SWIFT AND GRAVITATIONAL WAVE COUNTERPART FOLLOW-UP

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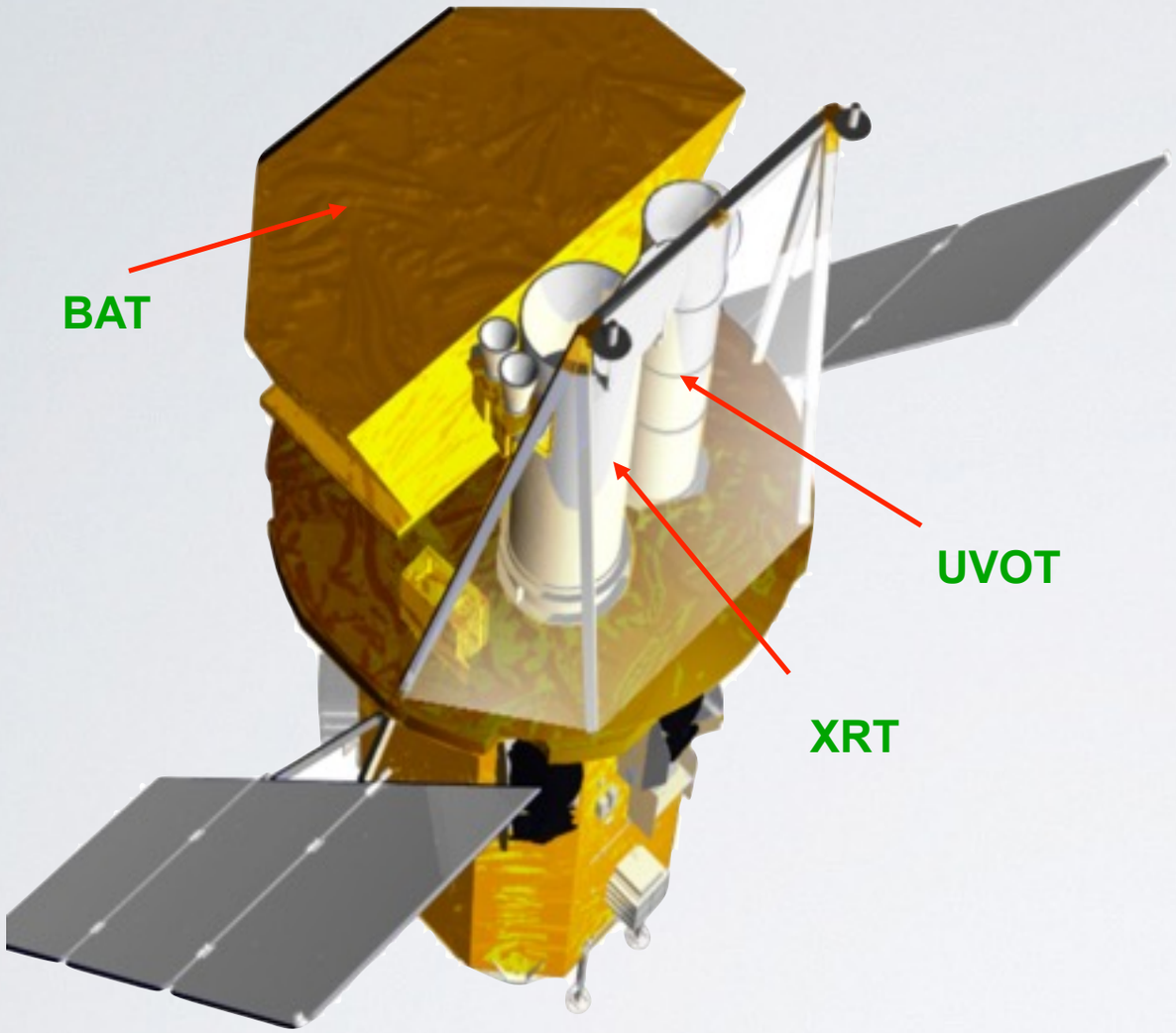
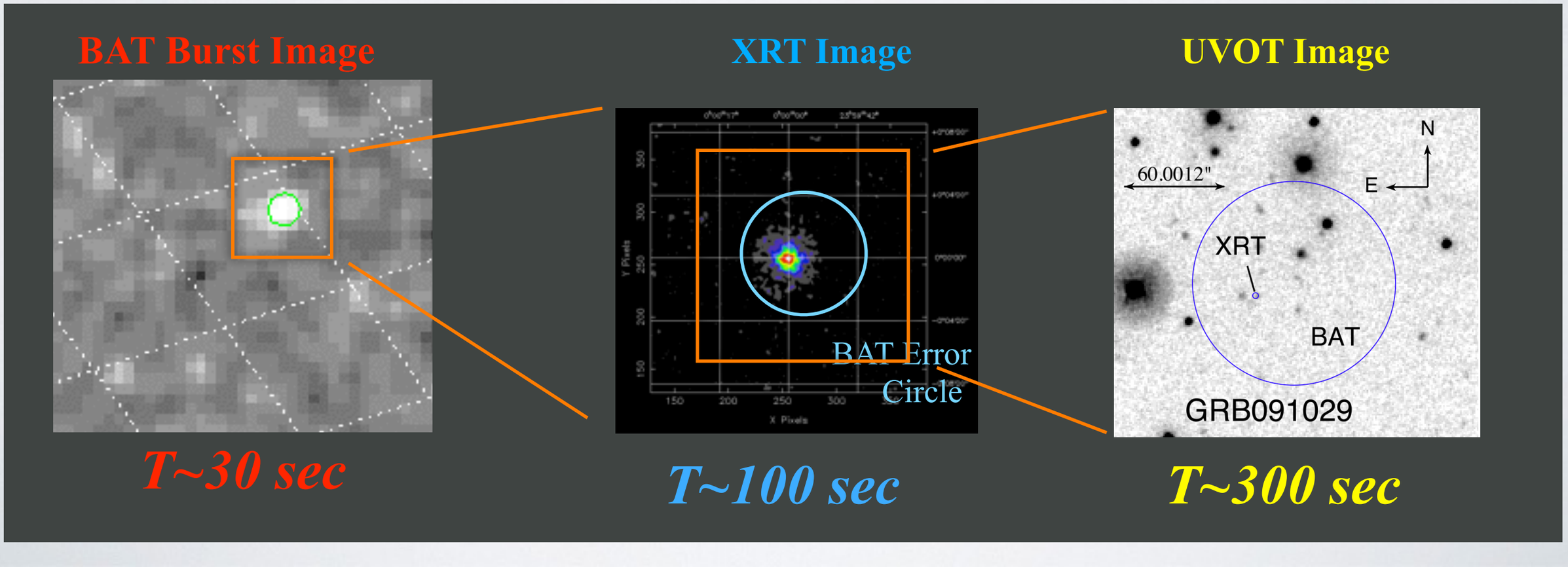
SWIFT



- **Burst Alert Telescope (BAT)**
  - 15-150 keV
  - 2 sr field of view
  - CdZnTe detectors
  - Detects ~100 GRBs per year
- **X-Ray Telescope (XRT)**
  - 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 DETECTS A GRB

1. Burst Alert Telescope triggers on GRB, calculates position to ~ 1- 3 arc-minutes, transmits to ground via TDRSS and distributed by GCN.
2. Spacecraft autonomously slews to GRB position in 1-2 minutes
3. X-ray Telescope: ~ 5 arcsec prompt, ~2 arcsec delayed position (distributed via GCN ASAP)
4. UV/Optical Telescope images field, transmits finding chart to ground
5. The Swift team analyzes the data in real time and sends out notice to the community in ~5 - 20 minutes.



SWIFT AS A GW COUNTERPART FINDER

- BAT triggering on a short GRB that ALIGO detects is clearly the "best case scenario".

- Swift's power however is it's capability of performing rapid Target of Opportunity (TOO) observations in order to search for things that it did not detect itself.

- For the rest of this talk I will discuss the mechanics of how Swift can quickly perform searches of LIGO error regions for afterglow candidates.

SWIFT OPERATIONS IN A NUTSHELL

- **FOT** command Spacecraft, look after health and safety, monitor trends, perform day to day engineering tasks.

- **SOT** plan observations, communicate with observations, receive and process TOOs (approvals by PI Neil Gehrels), send plans/TOOs to FOT.

  - Observatory Duty Scientists (ODS) main interface between SOT and community. ODS can approve TOOs out of hours.

- MOC operates from **8-5pm Monday-Friday**.

  - On-call ODS/FOT outside of those hours.

  - On call person cycles weekly.

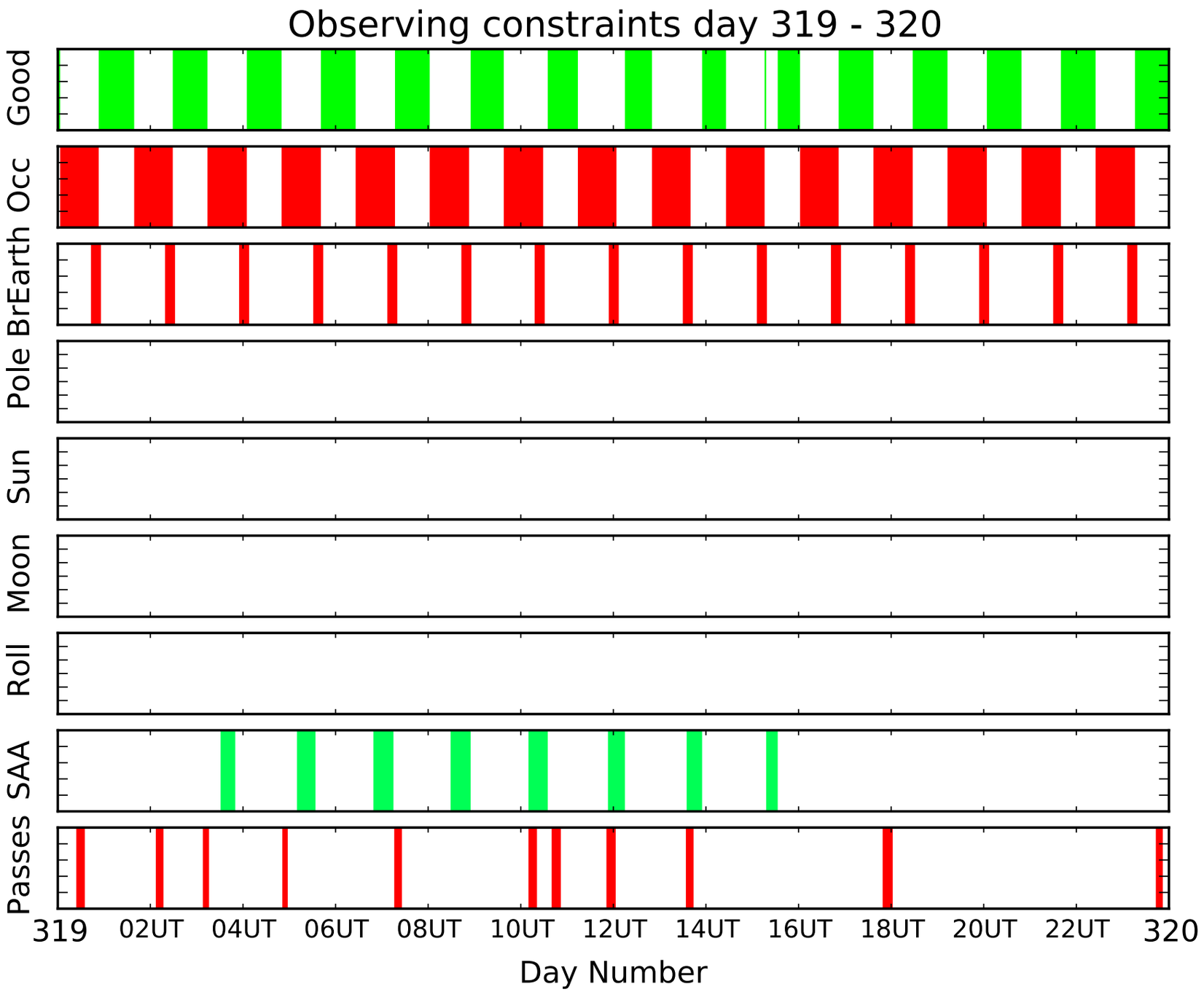
TOO INTERFACE

- Swift has a TOO web page which scientists use to submit requests for observations.
  - In 2014 we received almost 1000 TOOs!
- We currently accept observations for monitoring and tiling.
- For some programs, we have a backdoor system that allows auto generated TOOs from an email.

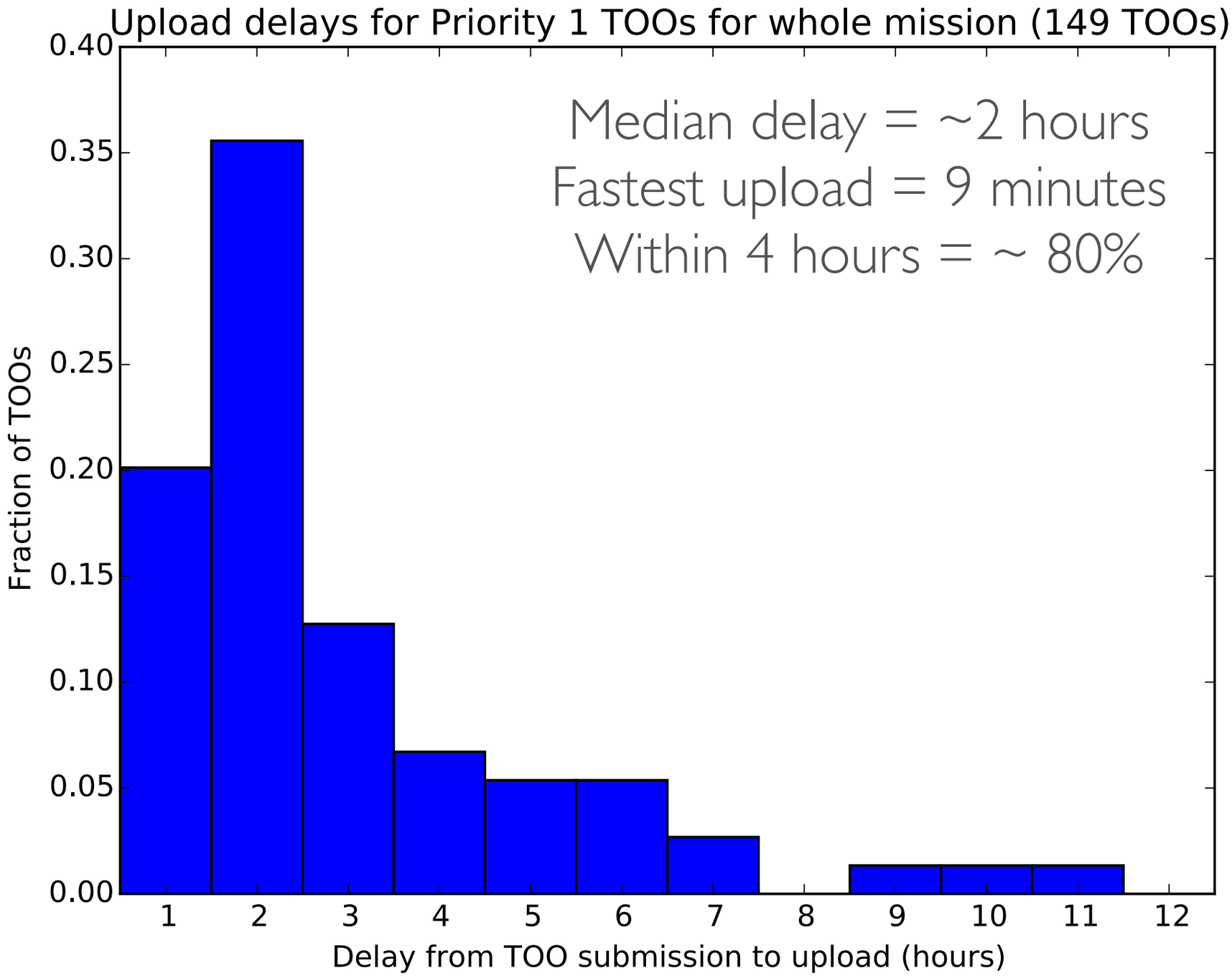
HOW QUICK CAN WE UPLOAD?

- Groundstation uploads:
  - Typically 9-12 ground-station passes per day.
  - Not all ground-stations are at the same location, so time between passes varies.
  - Sometimes as short as 20 minutes, sometimes 5-6 hours.
  - Uploads can be performed out of hours without FOT involvement.
- TDRSS:
  - TDRSS uploads can be scheduled at any time 24/7 with a 15 minute overhead.
  - TDRSS uploads outside of working hours require calling in on-call FOT, so add time of travel into MOC (~15-45 minutes) to already 15 minute overhead.
  - **For majority of cases, ground-station uploads will be adequate/faster than TDRSS.**

EXAMPLE VISIBILITIES



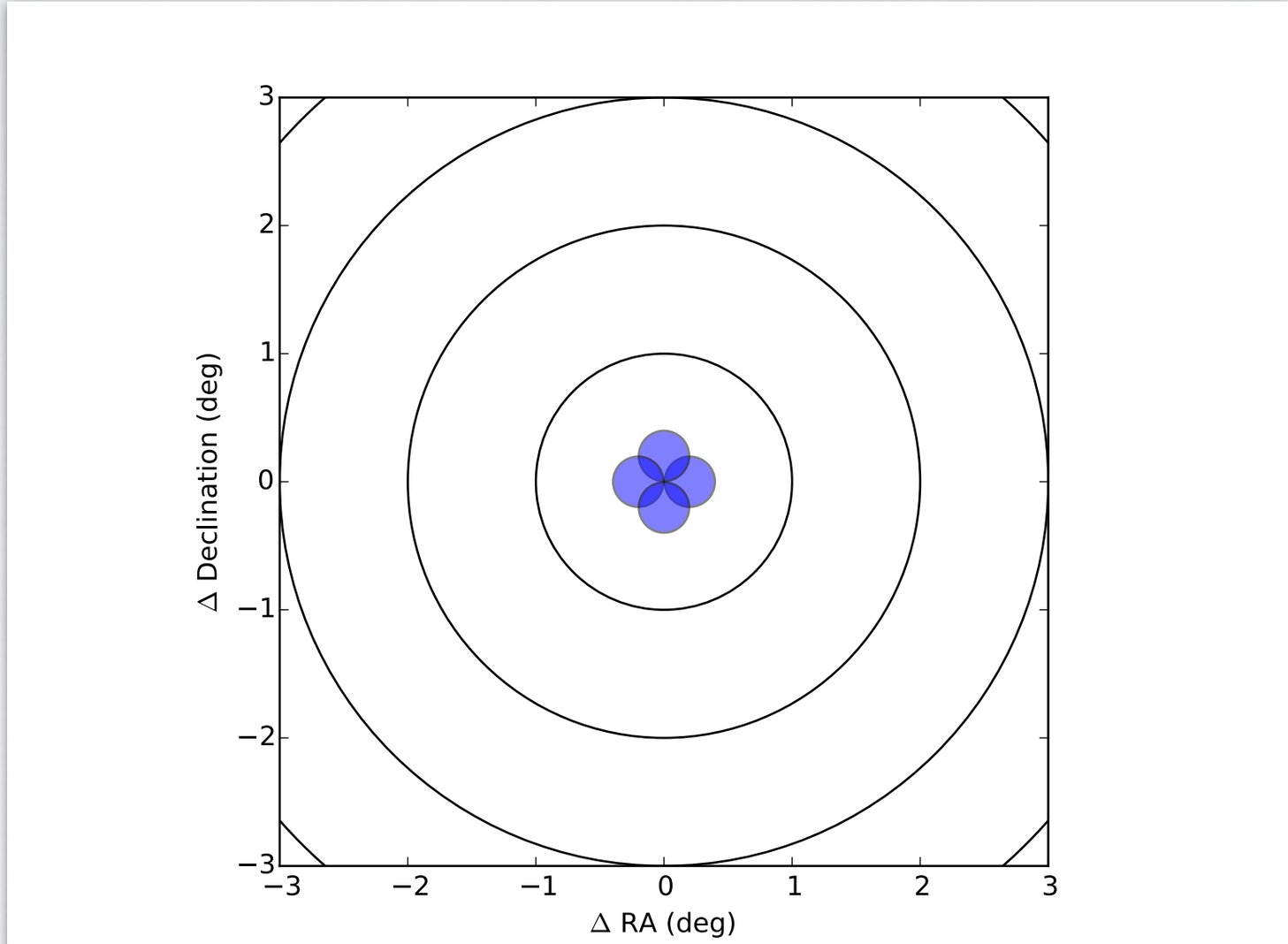
UPLOAD TIME STATISTICS



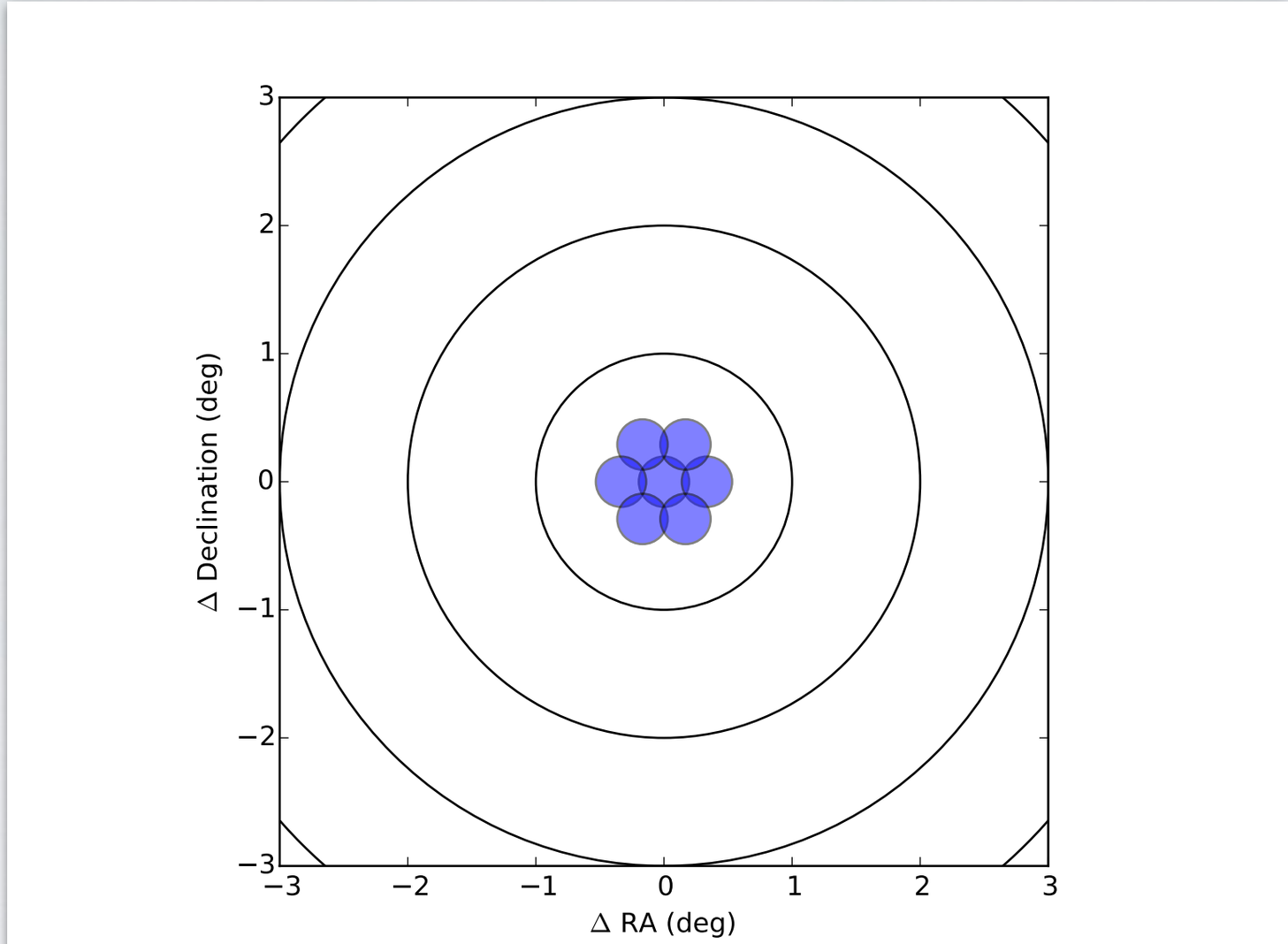
HOW DO WE COVER LARGE REGIONS?

- In-built tiling can cover hexagonal regions
  - 4, 7 point tiling utilized frequently by Swift
  - 19, 37 point tiling available but never tested/utilized.
  - Can cover larger regions by uploading multiple TOOs over multiple passes (but will take forever to cover GBM error boxes)
- Uploadable lists of RA/Dec to cover non-circular error boxes. **Requires BAT FSW update, in development…**
- PPST Jamming concept.

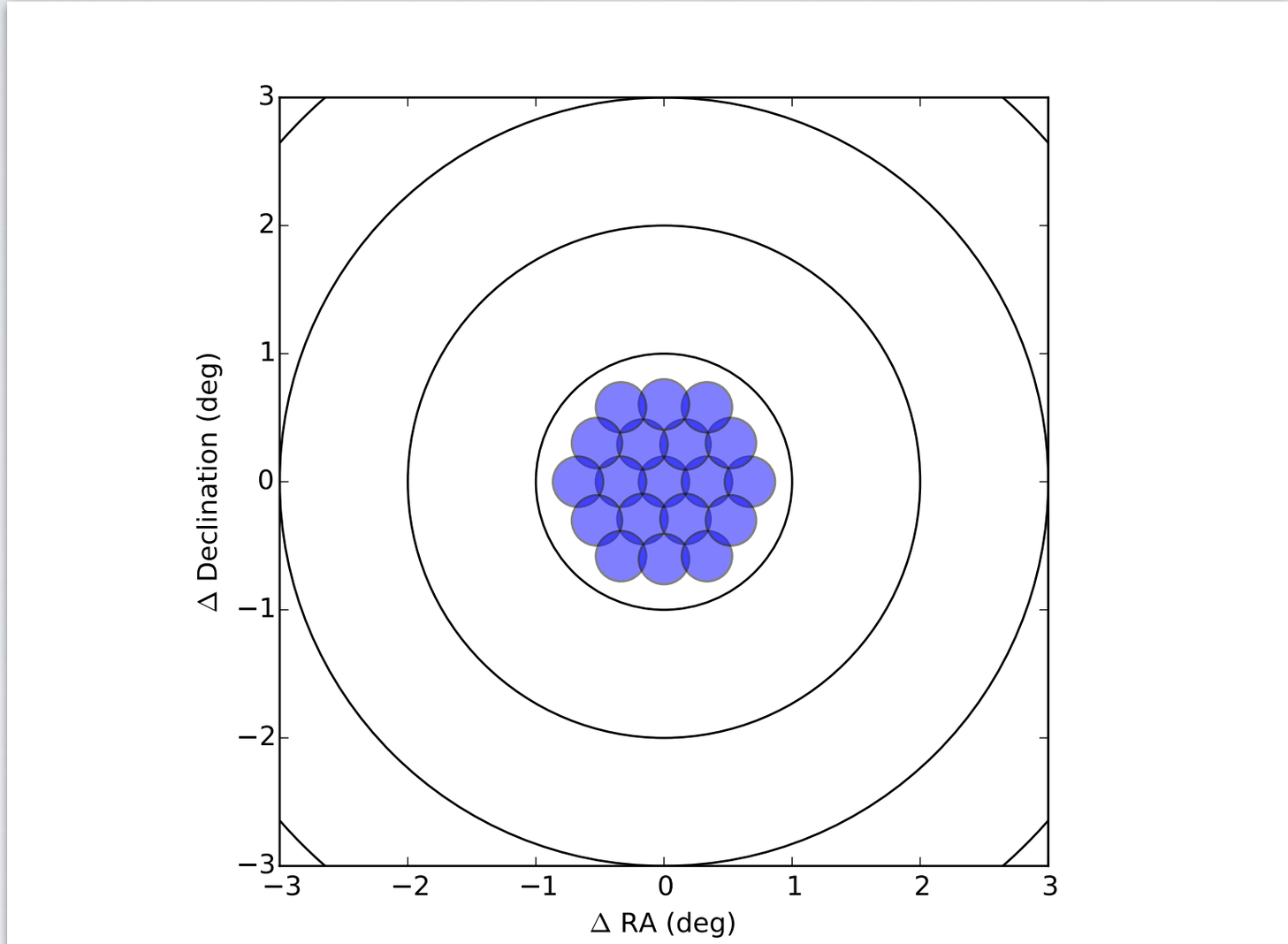
4-POINT TILING



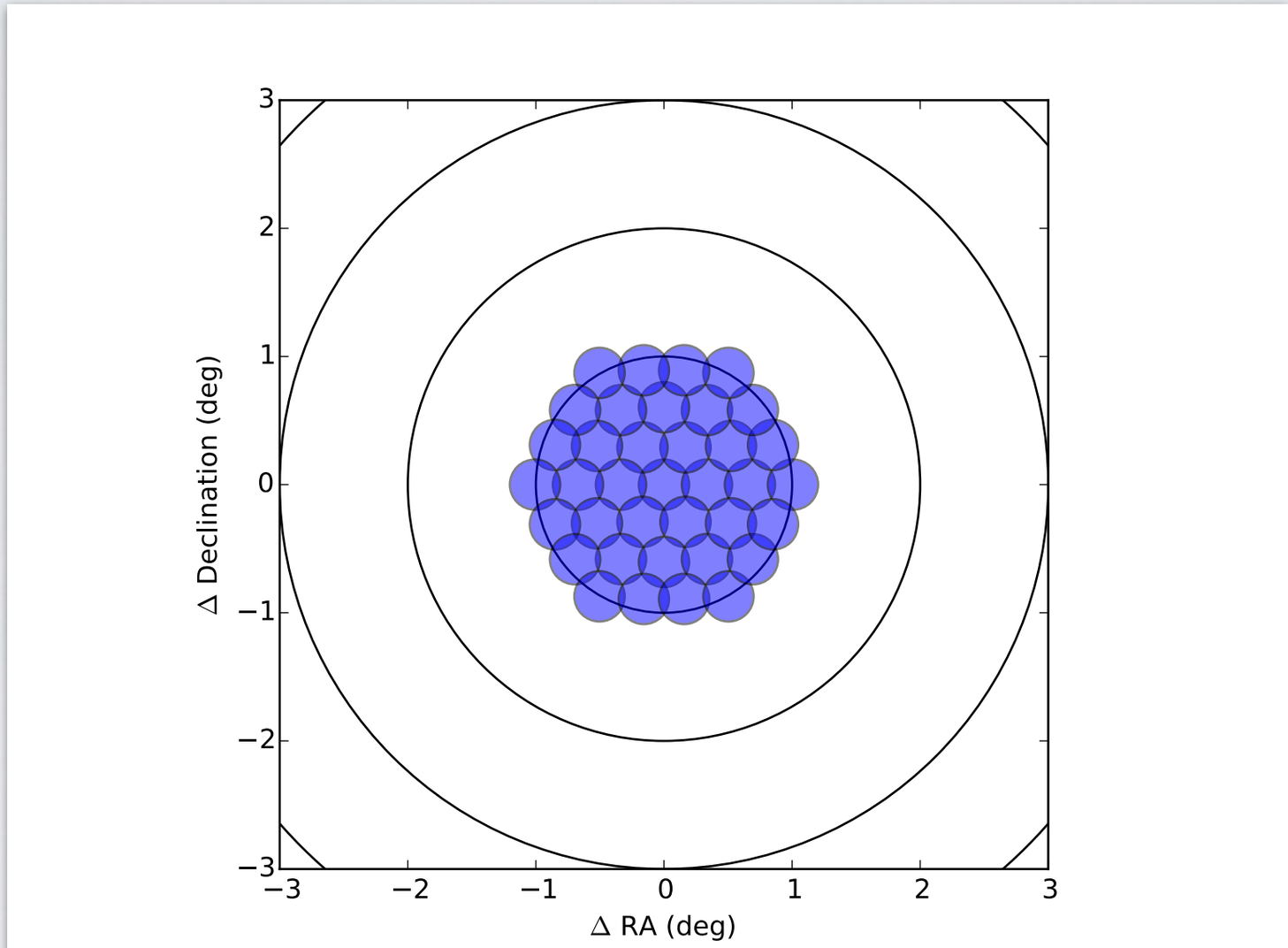
7-POINT TILING



19-POINT TILING



37-POINT TILING



PPST JAMMING

- Alternative is to upload a PPST to S/C that contains all the pointings required to cover error box/region.
  - PPST would replace current onboard schedule.
  - Upload could only happen at groundstation pass
- PPST created using automated software, likely a larger impact on other science that Swift is performing. However there would be a non-zero overhead time to create the new PPST.
  - May require non-neglible updates to planning software to allow this to work.
- **Without FSW updates, this the only viable way of covering error boxes that cannot be easy covered by tiling.**

AUTO ANALYSIS OF DATA

- For GRB/Neutrino tiling we (Phil Evans @ University of Leicester) auto analyze the data to find potential counterparts.

- Can easily expand this system to cover search for counterparts from tiling of GBM error regions and/or LIGO error regions.

- Of course, the larger the area covered, the more likely to find spurious sources.

  - Will need some follow-up of likely counterparts later on to confirm fading.

CONCLUSIONS

- Swift is prepared to try to find electromagnetic counterparts of GW triggers other than those seen by BAT or GBM, but will be significantly challenging.

- Typically Observations will start at best within 15 mins of trigger. Median time is ~2 hours. Not clear if this can be improved easily.

- Likely going to need some changes in Swift operations to cover large error boxes.

- Possible BAT FSW coming online in future can help.

- "PPST Jamming" may allow us to cover larger error regions right now, with relatively low latency, but will require some development.