# GRB Observations and GLAST

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NASA-GSFC

GLAST Symposium

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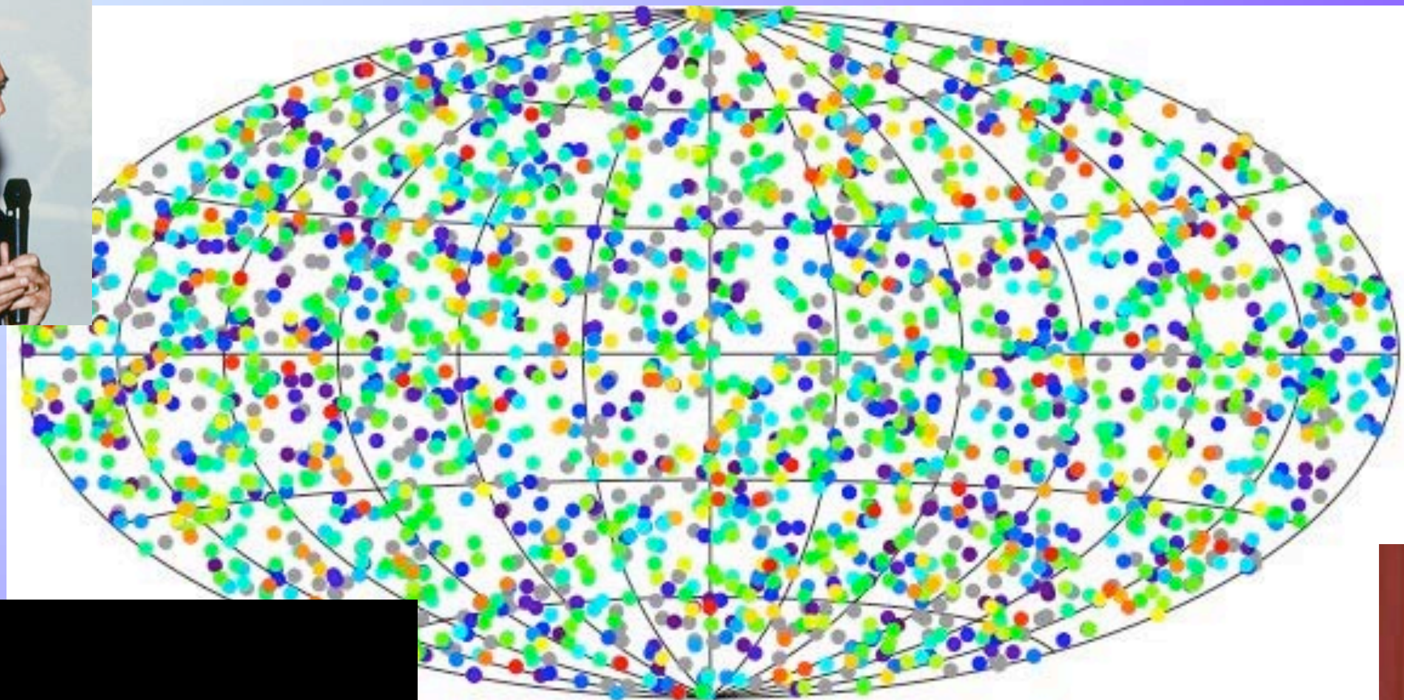
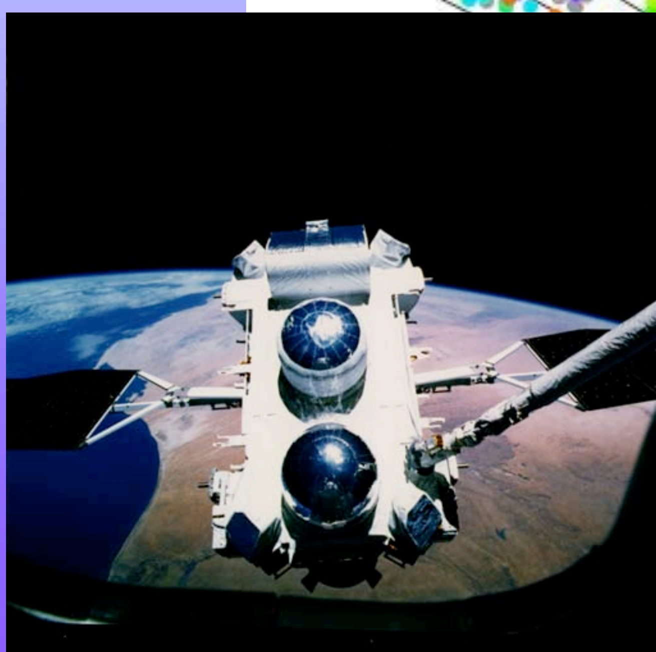
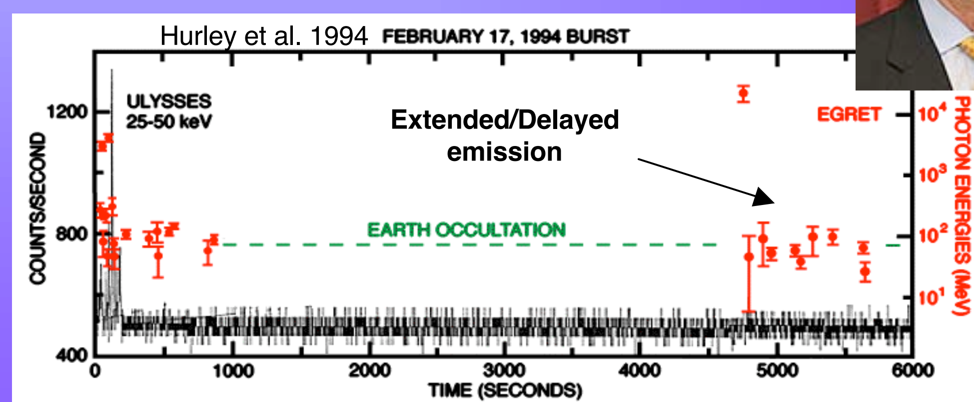
**Outline**

- Latest results on GRBs
- High energy emission from GRBs
- Capabilities of GLAST

# Compton Observatory Era

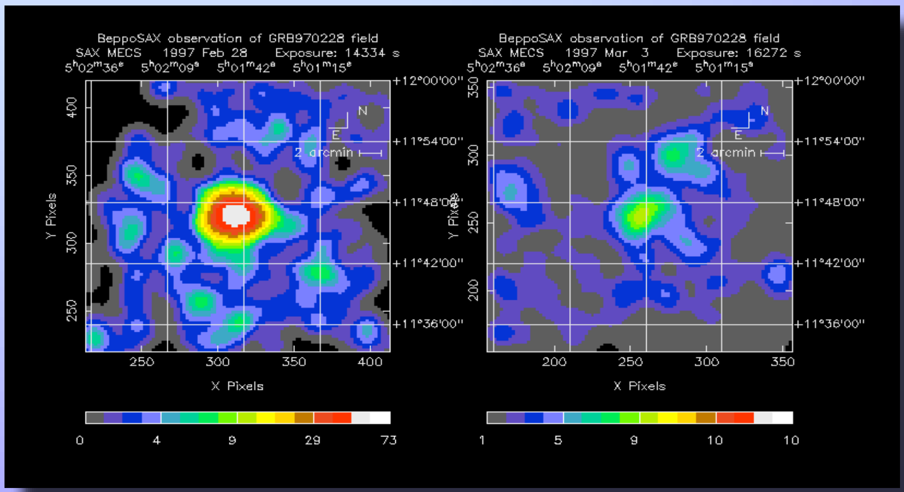






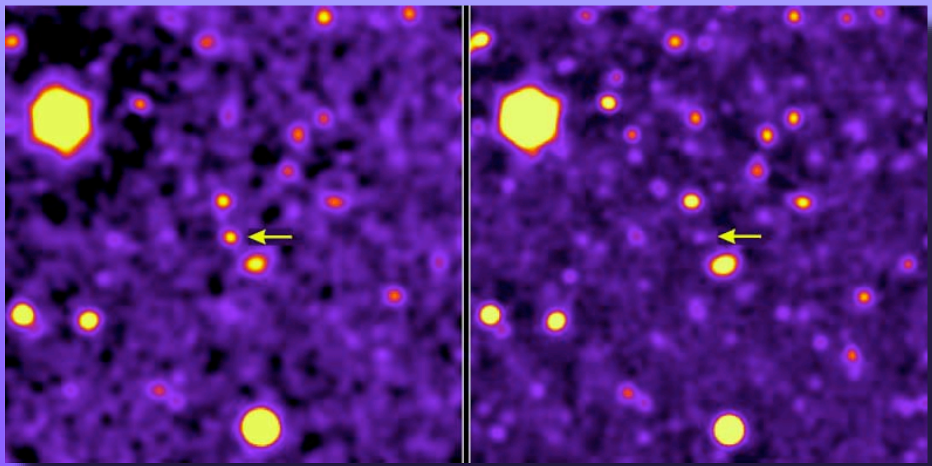

# Beppo-SAX & HETE-2 Era

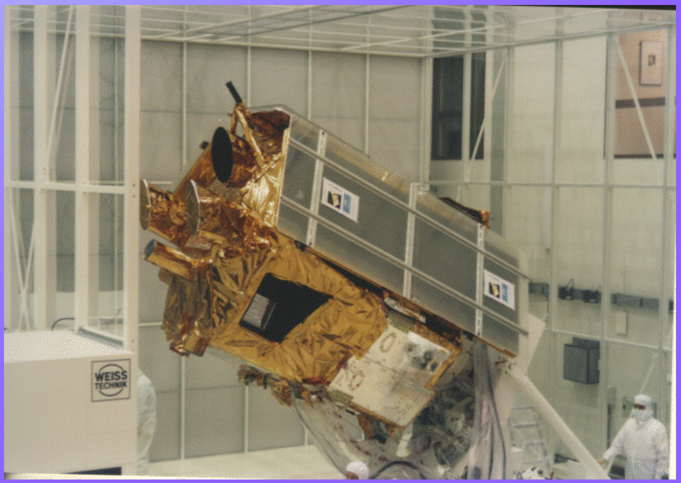
**GRB 970228 - BeppoSAX**



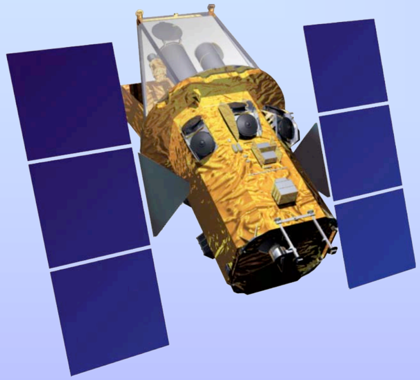

- ⇒ GRBs in distant galaxies
- ⇒ Collimated outflows with $\Gamma > 100$
- ⇒ Energy $\sim 10^{51}$ ergs in $\gamma$-ray flash
- ⇒ Origin related to black hole birth

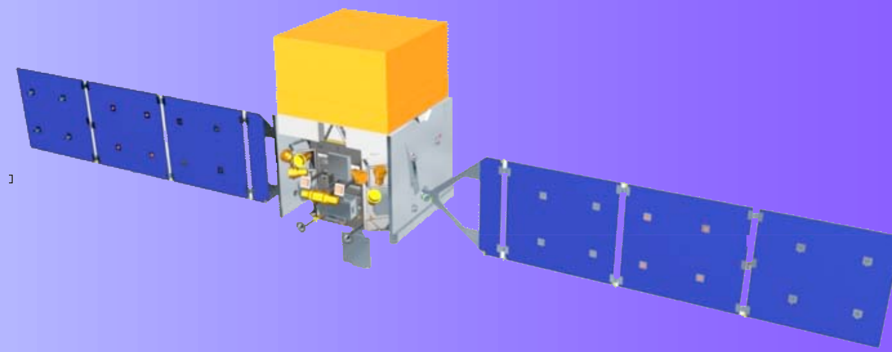
**GRB 971214 - Keck**





# Swift - GLAST Era





**Prompt:**

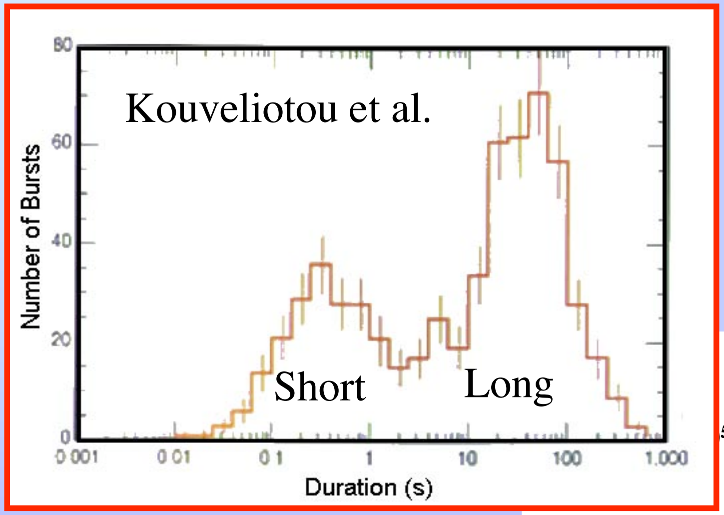
- hundreds of GRBs
- 10 keV - 100 GeV
- Versatile GRB triggers
- Accurate rapid positions

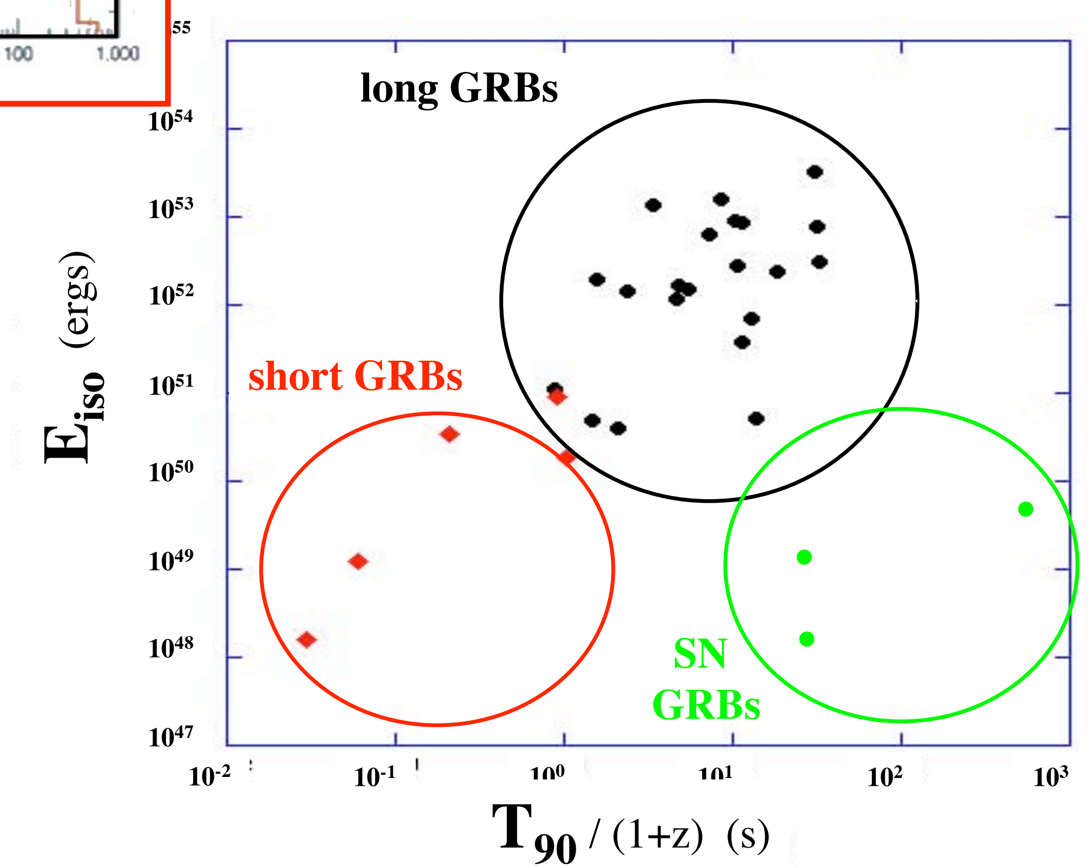
**Follow-up**:

- Swift XRT & UVOT
- 10's of dedicated telescopes
- 8 m telescopes with rapid response
- spectrographs typically available
- IR coverage
- HST, Chandra, XMM, Spitzer
- radio: VLA upgrade, ALMA coming
- neutrino detectors coming on-line
- grav. wave interferometers on-line

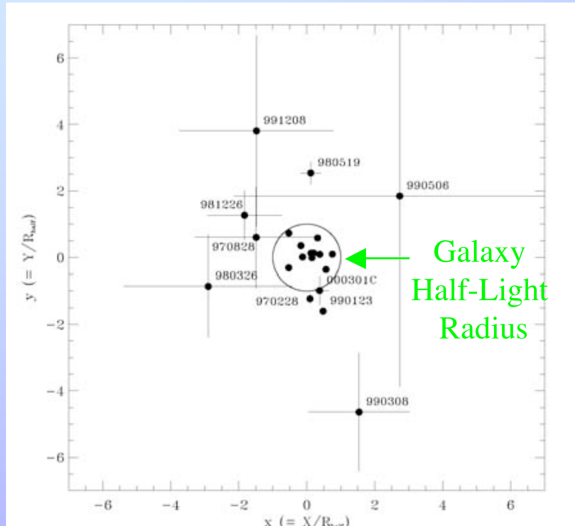
Swift & GLAST likely will be simultaneously in orbit for >10 years

# Classes of GRBs

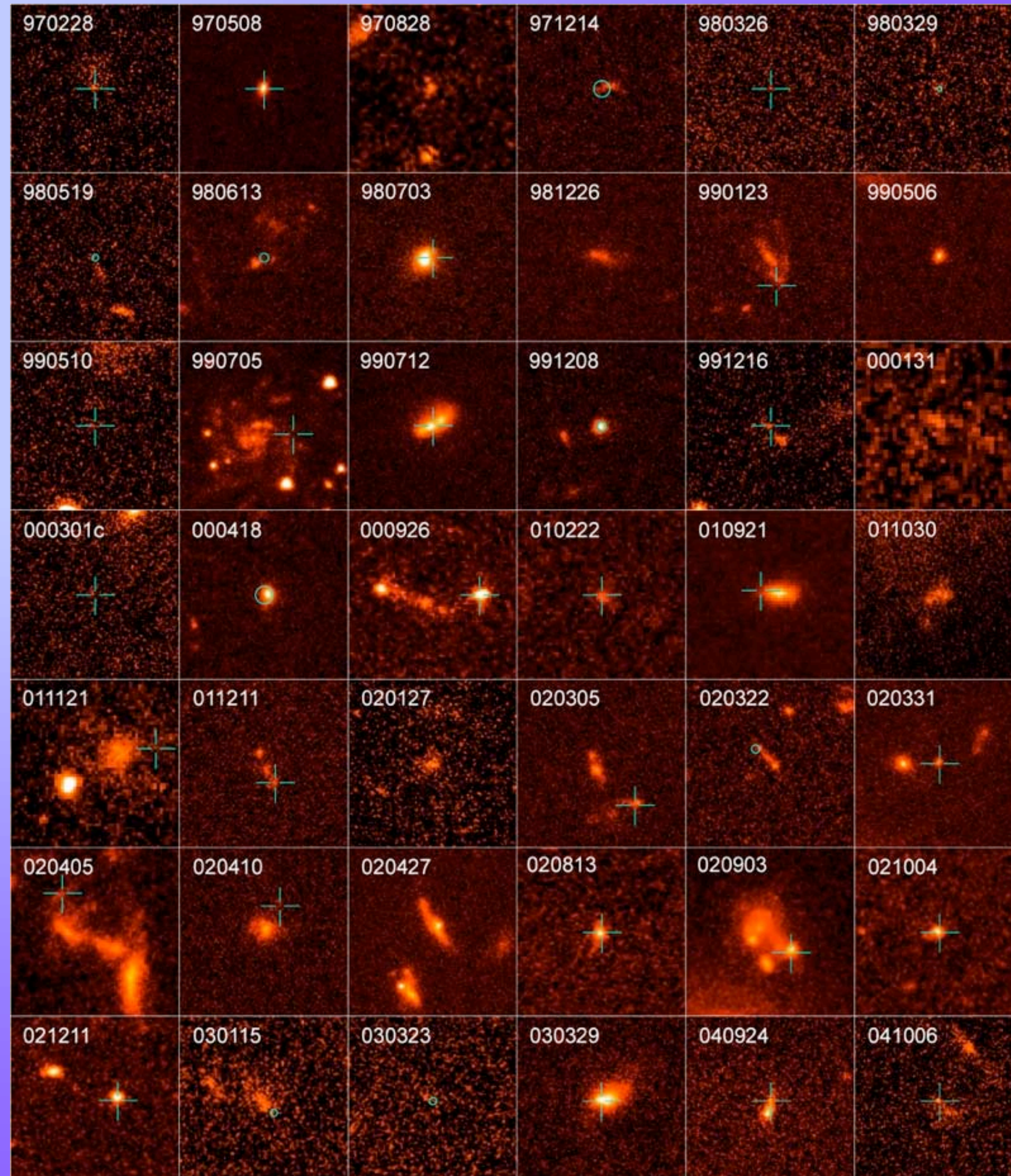


# Long GRB Hosts

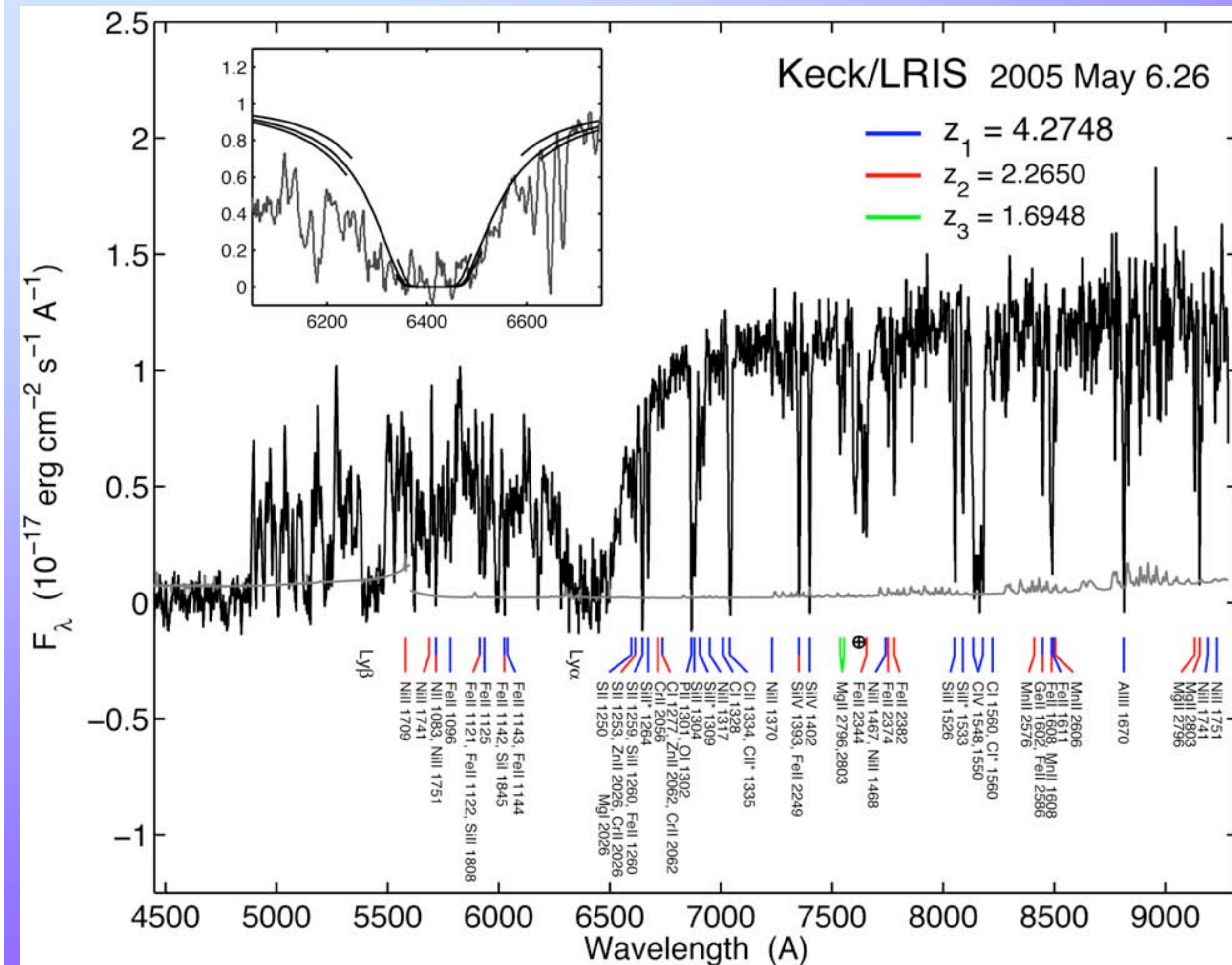



- Associated with SF galaxies
- Concentrated in regions of most massive stars
- Hosts are sub-luminous irregular galaxies
- Average redshift z~2.5 (Swift)




Fruchter et al. 2006

# Spectroscopy of Swift GRB 050505




$z = 4.275$

Damped Ly$\alpha$

N(HI)=$10^{22}$ cm$^{-2}$

n ~ $10^{2}$ cm$^{-3}$

$Z = 0.06\ Z_{\odot}$

$M_{progenitor} < 25\ M_{\odot}$

Berger et al. 2005

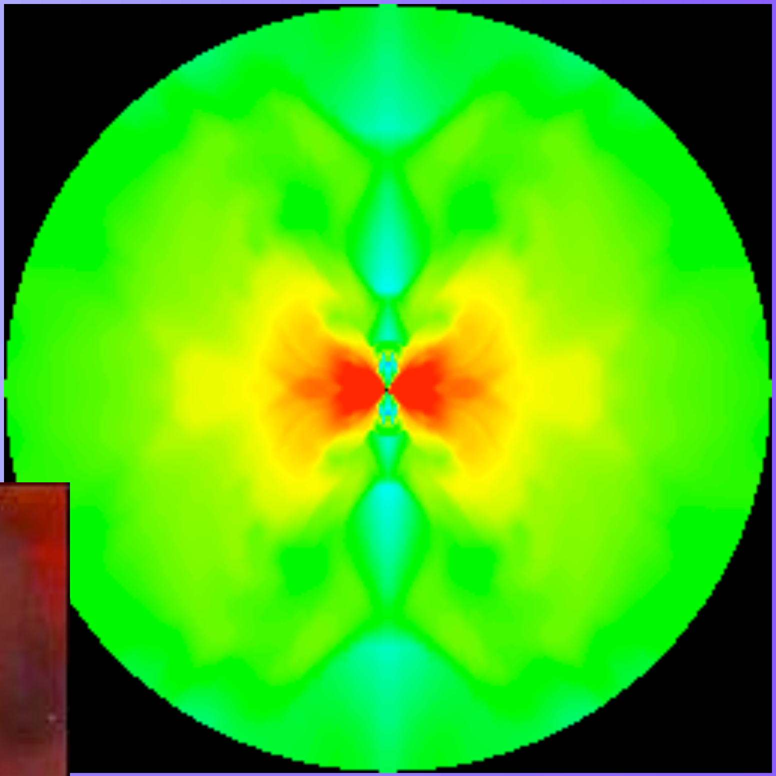
# Long GRB Summary

1) Massive star with core collapse to BH

2) Rotation required for jet escapce

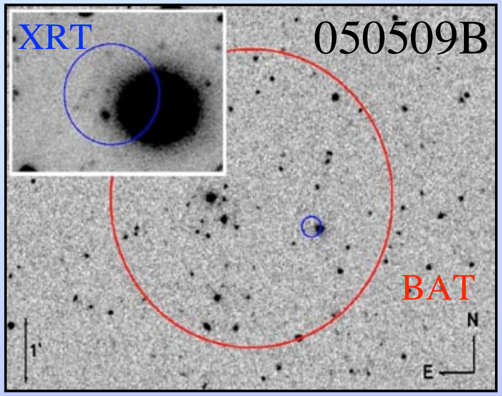
3) Low metallicity may be indicated
   - Tighter binding energy
   - Low winds to maintain rotation

Collapsar Jet Emergence



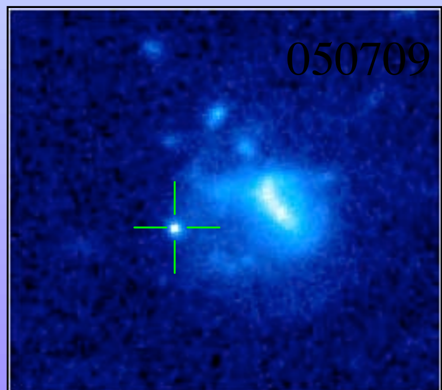

MacFadyen & Woosley

# Short GRBs

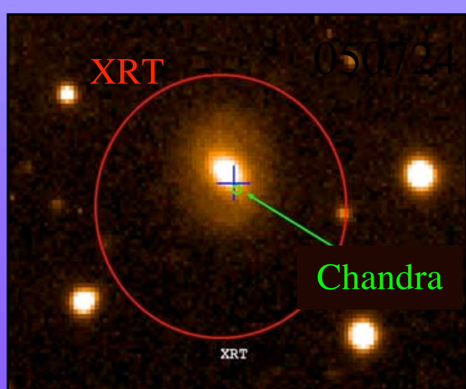



cD elliptical

SFR < 0.2 $M_O$ $yr^{-1}$




SF galaxy
with offset




elliptical

SFR < 0.02 $M_O$ $yr^{-1}$

- Associated with SF and non-SF galaxies

- Average redshift ~ 0.7

- Weaker X-ray afterglows than long GRBs (at $t_o$+90s)

  $< F_{short} > = 7 \times 10^{-10}$ erg $cm^{-2}$ $s^{-1}$

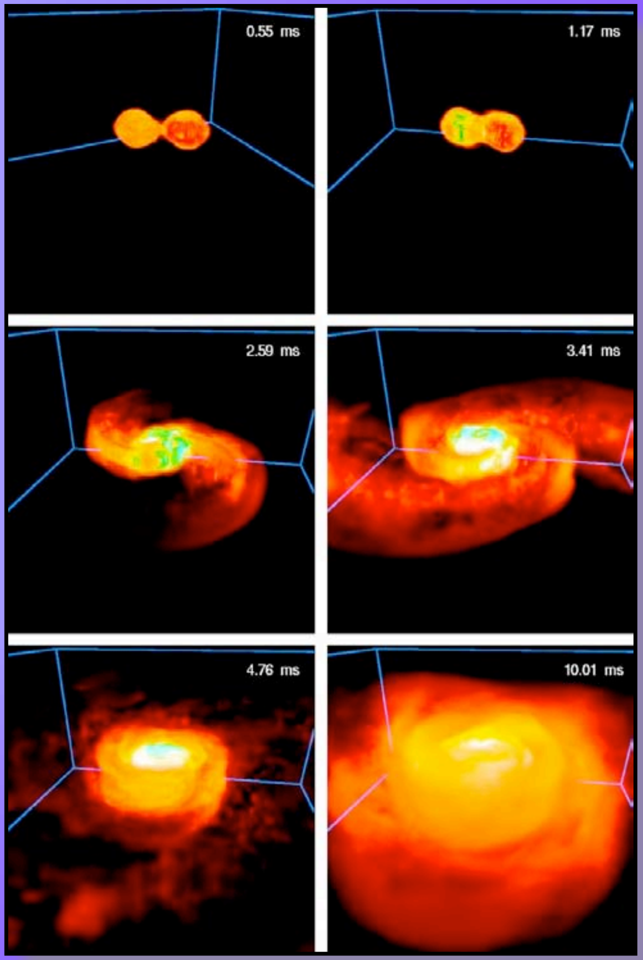
  $< F_{long} > = 3 \times 10^{-9}$ erg $cm^{-2}$ $s^{-1}$

# Short GRB Summary

1) Detections in non-SF galaxies ruled out hypernova model and support NS-NS merger model

2) Weak afterglow consistent with rarified medium around NS-NS merger

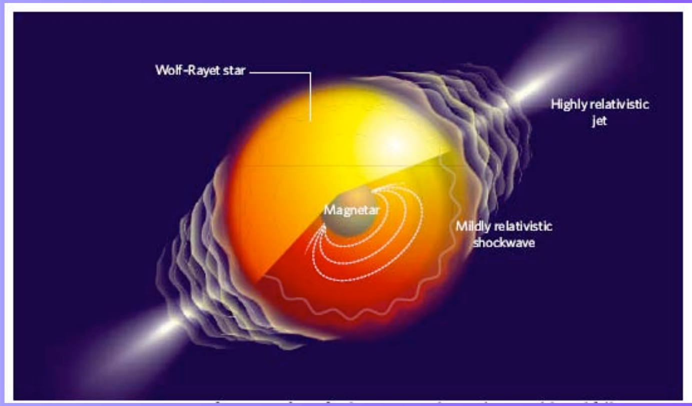
3) Lots of work remains to understand short burst population



# Supernova GRBs

Four nearby (z<0.1) GRBs have coincident SNe

GRB 980425 - SN 1998bw z=0.0085
GRB 030329 - SN 2003dh z=0.168
GRB 031203 - SN 2003lw z=0.105
GRB 060218 - SN 2006aj z=0.0331




Underluminous GRBs (E ~ $10^{49}$ erg)

SN I b/c type of supernovae

GRB trigger provides SN early warning

| Event Type | Rates (1/$Gpc^3$-yr) | Comments |
|---|---|---|
| SN II | 200,000 | |
| SN Ib/c | ~20,000 | (Guetta & della Valle) |
| GRBs | ~100 | (1000 $yr^{-1}$ to z=4, $\theta_b$=5˚) |
| Underluminous GRBs | 700 | (Soderberg et al.) |
| Short GRBs no beaming | 10 | (250 $yr^{-1}$ to z=0.5, $\theta_b$=4π) |
| Short GRBs with beaming | 300 | (250 $yr^{-1}$ to z=0.5, $\theta_b$=15˚) |
| Short GRBs with logN-logS | 100,000 | (Nakar et al.) |

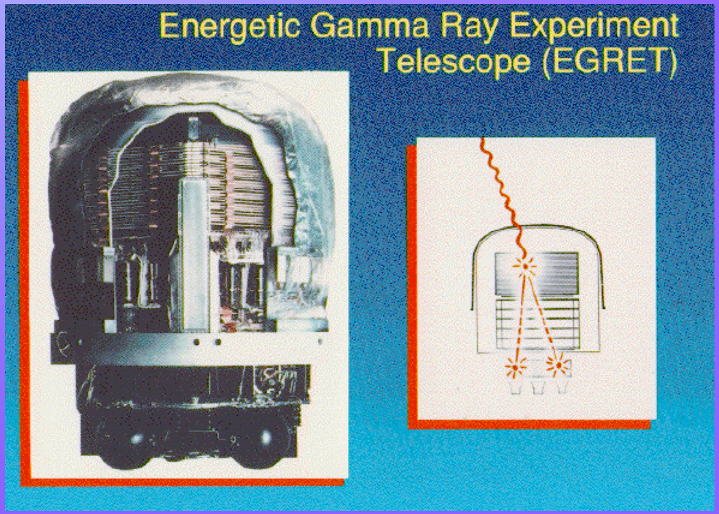
# High Energy Gamma Ray Emission

EGRET discovered >30 MeV emission from GRBs

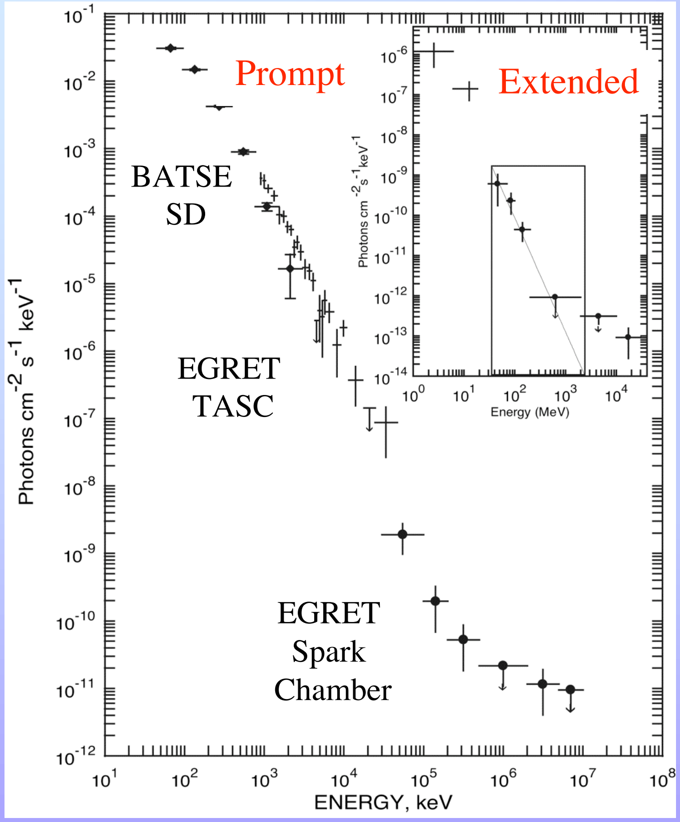
Five GRBs found with spark chamber EGRET events
in coincidence with a BATSE GRB

GRB 910503
GRB 910601
GRB 930131 - Queen Beatrix GRB
GRB 940217 - Hurley et al. extended emission
GRB 940301

4 long GRBs
perhaps, 1 short GRB



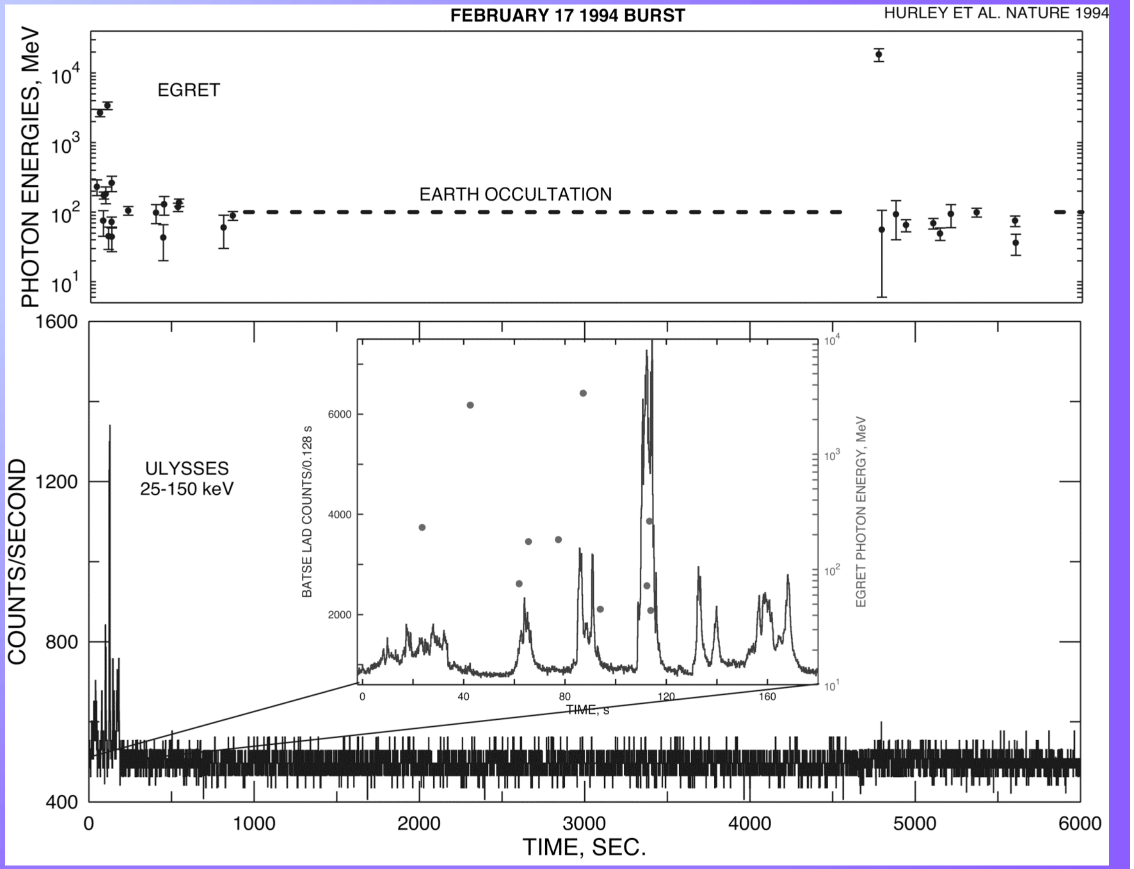
# Famous GRB 940217




$T_{90}$ = 150 s

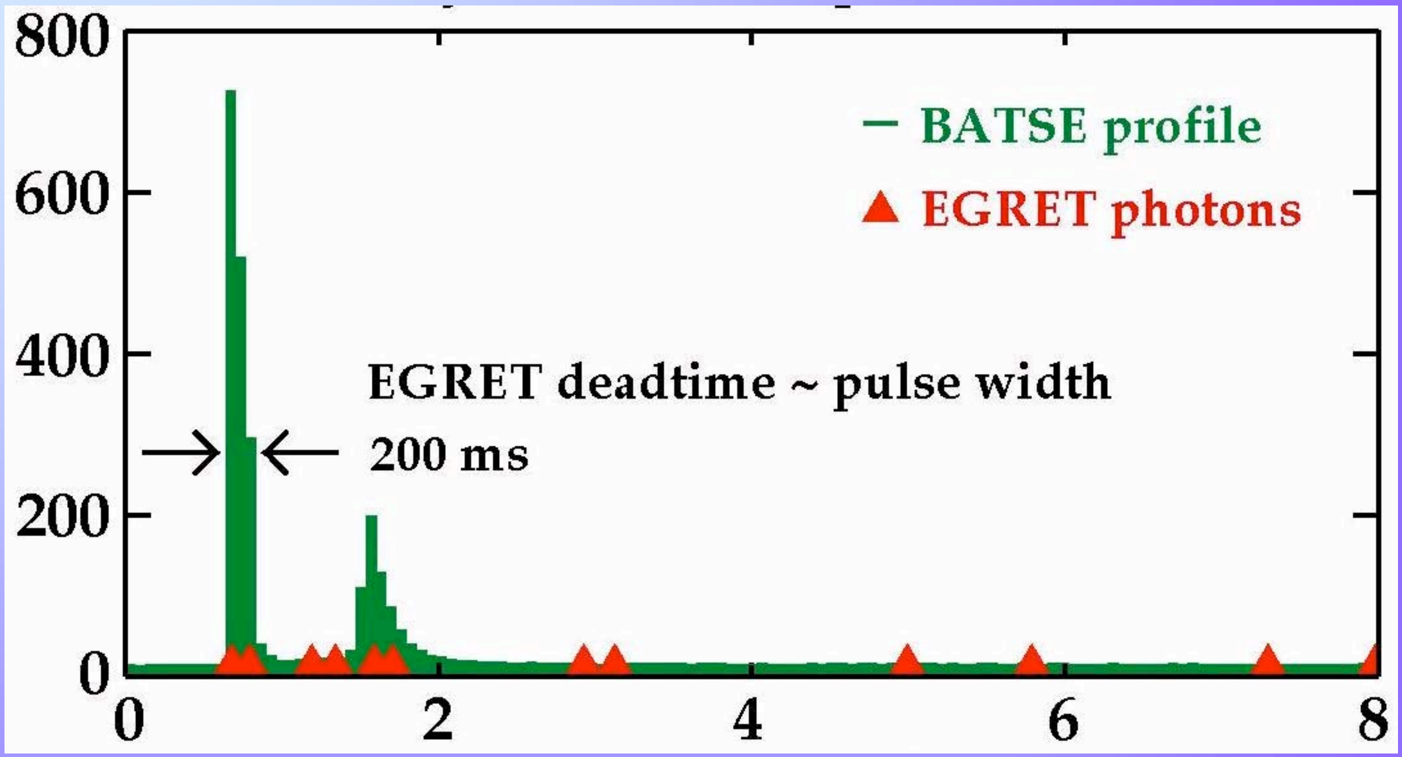
S = 1.2 x $10^{-4}$ erg cm$^{-2}$

100 MeV γ's for >1 hr




Hurley et al. 1994

# Queen Beatrix GRB 930131



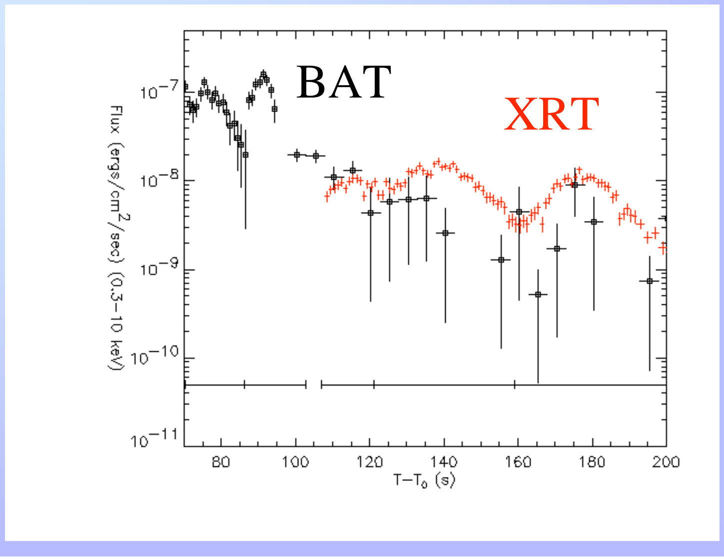

$T_{90}$ = 14 s
(but short-hard main emission of ~1s - short GRB?)

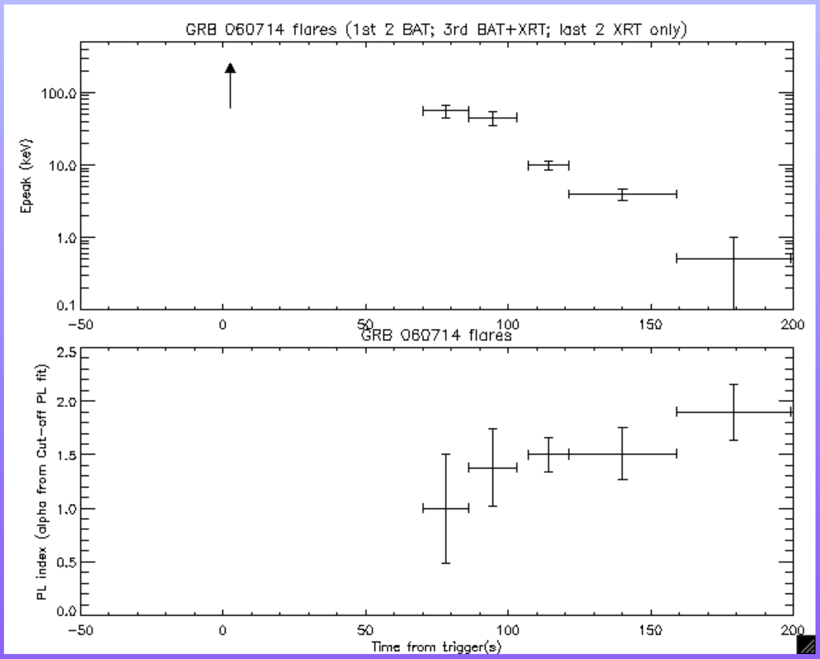
S = 1.2 x $10^{-5}$ erg $cm^{-2}$

100 MeV γ's past main prompt phase

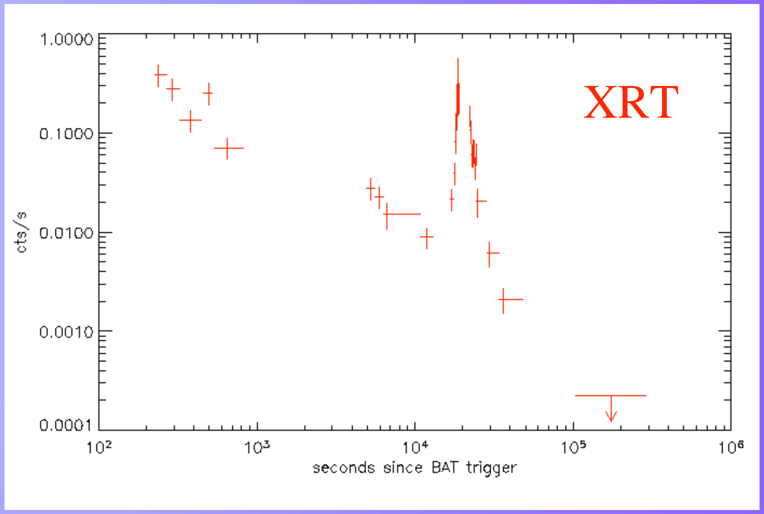
# Late X-ray Flares

GRB 060714



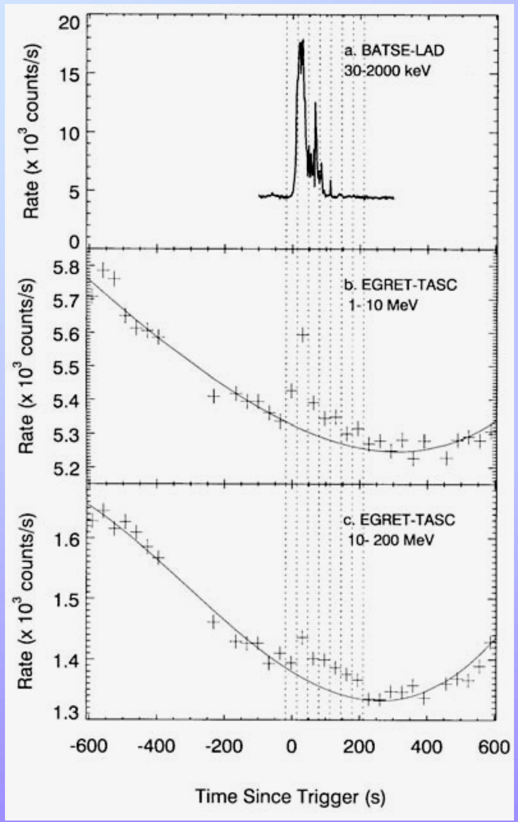



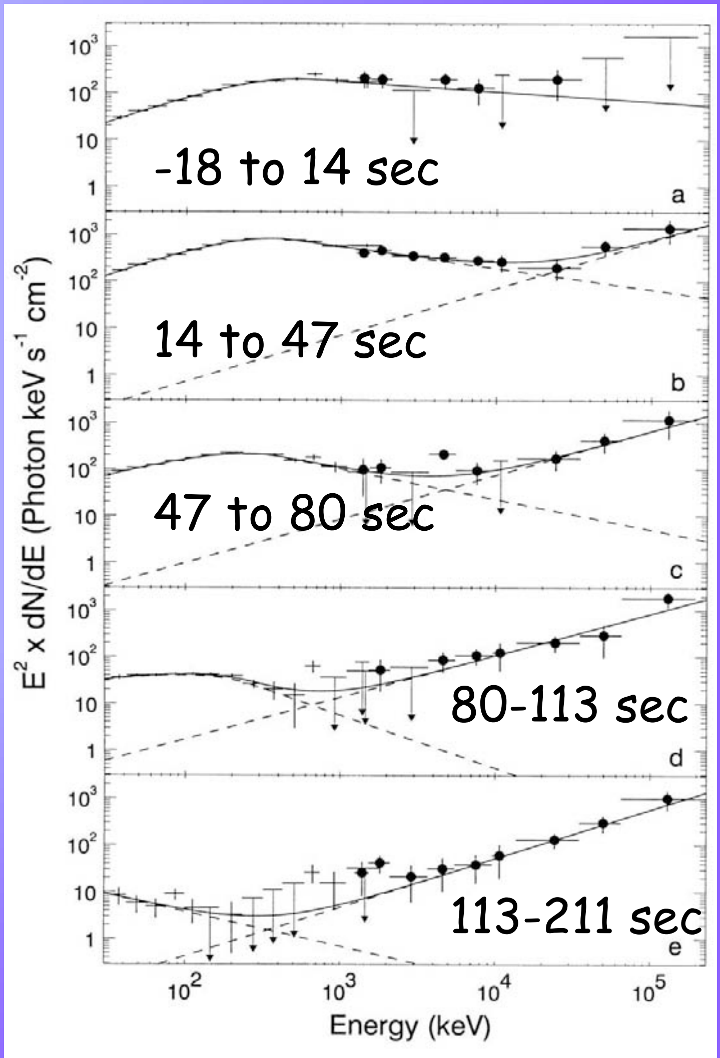

GRB 050916




Late X-ray flares likely due to central engine activity on hour time scales

# GRB941017 High Energy Component




BATSE + EGRET/TASC spectra
show high-E component

Different time evolution

Gonzalez, Dingus et al., Nature, 424, 749, 2003

# Opportunities for GLAST

## Key Questions:

- What is the nature of the fireball explosion?
  - Observations of GRBs with prompt and extended high energy emission
  - Overall SED

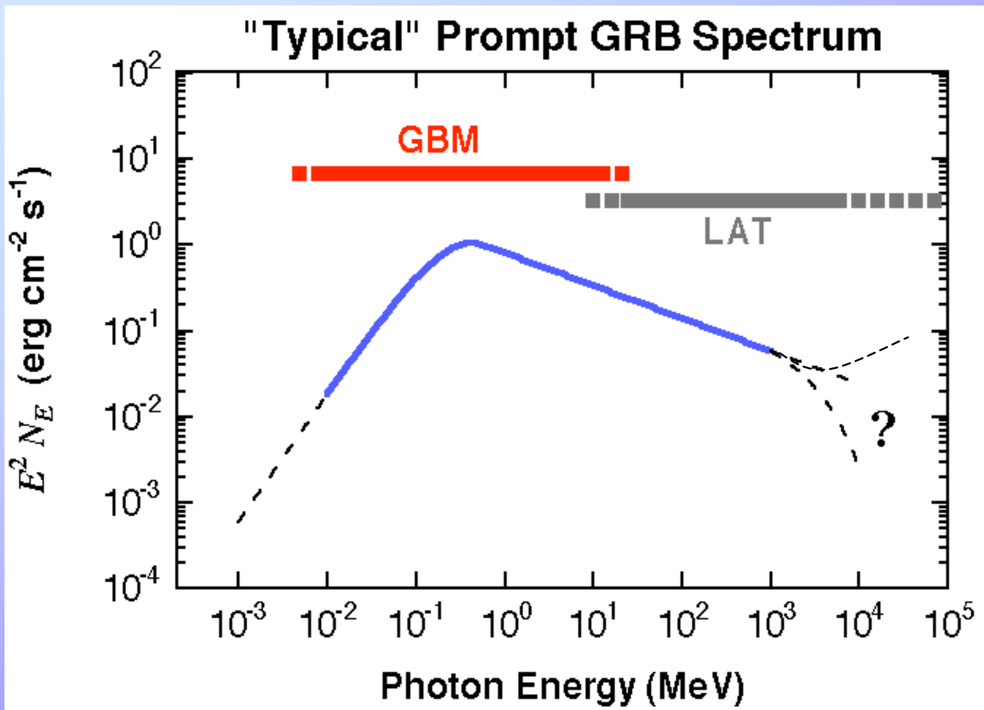
- What is the origin of short GRBs?
  - Time profile of high energy emission
  - Variability of prompt and extended emission

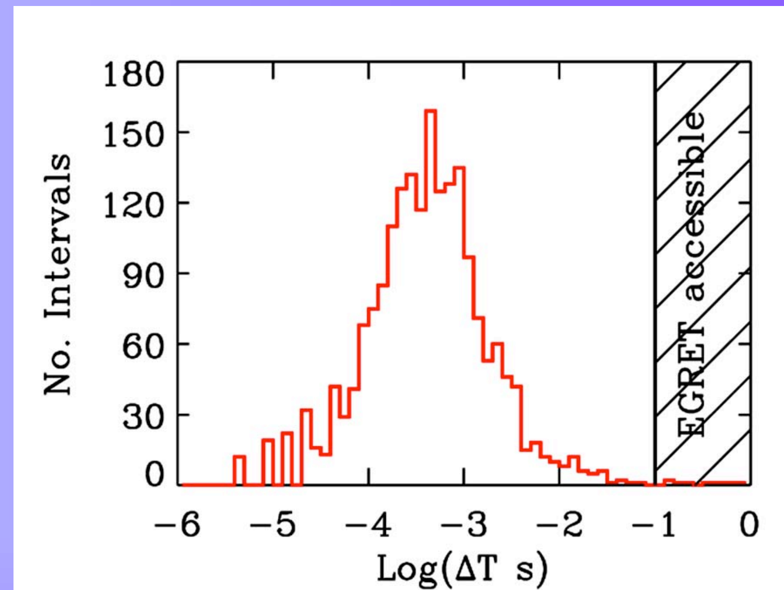
- What can be learned about universe from GLAST (+Swift) GRB observations?
  - EBL studies with GRB spectra
  - Quantum gravity tests using photon dispersion (e.g., Scargle, Norris & Bonnell)

## Requirements:

- Hundreds of GRBs
- GBM plus LAT observations of prompt emission
- Repointing to search for extended emission
- Swift and ground follow-up to measure afterglows and determine redshifts

# GLAST Performance



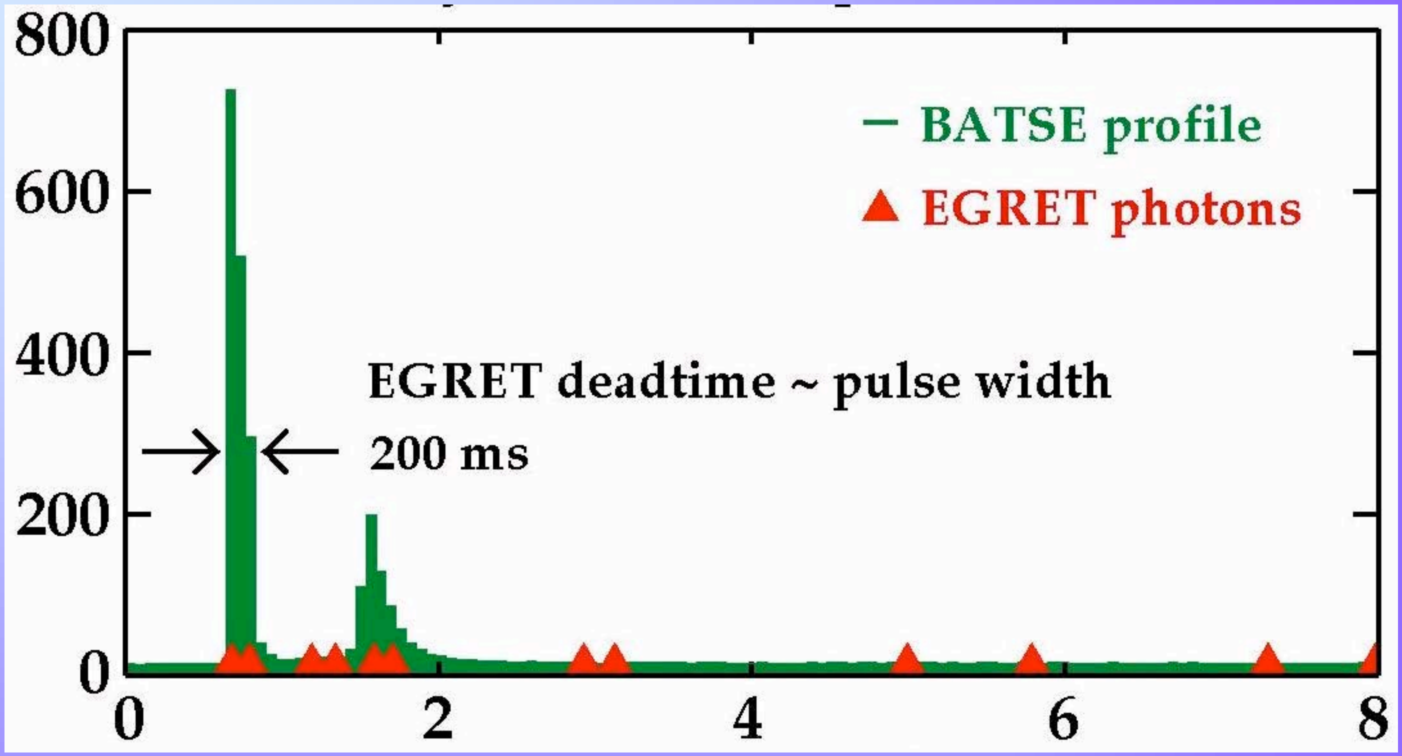




| | |
|---|---|
| ~50 GRBs/yr with | LAT |
| ~200 GRBs/yr with | GBM |
| 15˚ (<5˚ on gnd) | GBM |
| ~arcmin-degree | LAT |

LAT - 27 μs deadtime

EGRET - 100 ms deadtime

# Queen Beatrix GRB 930131




$T_{90}$ = 14 s
(but short-hard main emission of ~1s - short GRB?)

S = 1.2 x $10^{-5}$ erg $cm^{-2}$

100 MeV γ's past main prompt phase

# GLAST Repoint Capability

Repointing to keep GRB in LAT field of view as much as possible

Purpose is continued coverage of prompt emission and search for extended emission

For GRBs in LAT field of view

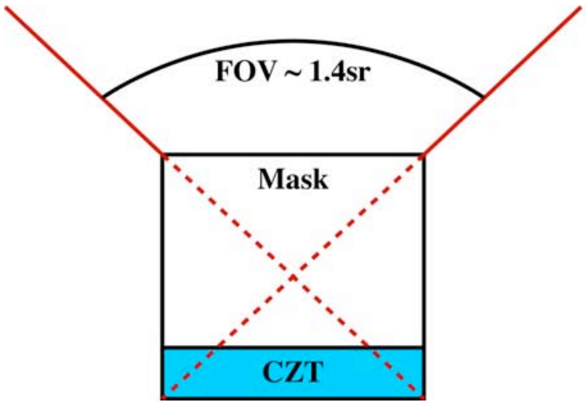
- Repoint to keep GRB in LAT field ~ once per week
- Will do this for every GRB trigger in early mission

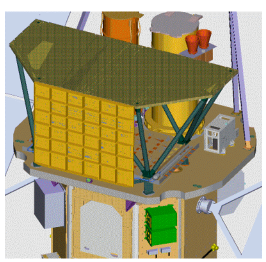
For GRBs detected by GBM

- Repoint for most interesting GRBs
- Will do this few times per year

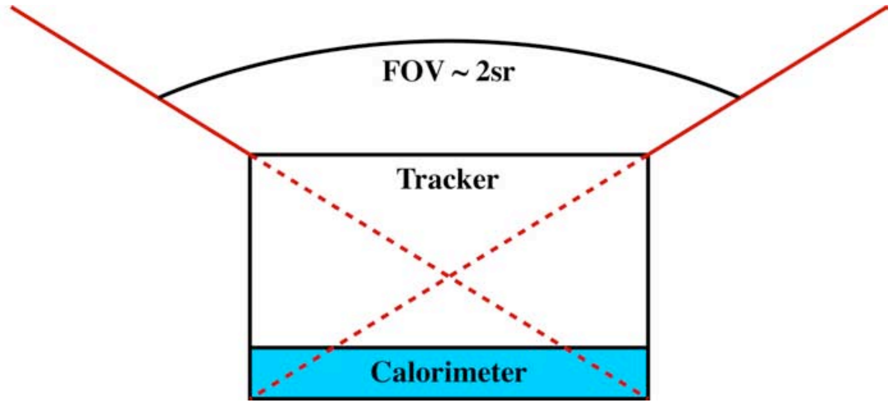
# Two Wide-Field Instruments

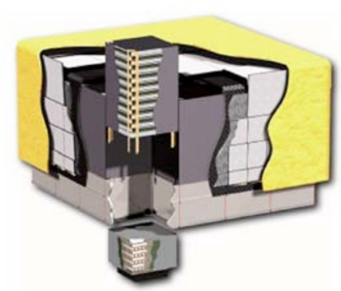
Swift/BAT



GLAST/LAT

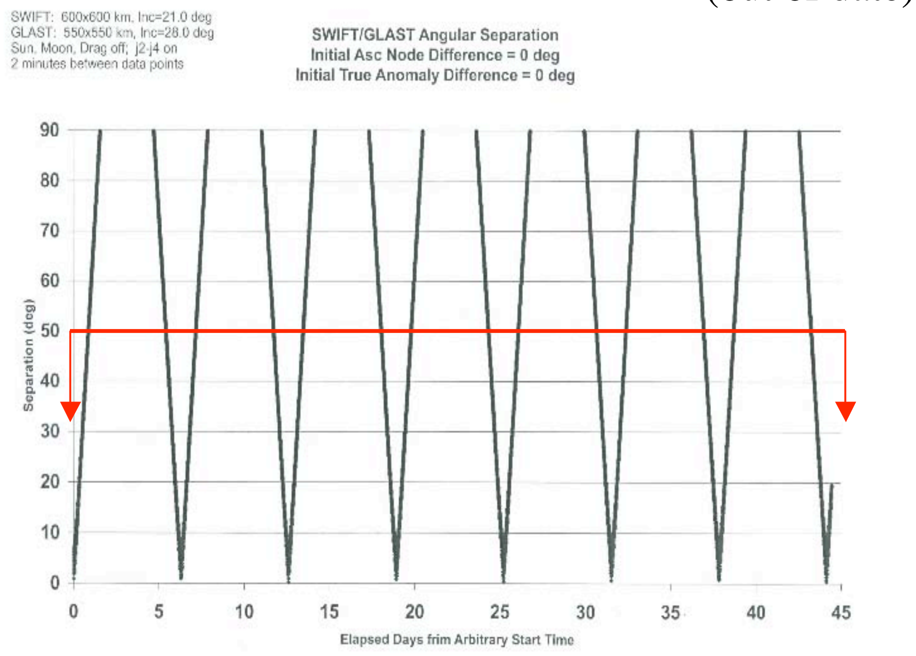


# Swift - LAT Joint GRB Operations

## BAT - LAT Joint Pointing

Assumes : Swift = 21˚ x 600 km & GLAST = 28˚ x 550 km
(out of date)

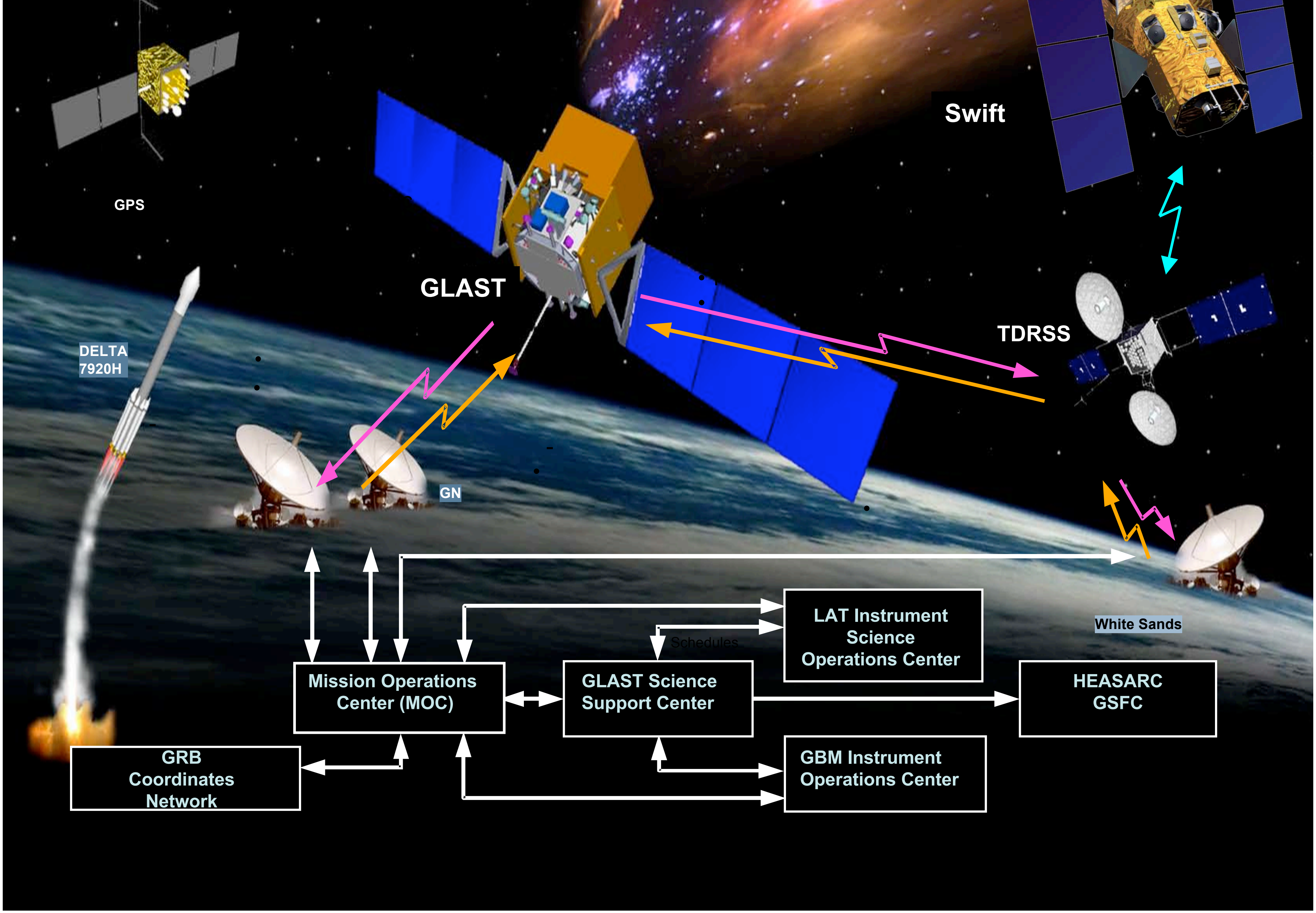



25% of time BAT & LAT field of view overlap

## XRT/UVOT Follow-up

- Rapid follow-up by Swift will give arc-sec locations and redshifts
- ~1 LAT GRB per month will fit in XRT FOV

# GLAST - Swift GRBs

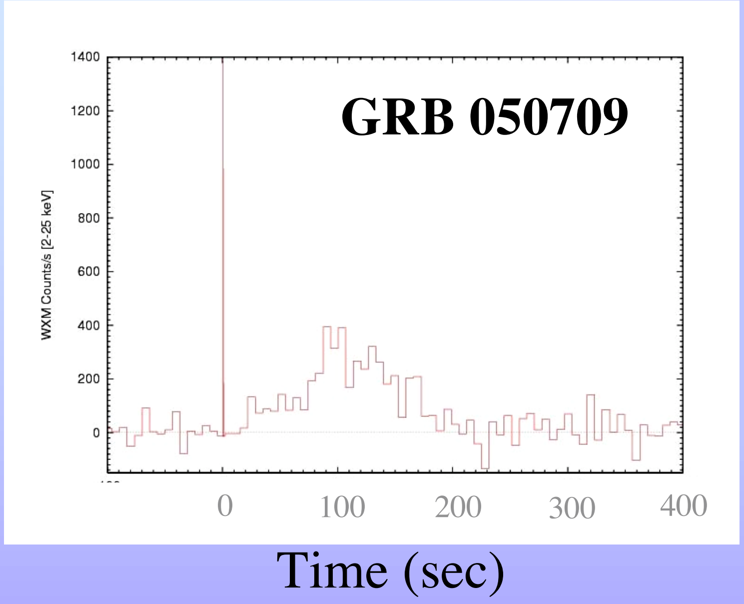


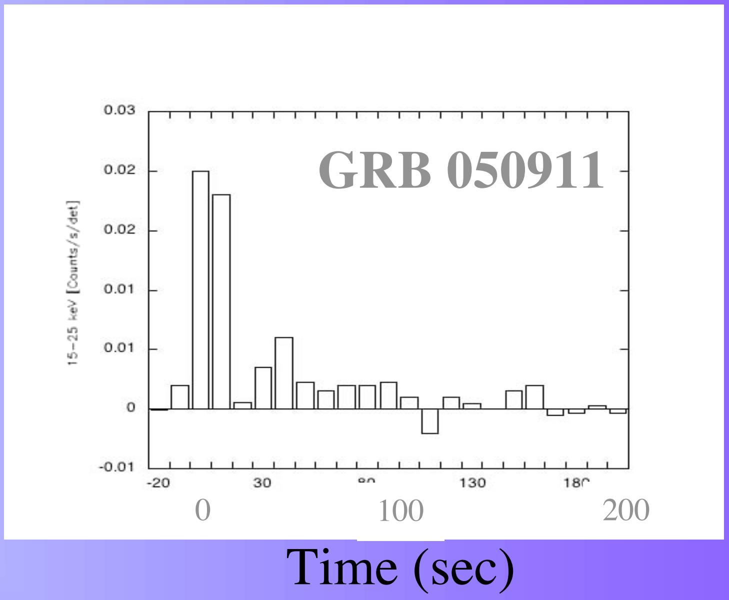
# Conclusion

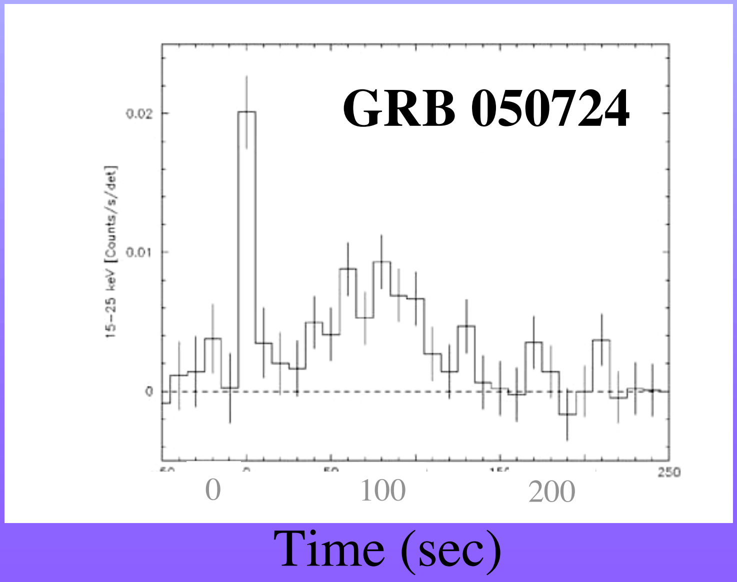
New GRB capabilities of GLAST
combined with Swift
combine with ground-based facilities

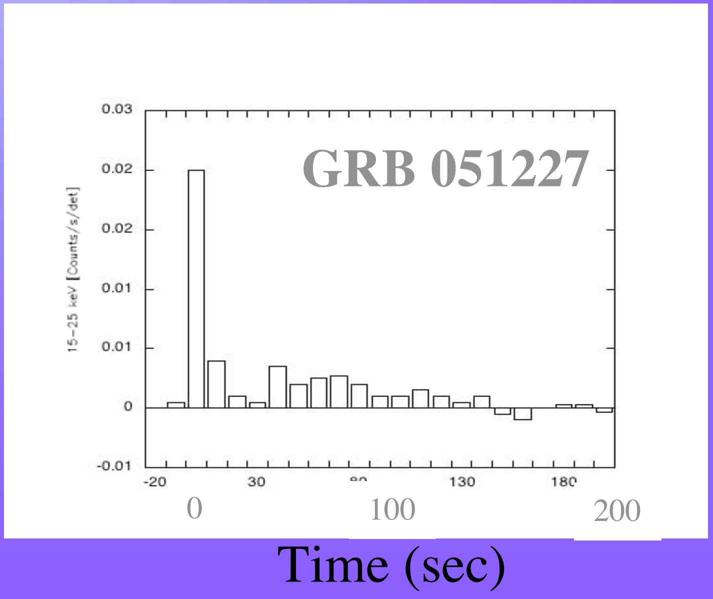
$\Rightarrow$ A golden age of GRB research is upon us

# Soft Gamma Ray Component

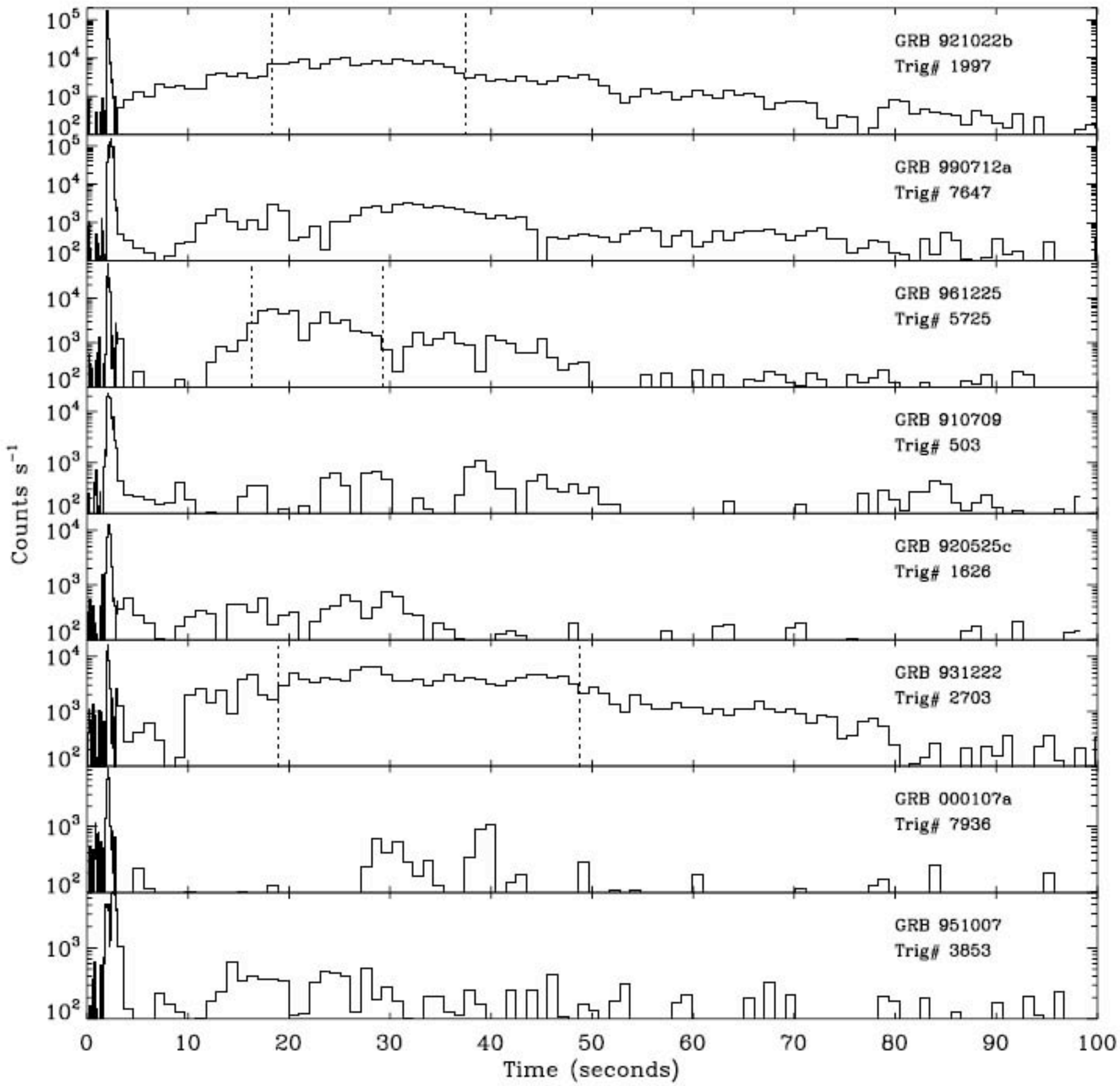


# BATSE




Norris & Bonnell (2006)

BATSE long GRBs with short-hard episode and long softer hump

# Non-GRB Joint Science Opportunities

BAT & LAT both monitors sky daily for blazar flares
(15 blazars in BAT survey out to z=3)

Joint campaigns of active sources  opt + UV + X-ray + gamma-ray

XRT & UVOT searches of LAT unidentified sources

XRT & UVOT observations of LAT pulsars

LAT observations of galactic transients found by BAT

New sources found by LAT can be rapidly observed by Swift
(>200 Swift ToO's performed in 2 years)