CEA-Irfu, Saclay
IAP, Paris
APC, Paris
CNES, Toulouse
NAOC, Beijing
XIOPM, Xi'an
IHEP, Beijing
SECM, Shanghai
IRAP, Toulouse
LAM, Marseille
CPPM, Marseille
GEPI, Meudon
LAL, Orsay
LUPM, Montpellier
University of Leicester
MPE, Garching

The SVOM mission

a pathfinder for THESEUS

Bertrand Cordier
CEA-Saclay/Irfu, France

On behalf of the SVOM consortium

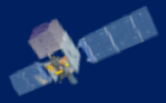
Open Questions

GRB studies

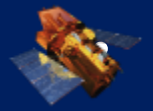
- Progenitors and central engines
- The physics of the relativistic ejecta
- Multi-messenger emission

Using GRBs as a tool for cosmology

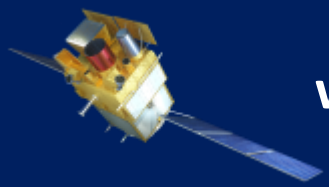
- Spectroscopy of the line of sight
- Host galaxies
- Very distant GRBs : first stars/reionization of the intergalactic medium ?



Fermi : short GRBs and excellent coverage of the prompt emission



Swift : study of the afterglow and measurement of the redshift



Build a homogeneous sample of GRBs with a good time and spectral coverage With redshift measurement

SVOM

SVOM: Space-based multiband astronomical Variable Objects Monitor

Satellite to be launched in 2021, mini satellite class

MXT

ECLAIRs

VHF Network
S, X Band antenna

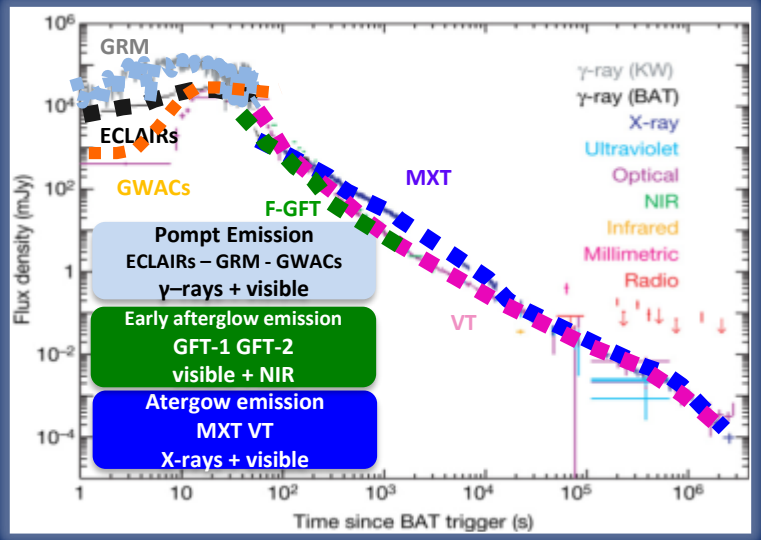
GRM

GWAC

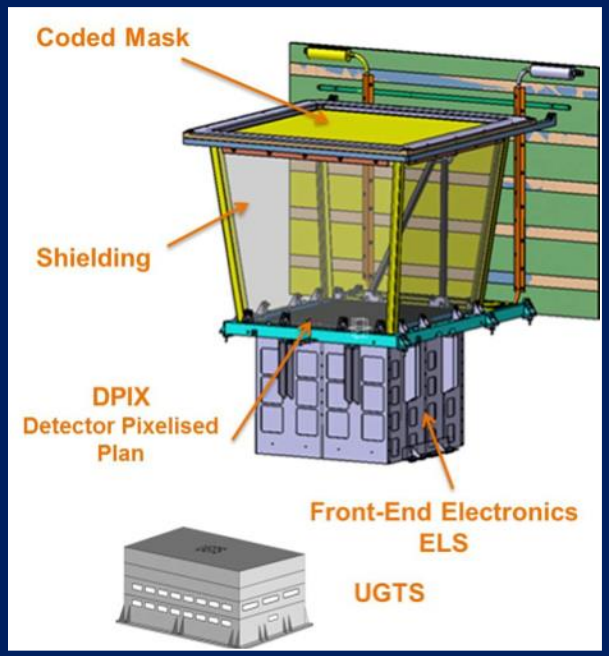
VT

GFT-1

GFT-2



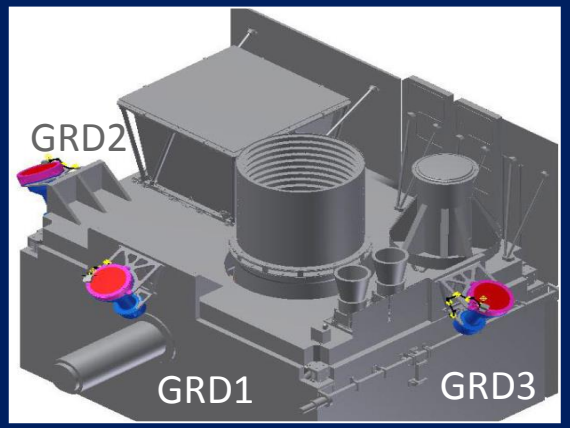
ECLAIRs - Trigger Camera



Coded mask telescope	60 GRBs/yr
Energy band	4-150 keV
FOV	2 sr
Mask	Open fraction = 0.4
Detector	6400 CdTe pixels - 4x4x1mm^3
Onboard processing	Count-Rate and Image Triggers
Localisation acc.	14’ at detection threshold 3’ for bright sources

GRM - Gamma Ray Monitor

3 NaI detectors (GRDs)	90 GRBs/yr
Energy band	15 keV – 5 MeV
FOV	2 sr per GRD
Detector	200 cm^2 (NaI, 1.5 cm thick)
Onboard processing	Count Rate Trigger
localisation accuracy	> 10°



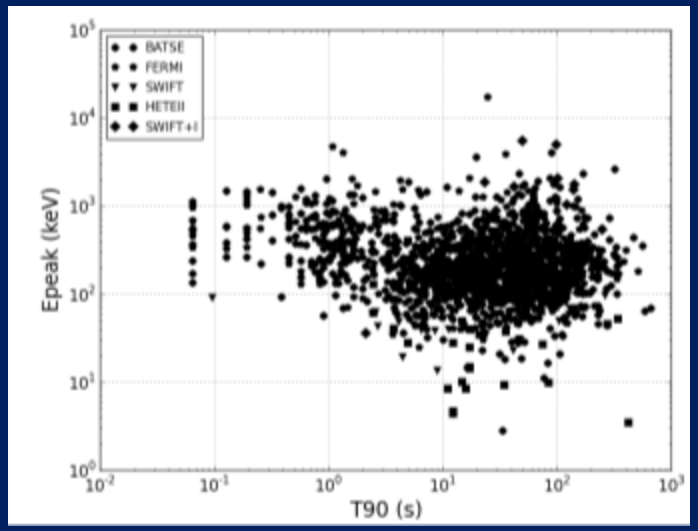
Caracteristics of the GRBs seen by ECLAIRs

- Number of GRBs detected by ECLAIRs:
- 64 ± **18 GRBs/yr at the alert threshold and 56 ± 18 GRBs/yr at the slew threshold**
- Same proportion of short GRBs as Swift/BAT (8%) : **5±1 GRBs/yr**

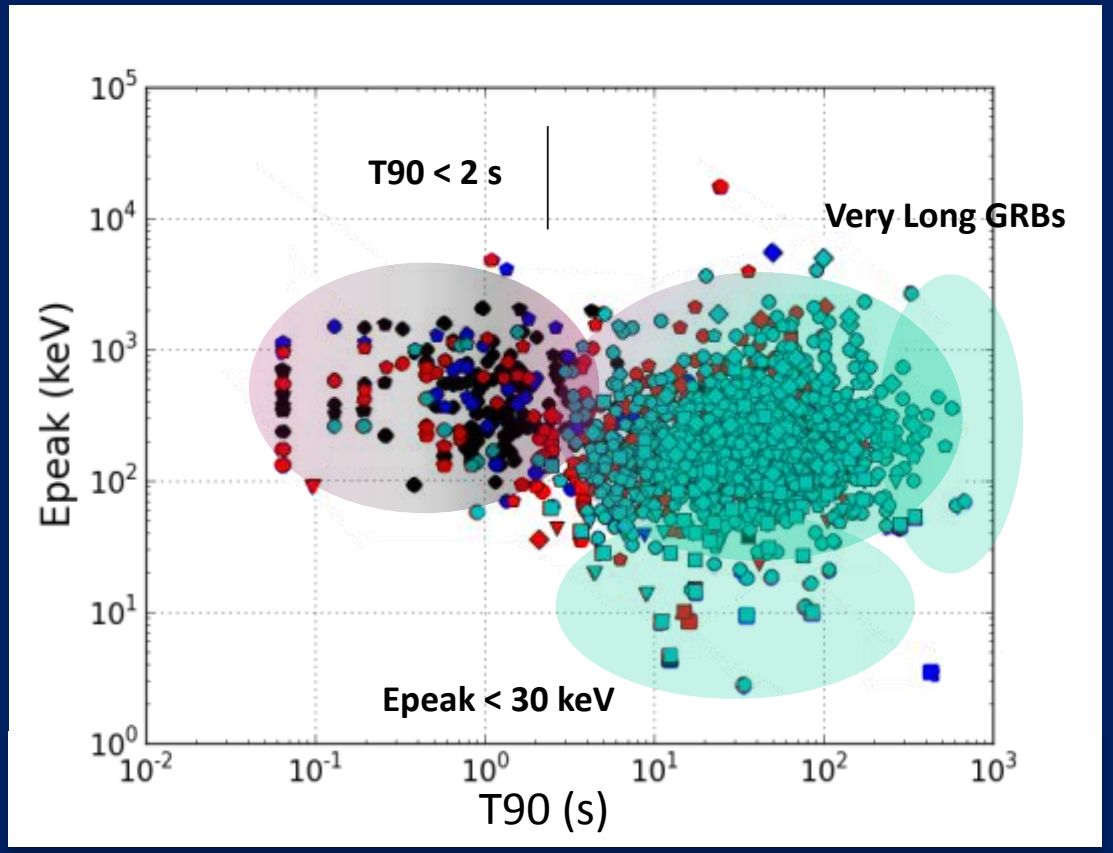
Symbol
BATSE
FERMI
SWIFT
HETEII
SWIFT+*

*Konus or GBM

ECLAIRs > ε_{GRB}
Black > 0.2
Blue > 0.5
Red > 0.7
Cyan > 0.9



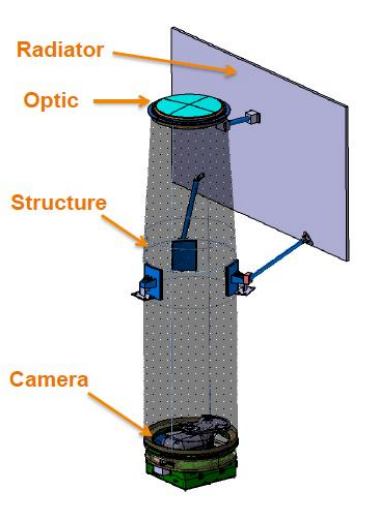
Input catalogs



ECLAIRs will be sensitive to all known GRBs

S.Antier, F.Daigne, S.Schanne et al. (2016)

MXT – Micro-channel X-ray Telescope

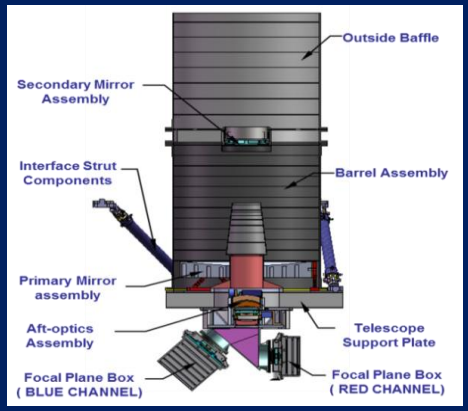


Micropore Optics (MPO) "Lobster eye"	
FOV	~ 1 deg^2
Focal Length	~1 m
Camera	256x256 PN CCD 27 cm^2 at 1 keV
Energy Band	0.2 – 10 keV
Onboard processing	sources positions
Localization accuracy	< 2' < 30'' bright sources

90% of ECLAIRs GRBs observable

VT - Visible Telescope

Ritchey Chretien Telescope	
Diameter	40 cm
2 channels	400 nm–650 nm (blue) 650 nm–950 nm (red)
Limiting Magnitude	22.5 (5σ, 300s)
FOV	26' x 26'
Spatial resolution	0.77''
Onboard Processing	List of potential transient srcs.



GWAC – Ground Wide Angle Cameras

12% of ECLAIRs GRBs observable

Set-up with 36 cameras	
Diameter	18 cm
Focal Length	22 cm
Camera	4k x 4k CCD detectors
Wavelength	500-800 nm
FOV	5000 deg^2 (63% of the ECLAIRs FOV)
Limiting Magnitude	V=16.5 (5 σ,10s)
Temporal resolution	1s

F-GFT - Ground-based Follow-up Telescope

- **Chinese Ground Follow-up Telescope (C-GFT)**
  - Robotic 1-m class telescope, Xinglong observatory
  - FoV = 21x21 arcmin^2, 400-950 nm
- **French Ground Follow-up Telescope (F-GFT)**
  - Robotic 1.3-m class telescope, San Pedro Martir (Mexico)
  - FoV = 26x26 arcmin^2
  - Multi-band photometry (400-1700 nm, 3 simultaneous bands)
- **Contribution to the LCOGT network (12x1m+2x2m tel.)**
  - >75% of ECLAIRs-detected GRBs immediately visible by one ground telescope (GFTs+LCOGT)

Observation Program:

GRB

Autonomous transient detection by ECLAIRs Top-Down

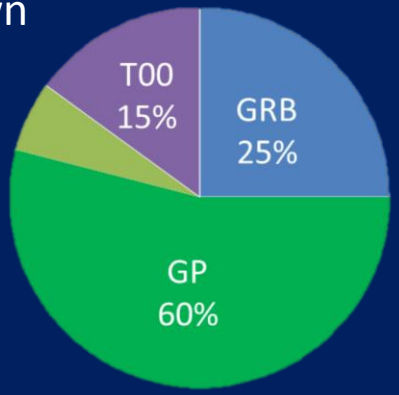
GP

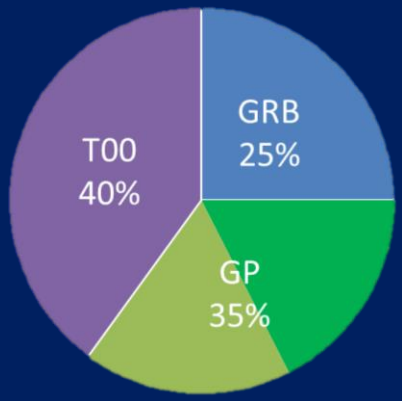
General Program Pre-planned Observations compliant with satellite law

ToO

Target of Opportunity Bottom-Up

Nominal mission





Extended mission

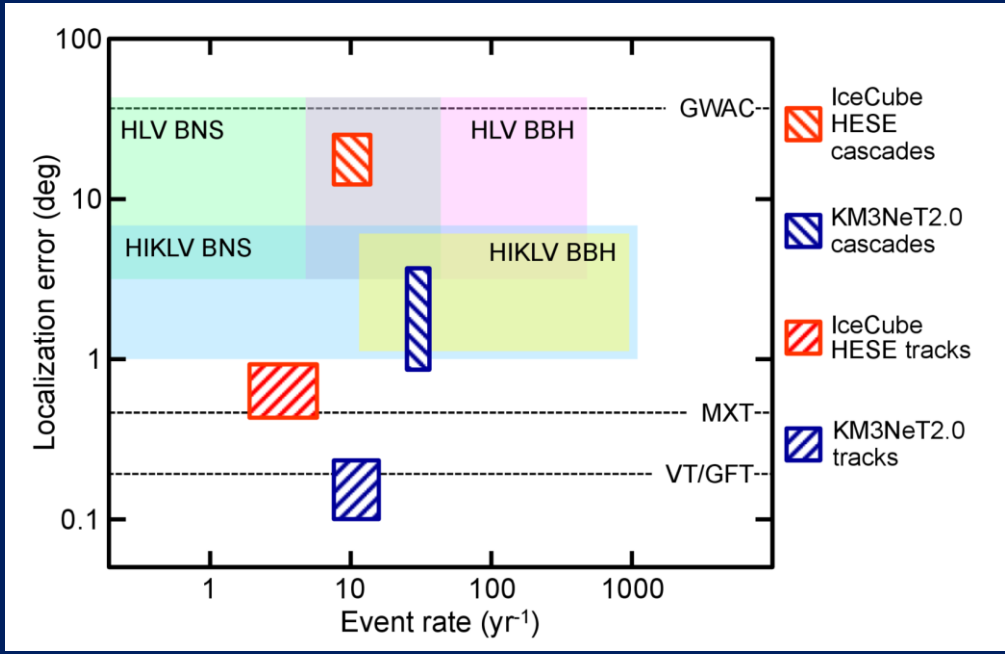
We are currently enlarging the ToO capabilities of SVOM. Very complex operations at system level

	ToO-NOM	ToO-EX/ToO-MM
Frequency	1/day	1/month
Standard delay	< 48h	< 12 h
Duration	> 1 orbit	7 – 14 orbits

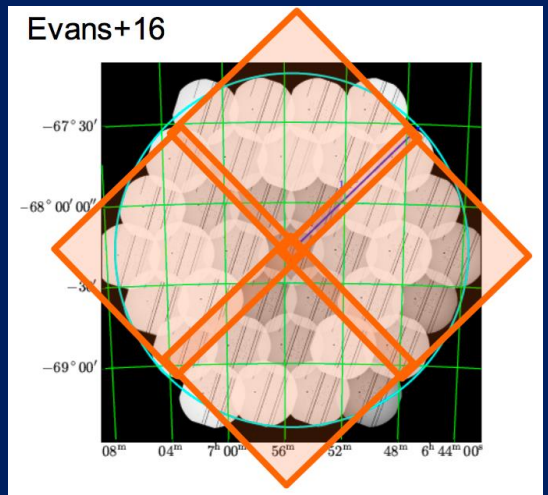
ToO-MM

ToO-MM is the ToO dedicated to EM counterpart search in response to a multi-messenger alert. What differs from the ToO-NOM and ToO-EX is the unknown position of the source within a large error box…

Tiling required !



Swift/XRT more sensituve than MXT but MXT has a larger FOV!



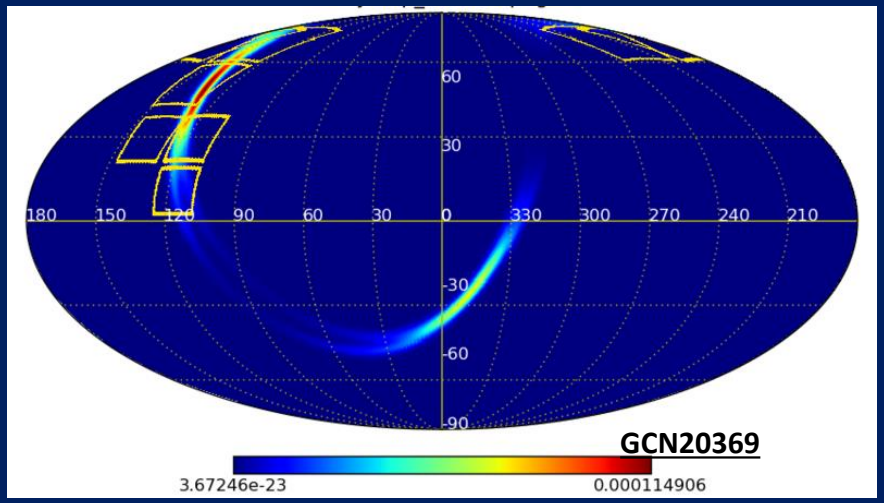
GW astronomy and SVOM

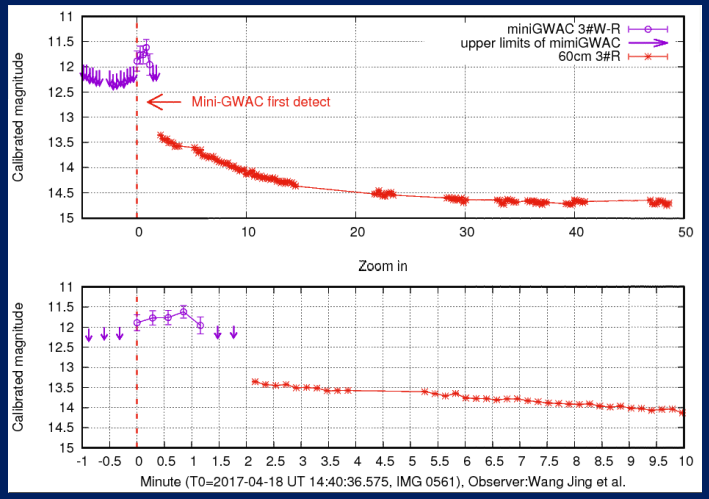
During O2 run: GW170104

Mini-GWAC observations (12 mag):

- Perform routine observations every night
- ToO from GW alerts and Antares neutrino alerts
- **GWAC available at fall 2017 (u.Limit 16 mag)**

Flaire star found by mini-GWAC/60 cm telescope
Wang Jing et al. at 14:40:36 UTC 18/04/2017
(10:45:28.75, 35:51:17.90)





- Starts Observations 2h20 after the GW trigger!
- Bayesien probability coverage: 84.4 %

SVOM performs the Largest Probability coverage for GW170104 in shortest latency for optical band

- No interesting transient found

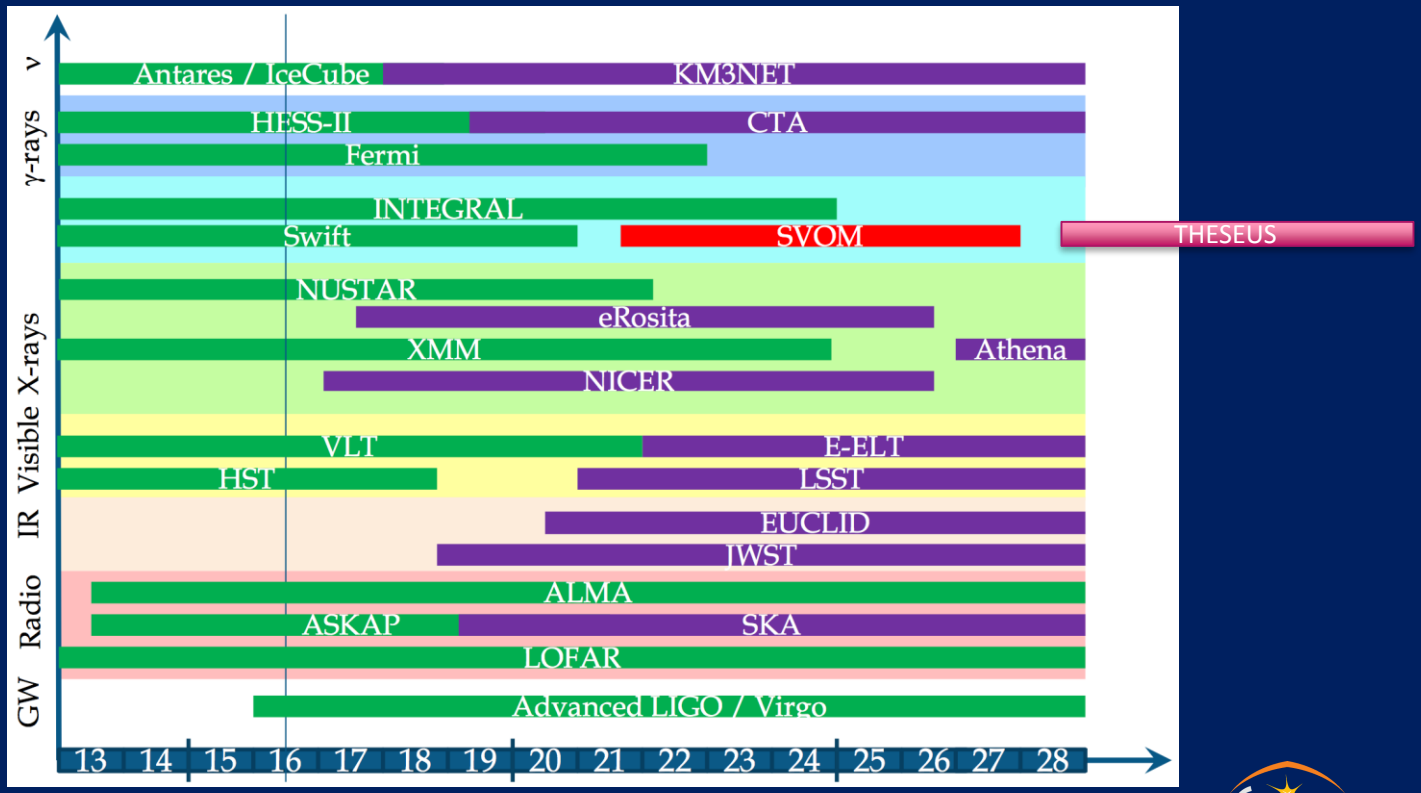
Possible (external) candidate follow-up :

- 2 robotics 60 cm telescopes (GCN20404)
- 1-m telescope (Xinglong)
- 2-m telescope (Xinglong)
- 2.16-m telescope in Lijiang Observatory

Conclusion and perspectives

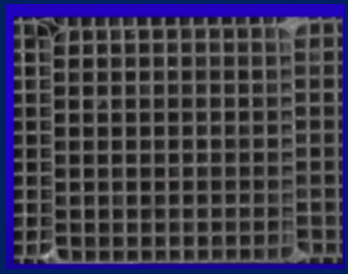
With the time domain and multi-messenger astronomy in strong developments, SVOM is ready to play an important role in the future…

And SVOM will help the development of the THESEUS mission



SVOM as a pathfinder for THESEUS

MPOs validation plan within the MXT project



The MXT optics is a small FOV version of the SXI optics
It is made by 5x5 MPOs of 40 microns of 1-2 mm thickness, 4 cm side

During MXT phase B, PHOTONIS produced Bread Board (BB) MPOs and a complete set of STM MPOs. This programme allowed to validate the :

- inner channel Ir coating (enhancing the reflectivity)
- MPO slumping procedure
- Al MPO surface coating
- thermal constraints constraints for the optic (thermal control is needed) and mechanical interfaces

At the same time, detailed MPO examination allowed the Leicester team to improve the optical model of the MPOs in order to better reproduce the PSF imperfections due to channel deviations → Better design for the THESEUS optices

SVOM as a pathfinder for THESEUS

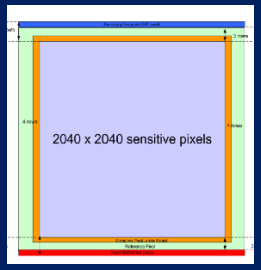
improving the MPOs TRL with the SVOM/MXT project

- The MXT optics BB has been extensively tested in Leicester and at MPE Panter X-ray testing facility facility in July 2016 -> TRL 4-5
- The MXT optics STM will be tested in Leicester and finally validated in Panter in July 2018 –> TRL 6
- In December 2019 (TBD) the MXT optics Flight Module will pass final performance validation in Panter -> TRL 7
- The complete MXT telescope will be tested end 2020 in Panter -> TRL 8
- End 2021-early 2022 MXT will be tested in flight -> TRL 9

SVOM as a pathfinder for THESEUS

Demonstrator of the scientific performance of an IR European detector

In the framework of the ALFA project (Astronomy Large Focal Plane Array) SOFRADIR in collabor
with ESA/CEA /Labex Focus develops a flight quality 2kx2k large-format NIR detector “European



- Dim of pixels : 15 x15 µm
- Spectral range : 0,8 – 3,1 µm
- Quantuma efficiency ≥ 70% over the spectral range
- Operating temperature : <110K
- Readour noise : < 20 e-
- Full frame read out time <1,5s

Development plan of the ALFA project

2016 — PHASE 3 — 2019 — PHASE 4 : optimisation TRL4 -> TRL6 — 2021 — THESEUS

2kx2k Generic TRL4

SVOM/F-GFT : Demonstrator on the sky

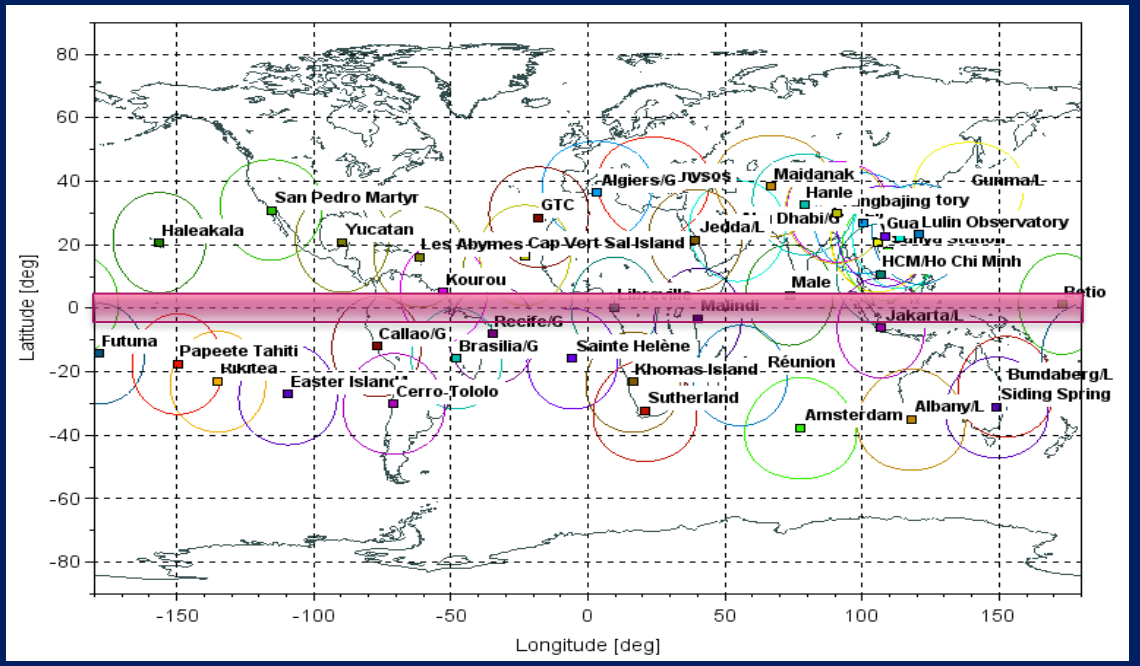
Mission adoption

SVOM as a pathfinder for THESEUS

Reuse of the alert network developed for SVOM, 45 stations

- 20 hosting sites provided by SVOM collaboration (Observatory, University)
- 25 hosting sites provided by institutional network (DORIS, REGINA, ARIAN

To make available to ground based telescopes the measured GRB celestial coordinates in no more than 30 seconds after localization for 2/3 of the localized GRBs



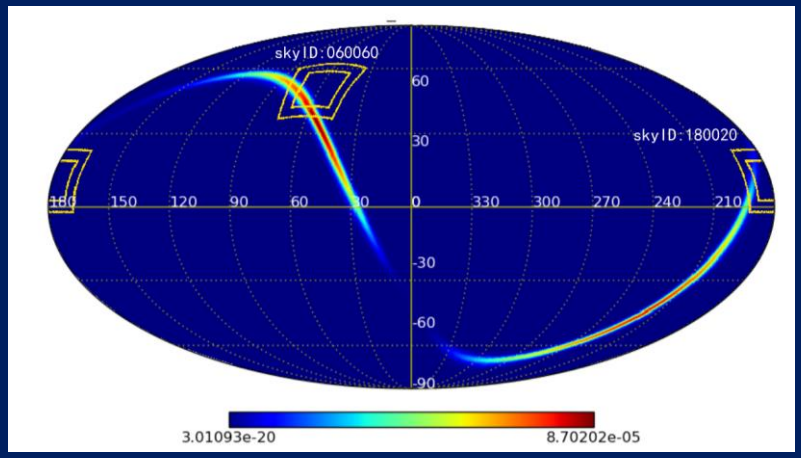
Due to the low inclination of THESEUS, we will re use only the central part of the network

SVOM white paper : arXiv:1610.0689
SVOM Website: http://www.svom.fr/en/

GW astronomy and SVOM

During O1 run: GW151226

Mini-GWAC observations



- Observations 12 h and 13.6 h

after the trigger time (2015-12-26 at 3:38:53 UTC)

- Duration 2.8 and 5.3 h
- Upper limit 11 mag
- Transient search with two pipelines:
  Catalog crossmatch and difference imaging analysis

Main requirements on the infrared camera

Camera requirements	
Number of detectors	**1**
Field of view	**26' round**
Photometric channels	**J & H**
Sensitivity	**Sky limited**
Total thermal background	**≤25 % of sky signal** **(sky level in OAN: J ~ 220 e-/s/pix & H ~ 1770 e-/s/pix)**
Readout noise	**< 20 e-**
Time to start a new observation, when already in operation	**≤10 s**
Time resolution	**2 s**
Timing accuracy	**0.01 s**
A fast shutter must be available to block the light during telescope slews	
Possibility to use a no-saturation mode	
The filter wheel must provide a closed position with no light arriving on the detector	

Main requirements on the infrared sensor

Number of pixels	2048 x 2048
Dimension of the pixels	15 x 15 µm
Spectral range	0.8 – 2.1 µm
Detector electronics	NGC or ARC card
Operating temperature	<110 K
Readout noise	<20 e-
Full frame readout time	<1.5 s
Well capacity	≥ 6 10^4 e-
Image latency	< 0.1 %

→A priori compatible with the expected performance of the SOFRADIR sensor…