David Band Symposium

The Burst Alert Telescope on Swift

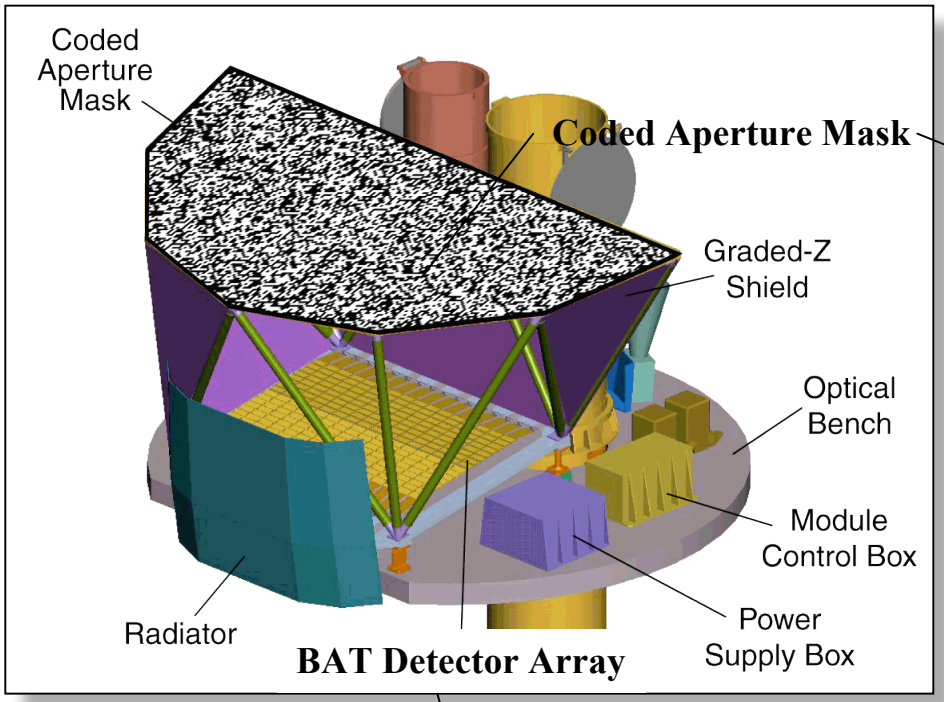
Scott Barthelmy
GSFC

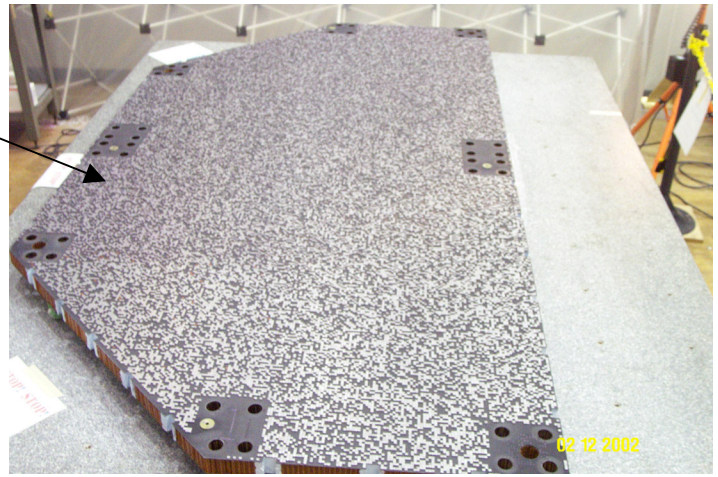
Table of Contents:

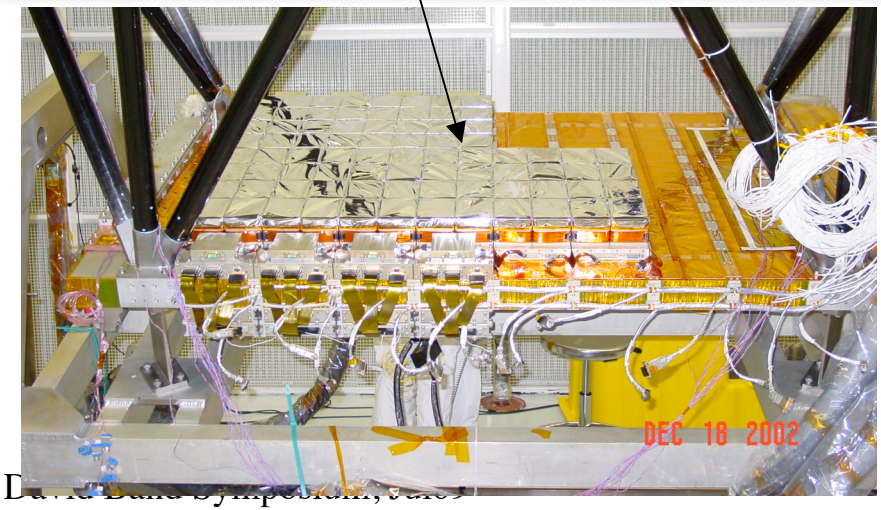
- BAT Enables
- Versatile BAT
- BAT Sensitivity
- BAT to the Future

To my friend, David.
"That's just the way it's done."

Burst Alert Telescope (BAT)







BAT Characteristics

- E Range: 15 - 150 keV (12-300)
- E Resoln: 7 kev (5)
- Loc Resoln: 1-4 arcmin (1-4)
- PSF: 22 arcmin (21.8)
- 2 steradian field of view
- 32K CZT dets, 5200 cm^2
- Autonomous operations

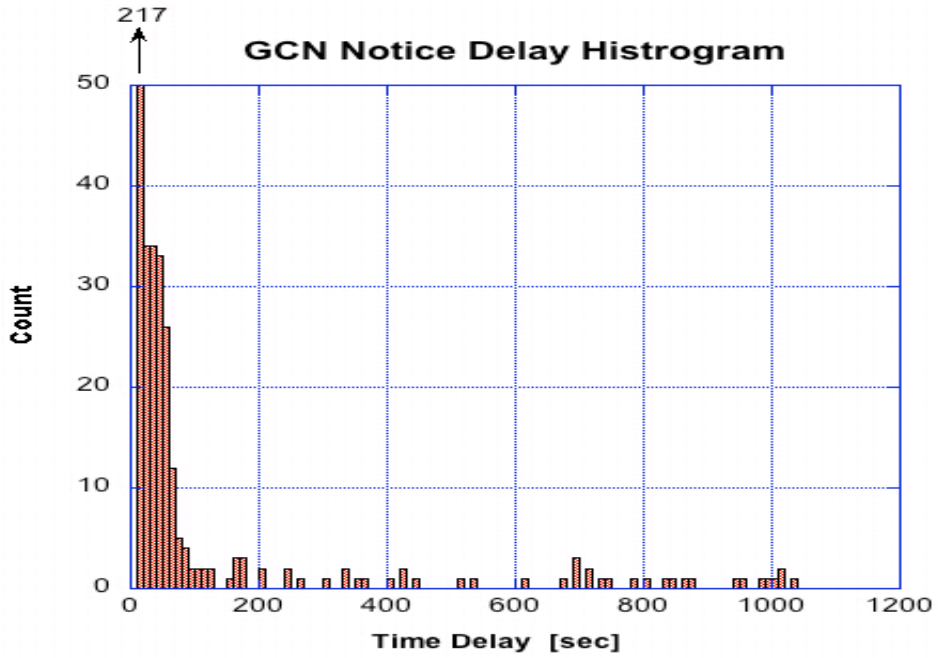
BAT Status

- 4.7 years and still doing fine.
- Still meeting all the Requirements.
- No hardware failures.
  - Except that LHP Heater Controller in 2005 (1 of 4 redundant).
- No degradation in any parameter:
  - GRB Detection Rate is constant.
  - Energy resolution is the same (7 KeV)
  - Increase in number of noisy detectors -- ~20%.
  - False triggers have decreased ("tuned" the trigger criteria).

BAT's 3 Data Products

- GRBs
  - Stare mode
    - 439 from Dec 04 to July 9, 2009
      - 34 Short Hard Bursts
  - During slews
    - 11 in the 12 months of operations
- Hard X-ray Transients
  - The other things that go bump in the sky.
  - 10's of triggered SGR events, 100's untriggered.
- Hard X-ray Survey
  - AGN, Blazars, micro-quazars, BHs, …

BAT is Fast and Accurate



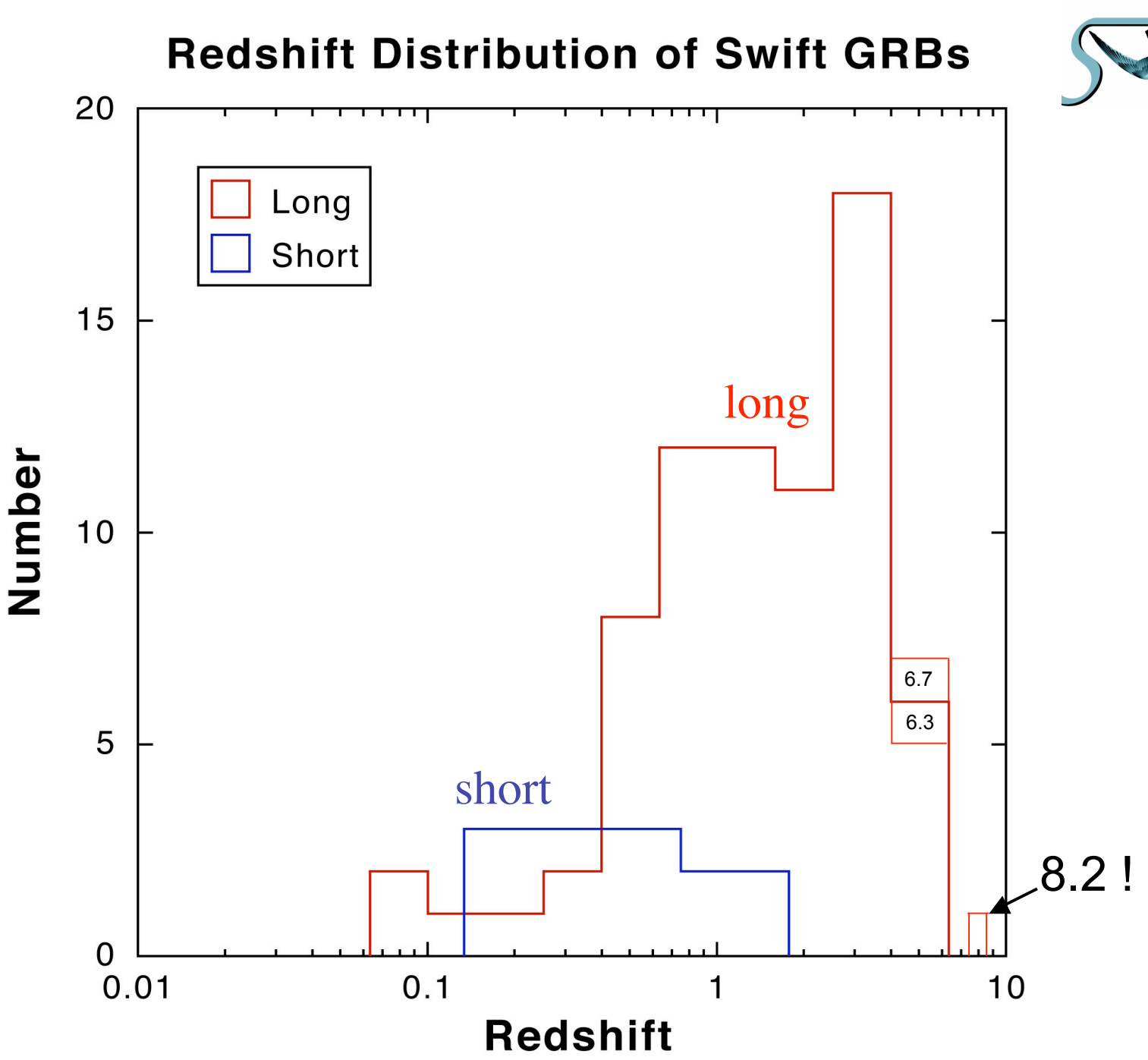
20% False positive on-board.

2% after real-time Ground processing.

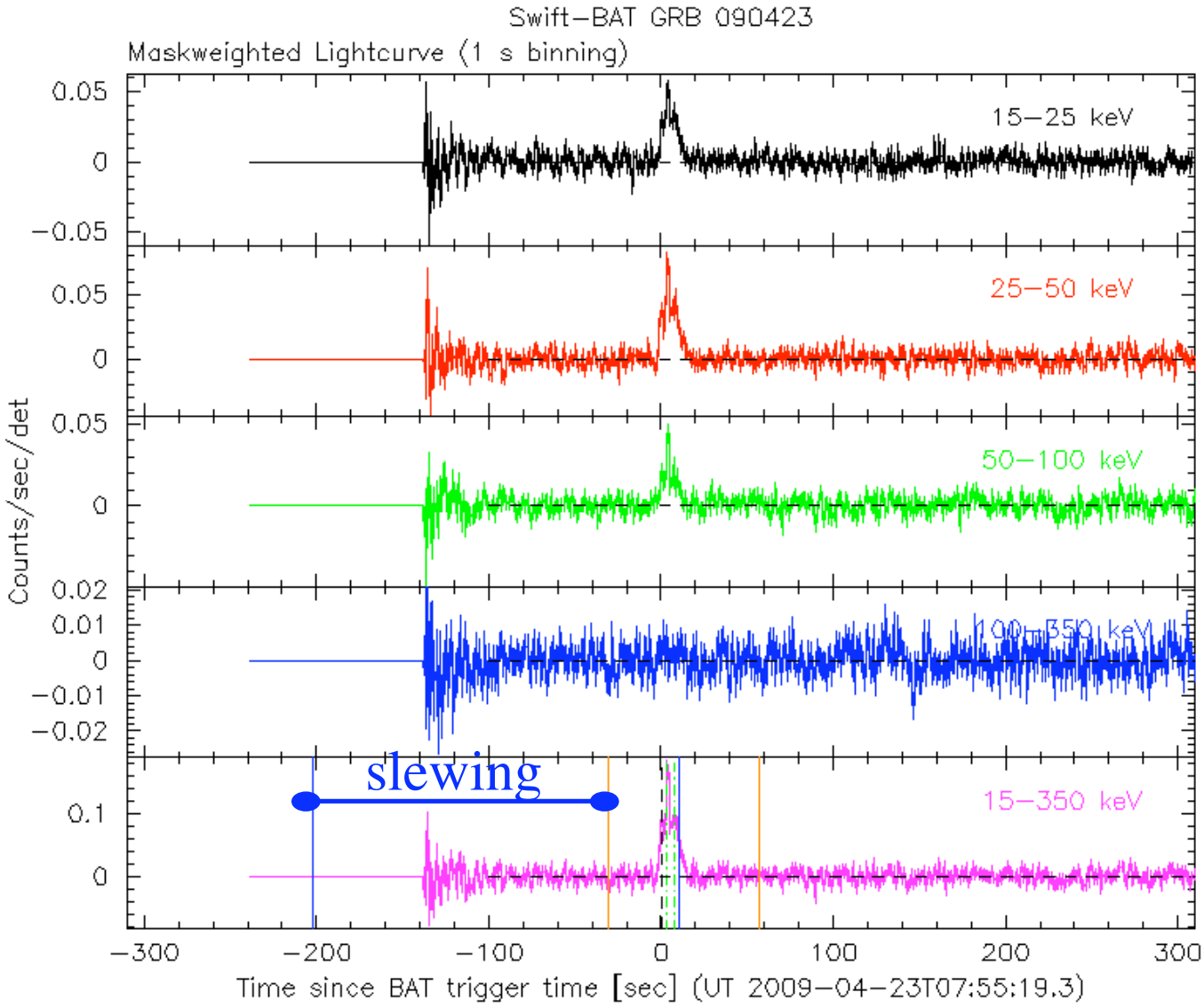
50% w/in 18 sec.
75% w/in 40 sec.
90% w/in 175 sec.
Long delays caused by Malindi downlinks.

BAT Enables

- Because of the small error-circles in real time:
- High redshift bursts:
- Naked eye burst: 080319B
- X-ray afterglow structure:
  - Flares
  - Plateau phase


Redshift Distribution of Swift GRBs
Long
Short
long
short
6.7
6.3
8.2 !
Number
Redshift
0
5
10
15
20
0.01
0.1
1
10

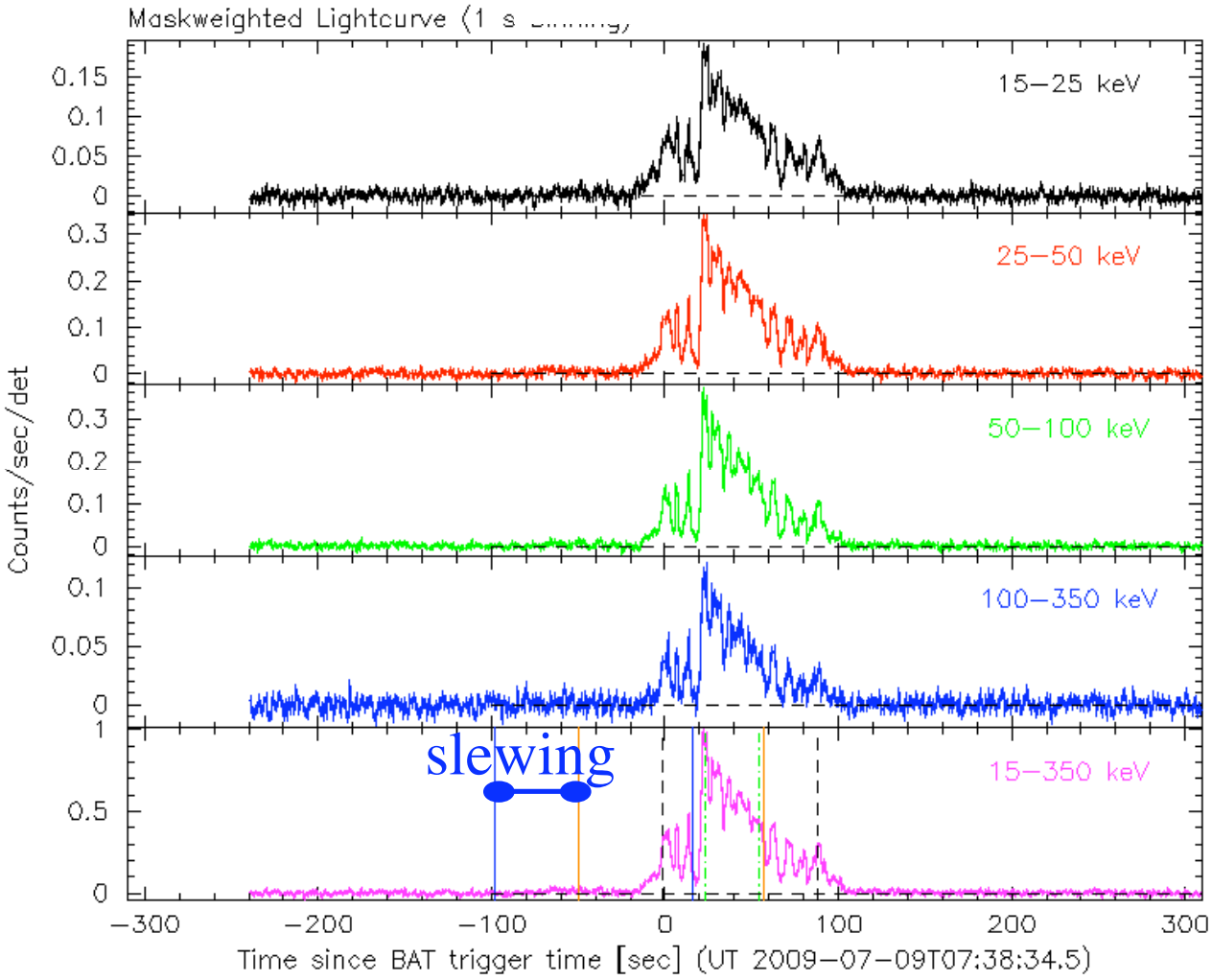
Farthest Object in the Universe



GRB 090423
Z = 8.2
400 Myr

An Even Farther Object ???

GRB 090709A



Z = 10-ish ?!

BAT Enables

- Because of the small error-circles in real time:
- High redshift bursts:
- Naked eye burst: 080319B
- X-ray afterglow structure:
  - Flares
  - Plateau phase

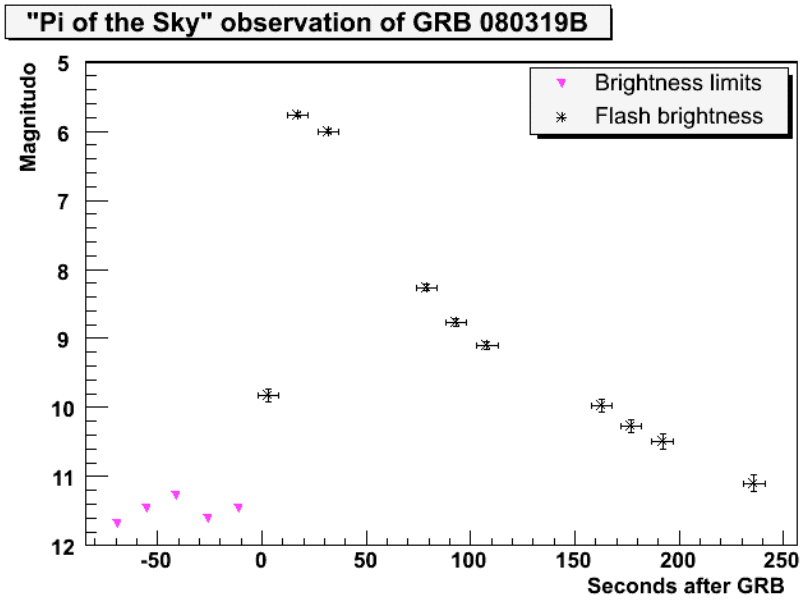
GRB 080319B
First "naked-eye" Burst

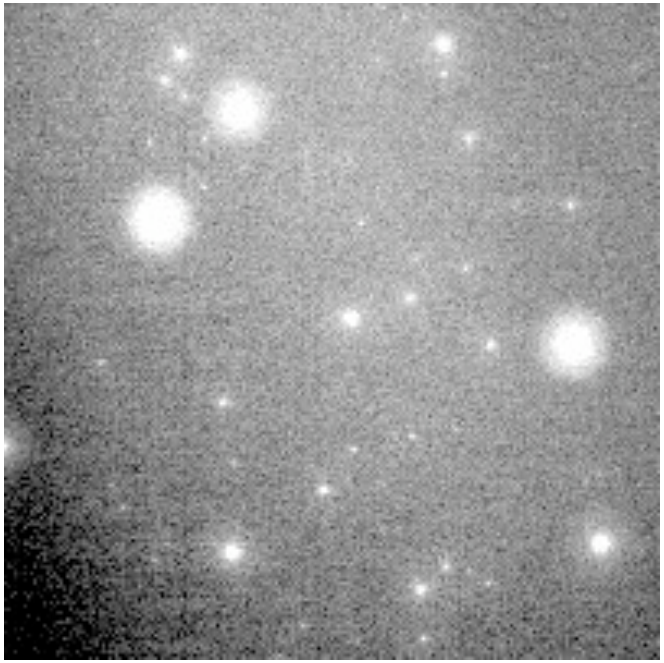
Brightest *Swift* GRB: 25 ph/cm^2/sec

z = 0.937 (7.5 G light yr)

Peak brightness of 5.6 magnitudes!!
(10x brighter than 990123)

Pi of the Sky – <u>still observing the "A" burst,</u>
caught "B" burst at edge of FOV.



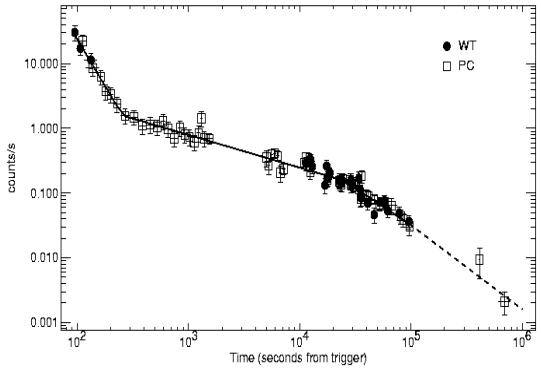


David Bar

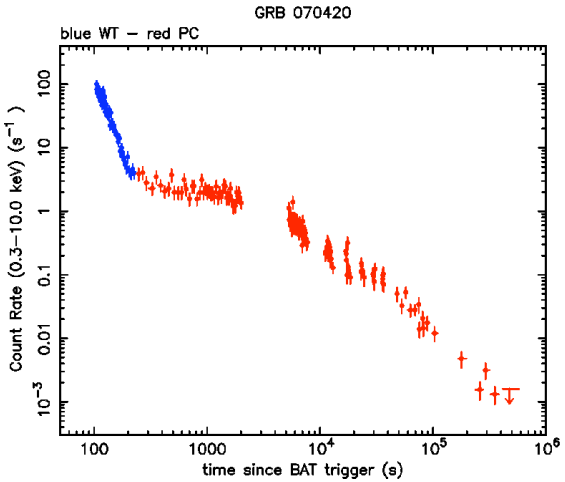
BAT Enables

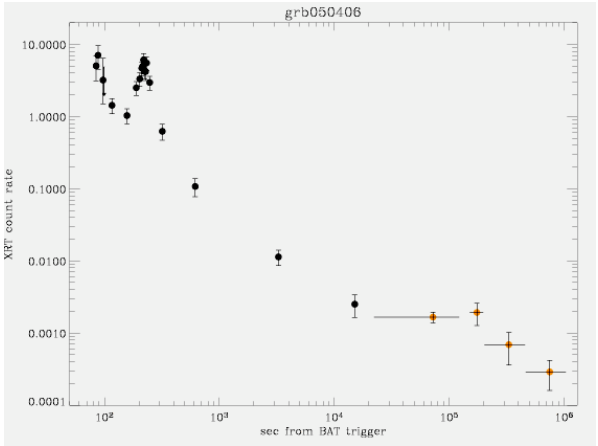
- Because of the small error-circles in real time:
- High redshift bursts:
- Naked eye burst: 080319B
- X-ray afterglow structure:
  - Flares
  - Plateau phase

Typical *Swift* X-ray Lightcurves

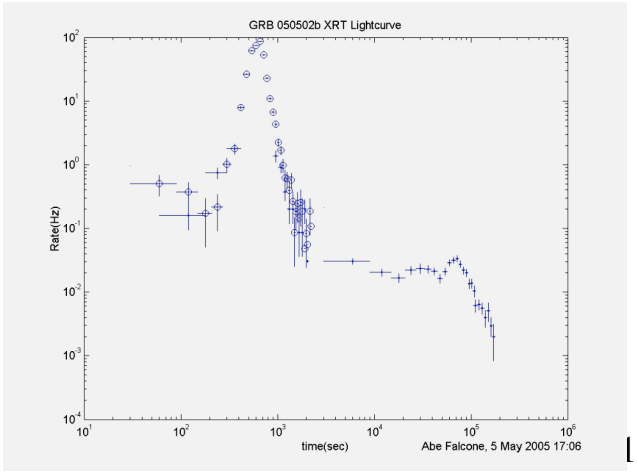


50% with bright early component





~40% with flares



The Flexible BAT

- BAT is able to adapt to the unknown.
  - But a lot of that unknown was scoped by David Band during the BATSE era.
- Produces a series of information to the spacecraft, the other 2 instruments, and the ground.
- Trigger criteria that cover a large dynamic range of phase space: time, energy, detector regions, and background.
- Changeable trigger criteria.
- Changeable data products.

BAT Post-Launch Enhancements

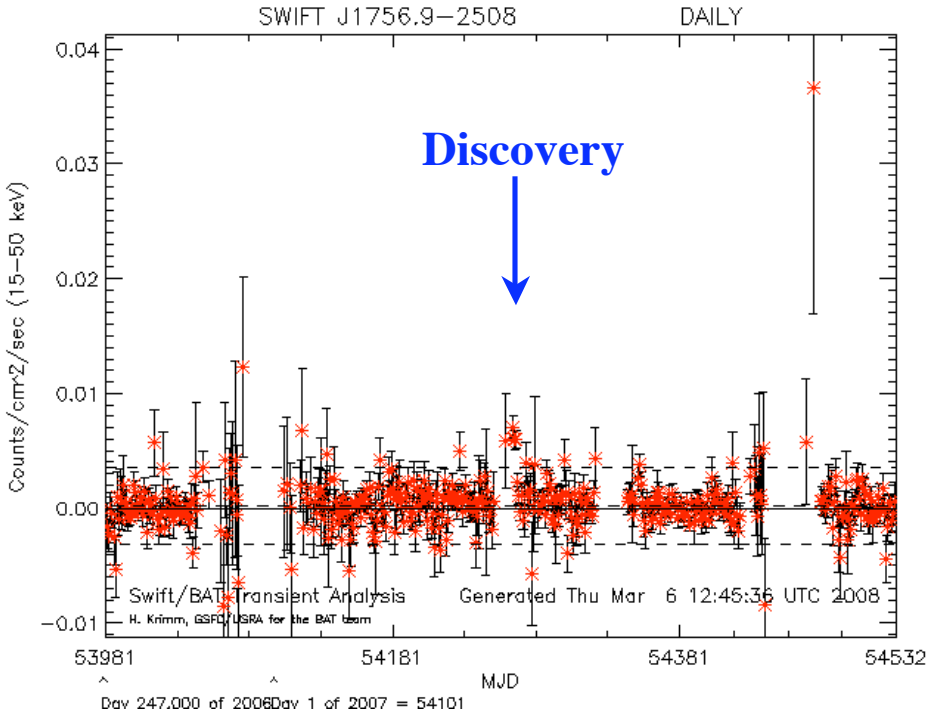
- DONE:
  - BAT Slew Survey (capturing the event data).
  - Long Image-triggers (>64 sec) changed from Transients to GRB response. (Going for hi-z bursts)
  - Catalog source-class Swift Response control
  - AT slewing to Known-source Transients
  - Transient Monitor (lightcurves) (ground work)
  - Redshift Prediction (ground work)
- ALMOST DONE:
  - SubThreshold: the fainter, the farther.
- FUTURE:
  - Catalog source-by-source Swift Response control

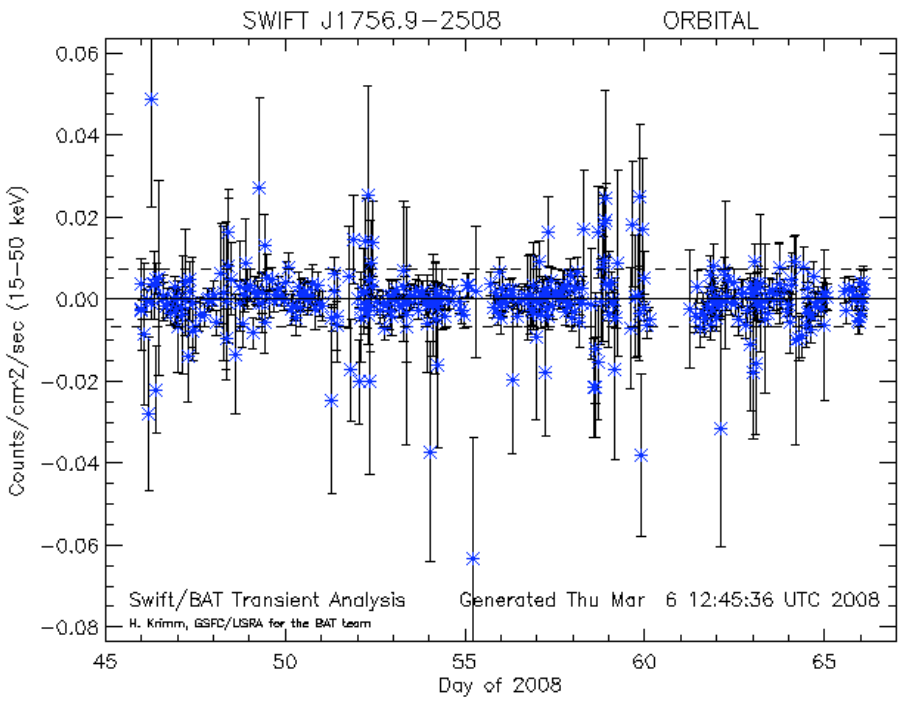
Lightcurves & Transients

- All-sky monitoring of source variability.
- http://swift.gsfc.nasa.gov/docs/swift/results/transients/
- 718 objects monitored/public
  - ~114 are routinely/daily detectable by BAT.
- Pointing-by-pointing and Daily-average lightcurves
- 7 previously unknown sources (msec pulsar, 2 BH, …)
- ~68 ATELs published
- Future:
  - 2-day, 4-day, & 8-day averaged lightcurves.
  - Automating the search/discovery of transient behavior.
  - Into HEASARC

Example of NEW Source

- Swift J1756.9-2508 msec pulsar
- Discovered in the Daily Image Mosaics
  - Lightcurve came afterwards.





BAT Slew Survey (1of2)

- Harvard: Antonio Copete and Josh Grindlay (Harvard)
- Look for GRBs (& transients) when Swift is slewing (~15%).
- More sky coverage per day; each slew is 2-3x BAT FOV.
- Capture event-by-event data during slews:
  - 120 sec only (ie only part of the slew).
  - 40-60% of the slews each day.
- Somewhat better sensitivity due to systematics removal.
- Several trigger criteria:
  - single slew, and multi-slew time domains
  - Various Energy-band criteria: 15-50, 50-150, & 15-150 keV.
- Not real-time (hours delay).

BAT Slew Survey (2of2)

- New GCN Notice type for these detections: BAT_Slew_Pos
- Discoveries:
  - GRB 070326: "first light" (T+3.8 mo)
  - GRB 080123: "flare" on the AT slew of a BAT-triggered burst (T+6 days)
  - GRB 080130: essentially normal ops mode (T+11 hr)
  - GRB 080605
  - MXB 0656-072
  - GRB 080613B
  - GRB 080702B
  - GRB or something else?
  - GRB 081025
  - GRB 081203B
  - GRB 081211B

BAT to the Future

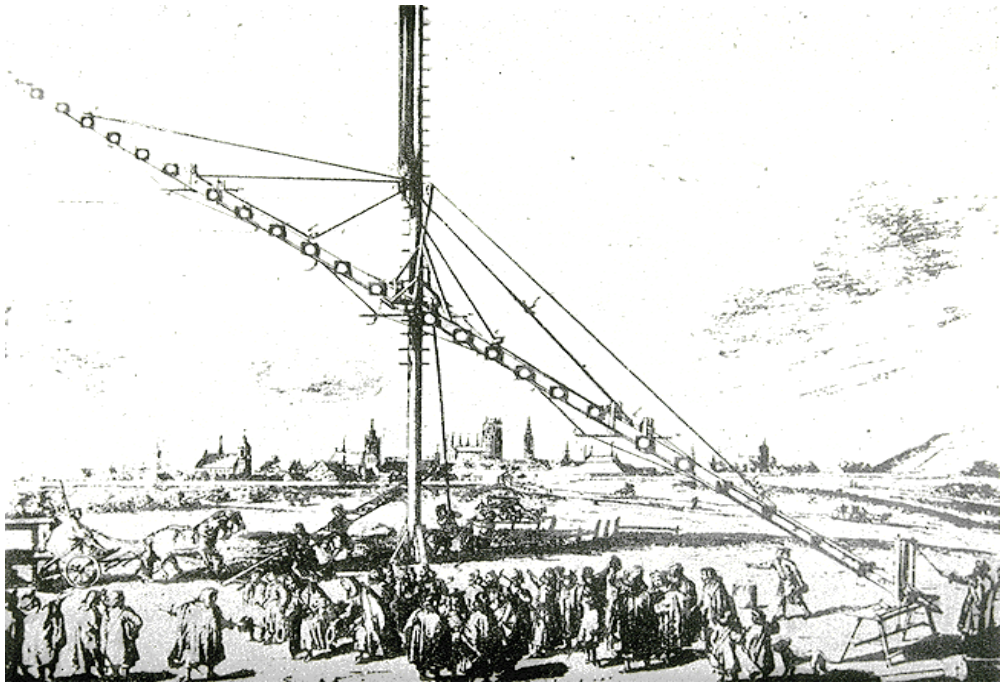
- Subthreshold bursts
  - Finds the bursts in the noise
  - Turning down the threshold: 6.5 --> ~5.6 sigma
  - Merit parameter controlled via scripts so the good Burst and Planned targets are not clobbered.
  - Shortened observation interval -- first orbit only.
  - XRT detection used to valid the good from the bad/noise.
  - Automated: Swift --> GCN --> U.Leicester --> GCN --> World
  - 2 GRBs in about 2 months of testing
  - Will go public in about a month

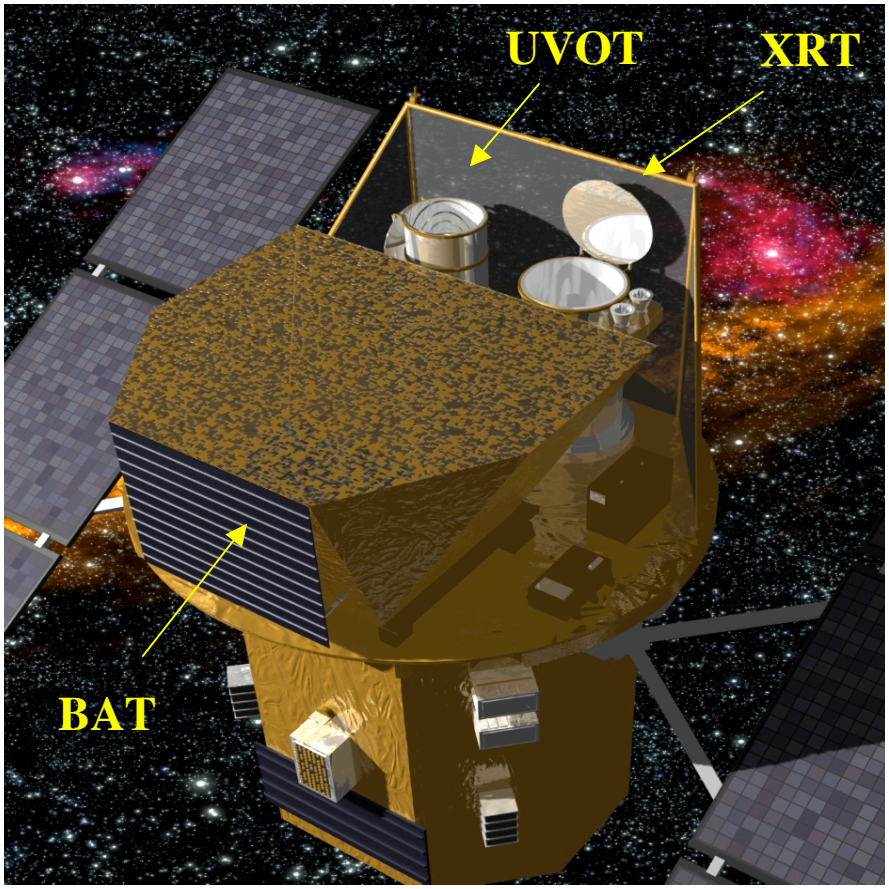
David Knew

- Understood the ramifications of BAT being softer than BATSE
  - The 15-150 keV vs 50-300 keV.
  - Lower E_Peaks, higher z.
- A little off on our low energy deficiency
  - But even we still do not understand that cause
- Predicted our sensitivity would be “around 90/yr”
  - We see 95/yr

How to do Autonomous Telescopes

Non-Robotic Telescope





Autonomous Robotic Telescope

“That’s just the way it’s done”

David -- my friend.