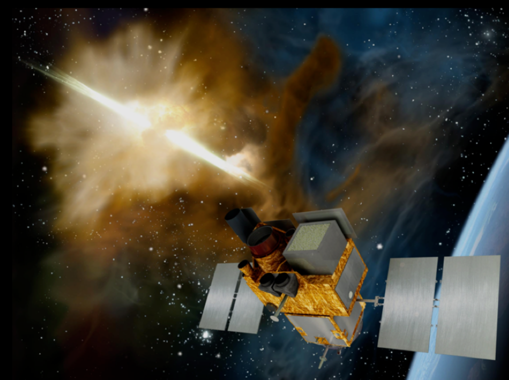
THE SVOM GRB SAMPLE

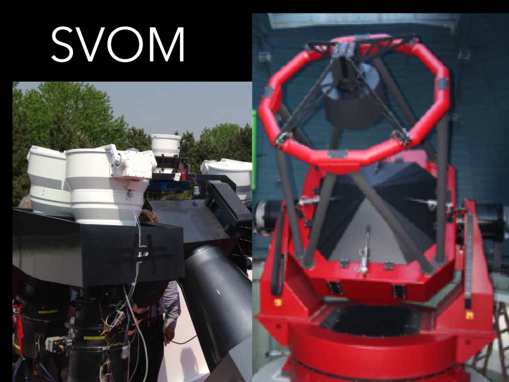
MULTI-MESSENGER ASTRONOMY WITH SVOM

Frédéric Daigne (Institut d'Astrophysique de Paris)
on behalf of the SVOM collaboration

Borrow 5 minutes to B. Zhang



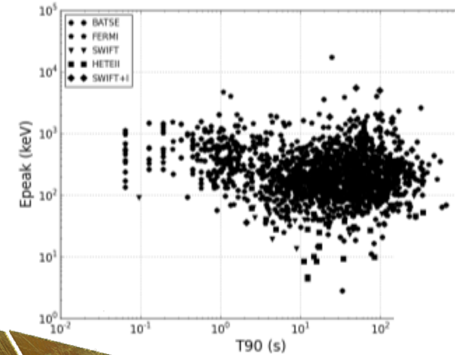
SVOM



SVOM CORE PROGRAM: GRB STUDIES

THE EXPECTED SVOM GRB SAMPLE

GRB TRIGGER

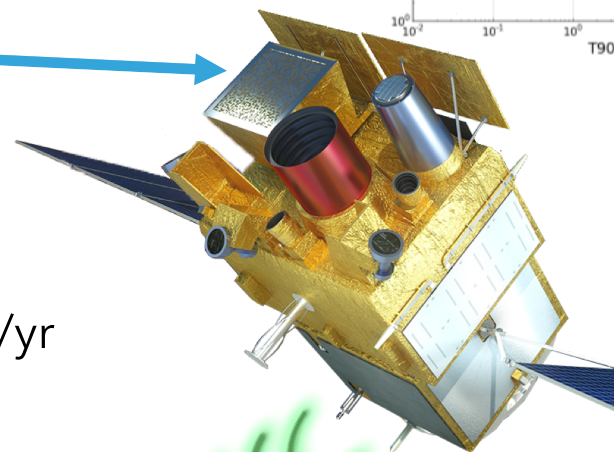


Original catalogs

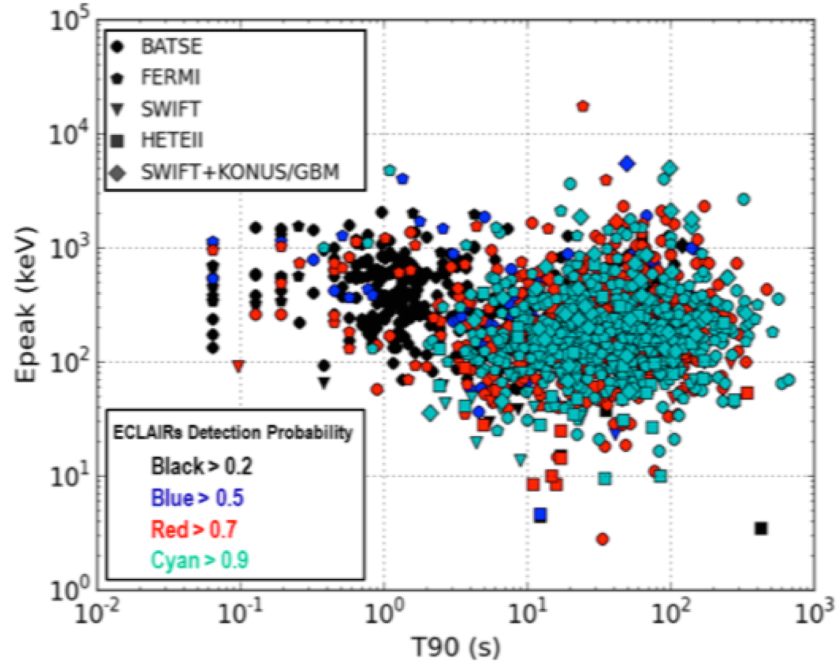
Simulation in ECLAIRs

ECLAIRS

(4 -150 keV)
~ 2 sr
Loc. < 12′



42-80 GRBs/yr



ECLAIRs is sensitive to all classes of GRBs

Classical long GRBs

Soft GRBs (XRR, XRF)

Short GRBs
(but with a moderate efficiency)

Detection probability by ECLAIRs
(simulations by S. Antier)
(Wei, Cordier et al. « Scientific prospects of the SVOM mission », arXiv:1610.06892)

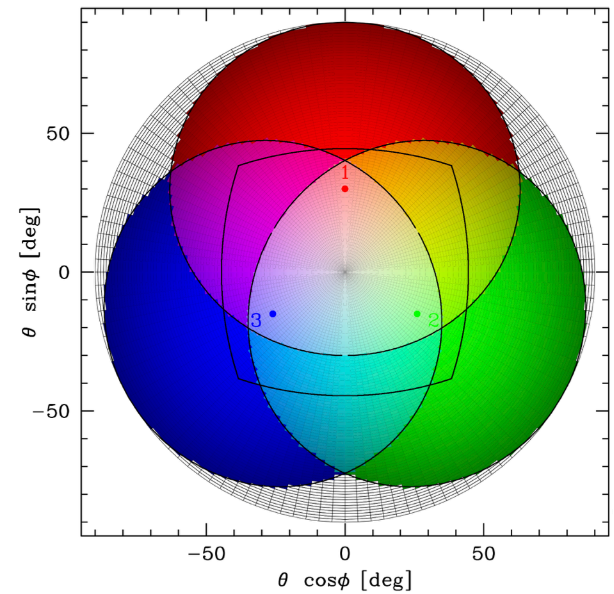
GRB TRIGGER

GRM

(30 keV-5 MeV) ~ 5.6 sr Loc.: 5-10° (3 GRDs)

~90 GRBs/yr

GRM field of view:



GRM has a larger field of view than ECLAIRs

ECLAIRs sensitivity to short GRBs can be improved by combining ECLAIRs+GRM

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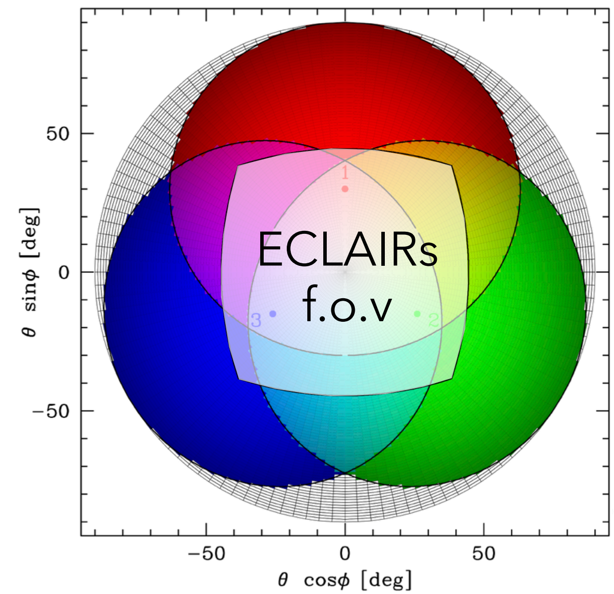

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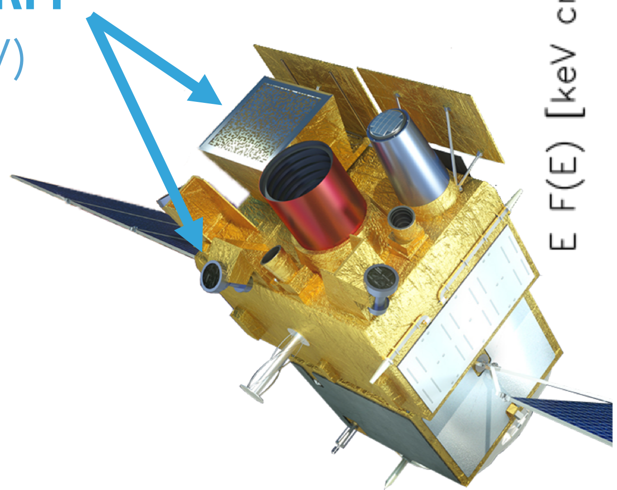
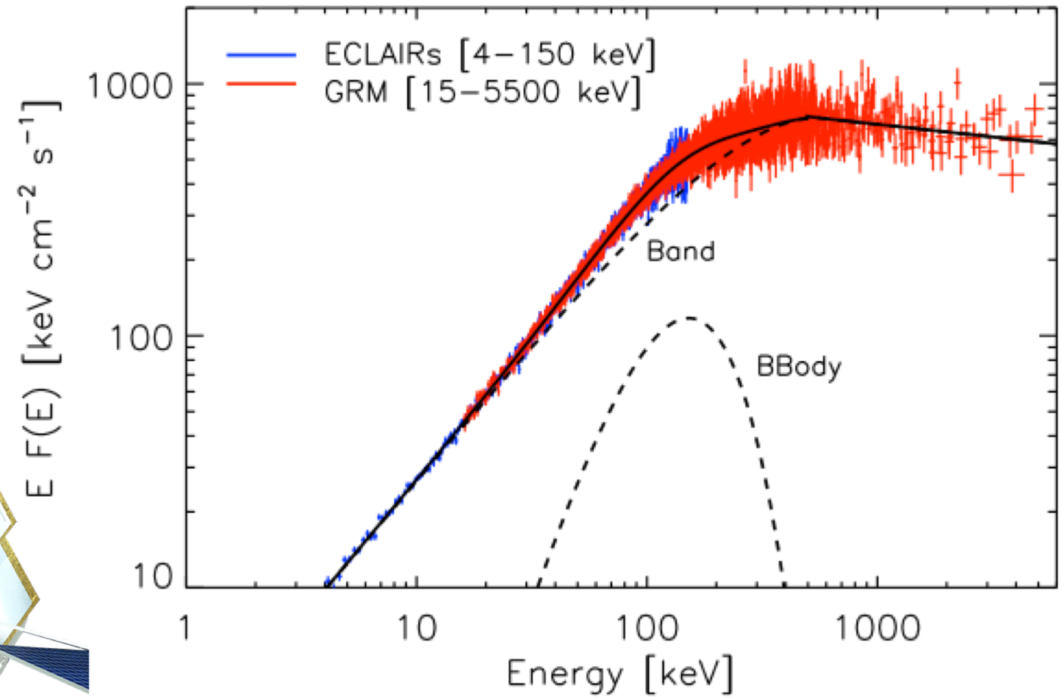
PROMPT EMISSION

ECLAIRS+GRM

(4 keV-5 MeV)





Multi-component spectrum of the Fermi burst GRB 100724B simulated in ECLAIRs+GRM. (Bernardini et al. 2017)

GWAC

2x5000 deg^2

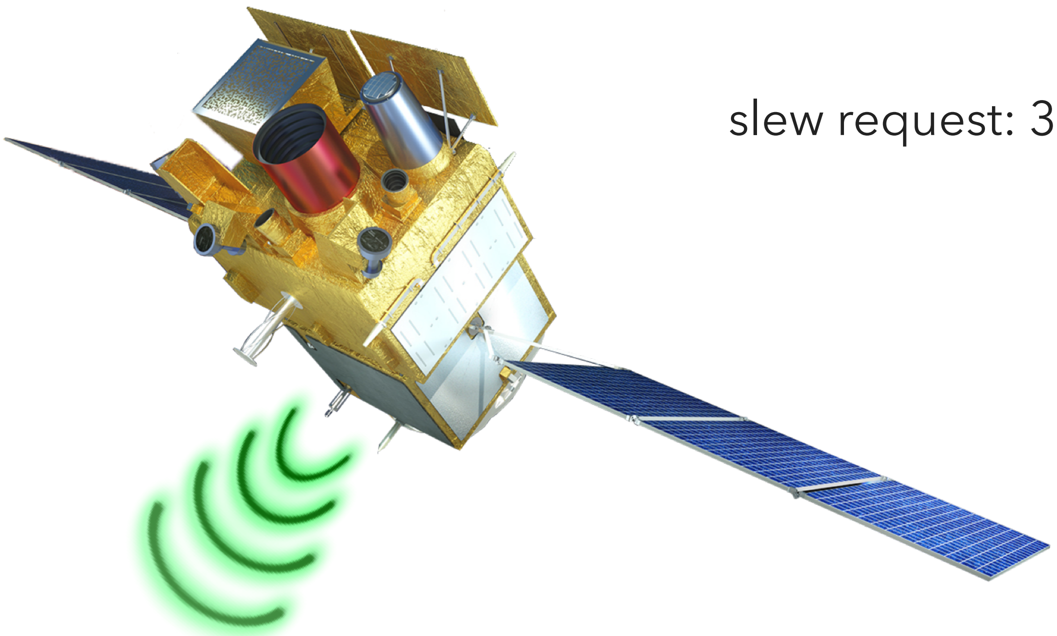
m_{lim} ~ 16-17

prompt visible emission in ~16% of cases

ECLAIRs+GRM can measure the prompt spectrum over 3 decades in energy

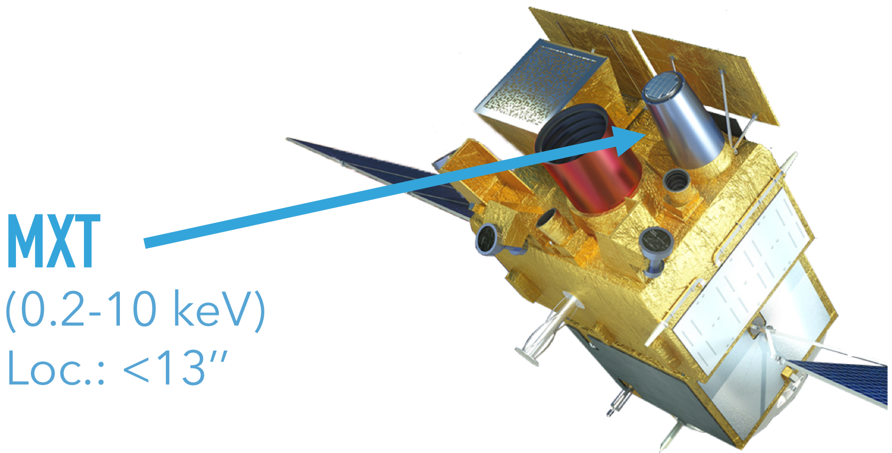
GWAC will add a constraint on the associated prompt optical emission in a good fraction of cases.

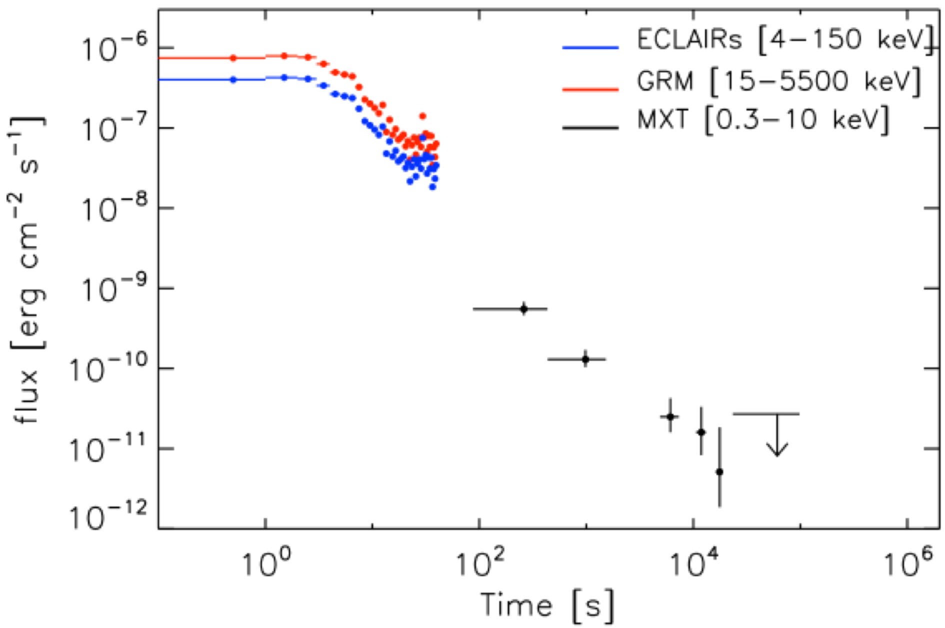
SLEW REQUEST



slew request: 36-72 GRB/yr

AFTERGLOW





The X-ray afterglow of the Swift burst GRB 091020 simulated in MXT. (Wei, Cordier et al. « Scientific prospects of the SVOM mission », arXiv:1610.06892)

MXT can detect and localize the X-ray afterglow in >90% of GRBs after a slew.

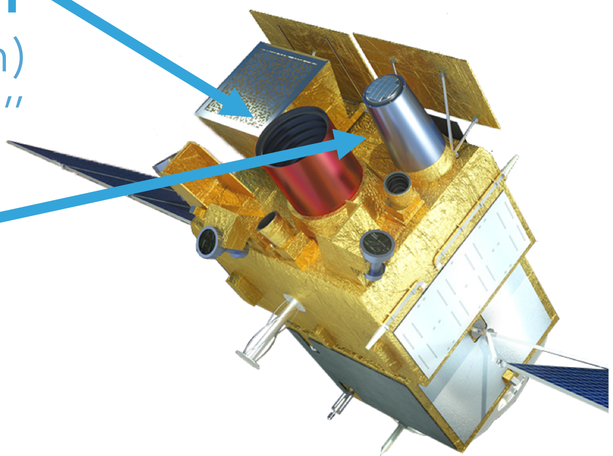
AFTERGLOW & DISTANCE

VT, C-GFT and F-GFT will detect, localize and characterize the V-NIR afterglows (lightcurve+photo-z).

Early observation by large telescopes are favored by SVOM's pointing strategy.

Redshift measurement is expected in ~2/3 of cases

VT
(400-1000 nm)
Loc.: <1″



MXT
(0.2-10 keV)
Loc.: <13″

GWAC
2x4000 deg^2
m_{lim} ~ 16-17

C-GFT
1.2 m
400-950 nm

F-GFT
1.3 m
400-1700 nm
multi-band

(Very) Large telescopes

A GRB SAMPLE WITH A COMPLETE DESCRIPTION

A unique sample of 30-40 GRB/yr with

- **prompt emission over 3 decades (+ optical flux/limit: 16%)**
- **X-ray and V/NIR afterglow**
- **redshift**

	Swift	Fermi	SVOM
Prompt	Poor	Excellent 8 keV -100 GeV	**Very Good 4 keV - 5 MeV**
Afterglow	Excellent	> 100 MeV for LAT GRBs	**Excellent**
Redshift	~1/3	Low fraction	**~2/3**

Physical mechanisms at work in GRBs

Nature of GRB progenitors and central engines

Acceleration & composition of the relativistic ejecta

see B. Zhang's presentation

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

Low-luminosity GRBs / X-ray rich GRBs / X-ray Flashes and their afterglow

GRB/SN connection

Short GRBs and the merger model

GW association

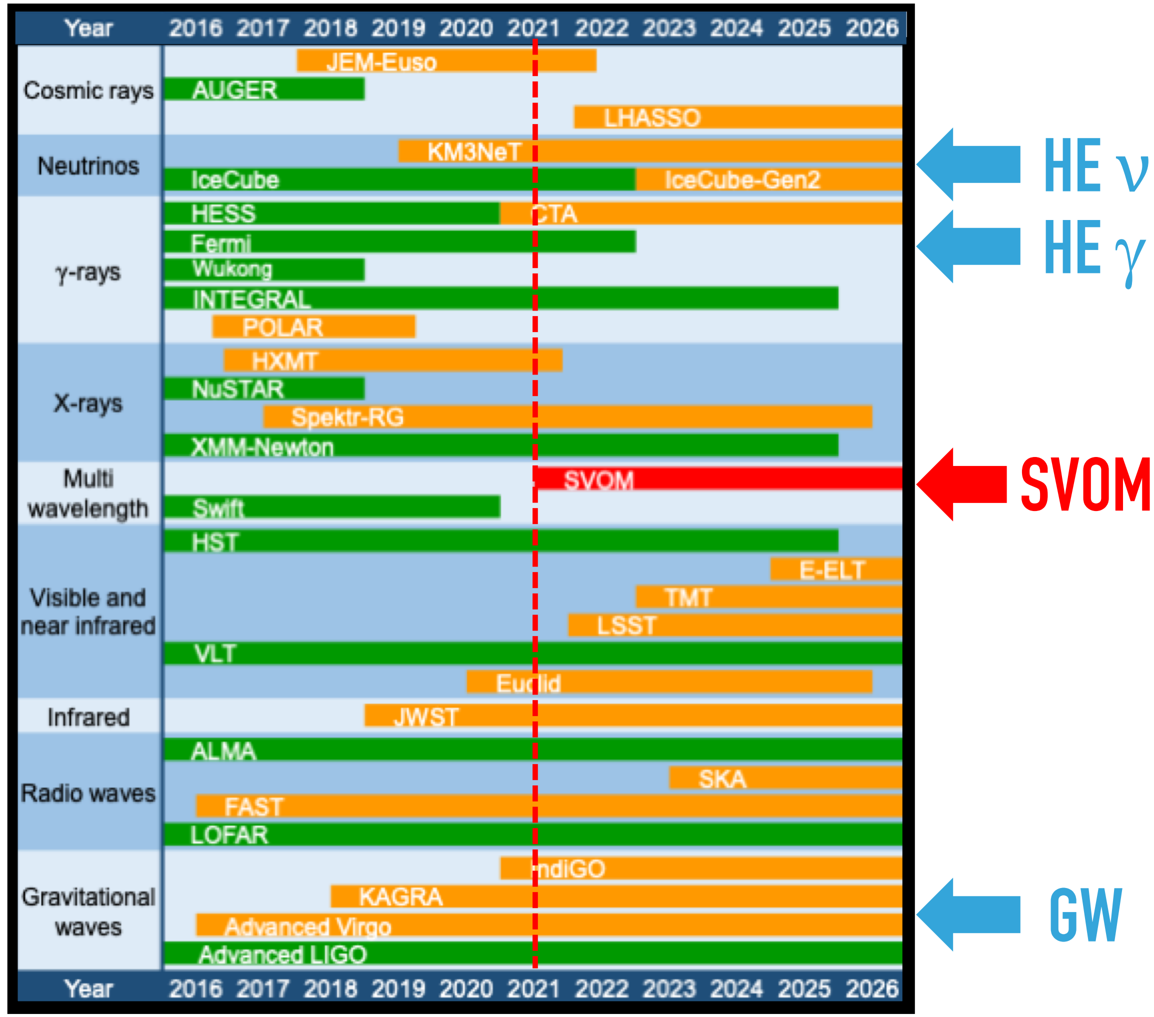
2022+

SVOM IN THE MULTI-MESSENGER ASTRONOMY CONTEXT

GW AND NEUTRINO DETECTORS IN 2022+

When SVOM will be operating, it is expected that:

- LIGO/Virgo will have reached their design sensitivity
- new GW detectors will have joined the network (KAGRA, LI)
- new HE neutrino detectors with larger detection volumes will be in operation (KM3NeT, IceCube-Gen2)
- Etc.



ELECTROMAGNETIC COUNTERPARTS?

GW

BBH: uncertain, probably very weak if any

BNS: kilonova, sGRB, afterglow (as illustrated by GW170817)
NSBH: similar to BNS counterparts?

Other?

Neutrinos

Many possible sources, including GRBs (P. Meszaros & K. Murase's talks)

Most of the candidates are transient and emit gamma-rays (neutrino production by pγ)

Among the various classes of GRBs, low-luminosity bursts appear as promising candidates. These bursts are usually softer.

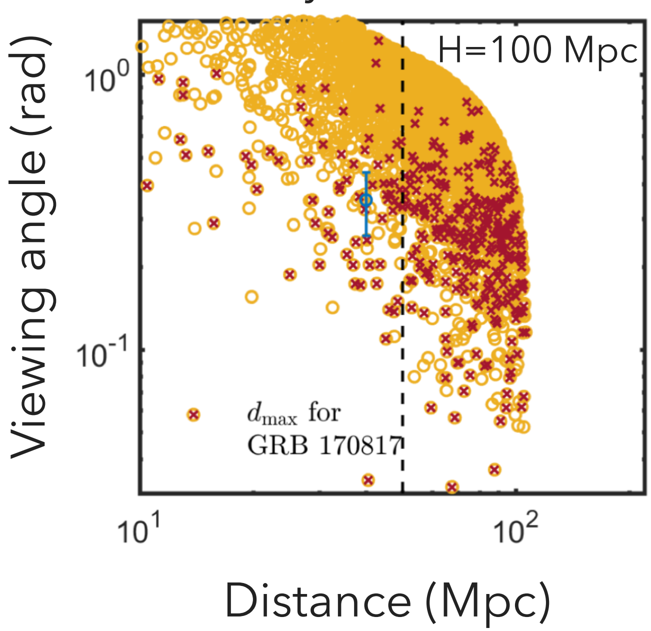
THE BNS/NSBH MERGER–SHORT GRB CONNECTION

Present: GW detectors probe the local distribution of mergers (low D, large θ_v)
sGRB/GW associations should remain rare

γ-ray satellites probe sGRBs at cosmological distance (large D, low θ_v)

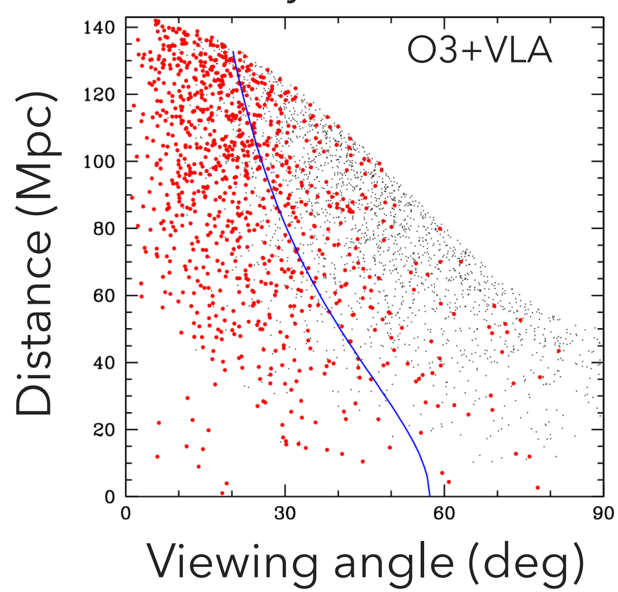
GW interferometers’ design sensitivity: the two populations should reconnect

GW only vs GW+GRB



Beniamini et al. 2019
astro-ph/1808.04831

GW only vs GW+radio



Duque, Daigne & Mochkovitch 2019
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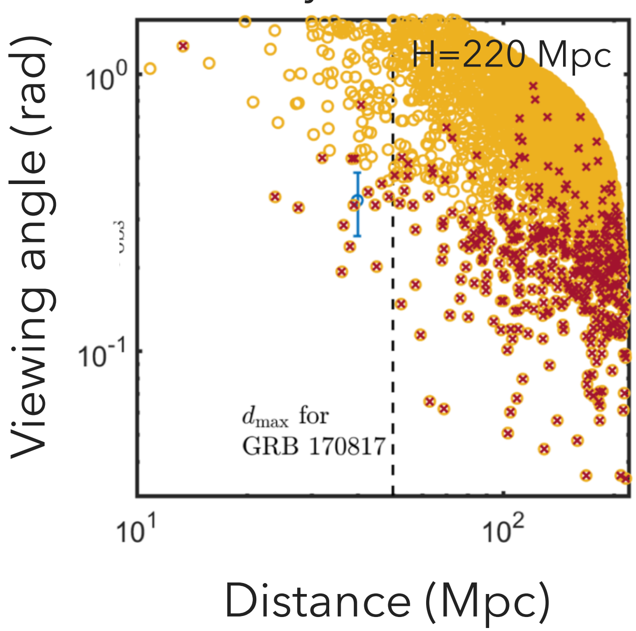

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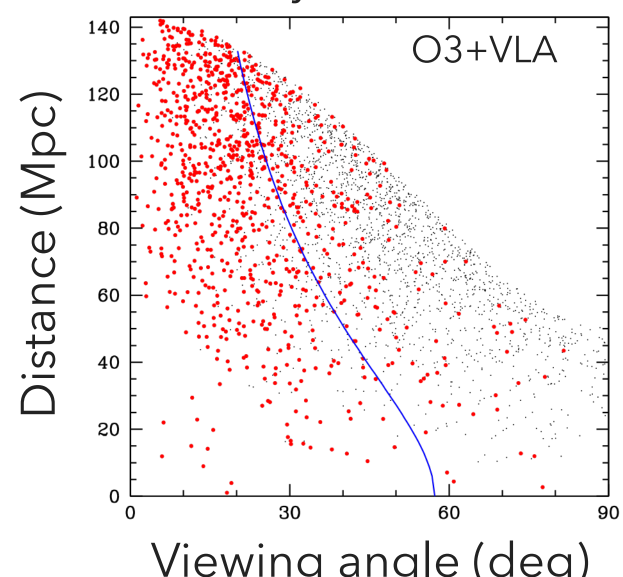
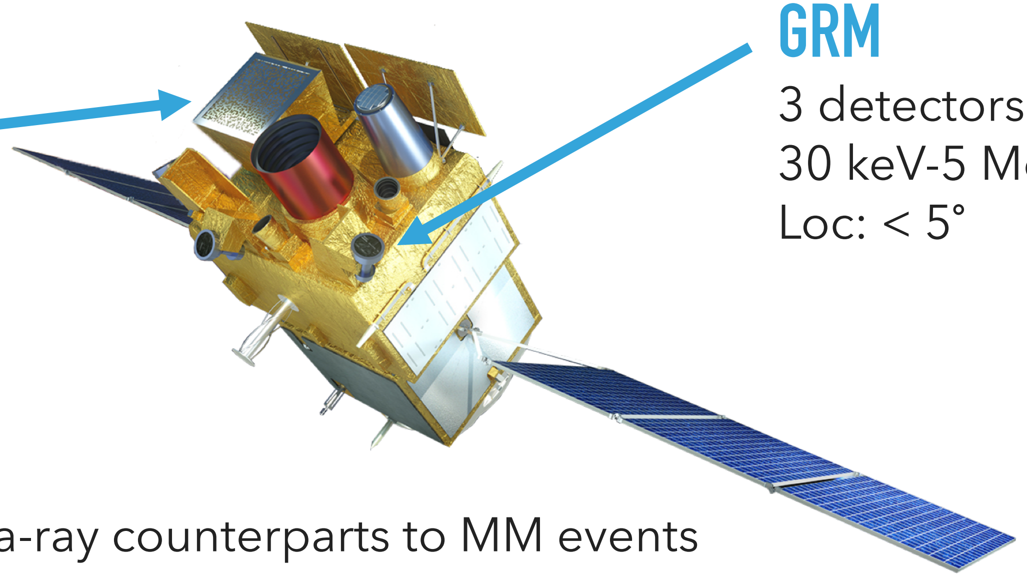


Duque, Daigne & Mochkovitch 2019
astro-ph/1905.04495

SVOM INSTRUMENTS with LARGE FIELDS of VIEW: in SPACE



ECLAIRS

4-150 keV, 2 sr

Loc: <12 arcmin

GRM

3 detectors (GRD)

30 keV-5 MeV, 3 sr/GRD

Loc: < 5°

- Search for gamma-ray counterparts to MM events
- **Detection/flux limit** (on board/offline analysis)**:** **f.o.v ~ 5.6 sr (GRM)**
- **Localization:** **f.o.v ~ 2 sr (ECL or 3 GRD)**
- **ECLAIRs has a good sensitivity to low-luminosity GRBs** (low energy thres.: 4 keV)
- **GRM has a good sensitivity to short GRBs** (spectral range 30 keV-5 MeV)
  ECLAIRs sensitivity to short GRBs can be improved in case of a detection by GRM

SVOM INSTRUMENTS with LARGE FIELDS of VIEW: on GROUND

GWAC

China: 5000 deg^2, m_V= 16 (10s)
Chili: 5000 deg^2, m_V= 17 (10s)

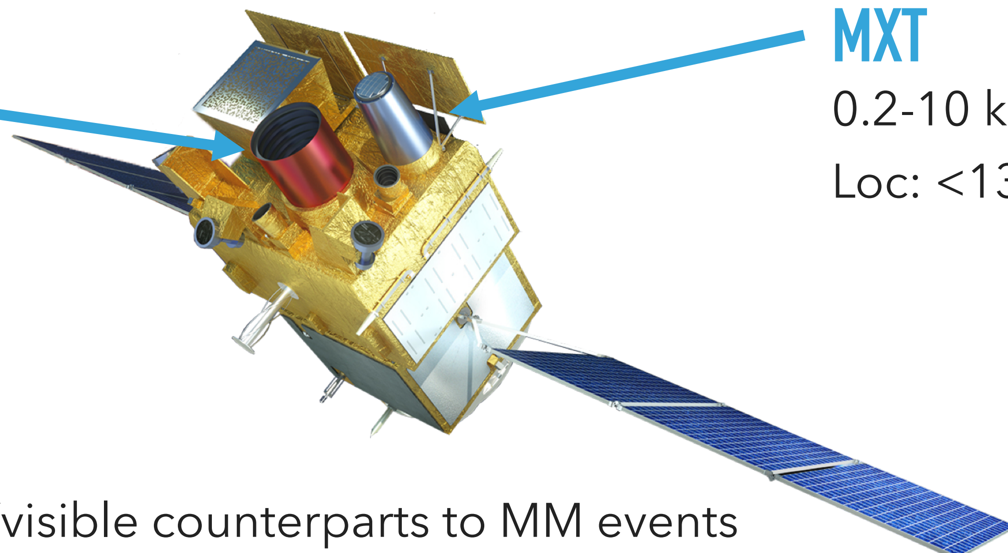
Already operating during O3

- Search for visible counterparts to MM events (e.g. a kilonova associated to a BNS)
- **Robotic telescopes: rapid response to an alert – covers a large area**
  Limitation: m_{lim} = 16-17
  Other robotic telescopes collaborate with SVOM with a deeper limit magnitude. (GRANDMA: J.-G. Ducoin's talk)
- Goal: detection and localization
- Needs spectroscopy for the classification of candidates
  (direct link to 2m class telescopes)

SVOM INSTRUMENTS with SMALL FIELDS of VIEW: in SPACE

VT

400-1000 nm
26^2 arcmin^2
Loc: < 1 arcsec



MXT

0.2-10 keV, 64^2 arcmin^2

Loc: <13 arcsec

- Search for X-ray/visible counterparts to MM events (e.g. kilonova/afterglow for mergers – expectations depend on the viewing angle)
- Requires a **slew** of the satellite
- Large error boxes: requires a **tiling strategy**

SVOM INSTRUMENTS with SMALL FIELDS of VIEW: on GROUND

C-GFT

(1.2 m, Changchun) 400-950 nm, 21^2 $arcmin^2$

F-GFT « COLIBRI »

(1.3 m, San Pedro Martir) 400-1700 nm, 26^2 $arcmin^2$ multiband photometry

- Search: galaxy targeting with error box
- **Characterize V-NIR counterparts to MM events: photometric follow-up** (e.g. a kilonova associated to a BNS)
- Needs an identified counterpart with an accurate localization (<30 arcmin)

OPERATIONAL SCENARIO FOR TOO-MM

SVOM'S REACTION TO A MM-ALERT

ECLAIRs/GRM

Large field of view
Slew only if a bright enough GRB is detected on-board by ECLAIRs

MXT/VT

Requires a decision to slew following the alert **ToO-MM**
Requires a tiling strategy if the error box is larger than 1 deg^2

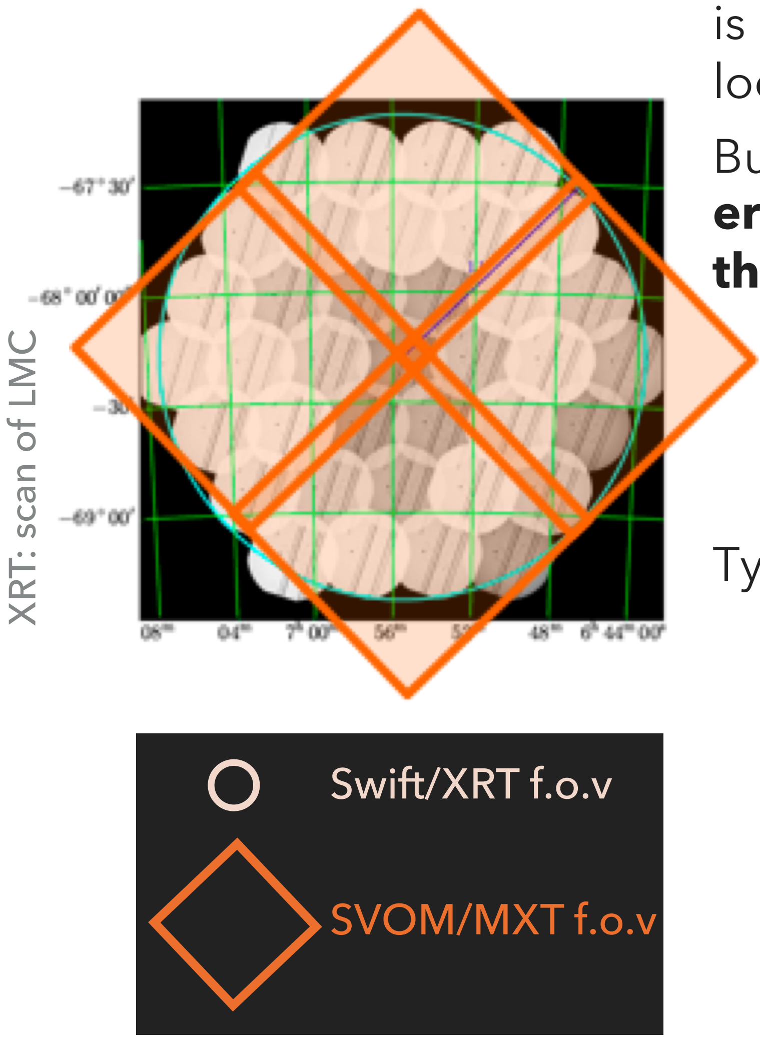
GWAC

Rapid automatic response

C-GFT/F-GFT

Rapid response
Needs an accurate localization (<30 arcmin)

TILING STRATEGY: MXT



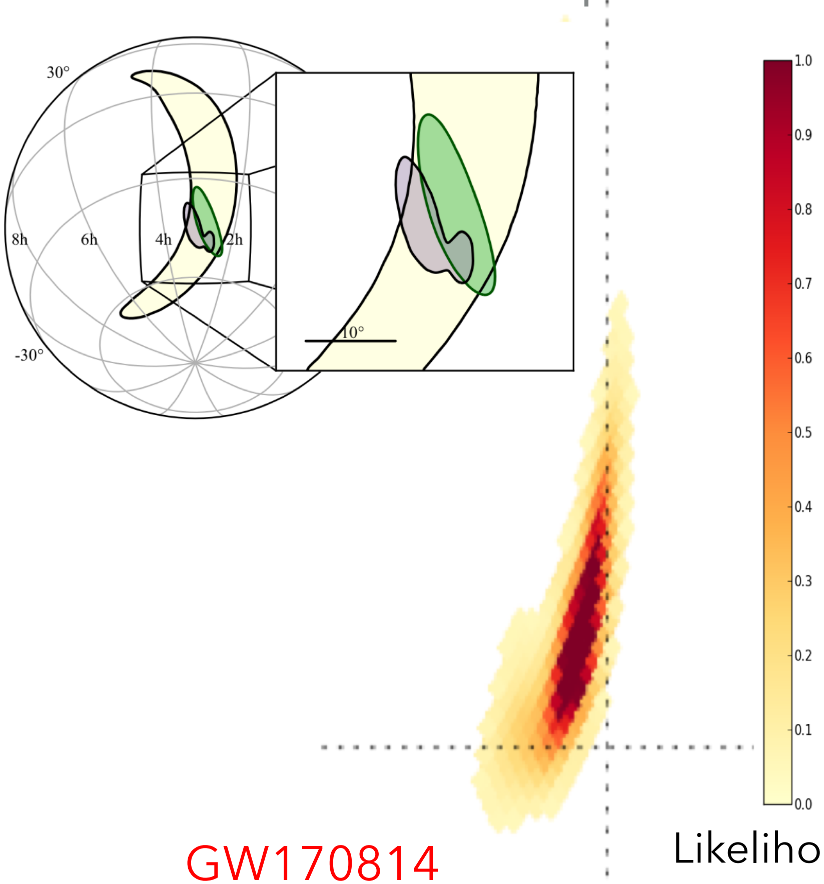
To follow multi-messenger alerts using tiles, Swift/XRT is better than SVOM/MXT in terms of sensitivity and localization accuracy.

But **MXT is very competitive to rapidly cover large error boxes with only a slightly reduced sensitivity thanks to its large field of view (1 deg²)**.

Typical scenario: 5 tiles/orbit – 15 orbits (~ 1 day)

TILES SEQUENCING SIMULATIONS: MXT

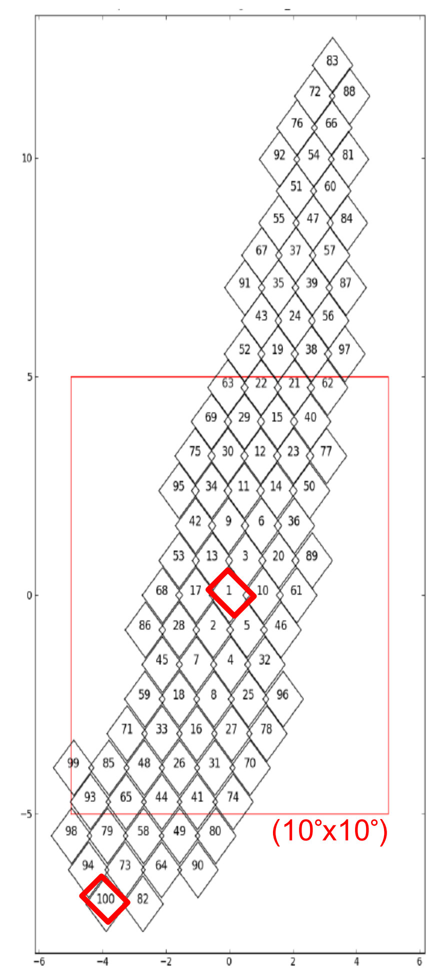
Simulation of a ToO-MM request



Likelihood

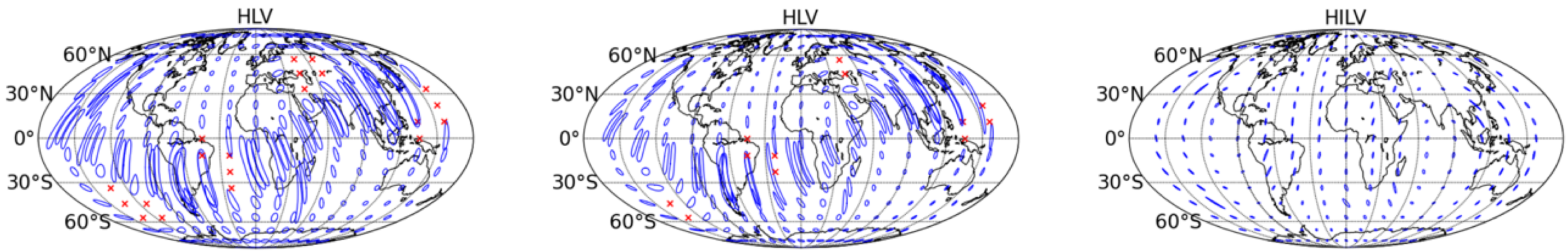
GW170814
Error box ~ 100 deg^2

Scenario	GW170814
Nb. tiles	**230**
RA min (°)	34.4
RA max (°)	53.4
Dec min (°)	-54.3
Dec max (°)	-7.8
LH total (%)	**90.0**
LH 75 (%)	**66.0**



First 100 tiles

SVOM FOLLOW-UP OF GW ALERTS HAS ALREADY STARTED!



2017 2019 2022

Error box ≥100 deg² → ≤10 deg²

GWAC
O2: Mini GWAC
O3: GWAC (m_{lim} 12 → 16) + GRANDMA
+ Direct link to spectrometry
to classify interesting triggers

GFTs

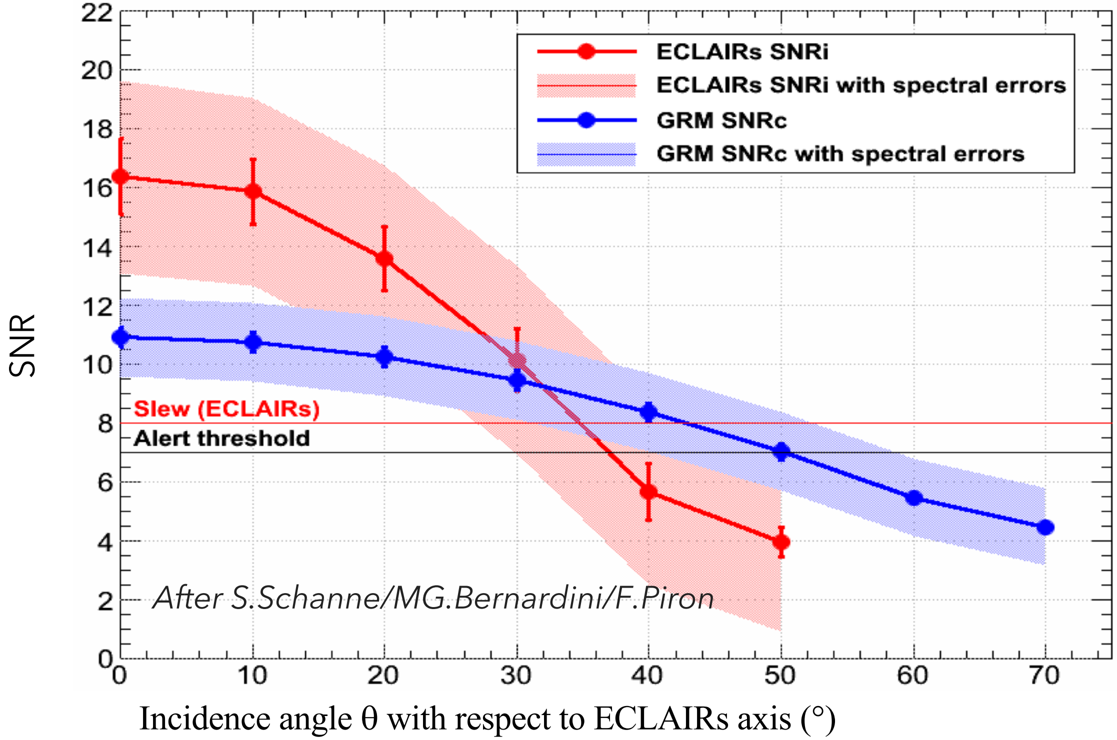
GRM, ECLAIRs
MXT, VT

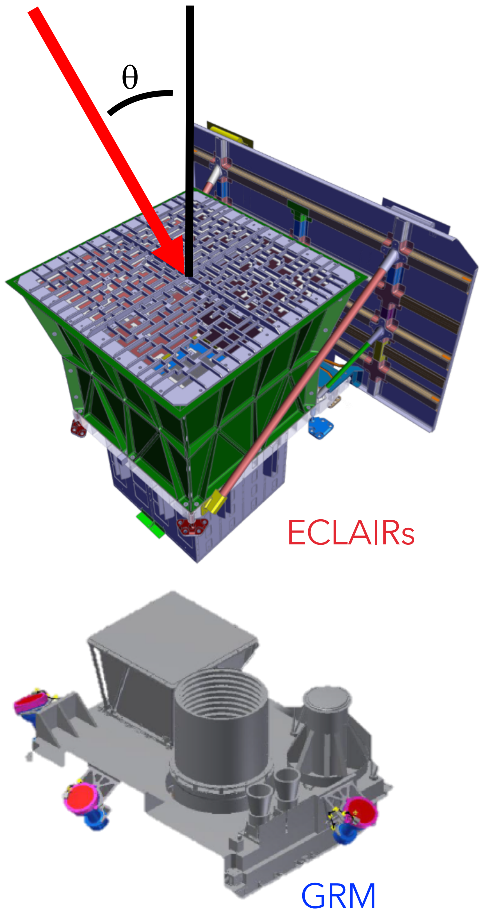
WHAT WOULD SVOM HAVE OBSERVED?

GW 170817 / GRB 170817A

ECLAIRS & GRM DETECTION OF THE GRB?

Simulation of the event GRB170817A + Cosmic X-ray Background with parameters from Fermi-GBM (public GCN 2017/8/17 20:00 TU)



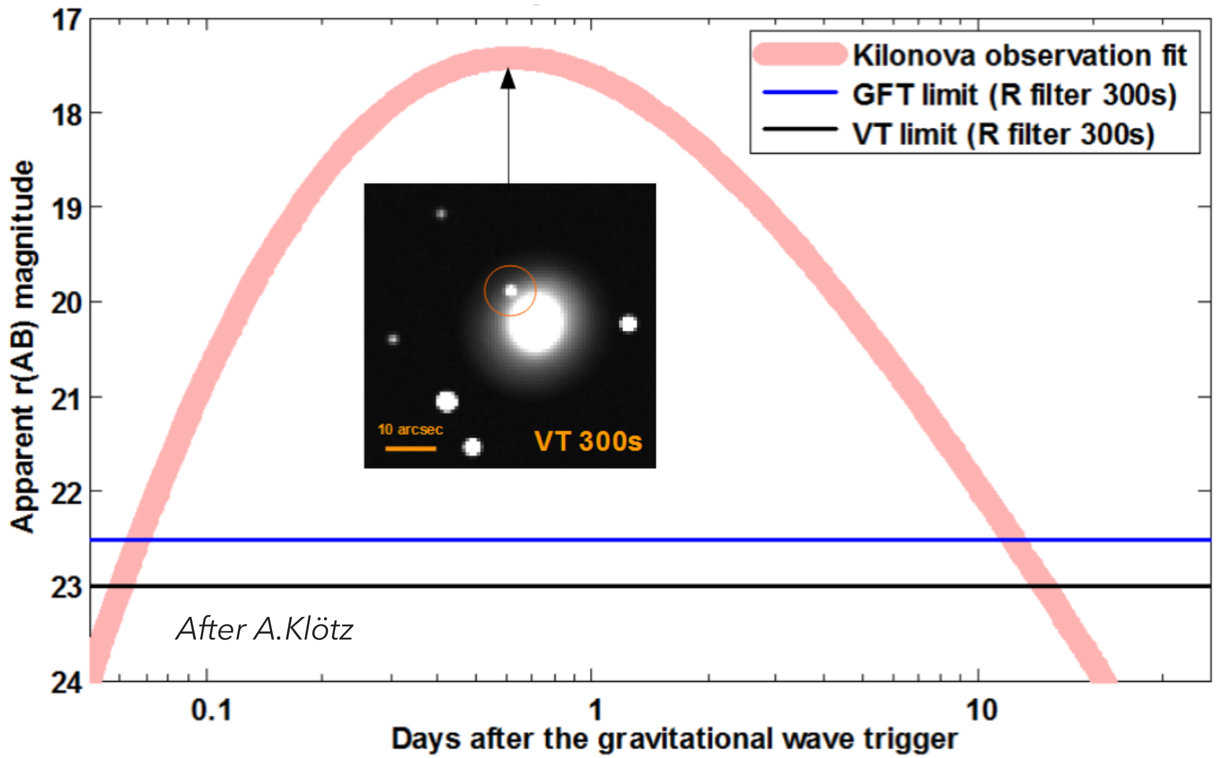


➔ **Up to 35° off axis: ECLAIRs triggers + alert is sent to the ground + slew is requested**

➔ **Up to 50° off-axis: GRM triggers + alert is sent to the ground (with rough localization)**

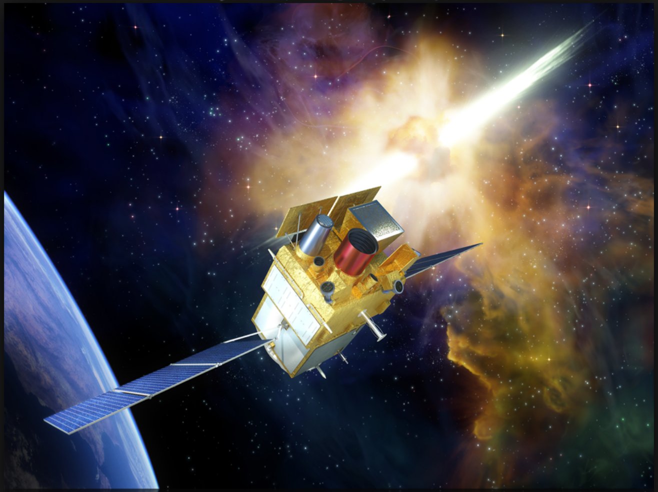
VT & GFT DETECTION OF THE KILONOVA?

Simulation of the kilonova in NGC 4993 as seen by VT in 300 s at peak magnitude



➔ **VT and GFTs have the capacity to detect the kilonova since T0+2h**
➔ **and can follow it during 10 days**

CONCLUSION



- 2022+: more GW/HE neutrino alerts with better localization.

- SVOM's set of instruments is well adapted to the search of electromagnetic counterparts to GW/HE neutrino events.

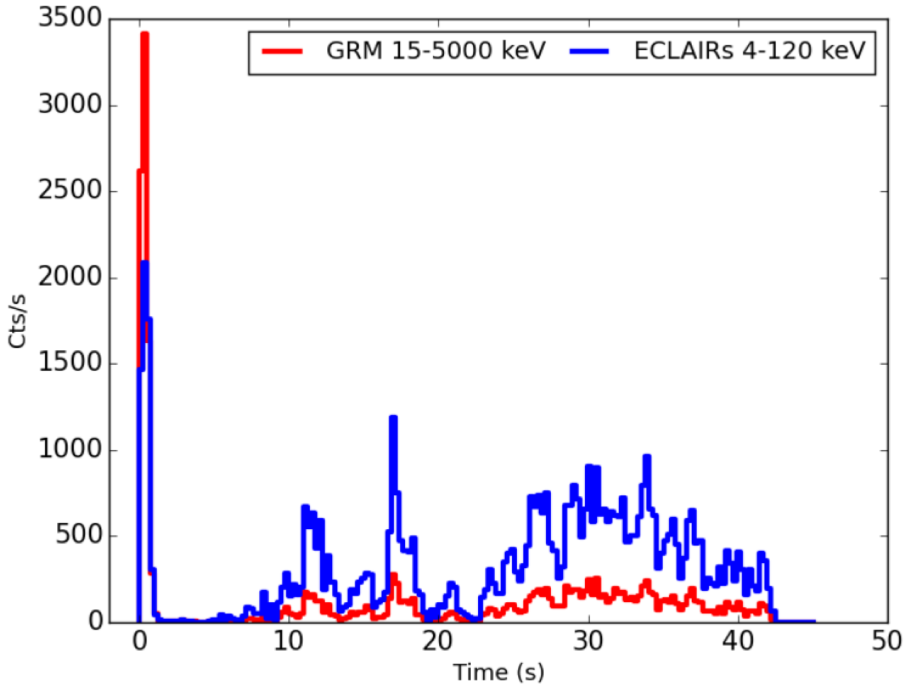
- Gamma-rays: ECLAIRs and GRM have a large field of view (~45% of the sky) and a good sensitivity to interesting classes of GRBs (short GRBs, low-luminosity GRBs, …).
  In case of a detection with ECLAIRs or 3 GRDs: localization (10′ → a few °).

- X-rays: MXT requires a slew + a tiling strategy for large error boxes.
  Can cover ~100 deg^2. In case of detection: localization (<13″).

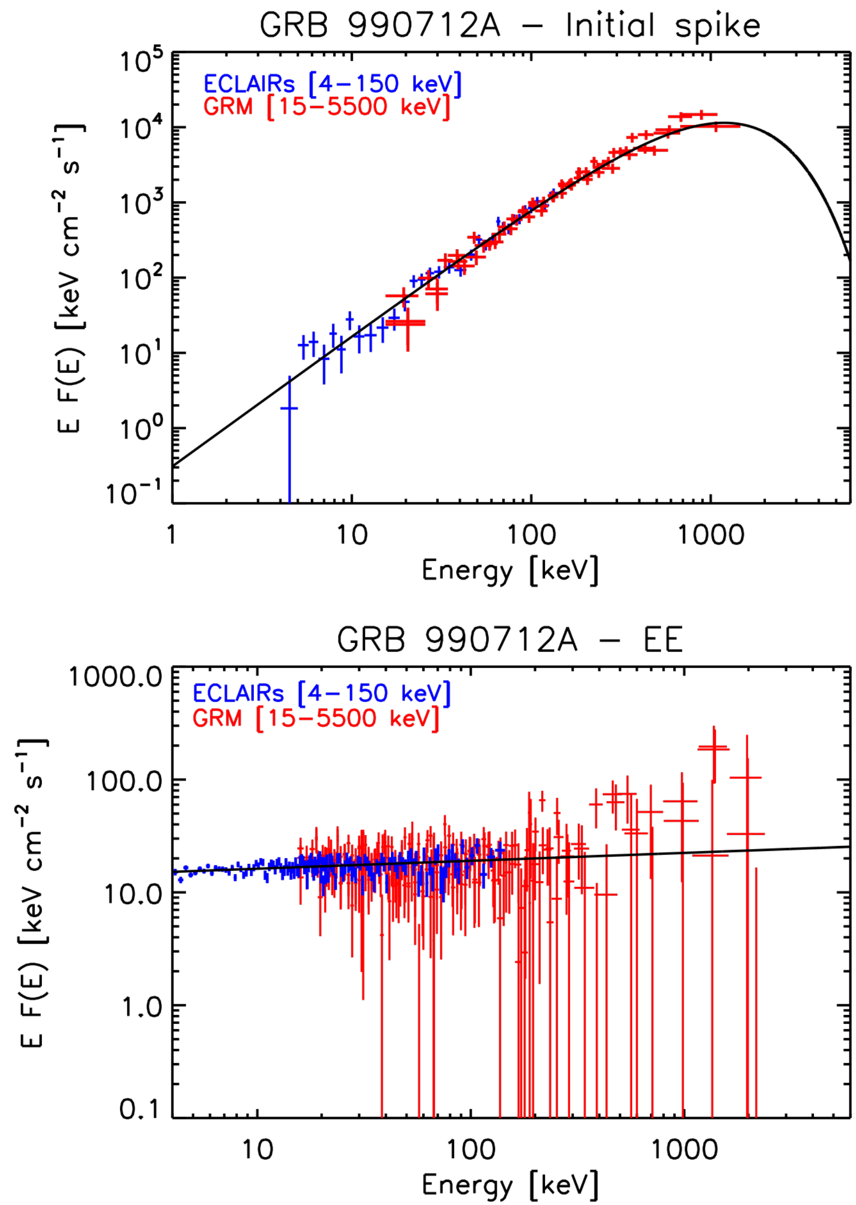
- Visible-NIR:
  VT follows the MXT tiling strategy, but with a narrower f.o.v.
  GWAC covers a large area (>1000 deg^2) but with m_{lim} ~17.
  C-/F-GFT can contribute to the photometric follow-up as soon as an electromagnetic counterpart is detected with a localization < 30 arcmin.

Supplementary Material

ECLAIRS + GRM OBSERVATION OF A SHORT GRB



Simulation of a short GRB with a soft tail in ECLAIRs+GRM (990712A)
Simulation
by S.Antier, M.-G. Bernardini, F. Xie et al.



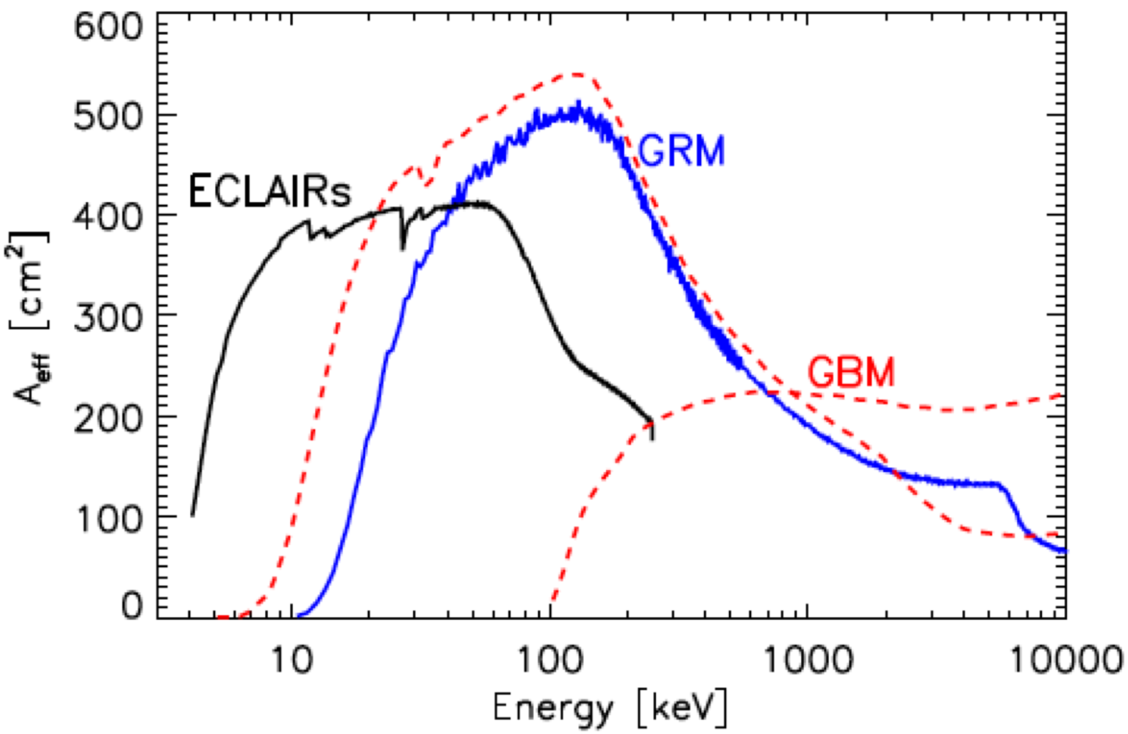
(Bernardini et al. 2017)
(Wei, Cordier et al. « Scientific prospects of the SVOM mission », arXiv:1610.06892)

ECLAIRS + GRM SPECTRUM

Simulations of Fermi/GRB bursts (Gruber+ 13)
(burst on-axis in ECLAIRs, 30° offaxis in GRM)
= 521 bursts (BAND or COMP) including 50 short

(Bernardini et al. 2017)

Effective area:



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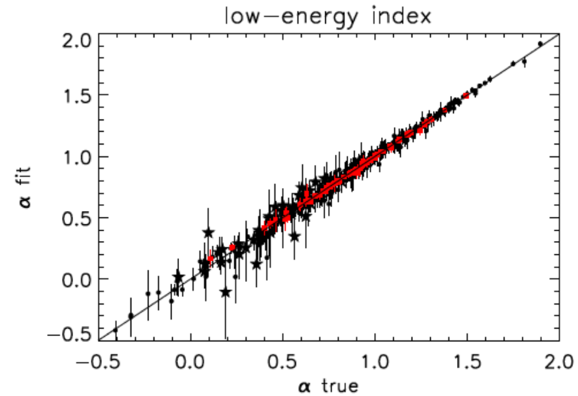
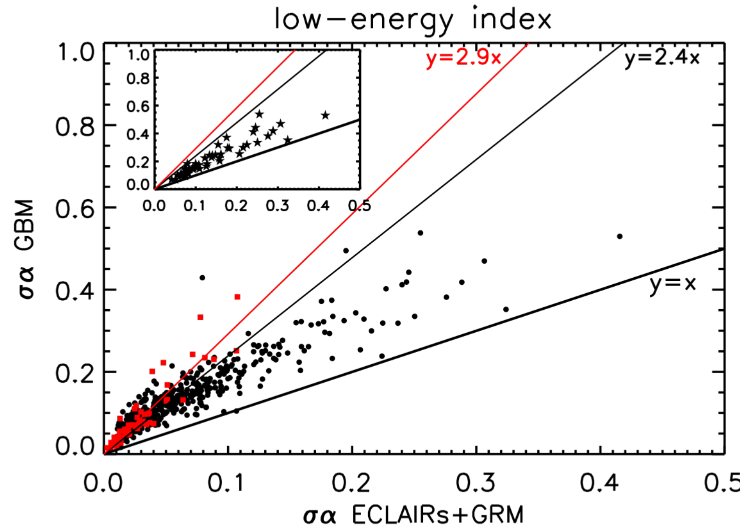
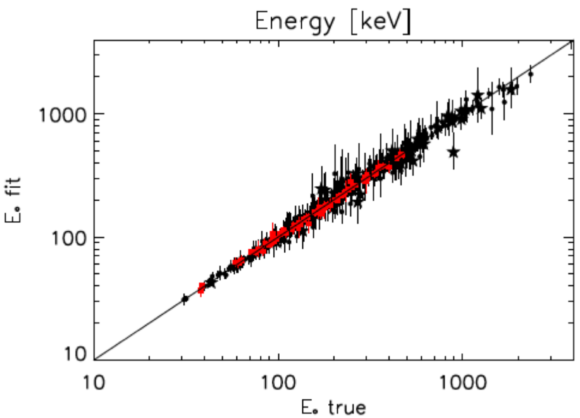
★ short GRBs

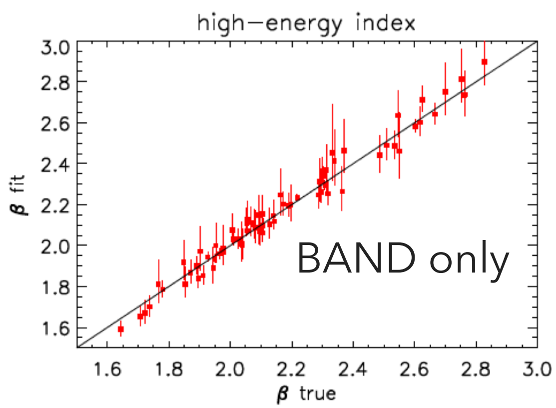




Error on low-energy slope:
SVOM vs GBM

ECLAIRs+GRM spectroscopic performances:
highly competitive,
at least as good as Fermi/GBM





Peak energy, low/high-energy slope

A GRB SAMPLE WITH A COMPLETE DESCRIPTION

- **Prompt emission:**
  ECLAIRS: 47-82 GRB/yr — GRM: ~90 GRB/yr
  ECLAIRs+GRM: ~40-60 GRB/yr — GWAC: 13-27% of alerts
- **Slew requests:** 36-72 GRB/yr
- **X-ray afterglow (MXT):** 90% of cases after a slew
- **Visible afterglow (VT):** 66% of slews followed by at least 5 min of visibility
- **Visible+NIR afterglow: (F-GFT+C-GFT)** 37% of ECLAIRs triggers (75% with LCOGT)
- **Early observation possible with a VLT:** 85% of MXT localizations
- **Redshift measurement expected in 2/3 of burst**

A unique sample of 30-40 GRB/yr with

- prompt emission over 3 decades (+ optical: 13-27%)

- X-ray and V afterglow

- redshift