Chapter 2

Description of the instruments used in the study

2.1 *Suzaku*

Suzaku, also known as ASTRO-EII, was a result of collaboration between Institute of Space and Astronautical Science of JAXA (Japan Aerospace Exploration Agency) and National Aeronautics and Space Administrations Goddard Space Flight Center (NASA/GSFC), USA. It was launched in July 2005 and continued it's science operations till September 2015. The satellite payloads consisted of five telescopes, one telescope with a calorimeter (X-ray spectrometer; XRS) as the focal plane instrument, and four X-ray Charge Coupled Devices (CCDs) co-aligned with the four other telescopes. It also has a non-imaging hard X-ray instrument with two components, PIN and GSO. A schematic view of *Suzaku* is given in Figure 2.1.

XRS was a new-generation micro-calorimeter detector designed to provide better spectral resolution than the gratings used in *XMM*-Newton and *Chandra*. Unfortunately it was only operational for 2 weeks.

In this thesis, we have made use of the XIS and HXD detectors which are described below followed by their observation modes.

2.1.1 XIS

The XIS operating in 0.2-12 keV range [85], consists of four X-ray Imaging Spectrometers (XIS), each with a 1024 $\times$ 1024-pixel X-ray-sensitive silicon Charge Coupled Device. This corresponds to 17.80 arcmin $\times$ 17.80 arcmin area on the sky (each pixel has 24 μm^2 square, so the physical size of the CCD is $\sim 25 \times 25$mm). One of the XIS (XIS1) CCD is back illuminated (BI) for improved low-energy ($<$ 1 keV) sensitivity, while the others use front-illuminated (FI) CCDs. The CCD devices are located at the focus of four X-ray telescopes (XRTs). XRTs are gold coated grazing-incidence reflective optics consisting of tightly nested, thin-foil conical mirror shells and high density nesting, thus providing large aperture efficiency for XIS energy range. The effective area was about 330 and 370 cm^2 on the FI and BI at 1.5 keV, and the angular resolution is $\sim 2\,'$.

2.1.2 HXD

The HXD, sensitive in the 10$-$600 keV range [86] is a non-imaging collimated instrument consisting of 16 main detectors arranged in 4 $\times$ 4 array and 20 crystal scintillators for active shielding. Each unit is composed of two detector layers at the bottom of a passive collimator (i.e. well): a GSO/BGO phoswich counter (scintilla-

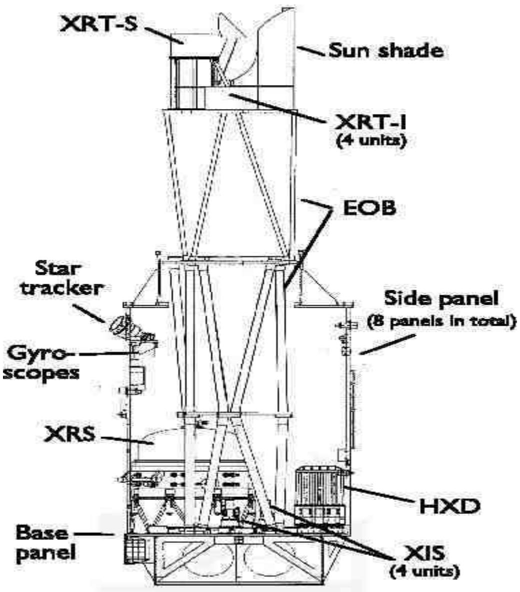

Figure 2.1: Side view of *Suzaku*. Figure courtesy: [5]

tor), sensitive above $\sim$ 30 keV; and on top of it is a 2 mm thick PIN silicon diode, sensitive below $\sim$ 60 keV. There are photomultiplier tubes below the crystals which reads the scintillator signals from GSO/BGO. Since the field of view of HXD is very low, the background rate of *Suzaku* is very low. The HXD features an effective area of $\sim$ 160 cm^2 at 20 keV, and $\sim$ 260 cm^2 at 100 keV. The energy resolution is $\sim$ 3 keV (FWHM) for the PIN diodes, and 7.6 /E_{MeV} % (FWHM) for the scintillators, where E_{MeV} is energy in MeV. It also has an excellent time resolution of 61 μs.

The observation modes for the *Suzaku* satellite are mainly characterized by these two specifications:

- Clock mode: The clock modes describe how the XIS CCD clocks are driven, and determine the exposure time, exposure region, and time resolution. Usually the Normal and Parallel sum clock modes are available. In Normal mode, all the pixels from the CCD are read out at every 8 seconds unless the window option is specified. Time resolution can be 8, 4 and 1 s depending on the window options which could be full, 1/2, 1/4 respectively. Additionally, Normal window mode can be used in combination of various 'window' and 'burst' options. In Parallel sum mode, pixel data from plural rows are summed in the Y-direction, and the sum is put in the pixel RAM as a single row.

- Nominal pointing: The instrument can be set to either XIS nominal pointing where the target is at the centre of the XIS field of view, or HXD nominal pointing where the target is at a point of maximum throughput of the HXD/PIN. For more detailed description, the reader is directed to the *Suzaku* ABC guidebook[1].

2.2 *RXTE*

The Rossi X-ray Timing Explorer (*RXTE*) was launched on December 30 1996 and remained operational till the beginning of 2012. It was developed, built, tested and operated by NASA's Goddard Space Flight Center. The mission had moderate spectral resolution from 3−250 keV but had excellent timing capability. The two coaligned instruments on board were the Proportional Counter Array - PCA [87] that covered the energy range from 3 to 60 keV and the High Energy X-ray Timing Experiment - HEXTE [88] which covered the higher energy range of 18−250 keV. The field of view of both the instruments were collimated to $\sim$ 1 degree, and hence provided a low background level of $\sim$ 0.2 mCrab. In addition to the pointed instruments,

[1] http://heasarc.gsfc.nasa.gov/docs/suzaku/analysis/abc/

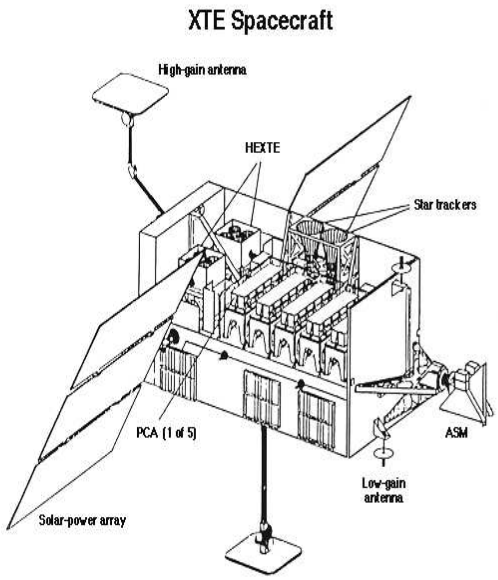

Figure 2.2: An image of *RXTE*. Image courtesy: NASA/GSFC

RXTE was also equipped with a small 1D coded mask All Sky Monitor - ASM [89] that scanned about 70 % of the sky in every revolution. It would regularly monitor the sky in order to detect numerous transient sources for which follow-up pointed observations could be carried with the main instruments on board *RXTE* and also other X-ray mission then operative. The advantage of observing most of the sources with a sensitivity of $\sim$ 20 mCrab per day allowed the monitoring of the activity of known persistent sources. Figure 2.2 shows a schematic view of *RXTE* with all the instruments onboard.

2.2.1 *RXTE*-PCA

PCA is a collimated array of proportional counters, and is composed of 5 Proportional Counter Units (PCUs) with a total photon collection area of 6500 cm^2 in the 3-6 keV range. The propane layer at the top acted as a veto layer. Also, an additional veto layer was situated at the bottom of the detector. The energy resolution was about 18 % at 6 keV.

2.2.2 *RXTE*-HEXTE

HEXTE consisted of two clusters (A and B) made up of four NAI(TI)/CsI(Na)-Phoswich scintillation detectors each [88]. It had a total effective area of about 1600 cm^2 at 50 keV. In it's time, *RXTE* had the largest effective area which allowed brilliant study of Galactic X-ray sources. It's new and improved successor *ASTROSAT* will now carry forward the legacy.

2.3 *Swift*

Swift is another NASA mission launched in November 2004. It is a gamma-ray burst explorer [29] having three co-aligned instruments on board, the Burst Alert Telescope - BAT [90], the X-Ray Telescope - XRT [91] and the Ultraviolet/Optical Telescope - UVOT [92]. BAT uses a coded-aperture mask of 52,000 randomly placed 5 mm lead tiles, 1 metre above a detector plane of 32,768 four mm CdZnTe hard X-ray detector tiles. It functions in the energy range of 15-150 keV. The XRT consists of a grazing incidence Wolter I telescope with 12 nested mirrors, focused onto a single MOS CCD similar to those used by the XMM-Newton EPIC MOS cameras. It operates in the 0.2-10.0 keV energy range.

2.4 *INTEGRAL*

INTernational Gamma-Ray Astrophysics Laboratory was constructed by the European Space Agency (ESA) jointly with Poland, the Czech Republic, Russia and the USA. It was launched in October 2002 and is operational till date. The scientific payload comprise two primary instruments: SPI (Spectrometer on INTEGRAL) and IBIS (Imager on Board the INTEGRAL Satellite). These provide complementary observations to each other with SPI/IBIS suited for high/moderate resolution spectroscopy of γ ray emission and low/high spatial resolution that helps increase efficiency in performance. Along with these, there are two instruments: JEM-X (Joint European X-Ray Monitor) and OMC (Optical Monitoring Camera) that observe in X-rays and optical energy bands. SPI, IBIS and JEM-X are all coded-mask telescopes which uses a series of perforated metal masks in front of the Cadmium Telluride and Germanium detectors. These coded-mask apertures are very much instrumental in separating and locating sources over a wide sky.

2.5 *MAXI*

Monitor of All-sky X-ray Image (*MAXI*) is developed by JAXA, Japan. It is comprised of highly sensitive X-ray detectors; the Gas Slit Camera (GSC) and the Solid-state Slit Camera (SSC) onboard the International Space Station (ISS) that orbits Earth. *MAXI* conducts a full sky survey every 96 minutes searching for variations in X-ray sources.

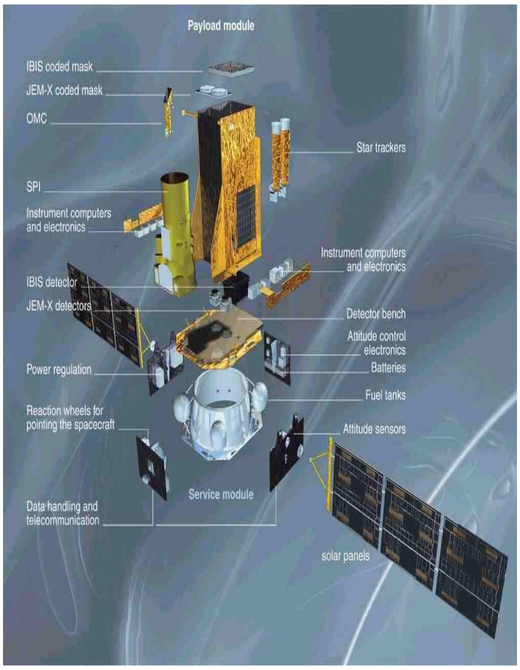

Figure 2.3: An image of *INTEGRAL*. Image courtesy: ESA