COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 4934

Konkoly Observatory
Budapest
5 August 2000

HU ISSN 0374 – 0676

A PROBABLE VARIATION IN THE POLARIZATION OF THE EARLY-TYPE ECLIPSING BINARY SYSTEM XZ Cep

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XZ Cep (BD +66°1512) is an eclipsing and double-lined spectroscopic binary system, consisting of late O and early B stars. The large reddening in its color (Saute & Martel, 1979) suggests the existence of a large amount of interstellar matter in the direction. A recent photometric study of this binary with the UBV photoelectric system was done by Antokhina & Kumsiashvili (1991), which yielded a semidetached configuration. Their light-curves were analyzed again by Harries et al. (1997), who also obtained a new radial-velocity curve of this system. Harries et al. confirmed that the system is a semidetached one and the cooler, less massive component is filling its critical Roche lobe.

Kreiner et al. (1990) performed a period study of the system, and derived a new photometric ephemeris as follows.

$$\text{Min I} = \text{HJD } 2426033.421 + 5\overset{\text{d}}{.}0972531 \times E.$$

Harries et al. (1997) employed this and we also use it here.

Saute & Martel (1979) made polarimetric observations (mainly in B filter) and reported that very large and rapid changes in the polarization of XZ Cep were detected in 1970–1971. They did not mention the cause of these variations explicitly, but commented that if the variations were real, they could originate only from very violent ejection of matter. There has been no polarimetric report on XZ Cep since then.

We observed this object with a low resolution spectropolarimeter (referred to as HBS, Kawabata et al., 1999), mounted at the 36-inch reflector at Dodaira Observatory of the National Astronomical Observatory of Japan. In the observations, we used a diaphragm of 17′ ϕ, which yields a spectral resolution of about 100 Å (limited by the seeing at Dodaira). On twelve nights from November 1998 to December 1999, we observed the object at various orbital phases and got around 10 sets of data at each night. To reduce the observed data, the standard reduction software for HBS was used (Kawabata et al., 1999). The nightly mean value of the polarization is shown in Table 1.

First, to see the wavelength dependence of polarization as precisely as possible, the Stokes parameters are binned in wavelength to a constant photon noise of 0.01%. The typical resolution goes down to about 300 Å after this procedure. The polarization spectra are displayed in Fig. 1.

Table 1: The journal of polarimetric observations. The meaning of the symbols are as follows. p: polarization degree, θ: polarization angle, q, u: Stokes parameters. The subscript B means synthetic B filter of the standard Johnson system.

Date	Mid. phase	p_B (%)	θ_B (°)	q_B (%)	u_B (%)
1998 Nov. 24	0.93	4.240 ± 0.064	73.45 ± 0.43	-3.552 ± 0.065	$+2.315 \pm 0.064$
1998 Nov. 25	0.10	4.227 ± 0.043	73.20 ± 0.29	-3.521 ± 0.042	$+2.339 \pm 0.044$
1998 Dec. 29	0.77	4.143 ± 0.041	73.01 ± 0.28	-3.435 ± 0.041	$+2.316 \pm 0.040$
1998 Dec. 30	0.98	4.242 ± 0.057	73.00 ± 0.39	-3.517 ± 0.057	$+2.372 \pm 0.057$
1999 Jan. 1	0.35	4.160 ± 0.055	73.30 ± 0.38	-3.473 ± 0.055	$+2.290 \pm 0.055$
1999 Jan. 2	0.55	4.216 ± 0.054	72.78 ± 0.37	-3.477 ± 0.054	$+2.384 \pm 0.054$
1999 Nov. 13	0.36	4.175 ± 0.026	73.13 ± 0.17	-3.472 ± 0.026	$+2.319 \pm 0.025$
1999 Nov. 16	0.95	4.160 ± 0.030	72.99 ± 0.21	-3.448 ± 0.030	$+2.327 \pm 0.030$
1999 Dec. 16	0.83	4.091 ± 0.017	73.09 ± 0.12	-3.399 ± 0.017	$+2.277 \pm 0.017$
1999 Dec. 19	0.42	4.173 ± 0.046	72.87 ± 0.32	-3.450 ± 0.045	$+2.349 \pm 0.047$
1999 Dec. 20	0.62	4.125 ± 0.039	74.11 ± 0.27	-3.507 ± 0.039	$+2.172 \pm 0.038$
1999 Dec. 21	0.80	4.243 ± 0.015	74.12 ± 0.10	-3.607 ± 0.015	$+2.234 \pm 0.015$

As seen in Fig. 1, XZ Cep shows large polarization degree up to 4.4%. The value had been almost constant throughout our observations at the whole wavelength. Furthermore, the feature of polarization degree versus wavelength is quite consistent with an empirical formula of interstellar polarization derived by Serkowski et al. (1975). Therefore, the interstellar polarization must be dominant in the observed polarization of XZ Cep. In general, the polarization angle does not depend on wavelength for interstellar polarization. But in our case, the polarization angle is not constant. This slight change (or rotation) of polarization angle versus wavelength may be caused by the existence of two or more interstellar clouds with different properties which lie between XZ Cep and us.

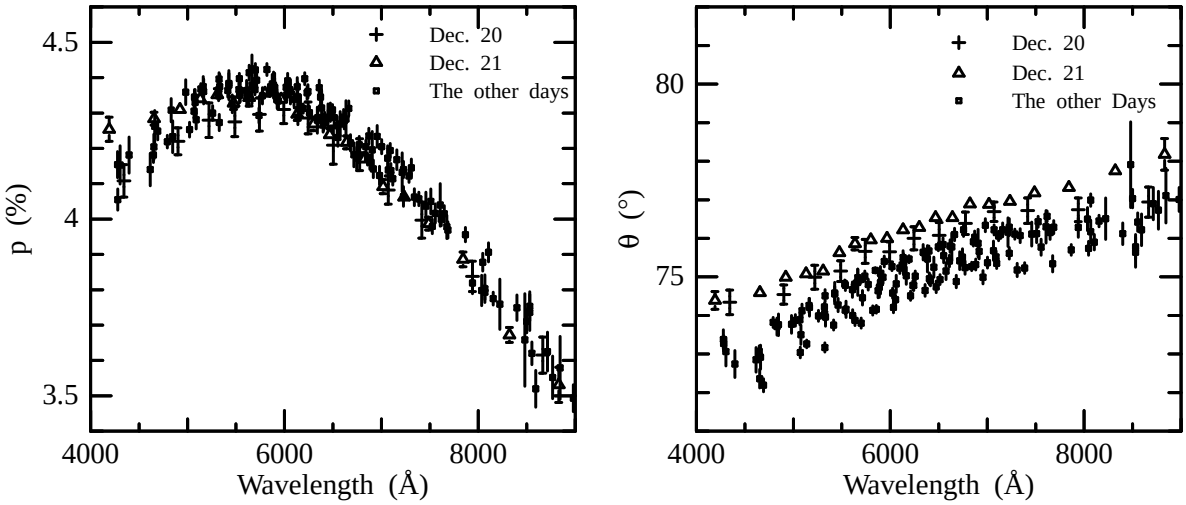

Figure 1. Dependence of the polarization on wavelength.
Left: polarization degree versus wavelength. Right: polarization angle versus wavelength.

Almost all polarization angles are between 73–76°, except those on December 20 and 21, 1999. The polarization angles shifted by $1 \sim 2$°as a whole on these two days. It is

noticed that the values of polarization degrees on these two days in Fig. 1 are also changed slightly, especially in blue wavelengths on Dec. 21.

We also observed polarized standard stars for the calibration. On Dec. 21, 1999 we observed the strongly polarized standard star HD 26433 after the observation of XZ Cep. The observation of this standard star was repeated on Nov. 4, 1999. The result for HD 26433 is shown in Table 2. The difference between the data for HD 26433 on these two days is roughly within the observational error. On the other hand, the difference, e.g. between the data on Dec. 16 and 21, is ten times larger than the error (~ 0.015) for XZ Cep. It should be noticed that the data on these nights have smaller errors than those of the other days because of the fine weather conditions. Hence, we conclude that these variations of polarization of XZ Cep are not instrumental, but intrinsic. We also mention that these variations do not depend on the orbital phase, because the data on Dec. 21 and Dec. 16 are different from each other, though the orbital phase of XZ Cep on Dec. 21 is close to that on Dec. 16.

Table 2: Observed data for HD 26433, a strongly polarized standard star

Date	p_B (%)	θ_B (°)	q_B (%)	u_B (%)
1999 Nov. 4	5.083 ± 0.026	135.23 ± 0.15	$+0.041 \pm 0.026$	-5.083 ± 0.026
1999 Dec. 21	5.062 ± 0.017	135.88 ± 0.09	$+0.156 \pm 0.016$	-5.060 ± 0.017

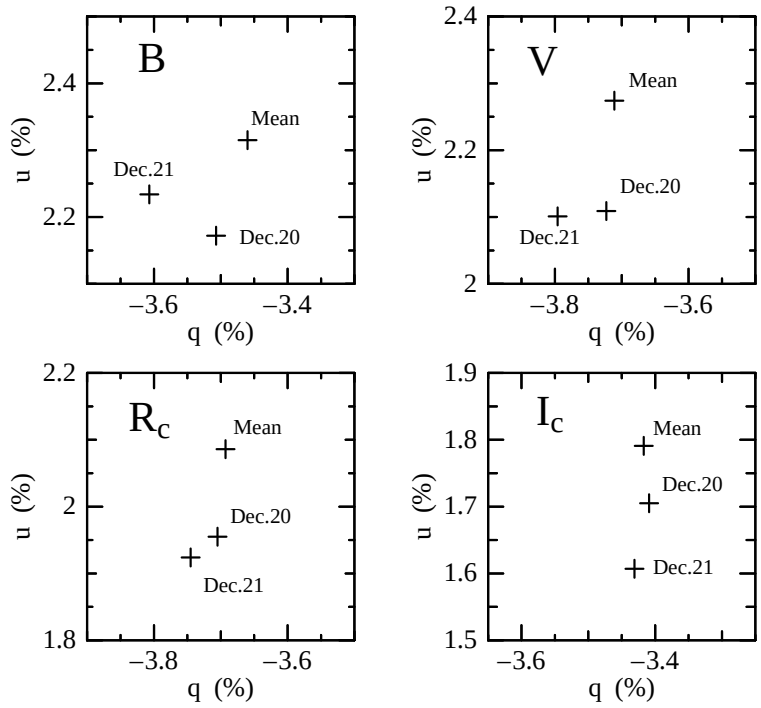

Figure 2. Polarization behaviors on the q–u plane. Left-up: B filter; right-up: V filter; left-down: R_c filter; right-down: I_c filter.

Next, to see the dependence of variation on the wavelength, we applied the synthetic standard Johnson–Cousins BVR_cI_c filters (Bessell 1990). Fig. 2 shows the values of Stokes parameter on Dec. 20 and Dec. 21 and the mean value of the other days for B, V, R_c, I_c

on the q–u plane. The Stokes parameter on Dec. 21 is different from that of Dec. 20 for each color.

The directions of the Stokes vector from the mean point to the point of Dec. 20 on the q–u plane are almost same in all filters. The Stokes vector from the point of Dec. 20 to that of Dec. 21 rotated compared to the vector from the mean point to the point of Dec. 20, except in the I_c filter. In the B filter, the vector is almost perpendicular to the one in the I_c. The angles of the rotation of the vectors are larger in shorter wavelength.

We detected a probable variation in the polarization of XZ Cep on Dec. 20 and 21, 1999, though its nature is not clear now. As the allocated telescope time to us for HBS observations ended on Dec. 21, we could not follow these variations in the whole season. We suggest here that the event happened around Dec. 20, 1999.

There are some reports on the temporal and irregular variations in the polarizations of early-type close binary systems (for example, U Cep, Piirola, 1980). Almost all variations of polarization reported so far (including the report of Saute & Martel, 1979) have short time scales (a few minutes up to a few tens of minutes). The variations reported here has a longer time scale (order of a few hours) compared with them. In the case of U Cep, a strong increase of polarization was observed in late 1975 (Piirola, 1980). Piirola suggested that this was caused by mass-transfer events which occurred in U Cep in late 1974 and 1975. And it was also reported that a period increase of U Cep occurred in late 1974 (Olson et al., 1981).

We appreciate useful discussions with K.S. Kawabata.

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