Catching the first stars with SVOM

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On behalf of the SVOM collaboration

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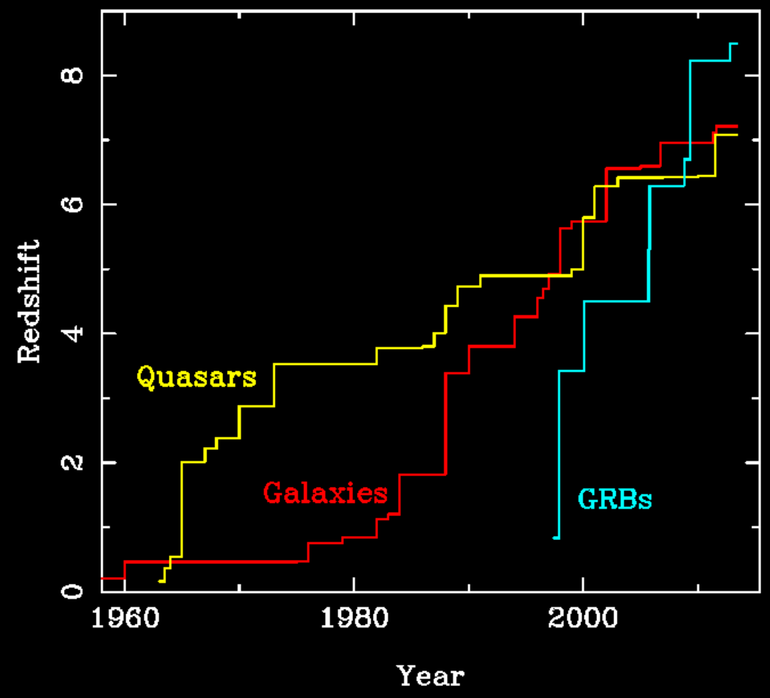
SVOM Scientific Rationale

- GRBs are unique laboratories and probes
  - Matter and radiation under extreme conditions
  - Black hole formation
  - Jet physics
  - Cosmic rays acceleration
  - Gravitational wave sources
  - Fundamental physics tests
  - Stellar Evolution
  - Cosmology and deep Universe



SVOM specific science goals

- GRB classification
- GRB physics
  - Acceleration and nature of the relativistic jet
  - Radiation processes
  - The early afterglow and the reverse shock
- GRB progenitors
  - The GRB-Supernova connection
  - Short GRB progenitors
- Cosmology
  - Constraining the chemical enrichment of the ISM
  - Sign posting the very first galaxies
  - Tracing star formation
  - Re-ionization of the Universe
  - Catching the first stars
- Fundamental Physics
  - Origin of high energy cosmic rays
  - Probing Lorentz invariance
  - Short GRBs and gravitational waves

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SVOM and Cosmology: high-z GRB as a unique probe of the early Universe

The observing strategy of SVOM will result in a higher rate of GRB identifications compared to previous experiments, and it will also be contemporary to the next generation of large optical and radio telescopes like JWST, the ELTs and SKA.

⇒ This will allow the use of GRB afterglows as cosmological probes at even higher redshift than obtained so far (z>9).

- Catching the first stars

Direct detections of Pop III or Pop II.5 stars in the early Universe appear highly unlikely even with up-coming observatories such as the James Webb Space Telescope (JWST) or the proposed 30–40 m ground-based telescopes (such as the ELT). Individual stars are much too faint, and only rich clusters of very massive stars might be bright enough to lie above the detection limits in long exposures (e.g. Johnson et al. 2009).

⇒ Massive, low-metallicity Pop III stars may produce very powerful long GRBs
Meszaros & Rees (2010): about 50% of the GRBs at z>6 from Pop III stars.

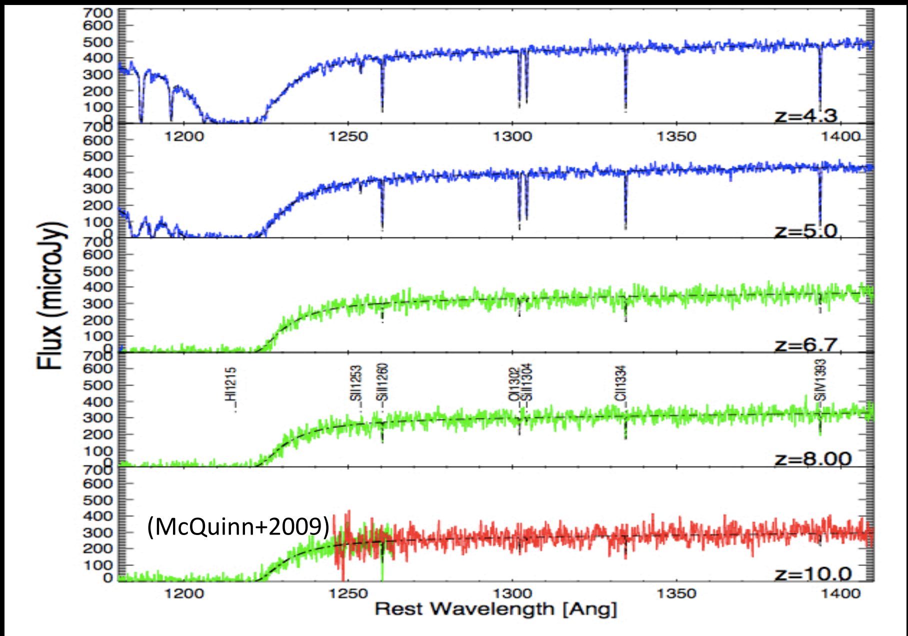
A radio signal is expected (Ghirlanda et al., 2013, MNRAS, in press): possibly detected by SKA.

SVOM and Cosmology: high-z GRB as a unique probe of the early Universe

- Probing the nature of reionization and constraining the metal enrichment of the ISM/IGM:

The nature of sources responsible for the reionization of the Universe at the end of the dark ages is still unclear. Absorption spectroscopy toward a large sample of sight-lines at z>7 will be necessary to disentangle between models, which will not be feasible with QSOs. GRBs thus appear as an essential tool for probing the nature and the epoch of reionization.

Simulated afterglows observed at T+2min with a 1m space-based telescope, or similarly with JWST / ELTs a few hours after the trigger.



The SVOM GRB afterglow spectra obtained with JWST or the ELTs at z>6 will have high enough signal to noise to allow disentangling between the absorption of the IGM and that of the local host galaxy ISM.

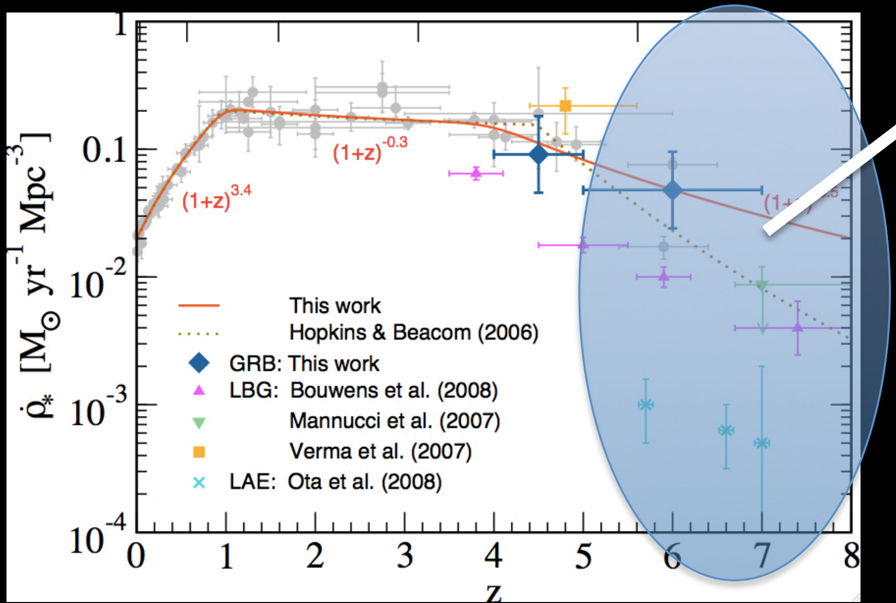
⇒ **With ~20 GRBs at z>5, SVOM should thus bring new constraints on the evolution with cosmic time of the fraction of neutral HI in the IGM and on the history of the ISM metal enrichment in galaxies.**

SVOM and Cosmology: high-z GRB as a unique probe of the early Universe

- Sign-posting the very first galaxies:

The follow-up of the most distant bursts should allow the identification of galaxies with spectroscopically-confirmed redshifts z>6, hence breaking the current record of the most distant galaxy observed so far (z~9). It will provide a unique list of targets for follow-up with JWST, ELTs, ALMA or SKA and help constraining the properties of the very first galaxies.

- Constraining the SFR history at early cosmic times:



* Current uncertainties > 2mags at z>5 !!!
* GRB rate = f (SFR, Z, …?)

⇒ The rate of detections at z>5 should bring more stringent constraints on the star formation history than what has been achieved so far.

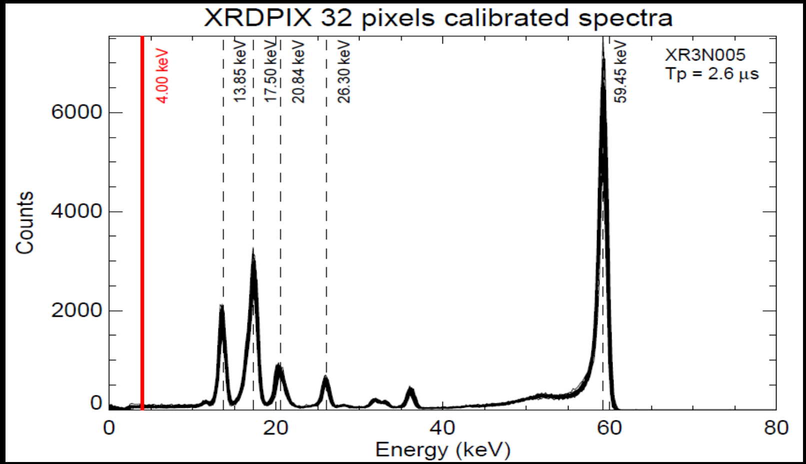
SVOM Scientific Requirements

- Detection of all types of GRBs, with special focus on *high z events*
- Provide fast, reliable and accurate GRB positions
- Measure the temporal and spectral GRB properties *from visible to MeV*
- Quickly identify the SVOM GRB afterglows and provide (sub-)arc sec positions
- Quickly provide redshift indicators for SVOM GRBs

SVOM Scientific Instruments

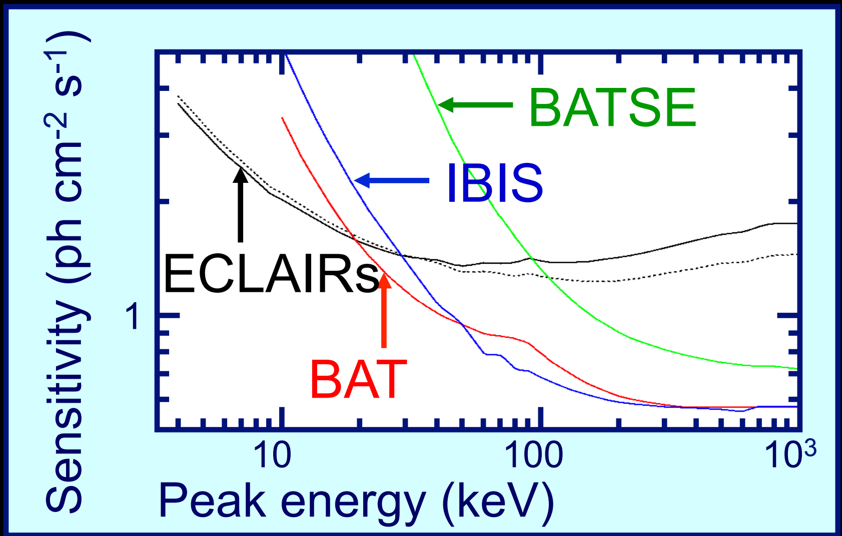
3+2 years mission
LEO ~600 km
i~30°

Instrument Performances: ECLAIRs



Main design objective

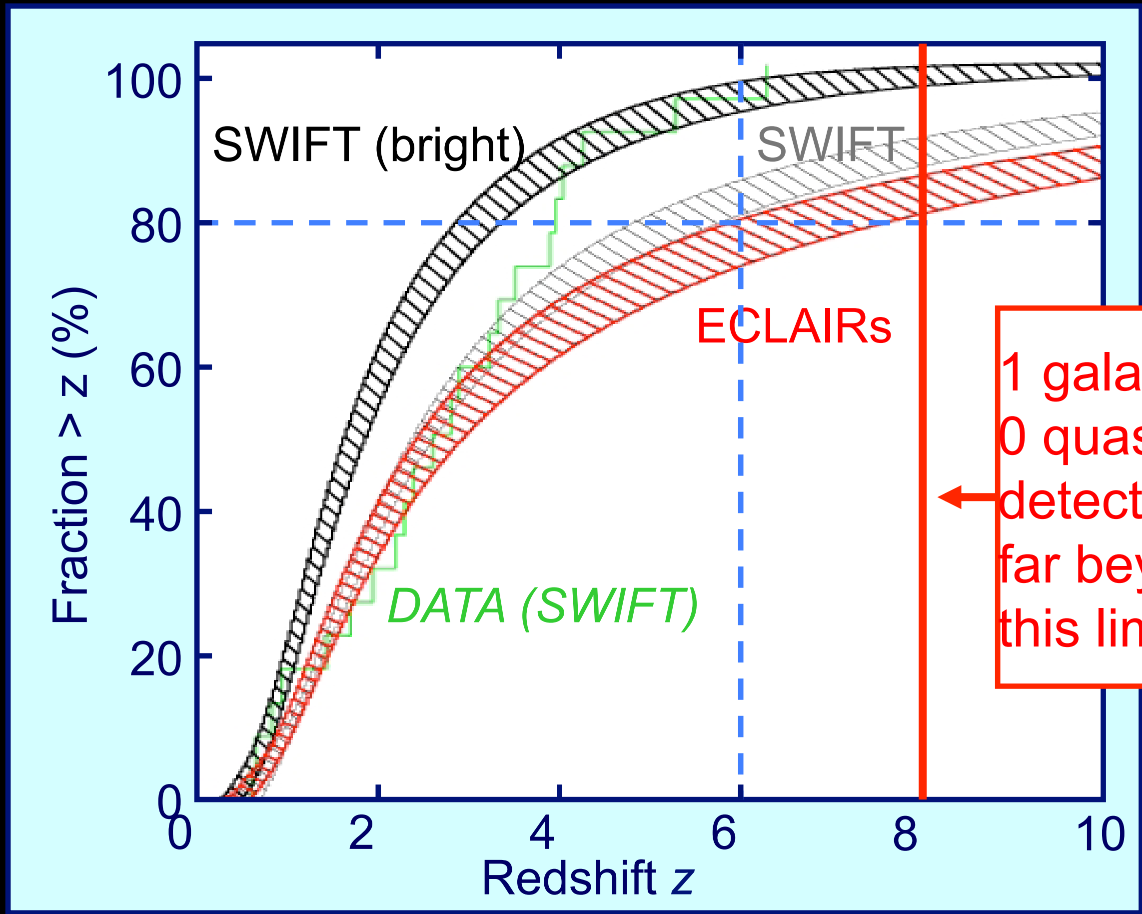
A low energy threshold in the X-ray domain



Simulated sensitivity

ECLAIRs expected to be more sensitive than SWIFT (BAT) for GRBs whose peak energy is < 20 keV

Instrument Performances: ECLAIRs

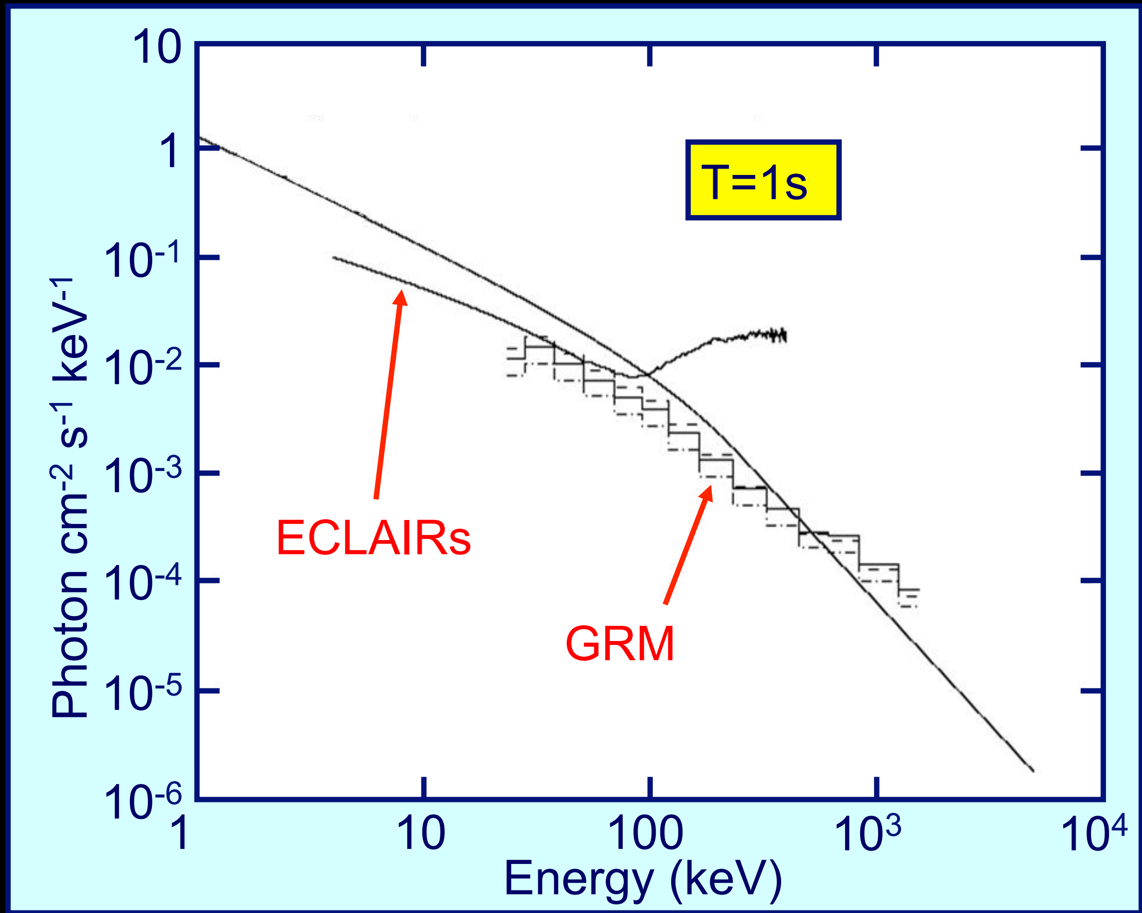


1 galaxy
0 quasar
detected so
far beyond
this limit

Simulated redshift distribution of long GRBs to be detected by ECLAIRs

Nearly 20% of ECLAIRs GRBs could be situated at high redshift (z > 6)

Instrument Performances: GRM

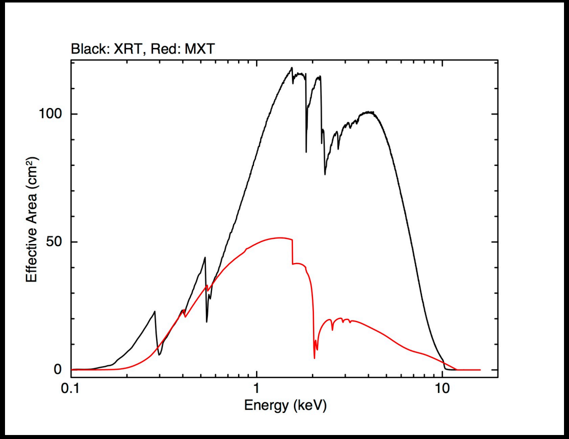


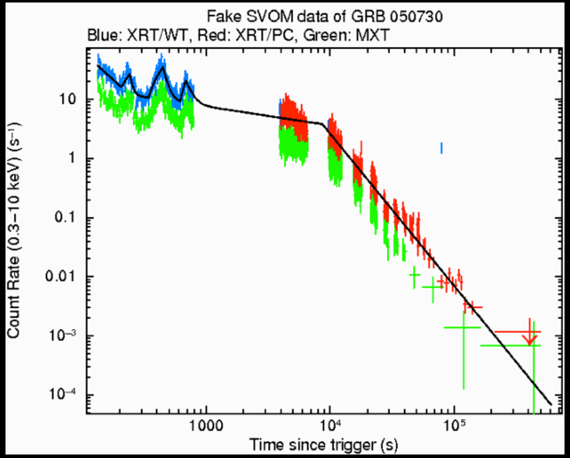
Average GRB spectrum with a 50-300 keV flux of 1 photon cm^{-2} s^{-1}

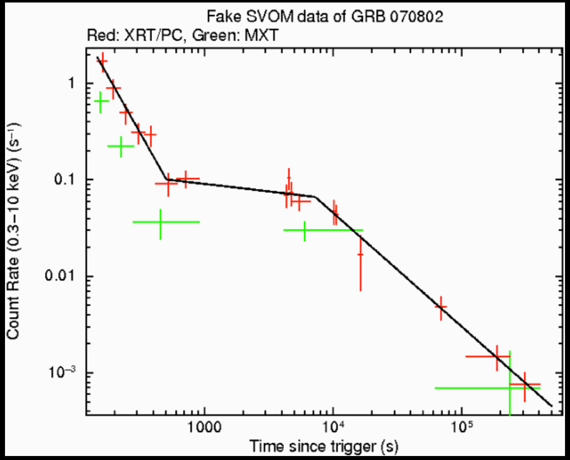
Enable E_{peak} measurements up to ~ 500 keV

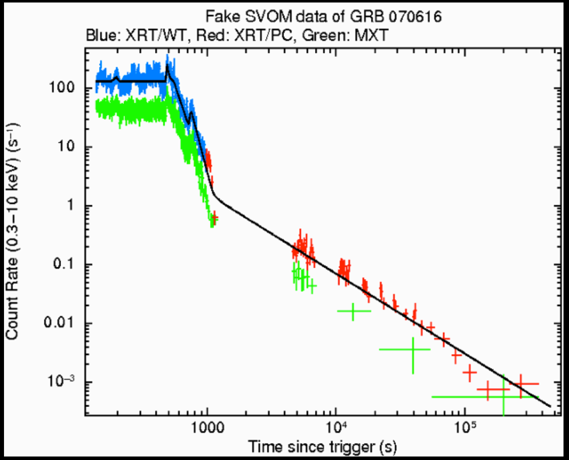
Instrument Performances: MXT

Despite the smaller effective area wrt. Swift/XRT, the spectral and timing performances are adequate for GRB studies.
It will typically localize GRBs to an accuracy of a few tens of arc sec 5 minutes after trigger.





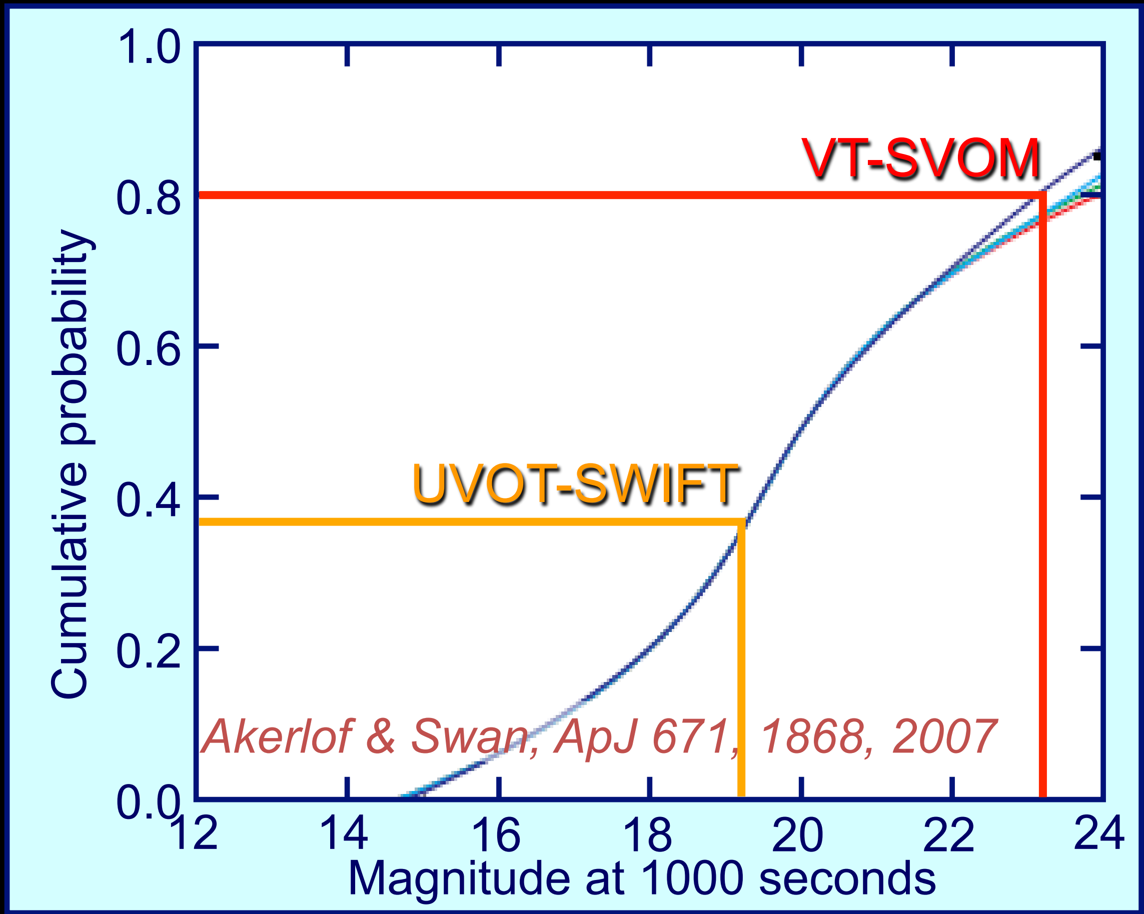




Expected MXT light curves of a "typical", a faint and a bright GRB afterglow

Enable detailed studies of the GRB afterglow X-ray light curves

Instrument Performances: VT



The intrinsic cumulative GRB apparent optical afterglow distribution

VT sensitive enough to detect ~ 80% of the SVOM GRBs

Space Instruments Required Performances

	Spectral band	Field of view	Allocation accuracy	GRBs/yr
GRM	50keV-5MeV	>2 sr	*Not applicable*	~80
ECLAIRs	4-250 keV	2 sr	10 arcmin	~70
MXT	0.3-6 keV	Diameter 1.1 deg	30 arcsec	~65
VT	400-650 nm 650-950 nm	21 × 21 arcsec	1 arcsec	~55

Ground Instruments

GWACs

Wavelength coverage: ~ 400-900 nm

Limiting magnitude: ~ 15 (5σ, 10s)

Overall field-of-view: ~ 90 deg. × 90 deg.

GFT-1

Diameter: ~ 100 cm

Field-of-view: ~ 23 arcmin × 23 arcmin

Wavelength coverage: ~ 400-950 nm

GFT-2

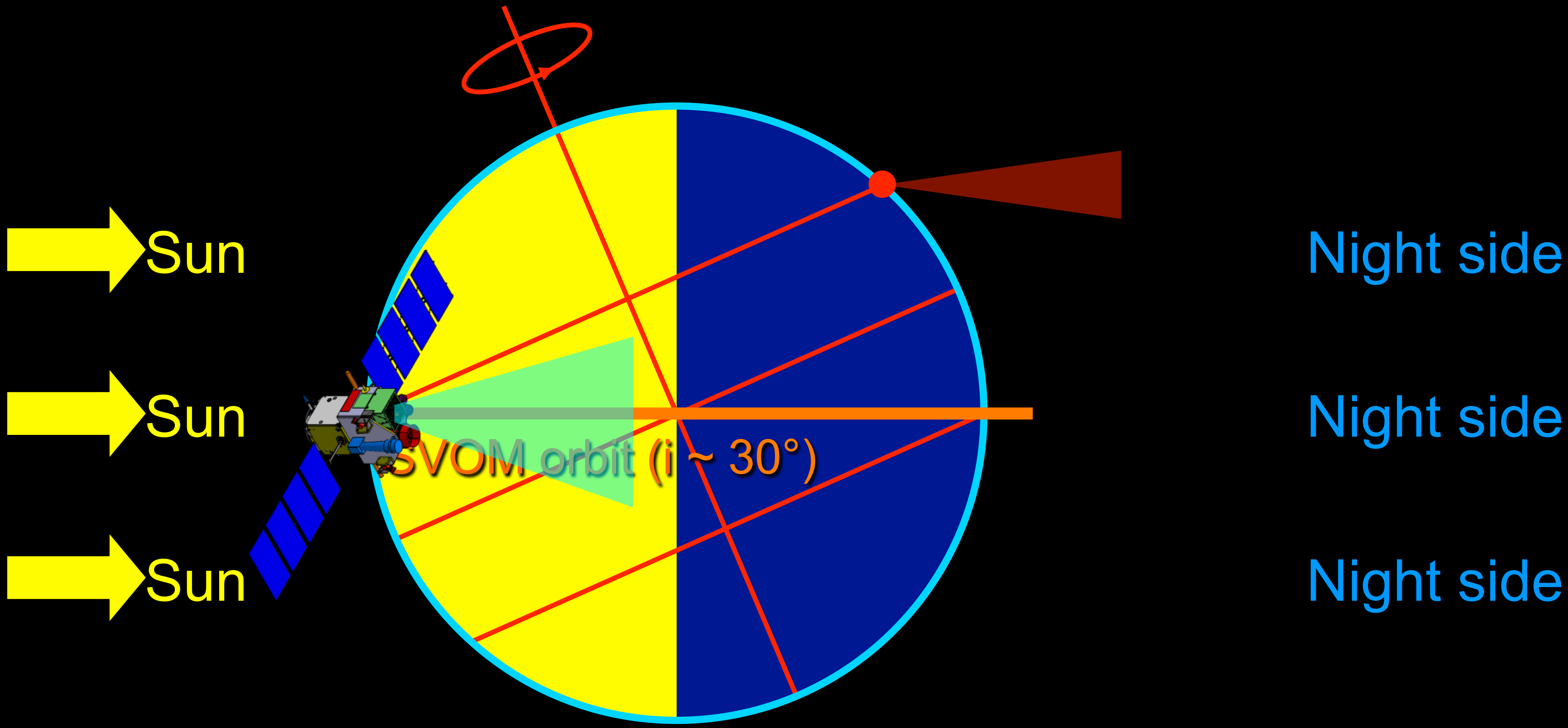
Diameter: ~ 100 cm

Field-of-view: ~ 30 arcmin × 30 arcmin

Photometric bands: B V R I J H

Photometric redshift of high *z* GRBs

SVOM Observing Strategy



Most of the GRBs detected by SVOM to be well above the horizon of large ground based telescopes all located at tropical latitudes

Conclusions

- SVOM is expected to be operational by the end of the decade and will be the successor of *Swift*
- The mission has been designed starting from the lessons learnt from previous experiments
- Its observation plan as well as its space- and ground-based instruments are optimized for catching the most distant GRBs, about 20 *with measured redshifts* at z>5 in 5 years are expected
- We expect SVOM GRBs to contribute to the deep Universe science