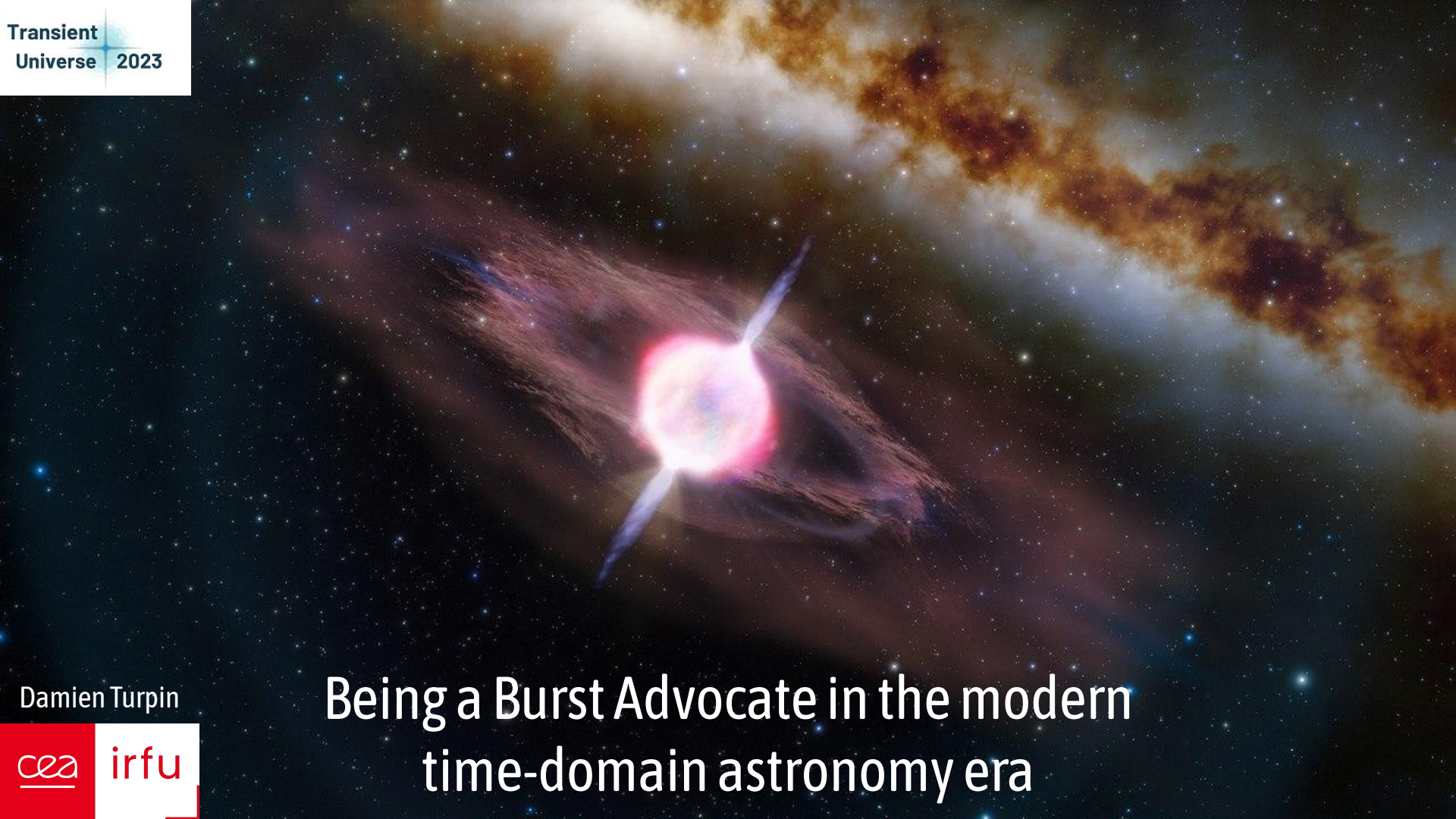
Transient Universe 2023



Being a Burst Advocate in the modern time-domain astronomy era

Damien Turpin

cea irfu

Transient Universe 2023

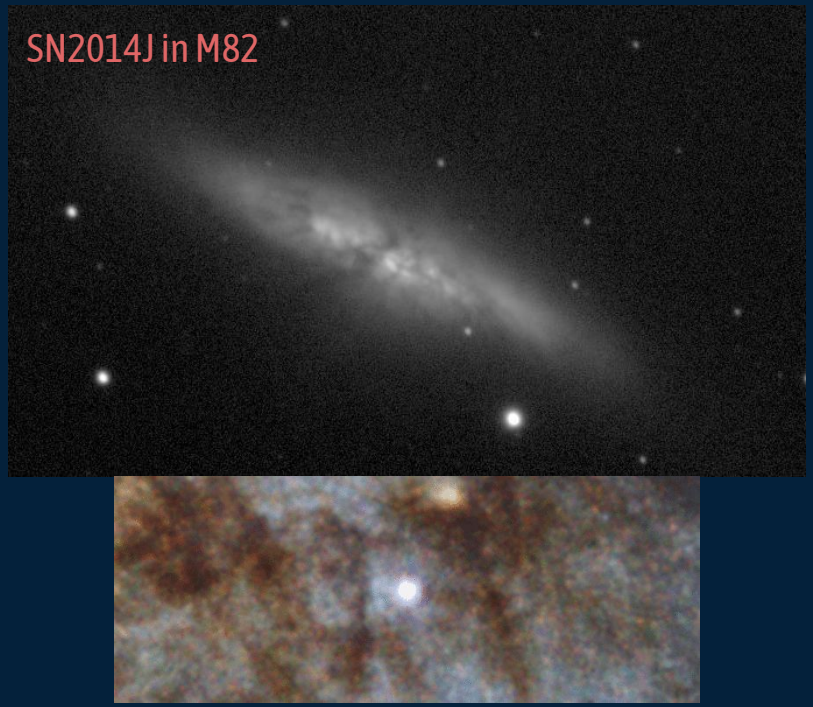
Outlines

1. The time-domain astronomy in a nutshell
2. AIs vs BA in the loop ?
3. Real-time Burst Advocate activities in transient astronomy
4. At 9.40a.m, get ready for your first SVOM GRB!

1

The time-domain astronomy in a nutshell

The Transient sky vs The Variable sky



Credits:
- UCL/University of London Observatory/Steve Fossey/Ben Cooke/Guy Pollack/Matthew Wilde/Thomas Wright - UCL Mathematical & Physical Sciences
- NASA, ESA and Y. Yang (Texas A&M and Weizmann Institute of Science, Israel)

Inside the M33 galaxy

(2 years of obs.)

Crédits: **T.A.Rector (NRAO/AUI/NSF and NOAO/AURA/NSF) and M.Hanna (NOAO/AURA/NSF)**

Transient Universe 2023

The Transient sky

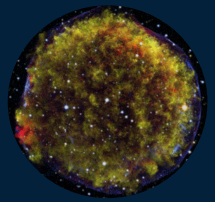
1. Cataclysmic events with an irreversible modification of the progenitor system
2. Unpredictable (time and space)
3. Sudden release of a large amount of energy (bright events)
4. Very short duration(ms/few month)
5. Not periodic
6. usually extragalactic (Luminous events)

The Variable sky

1. Objects that exhibit a significant change in luminosity while keeping the nature of the progenitor unchanged
2. Known sky position and sometimes predictable in time
3. Release of energy or external factors (body motions mainly)
4. Very short to long duration (ms/years)
5. Some are periodic
6. SSO, Galactic and extragalactic

The time domain astronomy: source classes

Transients



Supernovae

Tidal disruption events

Gamma-ray Bursts

Fast Radio bursts ?

Variable objects

AGNs

Pulsars

Magnetar flares

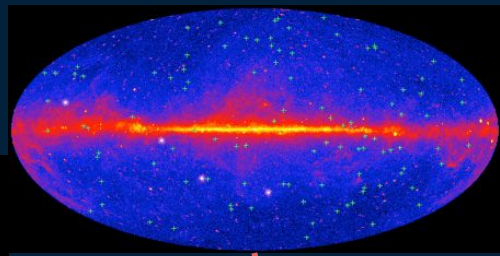
X-ray Binaries

Variable stars

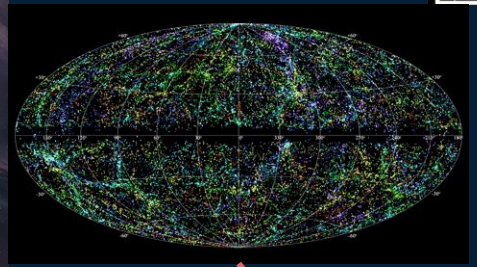
The time domain astronomy is multi-wavelength !

Credit : **LSGT/Siding Spring Observatory**

https://nasa.tumblr.com/post/176492220069/embed



Crédit: **NRAO Outreach / T. Jarrett (IPAC / Caltech)**



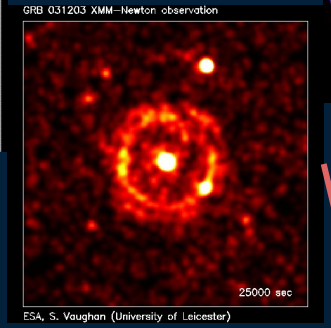
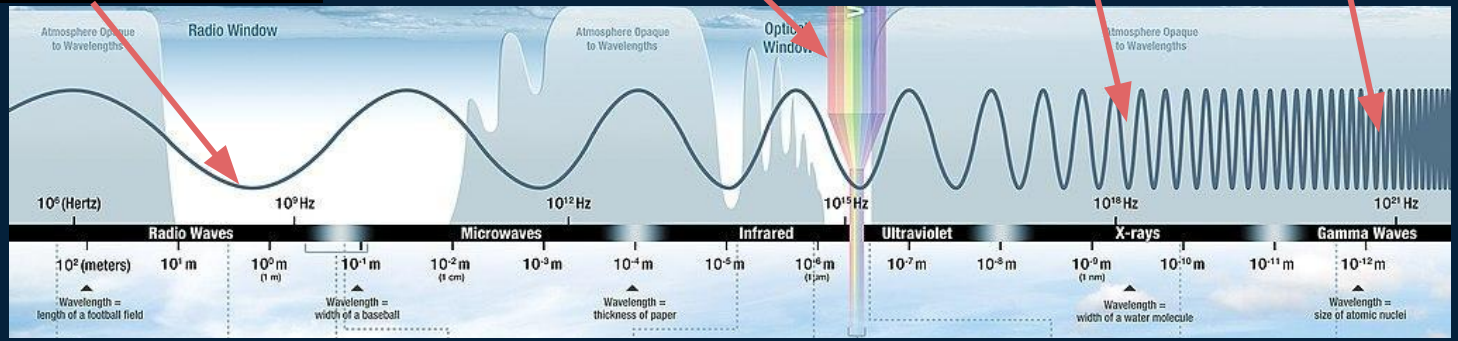
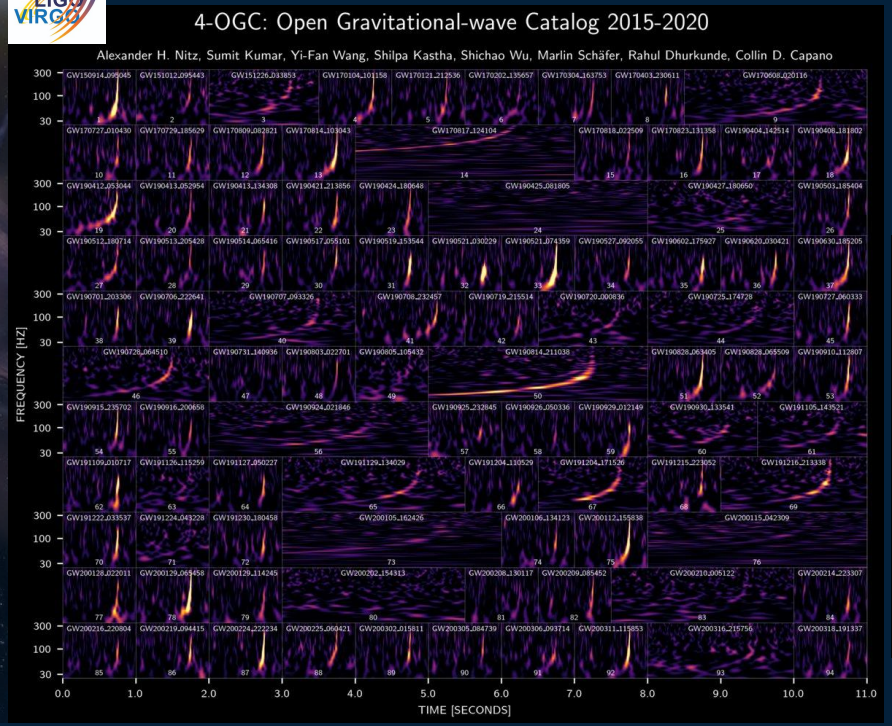


Image courtesy of Simon Vaughan (University of Leicester) and ESA

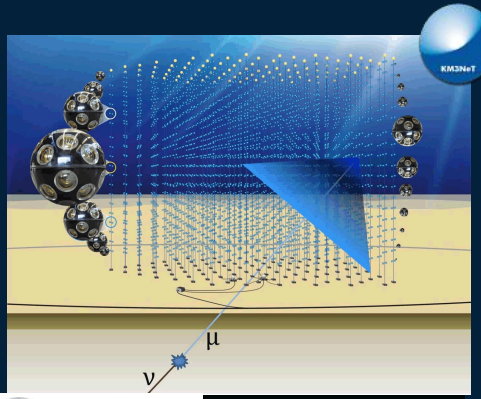


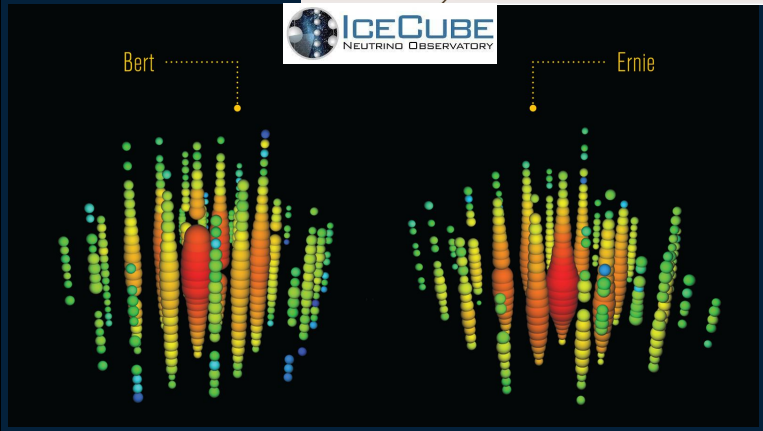
The time domain astronomy is multi-messenger !

Gravitational waves



TeV-PeV neutrinos



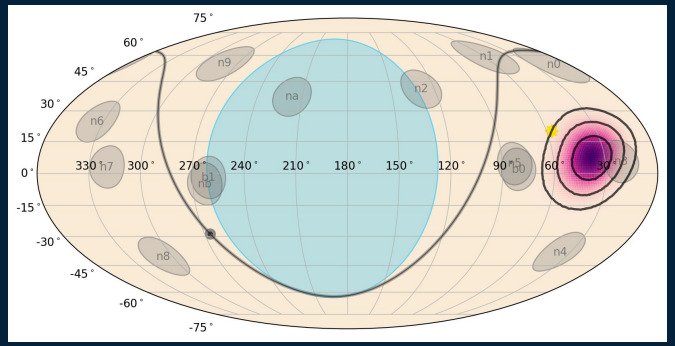


PeV neutrino Cerenkov light-track signal in the IceCube detector

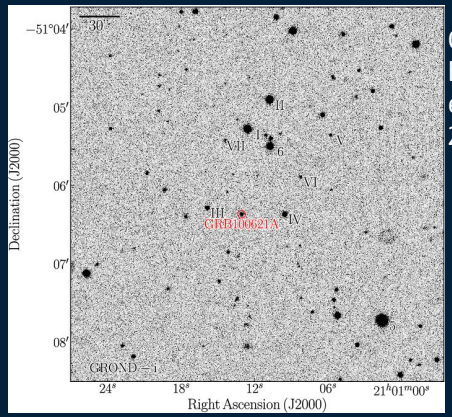
The multi-messenger transient source localisation zoo

Very poorly localised Fermi Bursts

https://gcn.nasa.gov/circulars/33839



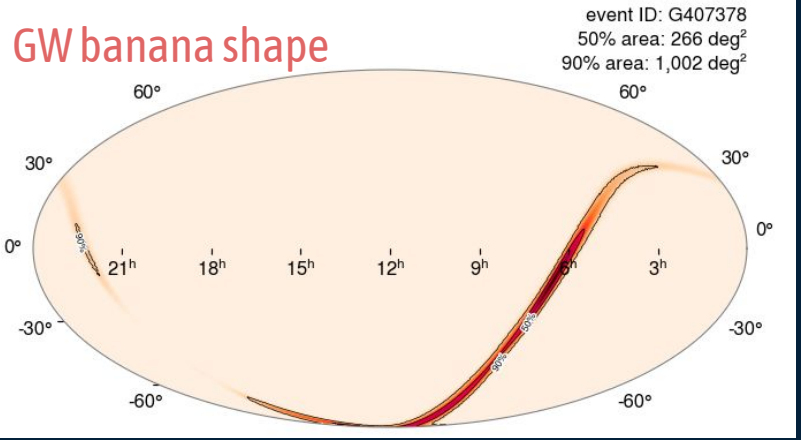
S230518h (LVK O4) : https://gracedb.ligo.org/superevents/public/#O4



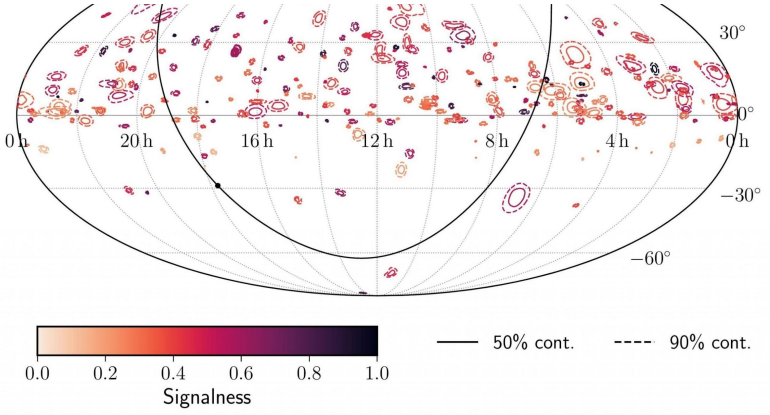
Greiner et al. (2013)
https://www.aanda.org/articles/aa/full_html/2013/12/aa21284-13/aa21284-13.html

point-like optical sources

GW banana shape

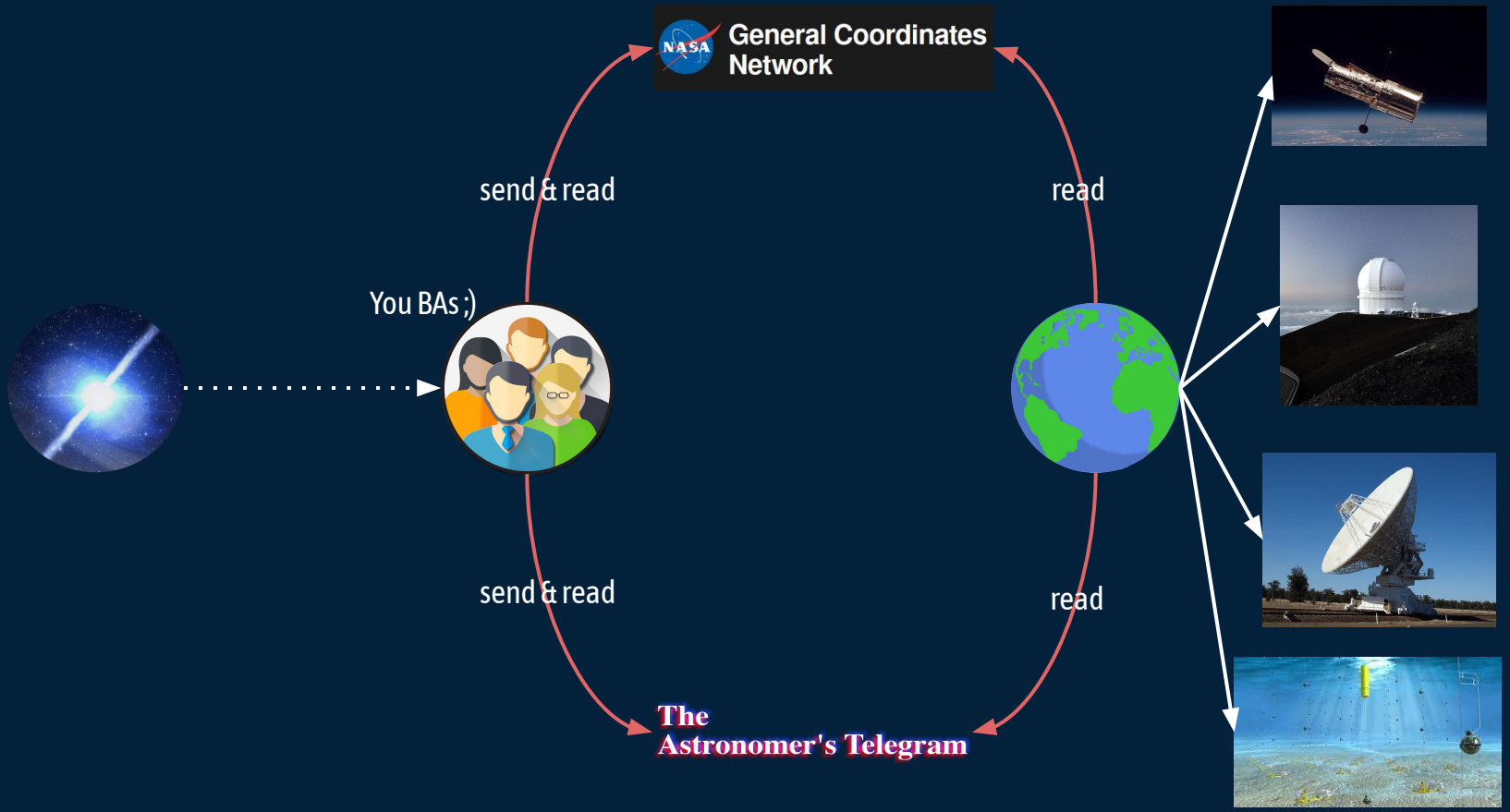


HE Neutrino heterogeneous loc. accuray



IC Collab.; Abbasi et al. (2022) https://arxiv.org/abs/2210.04930

(Near) Real-time communication in time-domain astronomy



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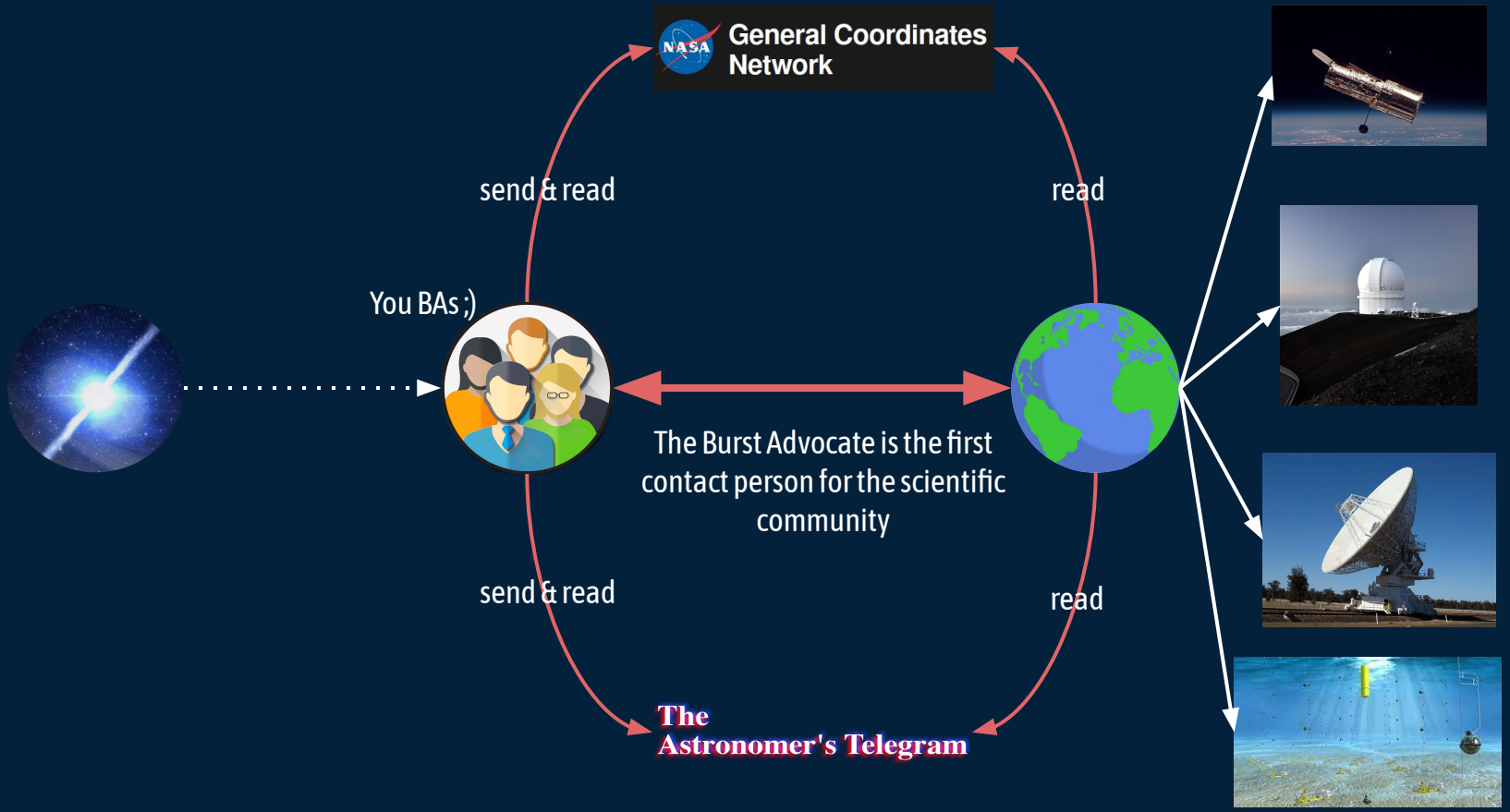
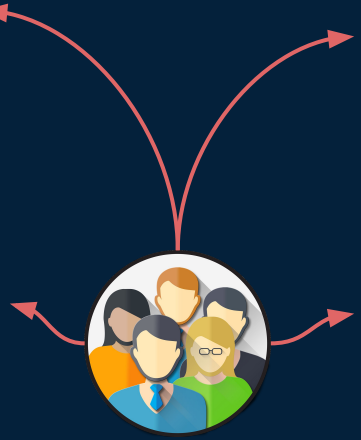


The Burst Advocate tasks require a lot of expertise!

The transient source time scale
Should I react fast or not ? Real-time ?

The expected multi-messenger signals from my source
Do I understand what are the different signals coming from different types of instruments ?
Which facilities should I trigger then ?



The transient source brightness/color evolution
How can I identify the right one?

The transient source environment
Is it in the direction of known large structures (MW center, close galaxies, etc.) or host-less ?

The Burst Advocate tasks require a lot of expertise!

The transient source time scale
Should I react fast or not ? Real-time ?

The expected multi-messenger signals from my source
Do I understand what are the different signals coming from different types of instruments ?
Which facilities should I trigger then ?

The detection technique & localisation accuracy
Can I easily crossmatch with catalogs ?
Should I wait for further localisation updates before taking any action ?

The transient source brightness/color evolution
How can I identify the right one?

The transient source environment
Is it in the direction of known large structures (MW center, close galaxies, etc.) or host-less ?

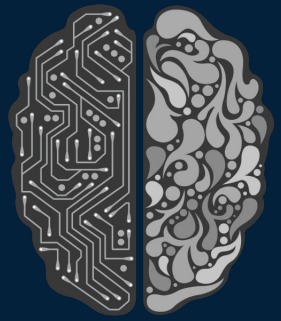
The detector environment (space, on-ground, under-water/ice)
Am I sure this is not a false detection ?
What metrics should I monitor or play with to ensure the detection is real?

2

AIs vs BA in the loop ?

Transient Universe 2023

How the AI can help us in the time-domain astronomy?



How the AI can help us in the time-domain astronomy?

Instrumental effect classification

Is my source real or a bogus?

- GW glitches classification: Georges et al. (2017)
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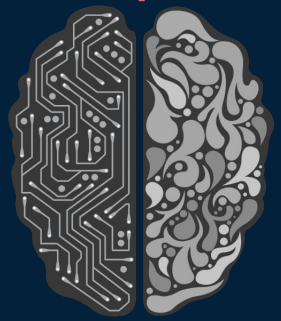

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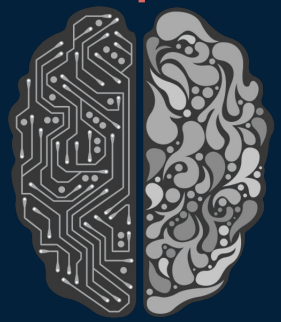

General astrophysical classification

Does my source look like a SNIa, a CV, a TDE?

- SN classification: Lochner et al. (2016); SuperNNova, Möller et al. (2020); SCONE, Qu et al. (2021)
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- CVs classifier: Mistry et al. (2022)
- TDE classifier: Gomez et al. (2022);

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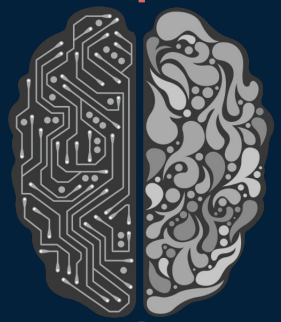

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Population (sub-class) classification

Does my source share more properties with short or long GRBs ?

- AGN type classifier: Falocco et al. (2021)
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- GRB type classifier: Luo et al. (2022);

Transient Universe 2023

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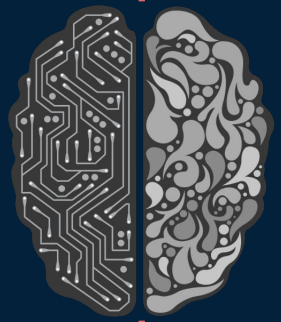

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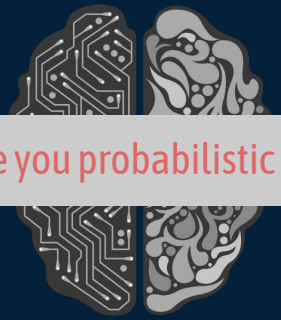
Flux evolution prediction

How the Sun is going to behave tomorrow based on today's activity ?

- Sun weather forecast: Yi et al. (2020); Stevenson et al. (2022)

What is still difficult to do with the AIs?

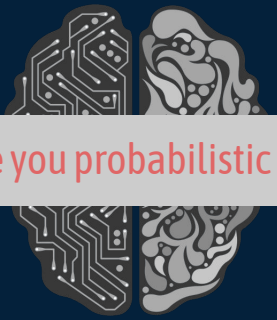


I'll give you probabilistic results

What is still difficult to do with the AIs?

1- Fully automated decision taking is risky

- Many (technical and human) contextual information may be missing in many situations
- The scientific good ways are also hardly reproducible by a full ML automation



I'll give you probabilistic results

2- AI prediction can be highly biased in time-domain astronomy

The training sets can be highly biased compared to the real world especially for rare transients with sparse data time series

3- AI does not give you THE candidate to study

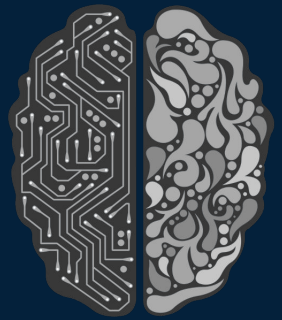
A short candidate list will still remain after a ML is applied. Only a ranking of these ones can be done

AI & BA in the loop

Filter out bogus

Astro classification

Flux prediction



Help in the scientific decision

Evaluate the genuineness of a trigger

Confirm the astrophysical origin

Apply a dedicated follow-up strategy

3

Real-time Burst Advocate activities

in transient astronomy

Step 0: The Burst Advocate working environment

Live Chat

slack

Mattermost

ROCKET.CHAT

Notifications

SMS

Step 0: The Burst Advocate working environment

Live Chat

slack

Mattermost

ROCKET.CHAT

Visio meeting

zoom

Microsoft Teams

Google Meet

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Web interfaces & Softwares

Alert/Data visualizations & action buttons

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Alert/Data visualizations & action buttons

Notifications

SMS

Transient astronomy tools

General Coordinates Network

The Astronomer's Telegram

Step 1: Validate the astrophysical origin of the trigger

Check list

- ✅ Background evolution
- ✅ Light curve shape
- ✅ Spectral shape
- ✅ SNR
- ✅ Sky localization
- ✅ Finding charts / Reconstructed image of the source
- ✅ Astro Classification (ML- or filtered-based)
- ✅ Catalog crossmatch results
- ✅ Detector's environment

Detection GCN notices sent

$T_{0,alert}$

slack

SMS

<+30'

Step 2: Send a confirmation or retraction GCN Circular

1st scientific output of the BA to the world wide community

Check list

- ✅ Background evolution
- ✅ Light curve shape
- ✅ Spectral shape
- ✅ SNR
- ✅ Sky localization
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- ✅ Detector's environment

Detection GCN notices sent

GCN Circular (confirmation or retraction) sent by the BA

$T_{0,alert}$

<+30'

slack

SMS

General Coordinates Network

Step 3: Long term monitoring of the EM counterparts

1st scientific output of the BA to the world wide community

Check list

- ✅ Background evolution
- ✅ Light curve shape
- ✅ Spectral shape
- ✅ SNR
- ✅ Sky localization
- ✅ Finding charts / Reconstructed image of the source
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- ✅ Catalog crossmatch results
- ✅ Detector's environment

Project / mission dependent Action list

- ✅ Ensure spectroscopic observations are taken
- ✅ Ensure photometric follow-ups are performed with the right pre-defined strategies
- ✅ Check if external teams are making follow-up
- ✅ Assess whether the event is exceptional or not
  - High-z event
  - flux evolution inconsistent with standard models
  - identification of rare spectro/photometric features
  - multi-messenger detection
  - etc.

Detection GCN notices sent

GCN Circular (confirmation or retraction) sent by the BA

$T_{0,alert}$

<+30'

slack

SMS

General Coordinates Network

slack

zoom

General Coordinates Network

Step 4: Send a follow-up GCN circular

1st scientific output of the BA to the world wide community

2nd scientific output of the BA to the world wide community

Check list

- ✅ Background evolution
- ✅ Light curve shape
- ✅ Spectral shape
- ✅ SNR
- ✅ Sky localization
- ✅ Finding charts / Reconstructed image of the source
- ✅ Astro Classification (ML- or filtered-based)
- ✅ Catalog crossmatch results
- ✅ Detector's environment

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  - etc.

Detection GCN notices sent

GCN Circular (confirmation or retraction) sent by the BA

GCN Circular follow-up information

$T_{0,alert}$

slack

SMS

<+30'

General Coordinates Network

slack

zoom

General Coordinates Network

+hours/ 1day

General Coordinates Network

Step 5: Advocate for longer term revisit observation

1st scientific output of the BA to the world wide community

2nd scientific output of the BA to the world wide community

Check list

- ✅ Background evolution
- ✅ Light curve shape
- ✅ Spectral shape
- ✅ SNR
- ✅ Sky localization
- ✅ Finding charts / Reconstructed image of the source
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  - etc.

If scientifically justified Action list

- ✅ Schedule ToO observations
- ✅ Ask the community to continue observing

Detection GCN notices sent

GCN Circular (confirmation or retraction) sent by the BA

GCN Circular follow-up information

$T_{0,alert}$ — SMS, slack

<+30' — slack, General Coordinates Network

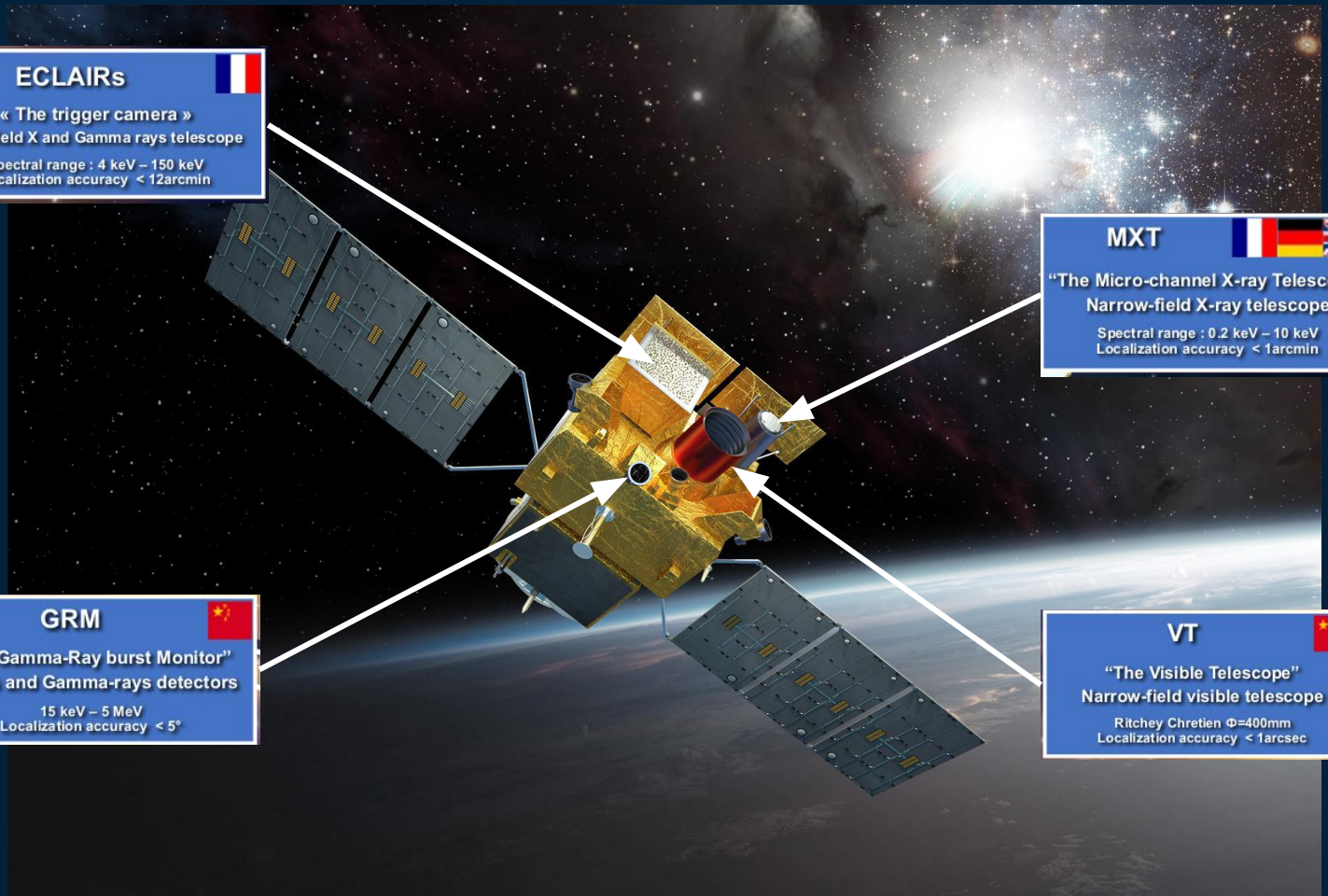
+hours/1day — slack, zoom, General Coordinates Network

slack, zoom, General Coordinates Network

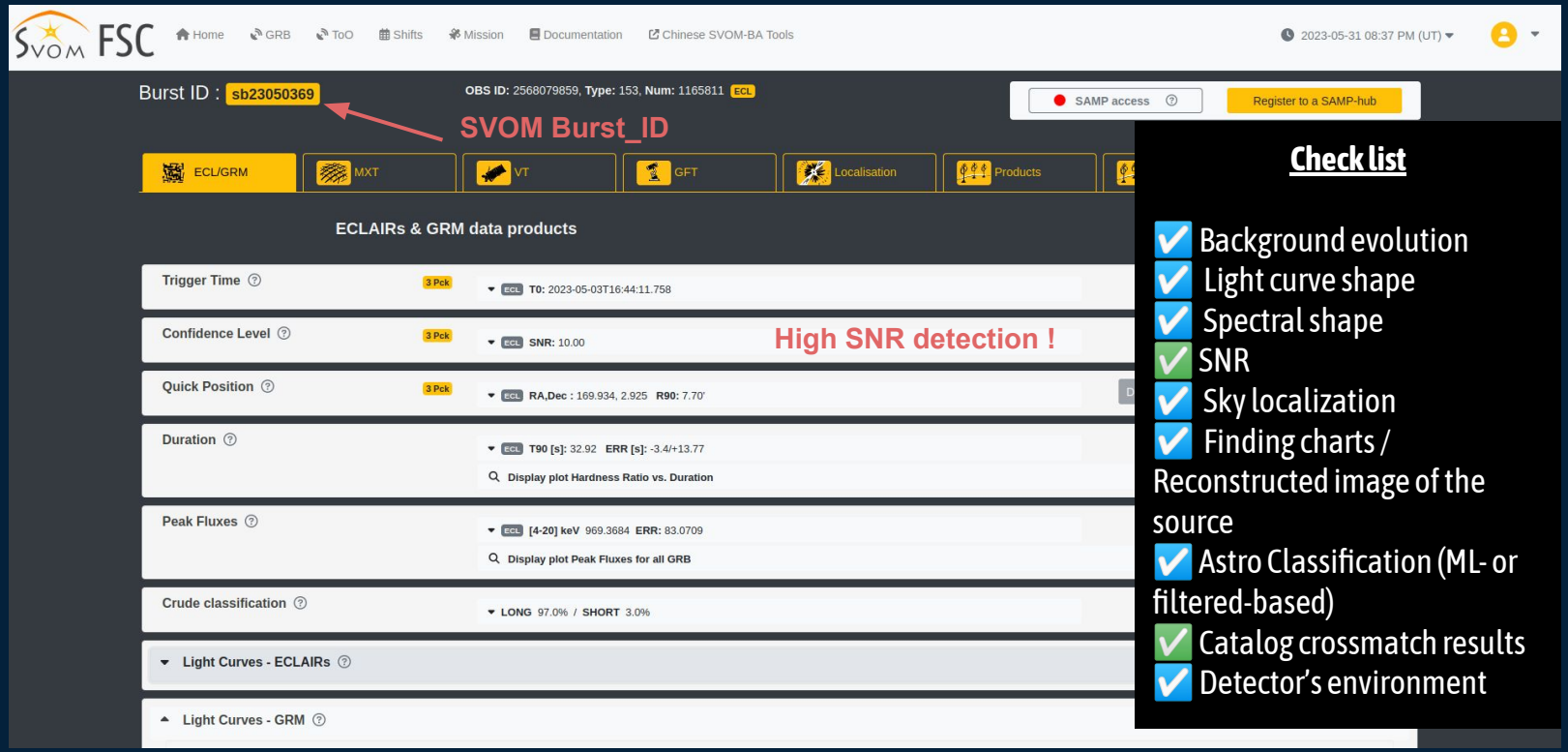
Let’s make a concrete example with

Gamma-ray Burst and the SVOM BA tools

SVOM Reminders



Validate the astrophysical origin of the trigger



Check list

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- ✔️ Detector's environment

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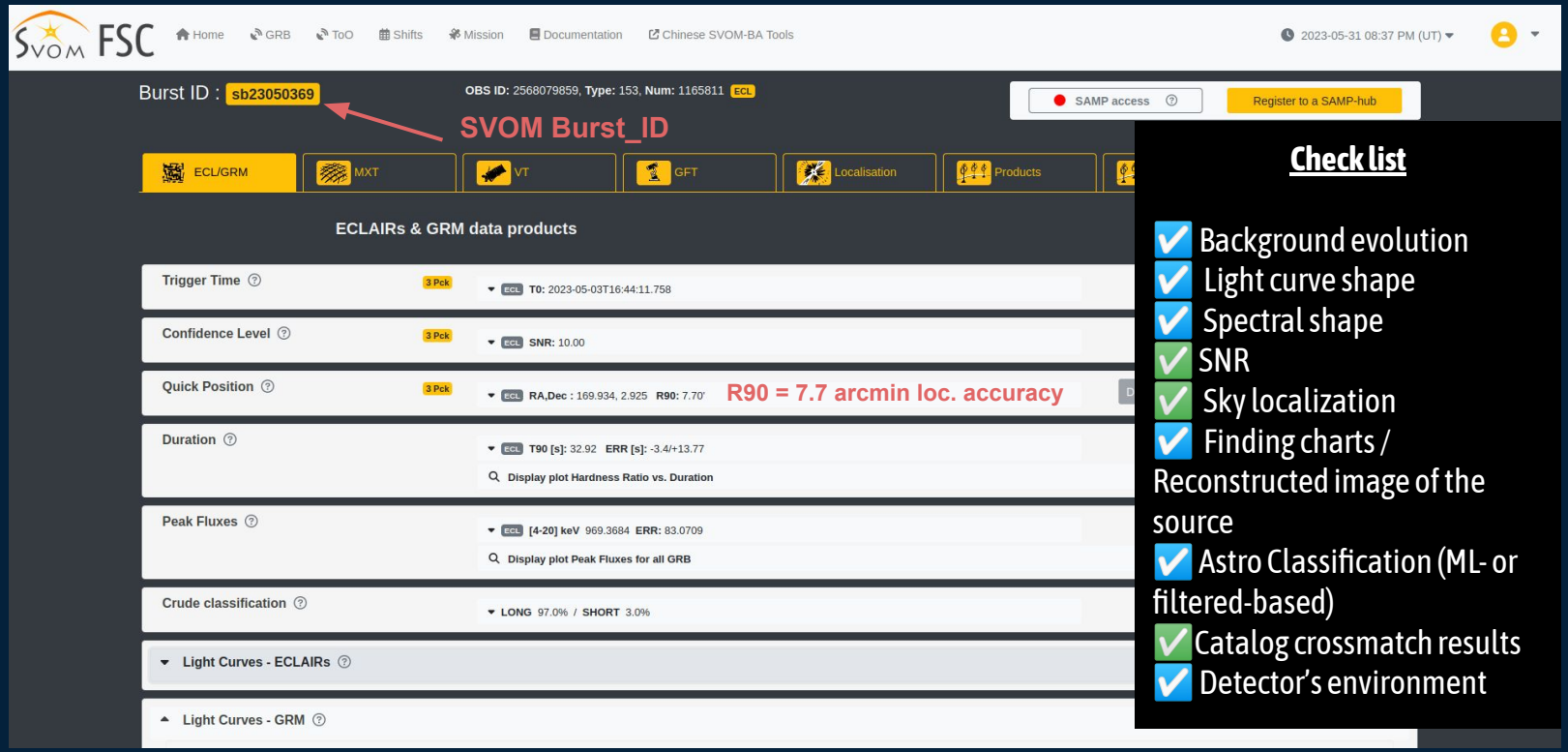

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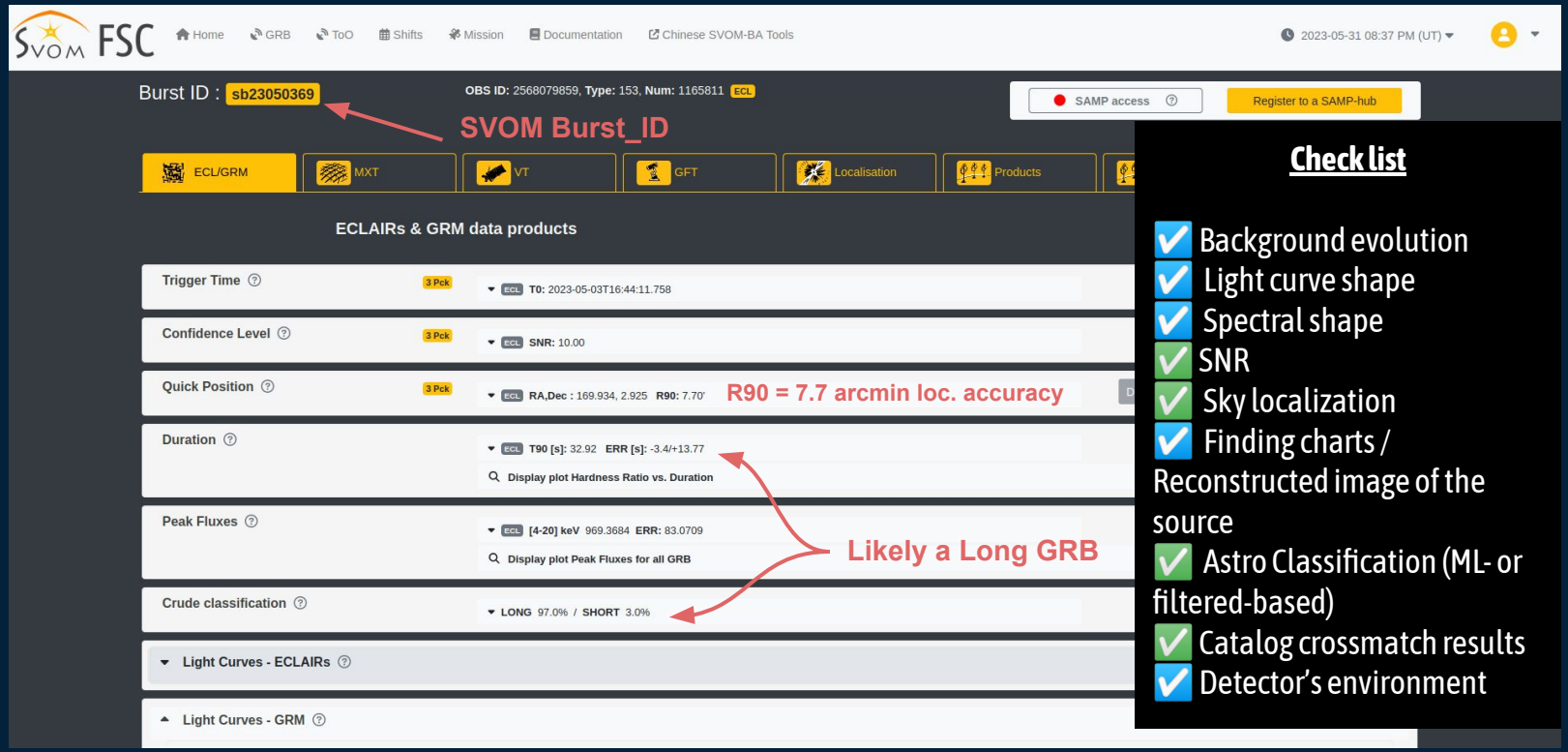

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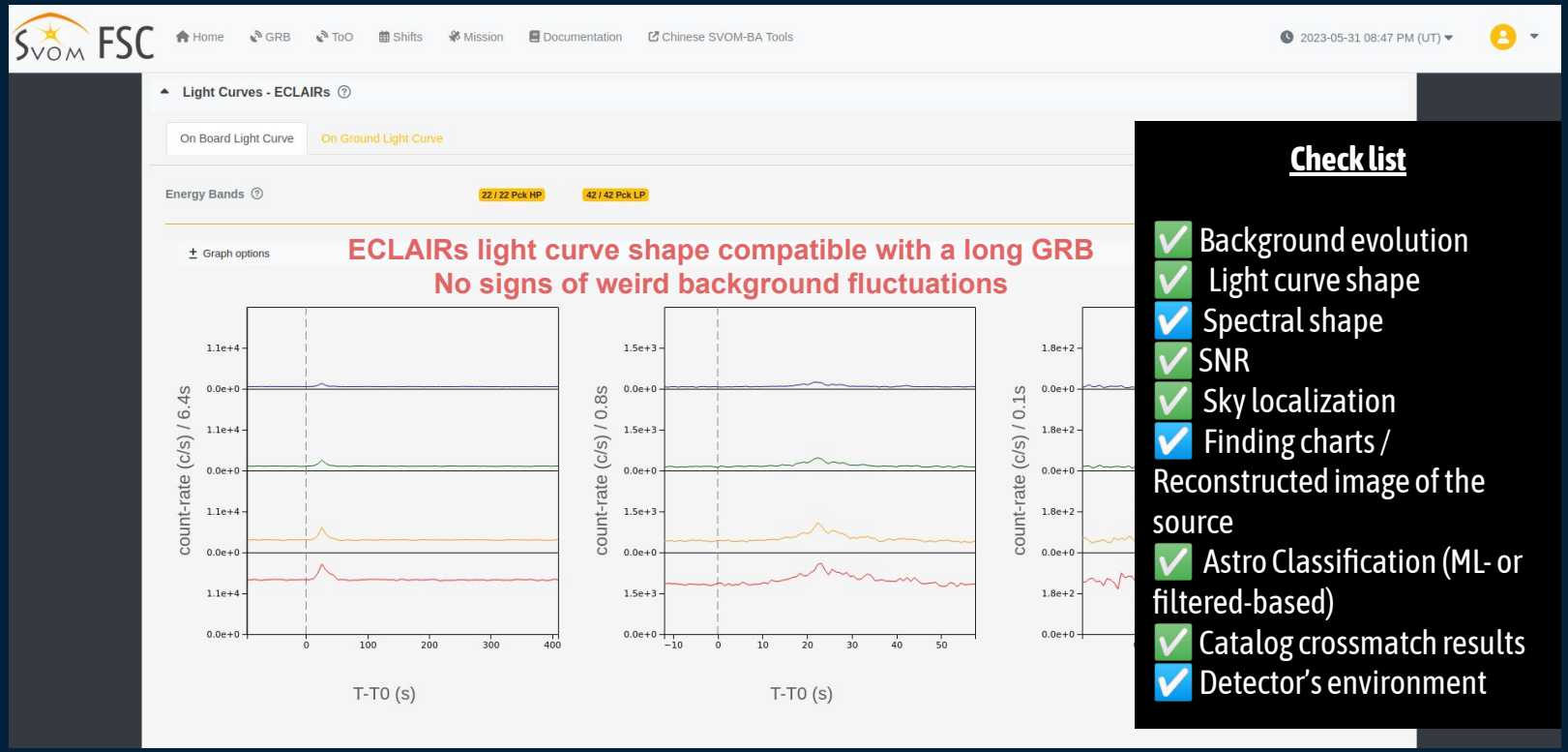
- ✅ Detector's environment

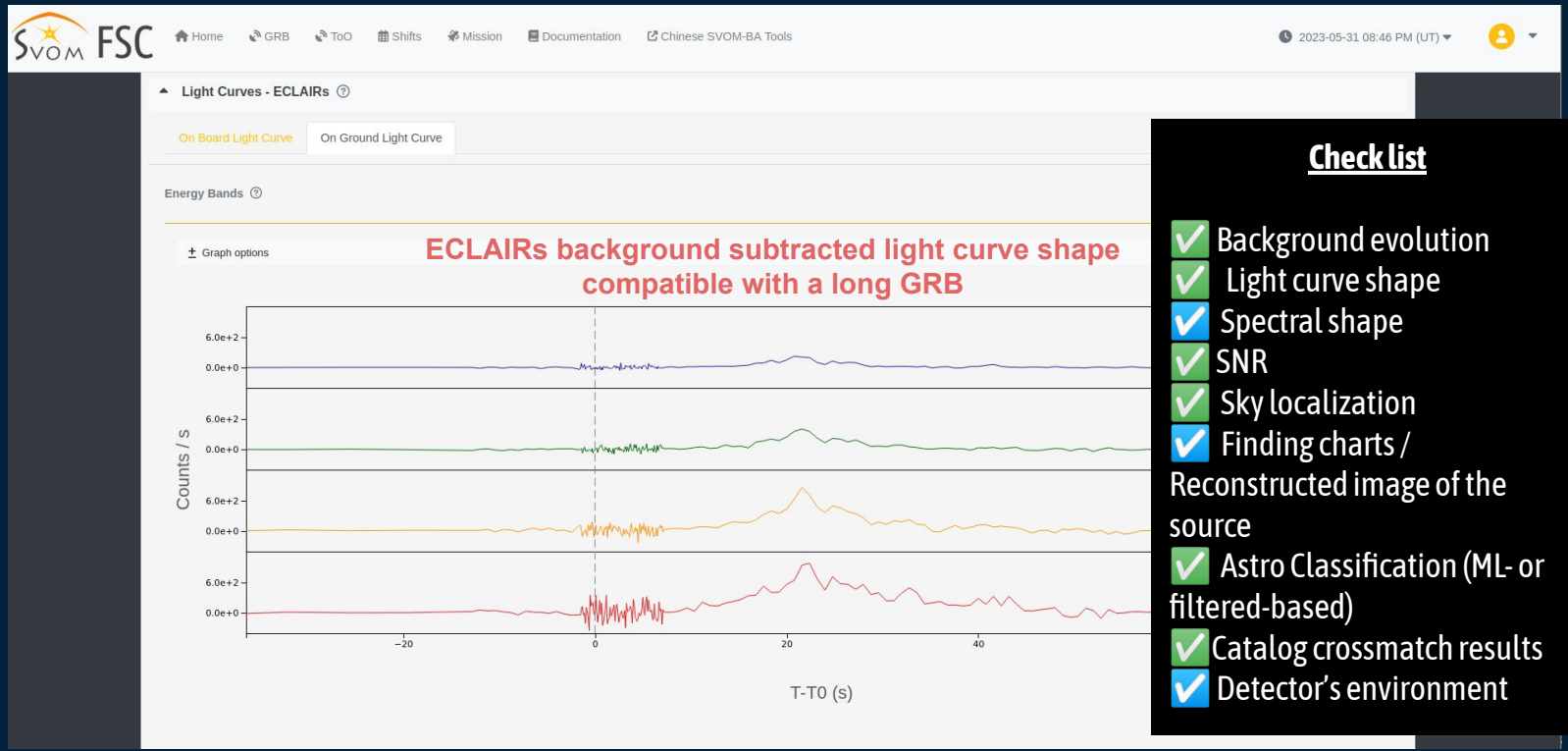
Validate the astrophysical origin of the trigger



Check list

- ✅ Background evolution
- ✅ Light curve shape
- ☑️ Spectral shape
- ✅ SNR
- ✅ Sky localization
- ☑️ Finding charts / Reconstructed image of the source
- ✅ Astro Classification (ML- or filtered-based)
- ✅ Catalog crossmatch results
- ☑️ Detector's environment

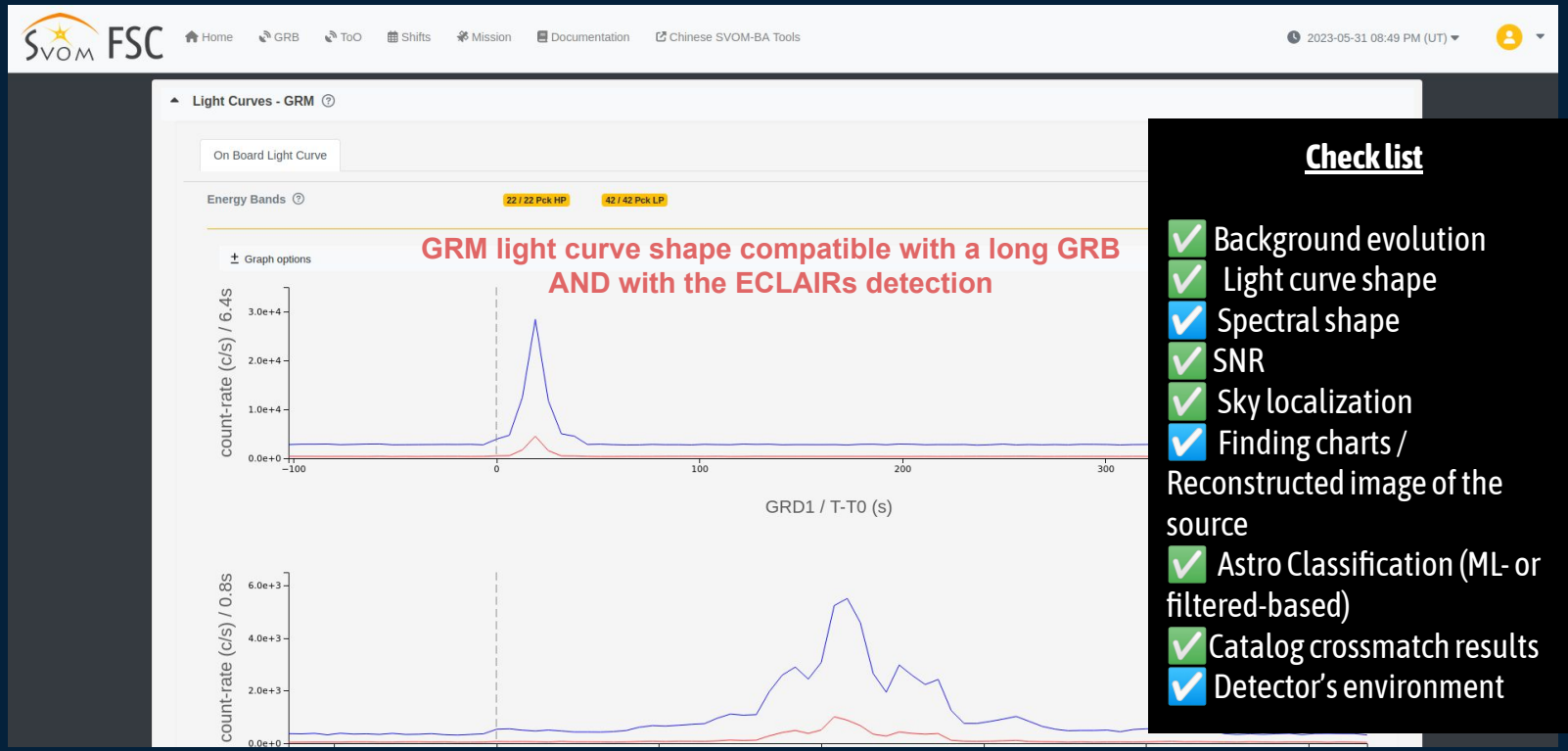
Validate the astrophysical origin of the trigger



Check list

- ✅ Background evolution
- ✅ Light curve shape
- ☑️ Spectral shape
- ✅ SNR
- ✅ Sky localization
- ☑️ Finding charts / Reconstructed image of the source
- ✅ Astro Classification (ML- or filtered-based)
- ✅ Catalog crossmatch results
- ☑️ Detector's environment

Validate the astrophysical origin of the trigger



Check list

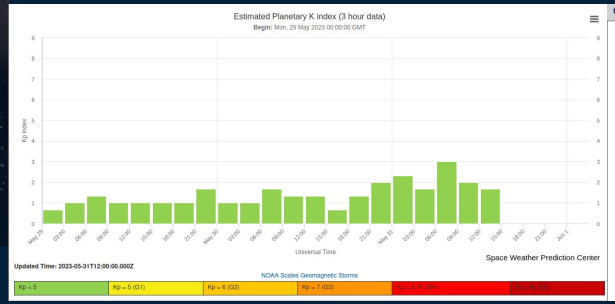
- ✅ Background evolution
- ✅ Light curve shape
- ☑️ Spectral shape
- ✅ SNR
- ✅ Sky localization
- ☑️ Finding charts / Reconstructed image of the source
- ✅ Astro Classification (ML- or filtered-based)
- ✅ Catalog crossmatch results
- ☑️ Detector's environment

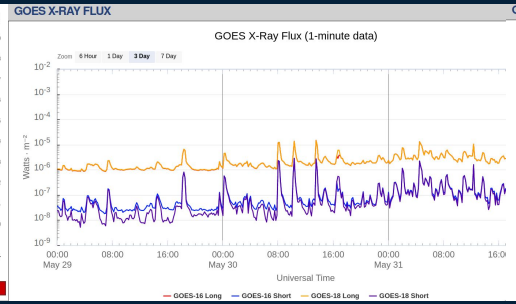
Validate the astrophysical origin of the trigger

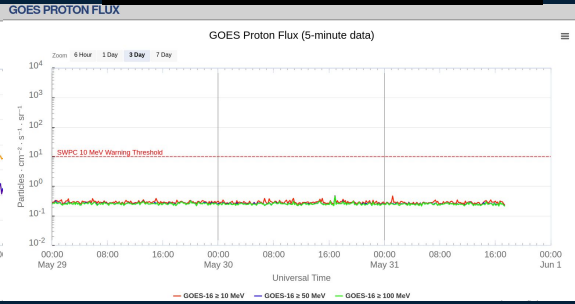
Quiet space weather and magnetospheric activity

Check list

- ✅ Background evolution
- ✅ Light curve shape
- ☑️ Spectral shape
- ✅ SNR
- ✅ Sky localization
- ☑️ Finding charts / Reconstructed image of the source
- ✅ Astro Classification (ML- or filtered-based)
- ✅ Catalog crossmatch results
- ✅ Detector's environment







Transient Universe 2023

Validate the astrophysical origin of the trigger

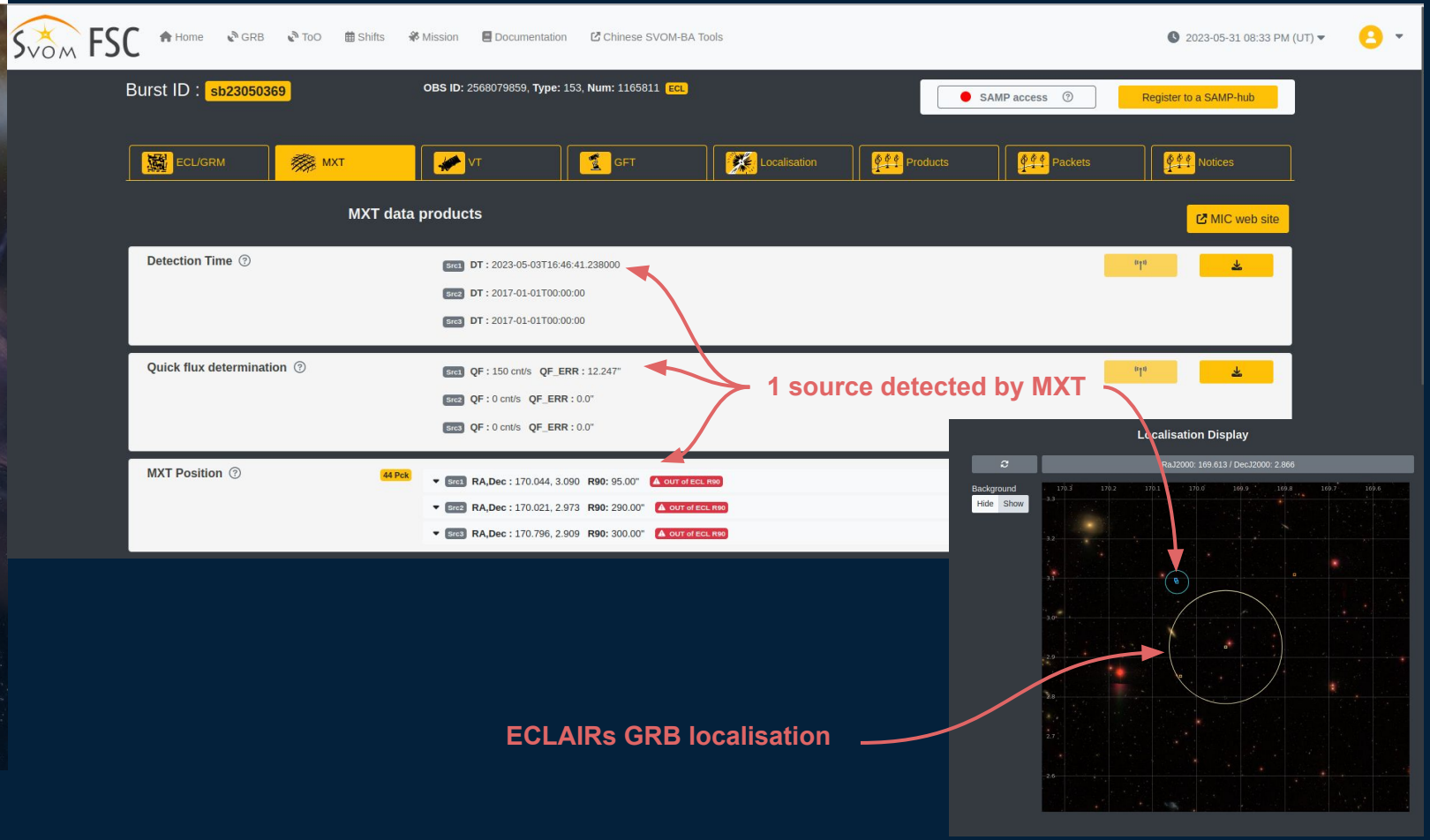
Check list

✅ Background evolution
✅ Light curve shape
✅ ~~Spectral shape~~
✅ SNR
✅ Sky localization
✅ Finding charts / Reconstructed image of the source (maybe implemented)
✅ Astro Classification (ML- or filtered-based)
✅ Catalog crossmatch results
✅ Detector's environment

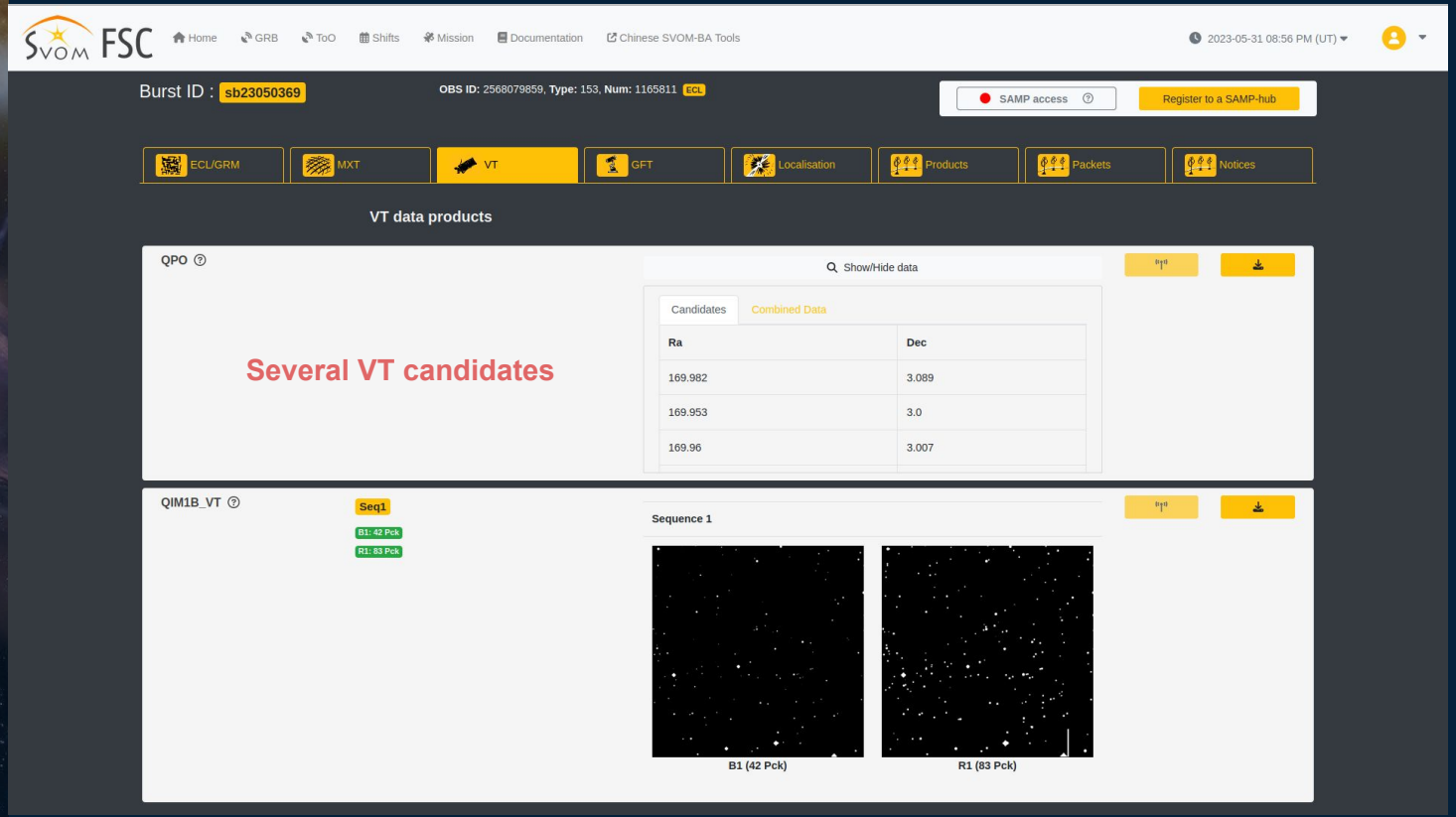
The trigger is of astrophysical origin ! It is likely a Long GRB

Any x-ray/optical counterparts to further confirm the GRB origin?

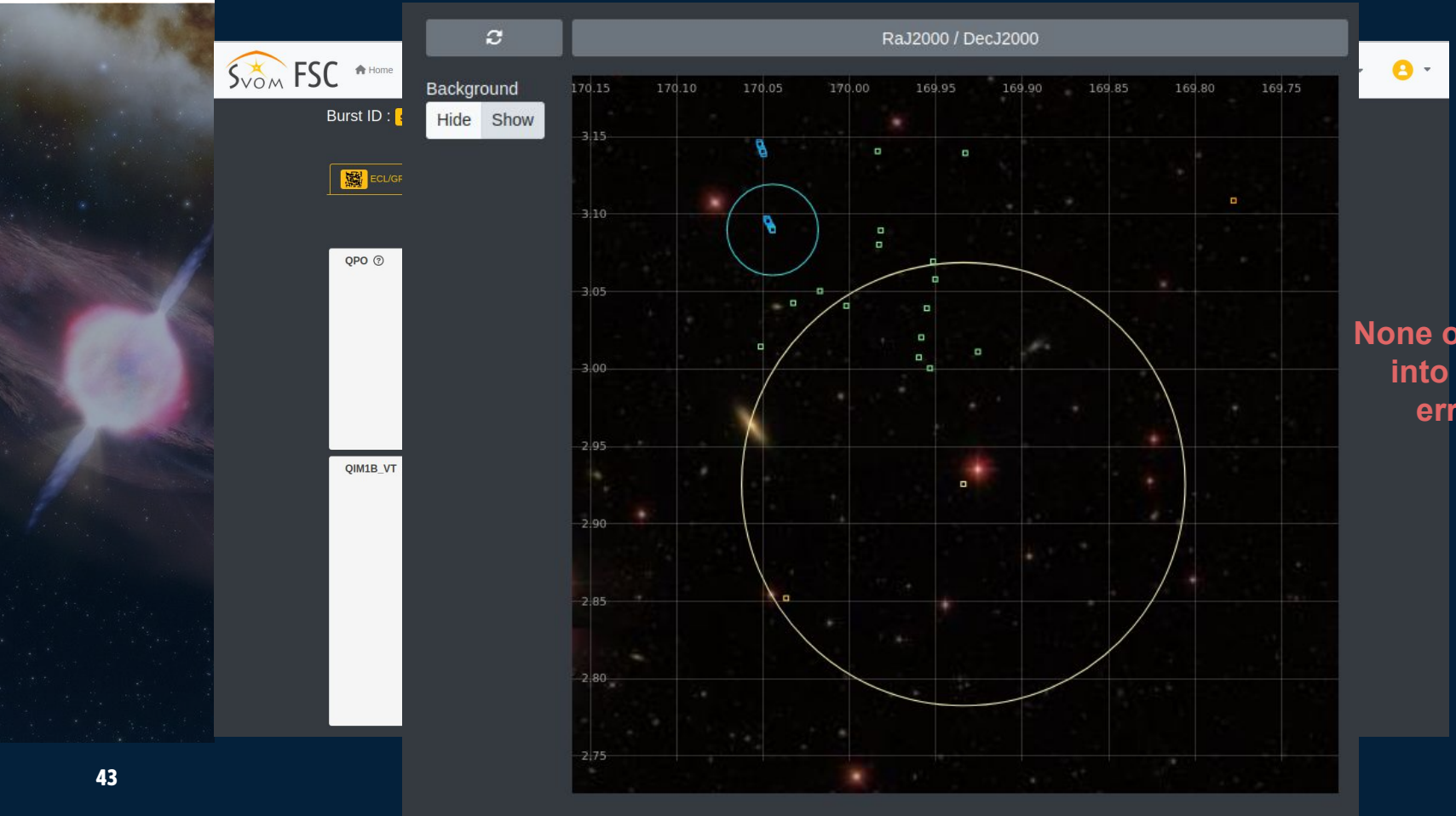
Validate the astrophysical origin of the trigger



Validate the astrophysical origin of the trigger

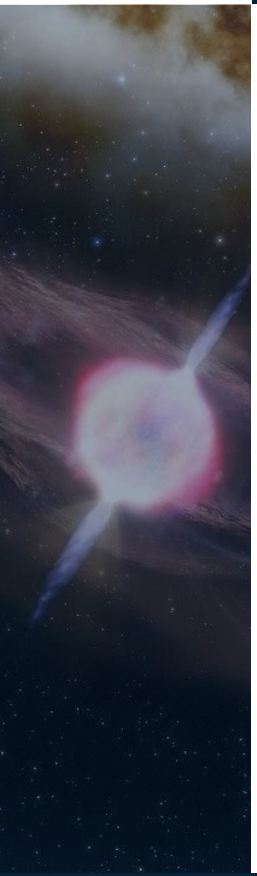


Validate the astrophysical origin of the trigger



None of them lies into the MXT error box

Time to edit the "detection" GCN Circular!



Subject GRB 230510A: Swift detection of a burst
Date 2023-05-10T12:44:51Z (a month ago)
From K.L. Page at U Leicester <klp5@leicester.ac.uk>

R. A. J. Eyles-Ferris (U Leicester), P. A. Evans (U Leicester),
J.D. Gropp (PSU), J. A. Kennea (PSU), F. E. Marshall (NASA/GSFC),
K. L. Page (U Leicester), P. Romano (INAF-OAB), T. Sakamoto (AGU),
B. Sbarufatti (INAF-OAB) and M. A. Williams (PSU) report on behalf of
the Neil Gehrels Swift Observatory Team:

At 12:06:28 UT, the Swift Burst Alert Telescope (BAT) triggered and
located GRB 230510A (trigger=1167973). Swift slewed immediately to the burst.
The BAT on-board calculated location is
RA, Dec 318.156, +34.443 which is
RA(J2000) = 21h 12m 37s
Dec(J2000) = +34d 26' 33"
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 60 sec. The peak count rate
was ~5100 counts/sec (15-350 keV), at ~13 sec after the trigger.

The XRT began observing the field at 12:07:31.9 UT, 63.4 seconds after
the BAT trigger. XRT found a bright, uncatalogued X-ray source located
at RA, Dec 318.1314, 34.4424 which is equivalent to:
RA(J2000) = 21h 12m 31.54s
Dec(J2000) = +34d 26' 32.6"
with an uncertainty of 6.5 arcseconds (radius, 90% containment). This
location is 73 arcseconds from the BAT onboard position, within the BAT
error circle. No event data are yet available to determine the column
density using X-ray spectroscopy.

SVOM GRB Circulars will have a similar layout than the Swift ones

UVOT took a finding chart exposure of 150 seconds with the White filter
starting 72 seconds after the BAT trigger. No credible afterglow candidate has
been found in the initial data products. The 2.7'x2.7' sub-image covers 100% of
the XRT error circle. The typical 3-sigma upper limit has been about 19.6 mag.
The 8'x8' region for the list of sources generated on-board covers 100% of the
XRT error circle. The list of sources is typically complete to about 18 mag. No
correction has been made for the expected extinction corresponding to E(B-V) of
0.144.

This trigger was initially marked as matching a source in the BAT
ground catalogue: IGR J21117+3427, a known gamma-ray source. However,
the XRT localisation is more than 9 arcmin from the known position of
IGR J21117+3427, outside its error region of 3.5 arcmin (ATel 873).
This, together with the BAT transient monitor light-curve showing
little sign of variation suggests that this is in fact a new GRB.

Burst Advocate for this burst is R. A. J. Eyles-Ferris (raje1 AT leicester.ac.uk).
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/)

You have < 30' to make it ;)

4

Let’s have fun with the SVOM BA tools

for Gamma-ray Burst science