SVOM: Catching Gamma-ray bursts & High Energy transients on the fly

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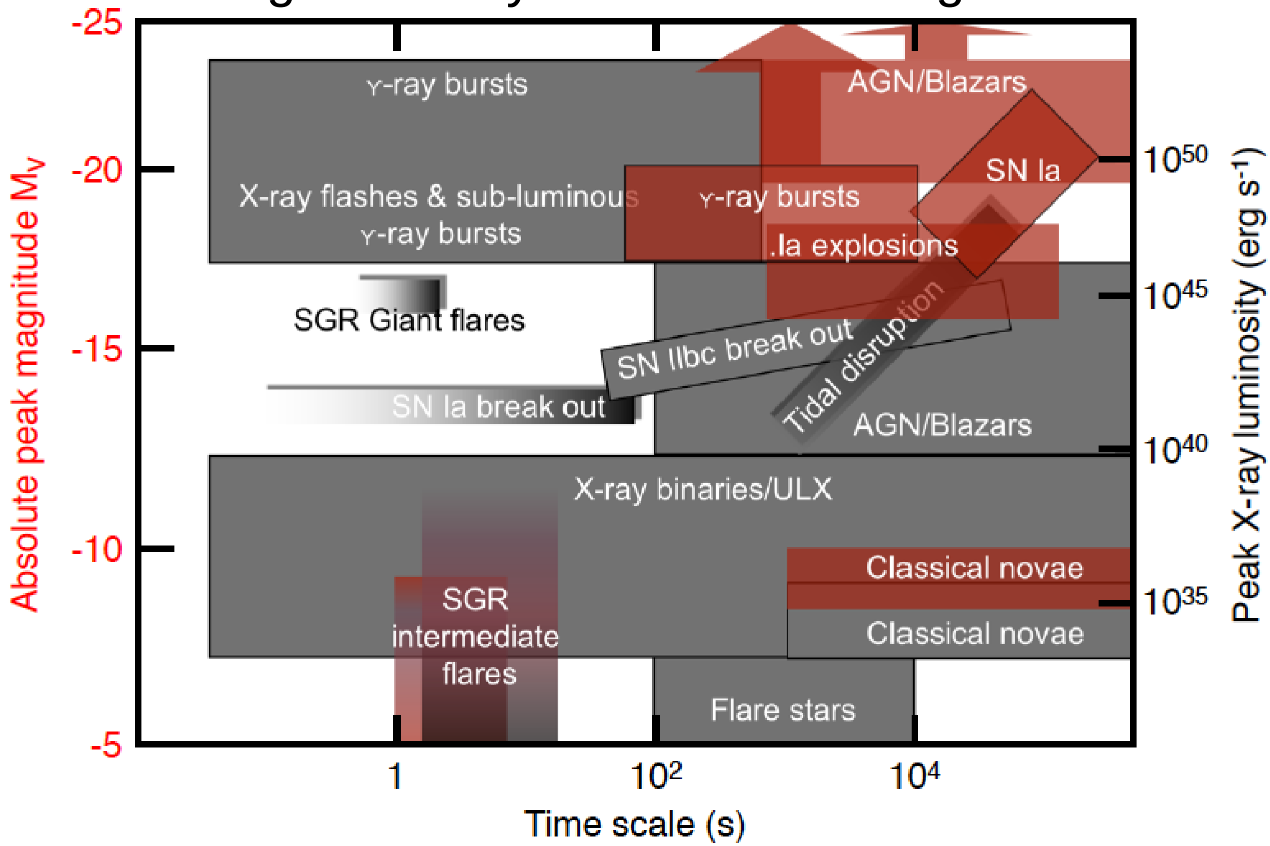
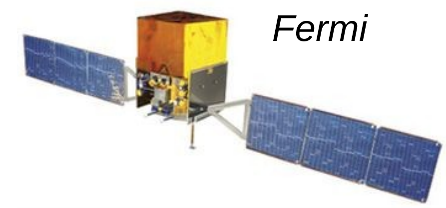
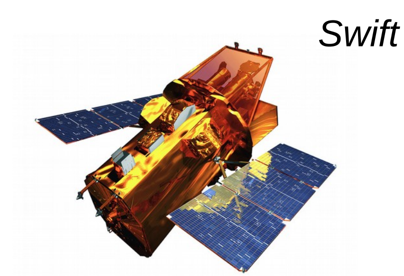
On behalf the SVOM team

Time domain astronomy

- Powerful variable and transient objects in HE over various timescales
- Lead to strong variability in other wavelength as well



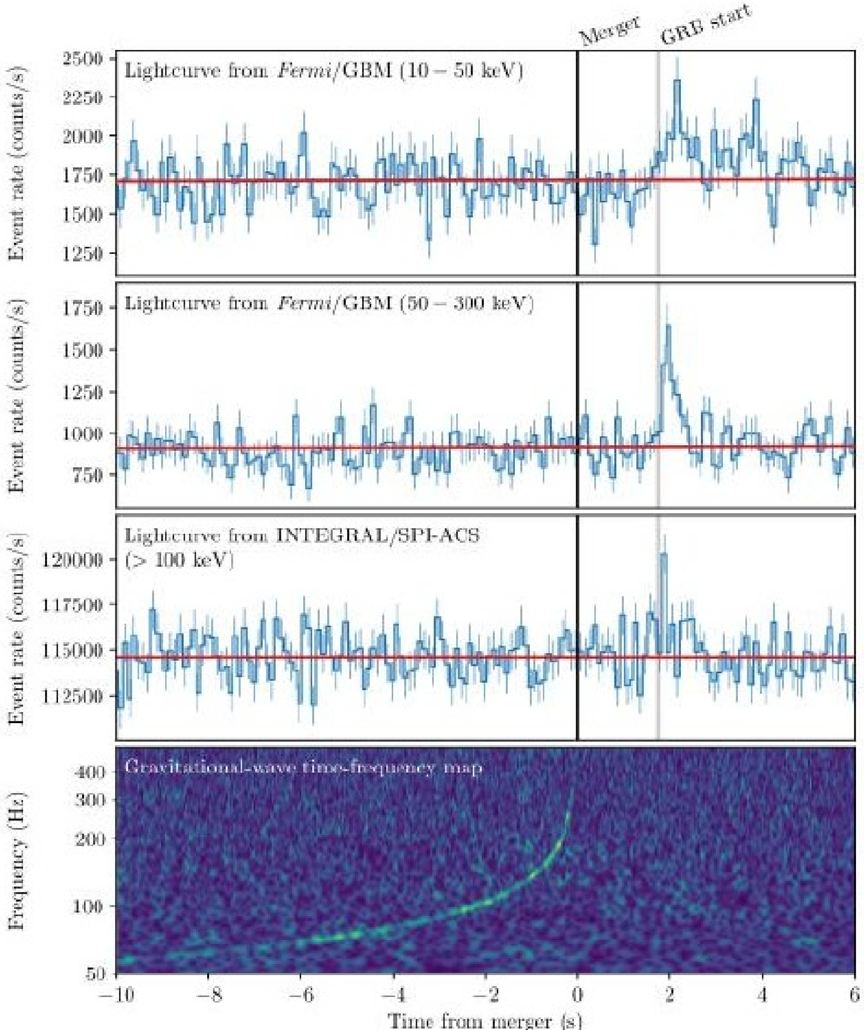




- New multi-λ transient phenomena continue to be discovered
  - Tidal disruption events (in particular jetted TDEs)
  - Supernova shock breakouts
  - Cosmic Fast Radio Bursts (not the micro-wave ones)
  - ...

Multi-messenger astronomy

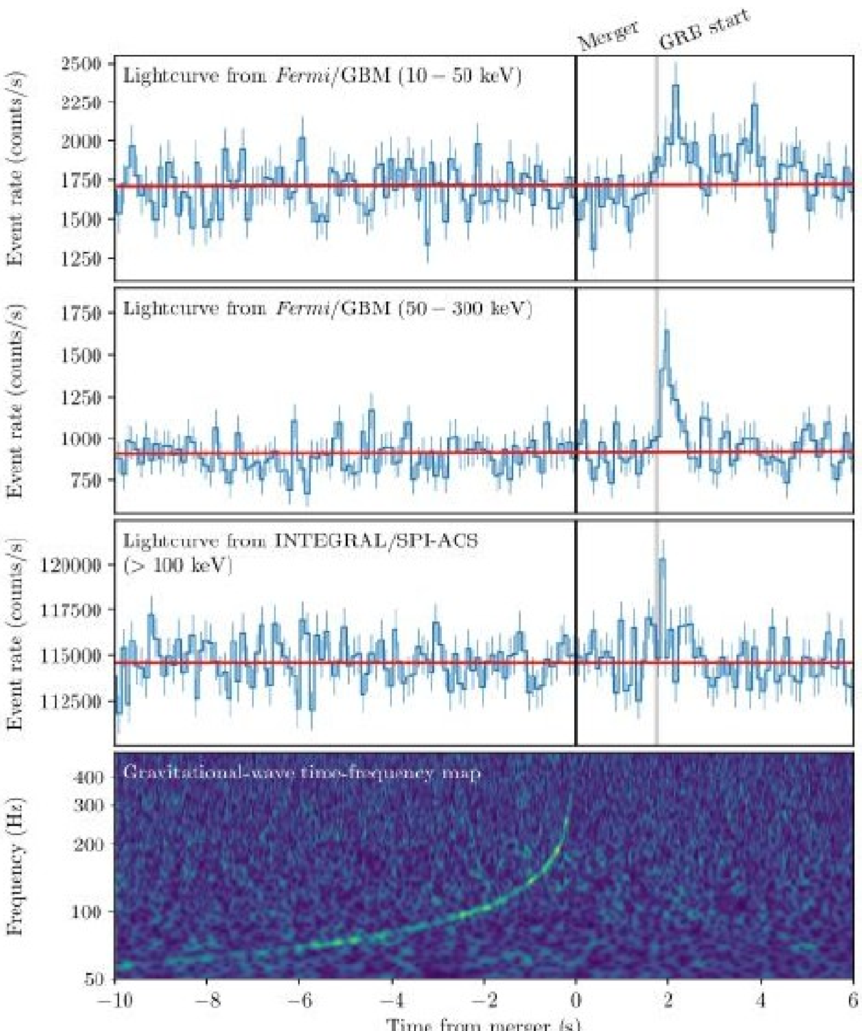
The first GW–EM event in 2017-08-17!!



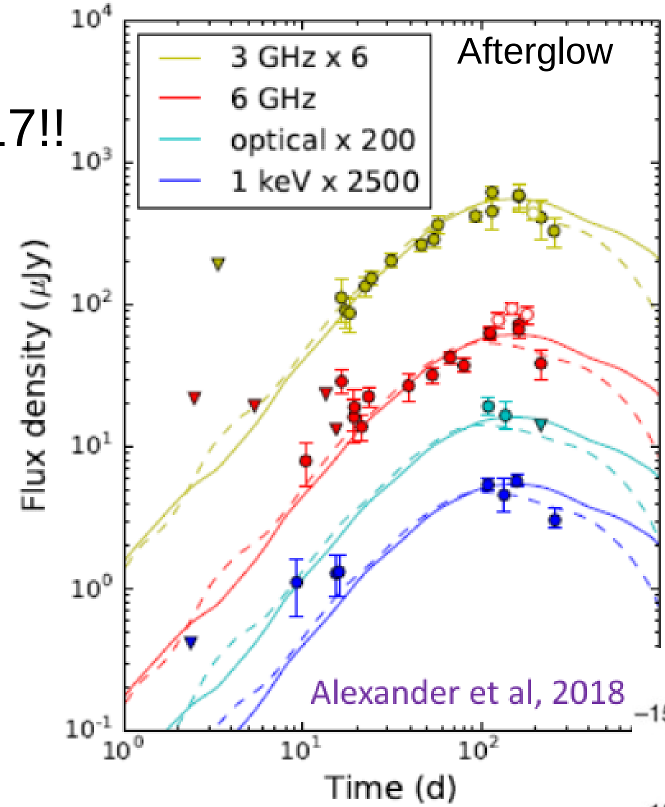
Abbott et al. (2017)

Multi-messenger astronomy (1)

The first GW–EM event in 2017-08-17!!

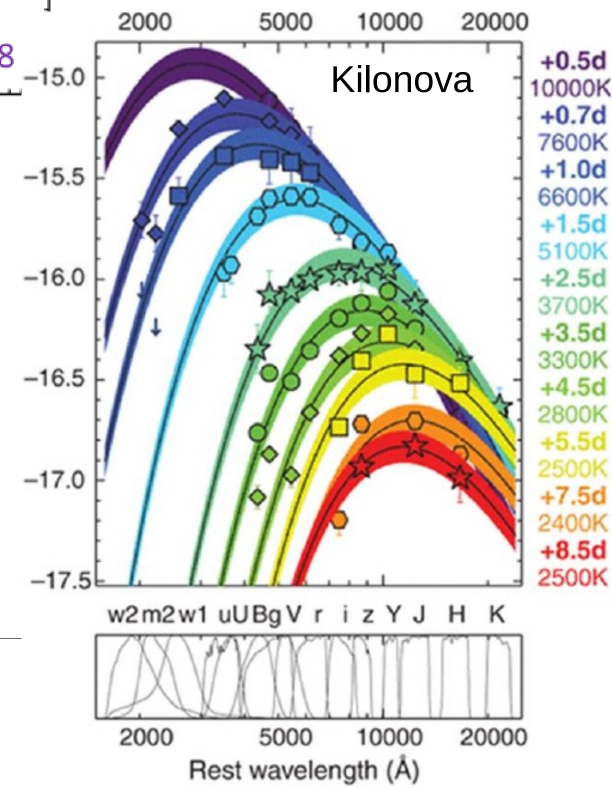


Abbott et al. (2017)



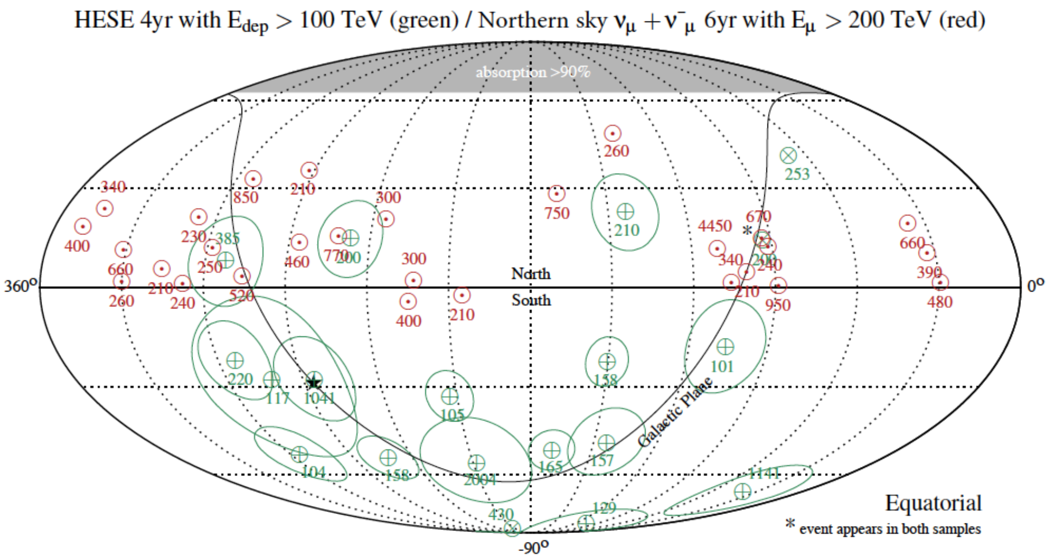
Alexander et al, 2018

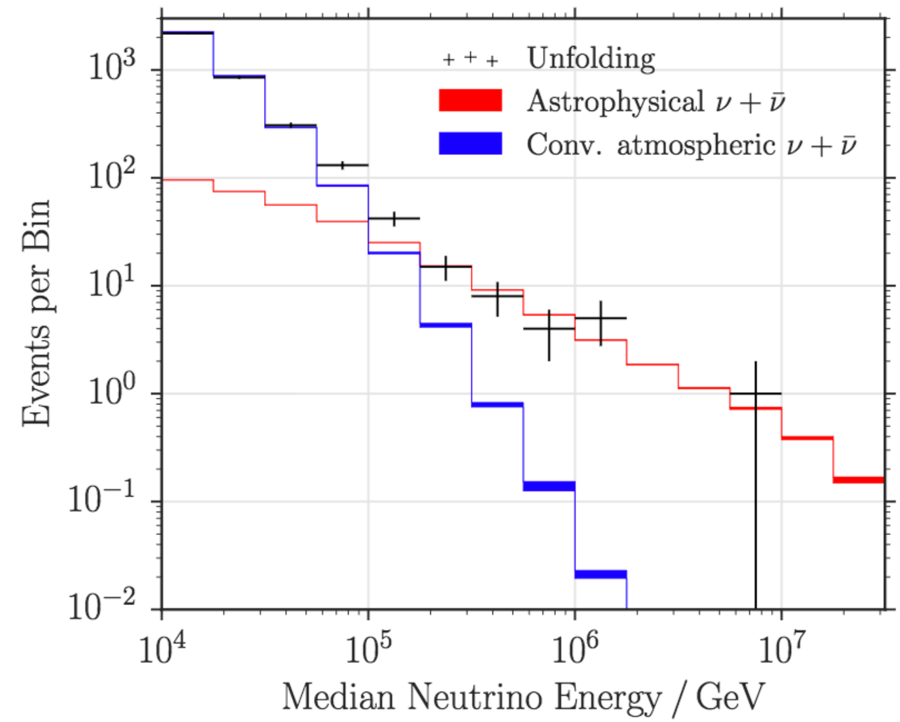
Drout et al., Science, 2017



Multi-messenger astronomy (2)

Detection of 80 cosmic neutrinos over 6 years!!

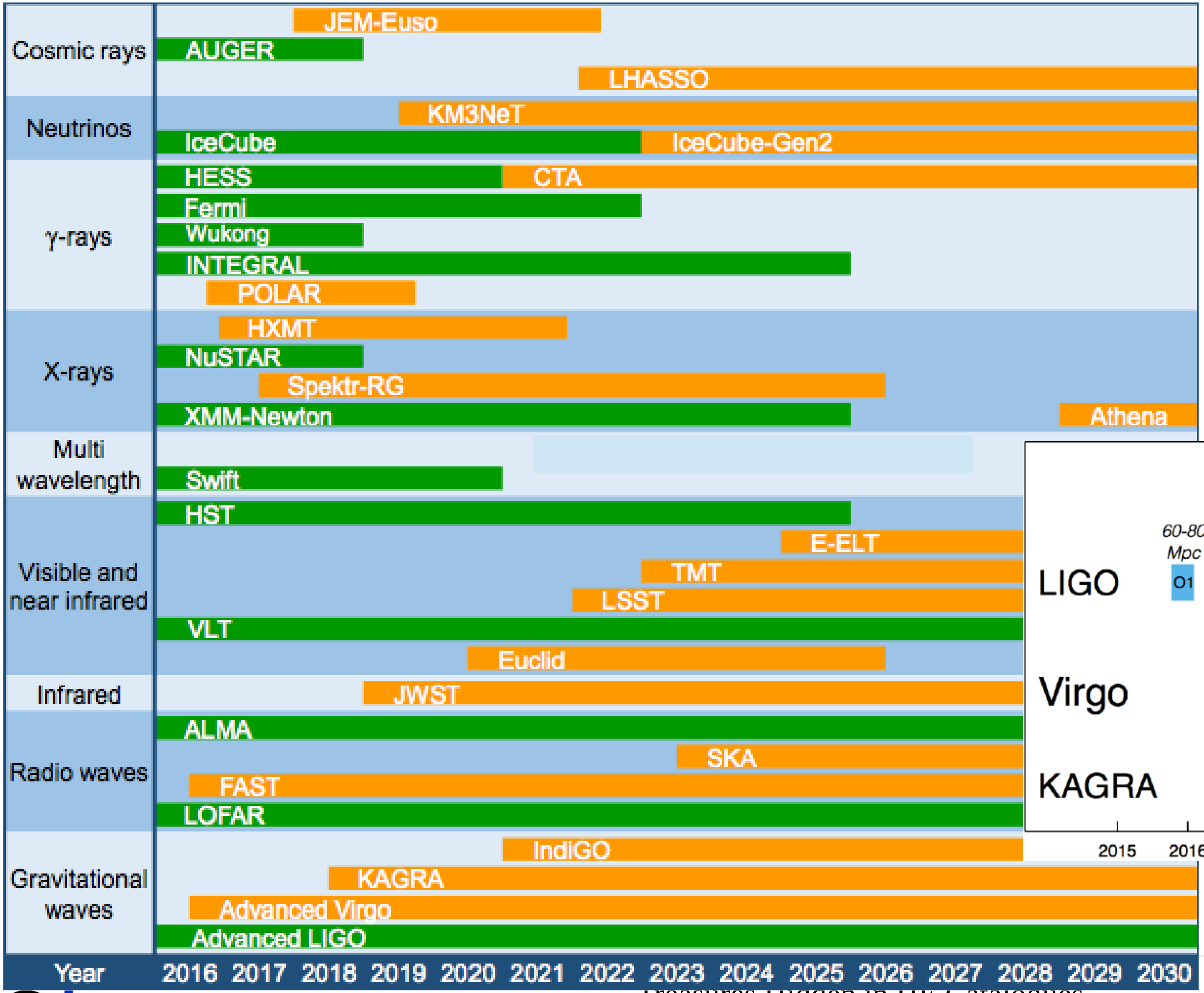




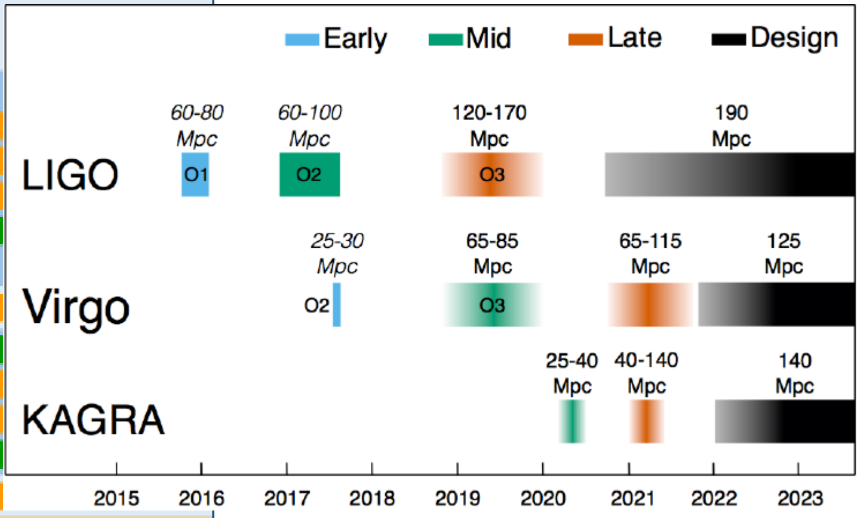
Plots from https://icecube.wisc.edu

A developing landscape

New facilities will be observing at full sensitivities at the beginning of 2020s



Need X/γ-ray alert providers
+
Rapid follow-up



A developing landscape

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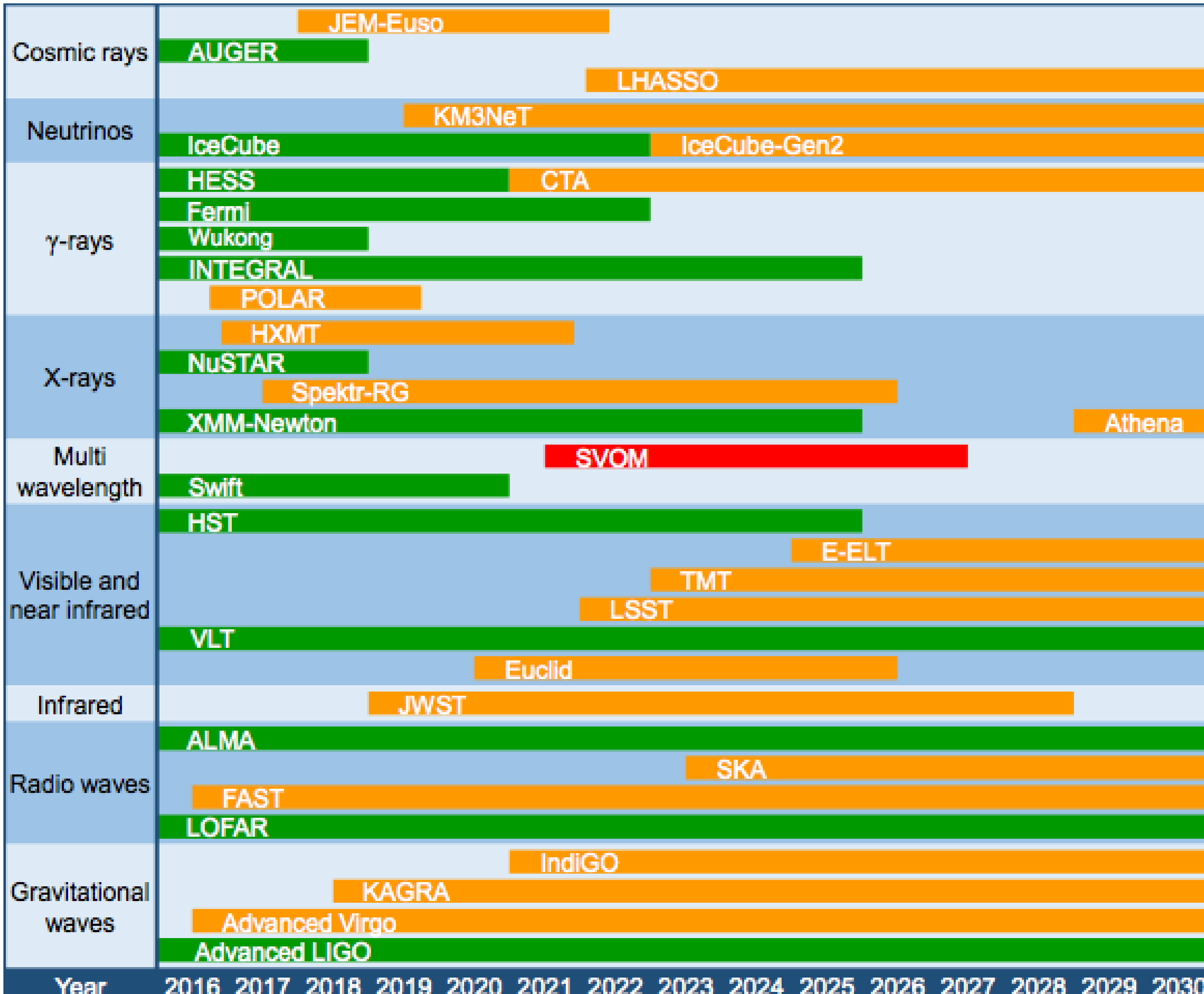

Need X/γ-ray alert providers
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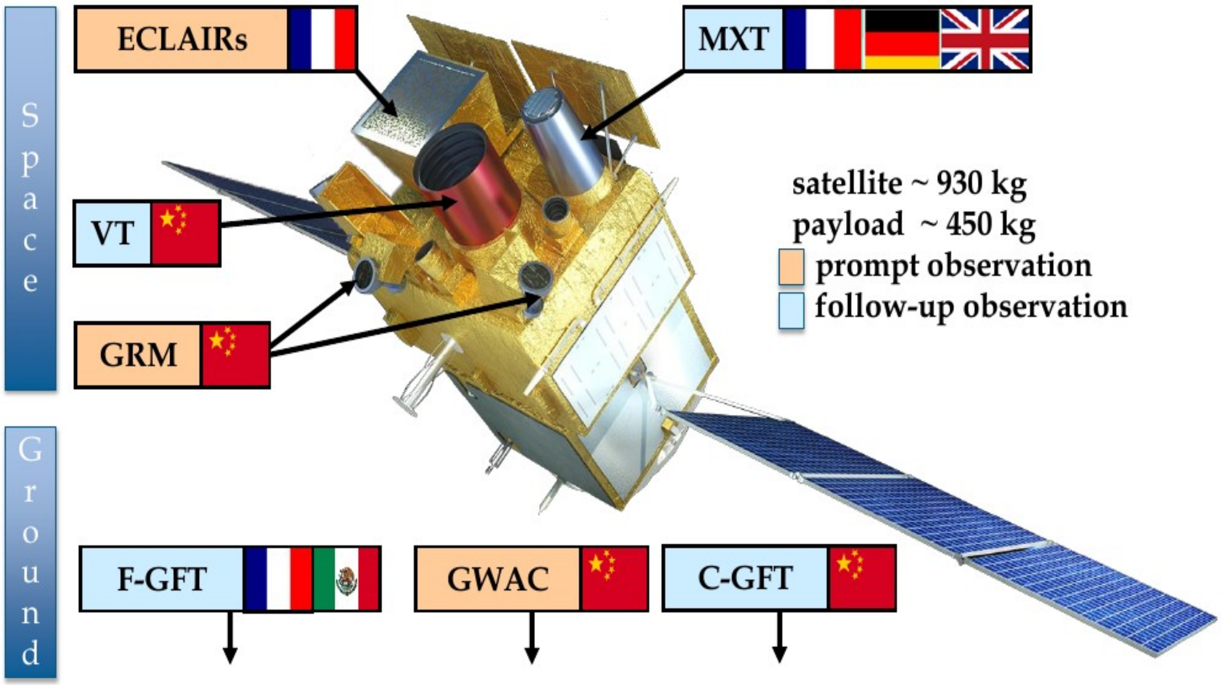
Rapid follow-up

The SVOM mission

- SVOM: Space based multi-band Variable Object Monitor (Wei et al. 2016, arXiv:1610.06892)
- CNES, CNSA & CAS collaboration
- PI mission
- Dedicated to study GRBs & HE transients
- Mission currently in Phase C
- Expected launch: end of 2021
- Mission lifetime: 3 yrs (nominal) + 2 yrs



- *Swift*-like mission:
  - 2 wide field instruments (4 keV – 5 MeV)
  - Autonomous onboard triggers
  - Fast alert downlink (< 30s in 60% of the case)
  - 2 narrow field telescopes in X-rays (0.2-10 keV) and optical (R & V)
  - A dedicated network of ground WF & NF robotic telescopes (nIR, optical)
  - Rapid repointing capabilities (<T0 + 5 min in 50% of the cases)

Main science drivers

Physics of the GRB explosions

nature of GRB progenitors and central engines

acceleration & composition of the relativistic ejecta

particle acceleration, non-thermal radiative processes

interaction of the ejecta with the circumburst medium

Diversity of GRBs: event continuum following the collapse of a massive star

X-ray rich GRBs/X-ray Flashes and their afterglow
underluminous GRBs/ultra-long GRBs/…

GRB/SN connection

Short GRBs and the merger model

GW emission from the final stages of orbital decay and merger

Production of r-process elements in the neutron-rich merger ejecta (kilonovae)

Cosmology

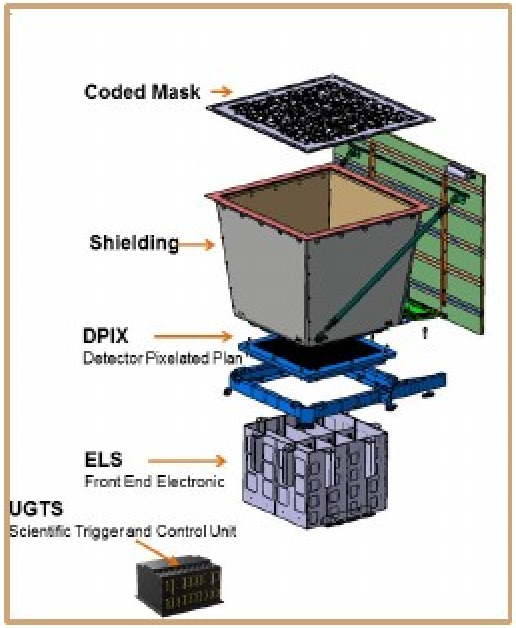
GRB host galaxy properties

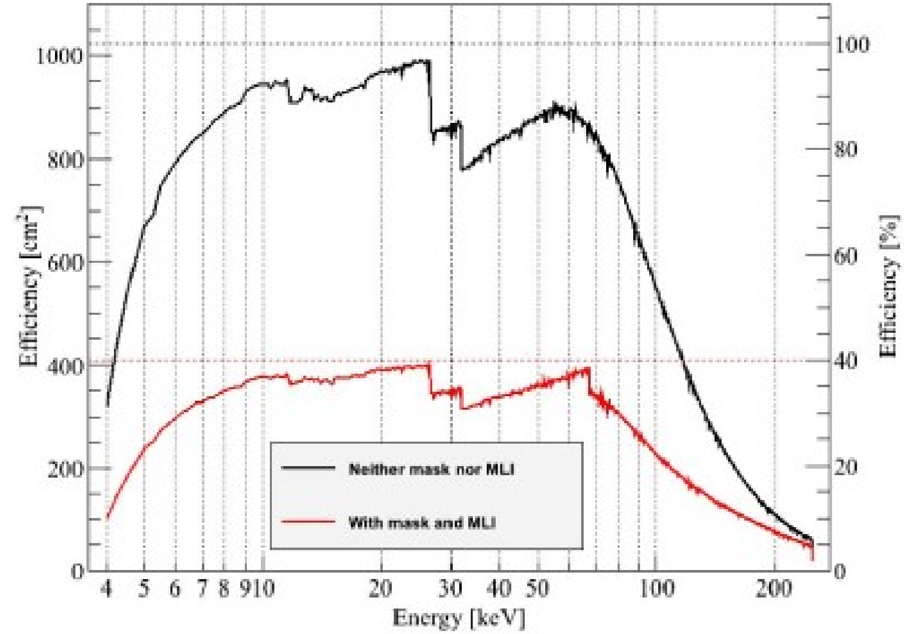
Properties of the IGM along GRB line of sight

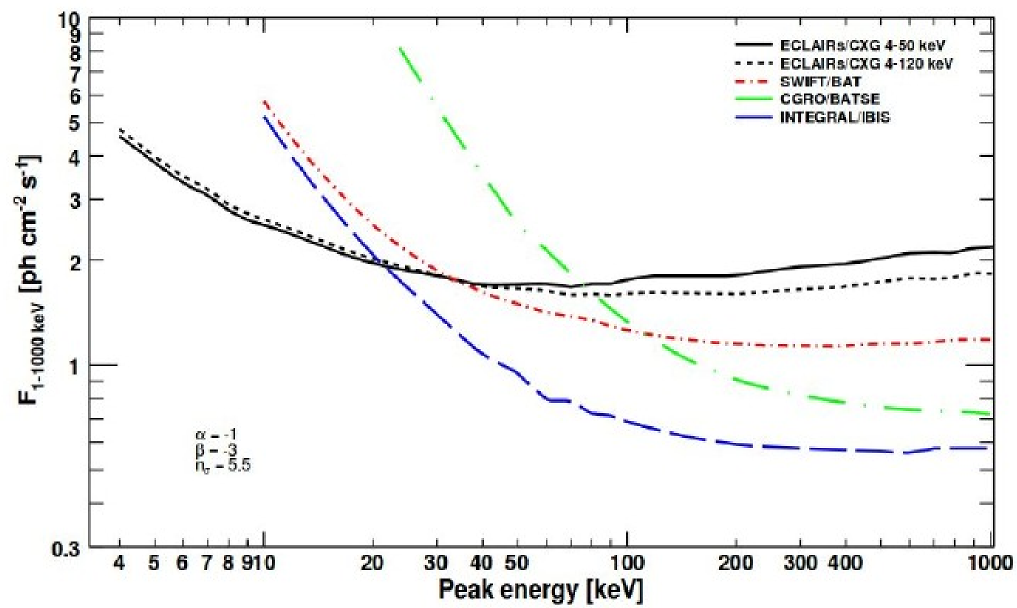
Reionization epoch using high-z GRBs

Wide-field instruments (1)

- **ECLAIRs: the GRB trigger camera**



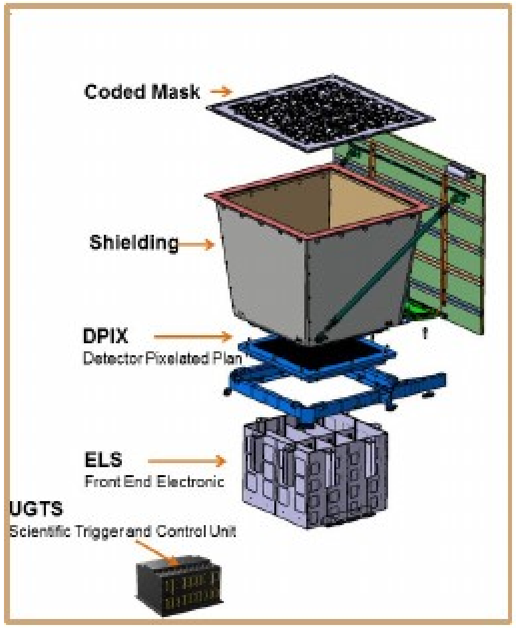


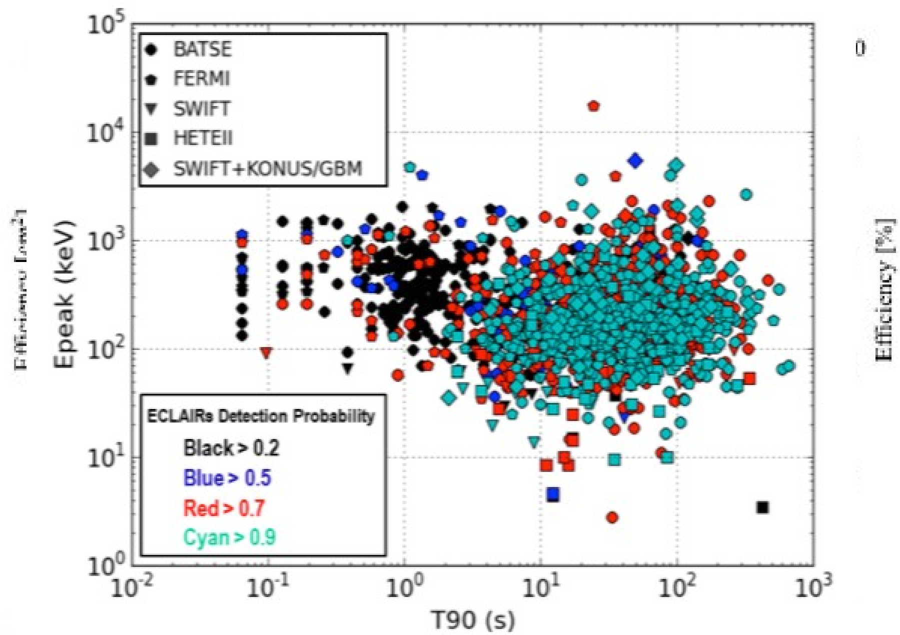


- Energy range: **4 – 150 keV**
- Geometrical surface ~ **1000 cm²** (6400 detectors)
- Mask transparency: 40%
- Working in **Photon Counting mode**
- Readout time: **10 us**
- Field of view ~ **2 sr**
- PSF size ~ **1 degree**
- Localization error radius **< 13' (90% c.l.)**
- Limiting sensitivity: **7 mCrab** in **200** ks
- Onboard trigger/localization: **~60 GRBs/yr**

Wide-field instruments (1)

- **ECLAIRs: the GRB trigger camera**





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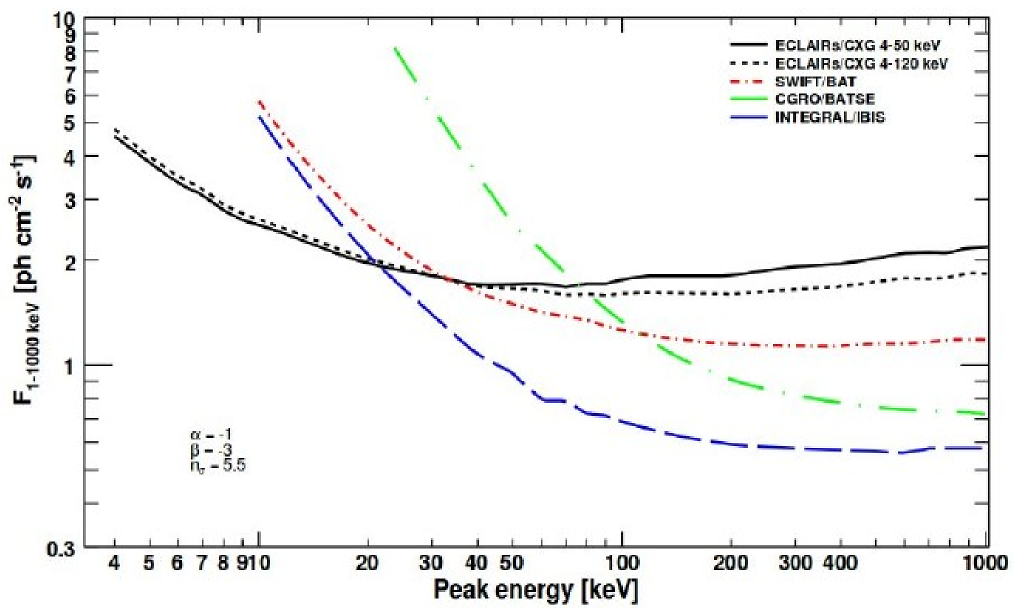
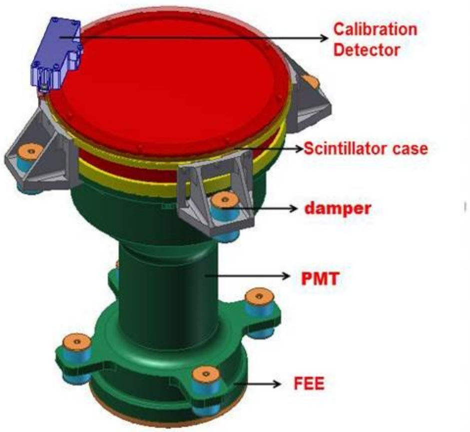
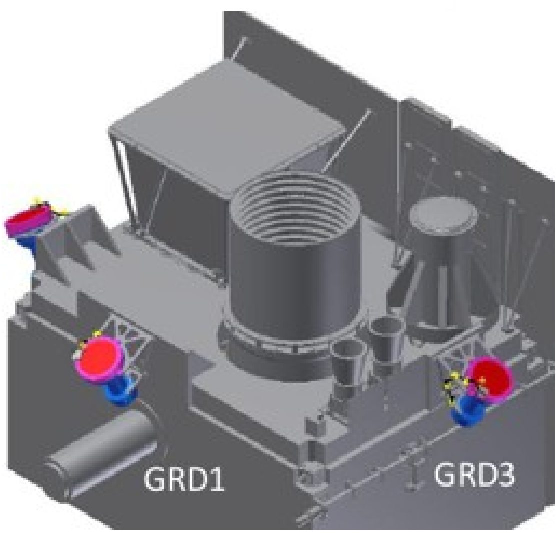


Wide-field instruments (2)

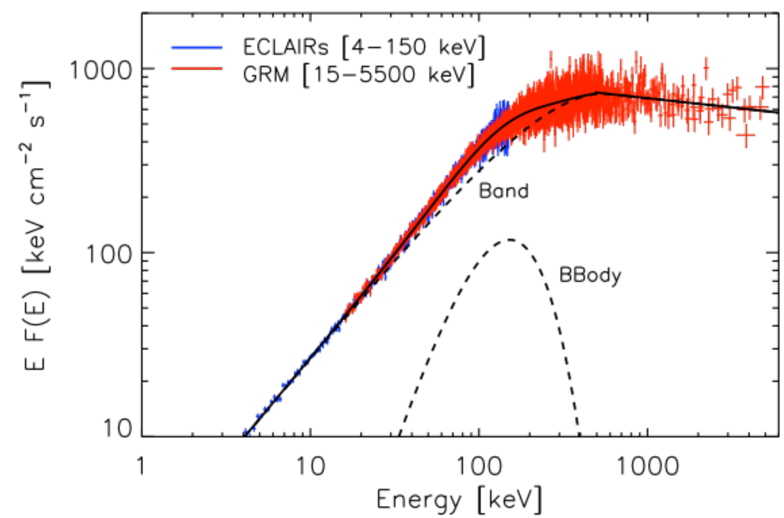
- **GRM: Gamma-Ray Monitor**





- 3 Gamma-ray Detectors + Particle Monitor
- NaI(Tl) (16 cm Ø, 1.5 cm thick)
- Plastic scintillator (6 mm) to monitor particle flux and reject particle events

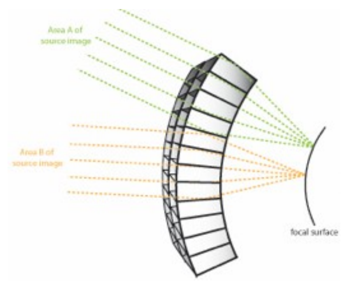
- GRD energy range: **~15 keV – 5 MeV**
- Aeff = **190 cm²** at peak
- FoV = **2 sr** per GRD
- Rough localization accuracy
- Expected rate: ~90 GRBs / year

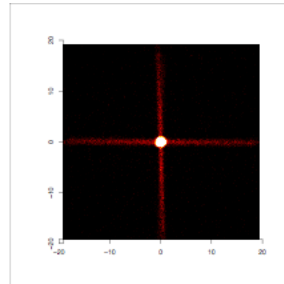


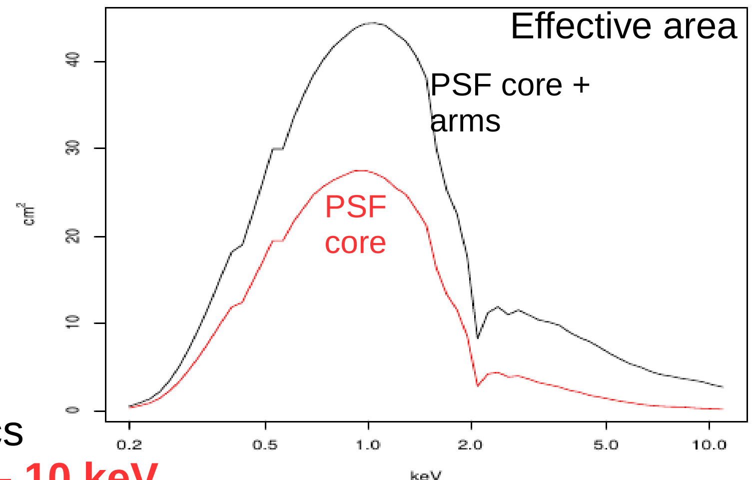
The multi-component spectrum of the Fermi/GBM burst GRB 100724B simulated in ECLAIRs+GRM.

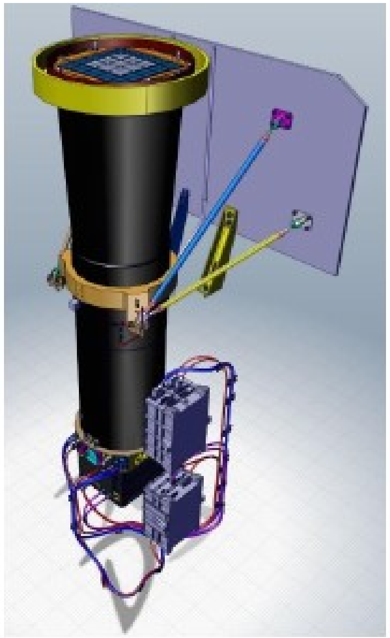
Narrow-field instruments

Lobster eye technic using 40um MPOs







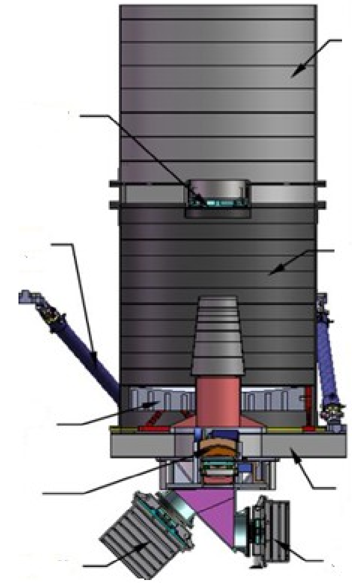


MXT Telescope

- 25 Micro Pore Optics
- Energy range : **0.2 – 10 keV**
- Field of view : **57 x 57 arcmin²**
- Readout time: **100 ms**

- PSF size **~ 6.5'**
- Localization accuracy: **<13"** within 5 min from trigger for 50% of GRBs
- Lim. sensitivity ~ 2 10^{-12} erg cm^{-2} s^{-1} in 10 ks

VT: Visible Telescope



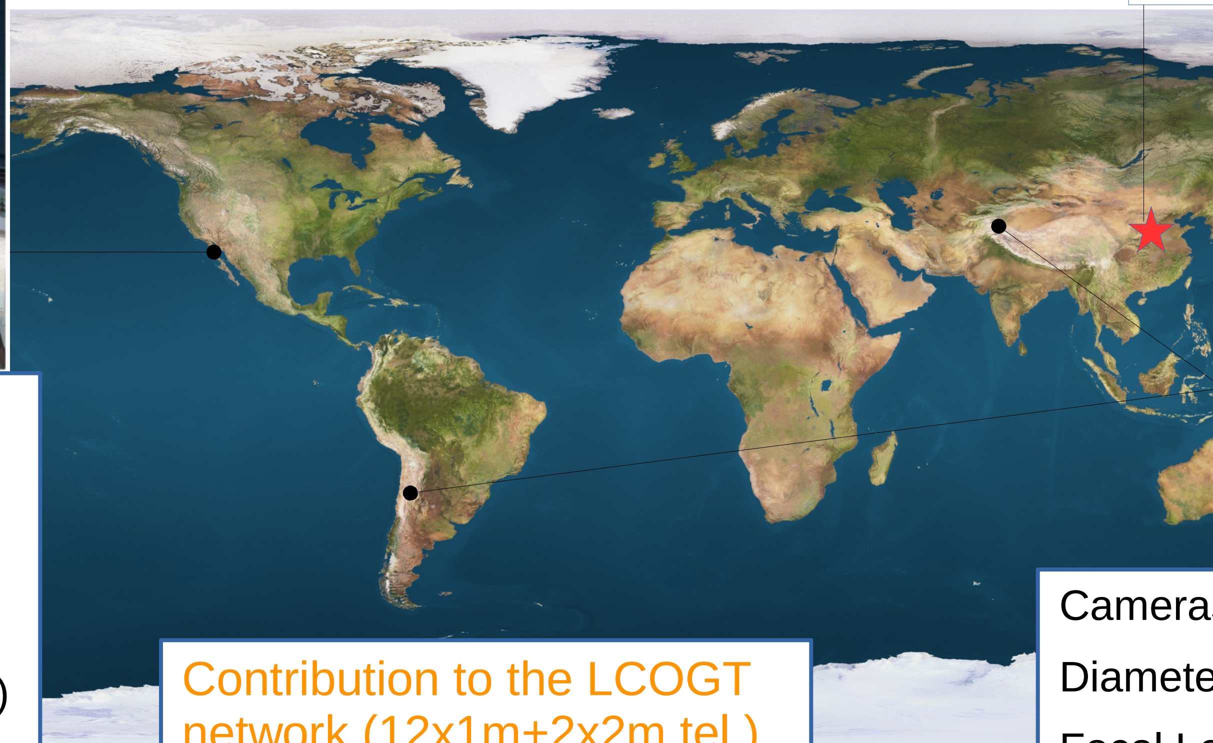
- Ritchey-Chretien telescope
- 40 cm Ø, focal length = 360 cm
- FoV = **26x26 arcmin²**
- Covering ECLAIRs error box in most cases
- 2 channels: blue (**400-650 nm**) and red (**650-1000 nm**)

- 2k * 2k CCD detector each
- Sensitivity **M_V = 22.5 in 300 s**
- Will detect ~80% of ECLAIRs GRBs
- Localization accuracy **<1"**

SVOM ground segment

- Ground Follow-up robotic telescopes located along the SVOM orbit
- Find an optical counterpart of EM & GW events / refine the position / measure photo-z

FoV = 26'
1.3 m in diameter
Obs starting < 20s after receiving an alert
Visible: B, g, r, I, z & y.
IR: J & H
Sensitivity (300 sec, 5σ)
• R = 22.0 mag
• J = 20.0 mag



Contribution to the LCOGT network (12x1m+2x2m tel.)

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

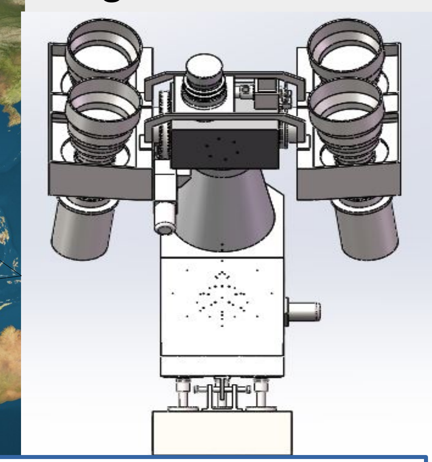
Chinese Ground Follow-up Telescope (C-GFT)

Robotic 1-m class telescope, Xinglong observatory

FoV = 21x21 arcmin^2,

400-950 nm

Ground Wide Angle Camera



Cameras: 40

Diameter: 180 mm

Focal Length: 220 mm

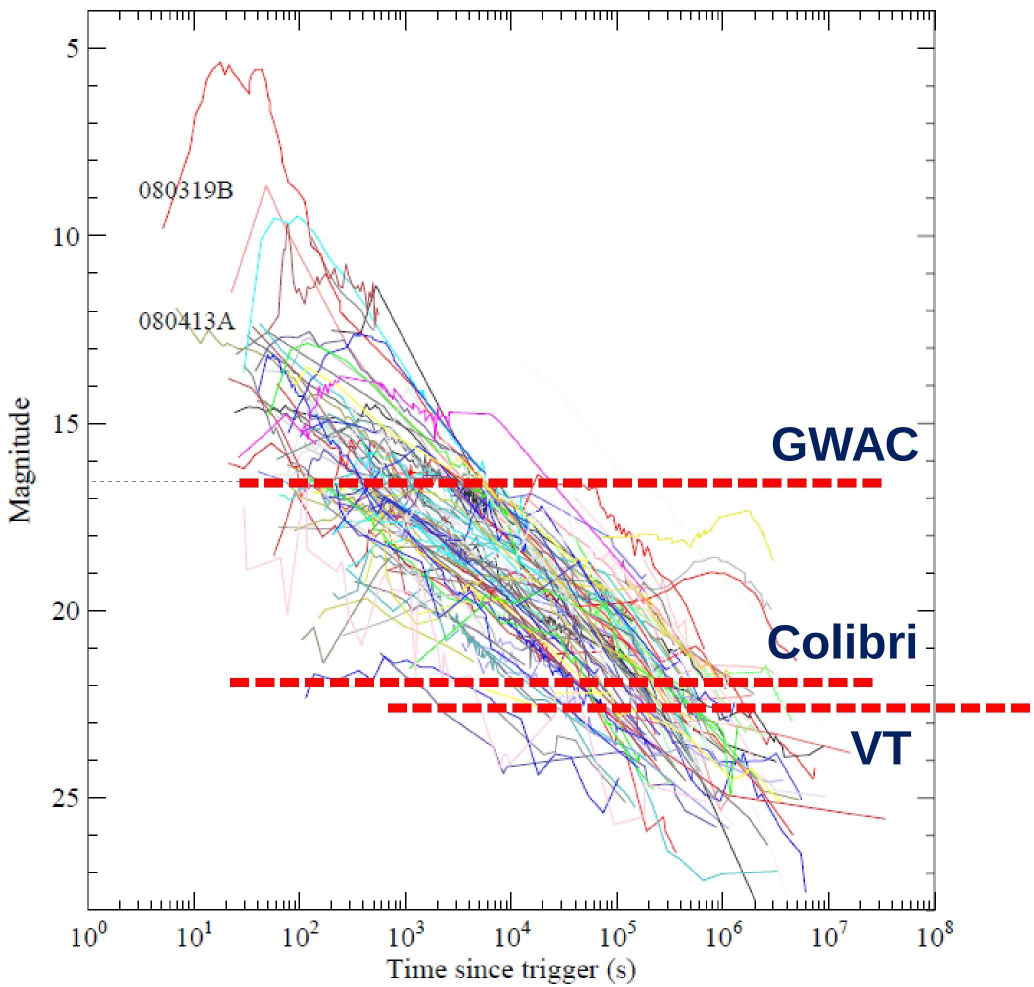
Wavelength: 500 – 800 nm

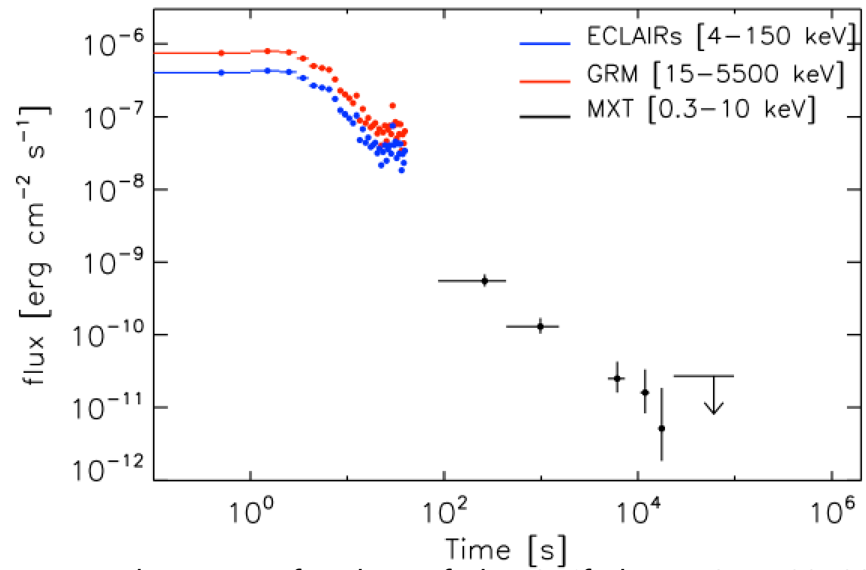
Total FoV: ~6000 Sq.deg

Limiting Mag.: 16 in V band

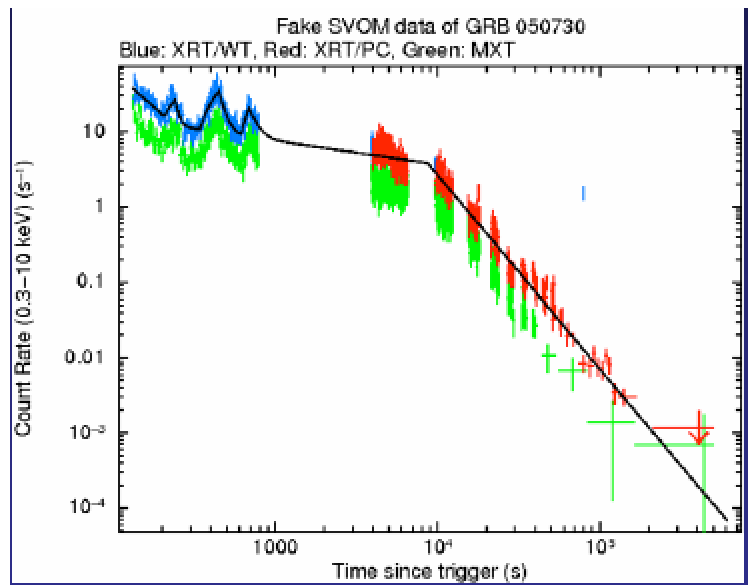
5σ @ 10 sec

Science capabilities



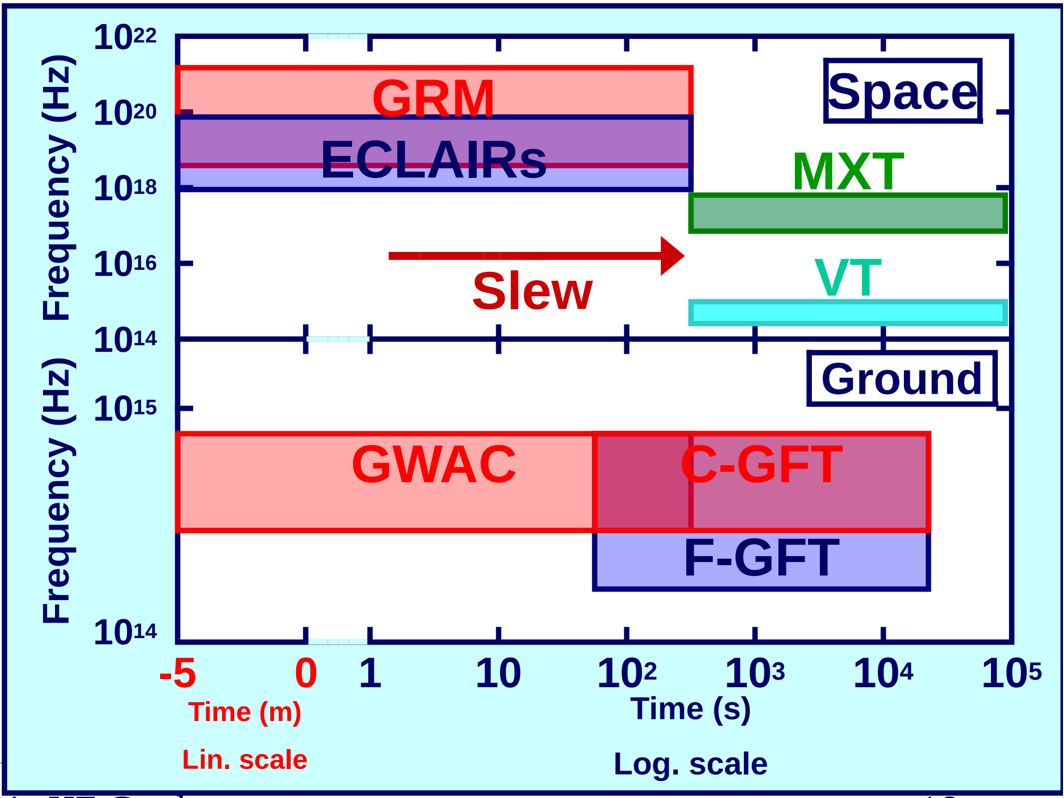


The X-ray afterglow of the Swift burst GRB 091020 simulated in MXT.



Observing strategy

- To be launched from Xichang (Sichuan) by an LM-2C rocket
- Circular LEO 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 (68% of duty cycle for ECLAIRs, about 50% for MXT & VT)
- Avoidance of the Galactic plane and Sco X-1
- Slew capability: 45° in 5 minutes (including stabilization)
- **Alerts downlinked through a network of ~40 VHF antennas distributed along the SVOM orbit**
- GRB follow-up during 14 orbits (about 1 day)
- Strong synergy between space and ground

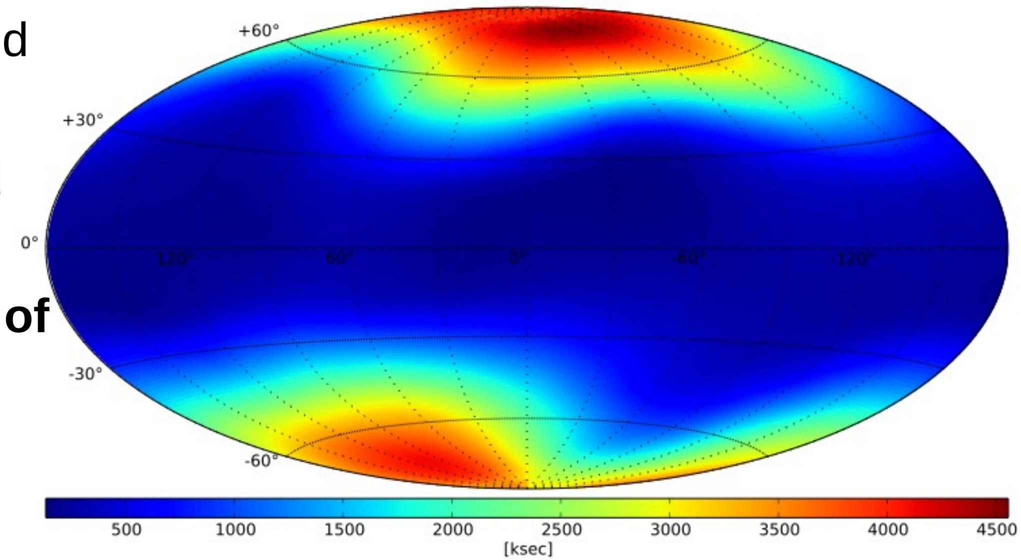


Observing strategy

- To be launched from Xichang (Sichuan) by an LM-2C rocket
- 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% forMXT and VT)
- Avoidance of the Galactic plane (most of the time) and Sco X-1
- Slew capability: 45° in 5 minutes (including stabilization)
- GRB follow-up during 14 orbits (about 1 day)
- Strong synergy between space and ground

=> 2/3 of SVOM GRBs with a measured redshift (against 1/3 for *Swift*)

=> Build an homogenous GRB sample of ~200 GRBs of all types from prompt to afterglow emission (up to 1 day or so)



Exposure map for 1 yr observation

How do we plan to use multi-λ catalogues?

- Not exhaustive

- **ECLAIRs onboard catalogue**
  Hundreds of X-ray sources (e.g. from XTE/ASM, *Swift*-BAT) to be flagged off by the trigger software
  Figure of merit for each source in the catalogue
  Possibility to trigger on sources of interest depending of FoM

- **Finding GRB counterpart in VT data**
  Downlink of VT finding chart images to the ground (based on the MXT error circle)

- **Using VT as a super star-tracker** (using e.g. USNO-B1) to astrometrically correct MXT positions on the ground

- **Tiling strategy for ToO-MM** to search for GW/neutrino detections (e.g. use of galaxy catalogues)

Mission profile (1)

Core Program observations		
GRB initial observation	Autonomous pointing	1 to 2 per week (14 orbits)
GRB Revisits	Request from ground by ToO NOM process	80% of the GRB
Transient source observations from ECLAIRs catalog		
CAT (cat source above a threshold)	On board Autonomous mechanism if pointed	1 per month (14 orbits)
Target of Opportunity Observations		
ToO-NOM (Astronomical Events)	Programmed in less than 48h	1 to 5 per day (1 orbit)
ToO-EX (Major Events)	Programmed in less than 12h	1 per month (14 orbits)
ToO-MM (tiling)	Programmed in less than 12h	1 per month - goal 1 per week
General Program Observations		
Pre-planned target and Survey	Programmed for one week	10° from B1 law (85% to 50%) from 1 to 14 orbits

Mission profile (2)

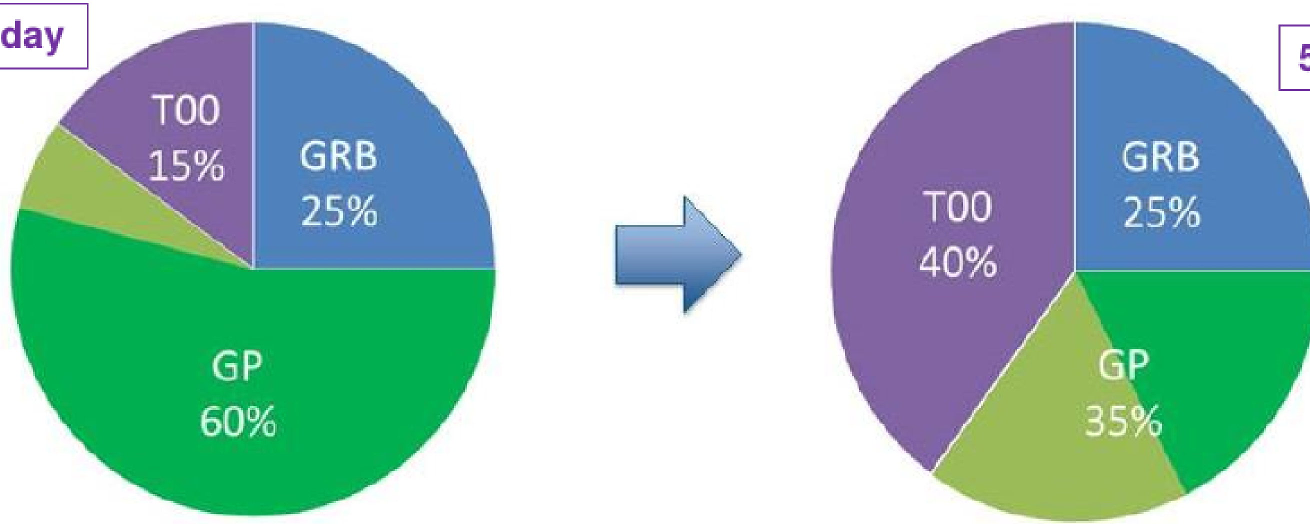
Scope of Mission Planning and Programming activities for SVOM

NOMINAL MISSION → **EXTENDED MISSION**

USEFUL MISSION TIME

1 ToO per day

5 ToO per day



85% of the GP within 10° / B1 pointing
50% UMT for A-targets

50% of the GP within 10° / B1 pointing
30% UMT for A-targets

60% UMT Chinese users / 40% UMT French users

Reminder :
The « B1 pointing law » is a reference inertial pointing defined for each day of the year and designed to favor the GRB detection by instrument ECLAIRs and their follow-up by ground telescopes.

Science legacy

- GRB catalogue with the main observed multi-λ properties
- Thanks to GRB pointings, coverture of all the sky like *Swift*. On average, at least 1 day on a particular GRB field, in some cases expected to perform several revisits.
- Examples of surveys we may be performing:
  - LMC survey of X-ray sources
  - Virgo cluster mapping (9 tiles of 1 degree with MXT) over the mission lifetime to detect TDEs
  - Galactic plane monitoring (strategy to be define)
  - Follow-up of eRosita sources, LSST fields
- Monitoring of blazars and other variable sources with ECLAIRs through a QLA tool (equivalent to what is done by the *Swift*-BAT)
- Maybe we can search for transients in MXT FoV (1x1 sq. deg) on the ground.

Wrap-up

- SVOM will work in a **favourable instrumental landscape** with the most sensitive EM and multi-messenger facilities working.
- **Major contributor in the time-domain & multi-messenger era** => successor of *Swift*
- SVOM will be a **transient factory** providing weekly alerts on various transient objects.
- Synergy with ground/space facilities to **perform multi-wavelength follow-ups**.
- SVOM will also be an **observatory** opened to the community (through SVOM co-Is) enabling to observe a large variety of objects.
- SVOM will conduct some **surveys through its 5 yrs lifetime** => science legacy
- SVOM will make use of multi-λ catalogues for instrument operations and science (core & GP) planning. => look forward to use your catalogues :)

(White Paper – Wei et al. 2016, arXiv:1610.06892)
website: http://www.svom.fr/en/#filter=.accueil