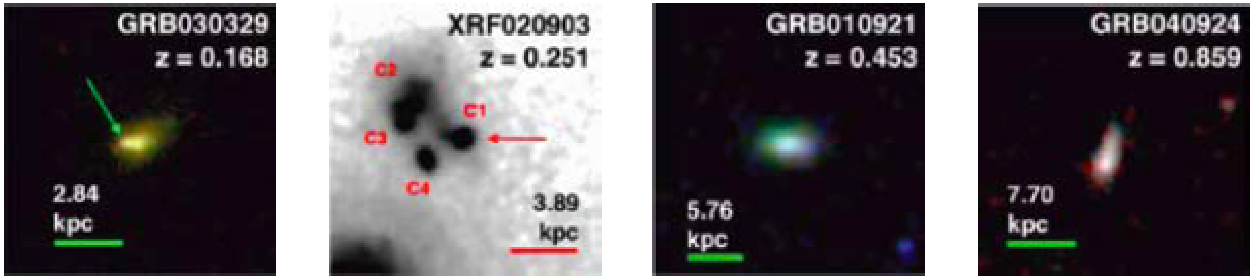


GRBs emitted at large radii, EM signals insensitive to the progenitors still give insight to the nature of the progenitors…

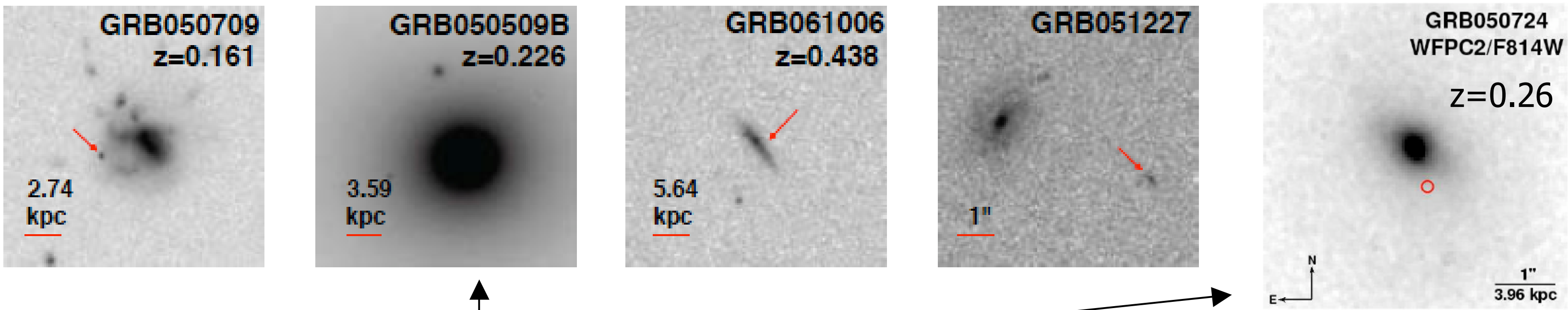
Observational Links: short bursts and NS-NS/NS-BH

- Host galaxies
- Offset from host galaxy centers: kicks
- Red shift distribution
- Deep limits to supernova

Long bursts found exclusively in star-forming galaxies



Gehrels et al. 2009



elliptical galaxies

Short bursts found in both no star-forming and star-forming galaxies

Host galaxy classification/properties

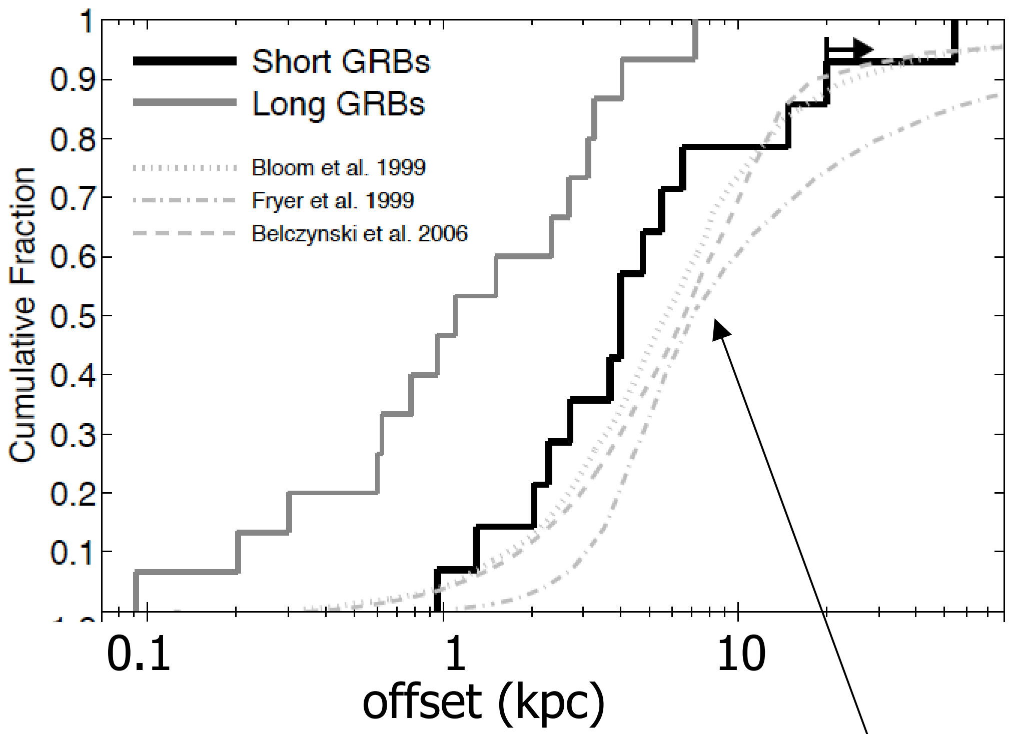
23 Short bursts localized to better than a few arcsec

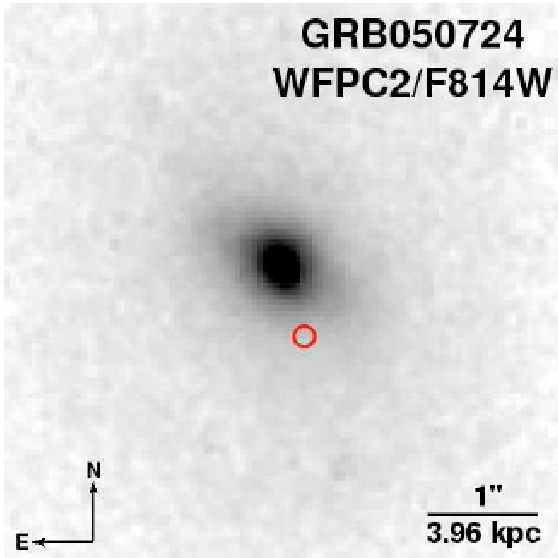
Berger 2009

- ~50% unclassified
  - due to their faintness, the absence of deep follow-up
- GRB 050724 in elliptical galaxy
  - GRB 050509b, GRB 050813
  - an older stellar population
- the others (the majority) in star-forming galaxies
  - LGRBs occurring in the brightest regions in host galaxies, SGRBs environments under-represent the light distribution
  - distinct from LGRB hosts: SFRs, Luminosities, metallicities
  - higher L and metallicities: lower SFRs

Offset Distribution

projected offsets of bursts relative to host centers





median offset
long bursts: ~1kpc
short bursts: ~5kpc

predicted distributions for NS-NS
based on pupulation synthesis models

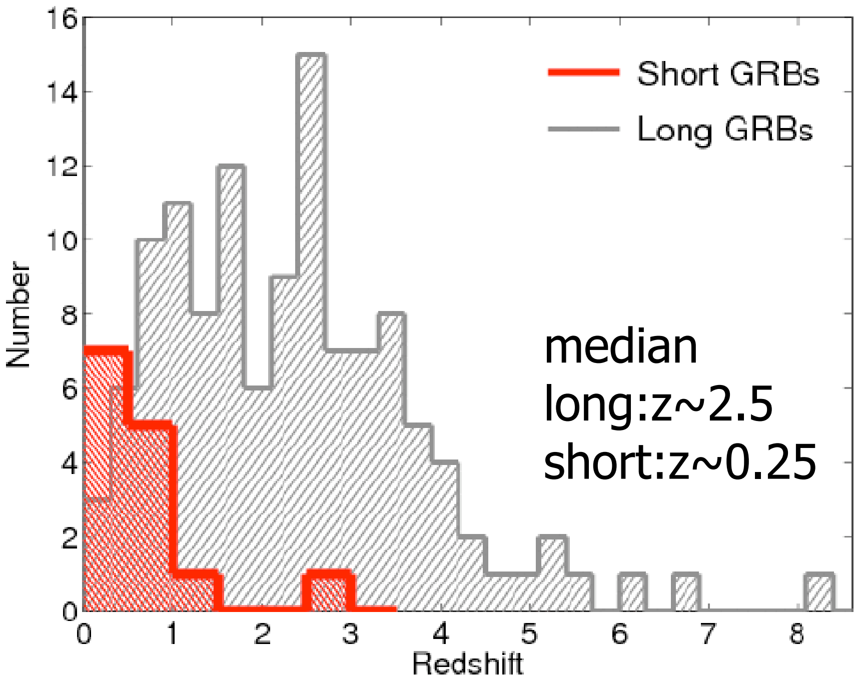
no LGRBs: > 7kpc
some SGRBs: >15kpc

Fong et al. 2009

Redshift Distribution

- Relatively high fraction at z<0.5, compared to long bursts
  - long-lived $\tau \geq 1\mathrm{Gyr}$ progenitors required

Ando 2004, Guetta&Piran 2005, Gal-Yam et al. 2005, Nakar et al. 2006,
Zheng and Ramirez-Ruiz 2007, Berger 2007. however, Virgili et al. 2009, Lazzati et al. 2009



median
long:z~2.5
short:z~0.25

Berger & Fong 2009

observed local rates
short: ~10 /Gpc^3/yr
long: ~0.5/Gpc^3/yr

Nakar 2007

NS-NS: 1-800 /Gpc^3/yr
NS-BH: 0.1-1000/Gpc^3/yr

Tanvir et al. 2005

- Angular cross correlation study
  - 400 BATSE short bursts with localization better than 10 degrees
  - 1,070 PSCz galaxies : most galaxies within about 25Mpc

10-25% of short GRBs originate at low redshifts $z<0.025$

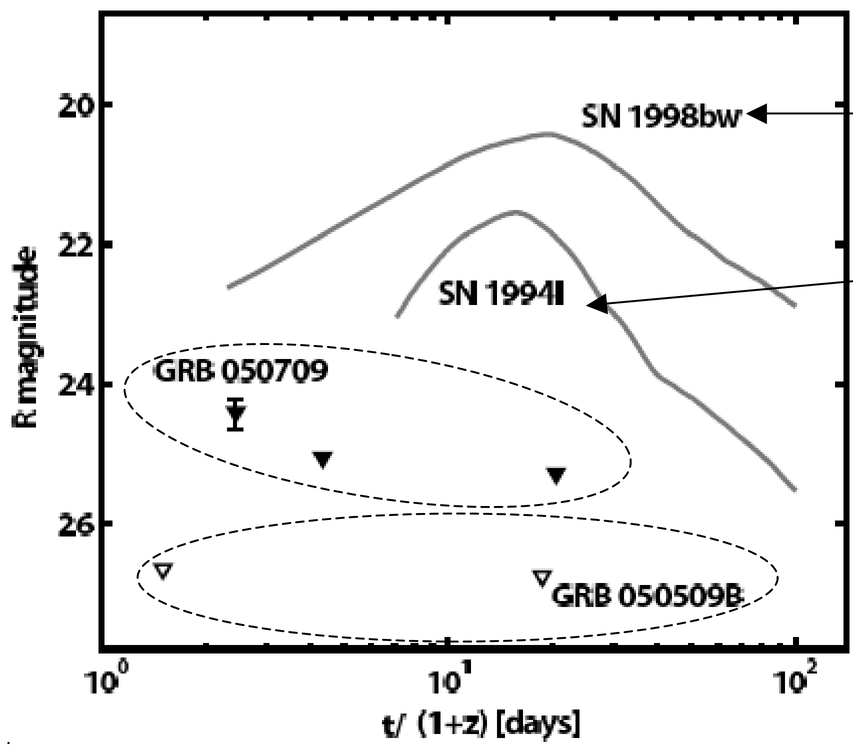
~100Mpc

A lack of an associated supernova with short bursts

low redshift short bursts: GRB 050509B (z=0.225) GRB 050709 (0.16)

Hjorth et al. 2005, Fox et al. 2005, Castro-Tirado et al. 2005, Bloom et al. 2006

- Optical observation limits:
  - over 50 times fainter than normal Type Ic
  - 5 times fainter than the faintest known Type Ic



energetic Type Ic associated with long GRB 980425

faint Type Ic

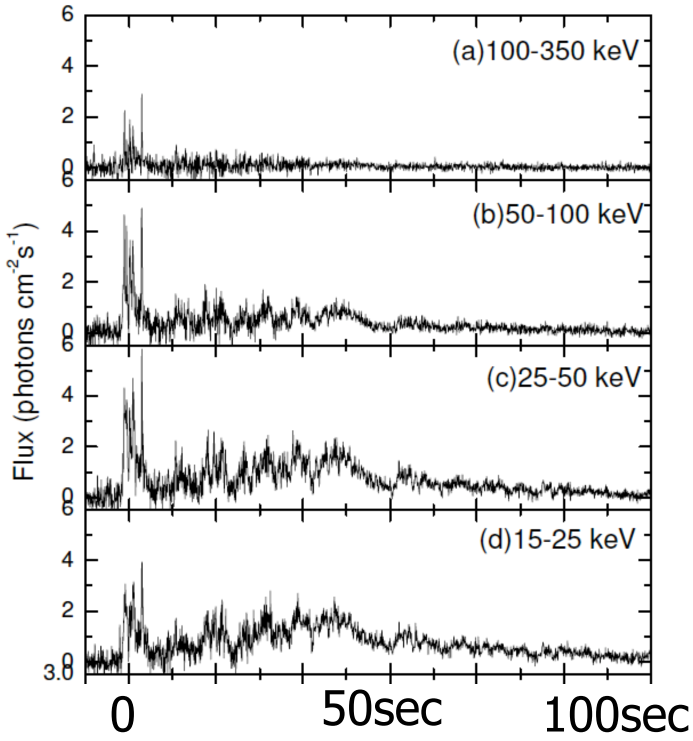
SN light curves as they would appear at z=0.225

Lee & Ramirez-Ruiz 2007

Long bursts: GRB 060505, 060614 without SN components challenge the usual classification of GRBs

Other LGRBs at z<0.4 have had SN features
GRB980425,031203,030329,011121

- GRB 060614: T90= 102sec
  - low redshift z=0.125, bright event
  - 100 times fainter than SN1998bw, fainter than the faintest known Type Ic
  - collapsar-type event without supernova? compact mergers with extended emission? something else?

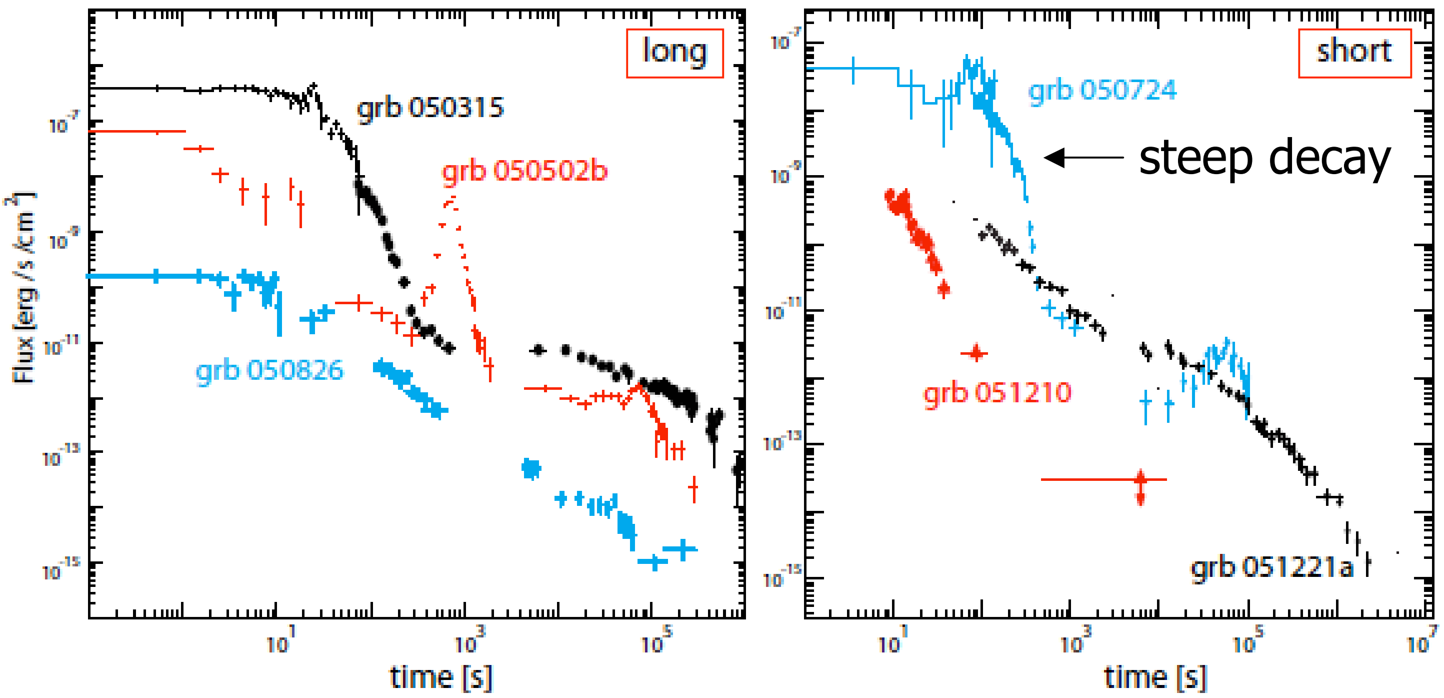


~0.2sec hard pulse+soft emission

Gal-Yam et al. 2006, Fynbo et al. 2006, Norris&Bonnell 2006, Zhang et al. 2007, Lazzati et al. 2001

Early X-ray Afterglow

X-ray Flares, sharp drop
Central engine activity t>100sec?



GRB 050724 in elliptic galaxy

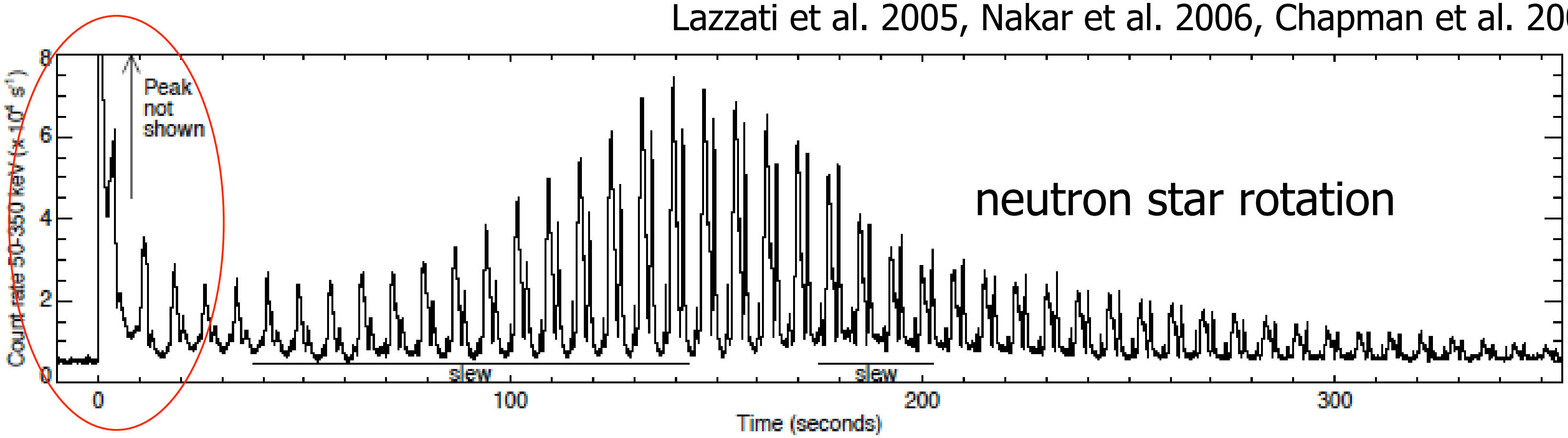
Gehrels et al. 2009

Giant flares from Soft Gamma-ray Repeaters

Stella's talk in the pre-conference meeting

- Magnetars
  - X-ray emission powered by strong magnetic field B~10^15G
  - Giant flares: once per 50 yrs per source
- SGR 1806-20 on 27th Dec 2004 at d=15kpc
  - the initial spike (0.2sec, 2x10^46ergs) could look like a typical short bursts if it had occurred much farther away (<40Mpc).
  - the isotropic distribution of BATSE SGRBs, the lack of excess events toward Virgo cluster: only small fraction < 5-15%.

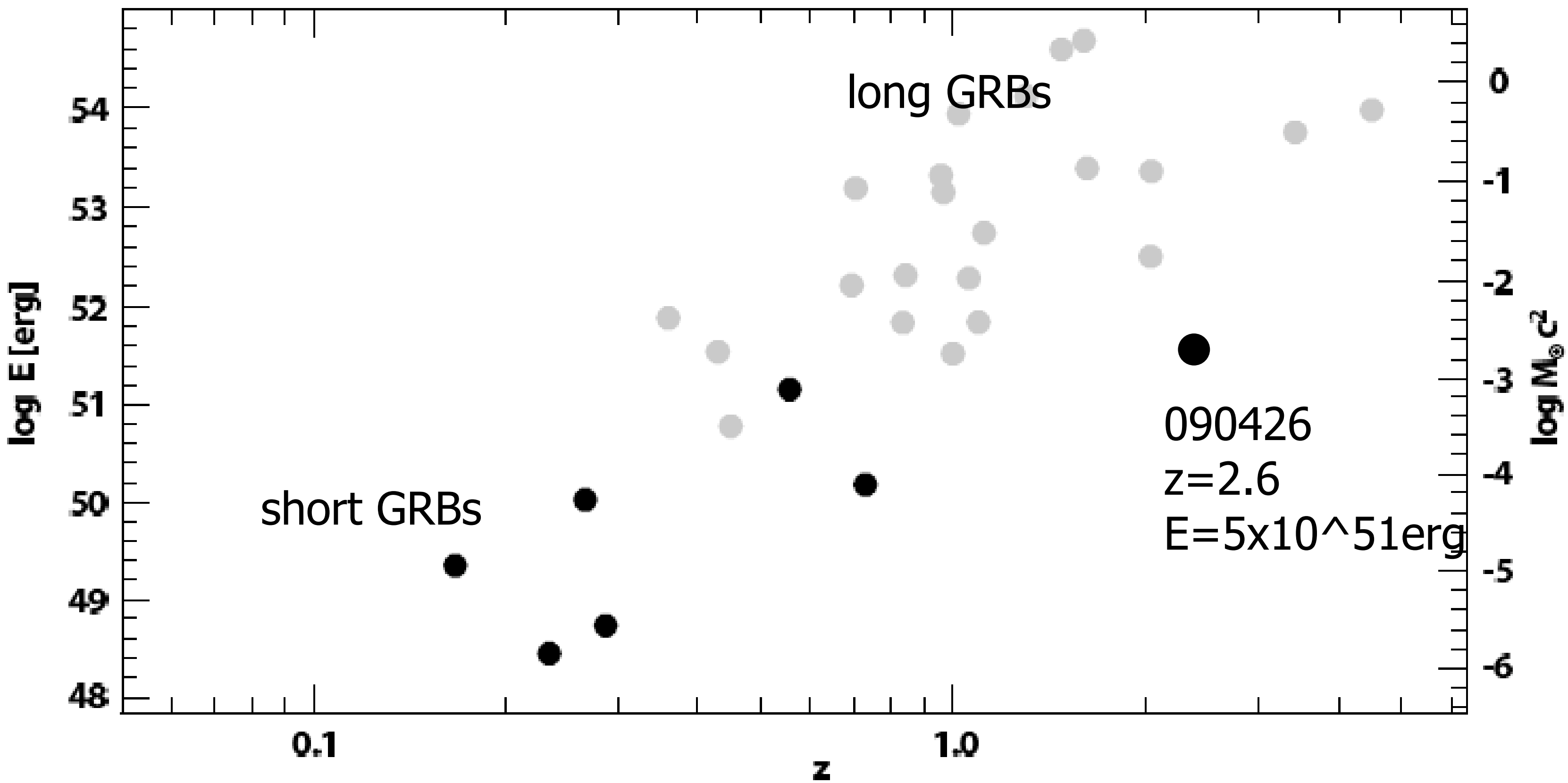
Lazzati et al. 2005, Nakar et al. 2006, Chapman et al. 2008



Palmer et al. 2005, Swift BAT >50keV

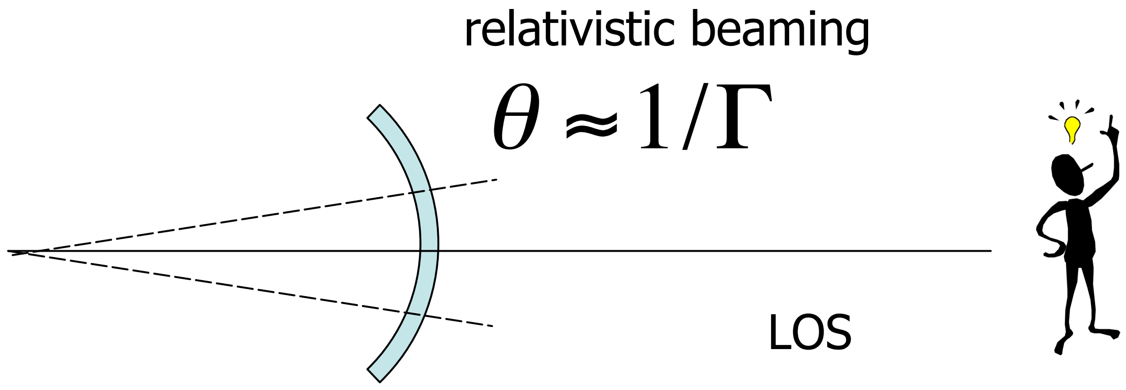
Isotropic gamma-ray energy and redshift

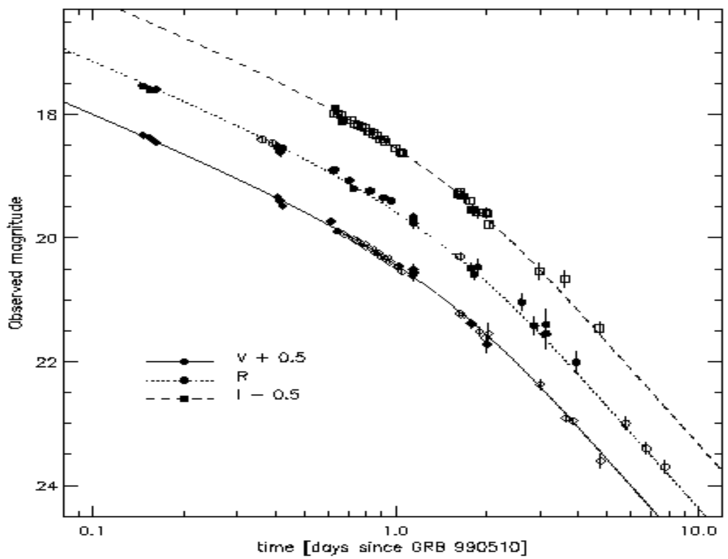
the spread in energy due to the spread in opening angle or energy release?



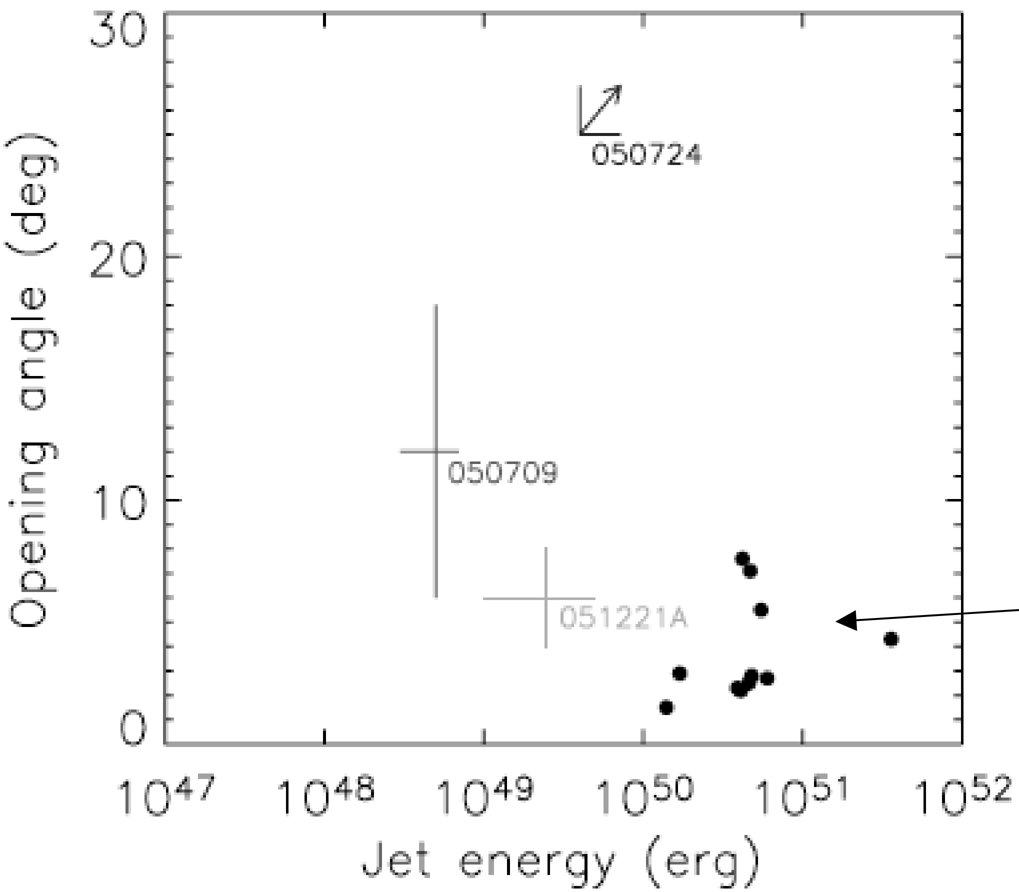
Li & Ramirez-Ruiz 2007
Antonelli et al. 209

Jet Break


relativistic beaming
$\theta \approx 1/\Gamma$
LOS


Observed magnitude
18
20
22
24
0.1
1.0
10.0
time [days since GRB 990510]
V + 0.5
R
I − 0.5

Collimation
collapsar: the stellar evelope of the collapsing star
merger: wind from the surrounding accretion disk?



Long bursts

beaming factor

$$\text{long}: \left\langle f_b^{-1} \right\rangle \approx 75$$

$$\text{short}: 1 < f_b^{-1} < 100$$

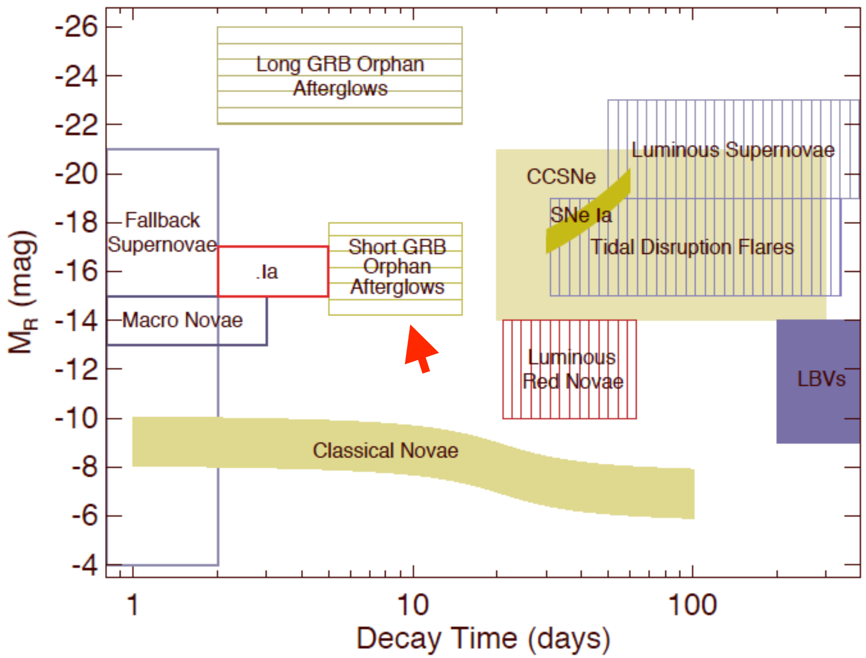
Nakar 2007

Burrows et al. 2006

•Upcoming Optical/X-ray "All-Sky" Surveys

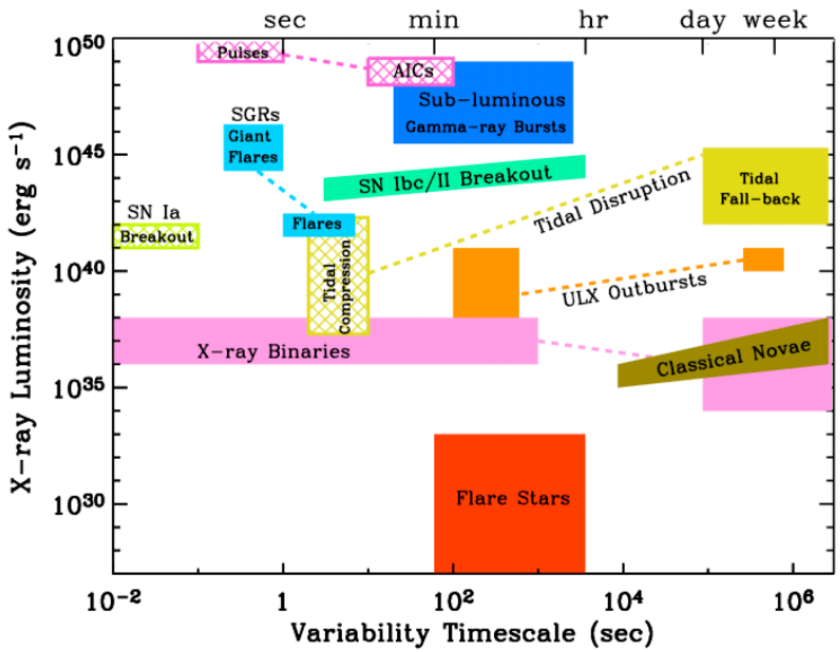
- –PannSTARRs, Palomar Transient Factory, LSST
- –EXIST

Optical transients



Rau et al. 2009

X-ray transients



Soderberg et al. 2009

Relativistic Jets

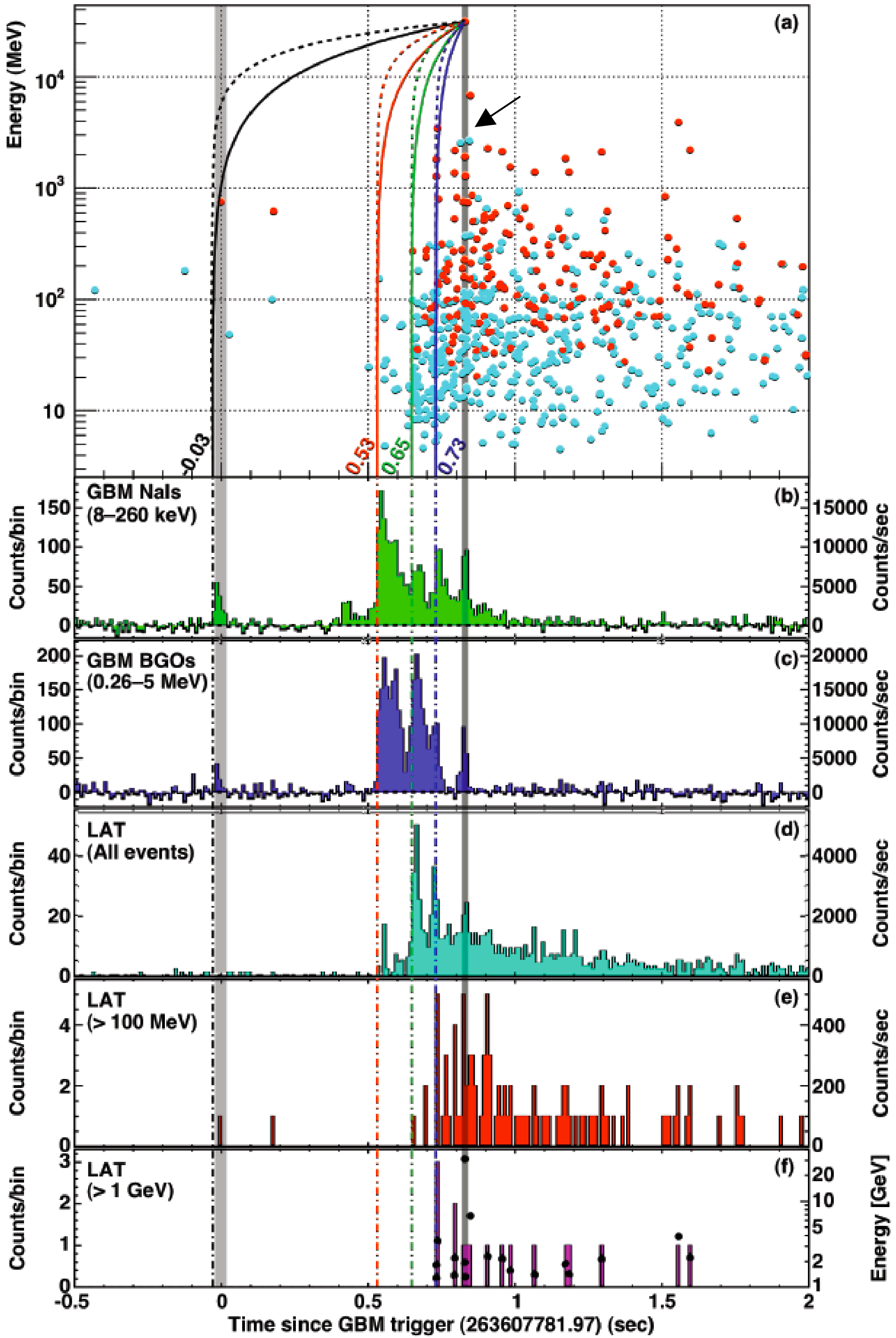
- Huge amount of energy in a compact source
  - optically thick sources expected $\gamma\gamma \to e^+e^-$

Introduction of relativistic motion allows optically thin sources

gamma/X-ray observations: BATSE, BeppoSAX, HETE, Swift

$$\text{Long bursts}: \ \Gamma \geq 100$$

$$\text{Short bursts}: \ \Gamma \geq \ \text{several tens}$$



Fermi
Short burst GRB 090510

Abdo et al. 2009

detection of ~30 GeV photon

high energy photons pass through the low-energy photon radiation within the source without pair-production $(\gamma\gamma \rightarrow e^+e^-)$

$$\Gamma \geq 1000$$

high energy emission lasts ~200s
external shock emission?
the onset consistent with high Γ

Corsi et al. 2009, Ghirlanda et al. 2009

Summary

- at least some fraction of short bursts occur in elliptic galaxies
  - an old stellar population
- the majority occur in star forming galaxies
  - progenitor's environments distinct from long bursts
- Redshift, offset distribution consistent with compact stellar mergers.
  - local rate: ~ 10/Gpc^3/yr
- the conventional distinction between short and long bursts has been called into question by some events.
- gamma-ray energy of short bursts: ~10^48-52 ergs
  - due to the spread in opening angle or energy release?
  - central engine activity: > 100 sec
- some short bursts associated with ultra-relativistic motion gamma >1000
- more observation needed: ~10 short burst afterglow per year