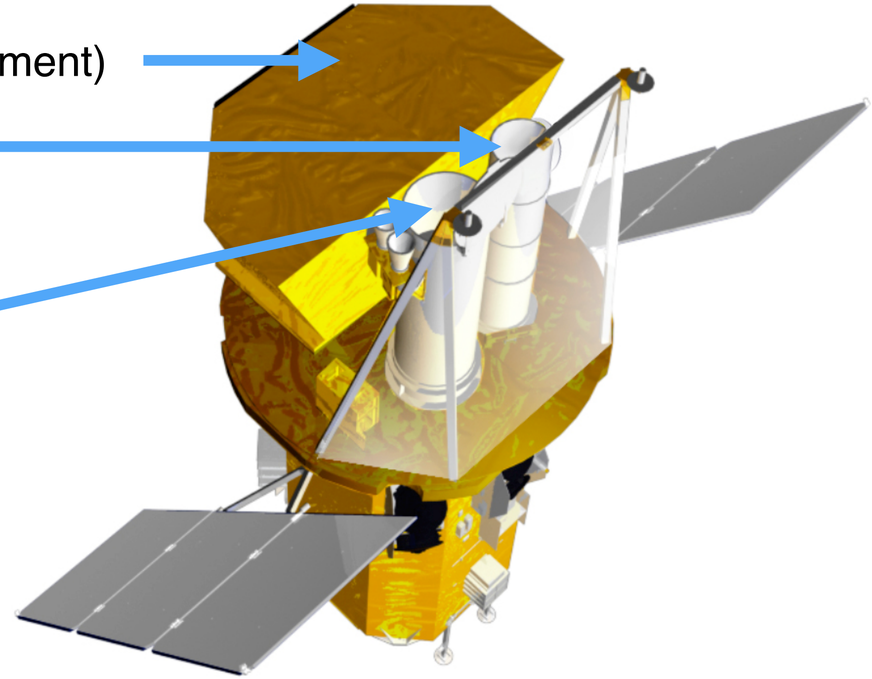
Low-latency response with *Swift*

Phil Evans

BAT (15-350 keV, trigger instrument)

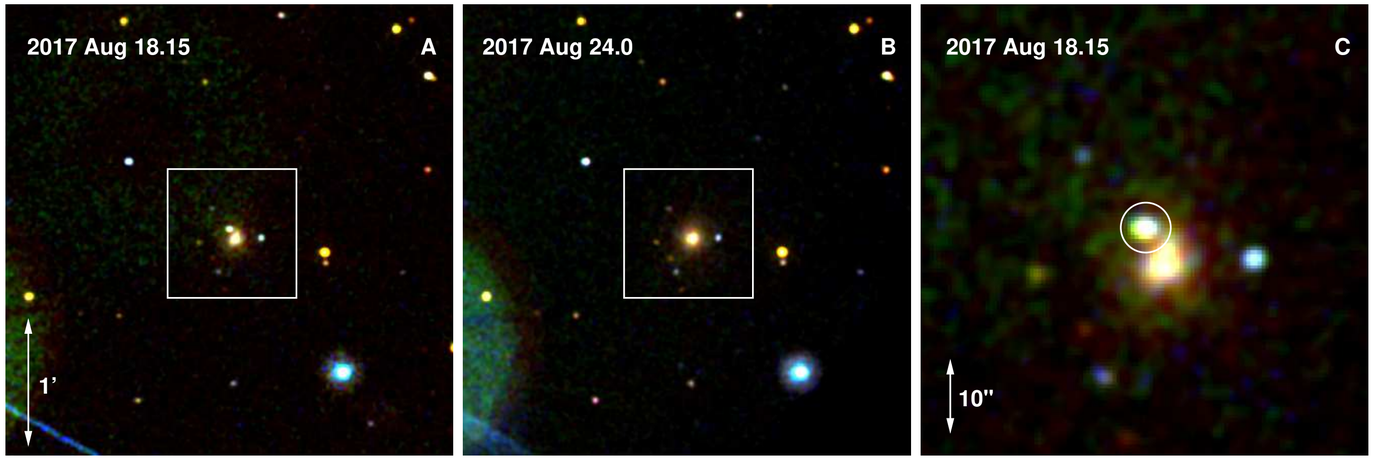
UVOT (~1900-7000 Å)

XRT (0.3-10 keV)



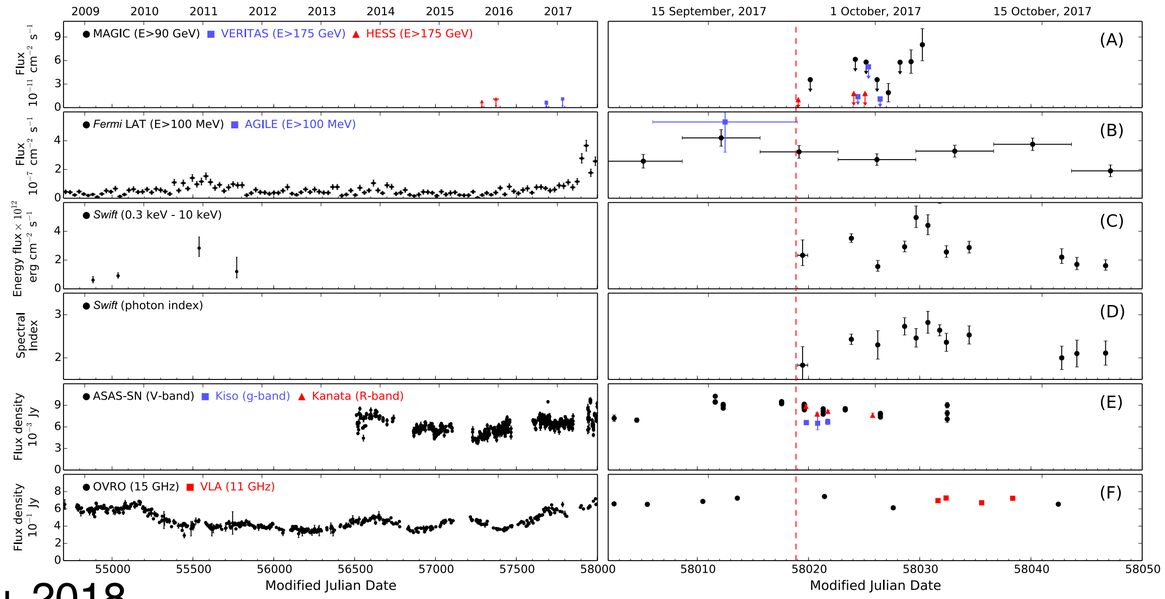
Two key Swift MMA discoveries to date

Evans+ 2017



UV discovery of GW 170817

X-ray discovery of IceCube 170922A



IceCube Collaboration+ 2018

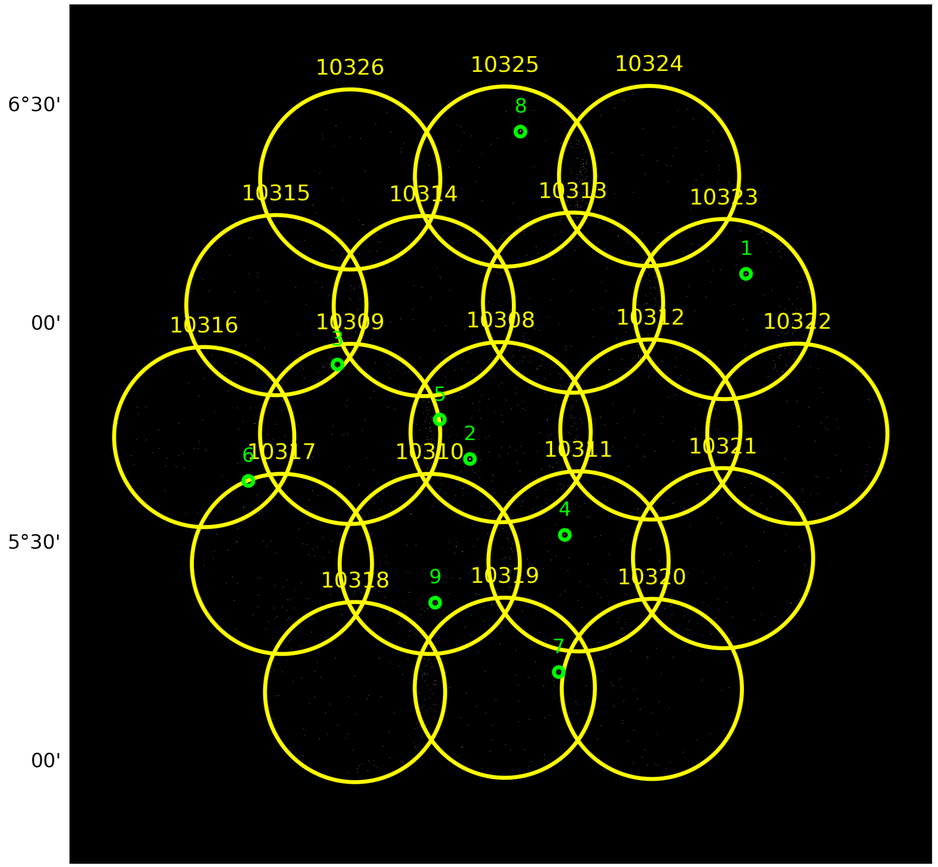
Future MMA/LL options

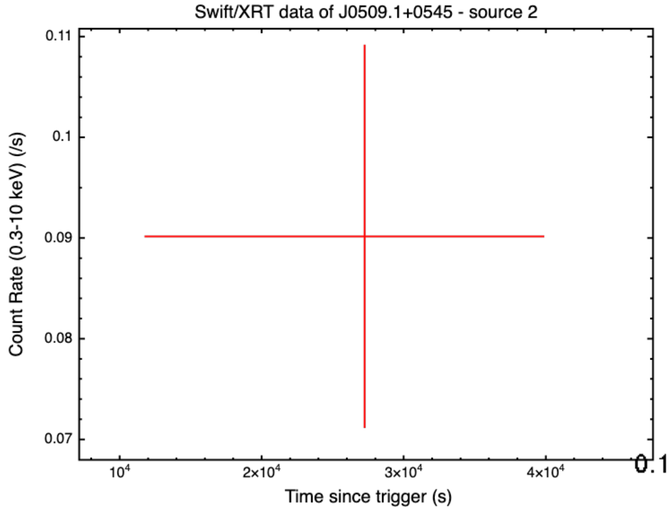
- LIGO/Virgo/KAGRA O4
- IceCube
- KM3NeT

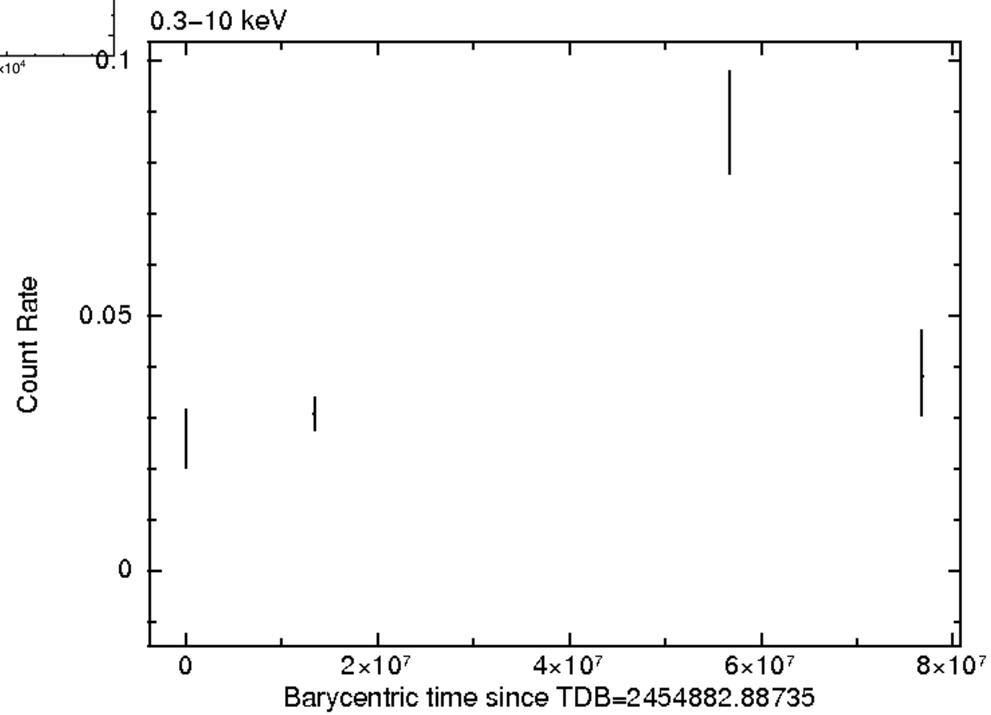
But it's not just multi-messenger that is giving interesting new time-domain science:

- HAWC
- CTA
- FRB (e.g. CHIME)
- VRO/LSST

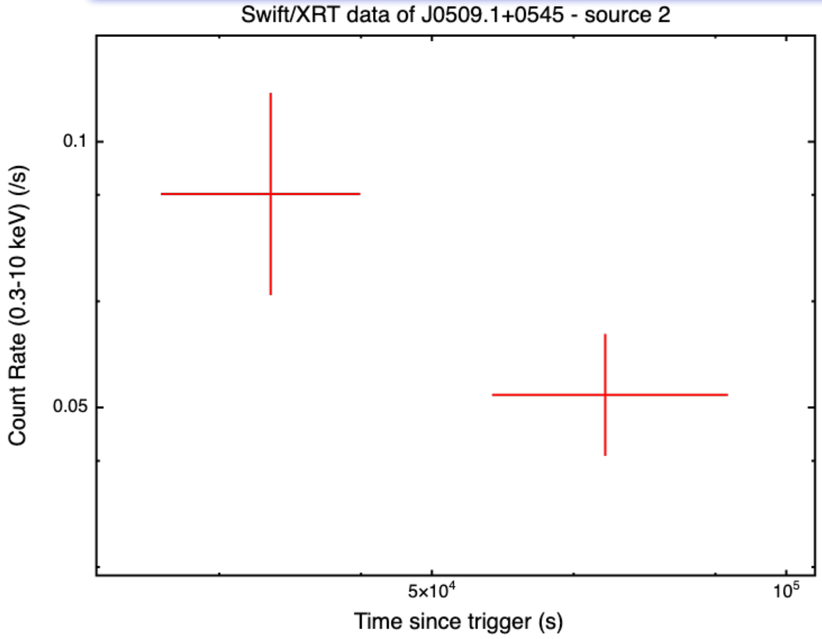
Some cautionary notes

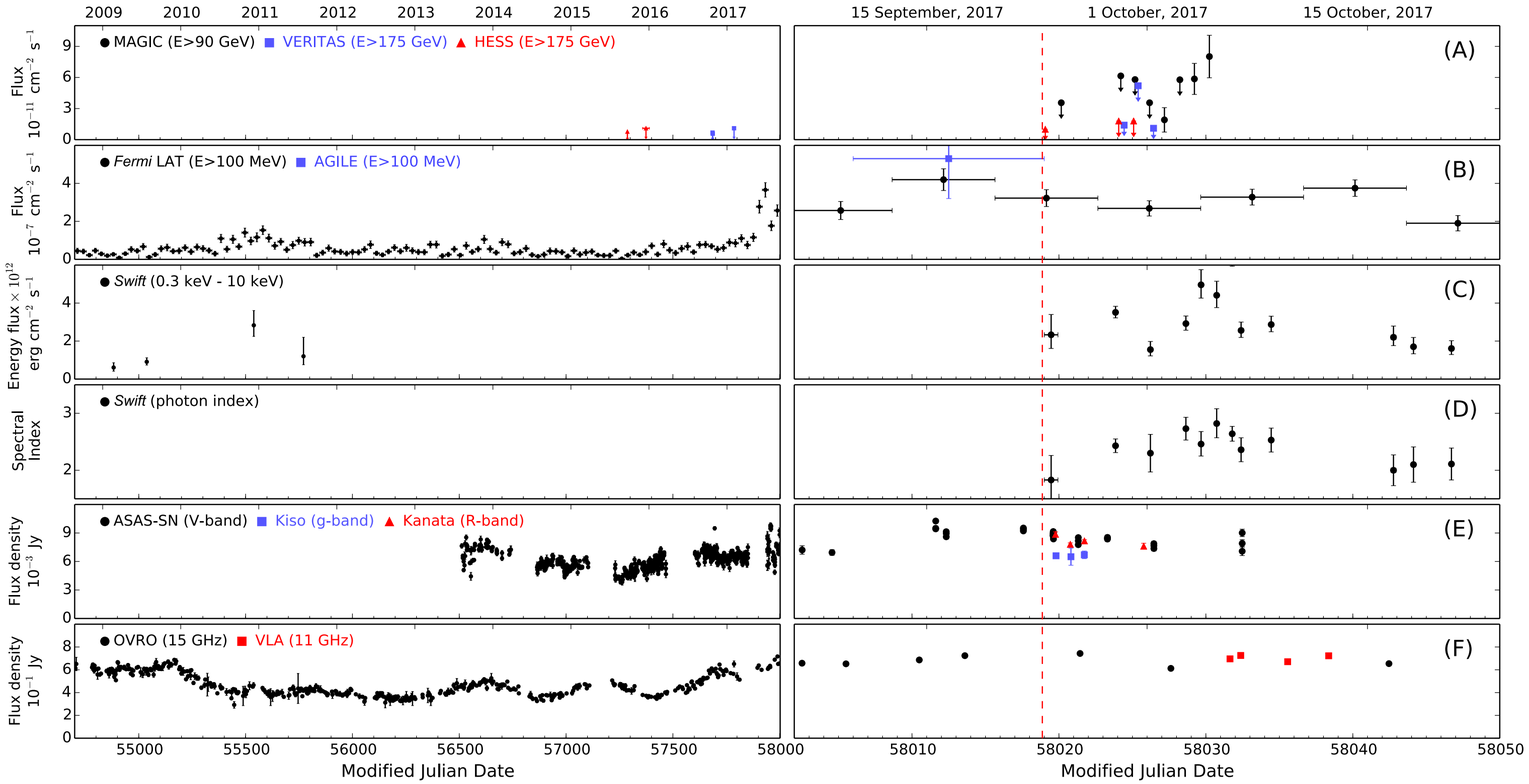






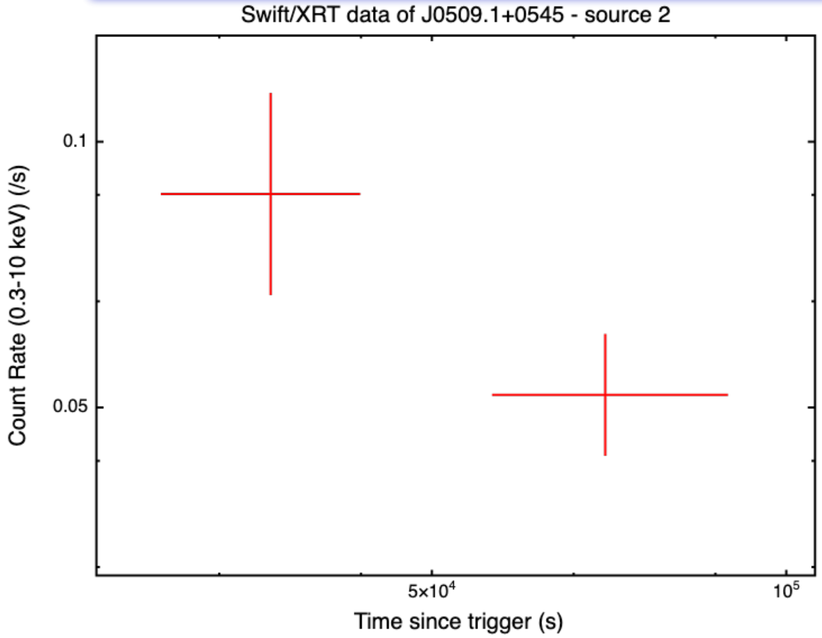
Some cautionary notes

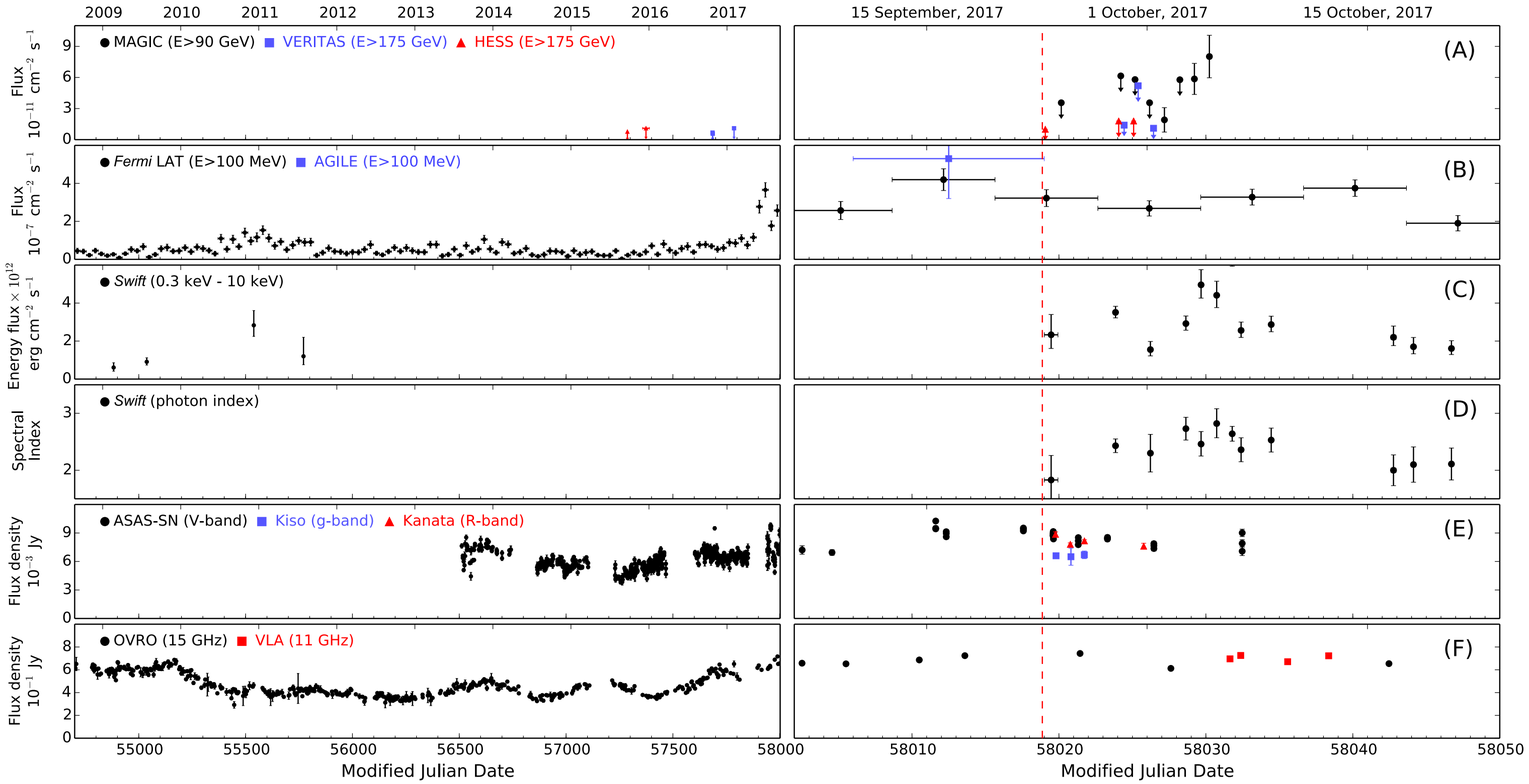




IceCube Collaboration+ 2018

Some cautionary notes





IceCube Collaboration+ 2018

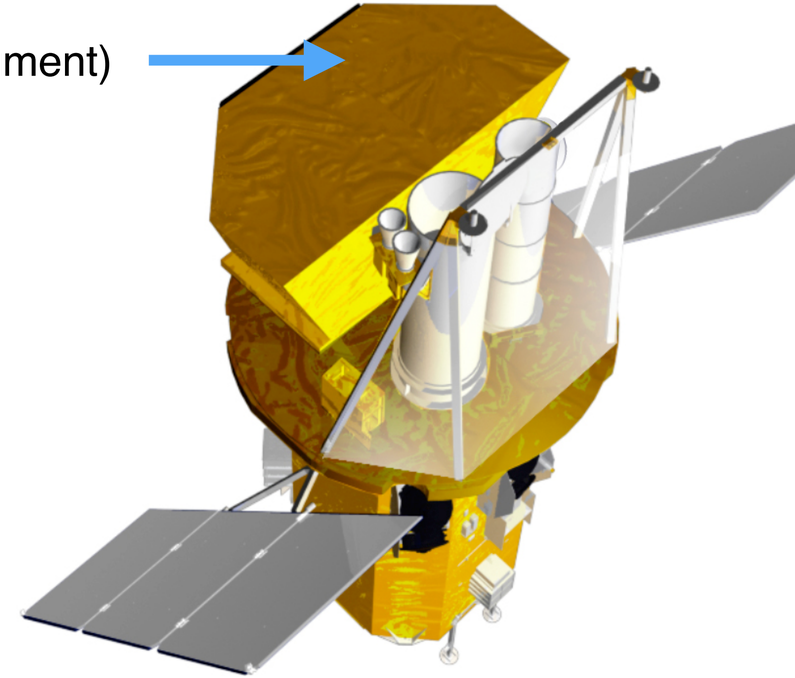
eRosita surveys will be a significant benefit in this area.

New Swift innovations — operations

- GUANO — Gamma-ray Urgent Archiver for Novel Opportunities
  - Tohuvavohu et al. 2020, ApJ, 900, 1

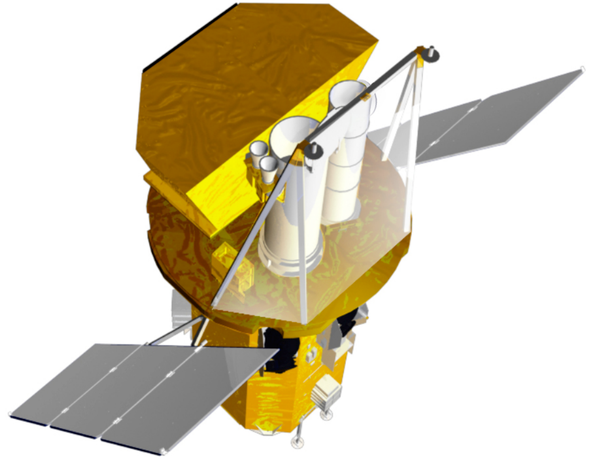
- If notified quickly enough, BAT event data can be saved and then searched offline with greater sensitivity.
- 35 GRBs so far, ***arcminute localisation.***

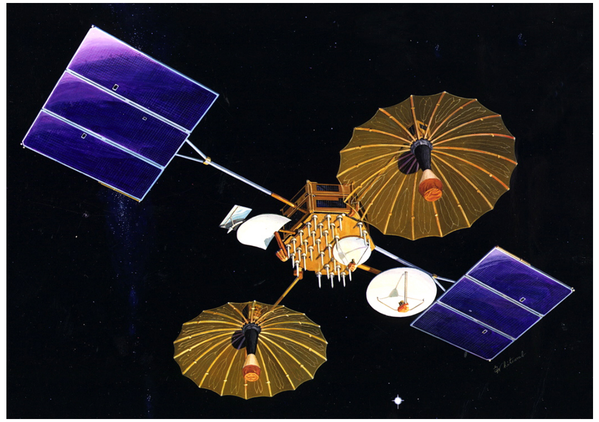
BAT (15-350 keV, trigger instrument)



New Swift innovations — operations

- GUANO — Gamma-ray Urgent Archiver for Novel Opportunities
- Automated ToO uploads.





New Swift innovations — operations

- GUANO — Gamma-ray Urgent Archiver for Novel Opportunities
- Automated ToO uploads.
- ToO submission API.
  - By Jamie Kennea: https://www.swift.psu.edu/too_api/

New Swift innovations — operations

- GUANO — Gamma-ray Urgent Archiver for Novel Opportunities
- Automated ToO uploads.
- ToO submission API.
  - By Jamie Kennea: https://www.swift.psu.edu/too_api/
- Tiling optimisation and “manypoint” upload tool.

New Swift innovations — analysis

- For Swift-team / collaboration projects, automated XRT analysis exists.

GW trigger S200115j ('GW 200115')

Please see the usage policy before using these data.

GW details	
Trigger Date:	2020-01-15 at 04:23:09.752 UT
Trigger type:	Compact Binary Coalescence
Distance:	340 ± 79 Mpc
$Prob_{ContainsNeutronStar}$:	1
$Prob_{EMBright}$:	1
False alarm rate:	2.095e-11 Hz = 1/1.5e+3 yr
GraceDB:	GraceDB

XRT details	
First observation:	T_0 + 118.1 min
Fields planned:	696
Fields observed:	518 [Search]
TargetID range:	7030400—7031478
LVC Prob observed	0.047 (raw), 0.097 (conv)
LVC Prob to observe	2.26e-3 (raw), 4.36e-3 (conv)
XRT sources:	146 (82 verified and public).
Candidate afterglows:	0
Possible afterglows:	9
Unlikely afterglows:	84
Known X-ray sources:	53

Externally-detected sources

There are 0 sources. Show.

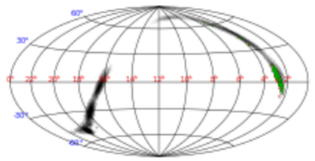
Find upper limit.

List of possible host galaxies.

Galaxy search.

Show constraints and BAT? ☐

Raw GW map | Convolved with 2MPZ



Green spots mark XRT fields observed, red spots mark those planned but not yet observed. Click the image for a larger version.

GW map (HEALPix) | GW map (FITS) | LALInference_convolved map (HEALPix) | LALInference_convolved map (FITS)

Query LIGO skymap

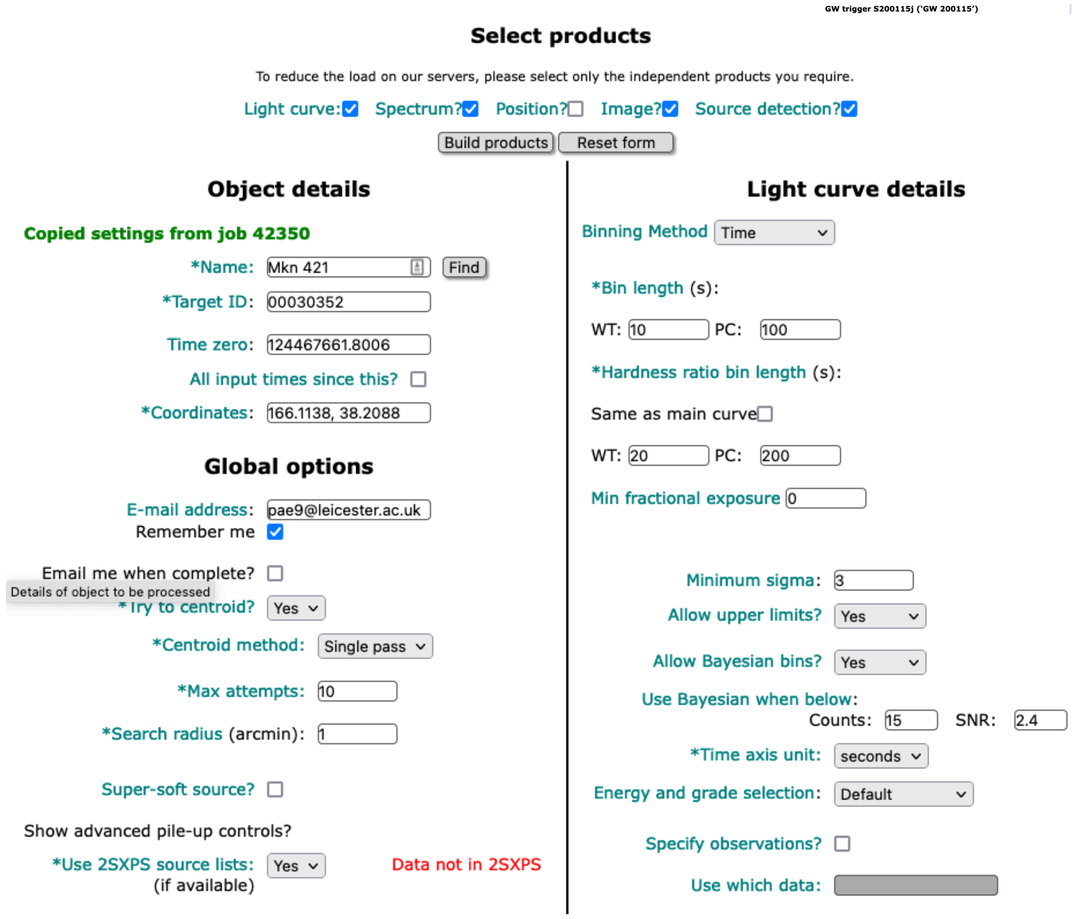
All X-ray sources

Coordinate style: Sexagesimal | Filter by position: | Radius: 20″ Go Clear

#	Position	Err[1]	Flag[2]	Class[3] (Rank)	Exp (s)	Cat source?	Fdiff (σ)[4]	Near Galaxy?	Near 2MASS	Near SIMBAD	Search /build	Notes
130	02h 59m 36.73s +07° 24′ 13.9″	5.2″	Good	I (2)	139	Y	3.4	N	Y	Yes	V|S|N|X|1S|3X [build]	• Will be prioritised in follow up
	02h 40m 12.18s										V|S|N|	• Will be

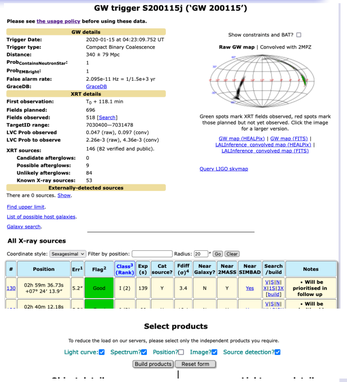
New Swift innovations — analysis

- For Swift-team / collaboration projects, automated XRT analysis exists.
- For any observation: XRT on-demand analysis.
  - https://www.swift.ac.uk/user_objects (Evans et al. 2009)



New Swift innovations — analysis

- For Swift-team / collaboration projects, automated XRT analysis exists.
- For any observation: XRT on-demand analysis.
  - https://www.swift.ac.uk/user_objects (Evans et al. 2009)
- Now available through an API
  - https://www.swift.ac.uk/user_objects/API


GW trigger S200115j ('GW 200115')

Please see the usage policy before using these data.

GW details

Trigger Date:	2020-01-15 at 04:23:09.752 UT
Trigger type:	Compact Binary Coalescence
Distance:	340 ± 79 Mpc
$Prob_{ContainsNeutronStar}$:	1
$Prob_{BNS|GW}$:	1
False alarm rate:	2.095e-11 Hz = 1/1.5e+3 yr
GraceDb:	GraceDB

XRT details

First observation:	T_0 + 118.1 min
Fields planned:	696
Fields observed:	516 [Search]
TargetID range:	7030400—7031478
LVC Prob observed	0.047 (raw), 0.097 (conv)
LVC Prob to observe	2.26e-3 (raw), 4.38e-3 (conv)
XRT sources:	146 (82 verified and public).
Candidate afterglows:	0
Possible afterglows:	9
Unlikely afterglows:	84
Known X-ray sources:	53

Externally-detected sources

There are 0 sources. Show.

Find upper limit.

List of possible host galaxies.

Galaxy search.

Show constraints and BAT? ☐

Raw GW map | Convolved with 2MPZ

Green spots mark XRT fields observed, red spots mark those planned but not yet observed. Click the image for a larger version.

GW map (HEALPix) | GW map (FITS) | LALInference_convolved map (HEALPix) | LALInference_convolved map (FITS)

Query LIGO skymap

All X-ray sources

Coordinate style: Sexagesimal | Filter by position: | Radius: 20 | Go | Clear

#	Position	Err[1]	Flag[2]	Class[3] (Rank)	Exp (s)	Cat source?	Fdiff (σ)[4]	Near Galaxy?	Near 2MASS	Near SIMBAD	Search /build	Notes
130	02h 59m 36.72s +07° 24' 13.9"	5.2"	Good	1 (2)	139	Y	3.4	N	Y	Yes	V1S/N [1.1S1X [build]	• Will be prioritised in follow up
	02h 40m 12.18s										V1S/N	• Will be

Select products

To reduce the load on our servers, please select only the independent products you require.

Light curve ☑ Spectrum ☑ Position ☐ Image ☑ Source detection ☑

Build products | Reset form

Build-the-request

First we need to create an `XRTProductRequest` object, and set some global parameters. By default, the object is created in 'silent' mode: it does not produce any output (unless an error is raised). For interactive use such as in this tutorial, the output can be helpful, so we will create it with `silent=False`.

The RA/Dec must be in decimal degrees, J2000.0. So:

```
In [1]: from swifttools.xrt_prods import XRTProductRequest
In [2]: myReq = XRTProductRequest('YOUR_EMAIL_ADDRESS', silent=False)
In [3]: myReq.setGlobalPars(getTargs=True, centroid=True, name='GRB 200416A', RA=335.6985, Dec=-7.5179,
centMeth='simple', useSXPS=False, T0=608713541.952, posErr=1)
```

OK, now lets add the products. For the light curve we will request counts binning, with the same settings as the XRT GRB light curve repository uses. For the spectrum we need to specify that we have no redshift, and beyond this we will accept the defaults. Likewise for the positions, we will accept the default parameters, except that we want to use all available data for the astrometric positions:

```
In [4]: myReq.addLightCurve(binMeth='counts', pcCounts=20, wtCounts=30, dynamic=True)
Successfully created a light curve

In [5]: myReq.addSpectrum(hasRedshift=False)
Successfully created a spectrum

In [6]: myReq.addStandardPos()
Successfully created a standard position

In [7]: myReq.addEnhancedPos()
Successfully created a enhanced position

In [8]: myReq.addAstromPos(useAllObs=True)
Successfully created a astrometric position
```

Swift API tools available via:

```
pip install swifttools
```

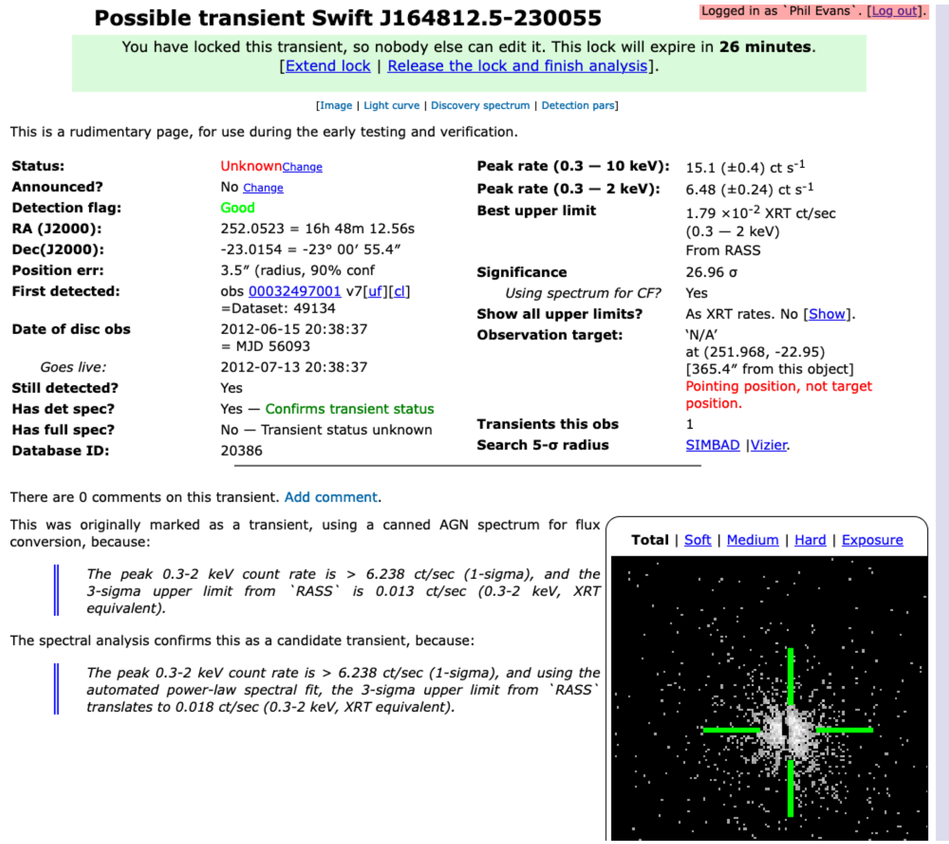
Forthcoming tool: LSXPS

- Several XRT point source catalogues exist (SwiftFT, 1SwXRT, 1SXPS, 2SXPS).
- All retrospective; good for mining and reference, bad for time-domain response.
- Swift observes ~75 fields/day = 7.5 sq degrees; lots of scope for discovery if we analysed in real time…

Forthcoming tool: LSXPS

- Several XRT point source catalogues exist (SwiftFT, 1SwXRT, 1SXPS, 2SXPS).
- All retrospective; good for mining and reference, bad for time-domain response.
- Swift observes ~75 fields/day = 7.5 sq degrees; lots of scope for discovery if we analysed in real time…

- LSXPS is updated in ~real time*.
- Searches for transients with each data delivery.
- Can often use itself as the best reference catalogue.



Possible transient Swift J164812.5-230055

Logged in as `Phil Evans`. [Log out].

You have locked this transient, so nobody else can edit it. This lock will expire in **26 minutes**.
[Extend lock | Release the lock and finish analysis].

[Image | Light curve | Discovery spectrum | Detection pars]

This is a rudimentary page, for use during the early testing and verification.

Status:	UnknownChange	**Peak rate (0.3 — 10 keV):**	15.1 (±0.4) ct s^{-1}
Announced?	No Change	**Peak rate (0.3 — 2 keV):**	6.48 (±0.24) ct s^{-1}
Detection flag:	Good	**Best upper limit**	1.79 $\times 10^{-2}$ XRT ct/sec (0.3 — 2 keV) From RASS
RA (J2000):	252.0523 = 16h 48m 12.56s		
Dec(J2000):	-23.0154 = -23° 00′ 55.4″		
Position err:	3.5″ (radius, 90% conf	**Significance**	26.96 σ
First detected:	obs 00032497001 v7[uf][cl] =Dataset: 49134	*Using spectrum for CF?*	Yes
		Show all upper limits?	As XRT rates. No [Show].
Date of disc obs	2012-06-15 20:38:37 = MJD 56093	**Observation target:**	'N/A' at (251.968, -22.95) [365.4″ from this object] Pointing position, not target position.
Goes live:	2012-07-13 20:38:37		
Still detected?	Yes		
Has det spec?	Yes — Confirms transient status		
Has full spec?	No — Transient status unknown	**Transients this obs**	1
Database ID:	20386	**Search 5-σ radius**	SIMBAD |Vizier.

There are 0 comments on this transient. Add comment.

This was originally marked as a transient, using a canned AGN spectrum for flux conversion, because:

> *The peak 0.3-2 keV count rate is > 6.238 ct/sec (1-sigma), and the 3-sigma upper limit from `RASS` is 0.013 ct/sec (0.3-2 keV, XRT equivalent).*

The spectral analysis confirms this as a candidate transient, because:

> *The peak 0.3-2 keV count rate is > 6.238 ct/sec (1-sigma), and using the automated power-law spectral fit, the 3-sigma upper limit from `RASS` translates to 0.018 ct/sec (0.3-2 keV, XRT equivalent).*

Total | Soft | Medium | Hard | Exposure

* Data are analysed on receipt, typically 1-4 hours after observation. Transients will be reported ASAP, catalogue is not updated for 28 days (TBD).

Final thoughts

- *Swift* remains a powerful, rapid-response, multi-wavelength facility optimally suited for the MMA/TDA era.
- Coordination between different facilities and rapid dissemination of information is important.
- Some means of collating and coordinating results would be very helpful.
- The Swift team are producing new innovations and tools to make it as easy as possible to use *Swift* for this science.

This is an exciting and fruitful field with a bright and immediate future!

Some cautionary notes

1) Are we going to see things that don’t follow expectations?

Some cautionary notes

1) Are we going to see things that don’t follow expectations?

Some cautionary notes

1) Are we going to see things that don't follow expectations?

Some cautionary notes

1) Are we going to see things that don’t follow expectations?

For example: how ‘low-latency’ should follow-up be?

Some cautionary notes

2) Can we find the needle in a… pot of needles?

Some cautionary notes

2) Can we find the needle in a… pot of needles?

Notable lessons

- Keep an open mind about appearance.
- Multiple observations and timescales to probe
  - Challenging with large position uncertainties!
- Rapid information exchange between facilities is key.
- GCN / ATEL / TNS?