CEA-Irfu, Saclay
IAP, Paris
APC, Paris
CNES, Toulouse
NAOC, Beijing
XIOPM, Xi'an
IHEP, Beijing
SECM, Shanghai
IRAP, Toulouse
LAM, Marseille
CPPM, Marseille
GEPI, Meudon
LAL, Orsay
LUPM, Montpellier
University of Leicester
MPE, Garching



# SVOM in the multi-messenger area

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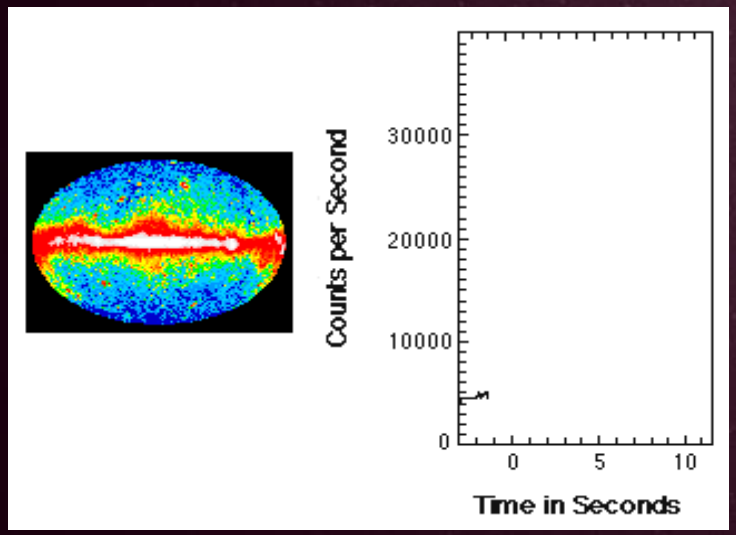
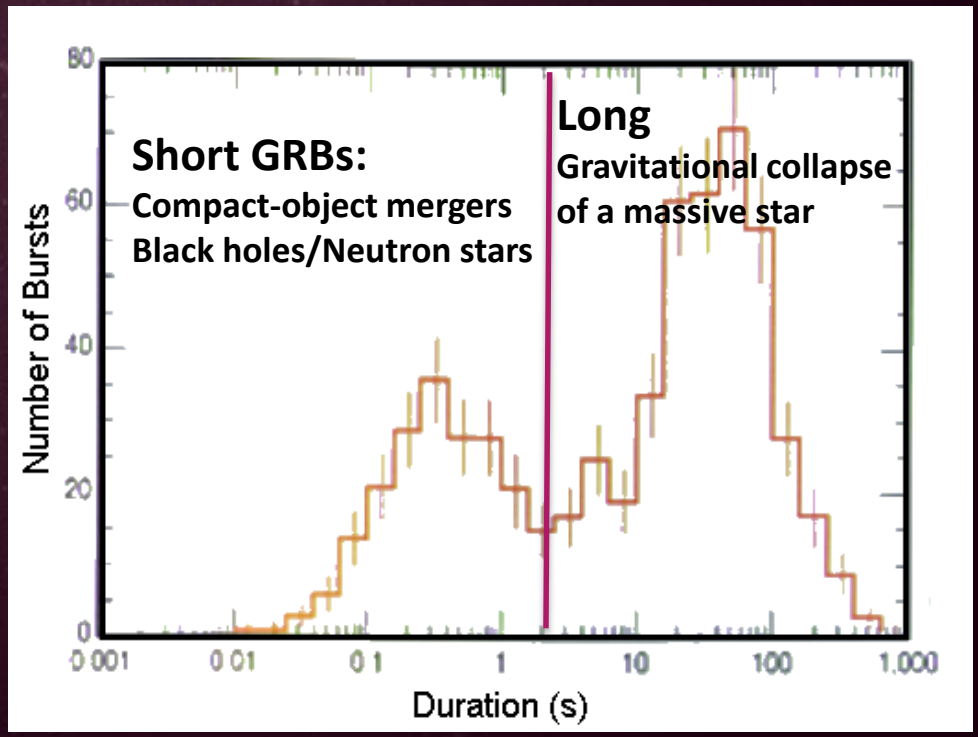
On behalf of the SVOM consortium

# What are Gamma-ray bursts ?

- Intense short pulse of gamma-rays : > $10^{51}$ erg
- Fast-Fading afterglow in x-rays, optical and radio
- Occur in distant galaxies

  → Current redshift range : 0.03 – 9.38



# Open Questions

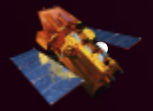
## GRB studies

- Progenitors and central engines
- The physics of the relativistic ejecta
- Multi-messenger emission

## Using GRBs as a tool for cosmology

- Spectroscopy of the line of sight
- Host galaxies
- Very distant GRBs : first stars/reionization of the intergalactic medium ?

Fermi : short GRBs and excellent coverage of the prompt emission



Swift : study of the afterglow and measurement of the redshift

Build a homogeneous sample of GRBs
with a good time and spectral coverage
With redshift measurement

SVOM

# SVOM: Space-based multiband astronomical Variable Objects Monitor

**Satellite to be launched in 2021**

MXT

ECLAIRs

**VHF Network**
**S, X Band antenna**

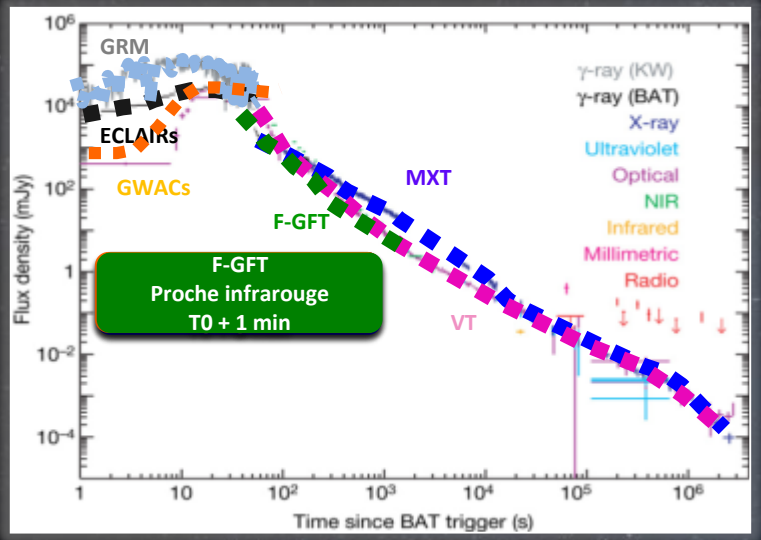
GRM

GWAC

VT

GFT-1

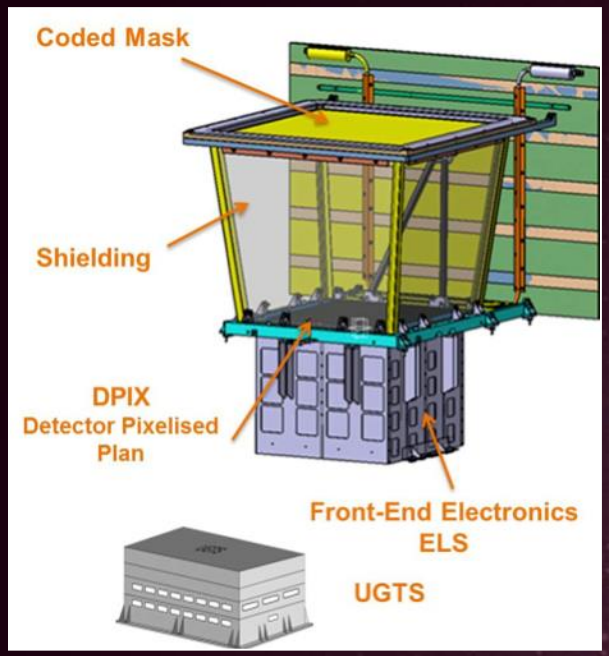
GFT-2




Cordier et al., PoS, *Swift:10* (2015)

# ECLAIRs - Trigger Camera

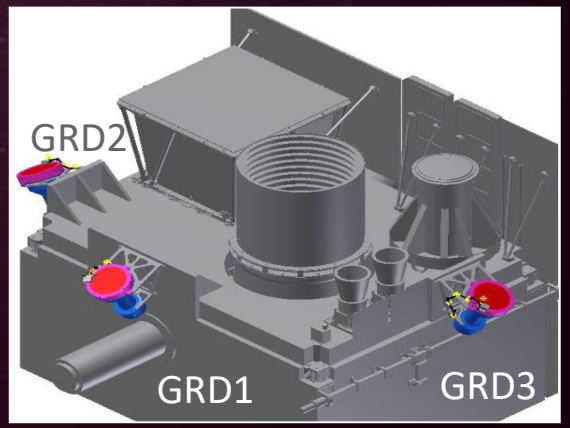





| Coded mask telescope | 60 GRBs/yr |
|---|---|
| Energy band | 4-150 keV |
| FOV | 2 sr |
| Mask | Open fraction = 0.4 |
| Detector | 6400 CdTe pixels - 4x4x1mm$^3$ |
| Onboard processing | Count-Rate and Image Triggers |
| Localisation acc. | 14’ at detection threshold<br>3’ for bright sources |

# GRM - Gamma Ray Monitor

| 3 NaI detectors (GRDs) | 90 GRBs/yr |
|---|---|
| Energy band | 15 keV – 5 MeV |
| FOV | 2 sr per GRD |
| Detector | 200 cm$^2$ (NaI, 1.5 cm thick) |
| Onboard processing | Count Rate Trigger |
| localisation accuracy | > 10° |



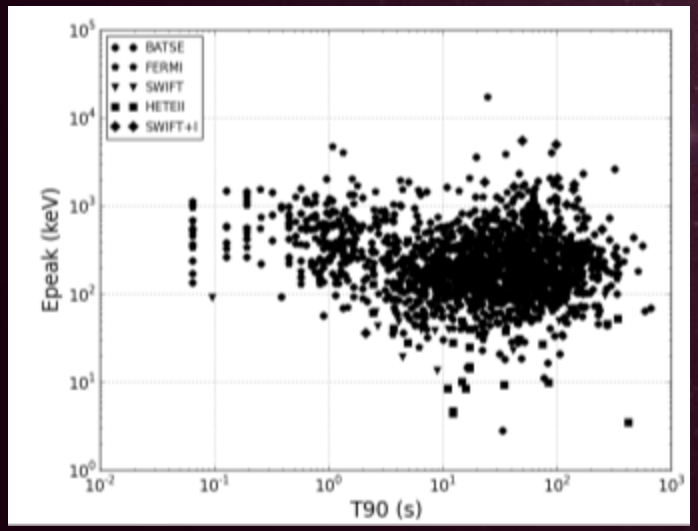
# Caracteristics of the GRBs seen by ECLAIRs

- Number of GRBs detected by ECLAIRs:
- 64 ± **18 GRBs/yr at the alert threshold and 56 ± 18 GRBs/yr at the slew threshold**
- Same proportion of short GRBs as Swift/BAT (8%) : **5±1 GRBs/yr**

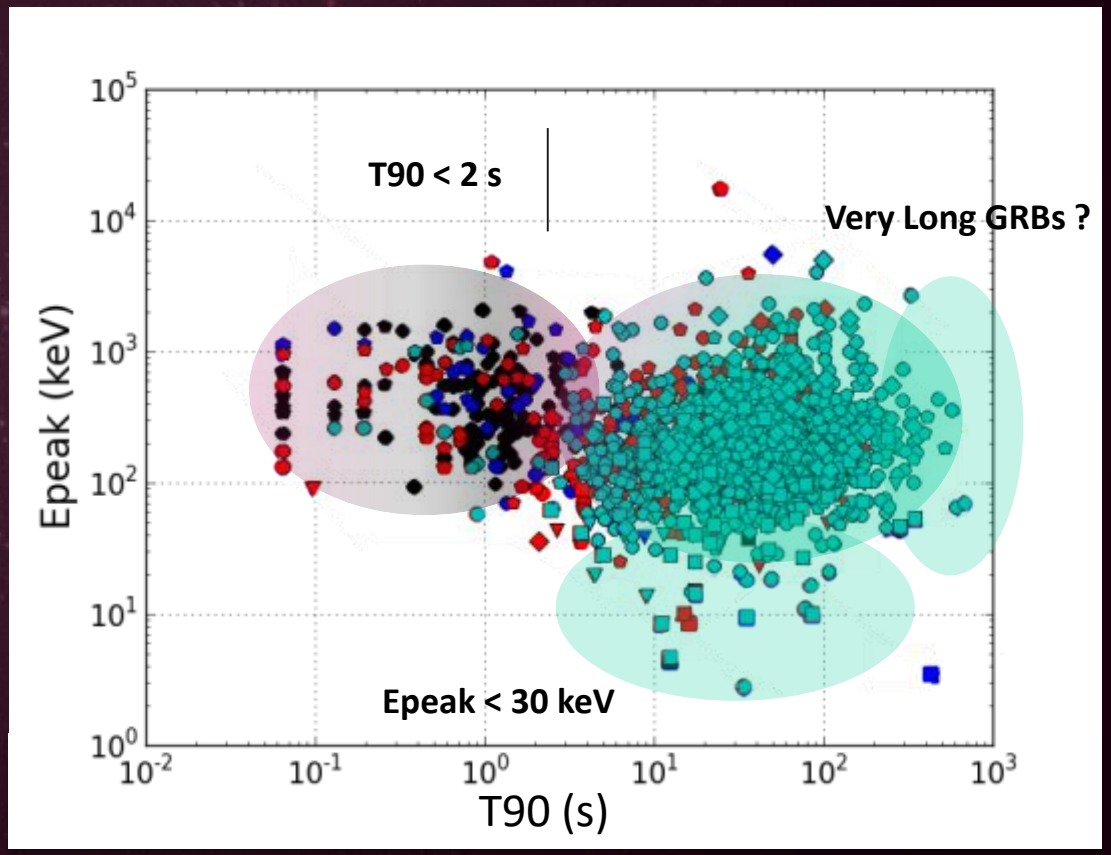
| Symbol |
|---|
| BATSE |
| FERMI |
| SWIFT |
| HETEII |
| SWIFT+* |

*Konus or GBM

| ECLAIRs > $\varepsilon_{GRB}$ |
|---|
| Black > 0.2 |
| Blue > 0.5 |
| Red > 0.7 |
| Cyan > 0.9 |



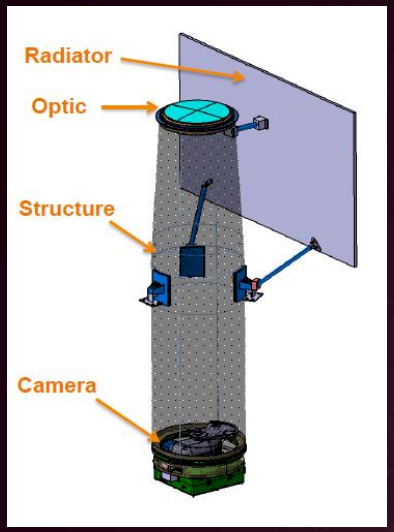

**Input catalogs**




**ECLAIRs will be sensitive to all known GRBs**

*S.Antier, F.Daigne, S.Schanne et al. (2016)*

# MXT – Micro-channel X-ray Telescope

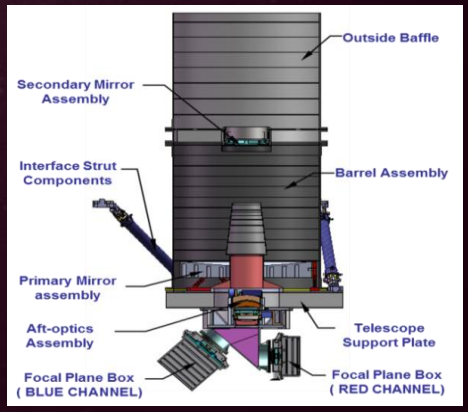



| Micropore Optics (MPO) "Lobster eye" | |
|---|---|
| FOV | ~ 1 deg$^2$ |
| Focal Length | ~1 m |
| Camera | 256x256 PN CCD<br>27 cm$^2$ at 1 keV |
| Energy Band | 0.2 – 10 keV |
| Onboard processing | sources positions |
| Localization accuracy | < 2'<br>< 30'' bright sources |

**90% of ECLAIRs GRBs observable**

# VT - Visible Telescope

| Ritchey Chretien Telescope | |
|---|---|
| Diameter | 40 cm |
| 2 channels | 400 nm–650 nm (blue)<br>650 nm–950 nm (red) |
| Limiting Magnitude | 22.5 (5σ, 300s) |
| FOV | 26' x 26' |
| Spatial resolution | 0.77'' |
| Onboard Processing | List of potential transient srcs. |



# GWAC – Ground Wide Angle Cameras

**12% of ECLAIRs GRBs observable**

| Set-up with 36 cameras | |
|---|---|
| Diameter | 18 cm |
| Focal Length | 22 cm |
| Camera | 4k x 4k CCD detectors |
| Wavelength | 500-800 nm |
| FOV | 5000 deg$^2$ (63% of the ECLAIRs FOV) |
| Limiting Magnitude | V=16.5 (5 σ,10s) |
| Temporal resolution | 1s |

# F-GFT - Ground-based Follow-up Telescope

- **Chinese Ground Follow-up Telescope (C-GFT)**
  - Robotic 1-m class telescope, Xinglong observatory
  - FoV = 21x21 arcmin², 400-950 nm
- **French Ground Follow-up Telescope (F-GFT)**
  - Robotic 1.3-m class telescope, San Pedro Martir (Mexico)
  - FoV = 26x26 arcmin²
  - Multi-band photometry (400-1700 nm, 3 simultaneous bands)
- **Contribution to the LCOGT network (12x1m+2x2m tel.)**
  - >75% of ECLAIRs-detected GRBs immediately visible by one ground telescope (GFTs+LCOGT)

# Observation Program:

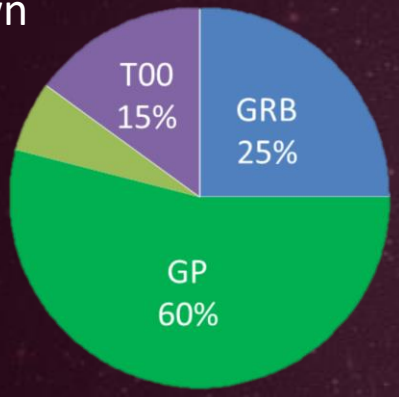
GRB ← GP → ToO

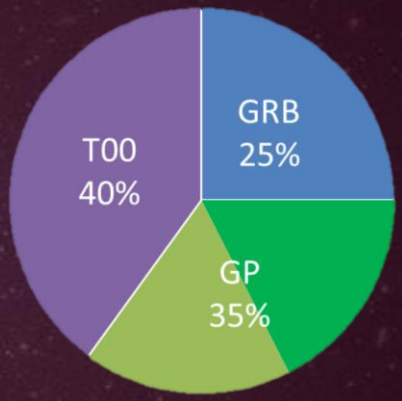
Autonomous transient detection by ECLAIRs Top-Down

General Program Pre-planned Observations compliant with satellite law

Target of Opportunity Bottom-Up

Nominal mission



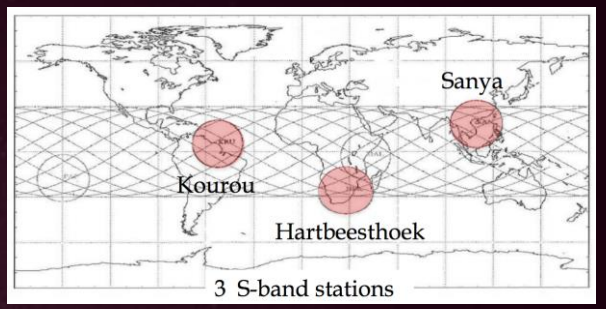

Extended mission

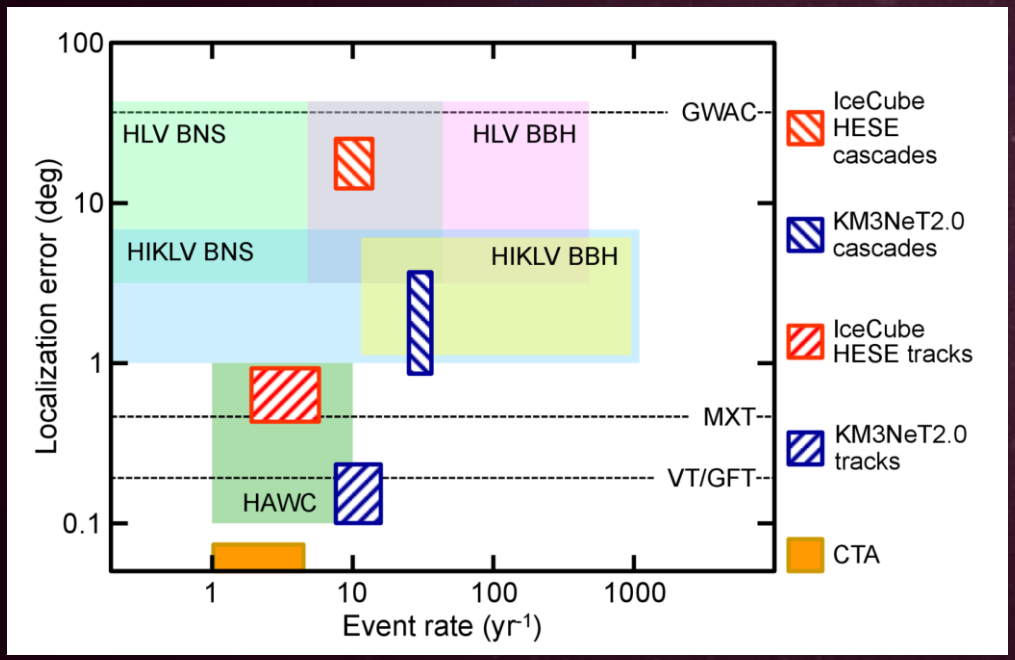
**We are currently enlarging the ToO capabilities of SVOM. Very complex operations at system level**

| | ToO-NOM | ToO-EX/ToO-MM |
|---|---|---|
| Frequency | 1/day | 1/month |
| Standard delay | < 48h | < 12 h |
| Duration | > 1 orbit | 7 – 14 orbits |

# ToO-MM

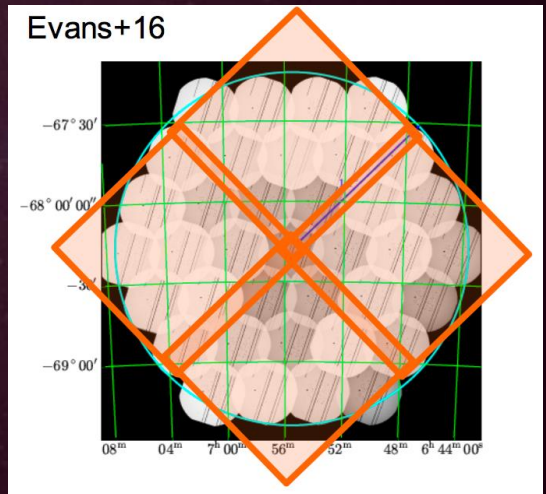
ToO-MM is the ToO dedicated to EM counterpart search in response to a multi-messenger alert.
What differs from the ToO-NOM and ToO-EX is the unknown position of the source within a large error box…
**Tiling required !**




J.Wei, B.Cordier, C.Lachaud, et al. (2016)

**Swift/XRT slightly better than MXT (35%) but MXT has a larger FOV!**




- **Send MXT photons through VHF link + ground analysis.**
- **If anything found :**
  **new ToO + Community alert**

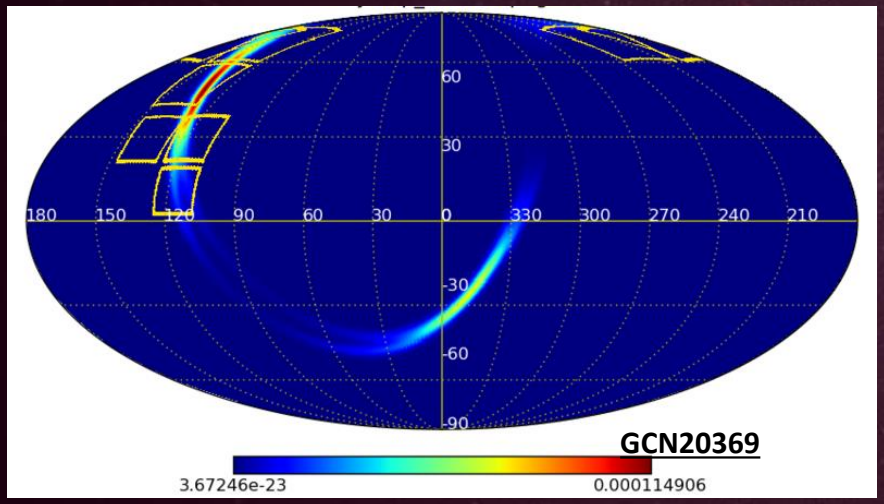
# GW astronomy and SVOM

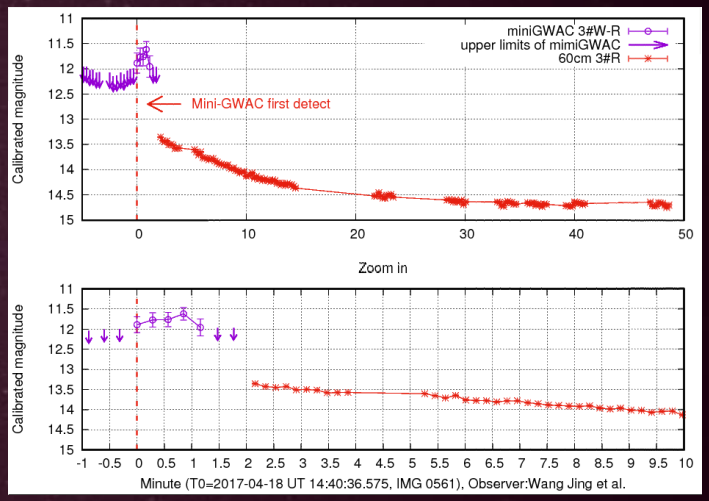
**During O2 run: GW170104**

## Mini-GWAC observations (12 mag):

- Perform routine observations every night
- ToO from GW alerts and Antares neutrino alerts
- **GWAC available at fall 2017 (u.Limit 16 mag)**

Flaire star found by mini-GWAC/60 cm telescope
Wang Jing et al. at 14:40:36 UTC 18/04/2017
(10:45:28.75, 35:51:17.90)




- Starts Observations 2h20 after the GW trigger!
- Bayesien probability coverage: 84.4 %

**SVOM performs the Largest Probability coverage for GW170104 in shortest latency for optical band**

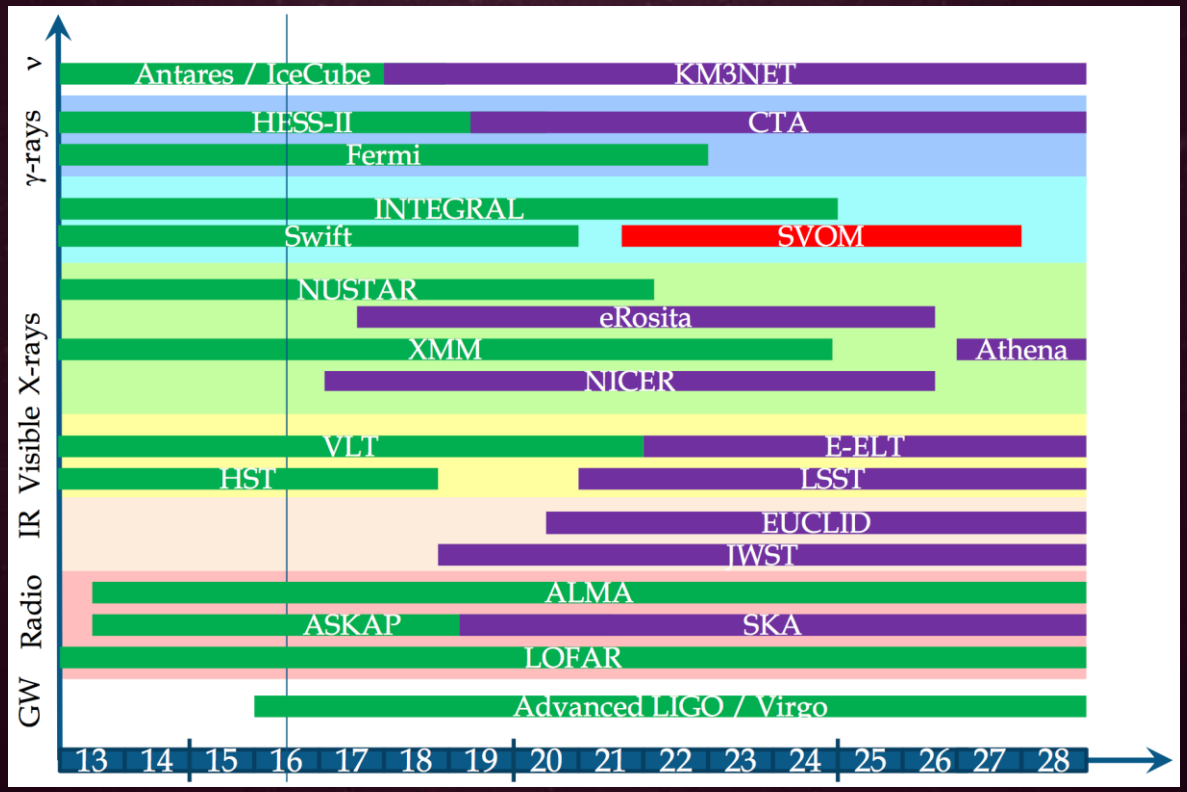
- No interesting transient found

**Possible (external) candidate follow-up :**

- 2 robotics 60 cm telescopes (GCN20404)
- 1-m telescope (Xinglong)
- 2-m telescope (Xinglong)
- 2.16-m telescope in Lijiang Observatory

# Conclusion and perspectives

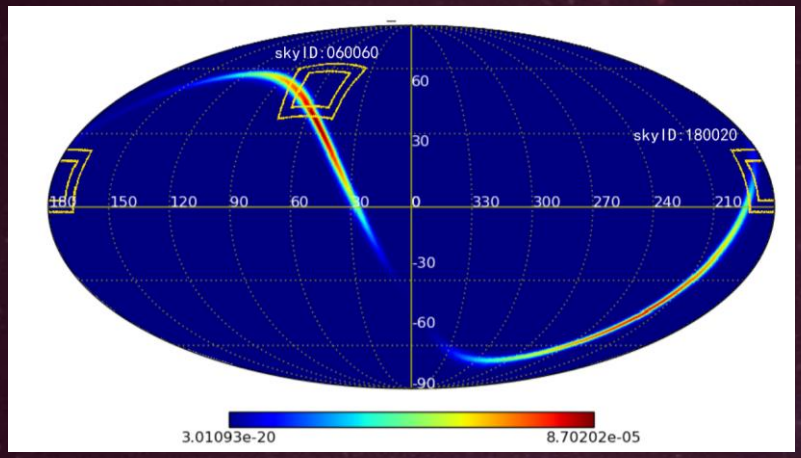
Now, with the time domain and multi-messenger astronomy in strong developments, SVOM is ready to play an important role in the future…



# GW astronomy and SVOM

**During O1 run: GW151226**

## Mini-GWAC observations




- Observations 12 h and 13.6 h

after the trigger time (2015-12-26 at 3:38:53 UTC)

- Duration 2.8 and 5.3 h
- Upper limit 11 mag
- Transient search with two pipelines:
  Catalog crossmatch and difference imaging analysis