The Neil Gehrels *Swift* Observatory

Phil Evans

University of Leicester

“The first two days of the workshop will consist of invited and contributed talks to discuss the current issues, challenges and opportunities in real-time multimessenger astronomy.”

Challenges and issues

- Where are all the BNS mergers?
  - Especially with EM counterparts!
- We have neutrino triggers (IceCube), but only one(?) definitive EM counterpart.
  - And also possibly/probable persistent source (Abbasi+ 2022)
  - Population correlations show there are more, but which ones?
- Aside… what was is about 2017?
- “Impatience fatigue”?

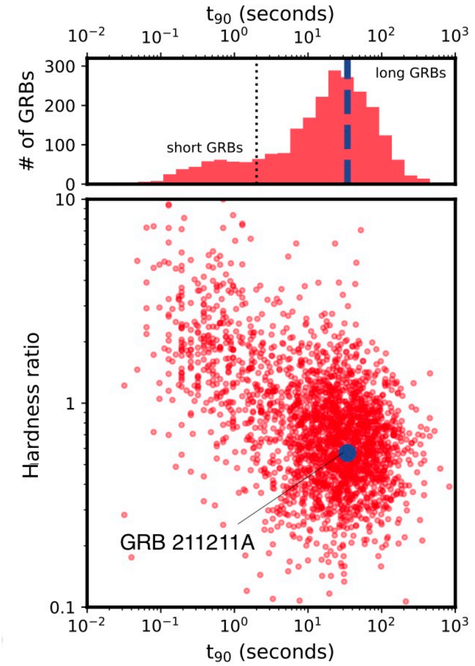
Opportunities

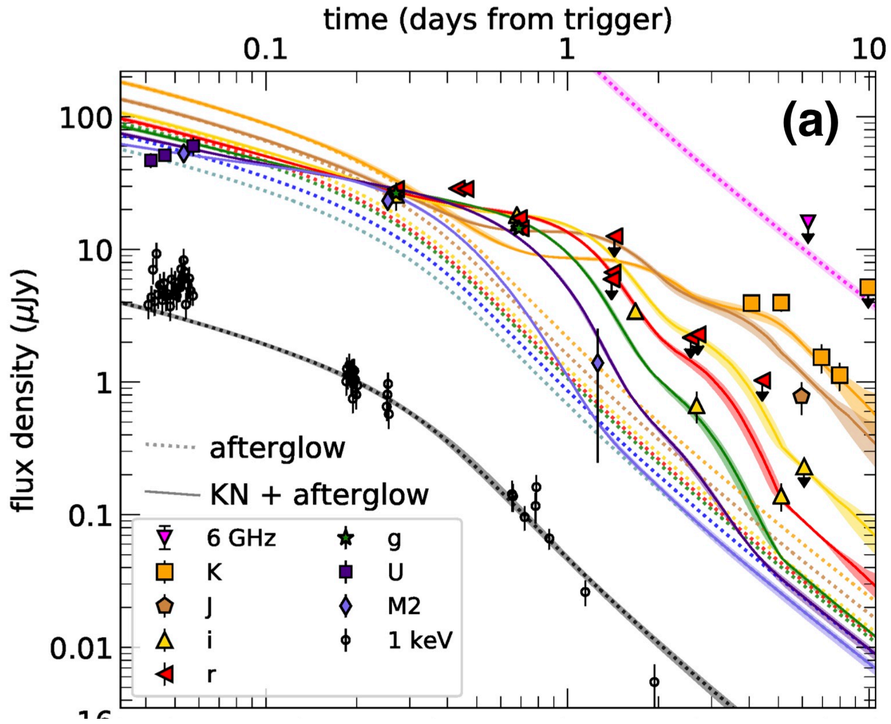
- GW network is still developing (KAGRA, LIGO-India, O5…)
- Neutrino facilities are being upgraded (IceCube) and developed (KM3NeT)
- New satellites are now online (*EinsteinProbe*, SVOM)
- VRO/LSST…
- “Long” merger events.

Opportunities

- GW network is still developing (KAGRA, LIGO-India, O5…)
- Neutrino facilities are being upgraded (IceCube) and developed (KM3NeT)
- New satellites are now online (*EinsteinProbe*, SVOM)
- VRO/LSST…
- “Long” merger events.

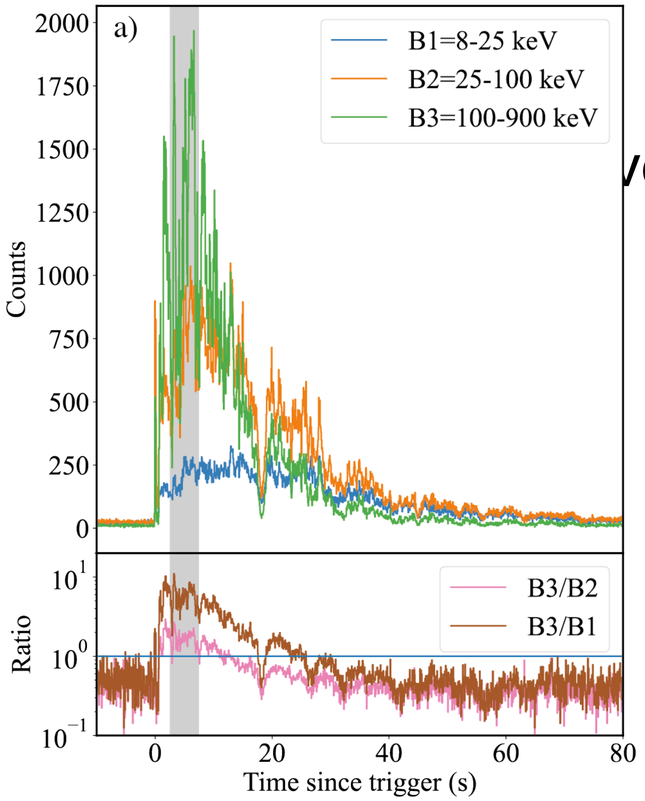
Rastinedjad et al. 2022





Opportunities

- GW network is still developing (KAGRA, LIGO-India, O5…)
- Neutrino facilities are being upgraded (IceCube) and developed (KM3NeT)
- New satellites are



Levan et al. 2023

And *Swift* (which is still not an acronym)

- The *Neil Gehrels Swift Observatory* was designed to detect and study GRB.
  - Including localising short ones.
  - And it found GW 170817
- **Multi-wavelength coverage** (UV, X-ray, hard X-ray).
- **Rapid slewing** (typically gets to new GRBs within 2 minutes).
- **Flexible planning** (daily planning telecons, rapid ToO response).
- **Open data.**

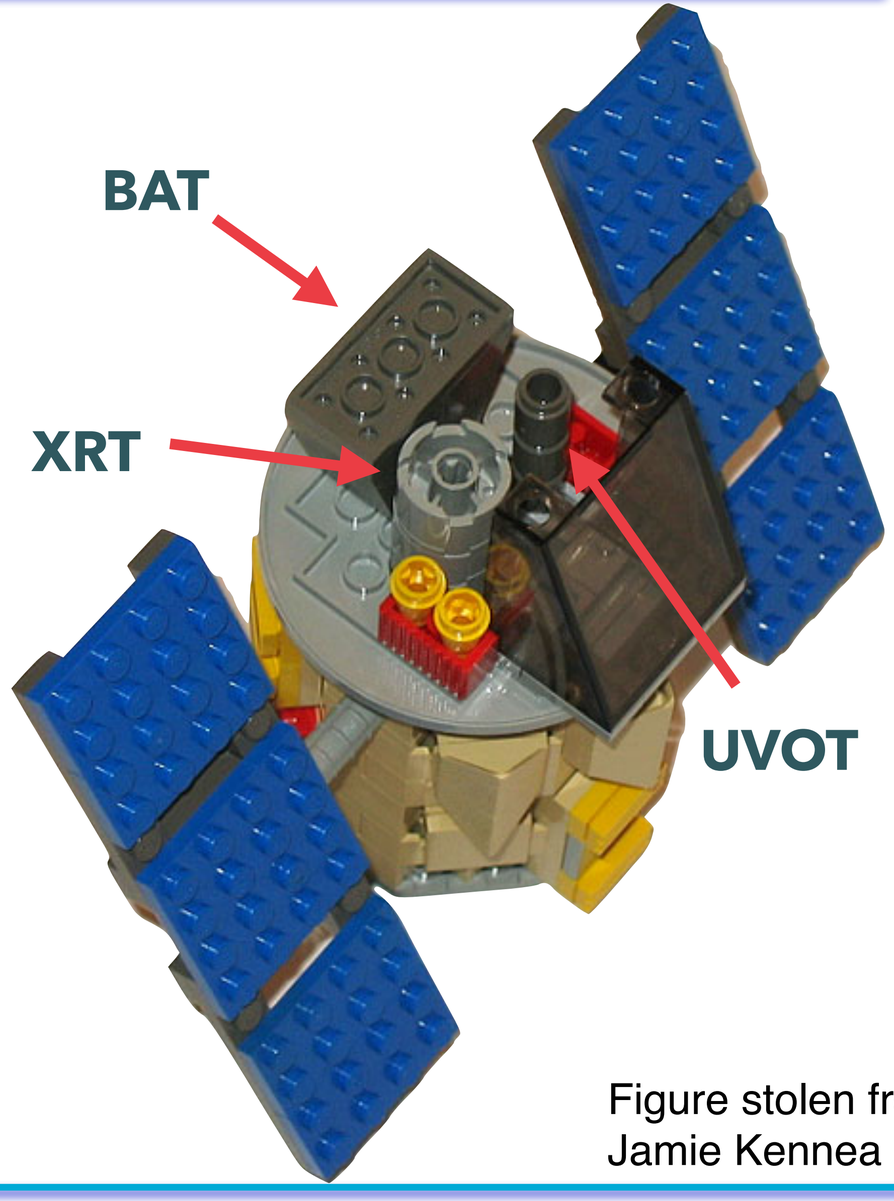


Figure stolen from Jamie Kennea

And *Swift* (which is still not an acronym)

- The *Neil Gehrels Swift Observatory* was designed to detect and study GRB.
  - Including localising short ones.
  - And it found GW 170817
- **Multi-wavelength coverage** (UV, X-ray, hard X-ray).
- **Rapid slewing** (typically gets to new GRBs within 2 minutes).
- **Flexible planning** (daily planning telecons, rapid ToO response).
- **Open data.**
- **Automated analysis** (for GRBs at first).
- **Efficient, evolving ground software** (ToO uploads, tiling, “manypoint”, continuous commanding…).

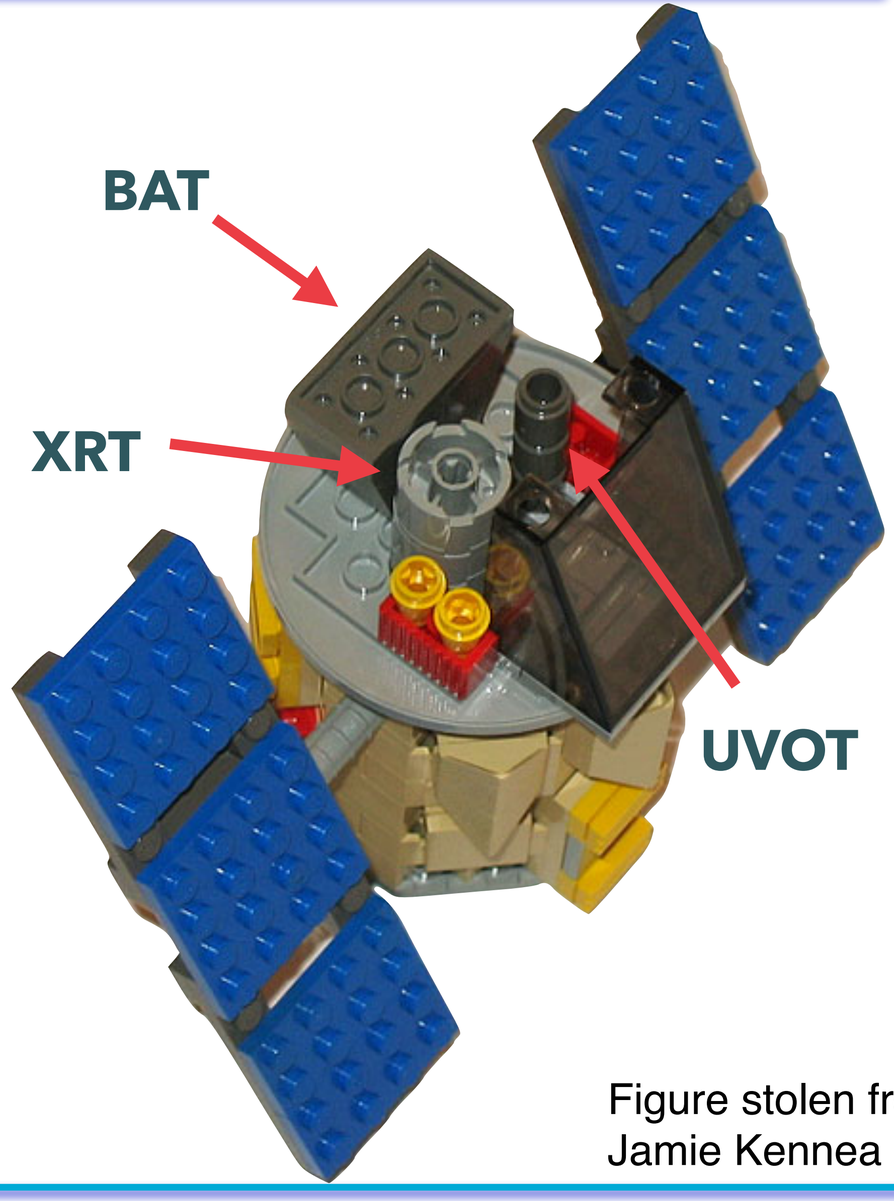
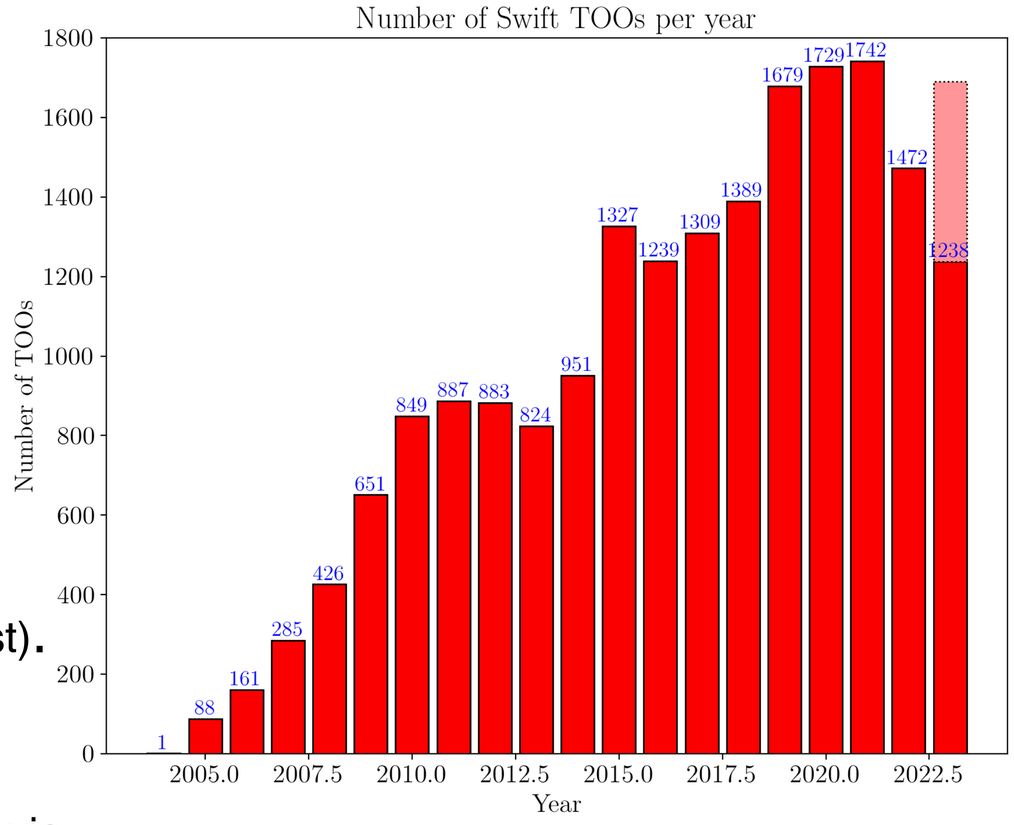


Figure stolen from Jamie Kennea

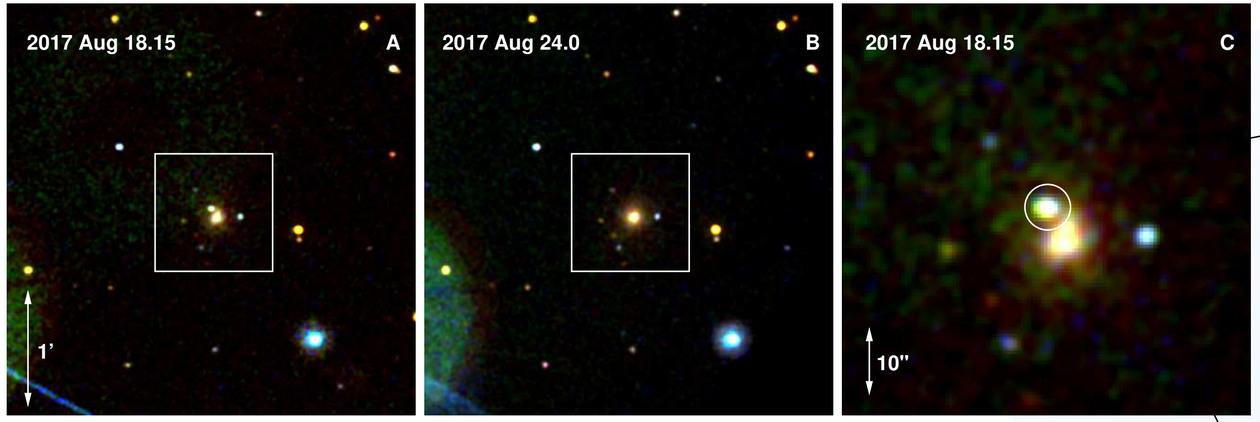
And *Swift* (which is still not an acronym)

- All these features enable a whole range of TDAMM science.
  - And boy do people use it…
  - … which is a good thing 😀
- **Multi-wavelength coverage**.
- **Rapid slewing** (we can be on-target within 2 minutes of upload).
- **Flexible planning** (we can upload within hours of the ToO request).
- **Open data** (and anyone can submit ToOs).
- **Automated analysis** (for many objects; on-demand for the rest, via website and API / Python `swifttools` module).
- **Efficient, evolving ground software** (ToO submission API (`swifttools`), enabling “mass tiling”, and some new things…).



This figure also stolen from Jamie Kennea

Swift TDAMM results: GW 170817



Evans et al. 2017

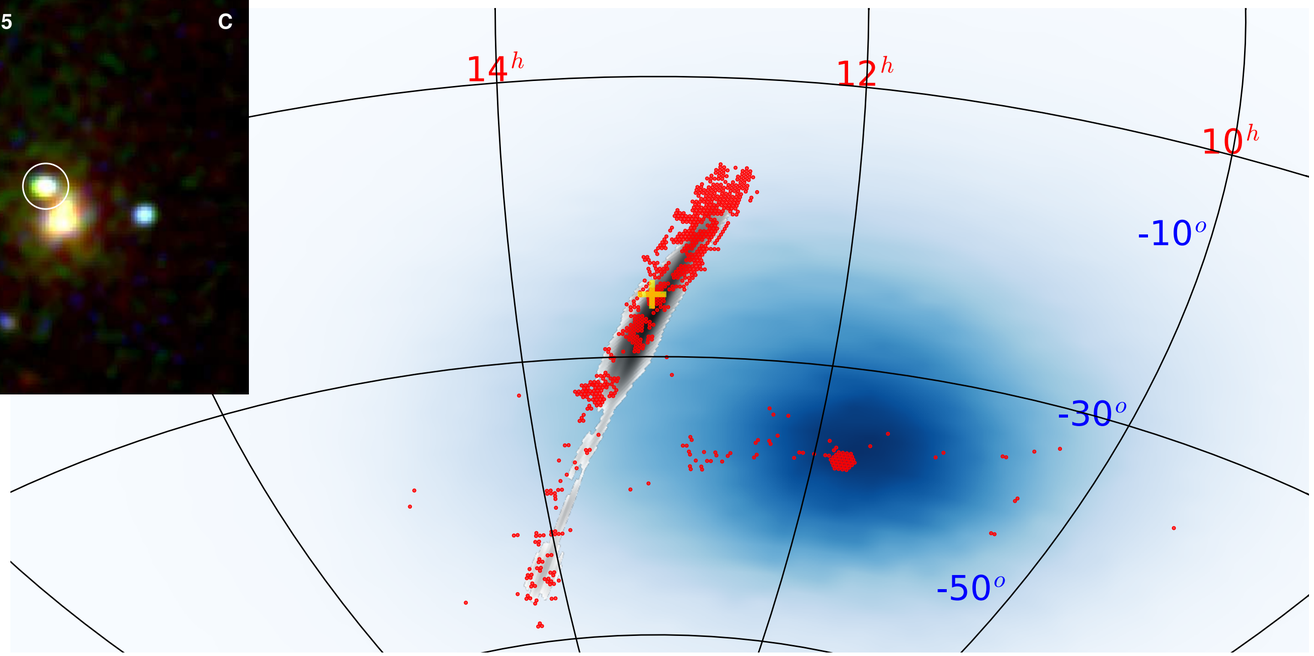


Figure stolen from Jamie Kennea who had stolen it from me.

In total Swift observed 744 fields.

There were… issues around this event. Without them we would have been on the afterglow within a few hours.

Mass tiling with *Swift*

- GW 170227A:
  - BNS trigger with probability: 100%
  - 90% region: 1800 sq deg
  - Distance 193 ± 61 Mpc.
  - Swift followed up 718 fields in 24 hours; 1,383 in 48 hours (60 s/field)
  - Second phase observations (500 s/field)
  - Total 1,751 observations, 1,408 fields, 171 sq degrees.

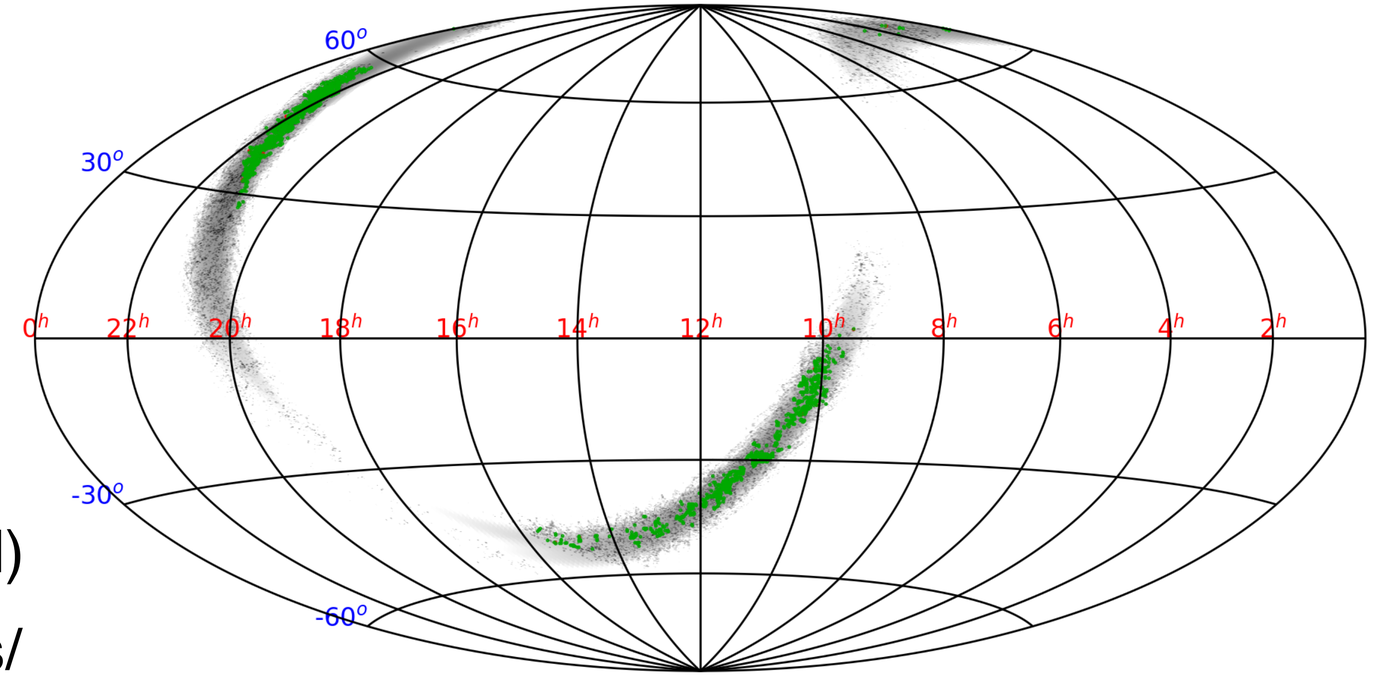


Figure authentically mine. Jamie had nothing to do with it. Except writing all the MOC software to enable the observations, but who cares about *that*?

Mass tiling with *Swift*

- GW 170227A:
  - BNS trigger with probability: 100%
  - 90% region: 1800 sq deg
  - Distance 193 ± 61 Mpc.
  - Swift followed up 718 fields in 24 hours; 1,383 in 48 hours (60 s/field)
  - Second phase observations (500 s/field)
  - Total 1,751 observations, 1,408 fields, 171 sq degrees.

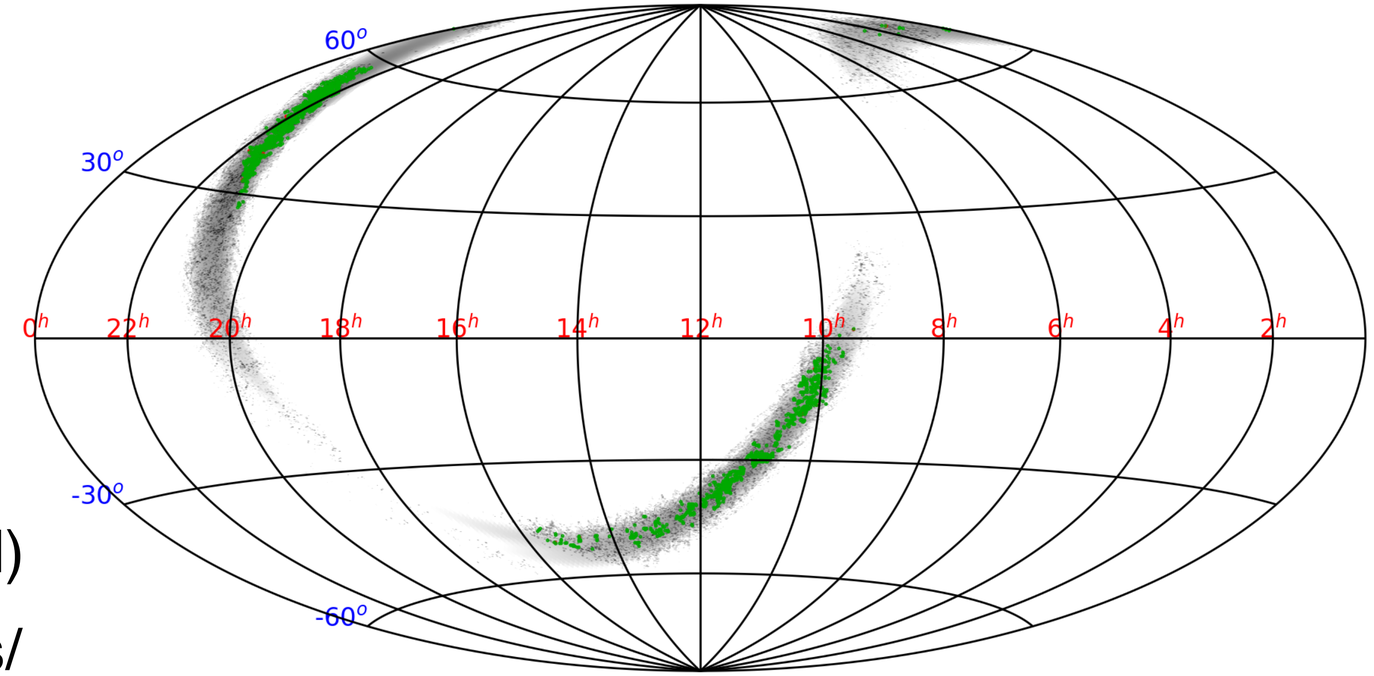


Figure authentically mine. Jamie had nothing to do with it. Except writing all the MOC software to enable the observations, but who cares about *that*?

The GW trigger was retracted!

Mass tiling with *Swift*

- GW 170227A:
  - BNS trigger with probability: 100%
  - 90% region: 1800 sq deg
  - Distance 193 ± 61 Mpc.
  - Swift followed up 718 fields in 24 hours; 1,383 in 48 hours (60 s/field)
  - Second phase observations (500 s/field)
  - Total 1,751 observations, 1,408 fields, 171 sq degrees.

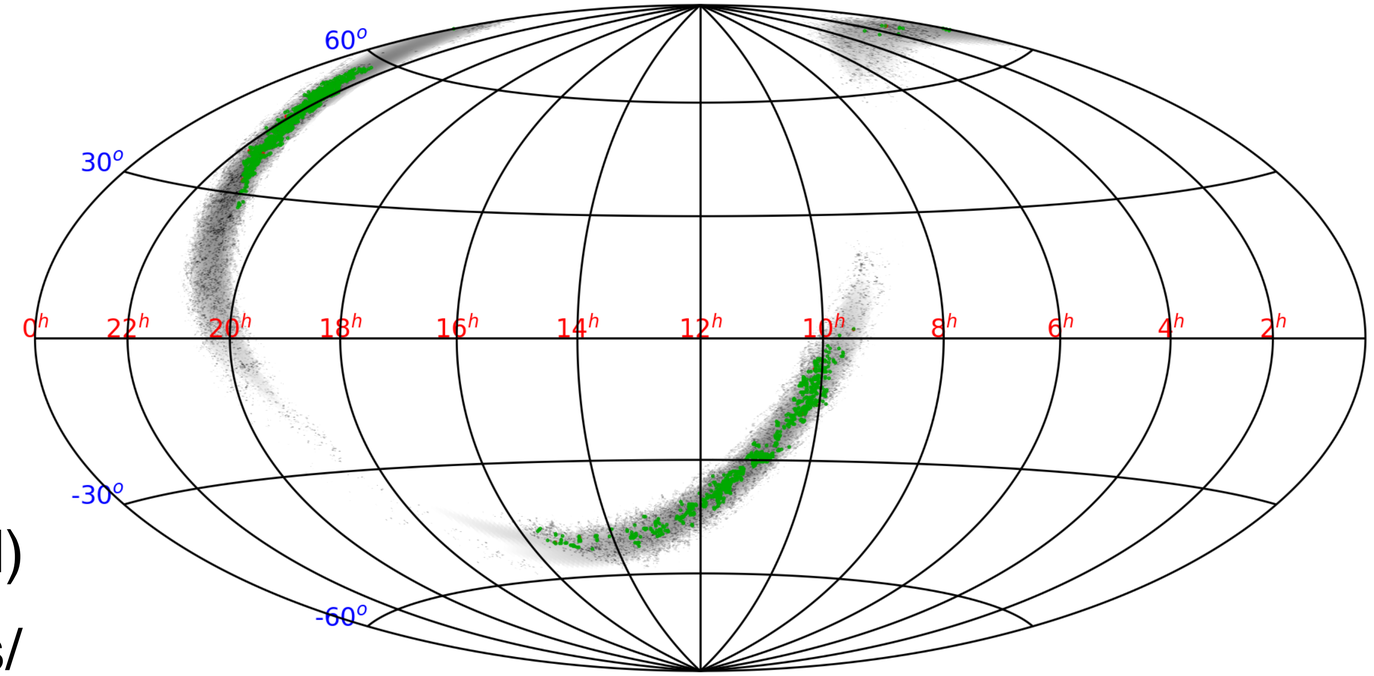
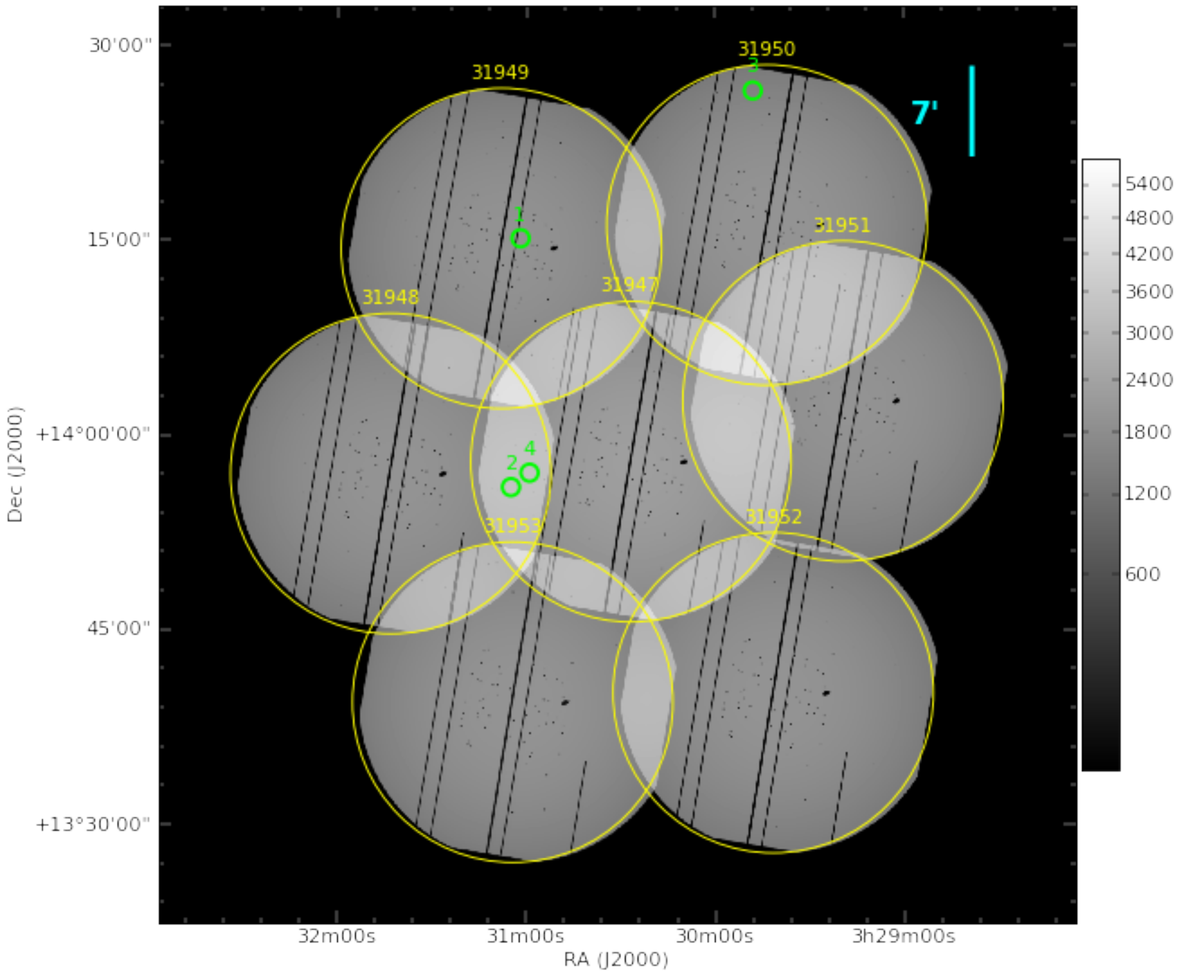
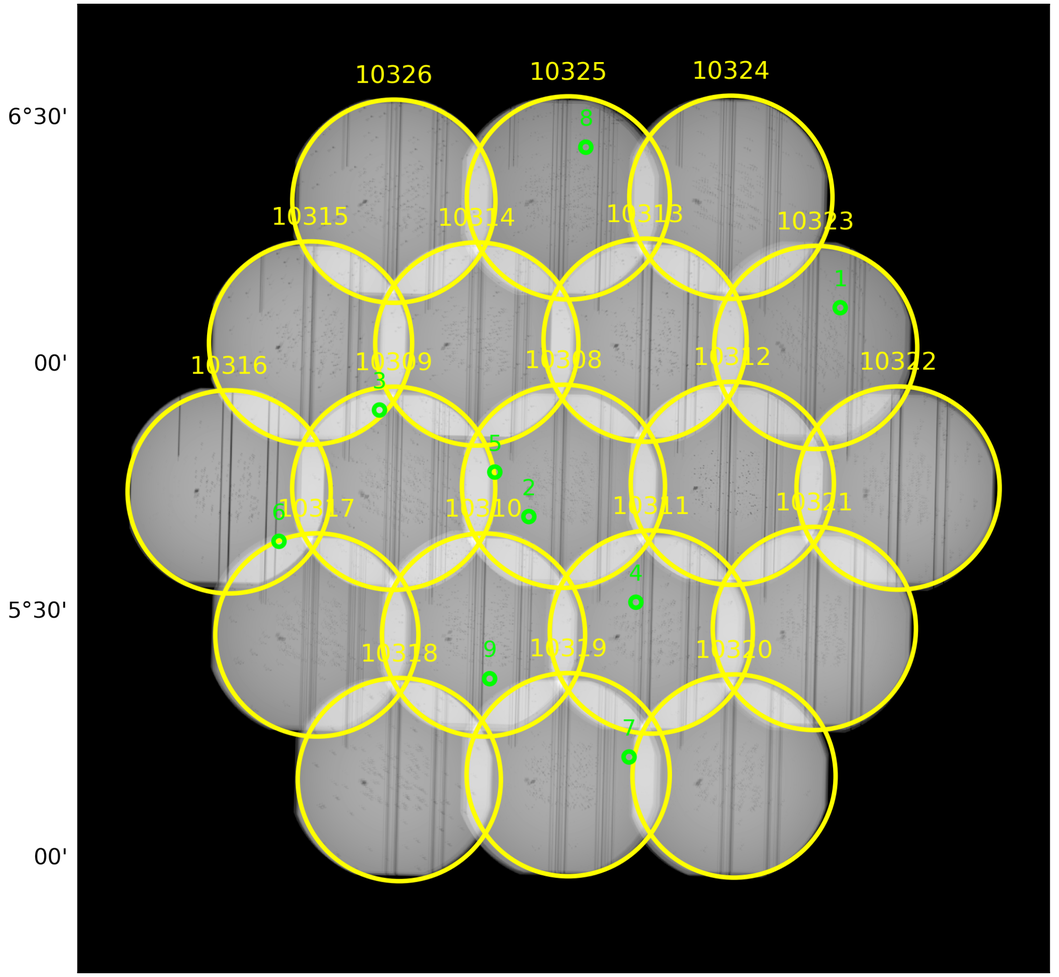


Figure authentically mine. Jamie had nothing to do with it. Except writing all the MOC software to enable the observations, but who cares about *that*?

This is a **unique** Swift capability.

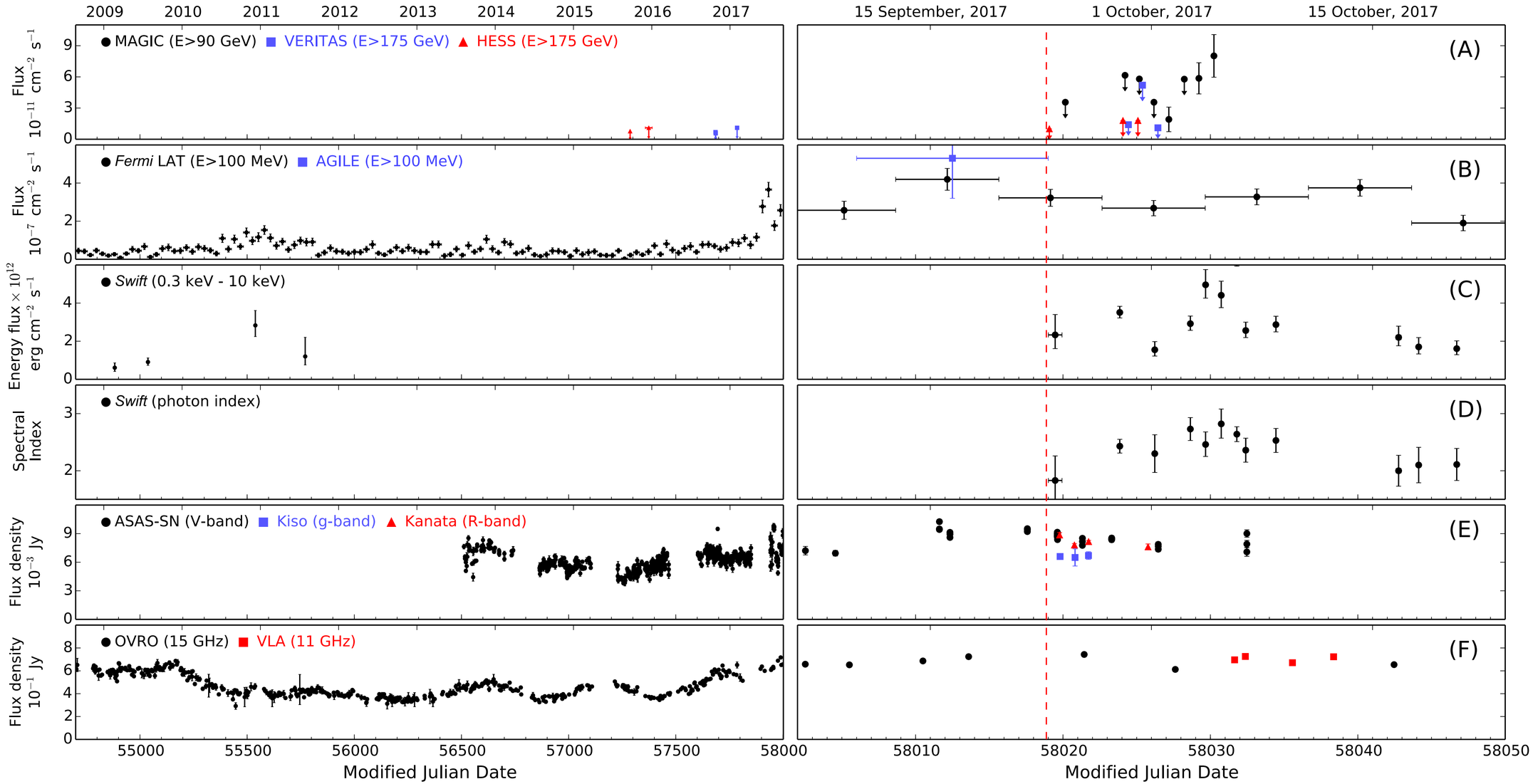
Swift TDAMM results: Neutrinos





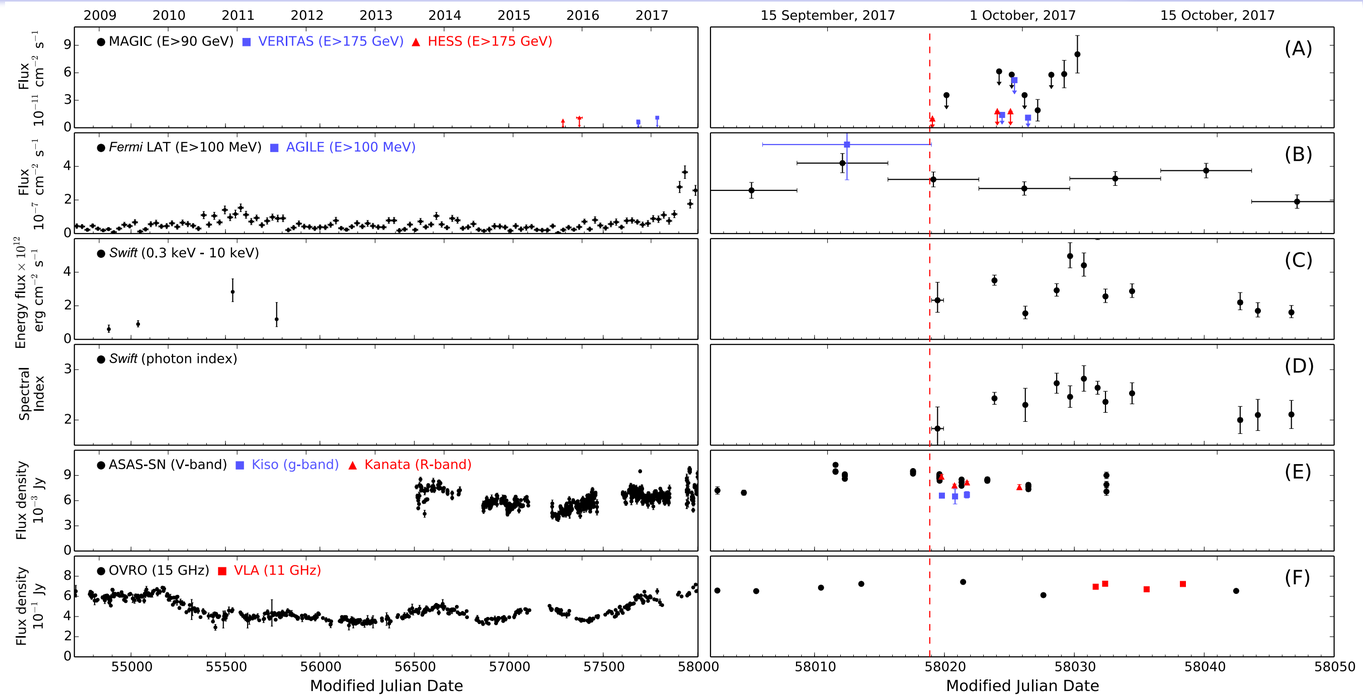
These are my figures too.

Swift TDAMM results: IceCube 170922A



IceCube Collaboration+ 2018

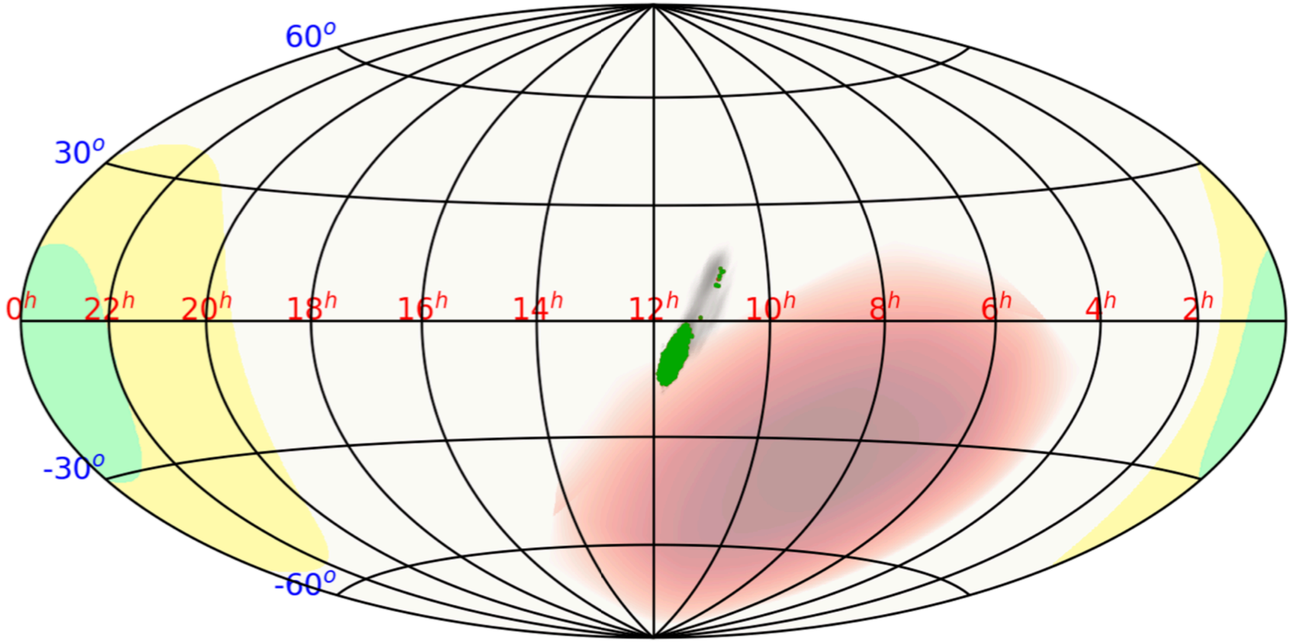
Swift TDAMM results: IceCube 170922A

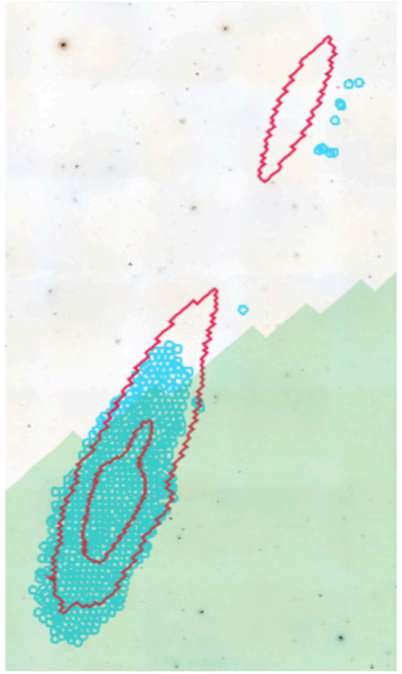


IceCube Collaboration+ 2018

- Swift on-target **3.25 hours** after IceCube detection.
- TXS 0506+056 detected by XRT as a possible counterpart. Later confirmed by Fermi monitoring.

Newer results from *Swift*





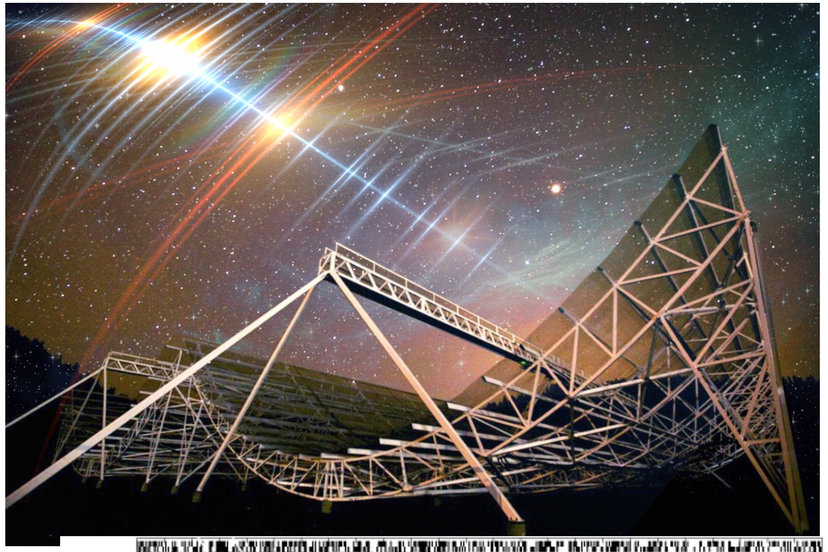
Klinger et al. (2020)*

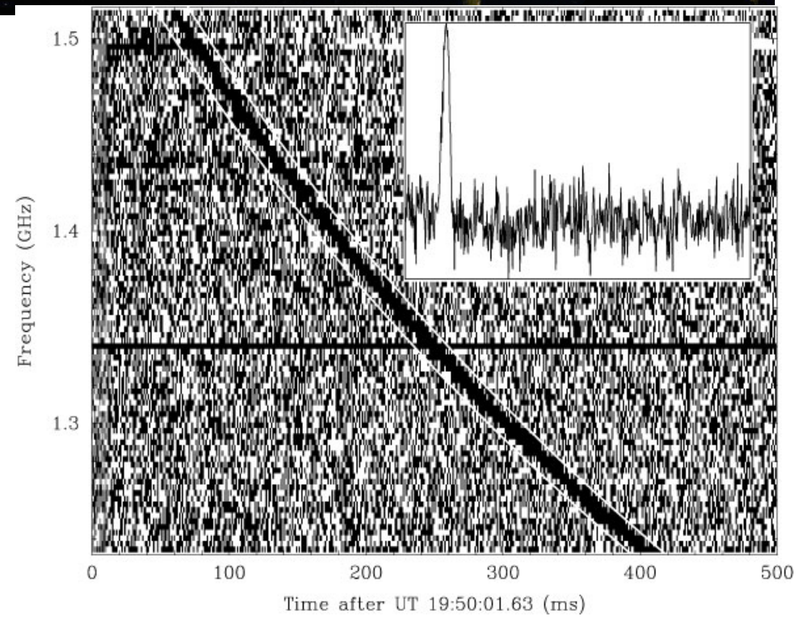
* But I pinched it from Jamie

- S200224A is a BH-BH merger
- Covered 79.2% (X-ray) and 62.4% (UV) of the GW error region.
- No candidates seen. Upper limit on isotropic-equivalent blast wave energy = 4.1×10^{51} erg (assuming GRB like parameters).

Other Swift follow up: FRBs

- We trigger off alerts from CHIME, (ex-MOU and now public).
- We try to observe with XRT/UVOT as rapidly as possible (automated)
- https://arxiv.org/abs/2006.04550: obs started at T0+32 mins.
- Two other FRBs have been followed-up in this way:
- FRB 20211122A at T0+39 minutes (ATEL #15055).
- FRB 20211211A at T0+21 minutes (ATEL #15114).
- In 2023, we reduced this latency to T0+3.9 minutes (ATEL #16233).





Entire slide adapted from one stolen from Jamie.

New *Swift* functionality

- LSXPS — the living XRT catalogue with transient detector.
  - Found a brand-new phenomenon within 3 months… not so much since!
- GUANO/NITRATES (see Jimmy's talk next).
- "Continuous commanding" — removing nearly all latency for ToO upload.
- "Urgency zero" ToOs — special cases with end-to-end automation.

Swift is nearly 20 years old but is *still* innovating, *still* unique, *still* a key TDAMM facility.

But *Swift* is 20 years old

- *Swift* is in remarkable health (thanks in no small part to Jamie).
- But the orbit is decaying…
- … and funding is ever tighter (SR 2025 due in December)

But *Swift* is TDAMM!

- The Astro2020 NASA Decadal View highlighted the vital importance of a *Swift*-like facility for TDAMM over the next decade.
- The only *Swift*-like facility is, umm, *Swift*.
- And *Swift* is still going strong, still pioneering, still productive… and still funded!

Stolen from my earlier slide. Which was stolen from Jamie.