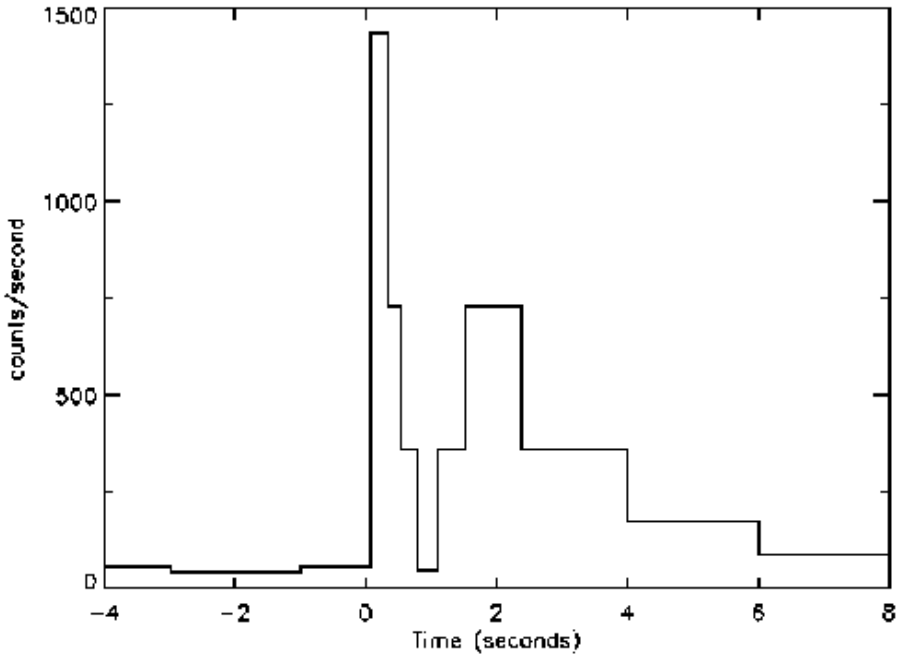
Gamma ray bursts

Tomasz Bulik
OAUW

The first GRB

Klebesadel, Strong i Olson

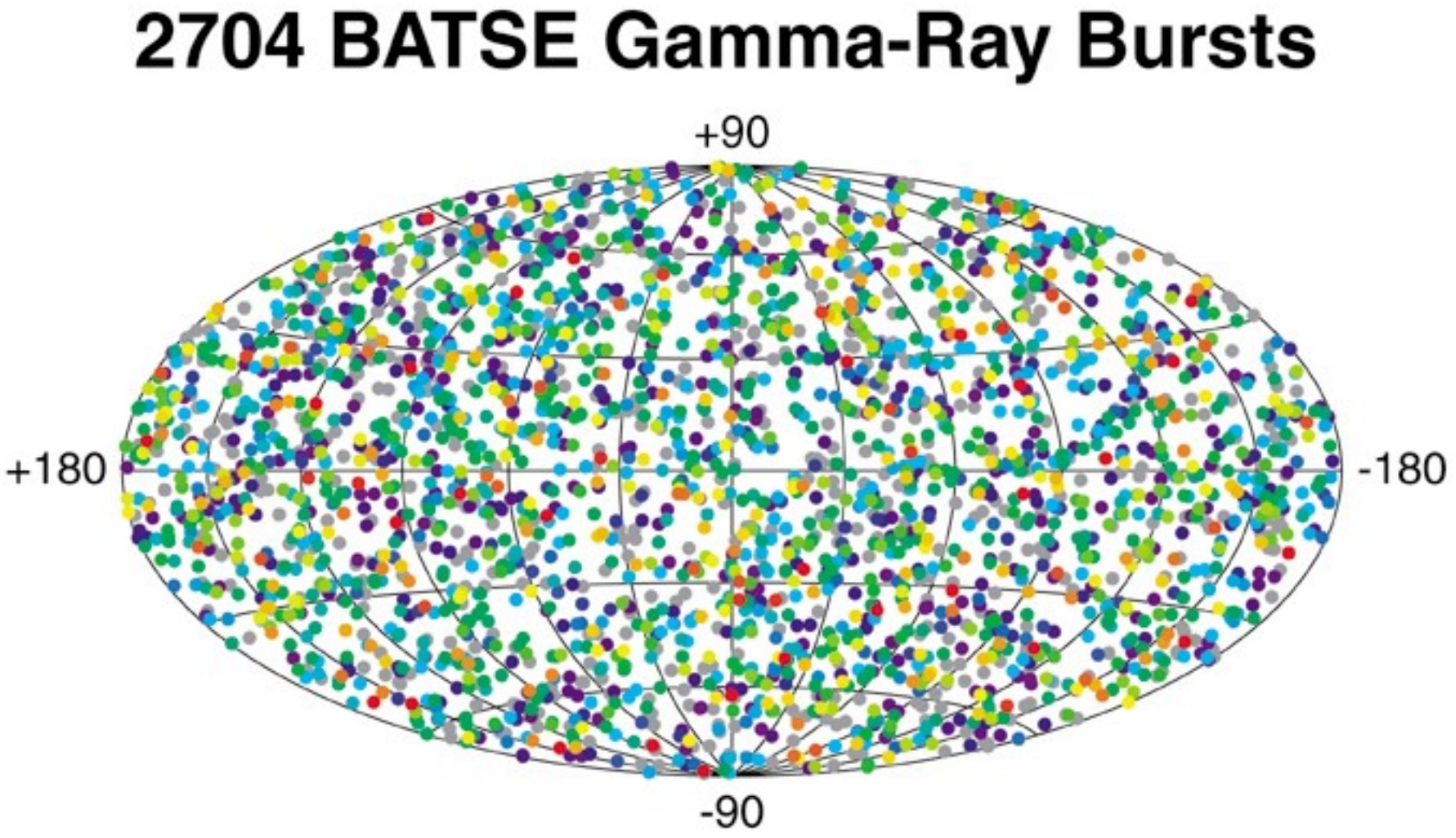
ApJ 182, L85 1973



Sixteen short bursts of photons in the energy range 0.2–1.5 MeV have been observed between 1969 July and 1972 July using widely separated spacecraft. Burst durations ranged from less than 0.1 s to ~30 s, and time-integrated flux densities from $\sim 10^{-5}$ ergs cm^{-2} to $\sim 2 \times 10^{-4}$ ergs cm^{-2} in the energy range given. Significant time structure within bursts was observed. Directional information eliminates the Earth and Sun as sources.

Subject headings: gamma rays — X-rays — variable stars

Distribution on the sky



Spatial distribution

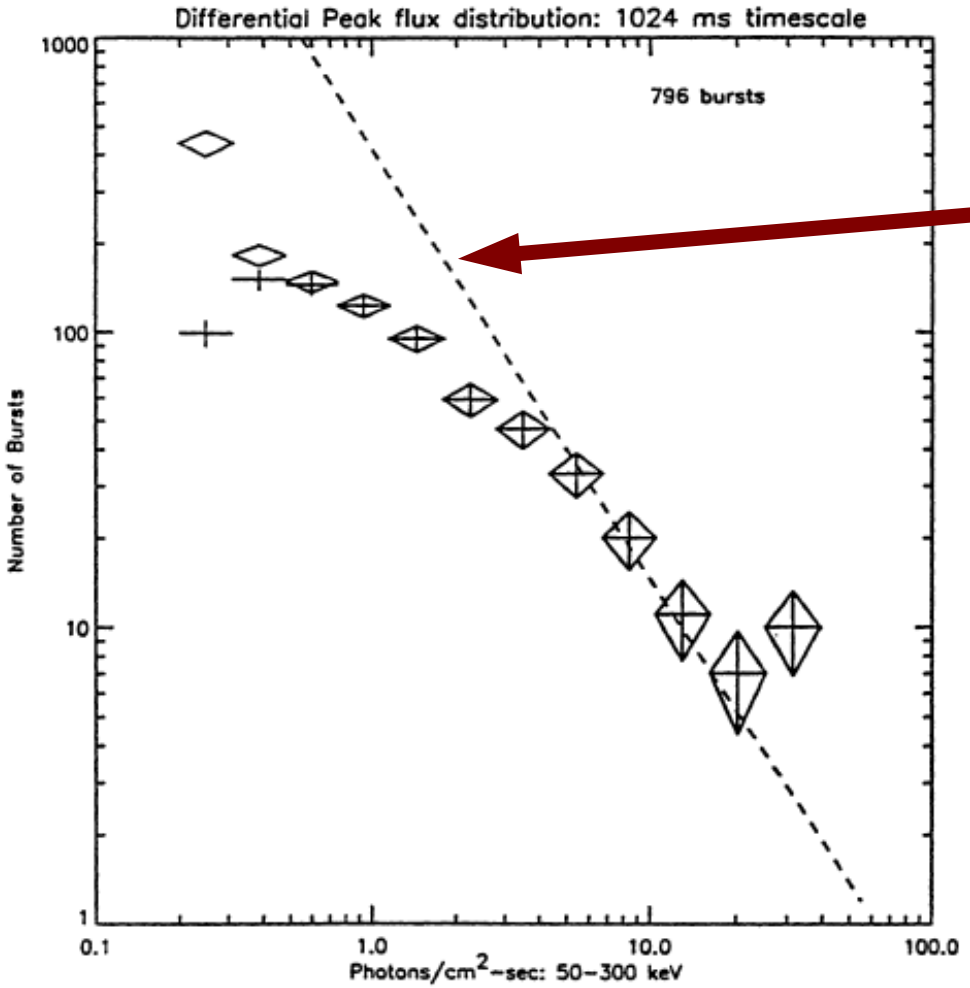
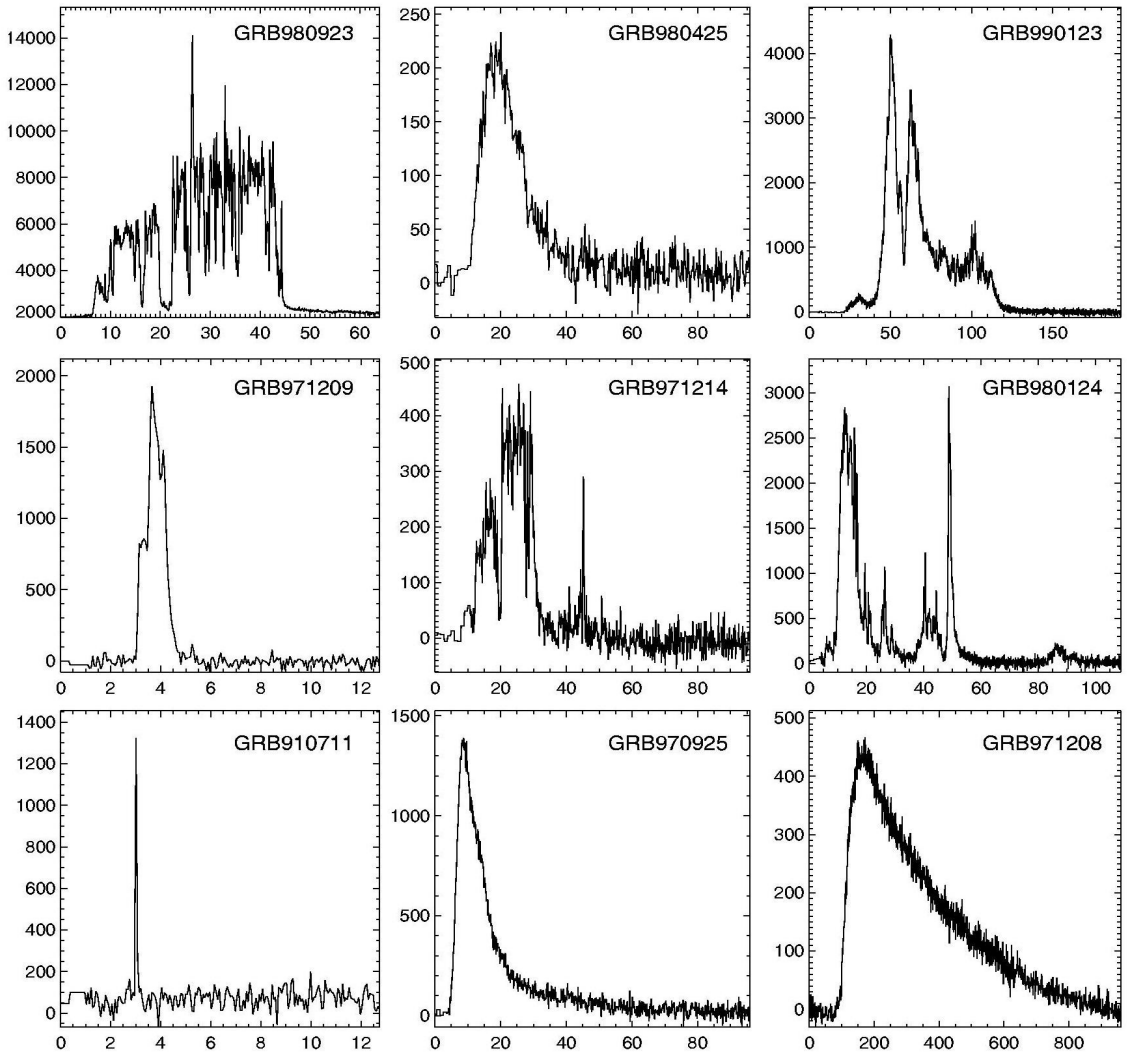


Figure 12 The peak flux distribution of 796 gamma-ray bursts observed by BATSE (Pendleton et al 1995). The flux is measured over the energy range 50–300 keV.

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

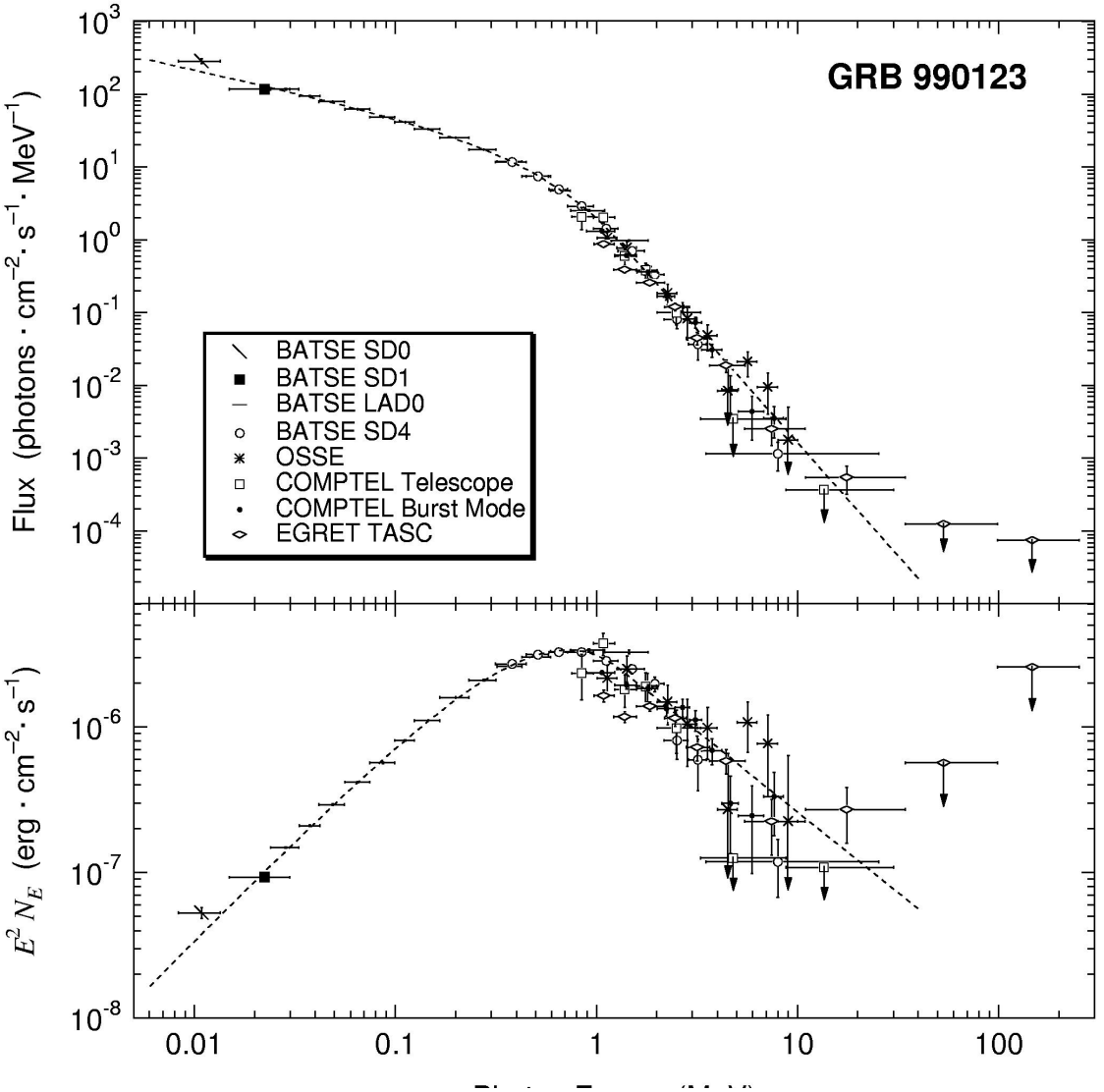
$$\langle V/V_{\max} \rangle = 0.330 \pm 0.010$$

Lightcurves

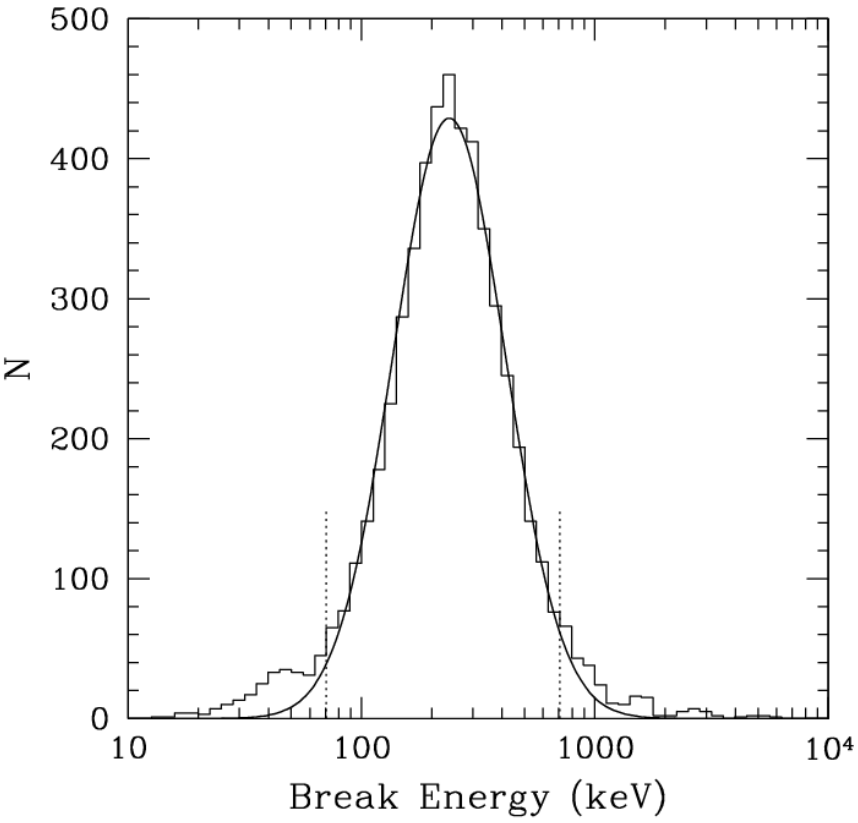


Each burst is different

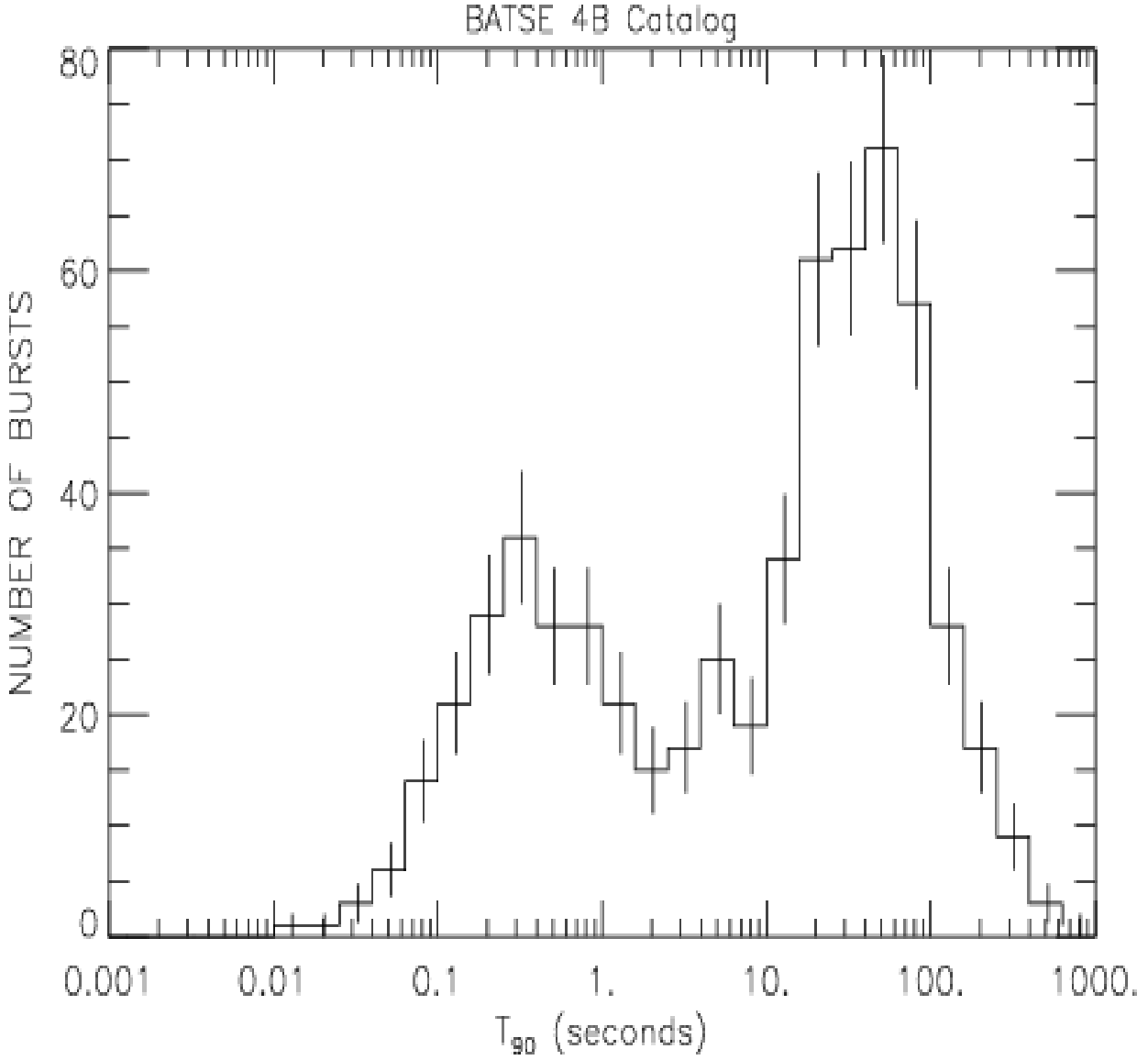
Spectra



E - peak
between 100keV and 1MeV



Duration – two classes



Short - hard

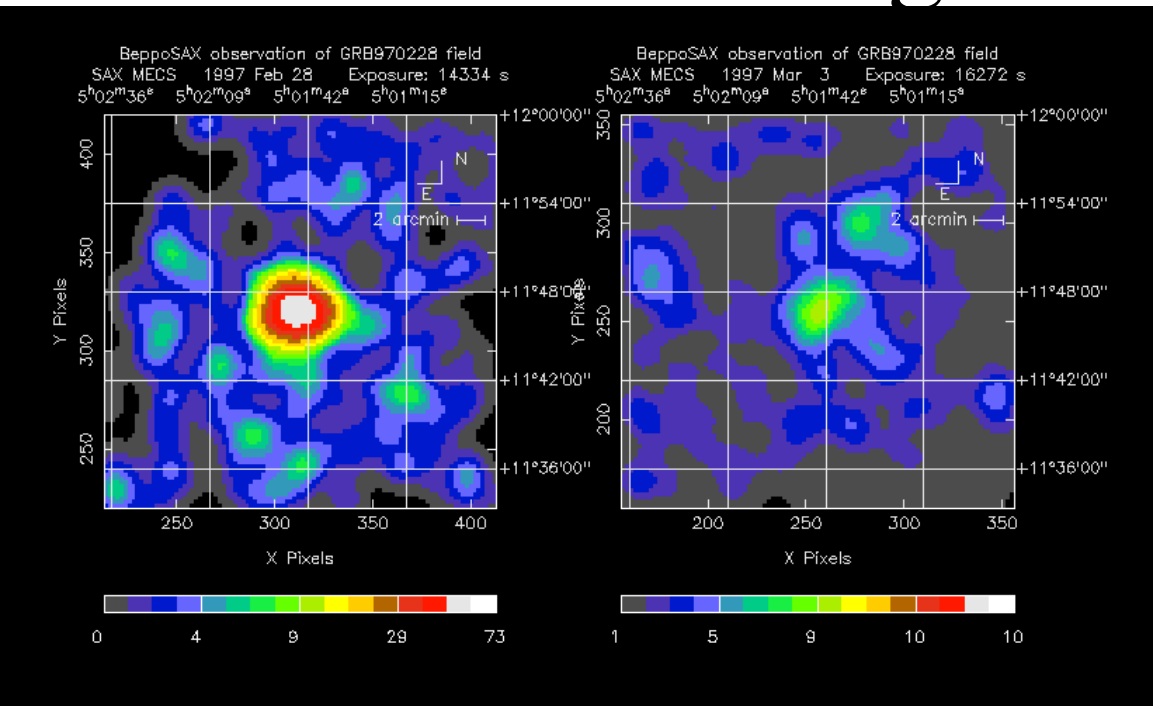
$$t_{90} < 2\text{s}$$

Long - soft

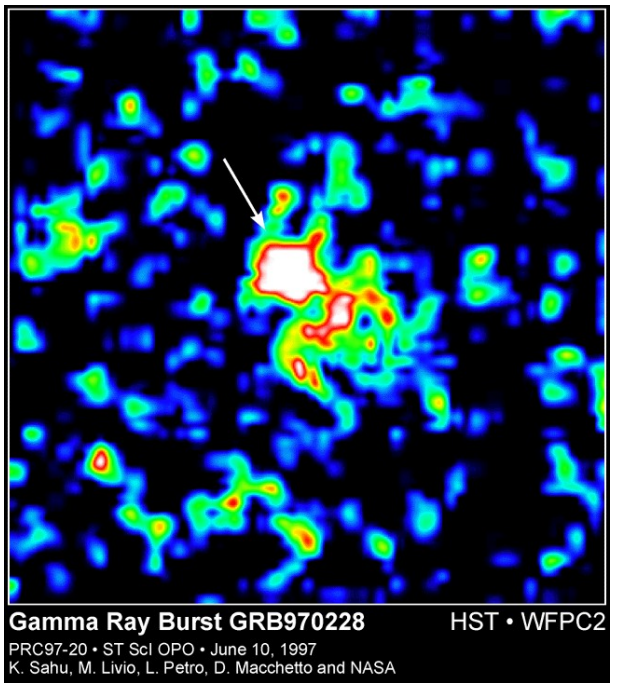
$$t_{90} > 2\text{s}$$

Afterglows

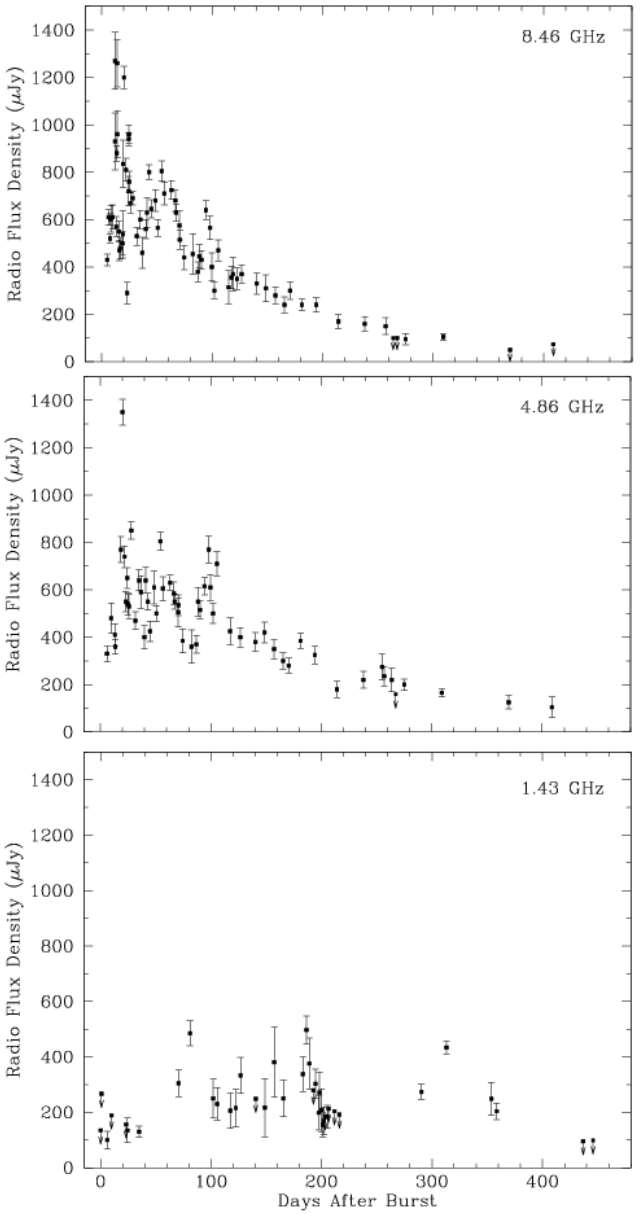
X-ray



Optical

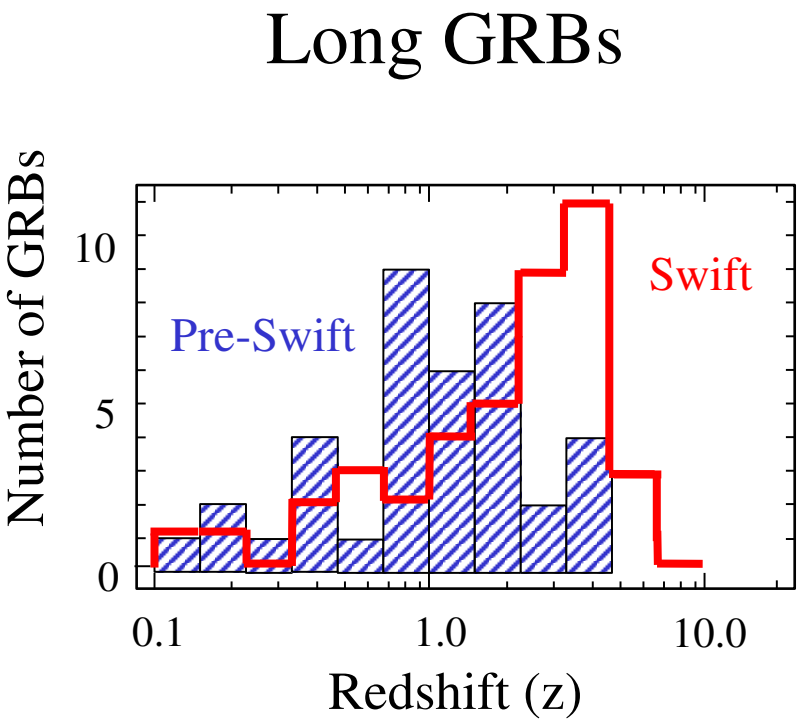


Radio

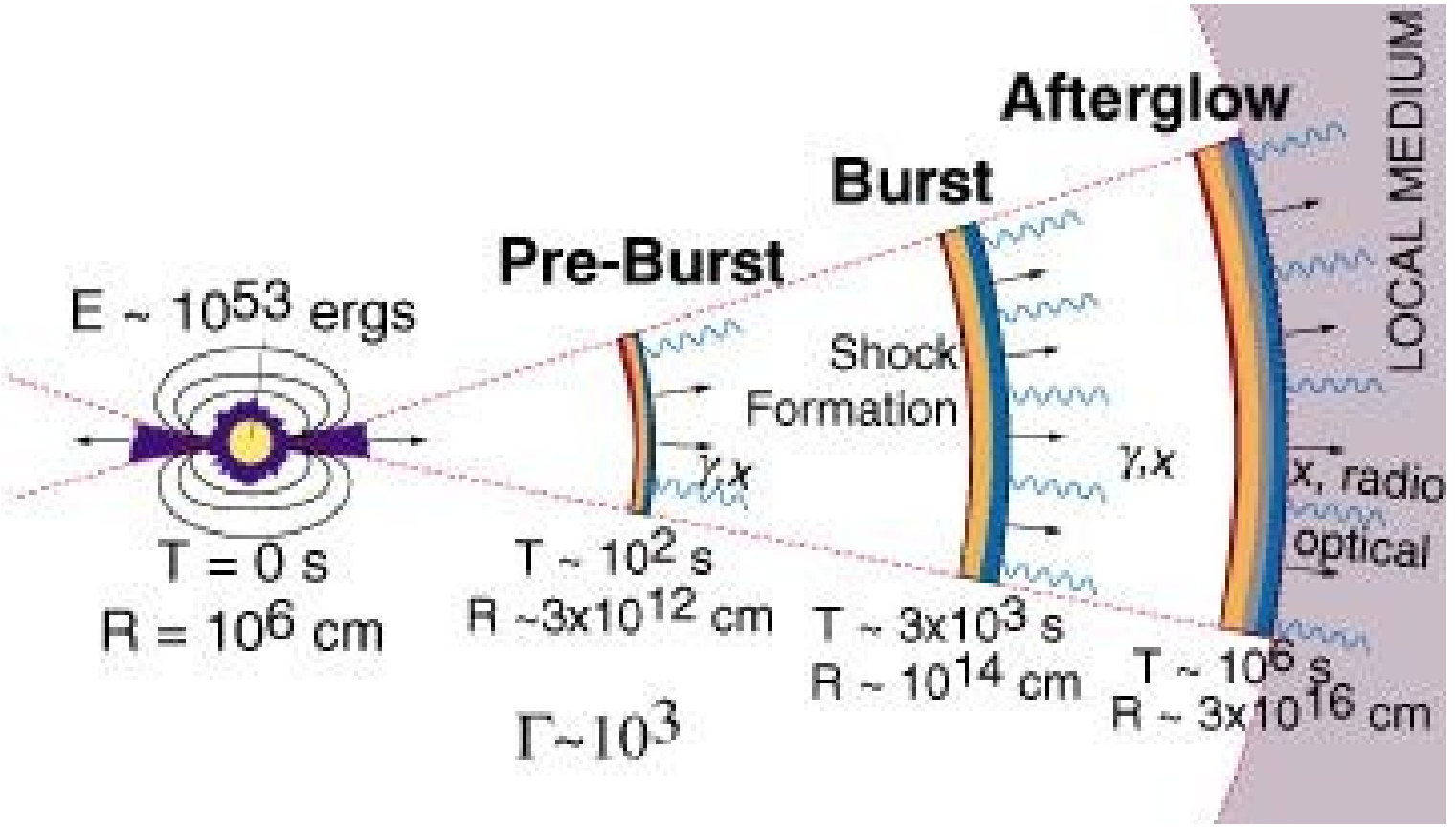


Redshifts

Most bursts between
1<z<2



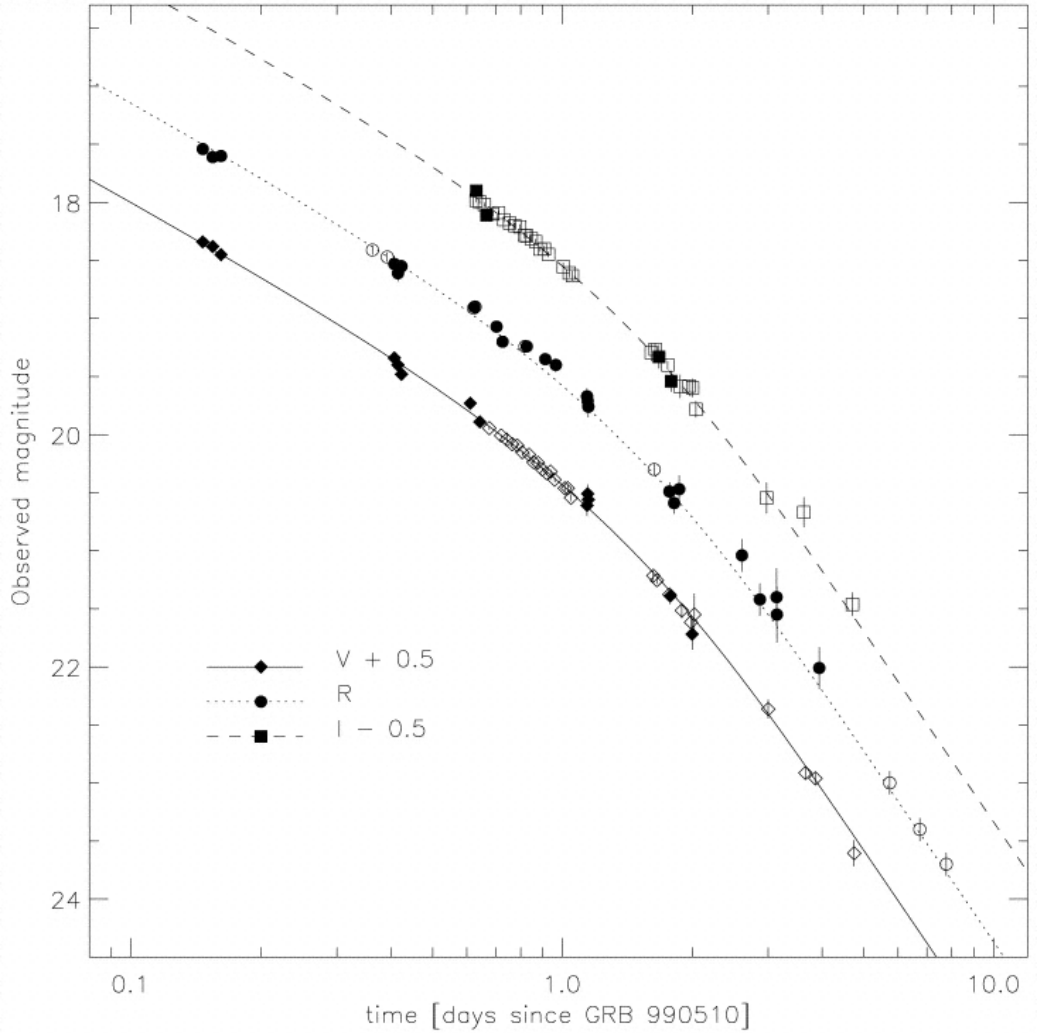
Blastwave model



Internal shocks - bursts

External shocks - afterglows

Afterglow lightcurve breaks

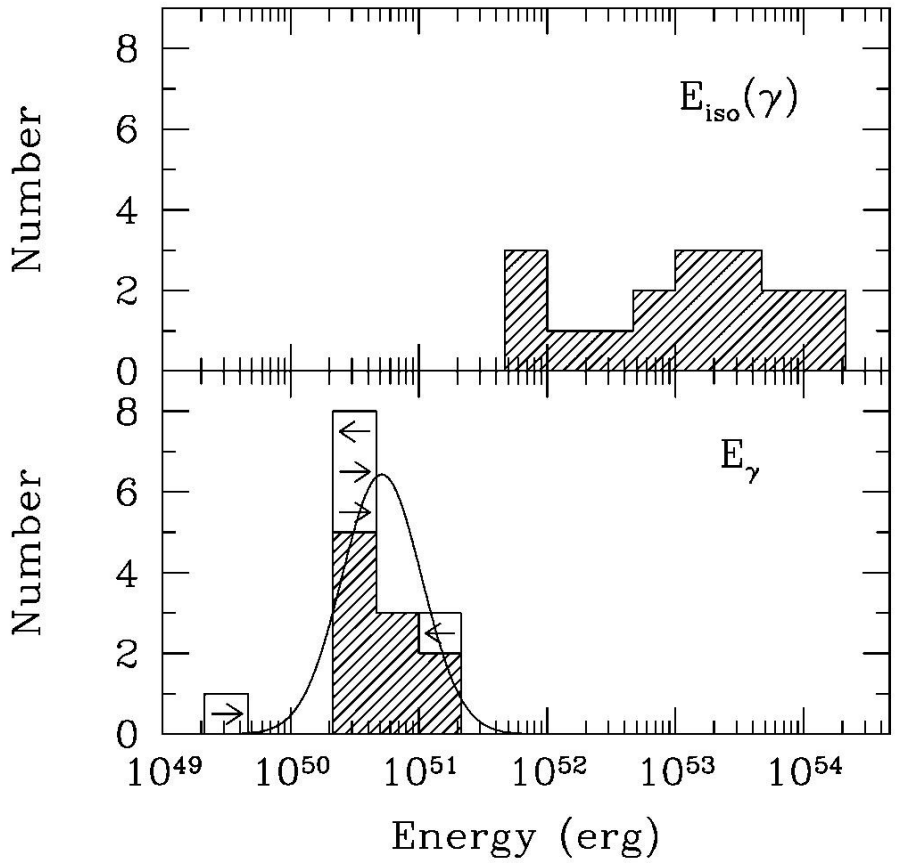


$$\Gamma = 1/\Theta$$

Achromatic breaks

$$t = 6.2 (E_{52}/n_1)^{0.33} (\Theta_0/0.1)^{2.66} h$$

Brightness distribution



Collimation corrected

- a nearly standard energy source

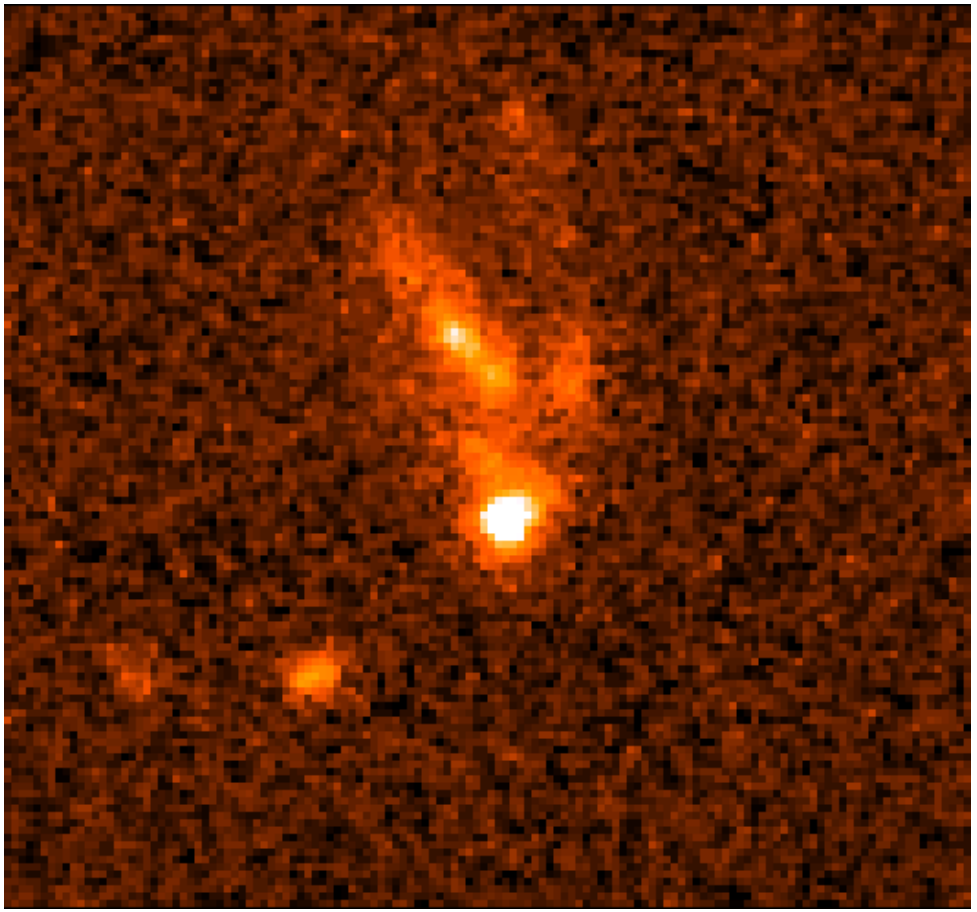
Basic properties - summary

- Distance: z=1-2
- Peak enrgy 300keV
- Brightness: $E = 10^{51} - 10^{54}\, erg$
- Duration: $0.01 - 10^{3}\, s$
- Collimation: $\Theta = 5^{o}$
- Rate: a few per day (observed), or about 1000/d

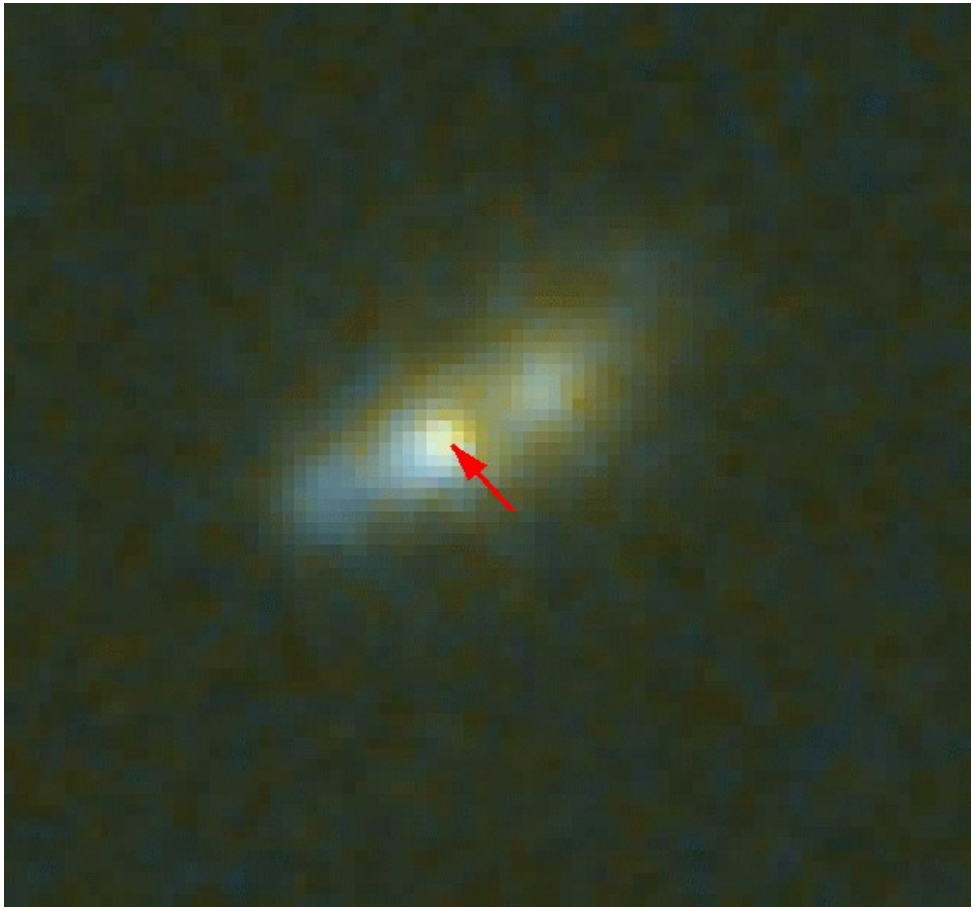
Objects responsible for bursts

- Compact object mergers:
  - Two neutron stars
  - Black hole and a neutron star
- Collapsars
- Magnetar collapse

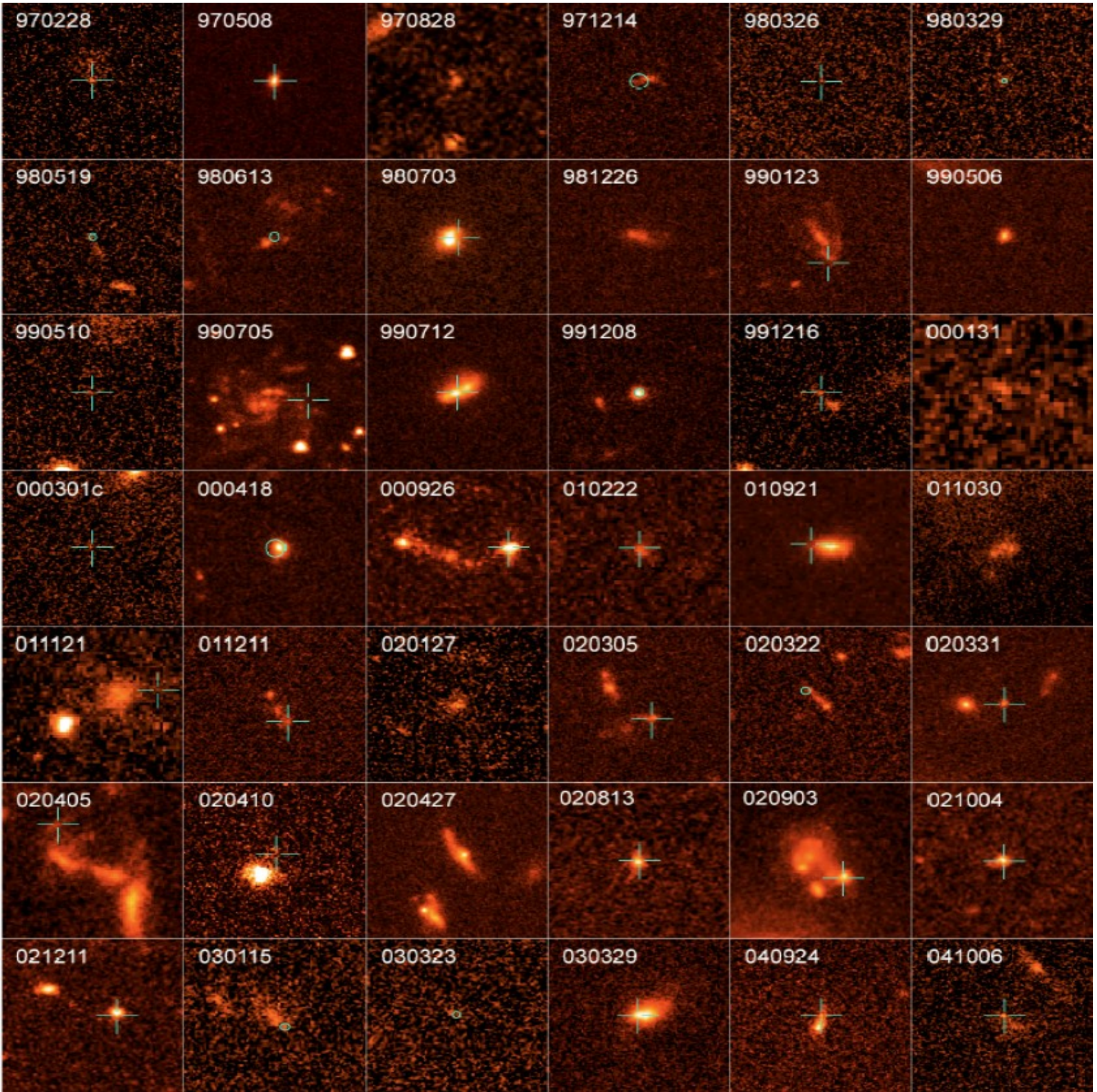
Location in host galaxies



GRB990123



GRB 990712



Fruchter (2006)

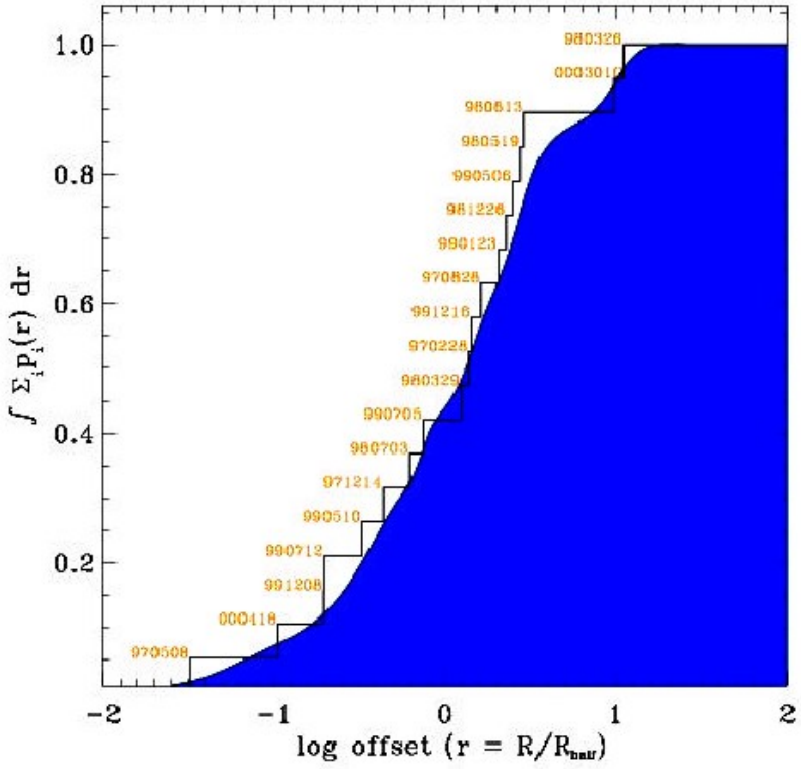
GRBs

and

Star formation

Host galaxies

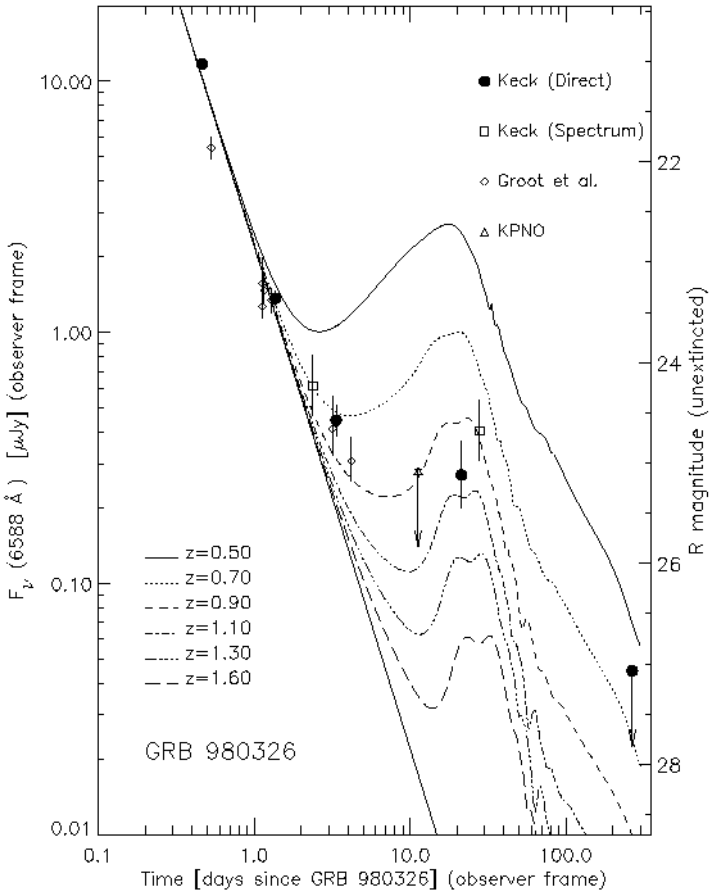
- Typical for their redshifts
- Active Star formation
- GRBS inside galaxies !
- Distribution in galaxies:
- Better correlation than SNe



GRBs and supernovae

SN 1998bw in Spiral Galaxy ESO184-G82

ESO PR Photo 39a/98 (15 October 1998)



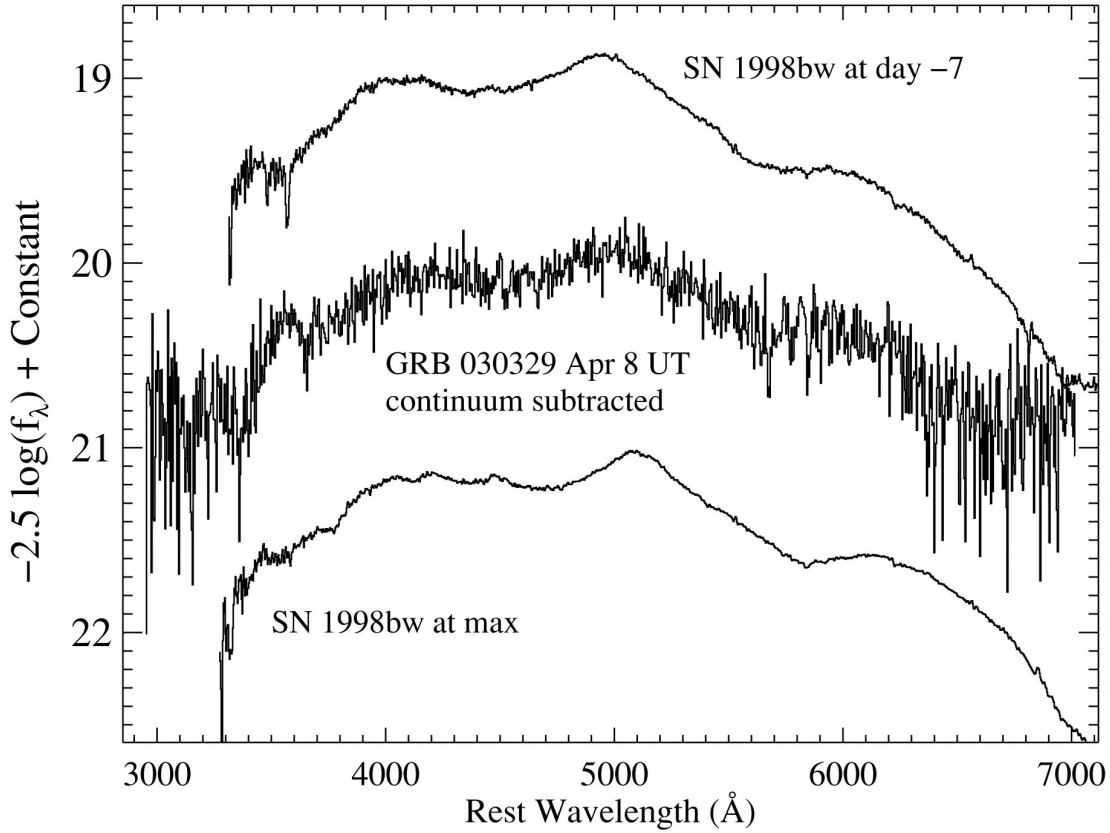
1998bw GRB980425

$L = 10^{46} erg\ ,\ z = 0.008$

Bloom et al 99

GRB 980326

Supernovae



Stanek et al 2003

GRB 030329

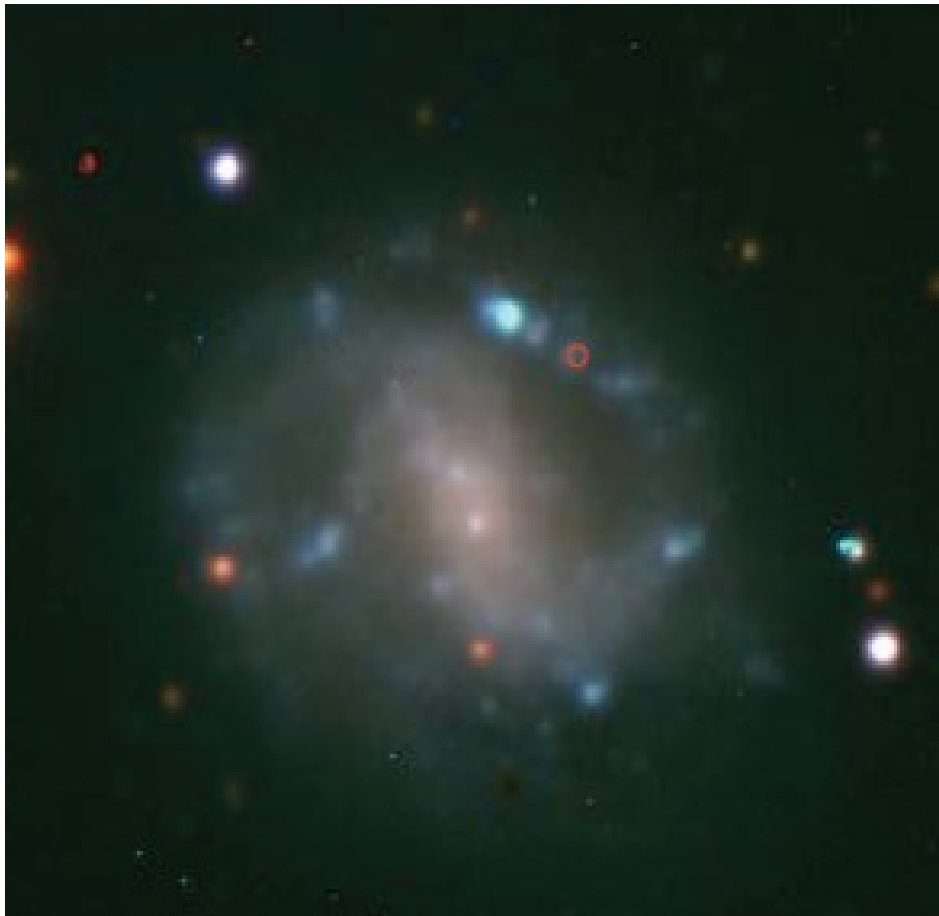
and a Ic supernova

Are all GRBs connected with supernovae?

Are they simultaneous?

But

- We see long GRBs with no SNe
- GRB060614, GRB060505

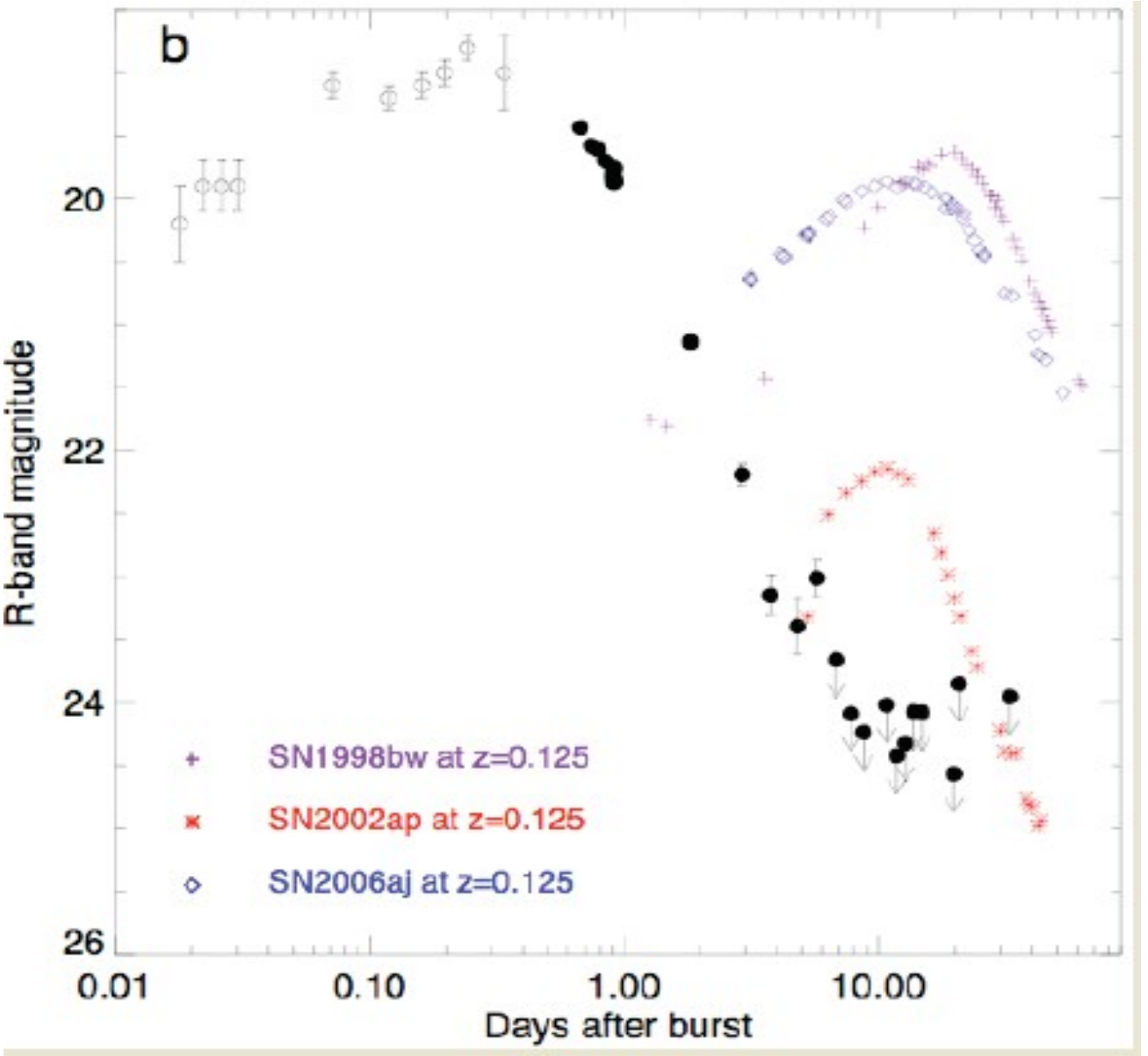


GRB 060614

Host galaxy redshift z=0.125

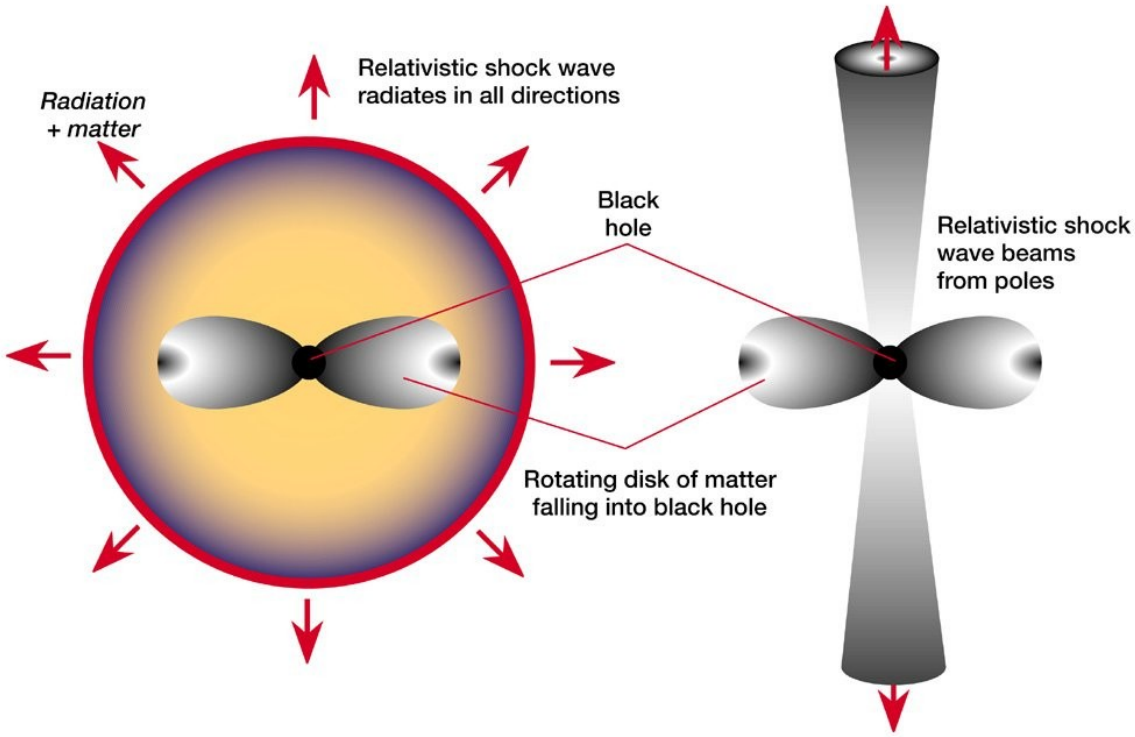
Brightness 5 mag less than expected

GRB in star formation region



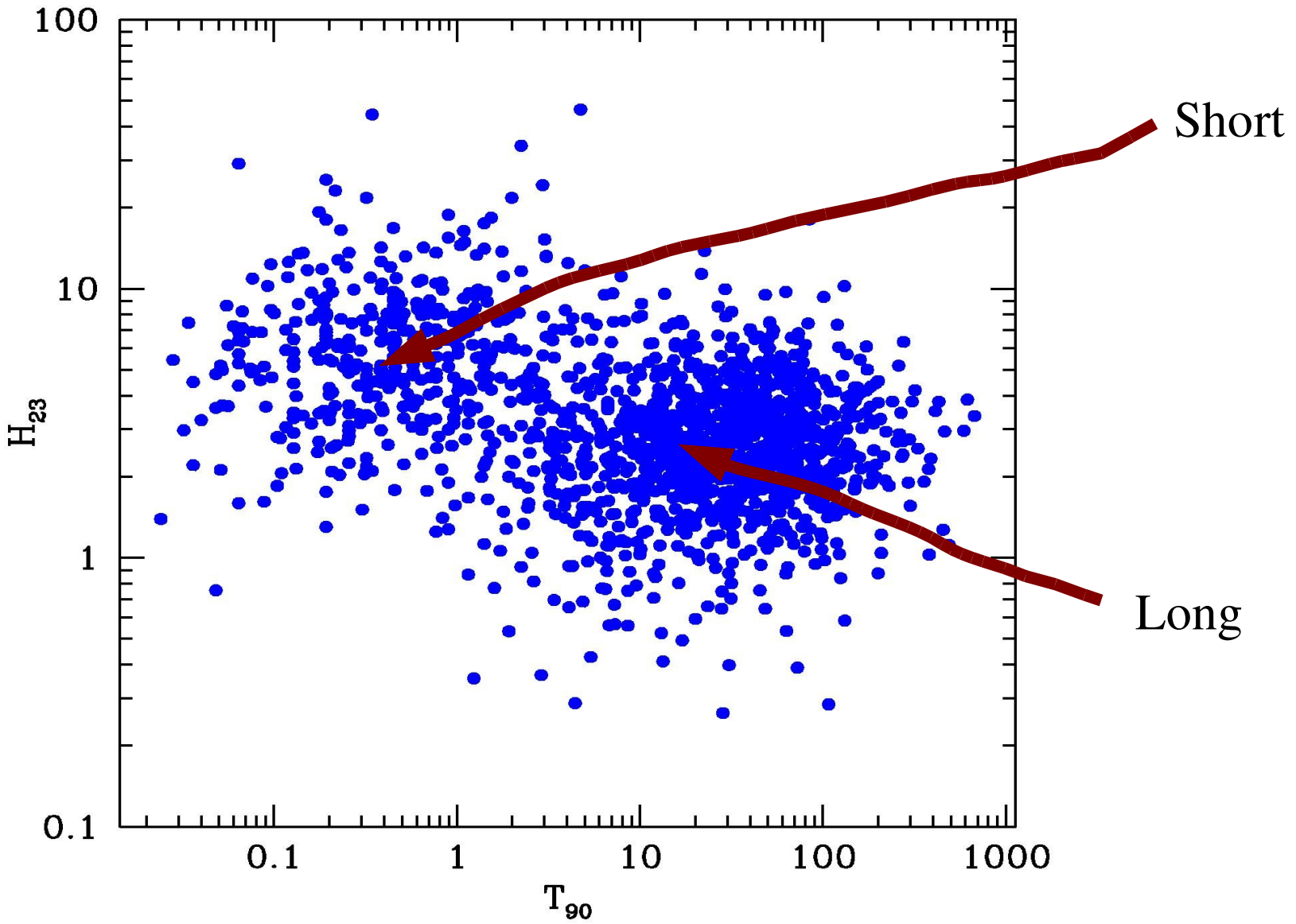
Collapsars

- Massive star collapse
- Rotatting black hole
- Dense matter torus
- Relativistic outflow



Movie

Hardness - duration

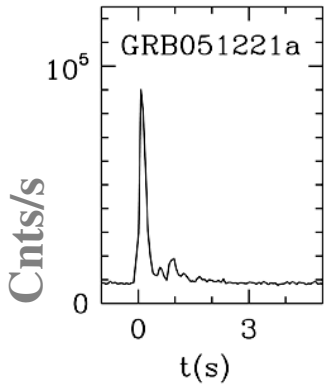


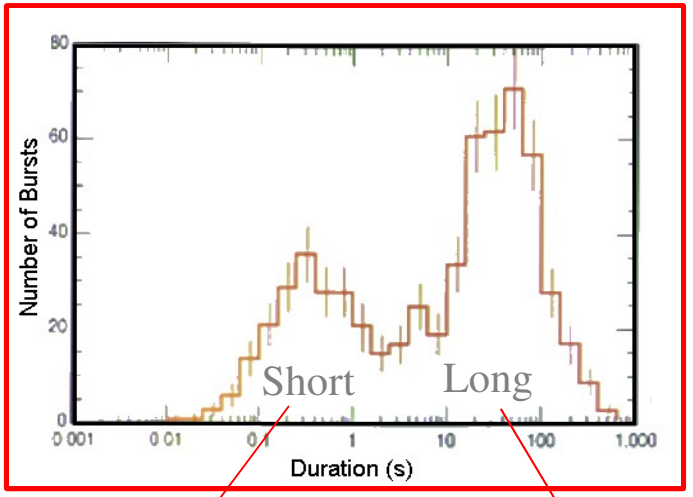
Short bursts

- Different population?
- Different objects?
- In or out of galaxies?
- Afterglows?

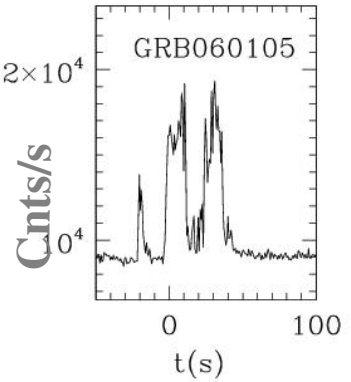
Short vs Long GRBs

Short GRB



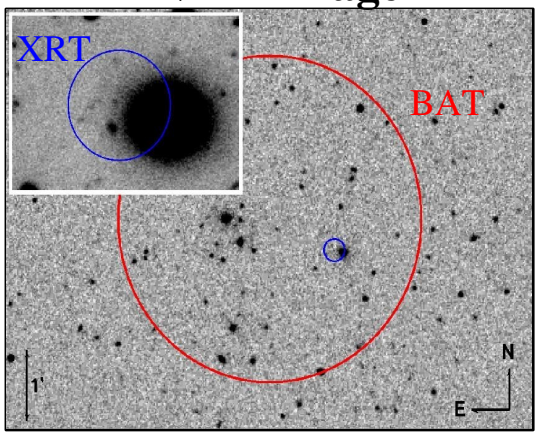


Long GRB

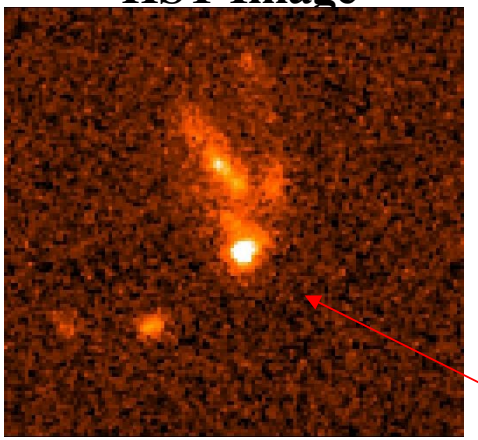


Swift first to discover counterpart to short GRB!

GRB 050509B - Swift VLT Image



GRB 990123 - BeppoSAX HST Image

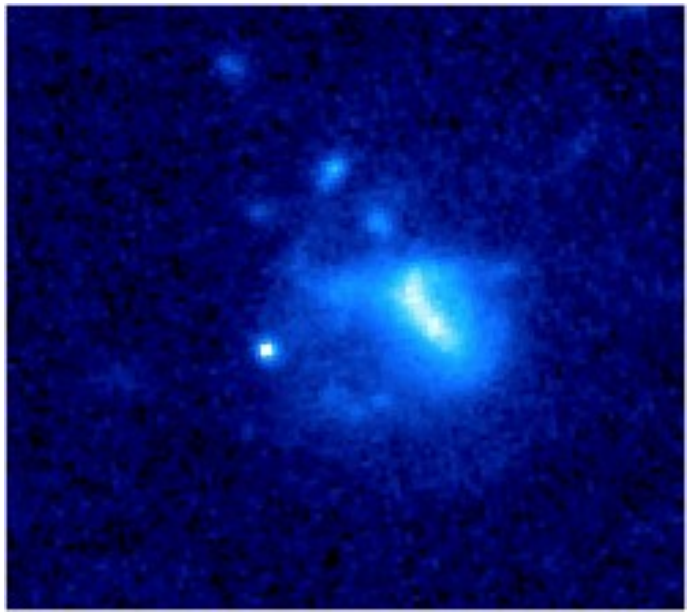


GRB

Short GRBs in non-SF galaxies/regions

Long GRBs in SF galaxies

GRB 050709



Fox et al.

z = 0.161

SF galaxy, but in dark region

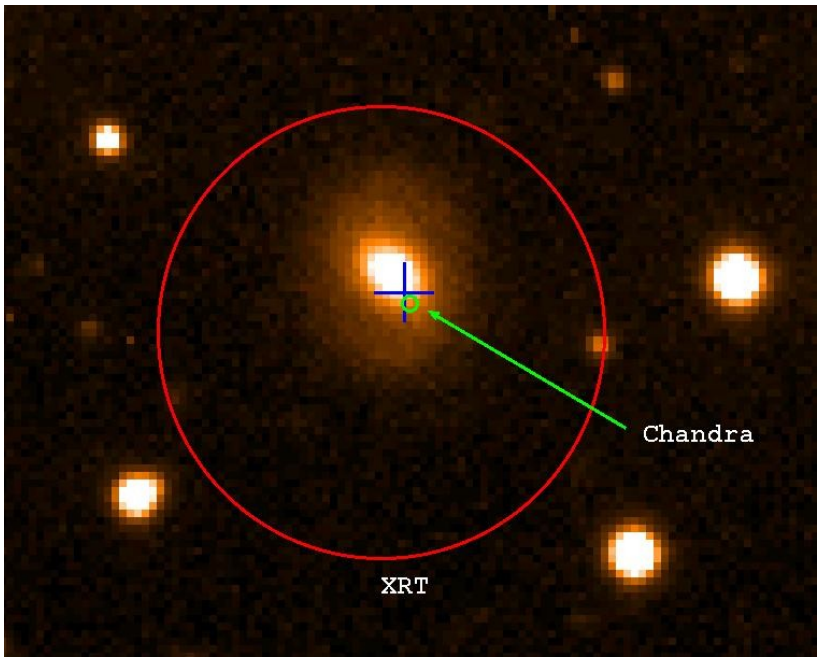
XT - XRT, Chandra

OT - ground-based, HST

No supernova seen

HETE-2 Villasenor et al. 2005

GRB 050724



z = 0.258

Elliptical host galaxy

XT - XRT, Chandra

OT - ground-based

RT - VLA

Barthelmy et al. 2005

Short GRB Summary Table

Name	Redshift	Afteglow	Host	E_{iso} (10^{50} erg)	Duration (s)	Temporal Lag (ms)	Extended ?	Origin /Comment
050509B	**0.225**	**X**	**elliptical@**	**~0.06**	**0.03**	**4.3±3.2**	**N**	**low SF region**
050709*	**0.161**	**X, O**	**SF galaxy**	**0.6**	**0.07**	**0.0±2.0**	**Y**	**low SF region**
050724	**0.258**	**X, O, R**	**elliptical**	**~4.7**	**3.0**	**-2±6**	**Y**	**low SF region**
050813	**? 0.7, 1.8**	**X**	**galaxy**	**2 - 17**	**0.60**	**-9.7±14?**	**N**	**-**
050906	**0.03?**	**-**	**? galaxy**	**0.001?**	**0.13**	**-**	**N**	**BAT only**
050911	0.165?	late slew	cluster@	0.9?	16	-20±20?	Y	is it short?
050925#	**-**	**-**	**in gal. plane**	**-**	**0.07**	**-**	**N**	**non-GRB?**
051105A	**-**	**-**	**-**	**-**	**0.03**	**6.3±5.3?**	**N**	
051210	**0.11?**	**X**	**? cluster@**	**0.1?**	**1.4**	**-1.0±16.0?**	**N**	**-**
051221A	**0.547**	**X, O, R**	**SF galaxy**	**31.**	**1.4**	**0.0±0.4**	**N**	**-**
051227	**-**	**X**	**-**	**-**	**0.9**	**2±10?**	**Y**	**-**
060121*	**>1.5**	**X, O**	**galaxy**	**-**	**2**	**2±29?**	**N**	**-**
060313	**-**	**X, O**	**? cluster@**	**-**	**0.7**	**0.8±0.6**	**N**	**-**
060502B	**0.287?**	**X**	**? elliptical**	**0.1?**	**0.09**	**-4.0±3.0**	**N**	**-**
060505	0.089	X, O	galaxy	~0.5	4.0	n.a.	?	is it short?
060614	0.125	X, O	dwarf gal.	3.7	103 (5)	3±6	Y	is it short?
060801	**1.131**	**X**	**galaxy?**	**~13**	**0.5**	**8±8?**	**N**	**-**

* = HETE GRB

= not spectrum.

@ galaxy in cluster

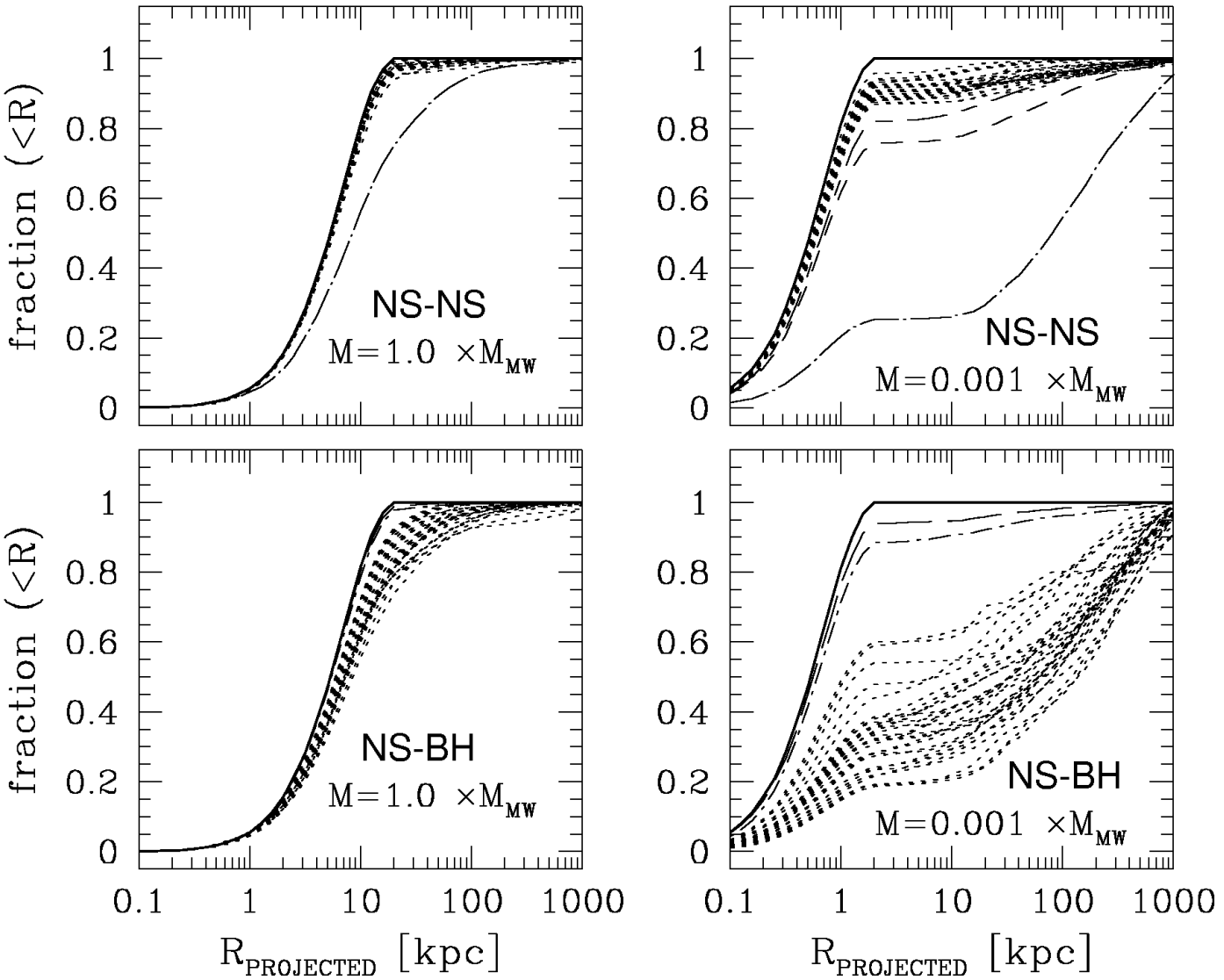
Data assembled by Neil Gehrels

Compact object coalescences

- Double neutron stars (or BHNS)
- Velocities
- Distribution around galaxies
- Different host types
- Delay between SFR and GRB

Movie

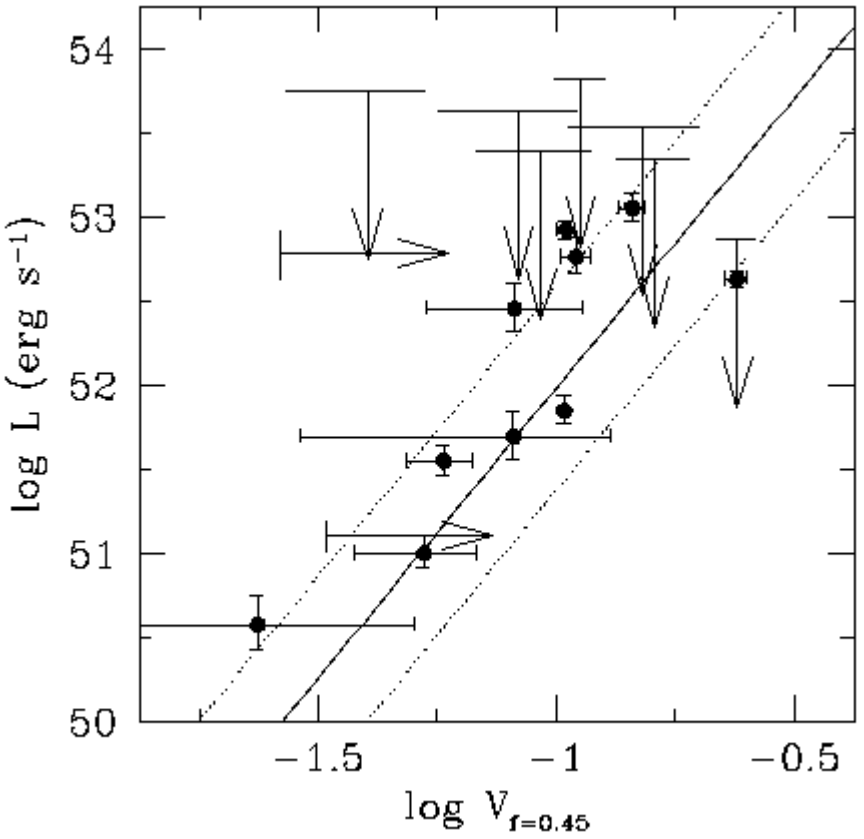
Expected distribution around galaxies



Belczyński
Bulik Rudak

????

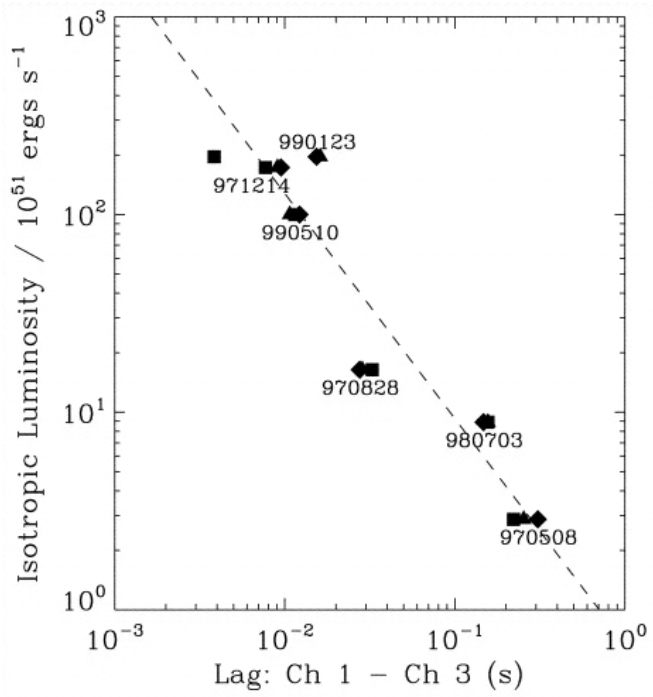
Funny correlations

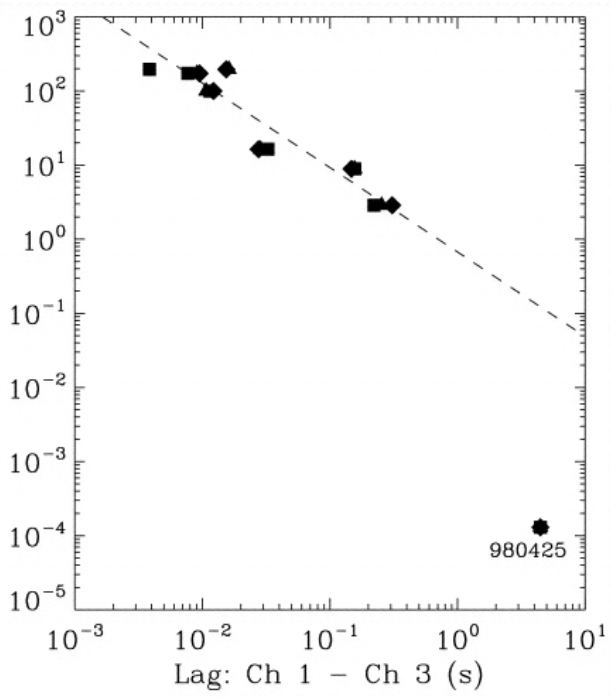


- Brightness - variability
- Lag - luminosity

Reichart etal 2001

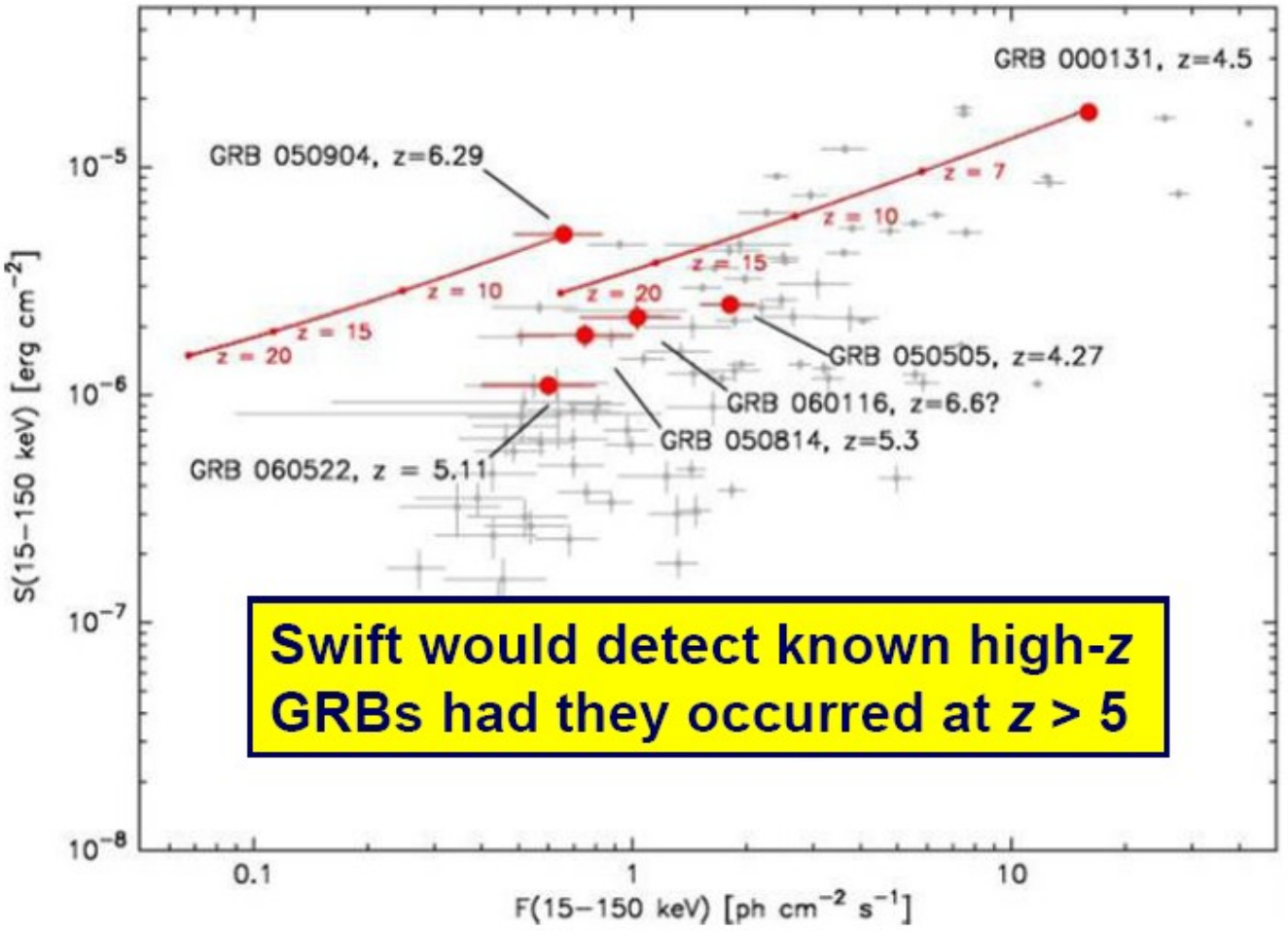
Do we see bursts
from z=10-30 ???





Norris etal 2001

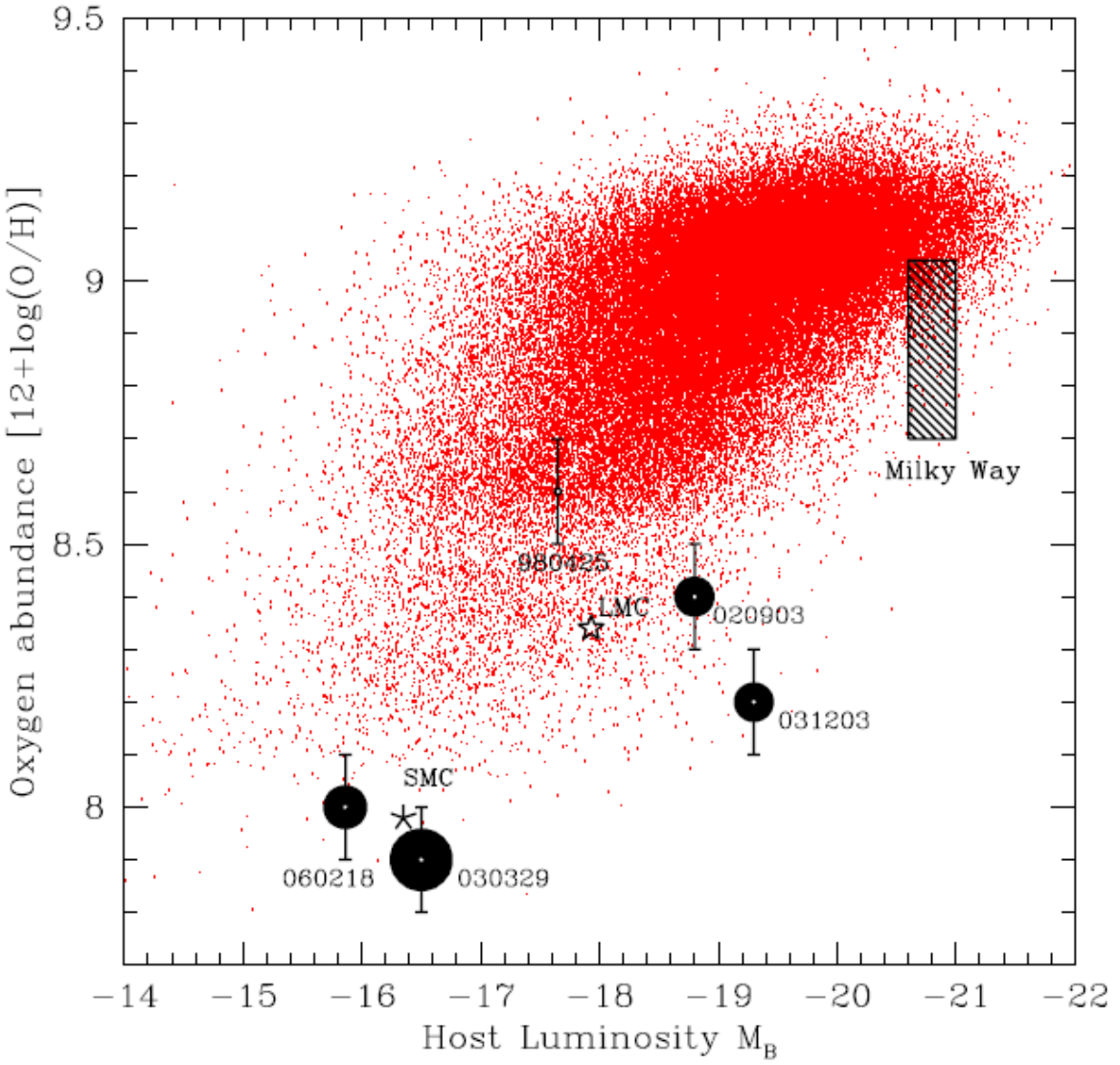
Early Universe



Lamb - 2006

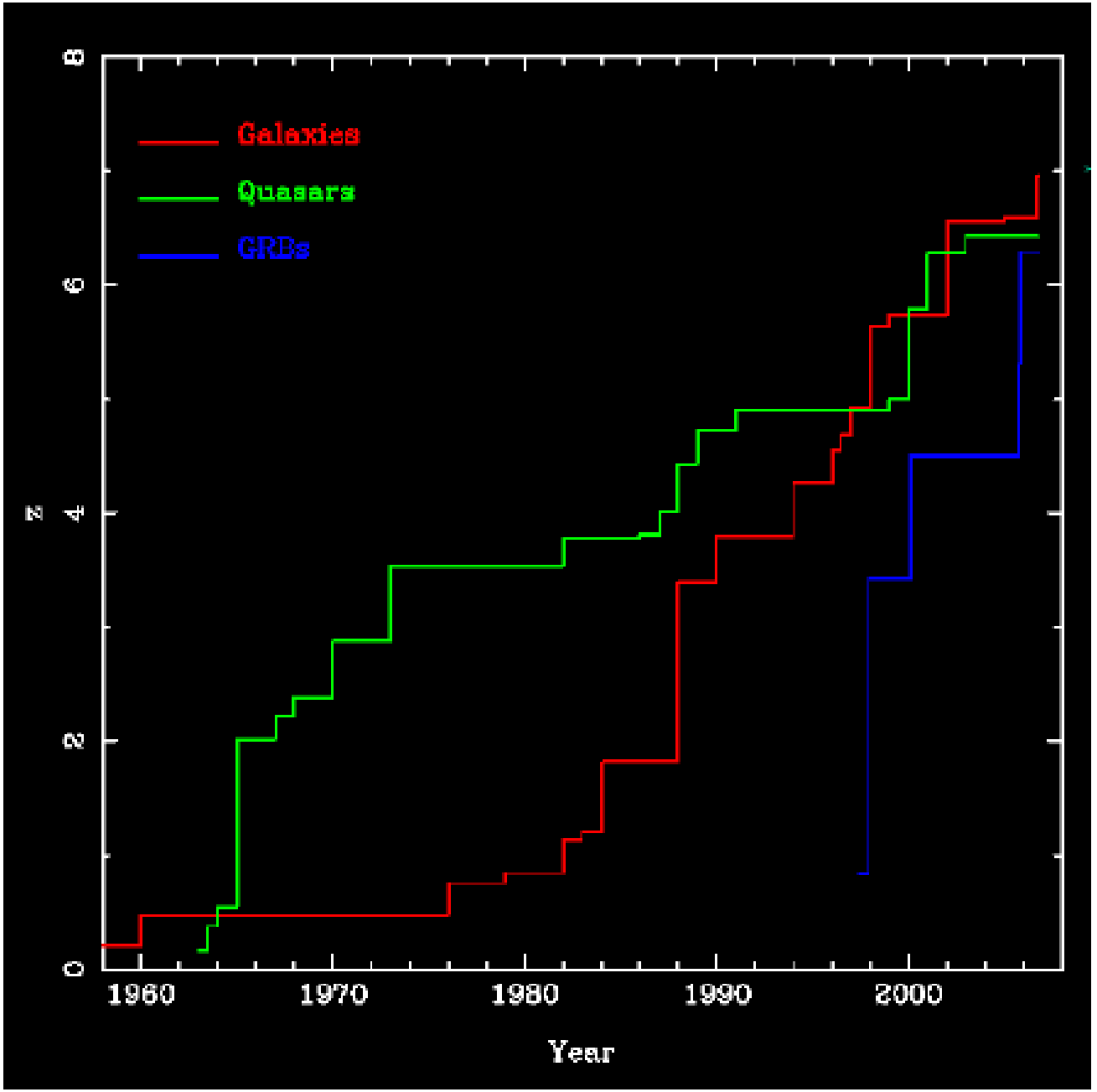
Population III?

GRBS connected
to low metallicity regions



Stanek et al 2006

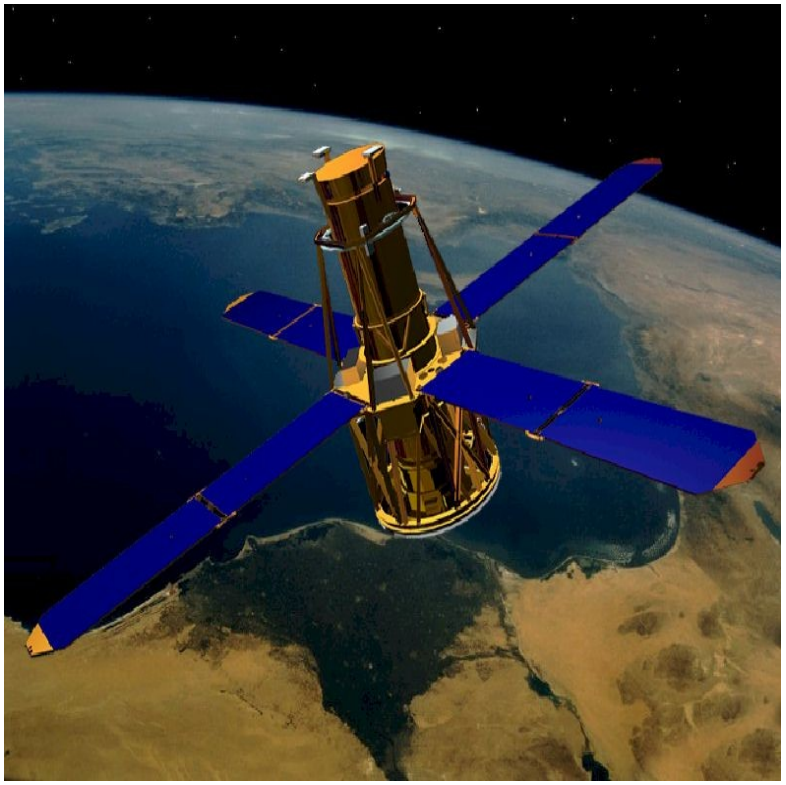
The high z race



Tanvir 2006

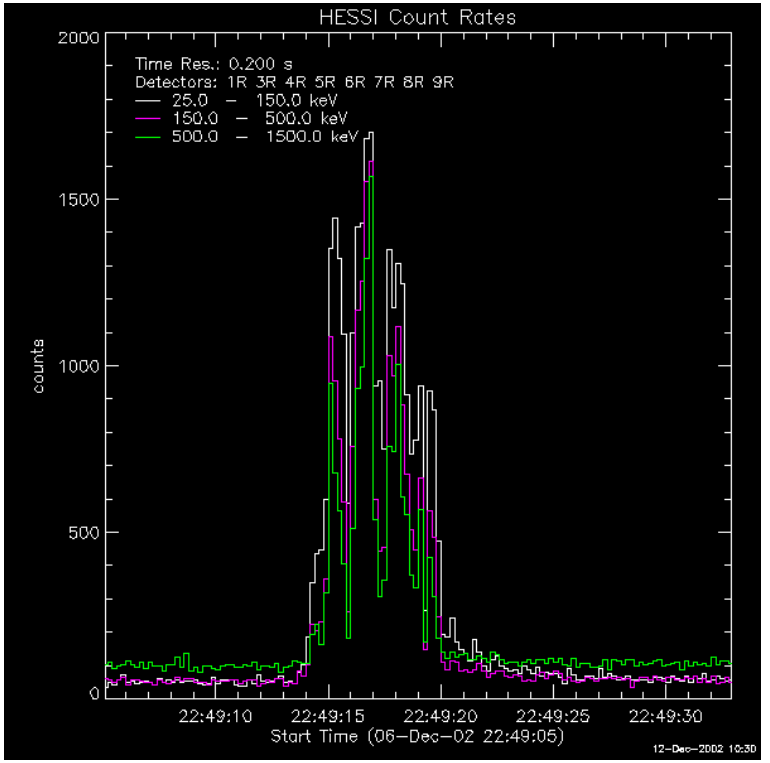
GRB polarization ?

$$\Pi = 80 \pm 20 \ \%$$



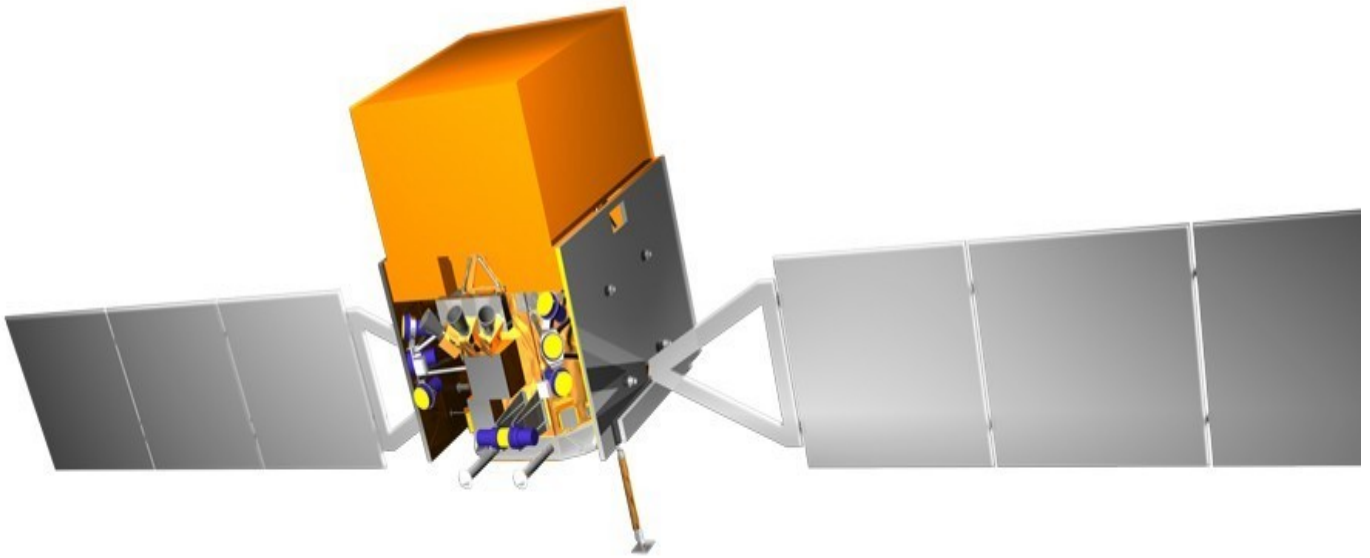
RHESSI

GRB 021206



Future

GLAST

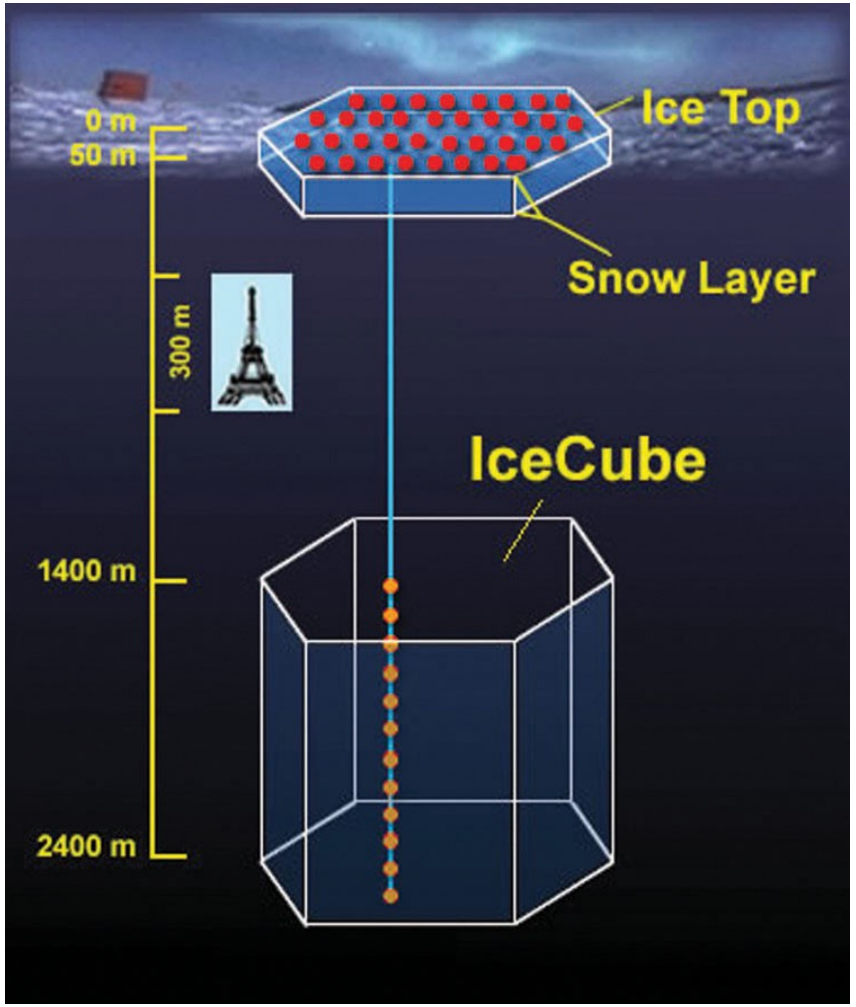


GBM – sensitive to GRBS 5keV – 25MeV

LAT – between 20MeV – 300GeV

Launch – 2007

Neutrina



- AMANDA
- Icecube
- NESTOR
- ANTARES

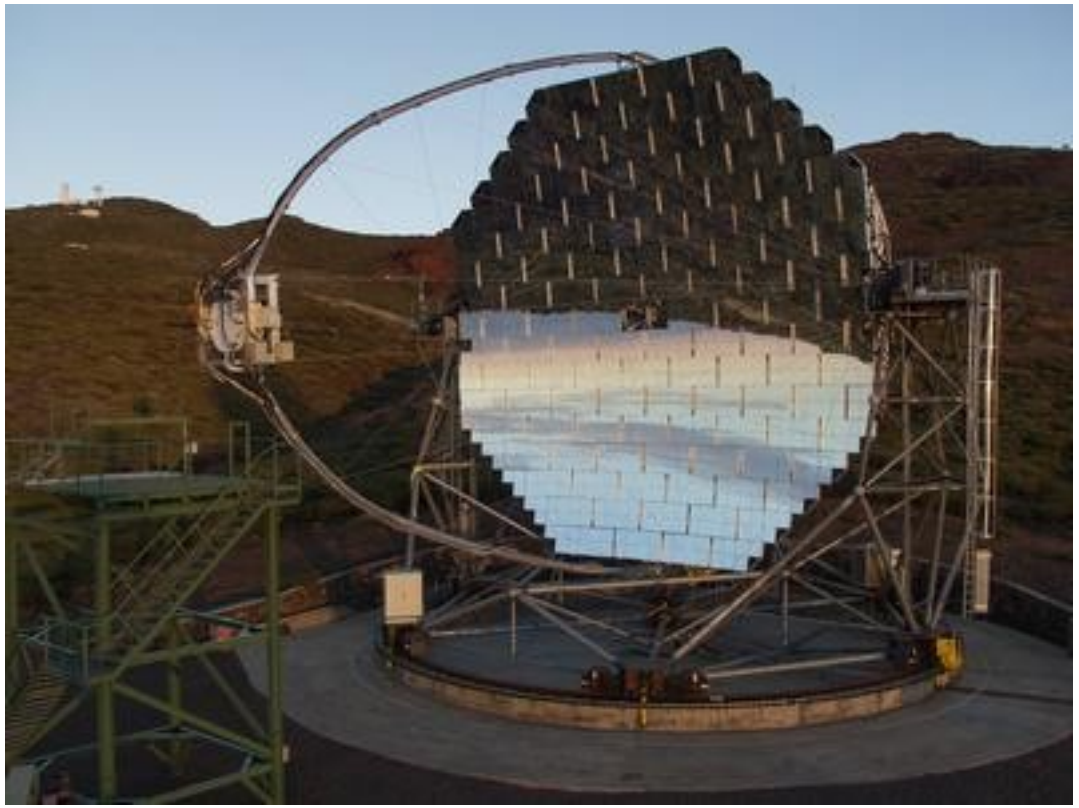
Fast protons – muon decays – neutrinos

Precursors from collapsars

Gravitational waves

- LIGO
- VIRGO

High energy photons



MAGIC

HESS