The Be Phenomenon in Early-Type Stars, IAU Colloquium 175
ASP Conference Series, Vol. 214, 2000
M. A. Smith, H. F. Henrichs, and J. Fabregat, eds.

X Per in 1996 - 1999: the Variability of Hydrogen and Helium lines

I. Kolka, T. Eenmäe, A. Puss and L. Leedjärv

Tartu Observatory, 61602 Tõravere, Estonia

Abstract. We present the results of high-resolution (0.24Å/pix) monitoring of the variability of Hα and He I 6678 lines in the spectrum of X Per in 1996-99 at Tartu Observatory. The main characteristics of the line variability distinguishable in our data are:

1) the intensity of emission peaks in both lines varies with a cycle-length $\approx$450 days, and displays a phase-lag between curves of two lines considered,

2) in a cycle, both violet or red emission peaks emerge at high Doppler velocities but attain their maxima and disappear gradually at much lower velocities,

3) despite of the considerable variability of equivalent width (EW) of both lines, the "relative emission measure" (EW(Hα)/EW(He I)) behaves more constantly.

1. Objectives and results of spectroscopic monitoring

X Persei is the optical counterpart of the X-ray source 4U0352+30, and belongs to a small group of "persistent Be/X-ray binaries" which are characterized by low X-ray luminosities ($L_x \approx 10^{34}$ ergs^{-1}) and relatively small amplitudes of X-ray variability. The optical brightness variability of X Per is most probably connected to the build-up and break-down of the gaseous disc of the Be-type primary (Telting et al. 1998).

The structure and the behaviour of the disc in X Per are best exposed in the varying features of high resolution emission line profiles. Our monitoring campaign on the Hα and He I 6678 lines in the spectrum of X Per was intended to discover the characteristics of the Be-type disc during the optical low state after the 1994–95 high state (Zamanov & Zamanova 1995), and it incorporates additionally the period of brightness rise in 1999 (Zamanov 1999).

The results of high-resolution (0.24Å/pix) monitoring of the variability of Hα and He I 6678 lines in the spectrum of X Per in 1996–99 at Tartu Observatory are presented in this investigation. The signal to noise ratio was around 100 at Hα, and about twice lower at He I 6678.

The profiles of both lines have been essentially variable during the period considered. For example, in Fig. 1 the set of profiles on both lines in the 1997/98 season is shown. In the case of He I 6678 the profiles are *rectified* – we present the difference between the actually observed profile and the one belonging to the underlying star at the moment of observation. The subtracted profile was the

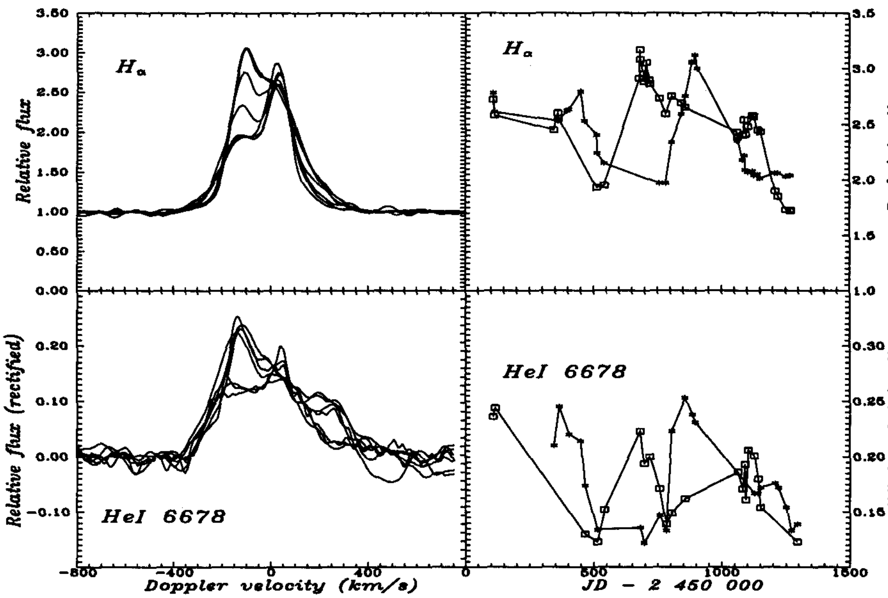

Figure 1. Left panel: the variable pattern of profiles in 1997/1998. Right panel: the variability of emission peaks (violet peaks – asterisks, red peaks – squares).

one observed in the discless phase of X Per in 1990 and corrected for the corresponding excess in brightness (due to the disc contribution to the continuum!) at the moment of observation (cf. Lyubimkov et al. 1997). For actual brightness data we have used interpolated values inbetween V-filter measurements by Zamanov (1999). In doing this, we consulted also the lightcurves presented by Piccioni et al. (1999). Resulting difference profiles exhibit the true distribution of line radiation emitted by the circumstellar disc. The rectification procedure was used, too, to get the *intrinsic* emission equivalent width of *both lines* under investigation.

We have discovered the cyclic behaviour of the intensity and wavelength positions of emission peaks in both lines with the characteristic timescale around 450 days (Fig. 1 and Fig. 2). The usually double-peak profiles are oscillating between two extremal asymmetric shapes with the blue- or redshifted one-peaked emission at the opposite phases. In the period of observations before JD 2451000 we could estimate a possible phase-lag in the variability cycles of considered lines – He I 6678 goes through it's trough and crest values about 30 days earlier than Hα.

We point to the typical evolution of emission peaks – they emerge at velocities with high absolute values, get their maximum intensities at much lower velocity values, and disappear gradually at even lower values (He I 6678) or approximately at the velocity attained with the intensity maximum (Hα). As a rule, corresponding velocities of peaks in He I 6678 are 20–40 km/s higher than in Hα. This difference gets more pronounced with data on violet peaks. It is

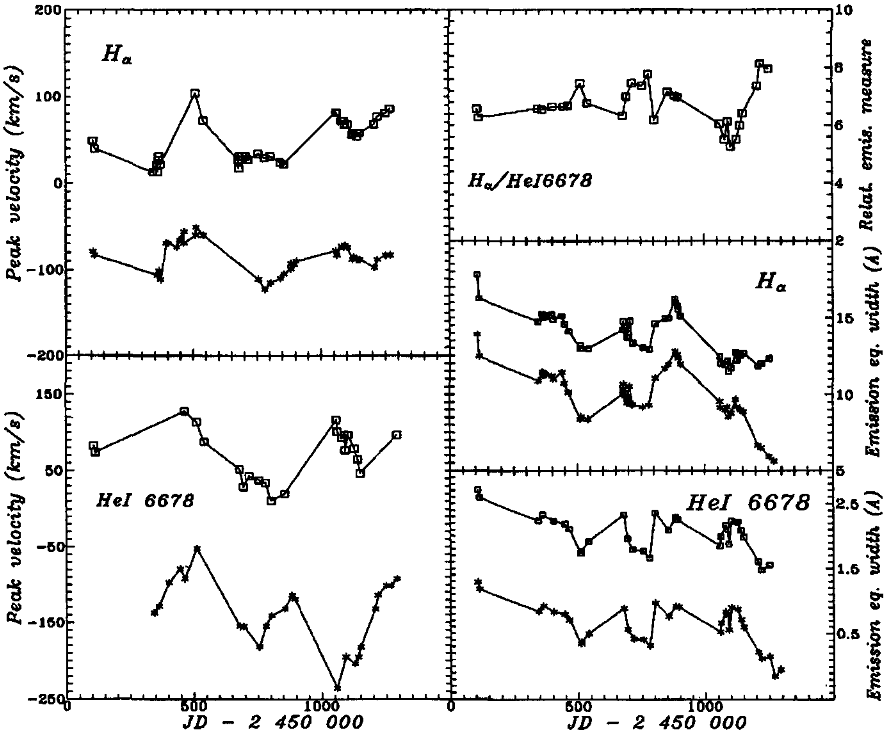

Figure 2. Left: Doppler velocities of blue- and redshifted emission peaks. Right: the equivalent width of emission lines, and their quotient (see text for more explanations).

interesting and essential that the lowermost Doppler velocities of emission peaks (independent of the used line and epoch) are positioned quite symmetrically around a "central velocity" (≈ -15 km/s) which is close to -21 km/s found by Reynolds et al. (1992) to be the average radial velocity of X Per.

The observed equivalent widths (EW) of both lines (asterisks in Fig. 2) have a special variability pattern caused by the variable double-peak nature of profiles. The relative random error of EW-s is estimated to be $\pm$ 2% for Hα, and $\pm$ 6% for He I 6678. We stress the common decline of EW-values starting from the beginning of 1999.

2. Discussion and conclusions

To consider the nature of EW variability we applied to it's rectified values the second step of correction to take into account the variability of the continuum to which the EW-s are related. The influence of the variable continuum is remarkable in the final period of the campaign (see the two-step-corrected EW-s

https://doi.org/10.1017/S0252921100056591 Published online by Cambridge University Press

marked by squares in Fig. 2 in contrast to observed ones marked by asterisks) which covers the steep rise of brightness started approximately at JD...51130 (Zamanov 1999). We point to the specific quite stable behaviour of the line-ratio ("relative emission measure") shown in Fig. 2. The local maxima of the EW-ratio are obviously connected to the local minima of the EW-curves. Their correlation with the brightness variability needs further investigation using more complete lightcurves.

The cyclic V/R-variability shown in Fig. 1 and 2 is similar to other certain Be stars except for relatively short timescale in our case. The modern interpretation of this phenomenon is based on global one-armed disc oscillations. In the case of X Per we suggest oscillations in the form of a spiral-like density wave in the disc that rotates slowly (period $\approx$450 days) around the primary. This model could explain the specific behaviour of emission peaks (phase-lag and intensity drop at small Doppler velocities i.e. far out in the Keplerian disc) indicated above.

This work has been supported by Estonian Science Foundation grants Nos. 827 and 3166.

References

Lyubimkov, L.S., Rostopchin, S.I., Roche, P., Tarasov, A.E. 1997, MNRAS 286, 549

Piccioni, A., Bartolini, C., Bernabei, S., Galleti, S., Guarnieri, A., Valentini, G. 1999, these proceedings

Reynolds, A.P., Hilditch, R.W., Bell, S.A., Pollacco, D.L., Edwin, R. P. 1992, MNRAS 258, 439

Telting, J.H., Waters, L.B.F.M., Roche, P., Boogert, A.C.A., Clark, J.S., de Martino, D., Persi, P. 1998, MNRAS 296, 785

Zamanov, R.K. 1999, private communication

Zamanov, R.K., Zamanova, V.I. 1995, IBVS No. 4189