PennState
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NASA NEIL GEHRELS SWIFT OBSERVATORY: THE TOO MACHINE

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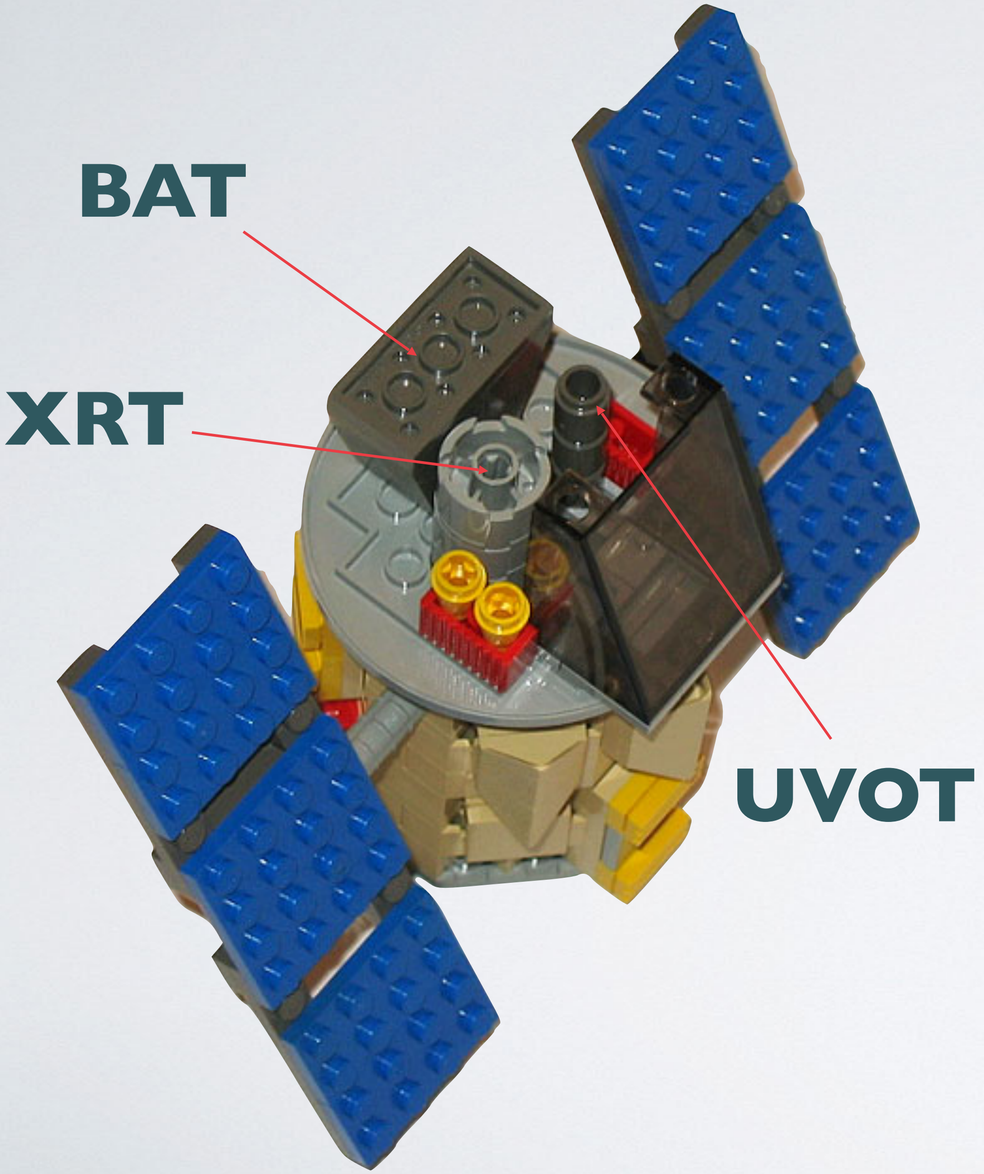
NEIL GEHRELS *SWIFT* OBSERVATORY



- **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 1.7") positions
  - X-ray CCD spectroscopy
- **UV/Optical Telescope (UVOT)**
  - 170 – 650 nm wavelength coverage
  - 17 arcminute width square FOV (~0.8 sq degree)
  - Sub-arcsecond positions (PSF ~2 arc-second FWHM)
  - Grism spectroscopy
  - 6 UV/optical broad-band filters
  - 22nd mag sensitivity (filtered)

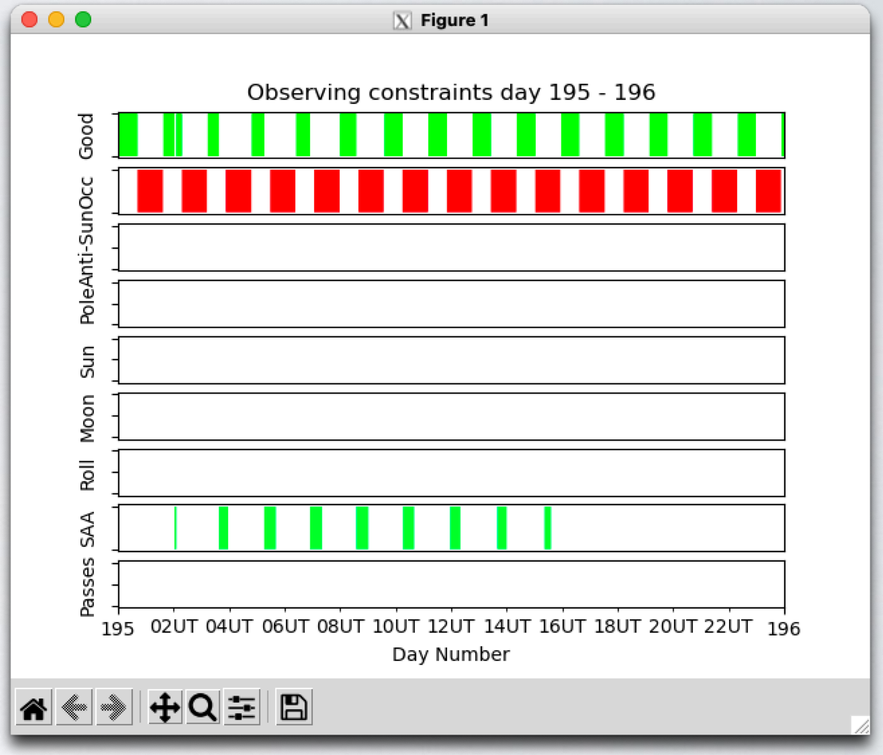
LEGO Swift credit: https://brickshelf.com/cgi-bin/gallery.cgi?f=114876

WHAT MAKES SWIFT UNIQUE

- **Multi-wavelength observations -** Hard X-ray/ X-ray / Optical / UV all in one package, simultaneously, makes Swift both powerful broad look at objects, but and also broadens the possible science as UV astronomy becomes more in demand.
- **Rapid slewing -** gets you to a GRB fast. Also allows for **very high efficiency** of operations (75%, despite being in LEO and spending time in SAA). Also allows **time domain astrophysics** due to ability to perform high cadence high sensitivity monitoring. Still fast even with a broken reaction wheel!
- **TOO capability -** capable of repointing Swift within minutes to hours to observe highly critical transients.
- **Constantly evolving ground and onboard software -** we don't stand still evolving the operations concept. We are constantly working on automation to allow us to do more with a very small team.
- **Motivated and agile team -** with the aid of software automation, Swift can be run by a small team on call 24/7, to respond rapidly to latest TOOs.
- **Open and broad TOO program with open data program -** Our TOO program is extremely open, with low rejection rates, and our data is made public ASAP - **no proprietary period.**
- **GRB Mission so interruptions are expected!** Observing plans are made 5 days a week so interruptions are expected. All observations are best effort and targets are ranked by merit. As we don't (usually) guarantee observations, we can be more flexible and response quicker.

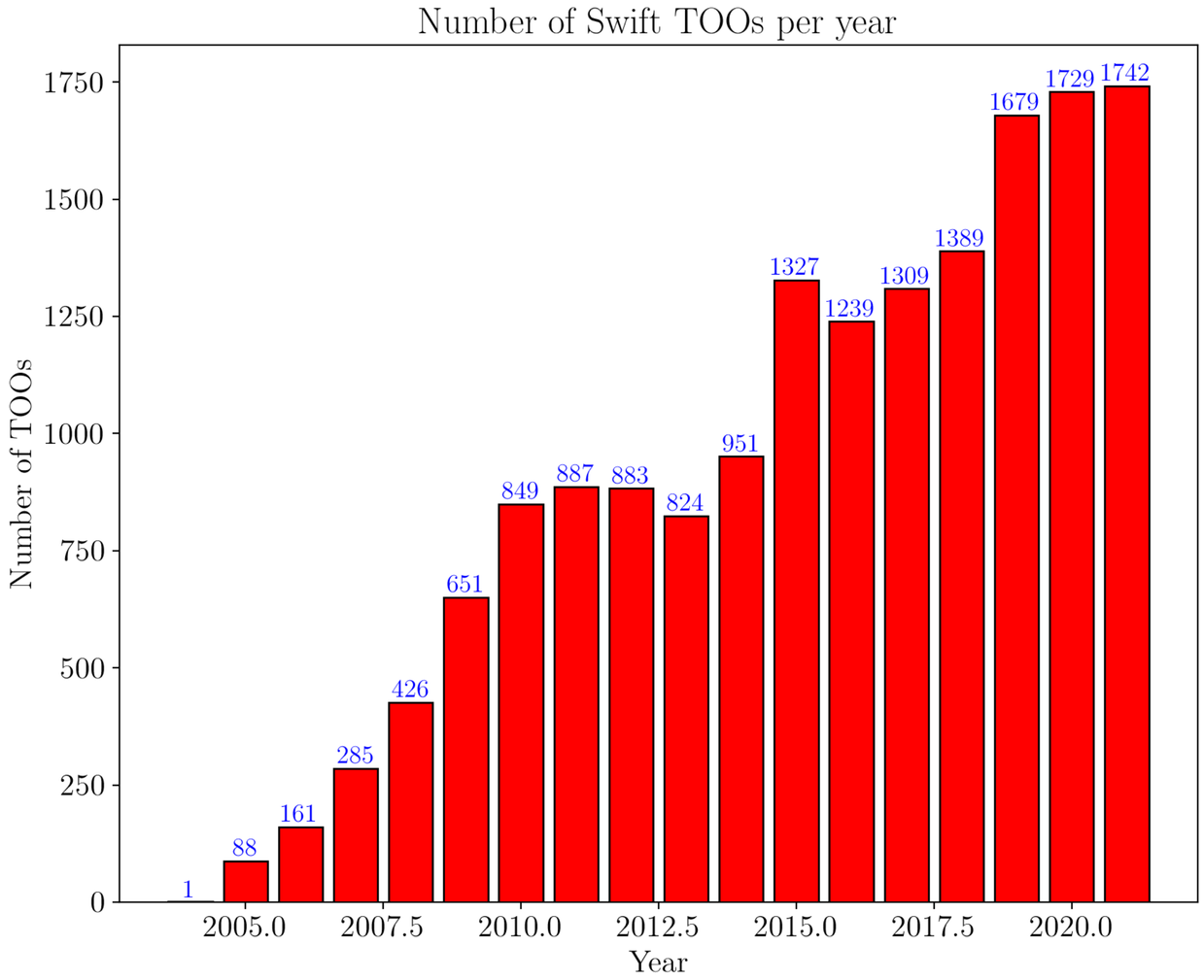
WHAT ARE SWIFT'S TOO AND OBSERVING CAPABILITIES?

- Observation limitations:
  - Swift is in LEO, with a 96 min orbit, so can only observe a target for maximum of 30 mins inside a 42 min window every orbit.
  - Swift can slew rapidly (minutes) to any visible target.
  - Swift cannot observe during passes through the South Atlantic Anomaly (SAA).
- Follow-up speed
  - Speed of observation is limited by our ability to make contact with Swift.
  - Most typical method is using a ground station pass. These occur 9-10 times per day, so typical wait times are ~60 mins, but can be longer.
  - Swift can also use TDRSS to to uplink TOO. 14 minute latency for scheduling TDRSS + visisbility constraints.
- Typical observation strategy
  - Swift observations typically are 1-5 ks each. Note anything over 1.8ks will have to be spread over several orbits.
  - Longer TOOs are possible, but remember how many TOOs we get and that there are only so many seconds in a day.

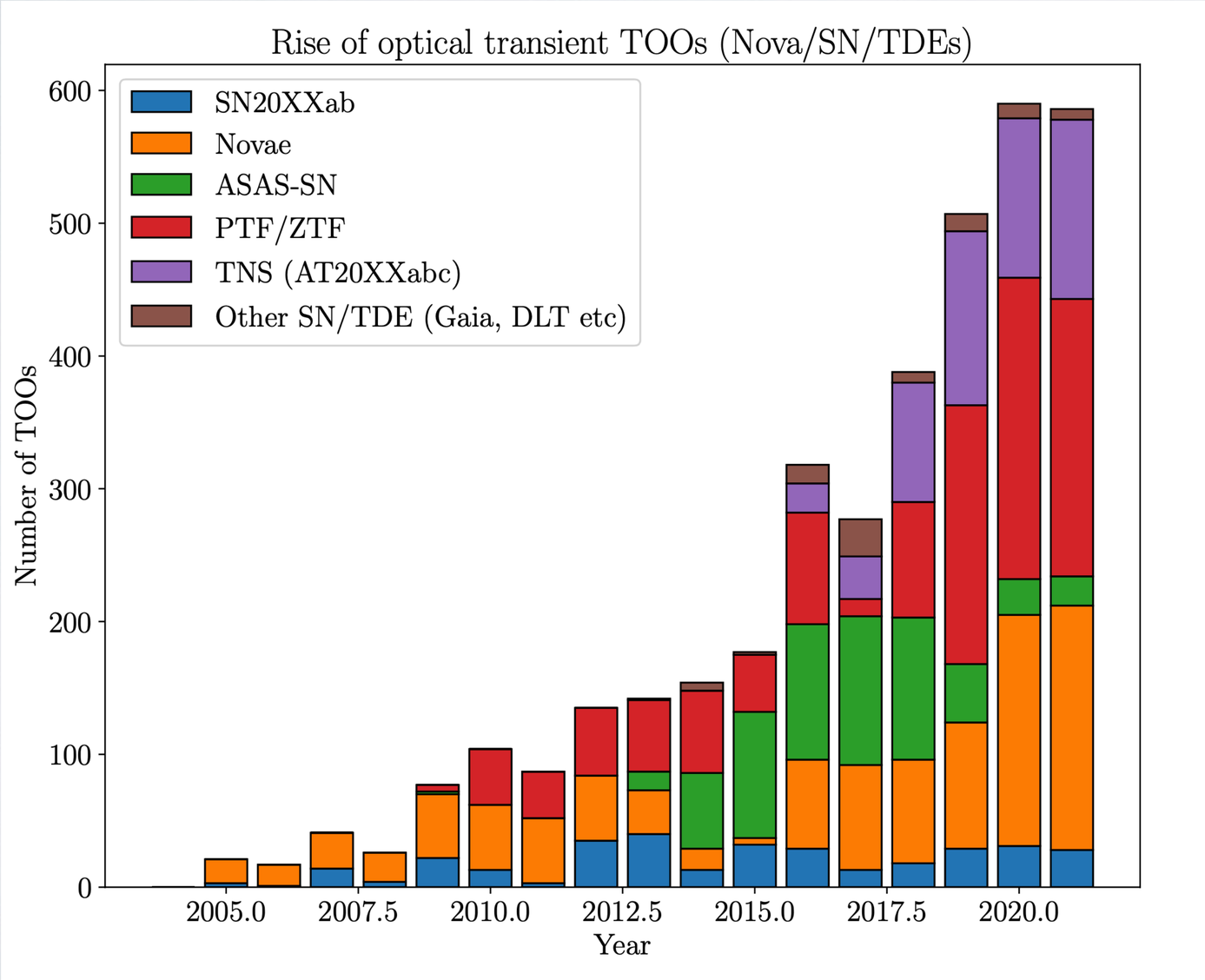


SWIFT RECEIVES A LOT OF TOOS

- 2021 - received 1742 TOOs in 1 year.
  - Approval rate ~99%.
  - TOOs performed on "best effort" basis.
  - Each TOO assigned a figure of merit value. The higher it is the more likely it is to be observed.
  - Figure of merit for TOOs approved through the Swift GI program is higher, so please apply for GI TOO time, to ensure observations occur.
  - Observations coordinated with other observatories recieve higher merit also.



WHAT'S BEHIND THE RISE IN TOOS?

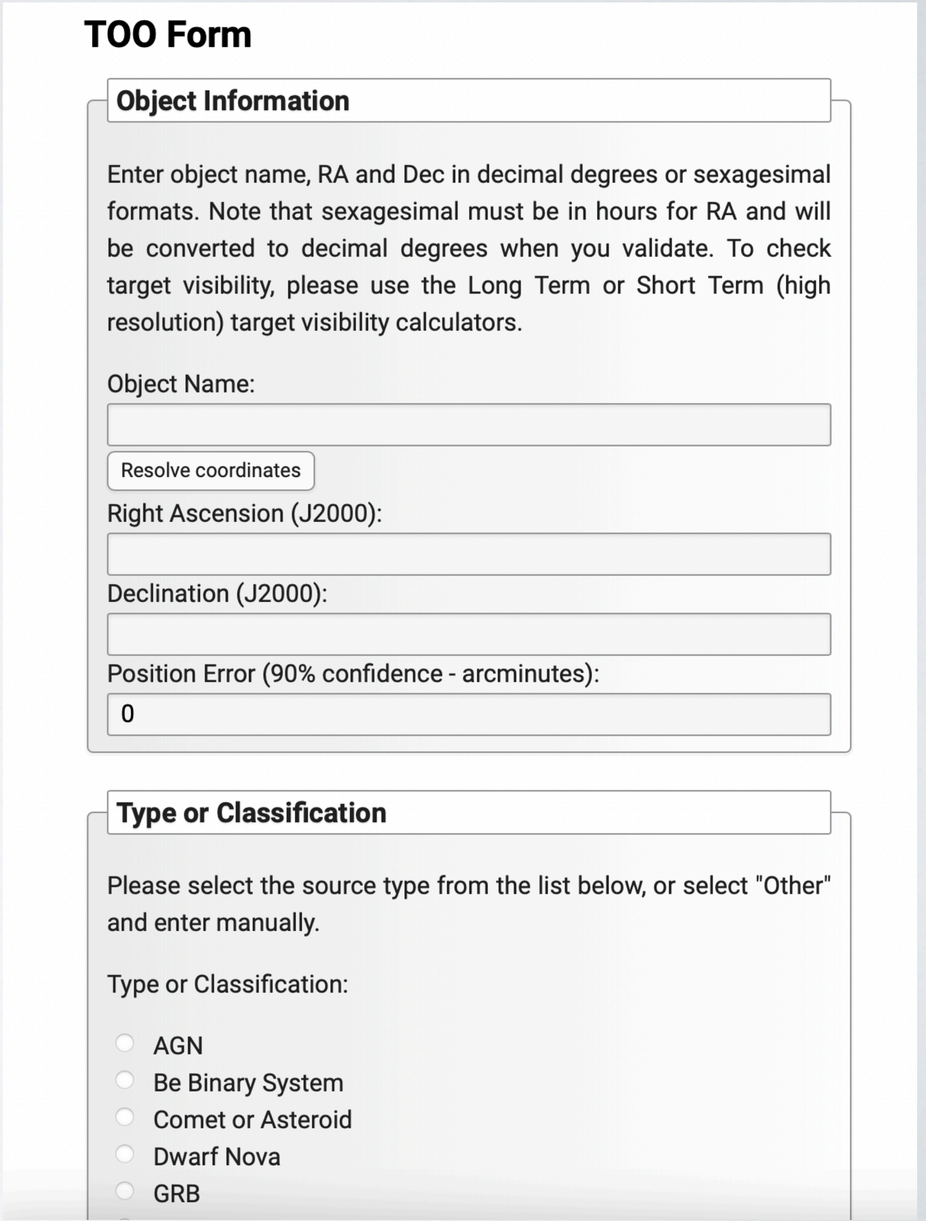


The future:

VERA C. RUBIN OBSERVATORY

HOW TO SUBMIT A SWIFT TOO (OLD WAY)

- ***TOO form on the PSU Swift Web site:***
  - Simple form to give coordinates, instrument modes, exposure, and science justification.
  - Link: https://www.swift.psu.edu/toop/too.php
- ***Urgency of the observation can be set to four values:***
  - Highest Urgency (1)- observations within 4 hours. Please only use for most exciting events as this wakes people up.
  - High Urgency (2) - observations within 24 hours. This should be used for time critical observations, most "discovery" TOOs use this. Will only page Swift people during working hours.
  - Medium Urgency (3) - days to a week. In reality this means the observation will go into the next scheduled plan. Typically plans are made 24-48 hours in advance.
  - Low Urgency (4) - weeks to a month. Essentially for anything that has no strong urgency.
  - **Expect most transient TOOs will be Urgency 1 or 2. Please only use 1+2 for first observation, not extending observation.**



TOO Form

Object Information

Enter object name, RA and Dec in decimal degrees or sexagesimal formats. Note that sexagesimal must be in hours for RA and will be converted to decimal degrees when you validate. To check target visibility, please use the Long Term or Short Term (high resolution) target visibility calculators.

Object Name:

Resolve coordinates

Right Ascension (J2000):

Declination (J2000):

Position Error (90% confidence - arcminutes):

0

Type or Classification

Please select the source type from the list below, or select "Other" and enter manually.

Type or Classification:

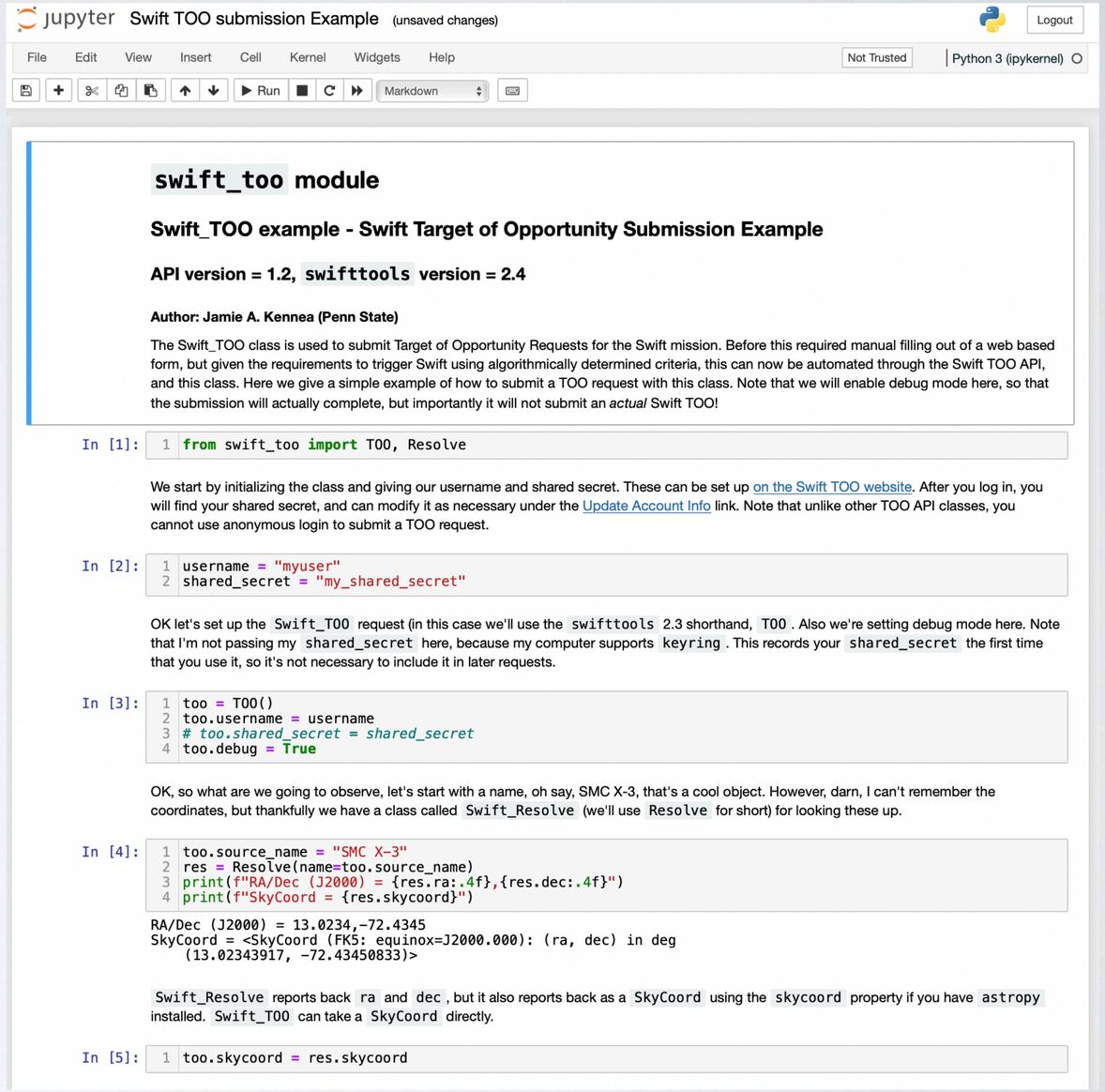
- AGN
- Be Binary System
- Comet or Asteroid
- Dwarf Nova
- GRB

SWIFT TOO API

- **Swift TOO API allows direct TOO submissions in a simple defined format (JSON), without the need to fill out a web form.**
  - Allows for automated submission of TOO without human in the loop.
- **Server side processing of TOO, allows filtering on specific criteria to limit TOOs.**
  - We could plug into a Rubin transient broker and auto-generate TOOs for the targets that meet specified criteria.
  - Criteria would need to be set to allow a sensible rate of TOO requests.
  - Groups should coordinate on this to limit rates. E.g. script that produces 1 TOO per day is fine, but not if there are 100 of those scripts running!
- **API clients can be implemented in any language for any platform.**
  - E.g. Swift TOO web form is actually TOO API client written in PHP.
- **TOO API also provides interface for a variety of TOO planning activities**
  - Can use to calculate target visibility, search for prior and upcoming observations, look at previously submitted TOOs and much more.

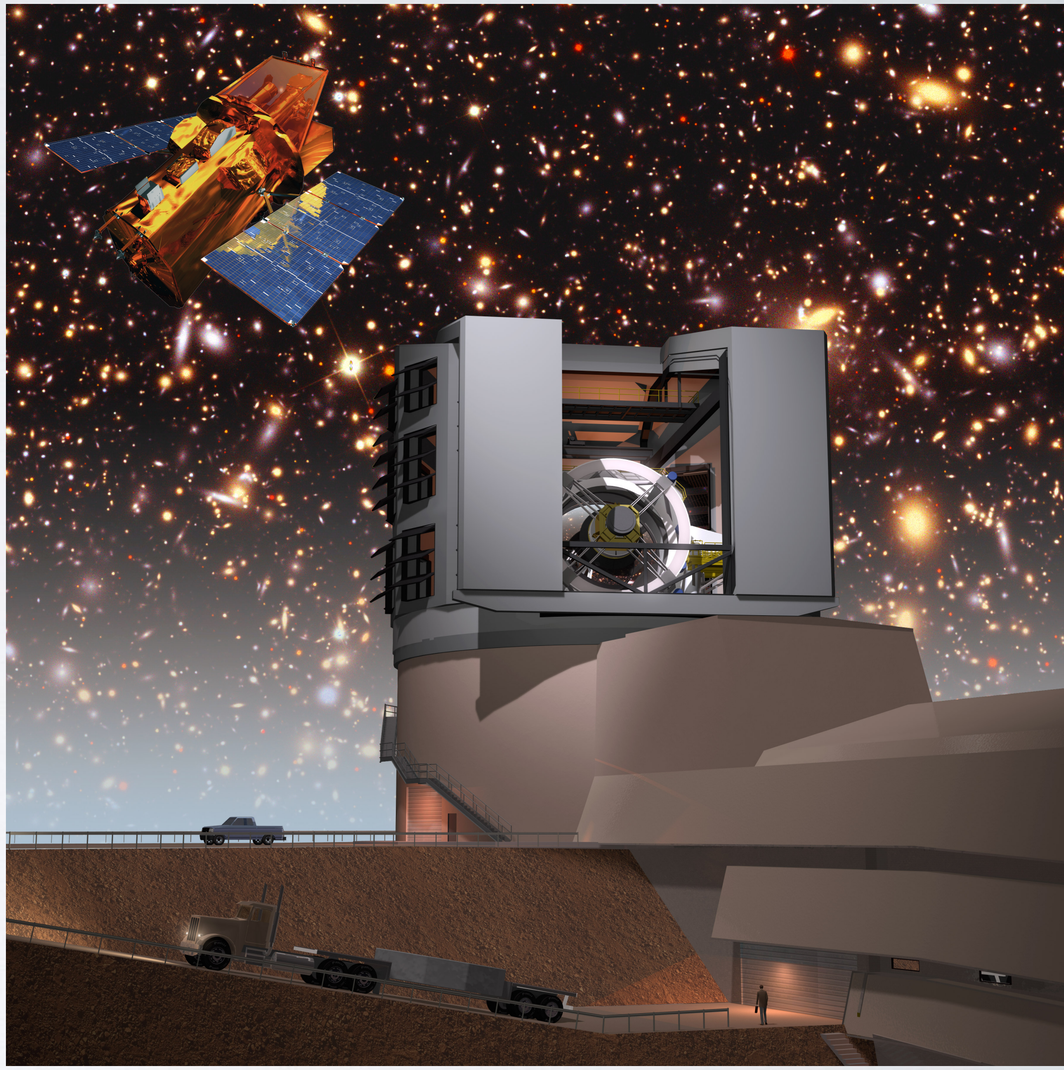
TOO API PYTHON MODULE IMPLEMENTATION

- **Swift TOO API reference implementation is a Python Module**
  - Part of the **`swifttools`** module, submodule **`swift_too`**.
  - Install with **`"pip install swifttools"`**
- Documentation / Jupyter Notebook examples here:
  - **https://www.swift.psu.edu/too_api/**
- TOO submission requires registration on the Swift TOO site. All other tools that are part of **`swift_too`** do not.



SWIFT AND RUBIN

- Swift is ready to support Rubin with TOO follow-up, covering unique X-ray and UV wavelengths.
- Swift currently handles a large number of TOOs, and with some developments can do more.
- Teams who wish to trigger Swift TOOs from Rubin transients should discuss with the Swift team trigger criteria and rates of TOOs.
  - We encourage you to apply to the Swift GI program!
- Remember - only so many seconds in the day, in the case of Swift about 60,000s.
  - Rubin transients can easily overwhelm Swift, despite it's flexibility.



CONCLUSIONS

- Swift's multi-wavelength instrument complement, rapid slewing and flexible software platform have allowed it to evolve from a GRB mission into a rapid response time domain astrophysics mission.
- Swift's popularity has turned it into a **TOO machine**, receiving 4-5 TOOs per day.
- Swift is capable of rapid follow-up,
- This number is going up driven by the increase in large scale optical surveys, wishing X-ray and UV follow-up. **Vera C. Rubin Observatory will take this to the next level.**
- We have developed a TOO API that allows both computer-to-computer interaction with Swift to submit TOOs and other tasks.
- **Swift is ready to support Rubin.** However, we need to work together to ensure that TOO request rates are reasonable (~few per day max), so Swift team is not overwhelmed!
- **THANK YOU**