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Photoelectric Observations of the Long-Period Eclipsing Binaries at Yonsei University Observatory*

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Abstract

A long-term project (ten-year; 1982-92) for the photoelectric observation in the *UBV* passbands of selected eclipsing binaries with P≥10 days has initiated at Yonsei University Observatory using 40-cm and 61-cm reflectors. The instrumentation used and the observation techniques and the reduction procedures applied to this investigation are described.

Out of 39 program stars, successful results have been obtained during our first two years for the 11 stars listed below, with the orbital period in days in the parenthesis, and the incomplete light curves of these stars are presented.

SX Cas (36.57)	AQ Cas (11.72)	UU Cnc (96.71)
RY Gem (9.30)	V373 Cas (13.42)	NY Cep (15.28)
RX Cas (32.32)	V396 Cas (15.28)	ZZ Cnc (25.60)
Zet Aur (972.2)	Eps Aur (9885.)	

For the rest of the stars, the observations made in the first two years are not sufficient to attempt any meaningful light curve construction; some of the data are too fragmented and others show large scatter.

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I. Introduction

There are over 3,000 stars known to display eclipsing phenomena between the component stars in binary systems. This number has sharply increased in recent years. While 1,266 stars were listed in *A Finding List For Observers of Eclipsing Variables* (Koch *et al.* 1963), it has now reached 3,546 stars 17 years later (Wood *et al.* 1980).

In contrast with this large number of known eclipsing binaries, the distribution of stars according to the orbital period, in days, is not uniform but overcrowded in the shortest period, say less than two days, and decreases drastically with longer periods. Figure 1 illustrates the distribution of these stars marked with open circles. In this figure, the open circles represent the number of eclipsing binaries in percentages, showing the largest number, 23%, for $P<1$ day and less than a few % for $P\gtrsim 10$ days.

Questions arise as to whether there really are fewer stars with longer orbital periods and this a realistic representation of the true nature of the binary statistics. Supplementary information is available in the *Seventh Catalogue Of The Orbital Elements Of Spectroscopic Binary Systems* (Batten *et al.* 1978). In Figure 1 the largest number, 11%, is found for those spectroscopic binaries marked with closed circles of $2<P<3$ days, instead of for $P<1$ day as in the case of the elipsing binaries, and the number decreases but less steeply than for the eclipsing binaries, showing more than 2% for stars of $P\gtrsim 10$ days.

The two major differences in numbers between eclipsing and spectroscopic binaries for $P\lesssim 2$ days and for $P\gtrsim 10$ days may easily be interpreted; the former is the result of difficulty in measuring the blended lines which may obscure the line shifts in the spectroscopic binaries with fast orbital motion, and the latter reflects the fact that photometric detection is difficult for long-period eclipsing variables, especially in case of small light variations due to a shallow eclipse and the short duration of eclipses compared to the orbital period.

It is, therefore, clear that as far as orbital elements are concerned the eclipsing binaries have a greater advantage at shorter periods, $P\lesssim 2$ days, but a disadvantage for longer ones. This is the primary reason for the fact that the relative number of eclipsing binaries for $P\gtrsim 10$ days is only about one-third of the spectroscopic binaries as seen in Figure 1. Determination of the orbital period of the long-period eclipsing binaries is not only a serious problem in studying these stars but a more serious one is that there are so few complete light curves available.

Much information on the evolution of the close binary stars, such as the Zet Aur-phenomenon,

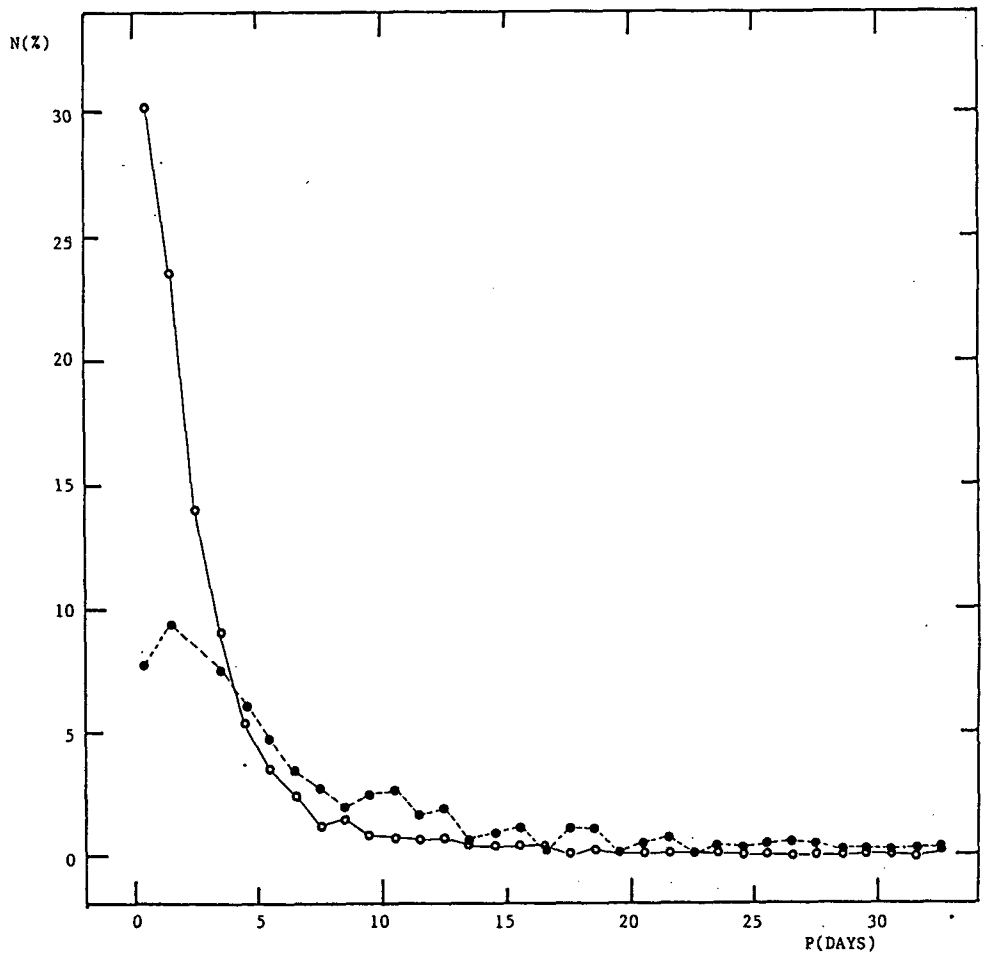

Figure 1. Number versus period diagram. The open circles and closed circles present the eclipsing and spectroscopic binaries, respectively.

accretion disk, mass exchange and mass loss, etc., can be obtained by observation of these stars. In this paper, we report our plan for the establishment of our long-term project, to last about 10 years, to obtain complete light curves for long-period eclipsing binaries in the standard *UBV* system.

II. Instrumentation

At Yonsei University Observatory a total of 39 long-period eclipsing binaries have been selected for the *UBV* photoelectric observations using 40-cm and 61-cm reflectors during the course of a ten-year project, 1982-92. Selection criteria for these stars were as follows.

(1) Orbital period: $P \gtrsim 10$ days,

(2) Brightness at maximum: $m_V = 11$ mag.,

(3) Declination range: Dec. > $+10^\circ$,

(4) Amplitude of light variation: $0^m.1$ or larger.

The two telescopes used for this project are located in seperate places. The locations and the equipments at the two observing stations of Yonsei University Observatory are as follows.
Campus Station: The telescope is a 40-cm Cave reflector, mounted on the Science Building (λ = 126°59′.0 E, ϕ=37°34′.0 N). The photometric system attached to the telescope is consists of standard *UBV* filetrs, D.C. amplifier, and Hamamatsu 1P21 phototube. The recorder is a strip chart.
Ilsan Station: The telescope is a 61-cm Goto reflector mounted on a small hill top (λ = 126°48′.5 E, ϕ = 37°41′.1 N) about 25 km west to the campus. The photometric and recording systems are the same as those on campus.

III. Observation and Reduction

Unless a photometric event for one specific program star, such as time of eclipse or a special phase, is expected on the observing night, the observation proceeds in the normal way. The selection of stars to observe and the normal sequence of observation for a night adopted by us are as follows.

(1) One or more extinction stars for the night must be observed continuously throughout the night. Extinction coefficients for the night at each observing station are to be determined independently every night. The airmass vs. magnitude diagram will serve to judge the quality of the data and of the night sky conditions later.

(2) Program Groups are selected for the night according to the season, sky transparency, moon age, observer's experience, etc. The number of Groups carried a night depend on the above conditions but mostly on the weather. Each Group has a different number of stars,

ranging from 1 to 5 stars located near each other in a small region of sky. The sky conditions tend to be different in the four directions, and thus each Groups may have its own extinction star. But the decision for this selection of the program group relies solely on the observer.

(3) The *UBV* observation sequence of one program star for one observation point is approximately same as that suggested by Harmanec *et al.*(1977). Each observation sequence requires at least 18 to 20 minutes. Each star in a given Group will have the sequences repeated and then the telescope is switched to the next member star in the same Group.

Recorded tracings on the chart paper which indicate the brightness of the star at a given time for each filter are readout with the sky brightness subtracted. For the comparison star the readings for the three filters can be determined at different times, but for the program star(s), and possibly including the check star, the observed time is fixed as the epoch of observation with the central filter.

The extinction coefficients in *UBV* are determined with the extinction star observations. When one extinction star observed on four different nights are illustrated in Figure 2. Different value of extinctions in the different directions are quite often possible at our stations; i.e., east

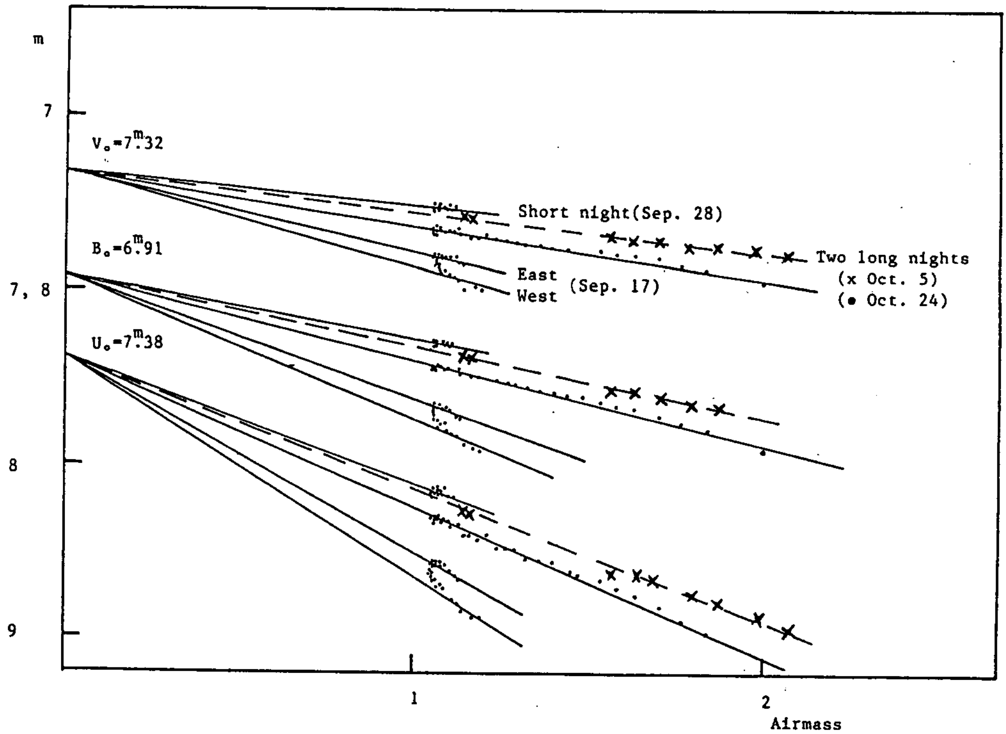

Figure 2. Airmass vs. magnitude diagram for the observations of BD+55°2534 made on four different nights in 1983 at Ilsan Station.

and west skies on Sept. 17 in Figure 2.

When the direct determination of the extinction coefficients from the airmass-mag. diagram is impossible because either airmass changes were too small or a large scatter of observations due to bad weather could not be avoided, the coefficients are derived with straight lines joining the observation points and the magnitudes of outside atmosphere; the case of Sept. 28. The magnitudes for outside atmosphere *u*, *b*, and *v* in the standard *UBV* system are deduced from the averages of those determined using the data from good, long nights during the whole given season; Oct. 5 and Oct. 24. Although the photometers used are not equipped with standard light sources which test the sensitivity of the detectors each night, our experience demonstrates that the magnitudes of outside atmosphere converged in a good accordance in each color. This is shown in Figure 2, in which two long-night observations with different slopes converge at zero airmass. The average measured magnitudes of outside atmosphere of a star tend to change due mainly to the electronic parts when they are repaired and to the different seasons. However, the colors *b-v* and *u-b* in the instrumental magnitude system have remained unchanged within observational error of $\pm 0^{m}.01$ in our photometry. These are well illustrated in Table I for two stars, Lamda Aurigae and BD+ 44°4044, as an example.

Table I. Instrumental magnitudes of outside atmosphere for stars at two stations.

	Lamda Aurigae						
	Ilsan Station				Campus Station		
	1982 Apr-Apr	1982 Sep-Oct	1982-83 Nov-Apr	1983-84 Sep-Apr	1982 Apr-May	1982-83 Sep-May	1983 Sep-Dec
u	2.63	2.63	4.55	4.88		4.02	4.02
b	2.10	2.10	4.04	4.36	2.00	3.50	3.50
v	1.80	1.80	3.75	4.06	1.70	3.20	3.20
u−b	0.53	0.53	0.51	0.51		0.52	0.52
b−v	0.30	0.30	0.29	0.30	0.30	0.30	0.30

	BD+44°4044				
	Campus Station				
	1981 Oct-Dec	1982 Sep-Oct	1982-83 Nov-Jan	1983 Aug-Nov	1983 Nov-Dec
b	3.64	2.35	2.68	2.42	2.60
v	4.00	2.72	3.05	2.83	2.97
b−v	- 0.36	- 0.37	- 0.37	- 0.41	- 0.37

Differential extinctions between the variable and comparison stars are corrected, for and the reduction of all observations to Δm(variable-comparison) has been made on the University Cyber 170-825 computer with a program given by Choi(1983).

Comparison stars used for the various program stars are standardized on the basis of measurements performed on several nights during each season at both stations by comparison with the *UBV* standard stars selected from *Photoelectric Catalogue* (Blanco *et al.* 1968). However, in all subsequent reductions of data on the program stars, since the magnitudes are all differentials between the program and its comparison stars, the transformation to the standard from the instrumental magnitudes of outside atmosphere(u, b, and v) are described as follow.

The equations of standardization have the usual forms

$$V-v = C_1 + C_2(B-V) \quad (1-1)$$
$$B-V = C_3 + C_4(b-v) \quad (1-2)$$
$$U-B = C_5 + C_6(u-b) \quad (1-3)$$

for any single star. Our initial reduction from the measurements has been performed for the instrumental differential magnitudes;

$$\Delta v = v_{p*} - v_{c*} \quad (2-1)$$
$$\Delta b = b_{p*} - b_{c*} \quad (2-2)$$
$$\Delta u = u_{p*} - u_{c*} \quad (2-3)$$

Here the subscripts $P*$ and $C*$ denote the program and the comparison stars, respectively. By combining Eqs. (1) and (2) for a differential standard system, one obtains

$$\Delta V = \Delta v + C_2\ C_4(\Delta b - \Delta v) \quad (3-1)$$
$$\Delta B = \Delta V + C_4(\Delta b - \Delta v) \quad (3-2)$$
$$\Delta U = \Delta B + C_6(\Delta u - \Delta b) \quad (3-3)$$

The determined standardization constants for the two stations are in Table II and Table III. The computation of the standardized differential magnitudes using Tables II and III has been made again on the University Cyber 170-825 computer with the program given by Jeong and Shin(1984).

Table II. Standadization constants at Ilsan Station.

Season	C_1	C_2	C_3	C_4	C_5	C_6
Apr. – Oct. 1982	2.76	− 0.048	0.315	0.883	− 0.315	1.123
Nov. 82 – Apr. 83	1.04	− 0.050	0.330	0.890	− 0.480	1.095
Sep. 83 – Apr. 84	0.85	− 0.050	0.330	0.895	− 0.490	1.135

Table III. Standadization constants at Campus Station.

Season	C_1	C_2	C_3	C_4	C_5	C_6
Nov. 82 – May. 83	1.506	− 0.069	0.415	0.867	− 0.625	1.167
Nov. 83 – May. 84	3.045	− 0.051	0.320	0.916	− 0.461	1.092

IV. Results and Discussion

The light curves are made for the program stars observed in the two years 1982-1984, and eleven stars among them are presented here. The number of observations for all of these stars is far from adequate for full light curves. If one takes into consideration, however, the relatively long orbital periods of the program stars and the short duration of observation, the data presented here seem to be encouraging.

SX Cas: The complicated $36^{d}.57$ eclipsing binary SX Cas observations with BD+55°0014 as the comparison star seems to be in a good agreement with that of Koch(1972). With our present light curve one minimum time JD2445737.21 is deduced(Fig. 3a).

AQ Cas: The smooth curve which represents the observations of AQ Cas may suggest that the minimum is shifted toward longer phase; the orbital period increased by about $+0^{d}.52$ in 53.3 years(Fig. 3a).

UU Cnc: The free-hand broken curve of UU Cnc is made using the information available.

RY Gem: Algol-type binary RY Gem has been known to have a variable period(Hall *et al.* 1982), but the present observation made after Hall's(1967-1979) shows no indication of a period variation in about four years(Fig. 3b).

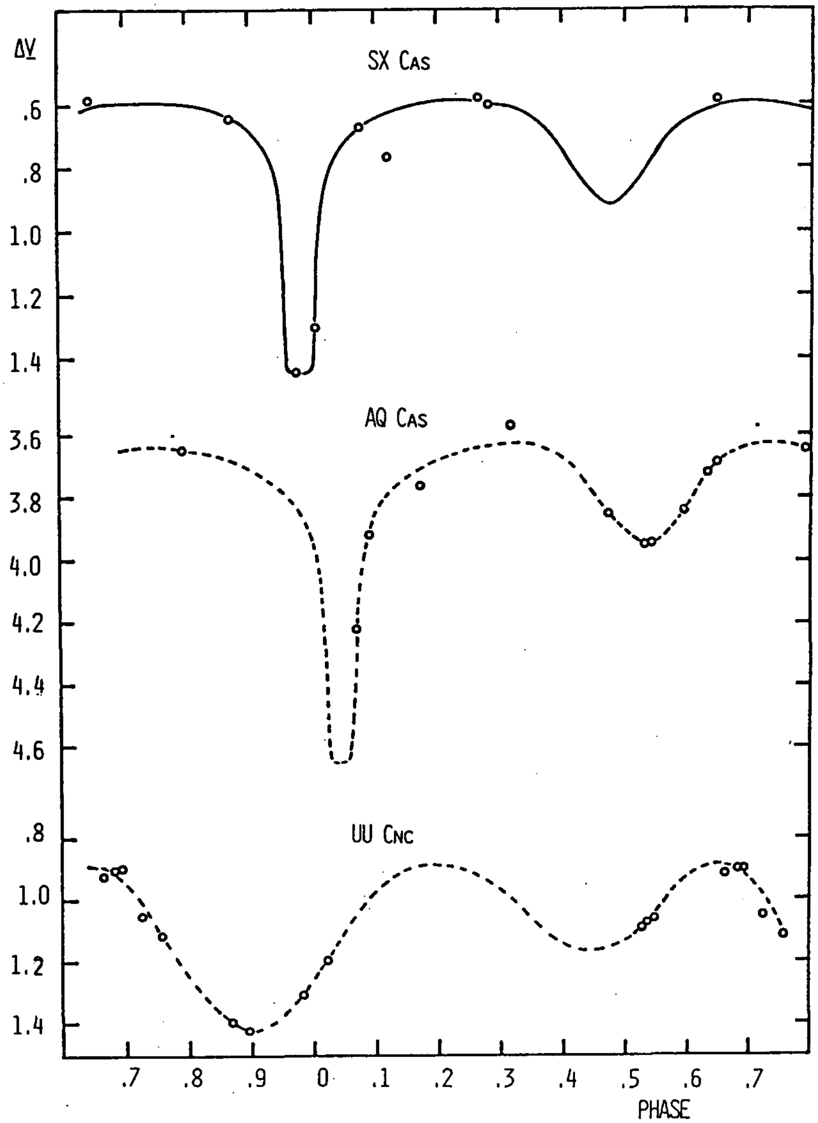

Figure 3a. Observed light curves of SX Cas, and UU Cnc in 1982-1984. The solid curve of SX Cas is adopted from Koch(1972). The broken curves for AQ Cas and UU Cnc are free-hand estimates.

V373 Cas: It is difficult to point out any eclipse phenomenon in the present observation whose phase coverage seems to be homogeneous. The agreement with Lynds(1959) is not satisfactory (Fig. 3b).

NY Cep: The observations made over two years are combined with the data of previous in-

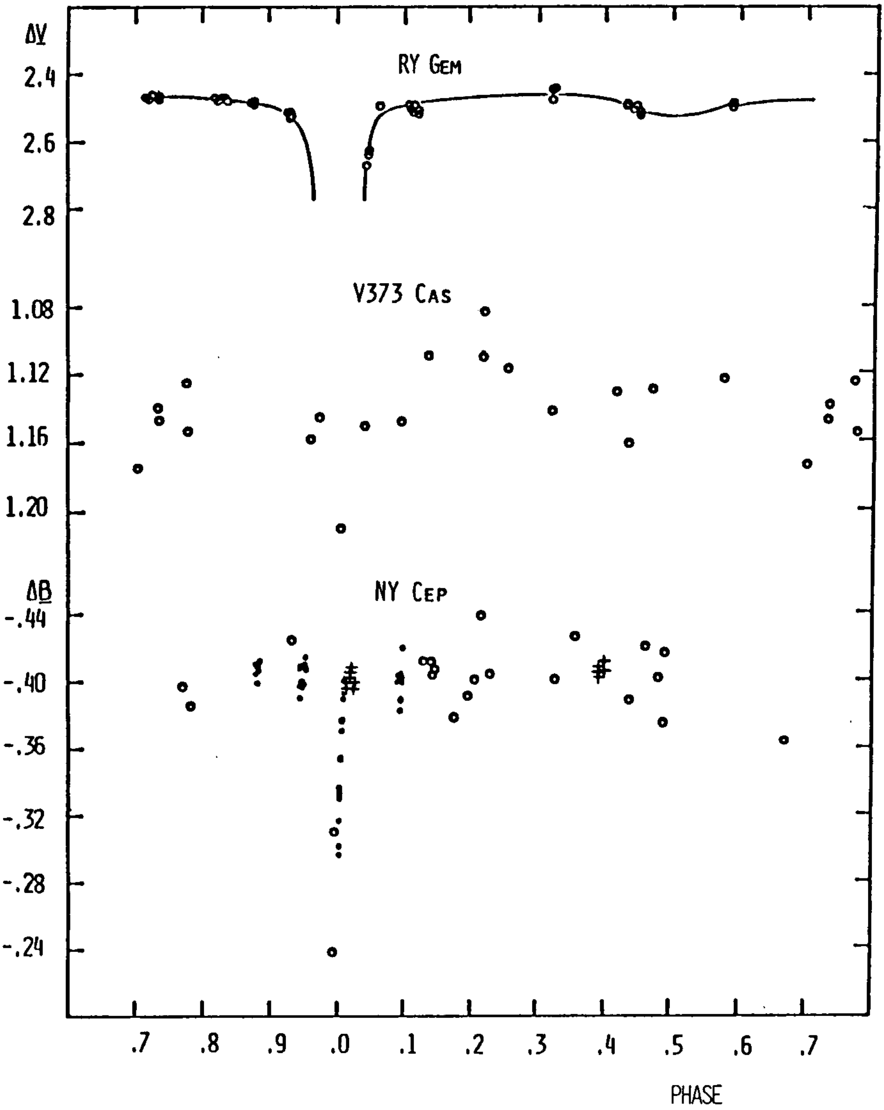

Figure 3b. Observed light curves of RY Gem, V373 Cas, and NY Cep in 1982-1984. The solid curve is adopted for RY Gem from Hall *et al.*(1982). The light curve of NY Cep is made from the combined data of Yonsei Univ. Obs.(o), Madore and Percy(●, 1973), and Mayer *et al.*(+, 1978).

vestigators(Madore and Percy 1973, Mayer *et al.* 1978). They are all in a good agreement (Fig. 3b).

RX Cas: The light variations for this star are so pronounced in our light curve that it is impossible to locate the phase of eclipse with our data(Fig. 3c).

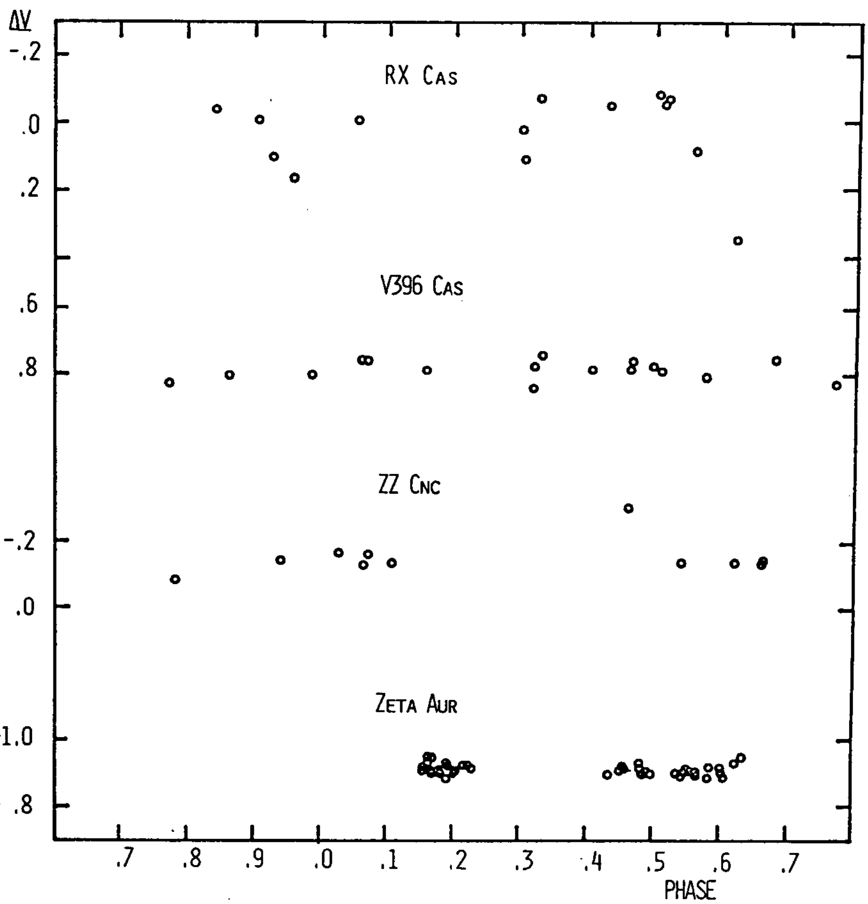

Figure 3c. Observed light curves of RX Cas, V396 Cas, ZZ Cnc, and Zet Aur in 1982-1984.

V396 Cas: Although this star is known to have a primary depth of $0^{m}.5$(Wood *et al.* 1980), the present light curve made using BD+55°2929 as comparison star shows no eclipsing phenomenon(Fig. 3c).

ZZ Cnc: The present observations do not sufficiently cover the phases of primary and secondary minima(Fig. 3c).

Zet Aur: The present observations for this star were initiated in the latter part of the first season. Nevertheless, observation is on going with a reasonable accuracy and a steady phase coverage to meet eclipse forth-coming(Fig. 3c).

Eps Aur: The observed light curve of this star shows that the bottom of the eclipse is not flat as was expected. Two brightenings are clear; one is at the phase right after the second contact and the other just before the third contact. Moreover the light curve had several flare phenomena, and one of them, marked with an open circle, had been reported elsewhere (Nha and Lee 1983). The dates for the second and third contacts are, respectively, JD2445309 and JD2445732, and therefore, the duration of the total eclipse is 423 days, which is longer than that of the 1955-57 eclipse by 29 days and that of 1928-30 by 93 days (Fig. 3d).

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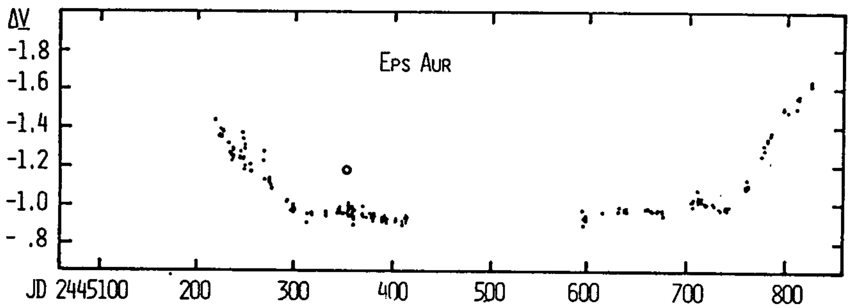

Figure 3d. Observed light curve of Eps Aur in 1982-1984. The open circle denotes the flare activity reported by Nha and Lee(1983).

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