

GRB Discoveries with Swift

Neil Gehrels
NASA/GSFC

Kyoto GRB Conference
November 11, 2013





Outline

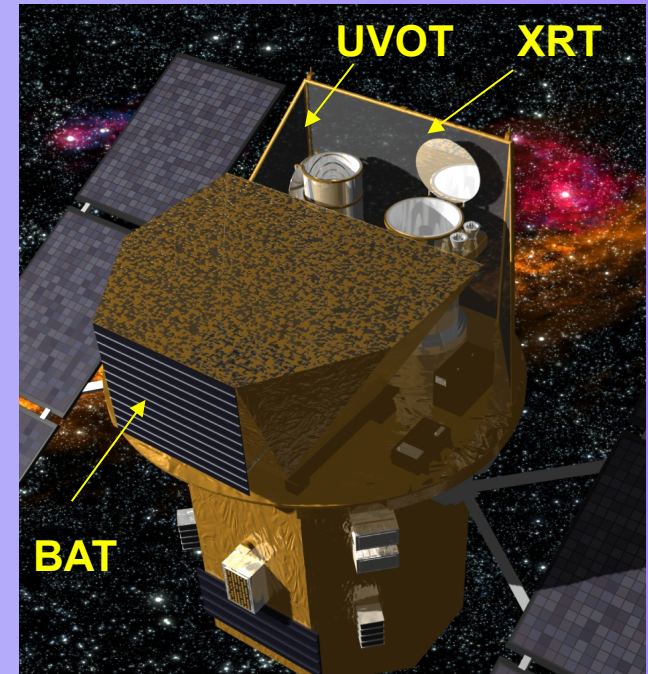
- *Swift* mission
- GRB background
- *Swift* discoveries
- *Swift* performance
- Open questions for the future



041120

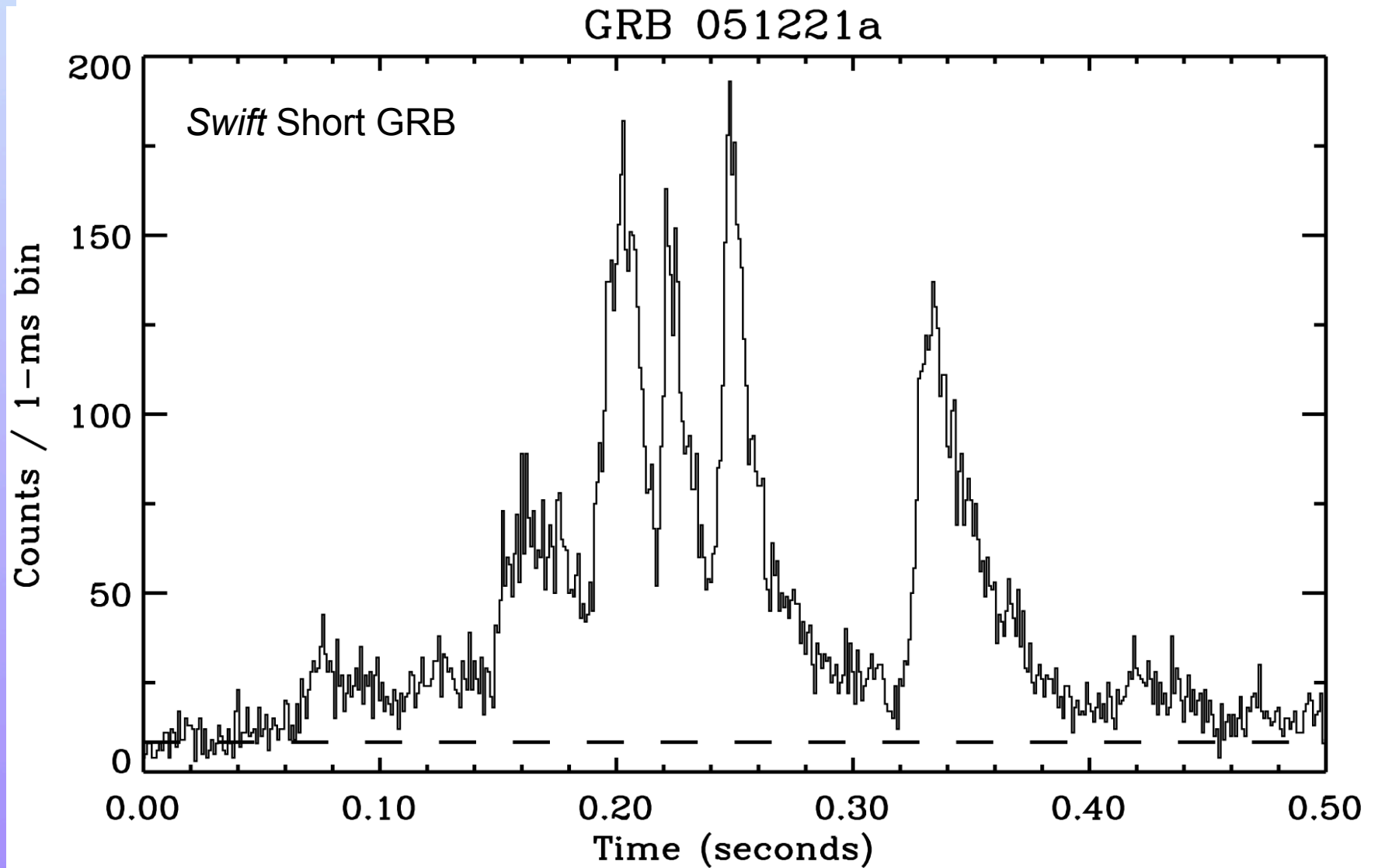
Swift – Time Domain Observatory

- **GRBs**
 - 95 GRBs/yr with arcsec positions
 - Hard X-ray prompt detection
 - Multiwavelength rapid (100 s) follow-up
- **Non-GRBs**
 - >700 TOOs per year
 - AGN, SNe, novae, CVs, LMXBs, stars, ...
 - Multiwavelength rapid (1 hr) response
 - BAT hard X-ray survey

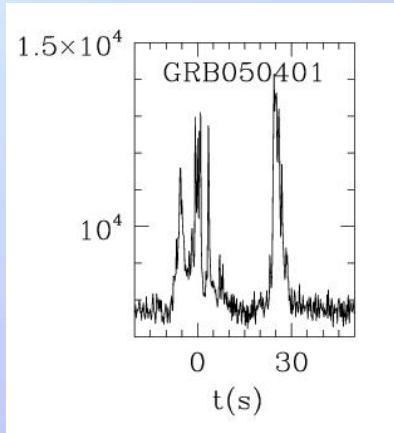


- **Instruments**
 - BAT (2 sr): 15-300 keV, 2 arcmin, 5000 cm²
 - XRT: 0.3-10 keV, 2 arcsec, 120 cm²
 - UVOT: 170-600 nm, <1 arcsec, 30 cm mirror

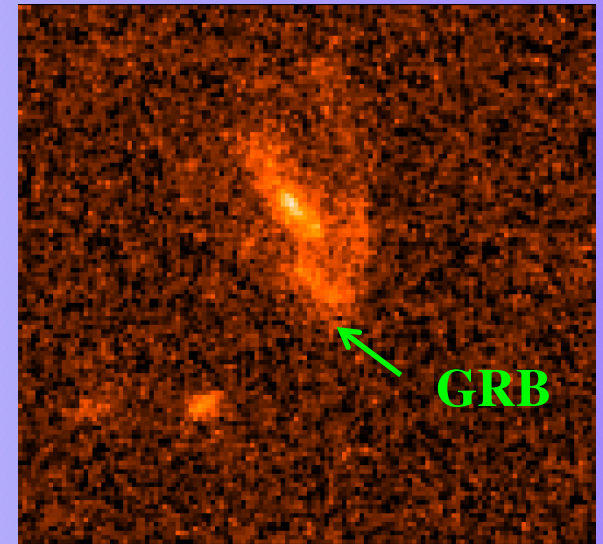
GRB Variability



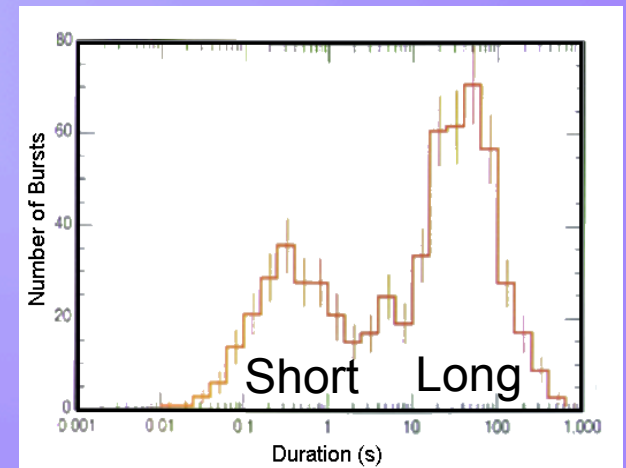
The GRB Phenomenon



GRB 990123 - HST



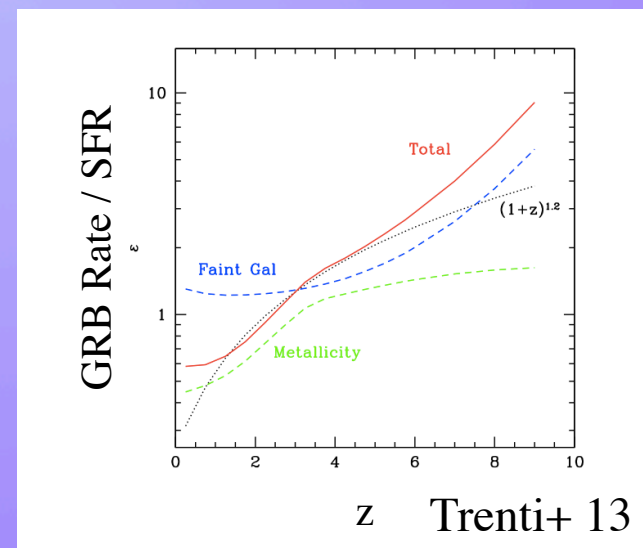
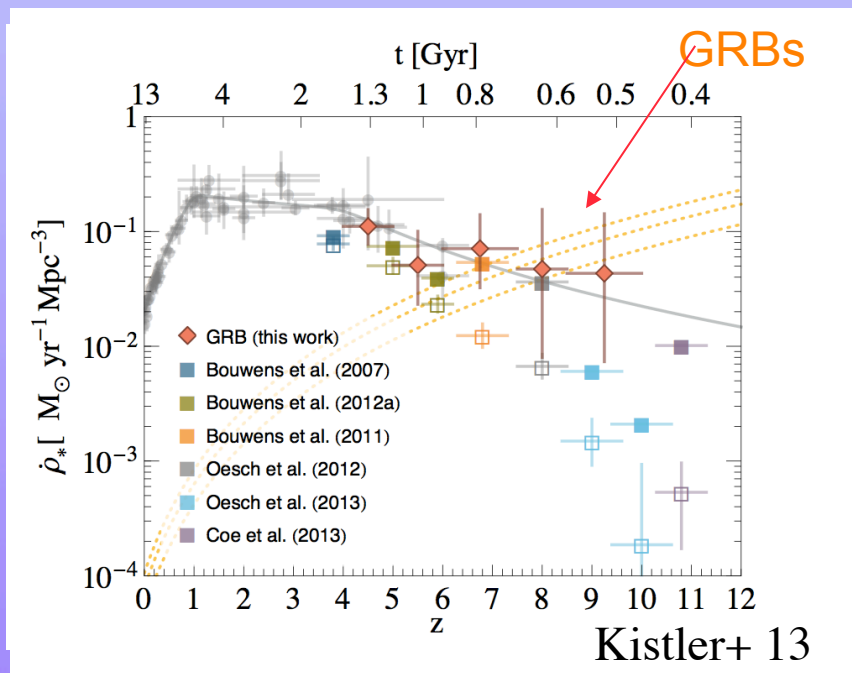
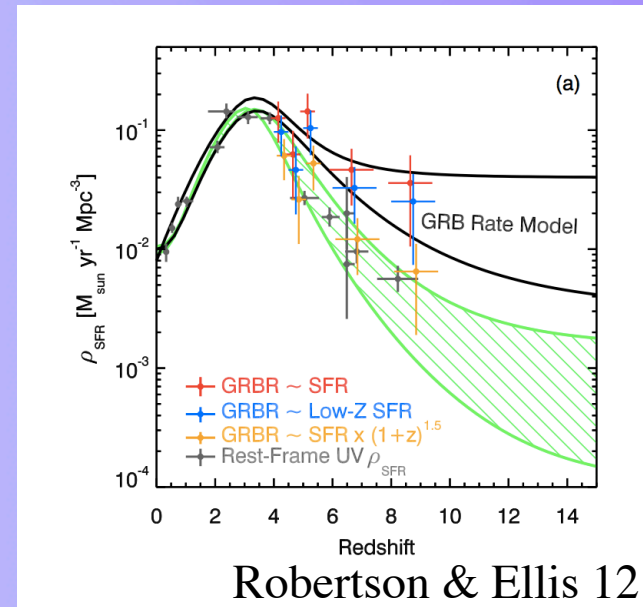
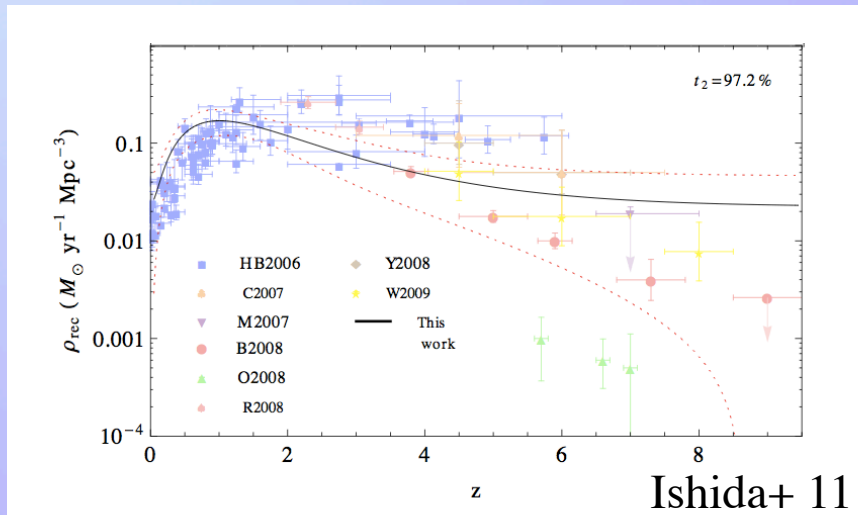
- ⇒ GRBs in distant galaxies
- ⇒ Distance $z \sim 2$
- ⇒ Energy $\sim 10^{51}$ ergs in γ -ray flash
- ⇒ Gamma rays in $\sim 5^\circ$ beams
- ⇒ Millisecond time structure



Kouveliotou+ 93

Long GRBs

Star Formation Rate from GRBs

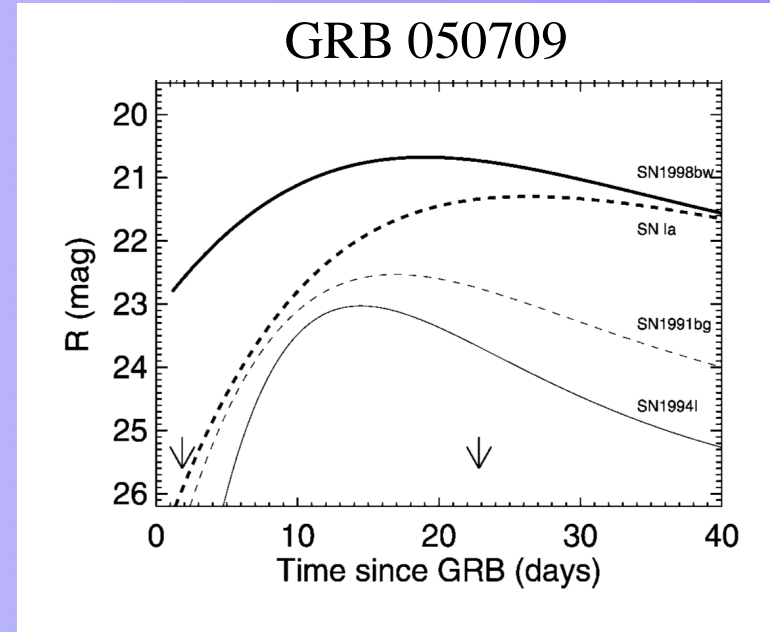
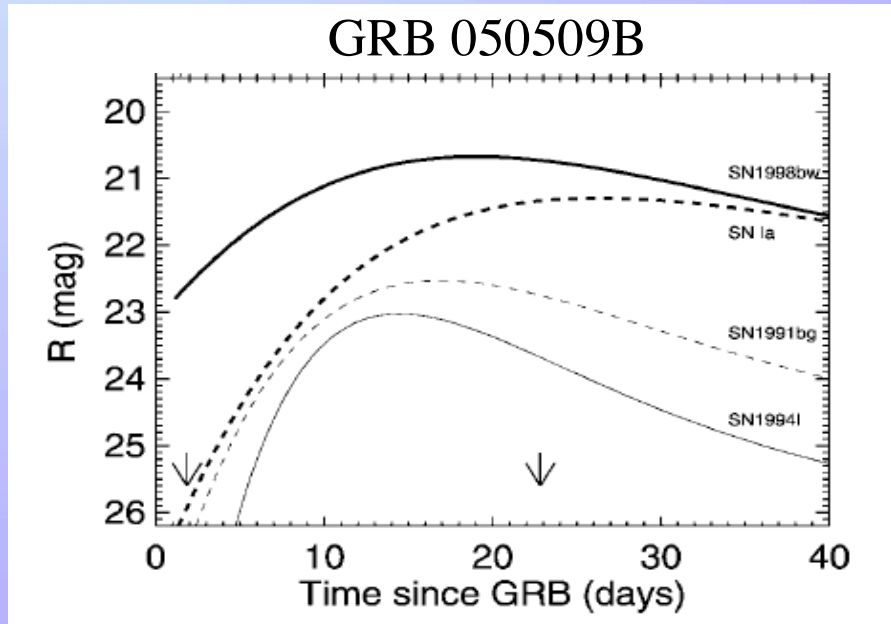


GRB Follow-up Spectroscopic Capabilities

Facility	Location	Aperture	Date	Wavelength Range	Resolution
VLT/XShooter	Chile	8.2	Current	320-2500 nm	5100/8800/5100
VLT/UVES	Chile	8.2	Current	300-1100 nm	80000
VLT/ISAAC	Chile	8.2	Current	1000-5000 nm	2000
VLT/SINFONI	Chile	8.2	Current	1100-2400 nm	2000-5000
VLT/KMOS	Chile	8.2	Current	8000-2500 nm	2000-4000
Gemini/GMOS	Hawaii/ Chile	8.1	Current	3600-1100 nm	1100-4000
Gemini/GNIRS	Hawaii	8.1	Current	900-2500 nm	1700-18000
Gemini/Flamingos-2	Chile	8.1	Current	900-2400 nm	1200-3000
SUBARU/IRCS	Hawaii	8.2	Current	900-2500 nm	200-1000
Magellan/MagE	Chile	6.5	Current	310-1000 nm	4000
Magellan/FIRE	Chile	6.5	Current	800-2500 nm	6000-8000
Magellan/LDSS3	Chile	6.5	Current	360-1000 nm	500-3000
TNG/DOLoRes	La Palma	3.5	Current	310-1000 nm	500-6000
GTC/OSIRIS	La Palma	10	Current	3500-1000nm	300-2500
WHT/ISIS	La Palma	4.2	Current	310-1100 nm	800-7000
Keck/LRIS	Hawaii	10	Current	300-1000 nm	1200-4000
Keck/HIRES	Hawaii	10	Current	310-1000 nm	25000-85000
Keck/MOSFIRE	Hawaii	10	Current	900-2400 nm	2300-4700
MMT/BCS/RCS	Arizona	6.5	Current	320-1000 nm	<5000
LBT/LUCI2	Arizona	2x8.4	Current	850-2400 nm	2000-8000
NOT/ALFOSC	La Palma	2.5	Current	320-1100 nm	600-4500
DCT/RIMAS	Arizona	4.2	2014-	900-2400 nm	25-5000
NOT/Heidi	La Palma	2.5	2014-	350-1600 nm	5000

Short GRBs

No Supernovae with Short GRBs



Hjorth+ 2005

Contrast with Long GRBs:

980425 - 98bw

021211 - 02lt

031203 - 03lw

030329 - 03dhc

050525A -05nc

060218 - 06aj

091127 - 09nz

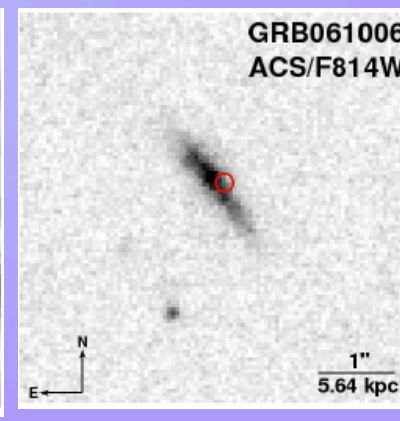
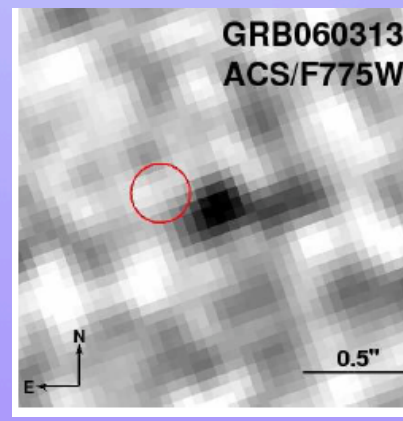
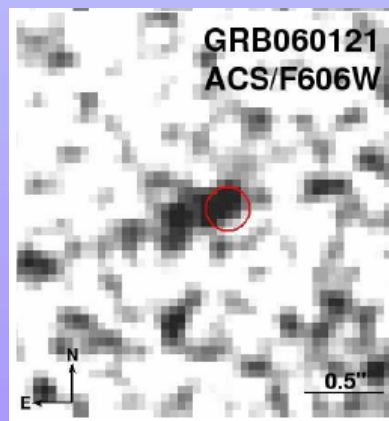
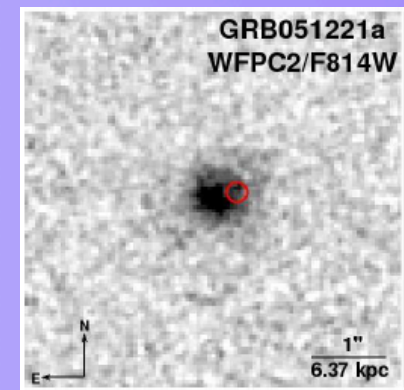
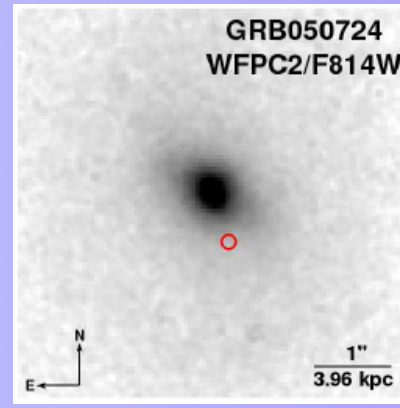
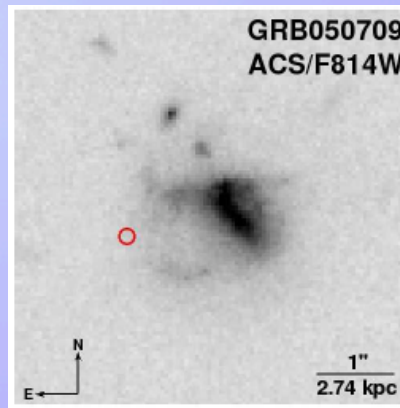
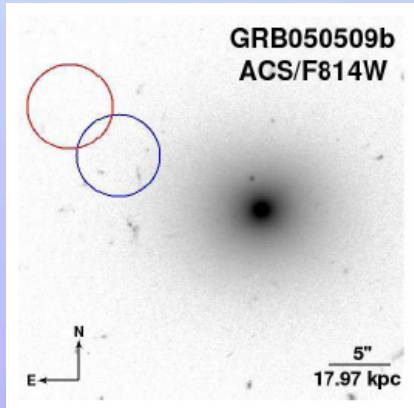
100316D -10bh

101219B -10ma

120422A -12bz

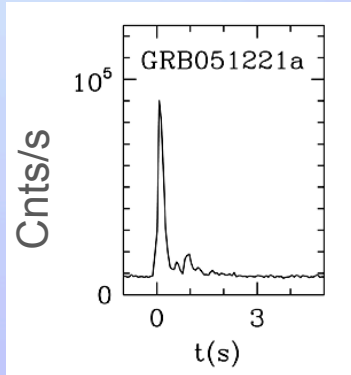
130427A -13cq

Short Burst HST Images



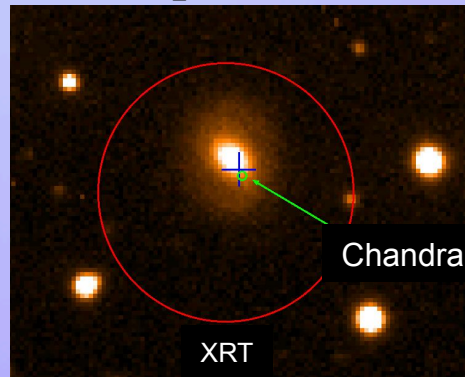
Fong+ 10, 13
Fruchter

Short GRB

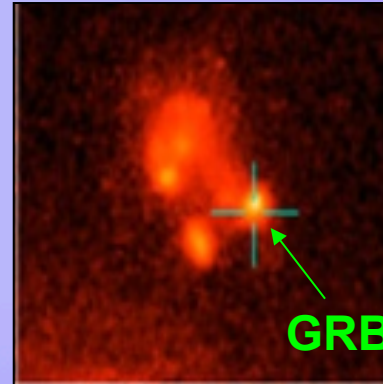


Short vs Long GRBs

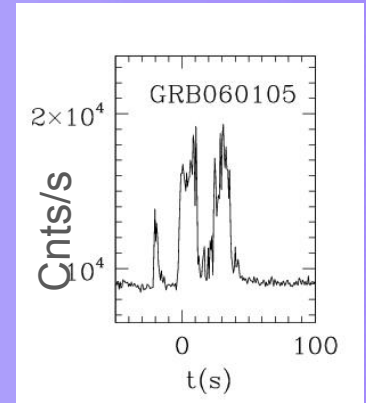
GRB 050724 - *Swift*
elliptical host



GRB 020903 - *SAX*
SF dwarf host



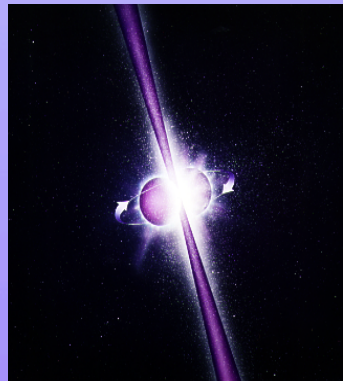
Long GRB



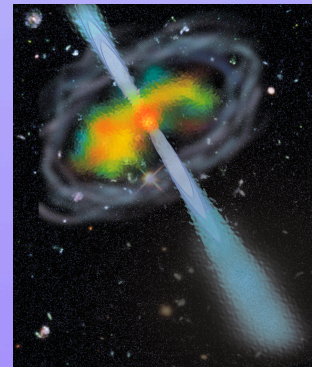
In non-SF
and SF galaxies

No SNe detected

Merger model
is likely



BH



In SF
galaxies

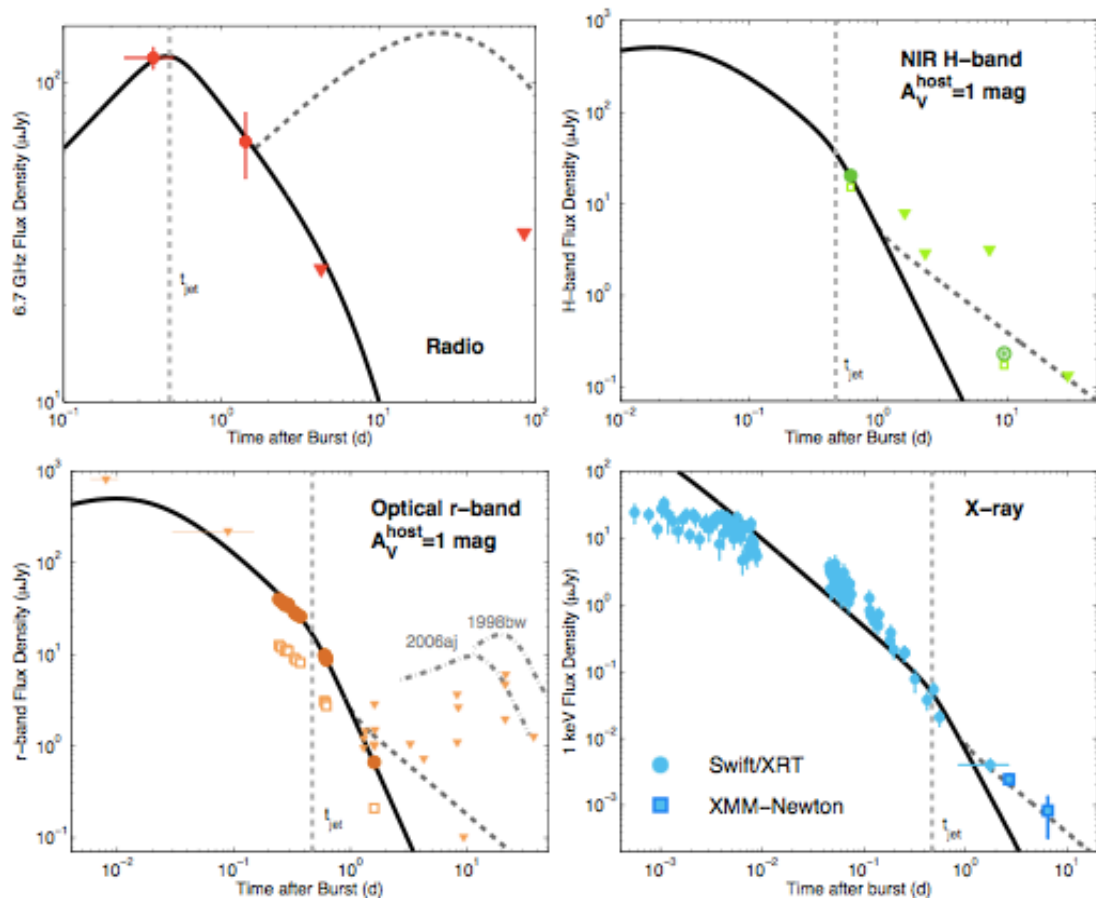
**Accompanied by
SNe**

Collapsar model
well supported

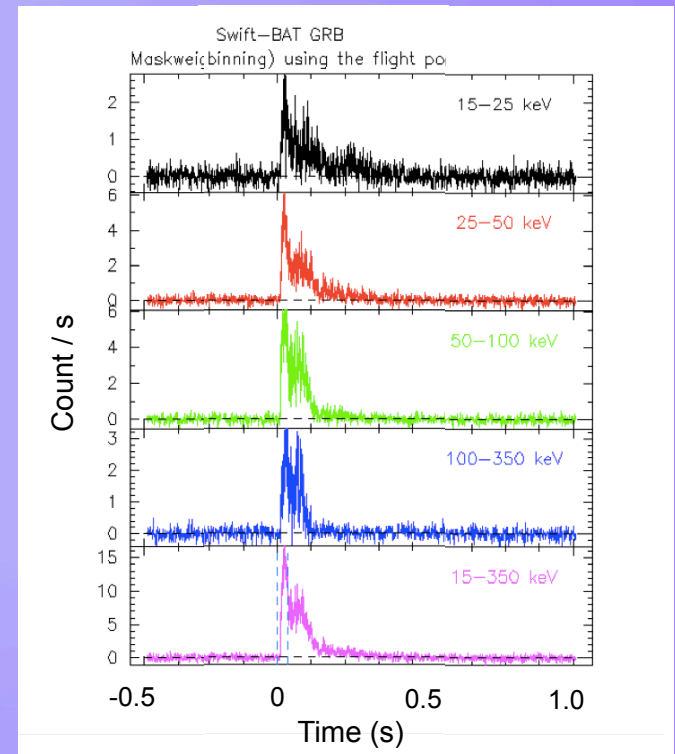
Name	Redshift	Afterglow	Host	Fleunce (γ-ray) (10 ⁻⁴ erg/cm ²)	Duration (s)	Spectral Lag (ms)	Extended Emission	Comment
050509B	0.225	X	elliptical [Ⓜ]	0.95±0.25	0.03	4.7±3.2	N	low SF, HST
050724	0.258	X, O, R	elliptical	39.±10.	3.0	-4.2±8.2	Y	low SF, HST
050813	? 0.7, 1.8	X	? galaxies, cluster	12.4±4.6	0.60	-9.7±14.0	N	-
051210	0.114?	X	? cluster [Ⓜ]	8.3±1.4	1.4	-1.0±16.0	N	HST
051221A	0.547	X, O, R	SF galaxy	116±4.	1.4	0.0±0.4	N	HST
051227	-	X, O	faint galaxy	0.23±0.03	0.9 (16)	2±10	Y	-
060313	-	X, O	? cluster [Ⓜ]	113±5.	0.7	0.8±0.6	N	HST
060502B	0.287?	X	elliptical @ 50kpc	4.0±0.5	0.09	-4.0±3.	N	73kpc offset
060801	1.131?	X	? galaxies	8.1±1.0	0.5	8±8	N	-
061006	0.4377	X, O	galaxy	143±14.	0.5 (130)	9.2±7.1	Y	HST
061201	0.111?	X, O	galaxy @ 34kpc [Ⓜ]	33±3.	0.8	2.7±3.3	N	HST
061210	0.41?	X	? galaxies	110±20.	0.19 (85)	1.0±0.5	Y	-
061217	0.827?	X	? galaxies	4.6±0.8	0.3	-	N	-
070429B	0.904	X, O	galaxy	6.3±1.0	0.5	7±5	N	4kpc, spec z
070714B	0.923	X, O	galaxy	72.±9.	2.9 (64)	14±7	Y	R~25.5 spec z
070724	0.457	X	galaxy	3.0±0.7	0.4	22±35	N	SF host @ 2"
070729	-	X	-	10.±2.	0.9	-113±63	-	-
070809	-	X, O	-	10.±1.	1.3	11±38	-	not very hard
071227	0.383	X, O	galaxy	22.±3.	0.18	4=14	Y	-
080123	-	X	-	57.±17.	-0.41 (115)	-	N	EE not real
080503	-	X, O	-	200±10	~0.5 (170)	-8±12	Y	rising LC opt
080702A	-	X	-	3.6±1.0	0.5	-15±20	N	-
080905A	-	X, O	nearby galaxy	14±2	1.0	-5±5	N	-
080919	-	X	-	7.2±1.1	0.6	97±23	N	-
081024	-	X	-	12±2	1.8	-	N	-
081211B	0.216?	X	cluster field	61.	2.9	-	Y	BATSS, <u>Konus</u>
081226A	-	X	-	9.9±1.8	0.4	-	N	-
090307	-	X, O	-	0.7±0.1	0.4	-	N	-
090417A	0.088?	X	2MASS galaxy	1.9±0.5	0.072	-	N	probably not SGR
090426	2.6	X, O	-	18.	1.2	1.7±12.5	N	long or short??
090510	0.903	X, O	-	34.±4.	0.3	0.8±1.0	N	LAT
090515	-	X	-	2.1±0.4	0.038	2.8±1.2	N	-
090531B	-	X	-	71±9	1.3	11±5	Y	-
090607	-	X	-	11±2	2.3	-	N	<u>subthreshold</u>
090621B	-	X	-	7±1	0.14	-	N	single spike
090916	-	X	-	95.±18.	0.32 (65)	-	Y	moon constrained
090927	1.37	X, O	-	22±3	2.2	-	N	short?
091109B	-	X, O	-	19±2	0.3	-	-	-
100117A	-	X	-	9.3±1.3-	0.3	-	-	single spike
100106A	-	X	-	14±2	0.12	-	-	-
100312A	-	X	-	17.±2	0.4	15.±15	Y	-

Short GRB 130603B

Multiwavelength Afterglow



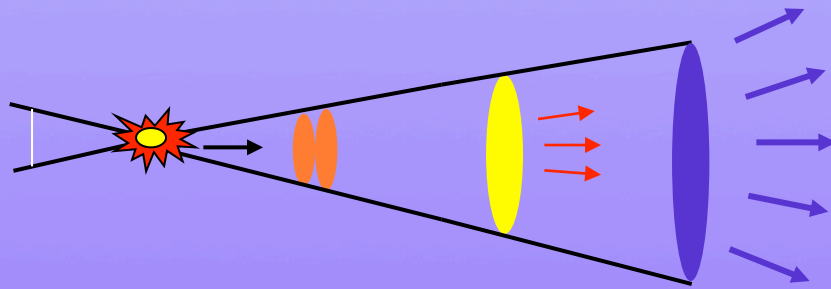
BAT Prompt



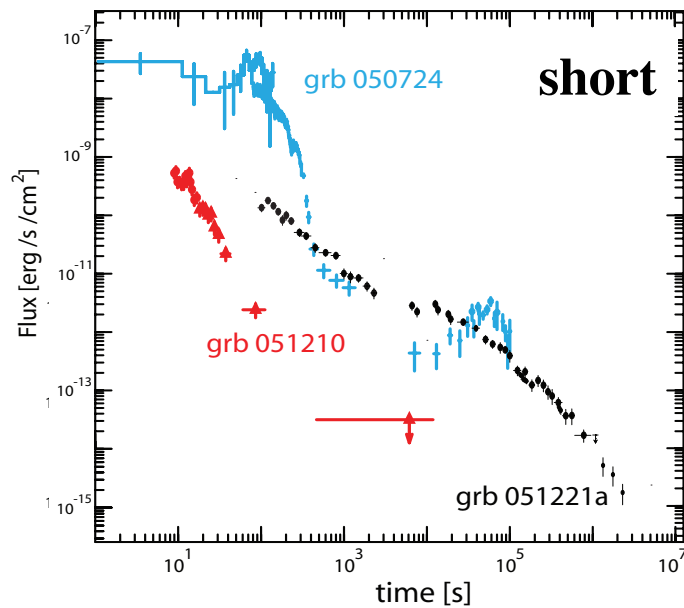
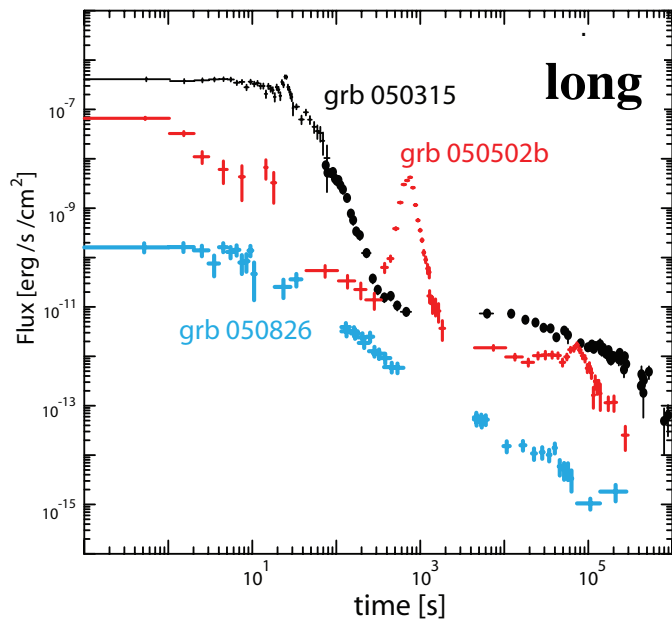
Fong+ 13

jet break at 0.5 day implies opening angle of 4 – 8 degrees

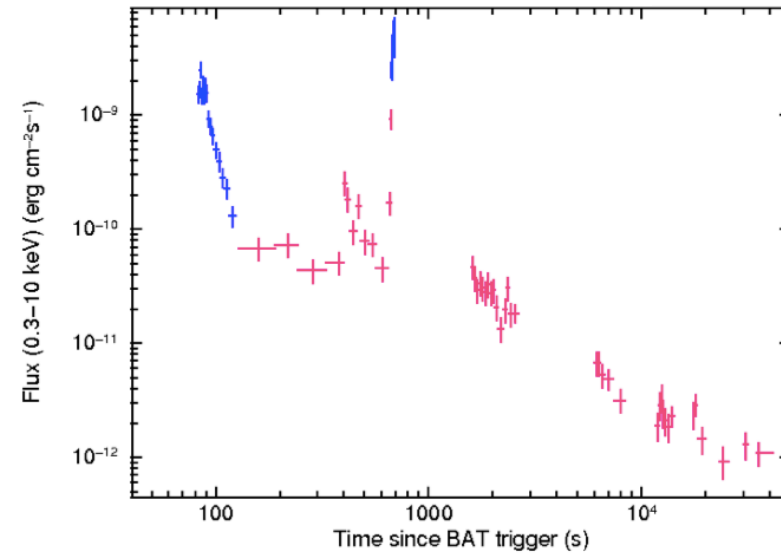
Fireball Outflow



Afterglows



GRB 131103A XRT

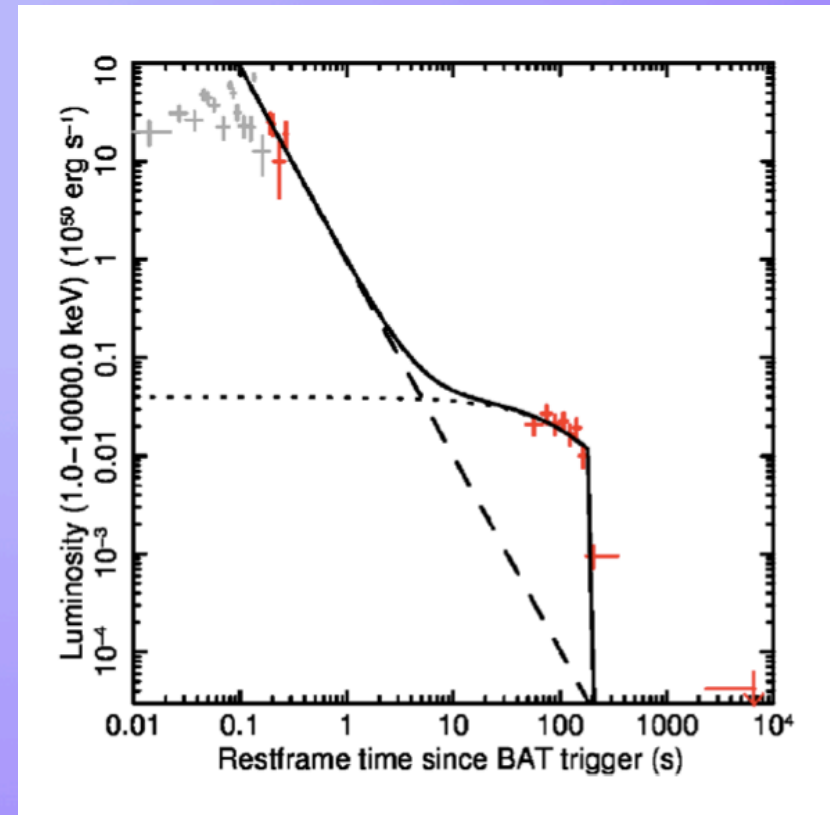
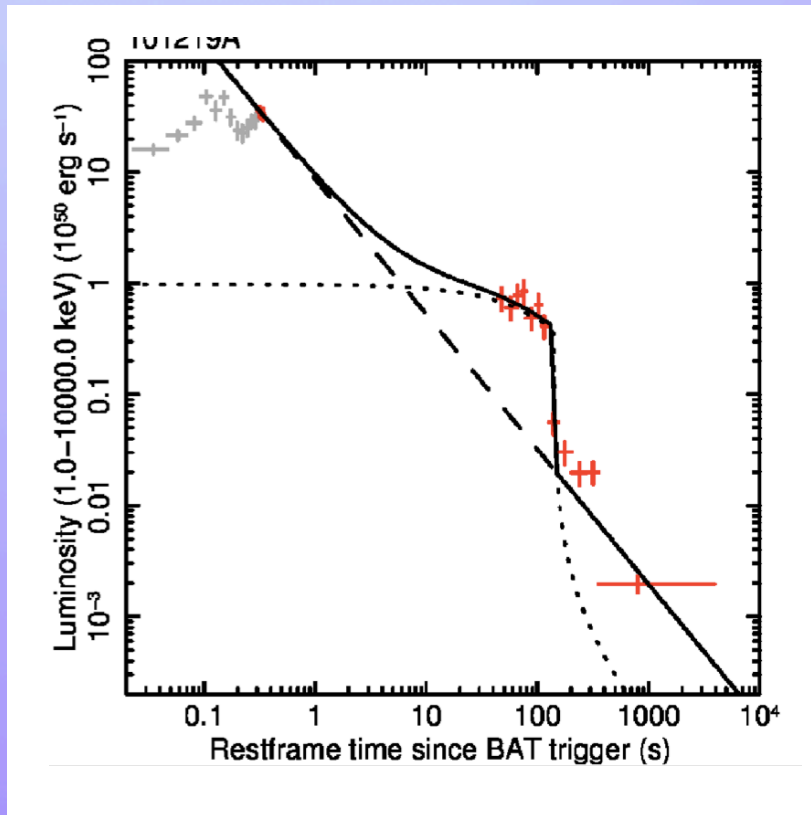


Gehrels, Ramirez-Ruiz & Fox 09

see also Zhang +06, Nousek+ 06, Kann+ 11

Hints of Magnetar Engine

Rapid fall-off after plateau phase in some short GRBs



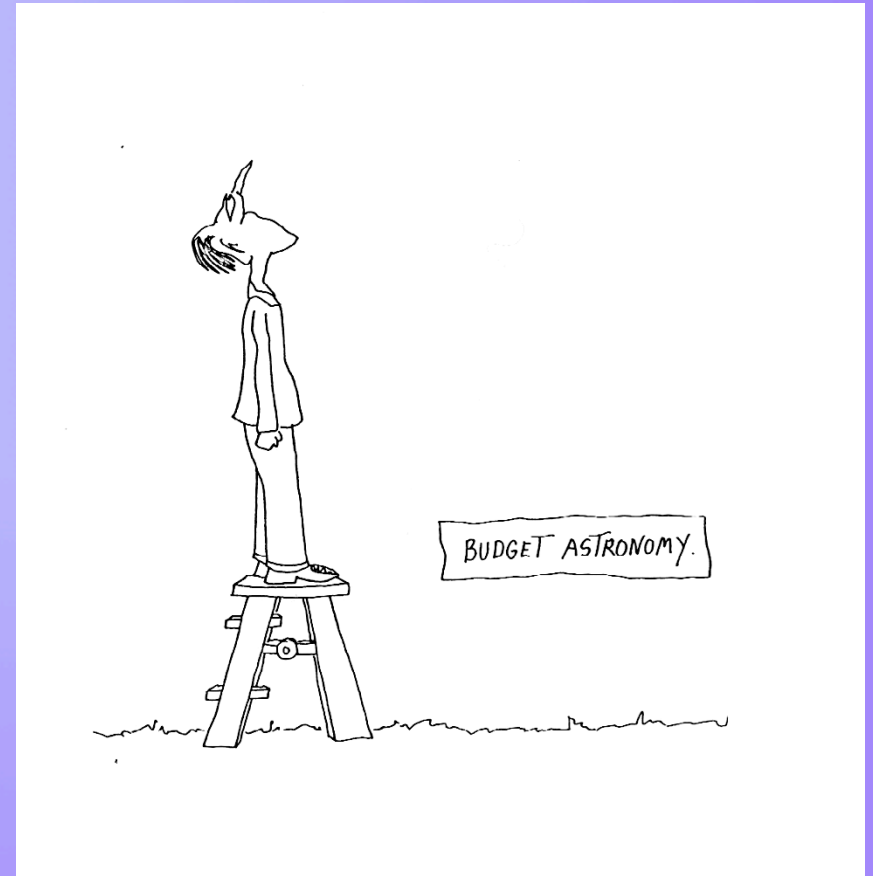
*Looking
Ahead*

Senior Review

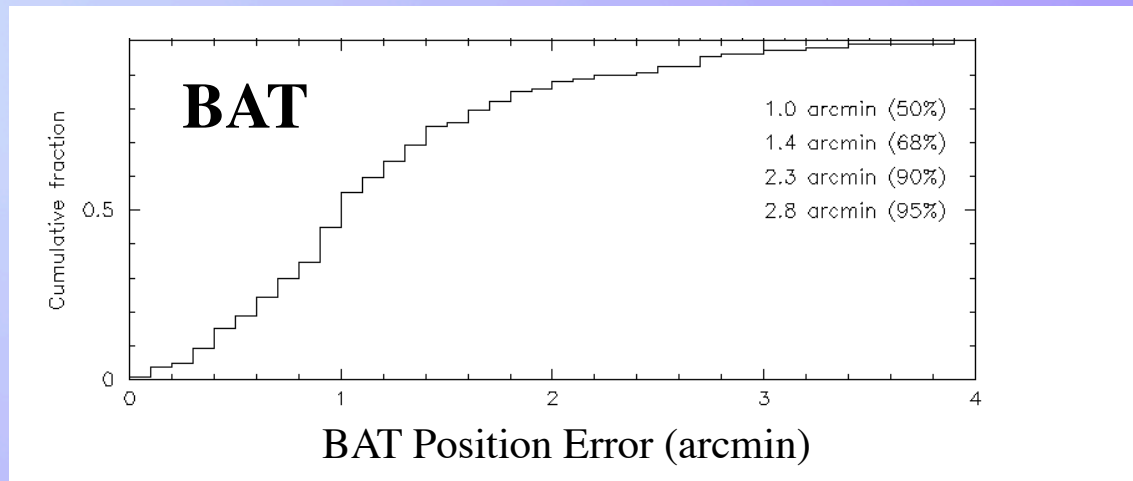
- NASA's review of operating missions every 2 years
- Missions under review
 - Fermi
 - Kepler
 - NEOWISE
 - NuSTAR
 - Planck
 - Spitzer
 - Suzaku
 - Swift
 - XMM
- HST and Chandra is separate review
- Proposals due January 15, 2014 with presentation in March

Senior Review

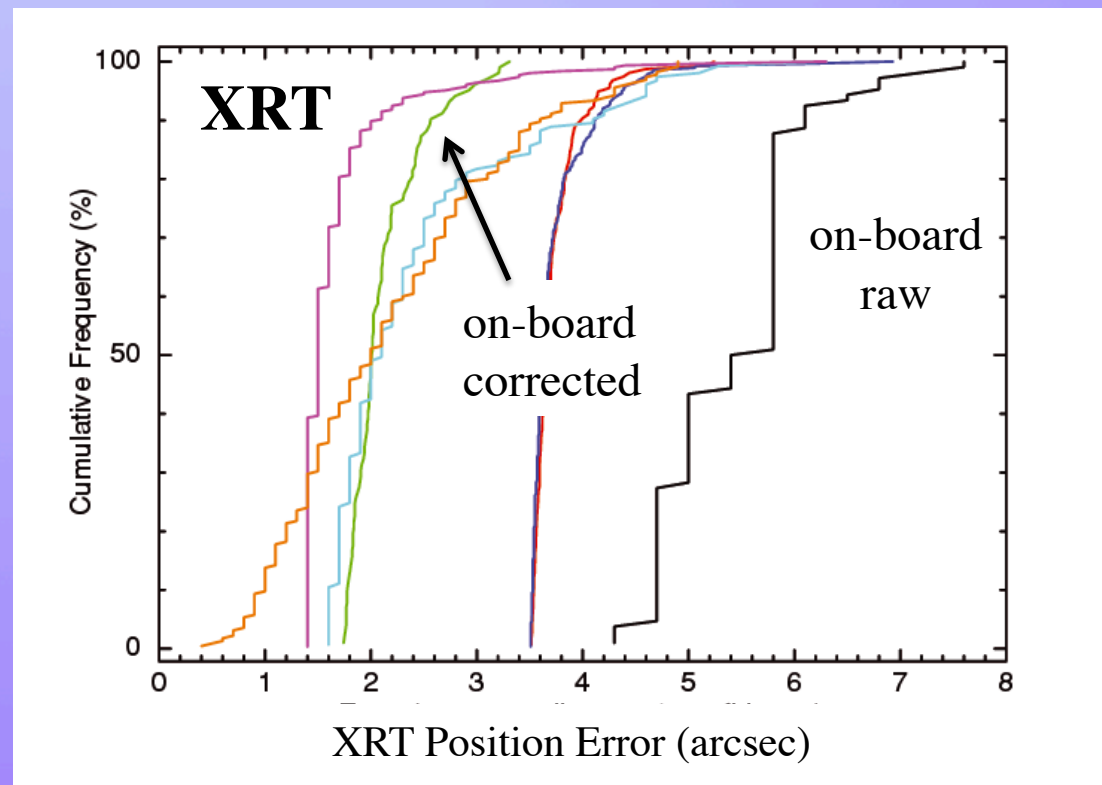
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BAT & XRT Rapid Positions

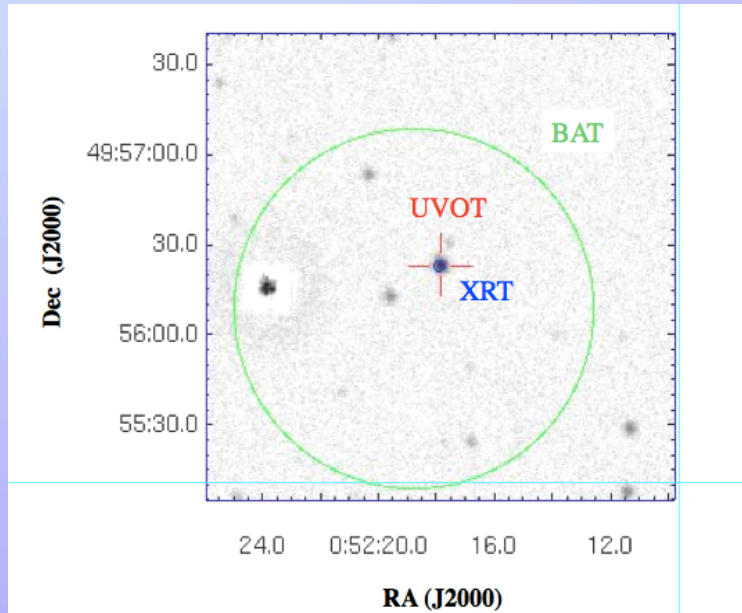


Sakamoto 07

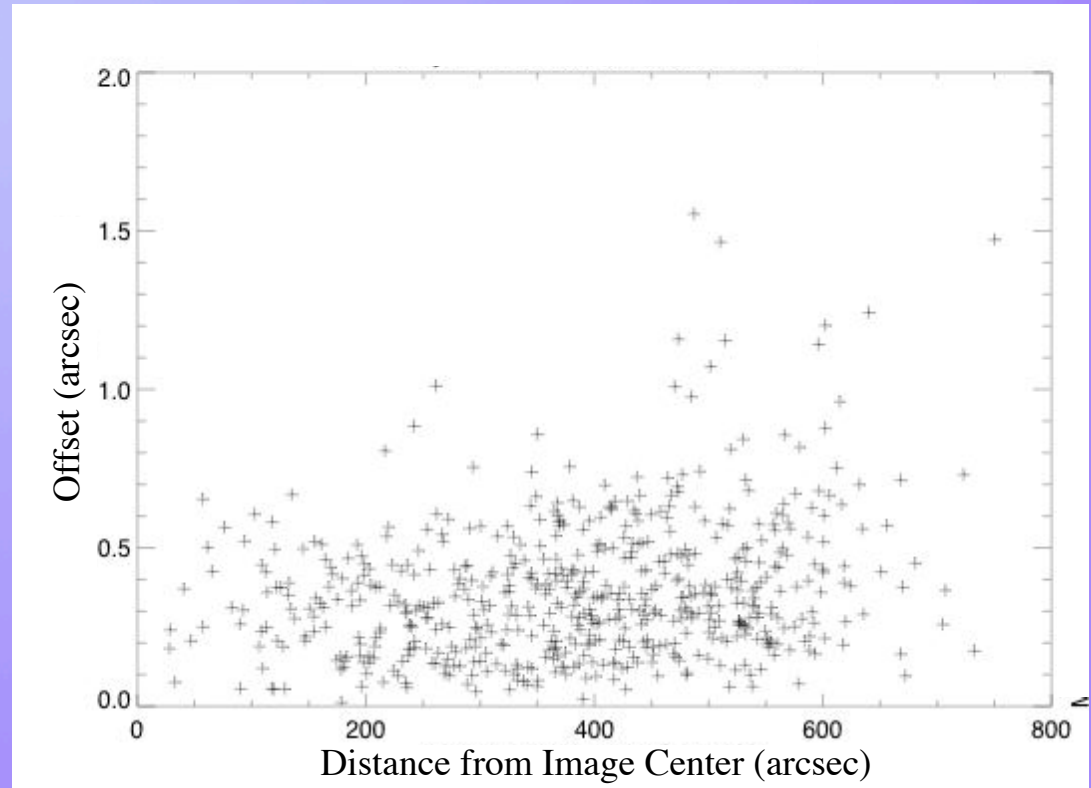


Evans+ 09

UVOT Performance



Median position accuracy for
583 stars is 0.33 arcsec

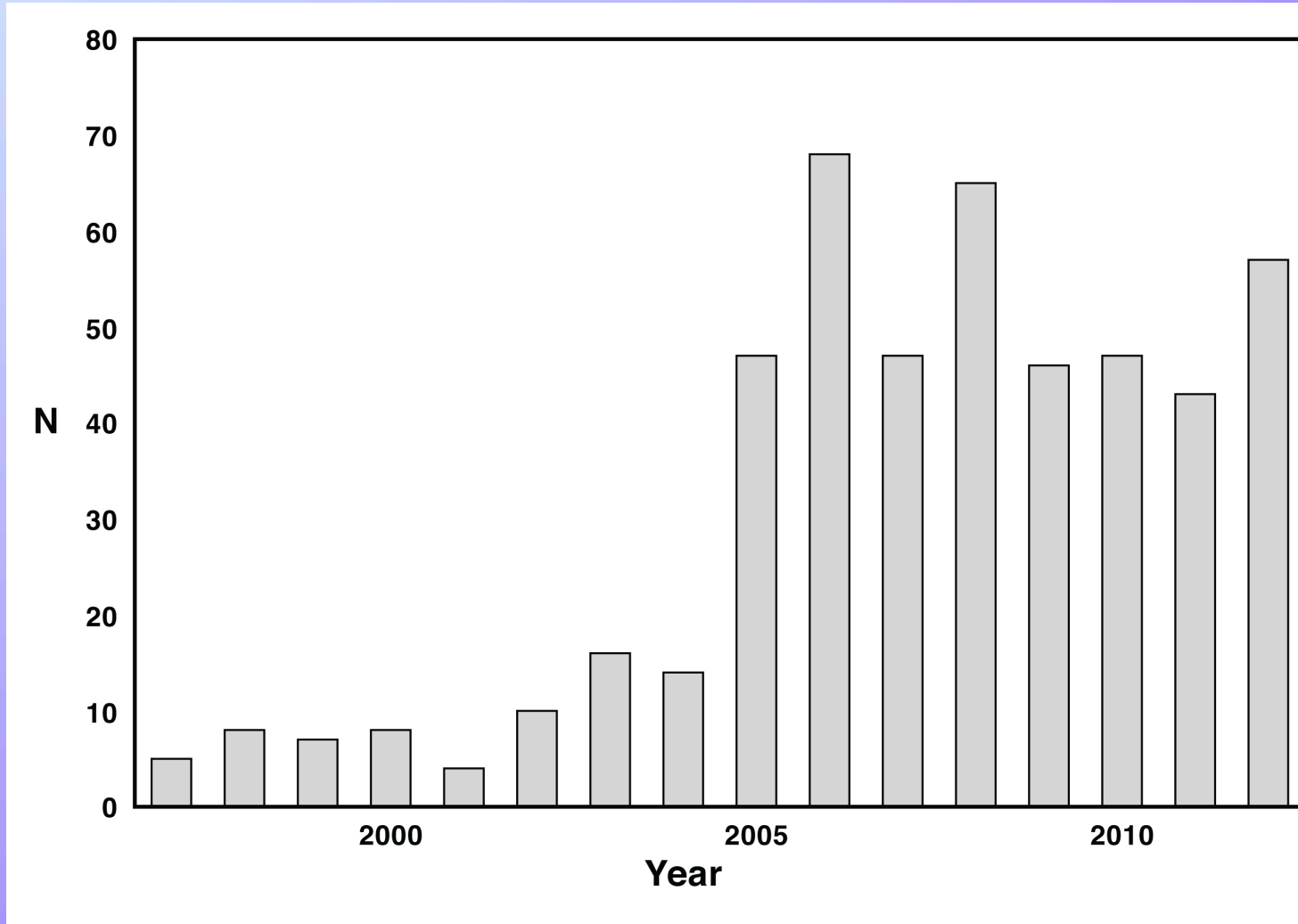


Typical Sensitivities

V=19 first GCN (<1 hr)

V=22 2nd GCN (~3 hr)

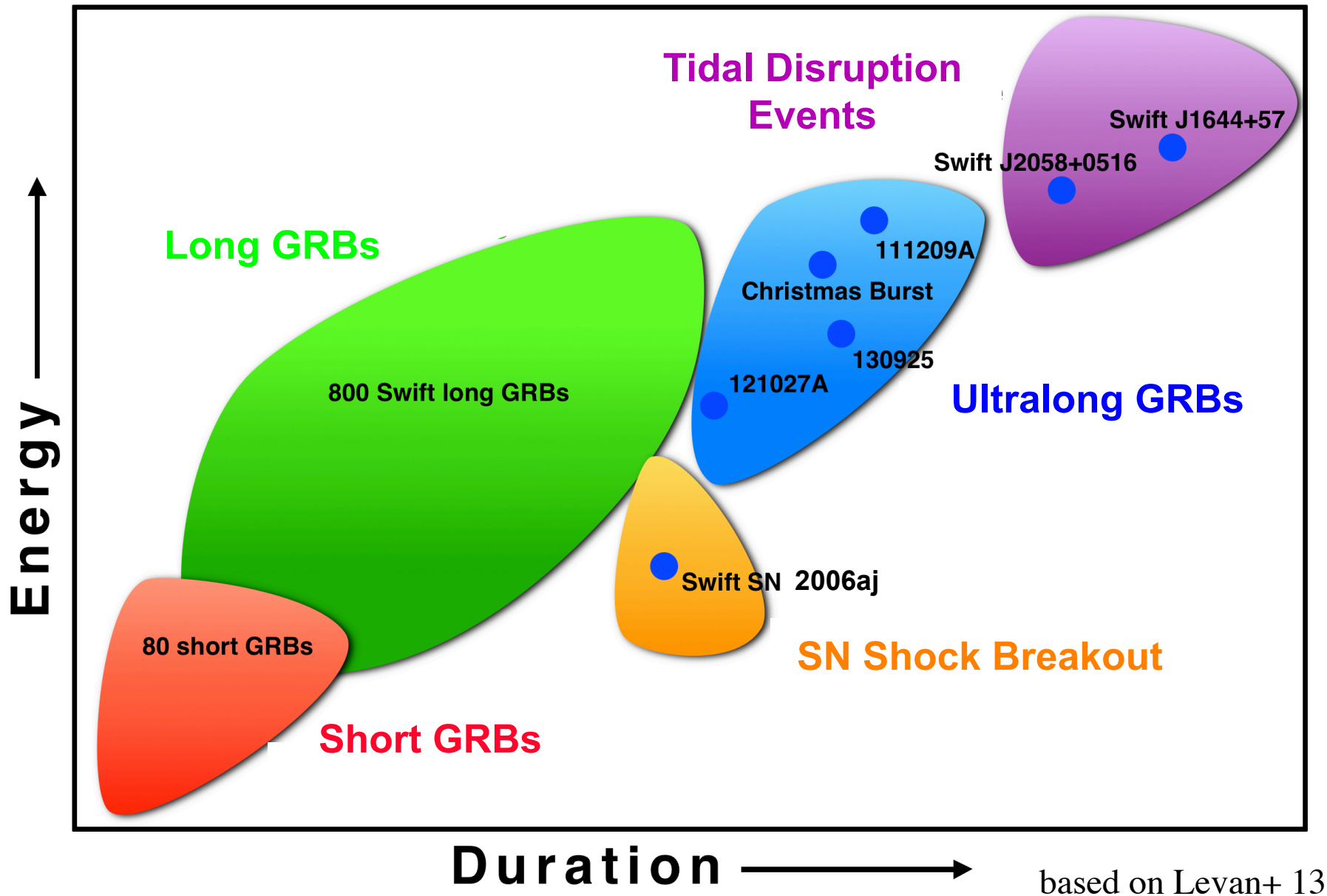
Number of GRB OT Detections



87% of GRB redshifts are from Swift

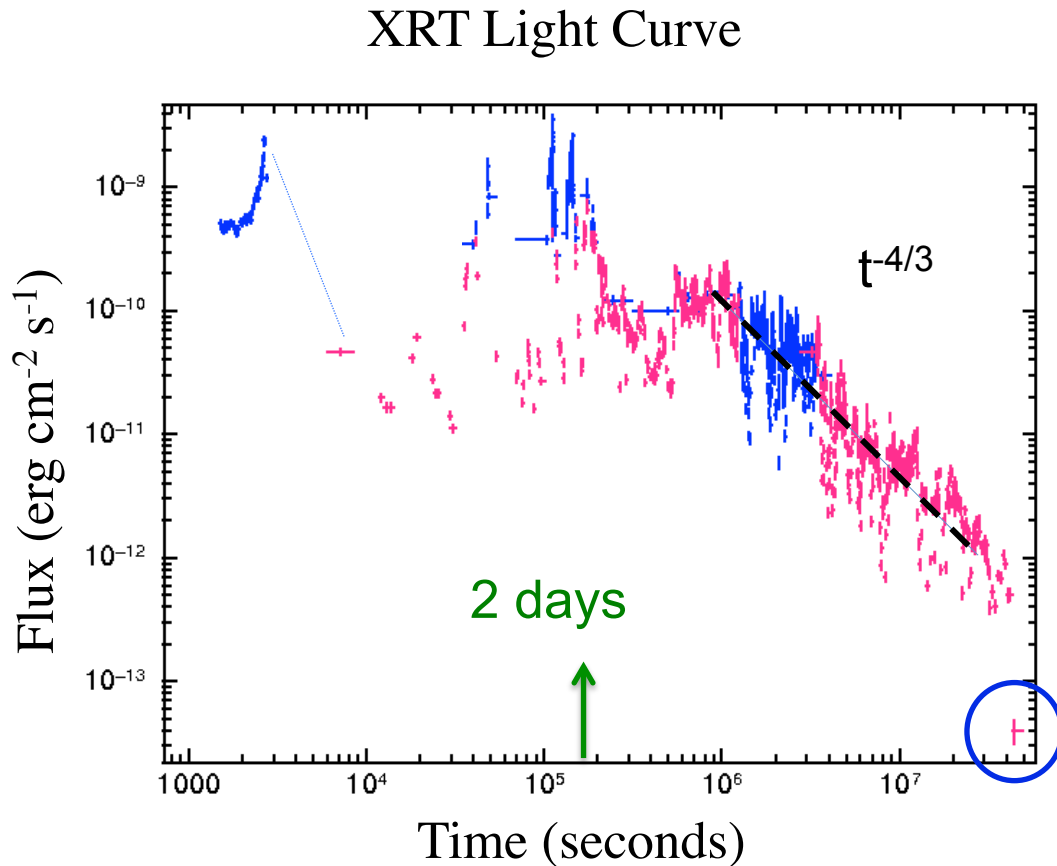
following Strom+ 12

Swift Discovery Areas



Swift Transient - Sw J1644+57

28 March 2011



Transient at center of dwarf non-AGN galaxy at $z=0.35$

$$L_x \sim 10^{48} \text{ erg s}^{-1}$$

$$E \sim 10^{51} \text{ ergs}$$

$$M_{\text{BH}} \sim 10^6 - 10^7 M_{\text{O}}$$

Bloom+, Burrows+, Levan+, Berger+ 11

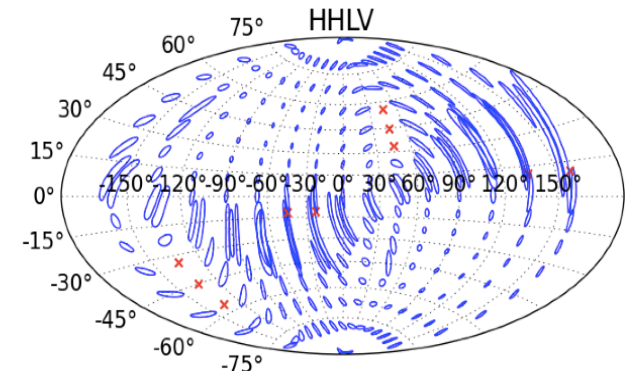


GW Electromagnetic Counterparts

- Advanced era for LIGO/Virgo: 2015+
- Great importance to finding EM counterparts
- GW error boxes will be 10's to 1000 sq deg
- Galaxy strategy used in *Swift* in LIGO S6

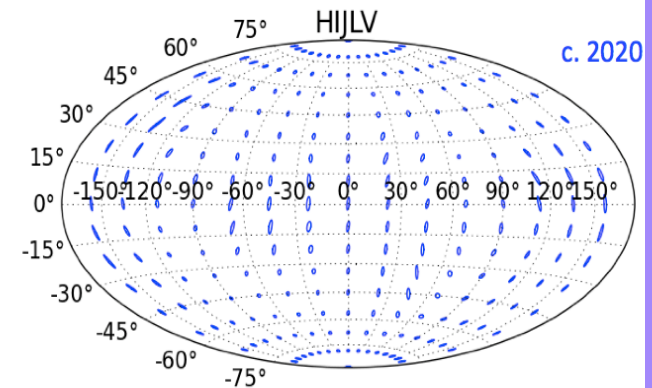
Epoch	BNS range (Mpc)		Median Area (deg ²)
	LIGO	Virgo	
2015	60 ± 20	—	2000
2016–17	100 ± 20	40 ± 20	70
2017–18	140 ± 30	70 ± 15	84
2019+	200	100 ± 15	31
2022+ (India)	200	130	11

Sky localization with 3 sites ...



11

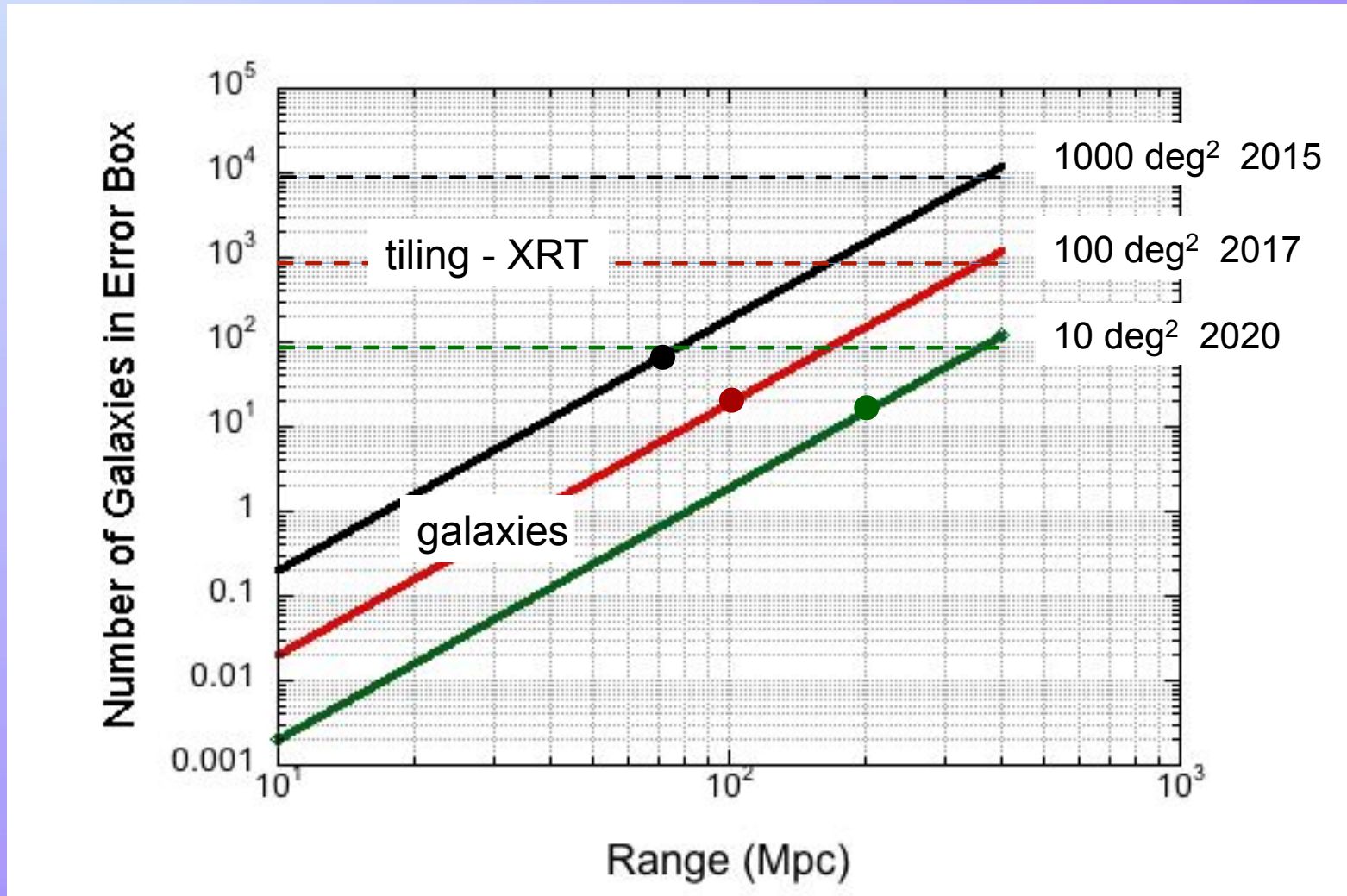
... and with 5 sites



c. 2020

Fairhurst (2011)

Large Error Boxes – Galaxy Strategy



galaxies to cover 50% of light
XRT FoV = 0.11 deg²

Kanner, Gehrels+ 2012