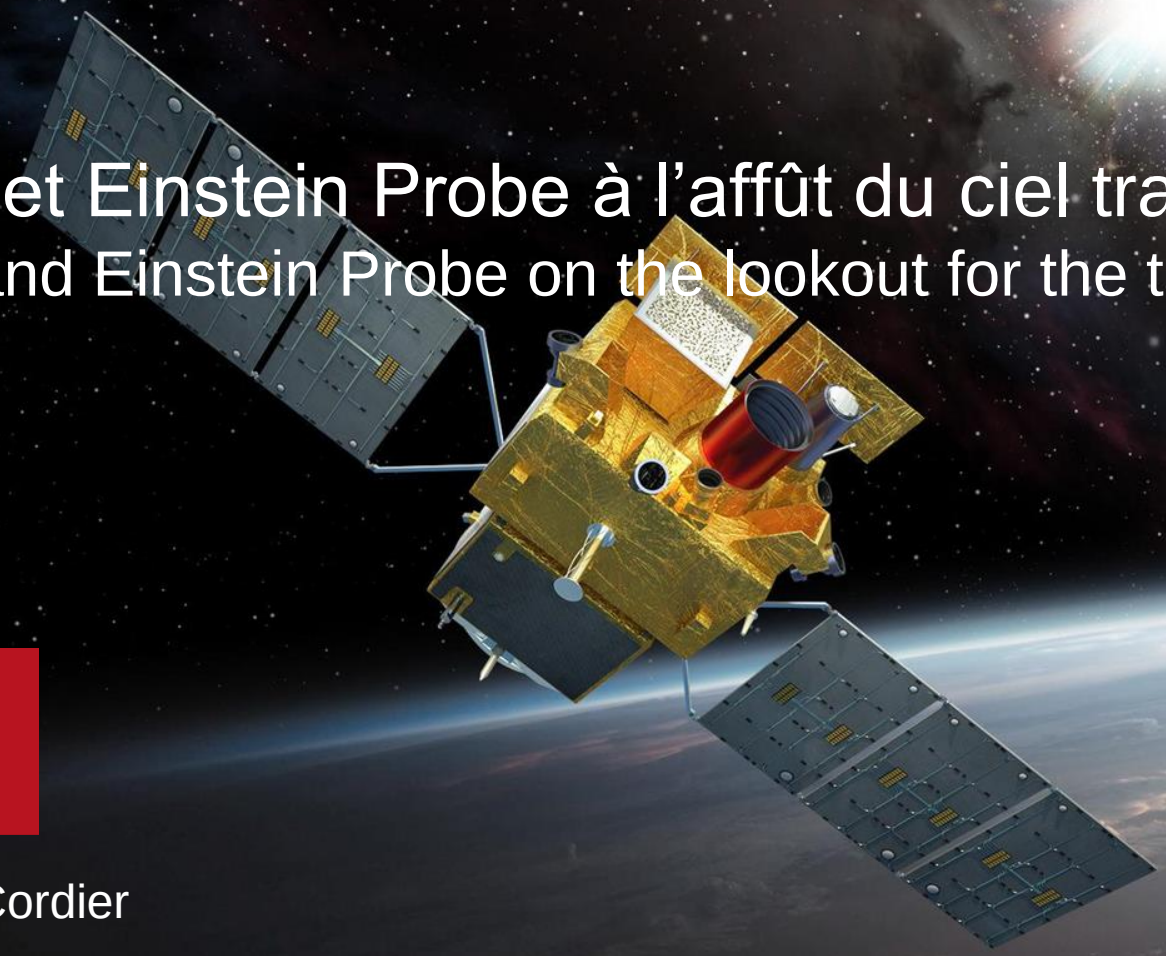
SVOM et Einstein Probe à l'affût du ciel transitoire
SVOM and Einstein Probe on the lookout for the transient sky

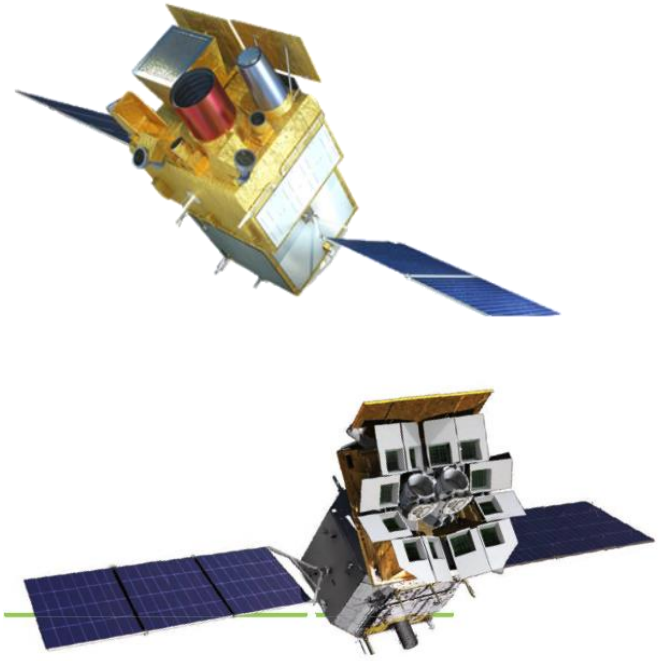


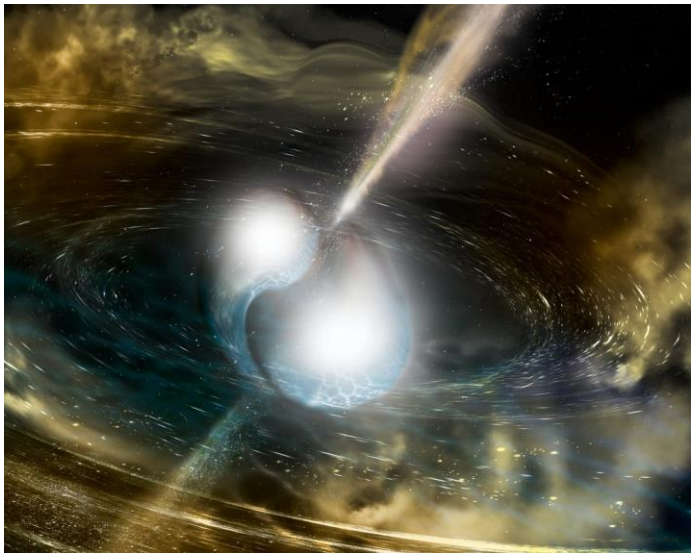
Bertrand Cordier

on behalf of the SVOM Collaboration

SVOM white paper: arxiv1610.06892

Outlines





I

1. What is SVOM ?

1. What is Einstein Probe?

II

1. How do we plan to face the new decades of alerts ?
2. How will we interact/collaborate with the scientific communities ?

I
What is SVOM ?

The SVOM Collaboration

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China (PI J. Wei) 

- SECM Shanghai
- NAOC Beijing
- IHEP Beijing
- GuangXi University Nanning

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France (PI B. Cordier) 

- CNES Toulouse
- CEA Saclay
- APC paris
- CPPM Marseille
- GEPI Meudon
- IAP Paris
- IJC Lab Orsay
- IRAP Toulouse
- LAM Merseille
- LUPM Montpellier
- OAS Strasbourg
- OCA Nice

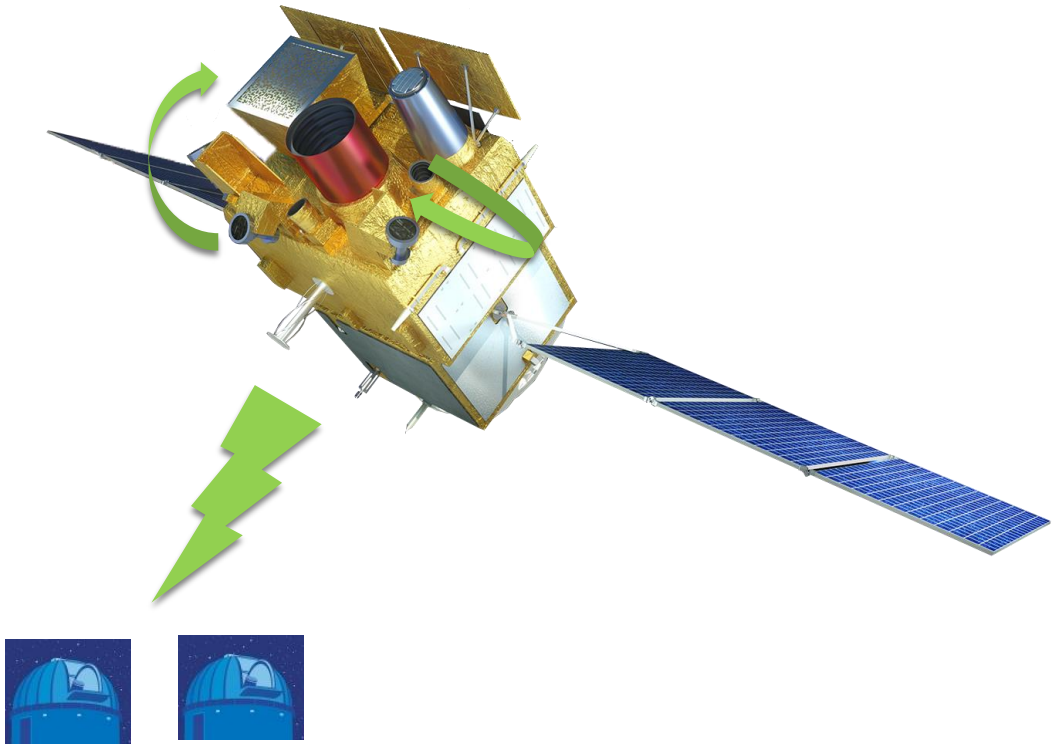
Mexico UNAM Mexico 

UK University of Leicester 

Germany MPE Garching 

SVOM "Space-based multi-band astronomical Variable Objects Monitor"
a Sino-French mission dedicated to GRBs and transient sources to be launched end 2022, duration 3+2 years

SVOM INSTRUMENTS COMMUNICATE WITH EACH OTHER



GRM -> ECLAIRs to help the detection of short GRB

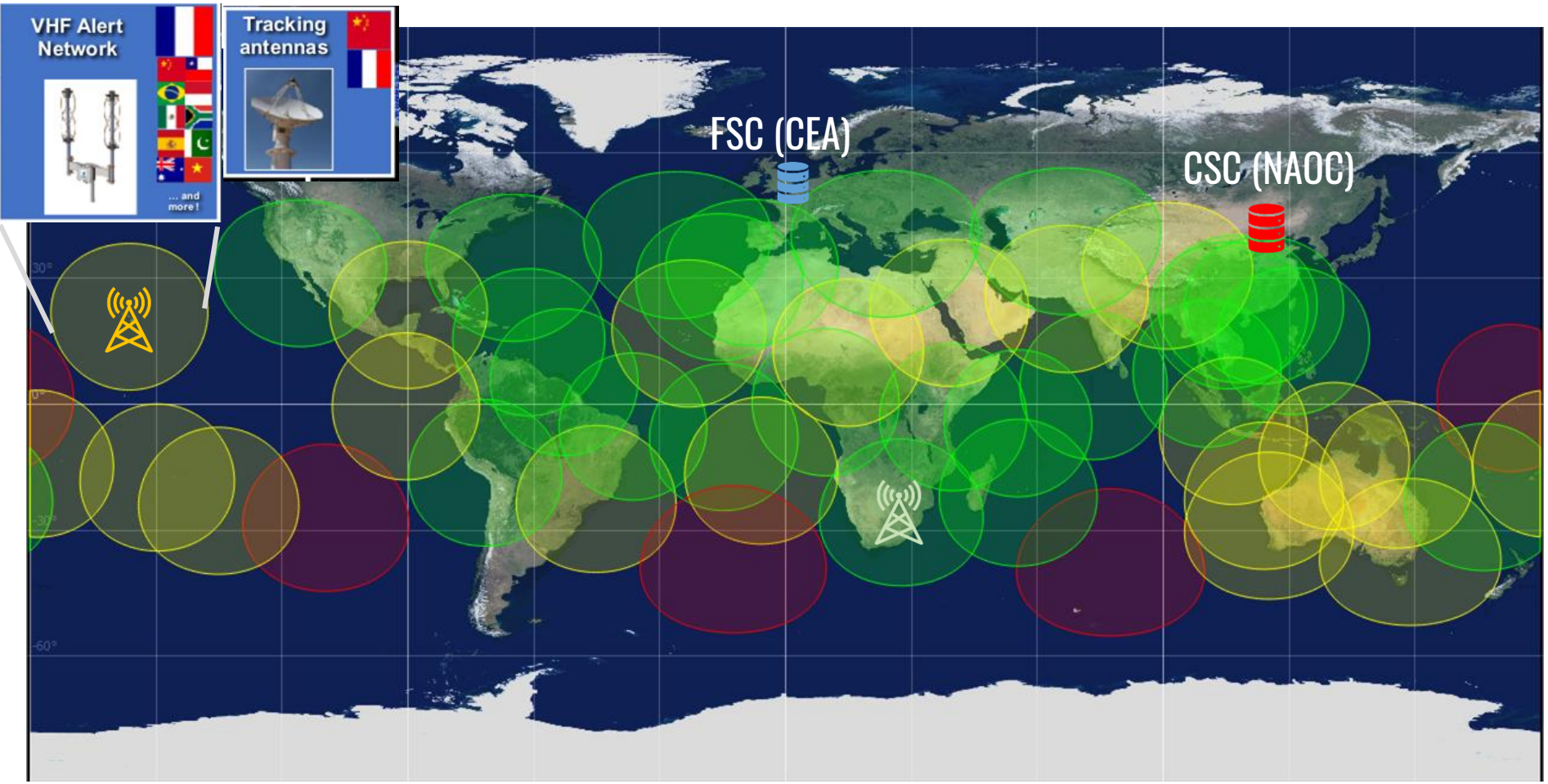
MXT-> VT to search for sources in the VT image inside the MXT error

ECLAIRs , MXT and VT -> GWAC and GFTs to indicate the coordinates of te GRB

GRM-> GWAC to indicate the time slice of the trigger

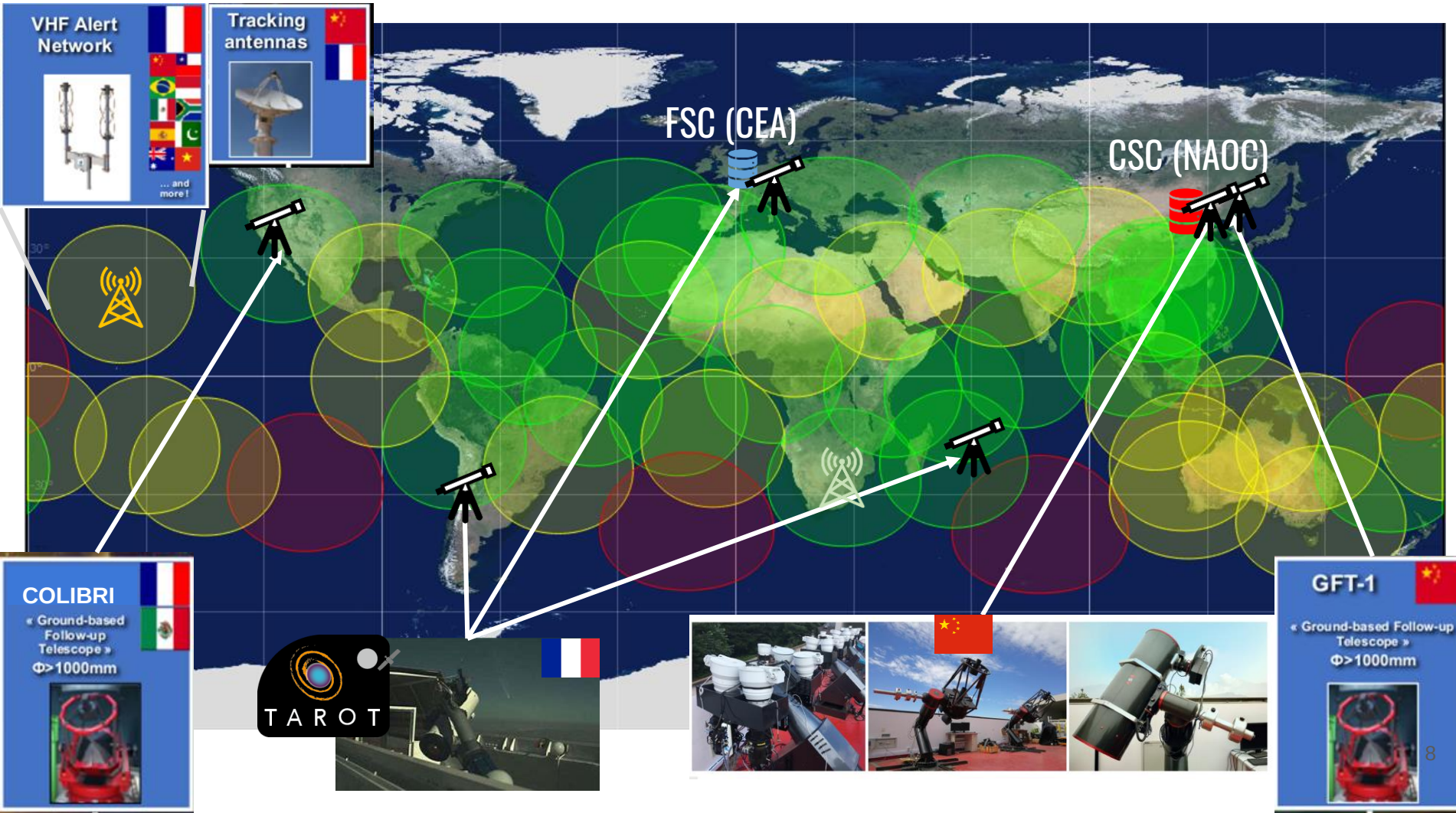
The SVOM ground segment

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.



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



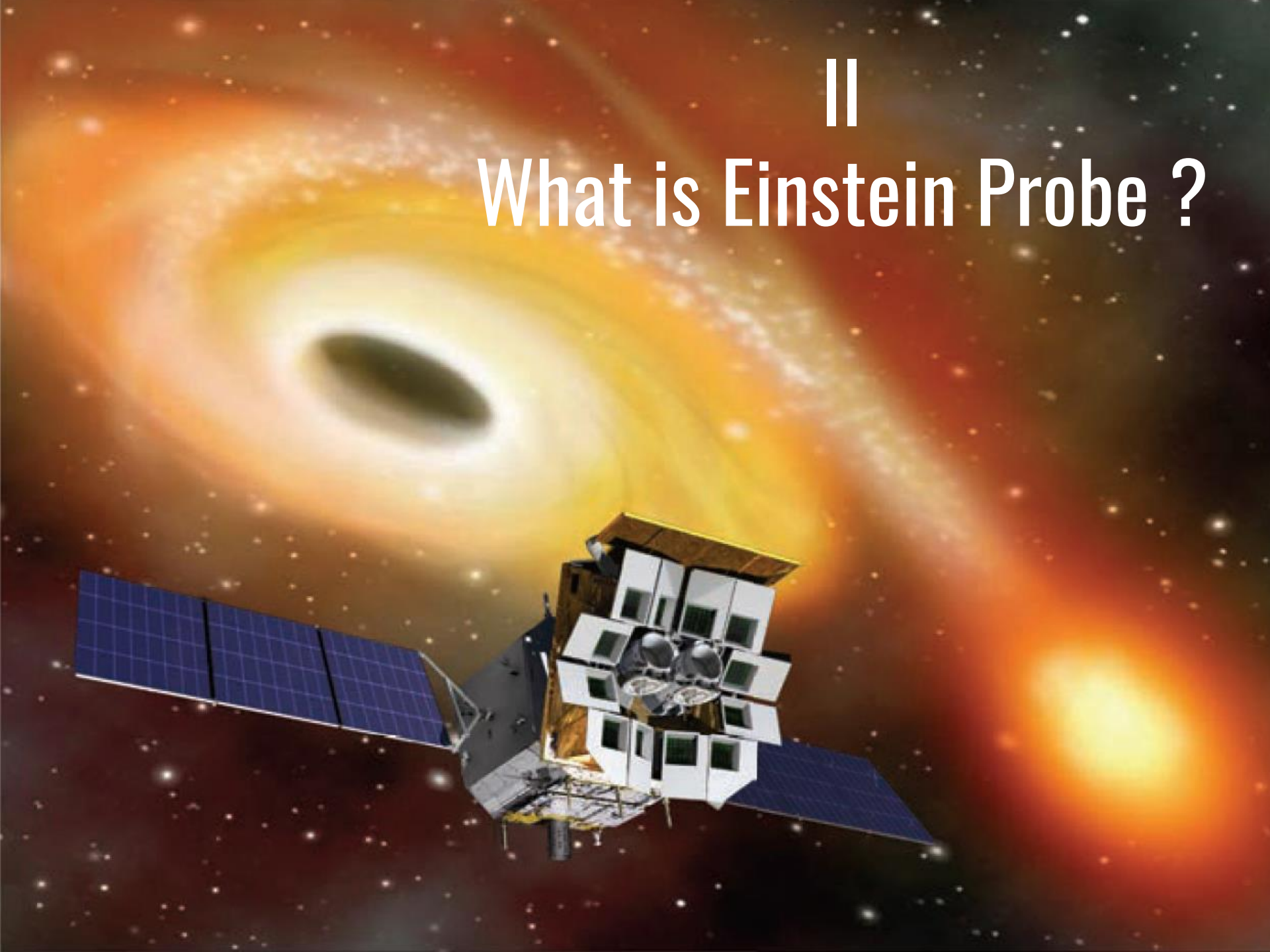
The SVOM scientific programs

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)

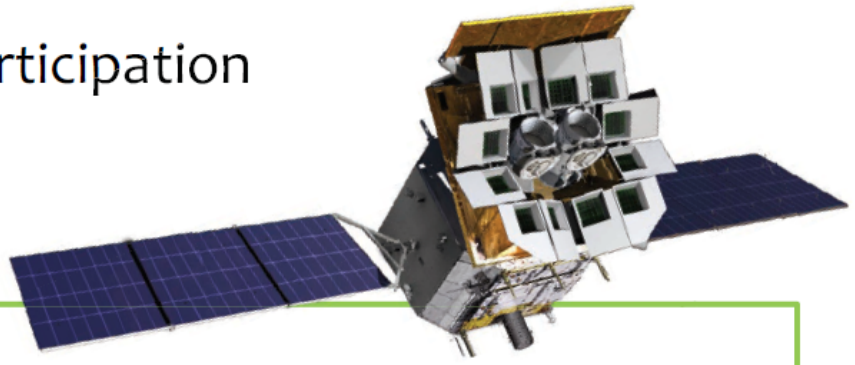
Target of Opportunity (ToO) program : alerts sent from the ground to the satellite. Initially 1 ToO per day focussed on time domain astrophysics including multi-messengers. ToO program devoted time increases during extended mission.

II
What is Einstein Probe ?



The Einstein Probe (EP) mission

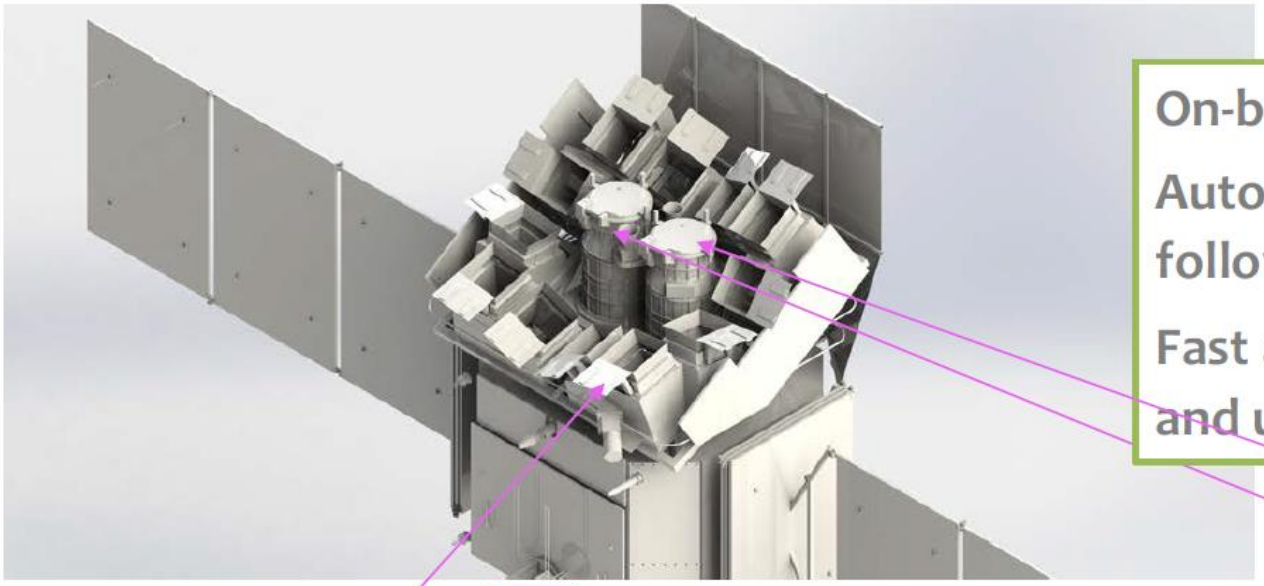
- A space observatory for all-sky monitoring to discover & study high-energy transients and variability in X-rays
- CAS's mission with international participation



- Large Field of View 3600 sq. deg.
- Monitoring: soft X-ray band: 0.5-4 keV
- Sensitivity: > 1 order of magnitude higher than those in orbit
- Good angular resolution (~5' fwhm) and positioning accuracy (<1')
- Autonomous X-ray follow-up (<10 arcsec localisation; 0.3-10keV)
- Fast alert data downlink and (possible) fast uplink (ToO)

Launch 2024 ?

Einstein Probe (EP) mission



On-board data processing

Autonomous slew & follow-up in 3-5 min

Fast alert data downlink and uplink (ToO)

WXT (12 modules) esa

lobster-eye MPO + CMOS

FoV: 3600 sq deg (1.1 sr)

band: 0.5 – 5 keV soft X-ray

eff. area: ~3 cm^2 @1keV

FWHM: ~ 5', positioning <1'

Sensitivity: 10-100 x increase

FXT(2 modules) esa

Wolter-1 type + CCD

FoV: 38'

band: 0.3-10keV

eff. area: 2x 300cm^2 @1keV

angular FWHM: 30"

positioning accuracy: <10"

Mission Management

- Mission management: EP is one of the CAS's missions in its Space Science Program (2nd phase).
- The project is managed by the CAS's National Space Science Center (NSSC) on behalf of CAS.
- The mission will be operated at the EP Mission Operation Center (EPMOC) hosted at NSSC.
- The science operation will be carried out at the EP Science Center (EPSC), which is the responsibility of and hosted mainly at National Astronomical Observatories of China (NAOC), CAS

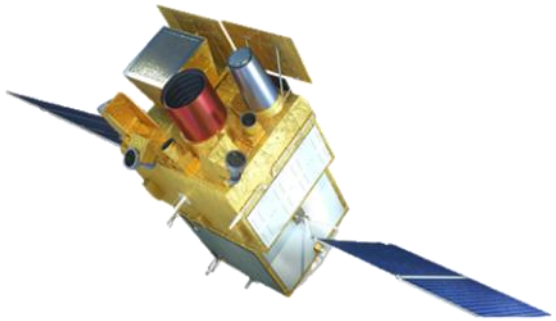
Status of international collaboration

- ESA -- mission of Opportunity (signed 2019)
  - FXT mirror assembly, WXT device/module testing/calibration, ground stations

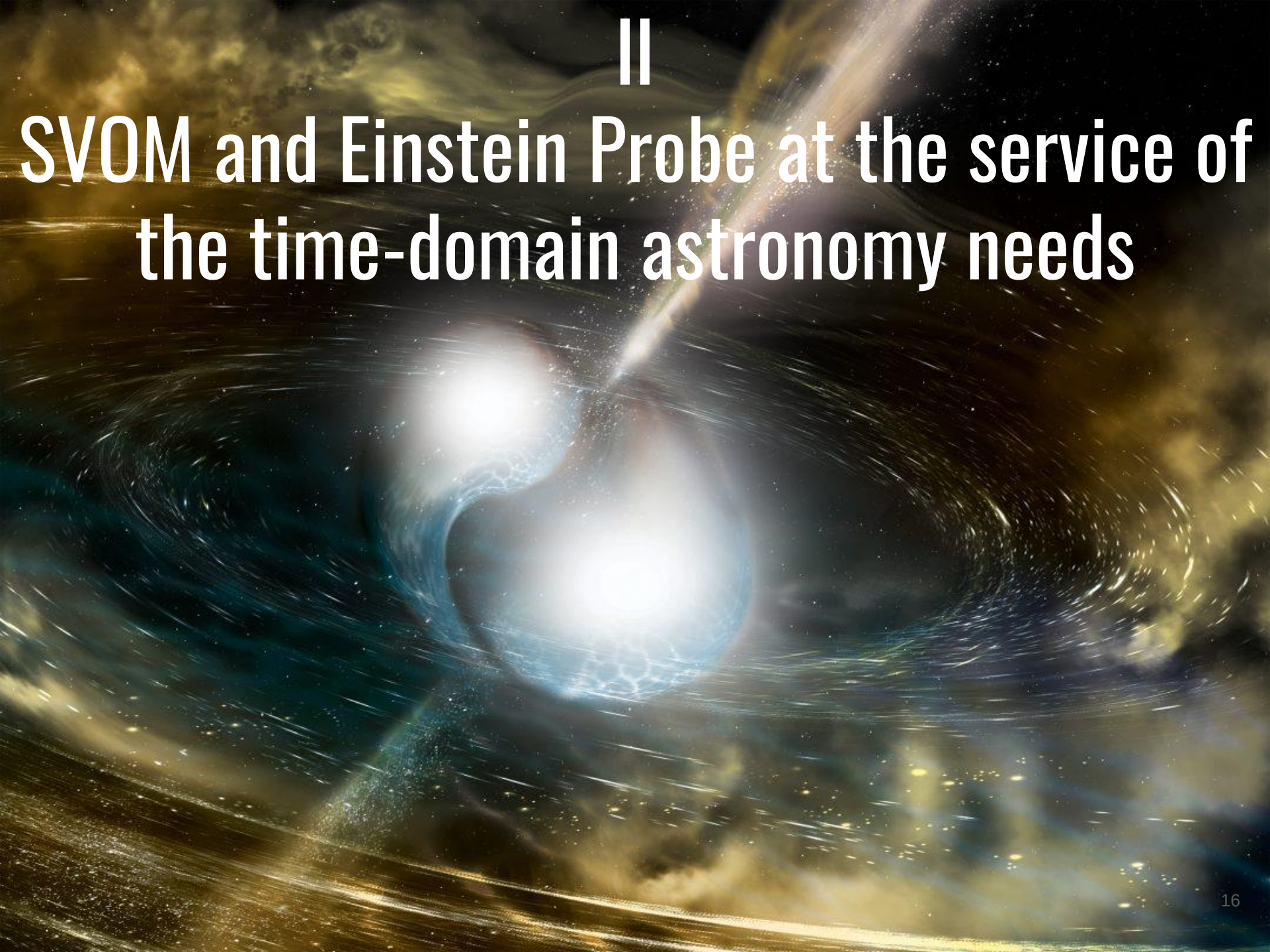
- Max-Placnk-Instit. for extraterrestrial Physics, Germany (signed 2019)
  - FXT CCD modules, mirror design and mandrels, one eROSITA MA DM and Flight Spare, ...

- France – SVOM scientific consortium (to be signed 2021)
  - SVOM VHF alert Network
    -> In return, scientific rights on 5% of EP data for SVOM coIs

Point communs SVOM / EP



- Même laboratoires chinois impliqués :
  Scientifiques : NAOC, IHEP
  Techniques SECM – même chef de projet pour les deux satellites…
- Même orbite : orbite basse inclinée à 30°
- Presque la même plateforme : beaucoup d'éléments communs (ordinateur de bord, roues inertiels, émetteurs VHF…)
- Système très similaire, même réseaux de communications Bande X, Bande-S, Beidou et réseau VHF
- Segment sol mutualisé côté chinois, opérations au NSSC, science au NAOC et même interlocuteurs que sur SVOM
- Follow-up?



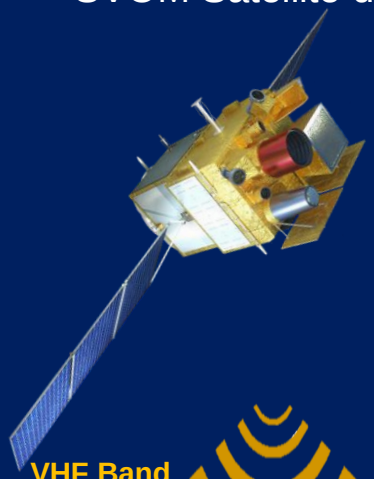
II
SVOM and Einstein Probe at the service of the time-domain astronomy needs

First take-away messages
the instrumental & data policy needs to study the transient Universe

- We must have wide FoV instruments in all bands -> SVOM instrument characteristics (ECLAIRs and GRM = 2str, MXT = 1deg², GWAC (500sq.deg), GWAC-F30 (~4sq.deg) (WXT = 1,1 str)
- We must have a world-wide network of telescopes with different sensitivities/FoV characteristics to continuously follow-up the phenomena.
- Synergies & Coordination between space and ground Observatories
- We must have a very responsive network of facilities: ToO-prog. for the satellite platform + dedicated follow-up telescopes on ground
- We should provide our detection/follow-up observational results as soon as possible to everybody

Operational Scenario for GRB detection by SVOM

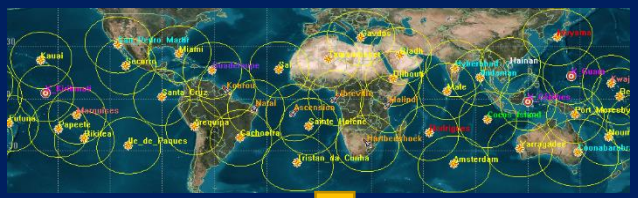
SVOM Satellite detects a GRB



VHF Band

X & S Band

Tracking antennas



VHF alert data

Science and HK data

Alert data processing by French Science Center + SVOM BA system

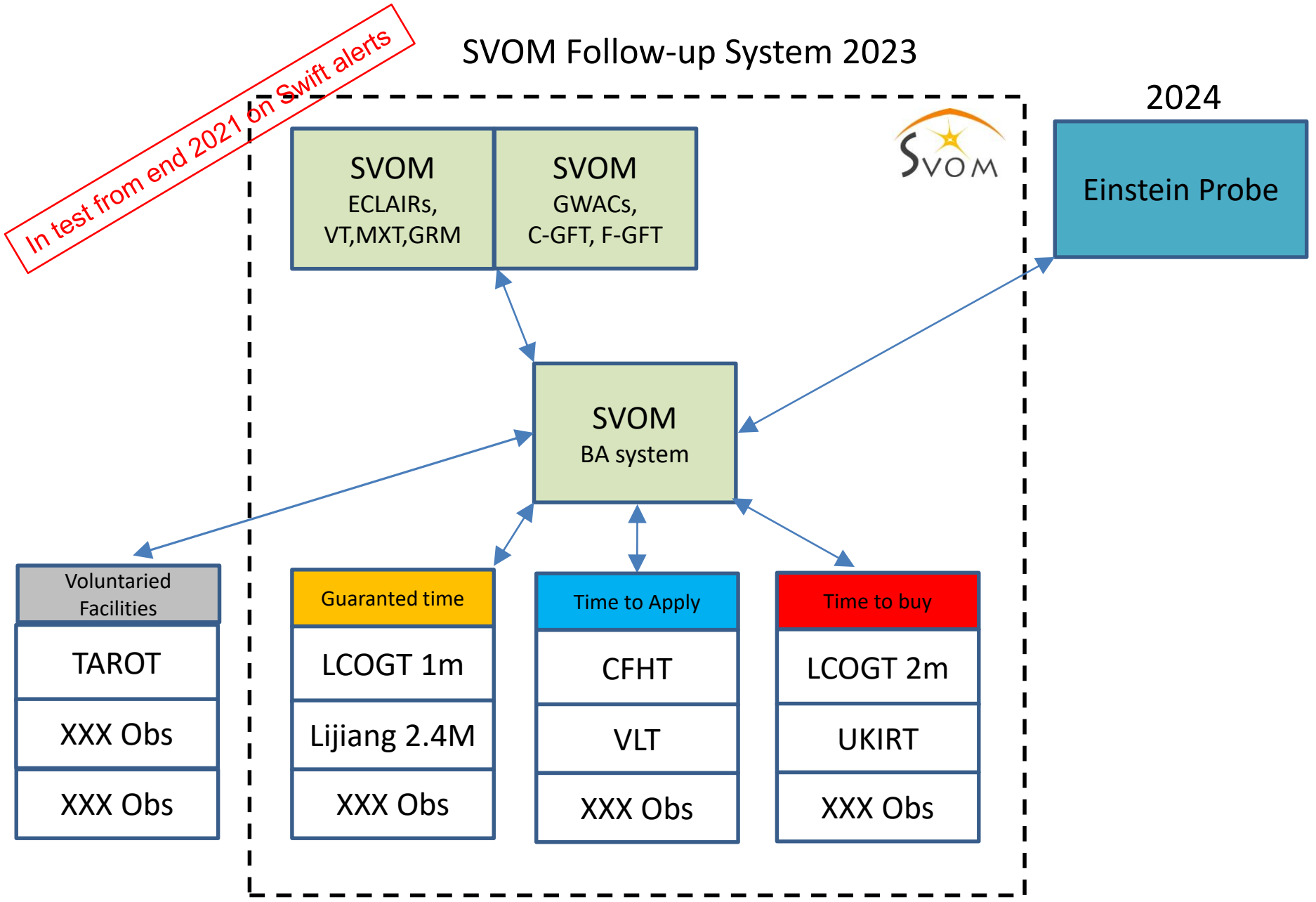
Science data processing by French and Chinese Science Centers

SVOM robotic telescopes

LCOGT

Others…

Large Ground Telescopes



Organization of the SVOM Follow-up system, operational end 2022 and based on the attractiveness of SVOM
The exchanges between SVOM and its various partners are (will be) defined in the updated SVOM Science Management Plan

... Now that this whole system is in place, SVOM is a powerful time domaine machine that can work in both direction

SVOM Satellite slews and observes a Target of Opportunity

Object detected by other observatories Space or Ground

LSST

LIGO VIRGO

Observation requests (ToO) analysed at French and Chinese Science Centers

Preparation of satellite TC plan by Mission Center

Chinese Control Center

Telecommands

Beidou and S Band

Tracking antennas

Science data

X Band

Tracking antennas

Science data processing by French and Chinese Science Centers

SVOM robotic telescopes

LCOGT

Others…

The SVOM ToO programs

SVOM WORLD

Only accessible by the SVOM CO-Is

ToO-Multi-Messenger

- 1/week
- Allocated time: 1-14 orbits (1 day)
- Max latency: 12h (S-Band) / <4h (Beidou)
- Instruments: MXT, VT + grd seg.

ToO-EXceptional

- 1/month
- Allocated time: 7-14 orbits (1 day)
- Max latency: 12h (S-band) / <4h (Beidou)
- Instruments: MXT, VT + grd seg.

SVOM + 

Accessible to everybody

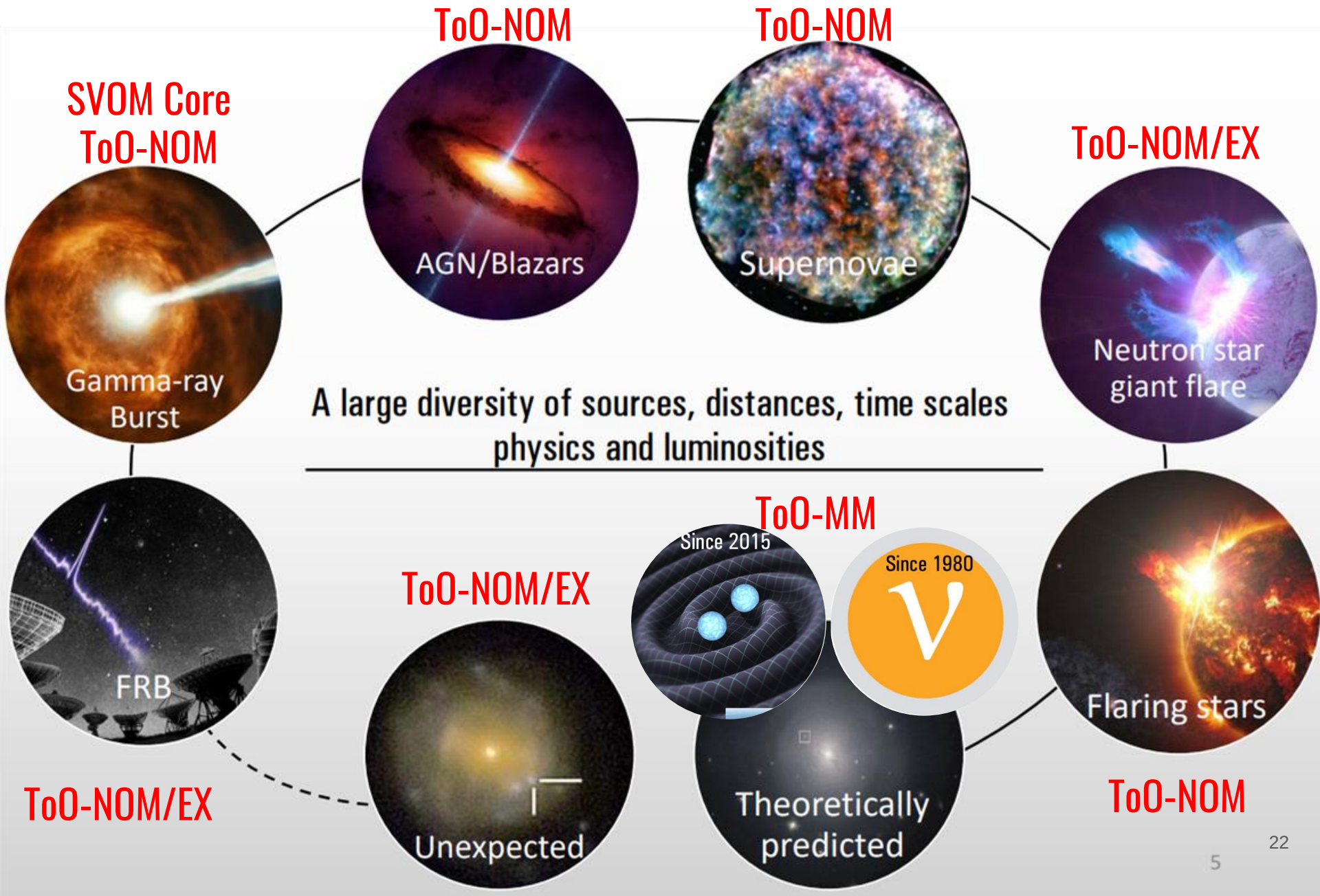
ToO-NOMinal

- 1/day
- Allocated time: 1 orbit (~45 min)
- Typical latency: 24-48h
- Instruments: MXT, VT + grd seg.

a % of sci. products public

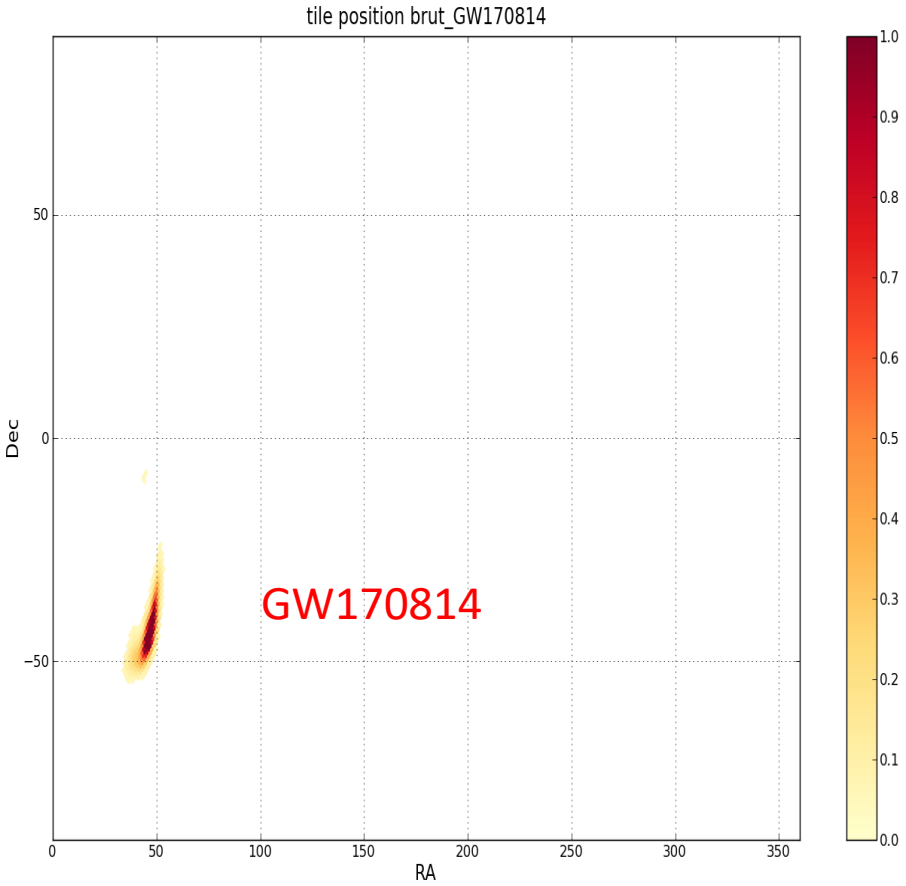
all sci. products public

The Transient Universe & the SVOM ToO programs



ToO Multi-Messenger : Tiles sequencing simulations

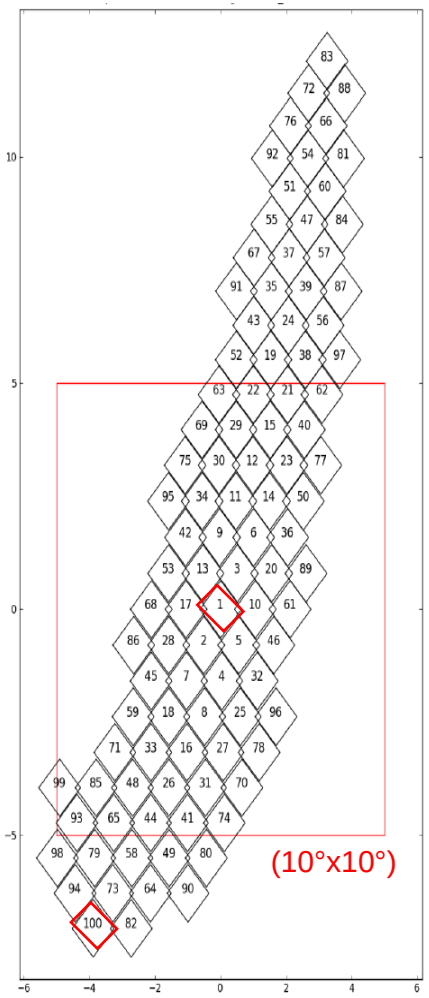
- First example of ToO-MM request : scenario « focused »



Likelihood

Scenario	170814 GW
Nb. tiles	230
RA min (°)	34.4
RA max (°)	53.4
Dec min (°)	-54.3
Dec max (°)	-7.8
LH total (%)	90.0
LH 75 (%)	66.0

GW170814

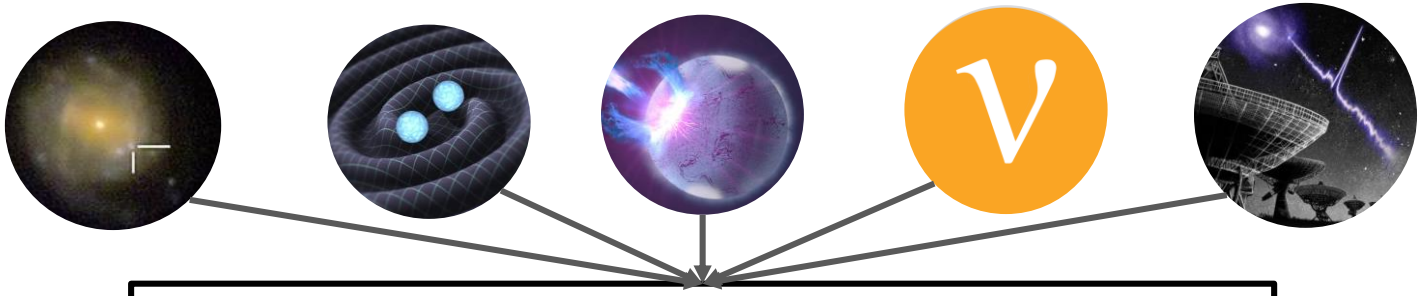


First 100 tiles

© cnes

SVOM ToO infrastructure

we think about this...



Alert channels / Alert processing / Alert filtering

New generation of Brokers to handle 10^6 alerts/night !
(dev. triggered by the Vera Rubin LSST transient prog.)

FINK

SVOM robotic telescopes

Only **ONE FILTERED** alert stream for SVOM

SVOM ToO manager

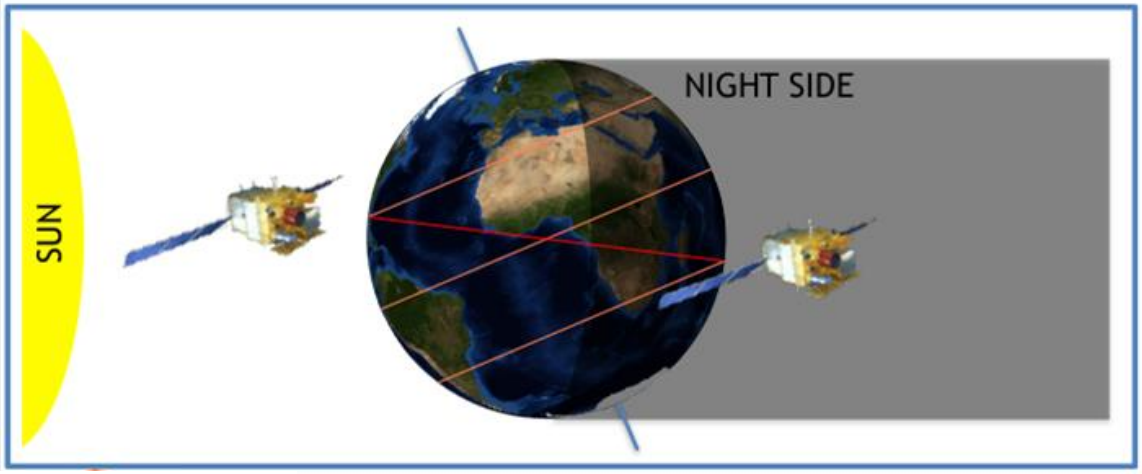
Thank you !

Questions, discussions and suggestions are welcome !

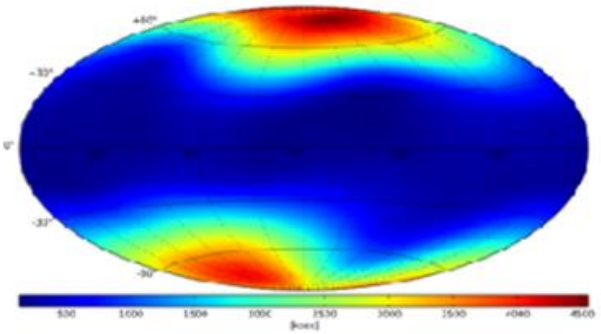
Back-up slides

The SVOM obs. strategy (onboard)

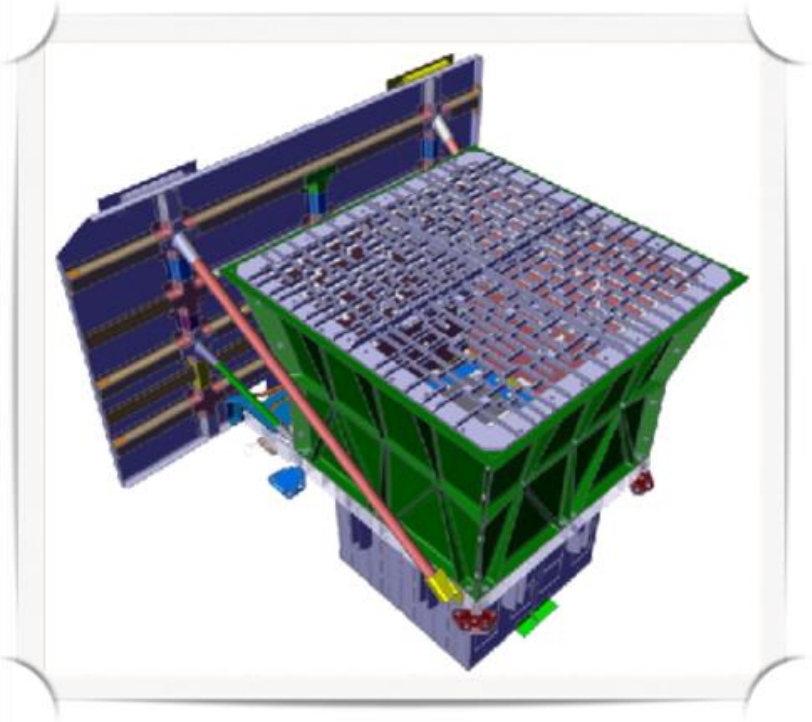
- **Launched** from **Xichang** (Sichuan) by an **LM-2C** rocket in June 2022
- **Circular low Earth orbit at 625 km** of altitude with an **inclination of about 30°**
- Nearly **anti-solar pointing** (so-called « **B1** » **attitude law**)
  => Earth in the field of view (**65% of duty cycle for ECLAIRs, about 50% for MXT and VT**)
- **Avoidance of the Galactic plane** (most of the time) and **Sco X-1**
- **Slew** capability: **45° in 5 minutes** (including arc sec stabilisation)
- **GRB follow-up** during up to **14 orbits** (about 1 day)



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



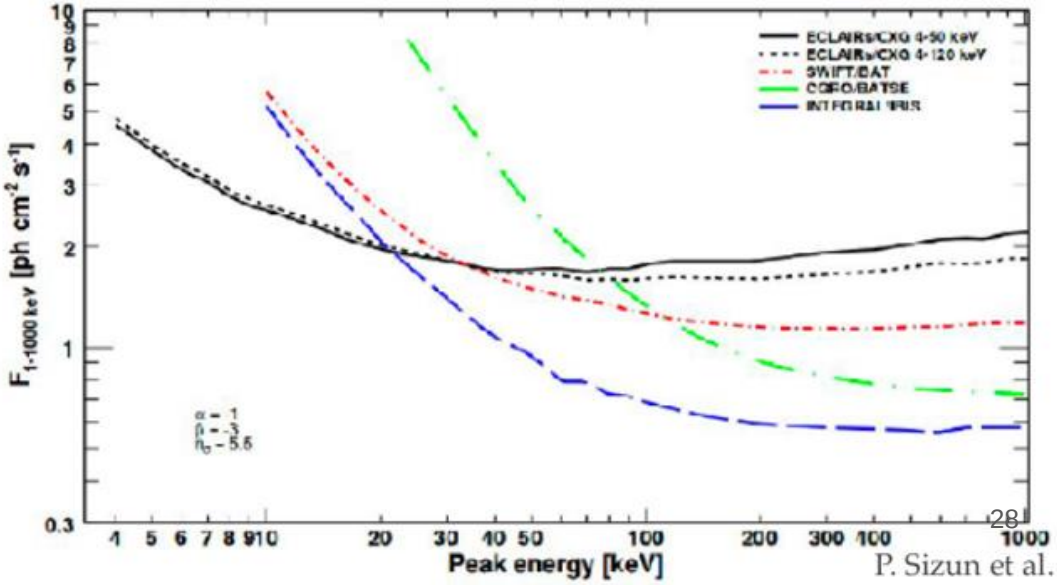
The SVOM instruments: ECLAIRs



Well adapted for the detection of low-Epeak GRBs

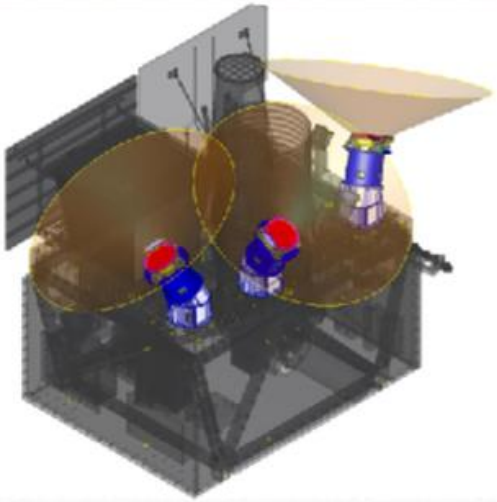
ECLAIRs (CNES, IRAP, CEA, APC)

- 40% open fraction
- Detection plane: **1024 cm²**
- **6400 CdTe pixels** (4x4x1 mm3)
- **FoV : 2 sr** (zero sensitivity)
- **Energy range:** 4**-150 keV**
- **Localisation** accuracy **<12'** for 90% of the sources at detection limit
- Onboard trigger and localization: about **65 GRBs/year**



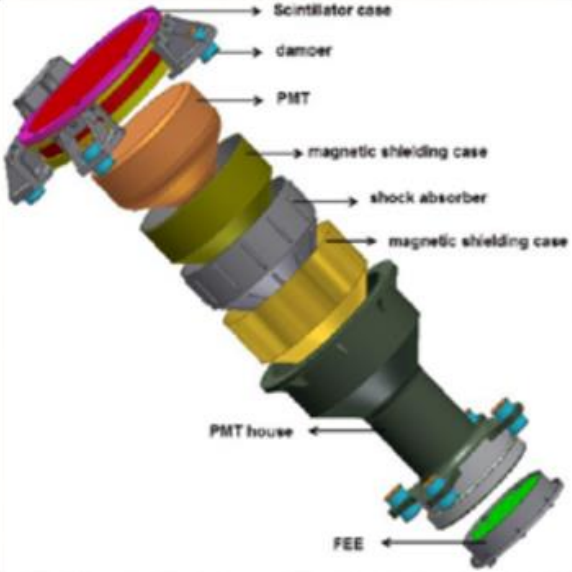
P. Sizun et al.

The SVOM instruments: GRM



Gamma-Ray Monitor (IHEP)

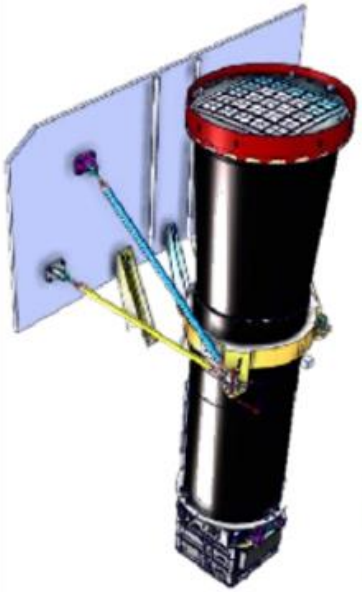
- **3 Gamma-Ray Detectors** (GRDs)
- **NaI(Tl)** (16 cm Ø, 1.5 cm thick)
- Plastic scintillator (6 mm) to monitor particle flux and reject particle events
- **FoV = 2 sr per GRD**
- **Energy range: 15-5000 keV**
- Aeff = 190 cm² at peak
- Rough localization accuracy
- **Expected rate: ~90 GRBs / year**



Will provide Epeak measurements for most ECLAIRs GRBs
Will be able to detect GRBs and transients out of the ECLAIRs FOV (poor localisation capabilities)

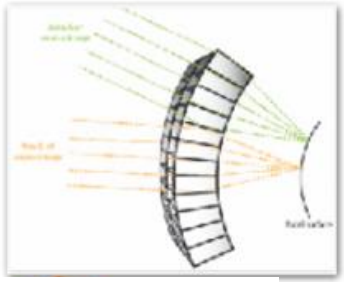
The SVOM instruments: MXT

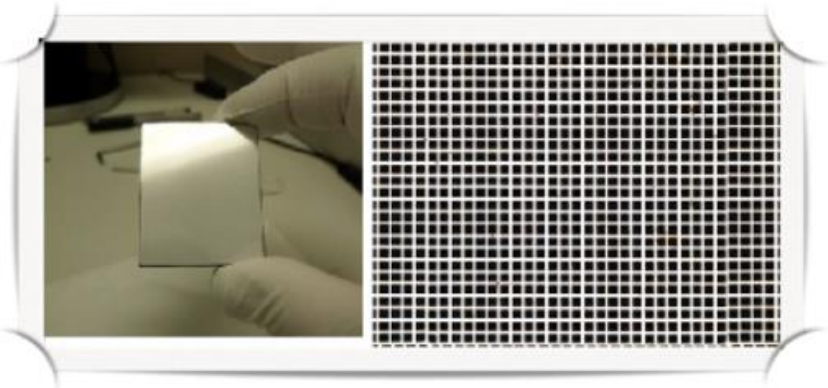
Micro-channel X-ray Telescope (CNES, CEA, UL, MPE)

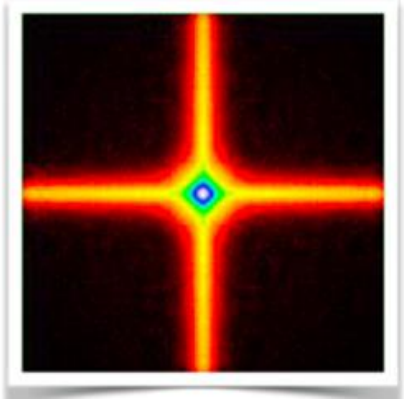


- **Micro-pores optics** (Photonis) with **square 40 micron size pores**
- pnCCD (MPE) based camera (CEA)
- **FoV = 57x57 arcmin²**
- Focal length: 1.15 m
- **Energy range: 0.2-10 keV**
- Aeff = 23 cm² @ 1 keV (central spot)
- **Energy resolution: ~80 eV @ 1.5 keV**
- **Localization accuracy <20″** within 5 min from trigger for 50% of GRBs (statistical error only)

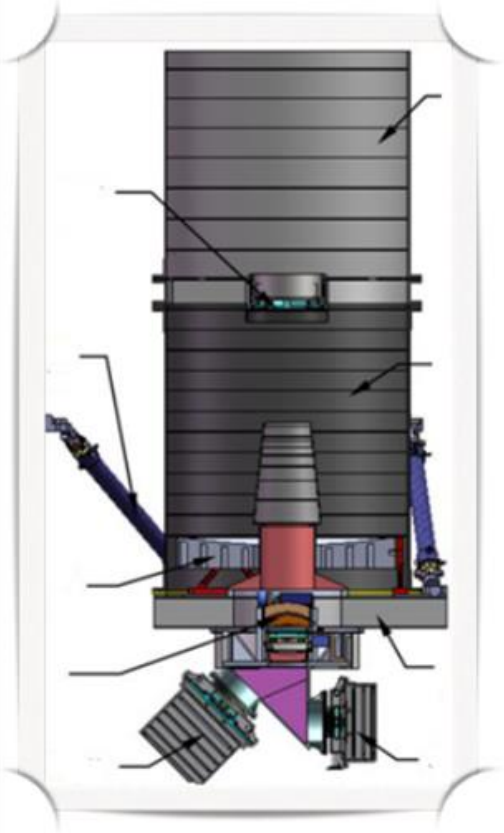
Implements innovative focussing X-ray Optics based on « Lobster-Eye » design
Will be able to promptly observe the X-ray afterglow







The SVOM instruments: VT

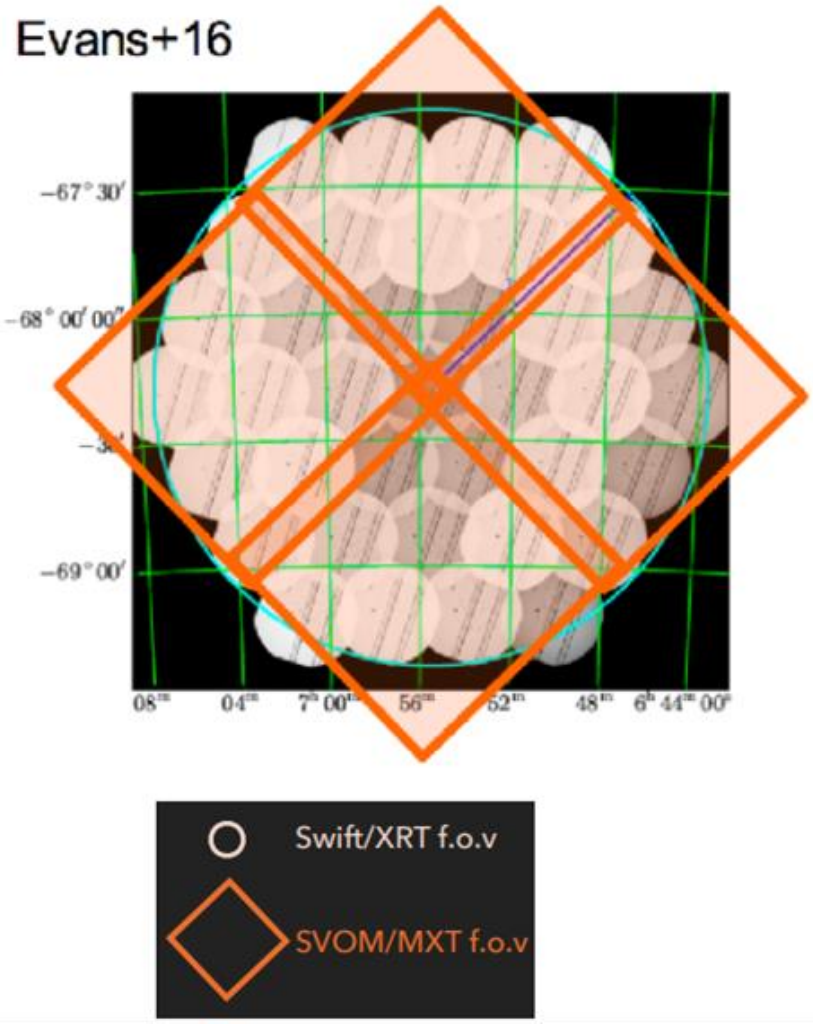


Visible Telescope (XIOMP, NAOC)

- Ritchey-Chretien telescope
- **40 cm Ø, f=9**
- **FoV = 26x26 arcmin²**
- Covering ECLAIRs error box in most cases
- **2 channels: blue (400-650 nm) and red (650-1000 nm)**
- 2k * 2k CCD detector each
- **Sensitivity MV=22.5 in 300 s**
- Will detect ~80% of ECLAIRs GRBs
- **Localization accuracy <1″**

Able to detect high-redshift GRBs up to z~6.5 (sensitivity cutoff around 950 nm)
Can quickly provide redshift indicators due to the presence of two channels

Tiling strategy with MXT in case of a MM alert



To follow multi-messenger alerts using tiles, Swift/XRT is better than SVOM/MXT in terms of sensitivity and localization accuracy.

But MXT is very competitive to rapidly cover large error boxes with only a slightly reduced sensitivity thanks to its large field of view (1 deg²).

Typical scenario: 5 tiles/orbit – 15 orbits (~ 1 day)