Large Area Xenon Proportional Counters of ASTROSAT

B. Paul (*on behalf of the ASTROSAT-LAXPC team*)
Tata Institute of Fundamental Research
Homi Bhabha Road, Colaba, Mumbai, 400005, India

Abstract

We present here salient features of the Large Area Xenon Proportional Counters (LAXPC) of ASTROSAT. A very large effective area for hard X-rays with good energy reslution will allow the LAXPCs to probe certain properties of bright and medium bright X-ray sources with unprecedented depth. The main science issues to be addressed with the LAXPCs are discussed here with some simulated results.

1 Introduction

Three Large Area X-ray Proportional Counters (LAXPCs), each with an effective area of at least 2 000 cm^2 and a total minimum effective area of 6 000 cm^2 alongwith a CZT array with an area of about 1 000 cm^2 are proposed to constitute the hard X-ray detector system on board the ASTROSAT. A large depth of 15 cm of the LAXPC detectors, and high gas pressure of 2.5–3.0 atm along with the large geometric area will make it a very sensitive instrument in a wide energy band of 2–100 keV. In the 20-100 keV energy band, the proposed LAXPC detector array will have an effective area that is about $\sim$5 times larger than that of the present largest instruments in this energy band, the PCA and HEXTE detectors onboard Rossi X-ray Timing Explorer (RXTE) and the PDS detector onboard Beppo-SAX. A comparison of the LAXPC effective area with the other presently operating instruments is shown in Figure 1. The combination of the LAXPC array, with its unprecedented sensitivity in the hard X-ray band and the Soft X-ray Telescope (SXT) with its low energy sensitivity and very good spectral capability will make ASTROSAT an unique observatory in its time frame.

The minimum effective area of the LAXPC array will be 6 000 cm^2 upto 50 keV and will have an equivalent area of 2 000 cm^2 even at 100 keV. The sensitivity of the LAXPC detectors has been estimated for a nominal orbit of altitude 600 km. With an exposure of 1 day one will be able to obtain spectra with good statistical significance for a 0.1 milli Crab intensity X-ray source. A Crab nebula like X-ray source will give 12 000 counts per sec in the LAXPCs. One will be able to successfully search quasi-periodic oscillations form the X-ray sources in the kHz range if the source intensity rises above 50 milli Crab level.

A very large effective area (6 000 cm^2), high detection efficiency over a broad energy band ($\sim$100% below 60 keV and $\sim$50% in 60–100 keV), high time resolution (10 micro-second), and good energy resolution (8% at 60 keV), will anable us to explore new phenomena in the hard X-ray band in a variety of astrophysical objects and also to carry out observations which are presently of great interest

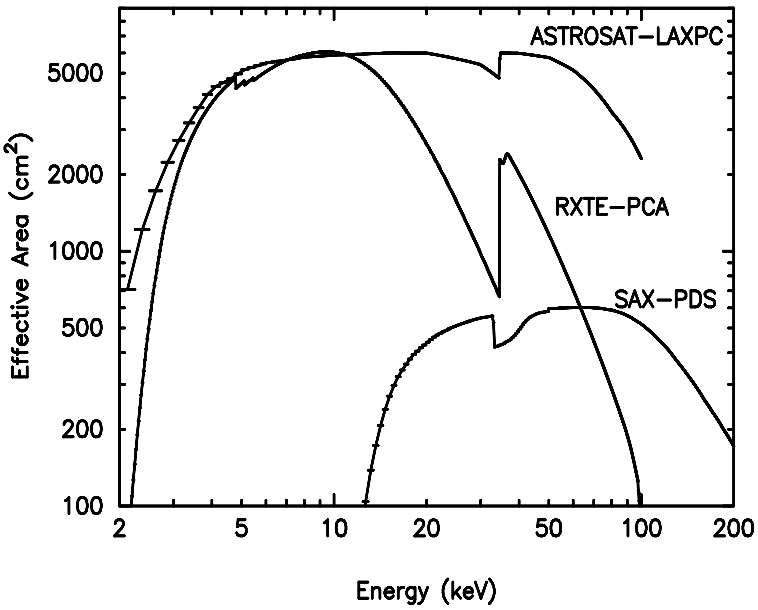

Figure 1: Effective area of the LAXPC is compared with the same of RXTE-PCA and SAX-PDS.

in astrophysics. The cosmic X-ray sources, which will be observed with these detectors, range from the nearby solar-mass Galactic X-ray binaries to the largest structures in the universe, the clusters of galaxies. The important astrophysical questions to be probed by the LAXPCs and the CZT array and in many cases in conjunction with the low energy counterpart, the Soft X-ray Telescope (SXT) of the ASTROSAT, are related to the physics of :

- Neutron stars in the form of low magnetic field ordinary pulsars and high magnetic field X-ray pulsars.
- Black holes of a wide mass range from the solar mass Galactic variety, medium mass predicted in some nearby galaxies, to the supermassive ones in the center of the Active Galactic Nuclei (AGN).
- Accretion onto the stellar mass and the supermassive compact objects.
- 'Magnetars', objects with the highest known magnetic field strength in the universe.
- Nonthermal processes in the largest structures in the universe, the clusters of galaxies.
- Investigation of the hard X-ray background radiation and identification of its possible constituents.

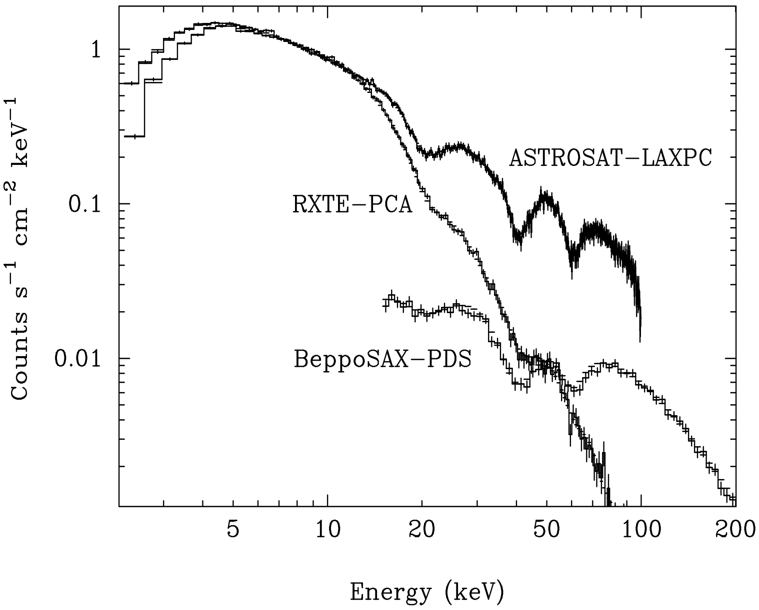

Figure 2: Simulation of a pulsar spectrum with a magnetic field strength of 1.7×10^{12} Gauss as would be detected in LAXPC, RXTE-PCA and SAX-PDS.

Some of the most interesting scientific topics to be probed in the initial stage of the operation of the ASTROSAT hard X-ray instruments are briefly mentioned here.

- Measurement of magnetic field strength of the X-ray pulsars will be performed through detection of cyclotron absorption lines. The sensitivity of the LAXPCs is unmatched compared to any other existing or upcoming experiment. We will characterise the broad band spectrum of the accreting binary X-ray pulsars extending upto 100 keV, this has so far been limited only to a handful of bright sources. Our observations of pulse period variations with luminosity in the transient X-ray pulsars will also improve the understanding of the accretion disk-magnetosphere interactions in these sources.

- Characterisation of the broad band X-ray spectrum of Galactic and extragalactic black hole sources will be carried out. In most of these sources, the spectrum in the 20-80 keV band is not available due to lack of sensitive measurements. LAXPCs, alongwith the CZT array will be able to measure the hard X-ray spectrum accurately for a very large number of galactic and extragalactic black hole sources.

- Discovery of new ‘Accreting Millisecond X-ray Pulsars’ will be possible by LAXPC follow-up observations of the transient sources that will be discovered by the Scanning Sky Monitor (SSM) of the ASTROSAT. These objects are the missing link between the millisecond radio pulsars and the low mass

X-ray binaries and the discovery of a few of this type of objects will give a complete understanding of the evolution of neutron stars. Only one of this type of object is known so far.

- Do the Anomalous X-ray Pulsars (AXPs) and Soft Gamma Repeaters (SGRs) have 'magnetars' (neutron stars with magnetic field strength of $\sim 10^{15}$ G) ? Detection of glitches and nonlinear pulse period evolution of AXPs and SGRs is a very important subject to study and is a test of the magnetar hypothesis. After RXTE, LAXPCs will be the only instrument capable to carry out continuous temporal study of about a dozen of objects suspected to be magnetars.

- Nature of the Kilo Hertz quasi-periodic oscillations (kHz QPOs) of the X-ray radiation in the low mass X-ray binary system is yet to be measured in the hard X-ray band. For most sources, the RXTE-PCA measurements extend only upto about 15 keV. With the LAXPCs, we hope to be able to probe the kHz QPOs and kHz oscillations upto about 50 keV.

- Among the other type of transient sources, temporal and spectral measurements of X-ray emission from new micro-quasars will be performed. Detection of high frequency QPOs from BHCs will give us a way of measuring the mass and spin of the black holes.

- Quasi-periodic and aperiodic variations of AGNs has not yet been studied in detail. Very long exposures of some selected AGNs will help us to detect and verify quasi-periodic intensity variations and also to calculated the power density spectrum of AGNs. With these measurements, we will be able to compare the temporal properties of the AGNs with their galactic analogues, the BHCs.

- We aim to make accurate measurement of the Cosmic X-ray Background (CXB) spectrum in the hard X-ray band. The quasars are believed to contribute most of the soft X-ray background (0.1–2.0 keV band), while normal galaxies and some obscured AGNs are believed to constitute the medium energy X-ray background (2–10 keV band). Accurate spectral measurements of different types of AGNs in the hard X-ray band may lead to identification of the constituents of CXB in this energy band.

- Nonthermal emission component in the cluster of galaxies is an unresolved mystery. Observation of several clusters of galaxies with the LAXPCs and the CZT array, which have very high hard X-ray sensitivity will allow us to study the Compton scattering of the cosmic microwave radiation in the clusters. We will be able to measure the magnetic field strength in the galaxy clusters and also the energy density of the electrons.

Acknowledgement

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