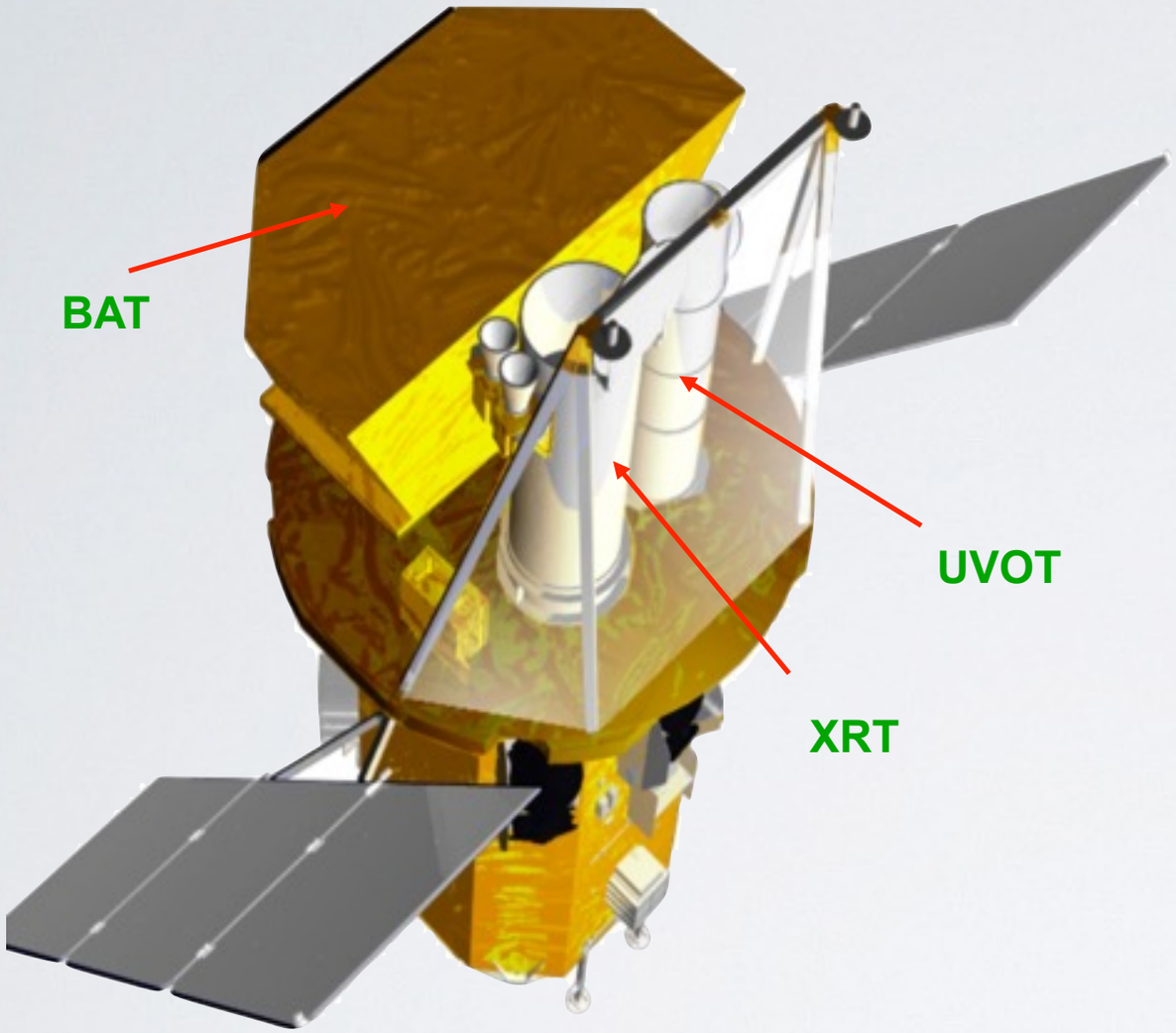
SWIFT AS A FOLLOW-UP TOOL

JAMIE A. KENNEA (Penn State)

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 AS A 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 ~0.75 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.
- Sensitive multi-wavelength coverage in pointed observations.
- Ability to perform regular monitoring of counterparts to determine temporal properties (i.e. "is it fading?")

SWIFT OPERATIONS IN A NUTSHELL

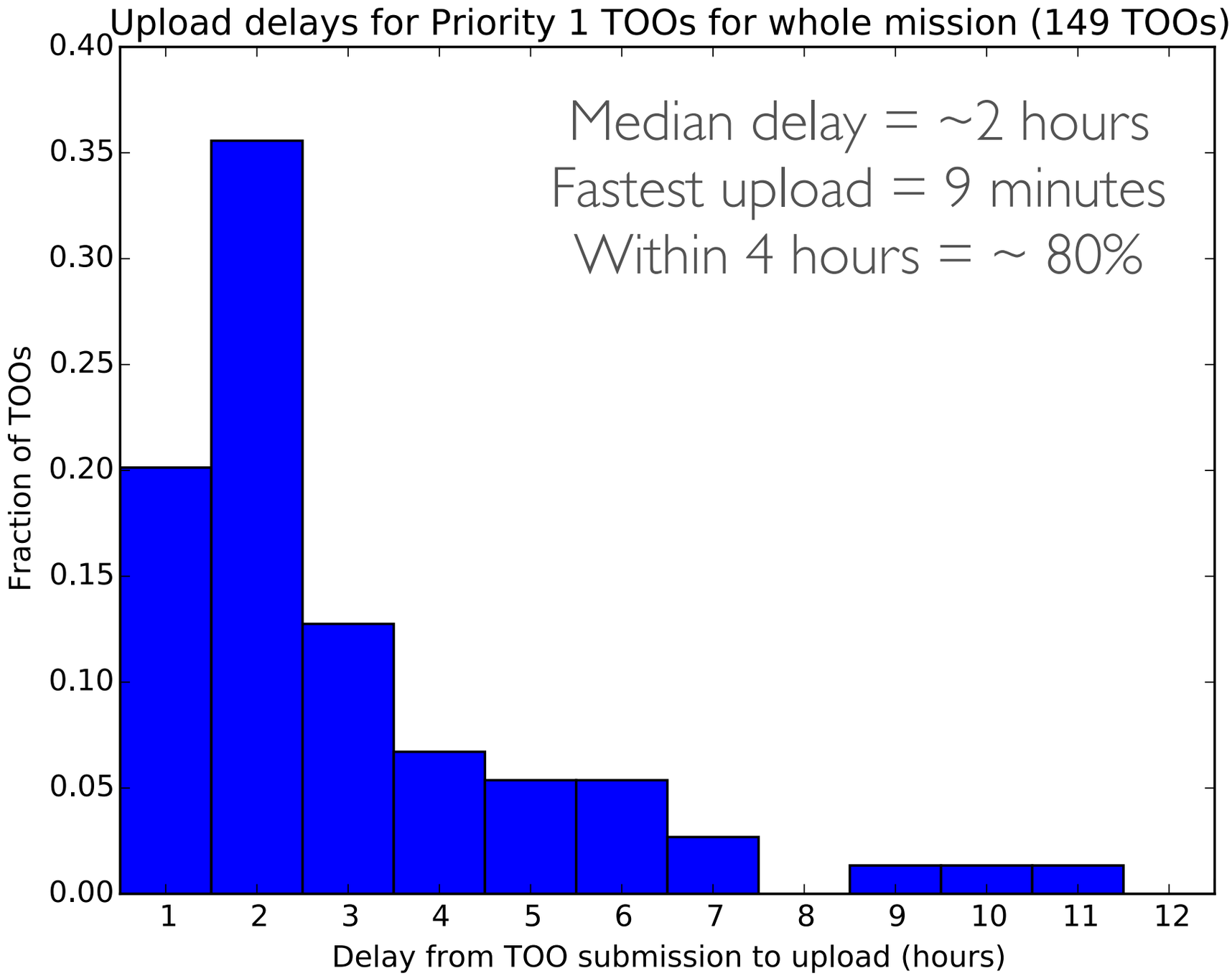
- MOC is at Penn State (about 2.5 miles away from here)
- MOC operates from 8-5pm Monday-Friday.
  - TOO requests come in 5 levels of priority. Priority 1 pages on-call ODS 24/7. Priority 2 pages during working hours (8-5pm Eastern).
  - On-call ODS outside of those hours to respond to priority 1 (<4 hours turn-around) TOOs
    - Often we respond to lower priority TOOs out of hours too.
- Swift can rapidly observe 1 TOO at a time through ground commanding.
  - Ground passes including ground station (usually ~1 per orbit, but there are gaps sometimes of up to 8 hours)
  - TDRSS can be used, but requires FOT presence in MOC, so only used during working hours or for very high priority events.

TOO INTERFACE

- Swift has a TOO web page which scientists use to submit requests for observations.
  - In 2015 we received 1,222 TOOs as of yesterday. 3.6 TOOs per day!
- We currently accept observations for monitoring and tiling to cover larger errors.
- For some programs (Neutrino, Fermi LAT GRB, LIGO/Virgo GW triggers), we have a backdoor system that allows auto generated TOOs.
  - Can allow for "private" TOOs.

http://www.swift.psu.edu

UPLOAD TIME STATISTICS



HOW DO WE COVER LARGE REGIONS?

- IPN, Neutrino and GW trigger error regions are often larger than the FOV of XRT/UVOT.

- In-built tiling can cover hexagonal regions

  - 4, 7 point tiling utilized frequently by Swift

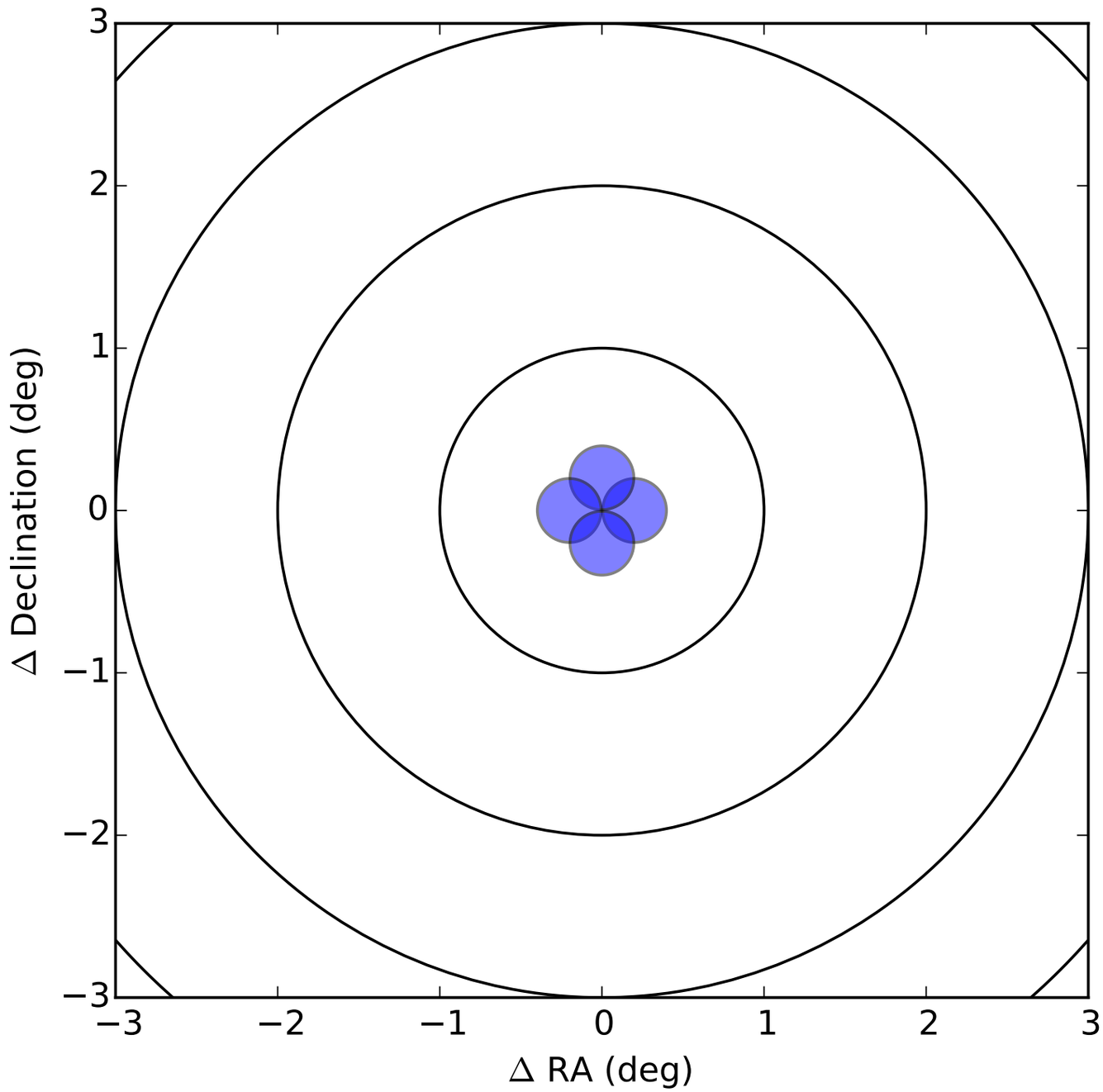
  - 19, 37 point tiling recently approved for use and tested *(not yet available to community)*

    - 37-point tiling still only covers 1 degree radius error circle!

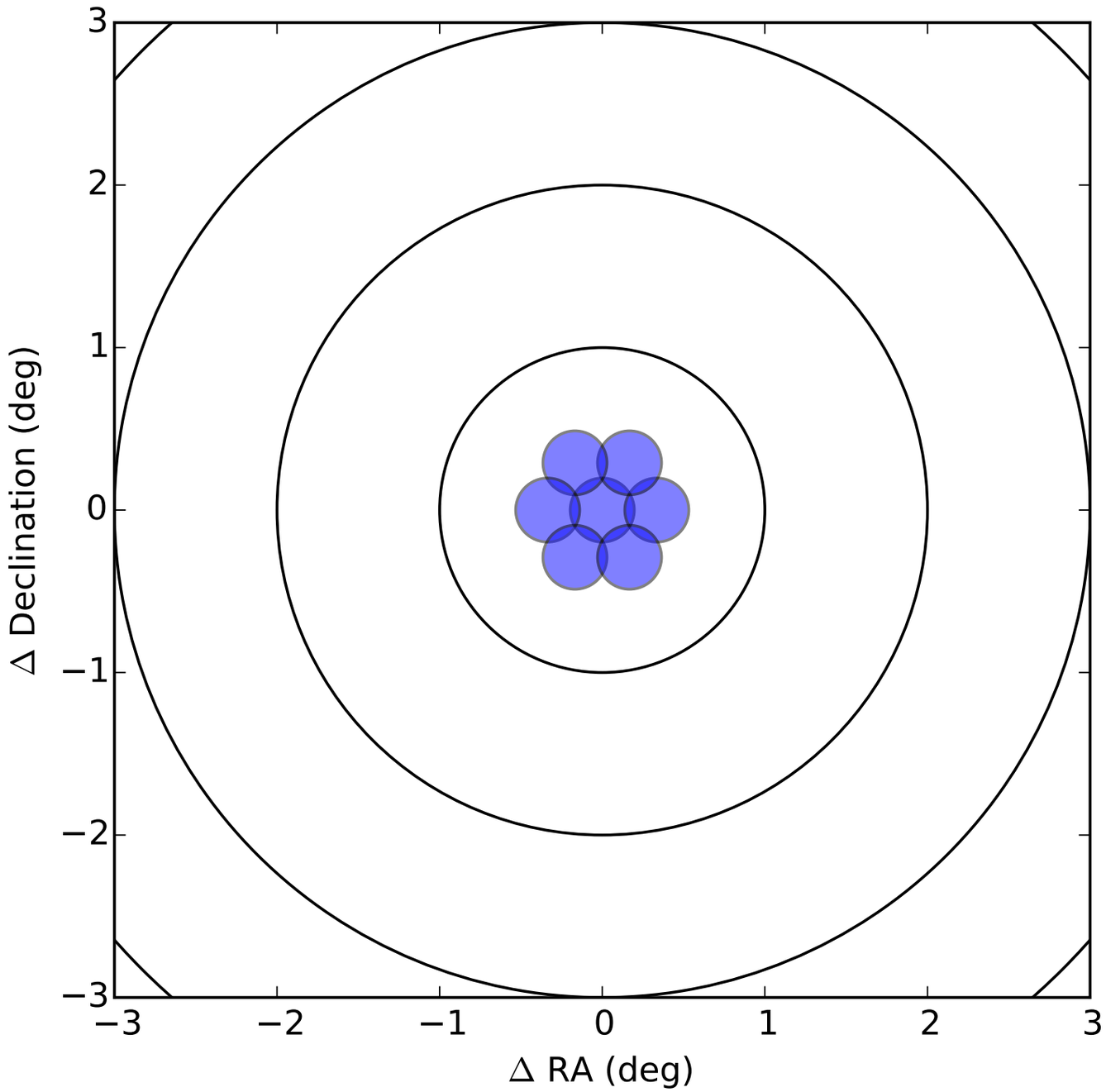
- Can cover larger regions by uploading multiple TOOs over multiple passes (e.g. IPN error regions).

  - Inefficient and slow, plus large strain on Swift Team!

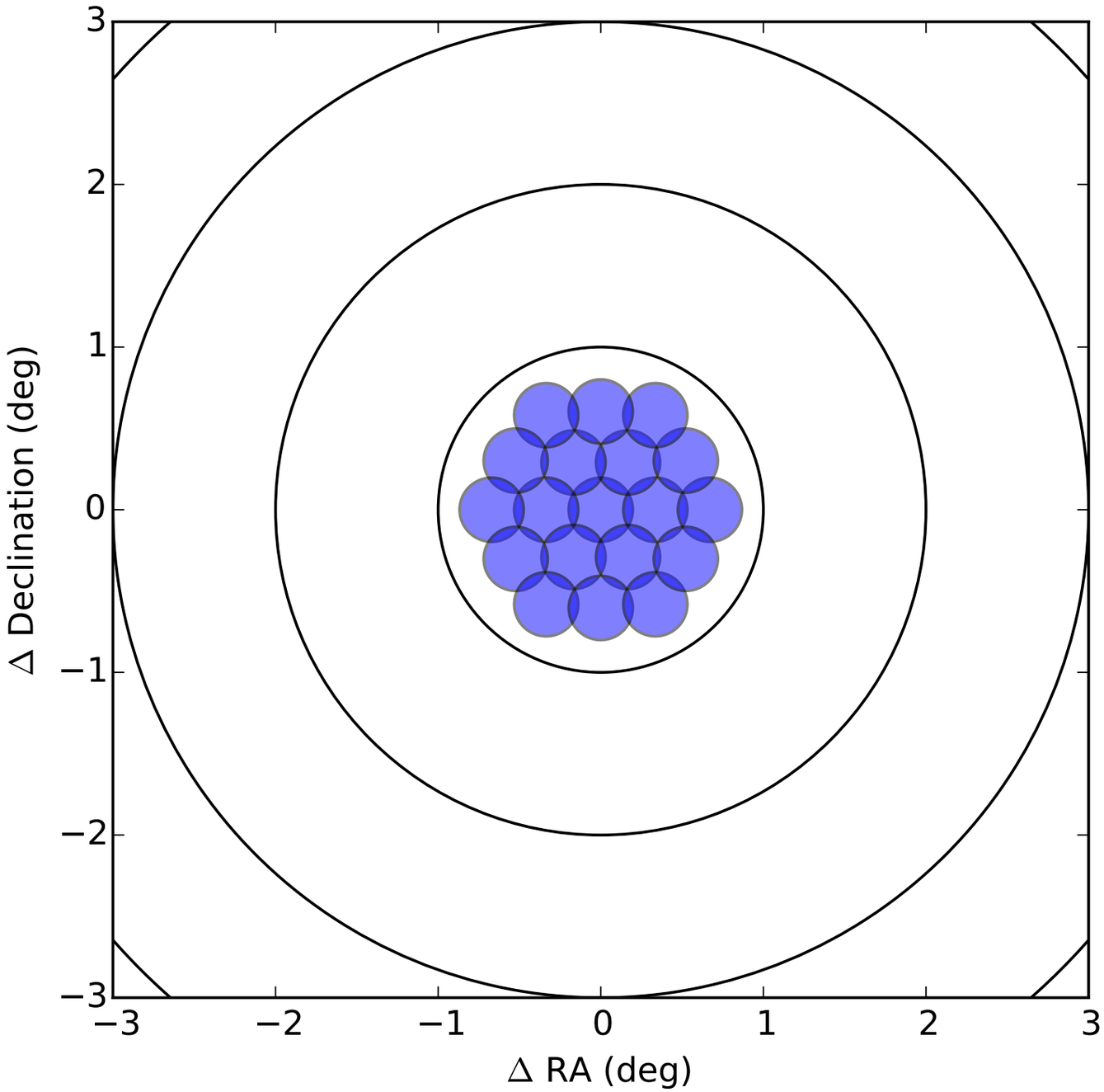
4-POINT TILING



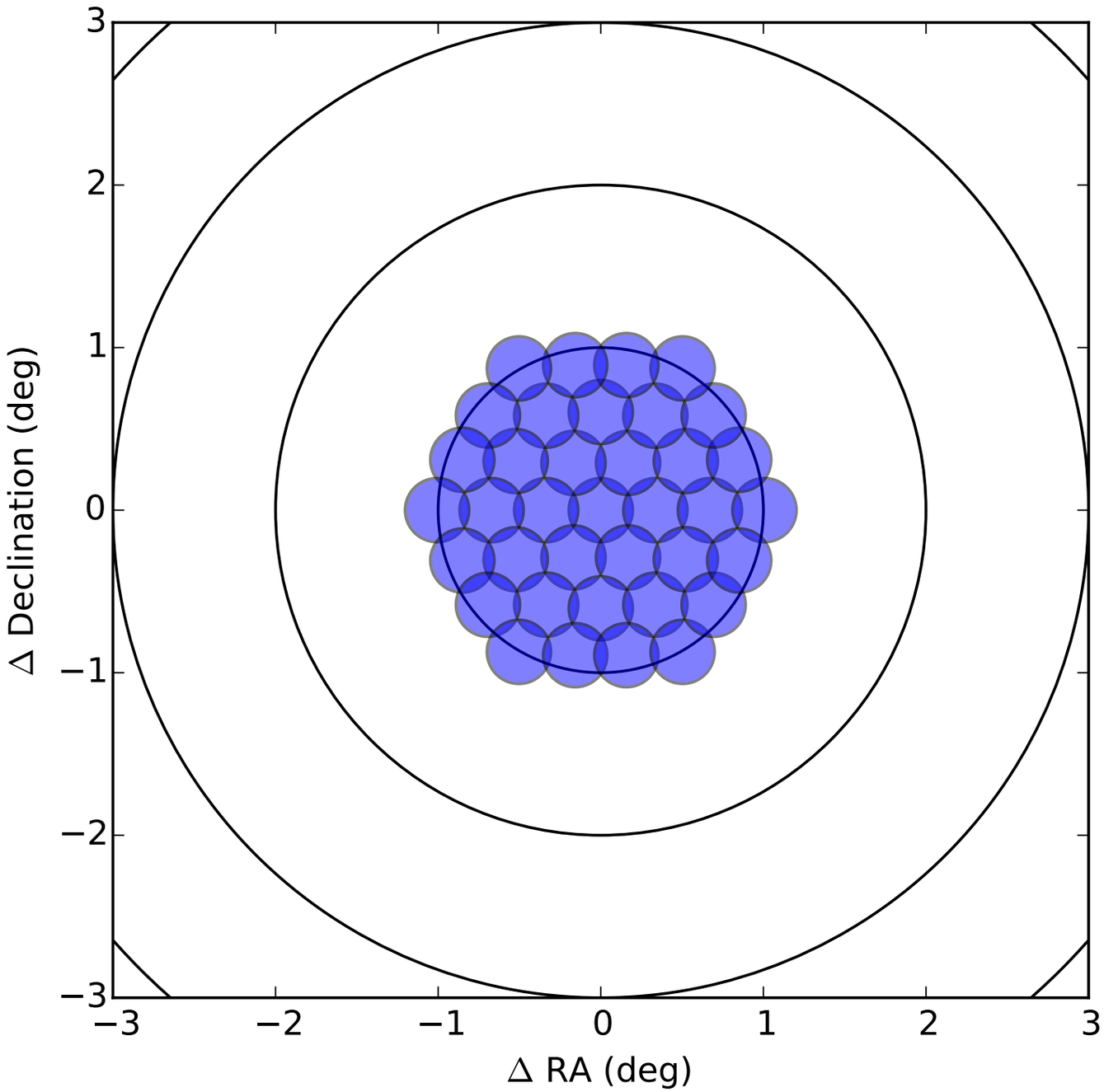
7-POINT TILING



19-POINT TILING



37-POINT TILING



MASS TILING TECHNIQUE

- Generate list of tiles that cover the large error region by tiling.
- Create from this a pre-planned science timeline (PPST) by merging these pointings with the current onboard plan.
- Upload this PPST to replace the on-board running PPST at the next ground station pass. Observations commence immediately.
- Minimum exposure time is 60s per field (hard limit). But with XRT ~10-20 mCrab sensitivity in 60s, so still useful for bright transients!
- Observations of a maximum of 450 targets in 24 hour period (set by onboard buffer size).

PROS AND CONS

- Pros
  - Only way to cover large number of sources / sky area
  - Can be done without FSW change - FSW change only allows us to get on target quicker.
- Cons
  - Will knock out a lot of targets when we're concentrating on GW follow-up!
  - BAT triggering severely impacted by short dwell time on tiles.
  - Slow to start due to need to wait for ground station pass.

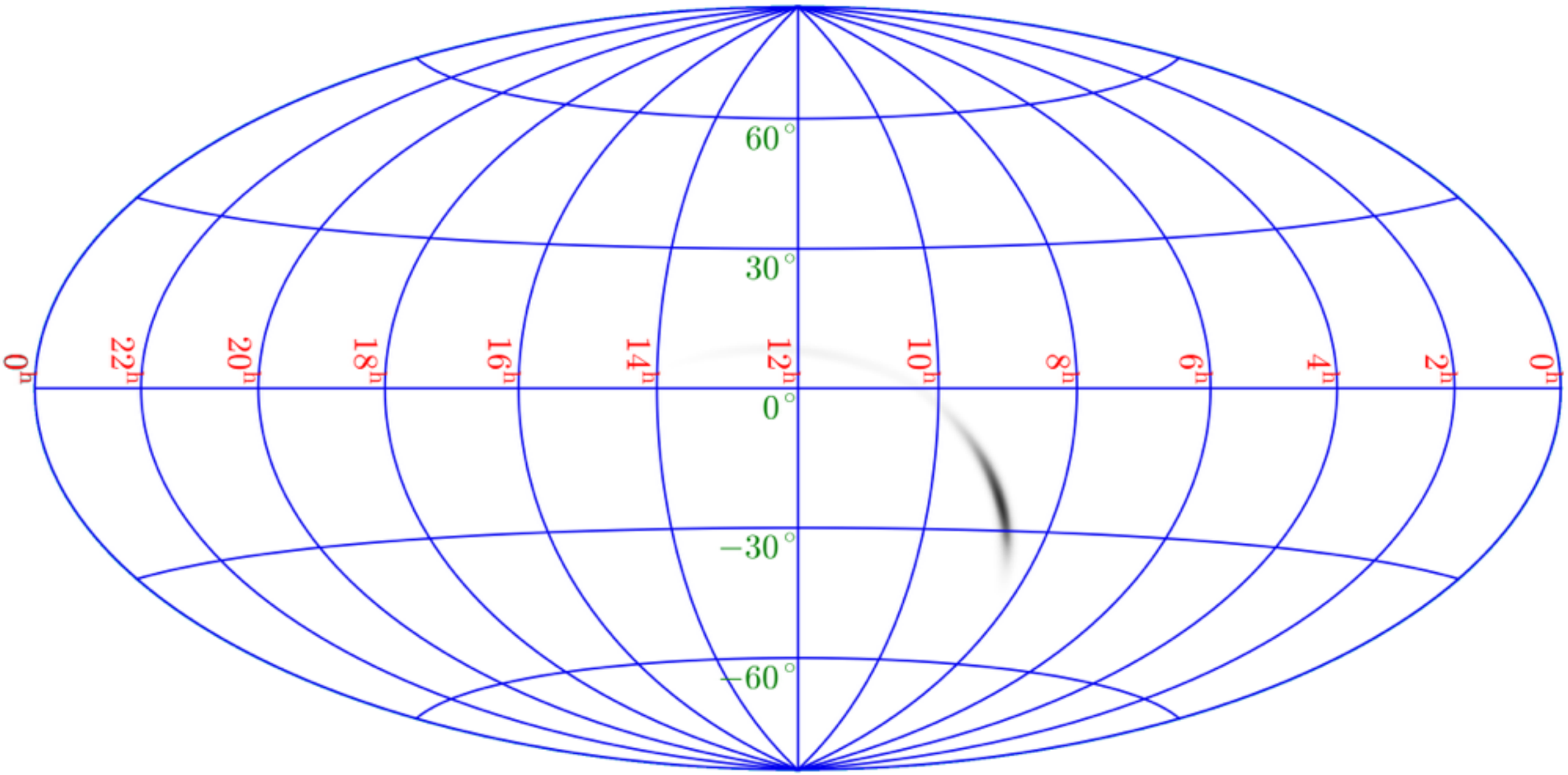
STATUS

- 19 and 37 point tiling has been tested and approved for use.
  - Importantly shows that many short (45-60s) exposures can be performed by Swift without harming spacecraft.
- Software to generate PPSTs from LIGO error regions has been written and tested.
- On-board testing of large scale tiling already began
  - 1 orbit test of 60s per-tile exposures performed and successful.
  - 4 orbit test to be performed imminently.

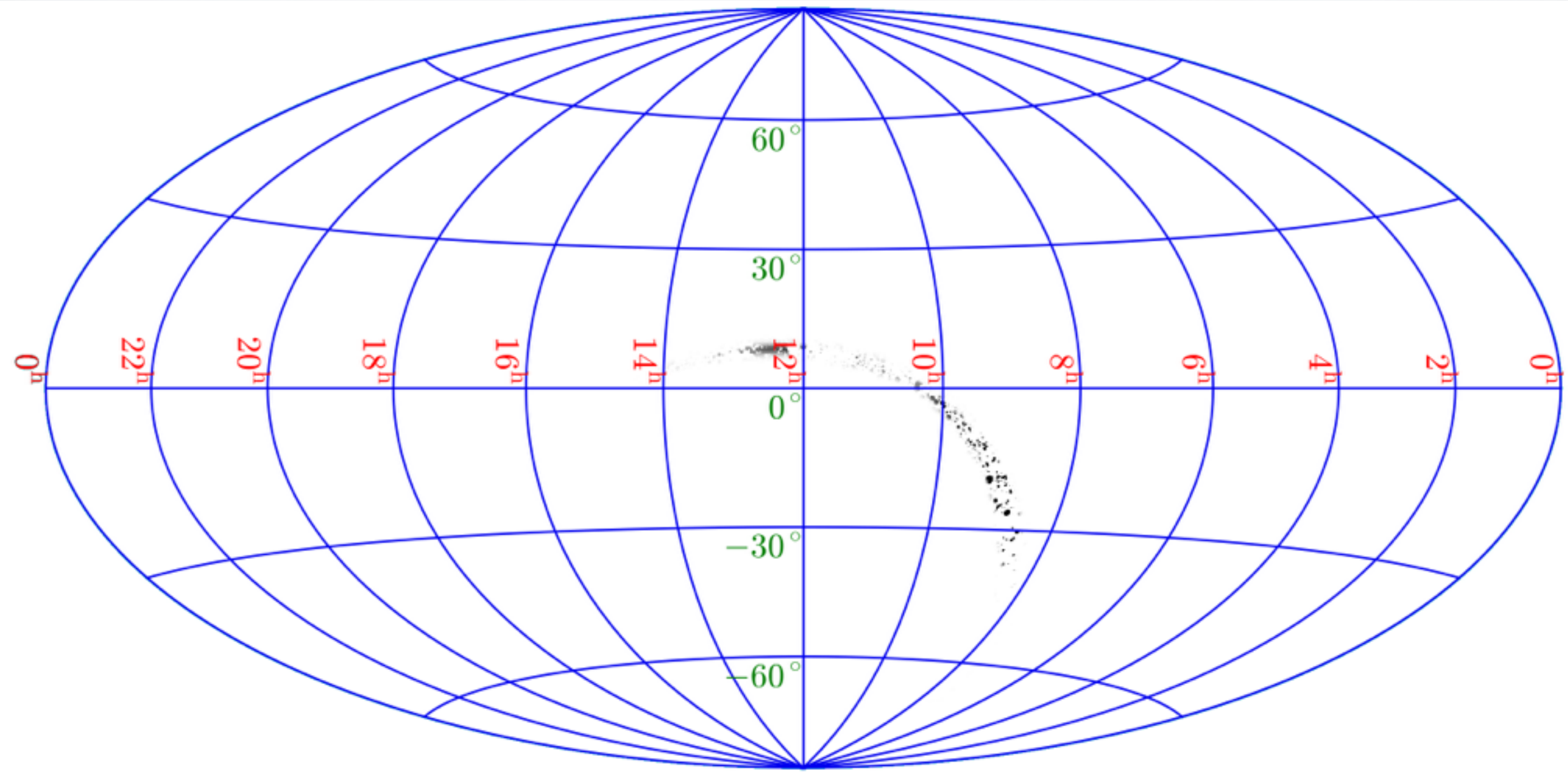
PLAN FOR LIGO/VIRGO TRIGGERS

- Trigger on compact binary coalescent events.
- Take BAYESTAR error region, convolve with Galaxy Catalog to target nearby galaxies.
- Upload PPST containing as many 60s exposures of the LIGO error regions for 48 hours to look for prompt emission.
- For following three days take as many 500s exposures of these galaxies again, in order to look for off-axis afterglows.
- Process validated for on-board use very soon. Waiting for the next trigger to occur.

EXAMPLE BAYESTAR MAP



CONVOLVED WITH GALAXY CATALOG



PLAN FOR LIGO/VIRGO TRIGGERS

- Trigger on compact binary coalescent events.
- Take BAYESTAR error region, convolve with Galaxy Catalog to target nearby galaxies.
- Upload PPST containing as many 60s exposures of the LIGO error regions for 48 hours to look for prompt emission.
- For following three days take as many 500s exposures of these galaxies again, in order to look for off-axis afterglows.
- Process validated for on-board use very soon. Waiting for the next trigger to occur.

CONCLUSION

- Swift is the only observatory capable of performing rapid, multi wavelength (optical/UV/X-ray/Hard X-ray) observations in response to TOO triggers.

- Swift use has been focused on following up objects with relatively well known localizations (coverable in 1-7 XRT pointings)

- New capability allows coverage of large areas of the sky with short exposures (60s) - used to look for LIGO/Virgo EM counterparts - but can be used for any number of projects tiling larger error regions.