Localization Algorithms for the Microchannel X-ray Telescope on board the SVOM Space Mission

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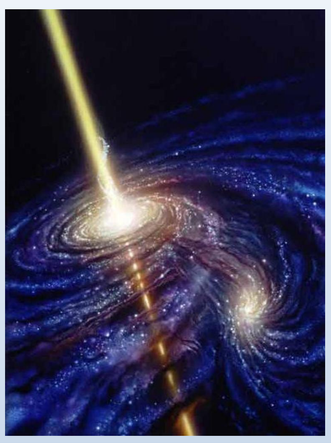
Abstract

SVOM is a French-Chinese space mission to be launched in 2021. Its goal is the study of Gamma-Ray Bursts, the most powerful stellar explosions in the Universe. The Micro-channel X-ray Telescope (MXT) is an X-ray focusing telescope, on board SVOM, with a field of view of 1° working in the 0.2-10 keV energy band. It is dedicated to the rapid follow-up of the Gamma-Ray Bursts counterparts and to their precise localization. In order to reduce the optics mass and to have an angular resolution of few arc minutes, a "Lobster-Eye" optical configuration has been chosen. Using a numerical model of the MXT point spread function (PSF) we simulated MXT observations of point sources in order to develop and test different localization algorithms to be implemented on board SVOM. These algorithms have to be a combination of speed and precision. We present the preliminary results of the different methods.

Gamma-Ray Burst



Definition
- Powerful explosions
- Brief gamma-ray phenomena
  - Few ms – hundreds seconds
- Random events in time and space
- Accretion disk + 2 sided jets

Formation
- *Long* (>2s) = Collapse of a massive star (>50 Msun)
- *Short* = Merging of 2 compact objects (neutron stars)

Scientific goals
- Distant GRBs = cosmological goal : investigate the early Universe (firsts stars)
- Understand physical processes associated with GRBs

Characteristics
- Emission from radio to gamma rays

SVOM

- Space based multi-band astronomical Variable Object Monitor

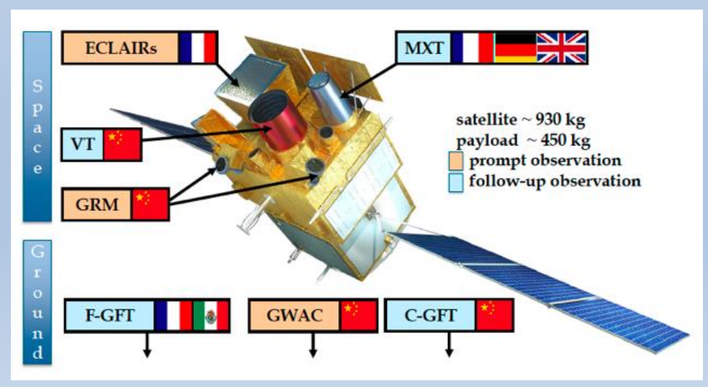
Collaboration
- The French Space Agency (CNES)
- The Chinese Academy of Sciences (CAS) and the Chinese Space Agency (CNSA)

Aim of the mission
- Study Gamma-Ray Bursts

Instruments on board
- 2 wide fields of view : ECLAIRs and GRM
- 2 narrow fields of view : MXT and VT

→ Operates from near-infrared to gamma rays

A GRB happens
- ECLAIRs will detect and localize the GRB
- SVOM will reorient itself thanks to ECLAIRs indication
- MXT will observe the GRB with a better precision and transmit the information to ground based telescopes



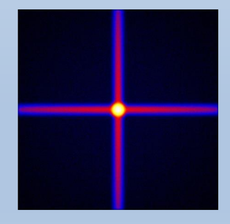
MXT

Goal
- Observe GRBs in X-rays (0.2-10 keV)
- Localize GRB afterglows in real time
- Transmit their positions to ground based telescopes

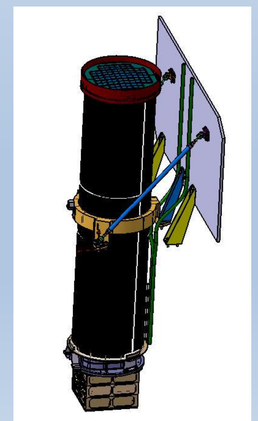
Localization of GRBs
- Field of view 64 x 64 arcmin
- Smaller Point Spread Function (PSF) than ECLAIRs : 4.5' vs 1°

Localization error
- Less than 1' vs less than 10' for ECLAIRs

Composition
- Detector of 256 x 256 pixels, 75µm side
- Optics in Lobster Eye configuration = focus X-rays thanks to reflections in micropores



PSF of MXT



MXT Simulator

Goals
- Simulate realistic MXT observations
- Develop and optimize the on board localization algorithms

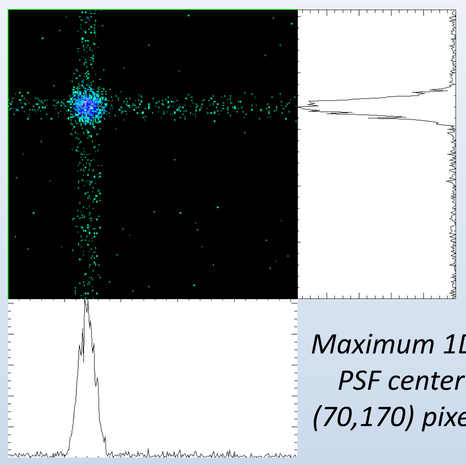
IN
GRB characteristics
- Duration
- Flux
- Spectral model
- Temporal model

→ ***Simulator***

OUT
Photon characteristics
- Position
- Energy
- Arrival time
- Origin (source / background)
- Pile-up

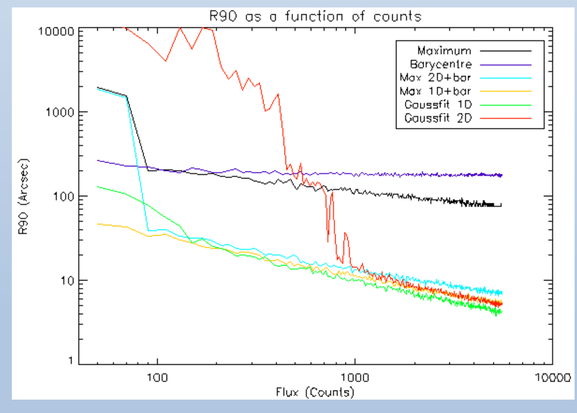
→ **Configurable PSF + event file**

Localization methods



Maximum 1D : PSF center (70,170) pixels

- **Maximum 2D + barycenter** = finds the maximum value of all the detector counts. A window of 60 x 60 pixels is drawn around this value and the barycenter is calculated on it.
- **Maximum 1D + barycenter** = same principle than the previous method but the maximum is calculated twice : on the sum of columns and the sum of rows.
- **Gaussfit 1D** = we find the maximum in one dimension of rows and columns and we used a gaussian fit to estimate the maximum of each axis.
- **Gaussfit 2D** = a Gaussian fit is applied on all the detector



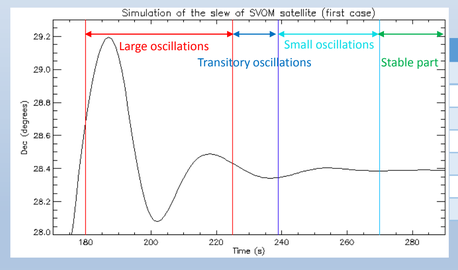
R90 = Radius in which 90% of the distances between the source true position and the found one are contained

→ **1D methods are better at high and low fluxes**

Satellite reorientation

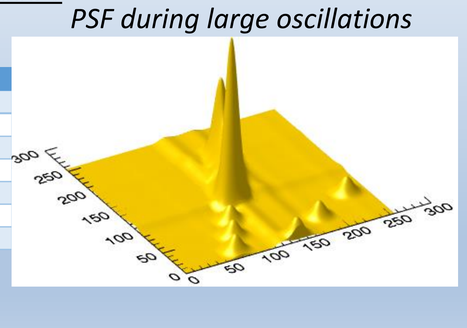
GRB afterglows decline rapidly with time. If we wait for the complete stabilisation of the satellite, we will miss data at highest fluxes.

Is it possible to have exploitable data during the slew satellite phase ?



GRB 160607 A			
Case 1	**Transitory oscillations**	**Small oscillations**	**Stable part**
Y ref	128	128	128
Z ref	130	130	130
R bar - ref	58.18 arcsec	23.20 arcsec	13.48 arcsec
R fit - ref	30.23 arcsec	15.05 arcsec	9.82 arcsec
Number of counts	84	160	115
Duration	14 s	30 s	30 s

PSF during large oscillations



- Distance simulations - reference < 1 arcmin

→ **MXT can observe the GRB during precious seconds before the complete stabilisation of SVOM**

References

L. Gosset et al., SPIE, 99051L (2016)
D. Götz et al., SPIE, 99054L (2016)
B. Cordier et al, ArXiv e-prints (2015)

Conclusions

We have developed a simulator to assess the scientific capabilities of MXT. It is highly configurable and produces event files and spectra for each observation. It demonstrates the gain in scientific performance of starting the localization algorithms before reaching the complete stabilization of SVOM. We plan to develop a simulation to include the defects of the optics and more detector effects.