The *SVOM* mission

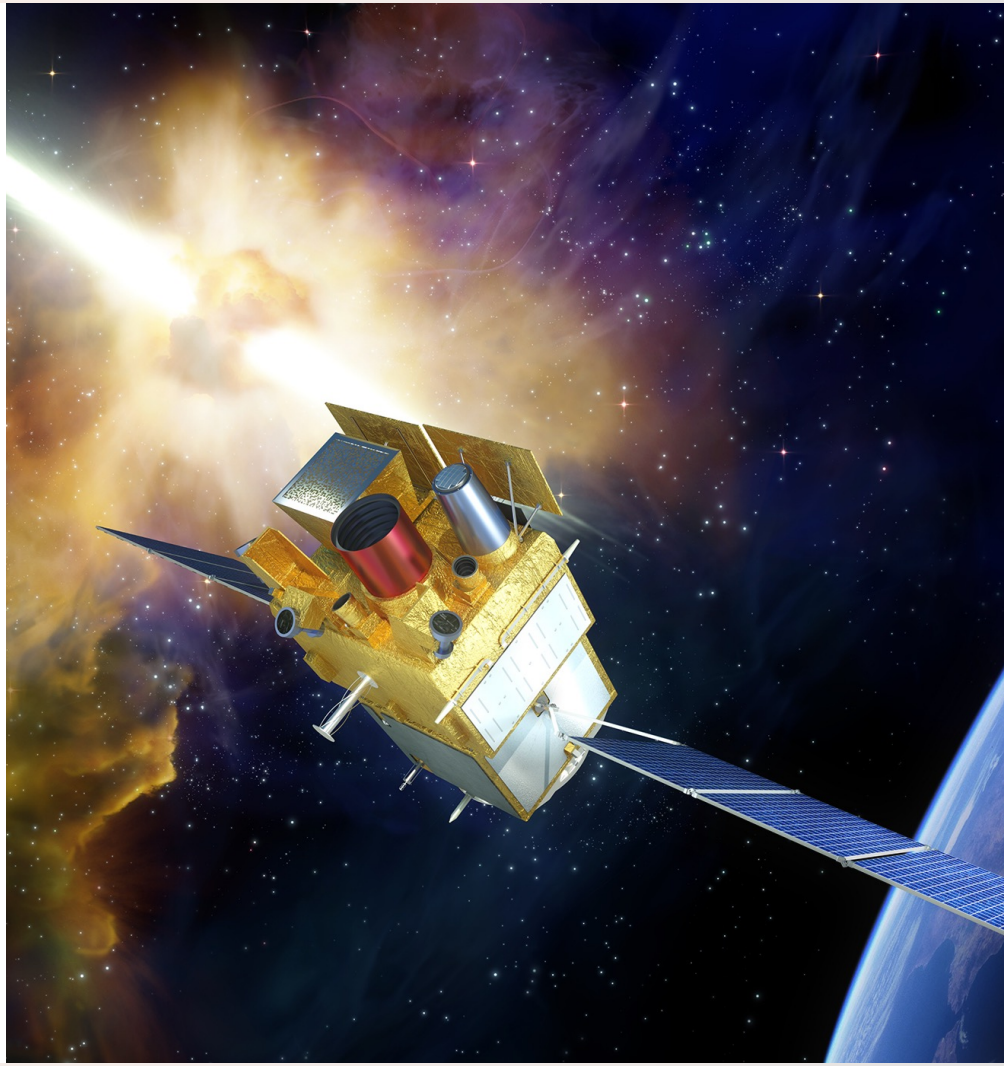
Your partner in multi-messenger astronomy

J-L Atteia – IRAP – Toulouse

on behalf of the SVOM Collaboration

The Collaboration

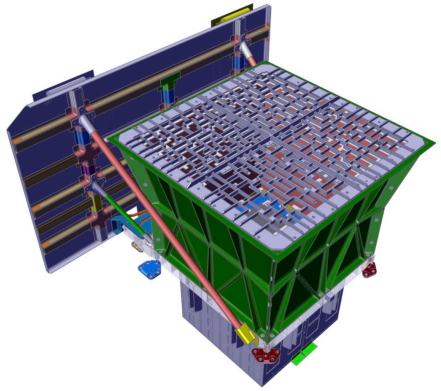
- **China (PI J. Wei)**
  - SECM Shanghai
  - Beijing Normal University
  - Central China University Wuhan
  - Guangxi University Nanning
  - IHEP Beijing
  - KIAA Peking University
  - Nanjing University
  - NAOC Beijing
  - National Astronomical Observatories
  - Purple Mountain Observatory Nanjing
  - 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
  - LAL Orsay
  - LAM Marseille
  - LUPM Montpellier
  - OAS Strasbourg
- **UK** University of Leicester
- **Germany**
  - MPE Garching
  - IAAT Tübingen

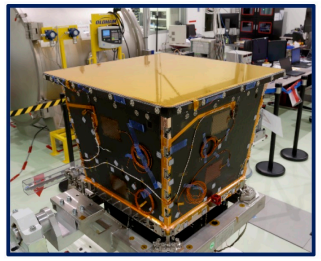


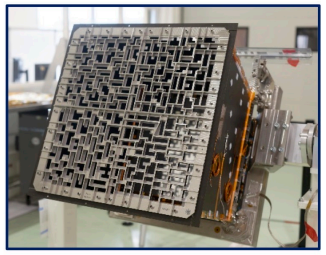
SVOM at a glance

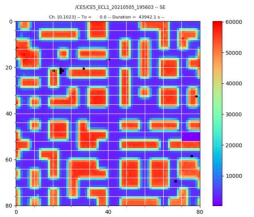
Two Wide-Field Instruments in Space

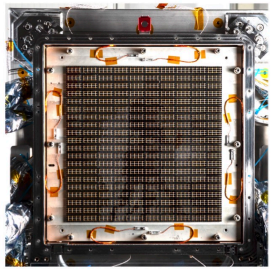
ECLAIRs

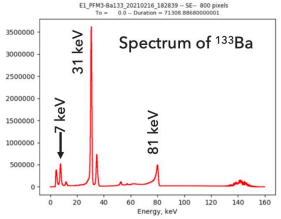










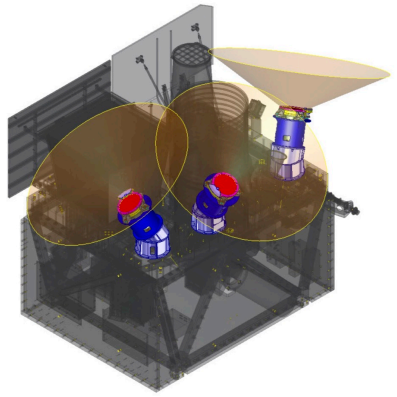


ECLAIRs (CNES, IRAP, CEA, APC)

- 40% open fraction
- Detection area: **1000 cm²**
- **6400 CdTe pixels** (4x4x1 mm³)
- **FoV: 2 sr** (zero sensitivity)
- Energy range: **4** - 150 keV
- **Localization** accuracy **<12 arcmin** for 90% of sources at detection limit
- Onboard trigger and localization: **~65 GRBs/year**

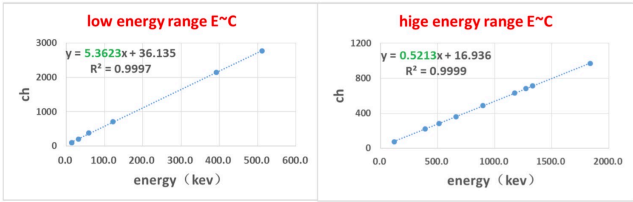
Well suited to detect long GRBs with low EPEAK

GRM



GRM Gamma-Ray Monitor (IHEP)

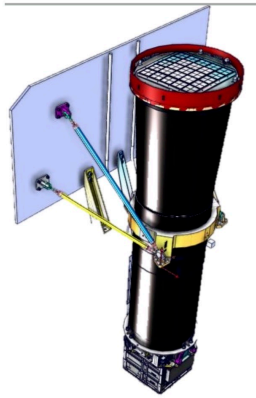
- **3 Gamma-Ray Detectors** (GRDs)
- **NaI(Tl)** (16 cm Ø, 1.5 cm thick)
- Plastic scintillator (6 mm) to monitor particle flux and reject particle events
- **FoV:2.6 sr per GRD**
- **Energy range: 15-5000 keV**
- Aeff = 190 cm² at peak
- Crude localization accuracy
- Expected rate: **~90 GRBs / year**

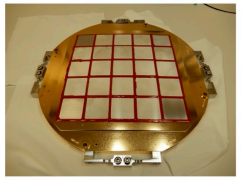


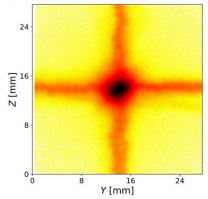
Will measure EPEAK for most ECLAIRs GRBs
Will detect short & long GRBs out of the ECLAIRs FOV

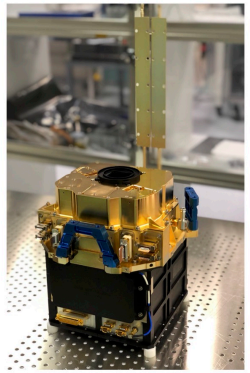
Two Narrow-Field Instruments in Space

MXT

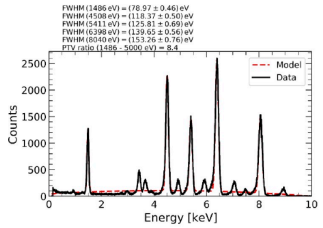








Energy calibration with multi-line spectrum:
79 eV @ 1,5 keV (single events),
88 eV @ 1,5 keV (all events)

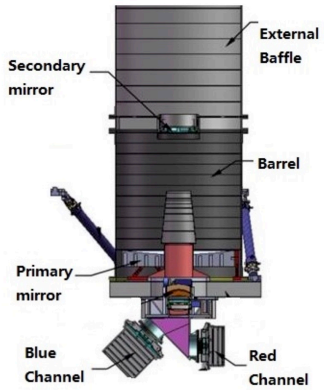


MXT Micro-channel X-ray Tel. (CNES, CEA, UL, MPE)

- **Micro-pores optics** (Photonis) with **square 40 µm pores** in a "Lobster Eye" conf. (UL design)
- pnCCD (MPE) based camera (CEA)
- **FoV: 64x64 arcmin²**
- Focal length: 1 m
- **Energy range: 0.2 - 10 keV**
- Aeff = 27 cm² @ 1 keV (central spot)
- Energy resolution: ~80 eV @ 1.5 keV
- **Localization accuracy <13 arcsec** within 5 min from trigger for 50% of GRBs

Innovative focusing « Lobster-Eye » X-ray optics
Will observe the X-ray afterglow promptly

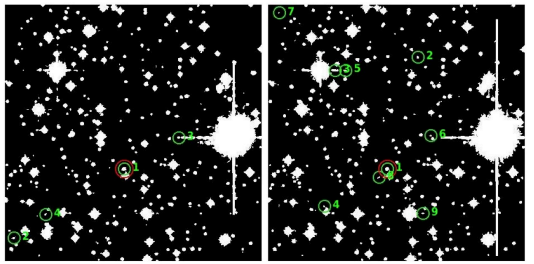
VT



VT Visible Telescope (XIOMP, NAOC)

- Ritchey-Chretien telescope, 40 cm Ø, f=9
- **FoV: 26x26 arcmin²**, covering ECLAIRs error box
- **2 channels: blue (400-650 nm) and red (650-1000 nm)**, with 2k * 2k CCD detector each
- **Sensitivity M_V=23 in 300 s**
- Will detect ~80% of ECLAIRs GRBs
- **Localization accuracy <1 arcsec**

Able to detect high-redshift GRBs up to z~6.5,
with two channels



On The Ground…

GFTs

GFTs permit the fast identification and measure of early optical/NIR afterglows (light-curve, SED) using the ECLAIRs positions, while the spacecraft is slewing to the source.

- C-GFTs is located at Weihai observatory (Jilin province)
- F-GFT will be located at OAN in San Pedro Mártir (Mexico)
- Contribution from the LCOGT network (12x1m+2x2m tel.)

Diameter : 130 cm
FOV: 26 x 26 arcmin
400 – 1700 nm

Diameter : 120 cm
FOV: 90 x 90 arcmin
400 – 900nm

>75% of ECLAIRs-detected GRBs immediately visible by one ground telescope (GFTs or LCOGT)

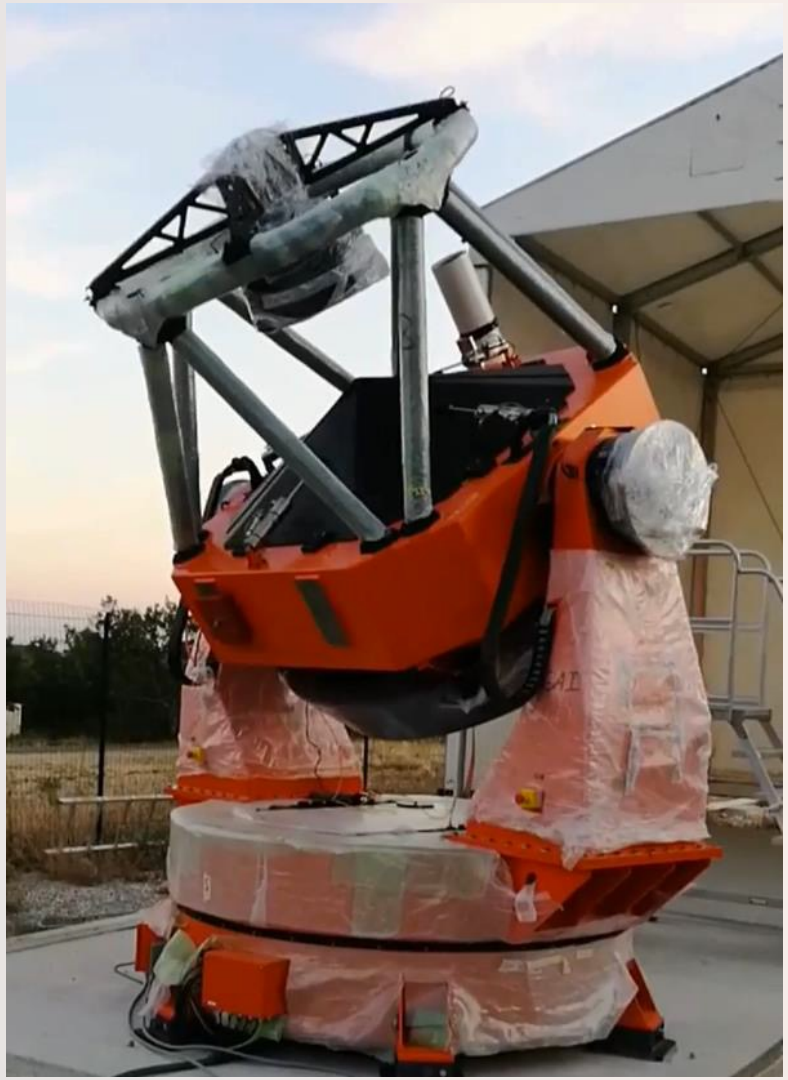
GWAC

GWAC Ground-based Wide Angle Camera

- Installed in Xinglong (5 units) and Muztagh Ata (4 units) observatories
- Each unit encompasses 4 JFoV cameras with an aperture of 180 mm and 1 FFoV camera with an aperture of 35 mm.
- The total FOV and limiting magnitude of JFoV cameras are respectively: **~6000 deg²**, and **V = 16 (10s)**

- One unit with 4 JFoV covers approximately the fully coded field of view of ECLAIRs
- Will scan the accessible sky each night
- Self triggering capabilities: will be able to catch autonomously optical transients
- The Chinese GWACs are in commissioning phase, already participating to the investigation of LIGO/VIRGO alerts

The GFTs



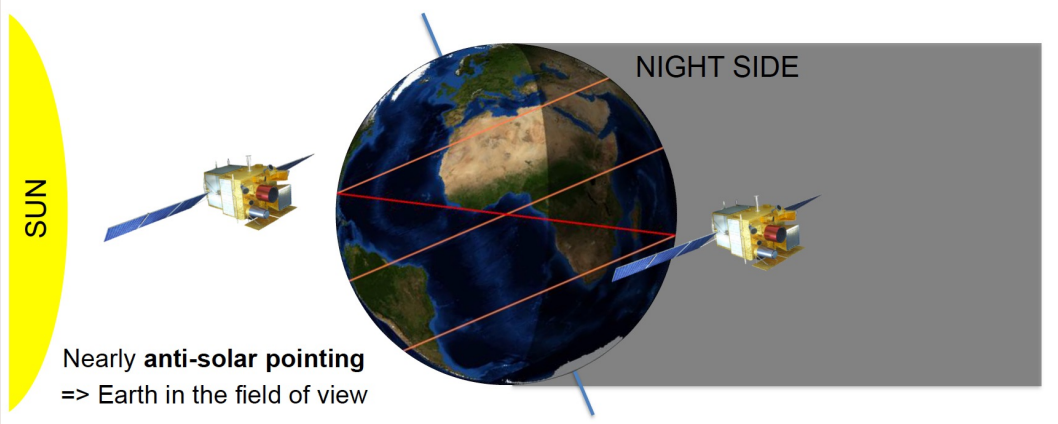
Colibri being tested at Haute-Provence Observatory ←

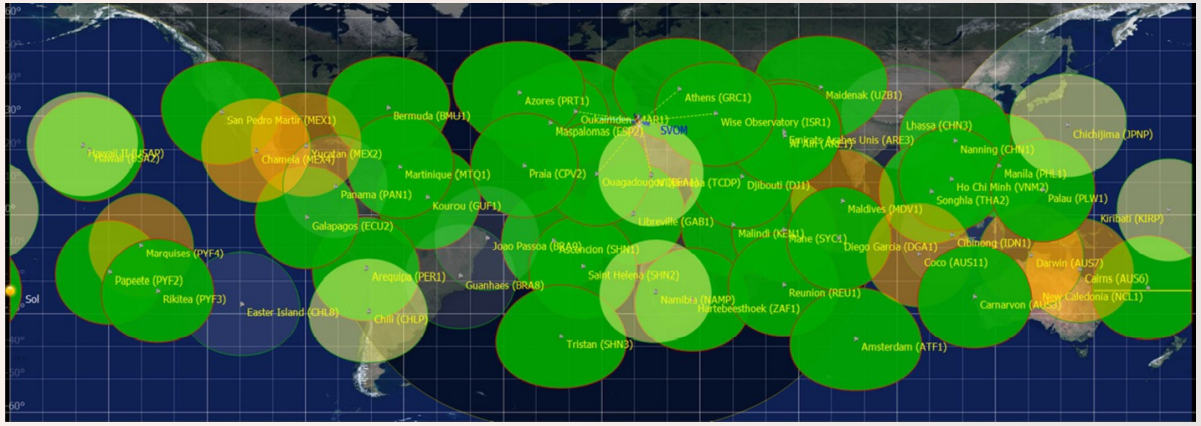
Diameter : 130 cm
FOV: 26 x 26 arcmin
400 – 1700 nm

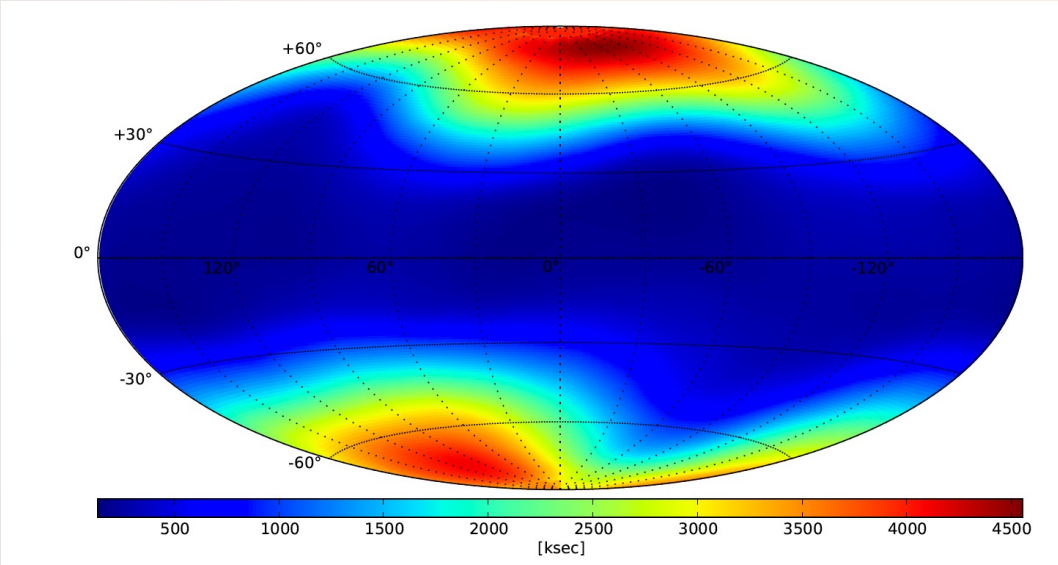
The Chinese GFT at Jilin Observatory →

Diameter : 120 cm
FOV: 90 x 90 arcmin
400 – 900nm

Pointing Strategy & Alert dissemination

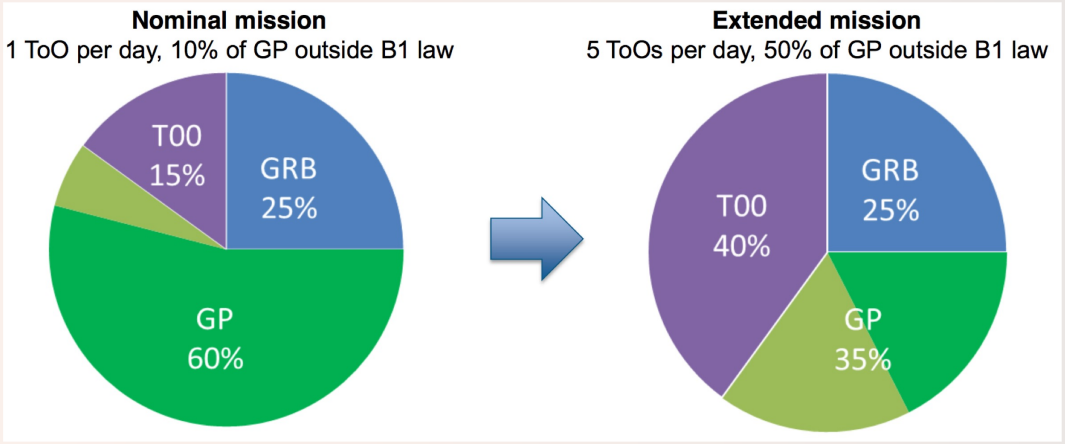






Three Observing Programs

- **Core Program (CP): GRB & HE transients detected by SVOM**
  - The CP includes the follow-up of SVOM detected transients.
- **General Program (GP)**
  - Observation proposals awarded by a TAC (a SVOM co-I needs to be part of your proposal).
  - 10% of the time spent on Galactic sources during the nominal mission, up to 50% during the extended mission.
- **Targets of Opportunity (ToO)**
  - ToO-NOM is the nominal ToO, used for GRB revisit, known source flaring, new transient,etc.
  - ToO-EX is a fast ToO used for exceptional astrophysical events to be observed rapidly.
  - ToO-MM is dedicated to multi-messenger alerts. It includes a **tiling strategy** needed to explore large error boxes
- **Initially 1 ToO/day, will increase during the extended mission.**
- **Many tools have been developed for the quick analysis of SVOM data**



ToO	Approval	From accep-tance/ trigger	GRB inter-ruption	Frequency	Duration
ToO-NOM	PI	<48h	Yes	MAX 1/day => 5/day	1 orbit
ToO-EX	PI	<12h	No	MAX 1/month	1-14 orbits

SVOM Generic and Specific Features

- On-board fast localization
- Automatic satellite slew

- On-board multi-wavelength capabilities

- Accurate localizations in minutes
- Fast alert dissemination

- ToO observations in 6-12 hours

SVOM Generic and Specific Features

- A mission designed to ease the **follow-up** of detected transients and foster **redshift** measurements:
  - Transients located in the night hemisphere
  - Strong follow-up capabilities included in the mission
  - Fast NIR follow-up with good sensitivity (high-z GRBs)
- A mission aimed at clarifying the **physics** of GRBs and enlarge **population** studies:
  - Broad frequency coverage of GRB prompt and afterglow emission
  - Balanced sensitivity between VT & MXT for GRBs afterglows (e.g. breaks)
  - Good sensitivity to soft transients
  - Long pointings allowing the detection of (ultra-) long transients
- A mission designed to operate in the broad context of **multi-messenger astrophysics**:
  - All HE photons are sent to the ground, allowing searches for off-line triggers and sub-threshold transients
  - A mission prepared to receive ToO requests and to perform tiled observations of large regions of the sky

SVOM science

- A large number of science questions require high-energy observations, some of them are listed below…
  - Stellar explosions – BNS mergers and the origin of heavy elements – BH astrophysics – Origin of magnetar activity…
  - Physics of relativistic jets, their role in VHE cosmic rays production
  - The high-z universe (with GRBs): IGM, first stars…
  - Tests of Lorentz Invariance
  - This is a non-comprehensive list…

- The diversity of HE transients require instruments with diverse observing strategies:
  - Gamma-ray bursts (of all types)
  - Mergers of compact objects
  - Active Galactic Nuclei & Relativistic Tidal Disruption Events
  - Galactic transients & Magnetars
  - Fast Radio Bursts?

SVOM in context

- The **transient sky** and **multi-messenger astrophysics** are two quickly developing fields of astrophysics. Both fields will benefit from a rich astronomical panorama in the 2020's:
  - Radio: SKA precursors & FRB detectors
  - Visible: Pan-STARRS – ZTF – VRO (LSST)
  - VHE γ-rays: CTA, HAWC, LHAASO
  - This is a non-comprehensive list…

  - GWs: LIGO – VIRGO – KAGRA
  - Neutrinos: KM3NeT – ICECUBE

- **High-energy observations** are an important component of multi-wavelength observations, and a crucial component of multi-messenger astrophysics

  → **Monitoring the High-Energy sky will be more needed than ever in the coming years.**

  → **SVOM brings some new capabilities.**

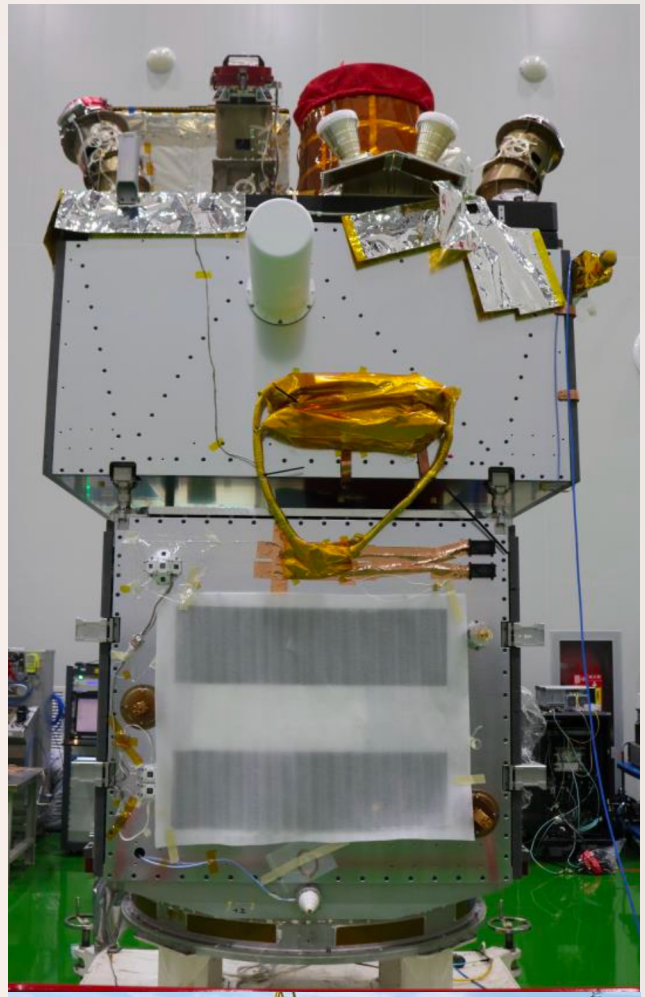
SVOM and O4

- The launch of SVOM in March 2024 (TBC), will bring additional capabilities for multi-messenger astronomy…
- New instruments for transient detection: GRM – ECLAIRs – GWAC
  - Sub-threshold triggers
- New instruments for follow-up: MXT, VT, C-GFT, Colibrí
- New opportunities to perform ToO observations
- *We are working hard to have SVOM ready to contribute to multi-messenger astrophysics during the second half of O4.*

Today…

- The 4 instruments are fully integrated on the payload module, itself mounted on the satellite (top right).
- Tests are going smoothly in the premises of the prime contractor in Shanghai.
- Heading for a launch in the first quarter of 2024.

- The Colibrí F-GFT has left OHP on June 19th (4 days ago), on its way to Mexico (bottom right).
- The GWAC and C-GFT are already operational.
- The majority of the VHF stations are installed and operational

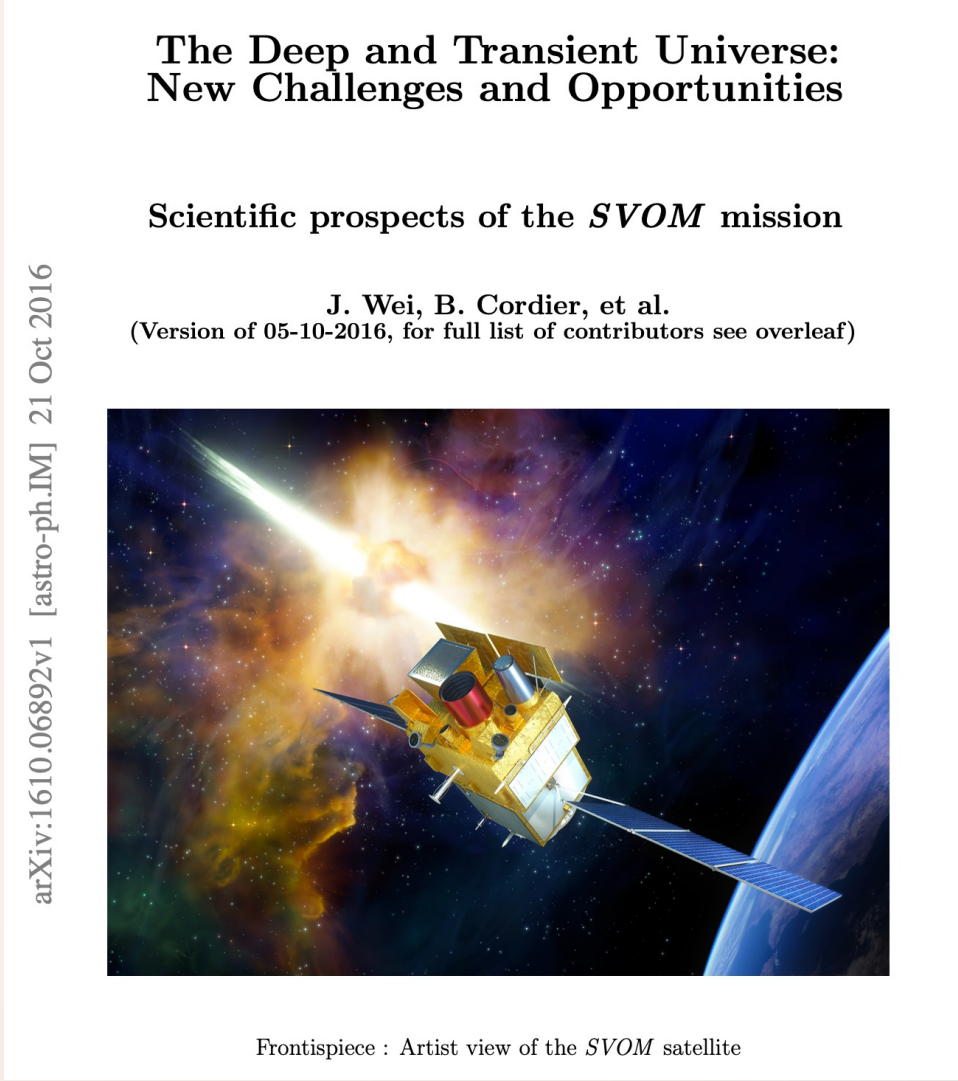


Pictures are **not** to scale

Conclusion…

- **In 2024+ *SVOM* will represent a new facility for the detection and follow-up of high-energy transients and the observation of multi-messenger transient sources.**
- **With some unique features, and working in synergy with new powerful instruments, *SVOM* will open a new window on these phenomena.**
- **➔ Stay tuned or contact us if you want to know more about the mission or even participate in *SVOM* science (encouraged)**
- **Additional information:**
  - SVOM White Paper: arXiv:1610.06892 (figure)
  - SVOM Website: http://www.svom.fr/en/
  - A recent conference paper (arXiv:2203.10962):

    IJMPD, Vol. 31, Issue 5, id. 2230008



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)

Frontispiece : Artist view of the *SVOM* satellite