The Scanning sky monitor on ASTROSAT

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Abstract

ASTROSAT is a planned Indian astronomical satellite aimed at simultaneous multiwavelength observations spanning from optical waveband to hard x-rays. The scanning sky monitor is one of the experiments proposed for ASTROSAT. It is an x-ray payload used to detect new transients and to monitor variability of known bright x-ray sources. An engineering model for the detector has been fabricated similar in design to the All sky monitor (ASM) on RXTE. This model has undergone preliminary tests. Planned changes proposed with respect to ASM, are discussed.

Key-words :X-ray, x-ray transients, sky monitor, satellite instrumentation, proportional counter

1 Introduction

The x-ray sky exhibits variability on a variety of timescales and amplitudes. There are however x-ray sources which vary by a factor of typically 100 or more, within a timescale of few days. These sources are termed as x-ray transients. Many of these transients may in fact be undetectable at their quiescent level and exhibit an increase in brightness by as much as a factor of 10,000 during outburst. Although the group of x-ray transients encompasses different types of sources including extragalactic objects, the brightest and best studied transients usually belong to the class of x-ray binaries. Nearly half of the known x- ray binaries are transients (Liu et al., 2000, 2001).

New x-ray transients may occur anywhere in space and at any time. It is necessary to detect, locate and monitor these sources in great detail. Therefore an x-ray sky monitor is an essential subsystem of most x-ray missions. In addition to detecting new transients, it is also an ideal instrument to record the intensity levels of already known sources at frequent intervals.

2 Scientific objectives

X-ray transients are divided broadly into two groups based on the spectral properties near the peak of outbursts (see e.g. White et al., 1984).
1. Hard x-ray transients: These are neutron stars with Be companions. They are binaries with a very long orbital period of the order of few weeks or longer. The outbursts are usually recurrent with brightening of the source when the neutron

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star comes close to the companion during the periastron passage. These objects usually have characteristic Bremsstrahlung temperatures $kT_{brem} > 15keV$.
2. Soft x-ray transients or x-ray novae: These objects are very similar to low mass x-ray binaries. They have episodic outbursts with no fixed period of recurrence which may be anywhere in the range of 1-50 years. Many of these transients are black hole binaries (Tanaka and Shibazaki, 1996). The outbursts may occur due to mass transfer instabilities from the companion, thermal-viscous disc instabilities, or advection dominated accretion flow in the inner regions.

The major advantage of studying transients is that, they provide an unique opportunity with a single source, to observe phenomena occuring over a wide range of luminosities from $10^{33} erg/s$ to $10^{38} erg/s$. This in turn allows us to study the effects of a large range of mass transfer rate dM/dt and the processes leading to disc instabilities. With a sky monitor the early phases of the transients can be studied and the nature and signatures of precursors can be understood. Accurately determining the location of the transient can further lead to the identification of the optical companion which in turn will provide information for the modelling of the orbital parameters of the system.

3 Instrument design and details

The Scanning Sky Monitor (SSM) is proposed as one of the instruments onboard the ASTROSAT to achieve the afore mentioned objectives(ref. report no. ISRO-ISAC-TR-0331, 1998). The SSM has a one dimensional coded mask viewed by a position sensitive detector and is similar in design to the All Sky Monitor (ASM) on RXTE (Levine et al., 1996). This is a proven design and we plan to develop the instrument in house with minor modifications in order to optimise the performance. The development of the instrument will be undertaken at Technical Physics Division at ISAC, whereas the design of the coded mask, image deconvolution techniques etc. will be done at the Astrophysics group at RRI. The detector consists of multiwire gas filled proportional counters with 8 resistive wires serving as anodes. The position of x-ray interaction along the wire is achieved by sensing the o/p on either ends of the anodes and using the charge division method. The detector will act as an image plane for the shadow of the coded mask cast by the x-ray sources in the field of view. Th coded mask is designed using the Hadamard transform and consists of 6 patterns each of 6 by 11 sqcm area and with 63 elements. Cross correlation technique is used for image reconstruction. The energy range of operation of this instrument is 2-10 keV and a position resolution better than 0.5 mm is the goal. The field of view(FOV) of each detector is $6°$ by $90°$ (FWHM). The detectors will be sensitive to a source strength of 10mCrab over a 1 day integration. Figure 1 gives a schematic view of one of the monitors. Most of the other instruments on ASTROSAT operate in the pointed mode observing one particular iregion of the sky for long periods of time. In order that the SSM patrol the sky for transients, it is necessary to have independent scanning capability. The whole spacecraft cannot be rotated because this will affect the imaging instruments onboard. Hence we have decided to mount the SSM on a boom with the capability to rotate in discrete steps which will allow for onboard triggering of a transient and also provide the required integration time for a given field. We propose to have two SSMs mounted such that their FOVs form an 'X' in the sky. By measuring the time difference of source detection in one counter and then the other, we will also get a handle on the position of the source perpendicular to the wires. One rotation of the boom will provide, a scan region in the form of a strip of 90° width. In order to access the region in the sky along the rotation axis of the boom, we will mount a third SSM with its FOV perpendicular to the rotation axis and to the other two SSMs.

The experiment is likely to have a mass of 48 kg excluding the boom arrangement. The onboard memory used to store the data will be 3x12 Mbyte. The overall power requirement is 18W.

4 Status and Conclusions

An engineering model of the detector has been fabricated. The counter is at present filled with P-10 gas at 800 torr and has a 50 micron mylar window. The eight resistive anodes consisting of 25 micron carbon coated quartz wires along with the veto layer have been wired and tested. The 17 preamplifiers have been wired, equalised and mounted on either ends of the anodes. All the wires except one exhibit comparable linearity. Figure 2 shows a plot of the o/p signal on the two ends of a wire along with the ratio of the signals. The residuals with respect to the linear fit is less than 0.5 mm. The analog to digital conversion and the other logic for the processing of the signals have been tested. It will be coupled with the detector o/ps and tested.The overall testing is to be completed by early 2002. The coded mask has been designed and the first model fabricated. The computer simulations using simulated data were extremely successful in the determination of the location and the strength of the source. Iterative removal of sources in order to improve dynamic range has also been implemented. Based on the results of these tests, constraints on the detector requirements have also been provided.

Since many transients have a soft spectra and count rate in the lower energies are much higher, all efforts will be made to extend the lower energy of detection to 1.5 keV. This implies that we may have to seal the counters with thinner and more appropriate windows. The options are beryllium, polypropylene etc. Alternate gas mixtures with Xenon and other resistive wires like graphite wire will also be explored in order to improve position resolution, avoid ageing problems and also to eliminate the chance occurrence of sparking in the anodes.

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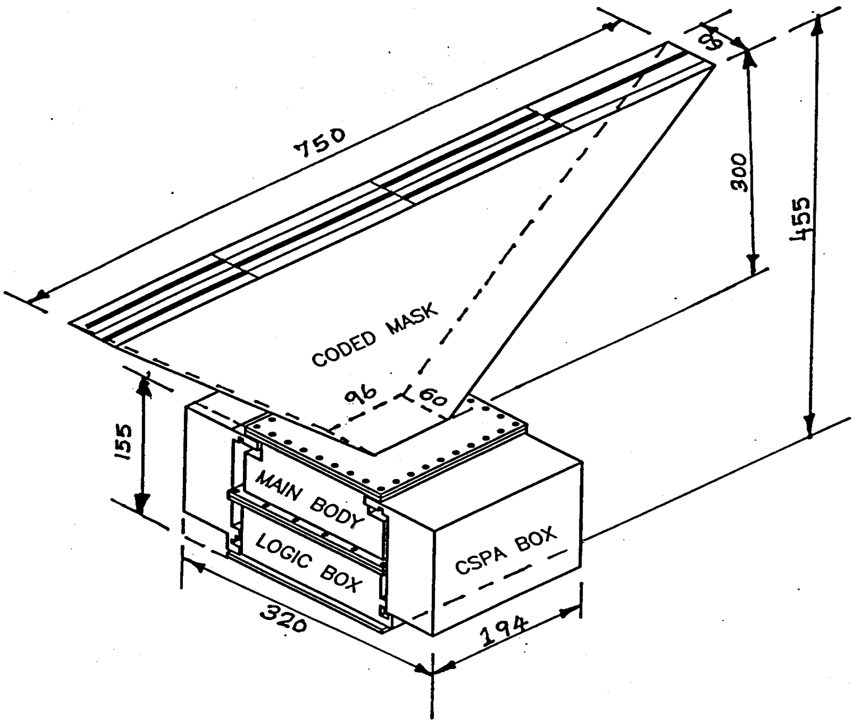
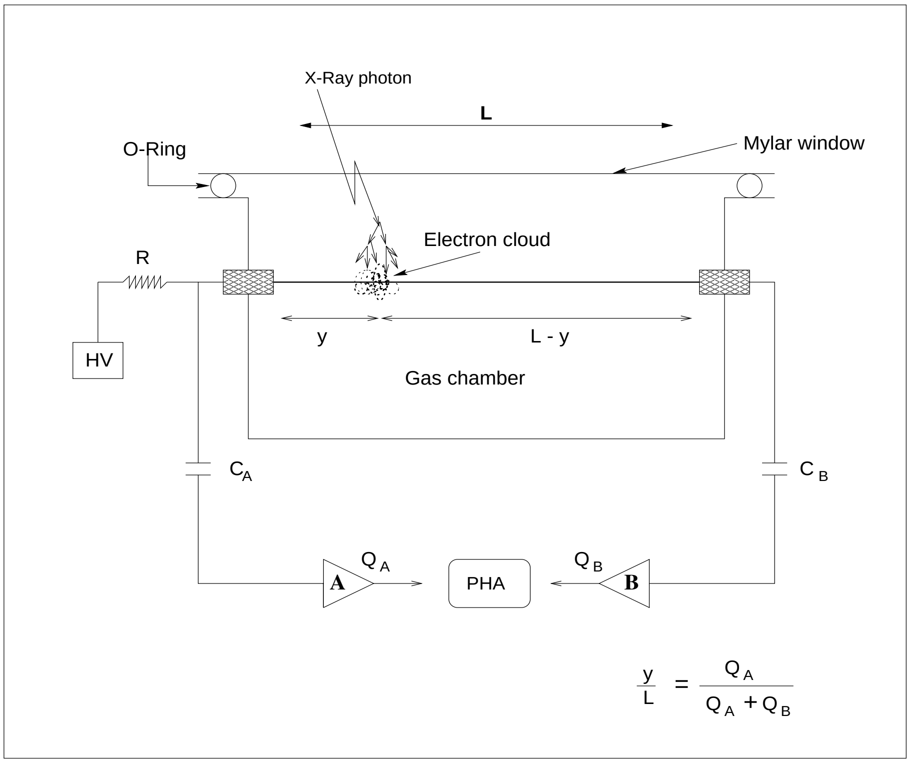


Figure 1: Schematic of the proposed monitor



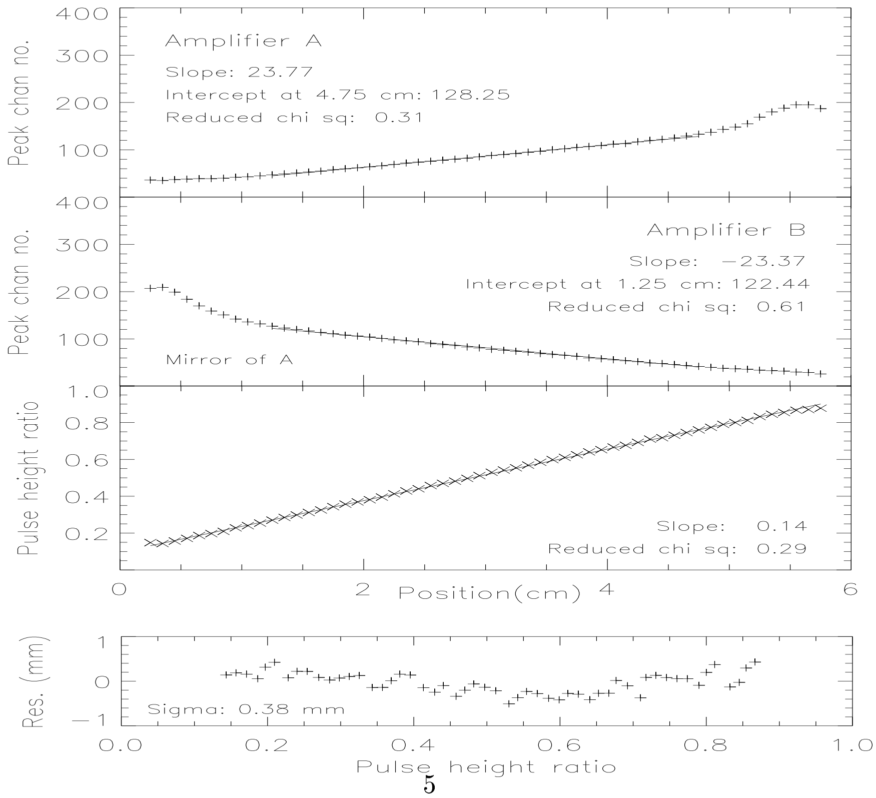


Figure 2: Output signals measured on either ends of the wire no. 4