Estimating the Tolerance limit on the jitter for the SSM cameras

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Abstract

The Scanning Sky Monitor aboard ASTROSAT is a system of three identical coded mask cameras mounted on a rotatable boom. This rotation, satellite slew and other mechanical operations on the spacecraft will cause jitter in the on-board instruments and this report is on the simulations we undertook to estimate the magnitude of the jitter that can be tolerated in the case of SSM cameras.

Introduction

The satellite level jitter specification for ASTROSAT is 0.3 arcsec root mean square (RMS) value for frequencies higher than 0.2 Hz. The spacecraft drift is expected to be less than 0.5 arcsec RMS for frequencies less than 0.2 Hz (as learnt from a communication from the SSM team at ISAC). For the SSM cameras, whose best angular resolution in the sky will be a few arc-minutes, this kind of a jitter with a magnitude of fraction of an arc-second should not affect seriously. We nevertheless decided to carry out the exercise of estimating the tolerable jitter on the SSM cameras, as an extensive mechanical analysis at the spacecraft level has not yet been taken up to estimate the final magnitude of jitter.

Simulation

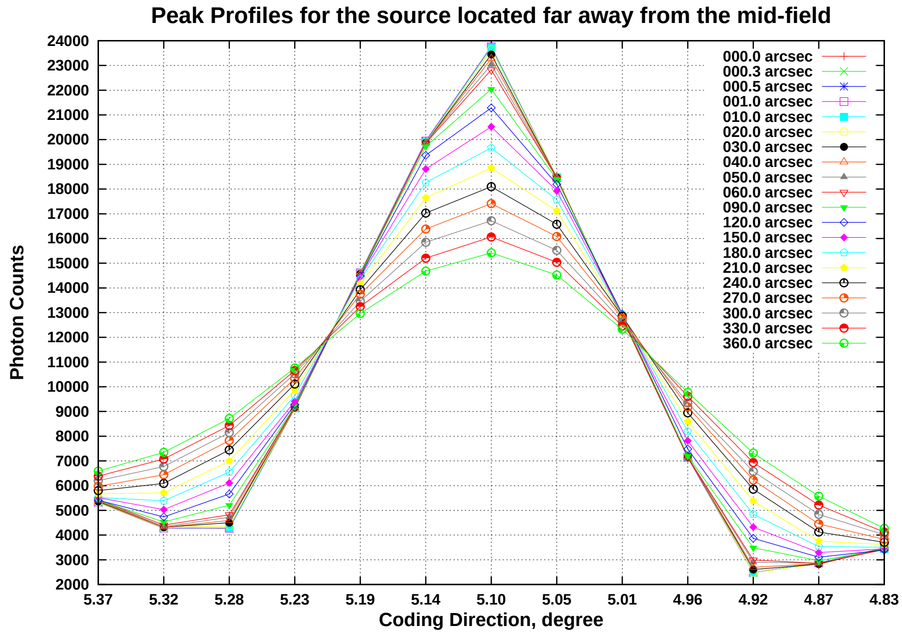
The Monte Carlo methods we use for the simulation of the operation of the SSM camera were slightly modified in order to simulate the jitter. We used a static camera simulation, collecting photons from a specified source in the field of view for a specified time duration. For the present work, the source direction was randomly shifted about the specified direction for every generated photon. This shift (in the source direction) was assumed to follow a Gaussian distribution with the specified source direction as the mean value and is also scaled by a specified RMS value. We have not simulated the frequency of the jitter (separately) and it depends on the flux of the source used (because the source direction is shifted for every generated photon).

Image Reconstruction and Analysis

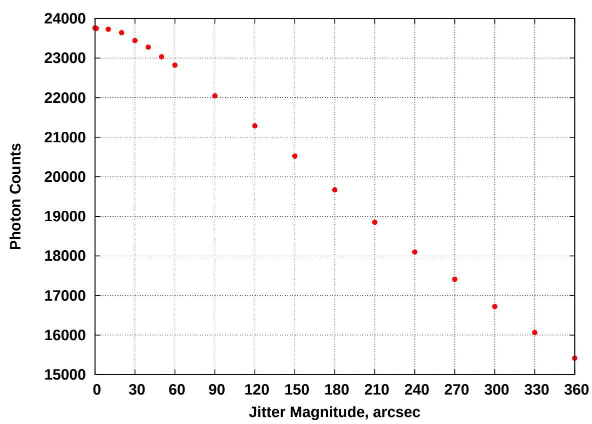
We have used the back-projection method for reconstructing the sky image. The back-projection method has been explained in the report RRI_SSM_0008 (in the present case, derotation and other steps meant specifically for a rotating camera were omitted).

The simulation has been carried out for different jitter magnitudes and every event list generated has been passed through the procedure of back-projection. The resulting sky images have been analysed. We have noticed that the source peak profiles change as a function of the jitter magnitude. The change in the profile is prominent only along the coding direction and not in the orthogonal direction which anyway has a poor intrinsic resolution of about 2.5°. Apart from this, the reconsturcted photon count in the direction of the source reduces as a function of increasing jitter magnitude. To estimate the values of the full-width-at-half-maximum (FWHM) of the source peak profile in every sky image, we select a few data-points around the source-peak (along a line in the coding direction passing through this peak) and fitted a straight-line or a quadratic function on either side of the peak-profile. The fit-equation is chosen based on the number of data-points available and the fitting has been done using the tool *gnuplot* which uses an implementation of the Marquardt-Levenberg algorithm. Then the plots of FWHM and photon counts at the source location as functions of the jitter magnitude are generated.

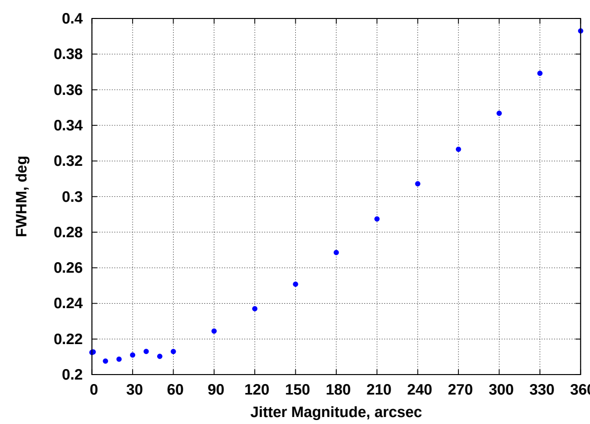
We have undertaken this exercise for two example sources: one present near the center of the field of view, at the center of a resolution element ($\theta_x = 0.18°$, $\theta_y = 0°$) and the other in an arbitrary direction within the field of view ($\theta_x = 5°$, $\theta_y = 40°$).



(a) Peak Profile



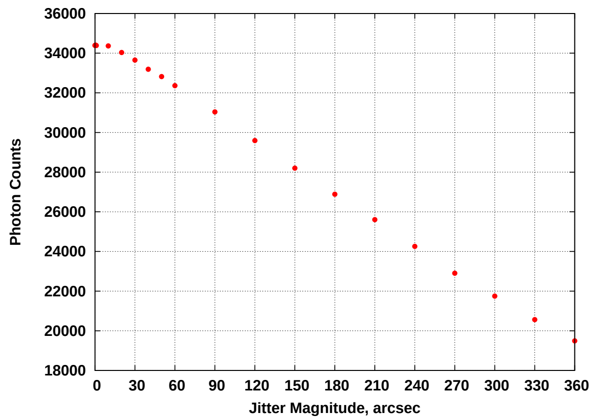
(b) Photon Counts Contribution to the source as a function of the jitter



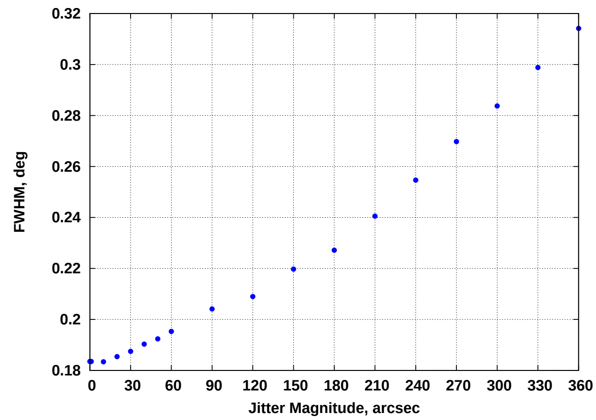
(c) FWHM of the source peaks as a function of the jitter

Figure 1: Source present at ($\theta_x = 5°$, $\theta_y = 40°$), away from the mid-field and also not present at the center of a resolution element.

The figure 1(a) shows the profiles of the source peaks for different values of jitter used during the simulation, for the case wherein the source is chosen away from the center of the field. For the same source, the figures 1(b) and 1(c) show the plot of the reconstructed photon count at source location and the FWHM as functions of the jitter magnitude respectively. Similar plots for a source near the center of the field are shown in figures 2(a) and 2(b) respectively. For both the sources, from the plots showing photon contribution as a function of the jitter magnitude, it is evident that there is approximately



(a) Photon Counts Contribution to the source as a function of the jitter.



(b) FWHM of the source peaks as a function of the jitter.

Figure 2: Source present at ($\theta_x = 0.1805977241°$, $\theta_y = 0°$) very close to the center of the field of view.

5% fall in the counts for a jitter of 1 arcmin. Even though the value of the FWHM does not increase by a large amount over the entire range, the systematics change significantly for a jitter of magnitude greater than about 1 arcmin. Based on these results, we recommend 1 arcmin as the tolerable limit of the jitter for the SSM cameras.

Addendum: Issues in the software to be checked

The back-projection code used is the one that had been implemented for a rotating case and for the present work has been used by setting the value of the *rate of rotation* to *zero*. For some unknown reason, for source directions simulated away from the mid-field, the source-peak profile as seen in the reconstructed sky image is shifted away from the expected location by a few pixels both along and across the coding directions. We are using 501 pixels along the coding direction (compared to the nominal 125 pixels) resulting in super-resolved sky elements of size ≈ 2.7 arcmin which is about a factor of four less than the nominal 10.8 arcmin. So the shift in the source peak profile along the coding direction seems to be less than the nominal resolution, but across the coding direction it is a significant shift of 5°–6°. This needs to be investigated, but we believe that the results of the tests we undertook for the effects of jitter will remain the same.