# ASTROSAT-LAXPC observations of MAXI transient sources

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Abstract

ASTROSAT is an astronomy satellite being made for a launch in 2009. It is designed for simultaneous multi-wavelength studies with five payloads in the optical/UV and a broad X-ray energy range. One of the instruments, a set of three large area xenon proportional counters (LAXPC) will enable high time resolution X-ray measurements in the 2-80 keV band with moderate energy resolution. There are two imaging X-ray spectrometers, one in the soft and one in the hard X-ray band. Two telescopes will provide multi-band imaging in three optical/UV channels. An X-ray sky monitor onboard ASTROSAT, that is similar in concept to the RXTE-ASM will be used to study long term intensity variations of bright X-ray sources. This instrument will also facilitate timely X-ray observations of transient and variable sources with the LAXPC and other payloads. Here we discuss the salient features of the LAXPC and its advantage of previous large area X-ray astronomy instruments. A very large effective area for hard X-rays with good energy resolution will allow the LAXPC to probe certain properties of X-ray sources with unprecedented detail. The main science issues to be addressed with the LAXPCs are discussed here with some simulated results. We particularly mention the science topics related to variable and transient X-ray sources for which the ASTROSAT observations will benefit from the all sky monitoring with MAXI.

Key words: Stars: neutron – (Stars:) pulsars: – X-rays: stars – (Stars:) binaries: general – X-rays: binaries

## 1. Introduction

ASTROSAT is a multi-wavelength astronomy satellite scheduled to be launched in 2009 (Agrawal 2006). It will carry five astronomy payloads covering a wide energy range from optical to hard X-rays and will provide a unique platform to make simultaneous multi-wavelength observations. The satellite will be placed in a near-equatorial orbit at an altitude of 650 km and the mission is expected to be functional for over five years.

The scientific payloads of ASTROSAT, in increasing order of energy are:

- Ultraviolet Imaging Telescopes (UVIT) with a pair of 40 cm diameter primary mirrors with three imaging instruments in the Optical, Near-UV and Far-UV bands.
- A Soft X-ray Telescope (SXT) in the energy band of 0.3-8.0 keV and effective area of 200 $cm^2$ at 1 keV. The SXT is made of an assembly of conical foil mirrors and an X-ray CCD in the focal plane.
- A Scanning Sky Monitor (SSM) in the the energy band of 2-12 keV. The SSM consists of three position-sensitive proportional counters with coded masks.
- Large Area Xenon Proportional Counter (LAXPC) array of three detectors. The LAXPC detectors will work in the energy band of 3-80 keV with an effective area in excess of 6000 $cm^2$ at 10 keV and timing resolution of 10 microsecond.
- A Cadmium-Zinc-Telluride coded-mask imager (CZTI). The CZTI, with an effective are of 100 $cm^2$ will work in the hard X-ray band of 10-150 keV.

## 2. LAXPC Characteristics

The LAXPC consists of three large area proportional counter detectors, each with a geometric area of 3,600 $cm^2$ and an effective area in excess of 2,000 $cm^2$. Compared to the previous generation large area proportional counter detectors for X-ray astronomy (EXOSAT-ME, GINGA-LAC and RXTE-PCA) the LAXPC detectors have a large depth of 15 cm, and gas pressure of 2 atm which makes it a very sensitive X-ray timing and continuum spectroscopic instrument in a wide energy band of 3-80 keV. In the 20-80 keV energy band, the LAXPC

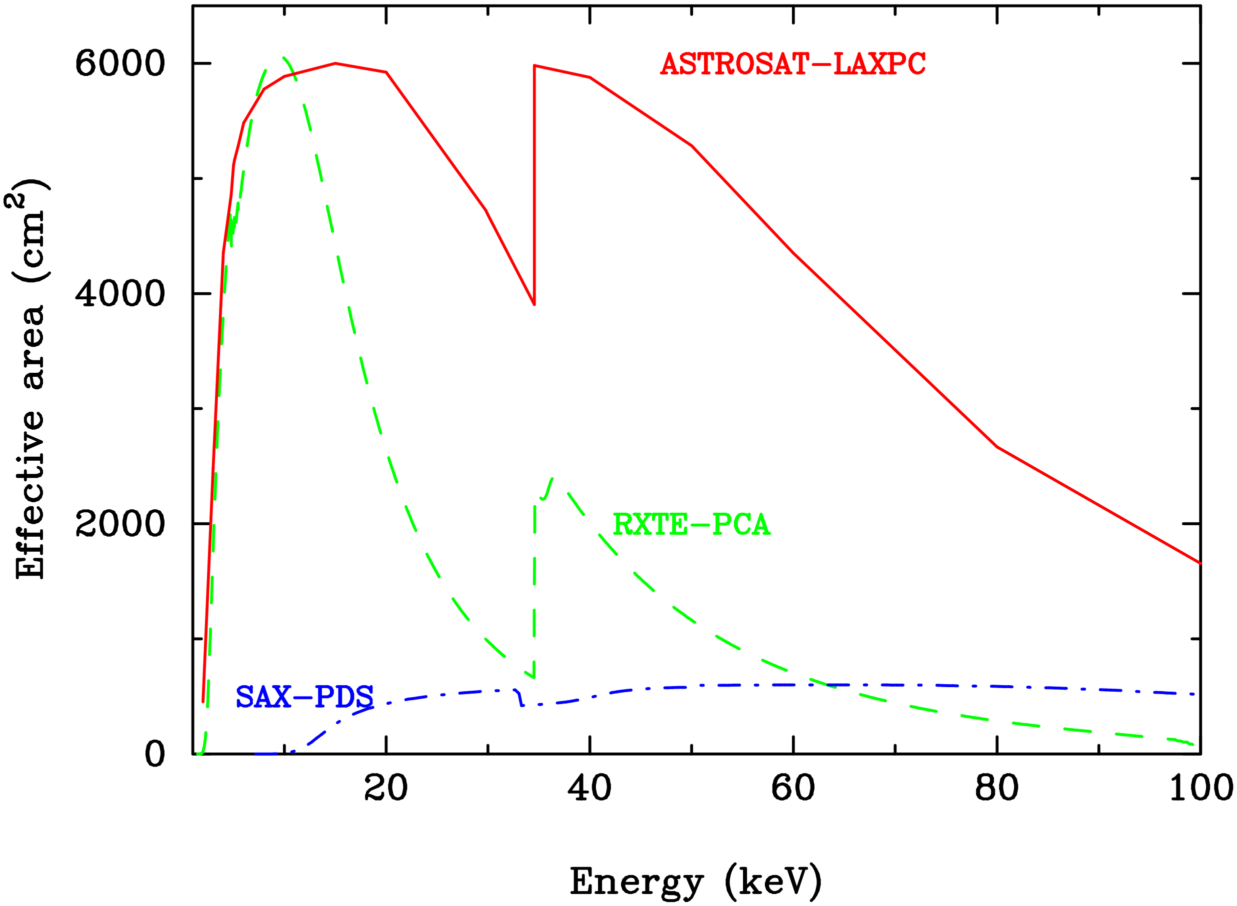


Fig. 1. The effective area of ASTROSAT-LAXPC is shown here along with the effective area of RXTE-PCA and BeppoSAX-PDS. The steps near 34 keV in the top two curves are the K-shell absorption edge of Xe. In the 20-80 keV band, LAXPC effective are is several times larger than that of the PCA.

detector array will have an effective area that is about 3-5 times larger than that of the previous largest instruments in this energy band, the PCA detectors onboard the Rossi X-ray Timing Explorer (RXTE) and the PDS detector onboard Beppo-SAX. A comparison of the LAXPC effective area with the RXTE-PCA and SAX-PDS is shown in Figure 1.

Important features of the LAXPC are:

- Total effective are in excess of 6000 cm$^2$. Detection efficiency of about 50% at 80 keV.
- Time resolution of 10 microsecond and similar absolute timing accuracy.
- Signal processing to be done separately for the three detectors.
- The LAXPC has multiple modes of operation and data formatting. Upto three data modes can be operated simultaneously for each detector. Different detectors can be operated in different modes.
- For every X-ray photon detected, the electronics dead time, only for its processing unit, is about 35 microsecond. For more accurate photon counting, in one of the datamodes that is applicable to bright sources, the dead time is reduced to 10 microsecond per X-ray photon.
- Energy resolution of 10-12 % achieved across the 20-80 keV band. Some calibration spectra are shown in Figure 2.
- A large fraction of the fluorescence emission from the xenon atoms are recaptured in the detector gas. These double events provide important clue to understand the detector characteristics and helps to improve the spectral resolution.
- Spectral leakage, due to escape of fluorescence emission from the xenon atoms is less compared to the RXTE-PCA. This will lead to greater reliability of continuum spectral measurement.
- Low and stable background level is expected due to

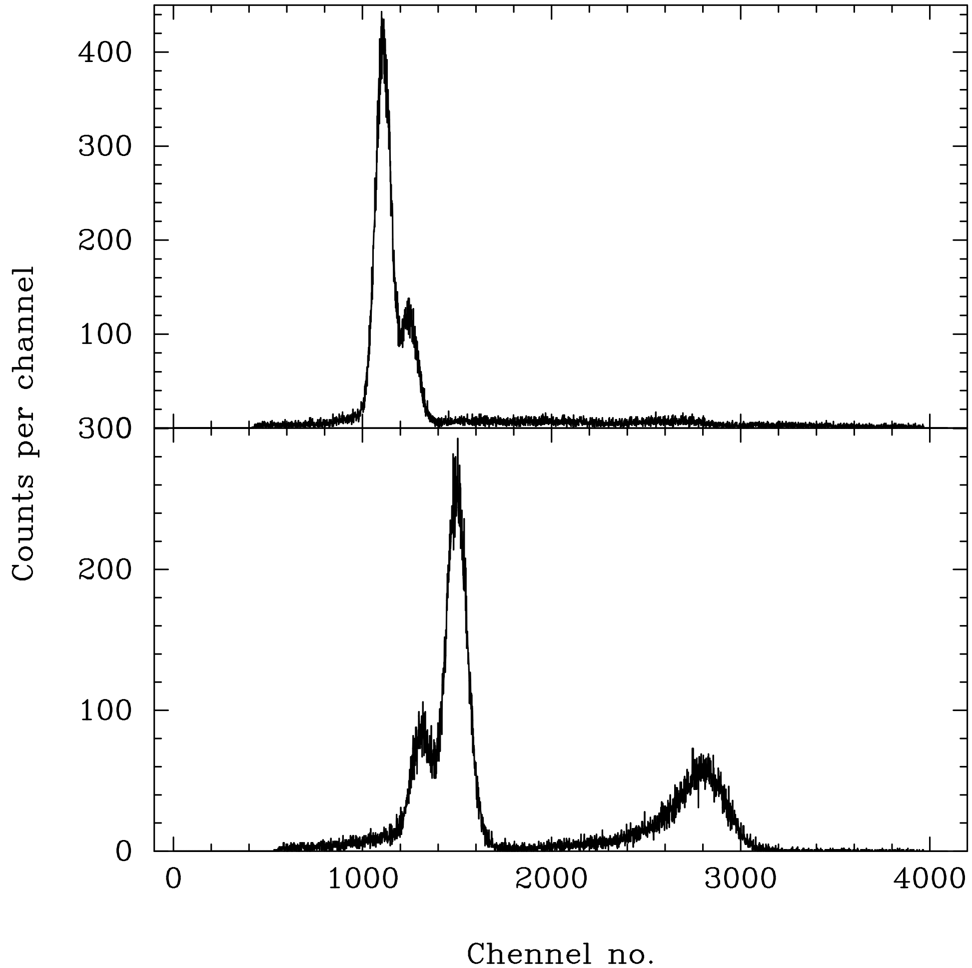


Fig. 2. Spectral response of one of the tests units of LAXPC is shown here. Response to 22 and 25 keV photons are shown in the top panel while response to 60 keV X-ray photons are shown in the bottom panel. A slight asymmetry in the response, with a low energy tail can be seen here. The 30 and 26 keV peaks in the bottom panel are due to energy loss associated with $K_\alpha$ and $K_\beta$ fluorescence emission from the xenon atoms. The response, shown here for one of the layers of LAXPC shows a large fraction of escape events. However, many of the escape photons get absorbed in other layers of the detector. Since the LAXPC processing electronics is designed to process the double events as genuine X-ray events, the effective spectral leakage will be much smaller.

a near-equatorial orbit of the ASTROSAT.

- Field of view of $1^\circ$ for energy above 20 keV and $0.7^\circ$ below 20 keV.
- ASTROSAT has large data storage capacity in the onboard data recorder. For X-ray sources with brightness upto about 1 Crab, it will be possible to store event data in LAXPC with complete detail except for three continuous satellite passes every day when data download to ground station will not be possible.

## 3. Scientific Objectives

The combination of the LAXPC array, with its unprecedented sensitivity in the hard X-ray band and the SXT with its low energy sensitivity and the CZTI with its better energy resolution in the hard X-ray band will make ASTROSAT an unique observatory.

One of the major scientific objectives of ASTROSAT is broad band X-ray spectroscopic studies of binary X-ray sources, AGNs and other Galactic and extragalactic X-ray sources. With broad band spectroscopy, multiple spectral components in the X-ray spectra, like thermal and non-thermal components, will be decoupled to understand the energy generation and dissipation mechanisms.

Some of the most interesting scientific topics to be pursued in the initial stage of the operation of LAXPC are briefly mentioned here.

Measurement of magnetic field strengths of accretion powered X-ray pulsars will be performed through detection of cyclotron resonance scattering features. The sensitivity of the LAXPC array for this measurement is

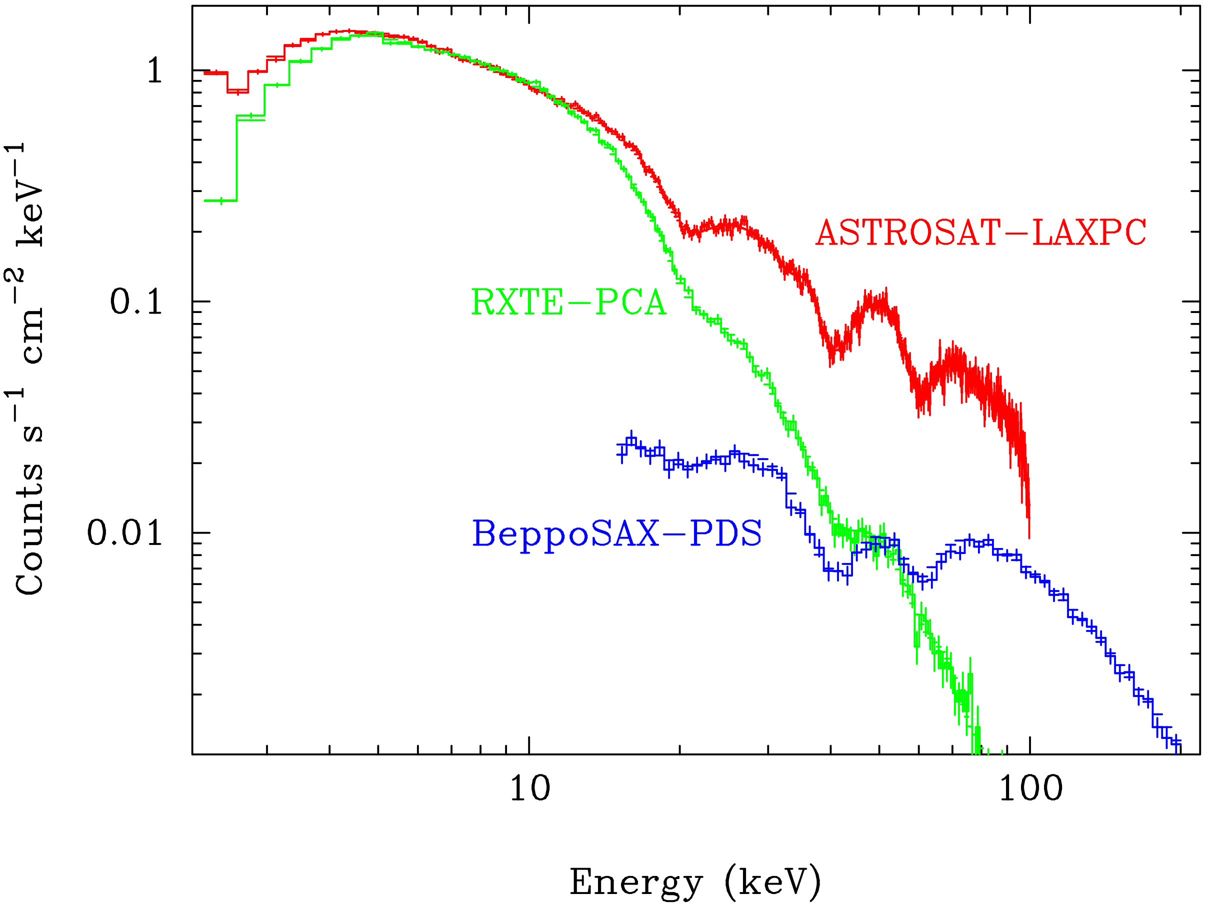


Fig. 3. X-ray spectra of an accretion powered pulsar with multiple cyclotron features simulated with the energy response matrices of ASTROSAT-LAXPC, RXTE-PCA and BeppoSAX-PDS are shown here.

unmatched compared to any other existing or upcoming experiment. LAXPC, SXT and CZTI spectra will also be very useful to characterise the broad band spectrum of the accreting binary X-ray pulsars extending from below 1 keV to more than 100 keV, this has so far been limited only to a handful of bright sources. Pulse phase resolved measurement of the cyclotron features will enable detailed realistic modeling of the pulsar magnetic filed structure. We will also measure the energy of the cyclotron feature as a function of X-ray luminosity in many transient X-ray pulsars that has been done for a few sources with GINGA, RXTE and SUZAKU observations during the decay of the X-ray outbursts (Nakajima et al 2006). Early detection of the onset of transient outbursts with MAXI will enable us to track the evolution of the cyclotron feature even during the rise of the X-ray outbursts. Simulated X-ray spectra of an accretion powered pulsar with multiple cyclotron features are shown in Figure 3 for ASTROSAT-LAXPC, RXTE-PCA and BeppoSAX-PDS.

SXT, LAXPC and CZTI observations together will be suitable to characterise the broad band X-ray spectrum of a large number of galactic and extragalactic black hole sources. Presence of the reflection component in the X-ray spectrum of black hole sources and its connection with the iron emission line profile and line strength will be investigated with ASTROSAT observations. MAXI detections of new transient sources and variability studies of AGNs will enable timely observations of these sources with ASTROSAT in different intensity states. Among the other type of transient sources, temporal and spectral measurements of X-ray emission from new micro-quasars will be performed with the LAXPC. Detection of high frequency QPOs from BHCs will give us a way of measuring the mass and spin of the black holes. In black hole sources, and the low mass X-ray binaries, the rms fraction of high frequency QPOs strongly increases with energy. LAXPC observations will be suitable for easier detection of the high frequency QPOs.

We expect discovery of several new accreting millisecond X-ray pulsars' by LAXPC follow-up observations of the faint transient X-ray sources that will be discovered with the MAXI. Often, the outbursts of these objects last only for a few days to few weeks. However, the outbursts

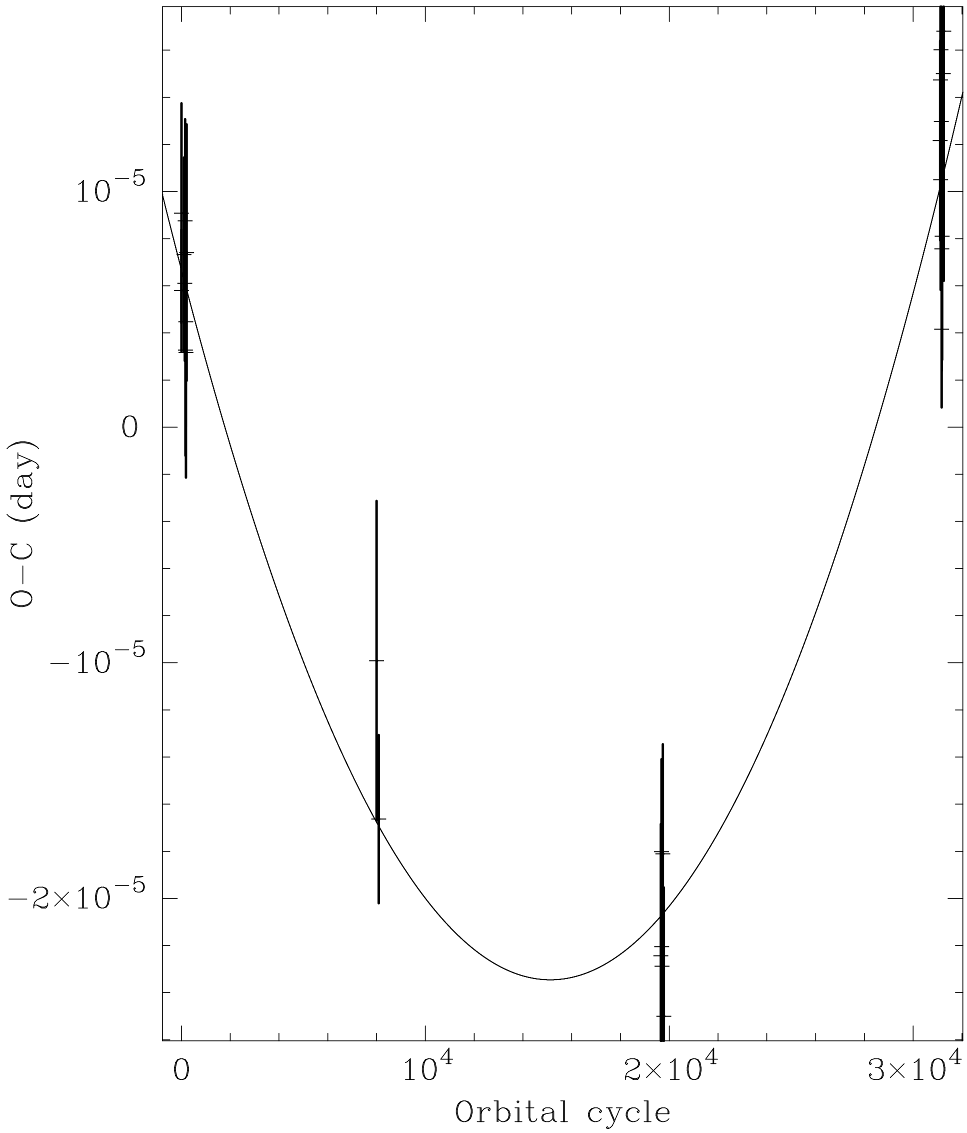


Fig. 4. Orbital evolution of the millisecond accretion powered X-ray pulsar is shown here.

of the presently known eight such sources were discovered with SAX, RXTE, SWIFT or INTEGRAL observatory. If there is an underlying population of fainter outbursts of such sources, MAXI will be able to detect those outbursts and LAXPC observations will be able to reveal their true nature. From observations of the known sources during their future outbursts, it will be possible to measure the spin and orbital evolution of these sources. Orbital evolution measurement of the first known accretion powered millisecond X-ray pulsar SAX J1808-5634, made with the RXTE-PCA observations (Jain, Dutta & Paul 2008) is shown in Figure 4.

Nonthermal emission component in the cluster of galaxies is an unresolved mystery (Nevalainen et al. 2004). Observation of several clusters of galaxies with the LAXPC will allow study of the Compton upscattering of the cosmic microwave radiation in the clusters by non-thermal electron population. This will lead to measurement of the magnetic field strength in the galaxy clusters and also the energy density of the non-thermal electrons.

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