# The Sino-French Gamma-Ray Burst Mission SVOM

(Space-based multi-band astronomical Variable Objects Monitor)


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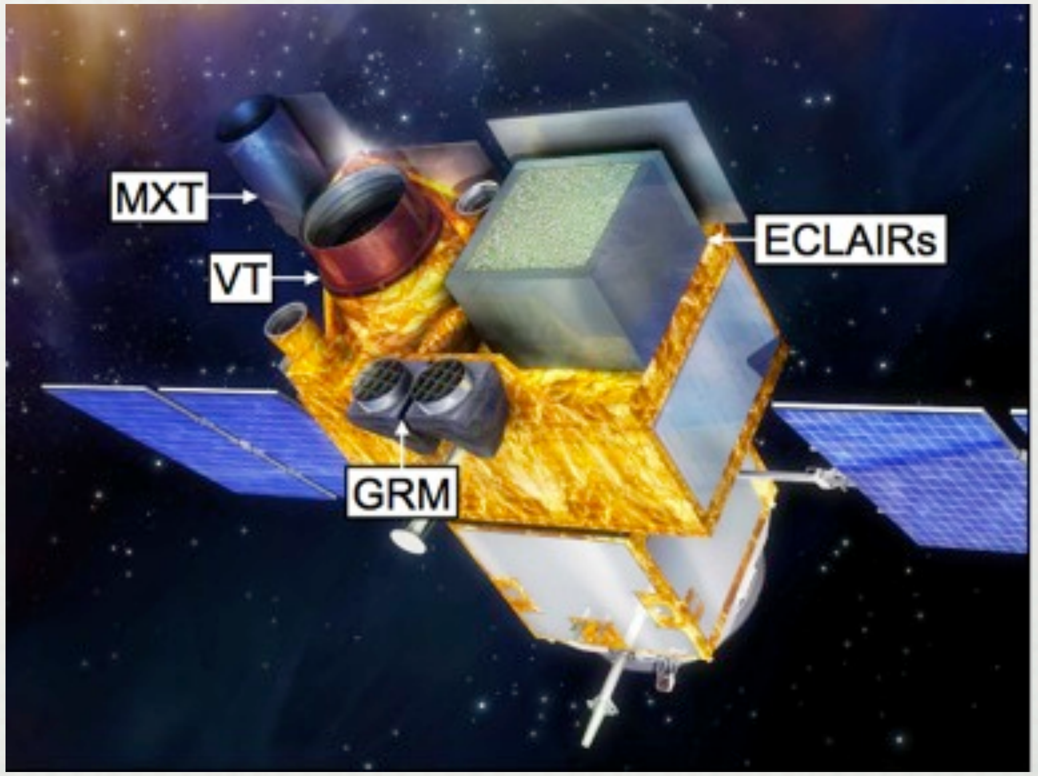
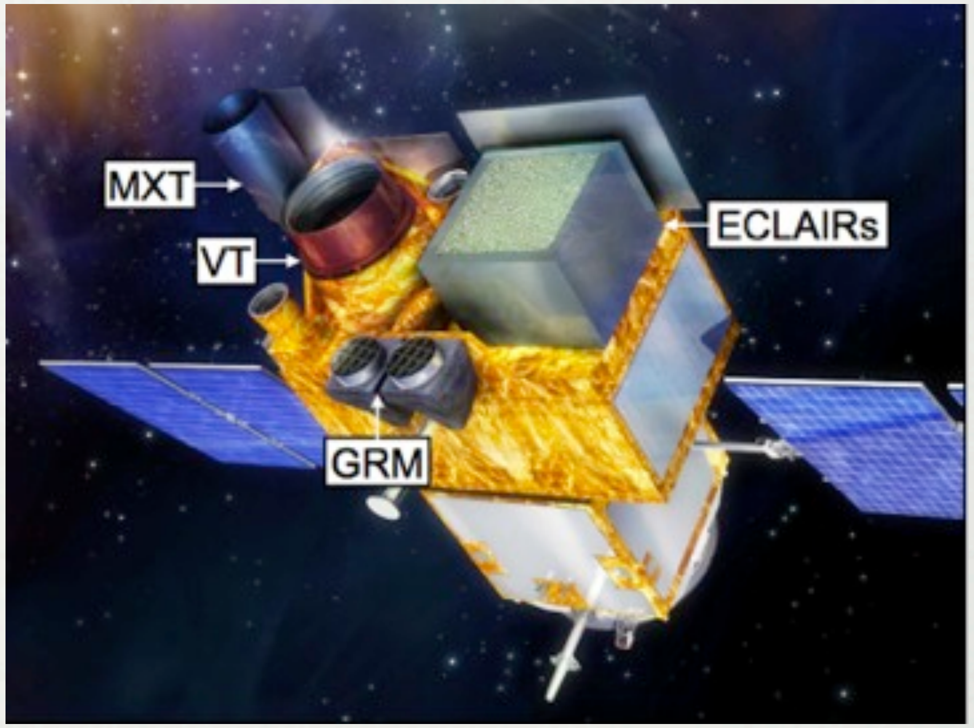
# Outline

- SVOM background
- SVOM scientific objectives
- SVOM payload
- SVOM mission profile
- Conclusions



# SVOM: A sino-french mission

- An international cooperation
  - NAOC Beijing
  - IHEP Beijing
  - CEA Saclay
  - IRAP Toulouse
  - APC Paris
  - LAM Marseille
  - University of Leicester
  - UNAM Mexico



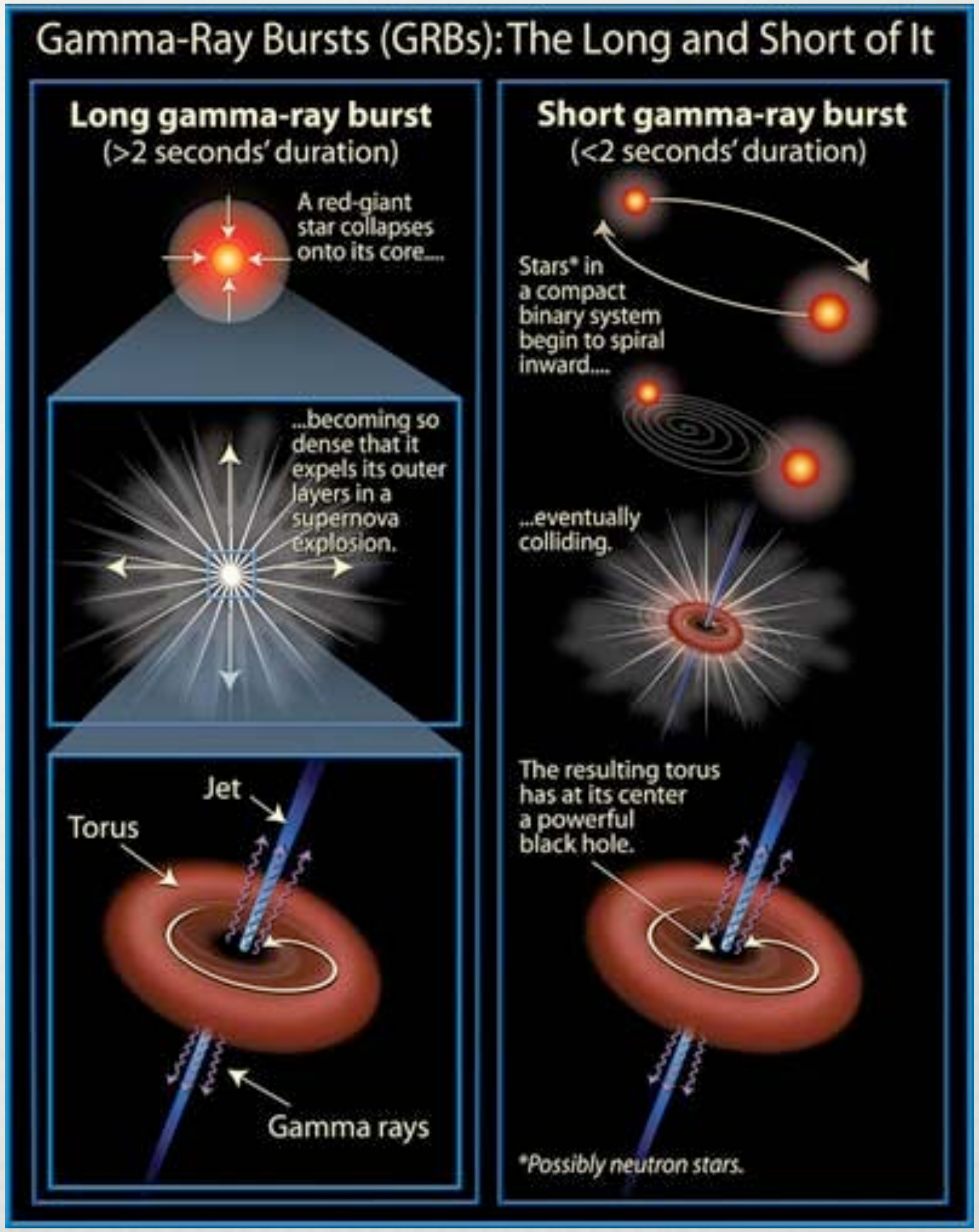

- With the support of CNES, France and its partners contribute to the science payload (ECLAIRs and MXT), provide the alert distribution network, French science ground segment, and launch services
- China contributes to the science payload (VT and GRM), provides the platform, the Chinese ground segment and will operate the mission after commissioning

# What do you need to know

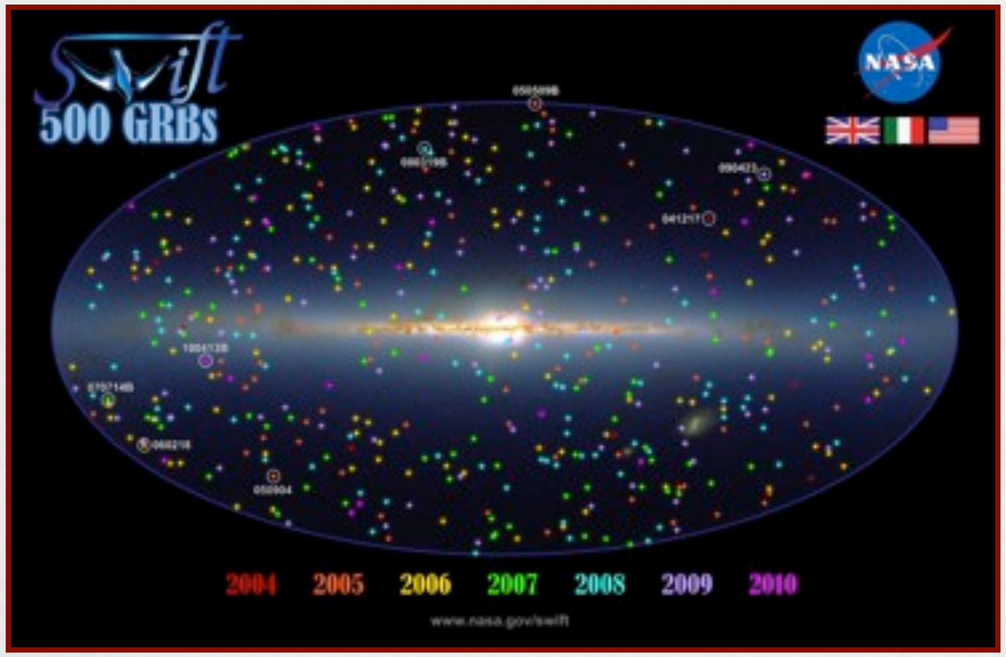
- Follow-up GRB mission after Swift
  - A agile satellite rapidly and autonomously slewing narrow field instruments (X-ray/optical telescopes) to a GRB position
  - Rapid distribution of the GRB positions to the ground with refining process on-board
- Outlined capabilities
  - Optimized for faint GRBs and high-z GRBs thanks to an optimized low energy threshold for the trigger telescope (required around 4 keV as opposed to > 10 keV for Swift)
  - A more sensitive redder optical telescope, allowing darker GRB afterglows to be detected on-board
  - A GRB monitor for sensitive broad band spectral coverage up to the MeV range for GRB classifications
  - A pointing strategy and ground segment to enable follow-up observations from large ground based telescopes, including the observation of any precursors

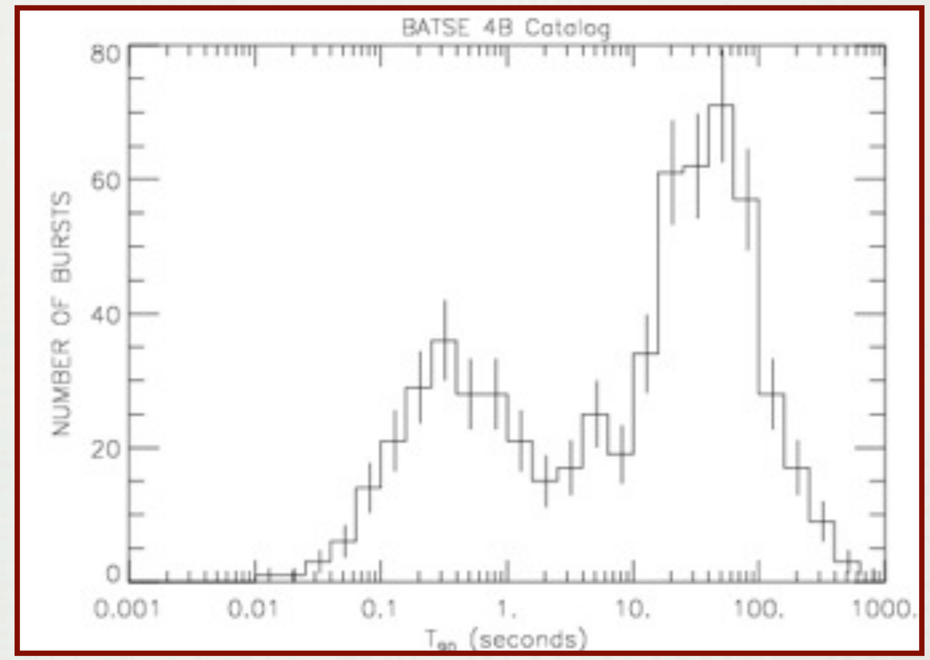
# Gamma-ray bursts

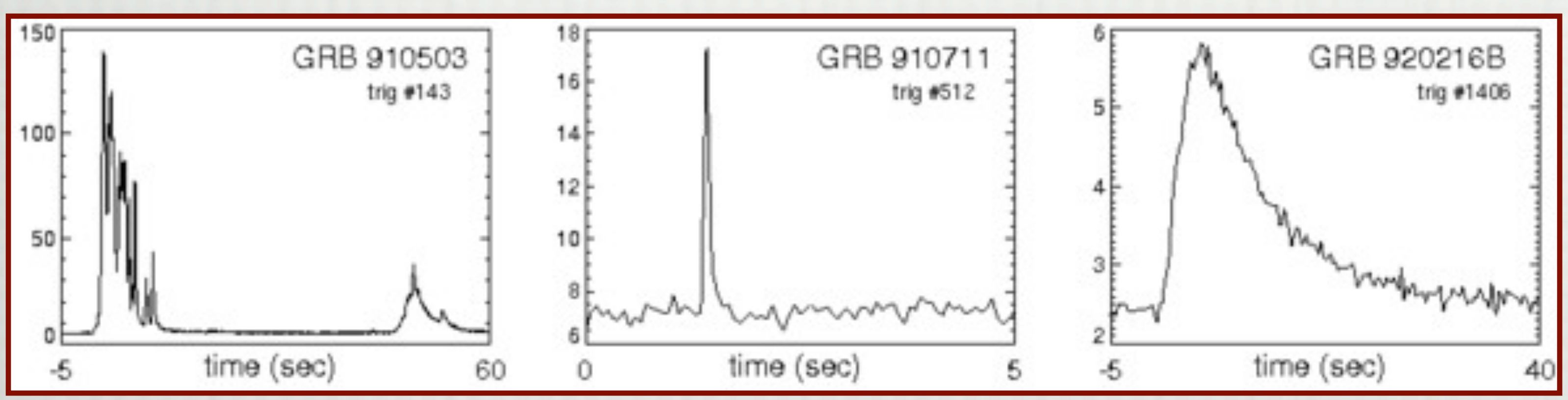
- Gamma-ray bursts are cosmological, powerful and brief explosions randomly distributed in the sky.
- They are associated with the catastrophic formation of black holes and ultra-relativistic jets,
  - following the collapse of a massive star or the merger of compact objects
- Tools relevant to many fields: stellar evolution, black hole formation, jet acceleration, accretion, extreme physics, cosmology, ...

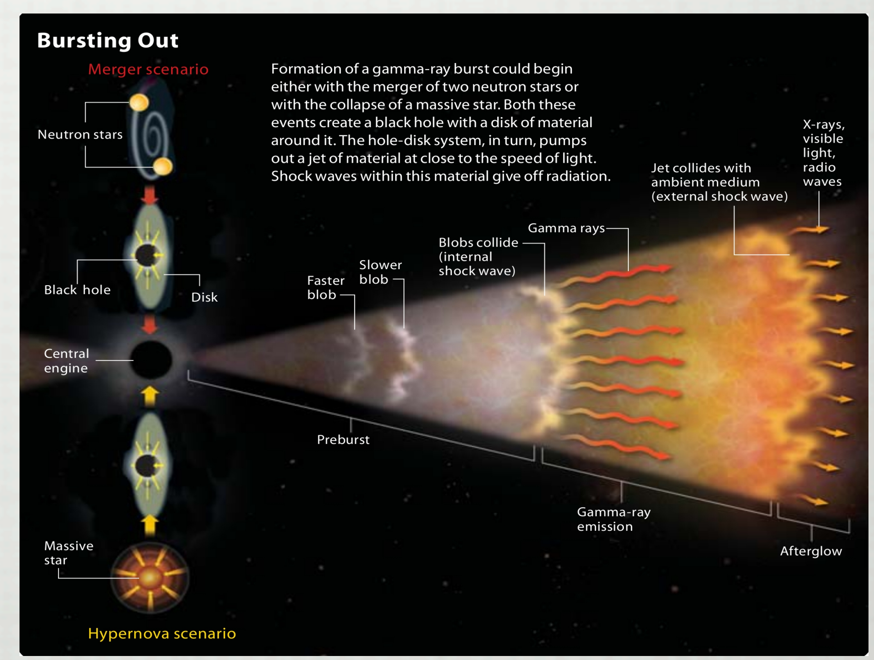


# GRB as astrophysical objects



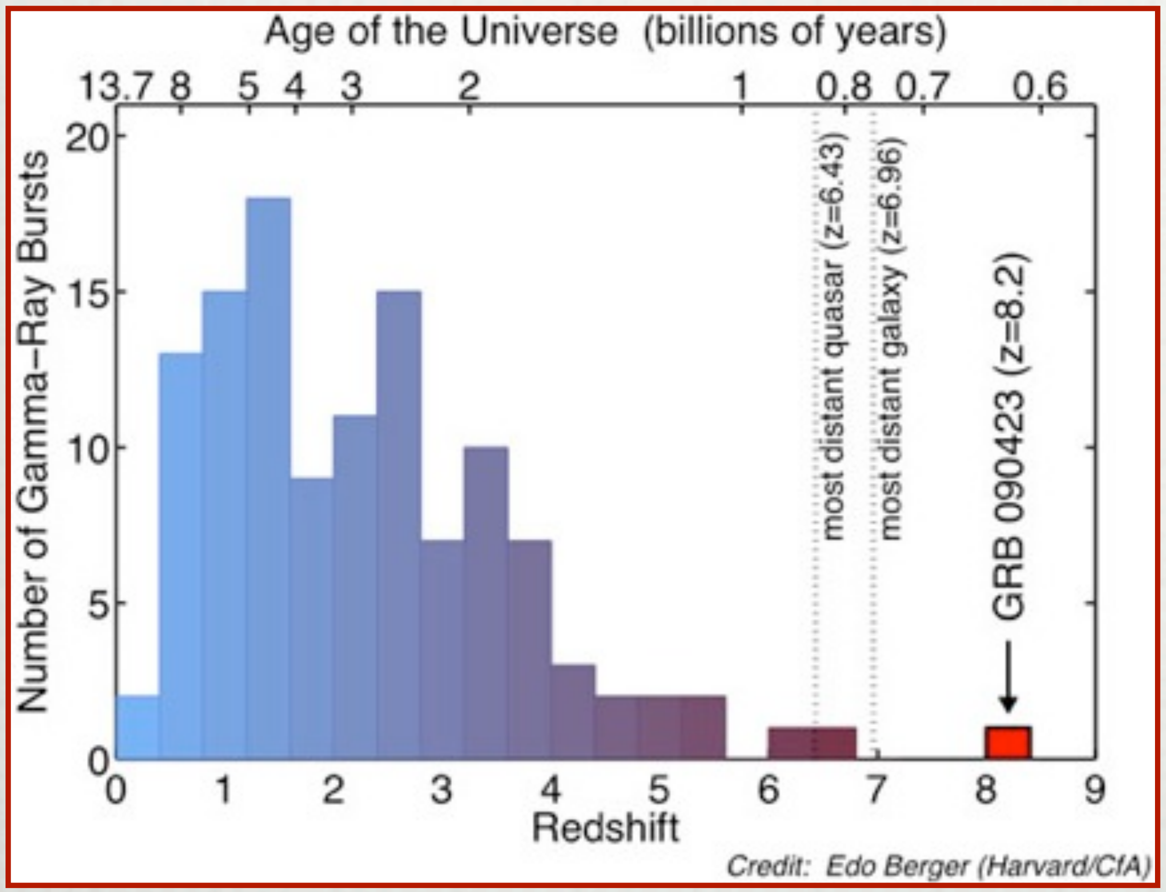



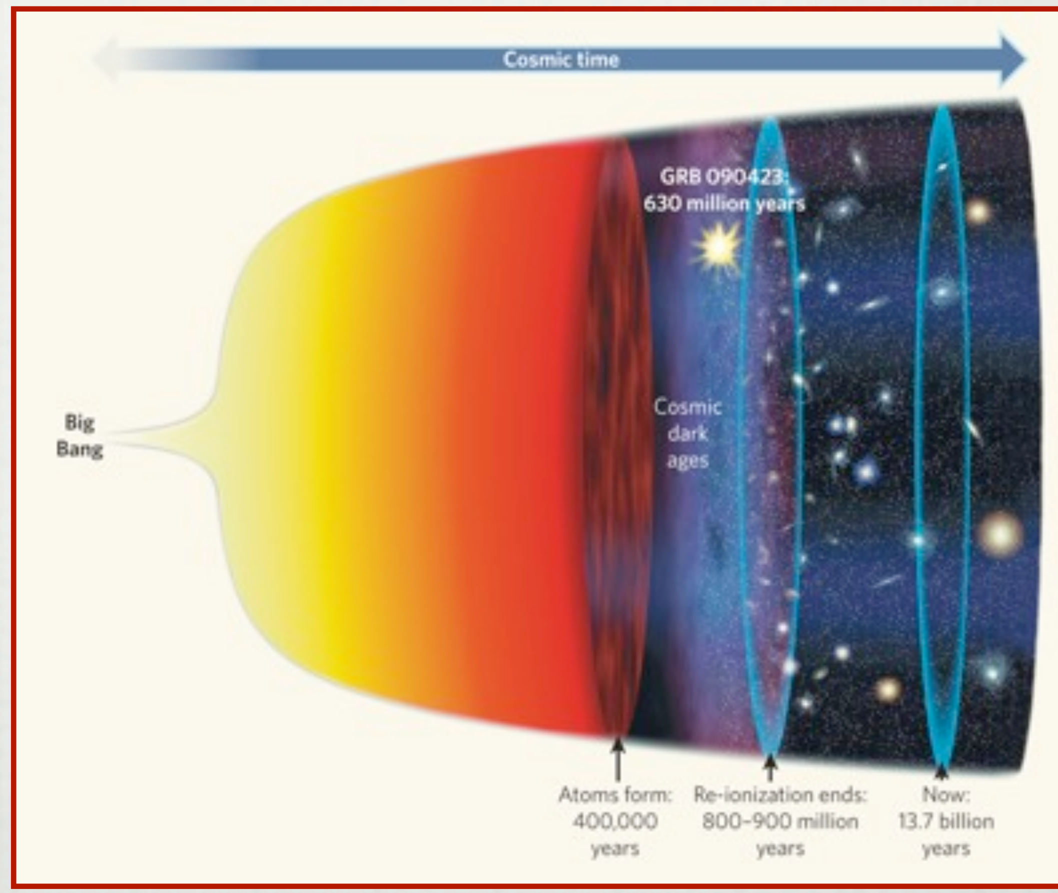



# GRB as a tool for cosmology

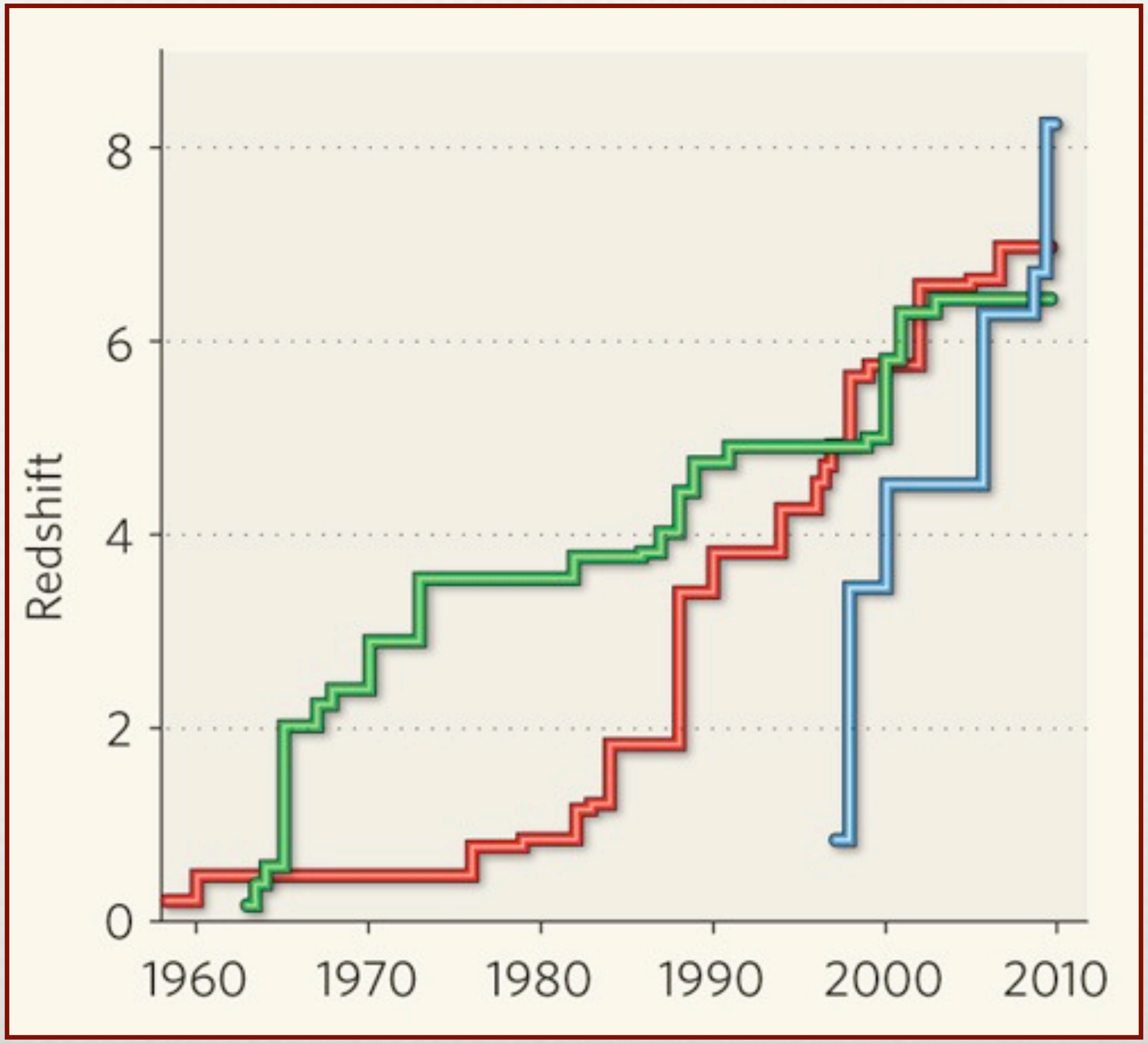
- **GRB 090423 (Tanvir, N. R. et al., Salvaterra, R. et al. Nature, 2009) produced only 630 million years after the big bang before the end of the re-ionization !**



# Probing the highest redshifts

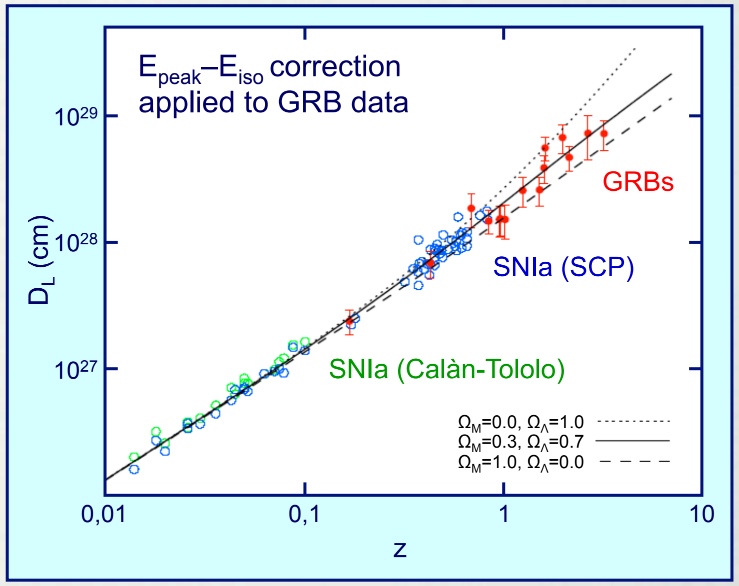
Timeline of redshift record-breaking for three classes of astronomical object: galaxies (red), quasars (green) and -ray bursts (blue). B. Zhang (2009) adapted from N. Tanvir

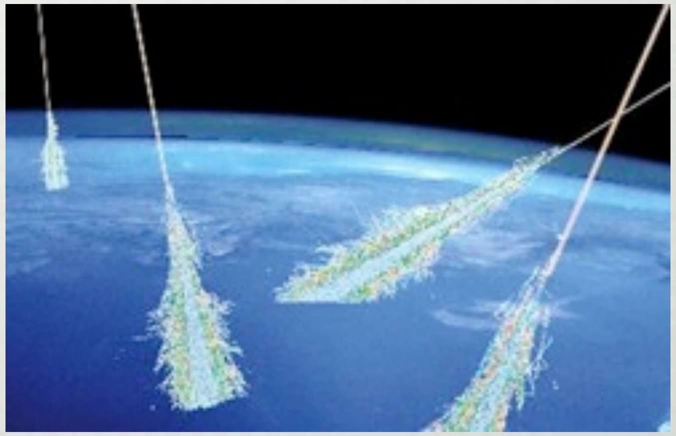


# Objectives for a GRB mission

## Objectives for Cosmology:

- To track directly the formation of stars in faraway galaxies to the extend that GRBs mark the end of the evolution of massive stars.
- To study the first generation of stars (population III stars) supposed having formed particularly massive stars, potentially able to generate GRBs at the end of their quick evolution.
- To enable the study of all the medium in the foreground, including those of the host galaxy, to track the history of the re-ionization of the Universe and its enrichment in metals.
- To extend the cosmology studies of the Universe by using "standard candles" up to redshift of z about 10-20.
- To enable a better determination of key Cosmology parameters.



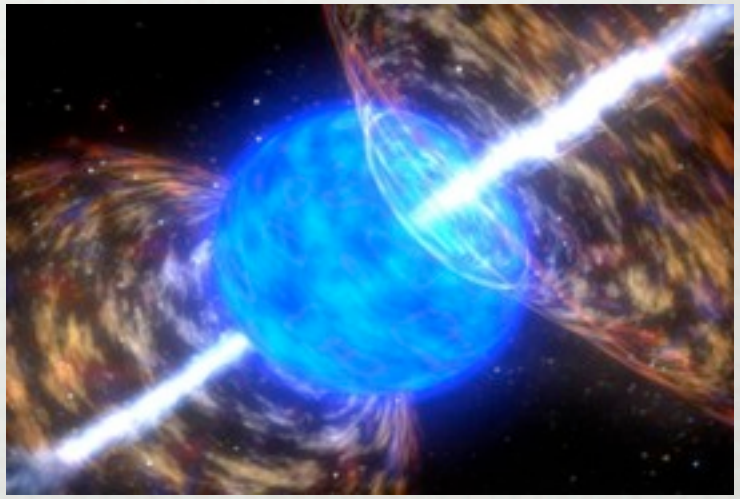



## Objectives for the fundamental physics:

- To test some aspects of the fundamental physics by bringing new constraints for a possible violation of the Lorentz invariance, and the origin of cosmic rays

# Objectives for a GRB mission

- Objectives for high energy astrophysics:
  - To explore different populations of GRBs (such as "dark" bursts or X-ray flashes).
  - To uncover the nature of the short bursts.
  - To study the nature of the prompt emission
  - To study the relations between the prompt emission and the afterglow.
  - To study the relationship between GRBs and supernovae explosions.
  - To explore the central engine of the GRBs, particularly by using an eventual precursor.
  - To study the physics of the relativistic ejections which are also at work in numerous astrophysics sites such as the Active Galaxi Nuclei (AGN) or the microquasars.
  - To determine the nature of the stars at the origins of the GRB, condition for a judicious use of the GRB in cosmology.

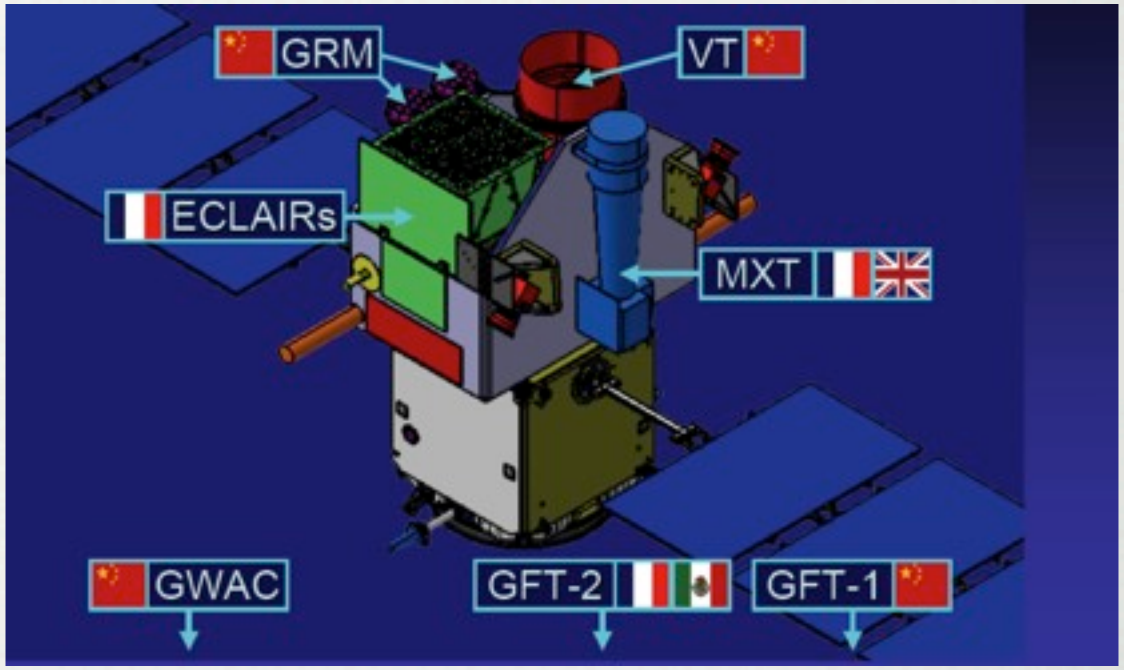


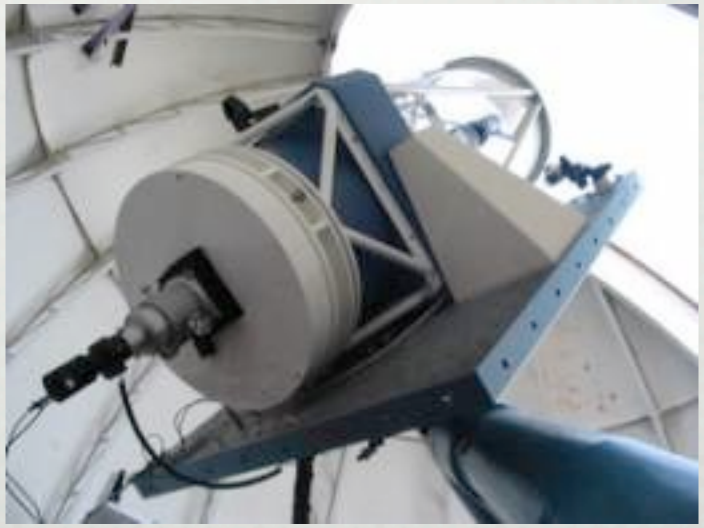
# Requirements for a new GRB mission

- To enable the detection of all know types of GRBs, with a special care on high-z GRBs and low-z, sub-luminous GRBs
- To provide fast, reliable and accurate GRB positions
- To measure the broadband spectral shape of the prompt emission (from visible to MeV)
- To measure the temporal properties of the prompt emission
- To quickly identify the afterglows of detected GRBs, including those which are highly redshifted (z>6)
- To quickly provide (sub-) arcsec positions of detected afterglows
- To quickly provide redshift indicators of detected GRBs

# Payload requirements

- ECLAIRs, a wide-field coded-mask telescope operating in the hard X-ray and soft gamma-ray band for GRB real-time localizations to few arcmin,
- GRM, a non-imaging spectro-photometer for monitoring the FOV of ECLAIRs in the gamma-ray energy range,
- MXT, a narrow FOV telescope for the study of the GRB afterglow in the soft X-ray band,
- VT, a narrow FOV telescope for the study of the GRB afterglow in the visible band
- The space instrumentation is complemented by ground based instruments:
  - GWAC, an array of cameras for monitoring the FOV of ECLAIRs in the visible,
  - GFTs, two robotic telescopes for the study of the GRB afterglow in the visible and NIR bands.



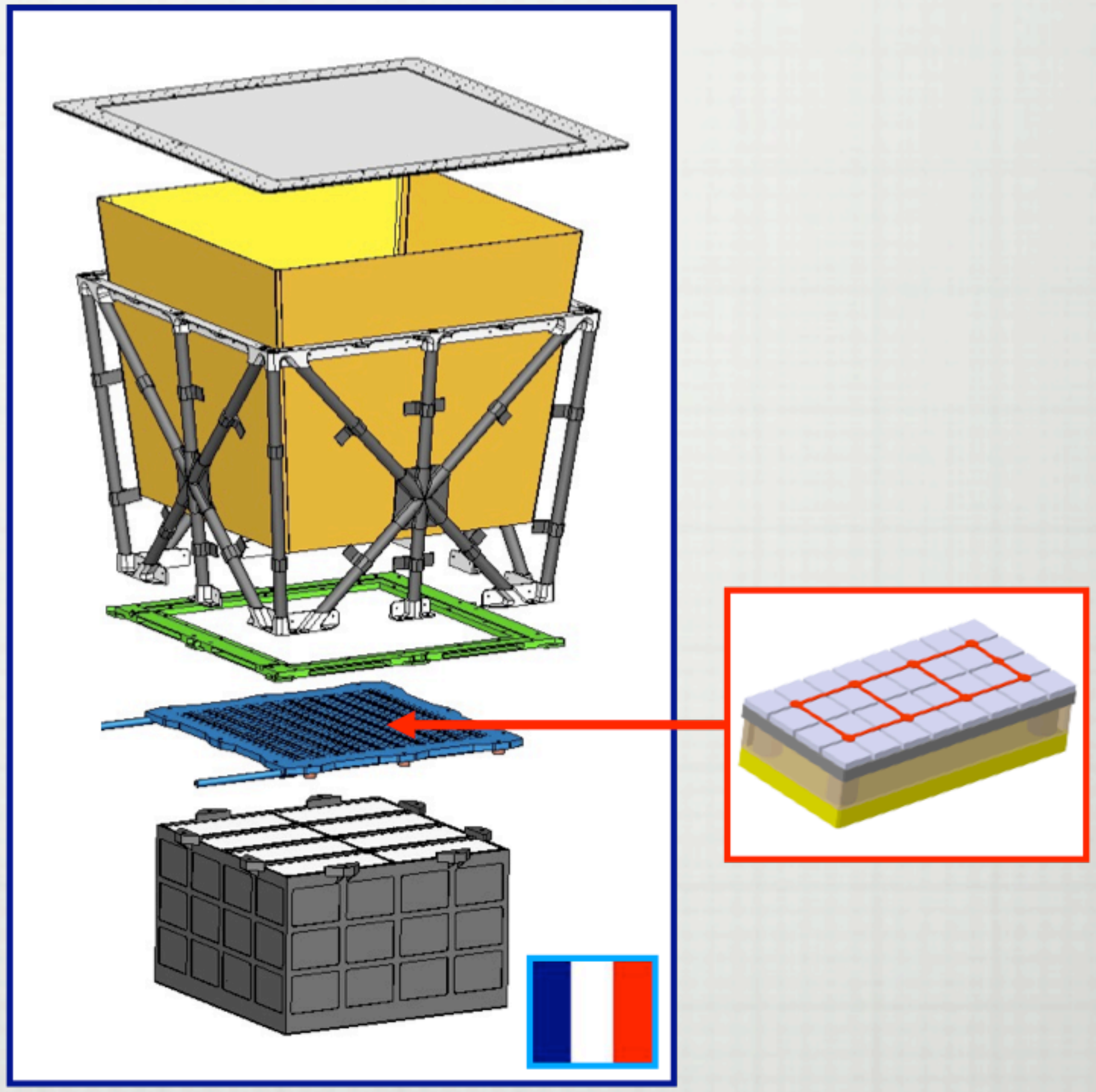



# ECLAIRs: The trigger telescope

- Objective: detection, localization and GRB characterization
  - Monitor the hard X-ray sky
- Main instrument parameters

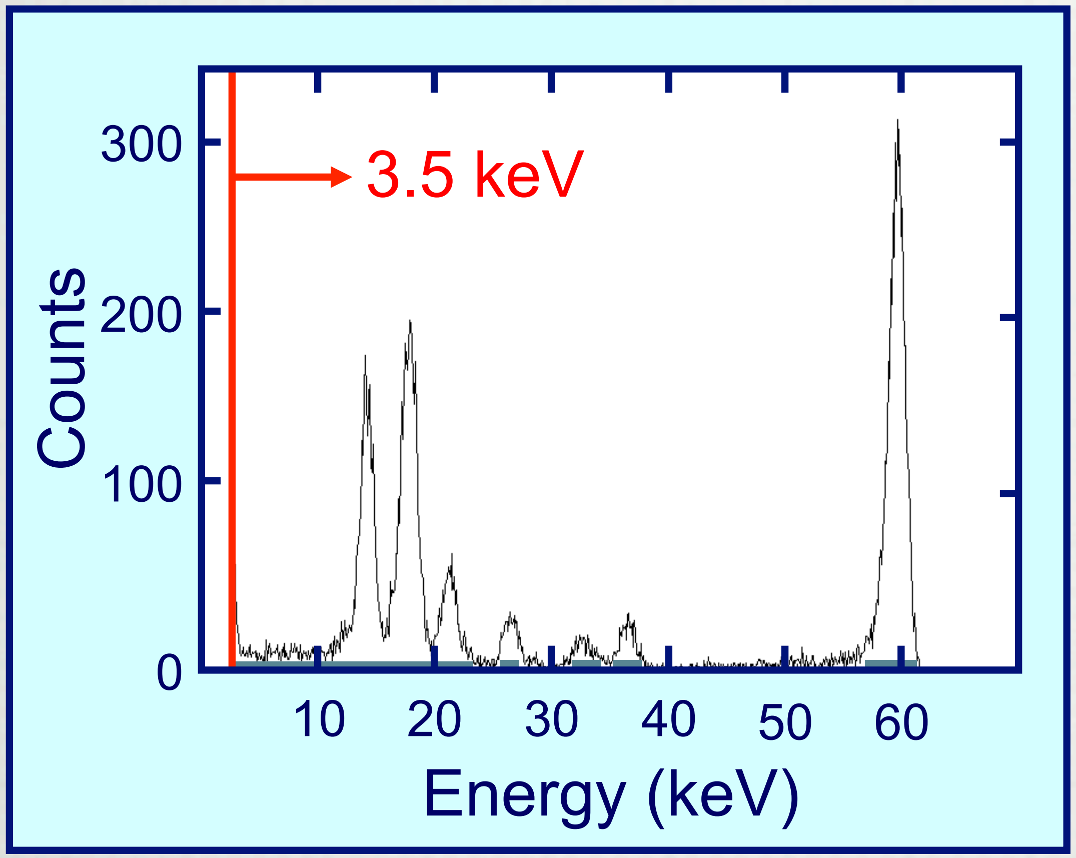
| | |
|---|---|
| Field of view | 2 steradians |
| Effective area | 1000 cm2 (5-80 keV) |
| Energy range | 4-250 keV |
| Localization accuracy | <10' |
| Sensitivity (5sigma, 1000 sec) | 30 mCrab |
| GRB detection rate | 70-90/yr |

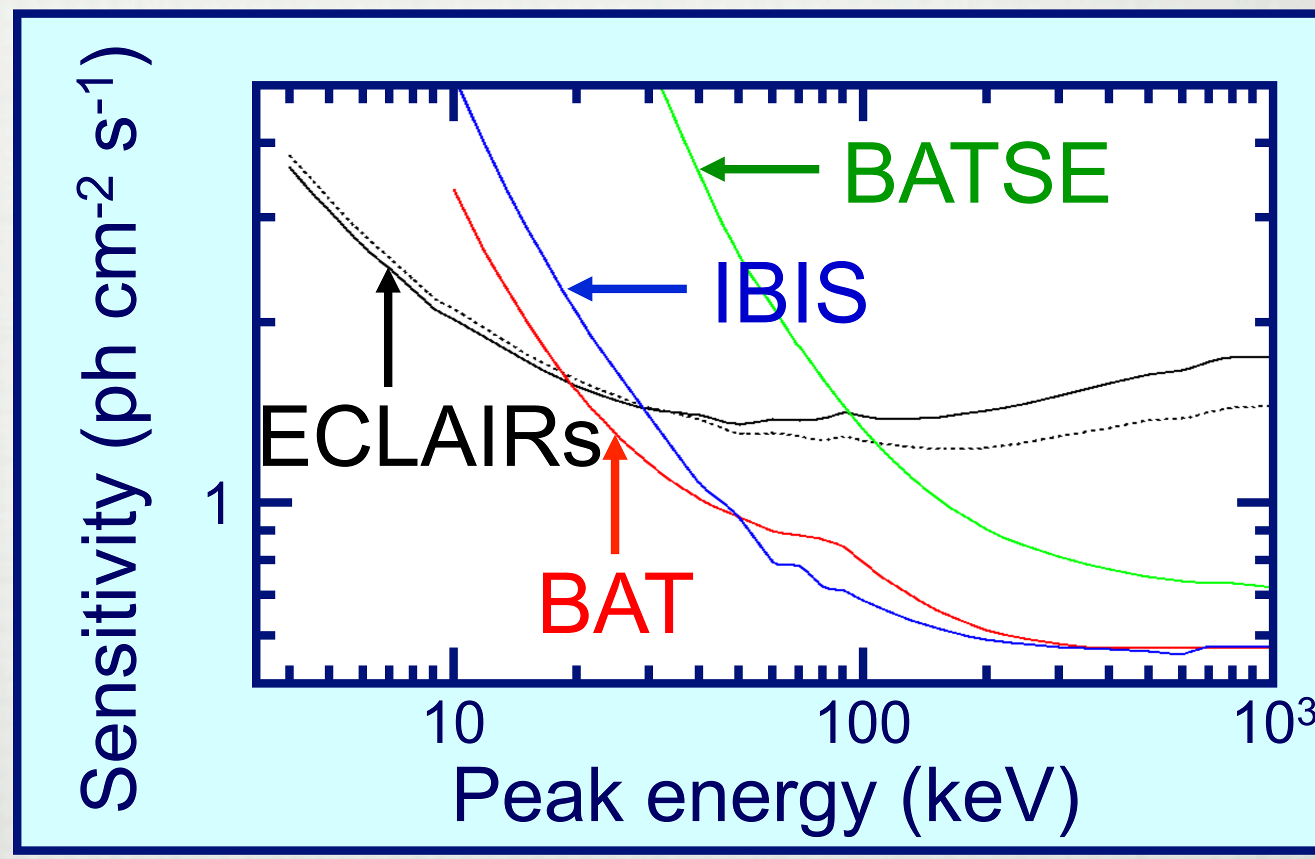
- ECLAIRs is a coded mask imager with a detection plane of 6400 CdTe pixels
  - selected one by one as to guaranty the low energy threshold

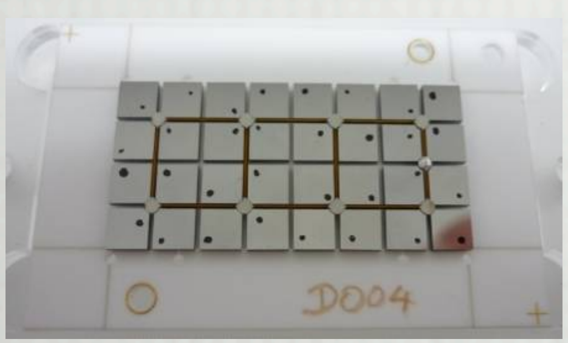


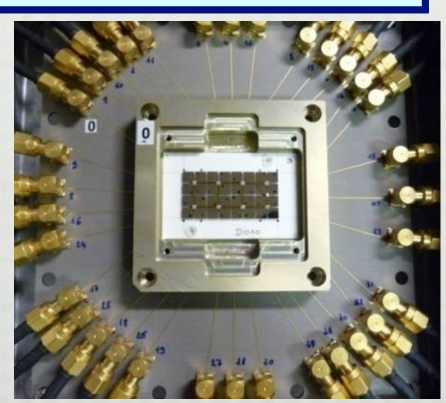
# ECLAIRs performance

- Lowering the energy threshold to about 4 keV



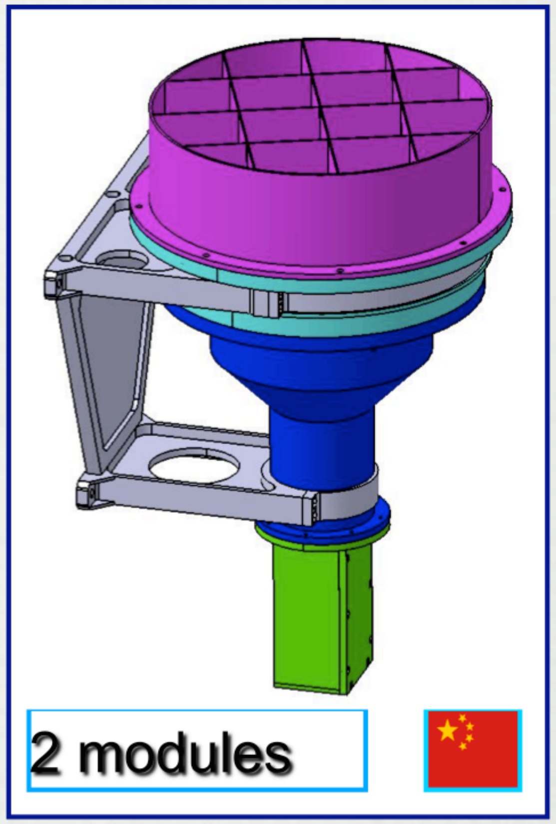



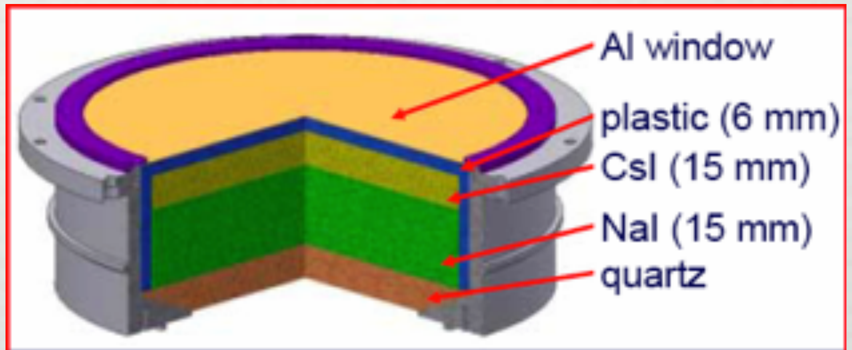



# Gamma-ray burst monitor

- Prompt emission up to the gamma-ray band
  - Epeak determination up to about 500 keV
- Main instrument parameters

| | |
|---|---|
| Field of view | 2 steradians |
| Effective area | 560 cm2 |
| Energy range | 30 keV - 5 MeV |
| GRB detection rate | >70-90/yr |



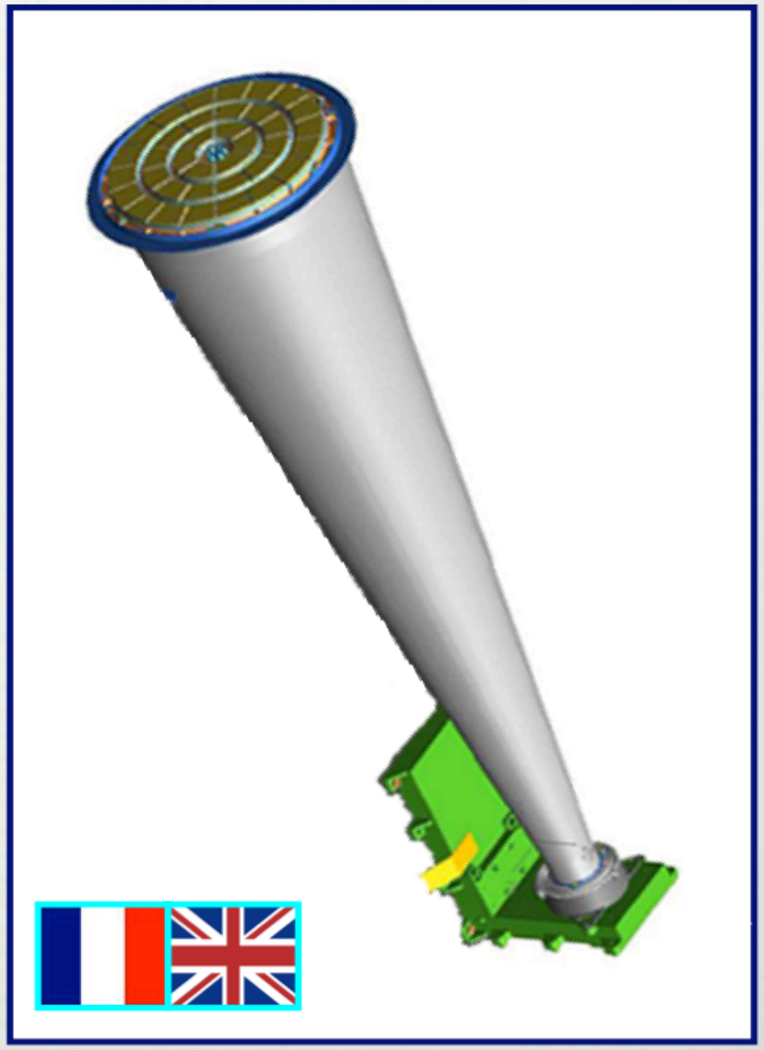



Scintillation (phoswich) detector

# The MXT

- The Micro-channel X-ray Telescope (MXT) is a focusing X-ray telescope, featuring a micro-channel plate lens inherited from MIXS-T, an instrument to be flown on the ESA Mercury mission Bepi-Colombo
- Objectives: refine position from ECLAIRs and afterglow follow-ups

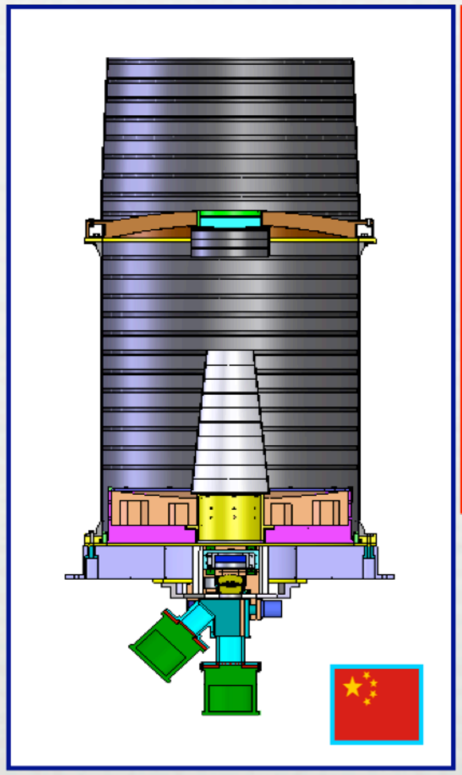
| | |
|---|---|
| Field of view | >25' |
| Effective area | 50 cm2 at 1 keV |
| Focal length | 1 m |
| Energy range | 0.3-6 keV |
| Angular resolution | 2' |
| GRB localization accuracy | <30" (50% of GRBs) |

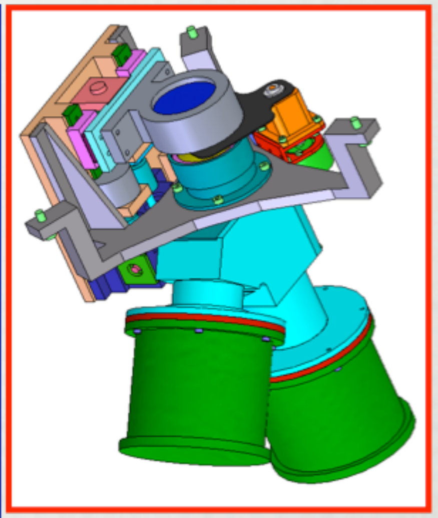


# The VT: Visible Telescope

- Objectives: Refine X-ray position and afterglow follow-up
- VT main parameters

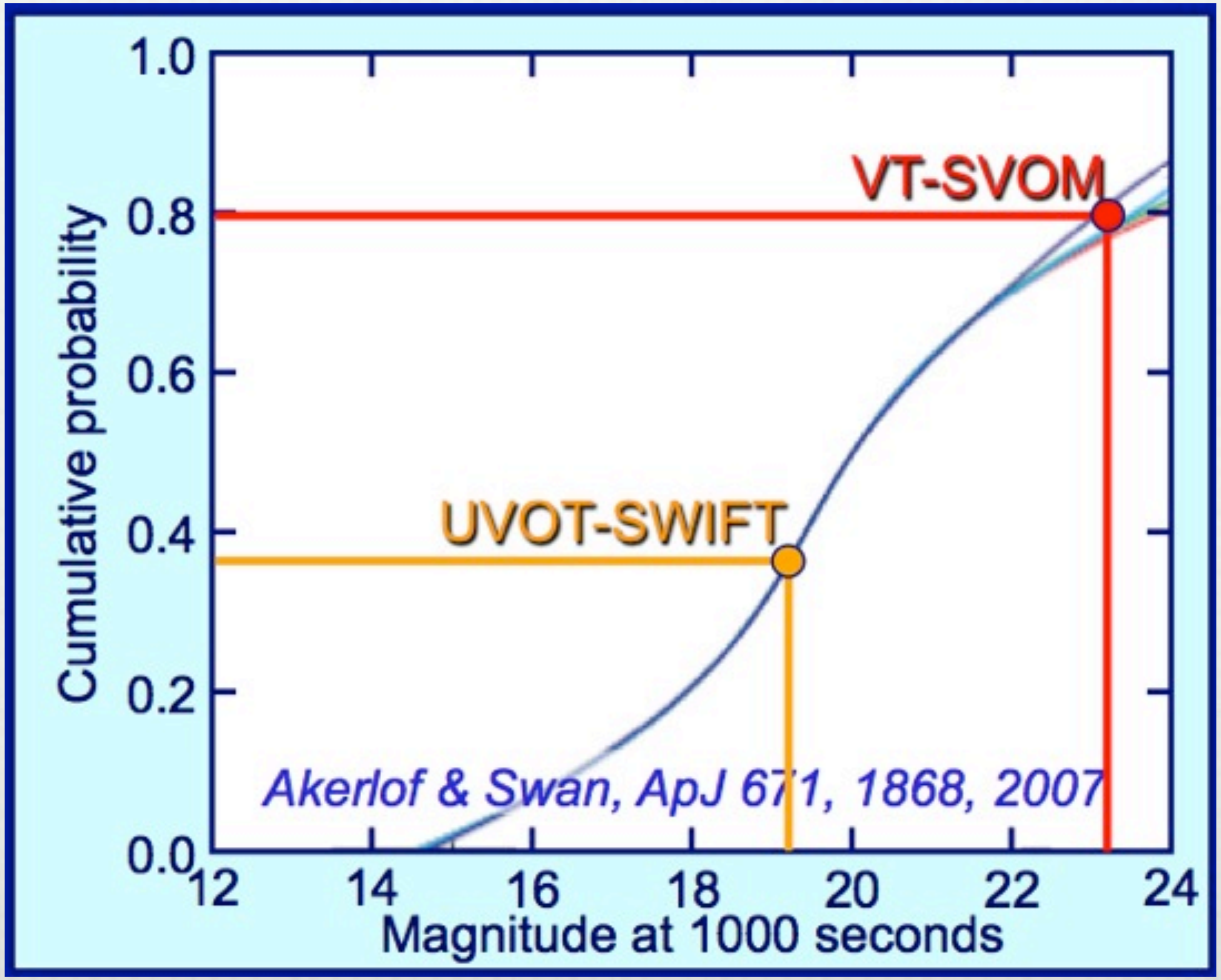
| | |
|---|---|
| Diameter | 45 cm |
| Optical design | Modified Ritchey-Chrétien |
| Field of view | 21' x 21' |
| Spectral bands | 400-650 nm and 650-950 nm |
| Detector | 2 CCDs |
| Angular resolution | 0.6" |
| Sensitivity (300 s, 5 sig) | Mv=23 |
| GRB observation rate | 80% of ECLAIRs GRBs |





# VT performance

- VT, reaching a magnitude of 23 (@ 1000 seconds) will be more sensitive than the SWIFT UVOT and will detect 80% of the ECLAIRs GRBs



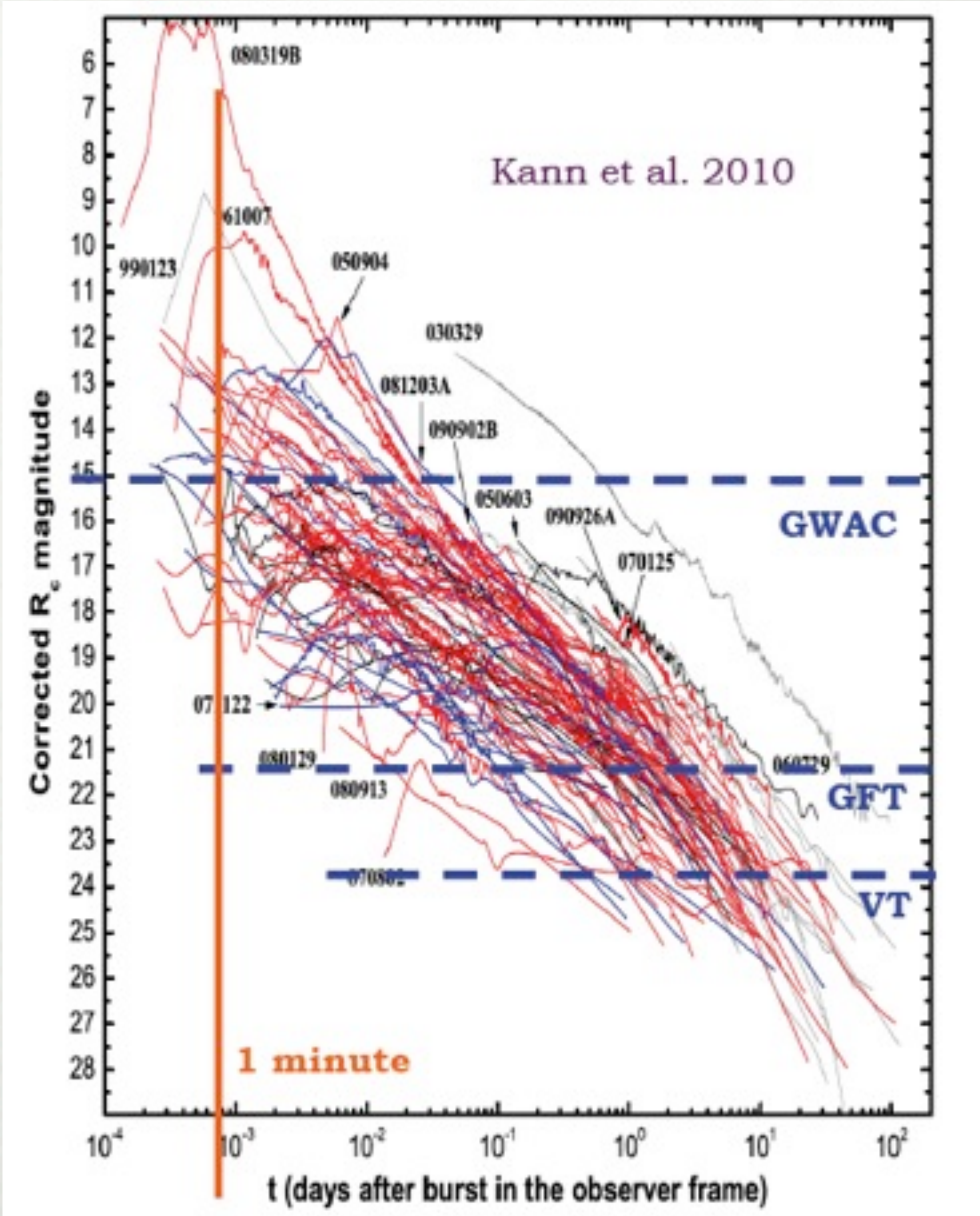
# Ground based telescopes

## Ground-based Wide-Angle Camera (GWAC)

| | |
|---|---|
| Number of units | 64 |
| Field of view | $\sim$8000 deg$^2$ ($\sim$130 deg$^2$ per unit) |
| Spectral band | 400-950 nm |
| Detector | 64 CCD cameras (one per unit) |
| Sensitivity (10 s, 5 $\sigma$) | $M_V$ = 16 (new Moon) |
| GRB observation rate | 20% of *SVOM* GRBs |

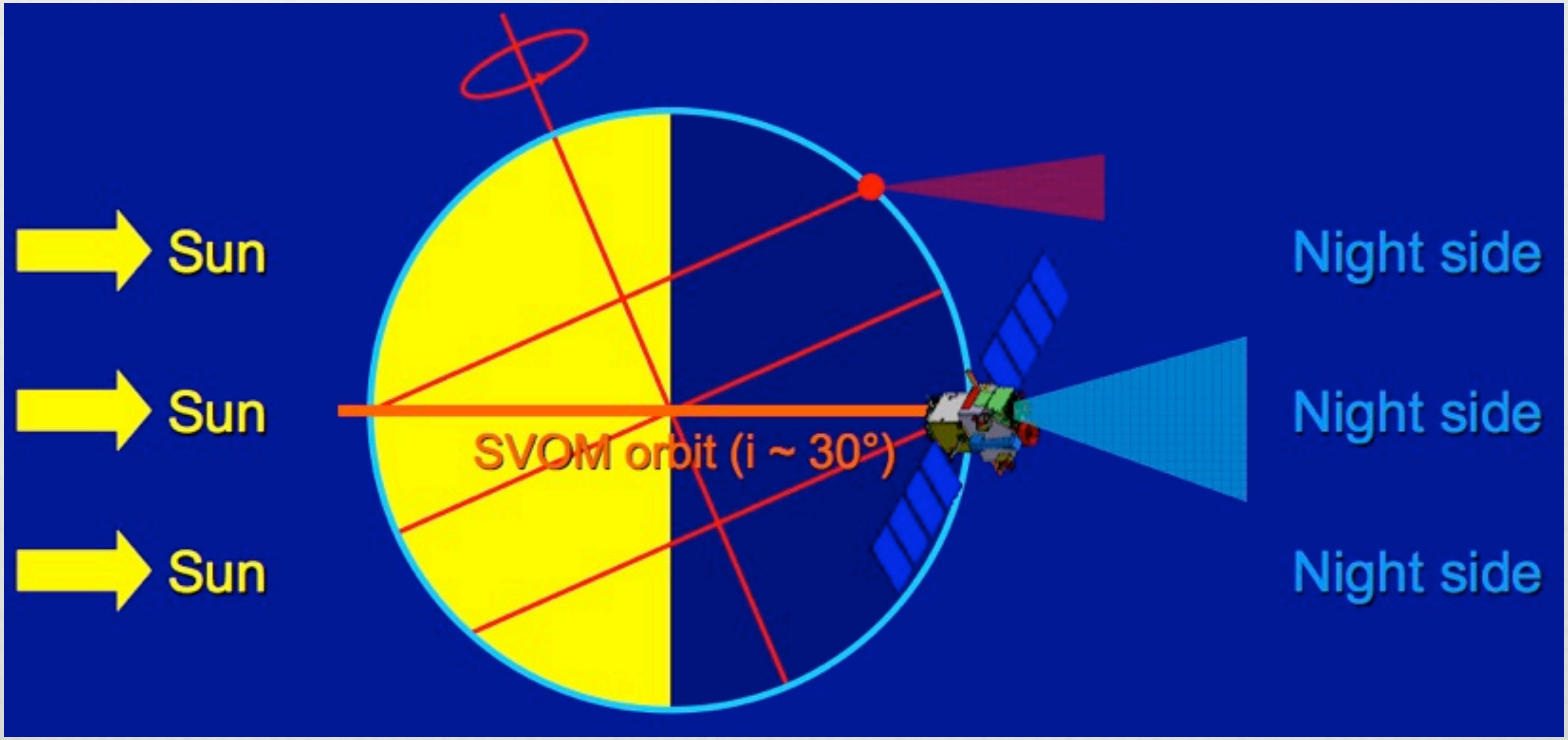
## Ground-based Follow-up Telescopes (GFTs)

| | Chinese GFT | French GFT |
|---|---|---|
| Spectral band | 400-950 nm | 400-1700 nm |
| Field of view | 21' $\times$ 21' | 30' $\times$ 30' |
| Aperture | 1 000 mm | 980 mm |
| Detector | 3 CCD cameras | 2 CCD / 1 IR camera |
| Sensitivity (5 $\sigma$) | $M_R$ = 21.5 (100 s) | $M_J$ = 18 (10 s) |
| GRB observation rate | 20% of *SVOM* GRBs | 20% of *SVOM* GRBs |



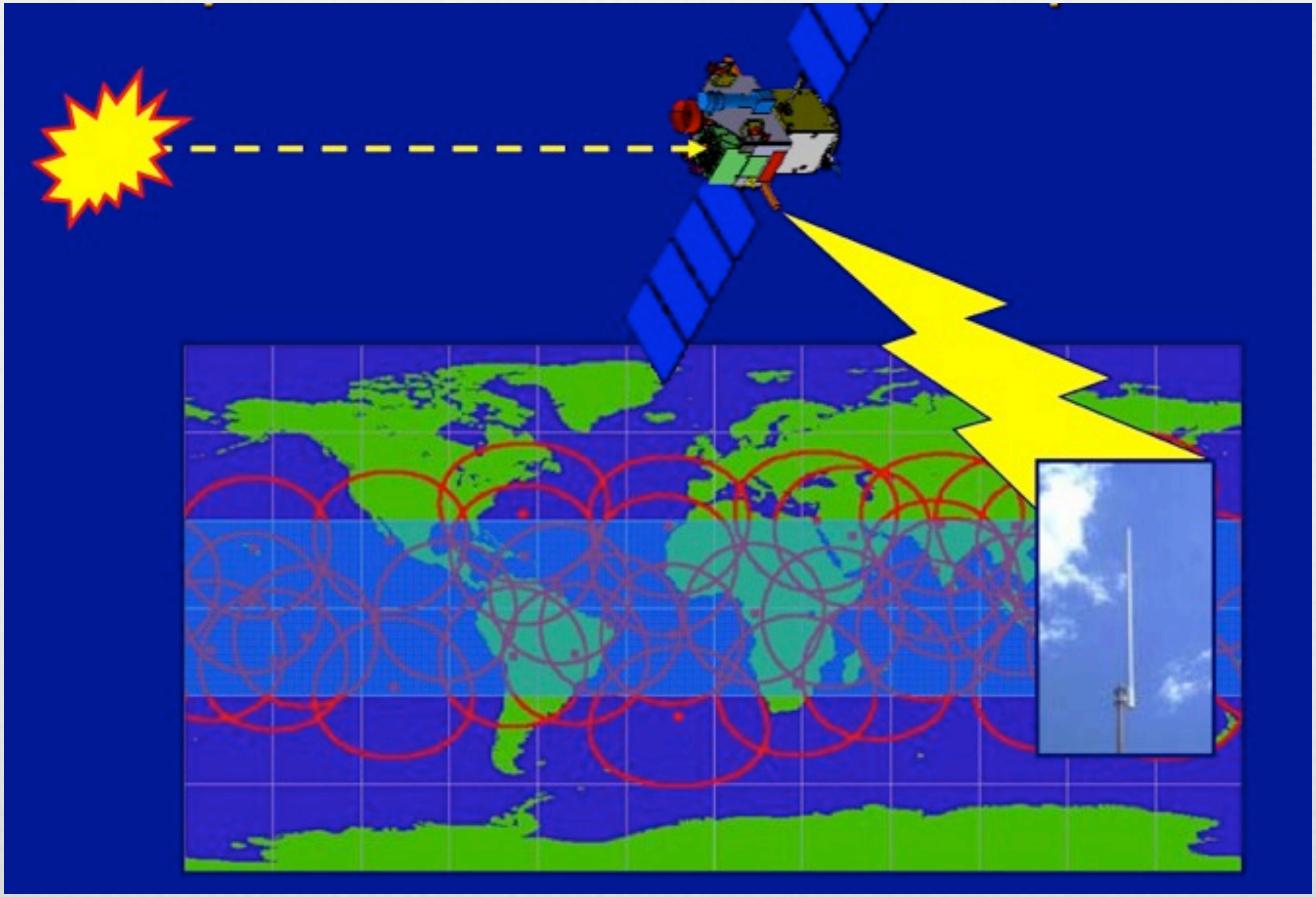
# Anti-solar pointing

- Most of the GRBs detected by SVOM to be well above the horizon of large ground based telescopes all located at tropical latitudes
- Fixed pointing avoiding the galactic plane

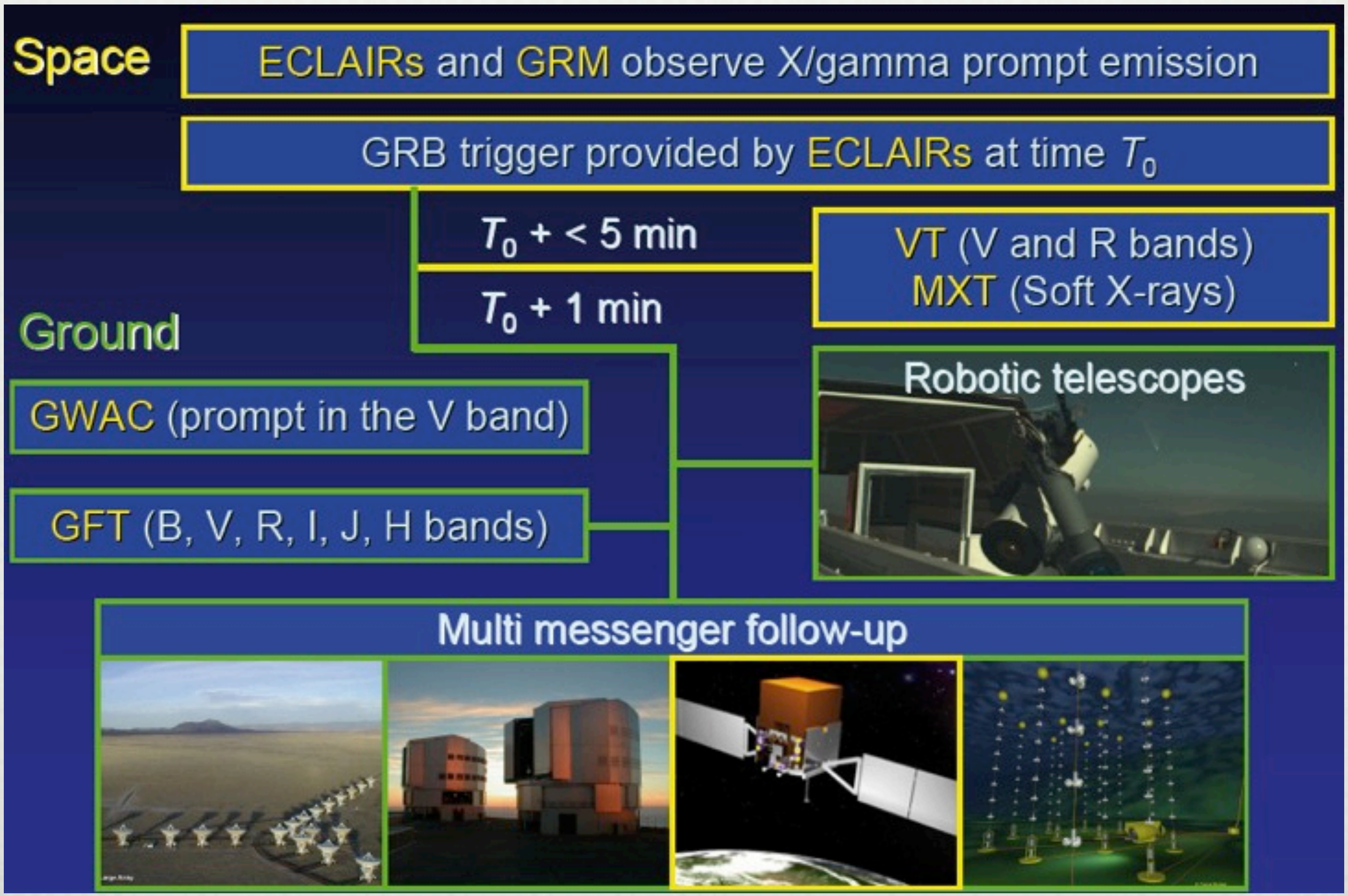


# Prompt distribution of the positions

- Make use of VHF network (heritage from HETE-2)



# SVOM observing strategy

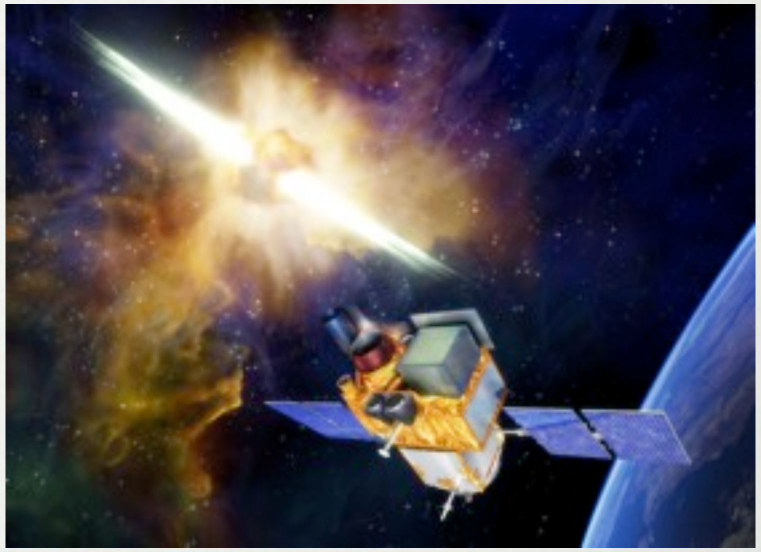


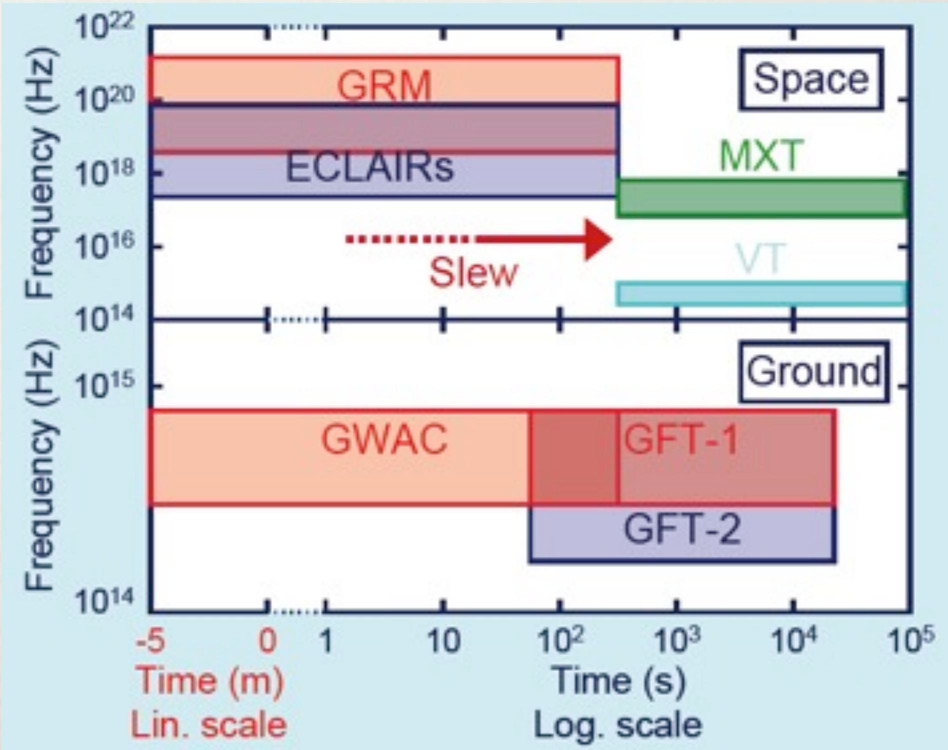
# Non GRB science

- With the sensitivity of its instruments, its constrained pointing law optimized for gamma-ray burst follow-up observations, the strengths of SVOM for non gamma-ray burst science can be summarized below:
  - Thanks to its wide field of view and sensitivity down to 4 keV, ECLAIRs will discover and monitor hard X-ray variable and transient sources, such as X-ray novae, magnetars, ... Some will be occasionally observed after satellite slews.
  - Thanks to its MXT (and VT), newly discovered sources will be located with arscecond accuracy with the MXT and VT
  - Thanks to its instrument suite, multi-wavelength observations will be performed from a wide sample of potentially interesting sources, with increased sensitivity in the optical band and extended coverage in the infrared with the GFT
- Although SVOM is a PI type mission, access to the observing time will be possible through the CoIs of the mission

# Conclusions

- ECLAIRs sensitive down to 4 keV allowing a very large diversity of detected population: classical GRBs, XRFs, under-luminous GRBs and high-z GRBs.
- SVOM GRBs will be immediately observable from the Earth night side by large facilities.
- SVOM will have a dedicated ground follow-up segment (NIR-optical).
- SVOM should detect a number of GRBs with measured redshift equal to or larger than Swift
- SVOM is currently ending a phase A study at mission level, and is scheduled for a launch post 2015





# The SVOM movie