PennState
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SWIFT OBSERVATIONS OF EVERYTHING (OR HOW I LEARNED TO STOP WORRYING AND LOVE TOOS)

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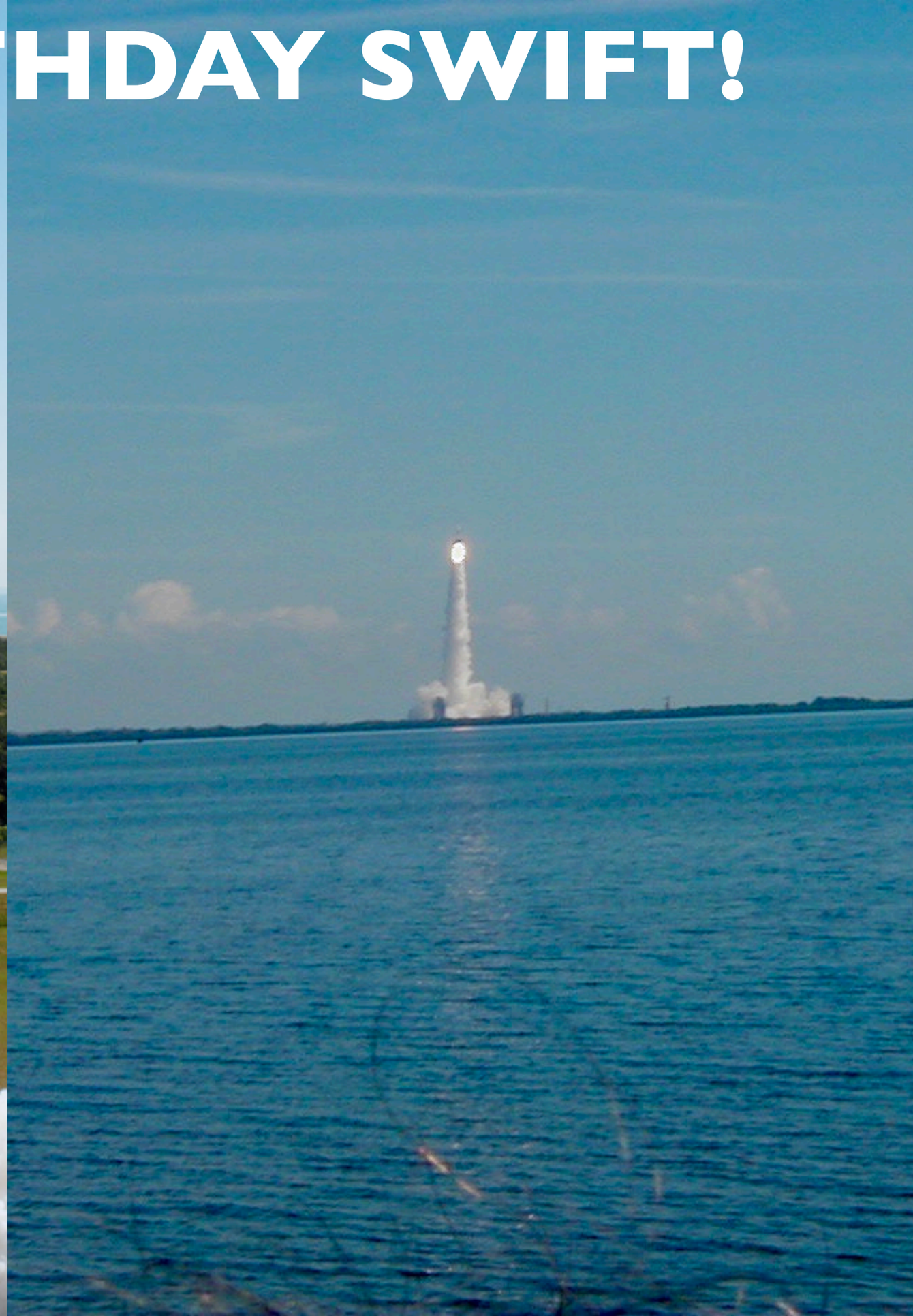
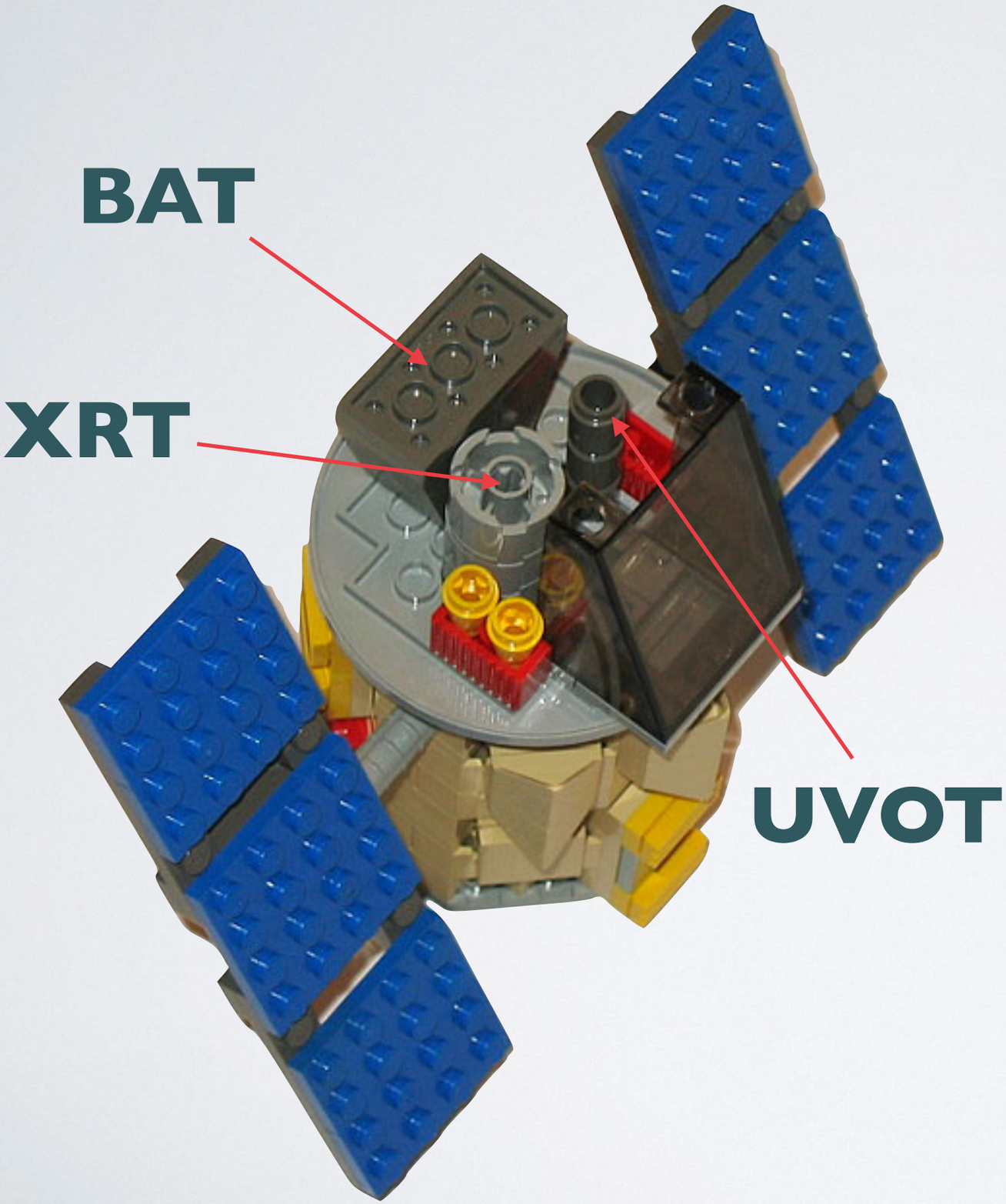
Swift launched 15 years ago today

Launched @ 12:16EST on Nov 20th, 2004

HAPPY BIRTHDAY SWIFT!



NEIL GEHRELS SWIFT OBSERVATORY

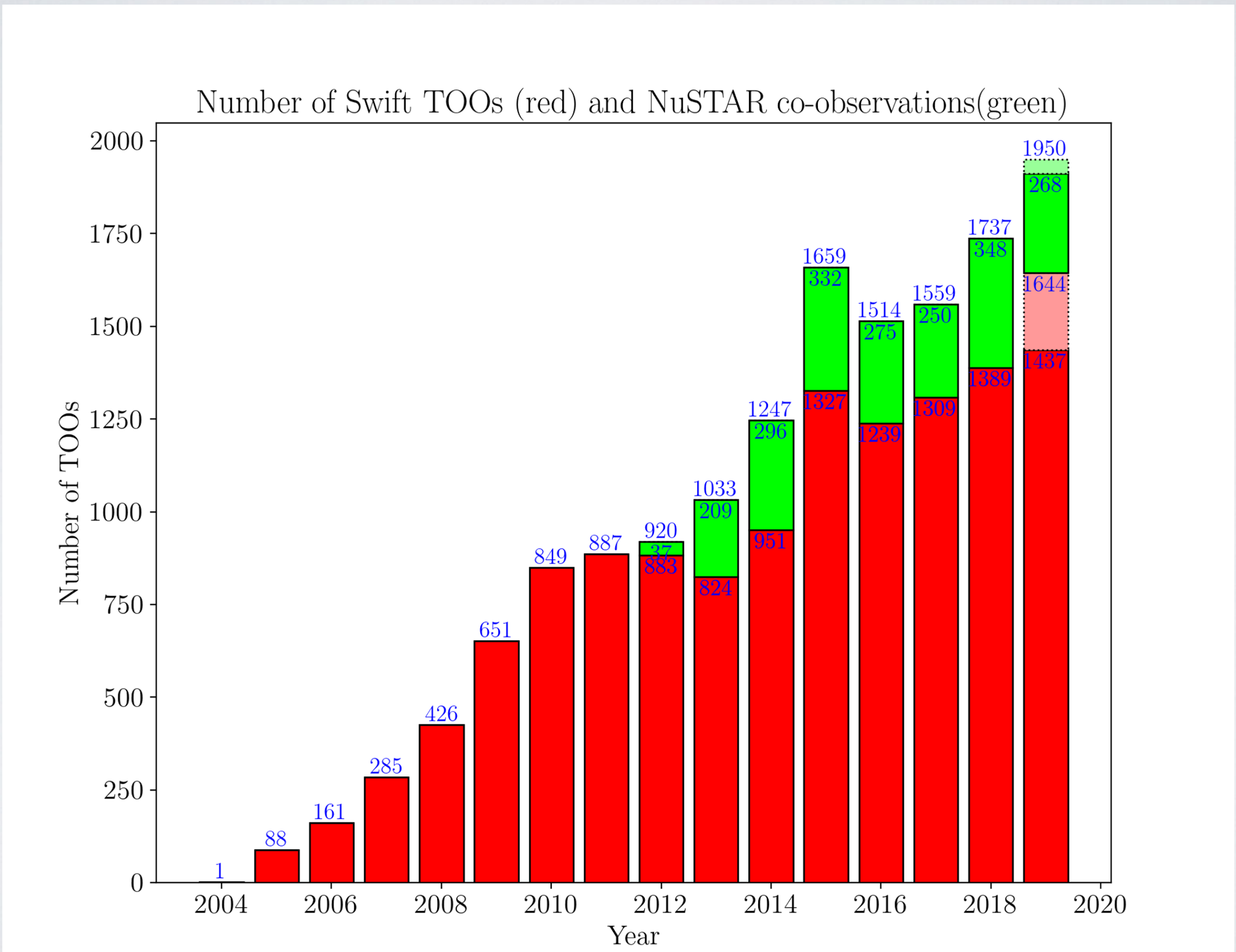


- **Burst Alert Telescope (BAT)**
  - "Hard X-ray" 15-150 keV
  - 2 sr field of view (1/6th of sky)
  - CdZnTe detectors
  - Detects ~100 GRBs per year
- **X-Ray Telescope (XRT)**
  - "Soft X-ray" 0.3-10 keV
  - 23.8 arcminute diameter FOV (~0.12 sq degree)
  - few arcsecond (as good as 1.8") positions
  - CCD spectroscopy
- **UV/Optical Telescope (UVOT)**
  - 170 – 650 nm
  - 17 arcminute width square FOV (~0.8 sq degree)
  - Sub-arcsecond positions
  - Grism spectroscopy
  - 6 UV/optical broad-band filters
  - 22nd mag sensitivity (filtered)

SWIFT OPERATIONS STATS

- In the past 28 days (as of Nov 15th, 2019):
  - Swift has received 93 Target of Opportunity (TOO) requests (3.3 per day)
  - 62 different TOO requesters in that time (diverse community)
  - TOOs were for 85 different celestial objects
  - On average Swift observed 94 unique targets per day.
    - Mean exposure per snapshot is 515s, max for scheduling is 1800s (30min), min usually 300s (although smaller with tiling).
- Swift's observing efficiency is ~70-75%. Rest of the time spent slewing and passing through SAA.
- LIGO O3 means that we spend a lot of time tiling LIGO regions with short (80s) exposures, taking hundreds over first 48 hours after trigger.

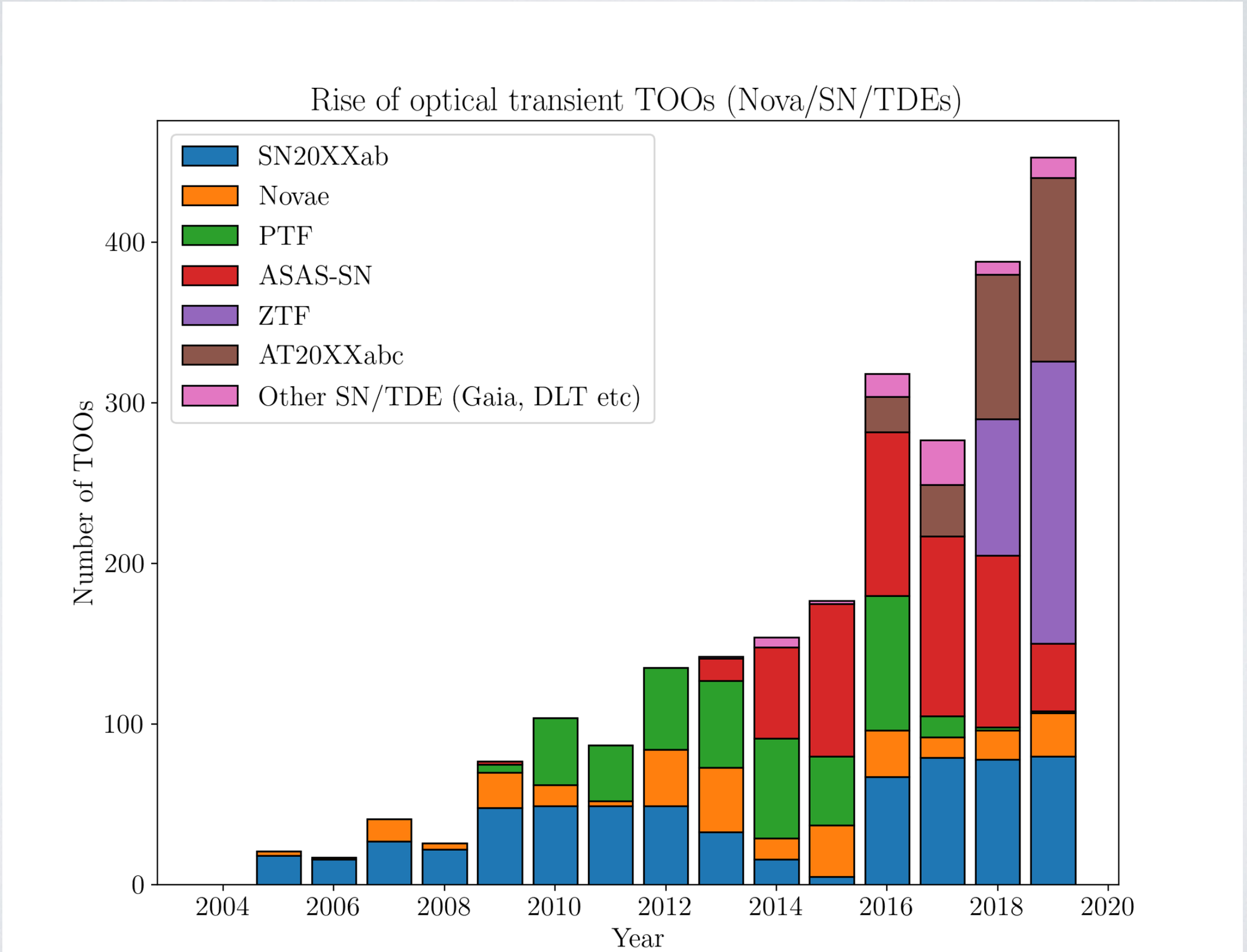
SWIFT DOES A LOT OF TOOS



TOO STATISTICS

- In 2019, we've had 1437 (as of Nov 15) TOOs so far, and estimate by the end of the year, this will be **~1640.** Approved TOO time is **~11Ms** (~50% of total exposure time available in a year).
- 2019 will be the record year for Swift TOOs, beating 2018's record by **>250 TOOs**.
- In 2019, Swift TOO approval rate was 98.3%. Apparently we're not too picky, or looking another way - we don't waste time with stringent evals.
- We also have a strong synergy with NuSTAR.
  - We observe every NuSTAR observation for at least 2ks,
  - NuSTAR accounts for ~300 observations per year.
- Observations coordinated with other observatories are given top priority.
- All Swift data public immediately.

WHAT'S BEHIND THE RISE IN TOOS?

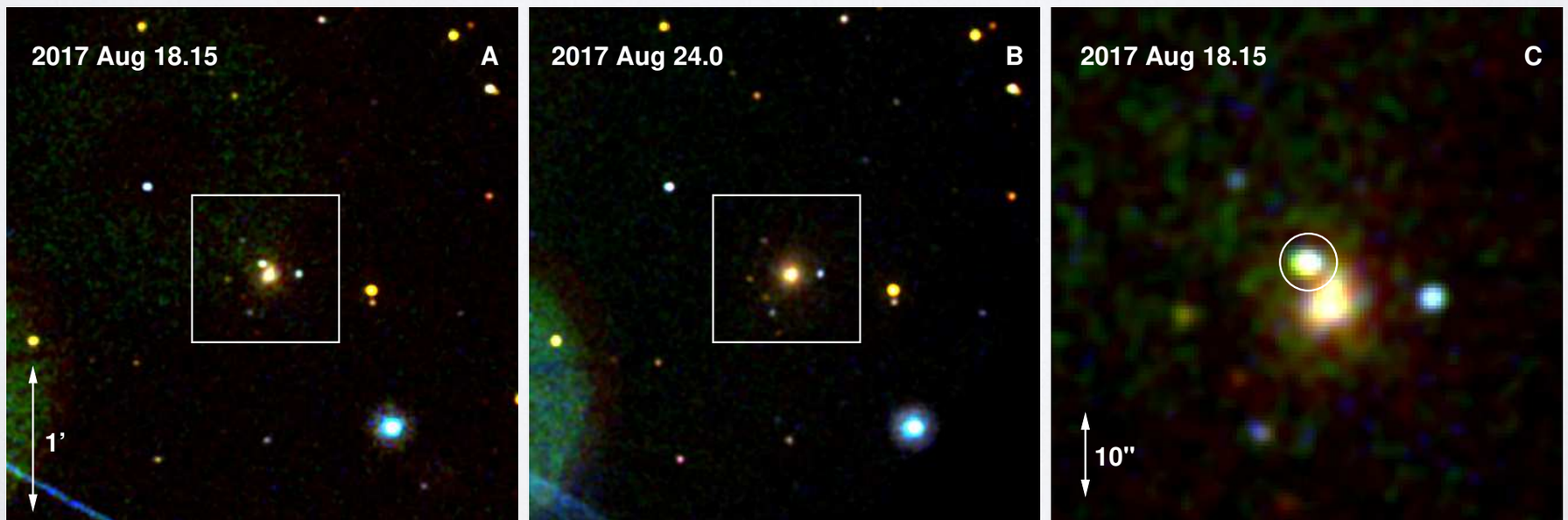


LARGE OPTICAL SURVEYS DRIVING TOO RATES

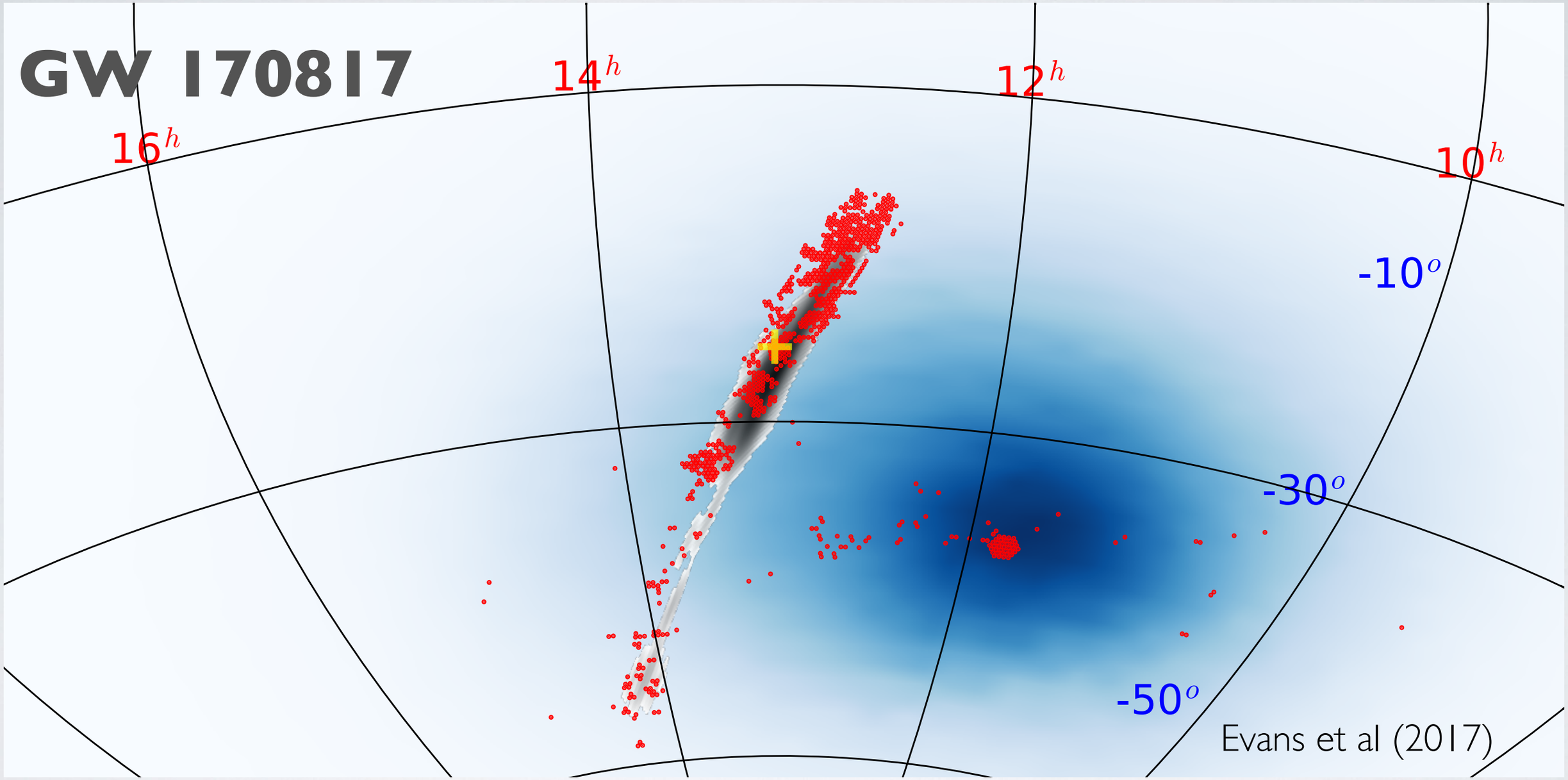
- **30%** of Swift TOOs in 2019 were following up optical transients (SN, TDEs, Novae), with UVOT
- Leaps in the numbers of these TOOs have followed the development of new discovery capabilities.
  - **Palomar Transient Factory** starting in 2007. Median was 42 TOOs per year, 84 in 2016, the last year 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** 😲

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.

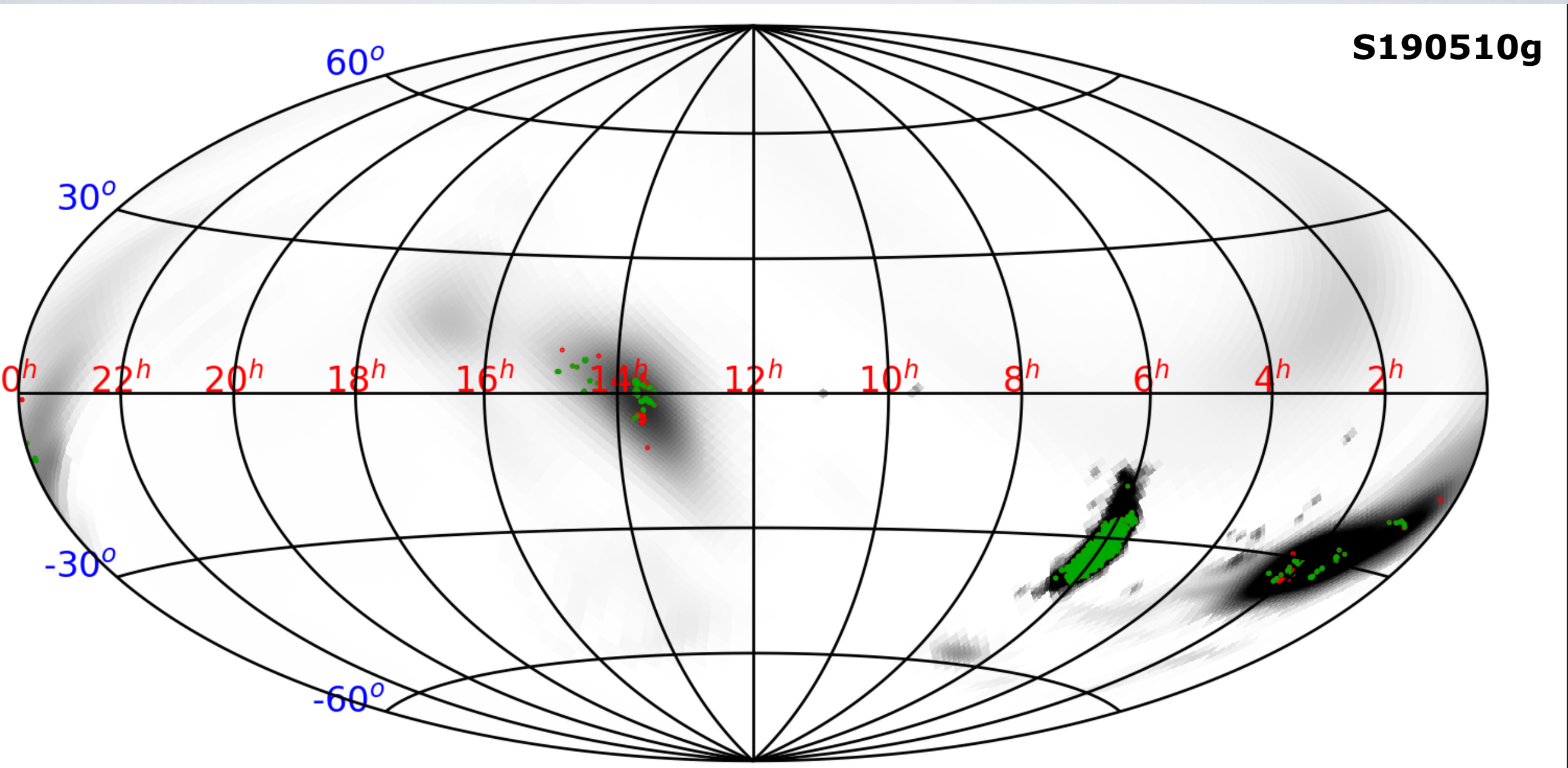


TILING LIGO ERROR REGIONS



- 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, 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.
- How do we do this?
  - 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.

THE FUTURE OF SWIFT TOO SUBMISSION

- We've determined that optical surveys are adding lots of TOOs to Swift.
  - LSST is coming, along with lots of others - how do we deal with additional TOOs?
- In addition how can we solve the user-end issue - submitting TOOs through a web form and is laborious.
  - Need to be able to request TOOs in real time, automated way.
  - Need to make it easier to request large numbers of targets, or large tiling areas.
- Right now we have a back-end process for auto-submitting TOOs for various programs (Fermi/LAT GRBs, IceCube Astrotrack Gold, LVC GW events)
- Plan to expand this effort to be generalized. Most recent Swift Senior Review approved and funding a program to develop an API for Swift TOO submission.

TOO API

- Idea is that TOO API allows direct submissions via computer-to-computer in a defined (VO?) format.
- Server side can filter on specific criteria to limit TOOs, i.e. we would be able to plug into the LSST transient broker and auto-generate TOOs for the targets that meet specified criteria.
- Will be able to plug into observatory coordination VO effort (see Erik's talk), to set up easy coordination.
- Traditional web-interface for TOOs just becomes an application that runs on this API.
- TOO API will include the ability to "pass through" requests to other observatories.
  - We are currently working with NICER to pass them Swift TOOs which better match their capabilities.
- Possibility that API could be adopted by other teams? Maybe NICER, certainly for future proposed missions (if approved).
- API development has not yet started, but will soon. Input and suggestions are appreciated.

OTHER SWIFT OPS DEVELOPMENTS

- Automated TDRSS pass operation (Oct 2019)
  - Can now pre-schedule TDRSS passes and use them without FOT on console. Preschedule TDRSS in pass gaps, reduce latency.
- Automated TDRSS pass scheduling (Dec 2019?)
  - This will reduce latency for rapid TOO follow-up with Swift down to ~15 mins.
- Automated BAT event dumps (May 2019)
  - BAT event data is too large to dump, but is much more sensitive for searching for EM counterparts of GW events.
  - We now auto-dump BAT event data whenever a GW event occurs (and others, IceCube, FRB)
  - Automation of TDRSS passes will allow this to happen for ~90% of all GW events. Right now it has to happen within 30 mins of a pass.
- Automated TOO uploads (2020+?)
  - Once we automate TOO submission, TDRSS pass scheduling and pass operation, the only latency left is the human-in-the-loop.
  - For very high importance events, we could auto-upload TOO observations to Swift, without the human intervention. Could be a game changer for catching events like UV/Opt/X-ray FRB emission?

CONCLUSIONS

- Swift's services are highly in demand, even after 15 years.
- >1600 TOO requests expected in 2019
- Swift can handle this because of an extremely rapid slewing and automated spacecraft.
- Also because a highly responsive and capable team, and continuous re-development of our planning and on-board software.
- Developments are in progress to handle the expected firehose of transients from LSST etc.
- Swift loves TOOs. Transient science keeps us highly ranked and funded!
- Swift won't last forever - please consider learning some of the lessons of Swift and including Swift like capabilities on future missions.

Swift NFI 15 Year All Sky Exposure Map