THE SVOM CONTRIBUTION TO MULTI-MESSENGER ASTROPHYSICS

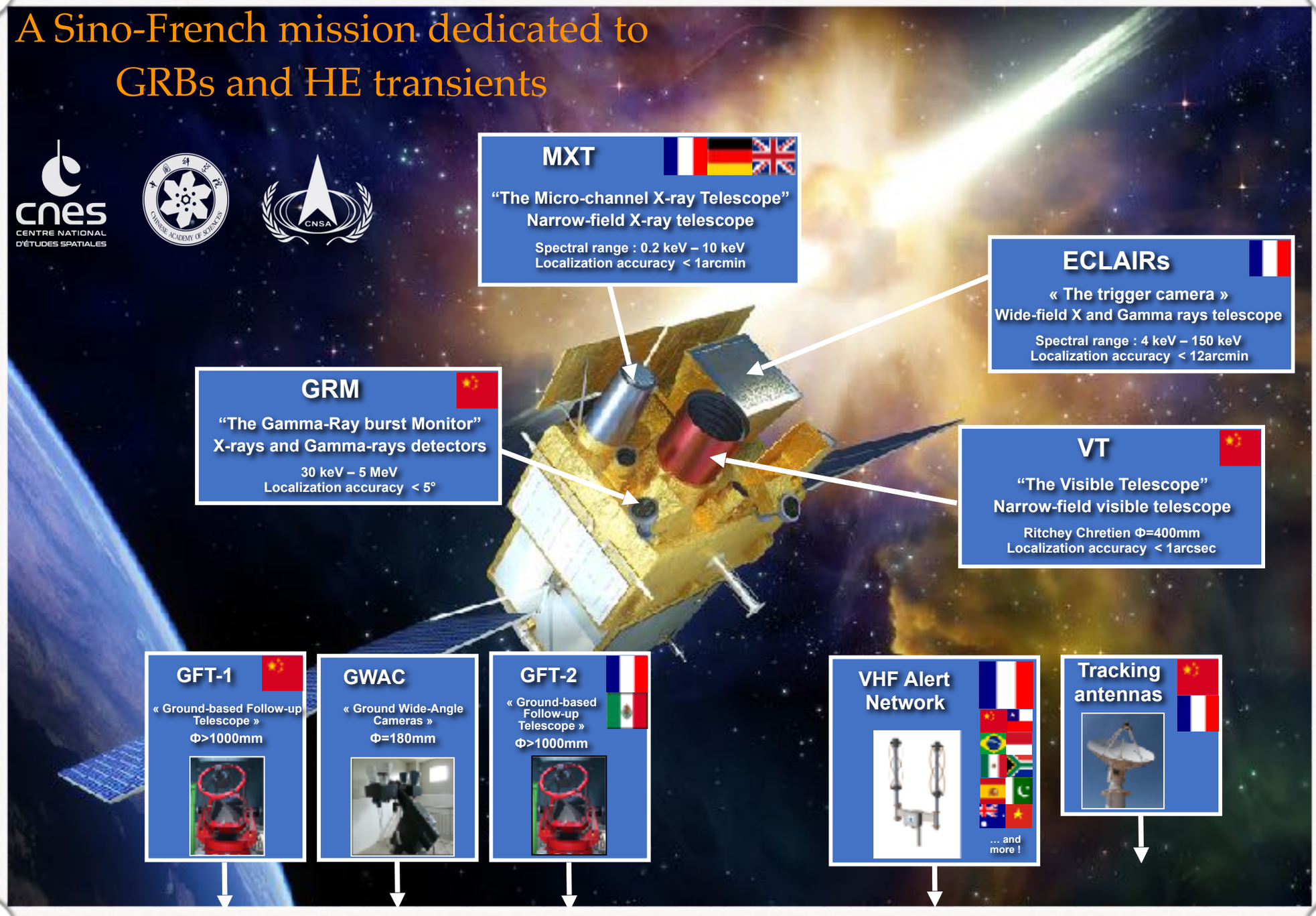
Diego Götz (CEA-Irfu/DAp - MXT PI)

on behalf of the SVOM collaboration

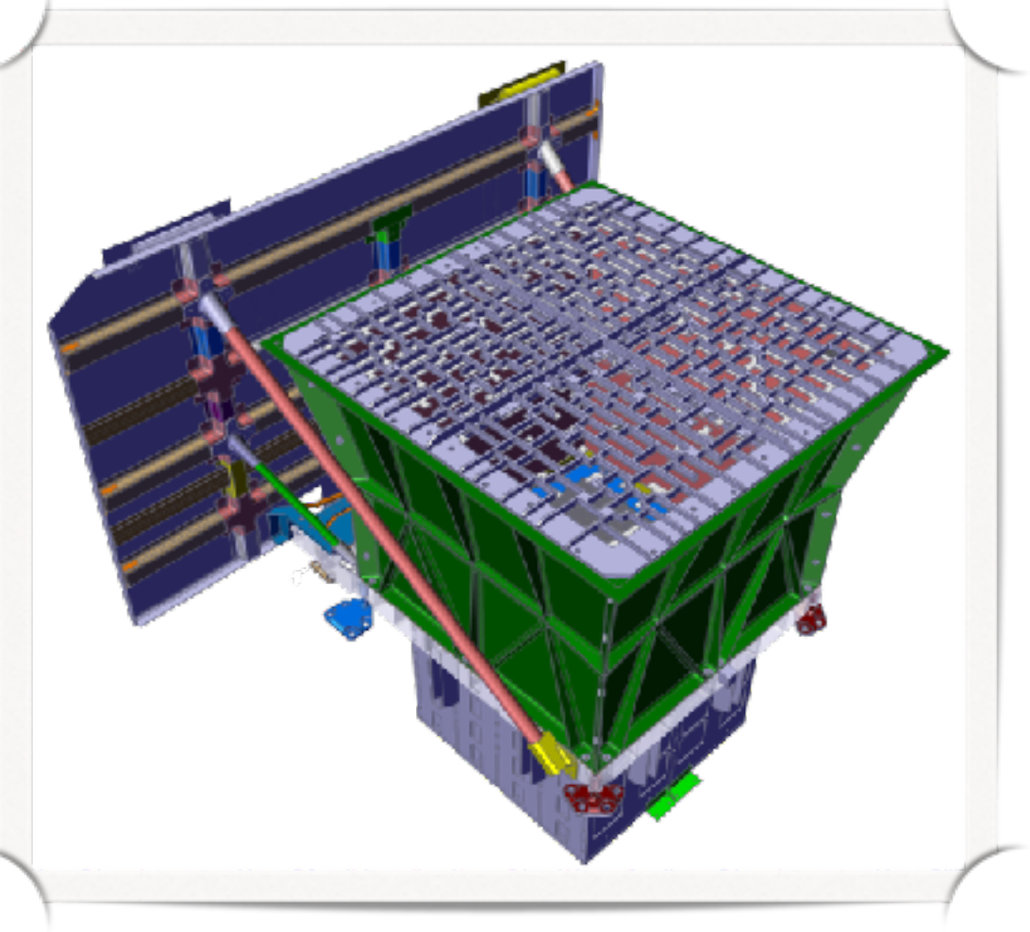
PLAN OF THE PRESENTATION

- Presentation of the SVOM mission
- On board Instruments & on ground Instruments
- Focus on ToO Programme

SPACE VARIABLE OBJECT MONITOR



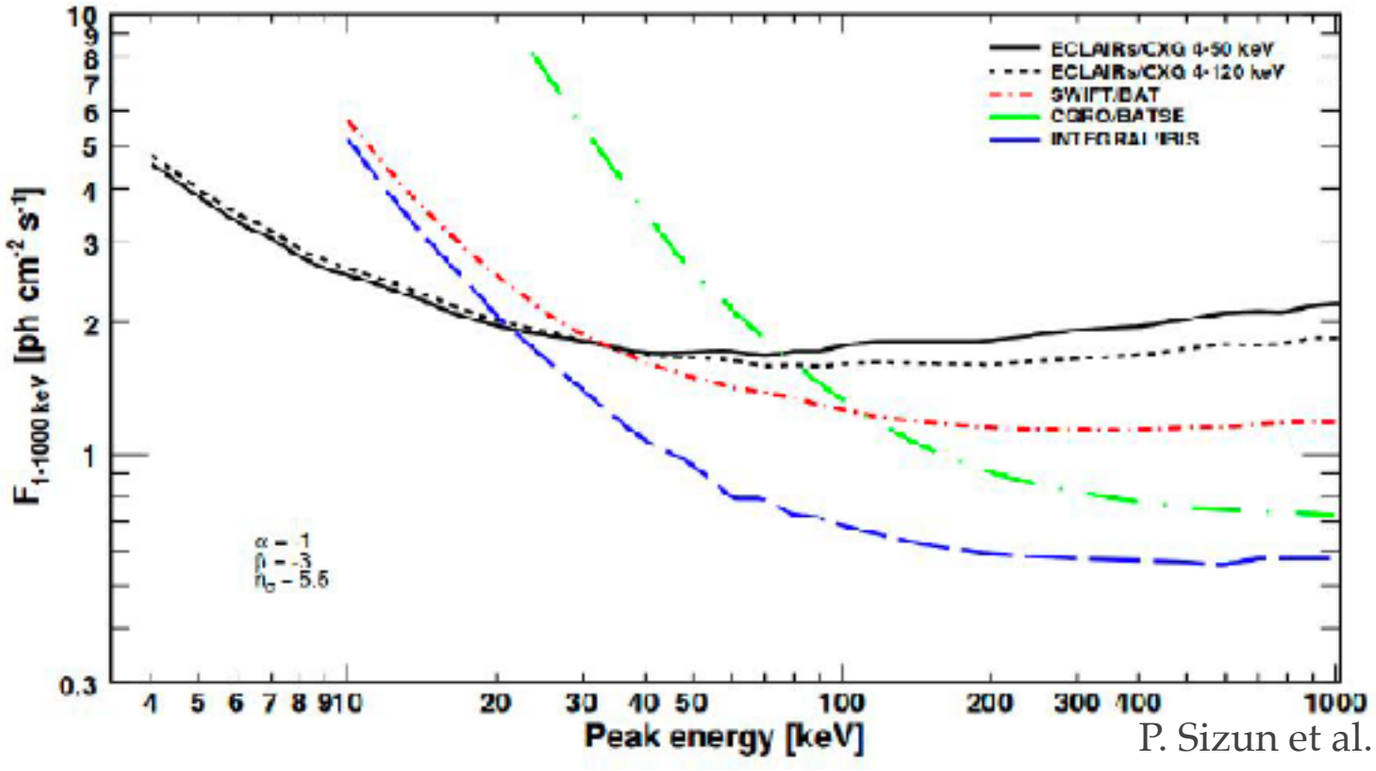
SVOM INSTRUMENTS: ECLAIRS



Well adapted for the detection of low-Epeak GRBs

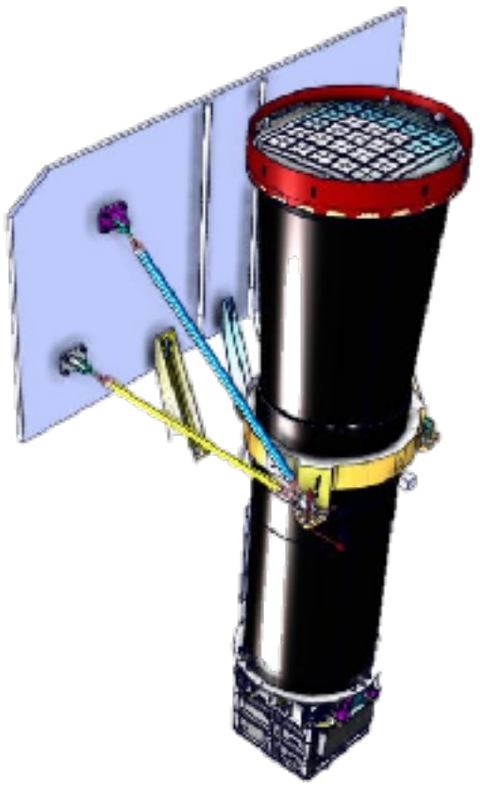
ECLAIRs (CNES, IRAP, CEA, APC)

- 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.

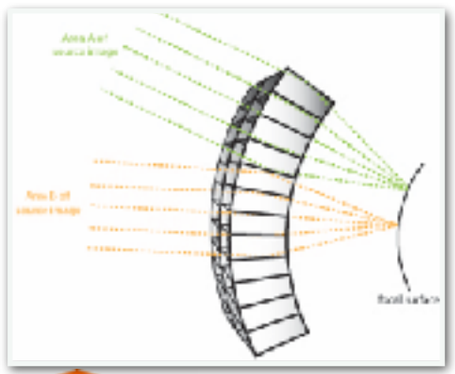
SVOM INSTRUMENTS: MXT

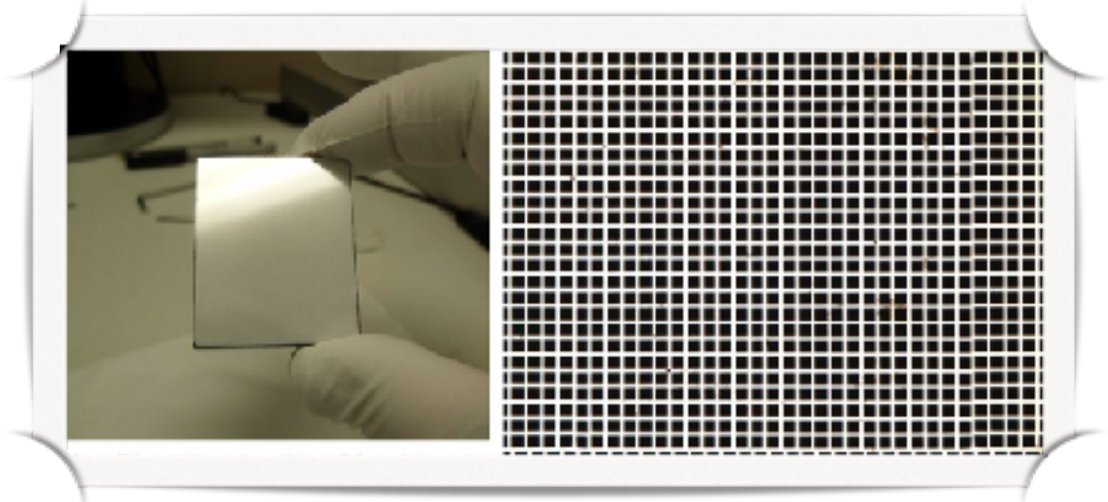


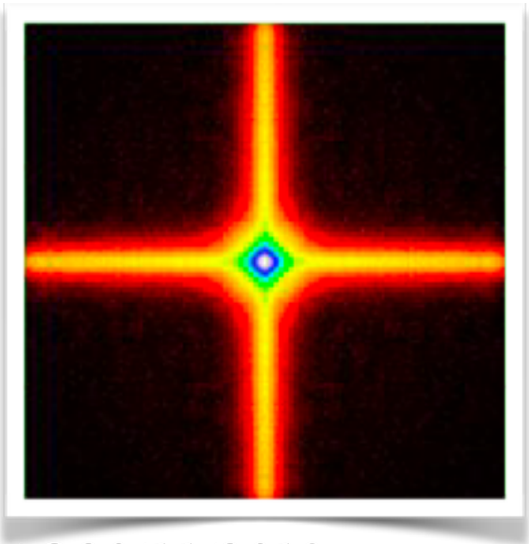
Micro-channel X-ray Telescope (CNES, CEA, UL, MPE)

- **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)

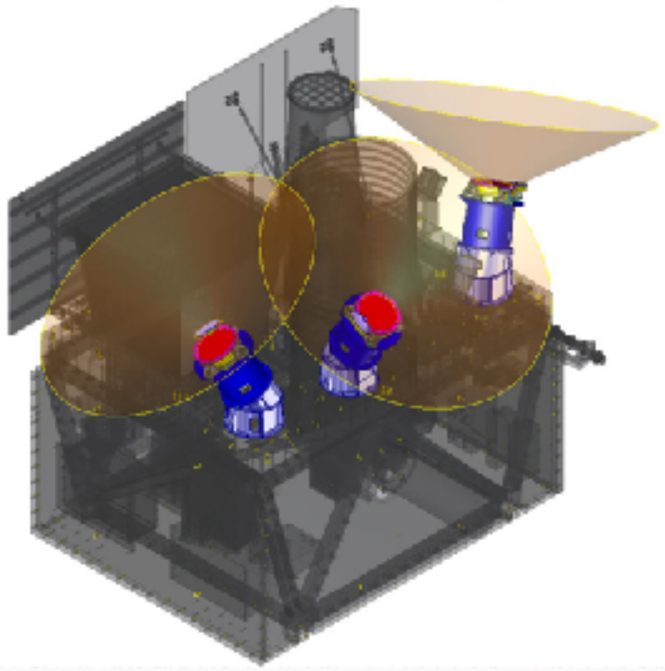
Implements innovative focussing X-ray Optics based on « Lobster-Eye » design
Will be able to promptly observe the X-ray afterglow





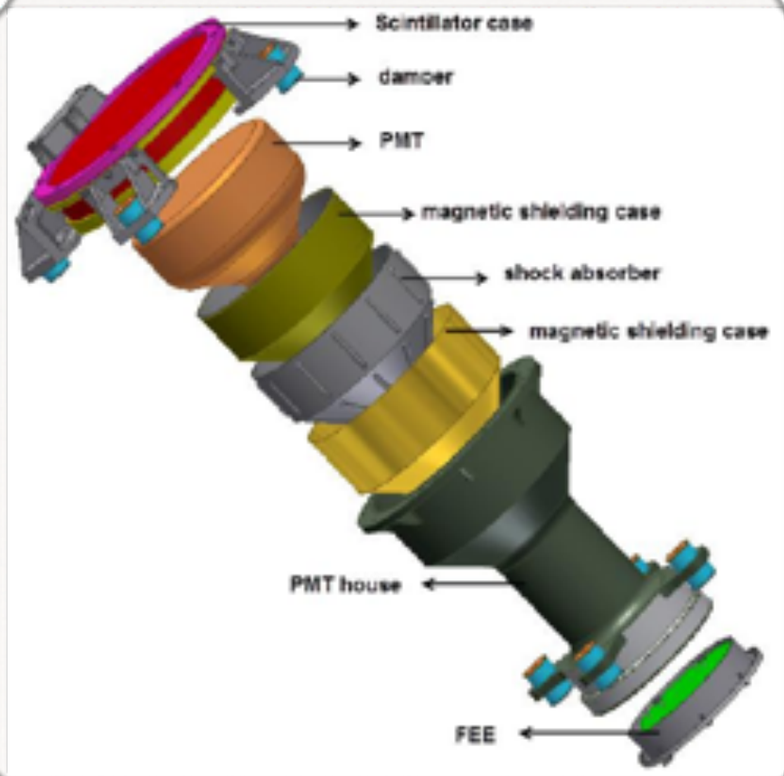


SVOM INSTRUMENTS: GRM



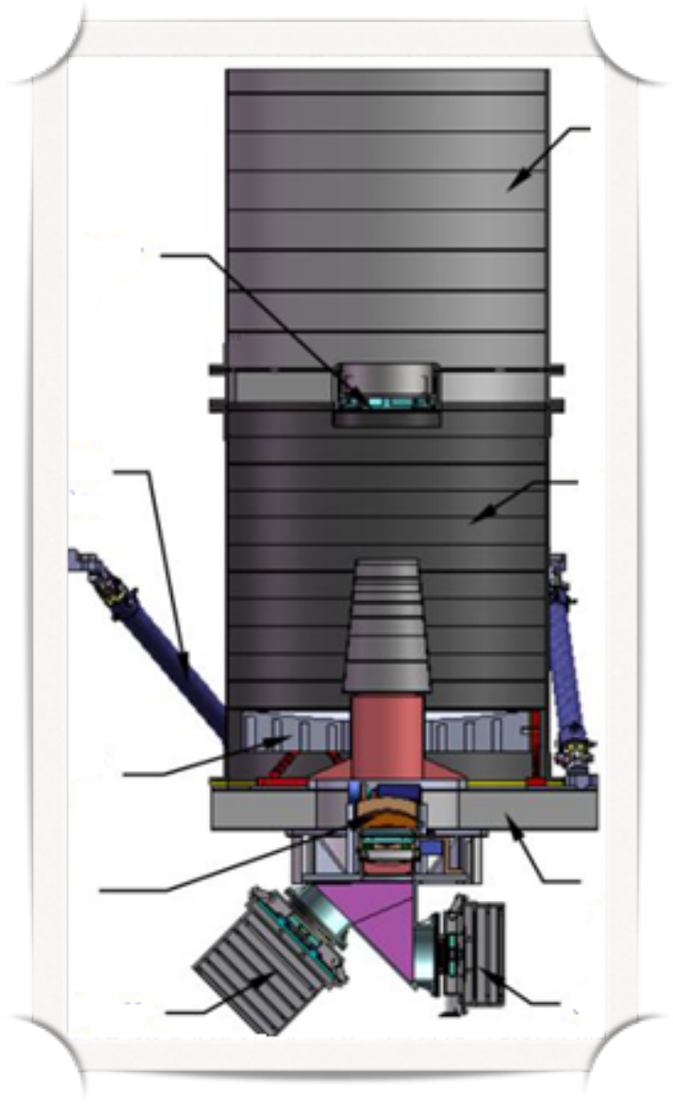
Gamma-Ray Monitor (IHEP)

- **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)

SVOM INSTRUMENTS: VT



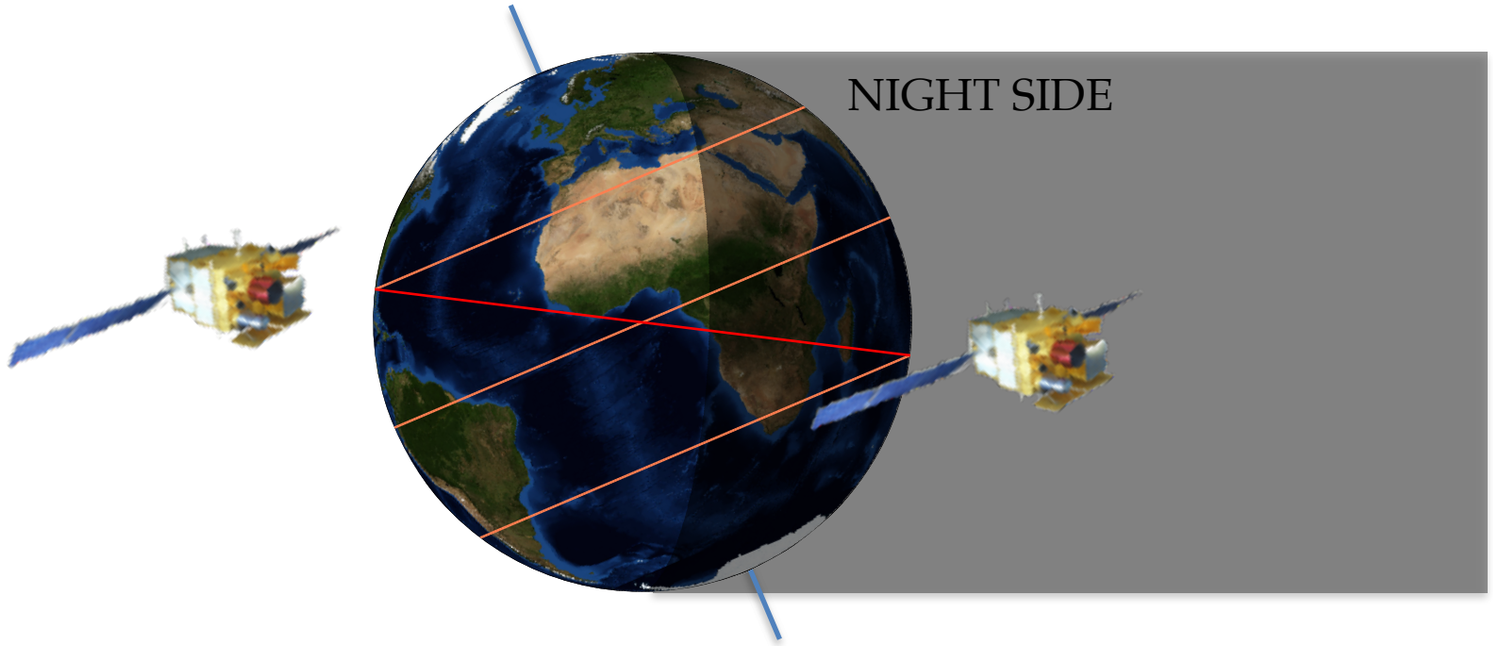
Visible Telescope (XIOMP, NAOC)

- 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

SVOM OBSERVATION STRATEGY

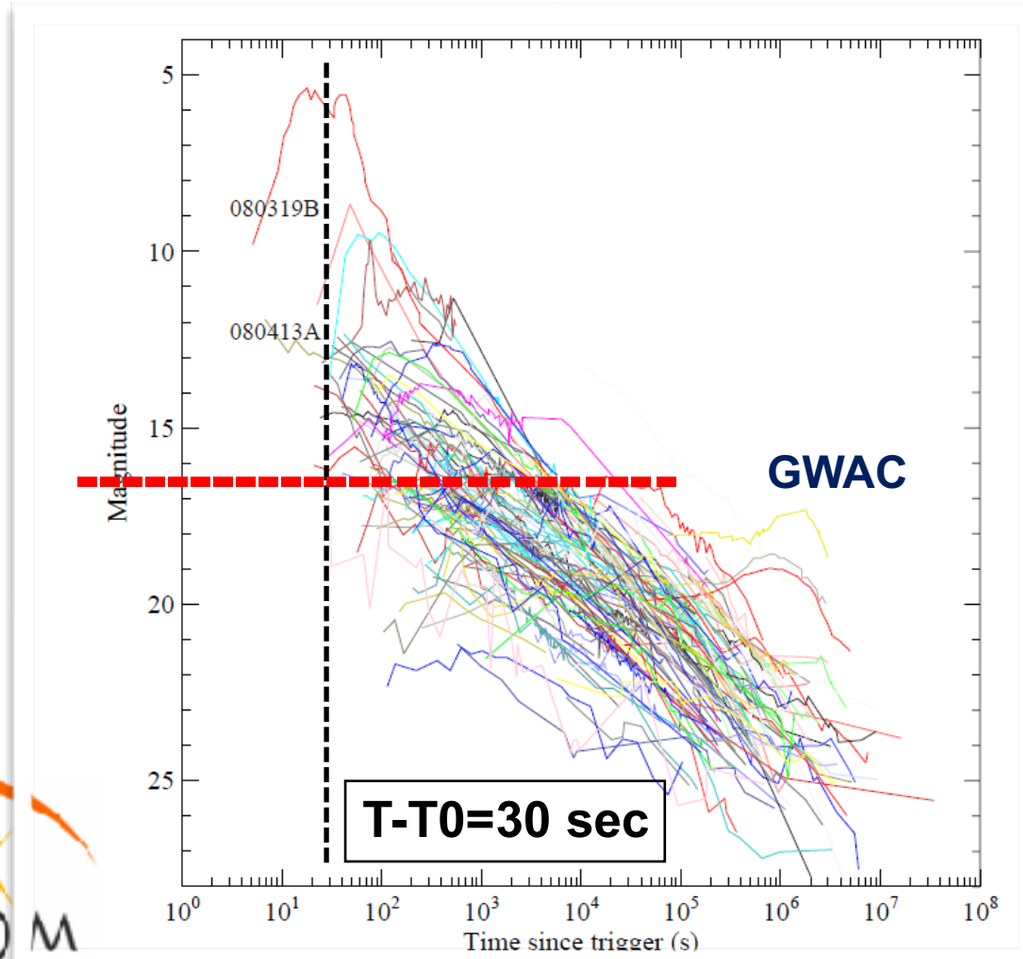
- **Launched** from **Xichang** (Sichuan) by an **LM-2C** rocket in D**ecember 2021**.
- **Circular low Earth orbit at 625 km** of altitude with an **inclination of about 30°**
- Nearly **anti-solar pointing** (so-called « **B1** » **attitude law**)
- => Earth in the field of view (**65% of duty cycle 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 arc sec stabilisation)
- **GRB follow-up** during up to **14 orbits** (about 1 day)



SVOM GROUND BASED INSTRUMENTS

GWACs - Ground based Wide Angle Cameras (NAOC)

- Partly installed in China (near Muztagh Ata) and partly in Chile to optimise the observation of prompt GRB optical emission
- In China: 40 cameras of 180 mm diameter; total FOV ~6000 sq degrees; limiting magnitude 16 (V, 10 s)
- In Chile (TBC): 50 cameras of 250 mm diameter; total FOV ~5000 sq degrees; limiting magnitude 17 (V, 10s)



Will cover instantaneously about 12% of the ECLAIRs FOV

Self triggering: will be able to catch autonomously optical transients (e.g. AT2018cow was discovered at magnitude of 14.7, see ATel 11727)

Will scan the entire accessible sky each night

The Chinese GWACs are in commissioning phase, will participate to 03 LIGO/VIRGO run.

SVOM GROUND BASED INSTRUMENTS

Chinese Ground Follow-up Telescope (C-GFT | 2020)

Robotic 1.2 m class telescope, Jilin observatory

FoV = 21x21 arcmin², 400-950 nm + primary focus 1.5x1.5 deg² FOV

French Ground Follow-up Telescope (F-GFT | 2020/2021)

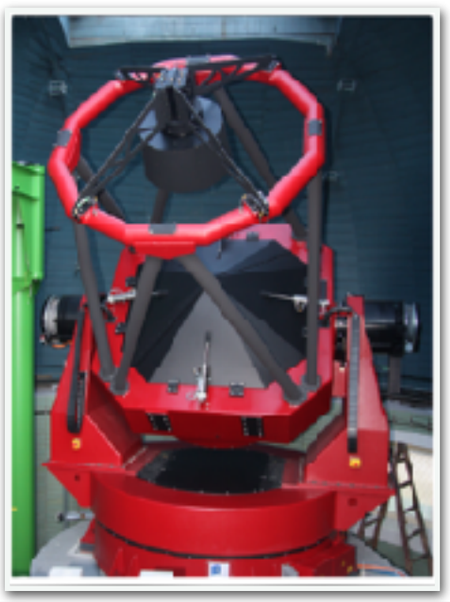
Robotic 1.3 m class telescope, San Pedro Martir (Mexico)

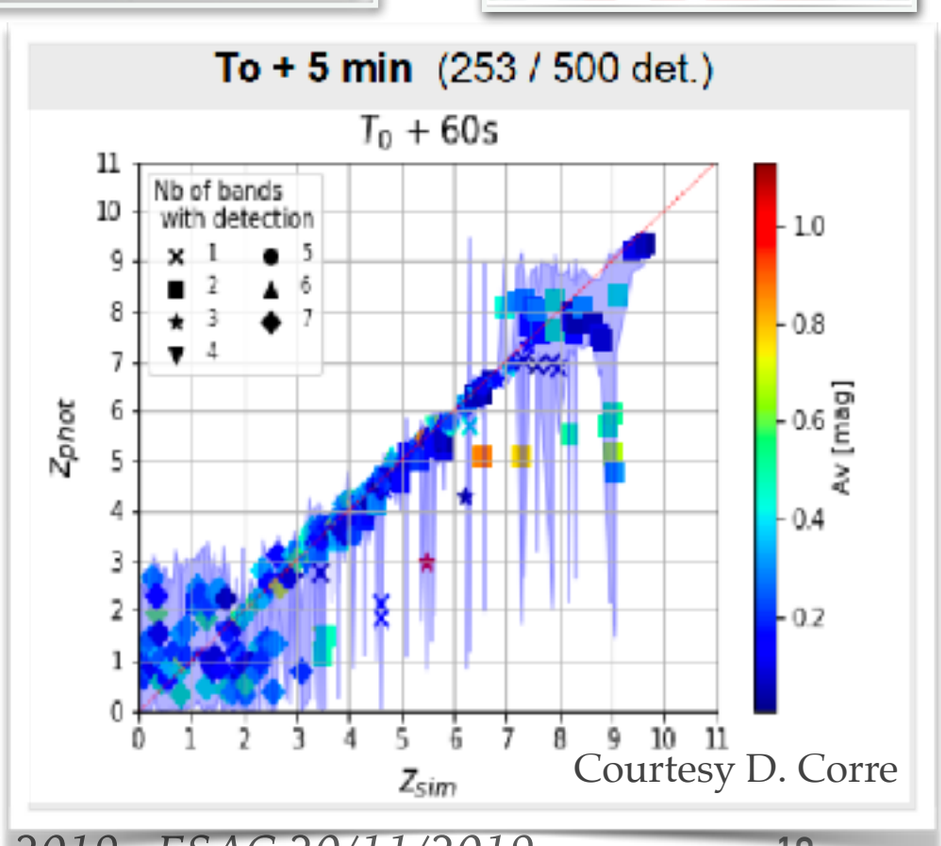
FoV = 26x26 arcmin²

Multi-band photometry (400-1700 nm, 3 simultaneous bands, allows for photo-z)

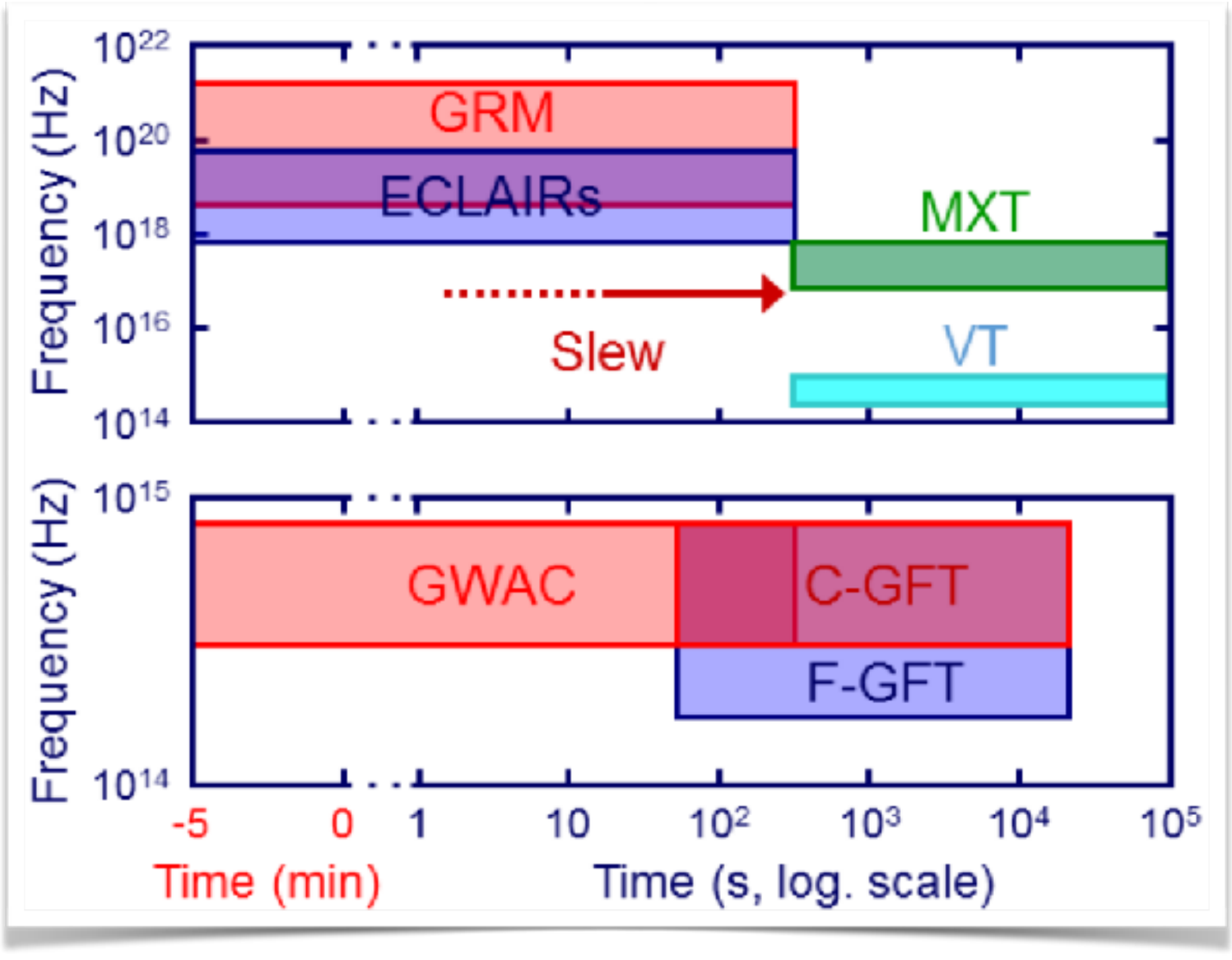
Contribution to the LCOGT network (12x1m+2x2m tel.)

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





SVOM MULTI-Λ COVERAGE



Space

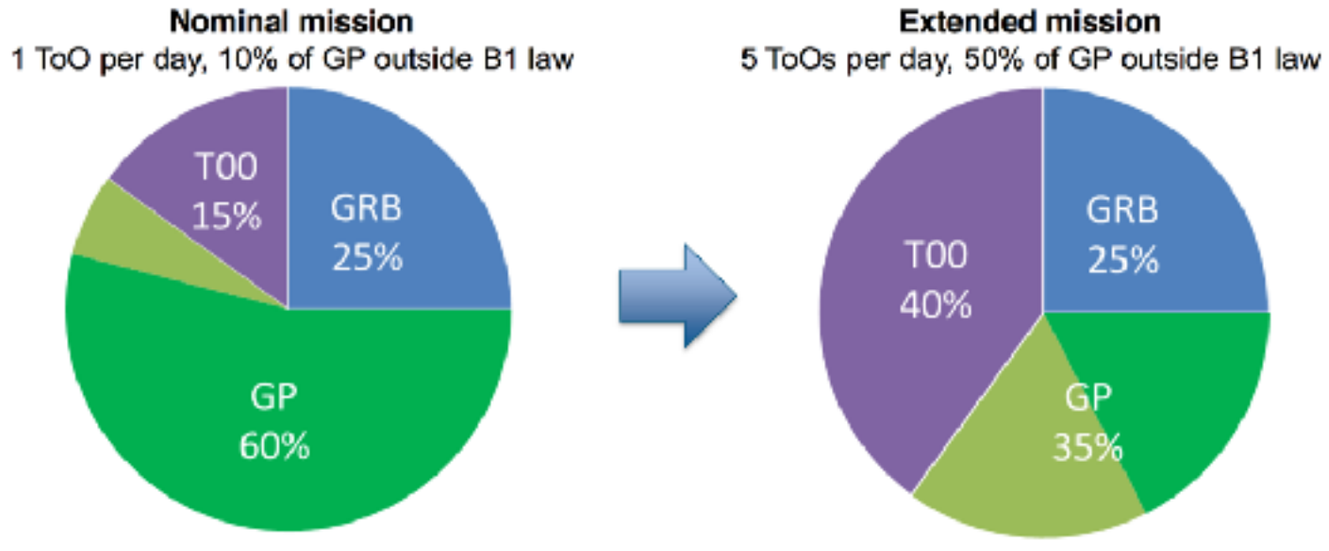
Ground

SVOM OBSERVATION PROGRAMMES

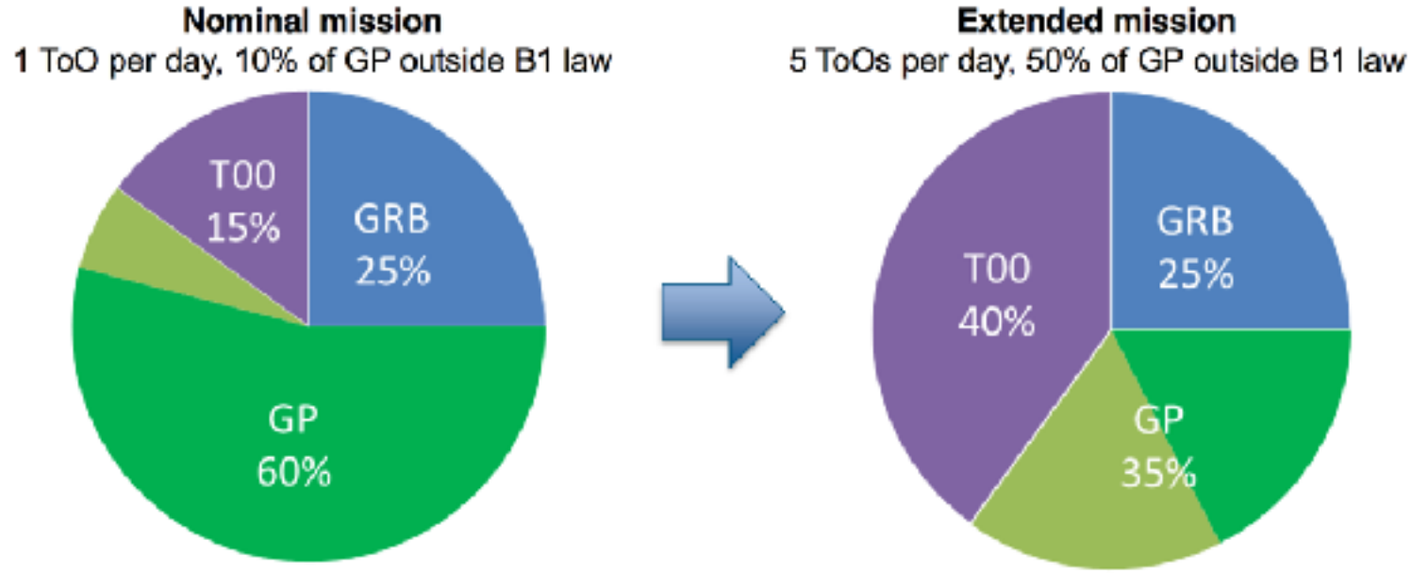
SVOM will be an open observatory : **general program (GP)** observations will be awarded by a TAC (a SVOM co-I needs to be part of your proposal). 10% of the time can be spent on low Galactic latitude sources during the nominal mission (up to 50% during the extended mission).

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.



THE SVOM OBSERVATION PROGRAMS



From 1 ToO/day and as much as 5 ToO/day in the extended mission.

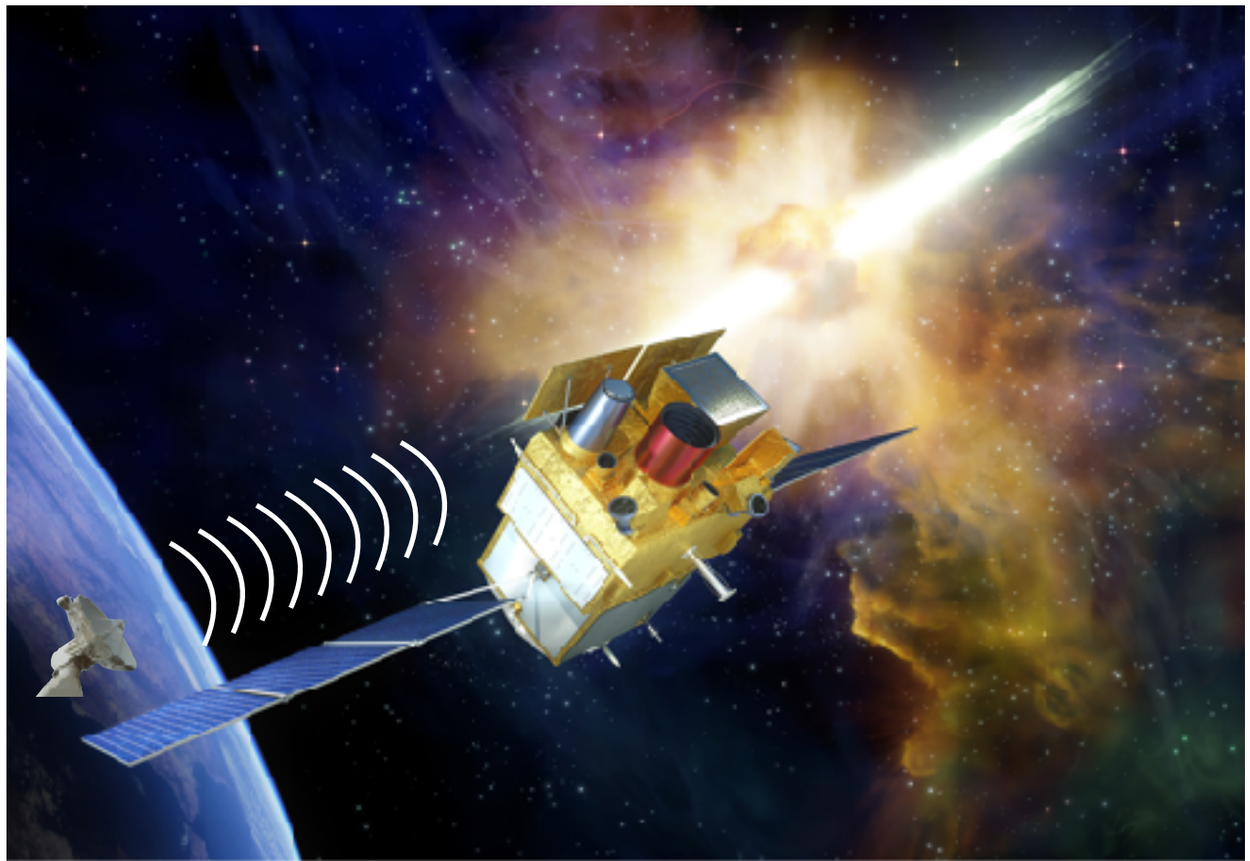
ToO	Approval	Delay	Interrupt GRB obs. ?	Frequency	Duration	Tiling	VHF data	Science product availability
ToO-NOM [SR5-NOM]	ToO scientists	<48h	No	1 (5) / day	1 orbit	No	No	24h
ToO-EX [SR5-EX]	PIs/ToO sc.	<12h	Yes	1/month	14 orbits	No	No	24h
ToO-MM [SR5-MM]	PIs/ToO sc.	<12h	Yes	1/week	7-14 orbits	Yes	MXT + VT	VHF < 1h X-band : 24h

THE SVOM TOO PROGRAM

Transient/event detected by other facilities

Target of Opportunity program

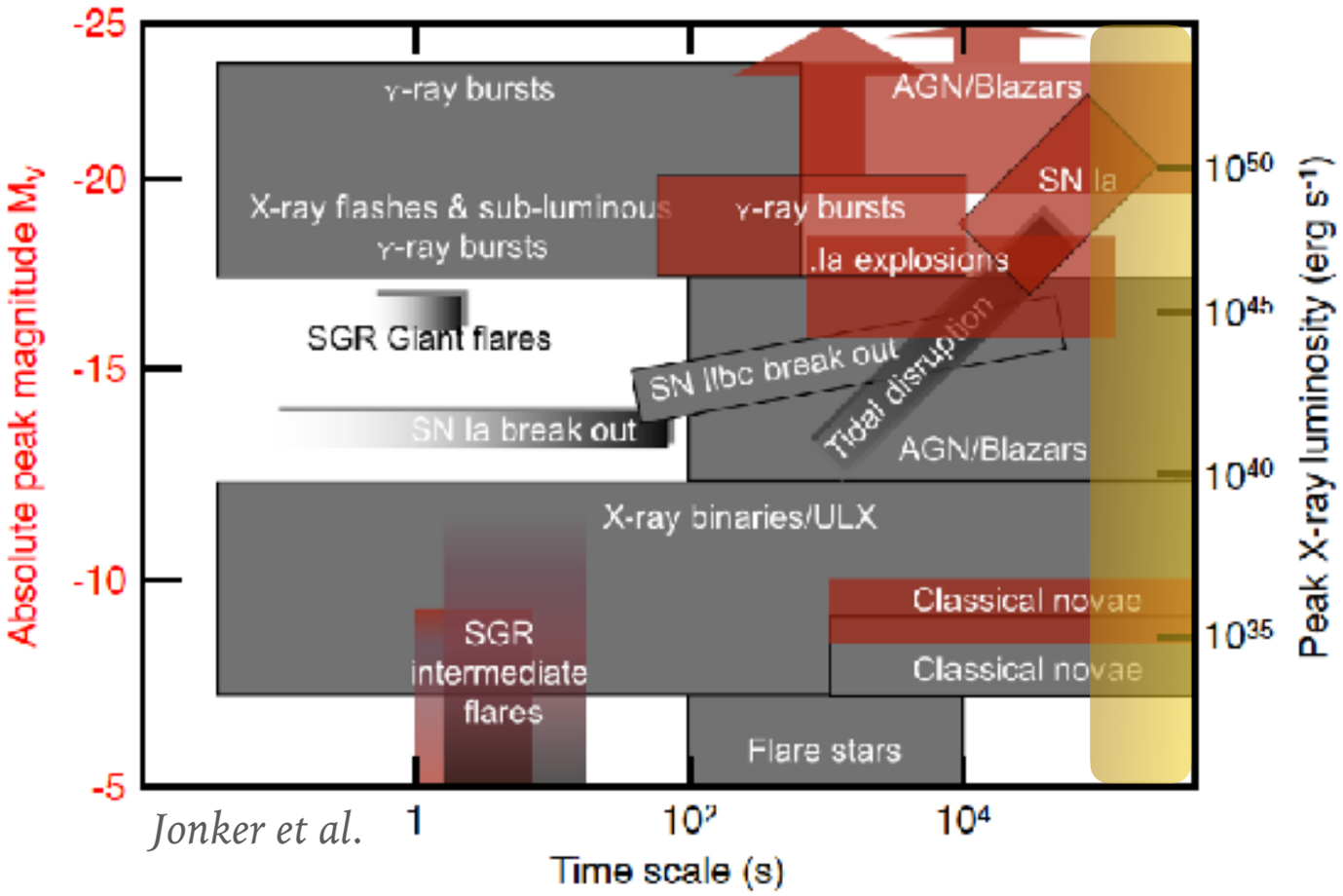
=> send commands to the satellite to trigger observations



Complex operations at system level

TOO-NOM

ToO-NOM is the nominal ToO which covers the basic needs for efficient transient follow-up.



Jonker et al.

Scientific target :

GRB revisit (CP; user : BA)

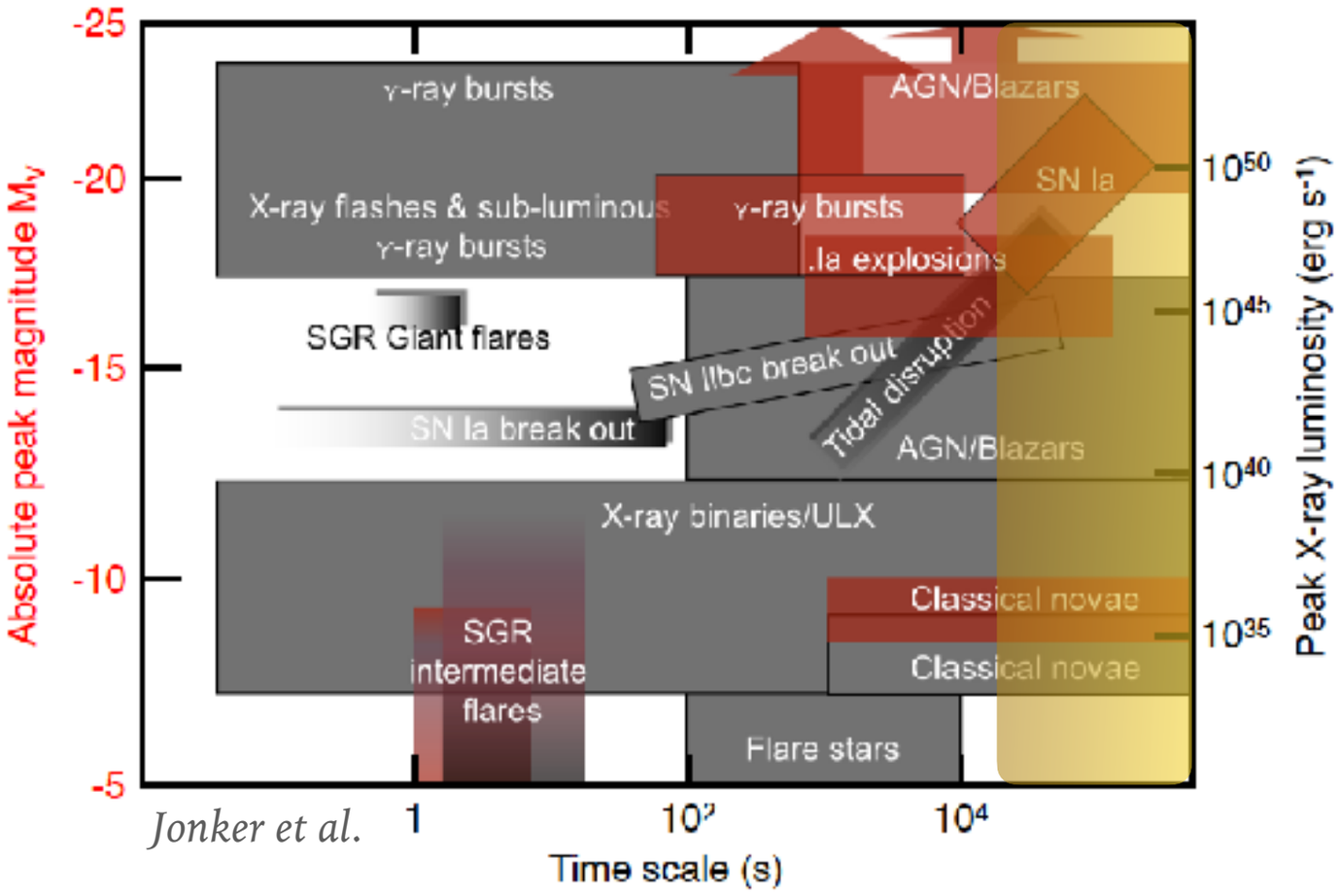
Pre-planned observations through a GP proposal waiting for a known source to flare (AGN,…)

New transient (LSST, CTA, …)

Main characteristics :
Frequency : 1/day
Standard delay : < 48h
Duration : 1 orbit (or more)

TOO-EX

ToO-EX is the exceptional ToO which covers the needs for a fast ToO-NOM in case of an exceptional astrophysical event we want to observe rapidly.



Main characteristics :
Frequency : 1/month
Standard delay : < 12h
Duration : 7-14 orbits

TOO-MM

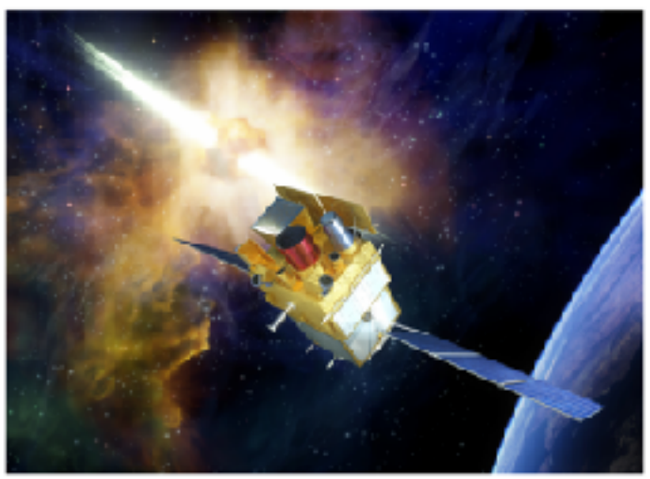
ToO-MM is the ToO dedicated to EM counterpart search in response to a multi-messenger alert. What differs from the ToO-NOM and ToO-EX is the unknown position of the source within a large error box…

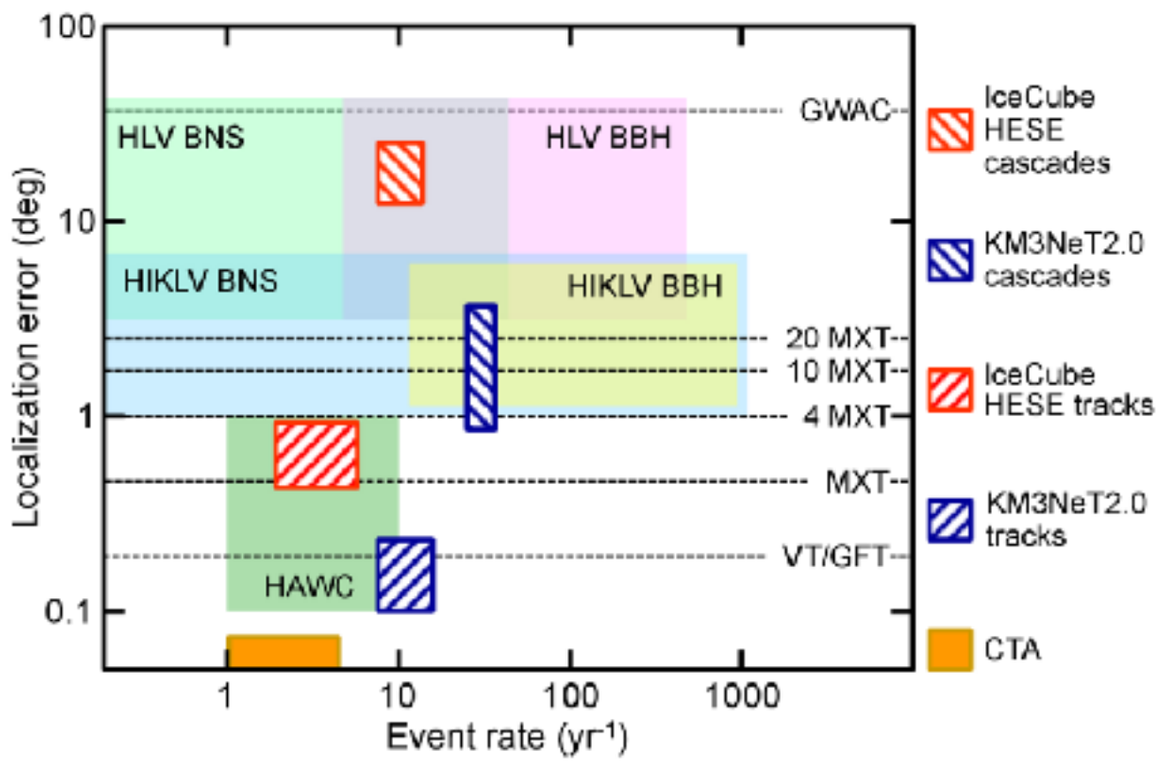
For the SVOM White paper we produced this figure :

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)

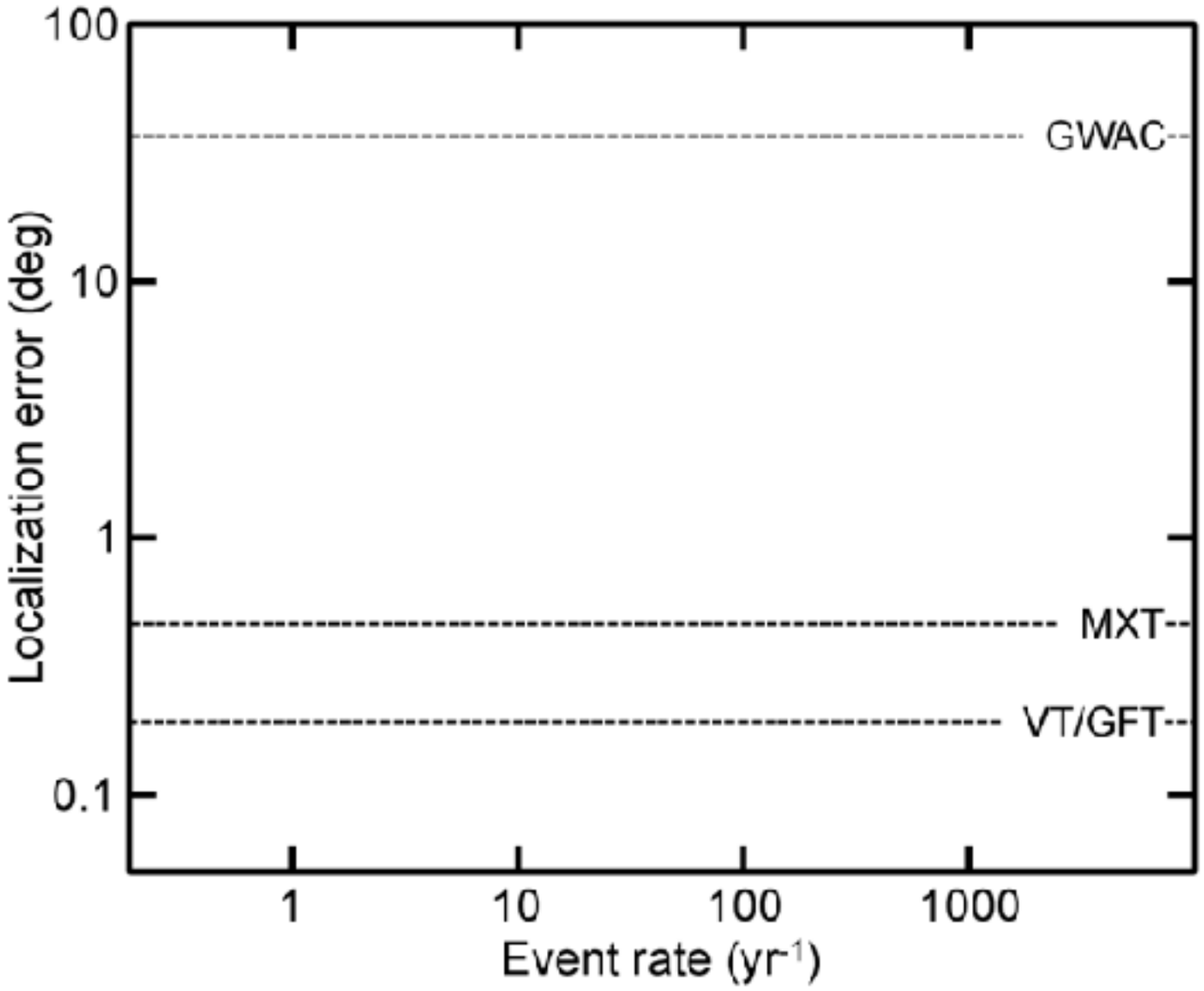




Let’s explain what it means and how things have changed since 2016.

TOO-MM

Axis : Event rate (or Alert rate) in yr^{-1} and localisation error in deg.



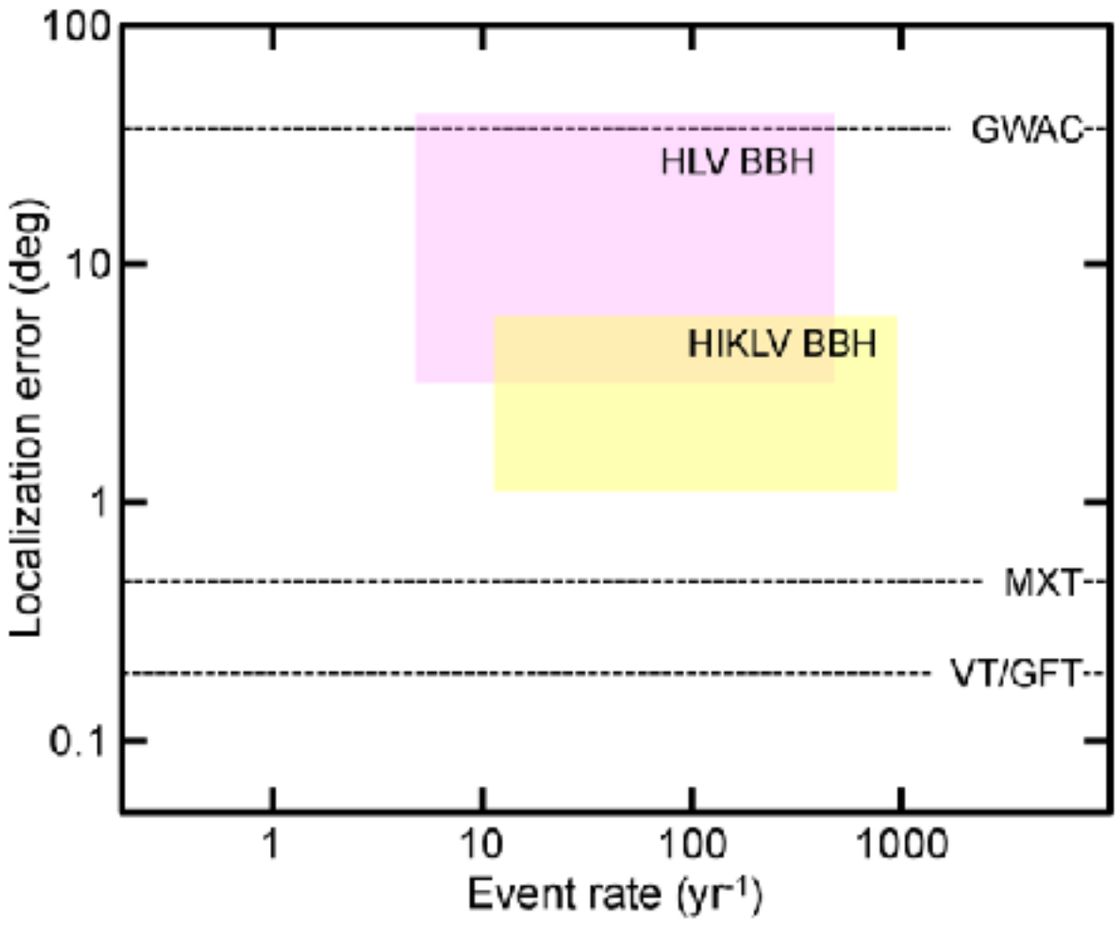
SVOM Instruments field of view coverage

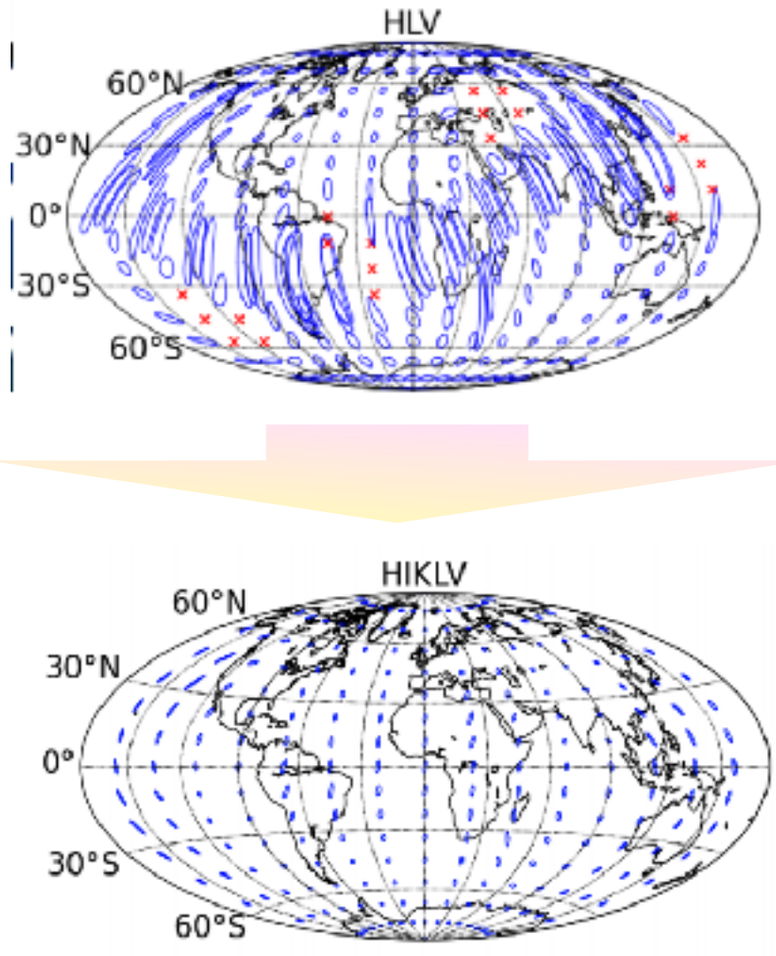
TOO-MM : GRAVITATIONAL WAVES

Binary Black Hole : BBH.

Probably no EM counterpart to be expected

Adding interferometers improve the localisation.



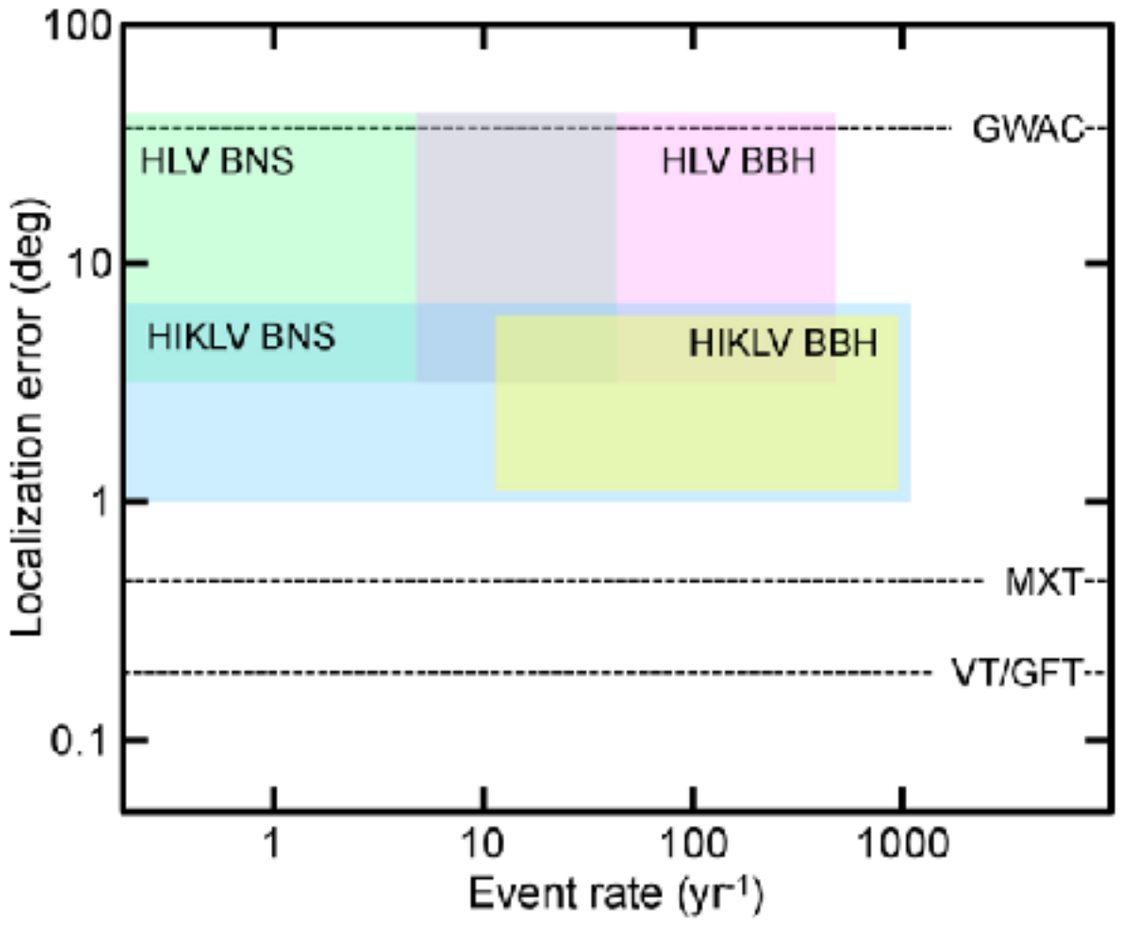


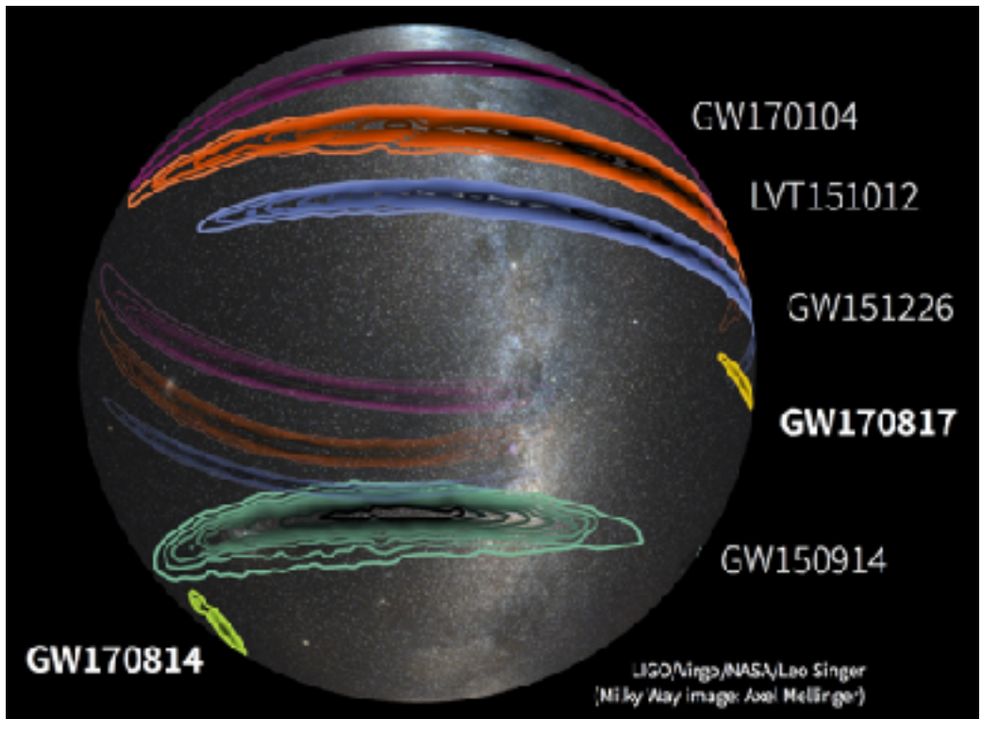
TOO-MM : GRAVITATIONAL WAVES

Concrete example showing the addition of Virgo to BBH detections (GW170814)

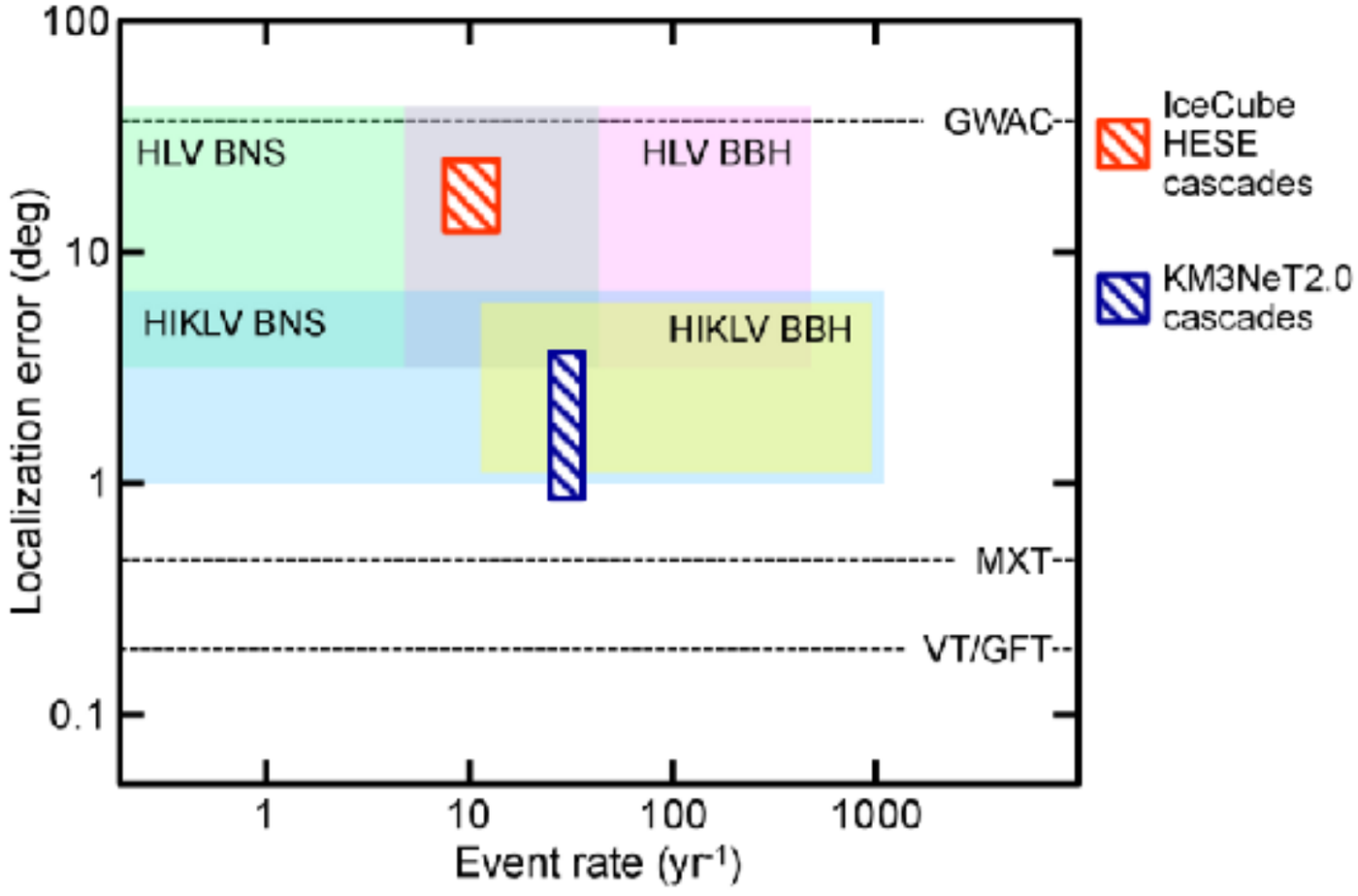
Binary Neutron Star : BNS. Most promising event.

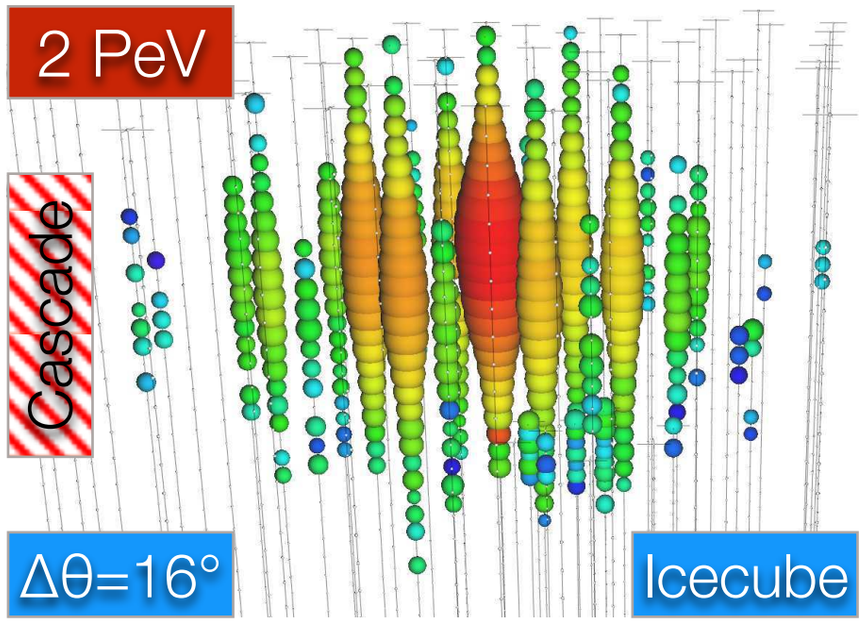
First BNS detected : GW170817.



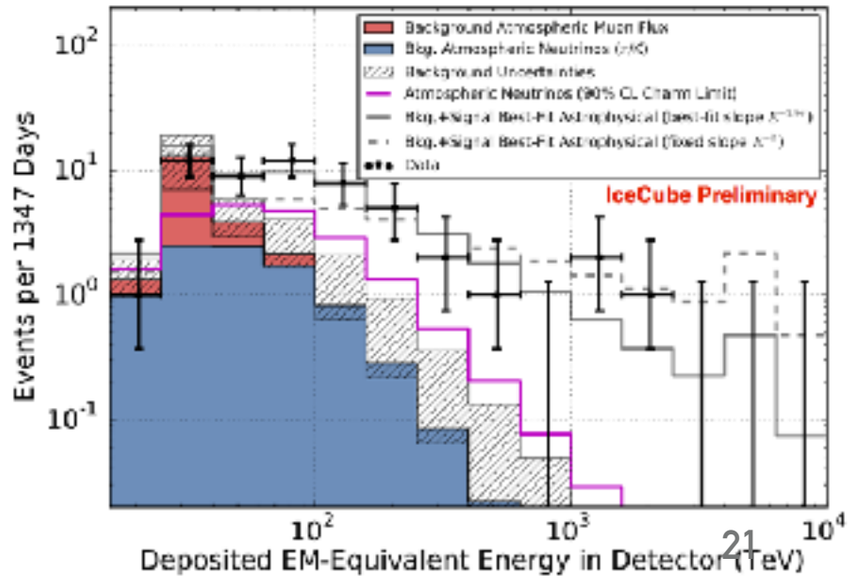


TOO-MM : NEUTRINOS





4-years IceCube (2010-2013). 53 HESE. E>60TeV.



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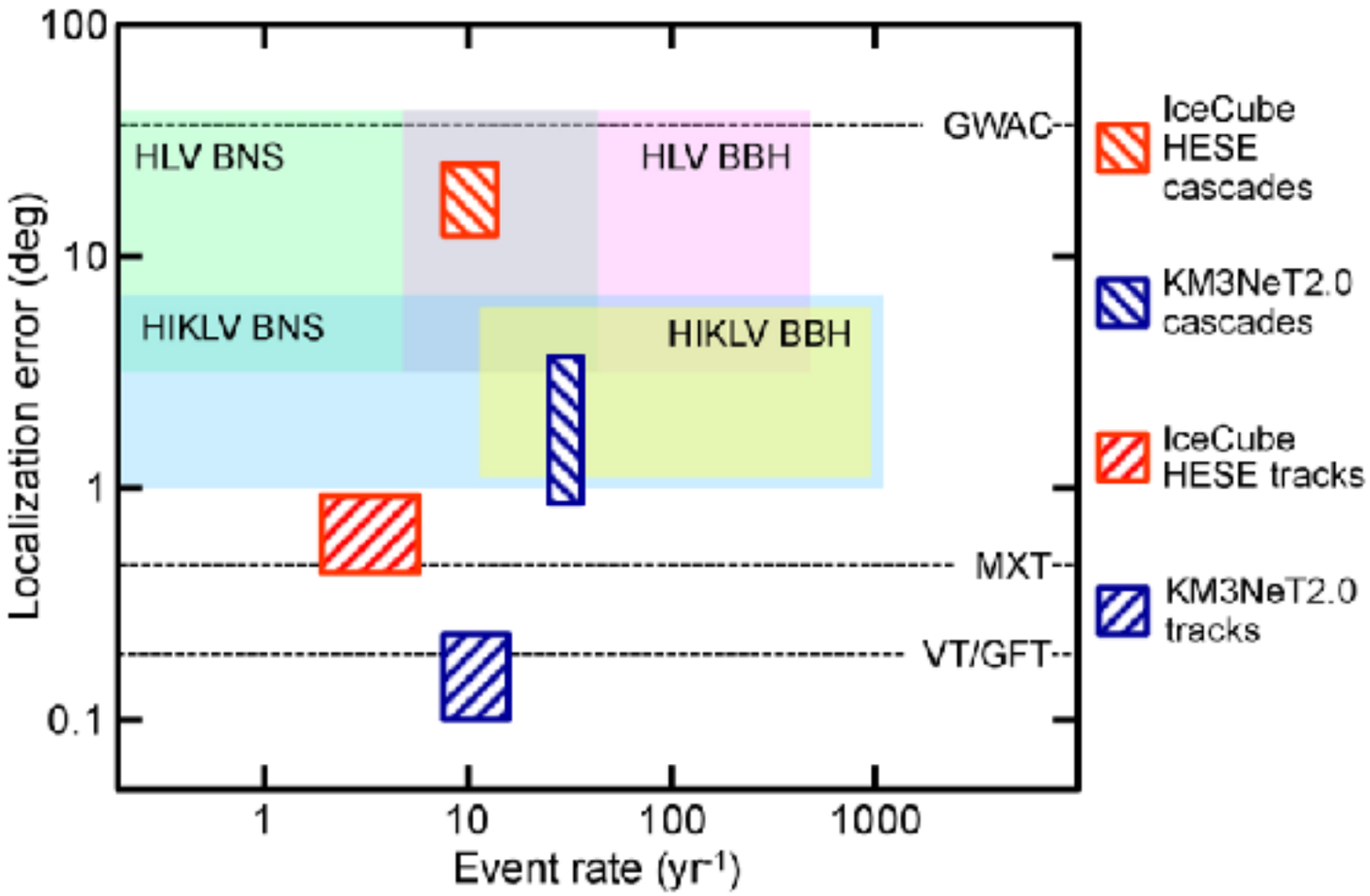

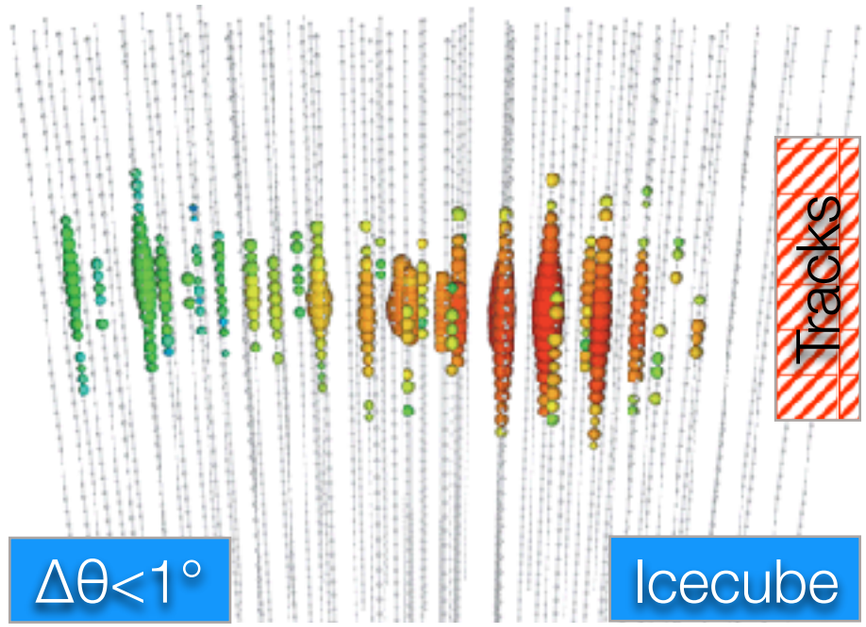

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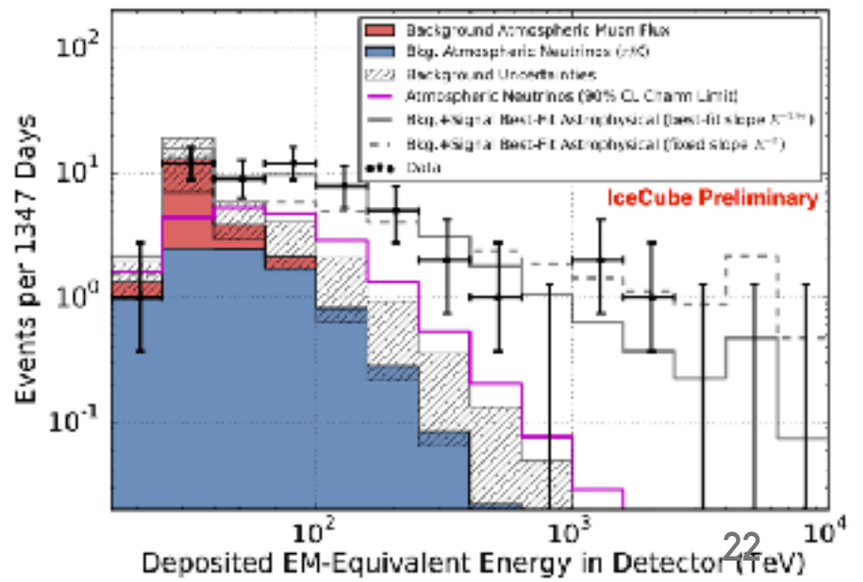
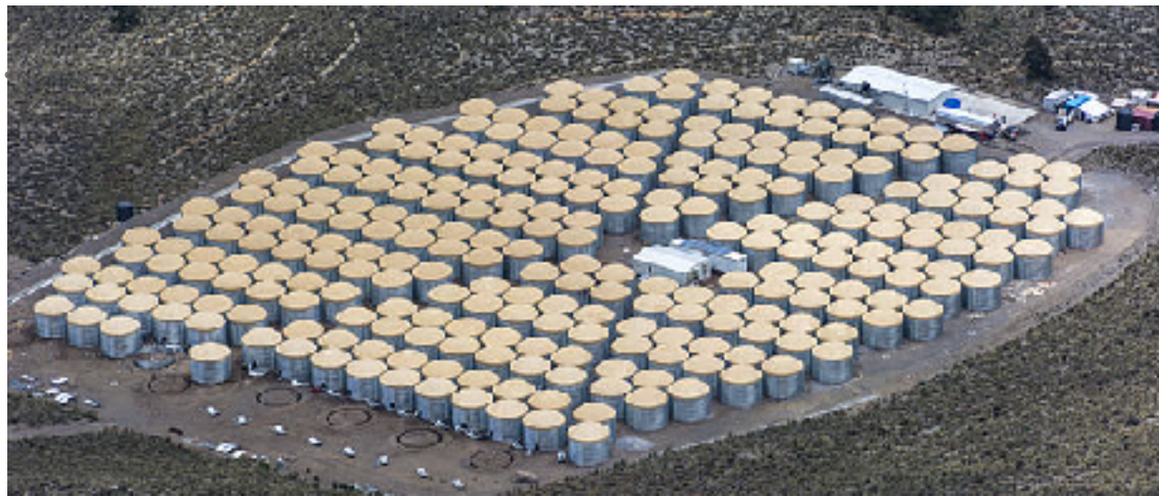
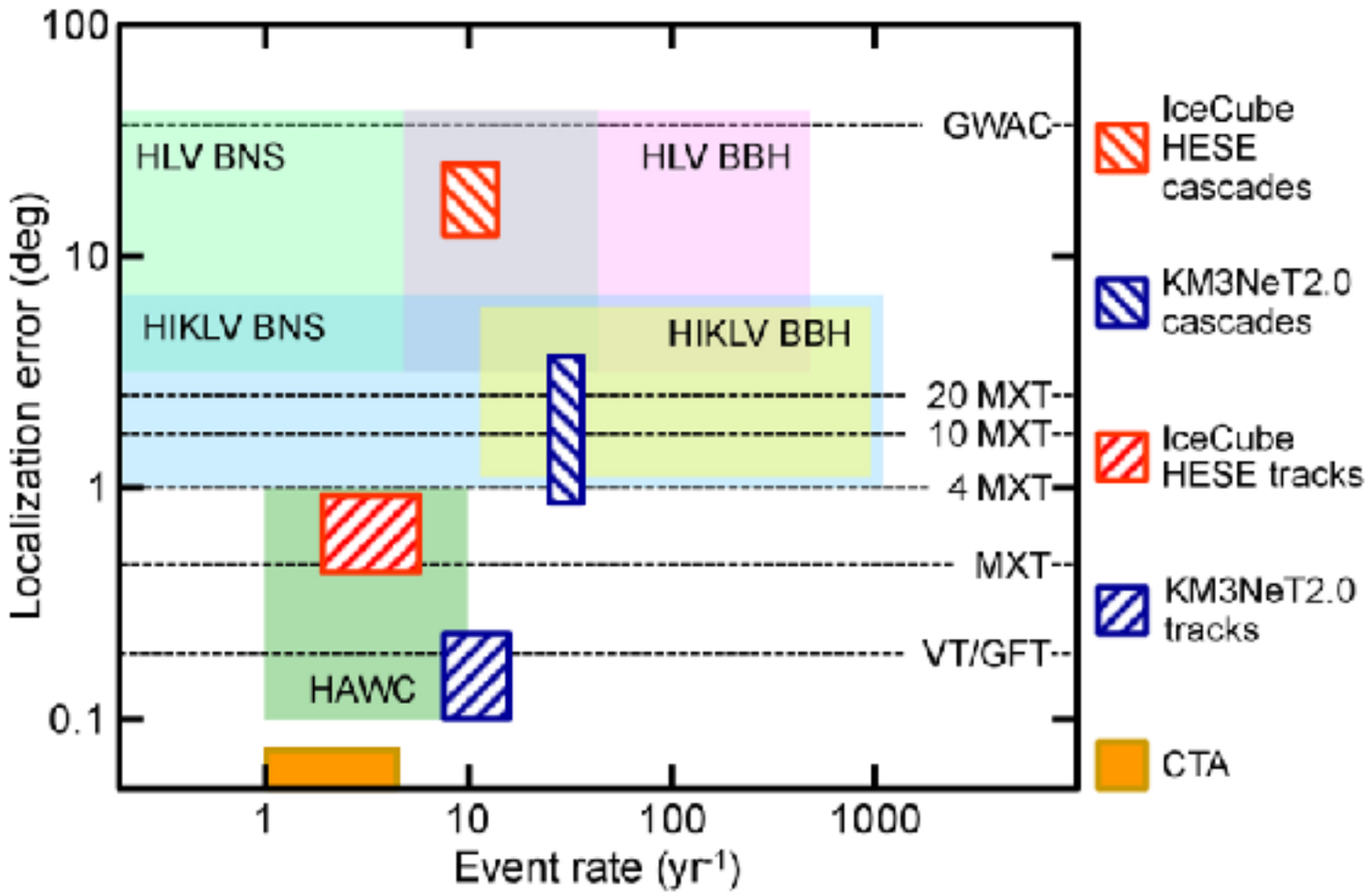
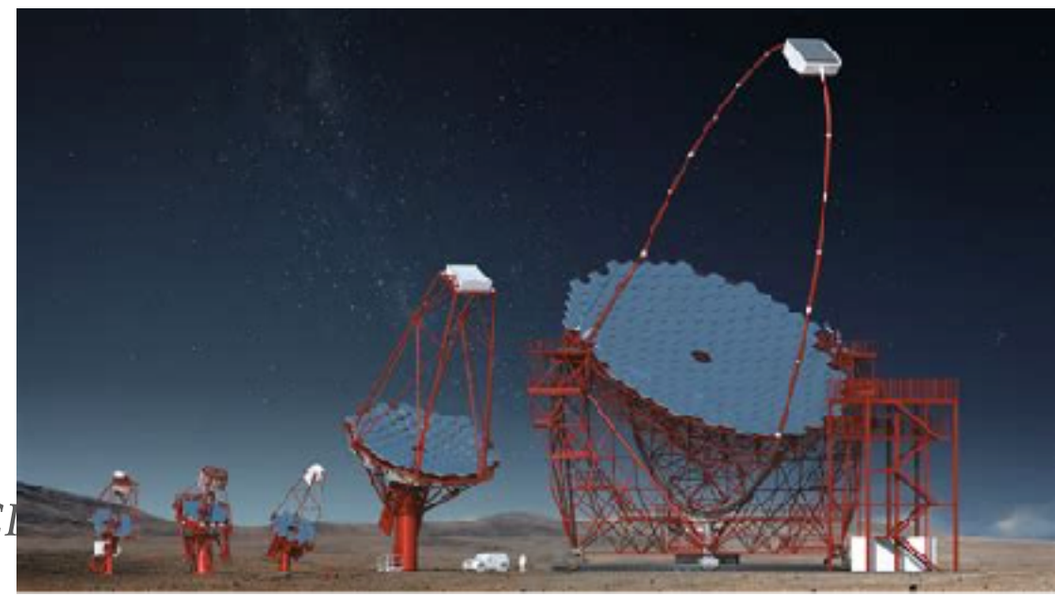


TOO-MM : HE GAMMAS...

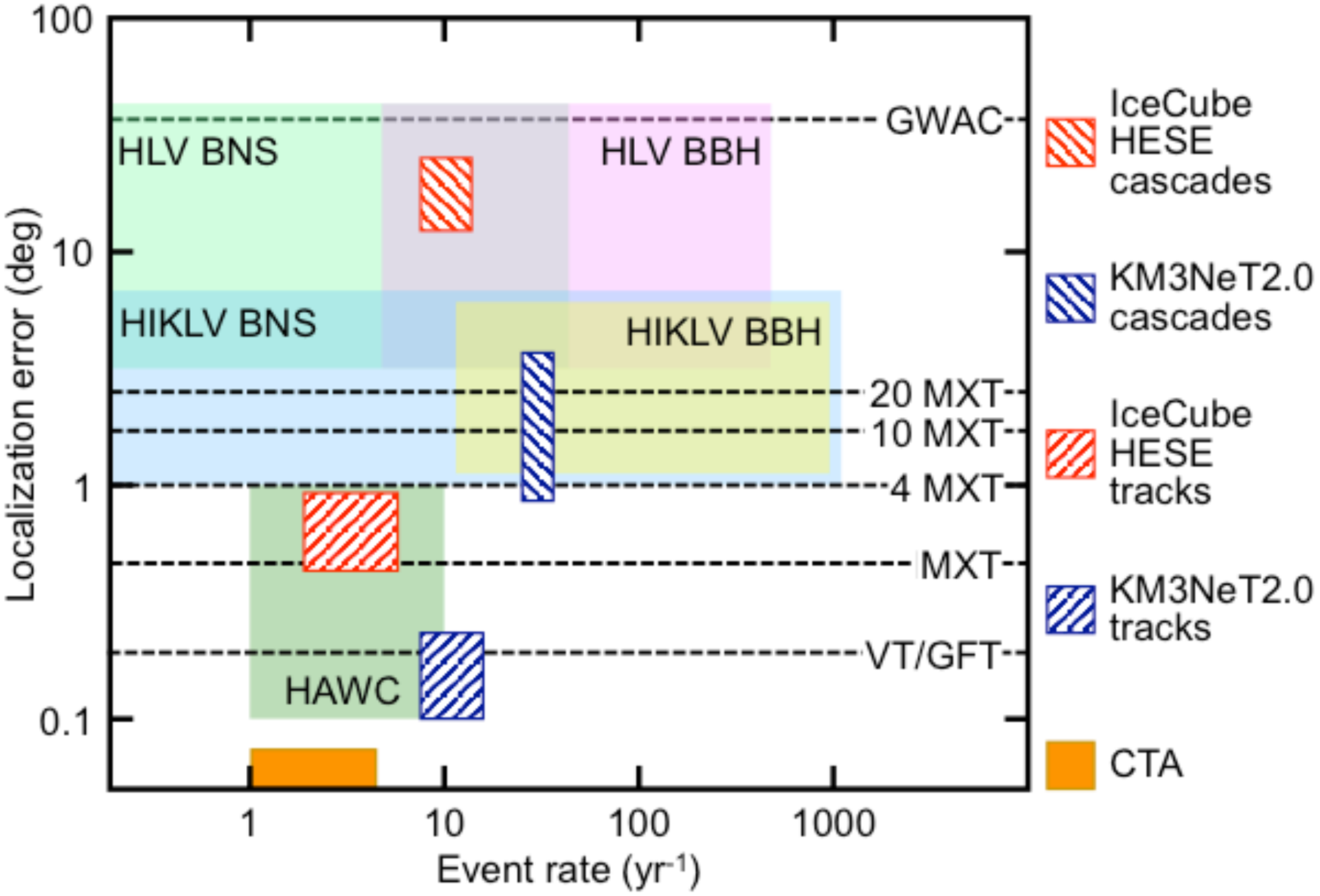






TOO-MM SUMMARY

Multi-messengers alerts

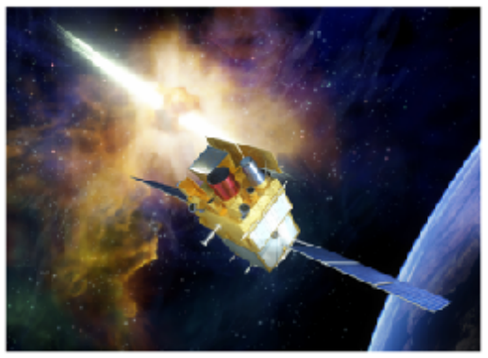


SVOM White Paper

The Deep and Transient Universe: New Challenges and Opportunities

Scientific prospects of the *SVOM* mission

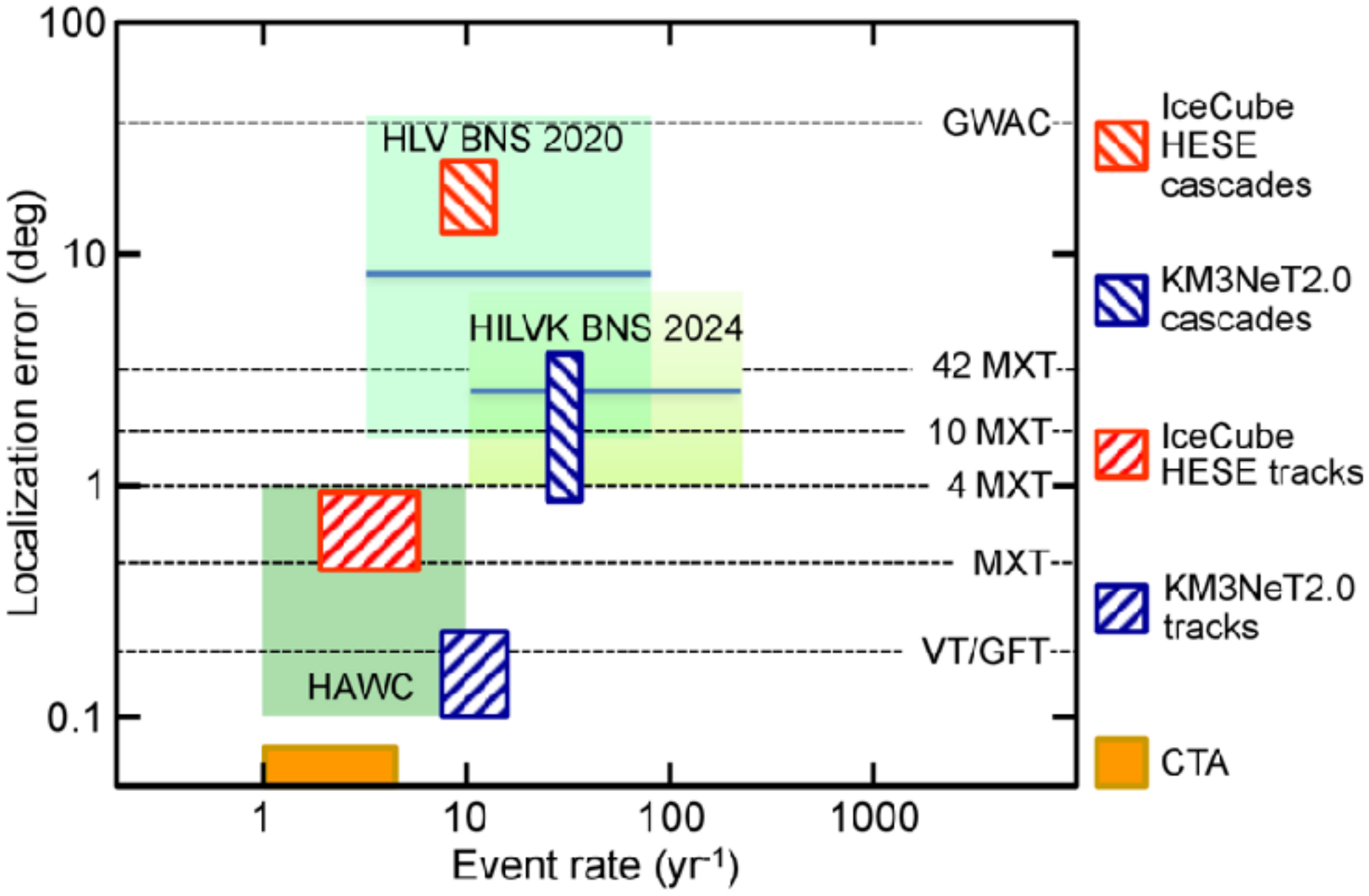
J. Wei, B. Cordier, et al.
(Version of 05-10-2016, for full list of contributors see overleaf)



Localization error are large : tiling is required

TOO-MM SUMMARY

Multi-messengers alerts



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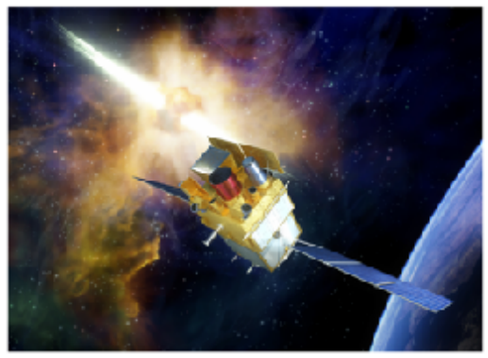
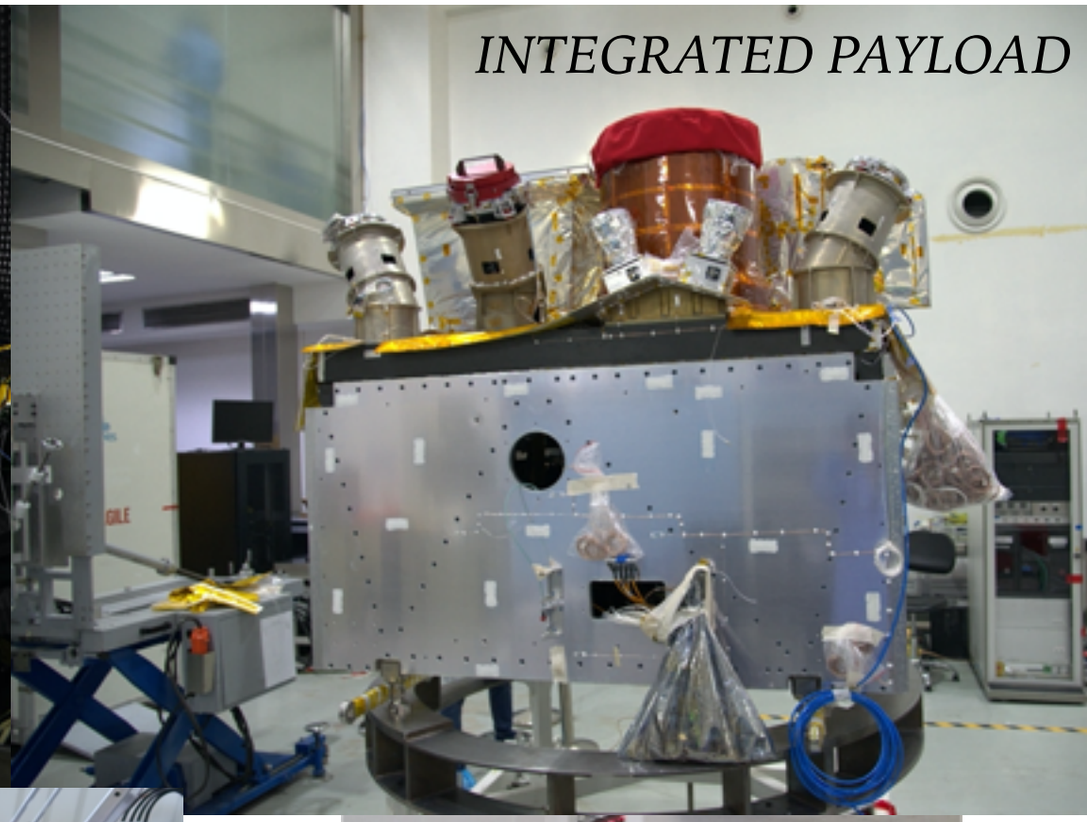


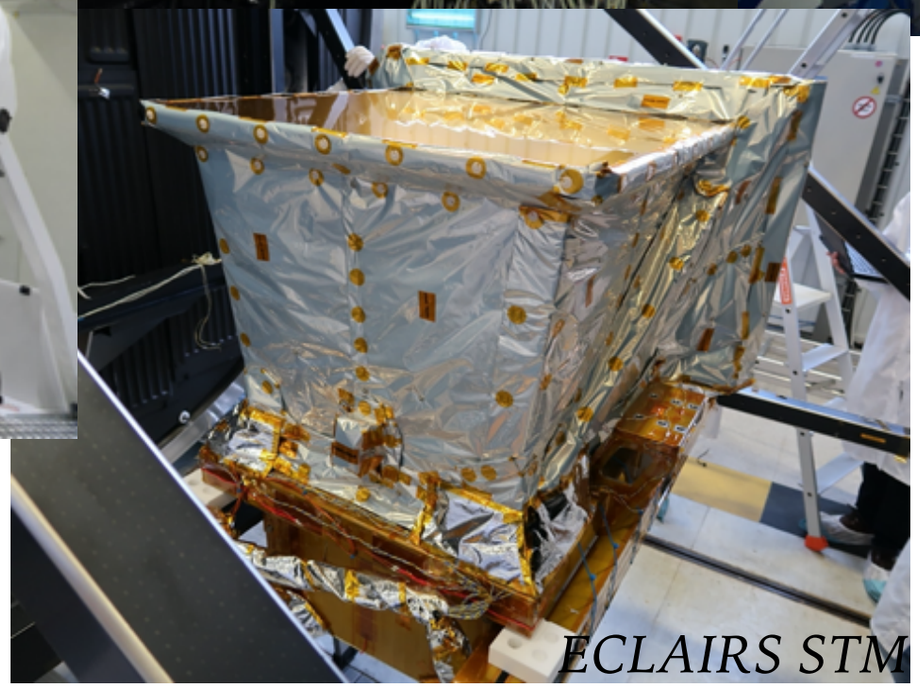
Localization error are large : tiling is required

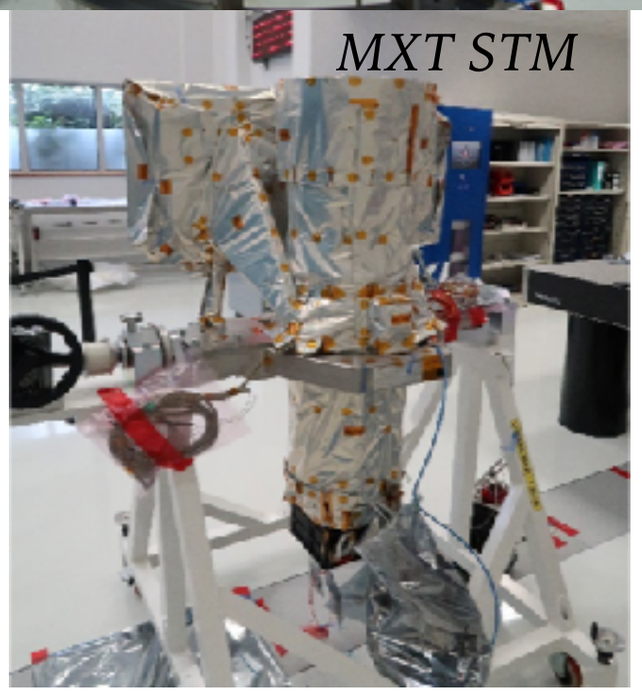
CONCLUSIONS

- SVOM has been designed to detect all types of GRBs, and in particular those with a soft spectrum (potentially high-redshift GRBs)
- SVOM is composed of a space and a dedicated ground segment and its observation strategy will be such that a high fraction of afterglows will be immediately visible from ground. The goal is to increase significantly (60-70%) the fraction of GRBs with measured redshift (currently about 1/3)
- SVOM alerts will be public and distributed through GCN and VOE
- SVOM will be open to the scientific community through regular calls for GO time (requires a SVOM co-I on the proposal) and ToO programmes
- The ToO implementation strategy will be focussed towards Multi-messenger astrophysics

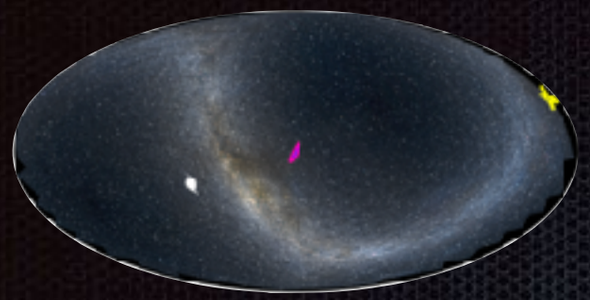
SVOM STM PICTURES (COURTESY SECM & CNES)







The ToO-MM programming loop



90% in 21.42 sq. deg.
D = 66±11 Mpc

MM Alert - T-MM

Verification of accessibility
Vs Sun/moon, and ToO MM
constraints (error box, etc…)

Alert Validation - T-Alert
PIs, ToO scientists

FSC
French Science Center

ToO-MM
Tiling Process
Providing updated scenarios…

MC ToO
MM Alert

S-band
selection

S-band pass selection process

Chinese Control Center

T-Uplink known after T-Alert+1h

ToO DB

Chinese Science Center

TC

TC plan
Uploading

CCC

1h

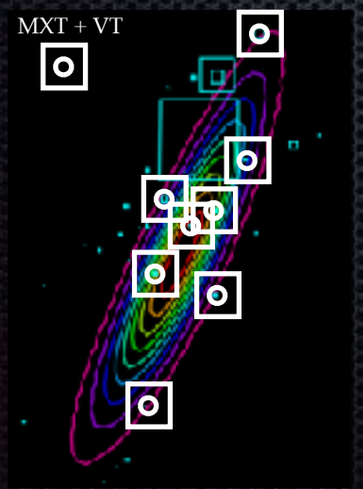
Start at T-Uplink - 5h30

Tiling : last
scenario
implementation

WorkPlan
Elaboration
1h30

OCG
30 min

TC Plan
Generation
Process
2h30

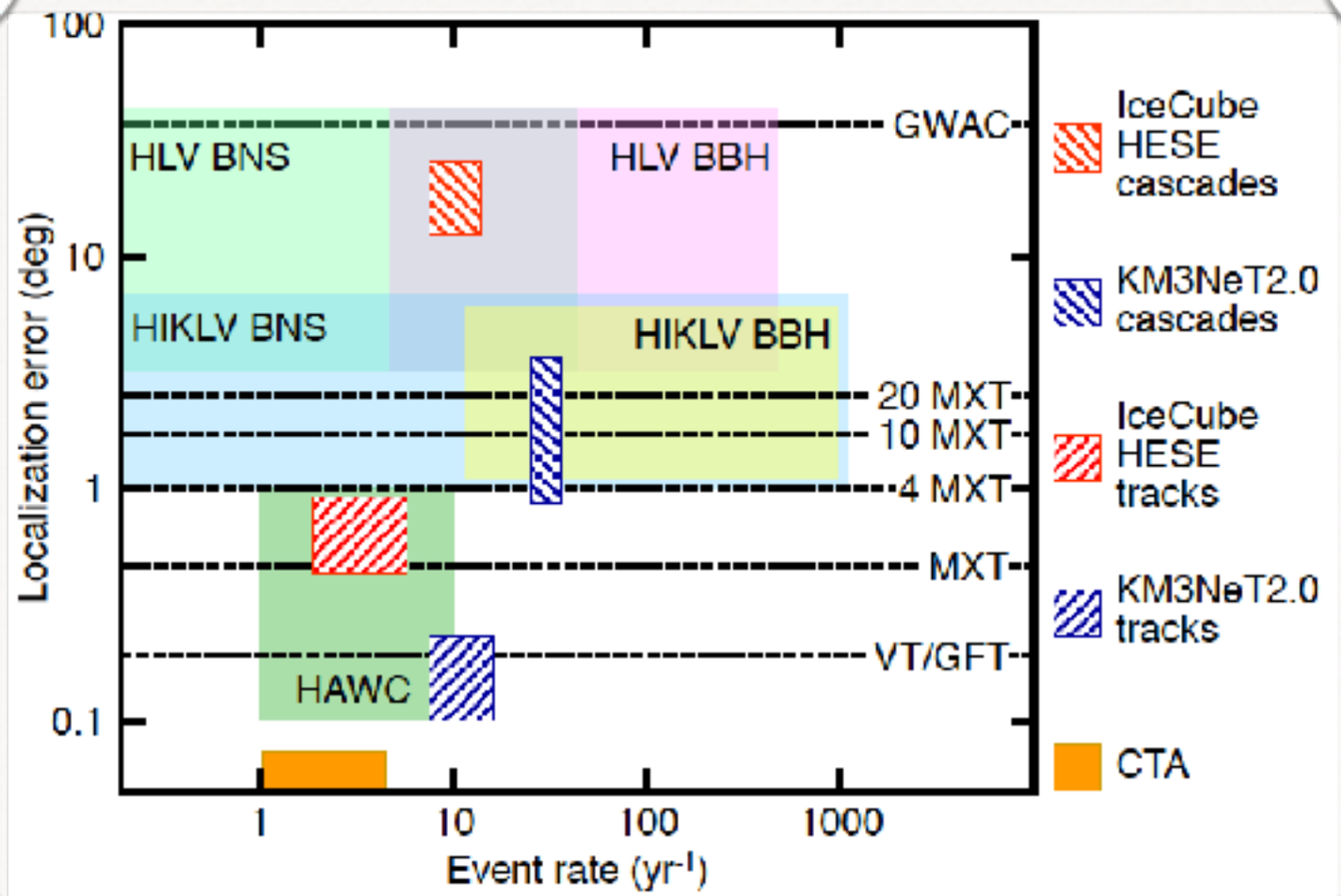


Mission Center computes the absolute times of observing slots for each tile of the sequence from scenario elaborated at FSC and available at CSC at T-Uplink– 5h30 with the following constraints :

- Orbit, Earth occultations & SAA crossings prediction
- Tiles sequencing criteria (e g, priorities assigned, likelihood, X-band visi)

BACKUP

MULTI-MESSENGER TARGET OF OPPORTUNITY

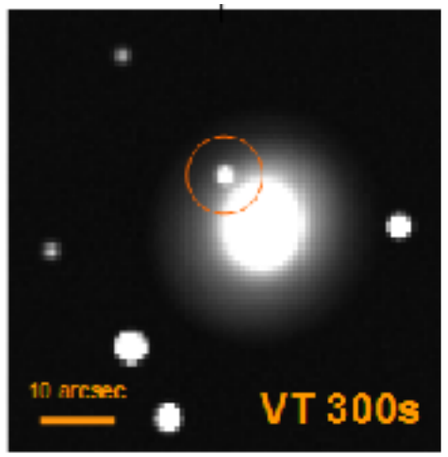


- MM -> Large Error Boxes
- Tiling With MXT will be performed (less sensitive than XRT but with a larger FOV of about 1 sq deg); autonomous on board source detection
- Galaxy Targeting with VT for nearby alerts will also be implemented

ToO-MM characteristics

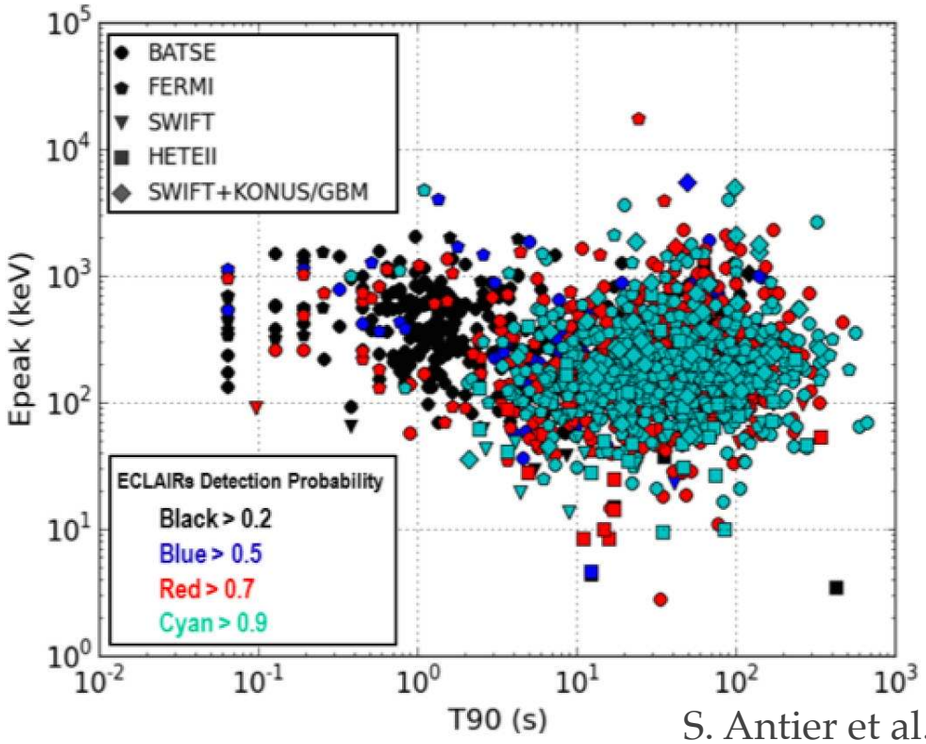
ToO	Approval	From accep-tance/ trigger	GRB inter-ruption	Frequency	Duration	Tiling process	Science product availabl-ity	VHF Canal	VHF data
ToO-MM	Automatic +PI	<12h	No	MAX 1/month	1-14 orbits	Yes, 3 tiles/orbit	VHF<1h BX 24h	Yes	MXT pho:on-list

GW 170817 Kilonova VT simulation

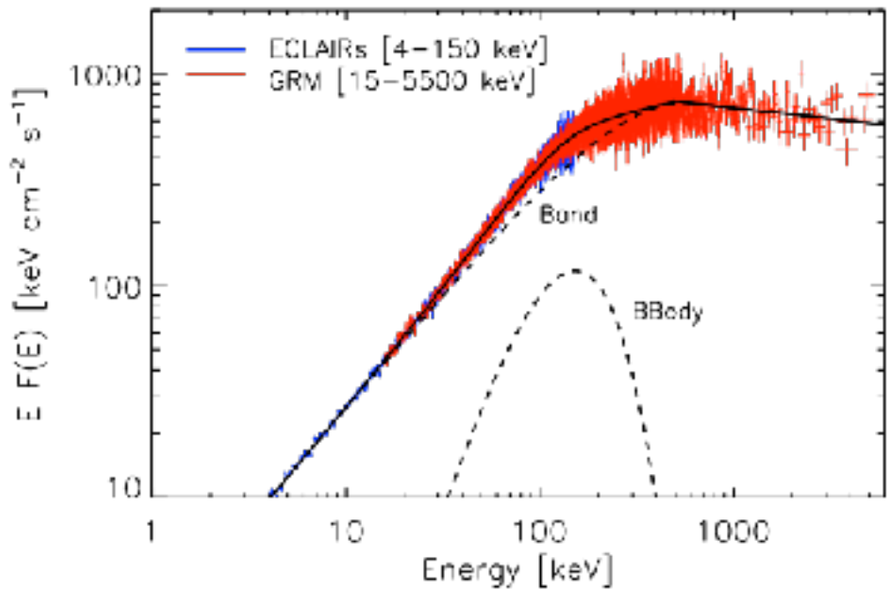


Same source at 400 Mpc -> M_V~22

CORE PROGRAMME



S. Antier et al.

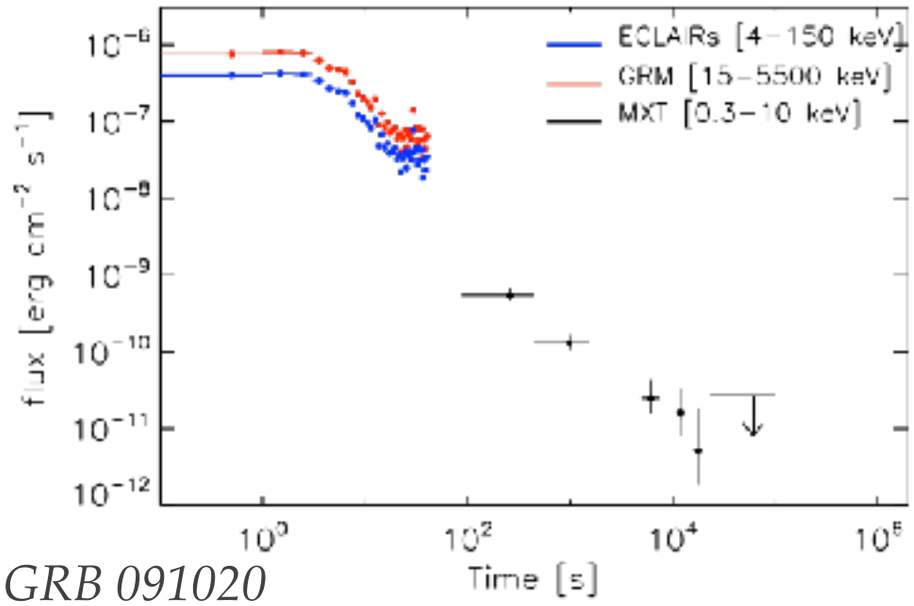


M.G. Bernardini et al.

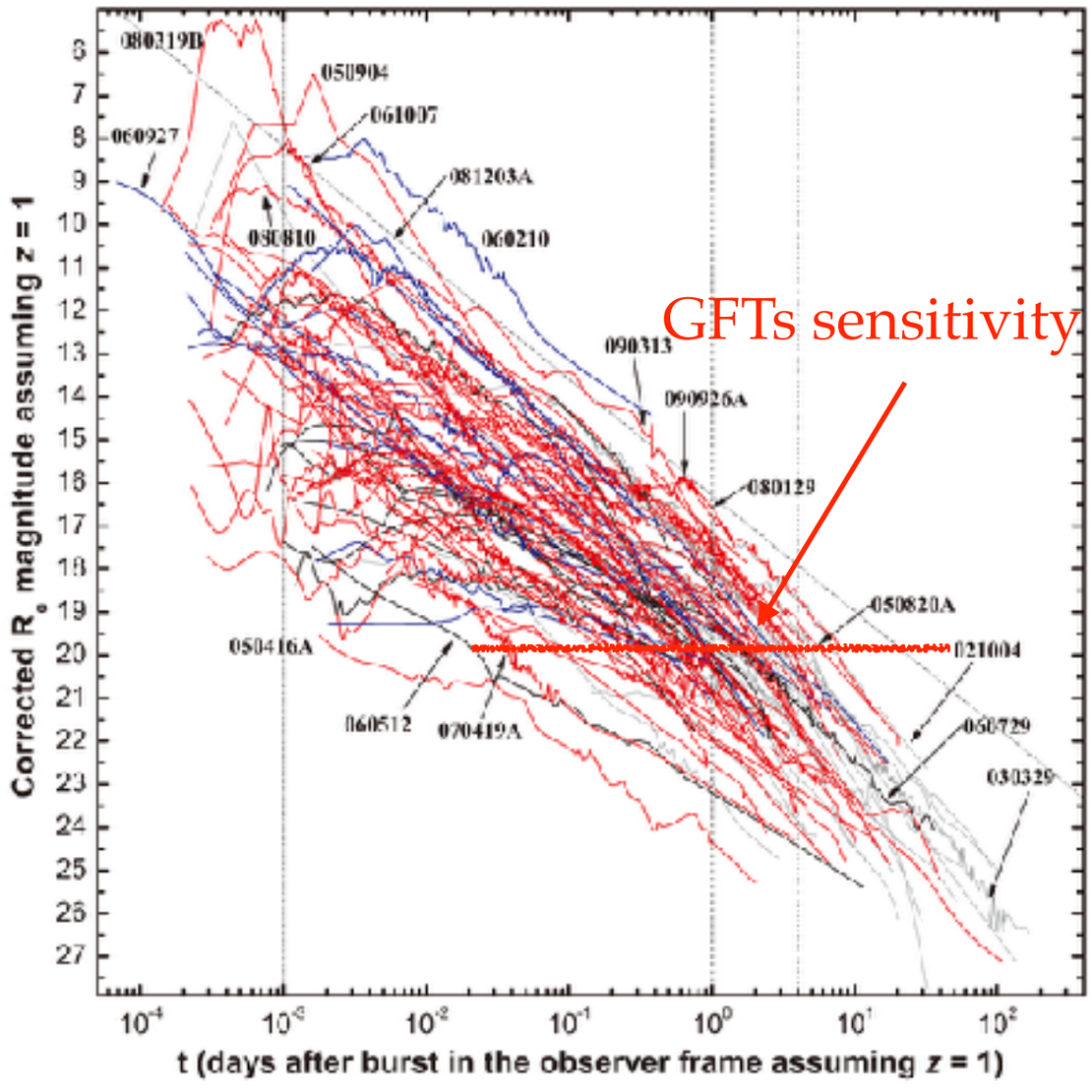
SVOM will be sensitive to all classes of GRBs

SVOM will provide ad accurate spectral description of the prompt phase, including optical emission through GWACs

CORE PROGRAMME



GRB 091020



SVOM will provide complete samples of early afterglow data + photometric redshift

SVOM white paper : arXiv:1610.0689

SVOM Website: http://www.svom.fr/en/