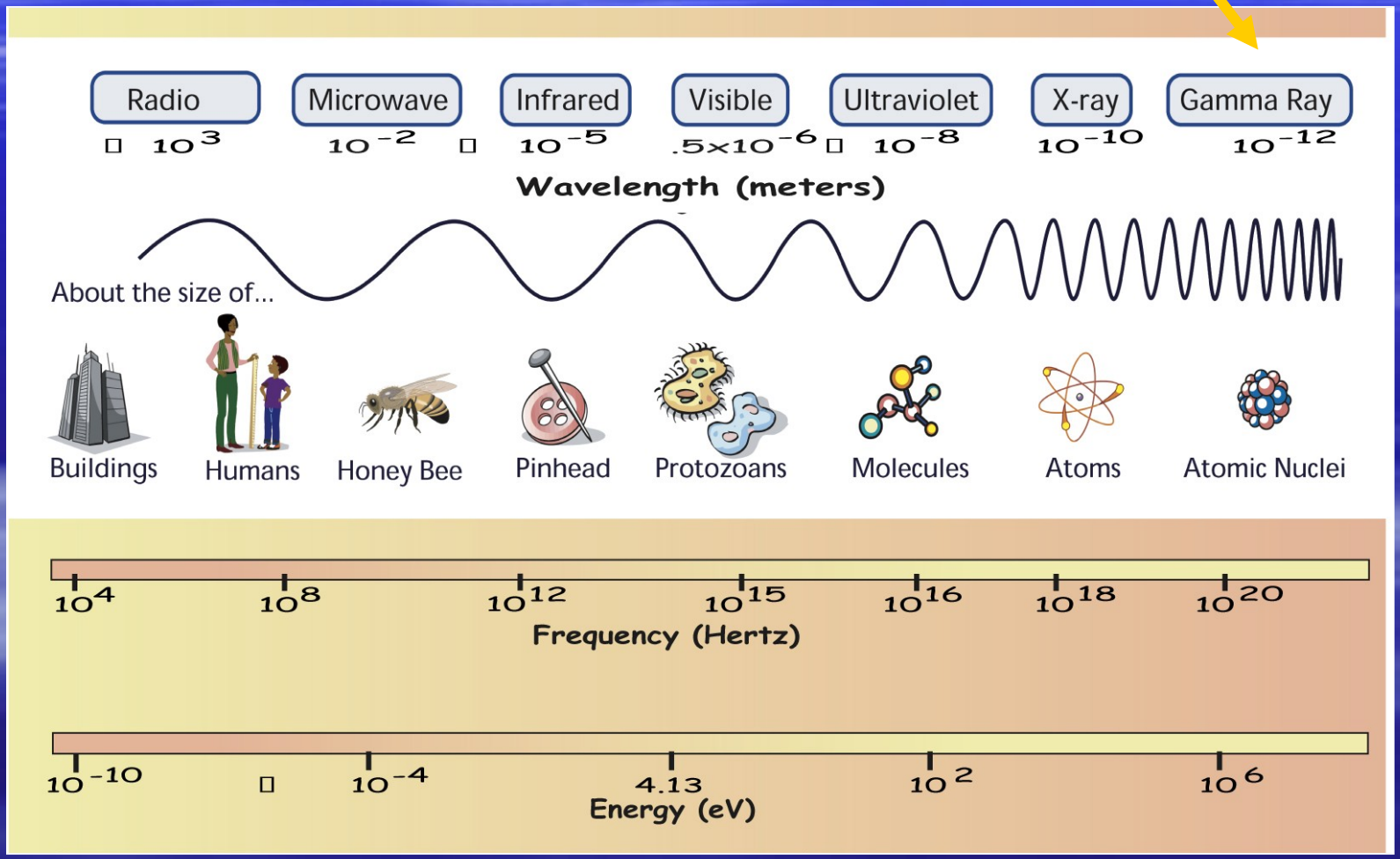
A *Swift* View of the Universe

Professor Lynn Cominsky

Department of Physics and Astronomy

Sonoma State University

Gamma rays: E > 10^6 eV

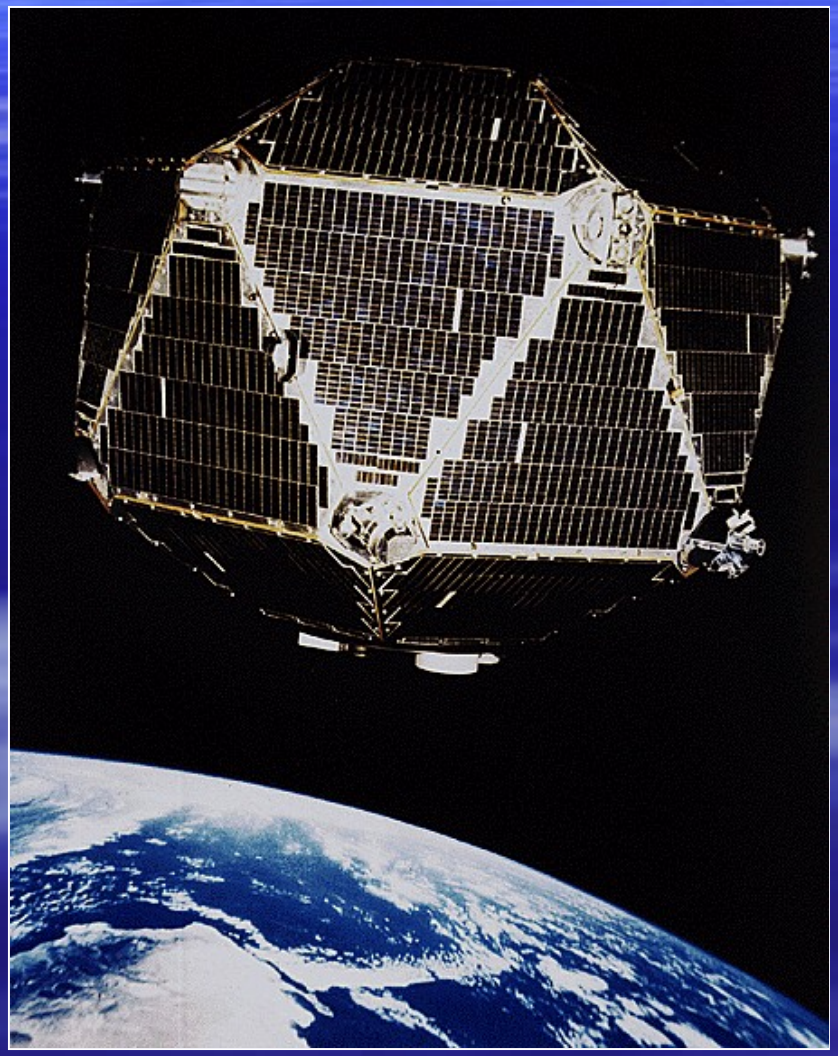


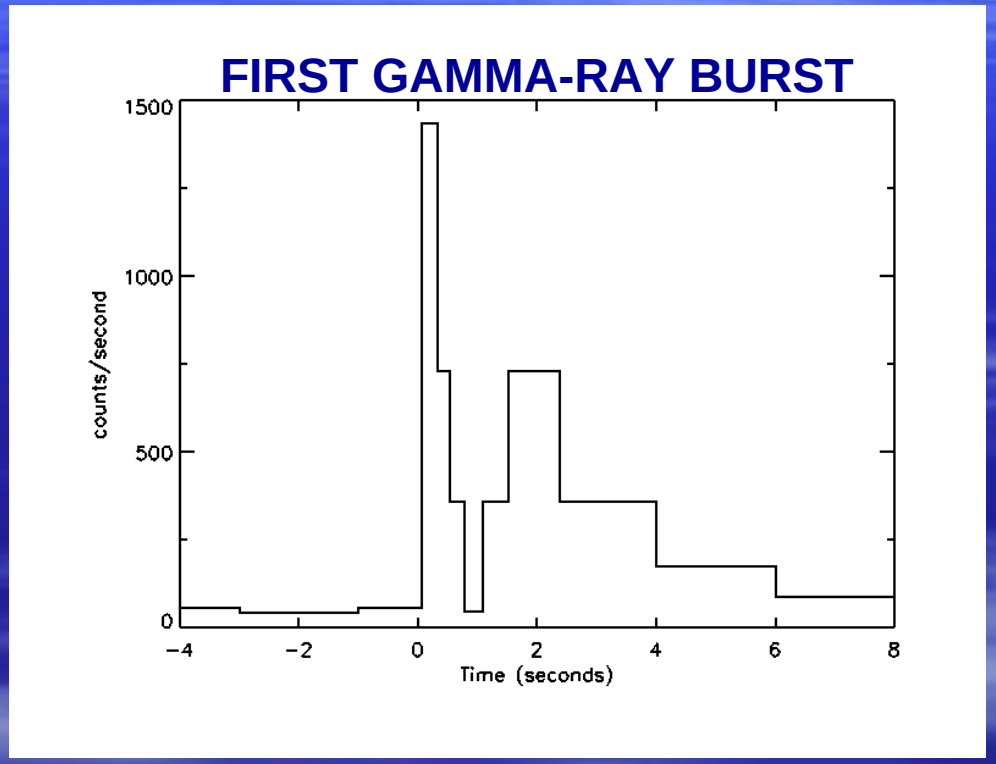
How to study Gamma rays?

- Absorbed by the Earth's atmosphere
- Use rockets, balloons or satellites
- Can't focus gamma rays
- Special detectors: NaI or CsI crystals, silicon-strips, CdZnTe

Balloon experiment

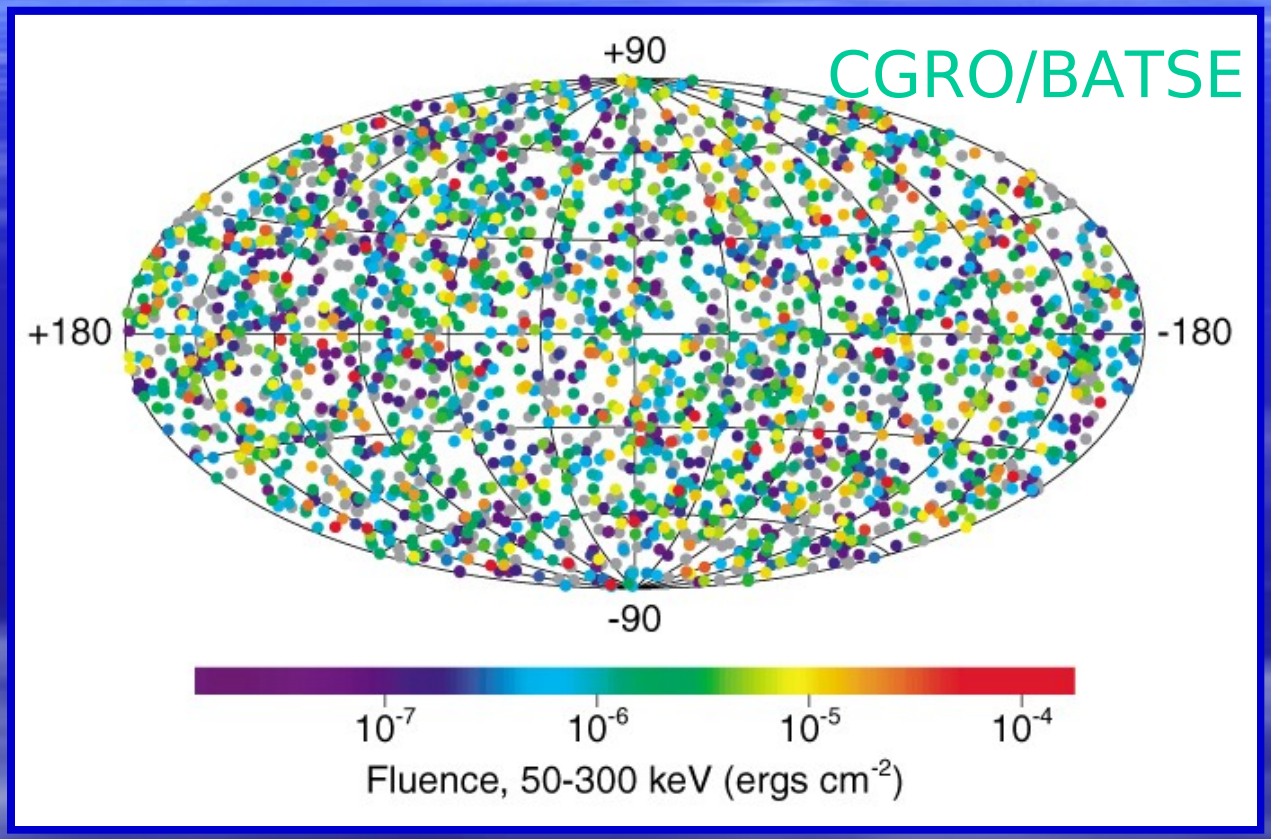
Vela Program (1969-1979)





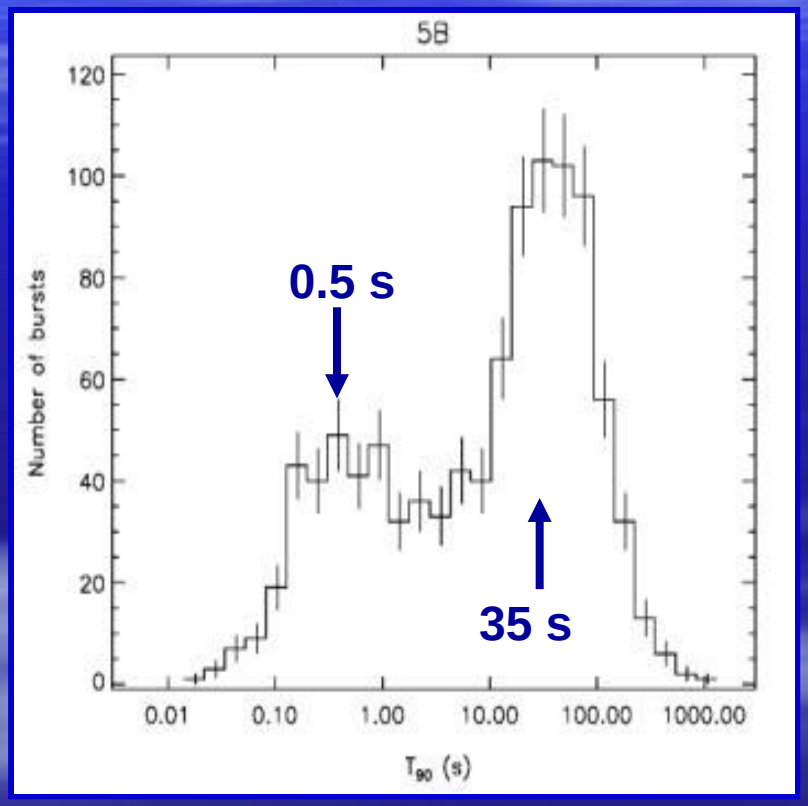
- Discovered in 1971 while looking for nuclear test ban violations

BATSE Gamma-ray Burst Sky



- 9 years of GRBs – no repeats in location
- Birth cries of black holes?

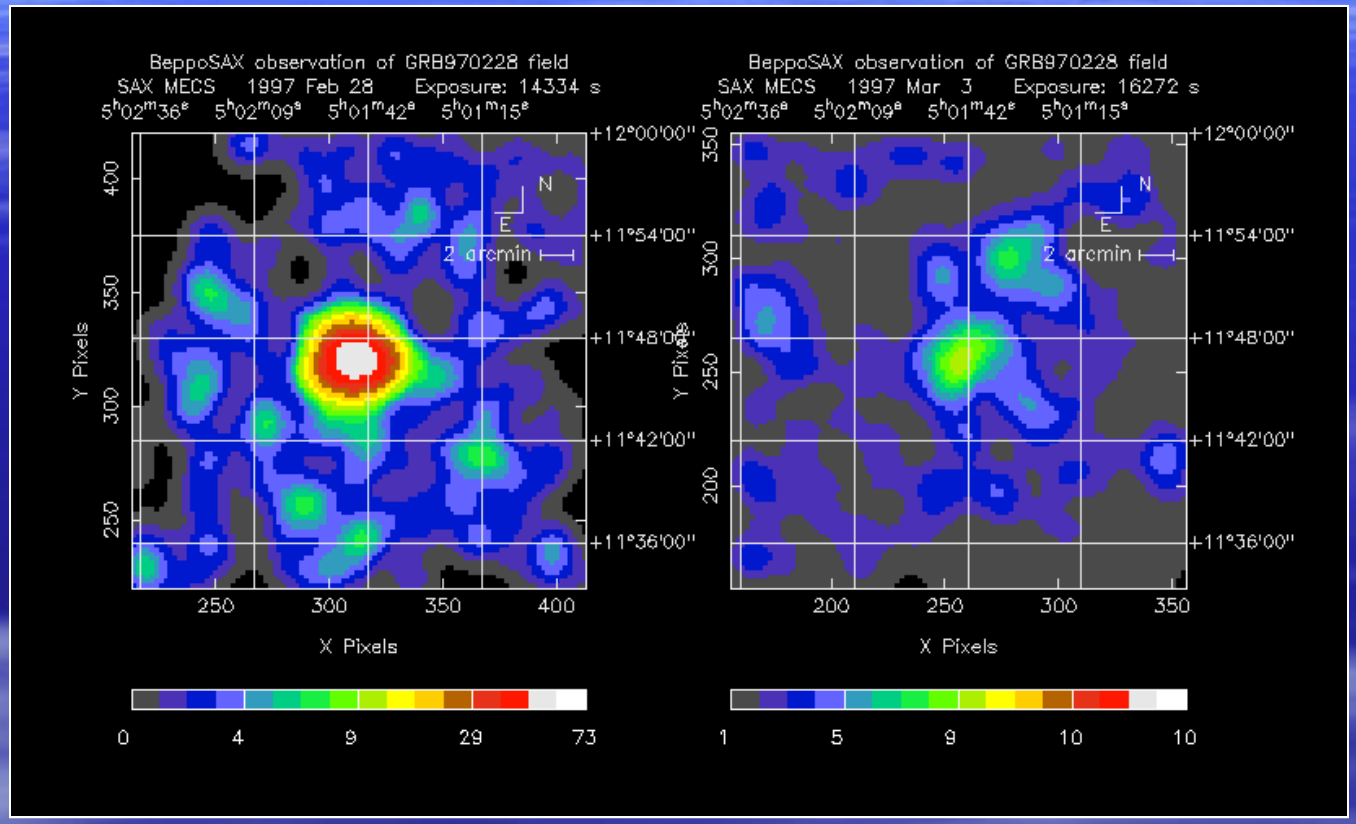
BATSE GRB Distribution



Briggs et al. 2002

- Shortest burst is 6 ms
- Longest is 2000 s
- Two classes
  - Divide at ~2 seconds
  - Shorter bursts are "harder"
- Only long bursts have "afterglows"

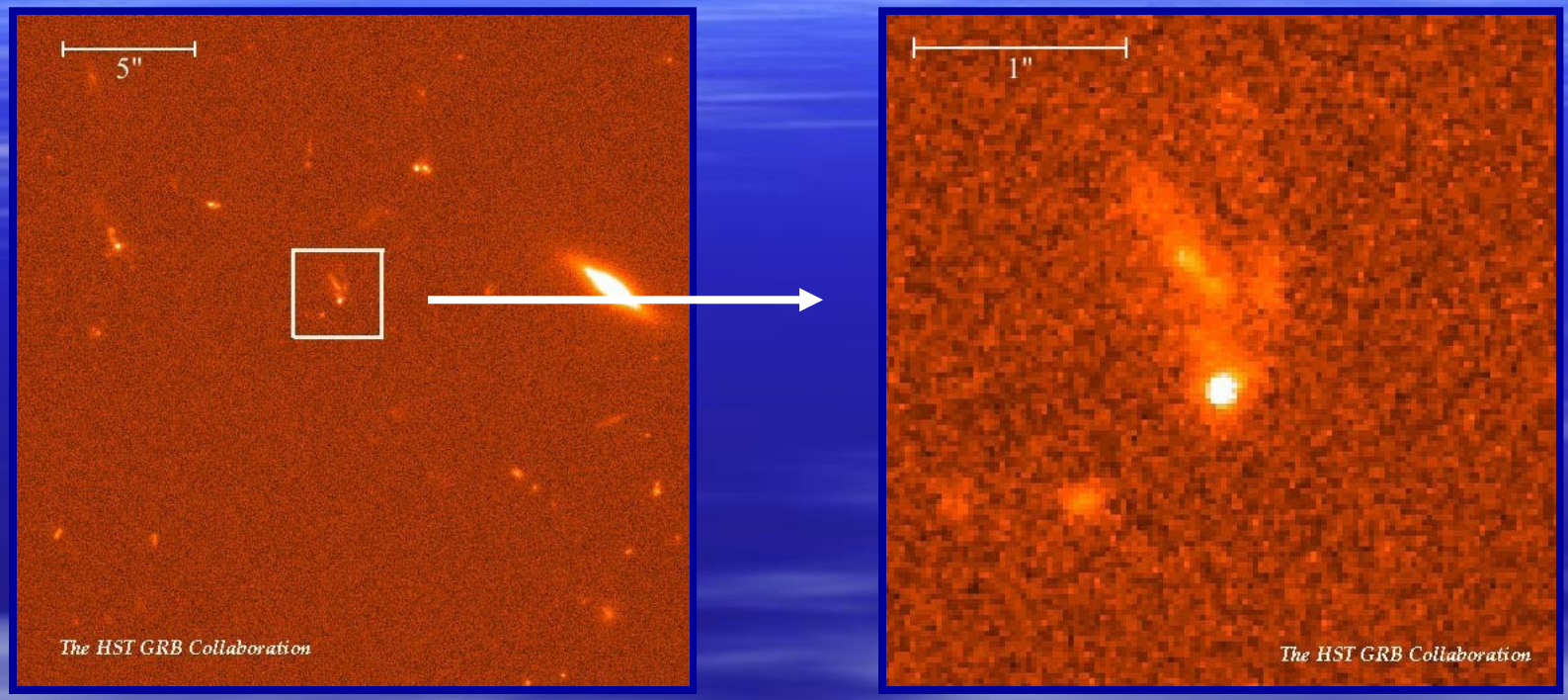
X-ray Afterglows



8.5 hours after GRB **5 days later**

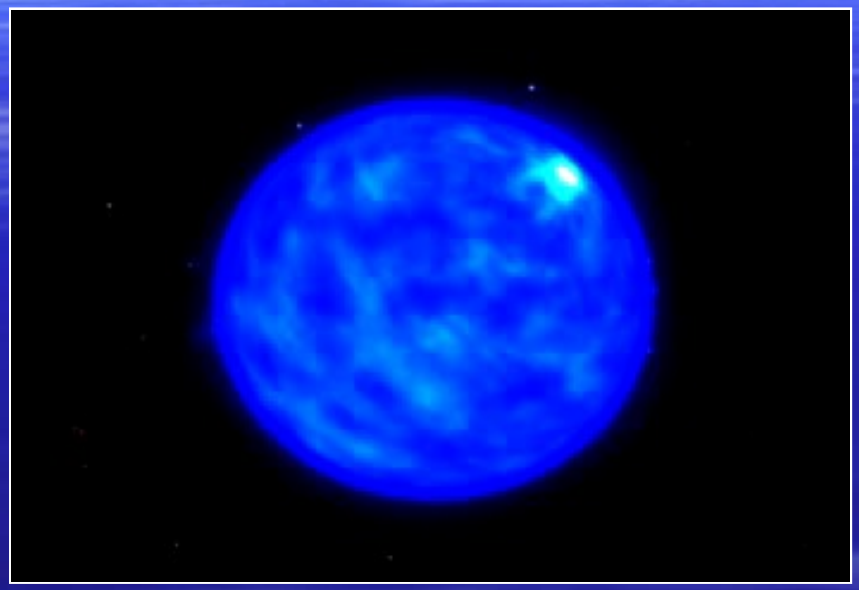
- Discovered in 1997 by BeppoSAX satellite

Visible Light Afterglows



- Fading visible light persists for months
- Redshifts from host galaxies → distances
- Record: z = 4.5 → 12 billion light years

Hypernova

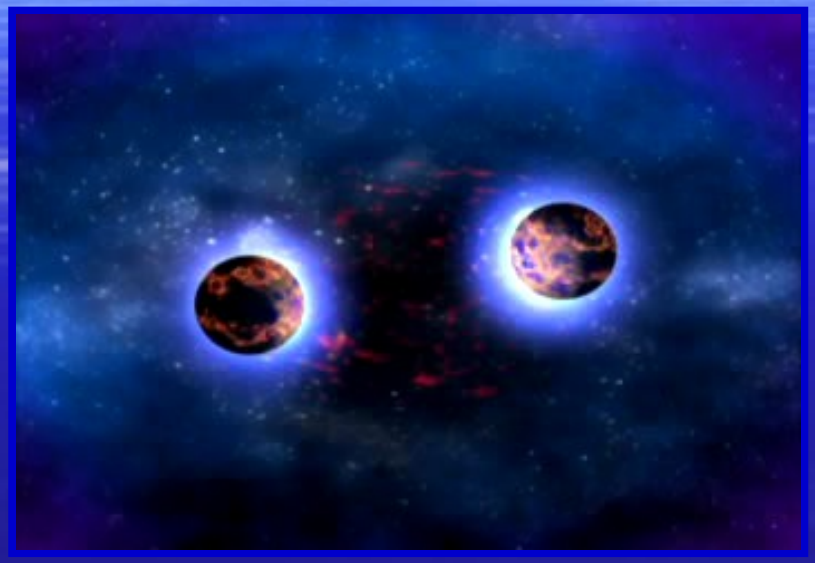


Credit: Dana Berry

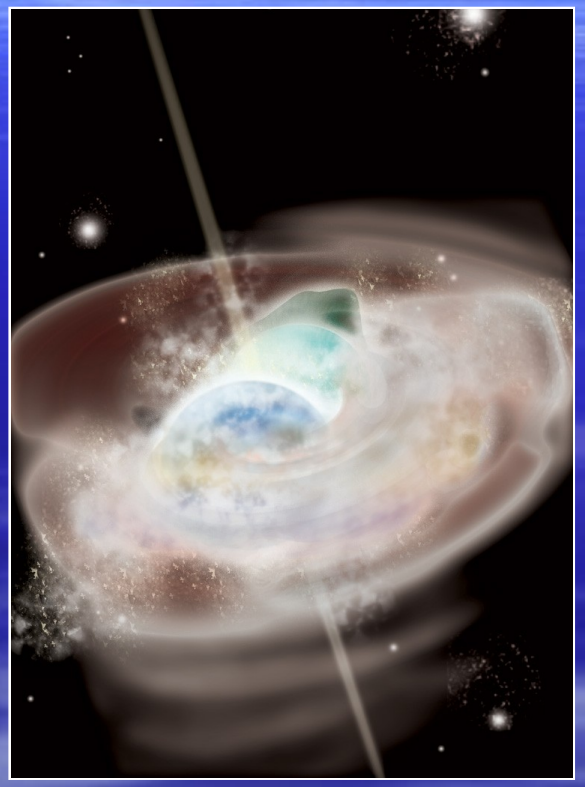
Credit: D. Armbrecht

- Super-supernova – death of star ~ 100 M_0
- Material remaining after burst → afterglow

Catastrophic Mergers



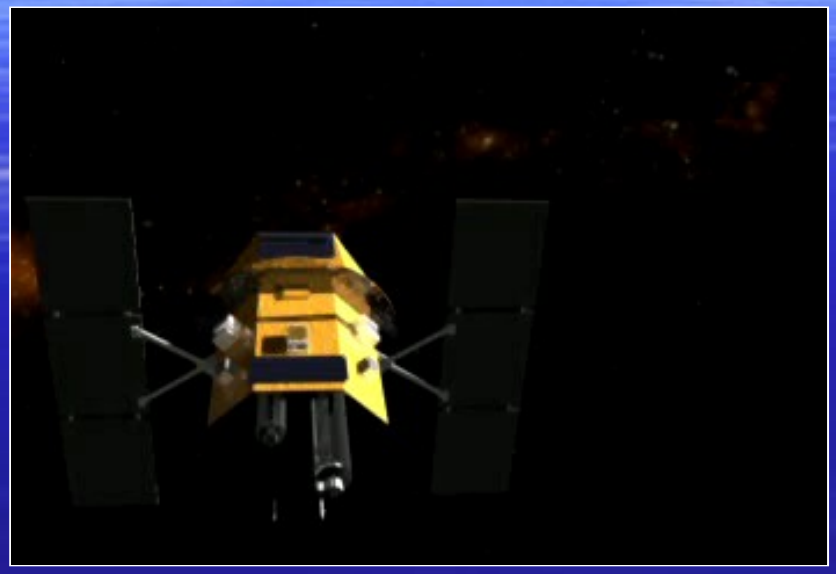
Credit: Dana Berry



Credit: Aurore Simonnet

- Death spiral of 2 neutron stars or black holes
- Possible origin of short bursts

Swift Gamma-ray Burst Mission



- Studies Gamma-Ray Bursts with a *swift* response
- Survey of “hard” X-ray sky
- Nominal 2-year lifetime

Swift Instruments

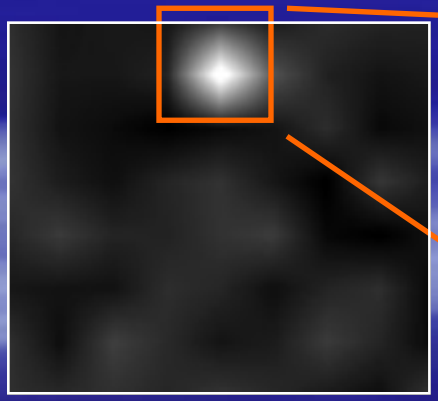
- Burst Alert Telescope (BAT)
- Ultraviolet/Optical Telescope (UVOT)
- X-ray Telescope (XRT)
- Autonomous re-pointing, 20 - 70 sec
- Onboard and ground triggers

Swift in GSFC clean room

Observing Strategy

- BAT triggers on GRB, calculates position to < 4 arcmin
- Spacecraft autonomously slews to GRB position in 20-70 s
- XRT determines position to < 5 arcseconds
- UVOT images field, transmits finding chart to ground

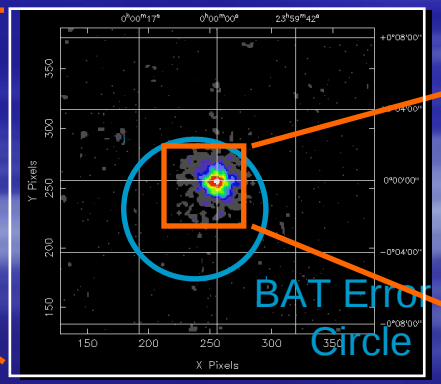
BAT Burst Image



T<10 sec

$\theta < 4'$

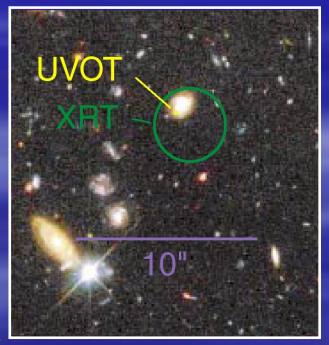
XRT Image



T<100 sec

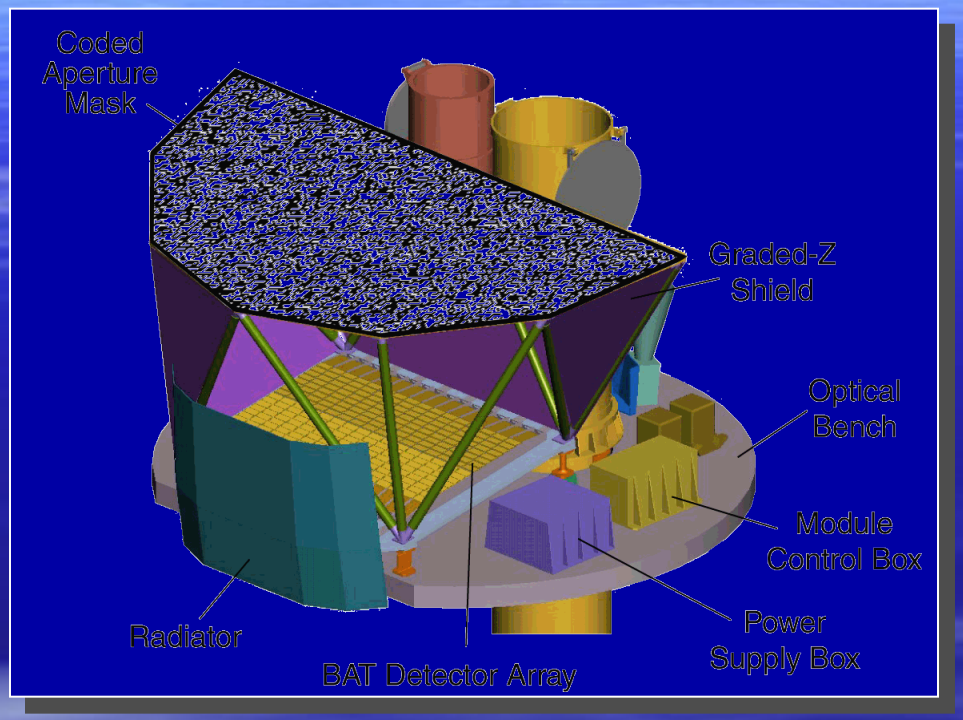
$\theta < 5''$

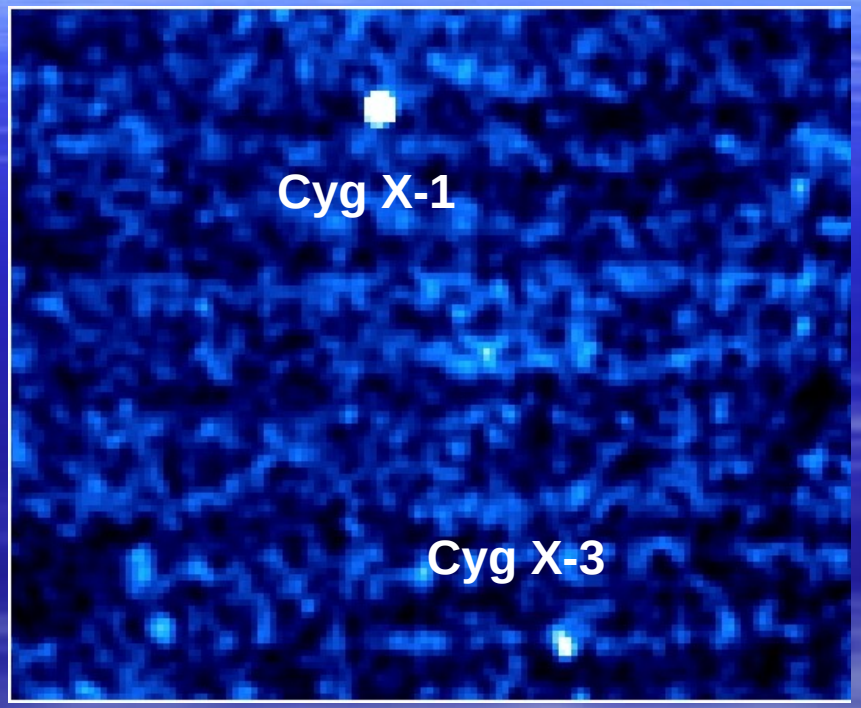
UVOT Image



T<300 sec

Burst Alert Telescope

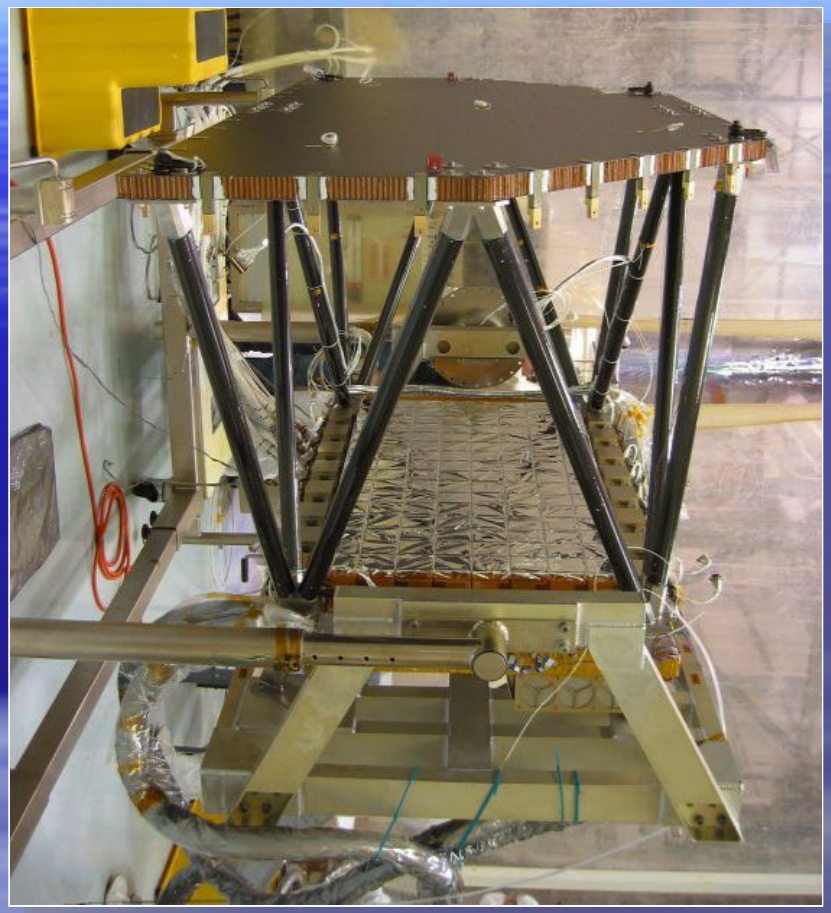




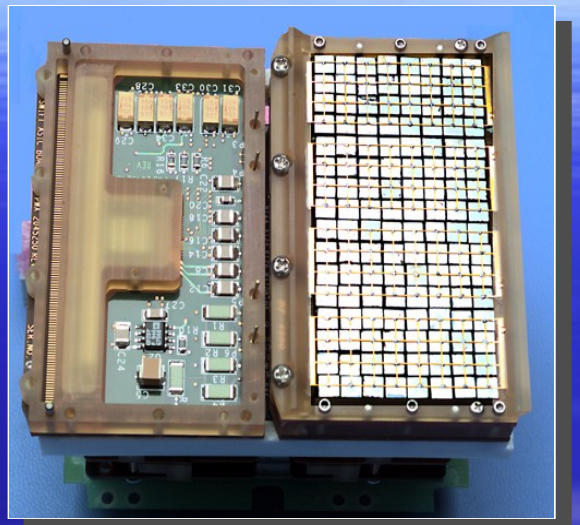
- Detect >100 GRBs per year
- Most sensitive gamma-ray imager ever
- CdZnTe detectors

First light image 1/5/05

BAT Hardware



BAT Structure



CdZnTe detectors

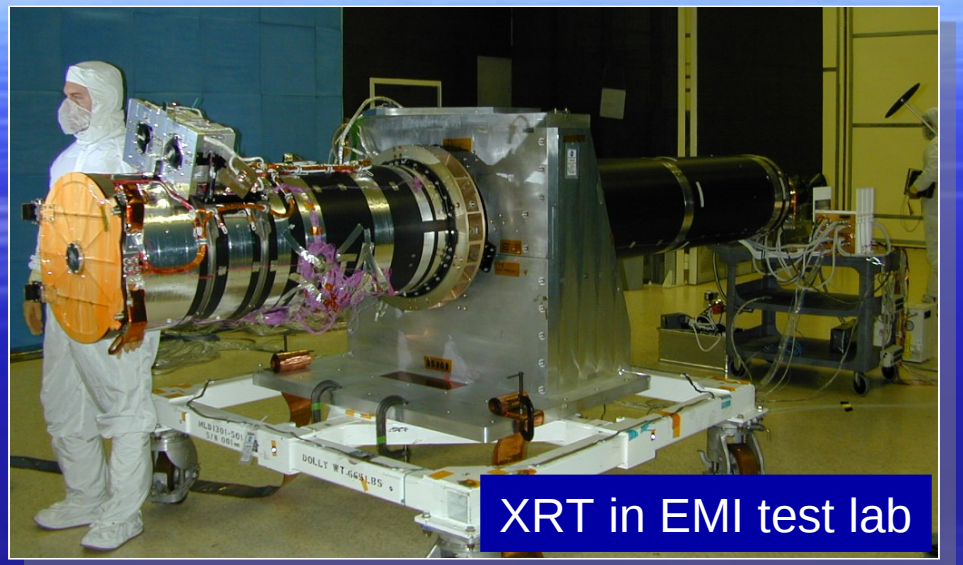
Coded aperture mask

BAT Specs

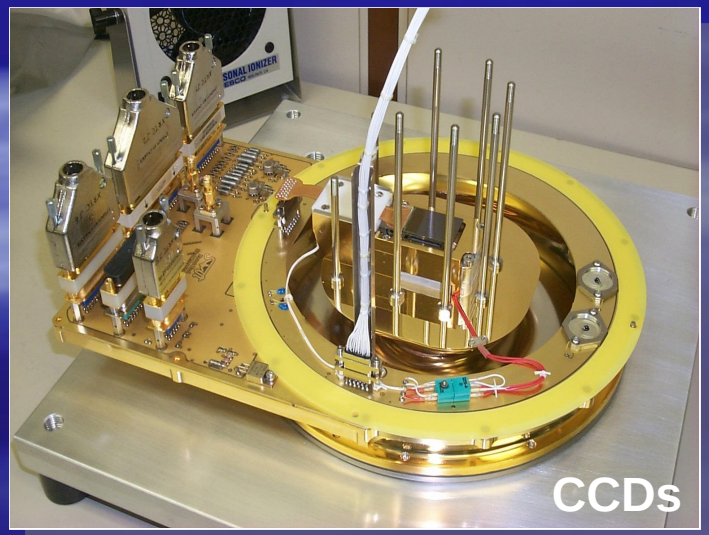
BAT Characteristics

Telescope	Coded Aperture
Telescope PSF	17 arcmin FWHM
Position Accuracy	1-4 arcminutes
Detector	CZT
Detector Format	32768 pixels
Energy Resolution	7 keV FWHM (ave.)
Timing Resolution	100 microseconds
Field of View	2 Steradians, partially-coded
Energy Range	15 – 150 keV
Detector Area	5200 cm^2
Sensitivity	0.2 photons/cm^2/s
Max Flux	195,000 cps (entire array)
Operation	Autonomous

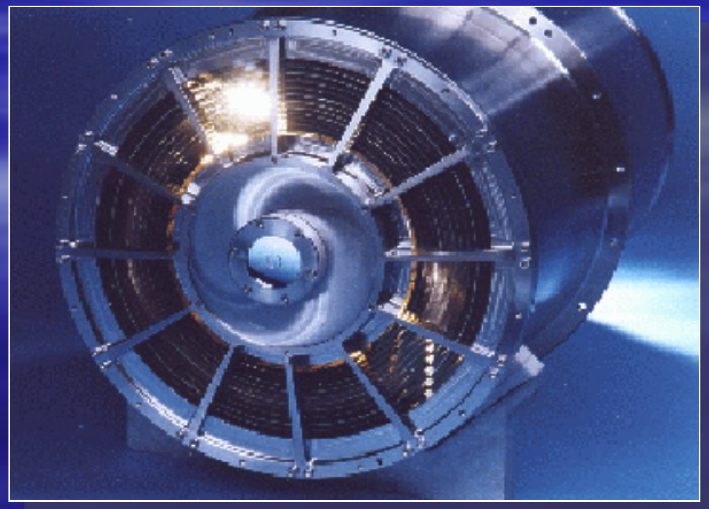
X-Ray Telescope


XRT in EMI test lab

- Arcsecond positions
- CCD spectroscopy


CCDs

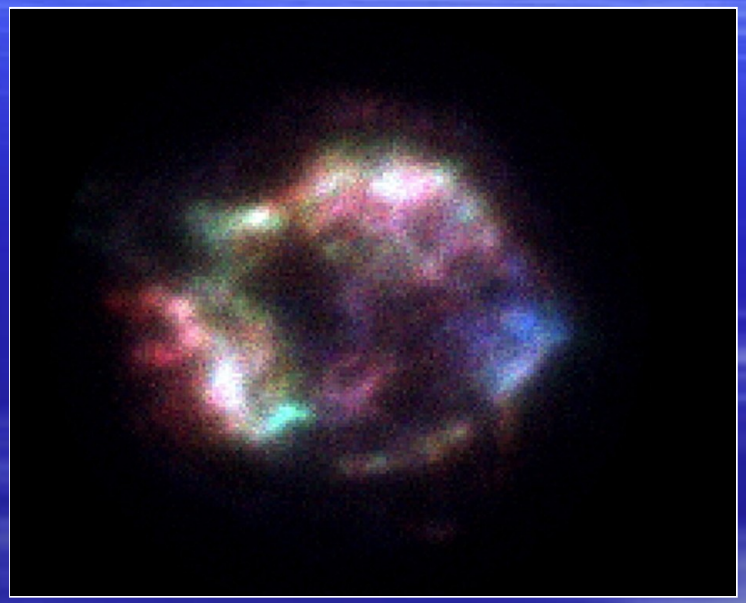
Grazing incidence mirrors



X-ray Telescope (XRT)

XRT Characteristics

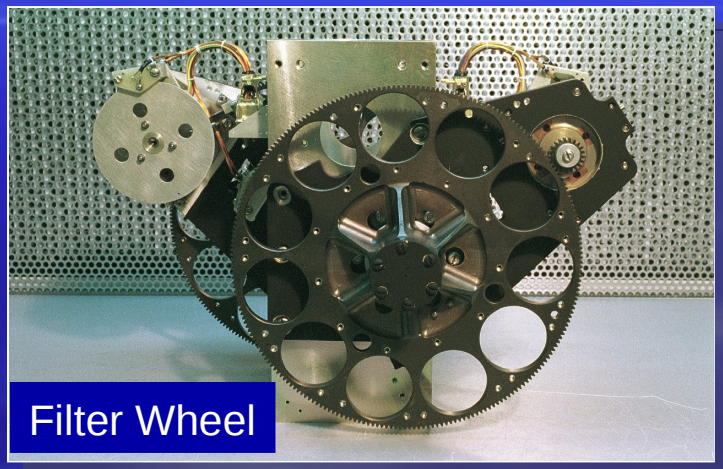
Telescope	3.5 m Wolter I, 12 shells
Telescope PSF	15 arcsec HPD @ 1.5 keV
Position Accuracy	2.5 arcseconds (2 sigma)
Detector	E2V CCD-22
Detector Format	600 x 600 pixels
Energy Resolution	140 eV @ 5.9 keV
Timing Resolution	0.14 / 1.1 milliseconds
Field of View	23.6 x 23.6 arcminutes
Pixel Scale	2.36 arcsec / pixel
Energy Range	0.2 - 10 keV
Effective Area	110 cm^2 @ 1.5 keV
Sensitivity	$2x10^{-14}$ erg $cm^{-2}s^{-1}$ in $2x10^4$ s
Max Flux	> 45 Crabs (45,000 cps)
Operation	Autonomous



Cas A

First light image 1/5/05

UV-Optical Telescope



- Arcsec imaging
- Grism spectroscopy
- 24th mag sensitivity (1000 sec)
- Finding chart for other observers

UVOT

UVOT Characteristics

Telescope	30 cm Ritchie-Cretien
Telescope PSF	0.9 arcsec FWHM @ 350 nm
Position Accuracy	0.3 arcseconds (2 sigma)
Detector	Microchannel-intensified CCD
Detector Format	2048 x 2048 pixels
Spectral Resolutn	>300 @ 300 nm for $M_v < 17$
Timing Resolution	11 milliseconds
Field of View	17 x 17 arcminutes
Pixel Scale	0.5 arcsec / pixel
Spectral Range	170 – 600 nm
Sensitivity	24th magnitude in 1000 s
Max source	8th magnitude
Operation	Autonomous

M101

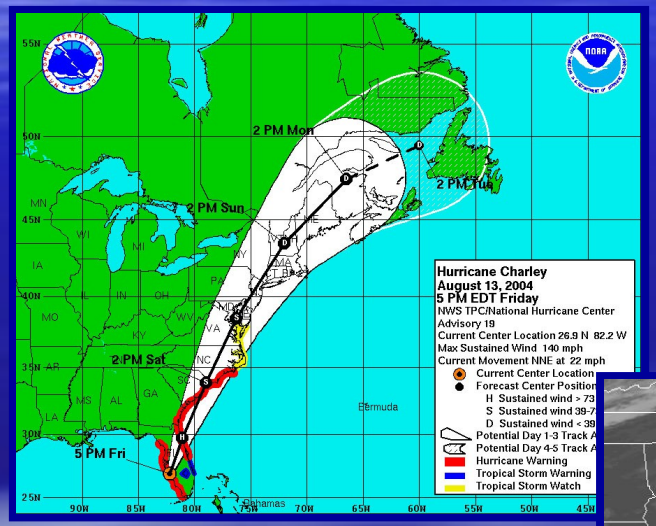
First light image 2/1/05

Spacecraft with XRT & UVOT Installed

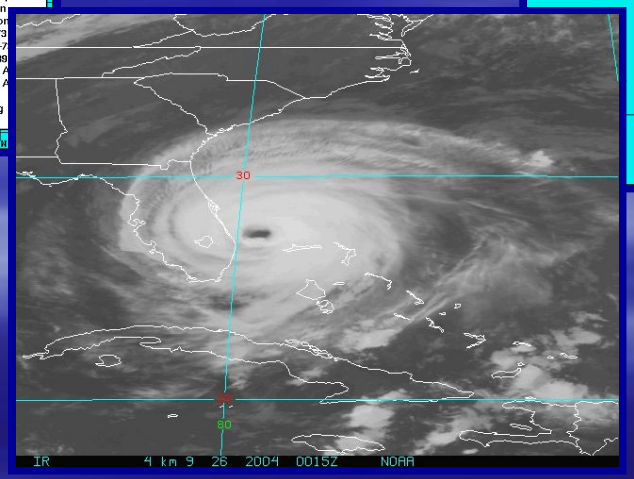
Swift arrives at KSC

Swift at KSC

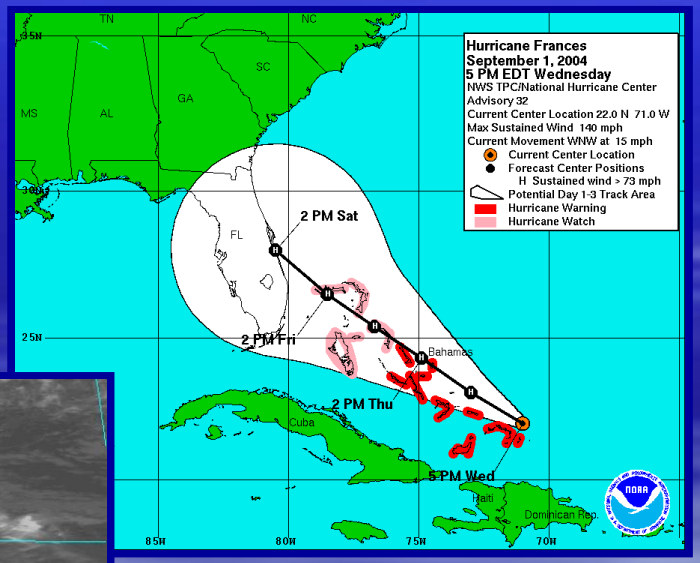
Florida becomes Hurricane Alley



Charley 8/13

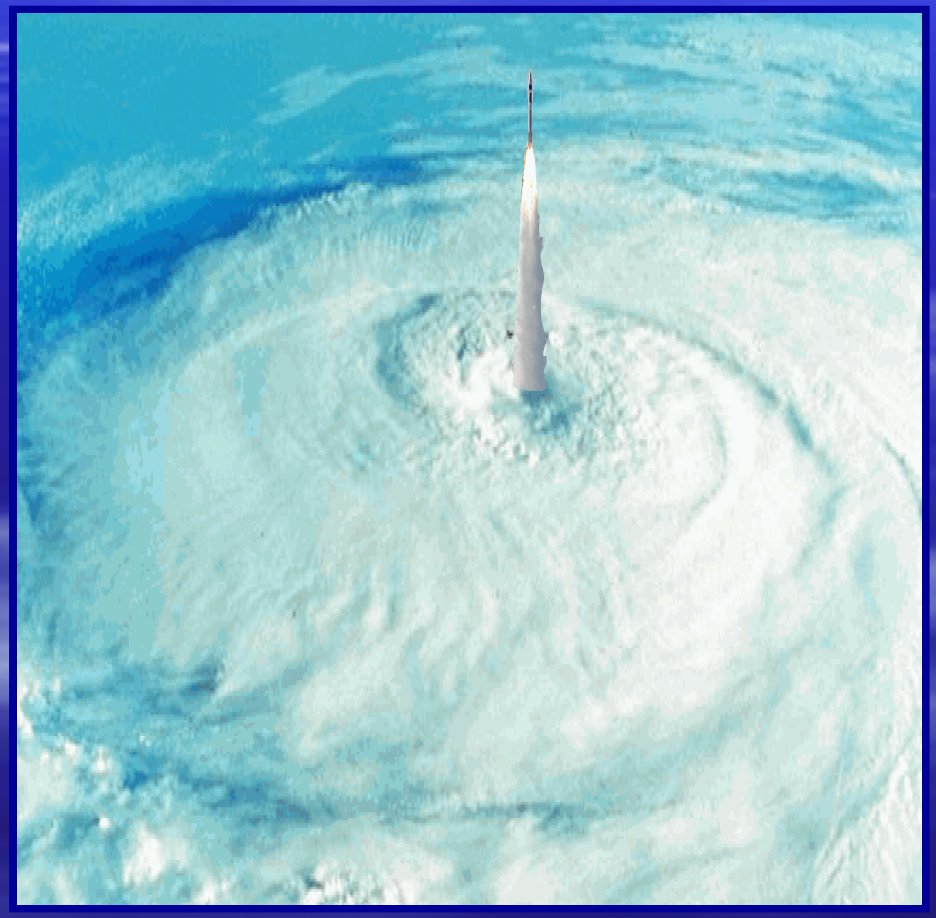


Jeanne 9/25



Frances 9/4

Let’s launch anyway!

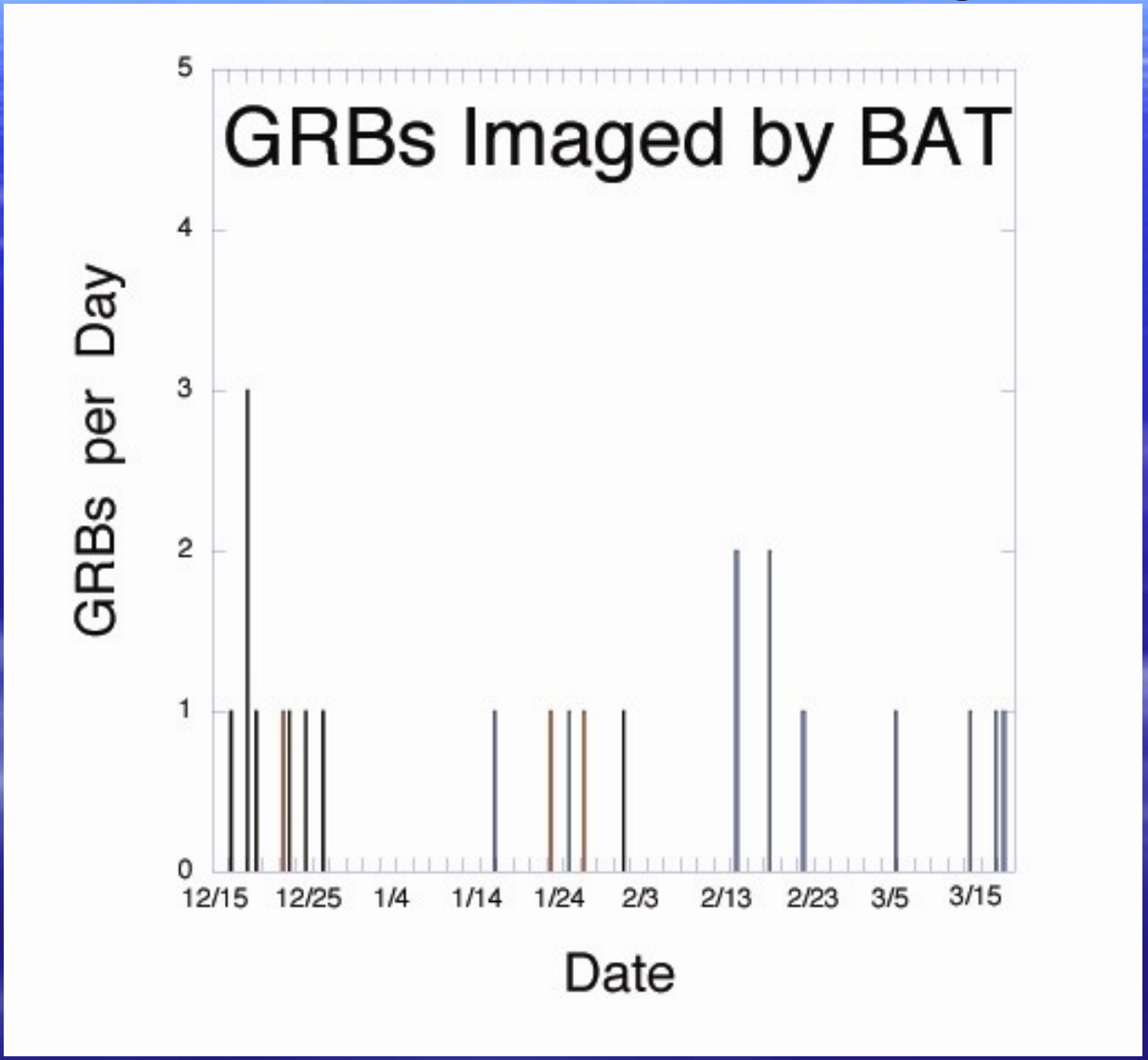


It’s just a little bit of wind…

Swift launch 11/20/04

Swift launch movie

Swift burst history

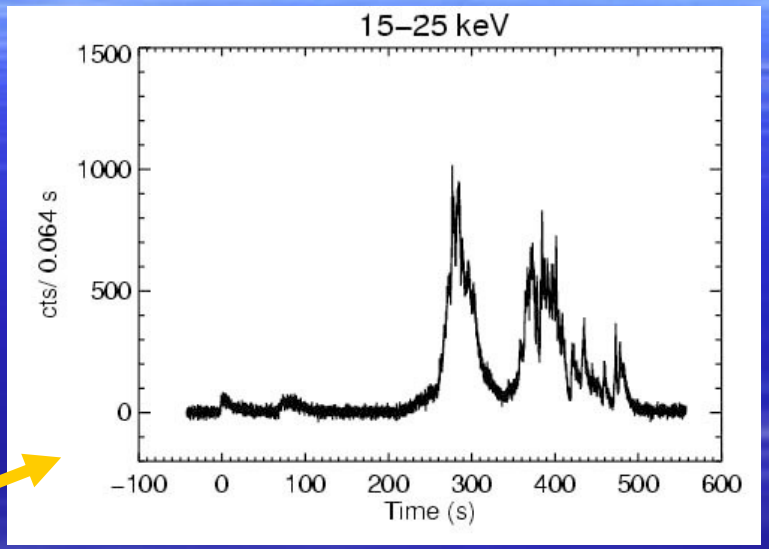


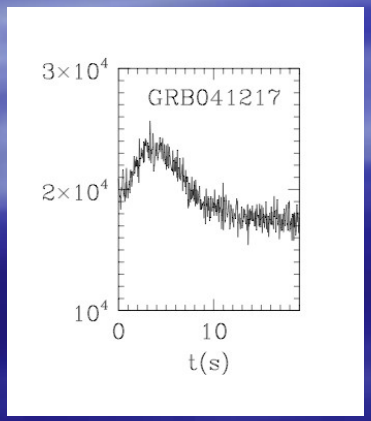
Swift status in March 2005

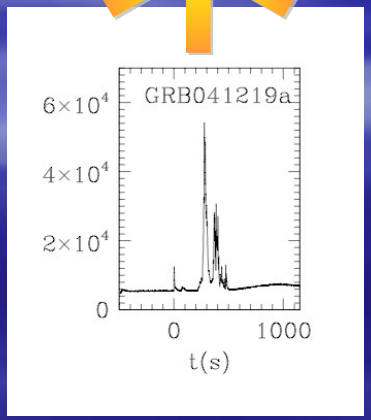
- All instruments activated
- BAT detection rate is 92 ± 20 GRBs/yr (cf. 100 predicted)
- Triggers include long GRBs, short GRB, XRF, SGR, XRBs
- BAT background is 12 kHz (cf. 17 kHz predicted)
- Autonomous slewing enabled and working
- Of 23 GRBs imaged by BAT, 9 autonomous slews & 3 ToO slews
- BAT GRB positions good to ~1 arcmin
- XRT GRB positions good to ~2 arcsec
- UVOT GRB positions good to <1 arcsec
- Prompt GCN notices now enabled for BAT & XRT
- Swift look direction soon to be a GCN notice
- Observatory will be fully operational by Apr. 5, as promised

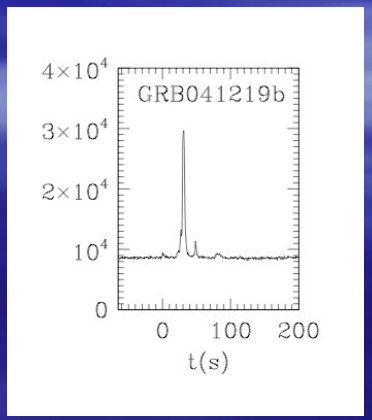
First 5 Swift bursts

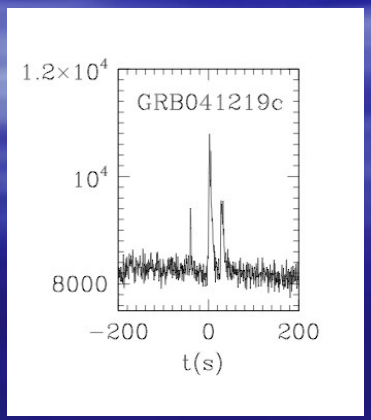
- GRB041219
  - fluence in top 1% of all bursts
  - duration in top 2% of all bursts
  - Optical and IR observations during prompt phase

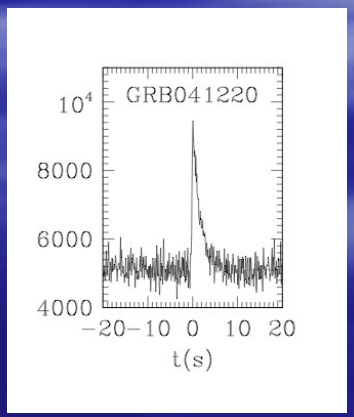






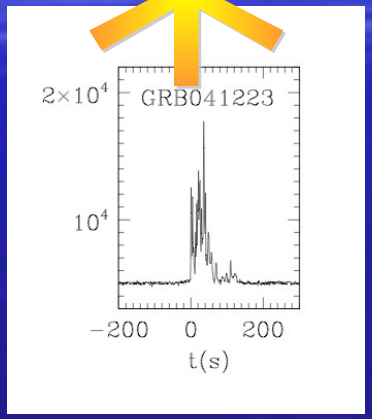


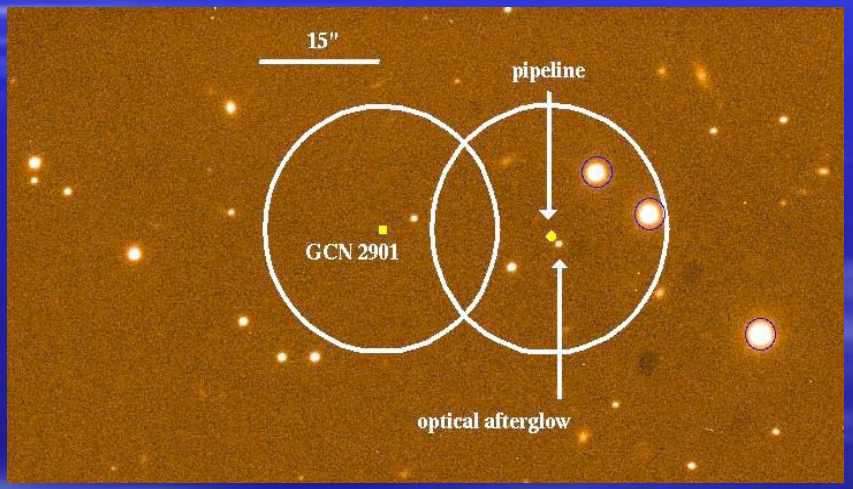


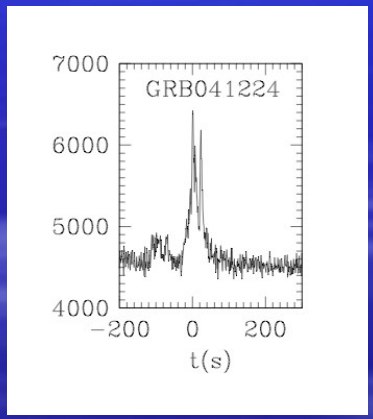


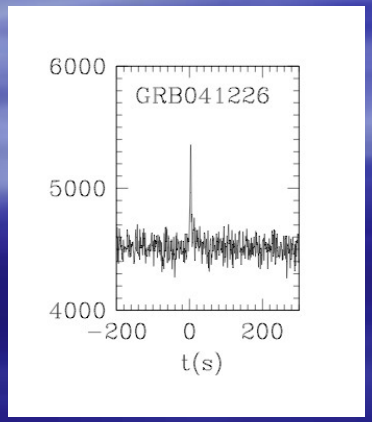
Next 6 Swift bursts

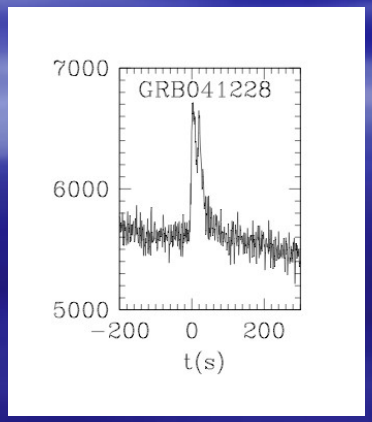
- GRB041223 – first x-ray afterglow

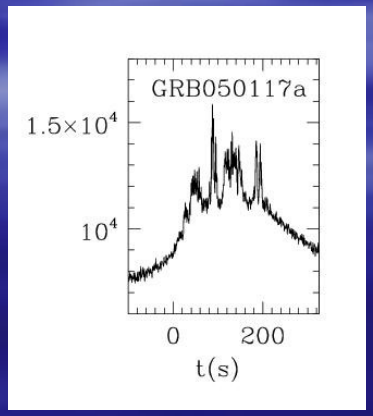


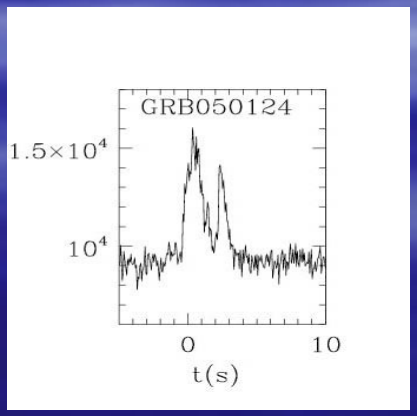






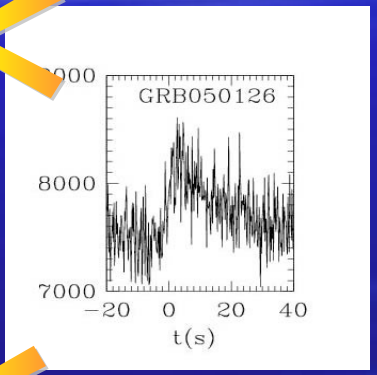


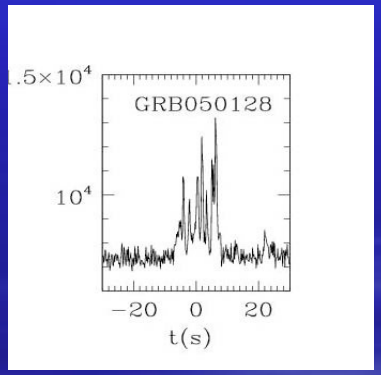


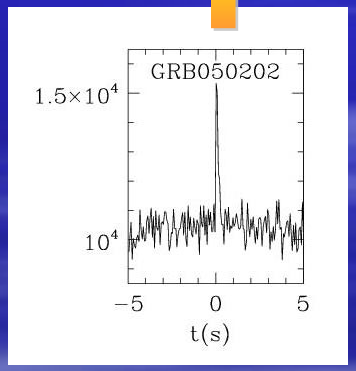


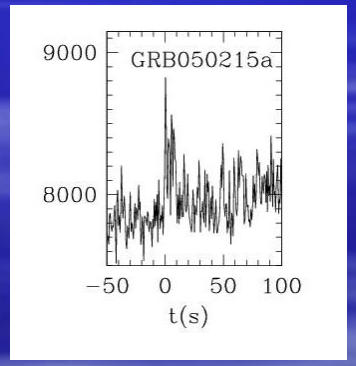
Next 5 bursts

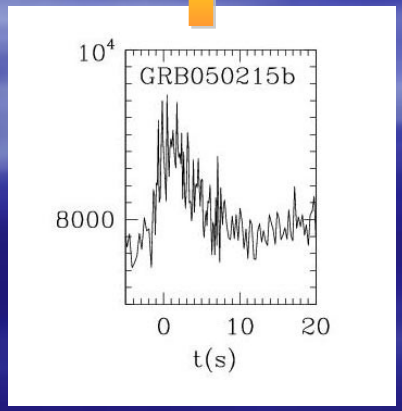
- GRB050126 – first redshift z=1.29 (Keck)
- GRB050202 – first short burst – but no slew

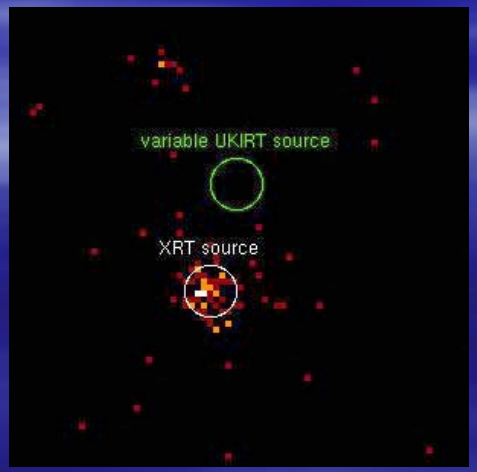










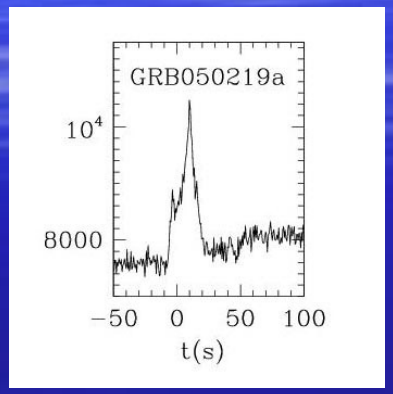


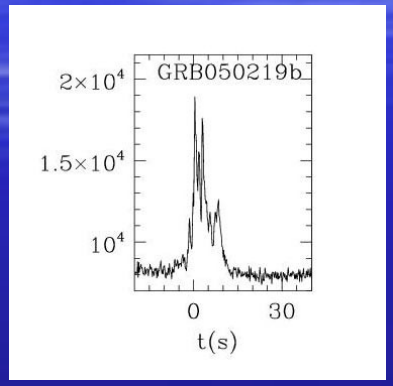
XRF050215b

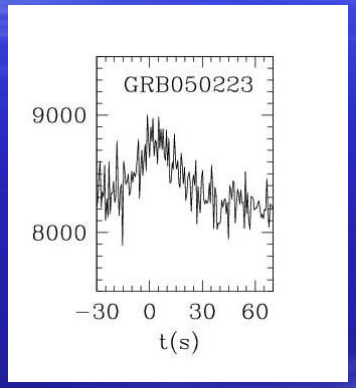
- Observed by Swift & HETE
- Epeak < 30 keV
- Very weak x-ray afterglow

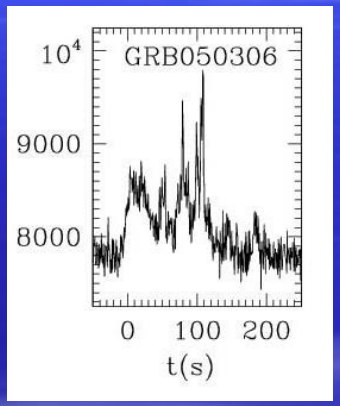
Most recent 7 bursts

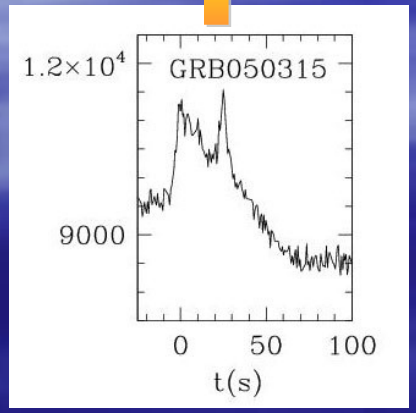
- GRB050315 – redshift 1.949 (Magellan)





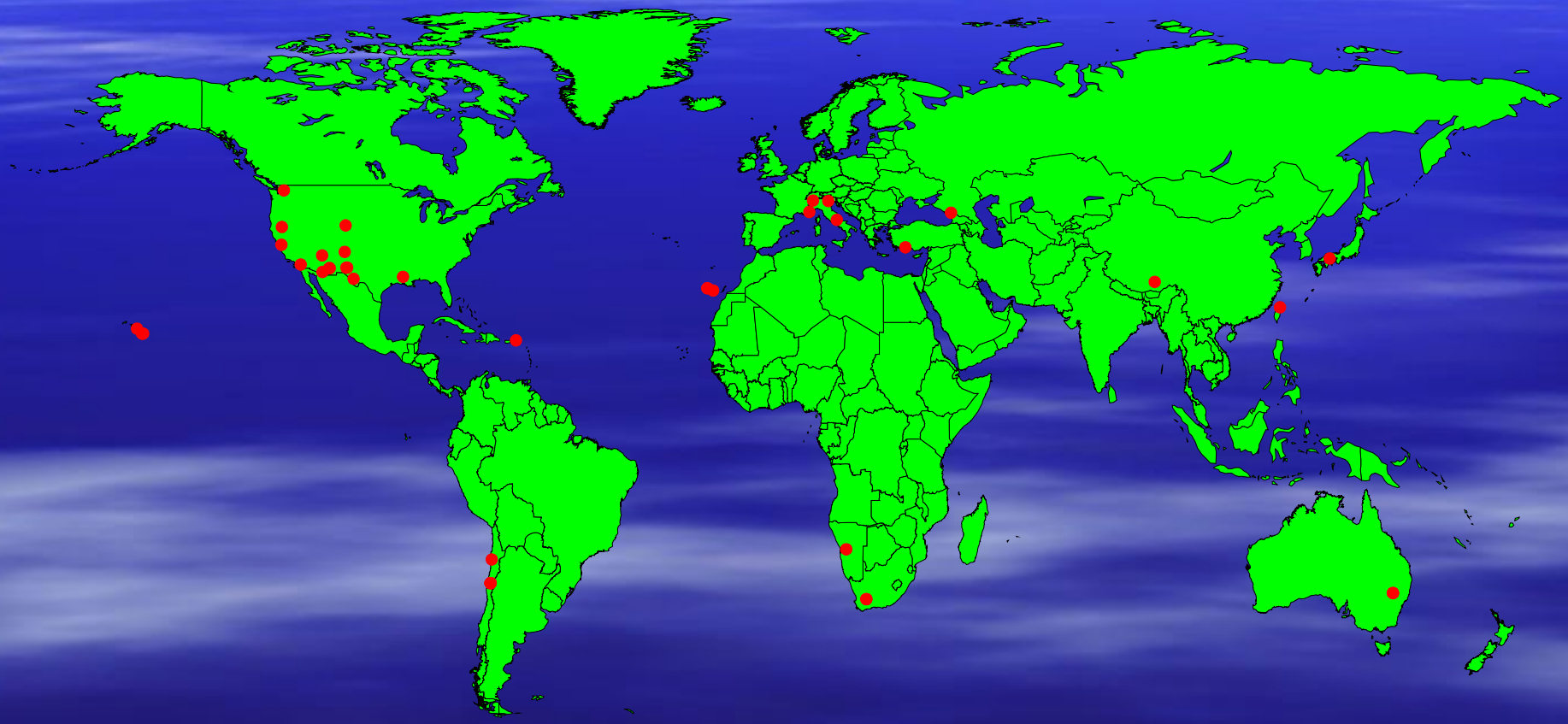






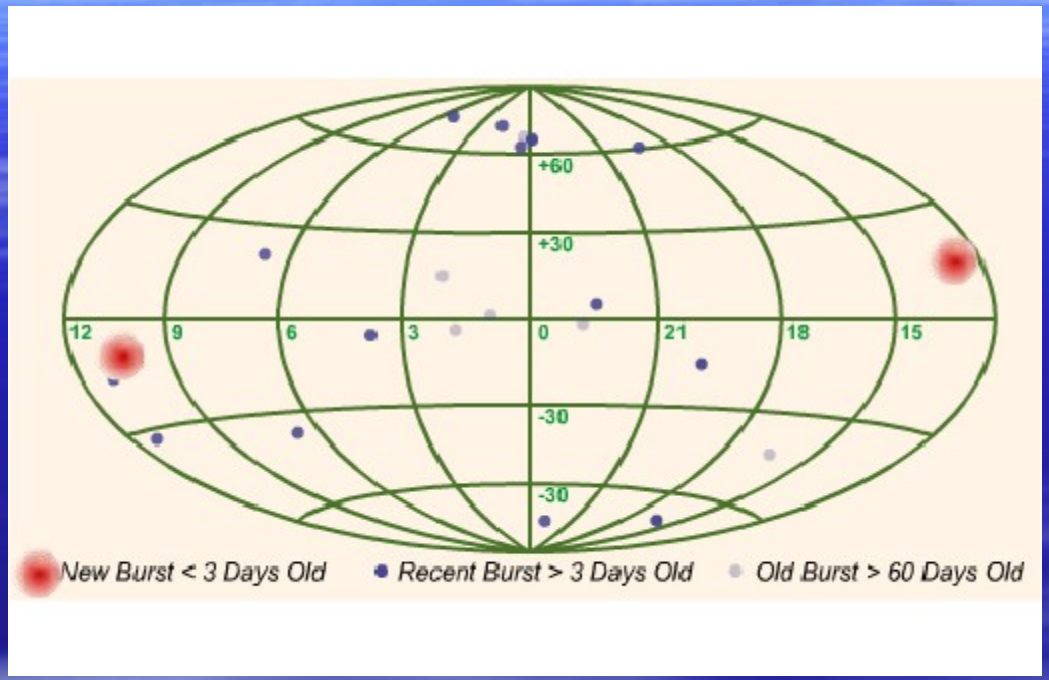
- GRB050318A –RXTE and Swift –Magellan redshift 1.44 – first UVOT afterglow detection!
- GRB050319A –Japanese 14 inch telescope detects afterglow! - ROTSE detects 16th mag object 27 s after burst

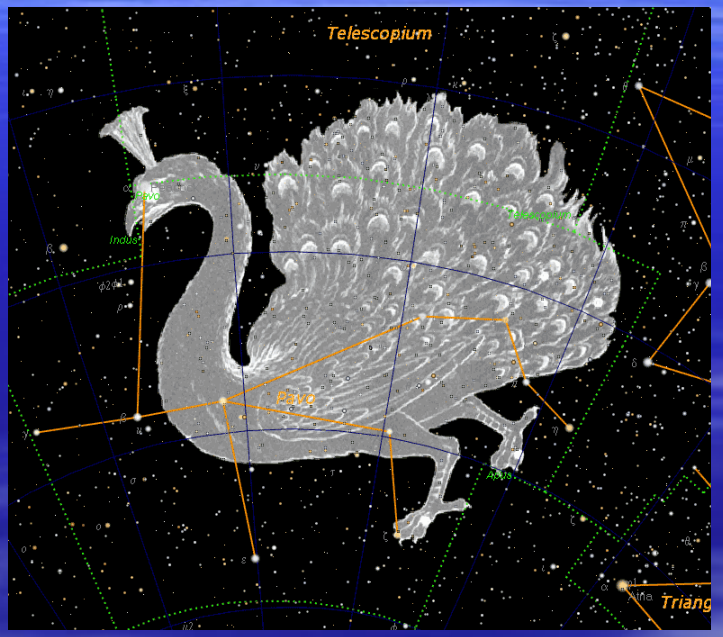
Follow Up Network



44 members using telescopes that span the globe

Fly the Gamma-ray Skies





- Follow GRBs, SGRs, etc. on the Gamma-ray Coordinates Network or the GRB Skymap site
- Join the Global Telescope Network and monitor GRBs and Blazars over the Internet (later talk)

For more information:

- http://swift.sonoma.edu
- http://grb.sonoma.edu
- http://gtn.sonoma.edu
- http://gcn.gsfc.nasa.gov
- http://imagine.gsfc.nasa.gov
- http://www.metroactive.com/papers/sonoma/01.12.05/blackholes-0502.html
  -or Google Cominsky Bohemian

Credit: Rory McNamara