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UBV LIGHT CURVES OF ζ AUR STAR 32 CYGNI[1]

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ABSTRACT

UBV observations of ζ Aur star 32 Cyg have been made at the Yonsei University Observatory using the 60-cm Goto reflector for five years, 1988 - 1992. Observations made during these years cover outside of eclipse phase only. No significant light variation which would represent the secondary eclipse of red supergiant by a hot main sequence star is found. The light levels in three passbands do not show any evidence of the proximate effect of this binary system. Some strong light variations, particularly in *U*, are discussed with no successful explanation.

1. INTRODUCTION

Eclipsing binary star 32 Cyg (HR 1218, $m_v = 3.98v$, K3Ib + B3V, P = 1147.8 days, $\alpha_{2000} = 20^h15^m28^s$, $\delta_{2000} = +47°42'$) was known to have eclipse nature noted first by McLaughlin (1950) who suggested the grazing total eclipse of nearly 20 day duration. Although a radial velocity curve was observed and spectroscopic elements computed as early as 1918, no reliable absolute dimensions of this system are derived due to number of reasons. For one thing as was mentioned by Sahade and Wood (1978), the orientatin of its orbital plane, *i.e.* the inclination, ranges from 72° to 82° depending on authors. In addition to this uncertainty of inclination, complete photometric light curve of this star has not yet been made.

Wood and Lewis (1954) were the first to detect the ingress of the 1953 eclipse of 32 Cyg and found the light variations of about $0^m\!.3$. Photoelectric observations were made since then for later eclipses in every three years; as for a few examples, Botsula (1962) for 1956, Chandra and Pande (1960) and Johansen *et al.* (1970) for 1959, Herczeg and Schmidt (1963) and Johansen *et al.*(1970) for 1962, Johansen *et al.* (1970) for 1965, Cester (1969) for 1968,

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Saito *et al.* (1972) and Bloomer and Wood (1974) for 1971, and Saito *et al.* (1975) for the 1974 eclipses. Skipping three later eclipses, the 1987 eclipse was observed by Böhme (1987).

Long term continuous observations from 1971 to 1973 using H_α and H_β filters were reported by Guinan and McCook (1974) who have observed the 1971 eclipse and the outside of eclipse until the time of secondary minimum to occur at JD Hel 2442006. They calculated the possible time of secondary minimum 749 days after the primary minimum.

2. OBSERVATIONS AND REDUCTIONS

UBV photoelectric observations of 32 Cyg have been made for five years since the 1988 Fall season as a part of the first *Ten-year Observing Program for Long Period Eclipsing Binary Stars (1982 - 1992) at Yonsei University Observatory (YUO)*. Except those of comparison and check stars, the instruments used in these years are the same as those described for VV Cep observations given earlier by Nha *et al.* (1992). Because of the reason already described for the case of VV Cep, this report present the observations of the 1991 season only.

Characteristics of 32 Cyg and two comparison stars, 26 Cyg and 30 Cyg, adopted from The Bright Star Catalogue (Hoffleit and Jaschek 1982) are given in Table 1. Although 26 Cyg had been used more frequently by previous observers, we observed 30 Cyg as many as 26 Cyg. The first four columns of Table 1 are self explanatory, and the last three are the magnitudes and colors of three stars determined by the present study using ten standard stars from The Bright Star Catalogue. The procedures of standardization are same as the case of *RI* photometry (Jeong *et al.* 1992).

Table 1. Spectra and photometric data of 32 Cyg, 26 Cyg and 30 Cyg.

Star	Sp	*V*	*B–V*	*U–B*	*V*	*B–V*	*U–B*
	Hoffleit and Jaschek (1982)				This paper		
32 Cyg	K3Ib + B3V	3.98	+1.52	+1.03	3 913	1 493	0 4
26 Cyg	A5IIIn	5 05	+1 11	+1.02	5 047	1.111	-
30 Cyg	K1II-III	4.83	+0.09	+0.15	4.994	0 129	-

Instrumental differential magnitudes in the sense Δm = 32 Cyg - 26 Cyg and Δm = 32 Cyg - 30 Cyg are thus made independently for *UBV* passbands and are corrected by differential extinction each night. Determination of the atmospheric extinction coefficients are made by the airmass diagrams of 26 Cyg. These are listed in Table 2 and are plotted in Figue 1. As is clear in the Figure 1, there is a strong linear correlation between two coefficients, k_V and k_B, as

$$k_B = 0.200 + 0.996\, k_V. \tag{1}$$

This correlation expressed in Eq.(1) does show a slight difference from that for VV Cep made in the same year(Nha *et al.* 1992). This difference may be resulted either due to a different sky or due to observational errors. The mean values of k_V and k_B determined by 26 Cyg are, respectively, 0.438 and 0.638.

Table 2. Atmospheric extinction coefficients at the Ilsan Station of YUO in 1991. Coefficients were derived by *B* and *V* magnitudes of 26 Cyg. Six nights have double entries because of variable sky conditions.

Date	k_V	k_B	Date	k_V	k_B
1991 Sep 06	1.006	1.074	Oct 27	0.371	0.590
Sep 07	0.622	0.761	Oct 28	0.293	0.496
Sep 08	0.603	0.769	Oct 29	0.532	0.812
Sep 09	1.016	1.134	Oct 30	0.289	0.485
Sep 12	0.363	0.517	Oct 31	0.593	0.907
Sep 13	0.354	0.518	Nov 03	0.210	0.533
Sep 14	0.335	0.532	Nov 04	0.345	0.563
Sep 19	0.623	0.858	Nov 04	0.410	0.631
Sep 19	0.489	0.694	Nov 05	0.571	0.835
Sep 21	0.459	0.620	Nov 06	0.785	1.090
Sep 22	0.623	0.834	Nov 08	0.260	0.438
Sep 22	0.553	0.759	Nov 10	0.359	0.574
Sep 30	0.504	0.658	Nov 11	0.299	0.531
Oct 01	0.441	0.607	Nov 12	0.316	0.519
Oct 05	0.220	0.429	Nov 12	0.367	0.562
Oct 07	0.208	0.415	Nov 13	0.248	0.442
Oct 09	0.195	0.383	Nov 14	0.250	0.440
Oct 10	0.180	0.384	Nov 17	0.366	0.563
Oct 11	0.224	0.410	Nov 18	0.819	1.121
Oct 13	0.313	0.537	Nov 24	0.261	0.450
Oct 14	0.645	0.877	Nov 26	0.475	0.708
Oct 17	0.239	0.395	Nov 30	0.472	0.632
Oct 18	0.220	0.398	Dec 01	0.570	0.758
Oct 20	0.200	0.394	Dec 05	0.601	0.817
Oct 20	0.291	0.517	Dec 09	0.374	0.540
Oct 23	0.387	0.618	Dec 11	0.465	0.643
Oct 23	0.477	0.742	Dec 12	0.368	0.550
Oct 25	0.777	0.952	Dec 19	0.470	0.592

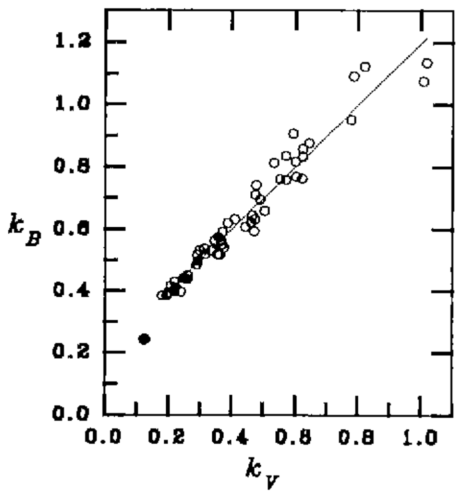

Figure 1. The k_V vs. k_B relation in the 1991 season. Comparison star used for the determination of k_s was 26 Cyg was. A large closed circle at the left end of the straight line represents extinction coefficient due to a pure Rayleigh scattering.

3. LIGHT CURVES AND DISCUSSION

Instrumental differential magnitude in the sense Δm = 30 Cyg - 26 Cyg and $\Delta(B\text{–}V)$ are plotted in Figure 2 according to the heliocentric Julian Dates to see if there is any light variation in either stars adopted as comparison star for 32 Cyg.

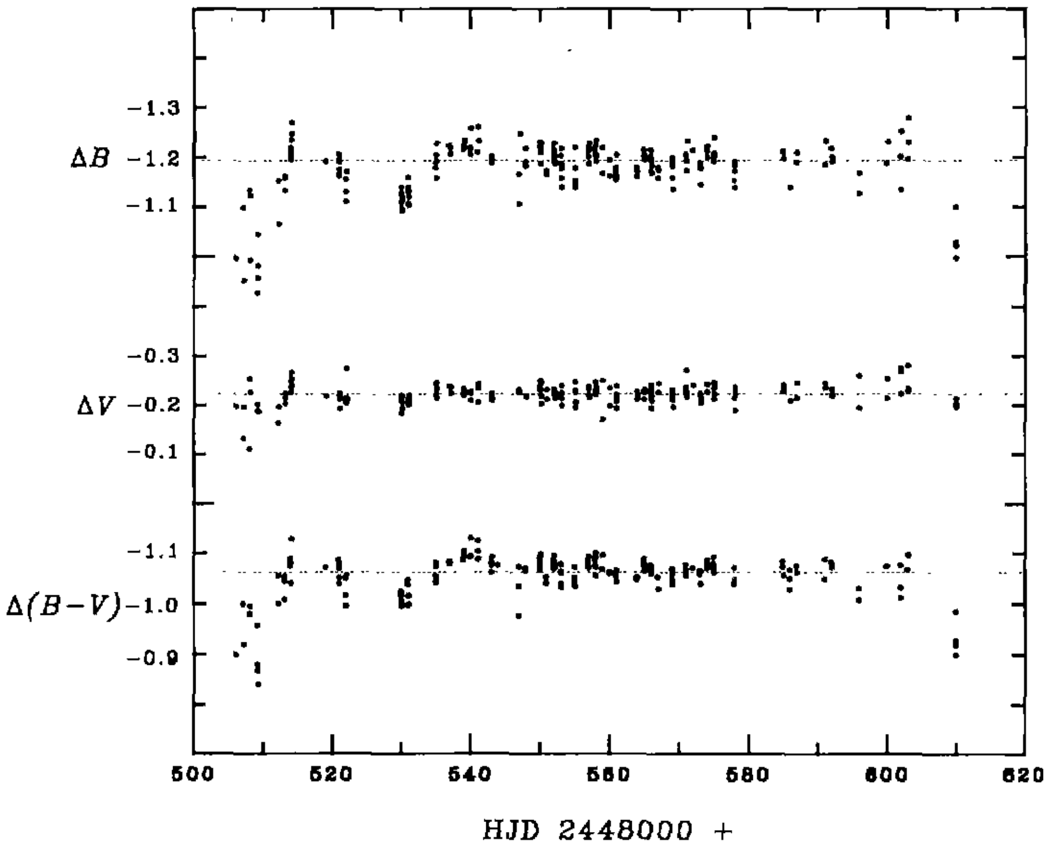

Figure 2. Differential B, V and $(B\text{–}V)$ curves in 1991 Fall and Winter season in the sense of Δm = 30 Cyg - 26 Cyg.

As is clear in this figure there are strong light variations, particularly on the ΔB curve. During first part of the observing season, from JD2448506 to about JD2448553, a strong indication of a cyclic variation with an amplitude of about $0\overset{m}{.}12$ in B can easily be noticed. Same is true in V curve, but the amplitude is much smaller, about $0\overset{m}{.}05$ and the phase has shifted toward left. After JD2448553 the brightness has remained constant until the sudden drops at the end of the season. These variations of the light curves are the results of the brightness changes of one of the two comparison stars.

In order to clarify which star is responsible for these light variations, two independent light curves are made in Figure 3; *one in the sense of* ΔB = 32 Cyg - 26 Cyg and the other ΔB = 32 Cyg - 30 Cyg. Only B curves were chosen in this figure because the light changes are more significant than in V curve. The result is puzzling; there are light variations in both curves in an exactly same fashion! This can only happen if 26 Cyg and 30 Cyg were believed behaving identically, which is unrealistic to assume. Only differences between the two comparison stars that one can point out are the two things. Firstly, the light changes in the figure are great in the bottom one, which is primarilly due to 30 Cyg. Secondly, the bottom one has more scatter than the other, which is again the result of unstable light behavior of 30 Cyg.

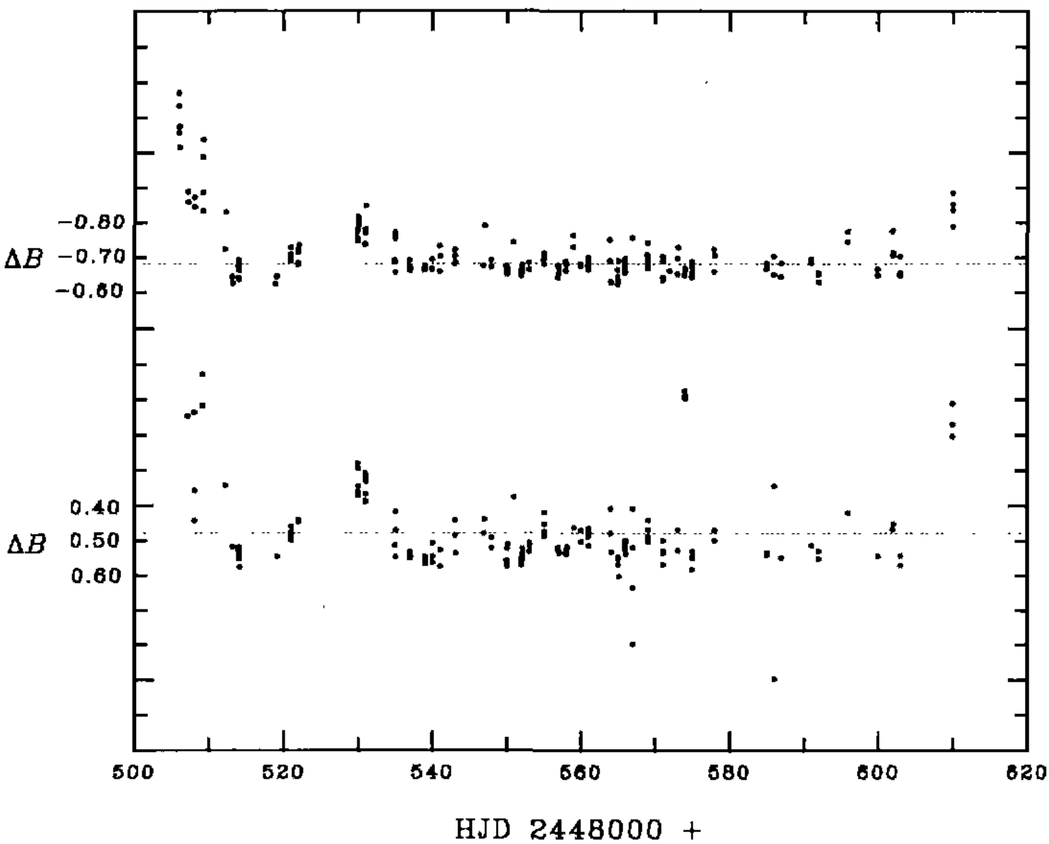

Figure 3. Instrumental differential B light curves of 32 Cyg in 1991. The upper curve is made with 26 Cyg as the comparison star, and the bottom one with 30 Cyg.

An alternate interpretation of the light variation in Figure 3 can be sought assuming the light variations were indeed originated in the 32 Cyg itself. All the observed data made for three stars were transformed into Johnson *UBV* system, and made individual *UBV* lights curves of these three stars. No light variation has been found for 26 Cyg, while light variation of cyclic nature appeared in Figure 2 are reproduced for 30 Cyg. Therefore, 30 Cyg is a variable star of irregular type.

U, *B*, *V* and *(B–V)* curves of 32 Cyg are made in Figure 4 according to the heliocentric Julian Dates. The observations of the *U* passband show very large scatter as clear in Figure 4(a). The variations of brightness are also existing in both *B* and *V* curves but with much reduced amount in *V*. Sharp decrease of the brightness in *U* light is the strongest, more than $5^m_.0$ and about $0^m_.50$ and $0^m_.11$, respectively, for *B* and *V* as shown in Figure 4(b). Therefore, it is considered as a unusual instance for the fact that *U* curve shows such an unusual variation. For other stars of same type like ϵ Aur (Nha *et al.* 1988), ζ Aur (Nha 1991) and VV Cep (Nha *et al.* 1992) every peculiar light variations appeared in their light curves tend to have this type of wavelength dependence, *i. e.* larger variation with shorter wavelength, but with much smaller amount. There are at least two more brightenings noticeable based on the mean light level of 5.9 in the *U* curve, one at the end of the season and the second one around JD 2448530.

(B–V) curve in Figure 4 resembles the shape of *B* curve reflecting it more than *V*. *(U–B)* curve has, on the other hand, not been attempted for its large scatter, which will prevent understanding of the general scope of the light variation of 32 Cyg system. Average *UBV* magnitudes of 26 Cyg, 30 Cyg and 32 Cyg are derived eliminating those observations for 30 Cyg and 32 Cyg. These are listed in Table 1. Comparison with the magnitudes and colors by Hoffleit and Jascheck (1982) a perfect agreement is there for 26 Cyg, but large differences for 30 Cyg as expected.

The phase coverage of these observations has the range from $0.^P31$ to $0.^P41$, about mid-point between the primary and the secondary eclipses. For the latter eclipse, Guinan and McCook (1974) predicted 749 days after the former indicating the phase $0.^P65$. Therfore, the YUO observations reveal the lights emitted by a K supergiant and a B main sequence components at their widest apparent separation in the line of sight. According to their prediction, YUO observations started on about 120 days before the aperiastron point and ended on just right point. This makes us difficult to understand which component has responsibility to those three brightenings mentioned above.

The range of phase coverage of the YUO observations is not large enough to bring any conclusive figure of the overall shape of light curve of 32 Cyg at its outside eclipse phase. However, it would be safe to say that there is no sign of proximate effect on the light curve, which could easily detect the tidal deformation of the K supergiant by a massive B companion if there were any.

It is unfortunate at this time that no definite conclusion has been made for the origin of the light variations in this difficult binary system. Further monitoring may only become possible to solve the puzzle.

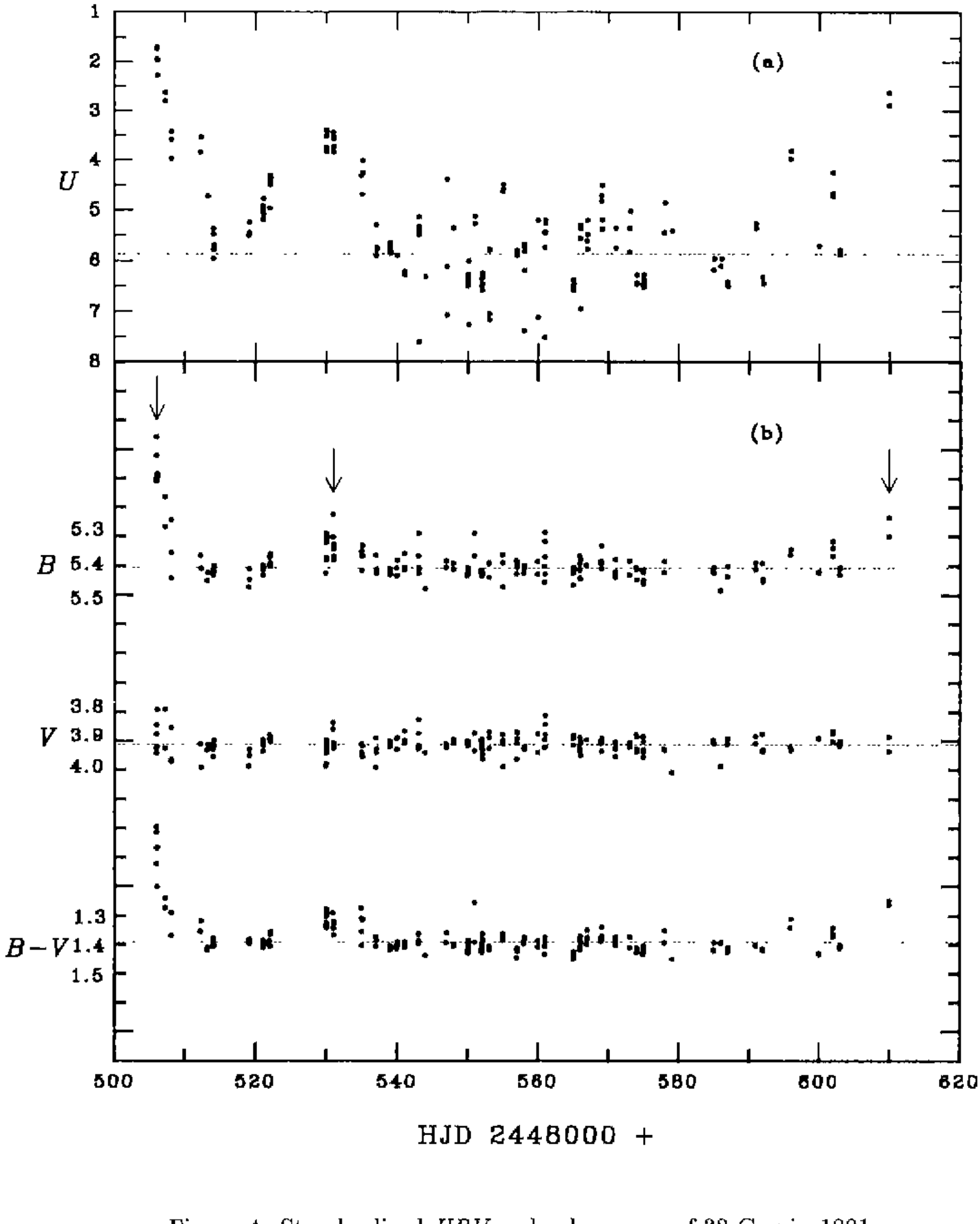

Figure 4. Standardized *UBV* and color curve of 32 Cyg in 1991. Arrow indicates the increased brightnesses.

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