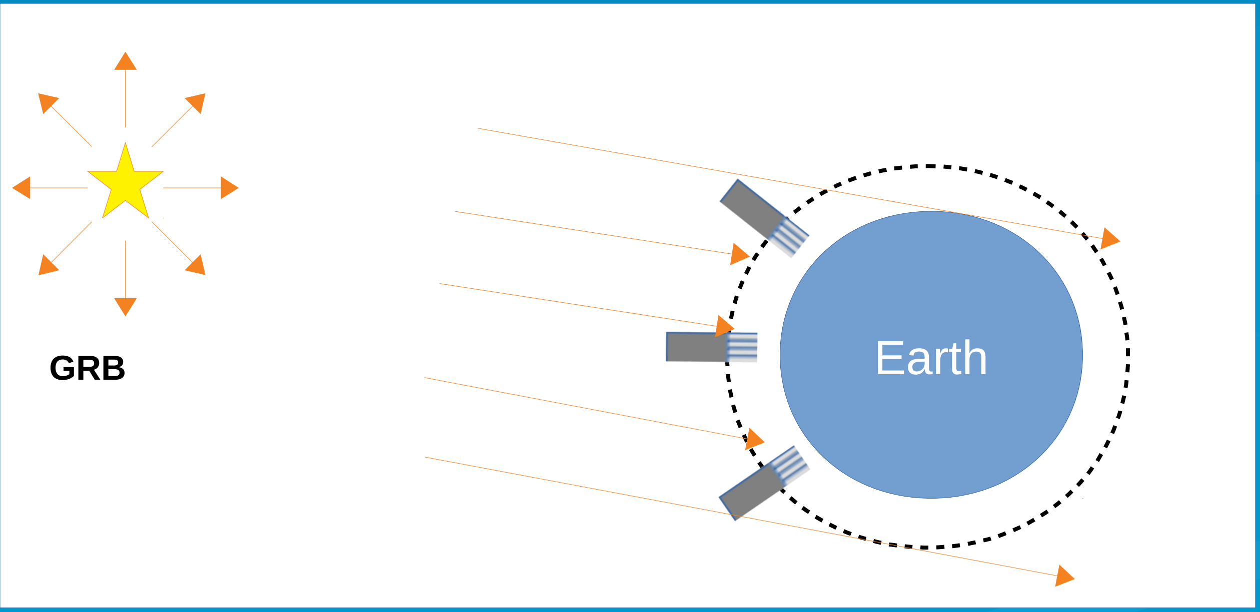
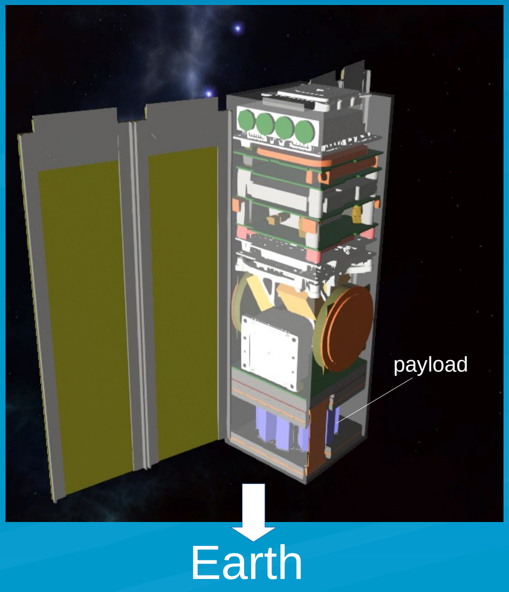
3U Transat

Nanosatellite constellations paving the way to multi-messenger astronomy





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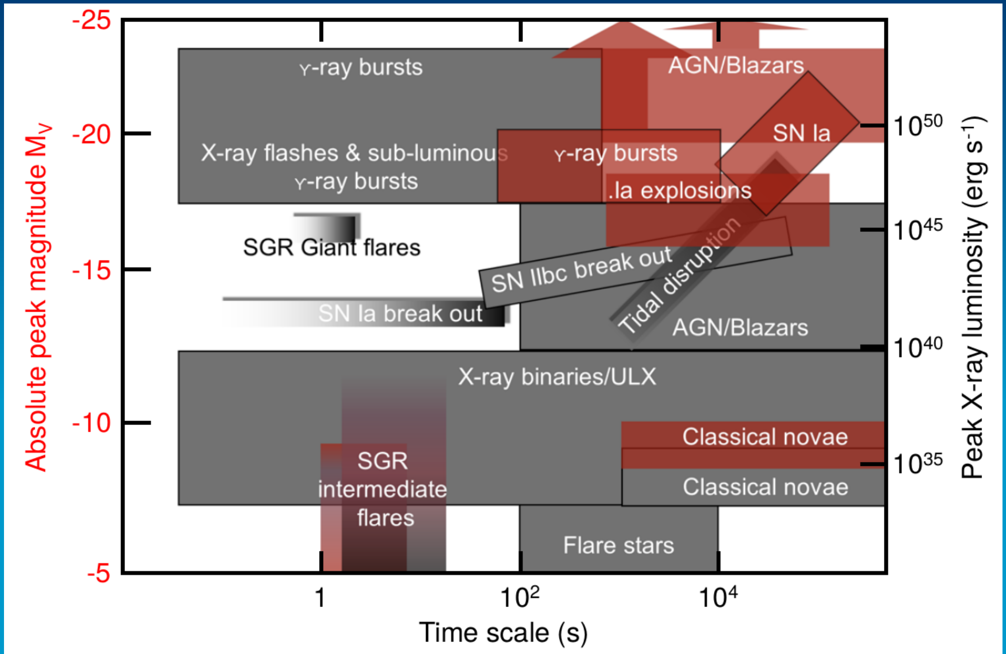
Collaborators: Jean-Luc Atteia, Didier Barret, Laurent Bouchet, Jean-Pascal Dezalay, Guillaume Orttner (project manager), Roger Pons and CNES colleagues

From time-domain astronomy …



- Often imply the birth, destruction or feeding of compact objects (stellar mass BHs, supermassive BHs, NS & WD)
- Deep radiative and mechanical feedback on the surroundings on multiple scales
- Very energetic and violent phenomena releasing huge amount of energy in various forms (EM, neutrinos, GW, …)
- Linked with multi-messenger astronomy!

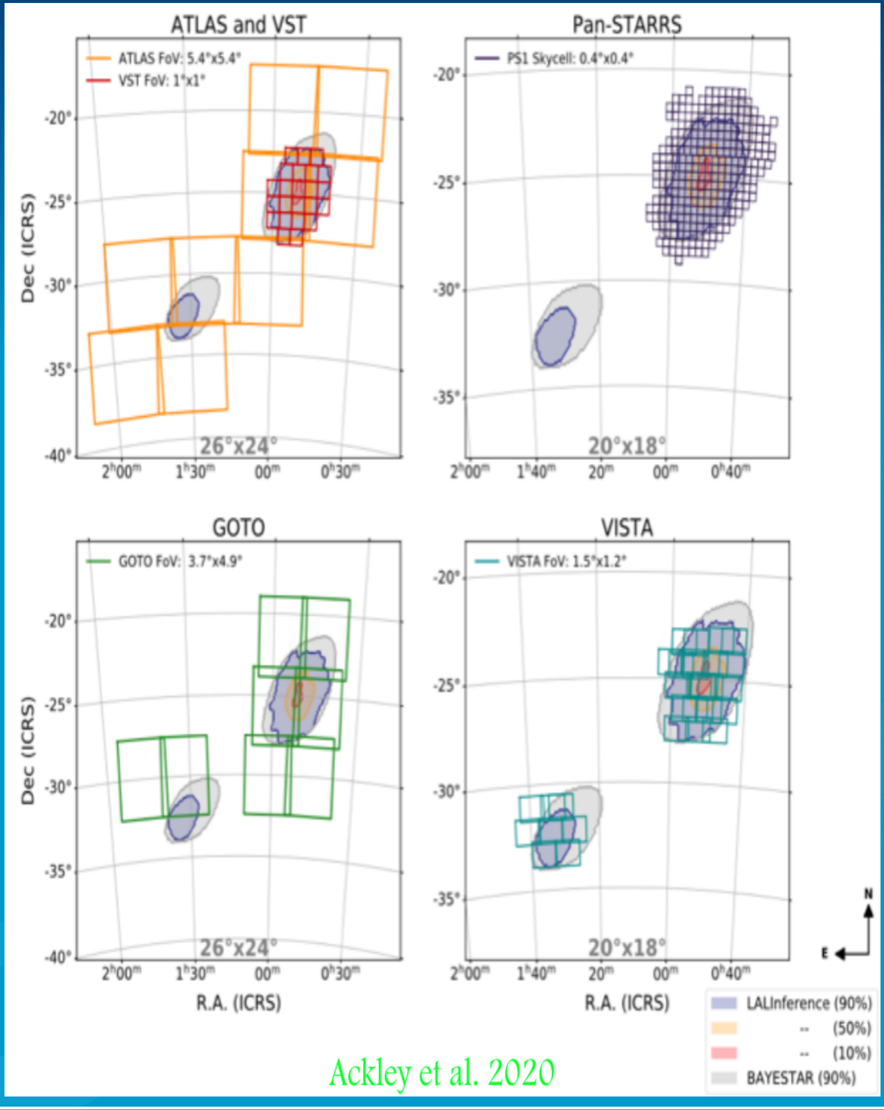
⇒ Role of compact objects in the structuration of matter in the Universe

- Demography of COs over cosmological timescales
- Growth of supermassive BHs / co-evolution with host galaxy
- Reprocessing of baryons / r-process nucleosynthesis
- Relativistic jet & wind physics

⇒ Make use of some of these objects as cosmological probes and to test fundamental physics

… To multi-messenger astronomy

- The advent of more sensitive neutrinos (IceCube, KM3Net) & gravitational (LVK, LISA, ET/CE) detectors opens a new window on the Universe!
- **These MM facilities survey all the sky all time**.
- They provide source localization of dozen – hundred of sq. deg or even larger
- EM ground segment (in particular in nIR/optical) now gathers wide-field instrumentation (+ observing strategies) enabled to probe rapidly such large error boxes. Even so, it is still challenging!



Ackley et al. 2020

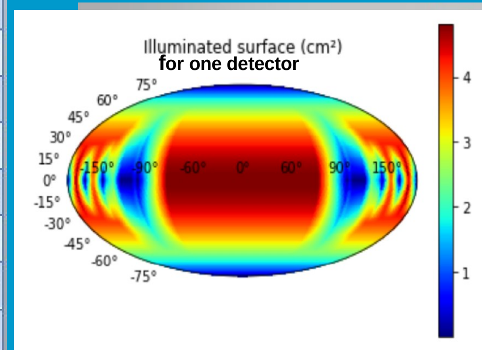
IRAP ambitions in this context

- **Development of innovative instrumentation in hard X-rays required to survey the transient sky (all-sky, good sensivitiy and all-time) in synergy with MM facilities**
- Future missions in the 2030s: one large mission, several small missions, **cubesat constellations** (several demonstrators under study, some in space)?
- **It is where the 3U cosmic TRANsient SATellites project comes along.**
  - **Building on the IRAP experience in the field of GRB detection from space**
  - **Goals:**
    - **Build an expertise in using scintillators coupled to SiPM for space HE applications**,
    - **Test a new strategy for detection and localization by keeping it simple,**
    - **Contribute to an international collaborative effort to combine all resources available in space for GRB/HE transient detection** (e.g. **by developping/being part of a collaborative ground segment**)
- **First step: Launch a demonstrator made of 3 clone satellites to be operated during the Ligo / Virgo KAGRA O5 run (2026) – work with SVOM & other nano/small sat. missions**
- **Mission duration: > 1 yr**

3U TRANSAT in a nutshell

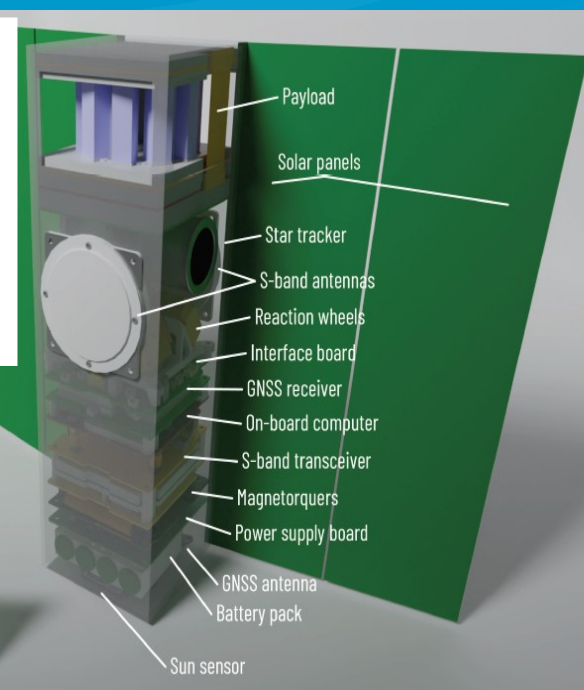
- **Project main characteristics/science drivers:**
  - **3U configuration**: 2U for the « high-performance » platform and 1U-ish for the science payload
  - Opportunist launch ⇒ SSO orbit (~90 min LEO polar orbits)
  - **All data measured in 4 energy bands** transmitted through S-band every orbit **to be processed on ground** (detection and localization, alert dissimination) **in less than 2 h**
  - **Science payload:** 10 detectors arranged in a cylindric configuration ⇒ **1-D localization**

Energy range	15 ~ 200 keV
Detectors number for 1 cubesat	10 NaI(Tl) scintillators coupled to SiPM
Effective geometrical area for 1 cubesat	Up to 38 cm^2
Field of view for 1 cubesat	≈ 3.46*π ≈ 10.9 sr total
Field of view for 1 cubesat (with Earth masking)	≈ 2.73*π ≈ 8.58 sr total
Time resolution	50 miliseconds
Peak count rate per detector	1500 cts/s/cm^2
Data rate for 1 cubsat	≤ 100 MB/day
Loc. accuracy Err90 for brightest GRBs	< 20 deg^2



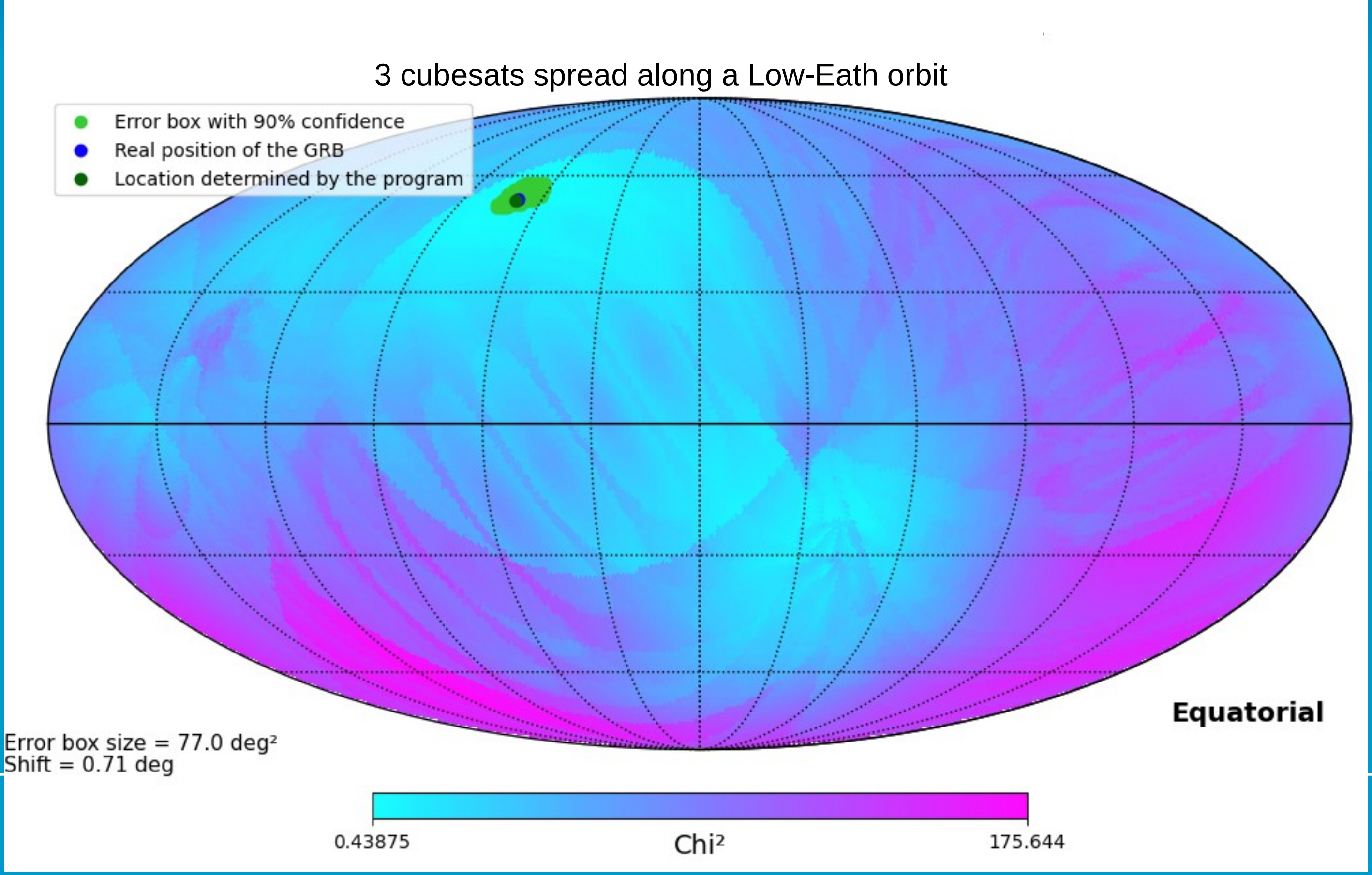
$M_{payload}$ ~ 1.6 kg including 20 % margin

See also the 3U Transat poster by G. Orttner for more details on the payload design and detector characterization



Detection & localization

- **Detection:** make use of data from the full constellation to search for coincidental excesses
- **Localization:** once an excess is detected, its position can be computed by comparing the counts measured on each detector with those expected from a given sky position using a maximum likelihood approach
- Compute visibility maps to further reduce the error boxes.
- Return healpix maps

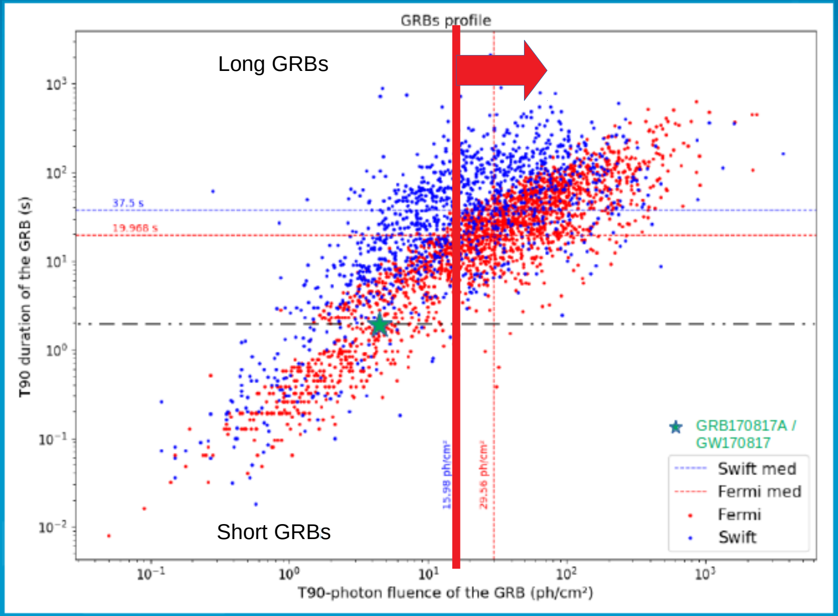


Project status

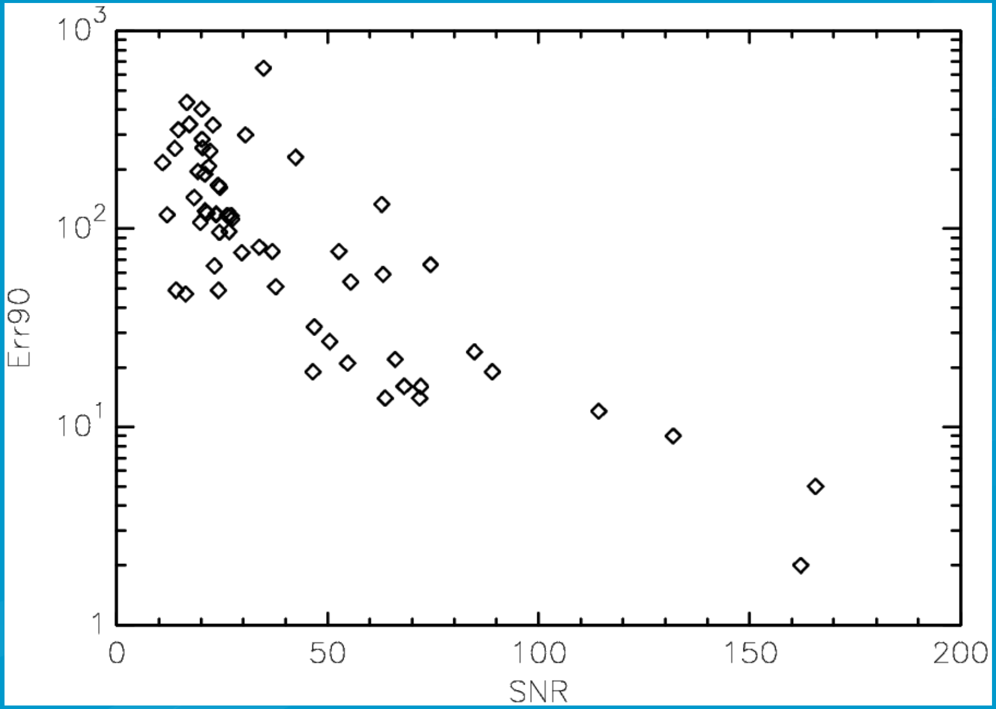
- **March 2020 – End of Sept. 2022:** Phase 0 study with the French Space Agency (CNES)
  - Endorsement of the proposed technical & programmatic operating point consisting of 3 clone 3U-satellites oriented towards « a high-performance platform »
  - 5 month concurrent design study with the U-SPACE company – study of the plateform architecture & costs
- **1.5 yr French gov. funding to build a complete prototype of the payload** with full thermal and mechanical characterization (TRL3 ⇒ TRL6)
- Submit a Phase A proposal before the end of 2022. If selected, the phase A should start at the beginning of 2023.

Performances

- Development of an end-to-end dynamical simulator to assess the constellation performances (from demonstrator to the ultimate configuration) & to optimize the payload design/cubesat. config.
- Localization performances on the brightest GRBs (T90 Photon fluence > 20 ph/cm²)



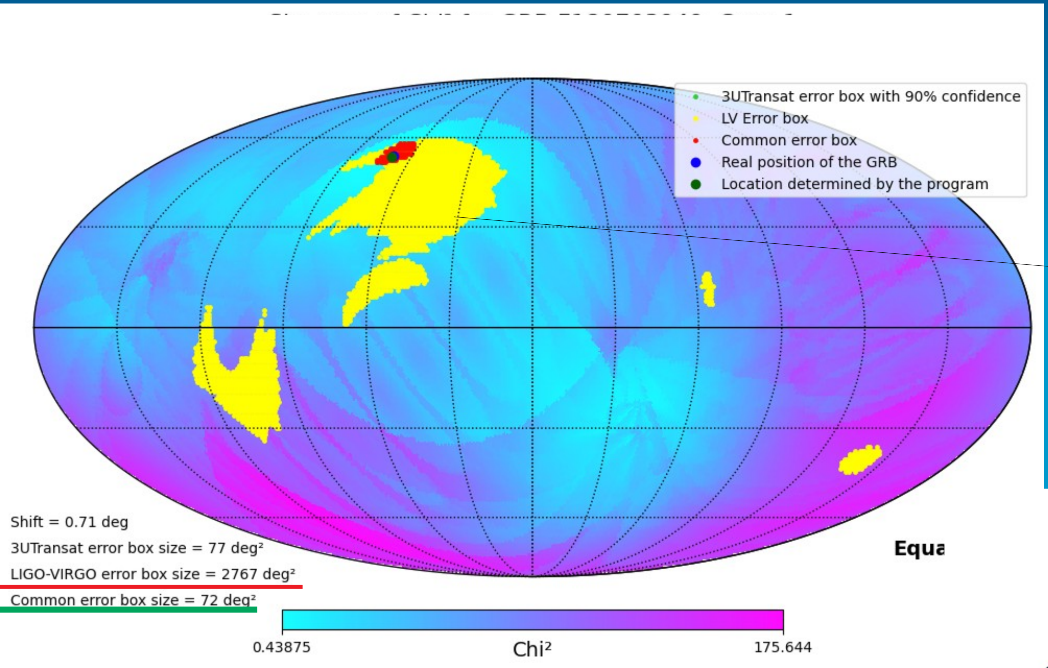
3 satellites over 1 orbital plan
58 detected GRBs over 164 simulated



Performances

- **Impacts of 3U Transat on the localization of short GRBs in synergy with GW events**

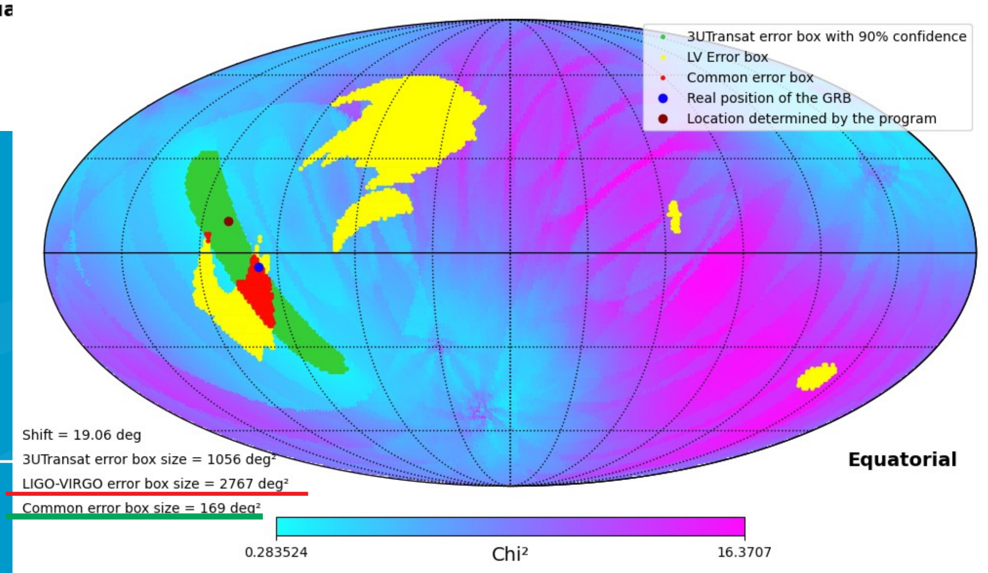
Ex: 3 cubesats



Bright short GRB

LV 90 % c.l. error box from a BNS merger

faint short GRB



Cross-correlation LVK–3UT Err90 improved in median LVK Err90 by a factor ~7

Take away

- Compact object transients = true multi-messenger sources
- Searches for EM counterparts of GW(/neutrino) events will benefit from prompt EM detections, in particular at HE
- **3U Transat = demonstrator of 3 LEO 3U-satellites to work during the LVK run O5 from mid-2026 to evaluate the localization capabilities based on nano-satellite technology**
- Project status: End of phase 0 – Proposal to CNES for a Phase A
- If all lights are green, phase A kick-off could start beginning of 2023.
- **If you have questions or if you want to join us, please contact me!** (ogodet@irap.omp.eu)

Performances

- Improvement of localization accuracy by increasing the number of satellites
- Same population of bright GRBs as before