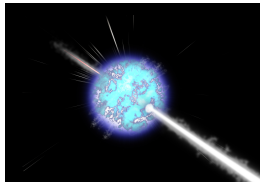


Swift Results and Advice for SVOM

Neil Gehrels

NASA-GSFC

SVOM Workshop

April 11, 2016

Outline

→ Swift – SVOM parameter comparison

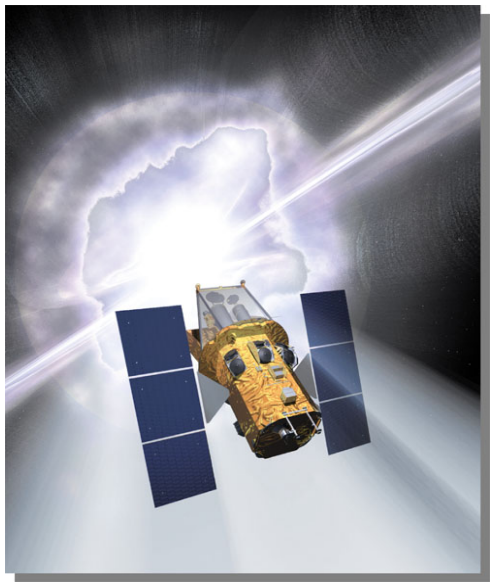
→ Time Domain Astronomy with Swift

→ Gamma ray bursts

→ GRB 160408A & 160410A

→ Swift lessons-learned advice for SVOM

Swift



SVOM

Parameter Comparison

Swift	*SVOM*
Wide-Field Prompt	
BAT 1.4 sr 15 – 150 keV code aperture 5200 cm^2 CZT	**ECLAIRs** 2 sr 4 – 150 keV code aperture 1024 cm^2 CdTe
	GRM 3 x 2 sr 15 keV – 5 MeV 3 x 280 cm^2 NaI common FoV 2 sr rough localization

Parameter Comparison

Swift	*SVOM*
X-ray Follow-up	
XRT	**MXT**
24 arcmin FoV (0.16 deg^2)	1 deg^2
Wolter I optic	micro-channel optic
0.3 – 10 keV	0.2 – 10 keV
120 cm^2 CCD	45 cm^2 pn-CCD
Optical Follow-up	
UVOT	**VT**
17 arcmin FoV	26 arcmin FoV
30 cm Ritchey-Chrétien	40 cm Ritchey-Chrétien
170 – 600 nm	400 – 950 nm

+ GWAC wide-field ground $m_V = 16$
+ Chinese GFT narrow-field robotic ground $m_R = 21$
+ French GFT narrow-field robotic ground $m_J = 18$

Swift - Multiwavelength Time Domain Observatory

GRBs

>1000 GRBs, most with arcsec positions

Rapid X-ray and UVOT on-board follow-up

Prompt notifications to other observatories

Non-GRBs

>1400 TOOs in 2015 (SN, AGN, CVs, comets…)

Joint science with aLIGO, *NuSTAR, Fermi*,
Kepler, AstroSat, …

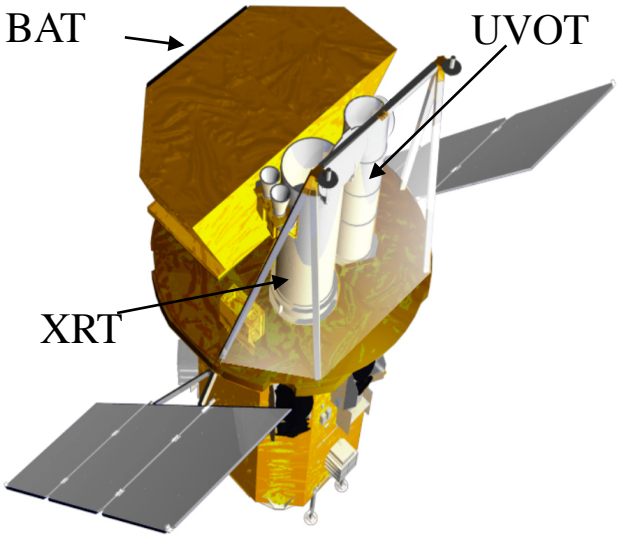
All-sky hard X-ray monitor (mCrab sensitivity)

Observatory Health

Excellent health. No consumables

Orbit to >2025

Best-guest lifetime through 2019



Launch November 2004

Swift Game-Changing Discoveries

2005: **Short burst mystery** solution. Binary neutron star mergers

2005: Flares & bright afterglows in GRBs

2008: **Shock breakout** from Type Ib supernova

2008: Naked-eye GRB from reverse shock in jet

2009: Discovery of **2 GRBs at z>8**

2010: Galaxy mergers in hosts of absorbed AGN

2011: **Tidal disruption flare** of star eaten by massive black hole

2012: Star formation rate and metallicity evolution to z>5

2012: Discovery of very young (2500 year old) supernova remnant

2013: Discovery of **ultra-long class of GRB**

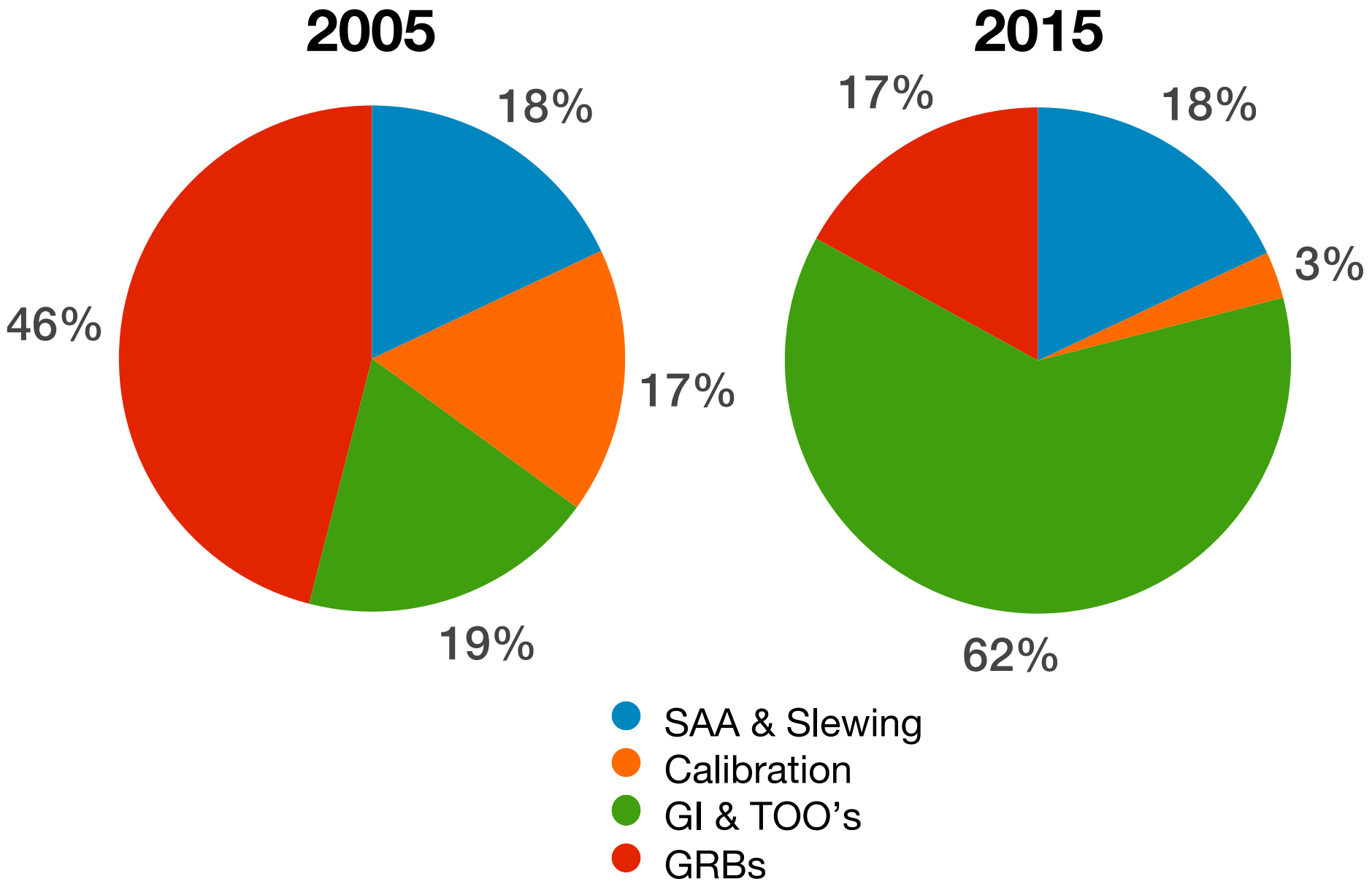
2013: Evidence for **kilonova** emission in short GRB

2014: Two UV color-classes of Type Ia supernova

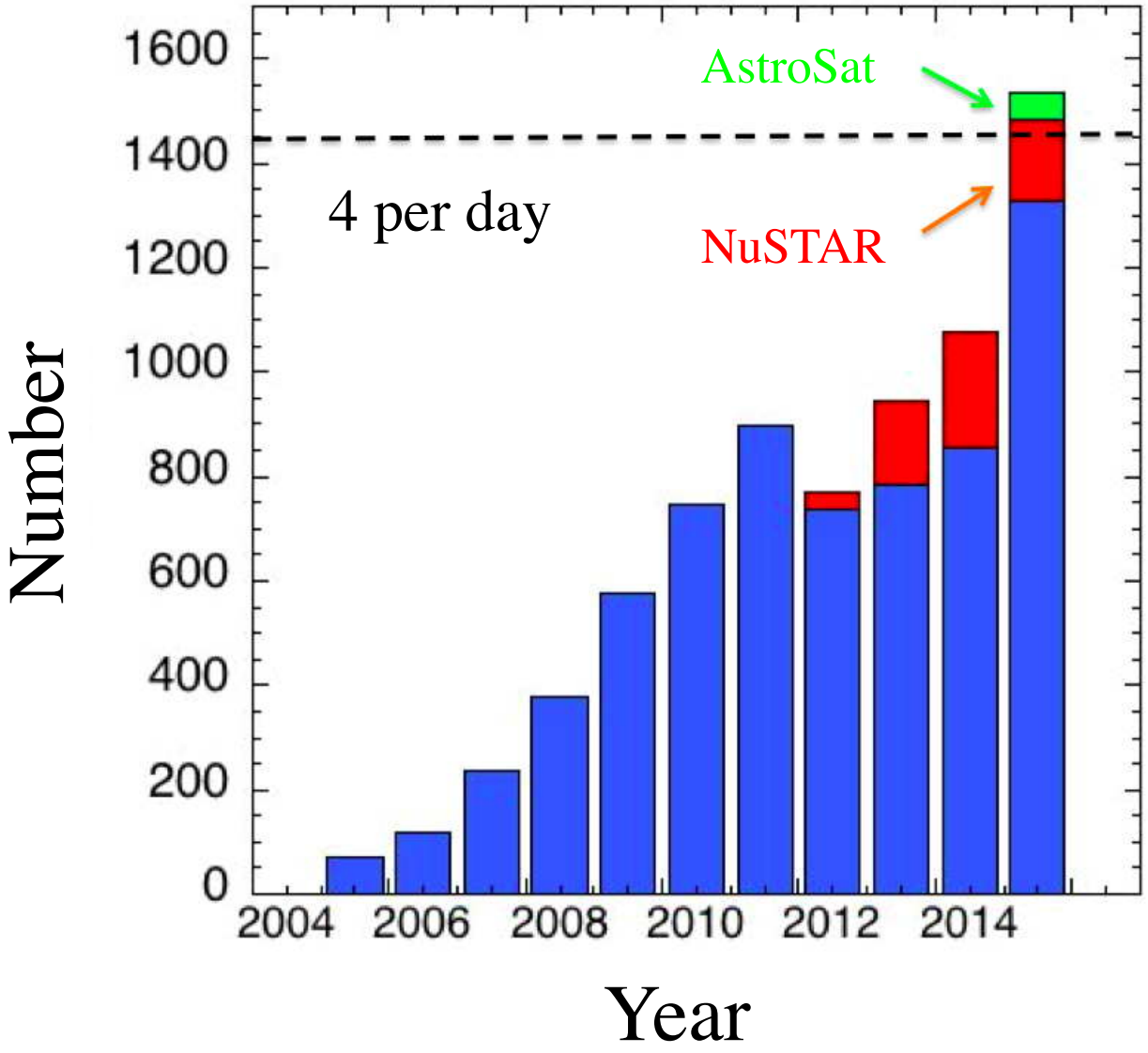
2015: **UV Pulse** from a young Type Ia supernova

2015: Luminous supernova from an ultra-long GRB

Evolving Observing Time



Approved TOOs Per Year



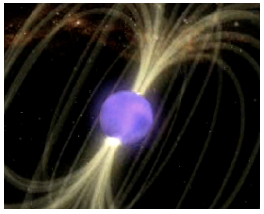
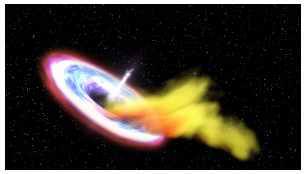
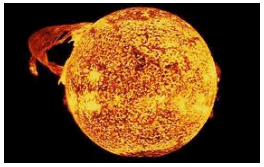
Synergies with Other Missions

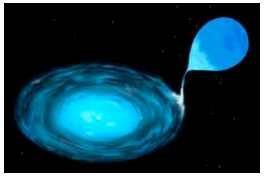
- NuSTAR: Swift obs of every NuSTAR field, NuSTAR obs of BAT sources
- Fermi: Follow-up of GRBs, blazars, unidentified sources, ...
- aLIGO/Virgo: Most active follow-up satellite. Crucial XRT/BAT coverage.
- Hitomi: Calibration / commissioning. UVOT data for all pointings
- Kepler: Swift observations of deep Kepler field for AGN studies
- JWST: Swift is only mission capable of providing high-z GRB triggers
- TESS: Swift follow-up of TESS transients
- AstroSat (India): Calibration / commissioning. Future joint observations
- INTEGRAL: Follow-up of transients, GRBs
- MAXI: XRT localization of transients, GRB follow-up
- Chandra, HST & XMM: Synergistic TOO programs & deep observations
- TeV observatories: Joint observations of blazars, Be binaries, ...
- IceCube & ANTARES : Follow up of neutrino triggers
- EVLA, ALMA & LOFAR: Triggers for GRB searches, transients
- Gaia: Follow-up triggers, joint program in time domain astronomy

X-ray / γ-ray Transients

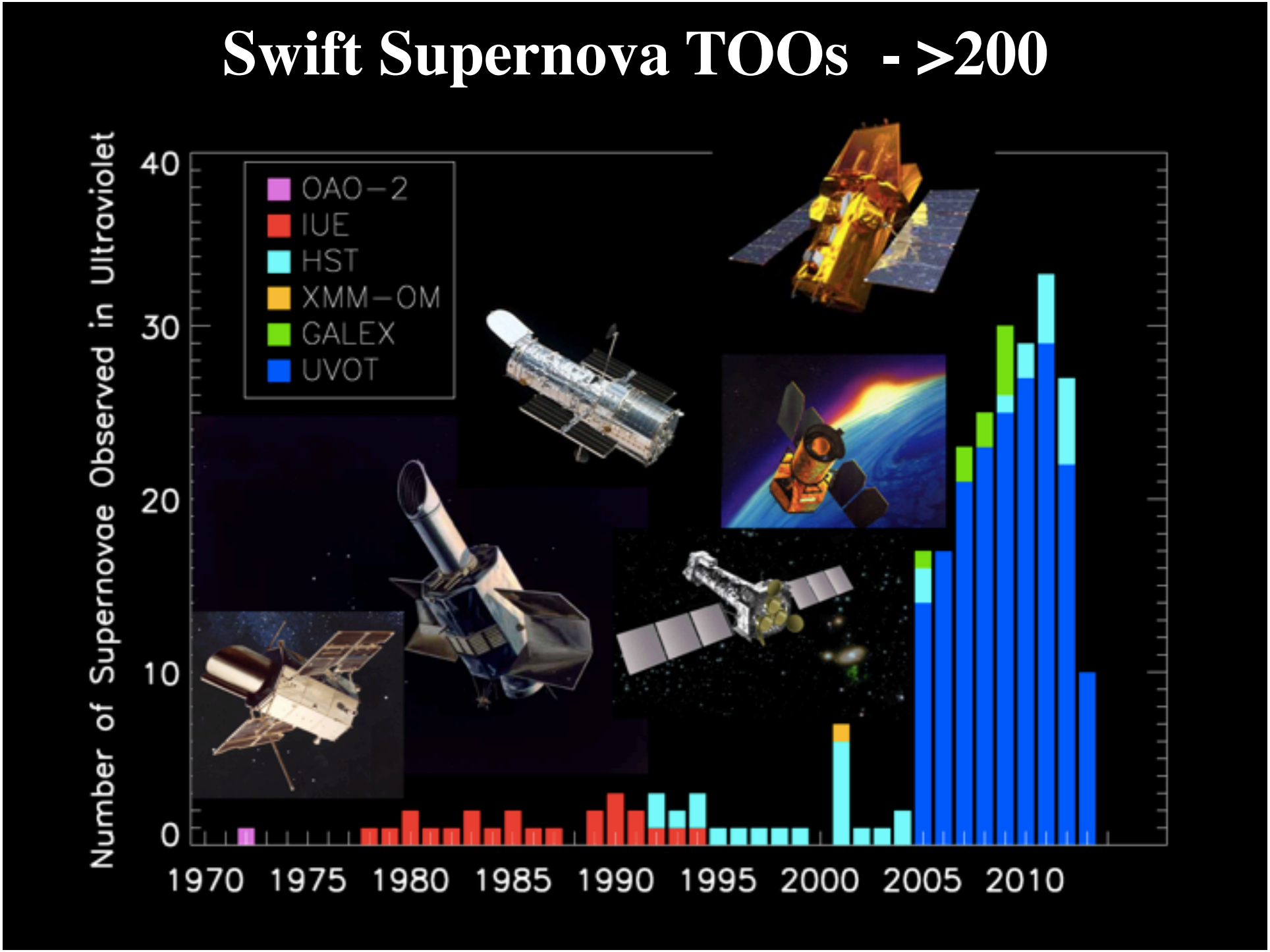
Object	Source - Energy
lightning	E field - 10^{10} erg
γ-ray burst	gravity - 10^{52} erg
magnetar	B field - 10^{44} erg
tidal disruption	gravity - 10^{52} erg
stellar flare	B field - 10^{32} erg
supernova/nova	nuclear - 10^{49} erg
accreting BH / NS	gravity - 10^{36} erg/s
AGN	gravity - 10^{43} erg/s



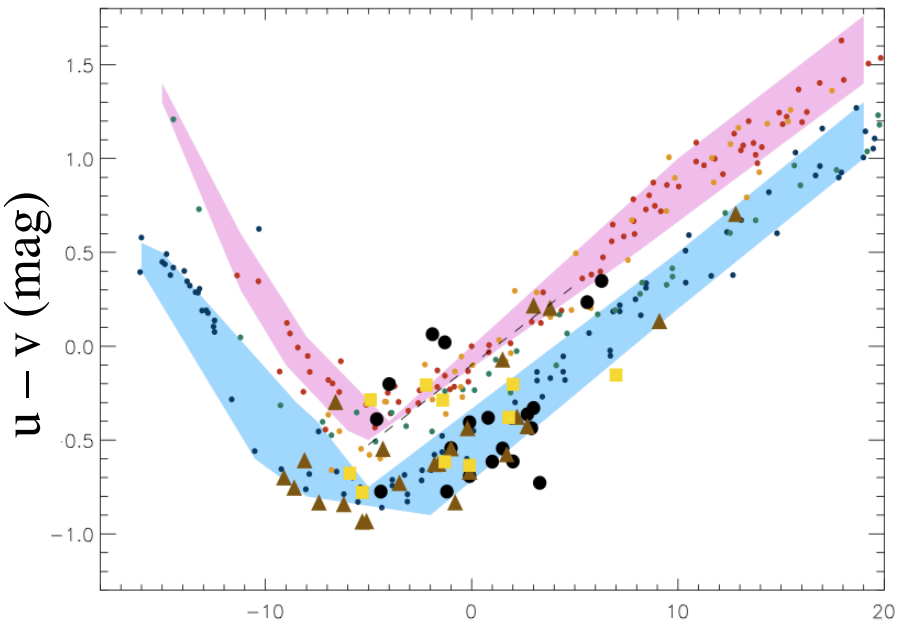







Swift Supernova TOOs - >200



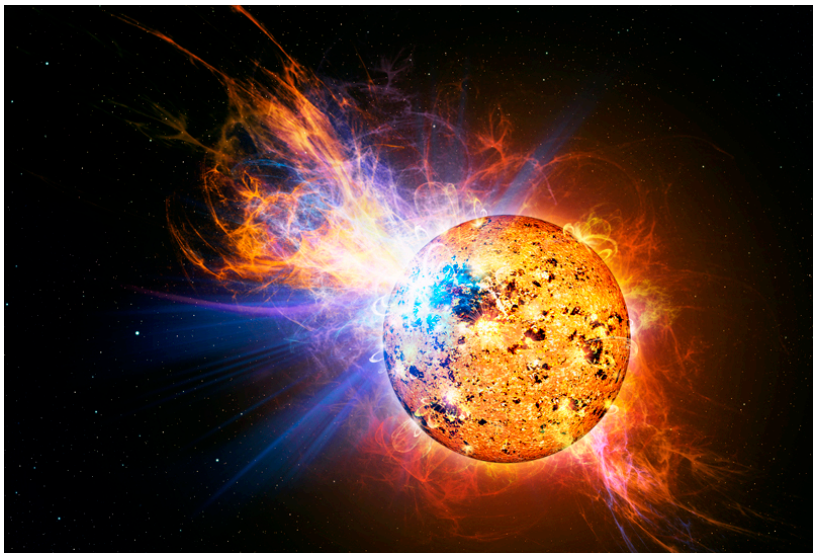
Swift Supernova Program



Milne+ 13

- SN Ia are standard candles for cosmology
- Optical observations at z=1 are rest-frame UV
- UV data have scatter which adds uncertainties
- UVOT finds hints that scatter is due to two distinct color classes with different extinctions

DG CVn Large Stellar Flare



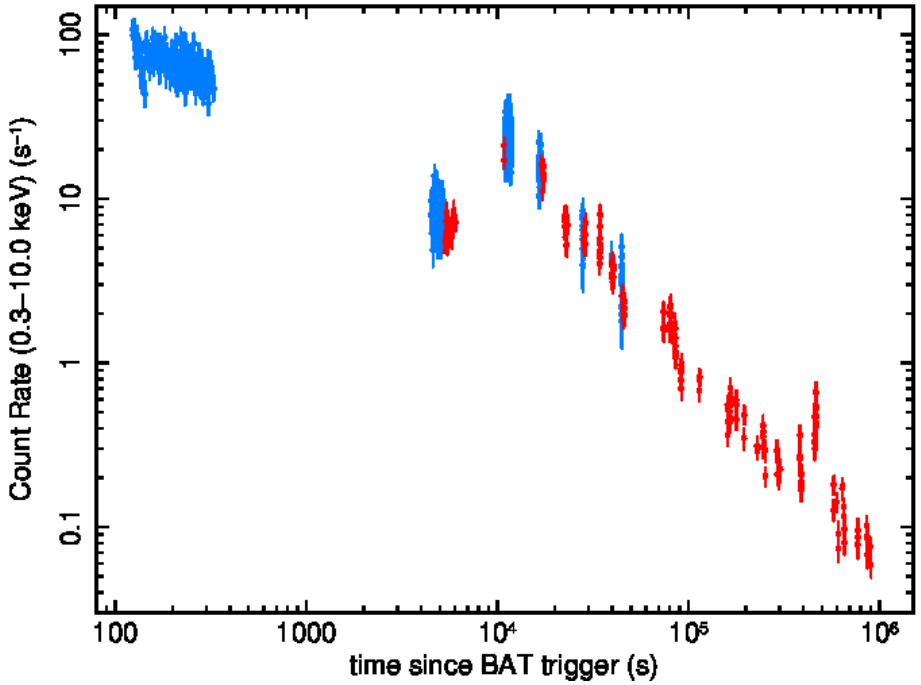
Large X-ray "super-flare"

Brighter than star luminosity

10,000x largest solar flare

Young red dwarfs at 18 pc

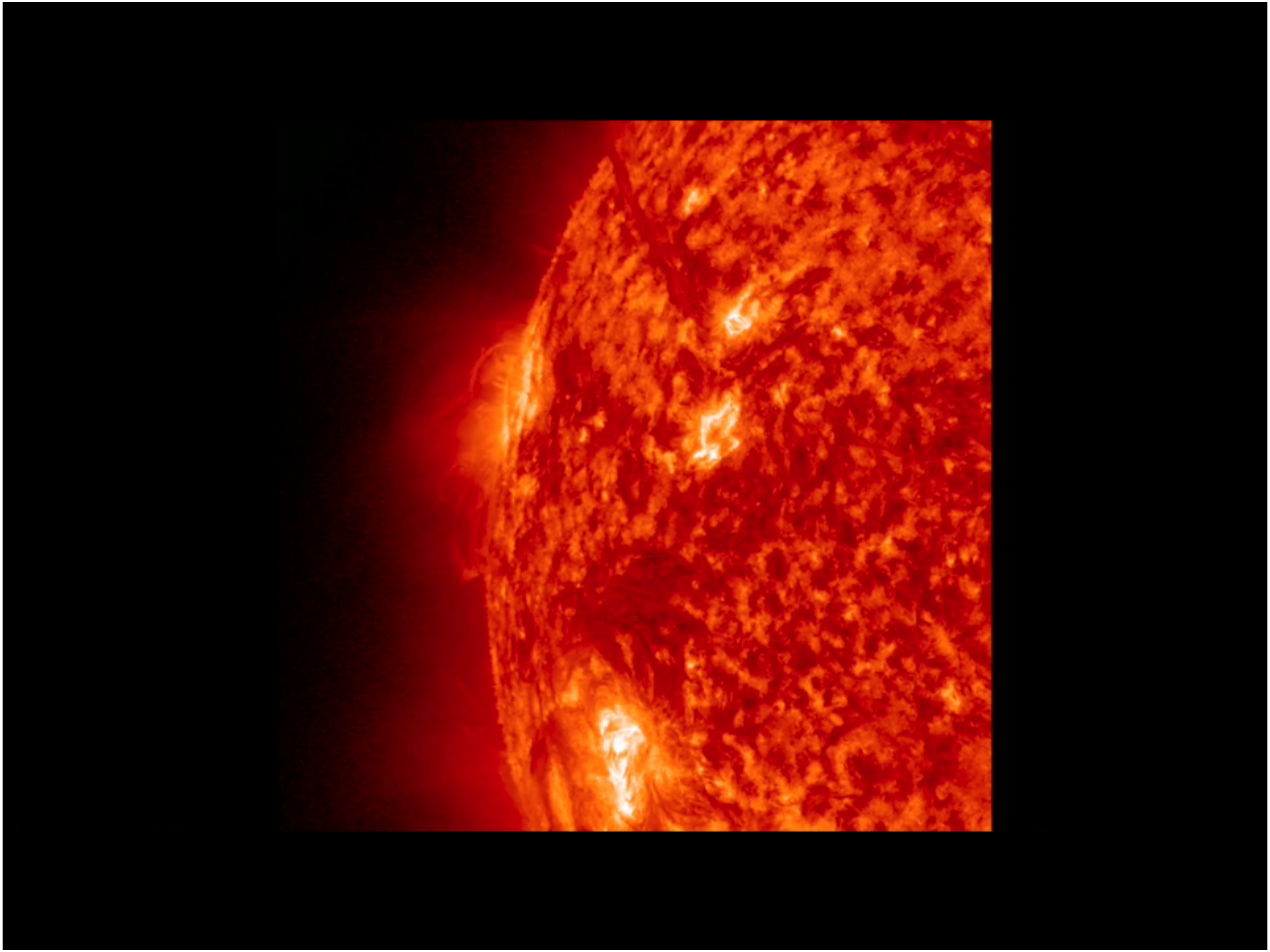
DG CVn - April 23, 2014



previous events: EV Lac, II Peg

Power source:
B field reconnection

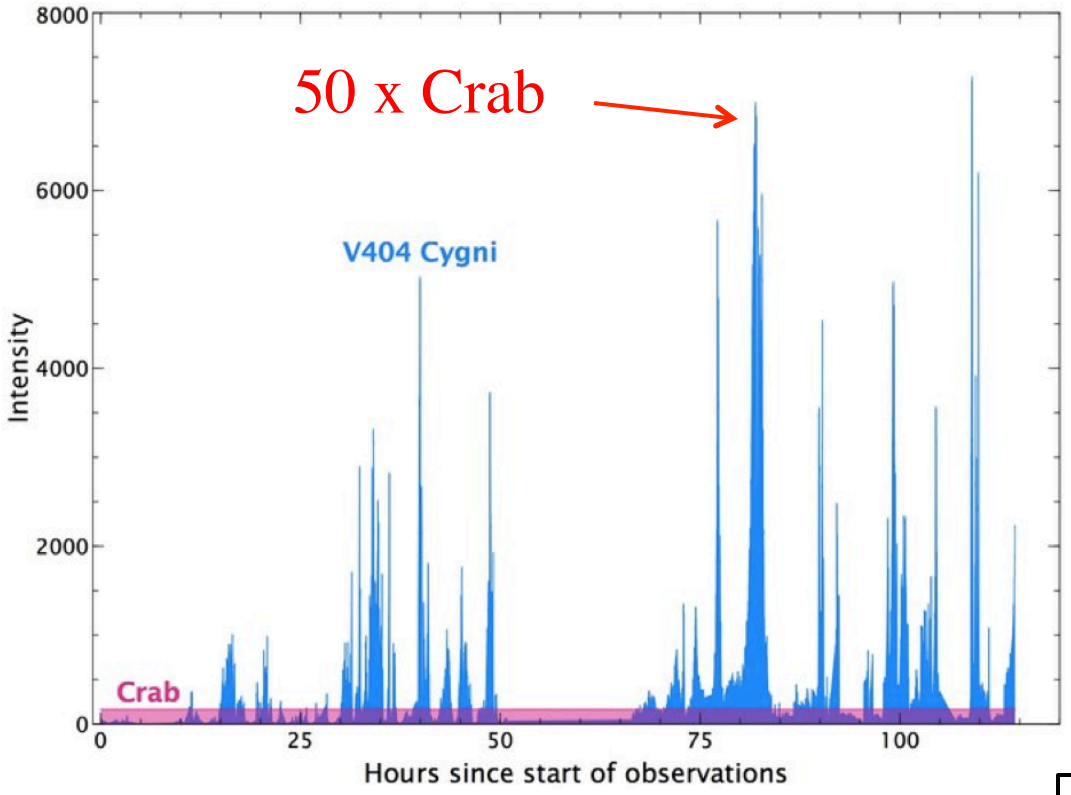
Drake, Osten, Page, Oats '14



V404 Cygni – July Outburst

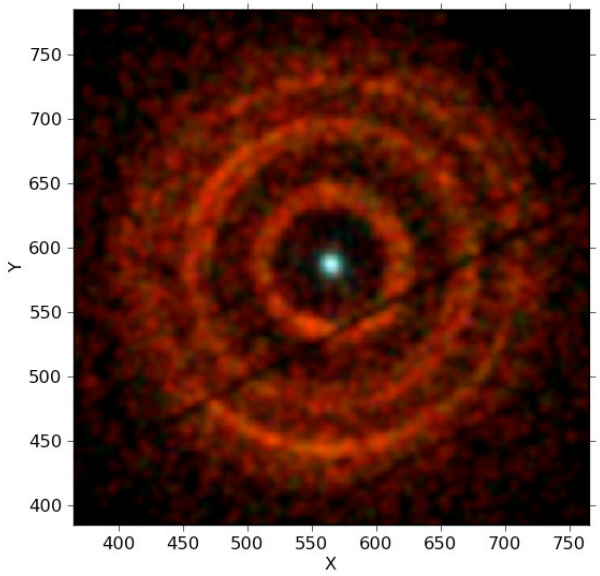
X-ray nova with BH accreting from companion star

INTEGRAL Hard X-ray Lightcurve



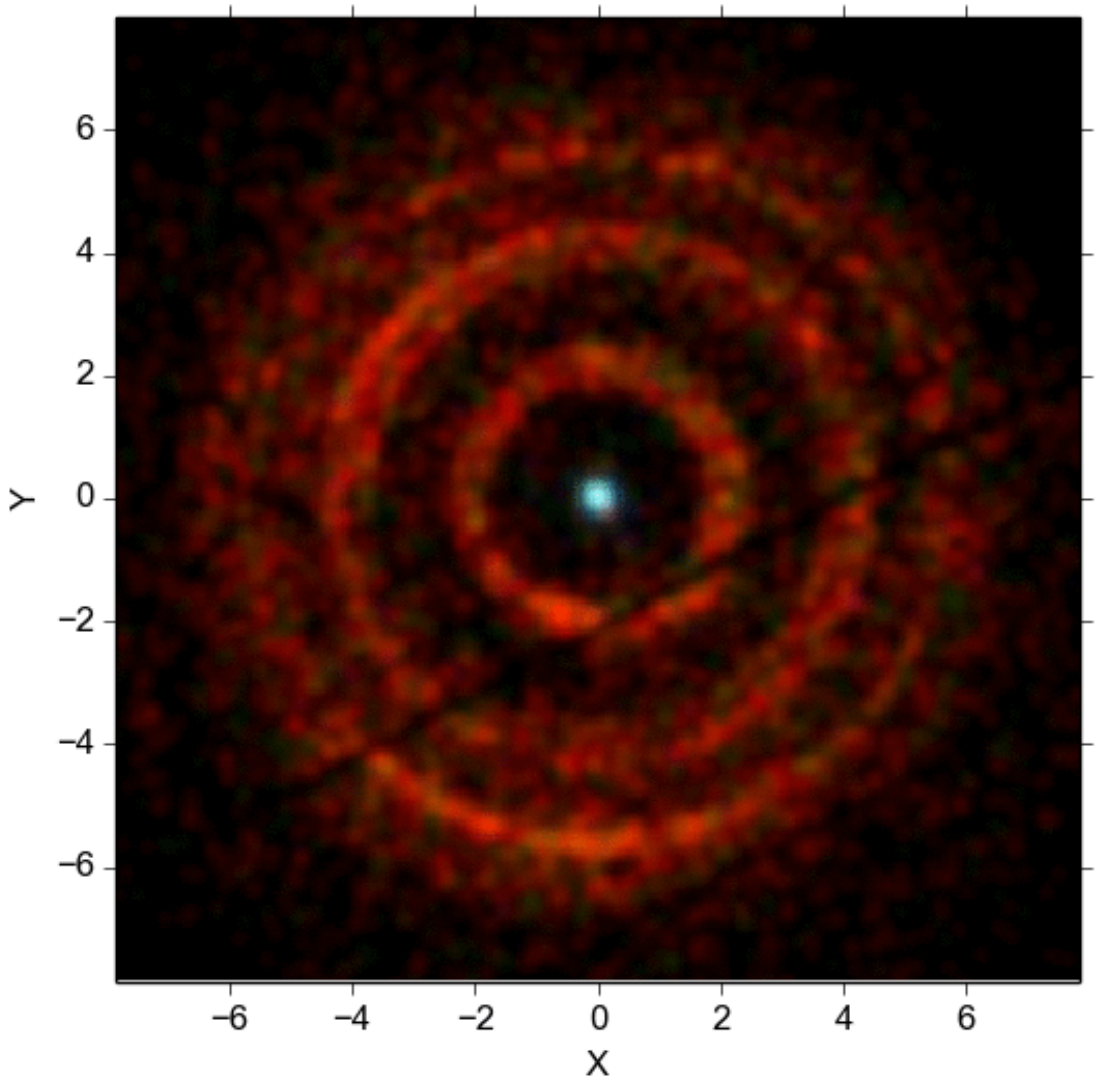
Kuulkers & Rodriguez

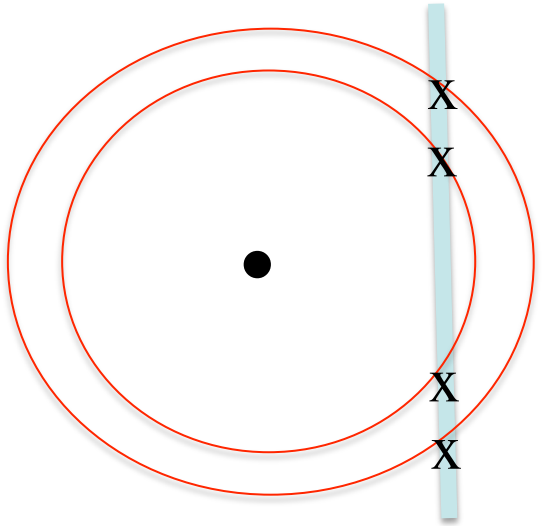
Swift XRT Image



Beardmore

Power source:
Gravity





dust sheet

Tidal Disruption Event - Sw J1644+57

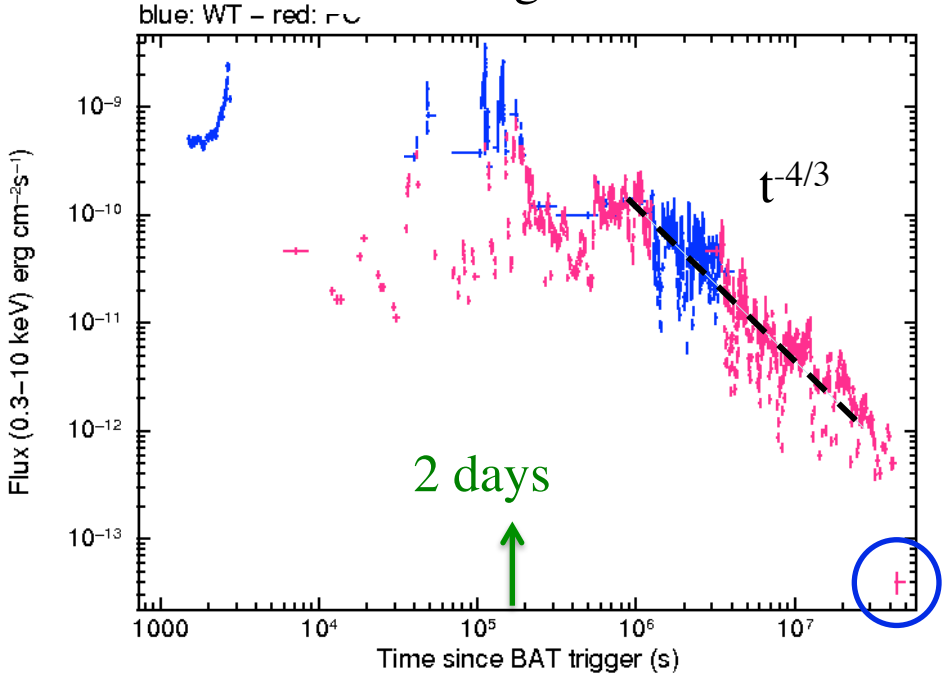
Highly erratic γ-ray and X-ray light curve, March 28, 2011

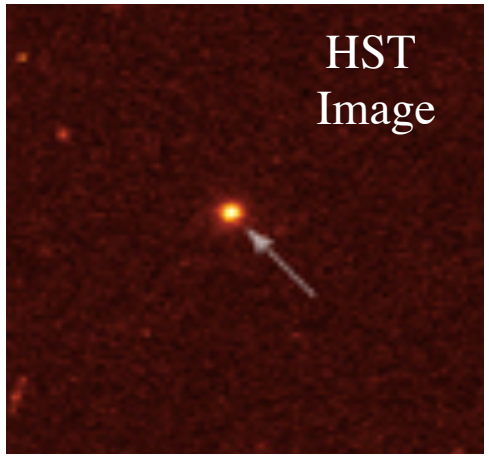
Like a GRB, but lasting 2 days instead of 20 second

Tidal disruption event beamed at us

$E \sim 10^{51}$ ergs $\quad M_{BH} = 10^6 - 10^7\ M_{solar}$

Swift Light Curve

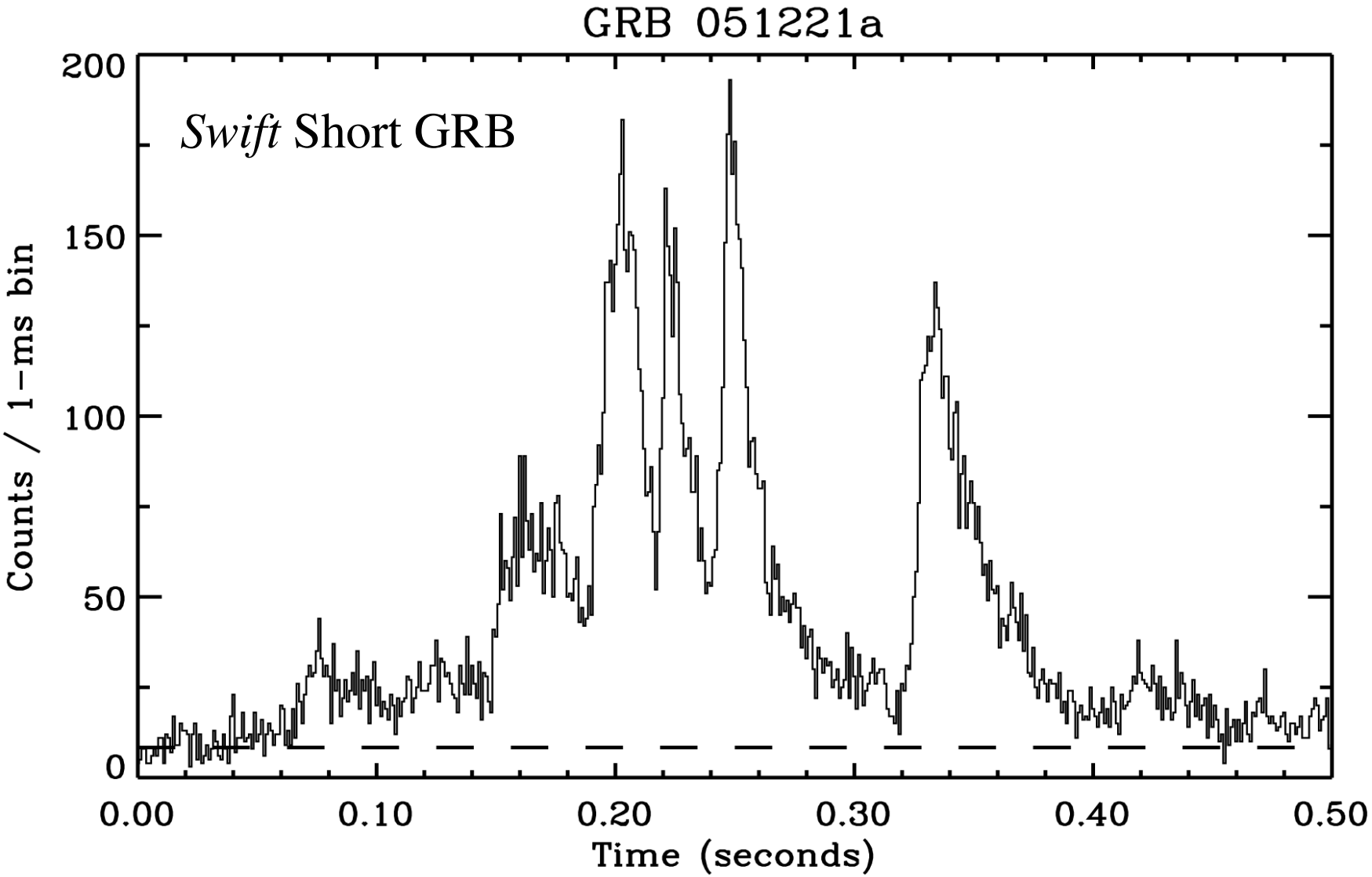




Center of galaxy at z=0.35

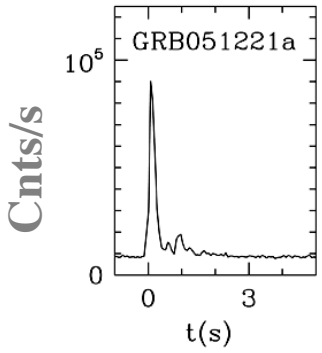
Bloom+, Burrows+, Levan+ ... '11

GRB Variability



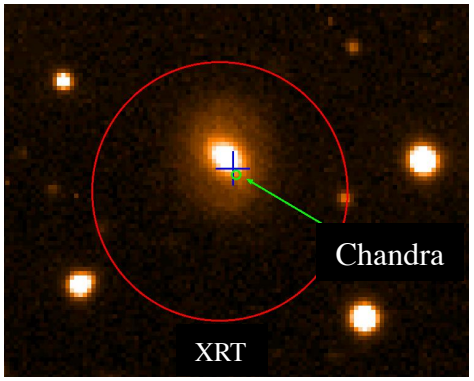
Short vs Long GRBs

Short GRB

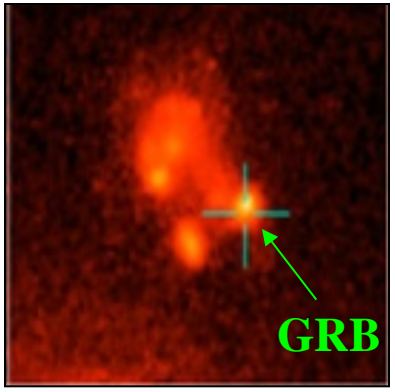


100 Swift short GRBs

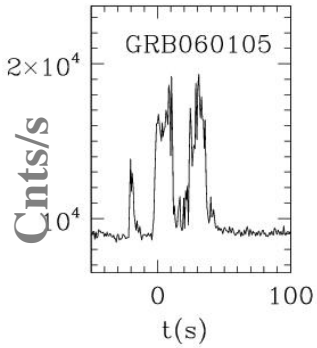
GRB 050724 - *Swift* elliptical host



GRB 020903 - *SAX* SF dwarf host



Long GRB

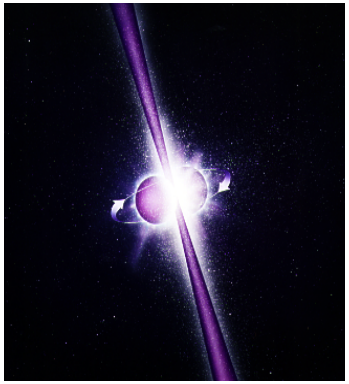


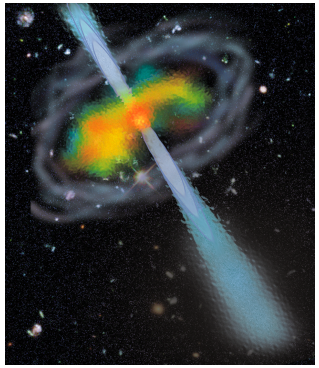
>1000 Swift long GRBs

In non-SF and SF galaxies

No SNe

Possible **merger** model





BH

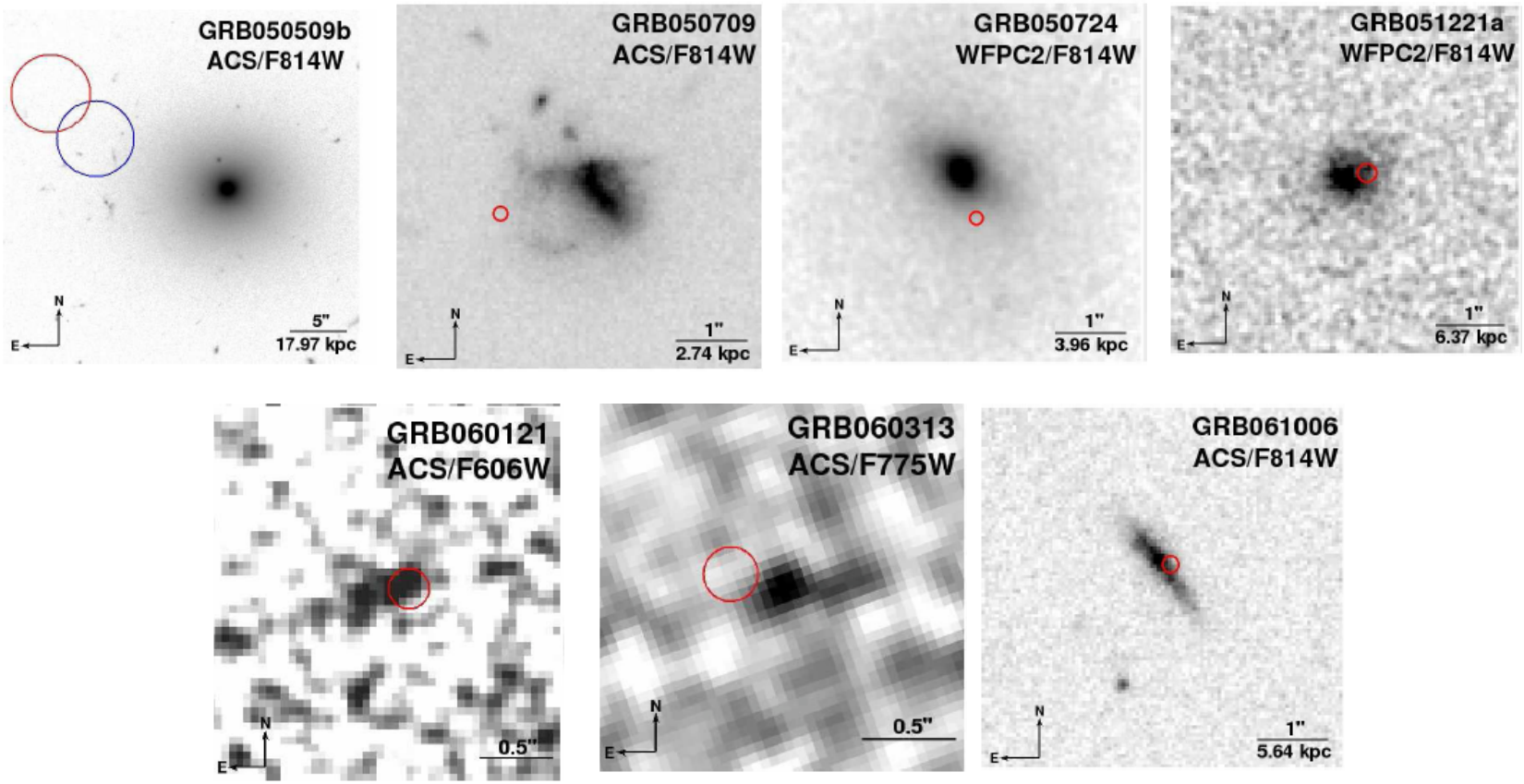
Gehrels, Ramirez-Ruiz & Fox '09

In SF galaxies

With SNe

Collapsar model well supported

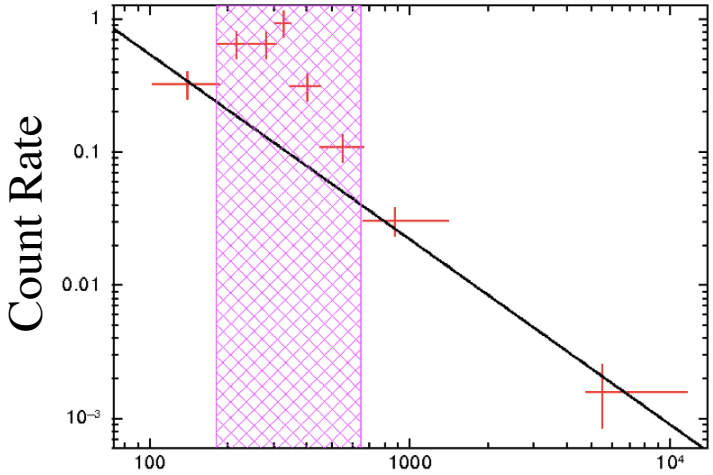
Swift Short Burst HST Images



Fong, Berger & Fox '10

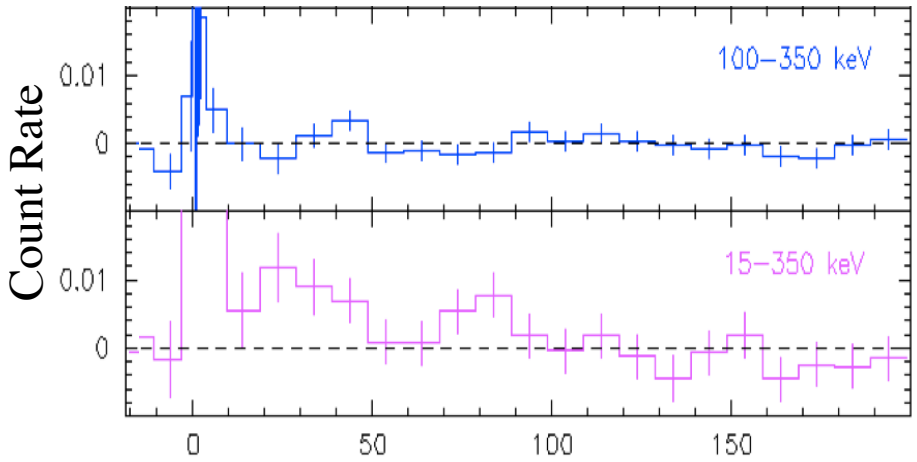
Short GRBs 160408A and 160410A

GRB 160408A
X-ray Flare



200 500 s

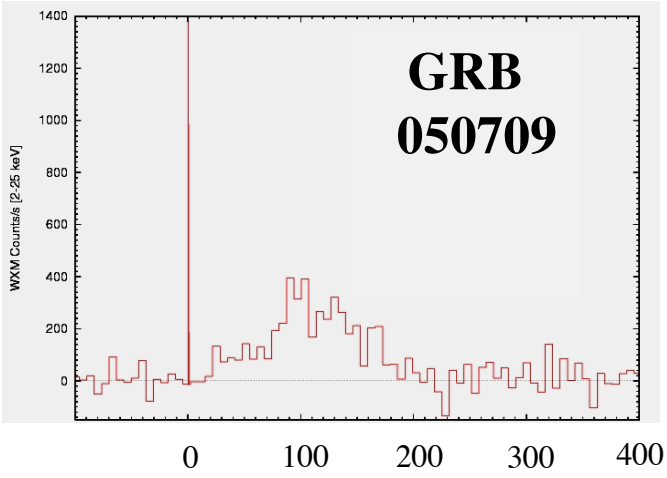
GRB 160410A
Extended Emission

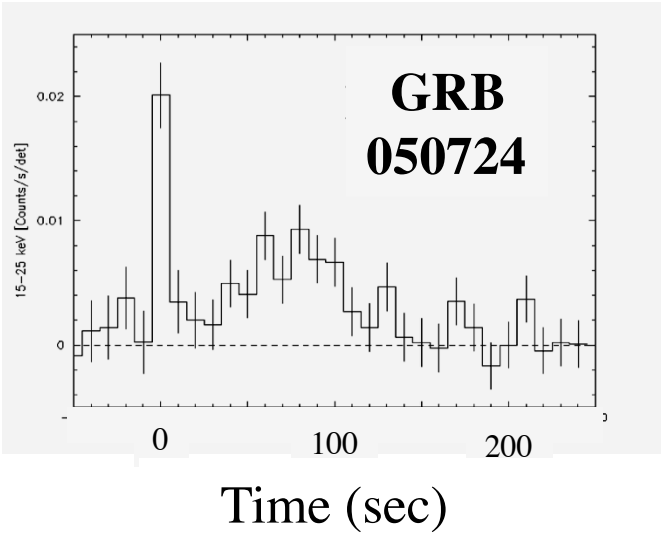


Gemini afterglow

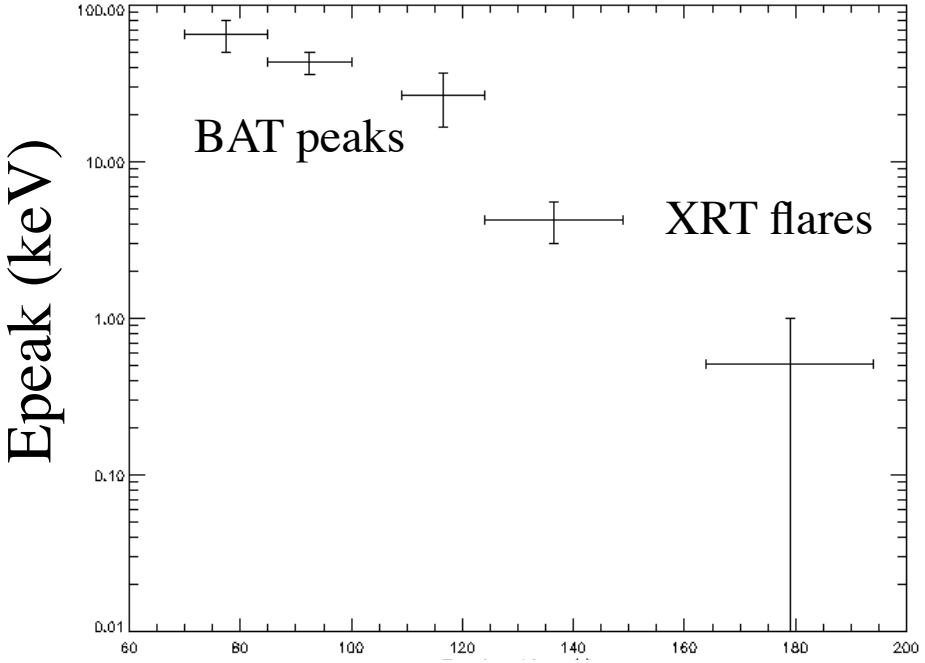
VLT X-Shooter z=1.717
UVOT detection

Earlier Examples of Extended Emission





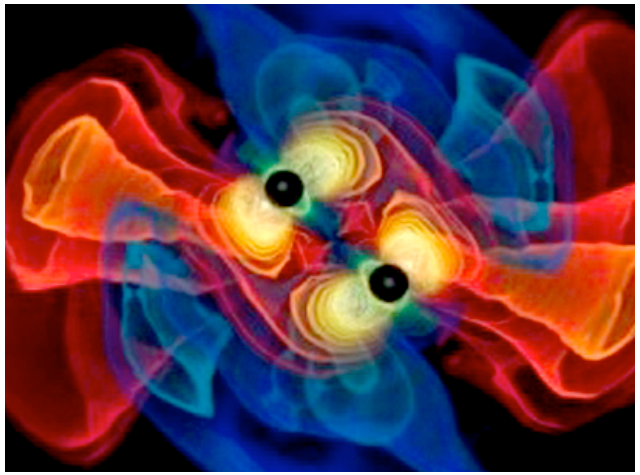
GRB 060714
Flare spectral evolution



Krimm+ '07

Short Burst Merger Model

Future: aLIGO-VIRGO GWs



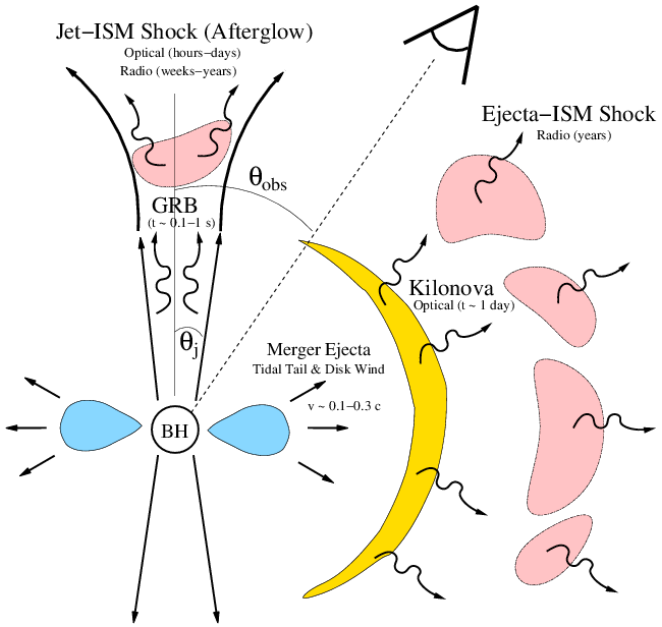
GW 150914 first detection was BH-BH merger

Bonanza of data from GW + EM counterparts expected for NS-NS or NS-BH mergers

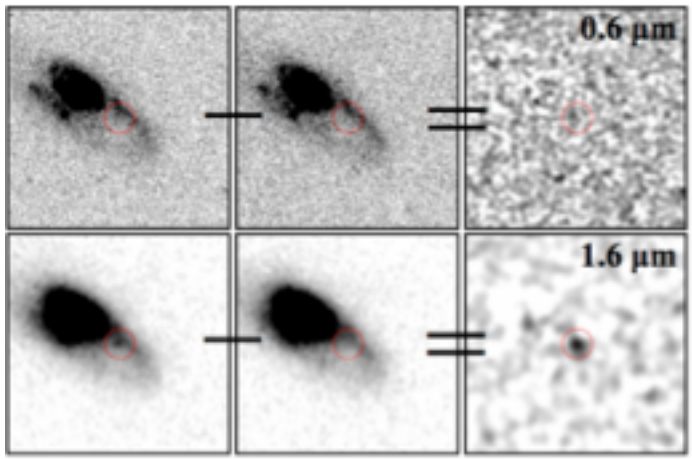
GRB or jetted afterglow will be rare

Great hope is isotropic kilonova emission

Swift GRB 130603B evidence for kilonova



Swift GRB 130603B
Red Lingering Afterglow

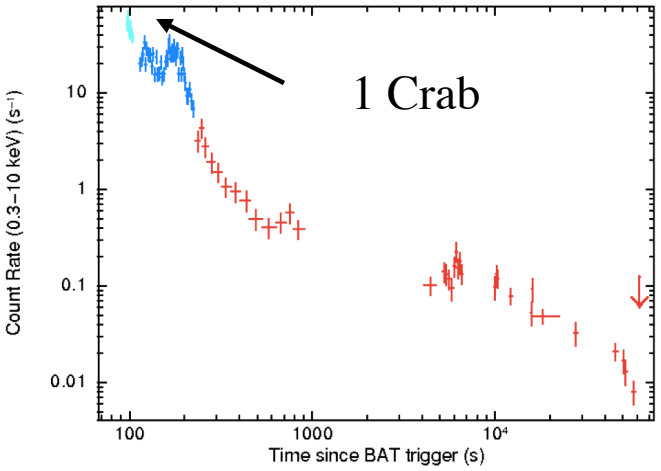


Tanvir+ '13

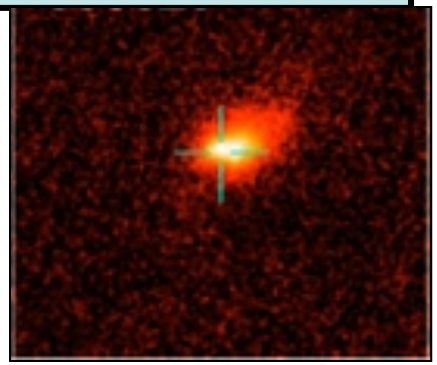
Long GRBs Seen to High z

z	Look-Back Time (Gyr)	GRB	Optical Brightness
9.4	13.1	090429B	K = 19
8.2	13.0	090423	K = 20
~8	13.0	120923A	
7.5	13.0	100905A	H ~ 19
6.7	12.8	080813	K = 19
6.3	12.8	140515A	
6.3	12.8	050904	J = 18
6.2	12.8	120521C	
5.6	12.6	060927	I = 16
5.3	12.6	050814	K = 18
5.11	12.5	060522	R = 21

X-ray Lightcurve
GRB 150711A



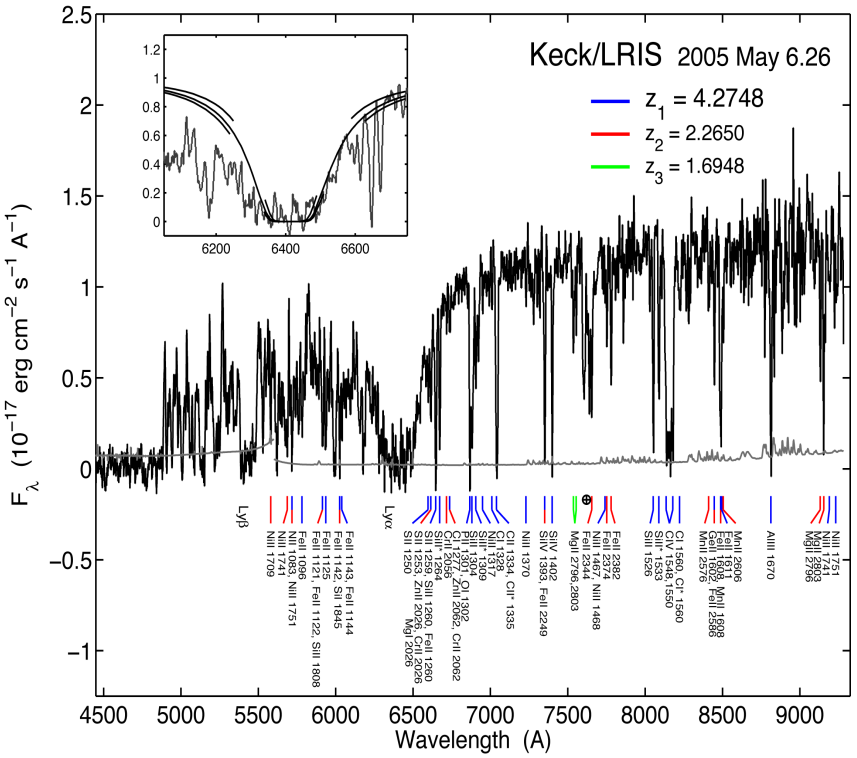
Most luminous source at all wavelengths



HST

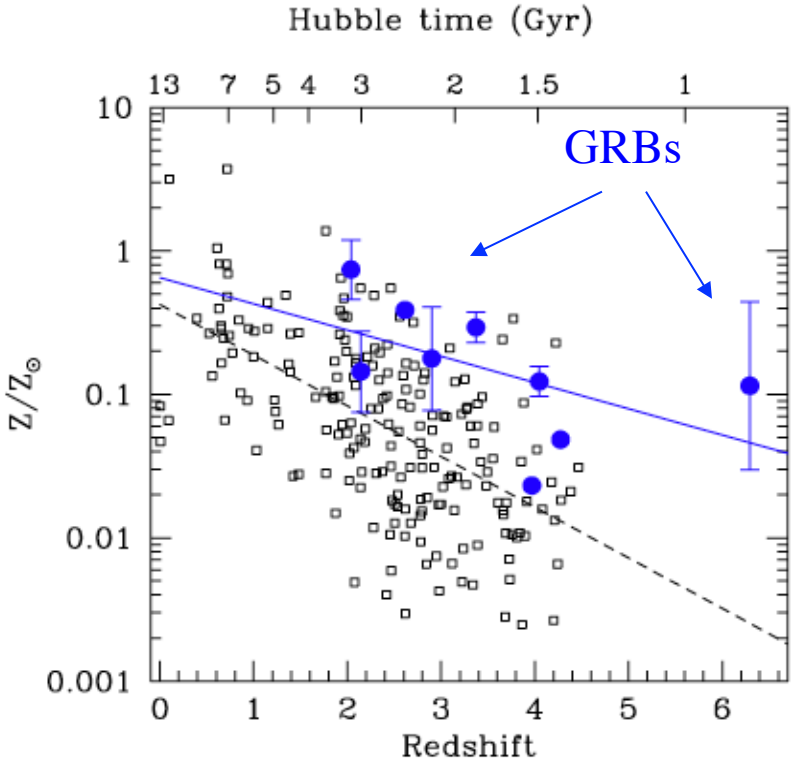
Tools to Study the High-z Universe

Swift GRB 050505
z=4.2 12.2 Gyr

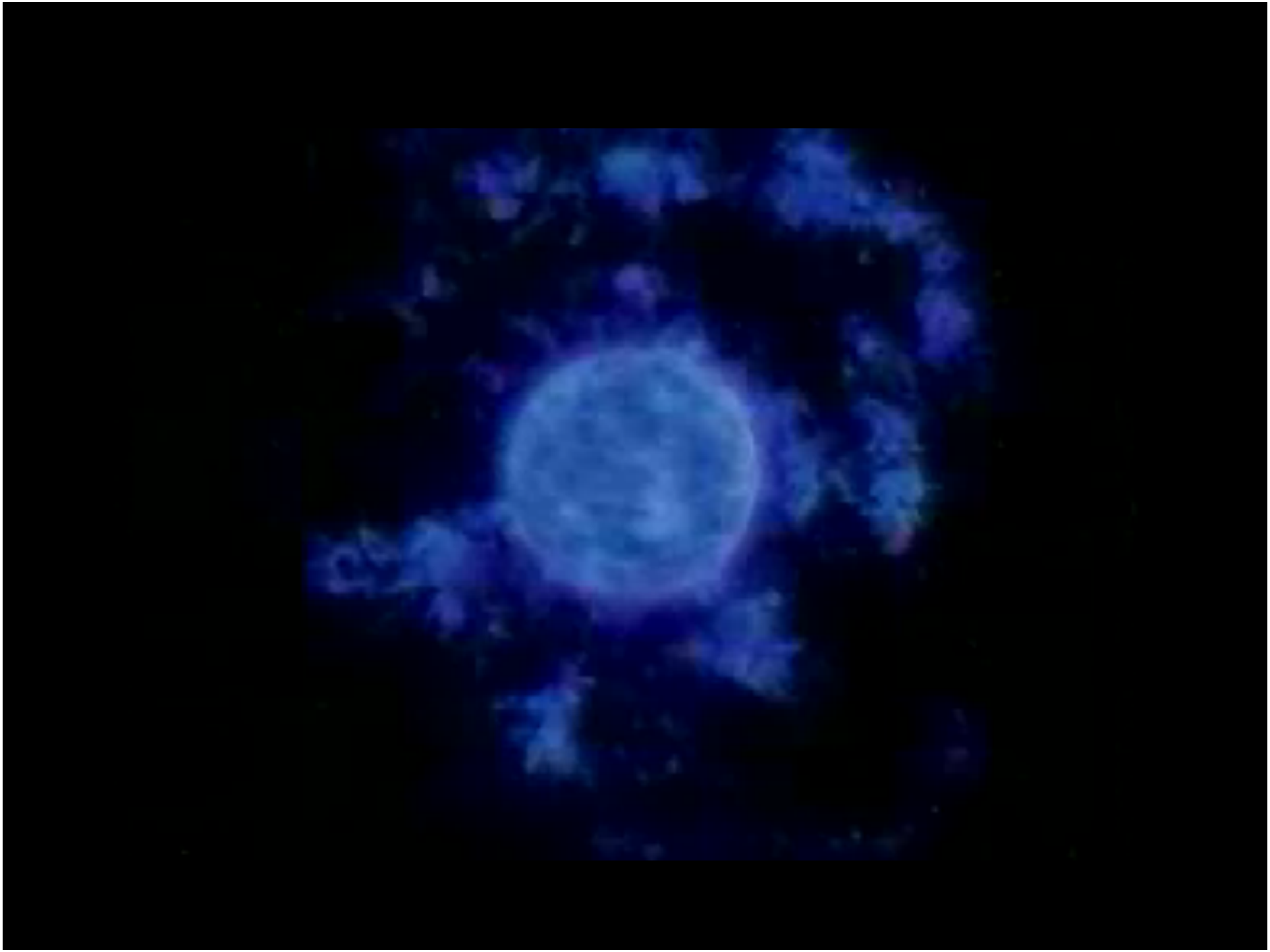


Berger+ '06

Metallicity



Savaglio '06

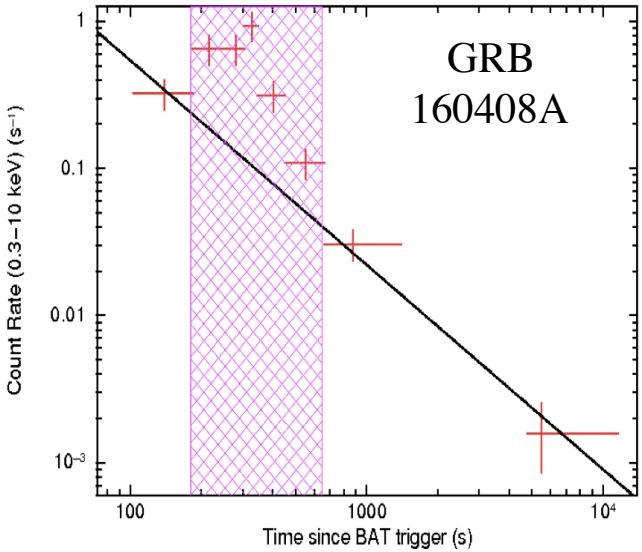


Advice for SVOM #1

It can be hard to tell at trigger time if a GRB will be interesting.

- Set up criteria to determine how high a priority to set for afterglow observations
  - Optical detection
  - Hints of high redshift (VT or ground)
  - Short GRB, ultralong, XRF
  - Bright, long, flaring X-ray afterglow
  - Position on sky (nearby galaxy)

Short GRB with X-ray flare



- Have a process for evaluating and altering the criteria
- Have good connections with multiwavelength – multimessenger communities for evidence of interesting detections to feed into prioritization

Advice for SVOM #2

Breakthroughs in understanding of Swift transients often comes from community observations. Open communications is important.

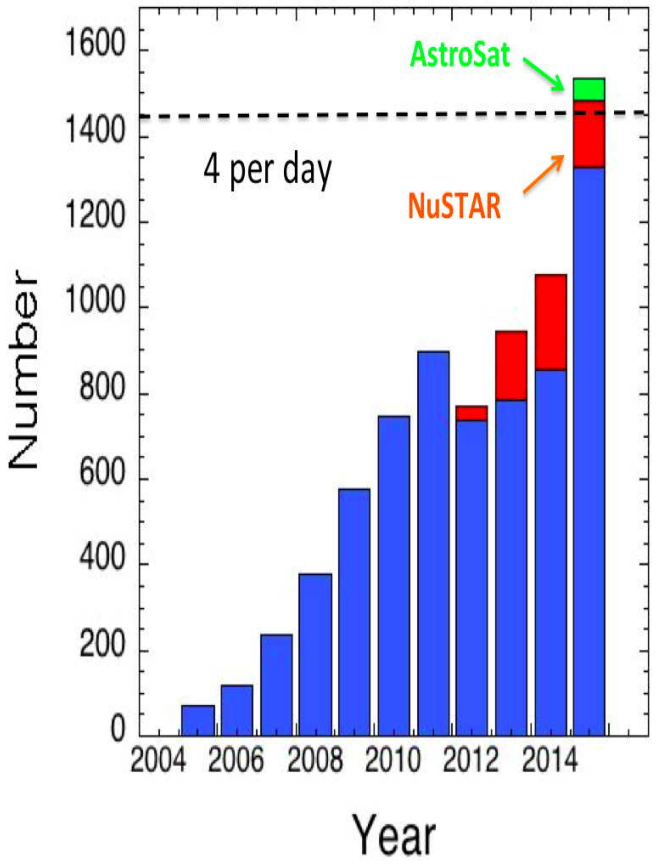
- Swift efforts to "organize" follow-up team had only modest success
  - LIGO-Virgo found greater success
- Good relations between SVOM team and follow-up observers beneficial
- For Swift, observers joined follow-up team as collaborators

Advice for SVOM #3

The science return from Swift TOO observations is greatly increasing

- First years of GRB observations filled the observing time as new Swift capabilities opened discovery space
- SVOM will experience this also with softer ECLAIRs trigger, redder VT and ground dedicated telescopes
- Swift team decided to spend less time on GRBs in later years as TOO pressure increased
- Efforts to augment SVOM TOO capabilities are underway

Swift TOO Rate



Advice for SVOM #4

The Swift burst response systems has worked well over 11 years:

- Telecons immediately follow triggers with **instrument experts** and **burst advocates** calling in
- BAs keep track of Swift and ground data and represent burst on later telecons
- Daily "9am" telecon held to plan Swift observations
- BAs chosen from volunteers. Rotating system among lead institutions
- SVOM might benefit from a BA system

Swift BA Wiki

Date UT	**Burst Advocate** *(Back up)*
MON APRIL 4 2016; DOY 95	00:00 - 14:00 UT **Tineke Roegiers**, *(Marissa McCauley)*, 14:00 - 24:00 UT **Daniele Malesani**, *(Michael Siegel)*
TUE APRIL 5 2016; DOY 96	00:00 - 14:00 UT **Daniele Malesani**, *(Michael Siegel)*, 14:00 - 24:00 UT **Beatriz Mingo/Andy Beardmore**
WED APRIL 6 2016; DOY 97	**Beatriz Mingo/Phil Evans**
THU APRIL 7 2016; DOY 98	**Beatriz Mingo/Andy Beardmore**
FRI APRIL 8 2016; DOY 99	**Beatriz Mingo/Phil Evans**
SAT APRIL 9 2016; DOY 100	**Kim Page**
SUN APRIL 10 2016; DOY 101	**Sarah Gibson**

Advice for SVOM #5

There can be a publication scramble following discovery observations. SVOM and community data may both be important components.

- GRB science requires open data
- SVOM publication policies that allow collaborative papers can be useful
- Rapid publication procedures can help SVOM team have discovery papers
- Good to set up collaborations with ground teams

Swift Discovery Papers

Sh**ort GRBs**
- 3 Swift team Nature papers out of 7

High-z GRBs
- Swift team members on ground-led papers

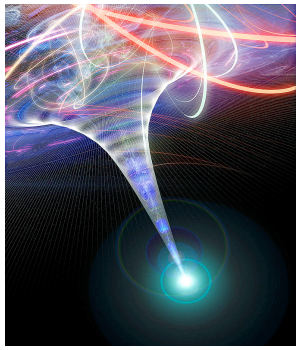
Tidal Disruption
- 10 total papers
- 4 papers w/ Swift team
- 2 papers led by Swift team

Conclusions

- The sky is rich in transients of many types.

- Swift is exploring the transient sky with unprecedented sensitivity and coverage

- Every year brings new discoveries in time domain science, including continuing GRB excitement.



- SVOM is the optimum follow-on to Swift. On line when Swift is in end-of-mission. New capabilities.