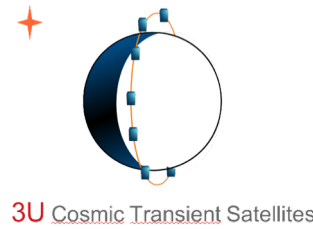


Monitoring the transient hard X-ray sky with 3UTranSat

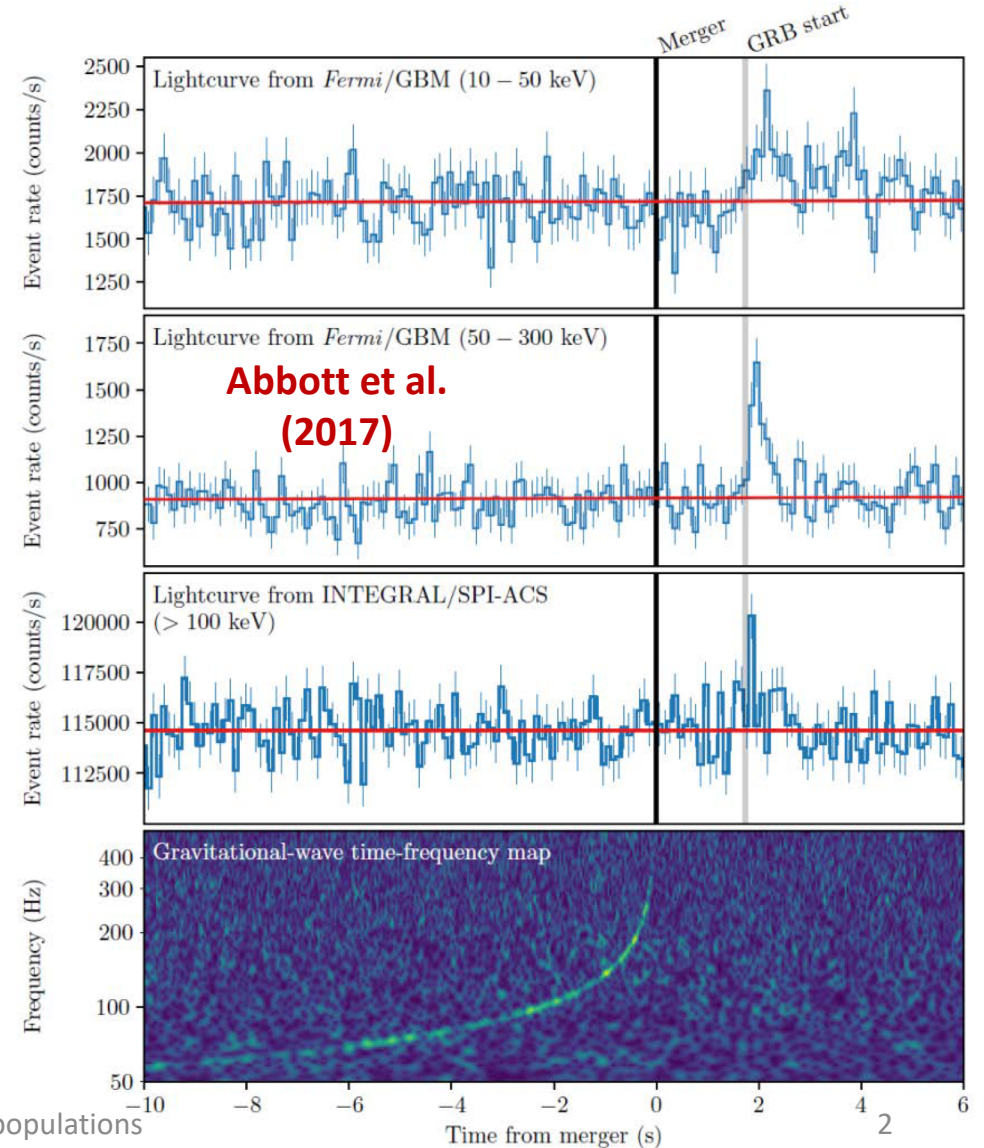
O. Godet, J.-L. Atteia, D. Barret, L. Bouchet, G. Orttner
(IRAP)

A. Laurens, F. Estève, I. Valenzuela
(CNES)

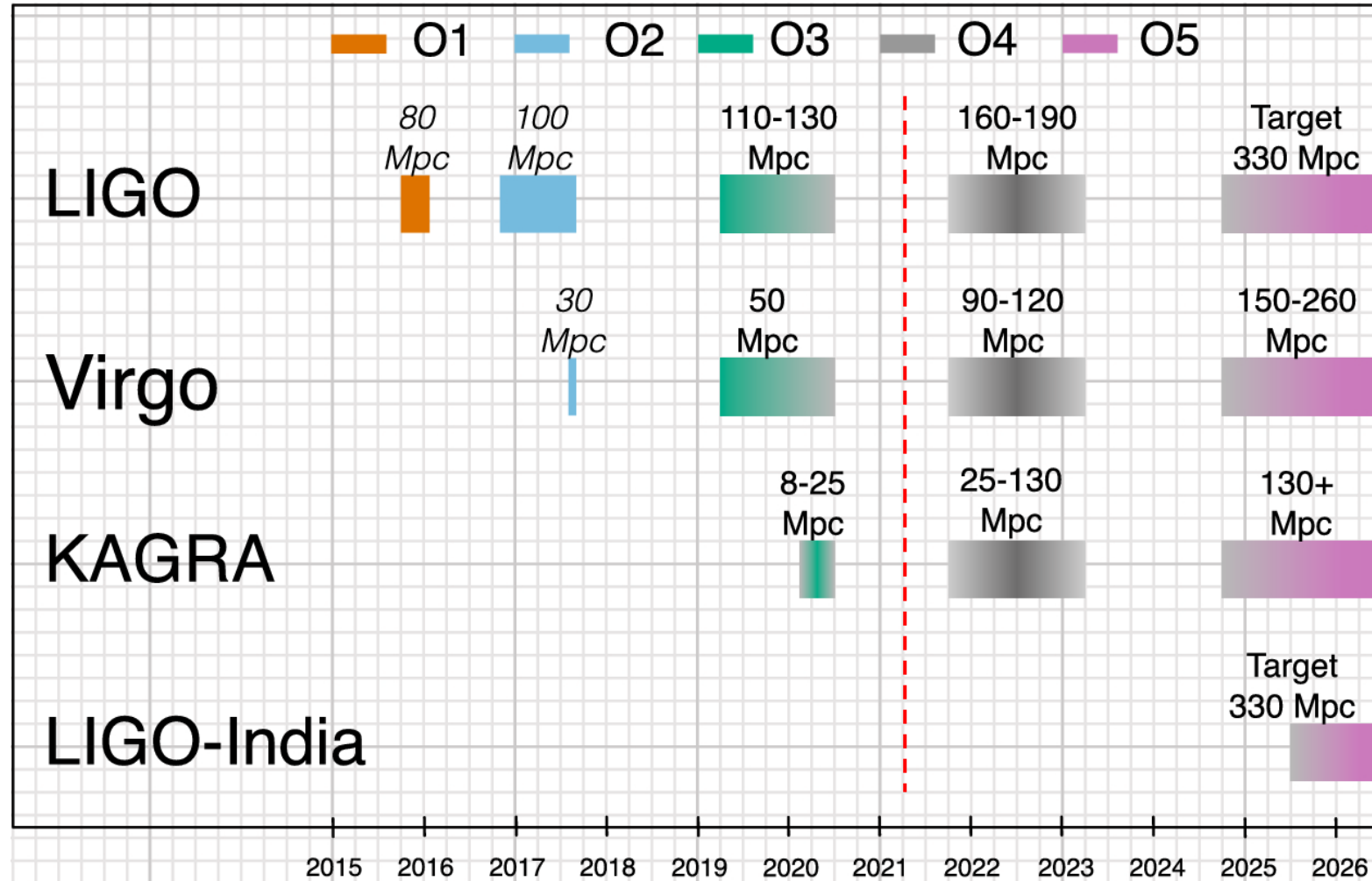
GW170817 & GRB 170817A



- BNS merger detected simultaneously in GWs and hard X-rays!
 - This has permitted extensive multi-WL followup and crucial steps in our understanding of these events.
 - Strong impact on fundamental physics, stellar evolution, chemical enrichment of galaxies, etc.
- BUT... this remains a unique event
- How can we improve the situation in the future?



The future of GW detection (on Earth)



Abbott et al. 2020

« Prospects for observing and localizing gravitational-wave transients with Advanced LIGO, Advanced Virgo and KAGRA »

GRB 170817A in hard X-rays

- GRB 170817A was a nearby event ($D = 40$ Mpc), seen off-axis ($\approx 20^\circ$).
- The closest Short/Hard GRBs seen on-axis are 10 times more distant \rightarrow GRB 170817A was a rare opportunity!
- The detection of more GRBs coincident with GWs calls for more sensitive GRB detectors to detect events like GRB 170817A at larger distances

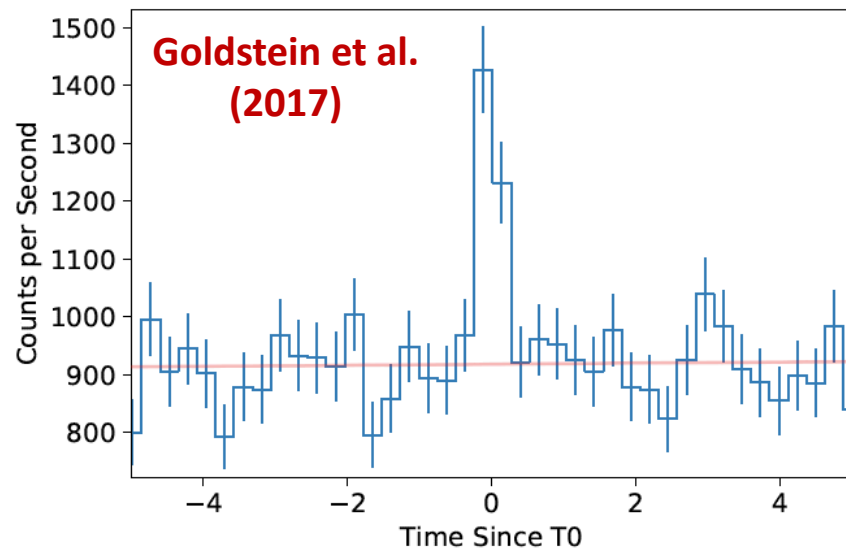
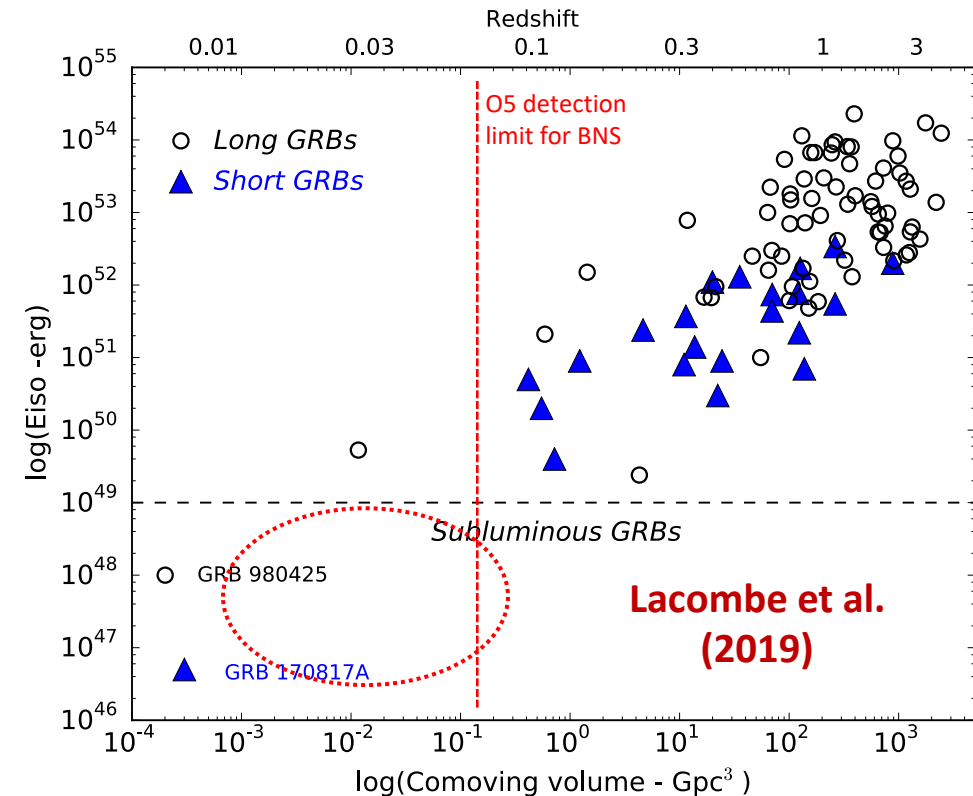


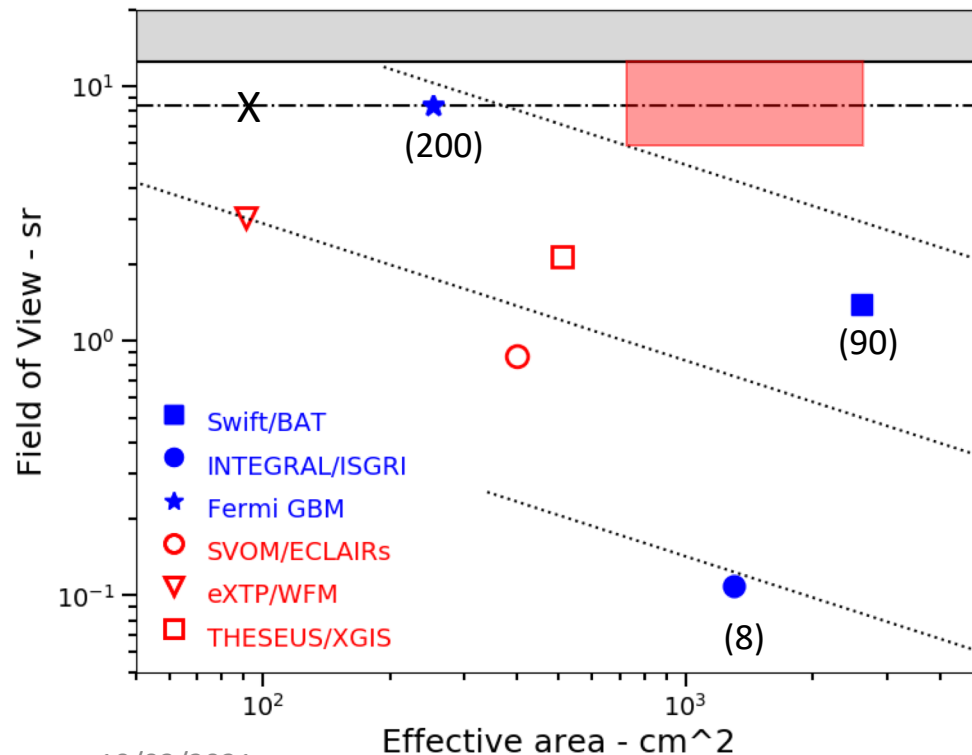
Figure 1. The 256 ms binned lightcurve of GRB 170817A in the 50–300 keV band for NaIs 1, 2, and 5. The red band is the un-binned Poisson maximum likelihood estimate of the background.



The future of GRB detection (in space)

Field_of_View vs Effective_Area of current and future GRB missions.

- The numbers show the average number of detected GRB/yr
- The dotted lines indicate roughly constant GRB detection rates



10/03/2021

- In order to increase the rate of coincidences, we need:
 - GRB detectors more sensitive than Fermi GBM
 - All sky
- This is the red zone

However...

- There is no planned large mission fulfilling these requirements.
- Several cubesat projects aim at performing all sky survey for GRB detection, but individually they are not sensitive enough (X symbol).

What is needed?

- We need few $\geq 10^3$ cm² looking at the whole sky permanently.
- How to achieve it?
 - Large missions are rare and expensive, they are usually designed to be very sensitive in a small field of view. There is no such mission planned for the moment.
 - Small instruments lack of sensitivity, but there are several proposals to send 1 or many cubesats in space to monitor the hard X-ray sky: *Hermes*, *Camelot*, *BurstCube*, *GRID*, *EIRsat-1*, etc.

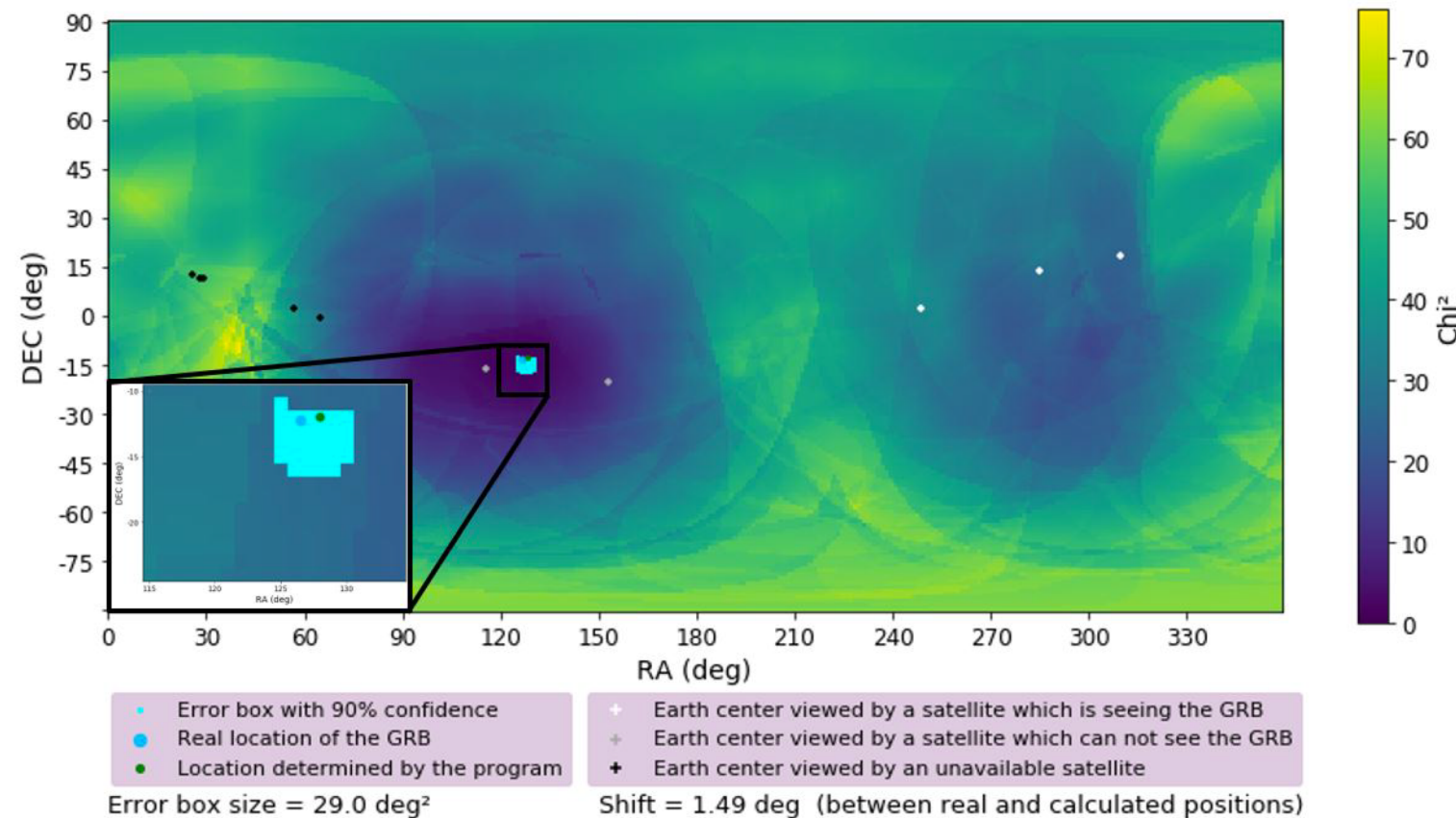
==> It is crucial to combine on the ground all the square cm² of high-energy detector in space for all-sky high-energy transient detection!

(see also Hurley et al. 2020, ApJ, 905, 82)

Detection & localization

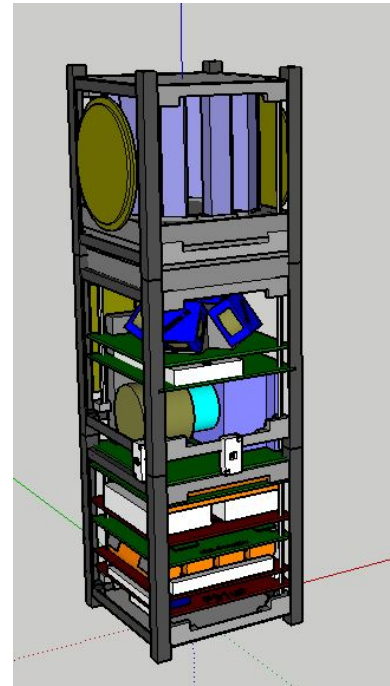
- **Detection:** For each sky position, we combine the signals of the detectors which look at it, searching for an excess.
- **Localization:** when an excess is detected, its position can be calculated by comparing the counts measured on each detector with the counts expected from a given position. Additional information may be used, like the time delay between satellite for very bright GRBs.
- This strategy requires data with good time resolution (typically 0.1 to 1 s) available within 1 or few hours.

Sky-map of χ^2 for GRB 190727B, Case 1



The 3U TranSat Project

- **3U** cosmic **Transient Satellite**
- Building upon the experience of IRAP in the field of GRB detection from space, we propose the 3UTranSat project *as a contribution to the construction of a future network of cubesats monitoring the hard X-ray sky*:
 - Add several 100 cm² of hard X-ray detectors in space.
 - Test the proposed strategy for detection and localization.
 - Contribute to an international collaborative effort to use all resources available in space for GRB detection.
 - ...
- Main characteristics:
 - Cubesats with several (≈ 10) detectors made of a Scintillator + SiPM
 - Rough (few degrees) 1D localization capability
 - All data send to the ground with short lag (0-90 min)
 - Detection and localization performed on the ground as soon as data become available
- Two steps:
 - A prototype made of three cubesats, **ready for O5**
 - An extension TBD: focused on the space segment (more cubesats) or on the ground segment (combining heterogeneous data) or both.

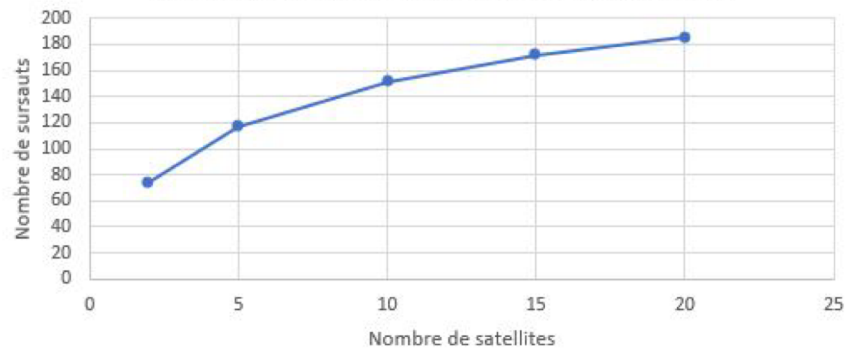


Status of the project

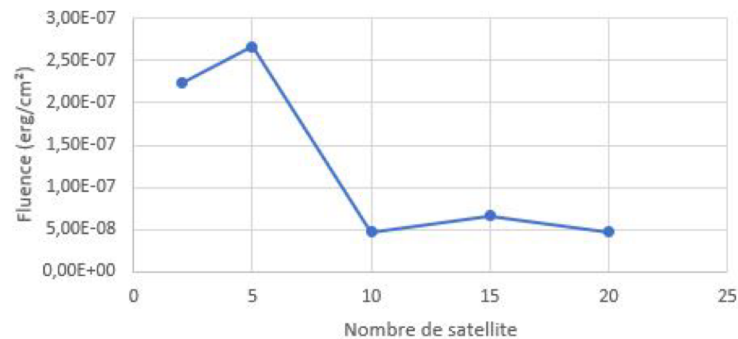
- The project is currently in phase 0 study at CNES and IRAP, various on-going studies concern the following points:
 - Mission scenario
 - Platform services and architecture
 - Payload design & performance: energy range, geometry, background, sensitivity, localization capability, radiation hardness, data rate etc.
 - Scientific performance & simulations: detection, sky reconstruction
 - This phase will end this fall.
- We are exploring various ways to finance the project.

- We have developed a complete software suite to assess the performance of various constellations of cubesats. This software takes into account various geometries, background and sensitivity computation, several input GRB catalogs, the reconstruction of sky images, etc.
- As an example, we show below the impact of the number of satellites in the constellation on various parameters. *From left to right:* Number of GRB detected, minimal fluence of detected GRBs and median of the error box area (with a large dispersion).

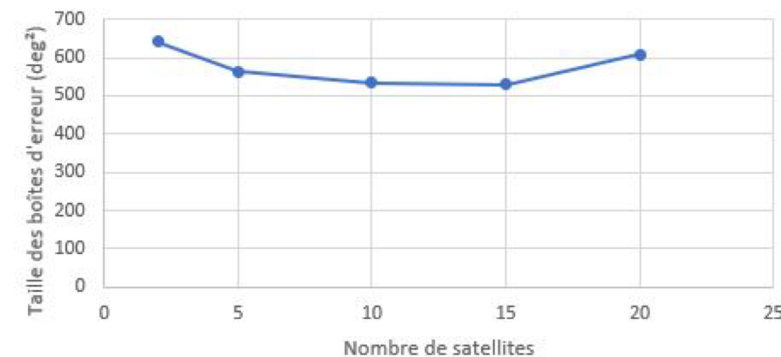
Moyenne du nombre de sursauts détectés sur les 300 en entrée en fonction du nombre de satellites



Moyenne de la fluence minimale détectée en fonction du nombre de satellites



Moyenne des 3 médianes des tailles des boîtes d'erreur en fonction du nombre de satellites



Perspectives

- A publication describing the project is in preparation.
 - This will serve as a basis to contact other groups proposing cubesats monitoring the hard X-ray sky, to study possible collaborations on the ground.
- We want to launch a prototype mission with three cubesats operating during O5.
- The strategy for the recombination of heterogeneous data on Earth will be tested in real conditions with 3UTranSat and the Gamma-Ray Monitor (GRM) of *SVOM* (*SVOM* will be launched in 2022), plus other willing cubesat projects.
- Contacts : O. Godet (PI) or J.-L. Atteia