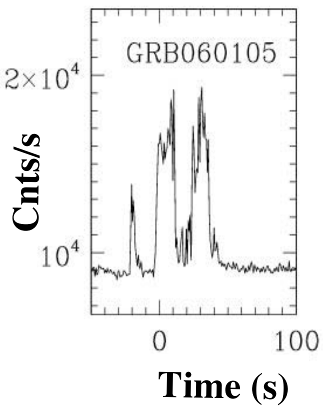
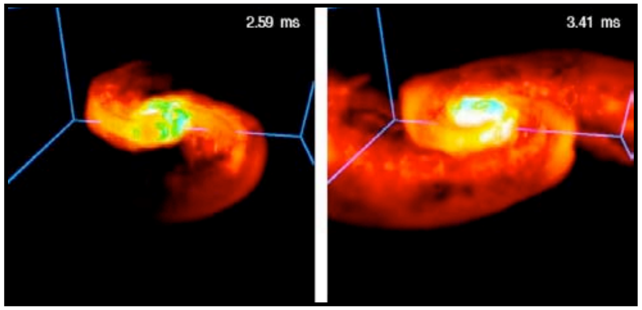


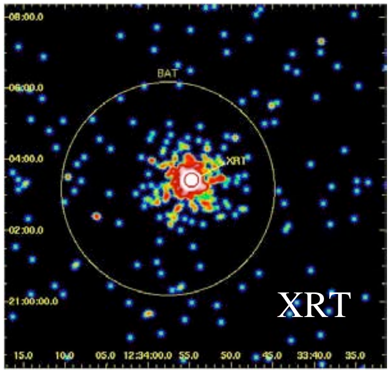


Swift Results on Gamma Ray Bursts

Neil Gehrels

NASA-GSFC

September 29, 2009
KITP Santa Barbara



Outline

Theme is comparing **short** and **long** GRBs.

→ High redshift long GRBs

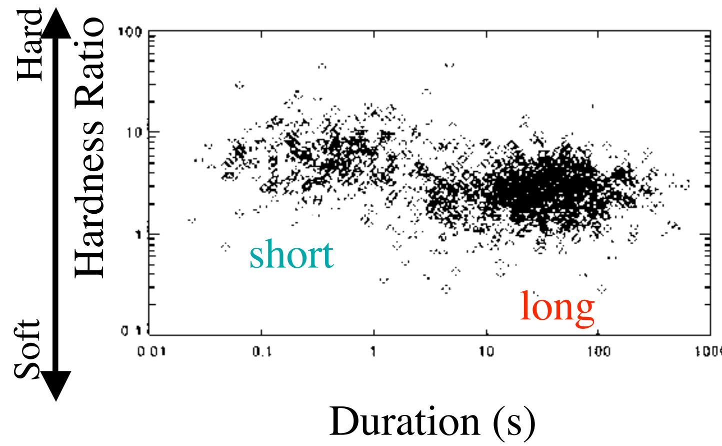
→ Short GRB latest results

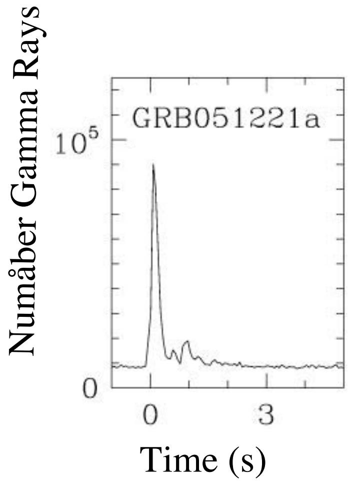
→ Jet outflows, collimation, shocks

•

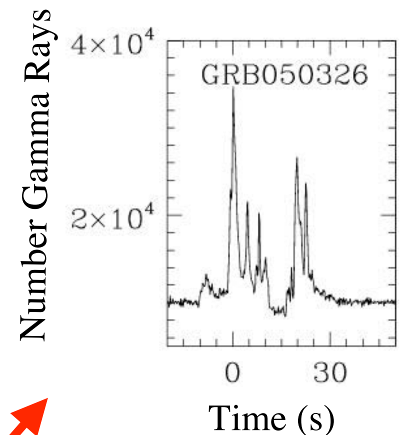
November 20, 2004

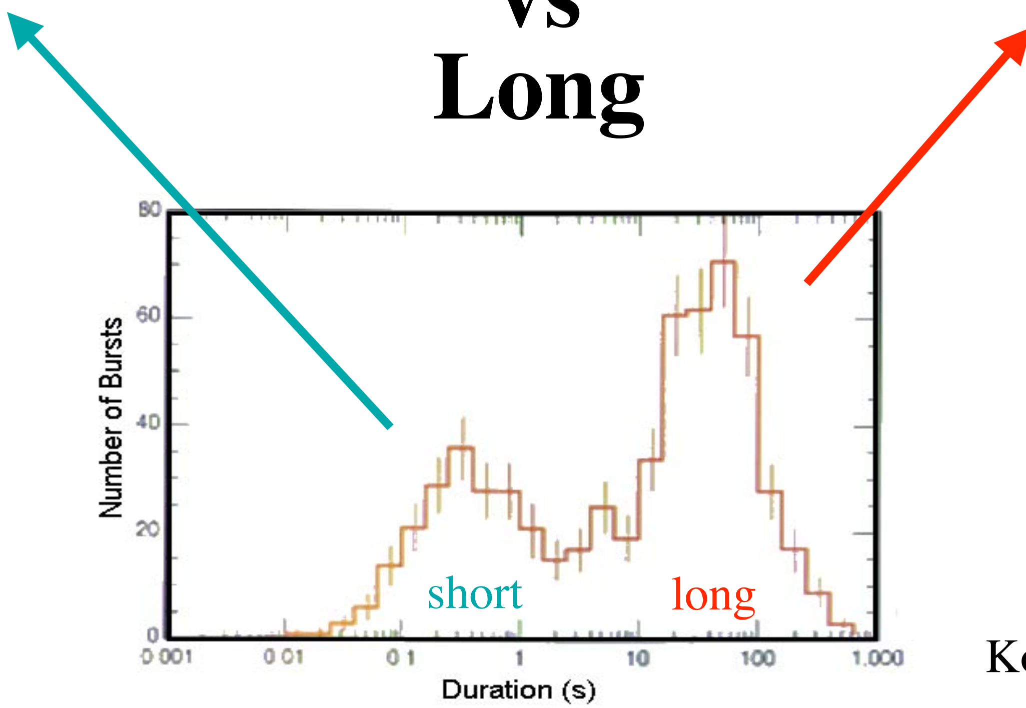
ARAA Annual Reviews 2009 Gehrels, Ramirez-Ruiz and Fox





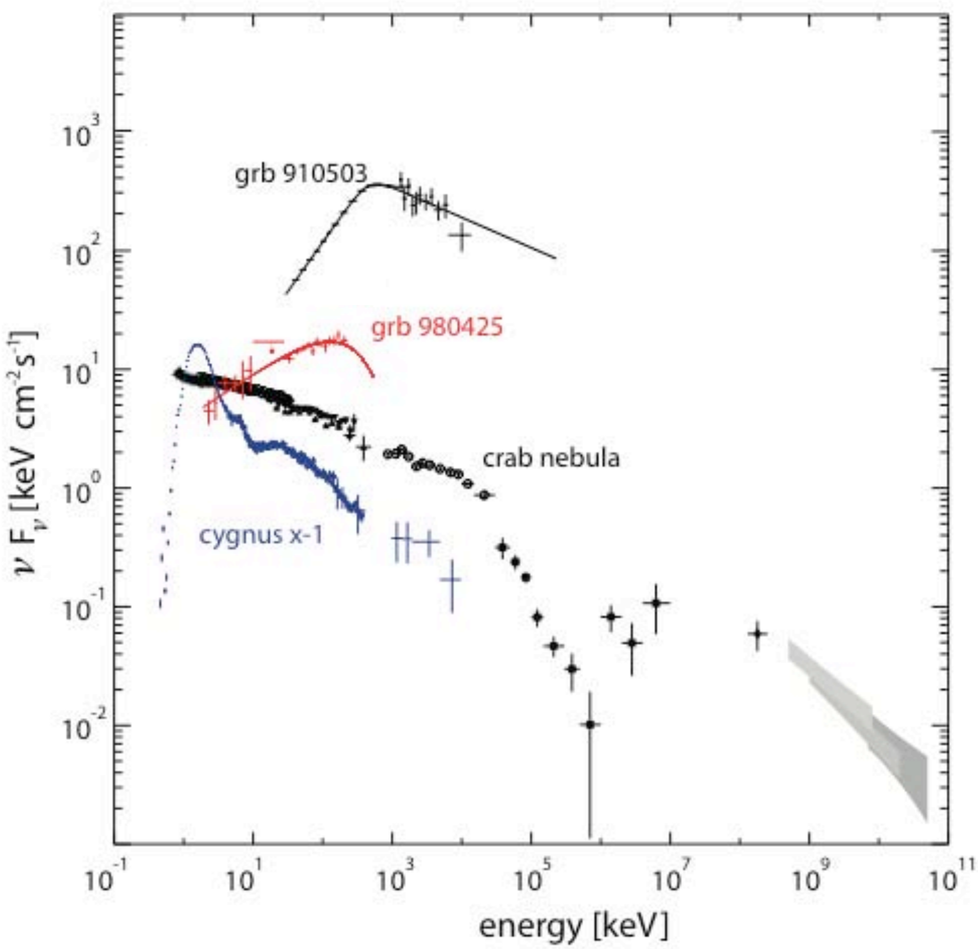
Short vs Long





Kouveliotou et al. 1993

Swift Era GRB Properties



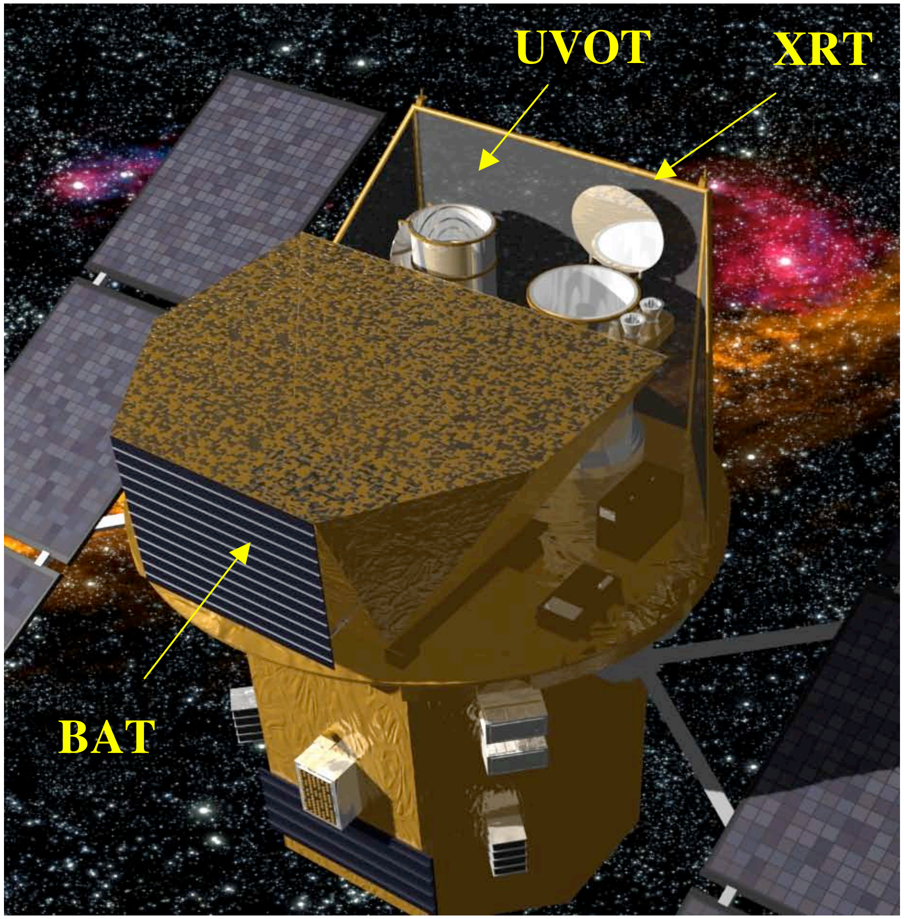
ARAA article

Two types:
Short GRBs (t < 2s)
Long GRBs (t > 2s)

Energy release:
10^{49}-10^{50} ergs SGRBs
10^{50}-10^{51} ergs LGRBs

Redshift range:
0.2 - ~2 SGRBs
0.009 - 8.2 LGRBs

Jet opening angle:
~10 (?) deg SGRBs
~5 deg LGRBs



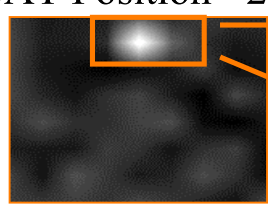
Swift Mission

3 instruments, each with:
- lightcurves
- images
- spectra

Rapid slewing spacecraft

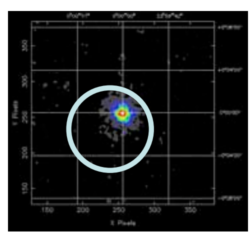
Rapid telemetry to ground

BAT Position - 2 arcmin



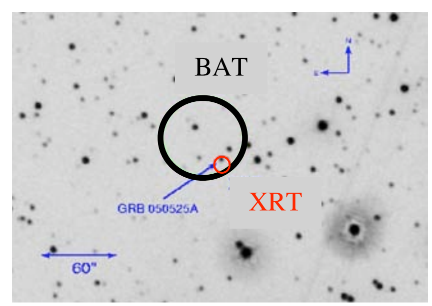
T<10 sec

XRT Position - 5 arcsec



T<90 sec

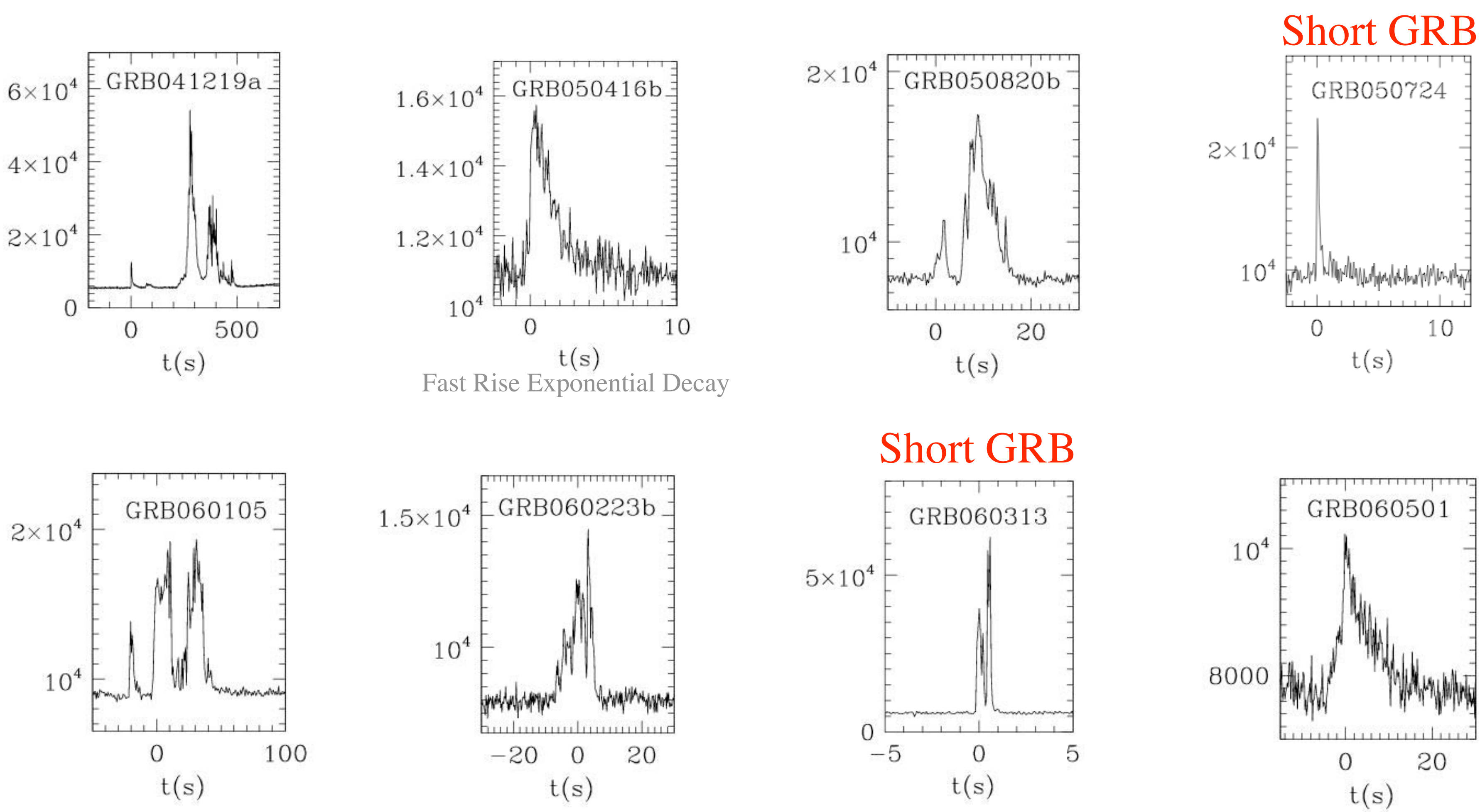
UVOT Position - < 1 arcsec



T<2 min

Swift Statistics

468 GRB as of this week
- 85% with x-ray detections
- ~60% with optical detection
- 151 with redshift (41 prior to Swift)
- **46 short GRBs** localized (0 prior to Swift)

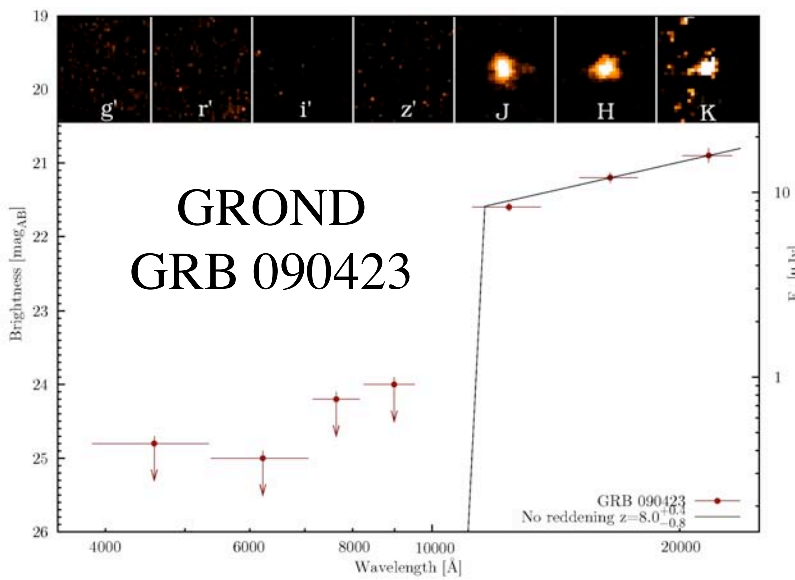


"The Year of High-z GRBs"

z	Time (10^9 years)	GRB	Optical Brightness
8.3	13.0	090423	K = 20 @ 20 min
6.7	12.8	080813	K = 19 @ 10 min
6.29	12.8	050904	J = 18 @ 3 hrs
5.6	12.6	060927	I = 16 @ 2 min
5.3	12.6	050814	K = 18 @ 23 hrs
5.11	12.5	060522	R = 21 @ 1.5 hrs

GRBs: brightest high redshift sources

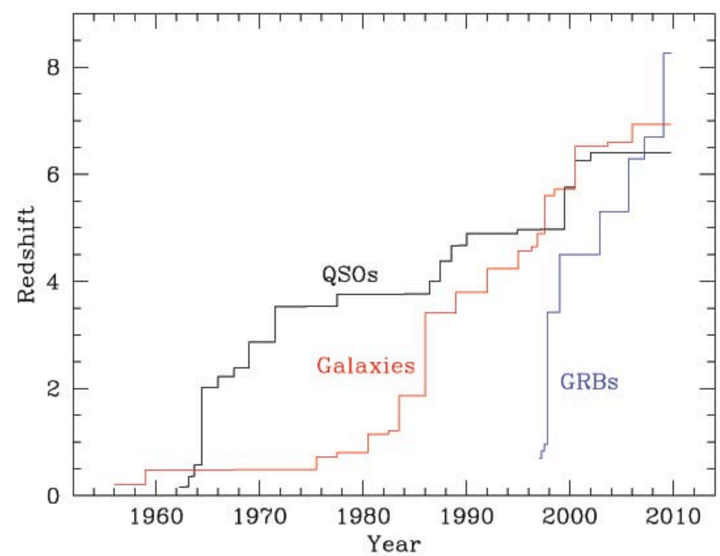
Lamb & Reichart 2000
Bromm & Loeb 2006



z = 8.29

13.0 Gyrs

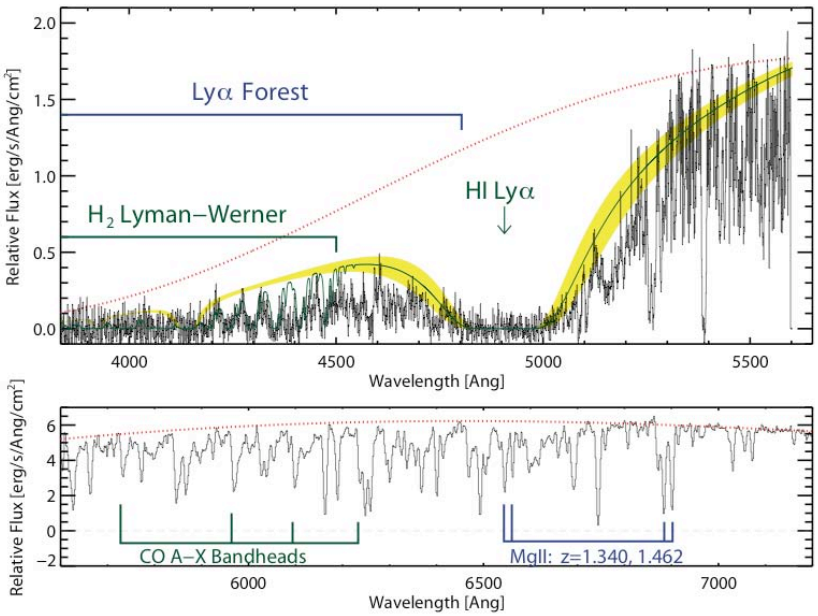
Salvaterra et al. Tanvir et al. 2009



Tanvir et al., update Savaglio

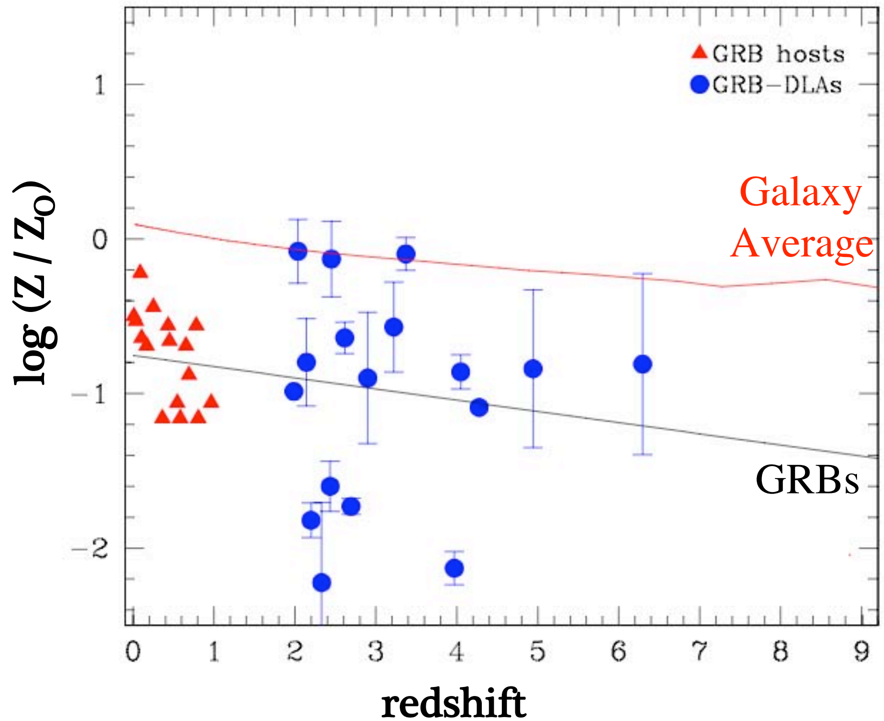
GRBs as Probes of the High-z Universe

GRB 080607
z=3.036



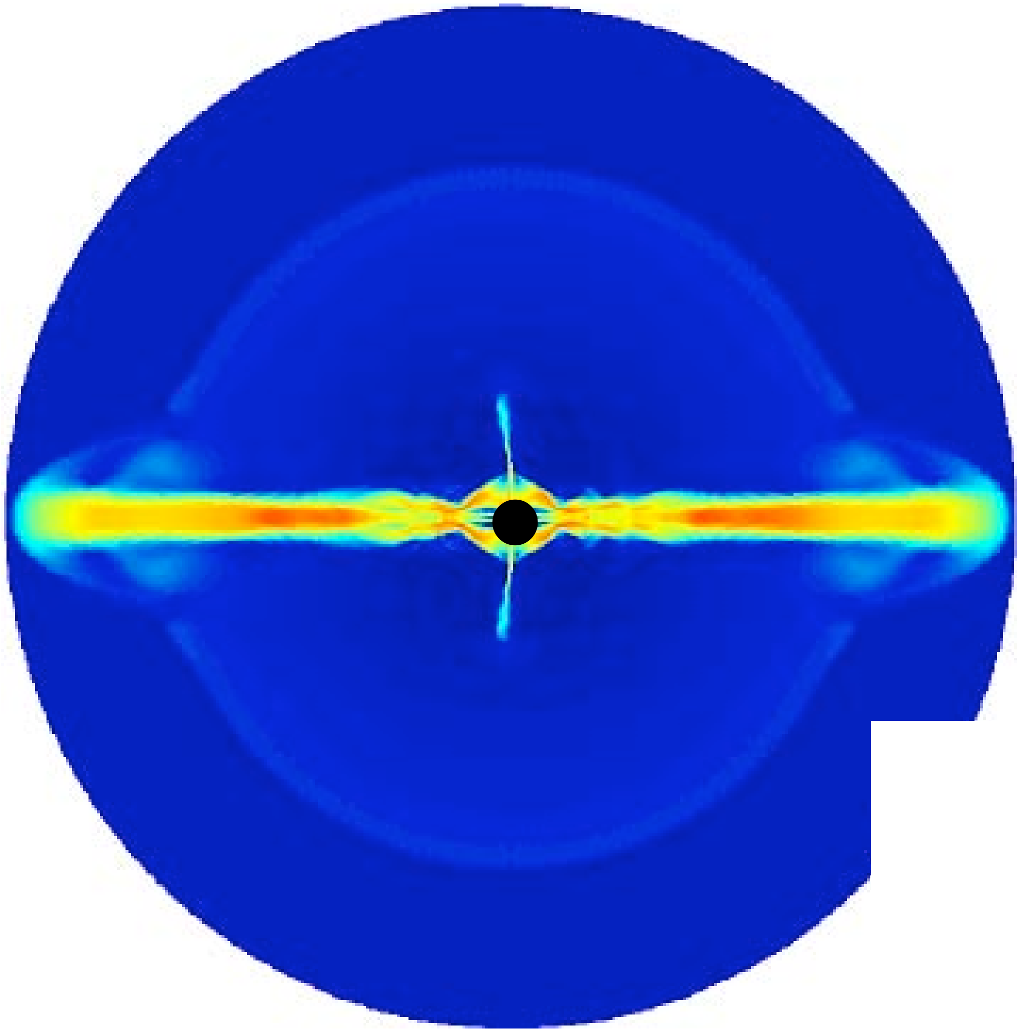
Prochaska et al. 2008

Metalicity vs z



Savaglio et al. 2009

Long GRBs
Collapsar Model

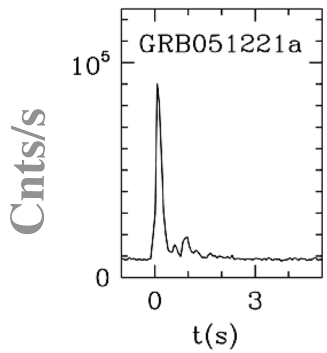


Barkov & Komissarov

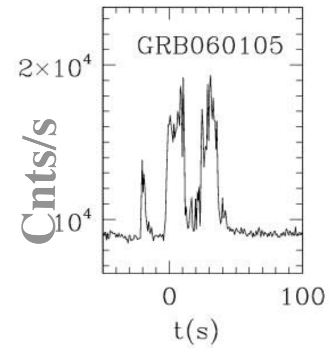
Zhang, Woosley & Heger

Short vs Long GRBs

Short GRB

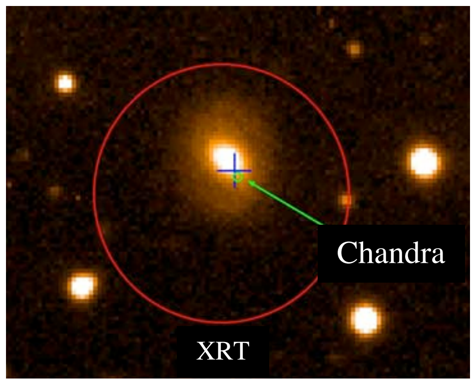


Long GRB

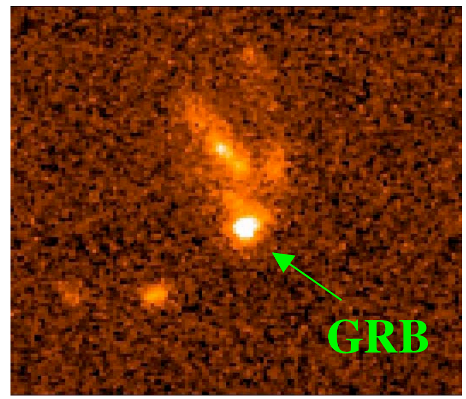


GRB 090916

GRB 050724 - *Swift*
elliptical host



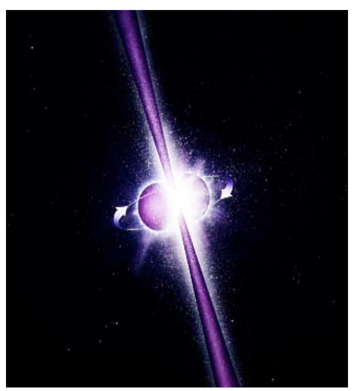
GRB 990123 - *SAX*
SF dwarf host

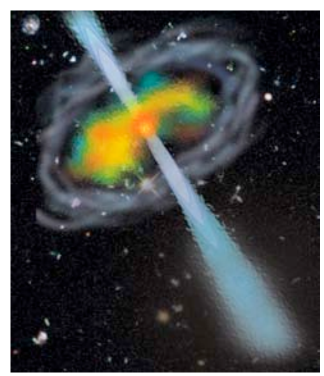


In non-SF
and SF galaxies

No SNe detected

Possible **merger** model





BH

In SF galaxies

Accompanied by SNe

Collapsar model well supported

Short GRBs Compared to Long GRB

46 short GRBs detected by Swift/BAT

Lower Redshifts

$< z > = 0.4$ short

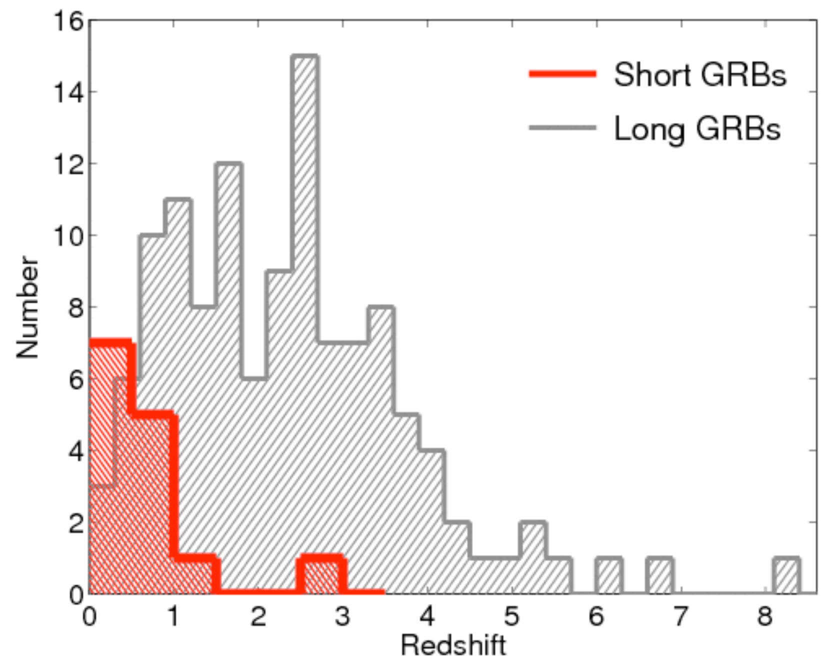
$< z > = 2.3$ long

Weaker Afterglows

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

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

Big push by GRB community to detect short GRB afterglows



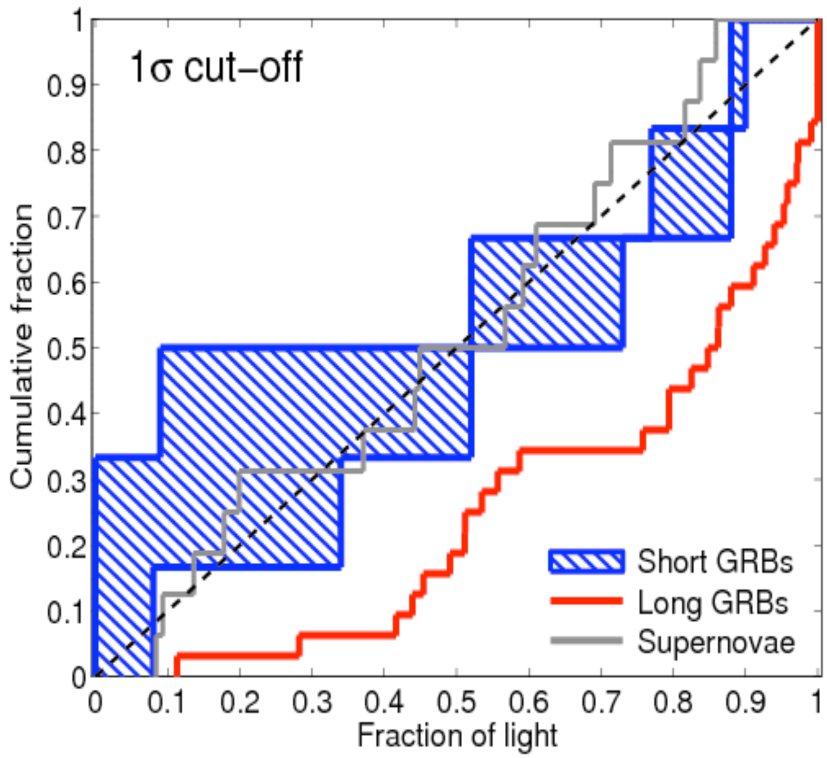
Berger 2009

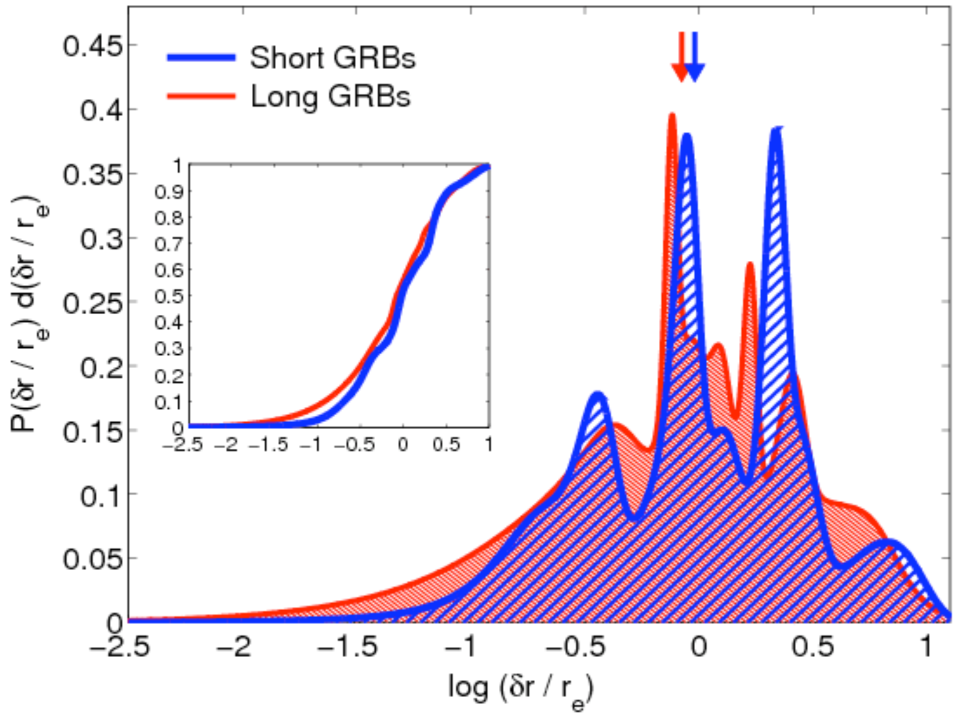
$\tau_{merger} \sim 3$ Gyr

Short GRBs - HST Imaging

Short GRBs trace the light distribution of their hosts

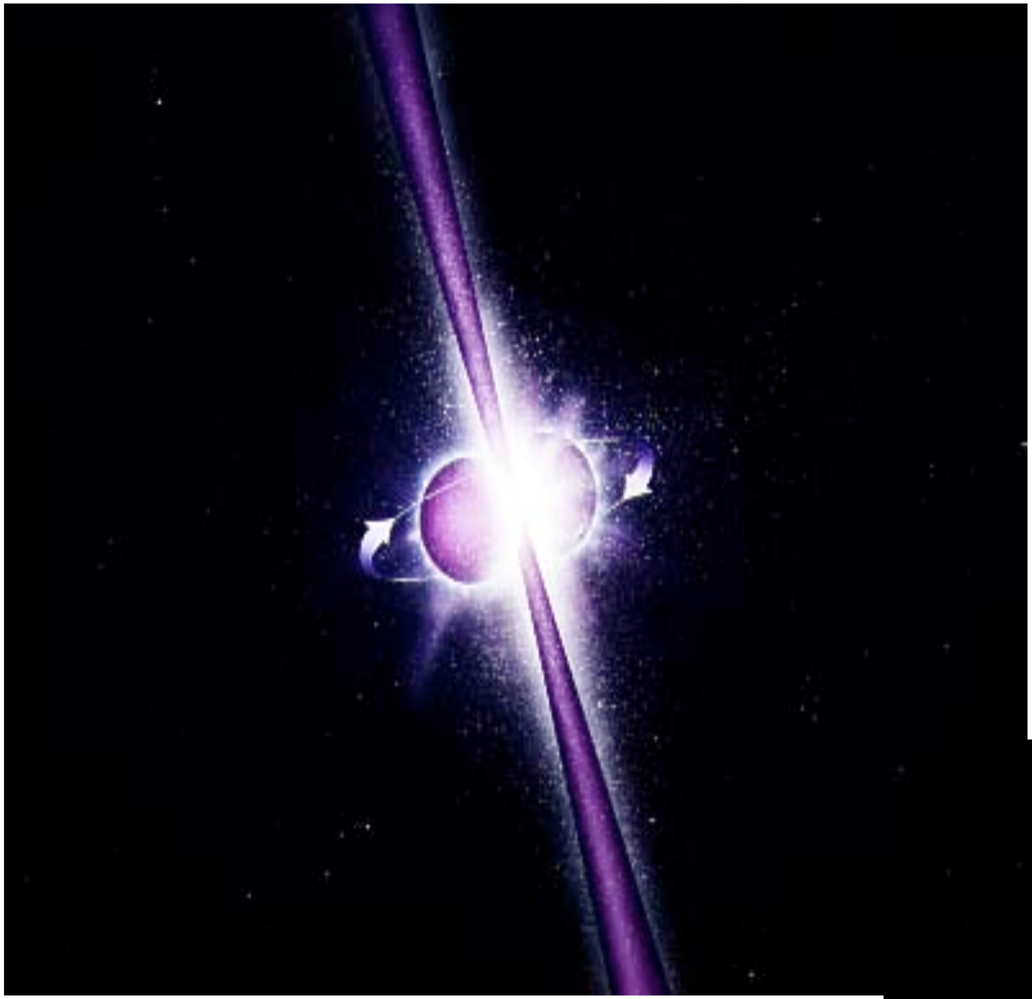
The host-normalize offsets of short and long GRBs are similar

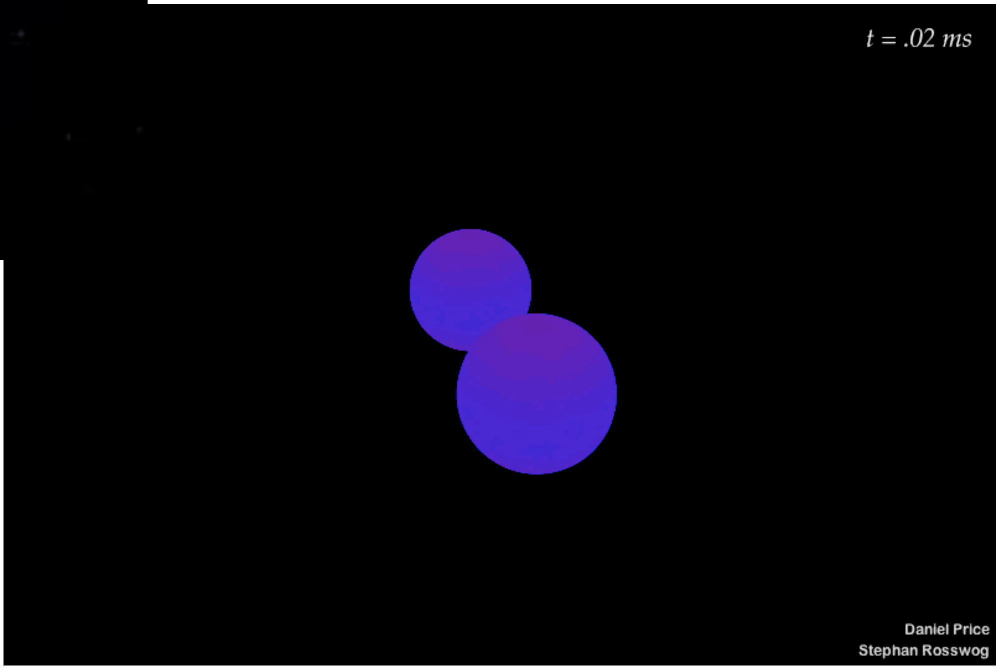




Fong, Berger & Fox 2009

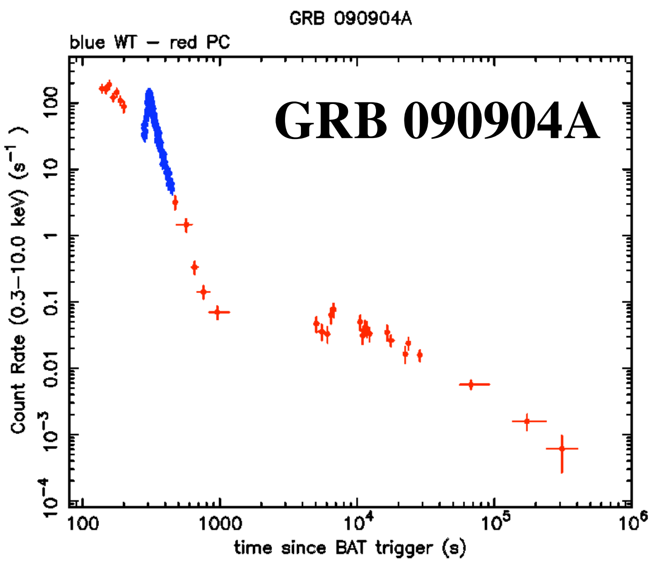
Short GRBs
Merger Model





Credit: Daniel Price and Stephan Rosswog

X-ray Afterglow & Flares



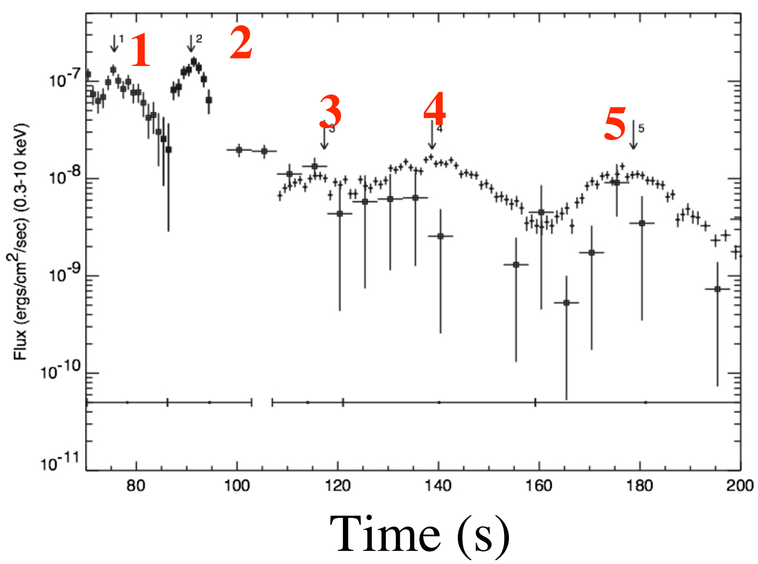
New components in afterglow
- Bright with rapid decay
- Plateau phase
- Flares

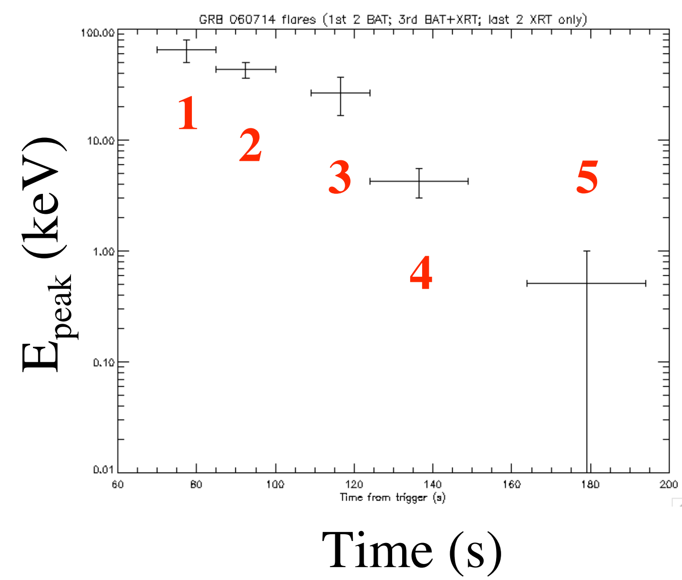
~30% of bursts have X-ray flares
Continuation of prompt "flares"

Nousek et al.
Zhang et al.
Burrows et al.

GRB 060714

Krimm et al.

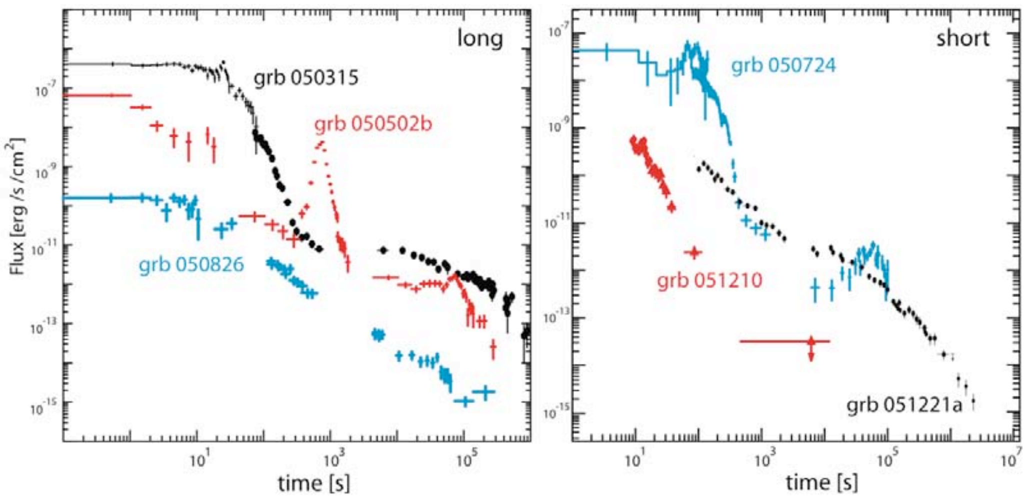




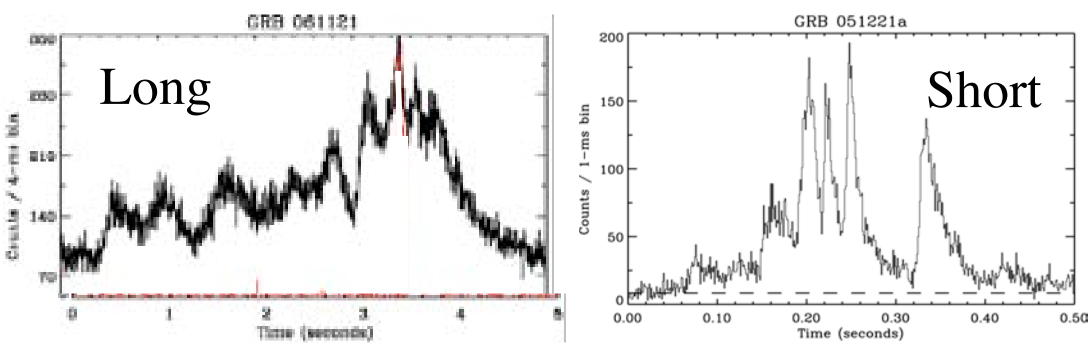
Similarities of Short & Long GRBs

Similar LC shapes

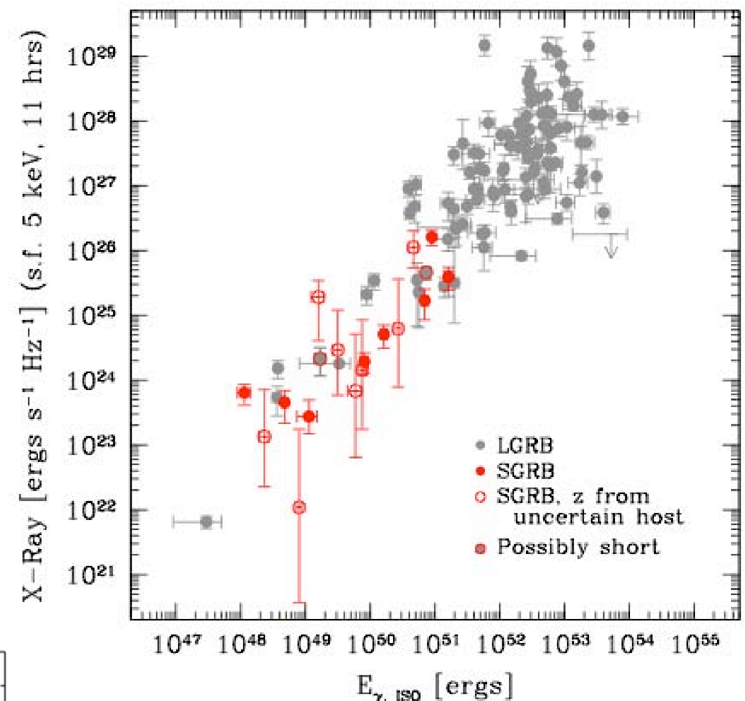
ARAA paper



Similar Variability



Similar L_X / $E_{\gamma\text{-iso}}$

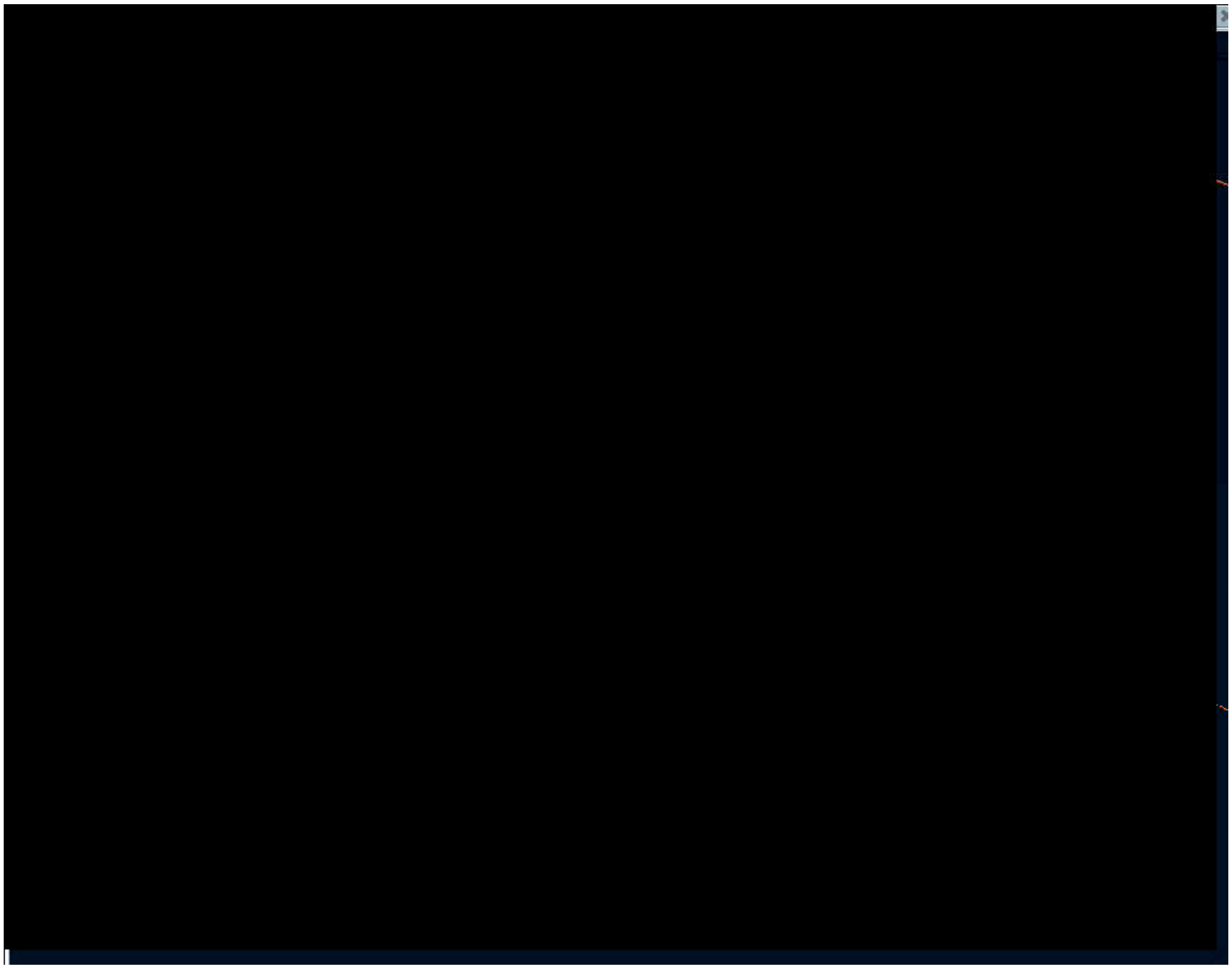


Nysewander, Fruchter & Pe'er 2009

Finding #1

GRB afterglow properties appear to be independent on nature of central engine

Zhang
Woosley
Heger



Finding #2

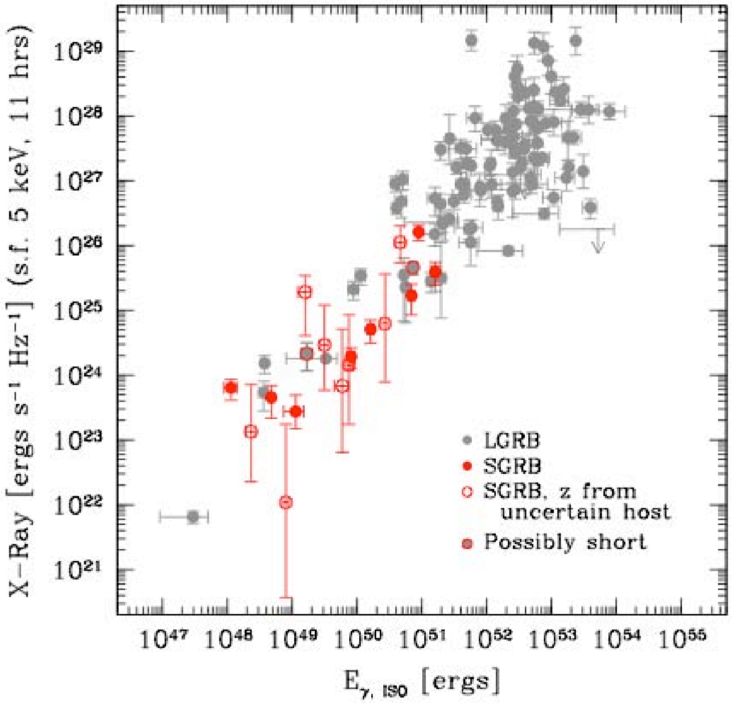
Similarity of L_X / $E_{\gamma\text{-iso}}$ implies

- densities at burst sites are similar

or

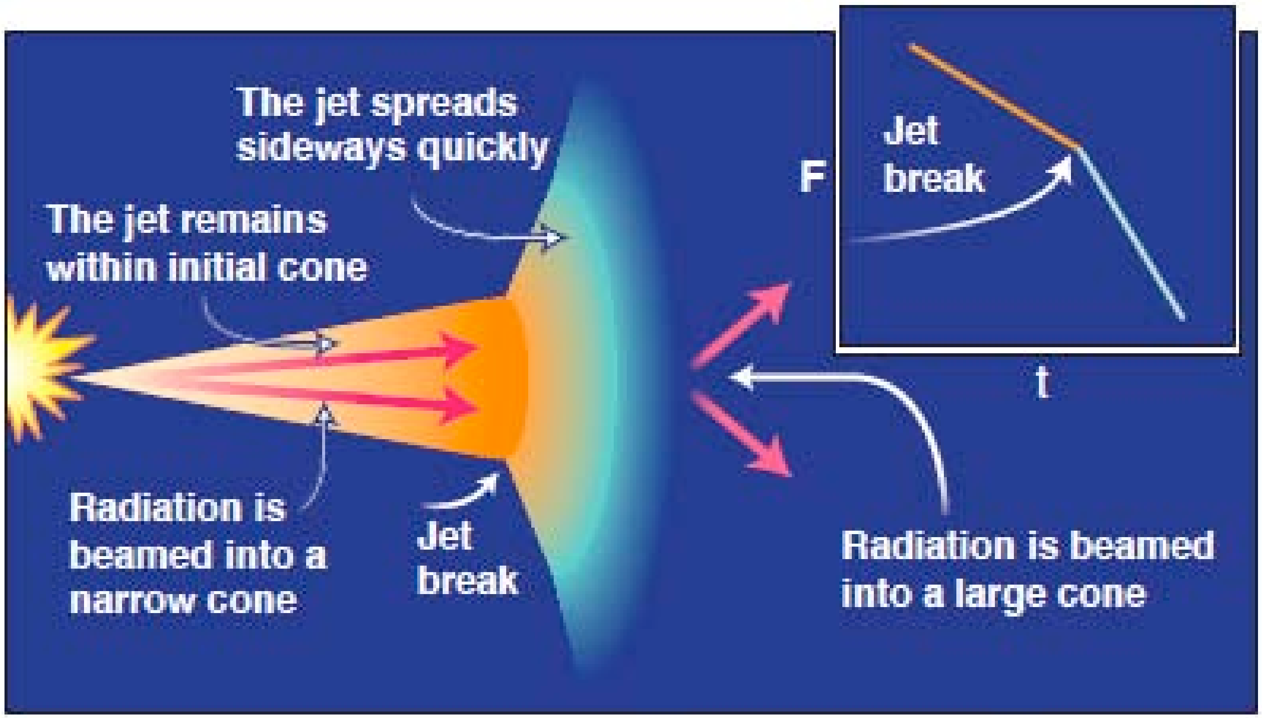
- afterglow does not depend on external medium (internal shocks)

Similar L_X / $E_{\gamma\text{-iso}}$



Nysewander, Fruchter & Pe'er 2009

Jet Breaks

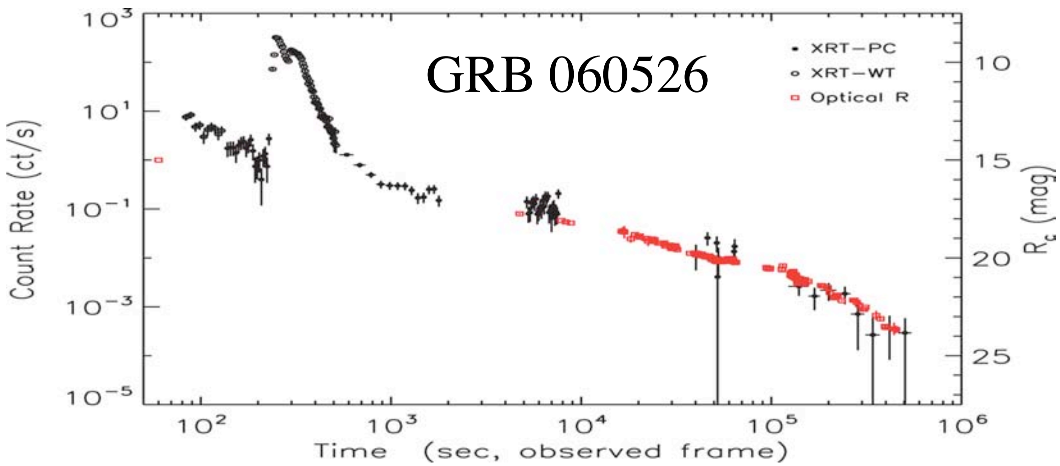


Piran 2002

beaming much less at late times

A Tale of 2 Bursts

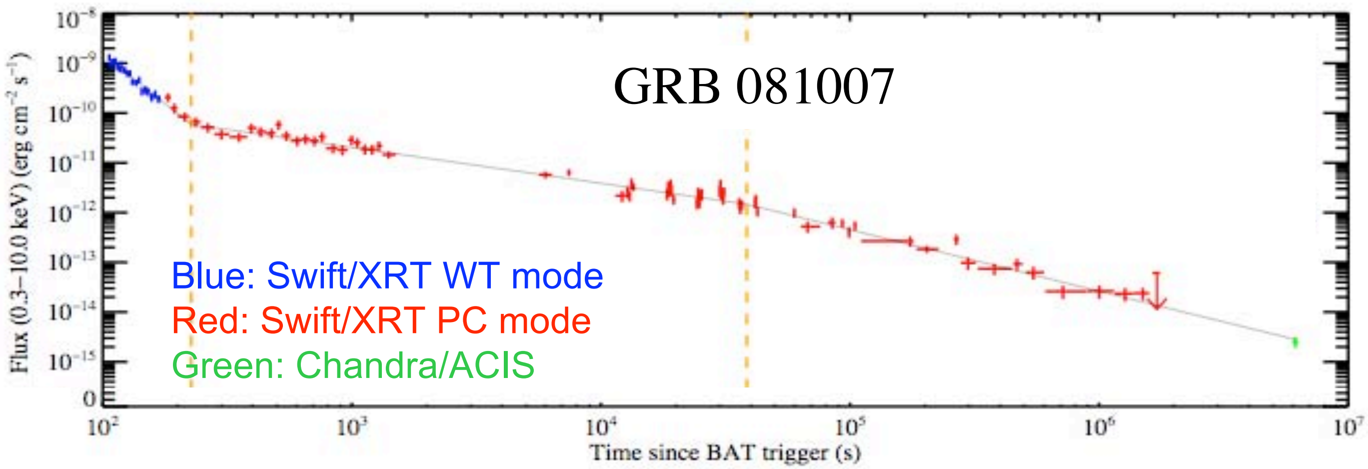
Dai et al. 2007



jet break

$\theta = 7^{\circ}$

Burrows Racusin et al.



NO jet break

$\theta > 20^{\circ}$

Sari et al. 1999; Frail et al 2001

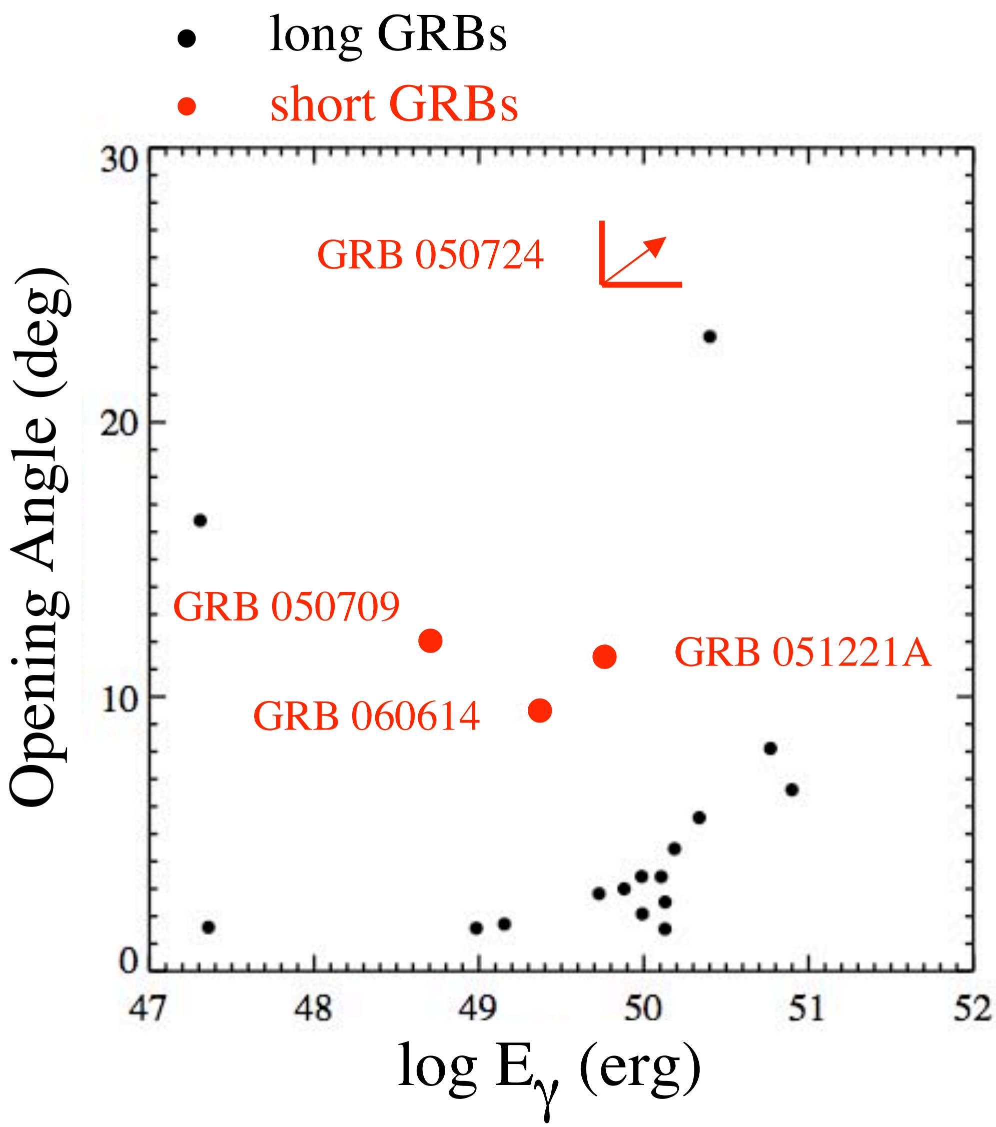
$$\theta = 3.3\ (t_{break}/1\text{day})^{3/8}\ ((1+z)/2)^{-3/8}\ (E_{iso\text{-}\gamma}/10^{53}\ \text{ergs})^{-1/8}\ (\eta_{\gamma}/0.2)\ (n/0.1\ \text{cm}^{-3})^{1/8}$$

Finding #3

Jet breaks are often not apparent in *Swift* era

Late radio observations with EVLA will give
- absolute E_γ
- θ_{jet}

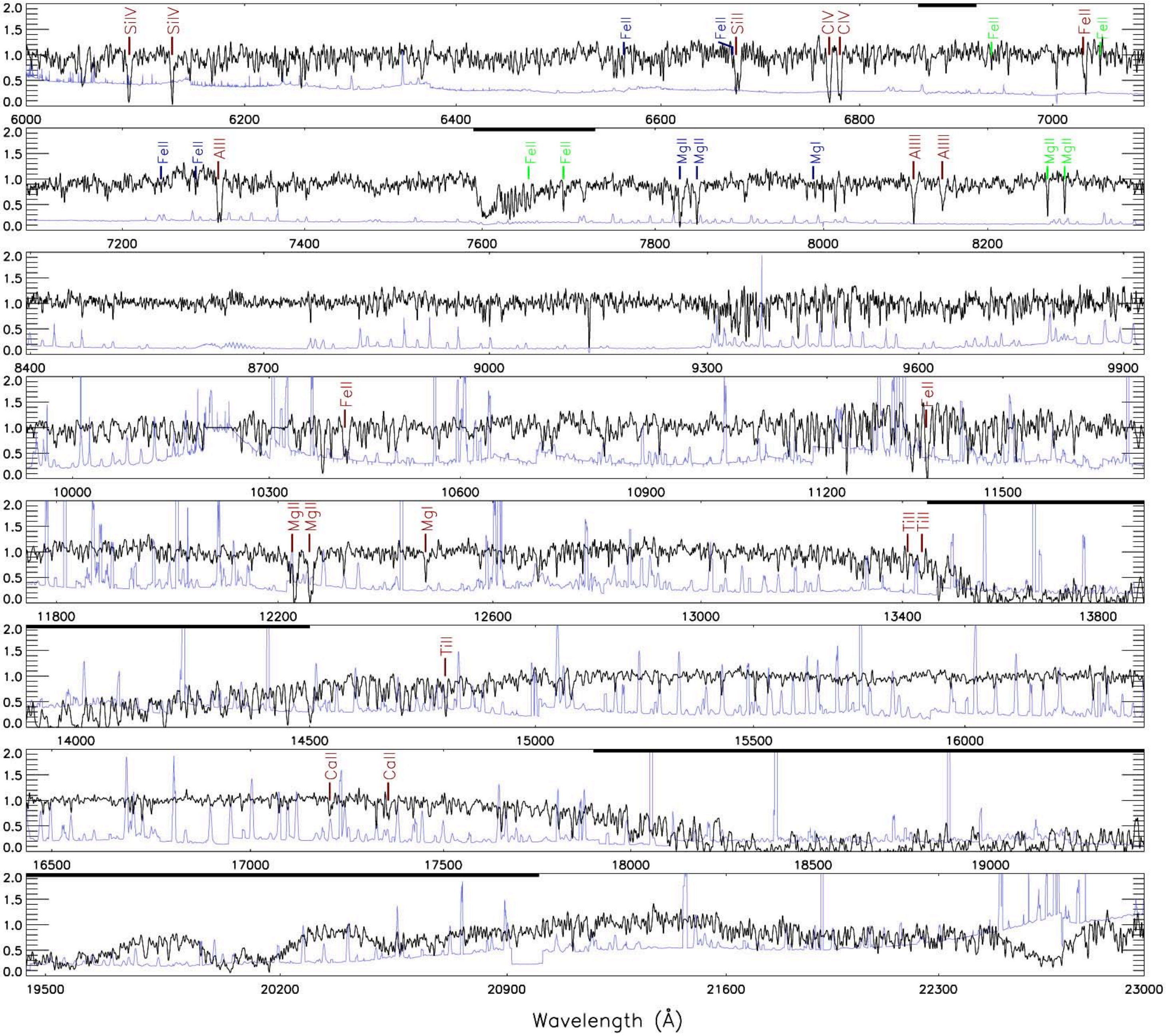
Frail 2009



$$E_{total\text{-}late} / E_{iso\text{-}early} = \Omega_{jet} / 4\pi$$

Racusin et al. 2009

GRB 090313 z = 3.375



X-Shooter

Spectrograph on VLT

300 - 2500 nm

R = 4000- 14000

De Ugarte Postigo