Abstract

This thesis is dedicated to understand the timing and spectral properties of accretion powered Be/X-ray binary pulsars. Accretion powered binary X-ray pulsars are system of highly magnetized neutron stars which accrete matter from non-degenerate companion and subsequently get powered in X-ray regime. Neutron stars are among the most compact objects in the universe, which contain more than a solar mass confined within spheres of ~10 km radii. This results in an average density of a neutron star to be $\sim 10^{14}$g cm^{-3}, i.e. as high as that of the nuclear matter. Apart from the extreme density, the magnetic field of neutron star in these binary systems is of the order of 10^{8-12} G. These aspects make them one of the most exotic objects in the universe. Therefore, study of the accretion mechanism in these systems provide us with the opportunity to probe the properties of matter under extreme conditions, which otherwise is impossible to achieve through laboratory experiments.

During the process of accretion, the matter accreted from the non-degenerate optical companion follows the magnetic field lines and gets dumped onto the magnetic poles of the neutron star. This forms an accretion mound on the magnetic poles of the neutron stars. However, when the mass acretion rate is high, a column like structure, known as the 'accretion column', is formed at the magentic poles of the neutron star. A radiation dominated shock is expected to form in the accretion column which decelerates the infalling plasma before settling on to the surface of neutron star. Consequently, the surface temperature at the magnetic poles reaches as high as 10^7 K, resulting in X-ray emission. The interaction of this radiation with the infalling plasma, through complex physical processes, shapes the resulting spectral continuum of the neutron star. As the spin and magnetic axes are usually misaligned, the beam of X-ray radiation from the magnetic poles of the neutron star can be detected once it sweeps through the line of sight of the observer. This result in apparent X-ray pulsations, hence the neutron star in these systems is known as pulsar.

The emission characteristics of this radiation depend upon the mass accretion rate and hence on the luminosity. Therefore, it is interesting to investigate the characteristic properties

of these X-ray sources at different luminosities. One such class of X-ray binaries, showing extreme variability in terms of luminosity is, Be/X-ray binary pulsars. The neutron star in these systems revolve in a wide eccentric orbit around its Be optical companion and remain in quiescence most of the time. However, once it approaches the periastron, mass accretion from the circumstellar disk of the Be star becomes possible and the neutron star consequently show strong X-ray outburst activities, known as Type I outburst. The X-ray luminosity during these outburst events can reach as high as 10-100 times the quiescent luminosity ($L_{quiescent} \approx 10^{34}$ erg s^{-1}). Another kind of X-ray enhancement, i.e. Type II outbursts are also detected from these systems. The Type II outbursts are rare and independent of the orbital motion of the binary system. The X-ray luminosity during these (giant outburst) events may even reach as high as $\geq 10^{38}$ erg s^{-1}. Due to extreme variability and strong mass accretion rate during these X-ray outburst events, Be/X-ray binaries are ideal sources to study the luminosity dependence of the emission characteristics of the X-ray pulsars, which is the main focus of the present thesis.

In this work, I have carried out a detailed and systematic investigation of the spectral and timing properties of Be/X-ray binary pulsar 2S 1417-624. Using large number of *RXTE* pointed observations, taken during the 2009 giant X-ray outburst of 2S 1417-624, a systematic change in the shape of the pulse profile of the pulsar was observed. The pulse profiles were found to exhibit a transition from two-peak structure to three-peak during the rise of 2009 Type II outburst, while a reverse trend was observed during the outburst decline. At the same time, the pulsed fraction of the pulsar was found to be anti-correlated with the source luminosity. This kind of variation was never seen previously, for any kind of X-ray activity observed from this source. In order to probe the cause of such variation, a detailed phase averaged and pulse phase resolved spectroscopy was performed for each epoch of the observation. The spectral continuum was found to be described well with an absorbed cut-off power law model with an additional Gaussian component for the iron emission due to Fe K_{α}. The dependence of the spectral parameters on the source luminosity was studied for the first time in great detail. It was found that the observed changes in spectral and timing properties of the pulsar pointed towards the change in the accretion geometry close to *critical luminosity* regimes. This subsequently allowed to constrain one of the most fundamental physical parameter of the pulsar, i.e. magnetic field strength, by using the relation between critical luminosity and the magnetic field strength (Becker et al., 2012).

Recently in 2018, 2S 1417-624 showed another giant outburst activity and was observed simultaneously with *NuSTAR* and *Swift* X-ray observatories at the outburst peak. This was the most luminous outburst detected from the pulsar till date and provided a unique opportunity to carry out a systematic analysis of the emission characteristic of the pulsar at even higher luminosity. The pulse profiles of the pulsar during this event was found to evolve further to four-peak structure. This was a direct observational evidence of the strong dependence of the emission geometry of pulsar on the mass accretion rate. The phase averaged spectrum of the pulsar was different as compared to its previous outburst events and found to be described only with a composite model consisting of an absorbed cut-off power law model, a Gaussain component for iron fluorescence emission and an additional blackbody emission component with a temperature of ≈1 keV (soft X-ray excess). The detection of soft-excess emission in the pulsar spectrum is quite rare. Therefore, a detailed pulse phase resolved spectroscopy was performed in order to probe the origin of this component. Moreover, a detailed physical modeling was carried out for the first time in this work to describe the X-ray spectrum of 2S 1417-624 self consistently, using physically motivated spectral continuum model `COMPMAG` (Farinelli et al., 2012). The results obtained from these studies are discussed in great detail in the thesis.

Keywords: X-ray binaries, Accretion powered Pulsars, Magnetic fields, Accretion, Pulse profiles, Spectroscopy, Pulse phase resolved spectroscopy, Critical luminosity.