Revealing the Nature of GRBs with Swift

Cargese school, April 7, 2006

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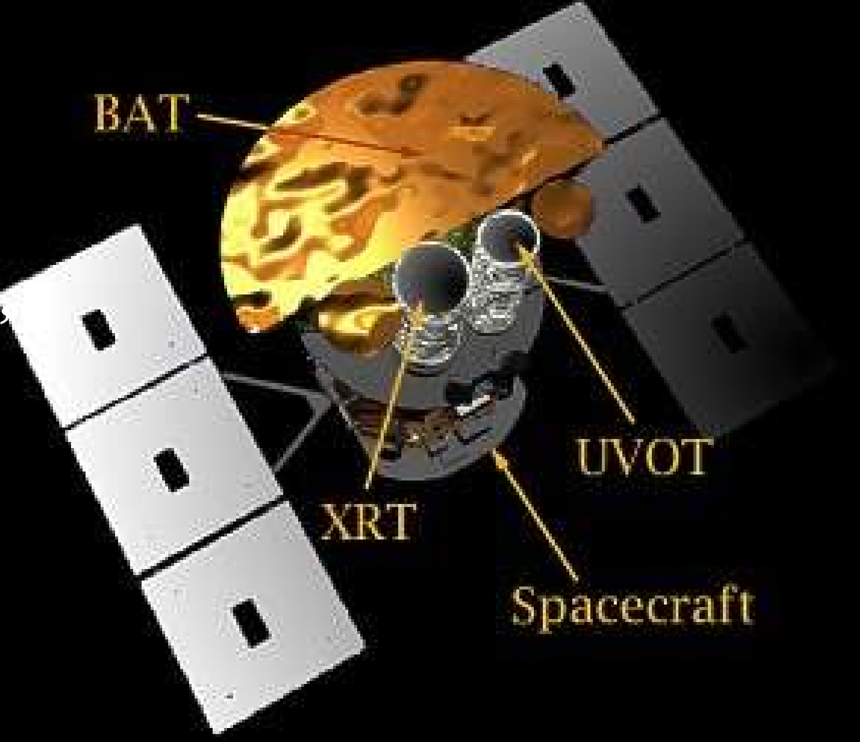
Overview

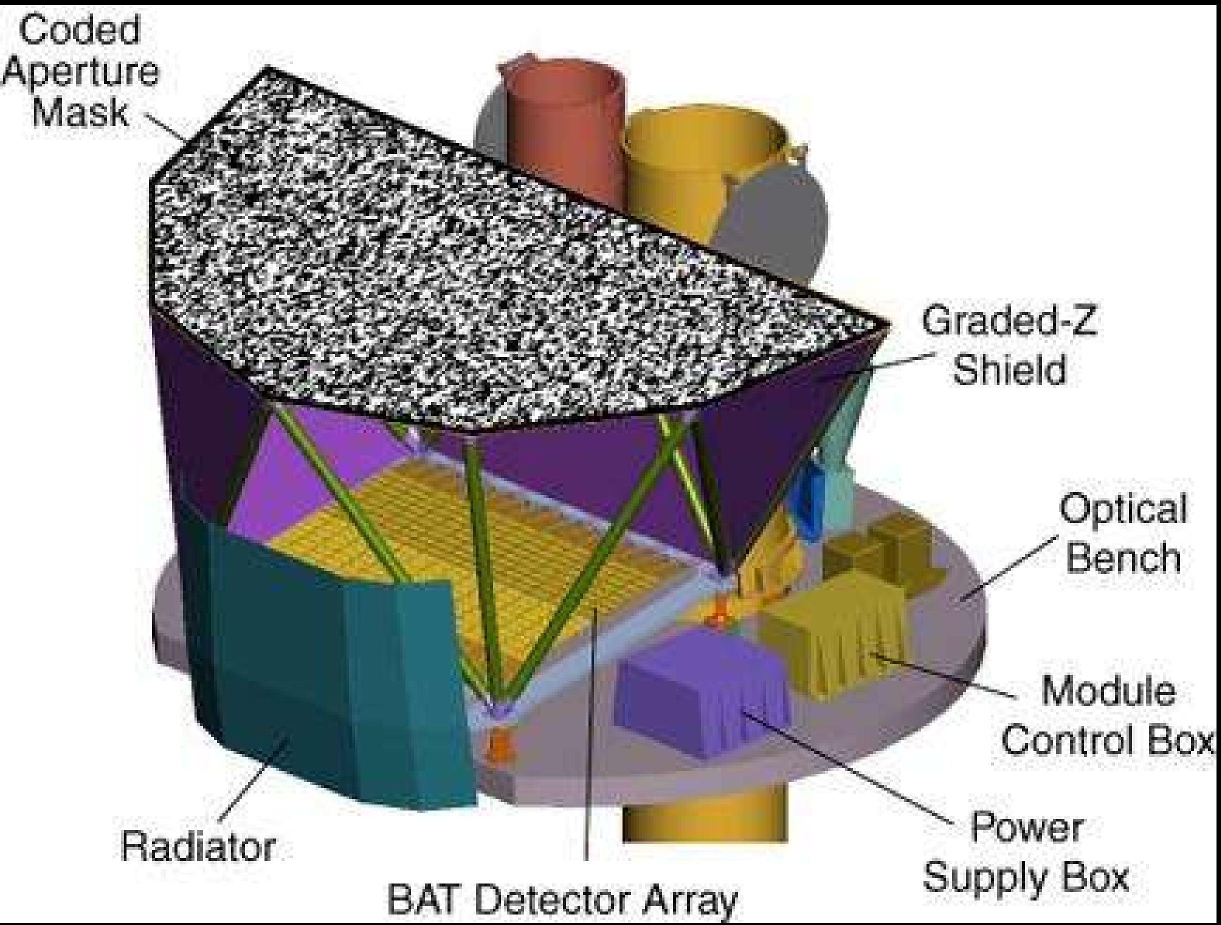
- Swift observatory
- In-flight performance
- Highlights from the first 1.5 years:
- short bursts, prompt emission, high redshift bursts
- Usage of Swift data
- Conclusions

The idea behind Swift

- How to best study Gamma-ray bursts (GRBs) ?
- Detect the prompt emission fast, then slew to the position of the GRB
- Follow up in the X-rays (better position!) and optical/UV (afterglow, redshift)
- Fast slew (1 minute)
- Fast on-board analysis (e.g. “is it worth to slew?”)

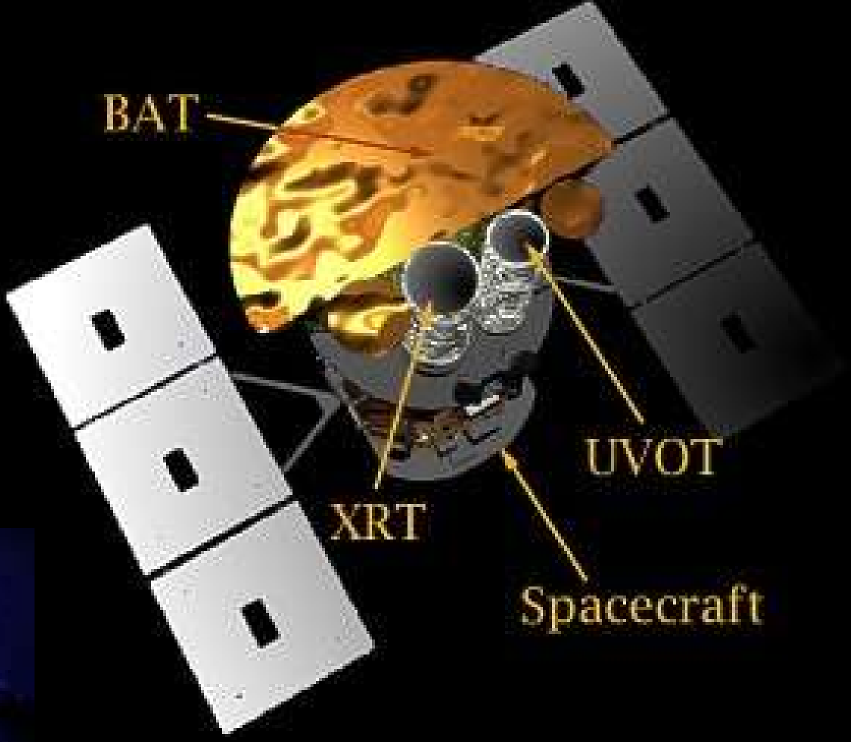
- Detect with Burst Alert Telescope (BAT) in 15 – 150 keV, get ~2 arcmin position
- Slew (~1 minute)
- observe with XRT (0.2-10 keVarcsec position), UVOT, and BAT.



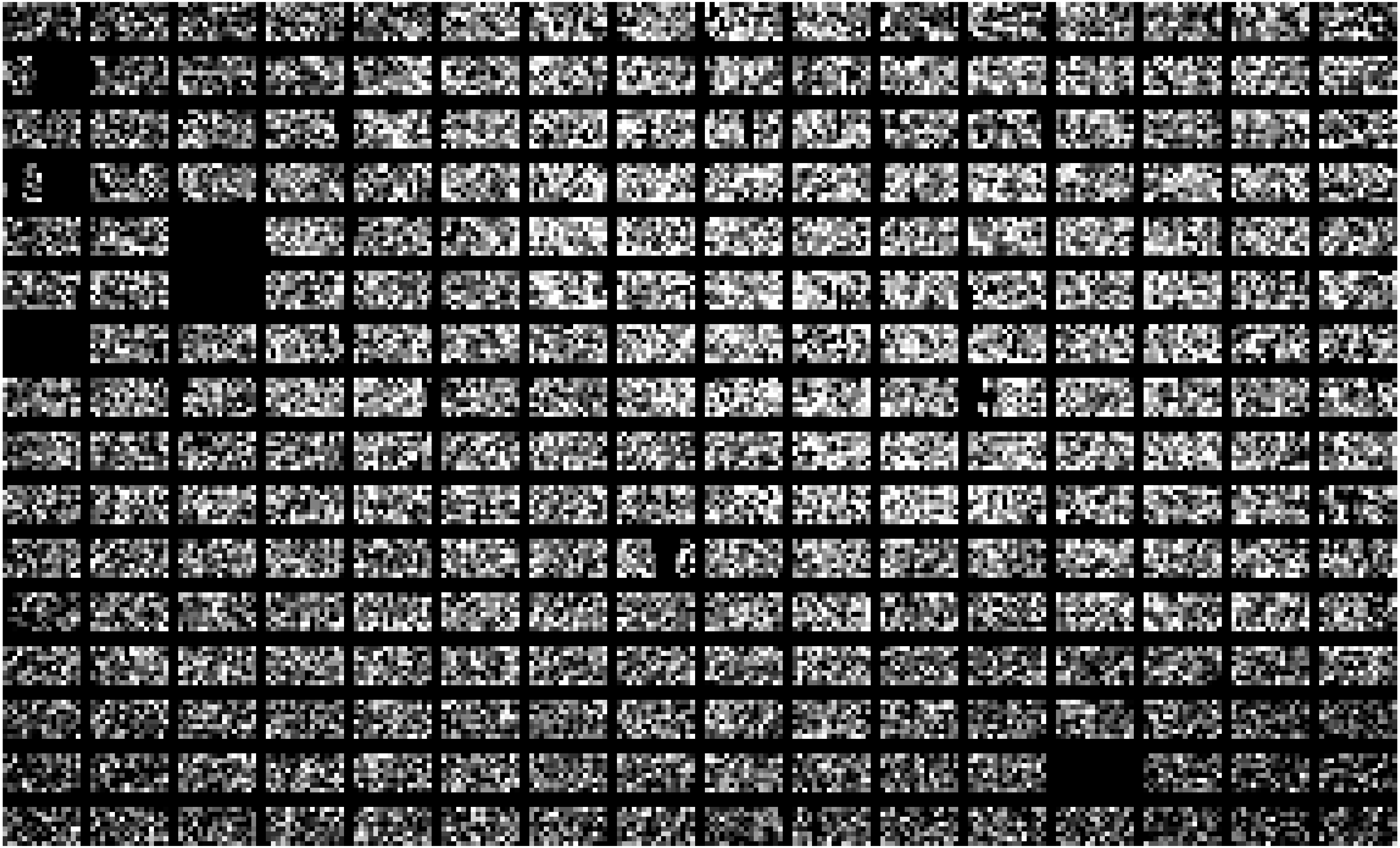


The Burst Alert Telescope (BAT); 15-150 keV

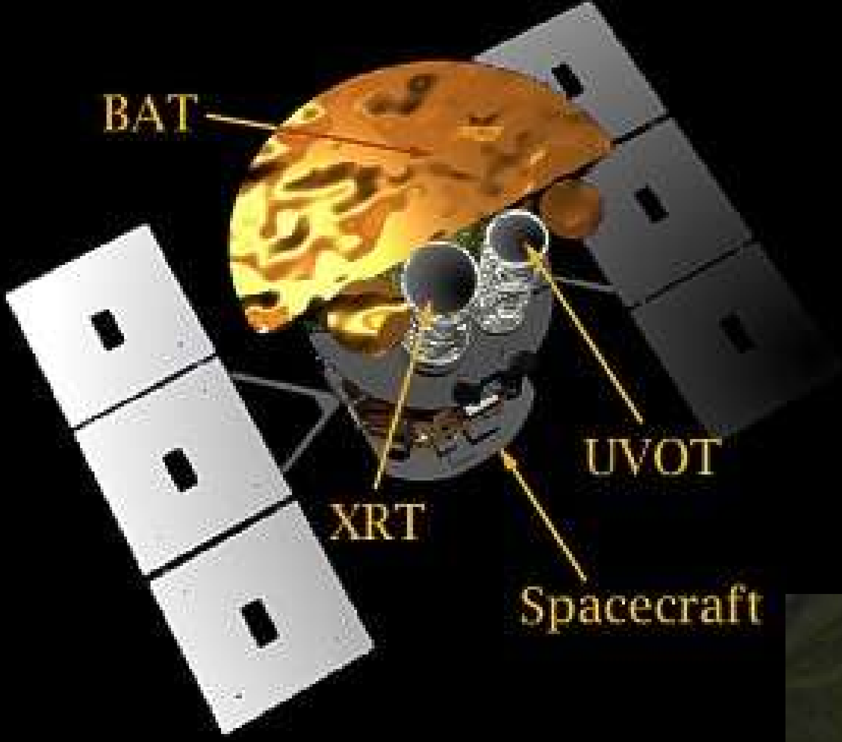
15 – 150 keV
~7 keV resolution
coded mask, random pattern, 50% open
1.4 sr half-coded field of view



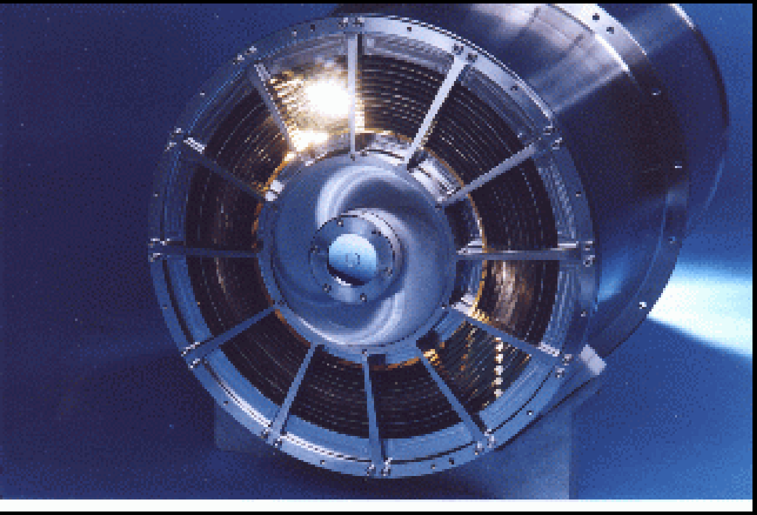
The coded mask of BAT



BAT shadowgram of GRB041217

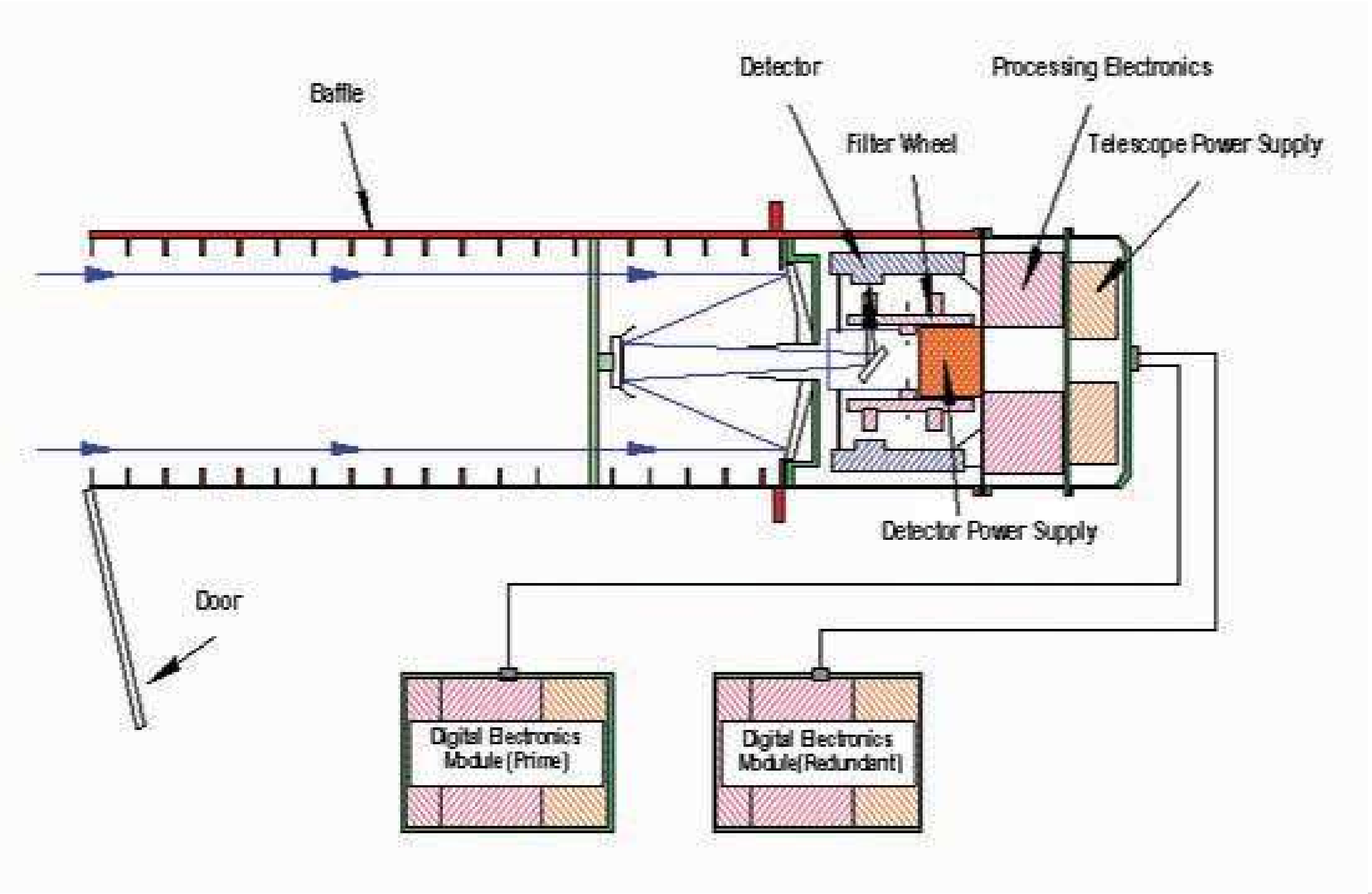


XRT: 0.2 - 10 keV
110 cm^2 at 1.5 keV
~150 eV at 6 keV
23.6' x 23.6' FoV
~1 mCrab in 10 ksec

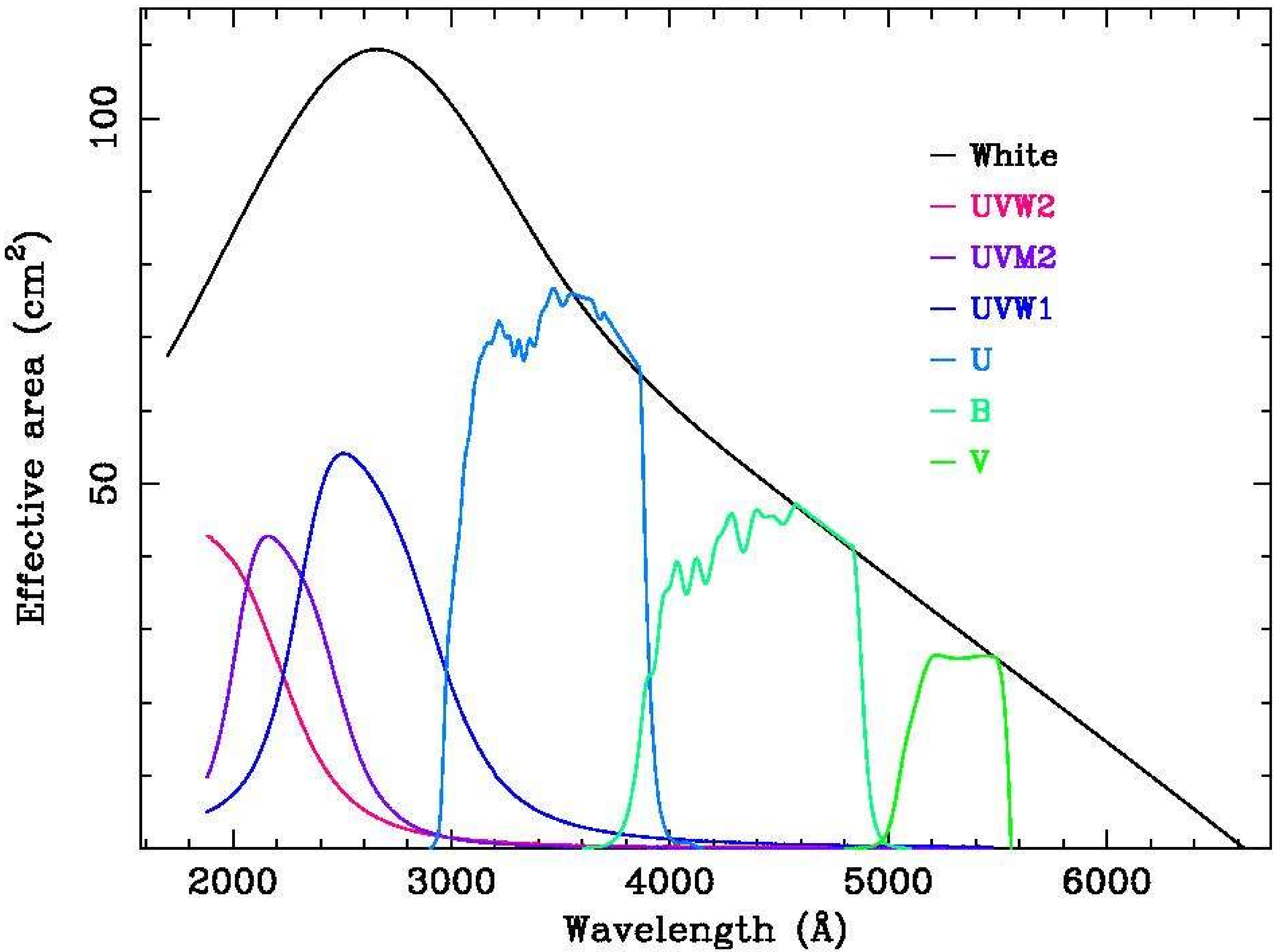


Swift UVOT

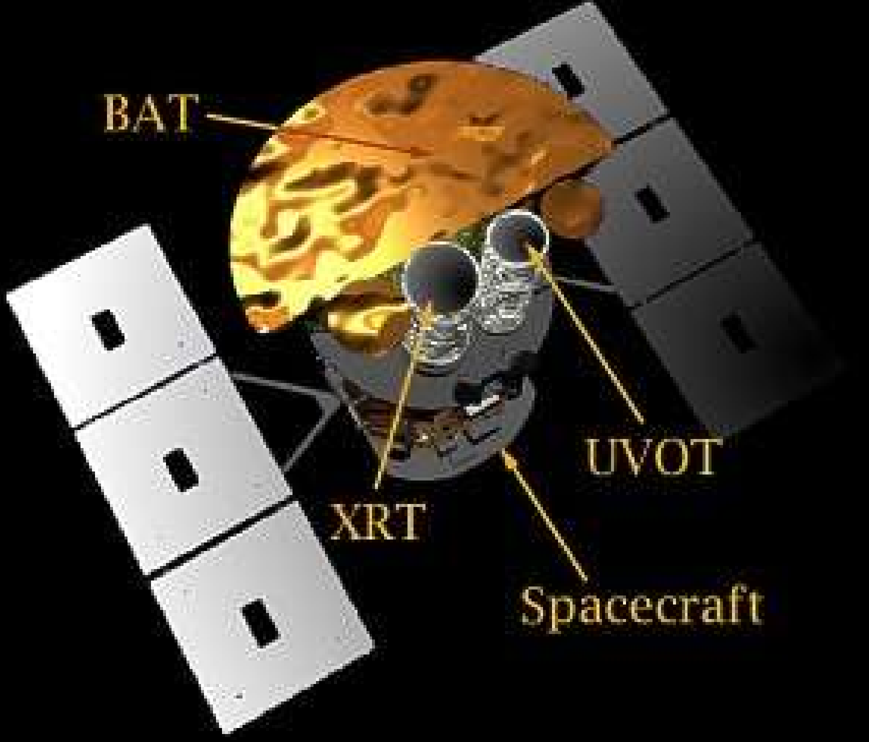
Modified Ritchey-Chretien, 30 cm diameter, 170-600 nm, 17'x17' FoV
2048 x 2048 CCD



Swift UVOT



White
UVW2
UVM2
UVW1
U
B
V
100
50
Effective area (cm^2)
2000
3000
4000
5000
6000
Wavelength (Å)



Swift at NASA/GSFC

Swift

Swift was launched successfully on a Delta 7320-10 on November 20, 2004

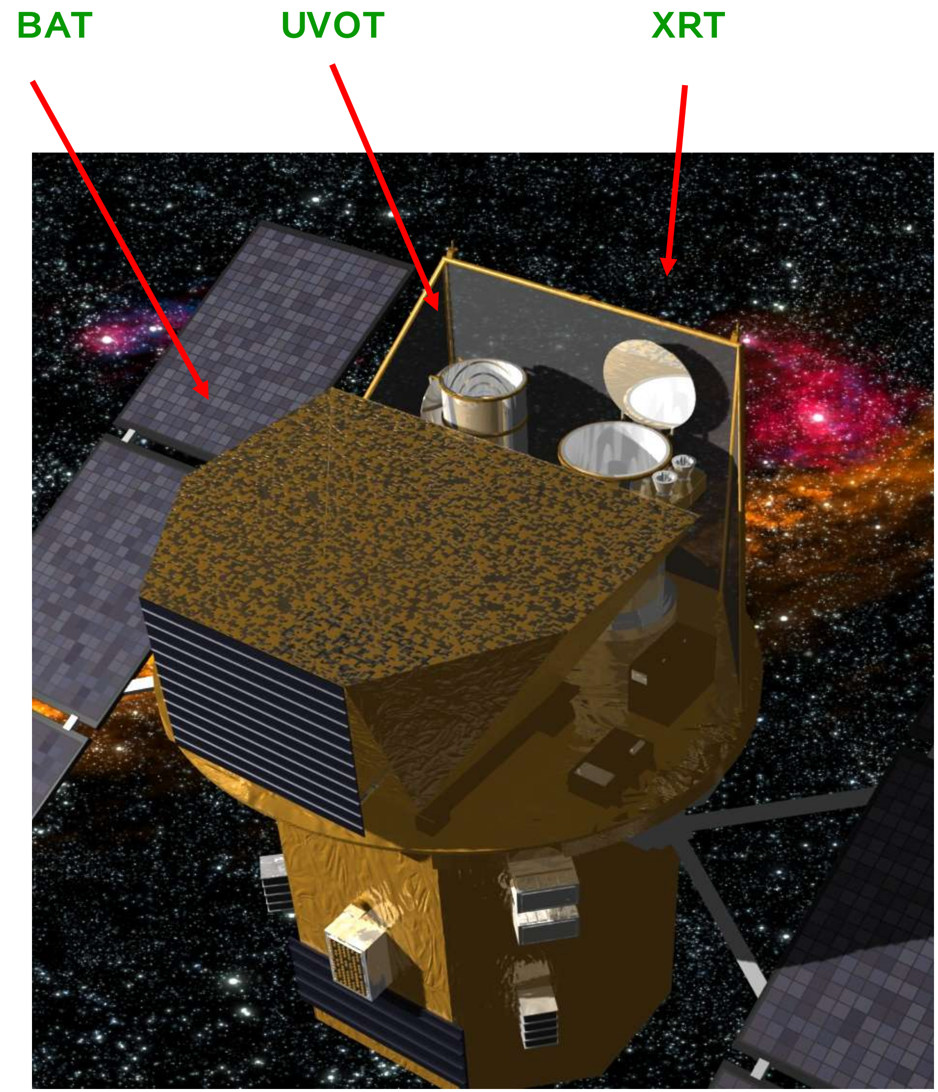
Low Earth orbit; 600 km altitude

Photo: NASA

Swift Observatory Performance

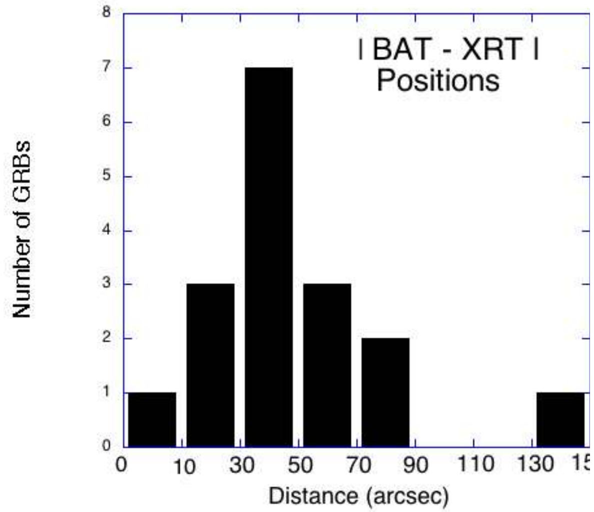
- All instruments operating to spec
- 92 GRBs detected (~100 per year)
- 72 XRT detections out of 79 observed
- 20 UVOT detections out of 68 observed

  (42 detections ground-based + UVOT)
- ~64 non-GRB TOO observations performed (>1 per week)
- ~50,000 slews performed
- Typical GRB slew time < 90 sec
- Observatory fully operational & all data publicly available since Apr. 5, 2005
- Swift observatory paper:
  Gehrels et al. 2004, ApJ, 611, 1005



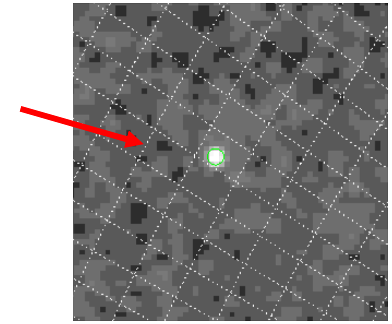
15 - 150 keV

BAT Performance



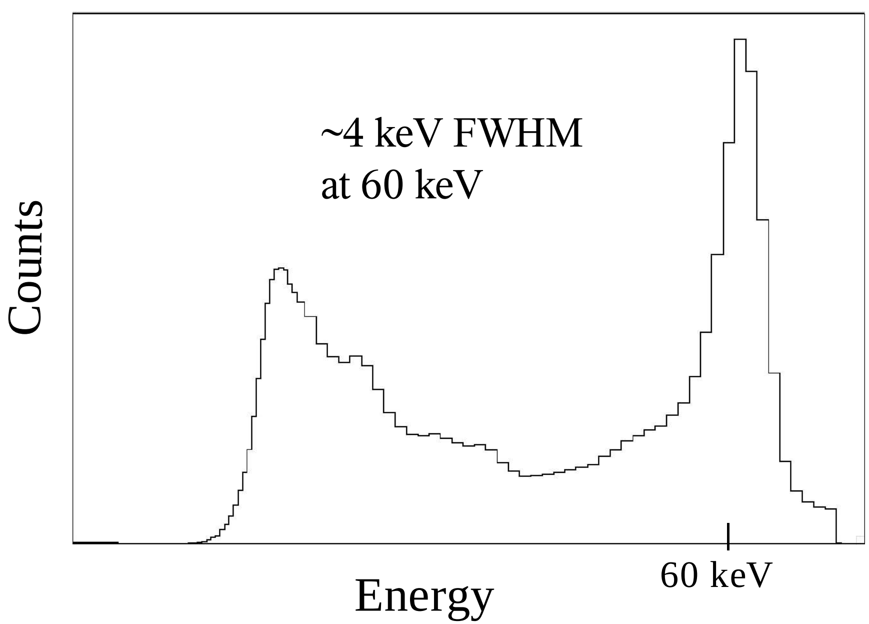
Source Positions
are < 2 arcmin

GRB 050525A

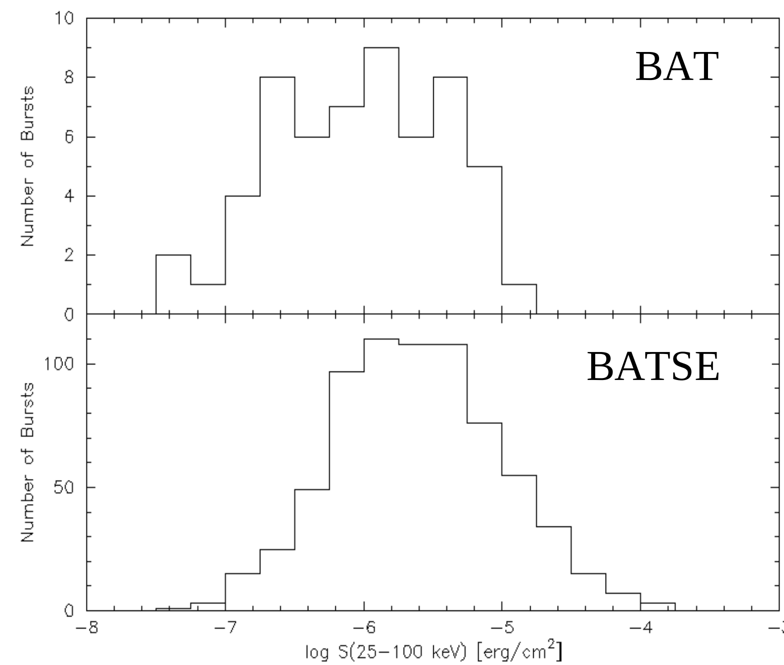


BAT is ~2.5 times more
sensitive than BATSE

Energy resolution is <7%

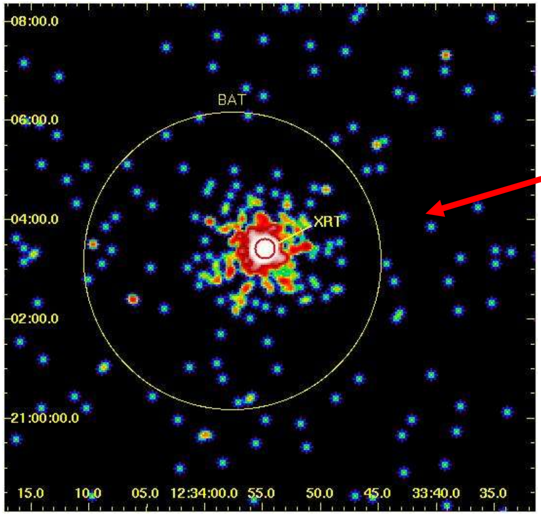


Fluence 25 - 100 keV. No short GRBs



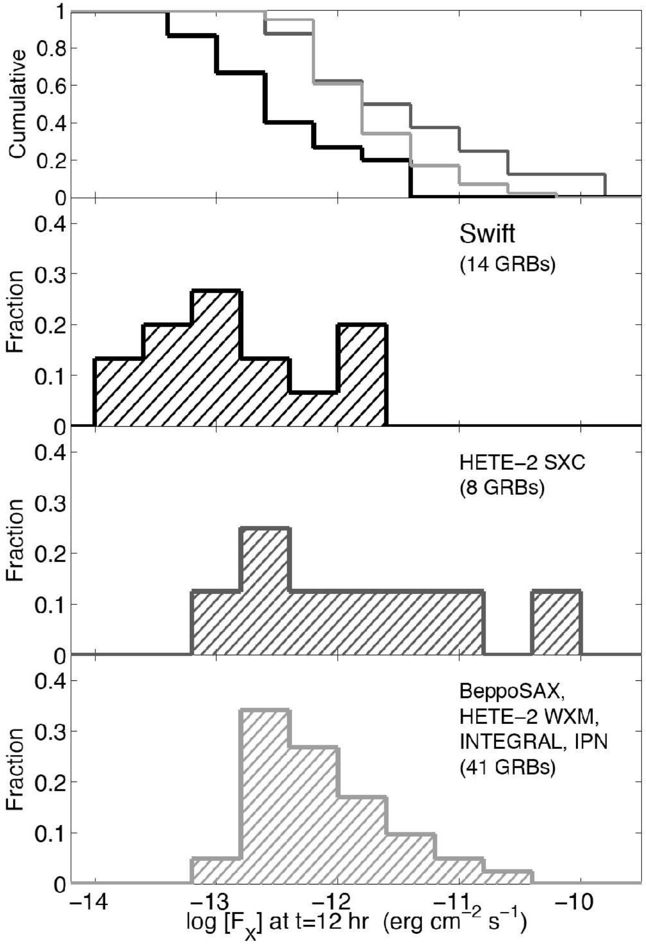
0.2 - 10 keV

XRT Performance



GRB 050525A

Sensitivity ~5 times better than BeppoSAX (F_x limit ~ $2x10^{-14}$ erg/cm^2-s)



Berger et al. 2005, ApJ, 634, 501

Source Positioning Accuracy

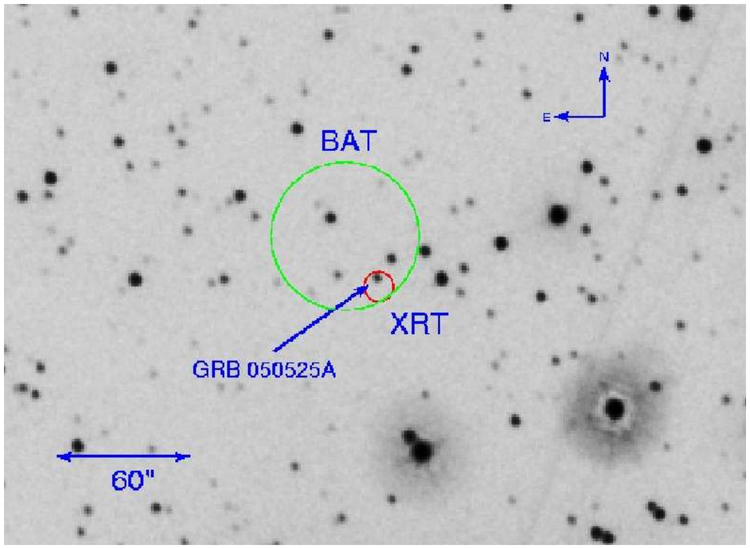
~ 6" in GCNs

1-2" with ultimate astrometry

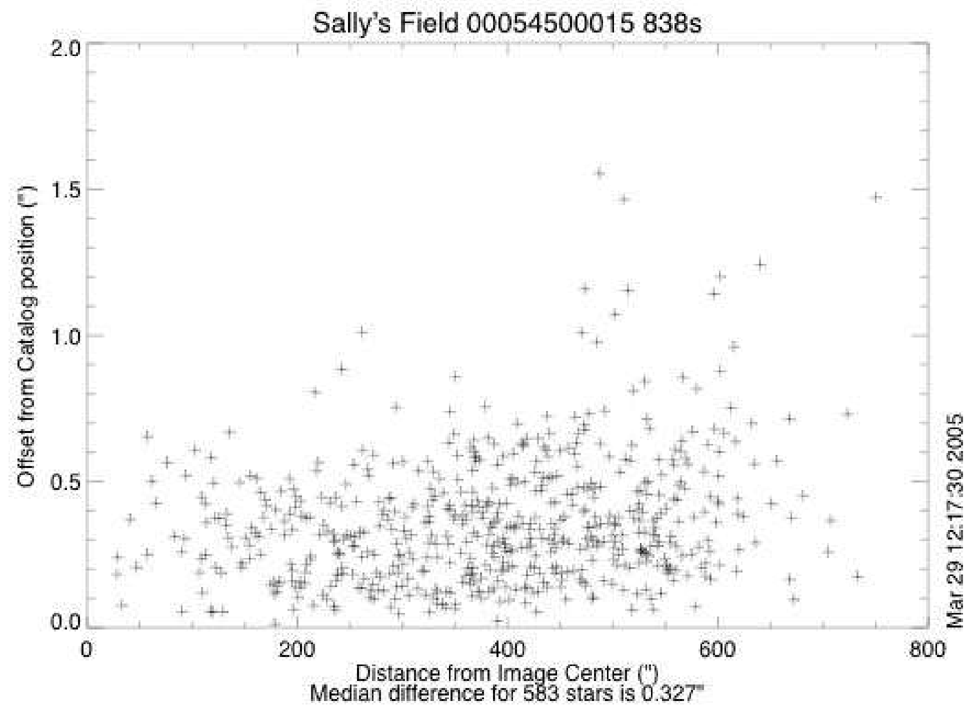
UVOT Performance

170 - 650 nm

UVOT image - 050525A



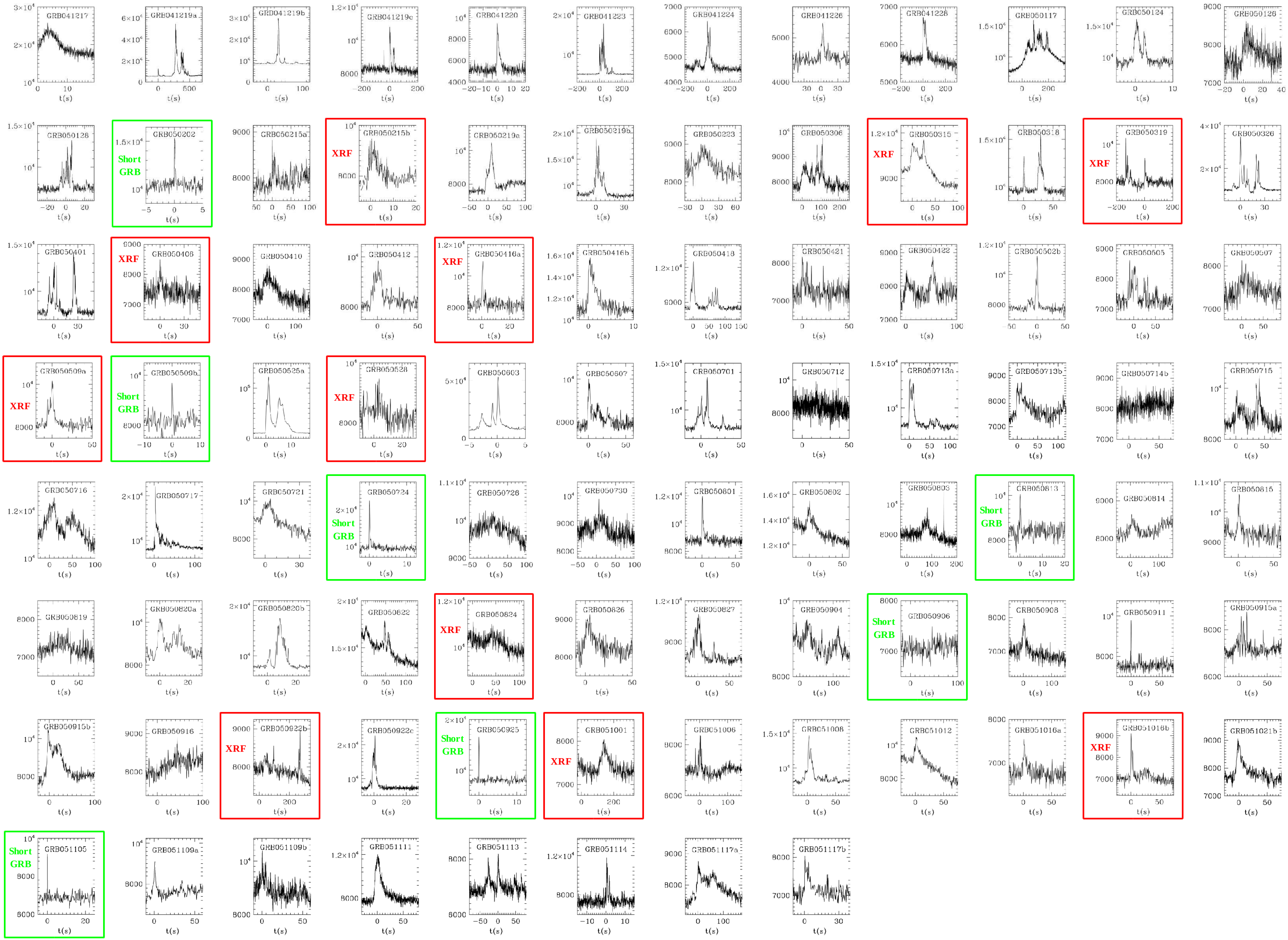
Median position accuracy for 583 stars is 0.33 arcsec



Typical Sensitivities

V=19 first GCN (<1 hr)

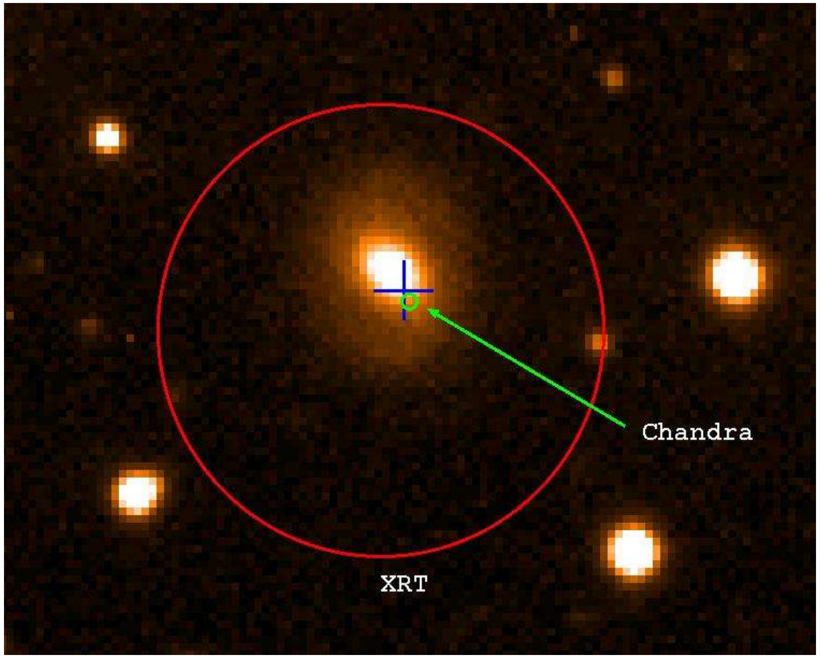
V=22 2nd GCN (~3 hr)

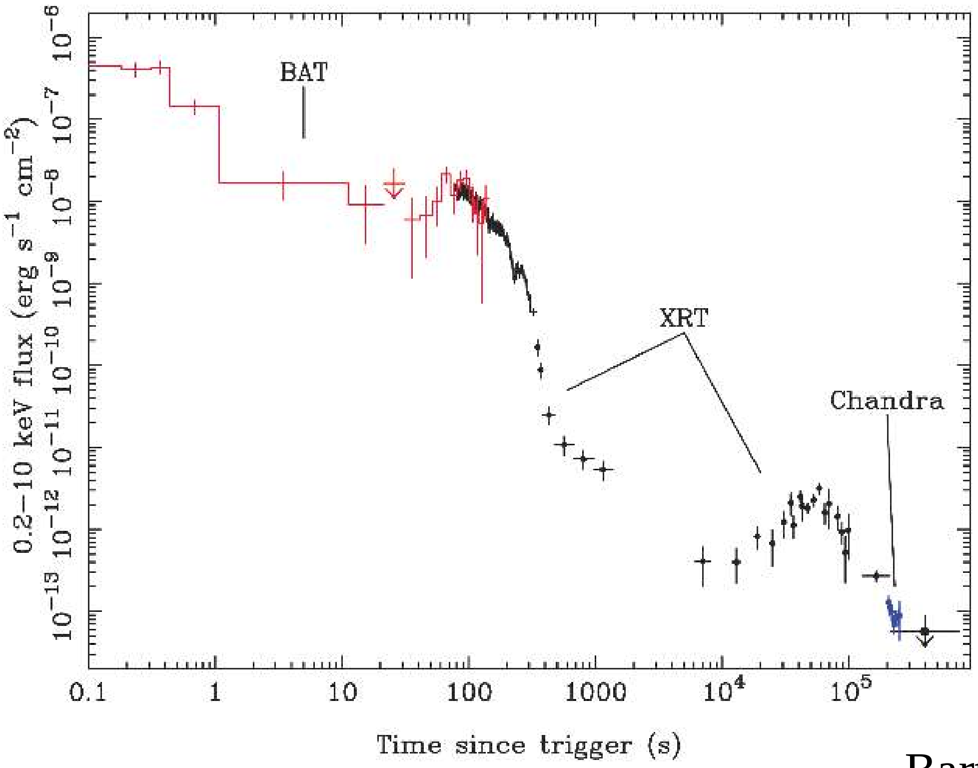

GRB041217
GRB041219a
GRB041219b
GRB041219c
GRB041220
GRB041223
GRB041224
GRB041226
GRB041228
GRB050117
GRB050124
GRB050126
GRB050128
Short GRB
GRB050202
GRB050215a
XRF
GRB050215b
GRB050219a
GRB050219b
GRB050223
GRB050306
XRF
GRB050315
GRB050318
XRF
GRB050319
GRB050326
GRB050401
XRF
GRB050406
GRB050410
GRB050412
XRF
GRB050416a
GRB050416b
GRB050418
GRB050421
GRB050422
GRB050502b
GRB050505
GRB050507
XRF
GRB050509a
Short GRB
GRB050509b
GRB050525a
XRF
GRB050528
GRB050603
GRB050607
GRB050701
GRB050712
GRB050713a
GRB050713b
GRB050714b
GRB050715
GRB050716
GRB050717
GRB050721
Short GRB
GRB050724
GRB050726
GRB050730
GRB050801
GRB050802
GRB050803
Short GRB
GRB050813
GRB050814
GRB050815
GRB050819
GRB050820a
GRB050820b
GRB050822
XRF
GRB050824
GRB050826
GRB050827
GRB050904
Short GRB
GRB050906
GRB050908
GRB050911
GRB050915a
GRB050915b
GRB050916
XRF
GRB050922b
GRB050922c
Short GRB
GRB050925
XRF
GRB051001
GRB051006
GRB051008
GRB051012
GRB051016a
XRF
GRB051016b
GRB051021b
Short GRB
GRB051105
GRB051109a
GRB051109b
GRB051111
GRB051113
GRB051114
GRB051117a
GRB051117b
t(s)

GRB 050724

BAT
- 250 ms hard spike (T_{90} = 3 s)
- $6x10^{-7}$ erg/cm^2 fluence

Afterglow
- bright fading X-ray afterglow with flares
- detected by Chandra days after GRB
- optical & radio

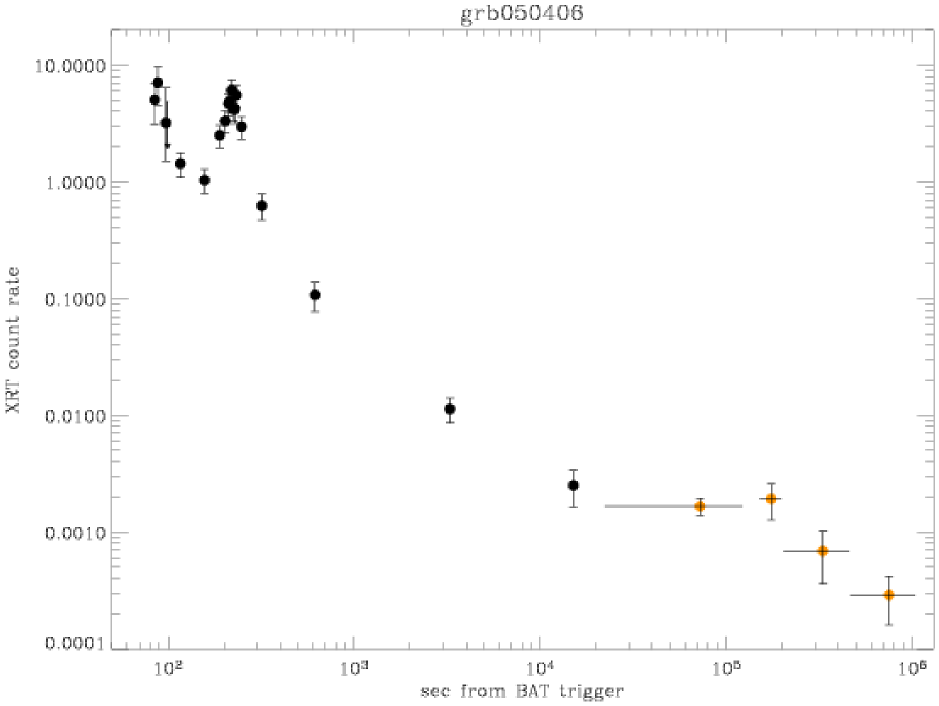


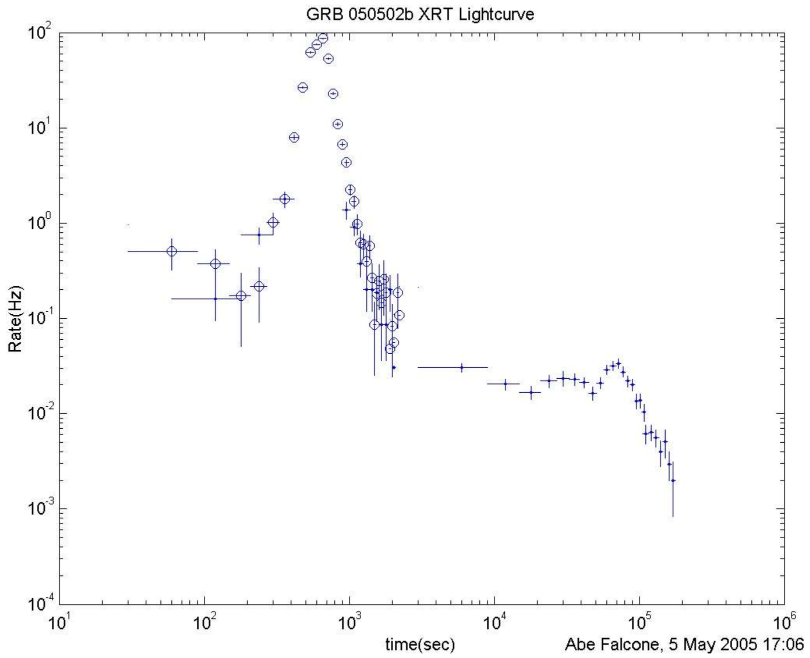


Host:
- Elliptical
- L = 1.7 L*
- z = 0.258
- SFR < 0.02 M_O yr^{-1}

Barthelmy et al. 2005, Nature, 438, 994, astro-ph/0511579

Afterglow Flares





Flares are common in the unexplored early time domain.

Burrows et al. 2005, Science, 309, 1833

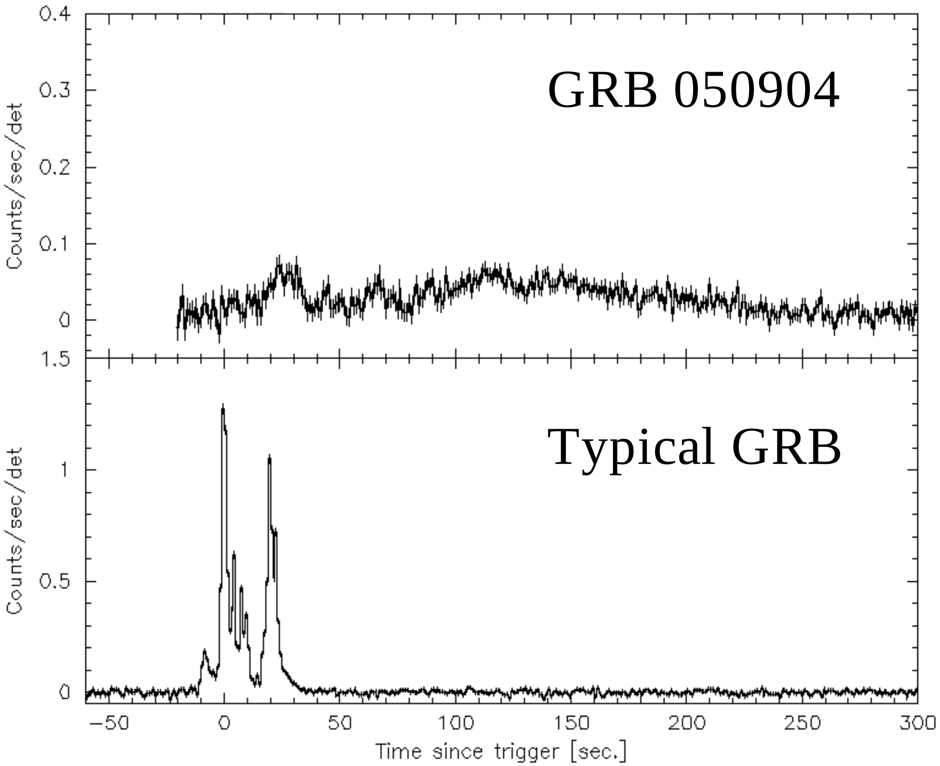
High redshift bursts: GRB 050904

Redshift z= 6.29 (12.8 Glyr)

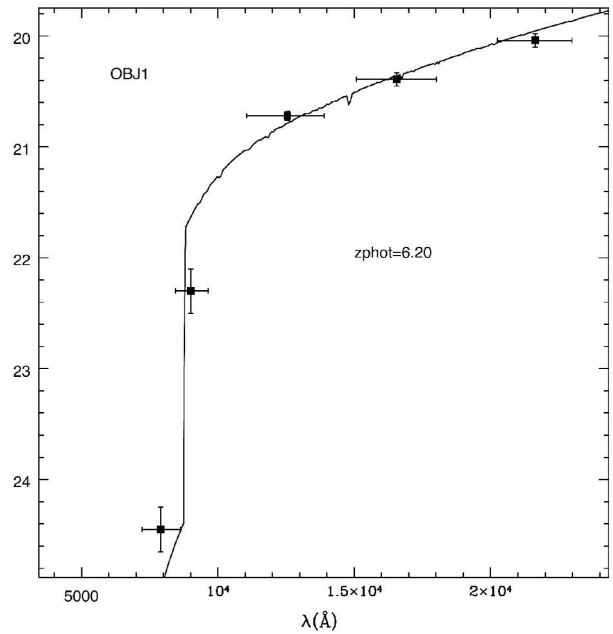
Duration = 225 sec

F (15-150 keV) = 5.4×10^{-6} erg cm^{-2}

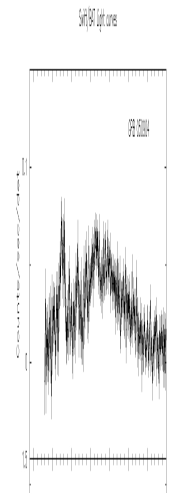
BAT Lightcurves



VLT Lyman Edge



Tagliaferri et al. 2005, A&A, 443, L1



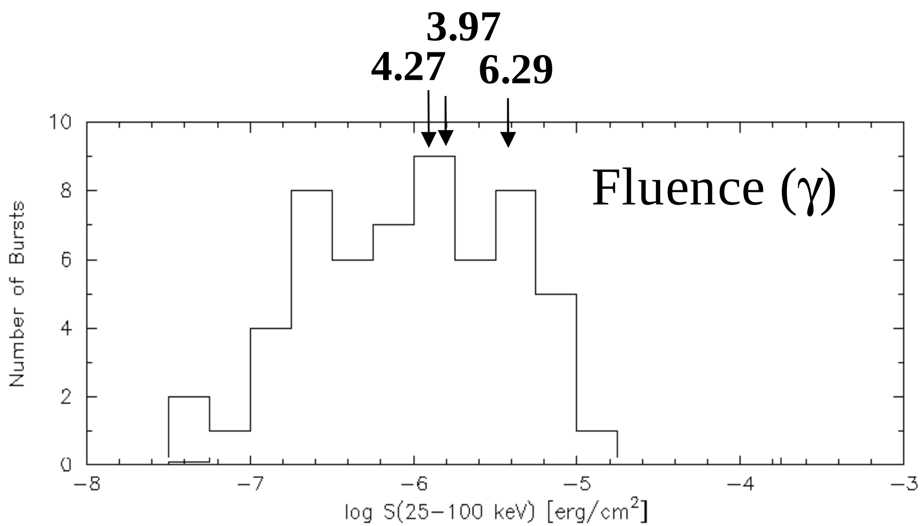
GRB 050904
undilated by z+1

Cusumano et al. 2005, Nature, astro-ph/0509737

Hints for High Redshift Superbursts

(1)

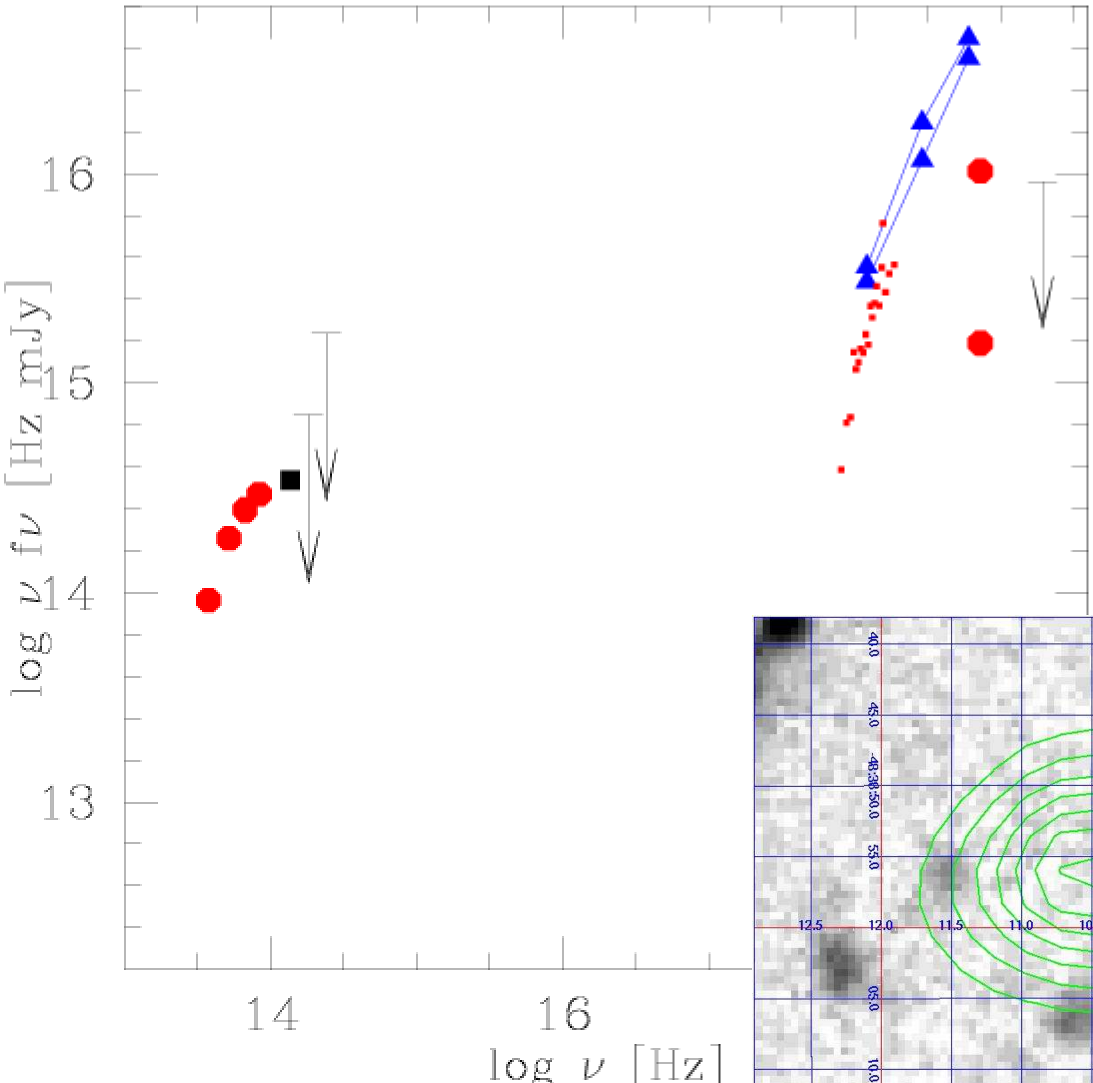
3 Highest-z GRBs

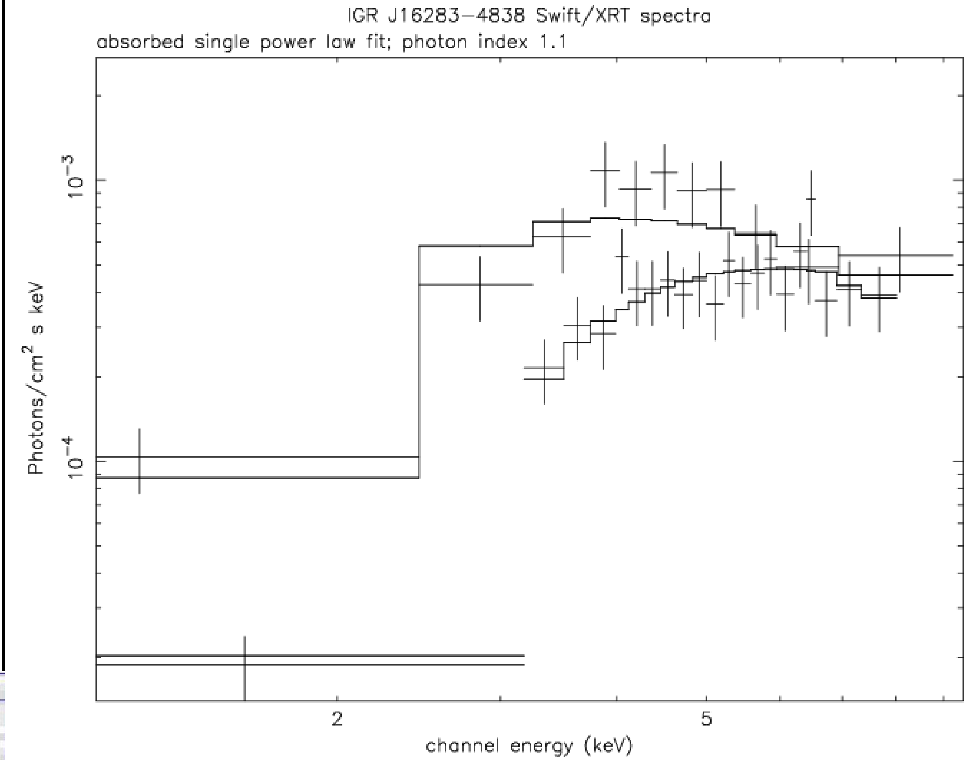


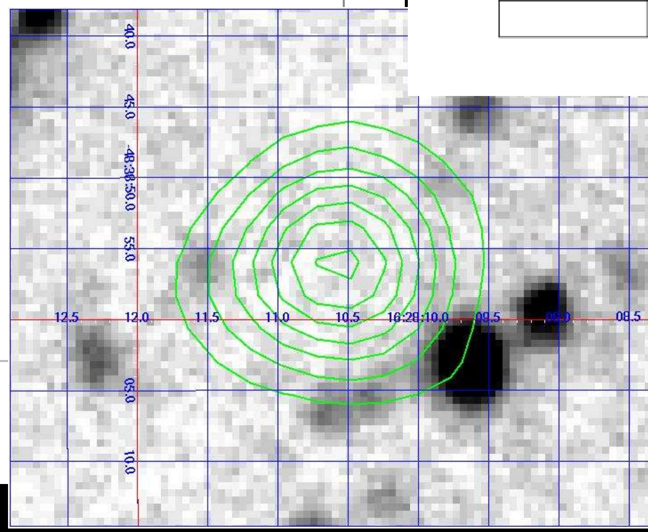
(2)

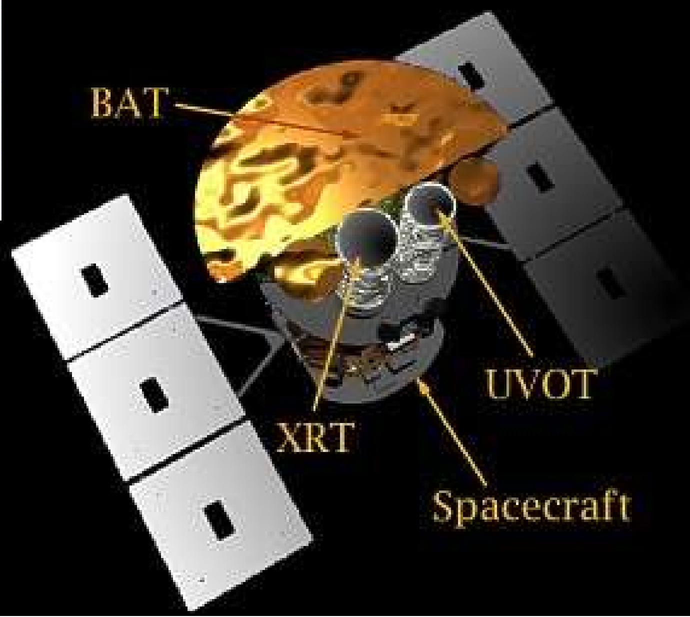
GRBs with Largest Flares

GRB 050730	z = 3.97
GRB 050820A	z = 2.61
GRB 050904	z = 6.29
GRB 050908	z = 3.35









Swift does a lot of non-GRB science

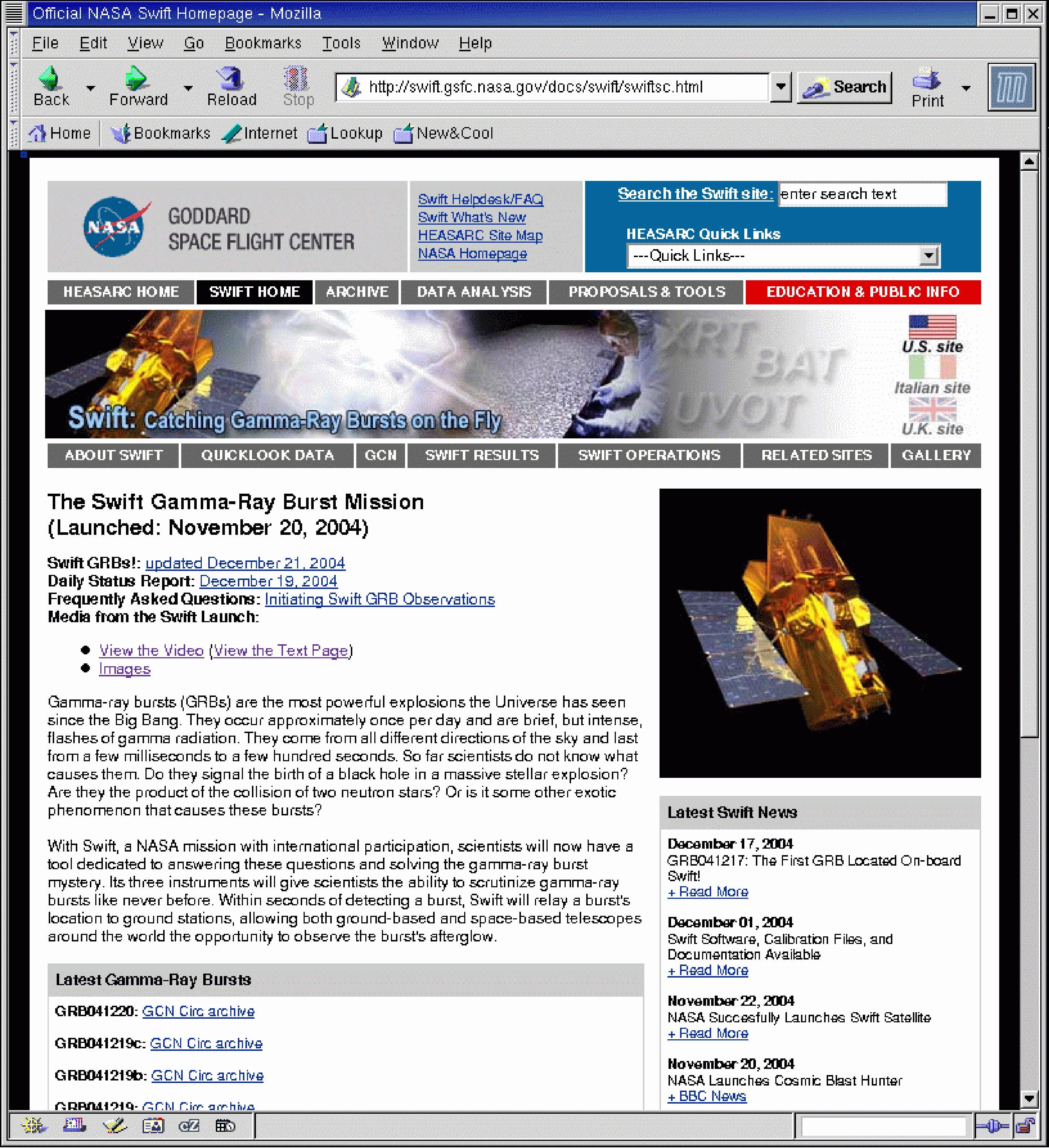
(e.g. Beckmann et al. 2005, ApJ, 631, 506)

How to use Swift data

- software and data can be downloaded through GSFC: http://swift.gsfc.nasa.gov

- after installation follow the user manual

- FTOOLS based software with simple scripts



Go to
http://swift.gsfc.nasa.gov

Ftools based programs
and simple scripts

Data can be downloaded
~2 hours after
the observation

Conclusions

- Swift: 15-150 keV all sky images+spectra
- XRT/UVOT for pointed observations (0.2-10 keV)
- strong on GRBs, AGN, transient sources (all-sky survey)

- Swift data accessible immediately

Swift Institutions

University of Leicester

NASA

GSFC

PENNSTATE 1855

UCL MSSL

agenzia spaziale italiana

ISAS

OSSERVATORIO ASTRONOMICO DI BRERA

SPECTRUMASTRO

eV PRODUCTS

MPE

SONOMA STATE UNIVERSITY LUX MENTIS · LUX ORBIS · 1960

THE UNIVERSITY OF CALIFORNIA LET THERE BE LIGHT 1868

SwRI

SWALES AEROSPACE

Los Alamos NATIONAL LABORATORY

OMITRON inc.

Special thanks to Neil Gehrels (NASA/GSFC) !

References for Swift and its instruments

- Gehrels, Chincarini, Giommi, et al. 2004, “The SWIFT Gamma-Ray Burst Mission”, ApJ, 611, 1005
- Barthelmy et al. 2005, “The Burst Alert Telescope on the Swift MIDEX mission”, Space Science Reviews, 120, 143-164, astro-ph/0507410
- Fenimore et al. 2003, “The Trigger Algorithm for the Burst Alert Telescope on Swift”, AIP, 662, 491, astro-ph/0408514
- Burrows et al. 2005, “The Swift X-ray Telescope”, Space Science Reviews, 120, 165, astro-ph/0508071
- Roming et al. 2005, “The Swift Ultra-Violet/Optical Telescope”, Space Science Reviews, 120, 95-142, astro-ph/0507413
- Li et al. 2006, “The Calibration of the Swift/UVOT optical observations: A recipe for photometry”, PASP, 118, 37-61, astro-ph/0505504

References for some Swift results

First redshift determination for the short hard GRB 050509B:
Gehrels et al. 2005, Nature, 437, 851

GRB 050724, a short hard burst with a lot of features:
Barthelmy et al. 2005, Nature, 438, 994, astro-ph/0511579
Berger et al. 2005, Nature, 438, 988, astro-ph/0508115

strong flares in the early afterglow:
Burrows et al. 2005, Science, 309, 1833

Achromatic jet break in GRB 050525A:
Blustin et al. 2005, ApJ, 637, 901, astro-ph/0507515

High redshift burst GRB 050904:
Cusumano et al. 2005, Nature, astro-ph/0509737
Tagliaferri et al. 2005, A&A, 443, L1

GRB X-ray afterglow lightcurves:
Zhang, Fan, Dyks, et al. 2006, ApJ, astro-ph/0508321

Afterglows, redshifts, and properties of Swift GRB:
Berger et al. 2005, ApJ, 634, 501, astro-ph/0505107