Development of a Python-Based Pipeline for Light Curve Analysis Search for Transients, Automated Peak Detection and GRB Cross-Matching using Multi-Level SSM Data from AstroSat

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Abstract

A Python-based pipeline for analyzing multi-level data from AstroSat's Scanning Sky Monitor (SSM) to detect GRBs, transients, and potential GW electromagnetic counterparts, supporting multi-messenger astronomy

Introduction

AstroSat is India's first dedicated multi-wavelength space observatory, launched to explore celestial sources across ultraviolet, optical, and X-ray spectral bands. It marks a significant milestone in India's astronomical capabilities by enabling simultaneous observations in multiple wavelengths from a single platform.

Scanning Sky Monitor (SSM) is one of the primary scientific payloads onboard AstroSat. It is designed to continuously monitor the X-ray sky for transient and variable sources. Operating in the 2.5–10 keV energy range, the SSM consists of three identical units, each equipped with a one-dimensional position-sensitive proportional counter and a coded mask aperture. This configuration enables source localization and temporal studies of X-ray transients.

1 Methodologis Included:

Designing scalable approach to uncover transients in AstroSat's Scanning Sky Monitor!

- Light-Curve analysis and search for Gamma Ray Bursts(GRBs) and transient signatures
- Integrated Count and Energy Distribution.
- Search for GRB event and cross verification of GRB event with SSM's FOV with referece to a standard GRB catalog.
- Studying all the sources in the SSM FOVs.
- Search for the EM Counterparts for Gravitational Waves.

tcolorbox.

The design philosophy of the SSM differ significantly from those of traditional X-ray detectors.[1]

a. **Wide-Sky Coverage:** Offers broad sky coverage over time, enabling effective monitoring of large regions of the sky

b. **Detect and locate transient sources:** Identify sudden or short-lived X-ray events across the sky.

c. **Monitor long-term variability:** Track changes in brightness and behavior of X-ray sources over extended periods.

d. **High Temporal Resolution:** Records individual photon arrivals, allowing for precise timing analysis of rapid events.

e. **Generate transient alerts:** Provide prompt notifications for follow-up observations of newly detected transients.

f. **Create and update catalogs:** Maintain records of detected sources, their characteristics, and variability patterns.

g. **"Step-and-Stare" Strategy:** The SSM stares at one region, collects data, and then moves to the next region, covering wide sky areas each day.

The Universe is whispering...are you ready to listen?

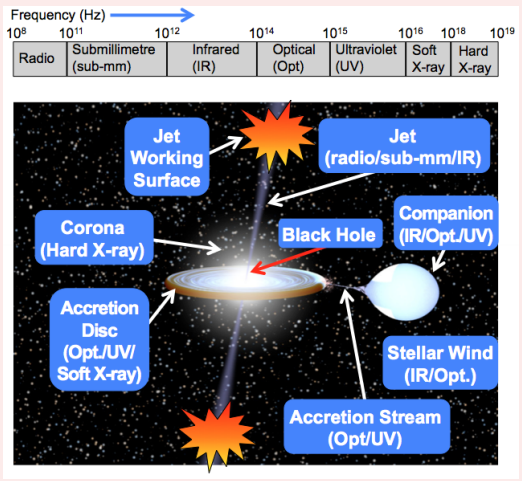

Figure: Schematic diagram of X-ray emission.

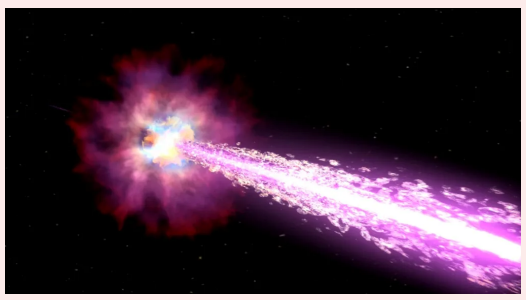

Figure: Artist's concept of Gamma Ray Burst.

AstroSat

Figure: Image of AstroSat, containing SSM in the yaw axis ans other 4 payloads on the Roll axis of the satellite.

Scanning Sky Monitor

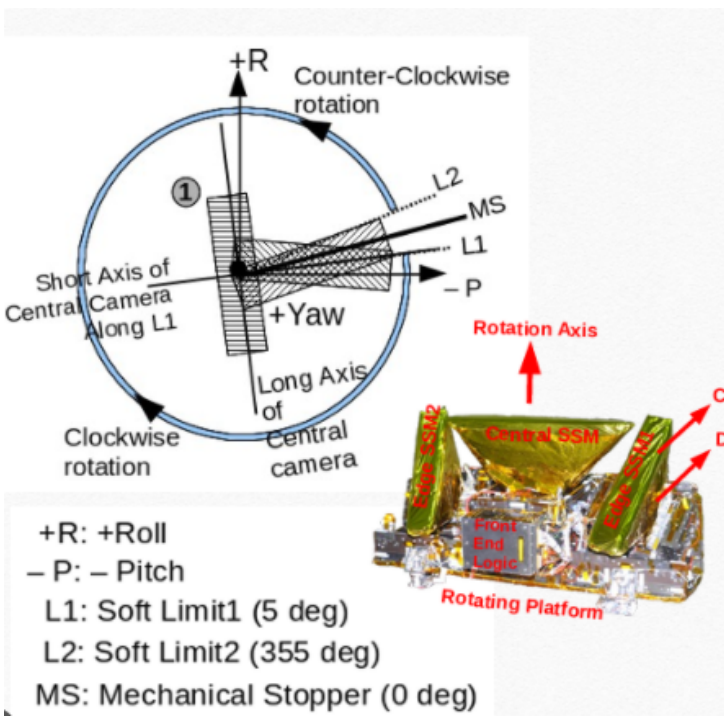

Figure: All 3 SSM detectors.

Abbreviations

SSM Scanning Sky Monitor
GW Gravitational Waves
EM Electromagnetic

References

[1] M. C. Ramadevi, D. Bhattacharya, A. R. Rao, S. Seetha, A. R. Sarwade, et al. "Scanning Sky Monitor (SSM) on-board AstroSat". In: *Experimental Astronomy* 43.3 (2017), pp. 237–256. DOI: 10.1007/s10686-017-9536-3.

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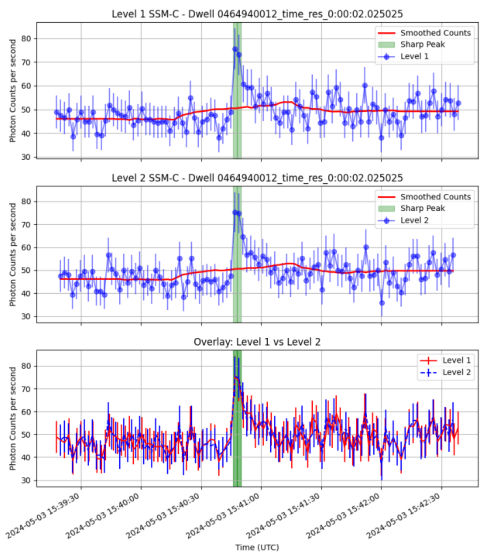
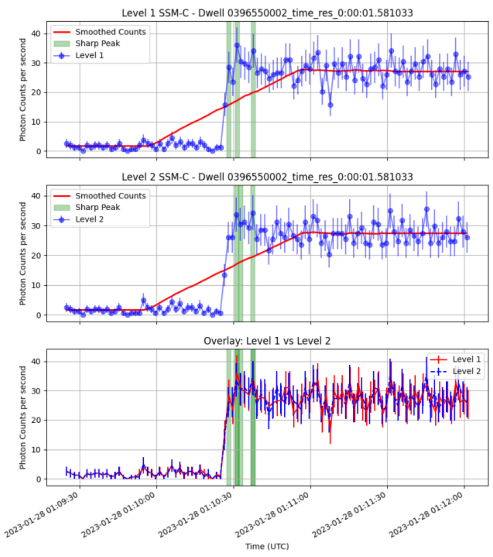
2 Results and Discussion

2.1 Light-Curve analysis and search for Gamma Ray Bursts (GRBs) and transient signatures.





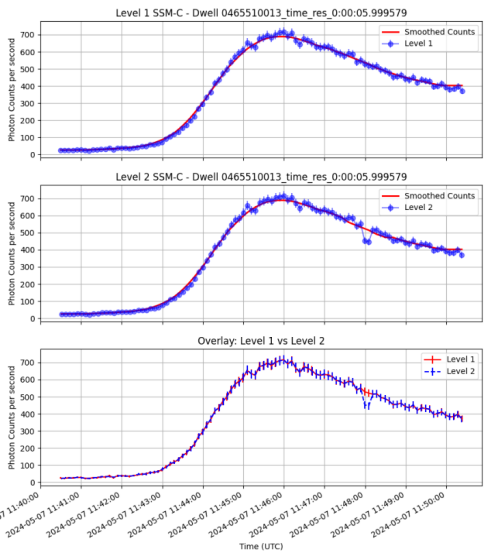


Figure: Resulted Light Curve Samples.

2.2 Count and Intensity Distribution over Time.

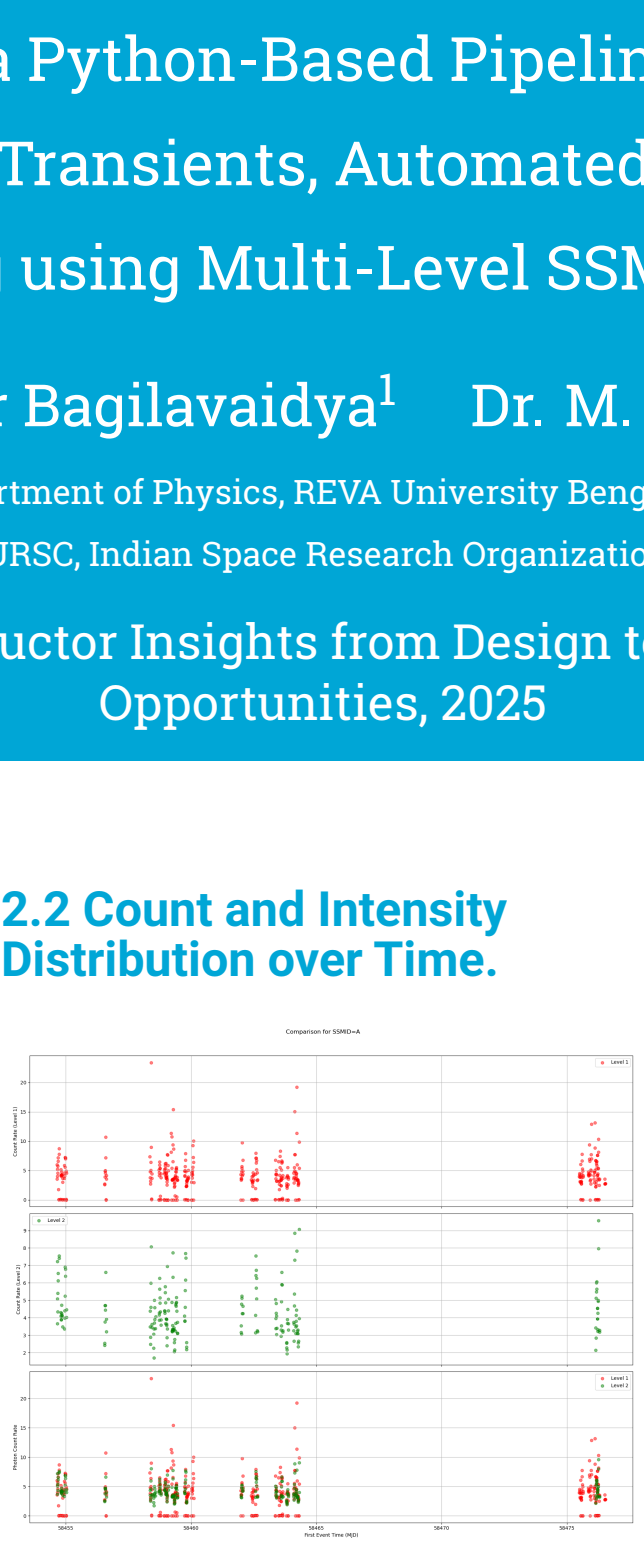


Figure: Resulted Integrated-Counts Light Curve Samples.

2.3 Search for GRB event and cross verification of GRB event with SSM's FOV with referece to a standard GRB catalog.

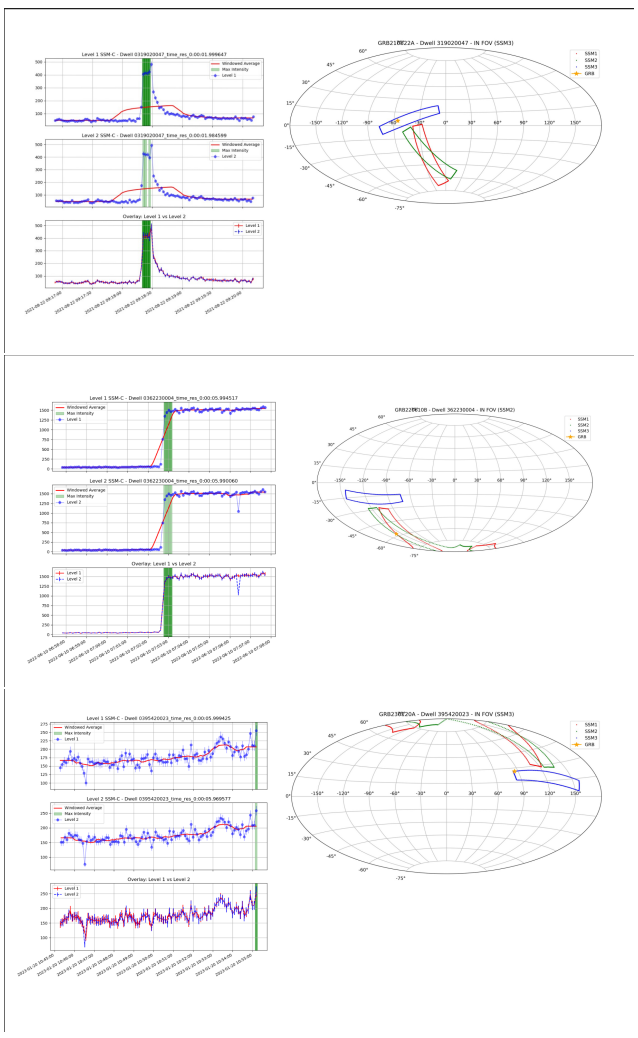


Figure: Some of the confident GRB's observed by the SSM.

Studying All the Sources in the SSM FOVs

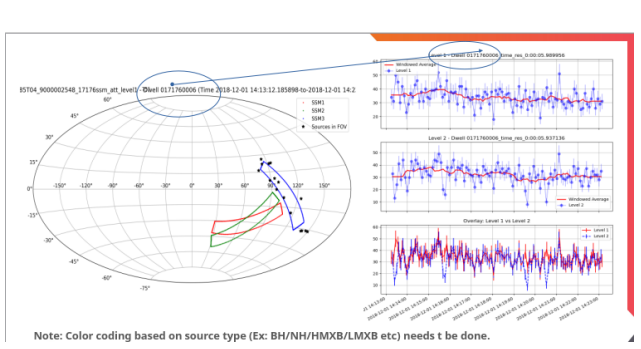


Figure: Source distribution across SSM's field of view.

Search for Gravitational Wave EM Counterparts

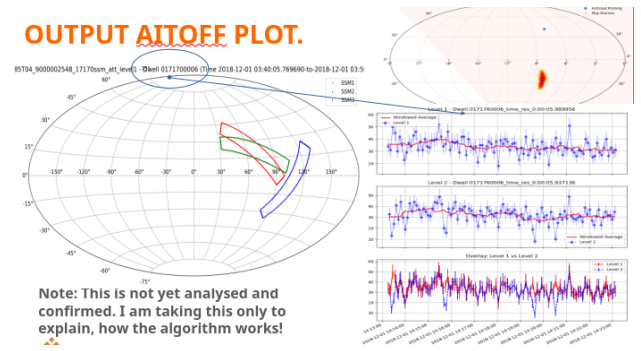


Figure: Light curve near GW trigger times from SSM data.

Github Repository

A digital version of this presentation and full pipeline code is available at: `https://github.com/kartikjbsky/project_scanning_sky_monitor`

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