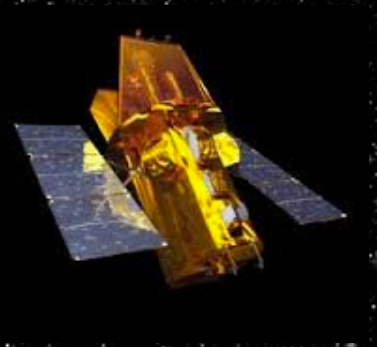


Swift-BAT as a Triggering Facility

Amy Lien

Scott Barthelmy, Hans Krimm

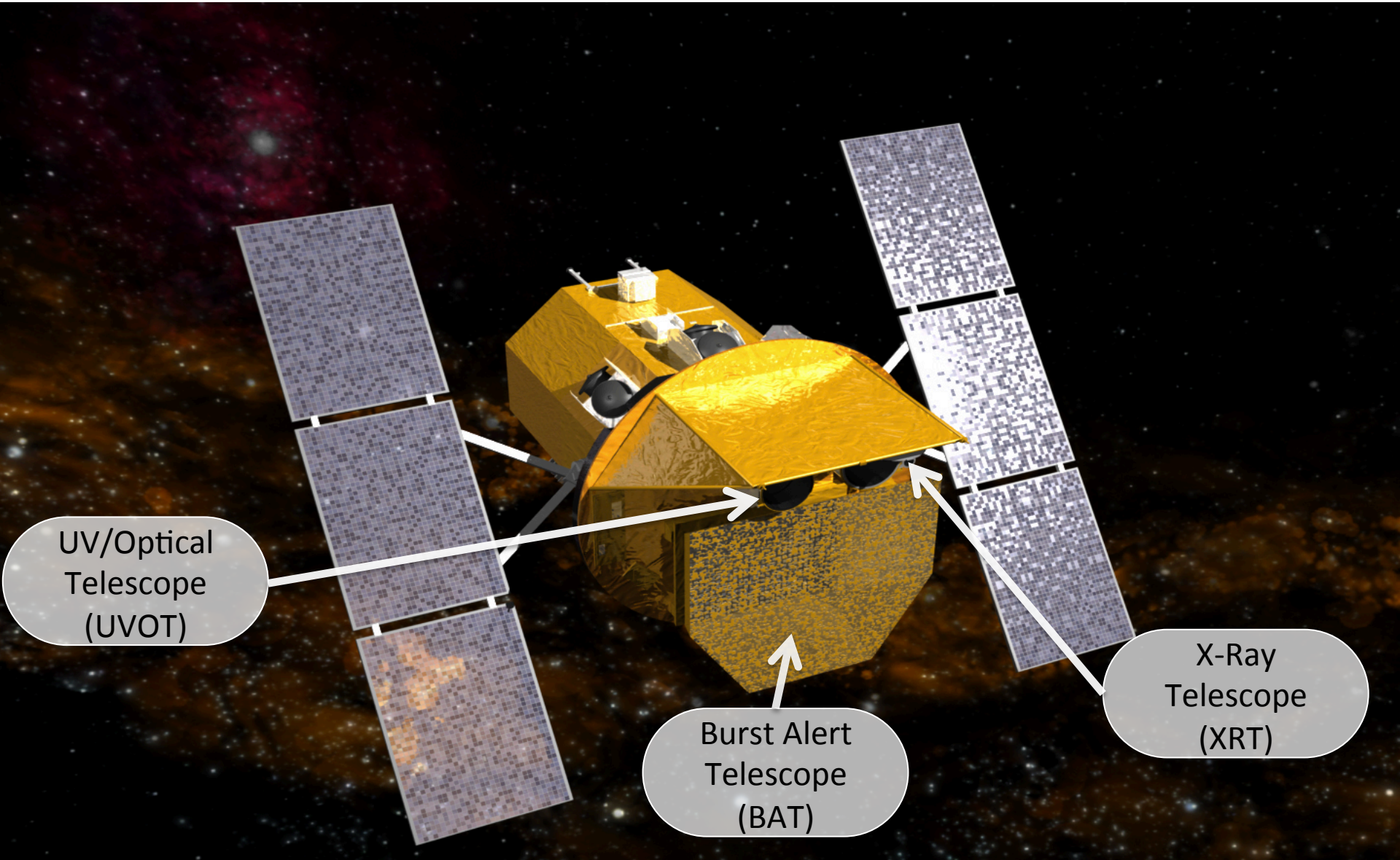
NASA Goddard Space Flight Center

The 4th AMON workshop, Penn State University, 2015/12/04

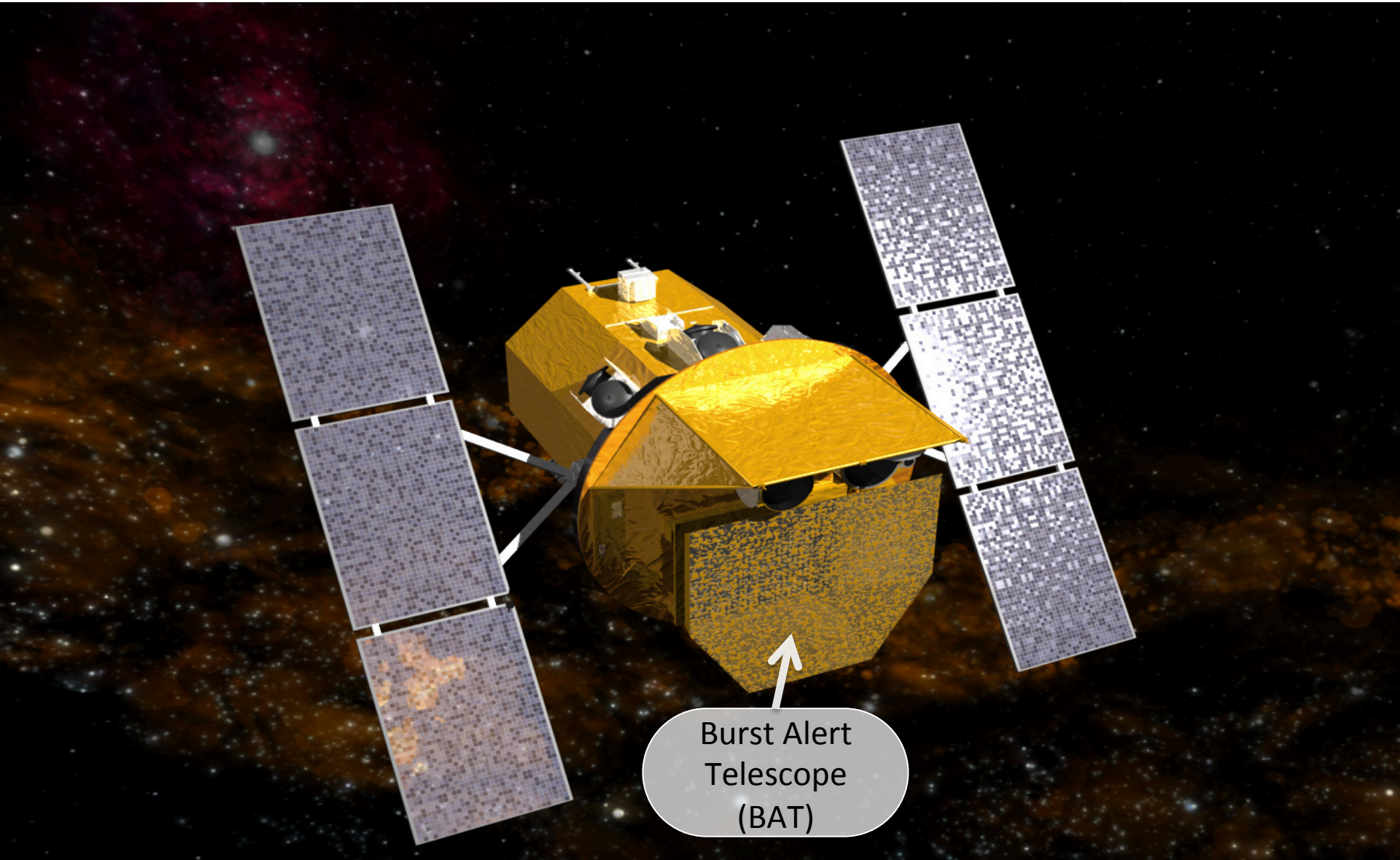
Outline

- BAT trigger algorithm
  - Normal triggers
  - Sub-threshold triggers
  - Sub-sub-threshold triggers
- Ground processes
  - Transient Monitor
  - Ground analysis
- Summary

Swift


UV/Optical
Telescope
(UVOT)
Burst Alert
Telescope
(BAT)
X-Ray
Telescope
(XRT)

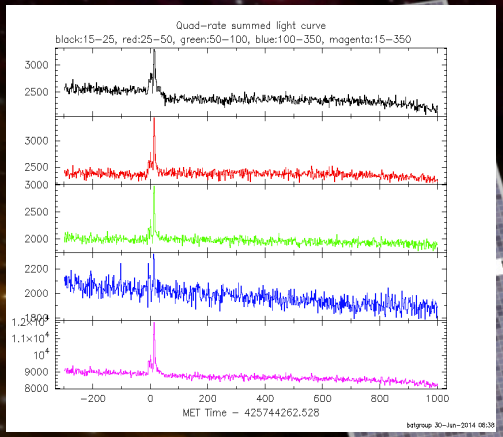
Swift

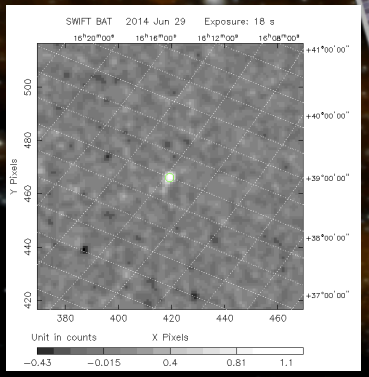


A. Rate trigger:

Stage 1: Rate trigger

Stage 2: Image threshold

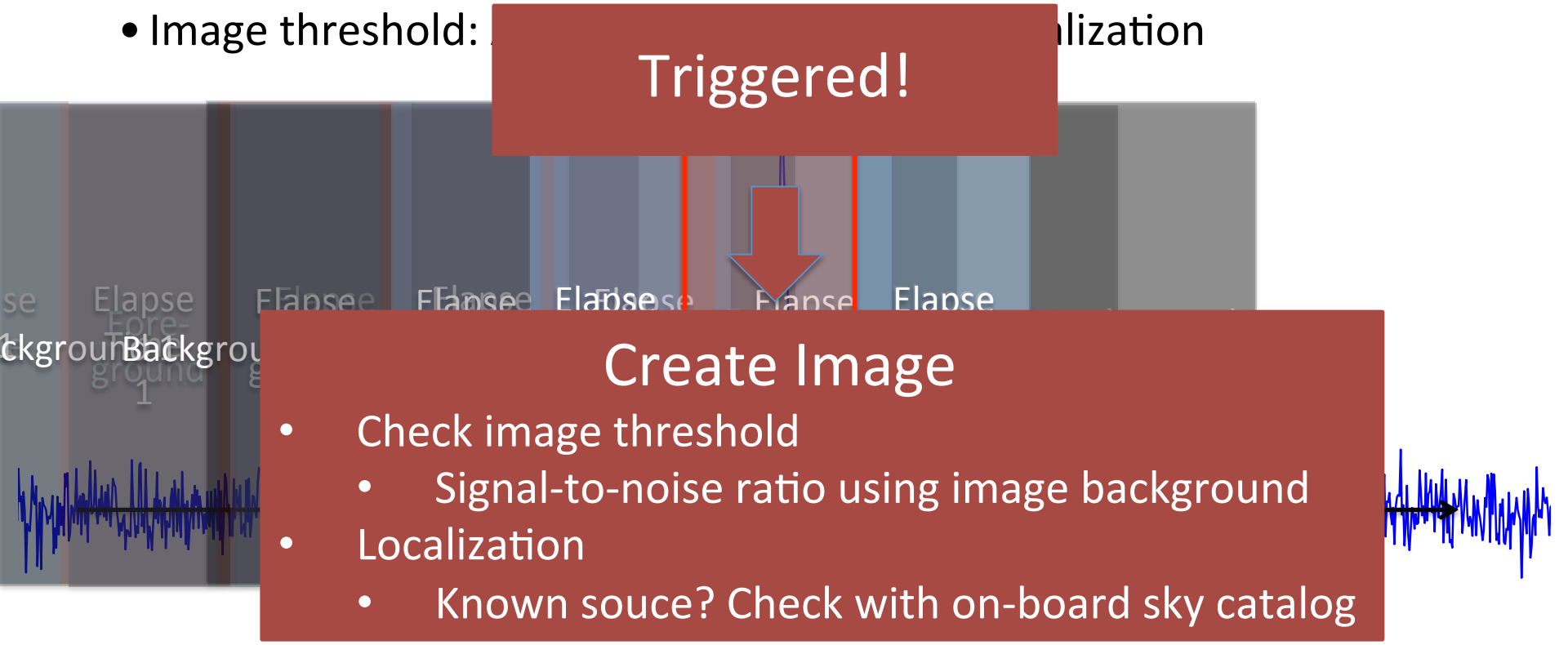




Burst Alert Telescope (BAT)

Trigger Algorithm of the BAT

1. Rate trigger followed by image threshold:
   - > 600 different trigger criteria
   - Each trigger criterion has different
     - energy bands, time periods, signal-to-noise thresholds, etc
   - Image threshold: lization



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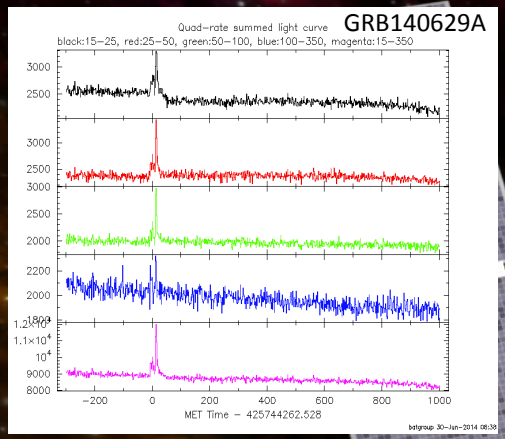
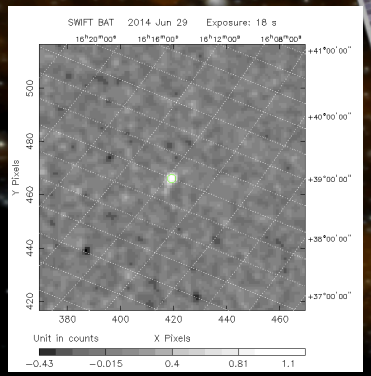
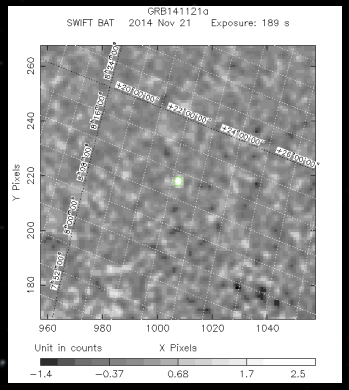
Stage 1: Rate trigger

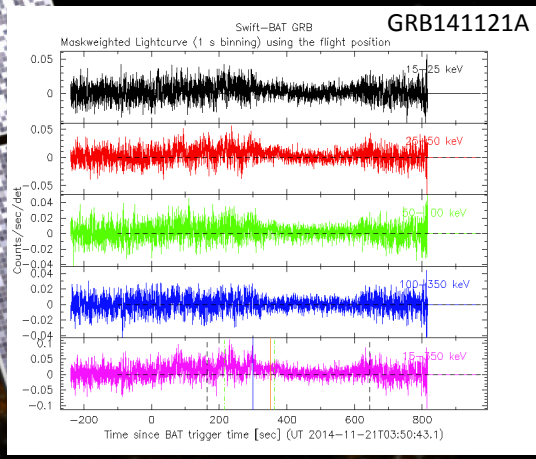
Stage 2: Image threshold





B. Image trigger:





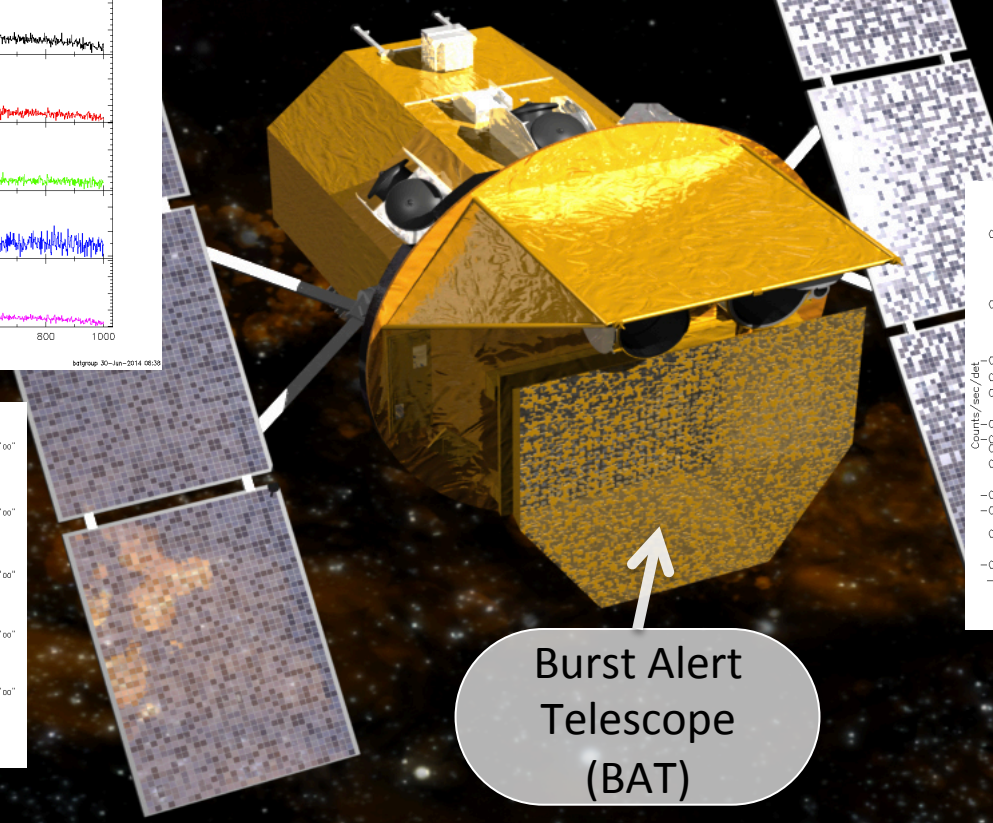


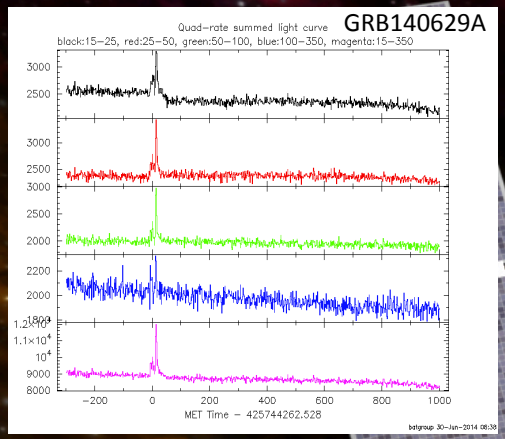
Image trigger

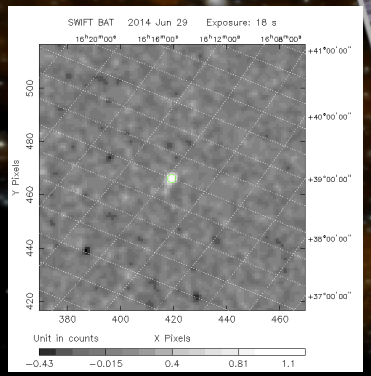
- 15-50 keV
- Typical image exposure time: 64 s, 320 s, full observation (1-43 min).
- When a rate trigger is active, the image trigger is extended by increment of 8 sec
  - (64+8x) sec

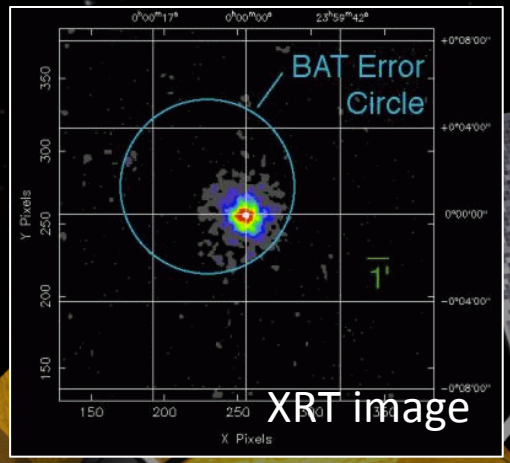
A. Rate trigger:

Stage 1: Rate trigger

Stage 2: Image threshold

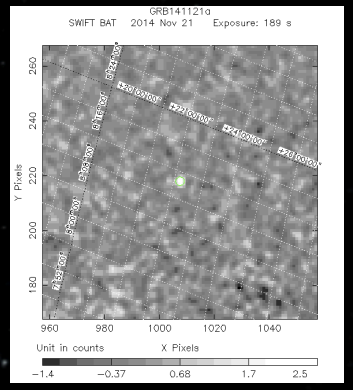


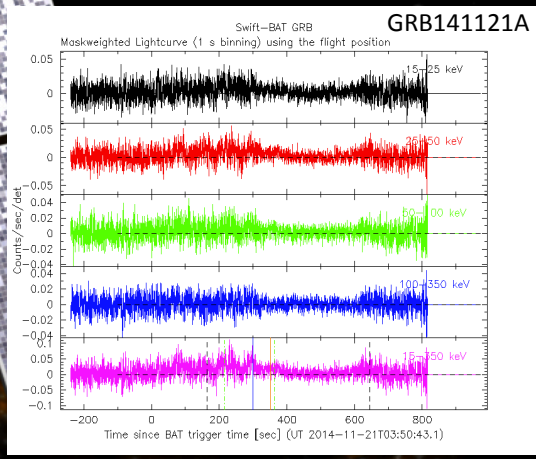




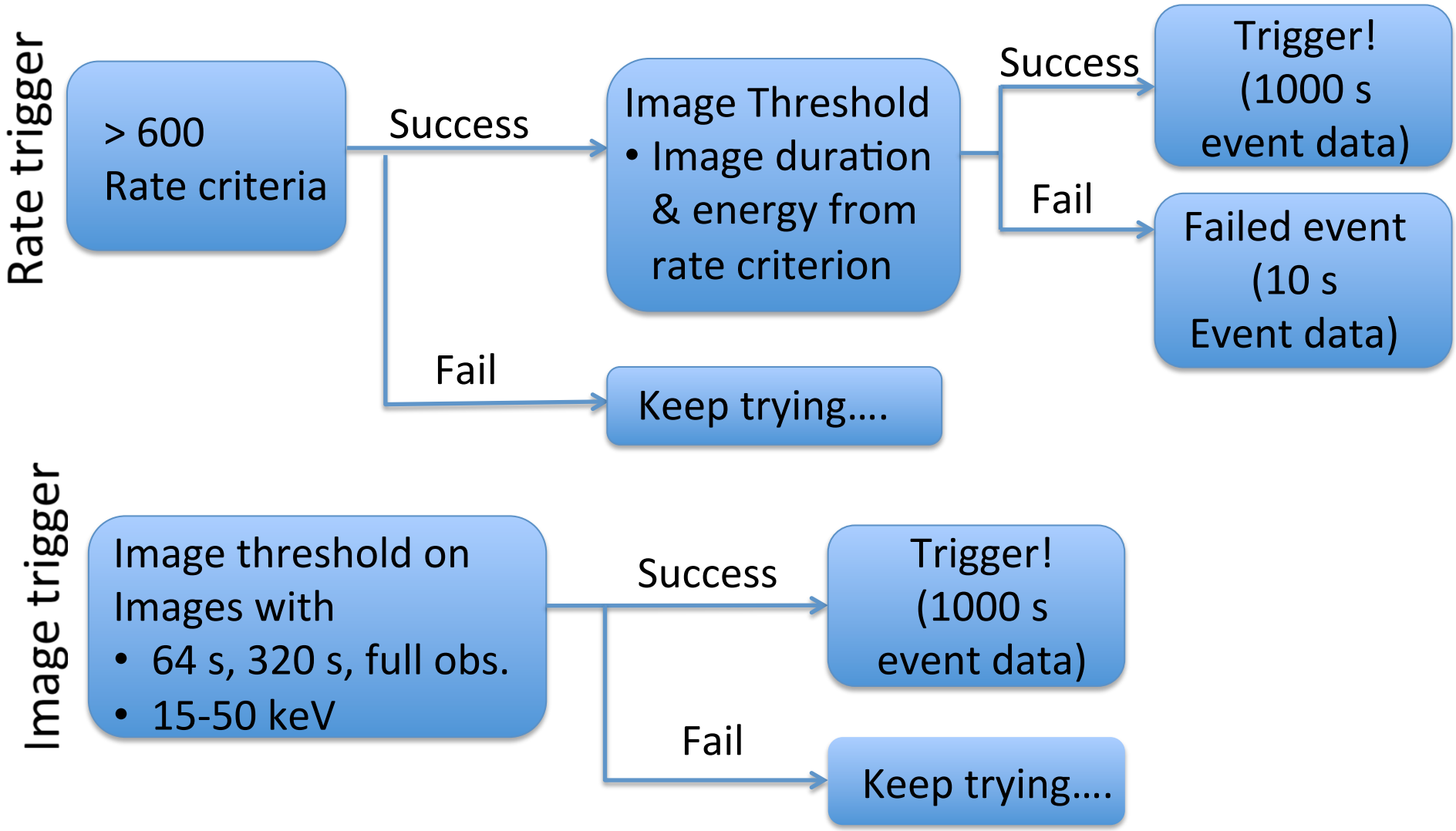
Burst Alert Telescope (BAT)

B. Image trigger:



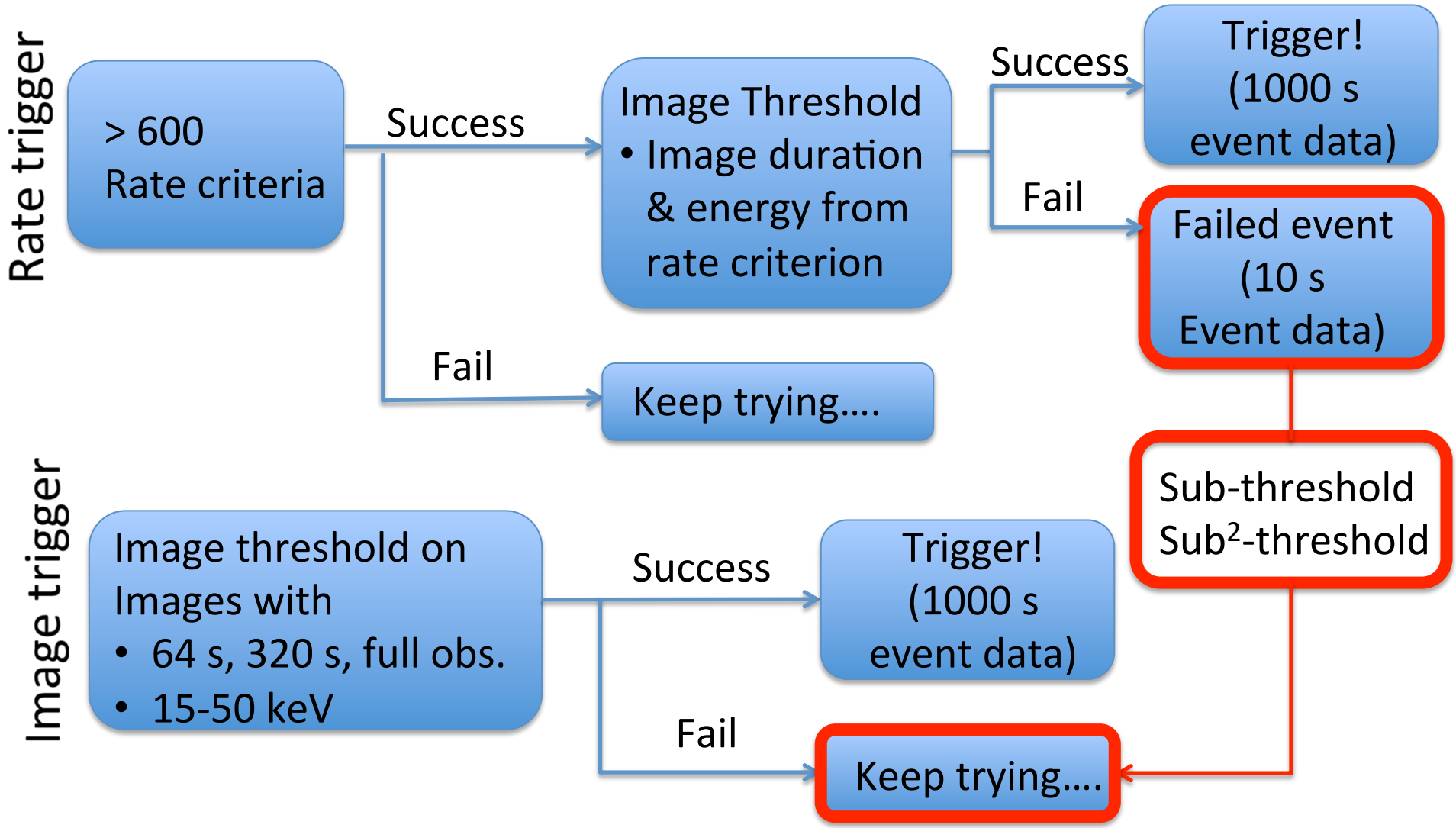


BAT triggers summary



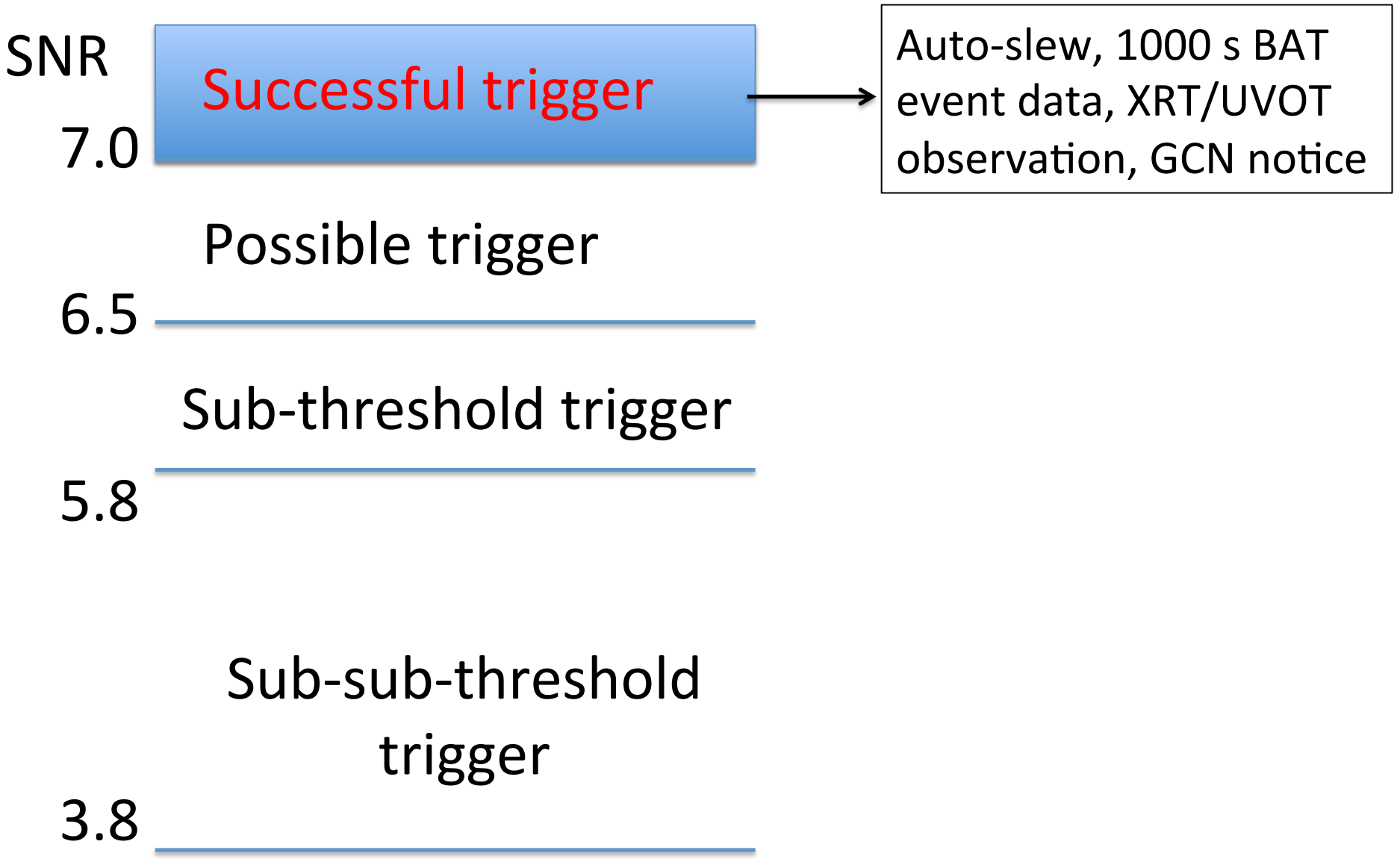
Courtesy to Scott Barthelmy

BAT triggers summary



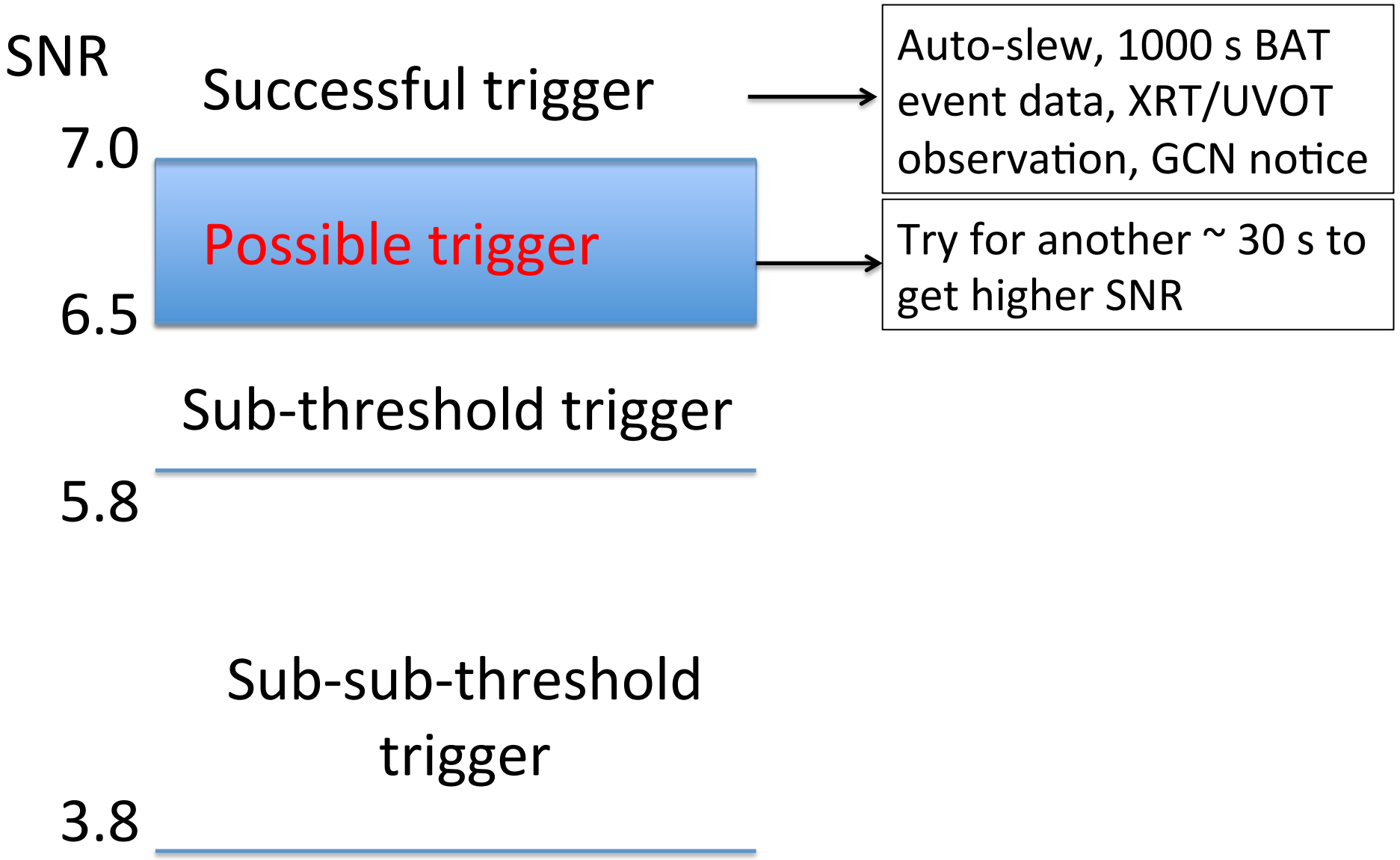
Courtesy to Scott Barthelmy

BAT triggers summary: Image threshold



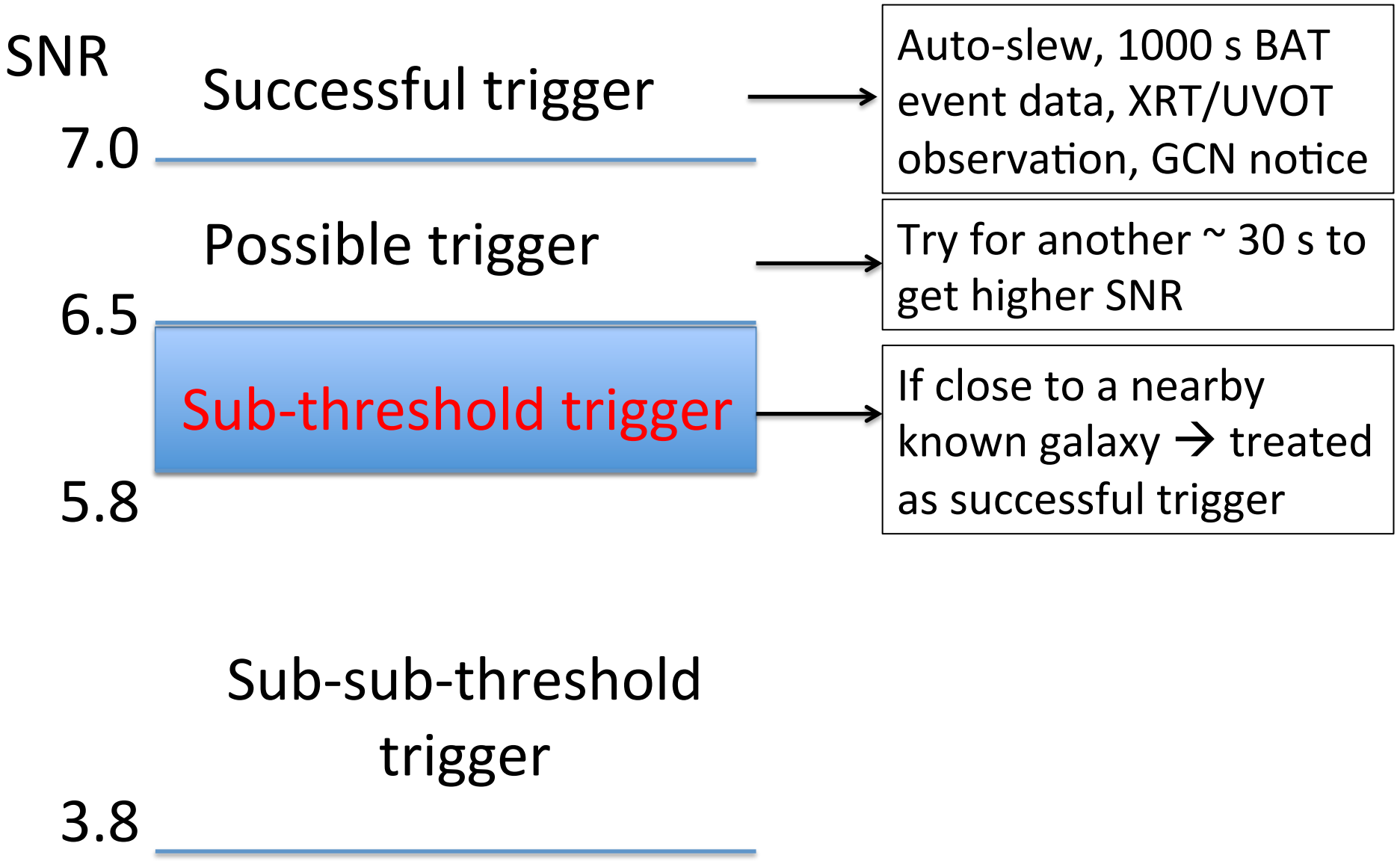
Courtesy to Scott Barthelmy

BAT triggers summary: Image threshold



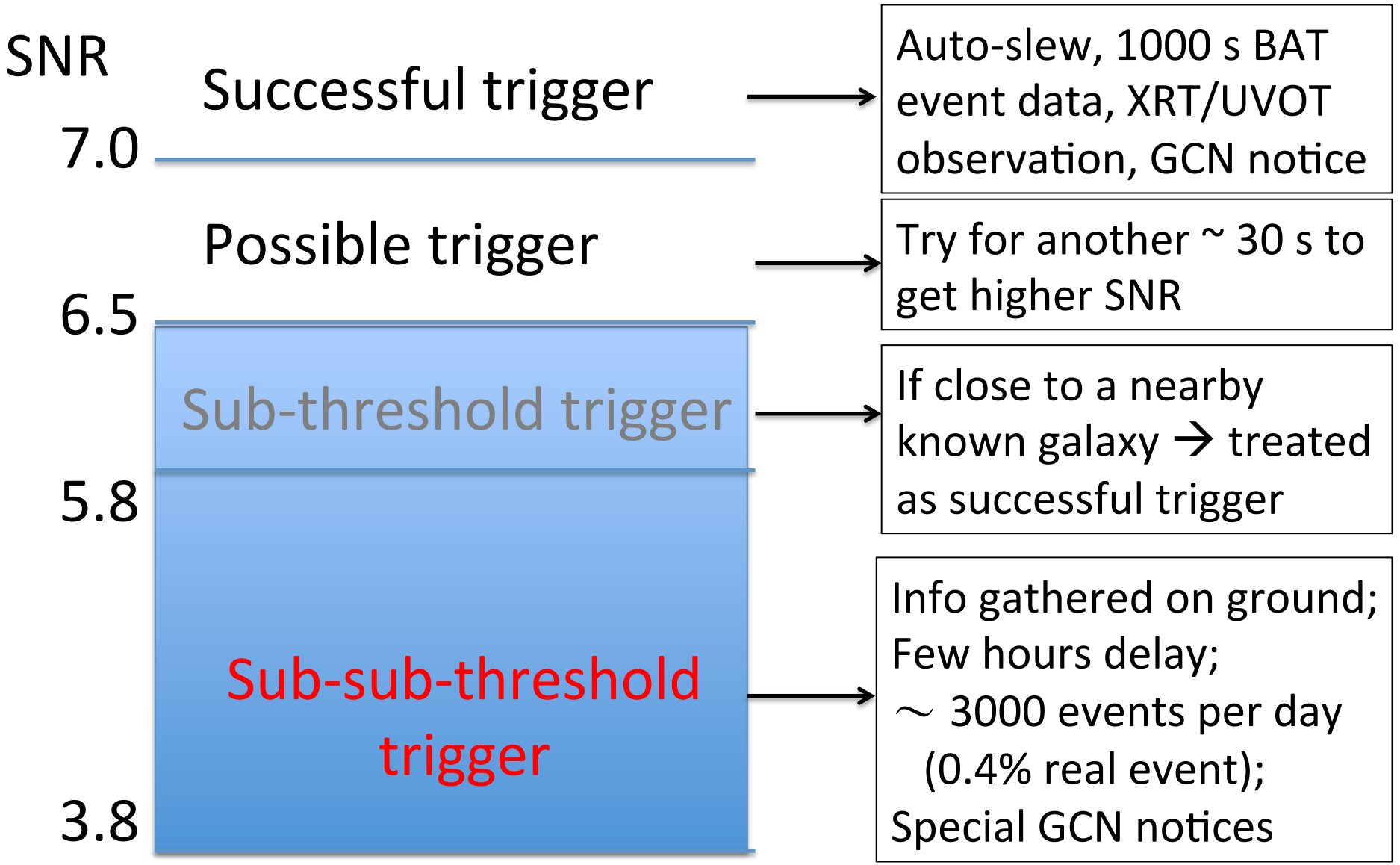
Courtesy to Scott Barthelmy

BAT triggers summary: Image threshold



Courtesy to Scott Barthelmy

BAT triggers summary: Image threshold



Courtesy to Scott Barthelmy

Detections from Ground Process

- Transient Monitor

- Ground-detected bursts

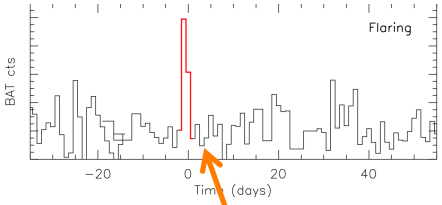
Detections from Ground Process

- Transient Monitor

- Ground-detected bursts

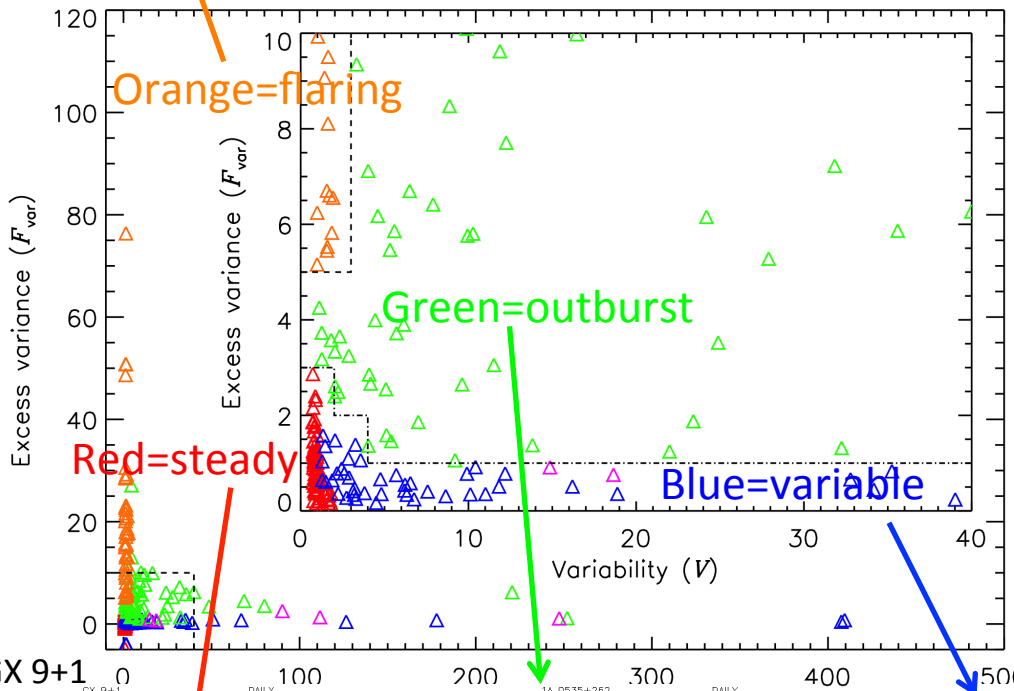
Slide from Hans Krimm

Swift/BAT hard X-ray transient monitor

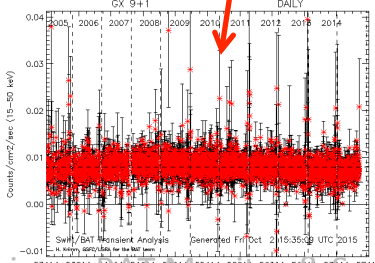


Very sensitive to variable sources

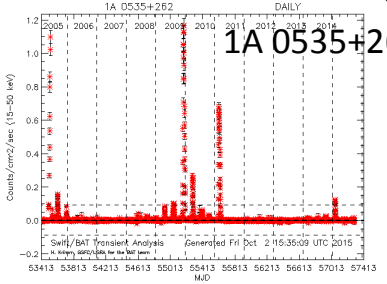
- 15-50 keV (single energy range)
- Built from on-board “scaled maps” from 64 to >1000 seconds duration.
- Rapid, near real-time pipeline processing
- 269 detected sources: 146 persistent and 123 in outburst



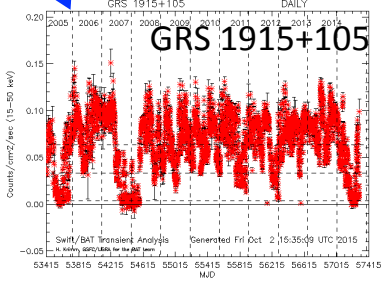
GX 9+1

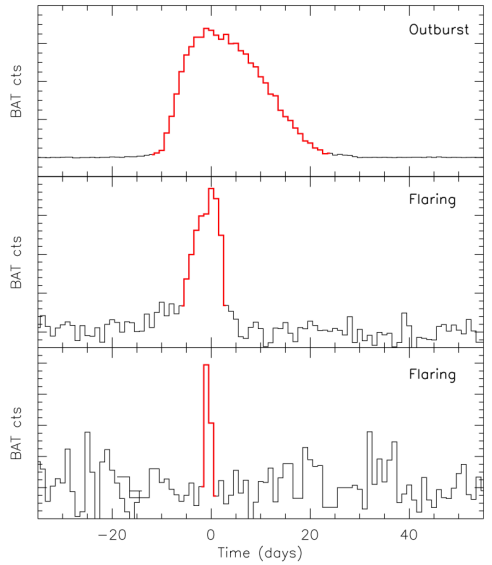


1A 0535+262



GRS 1915+105





Results from monitor paper: Krimm et al, ApJSS **209**, 2013

Detections from Ground Process

- Transient Monitor

- Ground-detected bursts

Detections from Ground Process

- Transient Monitor
  - Energy range: 15-50 keV
  - Delay time: few hours
  - Image exposure: $\sim$ 1200 s to days
  - Currently the public results only include known sources
- Ground-detected bursts

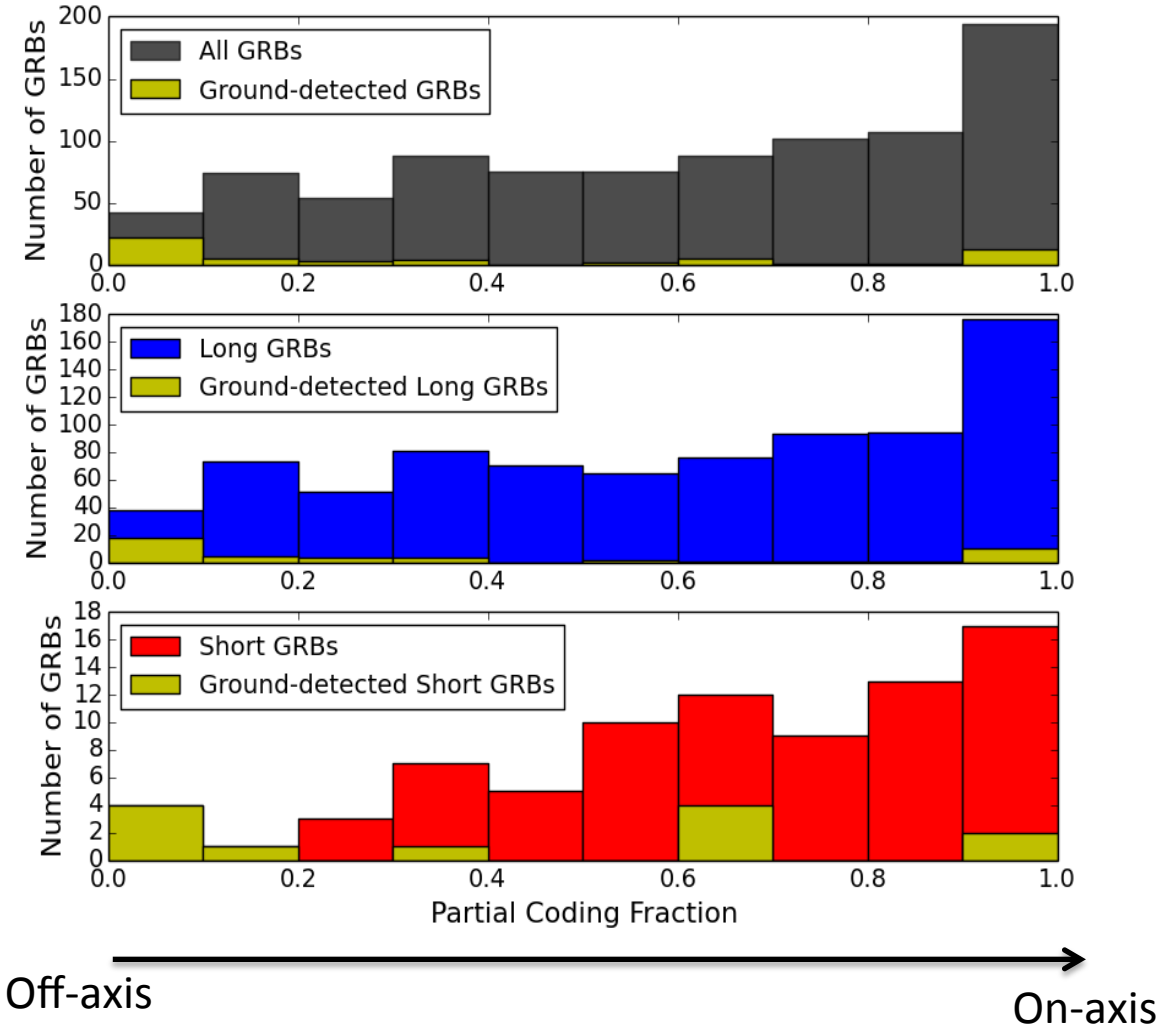
Detections from Ground Process

- Transient Monitor
  - Energy range: 15-50 keV
  - Delay time: few hours
  - Image exposure: $\sim$ 1200 s to days
  - Currently the public results only include known sources
- Ground-detected bursts

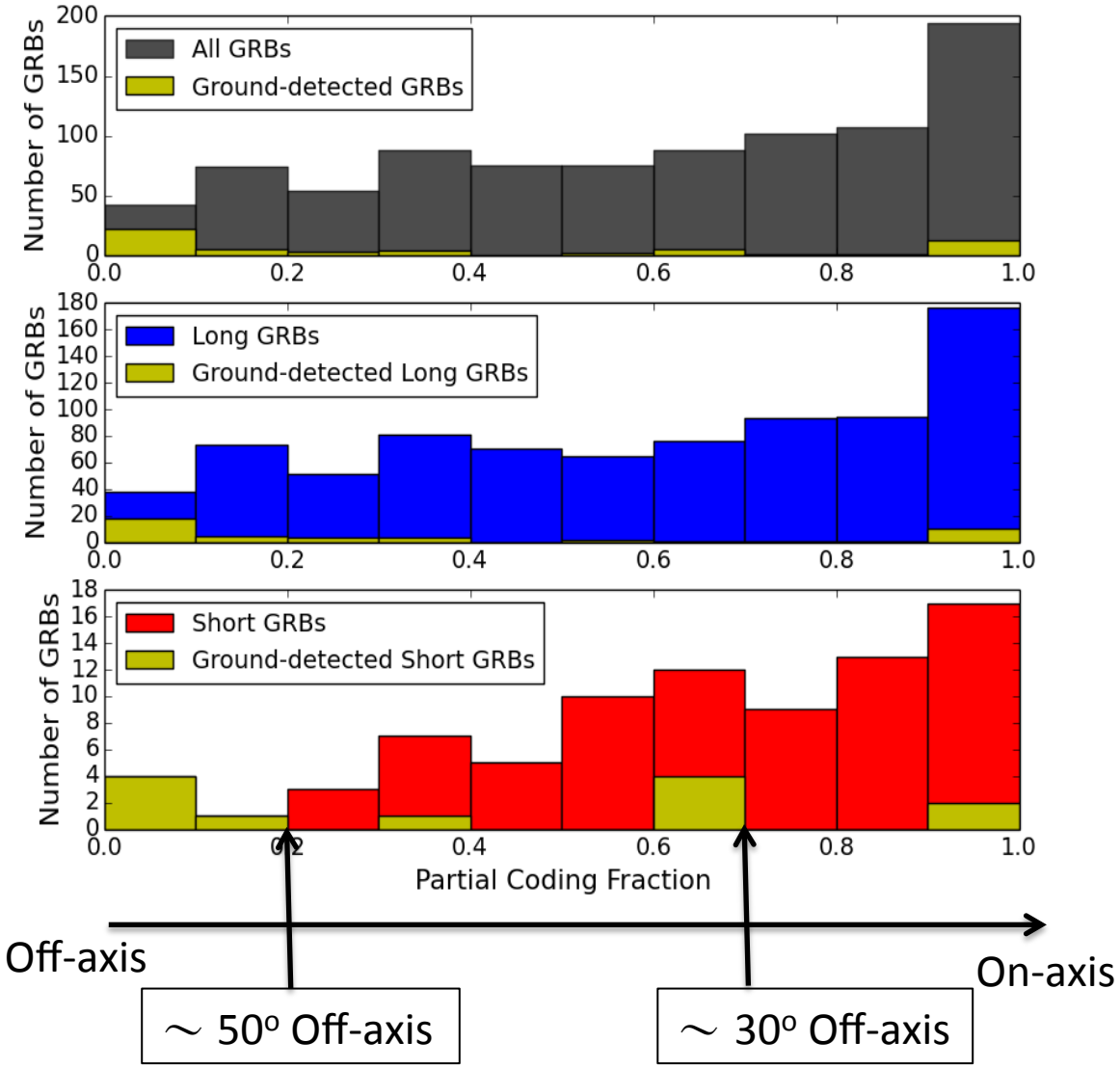
Detections from Ground Process

- Transient Monitor
  - Energy range: 15-50 keV
  - Delay time: few hours
  - Image exposure: $\sim$ 1200 s to days
  - Currently the public results only include known sources
- Ground-detected bursts
  - Failed-event data ($\sim$ 10 s; pass rate failed image)
    - Auto search: ground scripts from Takanori Sakamoto
    - Human search: Jay Cummings/David Palmer

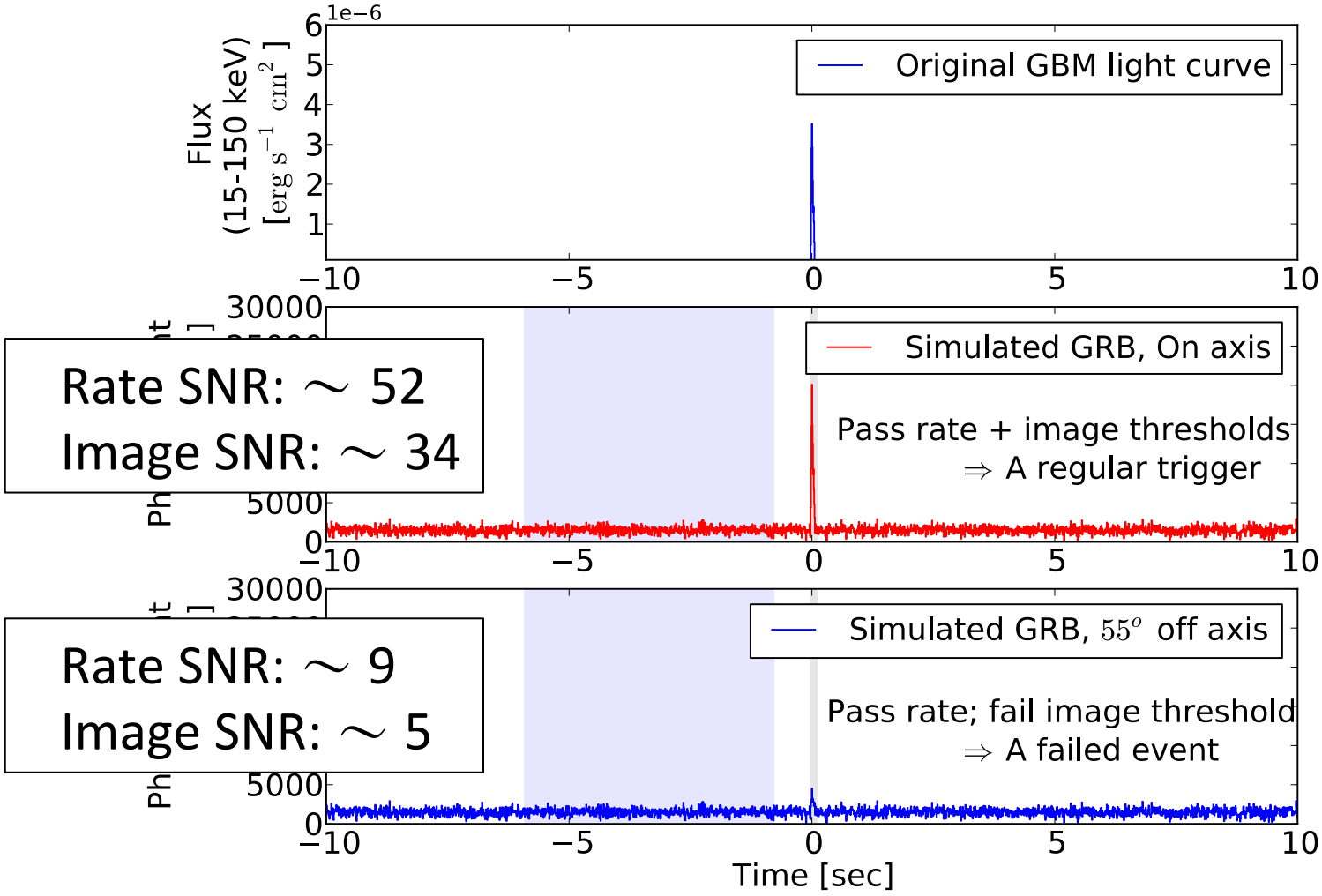
GRBs missed by on-board triggers



GRBs missed by on-board triggers



Sub-threshold short GRBs (from the BAT trigger simulation)

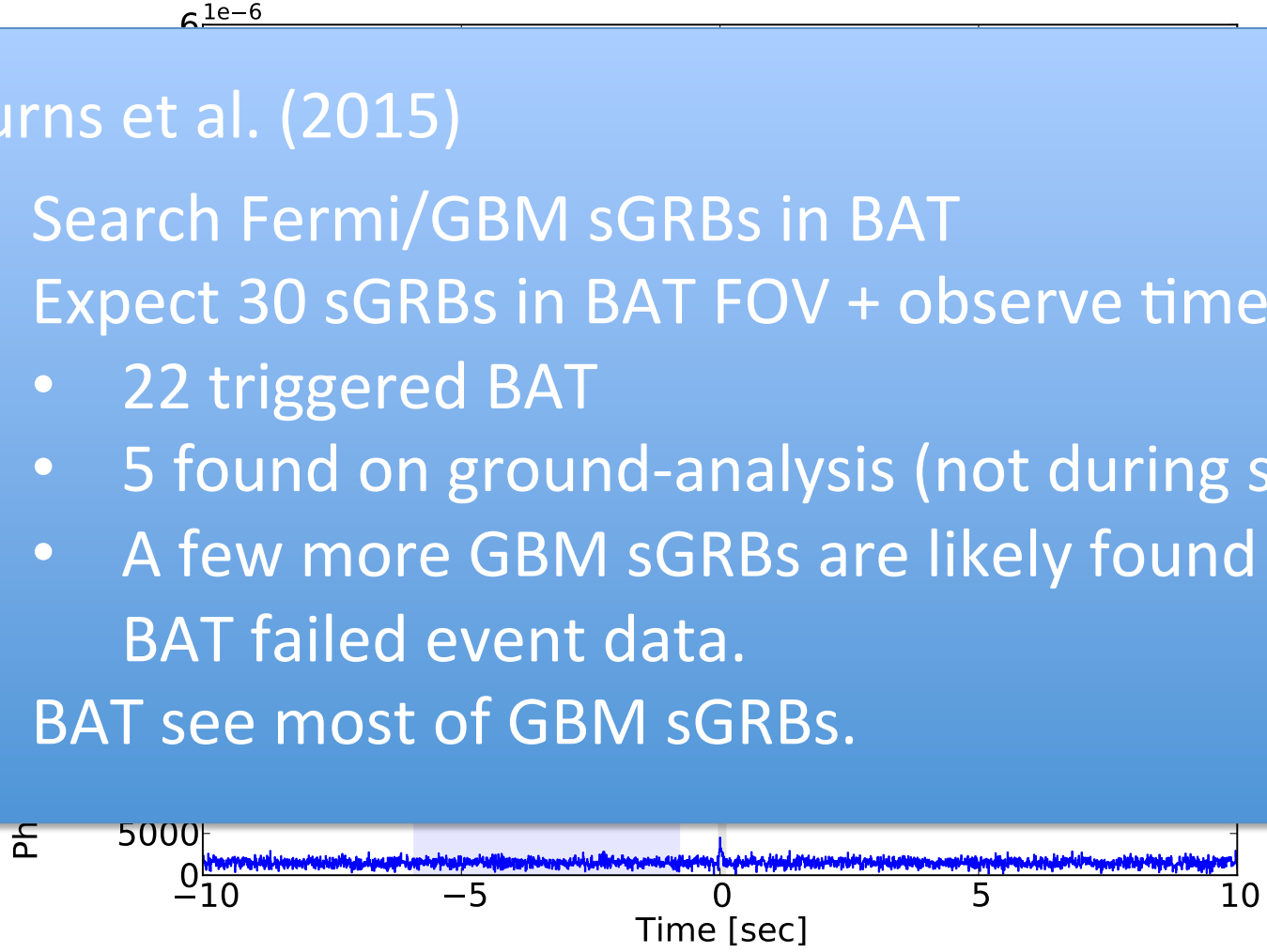


Rate SNR: ∼ 52
Image SNR: ∼ 34

Rate SNR: ∼ 9
Image SNR: ∼ 5

Troja, Lien et al.

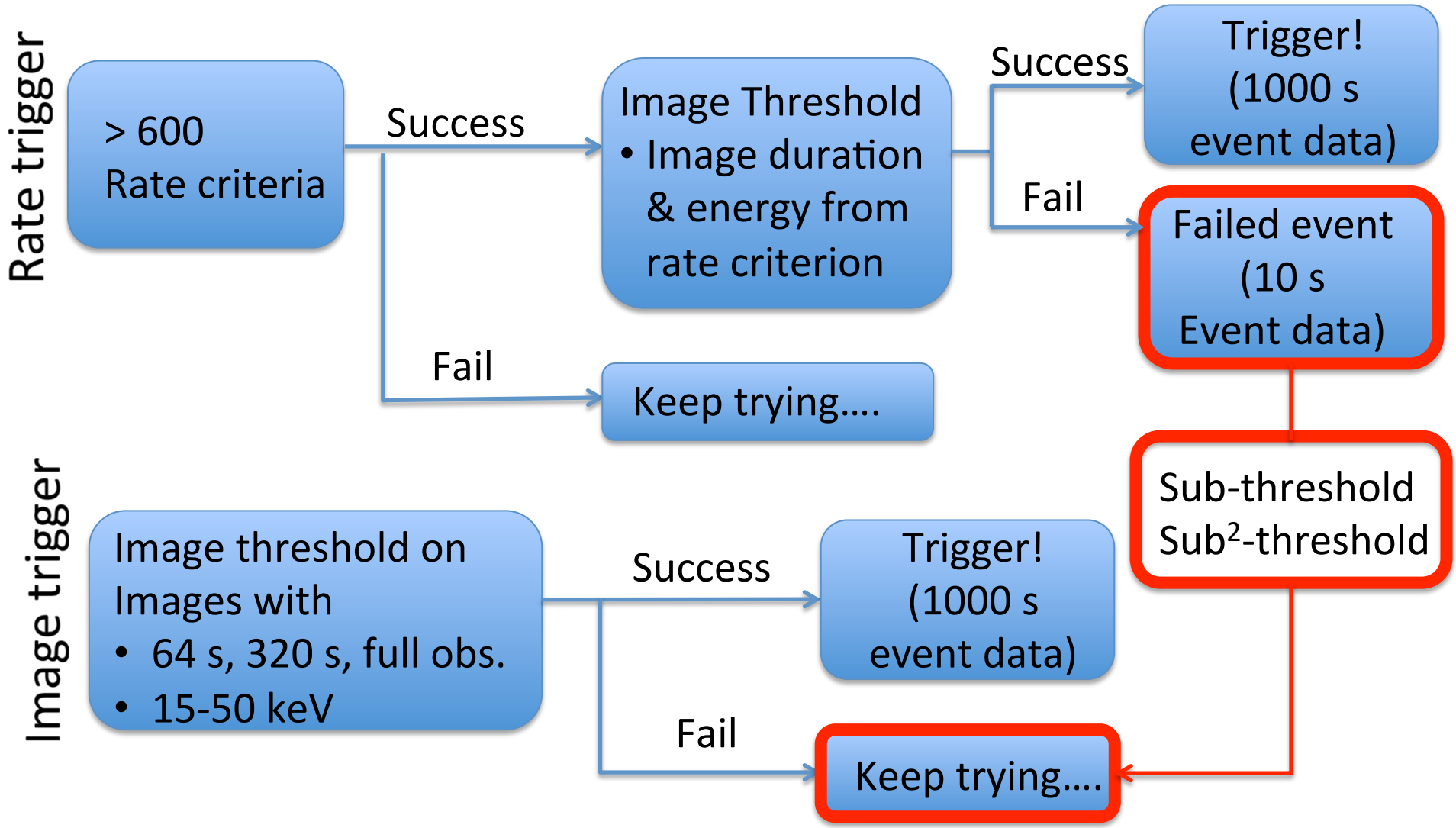
Sub-threshold short GRBs (from trigger simulation)



Burns et al. (2015)

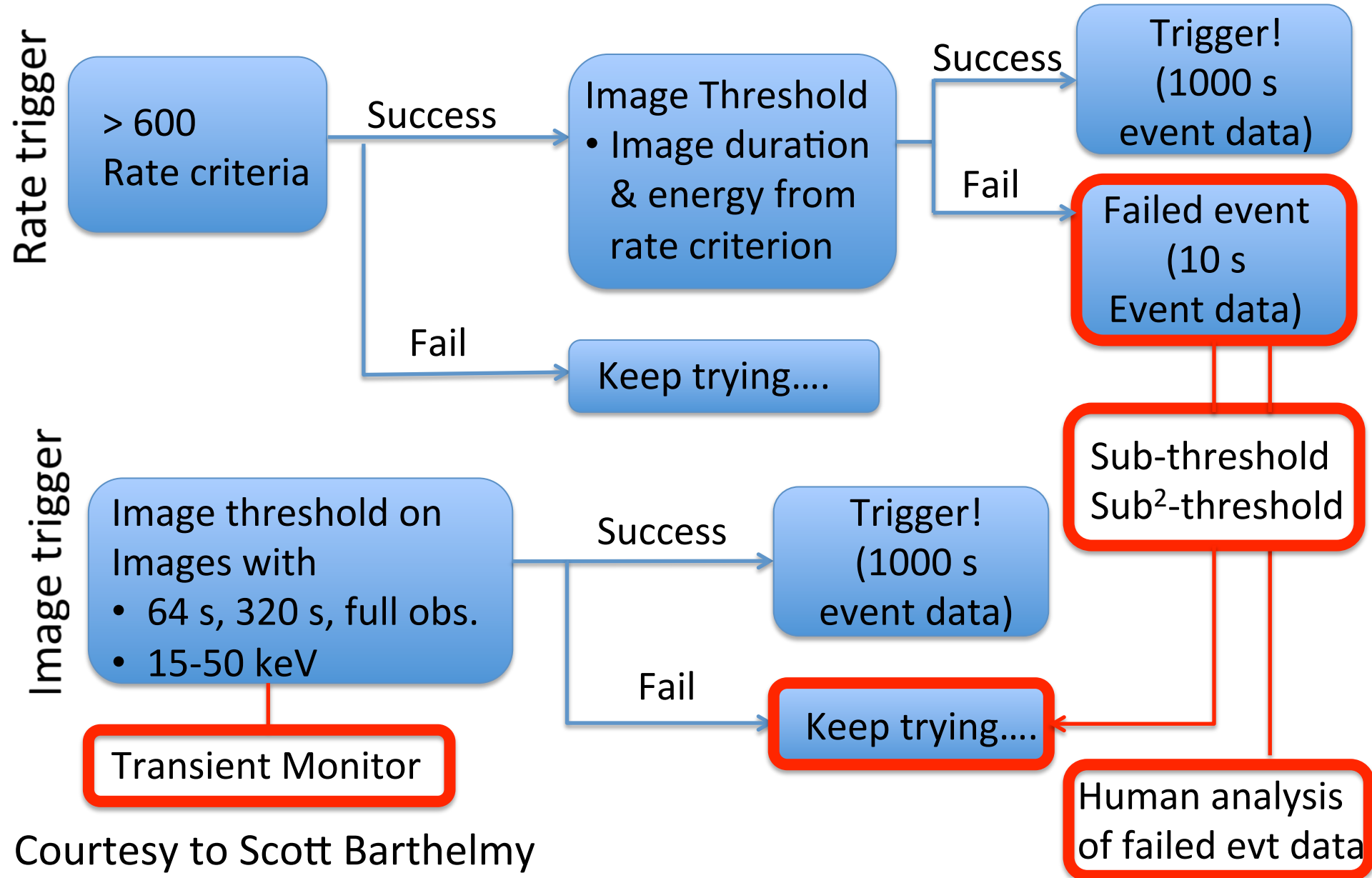
- Search Fermi/GBM sGRBs in BAT
- Expect 30 sGRBs in BAT FOV + observe time
  - 22 triggered BAT
  - 5 found on ground-analysis (not during slew)
  - A few more GBM sGRBs are likely found in BAT failed event data.
- BAT see most of GBM sGRBs.

BAT triggers summary



Courtesy to Scott Barthelmy

BAT triggers summary



Courtesy to Scott Barthelmy

Thank you!

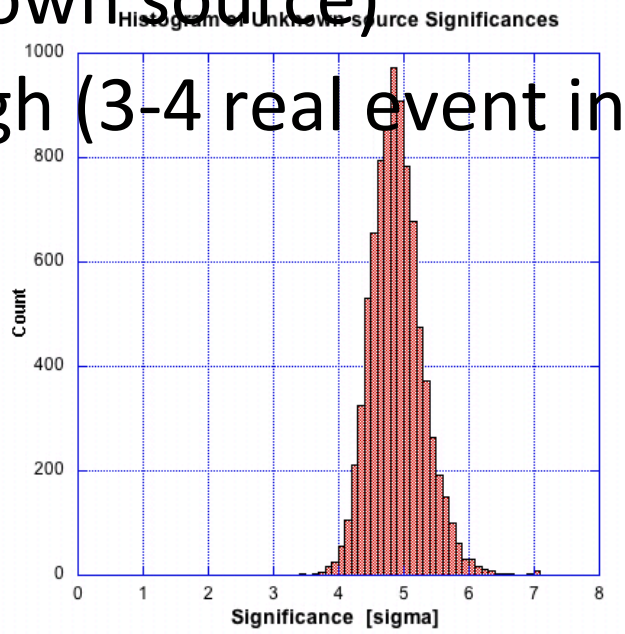
Back-up slides

Sub-threshold

- Normal image-domain threshold=6.5 sigma
- Subthreshold Notices (image sigma is in the 5.7-6.5 range)
- Location uncertainty: 2-4 arcmin (90% CL)
- False-positive rate: ~ 96% (3 real astrophysical sources in 75 subthreshold triggers) – ~6.3

Sub-sub threshold

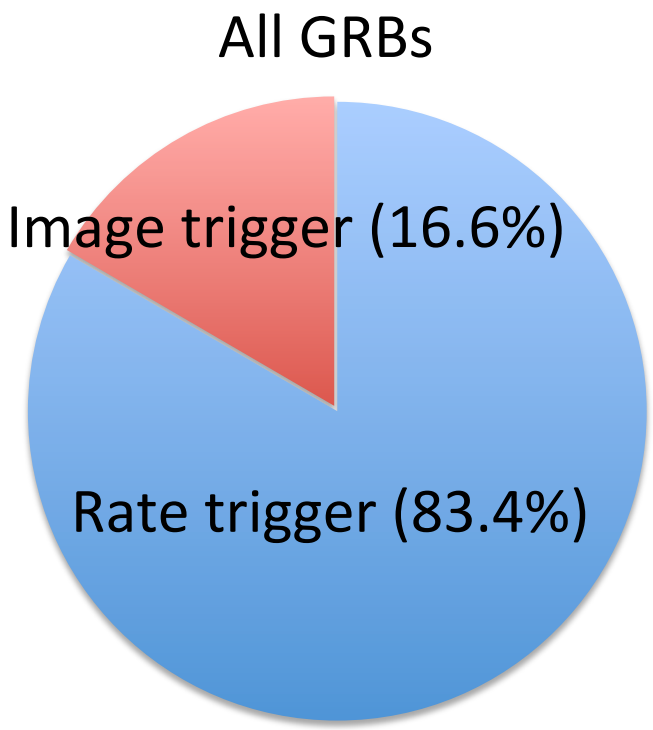
- Scaled-map images (from the shortest duration of the rate foreground period up to full observation of 43 min)
- SNR: 3.8-6.5
- Rate: 3000 per day (1000 known source)
- False-detection rate: very high (3-4 real event in 1000 notice)
- Time delay: 1-8 hours
- Location error: 1-4 arcmin

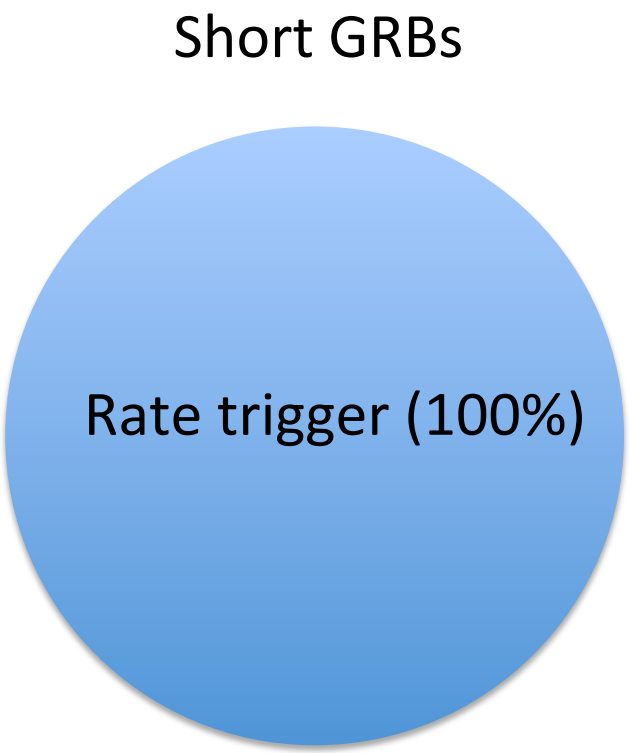


BAT transient monitor

- Based on scaled map (15-50 keV)
- Search known and unknown sources in images for each pointing (~ 1200 s), 1, 2, , 4, 8, 16 days

Trigger statistics for the successful triggers





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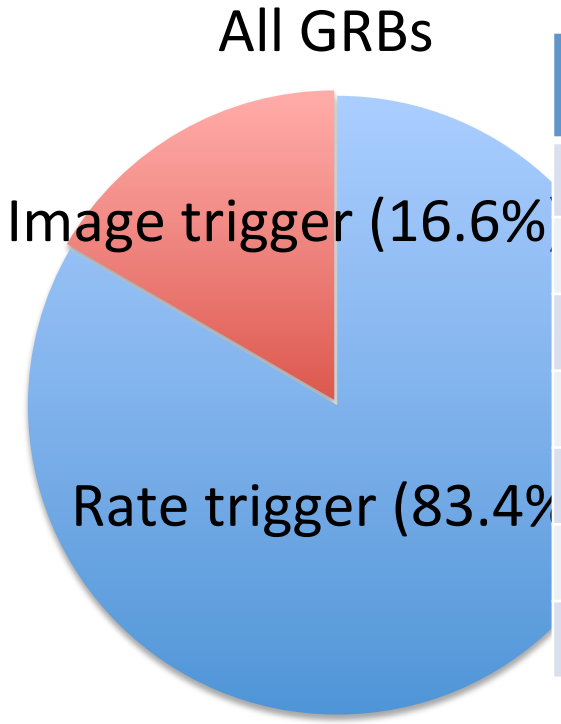

Foreground time	Number of sGRB triggers
0.512	12
1.024	8
0.032	9
0.256	12
0.064	23
0.128	8
0.384	2