# The SVOM mission

## exploring the high energy transient sky in the multi-messenger era

https://arxiv.org/pdf/1610.06892.pdf

https://www.svom.eu/

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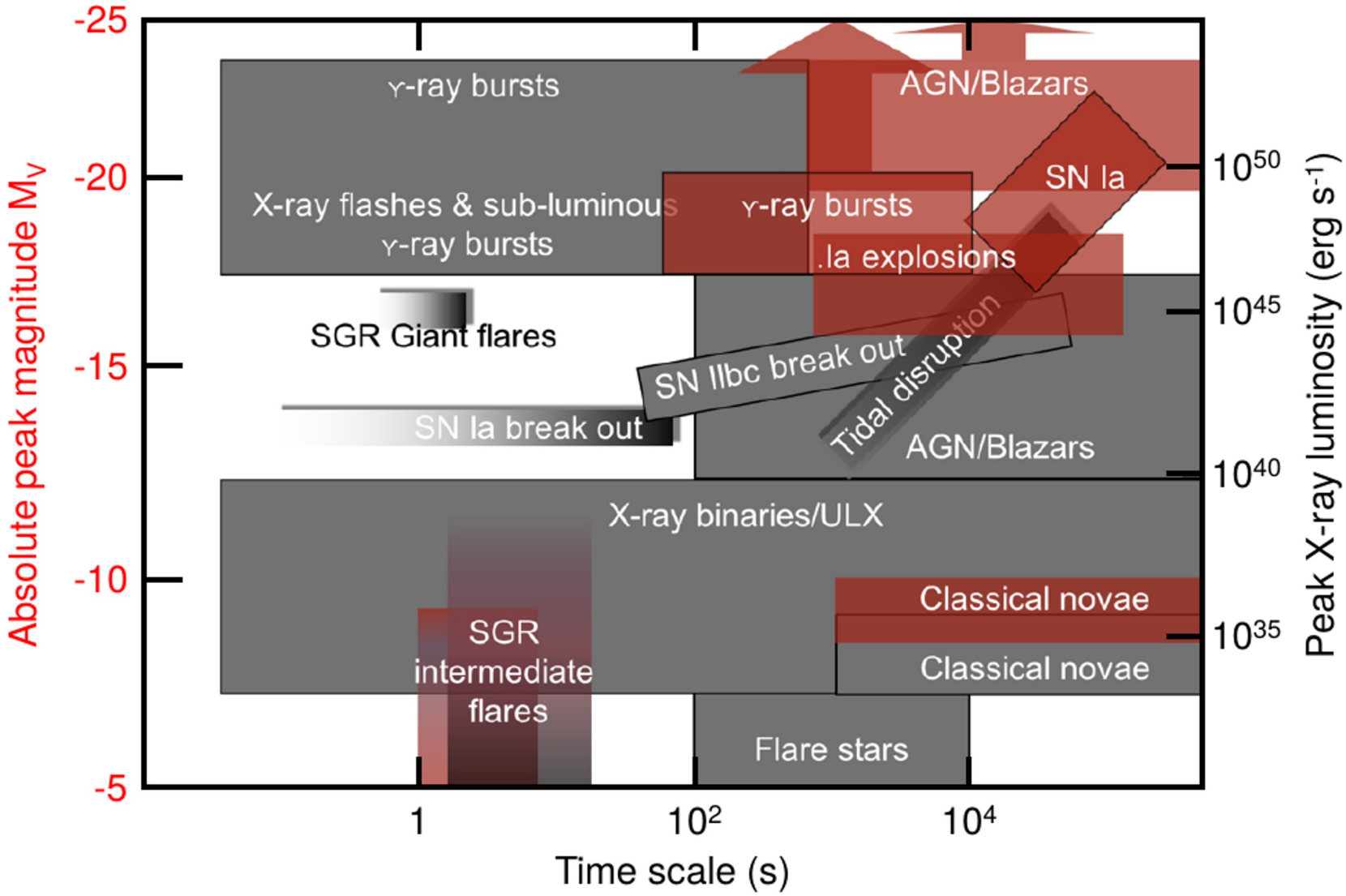
On behalf of
the SVOM consortium

6 ème Assemblée Générale du GDR OG
Toulouse 2022

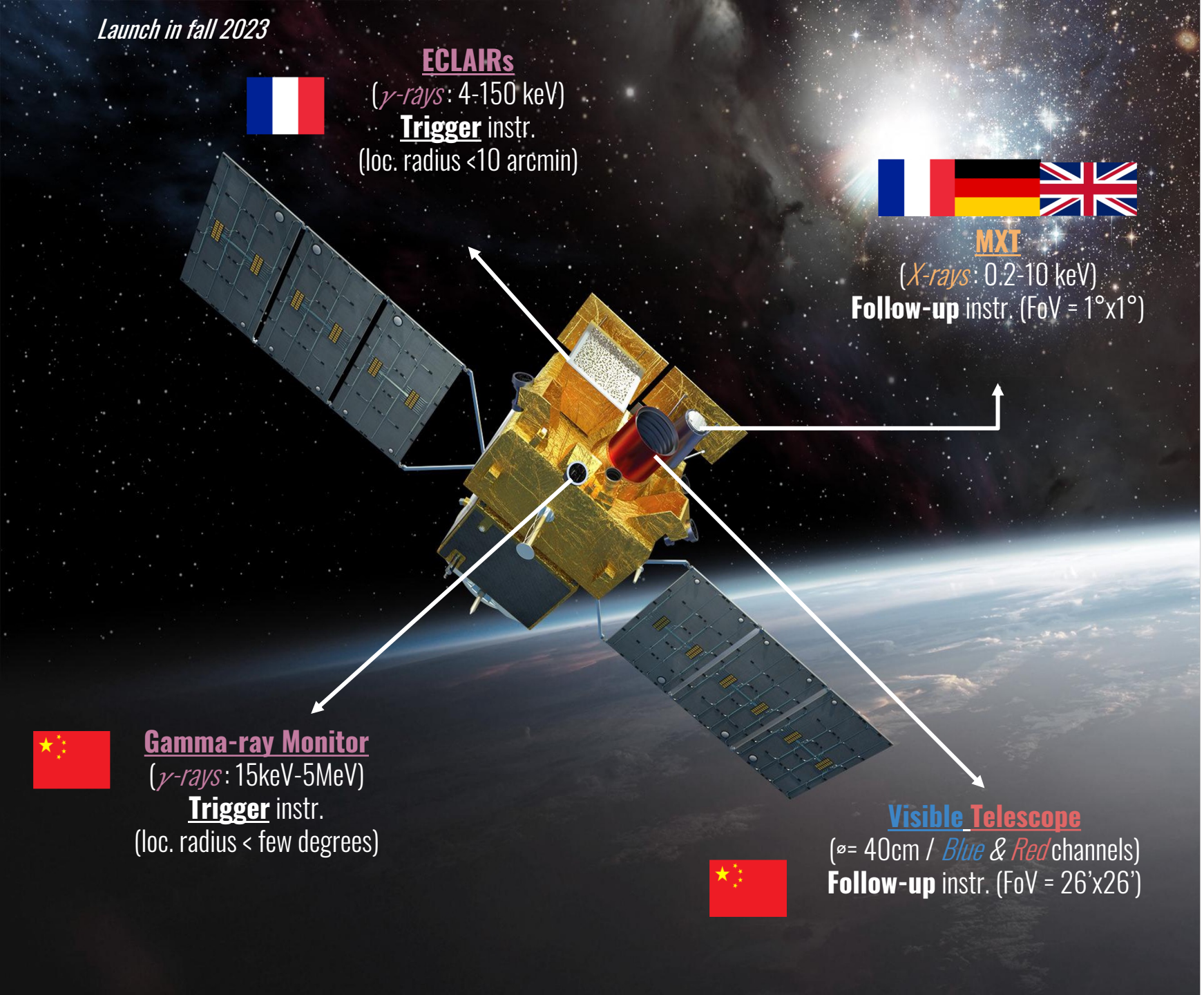
# Exploring the transient sky with SVOM



# The SVOM consortium

- **China (PI J. Wei)** 
  - SECM Shanghai
  - NSSC Beijing
  - NAOC Beijing
  - IHEP Beijing
  - GuangXi University
- Mexico UNAM (Colibri) 
- UK University of Leicester (MXT) 
- Germany MPE Garching & IAAT Tübingen (MXT) 

- **France (PI B. Cordier)** 
  - CNES Toulouse
  - APC Paris
  - CEA Saclay
  - CPPM Marseille
  - GEPI Meudon
  - IAP Paris
  - IJCLab Orsay
  - IRAP Toulouse
  - LAM Marseille
  - LUPM Montpellier
  - ObAS Strasbourg



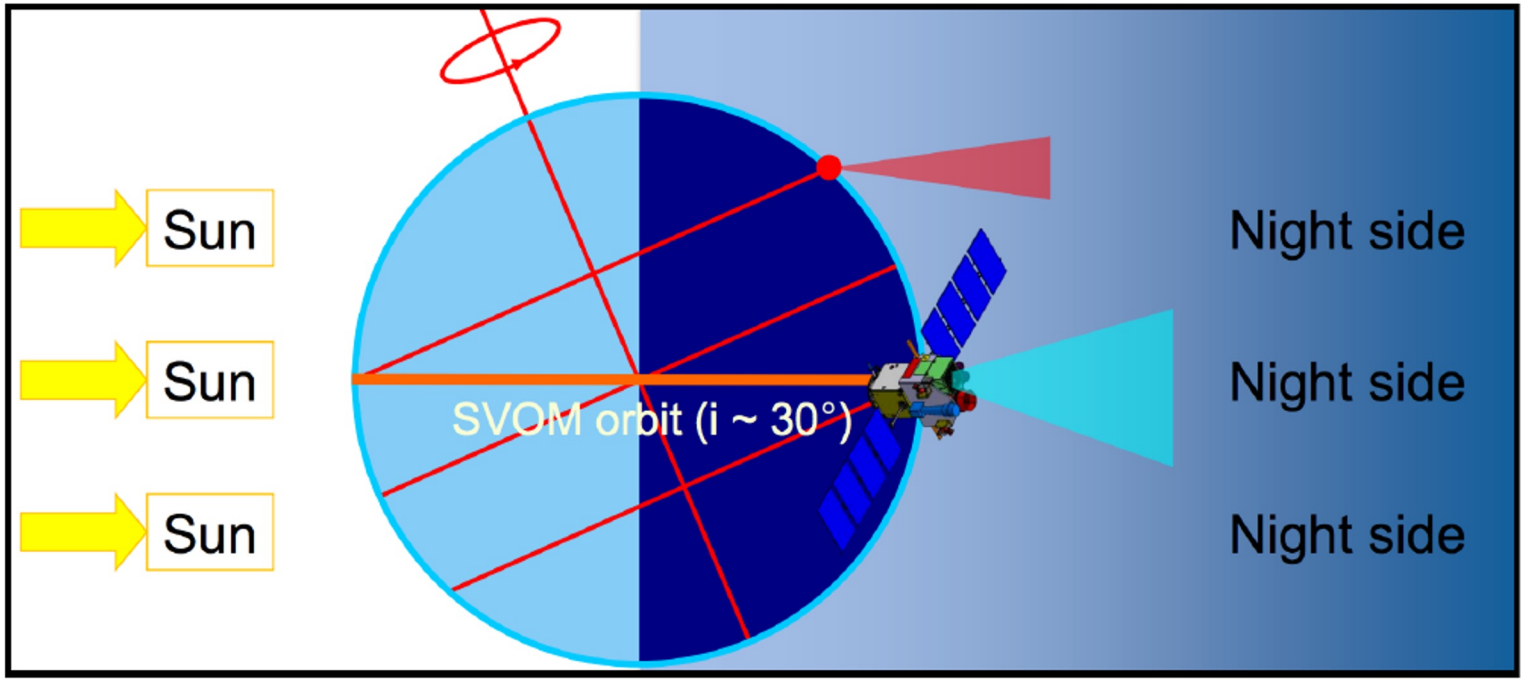

SVOM

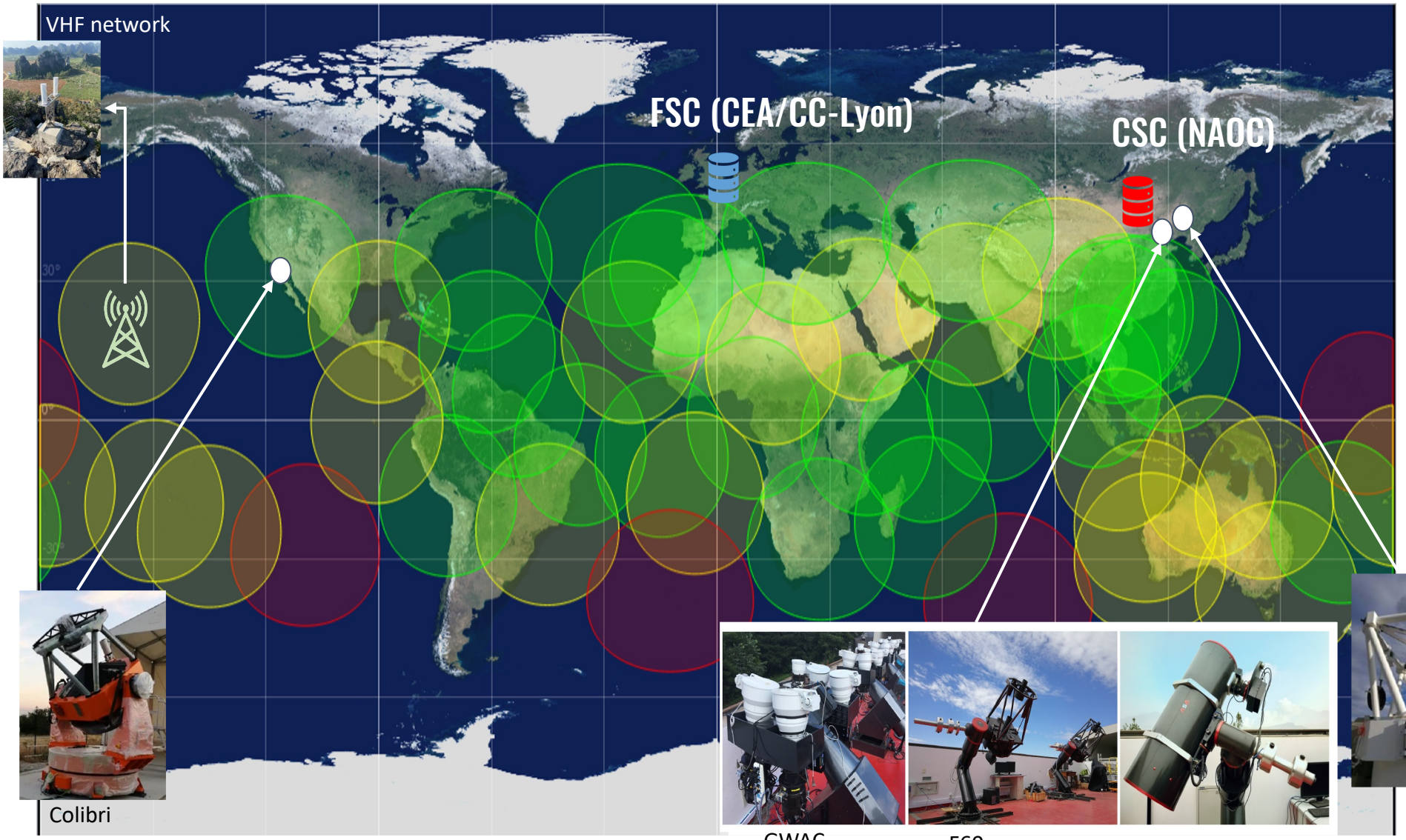
A multi wavelengths mission
Including a satellite :

- 4 multi-wavelength instruments (ECLAIRs, GRM, MXT, VT)
- Trigger on gamma-ray events (4-150keV & 15keV-5MeV)
- Real-time ECLAIRs and GRM trigger alerts broadcasted on ground via a VHF antenna network
- Automatic follow-up sequence on board (slew & fast x-ray/opt follow-up with MXT and VT)
- Capability to perform quick ToO via VHF and BeiDou systems with MXT and VT instr.

# SVOM orbit and pointing law

- **Launch from Xichang by a LM-2C rocket**
  - Low Earth Orbit (625 km, 96 min), 30° inclination
  - 1 orbit in 90 minutes
- **Nearly anti-solar pointing to facilitate follow-up observations from ground**
  - Redshift measurement for ~2/3 of detected GRBs
  - Earth in the FoV: 65% duty cycle for ECLAIRs (50% for MXT and VT)
  - ECLAIRs FoV: avoidance of Galactic plane and Sco-X1
- **Repointing in <5 min, GRB follow-up up to 14 orbits (~1 day)**
  - Slew capability : 9deg/min including arcsec stabilization





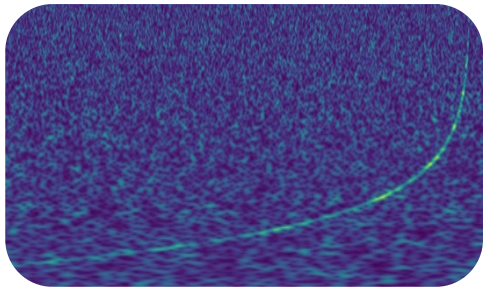

A multi wavelengths mission
Including a ground segment :

- A Very High Frequency (VHF) antenna network to communicate (downlink only) in real-time with the satellite – Beidou system under review
- optical/IR dedicated robotic follow-up telescopes + partnership with (TAROT, LCOGT, NOT2.5m, Xinglong2.12m, Lijiang 2.4m + ....

VHF : 65 % of the alerts within 30s on ground – X-band (full data) within 12h

# Science topics

***Target-of-Opportunity Program (ToO)***



***Multi-messenger astronomy***

- EM counterparts from GW sources (GRBs & kilonovae)
- EM counterparts from external very high-energy triggers (KM3NeT/IC, CTA, MAGIC, HESS, etc.)
- Follow-up of “special” events (FRBs, FBOTs, etc.)
- Other scientific opportunities….

***Mission Core Program (CP)***

***Gamma-ray Burst science***

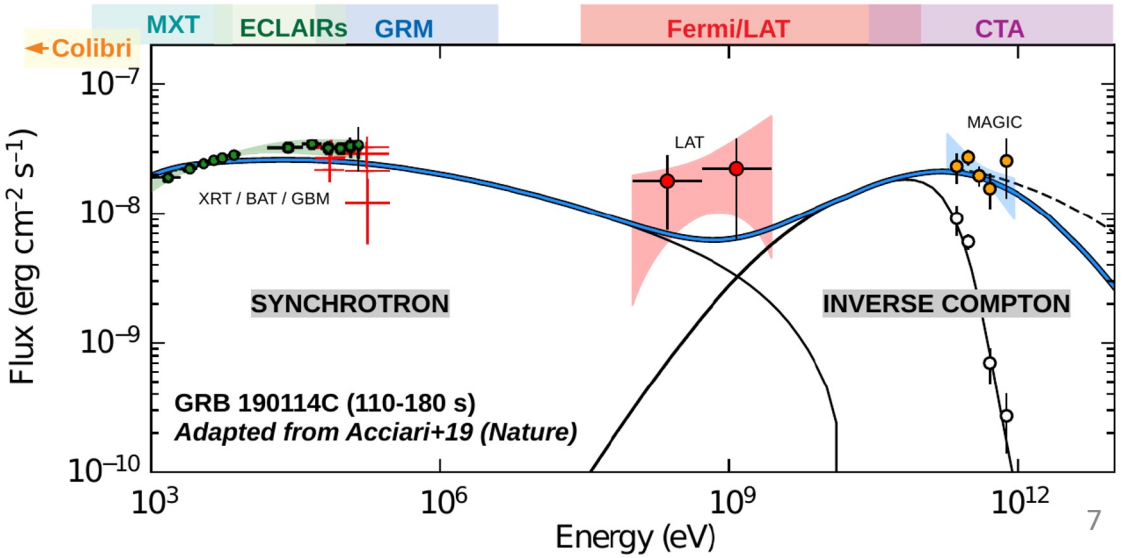
- GRB physics (prompt & afterglow, progenitor systems, etc.)
- GRB environment (host and ISM)
- Star formation history (high-z GRBs)
- Cosmology

***General Program (GP)***

***SVOM as an open Observatory***

Any science that would require the SVOM instrument capabilities

Open call for proposals



# SVOM timeline and mission programs

***Nominal mission (3 years / expected launch date : fall 2023)***

*Target-of-Opportunity Program (ToO)*

***15% mission time***
***up to 1 ToO/day***

*Mission Core Program (CP)*


*General Program (GP)*


***Extended mission (2 years / End of mission : 2028)***

*Target-of-Opportunity Program (ToO)*

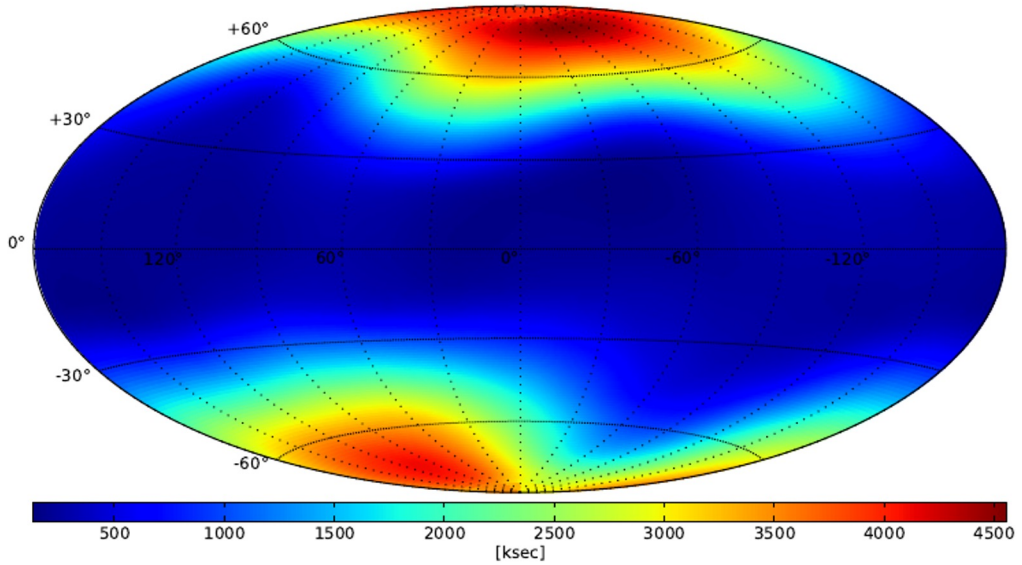
***40% mission time***
***up to 5 ToO/day***

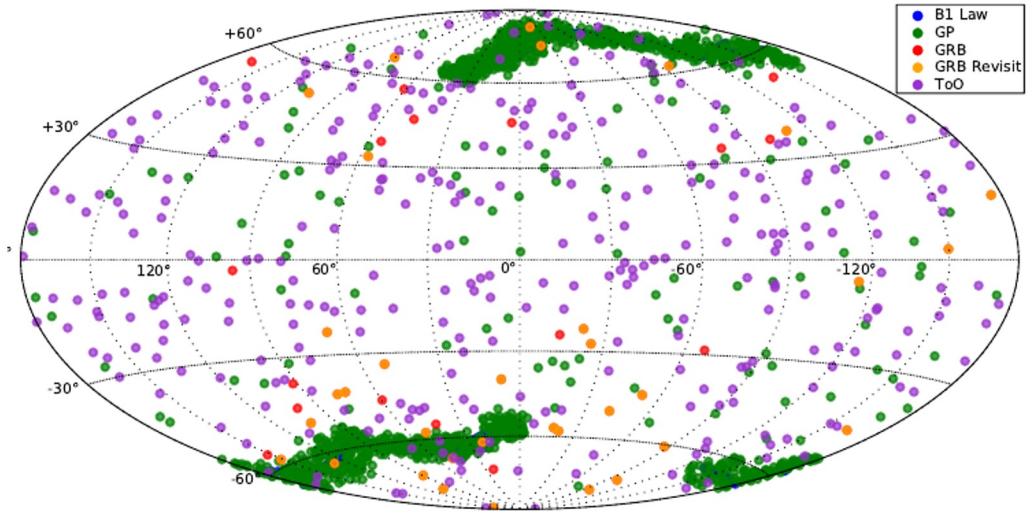
*Mission Core Program (CP)*


*General Program (GP)*

# One year of simulated observations

- **Following the B1 attitude law**
  - Including 65 GRBs & 1 ToO / day
- **ECLAIRs sky exposure**
  - ~4 Ms near the galactic poles
- **MXT and VT pointing direction**




Galatic coordinates

# ECLAIRs : gamma-ray imager

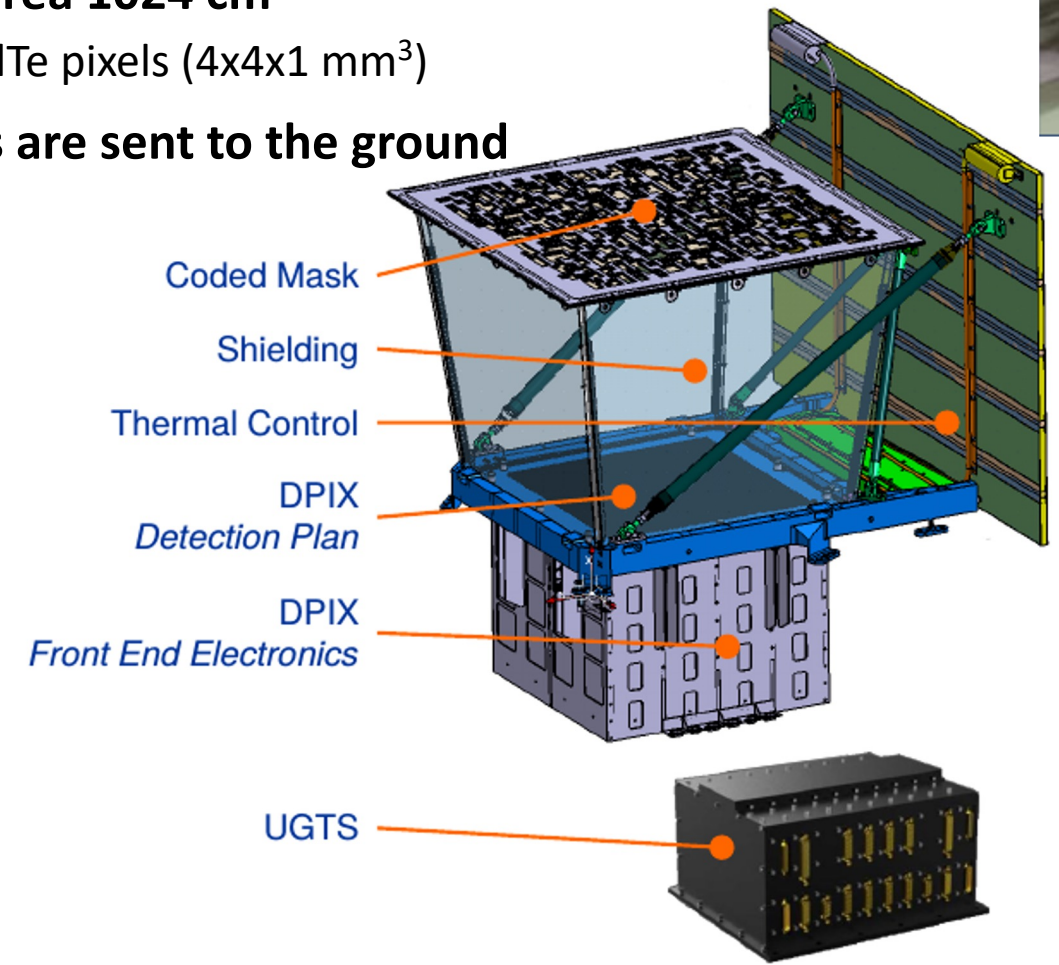
**54x54 cm² coded mask**

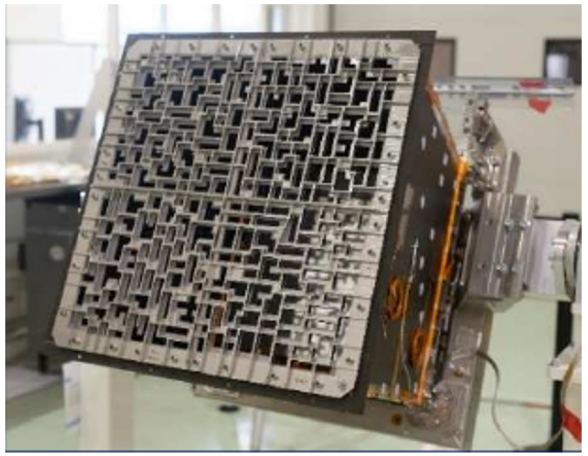
- 40% open fraction
- 46 cm above detection plane

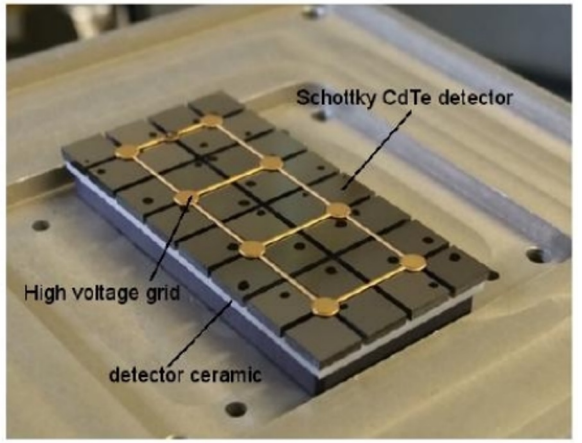
**Detecting area 1024 cm²**

- 6400 CdTe pixels (4x4x1 $mm^3$)

**All photons are sent to the ground**



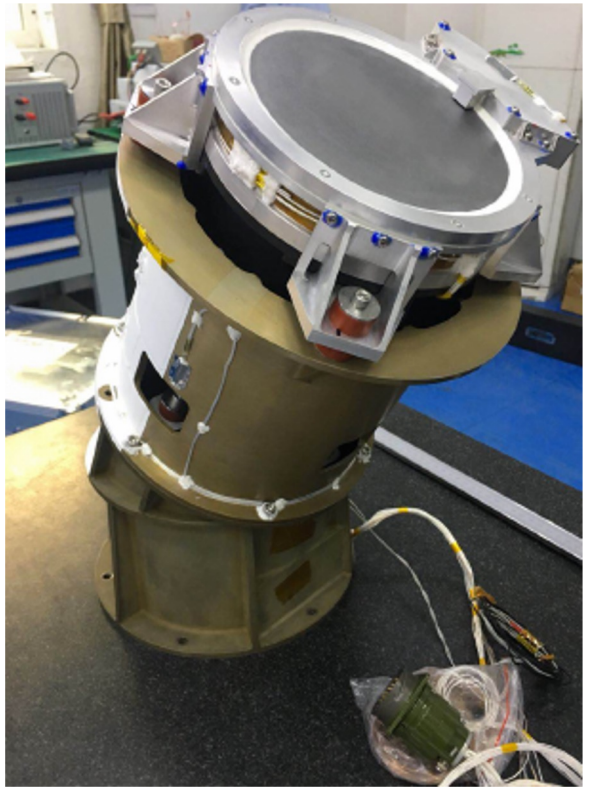



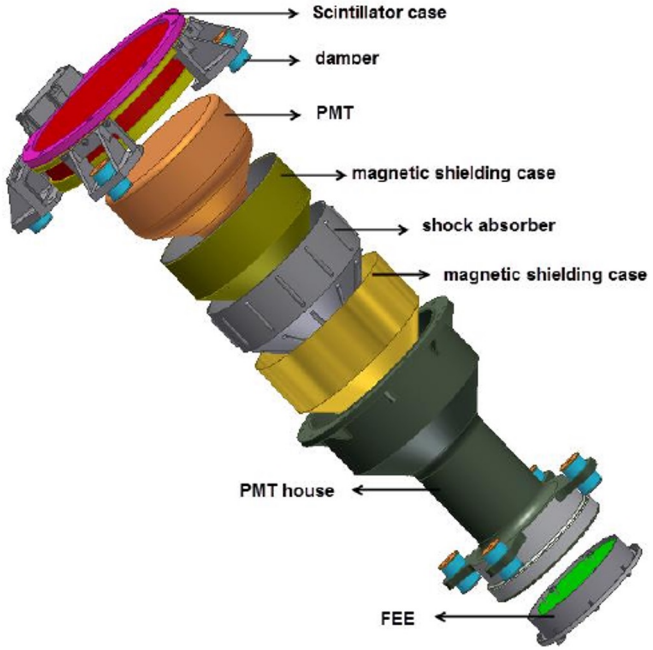


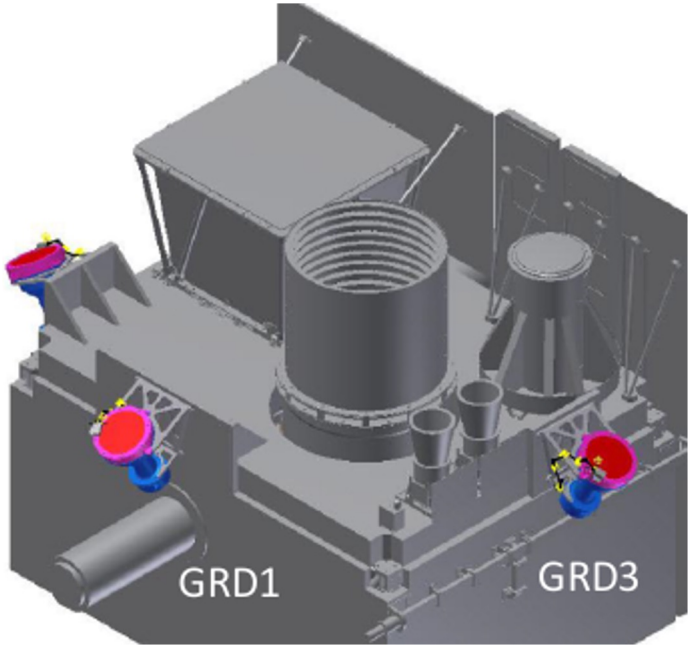

- **Onboard trigger and localization**
  - Strongly varying background modulated by Earth transit through the FoV every orbit
  - Time scales from 10 ms to 20 min
  - 4 energy bands, 9 detector zones
  - Rate trigger and image trigger
- **Performance**
  - FoV ~ 2 sr total
  - Energy range: 4-150 keV
  - Energy resolution <1.6 keV @60 keV
  - $A_{eff}$ = 200 cm² @6 keV
  - Localisation accuracy <12' for 90% of the sources at detection limit

# Gamma-Ray Monitor (GRM)

- **3 Gamma-Ray Detectors (GRDs)**
  - NaI(Tl) (16 cm Ø, 1.5 cm thick)
  - Plastic scintillator (6 mm) to monitor particle flux and reject particle events
  - 30° inclination w.r.t. ECLAIRs optical axis

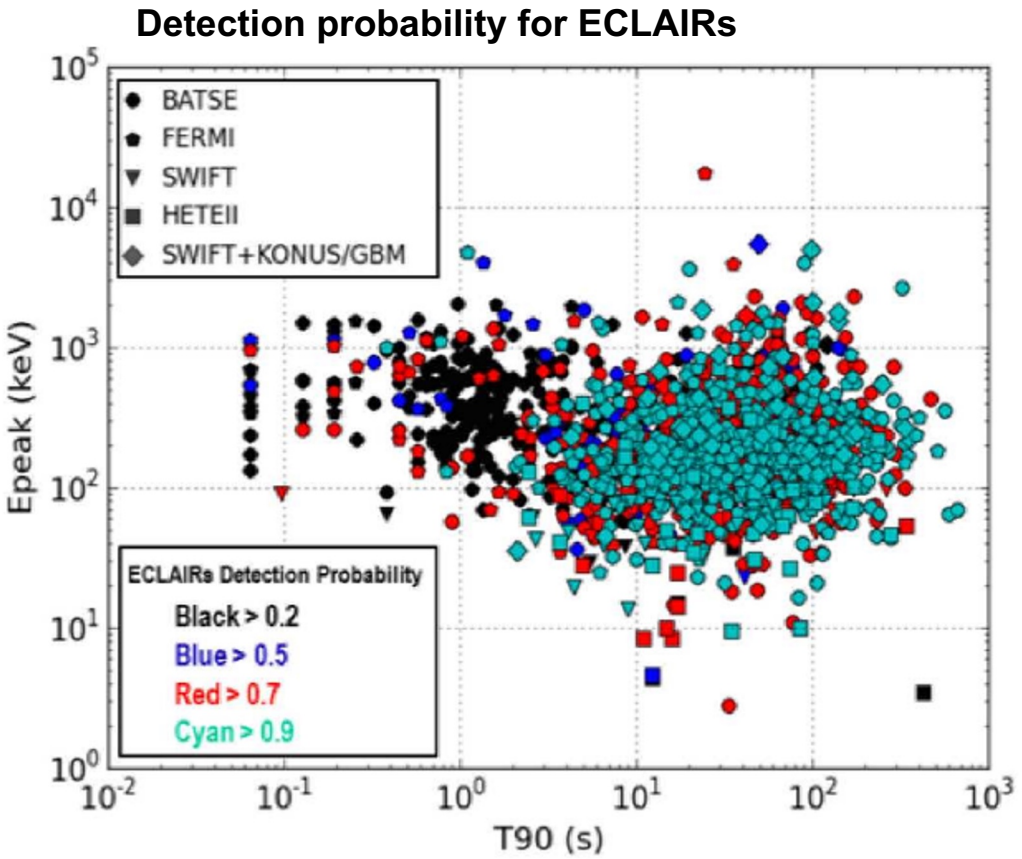




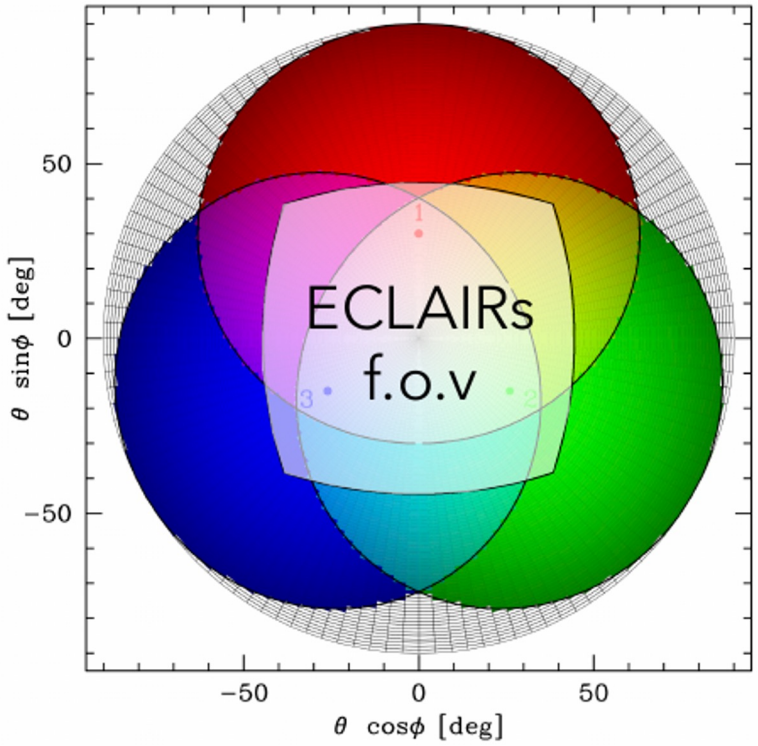




- **Onboard rate trigger (2 GRDs)**
- **Performance**
  - FoV ~ 5.6 sr (~2 sr per GRD)
  - Energy range: 15-5000 keV
  - $A_{eff}$ = 190 cm² at peak (each unit)
  - Rough localization accuracy

# GRB detection

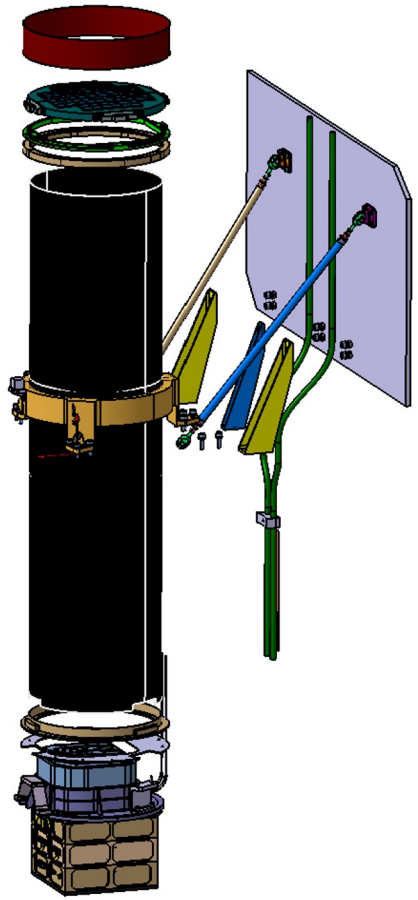


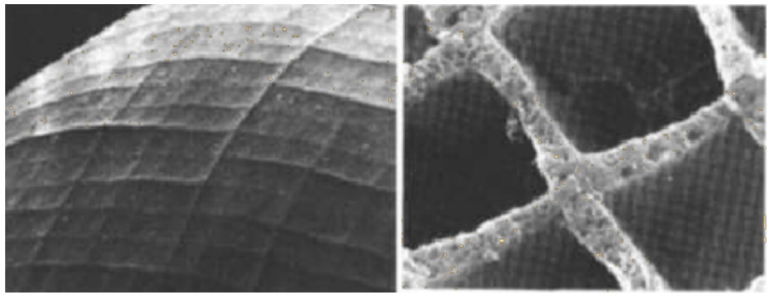

- **ECLAIRs is sensitive to all classes of GRBs**
  - Classical long GRBs
  - Soft GRBs (XRR, XRF)
  - Short GRBs (with a moderate efficiency)
  - **42 to 80 GRBs / year**
  - **Including 3-4 GRBs / year at z>5**
  - **Loc. <12'**



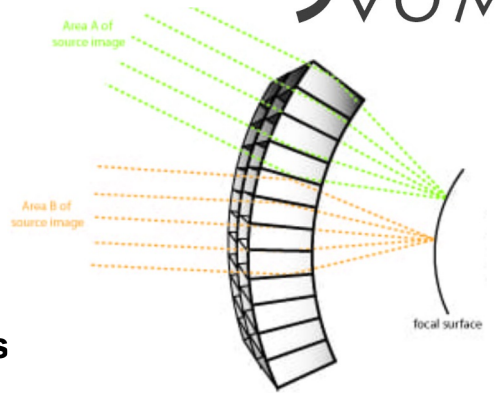

- **GRM has a larger FoV than ECLAIRs**
  - **~90 GRBs / year**
  - **Loc. ~ 5-10 deg (3 GRDs)**
  - ECLAIRs sensitivity to short GRBs can be improved when combined with the GRM

# The Micro-channel X-ray telescope

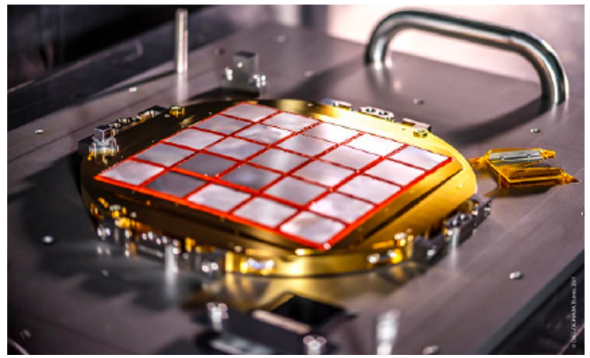





Real vs. manufactured “lobster eyes




- **Micro-channel plate optics**
  - 20 micron size pores in a “lobster eye” configuration
  - Focal length: 1 m
  - pnCCD camera (256x256 pixels of 75 microns)

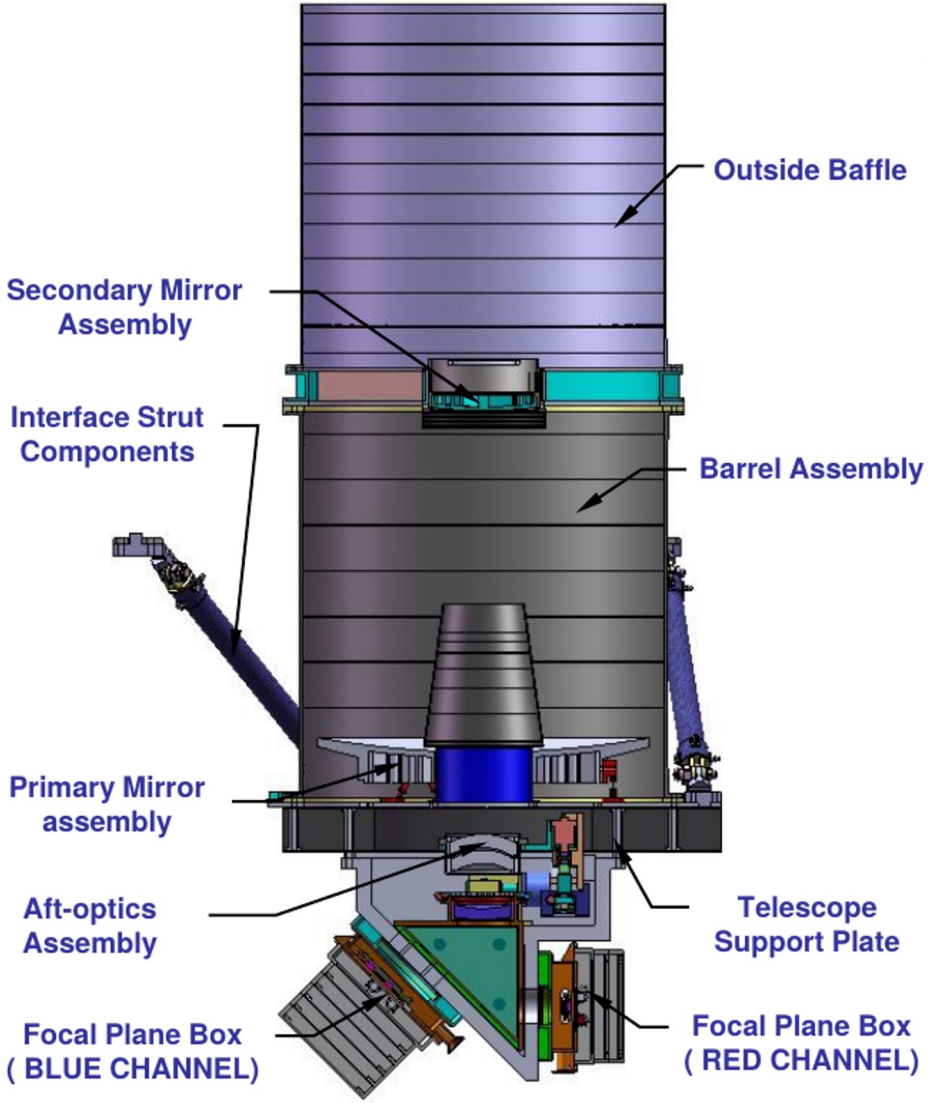


- **Performance**
  - FoV = 64x64 arcmin²
  - Energy range: 0.2-10 keV
  - Energy resolution ~60 eV @5.9 keV
  - $A_{eff}$ = 27 cm² @1 keV (central spot)
  - Localization accuracy <13” within 5 min from trigger for 50% of GRBs

# The Visible Telescope

- **Ritchey-Chretien telescope**
  - 40 cm Ø, f=9
  - Focal length: 3.6 m
- 2 channels: blue (400-650 nm) and red (650-1000 nm)
- 2k * 2k CCD detector each

- **Performance**
- FoV 26x26 arcmin²
- → covering ECLAIRs error box in most cases
- Sensitivity $M_V$=22.5 in 300 s
- → will detect ~80% of ECLAIRs GRBs
- Localization accuracy <1”



# Ground segment telescopes

- **Ground-based Wide Angle Camera (GWAC)**
  - 36 camera units covering 5400 deg² (~1/2 ECLAIRs FoV)
  - Installed in Ali (China) and CTIO (Chile)
  - 500-800 nm; $m_{lim}$=16-17 (10 s exposure)
  - Explore the prompt optical emission
  - Also F30 and F60 telescopes for follow-up

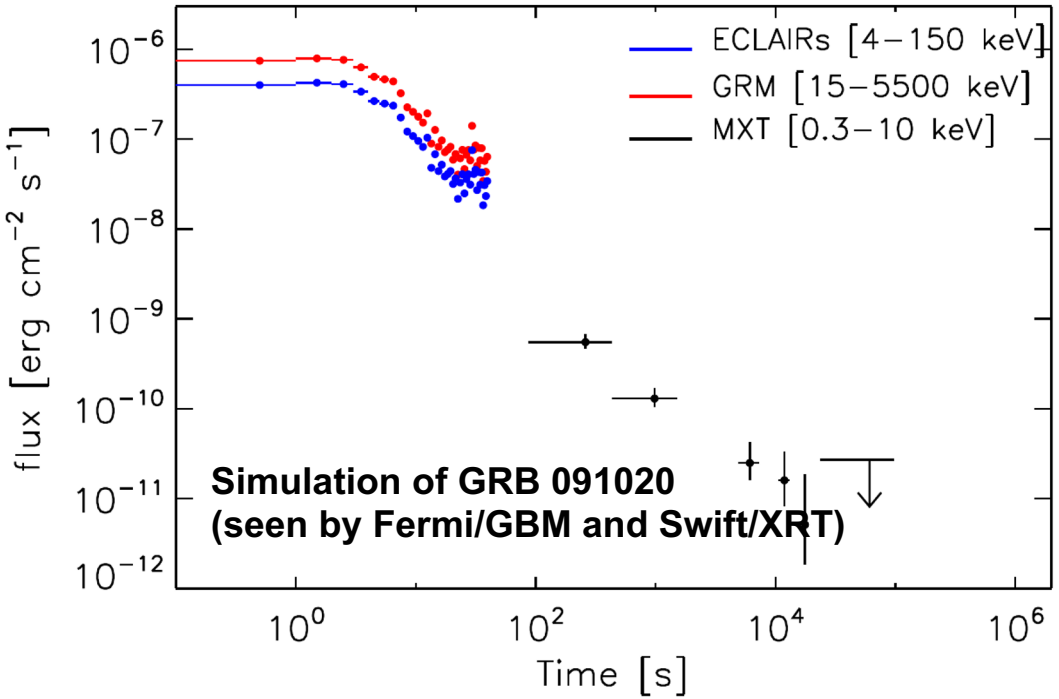
- **Ground Follow-up Telescopes (GFTs)**
  - Robotic 1-m class telescopes (fast repointing, <30 s)
  - San Pedro Martir (Mexico) and Xinglong observatory (China)
  - C-GFT: 1.2 m, FoV = 21x21 arcmin², 400-950 nm
  - F-GFT (a.k.a. Colibri): 1.3 m, FoV = 26x26 arcmin², multi-band photometry (400-1700 nm, 3 simultaneous bands)
  - Accurate GRB localization → observations with large telescopes

- **Agreement to use the LCOGT network**
- **>75% of ECLAIRs GRBs immediately visible by one ground telescope (GFTs+LCOGT)**
- **Early observation by large telescopes favored by pointing strategy → redshift measurement expected in ~2/3 of cases**

# GRB afterglow emission

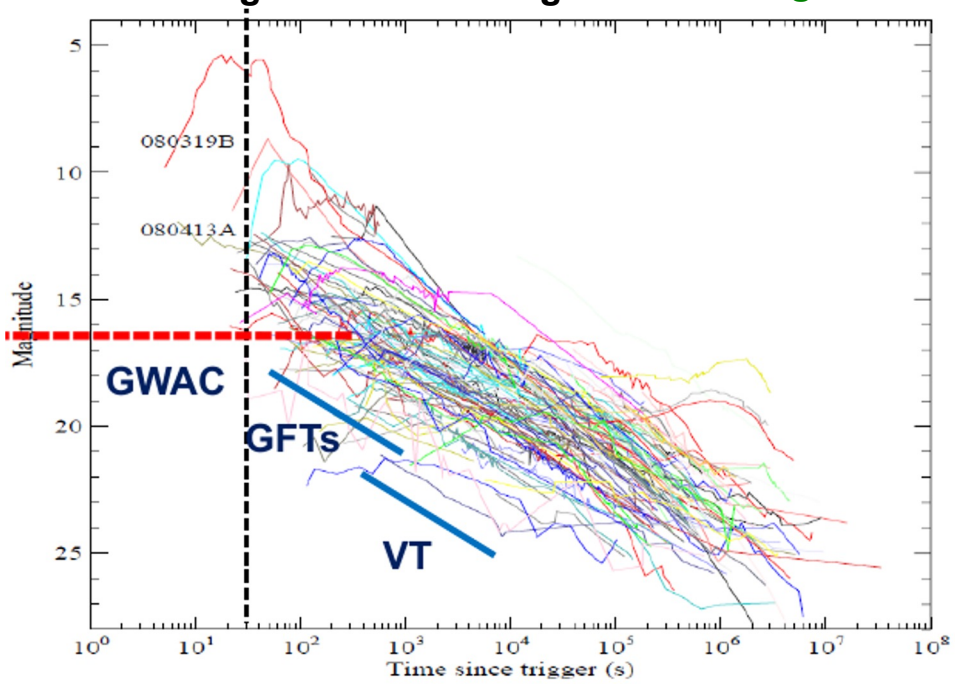
- **ECLAIRs will cause a slew of the satellite for 36-72 GRBs / year**

- **MXT will detect and localize the X-ray afterglow in >90% of GRBs after a slew**




- **VT, C-GFT and F-GFT will detect, localize and characterize the NIR / visible afterglows**
- **(lightcurve + photo-z)**

**Visible light curves of long GRBs** Wang+2013



# GRB sample

- **A unique sample of 30-40 GRBs / year with**
  - Prompt emission over 3 decades (+ optical flux/limit: 16%)
  - X-ray and visible / NIR afterglow
  - Redshift

| | Swift | Fermi | SVOM |
|---|---|---|---|
| **Prompt** | Poor | Excellent<br>8 keV -100 GeV | **Very Good**<br>**4 keV - 5 MeV** |
| **Afterglow** | Excellent | > 100 MeV for LAT GRBs | **Excellent** |
| **Redshift** | ~1/3 | Low fraction | **~2/3** |

- **Physical mechanisms at work in GRBs**
  - Nature of GRB progenitors and central engines
  - Acceleration, composition, dissipation & radiation processes of the relativistic ejecta
- **Diversity of GRBs: event continuum following the collapse of a massive star**
  - Low-luminosity GRBs / X-ray rich GRBs / X-ray Flashes and their afterglow
  - GRB/SN connection
- **Short GRBs and the merger model**
  - GW association / Short GRBs with extended soft emission
- **GRBs as a tool to study the distant Universe**

# SVOM data policy

## Core Program (GRB)

**Real-time VHF scientific products** (under the supervision of the Burst Advocates) will be **public as soon as they are available** => similar to Swift or Fermi-GBM.

All the **scientific products are public six months** after the data production.

## General Program (GP)

**Semester Call for proposal** (**in association with a SVOM Co-I**), it can include ToO.

All the SVOM data will be distributed to the Responsible Co-I.

**One year of proprietary period** before all the scientific products become public.

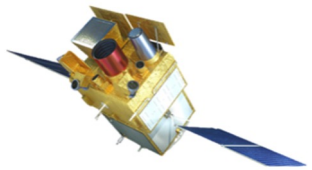
## ToO Program (still under discussion)

**ToOs triggered by the SVOM CO-Is** => we will make **publicly available as soon as possible** any scientific product that is relevant to perform follow-up observations. The number of products to be publicly released will be addressed case by case.

**ToOs triggered by non SVOM CO-Is** => **all the scientific products will be public** as soon as they are available.

- First SVOM BA GCN Circulars should arrive within 30 minutes after the trigger time

# Real Time alert for GRB



space to ground

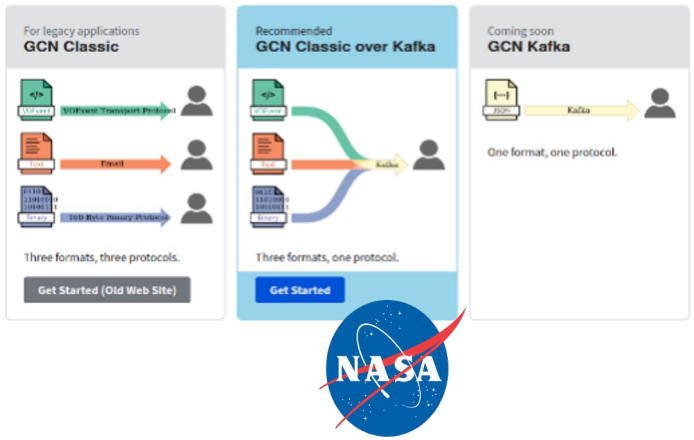
VHF antenna location to SVOM/FSC

**- 30s to reach the subscribers**
**- All VHF scientific products are public!**
**- The content of the SVOM alert notices is now under construction (VOEvent)**

**SVOM Real-time alerts system**
at the French Science Center
(CC Lyon/IN2P3)

broadcast

we are going to follow the GCN notices system to quickly broadcast our alerts




broadcast

we also have our own SVOM alert broker (Comet broker sending VOEvent messages) at the SVOM/FSC

**Alert subscribers**

**FSC**

# ToO program

***ToO nominal***

- 1/day
- Allocated time : 1 orbit (~45min)
- Max latency : 24-48h
- Instr: MXT and VT

***ToO MM***

- 1/week
- Allocated time : 1-14 orbits (24h max)
- Max latency : 12h (S-band) / <4h (BeiDou)
- Instr: MXT and VT

***ToO Exceptional***

- 1/month
- Allocated time : 7-14 orbits (24h max)
- Max latency : 12h (S-band) / <4h (BeiDou)
- Instr: MXT and VT

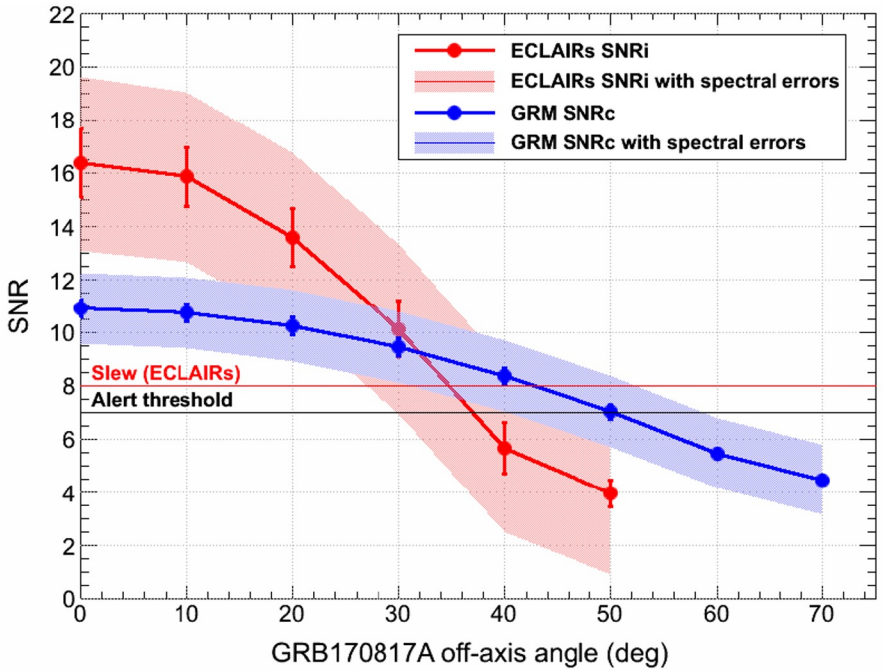
**Open-access**

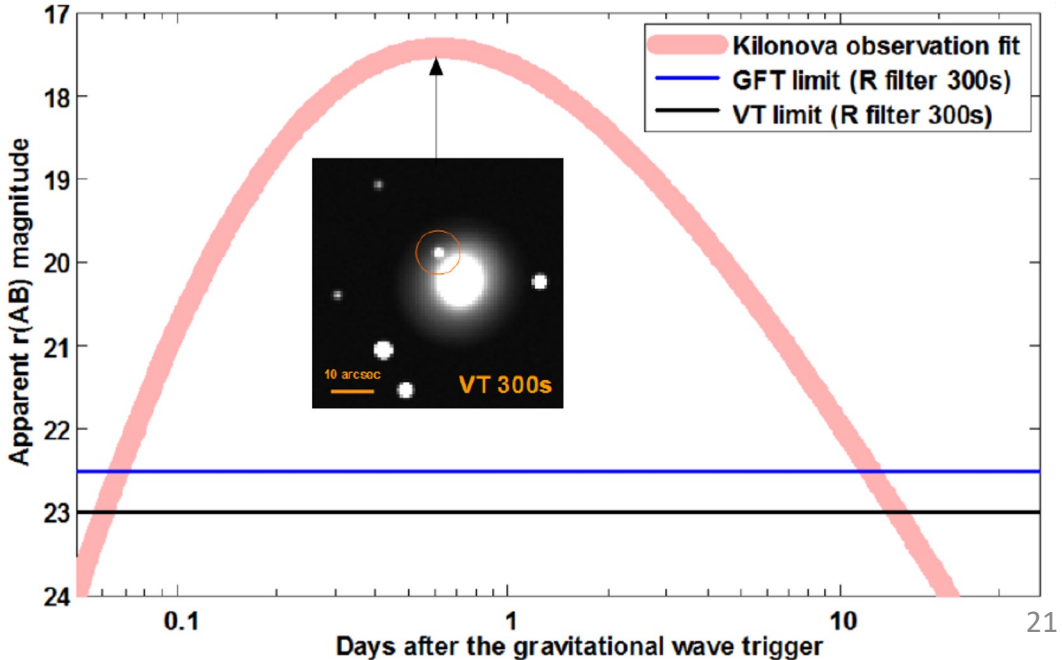
**100% of the scientific products will be delivered to the scientific community as soon as they are available**

**100% of the informations that are needed to trigger external follow-ups will be publicly available as soon as possible (within few minutes)**

# SVOM expected signal with GW170817/GRB170817A

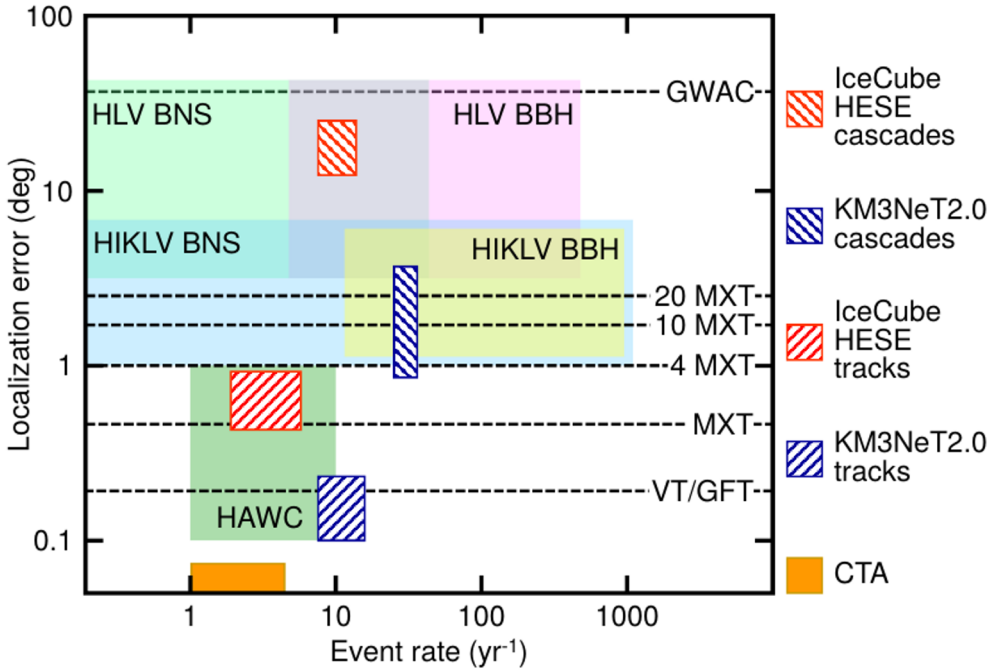
- **It the GRB appeared in ECLAIRs or GRM field of view**
  - ECLAIRs & GRM detection with high probability → slew request sent by ECLAIRs
  - MXT and VT follow-up observations → kilonova easily detected by the VT
- **If not in ECLAIRs and GRM field of view**
  - LIGO-Virgo alert received at the French scientific center → GFT observations triggered, nearby galaxy targeting within the GW error contour (several observation cycles)
  - Thanks to its NIR channel, Colibri would certainly have detected the kilonova

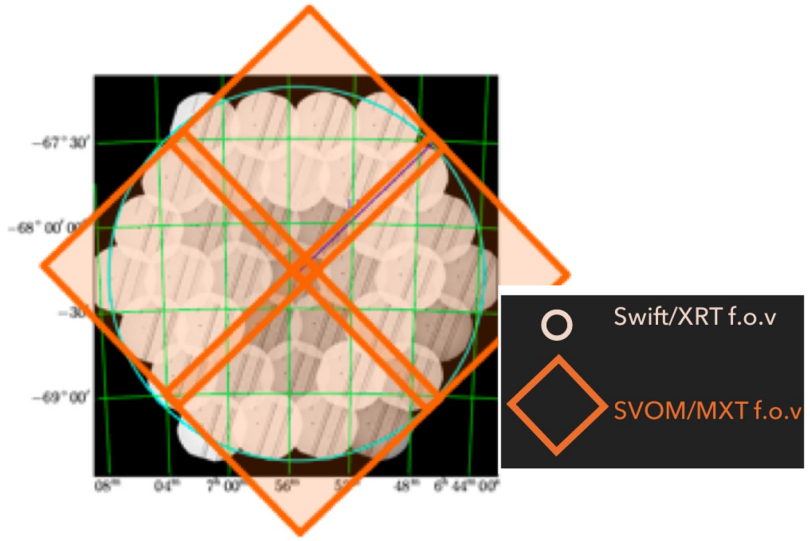


# MM strategy

- **Search for X-ray / visible counterparts to MM events with MXT and VT**
  - Examples: Gravitational Wave sources (large error boxes), kilonova / afterglow (expectations depend on the viewing angle), neutrinos, VHE transients
  - Requires a tiling strategy




- **Search for NIR / visible counterparts to MM events with the GFTs**
  - Search: galaxy targeting within error box
  - Photometric follow up to characterize the counterpart (e.g. kilonova from BNS): requires accurate localization (<30')

# Conclusions

- SVOM will be a versatile observatory from IR to GeV energies and will monitor the transient sky
- 60-90 GRBs detected/year with a 24h continuous follow-up
  - Excellent temporal and spectral coverage of the prompt and afterglow emission
  - Optimized strategy to measure redshift
- A dedicated program for MM astrophysics with 1 ToO/week
  - Optimizing the follow-up strategy using tiling
  - Collaboration on-going with tools like Fink
- Starting in 2023 SVOM will be one of the major actor in the GW follow-up

**Qualification Model of SVOM satellite**

# LATENCY SUMMARY