Transient university 2023

ECLAIRs on-board trigger performance impacted by efficiency inhomogeneity and heat-pipe noise in 4-8 keV

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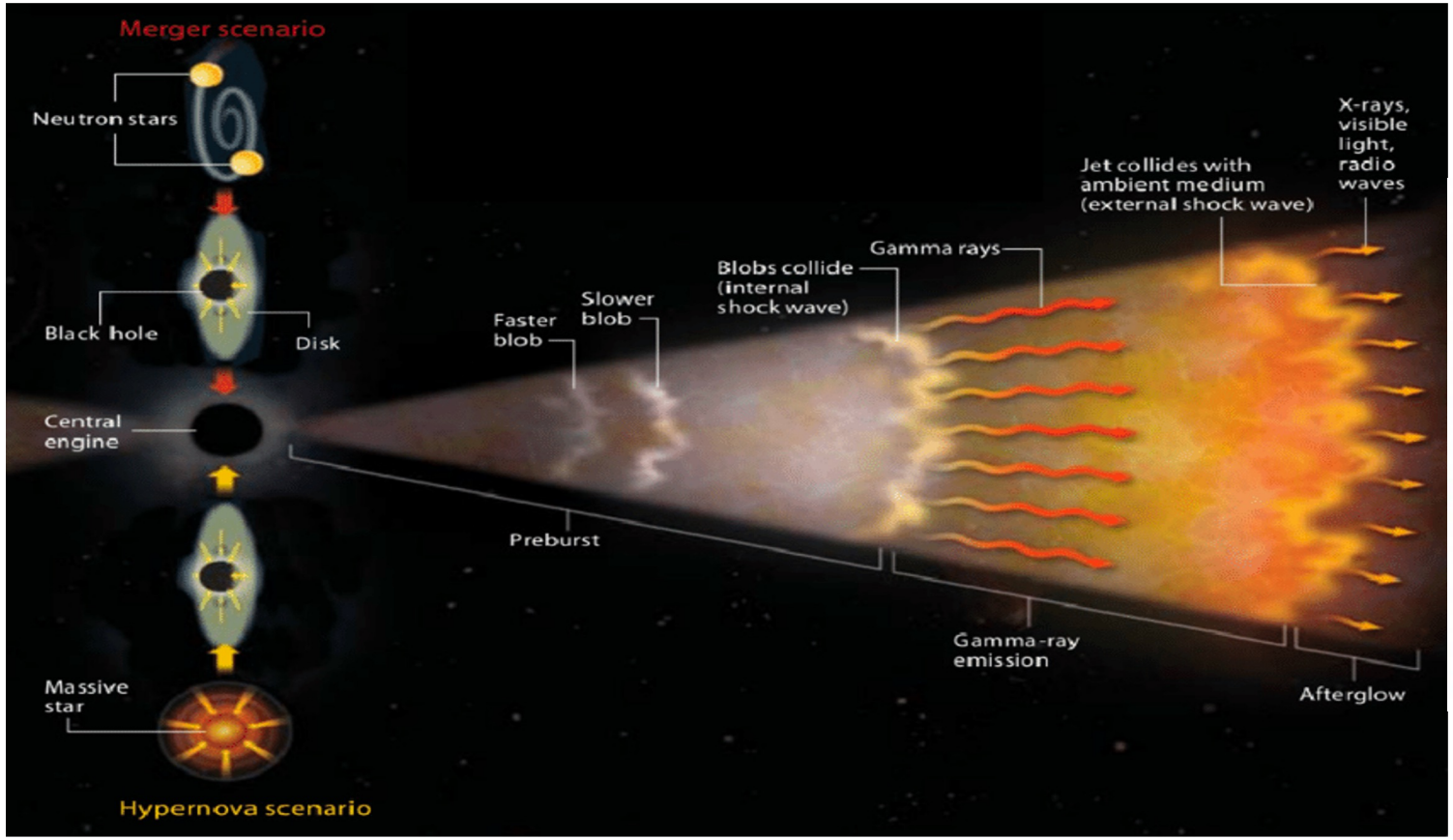
Outline:

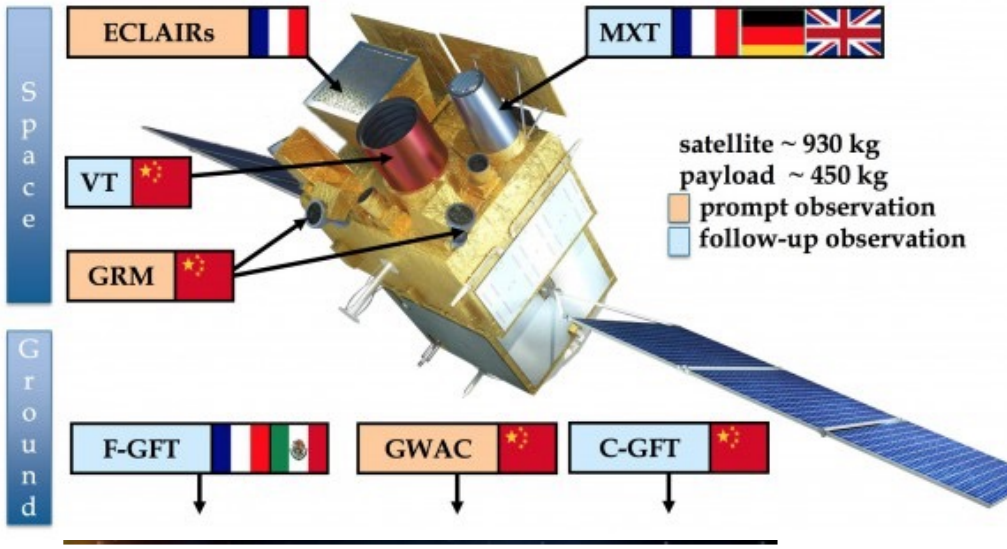
1. Gamma ray burst (GRB) and SVOM mission
2. **Study of the ECLAIRS detection plane inhomogeneity** in the low energy band and optimization for imaging performances
3. **Impact of heat-pipe noise on the ECLAIRs** detector plane and minimize the impact for performances
4. Summary

Gamma ray burst and SVOM mission



credit NASA

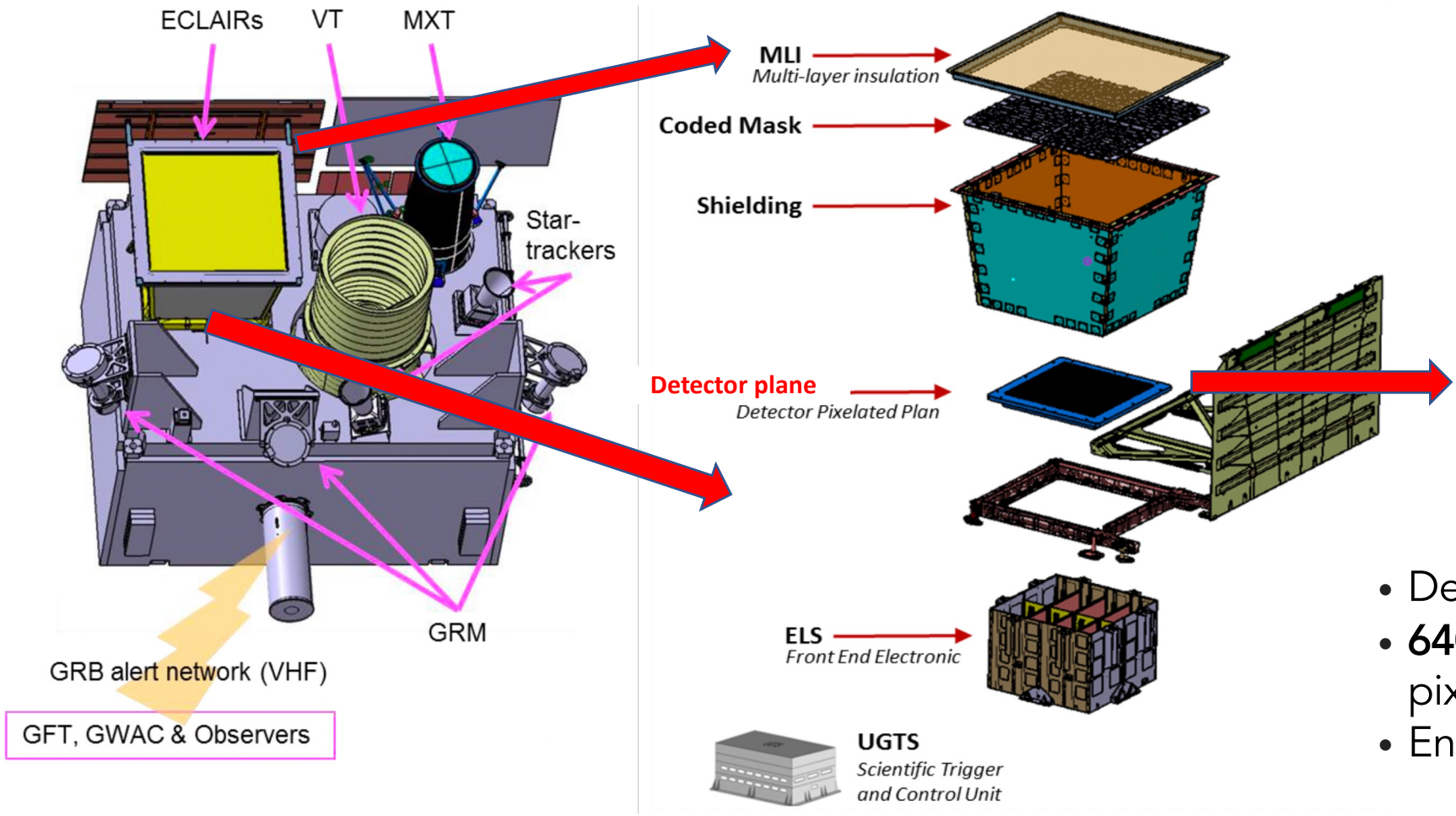
Thanks to the SVOM/ECLAIRs low energy threshold **at 4 keV**, we could detect a large fraction of X-ray rich and high redshift GRBs (with respect to Swift)

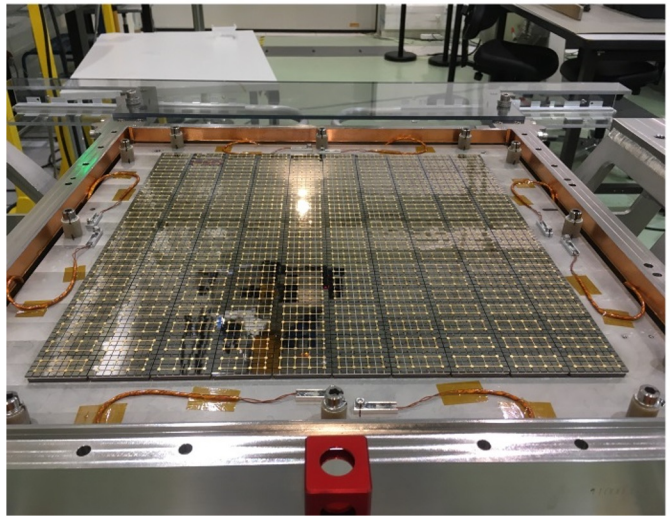


It is the first time to localise GRB prompt emission down to **4 keV**

https://www.svom.eu/en/the-svom-mission/

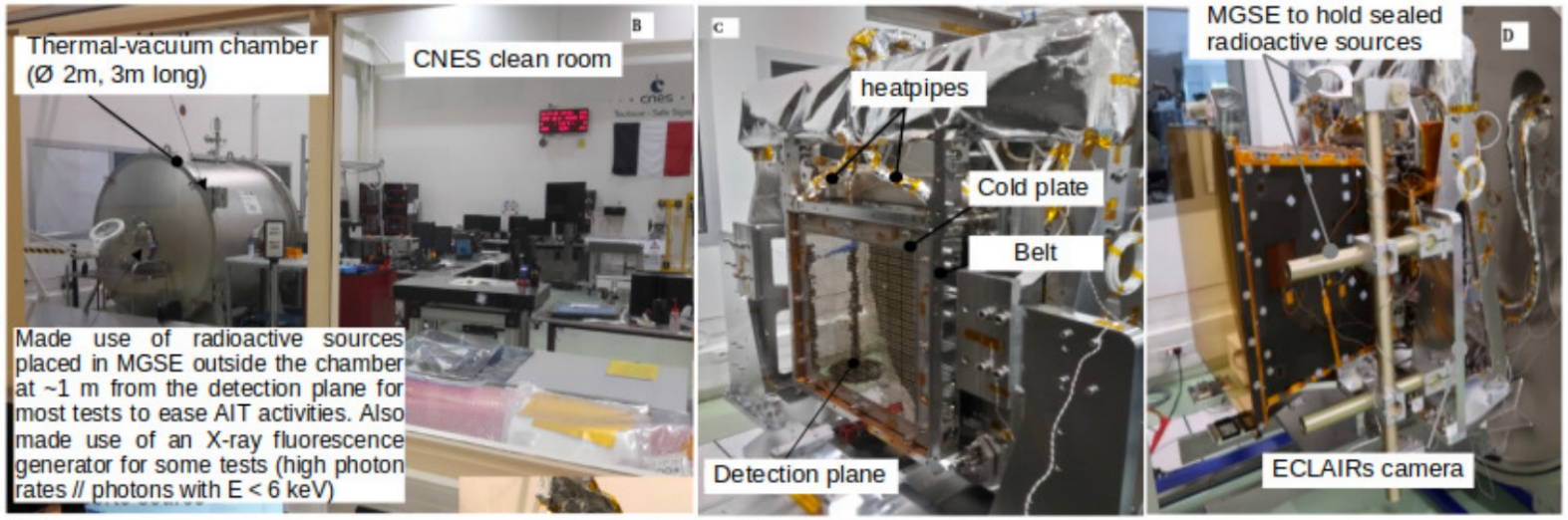
ECLAIRs detector plane and the tests in 2021

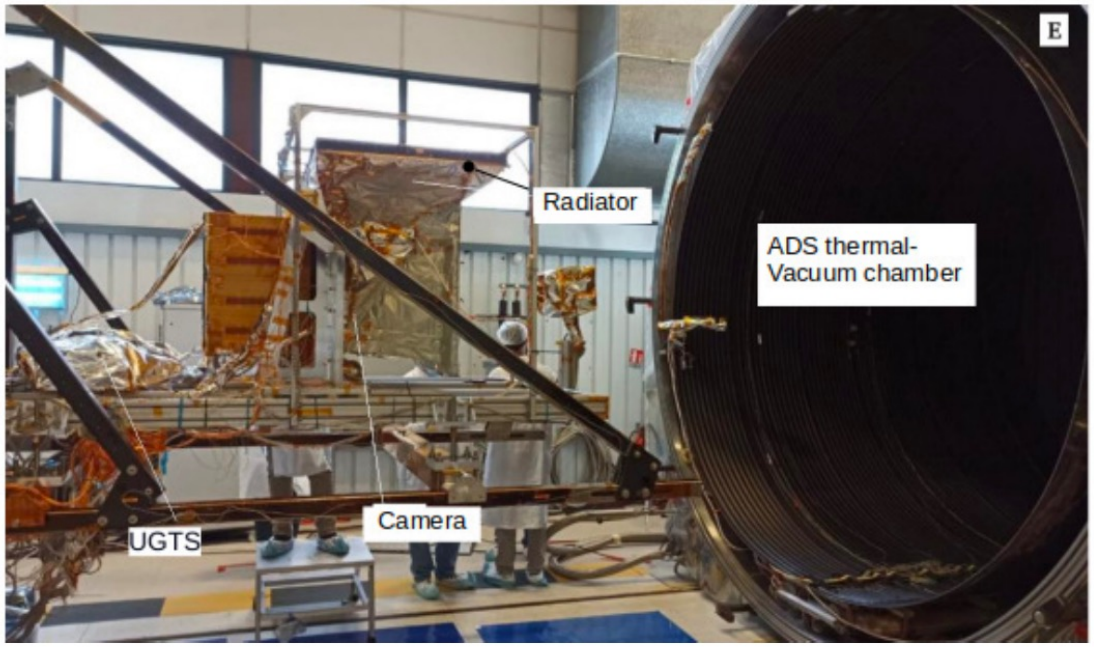


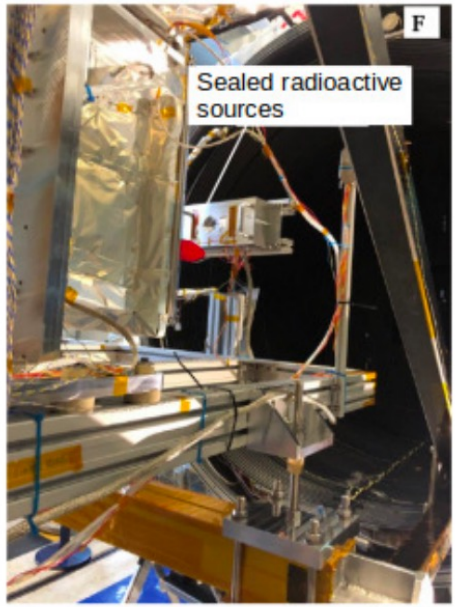


- Detection area: ~1000 cm²
- **6400 CdTe** (cadmium telluride) pixels (4x4x1 mm³)
- Energy range: **4 - 150** keV

ECLAIRs detector plane and the tests in 2021







2020.05
Assembly of the detection modules

2021.03
ECLAIRs calibration , down to 4 keV

2021.10
Thermal Vacuum Tests (TVAC)

2023.03
Sent to China assembly, integration

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Detector plane efficiency Inhomogeneity in the 4-8 keV band

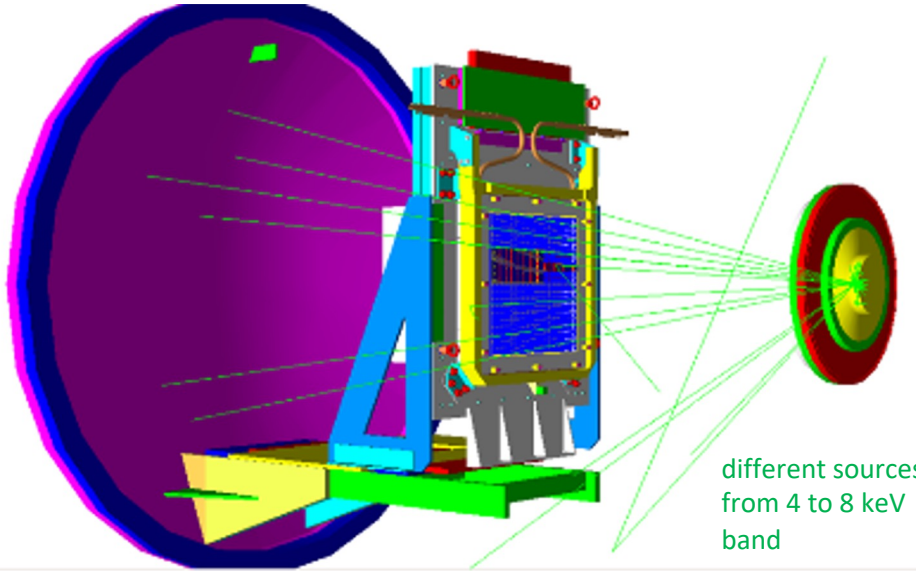
2021.03
ECLAIRs calibration down to 4 keV

We identify three families of pixels:

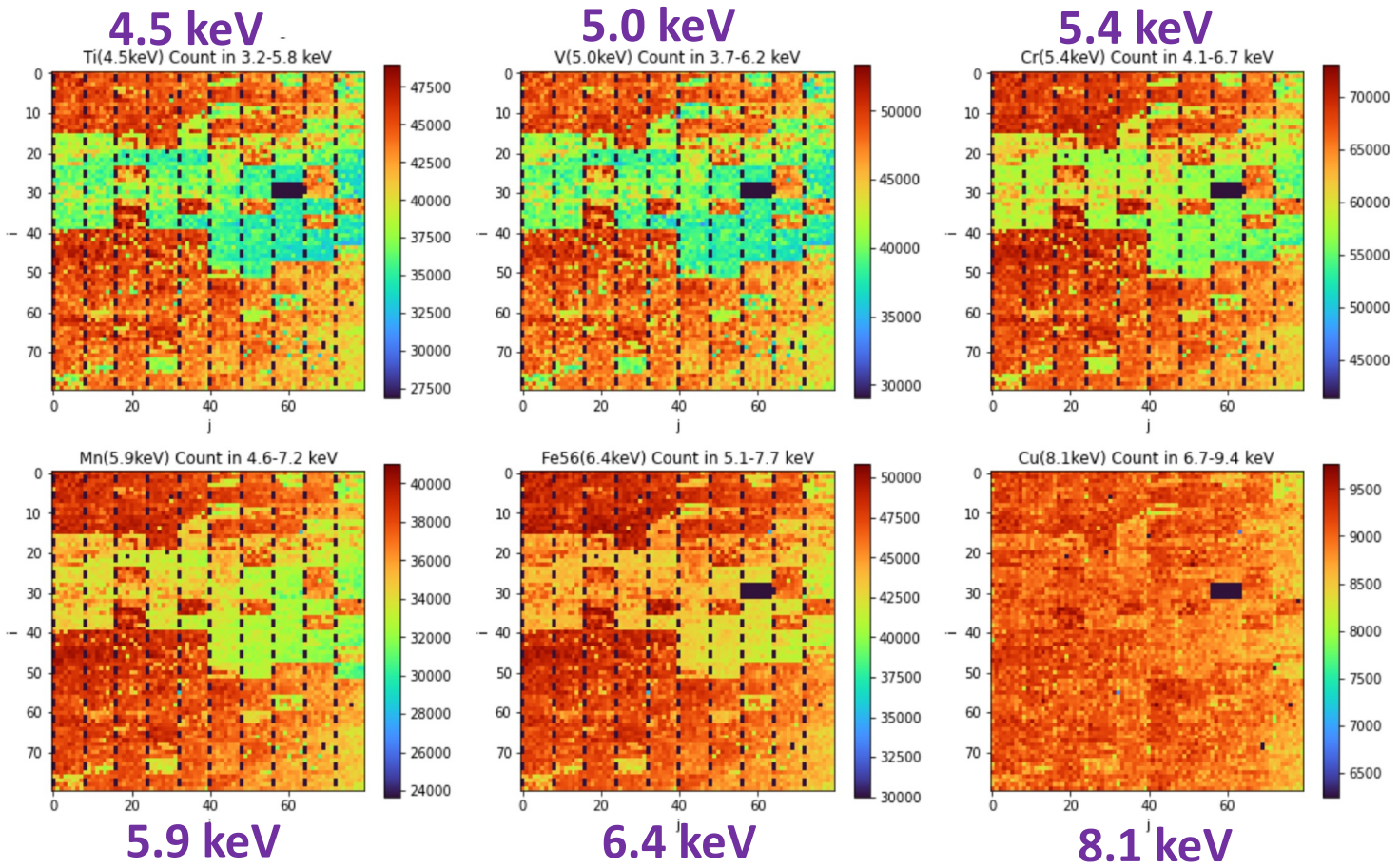
- High Threshold Pixels (HTP)
- Low Efficiency Pixels (LEP) + High Efficiency Pixels (HEP)

High threshold pixels (HTP): noise caused by cross-talk effects in the ASIC for pixel 8 and pixel 16 of each module.

Consequence: we raise the thresholds for these pixels -> efficiency = 0 in 4-8 keV band



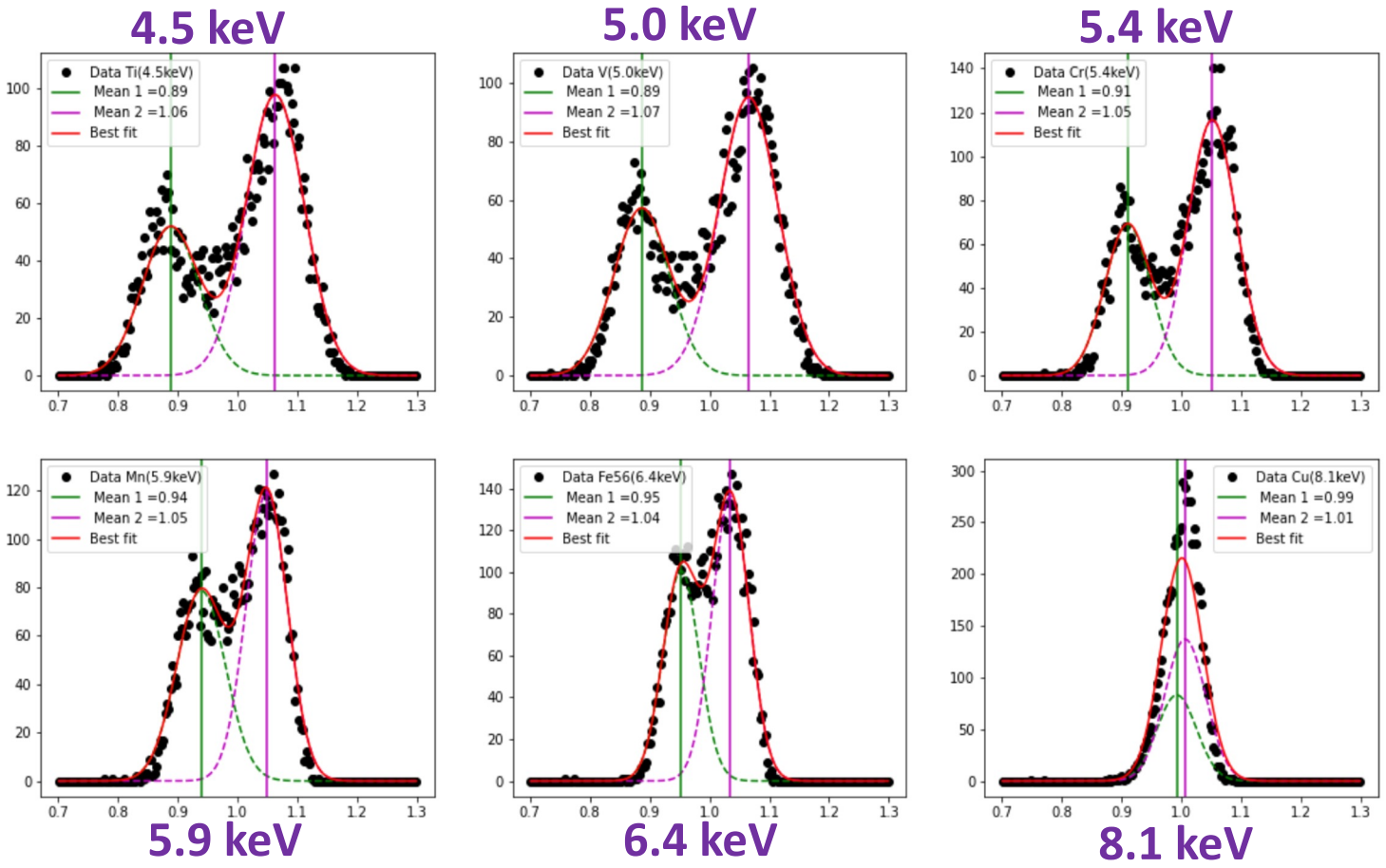
different sources from 4 to 8 keV band

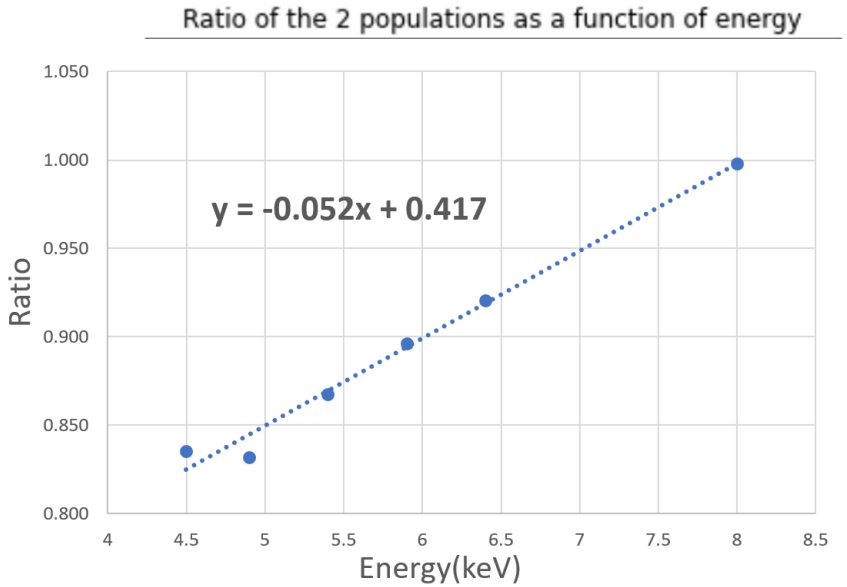


Colors indicates the different number of counts

Detector plane efficiency Inhomogeneity in the 4-8 keV band

Low Efficiency Pixels (LEP) and High Efficiency Pixels (HEP) relative count distribution in 4-8 keV band





The higher the energy, the smaller the gap, with a count ratio close to approximately 1 at 8 keV

The CdTe pixels of ECLAIRs are made at two different periods (2008 and 2016). The detectors that count less come from the 2016 batch.

Above 8 keV, the two pixel families have the same performance

Impact of efficiency Inhomogeneity on the ECLAIRs trigger threshold

ECLAIRs Trigger threshold = 6.5 * Std (SNR)

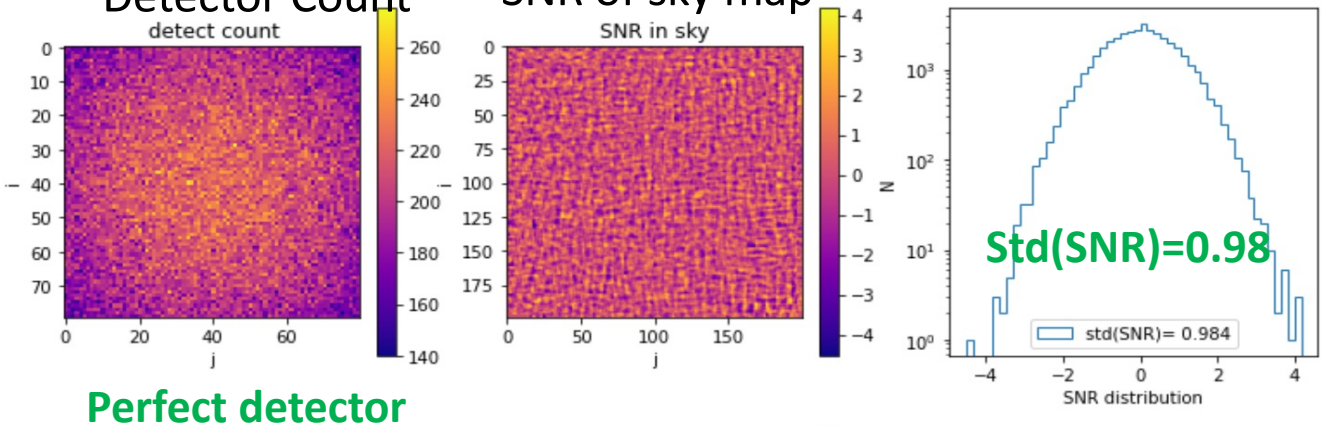
Std (SNR): standard deviation of signal noise ratio in sky map.

For SVOM/ECLAIRs, Ideal std (SNR) = 1

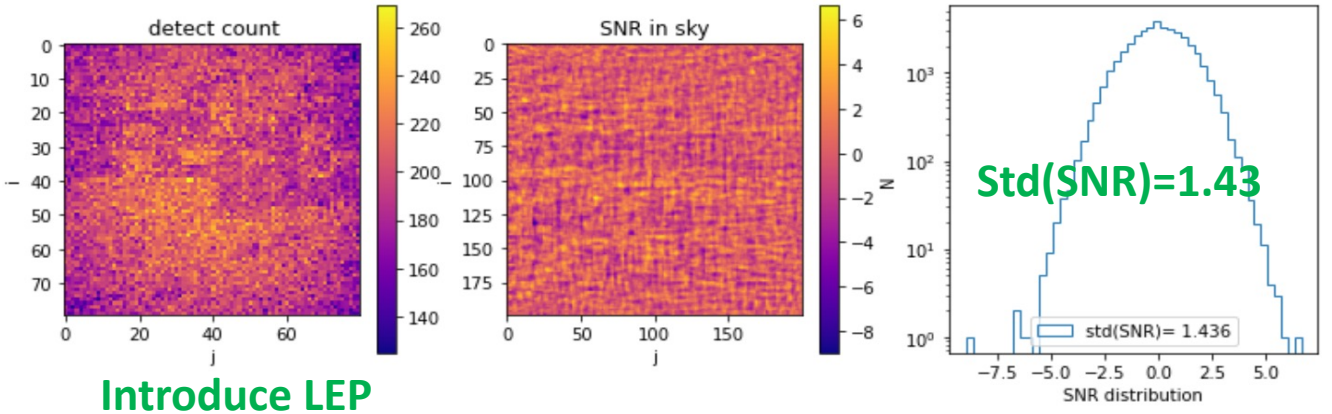
The trigger threshold will increase **5.8 times** after involving the Impact of LEP and HTP in **20 mins** observation in **4-8 keV**

Detector Count

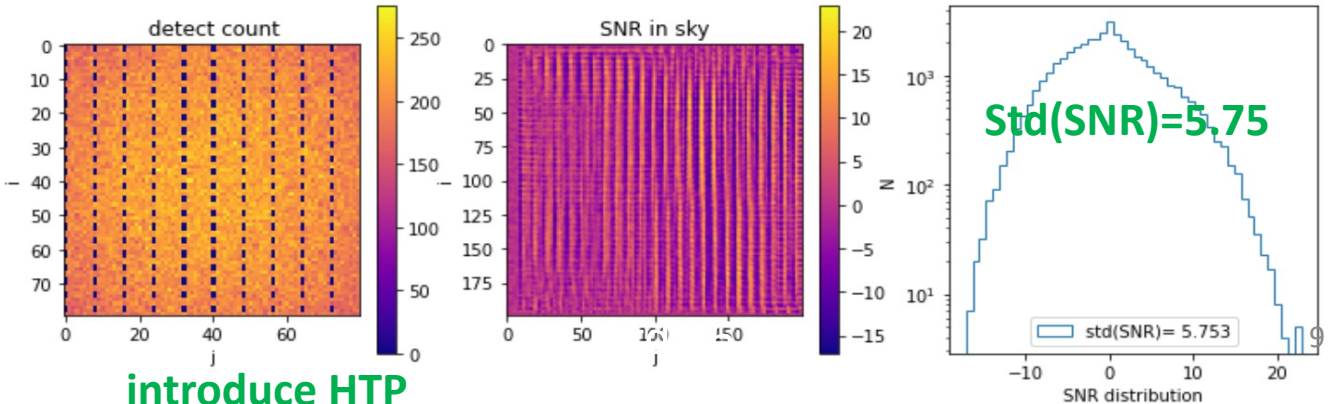
SNR of sky map



Perfect detector



Introduce LEP



introduce HTP

optimization for imaging performances

Solution for LEP and HTP

LEP: Make efficiency correction for LEP

HTP: Remove HTP during the CXB Fitting and deconvolution **(Ideal std (SNR) = 1)**

Background	Include effect	StdSNR without correction	StdSNR after correction
CXB	LEP	1.436	0.997
	HTP	5.753	0.997
	LEP and HTP	5.785	1.012
10× CXB	LEP	3.128	1.138
	HTP	16.059	1.035
	LEP and HTP	16.135	1.138

After applying the method to make corrections , the stdSNR could be decreased from 5.78 to ~ 1.01. The consequence is that the trigger threshold of ECLAIRs will increase a bit to avoid false trigger.

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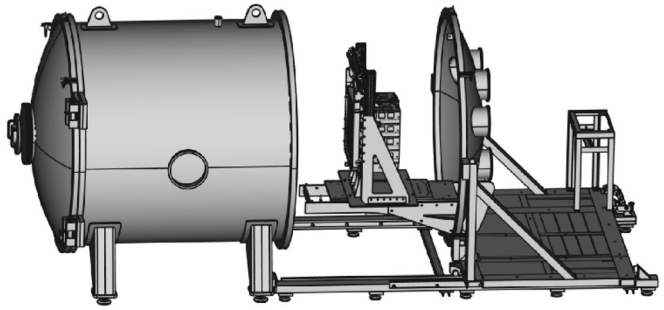
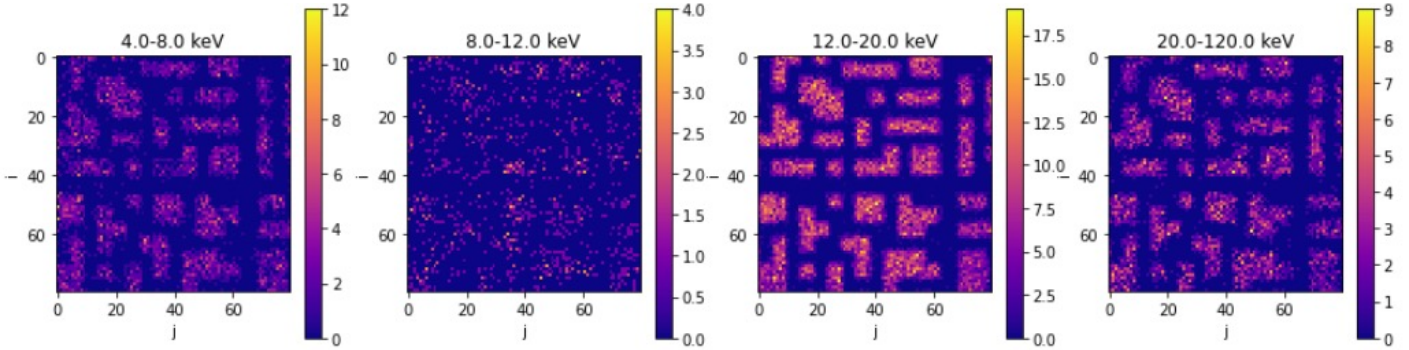
3. Impact of the heat-pipe noise in 4-8 keV

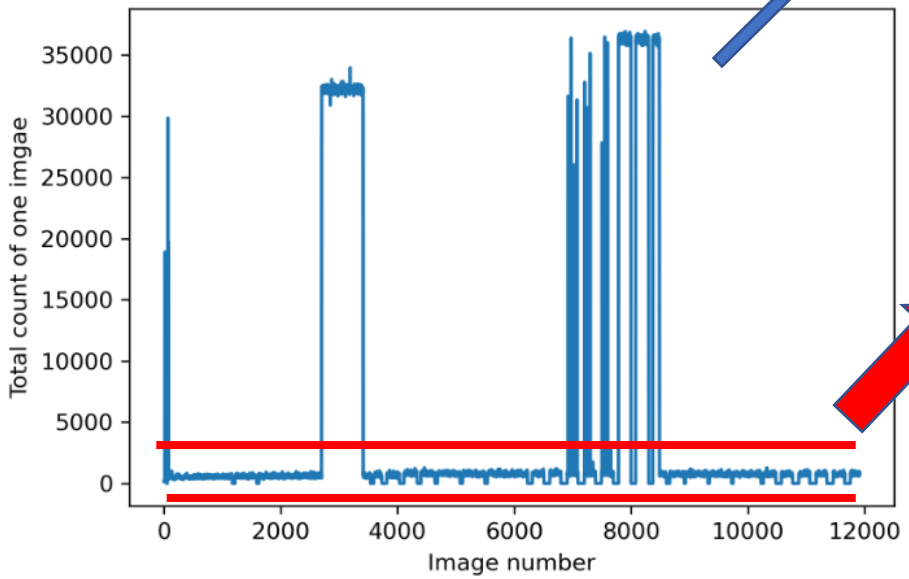
2021.10
Thermal Vacuum Tests (TVAC)



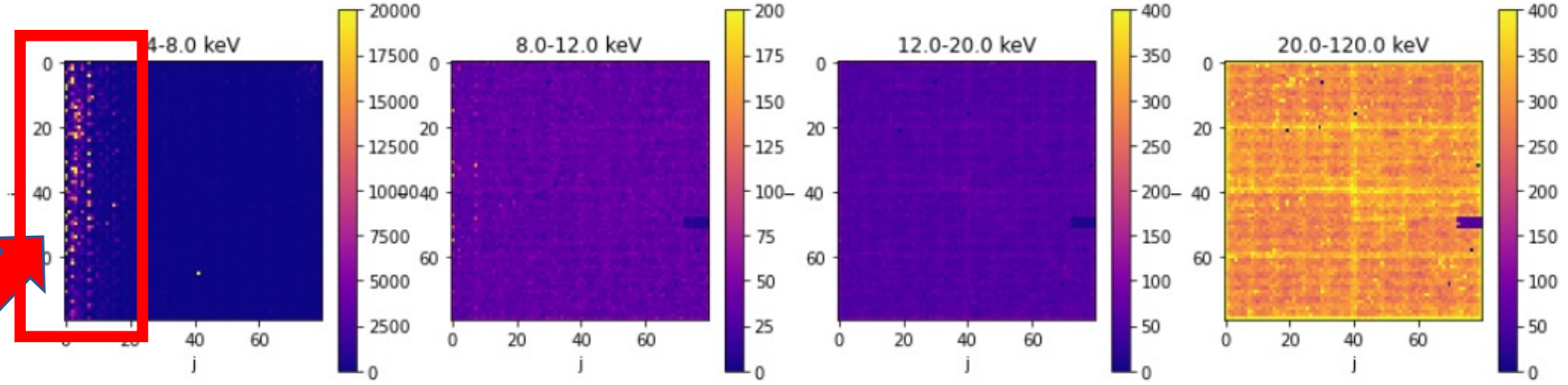
example of one image with source



We are interested in the images without source, only background.
Excluding the data with counts from the radioactive source (above) ,

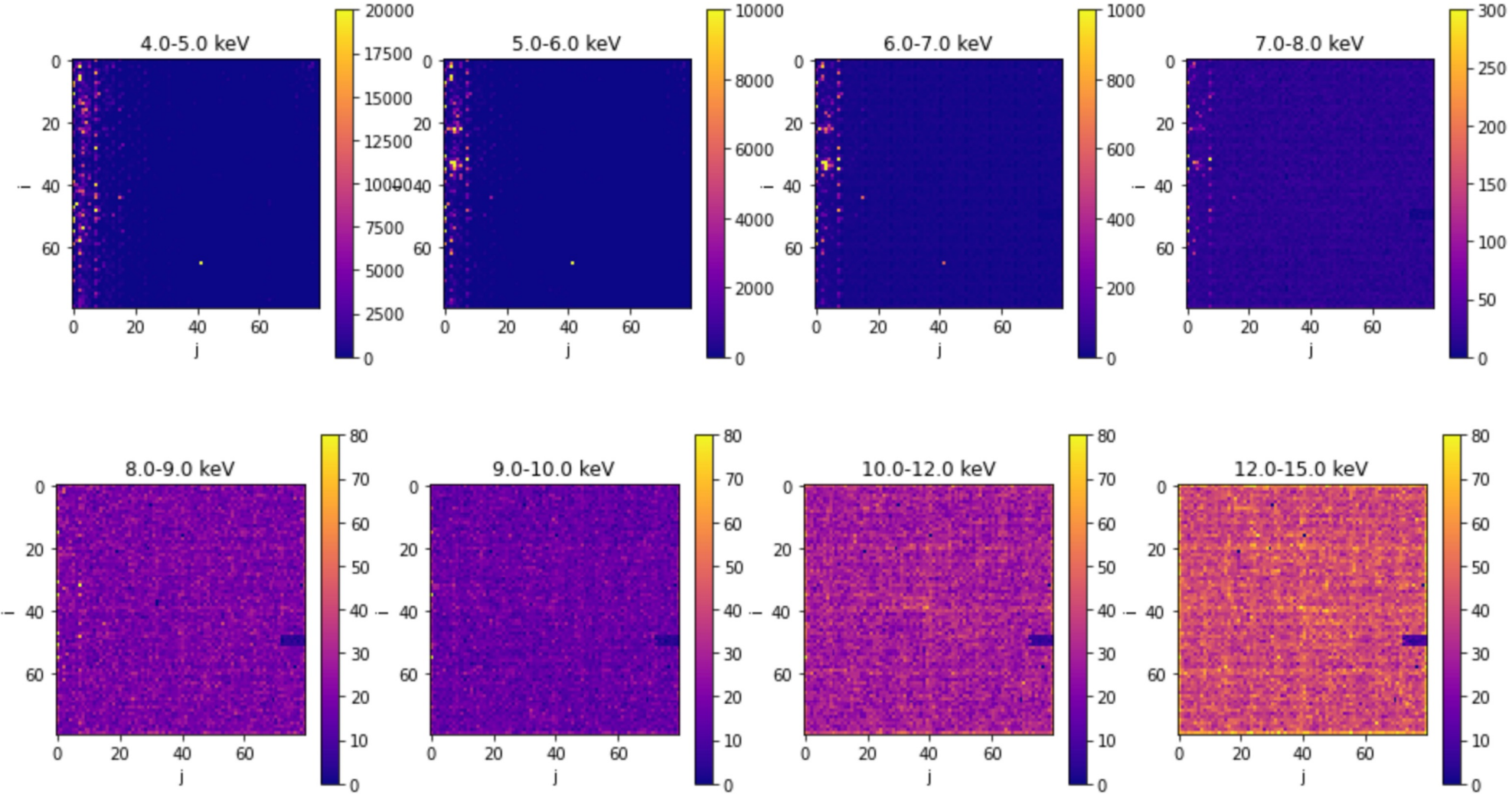


Extract the data with only background into 8800 images, each with 20.48 s.



Shadowgrams Integrated over the entire test period (8800 images)

Data analysis : 1.74 10^5 s data count in 1 keV energy bin



A noise called “heat-pipe noise” occurs mainly in **4-8 keV band.**

It seems to be related to the heat pipe operation.

Shadowgrams integrated over the entire test period (without the radioactive source)

Heat-pipe noise impact on count rate trigger in 4-8 keV

The impact mainly include:

1. Increase the trigger threshold (ECLAIRs Trigger threshold = 6.5 * Std SNR)

2. Make false trigger

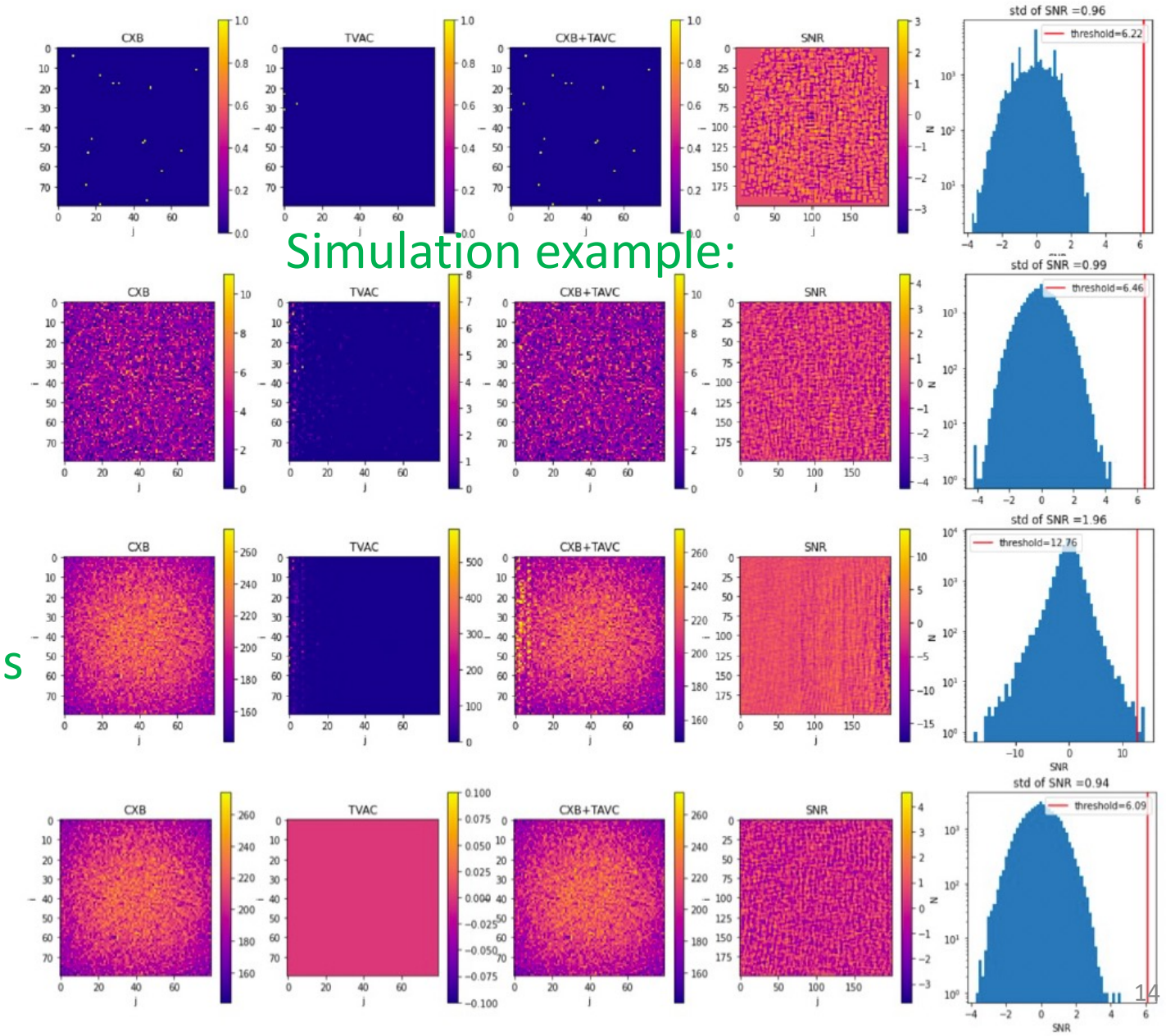
0.01 s

20 s

20 mins

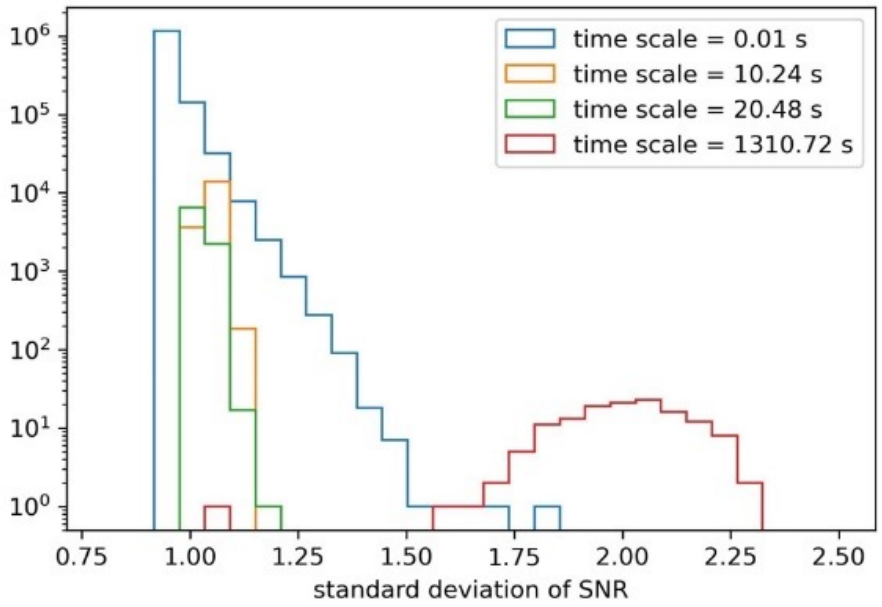
20 mins without noise

Simulation example:



Heat-pipe noise impact on count rate trigger in 4-8 keV

Increase the trigger threshold (left) and make false trigger onboard (right)

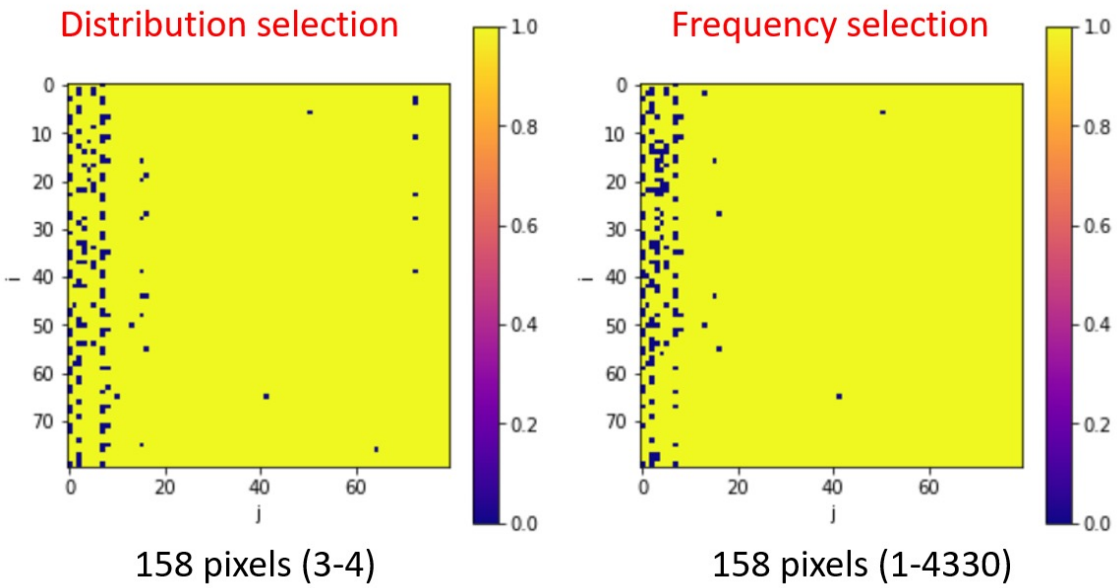


Timescale (s)	20.48	40.96	81.92	163.84	327.68	655.36	1310.72
4-8 keV	0.091% (8/8750)	0.069% (3/4352)	0.092% (2/2170)	0% (0/1084)	2.399% (13/542)	60.886% (165/271)	**99.259% (134/135)**
4-120 keV	0.126% (11/8750)	0% (0/4352)	0% (0/2170)	0% (0/1084)	0% (0/542)	0% (0/271)	**4.444% (6/135)**

Trigger threshold = 6.5 StdSNR

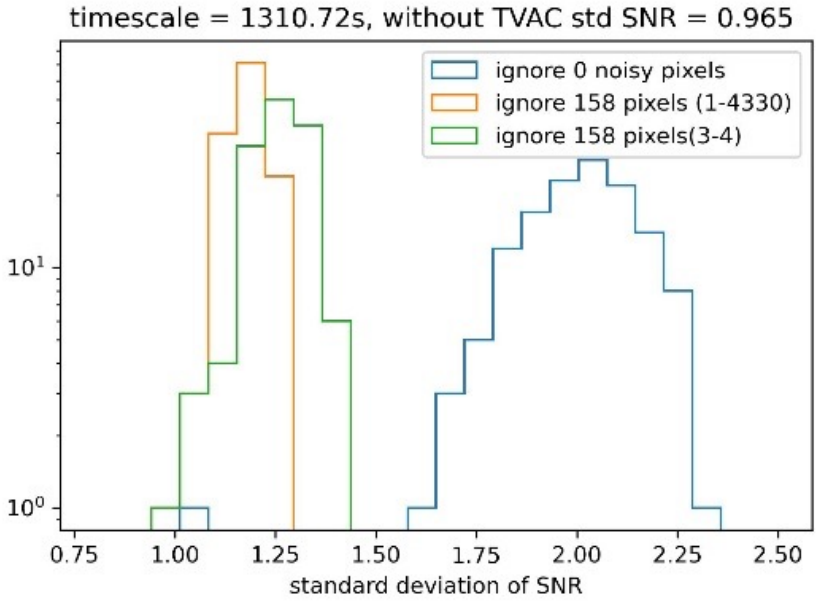
We make the simulation combining the TVAC data : 1.74 x 10^5 s.
The impact of heat-pipe noise mainly in long time observation.

Select the noise pixels and ignore its data



158 pixels (3-4)

158 pixels (1-4330)

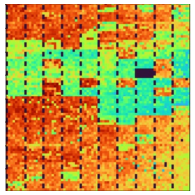
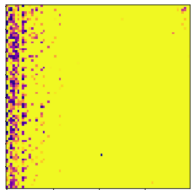


Two different selections for different timescales.

After removing the selected noise pixels (2.5 % of total pixels) :

1. **The False trigger rate = 0**
2. **Trigger threshold value decreases** from ~100% to **20%** (From double to 1.2 times)

Summary

- Inhomogeneity 
  - We investigate the effect of the Low Efficient Pixels (LEP), High Threshold Pixels(HTP) on the image triggering algorithm. **This inhomogeneity appears in 4-8 keV**.
  - The impact of HTP can be cancelled by ignoring pixels counts during the CXB subtraction and deconvolution. The impact of LEP can be reduced by applying a count correction
- Heat-pipe noise 
  - The **heat-pipes noise occurs in the 4-8 keV band**.
  - heat-pipe noise would raise the trigger threshold up to 100 % for 20 mins observation (image trigger) and generate false trigger (4.44%)
  - The heat-pipe noise could be reduced by **removing pixels that have noisy behavior. By choosing a loss of 2.5 % of identified noisy pixels.** the trigger threshold could be reduced to an increase ~20 % in 20 minutes detection, and avoid a False trigger.

Thank you!

Comments and questions are welcome

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