

Joint studies of the Gamma-ray Bursts phenomena with the SVOM mission and the Vera Rubin Observatory



Damien Turpin (CNES/CEA-Saclay Irfu)

on behalf of

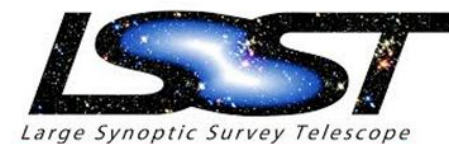
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cea

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University of Chinese Academy of Sciences

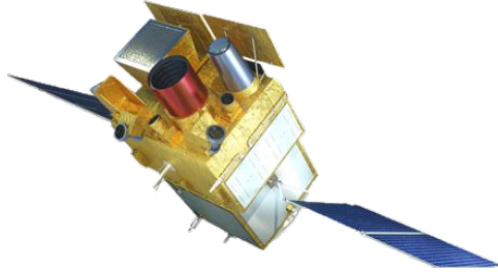


Rubin Observatory



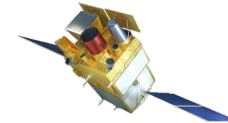
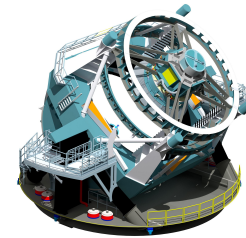
Journées LSST France
LPNHE
Nov, 23th 2021

Outlines



I

**SVOM and its GRB science
in a nutshell**



II

FINK

**the SVOM's gateway to the
Vera Rubin transient sky**



|

SVOM and its GRB science in a nutshell

The SVOM Collaboration

- **China (PI J. Wei)**



- SECM Shanghai
- Beijing Normal University
- Central China University Wuhan
- Guangxi University Nanning
- IHEP Beijing
- KIAA Peking University
- Nanjing University
- NAOC Beijing
- National Astronomical Observatories
- Purple Mountain Observatory Nanjing
- Shanghai Astronomical Observatory
- Tsinghua University Beijing

- **Mexico** UNAM Mexico



- **France (PI B. Cordier)**



- CNES Toulouse
- APC Paris
- CEA Saclay
- CPPM Marseille
- GEPI Meudon
- IAP Paris
- IRAP Toulouse
- IJCLab, Orsay
- LAM Marseille
- LUPM Montpellier
- OAS Strasbourg

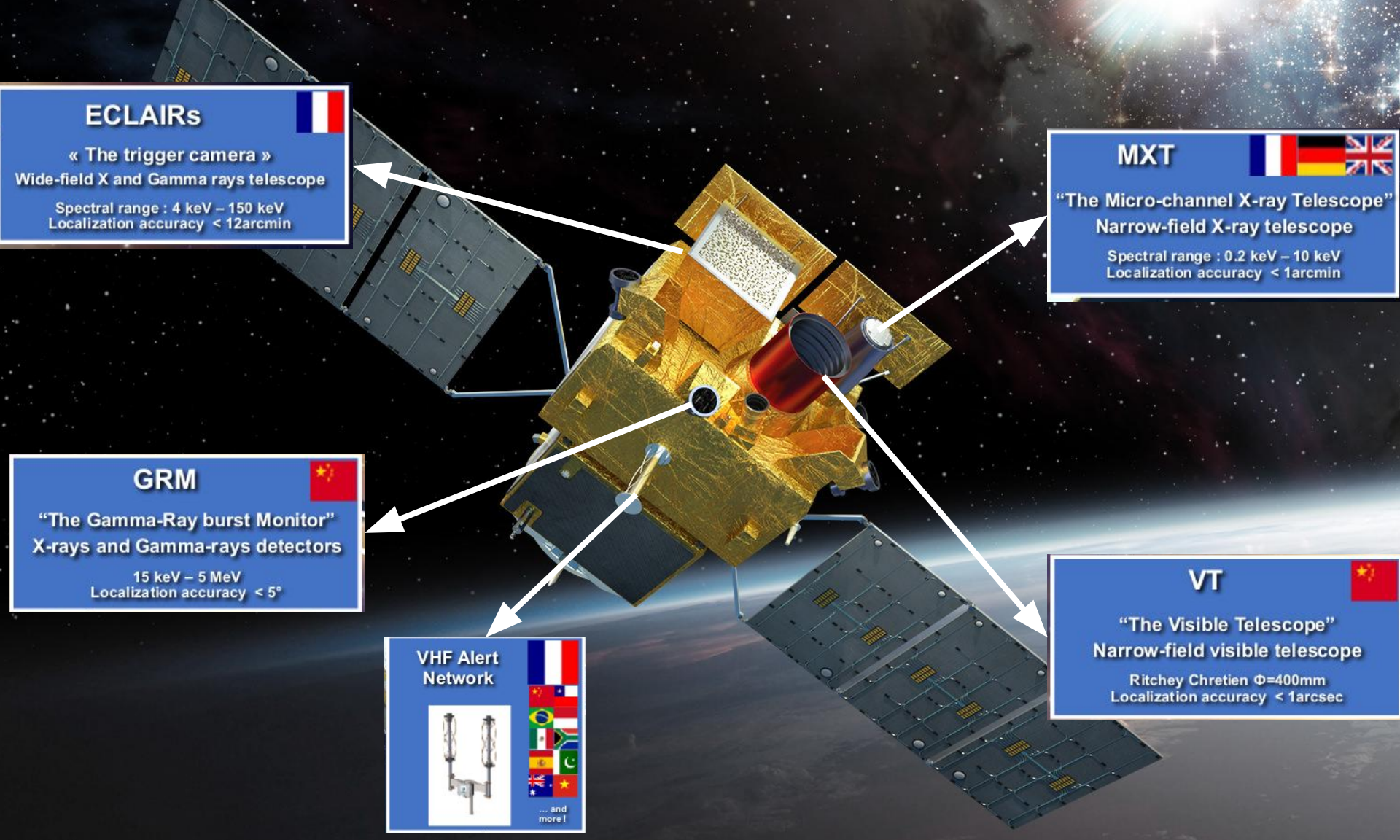
- **UK** University of Leicester



- **Germany**

- MPE Garching
- IAAT Tübingen





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

VHF Alert Network 

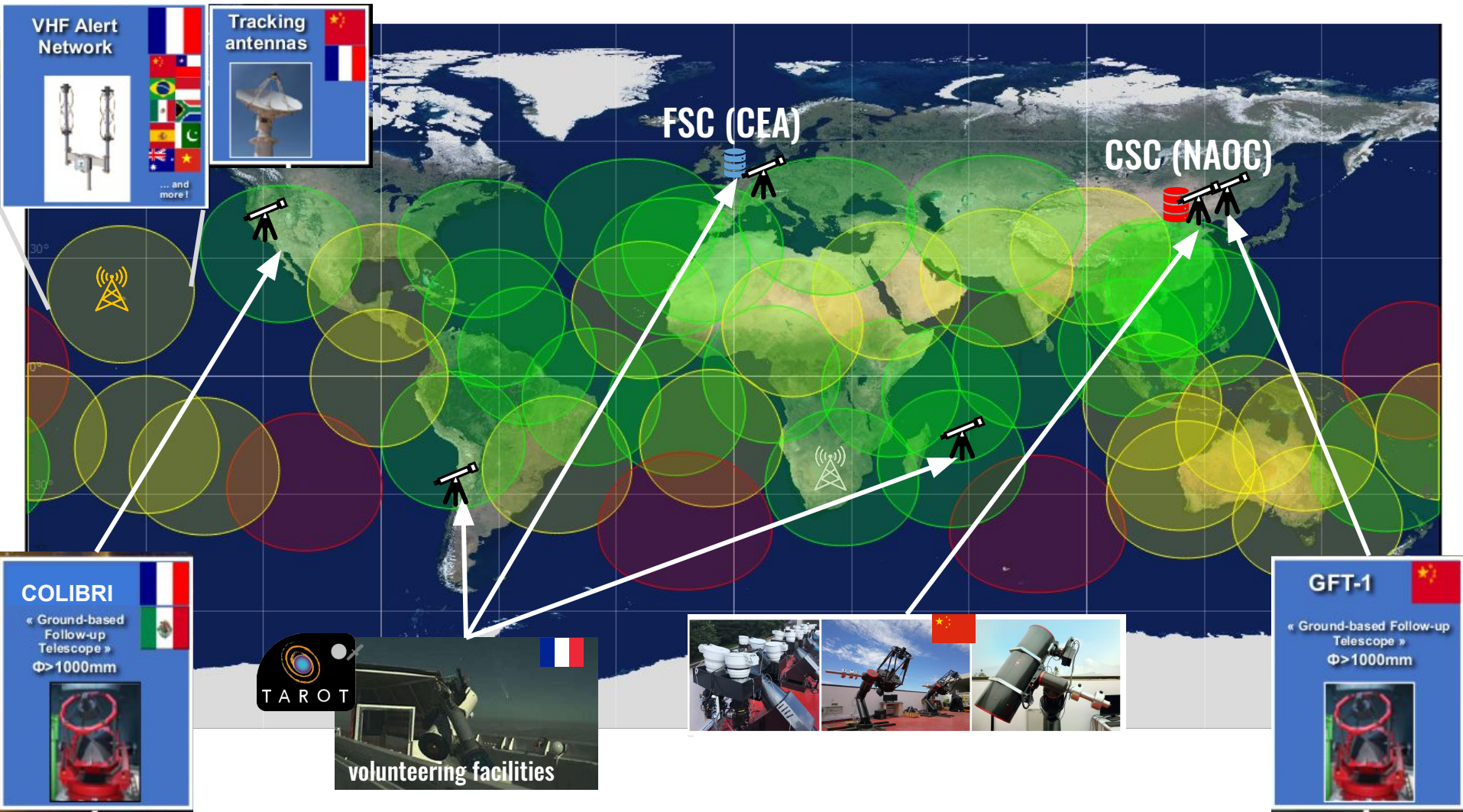
... and more!

The Space-based multi-band astronomical Variable Object Monitor (SVOM) satellite

Launch : Early 2023 for 3 (nominal) +2 (extended) years

The SVOM ground segment

1. **An alert network:** ~40 VHF receivers on Earth / 65% of the alerts received within 30s at the French Science Center (FSC) / We are also planning to be connected to the chinese Beidou network.
2. **A telescope network for the SVOM follow-up activities**

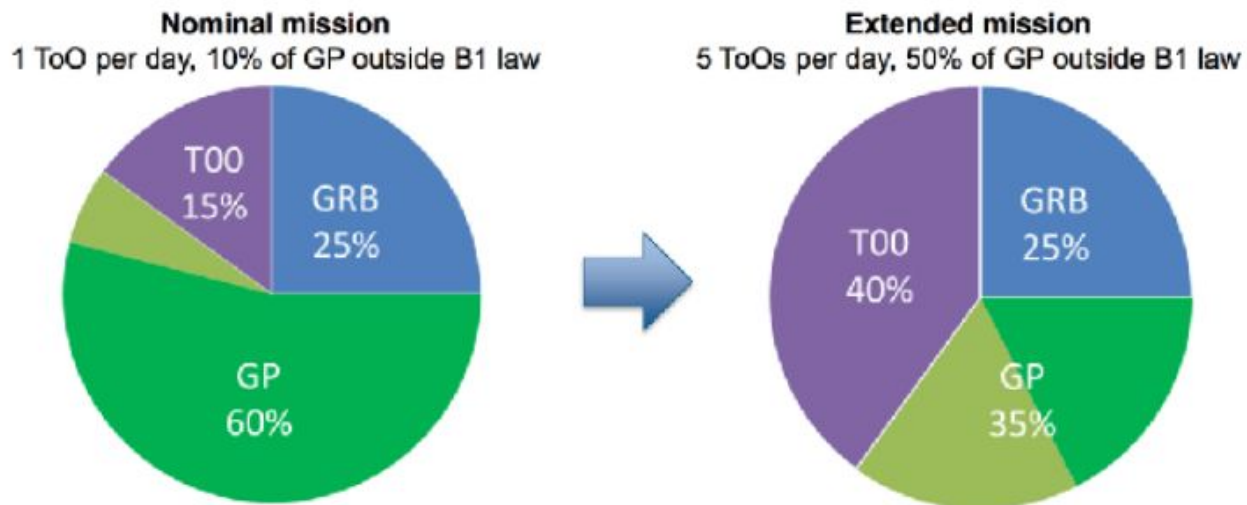


The SVOM scientific programs

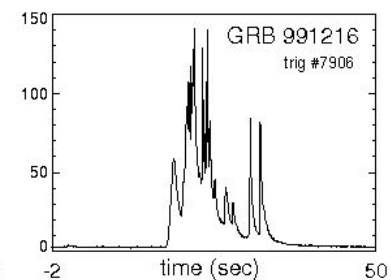
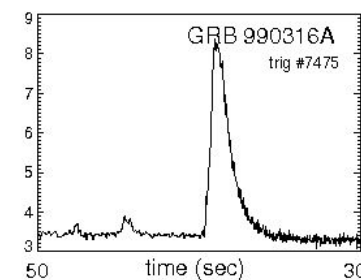
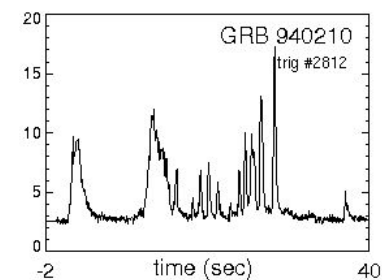
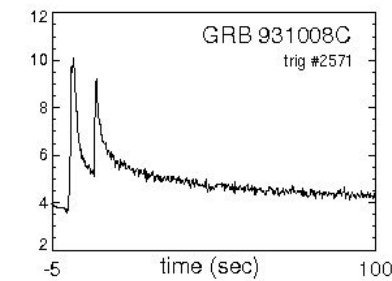
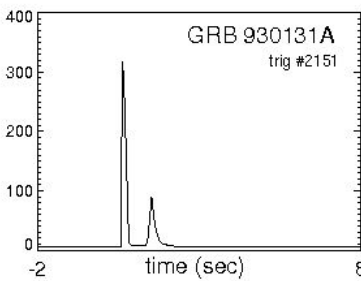
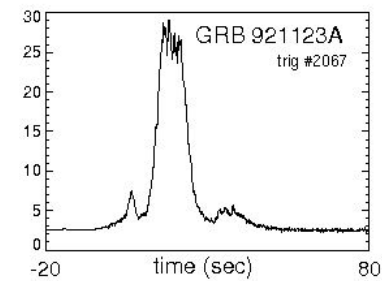
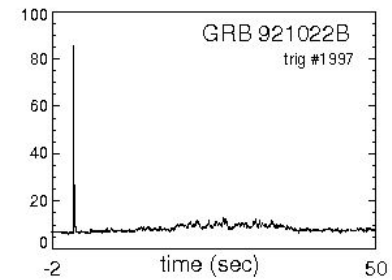
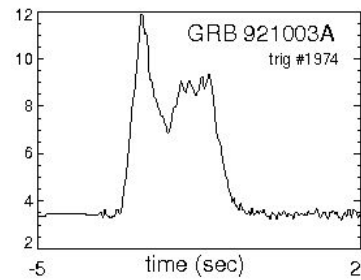
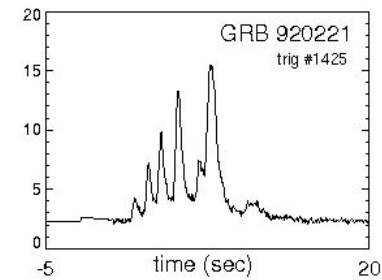
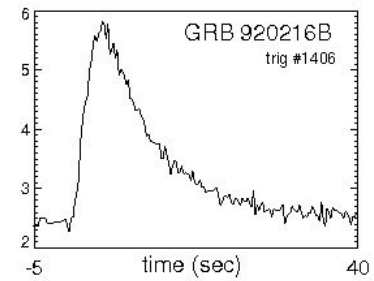
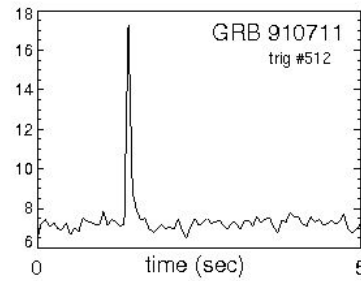
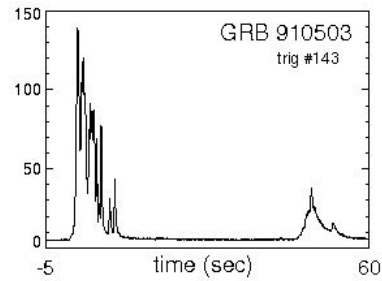
SVOM will be an open observatory : **general program (GP)** observations will be awarded by a TAC (a SVOM co-I needs to be part of your proposal). 10% of the time can be spent on low Galactic latitude sources during the nominal mission (up to 50% during the extended mission).

The Core Program (GRB). GRB data products (position, light curve, pre-computed spectra will be made public immediately)

Target of Opportunity (ToO) program : alerts sent from the ground to the satellite. Initially 1 ToO per day focussed on time domain astrophysics including multi-messengers. ToO program devoted time increases during extended mission.



Gamma-ray Bursts in a nutshell

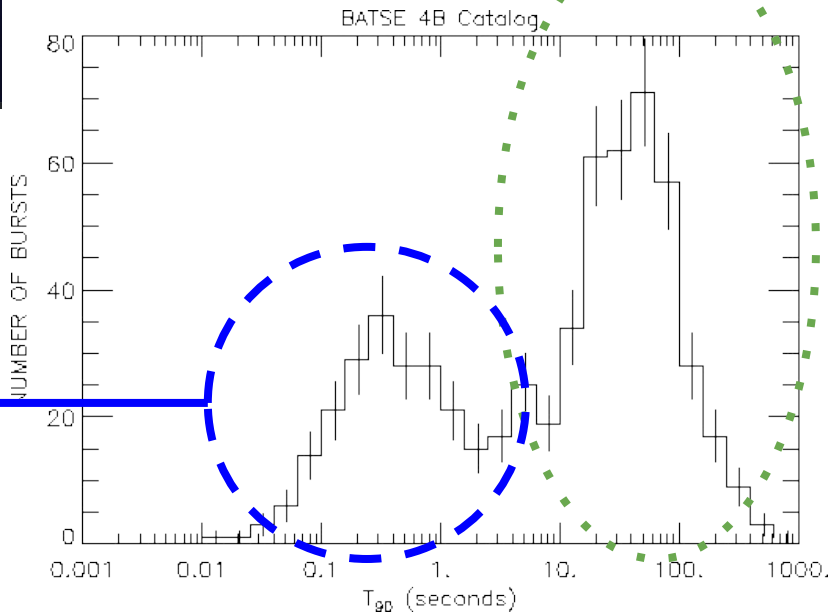


From the NASA
CGRO mission
BATSE instrument:
20keV - 1MeV

Gamma-ray Bursts in a nutshell

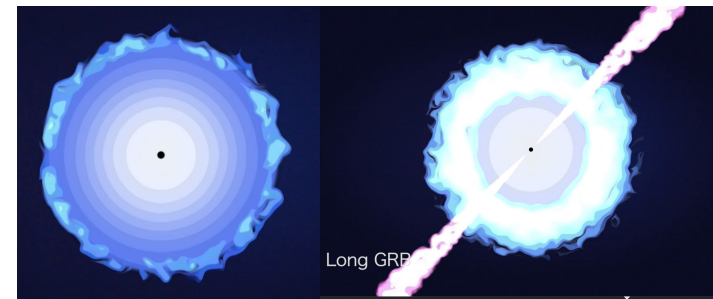


short GRB (+kilonova) from compact BNS merger

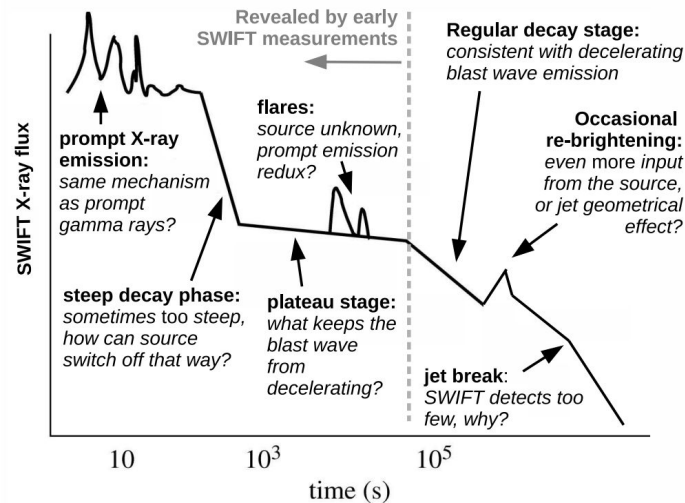
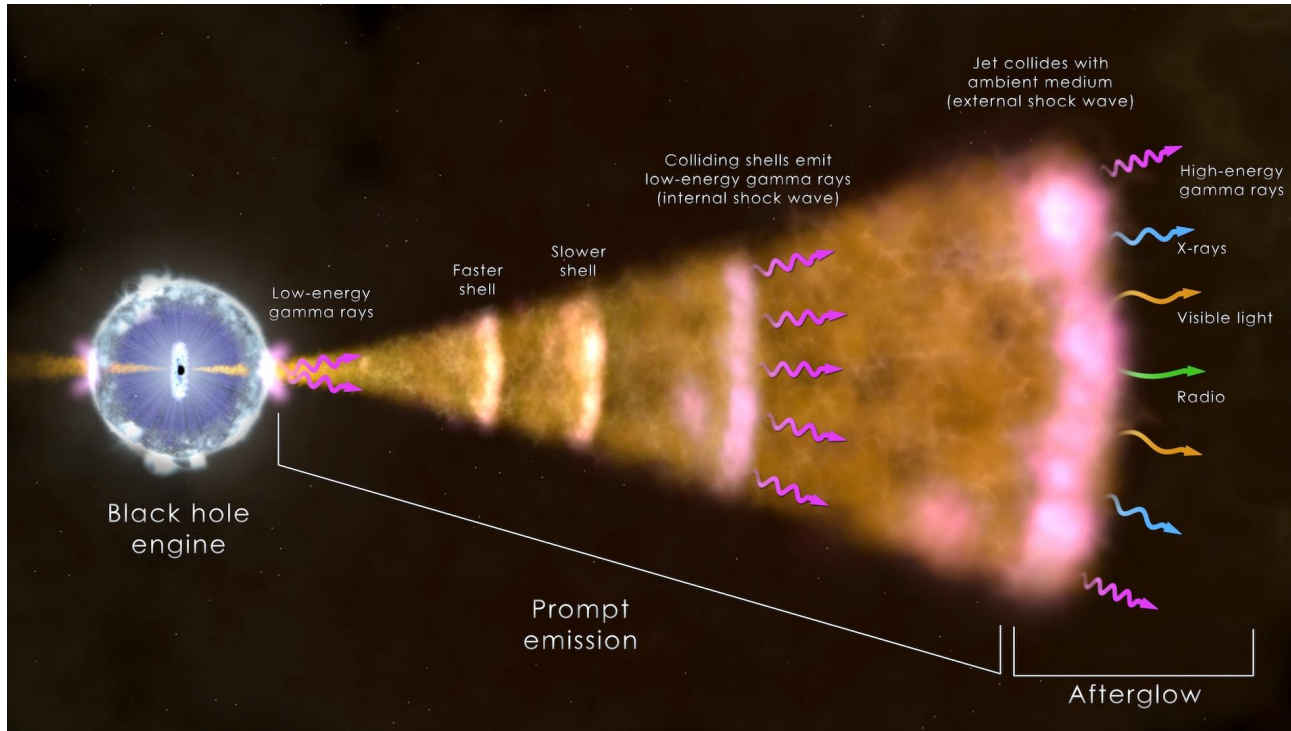


Long GRB from type Ib/c supernovae

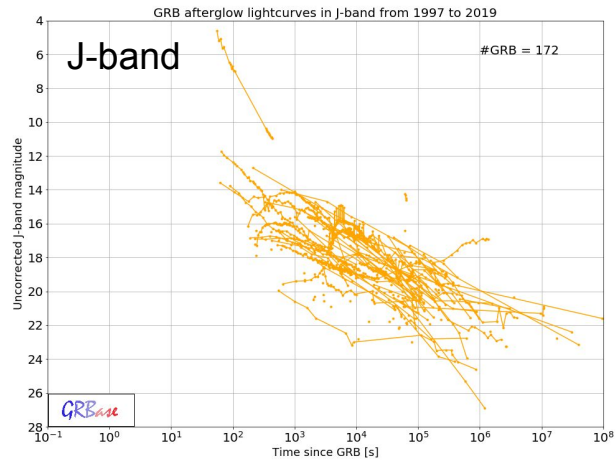
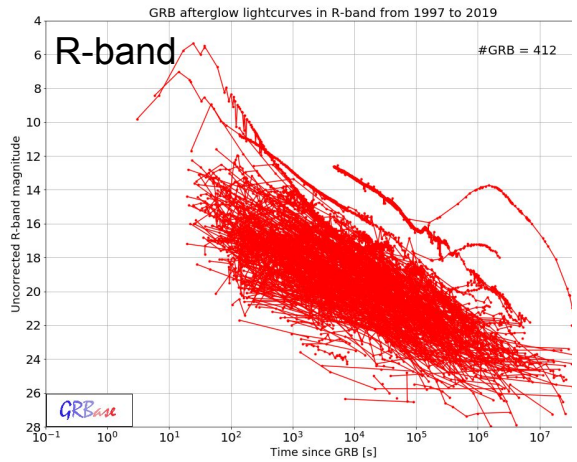
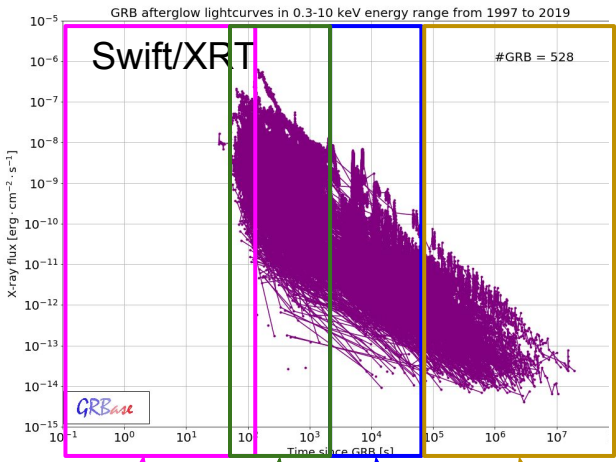
These two cataclysmic events can launch a (ultra) relativistic jet in the interstellar medium



Gamma-ray Bursts in a nutshell



State of the art of GRB follow-up observations



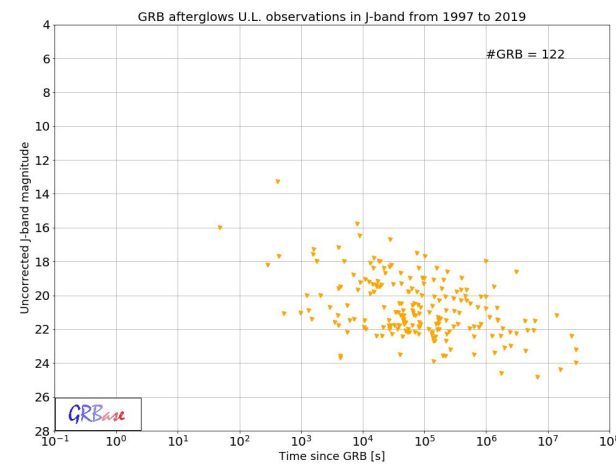
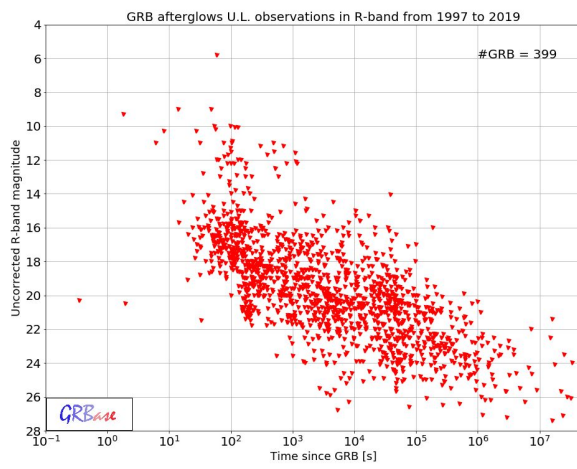
prompt emission up to 100s

Early afterglow emission <1h

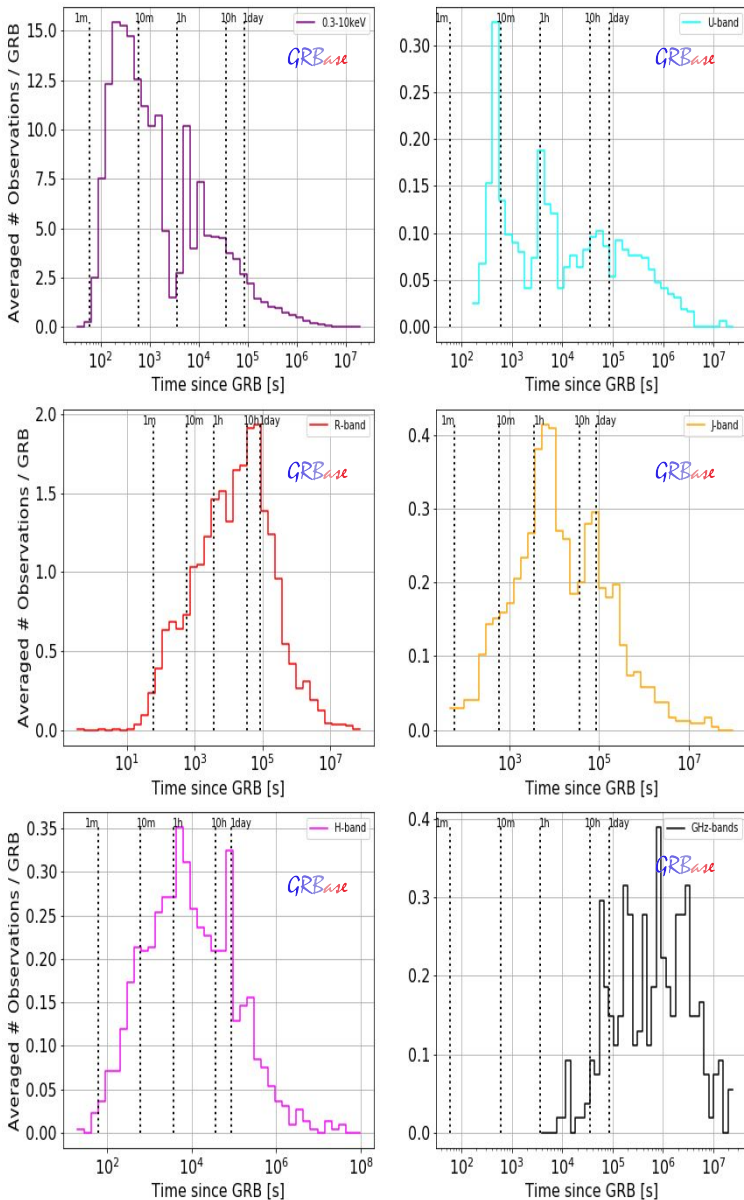
Late afterglow emission >1h

Very late afterglow emission >1day

GRBbase



State of the art of GRB follow-up observations



Take away message from past Swift follow-up campaigns

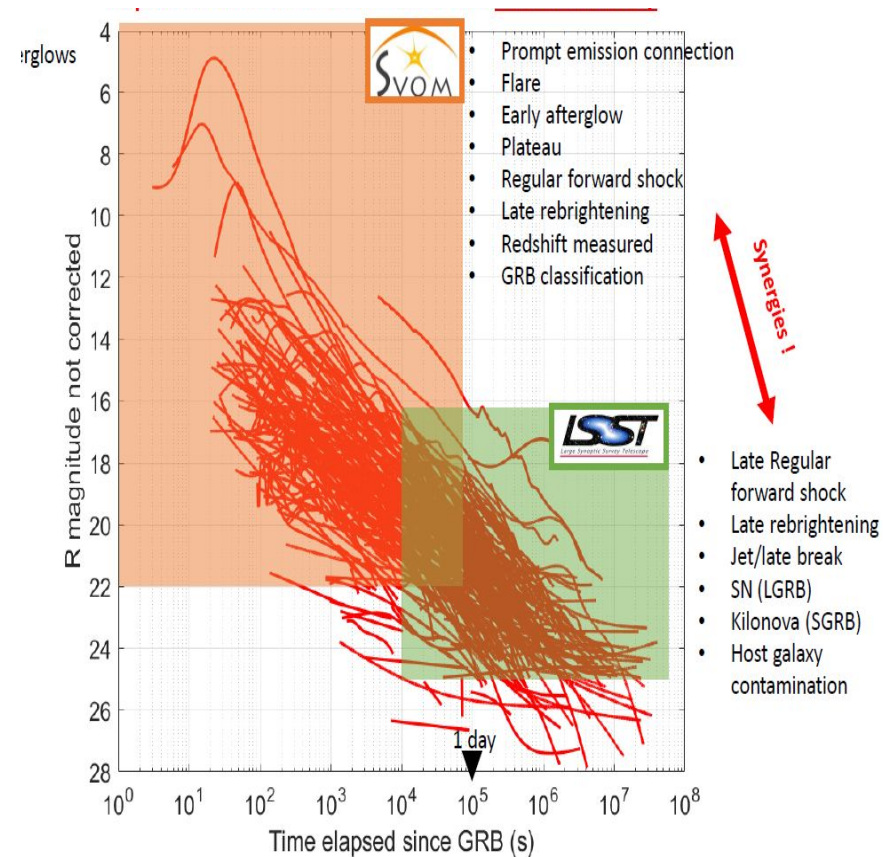
1. The **prompt emission** (T_{GRB} up to 100s) is usually poorly covered in all bands (except for the longest GRBs in x-rays) : **it is a very complicated task !**
2. The **early afterglow emission** ($T_{\text{GRB}} < 1\text{h}$) is already well covered in x-rays BUT barely in R-band and poorly covered in IR bands. **SVOM job !**
3. The **late afterglow emission** ($T_{\text{GRB}} > 1\text{h}$) is well covered in x-rays and R-band and reasonably covered in IR bands. **SVOM should perform pretty well !**
4. The **very late afterglow emission** ($T_{\text{GRB}} > 1\text{day}$) is poorly covered in all bands. **Beyond the scope of the SVOM instruments. VR-LSST could help !**

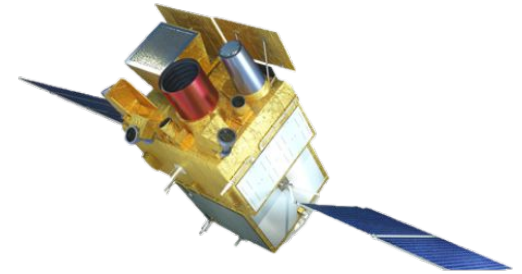
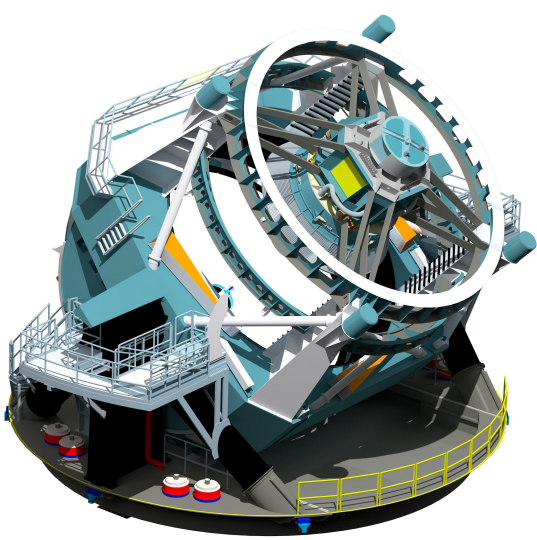
The SVOM/VR-LSST synergies for the GRB science

GRB Science case

GRB science case	SVOM tasks	LSST advantages
General GRB science	<ul style="list-style-type: none"> Complete catalog of GRB in terms of observation coverage from IR-gamma-rays 	<ul style="list-style-type: none"> Great sensitivity Auto survey of some SVOM GRB positions for several days/weeks
Orphan/untriggered GRB	<ul style="list-style-type: none"> Systematic searches for subthreshold events 	<ul style="list-style-type: none"> Great sensitivity Sky survey Transient alert mode
High-z GRB	<ul style="list-style-type: none"> Study the physics and environment of the GRBs at $z > 4$ 	<ul style="list-style-type: none"> Great sensitivity
LGRB-SNe connection LGRB progenitor study	<ul style="list-style-type: none"> Provide LGRB classification + redshift + flux prediction of the potential SNe Can trigger spectro follow-up with large telescopes 	<ul style="list-style-type: none"> Great sensitivity Sky Survey at daily cadency
SGRB-merger connection kilonova	<ul style="list-style-type: none"> Provide SGRB classification Answer to LVC alerts with all SVOM instruments 	<ul style="list-style-type: none"> Great sensitivity Sky Survey at daily cadency
GRB-neutrino connection	<ul style="list-style-type: none"> Answer to neutrino alerts with all SVOM instruments 	<ul style="list-style-type: none"> Great sensitivity

SVOM/LSST GRB afterglow follow-up synergies

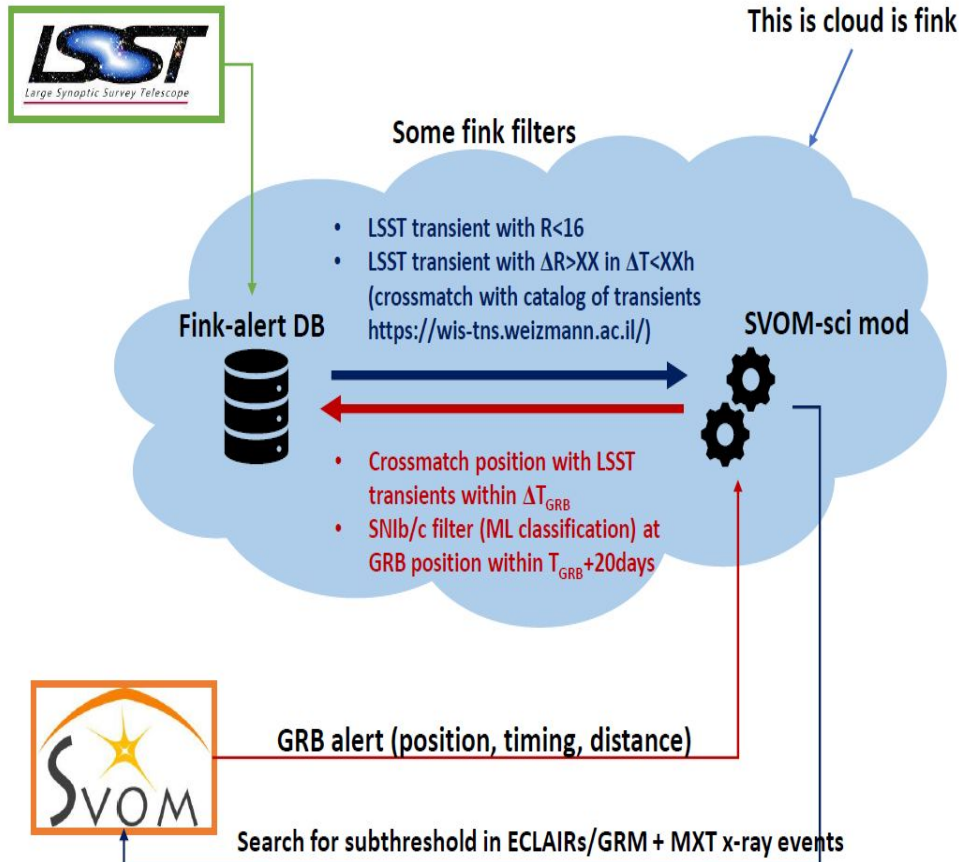




II
FINK
the SVOM's gateway to the Vera Rubin
transient sky



a unique French broker to prepare the future of the time-domain astronomy



The SVOM scientific module to be setup in Fink for performing SVOM/LSST GRB science

1. **Searches for GRB afterglow (also supernovae/kilonovae) candidates in the LSST stream as soon as a SVOM GRB is detected and localized.**
2. *Searches for untriggered/subthreshold SVOM GRB counterparts from LSST identified orphan afterglows. (see the talk of Johan Bregeon about searches for untriggered/orphan GRB afterglows in LSST alert stream)*

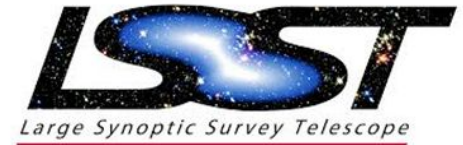
The SVOM GRB scientific module in Fink, how does it work ?

GRB detected by SVOM



RA, dec, error radius, Trigger time

LSST alert stream
(prefiltered by FINK or not)



RA, dec, Trigger time, mags

The SVOM GRB scientific module in Fink, how does it work ?



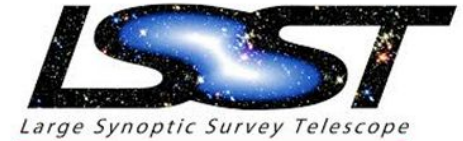
GRB detected by SVOM



RA, dec, error radius, Trigger time

1/ Space and time crossmatch

LSST alert stream
(prefiltered by FINK or not)



RA, dec, Trigger time, mags



candidate list 1
(**bronze events**, several
tens to hundreds)

The SVOM GRB scientific module in Fink, how does it work ?

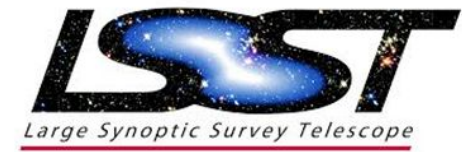


GRB detected by SVOM



RA, dec, error radius, Trigger time

LSST alert stream
(prefiltered by FINK or not)



RA, dec, Trigger time, mags

1/ Space and time crossmatch



candidate list 1
(**bronze events**, several
tens to hundreds)

2/ Science filter

- source type = SN, ambiguous or unknown
- Proba Real/bogus > 0.9
- Proba not associated by chance > 5σ



candidate list 2
(**silver events**, severals
up to tens)

The SVOM GRB scientific module in Fink, how does it work ?

GRB detected by SVOM

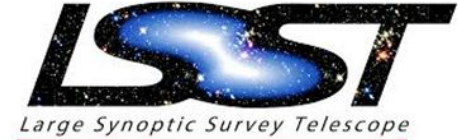


RA, dec, error radius, Trigger time



1/ Space and time crossmatch

LSST alert stream
(prefiltered by FINK or not)



RA, dec, Trigger time, mags

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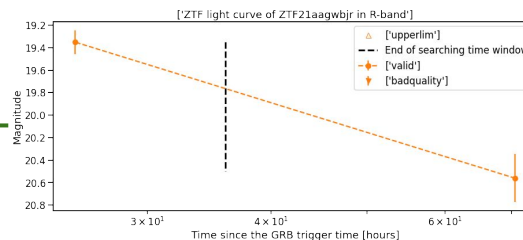
candidate list 1
(**bronze events**, several
tens to hundreds)

candidate list 2
(**silver events**, several
up to tens)

3/ fast transient filter

- $g-r > XX$
- $\Delta mag_r > 0.3 \text{ mag} \cdot \text{day}^{-1}$

candidate list 3
(few, **gold events**)



The SVOM GRB scientific module in FINK, how does it work ?

GRB detected by SVOM

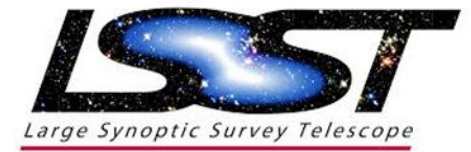


RA, dec, error radius, Trigger time



1/ Space and time crossmatch

LSST alert stream
(prefiltered by FINK or not)



RA, dec, Trigger time, mags



candidate list 1
(**bronze events**, several
tens to hundreds)

2/ Science filter

- source type = SN, ambiguous or unknown
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- Proba not associated by chance > 5σ



candidate list 2
(**silver events**, several
up to tens)

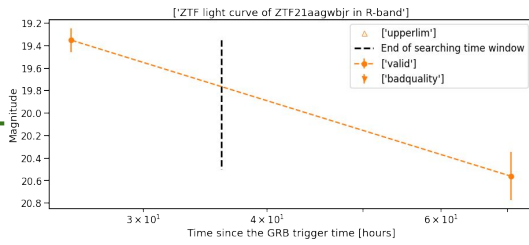
4/ Candidate validation



candidate list 3
(few, **gold events**)

3/ fast transient filter

- $g-r > XX$
- $\Delta mag_r > 0.3 \text{ mag} \cdot \text{day}^{-1}$



visual inspection by SVOM scientists
Complete the SVOM afterglow data set for
further analysis

The SVOM GRB scientific module in Fink, how does it work ?

The FINK/SVOM sci. module will be run :

- offline after each night of VR/LSST (**ready !**)
- online if a GRB is detected during the night at VR-LSST (**will be implemented soon by the end of the year**)

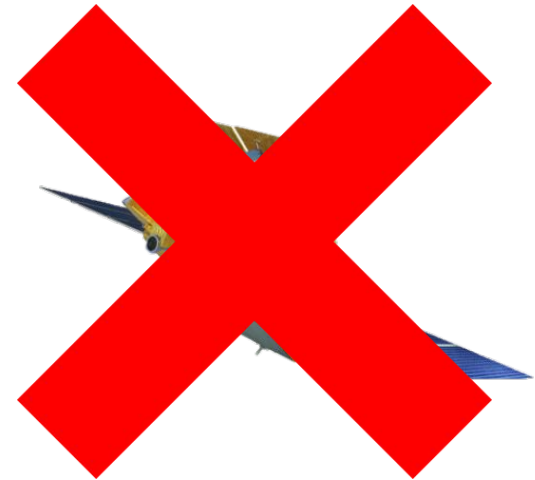
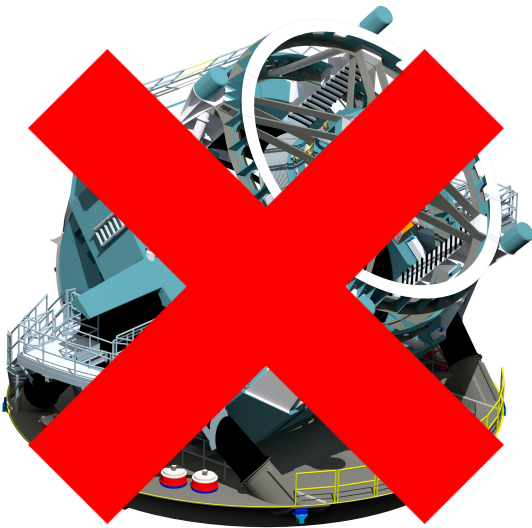
One problem remains.....

The SVOM GRB scientific module in Fink, how does it work ?

The FINK/SVOM sci. module will be run :

- offline after each night of VR/LSST **(ready !)**
- online if a GRB is detected during the night at VR-LSST **(will be implemented soon by the end of the year)**

One problem remains for now...



The SVOM GRB scientific module in Fink, how does it work ?

The FINK/SVOM sci. module will be run :

- offline after each night of VR/LSST (**ready !**)
- online if a GRB is detected during the night at VR-LSST (**will be implemented soon by the end of the year**)

But we have...



Prior to SVOM & LSST : Swift/Fermi & ZTF era



Fink-alert DB



Some fink filters

- Crossmatch Swift GRB position with ZTF transients within ΔT_{GRB}
- Crossmatch ZTF transients compatible with GRB positions with catalogs (PS, SDSS, DSS, GAIA, DES, etc.)
- SNIb/c filter (ML classification) at GRB position within $T_{\text{GRB}} + 20\text{days}$

This is cloud is fink



GRB-sci mod



GRB alert (position, timing, distance)



Swift/Fermi & ZTF era : results with Fink

ZTF afterglows from Swift GRBs :

0

ZTF afterglows from Fermi GRBs :

1 found with the GRB science module !

ZTF21aagwbjr association confirmed with GRB 210204A

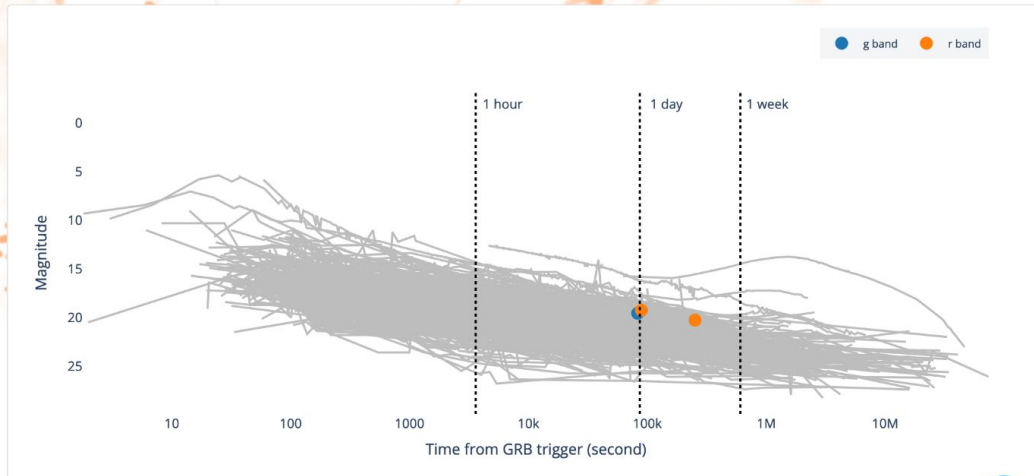
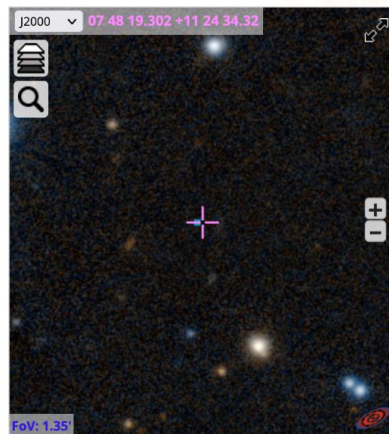
Light curve visualization of the GRB afterglow candidates in FINK
(preliminary)

Fink Science portal 0.10 Search API Tutorials Info

Summary Supernovae variable stars microensing Solar System GRB

ZTF21aagwbjr

Enter a GRB trigger time in UTC (YYYY-MM-DD hh:mm:ss) to display the alert measurements, and hit search.



Inspect alert data

Get object data

We show GRB lightcurves collected and curated by Damien Turpin.



Conclusions & perspectives

- **There is a room for common studies of the GRB afterglows between SVOM (early phases) and VR-LSST (very late phases) using the public alert stream**
- The SVOM Collaboration (+ GRB experts) is developing a FINK/SVOM sci. module to search for GRB optical afterglow counterparts in ZTF/LSST alert stream
- The GRB module is also publicly available and will be constantly upgraded (https://github.com/dturpin-svom/fink_grb_module)
- The results of the GRB sci. module are publicly available in FINK!
- The offline search for GRB afterglows is now running on Swift and Fermi to finely tune the different parameters of the filters.
- **We found one confirmed GRB afterglow with our filters! ZTF21aagwbjr - GRB210204A !**
- The online search in ZTF alert stream will be available soon (by the end of the year)
- Blind searches for optical afterglows in ZTF/LSST data streams will be investigated (*see the talk of J. Bregeon*). In case of a discovery, SVOM will search for subthreshold events in the ECLAIRs data.
- Search for KN/SN candidates potentially associated to SVOM S/L GRBs must be done systematically too