“Lessons learned”

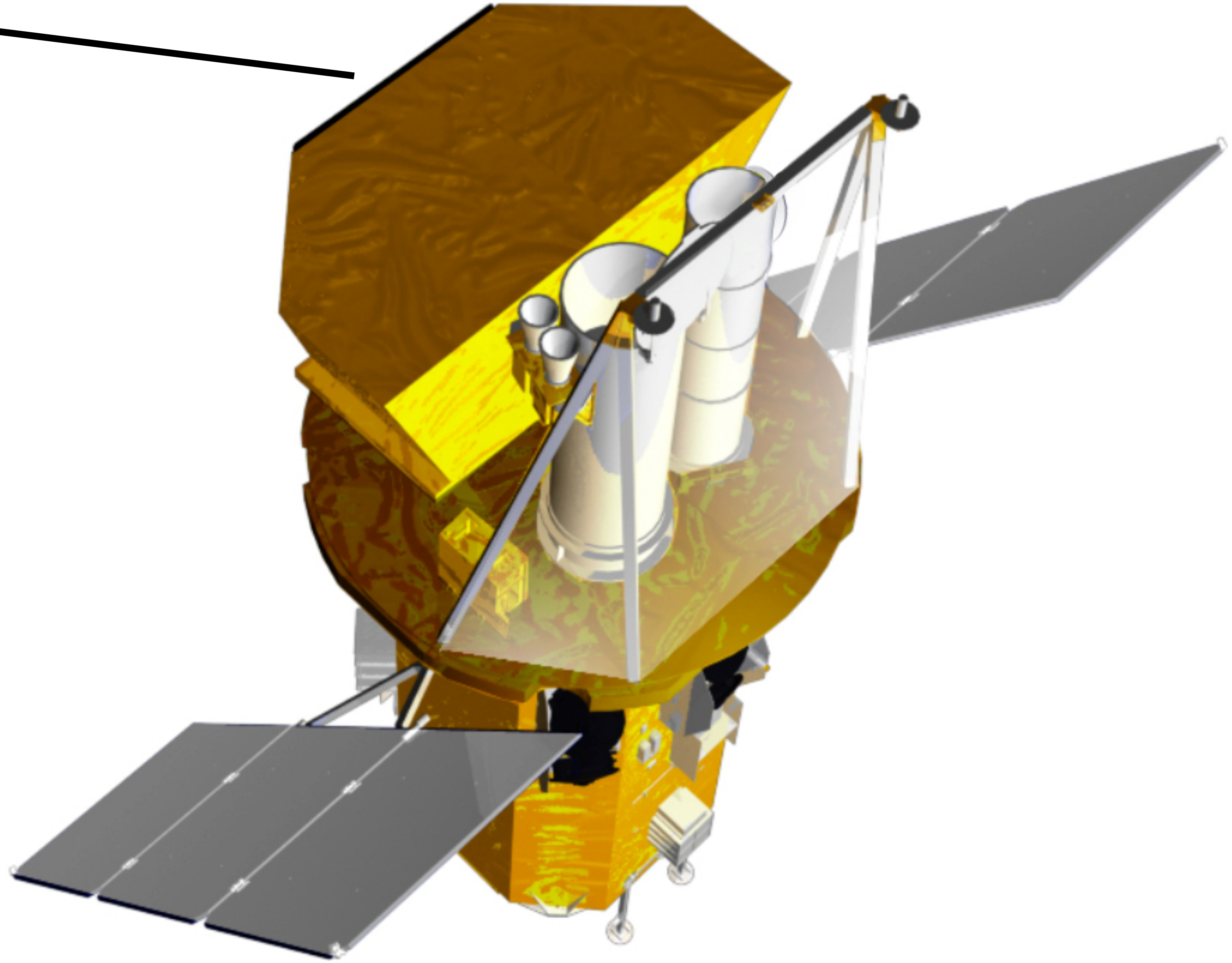
After 15 years of Swift operations

Phil Evans
(University of Leicester)

Introducing *Swift*

Burst Alert Telescope (BAT)

- 15-350 keV, coded mask - 3' positions.
- Field of view: 1/6 sky



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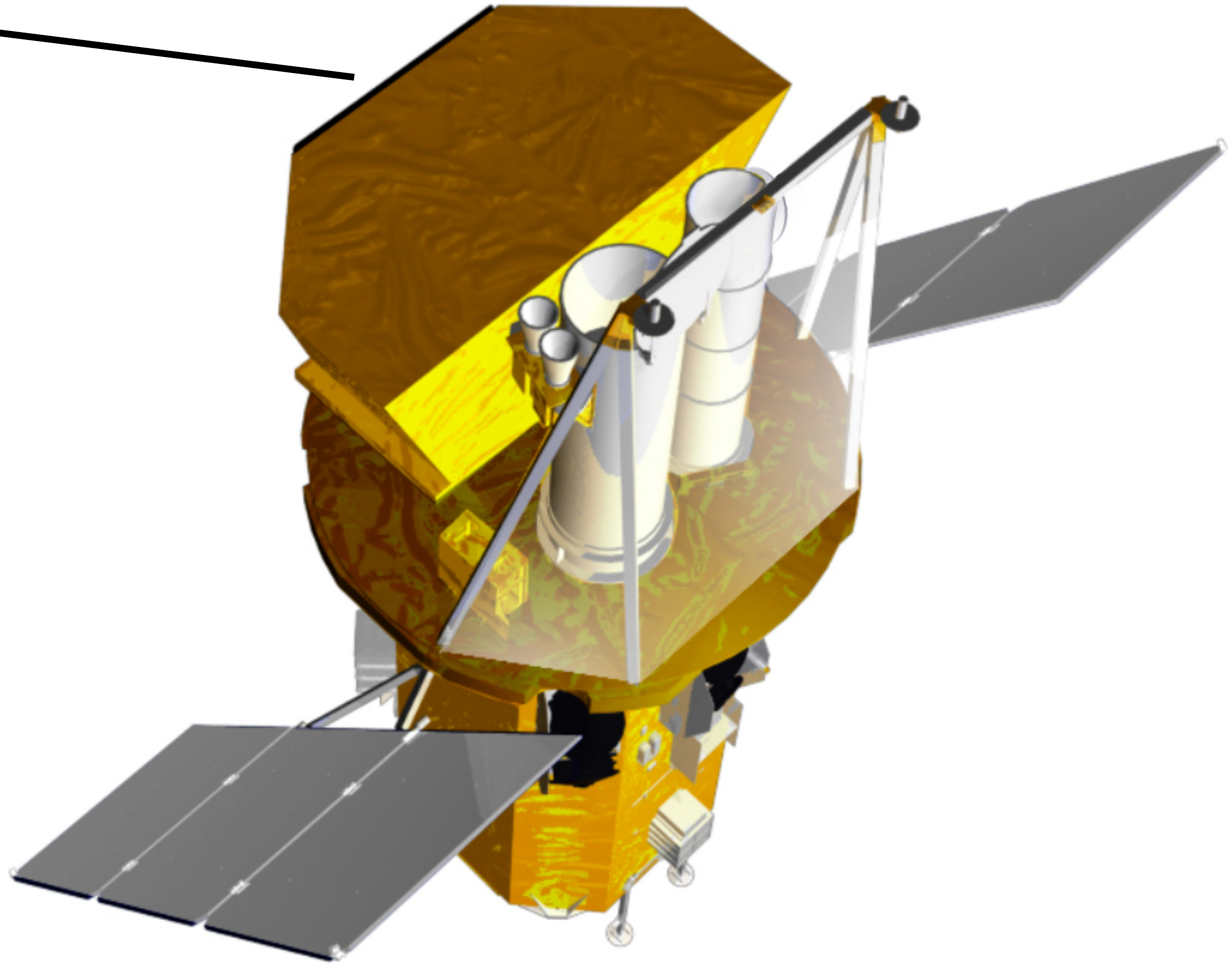

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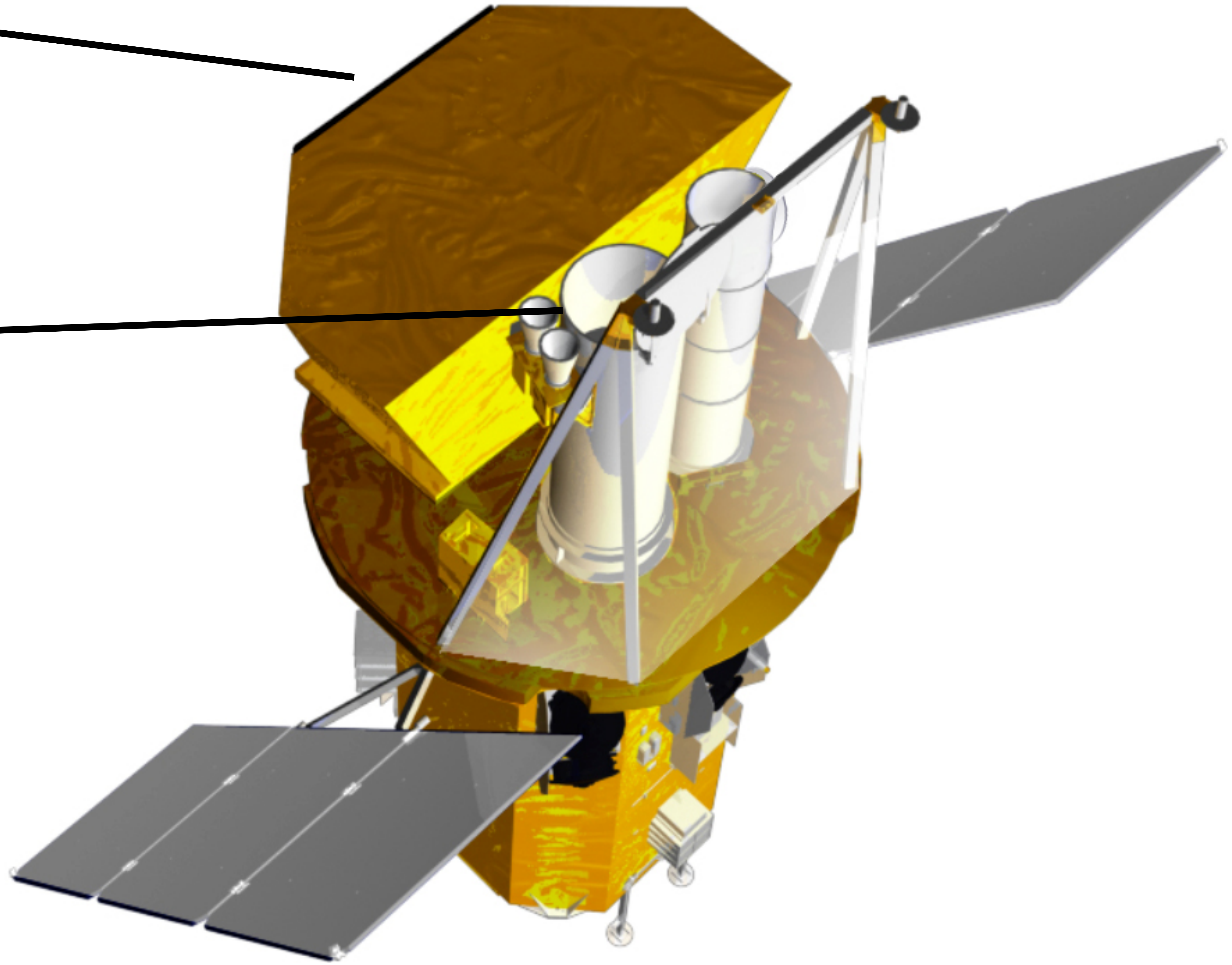
X-ray Telescope (XRT)

- 0.3-10 keV; Wolter-I. 12.5’ fov



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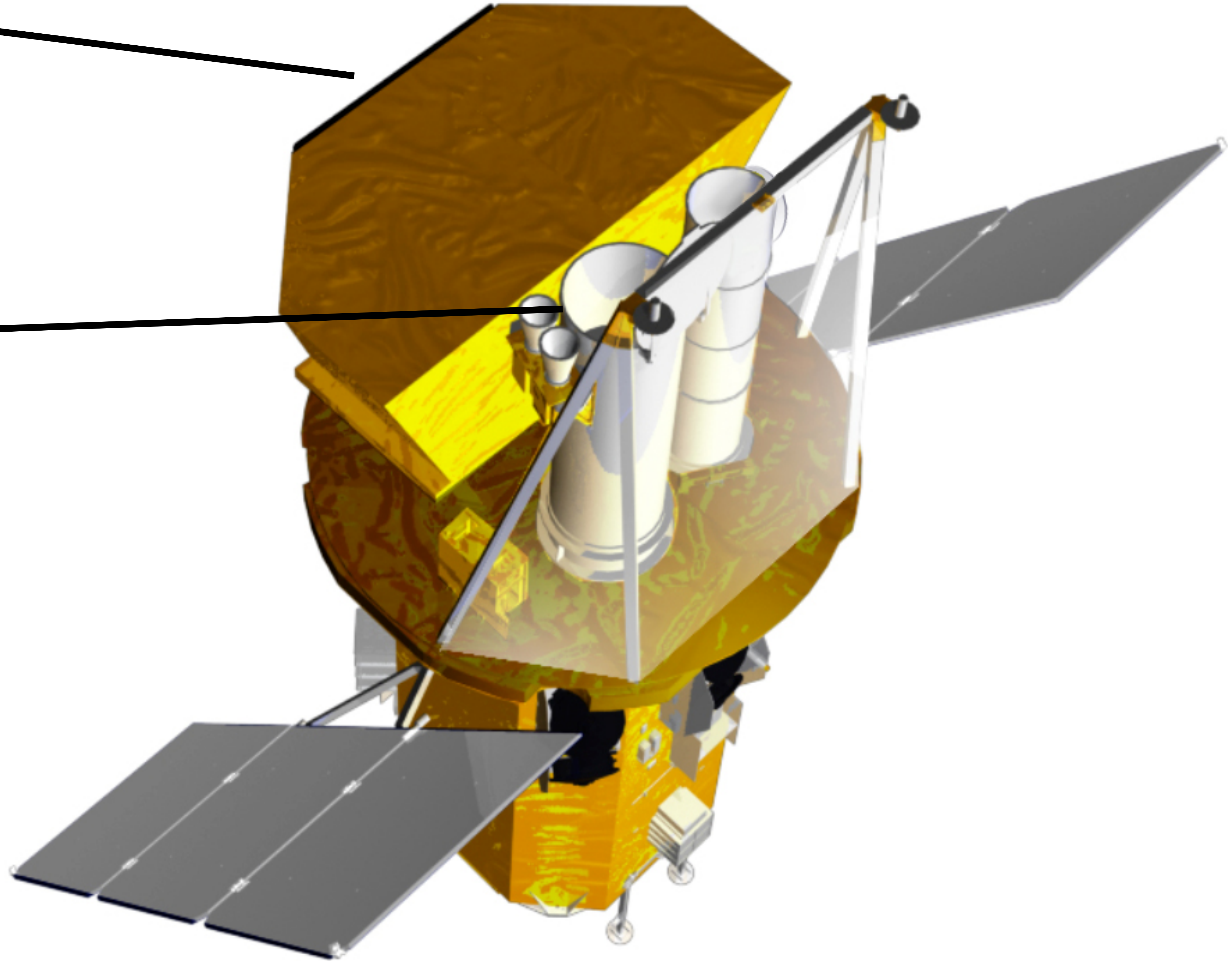

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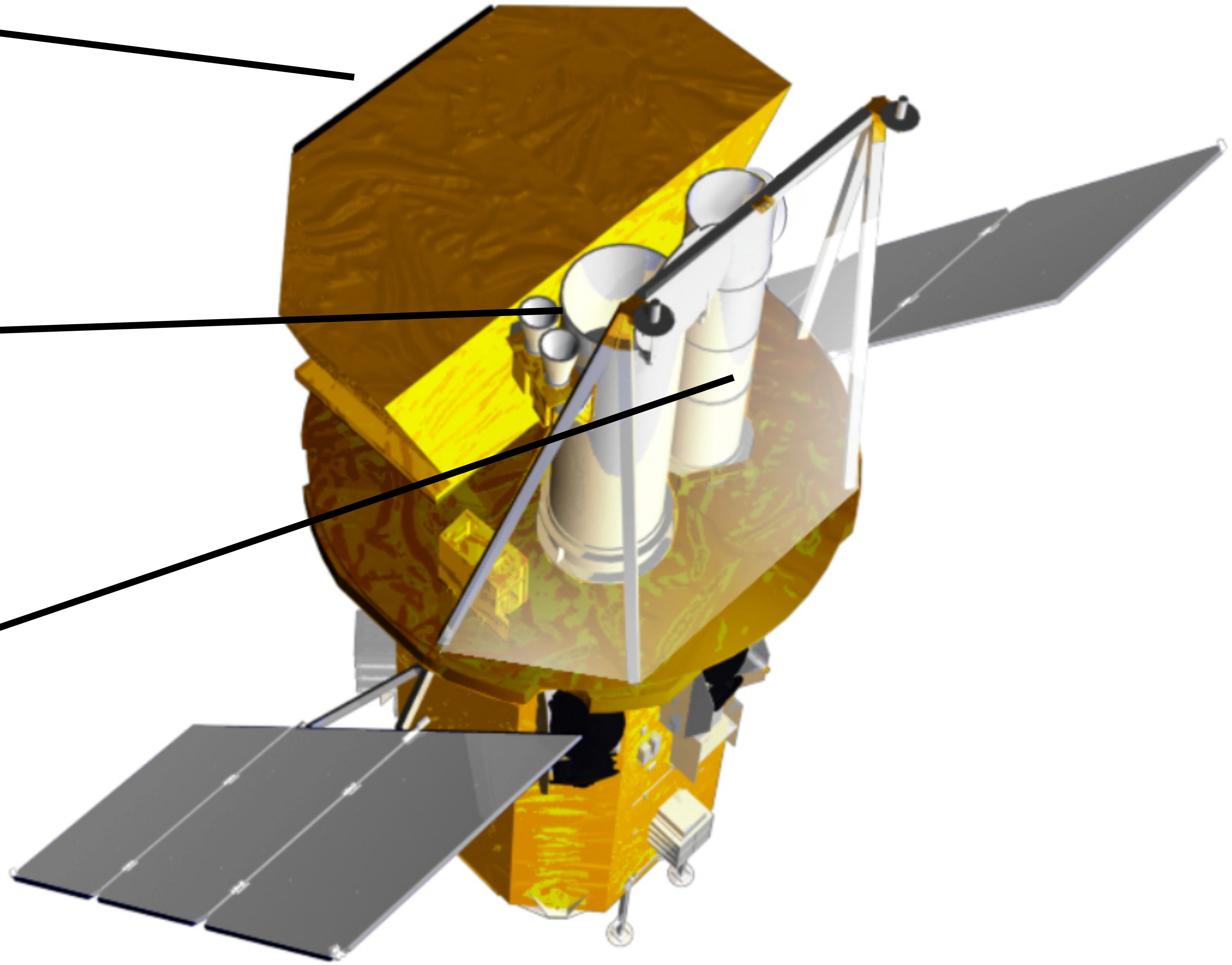
UV/Optical Telescope (UVOT)

- 170-650mm. 17'x17' fov



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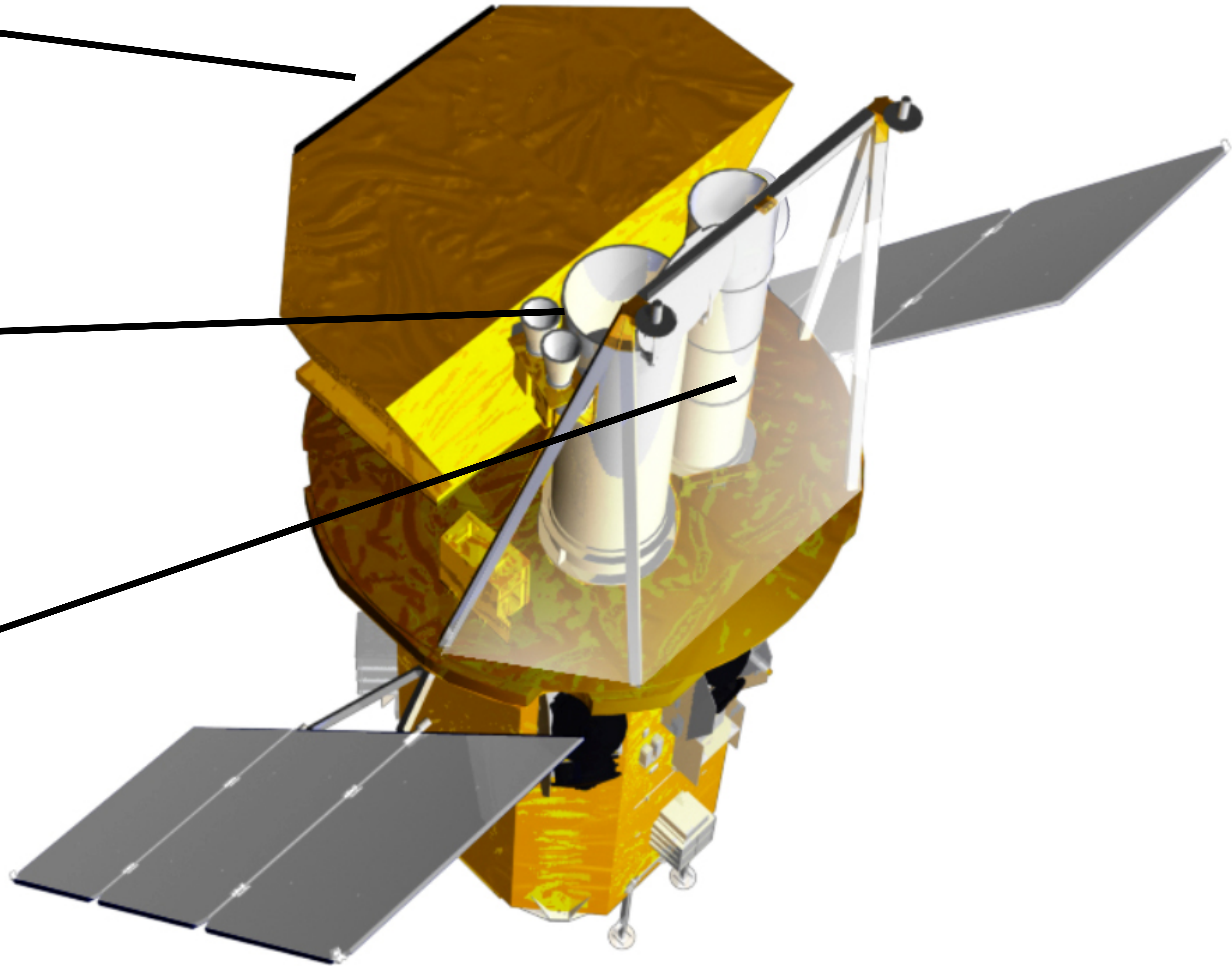
=VT



GRB response (1): synposis

- T_0 BAT triggers on the GRB; SMS alerts sent to on-call team.
- T_0+2 min On-call team convene telecon, log into web tools.
- … Limited data products downlinked over TDRSS.
- T_0+20-30 min Initial GCN Circular produced.

…

- T_0+2+hr Full dataset downlinked via ground stations.
- T_0+12-24 hr “Refined anlaysis” circulars produced.

…

- Daily Reports on evolution and external follow up, decisions made about further observations.

Anatomy of a notice

```
TITLE:            GCN/SWIFT NOTICE
NOTICE_DATE:      2020-03-06T22:51:20
NOTICE_TYPE:      Swift-BAT GRB Position
TRIGGER_NUM:      960102
SEG_NUM:          0
GRB_RA:           198.582d {13h 14m 20s}
GRB_DEC:          +11.255d {+11d 15' 18"}
GRB_ERROR:        3.00 [arcmin radius, statistical only]
GRB_INTEN:        10731 [cnts]    Image_Peak=262 [image_cnts]
TRIGGER_DUR:      4.096 [sec]
TRIGGER_INDEX:    307      E_range: 50-350 keV
BKG_INTEN:        83343 [cnts]
BKG_TIME:         82183.44 SOD; {22:49:43.44} UT
BKG_DUR:          40 [sec]
GRB_DATE:         18914 TJD;   66 DOY;   2020/03/06
GRB_TIME:         82239.06 SOD; {22:50:39.06} UT
GRB_PHI:          58.49 [deg]
GRB_THETA:        30.63 [deg]
SOLN_STATUS:      0x2003
RATE_SIGNIF:      14.10 [sigma]
IMAGE_SIGNIF:     7.35 [sigma]
```

Interlude: the initial circular

J.D. Gropp (PSU), S. D. Barthelmy (GSFC), D. N. Burrows (PSU),
J. A. Kennea (PSU), S. Laha (GSFC/UMBC/CRESST),
A. Y. Lien (GSFC/UMBC), F. E. Marshall (NASA/GSFC),
D. M. Palmer (LANL), B. Sbarufatti (PSU), M. H. Siegel (PSU) and
A. Tohuvavohu (U Toronto) report on behalf of the Neil Gehrels Swift
Observatory Team:

Authors

At 22:50:39 UT, the Swift Burst Alert Telescope (BAT) triggered and
located GRB 200306C (trigger=960102). Swift slewed immediately to the burst.
The BAT on-board calculated location is
RA, Dec 198.582, +11.255 which is
   RA(J2000) = 13h 14m 20s
   Dec(J2000) = +11d 15' 18"
with an uncertainty of 3 arcmin (radius, 90% containment, including
systematic uncertainty). The BAT light curve showed a complex
structure with a duration of about 50 sec. The peak count rate
was ~1800 counts/sec (15-350 keV), at ~3 sec after the trigger.

BAT paragraph

Interlude: the initial circular

XRT paragraph

```
The XRT began observing the field at 22:52:35.9 UT, 116.9 seconds after
the BAT trigger. Using promptly downlinked data we find a fading,
uncatalogued X-ray source located at RA, Dec 198.55562, 11.26981 which
is equivalent to:
   RA(J2000)  = 13h 14m 13.35s
   Dec(J2000) = +11d 16' 11.3"
with an uncertainty of 3.5 arcseconds (radius, 90% containment). This
location is 107 arcseconds from the BAT onboard position, within the
BAT error circle.
```

Interlude: the initial circular

UVOT paragraph

```
UVOT took a finding chart exposure of 250 seconds with the U filter starting
117 seconds after the BAT trigger. There is a candidate afterglow in the list
of sources generated on-board at
  RA(J2000)  = 13:14:13.44 = 198.55602
  DEC(J2000) = +11:16:11.5  =  11.26985
with a 90%-confidence error radius of about 1.10 arc sec. This position is 1.4
arc sec. from the center of the XRT error circle. The estimated magnitude is
17.47. No correction has been made for the expected extinction corresponding to
E(B-V) of 0.02.
```

Extra paragraph

```
Burst Advocate for this burst is J.D. Gropp (jdg44 AT psu.edu).
Please contact the BA by email if you require additional information
regarding Swift followup of this burst. In extremely urgent cases, after
trying the Burst Advocate, you can contact the Swift PI by phone (see
Swift TOO web site for information: http://www.swift.psu.edu/)
```

The biggest, most important lesson

The biggest, most important lesson

QUICKGCN

What is quickGCN?

quickGCN is a custom-built web facility for creating our initial GCN circulars.

Much more helpful than the Google doc we used this morning!

It manages:

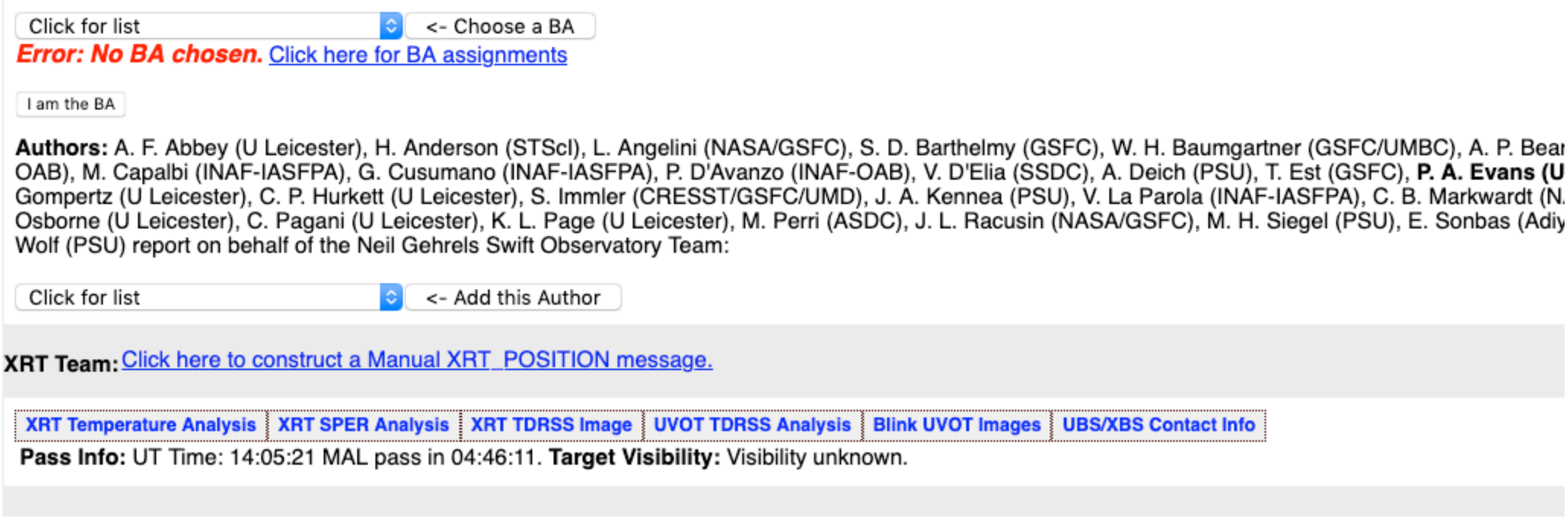
- Authors and author lists
- Providing observing information about the ongoing trigger.
- Construction of the GCN; including provision of templates and ingesting automated analysis.
- Submitting the circular.
- Notifying the auto-analysis systems of the trigger.

I will give a light-touch overview here, but I am very willing to discuss this in much detail if desired. The system was **not** made by me however, but by Jamie Kennea (PSU).

quickGCN - overview

- Login controlled, i.e. all team members need an account.
- Each user has available roles (BAT, XRT, UVOT, ODS or super user)
  - This determines what controls they can access. e.g. XRT members can't edit BAT details.
  - I am a superuser which is why all controls are visible on the following slides!
- Users can edit their name/affiliation: reduces maintenance burden on admin.

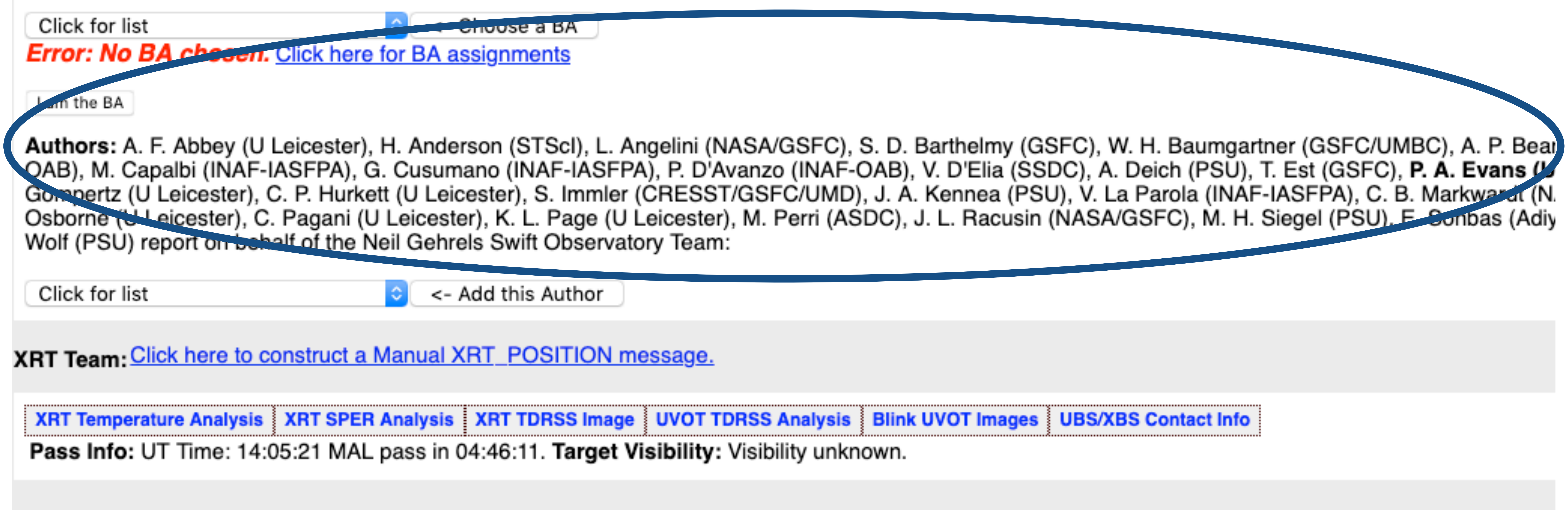
quickGCN - overview



quickGCN - overview

BA identifies themselves, or is added by a superuser.

When users log in and click to join, the author list updates automatically.



quickGCN - overview

Click for list | <- Choose a BA

Error: No BA chosen. [Click here for BA assignments]

I am the BA

Authors: A. F. Abbey (U Leicester), H. Anderson (STScI), L. Angelini (NASA/GSFC), S. D. Barthelmy (GSFC), W. H. Baumgartner (GSFC/UMBC), A. P. Bear
OAB), M. Capalbi (INAF-IASFPA), G. Cusumano (INAF-IASFPA), P. D'Avanzo (INAF-OAB), V. D'Elia (SSDC), A. Deich (PSU), T. Est (GSFC), **P. A. Evans (U**
Gompertz (U Leicester), C. P. Hurkett (U Leicester), S. Immler (CRESST/GSFC/UMD), J. A. Kennea (PSU), V. La Parola (INAF-IASFPA), C. B. Markwardt (N
Osborne (U Leicester), C. Pagani (U Leicester), K. L. Page (U Leicester), M. Perri (ASDC), J. L. Racusin (NASA/GSFC), M. H. Siegel (PSU), E. Sonbas (Adiy
Wolf (PSU) report on behalf of the Neil Gehrels Swift Observatory Team:

Click for list | <- Add this Author

XRT Team: Click here to construct a Manual XRT_POSITION message.

XRT Temperature Analysis | XRT SPER Analysis | XRT TDRSS Image | UVOT TDRSS Analysis | Blink UVOT Images | UBS/XBS Contact Info

Pass Info: UT Time: 14:05:21 MAL pass in 04:46:11. **Target Visibility:** Visibility unknown.

Is the target visible? Are we in a pass? Or the SAA?

Introducing *Swift*

Trigger Type: (●) Is a burst. ( ) Not a burst. ( ) Possible burst. → To inform auto processing

TITLE: EDIT

```
GRB 060111B: Swift detection of a burst
```

→ Auto completed (inc letter)

BAT Paragraph: EDIT GET AUTO PARAGRAPH

```
At 20:15:43 UT, the Swift Burst Alert Telescope (BAT) triggered and
located GRB 060111A trigger=176918).  Swift slewed immediately to the burst.
The BAT on-board calculated location is
RA, Dec 286.337, +70.360 which is
   RA(J2000) = 19h 05m 21s
   Dec(J2000) = +70d 21' 35"
with an uncertainty of 3 arcmin (radius, 90% containment, including
systematic uncertainty).  The BAT light curve showed a [**double-peaked**]
structure with a duration of about TTT sec.  The peak count rate
was ~3219 counts/sec (15-350 keV), at ~181 sec after the trigger.
```

→ Early days: template provided for BBS to edit.

Modern: main details auto-completed from the GCN notices.

XRT Paragraph: EDIT GET AUTO PARAGRAPH

```
The XRT began observing the field at 04:19:33.8 UT, 75.9 seconds after
the BAT trigger. Using promptly downlinked data we find a bright,
uncatalogued X-ray source located at RA, Dec 312.79535, -78.38431 which
is equivalent to:
   RA(J2000)  = 20h 51m 10.88s
   Dec(J2000) = 78d 23' 03.5"
with an uncertainty of 3.0 arcseconds (radius, 90% containment). This
location is 59 arcseconds from the BAT onboard position, within the BAT
error circle.
```

→ Early days: template provided for XBS to edit.

Modern: fully automated, updates ingested automatically.

Also XRT provides ‘flags’ to quickGCN.

quickGCN summary

Cannot emphasize this strongly enough: quickGCN is invaluable. If you do one thing pre-launch to aid rapid response, make a facility like this.

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Cannot emphasize this strongly enough: quickGCN is invaluable. If you do one thing pre-launch to aid rapid response, make a facility like this.

But if you do two things… automate!

All the other "lessons" relate to automation, both some bonus side-effects, and important things to be aware of if you automate (things we learned the hard way)!

Automation!

Pros:

- Reduces human effort.
- Reduces human error (especially at 3am)!
- Can be more reliable/accurate than humans, or enable extra products.
- By posting products online reduces the need for regular GCNs etc.
  - But make sure you provide a citable reference!
- The tools you create work for more than GRBs. (*Don't underestimate the value of this).*
- Makes it easy for others to use your data.

Automation!

Cons / warnings:

- How do you know it's correct?
- Will fail in some cases.
  - You can catch for these; my code 'knows' its limits and mitigates.
- Potential loss of expertise - can lead to bad consequences if automation unavailable.
- Makes it easy for others to use your data.

Automation - examples: XRT

Before automation:

- ***Prompt:***
  - A template XRT paragraph was produced. Basic details automatically completed.
  - When new data were received, humans analysed them and updated the paragraph.
  - And again when new data were received… and again.
- ***Later***:
  - Humans had to construct light curve and spectrum from the ground data.
  - Write a “refined analysis” GCN
  - Update the light curve at least daily, model it, predict tomorrow’s flux and advise on future observations.

Automation - examples: XRT

After automation:

- ***Prompt:***
  - An XRT paragraph is produced. All details automatically completed.
  - When new data are received, paragraph is updated and ingested by quickGCN.
  - And again when new data are received… and again.
  - Also created prompt light curve and spectrum - posted online
- ***Later***:
  - Receipt of data triggers automatic build/update of all products - posted online.
  - “Refined analysis” GCN automatically written and distributed.
  - Light curve automatically modelled, flux productions made and shared online.

(Not really sure what the XRT team does anymore 😂)

Addressing the warnings

How do we know that the circulars are correct?

- We had 200+ GRBs by the time I started automating things - that's a great test case.
  - Simulations? Or don't automate at first (mitigate loss of expertise issue).
- Someone from PSU independently verified my results.
- We ran for about a year where I tracked every time that the automated circular draft was edited before submission.
  - ~all edits were superfluous and often actually made the circular incorrect!

Addressing the warnings

What about failure cases:

- Key is to identify limits of code, and catch for them. Examples:
  - ☐ Prompt data are corrupted, can't be analysed.
    - ☑ XRT paragraph reports this.
  - ☐ Flares in the light curve invalidate modelling.
    - ☑ Identify when flares are present, and ignore the first 2,000 s.
  - ☐ No XRT afterglow was found promptly, so we don't know which source on the ground is the afterglow.
    - ☑ Don't send the automated circulars - alert the XRT team to do some work!
      - ☑ Later fix, automated this case too!

Addressing the warnings

Really important lesson learned in this automation:

1) The automation needs to know if the BAT trigger was not a GRB

- e.g. we decide the prompt event is not a GRB but a new SGR, Swift J1234+5678
- But the auto analysis indexes it as GRB 200318A and sends circulars about it. 🤭

This happened.

2) The automation needs to know the GRB name

- e.g. we trigger, but Fermi has already seen two GRBs, so we call it GRB 200101C
- Auto analysis calls it 200101A and sends circulars about it. 🤭

This happened as well.

Solution - quickGCN rocks

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So, when quickGCN submits the circular, it also tells my system the trigger type and the circular title.

Other notable lessons

There is no good 'recent transient' checking tool.

(I wrote one, then ATEL broke it)

- Sometimes a BAT trigger turns out to be a transient recently reported by someone else.
- It's a bit embarrasing when you announce a GRB, or 'new transient', then someone else points out that it's not.

I don't have (currently) a good solution except "check recent ATELs".

Another key lesson

With automation in *Swift,* there are very few people who are required to respond rapidly (ODS, BBS).

But what if something goes wrong…

- May 28th, 2014. BAT reported a subthreshold trigger (probably noise), near M31.
- XRT centroided onboard on a known-source in M31.
- The SPER data were corrupted; my automation could not produce light curve etc.
- No XRT person was on the telecon.
- Those online looked at the TDRSS 'lightcurve' (that unreliable one that isn't actually a light curve) and thought the source was in outburst.
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We do have a policy for these cases, but it was not followed:

If the automation fails and no expert is online: **call one!**

Last remarks and warnings

- Do we lose out by making data public, or making analysis easier?
  - No! Give a citable reference.
  - High paper count is good for the mission.
- There will always be… difficult people.
  - (Rude) emails because people haven't read the documentation!
  - Some people won't trust your results
    - "My results differ from yours… so yours are wrong."
    - (Do make sure the limitations of the tools are clearly documented).