Gamma-Ray Burst Explorer:

Latest Results

John Nousek (Penn State University)

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Relativistic Jets, Krakow, Poland, 25 June 2006

Swift launch:

20 Nov 2004 !!

MOC Facility

Located in State College, PA

~ 4 km. from Penn State campus

Flight Operations Team (FOT)

– responsible for observatory Health & Safety

Science Operations Team (SOT)

- responsible for scientific operation of Swift

Has continuously operated *Swift* successfully from L+80 minutes to now!

Swift Observatory Status

Swift meets or exceeds all Level 1 requirements !

- **Observatory Science Up-time: 96.7%**
  - Except for rare spacecraft or instrument down-time and SAA passage, Swift collects data continuously
- **Ground Station Status: Nominal**
  - Malindi 5607 passes since Launch, 99.3% successful
  - TDRSS DAS currently providing 99.3% success rate
  - USN backup provided 3 successful of 3 requested passes since Apr, 2005
- **Observatory Status: Nominal**
  - ACS: executed 41,453 slews, >99% within 3' accuracy
  - All systems functioning properly, without any signs of degradation
- **Observatory Lifetime: Above prediction**
  - Orbital life expected to >2013, no observatory or instrument limits known
- **Flight Operations Team Response: Excellent**
  - On average, there was an FOT after hours response once every three days
- **Science Operations Team Response: Excellent**
  - SOT has prepared schedules for Swift every day without an SOT induced error
  - SOT/BA team has responded to every GRB with prompt (typical < 1 hour) data analysis and preparation of GCN circulars, ATELs etc for about 200 events

Statistics from Rob Laverghetta, FOT as of 21 May 2006

Publications

Publications in first 1.5 years

- ~120 papers published in ApJ, A&A, MNRAS
- ~60% with first author not on Swift team
- 13 Letters in Nature & Science (http://swift.gsfc.nasa.gov/docs/swift/results/publist for list of papers and links)
- ~600 Swift GCN Circulars (plus ~800 community GCNs for Swift GRBs)
- ~50 ATELs and IAU Circulars
- 4 press events

Statistics courtesy of Neil Gehrels – Apr, 2006

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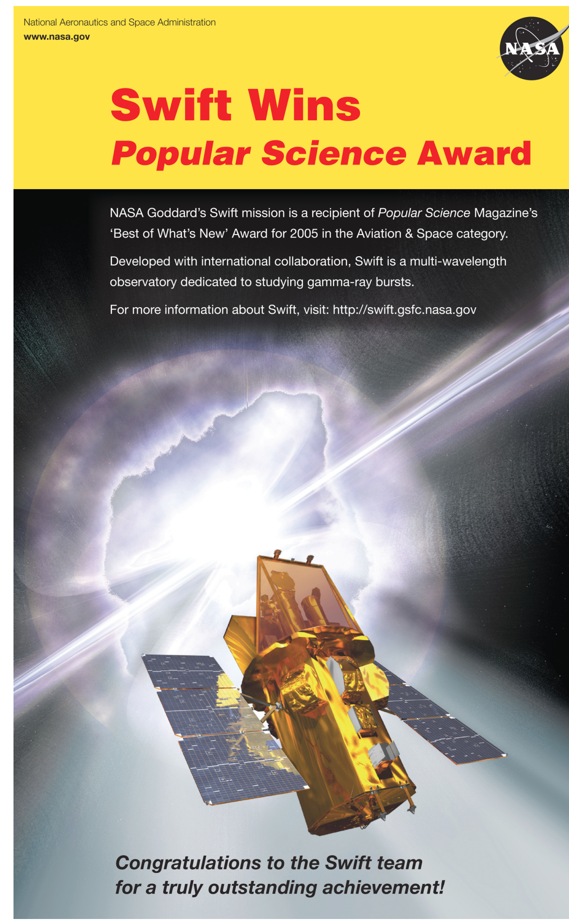
Popular Science "Best of What's New in Space Science"



Swift Observing Strategy

SOT prioritizes targets by following criteria:

- **GRB automated response, afterglow followup, GRB ToO: 64%**
  - Visible GRB afterglows receive top priority
  - Typically 2-6 afterglows visible each day, but require ~4 targets per orbit
- **Targets of Opportunity (non-GRB ToO): 10%**
  - Currently solicited via public webpage with 5 levels of urgency
  - Approved by Neil Gehrels, Swift PI
  - Swift AO-3 will allow peer review of ToO proposals
- **Instrument Calibration: 6%**
  - Proposed by instrument teams as needed
- **Fill-in Targets: 18%**
  - Selected from lists proposed by Swift team which survived internal peer review
  - Only observed when no targets in higher priority levels are available
  - Chosen with consideration to maximize sun angle and reduce XRT temperature
  - Swift AO-4 will allow peer review of target proposals from general community

BAT Bursts

- **142 GRBs detected/imaged 17 Dec 04 to 15 May 06 => 102/yr**

041217
041219A,B,C
041220
041223
041224
041226
041228
050117
050124
050126
050128
050202
050215A
050215B
050219A,B
050223
050306
050315
050318
050319
050326
050401
050406
050410
050412
050416A,B
050418
050421
050422
050502B
050505
050507
050509A,B
050525
050528
050603
050607
050701
050712
050713A,B
050714B
050715
050716
050717
050721
050724
050726
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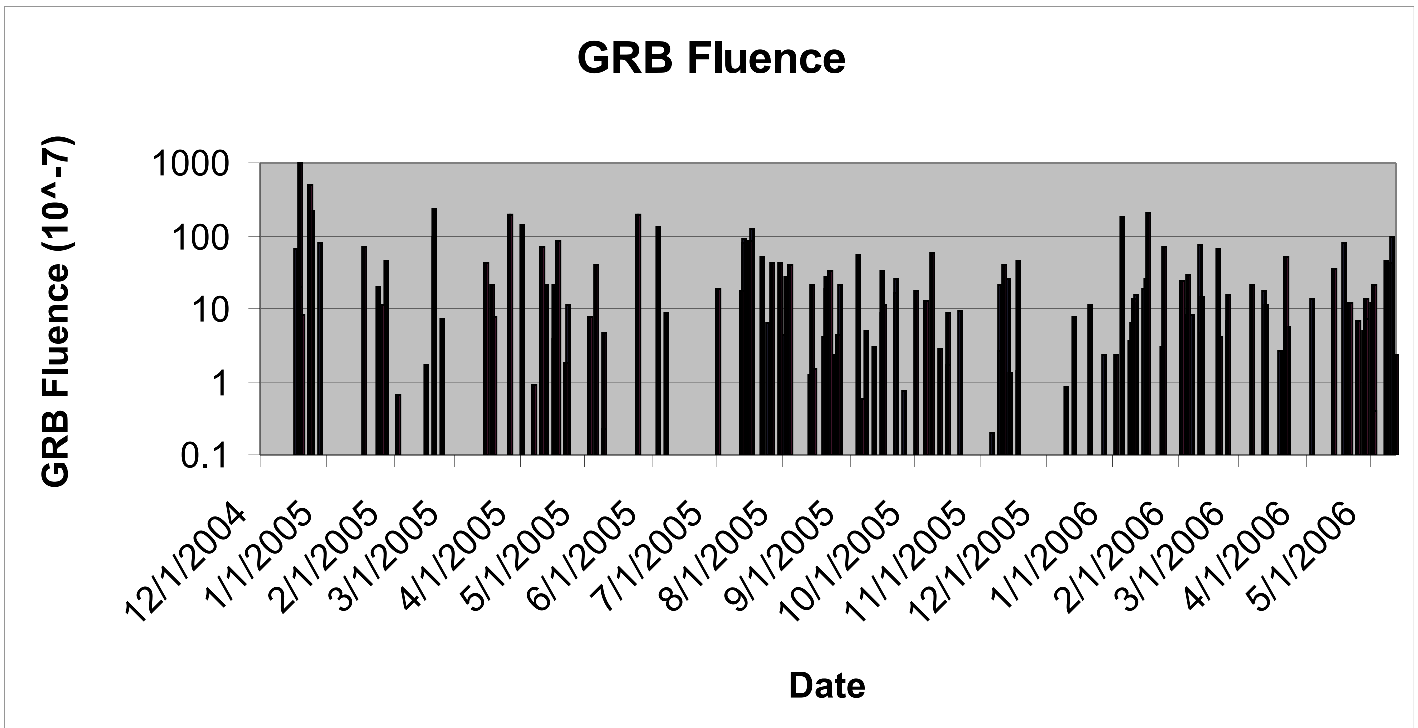
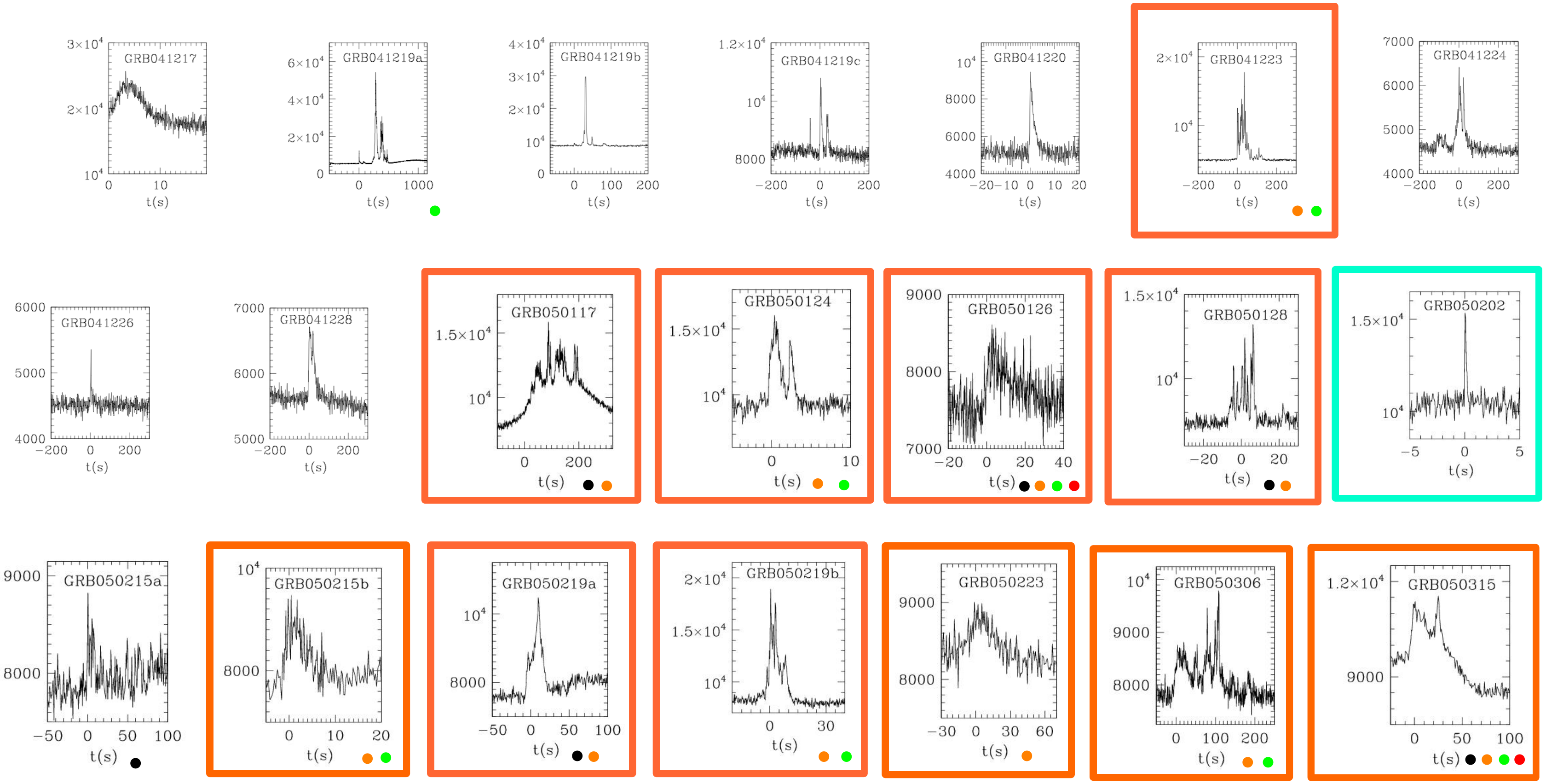
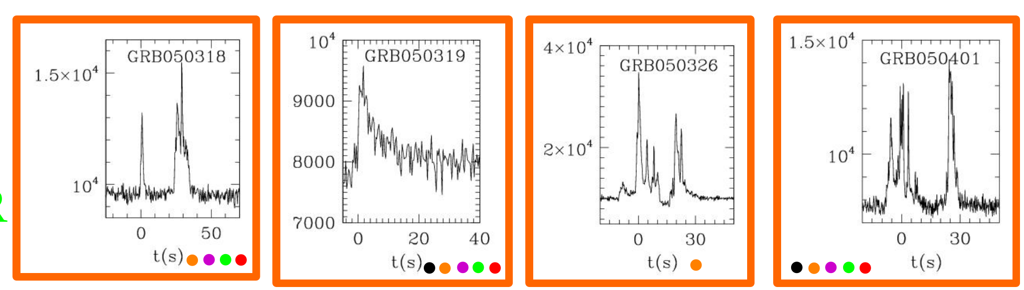
050824
050826
050827



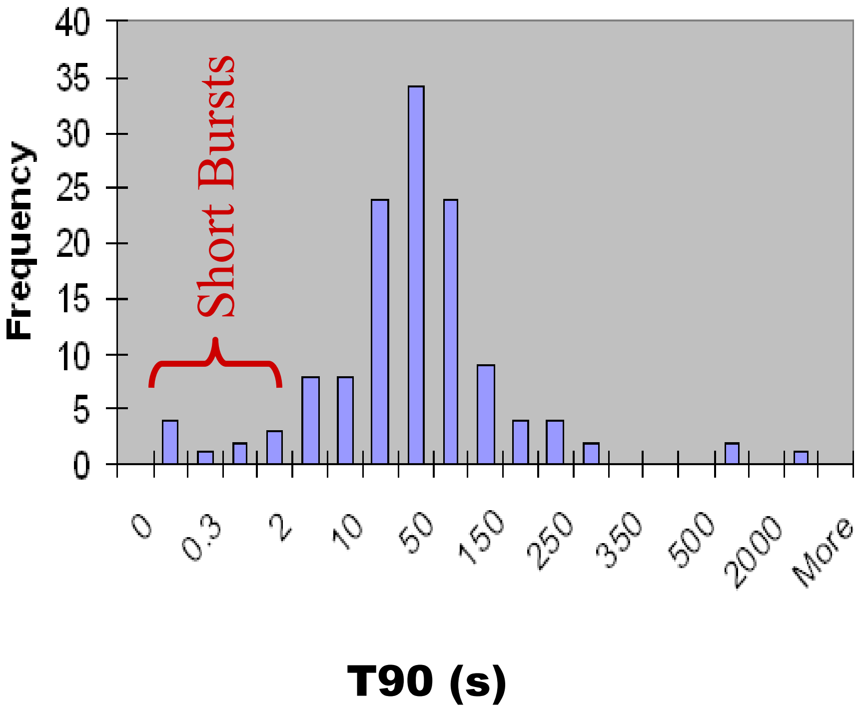
Light Curves of First 25 BAT GRBs

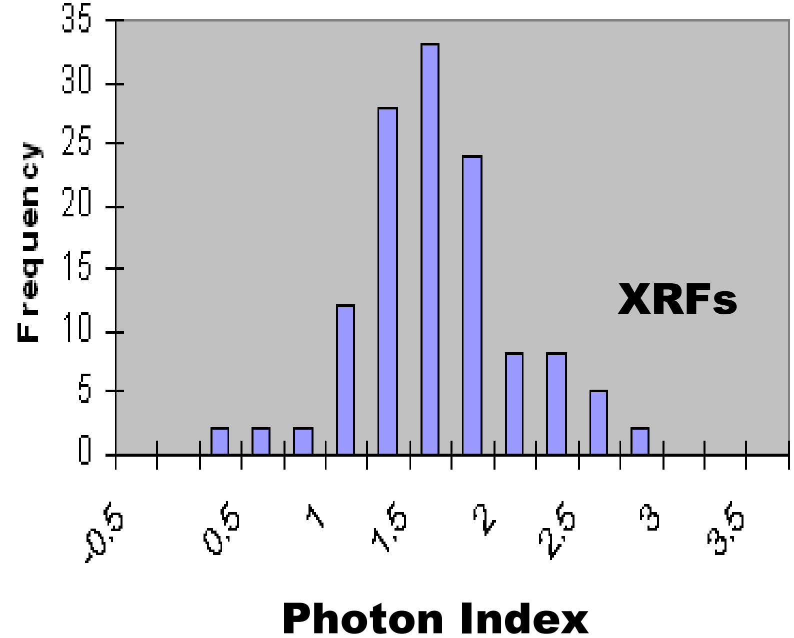


- • = prompt slew
- • = detected by XRT
- • = detected by UVOT
- • = detected by ground-based optical/IR
- • = redshift measurement



BAT GRB T90 & Photon Indices



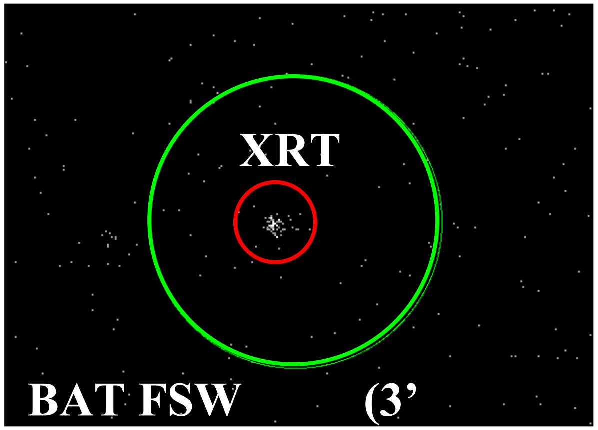


Mean = 1.67
Median = 1.62

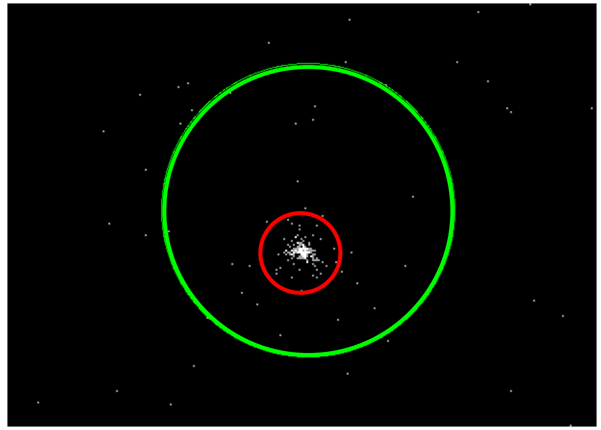
Statistics courtesy of Dave Burrows

BAT GRB Position Accuracy

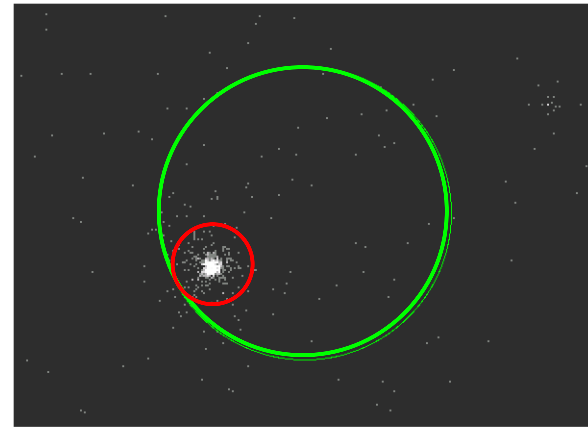
GRB 050215b



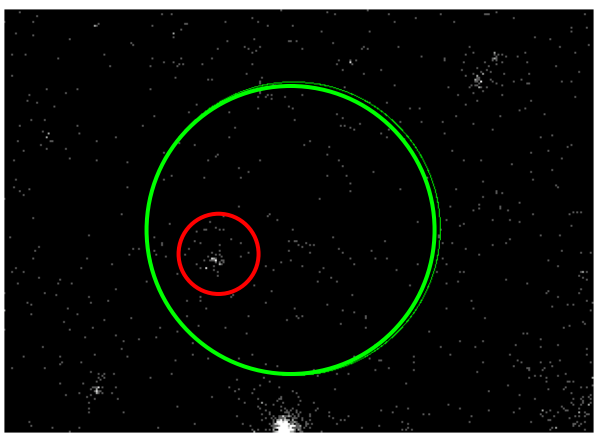
GRB 050315



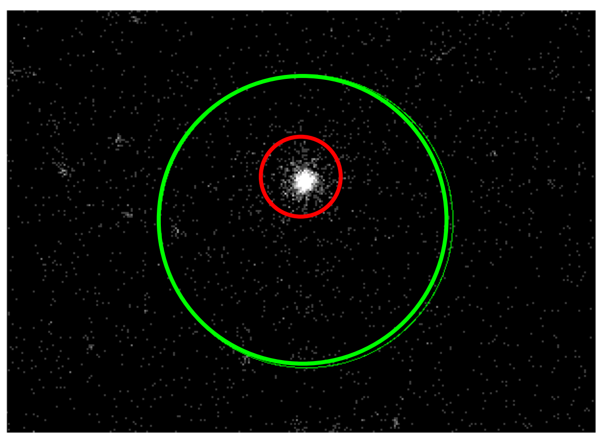
GRB 050319



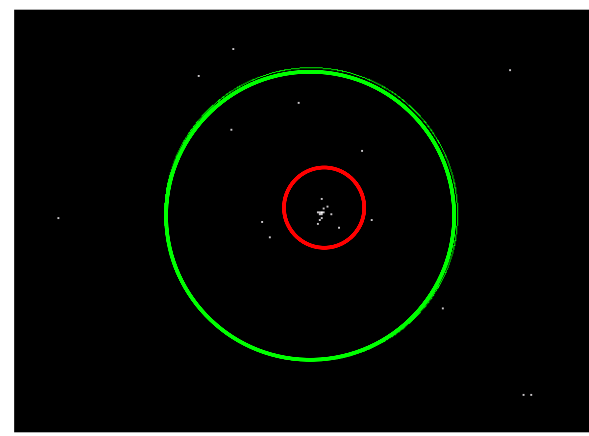
GRB 050406



GRB 050416a



GRB 050509a



Mean BAT position error: 52 arcseconds

XRT Detections of BAT GRBs

- LGRBs:
  - Detected **109/110 = 99%** with XRT (observed @ T < 200 ks)
    - Compare with 55 LGRB afterglows before Swift launch
  - ~80% had prompt slews
    - 95% of prompt XRT observations (< 350 s) yielded detections
    - ~80% have fast decline or flare within first ~5 minutes

- SGRBs:
  - Detected **8/12 = 67%** with XRT (observed @ T < 200 ks)
    - Compare with 0 SGRB afterglows before Swift launch
  - ~90% had prompt slews (one – 051114 – was delayed for 1.5d)

Statistics courtesy of Dave Burrows

UVOT Detections of BAT GRBs

- Detected 34/113 = 30% with UVOT
  - 93 were prompt observations => 37% UVOT detection rate for prompt observations

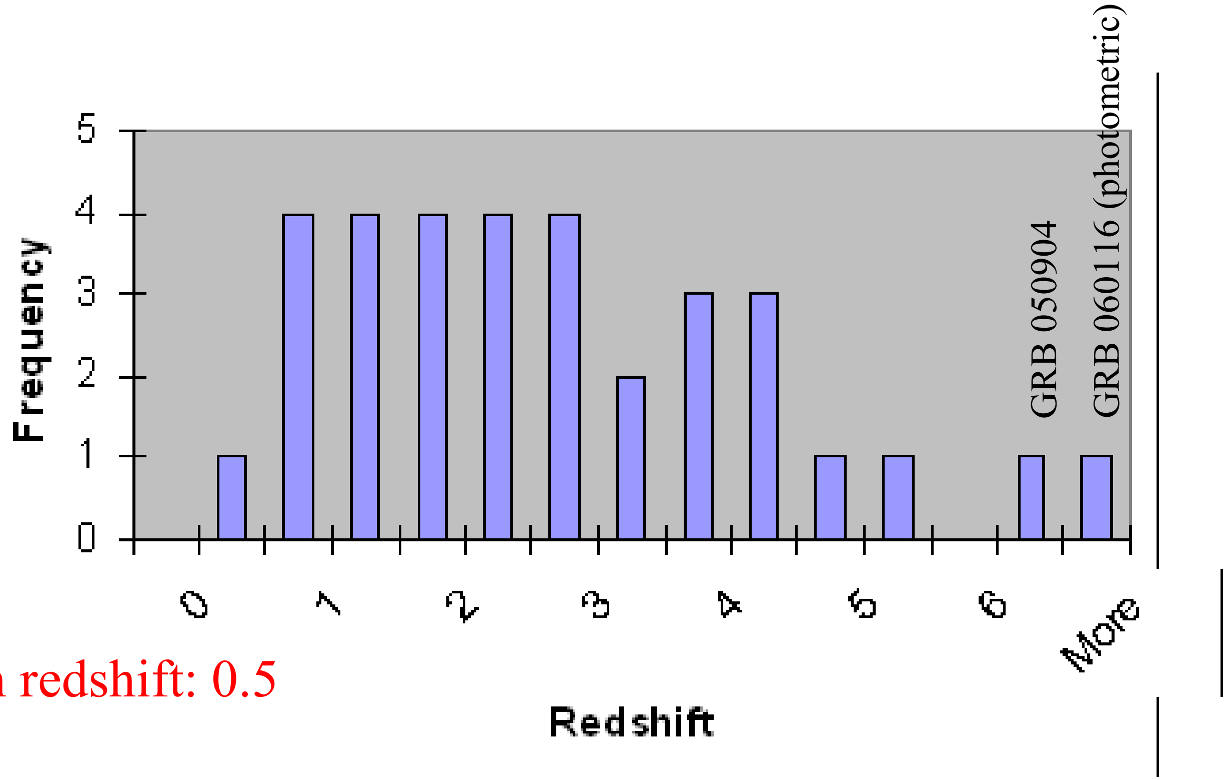
  - Recently changed observing sequence to include ‘white’
    - May increase UVOT detection rate to ~45-50%

  - UVOT upper limits are quite faint and very early for most of these

  - However, 70 have ground-based detections (typically R, I, J, or K)
    - Dust extinction? (some evidence supporting this)
    - Magnetic suppression?
    - High z? (certainly in some cases)

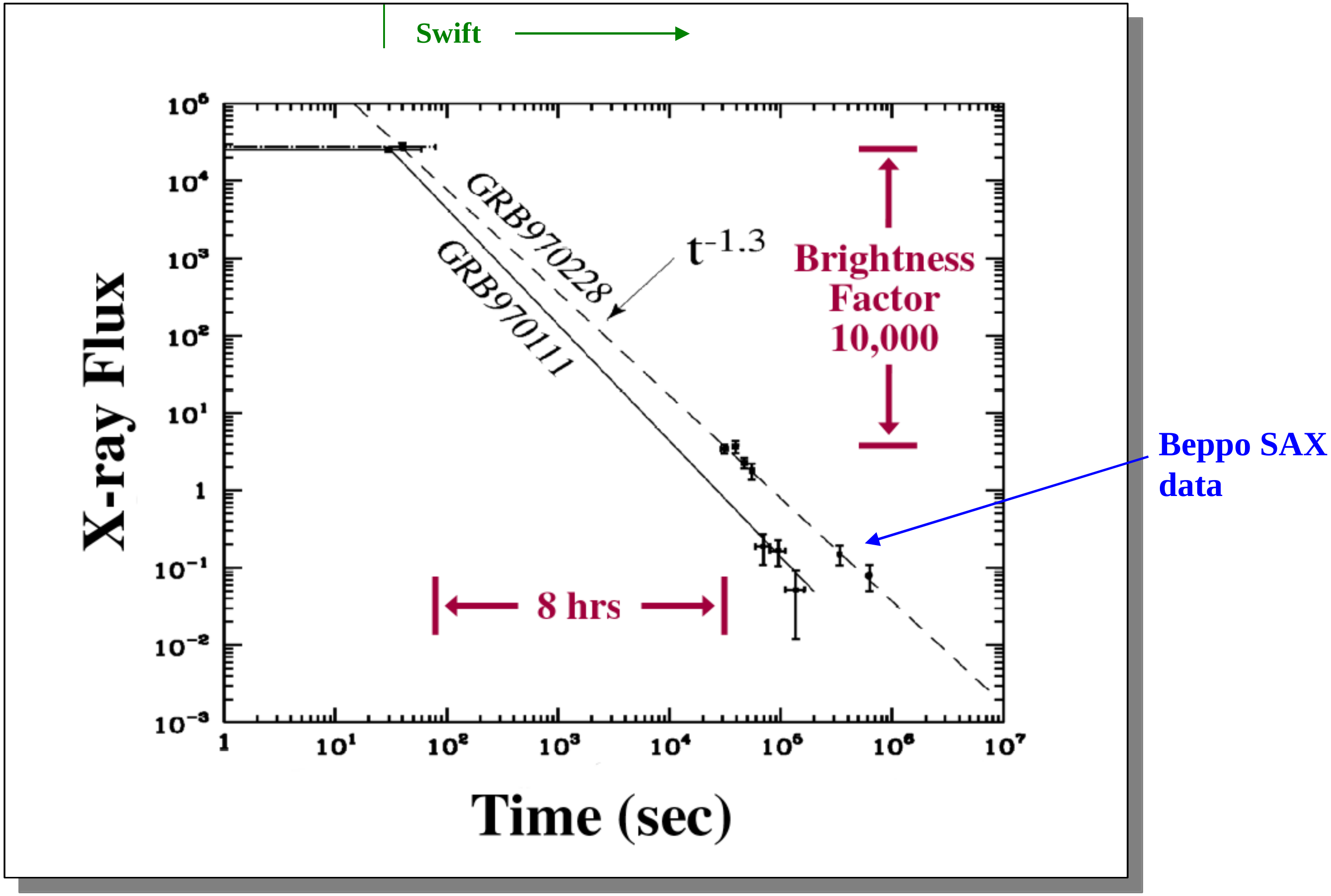
Redshifts of BAT GRBs

- 35 have redshift measurements:
  - Average redshift for LGRBs: 2.7
    (compared with about 1 for Beppo-SAX bursts)
    - Highest redshift: 6.29
  - 12 GRBs with z>3.9



- SGRB mean redshift: 0.5

Afterglow Evolution – Pre-Swift



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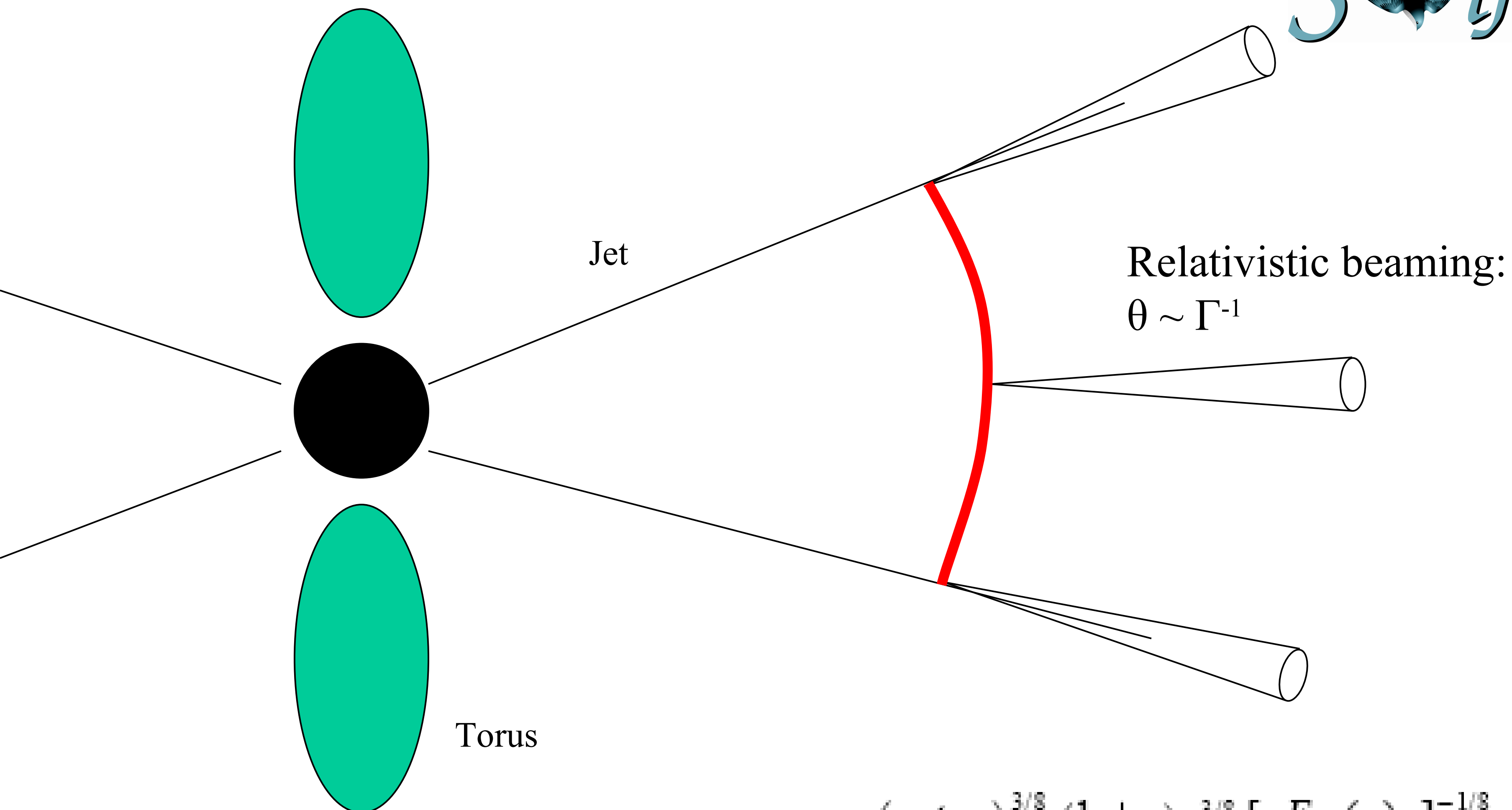
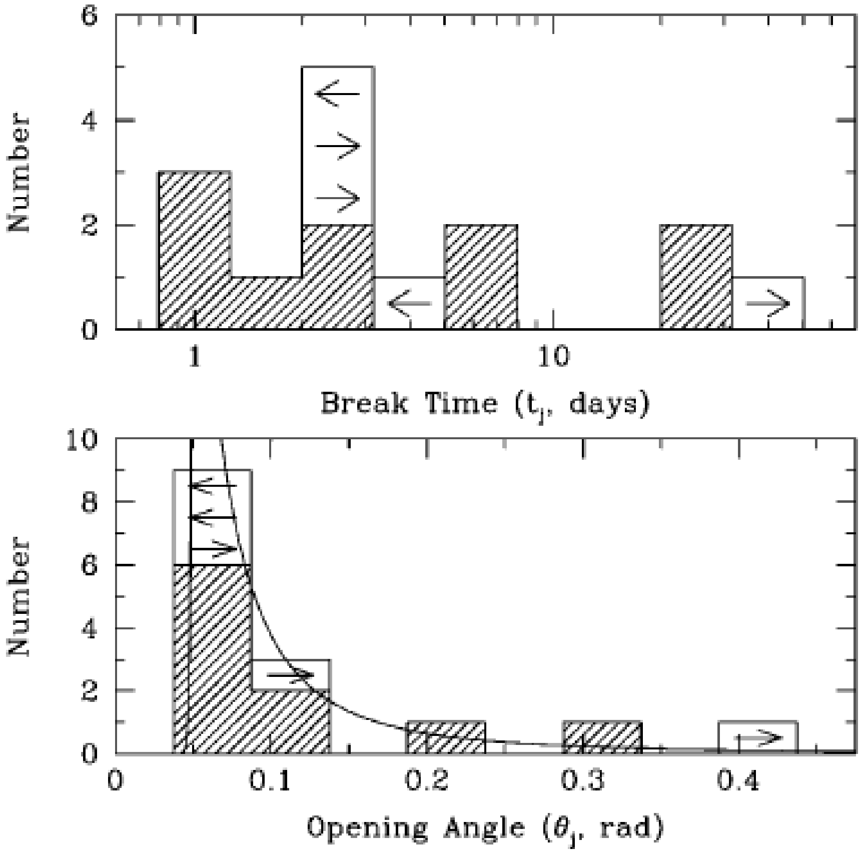
Jet Break

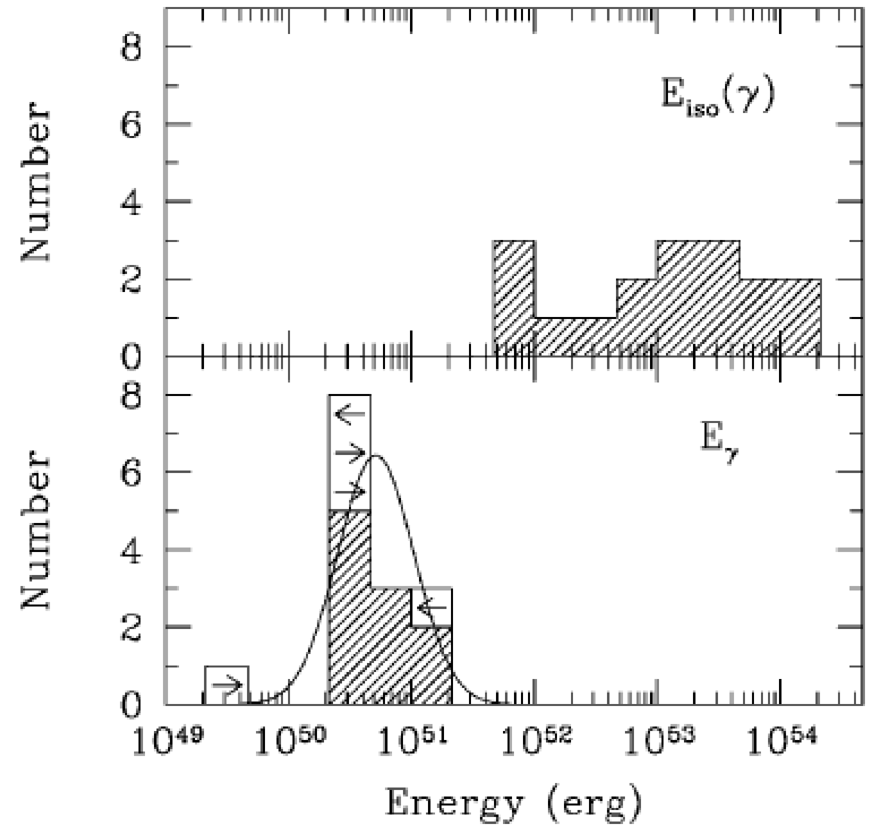


$$\theta_j = 0.057 \left(\frac{t_j}{1\ \mathrm{day}}\right)^{3/8} \left(\frac{1+z}{2}\right)^{-3/8} \left[\frac{E_{\mathrm{iso}}(\gamma)}{10^{53}\ \mathrm{ergs}}\right]^{-1/8} \times \left(\frac{\eta_\gamma}{0.2}\right)^{1/8} \left(\frac{n}{0.1\ \mathrm{cm}^{-3}}\right)^{1/8},$$

Frail et al. 2001, ApJ, 562, L55

Jet Break



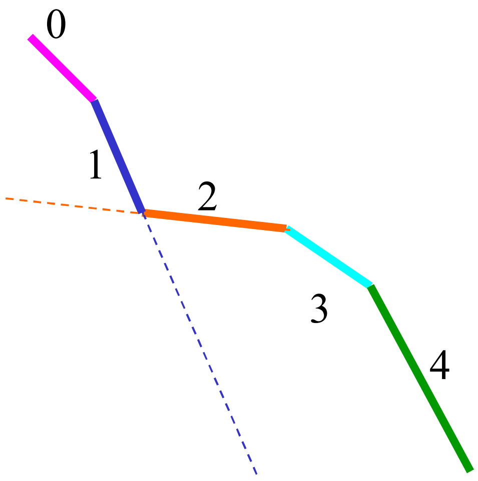


Jet break knowledge is critical for GRB energetics:

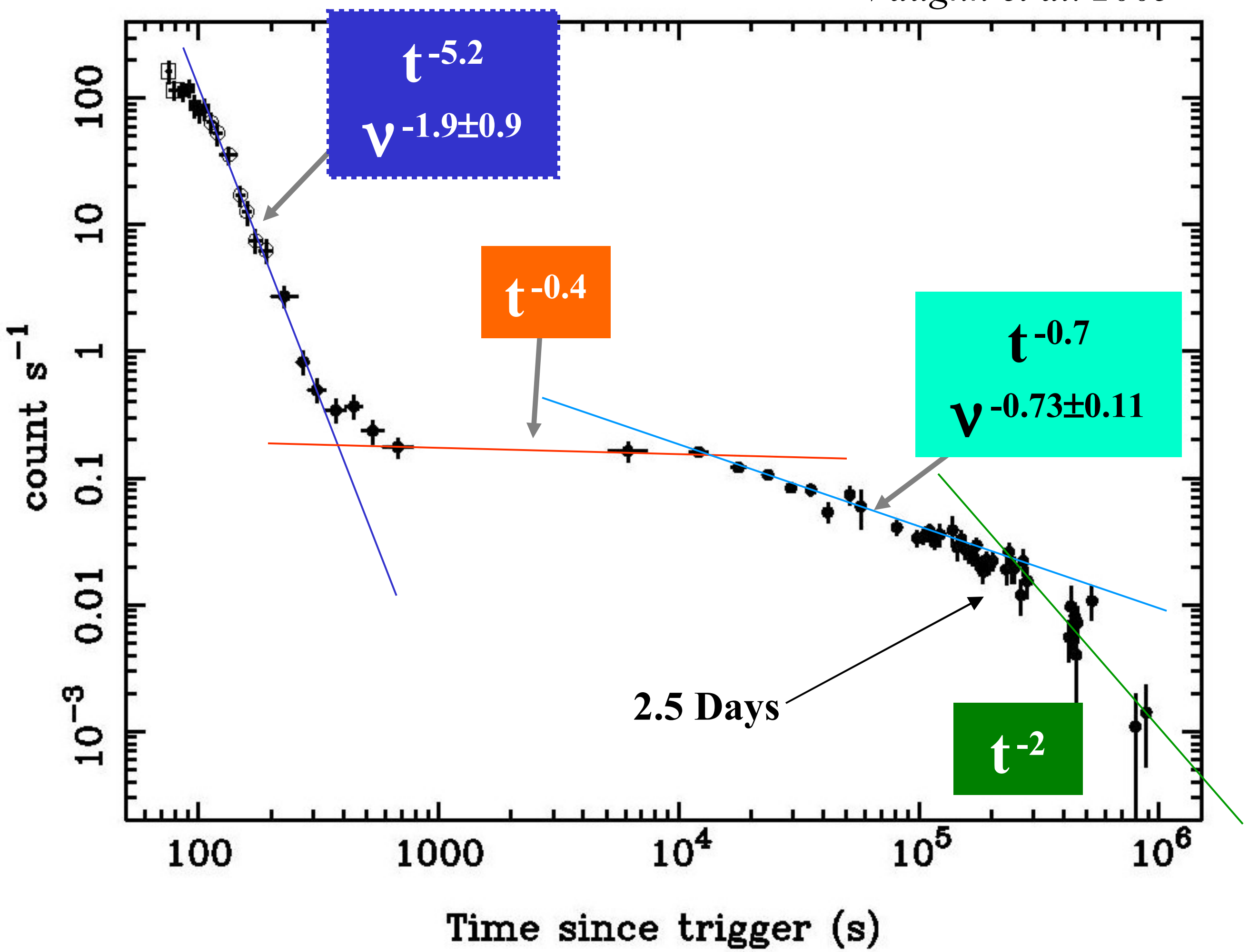
$$E_\gamma = E_{iso}(1 - \cos\theta_j)$$

Frail et al. 2001, ApJ, 562, L55

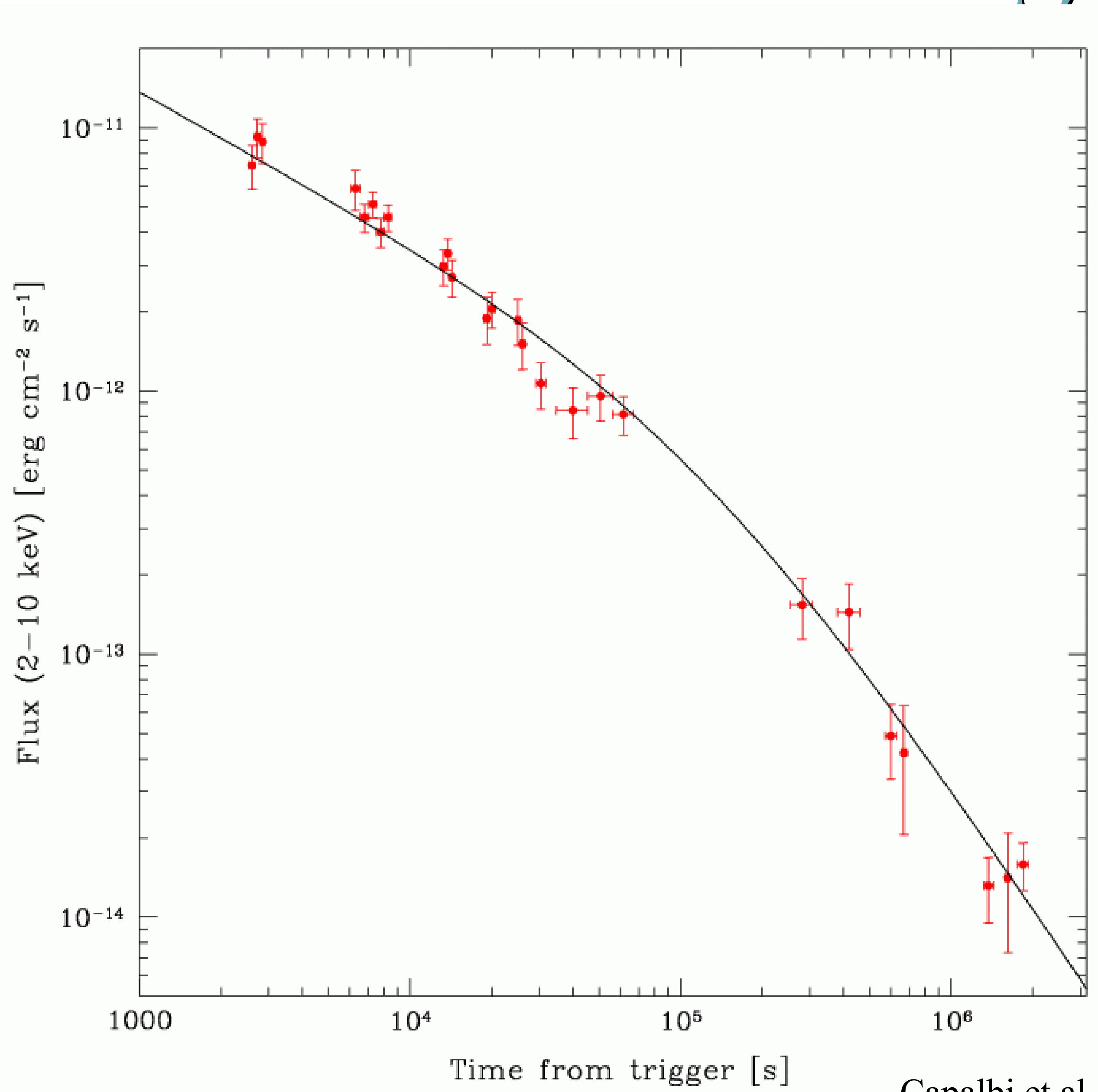
Jet Break in GRB 050315



Vaughn et al. 2005

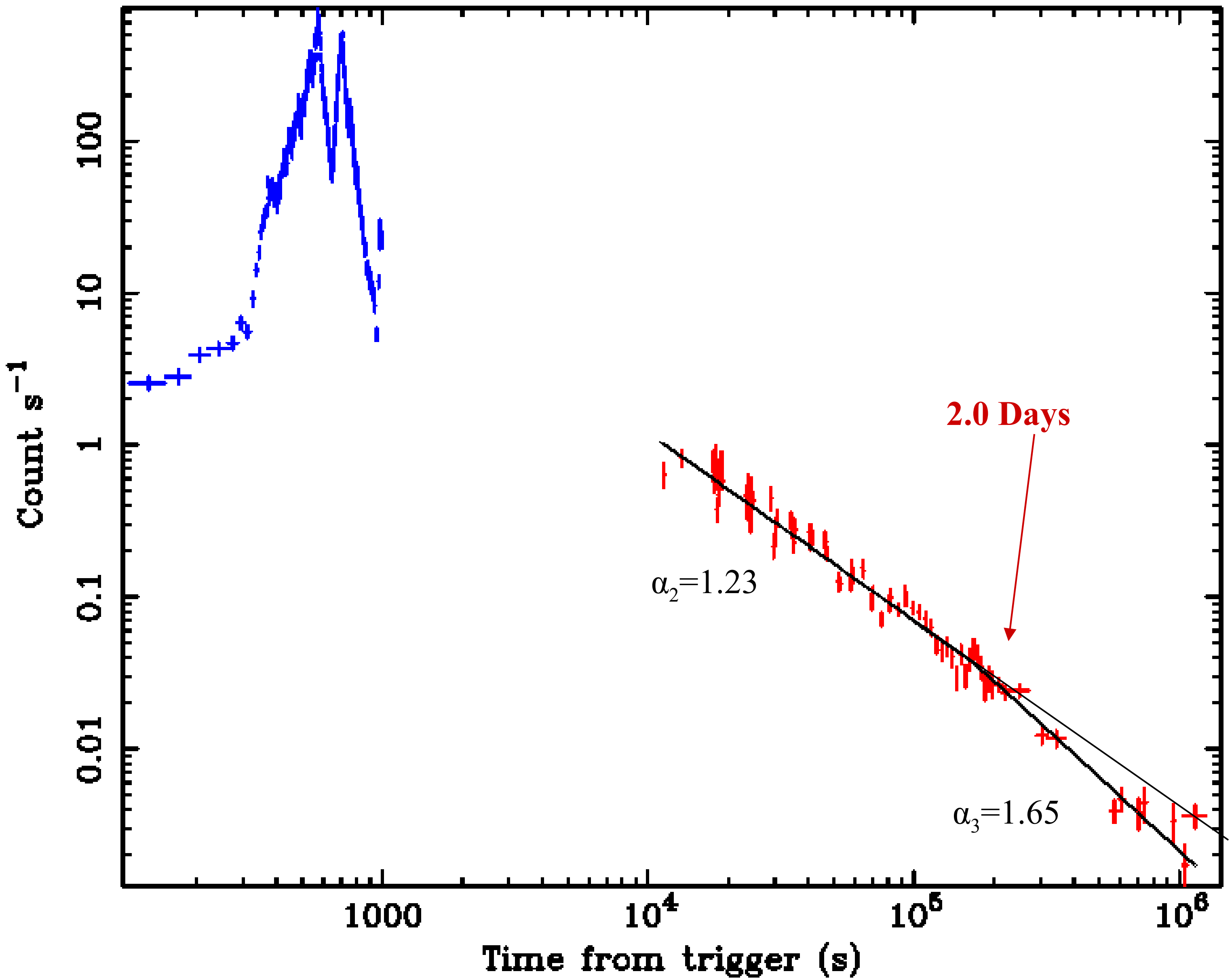


Jet Break in GRB050408



Capalbi et al. 2006

Jet Break in GRB060124



Romano et al. 2006)

Jet Break Implications

Are there two "classes" of jet breaks?

- **Cases with measured XRT jet breaks seem to be systematically different from cases without measured breaks. This is an observational fact that now must be addressed.**
- **Bursts with optical/radio jet breaks seem to be systematically different from those with X-ray observations. We must address chromatic breaks in optical/X-ray (Panaitescu et al. 2006).**

1. **If early X-ray breaks are jet breaks, then**
   1. **p < 2**
   2. **Jet angles very small**

6. **If early X-ray breaks are not jet breaks, then:**
   1. **Collimation is less common than thought previously**
      - ⇒ **Energy in jet is not standard candle**
   2. **If jets are truly collimated with angles of a few degrees, then**
      1. **Efficiency may vary widely (0.1% to 90%?: Zhang et al. 2006; Panaitescu et al. 2006)**
      2. **Density is low: could reconcile these results with measured jet breaks if n~0.001 cm^{-3}.**
         1. **Consistent with multi-phase ISM?**
         2. **Consistent with lack of optical and radio afterglows:**
            1. **~75% of X-ray afterglows are consistent with $\nu>\nu_c$.**
            2. **In this case X-ray afterglow is independent of density**
            3. **=> low densities could produce very weak AGs in optical and radio.**
            4. **Apparent discrepancy could result from selection bias in optical/radio.**
            5. **BUT: 060206 seems to rule out this explanation**

Swift Institutions

GSFC

Executive Committee

G. Chincarini - Brera Obs.
N. Gehrels - GSFC
P. Giommi - ASI
K. Mason - MSSL
J. Nousek - PSU
J. Osborne - U. Leicester
A. Wells - U. Leicester
N. White - GSFC

Fill-in Target Progress

- Swift team provided targets in two rounds
  - New round to be solicited by Neil Gehrels
- With Swift AO-4 non-team proposers will be able to request targets
  - Subject to peer review, US proposers eligible to receive NASA funding
- Individual targets not guaranteed
  - Equivalent to ROSAT, ASCA, etc, Type C time

	Round 1	Round 2	Total
Finished (>90%)	201	136	337
Incomplete	45	63	108
Unobserved	21	111	132
Total	267	310	577
Total time	3.97 Msec	1.30 Msec	5.28 Msec
Requested time	2.39 Msec	1.96 Msec	4.35 Msec
Target Completion (%)	77.8%	41.9%	61.6%

Swift Observing Statistics

- *Swift* observing time divided its time as follows:

All GRB obs:		56.3%
New triggers		8.4%
Planned follow-up		42.6%
GRB ToOs		5.5%
Non-GRB ToO*s:		8.8%
Calibration:		5.1%
Planned non-GRB targets:		17.6% (5 Msec/yr)
SAA & non-science:		12%

Cycle 3 will open ToO's to GI proposal

Cycle 4 will open planned non-GRB targets to GI proposal

* 153 ToO's requested/ 103 approved. Examples: Comet Tempel, RS Oph, supernovae

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Statistics through May 16 – courtesy of Kim Page

Backup Slide – MAL Stats

Reporting Period	DOY Span	Total Passes	Successful Passes	Unsuccessful Passes
Nov-04	325-335	113	112	1
Dec-04	336-366	317	314	3
Jan-05	001-031	323	319	4
Feb-05	032-059	308	307	1
Mar-05	060-090	345	344	1
Apr-05	091-120	335	335	0
May-05	121-151	345	343	2
Jun-05	152-181	334	328	6
Jul-05	182-212	344	343	1
Aug-05	213-243	346	340	6
Sep-05	244-273	332	325	7
Oct-05	274-304	344	343	1
Nov-05	305-334	337	333	4
Dec-05	335-365	345	344	1
Jan-06	001-031	344	343	1
Feb-06	032-059	200	198	2
Mar-06	060-090	301	300	1
Apr-06	091-120	294	294	0
May-06	121-141	208	206	2
Grand Totals		**5607**	**5565**	**44**

Malindi Success Percentage since Launch: 99.25%

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Backup Slide – Sci Uptime

	Hours	Mins	Total Mins Down	Cum mins Down	Days per month	Mins per month	Cum mins month	Monthly %	Since Apr 05%
Apr-05	0	0	0	0	30	43200	43200	100.0%	100.0%
May-05	13	26	806	806	31	44640	87840	98.2%	99.1%
Jun-05	86	87	5247	6053	30	43200	131040	87.9%	95.4%
Jul-05	37	60	2280	8333	31	44640	175680	94.9%	95.3%
Aug-05	0	0	0	8333	31	44640	220320	100.0%	96.2%
Sep-05	0	55	55	8388	30	43200	263520	99.9%	96.8%
Oct-05	1	50	110	8498	31	44640	308160	99.8%	97.2%
Nov-05	29	20	1760	10258	30	43200	351360	95.9%	97.1%
Dec-05	0	0	0	10258	31	44640	396000	100.0%	97.4%
Jan-06	9	49	589	10847	31	44640	440640	98.7%	97.5%
Feb-06	104	126	6366	17213	28	40320	480960	84.2%	96.4%
Mar-06	1	33	93	17306	31	44640	525600	99.8%	96.7%
Apr-06	22	70	1390	18696	30	43200	568800	96.8%	96.7%
May-06	4	7	247	18943	31	44640	613440	99.4%	96.9%