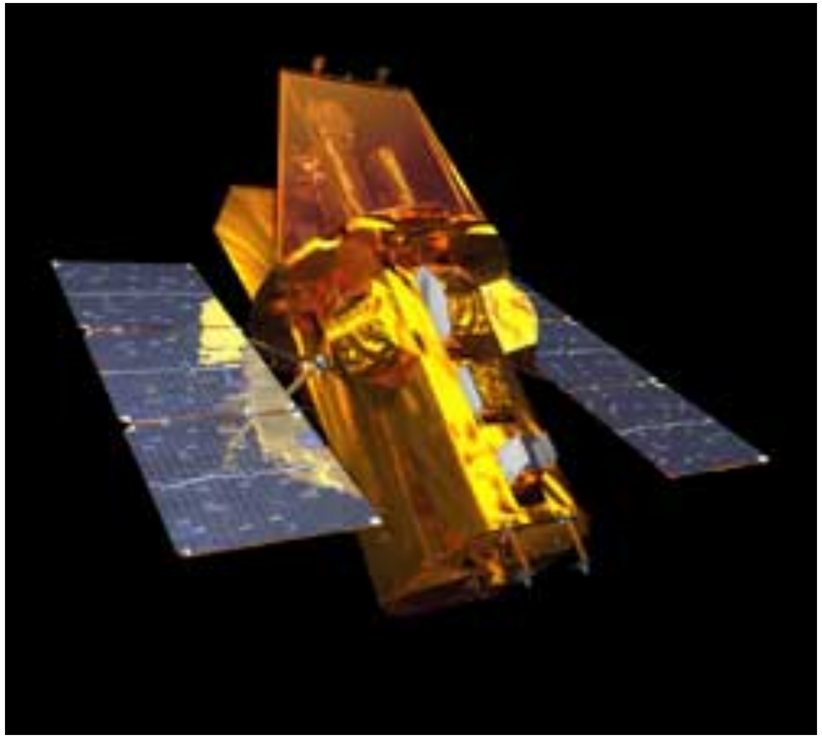
Swift

Hanna Sai
Tutor：Wei Cui



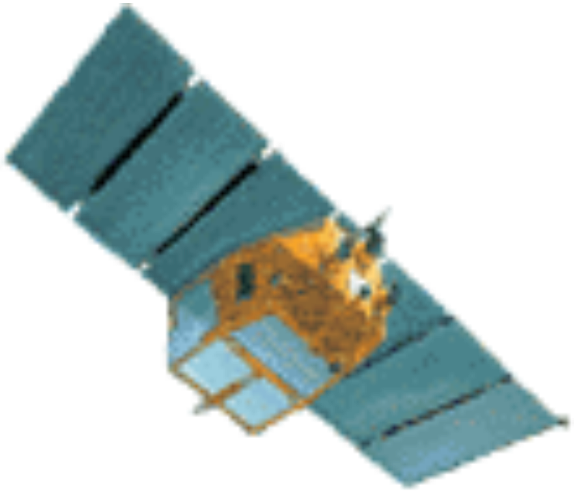
- Gamma-ray burst (GRB) science
- Three instruments work together to observe GRBs and afterglow in the gamma-ray, X-ray, optical, and ultraviolet wavebands
- It was launched into a low-Earth orbit on a Delta 7320 rocket on November 20th, 2004

Name

- Swift is named for a bird of the same name.
- It can change angles very quickly in mid-flight, like Swift will do.

History

- For over 30 years astrophysicists have puzzled over the origin of gamma-ray bursts
- 1997—BeppoSAX discovered lingering X-ray emission from a GRB called afterglow



The main mission objectives

- Determine the origin of gamma-ray bursts.
- Classify gamma-ray bursts and search for new types.
- Use gamma-ray bursts to study the early universe.
- Perform a sensitive survey of the sky in the hard X-ray band.

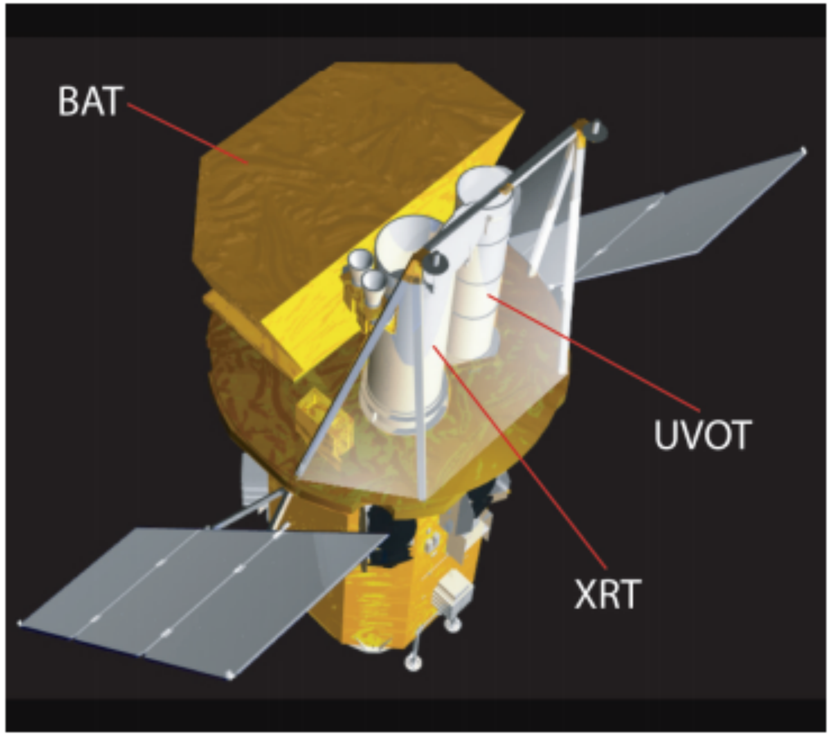
BAT

- monitors the entire sky to catch a GRB and calculate an initial position

XRT

- Armed with the position, the Swift spacecraft autonomously slews to bring the GRB into the Swift's X-Ray Telescope (XRT) and Ultra-Violet/Optical Telescope (UVOT) fields-of-view within 90 seconds

UVOT



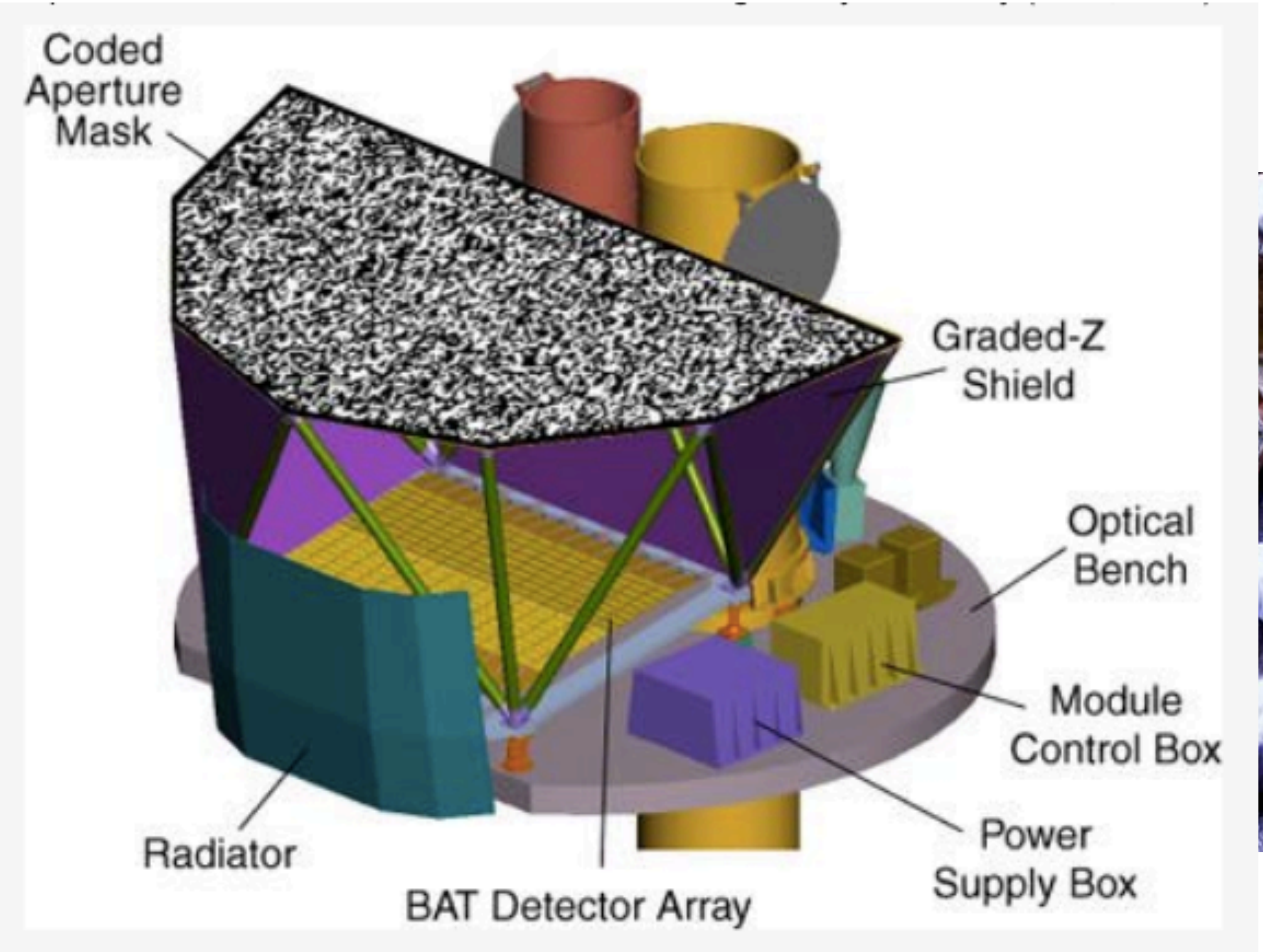
What is the timeline of events that occur when a GRB is detected?

- 0s: GRB detection
- 20s: Slew Begins/BAT approximate location distributed
- ~ 50s: GRB acquired
- 70s: XRT location distributed
- 240s: UVOT finding chart distributed
- 300s: XRT light curve distributed
- 1200s: XRT spectrum distributed
- ~ 60,000s: All automated observations complete (20,000 sec exposure)

Burst Alert Telescope	
Aperture	Coded Mask
Detecting Area	5200 cm^2
Detector	CdZnTe
Detector Operation	Photon Counting
Field of View	2.0 sr (partially coded)
Detection Elements	256 modules of 128 elements
Detector Size	4mm x 4mm x 2mm
Telescope PSF	17 arcminutes
Location Accuracy	1 - 4 arcminutes
Energy Range	15 - 150 keV
Burst Detection Rate	>100 bursts/year

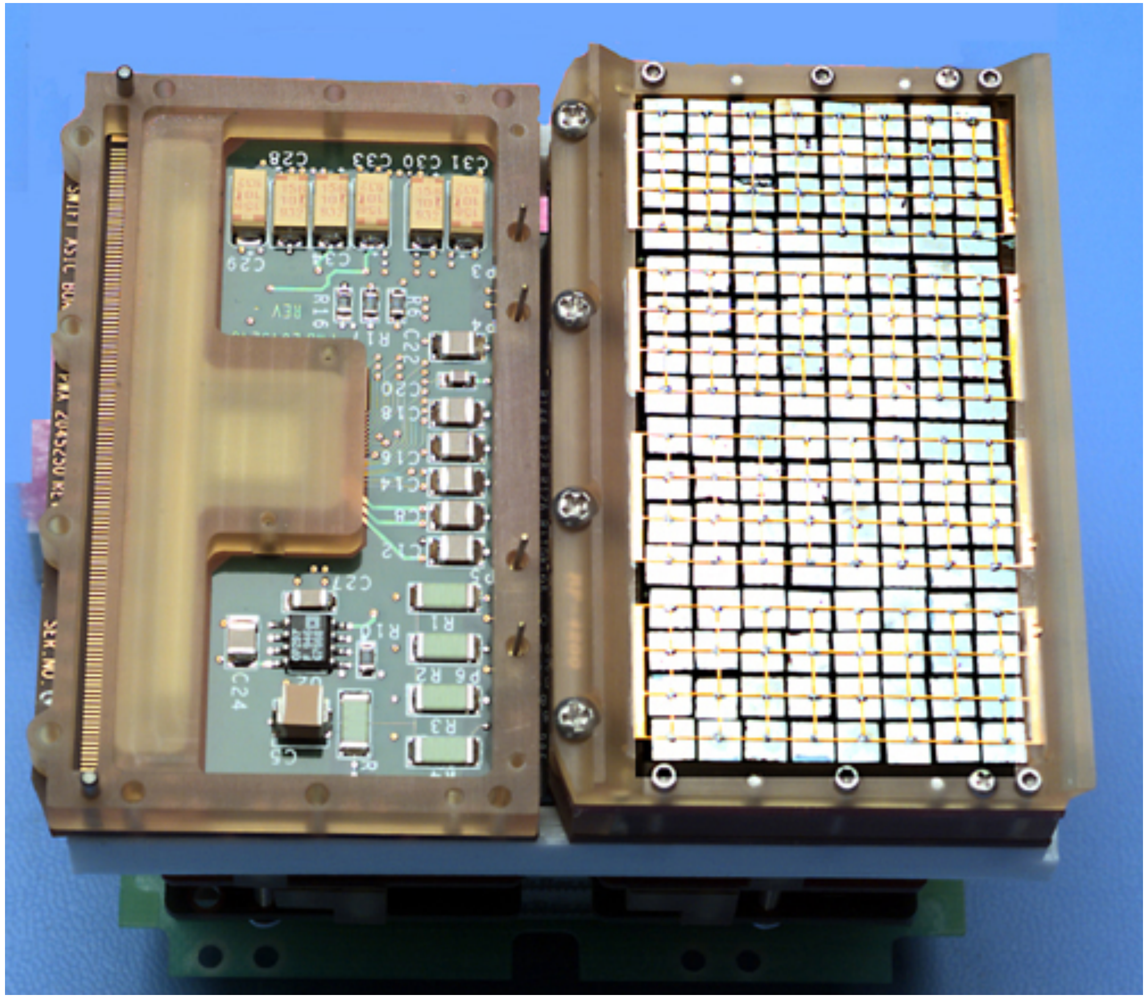
BAT


Incoming light
Shadow patte
Credit: B.J. Mattson, L3/NASA/GSFC

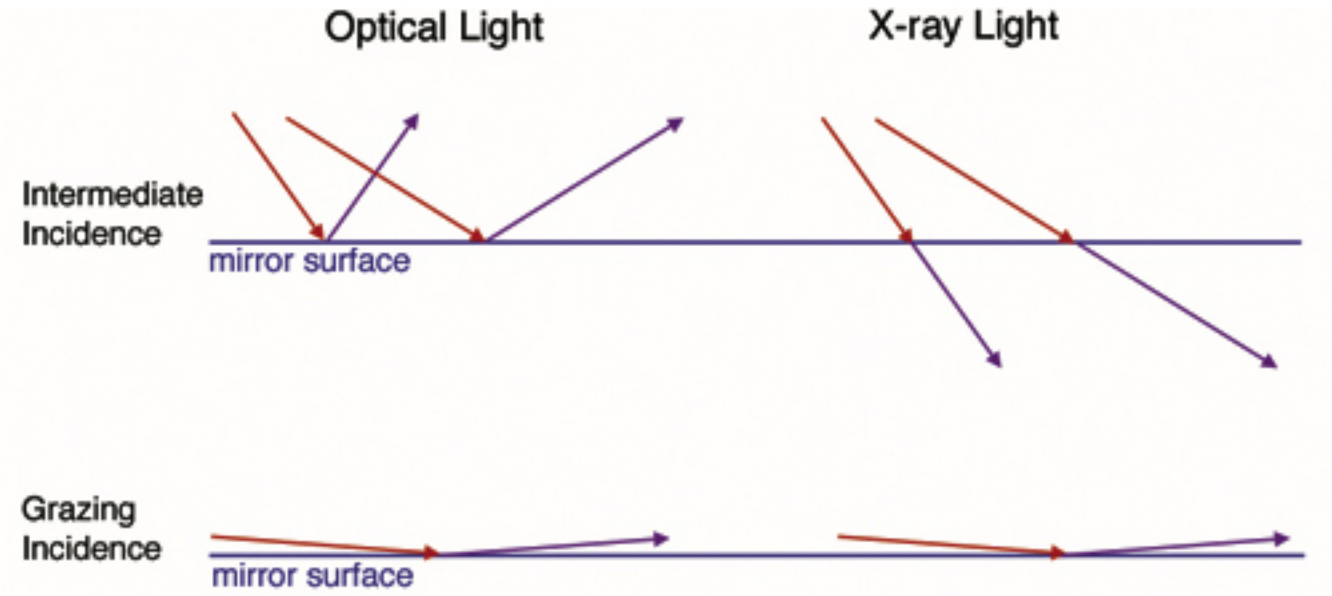

Coded Aperture Mask
Graded-Z Shield
Optical Bench
Module Control Box
Power Supply Box
Radiator
BAT Detector Array

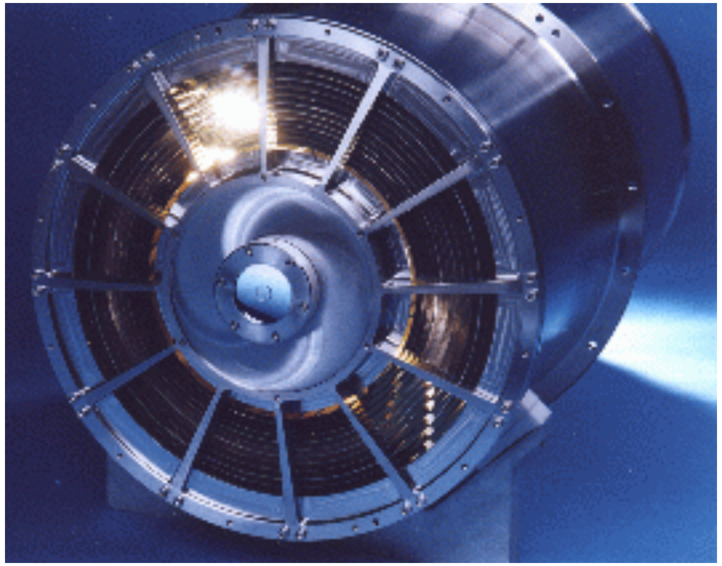
Burst Alert Telescope	
Aperture	Coded Mask
Detecting Area	5200 cm^2
Detector	CdZnTe
Detector Operation	Photon Counting
Field of View	2.0 sr (partially coded)
Detection Elements	256 modules of 128 elements
Detector Size	4mm x 4mm x 2mm
Telescope PSF	17 arcminutes
Location Accuracy	1 - 4 arcminutes
Energy Range	15 - 150 keV
Burst Detection Rate	>100 bursts/year

BAT detector--CZT

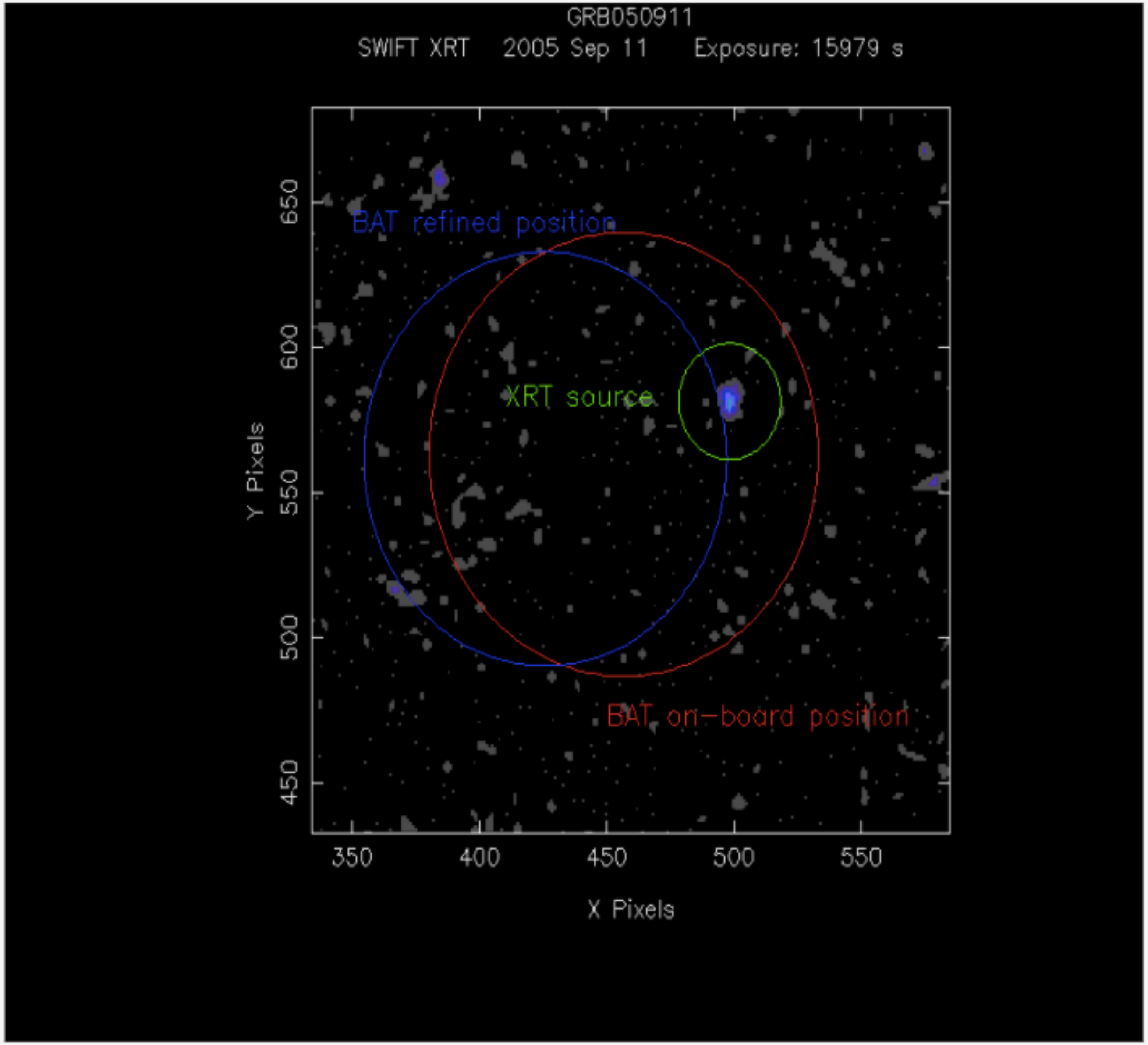


XRT


Optical Light
X-ray Light
Intermediate Incidence
mirror surface
Grazing Incidence
mirror surface

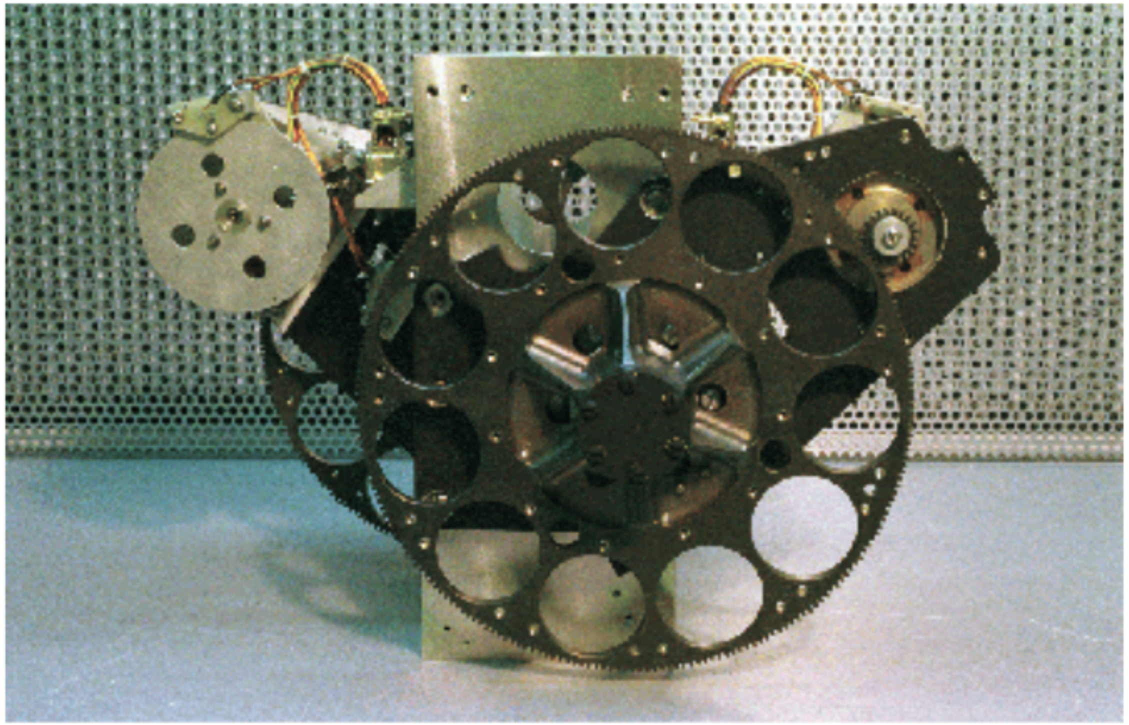


X-Ray Telescope	
Telescope	Wolter I
Detector	XMM EPIC CCD
Effective Area	135 cm^2 @ 1.5 keV
Detector Operation	Photon Counting, Integrated Imaging, & Rapid Timing
Field of View	23.6 x 23.6 arcminutes
Detection Element	600 x 600 pixels
Pixel Scale	2.36 arcsec/pixel
Telescope PSF	18 arcsec HPD @ 1.5 keV
Location Accuracy	3 - 5 arcseconds
Energy Range	0.2 - 10 keV
Sensitivity	2×10^{-14} ergs cm^{-2} s^{-1} in 10^4 sec



GRB050911
SWIFT XRT 2005 Sep 11 Exposure: 15979 s
BAT refined position
XRT source
BAT on-board position
Y Pixels
450
500
550
600
650
350
400
450
500
550
X Pixels

UVOT



These are the filter wheels that will be on the UVOT
(one in front, the other in back)

- a white light filter;
- a field magnifier;
  two grisms;
- U, B, and V filters;
- two broadband UV filters centered on 180 and 260 nm;
- a narrow UV filter centered on 220 nm.

UltraViolet/Optical Telescope	
Telescope	Modified Ritchey-Chrétien
Aperture	30 cm diameter
F-number	12.7
Detector	Intensified CCD
Detector Operation	Photon Counting
Field of View	17 x 17 arcminutes
Detection Element	2048 x 2048 pixels
Telescope PSF	0.9 arcsec @ 350 nm
Location Accuracy	0.3 arcseconds
Wavelength Range	170 nm - 650 nm
Colors	6
Spectral Resolution (Grisms)	$\lambda/\Delta\lambda \sim 200$ @ 400 nm
Sensitivity	B = 24 in white light in 1000 sec
Pixel Scale	0.48 arcseconds
Bright Limit	$m_V = 7$ mag

Table 2. UVOT sensitivity limits. The counts are for an AOV star (Vega).

UVOT sensitivity: *v* = 20, in 1000 s gets:	
v	143 counts
b	441 counts
u	217 counts
uvw1	99 cts
uvm2	53 counts
uvw2	87 counts
white	1306 counts
Sensitivity to Lymap-alpha cutoff	
uvm2-uvw2	$z \sim 1.3$
uvw1-uvm2	$z \sim 1.7$
u-uvw1	$z \sim 2.3$
b-*u*	$z \sim 3.2$
v-*b*	$z \sim 5$

UVOT Broad Band Filters

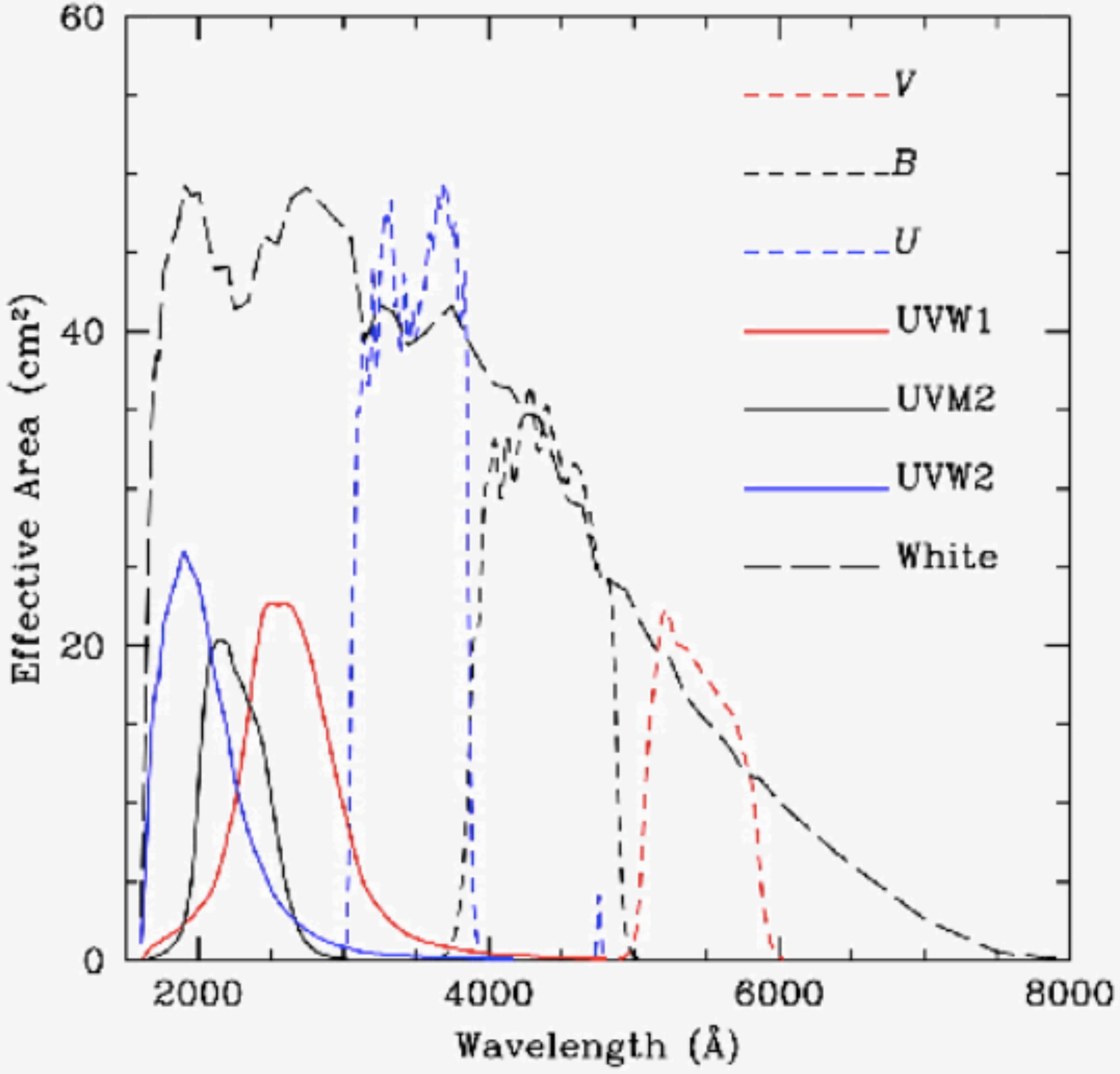


Figure 4. Effective area curves for the seven broadband UVOT filters shown as square centimeters versus wavelength in Angstroms. The white filter is shown in long dashed black. Dashed red--*v*, dashed black--*b*, dashed blue--*u*, solid red--uvw1, solid black--uvm2, solid blue--uvw2.

Swift results--GRB

GRB	Time [UT]	Trigger Number	BAT RA (J2000)	BAT Dec (J2000)	BAT T90 [sec]	BAT Fluence (15-150 keV) [10^{-7} erg/cm^2]	XRT RA (J2000)	XRT Dec (J2000)	XRT Time to First Observation [sec]	XRT Early Flux (0.3-10 keV) [10^{-11} erg/cm^2/s]	UVOT RA (J2000)
180325A	01:53:02	817564	157.416 10:29:39.8	24.461 24:27:39.6	94.1	65	10:29:42.57	24:27:48.9	73.38	468	10:29:42.5
180324A	04:37:09	817345	76.581 05:06:19.4	56.744 56:44:38.4	7.2	5.6	05:06:06.55	56:42:50.1	67.84	n/a	n/a
180316A	04:57:25	814677	265.422 17:41:41.3	0.737 00:44:13.2	87.0	49	17:41:42.85	00:44:53.2	95.44	61.4	17:41:42.87
180314B	22:23:36	814305	297.855 19:51:25.2	23.634 23:38:02.4	73.0	9.6	19:51:32.80	23:37:26.9	87.04	64.4	n/a

Swift results--supernova

- This large-size star is expected to be a red supergiant star with an initial mass of 19–20 M☉ based on the mass–radius relation of the Galactic red supergiants, and it represents one of the most largest and massive progenitors found for SNe IIP.

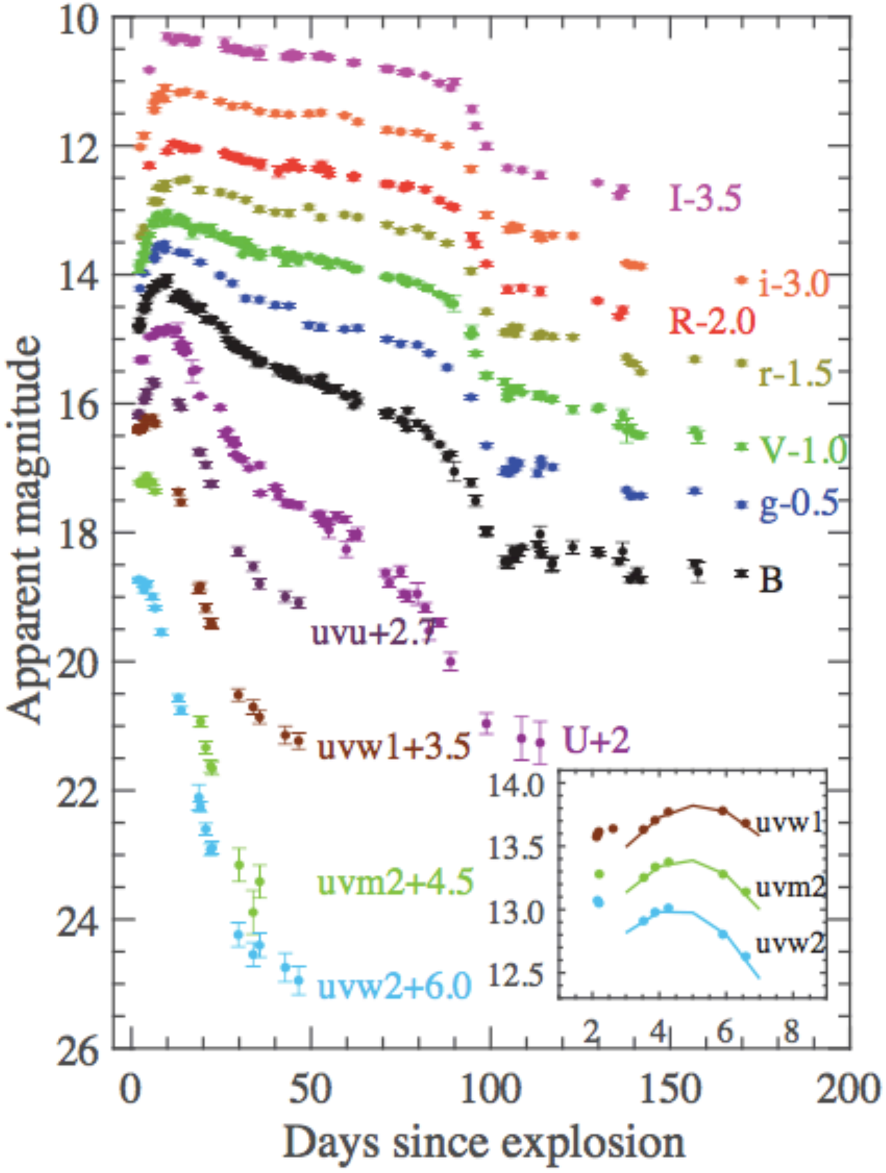


Figure 2. Light curves of SN 2016X in UV and optical bands. The insert is a zoom on the early-time UV light curve, with polynomial fitting to the data around maximum. Prominent UV emission is clearly seen at a few days before the primary UV peaks. The phase is given relative to the estimated explosion date, MJD = 57405.92.

TABLE 1 Some of the specifications

PARAMETERS	WXT	FXT
Number of modules	8	1
FOV	60°×60°	1°×1°
Focal length (mm)	375	1,400
Angular resolution (arcmin)	<5	<5
Banpass (keV)	0.5-4 keV	0.5-4 keV
Energy resolution @1keV	40%	100eV
Effective area (central focus) (cm^2)	3 @0.7KEV	60 @1keV
Sensitivity (erg/s/cm^2 @1ks)	~ 1e-11	~ 3e-12

Summary

- With its large field-of-view and high sensitivity, the BAT detects about 100 GRBs per year, and computes burst positions onboard the satellite with arc-minute positional accuracy.
- The XRT takes images and is able to obtain spectra of GRB afterglows during pointed follow-up observations. The images are used for higher accuracy position localizations, while light curves are used to study flaring and the long-term decay of the *X*-ray afterglow.
- The UVOT takes images and can obtain spectra of GRB afterglows during pointed follow-up observations. The images are used for 0.5 arc second position localizations and following the temporal evolution of the UV/optical afterglow. Spectra can be taken for the brightest UV/optical afterglows, which can then be used to determine the redshift via the observed wavelength of the Lyman-alpha cut-off.

References

- https://swift.gsfc.nasa.gov/about_swift/#science
- http://ep.bao.ac.cn/
- Huang, F., Wang, X.-F., Hosseinzadeh, G., et al.2018, MNRAS, 475, 3959
- "The Burst Alert Telescope (BAT) on the Swift MIDEX Mission", Barthelmy, S. D., Barbier, L. M., Cummings, J. R., Fenimore, E. E., Gerhels, N., Hullinger, D., Krimm, H. A., Markqardt, C. B., Palmer, D. M., Parsons, A., Goro, S., Suzuki, M., Takahashi, T., Tashiro, M., & Tueller, J, 2005, Space Sci. Rev., 120, 143-164