Synopsis

X-ray astronomy began in the 1960s and has now reached a mature stage with rapid advancements in technologies. Studies in this field provide us with information on some of the most extreme conditions in the Universe. The Earth's atmosphere is opaque to cosmic X-rays and hence payloads/satellites carrying X-ray detectors have to be flown outside the atmosphere. Compared to the earlier detectors, present day detectors allow long exposures, high sensitivity and high resolution. The **Rossi X-ray Timing Explorer (RXTE)**, with its unique capabilities of large collecting area, broad band spectral coverage and micro-second timing resolution, launched in 1995 by NASA, has changed our view of the X-ray sky. The mission has remained operational for over 16 years, acquiring vast amounts of data on X-ray sources, especially on the most luminous X-ray sources known in the Universe – X-ray binaries and on active galactic nuclei and quasars.

The first X-ray source discovered was Scorpius X-1, a member of a binary system. Most stars in our galaxy are members of binary systems and X-ray binaries are the brightest objects in the X-ray sky. These are highly variable. An X-ray binary system consist of a normal star (companion star) gravitationally bound to a compact star, orbiting about the common center of mass. The compact star may be a white-dwarf, a neutron star or a black hole. Accretion is the most efficient mechanism known in the Universe for liberating energy, and X-ray binary systems are powered by the gravitational energy released when the material accreted from the companion star falls on to the compact object. These systems emit X-rays from regions in them where extreme conditions like hot temperatures, strong magnetic fields and strong gravitational fields prevail. Such conditions cannot be produced in an Earth based laboratory. Studying these objects provides us with information regarding the behaviour of matter at these extreme conditions and also on the final stages of stellar evolution.

X-ray binary systems may be broadly classified on the basis of the mass and evolution-ary state of the companion star as High Mass X-ray Binary Systems (HMXBs) and Low Mass X-ray Binary Systems (LMXBs). In HMXBs the mode of mass transfer is by stellar wind accretion and in LMXBs the mass transfer takes place via Roche lobe overflow. In this thesis, we mainly discuss a class of binary systems which consist of a non-degenerate companion star and a strongly magnetized neutron star. These are called Accretion Powered X-ray Pulsars, also known as X-ray Binary Pulsars (XBPs). More than 150 XBPs are known till today and most of them are HMXBs. These pulsars may be transient or persistent in X-rays. Persistent pulsars are those which are active all the time; however, they can show variability. Transient pulsars or Be/X-ray Binary Pulsars (BeXBPs) are those consisting of a Be spectral type companion star on a wide eccentric orbit about a neutron star. Most of the HMXBs discussed till now are seen to be BeXBPs. BeXBPs form a dominant subclass of HMXBs. They exhibit charac-teristic recurrent outbursts which identifies the source. X-ray outbursts observed in BeXBPs are generally associated with the periastron passage of the neutron star where it crosses the circumstellar disk of the Be star. Luminosity of BeXBPs can vary over a wide range between quiescence and outburst: from 10^{32}–10^{33} ergs s^{-1} to 10^{36}–10^{37} ergs s^{-1} . So, these transient sources are good candidates for studying the X-ray production mechanisms over a wide range of X-ray luminosities.

X-ray Binary Pulsars (XBPs) are characterised by their strong magnetic fields ($\sim 10^{12}$ Gauss). The strong magnetic field channels the accretion flow, producing an accretion column, guiding the material on to the magnetic poles of the neutron star. The material decelerates rapidly on reaching the surface of the neutron star and X-rays are produced. The region appears as a hot spot. Depending on the mass accretion rate, the size of the hot spot and the density of the accretion column can vary. Hence, the radiation pressure near the surface of the neutron star can vary. The emission from the magnetic poles can become highly anisotropic. If the rotation axis and the magnetic axis of the pulsar are not aligned then the emitted radiation appears to be pulsed for any distant observer whose line of sight to the object intersects the emission region at periodic intervals, as the pulsar rotates.

The pulse profiles of accretion powered pulsars show dramatic variations with intensity, as well as energy, both in transient as well as in persistent sources. These variations could be due to the changes in the physical processes taking place near the neutron star, changes in the viewing geometry, and/or changes in the level of interaction with the wind of the companion star. The radiation emitted from the hot spots is scattered by the hot relativistic plasma in the accretion columns. The anisotropy and energy dependence of the scattering cross section produces a complex energy dependence for the pulse profiles. An important feature observed in the pulse profiles of XBPs are absorption dips – a sudden sharp drop in intensity at some phase of the pulsar rotation.

The energy spectra of XBPs are the net result of the various physical processes involved in the interactions of the X-rays produced from the surface of the neutron star with the strongly magnetized plasma in its vicinity. The main physical process taking place when the radiation passes through the hot plasma is the Comptonization of the soft photons – inverse Compton scattering. By this, soft X-rays disappear from the softer region and appear in the harder portion of the spectrum. The energy spectrum of XBPs generally have a power law form with an exponential decay above a cut off energy around 10–20 keV, with emission (iron fluorescence line) and absorption (Cyclotron line) features and also a black body.

In this thesis, we present a study of the pulse profiles and energy spectra of XBPs. We have analysed the energy and intensity dependence of the variations in the pulse profiles of 50 XBPs. We detected sharp absorption dips (sudden drops in intensity) in the pulse profiles of a dozen pulsars. We see that this feature is not very common among XBPs and has not received much attention till now. In order to understand more about this phenomenon, we have performed detailed timing and spectral studies for two BeXBPs – 1A 1118–61 and GX 304–1. These sources were in quiescence for several decades and went into giant outbursts during 2009 and 2010 respectively. We have analysed the data for these periods and have found dips in the pulse profiles, which have strong intensity and energy dependence. Pulse phase resolved spectroscopic analysis may be used to probe the changes across the pulse phase, especially during the phases where the dips are present. We could clearly establish the reason for the dip phenomenon as due to the partial eclipse of the emitted radiation by the accretion column as the pulsar rotates. Analysing the energy spectrum of GX 304-1, we see that the source shows significant evolution of the energy spectrum during the decay phase of the outburst. So we then determined the energy spectrum of 17 BeXBPs on a daily basis. We find that most of these show significant evolution of their spectra over the outburst. We also checked the relative frequency of pulsars showing double peaked/single peaked pulse profiles.

This thesis is organised as follows:

Chapter 1 presents an overview of X-ray binary systems. We discuss their general observable features including the different modes of mass transfer and also the clas-sification of X-ray binaries. In the further sections, we specifically discuss a class of X-ray binaries called accretion powered pulsars, characteristics of their pulse profiles and energy spectra. We also discuss various models for the continuum and also present the results of fitting the partial covering model to it. The last section of this chapter presents a brief description on the **RXTE** satellite and its instruments, the data from which have been used for all the analyses presented in this thesis.

Chapter 2 describes the search and the detection of absorption dips in the pulse profiles of XBPs. We have analysed 50 XBPs and found dips in a few transient and persistent accretion powered pulsars. The dips in the pulse profiles are believed to occur due to the obscuration of the emitted radiation by the accretion column, phase locked with the neutron star. The width and depth of the dip shows strong dependence on energy. The energy dependence and the nature/behaviour of the dips observed in these sources are described in detail. 1A 1118–61 is a transient X-ray pulsar orbiting a Be spectral type companion star. The source underwent an outburst in January 2009.

Chapter 3 reports the detection of the dip feature in BeXBP 1A 1118–61 and the results of detailed timing and spectral studies of observations on this source. The source GX 304-1 had an outburst in 2010 August. We detected strong intensity-and energy-dependent variations in the pulse profiles during the outburst.

Chapter 4 reports the detection of the dip feature in BeXBP GX 304–1 and the results of detailed temporal and spectral studies of observations on this source. Be/X-ray binary pulsars are known to exhibit small and large outbursts. As an outburst starts, reaches the peak and decays, the changes in the mass accretion rate leads to observable effects in the accretion flow pattern, interactions between the accretion disk and magnetosphere and also the emission geometry.

Chapter 5 presents the analysis of the continuum spectrum of 17 BeXBPs over their outbursts. The pulse profiles of XBPs appear in a variety of shapes. This complexity in pulse profiles is due to various scattering and absorption effects. So, if we analyse the pulse profiles at higher energies, we could understand the intrinsic beam pattern of the pulsar and hence the pulsar geometry. **Chapter 6** presents the uniform analysis of the statis-tics of pulse profiles of XBPs using data from a single satellite, the **Rossi X-ray Timing Explorer**. We also make an attempt to morphologically classify the pulse profiles.

Chapter 7 presents a summary and a discussion on the results of this study.