

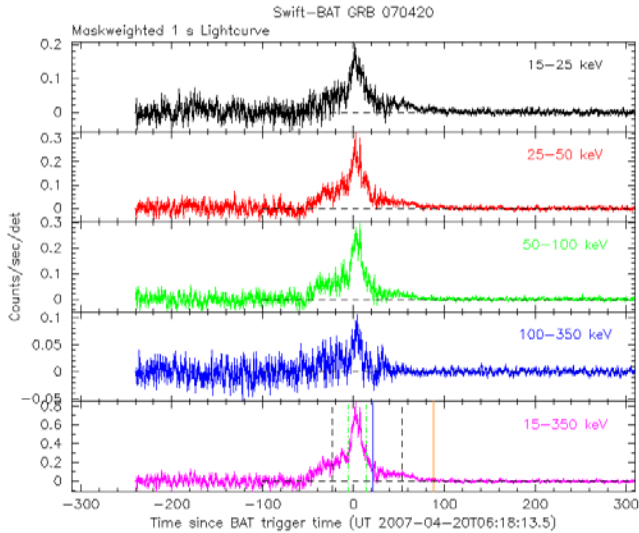
# **GRB Discoveries with Swift**

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**NASA-GSFC**

# Swift GRB 070420

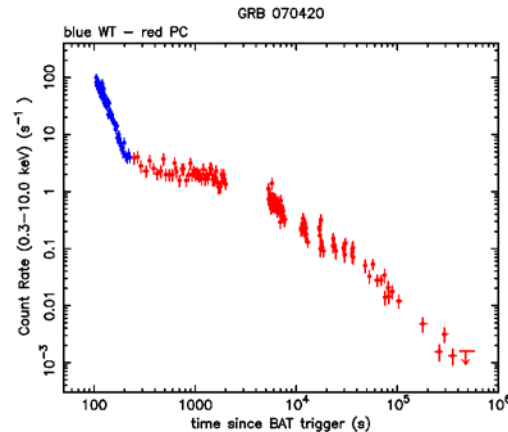
## BAT prompt emission



**3 instruments, each with:**

- lightcurves
- images
- spectra

## XRT afterglow



# Long GRBs

# 63 *Swift* Long GRB Redshifts

6.29	050904
5.47	060927
5.3	050814
5.11	060522
4.9	060510B
4.41	060223A
4.27	050505
4.05	060206
3.97	050730
3.91	060210
3.71	060605
3.69	060906
3.62	070721B
3.53	060115
3.44	061110B
3.43	060707
3.36	061222B
3.34	050908
3.24	050319
3.21	060926
3.21	060526
3.08	060607A
2.95	070411
2.90	050401
2.82	050603
2.71	060714
2.68	060604
2.61	050820A
2.50	070529
2.45	070802
2.43	060908
2.35	051109A

2.35	070110
2.31	070506
2.30	060124
2.20	050922C
2.17	070810
2.04	070611
1.95	050315
1.71	050802
1.55	051111
1.51	060502A
1.50	070306
1.49	060418
1.44	050318
1.31	061121
1.29	050126
1.26	061007
1.17	070208
0.97	070419A
0.94	051016B
0.84	070318
0.83	050824
0.76	061110A
0.70	060904B
0.65	050416A
0.62	070612A
0.61	050525A
0.54	060729
0.44	060512
0.125	060614
0.089	060505
0.033	060218

<b>z</b>	<b>GRB</b>	<b>Optical/IR Brightness</b>
<b>6.29</b>	<b>050904</b>	<b>J = 18 @ 3 hrs</b>
<b>5.6</b>	<b>060927</b>	<b>I = 16 @ 2 min</b>
<b>5.3</b>	<b>050814</b>	<b>K = 18 @ 23 hrs</b>
<b>5.11</b>	<b>060522</b>	<b>R = 21 @ 1.5 hrs</b>

# GRB Host Spectroscopy

GRB 050505

$z = 4.275$

Damped Ly $\alpha$

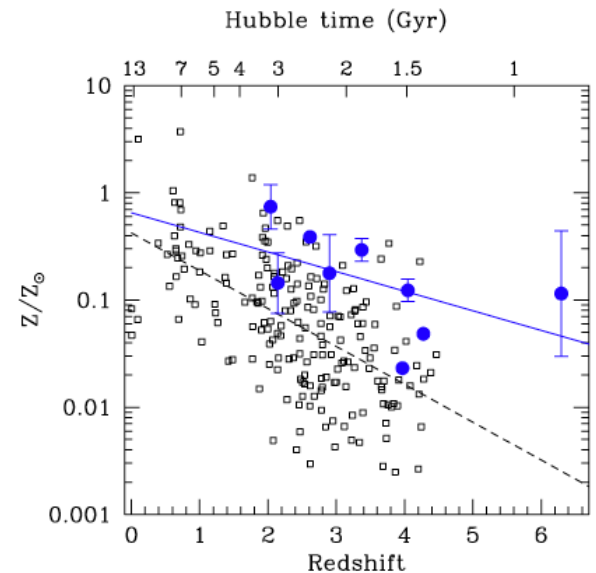
$N(\text{HI}) = 10^{22} \text{ cm}^{-2}$

$n \sim 10^2 \text{ cm}^{-3}$

$Z = 0.06 Z_{\odot}$

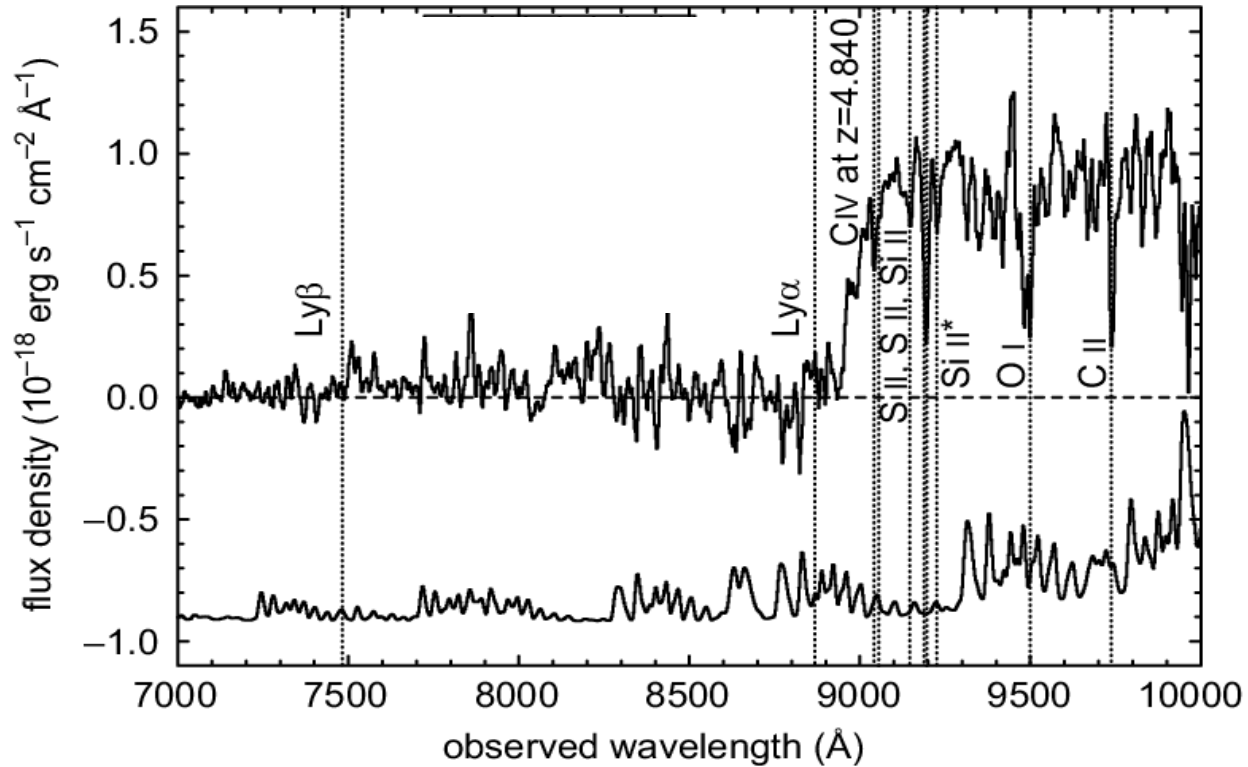
$M_{\text{progenitor}} < 25 M_{\odot}$

## Metallicity vs Redshift



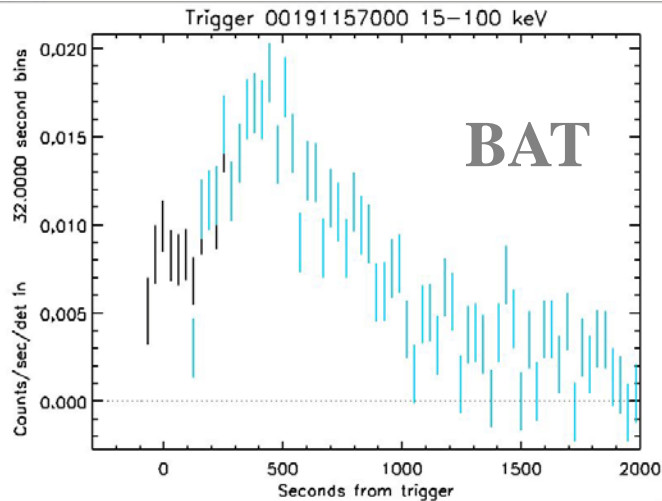
Savaglio 2006

# GRB 050904 $z=6.29$



Subaru Telescope  
Kowai et al. 2006

# GRB 060218: GRB + Supernova



Super-long GRB - ~35 minutes

BAT, XRT, UVOT during GRB

**$z = 0.033$   $d = 145$  Mpc**

SN 2006aj SN Ib/c

$E_{\text{iso}} = \text{few} \times 10^{49}$  erg - **underluminous**

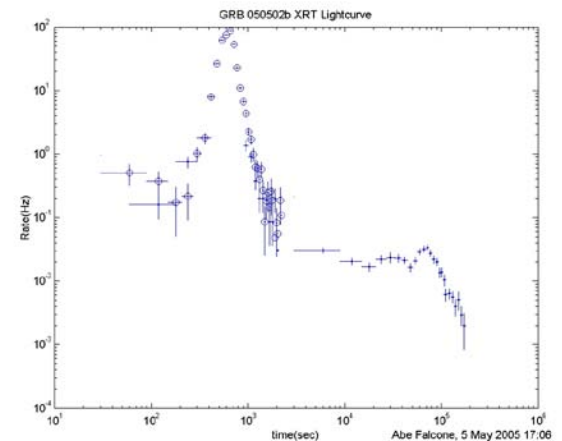
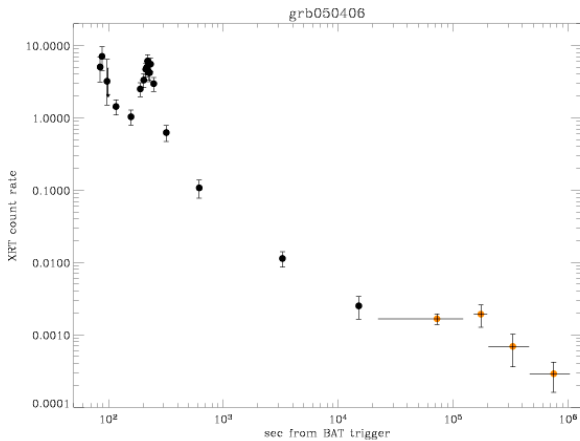
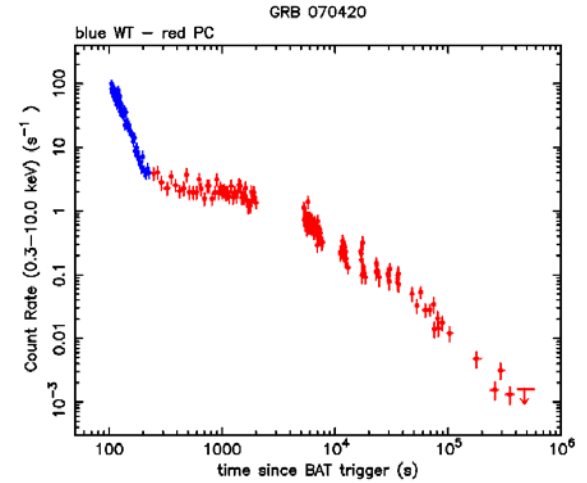
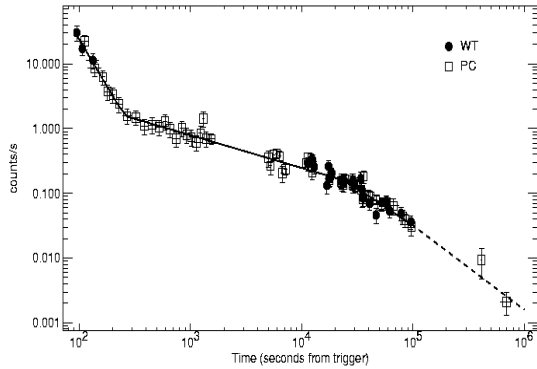
# Afterglows



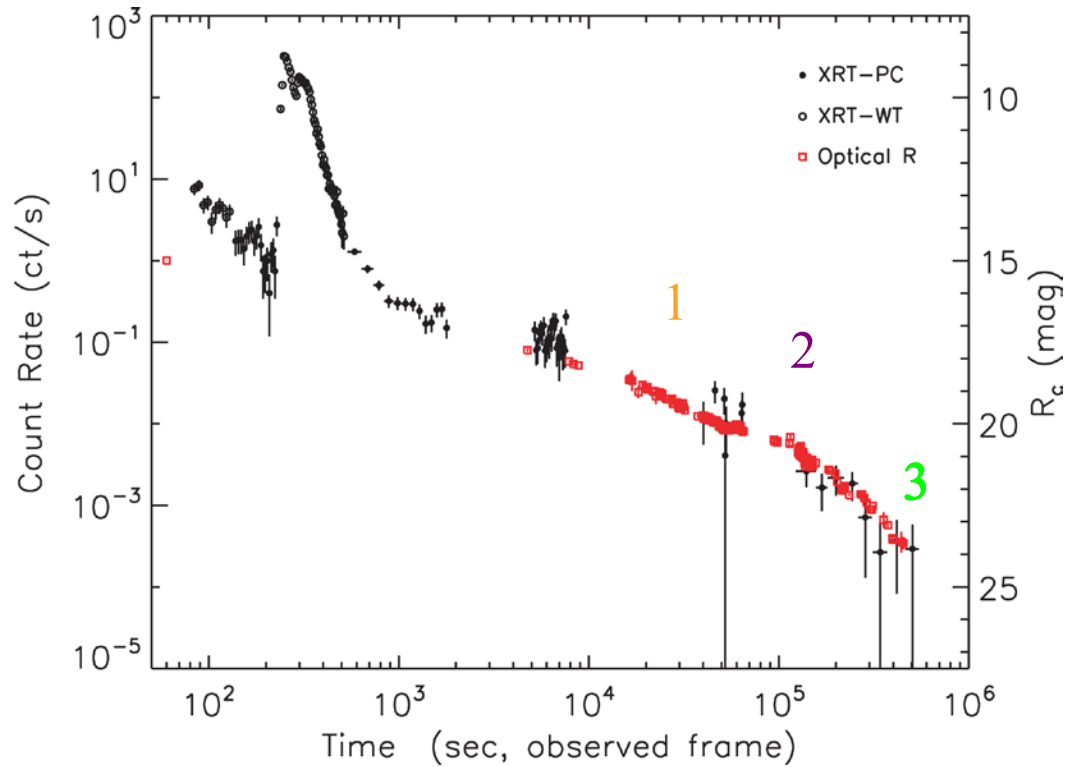
# Typical *Swift* X-ray Lightcurves

**50% with  
bright early  
component**

**>30% with  
flares**



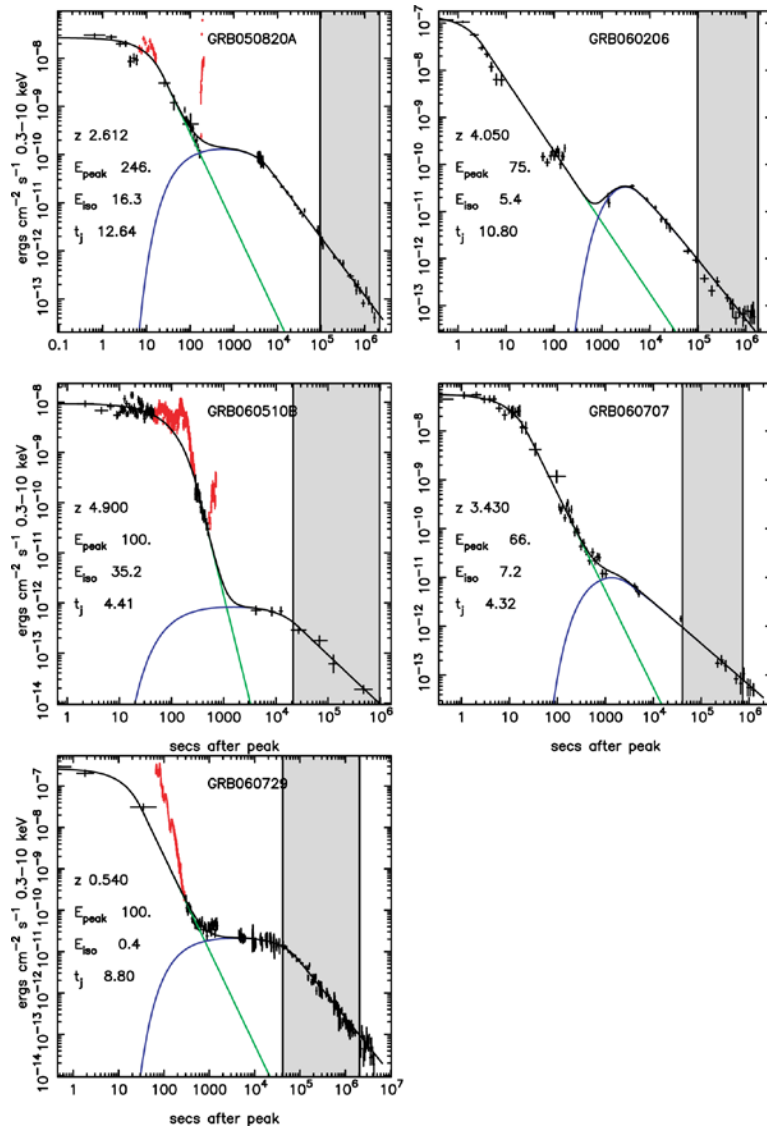
# Achromatic Jet Break - GRB 060526



$z=3.21$   
jet angle =  $7^\circ$

Dai et al. 2007

# Puzzling Data



Willingale et al. 2007

- Many GRBs do not show jet breaks
- In other cases, optical and X-ray breaks are not coincident.
- Complex shape of afterglow lightcurves makes jet breaks hard to find

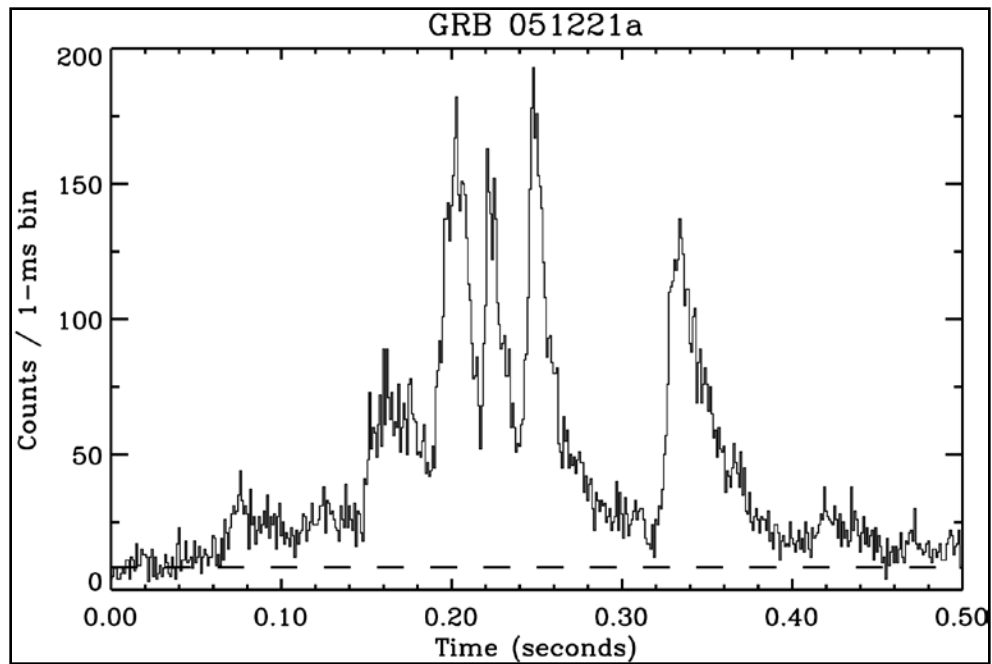
Other new papers:

Curran et al. (astro-ph 0706.1188) - evidence for achromatic breaks in several Swift GRBs

Oates et al. (astro-ph 0706.0669) - GRB 050802 case with X-ray break clearly seen but no optical break

# Short GRBs

# Short GRB Time Structure



# Short GRB - Current Status

## *Swift* short GRB observations

- 23 short bursts detected (+ 2 from HETE, +1 from INTEGRAL)
- 78% with X-ray afterglow detected by XRT (95% long GRBs)
- 28% with optical detection (58% long GRBs)
- ~50% with host IDs

~1/2 shorts accompanied by soft  
extended emission up to 100 sec

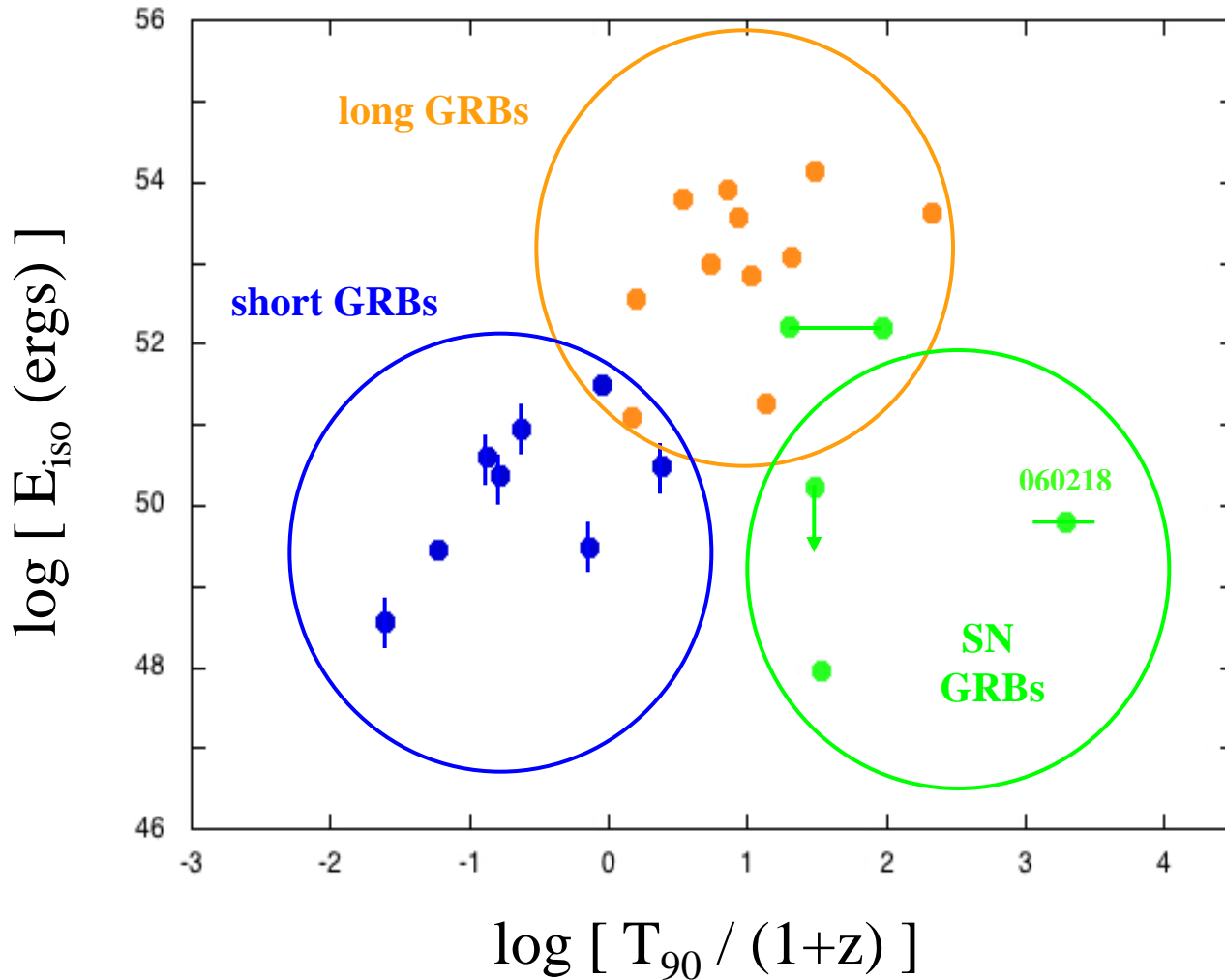
Redshift range from  $z = 0.2$  to 1

- $\langle z \rangle_{\text{short}} = 0.6$
- $\langle z \rangle_{\text{long}} = 2.3$

GRB 070714B  $z = 0.92$   
(Graham et al. 2007)

# 3 Types of GRBs

*Swift* GRBs (mostly)



# Implications for Grav. Wave Detections

Assuming all short GRBs are due to NS-NS mergers, merger rate is  $\sim 300 \text{ Gpc}^{-3} \text{ yr}^{-1}$

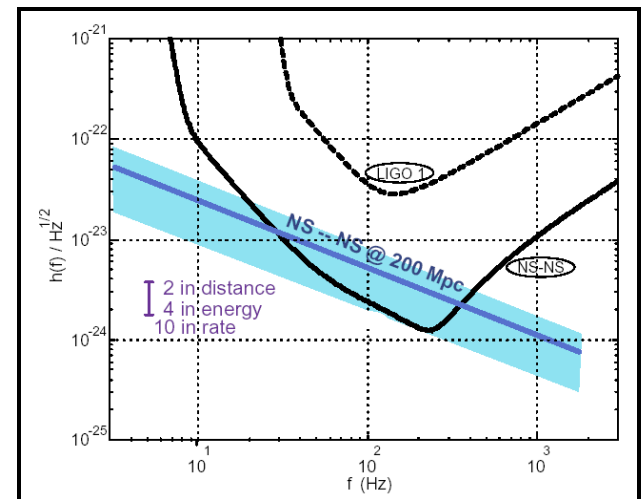
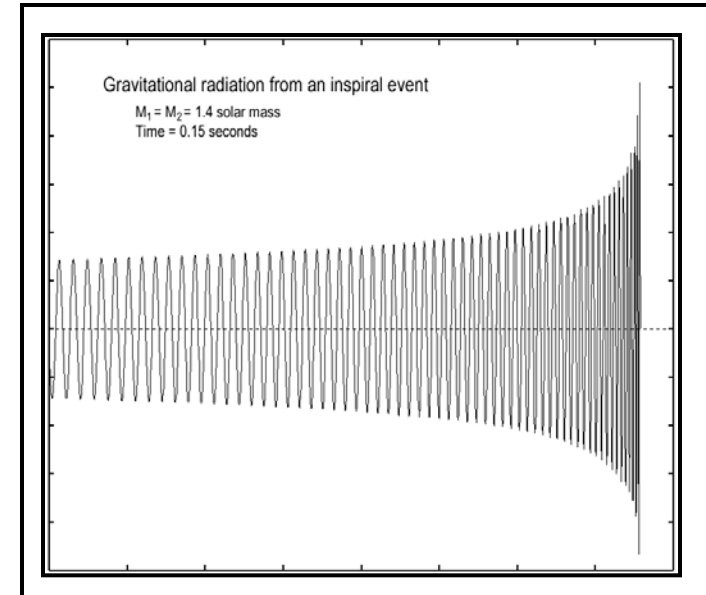
[Consistent with NS-NS population synthesis modeling O'Shaughnessy, Kalogera, & Belczynski (2005)]

⇒ Advanced LIGO detection rate of  $\sim 30 \text{ yr}^{-1}$

Nakar et al.:

Possible much higher rates of  $10^5 \text{ Gpc}^{-3} \text{ yr}^{-1}$ .

⇒ Detection with enhance LIGO



**Swift will be in orbit until > 2020**