Gamma Ray Burst Discoveries with the Swift Mission

Neil Gehrels
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Gamma-ray bursts (GRBs) are among the most fascinating occurrences in the universe. They are powerful explosions, visible to high redshift, and thought to be the signature of black hole formation. The Swift Observatory has been detecting 100 bursts per year for 3 years and has greatly stimulated the field with new findings. Observations are made of the X-ray and optical afterglow from ~1 minute after the burst, continuing for days. Evidence is building that the long and short duration subcategories of GRBs have very different origins: massive star core collapse to a black hole for long bursts and binary neutron star coalescence to a black hole for short bursts. The similarity to Type II and Ia supernovae originating from young and old stellar progenitors is striking. Bursts are providing a new tool to study the high redshift universe. Swift has detected several events at $z>5$ and one at $z=6.3$ giving metallicity measurements and other data on galaxies at previously inaccessible distances. The talk will present the latest results from Swift in GRB astronomy.

GRB Discoveries with Swift

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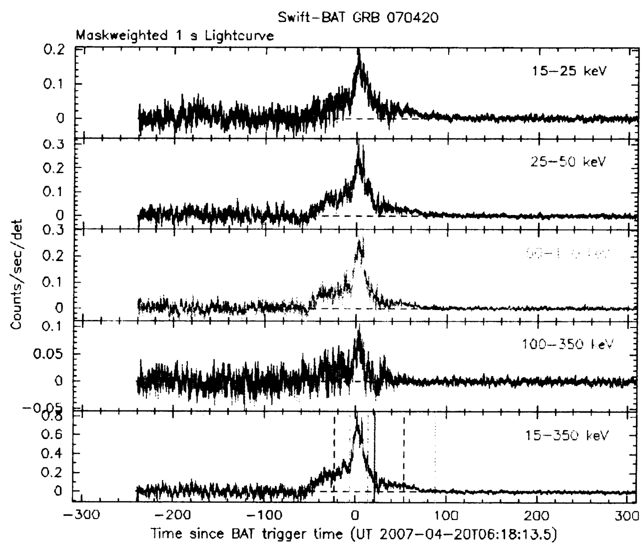
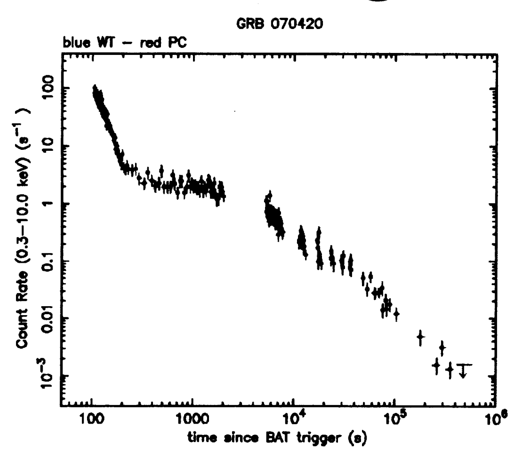
Swift GRB 070420

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

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

GRB Host Spectroscopy

GRB 050505

$z = 4.275$

Damped Lyα

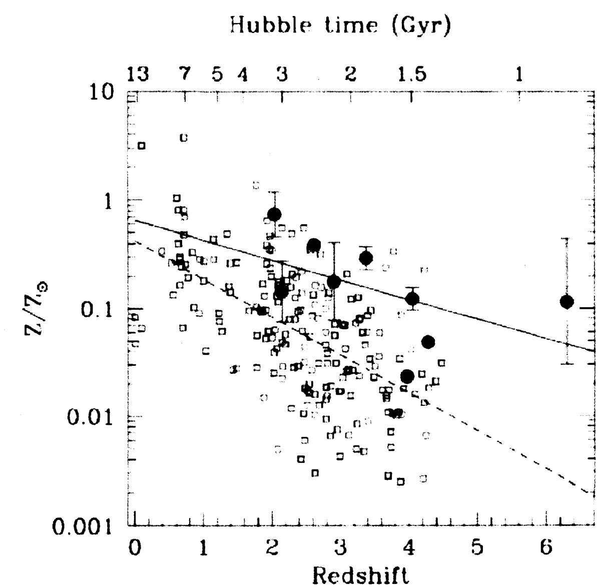
$N(HI)=10^{22}$ cm^{-2}

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

$Z = 0.06\ Z_O$

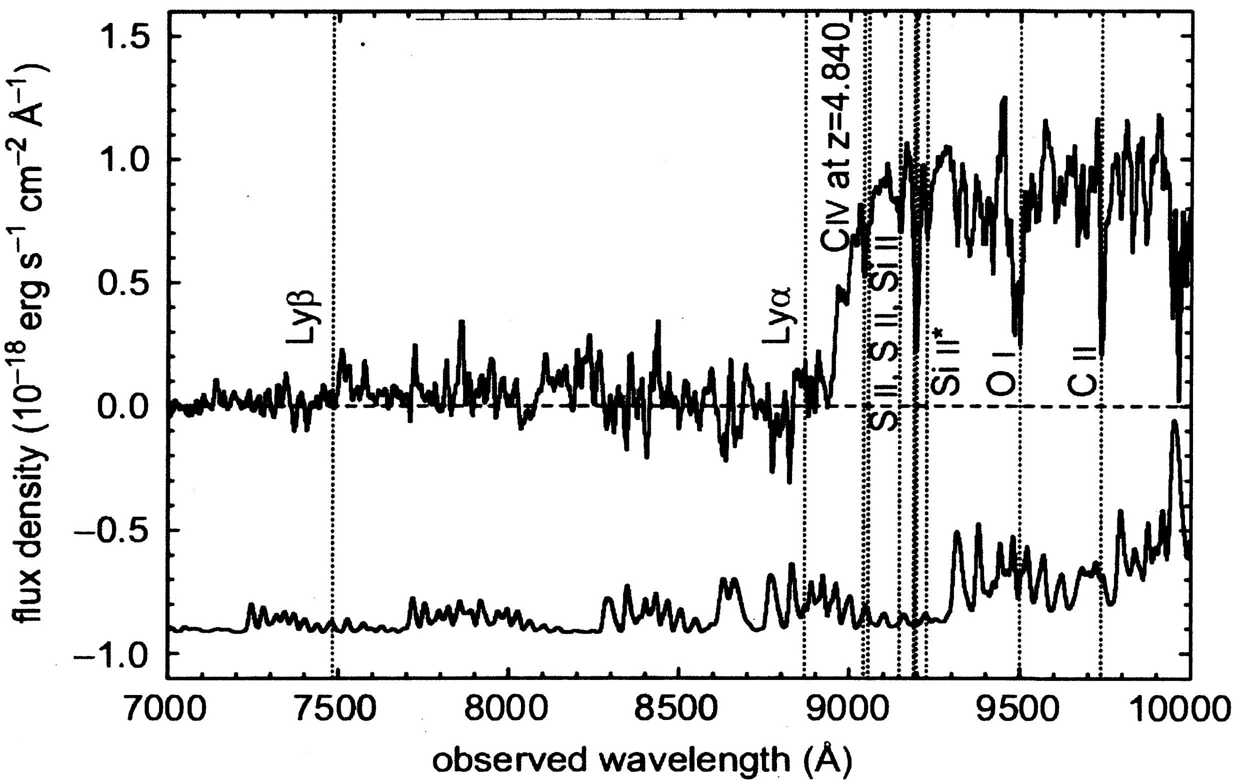
$M_{progenitor} < 25\ M_O$

Metallicity vs Redshift



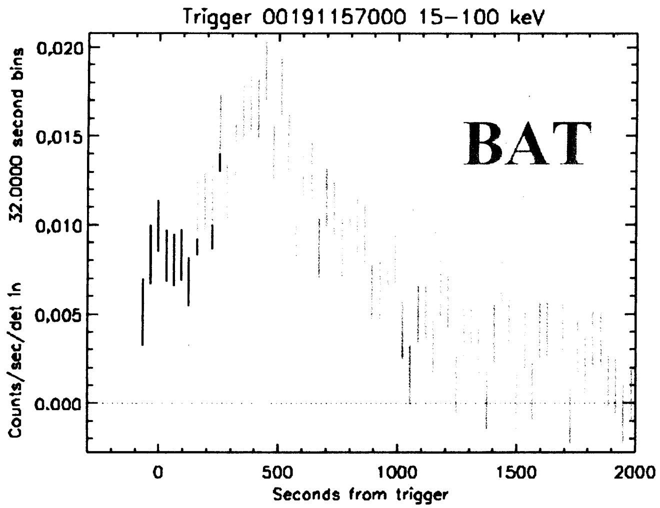
Savaglio 2006

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

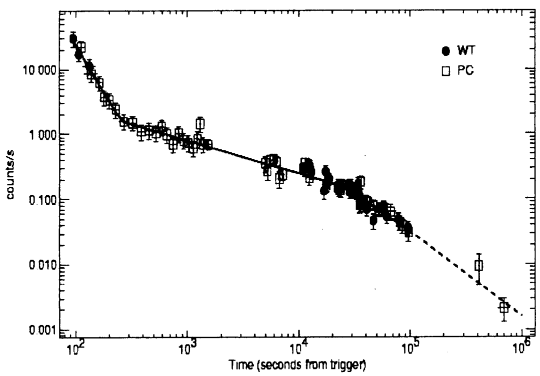
z = 0.033 d = 145 Mpc

SN 2006aj SN Ib/c

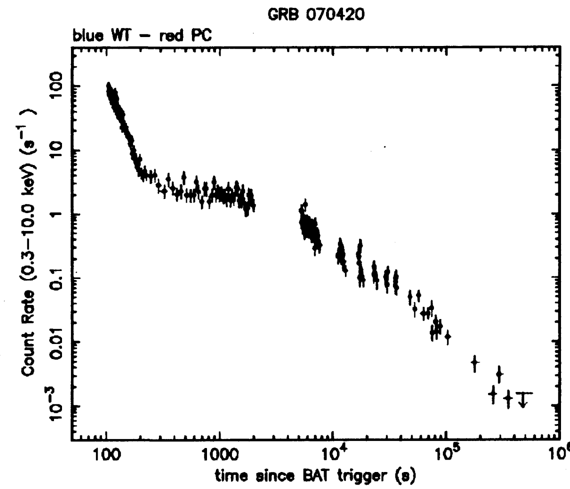
E_{iso} = few x 10^{49} erg - **underluminous**

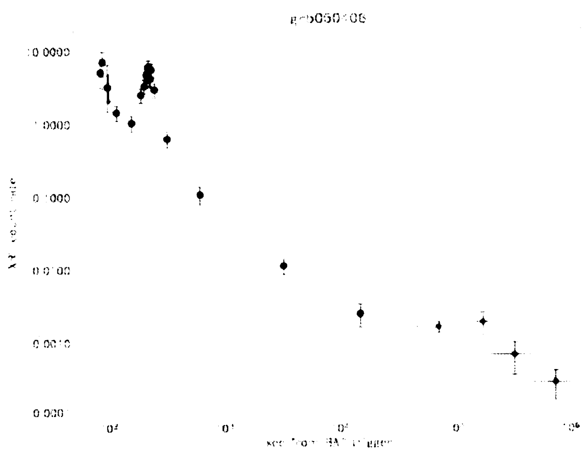
Afterglows

Typical *Swift* X-ray Lightcurves

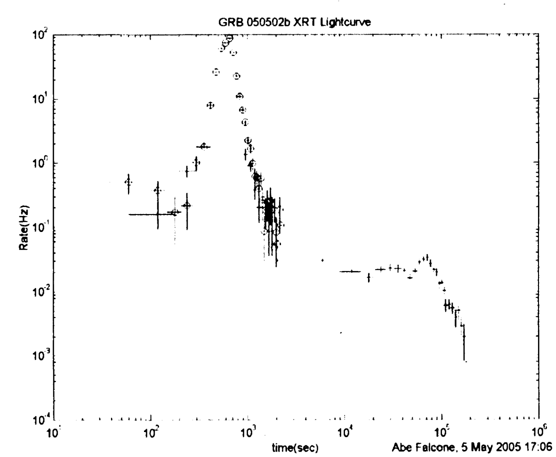


50% with bright early component



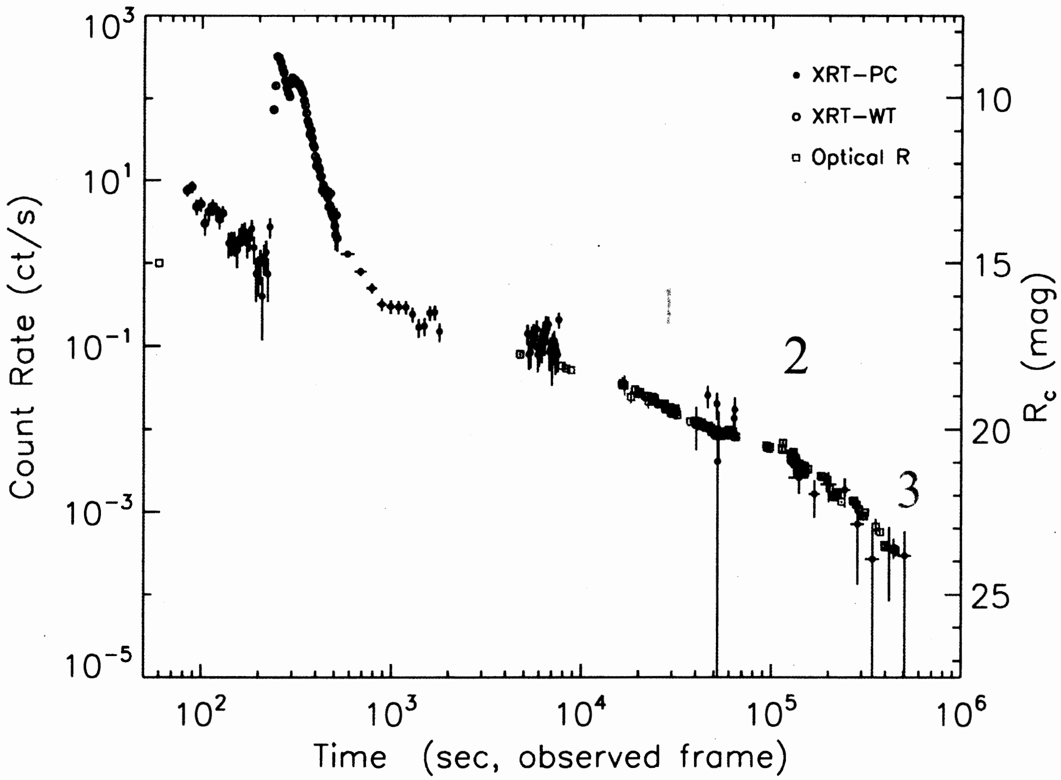


>30% with flares



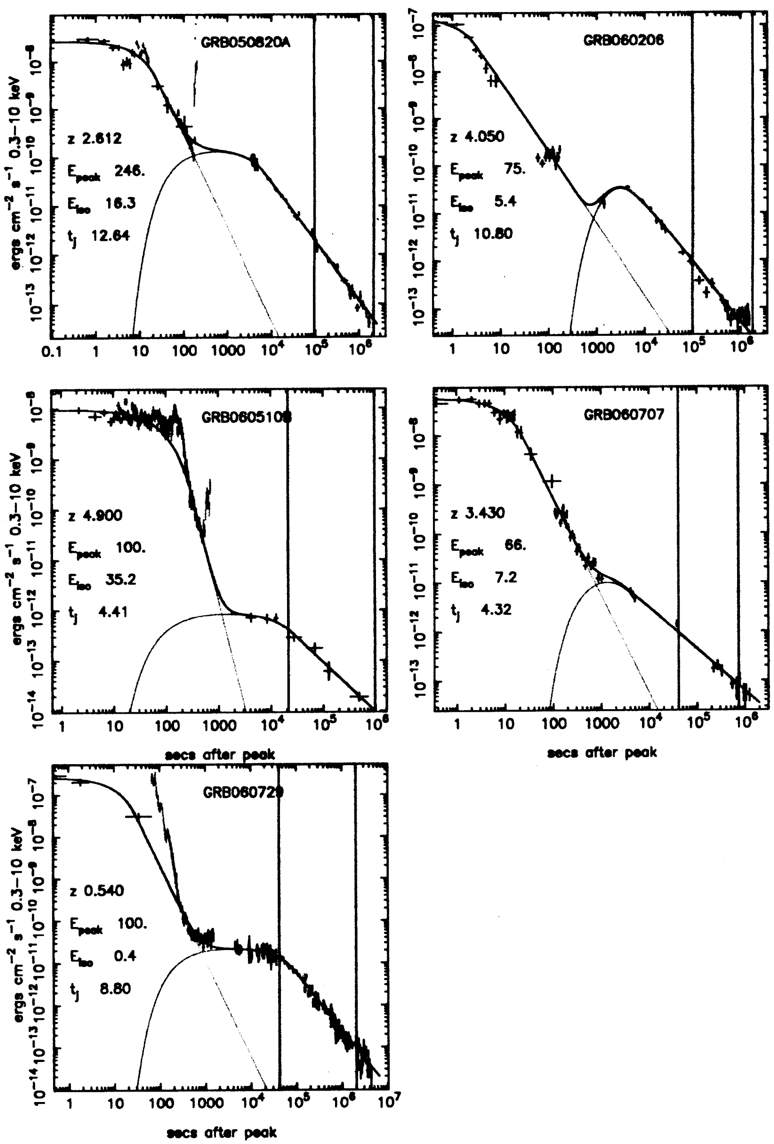
Burrows et al. 2005

Achromatic Jet Break - GRB 060526



z=3.21
jet angle = 7°

Dai et al. 2007



Willingale et al. 2007

Puzzling Data

- 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

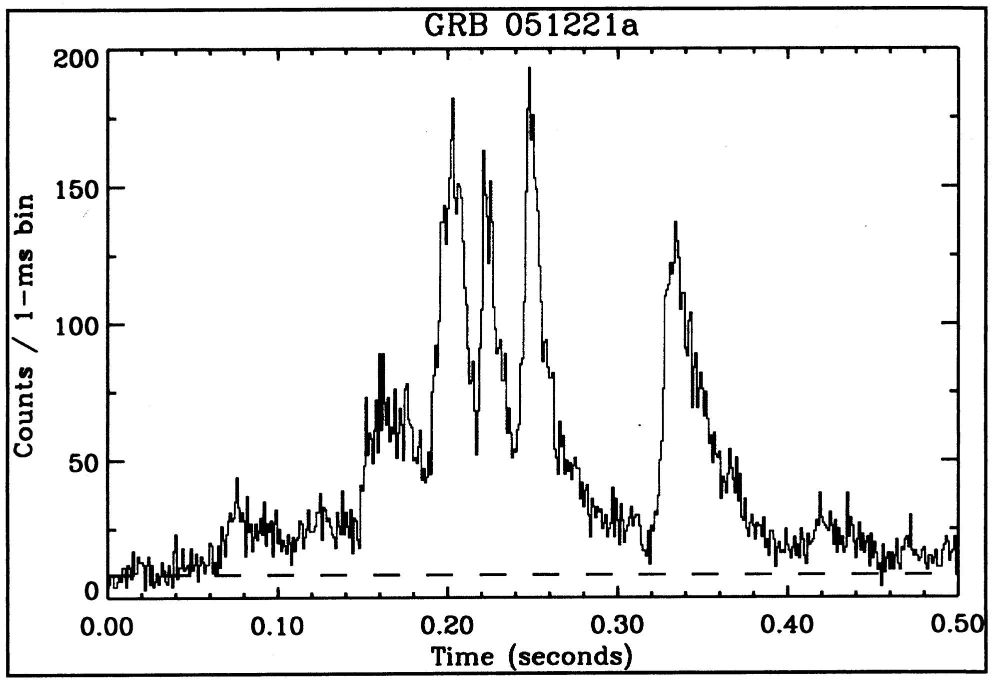
Other new papers:

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

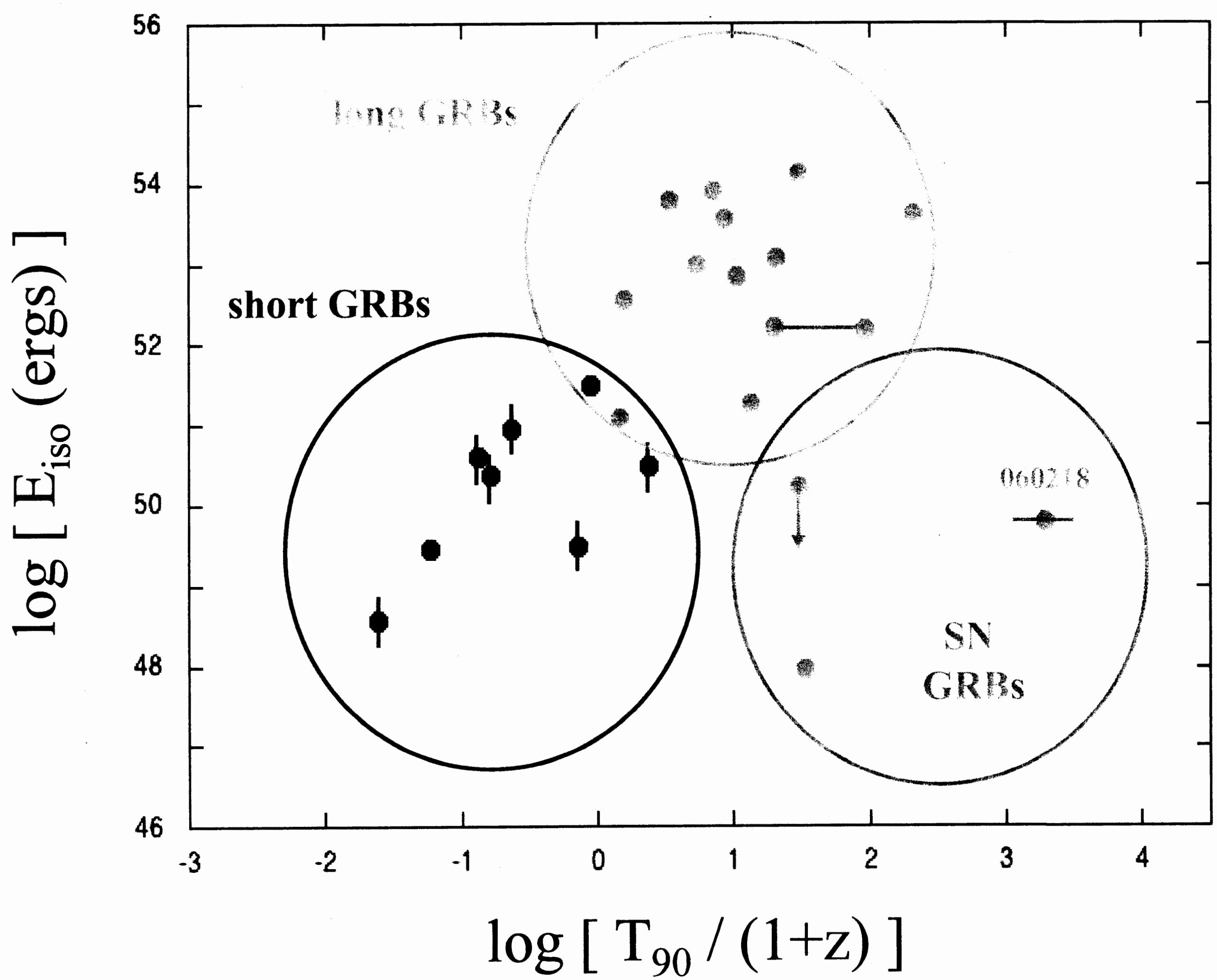
Redshift range from z = 0.2 to 1

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

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 ~300 Gpc^{-3} yr^{-1}

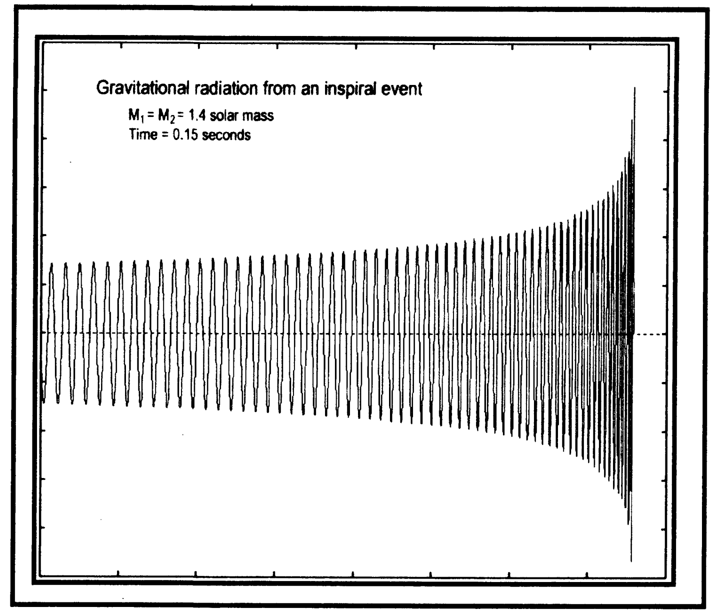
[Concsistent with NS-NS population synthesis modeling O'Shaughnessy, Kalogera, & Belczynski (2005)]

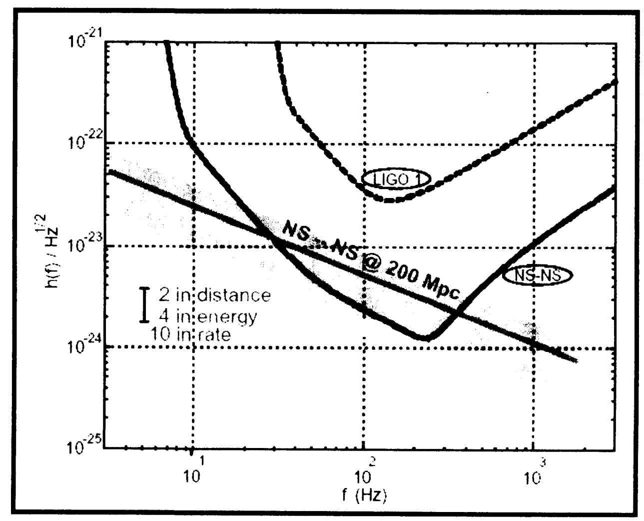
⇒ Advanced LIGO detection rate of ~30 yr^{-1}

Nakar et al.:

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

⇒ Detection with enhance LIGO





Swift will be in orbit until > 2020