Ultra-Long Gamma-Ray Bursts detection with SVOM/ECLAIRs

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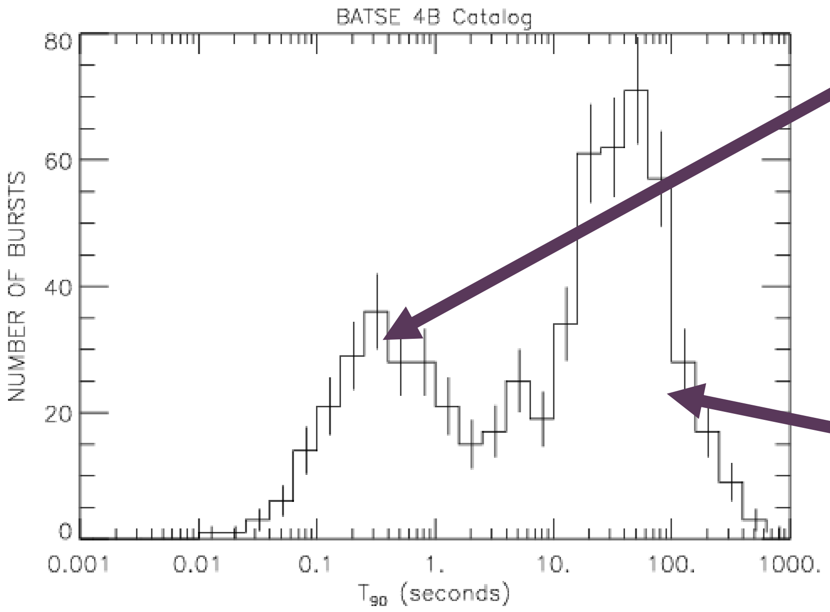
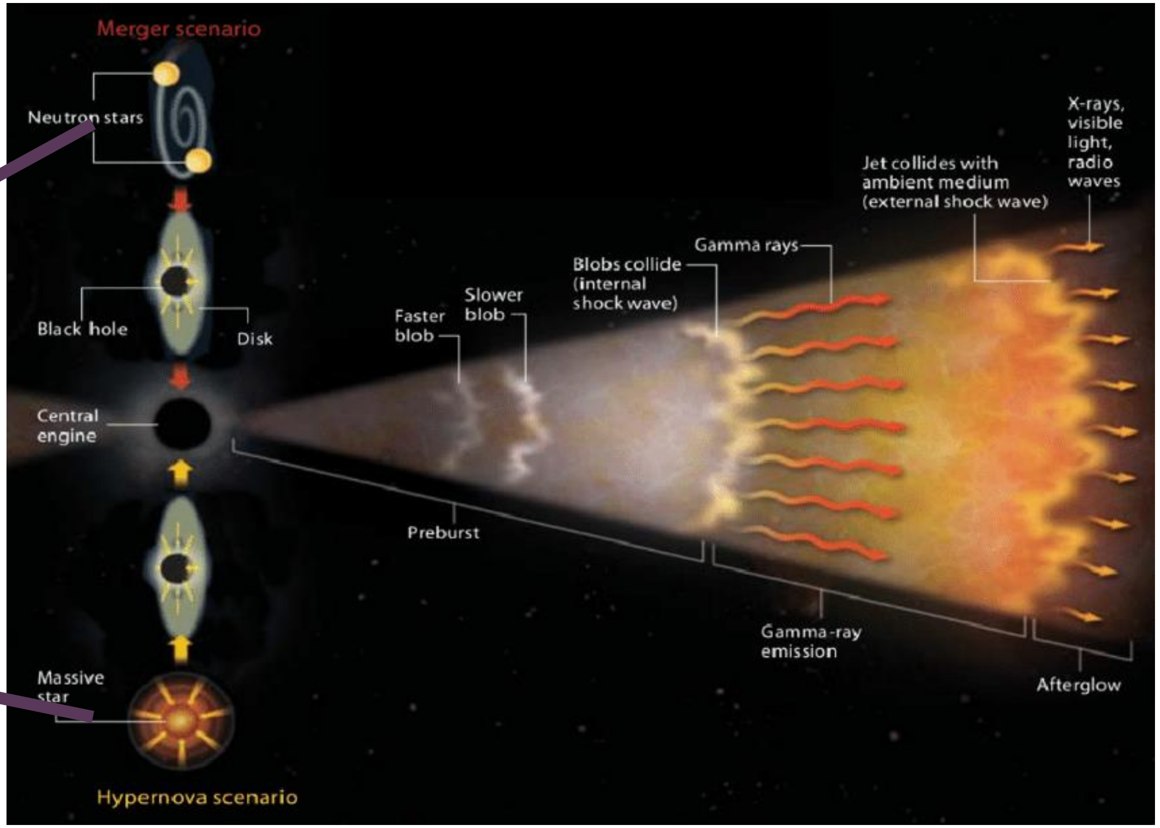
Gamma ray bursts are the most energetic (electromagnetic) phenomena in the universe. Results of two scenarios (stellar fate).



Durations of the 4B Catalog GRBs detected by BATSE (Paciesas et al., 1999)



Fireball model (NASA)

Space based multi-band astronomical Variable Object Monitor
French (CNES) – Chinese (CNSA/CAS) collaboration
Expected to begin operation in 2022
A multi wave-length mission with space based and ground based instruments

ECLAIRs
- Wide field X-ray/gamma telescope
- GRB trigger

MXT
- Narrow field X-ray telescope

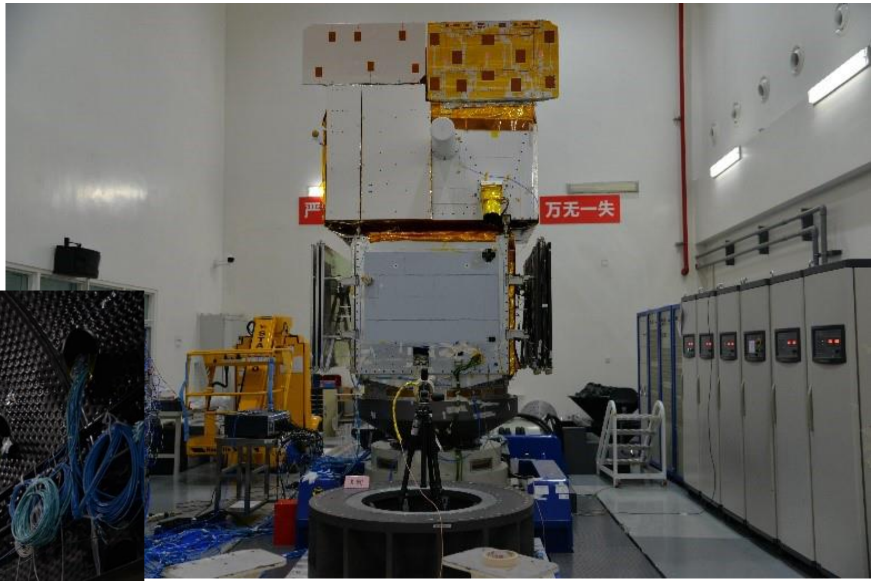
GRM
- Gamma-ray monitor (x3)

VT
- Narrow field visible telescope

Mechanical and thermal models of the instruments on the satellite qualification model (CNES/SECM)

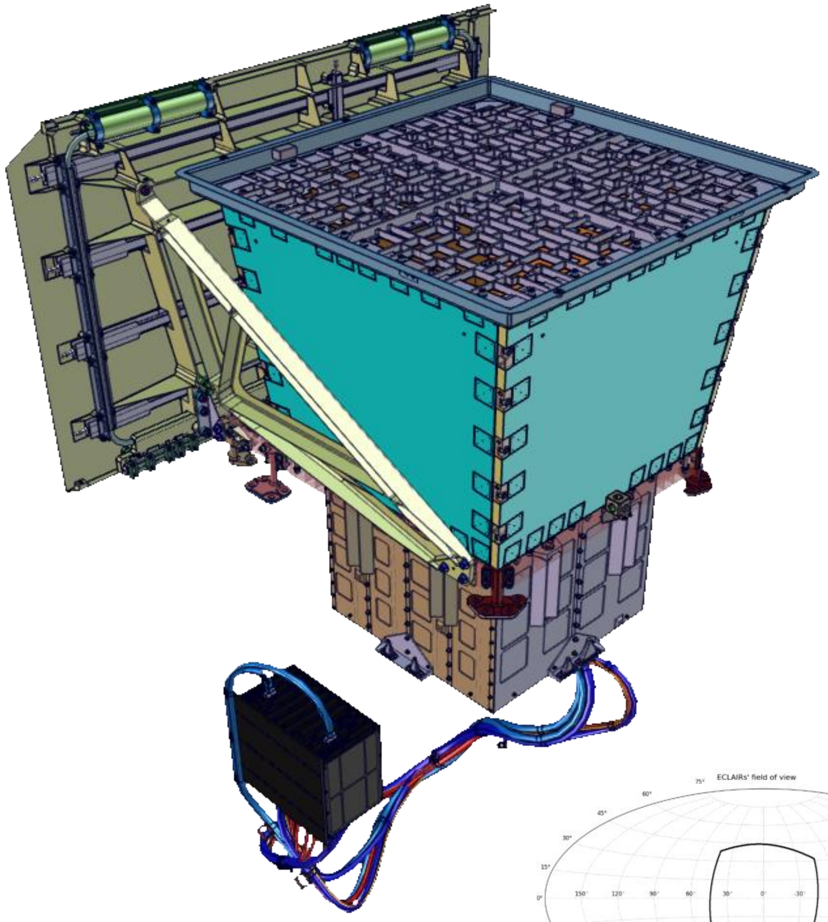
Ground instruments
- Ground follow-up telescopes
- Ground Wide Angle Cameras
- VHF network for real-time GRB alert transmission

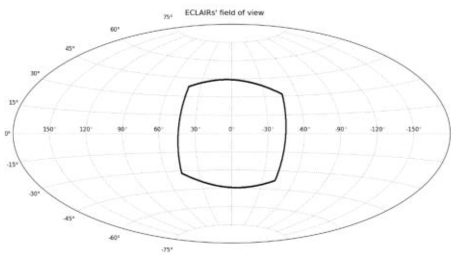
Mechanical and thermal models (STM) of the instruments on the satellite qualification model and environmental tests (CNES/SECM)

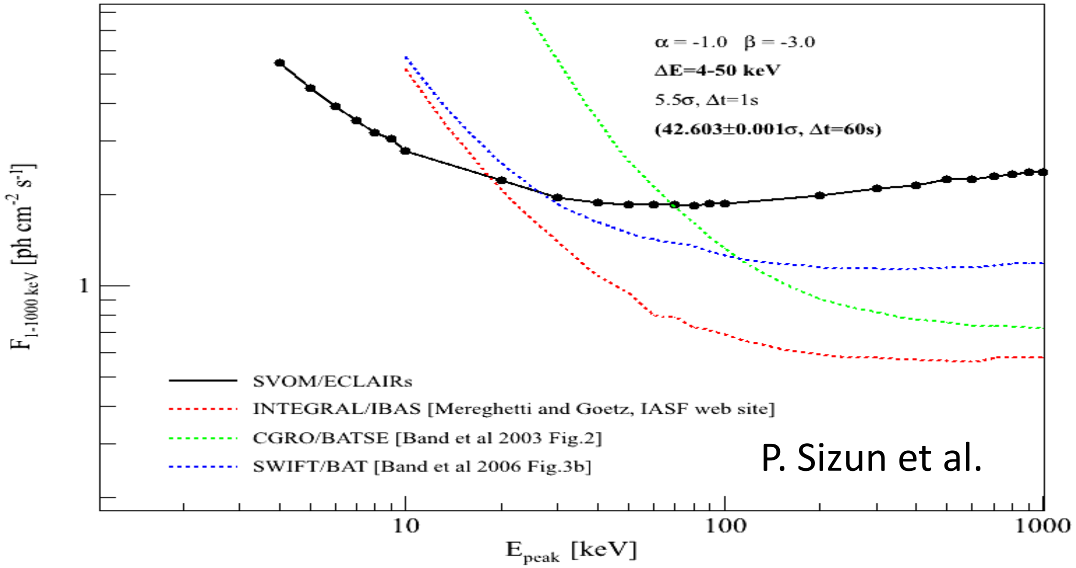


Hard X-ray and gamma coded mask telescope

- 4 – 150 keV
- Wide field of view (2sr ~ 1/6 of the sky)
- Localization < 12 arcmin
- Triggers: Count-rate trigger with imaging (10 ms – 20s) and Image trigger (20s – 20 min)
- Onboard triggers with localization: about 65 GRB/year
- Well adapted to low E-peak GRBs

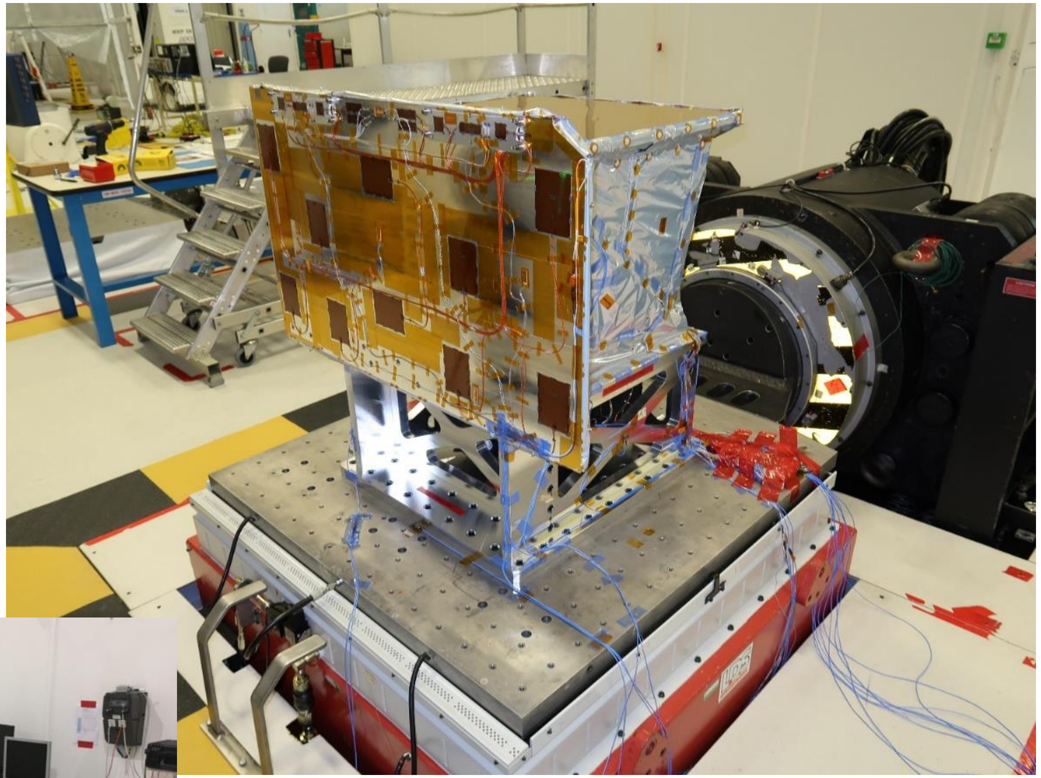


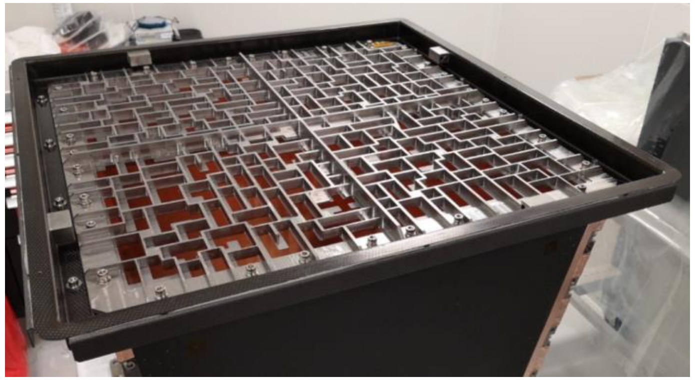




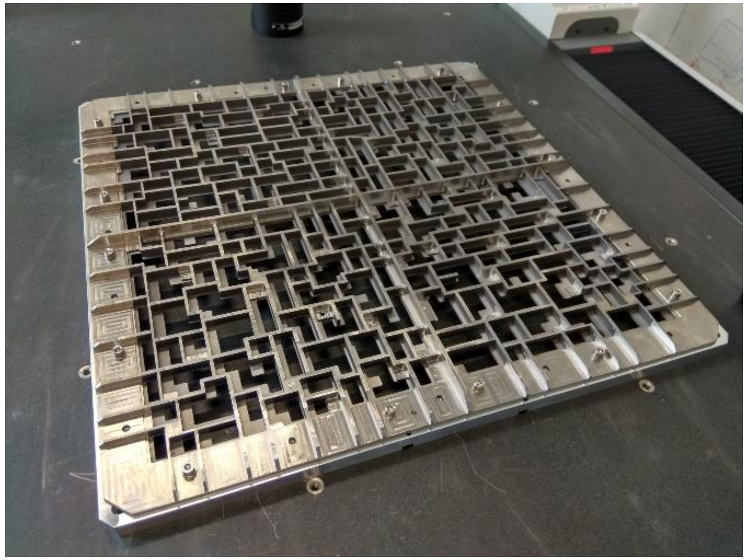
P. Sizun et al.

STM vibration test





UGTS



Mask

Some GRBs show an extraordinarily long duration of more than 1000 s (Gendre et al., Levan et al., 2013).

~ 10 have been detected by Swift/BAT.

Possible progenitors (central engine has to be powered during a longer time than usual long GRBs) :

- Collapse of low-metallicity supergiant blue star (Gendre et al., 2013)
- Magnetar birth following the collapse of a massive star (Greiner et al., 2015)
- Collapse of a Pop III star (Nakauchi et al., 2012, Kinugawa et al., 2019)
- Just the tail of the distribution ? (Virgili et al., 2013)

→ To better understand ulGRBs (duration, prompt and afterglow phase) and distinguish from long GRBs:

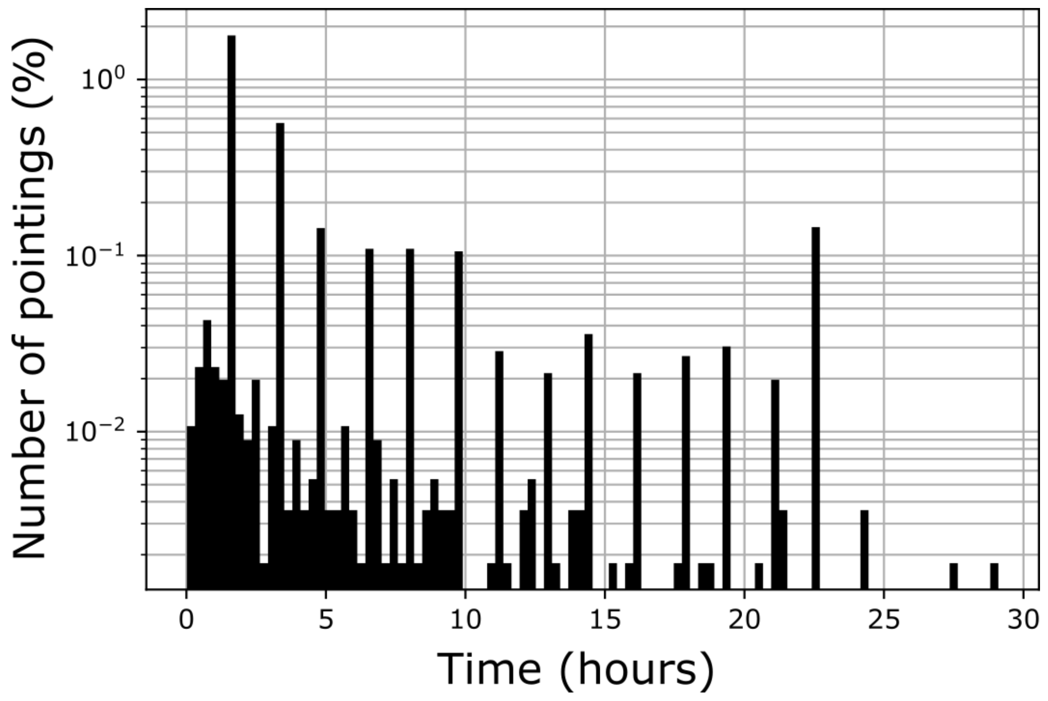
- requires long pointings
- requires follow-up observations

SVOM/ECLAIRs may help!

- SVOM has long stable pointings (up to ~ one day)
- SVOM has multi-wavelengths instruments

How would ECLAIRs have seen Swift ulGRBs ?

SVOM pointings durations over one year



Inputs:

- 10 ulGRBs detected by Swift/BAT (lightcurves and spectra)

Assumptions:

- Only the GRB is in the field of view (no Earth, no know X-ray sources)
- Background is only Cosmic X-ray background (Moretti et al,. 2009)

Parameters:

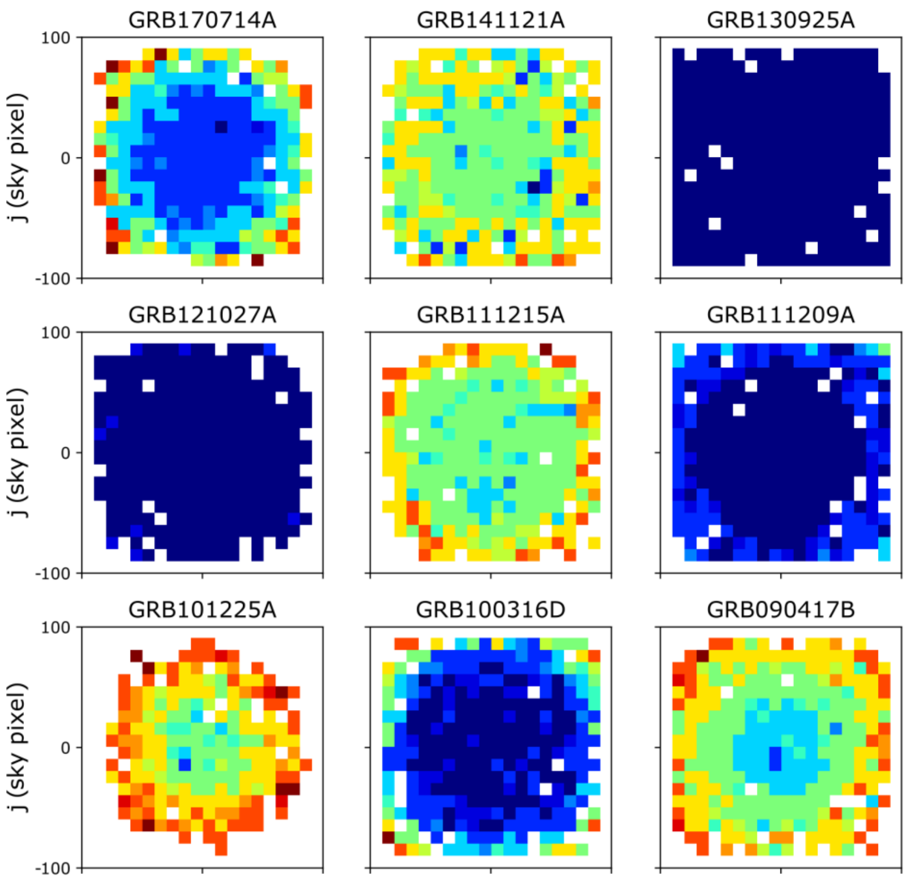
- Each burst is injected at 1000 different positions in the field of view

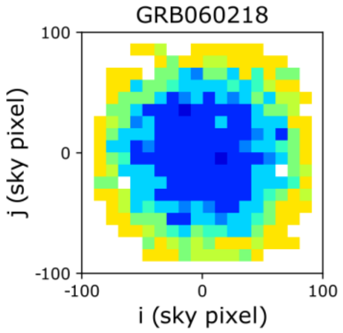
→ Ray-tracing simulation (GRB + background photons are projected one by one through the mask)

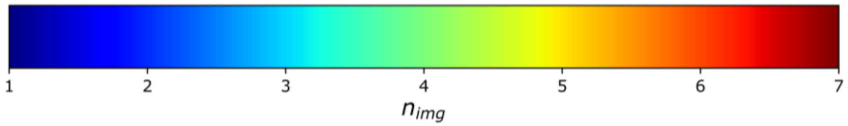
→ Trigger prototype software

Output:

- GRB signal to noise ratio
- Detection time scale (within 10ms – 20min)
- Detection energy scale (within 4-120 keV)
- Localization error
- Detection ratio (number of detections over the 1000 simulations)

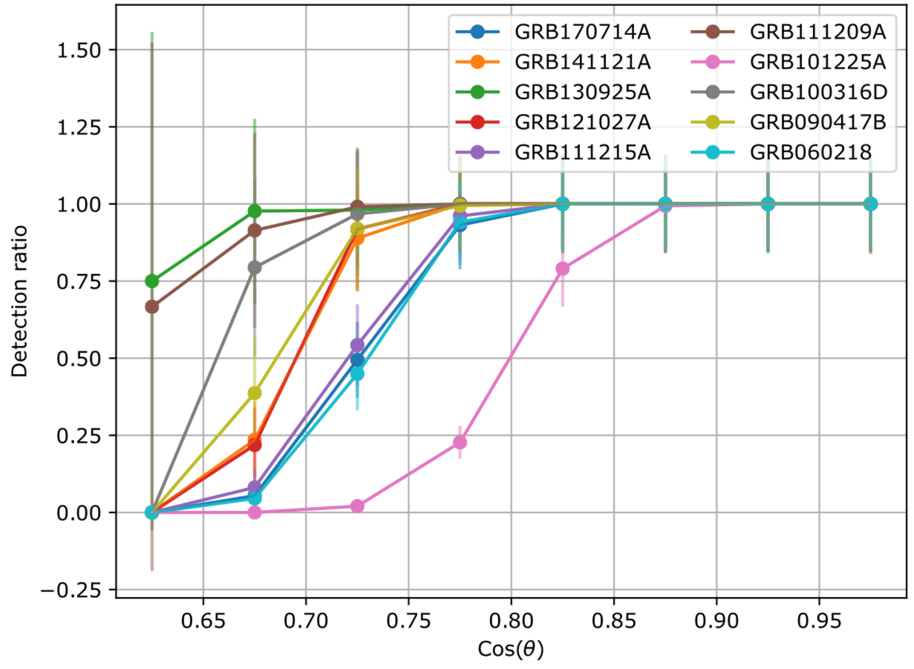






Detection time scale with the image trigger $(T = 20.48s \times 2^{n-1})$

- 2 very bright bursts are detected in the first scale everywhere in the FoV
- For the others, detection occurs on a longer scale when the burst is off-axis.

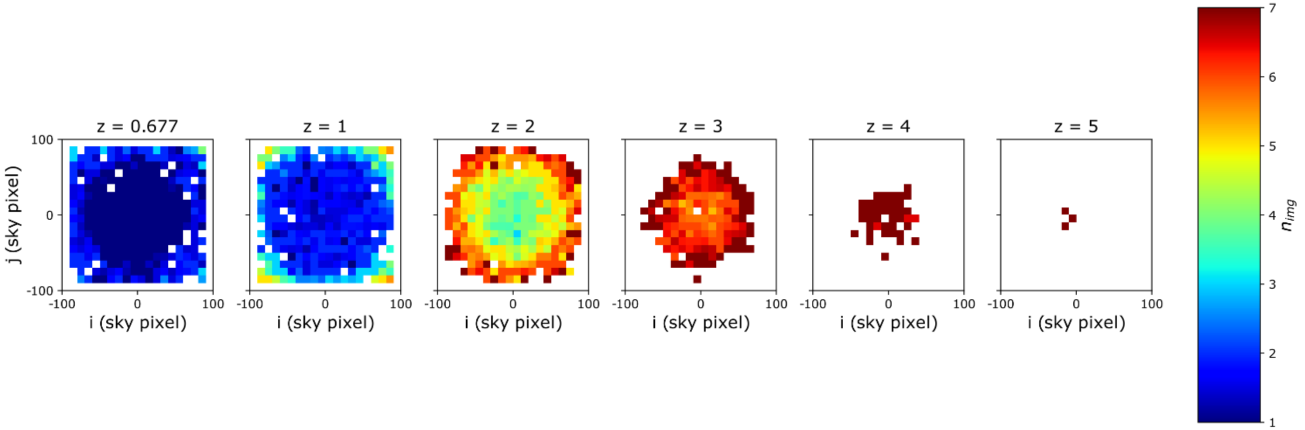


Dagoneau et al., 2020 (submitted)

Redshifted ulGRBs

As we know the ulGRBs redshift we can compute redshifted lightcurves and spectra to create a synthetic population → Detection ratio according redshift.

Detection time scale with the image trigger $(T = 20.48s \times 2^{n-1})$



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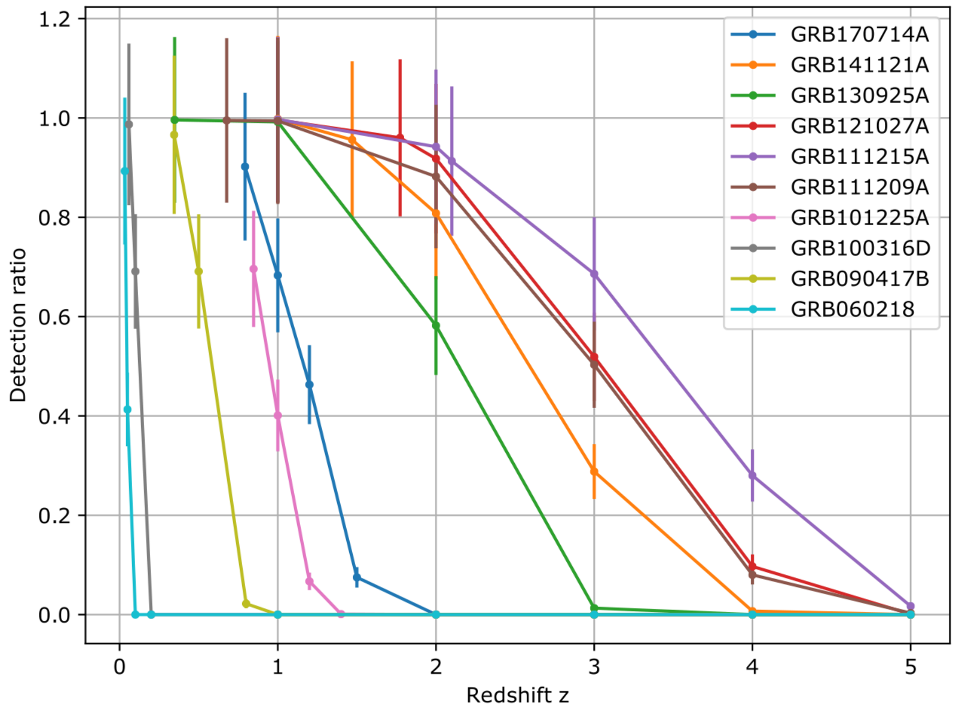


Expected ulGRBs rate in ECLAIRs (compared to Swift-like bursts)

$$R = \frac{N_{Eclairs}(< z_h)}{N_{Swift}(< z_h)}$$

Number of bursts (closer than redshift horizon) is estimated from GRB population model (determined by the star-formation rate under the assumption there is no GRB redshift evolution) (Atteia et al., 2017) for ECLAIRs and Swift

$$N(< z_{h,Swift}) \propto \int_0^{z_{h,\mathrm{Swift}}} \mathrm{SFR}(z) \frac{1}{1+z} \frac{dV(z)}{dz} dz$$

→ For ECLAIRs, redshift horizon is determined by simulation (last redshift at which the burst is detected).

→ For Swift, redshift horizon is estimated from the number of photons in redshifted lightcurves. Redshift horizon is reached at SNR=6.5 (same threshold than ECLAIRs).

$$\mathrm{SNR}_{\mathrm{fcfv}}(z) = \mathrm{SNR}(z_0) \frac{N_{\mathrm{ph}}(z_0)}{N_{\mathrm{ph}}(z)} \frac{1}{f_{\mathrm{coding}}}$$

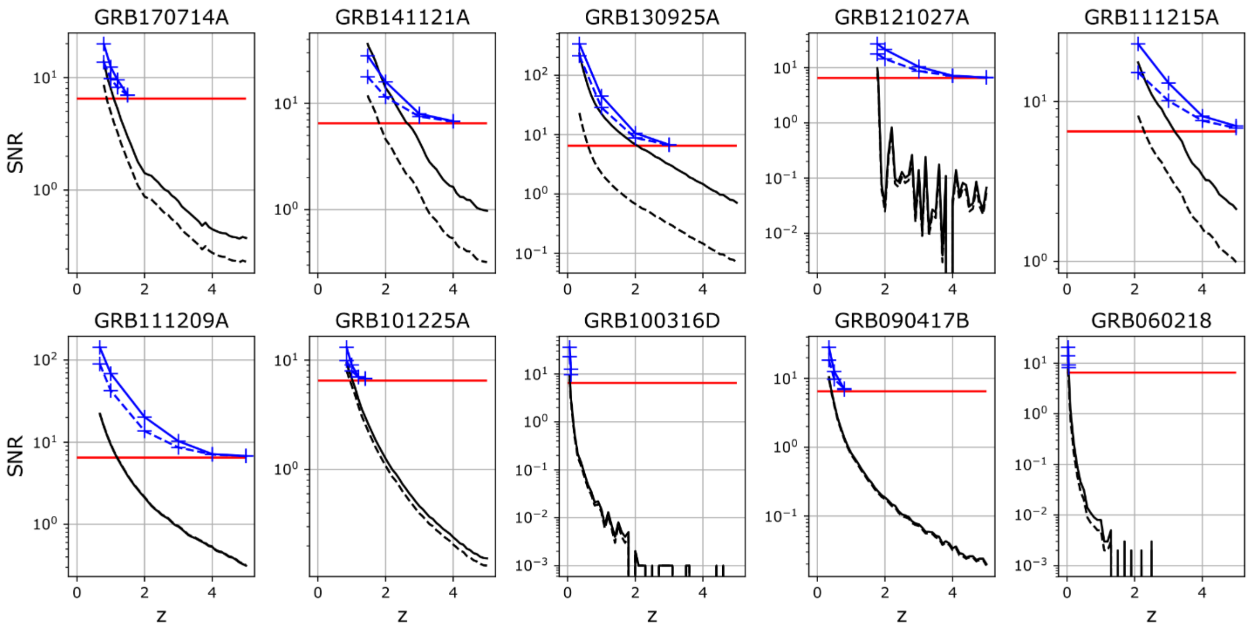
Expected ulGRBs rate in ECLAIRs (compared to Swift-like bursts)

- A rate is determined for each burst
- After normalization (mission duty cycle and size of field of view), **we got a global mean factor: 1.57 in favor of ECLAIRs**.

ECLAIRs benefits from long imaging scales (up to 20 min) and low-energy threshold (4 keV).

The « offline ground trigger » could enhance the detection results (but with singificant delay ~12 h, no follow-up observations).

We only simulated events detected by Swift, some may be missed: discovery space!



SNR vs redshift. (Blue: ECLAIRs, black: Swift)

Conclusion

- Gamma-ray burst are transient very energetic events
- Ultra-long GRBs may form a specific family of bursts
- SVOM may operated in 2022 with space and ground multi-wavelengths instruments
- SVOM may play a role in understanding ulGRBs (may detect ulGRBs at a rate x 1-2 of Swift)
- SVOM will open a discovery space thanks to its low energy threshold (4 keV vs. 15 keV for Swift) and long time imaging.

Perspectives:

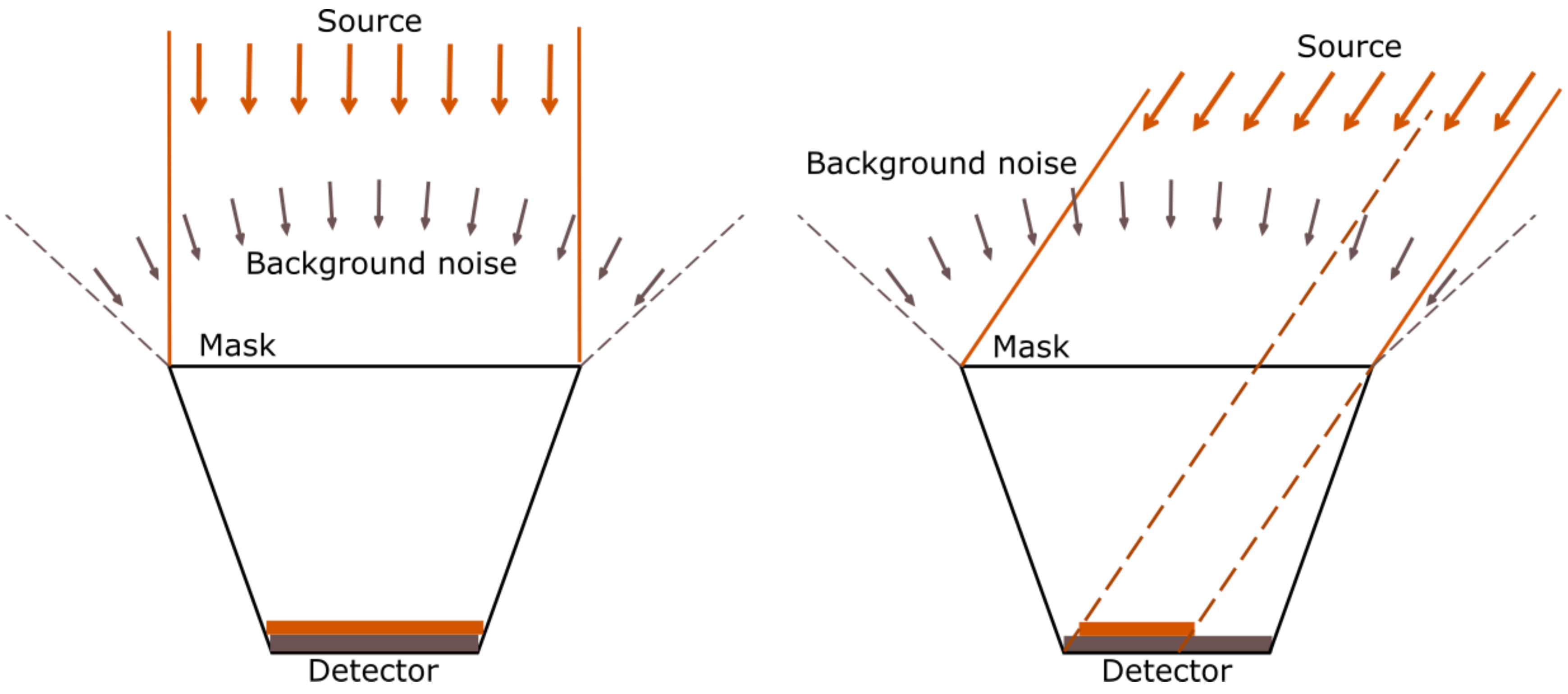
- Influence of the low energy threshold on the detection rate (what if 4 keV cannot be achieved ?)

Thanks 谢 谢

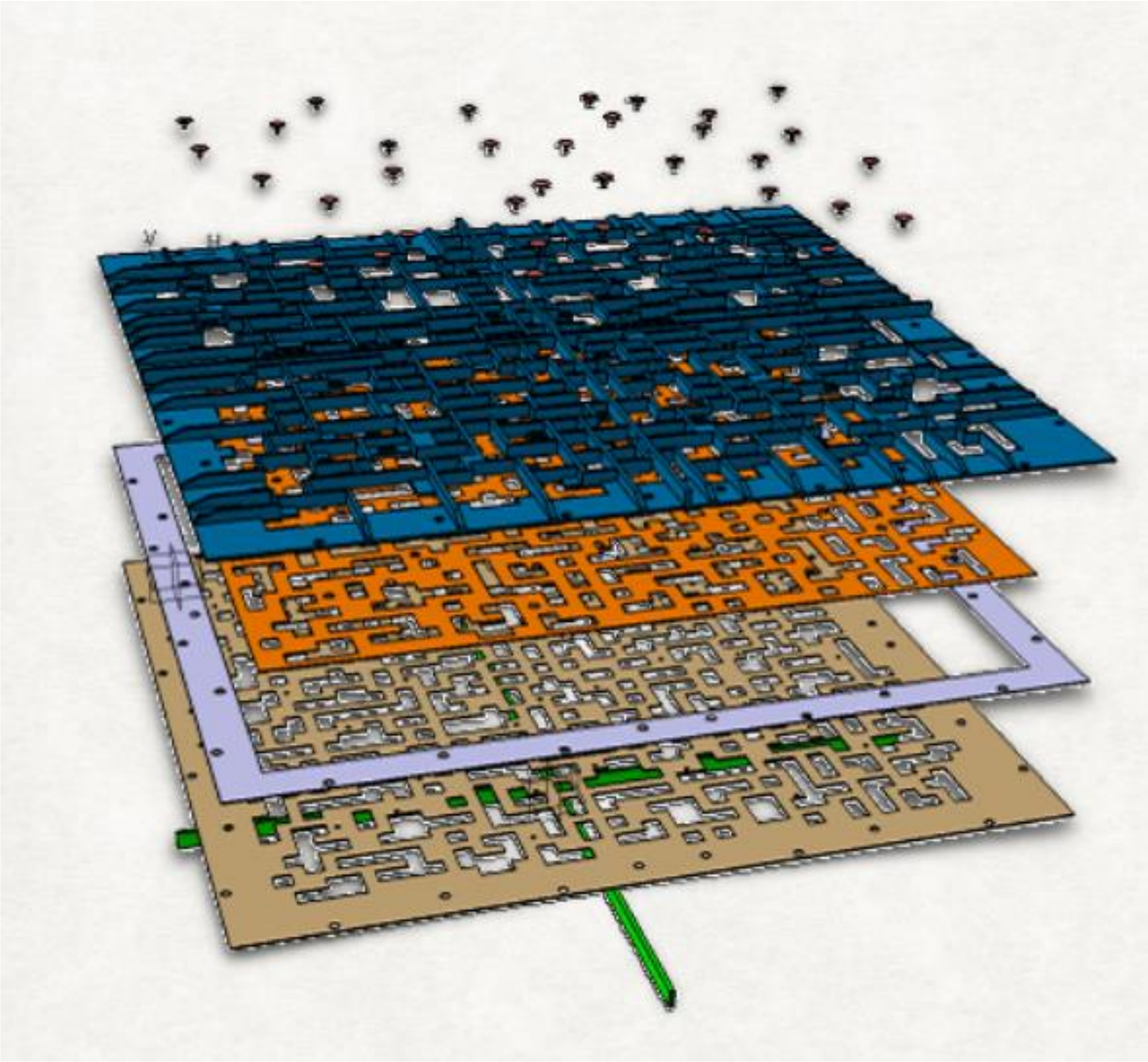
Follow @SVOM_mission !

Backup

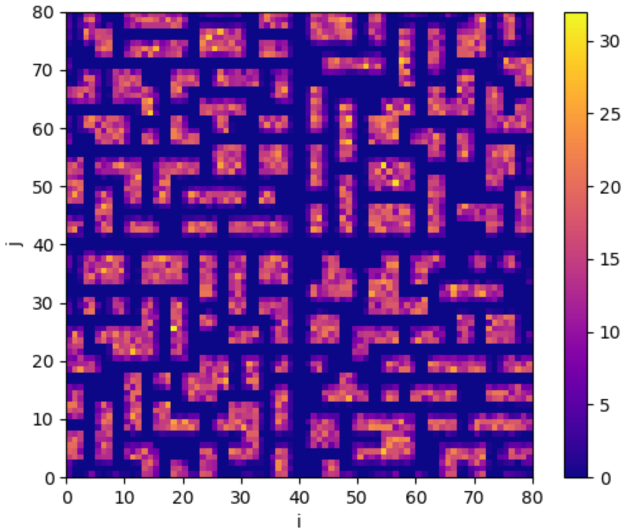
ECLAIRs field of view

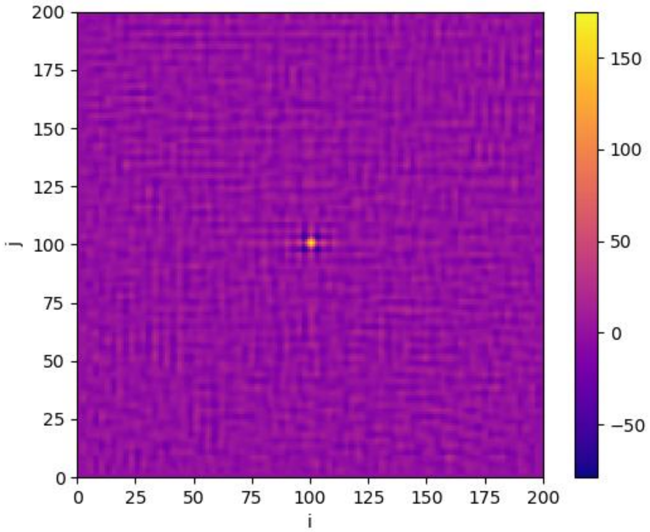


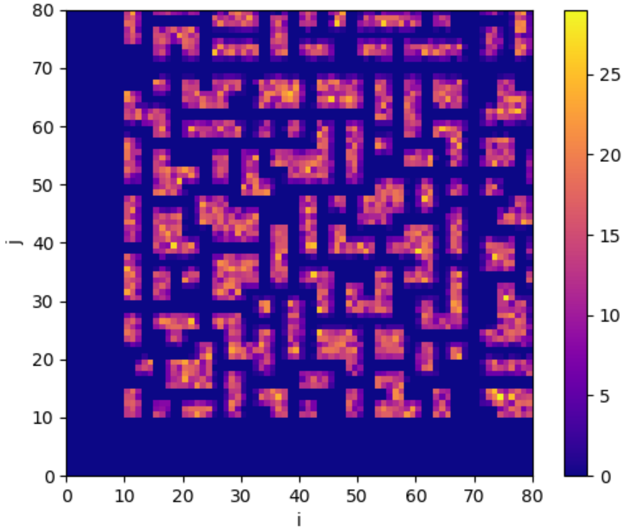
Mask

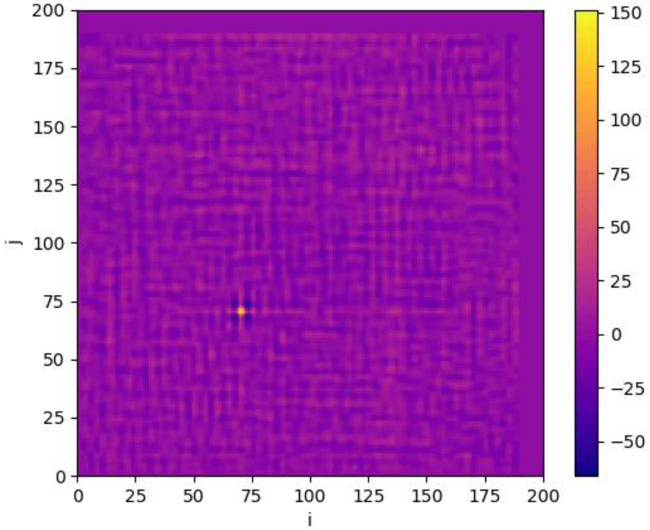


From detector image to sky image









VHF network

Santa Maria