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UBV PHOTOMETRY AT THE OUTSIDE ECLIPSE PHASE OF AZ CASSIOPEIAE [1]

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ABSTRACT

VV Cep-type long period spectroscopic-eclipsing binary AZ Cas has been observed for five years, 1985 Oct ~ 1990 Feb, in *UBV* at the Ilsan Station of Yonsei University Observatory. A total of 431 observations (U=129, B=142 and V=160) are made for 86 nights. Instrumental differential UBV and $B-V$ light curves made with these observations cover phases nearly a half of one period. There is no appreciable light variation in V but in other two passbands a gradual decrease of the brightness is clearly noticed. The loss of light in B resulted in a reddening in $\Delta(B-V)$ by +0.06 at phases between 0.4 ~ 0.5 as compared with that of at phase ~ 0.1. This intrinsic reddening arouses a question why at the orbital phase of the transit of a hot star in front of a cool M supergiant the heating of the facing hemisphere of M supergiant by the strong radiation from the B star is absent. With regard to this unusual situation we propose a hypothesis that a large amount of gas stream of low temperature ejected from the surface of M supergiant component towards the B star dominates the brightness of B star and the reflection effect.

1. INTRODUCTION

AZ Cas (BD+60°310, m_V=11.0, B0+M0Ib) was discovered as an eclipsing binary star with a period of about 9.3 years by Ashbrook (1956). He derived the ephemeris of this star using the Harvard patrol plates covering the eclipses between 1901 and 1947,

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$$\text{Min I} = \text{JD2432484} + 3406^d E.$$

Bonnell and Herczeg (1976) deduced a shorter period, 3402 days, from the Norman collection made between JD2435696 and JD2435859.

In spite of favorable position in the northern sky to many observers in the intermediate northern latitudes, AZ Cas has been attracted not many observers due mainly to its faintness. Furthermore, even though there were ten eclipses since the 1901 eclipse by Ashbrook (1956), the occurrence of night lower culmination of the star prevented the observations of either the beginning or the end of the eclipse when its mid-eclipse time entered in Spring. In this respect of the observational difficulty for those lower latitude observers, the full coverage of the eclipse warranted four times only in the past until the last eclipse of the 1985 January. Nevertheless, no single full coverage of any eclipse from its ingress to egress via totality has been reported. For these reasons, the photometric investigation of AZ Cas may totally depend on only a limited number of partial observations of each eclipse.

Here are the chronological survey of photoelectric observations. The first pe observation was made for the later part of the 1957 eclipse covering some of the totality and the 3rd and 4th contacts by Larsson-Leander (1959). This data with the photographic data by Bonnell and Herczeg (1976) was used later for the determination of the duration of the totality, $\sim 95d$, by Cowley *et al.* (1977).

Tempesti (1966) called attention of participants for the 1966 eclipse but failed in collecting data other than a few points made by himself. Nevertheless, he was successful in making observations of ingress and mid-eclipse phases of AZ Cas at its 1975 eclipse (Tempesti 1975). His observations and Florkowsky's (Cowley *et al.* 1977) were sufficient enough to derive accurate durations of the partial phase of about 10 days and of the totality of longer than 105 days by Cowley *et al.*. They claimed that the duration of the totality has been increased by about 10 days, and postulated two possible interpretations: (1) A real variation in the radius of the M star has occured which would correspond to about a 5 % change and (2) the highly interaction nature of the stars during the periastron passage (e=0.55) may give rise to an apsidal motion.

The latest eclipse in the 1984~85 would have provided excellent chance, but unfortunately for some reason no additional observation had been reported as to the present author's knowledge.

The best known ephemeris to-date obtained by Cowley and Hutchings (1977) are

$$\text{Min I} = \text{JD}2432481 + 3404(\pm 1^d)\, E.$$

For phases other than the primary eclipse, no single observation has been reported naturaly, and thus the investigation on the AZ Cas system is confined to the extrapolation of light levels of shoulders.

With regard to the facts that the duration of the primary eclipse takes parts of only about 4 % of the orbit and the insignificant contribution of B star to the total light of the system, it may be safe to account there would be no complicated light variation out of eclipse phase. However, the present author has experienced the light variations of other stars of extreme long period, such as VV Cep and ε Aur. This led us to make observations in *UBV* at phases other than the eclipse.

There are two most recent works on AZ Cas. With the identification of absorption lines of the AZ Cas in the low dispersion IUE spectra, Kang (1994) estimates that the temperature of this B star ranges between 15,000 ~ 20,000 K. Lee (1994) recently made observations of AZ Cas in R and I wavelengths at phases $0.^P7 \sim 0.^P8$, and found no appreciable light variation.

AZ Cas had been observed as one of the program stars of the *First Ten-year Observing Program For Long-Period Eclipsing Binary Stars* (1982~1992) at Yonsei University Observatory (YUO). This project for stars more than twenty with period longer than 10 days and at declination >+10 deg. had been successfully carried out without interruption of a single year. The photometric analysis of AZ Cas, which belongs to the stars of the longest period, is now partially ready to be reported as one of the first results deduced from this project.

2. OBSERVATIONS AND LIGHT CURVES

For five years from 1985 to 1990, AZ Cas was observed differentially with respect to the comparison star BD+60°0308 (m_V = 6.5, B8) at the Ilsan Station of YUO. In order to check the constancy of the light of the comparison star, BD+60°0296 (m_V = 7.2, G0) was observed as a check star. Photometer used in this period of observations was equipped with those recommended Johnson *UBV* filters and with an uncooled 1P21 photomultiplier phototube. Each measurement was derived from

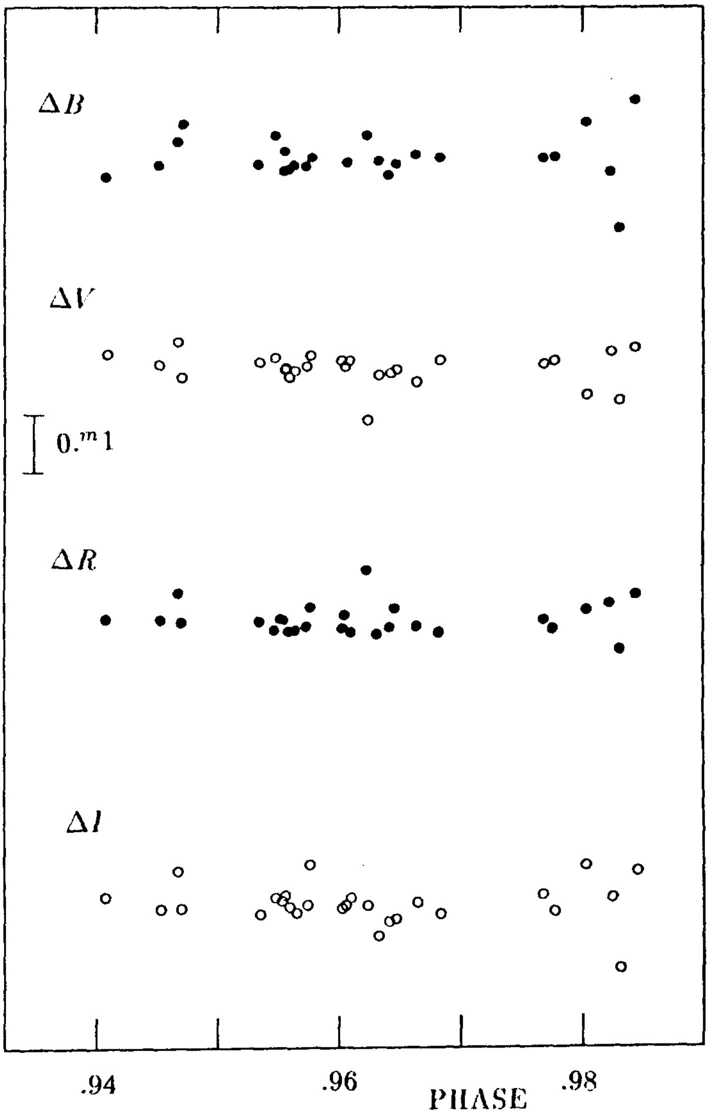

Figure 1. Instrumental differential $BVRI$ light curves of comparison star in the sense $\Delta m(ch * - c*)$ in the 1993 $\sim$ 1994 season. The abscissa represents the phase of AZ Cas.

about 60~90 seconds of *dc* amplification of the multiplied photocurrent traced onto the strip recorder chart.

The magnitudes of three stars were corrected for atmospheric extinction every night. Altogether 86 nights were observed for AZ Cas and its comparison star, and a less number of nights for the check star. Due to a long period of AZ Cas, the combined data of these five seasons show phase coverage from 0.09 to 0.54, which is equivalent to a half the period of AZ Cas.

The spectral type of the comparison star is very different from that of the primary component of AZ Cas but with a close match to the hotter component. Since the comparison star has not been observed previously by others, it is obviously required to check the constancy of the brightness of the comparison star during our observation run. This had not, however, been made in our season, but fortunately accomplished four years later in the 1993 ~ 1994 season. The light curves of differential magnitudes, $\Delta m(ch* - c*)$, made in this season are presented in Figure 1. The horizontal axis represents the phase of AZ Cas. The observations show no light variation of both stars and remained constant within the mean errors of $\pm 0.^m05$ and $\pm 0.^m05$ for V and B, respectively.

Figure 2 shows the instrumental differential UBV and $B - V$ curves of AZ Cas observed for five years, 1985 ~ 1990. Each point represents observation of nightly average, but the most of points made in the 1985 ~ 1989 seasons are made of a single observation while two or more are abundant in the last season, 1989 ~ 1990. The observations plotted on Figure 2 have scatters larger than those of in Figure 1. This larger scatter is mainly due to the faintness of AZ Cas.

The present observation was initiated in the first year after the latest eclipse in 1984 ~ 1985 was over and lasted in the beginning of the 1990. The phase coverage made in these five years is equivalent to nearly a half of the orbital period of AZ Cas. This implies that our observations should have covered the phase of the secondary eclipse, *i.e.*, the transit of the hot B star in front of the cooler supergiant component in 1987 ~ 1989 at the phase between 0.3 ~ 0.4 due to its high eccentricity, 0.55.

Although the observations are two fragmental in two seasons, 1986 ~ 87 and 1987 ~ 88, the general scope of light curves has been well established for the scrutinization of the light variation. There are a number of features to be worth of overview. The most significant one is the gradual decrease of light both in the B and U passbands. The mean magnitudes in the first season, 1985 ~ 86, at around $0.^P1$ are $\Delta B =$

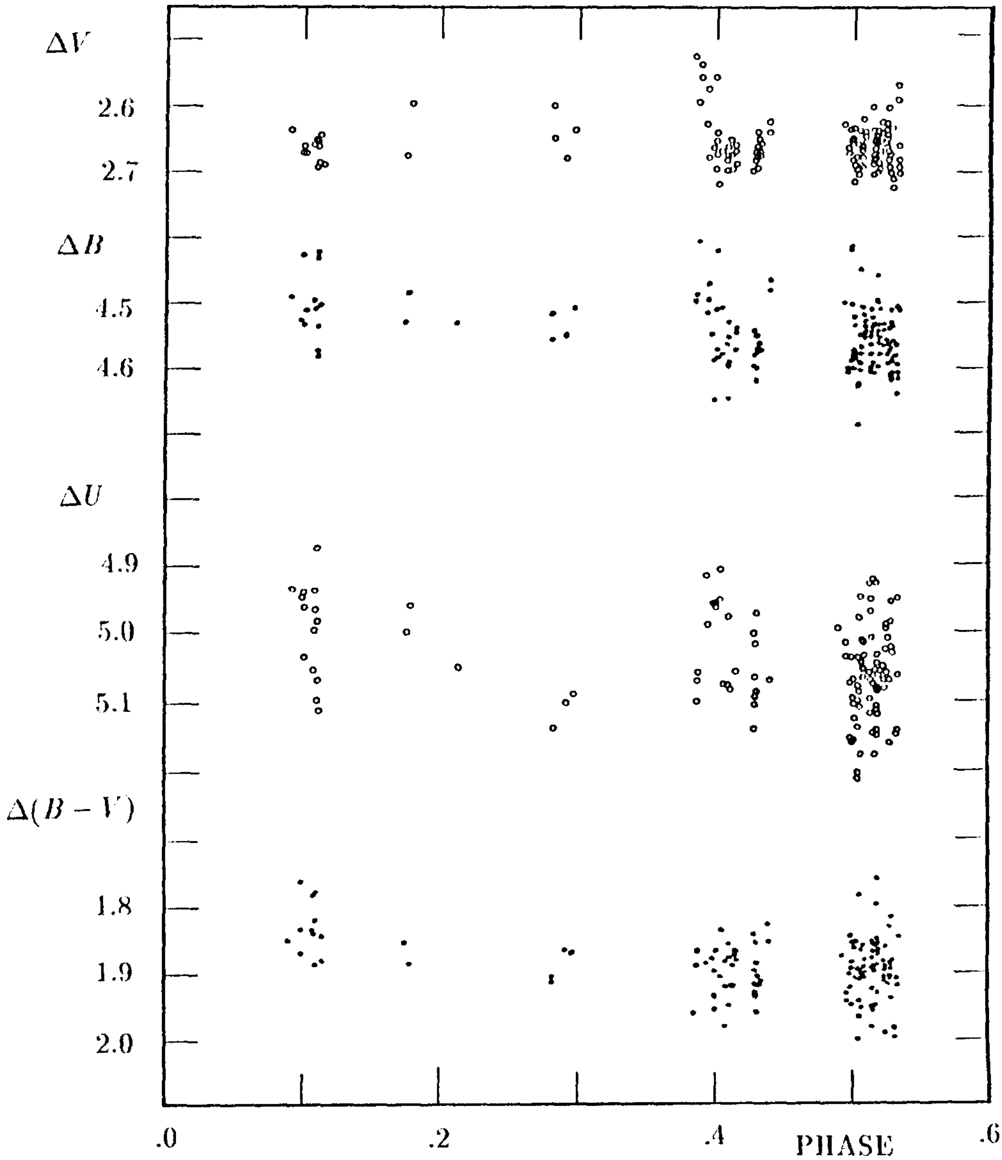

Figure 2. Instrumental differential U, B, V and $B - V$ curves of AZ Cas observed at Ilsan Station of YUO for five years, 1985 ~ 1990.

4.51 and $\Delta U = 5.00$, while $\Delta B = 4.56$ and $\Delta U = 5.06$ in the last season, 1989 $\sim$ 90, at around $0.^P52$. The light variation in V is not noticeable or absent, and therefore, this reflects the $B - V$ variation of about $0.^m05$, redder in the later years as compared with that of the first year. Another pecularity noticeable in the U light curve is a dip of nearly $0.^m1$ in the 1987 $\sim$ 88 season, which seems real.

Further outlook may be possible for any short-term variation of any type. Observations made in the last two seasons would suggest that the large scatter of points may not be accounted to only simple scatter due to the faintness of AZ Cas. Although the observations in the first year show scatters of comparable size, only the observations in the last two years were shown in an expanded Figure 3 for their longer durations; 180 days and 140 days in the 1988 $\sim$ 89 and the 1989 $\sim$ 90 seasons, respectively.

General feature of light curves made with nightly average magnitude in Figure 3 seems indicate of no appreciable light variation both in V and B, except those of marginal points in each year. The $B - V$ color curve represents a straight line at $\Delta(B - V) = +1.90$, accordingly. U curve in the 1988 $\sim$ 89 season is the only curve which would give an impression of intrinsic variation. However, this apparent variation may not have its origin other than the observational errors in this shortest wavelength.

3. RESULTS AND DISCUSSION

UBV observations of AZ Cas, a rather faint object for a small telescope, have been successfully carried out for five years from 1985 to 1990. With the data combined, the observations were sufficient enough to make light and color curves covering the phase range of $0.^P09 \sim 0.^P52$.

According to Cowley *et al.*(1977), the system AZ Cas is known to consist of a B0 main-sequence star ($\sim 13m_\odot$) and an M0 supergiant ($\sim 18m_\odot$) in an eccentric orbit in which the M star fills or overfills its Roche lobe at periastron. In Figure 4, we reproduce Figure 3 of Cowley *et al.* for the orbital plane of the AZ Cas system in order to explain the light and color variations in our observations. The first year of our observations was equivalent to the periastron passage. Therefore, a large amount of mass from the M supergiant would have been released toward the B star. This may have caused the light and color variations mentioned earlier.

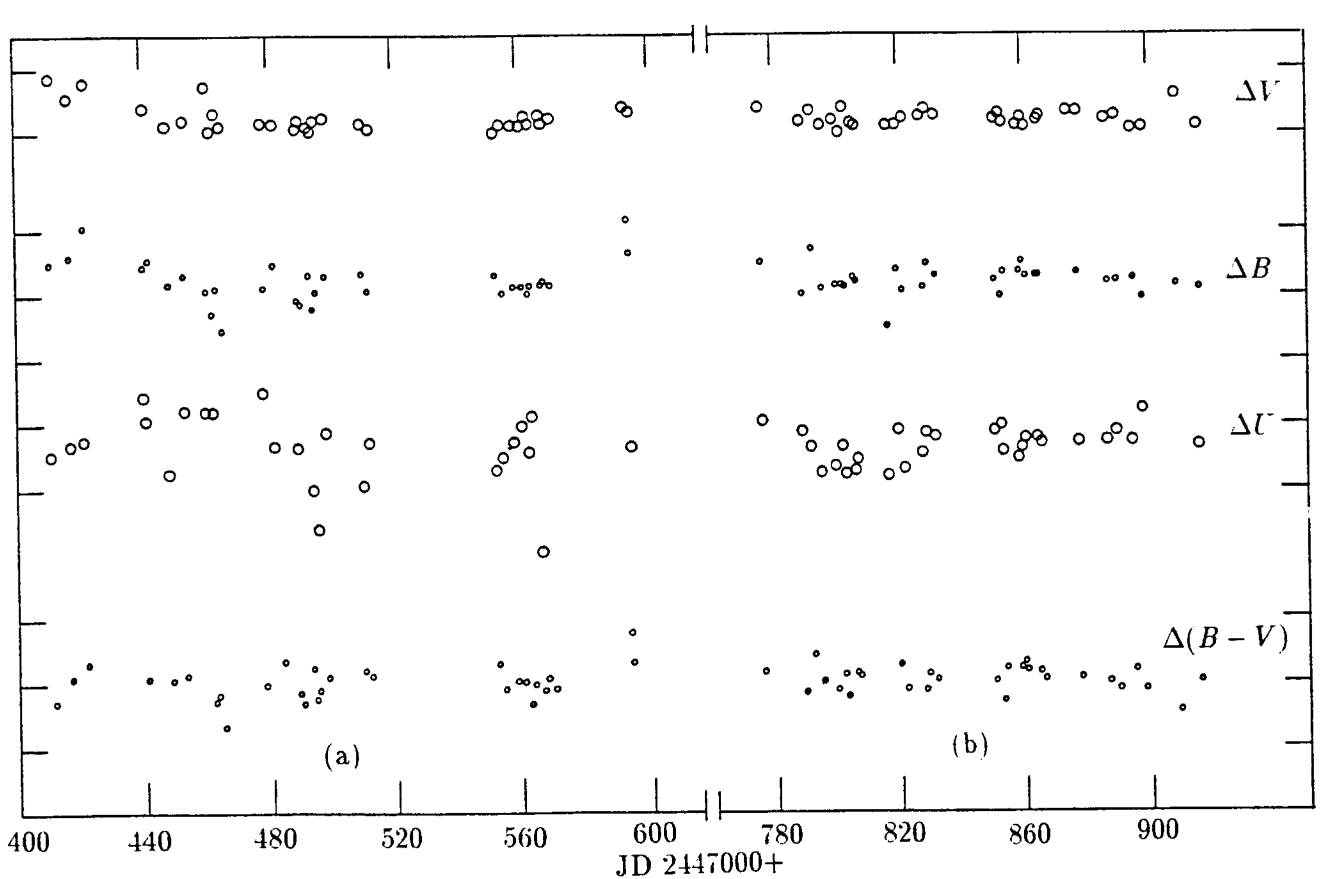

Figure 3. Instrumental differential UBV and $B-V$ curves made with observations in the 1988 ~ 1989 season(a) and in the 1989 ~ 1990 season(b)

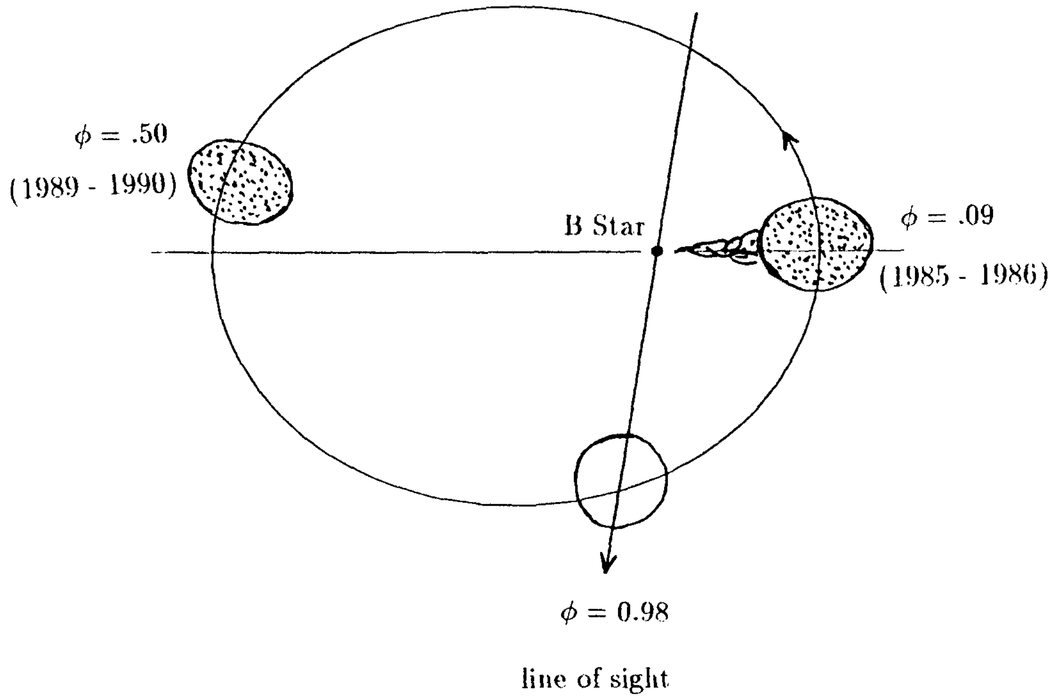

Figure 4. The orbital plane of the AZ Cas system, a partial reproduction of Figure 3 of Cowley *et al.* (1977). The size of M star is arbitrary.

One typical characteristics of the short-term light variation of VV Cep-type stars is the semi-regular in shape with the period around 100 days. The amplitudes of the light variation depend on the wavelength, larger with shorter wavelength (Nha *et al.* 1988, Nha 1992). There is, however, no trace of this kind of light variation in the system of AZ Cas. The observations made in the last two long seasons, 1988 $\sim$ 1989 and 1989 $\sim$ 1990, demonstrate the constant light except those marginal points in each year as mentioned already. This may suggest the difference between cool supergiants of ζ Aur-type and VV Cep-type; the former are characterized with the K spectral type while the latter with M type.

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