Detection of X-ray sources with MXT telescope of SVOM satellite

Shaymaa Hussein

IJCLab (Laboratoire de Physique des 2 Infinis Irène Joliot Curie)
SVOM satellite

- **Space Variable Objects Monitor.**
- A French-Chinese mission
- dedicated to GRBs and other high energy transient on the sky.
- SVOM has a complementary set of ground and space based instruments
- To be launched by the end of 2022.

**ECLAIR:** Wide field X and gamma rays telescope (4-250 keV)

**GRM:** the gamma-ray monitor (15 keV-5 MeV)

**VT:** the visible telescope

**MXT:** soft X-ray telescope (0.2-10 keV)

**GFT:** Ground-based Follow up Telescope

**GWAC:** Ground Wide Angle Camera

**VHF alert network**

**Tracking antennas**

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Science observation programs

Core program:

- Observe all types of gamma ray bursts

General program:

- Active Galactic Nuclei, Accreting objects, Flaring objects

Target of opportunity program:

- Unplanned observations of transient and variable sources, ex: follow-up of multi-messenger alerts from experiments like LIGO-VIRGO, the IceCube, the Cherenkov Telescope Array .. etc.

MXT will observe these sources in X-ray range to achieve 2 requirements:

- Localize the source down to 2’ within few minutes —> better understanding of the source, ex: measure the redshift, host galaxy .. etc.
- Provide a good photometry and spectroscopy of the source —> determine the astrophysical origin of the source

MXT needs a specific design + onboard scientific software.
Main features:

- ~35 kg & ~1.2 m.
- FoV: 1.1° x 1.1°.

MXT optics:

- Micropore optics arranged in a lobster-eye configuration
- Point spread function composed of a central spot and cross arms

MXT camera:

- PnCCD detector, 256x256 pixels

MXT data processing unit:

- handle the instrument power distribution.
- telemetry and telecommand management.
- the scientific data processing
IJCLab in collaboration with CEA and CNES teams took the responsibility of developing and implementing the onboard scientific software of MXT:

- Camera noise characterization
- Photon reconstruction and source localization
- Data monitoring
- Science telemetry packets (VHF and X-band)

* As this algorithm is implement onboard, it is highly constrained, and to achieve the scientific requirements; the algorithm must be fast, optimised and robust against all space conditions.
Photon reconstruction

- X-ray photons interact with the camera by depositing energies in one or few adjacent pixels forming a pattern depending on it is energy
- Contiguous pixels are clustered together
- Photons are identified using the XRT photon patterns
- Photons are accumulated in a table “photon map” with a 128x128 grid resolution
Phonon reconstruction

Photon map and the point spread function PSF are the inputs of the onboard localization algorithm.

* MXT PSF is energy independent.
* It is twice the camera plane size to cover all incoming directions.
First the source peak position is computed in the photon map then it is transformed to the sky location in spherical coordinates.

To find the peak position, the centroid method (as used for XRT\swift) is simple, but it’s limited in low photons intensity.

A method based in cross correlation between the PSF and the photon map, and the 2D barycentre is implemented onboard.

**Cross-correlation**

- Cross correlate the photon map with the PSF in the Fourier domain.

\[
C_{i,j} = \mathcal{F}^{-1}[\mathcal{F}\{PSF_{i,j}\} \cdot \mathcal{F}\{PhMap_{i,j}\}]
\]
2-D barycentre:

The peak position is given by the 2D barycentre within a window centred on the max value at the correlation map.

The peak position \((y_p, z_p)\) is then transformed to polar and azimuthal angle \((\theta, \phi)\).

This coordinate is transferred to ground centre for the follow up.
Advantage of this method appears when a faint source is detected.
Localization performance

For a given source flux and background counts:

- Generate ~1000 simulations with random source positions within MXT FoV.
- For each simulation run loc algorithm.
- Compute difference between measured and true source positions $dr$.
- $r_{90}$ is given by the 90th percentile.

* The performance of the localization algorithm is determined by computing $r_{90}$ value.
Localization performance

PSF: 2020 at 1 keV

MXT spec r90

Number of photons

R90 [arcsec]

10^2

10

10^3

background cts

• 30 cts
• 300 cts
• 600 cts

~100 photons
~140 photons
~175 photons

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To compute \( r_{90} \) onboard -> SNR is computed.

Use transfer function to convert SNR to \( r_{90} \): \( r_{90} = a \times SNR^b + c \).

A quality factor is given for sub ranges of \( r_{90} \) values.

This quality factor is transferred to the ground, and the follow up is planed depending on this factor.
Multiple sources in the FoV

It is possible to have > 1 source in the FoV —> extend the algorithm to localize multiple sources.

**Method:** Iterative subtraction of the previous peak:

1. Detect Brightest peak
2. Peak subtraction
3. Detect the next peak
The main requirement of MXT is to localize the source rapidly down to 2’.

Localization algorithm are now fully implemented and tested using data from X-ray source test facility at Munich.

I have characterized the algorithm in different cases: having different source intensities, having source in the edge of the telescope, having corrupted pixels in the camera .. etc.

In the next year of my PhD I will work in characterizing the onboard scientific algorithm with realistic gamma ray bursts observation scenarios.

Use data from previous similar mission like xrt\swift and convert it to MXT observation.

What we can learn about GRBs with MXT?
Back up slides