A Ground Follow-up Telescope for SVOM GRBs

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on behalf of the SVOM consortium

Outline

- GRBs

  Gamma-**R**ay **B**ursts

- SVOM

  Space-based multi-band astronomical Variable Objects Monitor

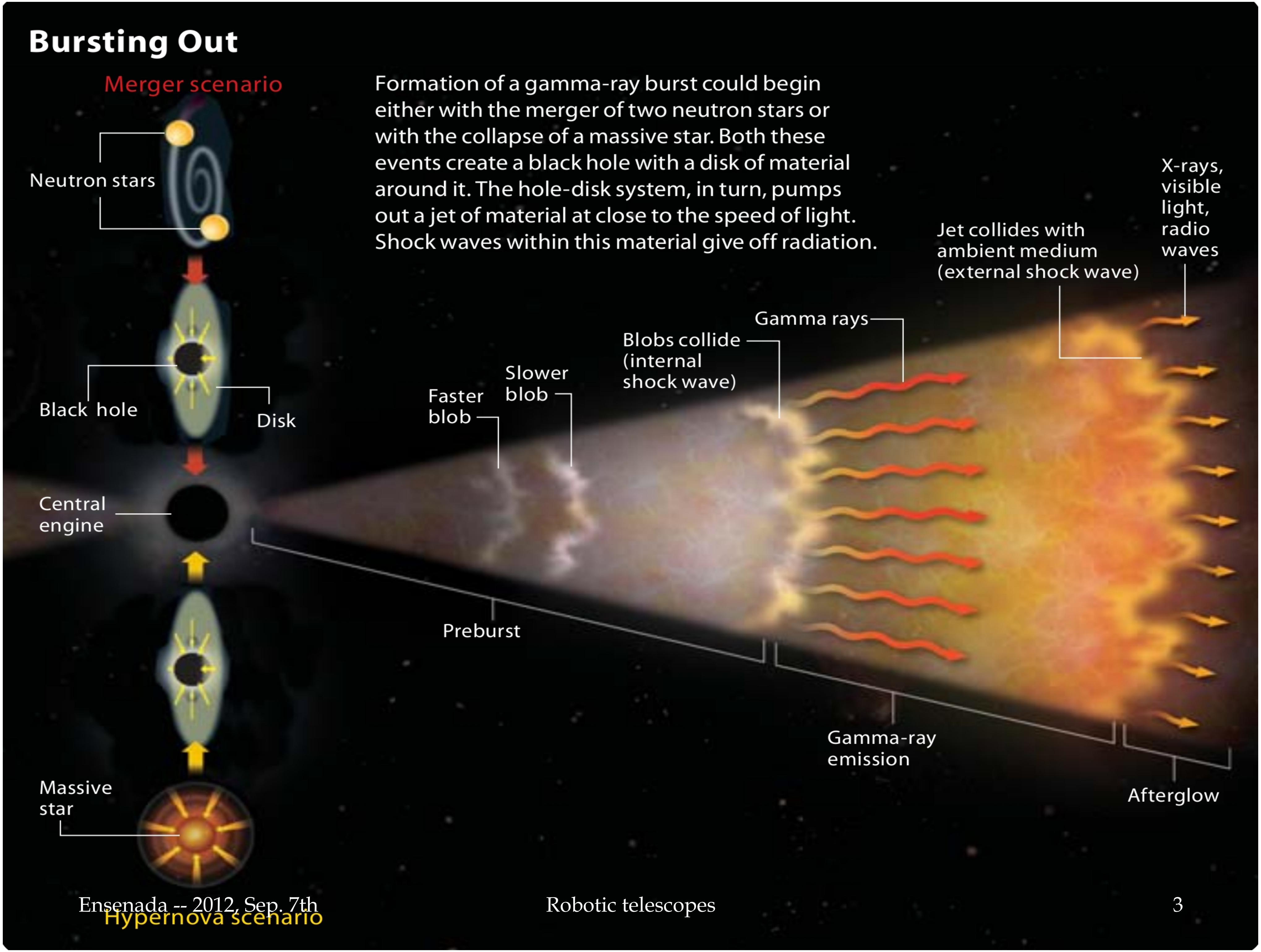
- GWAC and GFTs

  Ground **W**ide **A**ngle **C**amera and **G**round **F**ollow-up **T**elescopes

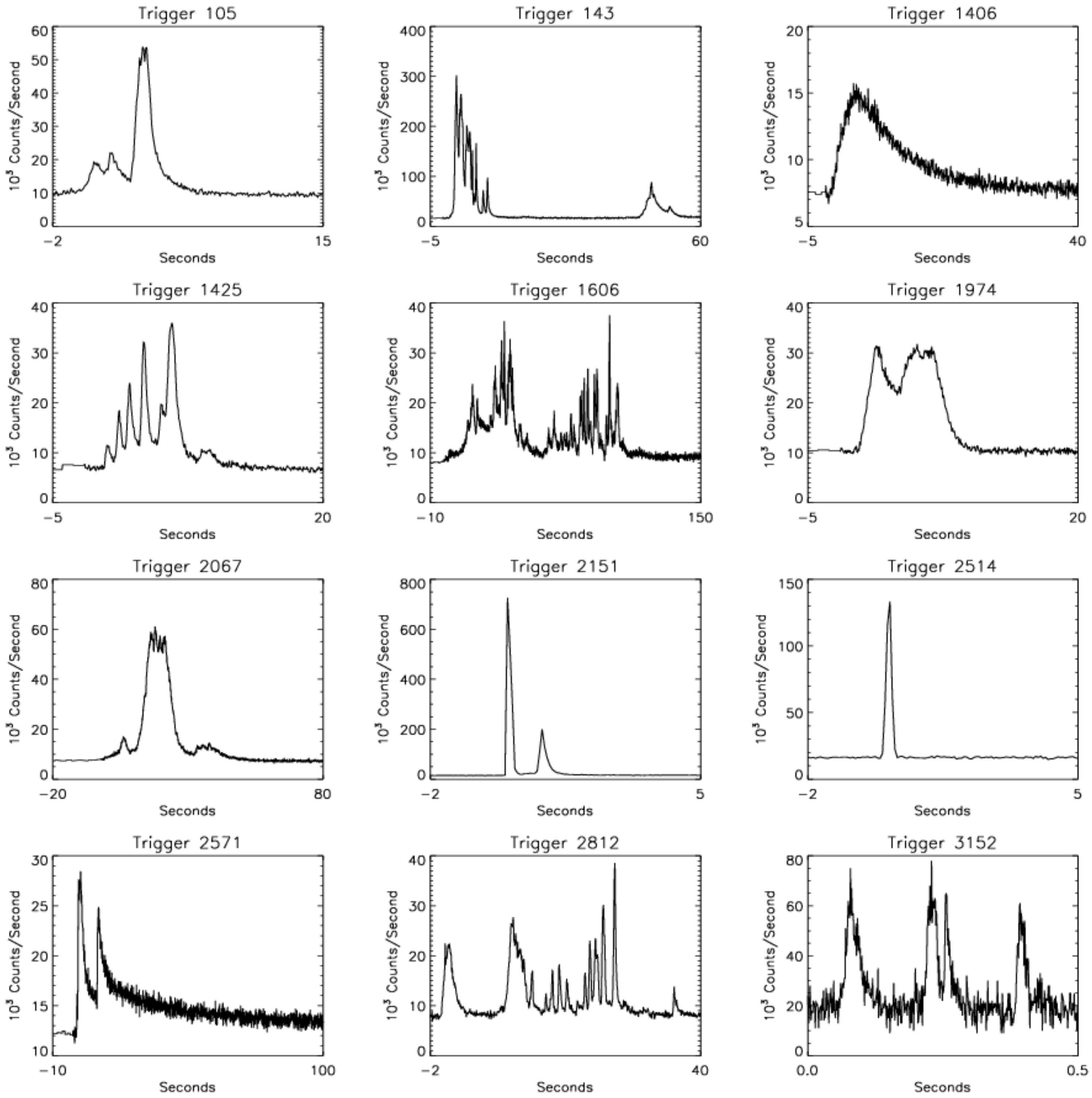
- CAGIRE – a NIR camera for the GFT

  CAtching **G**rb **I**nfra**R**ed **E**mission

- Conclusion


Bursting Out
Merger scenario
Formation of a gamma-ray burst could begin either with the merger of two neutron stars or with the collapse of a massive star. Both these events create a black hole with a disk of material around it. The hole-disk system, in turn, pumps out a jet of material at close to the speed of light. Shock waves within this material give off radiation.
Neutron stars
Black hole
Disk
Central engine
Massive star
Hypernova scenario
Faster blob
Slower blob
Blobs collide (internal shock wave)
Gamma rays
Jet collides with ambient medium (external shock wave)
X-rays, visible light, radio waves
Preburst
Gamma-ray emission
Afterglow

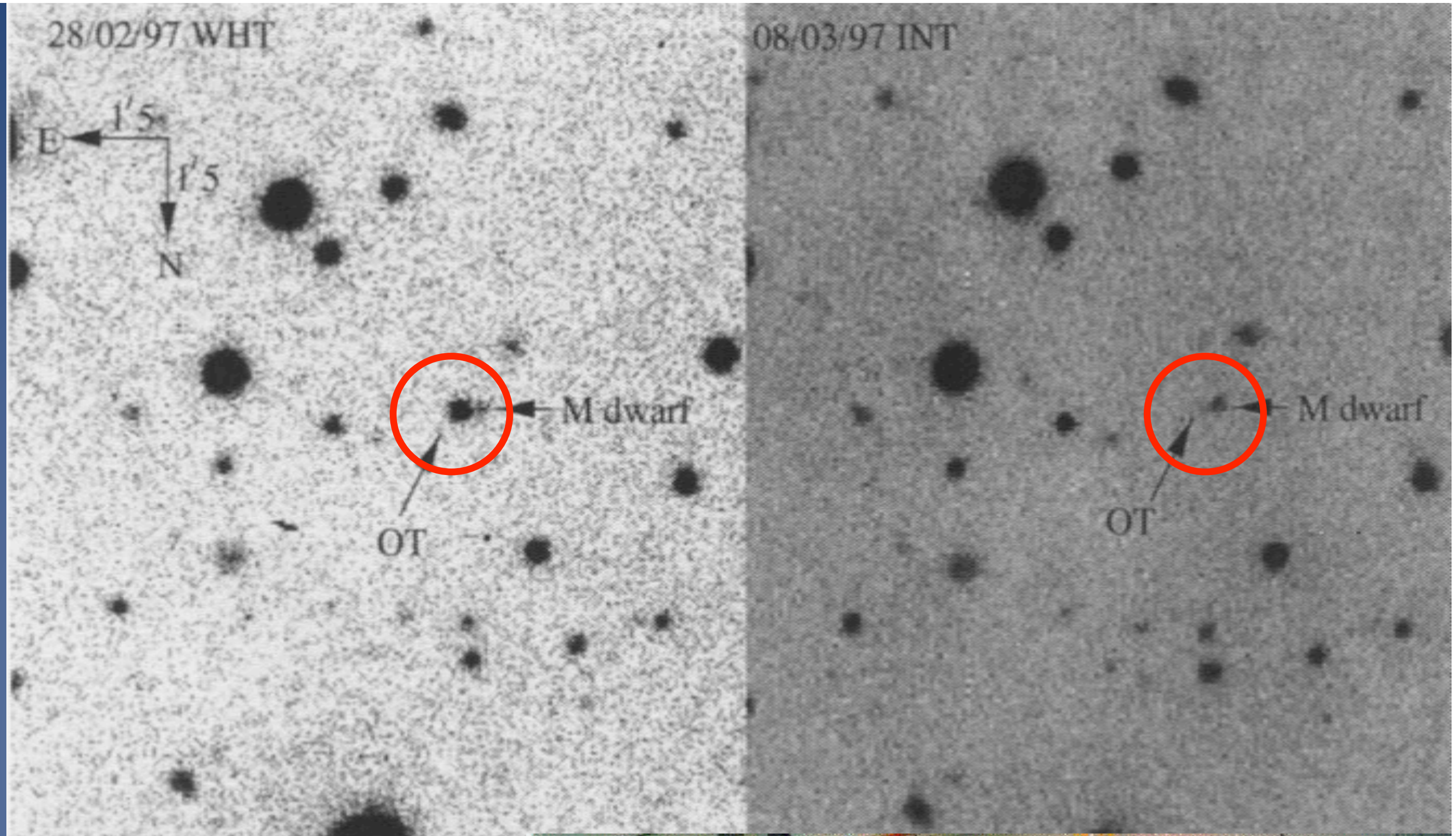
GRB ligth-curves



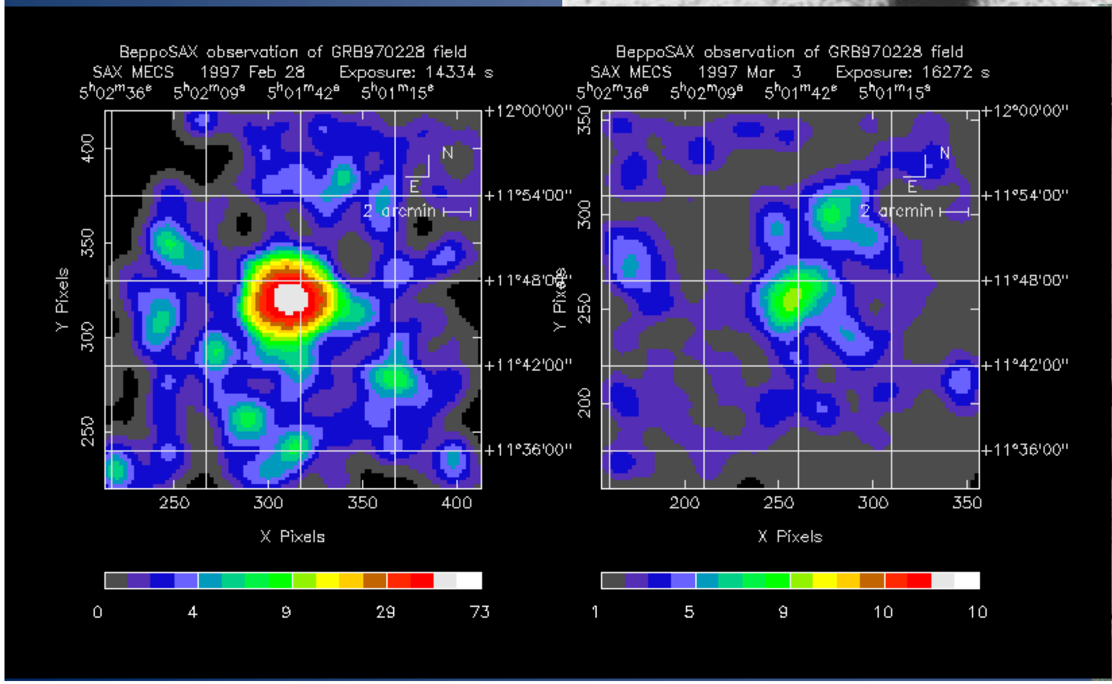
GRB 970228:

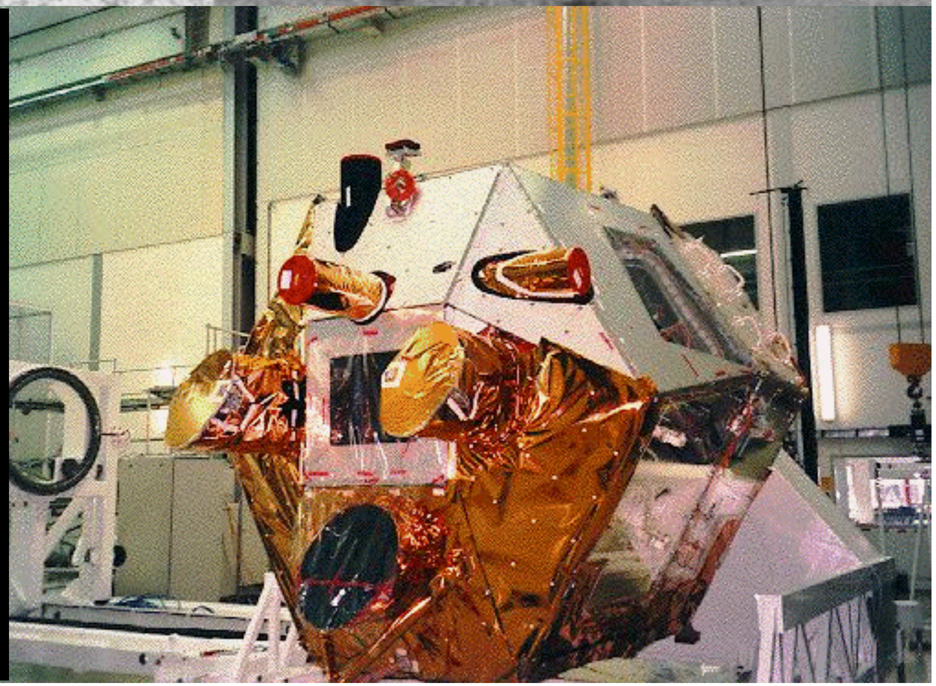
the discovery of GRB afterglows

Visible →



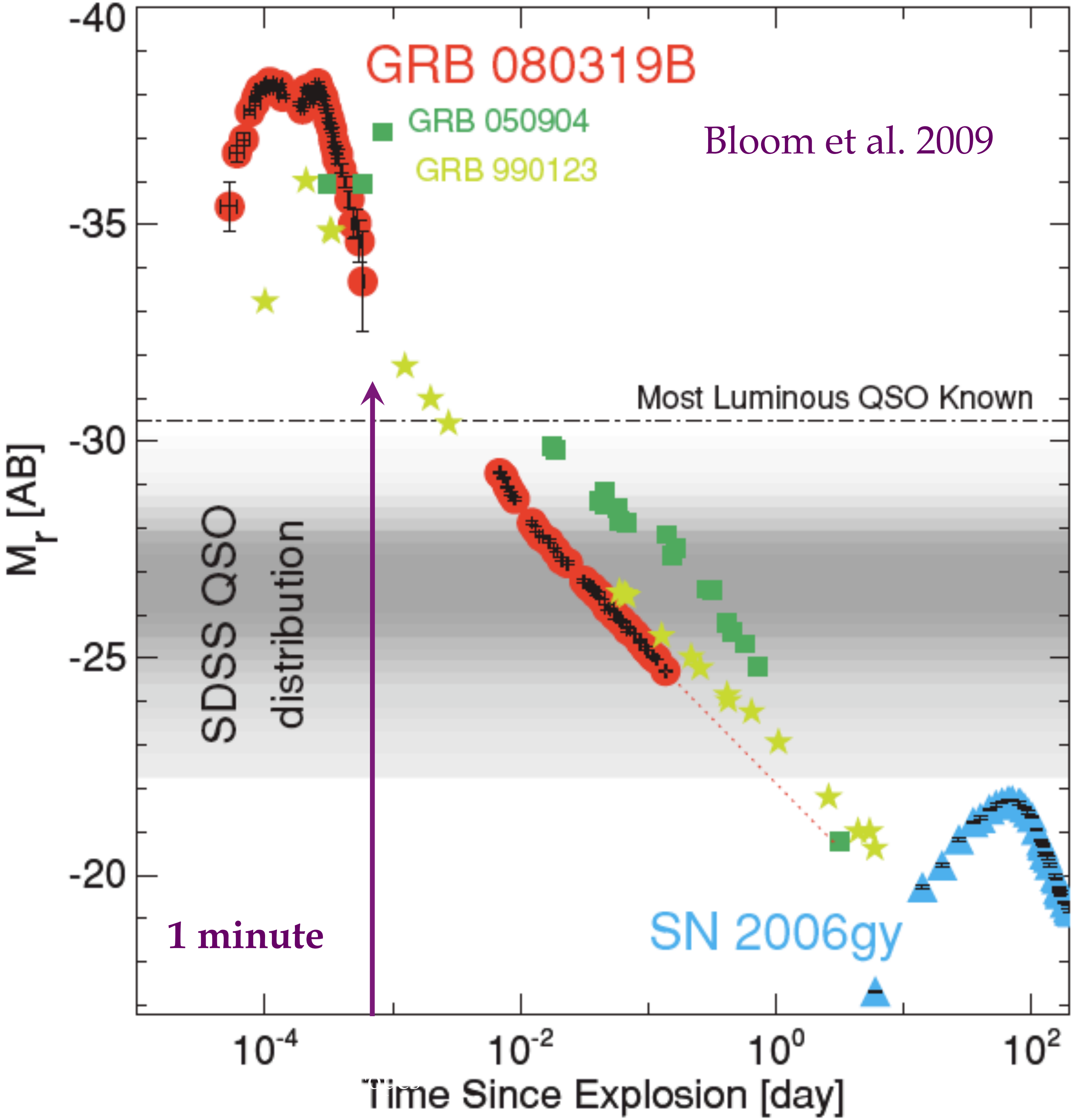
X-rays





GRB 080319

In K, GRB 080319 could have been detected up to z~17 !



Gamma-ray bursts are important !

- GRBs permit various studies:
  - The physics of stellar explosions
  - The physics of relativistic jets
  - The death of massive stars and the birth of stellar mass black holes

  - The composition and physical state of distant galaxies
  - The evolution of the IGM and the epoch of reionization
  - The cosmological parameters (standard candles)

  - GRBs are potential sources of GWs, neutrinos and CRs...

  - They can test some predictions of fundamental physics (Lorentz invariance…)

- Addressing these questions require complex observing strategies due to the diversity of GRBs and the dynamic range of timescales and luminosities

The detection of GRBs

- All GRBs known to date have been detected from space in X-rays or gamma-rays (space provides the energetics).
- All distances have been measured on the ground.

==> GRBs require an excellent synergy between space and ground.

==> Robotic telescopes have always played a privileged role

- Note: the direct detection of GRB afterglows in visible from the ground is still awaited
  - We tried with Megacam at the CFHT without success (Malacrino et al. 2007)
  - The LSST may detect a few dozen GRB afterglows per year

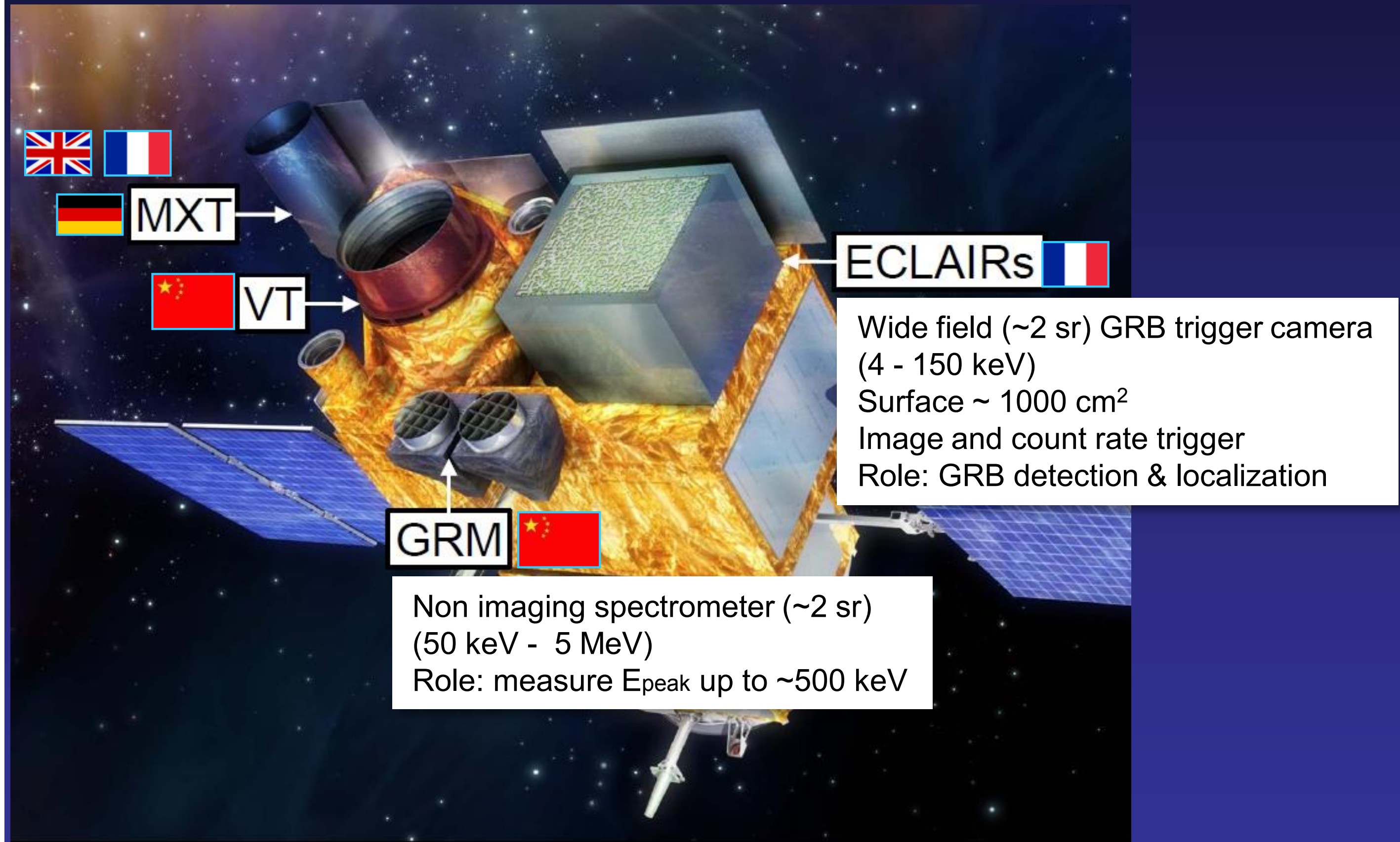
SVOM

The next GRB mission

SVOM science payload

a combination of a multi-wavelength space payload

Space payload

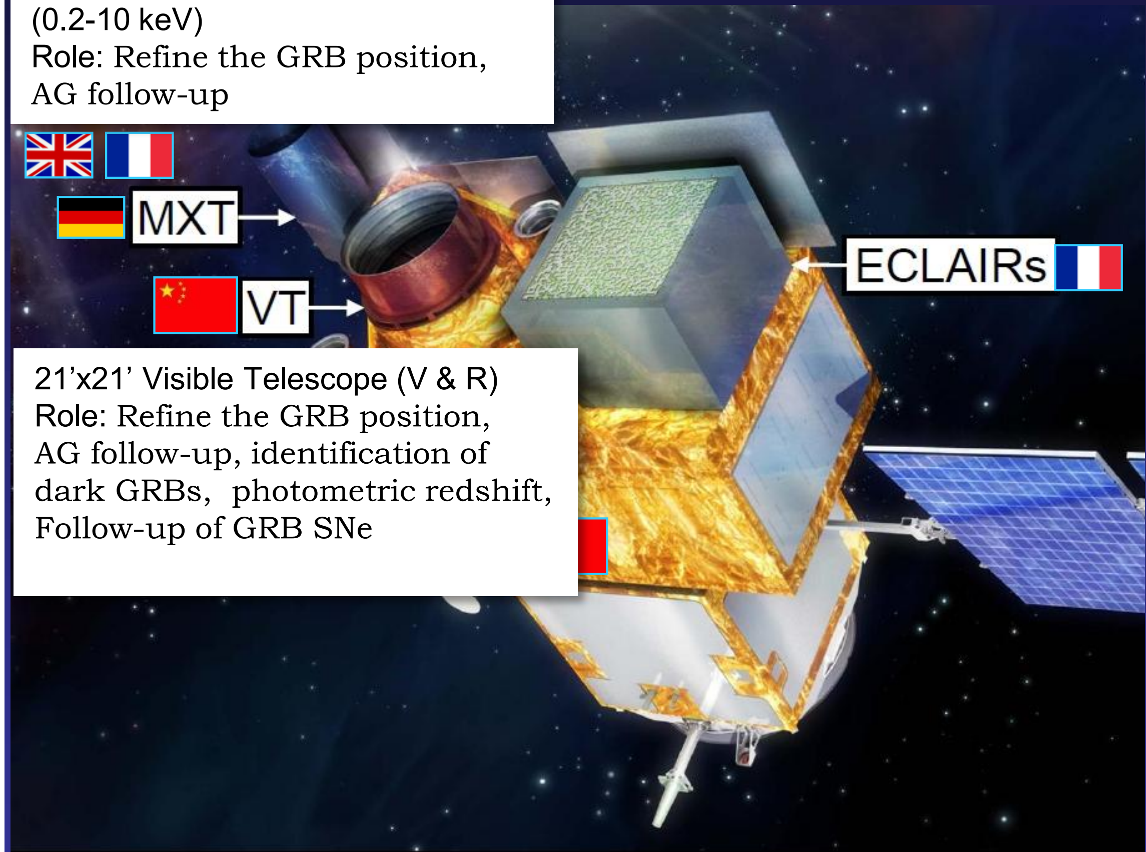


SVOM science payload

a combination of a multi-wavelength space payload

payload

64’x64’ 1 m length X-ray Telescope (0.2-10 keV)
Role: Refine the GRB position, AG follow-up

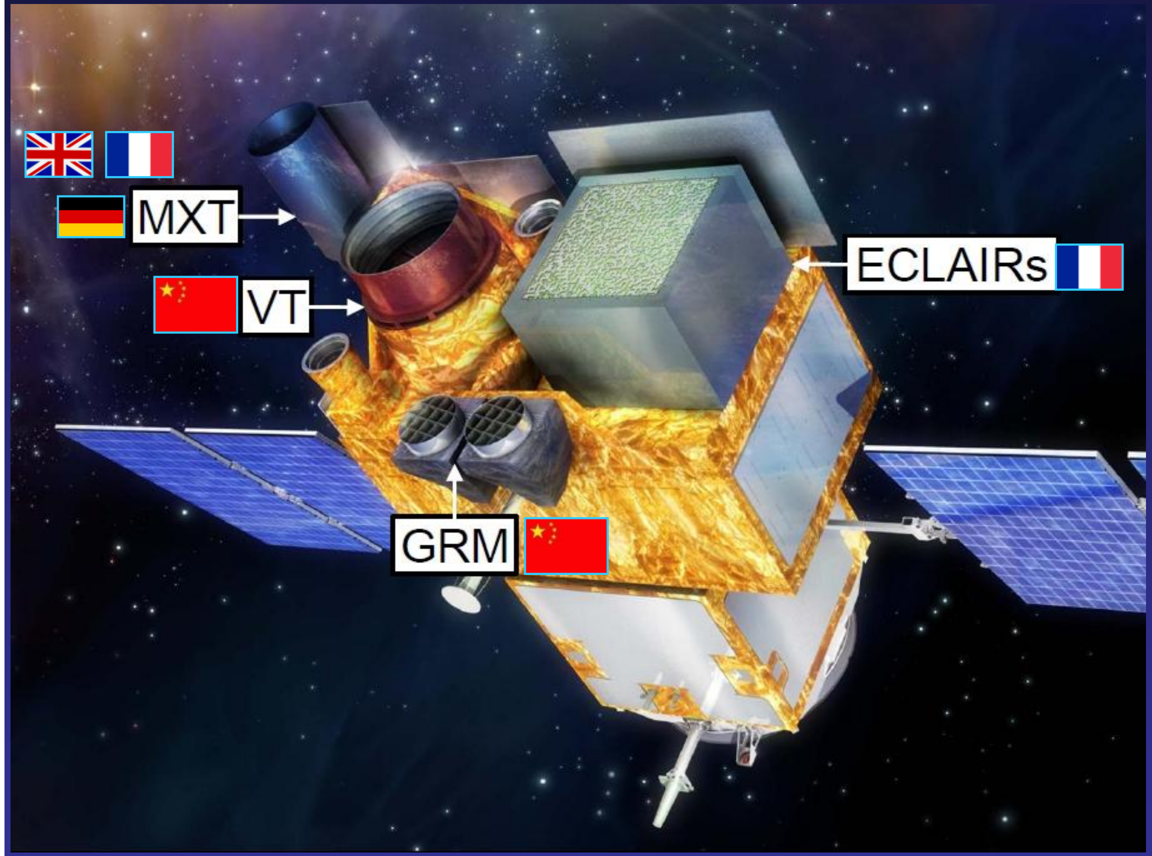


21’x21’ Visible Telescope (V & R)
Role: Refine the GRB position, AG follow-up, identification of dark GRBs, photometric redshift, Follow-up of GRB SNe

SVOM science payload

a combination of a multi-wavelength space payload
with a dedicated ground NIR/optical instruments

Space payload



Ground segment

GWAC

Ground Wide (~2 sr) Angle Camera (V band)
Role: study of the prompt optical emission

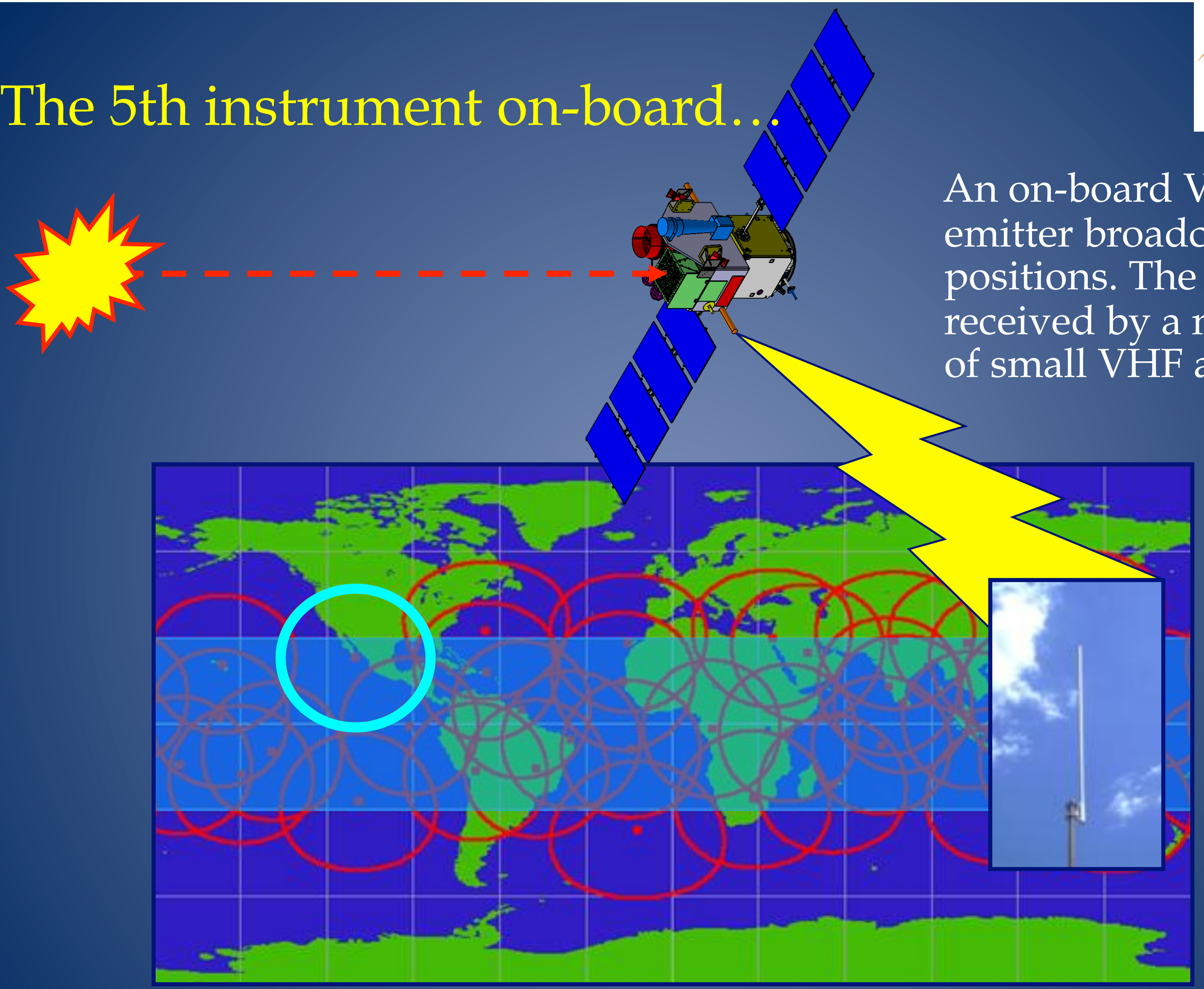
GFT-1

GFT-2

Ground follow-up telescope
(BVRI – J & H)
Role: Identification & localisation of AG using ECLAIRs positions, localisation of dark GRBs, follow-up of the early AG in NIR/optical, Spectral distribution of the early AG, measure the prompt optical emission of long GRBs

The 5th instrument on-board…

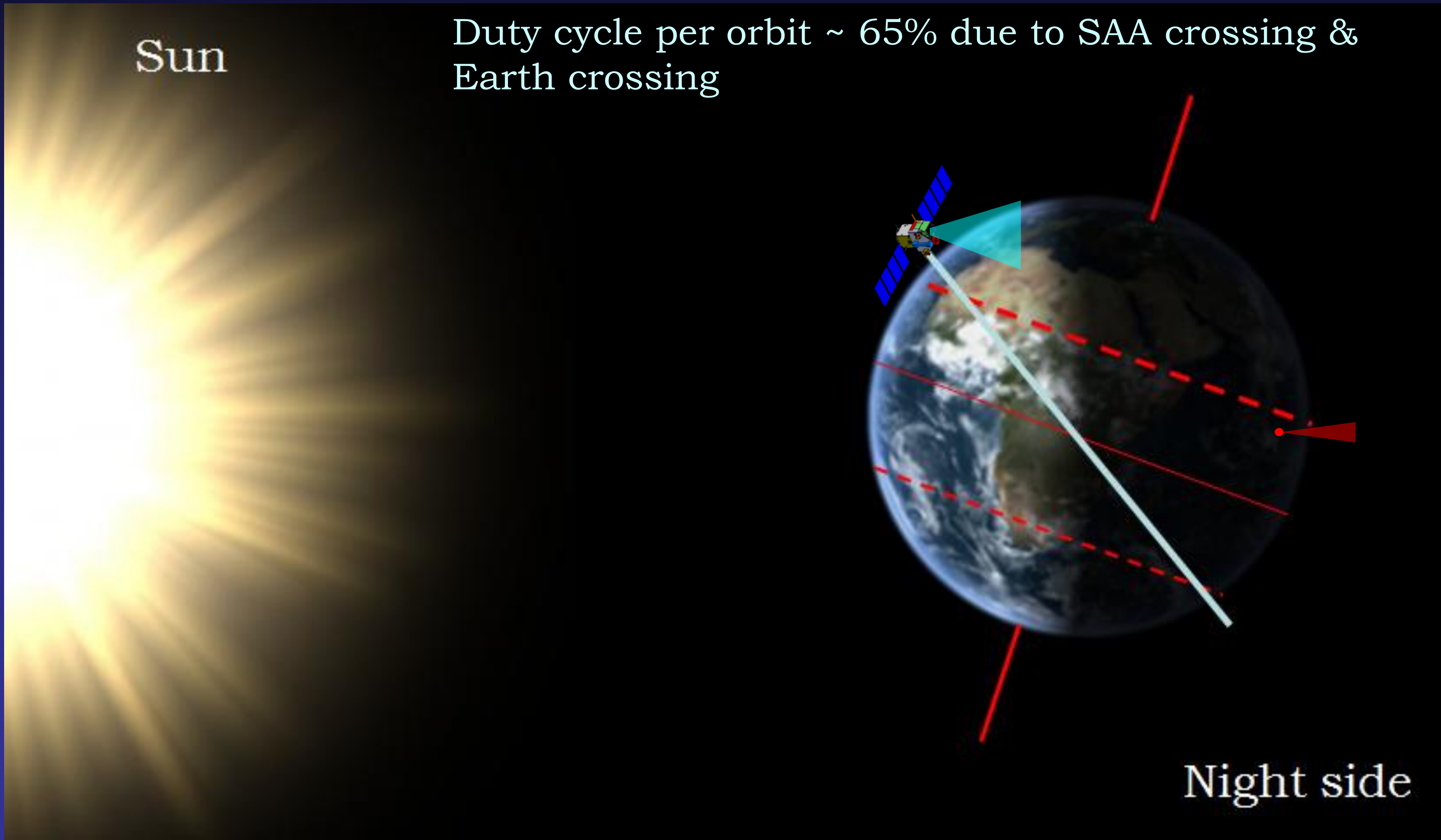
An on-board VHF emitter broadcasts GRB positions. The signal is received by a network of small VHF antennas



SVOM orbit

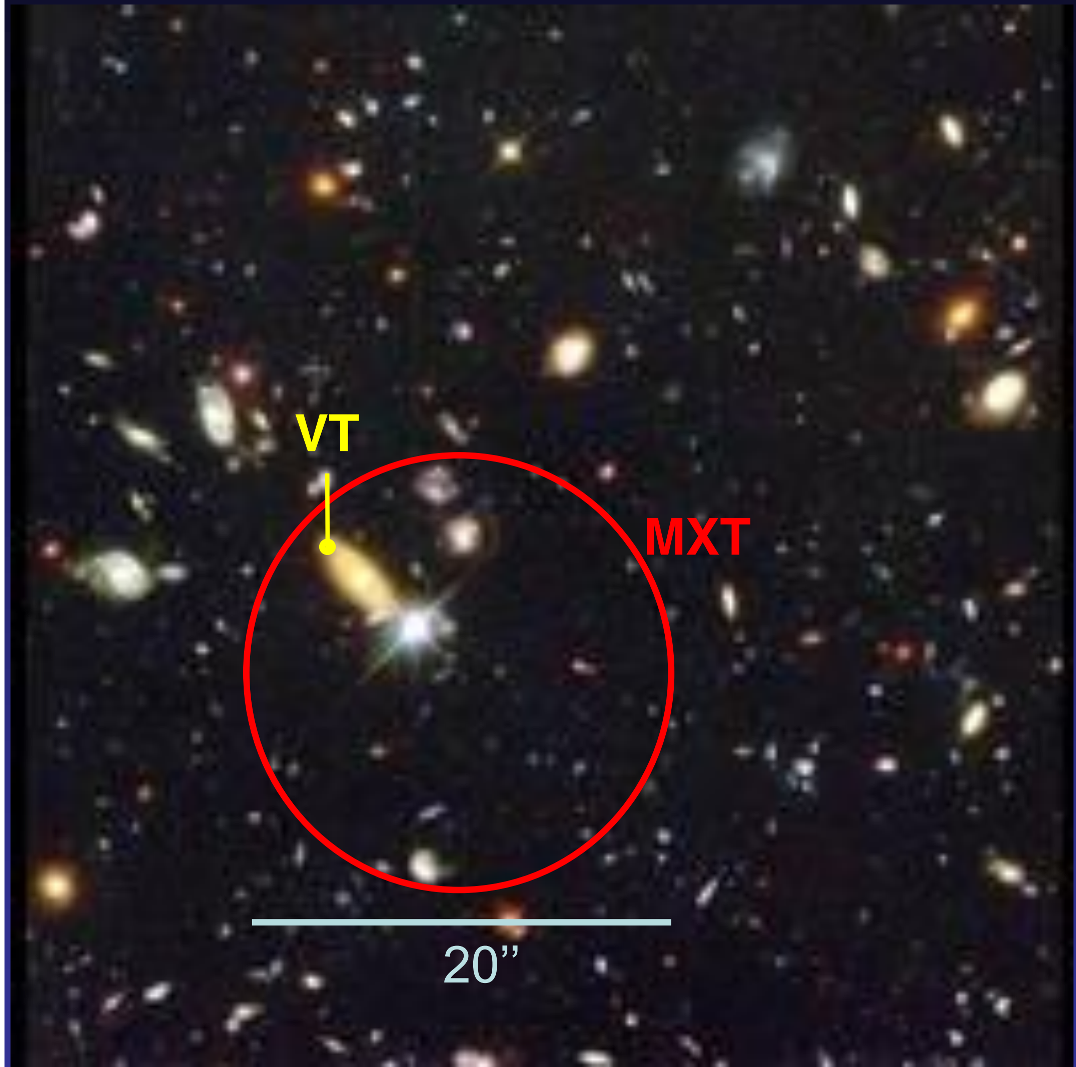
Orbit: LEO (625-650 km) with an inclination of ~30° & Anti-Sun pointing

Avoidance of the Galactic Centre as well as the brightest X-ray sources



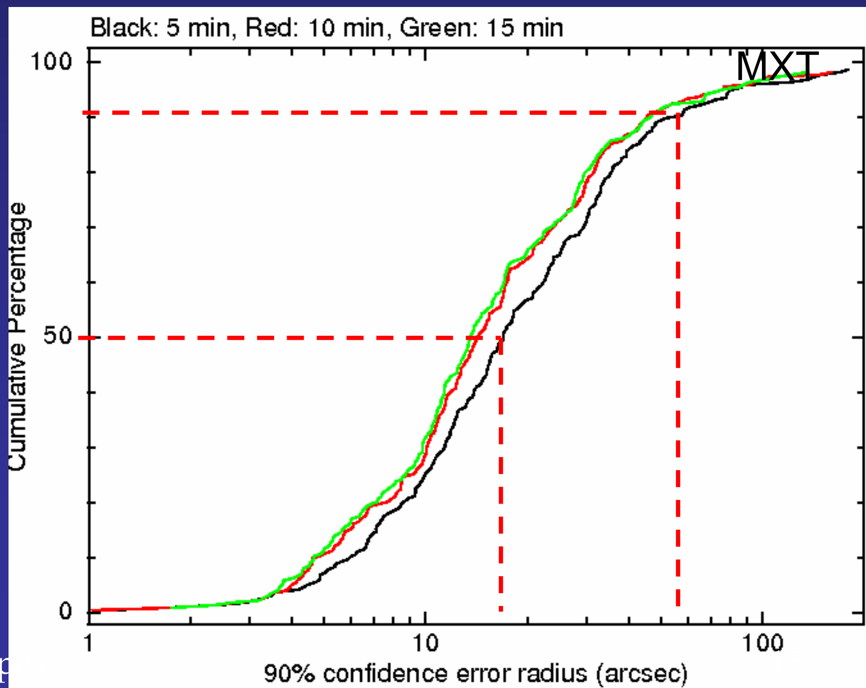
Most of the GRBs (up to 75-80%) detected by SVOM to be well above the horizon of large ground based telescopes all located at tropical latitudes

GRB localisation budget



Required loc. Accuracy (90% c.l.)	
ECLAIRs	< 12 arcmin
MXT*	< 17" for 50% of loc. sources < 53" for 90% of loc. sources
VT	< 1 arcsec

* Assuming an obs. start time at T_0 + 5 min



The strengths of SVOM

- ECLAIRs extends the energy range for GRB detection down to 4 keV, allowing the detection of many classes of GRBs:
  GRBs, XRFs, sub-luminous GRBs, high-z GRBs

- Excellent coverage of the prompt emission: from visible to MeV

- Good match of the sensitivities of the MXT and VT. A great majority of SVOM GRBs will be detected by both telescopes

- SVOM GRBs are immediately observable from the dark side of the Earth

- Some ground follow-up is included in the mission: early visible and NIR photometry, with good temporal resolution

- ***Due to the observing strategy, optimized for the follow-up from the ground, SVOM is expected to provide each year as many GRBs with a redshift as Swift***

Ground follow-up of SVOM GRBs

GWAC

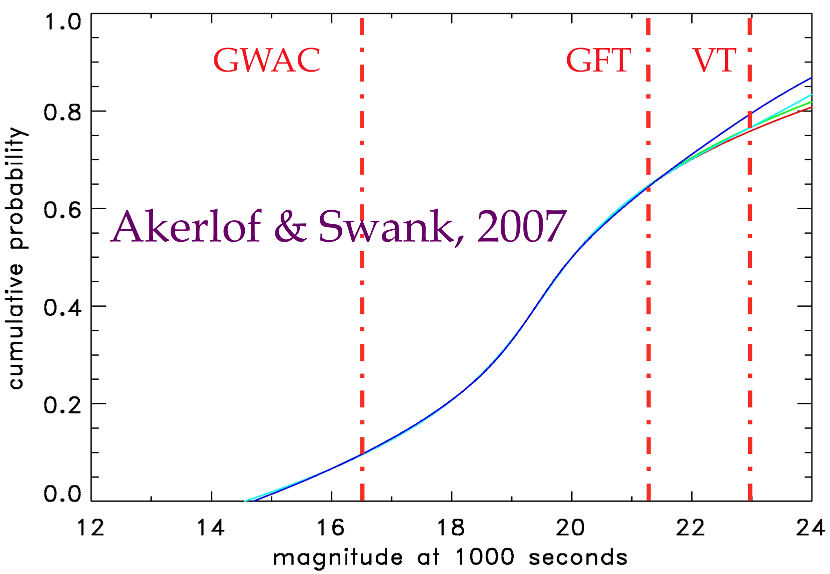
GFT-1

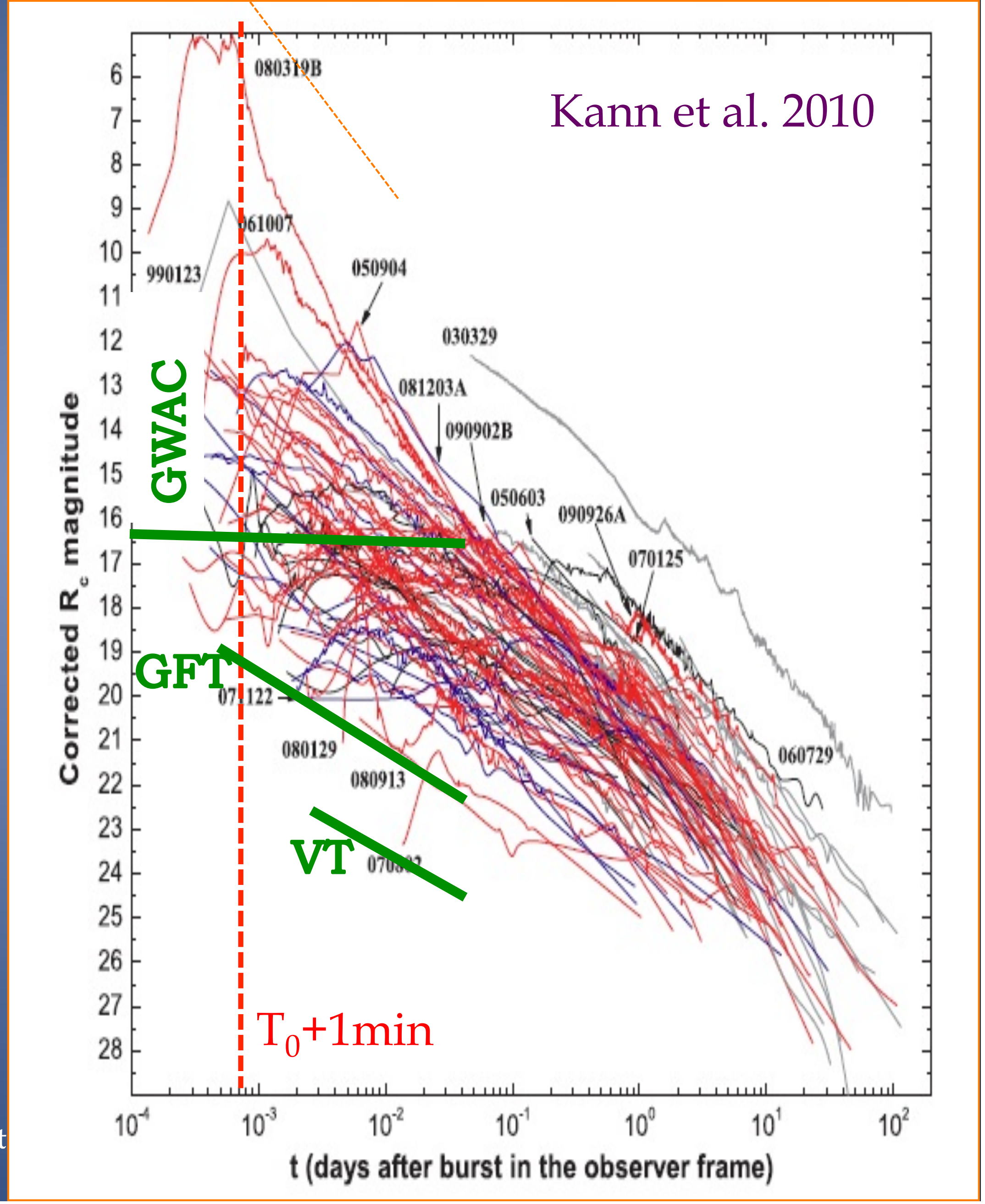
GFT-2 (CAGIRE)

Optical follow-up - summary

Limiting magnitudes:
(R-band - 300 sec)

- GWAC: R = 16.5
- GFT: R = 21.2 ; J=19
- VT: R = 23





Parameters of GWAC

- Cameras： 72 – 2 sites
- Mounts: 18
- Diameter： 180 mm
- Focal Length： 213 mm
- Wavelength： 450－900 nm
- Total FoV： 9000 sq.deg
- Limiting Mag (V)： 16.5（5σ,10s)

Prompt optical emission detection down to $M_V \sim 16.5$ (10 s exposure)

Two Ground-based Follow-up Telescopes

- The prime goal of the 2 GFTs is the early identification of GRB afterglows from the ECLAIRs positions

  - GFT-1 is the chinese GFT at Xinglong observatory (TNT / EST)
  - GFT-2 is the French-Mexican GFT at OAN-SPM

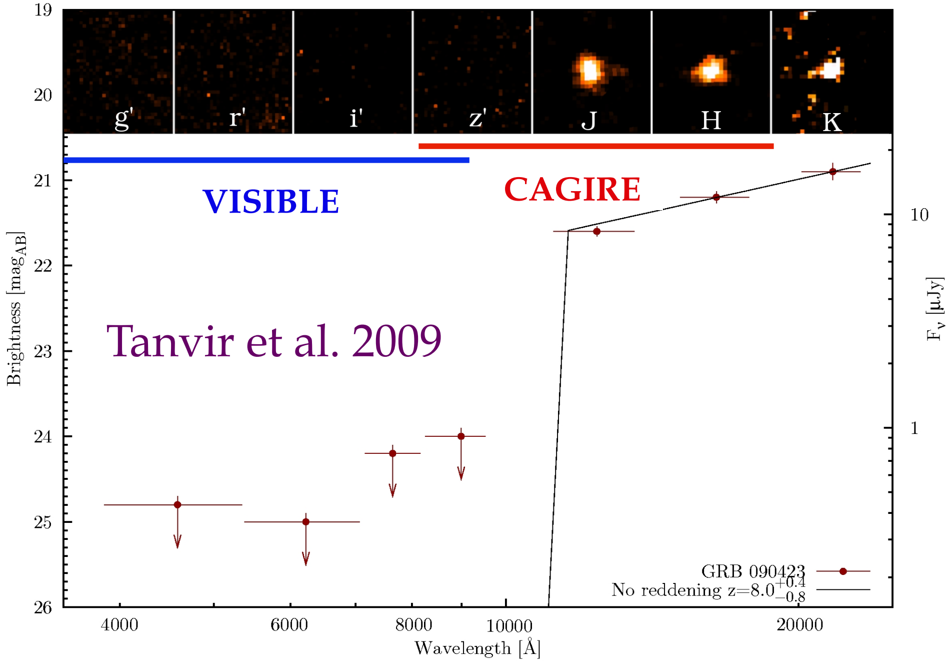
- Instrumentation of GFT-2 (2 channels)
  - 1 visible camera 4k x 4k
  - 1 NIR camera 2k x 2k H2RG
  - *1 medium resolution spectrograph (TBC)*

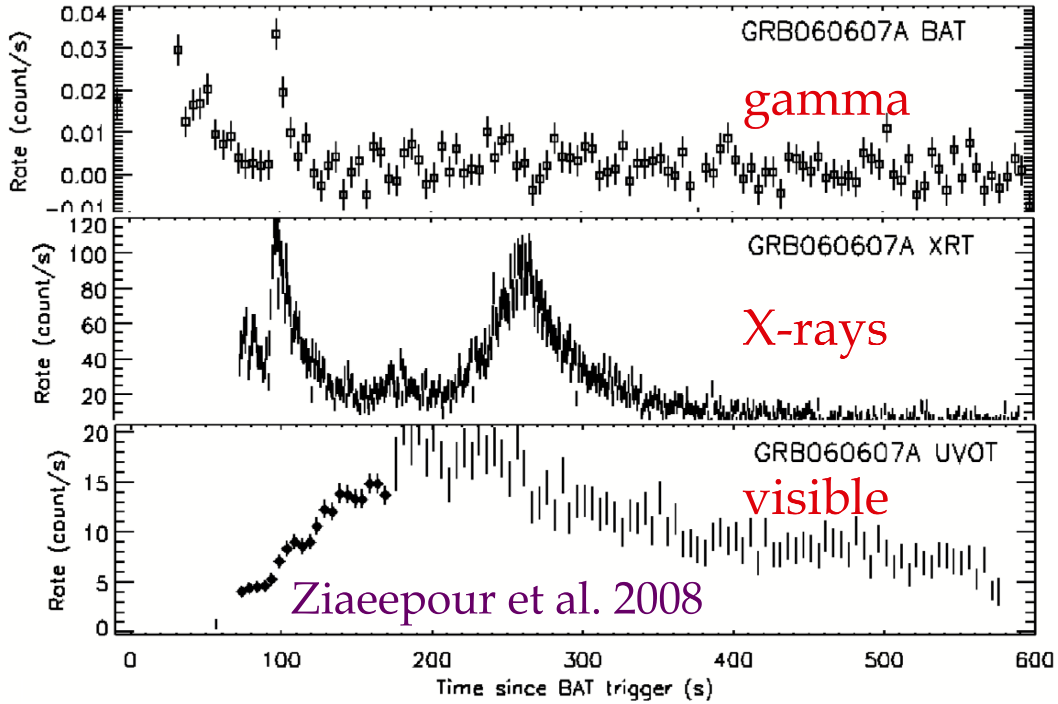
- GRB objectives of GFT-2:
  - Localization of SVOM GRBs, including dark GRBs
  - Observation of the early afterglow in visible/NIR
  - SED of the early afterglow
  - Study of the prompt visible emission of long GRBs

GRB science…

The GFT permits the detection of GRB afterglows at visible and NIR wavelengths.

The GFT measures the early optical afterglow with excellent sensitivity, spectral coverage and temporal resolution. It will provide new constraints on the complex physics at work during this phase.

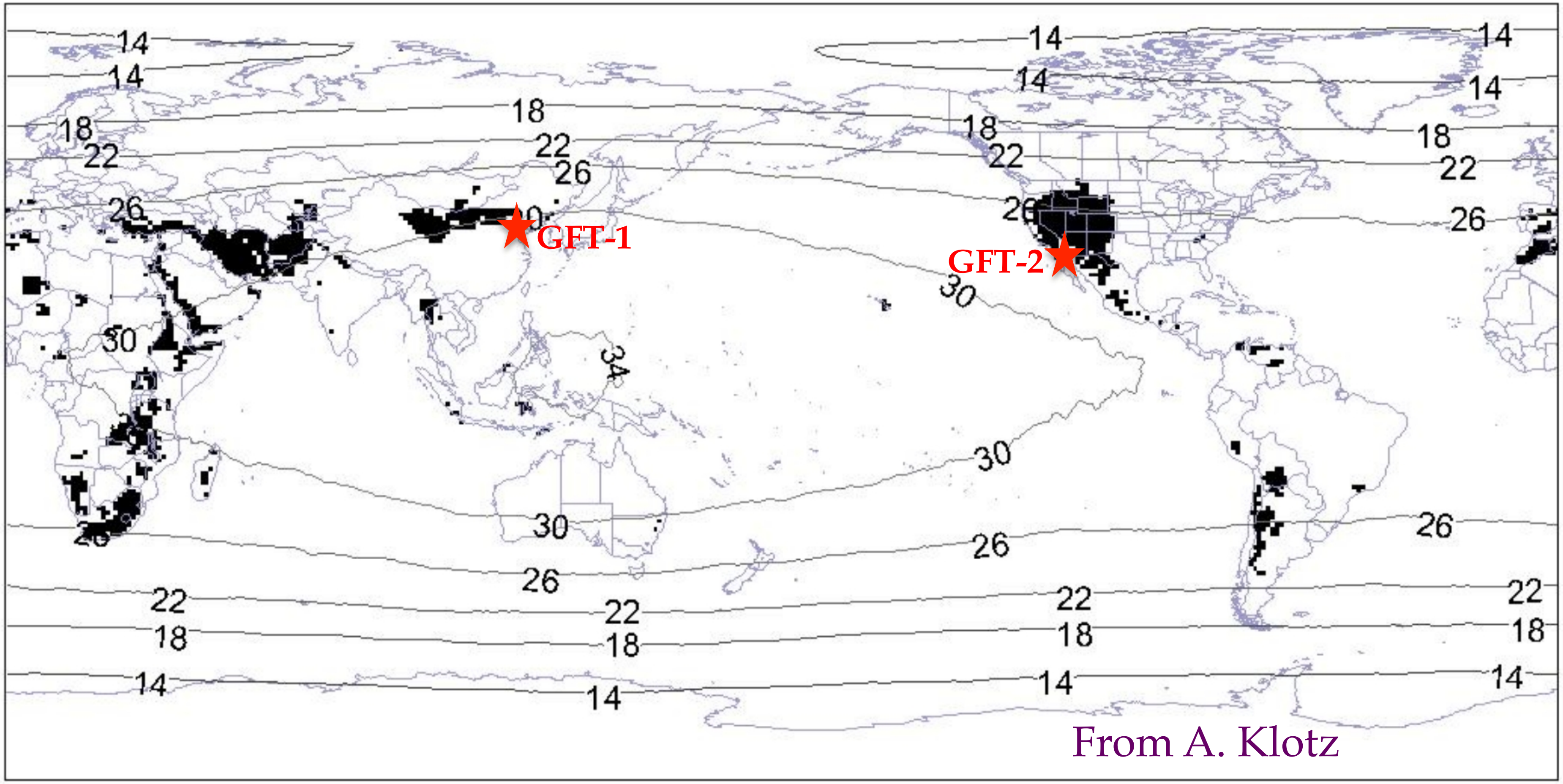




Period of GFT observation

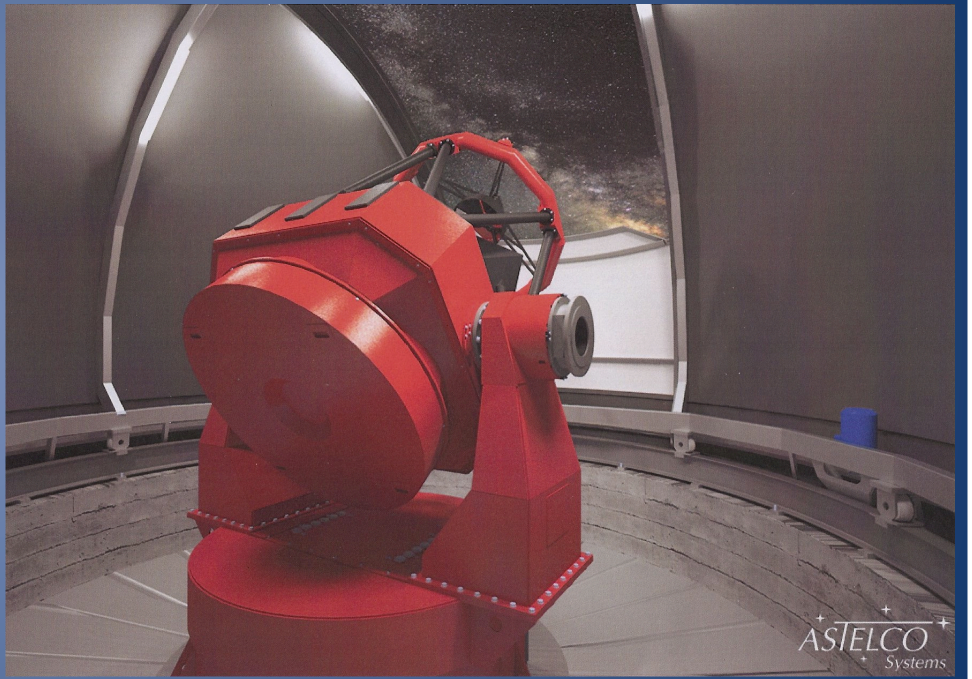
SVOM GRB illumination map

GRB prompt lightening detected by SVOM. grbris*sunset*(meteo>60%)*altitude(>1500m) (percent)

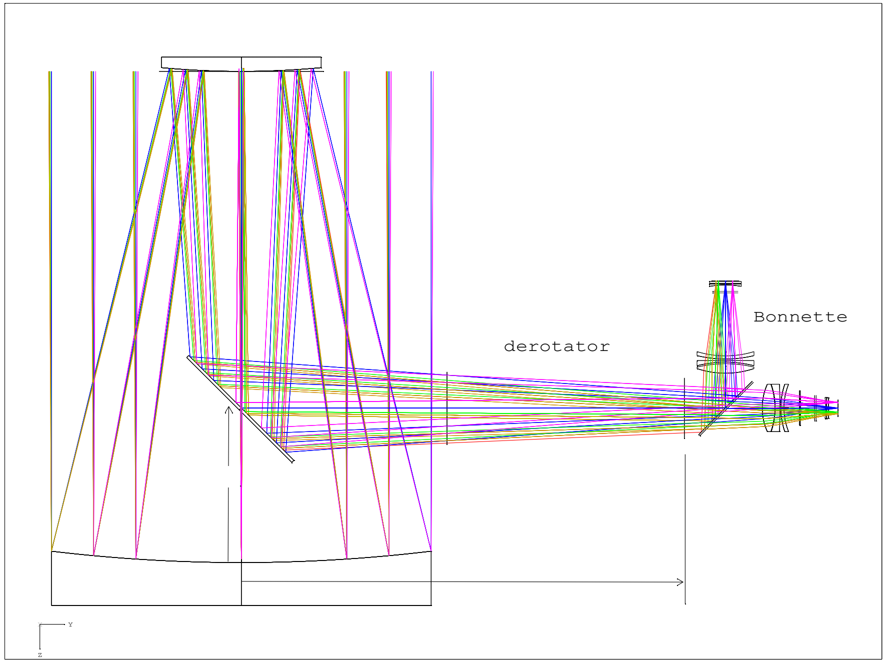


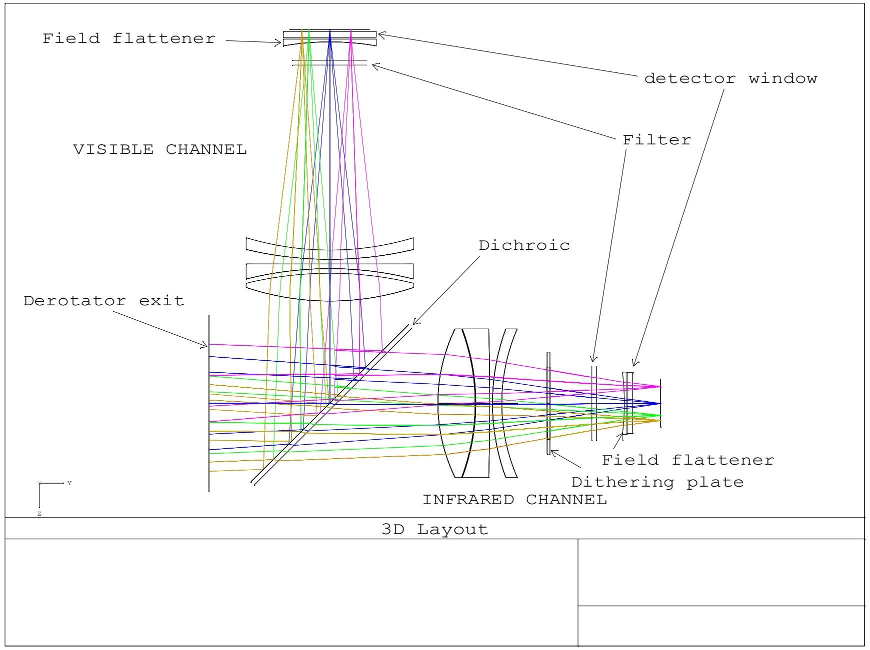
Characteristics of GFT-2

Name	GFT
Diameter	1.2
Field of view	30' x 30'
Mount	Alt-Az
Pointing speed	10°/sec
Duty cycle	90%
Site	OAN-SPM, Mexico
Fraction of quickly observable GRBs	~20%
Photometric channels	B, V, R, I, z, J, H
Number of channels	1 visible + 1 NIR
Limiting magnitude (300 sec, 10σ)	R = 21.2 J = 19.0
Duration of real-time analysis	<4 min
Reference catalogs	NOMAD…



GFT-2 optical design





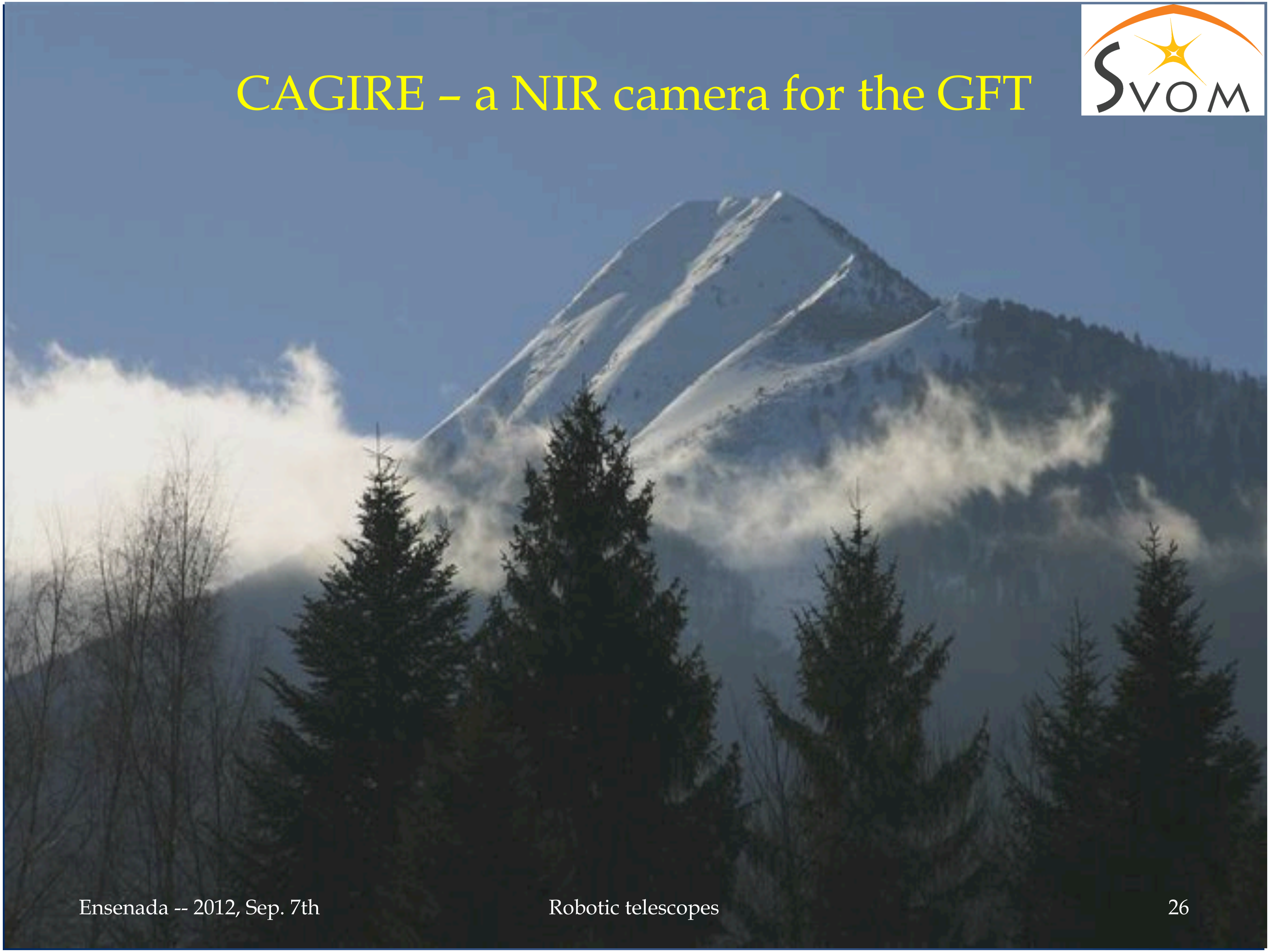
Science goals beyond GRBs

- Priority to all types of alerts:
  - GW alerts --> need mozaicing
  - Neutrino alerts
  - Microlensing events

- Between alerts:
  - Medium resolution spectroscopy of various transients: novae, SNe
  - Variable stars
  - Solar system objects: NEO, comets
  - …

- Some challenges:
  - Reliability of the observatory
  - Scheduling and execution of the observations
  - Real-time analysis

CAGIRE – a NIR camera for the GFT



Why CAGIRE?

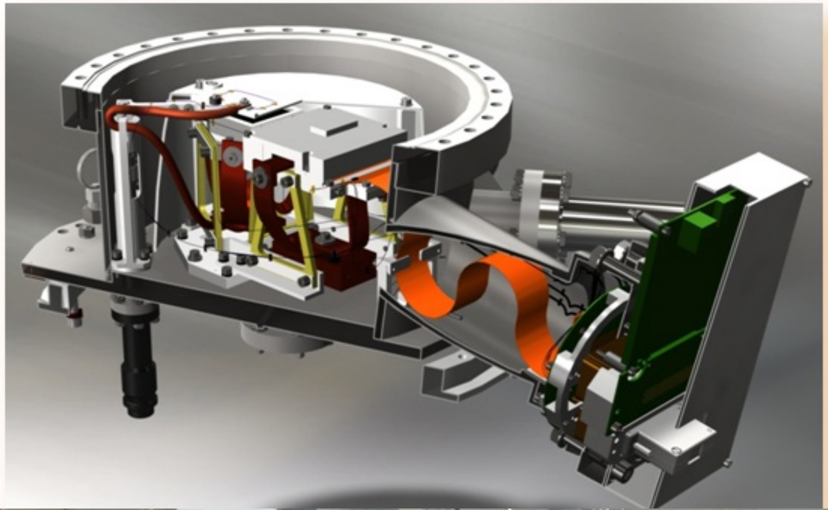
- Rationale: developing a NIR camera for a robotic telescope
- Science goals:
  - Systematic NIR imaging and photometry of all types of explosive events during the first minutes
  - Early detection of the afterglows of dark GRBs (extinct or distant)
  - Extending the range of photometric measurements for observations between the alerts

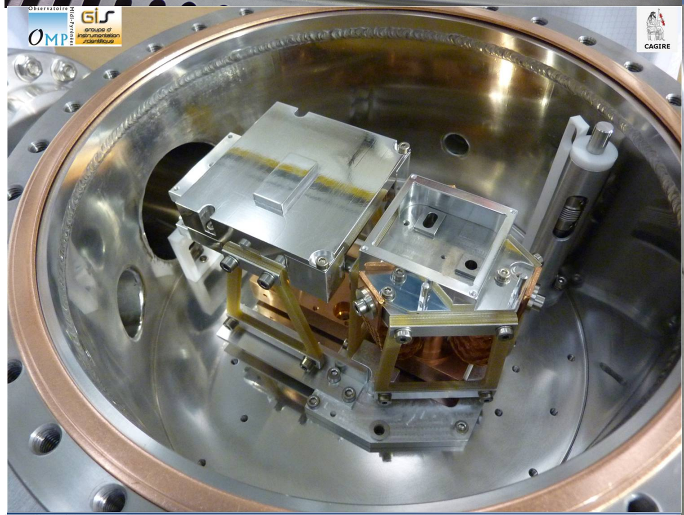
Status of CAGIRE

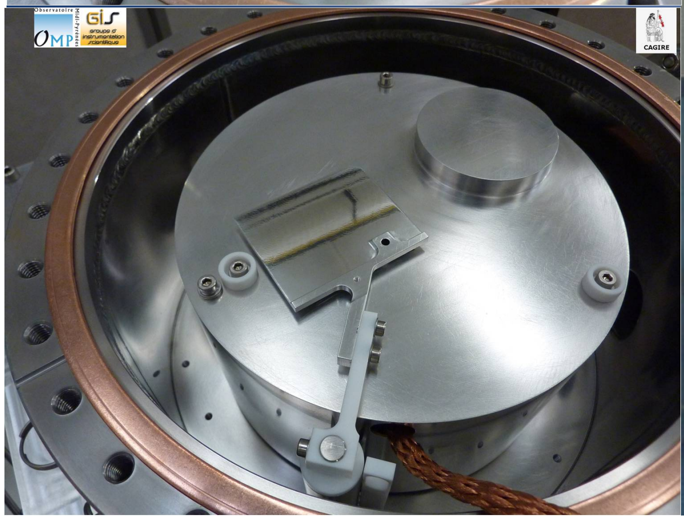
- The prototype is under construction:
  - Design, construction and now test of the cryostat
  - The control command of the detecteur with the IDECAR ASIC, and acquisition software are operational
  - We have ordered an engineering detector which should be delivered by the end of this year
  - The test bench is designed, and the material commanded

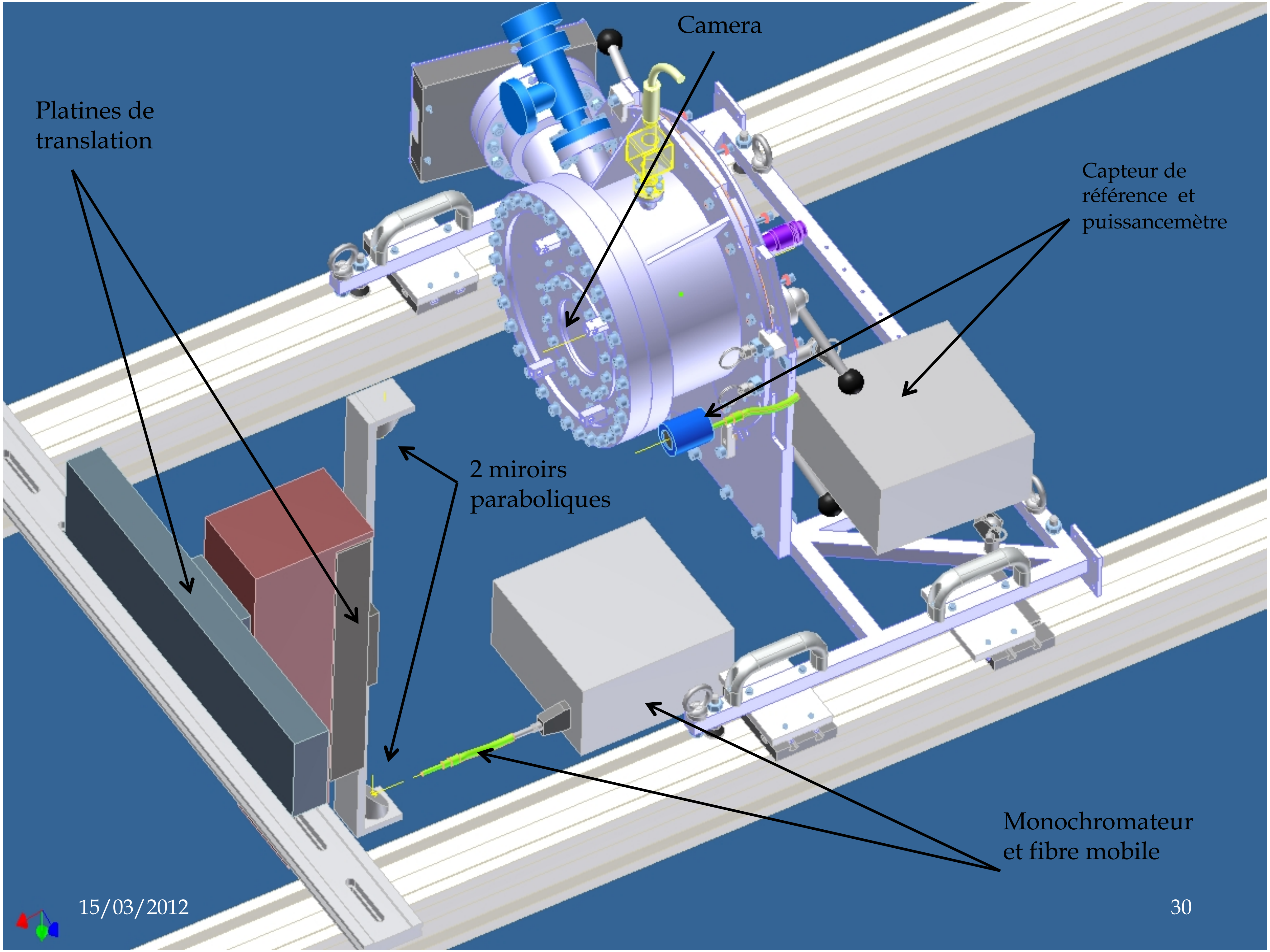
  - Year 2013 will be dedicated to the measure of the performance of the prototype camera

CAGIRE cryostat



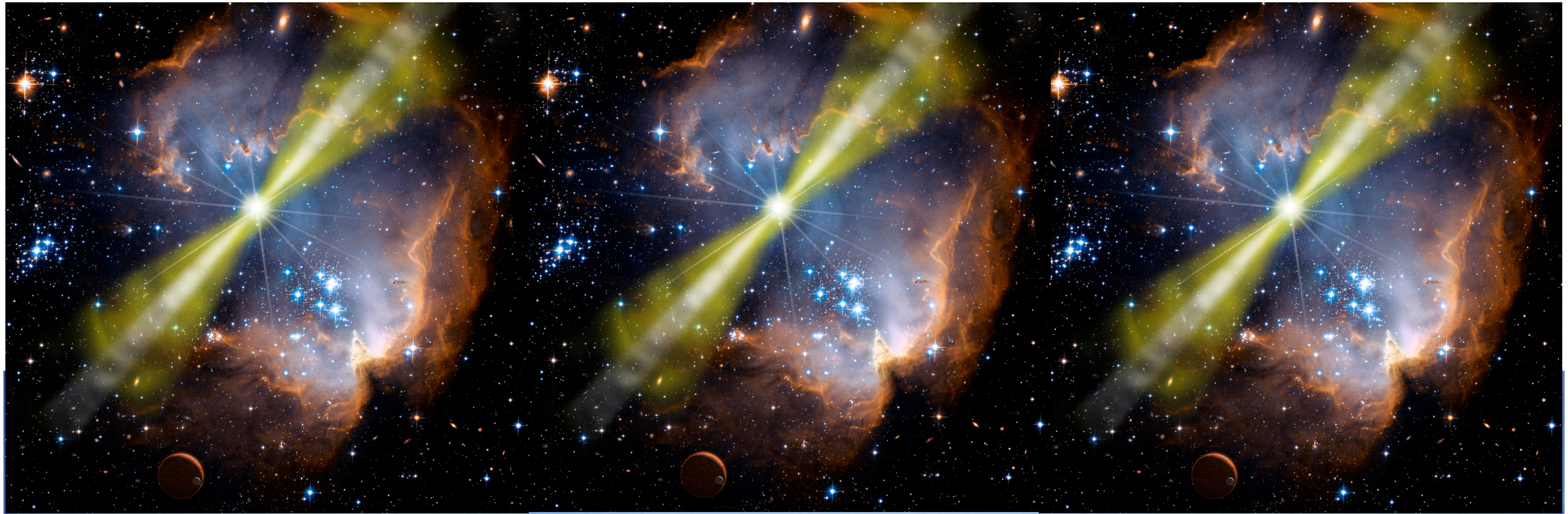





Camera
Platines de translation
Capteur de référence et puissancemètre
2 miroirs paraboliques
Monochromateur et fibre mobile

SVOM: status of the project

- SVOM is starting again after a three-year freeze period: a decision will be taken soon about the platform
- GFT-1 exists at Xinglong observatory
- The funding of GFT-2 has been approved within the framework of a french "Laboratory of Excellence"
- The CAGIRE NIR camera is under development at IRAP (Toulouse), a prototype will be available next year for laboratory testing




SEA RAGE