Monitoring and Detecting X-ray Transients with the Swift Observatory

A Multiwavelength Observatory for Rapid-Response Observations of Transient Targets

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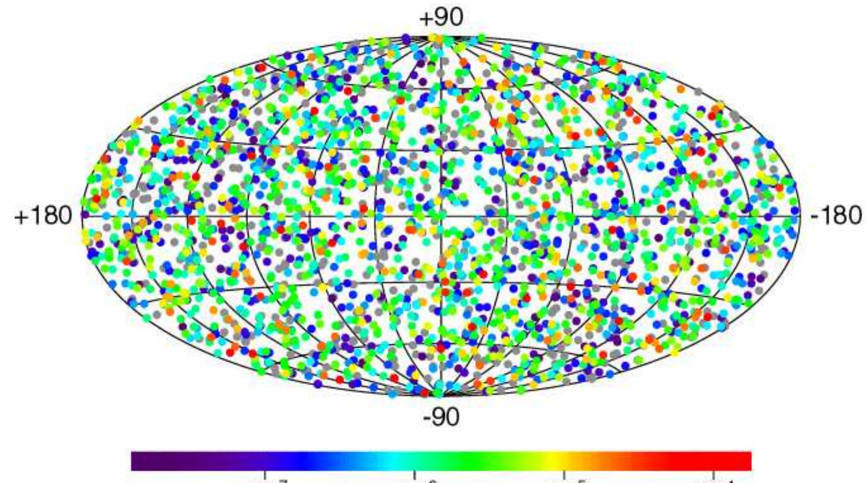
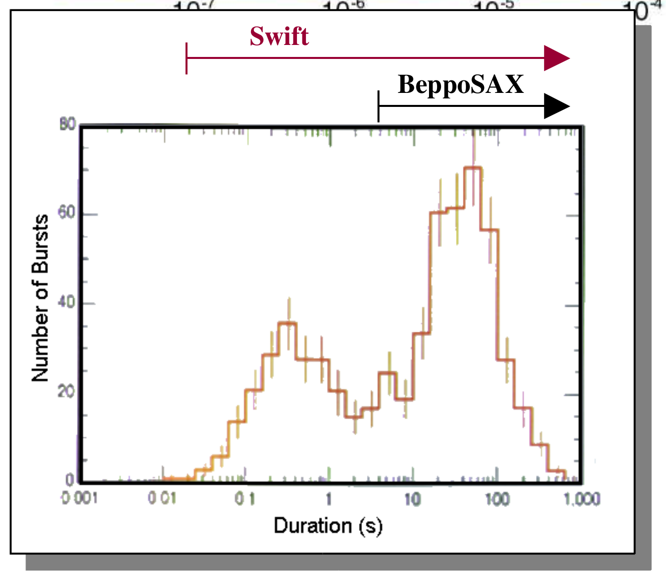
for the Swift Team

Gamma-Ray Bursts

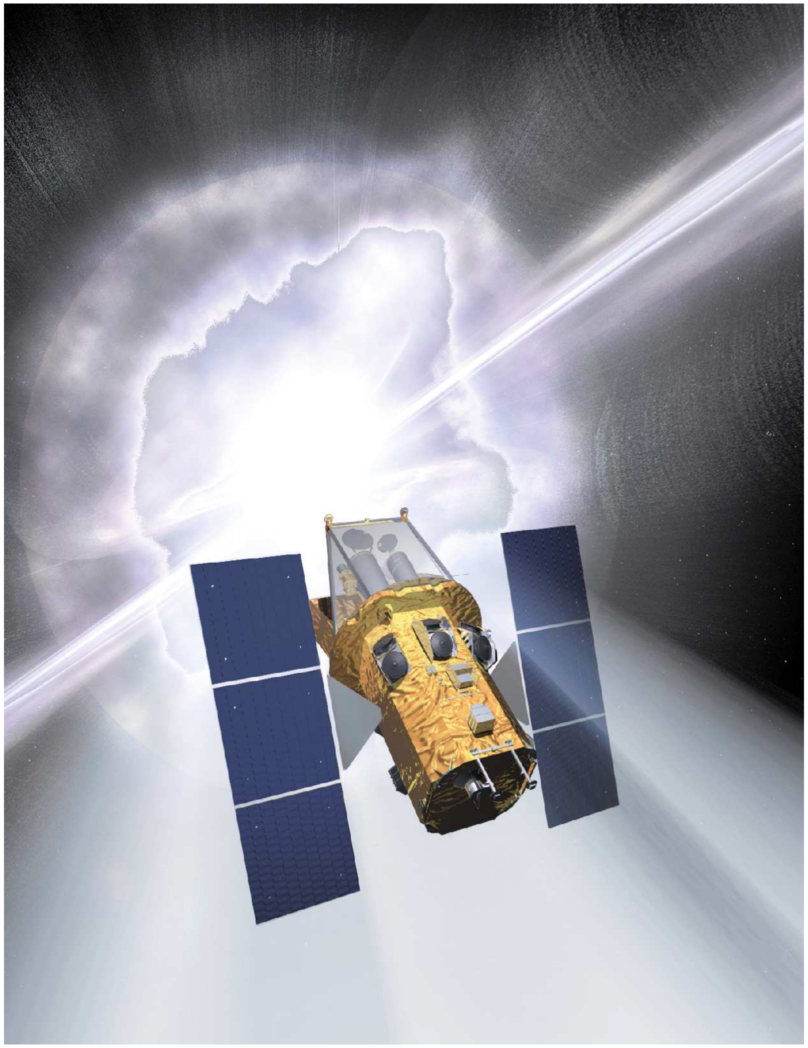
- Isotropic Distribution on Sky
  (BATSE bursts)



- Wide range of variability time scales
  (10 ms –1000 s)



Swift Mission



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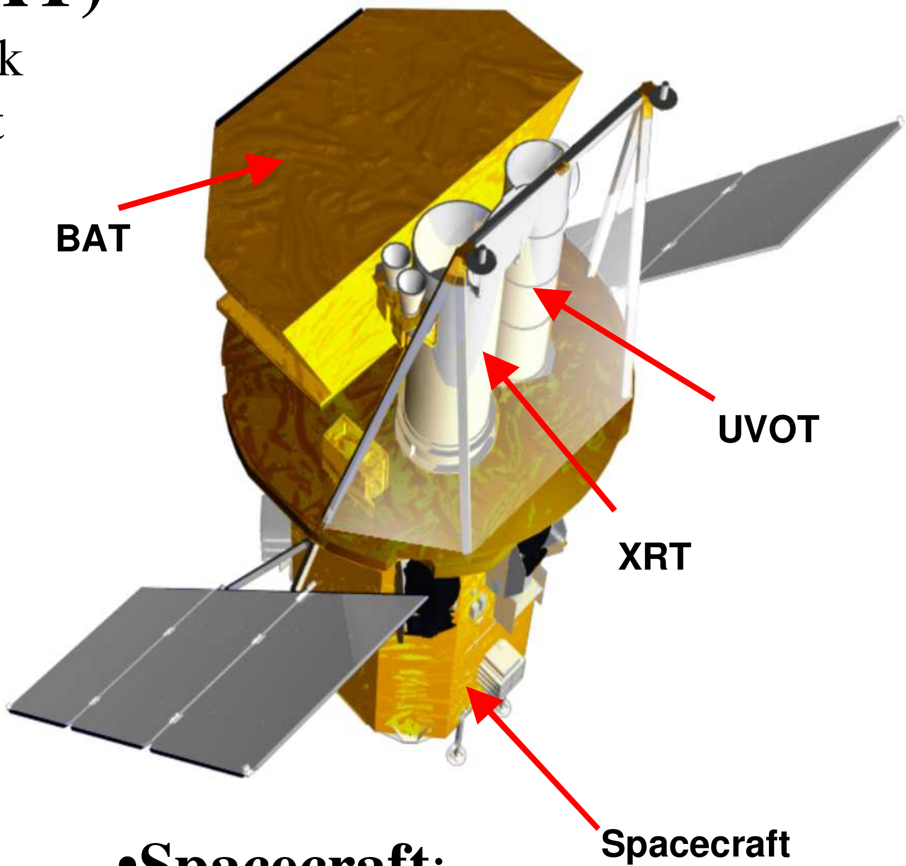
Swift GRB Science Questions

- **Swift will address the current fundamental questions about gamma-ray bursts:**
  - **What are the sites and nature of gamma ray burst progenitors?**
  - **What are the true mechanisms for burst production?**
  - **What is the local environment near the burst?**
  - **Are there multiple classes of gamma ray bursts?**
  - **What can gamma ray bursts tell us about the early Universe?**

Swift Instruments

- **Burst Alert Telescope (BAT)**
  - CdZnTe detectors with coded mask
  - GRB & Transient trigger for Swift
  - Most sensitive gamma-ray imager ever
- **X-Ray Telescope (XRT)**
  - Arcsecond positions
  - CCD spectroscopy
- **UV/Optical Telescope (UVOT)**
  - Sub-arcsec imaging
  - Grism spectroscopy
  - 24^{th} mag sensitivity (1000 sec)
  - Finding chart for other observers



- **Spacecraft**:
  - Rapidly re-pointing (~ 1 minute response)

Swift

Burst Alert Telescope (BAT)

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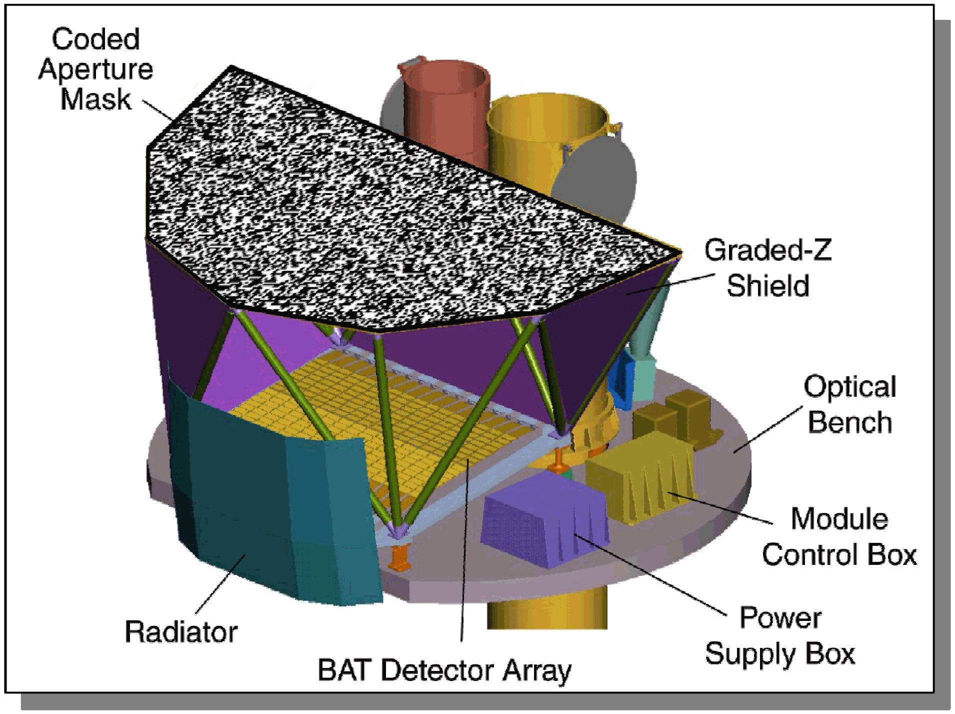
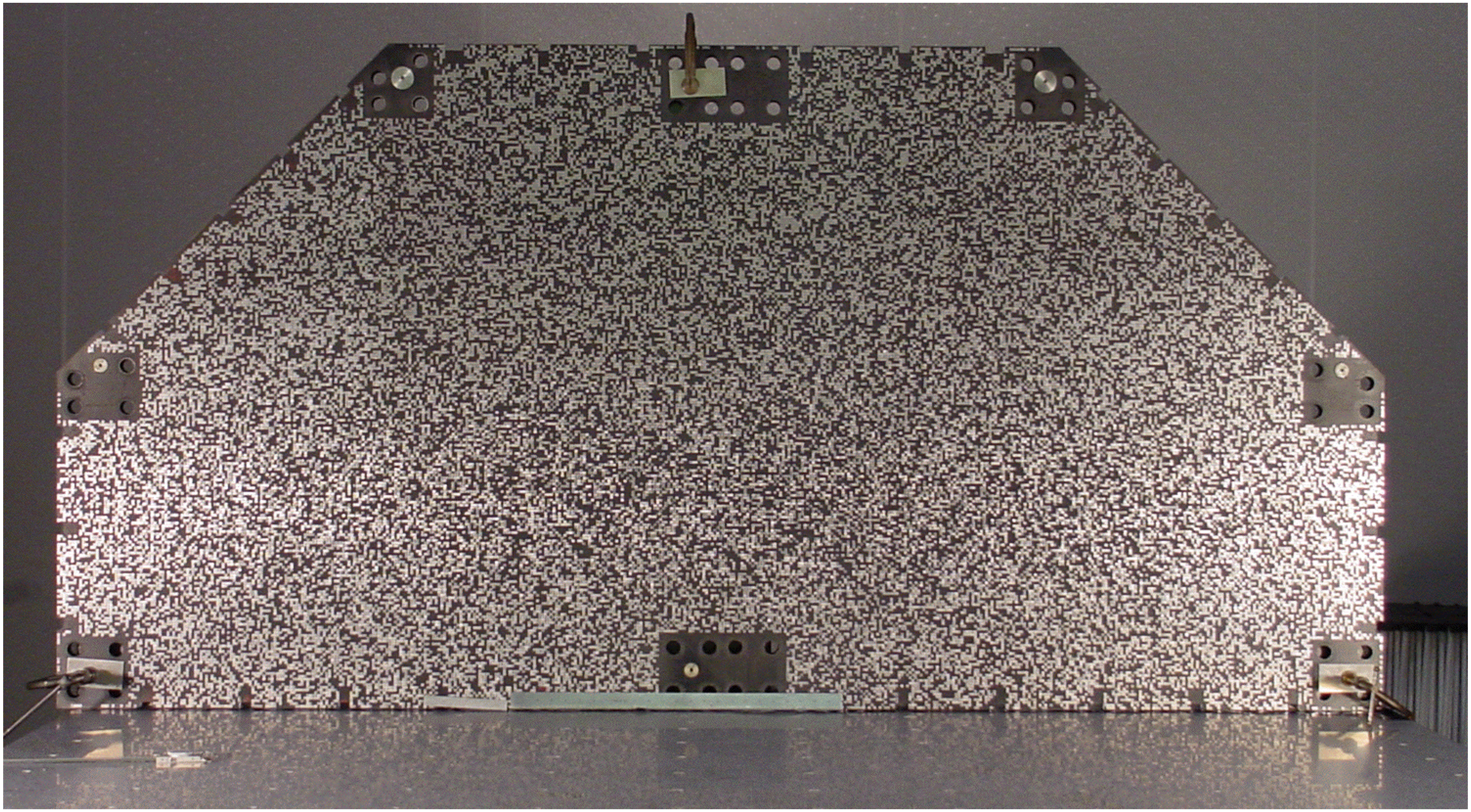
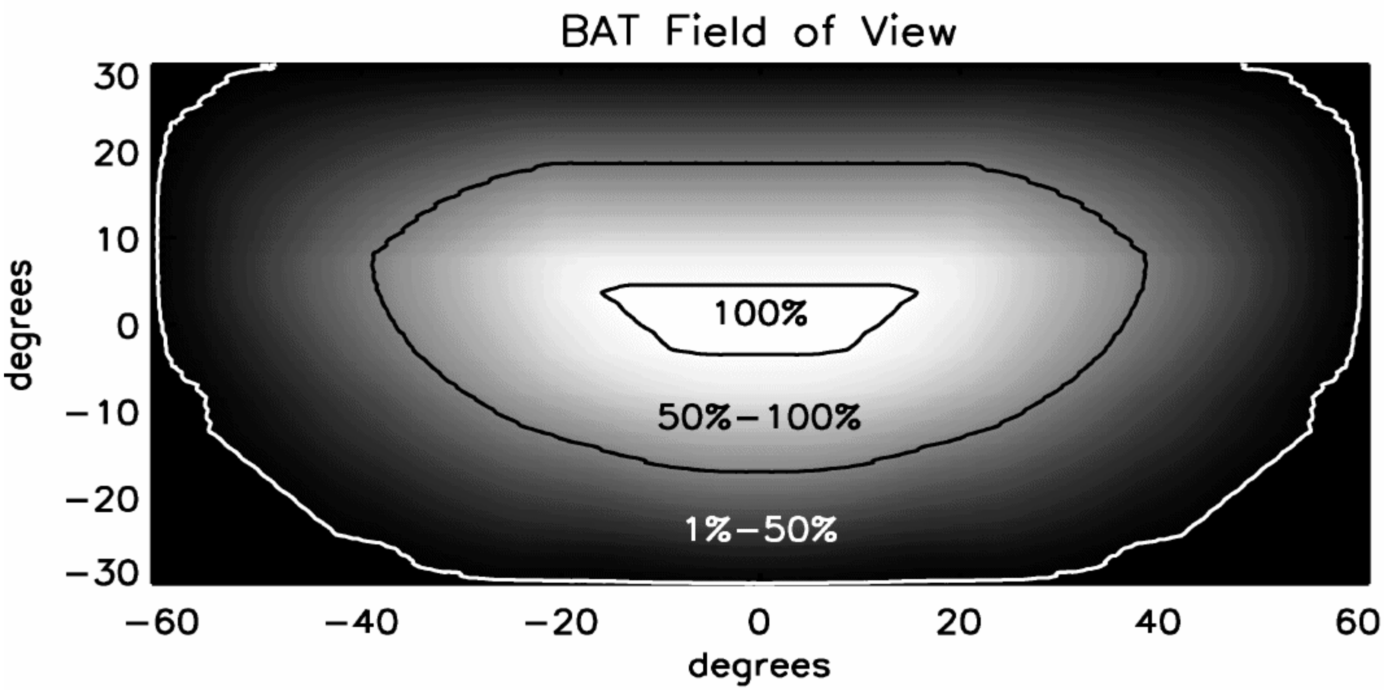
- **Real time transient detections and positions**
  - Half coded 1.4 steradian FOV
  - 5200 cm^2 CdZnTe pixel array
  - 15 - 150 keV band
  - 5 times more sensitive than BATSE
  - Several bursts per week detected
  - Angular resolution of 17 arcmin giving positions of 1 - 4 arcmin
  - Onboard processing to provide prompt arc-minute position to satellite and to the ground



BAT Mask (50K Pb tiles)



BAT: Transient Sky Monitor



- >50% partial coding over ~1.4 sr of sky.
- Observing policy: one or more pointings per Swift orbit; BAT always taking pointed data.

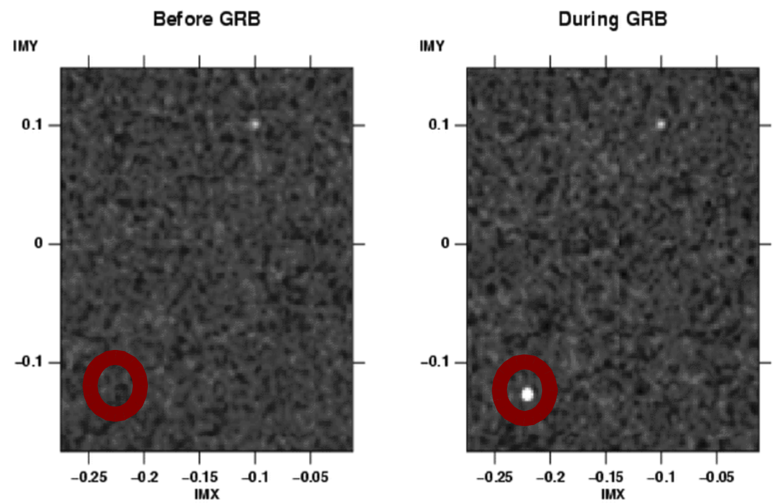
Monitoring Comparison

	XTE ASM	SAX WFC	Swift BAT
Energy Range	2–10 keV	2–30 keV	15–200 keV
Field of View	6º × 90º	40º × 40º	120º × 60º
Position Acc.	3' x 15'	2'	4'
Sky Coverage	~80%	7%	50%
Sensitivity	~30 mCrab	~10 mCrab	~10 mCrab

- Sky Coverage and Sensitivity quoted "per orbit"
- Similar energy range to BATSE, but a factor of ~10 times more sensitive, and ~arcminute positioning

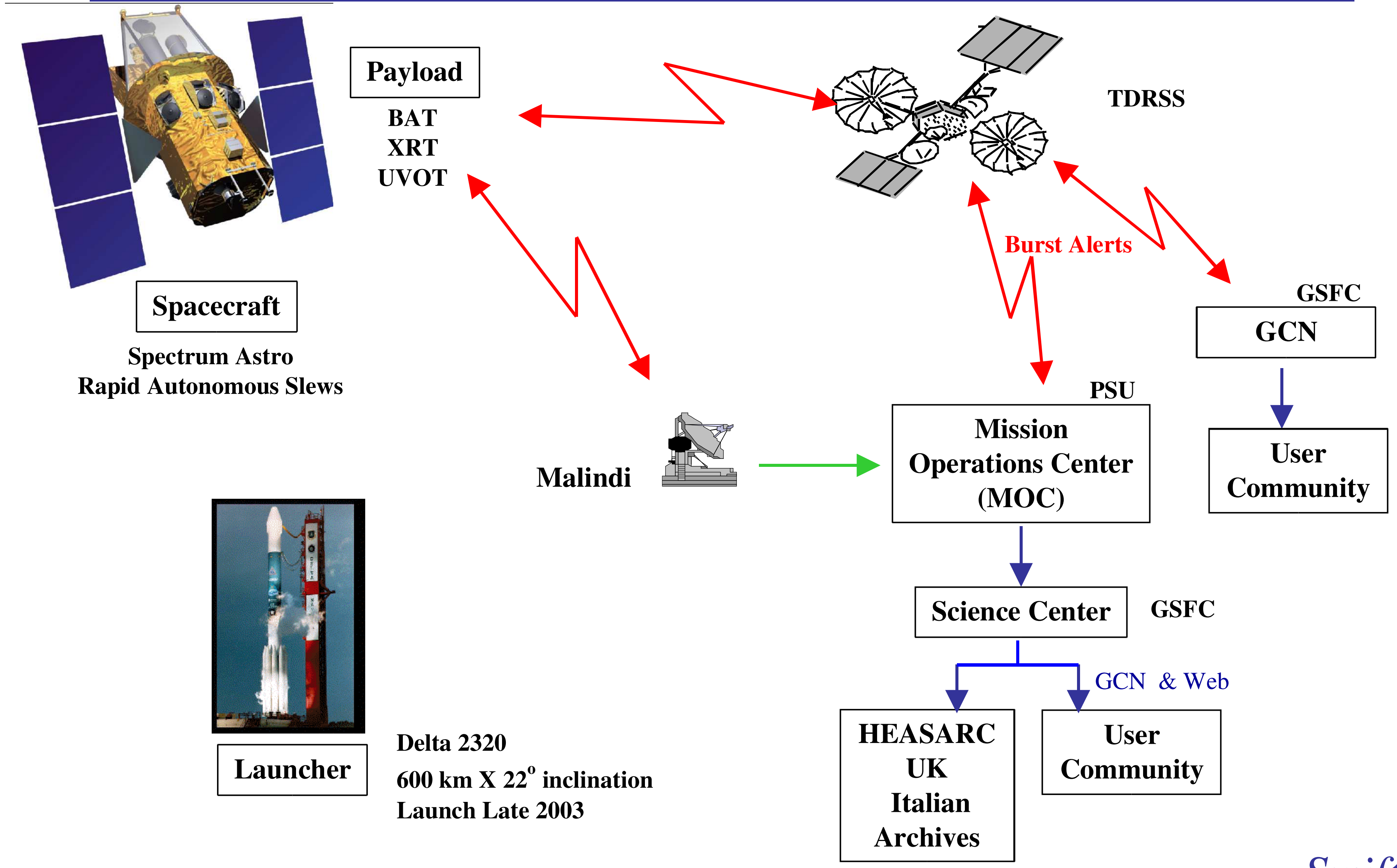
Transient Triggers

- Flight Software
  - Rate trigger (many time scales)
  - Imaging trigger
  - Response time ~sec
  - On-board catalog of known sources, pre-programmed responses (ignore, send event data)



- Ground Software Transient Processing
  - Survey image processing (more sensitive)
  - Response time ~hours

Swift Mission Communications

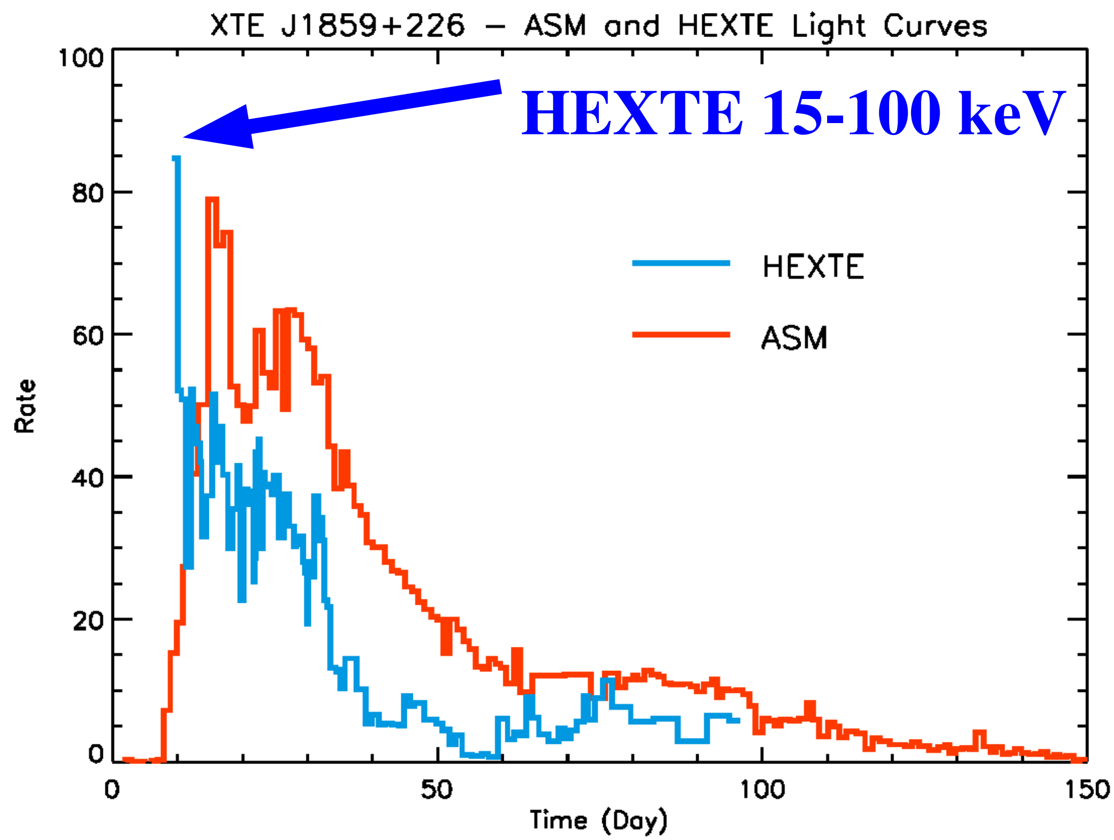


BAT Flight Science Data

- Gamma-Ray Burst
  - Event data – 100 μsec resolution
  - Nominally 10 minutes of data around burst
  - Transient positions via TDRSS and GCN
- Normal Operations
  - "Survey" mode – accumulated histograms
  - nominally 5-minute resolution
- Special Requests
  - Event data upon command (usually diagnostic)

Hard X-ray Transient Science

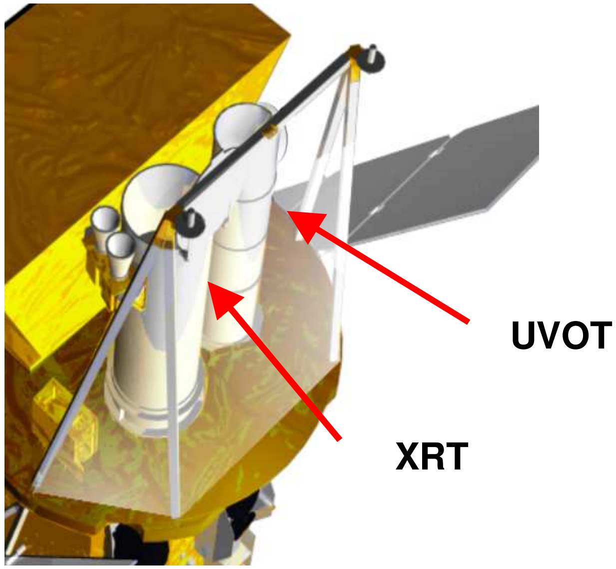
- X-ray Novae (BH)
- Early accretion disk evolution (XTE J1859+226)
- Broad Fe Lines (relativistic or Compton broadenin
- Microquasar jets?



- Hard X-rays decoupled from soft
- Recurrences of Be binaries; AGN flares

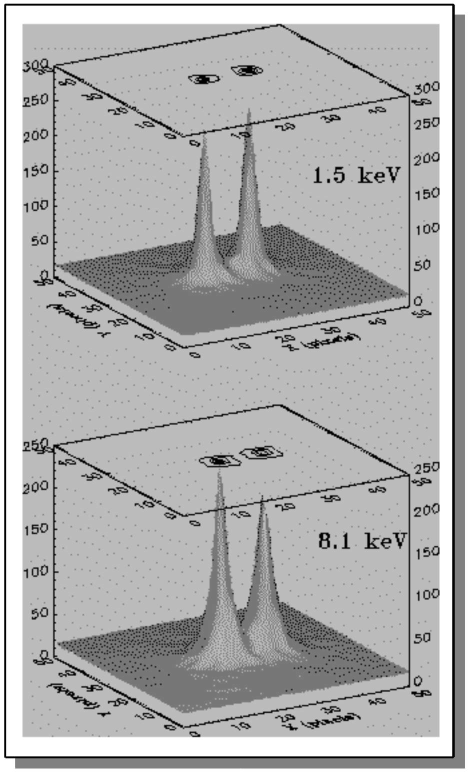
Observing TOOs with Swift

- Swift has two Narrow Field Instruments
- Together, these two instruments provide imaging and spectroscopy follow-up coverage from UV through 10 keV X-rays

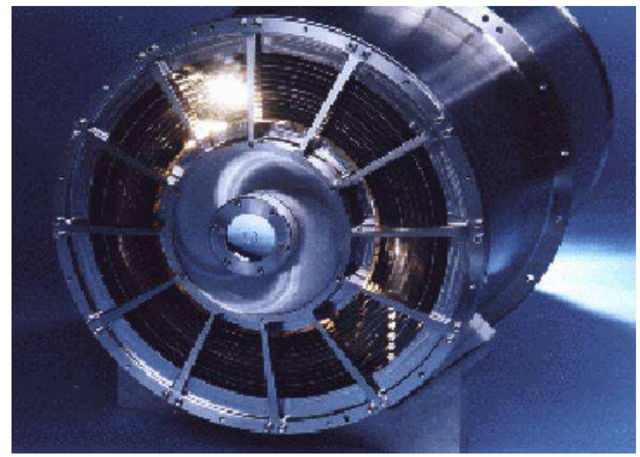


- Multiwavelength capability in one package
- BAT also can also be used for follow-up, but source does not need to be on-axis

XRT Instrument

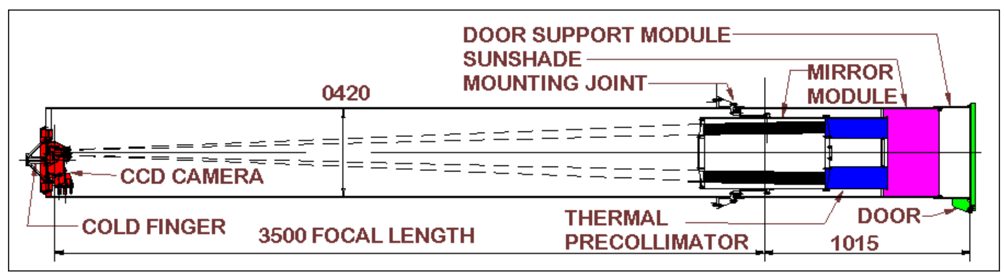


- Flight spare JET-X module
- 15 arc-second half energy width
  - sharp core yields 2.5 arcsec locations
- ~100 cm^2 at 1.5 keV
- Imaging mode yields accurate centroids up to 26X Crab flux
- Photon counting mode for spectroscopy and time structure



XRT Mirror Module

- CCD array covers 0.2-10 keV band
  - uses spare XMM chip
  - 24 x 24 arcmin field of view
  - Cooled to -100 degrees C



3.5 m focal length

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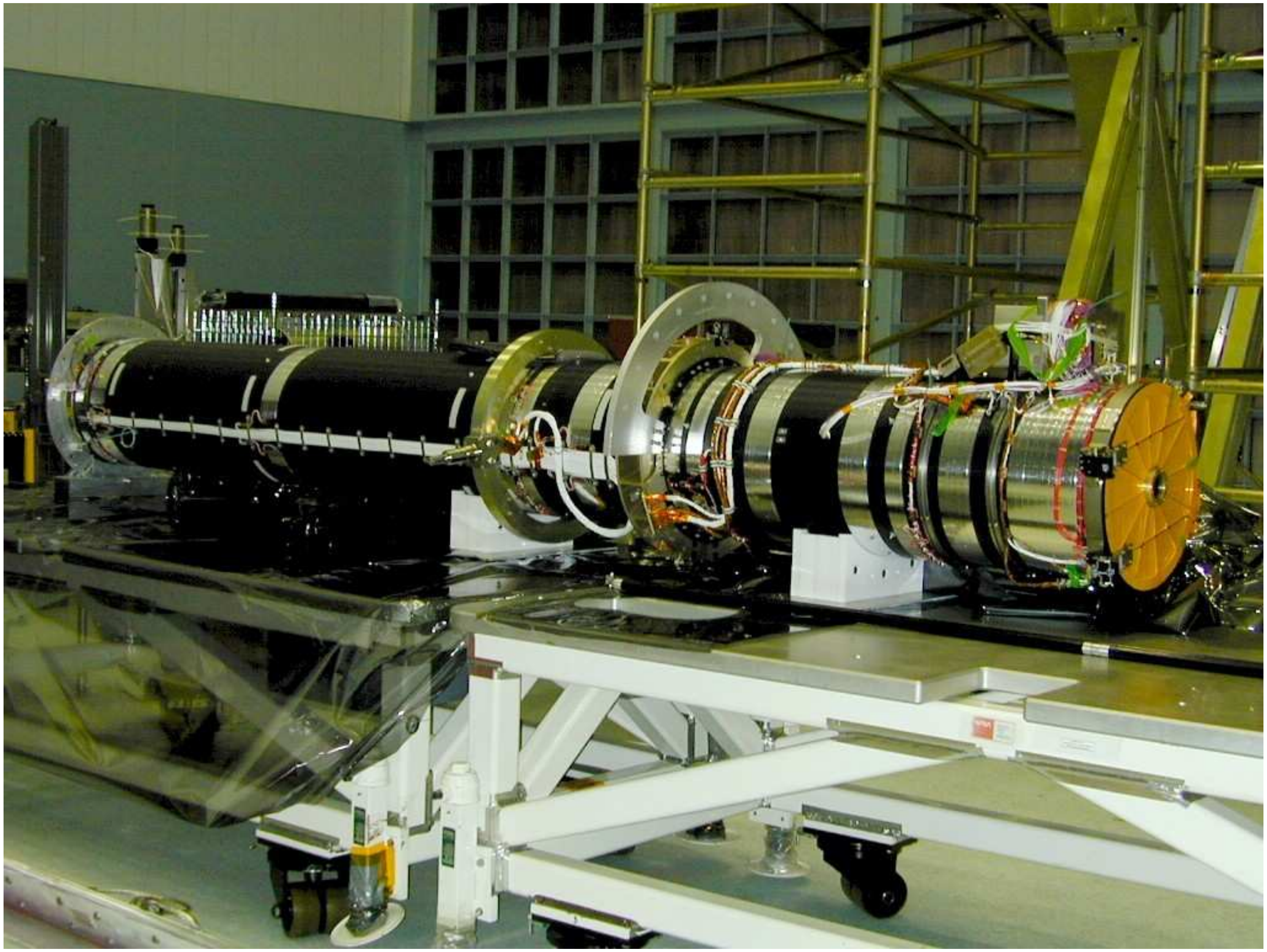
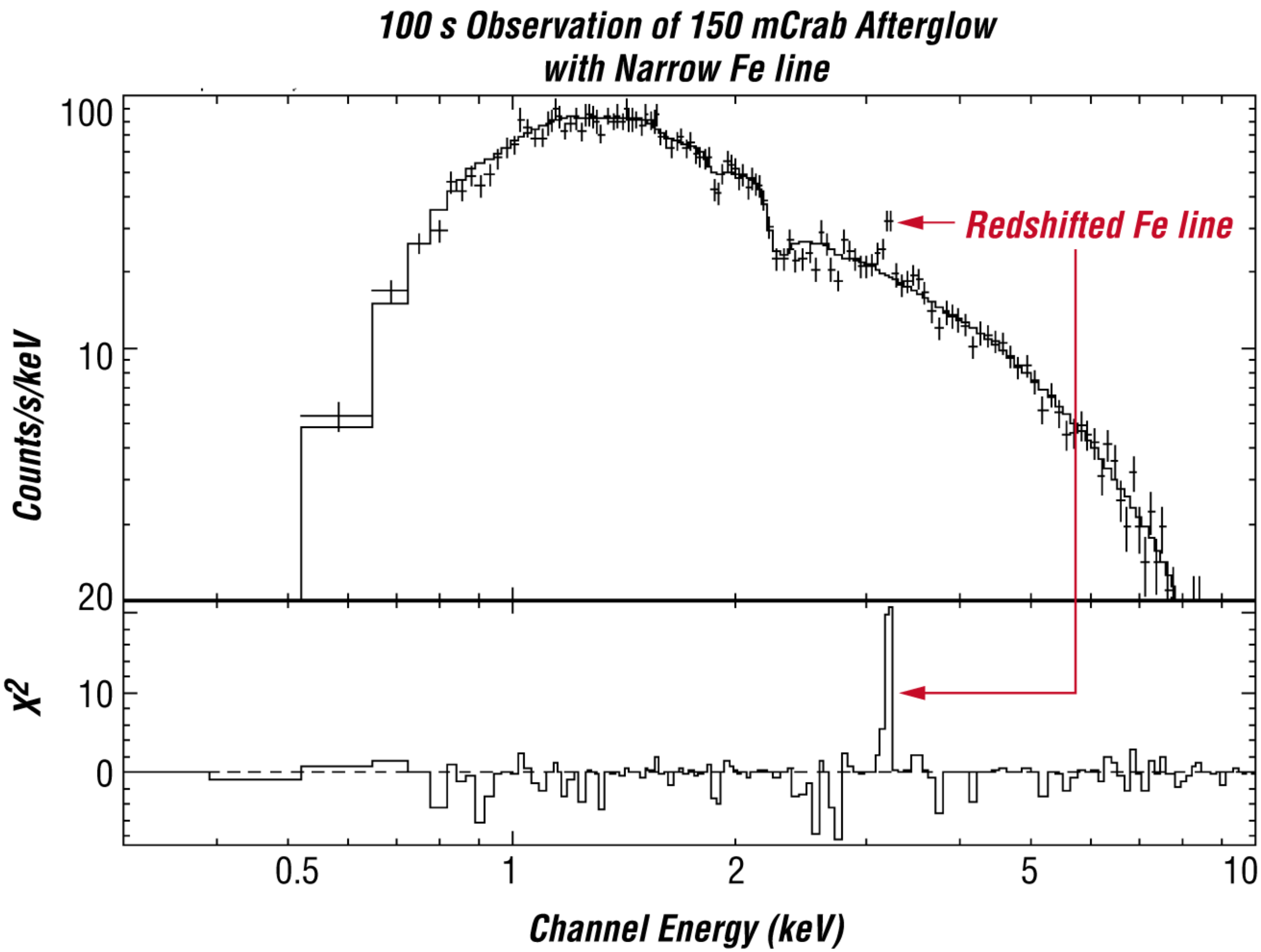
XRT Integrated Tube



Redshift Measurement



Spectral Parameters:

- $I(E) = A\ E^{-2.0}$
- $N_H = 2.5 \times 10^{22}$
- Eline = 6.4 keV
- R = 150 cps
  (150 milliCrab source)
- t = 100 s

(simulation from
J. Nousek)

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UVOT Instrument

- Based on XMM OM design to minimize cost and risk
  - Covers 170 nm to 650 nm
  - 30 cm Ritchey-Chrétien telescope
  - 24 mag in 1000 s with 17 arcmin FOV
  - Detector is image intensified CCD array
  - Unique coverage 20-70 s after trigger
  - Positions to 0.3 arcseconds using onboard image registration

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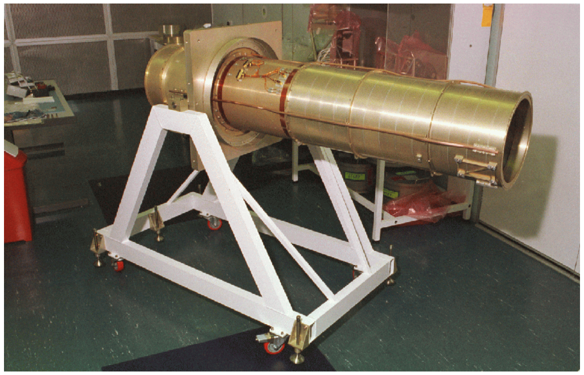
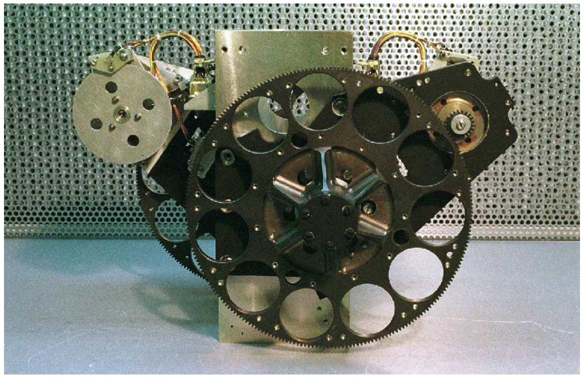
XMM OM



Filter Wheel



UVOT Capabilities

- Localize the source:
  - High spatial resolution
  - Fast finding chart

- Handle any source brightness:
  - Grisms (transmission grating etched onto a prism) for bright bursts
  - Excellent dynamic range (follow burst afterglows down to $B = 25$)

- Measure its redshift:
  - Possible down to $V = 21$
  - Grisms give direct measurement for $8<B<17$
  - 6 broadband filters give Spectral Energy Distribution

- Monitor its light curve:
  - Cycle through broadband filters
  - Photon-counting
    - Good timing resolution
    - Measure brightness fluctuations

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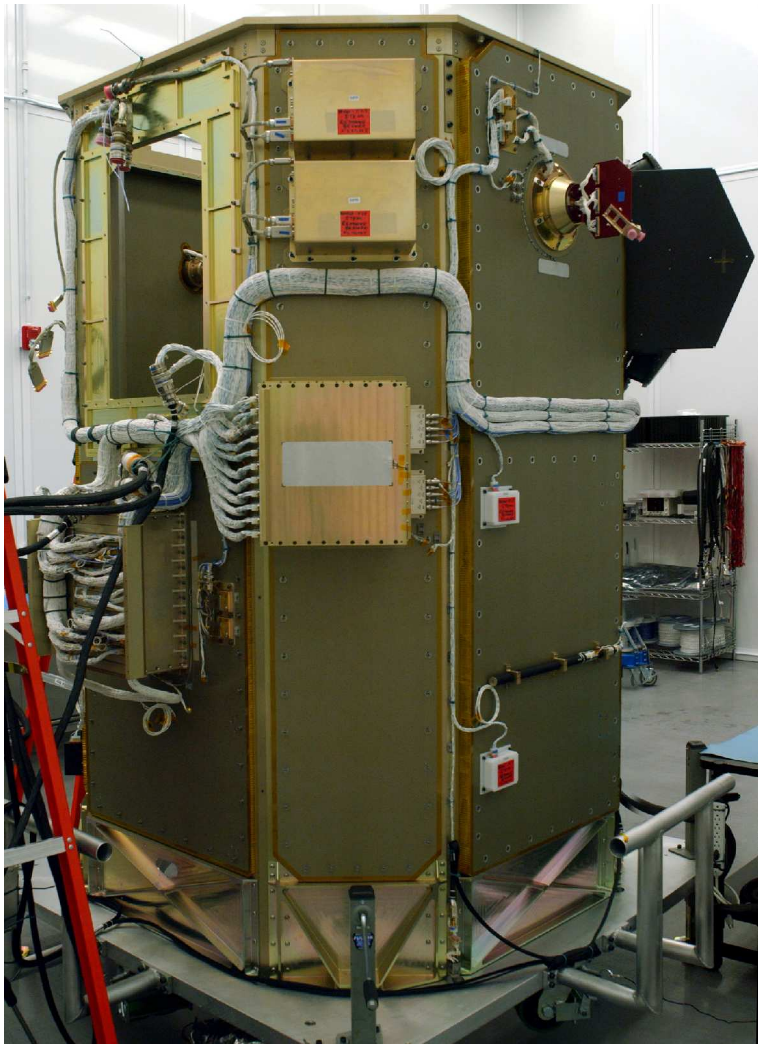
Swift TOO Requests

- The Swift project will entertain TOO requests from the observer community
- Mission PI or designate will decide
- Science re-plan
  - ~hours response time
  - Response also depends on constraints and other science target priorities
- GI program recently approved for Swift by NASA HQ (primarily for GRB studies or follow-ups)
- Cycle 2 *may* allow guest investigators to request Swift repointing

Spacecraft



Swift

Conclusions

- Swift is a multiwavelength observatory (all instruments in one package)
- BAT as a Hard X-ray all sky monitor
- Rapid response to new transients is key
- Swift is largely complementary to the other dedicated X-ray observatories
- Modest collecting area (XRT vs. XMM)
- Modest spectral response (XRT vs. HETG)
- Swift can provide indicators for further XMM and Chandra observations

Swift Status

- Spacecraft: delivered to GSFC from Spectrum Astro
- XRT: calibration at Panter facility completed
- UVOT: calibration under way at GSFC
- BAT: structure and mask nearly complete; 9 of 16 flight detector blocks built, and testing is in progress