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RI PHOTOMETRY OF 32 CYGNI[1]

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ABSTRACT

Surface activity of the late-type supergiant component of ζ Aur-type eclipsing binary 32 Cyg has been searched in *R* and *I* pass-bands for 53 nights in the 1991 season. Atmospheric extinctions in these wavelength regions are made and a linear relation between the two coefficients has been found. All the data are standardized and determined the magnitudes and colors of 32 Cyg. *R*, *I* and color curves of 32 Cyg at the outside eclipse phase are presented.

1. INTRODUCTION

The star 32 Cyg is an extremely long period ($\sim$ 3.15 years) eclipsing binary star consisting of a K-type supergiant and a B main sequence components. A brief history of this star is given in a paper in this volume (Nha *et al.* 1992b).

Except $H\alpha$ observations by Guinan and McCook (1974), no one has ever been attempted the observation for 32 Cyg in the longer wavelength regions than the conventional regions, such as *U*, *B* and *V*. It is, thus, our primary object to report the Yonsei University Observatory observations made with Johnson's *R* and *I* filters for 53 nights in the 1991 season. This is an attempt to see the light behavior of K supergiant component which dominates in the brightness of 32 Cyg system at the phase of outside eclipse.

2. OBSERVATIONS AND REDUCTIONS

Observations of 32 Cyg with *R* and *I* filters have been made for 53 nights in 1991 in order to widen the wavelength regions longer than beyond *V* region. This effort is a part of

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the first *Ten-year Observing Program for Long Period Eclipsing Binary Stars (1982 - 1992) at Yonsei University Observatory (YUO)*. Observational techniques used and the reduction procedures adopted are same as those of *UBV* monitoring of VV Cep given by Nha *et al.* (1992a). As the case of *UBV* observations of 32 Cyg (Nha *et al.* 1992b), same comparison stars, 26 Cyg and 30 Cyg, were observed. Determination of the atmospheric extinctions in *R* and *I* regions has been made with the 26 Cyg, and the values of k_R and k_I of each night were used to correct for the differential extinctions of each star observed on that night.

List of extinction coefficients obtained for 26 Cyg in *R* and *I* are given in Table 1. The mean extinction coefficients for the 1991 season are 0.399 and 0.363 for $\bar{k}_R$ and $\bar{k}_I$, respectively. These values are much smaller than that of $\bar{k}_V$ made in the same season at YUO (Nha *et al.* 1992b).

Table 1. Atmospheric extinction coefficients at the Ilsan Station of YUO in 1991. Coefficients were derived by 26 Cyg in the *R* and *I*. Six nights have double entries because of the variable sky conditions.

Date	k_R	k_I	Date	k_R	k_I
1991 Sep 06	0.887	0.881	Oct 27	0.350	0.266
Sep 07	0.545	0.550	Oct 28	0.276	0.237
Sep 08	0.570	0.610	Oct 29	0.460	0.380
Sep 09	0.865	0.750	Oct 30	0.280	0.250
Sep 12	0.350	0.330	Oct 31	0.460	0.390
Sep 13	0.329	0.385	Nov 03	0.335	0.296
Sep 14	0.340	0.381	Nov 04	0.315	0.271
Sep 19	0.675	0.685	Nov 04	0.352	0.303
Sep 19	0.480	0.505	Nov 05	0.520	0.471
Sep 21	0.450	0.495	Nov 06	0.660	0.541
Sep 22	0.565	0.580	Nov 08	0.247	0.213
Sep 22	0.495	0.493	Nov 10	0.320	0.255
Sep 30	0.520	0.526	Nov 11	0.300	0.190
Oct 01	0.392	0.401	Nov 12	0.280	0.241
Oct 05	0.230	0.251	Nov 12	0.312	0.251
Oct 07	0.231	0.205	Nov 13	0.232	0.154
Oct 09	0.220	0.221	Nov 14	0.232	0.167
Oct 10	0.185	0.211	Nov 17	0.240	0.250
Oct 11	0.217	0.220	Nov 18	0.660	0.521
Oct 13	0.275	0.281	Nov 24	0.236	0.156
Oct 14	0.595	0.566	Nov 26	0.435	0.313
Oct 17	0.230	0.195	Nov 30	0.460	0.381
Oct 18	0.214	0.186	Dec 01	0.542	0.455
Oct 20	0.200	0.194	Dec 05	0.540	0.441
Oct 20	0.270	0.231	Dec 09	0.308	0.251
Oct 23	0.350	0.285	Dec 11	0.440	0.360
Oct 23	0.410	0.330	Dec 12	0.355	0.251
Oct 25	0.695	0.770	Dec 19	0.416	0.351

Values given in Table 1 are plotted in Figure 1 to see if there also exists any appreciable correlation as that found for k_V *vs.* k_B (Nha *et al.* 1992b). As is clear in the Figure 1 a linear distribution with a larger scatter than those of k_V and k_B presents following relation,

$$k_I = \underset{12}{-0.026} + \underset{28}{0.974}\, k_R. \tag{1}$$

No successful explanation can be found why the longer passbands have a correlation with larger scatter than that expressed in Eq.(1) for B and V by Nha *et al.* (1992b). Ilsan Station has recently been suffered from dusts and night illuminations coming from the nearby constructions around the station. Nevertheless, the Eq. (1) satisfies the extinction coefficients for the pure Rayleigh scattering at the sea level.

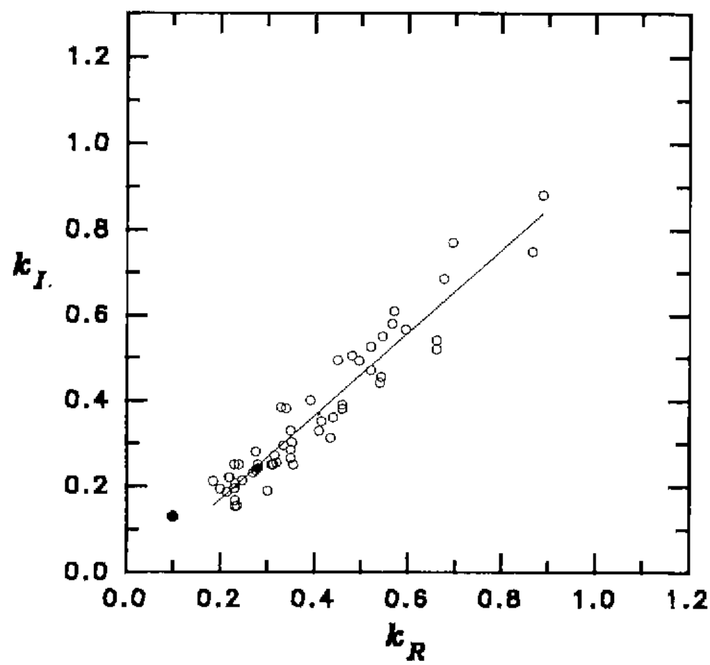

Figure 1. The k_R vs. k_I relation in the season of 1991. Comparison star 26 Cyg was used for the determination of k. A large closed circle at the left end of the straight line represents a pure Rayleigh scattering.

3. STANDARDIZED LIGHT CURVES

Instrumental differential magnitudes in the sense of Δm = 30 Cyg - 26 Cyg were computed and ΔR and ΔI light curves are made in Figure 2. As the case of B and V curves in this same issue by Nha *et al.* (1992b), brightness of both stars remained constant within observational errors throughout observing season. The mean light levels and the probable errors for a single observation in ΔR and ΔI are $0\overset{m}{.}378 \pm 0.012$ and $0\overset{m}{.}789 \pm 0.014$, respectively.

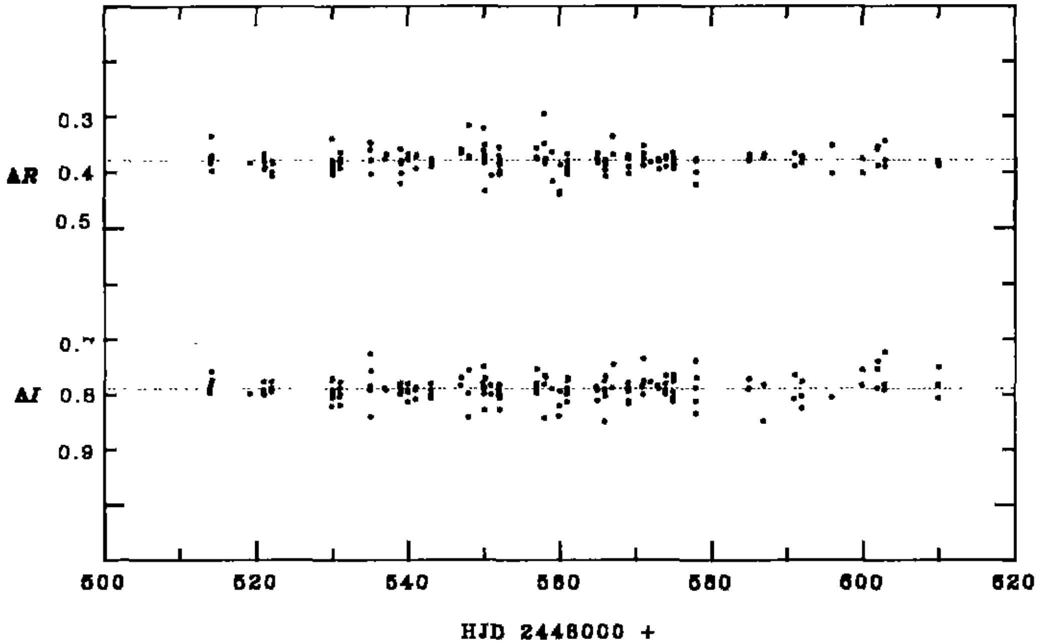

Figure 2. Light and color curves of 30 Cyg in R and I. Comparison star used was 26 Cyg. Mean light levels are 0.378 ± 0.012 and 0.789 ± 0.014, respectively, for ΔR and ΔI.

Ten standard stars are selected from the Bright Star Catalogue (Hoffleit and Jaschek 1982) and these are listed in Table 2. First six columns are those in the Bright Star Catalogue, but the last three columns are the magnitudes and colors determined by the present study, which will be discussed later in this section. All of these stars are observed repeatedly more than two nights. The last column indicates the number of observations observed for each star. The number of observation points made for these standard stars in each night is 3 to 6. In order to standardize the observations of 32 Cyg and its two comparison stars, the instrumental colors versus standard colors in the Catalogue for the ten stars in Table 2 are plotted in Figures 3 and 4. We denote $v - r$ and $r - i$ for the instrumental observed colors, and v magnitudes are adopted from the observations by Nha *et al.* (1992b).

Table 2. List of ten standard stars observed.

STAR	HR	V^B	$V-R^A$	$R-I^B$	SP^B	V	$V-R$	$R-I$	n
10 Lac	8622	4.88	-0.09	-0.22	O9V	5.07	-0.02	-0.19	6
18 Tau	1144	5.64	+0.03	-0.07	B8V	5.75	-0.01	-0.08	9
134 Tau	2010	4.91	+0.02	-0.08	B9IV	5.02	+0.03	-0.06	16
	1046	5.09	+0.09	-0.01	A1V	5.25	+0.09	-0.02	24
54 χ^1 Ori	2047	4.41	+0.51	+0.31	G0V	4.40	+0.50	+0.33	12
30 μ Cas	321	5.17	+0.63	+0.42	G5V_P	5.20	+0.56	+0.46	12
	8832	5.56	+0.83	+0.53	K3V	5.70	+0.81	+0.50	20
61 Cyg A	8085	5.21	+1.03	+0.65	K5V	5.18	+1.00	+0.65	7
61 Cyg B	8086	6.03	+1.17	+0.83	K7V	5.99	+1.16	+0.84	12
89 χ Peg	45	4.80	+1.34	+1.13	M2III	4.75	+1.37	+1.13	12

A: Astronomical Almanac (1991), B: Bright Star Catalogue (1982)

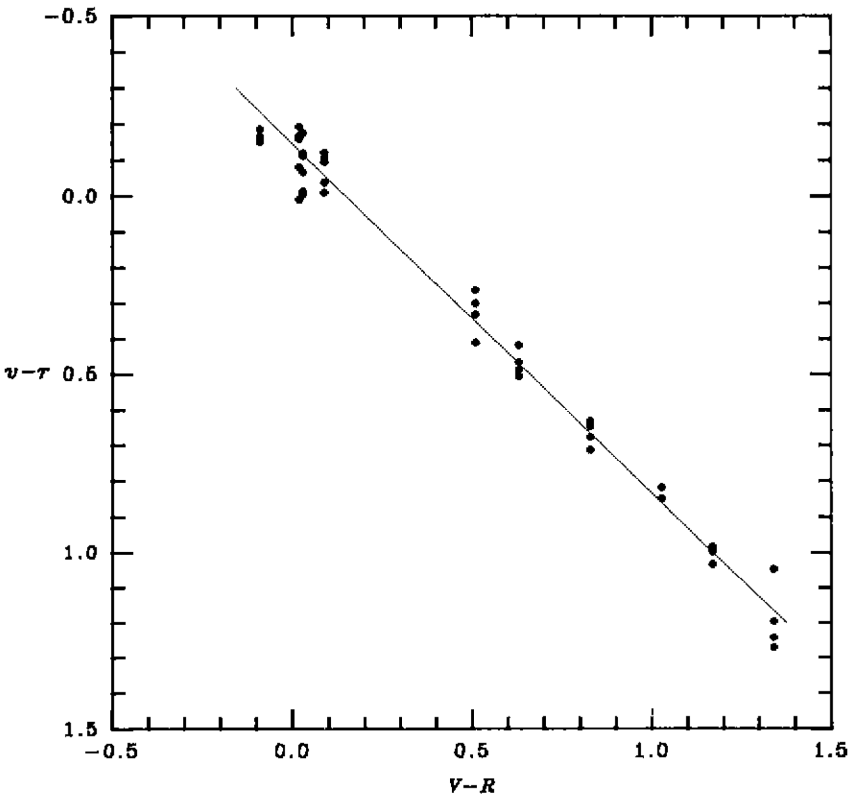

Figure 3. Standardized *vs.* observed color diagram; *(V–R) vs. (v–r)*.

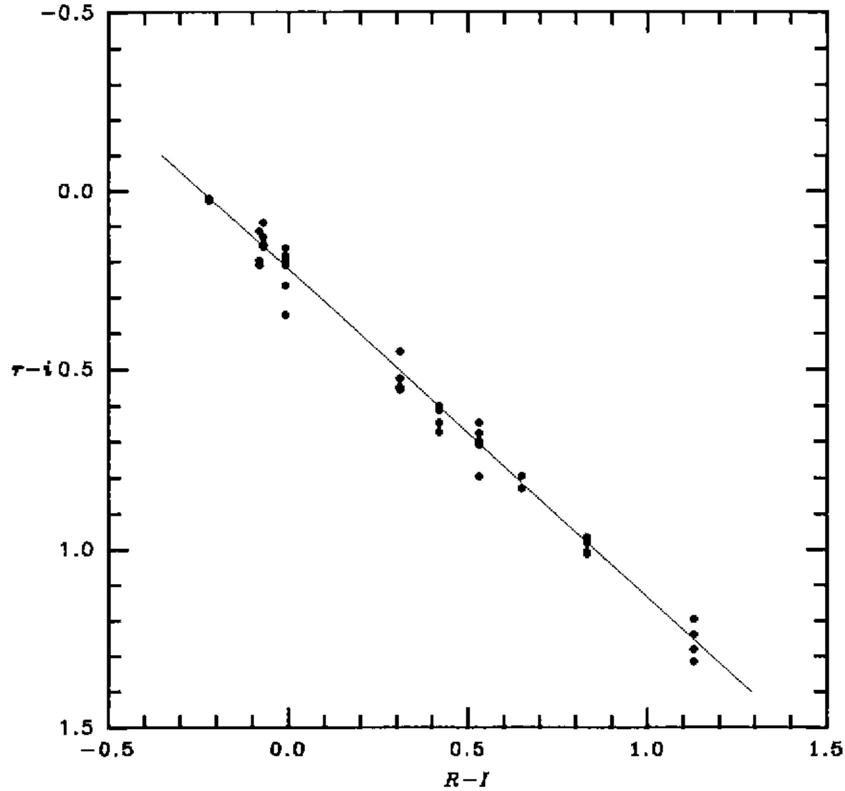

Figure 4. Standardized *vs.* observed color diagram; *(R–I) vs. (r–i)*.

There are excellent agreements in Figures 3 and 4 between the standard colors and the observed colors. Standardization coefficients derived from the Figures satisfiy the linear relations below:

$$\begin{aligned} V-R &= \ \ 0.151+1.021(v-r) \\ R-I &= -0.242+1.095(r-i) \end{aligned} \tag{2}$$

Internal probable errors for a single observation for the determination of $V–R$ and $R–I$ by Eq. (2) are, respectively, ±0.06 and ±0.03.

Transformation of the instrumental magnitudes and colors into the standard system for the 32 Cyg and two comparison stars along with the ten standard stars in Table 2 has been computed by IBM386 PC using the reduction program by one of us(YK).

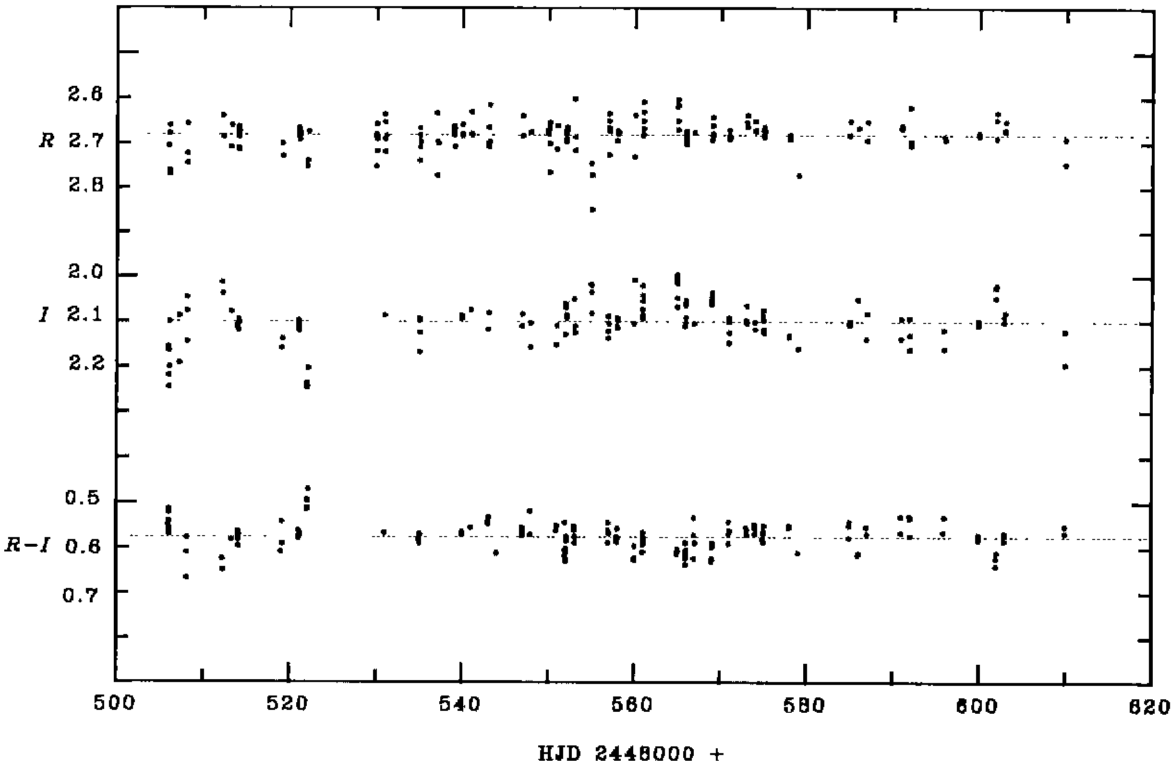

Figure 5. Standardized *R*, *I* and *R–I*, curves of 32 Cyg.

Standardized *R*, *I* and *R–I* curves of 32 Cyg are made according to the heliocentric Julian Dates in Figure 5. Although unexpected large scatters are shown in the light and color curves, one can easily notice the difference between the *R* and *I* curves. During the monitoring of time span, about 100 days, the brightness of 32 Cyg in *R* passband remained constant, but the brightness in *I* passband show irregular fluctuation with an amplitude of about $0^m_.1$.

Since the ratio of fluxes of K supergiant and B components F_K/F_B is larger with longer wavelengths, the surface activity of K supergiant component can be demonstrated better in *I* region than in *R*. From their IUE observations Reimers and Schröder (1983) and Hempe (1983) found the existence of transient hight velocity clouds in the circumstellar envelope of ζ Aur stars. Therefore, the irregular light variations exihibited on *I* curve may be interpreted as the case of this cloud.

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