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X-ray studies of Be/X-ray binaries

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In this thesis a study of some X-ray binaries in which a Be star is a primary has been undertaken in an effort to understand the nature of X-ray emission from these sources. The work attempts to answer questions regarding the structure of the circumstellar disk and its evolution with time.

The thesis consists of two parts. The first part is devoted to the analysis of X-ray data of two Be stars observed by the EXOSAT. The objects selected were 2S0114 + 65 and 4U2206 + 54. In the second part of the thesis we concentrate on the empirical modelling of the circumstellar envelopes of the stars using the neutron star as a passive probe. An attempt has been made to model the circumstellar environment of the Be/X-ray binary 4U1907 + 09. A brief outline of the thesis is given below.

The results obtained from the present study on 2S0114 + 65 and 4U2206 + 54 are described. It is seen that,

(1) The transient source 4U2206 + 54 shows complex spectral changes which are independent of the intensity variations. The spectral analysis of the source has shown that during the outburst phases not only does the overall flux level increase and the source shows flaring activity, but that the spectrum also changes. There is in fact a clear tendency towards hardening of the spectrum during the outburst phase compared to the quiescent one. Further, colour variations seem to occur within the outburst phase itself as is seen from the time variability of the X-ray spectrum. It can be concluded from this that both N_H and α vary during the outburst in a random fashion. An interesting result from the present study is the possible detection of the spin period of the compact object. X-ray pulsations with a period of $\approx$ 392s are detected at a confidence level of 99% indicating the presence of a pulsar in this system.

(2) The source 2S0114 +65 shows several X-ray flares of few hours duration. The X-ray spectrum shows a distinct time variability within a single day. The most interesting result from the present observations is that the hardness ratio shows an inverse correlation with intensity. This indicates that the intensity variations are most likely due to a change in the absorption column density. This further implies density variations in the gas disk round the Be star. The size of these gas clumps is of the order of 10^{11} cm. If one assumes the size of the inhomogeneities of about 10^{11} in the radial direction also, then using $N_H \approx 2*10^{22}$ cm^{-2}, the density of the gas in the envelope is of the order of $2*10^{11}$ atoms cm^{-3}. A fluorescence Fe line emission at 6.4 keV was observed when the absorption was high. The source showed quasi-periodic oscillations with a period of 2000s. The pulsar period at $\approx$ 894s, as reported in some of the earlier studies of this source, is not detected.

The results of our investigation of the nature of the circumstellar envelope of the binary 4U1907 + 09 are described next. The validity of the two main models which have been proposed as an explanation for the Be phenomenon are investigated. The first model is known as the 'disk' model while the second model is known as the 'Spheroidal/Ellipsoidal' model.

Using the information on the densities and velocities derived from the ellipsoidal envelope model, it is shown in this thesis, that the X-ray flux of the binary 4U1907 + 09 cannot be explained in terms of a Spheroidal/Ellipsoidal sphere around the star. It is further demonstrated that this model consistently gives an underestimation of the X-ray luminosity of the system, compared to the observed one.

The discrepancy shown by the ellipsoidal envelope model in predicting the average X-ray luminosity of 4U1907 + 09 motivated us to model the circumstellar envelope of the source using the disk hypothesis. Accordingly the massive transient outburst of the source covering about four orbital cycles was modelled. The effects of the disk geometry, the velocities and the densities in the expanding disk of the Be star, and the orbital motion of the neutron star on the expected X-ray luminosity are investigated. It is shown that the shapes of the X-ray light curves depend strongly on the expansion velocity of the gas ejected by the Be star. It is demonstrated that the disk model can explain with reasonable accuracy the observed light curve of the binary. On the basis of this it is argued that :

(1) The companion of 4U1907 + 09 is a Be star and not a supergiant,

(2) The disk model withstands a more rigorous scrutiny with respect to this system than does the ellipsoidal envelope model.