SVOM

Space-based multi-band astronomical Variable Objects Monitor

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

CNSA

C. Lachaud (APC) - IN2P3 - Conseil Scientifique - 30 Juin 2020

THE SVOM CONSORTIUM

- **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

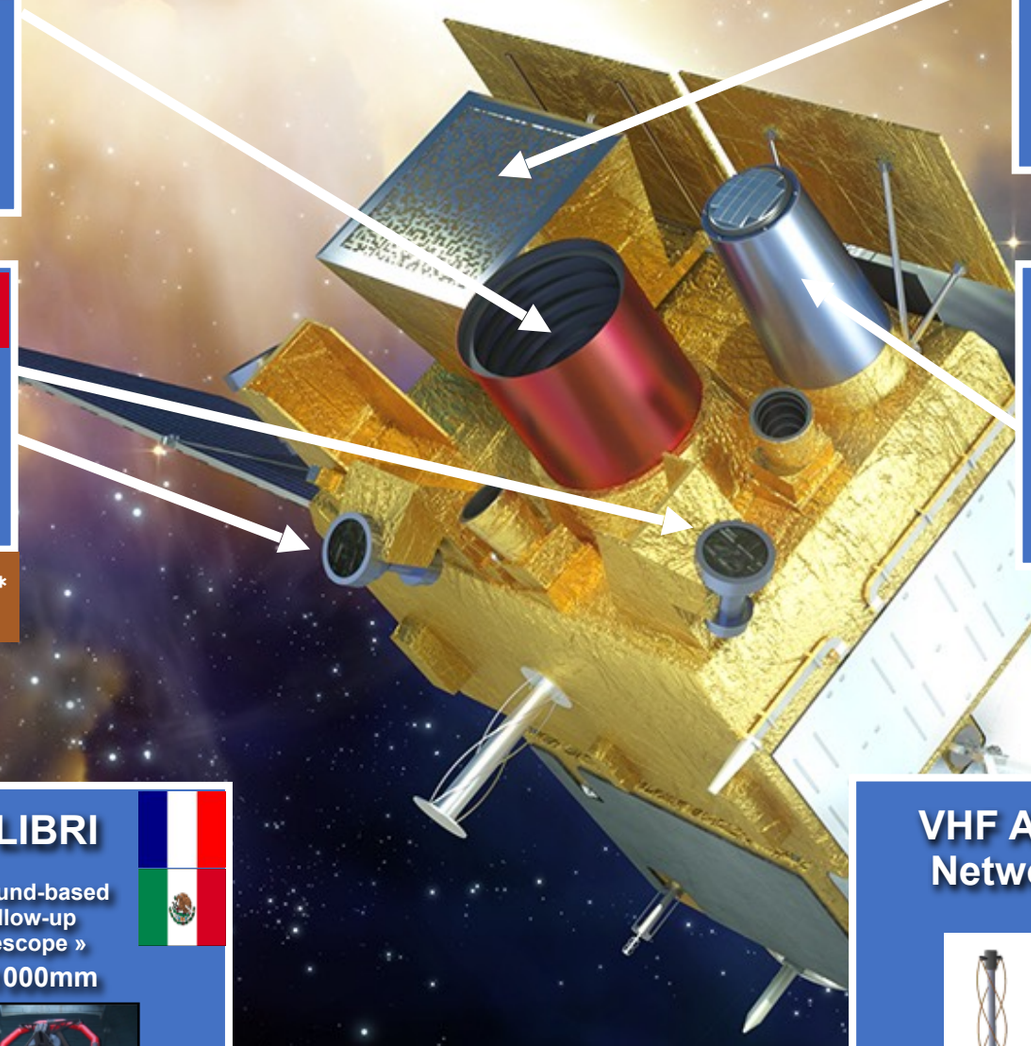
- **UK** University of Leicester

- **Germany**
  - MPE Garching
  - IAAT Tübingen

I. THE MISSION

The SVOM mission

« Space-based multi-band astronomical Variable Objects Monitor »
Launch in June 2022 (TBC), for 3+2 years



VT

"The Visible Telescope"
Narrow-field visible telescope

Ritchey Chretien Φ=400mm
Localization accuracy < 1arcsec

ECLAIRs

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

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

APC*

GRM

"The Gamma-Ray burst Monitor"
X-rays and Gamma-rays detectors

15 keV – 5 MeV
Localization accuracy < 5°

LUPM*

MXT

"The Micro-channel X-ray Telescope"
Narrow-field X-ray telescope

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

IJCLab*

C-GFT

« Ground-based Follow-up Telescope »
Φ>1000mm

GWAC

« Ground Wide-Angle Cameras »
Φ=180mm

COLIBRI

« Ground-based Follow-up Telescope »
Φ>1000mm

CPPM*

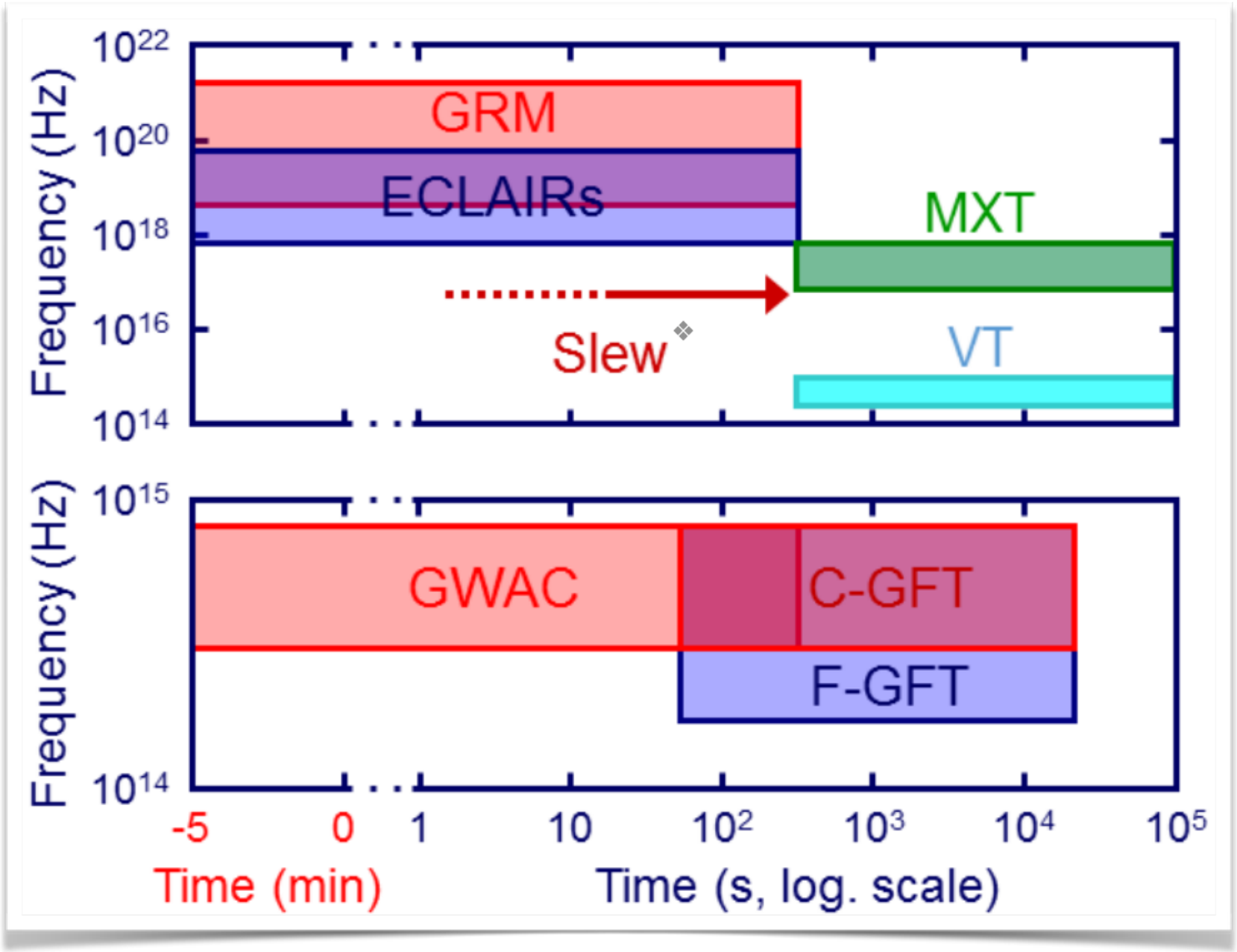
VHF Alert Network

… and more !

Tracking antennas

(*) IN2P3 Laboratories Main Contributions

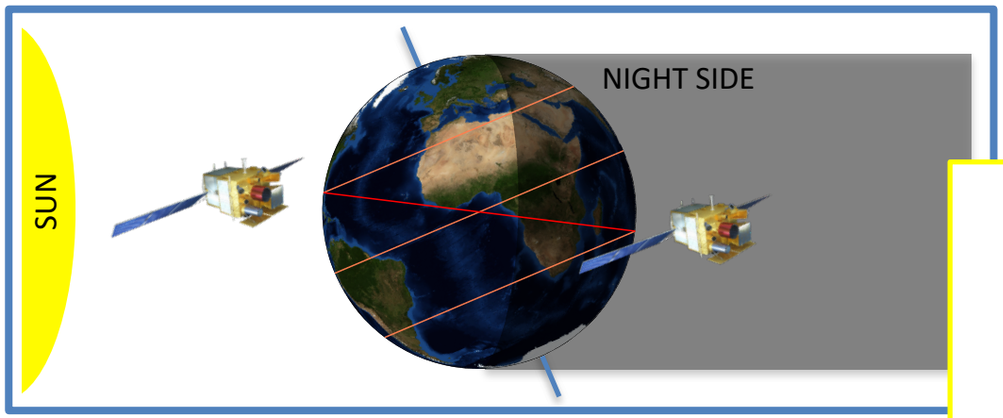
SVOM MULTI-λ COVERAGE

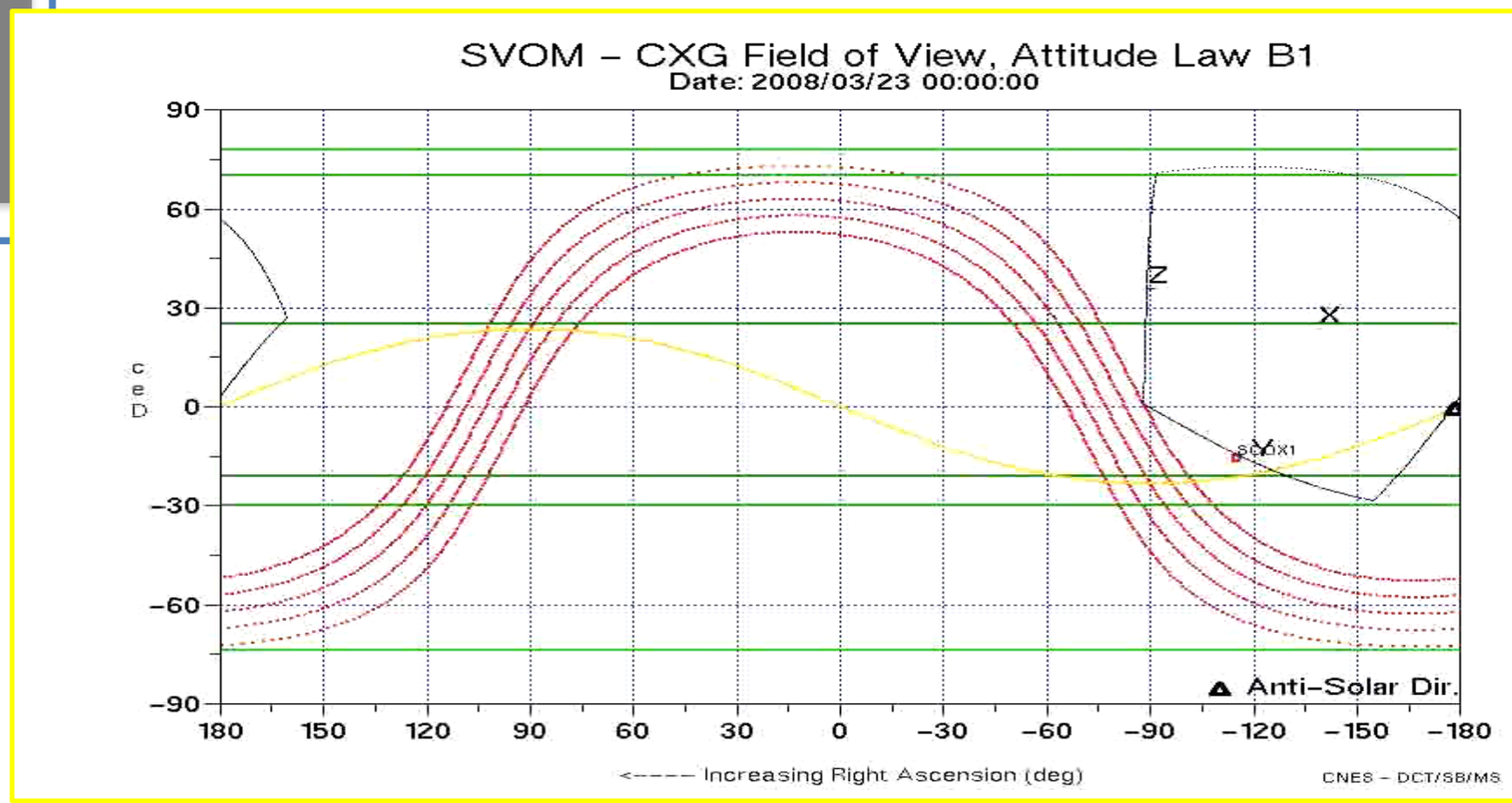


- **Slew** capability: **45° in 5 minutes** (including arc sec stabilisation)

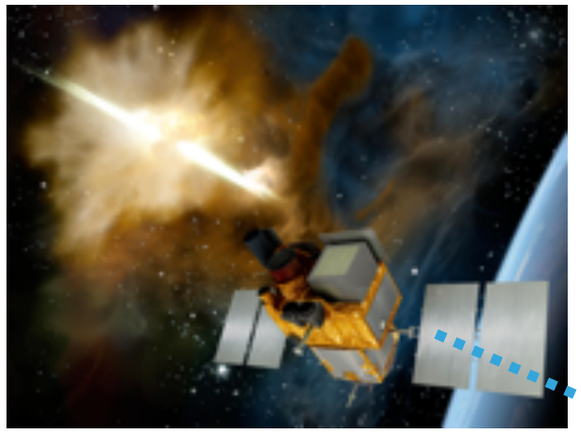
SVOM OBSERVATION STRATEGY

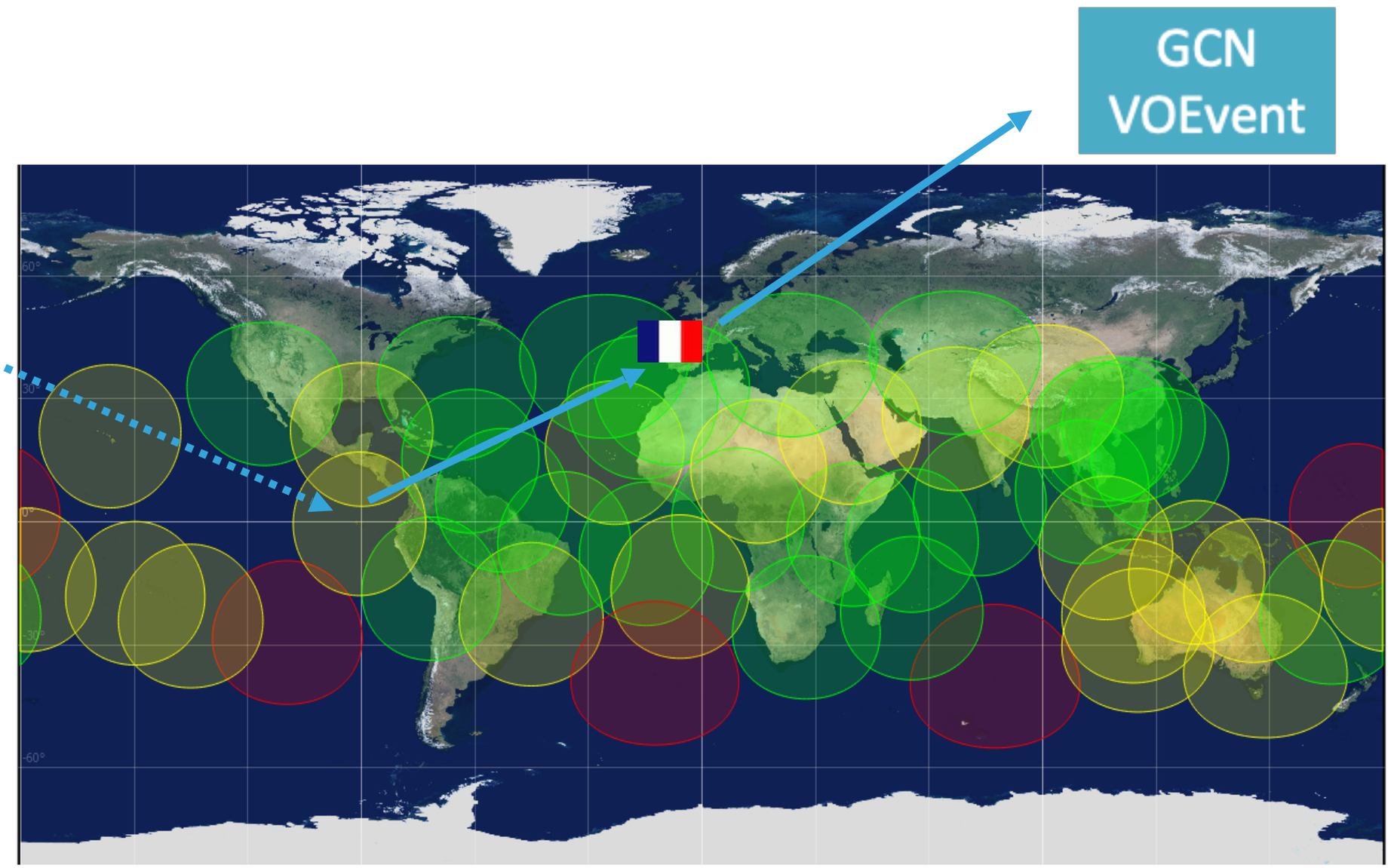
- **Launched** from **Xichang** (Sichuan) by an **LM-2C** rocket in **June 2022 (TBC)**.
- **Circular low Earth orbit at 635 km** of altitude with an **inclination of about 29°**
- Nearly **anti-solar pointing** (so-called « **B1** » **attitude law**) **to favor quick ground follow-up**
  => Earth in the field of view (**65% of duty cycle for ECLAIRs, about 50% for MXT and VT**)
- **Avoidance of the Galactic plane** (most of the time) and **Sco X-1**





VHF NETWORK





Alerts are transmitted to a network of 45 VHF receivers on Earth

Goal: 65% of the alerts received within 30 s at the French Science Center

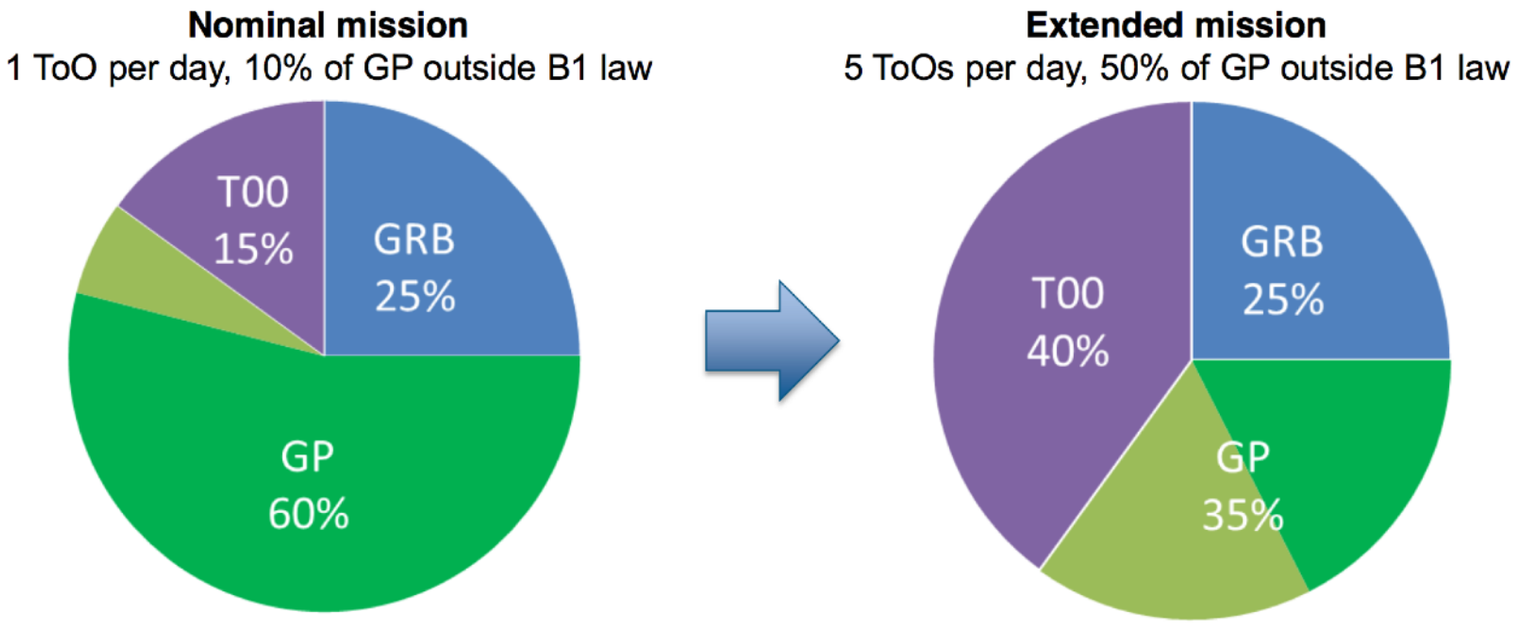
II. OBSERVATION PROGRAMS

SVOM OBSERVATION 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).
French GP scientist : Andrea Goldwurm (APC).

The Core Program (GRB). GRB data products (position, light curve, pre-computed spectra will be made public immediately).
French CP scientist : Frédéric Daigne (IAP).

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



CORE PROGRAM : GAMMA RAY BURSTS

Short GRB

Neutron stars

Gravitationnal waves

Black hole

Disk

ν ?

Faster shell

Slower shell

Colliding shells emit gamma rays (internal shock wave model)

Jet collides with ambient medium (external shock wave)

Which GRBs ?

Very high-energy gamma rays (> 100 GeV)

High-energy gamma rays

X-rays

Visible light

Radio

ν ?

UHECR ?

low-energy (< 0.1 GeV) to high-energy (to 100 GeV) gamma rays

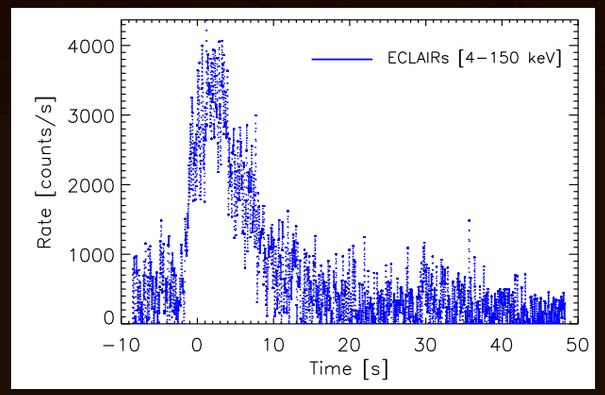
Prompt emission

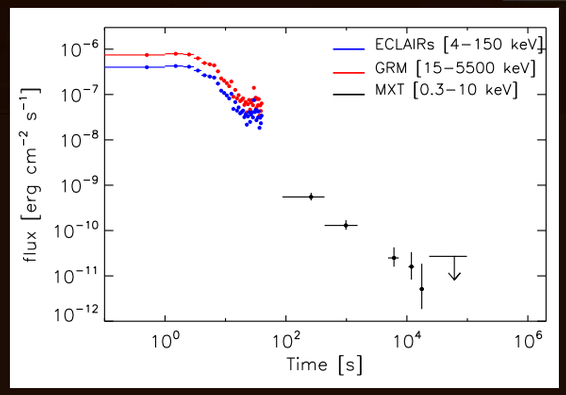
Afterglow

Massive star

Gravitationnal waves ?

Long GRB





GRB091020: simulation for prompt and afterglow emissions

CORE PROGRAM : A SAMPLE OF WELL-CHARACTERIZED GRBs

***ECLAIRs** will provide about 65 GRBs alerts per year with localisation < 12 arcmin.*

We expect in the end a unique sample of 30-40 GRB/yr with

- prompt emission over 3 decades in energy

(+ optical flux/limit: 16%)

- X-ray and V/NIR afterglow

- redshift

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

Science objectives of IN2P3 teams:

Physical origin of GRB emission

Acceleration and composition of the relativistic jet

Internal dissipation mechanism, microphysics,

dominant radiative processes

GRBs as particle accelerators

VHE photon and neutrino emissions from very/ultra-high energy cosmic rays

Low-luminosity and/or choked GRBs

Short GRBs and the compact star merger model

GW emission from the final stages of orbital decay and merger

LIV and Cosmology (GRBs as standard rulers?)

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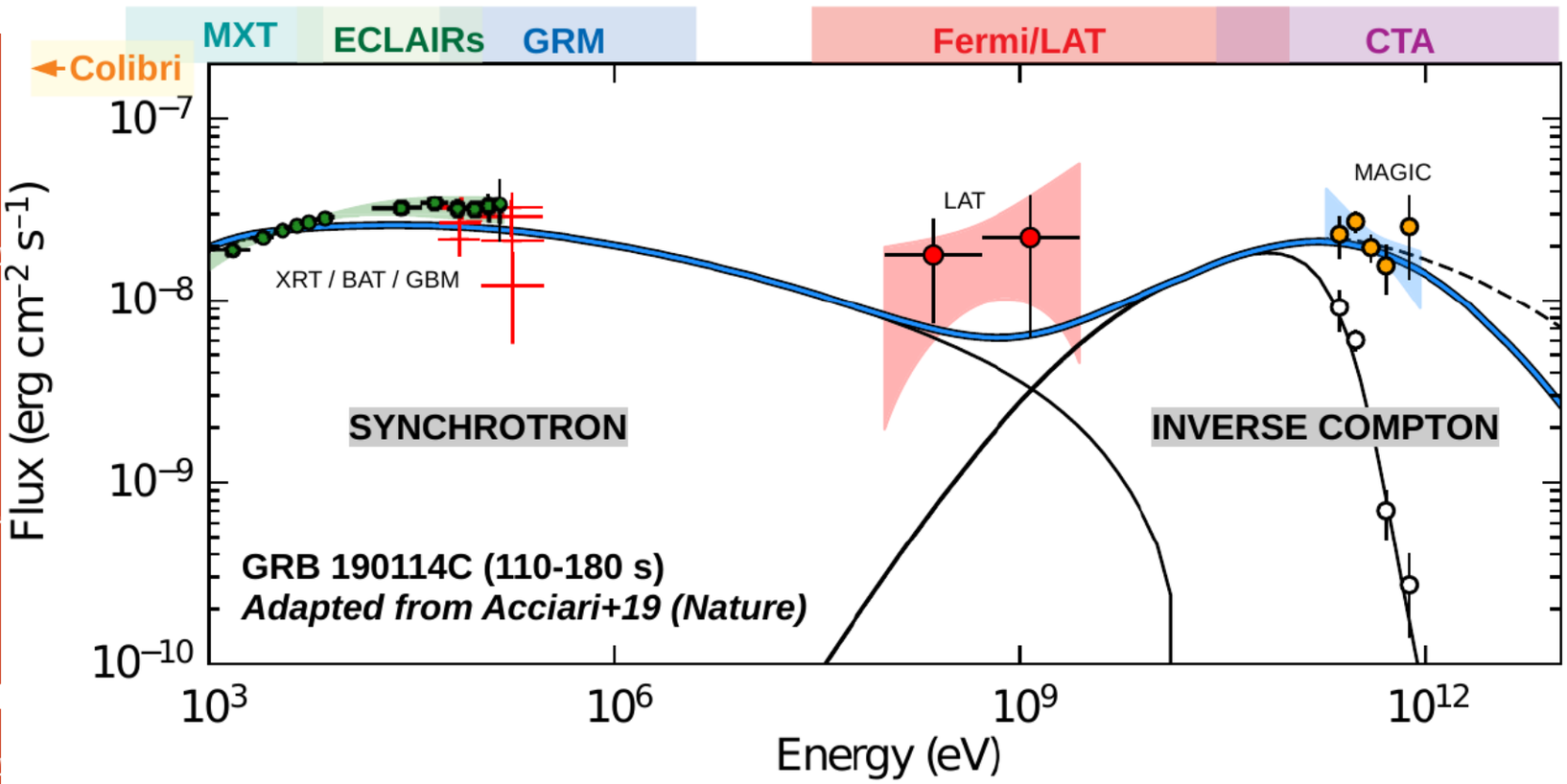


GENERAL PROGRAM : MULTIWAVELENGTH OBSERVATIONS

The General Program is built around 2 axes :

- study (mostly) extragalactic sources with the small FOV instruments MXT and VT

- survey mode with the large FOV instruments ECLAIRs and GRM (to detect flaring AGN/Blazars, new sources…)

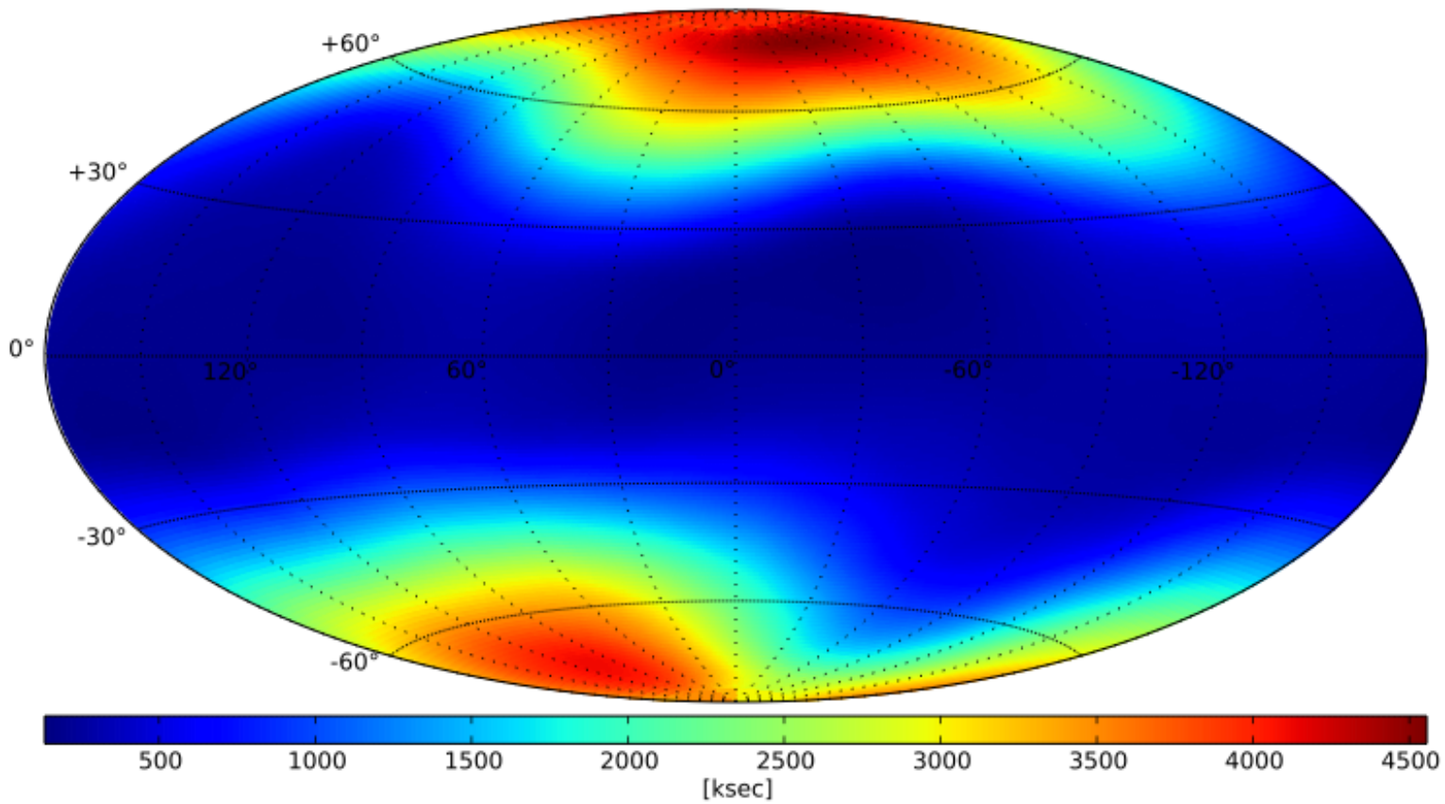
A call for observations will be performed every year.

Joint observations with external facilities are encouraged (CTA…).

ECLAIRs exposure map

(65 GRBs/year, 1 ToO per day)

- 4 Ms in the direction of the galactic poles
- 500 ks on the galactic plane



ToO PROGRAM : EXTERNAL TRANSIENTS TO MULTIMESSENGER ASTRONOMY

The Target of Opportunity (ToO) program allows a « fast » programmation of the satellite after an alert has been received on the ground from external facilities.

3 types of ToO cover our scientific needs :

ToO	Approval	Delay	Interrupt GRB obs. ?	Frequency	Duration	Tiling	VHF data	Science product availability
ToO-NOM [SR5-NOM]	ToO scientists	<48h	No	1 (5) / day	1 orbit	No	No	24h
ToO-EX [SR5-EX]	PIs/ToO sc.	<12h	Yes	1/month	14 orbits	No	No	24h
ToO-MM [SR5-MM]	PIs/ToO sc.	<12h	Yes	1/week	14 orbits	Yes	MXT + VT	VHF < 1h X-band : 24h

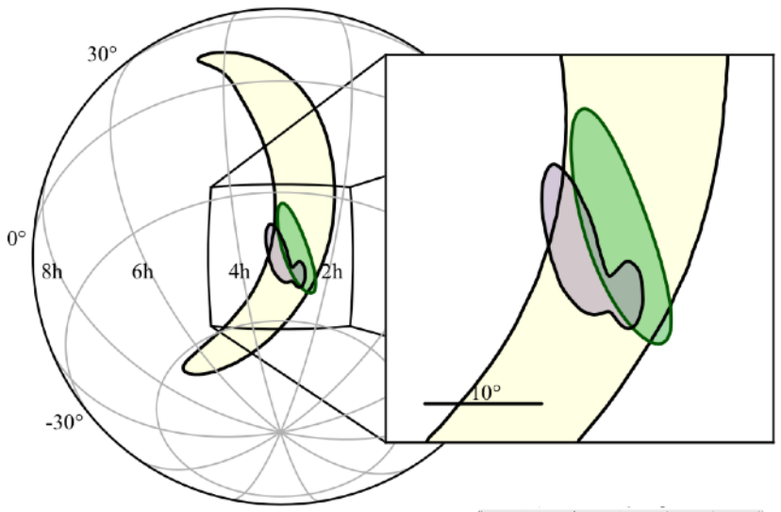
ToO-NOM and ToO-EX will allow us to study interesting transients (with localisation precision < 12 arcmin)

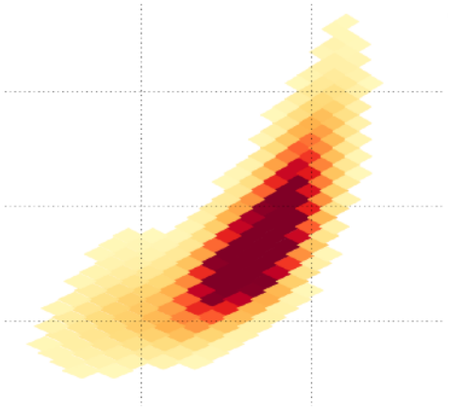
=> LSST will provide a huge number of transients per night to be classified

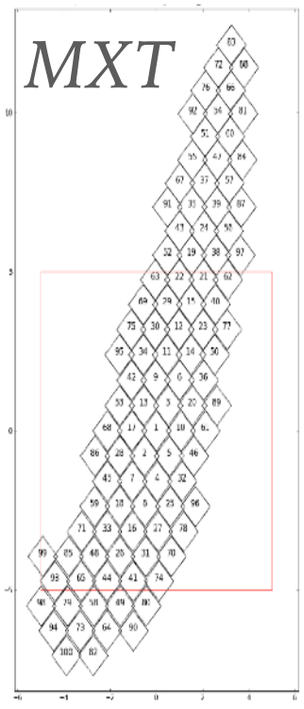
ToO PROGRAM : EXTERNAL TRANSIENTS TO MULTIMESSENGER ASTRONOMY

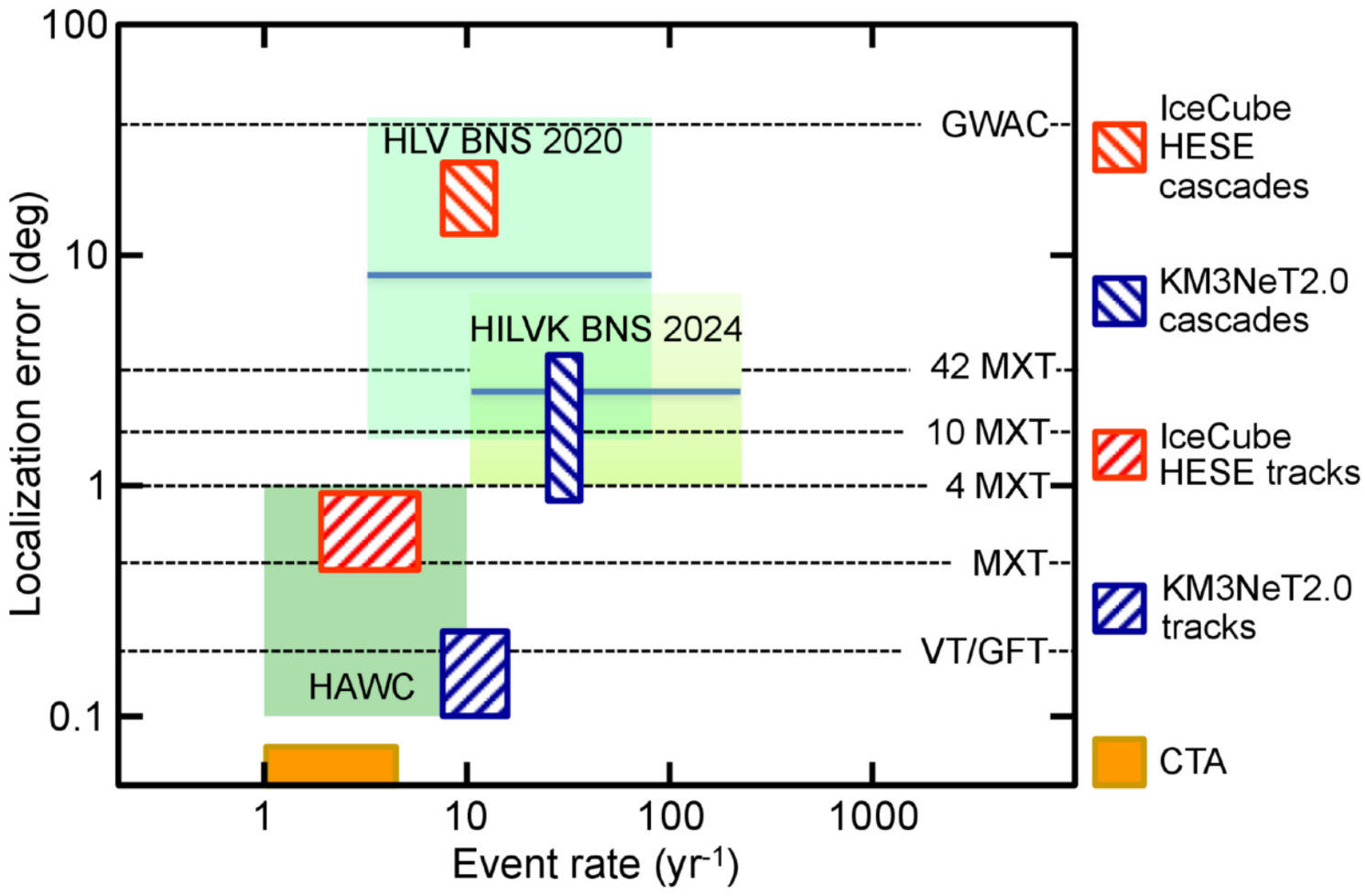
ToO-MM is the ToO adapted to poorly localized events, we will perform a tiling of the error box (very complex operations from a system point of view).

Example : GW170814









We will be able to follow the LIGO/Virgo, KM3NeT and CTA alerts…

SCIENCE WITH SVOM

SVOM white paper : Wei, Cordier et al.

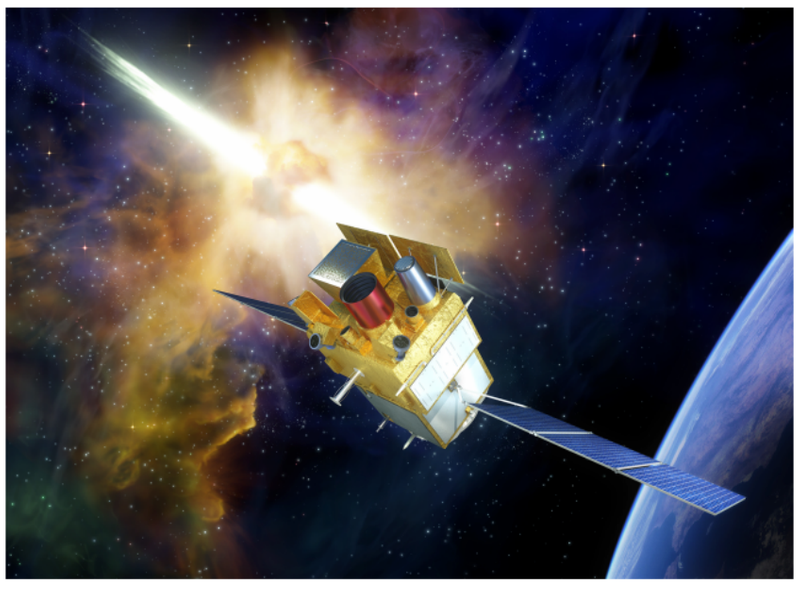
« Scientific prospects of the SVOM mission »

arXiv:1610.06892

The Deep and Transient Universe:
New Challenges and Opportunities

Scientific prospects of the *SVOM* mission

J. Wei, B. Cordier, et al.
(Version of 05-10-2016, for full list of contributors see overleaf)



The science of SVOM at IN2P3.

Prospective IN2P3 - GT04 Astroparticules

Prospectives IN2P3 - GT04 astroparticules

The Science of SVOM at IN2P3

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More informations : svom.fr.

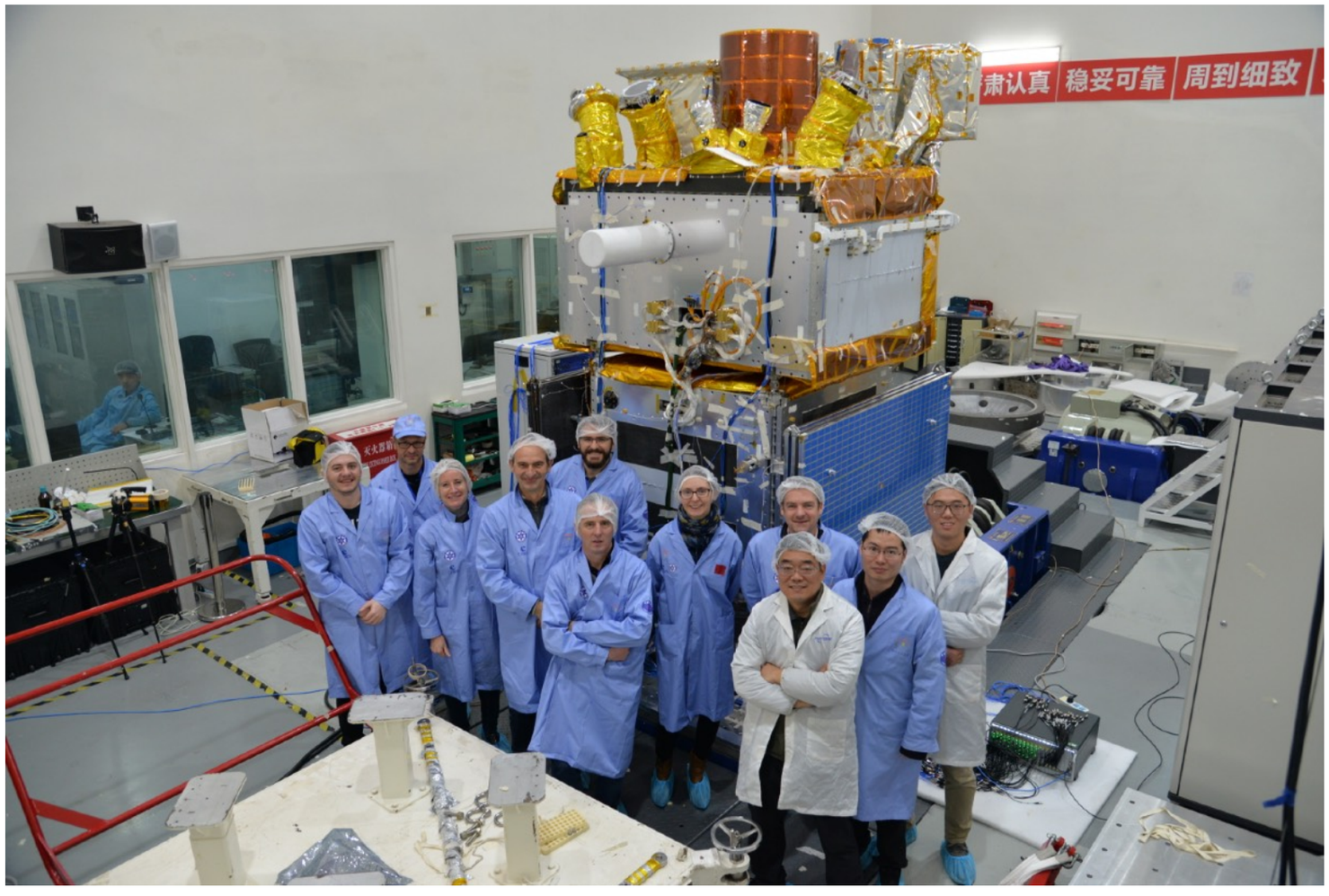
(short note on GW170817/GRB170817A/Kilonova as seen by SVOM)

III. NOUVELLES DU PROJET

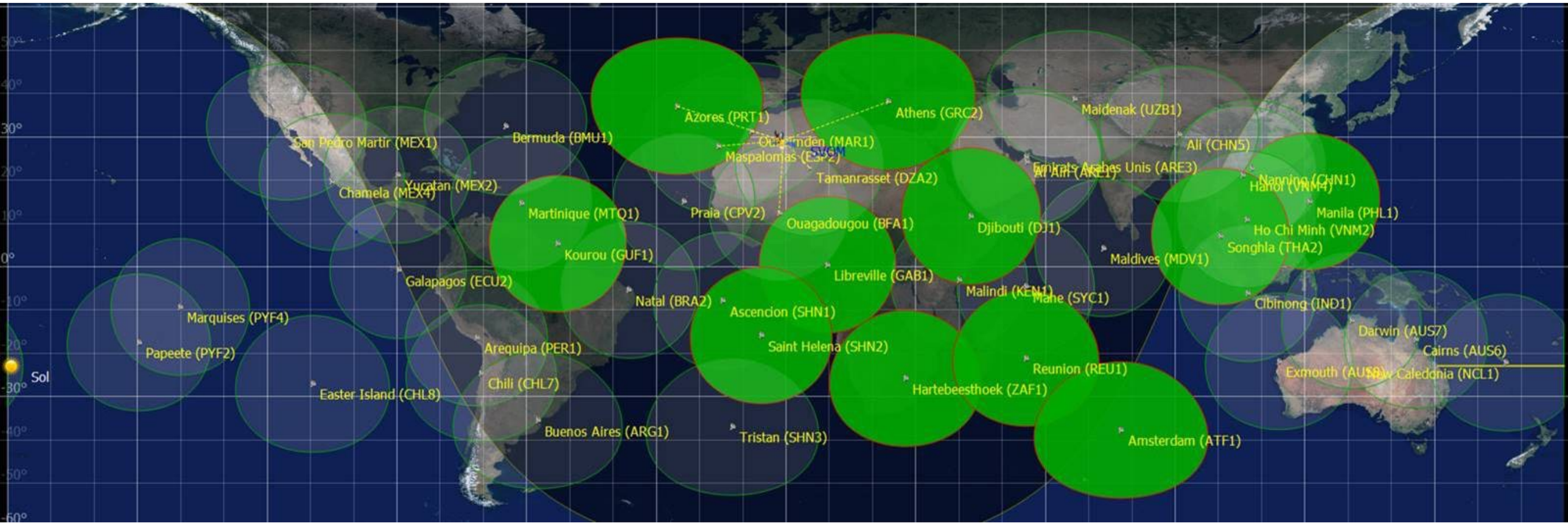
QUALIFICATION CAMPAIGN ON THE SVOM QM SATELLITE

The qualification tests (vibrational and thermal) of the SVOM QM satellite have been very intense from September 2019 to early 2020 !

Successful tests of all satellite components !



VHF NETWORK : DEPLOYMENT IN PROGRESS



Kourou

Currently, 11/45 VHF antennas deployed.

Objective :

- 30/45 antennas deployed at the end 2020

- 15 antennas to be deployed in 2021

CONSTRUCTION OF THE COLIBRI TELESCOPE (F-GFT)

Ground-breaking (05/2018)

Mirrors now polished and installed on the mount August 2020

Very intensive AITs/AIVs between September and December 2020

Construction of the building is on-going

Transportation and installation in Mexico between January and June 2021

First test of the ALFA NIR detector for CAGIRE

Telescope mount at OHP (06/2019)

CALENDAR

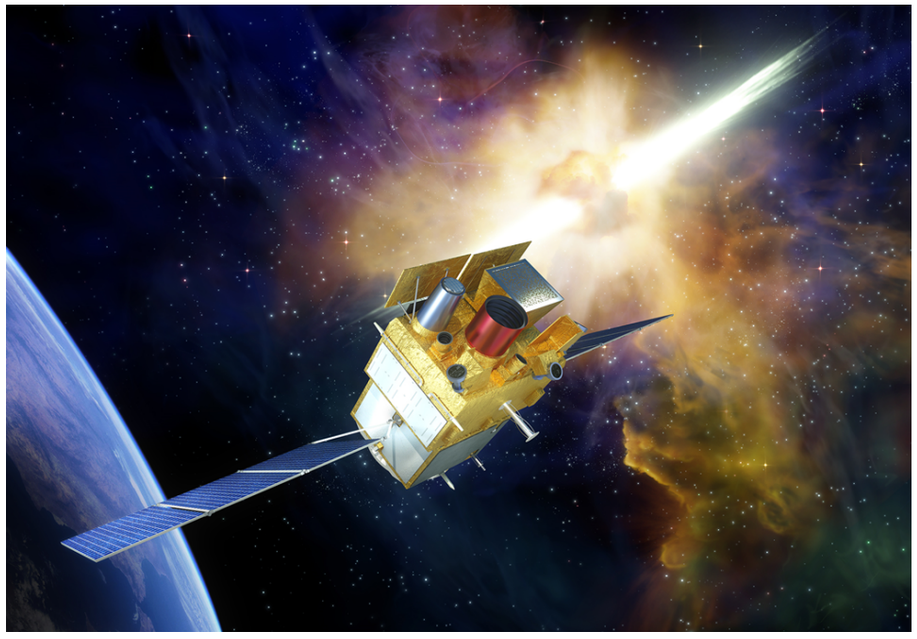
CDR mission / system SVOM : 29/06 to 10/07 (visio)

JSC SVOM : September 2020 (visio) => Phase D

Coded mask FM delivery to CNES : October 2020

ECLAIRs and MXT delivery to SECM : Fall 2021

Launch date : June 2022 (TBC)



First light and scientific exploitation : October 2021

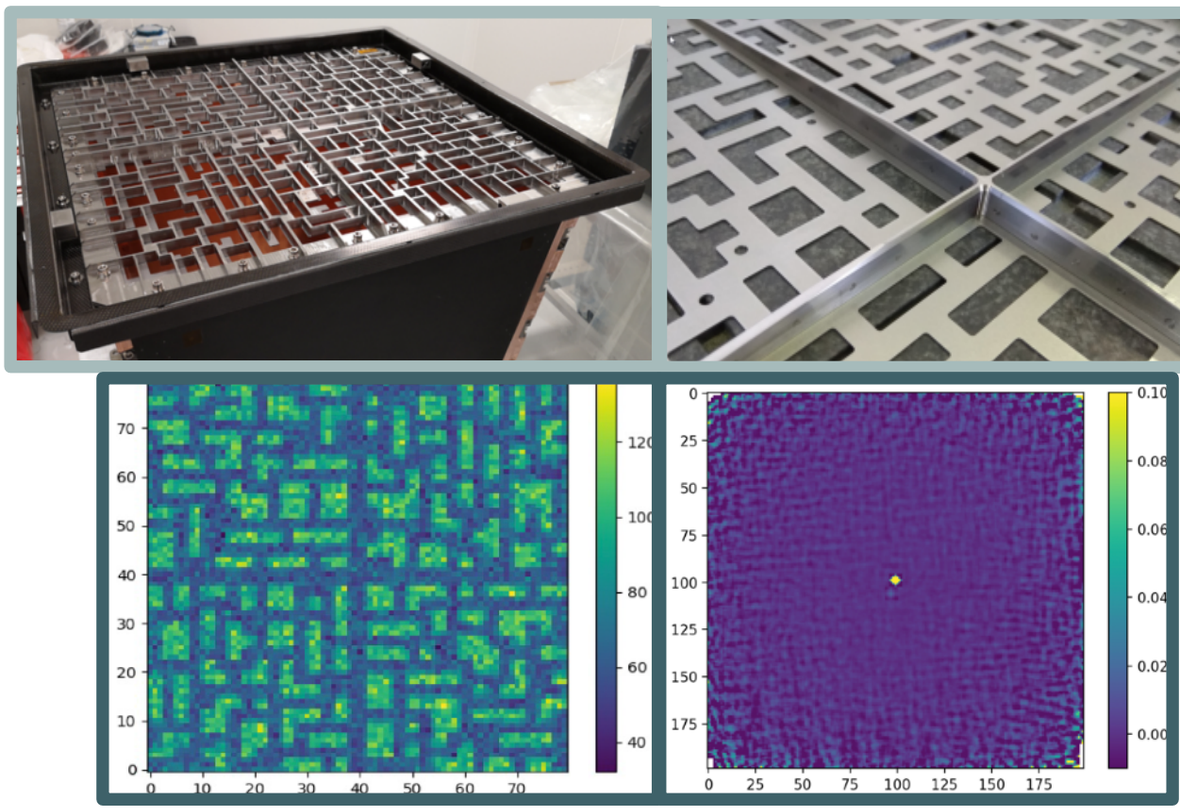
Installation of CAGIRE : January-February 2022

IV. SVOM@IN2P3

LABORATORIES DEVELOPMENT

APC is in charge of the scientific and technical developments of the ECLAIRs coded mask, and of the ECLAIRs scientific pipeline for the General Program. In addition APC contributes to the development of the ToO and GP programs and to the Burst Advocate Tools.

Coded mask of ECLAIRs (QM)



Shadowgram and sky reconstruction

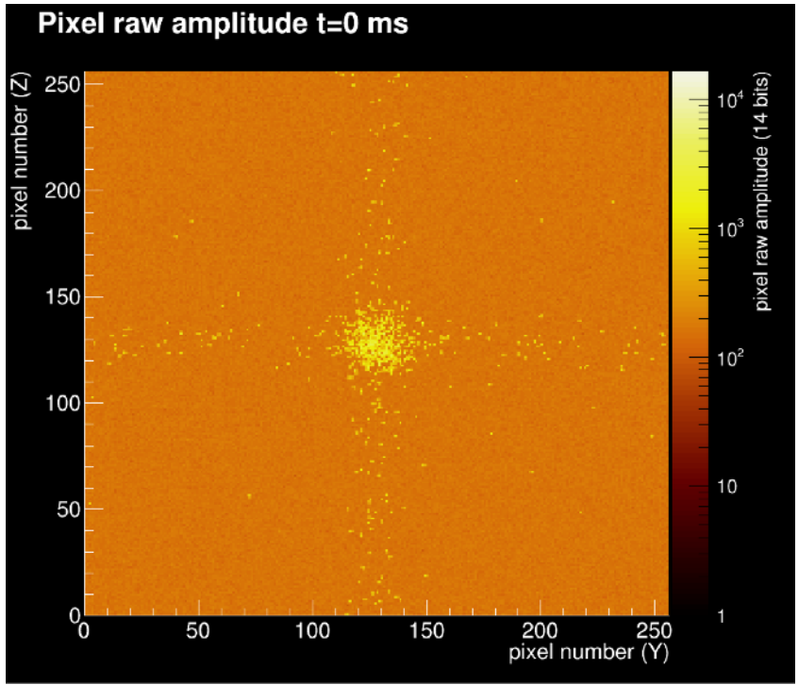
CPPM is in charge of software activities for the COLIBRI telescope (one of the SVOM ground follow-up telescope). CPPM is responsible for the scientific and technical developments of the COLIBRI Instrument Center (GIC), for part of the image analysis processing, and for the interface with the SVOM FSC (data products, alert…). Characterization of the NIR sensor of CAGIRE/COLIBRI. CPPM works also on the link between KM3NeT and SVOM.

COLIBRI mount at OHP

LABORATORIES DEVELOPMENT

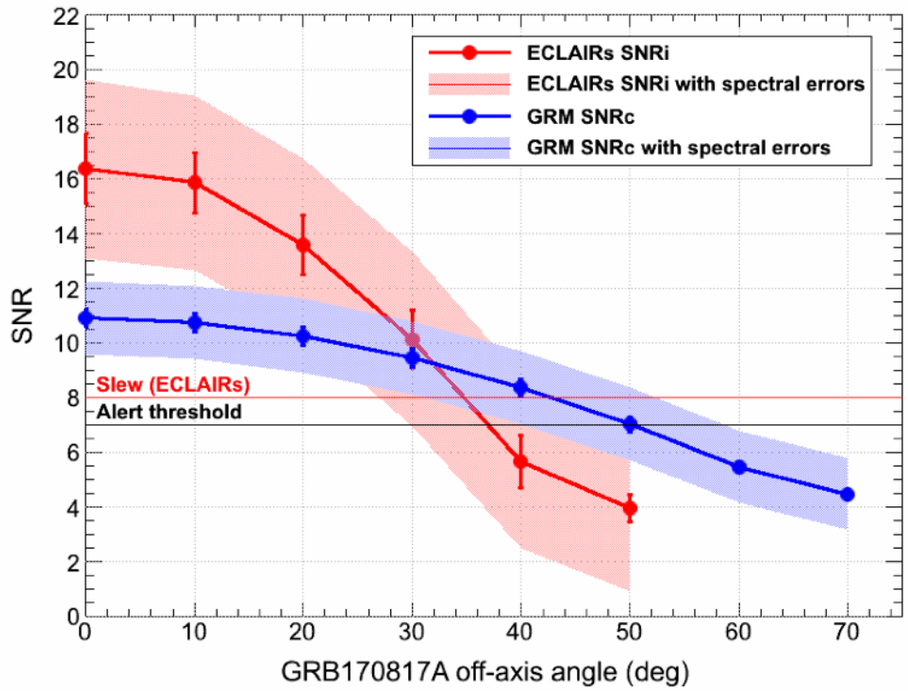
IJCLab is responsible for the on-board scientific partition of the MXT instrument. The group also develops the pipeline using the VHF data from the MXT instrument. It has been leading the activities around the program for Target of Opportunity on multi-messengers alerts. IJCLab works at the interface with LIGO/Virgo and LSST. Finally, it proposed the Virtual Data infrastructure as an integration center for the French Scientific Center.

Simulation of a GRB in MXT camera



LUPM is in charge (with IAP/INSU) of the ECLAIRs and GRM data analysis pipelines (VHF and X-band) for the Core Program at the French Science Center. For this purpose, LUPM is also coordinating the Sino-French ECLAIRs/GRM analysis group. LUPM works also on the synergy with CTA (and Fermi), making the link with the Transient Working Group of the CTA Consortium.

Simulation of ECLAIRs and GRM response to GRB170817A



SUMMARY BY THEME

GRB alerts and multi-wavelength analysis

Coded mask

ECLAIRs pipeline (imaging)

ECLAIRs-GRM pipeline

Links with Fermi and CTA

MXT pipeline

COLIBRI pipeline

Multi-messenger transient sky

ToO scientist

ToO-MM tiling

Links with LIGO/Virgo and LSST

Links with Fermi and CTA

Link with KM3NeT

Observatory science

GP scientist

ECLAIRs pipeline

LABORATORIES HUMAN RESOURCES

	Lab.	Researchers	IR	IE	T	CDD	Postdoc	PhD
2020	APC	3 (2EC + 1CEA) : 1.3	5 : 1.6	1 : 0.4	1 : 0.1	2 : 2	1 : 0.5	0
	CPPM	2 : 0.65	1 : 0.5	0	0	1 : 1	0	0
	IJCLab	2 : 0.9	2 : 1.05	1 : 0.7	0	0	1 : 0.2	2 : 1.3
	LUPM	2 : 0.85	1 : 1 (retired / SAPHIR)	1 : 0.5	0	0	0	0
	Total	**9 : 3.7**	**9 : 4.15**	**3 : 1.6**	**1 : 0.1**	**3 : 3**	**2 : 0.7**	**2 : 1.3**

Evolution :

- we expect PhD to increase starting next year (PhD thesis (IN2P3/CNES) expected to start at LUPM in 2020 (TBC))

- postdoc support from CNES and IN2P3 is expected especially during the exploitation phase

Strength, Weakness, Opportunity and Threat Analysis

Strength

SVOM will be a major actor of the transient sky astrophysics with a special focus on GRBs and Multi-Messenger related searches in the next decade.

Full data access is private and reserved to SVOM co-I members (only some scientific products will be public). IN2P3 laboratories have strategic positions in the project for the ToO, GP and CP programs, and excellent expertise of the ECLAIRs, MXT, GRM and COLIBRI instruments.

SVOM will be the product of a common effort of the transient sky community at IN2P3, INSU and CEA.

Weakness

The current IN2P3 researchers involved in this ambitious mission constitute a small team (9 scientists including 1 CEA and 2 associate professors at Université de Paris, for only 3.7 FTE).

Despite key responsibilities in the project, we are lacking manpower to lead all of the activities that SVOM may develop within the IN2P3 scientific perimeter.

Strength, Weakness, Opportunity and Threat Analysis

Opportunity

The SVOM / IN2P3 scientists are strongly involved in the "Transient Sky 2020" French network, which is a natural place to explore new ideas and to foster new developments and collaborations for multi-wavelength and multi-messenger observations of transient celestial sources.

Threat

The project schedule has been impacted by the Covid-19 pandemic. The launch date is now planned in June 2022 (TBC).

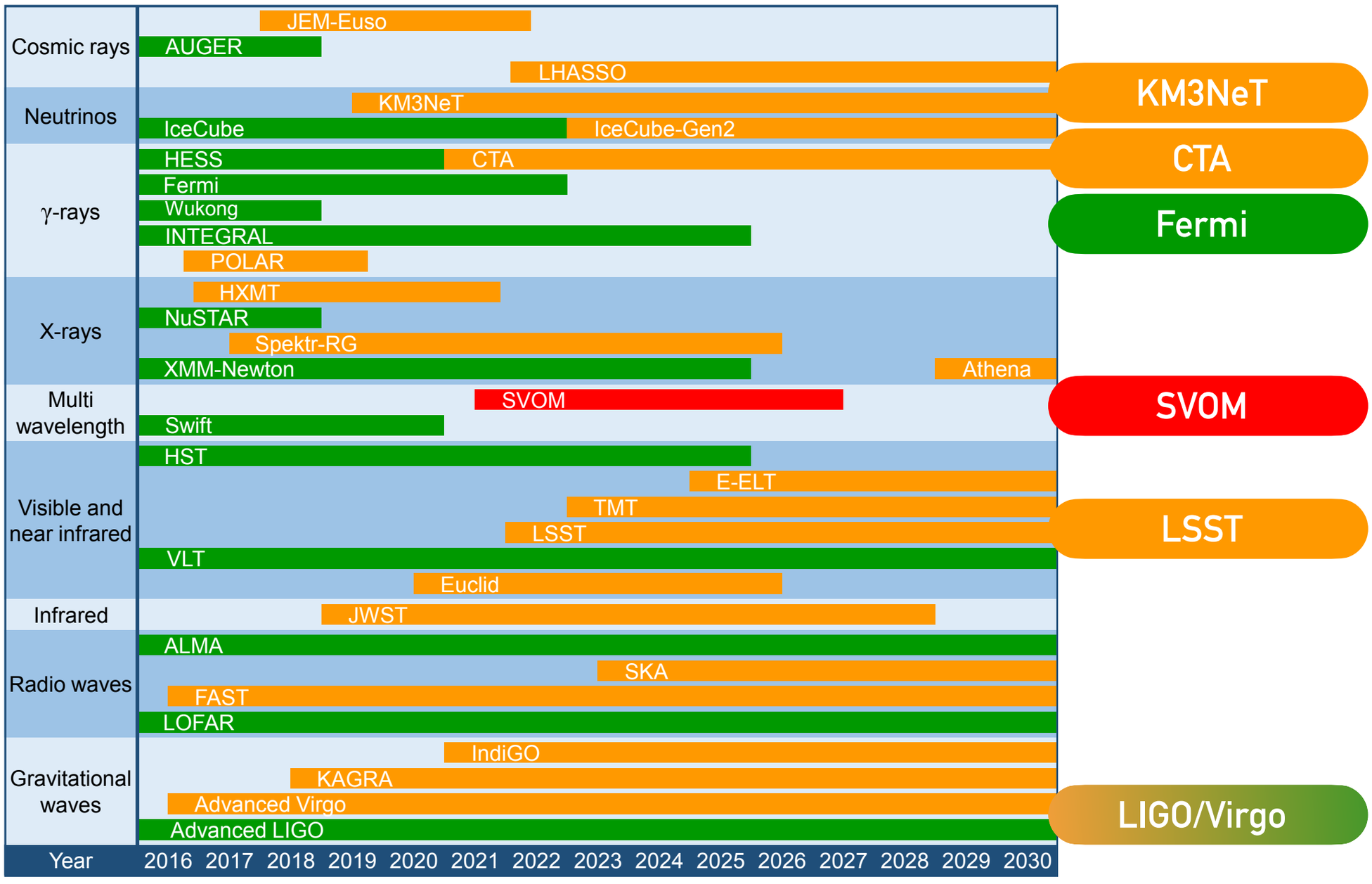
Due to the limited number of scientists in the team, imponderables in the development of the technical projects can sometimes be difficult to overcome.

CPPM and LUPM benefited from significant resources from the Ocevu Labex during the past years. This Labex ended in 2019 and no organization is planned at the regional scale to keep the current projects related to SVOM alive.

CONCLUSION

CONCLUSION

SVOM will be an important partner of the IN2P3 major programs in Astroparticle



Building strong synergies is essential to maximize the scientific return (e.g. as shown by GW170817, and the recent VHE GRBs from HESS and MAGIC)

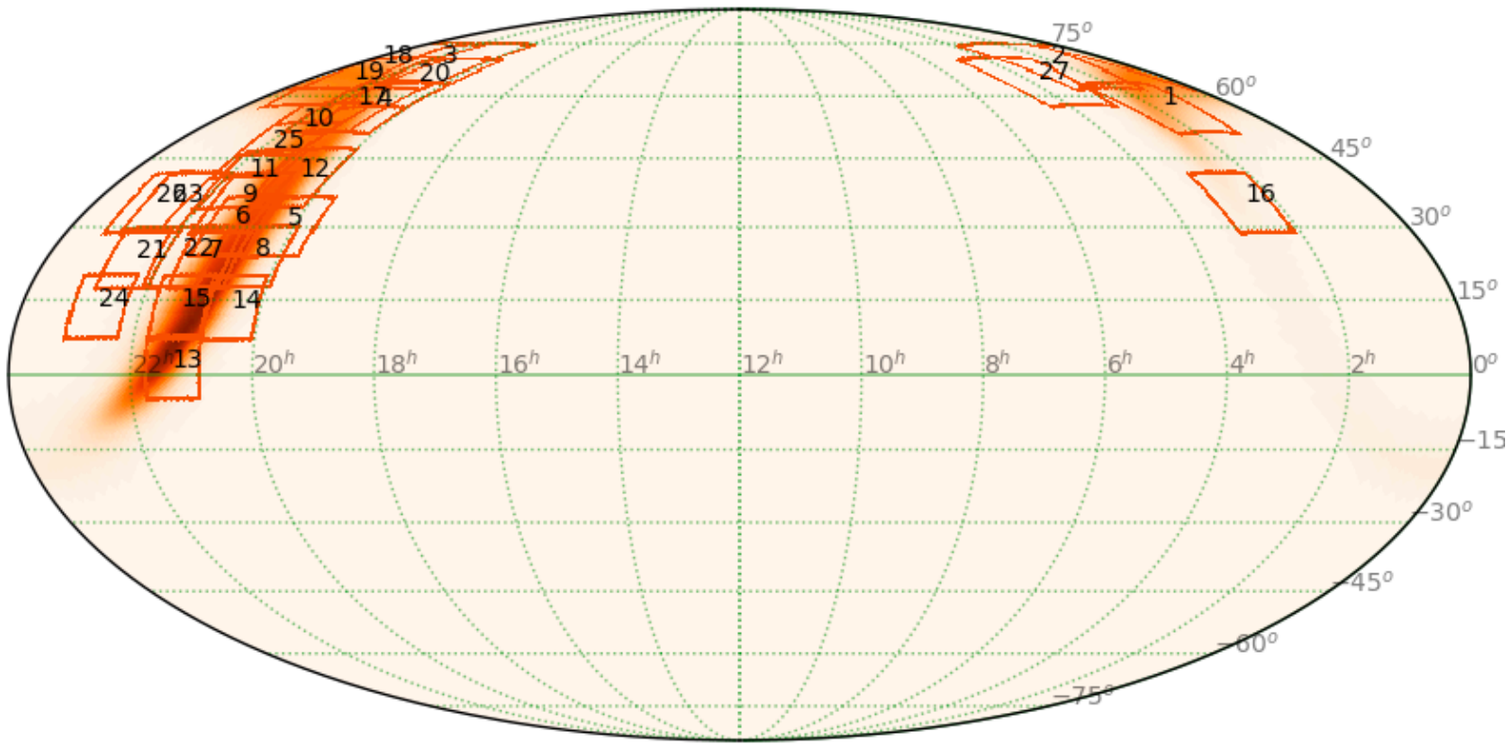
CONCLUSION

SVOM will be a major actor of the GRB and transient sky community after its launch in June 2022 (TBC). COLIBRI will start the scientific exploitation in October 2021.

All instruments under French responsibility are in development and should be delivered in 2021.

Intense activity on the instrument pipelines development until launch !

Science with SVOM already began with the follow-up of O2 and O3 runs from LIGO/Virgo with GWAC instruments.



S190930s MassGap event. 77.2% of chance to have a tile with the source inside.

SVOM STM PICTURES