Simulations and Estimation of Background for ECLAIR's Gamma Ray Camera of SVOM

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The SVOM Mission

The Space Variable Object Monitor (SVOM [1]) is a French – Chinese mission dedicated for study of Gamma Ray Bursts (GRB) and other high energy transients to be launched in 2021. The primary objective of the mission is to detect GRBs and follow them up in near real time with help of space based and ground based telescopes in multi-wavelengths. The IRAP is responsible for the ECLAIRs instrument.

The on-board Instruments are –

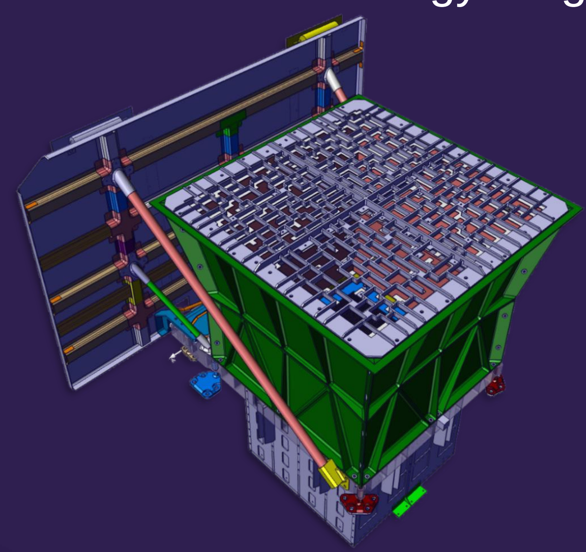
- ECLAIRs : Hard X-ray coded mask imager (CdTe, 4 – 150 keV)
- GRM : Gamma Ray spectrometer (NaI, 0.015 – 5 MeV)
- MXT : Micro Channel X-ray Telescope (0.2 – 10 keV)
- VT : Visible Telescope (400 – 960 nm)

The ground Instruments are –

- GWAC : Ground Wide Angle Camera (500 – 800 nm, 5000 deg^2), already operational.
- GFT : Ground Follow-up Telescope (400 – 1800 nm)

The ECLAIRs Imager

The ECLAIRs [2] instrument of SVOM is a hard X-ray / soft γ-ray camera with a coded mask aperture to image the sky. The primary goal of the camera is to monitor (in event mode) the soft γ-ray / X- ray sky at various timescales (20 ms – 20 min) and promptly detect and localize GRBs with the help of onboard processing electronics and software [3]. ECLAIRs will send slew trigger to the satellite and an alert to the ground telescopes for follow-up and to the community. Together with GRM, ECLAIRs will act as core part of the mission providing localization of transients as well as spectral information of prompt emission in a wide energy range.



Area	1024 cm^2
Detector	Schottky CdTe
Pixels	6400 (80 x 80)
Pixel Size	4 x 4 x 1 mm
Field of View	2 sr (89° x 89°)
Angular Resolution	< 13 arcmin
Energy Resolution	~ 1.6% @ 60 keV
Energy Range	4 – 150 keV

The Ground Based Trigger and Estimation of Background

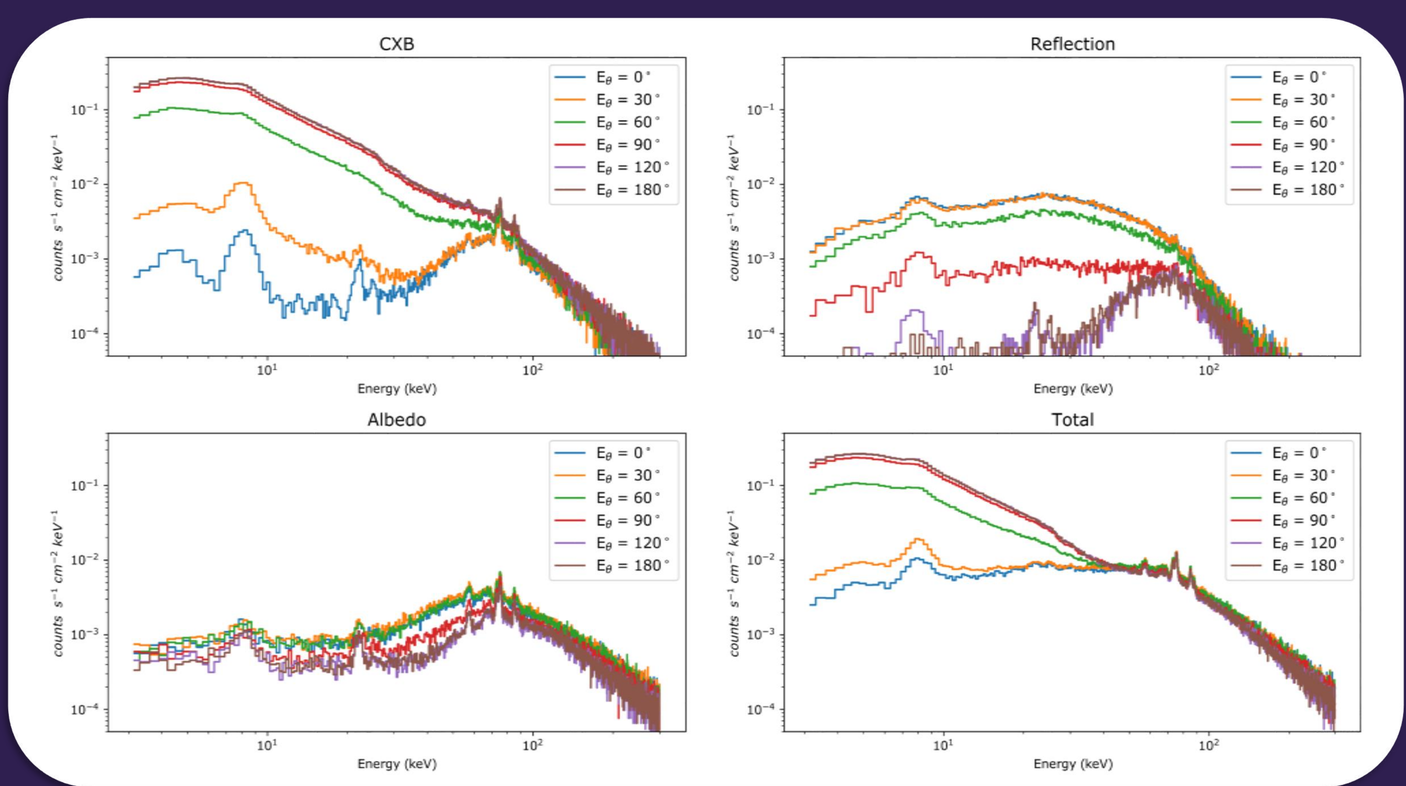
As resources (better algorithms, data storage, processing power etc.) are limited for onboard systems, number of sources ECLAIRs can detect in near real time is limited. However, on ground, we are not limited by the resources and all the photons detected by the instrument are sent to ground . This enables us to apply elaborate data processing techniques on the available data to extract more information and to find sources which might have been missed by the onboard trigger. With this, we can detect sources which vary on longer timescales (> 20 mins) or are very faint and are buried in the background (Ultra long GRB, Tidal Disruption Events etc). Similar to the onboard trigger, information from the ground trigger will be relayed to the follow-up telescopes for the multi-wavelength follow-up.

The first step of developing an algorithm to detect the sources in an data is to estimate the background distribution, both temporal and spatial. As the SVOM has low earth orbit, along with diffuse Cosmic X-ray Background (CXB), ECLAIRs also detects reflection of CXB (Reflection) from Earth atmosphere and X-ray emission from Earth atmosphere (Albedo) due to the interaction of charged particles with magnetic field and the atmosphere. Also, during the passage of the satellite through the South Atlantic Anomaly (SAA) region high count rate will be observed due to the interaction of charged particles (electrons and protons).

To estimate the above components, ECLAIRs mass model is simulated with the simulation toolkit GEANT4. As the background varies with time and direction of Earth during one orbit, it is impossible to simulate all the possibilities individually. Hence we adapt the approach of adding the effect of Earth in "post processing" for all the components. We simulate isotropic emission in GEANT4 with corresponding incident spectrum for each background component and we vary the rate based on the Earth direction and position of satellite in the orbit. The interacting photons on the detector are selected or deleted based on the new rate and other positional parameters. With this approach we avoid the need to carry a new simulation for every orbit and can reconstruct the background for any scenario from a fixed database. This approach saves a lot of time (about factor of 100) as Monte Carlo simulations are computationally expensive.

Validation of Method

We validate our method by comparing expected spectrum of various components as function of Earth position with case the where spectrum is obtained by running exact simulation for each earth position. Following figure shows spectrum obtained by our method at various Earth positions with respect to ECLAIRs Field of View [4, 5, 6, 7] .



Future Work

- To add known bright X-ray sources to the background photon list.
- Add bursts (transients) to simulate real scenario.
- Generate near real data by passing this photon list through the hardware simulator of the instrument which adds electronic effects to the data.
- Develop algorithms to detect the bursts and optimise them.

Background as Function of Orbit

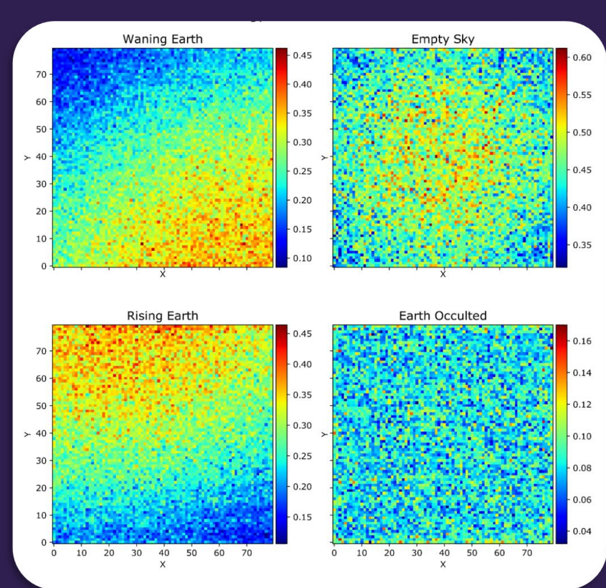
Currently a post processing software is under development which generates background photon list as function of orbit for all the components including the SAA passage. To generate this we use simulated orbital parameters and a fixed GEANT4 simulation database, calculated separately for each component based on incident spectrum as input. For CXB, Reflection and Albedo the effect of Earth is added based on position of satellite in the orbit and while in case of SAA passage the rate and spectrum of incident particles is varied to get the desired spectrum [4].

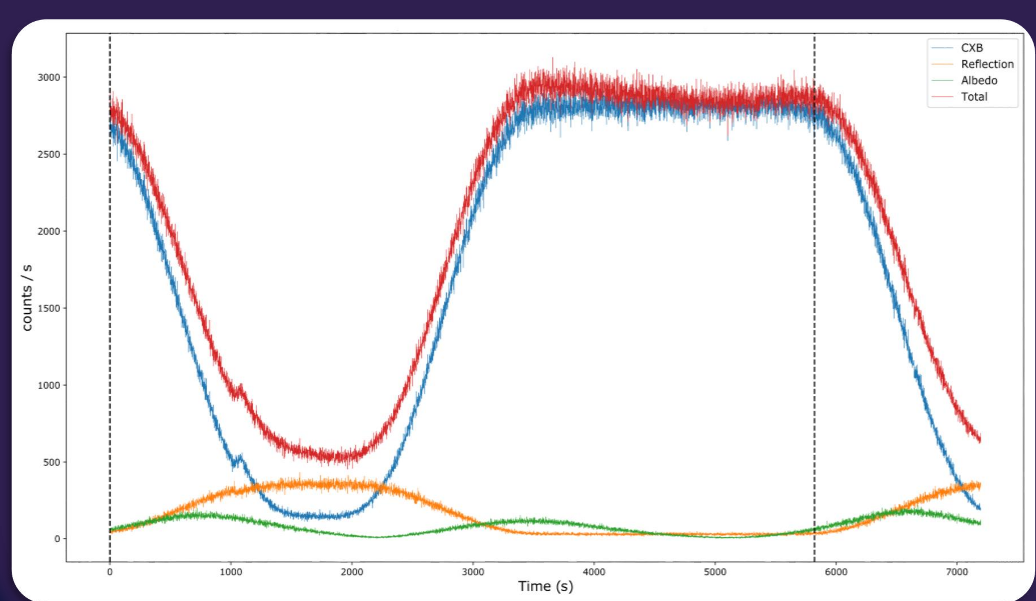
Figures :

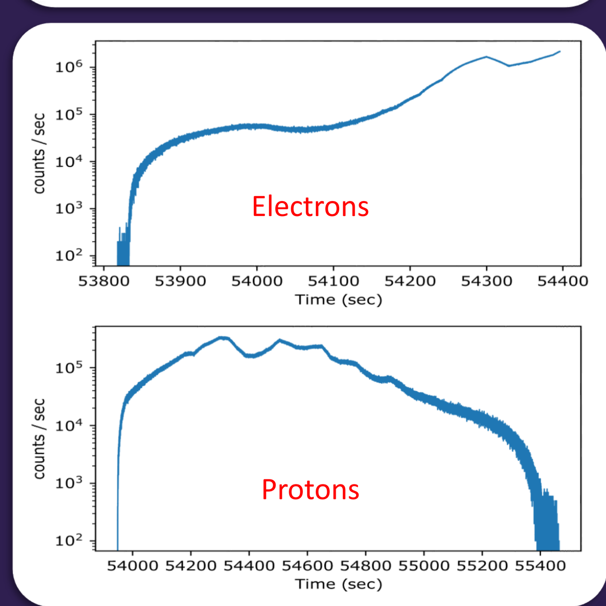
a) On bottom left, background counts for three components is shown. The vertical dotted lines mark duration of one orbit. We can also see the effect of slew at around 1000 sec. Time binning = 1 sec

b) On bottom right, detected count rate for SAA passage is shown for electrons and protons. Time binning = 0.01 sec

c) On top right, detector plane image is shown for different Earth positions during one orbit. We can see the effect of Earth on the image.







References

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