SWIFT OBSERVATIONS OF EVERYTHING

(OR
HOW
I LEARNED
TO STOP
WORRYING
AND LOVE
TOOS)

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NASA Neil Gehrels Swift Observatory
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)
  - TOO's 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

Number of Swift TOOs (red) and NuSTAR co-observations (green)

Year

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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?

Rise of optical transient TOOs (Nova/SN/TDEs)

- SN20XXab
- Novae
- PTF
- ASAS-SN
- ZTF
- AT20XXabc
- Other SN/TDE (Gaia, DLT etc)
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 😮**
• 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.
GW 170817

- 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.
• **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 TOO's. 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.