Flying Swift for 20 Years

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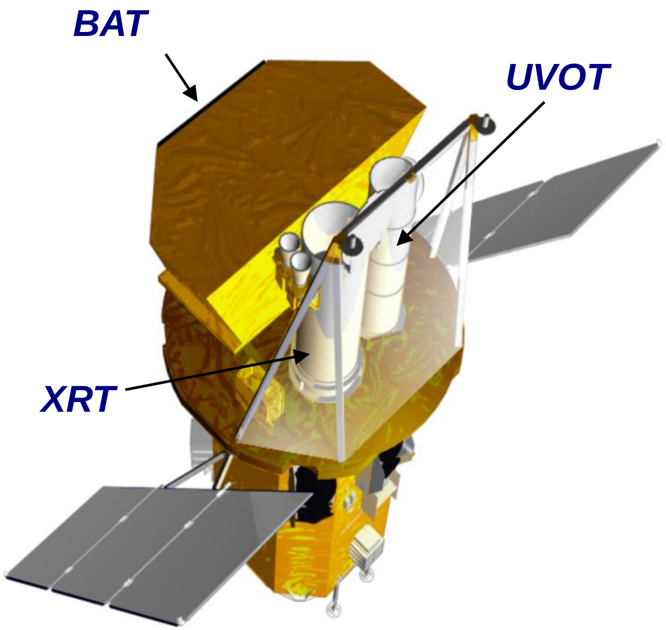
HAPPY BIRTHDAY SWIFT!

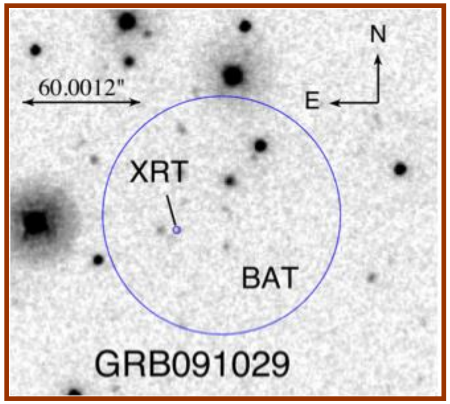
Swift – The World's GRB Factory



- **GRBs**
  - >1500 GRBs with arcsec positions
  - Primary GRB localization mission

- **Non-GRBs**
  - >1800 TOOs per year AGN, SNe, novae, CVs,
    comets, ...
  - First sensitive hard X-ray all sky survey

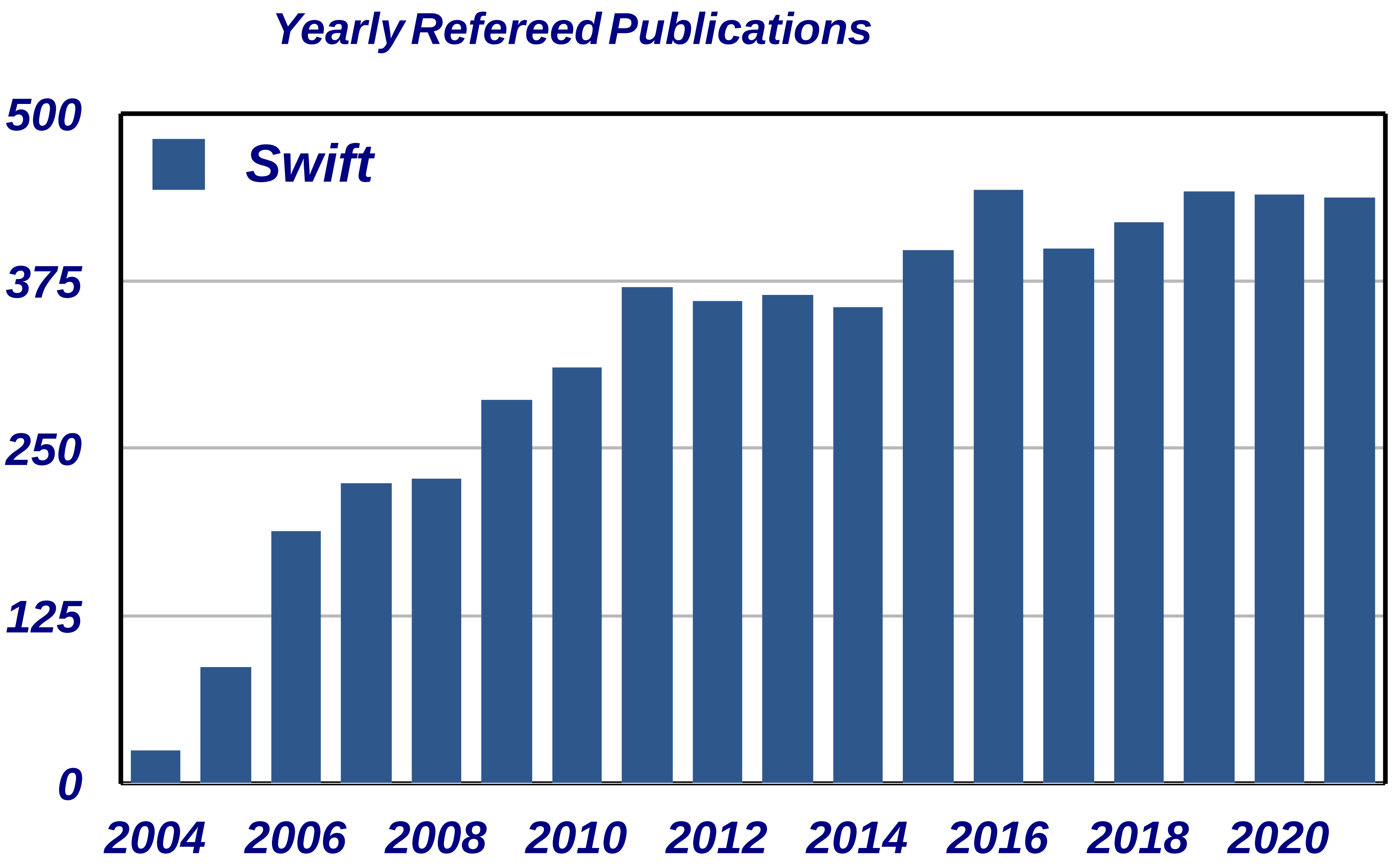
- **GI program**
  - > 4 oversubscription, $1.2M, 5Ms time per year



Swift Operations Statistics

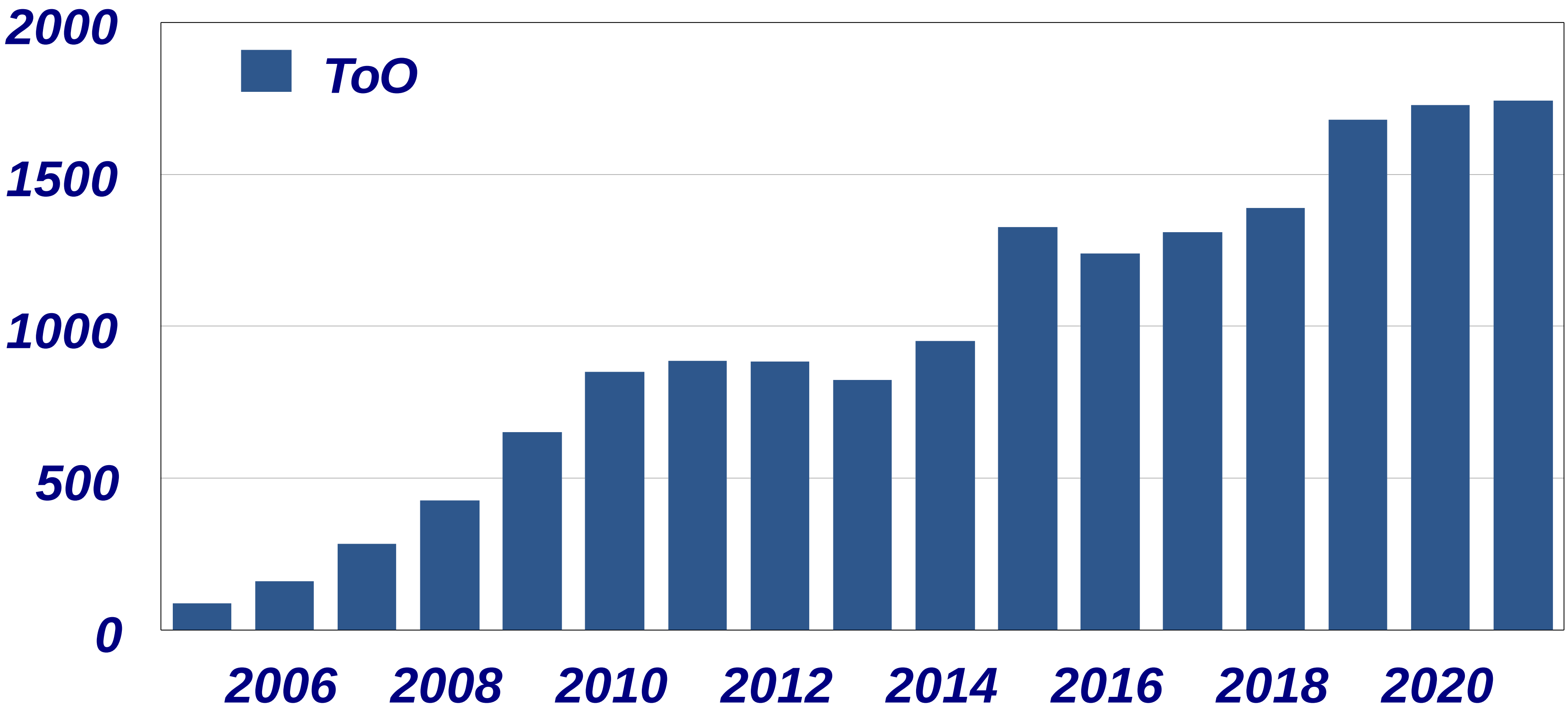
- **In a typical month:**
  - Swift received 93 Target of Opportunity (ToO) requests
  - 62 different (i.e. unique) ToO requesters
  - ToOs were for 85 different celestial objects
  - On average, Swift observed 94 different targets on the sky (per day)
  - Mean exposure per snapshot is 515 s, max for scheduling is 1800 s
- **Swift's observing efficiency is ~70-75%**
  - Other time is spent slewing and/or in SAA
- **LIGO Swift follow-up will have many more short obs (~80 per tile)**
  - Hundreds of fields to be scanned based on nearby galaxy priority weighting

Scientific Productivity



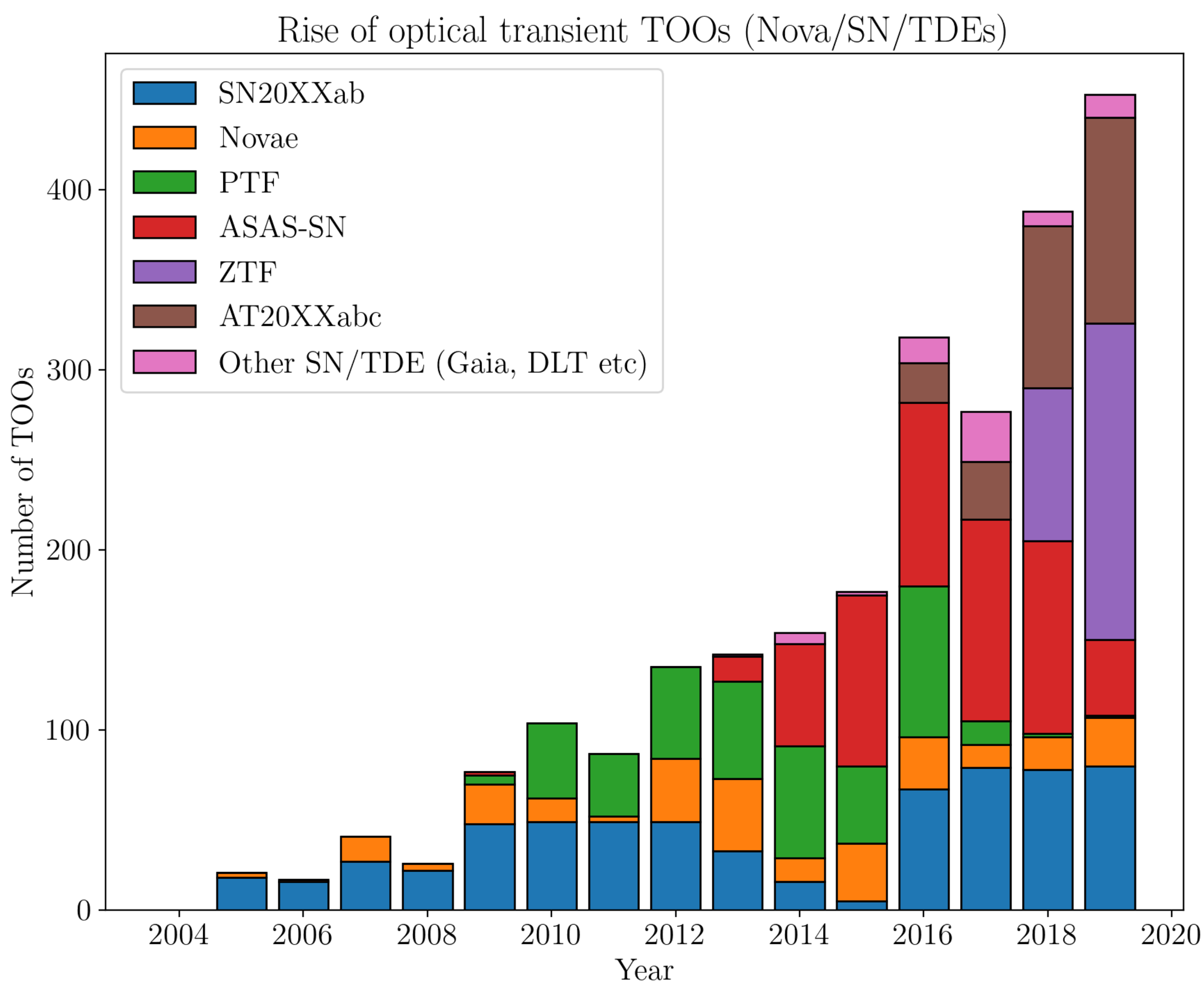
Brad Cenko

TOOs per year



Jamie Kennea

What's behind the rise in TOOs?



Large Optical surveys driving TOO rates

- **Leaps in the numbers of these TOOs have followed the development of new discovery capabilities.**
  - **Palomar Transient Factory** starting in 2007. Median was 42 TOOs per year, 84 in 2016, the last year of PTF**.**
  - **ASAS-SN:** Since turn-on in 2013, it ramped up to ~110 TOOs per year in 2016-2018.
  - **TNS:** Since 2016, the optical transients named by the Transient Name Server have accounted for more and more. 114 TOOs in 2019.
  - **Zwicky Transient Facility.** ZTF Exploded out of the gate in 2018 with 85 TOOs, and 176 so far in 2019!
  - **Next: LSST** 😱

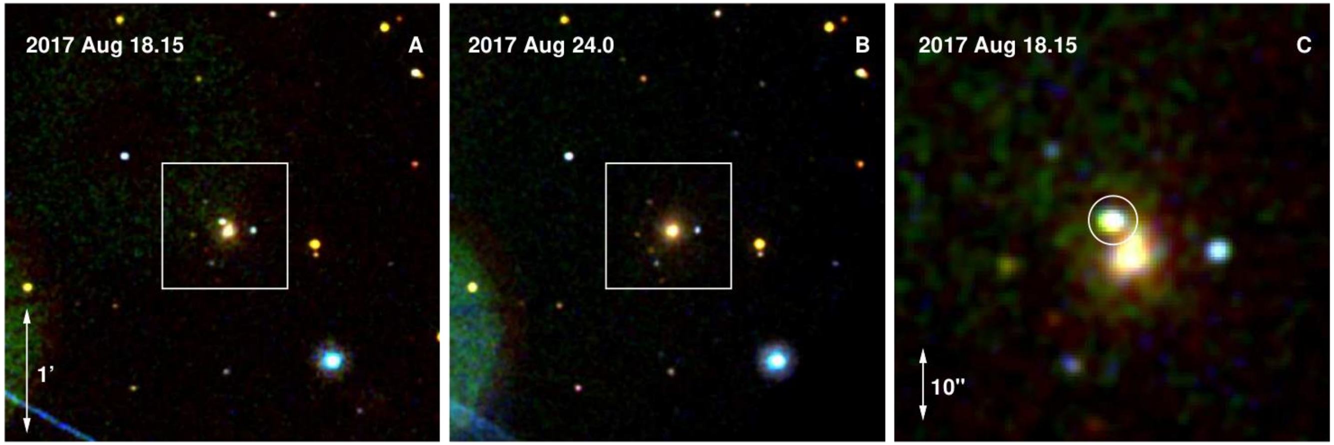
Jamie Kennea

Swift as an E-M counterpart finder

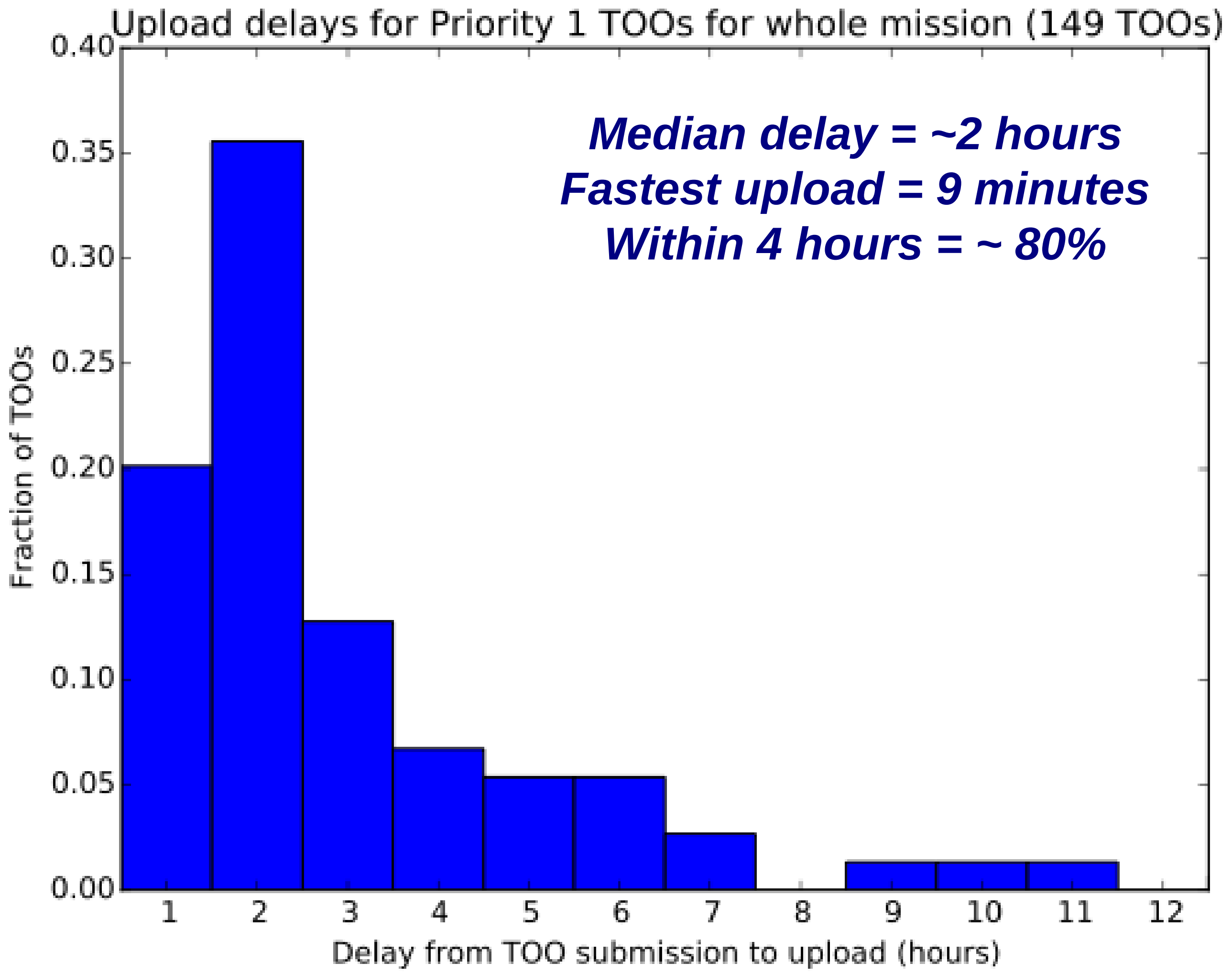
- **Swift's unique capabilities:**
  - Performing rapid Target of Opportunity (TOO) observations
    - TDRSS and Groundstation uploads with low latency.
  - Rapid slewing allows for high efficiency/low overhead observing
    - Swift average slew rate ~0.6 deg/second.
  - Ability to see a large area of the sky over a short period (96 min orbit) vs ground based observatories waiting for night-time, and latitude limited viewing areas.
  - Can do regular followup to check for fading (with wavelength coverage from optical-UV-Xray)

Multi-messenger TOOs

- Into the crowded field arrives the dawn of Multi-Messenger Astrophysics!
- Now we're triggering on events from LIGO/Virgo (Gravitational Waves) and IceCube/Antares (Neutrino detections).
- Neither of these localizes particularly well (GW is especially bad), requiring novel and/or large scale observation strategies.
- These require fast response. e.g. The UV counterpart of GW170817, detected by Swift, was gone within 24 hours.



Upload time statistics



Planning Automation Status

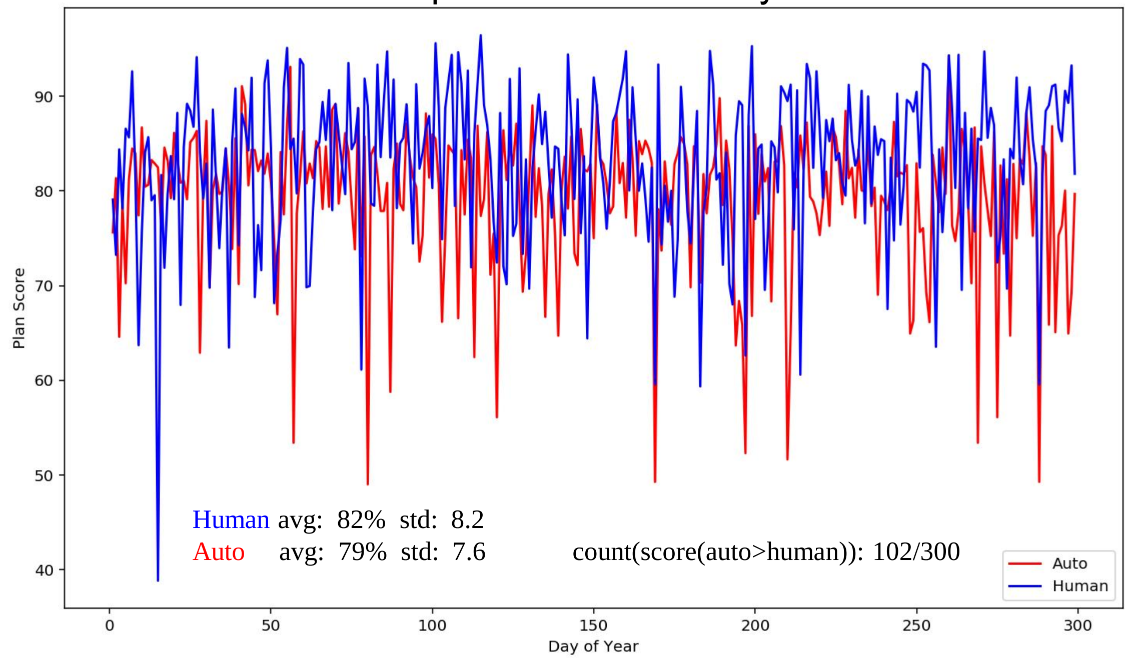
-Aaron Tohuvavohu & Jeff Gropp

- Current Automation can outperform humans consistently if allowed to run for ~20 mins.
- ‘Rapid’ option (avg runtime 100 seconds) has avg score within 3% of humans, and outperforms ⅓ of time. (see fig ---->)
- Can produce both normal PPST format, and PPTOO format plans.
- Automated run over 300 days of 2018 produced 6 failures. All of these bugs have been addressed. Rerun produced 1 failure. (0.3% rate)
- Even failed runs can be edited by humans to make acceptable, and cut the production time from ~5 hours to < 1 hour.
- All plans produced are safe for spacecraft.

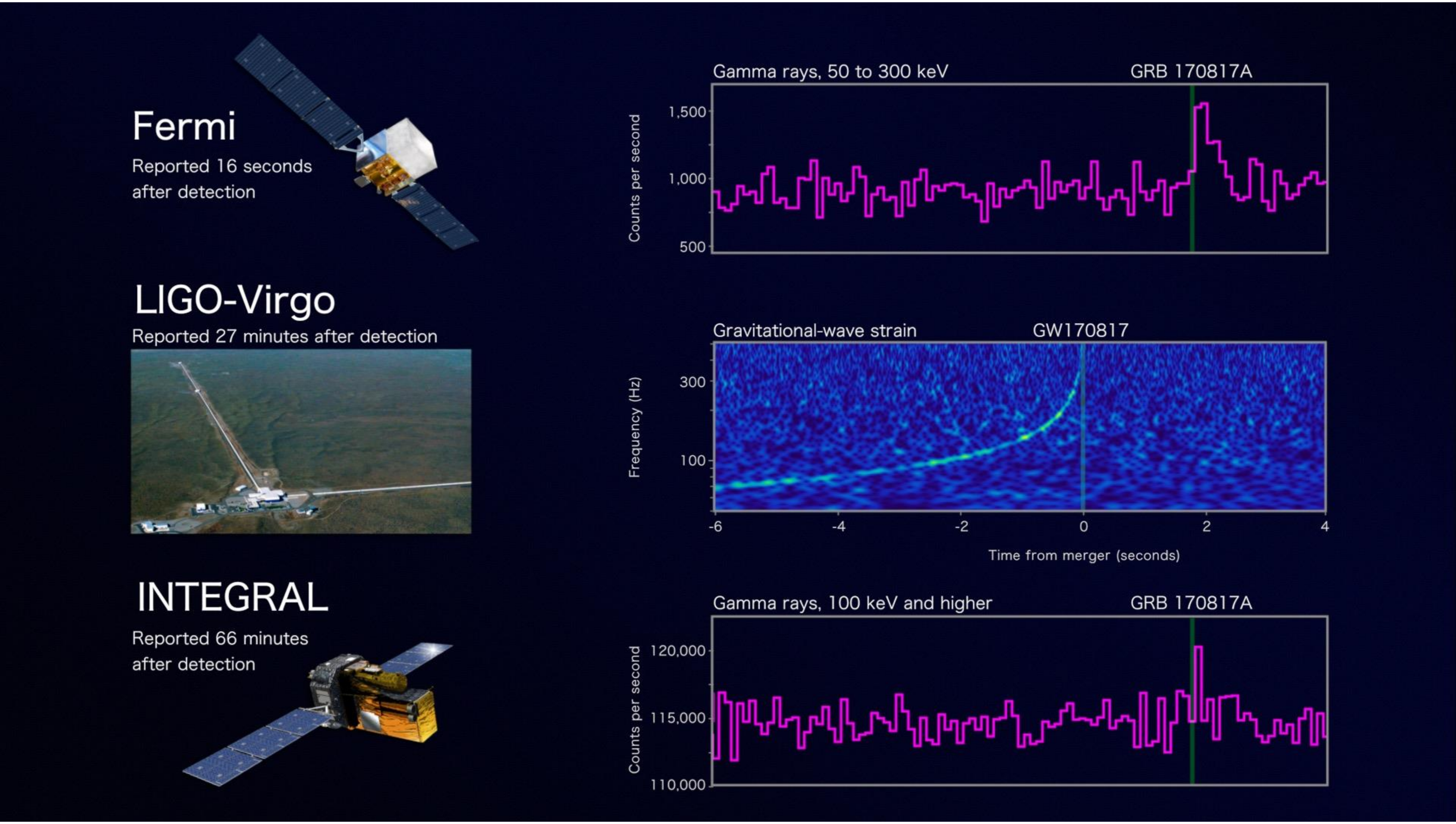
Future:

- Clear room for even better performance, and we know how to do it.
  - Project we can have ‘rapid’ option outperform humans >90% of time.
  - Within 1% of humans >99% of time
- Currently implementing wide-field tiling capability (LIGO)
- New science opportunities apart from rapid response and higher efficiency:
  - BAT biasing for LIGO or Fermi has been tested, is feasible.

Results of ‘rapid’ run over 300 days in 2018



GW170817 – First EM counterpart



GW170817 – Swift Followup

Swift response time: 16 minutes after EM target announced!

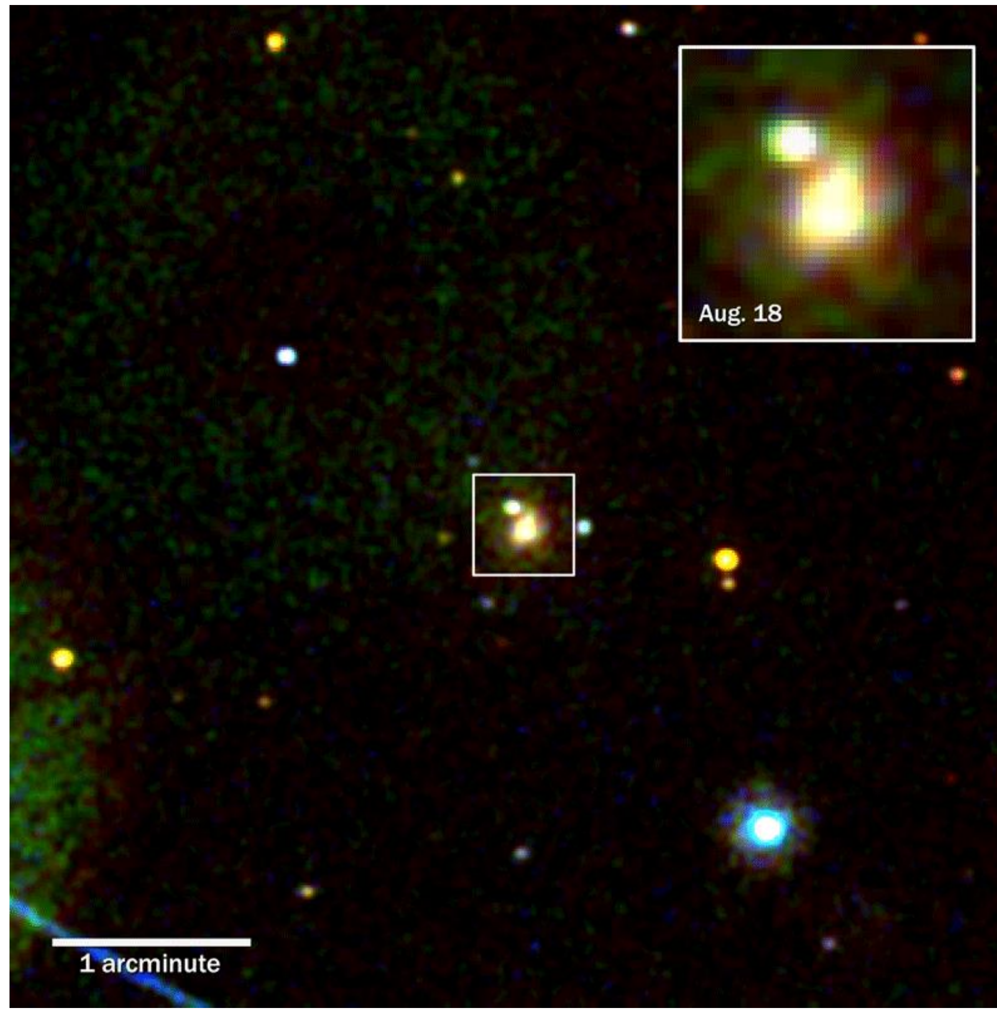
Covered 750 fields

92% of error region covered

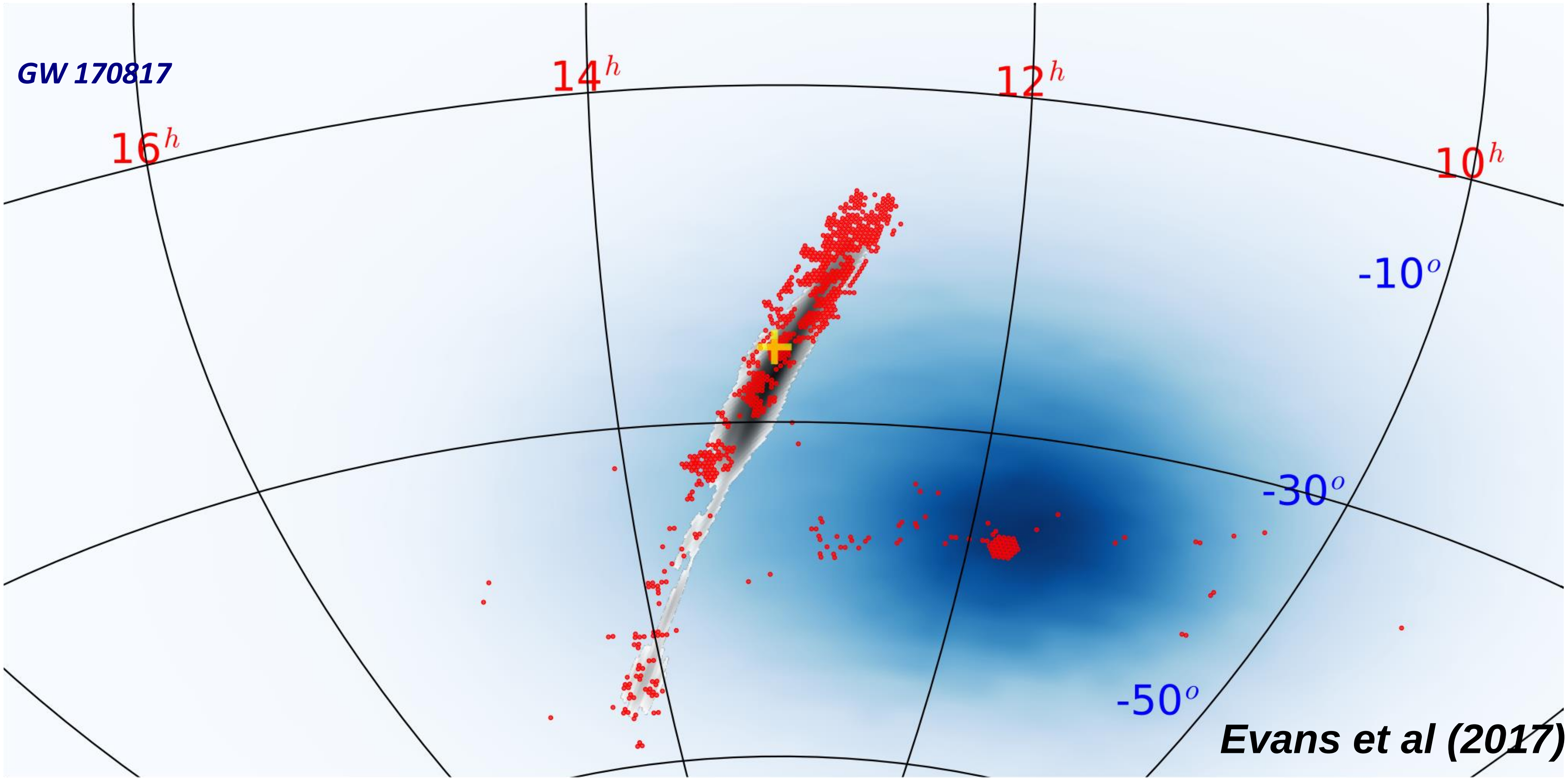
~200 ksec on AT 2017 gfo

Discovered UV emission

Most stringent limits on other X-ray and UV transients in error region



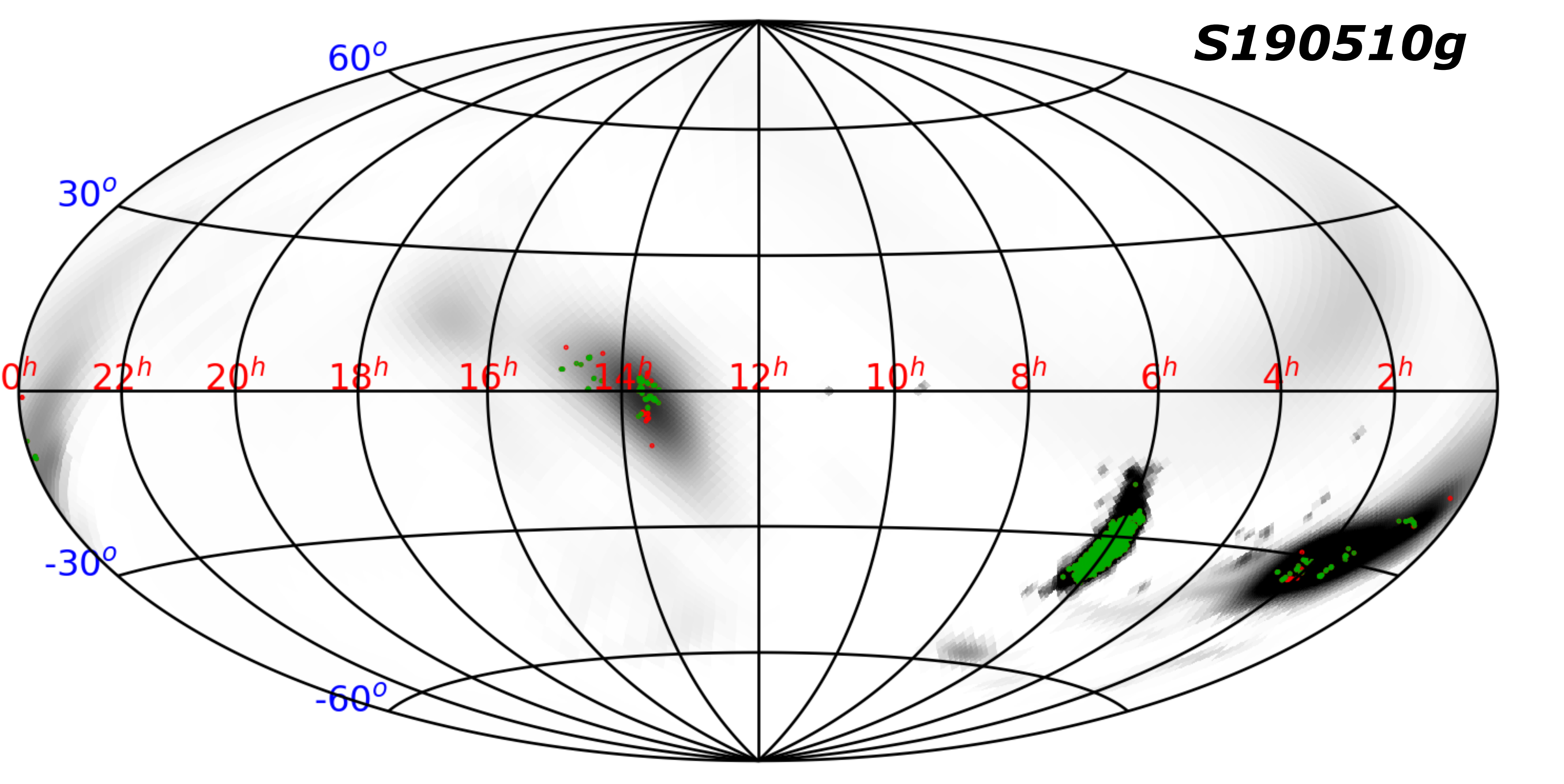
TILING LIGO ERROR REGIONS



♦ **GW170817:**

- 744 fields observed by Swift.
- 92% of distance-weighted GW localization covered.

Example o3 follow-up



- S190510g: 67% of the probability region covered by Swift observations in 977 pointings.

HOW Does Swift deal with So many TOOs?

- **Despite record breaking number of TOO requests in 2019-2023, we're doing a good job actually performing them.**
  - We consider reaching 80% of the requested exposure time as being "done".
  - We reached this goal for **91%** of all approved TOOs in 2019. 83% are 95% complete.
- **<u>How do we do this?</u>**
  - Firstly, Swift is extremely capable and fast. Rapid slewing means high efficiency when performing many short observations.
  - We continuously re-develop our planning software and on-board software to cope with the changing landscape.
    - Recently updated onboard software so instead of one TOO at a time, we can do many, in the case of GW follow-up, hundreds.
  - We have automated our planning software, so science plans can be generated quickly (daily) and if necessary, re-written on the fly in minutes.
  - Understanding community - they understand that even in space, sometimes it's too cloudy to observe their object.