Multi-wavelength observations of phase changes in X Persei

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Abstract. — X Persei is the optical counterpart to the pulsating X-ray source 4U0352+30. The system consists of a neutron star secondary accreting from an O9.5IIIe primary via stellar wind processes. In mid-1990, X Per underwent a dramatic phase change, losing its circumstellar shell, infrared excess and Hα emission line. Detailed optical and infrared measurements throughout this change are presented and compared with earlier, archival material which suggests that a similar event took place in 1974–1977. We examine the X-ray data available from this earlier phase change, and discuss the X-ray behaviour of the system during and after the event. We find a clear correlation between the optical, infrared and X-ray behaviour during the 1974–1977 phase change, followed by an extended period where the X-ray behaviour appears to be unrelated to that in the optical or infrared. Based on this we expect X Per to have undergone a period of spin-up during 1990–1991.

Key words: stars: binaries: general — stars: emission — line, Be — stars: pulsars: general — infrared: stars — X-rays: stars.

1. Introduction.

We have been monitoring a number of transient X-ray sources (high mass systems consisting of Oe or Be primaries with accreting neutron star companions) using optical spectroscopy and infra-red photometry since 1987 (see Coe et al. this conference). The aim is to compare these measurements with X-ray observations since this allows detailed modelling of the physical properties of the circumstellar disk which is believed to fuel the X-ray emission.

Recent observations of such X-ray transients in their “outburst” phases (thought to be associated with increased emission at or near periastron passage of the neutron star through the disk or with “shell–events”) have led to an increased interest in these sources. We will discuss here another transient form of behaviour not previously examined in the X-ray region, namely a phase change in the Oe/Be primary.

2. Phase changes — the evidence.

A phase change is simply a change in state from an Oe/Be star to a normal O/B-type star caused by the loss of the circumstellar disk of material which is responsible for the characteristic Balmer emission lines and the strong infrared excess. Such phase changes have been noted previously in several isolated Be stars, but only one other Be/X-ray binary has been observed to undergo such a change (ie. 4U1258–613, GX304–1; Corbet et al. 1986). A phase change in such a binary system is expected to have a marked effect on the X-ray properties of that system. The X-ray flux could either increase or decrease, depending on whether the circumstellar disc re-forms around the neutron star or whether it disperses completely (see later). The details are likely to depend on the nature of the binary orbit and the orbital phase at which the disk-loss occurs.

During the monitoring campaign, we observed a dramatic phase change in X Persei (Norton et al. 1991) as evidenced by the Hα spectra (Fig. 1) and the optical and infrared lightcurves (Figs. 2 & 3). As a result, it would appear that we are now seeing an unobscured O9.5III star at a distance of 1300 ± 400pc (Fabregat et al. 1992). A paper discussing this most recent phase change in more detail is currently in preparation (Roche et al. in prep). Here we will concentrate on an earlier phase change uncovered by our archive search, apparent in Figures 2 & 3 as occurring during 1974–1977. This earlier phase change shows similar optical and infrared magnitudes, similar colours and the same lack of optical variability that is currently being seen from X Per. Note, however, that there are no reports of Hα being seen in absorption during 1974–1977, although “...an absence of emission...” of other Balmer series lines

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was noted by de Loore et al. (1979). The added interest in this earlier phase change comes from the fact that we also have X-ray observations spanning the event.

3. Optical, infrared and X-ray correlations.

Having established that X Per has undergone two major phase changes recently, we have examined the X-ray behaviour of the system during the earlier (1974–1977) event, in the hope of predicting the systems current behaviour. Figure 4 shows Ariel V observations of X Per, illustrating the X-ray flux during and after the disk-less phase. It would appear that the 2–10 keV flux of X Per faded almost linearly during the 1974–1977 optical low. Later observations show that X Per has continued in an X-ray low state since then (Robba & Warwick 1989; Warwick, private communication). Hence there is no link between the X-ray flux of X Per and the optical or infrared magnitudes after the 1974–1977 low.

In contrast, examination of the pulse period history of X Per (Fig. 5) reveals that a spin-up episode coincided with the onset of the phase change event (1974). This spin-up of the neutron star lasted until the end of the optical low phase (1977), whereupon the system reverted to a state of steady spin-down, which lasted until at least Jan. 1990. There would therefore appear to be a clear link between the neutron star pulse period and the Be star phase change.


Whilst X Per was in its disk-less state (Norton et al. 1991), we would expect its X-ray behaviour to resemble that of 1974–1977. We therefore expect that the pulsar was spinning up during the period mid–1990 to late 1991 (when evidence for the disk-return phase was seen, Corbet & Thomas 1991). Analysis of the long-term X-ray lightcurve of X Per suggests that the system entered a high state

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**Figure 1.** Spectra of X Persei taken at the Isaac Newton Telescope, La Palma, showing the Hα line in (a) emission, Feb. 1990 and (b) absorption, Sept. 1990.

**Figure 2 & 3.** The long-term V band lightcurve of X Persei, showing the optically faint phases in 1974–1977 and 1990–present that have been identified as "disk-loss" episodes (data from de Loore et al. 1979; Ferrari-Tonico et al. 1977,1978; Latysheva & Lyutyi 1988; Margon et al. 1976,1977; Mazeh & Brosc 1981; Mook et al. 1974; Persi et al. 1977). The K band lightcurve shows a similar linear fade immediately prior to the 1990 disk-loss event, and faint K magnitudes during the 1974–1977 optical low (data from Larionov & Larionova 1989; Norton et al. 1991.)

**Figure 4 & 5.** Ariel V 2–10keV flux of X Per during the optical low of 1974–1977 showing an almost linearly decreasing flux (McHardy, private communication). This contrasts with the spin-up phase that the pulsar entered at the same time. The pulsar reverted to a spin-down phase immediately after the 1974–1977 optical low ended (data from Nagase 1989; Warwick, private communication).
prior to the 1974–1977 event, followed by a decrease in the flux during the disk-loss event. It has subsequently remained in a low X-ray state. It is therefore necessary to explain (for the 1974–1977 event) the spin-up of a pulsar (which implies an increased accretion rate, presumably by the formation of an accretion disk around the neutron star by the expelled disk material) concurrent with a decreasing X-ray flux (which would suggest a decrease in the amount of accretion).

References

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