The Gamma-Ray Burst mission

SVOM

on behalf of the
SVOM collaboration

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Gamma-Ray Burst science questions

GRB phenomenon	• Diversity and unity of GRBs, central engine
GRB physics	• Acceleration and nature of the relativistic jet • Radiation processes, gamma-ray emission • The early afterglow and the reverse shock
GRB progenitors	• Long GRB-supernova connection • Short GRB-merger connection
Cosmology	• Cosmological lighthouses (absorption systems) • Host galaxies • Star formation tracer • Re-ionization of the universe • Cosmological parameters
Fundamental physics	• Short GRBs and gravitational waves • Origin of high-energy cosmic rays • Lorentz invariance test

Need of a complete sample of GRBs, with spectral and temporal coverage and a distance measurement

SVOM overview

Space-based multi-band astronomical Variable Objects Monitor

- Devoted to GRBs
- Launch scheduled: Dec. 2021
- Orbit 600 km, 30° inclination
- Operations: 3+2 years

Scientific requirements

- Trigger on all known types of GRBs (>200 in 3 years)
  in particular X-ray rich GRBs, high-z GRBs and under-luminous GRBs
- Provide fast, reliable and accurate positions of GRBs, and send alerts to the community
- Measure the broadband spectral shape (from visible to MeV) and temporal properties of GRBs prompt emission
- Study the afterglows and provide quick arcsec positions of GRBs
- Provide redshift indicators for GRBs

SVOM Chinese-French bilateral project

CNSA (Chinese Space Agency)
CAS (Chinese Academy of Sciences)

- Launcher + launch service
- Satellite platform + payload module
- 2 space + 2 ground instruments

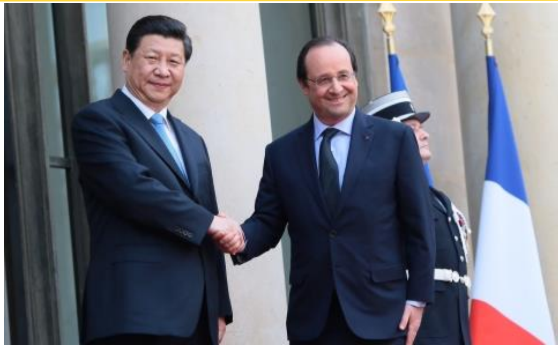
CNES (French space agency)

- 2 space + 1 ground instruments

Institutes

- **China (PI J. Wei, NAOC)**
  - **SECM Shanghai**
  - **NAOC Beijing**
  - **IHEP Beijing**
  - **Nanjing University**
- **France (PI B. Cordier, CEA)**
  - **CNES Toulouse**
  - **APC Paris**
  - **CEA Paris-Saclay**
  - **CPPM Marseille**
  - **GEPI Meudon**
  - **IAP Paris**
  - **IRAP Toulouse**
  - **LAL Orsay**
  - **LAM Marseille**
  - **LUPM Montpellier**
  - **OAS Strasbourg**
- **Germany**
  - **MPE Garching**
  - **IAAT Tübingen**
- **UK Univ. Leicester**
- **Mexico UNAM**

SVOM passed milestones



- 2006/03, Toulouse   Phase 0 kick-off
- 2007/03, Xi'an   Phase A kick-off
- 2008/10, Beijing   PRR
- 2013/10, Shanghai   Delta PRR (new config.)

- 2014/04 Common statement of Presidents Xi Jinping and François Hollande:

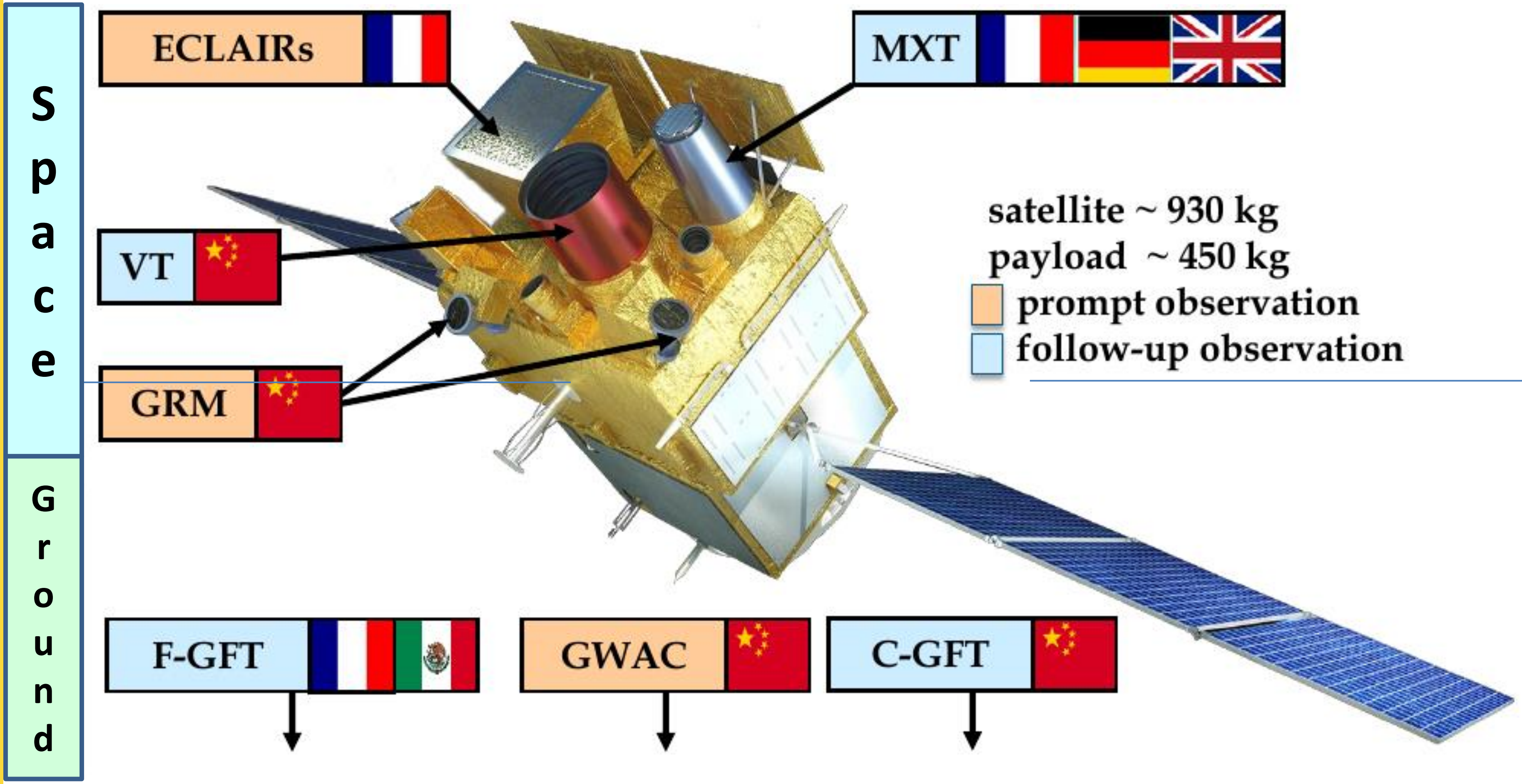
« Poursuivre la coopération sur les projets CFOSat et SVOM »

- 2014/09, Shanghai   Phase B kick-off
- 2016/07, Yantai   PDR
- 2017/01, Sanya   Phase C kick-off

SVOM instruments

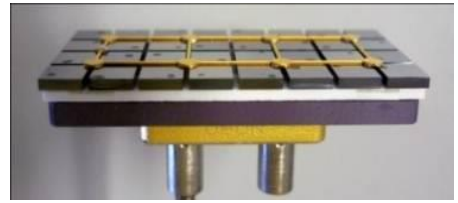
4 space instruments:
- ECLAIRs gamma-ray imager & trigger
- GRM gamma-ray monitor
- MXT X-ray focusing telescope
- VT visible band telescope

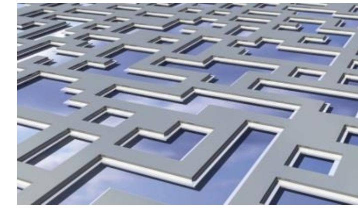
3 ground telescopes
- GWAC ground wide angle camera
- F-GFT & C-GFT: ground follow-up telescopes



ECLAIRs onboard Imager and Trigger

CNES, IRAP, CEA, APC

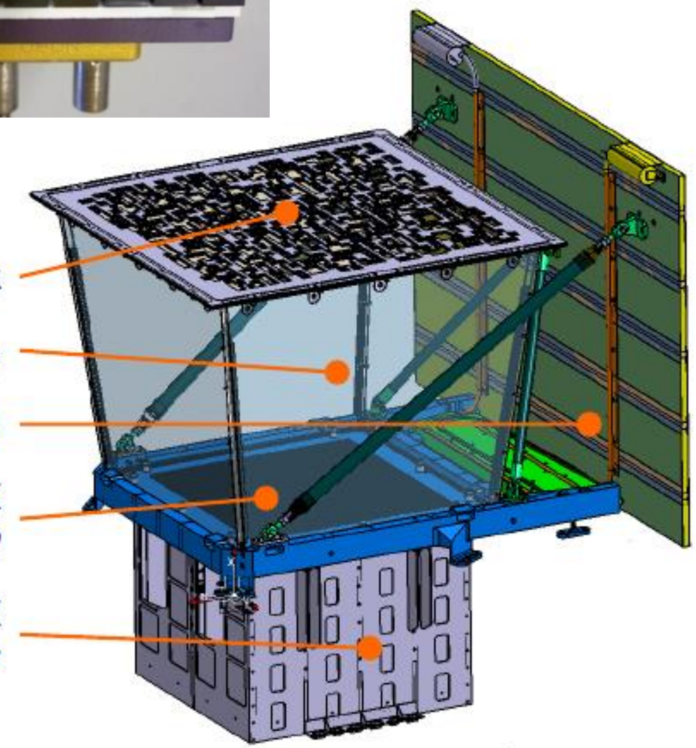




- **Detection plane**: 1024 cm²
- 6400 CdTe pixels (4x4x1 mm^3)
- Energy range: 4-150 keV
- Aeff = 200 cm² @ 6 keV

- **Mask**: Ta, 40% open, self supporting
- FoV = 2 sr (total)
- Localisation accuracy <12'

(at detection limit, 90% C.L.)



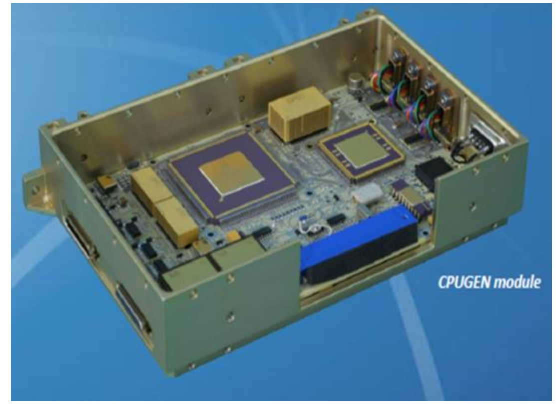
- **control and trigger unit UGTS**
- All photons sent to ground (6-12 h delay)
- GRB trigger & localization:
    - alert to ground via VHF
    - spacecraft slew for follow-up

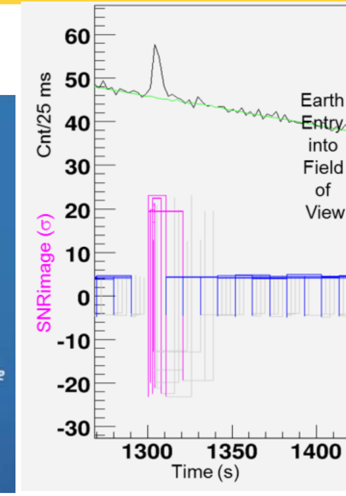
Trigger Unit onboard ECLAIRs

- **FPGA + CPU** (Leon3, 2×50 Mflops)
- **2 algorithms** (on 4 energy bands):

Count-rate (<20 s) + Image trig (<20 min)

CNES, CEA



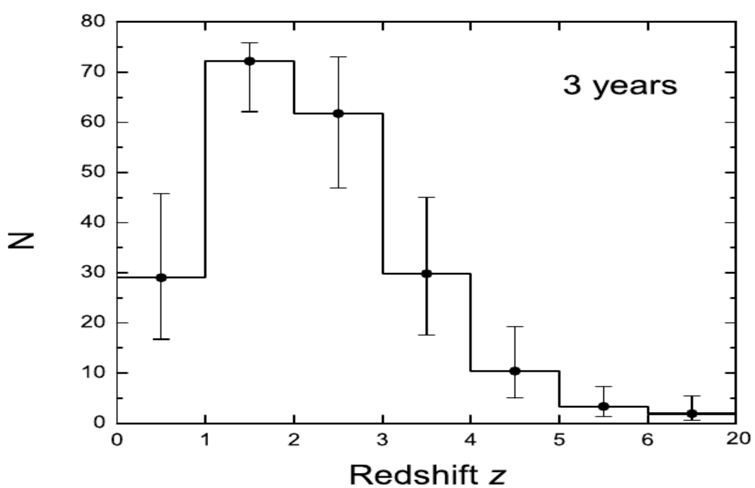


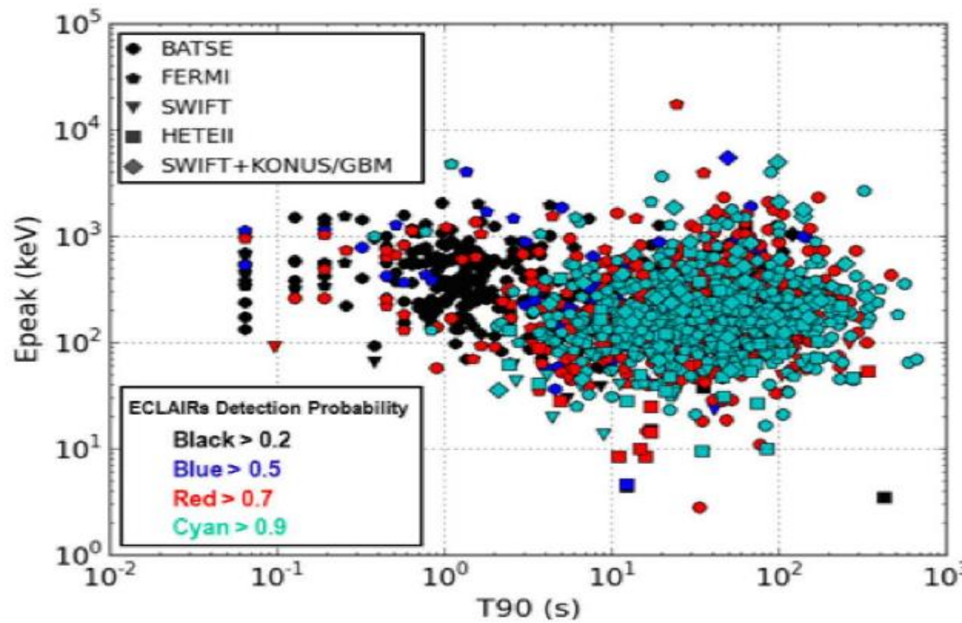
- **Trigger all GRB types**

➔ sensitive to Long, Short, Soft…

- **Expected ECLAIRs rate:**
  42-80 GRBs/yr
  3-4 GRBs/yr at z>5

Detailed simulations of algorithm prototypes on GRB databases of previous missions





GRM onboard Gamma-Ray Monitor

IHEP

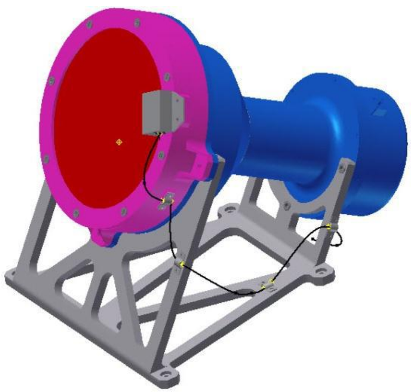
- **3 Gamma-Ray Detectors** (GRDs)
- NaI(Tl) (16 cm Ø, 1.5 cm thick)
- Plastic scintillator (6 mm) to monitor and reject particle events
- FoV = 2 sr per GRD

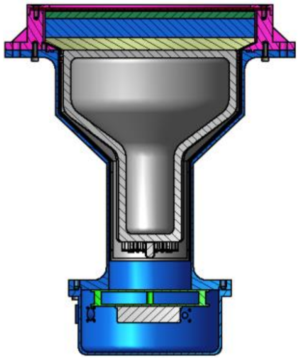
- Energy range: 15-5000 keV
- Aeff = 190 cm² @ peak
- Rough localization accuracy

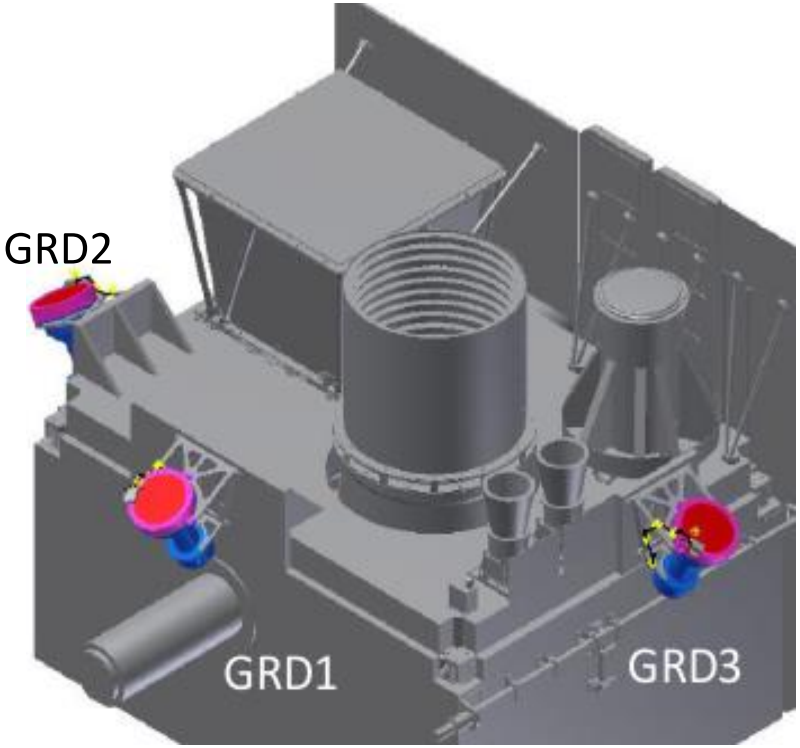
- Expected GRD rate: ~90 GRB/yr

- GRM data sent to ECLAIRs

→ enhance Trigger sensitivity to short GRBs



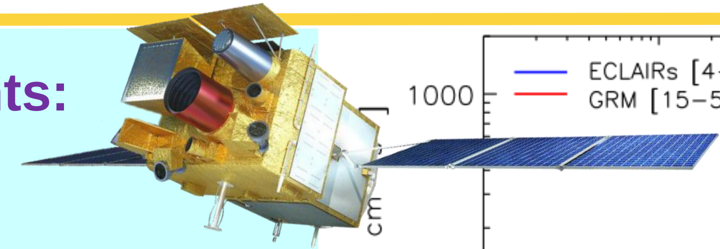




GRB prompt observations by SVOM

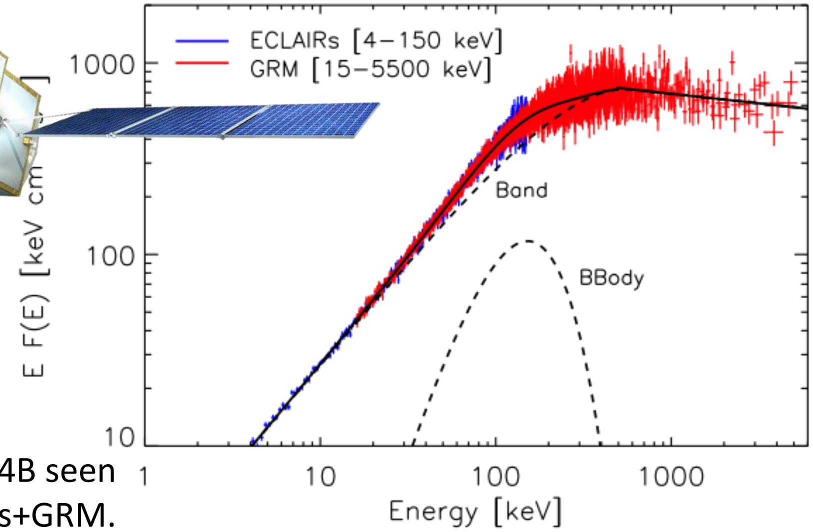
- **Space based instruments:**

ECLAIRs + GRM



- Broad-band coverage 4 keV – 5 MeV

➔ Well measured prompt gamma (Epeak, …



Multi-component spectrum of GRB100724B seen by Fermi/GBM imulated in ECLAIRs+GRM.

- **Ground-based Wide Angle Camera (GWAC)**

- dedicated to SVOM, partially operational in 2017
- sites: Ali (China) and CTIO (Chile)

- 36 camera units, 5400 deg², following ECLAIRs FoV
- band: 0.50-0.85 µm; sensitivity: M_V=15 in 10 s

~16% of ECLAIRs-triggered GRBs observable by GWAC

MXT onboard X-ray Telescope

CNES, CEA, UL, MPE

- Micro-pores optics (Photonis)

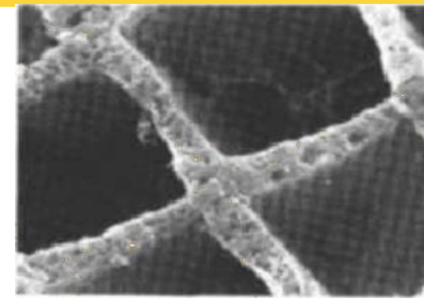
with square 40 µm-size pores

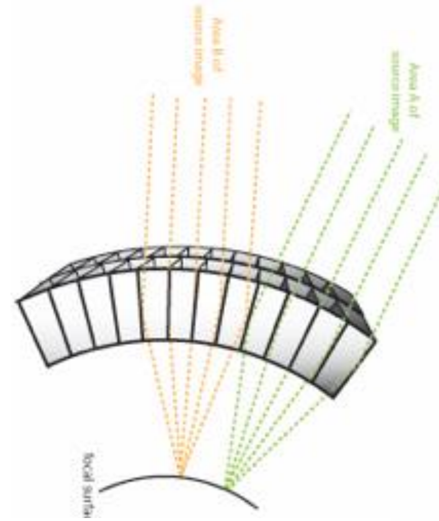
in a “Lobster Eye” configuration

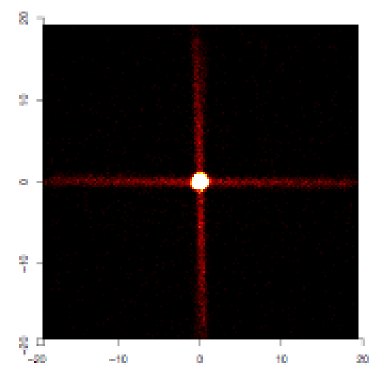
- Focal length: 1 m
- FoV = 64x64 arcmin²

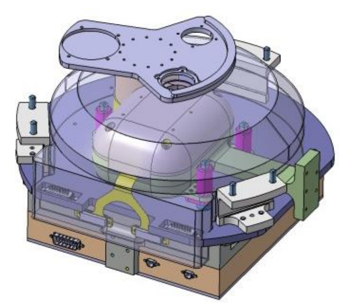
- pnCCD camera
- Energy range: 0.2-10 keV
- Aeff = 27 cm² @ 1 keV (central spot)
- Energy resolution: ~80 eV @ 1.5 keV
- Localization accuracy <13”

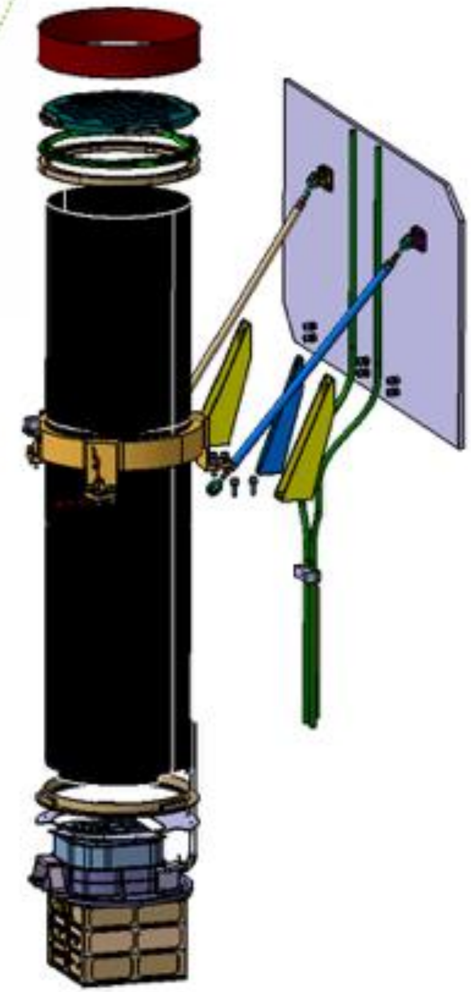
within 5 min (for 50% of GRBs)







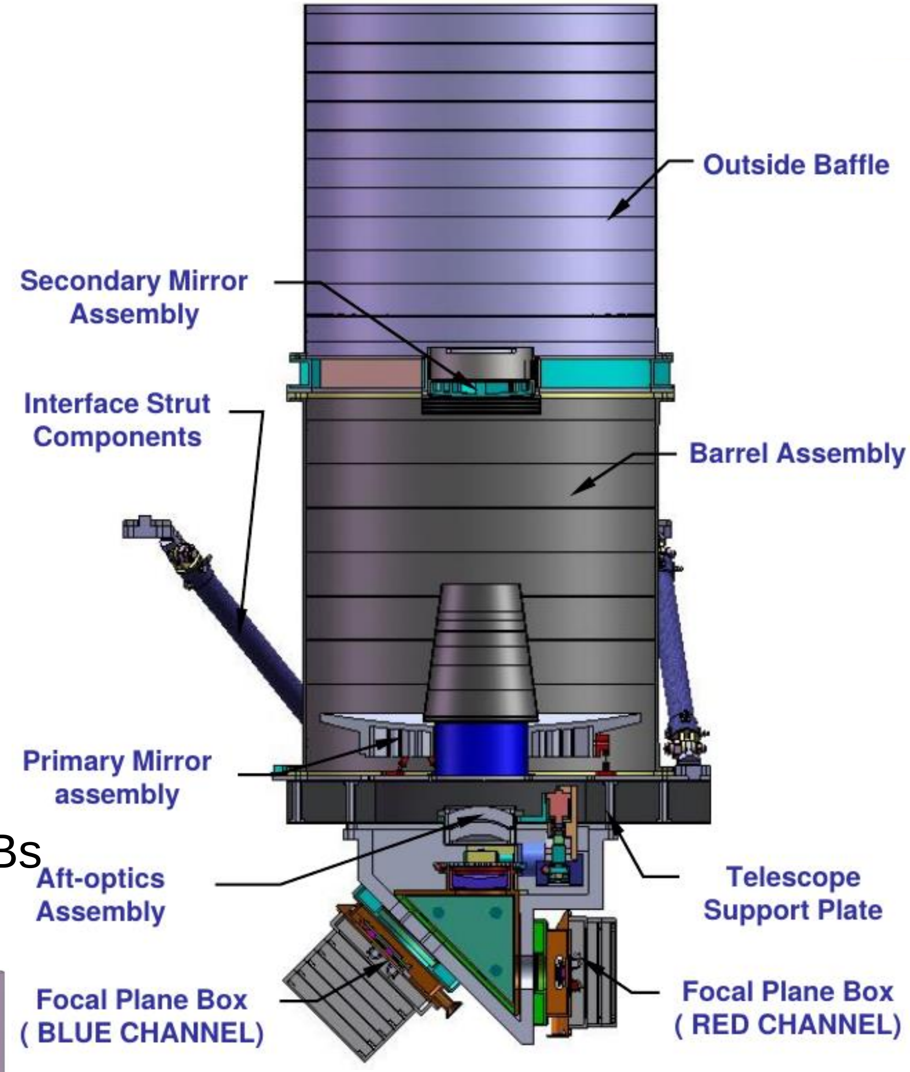


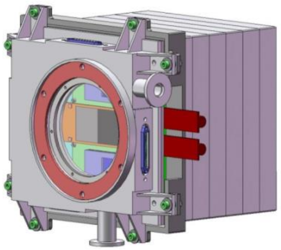


VT onboard Visible Telescope

NAOC, XIOPM

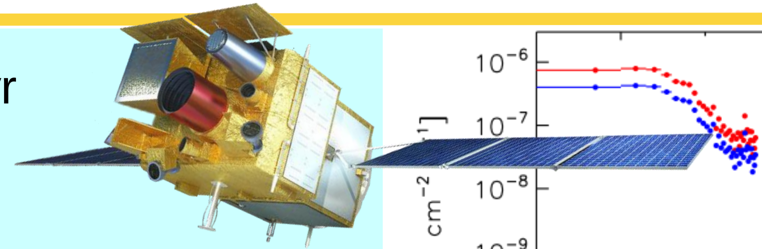
- Ritchey-Chretien telescope
- Ø=40 cm, f=9
- FoV = 26x26 arcmin² covering ECLAIRs localization error box
- Focal length: 3.6 m
- 2 channels: blue (400-650 nm) and red (650-1000 nm)
- Each channel: 2k x 2k CCD detector
- Sensitivity M_V=22.5 in 300 s
- Expect to detect ~80% of ECLAIRs GRBs
- Localization accuracy <1”





GRB afterglow observations by SVOM

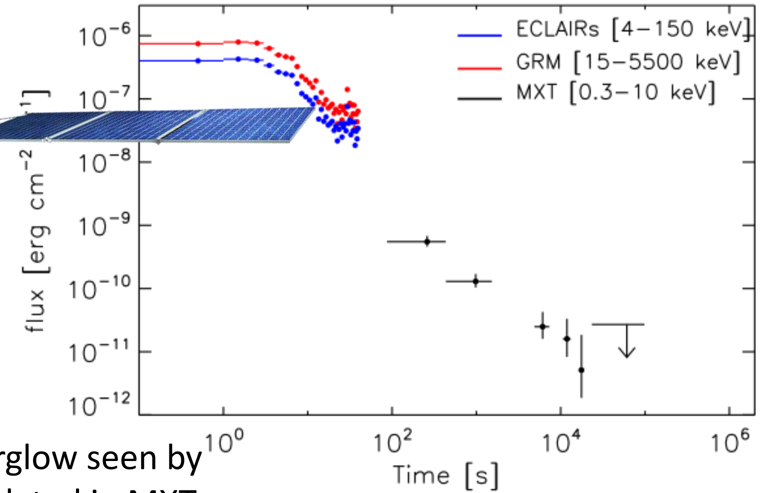
Spacecraft slew: 36-72 GRB/yr



- **Space-based follow-up:**

MXT X-ray afterglow for 90% of slewed GRBs

VT Visible/nIR afterglow + photometric redshift



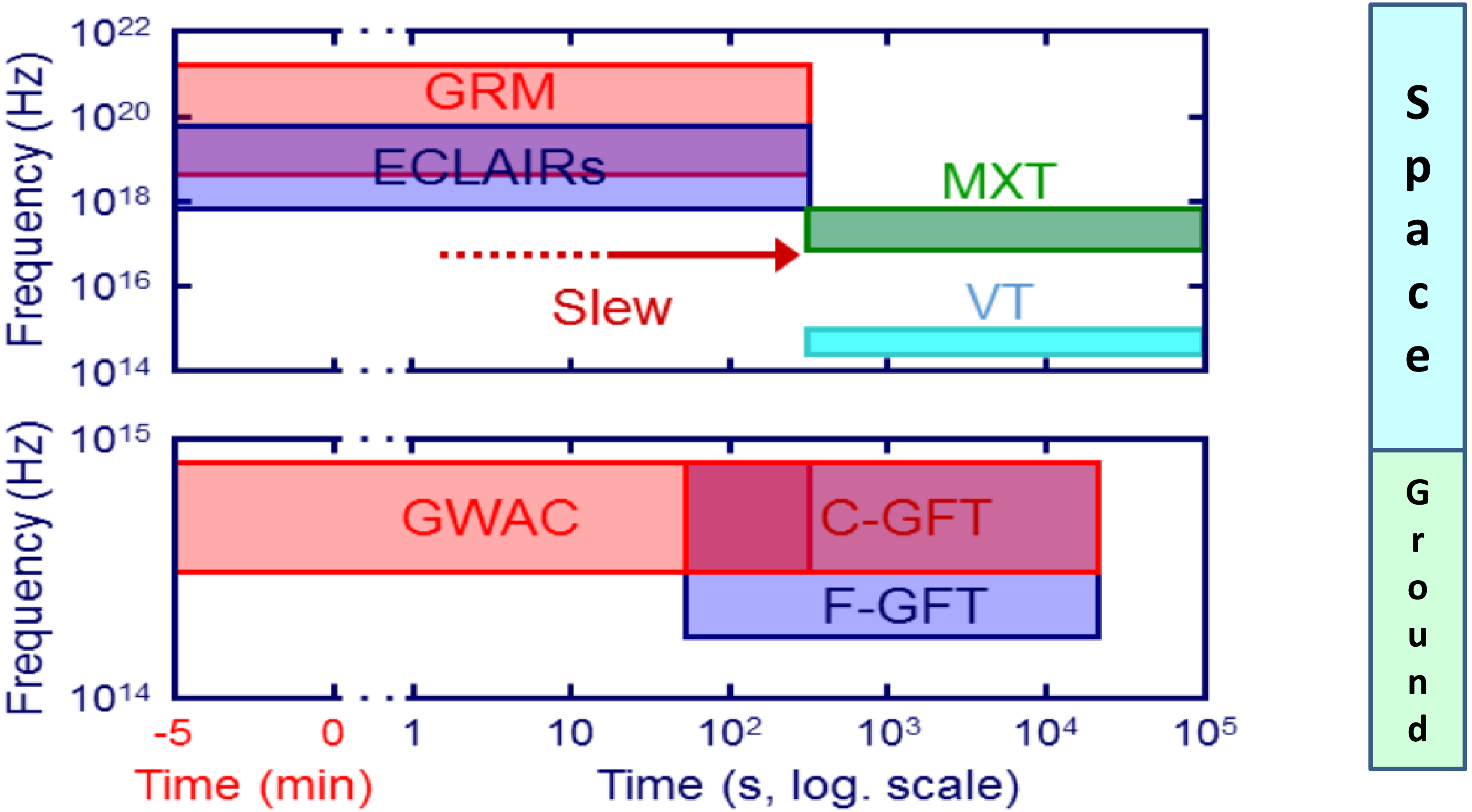
GRB 091020 afterglow seen by Swift/XRT simulated in MXT.

- **Ground Follow-up Telescopes (GFTs)**
  - **Chinese Ground Follow-up Telescope (C-GFT)**
    - Robotic 1m class telescope, Xinglong observatory
    - FoV = 21x21 arcmin², 400-950 nm
  - **French Ground Follow-up Telescope (F-GFT)**
    - Robotic 1m class telescope, San Pedro Martir (Mexico)
    - FoV = 26x26 arcmin²
    - Multi-band photometry (400-1700 nm, 3 simultaneous bands)
  - **Contribution to LCOGT network** (12×1m + 2×2m tel.)

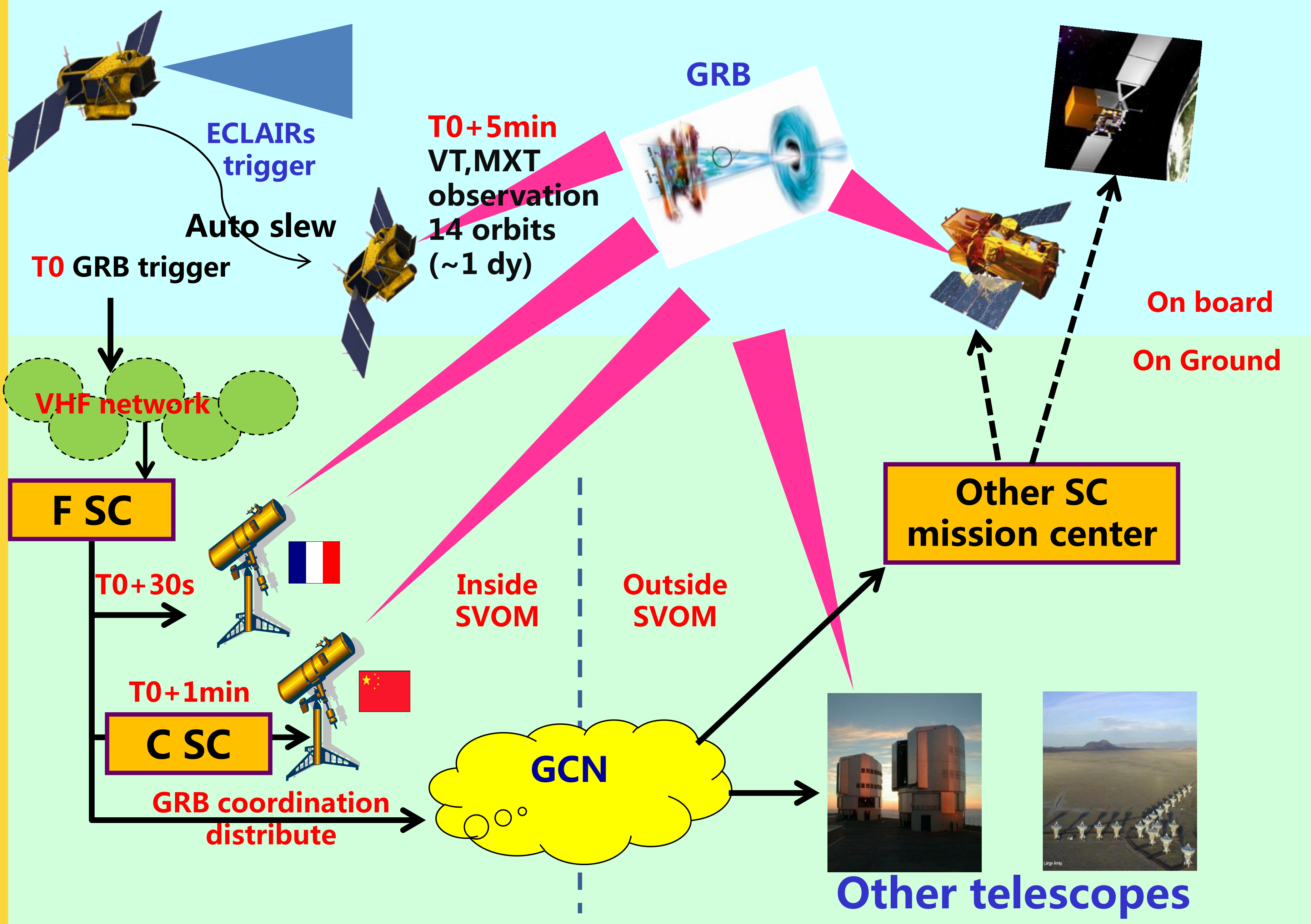
~75% of ECLAIRs-triggered GRBs immediately visible by one ground telescope (GFTs+LCOGT)

➔ Very large telescopes for redshift determination

Temporal & spectral GRB coverage



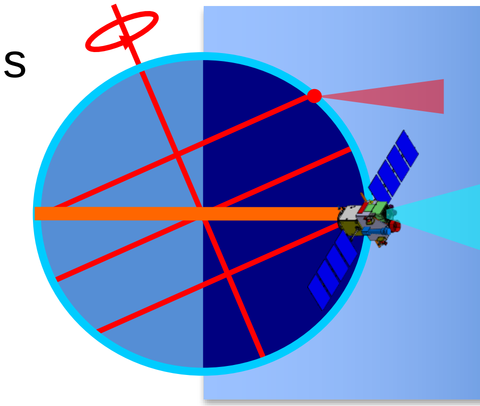
SVOM GRB observation scenario



SVOM pointing strategy

For optimal ground follow-up to determine redshift :

- favor sky observable from Hawaii, Chile and Canary Islands
- satellite attitude roughly antisolar towards the night

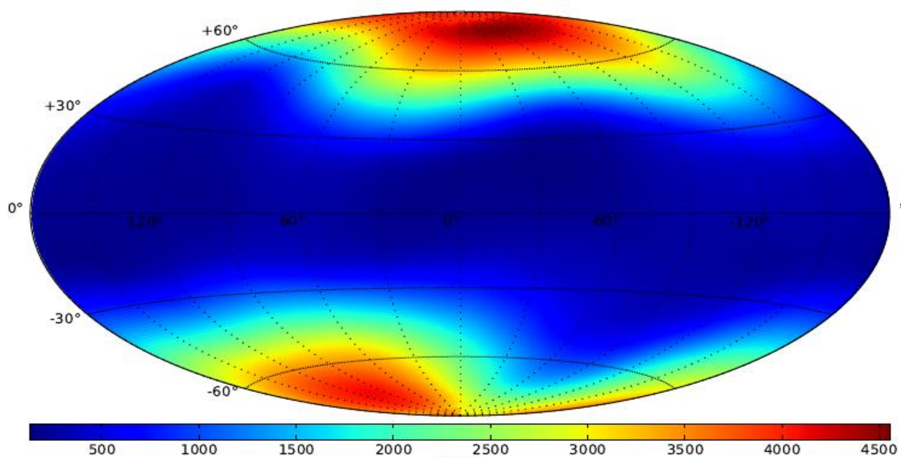


To maintain satellite radiators cold :

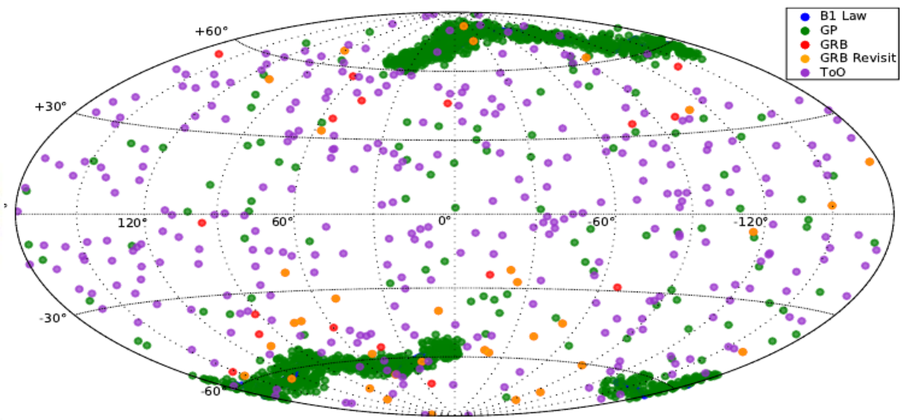
- satellite attitude antisolar within 45°

For best GRB detection performance :

- keep Sco X-1 and Galactic Plane outside the ECLAIRs FoV



ECLAIRs sky exposure
(4.5 Ms towards Galactic poles in 1 yr)

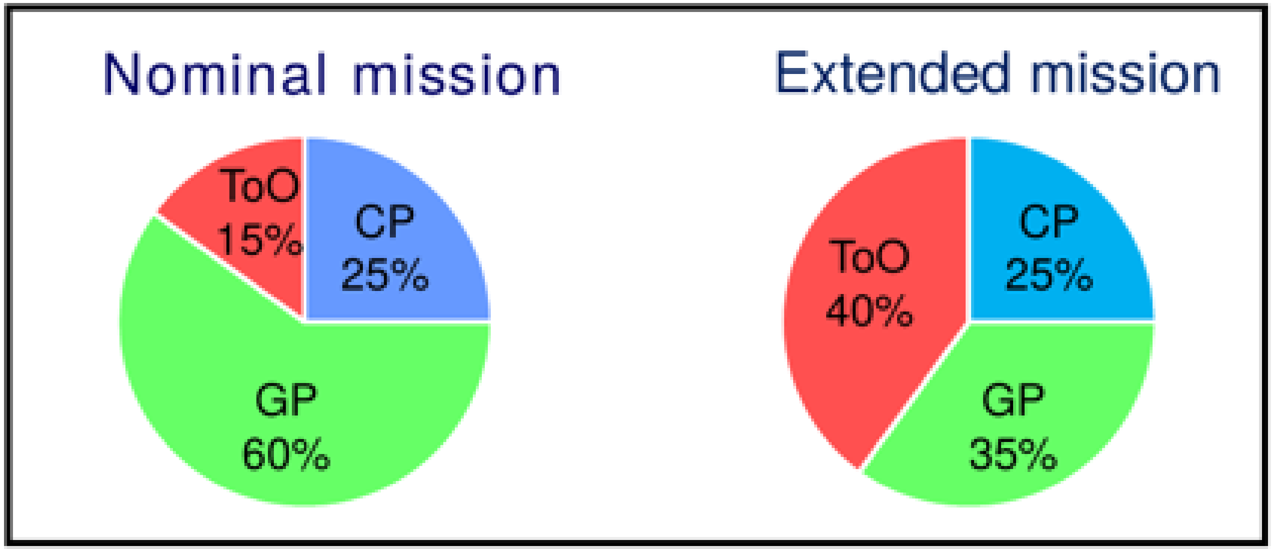


MXT and VT pointings
(in 1 yr nominal mission)

The 3 scientific programs of SVOM

- **Core Program (CP)** : follow-up GRB triggers of ECLAIRs
- **General Program (GP)** : AGN, ULX, TDE, Galactic sources (CV, XRB, pulsars, magnetars, TGF), background studies (CXB), etc
- **Targets of Opportunity (ToO)**, 1 / day: follow-up external triggers: multi-wavelength (SKA, LSST, CTA, HAWC) or multi-messenger (GW, neutrino)

Observing time allocation



Extended mission (after 3 first years)

- ToO rate increased (up to 5/day)
- GP time outside the “B1 law” increased (10% → 50%)

The 3 scientific programs of SVOM

- **Core Program (CP)** : follow-up GRB triggers of ECLAIRs
- **General Program (GP)** : AGN, ULX, TDE, Galactic sources (CV, XRB, pulsars, magnetars, TGF), background studies (CXB), etc
- **Targets of Opportunity (ToO)**, 1 / day: follow-up external triggers: multi-wavelength (SKA, LSST, CTA, HAWC) or multi-messenger (GW, neutrino)

Data policy:

- **Core Program** Most scientific products generated by the Burst Advocate are public as soon as they are available. All scientific products are public 6 months after data observation
- **General Program** All data products are distributed to the responsible Co-I. Proprietary period: 1 year, after which the data products are public
- **Targets of Opportunity** SVOM ToO: same policy as Core Program
  - MoU ToO: policy follows the agreement of MoU
  - Other ToO: data public as soon as available

Conclusions

SVOM designed to study the diversity of GRBs and get a complete sample, good spectral and temporal coverage of the prompt and afterglow, optimized follow-up strategy to get redshift of a large GRB fraction (~50%)

SVOM observation plan and instruments (space+ground-based) suited to detect high redshift GRBs (20 GRBs with measured z>5 in 5 yr)

SVOM is prepared for multi-messenger era: ToO follow-up of GW and neutrino alerts

More information: "*The Deep and Transient Universe in the SVOM Era: new Challenges and Opportunities,* ***Scientific prospects of the SVOM mission***", J. Wei, B. Cordier et al., arXiv:1610.06892


In memory of
Neil Gehrels
1952 – 2017
Conclusions
• The sky is rich in transients of many types.
• Swift is exploring the transient sky with unprecedented sensitivity and coverage
• Every year brings new discoveries in time domain science, including continuing GRB excitement.
• SVOM is the optimum follow-on to Swift. On line when Swift is in end-of-mission. New capabilities.
Workshop in Les Houches, April 11, 2016
The deep and transient universe in the SVOM era

Thank you