

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

Damien Turpin

# 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



SN2014J in M82



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)

## 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)

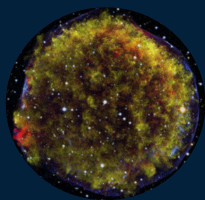
## The Variable sky

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

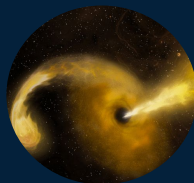


# The time domain astronomy: source classes

## Transients



Supernovae



Tidal disruption events



Gamma-ray Bursts



Fast Radio bursts ?

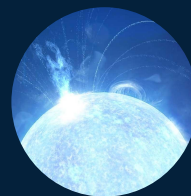
## Variable objects



AGNs



Pulsars



Magnetar flares



X-ray Binaries



Variable stars

# The time domain astronomy is multi-wavelength !

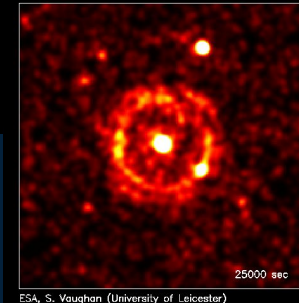
Credit : LSGT/Siding Spring Observatory

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

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

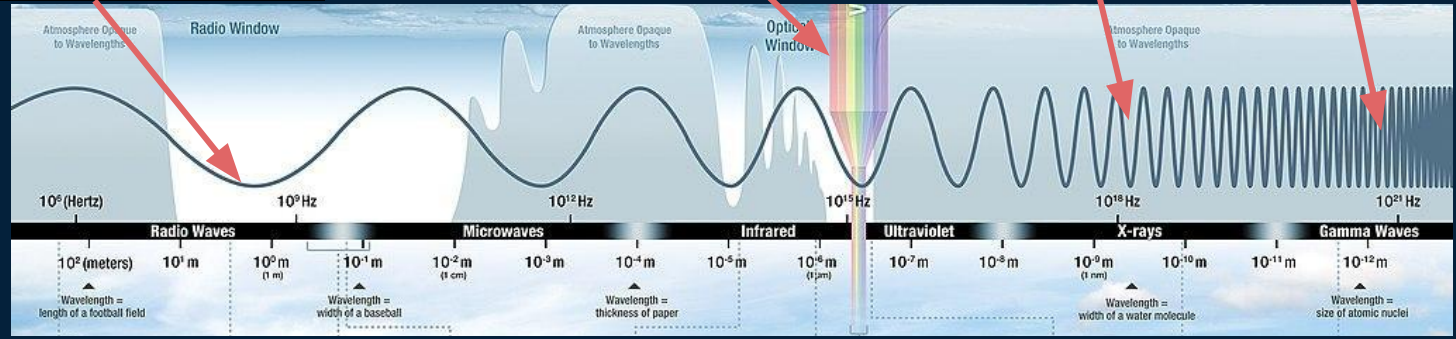
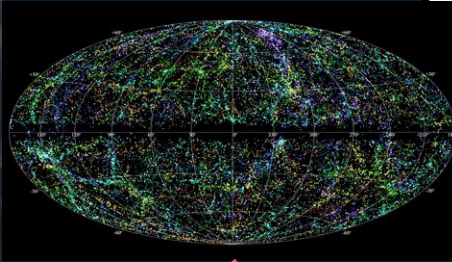
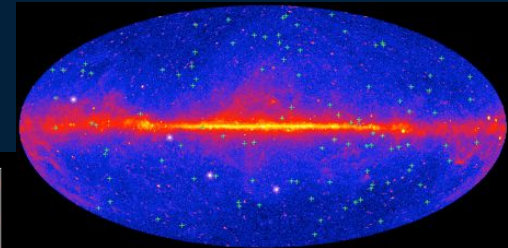


GRB 031203 XMM-Newton observation



ESA, S. Vaughan (University of Leicester)

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



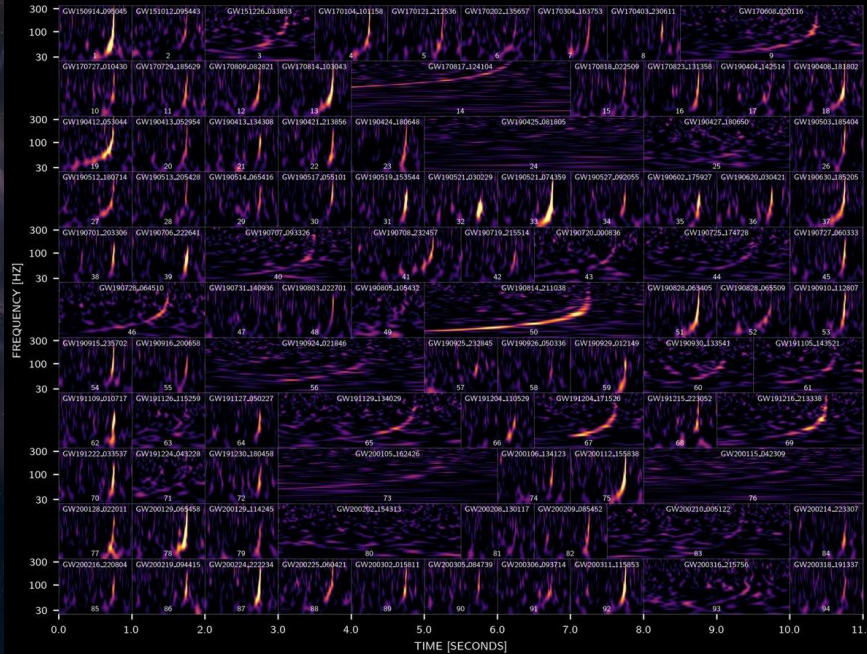
# The time domain astronomy is multi-messenger !

## Gravitational waves

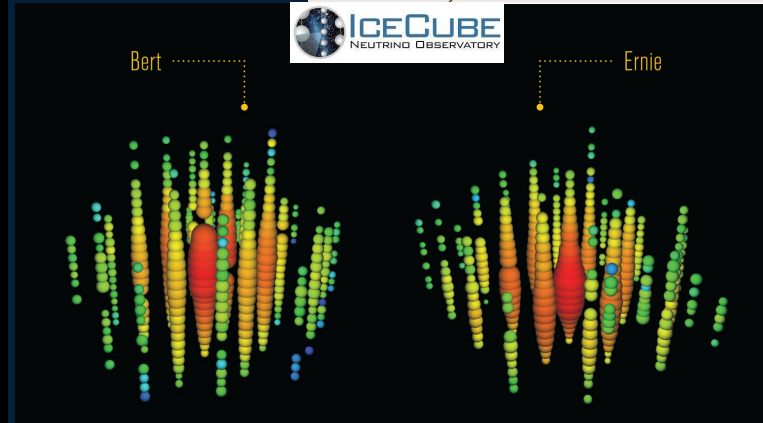
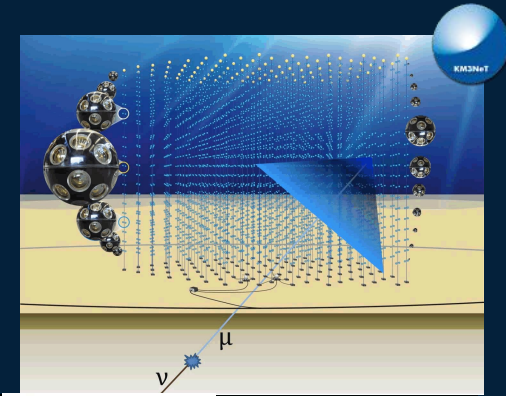


4-OGC: Open Gravitational-wave Catalog 2015-2020

Alexander H. Nitz, Sumit Kumar, Yi-Fan Wang, Shilpa Kastha, Shichao Wu, Marlin Schäfer, Rahul Dhurkunde, Collin D. Capano



## TeV-PeV neutrinos



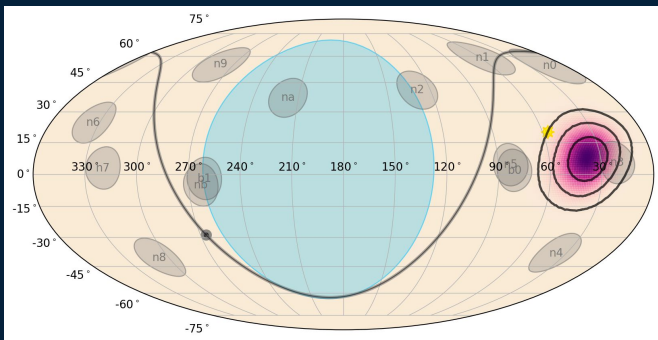
PeV neutrino Cerenkov light-track signal in the IceCube detector



# The multi-messenger transient source localisation zoo

## Very poorly localised Fermi Bursts

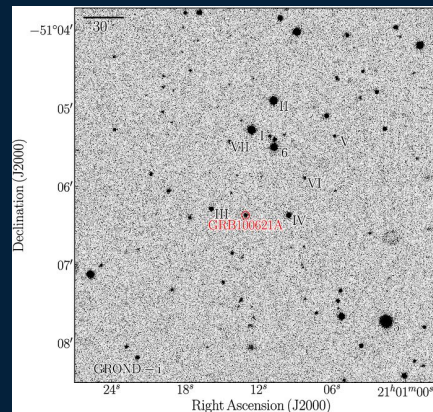
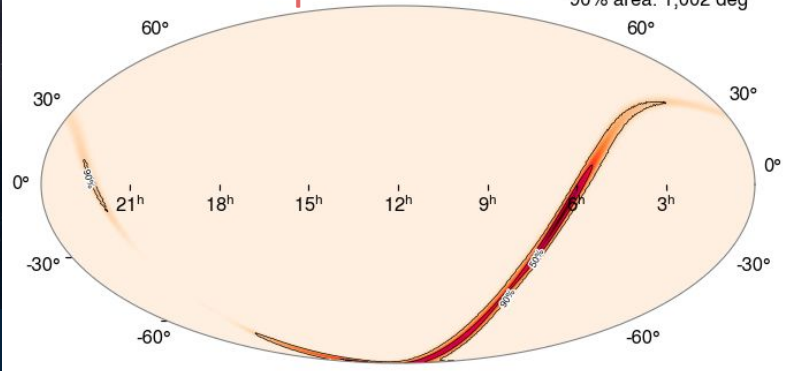
<https://gcn.nasa.gov/circulars/33839>



S230518h (LVK O4) : <https://gracedb.ligo.org/superevents/public/#04>

## GW banana shape

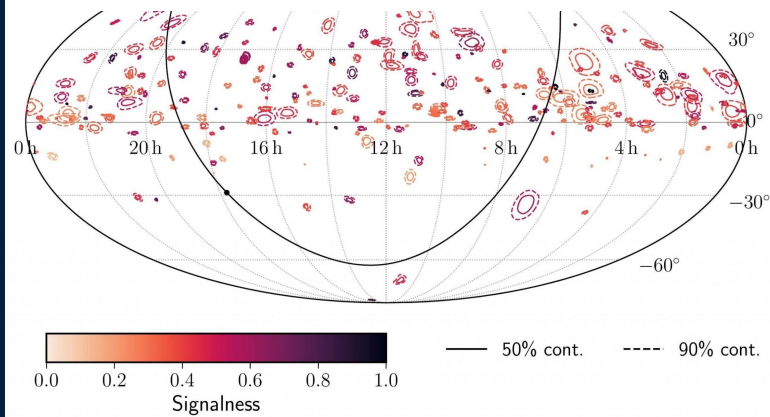
event ID: G407378  
 50% area: 266 deg<sup>2</sup>  
 90% area: 1,002 deg<sup>2</sup>



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

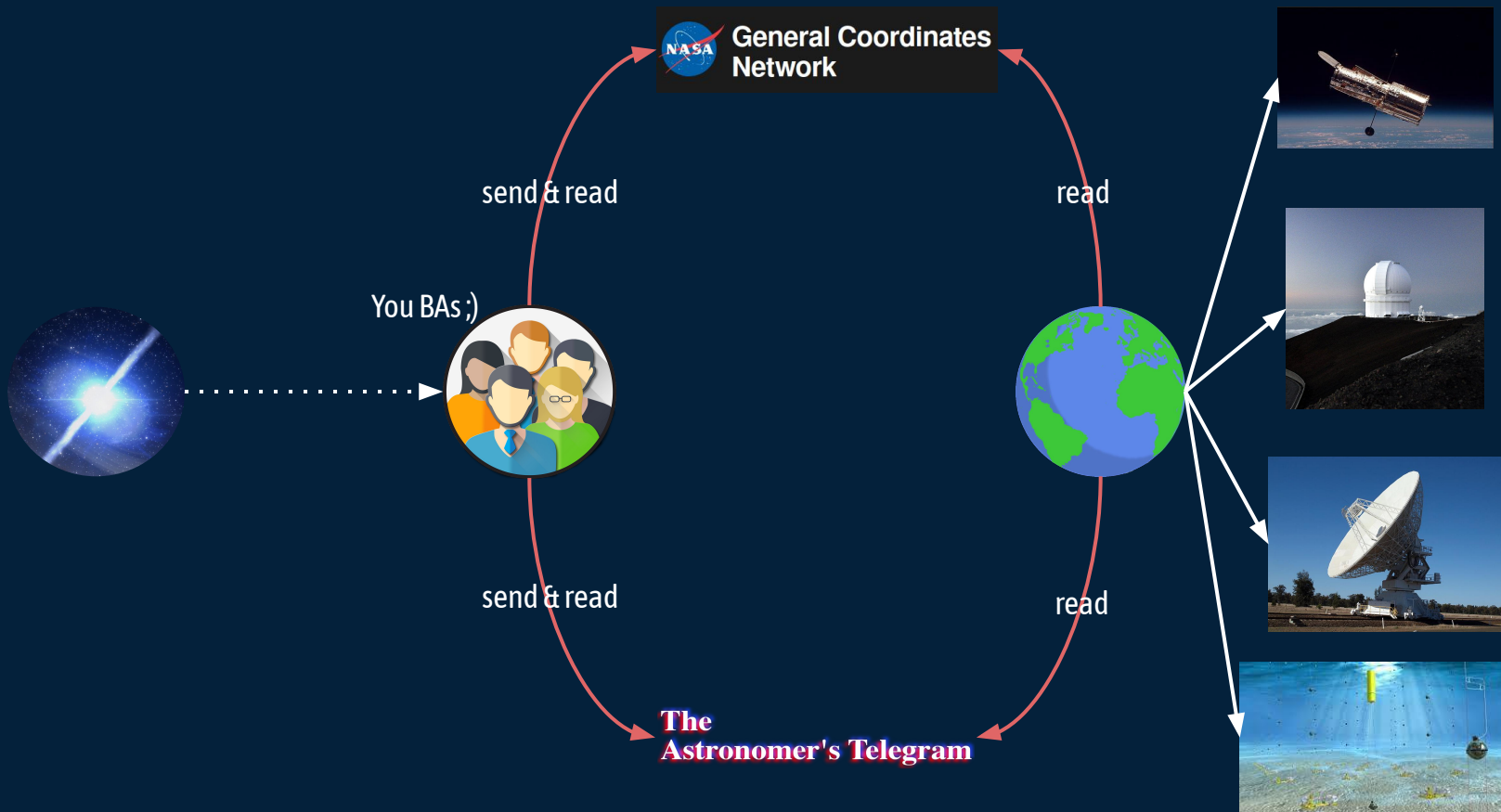
point-like optical sources

## HE Neutrino heterogeneous loc. accuray

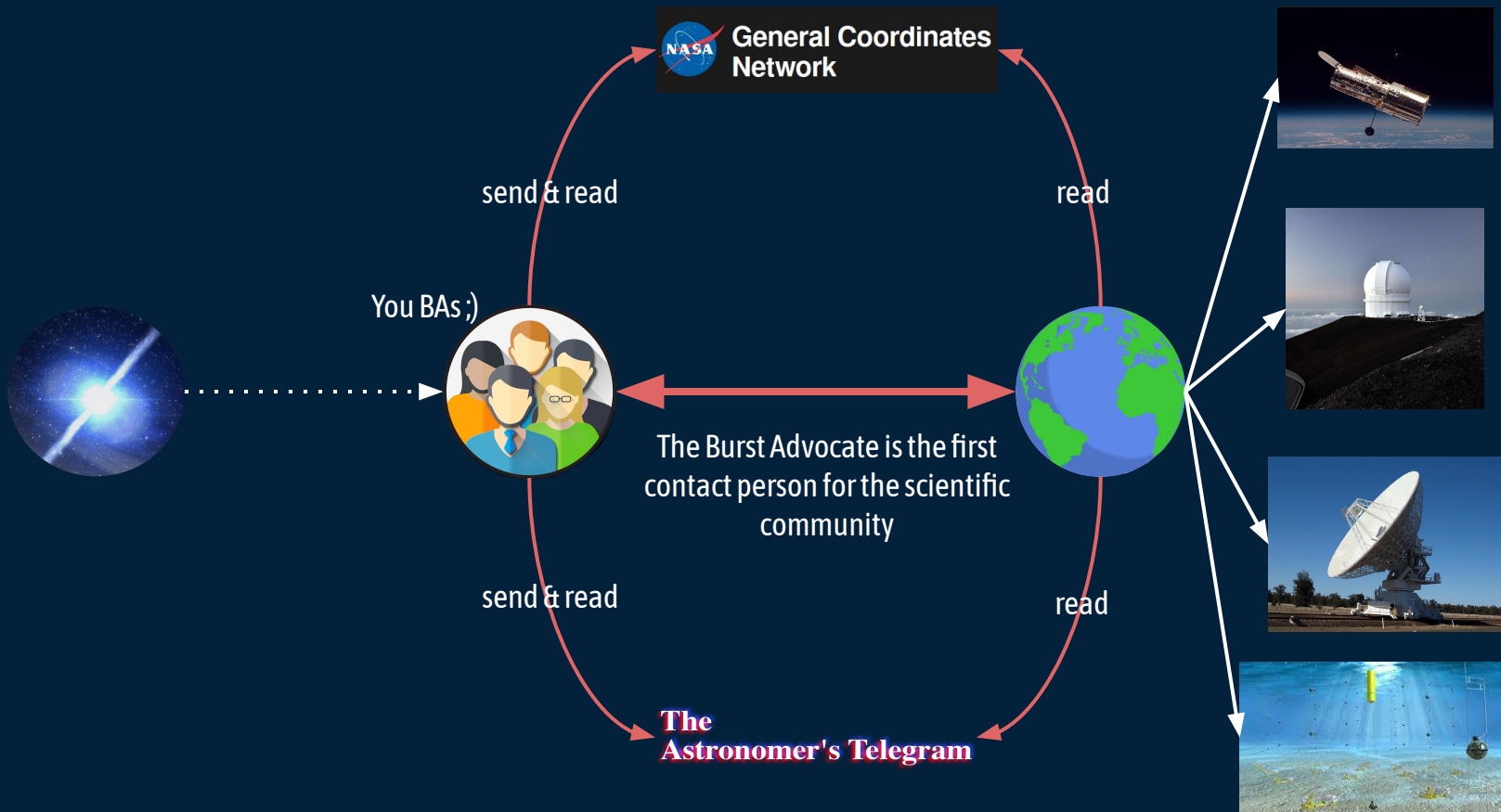


IC Collab.; Abbasi et al. (2022) <https://arxiv.org/abs/2210.04930>

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



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



# 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?

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## 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?

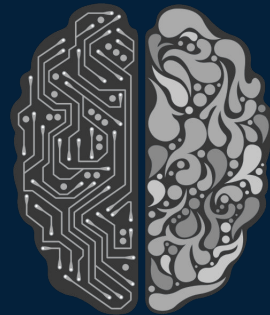




2

Als vs BA in the loop ?

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

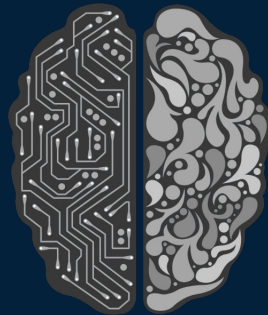


# How the AI can help us in the time-domain astronomy?

## Instrumental effect classification

Is my source real or a bogus?

- [GW glitches classification](#): Georges et al. (2017)
- [Real/bogus at optical wavelengths](#): Burke et al. (2019); Duev et al. (2019); Makhlouf et al. (2022)





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

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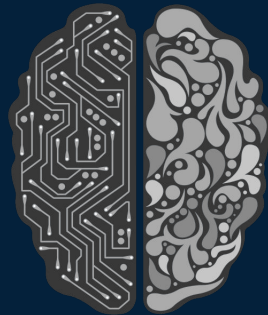
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## General astrophysical classification

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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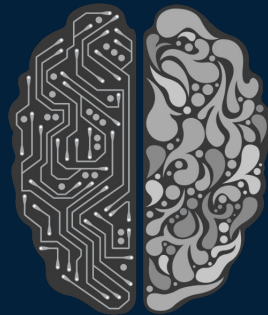
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## Population (sub-class) classification

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

- AGN type classifier: Falocco et al. (2021)
- GeV neutrino type classifier: Aurisano et al. (2016); IC, Abbasi et al. (2022)
- GRB type classifier: Luo et al. (2022);

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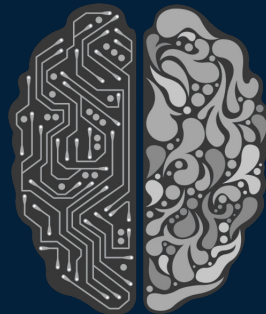
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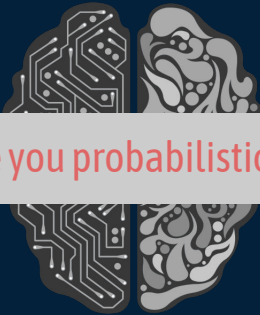
## Flux evolution prediction

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?

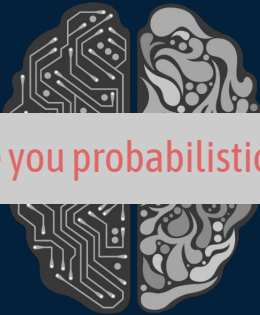


I'll give you probabilistic results

# 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

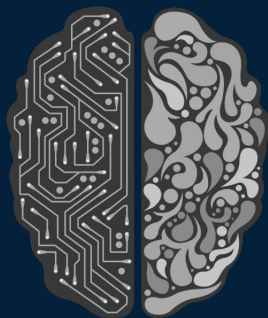
A short candidate list will still remain after a ML is applied. Only a ranking of these ones can be done

# 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

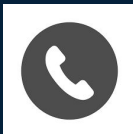
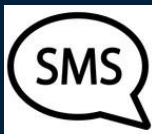
# Real-time Burst Advocate activities in transient astronomy

# Step 0: The Burst Advocate working environment

## Live Chat



## Notifications



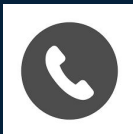
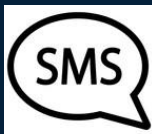


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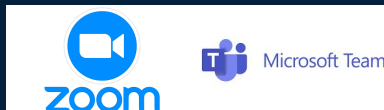
## Live Chat



## Notifications



## Visio meeting

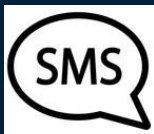


# Step 0: The Burst Advocate working environment

## Live Chat



## Notifications



## Visio meeting



## Web interfaces & Softwares

### Alert/Data visualizations & action buttons

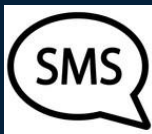


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## Live Chat



## Notifications



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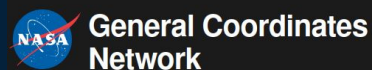


## Web interfaces & Softwares

### Alert/Data visualizations & action buttons



## Transient astronomy tools



**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

$T_{0,alert}$



$<+30'$



# Step 2: Send a confirmation or retraction GCN Circular



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

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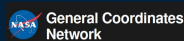
GCN Circular (confirmation  
or retraction) sent by the BA



T<sub>0</sub>, alert



<+30'



# Step 3: Long term monitoring of the EM counterparts



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

## Check list

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- ✓ Spectral shape
- ✓ SNR
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## Project / mission dependent Action list

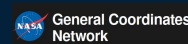
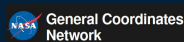
- ✓ Ensure spectroscopic observations are taken
- ✓ Ensure photometric follow-ups are performed with the right pre-defined strategies
- ✓ Check if external teams are making follow-up
- ✓ Assess whether the event is exceptional or not
  - High-z event
  - flux evolution inconsistent with standard models
  - 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'



# Step 4: Send a follow-up GCN circular



Detection GCN notices sent

## Check list

- ✓ Background evolution
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- ✓ Spectral shape
- ✓ SNR
- ✓ Sky localization
- ✓ Finding charts / Reconstructed image of the source
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1st scientific output of the BA to the world wide community



GCN Circular (confirmation or retraction) sent by the BA

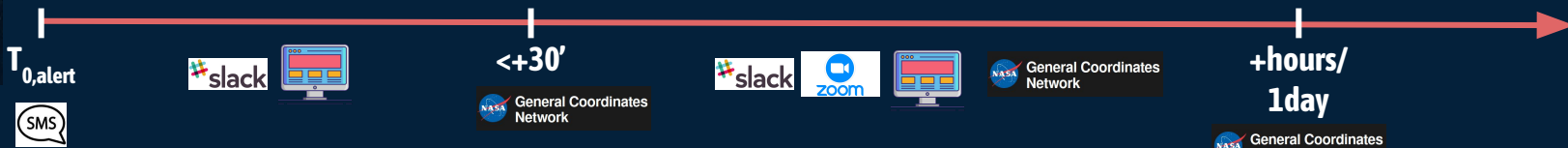
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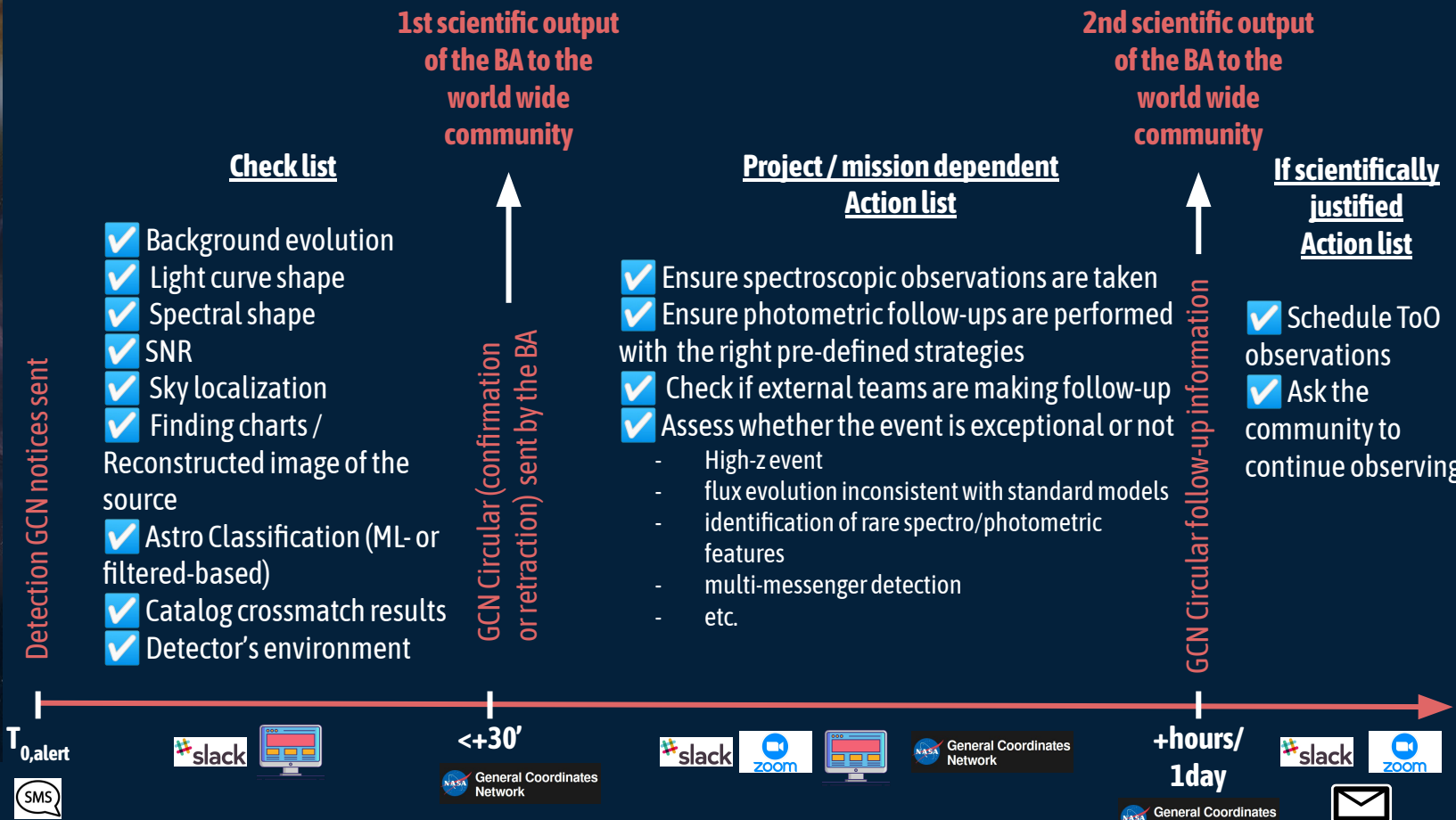
2nd scientific output of the BA to the world wide community



GCN Circular follow-up information



# Step 5: Advocate for longer term revisit observation








Let's make a concrete example with  
Gamma-ray Burst and the SVOM BA tools

# SVOM Reminders

**ECLAIRs** 

« The trigger camera »  
Wide-field X and Gamma rays telescope

Spectral range : 4 keV – 150 keV  
Localization accuracy < 12arcmin

**MXT** 

“The Micro-channel X-ray Telescope”  
Narrow-field X-ray telescope

Spectral range : 0.2 keV – 10 keV  
Localization accuracy < 1arcmin

**GRM** 

“The Gamma-Ray burst Monitor”  
X-rays and Gamma-rays detectors

15 keV – 5 MeV  
Localization accuracy < 5°

**VT** 

“The Visible Telescope”  
Narrow-field visible telescope

Ritchey Chretien  $\Phi=400\text{mm}$   
Localization accuracy < 1arcsec

# Validate the astrophysical origin of the trigger

**SVOM FSC** Home GRB ToO Shifts Mission Documentation Chinese SVOM-BA Tools

2023-05-31 08:37 PM (UT)

Burst ID : **sb23050369** OBS ID: 2568079859, Type: 153, Num: 1165811 ECL

**SVOM Burst\_ID**

SAMP access Register to a SAMP-hub

ECL/GRM MXT VT GFT Localisation Products

**ECLAIRS & GRM data products**

Trigger Time **3 Pck** ECL T0: 2023-05-03T16:44:11.758

Confidence Level **3 Pck** ECL SNR: 10.00 **High SNR detection !**

Quick Position **3 Pck** ECL RA,Dec : 169.934, 2.925 R90: 7.70°

Duration **3 Pck** ECL T90 [s]: 32.92 ERR [s]: -3.4/+13.77  
Q Display plot Hardness Ratio vs. Duration

Peak Fluxes **3 Pck** ECL [4-20] keV 969.3684 ERR: 83.0709  
Q Display plot Peak Fluxes for all GRB

Crude classification **3 Pck** LONG 97.0% / SHORT 3.0%

Light Curves - ECLAIRS

Light Curves - GRM

**Check list**

- Background evolution
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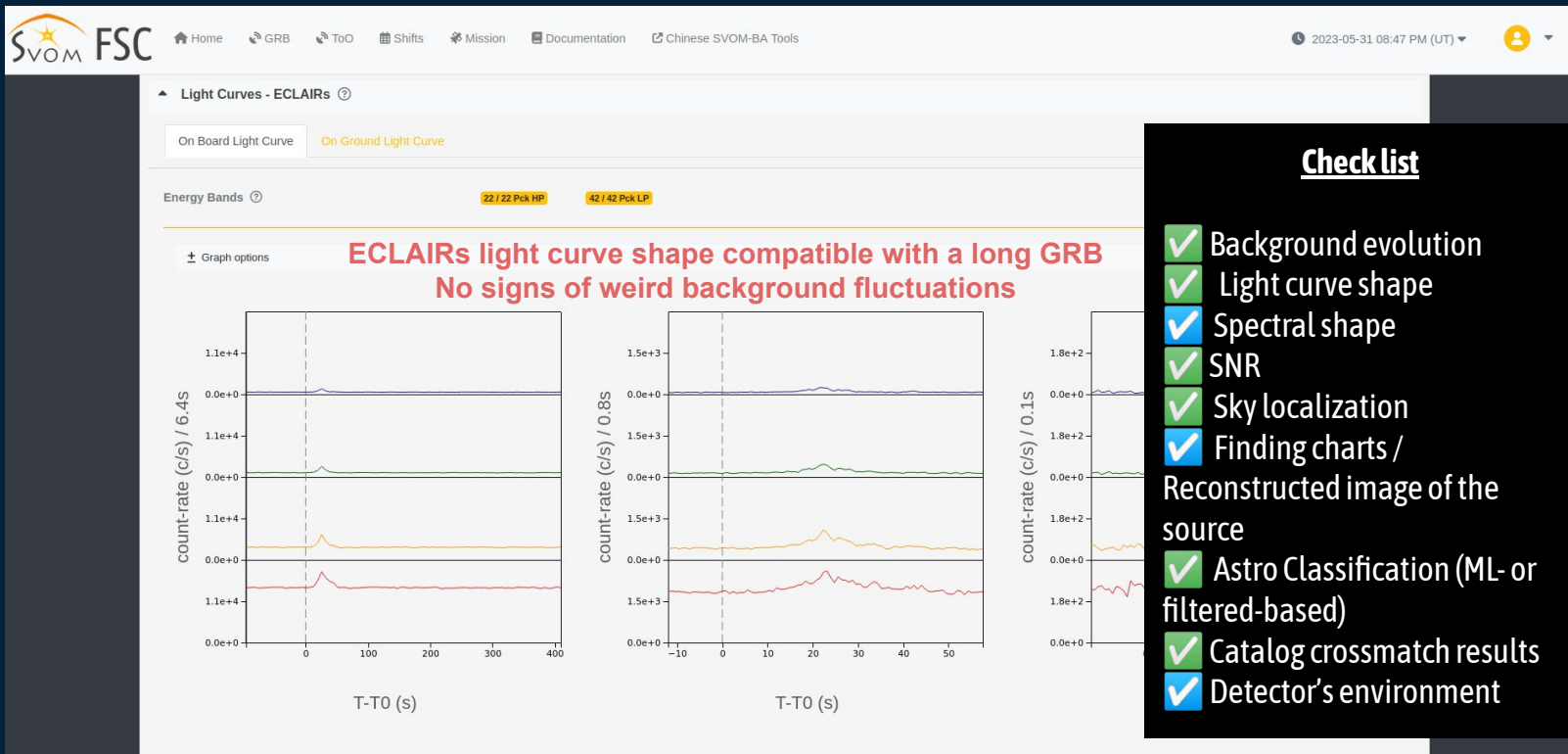
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Light Curves - GRM		

**Check list**

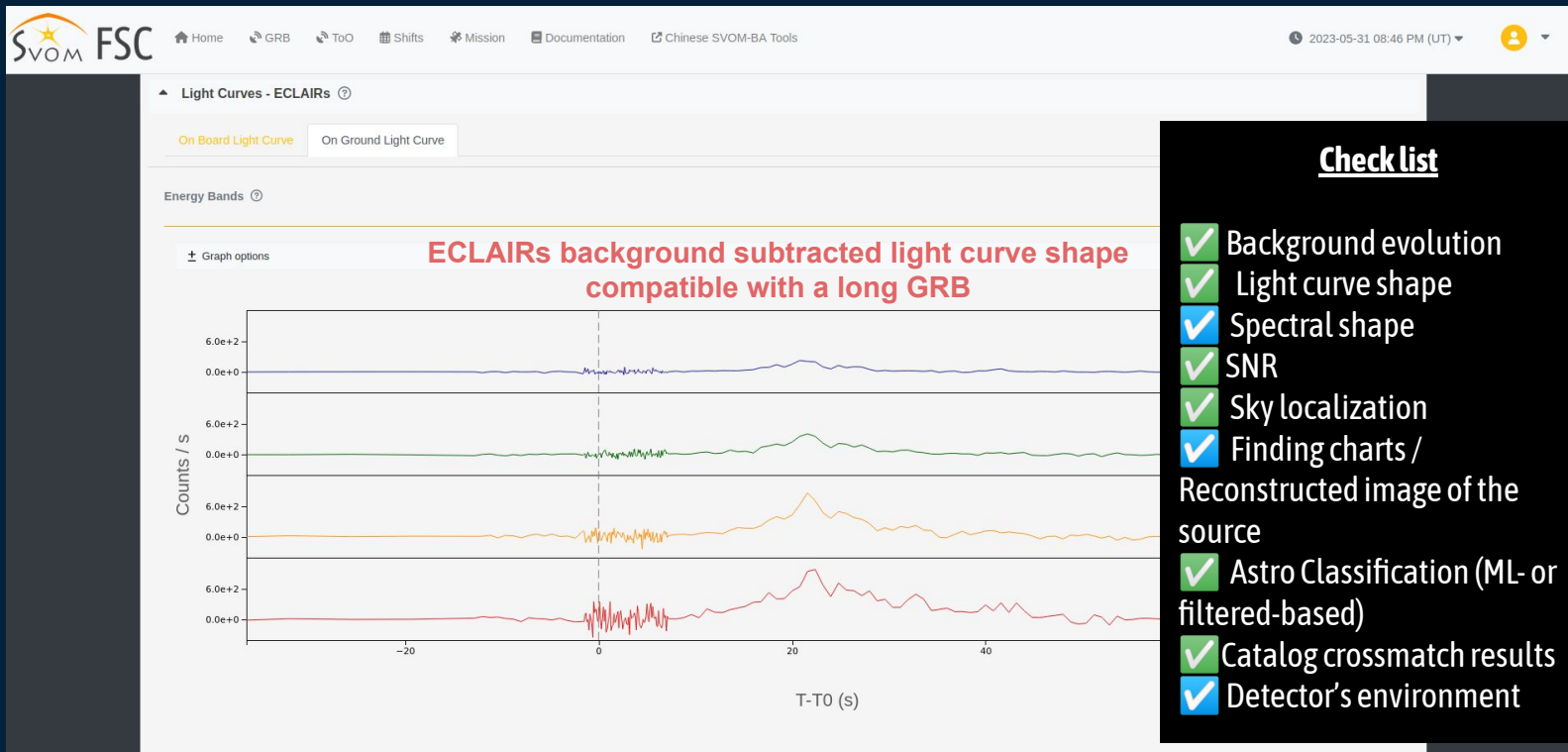
- ✓ Background evolution
- ✓ Light curve shape
- ✓ Spectral shape
- ✓ SNR
- ✓ Sky localization
- ✓ Finding charts / Reconstructed image of the source
- ✓ Astro Classification (ML- or filtered-based)
- ✓ Catalog crossmatch results
- ✓ Detector's environment

**Likely a Long GRB**

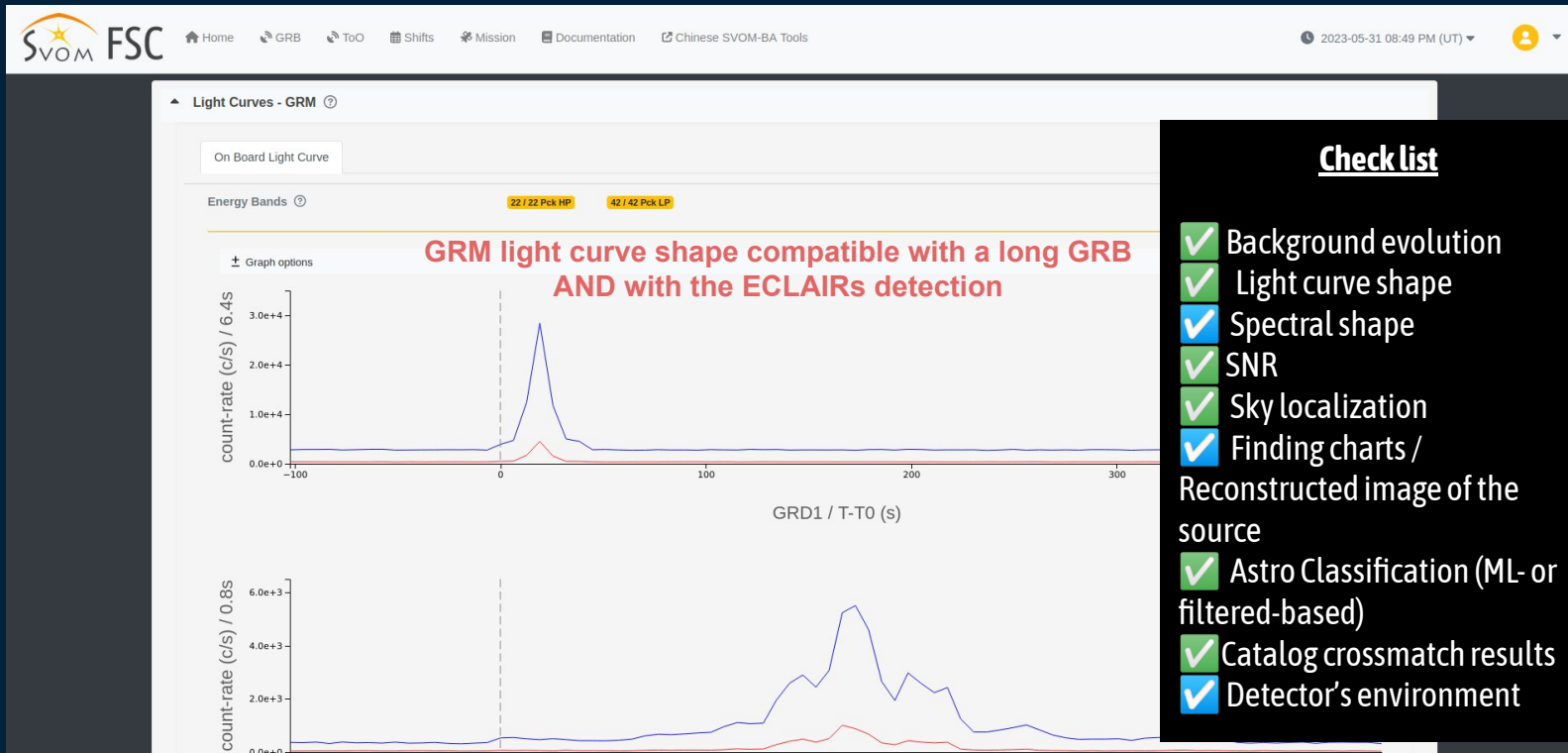
# Validate the astrophysical origin of the trigger



# Validate the astrophysical origin of the trigger



# Validate the astrophysical origin of the trigger





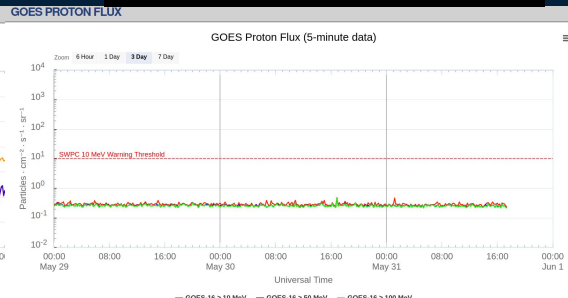
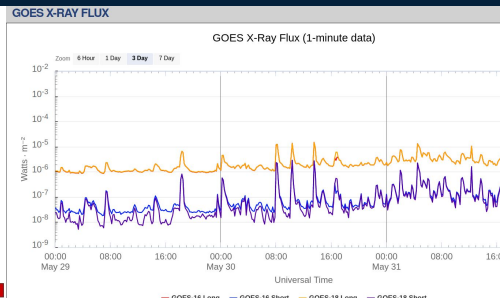
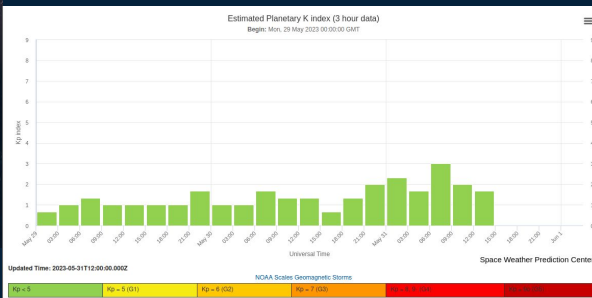
# Validate the astrophysical origin of the trigger

## 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



# 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

SVOM FSC Home GRB ToO Shifts Mission Documentation Chinese SVOM-BA Tools 2023-05-31 08:33 PM (UT) [User]

Burst ID : **sb23050369** OBS ID: 2568079859, Type: 153, Num: 1165811 **ECL** [SAMP access] [Register to a SAMP-hub]

ECL/GRM MXT VT GFT Localisation Products Packets Notices

### MXT data products [MIC web site]

**Detection Time**

- src1 DT : 2023-05-03T16:46:41.238000
- src2 DT : 2017-01-01T00:00:00
- src3 DT : 2017-01-01T00:00:00

**Quick flux determination**

- src1 QF : 150 cnt/s QF\_ERR : 12.247"
- src2 QF : 0 cnt/s QF\_ERR : 0.0"
- src3 QF : 0 cnt/s QF\_ERR : 0.0"

**MXT Position** **44 Pck**

- src1 RA,Dec : 170.044, 3.090 R90: 95.00" **OUT OF ECL R90**
- src2 RA,Dec : 170.021, 2.973 R90: 290.00" **OUT OF ECL R90**
- src3 RA,Dec : 170.796, 2.909 R90: 300.00" **OUT OF ECL R90**

**1 source detected by MXT**

**ECLAIRs GRB localisation**

**Localisation Display**

RA: 170.613 / Dec: 2.966

Background [Hide] [Show]

# Validate the astrophysical origin of the trigger

The screenshot shows the SVOM FSC (Fast Scanning Camera) website interface. At the top, the SVOM logo and 'FSC' are displayed. Navigation links include Home, GRB, ToO, Shifts, Mission, Documentation, and Chinese SVOM-BA Tools. The current date and time are 2023-05-31 08:56 PM (UT). A user profile icon is visible in the top right.

The main content area displays burst information: Burst ID: sb23050369, OBS ID: 2568079859, Type: 153, Num: 1165811, and ECL. There are buttons for 'SAMP access' and 'Register to a SAMP-hub'.

A horizontal menu contains icons for ECL/GRM, MXT, VT (highlighted in yellow), GFT, Localisation, Products, Packets, and Notices.

The 'VT data products' section is active. It shows a search bar with 'QPO' and a 'Show/Hide data' button. A large red text overlay reads 'Several VT candidates'. Below this is a table with columns 'Ra' and 'Dec':

Candidates	Combined Data
Ra	Dec
169.982	3.089
169.953	3.0
169.96	3.007

Below the table, there are buttons for 'Print' and 'Download'.

The 'QIM1B\_VT' section shows 'Seq1' with two data points: 'B1: 42 Pck' and 'R1: 83 Pck'. Below this, 'Sequence 1' is displayed with two side-by-side star field images. The left image is labeled 'B1 (42 Pck)' and the right image is labeled 'R1 (83 Pck)'. Both images show a dense field of stars against a black background.

# Validate the astrophysical origin of the trigger



Burst ID :

Background

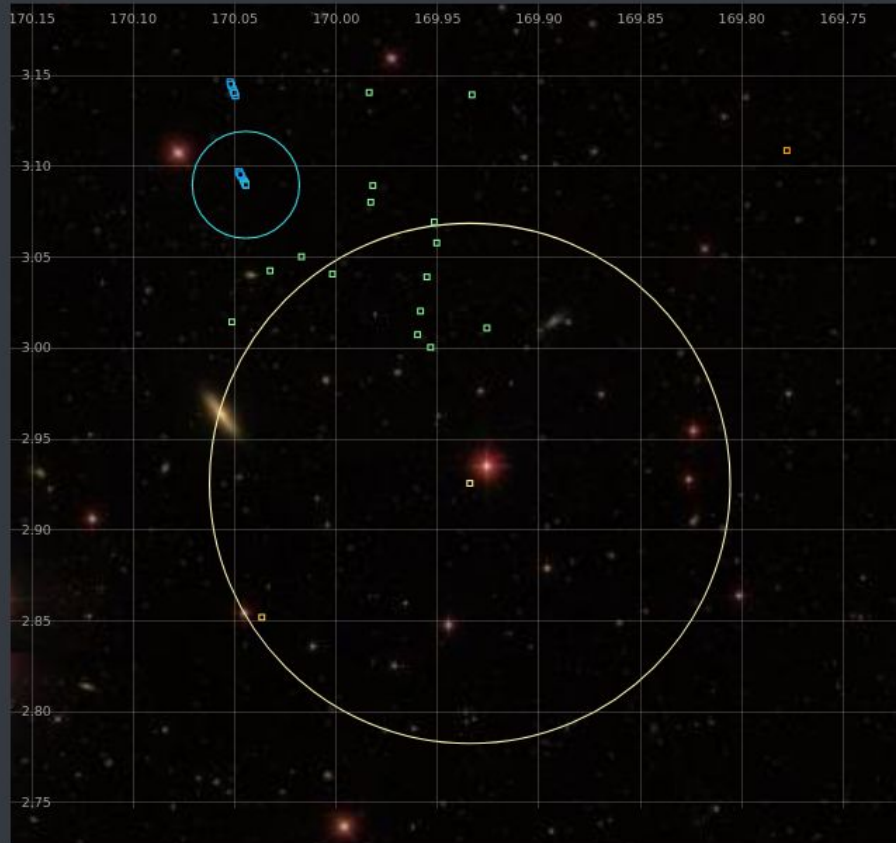
Hide Show



QPO ©

QIM1B\_VT

RaJ2000 / DecJ2000



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