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PERIOD CHANGES OF BRIGHT SOUTHERN CEPHEIDS

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ABSTRACT

O-C diagrams have been constructed for 44 bright southern Cepheids, mainly for studying the effects of duplicity on the pulsation period. Because the light-time effect in the O-C diagrams of binary Cepheids has to be accompanied with properly phased variations in the γ-velocity, the radial velocities of the programme stars have been studied, as well. Light-time effect is found or suspected in eleven cases (V496 Aql, AX Cir, AG Cru, BG Cru, BF Oph, AP Pup, AT Pup, Y Sgr, AP Sgr, R TrA, and V Vel), and a preliminary value of the orbital period is suggested for 14 Cepheid binaries (V496 Aql, AX Cir, AG Cru, Y Oph, BF Oph, AP Pup, AT Pup, U Sgr, Y Sgr, AP Sgr, BB Sgr, RV Sco, R TrA, and V Vel). The phenomenon of the phase jump (i.e. the return of the pulsation period to an earlier value) is present in the O-C diagram of eight Cepheid binaries (U Aql, YZ Car, KN Cen, S Mus, S Nor, Y Oph, U Sgr, and V350 Sgr).

INTRODUCTION

Period changes of more than a hundred northern Cepheids were studied in a series of papers (*Szabados*, 1977, 1980, 1981, 1983, and 1984). The large number of the programme stars and the homogeneous method of the analysis enabled the determination of the period changes as a function of the pulsation period. A general agreement of the observed period changes with the theoretically calculated values was found. In addition to the frequently occurring parabolic O-C diagrams corresponding to the continuous period change as a result of the stellar evolution, two special kinds of period variations were also revealed in several cases, both of them being characteristic of binary Cepheids:

1. light-time effect due to the orbital motion,
2. stepwise O-C graph, i.e. rejump (return) of the pulsation period to an earlier value. In what follows, the term "phase jump" will be used for this phenomenon.

This paper is dealing with a similar study: period changes of 44 (mostly bright) southern Cepheids are discussed here. Because the southern Cepheid variable stars were observed on rare occasions before the photoelectric era, secular period variations have remained undiscovered in most cases. The time interval of less than fifty years covered with photoelectric observations is not long enough to reveal the evolutionary period changes unambiguously (there are, however, some exceptions). At the same time, due to their accuracy, these photoelectric observations can be used successfully for searching for both light-time effect and phase jump in the O-C diagrams.

For this reason the sample of stars studied here is arbitrarily chosen: it contains the bright southern Cepheids for which presence of a companion has been suspected or discovered. In addition, some other bright Cepheids without any evidence for duplicity have also been included, considering that any evolutionary period changes are likely to be expected in these very bright Cepheids with the longest available coverage of photometric observations.

The current ephemerides (the moment of the light maximum, and the value of the pulsation period) are also determined, and these pieces of information may be useful for planning future observations in any wavelength interval, or for determining their phases.

Due to the inhomogeneous (and arbitrary) selection of the programme stars, the statistical study of the period changes has not been attempted. Instead, duplicity effects are placed in the centre of interest. Because the most straightforward way to discover the presence of a companion is to detect variations in the mean radial velocity (so called γ-velocity), the radial velocity data are also analysed and intercompared with the relevant parts of the O-C diagrams.

O-C DIAGRAMS

In order to study the period changes, all the available photometric observations have been analysed. At the final step, however, the results based on visual observations were omitted because of their very low accuracy. Nevertheless, there are one or two cases where the very early visual data have been used but after J.D.2420000 only the photographic and photoelectric observations were taken into account.

Homogeneity of the O-C diagrams has been achieved by re-analysing all observations without accepting the originally published moments of normal maxima. The new moments of normal maxima were determined by fitting the master light curve to the light curve to be analysed. The master light curve has been the most reliable seasonal light curve available in the literature for the given star (mostly but not necessarily from the paper by *Moffett* and *Barnes*, 1984). Whenever it was possible, the longer observational series were grouped into seasonal light curves.

Depending on the number and quality of the observations and the distribution of the data points, a weight has been assigned to each light curve. This weight is 3 for the master curves and other best quality light curves, and 2 or 1 is assigned to the light curves of poorer coverage and/or showing wide scatter. Note that these weights were determined before performing the curve fitting procedure, i.e. without knowing how much the corresponding O-C residual will deviate from the final O-C curve.

The weight was never larger than 1 in the case of the photographic observations, and there are numerous O-C residuals in the tables of this paper where no weight has been assigned (these are based on visual or photographic observations without exception). These latter O-C residuals are still useful but have not been taken into account when determining the shape of the O-C curve.

The exact calculation of the error for each O-C residual would have been extremely time-consuming. Instead, based on the large body of the previous O-C diagrams (*Szabados*, 1977, 1980, 1981) the following average uncertainties could be deduced: for w=3, 2, and 1 the standard deviation is about 0.002 , 0.004 and 0.008 part of the pulsation period.

Throughout this study the blue (or closest to Johnson's B band) light curves were analysed. There are quite a few series of photometric observations obtained in red and/or infrared bands. Although these observations are very important in some respects, they were omitted from this study because the shape of the light curve at long wavelength differs from the blue light curve, and the necessary corrections to be applied for removing the systematic differences between the moments of maxima in different spectral regions have not been determined yet.

The O-C residuals are given in tabular form and shown plotted in figures. The successive columns in the tables of the O-C residuals contain the following data:

1. Moment of normal maximum ;

2. The corresponding epoch;
3. O-C residual (in days);
4. Type of observation and the weight assigned to the residual (pe for photoelectric, pg for photographic, and vis for visual observations);
5. Source of the observational data.

The O-C diagram (usually the upper panel of the figure) shows the O-C residuals listed in the corresponding table, and the curve thought to be the best interpretation of the O-C plot is also drawn. These curves were obtained by the weighted least squares method applied to the data points. The weights are visualized in the figure as circles of increasing diameter. Photoelectric observations are denoted with filled circles, while open circles refer to the O-C residuals based on photographic observations. If no weight has been assigned to an O-C residual, it is shown plotted as a small dot.

RADIAL VELOCITIES

Because one of the main aims of this study is to search for light-time effect in the O-C diagrams, it was appropriate to carry out a simultaneous investigation of the radial velocity measurements in order to check the results on duplicity obtained from the O-C diagrams.

The radial velocity data have been collected from the literature, and they were analysed after the trend of the period variation had been determined from the O-C diagram. This step is crucial because any fitting error due to the use of an inaccurate pulsation period can be eliminated, and only the observational (and in some cases a systematic zero-point) error of the radial velocity measurements remains as a possible source of error.

It is almost impossible to get rid of the systematic errors because most of the early papers containing radial velocity data do not give enough information for converting the data into a common system. Nevertheless, thanks to the existence of the IAU standard radial velocity system, these systematic errors have become much smaller in the last decades, e.g. according to *Welch* et al. (1987) the zero-point correction applied to the radial velocity measurement series of U Aql is less than 1 km/s for eight instruments, and the correction slightly exceeds 1 km/s in only one case.

In view of this, no corrections have been applied to the observational data analysed here, and, of course, this can be an additional source of error. The only exception is *Paddock*'s (1917) radial velocity measurement series, for which *Lloyd Evans* (1982) introduced +4 km/s correction, and this value is so large that it was also applied here.

The individual radial velocity series were used for constructing the seasonal radial velocity curves using the accurate value of the pulsation period. The centre-of-mass velocity of the Cepheid (i.e. the γ-velocity) was then determined in two steps. At first, the γ-velocity of the best radial velocity curve was determined graphically for each variable, then these radial velocity normal curves were fitted to the properly phased other radial velocity curves. If the γ-velocity seemed to be constant, the radial velocity measurement series were not always divided into seasonal curves.

As to variability of the γ-velocity, there is a reasonable lower limit (4-5 km/s), and if the fluctuation of the γ-velocity exceeds this value, the presence of a companion to the Cepheid is suspected. It is hoped that the above limit overestimates the real threshold of detection because much smaller variations in the γ-velocity can be revealed by using the recent radial velocity measurement techniques. Unfortunately most of the available radial velocity data have been obtained at a higher level of uncertainty.

Because the relative errors of the radial velocity measurements are larger than those of the photometric measurements, the standard deviations have been calculated for the individual radial velocity measurement series. The standard deviation of the date of observation is formal, and it only indicates the length of the observational interval. The standard deviation of the γ-velocity does not contain the contribution of the possible zero-point error.

The successive columns in the tables of the γ-velocities give the following data:

1-2. Mean date of the observations and its standard deviation;

3-4. γ-velocity and its standard deviation;

5. Number of radial velocity observations used;

6. Source of the observational data.

The γ-velocity data of the individual Cepheids are plotted in most cases in the lower panel of the figures. The plot is missing in those cases where no obvious change in the γ-velocity is seen. Error bars (according to the standard deviations listed in the tables) are only shown, if the bar exceeds the size of the circle.

REMARKS ON THE INDIVIDUAL VARIABLES

The list of the programme stars can be found in Table 1. The ordinal number following the name of the Cepheid gives the page number where the discussion on the given star begins. The Cepheids involved in this study are arranged in alphabetical order of constellations, and within one constellation, according to the IAU nomenclature of variable stars.

Table 1. Programme stars

It was not my intention to give a comprehensive history on each variable. I do hope, however, that neither photoelectric or photographic, nor radial velocity observation published in the literature escaped my attention. The additional remarks on the individual Cepheids mostly concern the previous studies on both the changes in the γ-velocity and the period variations. The available other evidence regarding the duplicity of these stars is also discussed briefly. A systematic application of the known duplicity tests is beyond the scope of this paper but such a study is planned for the near future. The compilation on the binary Cepheids will be published in due time.

Although the phase difference between the γ-velocity variations and the sinusoidal wave in the O-C diagram is a good indicator whether this phenomenon can be interpreted as a light-time effect, there is an additional criterion that makes use of the amplitude of these oscillations. Assuming a circular orbit, the radial velocity and O-C variations have to obey the following relationship in a binary system:

$$2K = a \cdot \mathit{sini} \cdot P_{orb}^{-1} \cdot 3.77 \cdot 10^6 \qquad (1)$$

where 2K is conventionally the total amplitude of the γ-velocity variation (in km/s), $a \cdot \mathit{sini}$ is the projected radius of the orbit, and at the same time this quantity is the half amplitude of the wave in the O-C diagram (in days), and P_{orb} is the orbital period (in days). This test is frequently used during this study as a very strong criterion when deciding whether light-time effect is expected or not (if the orbital period has been known from radial velocity measurements), and to judge reality of interpreting the O-C wave in terms of duplicity.

U Aquilae

U Aql is one of the spectroscopic binary Cepheids with known orbit (*Welch* et al., 1987). According to various estimates, the companion is a main-sequence B8-A1 star (*Leonard* and *Turner*, 1986). The radial velocity observations have not been re-analysed here, the orbital period of 1856.4 days (*Welch* et al., 1987) is accepted, although the more recently published radial velocity data (*Wilson* et al., 1989) may slightly alter this value.

The O-C residuals are listed in Table 2, and are shown plotted in Figure 1. The O-C diagram of U Aql can be well approximated by two lines showing a phase jump (i.e. rejump of the period). The O-C residuals have been calculated with the formula:

$$C = \underset{\pm.031}{2434922.400} + \underset{\pm.000029}{7\overset{d}{.}023958} \cdot E \qquad (2)$$

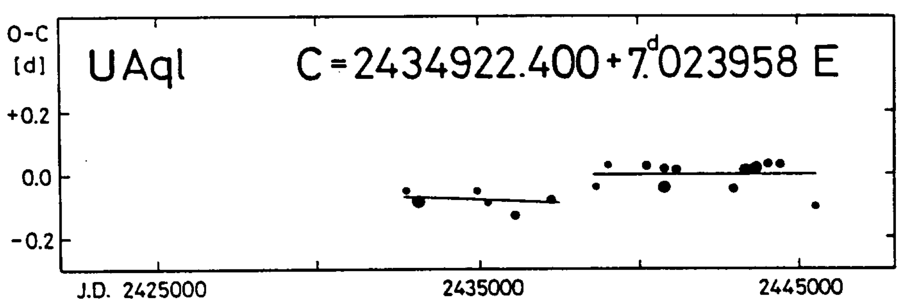

Figure 1. **O-C diagram of** U Aql

Table 2. O-C residuals for U Aql

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
32765.994	-307	$-0^{d}.051$	pe 2	Eggen (1951)
33110.132	-258	-0.087	pe 3	Eggen (1951)
34950.444	+ 4	-0.052	pe 1	Walraven et al. (1958)
35294.581	+ 53	-0.089	pe 1	Irwin (1961)
36109.319	+169	-0.130	pe 1	Svolopoulos (1960)
37233.200	+329	-0.082	pe 2	Mitchell et al. (1964)
38673.155	+534	-0.039	pe 1	Wisniewski and Johnson (1968)
39059.541	+589	+0.030	pe 1	Wisniewski and Johnson (1968)
40253.609	+759	+0.025	pe 2	Feltz and McNamara (1980)
40801.469	+837	+0.016	pe 2	Feltz and McNamara (1980)
40822.484	+840	-0.041	pe 3	Pel (1976)
41194.809	+893	+0.015	pe 2	Feltz and McNamara (1980)
42922.639	+1139	-0.049	pe 2	Dean (1977)
43365.210	+1202	+0.012	pe 3	Moffett and Barnes (1984)
43674.270	+1246	+0.018	pe 3	Moffett and Barnes (1984)
44039.528	+1298	+0.031	pe 2	Moffett and Barnes (1984)
44467.988	+1359	+0.029	pe 2	Eggen (1985)
45563.595	+1515	-0.101	pe 1	Eggen (1985)

This period is valid after J.D.2438600 , while between J.D.2432700 and J.D.2437300 the pulsation period was $7.023920 \pm 3.0\cdot10^{-5}$ days. The phase jump occurred at about J.D.2438000, and it amounts to 0.1 day.

There are no early photographic observations available in the literature, therefore the longer time-scale behaviour of the O-C diagram of U Aql cannot be studied. According to the phase relations of the radial velocity curves, the O-C residuals might be even more negative at about J.D.2421840 . A single straight line fitted to the photoelectric O-C residuals is almost as good as the phase jump approximation. In view of the values of the orbital period and the orbital radial velocity amplitude, the expected light-time effect has such a low amplitude (see equation (1)) that the effect cannot be detected.

V496 Aquilae

Its spectroscopic binary nature was revealed by *Gieren* (1982) but there is no agreement on the type of the companion (*Leonard* and *Turner*, 1986). The variable γ-velocity of V496 Aql is well illustrated in Figure 2 (lower panel), and in Table 3. There is a number of periods that fits the data points reasonably well: 1200, 1780, 2700, 3600, 5350, and 10750 days. It is impossible to choose the true value of the orbital period from the available radial velocity measurements alone.

Table 3. γ-velocities of V496 Aql

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
33918	31	6.8	0.8	15	Stibbs (1955)
34202	28	0.6	1.5	5	Stibbs (1955)
40448	27	6.8	0.4	4	Lloyd Evans (1980)
44053	10	18.0	4.0	2	Barnes et al. (1988)
44423	4	7.7	0.4	25	Gieren (1981a)
44486	46	14.5	1.6	7	Barnes et al. (1988)
44822	47	4.6	2.3	4	Barnes et al. (1988)

The O-C diagram (see Table 4 and the upper panel of Figure 2) can be approximated by a straight line with the light-time effect superimposed on it. The sine-wave was fitted by using the method of weighted least squares, and the 1500 - 13000 day interval was analysed. The best fit was achieved assuming an orbital period of 1882 ± 23 days. The moments of the light maxima can be predicted as follows:

$$C = \underset{\pm.004}{2436017.084} + \underset{\pm.000008}{6^{d}.807055}E - \underset{\pm.008}{0^{d}.023}\cos(2\pi(\underset{\pm.00004}{0.00362}E - \underset{\pm.031}{0.006})) \qquad (3)$$

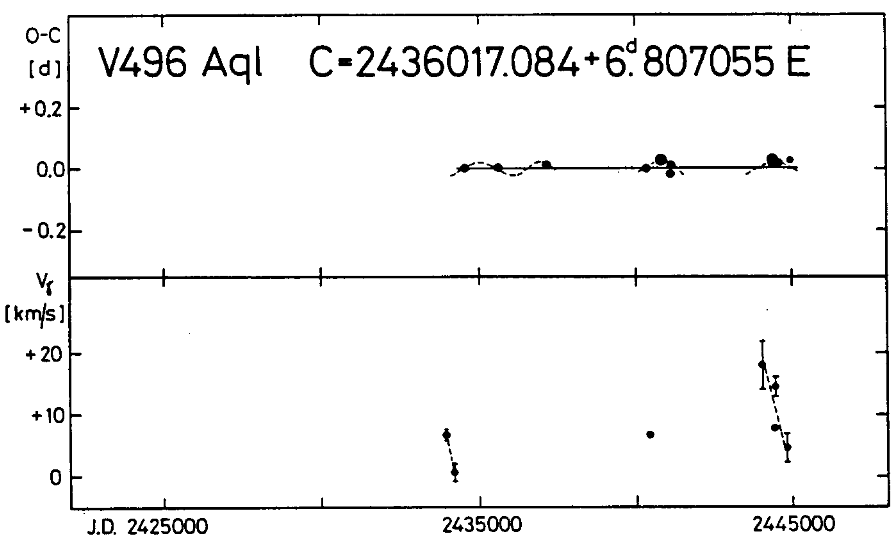

Figure 2. Upper panel: O-C diagram of V496 Aql
Lower panel: γ-velocities for the same Cepheid

Table 4. O-C residuals for V496 Aql

Norm.max JD2400000+	E	O-C	Type, weight	Reference
34567.181	-213	$0^{d}_{.}000$	pe 2	Eggen et al. (1957)
35608.663	- 60	+0.002	pe 2	Walraven et al. (1958)
37187.908	+172	+0.011	pe 2	Mitchell et al. (1964)
40366.791	+639	-0.001	pe 2	Stobie (1970)
40809.275	+704	+0.024	pe 3	Pel (1976)
41122.357	+750	-0.018	pe 2	Pel (1976)
41149.613	+754	+0.010	pe 2	Feltz and McNamara (1980)
44410.200	+1233	+0.017	pe 3	Moffett and Barnes (1984)
44410.214	+1233	+0.031	pe 3	Gieren (1981b)
44621.218	+1264	+0.016	pe 2	Eggen (1985)
44907.121	+1306	+0.023	pe 1	Moffett and Barnes (1984)

This value of the orbital period is in reasonable agreement with the 1780 day period, one of the values suggested by the radial velocity data. The amplitude of the wave is, however, twice larger than the value expected from equation (1). This suggests that the orbital period may be longer. More spectroscopic and photometric data are necessary to determine the value of the orbital period unambiguously.

The O-C residuals have been calculated with the elements:

$$C = \underset{\pm.004}{2436017.084} + \underset{\pm.000008}{6^{d}_{.}807055} \cdot E \qquad (4)$$

If no sinusoidal term is assumed in the O-C diagram, then the least squares fit results in the following formula:

$$C = \underset{\pm.004}{2436017.085} + \underset{\pm.000005}{6^{d}_{.}807070} \cdot E \qquad (5)$$

which is practically identical with the linear part of the sinusoidal fit (i.e. with equation (4)).

V Carinae

V Car was reported to be a suspected binary (*Lloyd Evans*, 1968) but later on *Lloyd Evans* (1982) explained the scatter in the radial velocity data as due to the variability of the bump on the velocity curve. Here the scatter in the radial velocity data is attributed to the variation in the γ-velocity (see Table 5 and the lower panel of Figure 3).

Table 5. γ-velocities of V Car

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
34009	20	15.2	0.8	14	Stibbs (1955)
34095	20	14.0	1.2	7	Stibbs (1955)
39252	64	8.7	1.1	4	Lloyd Evans (1968)
39611	41	8.3	1.1	4	Lloyd Evans (1968)
39932	48	12.2	0.6	2	Lloyd Evans (1980)
40338	16	12.5	0.3	5	Lloyd Evans (1980)
40666	51	13.2	0.3	6	Lloyd Evans (1980)

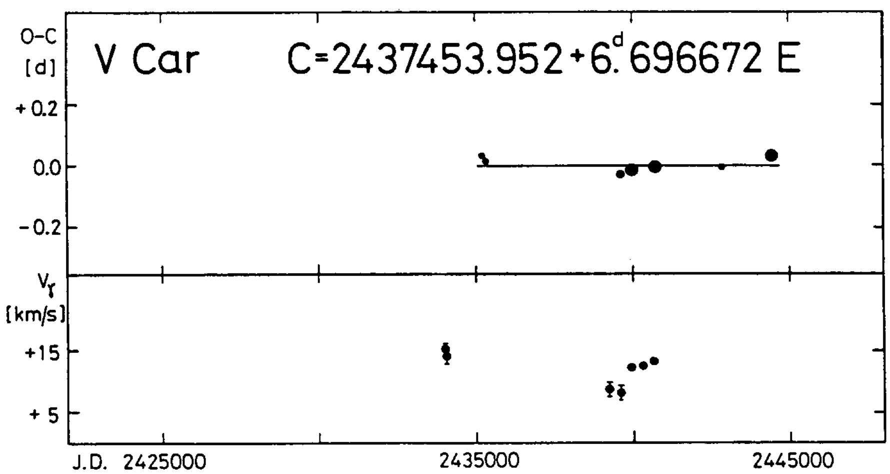

Figure 3. Upper panel: O-C diagram of V Car
Lower panel: γ-velocities for the same Cepheid

Table 6. O-C residuals for V Car

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
35230.691	-332	$+0^d.034$	pe 1	Irwin (1961)
35351.218	-314	+0.021	pe 1	Walraven et al. (1958)
39630.343	+325	-0.027	pe 2	Cousins and Lagerweij (1968)
39958.494	+374	-0.013	pe 3	Cousins and Lagerweij (1968)
40742.012	+491	-0.006	pe 3	Pel (1976)
42858.163	+807	-0.003	pe 1	Dean (1977)
44425.219	+1041	+0.031	pe 2	Eggen (1985)

The O-C diagram (Table 6 and the upper panel of Figure 3) contains very few points, and for the sake of simplicity it is approximated by a straight line:

$$C = 2437453.952 + 6\overset{d}{.}696672 \cdot E \qquad (6)$$
$$\quad \pm.009 \quad \pm.000016$$

Further observations are to be obtained in order to decide whether a parabola fits better, and even the light-time effect cannot be excluded.

YZ Carinae

According to *Coulson* (1983) YZ Car belongs to a binary system with an orbital period of about 850 days. *Coulson* also derived tentative orbital parameters, and concluded that the companion is probably a main-sequence A0 star. The radial velocity measurements of YZ Car have not been analysed again here.

Table 7. O-C residuals for YZ Car

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
34725.613	- 10	$+0\overset{d}{.}197$	pe 2	Walraven et al. (1958)
35216.089	+ 17	+0.202	pe 3	Irwin (1961)
37831.903	+161	+0.173	pe 3	Walraven et al. (1964)
41737.333	+376	+0.006	pe 3	Madore (1975)
43989.866	+500	+0.008	pe 2	Coulson and Caldwell (1985)
44280.475	+516	-0.033	pe 2	Coulson and Caldwell (1985)
44280.593	+516	+0.085	pe 1	Eggen (1983b)
44680.082	+538	-0.068	pe 2	Coulson and Caldwell (1985)
44771.006	+543	+0.028	pe 2	Eggen (1983b)
45007.127	+556	-0.004	pe 3	Coulson and Caldwell (1985)
45715.615	+595	+0.027	pe 2	Coulson and Caldwell (1985)

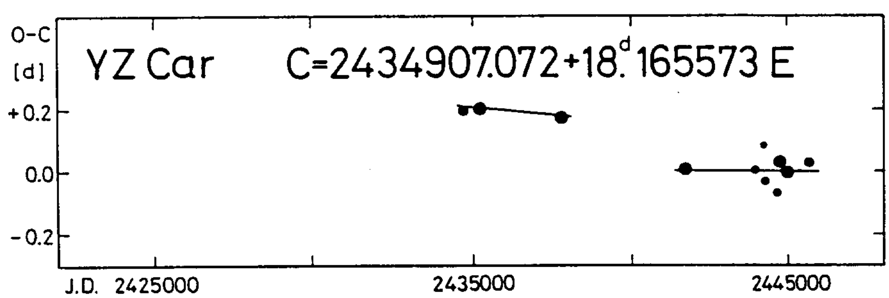

Figure 4. O-C diagram of YZ Car

The O-C diagram has been constructed on the basis of the available observations listed in Table 7. The plot of the O-C residuals (see Figure 4) can be well approximated by two sections of straight lines showing the phenomenon of the phase jump seen in numerous binary Cepheids.

The O-C residuals have been calculated with the elements:

$$C = \underset{\pm .071}{2434907.072} + \underset{\pm .000137}{18\overset{d}{.}165573} \cdot E \qquad (7)$$

The previous value of the pulsation period (between J.D.2434700 and 2437900) was $18.165412 \pm 2.0 \cdot 10^{-5}$ days, therefore it can be stated that the star returned to the same pulsation period after an 0.16 day phase jump, occurred at about J.D.2440000 .

Another fact worth mentioning is that the pulsation period differs considerably from the value given in the GCVS (*Kholopov* et al., 1985-1987). *Coulson* (1983) used an almost correct value of the pulsation period but did not call the attention explicitly to the correction to be applied to the period in the catalogue.

ℓ Carinae

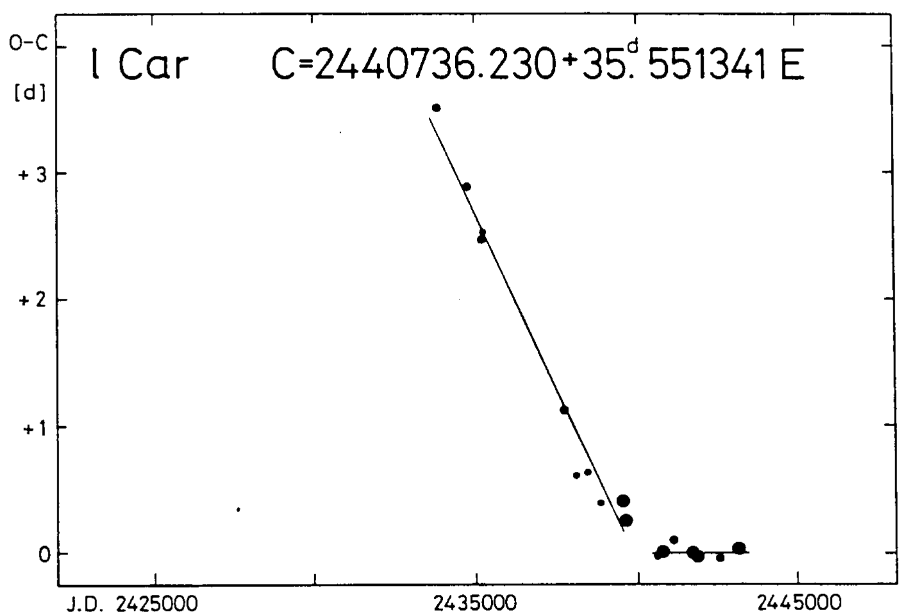

Figure 5. **O-C diagram of** ℓ Car

The γ-velocity of this long period Cepheid can be considered as being constant (see Table 8), therefore the individual values of the γ-velocity are not plotted in a diagram.

The O-C diagram (see Table 9 and Figure 5) is based on only the photoelectric normal maxima. The previous values of the pulsation period can be followed in *Parenago*'s (1956) paper. The O-C residuals have been calculated with the formula:

$$C = 2440736.230 + 35\overset{d}{.}551341 \cdot E \qquad (8)$$
$$\pm.015 \qquad \pm.000397$$

Table 8. γ-velocities of ℓ Car

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
17441	402	2.2	0.8	17	Jacobsen (1934)
21655	25	2.0	0.8	15	Jacobsen (1934)
22435	19	1.8	0.6	28	Jacobsen (1934)
34086	61	1.0	0.7	21	Stibbs (1955)
35641	19	0.7	1.0	5	Lloyd Evans (1968)
37722	52	4.4	0.7	21	Dawe (1969)
39238	33	0.9	1.1	4	Lloyd Evans (1968)
39901	38	2.0	0.3	5	Lloyd Evans (1980)
40307	61	3.2	0.2	12	Lloyd Evans (1980)
40663	44	0.0	0.3	6	Lloyd Evans (1980)

Table 9. O-C residuals for ℓ Car

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
33807.235	-195	$+3\overset{d}{.}516$	pe 2	Eggen et al. (1957)
34766.489	-168	+2.884	pe 2	Eggen et al. (1957)
35228.242	-155	+2.470	pe 2	Irwin (1961)
35263.849	-154	+2.526	pe 1	Walraven et al. (1958)
37751.037	- 84	+1.120	pe 2	Lake (1962)
38141.594	- 73	+0.612	pe 1	Feinstein and Muzzio (1969)
38461.577	- 64	+0.633	pe 1	Feinstein and Muzzio (1969)
38852.400	- 53	+0.391	pe 1	Feinstein and Muzzio (1969)
39563.259	- 33	+0.223	pe 3	Feinstein and Muzzio (1969)
39563.437	- 33	+0.401	pe 3	Landolt (1971)
40629.547	- 3	-0.029	pe 2	Eggen (1971)
40736.226	0	-0.004	pe 3	Pel (1976)
41127.387	+ 11	+0.092	pe 2	Pel (1976)
41731.656	+ 28	-0.012	pe 3	Madore (1975)
41838.299	+ 31	-0.023	pe 3	Dean et al. (1977)
42549.300	+ 51	-0.048	pe 2	Dean et al. (1977)
43189.300	+ 69	+0.027	pe 3	Dean (1981)

Two values of the pulsation period are apparent in Figure 5: before J.D.2440000 the period was $35.531758 \pm 6.21 \cdot 10^{-4}$ days, while after this epoch the value of the period has been $35.551341 \pm 3.97 \cdot 10^{-4}$ days. Although Figure 5 suggests a continuous period increase, a parabolic fit was not attempted because the early part of the O–C diagram (*Parenago*, 1956) would contradict to this interpretation.

V Centauri

Although *Gieren* (1982) found no evidence for the variable γ-velocity, according to the present study variability in the γ-velocity cannot be ruled out (see Table 10 and the lower panel of Figure 6). Especially *Stibbs*' (1955) seasonal curves suggest a short period (several hundred days) variation.

Table 10. γ-velocities of V Cen

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
33848	22	-25.1	1.1	9	Stibbs (1955)
34165	54	-19.5	1.1	8	Stibbs (1955)
39268	37	-23.9	1.0	5	Lloyd Evans (1968)
40371	28	-23.2	0.3	4	Lloyd Evans (1980)
40759	15	-20.8	0.3	3	Lloyd Evans (1980)
44422	4	-23.9	0.4	26	Gieren (1981a)

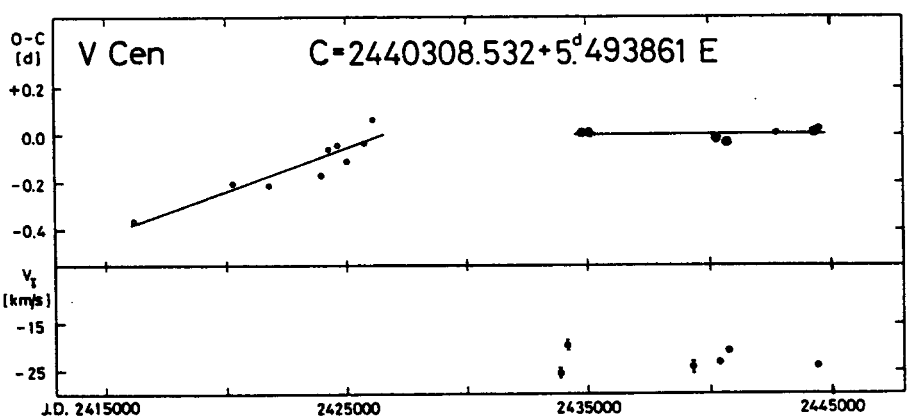

Figure 6. Upper panel: O–C diagram of V Cen
Lower panel: γ-velocities for the same Cepheid

Table 11. O-C residuals for V Cen

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
16162.649	-4395	$-0\overset{d}{.}364$	pg 1	Shapley (1930)
17953.707	-4069	-0.305	pg 1	Shapley (1930)
20272.216	-3647	-0.205	pg 1	Shapley (1930)
21794.004	-3370	-0.216	pg 1	Shapley (1930)
23986.101	-2971	-0.170	pg 1	Shapley (1930)
24260.903	-2921	-0.061	pg 1	Voute (1927b)
24656.476	-2849	-0.046	pg 1	Voute (1927b)
25035.485	-2780	-0.113	pg 1	Voute (1927b)
25793.717	-2642	-0.034	pg 1	Dartayet et al. (1949)
26139.928	-2579	+0.064	pg 1	Dartayet et al. (1949)
34869.621	- 990	+0.011	pe 3	Walraven et al. (1958)
35193.758	- 931	+0.011	pe 3	Irwin (1961)
40335.980	+ 5	-0.021	pe 3	Stobie (1970)
40748.007	+ 80	-0.034	pe 3	Pel (1976)
42852.197	+ 463	+0.007	pe 2	Dean (1977)
44417.952	+ 748	+0.012	pe 3	Gieren (1981b)
44494.877	+ 762	+0.023	pe 2	Eggen (1985)

The O-C diagram (Table 11 and the upper panel of Figure 6) shows one period change. The O-C residuals have been computed using the ephemeris:

$$C = \underset{\pm .005}{2440308.532} + \underset{\pm .000007}{5\overset{d}{.}493861} \cdot E \tag{9}$$

The period change occurred at about J.D.2427000 , and before that epoch the pulsation period was 5.494058 $\pm$ $2.6 \cdot 10^{-5}$ days.

XX Centauri

Spectroscopic binary nature of XX Cen was discovered by *Coulson* et al. (1985). The value of the orbital period was determined recently (*Szabados*, 1989), its value is 909.4 $\pm$ 29.0 days.

According to equation (1), no detectable light-time effect is expected in the O-C diagram, therefore the phase shift mentioned by *Coulson* et al. (1985) is not caused by the orbital motion but, instead, it reflects the strong period change determined here.

The O-C residuals have been calculated with the formula:

$$C = \underset{\pm .010}{2440366.125} + \underset{\pm .000027}{10\overset{d}{.}954027} \cdot E \tag{10}$$

As is seen in the O-C diagram (see Table 12 and Figure 7), the period of

XX Cen is continuously decreasing as follows:

$$P = 10^{d}.954027 - 15^{d}.5 \cdot 10^{-7} \cdot E \qquad (11)$$
$$\quad \pm.000027 \qquad \pm.6$$

where the E epoch number is the same as in equation (10).

Table 12. O-C residuals for XX Cen

Norm.max JD2400000+	E	O-C	Type, weight	Reference
26398.368	-1275	$-1^{d}.373$	pg 1	van Gent and Oosterhoff (1948)
27691.409	-1157	-0.907	pg 1	van Gent and Oosterhoff (1948)
34812.261	- 507	-0.172	pe 1	Walraven et al. (1958)
35206.584	- 471	-0.194	pe 3	Irwin (1961)
35469.522	- 447	-0.153	pe 1	Walraven et al. (1958)
37846.692	- 230	-0.007	pe 3	Walraven et al. (1964)
40377.080	+ 1	+0.001	pe 3	Stobie (1970)
41110.923	+ 68	-0.076	pe 2	Grayzeck (1978)
41592.936	+ 112	-0.040	pe 1	Grayzeck (1978)
41768.228	+ 128	-0.012	pe 2	Madore (1975)
42874.573	+ 229	-0.024	pe 3	Dean (1977)
44068.488	+ 338	-0.098	pe 3	Coulson et al. (1985)
44659.979	+ 392	-0.125	pe 3	Coulson et al. (1985)
45010.518	+ 424	-0.114	pe 3	Coulson et al. (1985)

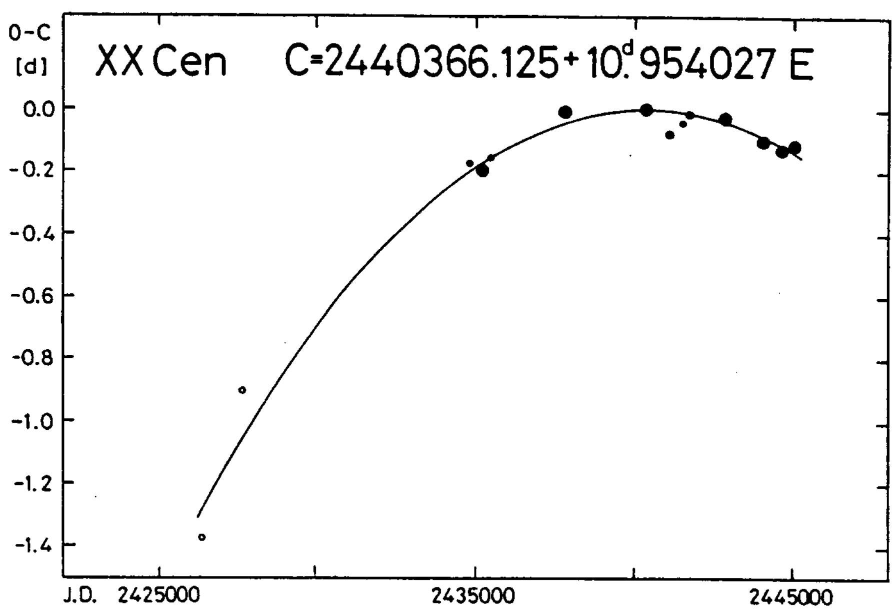

Figure 7. O-C diagram of XX Cen

AZ Centauri

AZ Cen may be a spectroscopic binary because *Balona* found a strongly discordant γ-velocity in comparison with other radial velocity measurements (*Gieren*, 1982). Unfortunately *Balona*'s observations have remained unpublished, and the available radial velocity data show a constant γ-velocity (see Table 13).

The O-C residuals have been computed with the formula:

$$C = \underset{\pm.011}{2435223.389} + \underset{\pm.000004}{3.^{d}212279} \cdot E \tag{12}$$

It should be emphasized that this pulsation period strongly differs from that given in the GCVS (*Kholopov* et al., 1985-1987). The O-C diagram is parabolic (see Table 14, and Figure 8) showing a continuous decrease in the period. The instantaneous value of the pulsation period can be obtained from the formula:

$$P = \underset{\pm.000004}{3.^{d}212279} - \underset{\pm.35}{9.^{d}79} \cdot 10^{-8} \cdot E \tag{13}$$

where the E epoch number is the same as in equation (12).

Table 13. γ-velocities of AZ Cen

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
34138	33	-12.1	0.9	11	Stibbs (1955)
43178	4	-11.5	0.4	7	Stobie and Balona (1979)
43311	37	-13.1	0.3	10	Stobie and Balona (1979)
43531	4	-12.5	0.6	4	Stobie and Balona (1979)
44423	4	-12.7	0.4	22	Gieren (1981a)

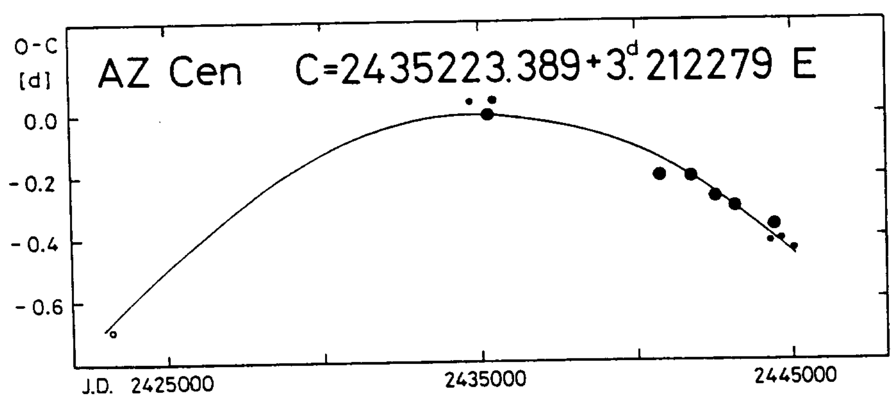

Figure 8. O-C diagram of AZ Cen

Table 14. O–C residuals for AZ Cen

Norm.max. JD2400000+	E	O–C	Type, weight	Reference
23253.740	−3726	$-0^{d}.697$	pg 1	de Jager (1947)
34709.464	− 160	+0.040	pe 1	Walraven et al. (1958)
35220.172	− 1	−0.005	pe 3	Irwin (1961)
35451.504	+ 71	+0.043	pe 2	Walraven et al. (1958)
40738.672	+1717	−0.200	pe 3	Pel (1976)
41795.508	+2046	−0.204	pe 3	Dean et al. (1977)
42540.691	+2278	−0.270	pe 3	Dean et al. (1977)
43179.904	+2477	−0.300	pe 3	Stobie and Balona (1979)
44316.936	+2831	−0.415	pe 1	Eggen (1985)
44400.508	+2857	−0.362	pe 3	Gieren (1981b)
44634.956	+2930	−0.410	pe 1	Eggen (1985)
45055.732	+3061	−0.443	pe 1	Eggen (1985)

KN Centauri

The presence of a companion to the Cepheid KN Cen has been suspected on various grounds: large UV excess (*Walraven* et al., 1964), peculiar loop in the two-colour diagram (*Stobie*, 1970; *Madore*, 1977; and *Pel*, 1978), the shape of the Ca II K line (*Lloyd Evans*, 1968), and finally the companion was revealed with the help of an IUE spectrum (*Böhm Vitense* and *Proffitt*, 1985). The available radial velocity observations also give evidence for the binary nature (see Table 15 and the lower panel of Figure 9). This variation has not been reported before.

Table 15. γ-velocities of KN Cen

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
41539	194	−48.8	4.5	6	Grayzeck (1978)
43975	5	−40.8	0.4	6	Coulson and Caldwell (1985)
44400	56	−40.0	0.4	9	Coulson and Caldwell (1985)
44703	35	−39.5	0.3	16	Coulson and Caldwell (1985)
45092	2	−38.0	0.5	3	Coulson and Caldwell (1985)

The O–C residuals (see Table 16 and upper panel of Figure 9) have been calculated with the elements:

$$C = \underset{\pm.195}{2436242.009} + \underset{\pm.000787}{34^{d}.029641} \cdot E \qquad (14)$$

Table 16. O-C residuals for KN Cen

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
34638.470	- 47	$-4\overset{d}{.}146$	pe 2	Walraven et al. (1958)
35216.974	- 30	-4.146	pe 3	Irwin (1961)
35250.816	- 29	-4.333	pe 1	Walraven et al. (1958)
37871.756	+ 48	-3.676	pe 1	Walraven et al. (1964)
40356.990	+121	-2.606	pe 2	Stobie (1970)
41106.302	+143	-1.946	pe 3	Pel (1976)
41582.839	+157	-1.824	pe 2	Grayzeck (1978)
44034.776	+229	-0.021	pe 2	Coulson and Caldwell (1985)
44647.361	+247	+0.031	pe 3	Coulson and Caldwell (1985)
45123.728	+261	-0.017	pe 3	Coulson and Caldwell (1985)

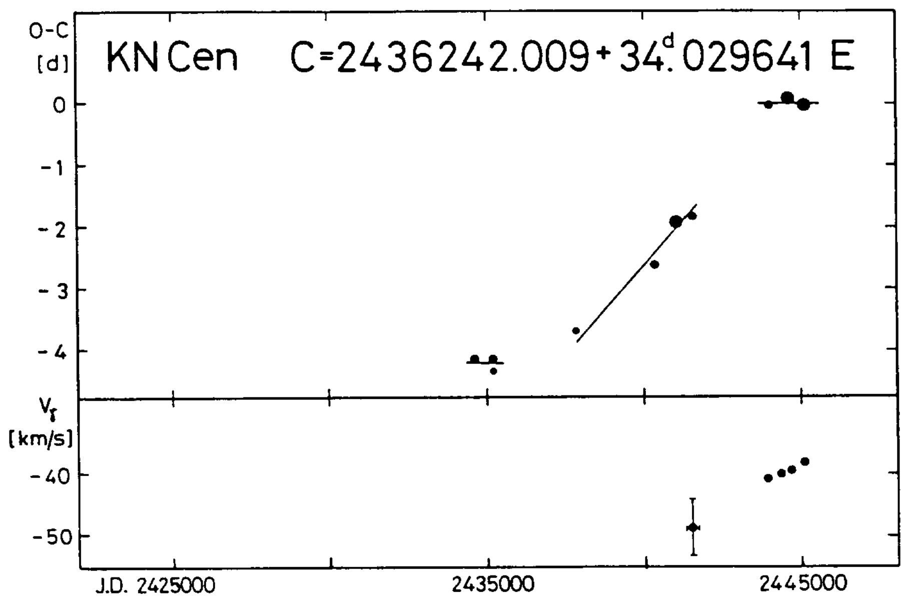

Figure 9. Upper panel: O-C diagram of KN Cen
Lower panel: γ-velocities for the same Cepheid

Three values of the pulsation period could be determined:

before J.D.2437000 $P = 34\overset{d}{.}026583 \pm \overset{d}{.}003999$

between J.D.2437000 and J.D.2444000 $P = 34\overset{d}{.}047490 \pm \overset{d}{.}001315$

after J.D.2444000 $P = 34\overset{d}{.}029641 \pm \overset{d}{.}000787$.

The first and the third value is nearly the same, i.e. a phase jump occurred, although not very suddenly.

Additional photometric and radial velocity measurements on this binary Cepheid are urgently needed both for confirming the rejump in the pulsation period, and in order to determine the orbital period.

AX Circinis

Its composite spectrum was discovered by *Jaschek* and *Jaschek* (1960). *Lloyd Evans* (1971) revealed the spectroscopic binary nature of AX Cir, while *Böhm Vitense* and *Proffitt* (1985) were able to detect the companion using IUE spectra.

The variable γ-velocity is shown in the lower panel of Figure 10 (see also Table 17). The observed extrema of the γ-velocity correspond to the full amplitude of the γ-velocity variation, as is seen in the O-C wave to be discussed below (see Figure 10).

Table 17. γ-velocities of AX Cir

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
38570	6	-17.7	0.9	6	Evans (1965)
39618	50	-26.0	1.1	4	Lloyd Evans (1968)
39900	33	-26.4	0.2	7	Lloyd Evans (1980)
40258	11	-26.8	0.6	2	Lloyd Evans (1980)
40387	46	-30.9	0.2	14	Lloyd Evans (1980)
40745	71	-33.3	0.2	15	Lloyd Evans (1980)

Table 18. O-C residuals for AX Cir

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
38220.425	+ 4	$-0^{d}.006$	pe 3	Cousins and Evans (1967)
39533.527	+253	+0.043	pe 3	Cousins and Evans (1967)
39617.878	+269	+0.021	pe 3	Mauder and Schöffel (1968)
42855.659	+883	-0.008	pe 3	Dean (1977)
42971.687	+905	+0.007	pe 3	Dean (1977)
44474.595	+1190	+0.023	pe 2	Eggen (1985)
45381.576	+1362	-0.005	pe 2	Eggen (1985)

The O-C residuals listed in Table 18 have been computed with the formula:

$$C = \underset{\pm .002}{2438199.338} + \underset{\pm .000008}{5^{d}.273306} \cdot E \qquad (15)$$

A sinusoidal term is superimposed on the straight line in the O-C graph. A weighted least squares fit applied to the O-C residuals resulted in the

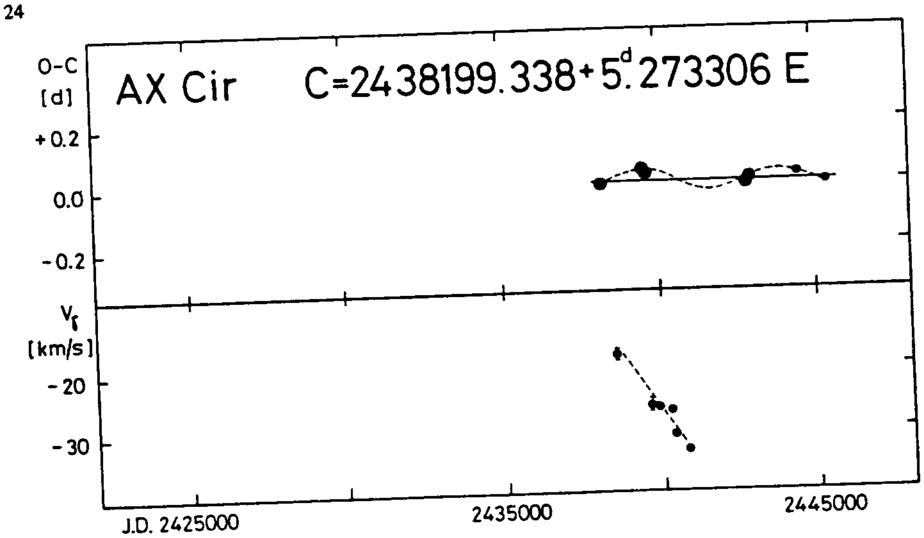

Figure 10. Upper panel: O–C diagram of AX Cir
Lower panel: γ-velocities for the same Cepheid

value of 4600 ± 83 days for the orbital period. The moments of the normal maxima can be predicted as follows:

$$C = \underset{\pm .002}{2438199.338} + \underset{\pm .000008}{5.^{d}273306} \cdot E - \underset{\pm .002}{0.^{d}032} \cos(2\pi(\underset{\pm .00002}{0.00115}E + \underset{\pm .018}{0.222})) \qquad (16)$$

Although each parameter (amplitude, phase, period) of this wave are in agreement with the pattern of the γ-velocity changes, further observations are desirable to confirm or refine the above value of the orbital period.

S Crucis

The γ-velocity of S Cru seems to be constant (see Table 19).

Table 19. γ-velocities of S Cru

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
33832	9	-6.0	1.3	6	Stibbs (1955)
34167	46	-6.9	1.1	8	Stibbs (1955)
40383	46	-5.0	0.2	7	Lloyd Evans (1980)
44423	4	-7.8	0.4	25	Gieren (1981a)

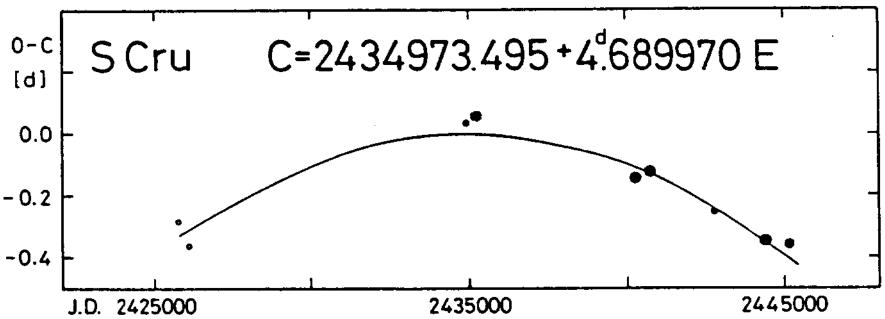

Figure 11. **O-C diagram of** S Cru

Table 20. **O-C residuals for** S Cru

Norm.max. **JD2400000+**	**E**	**O-C**	**Type, weight**	**Reference**
25785.558	-1959	$-0^{d}.286$	pg 1	Dartayet et al. (1949)
26109.086	-1890	-0.366	pg 1	Dartayet et al. (1949)
34921.939	- 11	+0.034	pe 1	Walraven et al. (1958)
35208.046	+ 50	+0.053	pe 2	Irwin (1961)
40310.536	+1138	-0.145	pe 3	Stobie (1970)
40774.862	+1237	-0.126	pe 3	Pel (1976)
42852.392	+1680	-0.253	pe 1	Dean (1977)
44414.058	+2013	-0.347	pe 3	Gieren (1981b)
45126.915	+2165	-0.365	pe 2	Eggen (1985)

The O-C residuals (listed in Table 20) have been computed with the elements:

$$C = \underset{\pm .015}{2434973.495} + \underset{\pm .000007}{4^{d}.689970} \cdot E \tag{17}$$

As is seen in Figure 11, the pulsation period is continuously decreasing. The instantaneous value of the period is:

$$P = \underset{\pm .000007}{4^{d}.689970} - \underset{\pm .109}{1^{d}.747} \cdot 10^{-7} \cdot E \tag{18}$$

where the E epoch number is the same as in equation (17).

T Crucis

On the basis of the available radial velocity measurements, variability in the γ-velocity can be suspected (see Table 21 and the lower panel of Figure 12). *Jaschek* and *Jaschek* (1956) found strong Ca II emission which may be partly caused by the presence of the companion.

Table 21. γ-velocities of T Cru

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
33831	9	-5.5	1.1	8	Stibbs (1955)
34106	19	-7.8	1.1	9	Stibbs (1955)
40363	34	-12.8	0.3	6	Lloyd Evans (1980)

Table 22. O-C residuals for T Cru

Norm.max JD2400000+	E	O-C	Type, weight	Reference
25794.799	-1299	$-0^{d}.022$	pg 1	Dartayet et al. (1949)
26117.971	-1251	-0.044	pg 1	Dartayet et al. (1949)
33814.110	- 108	+0.052	pe 2	Eggen et al. (1957)
34871.193	+ 49	+0.023	pe 3	Eggen et al. (1957)
34958.726	+ 62	+0.025	pe 1	Walraven et al. (1958)
35214.551	+ 100	-0.012	pe 2	Irwin (1961)
40318.333	+ 858	+0.008	pe 1	Stobie (1970)
40742.458	+ 921	-0.059	pe 3	Pel (1976)
41819.814	+1081	-0.014	pe 3	Dean et al. (1977)
42102.620	+1123	-0.002	pe 3	Dean et al. (1977)
42587.418	+1195	+0.006	pe 2	Dean et al. (1977)
43260.823	+1295	+0.091	pe 1	Dean (1981)

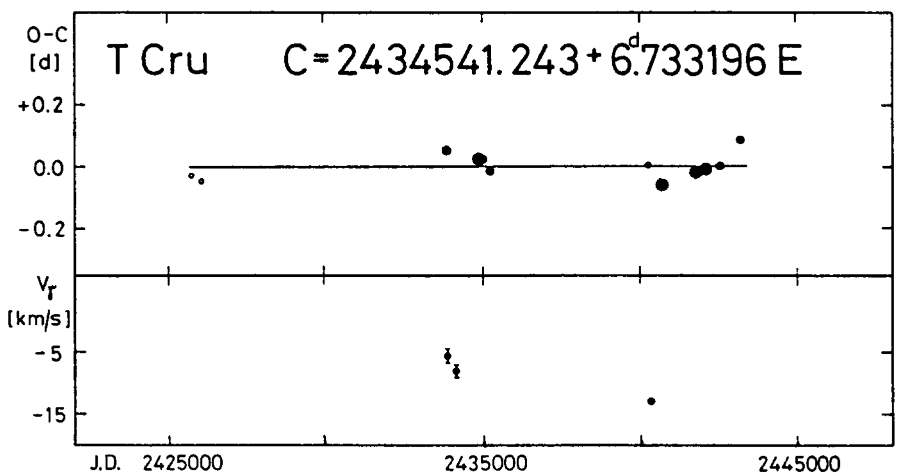

Figure 12. Upper panel: O-C diagram of T Cru
Lower panel: γ-velocities for the same Cepheid

The O-C diagram contains very few data points (see Table 22). The residuals have been calculated with the elements:

$$C = 2434541.243 + 6^{d}.733196 \cdot E \qquad (19)$$
$$\pm.010 \quad \pm.000011$$

The photographic observations have also been taken into account in the fitting procedure. If the deviations from the straight line (see Figure 12, upper panel) are caused by a light-time effect, the γ-velocity variations may well exceed the range observed so far. In any case, more photometric and spectroscopic observations are needed.

AG Crucis

Gieren (1982) already noted that AG Cru might belong to a spectroscopic binary. The present study based on the same radial velocity data (see Table 23 and the lower panel of Figure 13) confirm his conclusion. The presence of a blue companion is also suspected in *Pel*'s (1978) photometry.

Table 23. γ-velocities of AG Cru

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
34154	41	-4.4	0.8	17	Stibbs (1955)
40577	199	-6.5	0.3	5	Lloyd Evans (1980)
44423	4	-8.5	0.4	23	Gieren (1981a)

Table 24. O-C residuals for AG Cru

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
27439.121	-1947	$+1^{d}.523$	pg	O'Herne (1937)
34778.239	- 34	-0.026	pe 2	Walraven et al. (1958)
35219.538	+ 81	-0.012	pe 3	Irwin (1961)
39559.471	+1212	-0.013	pe 3	Landolt (1971)
40760.517	+1525	-0.027	pe 3	Pel (1976)
41098.205	+1613	-0.018	pe 2	Pel (1976)
42894.075	+2081	+0.017	pe 2	Dean (1977)
44421.305	+2479	+0.020	pe 3	Gieren (1981b)

Although the O-C diagram contains very few data points (see Table 24 and the upper panel of Figure 13), a sine wave can be reliably fitted to the O-C residuals. Moreover, the parameters of the light-time effect wave are in agreement with the changes in the γ-velocity. The O-C residuals have been computed with the elements:

$$C = \underset{\pm.001}{2434908.732} + \underset{\pm.000001}{3^{d}.837254}\cdot E \qquad (20)$$

and the moments of the light maxima can be predicted as follows:

$$C = \underset{\pm.001}{2434908.732} + \underset{\pm.000001}{3^{d}.837254}\cdot E - \underset{\pm.001}{0^{d}.026}\cos(2\pi(\underset{\pm.000008}{0.000604}E + \underset{\pm.012}{0.110})) \qquad (21)$$

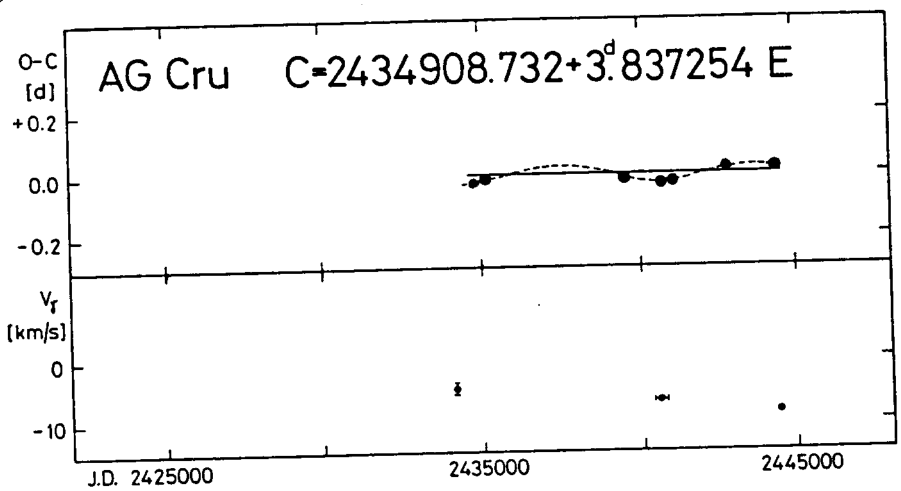

Figure 13. Upper panel: O-C diagram of AG Cru
Lower panel: γ-velocities for the same Cepheid

The orbital period is 6350 ± 90 days. According to the phase relations no radial velocity observation of AG Cru was performed during the epochs when the Cepheid was strongly moving away on its orbit. Therefore the expected amplitude of the γ-velocity variations may reach 10 km/s (see equation 1).

If the first O-C residual is correct, a period change might have occurred before J.D.2435000, but *O'Herne*'s (1937) photographic normal maximum seems to be of very low quality (this O-C residual has not been plotted in Figure 13).

BG Crucis

According to the available radial velocity observations, BG Cru is a new spectroscopic binary. Its duplicity can also be suspected on the basis of the extremely low amplitude light variations in the ultraviolet band (*Dean*, 1981). In addition to the data points listed in Table 25 (shown plotted in the lower panel of Figure 14), there is one more series of radial velocity observations (*Lunt*, 1921). These latter data, however, cannot be used because the moments of these three observations have not been published. The average value of these radial velocity measurements is -14.9 km/s, being more positive than any other γ-velocity determined for BG Cru.

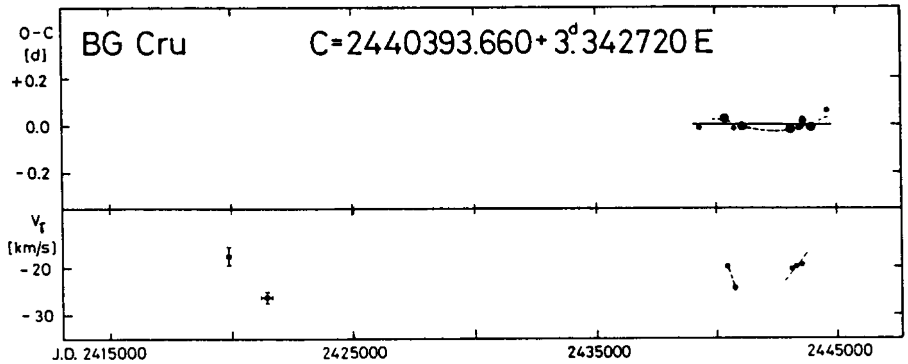

Figure 14. Upper panel: O-C diagram of BG Cru
Lower panel: γ-velocities for the same Cepheid

Table 25. γ-velocities of BG Cru

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
19902	1	-17.4	2.0	2	Campbell and Moore (1928)
21449	175	-26.2	1.2	4	Campbell and Moore (1928)
40449	9	-19.9	0.4	3	Lloyd Evans (1980)
40728	62	-24.4	0.2	16	Lloyd Evans (1980)
43178	4	-20.9	0.4	9	Stobie and Balona (1979)
43319	29	-20.0	0.3	10	Stobie and Balona (1979)
43533	4	-19.6	0.3	10	Stobie and Balona (1979)

Table 26. O-C residuals for BG Cru

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
39327.323	-319	$-0.^{d}009$	pe 1	Stobie and Alexander (1970)
40393.683	0	+0.023	pe 3	Stobie and Alexander (1970)
40771.369	+113	-0.018	pe 1	Cousins and Lagerwey (1971)
41112.338	+215	-0.007	pe 3	Cousins and Lagerwey (1971)
43181.468	+834	-0.021	pe 3	Stobie and Balona (1979)
43562.551	+948	-0.008	pe 2	Dean (1981)
43636.112	+970	+0.014	pe 2	Eggen (1985)
43997.102	+1078	-0.010	pe 3	Arellano Ferro (1981)
44622.258	+1265	+0.057	pe 1	Eggen (1985)

More than ten values could be determined as possible orbital periods using a least squares sinus fit but after comparing these values with the O-C diagram to be discussed below, three values remained as the most probable ones: 4050, 4950, and 6650 days.

The O-C residuals have been computed with the formula:

$$C = \underset{\pm .008}{2440393.660} + \underset{\pm .000010}{3.^{d}342720} \cdot E \qquad (22)$$

Although the light-time effect is apparent (see Table 26 and the upper panel of Figure 14), an exact determination of the orbital period cannot be carried out because of the limited time interval covered with photometric observations. The pattern of the O-C graph is in agreement with a nearly 5000 day long orbital period. Both much shorter and much longer values can be excluded.

β Doradus

The γ-velocity of this Cepheid variable is constant (see Table 27). *Lloyd Evans* (1968) could not find any variation larger than 3 km/s in the γ-velocity of β Dor either. Moreover, this star has not been suspected as having a companion by any other method.

Table 27. γ-velocities of β Dor

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
16619	191	5.1	1.3	6	Lunt (1924)
17297	798	7.9	0.7	12	Applegate (1927)
19129	921	6.1	1.7	4	Lunt (1924)
21712	564	8.0	0.3	54	Applegate (1927)
22815	136	6.9	0.5	35	Lunt (1924)
34024	29	8.8	0.6	23	Stibbs (1955)
40281	514	7.9	0.5	13	Lloyd Evans (1968, 1980)

Table 28. O-C residuals for β Dor

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
25639.776	-1551	$+0^{d}.108$	pg	Dartayet et al. (1949)
25993.962	-1515	-0.033	pg	Dartayet et al. (1949)
26397.617	-1474	+0.082	pg	Dartayet et al. (1949)
34438.765	- 657	-0.031	pe 1	Eggen et al. (1957)
34812.843	- 619	+0.035	pe 2	Eggen et al. (1957)
35216.360	- 578	+0.013	pe 2	Irwin (1961)
35570.654	- 542	-0.021	pe 1	Walraven et al. (1958)
40511.600	- 40	+0.028	pe 2	Hutchinson et al. (1975)
40796.967	- 11	-0.035	pe 3	Hutchinson et al. (1975)
40924.940	+ 2	-0.014	pe 3	Pel (1976)
41732.014	+ 84	-0.019	pe 3	Dean et al. (1977)
43198.610	+ 233	+0.056	pe 1	Dean (1981)
43493.849	+ 263	+0.022	pe 2	Eggen (1985)
43887.415	+ 303	-0.109	pe 1	Schmidt and Parsons (1982)
44665.128	+ 382	+0.053	pe 2	Eggen (1985)

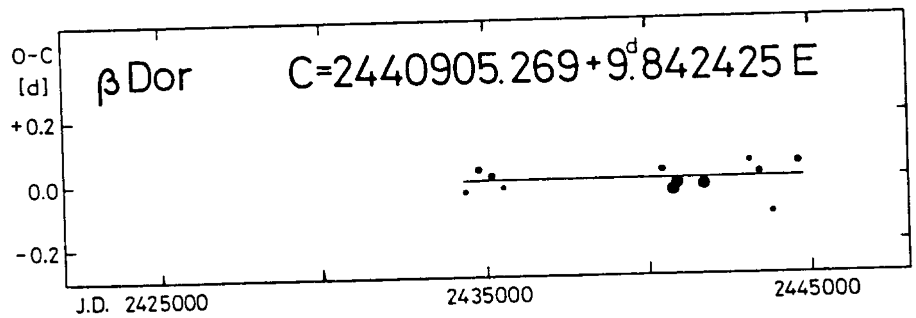

Figure 15. O-C diagram of β Dor

The early part of the O-C diagram of β Dor was published by *Iroshnikov* (1958). In the present study the O-C residuals have been calculated with the elements:

$$C = 2440905.269 + 9\overset{d}{.}842425 \cdot E \qquad (23)$$
$$\qquad\quad \pm .008 \qquad \pm .000024$$

The photoelectric part of the O-C diagram (see Table 28 and Figure 15) can be well approximated by a straight line, assuming a constant period during the last decades. A parabolic fit to these O-C residuals (including the photographic points at about J.D.2426000) would contradict to the O-C pattern determined by *Iroshnikov* (1958).

GH Lupi

The variation in the γ-velocity of GH Lupi has not been reported yet. Although the effect is not very large, it can be readily detected especially in the radial velocity observational series obtained by *Coulson* and *Caldwell* (1985) (see Table 29 and the lower panel of Figure 16). This variation might have been hidden till now because the pulsation period was not known accurately enough. The unusually low amplitude light variation

Table 29. γ-velocities of GH Lup

JD 2400000+	σ [d]	V_γ [km/s]	σ [km/s]	n	Reference
41602	214	-21.5	4.5	6	Grayzeck (1978)
43974	5	-15.0	0.4	7	Coulson and Caldwell (1985)
44408	52	-16.0	0.3	10	Coulson and Caldwell (1985)
44721	32	-16.9	0.3	17	Coulson and Caldwell (1985)
45092	2	-18.9	0.6	4	Coulson and Caldwell (1985)

Table 30. O–C residuals for GH Lup

Norm.max. JD2400000+	E	O–C	Type, weight	Reference
38202.145	-315	$-0^{d}.474$	pg	Strohmeier (1967)
41088.014	- 4	-0.047	pe 3	Pel (1976)
41413.010	+ 31	+0.221	pe 1	Grayzeck (1978)
44029.154	+313	-0.017	pe 3	Coulson and Caldwell (1985)
44455.880	+359	-0.076	pe 3	Coulson and Caldwell (1985)
44651.017	+380	+0.224	pe 1	Eggen (1985)
44734.257	+389	-0.038	pe 3	Coulson and Caldwell (1985)
45142.455	+433	-0.069	pe 2	Coulson and Caldwell (1985)
45569.543	+479	+0.233	pe 1	Eggen (1985)

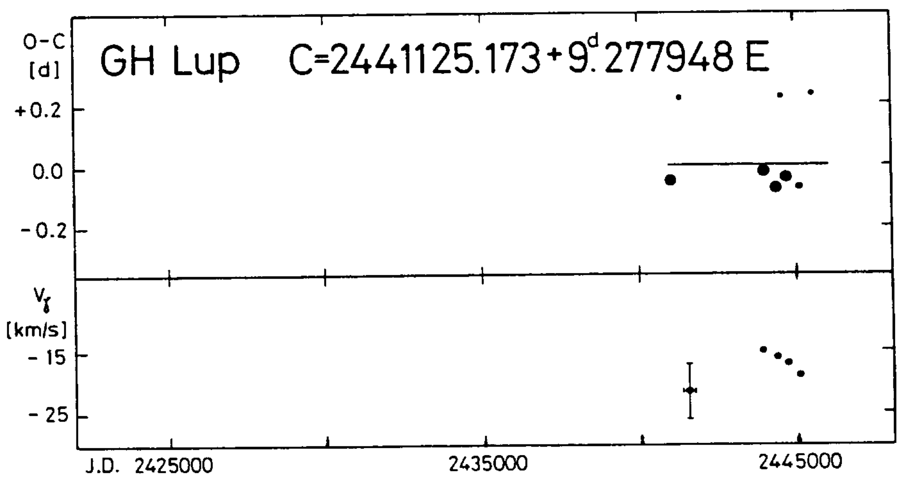

Figure 16. Upper panel: O–C diagram of GH Lup
Lower panel: γ-velocities for the same Cepheid

may be also due to the presence of a companion. *Pel*'s (1978) photometry gives evidence for a red companion.

The O–C residuals listed in Table 30 and plotted in Figure 16 (upper panel) have been computed by the formula:

$$C = 2441125.173 + 9^{d}.277948 \cdot E \qquad (24)$$
$$\pm.056 \quad \pm.000167$$

This value of the pulsation period, assumed to be constant between J.D.2441000 and 2445600, considerably differs from the value given in the GCVS (*Kholopov* et al., 1985–1987). A change in the period might have occurred before J.D.2441000, if the photographic O–C residual obtained from *Strohmeier*'s (1967) data is real.

R Muscae

The Cepheid R Muscae is probably a spectroscopic binary (*Lloyd Evans*, 1982). This earlier conclusion is confirmed here (see Table 31 and the lower panel of Figure 17). There is, however, no sign of any companion in the study made by *Eichendorf* et al. (1982) covering an exceptionally wide wavelength range.

The O–C residuals listed in Table 32 have been calculated with the elements:

$$C = \underset{\pm .020}{2426496.033} + \underset{\pm .000028}{7.^{d}510159} \cdot E \tag{25}$$

As is readily seen in Figure 17, R Mus has a continuously increasing period:

$$P = \underset{\pm .000028}{7.^{d}510159} + \underset{\pm .10}{1.^{d}25} \cdot 10^{-7} \cdot E \tag{26}$$

where the E epoch number is the same as in equation (25). The photographic O–C residuals were also taken into account during the fitting procedure. A sine-wave superimposed on the parabola was also searched for but without any physically acceptable result.

Table 31. γ-velocities of R Mus

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
33832	9	+4.2	1.2	7	Stibbs (1955)
34125	31	+2.4	1.2	7	Stibbs (1955)
40389	43	−2.0	0.2	14	Lloyd Evans (1980)
40727	67	+1.3	0.2	18	Lloyd Evans (1980)

Table 32. O–C residuals for R Mus

Norm.max JD2400000+	E	O–C	Type, weight	Reference
19346.327	− 952	$-0.^{d}035$	pg	Hertzsprung (1928)
26105.508	− 52	+0.003	pg 1	Dartayet et al. (1949)
26473.501	− 3	−0.002	pg 1	Dartayet et al. (1949)
34141.479	+1018	+0.104	pe 1	Eggen et al. (1957)
34839.906	+1111	+0.086	pe 3	Walraven et al. (1958)
34907.506	+1120	+0.094	pe 3	Eggen et al. (1957)
35207.854	+1160	+0.037	pe 3	Irwin (1961)
37836.518	+1510	+0.145	pe 3	Walraven et al. (1964)
42853.512	+2178	+0.359	pe 2	Dean (1977)
43596.970	+2277	+0.305	pe 3	Eggen (1985)
44648.445	+2417	+0.358	pe 3	Eggen (1985)

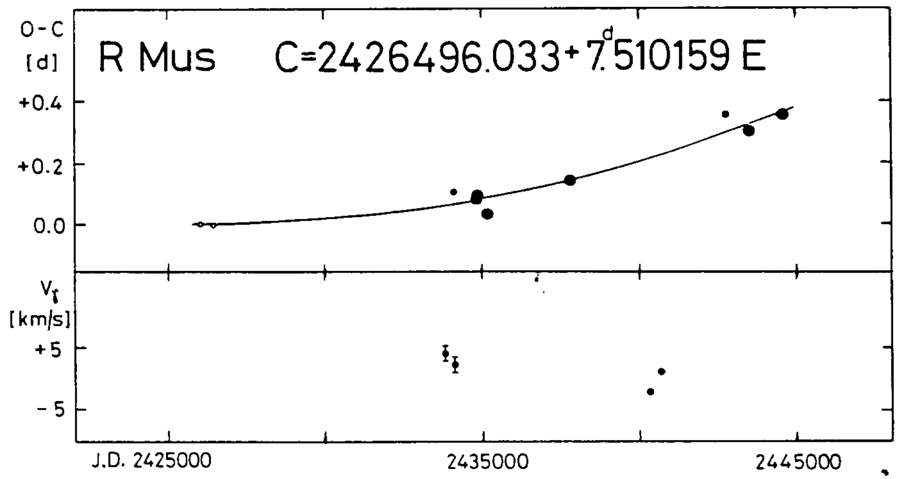

Figure 17. **Upper panel: O-C diagram of** R Mus
Lower panel: γ**-velocities for the same Cepheid**

S Muscae

This Cepheid has long been known as a spectroscopic binary. Its orbital period is 506 days (*Lloyd Evans*, 1971). The presence of a blue companion is predicted by the two-colour diagrams (*Stobie*, 1970; *Dean*, 1977; *Pel*, 1978). *Böhm-Vitense* and *Proffitt* (1985) detected the effect of the companion in the IUE spectrum of S Mus. The radial velocity observations of S Muscae are not re-discussed here.

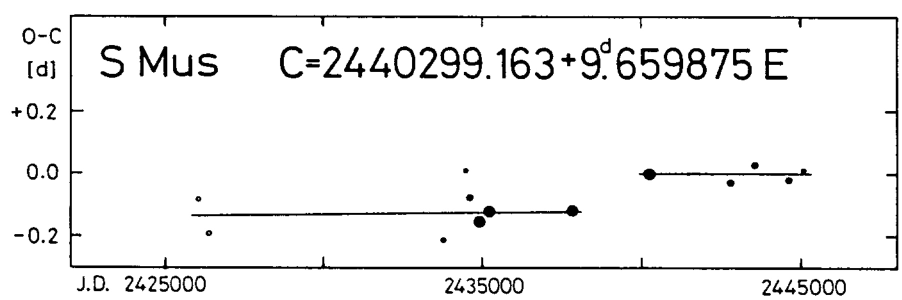

Figure 18. **O-C diagram of** S Mus

Table 33. O–C residuals for S Mus

Norm.max. JD2400000+	E	O–C	Type, weight	Reference
26128.045	−1467	$-0^{d}.081$	pg 1	Dartayet et al. (1949)
26466.032	−1432	−0.190	pg 1	Dartayet et al. (1949)
33807.521	− 672	−0.206	pe 1	Eggen et al. (1957)
34541.889	− 596	+0.012	pe 1	Eggen et al. (1957)
34628.743	− 587	−0.073	pe 2	Walraven et al. (1958)
34918.458	− 557	−0.155	pe 3	Eggen et al. (1957)
35227.609	− 525	−0.120	pe 3	Irwin (1961)
37845.449	− 254	−0.106	pe 3	Walraven et al. (1964)
40308.825	+ 1	+0.002	pe 3	Stobie (1970)
42859.006	+ 265	−0.024	pe 2	Dean (1977)
43602.870	+ 342	+0.030	pe 2	Eggen (1985)
44694.391	+ 455	−0.015	pe 2	Eggen (1985)
45148.433	+ 502	+0.013	pe 1	Eggen (1985)

The light curve of this Cepheid is double-peaked. The moment of the first maximum was used when constructing the O–C diagram. The O–C residuals listed in Table 33 have been calculated with the elements:

$$C = \underset{\pm .012}{2440299.163} + \underset{\pm .000036}{9^{d}.659875} \cdot E \qquad (27)$$

The O–C diagram in Figure 18 can be best approximated by two almost parallel lines. The phase jump occurred at about J.D.2439000, before that epoch the pulsation period was $9.659899 \pm 4.0 \cdot 10^{-5}$ days (taking into account the photographic O–C residuals, as well). The value of the phase jump was about 0.1 day, and after the phase jump the elements given in equation (27) have been valid. The parabolic fit would be somewhat worse. The amplitude of the light-time effect expected according to equation (1) is about 0.01 day, therefore this effect can hardly be pointed out in the O–C diagram of S Muscae.

S Normae

S Nor is one of the most important stars among the Cepheid variables because of its membership in the open cluster NGC 6087. This calibrating Cepheid may belong to a spectroscopic binary system (*Breger*, 1970). Its duplicity is also suspected on the basis of photometric evidence (*Madore*, 1977). The γ-velocities listed in Table 34, including more recent than *Breger*'s data suggest a variation with a period of either 3300 or 6350 days (see the lower panel of Figure 19). Even longer periods can be excluded because the corresponding light-time effect is not seen in the O-C diagram (see below).

Table 34. γ-velocities of S Nor

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
18418	11	-5.8	1.0	5	Campbell and Moore (1928)
33905	22	+3.8	0.9	12	Stibbs (1955)
34213	22	+3.5	1.2	7	Stibbs (1955)
38514	44	+5.6	0.3	12	Feast (1967)
38619	7	+9.4	0.5	5	Feast (1967)
38953	17	+7.1	0.1	20	Breger (1970)
39288	121	+8.0	1.9	2	Lloyd Evans (1968)
40377	29	+3.4	0.2	8	Lloyd Evans (1980)
40814	12	+3.1	0.3	3	Lloyd Evans (1980)
41412	4	+2.6	7.1	3	Grayzeck (1978)
41793	4	-2.4	5.8	4	Grayzeck (1978)
45772	198	+5.9	0.2	10	Mermilliod et al. (1987)
46286	53	+5.8	0.1	13	Mermilliod et al. (1987)

Table 35. O-C residuals for S Nor

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
16580.963	-2813	$+0\overset{d}{.}767$	pg	Shapley (1930)
18199.911	-2647	+0.511	pg	Shapley (1930)
20248.050	-2437	+0.259	pg	Shapley (1930)
21350.020	-2324	-0.001	pg	Shapley (1930)
23203.204	-2134	-0.123	pg	Shapley (1930)
24276.419	-2024	+0.125	pg 1	ten Bruggencate (1927a)
24676.279	-1983	+0.061	pg 1	ten Bruggencate (1927a)
25037.357	-1946	+0.232	pg 1	ten Bruggencate (1927a)
34576.828	- 968	+0.052	pe 3	Walraven et al. (1958)
35230.372	- 901	+0.062	pe 3	Irwin (1961)
36830.115	- 737	+0.109	pe 2	Fernie (1961)
37844.464	- 633	+0.016	pe 3	Walraven et al. (1964)
38888.164	- 526	+0.012	pe 3	Breger (1970)
39268.525	- 487	-0.042	pe 3	Breger (1970)
39678.266	- 445	+0.021	pe 2	Schmidt (1971)
41424.213	- 266	-0.042	pe 1	Grayzeck (1978)
41882.705	- 219	0.000	pe 3	Dean et al. (1977)
42545.994	- 151	+0.001	pe 3	Dean et al. (1977)
43492.182	- 54	+0.027	pe 3	Dean (1981)
43784.761	- 24	-0.021	pe 2	Eggen (1980)

The O-C residuals have been computed with the ephemeris:

$$C = \underset{\pm .009}{2444018.884} + \underset{\pm .000024}{9\overset{d}{.}754244} \cdot E \qquad (28)$$

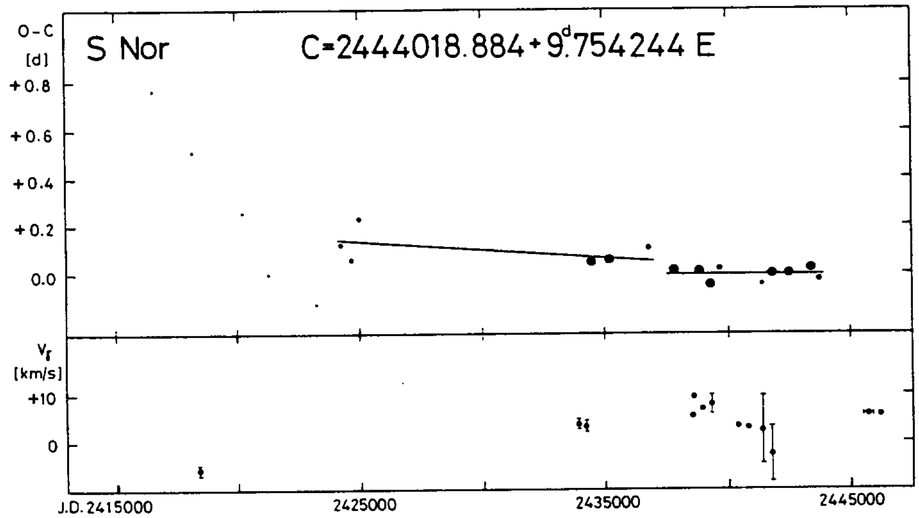

Figure 19. **Upper panel: O-C diagram of S Nor**
Lower panel: γ-velocities for the same Cepheid

The O-C diagram is approximated by two sections of almost parallel lines (see Table 35 and the upper panel of Figure 19). Before the phase jump the most reliable photographic observations have been taken into account in the fitting procedure which resulted in the period P = 9.754190 $\pm 3.0 \cdot 10^{-5}$ days. The phase jump might have occurred at about J.D.2437500, and it amounted to 0.06 day. The observed changes in the γ-velocity are too small to cause any noticeable light-time effect, assuming an orbital period of several thousand days.

RS Normae

RS Nor has been completely neglected spectroscopically: there is not a single radial velocity measurement published in the literature. The situation is not much better as far as photometric observations are concerned, because the O-C diagram (see Table 36 and Figure 20) contains a few scattered points. *Madore* (1977) gives evidence for a B8 dwarf photometric companion.

The O-C residuals have been computed with the elements:

$$C = \underset{\pm .009}{2435308.175} + \underset{\pm .000012}{6\overset{d}{.}198136} \cdot E \qquad (29)$$

Table 36. **O–C residuals for** RS Nor

Norm.max. JD2400000+	E	O–C	Type, weight	Reference
25583.330	-1569	$+0^{d}.030$	pg 1	Kruytbosch (1930b)
34737.872	- 92	-0.074	pe 1	Walraven et al. (1958)
35227.600	- 13	+0.001	pe 3	Irwin (1961)
35332.962	+ 4	-0.006	pe 1	Walraven et al. (1958)
40768.737	+ 881	+0.004	pe 3	Pel (1976)
41103.449	+ 935	+0.017	pe 2	Pel (1976)

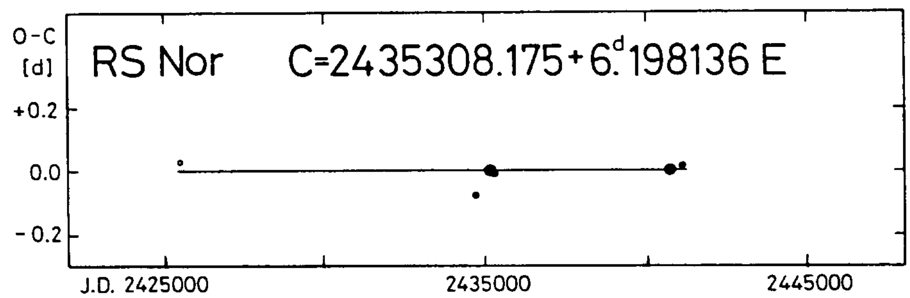

Figure 20. **O–C diagram of** RS Nor

The early photographic observations were also used when determining the average pulsation period.

SY Normae

An early type photometric companion to this Cepheid was suspected by *Madore* (1977). A companion was later found using IUE measurements (*Böhm-Vitense* and *Proffitt*, 1985) but it cannot be ruled out that these two stars form only an optical pair. Radial velocity measurements would be very important in order to find the physical relation between the two stars, if it really exists. The only available radial velocity data published by *Grayzeck* (1978) are not suitable for drawing any conclusion.

The O–C residuals listed in Table 37 and plotted in Figure 21 have been calculated with the elements:

$$C = \underset{\pm .004}{2440731.750} + \underset{\pm .000016}{12^{d}.645687} \cdot E \qquad (30)$$

The pulsation period has been stable since J.D.2434700. It is worth mentioning that the moment of the normal maximum given in equation (30) strongly differs from the value given in the GCVS (*Kholopov* et al.,

Table 37. O-C residuals for SY Nor

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
25600.646	-1197	$+5\overset{d}{.}783$	pg	Kruytbosch (1930a)
34750.337	- 473	-0.003	pe 3	Walraven et al. (1958)
35218.235	- 436	+0.005	pe 3	Irwin (1961)
40390.261	- 27	-0.055	pe 1	Stobie (1970)
40769.693	+ 3	+0.006	pe 3	Pel (1976)
41111.126	+ 30	+0.005	pe 3	Pel (1976)
41591.643	+ 68	-0.014	pe 2	Grayzeck (1978)
41920.457	+ 94	+0.012	pe 3	Madore (1975)

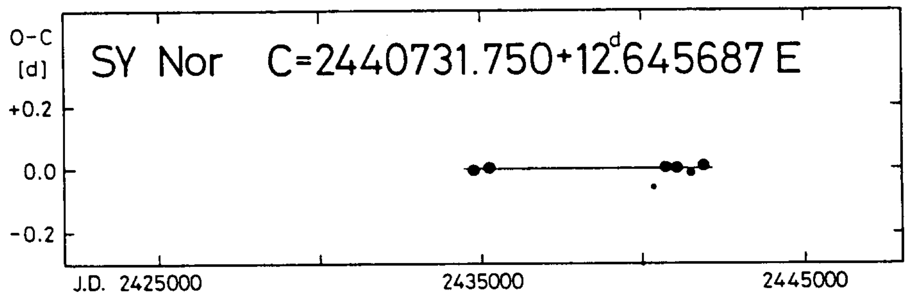

Figure 21. **O-C diagram of** SY Nor

1985-1987). This deviation is probably caused by *Kruytbosch*'s (1930a) ephemeris. Unfortunately the original photographic observations have not been published, therefore it cannot be decided whether there was a real period change, or *Kruytbosch* published an erroneous ephemeris.

Y Ophiuchi

Y Oph belongs to a spectroscopic binary system. Its orbital period was determined by *Abt* and *Levy* (1978) as being 2612 days. *Evans* and *Lyons* (1986) questioned this value of the orbital period, and even doubted the variability in the γ-velocity. The presence of a blue photometric companion is suspected by *Pel* (1978) but such a blue star is not seen in an IUE spectrum (*Evans* and *Lyons*, 1986). All the available radial velocity data were subjected to a period analysis which resulted in the value of 1222.5 ± 10 days for the orbital period. The γ-velocities are listed in Table 38, and the orbital radial velocity curve folded with the recently determined period is shown in Figure 22. In this figure open circles denote

Table 38. γ-velocities of Y Oph

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
17066	27	-4.9	0.3	42	Albrecht (1907)
17440	6	-9.4	2.0	2	Albrecht (1907)
25356	13	-4.8	1.0	5	Sanford (1935)
26549	32	-1.0	0.6	14	Sanford (1935)
26911	35	-8.3	0.8	7	Sanford (1935)
27226	45	-11.8	0.6	11	Sanford (1935)
34482	29	-7.0	0.6	12	Abt (1954)
34599	32	-7.9	1.1	4	Abt (1954)
40365	36	-5.8	0.2	9	Lloyd Evans (1980)
40718	25	-7.8	0.5	4	Abt and Levy (1978)
40762	50	-6.4	0.2	7	Lloyd Evans (1980)
40792	28	-7.3	0.4	4	Evans and Lyons (1986)
41110	23	-6.3	0.5	3	Evans and Lyons (1986)
41116	36	-7.2	0.6	4	Abt and Levy (1978)
41534	79	-6.1	0.3	6	Abt and Levy (1978)
42228	86	-6.5	0.2	3	Abt and Levy (1978)
42565	35	-7.3	0.3	2	Abt and Levy (1978)
42900	27	-10.1	0.5	6	Abt and Levy (1978)
43281	26	-8.2	0.5	4	Abt and Levy (1978)
43350	46	-9.4	1.1	13	Wilson et al. (1989)
43639	46	-5.1	1.0	17	Barnes et al. (1987)
43976	5	-5.8	0.5	5	Coulson and Caldwell (1985)
44013	58	-10.1	1.1	12	Barnes et al. (1987)
44049	4	-9.0	0.5	3	Evans and Lyons (1986)
44181	3	-10.0	1.0	2	Coulson and Caldwell (1985)
44415	47	-6.4	0.4	9	Coulson and Caldwell (1985)
44446	23	-7.9	0.5	3	Evans and Lyons (1986)
44449	1	-12.5	1.3	1	Beavers and Eitter (1986)
44759	36	-8.8	0.6	4	Coulson and Caldwell (1985)
44819	25	-6.2	0.7	2	Evans and Lyons (1986)
45092	2	-7.2	0.7	3	Coulson and Caldwell (1985)
45388	1	-9.5	2.7	3	Barnes et al. (1987)
45501	21	-8.6	0.3	6	Evans and Lyons (1986)
45875	1	-9.9	0.7	1	Evans and Lyons (1986)

those low weight γ-velocities that are based on one or two radial velocity measurements. The semi-amplitude of the orbital radial velocity variations is 1.60 ± 0.47 km/s. In spite of its low amplitude, the orbital effect seems to be real because its consequences also appear in the O-C diagram (see below).

The early part of the O-C diagram was constructed by *Detre* (1970). In the present paper all the photoelectric and photographic series of observations are discussed. The O-C residuals listed in Table 39 have been calculated with the elements:

$$C = \underset{\pm .033}{2439853.173} + \underset{\pm .000139}{17\overset{d}{.}126908} \cdot E \qquad (31)$$

Table 39. O-C residuals for Y Oph

Norm.max JD2400000+	E	O-C	Type, weight	Reference
25077.192	-863	$+4^{d}.541$	pg	ten Bruggencate (1927b)
32781.493	-413	+1.733	pe 2	Eggen (1951)
33106.646	-394	+1.475	pe 3	Eggen (1951)
34322.185	-323	+1.003	pe 3	Abt (1954)
34733.130	-299	+0.902	pe 2	Walraven et al. (1958)
35281.188	-267	+0.899	pe 3	Irwin (1958)
35691.858	-243	+0.524	pe 2	Prokof'yeva (1961)
37079.101	-162	+0.487	pe 2	Mitchell et al. (1964)
37472.819	-139	+0.286	pe 1	Mitchell et al. (1964)
37815.507	-119	+0.436	pe 1	Williams (1966)
38603.166	- 73	+0.257	pe 1	Wisniewski and Johnson (1968)
39014.145	- 49	+0.190	pe 3	Wisniewski and Johnson (1968)
39682.123	- 10	+0.219	pe 3	Schmidt (1971)
40401.559	+ 32	+0.325	pe 1	Feltz and McNamara (1980)
40778.016	+ 54	-0.010	pe 3	Pel (1976)
40812.402	+ 56	+0.122	pe 1	Feltz and McNamara (1980)
40829.354	+ 57	-0.053	pe 2	Evans (1976)
41188.978	+ 78	-0.093	pe 2	Feltz and McNamara (1980)
42953.217	+181	+0.074	pe 3	Dean (1977)
43038.950	+186	+0.172	pe 2	Dean (1981)
43312.747	+202	-0.061	pe 3	Moffett and Barnes (1984)
43672.337	+223	-0.136	pe 2	Moffett and Barnes (1984)
44015.145	+243	+0.133	pe 3	Moffett and Barnes (1984)
44032.132	+244	-0.007	pe 2	Coulson and Caldwell (1985)
44443.162	+268	-0.022	pe 3	Coulson and Caldwell (1985)
44460.261	+269	-0.050	pe 3	Eggen (1983b)
44871.342	+293	-0.015	pe 3	Coulson and Caldwell (1985)
46292.876	+376	-0.014	pe 3	Berdnikov (1987)
46601.179	+394	+0.004	pe 1	Lloyd et al. (1987)

Table 40. Changes in the pulsation period of Y Oph

J.D. interval	P
2432781 - 2433106	$17^{d}.113288 \pm .000010$
34733 - 35281	$17.126813 \pm .000007$
35281 - 35691	$17.111255 \pm .000001$
39014 - 39682	$17.127643 \pm .000001$
40778 - 46601	$17.126908 \pm .000139$

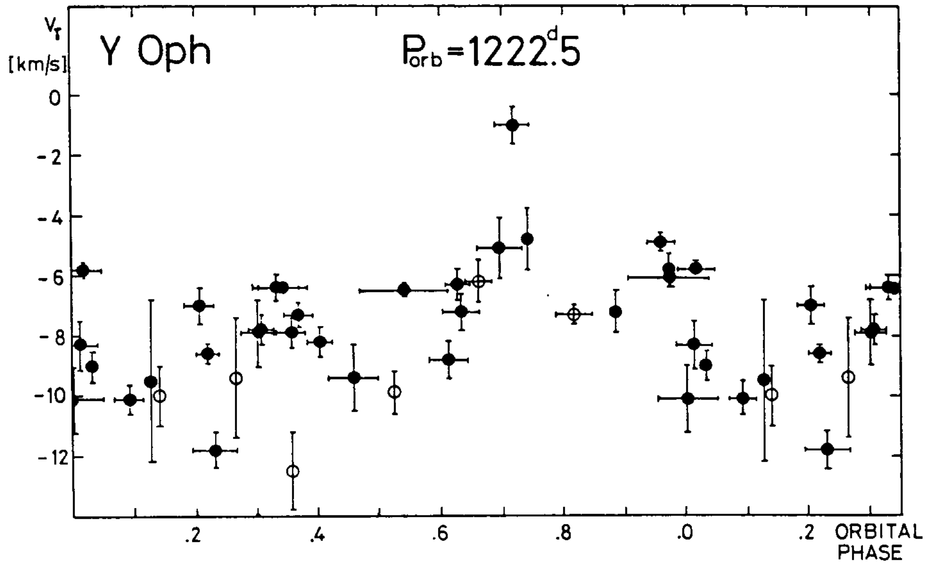

Figure 22. **Orbital velocity curve of Y Oph**

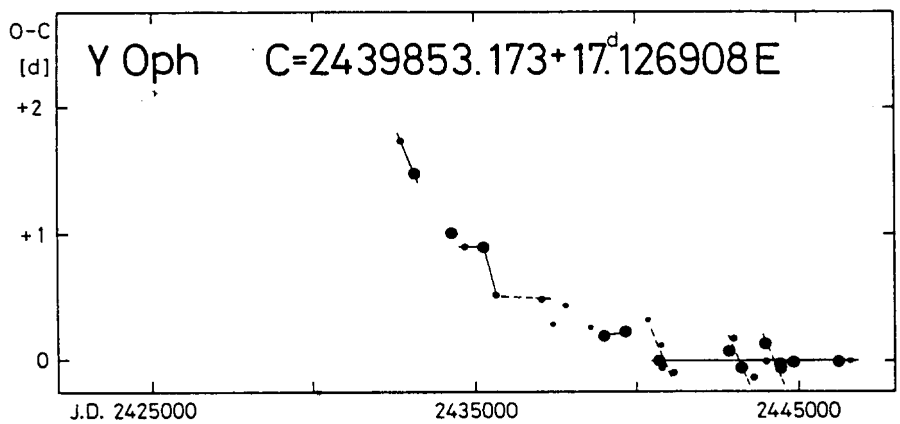

Figure 23. **O-C diagram of Y Oph**

The O-C diagram (see Figure 23) is of complex structure. It is approximated with sections of straight lines, representing two characteristic periods: either 17.112 or 17.127 days. Table 40 summarizes the individual periods and the time intervals in which the given period was valid.

The alternating periods can be considered as a special case of the phase jump: there is an interval of finite length when the star pulsates with another period before returning to the "original" pulsation period. As in the previous cases, the phase jump is a characteristic feature of binary Cepheids. Moreover, the final part of the O-C diagram (after J.D.2440000) shows unusually wide scatter, if approximated by a single period. The dashed lines, however, suggest that this part also consists of several phase jumps, and the predominant period is the shorter one (17.112 days). The cyclic occurrence of this pulsation period can also be suspected, the cycle length being about 2400 days in the first case, and about 1200 days in the second case (N.B. the orbital period determined above is just over 1200 days). This phenomenon cannot be interpreted as a light-time effect because of the large amplitude but it gives a further support to the reality of the 1222.5 day spectroscopic orbital period, and calls the attention that the binary companion is able to control the changes in the pulsation period.

BF Ophiuchi

According to *Mianes* (1963) and *Balona* (1977), BF Oph has a red photometric companion, while *Gieren* (1982) already suspected the spectroscopic binary nature of this Cepheid. The analysis of the available radial velocity data (see Table 41) suggests an orbital period of 4420 ± 80 days. The orbital velocity curve is shown in Figure 24. Although the plot of the data is not too convincing, this period is also supported by the features in the O-C diagram (see below).

Table 41. γ-velocities of BF Oph

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25597	219	-32.5	2.6	4	Joy (1937)
26152	45	-33.2	2.2	5	Joy (1937)
33905	21	-30.0	1.1	9	Stibbs (1955)
34199	14	-31.8	1.5	5	Stibbs (1955)
40559	210	-29.4	0.2	13	Lloyd Evans (1980)
44233	207	-28.3	1.1	13	Barnes et al. (1988)
44423	4	-29.2	0.4	22	Gieren (1981a)
44945	295	-28.2	2.3	4	Barnes et al. (1988)

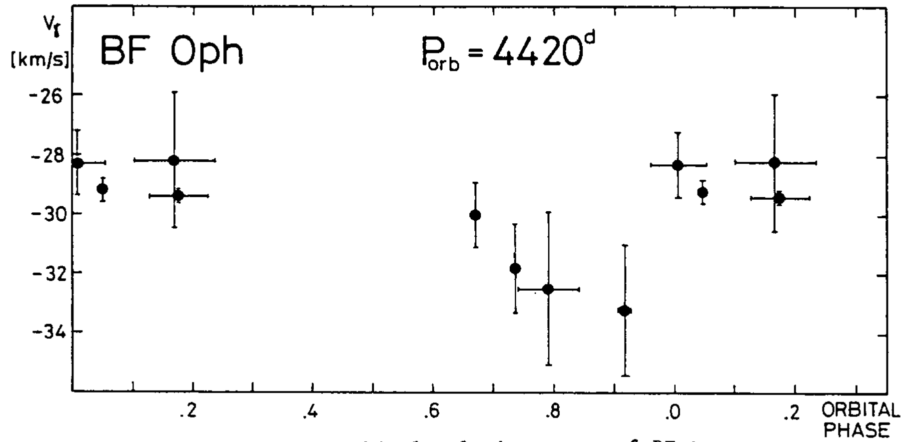

Figure 24. Orbital velocity curve of BF Oph

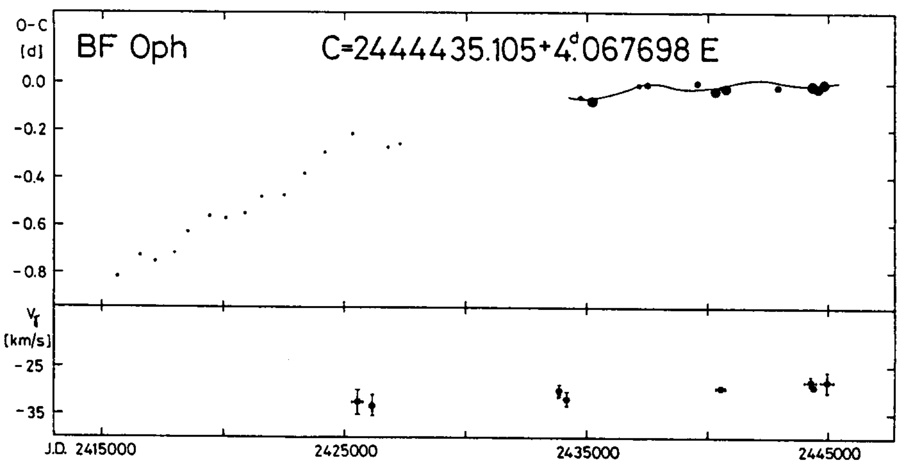

Figure 25. Upper panel: O–C diagram of BF Oph
Lower panel: γ-velocities for the same Cepheid

The O–C residuals listed in Table 42 have been calculated with the elements:

$$C = \underset{\pm.005}{2444435.105} + \underset{\pm.000001}{4\overset{d}{.}067698}\cdot E \qquad (32)$$

The O–C diagram (Figure 25) can be best represented by a sine-wave superimposed on a parabola. The moments of the normal maxima can be predicted as follows:

$$C = \underset{\pm.005}{2444435.105}+\underset{\pm.000001}{4\overset{d}{.}067698}E-\underset{\pm.89}{4\overset{d}{.}87}\cdot 10^{-9}\cdot E^2-\underset{\pm.005}{0\overset{d}{.}017}\cos(2\pi(\underset{\pm.000073}{0.000904}E+\underset{\pm.081}{0.046})) \qquad (33)$$

Table 42. O-C residuals for BF Oph

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
15618.712	-7084	$-0^{d}.820$	pg	Shapley (1930)
16558.440	-6853	-0.731	pg	Shapley (1930)
17180.773	-6700	-0.755	pg	Shapley (1930)
18030.957	-6491	-0.720	pg	Shapley (1930)
18572.053	-6358	-0.628	pg	Shapley (1930)
19479.214	-6135	-0.564	pg	Shapley (1930)
20069.022	-5990	-0.572	pg	Shapley (1930)
20870.376	-5793	-0.554	pg	Shapley (1930)
21541.624	-5628	-0.477	pg	Shapley (1930)
22440.589	-5407	-0.473	pg	Shapley (1930)
23351.842	-5183	-0.384	pg	Shapley (1930)
24149.199	-4987	-0.296	pg	Shapley (1930)
25320.776	-4699	-0.216	pg	Shapley (1930)
26781.021	-4340	-0.275	pg	O'Connell (1937)
27269.159	-4220	-0.260	pg	O'Connell (1937)
34790.528	-2371	-0.065	pe 1	Walraven et al. (1958)
35229.827	-2263	-0.077	pe 3	Irwin (1961)
37113.244	-1800	-0.005	pe 1	Mitchell et al. (1964)
37471.204	-1712	-0.002	pe 2	Mitchell et al. (1964)
39549.798	-1201	-0.002	pe 2	Takase (1969)
40338.898	-1007	-0.035	pe 3	Stobie (1970)
40761.959	- 903	-0.015	pe 3	Pel (1976)
42856.824	- 388	-0.014	pe 2	Dean (1977)
44361.869	- 18	-0.017	pe 3	Moffett and Barnes (1984)
44414.749	- 5	-0.018	pe 3	Gieren (1981b)
44809.332	+ 92	-0.001	pe 3	Eggen (1985)

Here only the photoelectric O-C residuals have been taken into account. According to the cosine term, the orbital period is 4500 ± 360 days, being in a very good agreement with the spectroscopic value. The amplitude and the phase of the wave is also adequate to the spectroscopic binary interpretation of the γ-velocity changes. It is worth mentioning that, according to this value of the orbital period, BF Oph has not been observed spectroscopically during the orbital phases when the Cepheid is strongly moving away from us, i.e. the amplitude of the γ-velocity variations is larger than observed so far.

A simple parabolic fit applied to the whole set of O-C residuals resulted in the pulsation period as a function of time:

$$C = \underset{\pm.000008}{4^{d}.067665} - \underset{\pm.22}{4^{d}.12} \cdot 10^{-8} \cdot E \qquad (34)$$

where the E epoch number is the same as in equations (32) and (33).

AP Puppis

This Cepheid is likely to be a spectroscopic binary with one of the largest orbital velocity amplitude (see Table 43 and the lower panel of Figure 26). The extremely large shift between *Joy*'s (1937) and the more recent radial velocity data was already noted by *Lloyd Evans* (1982) but no subsequent radial velocity observations followed this discovery.

The O-C residuals have been calculated with the elements:

$$C = \underset{\pm.019}{2440689.133} + \underset{\pm.000027}{5\overset{d}{.}084274}\cdot E \qquad (35)$$

Table 43. γ-velocities of AP Pup

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
28620	27	46.1	2.3	5	Joy (1937)
33980	26	17.0	0.7	21	Stibbs (1955)
34138	36	18.5	3.0	2	Stibbs (1955)
40335	17	13.7	0.3	4	Lloyd Evans (1980)
40629	8	13.0	0.4	3	Lloyd Evans (1980)

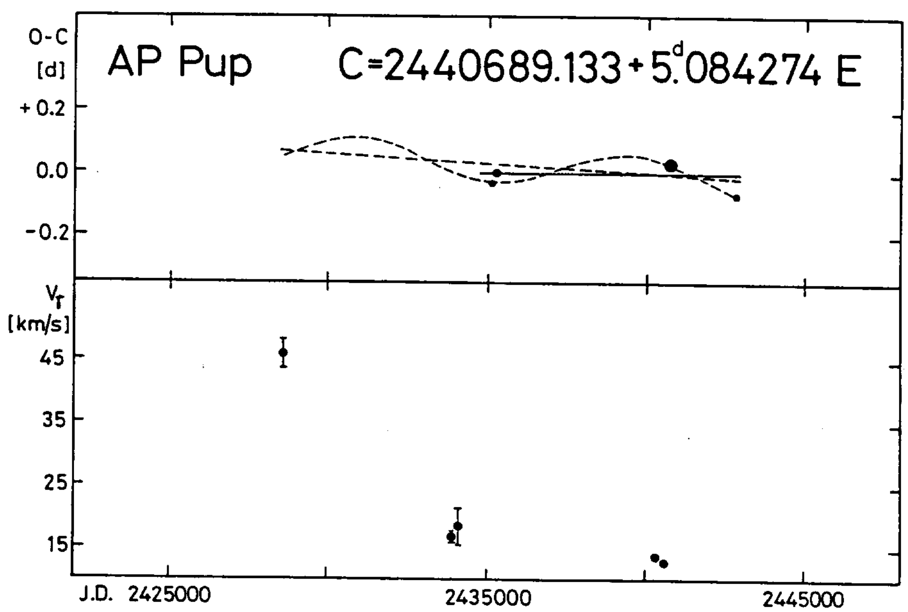

Figure 26. Upper panel: O-C diagram of AP Pup
Lower panel: γ-velocities for the same Cepheid

Table 44. O-C residuals for AP Pup

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
35182.832	-1083	$-0\overset{d}{.}032$	pe 1	Irwin (1961)
35299.806	-1060	+0.003	pe 2	Walraven et al. (1958)
40740.008	+ 10	+0.032	pe 3	Pel (1976)
42854.964	+ 426	-0.070	pe 1	Dean (1977)

The small number of the photometric observational series (see Table 44 and the upper panel of Figure 26) does not allow a reliable search for the light-time effect expected in this binary system. The plot of the O-C residuals can be approximated by a free-hand sinusoidal term (taking into account the phases prescribed by the γ-velocity variations) suggesting a long (about 9000 - 10000 days) orbital period, and a slightly shorter pulsation period than used in equation (35). Any further photometric and/or spectroscopic observations may play a decisive role in determining the orbital period of this neglected star.

AT Puppis

The changing γ-velocity of AT Pup was first reported by *Gieren* (1985). His conclusion is confirmed here (see Table 45 and the lower panel of Figure 27).

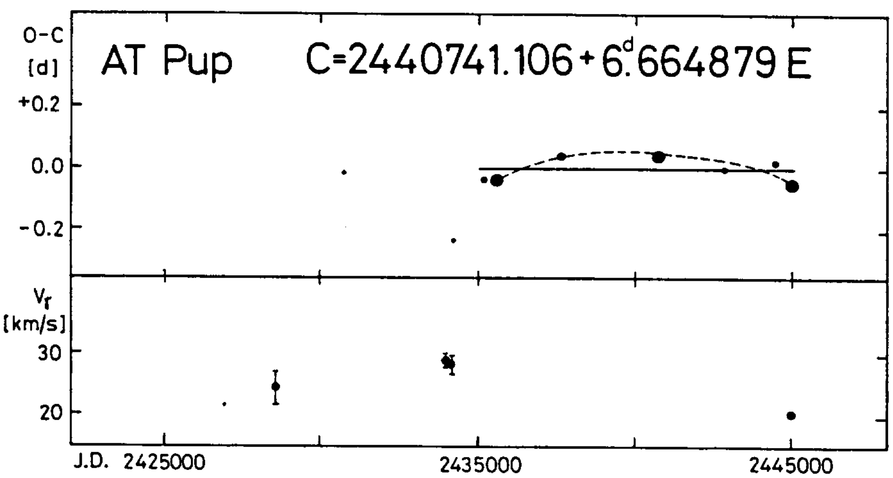

Figure 27. Upper panel: O-C diagram of AT Pup
Lower panel: γ-velocities for the same Cepheid

Table 45. γ-velocities of AT Pup

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
28614	25	24.2	2.6	4	Joy (1937)
34019	42	29.1	0.8	16	Stibbs (1955)
34163	20	28.2	1.5	5	Stibbs (1955)
45042	2	20.6	0.5	20	Gieren (1985)

Table 46. O-C residuals for AT Pup

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
30750.437	-1499	$-0^{d}.015$	pg	Erleksova (1961)
34142.642	- 990	-0.234	pg	Erleksova (1961)
35215.887	- 829	-0.034	pe 1	Irwin (1961)
35589.121	- 773	-0.034	pe 3	Walraven et al. (1958)
37648.645	- 464	+0.043	pe 2	Mitchell et al. (1964)
40741.152	0	+0.046	pe 3	Pel (1976)
42893.867	+ 323	+0.005	pe 1	Dean (1977)
44513.455	+ 566	+0.027	pe 1	Eggen (1985)
45046.576	+ 646	-0.042	pe 3	Gieren (1985)

The O-C residuals have been calculated with the ephemeris:

$$C = \underset{\pm .011}{2440741.106} + \underset{\pm .000020}{6^{d}.664879} \cdot E \qquad (36)$$

Gieren's (1985) observations made in 1981 were omitted because there can be a systematic error of unknown origin in the published moments of the observations in the case of each of the three stars (AT Pup, T Vel, V Vel) studied here from his sample. Such an error is not present in *Gieren*'s 1982 observations, both the O-C residual, and the light curve is the most reliable among the observations on AT Pup. This latter statement is also true for the 1982 observations on T Vel and V Vel.

The wave-like pattern of the photoelectric O-C residuals (see Table 46 and the upper panel of Figure 27), together with the variation in the γ-velocity, is in accord with a very long (about 20000 days) orbital period. From the radial velocity observations alone the orbital period can be much shorter but in that case the light-time effect interpretation of the O-C diagram fails.

MY Puppis

No variability in the γ-velocity of MY Pup is seen in the available data (see Table 47).

The O-C residuals have been computed with the elements:

$$C = 2441043.597 + 5^{d}.694998 \cdot E \qquad (37)$$
$$\pm.013 \quad \pm.000031$$

The plot of the O-C residuals (see Table 48 and Figure 28) can be well approximated by a parabola. This is the only star in this sample where

Table 47. γ-velocities of MY Pup

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
24422	301	11.4	1.0	5	Neubauer (1929)
43172	56	13.4	0.2	23	Stobie and Balona (1979)
43533	4	12.8	0.4	9	Stobie and Balona (1979)

Table 48. O-C residuals for MY Pup

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
24421.80	-2919	$+1^{d}.90$	v_r 1	Neubauer (1929)
39107.348	- 340	+0.050	pe 1	Stobie (1972)
41043.599	0	+0.002	pe 3	Stobie (1972)
43184.919	+ 376	+0.003	pe 3	Stobie and Balona (1979)
44284.122	+ 569	+0.071	pe 1	Eggen (1985)
44568.948	+ 619	+0.147	pe 1	Eggen (1985)

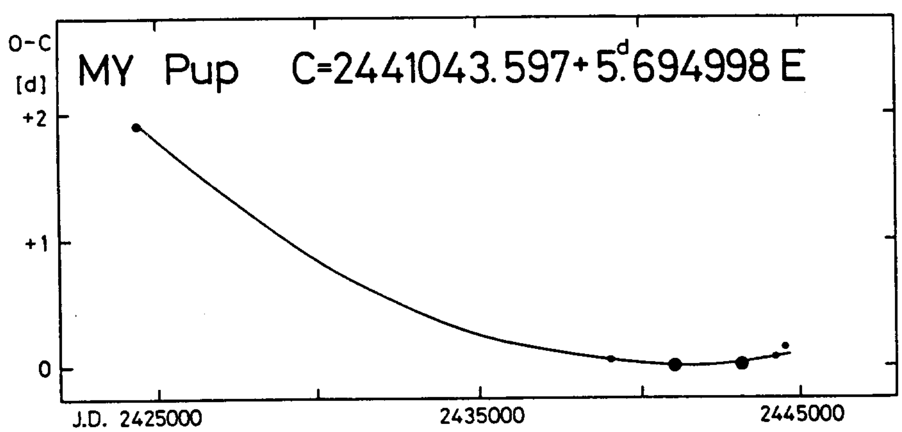

Figure 28. O-C diagram of MY Pup

radial velocity measurements were also used when determining the shape of the O-C graph. The period change has been so strong since the twenties that it could not be avoided making exceptions lacking suitable photometric observations. The continuously increasing period can be calculated as follows:

$$P = 5\overset{d}{.}694998 + 4\overset{d}{.}47 \cdot 10^{-7} \cdot E \qquad (38)$$
$$\pm.000031 \quad \pm.12$$

where E corresponds to the epoch number used in equation (37).

U Sagittarii

U Sgr is the other "classical" cluster-member Cepheid, it belongs to the open cluster M25. Duplicity of U Sgr has long been debated, the various pieces of evidence are summarized by *Leonard* and *Turner* (1986). *Gieren* (1982) suspected the variation in the γ-velocity, preferring a long orbital period, similarly to an earlier study performed by *Wallerstein* (1960). Table 49 summarizes the γ-velocities of U Sgr. *Joy*'s (1937) and *Hayford*'s (1932) data have been omitted because of much lower quality of those early observations. The 800 - 8000 day interval was studied when searching for the possible orbital period. The best curve was obtained at P_{orb} = 4550 ± 230 days. The γ-velocities folded with this period are shown

Table 49. γ-velocities of U Sgr

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
33916	33	3.5	0.8	14	Stibbs (1955)
34202	27	5.1	2.1	3	Stibbs (1955)
37223	151	3.8	0.6	11	Jacobsen (1970)
38200	28	3.7	2.0	2	Jacobsen (1970)
38955	19	6.8	0.5	14	Breger (1967)
39314	1	5.0	2.0	1	Jacobsen (1970)
39377	5	3.5	1.9	2	Lloyd Evans (1968)
40392	49	3.0	0.2	7	Lloyd Evans (1980)
40816	12	1.4	0.4	3	Lloyd Evans (1980)
43361	42	3.4	1.2	12	Wilson et al. (1989)
43668	31	7.1	1.2	11	Barnes et al. (1987)
44015	61	2.7	1.4	8	Barnes et al. (1987)
44112	146	2.9	0.2	6	Mermilliod et al. (1987)
44423	4	0.1	0.4	26	Gieren (1981a)
45182	18	2.0	0.5	2	Mermilliod et al. (1987)
45880	3	2.0	0.3	4	Mermilliod et al. (1987)
46275	10	2.6	0.1	30	Mermilliod et al. (1987)

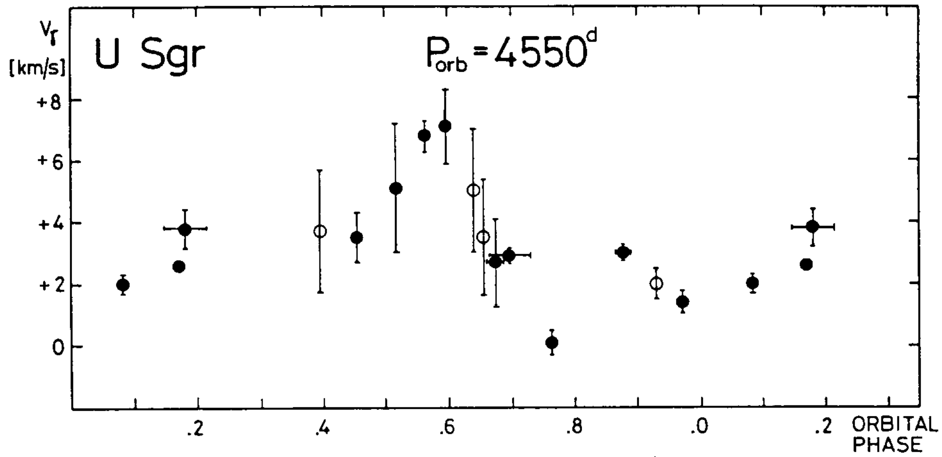

Figure 29. Orbital velocity curve of U Sgr

Table 50. O–C residuals for U Sgr

Norm.max JD2400000+	E	O–C	Type, weight	Reference
14496.341	−2316	$+0^d.336$	vis	Pickering (1904)
15946.443	−2101	+0.214	pg	Shapley (1930)
17329.147	−1896	+0.146	pg	Shapley (1930)
18475.855	−1726	+0.165	pg	Shapley (1930)
19609.067	−1558	+0.179	pg	Shapley (1930)
20459.006	−1432	+0.219	pg	Shapley (1930)
21308.978	−1306	+0.292	pg	Shapley (1930)
23244.642	−1019	+0.075	pg	Shapley (1930)
24674.684	− 807	+0.129	pg	Voute and ten Bruggencate (1927)
24694.765	− 804	−0.026	pg	Shapley (1930)
25059.149	− 750	+0.116	pg	Voute and ten Bruggencate (1927)
33133.030	+ 447	−0.042	pe 2	Eggen (1951)
34758.595	+ 688	−0.078	pe 2	Walraven et al. (1958)
35284.729	+ 766	−0.071	pe 3	Irwin (1961)
35952.493	+ 865	−0.085	pe 2	Johnson (1960)
36782.149	+ 988	−0.092	pe 3	Sandage (1960)
37099.195	+1035	−0.072	pe 3	Wampler et al. (1961)
37119.444	+1038	−0.059	pe 2	Mitchell et al. (1961)
37180.138	+1047	−0.072	pe 2	Mitchell et al. (1964)
37800.793	+1139	+0.022	pe 1	Williams (1966)
38920.467	+1305	−0.012	pe 2	Wisniewski and Johnson (1968)
39675.918	+1417	−0.026	pe 2	Schmidt (1971)
40788.948	+1582	+0.041	pe 3	Pel (1976)
40829.379	+1588	0.000	pe 1	Feltz and McNamara (1980)
42448.200	+1828	−0.034	pe 2	Dean et al. (1977)
43486.971	+1982	−0.028	pe 3	Dean (1981)
43608.399	+2000	−0.014	pe 3	Moffett and Barnes (1984)
44411.081	+2119	−0.014	pe 3	Gieren (1981b)
44458.345	+2126	+0.033	pe 3	Eggen (1985)
44721.388	+2165	+0.012	pe 3	Berdnikov (1986)

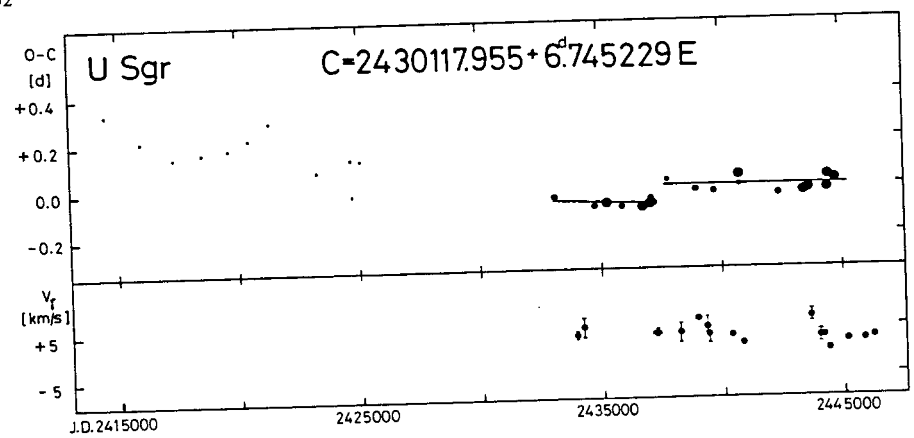

Figure 30. Upper panel: O-C diagram of U Sgr
Lower panel: γ-velocities for the same Cepheid

in Figure 29 (the zero phase is arbitrarily chosen at J.D.2400000). In this figure open circles denote those γ-velocities which are only based on two velocity measurements. Assuming that this orbital period is correct, the full amplitude of the orbital radial velocity variation is $2K = 3.6 \pm 1.3$ km/s.

Although Figure 29 is not fully convincing, i.e. another value of the orbital period cannot be excluded, the O-C diagram gives a further support to binary nature of U Sgr. The O-C residuals have been computed with the elements:

$$C = \underset{\pm .030}{2430117.955} + \underset{\pm .000016}{6^{d}.745229} \cdot E \qquad (39)$$

As is seen in Figure 30 (based on the data listed in Table 50), the O-C diagram can be characterized by a phase jump occurred at about J.D.2437500. Before the phase jump (of an amplitude of 0.07 day) the pulsation period was $6.745192 \pm 1.5 \cdot 10^{-5}$ days. This pattern of the O-C diagram cannot be explained with a light-time effect because its expected amplitude is less than 0.01 day. According to numerous other cases, the rejumping period is a typical feature of binary Cepheids, therefore duplicity of U Sgr can be stated beyond doubt.

W Sagittarii

This Cepheid belongs to a multiple star system: at present four components are identified (*Babel* et al., 1989, and references therein). The

Cepheid itself is a member of a spectroscopic binary system in this hierarchy. The orbital period is 1780 ± 5 days, and the orbital velocity amplitude is the least among the well-studied spectroscopic binary Cepheids (K = 2.35 ± 0.47 km/s , - *Babel* et al., 1989).

The O-C residuals have been calculated with the elements:

$$C = \underset{\pm .006}{2443374.622} + \underset{\pm .000008}{7^{d}.594904} \cdot E \qquad (40)$$

The O-C diagram (see Table 51 and Figure 31) can be well described assuming a constant period. Although *Babel* et al. (1989) approximate the

Table 51. O-C residuals for W Sgr

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
14491.629	-3803	$+0^{d}.427$	vis	Pickering (1904)
15220.531	-3707	+0.218	pg	Shapley (1930)
16306.666	-3564	+0.282	pg	Shapley (1930)
17392.573	-3421	+0.118	pg	Shapley (1930)
18471.022	-3279	+0.090	pg	Shapley (1930)
19640.603	-3125	+0.056	pg	Shapley (1930)
20605.127	-2998	+0.027	pg	Shapley (1930)
21782.113	-2843	+0.197	pg	Shapley (1930)
23232.817	-2652	-0.120	pg	Shapley (1930)
24440.488	-2493	-0.038	pg	Shapley (1930)
24577.282	-2475	+0.047	pg	Voute (1927a)
25443.229	-2361	+0.175	pg	Shapley (1930)
34572.151	-1159	+0.023	pe 2	Walraven et al. (1958)
34868.304	-1120	-0.026	pe 3	Eggen et al. (1957)
35248.090	-1070	+0.015	pe 3	Irwin (1961)
37253.091	- 806	-0.039	pe 1	Mitchell et al. (1964)
37883.539	- 723	+0.033	pe 3	Walraven et al. (1964)
38650.553	- 622	-0.039	pe 2	Wisniewski and Johnson (1968)
40017.674	- 442	0.000	pe 3	Cousins and Lagerweij (1968)
42858.147	- 68	-0.022	pe 2	Dean (1977)
43617.650	+ 32	-0.009	pe 3	Moffett and Barnes (1984)
43754.383	+ 50	+0.016	pe 3	Babel et al. (1989)
45508.797	+ 281	+0.007	pe 3	Babel et al. (1989)

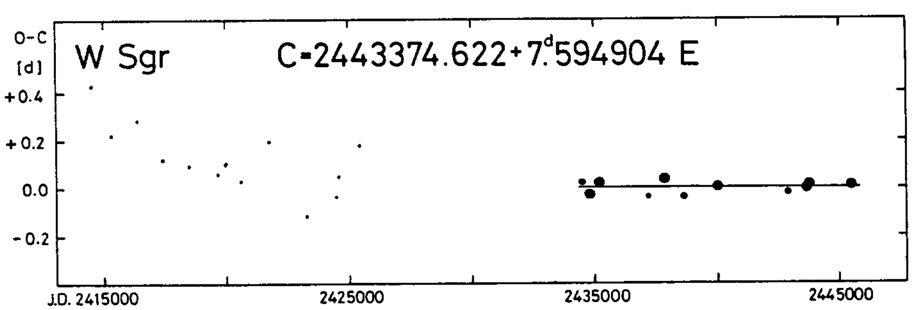

Figure 31. O-C diagram of W Sgr

O-C graph by a parabola (continuous period increase), the parabolic fit to the data in Table 51 has been of much lower accuracy as compared with the linear fit. No effect of duplicity is seen in the O-C diagram, since the amplitude of the light-time effect is much smaller than the limit of detection.

X Sagittarii

X Sgr belongs to a spectroscopic binary system with an orbital period of 507.25 days (*Szabados*, 1989). Because the effect of the orbital motion on the radial velocity variations is rather small, the value of the orbital period is tentative, and needs confirmation. Nevertheless, a blue photometric companion to X Sgr has been suspected by *Pel* (1978).

The O-C residuals listed in Table 52 have been calculated with the elements:

$$C = \underset{\pm.015}{2440741.492} + \underset{\pm.000028}{7\overset{d}{.}012777}\cdot E \tag{41}$$

Table 52. O-C residuals for X Sgr

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
15531.897	-3595	$+1\overset{d}{.}338$	pg 1	Shapley (1930)
16422.246	-3468	+1.065	pg 1	Shapley (1930)
17228.609	-3353	+0.958	pg 1	Shapley (1930)
17922.830	-3254	+0.914	pg 1	Shapley (1930)
18652.136	-3150	+0.892	pg 1	Shapley (1930)
19144.481	-3037	+0.793	pg 1	Shapley (1930)
20152.889	-2936	+0.910	pg 1	Shapley (1930)
20888.857	-2831	+0.537	pg 1	Shapley (1930)
21569.130	-2734	+0.570	pg 1	Shapley (1930)
22501.724	-2601	+0.465	pg 1	Shapley (1930)
23329.154	-2483	+0.387	pg 1	Shapley (1930)
24353.118	-2337	+0.486	pg 1	Shapley (1930)
24514.329	-2314	+0.403	pg 1	Voute (1927a)
25440.009	-2182	+0.396	pg 1	Shapley (1930)
34871.956	- 837	+0.158	pe 1	Eggen et al. (1957)
35222.549	- 787	+0.112	pe 3	Irwin (1961)
35250.607	- 783	+0.119	pe 2	Walraven et al. (1958)
37129.933	- 515	+0.021	pe 2	Mitchell et al. (1964)
39051.428	- 241	+0.015	pe 3	Wisniewski and Johnson (1968)
40762.530	+ 3	0.000	pe 3	Pel (1976)
42852.333	+ 301	-0.005	pe 3	Dean (1977)
43658.808	+ 416	0.000	pe 3	Moffett and Barnes (1984)
44437.218	+ 527	-0.007	pe 3	Eggen (1985)

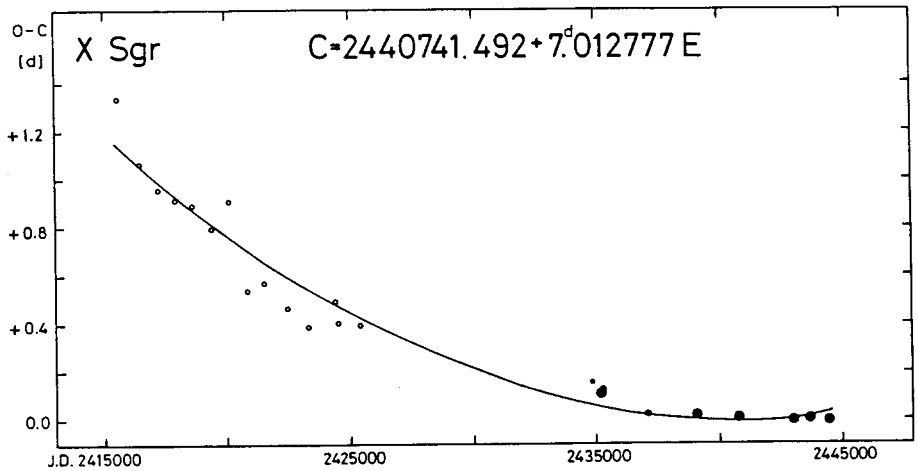

Figure 32. O-C diagram of X Sgr

As is seen in Figure 32, the O-C diagram of X Sgr is parabolic. The parabola fitted to the photographic and photoelectric O-C residuals has resulted in the following temporal variation in the pulsation period:

$$P = 7\overset{d}{.}012777 + 1\overset{d}{.}65 \cdot 10^{-7} \cdot E \qquad (42)$$
$$\pm .000028 \quad \pm .21$$

where the E epoch number is the same as in equation (41). It has to be noted, however, that the period increase used to be even stronger during the visual observations made by *Schmidt* (*Hertzsprung*, 1934) in the last century.

Y Sagittarii

Table 53. γ-velocities of Y Sgr

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
16615	173	+1.5	1.1	8	Duncan (1908)
18152	22	+2.7	0.6	27	Duncan (1908)
22691	368	-6.0	0.6	24	Duncan (1922)
23377	165	-6.0	0.4	22	ten Bruggencate (1930)
23550	363	-3.0	0.5	16	Campbell and Moore (1928)
24134	141	-4.9	0.6	14	ten Bruggencate (1930)
25089	90	-3.5	0.6	15	ten Bruggencate (1930)
25794	20	-4.0	0.5	16	ten Bruggencate (1930)
40380	47	-3.3	0.2	8	Lloyd Evans (1980)
40765	51	-1.8	0.2	7	Lloyd Evans (1980)
43354	45	-1.1	1.2	12	Wilson et al. (1989)
43649	41	-3.6	1.1	14	Barnes et al. (1987)
44014	62	-2.7	1.4	8	Barnes et al. (1987)
44796	1	-6.6	1.3	1	Beavers and Eitter (1986)

The changing γ-velocity of Y Sgr was first reported by *ten Bruggencate* (1930). The recent determination of the γ-velocities confirms this conclusion (see Table 53 and the lower panel of Figure 33). The pattern of the γ-velocity changes suggests a very long (P > 10000 days) orbital period.

Table 54. O-C residuals for Y Sgr

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
14499.428	-4549	$+0^{d}.205$	vis	Pickering (1904)
18176.856	-3912	-0.010	vis	Nijland (1923)
18962.147	-3776	+0.101	vis	Nijland (1923)
24712.345	-2780	+0.012	pg	ten Bruggencate (1928)
25070.247	-2718	-0.035	pg	ten Bruggencate (1928)
25439.689	-2654	-0.089	pg	ten Bruggencate (1928)
29839.040	-1892	-0.054	pg	Filin (1950b)
30681.845	-1746	-0.163	pg	Filin (1950b)
31449.885	-1613	+0.018	pg	Filin (1950b)
32408.117	-1447	-0.131	pg	Filin (1950b)
33118.360	-1324	-0.014	pe 2	Eggen (1951)
33141.471	-1320	+0.004	pg	Filin (1950b)
34879.244	-1019	-0.011	pe 2	Walraven et al. (1958)
35271.837	- 951	-0.008	pe 3	Irwin (1961)
36097.317	- 808	-0.121	pe 1	Svolopoulos (1960)
37130.873	- 629	0.000	pe 2	Mitchell et al. (1964)
37800.726	- 513	+0.141	pe 1	Williams (1966)
38937.984	- 316	+0.043	pe 1	Wisniewski and Johnson (1968)
40779.682	+ 3	+0.033	pe 3	Pel (1976)
40820.055	+ 10	-0.008	pe 2	Feltz and McNamara (1980)
42881.153	+ 367	-0.006	pe 2	Dean (1977)
43441.162	+ 464	-0.015	pe 3	Moffett and Barnes (1984)
44041.585	+ 568	-0.024	pe 3	Moffett and Barnes (1984)
44821.027	+ 703	+0.012	pe 1	Eggen (1985)

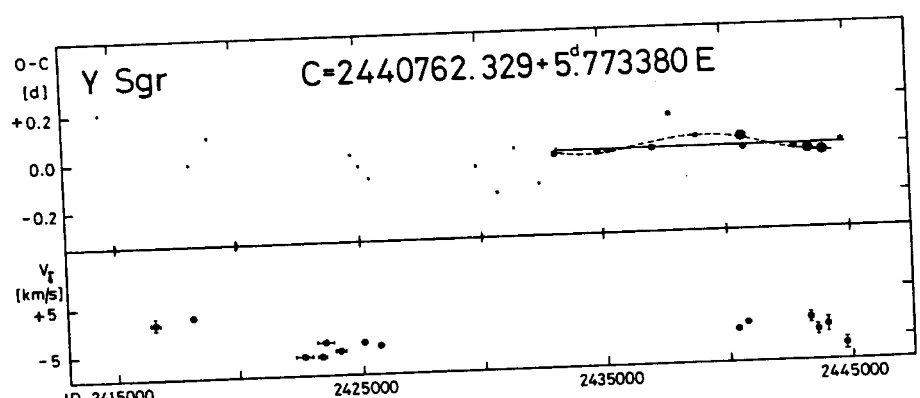

Figure 33. Upper panel: O-C diagram of Y Sgr
Lower panel: γ-velocities for the same Cepheid

The O-C residuals have been computed with the elements:

$$C = 2440762.329 + 5\overset{d}{.}773380 \cdot E \qquad (43)$$
$$\pm.009 \quad \pm.000013$$

The light-time effect expected in such a long period spectroscopic binary is present in the O-C diagram (see Table 54 and the upper panel of Figure 33) but the limited time-base of the photoelectric observations does not allow the successful determination of the long orbital period. A cycle length as long as 10000 - 12000 days is in accordance with the photoelectric O-C residuals but a much longer period cannot be ruled out, either.

WZ Sagittarii

The available radial velocity measurements might indicate a variable γ-velocity (see Table 55 and the lower panel of Figure 34). *Joy*'s (1937) first two observations have not been taken into account here. Further good quality radial velocity data are necessary.

Table 55. γ-velocities of WZ Sgr

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25985	282	-10.6	1.8	8	Joy (1937)
44327	231	-12.5	2.8	3	Barnes et al. (1988)
44589	297	-18.3	0.2	21	Coulson and Caldwell (1985)

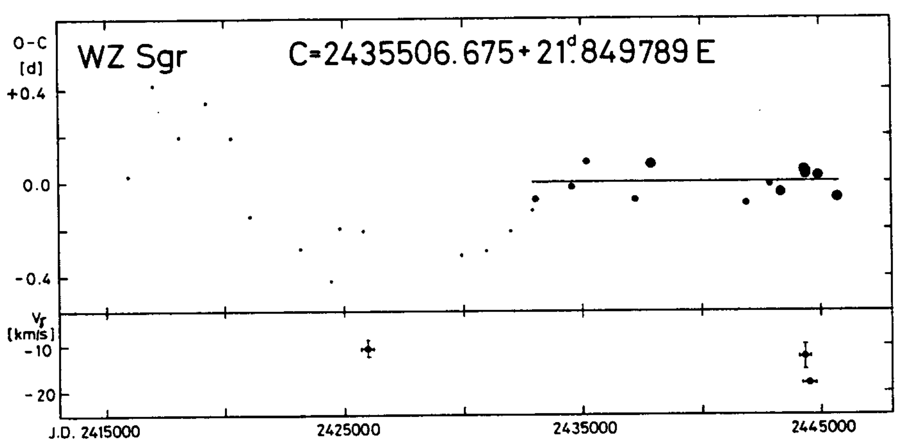

Figure 34. Upper panel: O-C diagram of WZ Sgr
Lower panel: γ-velocities for the same Cepheid

Table 56. O-C residuals for WZ Sgr

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
15929.289	-896	$+0\overset{d}{.}025$	pg	Shapley (1930)
17022.168	-846	+0.414	pg	Shapley (1930)
18114.435	-796	+0.192	pg	Shapley (1930)
19250.773	-744	+0.341	pg	Shapley (1930)
21129.367	-658	-0.147	pg	Shapley (1930)
23183.108	-564	-0.286	pg	Shapley (1930)
24450.260	-506	-0.422	pg	Shapley (1930)
24865.634	-487	-0.194	pg	Voute (1930a)
25805.161	-444	-0.208	pg	Voute (1930a)
29956.518	-254	-0.311	pg	Filin (1950b)
30983.476	-207	-0.293	pg	Filin (1950b)
32010.500	-160	-0.209	pg	Filin (1950b)
32971.974	-116	-0.125	pg	Filin (1950b)
33124.977	-109	-0.071	pe 2	Eggen (1951)
34632.661	- 40	-0.022	pe 2	Walraven et al. (1958)
35244.562	- 12	+0.084	pe 2	Irwin (1961)
37232.733	+ 79	-0.075	pe 2	Mitchell et al. (1964)
37910.227	+110	+0.075	pe 3	Walraven et al. (1964)
41908.570	+293	-0.093	pe 1	Madore (1975)
42870.045	+337	-0.009	pe 2	Dean (1977)
43372.555	+360	-0.044	pe 3	Dean (1981)
44399.590	+407	+0.051	pe 3	Coulson and Caldwell (1985)
44486.967	+411	+0.029	pe 3	Moffett and Barnes (1984)
44508.828	+412	+0.040	pe 1	Eggen (1983b)
44923.961	+431	+0.027	pe 3	Coulson and Caldwell (1985)
45776.012	+470	-0.064	pe 3	Berdnikov (1986)

The O-C residuals have been computed with the elements:

$$C = \underset{\pm .017}{2435506.675} + \underset{\pm .000053}{21\overset{d}{.}849789} \cdot E \qquad (44)$$

The pulsation period has been constant since the early photoelectric observations (see Table 56 and the upper panel of Figure 34), while before J.D.2433000 some changes occurred in the period. However, those earlier variations were not secular ones (such long period Cepheids usually show much larger continuous period changes indicating stellar evolution (*Szabados*, 1981)).

AP Sagittarii

The present study confirms *Gieren*'s (1982) statement concerning the variable γ-velocity of AP Sgr. The data in Table 57 (shown plotted in the lower panel of Figure 35) were analysed for possible periodicity. A number of periods (5625, 6725, 7200, and 7500 days) describe the variable γ-velocity reasonably well, the most probable value of the orbital period

Table 57. γ-velocities of AP Sgr

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
21733	1	- 6.4	4.5	1	Joy (1937)
24694	700	-18.9	2.6	3	Joy (1937)
26313	157	-18.3	2.0	6	Joy (1937)
39279	19	-19.7	0.8	6	Lloyd Evans (1968)
40592	219	-18.6	0.2	10	Lloyd Evans (1980)
44062	2	- 8.3	2.3	4	Barnes et al. (1988)
44423	4	-14.7	0.4	22	Gieren (1981a)
44579	168	-13.5	1.4	9	Barnes et al. (1988)

Table 58. O–C residuals for AP Sgr

Norm.max JD2400000+	E	O–C	Type, weight	Reference
16021.186	-3959	$-0\overset{d}{.}053$	pg	Shapley (1930)
17381.853	-3690	+0.035	pg	Shapley (1930)
18469.235	-3475	-0.035	pg	Shapley (1930)
19652.935	-3241	+0.113	pg	Shapley (1930)
20750.509	-3024	+0.119	pg	Shapley (1930)
21640.649	-2848	+0.066	pg	Shapley (1930)
23679.094	-2445	+0.171	pg	Shapley (1930)
25868.992	-2012	-0.009	pg 1	Voute (1930b)
29829.379	-1229	+0.030	pg	Filatov (1966)
31280.959	- 942	-0.012	pg	Filatov (1966)
32540.355	- 693	-0.037	pg	Filatov (1966)
33369.887	- 529	-0.003	pg	Filatov (1966)
34391.562	- 327	-0.027	pg	Filatov (1966)
34720.309	- 262	-0.045	pe 2	Walraven et al. (1958)
35276.695	- 152	-0.030	pe 2	Irwin (1961)
36010.163	- 7	+0.040	pg	Filatov (1966)
37208.869	+ 230	+0.020	pe 1	Mitchell et al. (1964)
39282.603	+ 640	+0.009	pe 1	Takase (1969)
40370.067	+ 855	+0.021	pe 2	Stobie (1970)
40794.903	+ 939	-0.008	pe 3	Pel (1976)
44077.489	+1588	-0.010	pe 3	Moffett and Barnes (1984)
44426.508	+1657	+0.013	pe 3	Gieren (1981b)
44492.235	+1670	-0.013	pe 3	Moffett and Barnes (1984)
44659.170	+1703	+0.011	pe 2	Eggen (1985)

being the longest one (see the discussion below).

The O–C residuals listed in Table 58 have been calculated with the elements:

$$C = \underset{\pm .004}{2436045.528} + \underset{\pm .000003}{5\overset{d}{.}057916} \cdot E \qquad (45)$$

The O–C diagram (see the upper panel of Figure 35) shows a wave-like pattern, the weighted least squares fit to the data points results in the following formula for predicting the moments of the normal maxima:

$$C = \underset{\pm .004}{2436045.528} + \underset{\pm .000003}{5\overset{d}{.}057916} \cdot E - \underset{\pm .006}{0\overset{d}{.}035} \cos(2\pi(\underset{\pm .000017}{0.000665}E + \underset{\pm .024}{0.151})) \qquad (46)$$

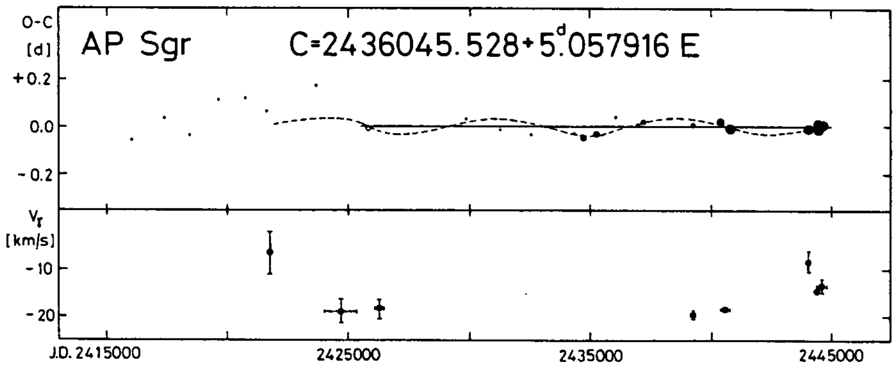

Figure 35. **Upper panel: O-C diagram of AP Sgr**
Lower panel: γ-velocities for the same Cepheid

indicating an orbital period of 7608 ± 194 days. The combination of the photometric and spectroscopic evidence (including the amplitude and phase relations) suggests that the orbital period is near 7500 days.

BB Sagittarii

The Cepheid BB Sgr may be a coronal member of the open cluster Cr394 (*Turner* and *Pedreros*, 1985). Its spectroscopic binary nature was first suspected by *Gieren* (1982), and later on confirmed by *Barnes* et al. (1988). *Gieren* assumes a red companion to BB Sgr. The study of the available observational data confirms the changing γ-velocity (see Table 59 and the lower panel of Figure 36) but the orbital period cannot be determined yet.

The O-C residuals have been calculated with the elements:

$$C = 2436053.475 + 6^{d}.637005\ E \qquad (47)$$
$$\pm.009 \qquad \pm.000005$$

Table 59. γ-velocities of BB Sgr

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25558	368	+ 8.6	2.6	4	Joy (1937)
26314	158	- 1.5	2.3	5	Joy (1937)
39284	16	+ 7.5	0.8	6	Lloyd Evans (1968)
40407	44	+ 8.2	0.3	4	Lloyd Evans (1980)
40799	27	+ 7.3	0.3	5	Lloyd Evans (1980)
44062	2	+15.1	4.0	2	Barnes et al. (1988)
44423	4	+ 4.1	0.4	24	Gieren (1981a)
44486	45	+11.1	1.8	6	Barnes et al. (1988)
44821	44	+ 8.3	2.3	4	Barnes et al. (1988)

Table 60. O-C residuals for BB Sgr

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
15644.972	-3075	$+0\overset{d}{.}287$	pg 1	Shapley (1930)
16680.382	-2919	+0.325	pg 1	Shapley (1930)
17788.766	-2752	+0.329	pg 1	Shapley (1930)
18837.317	-2594	+0.233	pg 1	Shapley (1930)
19958.922	-2425	+0.184	pg 1	Shapley (1930)
21067.273	-2258	+0.155	pg 1	Shapley (1930)
22096.026	-2103	+0.173	pg 1	Shapley (1930)
23337.157	-1916	+0.184	pg 1	Shapley (1930)
25819.325	-1542	+0.112	pg 1	Voute (1930d)
34938.469	- 168	+0.011	pe 1	Walraven et al. (1958)
35283.586	- 116	+0.004	pe 2	Irwin (1961)
36756.971	+ 106	-0.027	pe 1	Weaver et al. (1961)
37141.943	+ 164	-0.001	pe 1	Mitchell et al. (1964)
40374.151	+ 651	-0.014	pe 1	Stobie (1970)
40447.184	+ 662	+0.012	pe 1	Lloyd Evans and Stobie (1971)
40805.592	+ 716	+0.021	pe 3	Pel (1976)
41157.395	+ 769	+0.063	pe 1	Feltz and McNamara (1980)
42239.185	+ 932	+0.021	pe 3	Dean et al. (1977)
42551.084	+ 979	-0.019	pe 3	Dean et al. (1977)
43526.814	+1126	+0.071	pe 2	Dean (1981)
44409.527	+1259	+0.063	pe 3	Moffett and Barnes (1984)
44422.808	+1261	+0.070	pe 3	Gieren (1981b)
44721.439	+1306	+0.035	pe 2	Turner and Pedreros (1985)
44907.311	+1334	+0.071	pe 3	Moffett and Barnes (1984)
45040.034	+1354	+0.054	pe 3	Turner and Pedréros (1985)
45212.646	+1380	+0.104	pe 3	Eggen (1985)

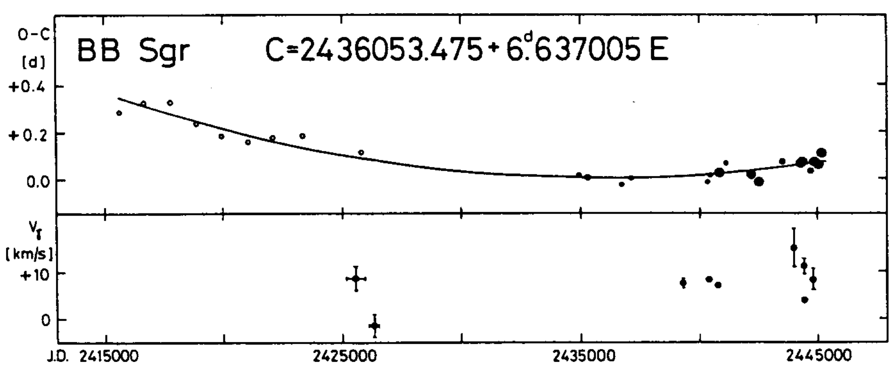

Figure 36. Upper panel: O-C diagram of BB Sgr
Lower panel: γ-velocities for the same Cepheid

The pattern of the O-C diagram (see Table 60 and the upper panel of Figure 36) shows a continuously increasing period:

$$P = 6\overset{d}{.}637005 + 7\overset{d}{.}2\cdot10^{-8}\cdot E \qquad (48)$$
$$\pm.000005 \quad \pm.6$$

where the E epoch number has to be calculated from the zero-point indicated in equation (47). A check on the presence of a possible light-time effect was also performed, and there is weak evidence for an approximately 4550 day orbital period (using only the photoelectric O-C residuals). Although this value is consistent with the tendency of the γ-velocity changes, a completely different orbital period cannot be ruled out.

V350 Sagittarii

Its spectroscopic binary nature was suspected by *Lloyd Evans* (1971), later on confirmed by *Gieren* (1982), and *Lloyd Evans* (1982). The orbital period was determined recently (*Szabados*, 1989), and its value is 1129 days.

The O-C residuals listed in Table 61 have been computed with the ephemeris:

$$C = \underset{\pm .020}{2435317.170} + \underset{\pm .000012}{5^{d}.154178} \cdot E \qquad (49)$$

The O-C diagram in Figure 37 offers two obvious approximations: a phase jump, or a parabolic O-C graph. Equation (49) has been obtained assuming that the first approximation is correct. In this case the formex value of the pulsation period was 5.154139 $\pm$ $1.9 \cdot 10^{-5}$ days. The 0.06 day phase jump

Table 61. O-C residuals for V350 Sgr

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
25560.345	-1893	$+0^{d}.034$	pg	Voute (1930c)
26106.715	-1787	+0.061	pg	Voute (1930c)
33075.072	- 435	-0.031	pe 1	Eggen (1951)
34940.902	- 73	-0.013	pe 2	Walraven et al. (1958)
35306.827	- 2	-0.035	pe 2	Irwin (1961)
37244.780	+ 374	-0.053	pe 2	Mitchell et al. (1964)
40373.404	+ 981	-0.015	pe 1	Stobie (1970)
40435.281	+ 993	+0.012	pe 1	Feltz and McNamara (1980)
41136.257	+1129	+0.020	pe 1	Feltz and McNamara (1980)
42883.488	+1468	-0.015	pe 1	Dean (1977)
44373.048	+1757	-0.013	pe 2	Moffett and Barnes (1984)
44414.287	+1765	-0.007	pe 3	Gieren (1981b)
44888.487	+1857	+0.008	pe 2	Moffett and Barnes (1984)
44919.423	+1863	+0.019	pe 2	Eggen (1985)

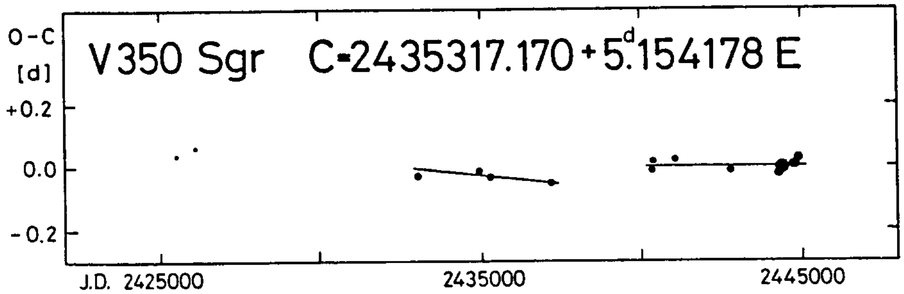

Figure 37. O-C diagram of V350 Sgr

occurred between J.D.2437500 and 2440000. If, however, the continuous period increase interpretation is accepted, the pulsation period can be calculated as follows:

$$P = 5\overset{d}{.}154168 + 3\overset{d}{.}04 \cdot 10^{-8} \cdot E \qquad (50)$$
$$\quad \pm.000004 \quad \pm.58$$

where the E epoch number has to be calculated according to equation (49). Additional observations are necessary to decide which of the above interpretations is the correct one.

RV Scorpii

Moffett and *Barnes* (1987) found almost 6 km/s discrepancy between their own and the previous γ-velocity determinations. The variable γ-velocity is also seen in the present study (see Table 62 and the lower panel of Figure 38).

The O-C residuals have been computed with the elements:

$$C = 2434925.379 + 6\overset{d}{.}061352 \cdot E \qquad (51)$$
$$\quad \pm.009 \quad \pm.000004$$

The whole data set (see Table 63) can be well approximated by a parabola,

Table 62. γ-velocities of RV Sco

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
18433	15	-23.0	1.2	7	Paddock (1917)
25104	238	-17.7	1.8	7	Joy (1937)
25983	338	-20.9	2.3	5	Joy (1937)
33942	145	-18.8	0.8	15	Stibbs (1955)
40530	213	-21.6	0.2	7	Lloyd Evans (1980)
44055	9	-13.0	1.6	7	Barnes et al. (1988)
44423	4	-18.9	0.4	24	Gieren (1981a)
44456	18	- 7.5	2.0	5	Barnes et al. (1988)
44798	1	-14.4	2.8	3	Barnes et al. (1988)

Table 63. O-C residuals for RV Sco

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
14474.195	-3374	$-0^{d}.181$	vis 1	Pickering (1904)
16274.495	-3077	-0.103	pg 1	Shapley (1930)
18141.361	-2769	-0.133	pg 1	Shapley (1930)
19638.618	-2522	-0.030	pg 1	Shapley (1930)
20753.897	-2338	-0.040	pg 1	Shapley (1930)
23196.583	-1935	-0.079	pg 1	Shapley (1930)
24342.277	-1746	+0.020	pg 1	Shapley (1930)
24711.873	-1685	-0.127	pg 1	Voute (1927c)
25075.607	-1625	-0.074	pg 1	Voute (1927c)
34901.138	- 4	+0.005	pe 1	Walraven et al. (1958)
35240.579	+ 52	+0.011	pe 3	Irwin (1961)
37277.192	+ 388	+0.009	pe 1	Mitchell et al. (1964)
40344.212	+ 894	-0.015	pe 3	Stobie (1970)
40780.652	+ 966	+0.008	pe 3	Pel (1976)
41574.662	+1097	-0.019	pe 3	Dean et al. (1977)
41950.453	+1159	-0.032	pe 3	Dean et al. (1977)
43538.527	+1421	-0.032	pe 3	Dean (1981)
44023.428	+1501	-0.039	pe 3	Gieren (1981b)
44247.691	+1538	-0.046	pe 3	Moffett and Barnes (1984)
44835.688	+1635	0.000	pe 2	Eggen (1985)

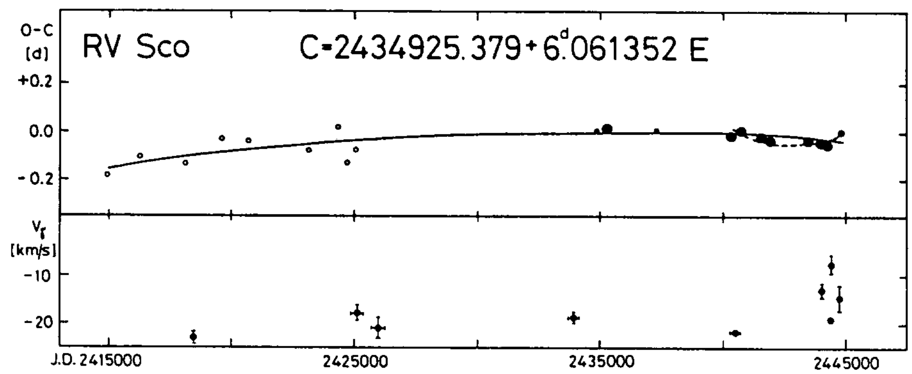

Figure 38. Upper panel: O-C diagram of RV Sco
Lower panel: γ-velocities for the same Cepheid

corresponding to a continuously decreasing period:

$$P = 6^{d}.061352 - 2^{d}.75\cdot10^{-8}\cdot E \qquad (52)$$
$$\pm.000004 \quad \pm.54$$

where the E epoch number is calculated according to equation (51). The O-C residuals based on the photoelectric observations made after J.D.2440000 seem to form a part of a wave superimposed on the parabola, indicating a possible light-time effect. Assuming an orbital period of about 8000 days, this interpretation is in agreement with the trend of the γ-velocity variations (see Figure 38). Further observations are needed before carrying out a more thorough analysis.

RY Scorpii

RY Sco is a member of a visual triple star system (*Proust* et al., 1981). The faint companions may or may not influence the photometric behaviour of this Cepheid. A blue photometric companion was reported by *Madore* (1977) and *Pel* (1978) but *Böhm-Vitense* and *Proffitt* (1985) failed to find any evidence for a blue companion using IUE spectra. The available spectroscopic data do not allow to draw any conclusion regarding the variation in the γ-velocity (see Table 64).

Table 64. γ-velocities of RY Sco

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
22868	1	-17.7	4.5	1	Joy (1937)
25515	270	-17.2	1.8	7	Joy (1937)
27034	315	-17.2	4.5	2	Joy (1937)
33934	94	-19.3	1.0	10	Stibbs (1955)
40579	242	-20.5	0.3	4	Lloyd Evans (1980)
44123	158	-15.4	1.8	6	Barnes et al. (1988)
44250	198	-17.8	0.2	18	Coulson and Caldwell (1985)
44785	149	-17.6	0.3	17	Coulson and Caldwell (1985)

Table 65. O-C residuals for RY Sco

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
16415.032	-583	$+8^d.149$	pg	Shapley (1930)
17938.584	-508	+7.690	pg	Shapley (1930)
19563.398	-428	+6.893	pg	Shapley (1930)
20762.244	-369	+6.850	pg	Shapley (1930)
23281.083	-245	+5.991	pg	Shapley (1930)
24439.079	-188	+5.739	pg	Shapley (1930)
25047.825	-158	+4.881	pg	Wallenquist (1928)
26673.167	- 78	+4.611	pg	Wallenquist (1928)
31019.120	+136	+2.053	pg	Filatov (1966)
33335.314	+250	+1.751	pg	Filatov (1966)
35244.432	+344	+0.775	pe 2	Irwin (1961)
35244.615	+344	+0.958	pg	Filatov (1966)
35487.784	+356	+0.286	pe 1	Mitchell et al. (1964)
38251.601	+492	+0.563	pg	Filatov (1966)
40343.964	+595	-0.049	pe 3	Stobie (1970)
41075.606	+631	+0.068	pe 3	Pel (1976)
41908.631	+672	-0.033	pe 1	Madore (1975)
44062.665	+778	+0.066	pe 1	Moffett and Barnes (1984)
44326.737	+791	-0.024	pe 3	Coulson and Caldwell (1985)
44529.910	+801	-0.052	pe 2	Moffett and Barnes (1984)
44875.432	+818	+0.027	pe 3	Coulson and Caldwell (1985)

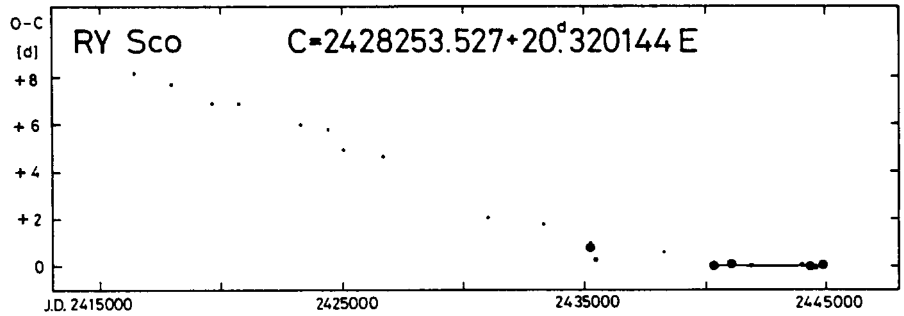

Figure 39. O-C diagram of RY Sco

The O-C residuals listed in Table 65 have been calculated with the elements:

$$C = \underset{\pm .101}{2428253.527} + \underset{\pm .000139}{20\overset{d}{.}320144} \cdot E \tag{53}$$

Figure 39 shows that the above elements are only valid after J.D.2440000. Before that epoch the pulsation period cannot be characterized by a single value.

V500 Scorpii

The discrepancy between the γ-velocities reported by *Moffett* and *Barnes* (1987) is confirmed here (see Table 66 and the lower panel of Figure 40). *Madore* (1977) assumed a blue photometric companion. Such a companion is not suspected on the basis of *Pel*'s (1978) photometry, nor in

Table 66. γ-velocities of V500 Sco

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
34182	37	-14.0	0.9	12	Stibbs (1955)
44359	343	- 7.4	1.3	10	Barnes et al. (1988)

Table 67. O-C residuals for V500 Sco

Norm.max JD2400000+	E	O-C	Type, weight	Reference
34729.921	-1038	$-0\overset{d}{.}038$	pe 1	Walraven et al. (1958)
35251.730	- 982	+0.028	pe 3	Irwin (1961)
37282.750	- 764	-0.023	pe 2	Mitchell et al. (1964)
37869.731	- 701	-0.003	pe 3	Walraven et al. (1964)
44335.597	- 7	-0.023	pe 3	Moffett and Barnes (1984)
44782.853	+ 41	+0.025	pe 3	Eggen (1985)

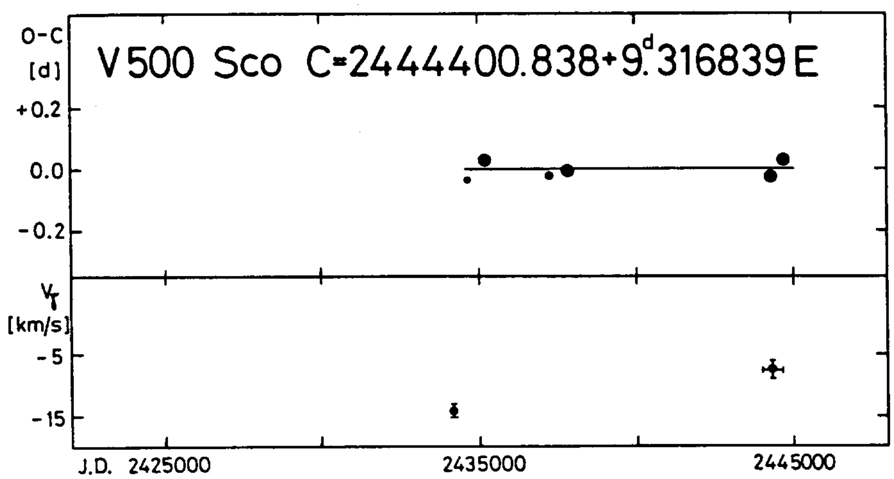

Figure 40. **Upper panel: O-C diagram of** V500 Sco
Lower panel: γ-velocities for the same Cepheid

the study of an IUE spectrum obtained by *Böhm-Vitense* and *Proffitt* (1985).

The O-C residuals listed in Table 67 have been computed with the elements:

$$C = 2444400.838 + 9\overset{d}{.}316839 \cdot E \qquad (54)$$
$$\pm.010 \quad \pm.000015$$

The O-C diagram (in the upper panel of Figure 40) simply shows a constant period.

V636 Scorpii

This Cepheid belongs to a spectroscopic binary system with an orbital period of 1318 days (*Lloyd Evans*, 1971). The blue companion has been discovered in an IUE study (*Böhm-Vitense* and *Proffitt*, 1985).

Table 68. O-C residuals for V636 Sco

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
34743.483	-827	+0.^{d}064	pe 2	Walraven et al. (1958)
35232.792	-755	-0.001	pe 3	Irwin (1961)
37849.532	-370	-0.051	pe 3	Walraven et al. (1964)
40350.817	- 2	-0.010	pe 2	Stobie (1970)
42852.033	+366	-0.038	pe 2	Dean (1977)
44456.179	+602	+0.049	pe 2	Eggen (1985)
45020.306	+685	+0.037	pe 1	Eggen (1985)
45706.740	+786	-0.012	pe 1	Eggen (1985)

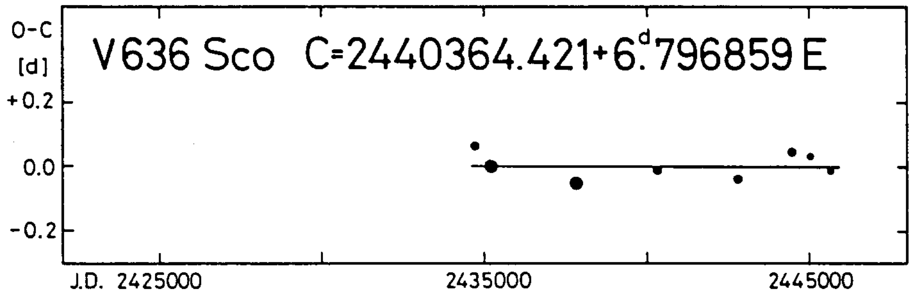

Figure 41. O-C diagram of V636 Sco

The O-C residuals listed in Table 68 have been calculated with the elements:

$$C = 2440364.421 + 6\overset{d}{.}796859 \cdot E \qquad (55)$$
$$\quad\pm.011 \quad \pm.000018$$

The O-C diagram plotted in Figure 41 has been approximated by a straight line. According to equation (1) no detectable light-time effect is expected.

Y Scuti

The variable γ-velocity of Y Scuti was first noticed by *Moffett* and *Barnes* (1987). Their conclusion is confirmed here (see Table 69 and the lower panel of Figure 42). The orbital period can be as long as several thousand days because the radial velocity data obtained by *Barnes* et al. (1988) cover three consecutive years, and no obvious change in the γ-velocity is seen in their data.

The O-C residuals have been calculated with the elements:

$$C = 2434947.209 + 10\overset{d}{.}341483 \cdot E \qquad (56)$$
$$\quad\pm.007 \quad \pm.000008$$

Photographic observations were also taken into account in the fitting procedure. The O-C graph can be best represented by a straight line (see Table 70 and the upper panel of Figure 42). The number of the O-C residuals

Table 69. γ-velocities of Y Sct

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25362	371	12.0	2.6	4	Joy (1937)
28080	425	3.5	2.0	6	Joy (1937)
44521	339	18.5	1.3	11	Barnes et al. (1988)

Table 70. O-C residuals for Y Sct

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
16342.813	-1799	$-0^{d}.068$	pg 1	Shapley (1930)
18028.602	-1636	+0.059	pg 1	Shapley (1930)
19631.411	-1481	-0.062	pg 1	Shapley (1930)
21337.791	-1316	-0.026	pg 1	Shapley (1930)
23220.027	-1134	+0.060	pg 1	Shapley (1930)
24347.261	-1025	+0.072	pg 1	Shapley (1930)
29869.583	- 491	+0.042	pg 1	Filin (1950a), Solov'yov (1956)
31317.362	- 351	+0.014	pg 1	Filin (1950a), Solov'yov (1956)
32610.015	- 226	-0.019	pg 1	Filin (1950a), Solov'yov (1956)
33106.422	- 178	-0.003	pg 1	Filin (1950a)
33178.761	- 171	-0.054	pg 1	Solov'yov (1956)
34833.443	- 11	-0.010	pe 1	Walraven et al. (1958)
36767.263	+ 176	-0.047	pe 2	Weaver et al. (1961)
37491.251	+ 246	+0.037	pe 2	Ponsen and Oosterhoff (1966)
40841.857	+ 570	+0.003	pe 3	Pel (1976)
44285.578	+ 903	+0.010	pe 3	Moffett and Barnes (1984)
44947.444	+ 967	+0.021	pe 3	Moffett and Barnes (1984)
45495.492	+1020	-0.030	pe 1	Berdnikov (1986)
45878.138	+1057	-0.019	pe 3	Berdnikov (1986)

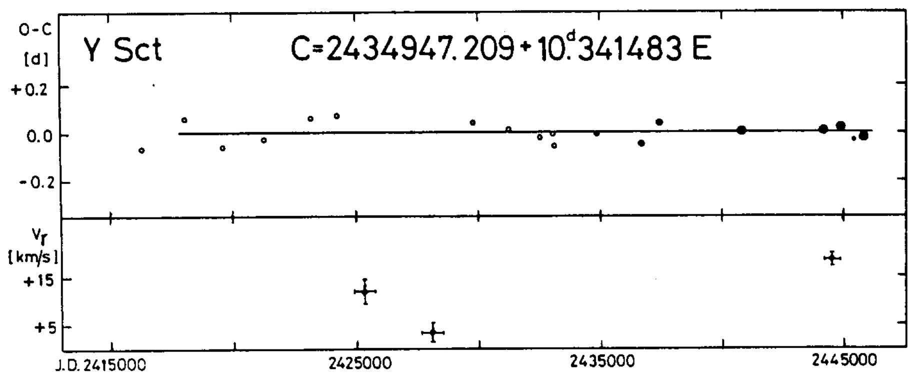

Figure 42. Upper panel: O-C diagram of Y Sct
Lower panel: γ-velocities for the same Cepheid

obtained from photoelectric observations is not enough to reveal the light-time effect expected in this case.

R Trianguli Australis

Its spectroscopic binary nature was already suspected by *Gieren* (1982). His conclusion is confirmed here (see Table 71 and the lower panel of Figure 43). It has to be noted that the γ-velocity obtained from *Paddock*'s

Table 71. γ-velocities of R TrA

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
18432	24	-16.4	0.9	13	Paddock (1917)
33849	23	- 7.5	1.1	8	Stibbs (1955)
34172	44	-10.2	1.2	7	Stibbs (1955)
39265	36	-14.9	0.8	6	Lloyd Evans (1968)
40364	28	-12.9	0.3	4	Lloyd Evans (1980)
40792	12	-14.1	0.3	4	Lloyd Evans (1980)
44423	4	-13.1	0.4	26	Gieren (1981a)

Table 72. O-C residuals for R TrA

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
16259.101	-7252	$+0\overset{d}{.}032$	pg 1	Shapley (1930)
18119.820	-6703	+0.033	pg 1	Shapley (1930)
20278.701	-6066	-0.062	pg 1	Shapley (1930)
21648.047	-5662	+0.012	pg 1	Shapley (1930)
23810.290	-5024	-0.110	pg 1	Shapley (1930)
25728.752	-4458	+0.015	pg 1	Dartayet et al. (1949)
34920.515	-1746	+0.032	pe 1	Walraven et al. (1958)
35201.826	-1663	+0.032	pe 3	Irwin (1961)
40339.938	- 147	-0.015	pe 1	Stobie (1970)
40770.398	- 20	+0.006	pe 3	Pel (1976)
42410.823	+ 464	+0.016	pe 3	Dean et al. (1977)
43234.389	+ 707	-0.015	pe 3	Dean (1981)
44417.257	+1056	-0.008	pe 3	Dean (1981)
44681.614	+1134	-0.015	pe 3	Eggen (1985)

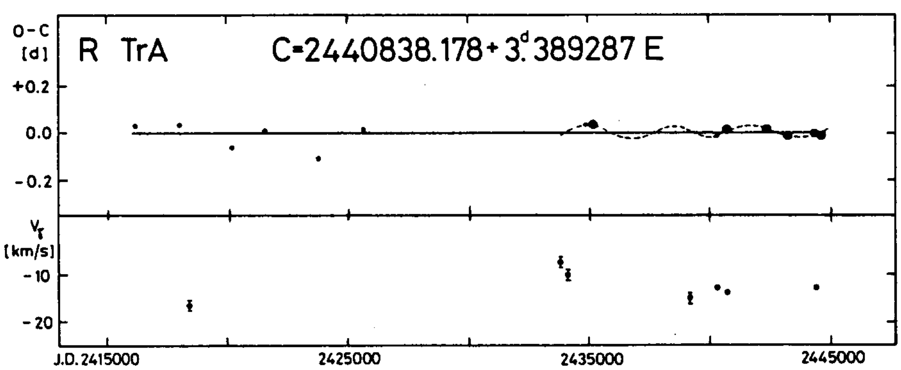

Figure 43. Upper panel: O-C diagram of R TrA
Lower panel: γ-velocities for the same Cepheid

(1917) observations still has the most negative value, although a +4 km/s correction has been applied to his data as discussed in the Introduction.

The O-C residuals have been calculated with the ephemeris:

$$C = 2440838.178 + 3\overset{d}{.}389287 \cdot E \qquad (57)$$
$$\pm.007 \qquad \pm.000002$$

The O-C residuals listed in Table 72 and shown plotted in the upper panel of Figure 43 suggest an orbital period of about 3500 days, if the wave-like pattern of the photoelectric O-C residuals is caused by a light-time effect. This value is in accord with the γ-velocity variations but further photometric and spectroscopic observations are necessary to confirm that the above hypothesis is correct.

S Trianguli Australis

The variability of the γ-velocity may or may not be real (see Table 73 and the lower panel of Figure 44). *Gieren* (1982) also noticed these changes but the question on the spectroscopic binary nature of S TrA is still open.

Table 73. γ-velocities of S TrA

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
18416	12	2.0	0.8	7	Campbell and Moore (1928)
20680	2	3.5	2.0	2	Campbell and Moore (1928)
33855	23	8.1	1.1	8	Stibbs (1955)
34173	38	5.0	1.1	8	Stibbs (1955)
39265	36	2.2	1.0	5	Lloyd Evans (1968)
40554	202	3.6	0.4	3	Lloyd Evans (1980)
44423	4	4.3	0.4	23	Gieren (1981a)

Table 74. O-C residuals for S TrA

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
15895.762	-3928	$-0\overset{d}{.}053$	pg 1	Shapley (1930)
17995.176	-3596	-0.030	pg 1	Shapley (1930)
20277.932	-3235	-0.045	pg 1	Shapley (1930)
21745.045	-3003	+0.024	pg 1	Shapley (1930)
24027.839	-2642	+0.048	pg 1	Shapley (1930)
25482.306	-2412	+0.118	pg 1	Dartayet et al. (1949)
25798.453	-2362	+0.091	pg 1	Dartayet et al. (1949)
34575.331	- 974	0.000	pe 3	Walraven et al. (1958)
35207.668	- 874	-0.010	pe 3	Irwin (1961)
37092.091	- 576	+0.021	pe 1	Eggen (1961)
40342.320	- 62	-0.011	pe 3	Stobie (1970)
40753.357	+ 3	0.000	pe 3	Pel (1976)
41518.515	+ 124	+0.019	pe 2	Dean et al. (1977)
42176.137	+ 228	+0.001	pe 3	Dean et al. (1977)
42555.556	+ 288	+0.012	pe 3	Dean et al. (1977)
43605.266	+ 454	+0.027	pe 1	Eggen (1985)
43681.122	+ 466	+0.001	pe 1	Dean (1981)
44420.971	+ 583	+0.005	pe 3	Gieren (1981b)
44642.260	+ 618	-0.027	pe 3	Eggen (1985)

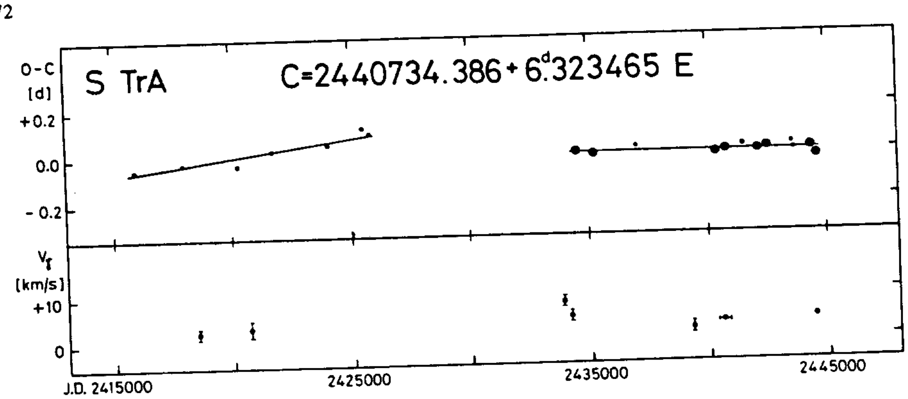

Figure 44. Upper panel: O-C diagram of S TrA
Lower panel: γ-velocities for the same Cepheid

The O-C residuals have been computed with the elements:

$$C = 2440734.386 + 6\overset{d}{.}323465 \cdot E \qquad (58)$$
$$\pm.003 \quad \pm.000005$$

As one can see in the upper panel of Figure 44 (based on the data listed in Table 74), a period change occurred between J.D.2426000 and 2434500. The former value of the pulsation period was $6.323570 \pm 1.8 \cdot 10^{-5}$ days.

T Velorum

Gieren (1985) suspects the presence of a red companion on the basis of the amplitude of the light variation in different colours. The γ-velocity study performed here (see Table 75 and the lower panel of Figure 45) is still inconclusive as far as variability in the γ-velocity is concerned.

The O-C residuals have been calculated with the elements:

$$C = 2440713.286 + 4\overset{d}{.}639819 \cdot E \qquad (59)$$
$$\pm.004 \quad \pm.000004$$

Table 75. γ-velocities of T Vel

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
34063	53	8.6	0.7	20	Stibbs (1955)
40473	190	6.3	0.3	5	Lloyd Evans (1980)
45042	2	5.2	0.5	20	Gieren (1985)

Table 76. O-C residuals for T Vel

Norm.max JD2400000+	E	O-C	Type, weight	Reference
18201.069	-4852	$+0^{d}.185$	pg	Hertzsprung (1937)
26302.088	-3106	+0.080	pg	Hertzsprung (1937)
33786.067	-1493	+0.031	pe 1	Eggen et al. (1957)
34741.844	-1287	+0.005	pe 1	Walraven et al. (1958)
34843.895	-1265	-0.020	pe 2	Eggen et al. (1957)
35205.814	-1187	-0.007	pe 2	Irwin (1961)
40745.774	+ 7	+0.009	pe 3	Pel (1976)
41803.658	+ 235	+0.015	pe 3	Dean et al. (1977)
42555.282	+ 397	-0.012	pe 3	Dean et al. (1977)
44299.894	+ 773	+0.028	pe 3	Eggen (1985)
44800.940	+ 881	-0.027	pe 2	Eggen (1985)
45052.229	+ 933	-0.008	pe 3	Gieren (1985)

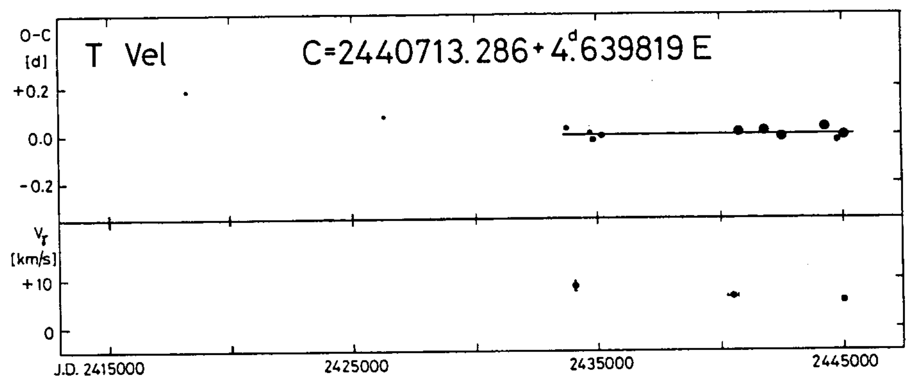

Figure 45. Upper panel: O-C diagram of T Vel
Lower panel: γ-velocities for the same Cepheid

The O-C residuals listed in Table 76 and shown plotted in the upper panel of Figure 45 show constancy of the period, at least in the photoelectric era. *Hertzsprung*'s (1937) observations suggest that the pulsation period of T Vel is increasing. Further observations will decide whether a parabolic fit is better. Similarly to AT Pup, *Gieren*'s (1985) observations made in 1981 have not been taken into account (see the remarks on AT Pup).

V Velorum

Pel (1978) suspects a blue photometric companion to this Cepheid. Variability of the γ-velocity is suspected here (see Table 77 and the lower panel of Figure 46).

Table 77. γ-velocities of V Vel

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
34092	45	-29.0	0.8	17	Stibbs (1955)
39245	40	-30.7	1.1	4	Lloyd Evans (1968)
40381	23	-29.4	0.3	4	Lloyd Evans (1980)
40690	57	-27.5	0.3	6	Lloyd Evans (1980)
45042	2	-26.3	0.4	21	Gieren (1985)

Table 78. O-C residuals for V Vel

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
34809.091	-1356	$+0^d.001$	pe 2	Walraven et al. (1958)
35233.090	-1259	+0.009	pe 2	Irwin (1961)
40268.520	- 107	-0.002	pe 3	Stobie (1970)
40766.834	+ 7	+0.013	pe 3	Pel (1976)
41789.624	+ 241	-0.021	pe 3	Dean et al. (1977)
42585.158	+ 423	-0.017	pe 3	Dean et al. (1977)
44412.289	+ 841	+0.018	pe 3	Eggen (1985)
45037.336	+ 984	+0.006	pe 3	Gieren (1985)

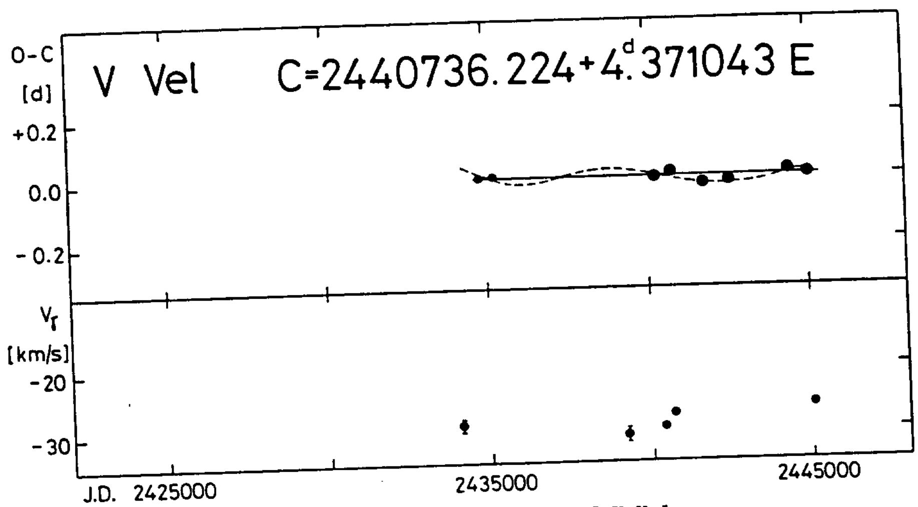

Figure 46. Upper panel: O-C diagram of V Vel
Lower panel: γ-velocities for the same Cepheid

The O-C residuals have been calculated with the elements:

$$C = 2440736.224 + 4^d.371043 \cdot E \qquad (60)$$
$$\pm.003 \qquad \pm.000006$$

These elements have been obtained by a linear least squares fit to the O-C residuals listed in Table 78. The upper panel of Figure 46, however, shows that a light-time effect interpretation of these data is also possible.

Assuming an orbital period of about 7500 days, the γ-velocity variations are properly phased with respect to the O-C wave. Similarly to AT Pup and T Vel, *Gieren*'s (1985) photometric observations obtained in 1981 have not been taken into account here (see the remark on AT Pup).

AH Velorum

AH Vel belongs to a binary system based on both photometric (*Gieren*, 1980b) and spectroscopic (*Lloyd Evans*, 1968 and 1982, and *Gieren*, 1980a) criteria. The orbital period cannot be determined yet. The individual γ-velocities are listed in Table 79 and shown plotted in the lower panel of Figure 47.

The O-C residuals have been calculated with the elements:

$$C = 2442035.703 + 4\overset{d}{.}227231 \cdot E \qquad (61)$$
$$\pm.007 \quad \pm.000007$$

Table 79. γ-velocities of AH Vel

JD 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
33979	22	25.8	0.7	18	Stibbs (1955)
34108	38	28.5	1.3	6	Stibbs (1955)
39230	44	22.5	0.8	6	Lloyd Evans (1968)
39643	72	21.3	0.8	7	Lloyd Evans (1968)
39899	30	23.0	0.2	8	Lloyd Evans (1980)
40300	54	23.2	0.2	12	Lloyd Evans (1980)
40653	49	21.0	0.2	9	Lloyd Evans (1980)
42036	7	24.5	0.3	37	Gieren (1977)

Table 80. O-C residuals for AH Vel

Norm.max. JD2400000+	E	O-C	Type, weight	Reference
33889.864	-1927	$+0\overset{d}{.}035$	pe 2	Eggen et al. (1957)
34824.060	-1706	+0.013	pe 1	Walraven et al. (1958)
35187.584	-1620	-0.005	pe 3	Irwin (1961)
40256.017	- 421	-0.022	pe 3	Stobie (1970)
40725.254	- 310	-0.007	pe 3	Pel (1976)
41765.136	- 64	-0.024	pe 3	Dean et al. (1977)
42035.677	0	-0.026	pe 3	Gieren (1980a)
43895.726	+ 440	+0.041	pe 1	Eggen (1980)
44681.992	+ 626	+0.042	pe 3	Eggen (1983a)

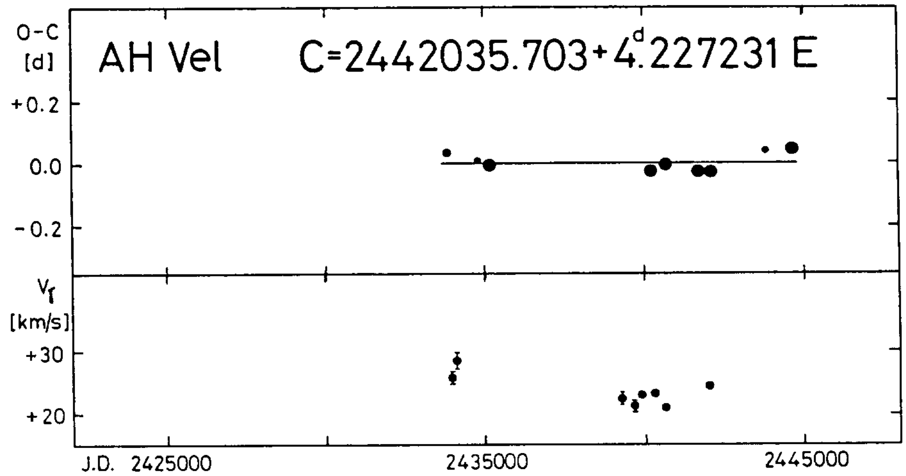

Figure 47. Upper panel: O-C diagram of AH Vel
Lower panel: γ-velocities for the same Cepheid

Although a constant period is assumed here (see the upper panel of Figure 47 and Table 80), neither a parabolic O-C graph, nor a light-time effect with a very long orbital period can be excluded. Further photometric and radial velocity observations are needed as for most of the previously discussed Cepheids.

GENERAL REMARKS

Because the sample of Cepheids studied here is inhomogeneous and is not large enough, any statistics concerning the period changes, including a comparison with previous results, may lead to false conclusions. It is, however, important to note that all kinds of period changes known from earlier studies are observed here, too. Particularly important among them are: the continuous period increase or decrease (due to stellar evolution), the wave-like pattern of the O-C graph (due to the light-time effect in binary systems), and the phase jump (return to an earlier value of the pulsation period). This latter kind of period change also occurs in binary Cepheids.

Table 81 summarizes the results on the period changes and variability of the γ-velocity of the Cepheids studied here. Because the normal maxima published in the GCVS (*Kholopov* et al., 1985-1987) were only modified in the discussion on the individual variables instead of transferring them to a more recent epoch, it is worthwhile to give the actual values of the normal maximum and the pulsation period valid for e.g. J.D.2445000, taking into account the period variations when necessary. The successive columns of Table 81 give the following data:

1. Name of the Cepheid
2. Moment of the normal maximum just following J.D.2445000
3. Pulsation period at J.D.2445000
4. Characteristic features in the O-C diagram (∿: light-time effect, -: decreasing period, +: increasing period)
5. Variability in the γ-velocity
6. Value of the orbital period
7. Reference to the paper where the value cited in the previous column has been published.

There are four stars in this sample for which the catalogued value of the pulsation period needs a considerable correction: YZ Car, AZ Cen, KN Cen, and GH Lup. In addition, the starting epoch needs a big correction in the case of SY Nor.

Light-time effect has been discovered in the O-C diagram of V496 Aql, AX Cir, AG Cru, BG Cru (uncertain), BF Oph, AP Pup, AT Pup, Y Sgr, AP Sgr, R TrA, and V Vel. A preliminary value of the orbital period has been suggested on the basis of the light-time effect and/or the variations in the γ-velocity for the following Cepheids: V496 Aql, AX Cir, AG Cru, Y Oph, BF Oph, AP Pup, AT Pup, U Sgr, Y Sgr, AP Sgr, BB Sgr, RV Sco, R TrA, and V Vel. A phase jump is revealed in the O-C diagram of U Aql, YZ Car, KN Cen, S Mus, S Nor, Y Oph, U Sgr, and V350 Sgr. If an O-C diagram can be equally well represented by a phase jump or a constant period of another value, the phase jump interpretation is preferred here. This more or less provocative step may encourage others to observe these stars photometrically. Similarly, some of the orbital periods, and even the variation in the γ-velocity assumed for a particular Cepheid variable can be doubted. In any case, more regular photometric and radial velocity observations would be desirable on each Cepheid studied here.

Even if some of the orbital periods suggested in Table 81 is not well determined, the half of the programme stars belongs to spectroscopic binary systems. Keeping in mind that the spectroscopic binaries can only be revealed in favourable cases (depending on the value of the orbital inclination), and that the binary nature can also be discovered on the

Table 81. Summary on the periods, period changes, and duplicity

Cepheid	Norm.max. JD2400000+	P	O-C diagram	V_{γ}	P_{orb} [day]	Source
U Aql	45001.780	$7^{d}.023958$	linear with phase jump	variable	1856.4	Welch et al. (1987)
V 496 Aql	45002.397	6.807055	linear ∿	variable	1780·n	present paper
V Car	45001.101	6.696672	linear	variable		
YZ Car	45007.131	18.165573	linear with phase jump	variable	∿ 850	Coulson (1983)
ℓ Car	45002.391	35.551341	two linear sections	constant		
V Cen	45000.289	5.493861	two linear sections	variable ?		
XX Cen	45010.493	10.953370	parabolic (-)	variable	909.4	Szabados (1989)
AZ Cen	45001.112	3.211981	parabolic (-)	variable ?		
KN Cen	45021.656	34.029641	linear with phase jump	variable		
AX Cir	45001.903	5.273306	linear ∿	variable	∿ 4600	present paper
S Cru	45000.251	4.689596	parabolic (-)	constant		
T Cru	45004.630	6.733196	linear	variable		
AG Cru	45000.710	3.837254	linear ∿	variable	∿ 6350	present paper
BG Cru	45003.271	3.342720	linear ∿:	variable		
β Dor	45009.560	9.842425	linear	constant		
GH Lup	45003.355	9.277948	linear :	variable		
R Mus	45001.446	7.510467	parabolic (+)	variable		
S Mus	45003.522	9.659875	linear with phase jump	variable	506	Lloyd Evans (1971)
S Nor	45004.063	9.754244	linear with phase jump	variable		
RS Nor	45002.060	6.198136	linear	not observed!		
SY Nor	45005.992	12.645687	linear	one series only		
Y Oph	45008.372	17.126908	linear with phase jumps	variable	1222.5	present paper

Table 81. (cont.)

Cepheid	Norm.max. JD2400000+	P	O-C diagram	V_γ	P_{orb} [day]	Source
BF Oph	45000.515	$4^d.067510$	parabolic ∿ (-)	variable	∿ 4500	present paper
AP Pup	45000.597	5.084274	linear ∿	variable	∿ 10000	present paper
AT Pup	45006.629	6.664879	linear ∿	variable	∿ 20000	present paper
MY Pup	45001.729	5.695309	parabolic (+)	constant		
U Sgr	45004.675	6.745229	linear with phase jump	variable	4550	present paper
W Sgr	45007.526	7.594904	linear	variable	1780	Babel et al. (1989)
X Sgr	45005.293	7.012877	parabolic (+)	variable	507.25	Szabados (1989)
Y Sgr	45005.763	5.773380	linear ∿	variable	⩾10000 :	present paper
WZ Sgr	45011.333	21.849789	linear + earlier changes	variable ?		
AP Sgr	45003.097	5.057916	linear ∿	variable	∿ 7500	present paper
BB Sgr	45000.224	6.637102	parabolic (+)	variable	∿ 4550 ?	present paper
V 350 Sgr	45002.267	5.154178	linear with phase jump	variable	1129	Szabados (1989)
RV Sco	45005.369	6.061306	parabolic (-)	variable	∿ 8000 ?	present paper
RY Sco	45017.646	20.320144	linear with period change	variable ?		
V 500 Sco	45006.433	9.316839	linear	variable		
V 636 Sco	45006.676	6.796859	linear	variable	1318	Lloyd Evans (1971)
Y Sct	45009.472	10.341483	linear	variable		
R TrA	45000.222	3.389287	linear ∿	variable	∿ 3500	present paper
S TrA	45002.725	6.323465	linear with period change	variable ?		
T Vel	45000.479	4.639819	linear	constant		
V Vel	45002.362	4.371043	linear ∿	variable	∿ 7500	present paper
AH Vel	45003.219	4.227231	linear	variable		

basis of a number of photometric methods not discussed here, the following conclusion may not be an exaggeration: the frequency of Cepheid binaries is higher than thought ever since these variables have been known as pulsating stars.

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Distribution of Late-Type Stars Around IC 4665

ABSTRACT

We have investigated 424 stars of F8 spectral types and later in a 19.5 sq. degree field around IC 4665. The main purpose of our study in this low latitude field (b=+16.5 in our case) was the testing of the plane-parallel hypothesis of the density distribution, i.e. the hypothesis that the spatial density of the Population I stars observed at great angular distance from the galactic caps is well approximated by the $z = r \sin(b)$ scaling of the distributions obtained in the polar regions.

We used the factor analysis of multivariate mathematical statistics in order to extract the effect of absorption from the photometric data. To identify the factor component describing the interstellar reddening we invoked the corresponding IRAS Sky Flux Data. We computed the spatial densities for the F8 - G5 dwarfs and the K giants separately. We used a maximum likelihood algorithm for obtaining the space densities. We arrived at the following main conclusions in our paper: The absorbing material concentrates closer than 150 pc in our area. There is a weak but still significant correlation between the optical measures of absorption and the IRAS 100 micron Sky Flux Maps data. The spatial densities of F8 - G5 dwarfs essentially reflect the densities obtained in the galactic plane. The distribution of distance moduli of K giants in our sample can be well modelled by the $z = r \sin(b)$ scaling of Upgren's data from the North Polar region. The actual form of the space density curve of the K giants can be satisfactorily fitted both by an isothermal model and an exponential model.

Key words: late-type stars - galactic structure - multicolour photometry - interstellar matter

1. INTRODUCTION

The disk of our Galaxy is strongly flattened and therefore the stellar distributions obtained in any line of sight are essentially the projections of the vertical distribution into the particular direction observed, even at great angular distances from the galactic caps. In our previous papers (*Balázs* 1975, 1977, 1984, *Paparó and Balázs* 1982, *Balázs* et al. 1985) we focussed our attention mainly on the *A* type stars at low galactic latitudes of about +15 degrees. With this choice one can check whether the spatial distributions observed in the galactic polar caps are still held after suitable scale transformation at greater angular distances from the polar direction or, on the contrary, one can pick up the possible deviations from a strict plane-parallel case. We have concluded that the spatial distributions obtained in the particular low latitude directions we studied can be satisfactorily described by the density laws in the polar cap directions after suitable scaling, i.e. substituting of $z = r\sin(b)$ into $D(z)$, where $z, r, b, D(z)$ mean the distance from the galactic plane, the distance in the line of sight, the galactic latitude of the field observed, and the density distribution of the stars in the polar caps, respectively. In two fields (a field in the Lyra and one around IC 4665) we found a good fit with the observed data by the suitably scaled model of *Woolley and Stewart* (1967), whereas the best fit was obtained by the isothermal model of *Bahcall* (1984) in the field around NGC 7686.

Unlike the A type stars at low galactic latitudes the physical background behind the observable distribution of F and later type stars is more complicated because in this case the lifetime of the objects is comparable with those of the Galaxy, and consequently we see a superposition of objects representing quite different stages of the dynamic and chemical evolution of our stellar system. A higher number of significant physical quantities is therefore required to describe the photometric and spectral properties of stars in the sample. In the case of main sequence A type stars the effective temperature and the interstellar reddening satisfactorily characterize the optical photometric properties of these stars. With the late-type stars, however, one has to add a further quantity describing the possible differences in chemical composition among the stars in the sample.

In statistical studies the most widely used photometric systems are the UBV and RGU systems because one can easily implement them on panoramic detectors (like CCD-s or photographic plates) and they are therefore well suited to statistical studies. In this paper we try to join the power of the UBV and RGU systems supplemented with small scale spectral classification in order to get a more reliable estimation of the physical parameters of stars in our sample. Our main purpose in this paper is the study of the vertical cross section of our Galaxy as free from a priori assumptions as possible.

2. OBSERVATIONAL MATERIAL AND DATA REDUCTION

Our work is based on the observations we made with the 60/90/180 cm Schmidt type telescope of the *Konkoly Observatory*. The spectra were obtained on IIa-O plates using a 5 degree ultraviolet transparent objective prism with a dispersion of 580 $Å/mm$ at $H\gamma$. We widened them by 18" corresponding to 0.16 mm on the plate. The spectral and UBV plates were the same as those used when studying the $F7$ and earlier type stars around IC 4665 (*Paparó and Balázs* 1982).

2.1 Multicolour photometry

As we mentioned in the introduction we have attempted to join the power of *UBV* and *RGU* photometry to get a more reliable estimation of the basic physical quantities of the stars in the sample. As a consequence we have supplemented our previous observational material with the *R* and *G* colours. The emulsion types, filters and exposures used are summarized in Table 1.

Table 1.

	Emulsion	Filter	Exp. time
U	Kodak 103a-O	Schott UG1 2mm	10 min
B	Kodak 103a-O	Schott GG13 2mm	5 min
V	Kodak 103a-D	Schott GG14 2mm	4 min
G	Kodak 103a-O	Schott GG5 2mm	10 min
R	Kodak 098-02	Schott RG5 2mm	10 min
Spectral plates	Kodak IIa-O	5° prism	24 min

The limiting *B* magnitude of the survey was about 13.5 mag. It was defined as the faintest star in the sample, but the limit of completeness is about 1.5 mag brighter. Fig.1 shows the distribution according to the apparent *B* magnitude of all program stars, $F-G$ stars and *K* stars, separately. For the calibration of both photometric systems we used *Alcaino*'s (1965) *UBV* photoelectric measurements on IC 4665. The transformations between the instrumental and international systems are given by the following equations:

$$
\begin{aligned}
V_{instr} &= V - 0.145(B-V) + 0.079 \\
(B-V)_{instr} &= 1.040(B-V) - 0.055 \\
(U-B)_{instr} &= 1.040(U-B) - 0.007
\end{aligned}
$$

The calibration of *RGU* colours proceeds utilizing *UBV* photoelectric standards. There are two implementations of this photometric system, i.e. the version of *Steinlin* (1968) and that of *Buser* (1978a,b). We tried both of them and got the impression that *Buser*'s was better suited to the data, and we therefore used this version in our work. The transformation of *UBV* standards into *RGU* requires knowledge of the $E(B-V)$ interstellar reddening of the standards. The published reddening measurements for this field (*Paparó and Balázs* 1982) revealed that the value varies between 0.2 and 0.3 mag. over the whole field in the case of distant stars. This means that except for the distant giant stars this term could be omitted from the transformation equations.

Table 2.

spectral type	criteria used for classification
F8	G-band $\leq H\gamma$ CaI4227 appears in luminosity class V. FeI4325 is noticeable.
G0	G-band $\approx H\gamma$ and CaI4227 $\approx H\delta$ FeI4325 $< H\gamma$
G2	G-band $> H\gamma$ and FeI4325 $< H\gamma$
G5	G-band $\gg H\gamma$ and FeI4325 $\geq H\gamma$
G8	G-band $\gg$ CaI4227 and FeI4325 $> H\gamma$
K0	CaII(H) and (K) at maximum strength H-lines disappear CaI4227 < G-band
K2	Continuum becomes weak in blue. CaI4227 < G-band Metallic blends appear.
K5	The strength of G-band is equal to CaI4227. Strong metallic blends in all spectral regions. (G-band is stronger than CaI4227 in all K types of highest luminosity classes.)
M0	TiO bands noticeable and CaI4227 $\gg$ G-band. The spectral pattern is dominated by $\lambda4227$ in luminosity class V. $\lambda4227$ decreases with increasing luminosity class.
M5	Spectrum fluted by strong molecular bands.

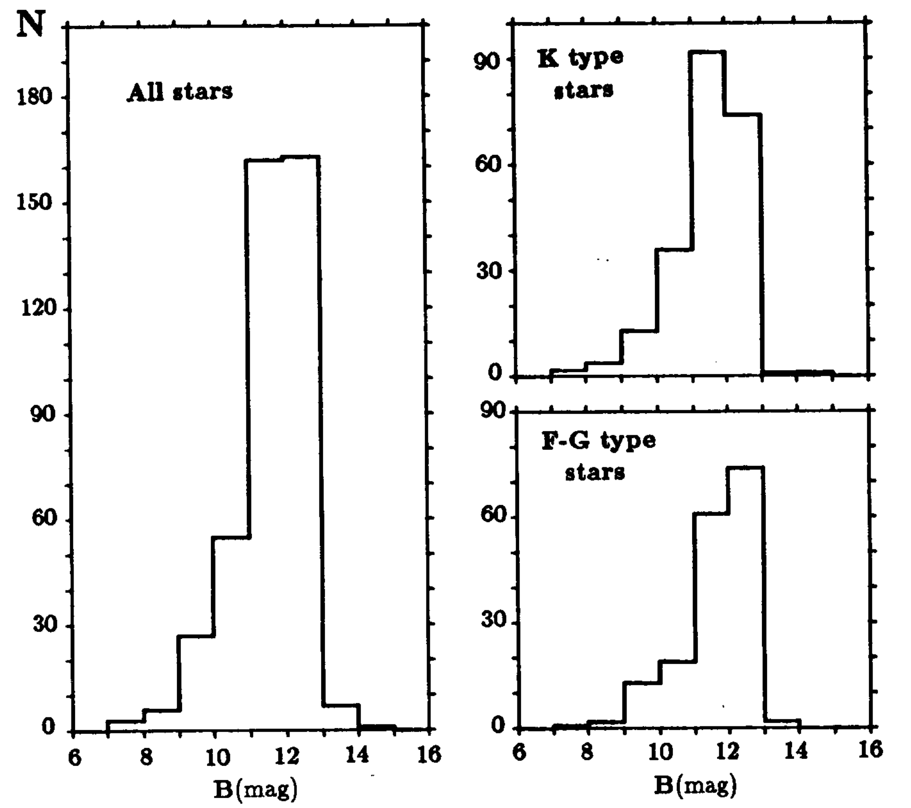

Fig. 1a-c. Distribution of stars according to the B magnitude (all stars, F - G type and K type stars respectively). The sharp edges at the right side of the diagrams are due to the magnitude limit of our sample.

Based on these calibrations we determined the photometric colours of the program stars using the Cuffey type iris photometer of the *Konkoly Observatory*. We measured 5 plates in UBV and 3 plates in the R and G colours. The corresponding accuracy of photometric magnitudes obtained in this way are ±0.07, ±0.06, ±0.05, ±0.08 and ±0.06 magnitudes for U, B, V, R and G respectively. The photometric data of our program stars in the international system are summarized in Table 6.

2.2 Spectral classification

The spectra obtained by the 5 degree prism were classified visually using the criteria of the Bonner Spectral Atlas (*Seitter* 1975). According to the sharpness of the criteria we can define the following normal groups (a concept introduced in *Morgan* 1951) to assign those stars which are indistinguishable from each other in respect of the given criteria and dispersion of spectra. Considering the resolving power of our

5 degree prism and the widening of our spectra we can set up the following groups: *F8, G0, G2, G5, G8, K0, K2, K5, M0, M5.*

We used the following general features in our work: Balmer lines decrease with advancing spectral type and disappear around *K0.* The spectral pattern is dominated by the CaII(H) and (K) lines, G-band and strong absorption in the region $\lambda4118-4216$ in the blue part of the spectrum. The CaI4227 increases rapidly with advancing spectral type after the *K0.* Blend MnI, FeI, SrII $\lambda4031 - 4078$ becomes increasingly strong with advancing spectral type and is the dominating feature in the blue spectral region of stars later than *G5* and luminosity classes *V.* TiO bands appear around *M0* and increase towards later types. $\lambda4215 - 4227$ is intense and $\lambda4200, 4176, 4155$ bands are noticeable in spectral type *K* at luminosity class *III.* The characteristic features of spectral groups are listed in Table 2. We have based our further discussion on these subgroups supplemented with multicolour data.

3. INTERSTELLAR REDDENING

Before entering into the details of the space distribution of stars of different spectral characteristics based on photometric parallax, we have to remove the effect of interstellar reddening from the photometric data. Spectral classification of small scale spectra enables us in principle to estimate the intrinsic colours of the stars and compare them with those actually measured. In the case of stars of *F8* and later, however, one encounters difficulties. The reddening path of late-type stars on the $B-V$, $U-B$ and $G-R$, $U-G$ two-colour diagrams makes a much smaller angle to the unreddened branch of Population I stars in these diagrams, unlike stars of *A5-F5* spectral types (see the model calculations of *Buser* 1978a). As a consequence, even small errors in the spectral classification could cause serious bias in determining the colour excesses in this way. An additional difficulty arises from the photometric effect of differences in chemical abundances. The blanketing effect, i.e. the photometric differences of stars due to their metal abundances, can become quite prominent among spectral types of *F5* and later, especially at higher galactic latitudes. The blanketing shifts the stars to the right and upwards on the two-colour diagrams. Both the reddening and the blanketing shift the stars rightwards on the two-colour diagrams but in the $U-B$ or $U-G$ direction, on the contrary, the results of these two effects are just the opposite: the reddening shifts downwards while the blanketing shifts upwards. If one knows the spectral type, therefore, one can in principle distinguish between these two effects. In reality, however, due to the uncertainty of spectral types of *G-K* stars on our small scale spectra, one encounters difficulties when trying to separate the blanketing from the reddening in this way. To study the distribution of absorbing material responsible for the interstellar reddening in this field, we therefore have to invoke the results of other investigations as well. The overall galactic optical absorption due to interstellar

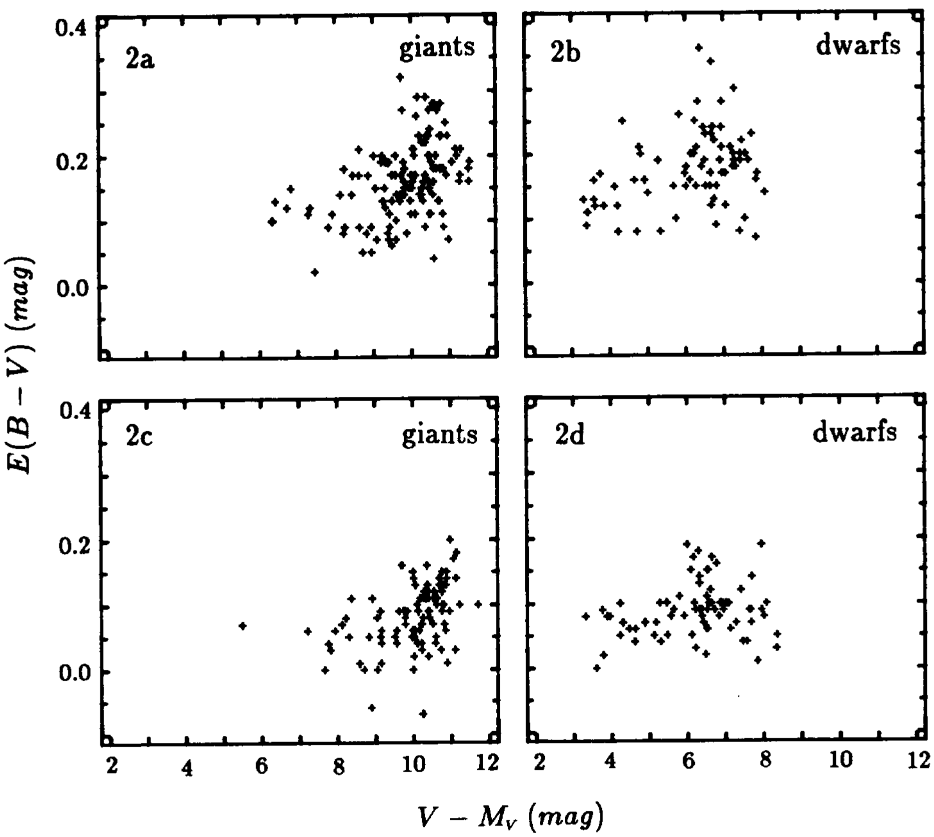

Fig. 2.a-d Plot of the E(B-V) colour excesses of the program stars, estimated by factor analysis, versus uncorrected distance moduli. (a-b: below and c-d: above the 425th line in the PL113 IRAS Sky Flux map). Note the similarity between the distribution of colour excesses of giants and dwarfs indicating the presence of a nearby obscuring cloud.

dust was studied by *FitzGerald* (1968) and *Neckel and Klare* (1980). The spatial resolution of their studies was fairly poor owing to the sparseness of stars in our 19.5 sq. degree field. Nevertheless, their studies indicated that the surface density of the absorbing material was non-uniform, i.e it was mostly concentrated in the smaller galactic latitude side of our field; and both studies showed an abrupt increase in the absorption within 200 pc, revealing the presence of a nearby absorbing cloud. These results were confirmed by our previous study on the distribution of stars of types *F7* and earlier based on 427 stars (*Paparó and Balázs* 1982). To get a more detailed picture of the distribution of absorbing material in our field we invoked the relevant IRAS Sky Flux Map. To compare the IRAS colours with our photometric data we sampled the 100 μm map of the PL113 plate at the positions of our program stars. Since the 100 μm radiation originates predominantly from the galactic dust clouds (*Hauser et al.* 1984) and the IRAS fluxes represent the total column density of the emitting material, we may expect good correlation with the optical absorption only with stars which are lying behind the absorbing material in the line of sight. The dust particles emitting the IRAS fluxes and those responsible for the optical absorption are not necessarily identical. Furthermore, the dust clouds may differ in their characteristic temperatures causing different infrared properties without affecting the optical properties of the absorbing material. All these effects work against a close correlation between the optical absorption and the measurable FIR radiation of the dust clouds. Our expectation is therefore only justified when the distribution of dust particles responsible for the infrared radiation is similar to the distribution of those making the optical absorption and there are no big differences in the temperatures of dust clouds in our area. A further difficulty arose from the influence of the Zodiacal Light dominating the 12 μm and 25 μm radiation in our field. It was an unfortunate circumstance that the general trend of the Zodiacal emission nearly corresponded to those of the interstellar reddening in our case. We cannot exclude the possibility that the correlation between the optical obscuration and the FIR might originates from this coincidence. Nevertheless, a comparison between the optical measures of absorption and the intensity of the FIR radiation may also have some significance.

To obtain a reliable measure for the optical absorption we tried to concentrate in one variable all the information our photometric data contained in respect of interstellar absorption. As we mentioned earlier in this paper the interstellar reddening shifts the stars rightwards to the unreddened loci of objects on the $B-V$, $U-B$ and $G-R$, $U-G$ two-colour diagrams. The orthogonal distance from the unreddened two-colour line due to this shift, depends on the spectral type and the actual functional form of the line joining the unreddened loci of objects in these diagrams. In the case of Population I objects this functional form is well approximated by straight lines in the following spectral ranges, based on the calibration of *Buser* (1978a):

- in the *F8-K0* spectral range the loci of dwarfs and *G5-G8* giants essentially define the same straight line on the two-colour diagrams within the accuracy of our photometric data;

- in the *K0-M0* domain, in contrast, the giants and dwarfs populate different lines;

- in the *M1* and *M6* domain the giants are well approximated by a straight line but both the photometric measurements and calibrations are rather uncertain because of the increasing dominance of molecular bands in this range. We assigned to all of these stars the spectral type *M5* in our sample. Because of the great uncertainties in their photometric data we omitted them from the further analysis.

Assuming that the real functional form can be well represented by these straight lines and, furthermore letting $B-V$, $U-B$, $G-R$ and $U-G$ be the respective measured colour indices in the UBV and RGU systems, then the orthogonal displacements of stars from the unreddened Population I two-colour lines can be written in the form of the equations:

$$DUBV = \alpha_1(B-V) + \beta_1(U-B) + \gamma_1$$
$$DRGU = \alpha_2(G-R) + \beta_2(U-G) + \gamma_2$$

The following table summarizes the value of coefficients in these equations, in the spectral ranges mentioned above.

Table 3.

	α_1	β_1	γ_1	α_2	β_2	γ_2
F8-K0 dwarf	+0.839	-0.543	-0.444	+0.815	-0.578	-0.006
K2-M0 dwarf	+0.761	-0.648	-0.202	+0.773	-0.634	+0.304
K0-M0 giant	+0.875	-0.481	-0.418	+0.869	-0.495	-0.039

These displacements may not only be due to interstellar reddening but may be partly accounted for by the blanketing effect. To get more information on these two physical quantities and to study their influence on the measured colours separately and in more detail, we subtracted the respective colour indices estimated on the basis of the spectral types of our program stars from the actually measured colour indices, i.e.:

$$EUB = (U-B) - (U-B)_0 \quad , \quad EUG = (U-G) - (U-G)_0$$
$$EBV = (B-V) - (B-V)_0 \quad , \quad EGR = (G-R) - (G-R)_0$$

The '$_0$' indices denote *Buser*'s normalized synthetic colours corresponding to the unreddened Population I values of the spectral types of our program stars. Although all of these quantities have some relevance in measuring the amount of optical absorption, we omitted from our further study the short wavelength colour differences, i.e. EUB and EUG, because blanketing affects them much more seriously; as it does the possible uncertainties that may be present in the spectral classification.

To concentrate the photometric effect of interstellar absorption into one variable we proceeded to estimate its effect contained in EBV, EGR, $DUBV$ and $DRGU$. To

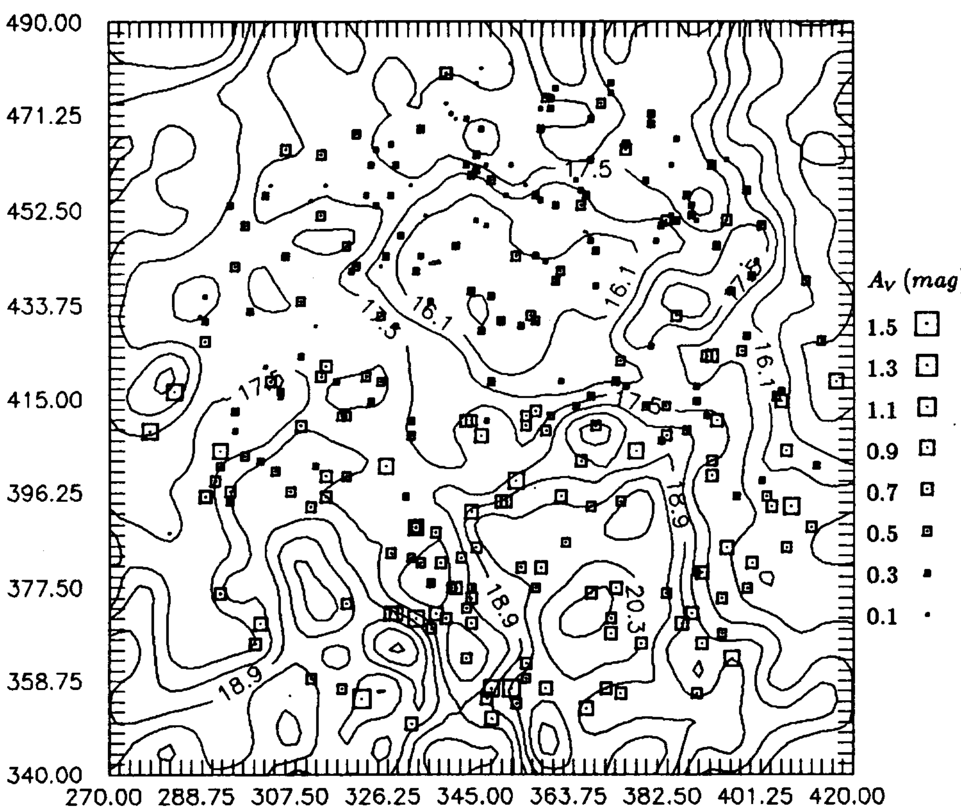

Fig. 3. Comparison of the 100 micron IRAS flux with the estimated visual absorption. Sizes of squares are proportional to the measure of visual absorption at the place of program stars. Both the 100 micron flux and the optical absorption are stronger in the southern part of our field. The numbers at the left side and the bottom of the figure refer to the lines and columns in the PL113 IRAS Sky Flux Map.

carry out this procedure we invoked a standard technique of multivariate mathematical statistics, factor analysis. According to the basic assumption of factor analysis we suppose that the components of an $\mathbf{X}$ observable m-dimensional statistical variable can be well represented by the linear combination of k other variables, called factors. This means

$$X_j = \sum_{l=1}^{k} c_{jl} f_l + e_j \quad , \qquad j = 1, ...m \; and \; k < m$$

where c, f and e are the factor coefficients (loadings), factor values (scores) and individual factors, respectively. There are a wide variety of methods published in the literature for estimating the different components of factor models . We used the solution based on principal components analysis (for further details on this method see *Murtagh and Heck* 1987). The factors obtained by principal components analysis are always uncorrelated. We have identified the components of **X** with EBV, EGR, $DUBV$ and $DRGU$ and therefore $m = 4$ in our case.

Performing factor analysis on our data field we got a set of uncorrelated variables describing the basic dependences between the variables observed. We made the assumption that there were some physical variables (interstellar reddening and blanketing in our particular case) behind the observed ones and that they determined the variables actually observed. If the transformation between this physical variables and those observed were linear we might expect some linear connection between the physical and factor variables as well.

The number of significant factor variables set an upper limit for the number of physical variables one can recognize in the given data field. To ensure the validity of the required linearity we performed the factor analysis in the spectral groups defined above, separately. According to the principal components analysis technique the variables measured were represented by linear combinations of eigen vectors of the correlation matrix of the variables observed. Factor analysis then proceeded by dropping eigenvectors with small eigenvalues and assumed only those to be significant which were above a certain threshold. In the SPSS software package what we used in computing the factor model, the default value of this threshold was set to equal 1. Table 4. summarizes the eigenvectors of the correlation matrix in the case of the F-G dwarfs and the K giants separately:

Table 4.

	F-G dwarfs		K giants	
factor	eigenvalue	cum.pct.	eigenvalue	cum.pct.
1	2.898	72.4	2.566	64.2
2	.860	93.9	.810	84.4
3	.213	99.3	.592	99.2
4	.029	100.0	.032	100.0

Examining Table 4. one can infer that in both cases there is only one eigenvalue lying above the default threshold. The second eigenvalues, however, are close to unity and we tried to reproduce the covariance matrix keeping these factor variables. In the case of the dwarf stars the use of these two factors gave satisfactory reproduction of the covariance matrix. In the case of giants this reproduction was not so good but was still acceptable. We therefore used these two factors in our further calculations.

There are no clear rules concerning the making of comparisons between the variables obtained by factor analysis and those representing real physical quantities. Since the 100 μm IRAS fluxes are good measures of the amount of galactic dust, we identified those factor variables with interstellar absorption which showed the maximum correlation between the intensity of FIR radiation and the factor values given by the analysis. We expected correlation between the optical measure of absorption and the 100 μm flux only with those stars which are lying at greater distances than the bulk of emitting dust material responsible for the FIR radiation and detected by the IRAS mission.

3.2 Distribution of the absorbing material

We plotted the estimated colour excesses against the distance modulus of the stars in our sample in Fig. 2a-d for giants and dwarfs separately. We divided the whole field by the 425. line of the respective IRAS Sky Flux map in order to demonstrate the assimmetry in the surface distribution of the obscuring material over the whole area. It was also apparent on these plots that there were no significant difference between the distributions of the optical absorption of dwarfs and giants. Furthermore, the absorption of dwarfs increased up to 0.7 mag near to 6.7 of uncorrected distance modulus and did not change remarkably among the giants. It means that the vast majority of the absorbing material was concentrated within the distance modulus near

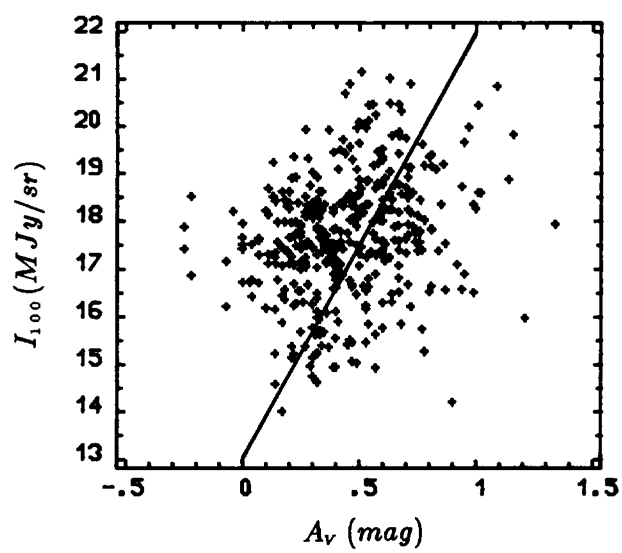

Fig. 4. Correlation between 100 micron IRAS flux and the estimated visual absorption. A line with 9 MJy/Sr per magnitude slope, found by de Vries and Le Poole (1985) for some high latitude dust clouds is also indicated.

to 6 corresponding to a distance of about 150 pc. We might therefore expect correlation between the IRAS fluxes and the stellar reddening with those stars which were lying behind this distance. The surface distribution of absorbing material was not uniform in this area, as was suggested by the earlier investigations. The patchy structure of the interstellar dust is also apparent on the IRAS Sky Flux maps. We plotted the reddening data of stars of $r > 150$ pc, represented in Fig. 3, in order to make a comparison between the surface distribution of the optical absorbing material and the FIR radiation. By doing this we recovered the results of the earlier investigations but with better angular resolution.

To get reliable correlation between the optical and infrared data we divided the stars in our sample into three groups: dwarfs $r < 150$ *pc* $(V - M_V < 6.7)$, dwarfs $r > 150$ *pc* and giants. Table 5. shows the correlations between the factor values and the 100 μm flux within each of these groups:

Table 5.

	dwarfs1			dwarfs2			giants		
	Flux.	$f1$	$f2$	Flux.	$f1$	$f2$	Flux.	$f1$	$f2$
Flux.(100)	1.00	.06	-.07	1.00	.33*	.18	1.00	.25**	-.03
$f1$	.06	1.00	.07	.33*	1.00	.01	.25**	1.00	.00
$f2$	-.07	.07	1.00	.18	.01	1.00	-.03	.00	1.00
number of cases:	91			52			204		

1-tailed Signif: * - 0.01 ** - 0.001

Examining this table one can clearly see that factor $f1$ has significant correlation with the FIR radiation in two of the groups, whereas $f2$ has not. The lack of significance in the first group and the significance in the second and third ones reflect the fact that the optical absorption, and also the FIR radiation, originate from a nearby dust cloud. Fig. 4 summarizes the dependence of the optical absorption measures on the 100 μm radiation. We computed a best fitting line to the points in this figure by extracting the common factor in A_V and 100 μm flux. The shape of this line was 5.4 MJy/Sr/mag while *de Vries* and *Le Poole* (1985) obtained 9 MJy/Sr/mag for some high latitude extended dust clouds. We adopted the estimated value of $f1$ as a measure of the optical absorption and converted it into factor-analysis-predicted EBV and EGR using the linear relation between the colour excesses and the factor values. The measure of the optical absorption can be obtained using the standard relationship between selective and total absorption. We used here the coefficients published by *Buser* (1978a).

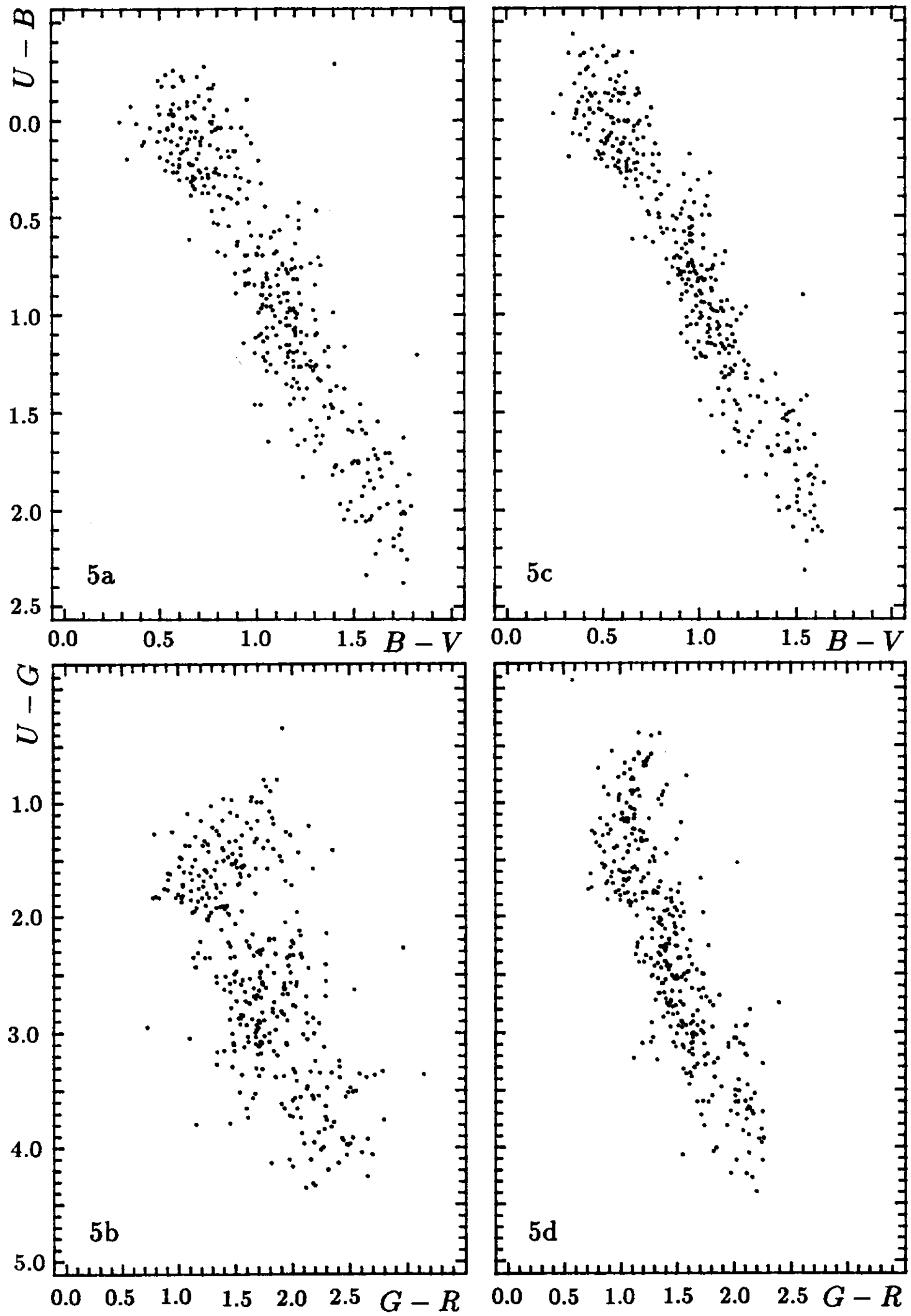

Fig. 5. Two-colour diagrams in UBV and RGU systems. Without (5a-b) and after (5c-d) correcting for the estimated interstellar reddening.

4. SPATIAL DISTRIBUTION OF THE STARS

4.1 Generalization of the convolution equation for multivariate case

After eliminating the effect of the interstellar reddening we could proceed to the determination of the spatial distribution of our stars. To check the reliability of the procedure we used for the elimination of reddening from our data we compared the two-colour diagrams of the non-corrected colour indices with those corrected using the method described in the previous paragraph. The power of this procedure is demonstrated in Fig. 5. To derive the space densities of our stars we made the usual assumption that their true absolute magnitudes are represented by a Gaussian random variable with a mean value given by their spectral type, luminosity class, chemical composition and σ standard deviation (*McCuskey* 1966). We have a multicolour sample in our case and consequently the absolute magnitude itself is also a multivariate Gaussian random variable with a mean according to the spectral characteristics of the stars and a Σ covariance matrix. We have omitted from the further calculations the U colour because, as we pointed out in the previous paragraph, the errors inherent in spectral classification affect this spectral band most seriously. Let

$$\Phi(\mathbf{M}|Sp) = \frac{exp(-(\mathbf{M}-\mathbf{M0})^T\Sigma^{-1}(\mathbf{M}-\mathbf{M0}))}{(2\pi)^{m/2}DET(\Sigma)}$$

a multivariate Gaussian where $\mathbf{M}$ represents the set of variables B, V, R and G (so we have a four dimensional variable in our case), Sp the spectral type given, $\mathbf{M0}$ the mean value of absolute magnitude and Σ the covariance matrix. With these notations we can generalize the standard integral equation of stellar statistics (*Kurth* 1967) in the form of

$$A(\mathbf{m}|Sp) = \int_{-\infty}^{+\infty} \Delta(\rho)\Phi(\mathbf{m}-\rho \mid Sp)d\rho$$

Where $\mathbf{m}$ and ρ are multivariate random variables representing the apparent magnitudes and distance modulus in different colour bands while A and Δ stand for their probability densities respectively. To solve this integral equation we approximated the integral expression with a sum of

$$A(\mathbf{m}|Sp) = \sum_{l=1}^{k} q_l\Phi(\mathbf{m}-\rho_l \mid Sp) \qquad l = 1, ..., k$$

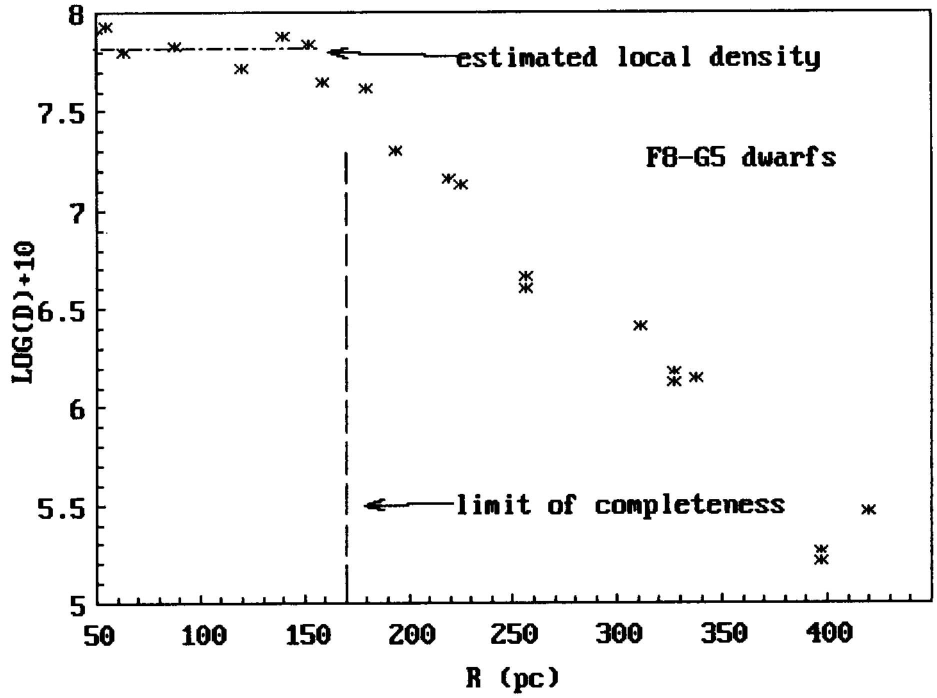

Fig. 6a. Dependence of logarithmic density on the distance in line of sight in case of F8-G5 dwarfs. The limit of completeness of our sample is marked by a vertical dashed line.

containing $q_l = \Delta(\rho_l)d\rho$ and ρ_l as unknown parameters to be determined. To estimate the set of the unknown parameters we used the maximum likelihood method. We defined the maximum likelihood function in the usual way:

$$L(\mathbf{a}) = \sum_{i=1}^{n} log A(\mathbf{m}_i \mid Sp).$$

In this equation **a** represents the set of parameters to be estimated and n the size of the sample. The maximum likelihood principle requires the estimation of those values of **a** which maximize $L(\mathbf{a})$, i.e.:

$$\frac{\partial L(\mathbf{a})}{\partial \mathbf{a}} = 0.$$

The derivatives of L(**a**) yielded a system of equations and the solution of this system resulted in the parameter values we were looking for. In the following we discuss the results of these computations in separate spectral subgroups.

4.2 F8-G5 stars

The $F8 - G8$ stars formed a separate group in our two-colour diagrams. After being corrected for interstellar reddening they satisfactorily concentrated along the unreddened main sequence line in the two-colour diagrams. We cannot distinguish among the subdwarfs, dwarfs, subgiants and giants in this spectral region using our small scale spectra. Using larger dispersion spectra for a magnitude limited sample, *Kharadze* et al. (1989) concluded that among their G type stars there were practically the same numbers of subgiants and dwarfs. On the other hand, in *Houk*'s (1983) HR diagram based on the Michigan spectral survey data, the stars mainly populated the main sequence in the $F8 - G5$ region. *Kharadze* et al. assigned all stars to subgiants which could not be classified as either giant or dwarf. Their number of subgiants may therefore perhaps have been overestimated. We made the assumption in our further analysis that the vast majority of our $F8 - G5$ stars belonged to the main sequence dwarfs.

As a result of the reddening correction a small number of the stars were shifted above the main sequence line. Their corrected position corresponded to those produced by the blanketing effect. The shift gave an ultraviolet excess of about 0.2 mag in the UBV and 0.3 mag in the RGU system and might be explained by metal deficiency in these stars. Measurements using a more sophisticated photometric system such as the Strömgren *uvby* photometry could prove the validity of this conclusion. With the exception of these UV objects we assumed that the $F - G$ stars were main sequence stars in our sample and assigned to them absolute magnitudes according to their spectral types given by *Allen* (1973).

The absolute magnitude increases very rapidly within this spectral group. From the value of 4.0 at $F8$ stars it reaches 5.5 at $G8$ in the V band. Since our sample was magnitude limited the limiting distance in our sample, i.e. the distance which the space densities were biased beyond, varied strongly from $F8$ to $G8$ as well. To get a greater limiting distance but still enough objects to make statistical studies we restricted ourselves to the spectral range of $F8 - G5$.

Performing the maximum likelihood algorithm outlined above we obtained an estimation of the space densities as a function of the distances from the Sun. Fig. 6a shows the logarithm of these densities as a function of the distances. The limit of completeness is also indicated. The points obtained run nearly horizontally in the unbiased range of the diagram. Since the limiting distance is about 250 pc in our case, the distance from the galactic plane is less than 70 pc in the unbiased range. This means that we are practically seeing the space density of $F8 - G5$ stars in the galactic plane.

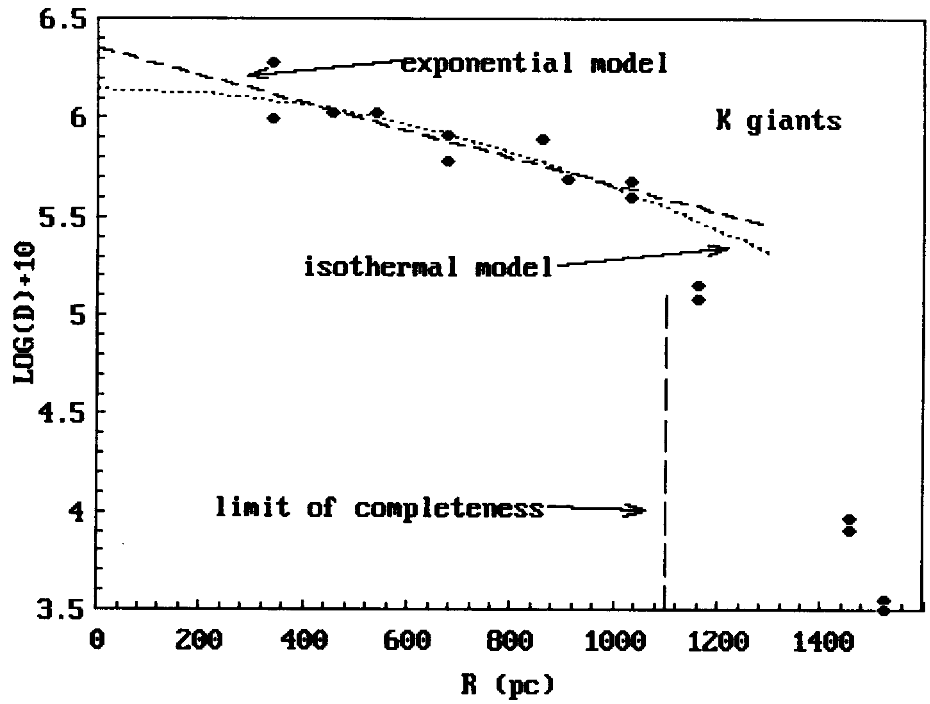

Fig. 6b. Dependence of logarithmic density on the distance in line of sight in case of K giants. The limit of completeness of our sample is marked by a vertical dashed line. Our fits with an isothermal and an exponentional model are also indicated.

4.3 K giants

The separation of K giants from the dwarfs is in principle possible on our small scale spectra. In practice, however, we succeeded in doing it with satisfactory reliability only with stars having well exposed spectra on our plates, i.e. with the brighter stars in our sample. Most of these stars appeared to be giants which nicely followed the line of the Population I giants on the two-colour diagrams after being corrected for reddening. The majority of fainter stars not bright enough for reliable luminosity class estimation also concentrated along the Population I giant line. In some cases, however, we had stars departing significantly from this line. In a considerable number of these cases the photometric images of objects in one of the colours distorted by a neighbouring star or the U colour was too faint for reliable brightness determination. Of course, we could not exclude the possibility that some of them were dwarfs, especially those lying along the dwarf line, or metal poor giants, if their positions on the two-colour diagram were realistic. Again, more accurate photometric or spectroscopic measurements would be desirable in these cases. We also omitted from the further analysis the stars with spectral types later than $M0$. We rejected 35 stars altogether in this way. Assuming that the stars remaining in the sample were Population I giants we assigned absolute magnitudes to them as given by *Allen* (1973). The space densities yielded by the maximum likelihood algorithm are displayed in Fig. 6b.

The main aim of our studying the space densities in this low latitude field was to compare spatial distributions in the galactic caps with those obtained in the present investigation. In particular, we were interested in testing the plane-parallel hypothesis, i.e. the hypothesis that the low latitude distributions can be well approximated by the substitution of $z = r\sin(b)$ into $D(z)$, the density in the direction of the polar caps, due to the high flattening of the galactic disc. The most extensive study in the direction of the North Polar Cap was the work of *Upgren* (1962) containing 4027 stars of spectral class $G5$ and later in a 396 square degree field down to a limiting photographic magnitude of 13.0 . We tested this hypothesis by substituting $z = r\sin(b)$ ($b = +16^{\circ}.5$ in our case) into *Upgren*'s density data and converted them into the distribution of the distance moduli which was the output of our maximum likelihood algorithm. The result of this comparison is shown in Fig. 7. This figure demonstrated with satisfactory significance that our points followed *Upgren*'s transformed curve up to a distance modulus of 10 mag corresponding to the limit of completeness in our sample . It has also been demonstrated that the plane-parallel approximation holds at least up to 1000 pc from the Sun in this direction.

In Fig. 6b we have shown the logarithmic space density of K giants of our sample as a function of the distance in the line of sight. The usual assumption that the space density is well approximated by an exponential function with a scale height depending on the absolute magnitude (see e.g. *Bahcall and Soneira* 1980) would result in a straight line in this figure. The scale height of the best fitting line corresponded to 200 pc perpendicular to the galactic plane. Assuming an isothermal model, on the other hand, we get

$$logD(z) - logD(0) = -\frac{u(z)}{\sigma_W^2}$$

where the gravitational potential $u(z)$ is well approximated by

$$u(z) \approx u(0) - \frac{u(0)''}{2} z^2$$

near to the galactic plane. This analytical form of the logarithmic density also fits satisfactorily with our data.

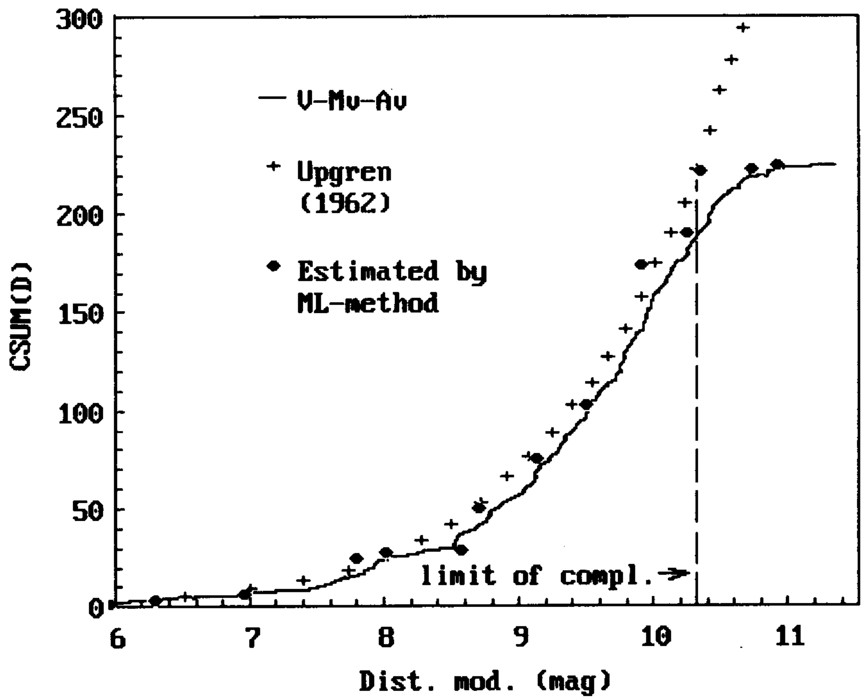

Fig. 7. The cumulative space density of K-type stars plotted against distance moduli for our program stars (full line) and for Upgren's (1962) data (crosses) after $z = r\sin(b)$ scaling. Departure from Upgren's data above 10 magnitude is due to the incompleteness of our sample in that range.

5. CONCLUSIONS

We have investigated 424 stars of spectral types of $F8$ and later in a 19.5 sq. degree field around IC 4665. The main purpose of our study was to make comparisons between the space densities of late-type stars in the galactic caps with samples taken from fields at great angular distances from the poles ($b = +16^\circ.5$ in our case). In particular, we were interested in testing the plane-parallel hypothesis of the density distribution, i.e. the hypothesis that the spatial density of the Population I stars observed at great angular distances from the galactic caps is well approximated by the $z = r\sin(b)$ scaling of the distributions obtained in the polar regions.

The major difficulty in making the comparison between our field and the polar region is the adequate treatment of the patchy distribution of the interstellar obscuring material over the field investigated and its elimination from the photometric data. To get an adequate estimation of the effect of the absorption we joined the power of the UBV and RGU photometric systems combined with the results of classification on small scale spectra. These data enabled us to get $E(B-V)$, $E(G-R)$ and perpendicular distances from the unreddened loci of the Population I stars in the two-colour diagrams, $DUBV$ and $DRGU$. We used the factor analysis of multivariate mathematical statistics in order to extract the effect of absorption from the data field defined by EBV, EGR, $DUBV$ and $DRGU$. To identify the factor component corresponding to the interstellar reddening we invoked the corresponding IRAS Sky Flux Data. After removing the interstellar reddening from our photometric data we computed the spatial densities for the $F8-G5$ dwarfs and the K giants separately. We used a maximum likelihood algorithm for obtaining the space densities from the photometric data. We can summarize the main conclusions of our paper as follows:

1. A significant amount of the absorbing material concentrates closer than 150 pc in our area producing $A_V = 1\ mag$ at the densest part of the obscuring cloud.

2. There is a weak but still significant correlation between the optical measures of absorption and the IRAS 100 μm Sky Flux Maps data. The shape of the best fitting line between A_V and 100 μm flux equalled 5.4 MJy/Sr/mag.

3. The spatial densities of $F8-G5$ dwarfs essentially reflect the densities obtained in the galactic plane. In a few cases UV excess seems to be present but this needs further confirmation based on measurements in more sophisticated photometric systems.

4. The distribution of distance moduli of K giants in our sample can be well modelled by the $z = r\sin(b)$ scaling of *Upgren*'s data from the North Polar region. The actual form of the space density curve of the K giants can be fitted by an exponential distribution with a scale height of 200 pc perpendicular to the galactic plane. A satisfactory fit can also be obtained by an isothermal model which is more realistic from the physical point of view. While the exponential model predicts a discontinuity in the density gradient at z=0, the isothermal version moves through this point with continuous derivative.

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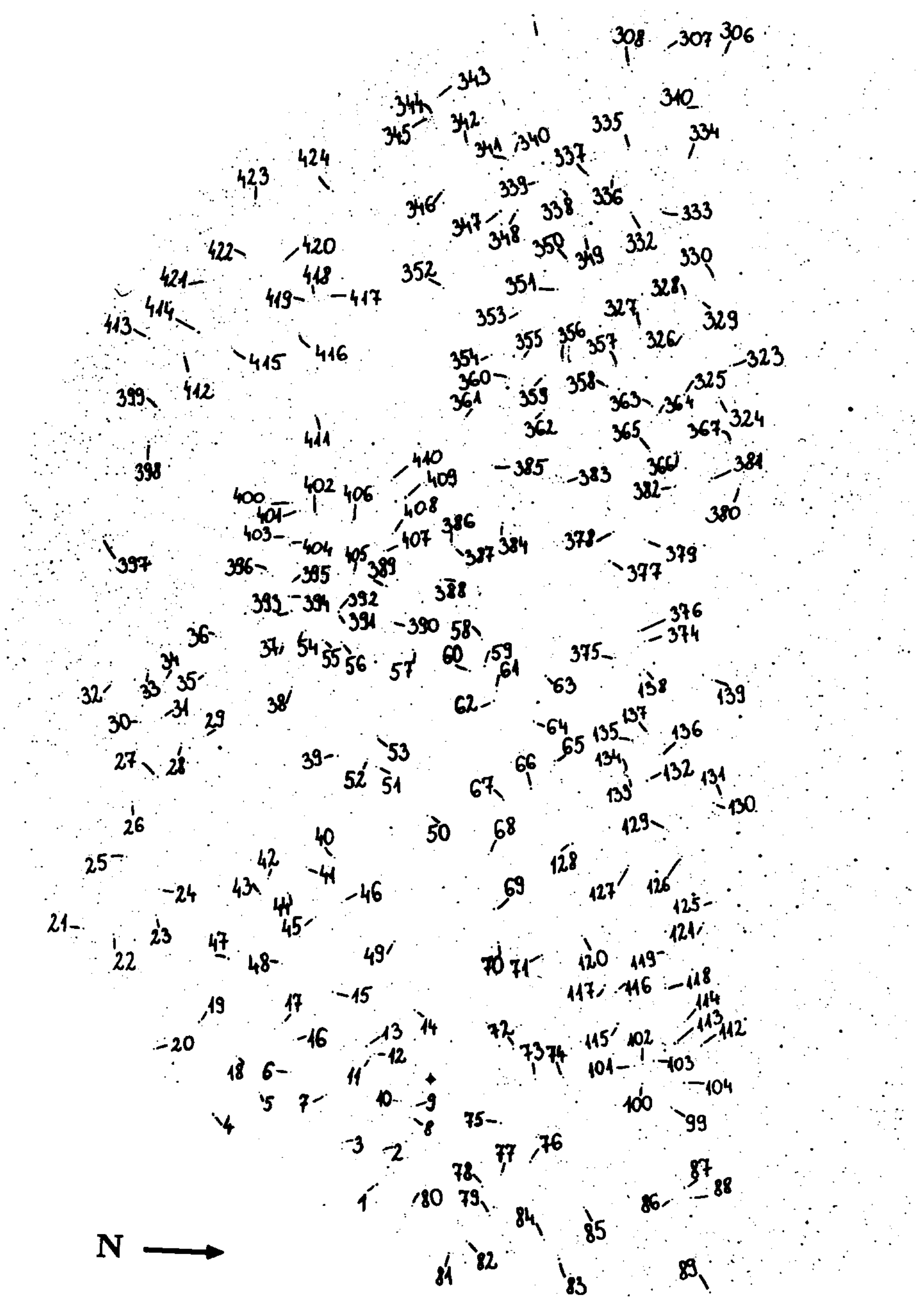
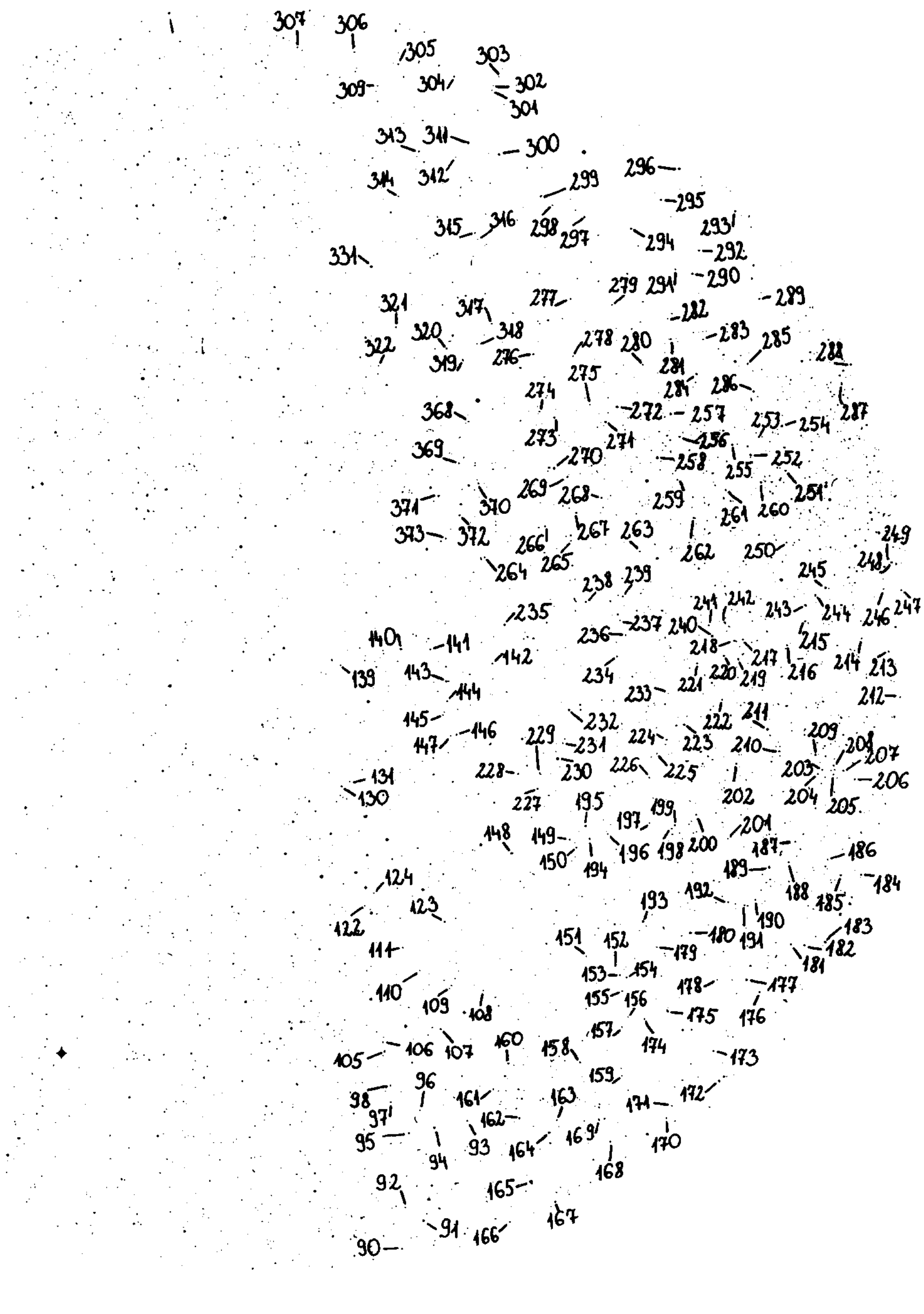


Finding chart of the survey stars



Finding chart of the survey stars

Table 6.

(Spectra and photometric data of survey stars)

No.	Sp.	V	B-V	U-B	G	G-R	U-G	remarks
1	G5 III	7.04	0.87	0.41	7.54	1.44	1.97	
2	K5:	11.34	1.62	1.74	12.59	2.59	3.35	
3	K2 III	10.03	1.39	1.48	10.83	2.01	3.31	
4	M5 III	10.43:	1.92:	1.39	11.87	3.24:	2.98:	
5	K5 III	9.78	1.63:	1.99:	10.70	2.48	3.97	
6	K2:	11.18	1.00	0.70	11.85	2.01	2.23	
7	K2 III	9.68	1.47	1.59	10.44	2.08	3.55	
8	G2	11.45	0.97	0.12	12.50	1.39:	1.15:	early
9	K0 III	11.29	1.18	0.77	12.06	2.09	2.35	
10	G2	11.40	0.92	0.04	11.91:	1.78:	1.57:	blend
11	M0 III	9.67	1.75	1.63	10.69	2.47	3.55	
12	G5:	11.75	0.77	0.01	12.22	1.55	1.45	
13	K5 III	8.01	1.58	2.05	8.92	2.26	4.01	
14	G8	9.72	0.78	0.35	10.06	1.27	1.99	
15	K0 III	9.56	1.15	1.02	10.13	1.83	2.82	
16	K2:	11.37	1.37	1.27	12.30	2.24	2.92	
17	K0 III	10.77	1.18	0.72	11.51	2.01	2.33	
18	G0	11.58	0.80	0.04	11.99	1.68	1.57	early
19	F8	9.74	0.53	0.10	9.84	1.34	1.74	
20	K5 III	11.07	1.56	1.61	11.95	2.49	3.51	early
21	K5:	11.52:	0.39:	0.66:	11.46	1.88:	2.44:	edge
22	G2	10.85	0.87	0.04	11.32	1.56:	1.56:	early
23	K5 III	9.63	1.74	2.02	10.60	2.61	4.04	
24	M0 III	10.67	1.78	1.82	11.56	2.53	3.91	
25	K2 III	10.95	1.41	1.37:	11.71	2.41:	3.24:	
26	K2	11.14	1.40	0.93	11.85	2.40	2.77	
27	K2 III	8.82	1.53	1.55	9.58	2.18	3.54	
28	M0 III	10.34	1.64	1.83	11.15	2.44	3.91	
29	M0:	10.89	1.74	2.10	11.93	2.70	4.06	
30	G8 III	11.19	1.07	0.61	11.73	1.85:	2.32	
31	M0 III	9.76	1.82	1.21	10.53	2.72	3.36	
32	K0:	11.00	1.16	0.50:	11.59	2.00:	2.21:	
33	K0 III	10.56	1.16	0.79	11.10	2.04	2.59	
34	K0 III	11.13	1.23	0.76	11.87	2.30:	2.41:	
35	K0	10.82	0.96	0.53	11.30	1.84	2.19	
36	K0 III	10.49	1.10	0.80	10.97	1.94	2.61	
37	K0 III	10.29	1.23	0.95	10.86	1.90	2.81	
38	G5:	11.33	0.77	-0.16:	11.74:	1.69:	1.31:	blend
39	K0 III	9.74	1.19	1.27	10.30	1.84	3.15	
40	M0 III	10.44	1.75	2.01	11.53	2.66	3.92	
41	G0:	11.01:	0.91:	0.30:	11.72:	1.75:	1.66:	early
42	G8	9.63	0.91	0.36	10.11	1.56	1.95	
43	K2 III	10.84	1.37	1.17	11.67	2.14	2.91	
44	G0	11.68	0.77	0.02	12.08	1.58	1.54	
45	G5:	11.09	0.86	0.41	11.60:	1.77:	1.95:	blend
46	K2 III	9.20	1.55	1.88	10.18	2.30	3.72	
47	K0 III	9.71	1.30	1.11	10.35	1.85	2.97	
48	K5	10.88	1.21	1.19	11.77	2.24	2.75	
49	G8	8.80	0.89	0.29	9.23	1.37	1.91	
50	K5 III	9.51	1.63	1.79	10.41	2.31	3.75	

Table 6.

(Continued)

No.	Sp.	V	B-V	U-B	G	G-R	U-G	remarks
51	K2 III	10.67	1.38	1.46	11.63	2.28	3.12	
52	K5	10.91	1.27	0.94	11.62	1.92	2.68	
53	M0 III	10.06	1.77	2.26	11.12	2.66	4.25	
54	K0 III	10.78	1.11	0.77	11.27	1.74	2.57	
55	K0 III	11.03	1.16	0.93	11.76	1.99	2.56	
56	M5 III	11.24	1.77	1.66	12.13	2.54	3.72	
57	F8	10.90	0.69	-0.22	11.26	1.34	1.24	
58	F8	10.94	0.76	-0.10	11.58	1.70:	1.15:	early
59	G0	11.20	0.68	-0.01	11.63	1.39	1.39	
60	G5	11.11	0.81	0.28	11.67	1.53	1.71	
61	F8	11.48	0.64	-0.09	12.06:	1.83:	1.13:	early
62	G0	11.34	0.78	-0.02	11.89	1.67	1.34	
63	G5	10.93	0.95	0.08	11.83:	1.95:	1.25:	early
64	G0:	11.68	0.95	-0.10	12.33:	1.99:	1.28:	blend
65	G0	11.14	0.53	-0.23	11.57	1.29:	1.02	
66	G8	8.92	0.79	0.27	9.38	1.38	1.78	
67	K5 III	9.20	1.79	1.98	10.24	2.51	3.96	
68	K2 III	10.22	1.40	1.78	11.11	2.19	3.57	
69	K2 III	10.02	1.20	1.02	10.83	1.93	2.62	
70	K0:	10.62	0.80	0.68	11.13:	1.60:	2.21:	
71	G0	10.68	0.67	0.23	11.23	1.56	1.55	
72	K5:	10.70	1.25	1.04	11.50	1.98	2.69	
73	K0 III	10.96	1.11	0.85	11.80	2.08	2.32	
74	K0 III	10.08	1.16	0.99	10.84	1.92	2.61	
75	K2 III	9.14	1.26	1.26	9.82	1.72	3.07	
76	G8 III	9.42	1.02	0.90	9.99	1.55	2.58	
77	K0 III	10.45	1.17	0.97	11.18	1.77	2.61	
78	G0	11.84	0.76	0.01	12.54	1.64	1.22	
79	K0 III	11.28	1.33	0.75	12.34	2.08	2.16	
80	K5 III	10.12	1.61	1.72	11.30	2.42	3.38	
81	K0 III	10.60	1.08	0.98	11.33	2.04	2.56	
82	G2	9.97	0.88	0.16	10.45	1.54	1.70	early
83	K0 III	8.75	1.10	1.30	9.35	1.74	3.08	
84	G5:	11.75	1.27	0.57:	12.57:	2.05:	2.14:	
85	M0 III	10.44	1.69	1.76	11.61	2.56	3.50	
86	K0 III	10.87	1.30	1.03	11.73	1.96	2.66	
87	G8 III	10.21	1.10	0.68	10.83	1.66	2.33	
88	K0 III	9.13	1.05	0.82	9.74	1.51	2.47	
89	K2 III	11.10	1.44	1.80	11.87	2.80:	3.75:	
90	K0 III	11.19	1.03	1.22	11.70	2.10:	3.01	
91	G5	8.85	0.73	0.34	9.16	1.29	1.96	
92	G5:	11.74	0.71	0.13	12.42:	1.79:	1.33:	blend
93	G0	9.84	0.68	0.30	10.19	1.21	1.83	early
94	F8	8.87	0.56	0.17	9.00	1.04	1.81	
95	G0	10.70	0.71	0.11	11.06	1.29	1.64	
96	K0 III	10.62	1.03	0.84	11.16	1.57	2.54	
97	K0 III	10.95	1.16	0.89	11.57	1.71	2.63	
98	M0	10.67	1.47	1.11	11.63	2.32	2.78	
99	G0	11.17	1.00	0.44	11.96:	1.79:	1.81:	blend
100	M0 III	10.80	1.68	1.71	12.02	2.65	3.38	

Table 6.

(Continued)

No.	Sp.	V	B-V	U-B	G	G-R	U-G	remarks
101	G8	10.84	0.75	0.38	11.35	1.33	1.83	
102	G0	11.20	0.60	0.20	11.59	1.18	1.63	
103	K2 III	9.60	1.22	1.38	10.30	1.73	3.17	
104	M0:	10.76	1.78	0.65:	12.09:	2.71:	2.12:	blend
105	K2 III	10.25	1.52	1.76	11.32	2.31	3.47	
106	K2 III	10.97	1.58	1.85	11.93	2.08	3.73	
107	K0	10.19	0.80	0.54	10.64	1.38	2.11	
108	G2	11.22	0.74	0.25	11.79	1.55	1.61	
109	F8:	11.94	0.64	-0.07	12.50	1.61	1.17	
110	K5	11.24	1.21	1.11	12.19	1.92	2.60	
111	K2 III	10.20	1.19	1.33	10.87	1.71	3.11	
112	K2 III	9.29	1.18	1.37	10.04	1.80	3.07	
113	K2 III	8.01	1.29	1.29	8.73	1.68	3.09	
114	K5	10.69	1.24	1.04	11.51	1.87	2.66	
115	K0 III	7.83	1.17	1.19	8.51	1.69	2.93	
116	F8	11.24	0.66	0.06	11.85	1.56	1.28	
117	K2 III	9.64	1.23	1.15	10.36	1.71	2.89	
118	F8:	12.08	0.57	-0.02	12.60:	1.30:	1.21:	
119	K2 III	11.03	1.19	1.27	11.92	1.91	2.82	
120	K0 III	11.17	1.28	0.74	12.22	2.07:	2.12	
121	F8	11.41	0.50	-0.03	11.83	0.95	1.25	
122	G5	11.22	0.82	0.19	11.83	1.52	1.56	
123	F8	9.78	0.55	-0.03	10.11	1.10	1.37	
124	K0 III	10.71	1.20	1.10	11.41	1.74	2.82	
125	G0	11.45	0.61	0.05	11.94	1.26	1.36	
126	K0 III	10.59	1.15	1.25	11.30	1.71	2.95	
127	K0 III	10.30	1.17	1.16	11.02	1.93	2.84	
128	K0 III	10.98	1.18	0.98	11.87	1.99	2.48	
129	G0:	11.96	0.56	-0.05:	12.36:	1.15:	1.29:	
130	M0 III	8.31	1.63	2.16	9.30	2.17	4.10	
131	G2	11.37	0.69	0.20	11.87	1.32	1.58	
132	K0 III	8.41	1.12	1.04	9.06	1.63	2.74	
133	G0	11.45	0.61	-0.22	11.90	1.46	1.08	
134	G2	10.99	0.82	0.04	11.60	1.75	1.39	
135	K0 III	8.96	1.19	0.82	9.68	1.72	2.47	
136	G0:	11.66	0.75	-0.16	12.40:	1.47:	0.97:	
137	F8	11.65	0.57	-0.08	12.37	1.65	0.94	
138	K5 III	8.76	1.49	1.76	9.63	2.05	3.65	
139	G8 III	10.59	0.97	0.60	11.20	1.65	2.15	
140	G2	8.90	0.73	-0.06	9.23	1.03	1.48	
141	K0 III	10.24	1.05	0.81	10.76	1.50	2.55	
142	K5 III	8.92	1.67	1.97	9.86	2.11	3.96	
143	K2 III	9.10	1.37	1.53	9.87	1.85	3.38	
144	F8	10.37	0.54	0.04	10.59	1.12	1.55	early
145	K2 III	10.63	1.21	1.35	11.43	1.76	3.02	
146	K2 III	10.18	1.49	1.60	10.90	1.91	3.61	
147	F8	11.69	0.49	-0.07	12.34	1.40	0.96	early
148	G8 III	7.80	0.96	0.84	8.32	1.42	2.51	
149	G5	11.20	0.67	0.29	11.54	0.98	1.83	
150	M5 III	10.95	1.74	1.07	12.16	2.55	2.70	

Table 6.
(Continued)

No.	Sp.	V	B-V	U-B	G	G-R	U-G	remarks
151	F8	12.35	0.29	0.01	12.53	1.22	1.37	
152	G8 III	9.64	1.03	0.70	10.06	1.34	2.51	
153	K0 III	10.86	1.19	0.97	11.65	1.74	2.58	
154	K5 III	10.00	1.50	1.75	10.80	1.98	3.71	
155	K5 III	10.55	1.73	1.96	11.32	2.01	4.16	
156	K2 III	11.90	1.31	1.10	12.67:	1.55:	2.84:	early
157	F8	12.33	0.38	0.02	12.69	0.79:	1.27	early
158	K0 III	10.76	1.20	1.09	11.35	1.55	2.92	
159	K0 III	11.56	1.22	0.43	12.10	1.44	2.22	
160	G5	9.72	0.64	0.30	10.03	1.11	1.85	
161	K0 III	10.67	1.16	1.22	11.33	1.69	2.97	
162	K0 III	11.13	1.09	1.01	11.76:	1.68:	2.70:	
163	G5	10.66	0.71	0.27	10.91	1.16	1.92	
164	G8 III	8.89	0.94	0.85	9.30	1.41	2.62	
165	K0 III	5.99	1.05	1.29:	6.51	1.72	3.10:	HR6590
166	M0 III	9.88	1.52	1.75	10.89	2.53	3.51	
167	G0	10.71	0.61	0.05	10.88	1.12	1.67	
168	K2 III	10.24	1.38	1.39	10.86	1.86	3.38	
169	G0	10.68	0.61	0.09	11.78:	1.75:	0.79:	early
170	K5 III	11.01	1.62	1.55	11.66	2.01	3.72	
171	G5	11.29	0.75	0.30	11.59	1.14	1.95	
172	K5 III	10.01	1.54	1.93	10.66	1.98	4.10	
173	K0 III	10.87	1.15	1.06	11.42	1.75	2.89	
174	K2 III	10.72	1.21	1.00	11.26	1.53	2.87	
175	K2 III	10.97	1.33	1.34	11.69:	1.70:	3.18:	
176	K0 III	10.46	1.16	1.20	10.80	1.34:	3.27	
177	G2	12.24	1.09	0.41	12.68:	1.47:	2.20:	
178	G0	11.96	0.54	0.21	12.26:	0.91:	1.67:	
179	G2	11.11	0.75	0.28	11.50:	0.83:	1.83:	
180	K0 III	8.61	1.22	1.27	9.19	1.35:	3.16	
181	G0	11.26	0.64	-0.01	11.45	1.05	1.60	early
182	G8 III	10.22	1.01	0.66	10.51	1.46	2.57	
183	G5	10.73	0.70	0.17	10.75	1.26	2.03	edge
184	K0 III	10.28	1.14	0.89:	10.36	1.41	3.15:	edge
185	K2 III	9.76	1.19	1.24	10.06	1.71	3.37	
186	K0 III	11.62	1.11	0.91	12.06	1.83	2.79	
187	F8	10.94	0.60	-0.06	10.90	0.88	1.75	early
188	G2	10.90	0.50	0.19	10.95	1.03	1.87	
189	F8	10.32	0.68	-0.09	10.45	1.11	1.61	
190	G8 III	11.35	0.90	0.65	11.83	1.74	2.28	
191	G8 III	11.74	1.22	0.56	12.33	1.72	2.32	
192	M5	10.87	1.57	1.57	12.14:	2.94:	3.09:	
193	G0	8.62	0.60	0.24	8.92	0.91	1.76	
194	M5 III	11.27	1.71	0.97	12.44	2.54	2.60	
195	G5	8.40	0.84	0.70	8.83	1.28	2.35	
196	K0 III	10.05	1.07	1.26	10.51	1.50	3.15	
197	K0 III	11.37	1.26	1.11	11.99	1.70	2.96	
198	K2 III	10.99	1.26	1.38	11.70	1.87	3.19	
199	M0 III	9.75	1.61	2.23	10.71	2.32	4.19	
200	K2 III	10.93	1.15	1.36	11.59	1.58	3.12	

Table 6.

(Continued)

No.	Sp.	V	B-V	U-B	G	G-R	U-G	remarks
201	G2:	11.97	0.53	0.26	12.29	1.33	1.71	
202	G0	11.10	0.61	0.17	11.33	1.18	1.75	
203	F8	11.45	0.42	0.11	11.51	1.04	1.71	
204	F8:	12.00	0.49	0.11	12.09	1.22:	1.73	
205	G0:	12.06	0.57	0.02	11.98	1.17	1.86	
206	G8 III	11.45	0.96	0.77	11.62	1.47	2.78	
207	G8	10.78	0.72	0.38:	10.75	1.13	2.35:	
208	K0 III	11.24	1.21	1.19	11.56	1.74	3.31	
209	K0 III	10.59	1.04	1.24	10.79	1.56	3.36	
210	K0 III	10.89	1.05	1.07	11.35	1.72	2.91	
211	G8	9.09	0.65	0.62	9.20	1.15	2.43	
212	K0 III	10.73	0.99	1.46:	10.71:	1.16:	3.79:	edge
213	K0 III	10.48	0.93	1.15	10.56	1.48	3.29	
214	G8 III	11.49	0.94	0.70	11.30:	1.10:	3.04:	
215	K0 III	10.01	1.03	0.95	10.22	1.48	3.00	
216	K0 III	10.48	0.99	1.12	10.87	1.68	2.99	
217	K2 III	11.15	1.19	1.20	11.78:	1.80:	3.00:	
218	F8:	12.08	0.44	0.18	12.18	1.65:	1.76	
219	G5	11.00	0.60	0.31	11.24	1.43:	1.90	
220	K0 III	10.51	0.99	1.20	10.91	1.49	3.08	
221	K0 III	11.05	1.17	1.06	11.63	1.65	2.88	
222	K5 III	10.90	1.43	1.97	11.66	2.20	3.95	
223	K2 III	8.77	1.21	1.67	9.31	1.60	3.65	
224	G0	11.41	0.51	-0.17	11.83	1.08	1.09	
225	G2:	11.83	0.61	0.04	12.05	0.91	1.61	
226	F8:	11.95	0.45	0.04	12.24	1.27	1.42	
227	K2 III	10.97	1.20	1.11	11.84	1.92	2.66	
228	M0 III	9.93	1.60	1.89	10.91	2.37	3.77	
229	G5	11.25	0.96	0.32	11.75	1.41	1.93	
230	K5 III	7.55	1.45	2.05	8.51	2.24	3.86	
231	K0 III	10.76	1.08	1.07	11.31	1.57	2.85	
232	K0 III	11.26	1.22	0.89	11.91	1.59	2.64	
233	M5 III	11.46	1.69	1.66	12.38	2.28	3.63	
234	G8 III	9.75	0.94	0.84	10.21	1.34	2.56	
235	K0 III	8.86	1.23	1.27	9.53	1.62	3.07	
236	K2 III	10.78	1.19	1.43	11.38	1.69	3.30	
237	G0	10.91	0.59	0.27	11.46	1.47	1.53	
238	G2	11.78	0.65	0.22	12.26	1.25	1.59	
239	G2	11.32	0.64	0.15	11.70	1.25	1.60	
240	K2 III	10.81	1.28	1.54	11.54	1.93	3.37	
241	K0 III	10.89	1.15	1.16	11.41	1.68	3.03	
242	G0	11.23	0.57	0.27	11.62	1.22	1.68	
243	M5 III	10.54	1.64	1.31	11.38	2.58	3.27	
244	K0 III	10.89	1.02	1.46	11.13	1.66	3.56	
245	K2 III	9.08	1.06	1.65	9.35	1.46	3.78	
246	K0 III	11.47	1.10	1.11	12.25:	2.30:	2.68:	
247	K0	9.71	1.09	1.18	-	-	-	edge
248	G8:	10.98	0.92	0.58	-	-	-	early
249	K0:	10.71	1.07	1.10	-	-	-	
250	K0 III	11.00	1.23	1.09	11.44	1.49	3.10	

Table 6.

(Continued)

No.	Sp.	V	B-V	U-B	G	G-R	U-G	remarks
251	G5	11.08	0.81	0.39	11.75	2.00	1.72	early
252	G5 III	9.52	0.83	0.46	9.70	1.17	2.31	
253	G5:	11.48	0.67	0.34	11.78:	1.34:	1.92:	
254	K0 III	10.85	1.05	0.96	11.36:	1.84:	2.73:	
255	G8 III	10.38	0.90	0.63	10.78	1.46	2.35	
256	K0 III	11.09	0.89	0.89	11.59	1.63	2.53	
257	G0	8.62	0.68	0.09	8.83	1.04	1.73	early
258	K5 III	7.73	1.51	2.06	8.62	2.28	3.99	
259	K0 III	11.31	1.05	1.12	11.81	1.60	2.93	
260	K5 III	9.82	1.56	2.06	10.43	2.19	4.31	
261	G0:	12.07	0.41	0.13	12.35	1.40	1.50	
262	F8:	11.84	0.33	0.20	12.02	0.93:	1.62	
263	M5 III	10.46	1.63	1.21	11.34	2.47	3.10	
264	K2 III	9.35	1.33	1.66	10.10	1.68	3.52	
265	K0 III	10.54	1.01	1.11	11.20	1.59	2.72	
266	F8:	12.08	0.50	0.06	12.52	1.23	1.33	
267	K0	10.50	0.78	0.53	10.83	1.19	2.21	
268	M0 III	9.81	1.70	2.19	10.66	2.21	4.33	
269	K0 III	10.33	1.02	0.97	10.88	1.66	2.68	
270	K2 III	7.85	1.24	1.83	8.52	1.61	3.73	
271	G0	10.57	0.65	0.10	10.73	1.11	1.77	
272	G0	8.27	0.66	0.23	8.56	1.00	1.80	
273	F8	11.40	0.67	-0.02	11.74	1.02	1.47	
274	G8 III	10.83	0.94	0.78	11.44	1.50	2.34	
275	K2 III	11.06	1.34	1.62	11.96	2.03	3.34	
276	G5:	11.86	0.79	0.05	12.43	1.40:	1.41	
277	K0 III	10.59	1.01	0.99	11.32	1.72	2.52	early
278	G5	11.41	0.84	0.29	11.89	1.27	1.83	
279	G2	9.96	0.72	0.30	10.39:	1.25:	1.79:	early
280	K0 III	11.18	1.19	1.08	11.85	1.74:	2.82	
281	K0 III	10.74	1.03	1.14	11.22:	0.73:	2.95:	
282	G5:	11.57	0.60	0.23	11.79:	0.81:	1.82:	
283	G2	11.20	0.69	0.06	11.29:	0.78:	1.83:	
284	K5 III	8.84	1.54	2.03	9.57	1.82	4.13	
285	K2 III	10.20	1.48	1.96	11.07:	2.09:	3.87:	
286	G8	9.96	0.68	0.36	10.32:	1.24:	1.90:	
287	K2	10.25	1.29	1.40	-	-	-	edge
288	K0:	13.21	1.00:	0.23:	-	-	-	edge
289	K0 III	10.20	1.03	0.86	11.26:	1.94:	2.05:	
290	K2 III	8.89	1.18	1.59	9.46	1.54	3.51	
291	K0 III	10.91	1.02	1.10	11.60:	1.73:	2.69:	
292	G5:	11.64	0.79	0.25	12.41:	1.48:	1.44:	
293	K0:	10.16	1.10	0.70	-	-	-	edge
294	K0 III	10.88	1.07	0.90	11.81:	1.63:	2.26:	
295	K0 III	8.71	1.12	1.17	9.38	1.55	2.87	
296	K5	7.45	1.66	2.52	-	-	-	edge
297	G5	10.56	0.67	0.31	10.92:	1.03:	1.83:	early
298	K0 III	11.37	1.03	0.90	12.33:	1.80:	2.19:	
299	G2	11.26	0.66	0.32	11.94:	1.34:	1.51:	
300	G8 III	8.40	0.89	0.79:	8.97:	1.23:	2.35:	

Table 6.
(Continued)

No.	Sp.	V	B-V	U-B	G	G-R	U-G	remarks
301	G2:	11.71	0.67	0.23	-	-	-	
302	G2:	11.52	0.61	0.15	-	-	-	
303	K2:	10.77	1.30	1.37:	-	-	-	edge
304	K5	11.08	1.82	2.30:	-	-	-	
305	K5	9.36	1.61	2.11	-	-	-	
306	K0	9.99	0.93	0.56	-	-	-	
307	K2	10.38	1.16	1.46	-	-	-	edge
308	K5 III	9.56	1.75	2.38	11.63:	3.15:	3.36:	
309	G2	11.38	0.86	0.19	12.70:	1.81:	0.89:	
310	K2 III	10.77	1.45	1.38	12.19:	2.55:	2.62:	
311	K5 III	8.95	1.47	2.00	10.07	1.93	3.65	
312	G0:	12.02	0.59	0.13	12.57:	1.06:	1.37:	
313	K2 III	9.89	1.35	1.19	10.78	1.87	2.86	
314	K0:	11.15	1.11	0.83	12.26:	1.87:	2.03:	
315	G2	11.22	0.65	0.22	11.67:	0.93:	1.62:	
316	G2:	11.61	0.72	0.09	12.04:	1.01:	1.55:	early
317	M0 III	10.36	1.70	2.15	11.56	2.45	3.93	
318	K5	11.07	1.11	1.07	11.89	1.82	2.60	
319	G5:	11.70	0.70	0.26	12.39:	1.44:	1.47:	
320	M5 III	11.48	1.59	1.83:	12.85	2.69	3.30:	
321	G8 III	10.19	0.99	0.85	10.77	1.50	2.49	
322	M0 III	11.11	1.72	1.88	12.47	2.51	3.47	
323	G0	11.32	0.77	0.06	11.91	1.55	1.39	
324	G8 III	11.57	0.86	0.55	12.12:	1.50:	2.06:	
325	M0:	11.87	1.80	0.86	13.52:	3.33:	2.07:	
326	G5	11.12	0.78	0.27	11.95:	1.84:	1.40:	
327	K2 III	10.85	1.35	1.47	11.92	2.20	3.00	
328	K5 III	10.38	1.41	1.77	11.36	2.13	3.48	
329	K5 III	10.16	1.59	2.03:	11.24	2.29	3.83:	
330	K5 III	11.32	1.60	1.69	12.55	2.42	3.29	
331	K5 III	7.25	1.56	2.34	8.14	2.12	4.35	
332	K0 III	9.99	1.05	1.20	10.48	1.61	3.03	
333	K0 III	11.01	1.17	0.97	11.64	1.51	2.72	
334	G0	10.83	0.85	0.40	11.76	1.51	1.50	early
335	K2:	10.97	1.00	0.63	12.12:	1.94:	1.67:	
336	K0	10.55	0.95	0.41	11.29	1.68	1.79	
337	K0 III	10.63	1.31	1.26	11.88:	2.30:	2.55:	
338	K2 III	9.62	1.24	1.43	10.46	1.95	3.10	
339	F8	11.32	0.57	0.03	12.12:	1.69:	0.99:	early
340	F8:	11.57	0.56	0.11	12.65:	1.87:	0.79:	
341	G0:	12.14	0.57	-0.25	13.26:	1.92:	0.34:	
342	G5:	11.61	0.85	-0.05	12.45:	1.80:	1.07:	
343	M5 III	9.57	1.63	1.26	10.85	2.71	2.76	
344	G5	11.41	1.12	0.57	12.69:	2.19:	1.57:	
345	G5	11.48	1.31	0.47	12.95:	2.36:	1.41:	
346	G8	10.89	0.84	0.23	11.75	1.66	1.38	
347	K0 III	7.78	1.07	0.96:	8.43	1.66	2.61:	
348	K2 III	8.82	1.30	0.85	9.65	1.84	2.48	
349	K0 III	11.21	1.21	0.82	11.78	1.46	2.64	
350	K0 III	11.36	1.04	0.45:	11.99:	1.25:	2.02:	

Table 6.

(Continued)

No.	Sp.	V	B-V	U-B	G	G-R	U-G	remarks
351	K0 III	9.99	1.07	0.86	10.65	1.72	2.48	
352	K0	9.65	1.09	0.58	10.19	1.71	2.29	
353	F8	11.85	0.57	-0.03	12.45	1.52	1.11	
354	K2 III	10.24	1.25	1.20	11.09	2.13	2.83	
355	K0	11.58	0.89	0.16	12.13	1.55	1.64	
356	F8	11.84	0.35	-0.07	12.19	1.20	1.15	
357	G5:	11.56	0.92	0.30	12.50:	2.06:	1.43:	blend
358	G2	8.28	0.90	0.43	8.81	1.45	1.98	
359	K0 III	9.87	1.20	0.99	10.66	1.93	2.60	
360	K2 III	10.79	1.28	1.24	11.67	2.19	2.87	
361	G5	11.34	1.02:	0.33:	12.15:	1.94:	1.68:	blend
362	G8 III	9.03	1.09	0.69	9.69	1.69	2.30	
363	G0 III	9.22	0.95	0.70	9.84	1.46	2.25	early
364	K2 III	10.48	1.28	1.27	11.37	1.96	2.89	
365	G5:	11.41	1.01:	0.40:	12.17:	1.98:	1.80:	
366	K2 III	10.07	1.17	1.46	10.91	1.95	3.08	
367	K2 III	10.69	1.39	1.82	11.65	2.24	3.54	
368	G5	11.18	0.76	0.13	11.89	1.45	1.34	
369	K5 III	10.55	1.57	1.74	11.47	2.30	3.63	
370	G2	11.22	0.62	0.16	11.62	1.23	1.58	
371	K0 III	9.63	1.05	1.07	10.12	1.46	2.88	
372	G5	10.21	0.66	0.39	10.52	1.12	1.96	
373	K0	11.07	0.77	0.47	11.63	1.40	1.90	
374	K0 III	9.82	1.20	1.07	10.55	2.01	2.76	
375	G8 III	11.06	1.22	0.52	11.97:	2.05:	1.96:	early
376	K2 III	9.43	1.44	1.50:	10.36	2.21	3.24:	
377	K2 III	6.92	1.31	1.58	7.67	2.04	3.41	
378	K0 III	9.82	1.02	0.60	10.37	1.62	2.25	
379	K2 III	9.80	1.30	1.70:	10.54	2.03	3.56:	
380	G5	11.61	0.90	0.25	12.29	1.62	1.63	
381	G8 III	10.91	1.00	0.69	11.60	1.80	2.20	
382	G5	11.08	0.85	0.16	11.72	1.50	1.52	early
383	G0	11.35	1.01	0.21	12.19:	1.91:	1.50:	blend
384	K5 III	9.18	1.54	1.59	9.95	2.01	3.58	
385	G5	11.20	1.40	-0.28	12.42:	1.77:	0.85:	blend
386	K0 III	10.97	1.39	0.99	11.83	2.13	2.68	
387	F8	11.89	0.49	-0.20	12.37	1.64:	0.98	
388	K0 III	10.23	1.05	0.79	10.92	1.96	2.35	
389	K5 III	8.66	1.76	2.02	9.72	2.49	3.97	
390	K0 III	11.43	1.13	0.75	12.07	1.78	2.42	
391	K0 III	10.08	1.15	0.77	10.76	1.97	2.42	
392	K5 III	10.37	1.53	1.46	11.23	2.35	3.34	
393	G5	8.94	0.70	-0.12	9.16	1.15	1.49	
394	K0 III	8.73	1.20	0.76	9.29	1.74	2.56	
395	K0 III	10.91	1.20	0.64	11.64	1.99	2.26	
396	K2 III	10.56	1.32	1.33	11.39	2.14	3.05	
397	K2 III	11.51:	1.45:	1.17	11.85	2.14:	3.46	
398	K2 III	9.92	1.30	1.27	11.45	2.97:	2.27	
399	K0 III	9.79	1.03	0.84	10.31	1.93	2.57	
400	K5 III	10.76	1.66	1.71	12.02	2.79	3.33	

Table 6.

(Continued)

No.	Sp.	V	B-V	U-B	G	G-R	U-G	remarks
401	K0 III	10.70	1.29	0.98	11.39	2.03	2.77	
402	G5	10.10	0.80	0.15	10.50	1.41	1.71	
403	K0:	11.62	1.19	0.19:	12.27:	1.94:	1.81:	
404	K0 III	10.89	1.32	0.71	11.61	2.15	2.44	
405	K5 III	10.29	1.57	1.81	11.12	2.35	3.81	
406	G0	10.93	0.62	-0.20	11.22	1.36	1.28	
407	K5 III	9.53	1.73	2.13	10.53	2.41	4.13	
408	K0 III	9.75	1.12	0.94	10.35	1.69	2.67	
409	K5 III	6.63	1.74	2.21	7.80	2.48	4.06	
410	K2	10.74	1.13	0.74	11.45	1.98	2.33	
411	G0:	11.84	0.57	-0.17	12.41:	1.73:	0.99:	blend
412	G0	11.35	0.54	0.05	11.96:	1.84:	1.18:	
413	G2	9.52	0.78	-0.18	9.90	1.51	1.33	early
414	K2 III	6.62	1.25	1.64	7.47	2.25	3.34	
415	G2	11.35	0.57	0.23	11.91	1.89	1.46	
416	K0	11.29	1.03	0.94	12.23:	2.30:	2.26:	
417	G8	11.16	1.04	0.74	11.99:	2.05:	2.15:	
418	K0	11.04	1.03	0.72	11.92	2.14	2.07	
419	F8	10.69	0.73	-0.27	12.44:	2.31:	-0.18:	early
420	K0 III	10.85	1.05	0.92	11.91	2.31	2.14	
421	K5:	11.21	1.55	0.65	12.23:	2.41:	2.25:	early
422	G2	11.55	0.64	0.12	12.30:	2.15:	1.20:	
423	G2:	11.49:	0.01:	0.12	11.88:	1.56:	1.07:	
424	K0 III	8.92	1.31	1.62	9.80	2.17	3.33	

Blend is remarked if the photographic image of the measured star is distorted by a neighbouring star.

Edge is remarked if the star is near the edge of the plate.

Early is remarked if the star was classified earlier than F8 in the previous paper (*Paparó* and *Balázs* 1982).

A colon beside the spectral type or figure denotes that the star was classified from one plate or the value was uncertain.

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PERIOD UPDATE AND DUPLICITY EFFECTS

ABSTRACT

O-C diagrams have been continued for 64 northern Cepheids with the primary aim of studying the effects of duplicity on the pulsation period. Because the light-time effect in the O-C diagrams of binary Cepheids has to be accompanied with properly phased variations in the γ-velocity, the radial velocity of the programme stars has been studied, as well. Light-time effect is suspected in the O-C diagram of FM Aql, RW Cam, Y Lac, and RS Ori, and confirmed for AW Per. One or more phase jumps are present or suspected in the O-C diagram of 19 northern Cepheids (FF Aql, BY Cas, DD Cas, DL Cas, X Cyg, SU Cyg, SZ Cyg, DT Cyg, V532 Cyg, V924 Cyg, TX Del, DX Gem, X Lac, CV Mon, RS Ori, SV Per, SZ Tau, T Vul, X Vul). In addition to the Cepheids with known spectroscopic orbit, the spectroscopic binary nature based on the variability of the γ-velocity has been confirmed, revealed or suspected for the majority of the programme stars. The most probable new spectroscopic binary Cepheids are: KL Aql, η Aql, SU Cas, V636 Cas, BZ Cyg, MW Cyg, V386 Cyg, W Gem, RZ Gem, AD Gem, RS Ori, SV Per, SW Tau, T Vul, and U Vul. A preliminary value of the orbital period is suggested for η Aql, SU Cas, RZ Gem, T Vul, and U Vul.

INTRODUCTION

Period changes of more than a hundred northern Cepheids were studied in a series of papers (*Szabados*, 1977, 1980 and 1981, hereinafter referred to as Papers I, II and III, respectively). As a result, the observed period changes were compared with the theoretical ones, predicted by the stellar evolutionary calculations (*Szabados*, 1983). In addition to the evolutionary changes (manifested in parabolic O-C graphs), two special kinds of period variations were also revealed in several cases, both of them being characteristic of binary Cepheids:

1. light-time effect due to the orbital motion,
2. phase jump, i.e. a stepwise O-C graph.

The origin of this latter type of the period change has not been clarified yet, but the phase jumps always occur in Cepheids having a companion star.

Later on, it became obvious that the extension of that study to southern Cepheids was of importance because the period variation of most Cepheids with negative declination had not been followed closely. The investigation of 44 bright southern Cepheid variables was published recently (*Szabados*, 1989 = Paper IV). Because the programme stars were selected arbitrarily, the primary goal of Paper IV was the study of duplicity effects in the O-C diagram, and no special attention was paid to follow the evolutionary period changes.

A companion star can also alter the observable γ-velocity of the given variable, if the orbital inclination significantly differs from zero. A light-time effect in the O-C diagram has to be accompanied with properly phased γ-velocity variations of the same period, and the amplitude of the oscillation in the O-C diagram is not independent from that deduced from the diagram γ-velocity vs. time. For this reason the study of period changes was supplemented with a comprehensive study of γ-velocity variations of the programme stars.

By the end of the eighties it became obvious that the frequency of the Cepheid binaries is much higher than thought before (*Szabados*, 1990b). The increase of the known spectroscopic binaries among Cepheids is mostly a result of the ultraviolet spectroscopy made with the IUE-satellite, and the thorough radial velocity studies performed in the last decade. In some cases, however, the available, sometimes sporadic, radial velocity measurements were even sufficient for revealing the orbital effect, or determining the orbital period (see e.g. *Szabados*, 1990a).

The aim of the present paper is to analyse the period changes of the known binary Cepheids of the northern sky, in order to study the effects of duplicity, and to search for γ-velocity variations in the case of suspected binary Cepheids with a declination larger than zero. Therefore the sample of stars studied here is selected arbitrarily: it contains 64 stars of various brightness (including four Population II Cepheids). Even some of the brightest Cepheids have been omitted (e.g. δ Cephei itself), being very probably single stars. Their period changes have to be also studied, but this paper is the last one in the extensive series on this topic, and the similar studies in the future will concentrate on individual Cepheids. Unfortunately the variable star astronomers have lost their interest in the regular photometry of the Cepheid variables, and it is to be afraid that the subtle but important period changes in these stars will pass unnoticed.

The programme stars are arranged in alphabetical order of constellations. The list of the Cepheids involved in this study is as follows (the ordinal number following the name of the Cepheid gives the page number where the discussion on the given star begins):

In addition to the binary Cepheids, some other Cepheid variables not having a companion were also studied, provided that the construction of a new O-C diagram contains relevant new information as compared with the original O-C plot published in Papers I-III. The new piece of information can be a recent period change, or larger accuracy due the new photoelectric O-C residuals overwhelming in the present O-C diagrams. Similarly, the shape of the O-C diagram is differently interpreted in the case of several binary Cepheids, as compared with the previous one. Besides the reasons listed above, the main cause of the modified shape of the O-C graphs is a recently discovered phase jump.

Since the duplicity effects in the O-C diagram (light-time effect and phase jump) are usually very subtle, only the photoelectric observations have been taken into account whenever possible. In a number of cases, however, photographic observations were also used when constructing the new O-C diagram, and for seven Cepheids (SU Cyg, VZ Cyg, W Gem, RZ Gem, ζ Gem, X Lac, SV Per) the early visual observations were also analysed. These latter exceptional cases are examples for either a parabolic O-C graph or an early phase jump, therefore the visual observations even from the last century are of primary importance.

The O-C residuals taken from Papers I-III have the same weight as that assigned to them originally. As far as the visual and the photographic observations are concerned, the O-C residuals based on such observations with a weight less than unity have not been used here.

The recently published photoelectric light curves are often superior to the previous ones. The new normal light curve determined for more than twenty programme stars showed a marked difference as compared with the previously used normal curve. In these cases the O-C residuals taken from Papers I-III were corrected accordingly. It has to be noted that, although solely photoelectric data have been used from among the recently published observations, several photoelectric observational series have been omitted, i.e. those obtained in the IR-region (e.g. *Schmidt*, 1976; *Welch* et al., 1984) because of the uncertain phase shift between the moments of maxima in the blue and infrared bands.

In the following discussion there are usually two tables and one figure for each Cepheid. The successive columns of the tables containing information on the O-C residuals give the following data:

1. Moment of normal maximum (an asterisk indicates that the given moment is a new one, not appearing in Papers I-III),
2. The corresponding epoch,
3. O-C residual (in days),
4. The weight assigned to the residual (a blank character means that the given residual has not been used in the curve-fitting procedure),
5. Source of the observational data.

The epoch and the O-C residual have been obtained using the linear ephemeris given in the discussion on each Cepheid.

The determination of the γ-velocities was performed in a similar manner as described in Paper IV. The successive columns in the Tables of the γ-velocities contain the following data:

1.-2. Mean date of the observations and its formal standard deviation,

3.-4. γ-velocity and its formal standard deviation,

5. Number of radial velocity observations used,

6. Source of the observational data.

Note that the uncertainty in the zero-point of the individual radial velocity measurement series tends to increase the standard deviation given in the tables, but no allowance was made for the zero-point differences.

The γ-velocity of a programme star is considered to be variable if its variation is larger than five km/s. The uncertainty of the zero-point hardly exceeds one km/s in the case of the modern radial velocity observations. The γ-velocity of the Cepheid-binaries with known orbit is not analysed here.

The figures visualizing the tabular data are usually divided into two parts. The upper panel shows the O-C diagram of the given variable. Filled circles denote the O-C residuals based on photoelectric observations, while open circles are those of photographic (or visual, in the case of the seven Cepheids listed above) origin. The size of the circles refers to the weight assigned to the O-C residual. The least squares fit (usually linear or parabolic) is also shown. It has to be noted, however, that the O-C residuals earlier than J.D. 2420000 are not plotted, even if they are listed in the corresponding table because those particular residuals were used during the curve-fitting procedure. In several cases sections of the O-C graph not studied here are also drawn for convenience (without listing the corresponding visual or low quality photographic O-C residuals). The ephemeris used for obtaining the O-C residuals is indicated at the top of the figure.

The lower panel of the figures shows the individual γ-velocities as a function of the Julian Date. The reliability of the data points can be estimated from the error bars (if the standard deviation exceeds the size of the dot). Again, the figure does not show the tabular values before J.D. 2420000.

REMARKS ON THE INDIVIDUAL VARIABLES

SZ Aquilae

The three more recent photoelectric observational series confirm the previous conclusion (Paper III) about the continuous period increase. The new O-C diagram has been constructed using the elements:

$$C = \underset{\pm .032}{2443807.165} + \underset{\pm .000233}{17^{d}.140554} \cdot E \qquad (1)$$

The momentary value of the period is as follows:

$$P = \underset{\pm .000233}{17^{d}.140554} + \underset{\pm .64}{3^{d}.29} \cdot 10^{-6} \cdot E \qquad (2)$$

Table 1. O-C residuals for SZ Aql

Norm.max. JD2400000+	E	O-C	W	Reference
29513.184	-834	1.487		Ahnert (1951)
29838.681	-815	1.308		Erleksova (1960)
31638.130	-710	0.758		Erleksova (1960)
32460.734	-662	0.616		Erleksova (1960)
33112.198	-624	0.739	3	Eggen (1951)
33454.820	-604	0.550		Erleksova (1960)
34414.613	-548	0.472		Erleksova (1960)
35494.235	-485	0.239		Erleksova (1960)
35580.096	-480	0.397	1	Walraven et al. (1958)
36231.149	-442	0.109		Erleksova (1960)
37156.786	-388	0.156	2	Mitchell et al. (1964)
37945.611	-342	0.515	1	Williams (1966)
40910.526	-169	0.115	3	Pel (1976)
41338.940*	-144	0.015	3	Feltz & McNamara (1980)
42898.836	-53	0.120	2	Dean (1977)
43807.095	0	-0.070	3	Szabados (1981)
44441.228*	37	-0.137	2	Eggen (1983b)
44612.842*	47	0.071	3	Moffett & Barnes (1984)

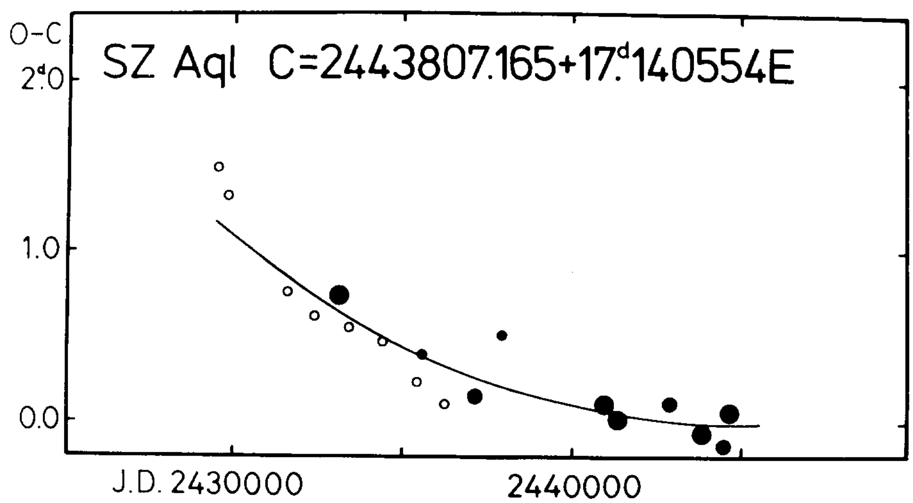

Figure 1. O-C diagram of SZ Aql

The O-C residuals are listed in Table 1 and shown plotted in Figure 1. The small number of radial velocity data (*Joy*, 1937; *Barnes* et al., 1988) does not allow the determination of accurate γ-velocities.

TT Aquilae

This bright Cepheid was frequently observed photometrically in the last two decades, thus making possible the reliable period determination based on photoelectric observations alone (see Table 2 and Figure 2). The current ephemeris is as follows:

$$C = 2443810.958 + 13\overset{d}{.}754954 \cdot E \qquad (3)$$
$$\pm.014 \qquad \pm.000043$$

Although the O–C residuals based on the photographic and the early photoelectric observations suggest a wave-like pattern, this tendency disappears after J.D. 2440000, as if a sudden change in the pulsation period occurred.

It is worth mentioning that the Julian Dates in *Connolly* et al.'s (1982) paper need a correction of –1 day. The revised pulsation period in their paper is also an artifact of this mistake.

The γ-velocities of TT Aql are collected in Table 3, and are shown plotted in the lower panel of Figure 2. A slight variation in the average radial velocity cannot be excluded but further high quality observations

Table 2. O–C residuals for TT Aql

Norm.max. JD2400000+	E	O–C	W	Reference
29385.963	-1016	0.038		Erleksova (1960)
30564.956	-963	0.019		Erleksova (1960)
31527.765	-893	-0.019		Erleksova (1960)
32449.337	-826	-0.029		Erleksova (1960)
33109.654	-778	0.050	3	Eggen (1951)
33494.741	-750	-0.002		Erleksova (1960)
34416.368	-683	0.044		Erleksova (1960)
35282.936	-620	0.049	2	Irwin (1961)
35502.954	-604	-0.012		Erleksova (1960)
35558.014	-600	0.028	2	Walraven et al. (1958)
36218.152	-552	-0.071		Erleksova (1960)
37208.525	-480	-0.055	3	Mitchell et al. (1964)
37937.601	-427	0.008	1	Williams (1966)
40413.494*	-247	0.010	2	Feltz & McNamara (1980)
40867.193	-214	-0.205	1	Evans (1976)
40867.331	-214	-0.067	3	Pel (1976)
41266.313*	-185	0.021	2	Feltz & McNamara (1980)
41912.777	-138	0.003	3	Landis (1976)
42916.670	-65	-0.216	2	Dean (1977)
43343.343*	-34	0.053	3	Moffett & Barnes (1984)
43810.884	0	-0.074	3	Szabados (1981)
43865.980*	4	0.002	3	Moffett & Barnes (1984)
44443.719*	46	0.033	3	Connolly et al. (1982)
44443.719*	46	0.033	3	Coulson et al. (1985)
44512.589*	51	0.128	3	Eggen (1983b)
44691.332*	64	0.057	2	Connolly et al. (1982)
44828.824*	74	-0.001	2	Coulson et al. (1985)

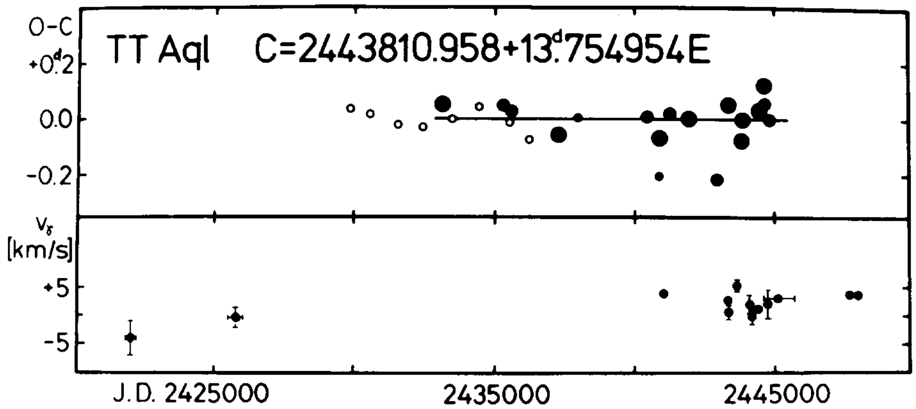

Figure 2. Upper panel: O-C diagram of TT Aql
Lower panel: γ-velocities for the same Cepheid

Table 3. γ-velocities of TT Aql

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
22002	152	-4.1	3.2	3	Joy (1937)
25809	260	-0.4	1.8	7	Joy (1937)
41031	146	4.0	0.2	7	Evans & Lyons (1986)
43317	31	3.0	0.4	3	Evans & Lyons (1986)
43369	36	0.8	1.2	12	Wilson et al. (1989)
43688	75	5.5	1.0	16	Barnes et al. (1987)
44036	47	2.1	1.8	6	Barnes et al. (1987)
44180	3	0.1	1.4	4	Coulson et al. (1985)
44427	10	1.3	0.5	27	Coulson et al. (1985)
44778	1	2.2	2.5	2	Coulson et al. (1985)
45133	521	3.3	0.2	7	Evans & Lyons (1986)
47745	34	3.9	0.4	15	Samus (1990)
48044	42	3.8	0.4	18	Samus (1990)

are necessary to make a firm statement. *Leonard* and *Turner* (1986) summarized the available information on duplicity of TT Aql. Although the photometric test by *Madore* and *Fernie* (1980) suggests the presence of a bright blue companion, no other positive evidence is available (see *Evans*, 1985; *Coulson* et al., 1986).

FF Aquilae

This variable is one of the most popular Cepheids among the observers, therefore a number of new results has been achieved. As to its photometry, the new O-C diagram (see Figure 3 and Table 4) clearly shows the existence

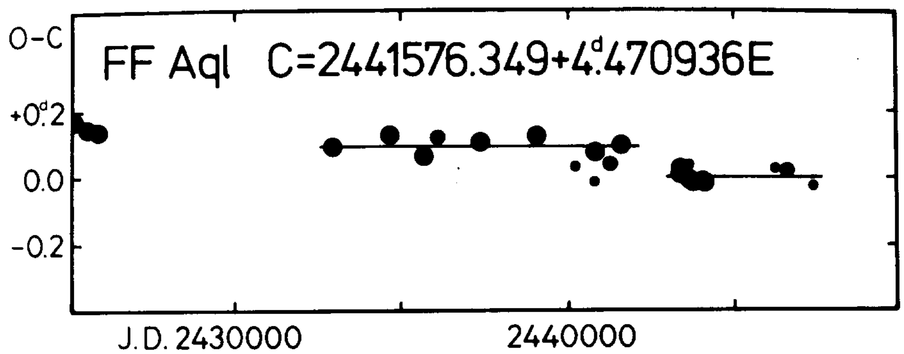

Figure 3. O-C diagram of FF Aql

Table 4. O-C residuals for FF Aql

Norm.max. JD2400000+	E	O-C	W	Reference
25096.650	-3686	0.171	3	Huffer (1931)
25490.067	-3598	0.146	3	Huffer (1931)
25811.968	-3526	0.139	3	Huffer (1931)
32960.946	-1927	0.091	3	Eggen (1951)
34628.641	-1554	0.127	3	Szabados (1977)
35625.598	-1331	0.065	3	Walraven et al. (1958)
36099.567	-1225	0.115	2	Svolopoulos (1960)
37320.127	-952	0.109	3	Mitchell et al. (1964)
39019.100	-572	0.126	3	Wisniewski & Johnson (1968)
40266.395*	-293	0.030	1	Feltz & McNamara (1980)
40789.448*	-176	-0.016	1	Feltz & McNamara (1980)
40811.901	-171	0.082	3	Pel (1976)
41245.539*	-74	0.039	2	Feltz & McNamara (1980)
41576.448	0	0.099	3	Szabados (1977)
43342.376*	395	0.007	3	Moffett & Barnes (1984)
43369.211*	401	0.017	3	present paper
43615.129*	456	0.033	1	Henden (1979)
43673.206*	469	-0.012	3	Moffett & Barnes (1984)
43731.324*	482	-0.016	3	present paper
44035.355*	550	-0.009	2	Moffett & Barnes (1984)
44853.537*	733	-0.008	3	Arellano Ferro (1984)
46284.270*	1053	0.025	1	"Carlsberg" (1989)
46624.056*	1129	0.020	2	present paper
47455.601*	1315	-0.029	1	Usenko (1990a)

of a phase jump, a phenomenon that has already been suspected by *Evans* et al. (1990b) on the basis of the new radial velocity data. The O-C residuals in Table 4 have been computed using the ephemeris:

$$C = \underset{\pm.009}{2441576.349} + \underset{\pm.000014}{4\overset{d}{.}470936}\cdot E \qquad (4)$$

and this ephemeris is valid for predicting the maxima after J.D. 2443000. Between J.D. 2433000 and 2442000 the following formula gives the best fit to the O-C residuals:

$$C = 2441576.423 + 4\overset{d}{.}470918 \cdot E \qquad (5)$$
$$\pm.011 \quad \pm.000010$$

Therefore the pulsation period remained constant during the two sections of the O-C graph, while the amount of the phase shift is about 0.08 day (or 0.02 phase). The phase jump occurred between J.D. 2442000 and 2443000. The different values of the pulsation period as determined from the O-C diagrams for the maximum and median brightness (see Paper I, page 92) can now be interpreted as a minor change in the light curve shape similarly to the other known case of SU Cyg (see Paper I and this paper, p. 159).

The radial velocity measurements of FF Aql are not analysed here because the study of *Evans* et al. (1990b) is so thorough and complete. Their paper includes a new determination of the orbit, and also contains all the available information concerning the companions to FF Aql. The only contribution here to the spectroscopic study is a single radial velocity measurement listed in Table 109.

FM Aquilae

The new O-C diagram based on only photoelectric observations (see Table 5 and Figure 4) gives a slightly longer period than that determined in Paper II. The new ephemeris is as follows:

$$C = 2442678.253 + 6\overset{d}{.}114265 \cdot E \qquad (6)$$
$$\pm.006 \quad \pm.000008$$

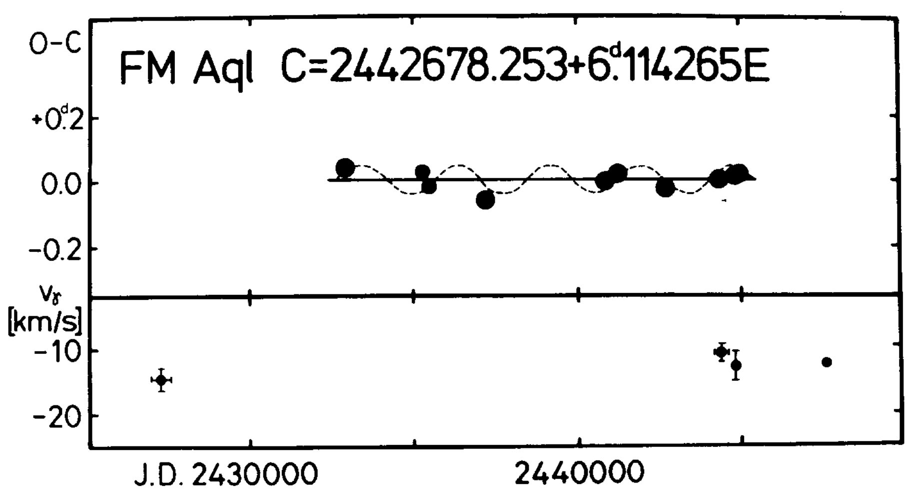

Figure 4. Upper panel: O-C diagram of FM Aql
Lower panel: γ-velocities for the same Cepheid

Table 5. O-C residuals for FM Aql

Norm.max. JD2400000+	E	O-C	W	Reference
32962.724	-1589	0.038	3	Eggen (1951)
35292.245	-1208	0.024	2	Irwin (1961)
35500.086	-1174	-0.020	2	Walraven et al. (1958)
37187.583	-898	-0.060	3	Mitchell et al. (1964)
40819.509	-304	-0.007	3	Pel (1976)
41223.078*	-238	0.020	3	Feltz & McNamara (1980)
42678.229	0	-0.024	3	Szabados (1980)
44335.221*	271	0.002	3	Moffett & Barnes (1984)
44830.486*	352	0.012	3	Eggen (1985)
44983.348*	377	0.017	3	Moffett & Barnes (1984)

Table 6. γ-velocities of FM Aql

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
27219	278	-14.5	1.7	8	Joy (1937)
44391	192	-10.8	1.4	9	Barnes et al. (1988)
44821	45	-12.8	2.3	4	Barnes et al. (1988)
47648	4	-12.4	0.2	6	Samus (1990)

Moreover, an apparent period variation caused by the light-time effect may be superimposed on the O-C graph (see Figure 4). The estimated period (about 2800 days) and the amplitude of the sinusoidal variation implies an orbital radial velocity variation that might be easily detected.

The available radial velocity measurements (see Table 6), however, do not support the variable γ-velocity hypothesis. Nevertheless, there have been evidence in favour of a blue companion. *Madore* (1977) derived a B9V type photometric companion, while *Pel* (1978) concluded that FM Aql had a peculiar colour - colour loop. The ultraviolet spectrum of this Cepheid, however, does not indicate the presence of a companion earlier than A0V (*Evans* et al. 1990a). Further spectroscopic observations are desirable to settle this problem.

KL Aquilae

There are no newly published photometric observations on this neglected Cepheid, thus the previous O-C diagram (Paper II, p. 53) cannot be replaced with a recent one. The existing radial velocity measurements, however, have not been analysed before. As one can see in Table 7, the γ-velocities show a strong variation on a time-scale of several hundred days. KL Aql seems to be a new spectroscopic binary Cepheid, worthy of immediate observation.

Table 7. γ-velocities of KL Aql

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
27543	124	-1.5	2.0	6	Joy (1937)
28097	1	-6.8	4.5	1	Joy (1937)
28396	21	-45.5	1.4	3	Abt (1973)
44735	129	-0.5	1.2	12	Harris & Wallerstein (1984)
45167	48	1.0	2.0	5	Harris & Wallerstein (1984)

V572 Aquilae

All the previous photoelectric observations have been analysed again, because *Henden*'s (1979) data form a better normal light curve than that used in Paper I. Therefore the moments of the normal maxima listed in Table 8 are different from the corresponding values listed in Paper I (p. 70). In spite of the reliable new normal light curve, the O-C residuals widely scatter around the best fitting line (see Figure 5) described with the formula:

$$C = 2441921.693 + 3\overset{d}{.}768001 \cdot E \qquad (7)$$
$$\pm.088 \quad \pm.000080$$

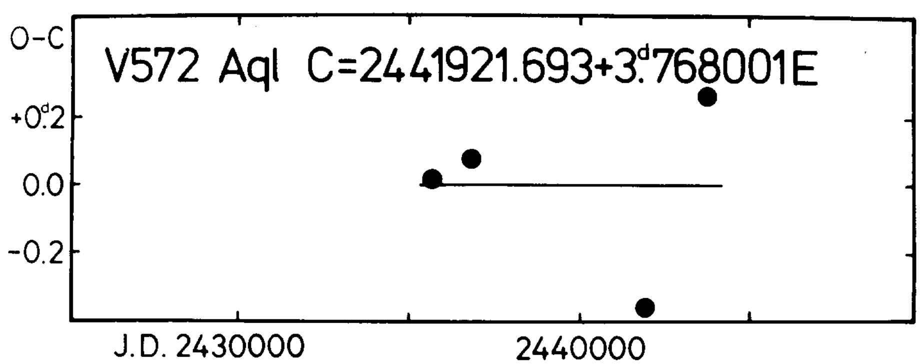

Figure 5. O-C diagram of V572 Aql

Table 8. O-C residuals for V572 Aql

Norm.max. JD2400000+	E	O-C	W	Reference
35666.826	-1660	0.015	3	Walraven et al. (1958)
36789.753	-1362	0.077	3	Oosterhoff (1960)
41921.334	0	-0.359	3	Szabados (1977)
43734.368*	481	0.267	3	Henden (1979)

These deviations are possibly caused by period changes (a previous change in the pulsation period was suspected in Paper I). Therefore the elements given here and in Table 110 are only tentative.

No radial velocity measurements have been published about this star.

V1344 Aquilae

Arellano Ferro's (1984) recent photoelectric observations form a new normal light curve superior to the previous one (*Kovács* and *Szabados*, 1979), therefore these earlier published observations were re-analysed when constructing the O-C diagram. The O-C residuals plotted in Figure 6 and listed in Table 9 have been calculated with the ephemeris:

$$C = 2443398.184 + 7^{d}.476787 \cdot E \quad (8)$$
$$\pm.015 \qquad \pm.000104$$

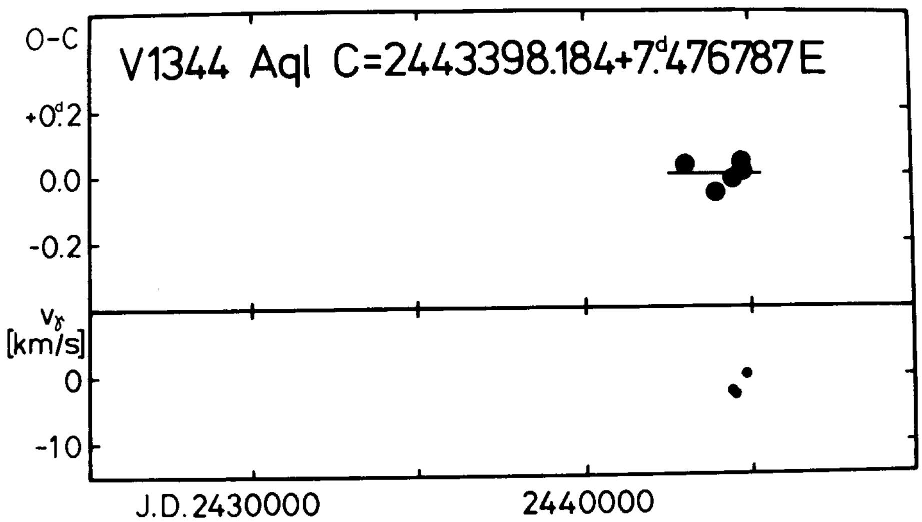

Figure 6. Upper panel: O-C diagram of V1344 Aql
Lower panel: γ-velocities for the same Cepheid

Table 9. O-C residuals for V1344 Aql

Norm. max. JD2400000+	E	O-C	W	Reference
43016.896	-51	0.028	3	Kovács & Szabados (1979)
43958.889	75	-0.054	3	Kovács & Szabados (1979)
44482.301*	145	-0.017	3	Fernie & Garrison (1981)
44781.430*	185	0.040	3	Arellano Ferro (1984)
44788.871*	186	0.005	3	Eggen (1985)

Table 10. γ-velocities of V1344 Aql

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
44424	27	-2.3	0.1	16	Balona (1981)
44528	15	-2.7	0.2	8	Balona (1981)
44832	6	0.2	0.6	8	Arellano Ferro (1984)

The available radial velocity data, although being very accurate, are not sufficient to draw a firm conclusion on the variability of the γ-velocity (see Table 10). If V1344 Aql is really a spectroscopic binary, then the orbital period has to be relatively short (several hundred days). An extension of the observations to a longer time-base both in photometry and spectroscopy would be necessary.

η Aquilae

Because the photoelectric observations obtained by *Moffett* and *Barnes* (1984) offered a better normal ligth curve than that used previously, this new normal curve has been used for determining the moments of normal maxima for the photoelectric observations published in the eighties. In order to eliminate the systematic difference in the phase of the maximum light between the recent and the previous normal curve, a correction of -0.029 day has been applied to the photoelectric O-C residuals published in Paper II. Both the corrected and the recently determined O-C residuals are listed in Table 11. A parabolic fit, i.e. a continuously increasing pulsation period is still the most appropriate interpretation of the O-C graph (see Figure 7). The O-C residuals have been calculated using the

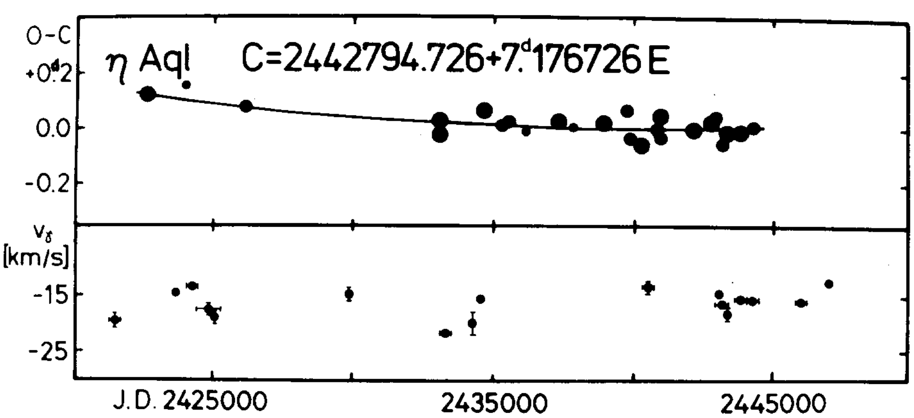

Figure 7. Upper panel: O-C diagram of η Aql
Lower panel: γ-velocities for the same Cepheid

ephemeris:

$$C = 2442794.726 + 7\overset{d}{.}176726 \cdot E \qquad (9)$$
$$\pm.006 \quad \pm.000014$$

The instantaneous value of the period can be predicted as follows:

$$P = 7\overset{d}{.}176726 + 3\overset{d}{.}16 \cdot 10^{-8} \cdot E \qquad (10)$$
$$\pm.000014 \quad \pm1.13$$

There is no significant difference between this value and that determined in Paper II.

Table 11. O–C residuals for η Aql

Norm.max. JD2400000+	E	O–C	W	Reference
22585.188	-2816	0.122	3	Wylie (1922)
23991.859	-2620	0.155	1	Pettit & Nicholson (1933)
26144.796	-2320	0.074	2	Bernheimer (1931)
33041.532	-1359	-0.023	3	Eggen (1951)
33070.289	-1355	0.027	3	Stebbins et al. (1952)
34613.324	-1140	0.066	3	Szabados (1980)
35295.055	-1045	0.008	2	Irwin (1961)
35574.965	-1006	0.025	2	Walraven et al. (1958)
36141.892	-927	-0.009	1	Oke (1961)
37283.027	-768	0.027	3	Mitchell et al. (1964)
37857.144	-688	0.005	1	Williams (1966)
38926.492	-539	0.021	3	Wisniewski & Johnson (1968)
39751.864	-424	0.070	2	Sudzius (1969)
39888.119	-405	-0.033	2	Schmidt (1971)
40239.753*	-356	-0.058	3	Feltz & McNamara (1980)
40857.010*	-270	0.000	2	Feltz & McNamara (1980)
40928.825	-260	0.048	3	Pel (1976)
40957.453	-256	-0.031	2	Evans (1976)
42127.285*	-93	-0.005	3	Depenchuk (1980)
42794.752	0	0.026	3	Szabados (1980)
42945.483	21	0.046	2	Dean (1977)
43203.745*	57	-0.054	2	Depenchuk (1980)
43311.439*	72	-0.011	2	Dean (1981)
43340.153*	76	-0.004	3	Moffett & Barnes (1984)
43864.047*	149	-0.011	3	Moffett & Barnes (1984)
44373.617*	220	0.011	2	Schmidt & Parsons (1982)

The study of the radial velocity observations, however, gives more novelty. It is a well-known fact that η Aql belongs to a binary system (*Mariska* et al., 1980). Based on the IUE spectra, *Böhm-Vitense* and *Proffitt* (1985) derived an A1V companion of ΔV = 4.6 mag. *Jacobsen* and *Wallerstein* (1981) suspected long period changes in the systemic radial velocity. As a matter of fact, the analysis of the radial velocity data collected from the literature (see Table 12 and Figure 7) strengthens their conclusion on the variability of the γ-velocity. It is not clear, however, what period can be assigned to the γ-velocity changes. The formal period search resulted in a value as short as 926 days. The deviations of the O–C residuals from the fitted parabola clearly show a

Table 12. γ-velocities of η Aql

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
14129	10	-16.7	0.9	13	Belopolski (1897)
14517	32	-15.0	0.6	28	Wright (1899)
19277	366	-13.7	2.1	3	Spencer Jones (1928)
21429	233	-19.6	1.2	4	Abt (1973)
23653	43	-14.4	0.6	28	Jacobsen (1926)
24226	173	-13.4	0.4	57	Henroteau (1928)
24869	461	-17.6	0.9	6	Abt (1973)
25084	23	-18.9	0.8	17	Henroteau & Vibert (1929)
29873	12	-14.6	1.2	4	Jacobsen (1961)
33292	190	-21.6	0.4	22	Jacobsen (1954)
34258	15	-19.8	2.0	2	Jacobsen (1954)
34548	32	-15.3	0.6	14	Jacobsen (1961)
40502	139	-13.3	1.0	5	Lloyd Evans (1980)
43049	33	-14.3	0.7	3	Jacobsen & Wallerstein (1981)
43141	206	-16.3	0.3	7	Beavers & Eitter (1986)
43384	4	-17.9	1.3	11	Wilson et al. (1989)
43828	206	-15.2	0.7	29	Barnes et al. (1987)
44290	143	-15.4	0.2	18	Jacobsen & Wallerstein (1981)
46033	157	-16.0	0.2	18	Jacobsen & Wallerstein (1987)
47027	1	-12.5	0.7	1	Samus (1990)

sinusoidal pattern at this period, as if it were a light-time effect, but this is too subtle to detect with an eye inspection in Figure 7. Further extensive radial velocity measurements are necessary to find the correct value of the spectroscopic orbital period.

RT Aurigae

Table 13. O-C residuals for RT Aur

Norm.max. JD2400000+	E	O-C	W	Reference
29603.272	-3251	-0.035	3	Bennett (1941)
33141.392	-2302	0.025	3	Eggen et al. (1957)
35799.601	-1589	0.029	3	Prokof'yeva (1961)
35881.611*	-1567	0.018	3	Bahner & Mavridis (1977)
36202.239*	-1481	0.021	3	Bahner & Mavridis (1977)
36616.072*	-1370	0.024	2	Bahner & Mavridis (1977)
37339.350	-1176	0.032	3	Mitchell et al. (1964)
37995.423	-1000	-0.058	2	Williams (1966)
38920.047	-752	-0.027	3	Wisniewski & Johnson (1968)
39359.960	-634	-0.041	3	Takase (1969)
40843.831*	-236	0.007	2	Feltz & McNamara (1980)
40996.642*	-195	-0.038	2	Evans (1976)
41429.115	-79	-0.036	3	Winzer (1973)
41723.711	0	0.032	3	Szabados (1977)
43539.286*	487	-0.025	2	Moffett & Barnes (1984)
44106.001*	639	0.003	3	Moffett & Barnes (1984)
44534.795*	754	0.055	2	Eggen (1985)

The eight new O-C residuals supplemented with the earlier photoelectric O-C values (see Table 13) confirm the value of the pulsation period as determined in Paper I. The O-C diagram has been calculated using the formula:

$$C = \underset{\pm .006}{2441723.679} + \underset{\pm .000005}{3^{d}.728198} \cdot E \qquad (11)$$

Although a very long (10000 - 15000 days) wave may be superimposed on the straight line in Figure 8, no spectroscopic confirmation of the light-time effect can be deduced from the available radial velocity data (Table 14). *Leonard* and *Turner* (1986) summarized the various arguments for and against duplicity of RT Aur and concluded that this Cepheid probably does not have a bright blue companion.

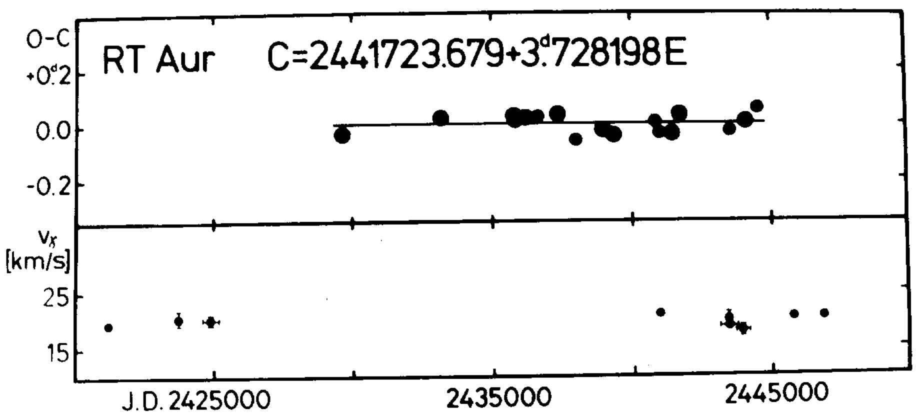

Figure 8. Upper panel: O-C diagram of RT Aur
Lower panel: γ-velocities for the same Cepheid

Table 14. γ-velocities of RT Aur

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
18230	18	21.5	0.6	24	Petrie (1932)
21210	65	19.5	0.6	30	Kiess (1917)
23723	30	20.6	1.3	6	Petrie (1932)
24955	253	20.1	0.7	19	Petrie (1932)
40979	9	21.0	0.3	4	Evans (1976)
43449	59	20.0	1.4	9	Wilson et al. (1989)
43457	275	18.7	0.4	5	Beavers & Eitter (1986)
43963	245	18.0	0.8	25	Barnes et al. (1987)
45717	9	20.4	0.1	45	Gieren (1985)
46866	1	20.4	0.5	2	Samus (1990)

AN Aurigae

Berdnikov's (1987) recent photometry confirms the period change suspected in Paper III but the phase jump interpretation does not seem to be correct. The O-C residuals listed in Table 15 have been obtained by the formula:

$$C = 2443799.022 + 10^{d}.289563 \cdot E \qquad (12)$$
$$\pm.017 \qquad \pm.000036$$

The photoelectric O-C residuals are plotted in Figure 9. It should be noted that *Berdnikov*'s (1987) photoelectric observations do not support the change in the light curve shape suspected in Paper III.

Nevertheless, AN Aur is a binary Cepheid, since the radial velocity observations show a variation in the γ-velocity. In Figure 10 the open circles denote *Joy*'s (1937) radial velocity data, while *Samus*' (1990) observations are plotted as filled circles. Zero phase is chosen arbitrarily, the pulsation period is according to Eq.(12). The deviation in the average radial velocity is even more obvious if the phase shift due to the period change occurred after the epoch of *Joy*'s observations is also taken into account. *Madore* (1977) estimates a B5 photometric companion. Further spectroscopic observations of this Cepheid would be of primary importance.

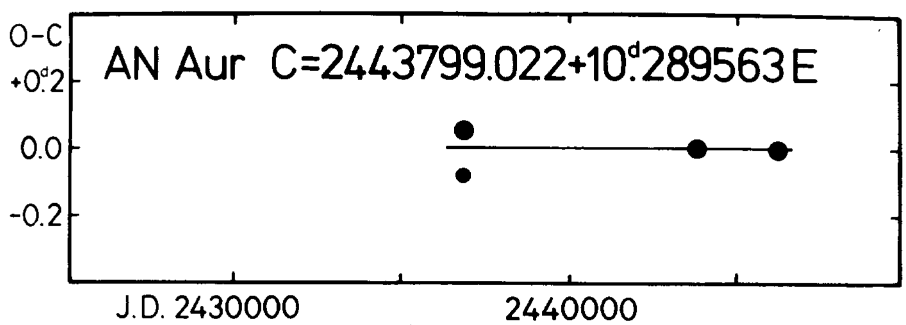

Figure 9. O-C diagram of AN Aur

Table 15. O-C residuals for AN Aur

Norm.max. JD2400000+	E	O-C	W	Reference
36832.907	-677	-0.081	2	Oosterhoff (1960)
36833.041	-677	0.053	3	Weaver et al. (1960)
43799.026	0	0.004	3	Szabados (1981)
46299.383*	243	-0.003	3	Berdnikov (1987)

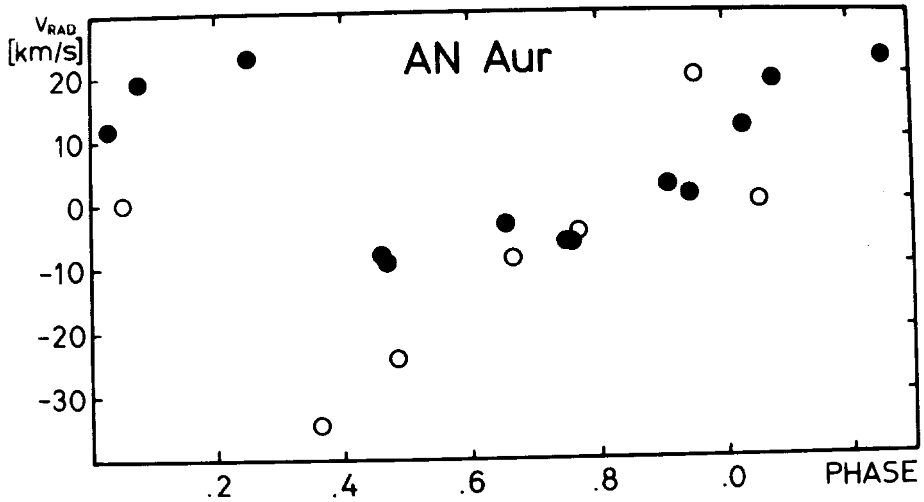

Figure 10. Radial velocity observations of AN Aur folded with the period 10.289563 days. Zero phase is chosen arbitrarily. Open circles: *Joy*'s (1937) data, filled circles: *Samus*' (1990) observations

RW Camelopardalis

The O-C diagram of this binary Cepheid supplemented with the recent O-C residuals (see Table 16) is plotted in Figure 11. The O-C residuals have been calculated using the ephemeris:

$$C = 2443840.694 + 16^{d}.415015 \cdot E \qquad (13)$$
$$\pm.020 \qquad \pm.000067$$

If the wave-like pattern is interpreted in terms of the light-time effect, an orbital period of about 7000 days characterizes the system. In

Table 16. O-C residuals for RW Cam

Norm.max. JD2400000+	E	O-C	W	Reference
36174.873	-467	-0.009	3	Bahner & Mavridis (1977)
36831.480	-427	-0.003	3	Oosterhoff (1960)
36831.546	-427	0.063	3	Weaver et al. (1960)
36880.608	-424	-0.120	3	Bahner et al. (1962)
39113.340	-288	0.170	3	Wamsteker (1972)
39786.182	-247	-0.003	2	Szabados (1981)
43840.515	0	-0.179	3	Szabados (1981)
44382.394*	33	0.005	2	Moffett & Barnes (1984)
45038.953*	73	-0.037	3	Moffett & Barnes (1984)
45695.611*	113	0.020	3	Berdnikov (1986)
46483.539*	161	0.028	2	present paper
47304.378*	211	0.116	2	present paper

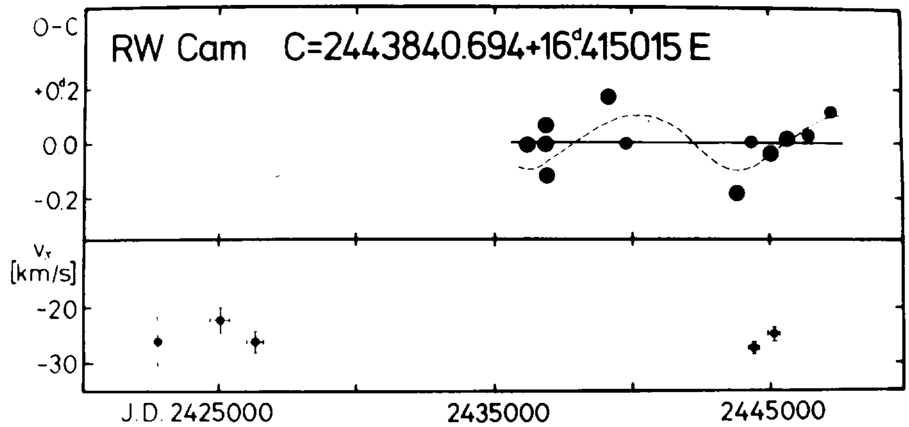

Figure 11. Upper panel: O-C diagram of RW Cam
Lower panel: γ-velocities for the same Cepheid

Table 17. γ-velocities of RW Cam

J.D. 2400000+	σ [d]	V_γ [km/s]	σ [km/s]	n	Reference
22740	1	-26.1	4.5	1	Joy (1937)
25050	340	-22.1	2.3	5	Joy (1937)
26364	288	-26.1	2.0	6	Joy (1937)
44456	160	-27.1	1.0	18	Barnes et al. (1988)
45168	223	-24.8	1.2	12	Barnes et al. (1988)

Paper III a somewhat shorter orbital period was suggested but *Joy*'s (1937) radial velocity measurements (see Table 17) prefer this longer value. The amplitude of the sinusoidal O-C variation is rather large, giving rise to considerable γ-velocity changes. Therefore the variation in the γ-velocity has to be larger than it has been observed till now. The phasing of the radial velocity data with the suspected orbital period, however, shows that RW Cam has never been observed spectroscopically during the phases when the Cepheid is approaching the observer. According to Figure 11, this orbital phase occurs just in the nineties, so any radial velocity study to be performed in the near future would answer the question whether the light-time effect interpretation is correct. If this is not the case, the other plausible interpretation of the O-C graph would be the occurrence of a phase jump. In any case, a regular coverage of the light variation is also desirable.

In addition to the previously published photometric evidence, the blue companion of RW Cam has been pointed out in the IUE spectra (*Böhm-Vitense* and *Proffitt*, 1985).

SU Cassiopeiae

The O–C diagram of this bright Cepheid based on only photoelectric observations is shown in Figure 12 (see also Table 18). The pulsation period has been constant since the discovery of the light variation of SU Cas. The current ephemeris

$$C = 2441645.913 + 1\overset{d}{.}949325 \cdot E \qquad (14)$$
$$\pm.003 \qquad \pm.000003$$

is practically the same as derived in Paper I. The same conclusion has been drawn by *Rhode* (1990a).

On the contrary, the study of the available radial velocity observations gives more interesting results. SU Cas also belongs to a binary system (*Evans*, 1985). This finding has been confirmed photometrically (*Usenko*, 1990b): the position of SU Cas on the two-colour diagram can be explained by assuming an A0 companion. In the light of these facts it is worth looking for any change in the γ-velocity of this Cepheid (see Table 19). There are four possible values of the orbital period: 462.5 , 928, 1375 and 1682 days. Although any data set can be folded with a "best fitting" sinusoid, and the periodicity does not necessarily bear physical significance, the 462.5 day period seems to be not simply an artifact of the data distribution. Of course, the "orbital velocity curve" plotted in Figure 13 has to be confirmed by additional radial velocity measurements.

Table 18. O–C residuals for SU Cas

Norm.max. JD2400000+	E	O–C	W	Reference
30404.167	-5767	0.011	3	Walter (1943)
30905.119	-5510	-0.013	3	Groeneveld (1944)
35755.041	-3022	-0.012	3	Prokof'yeva (1961)
36121.522*	-2834	-0.004	3	Bahner & Mavridis (1977)
36199.516	-2794	0.017	2	Svolopoulos (1960)
36836.942	-2467	0.014	2	Bahner et al. (1962)
37439.297	-2158	0.027	3	Mitchell et al. (1964)
38384.671	-1673	-0.021	3	Wisniewski & Johnson (1968)
39055.269	-1329	0.009	3	Milone (1970)
39361.299	-1172	-0.005	3	Takase (1969)
39447.074	-1128	0.000	3	Wamsteker (1972)
39751.198	-972	0.029	2	Sudzius (1969)
39864.198	-914	-0.032	3	Reed (1968)
40180.041*	-752	0.020	2	Feltz & McNamara (1980)
40963.647*	-350	-0.002	3	Feltz & McNamara (1980)
41645.925	0	0.012	3	Szabados (1977)
41930.480	146	-0.034	3	Gieren (1976)
43347.688*	873	0.014	3	Niva & Schmidt (1979)
43690.749*	1049	-0.006	3	Moffett & Barnes (1984)
44178.083*	1299	-0.003	3	Moffett & Barnes (1984)
47149.804*	2962	-0.010	3	Rhode (1990a)

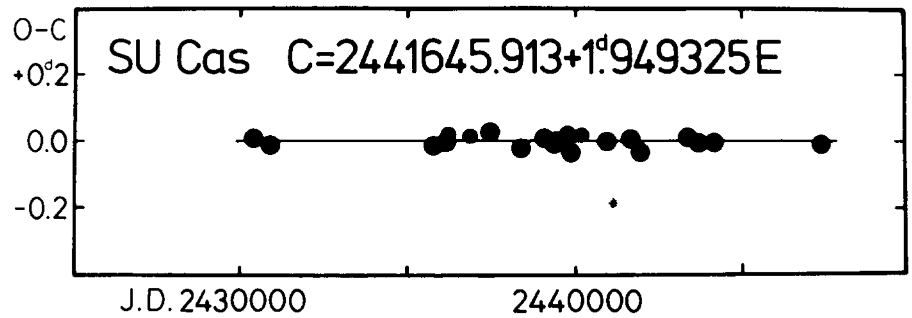

Figure 12. O-C diagram of SU Cas

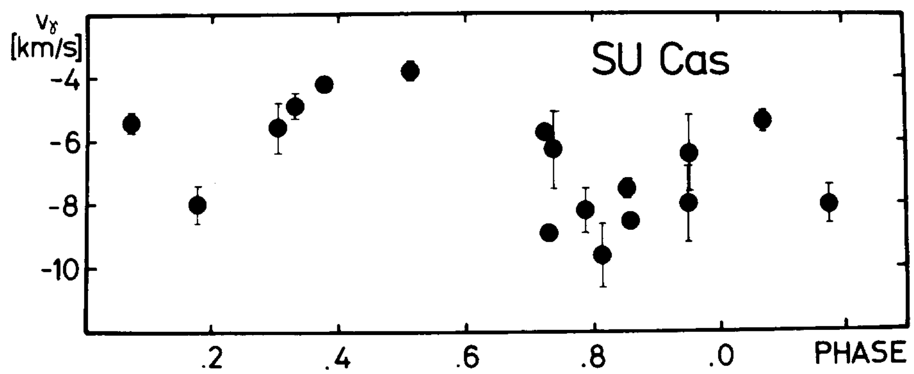

Figure 13. γ-velocity values of SU Cas folded with the 462.5 day period

Table 19. γ-velocities of SU Cas

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
20229	162	-6.3	1.2	4	Adams & Shapley (1918)
21252	153	-8.0	1.2	4	Adams & Shapley (1918)
34307	17	-8.0	0.6	4	Abt (1959)
34621	23	-8.5	0.3	14	Abt (1959)
35051	1	-8.2	0.7	3	Abt (1959)
36451	1	-9.6	1.0	1	Abt (1959)
40943	47	-3.8	0.3	7	Niva & Schmidt (1979)
41962	29	-8.9	0.1	63	Gieren (1976)
43406	3	-7.5	0.1	27	Niva & Schmidt (1979)
43453	59	-6.4	1.2	12	Wilson et al. (1989)
43810	28	-5.7	0.1	51	Beavers & Eitter (1986)
44079	264	-5.6	0.8	23	Barnes et al. (1987)
44574	46	-4.2	0.2	14	Häupl (1988)
44895	54	-5.4	0.3	11	Häupl (1988)
46866	1	-4.9	0.4	2	Samus (1990)

SZ Cassiopeiae

The very rapid increase in the pulsation period of SZ Cas has been continuing (see Figure 14). The O-C diagram based on the photoelectric O-C residuals, however, results in an ephemeris slightly different from that determined in Paper III. The O-C residuals listed in Table 20 have been obtained using the new elements:

$$C = \underset{\pm .029}{2443817.978} + \underset{\pm .000305}{13^{d}\!.636857} \cdot E \qquad (15)$$

The value of the period as a function of the epoch elapsed can be given as follows:

$$P = \underset{\pm .000305}{13^{d}\!.636857} + \underset{\pm 1.37}{18^{d}\!.72} \cdot 10^{-6} \cdot E \qquad (16)$$

Coker et al. (1989) obtained very accurate radial velocity measurements on SZ Cas, resulting in one of the best radial velocity

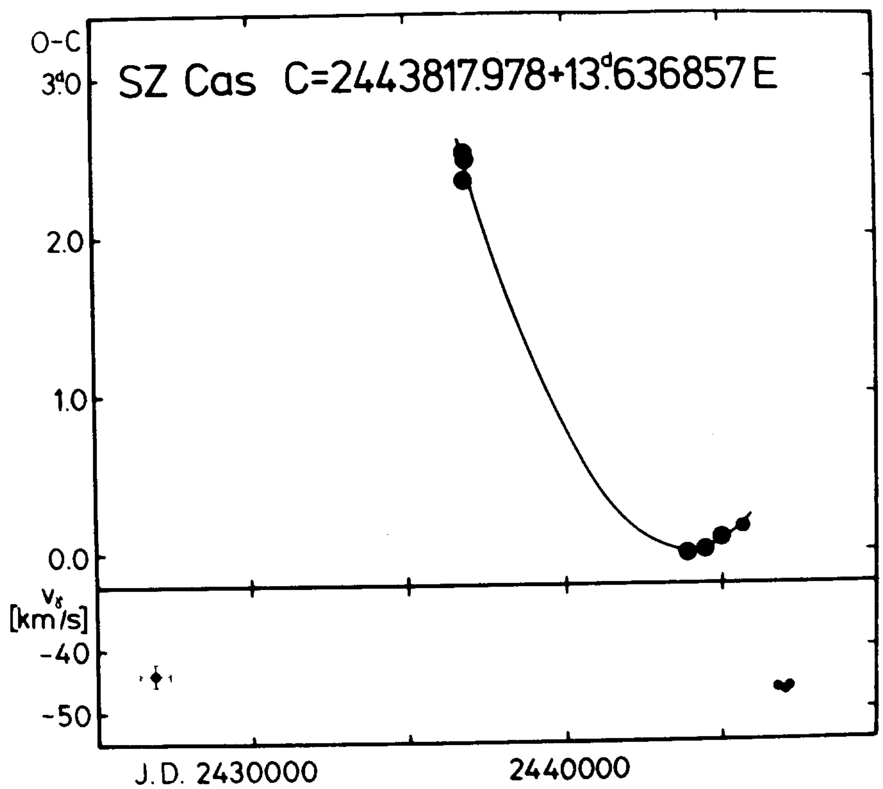

Figure 14. Upper panel: O-C diagram of SZ Cas
Lower panel: γ-velocities for the same Cepheid

Table 20. O-C residuals for SZ Cas

Norm.max. JD2400000+	E	O-C	W	Reference
36824.793	-513	2.523	3	Oosterhoff (1960)
36838.243	-512	2.336	3	Weaver et al. (1960)
36892.930	-508	2.475	3	Bahner et al. (1962)
43817.966	0	-0.012	3	Szabados (1981)
44404.379*	43	0.016	3	Moffett & Barnes (1984)
44963.567*	84	0.093	3	Moffett & Barnes (1984)
45672.744*	136	0.153	2	Berdnikov (1986)

Table 21. γ-velocities of SZ Cas

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
26892	488	-43.8	1.8	7	Joy (1937)
46794	91	-46.5	0.1	24	Coker et al. (1989)
47024	47	-46.9	0.1	26	Coker et al. (1989)
47194	94	-46.3	0.1	20	Coker et al. (1989)

curves ever observed for a Cepheid. There is a hint that the γ-velocity slightly varies from year to year (see Table 21), but further accurate measurements are necessary to confirm this suspicion. The recent study about the the position of SZ Cas on the two-colour diagram (*Usenko*, 1990b) assumes a B3 - B4 companion to this Cepheid.

BY Cassiopeiae

The new version of the O-C diagram suggests an early phase jump in addition to the recent period change (see Table 22 and Figure 15). The pulsation of BY Cas can be characterized with the following periods during the various time intervals:

between J.D. 2428500 and 2432000 P = 3.221315 ±.000112 days,
between J.D. 2432000 and 2434500 P = 3.221557 ±.000104 days,
between J.D. 2435500 and 2440000 P = 3.222618 ±.000037 days,
after J.D. 2443000 P = 3.222199 ±.000031 days.

The O-C residuals have been calculated with this latter period:

$$C = \underset{\pm.019}{2441774.634} + \underset{\pm.000031}{3\overset{d}{.}222199} \cdot E \tag{17}$$

The phase jump occurring at J.D. 2432000 was as large as 0.2 day. The type of the most recent period change is not clear yet. Further photometric observations are necessary.

The available sporadic radial velocity observations (*Joy*, 1937; *Samus*, 1990) are not enough for the determination of the radial velocity curve itself. Nevertheless, BY Cas is a promising candidate for binarity: *Usenko*

Table 22. O-C residuals for BY Cas

Norm.max. JD2400000+	E	O-C	W	Reference
28563.344	-4100	-0.274	1	Parenago (1940)
29223.824	-3895	-0.345	1	Kukarkina (1954)
30480.163	-3505	-0.664	1	Satyvaldiev (1970)
30650.693	-3452	-0.910	1	Dirks & Vaucouleurs (1949)
31014.735	-3339	-0.977	1	Satyvaldiev (1970)
31781.530	-3101	-1.065	1	Ashbrook (1954)
32048.696	-3018	-1.341	1	Dirks & Vaucouleurs (1949)
32132.390	-2992	-1.425	1	Satyvaldiev (1970)
33524.240	-2560	-1.565	1	Satyvaldiev (1970)
33736.708	-2494	-1.761	1	Kukarkina (1954)
33878.460	-2450	-1.786	1	Ashbrook (1954)
34361.768	-2300	-1.808	1	Kheilo (1962)
35557.258	-1929	-1.754	1	Kheilo (1962)
35615.515	-1911	-1.497	1	Satyvaldiev (1970)
36143.784	-1747	-1.668	1	Kheilo (1962)
36820.545	-1537	-1.569	3	Oosterhoff (1960)
36827.004	-1535	-1.555	3	Weaver et al. (1960)
36843.175	-1530	-1.495	1	Kheilo (1962)
36910.801	-1509	-1.535	3	Bahner et al. (1962)
38248.220	-1094	-1.328	1	Satyvaldiev (1970)
38409.256	-1044	-1.402	3	Malik (1965)
38660.818	-966	-1.172	1	Satyvaldiev (1970)
39785.406	-617	-1.131	3	Szabados (1977)
41774.189	0	-0.445	3	Szabados (1977)
43079.635	405	0.010	2	Szabados (1977)
43456.607*	522	-0.015	2	present paper
44168.732*	743	0.004	3	present paper

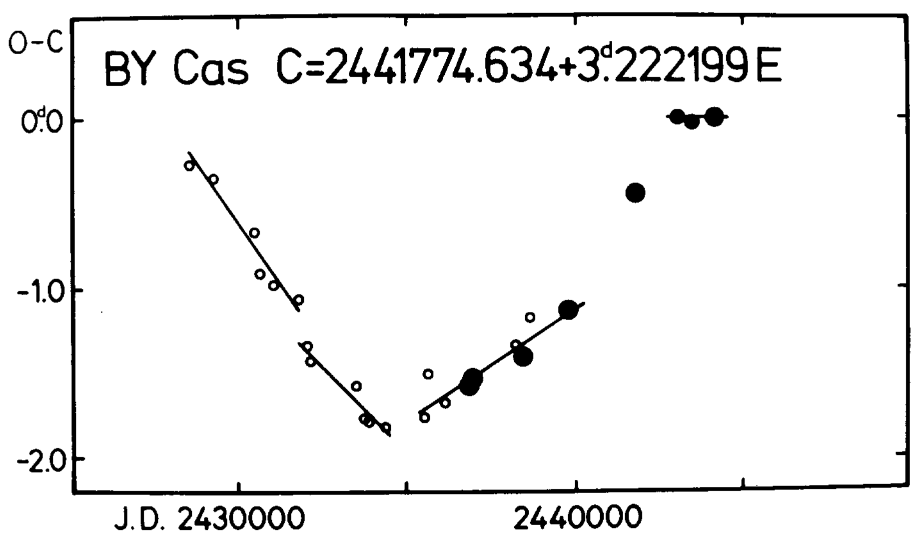

Figure 15. O-C diagram of BY Cas

(1990b) assumes a B5 photometric companion, thus supporting the earlier suspicion published by *Kurochkin* (1966) and *Madore* and *Fernie* (1980). The phase jump in the pulsation is a further evidence for duplicity.

DD Cassiopeiae

The normal light curve formed on the basis of the observations obtained by *Moffett* and *Barnes* (1984) made the re-discussion of the previous O-C diagram possible. According to the recent photoelectric observations (see Table 23 and Figure 16) a period change occurred between J.D. 2438000 and 2442500. The O-C residuals have been calculated with the ephemeris:

$$C = \underset{\pm.009}{2442780.426} + \underset{\pm.000060}{9\overset{d}{.}811656} \cdot E \tag{18}$$

The O-C residuals based on earlier photographic observations are compatible with the phase jump interpretation, because DD Cas was pulsating with practically the same period between J.D. 2430000 and 2438000, the phase jump being about 0.2 day. The light-time effect

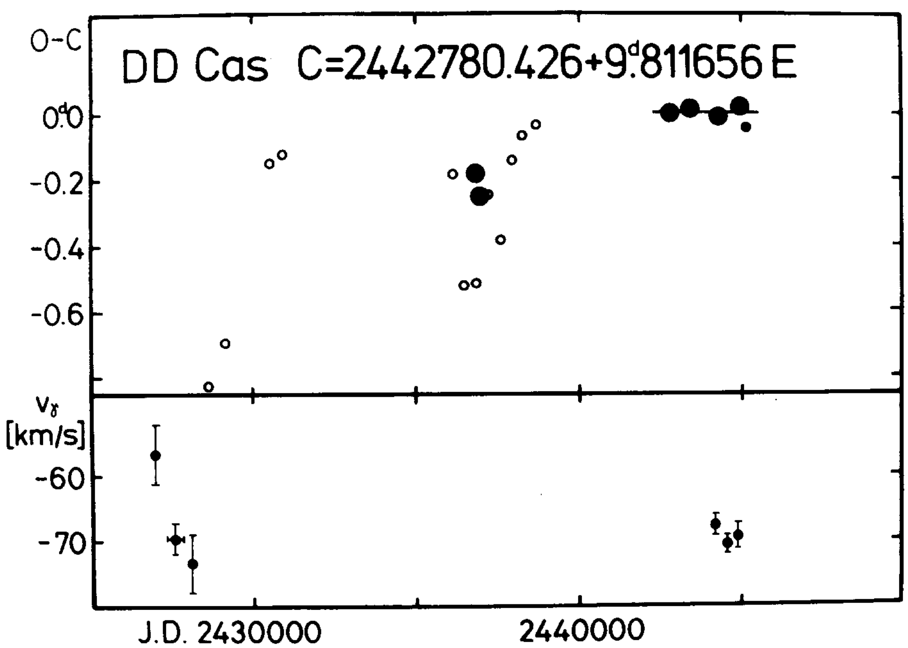

Figure 16. Upper panel: O-C diagram of DD Cas
Lower panel: γ-velocities for the same Cepheid

Table 23. O-C residuals for DD Cas

Norm.max. JD2400000+	E	O-C	W	Reference
17063.619	-2621	-0.457		Parenago (1940)
28601.761	-1445	-0.822		Parenago (1940)
29170.967	-1387	-0.692		Parenago (1940)
30584.392	-1243	-0.146		Solov'yov (1958)
30976.882	-1203	-0.122		Solov'yov (1958)
36137.753	-677	-0.182		Makarenko (1969)
36490.636	-641	-0.519		Makarenko (1969)
36804.942	-609	-0.185	3	Oosterhoff (1960)
36843.862	-605	-0.512		Makarenko (1969)
36932.426	-596	-0.253	3	Bahner et al. (1962)
37197.343	-569	-0.251		Makarenko (1969)
37579.865	-530	-0.383		Makarenko (1969)
37923.516	-495	-0.140		Makarenko (1969)
38296.432	-457	-0.067		Makarenko (1969)
38688.932	-417	-0.033		Makarenko (1969)
42780.422	0	-0.004	3	Szabados (1980)
43388.760*	62	0.011	3	Chekhanikhina (1982)
44252.160*	150	-0.014	3	Moffett & Barnes (1984)
44958.635*	222	0.021	3	Moffett & Barnes (1984)
45125.371*	239	-0.041	1	present paper

Table 24. γ-velocities of DD Cas

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
26983	15	-56.5	4.5	2	Joy (1937)
27565	178	-69.5	2.3	5	Joy (1937)
28097	1	-73.3	4.5	1	Joy (1937)
44184	57	-67.5	1.6	7	Barnes et al. (1988)
44508	49	-70.6	1.3	10	Barnes et al. (1988)
44877	76	-69.1	2.0	5	Barnes et al. (1988)

suggested in Paper II cannot be responsible for the shape of the O-C graph, since the amplitude of the wave would correspond to an enormously massive companion.

Duplicity of DD Cas suggested by *Madore* (1977) and *Madore* and *Fernie* (1980) has been checked by the radial velocity measurements, too. As Table 24 and the lower panel of Figure 16 shows, the variation in the γ-velocity is very probable, but further observations have to confirm the orbital motion.

DL Cassiopeiae

The new normal light curve based on the observations obtained by *Moffett* and *Barnes* (1984) defines the moment of light maxima more clearly than the previously used one. Owing to the new normal curve, a systematic correction of -0.192 day has been applied to the photoelectric O-C residuals published in Paper II. These corrected values, together with the more recent O–C residuals are listed in Table 25 and shown plotted in Figure 17. The new ephemeris for calculating the moments of maxima is as follows:

$$C = 2442780.172 + 8\overset{d}{.}000598 \cdot E \qquad (19)$$
$$\pm.011 \quad \pm.000022$$

The pulsation period of DL Cas has remained constant for the last decades, although *Meyers* (1988) determined a continuously increasing period. This latter study was based on photographic observations and, in my opinion, *Meyers*' (1988) O–C diagram can be better represented with two linear sections and a phase jump in between. The phase jump might occur at about J.D. 2429000, therefore unnoticeable in the O–C diagrams both in Paper II and here, in Figure 17.

Table 25. O–C residuals for DL Cas

Norm.max. JD2400000+	E	O–C	W	Reference
36163.576	-827	-0.101	3	Arp et al. (1959)
36803.750	-747	0.025	3	Oosterhoff (1960)
37219.860	-695	0.104	2	Mitchell et al. (1964)
37947.796	-604	-0.015	2	Williams (1966)
38707.934	-509	0.066	2	Haug (1970)
42692.156*	-11	-0.009	3	Szabados (1980)
43468.311*	86	0.088	1	Szabados (1980)
44292.283*	189	-0.002	3	Moffett & Barnes (1984)
44532.191*	219	-0.112	2	Eggen (1983a)
44972.332*	274	-0.004	3	Moffett & Barnes (1984)
45684.408*	363	0.019	3	Berdnikov (1986)
46284.450*	438	0.016	3	Berdnikov (1987)

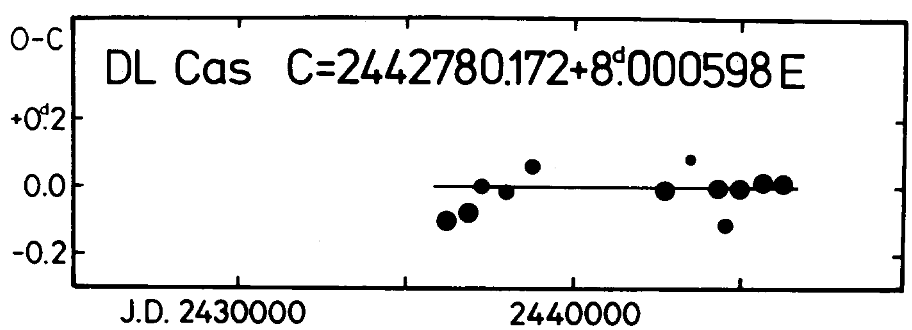

Figure 17. O–C diagram of DL Cas

The spectroscopic binary nature of DL Cas was discovered quite recently, independently by two groups (*Harris* et al., 1987; *Mermilliod* et al., 1987). The orbital period is rather short, at least among the Cepheid binaries: 688.0 days (*Harris* et al., 1987). The orbital radial velocity curve gives an approximate value for the amplitude of the light-time effect in the O-C diagram. The full amplitude of this wave is about 0.02 day, therefore it can hardly be pointed out from the available photometric data.

It is worth mentioning that DL Cas is one of the calibrating Cepheids for the period - luminosity relationship, because this Cepheid belongs to the open cluster NGC 129 (see *Walker*, 1987 and the references therein).

IX Cassiopeiae

Being a newly discovered spectroscopic binary (*Harris* and *Welch*, 1989), this Population II Cepheid would deserve more attention. The part of the O-C diagram based on photoelectric observations is shown in Figure 18 (see also Table 26). The frequent variations in the pulsation period are intrinsic to this star, and the straight line fit to the recent O-C residuals:

$$C = \underset{\pm .030}{2442780.264} + \underset{\pm .000104}{9\overset{d}{.}154549} \cdot E \tag{20}$$

does not necessarily mean constancy of the period. When determining the O-C residuals, a new normal curve based on the photometric observations made by *Harris* and *Welch* (1989) was used. The earlier O-C residuals have also been altered according to the new normal curve.

The radial velocity measurements of IX Cas were published by *Harris* and *Wallerstein* (1984) and *Harris* and *Welch* (1989). Moreover, this latter paper also deals with the determination of the orbital parameters: the orbital period of IX Cas is 110.29 days.

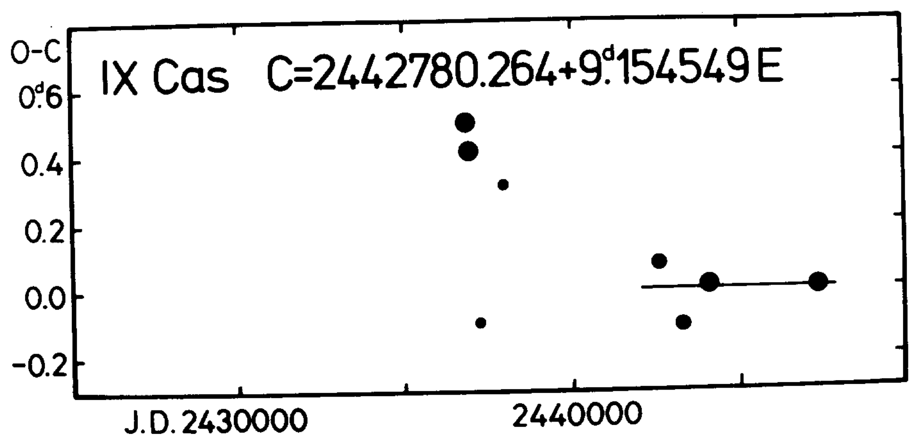

Figure 18. O-C diagram of IX Cas

Table 26. O-C residuals for IX Cas

Norm.max. JD2400000+	E	O-C	W	Reference
36802.848	-653	0.504	3	Oosterhoff (1960)
36903.457	-642	0.413	3	Bahner et al. (1962)
37205.051	-609	-0.093	1	Mitchell et al. (1964)
37974.445	-525	0.319	1	Williams (1966)
42560.633*	-24	0.078	2	Szabados (1980)
43247.037*	51	-0.109	2	Szabados (1980)
44034.452*	137	0.015	3	Harris & Welch (1989)
47348.390*	499	0.006	3	Harris & Welch (1989)

<u>V636 Cassiopeiae</u>

V636 Cas is one of the recently discovered Cepheid variables (*Burki* and *Benz*, 1982), therefore it does not have a long history of observations. The new photometric observations of this Cepheid listed in Table 108 are differential magnitudes with respect to BD+62°259. The O-C residuals in Table 27 and in Figure 19 (upper panel) have been calculated using the formula:

$$C = \underset{\pm.009}{2444519.260} + \underset{\pm.000039}{8^{d}.375735} \cdot E \qquad (21)$$

The number of the existing radial velocity observational series is also small but it can be stated with certainty that the γ-velocity of V636 Cas is varying. In addition to the γ-velocity values listed in Table 28, there are two more series of observations with no information about the moment or epoch of the measurements. *Redman* (1930) published a single radial velocity value of -19 km/s, being more positive than any other velocity value published for this star. *Boulon* et al. (1958) gave -31 km/s as the average of seven measurements. This latter value is even more negative than the extreme γ-velocity obtained from *Samus*' (1990) radial velocity data. Note that the value published by *Boulon* et al. is probably close to the γ-velocity because of the short pulsation period and very low amplitude variation. However, the companion is not bright and blue enough to appear in the IUE spectrum of the Cepheid (*Arellano Ferro* and *Madore*, 1986).

Table 27. O-C residuals for V636 Cas

Norm.max. JD2400000+	E	O-C	W	Reference
41964.655*	-305	-0.006	3	Burki & Benz (1982)
44519.250*	0	-0.010	3	Burki & Benz (1982)
45231.237*	85	0.040	2	present paper
47794.140*	391	-0.032	1	present paper

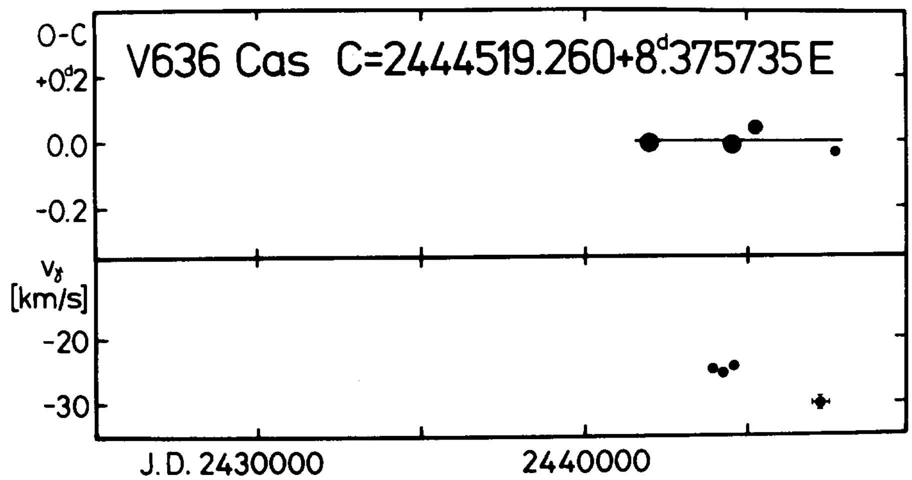

Figure 19. Upper panel: O-C diagram of V636 Cas
Lower panel: γ-velocities for the same Cepheid

Table 28. γ-velocities of V636 Cas

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
43855	42	-24.5	0.1	12	Burki & Benz (1982)
44201	26	-25.2	0.1	20	Burki & Benz (1982)
44558	57	-24.3	0.1	20	Burki & Benz (1982)
47282	266	-30.0	0.8	2	Samus (1990)

IR Cephei

The new photoelectric observations published here (see Table 108) confirm the value of the pulsation period determined in Paper I. This means that no new change has occurred in addition to that noted in Paper I (p. 43). The O-C residuals in Table 29 and in Figure 20 have been calculated using the equation:

$$C = \underset{\pm .005}{2441696.581} + \underset{\pm .000004}{2^{d}.114088} \cdot E \qquad (22)$$

Table 29. O-C residuals for IR Cep

Norm.max. JD2400000+	E	O-C	W	Reference
40965.096	-346	-0.011	3	Wachmann (1976)
41696.580	0	-0.001	3	Szabados (1977)
43045.394	638	0.025	2	Szabados (1977)
47413.066*	2704	-0.009	2	present paper

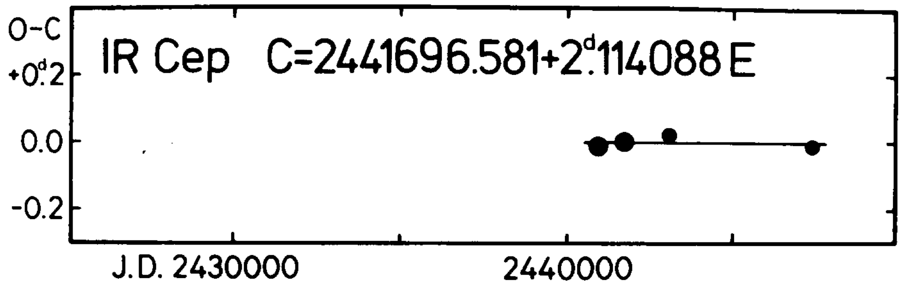

Figure 20. O-C diagram of IR Cep

There is only one radial velocity measurement series on IR Cep (*Samus*, 1990), giving -4.9 km/s for the γ-velocity. Although the membership of IR Cep in Cep OB2 association has been doubted on account of the age difference between the Cepheid and the association (*Kun* and *Szabados*, 1988), it should be noted that the γ-velocity of IR Cephei derived here is in a good agreement with the radial velocity of some bona fide members of Cep OB2. For example, the bright O-star, HD 206267, the most massive member of the IC 1396 + Tr 37 complex, forming one part of Cep OB2 (*Kun*, 1986), has an average radial velocity of -8 km/s (*Hoffleit* and *Jaschek*, 1982).

V351 Cephei

This relatively new Cepheid variable has been observed frequently since the discovery of its light variability (see Table 30 and Figure 21). The pulsation period is considered to be constant during the interval of the photoelectric observations, although *Erleksova* (1978) was able to point out two major period changes on the basis of archival photographic observations. The O-C residuals have been calculated here using a new

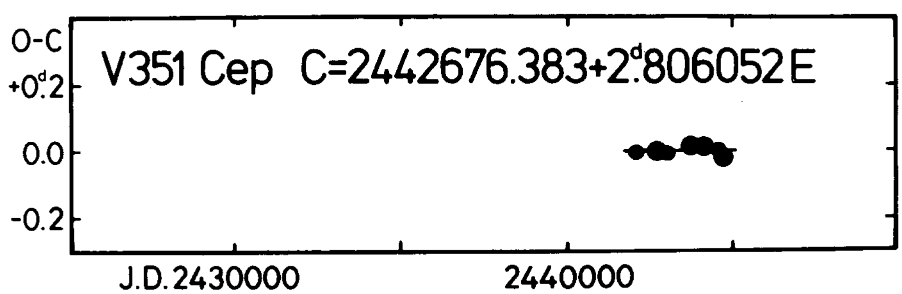

Figure 21. O-C diagram of V351 Cep

Table 30. O-C residuals for V351 Cep

Norm.max. JD2400000+	E	O-C	W	Reference
42030.985	-230	-0.006	2	Percy (1975)
42676.380	0	-0.003	3	Szabados (1977)
42993.459*	113	-0.008	2	Szabados (1977)
43700.608*	365	0.016	3	Henden (1979)
44071.005*	497	0.014	3	Diethelm & Tammann (1982)
44528.380*	660	0.003	2	Eggen (1985)
44696.720*	720	-0.020	3	Arellano Ferro (1984)

normal light curve based on *Arellano Ferro*'s (1984) observations and the following ephemeris:

$$C = 2442676.383 + 2^{d}.806052 \cdot E \qquad (23)$$
$$\pm.005 \qquad \pm.000010$$

Unfortunately no radial velocity measurements have been made on this Cepheid so far.

X Cygni

Although X Cygni belongs to the most frequently observed Cepheids, its O-C diagram has not yet been interpreted concordantly. The most comprehensive analysis has been performed by *Evans* (1984). In the present paper, however, I propose a new interpretation, viz. a phase jump in the O-C diagram, that has not been mentioned in the literature on X Cygni so

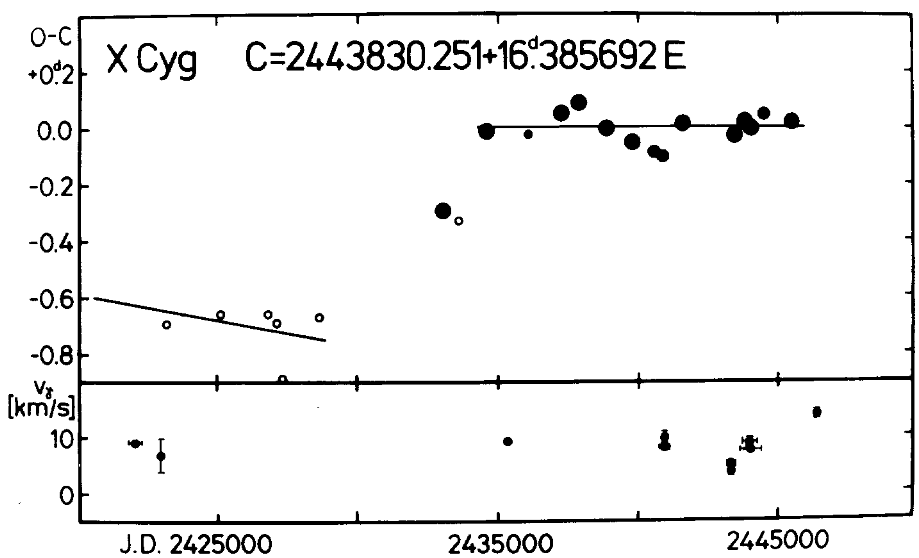

Figure 22. Upper panel: O-C diagram of X Cyg
Lower panel: γ-velocities for the same Cepheid

Table 31. O-C residuals for X Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
17055.372	-1634	-0.658	1	Wilkens (1906)
17694.729	-1595	-0.343	1	Jordan (1919)
23183.584	-1260	-0.695	1	Henroteau (1924)
25117.137	-1142	-0.654	1	Hellerich (1935)
26804.859	-1039	-0.658	1	Kox (1935)
27148.928	-1018	-0.689	1	Dziewulski (1948)
27328.968	-1007	-0.891	1	Liau (1935)
28672.816	-925	-0.670	1	Dziewulski (1948)
33031.783	-659	-0.297	3	Eggen (1951)
33605.249	-624	-0.330	1	Romano (1951)
34605.093	-563	-0.013	3	Szabados (1981)
36096.180	-472	-0.024	1	Svolopoulos (1960)
37226.867	-403	0.050	3	Mitchell et al. (1964)
37898.718	-362	0.088	3	Williams (1966)
38881.767	-302	-0.005	3	Wisniewski & Johnson (1968)
39782.931	-247	-0.054	3	Szabados (1981)
40585.795*	-198	-0.089	2	Feltz & McNamara (1980)
40929.879	-177	-0.105	2	Evans (1976)
41618.198	-135	0.015	3	Landis (1973)
43486.127*	-21	-0.024	3	Moffett & Barnes (1984)
43830.274	0	0.023	3	Szabados (1981)
44092.421*	16	-0.001	3	Moffett & Barnes (1984)
44534.885*	43	0.049	2	Eggen (1983b)
45534.385*	104	0.022	3	Berdnikov (1986)

Table 32. γ-velocities of X Cyg

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
22094	191	9.3	0.5	23	Duncan (1921)
22973	1	7.0	3.0	1	Harper (1934)
35332	21	9.5	0.2	17	Abt (1978)
40945	36	10.1	1.1	3	Schmidt (1974)
40952	169	8.2	0.3	5	Evans (1976)
43329	150	5.6	0.3	8	Beavers & Eitter (1986)
43393	49	4.2	1.1	15	Wilson et al. (1989)
44013	271	9.2	0.7	27	Barnes et al. (1987)
44055	382	7.9	0.5	18	Wallerstein (1983)
47473	1	13.9	0.7	1	Samus (1990)

far. The photoelectric O-C residuals supplemented with the early photographic ones are listed in Table 31. After J.D. 2434000 the photoelectric O-C residuals can be best represented by a straight line as follows:

$$C = 2443830.251 + 16\overset{d}{.}385692 \cdot E \qquad (24)$$
$$\pm .011 \qquad \pm .000041$$

As one can see in Figure 22 (the two residuals from the epoch earlier than J.D. 2420000 have not been plotted here), the O-C residuals before J.D. 2429000 define a slightly shorter, though constant period: P = 16.385356 ± 0.000176 days. According to this interpretation the phase jump with an amplitude of 0.8 day occurred between J.D. 2429000 and 2434000.

The γ-velocity values of X Cyg are listed in Table 32 and shown plotted in the lower panel of Figure 22. The variation in the γ-velocity seems to be larger than determined by *Evans* (1984) but its physical reality cannot be supported with definitive evidence for duplicity. The phase jump interpretation of the O-C diagram, however, implies the duplicity of X Cyg because such phenomena only occur in binary Cepheids.

SU Cygni

The phase jump reported in Paper I is confirmed here. Because the phase jump in the pulsation period of SU Cyg seems to be the best documented example for this phenomenon, the whole O-C diagram has been studied again (including the O-C diagram for the median brightness), only omitting the very uncertain visual observations before the jump and all visual data after the phase jump. The O-C residuals corresponding to the maximum light, listed in Table 33, have been calculated with the current ephemeris:

$$C_{max} = \underset{\pm.004}{2441778.977} + \underset{\pm.000004}{3\overset{d}{.}845512} \cdot E \tag{25}$$

while those for the median brightness (see Table 34) have been computed as follows:

$$C_{med} = \underset{\pm.005}{2441778.616} + \underset{\pm.000010}{3\overset{d}{.}845500} \cdot E \tag{26}$$

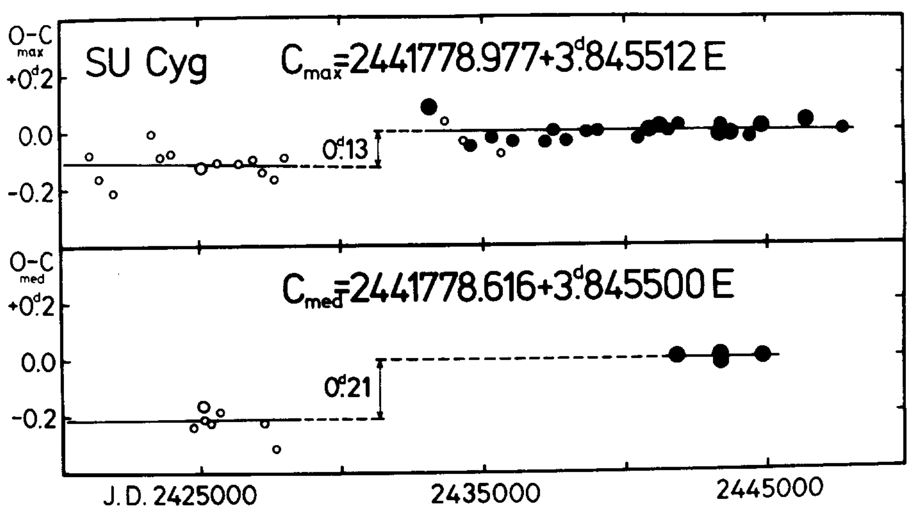

Figure 23. Upper panel: O-C diagram of SU Cyg (maximum brightness)
Lower panel: the same for the median brightness

Table 33. O-C residuals for SU Cyg (maximum brightness)

Norm.max. JD2400000+	E	O-C	W	Reference
14256.621	-7157	-0.027	1	Müller & Kempf (1897)
14491.161	-7096	-0.063	1	Zinner (1932)
14564.221	-7077	-0.067	1	Luizet (1899)
14591.118	-7070	-0.089	1	Wendell (1913)
17052.191	-6430	-0.144	2	Wilkens (1906)
17829.048	-6228	-0.080	1	Zeipel (1908)
17882.822	-6214	-0.143	1	van der Bilt (1925)
18175.117	-6138	-0.107	1	van der Bilt (1925)
18528.908	-6046	-0.103	1	van der Bilt (1925)
19271.104	-5853	-0.091	1	van der Bilt (1925)
21086.203	-5381	-0.074	1	Luyten (1922)
21443.751	-5288	-0.159	1	Luyten (1922)
21943.616	-5158	-0.210	1	Luyten (1922)
23320.515	-4800	-0.004	1	Hellerich (1925)
23662.684	-4711	-0.086	1	Hellerich (1925)
24028.020	-4616	-0.074	1	Hellerich (1925)
25100.868	-4337	-0.123	2	Hellerich (1935)
25696.940	-4182	-0.106	1	Zverev (1936)
26423.739	-3993	-0.109	1	Zverev (1936)
26923.669	-3863	-0.095	1	Florya & Kukarkina (1953)
27277.410	-3771	-0.141	1	Florya & Kukarkina (1953)
27677.322	-3667	-0.162	1	Krebs (1935)
28050.410	-3570	-0.089	1	Krebs (1936)
33126.659	-2250	0.084	3	Eggen (1951)
33680.364	-2106	0.035	1	Chuprina (1952)
34368.640	-1927	-0.035	1	Shteiman (1958)
34591.666	-1869	-0.049	2	Szabados (1977)
35356.949	-1670	-0.023	2	Walraven et al. (1958)
35645.305	-1595	-0.080	1	Shteiman (1958)
36099.119	-1477	-0.037	2	Svolopoulos (1960)
37172.013*	-1198	-0.041	2	Mitchell et al. (1964)
37498.922*	-1113	0.000	2	Mitchell et al. (1964)
37941.117	-998	-0.039	2	Williams (1966)
38664.105*	-810	-0.007	2	Wisniewski & Johnson (1968)
39029.433*	-715	-0.003	2	Wisniewski & Johnson (1968)
40452.240*	-345	-0.035	2	Feltz & McNamara (1980)
40867.591*	-237	0.000	3	Evans (1976)
41225.237*	-144	0.014	3	Feltz & McNamara (1980)
41540.552*	-62	-0.003	2	Szabados (1977)
41932.815*	40	0.018	2	Szabados (1977)
43344.084*	407	-0.016	3	Moffett & Barnes (1984)
43367.170*	413	-0.003	3	Fernie (1979b)
43378.722*	416	0.012	2	present paper
43786.320*	522	-0.014	3	Moffett & Barnes (1984)
44474.659*	701	-0.022	2	Berdnikov & Bogdanov (1987)
44866.935*	803	0.012	3	present paper
46412.858*	1205	0.039	3	present paper
47793.366*	1564	0.008	2	present paper

The difference between the periods as determined from the various parts of the O-C diagram (see Figure 23) is insignificant:

for the maximum brightness:

before the phase jump $P = 3.845502 \pm 0.000007$ days

after the phase jump $P = 3.845512 \pm 0.000004$ days ,

Table 34. O-C residuals for SU Cyg (median brightness)

Norm.max. JD2400000+	E	O-C	W	Reference
14590.722	-7070	-0.209	1	Wendell (1913)
17051.794	-6430	-0.257	2	Wilkens (1906)
17828.641	-6228	-0.201	1	Zeipel (1908)
24738.969	-4431	-0.237	1	Moncibowitz (1938)
25100.518	-4337	-0.165	2	Hellerich (1935)
25131.234	-4329	-0.213	1	Moncibowitz (1938)
25323.499	-4279	-0.223	1	Moncibowitz (1938)
25696.552	-4182	-0.183	1	Zverev (1936)
27277.010	-3771	-0.226	1	Florya & Kukarkina (1953)
27676.857	-3667	-0.311	1	Krebs (1935)
41778.619	0	0.003	3	Szabados (1977)
43343.719*	407	-0.016	3	Moffett & Barnes (1984)
43366.817*	413	0.010	3	Fernie (1979b)
44866.555*	803	0.003	3	present paper

for the median brightness:

before the phase jump P = 3.845502 ± 0.000011 days

after the phase jump P = 3.845500 ± 0.000010 days.

(Note that the O-C residuals before J.D. 2420000 listed in the respective tables do not appear in Figure 23.) The amount of the phase jump, however, clearly differs if the two O-C diagrams are compared. The phase jump is 0.13 day for the maximum brightness, while the value of 0.21 day can be determined from the moments of the median brightness. This difference is a manifestation of a noticeable change in the shape of the light curve, in the sense that the ascending branch has become steeper since the phase jump. The moment of the phase jump is not known yet: it might occur between J.D. 2428000 and 2433000.

SU Cyg belongs to the most thoroughly studied Cepheids from the spectroscopic point of view, as well. The spectroscopic orbit was recently published by *Evans* (1988), while the detailed study of the companion (a spectroscopic binary itself) was performed by *Evans* and *Bolton* (1990). The orbital period is too short (549.16 days) to cause noticeable light-time effect in the O-C diagram.

SZ Cygni

The new version of the O-C diagram (see Table 35 and Figure 24) is interpreted as one more case for a phase jump. The earlier suggestion on the light-time effect (see Paper III) is not tenable any more because the amplitude of the O-C wave would involve much too large orbital velocity variations that are not observed (see below). The O-C residuals have been calculated using the ephemeris:

$$C = 2443760.344 + 15\overset{d}{.}110228 \cdot E \qquad (27)$$
$$\pm.033 \quad \pm.000078$$

This period describes well the behaviour of the pulsation after J.D. 2430000 , while before that epoch the period was 15.110536 ± 0.000161

Table 35. O-C residuals for SZ Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
14991.044	-1904	0.574	1	Williams (1900)
15973.353	-1839	0.718	1	Florya & Parenago (1933)
17499.452	-1738	0.684	1	Florya & Parenago (1933)
22667.246	-1396	0.780	1	Henroteau (1924)
30659.819	-867	0.043	1	Filin (1951)
31702.567	-798	0.185	1	Filin (1951)
32201.239	-765	0.219	1	Kulikov (1957)
32820.760	-724	0.221	1	Filin (1951)
34588.194	-607	-0.241	1	Kulikov (1957)
35389.154	-554	-0.124	1	Kulikov (1957)
36779.369	-462	-0.050	3	Oosterhoff (1960)
36794.540	-461	0.011	3	Weaver et al. (1960)
37217.632	-433	0.017	2	Mitchell et al. (1964)
37942.574	-385	-0.332	1	Girnyak (1971)
38229.979	-366	-0.022	3	Kwee & Braun (1967)
39302.479	-295	-0.348	1	Girnyak (1971)
43760.486	0	0.142	3	Szabados (1981)
44349.673*	39	0.030	3	Moffett & Barnes (1984)
44999.388*	82	0.005	3	Moffett & Barnes (1984)
45603.789*	122	-0.003	3	Berdnikov (1986)

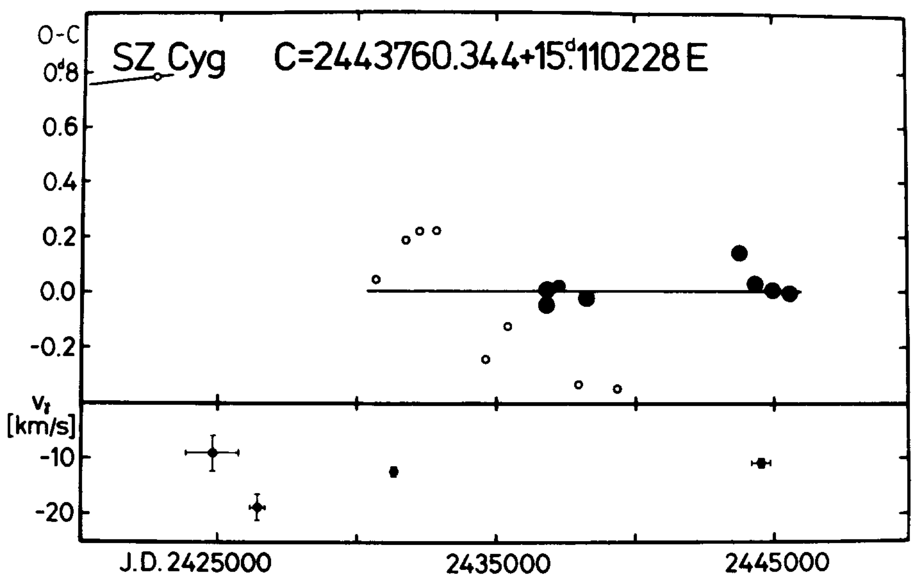

Figure 24. Upper panel: O-C diagram of SZ Cyg
Lower panel: γ-velocities for the same Cepheid

Table 36. γ-velocities of SZ Cyg

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
24819	962	-8.9	3.2	3	Joy (1937)
26435	231	-18.7	2.3	5	Joy (1937)
31304	7	-12.2	0.8	17	Struve (1945)
44529	309	-10.7	0.9	21	Barnes et al. (1988)

days. The phase jump was as large as 0.8 day (or about 0.05 pulsation period). The visual observations also support the occurrence of a phase jump at about J.D. 2430000. Nevertheless, these low quality observations have not been taken into account in the line fitting procedure.

The analysis of the available radial velocity data leads to the conclusion that the γ-velocity of SZ Cyg is variable (see Table 36) but further spectroscopic observations are desirable in order to point out definitely the effect of the hypothetical B4 photometric companion (*Madore*, 1977).

TX Cygni

The recent photoelectric observations clearly show the major period change suspected in Paper III. Both the recent value of the pulsation period and the moment of the sudden increase can be determined from the available data. The O-C residuals listed in Table 37 (see also Figure 25) can be represented with the elements:

$$C = \underset{\pm .019}{2443795.007} + \underset{\pm .000272}{14\overset{d}{.}711635} \cdot E \qquad (28)$$

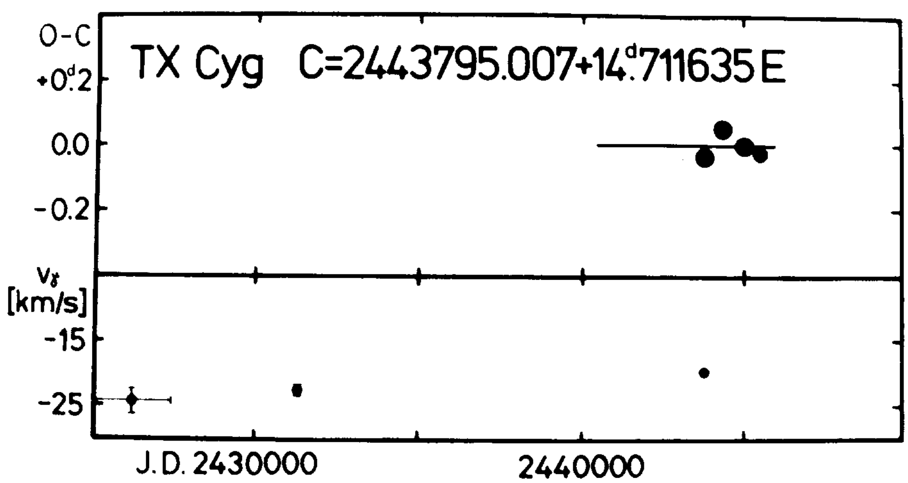

Figure 25. Upper panel: O-C diagram of TX Cyg
Lower panel: γ-velocities for the same Cepheid

Table 37. O-C residuals for TX Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
43794.971	0	-0.036	3	Szabados (1981)
44339.391*	37	0.054	3	Moffett & Barnes (1984)
45001.361*	82	0.000	3	Moffett & Barnes (1984)
45545.668*	119	-0.024	2	Berdnikov (1986)

Table 38. γ-velocities of TX Cyg

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
26188	1256	-24.4	1.8	7	Joy (1937)
31306	6	-22.5	0.8	14	Struve (1945)
43741	1	-19.6	0.3	1	Harris et al. (1979)

Combining the above elements with those published in Paper III, the change in the period occurred at about J.D. 2440500. Since the period valid previously was 14.708157 days, the difference (0.024 per cent) is unusually large for a classical Cepheid. It is interesting to note that *Kovács* et al. (1990) determined a value of 14.1369 days for the period on the basis of the available radial velocity data. None of the recent photoelectric observational series, however, supports a period as short as this.

The γ-velocity of TX Cyg may be variable (see Table 38) but further observations are necessary to confirm this suspicion.

VZ Cygni

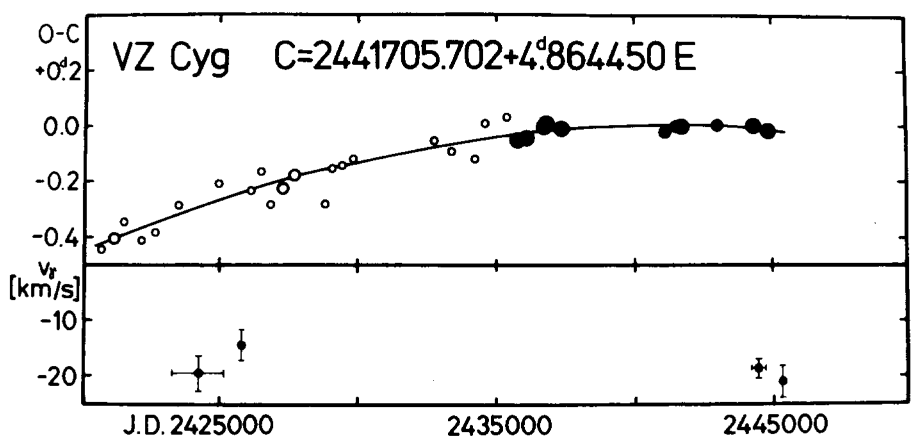

Figure 26. Upper panel: O-C diagram of VZ Cyg
Lower panel: γ-velocities for the same Cepheid

The plot of O-C residuals supplemented with the data derived from the recently published photoelectric observations (see Table 39 and Figure 26) can best be represented with a parabola, indicating a continuous period decrease. The O-C residuals have been calculated as follows:

$$C = \underset{\pm .007}{2441705.702} + \underset{\pm .000008}{4\overset{d}{.}864450} \cdot E \qquad (29)$$

The value of the pulsation period can be calculated using the formula:

$$P = \underset{\pm .000008}{4\overset{d}{.}864450} - \underset{\pm .44}{4\overset{d}{.}55} \cdot 10^{-8} \cdot E \qquad (30)$$

Table 39. O-C residuals for VZ Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
20627.598	-4333	-0.442	1	Doberck (1920)
21114.079	-4233	-0.406	2	Jordan (1929)
21498.432	-4154	-0.345	1	Doberck (1920)
22179.388	-4014	-0.412	1	Doberck (1920)
22656.134	-3916	-0.382	1	Jordan (1929)
23507.509	-3741	-0.286	1	Nielsen (1954)
24996.109	-3435	-0.207	1	Wachmann (1935)
26163.550	-3195	-0.234	1	Wachmann (1935)
26513.862	-3123	-0.163	1	Wachmann (1935)
26898.035	-3044	-0.281	1	Wachmann (1935)
27321.296	-2957	-0.227	2	Gesundheit (1938)
27739.687	-2871	-0.179	2	Gesundheit (1938)
28848.680	-2643	-0.281	1	Abidov (1963)
29096.894	-2592	-0.154	1	Abidov (1963)
29452.007	-2519	-0.145	1	Abidov (1963)
29812.004	-2445	-0.118	1	Abidov (1963)
32755.060	-1840	-0.054	1	Novikov (1951)
33387.402	-1710	-0.091	1	Abidov (1963)
34219.193	-1539	-0.120	1	Abidov (1963)
34589.022	-1463	0.010	1	Abidov (1963)
35362.501	-1304	0.042	1	Vyskupaitis (1961)
35732.104*	-1228	-0.053	3	Bahner & Mavridis (1977)
36106.672*	-1151	-0.048	3	Bahner & Mavridis (1977)
36773.146	-1014	-0.004	3	Weaver et al. (1960)
36802.348	-1008	0.012	3	Oosterhoff (1960)
37352.009	-895	-0.010	3	Mitchell et al. (1964)
41160.858*	-112	-0.026	2	Feltz & McNamara (1980)
41525.716*	-37	-0.001	2	Feltz & McNamara (1980)
41705.698	0	-0.004	3	Szabados (1977)
43062.886	279	0.002	2	Szabados (1977)
44366.557*	547	0.001	3	Moffett & Barnes (1984)
44911.356*	659	-0.019	3	Moffett & Barnes (1984)

Table 40. γ-velocities of VZ Cyg

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
24235	949	-19.4	3.2	3	Joy (1937)
25819	37	-14.4	2.6	4	Joy (1937)
44489	241	-18.5	1.8	6	Barnes et al. (1988)
45342	1	-21.0	2.8	3	Barnes et al. (1988)

Variations in the γ-velocity of VZ Cyg cannot be excluded (see Table 40) but further radial velocity measurements are necessary to make a firm statement on this matter.

BZ Cygni

The pulsation period keeps on being constant, but its value is slightly modified with respect to that published in Paper III. The O-C residuals listed in Table 41 and plotted in Figure 27 can be approximated with a line:

$$C = \underset{\pm.032}{2443774.199} + \underset{\pm.000065}{10\overset{d}{.}142222}\cdot E \tag{31}$$

As to the radial velocity measurements of BZ Cyg, a difference as large as 20 km/s can be seen between the γ-velocity of the available radial velocity measurement series (see Table 42 and the lower panel of

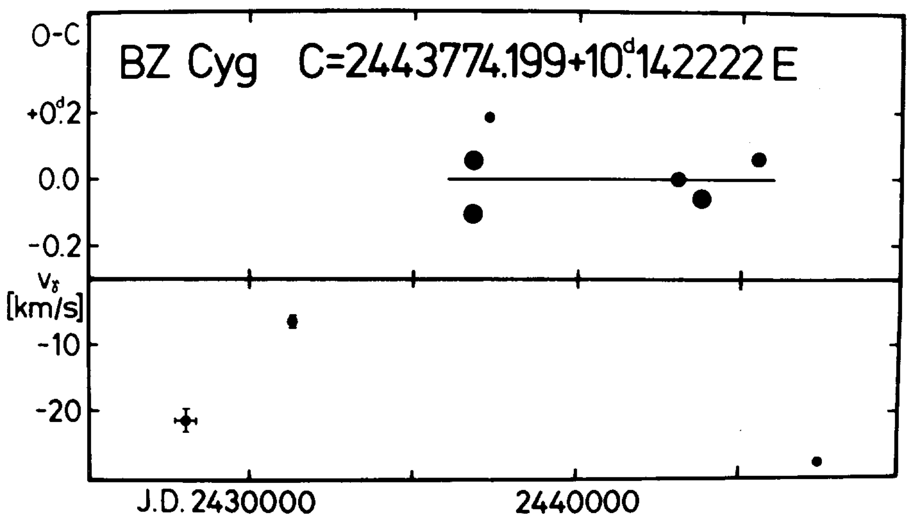

Figure 27. Upper panel: O-C diagram of BZ Cyg
Lower panel: γ-velocities for the same Cepheid

Table 41. O-C residuals for BZ Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
36786.104	-689	-0.104	3	Weaver et al. (1960)
36796.408	-688	0.058	3	Oosterhoff (1960)
37273.217	-641	0.182	1	Mitchell et al. (1964)
43013.533*	-75	0.001	2	Chekhanikhina (1982)
43774.144	0	-0.055	3	Szabados (1981)
45539.006*	174	0.060	2	Berdnikov (1986)

Table 42. γ-velocities of BZ Cyg

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
28000	312	-21.4	1.8	7	Joy (1937)
31306	6	-6.4	0.8	14	Struve (1945)
47473	1	-27.0	0.6	1	Samus (1990)

Figure 27). Since BZ Cyg is a new spectroscopic binary beyond doubt, this Cepheid deserves immediate attention of the spectroscopists.

DT Cygni

This bright Cepheid was frequently observed photoelectrically during the last two decades, therefore the most recent part of the O-C diagram (see Table 43 and Figure 28) is of exceptionally good quality. Due to the new normal light curve based on the observations obtained by *Moffett* and *Barnes* (1984), a correction of -0.080 day has been applied to the previously determined O-C residuals (taken from Paper I). The section of the O-C diagram between J.D. 2440000 and 2447000 can be approximated with the line:

$$C = \underset{\pm.005}{2441737.702} + \underset{\pm.000005}{2\overset{d}{.}499086} \cdot E \qquad (32)$$

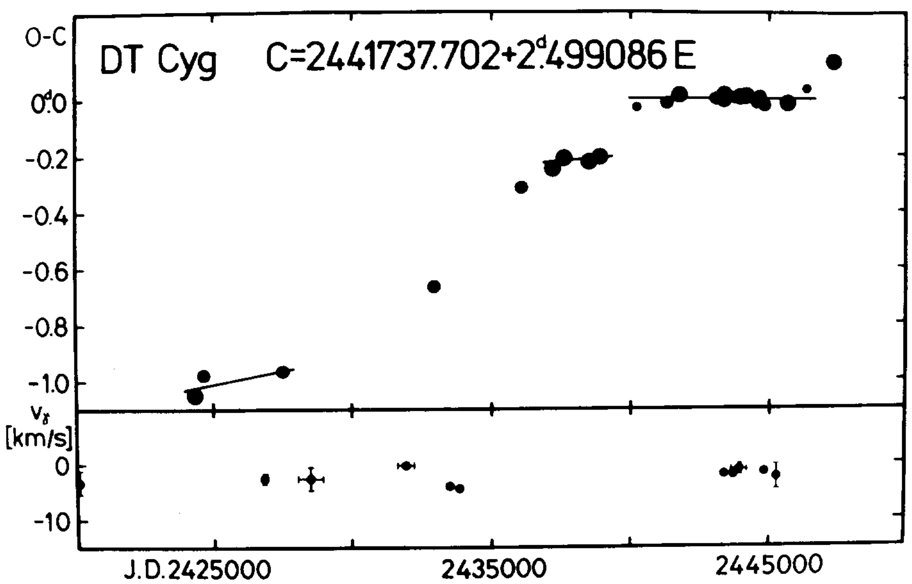

Figure 28. Upper panel: O-C diagram of DT Cyg
Lower panel: γ-velocities for the same Cepheid

Table 43. O-C residuals for DT Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
24375.503	-6947	-1.049	3	Huffer (1928b)
24695.458	-6819	-0.977	2	Huffer (1928b)
27546.928	-5678	-0.964	2	Schneller (1936)
32975.235	-3506	-0.667	2	Eggen (1951)
36099.447	-2256	-0.317	2	Svolopoulos (1960)
37176.620	-1825	-0.250	3	Mitchell et al. (1964)
37579.011	-1664	-0.212	3	Johansen (1971)
38496.161	-1297	-0.226	3	Johansen (1971)
38871.042	-1147	-0.208	3	Wisniewski & Johnson (1968)
40185.742*	-621	-0.028	1	Feltz & McNamara (1980)
41297.846*	-176	-0.017	2	Feltz & McNamara (1980)
41737.718	0	0.016	3	Szabados (1977)
43044.725	523	0.001	2	Szabados (1977)
43379.606*	657	0.004	3	Moffett & Barnes (1984)
43399.611*	665	0.017	3	present paper
43754.468*	807	0.004	2	present paper
43871.925*	854	0.004	3	Moffett & Barnes (1984)
44149.328*	965	0.008	3	present paper
44534.159*	1119	-0.020	1	Eggen (1985)
44684.129*	1179	0.005	2	present paper
44869.031*	1253	-0.026	2	Arellano Ferro (1984)
45646.256*	1564	-0.017	3	Guetter & Hewitt (1984)
46341.053*	1842	0.035	1	"Carlsberg" (1989)
47343.284*	2243	0.132	3	Rhode (1990b)

Two other linear sections are also marked in the O-C graph in Figure 28, viz.:

between J.D. 2424000 and 2428000 P = 2.499137 ± 0.000022 days, and
between J.D. 2437000 and 2439000 P = 2.499101 ± 0.000023 days.

Between the intervals of pulsating with the periods listed above, phase jumps caused some shifts in the O-C diagram. Since the visual and the photographic observations have not been taken into account in this study, only the last phase jump is seen well, the amount of the jump being about 0.2 day. The suggestion put forward in Paper I (p. 49) concerning the regular phase shift (about 0.22 day or its multiple) cannot be confirmed here, its verification should wait until the next occurrence of the phase jump. A new period change event can be suspected at the most recent O-C residual in Figure 28. Further observations will clarify whether this change will turn out to be a new phase shift. In any case, the prediction for the moment of the light maximum near J.D. 2450000 in Table 110 may not be accurate.

The phase jump is a characteristic feature of the binary Cepheids. There are a few pieces of evidence concerning the duplicity of DT Cygni. Most of them are summarized by *Leonard* and *Turner* (1986), concluding that the existence of an early type companion is uncertain. However, according

Table 44. γ-velocities of DT Cyg

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
20080	29	-3.3	2.1	3	Sanford (1930)
26865	93	-2.5	0.9	12	Sanford (1930)
28519	446	-2.5	2.1	3	Young (1939)
31905	284	0.0	0.4	7	Sanford (1951)
33486	25	-3.8	0.3	11	Grassberger & Herbig (1952)
33843	24	-4.1	0.4	9	Grassberger & Herbig (1952)
43392	43	-1.7	0.6	46	Wilson et al. (1989)
43711	206	-1.7	0.2	15	Beavers & Eitter (1986)
43946	218	-0.9	0.8	23	Barnes et al. (1987)
44832	2	-1.3	0.7	6	Arellano Ferro (1984)
45270	1	-2.4	2.3	1	present paper

to a very recent paper by *Usenko* (1990b), DT Cyg has an A2-A3 type photometric companion. An early evidence for the changes in the γ-velocity was published by *Lloyd Evans* (1968). His conclusion is confirmed here (see Table 44 and Figure 28). The extreme values of the γ-velocity differ from each other by more than four km/s, and this difference exceeds the observational uncertainty. New high quality radial velocity measurements will hopefully solve the problem of duplicity of DT Cygni because the amplitude of the expected γ-velocity changes is rather low.

MW Cygni

The two recent O-C residuals (see Table 45 and Figure 29) indicate that the pulsation period is slightly longer than determined in Paper II. The O-C graph can be approximated with a line as follows:

$$C = 2442923.907 + 5^{d}\!.954666 \cdot E \qquad (33)$$
$$\pm.007 \qquad \pm.000007$$

There is an obvious variation in the γ-velocity of MW Cyg. According to the data listed in Table 46, *Moffett* and *Barnes* (1987) underestimated

Table 45. O-C residuals for MW Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
30532.222	-2081	-0.025	1	Solov'yov (1946)
31038.435	-1996	0.041	1	Solov'yov (1946)
33884.781	-1518	0.057	1	Shteiman (1958)
34539.757	-1408	0.020	1	Shteiman (1958)
35677.074	-1217	-0.004	1	Shteiman (1958)
36802.499	-1028	-0.011	3	Oosterhoff (1960)
36820.339	-1025	-0.035	3	Weaver et al. (1960)
42923.911	0	0.004	3	Szabados (1980)
44364.932*	242	-0.004	3	Moffett & Barnes (1984)
44877.050*	328	0.013	3	Moffett & Barnes (1984)

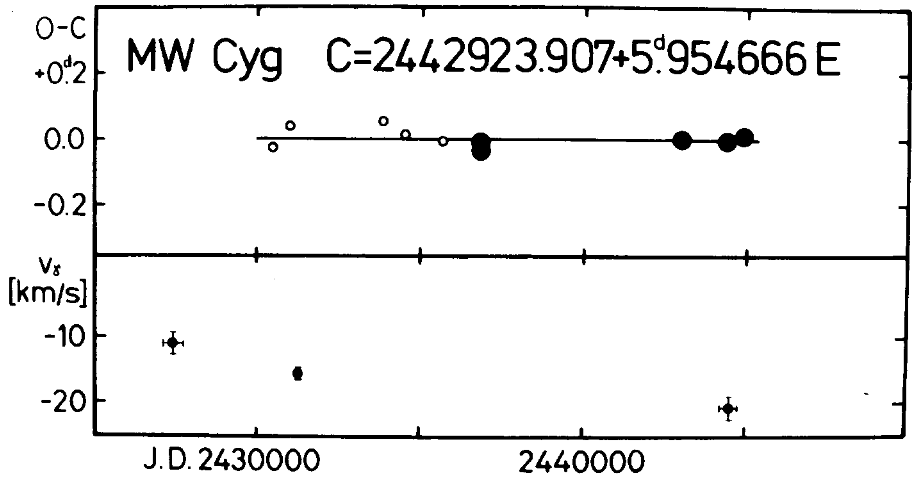

Figure 29. Upper panel: O-C diagram of MW Cyg
Lower panel: γ-velocities for the same Cepheid

Table 46. γ-velocities of MW Cyg

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
27487	311	-11.0	1.7	8	Joy (1937)
31304	7	-15.5	0.8	15	Struve (1945)
44514	282	-20.6	1.8	6	Barnes et al. (1988)

the difference between the γ-velocities determined from *Joy*'s (1937) and their own data. While *Moffett* and *Barnes* derived -2.8 km/s, now the difference is -9.4 km/s. The deviating result is probably caused by the different methods in determining the γ-velocities. In the present study the normal radial velocity curve has been based on *Struve*'s (1945) measurements, and the other radial velocity measurements have been fitted to this normal curve. MW Cyg is therefore a new spectroscopic binary Cepheid candidate.

V386 Cygni

The O-C diagram (see Table 47 and Figure 30) confirms the earlier conclusion (in Paper II) about the constancy of the pulsation period of V386 Cygni. The new, slightly modified ephemeris for the moments of maxima is as follows:

$$C = \underset{\pm .003}{2442777.141} + \underset{\pm .000004}{5^{d}.257635} \cdot E \tag{34}$$

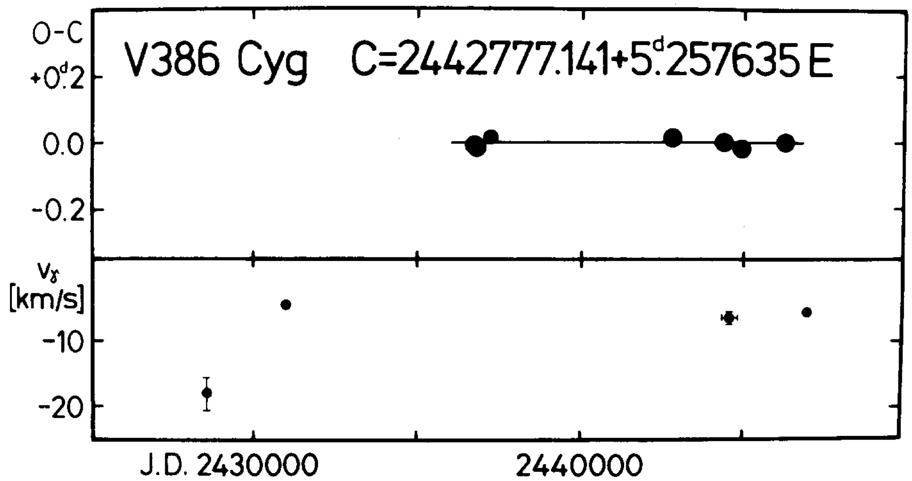

Figure 30. Upper panel: O-C diagram of V386 Cyg
Lower panel: γ-velocities for the same Cepheid

Table 47. O-C residuals for V386 Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
36762.403	-1144	-0.004	3	Weaver et al. (1960)
36804.456	-1136	-0.012	3	Oosterhoff (1960)
37251.385	-1051	0.018	2	Mitchell et al. (1964)
42777.160	0	0.019	3	Szabados (1980)
44359.691*	301	0.002	3	Moffett & Barnes (1984)
44927.497*	409	-0.017	3	Moffett & Barnes (1984)
46289.243*	668	0.002	3	Berdnikov (1987)

Table 48. γ-velocities of V386 Cyg

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
28571	90	-17.9	2.6	4	Joy (1937)
31006	7	-4.2	0.8	16	Struve (1945)
44581	257	-6.5	0.9	19	Barnes et al. (1988)
47010	15	-5.6	0.3	8	Metzger et al. (1990)

The study of the γ-velocity gives a new piece of evidence for the binary nature of V386 Cyg. It is noteworthy that there is a difference as large as 13.7 km/s between the γ-velocities on a time-base of about 2500 days (see Table 48 and Figure 30, lower panel). Although *Moffett* and *Barnes* (1987) gave a smaller value for the discrepancy between the individual γ-velocity values, the other pieces of evidence (*Kurochkin*, 1966; *Madore*, 1977; *Madore* and *Fernie*, 1980) make the spectroscopic binary interpretation very reasonable.

V532 Cygni

The new photoelectric observations confirm the occurrence of the phase jump first suggested in Paper I. Because a new normal light curve was used here, the previously determined normal maxima have been corrected by 0.102 day accordingly (see Table 49 and Figure 31). The O-C residuals have been calculated with the elements:

$$C = 2441706.686 + 3\overset{d}{.}283494 \cdot E \qquad (35)$$
$$\pm.007 \qquad \pm.000007$$

Table 49. O-C residuals for V532 Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
33889.249	-2381	0.562	1	Shteiman (1958)
34434.386	-2215	0.639	1	Shteiman (1958)
35642.593	-1847	0.520	1	Shteiman (1958)
36817.805	-1489	0.242	3	Oosterhoff (1960)
37684.512*	-1225	0.106	1	Girnyak (1971)
38229.434	-1059	-0.032	3	Kwee & Braun (1967)
38439.599*	-995	-0.010	1	Girnyak (1971)
39024.197*	-817	0.126	1	Girnyak (1971)
39411.594*	-699	0.070	1	Girnyak (1971)
41338.896*	-112	-0.039	2	Feltz & McNamara (1980)
41706.661	0	-0.025	3	Szabados (1977)
43026.673	402	0.022	2	Szabados (1977)
43420.683*	522	0.013	3	present paper
44149.609*	744	0.003	2	present paper
44438.557*	832	0.004	3	Moffett & Barnes (1984)
44911.371*	976	-0.005	3	Moffett & Barnes (1984)
45009.840*	1006	-0.041	2	present paper
46490.739*	1457	0.002	2	present paper
47534.898*	1775	0.010	3	present paper

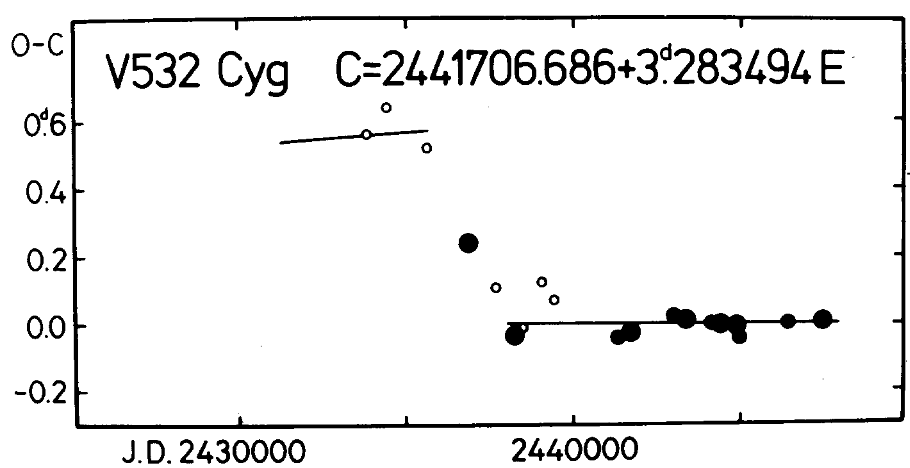

Figure 31. O-C diagram of V532 Cyg

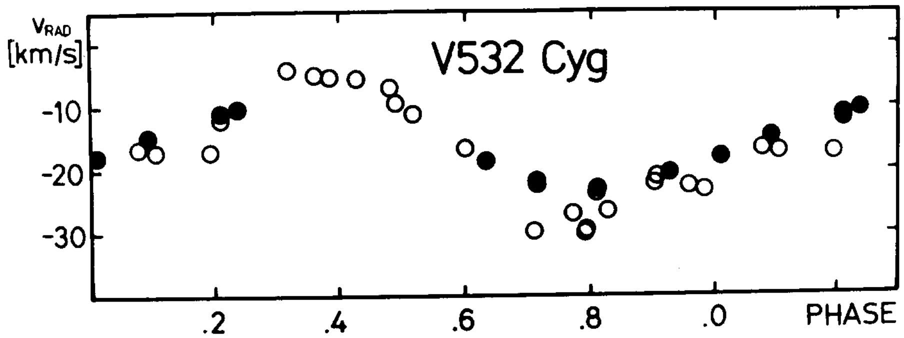

Figure 32. Radial velocity observations of V532 Cygni folded with the 3.283494 day pulsation period. Zero phase is chosen arbitrarily at J.D. 2440000. Open circles: *Barnes* et al.'s (1988) data, filled circles: *Metzger* et al.'s (1990) observations

This formula can be used for predicting the maxima after J.D. 2438000. Before that epoch a phase shift occurred: between J.D. 2431200 and 2435700 the pulsation period was 3.283514 ± 0.000056 days. This latter period was determined on the basis of the three O–C residuals listed in Table 49 supplemented with four other, less reliable O–C residuals taken from Paper I. These low quality residuals have not been listed nor plotted here. The phase difference, that can be seen between J.D. 2435700 and 2438000 is about 0.58 day (= 0.18 pulsation period).

Because the phase jump is a characteristic feature of the binary Cepheids, one expects that V532 Cygni also belongs to a binary system. In addition to the previous photometric evidence for a B8 companion (*Madore*, 1977), in a more recent paper *Usenko* (1990b) also assumes a B7 – B8 photometric companion. The available radial velocity measurements are not enough for the numerical determination of the γ-velocity itself, but the composite phase diagram of the two available radial velocity series indicates that a shift in the γ-velocity might occur between the epochs of observation of the respective series. In Figure 32 open circles denote the data obtained by *Barnes* et al. (1988), while *Metzger* et al.'s (1990) velocity measurements are plotted as filled circles. Zero phase is arbitrarily chosen at J.D. 2440000, and the data are folded with the period given in Eq.(35). It is very unfortunate that *Metzger* et al. could not cover the phases of least negative velocities, because the systematic difference between the most negative values of the two radial velocity series is clearly seen. Further photometry and spectroscopy of V532 Cygni is extremely important.

V924 Cygni

This very low amplitude Cepheid continues to be a rather neglected variable. The O-C residuals based on the photoelectric observations published in the literature are listed in Table 50. These residuals have been calculated using the elements:

$$C = 2443065.993 + 5\overset{d}{.}571305 \cdot E \qquad (36)$$
$$\pm.017 \quad \pm.000044$$

In addition to the photoelectric O-C residuals, and the line fitted to these residuals, Figure 33 also shows another section of line corresponding to the O-C residuals from earlier epochs. Those rather inaccurate photographic O-C residuals are listed in Paper II, where the deviating part was explained as a systematic difference caused by the fact that the two sections had been obtained by different methods (because the early photographic observations have been unpublished, and the originally published normal maxima were used in Paper II). There is, however, another possibility, viz. the phase jump interpretation of the O-C diagram. The former pulsation period was 5.571106 ± 0.000029 days.

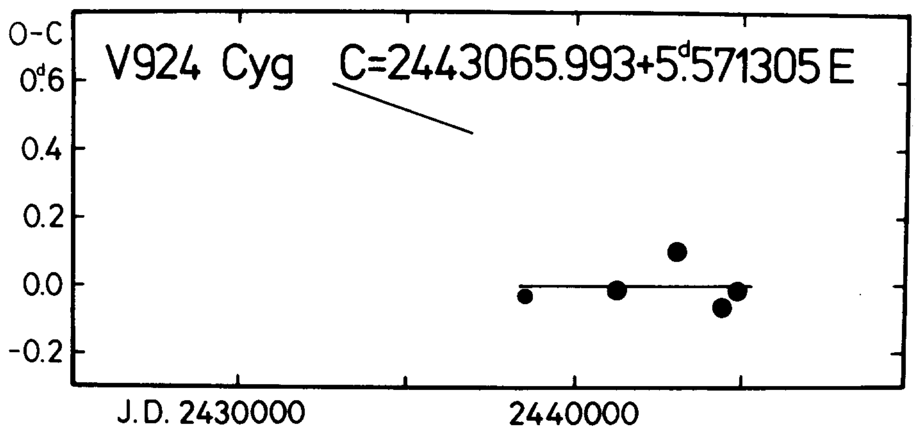

Figure 33. O-C diagram of V924 Cyg

Table 50. O-C residuals for V924 Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
38558.778	-809	-0.029	2	Eggen (1969)
41260.881	-324	-0.009	3	Wachmann (1976)
43066.098	0	0.105	3	Szabados (1980)
44391.902*	238	-0.062	3	Moffett & Barnes (1984)
44893.368*	328	-0.013	3	Moffett & Barnes (1984)

Again, the phase jump implies the existence of a companion. As to duplicity of V924 Cygni, the only evidence is the assumption of a B8 - B9 photometric companion by *Usenko* (1990b). It is worth mentioning, however, that V924 Cyg is one of the lowest amplitude Cepheids, and the extremely low amplitude light variability can well be explained with the photometric effect caused by the extra (and constant) light of a secondary star. Unfortunately, no radial velocity measurements of this interesting Cepheid have been performed yet.

V1334 Cygni

Arellano Ferro's (1984) photoelectric light curve served as the new normal curve for determining the moments of the normal maxima. The O–C residuals listed in Table 51 and plotted in Figure 34 have been calculated with the elements:

$$C = 2441760.896 + 3\overset{d}{.}332804 \cdot E \qquad (37)$$
$$\pm.018 \qquad \pm.000024$$

V1334 Cygni has long been known as a visual binary (ADS 14859). Now there is growing evidence, including this paper, that the Cepheid component of the visual pair is itself a spectroscopic binary. As to the visual binary, *Abt* and *Levy* (1970) determined an orbital period of about 30 years from position angle measurements, while *Henriksson* (1982) derived an 80 year orbital period in the same manner. The γ-velocity data of V1334 Cyg listed in Table 52, shown plotted in the lower panel of Figure

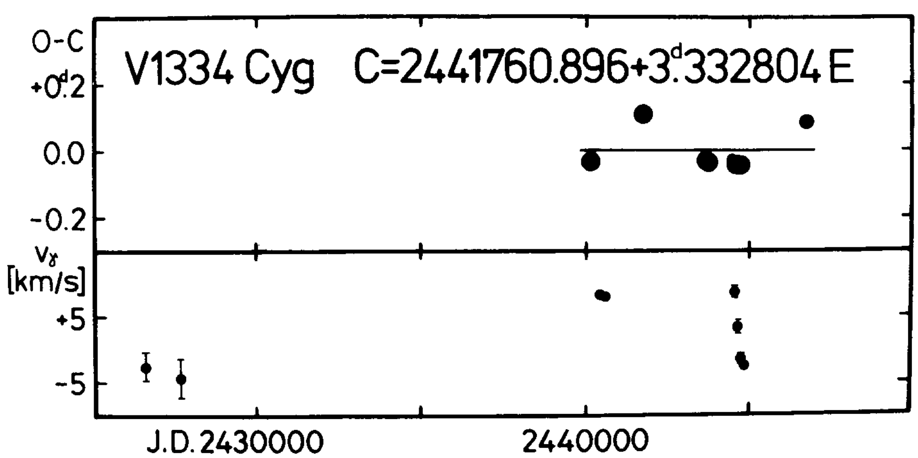

Figure 34. Upper panel: O–C diagram of V1334 Cyg
Lower panel: γ-velocities for the same Cepheid

Table 51. O-C residuals for V1334 Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
40117.791	-493	-0.033	3	Millis (1969)
41761.010	0	0.114	3	Szabados (1977)
43657.233*	569	-0.028	3	Henden (1979)
43720.554*	588	-0.031	3	Percy et al. (1979)
44480.439*	816	-0.025	1	Parsons & Montemayor (1982)
44530.424*	831	-0.032	3	Bartolini et al. (1981)
44743.717*	895	-0.039	3	Arellano Ferro (1984)
46726.861*	1490	0.087	2	Arellano Ferro et al. (1987)

Table 52. γ-velocities of V1334 Cyg

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
26580	5	-2.4	2.1	3	Harper (1934)
27666	7	-4.2	3.0	2	Harper (1937)
40449	35	8.4	0.2	10	Abt & Levy (1970)
40551	23	8.3	0.2	10	Abt & Levy (1970)
44536	23	8.7	0.8	5	Arellano Ferro (1984)
44672	108	3.5	1.0	2	Parsons (1983)
44747	17	-1.5	0.8	5	Arellano Ferro (1984)
44831	6	-2.5	0.5	9	Arellano Ferro (1984)

34 clearly demonstrate that the γ-velocity varies on a much shorter time-scale. This variation was already reported by *Abt* and *Levy* (1970) and *Henriksson* (1982), but now an upper limit can be deduced for the spectroscopic orbital period. A formal period search routine applied to the data set resulted in 1240 days as the most reliable value of the orbital period, but a number of other values between 500 and 1150 days would also give a resonable preliminary orbit. The 4.5 year long orbital period determined by *Henriksson* seems to be too long but the orbital velocity amplitude derived by him (23 km/s) is confirmed here, based on the data listed in Table 52, and one more value of the γ-velocity, not reported in that table, because *Shajn* and *Albitzky* (1932) published -15.2 km/s as the average radial velocity of V1334 Cyg without reporting the epoch of the observation. The close companion to V1334 Cyg is an early type star: *Henriksson* derived a spectral type of B8III from the ultraviolet spectrum, while *Usenko* (1990b) assumes a B4 photometric companion. In the latest edition of the catalog of interferometric measurements of binary stars *McAlister* and *Hartkopf* (1988) reported that *Yu. Balega* had been able to separate the two components of the close pair at an angular distance of 0.035 arcsecond (epoch 1986.66).

The shorter orbital period is expected to cause a light-time effect that cannot be pointed out in the O-C diagram, but the same statement is not valid a priori for the orbital motion of the visual pair. Therefore regular photometric and spectroscopic observations are recommended.

V1726 Cygni

There are only two series of photoelectric observations on this Cepheid, variability of which was only discovered in 1979. The two O-C residuals are listed in Table 53. The moments of light maxima can be predicted by using the following elements:

$$C = 2444105.697 + 4^{d}.236978 \cdot E \tag{38}$$

A very recently obtained radial velocity measurement series (*Metzger* et al., 1990) gives -15.3 ± 0.3 km/s for the γ-velocity at an epoch of J.D. 2447002. Further observations, both photometric and spectroscopic, are desirable.

Table 53. O-C residuals for V1726 Cyg

Norm.max. JD2400000+	E	O-C	W	Reference
44105.697*	0	0.000	3	Platais & Shugarov (1981)
45622.535*	358	0.000	3	Berdnikov (1986)

TX Delphini

This star is one of the Population II Cepheids in this sample. Because of its belonging to a spectroscopic binary system (*Harris* and *Welch*, 1989), TX Del deserves a special attention. The photoelectric observations have been analysed using a new normal light curve, based on *Moffett* and *Barnes*' (1984) observations. The O-C graph (see Table 54 and Figure 35) has been approximated with a straight line as follows:

$$C = \underset{\pm .012}{2442947.138} + \underset{\pm .000023}{6^{d}.165904} \cdot E \tag{39}$$

The deviations from this straight line are in some cases much larger than expected due to the observational errors. The dashed lines in Figure 35 suggest a plausible solution to this anomaly: several successive phase jumps might occur, similarly to the case of Y Oph (Paper IV, p. 42). The pulsation period corresponding to the dashed lines is about 6.1664 days, being in excellent agreement with the period valid before J.D. 2436600: P = 6.166585 days (see Paper II, p. 58). Reality of the phase jump approximation, however, has to be proven by future observations.

Table 54. O-C residuals for TX Del

Norm.max. JD2400000+	E	O-C	W	Reference
35665.108	-1181	-0.097	3	Walraven et al. (1958)
37293.130	-917	0.126	3	Mitchell et al. (1964)
39099.574	-624	-0.040	3	Takase (1969)
40819.978	-345	0.077	3	Pel (1976)
41929.732*	-165	-0.032	3	Dean et al. (1977)
42293.514*	-106	-0.038	3	Dean et al. (1977)
42361.345*	-95	-0.032	3	Harris & Welch (1989)
42947.169	0	0.031	3	Szabados (1980)
43816.622*	141	0.092	3	Harris & Welch (1989)
44359.105*	229	-0.025	3	Moffett & Barnes (1984)
44457.760*	245	-0.024	2	present paper
44926.369*	321	-0.024	3	Moffett & Barnes (1984)
45549.100*	422	-0.049	1	Diethelm (1986)

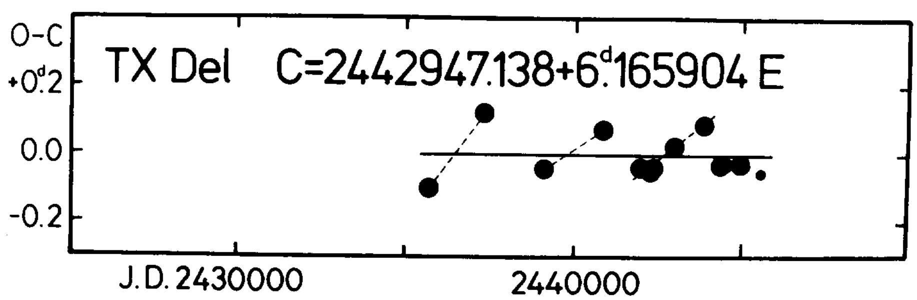

Figure 35. O-C diagram of TX Del

Because the orbital period is as short as 133.15 days (*Harris* and *Welch*, 1989), the orbital light-time effect cannot cause an observable wave in the O-C diagram.

The radial velocity observations of TX Del are not discussed here, because a detailed analysis was performed recently (*Harris* and *Welch*, 1989).

W Geminorum

The reliable O-C residuals from Paper II supplemented with those obtained from the more recent photoelectric observations can be better approximated with a parabola instead of a single sudden period decrease suggested in Paper II. The residuals in Table 55 (see also Figure 36) have been obtained using the equation:

$$C = \underset{\pm .024}{2442755.176} + \underset{\pm .000047}{7^{d}.913624} \cdot E \qquad (40)$$

Table 55. O-C residuals for W Gem

Norm.max. JD2400000+	E	O-C	W	Reference
14136.862	-3616	-2.650	1	Pickering (1904)
17318.675	-3214	-2.113	1	Wendell (1913)
17659.022	-3171	-2.052	1	Zeipel (1908)
17944.327	-3135	-1.638	1	van der Bilt (1926b)
18324.126	-3087	-1.693	1	van der Bilt (1926b)
18807.014	-3026	-1.536	1	van der Bilt (1926b)
19748.851	-2907	-1.420	1	van der Bilt (1926b)
24980.146	-2246	-1.030	1	Carrasco (1932)
25296.648	-2206	-1.073	2	Hellerich (1935)
25716.263	-2153	-0.881	1	Zverev (1936)
26578.991	-2044	-0.738	1	Zverev (1936)
26666.149	-2033	-0.629	1	Kukarkin (1940)
26895.429	-2004	-0.845	1	Kox (1935)
27030.096	-1987	-0.709	1	Florya & Kukarkina (1953)
29364.701	-1692	-0.623	1	Koshkina (1963)
35165.909	-959	-0.102	1	Irwin (1961)
35561.781	-909	-0.089	1	Nikulina (1959)
35569.363	-908	-0.242	2	Walraven et al. (1958)
36186.729	-830	-0.139	1	Latyshev (1969)
37270.925	-693	-0.110	3	Mitchell et al. (1964)
37927.814	-610	-0.051	1	Fridel' (1971)
39043.666	-469	-0.020	3	Wisniewski & Johnson (1968)
39083.150	-464	-0.104	3	Takase (1969)
39502.615	-411	-0.062	3	Wamsteker (1972)
39787.563	-375	-0.004	3	Szabados (1980)
40903.421*	-234	0.033	2	Feltz & McNamara (1980)
40927.150	-231	0.021	3	Pel (1976)
41006.204	-221	-0.061	2	Evans (1976)
42755.172	0	-0.004	3	Szabados (1980)
43878.923*	142	0.012	3	Moffett & Barnes (1984)

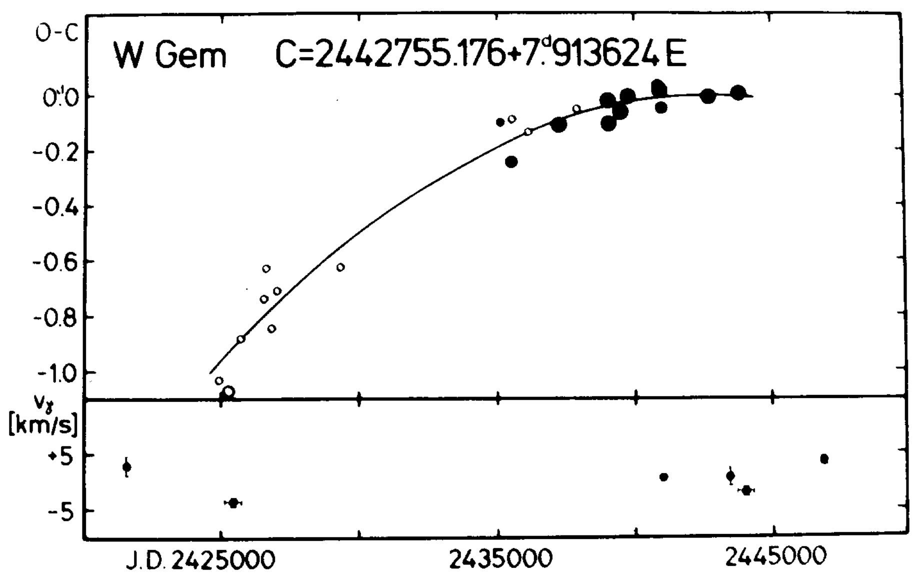

Figure 36. Upper panel: O-C diagram of W Gem
Lower panel: γ-velocities for the same Cepheid

Table 56. γ-velocities of W Gem

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
21600	30	3.0	1.7	4	Sanford (1930)
25468	305	-3.5	0.7	19	Sanford (1930)
41011	29	0.7	0.3	4	Evans (1976)
43445	63	0.9	1.5	8	Wilson et al. (1989)
44015	318	-1.8	0.8	24	Barnes et al. (1987)
46866	1	3.7	0.7	2	Samus (1990)

The continuous period decrease is represented with the formula:

$$P = \underset{\pm.000047}{7\overset{d}{.}913624} - \underset{\pm.29}{3\overset{d}{.}79}\cdot 10^{-7}\cdot E \tag{41}$$

The γ-velocities determined for W Gem listed in Table 56 are shown plotted in the lower panel of Figure 36. The total variation of the γ-velocity is larger than 7 km/s, a value far exceeding the uncertainty due to the observational errors. Thus W Gem is a spectroscopic binary Cepheid candidate. The information on the duplicity of W Gem is summarized by *Leonard* and *Turner* (1986). They conclude that W Gem does not have an early type companion. The amplitude ratios determined from the BVRI photometry obtained by *Moffett* and *Barnes* (1984) imply a late type companion. In any case, W Gem is a promising target for further spectroscopic observations.

RZ Geminorum

Similarly to W Gem, the new O-C diagram of this Cepheid is also approximated with a parabola, instead of two linear sections (see Table 57 and the upper panel of Figure 37). The O-C residuals have been obtained using the elements:

$$C = \underset{\pm.012}{2442714.955} + \underset{\pm.000015}{5\overset{d}{.}529166}\cdot E \tag{42}$$

The value of the continuously decreasing period can be calculated as follows:

$$P = \underset{\pm.000015}{5\overset{d}{.}529166} - \underset{\pm.08}{1\overset{d}{.}70}\cdot 10^{-7}\cdot E \tag{43}$$

The γ-velocity of RZ Gem shows an obvious variation (see Table 58 and the lower panel of Figure 37). Because this variation seems to be very rapid (i.e. the orbital period is rather short, at least for a Cepheid), a separate γ-velocity has been determined for each season whenever the radial velocity of RZ Gem was measured. The formal period search routine resulted in the value of 886 days, and this value is considered as the

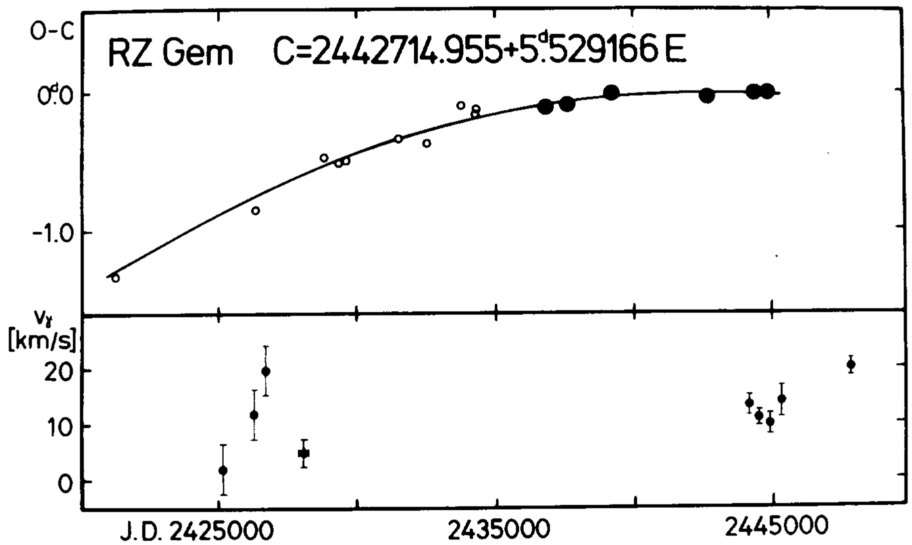

Figure 37. Upper panel: O-C diagram of RZ Gem
Lower panel: γ-velocities for the same Cepheid

Table 57. O-C residuals for RZ Gem

Norm.max. JD2400000+	E	O-C	W	Reference
18324.181	-4411	-1.623	1	Enebo (1909)
18832.935	-4319	-1.552	1	Enebo (1911)
21277.055	-3877	-1.323	1	Jordan (1929)
26375.422	-2955	-0.847	1	Kukarkin (1940)
28869.451	-2504	-0.472	1	Koshkina (1963)
29383.624	-2411	-0.512	1	Koshkina (1963)
29632.453	-2366	-0.495	1	Chudovicheva (1952)
31556.759	-2018	-0.339	1	Chudovicheva (1952)
32557.503	-1837	-0.374	1	Chudovicheva (1952)
33801.844	-1612	-0.095	1	Koshkina (1963)
34304.930	-1521	-0.164	1	Koshkina (1963)
34327.082	-1517	-0.128	1	Rosino & Nobili (1955)
36831.810	-1064	-0.112	3	Weaver et al. (1960)
37633.563	-919	-0.088	3	Mitchell et al. (1964)
39248.161	-627	-0.007	3	Takase (1969)
42714.927	0	-0.028	3	Szabados (1980)
44440.044*	312	-0.011	3	Moffett & Barnes (1984)
44976.380*	409	-0.004	3	Moffett & Barnes (1984)

tentative orbital period. The γ-velocities folded with this period are plotted in Figure 38. Zero phase is arbitrarily chosen at J.D. 2400000. This orbital radial velocity curve is very promising, but another value for the orbital period cannot be excluded (e.g. 930 days). Duplicity of RZ Gem is supported by other facts, as well. *Madore* (1977) assumes a B5 photometric companion, and the phase-test by *Madore* and *Fernie* (1980) is

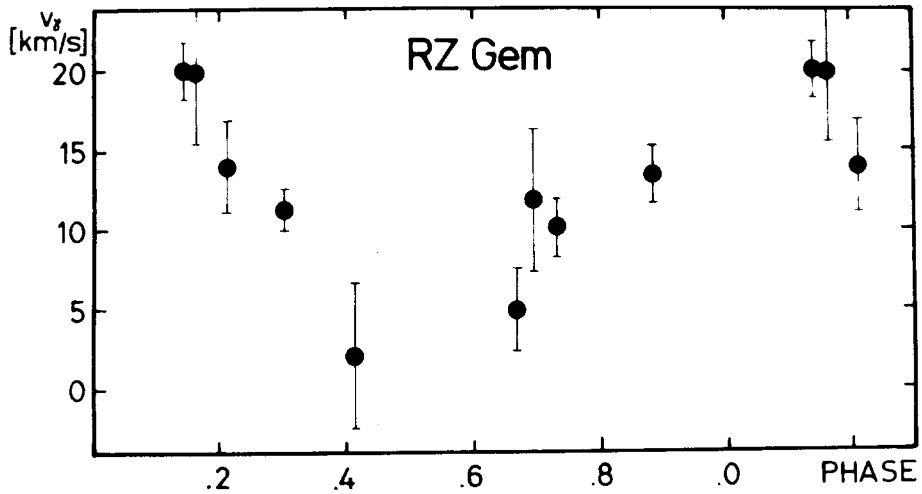

Figure 38. γ-velocity values of RZ Gem folded with the 886 day period

Table 58. γ-velocities of RZ Gem

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25175	18	2.1	4.5	2	Joy (1937)
26311	1	11.9	4.5	1	Joy (1937)
26724	1	20.0	4.5	1	Joy (1937)
28058	146	5.0	2.6	4	Joy (1937)
44196	20	13.5	1.8	6	Barnes et al. (1988)
44568	43	11.3	1.3	11	Barnes et al. (1988)
44948	51	10.1	1.8	6	Barnes et al. (1988)
45373	26	14.0	2.9	3	Barnes et al. (1988)
47970	9	20.1	1.8	3	Samus (1990)

another piece of evidence for an early type companion. The discrepancy in the γ-velocity was already apparent in the compilation of *Moffett* and *Barnes* (1987). New radial velocity observations would be extremely valuable, especially because the whole orbit can be covered within three years.

AD Geminorum

The photoelectric O–C residuals including those published in Paper I (and modified according to the new normal light curve) have been approximated with a constant period (see Table 59 and Figure 39):

$$C = \underset{\pm .004}{2441694.999} + \underset{\pm .000005}{3^{d}\!.787990} \cdot E \qquad (44)$$

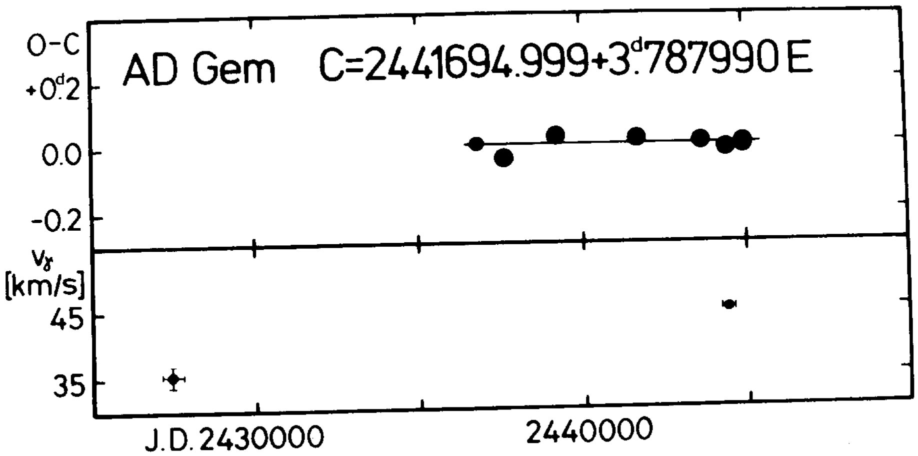

Figure 39. Upper panel: O-C diagram of AD Gem
Lower panel: γ-velocities for the same Cepheid

Table 59. O-C residuals for AD Gem

Norm.max. JD2400000+	E	O-C	W	Reference
36835.010	-1283	0.002	2	Weaver et al. (1960)
37630.445	-1073	-0.041	3	Mitchell et al. (1964)
39202.527	-658	0.025	3	Takase (1969)
41695.016	0	0.017	3	Szabados (1977)
43649.613*	516	0.011	3	Henden (1979)
44407.186*	716	-0.014	3	Moffett & Barnes (1984)
44960.239*	862	-0.007	3	Moffett & Barnes (1984)
44964.034*	863	0.000	3	Connolly et al. (1983)

Table 60. γ-velocities of AD Gem

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
27438	329	35.4	1.7	8	Joy (1937)
44406	195	45.0	0.1	38	Imbert (1983)

The γ-velocity of AD Gem may be variable (see Table 60 and the lower panel of Figure 39). This suspicion can be supported by the facts that *Joy*'s (1937) radial velocity data give a deviating value from the γ-velocity determined from *Imbert*'s (1983) observations, and *Imbert*'s radial velocity measurements themselves seem to show a systematic trend in the sense that the more recent observations imply a more positive γ-velocity. Further spectroscopic study of AD Gem would be desirable.

DX Geminorum

The photographic and photoelectric O-C residuals obtained by fitting the new normal light curve based on *Moffett* and *Barnes*' (1984)

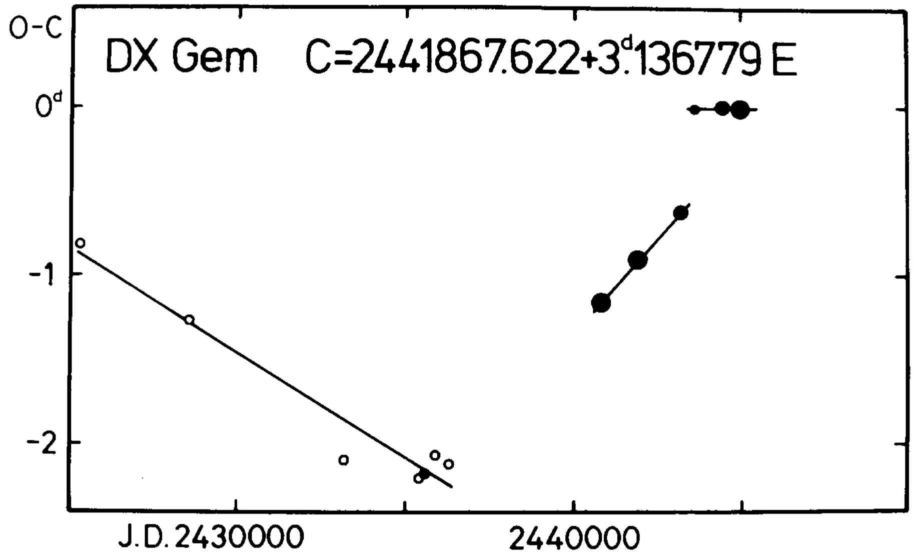

Figure 40. O-C diagram of DX Gem

Table 61. O-C residuals for DX Gem

Norm.max. JD2400000+	E	O-C	W	Reference
25295.211	-5283	-0.808	1	Bartkus & Puchinskas (1961)
28594.649	-4231	-1.261	1	Meshkova (1940)'
33182.929	-2768	-2.089	1	Satyvaldiev (1970)
35413.074	-2057	-2.194	1	Satyvaldiev (1970)
35554.252	-2012	-2.171	1	Walraven et al. (1958)
35896.275	-1903	-2.057	1	Bartkus & Puchinskas (1961)
36275.769	-1782	-2.113	1	Bartkus & Puchinskas (1961)
40793.694	-342	-1.150	3	Pel (1976)
41866.721	0	-0.901	3	Szabados (1977)
43165.632	414	-0.617	2	Szabados (1977)
43614.804*	557	-0.004	1	Henden (1979)
44439.787*	820	0.006	2	Moffett & Barnes (1984)
44954.210*	984	-0.003	3	Moffett & Barnes (1984)

observations are listed in Table 61 (see also Figure 40). The following ephemeris was used when computing the O-C residuals:

$$C = 2441867.622 + 3^{d}\!.136779 \cdot E \qquad (45)$$
$$\pm.012 \quad \pm.000013$$

The photoelectric data clearly show a recent phase jump with an amplitude of 0.2 period. This phase jump can also be suspected in the O-C diagram based on the Sonneberg photographic observations (*Hacke*, 1989). Although its scatter is very wide, *Hacke*'s O-C diagram also shows a further period change (after J.D. 2445000) that cannot be seen here, because no such recent photoelectric observations are available. Consequently the ephemeris given in Eq. (45) might not be correct for predicting the maxima occurring even in the near future (the true period is expected to be shorter: 3.13669 days according to *Hacke*). Another phase jump might occur just before J.D. 2440500, but this phase shift cannot be traced with the photoelectric observation. The following values of the pulsation period can be derived from the existing data:

before J.D. 2436500	P = 3.136387 ± 0.000041 days
between J.D. 2440700 and 2443200	P = 3.137486 ± 0.000005 days
after J.D. 2443600	P = 3.136779 ± 0.000013 days.

The occurrence of the phase jump(s) in the O-C diagram of DX Gem is in accordance with the suspected spectroscopic binary nature of this Cepheid (*Burki*, 1985). Unfortunately the radial velocity data have not been published yet.

ζ Geminorum

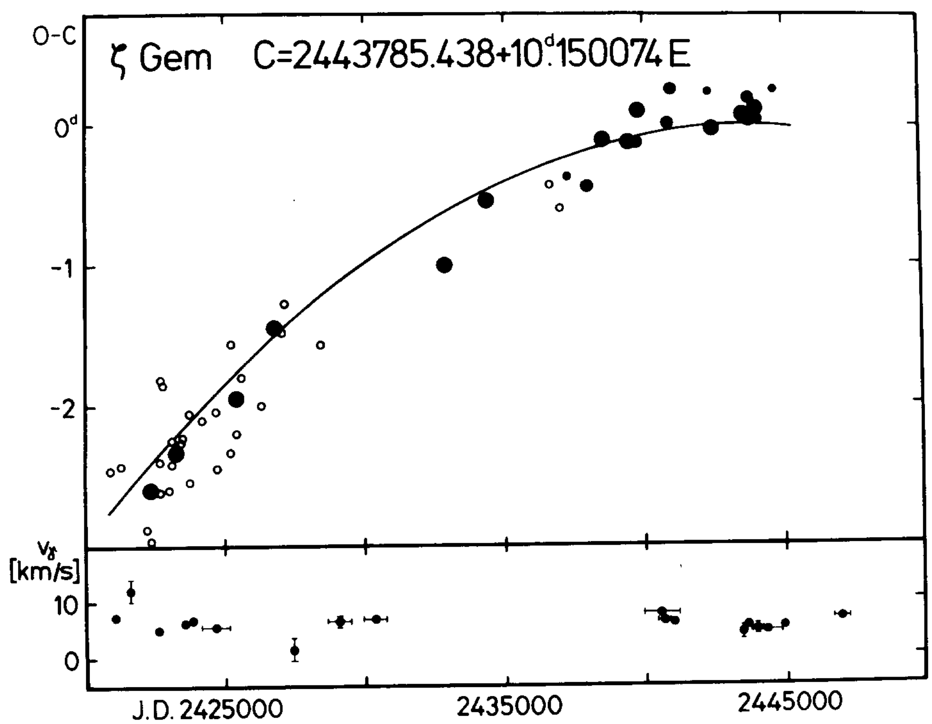

Figure 41. Upper panel: O-C diagram of ζ Gem
Lower panel: γ -velocities for the same Cepheid

Table 62. O-C residuals for ζ Gem

Norm.max. JD2300000+	E	O-C	W	Reference
96027.855	-4704	-11.635	1	Hagen (1903)
96088.465	-4698	-11.925	1	Argelander (1869)
96474.176	-4660	-11.917	1	Argelander (1869)
96565.026	-4651	-12.418	1	Hagen (1903)
97154.525	-4593	-11.623	1	Argelander (1869)
97459.537	-4563	-11.113	1	Hagen (1903)
97519.975	-4557	-11.576	1	Argelander (1869)
97875.456	-4522	-11.347	1	Argelander (1869)
98241.363	-4486	-10.843	1	Argelander (1869)
98536.305	-4457	-10.253	1	Hagen (1903)
98586.501	-4452	-10.807	1	Argelander (1869)
98982.738	-4413	-10.423	1	Argelander (1869)
99317.451	-4380	-10.663	1	Argelander (1869)
99632.685	-4349	-10.081	1	Zinner & Wachmann (1931)
99723.768	-4340	-10.349	1	Argelander (1869)
2400000+				
00099.937	-4303	-9.733	1	Argelander (1869)
01927.501	-4123	-9.182	1	Argelander (1869)
02313.385	-4085	-9.001	1	Valentiner (1900)
02648.656	-4052	-8.682	1	Valentiner (1900)
02993.591	-4018	-8.850	1	Valentiner (1900)
03785.426	-3940	-8.720	1	Valentiner (1900)
03786.543	-3940	-7.603	1	Zinner & Wachmann (1931)
04090.631	-3910	-8.018	1	Valentiner (1900)
04466.252	-3873	-7.949	1	Valentiner (1900)
04608.424	-3859	-7.878	1	Zinner & Wachmann (1931)
04831.417	-3837	-8.187	1	Valentiner (1900)
05166.882	-3804	-7.674	1	Valentiner (1900)
05552.714	-3766	-7.545	1	Valentiner (1900)
05928.082	-3729	-7.730	1	Valentiner (1900)
10009.990	-3327	-6.152	1	Hagen (1891)
13564.137	-2977	-4.531	1	Plassmann (1900)
13950.417	-2939	-3.954	1	Plassmann (1900)
13979.885	-2936	-4.936	1	Pickering (1904)
14335.691	-2901	-4.382	1	Pickering (1904)
14478.219	-2887	-3.955	1	Plassmann (1900)
14487.821	-2886	-4.503	1	Wirtz (1901)
15320.879	-2804	-3.752	1	Plassmann (1900, 1901, 1908)
15605.224	-2776	-3.609	1	Tass (1925)
15787.268	-2758	-4.266	1	Plassmann (1908)
15787.949	-2758	-3.585	1	Nijland (1923)
15797.704	-2757	-3.980	1	Kopff (1902)
15970.085	-2740	-4.150	1	van der Bilt (1926a)
16143.288	-2723	-3.498	1	Plassmann (1908)
16172.918	-2720	-4.319	1	Lau (1904)
16406.864	-2697	-3.824	1	Götz (1906)
16508.718	-2687	-3.471	1	Plassmann (1908)
16711.866	-2667	-3.325	1	Olivier (1952)
16721.611	-2666	-3.730	1	van der Bilt (1926a)
16874.025	-2651	-3.567	1	Tass (1925)
16874.320	-2651	-3.272	1	Tass (1925)
16883.963	-2650	-3.779	1	Plassmann (1908)
16894.896	-2649	-2.996	1	Schiller (1906)
17228.908	-2616	-3.936	1	van der Bilt (1926a)
17238.785	-2615	-4.209	1	Plassmann (1908)

Table 62. (cont.)

Norm.max. JD2400000+	E	O-C	W	Reference
17310.450	-2608	-3.595	1	Lohnert (1909)
17594.592	-2580	-3.655	1	Olivier (1952)
17604.986	-2579	-3.411	1	Nijland (1923)
17614.853	-2578	-3.694	1	van der Bilt (1926a)
17777.885	-2562	-3.063	1	Plassmann (1908)
17939.841	-2546	-3.509	1	Nijland (1923)
17950.165	-2545	-3.335	1	van der Bilt (1926a)
18315.716	-2509	-3.186	1	Nijland (1923)
18417.041	-2499	-3.362	1	Mündler (1911)
18559.427	-2485	-3.077	1	Olivier (1952)
18640.796	-2477	-2.909	1	Nijland (1923)
19899.406	-2353	-2.908	1	Kaiser (1915)
20904.713	-2254	-2.458	1	Luyten (1922)
21320.897	-2213	-2.427	1	Luyten (1922)
22244.104	-2122	-2.877	1	Rabe (1923)
22366.187	-2110	-2.595	3	Guthnick (1921)
22375.973	-2109	-2.959	1	Bellemin (1922)
22721.639	-2075	-2.395	1	Leiner (1922)
22731.566	-2074	-2.619	1	Rabe (1923)
22732.368	-2074	-1.817	1	Gallisot (1923)
22803.383	-2067	-1.852	1	Bellemin (1922)
23056.382	-2042	-2.605	1	Rabe (1923)
23137.772	-2034	-2.415	1	Nielsen (1927a)
23168.397	-2031	-2.241	1	Zverev (1936)
23269.793	-2021	-2.345	3	Bottlinger (1928)
23442.428	-2004	-2.262	1	Leiner (1928)
23543.967	-1994	-2.223	1	Parenago (1938)
23736.995	-1975	-2.047	1	Hopmann (1926)
23797.392	-1969	-2.550	1	Leiner (1928)
24203.841	-1929	-2.104	1	Leiner (1928)
24711.413	-1879	-2.036	1	Leiner (1928)
24761.751	-1874	-2.448	1	Kukarkin (1940)
25228.769	-1828	-2.334	1	Hellerich (1935)
25280.295	-1823	-1.558	1	Leiner (1928)
25310.362	-1820	-1.941	1	Collmann (1930)
25340.804	-1817	-1.950	3	Güssow (1930)
25462.360	-1805	-2.194	1	Kukarkin (1940)
25625.169	-1789	-1.787	1	Zverev (1936)
26325.312	-1720	-1.999	1	Zverev (1936)
26802.918	-1673	-1.446	3	Hall (1934)
27056.638	-1648	-1.478	1	Florya & Kukarkina (1953)
27198.938	-1634	-1.279	1	Nielsen (1941)
28436.956	-1512	-1.570	1	Günther (1939)
32883.249	-1074	-1.010	3	Eggen (1951)
34416.368	-923	-0.552	3	Harris (1953)
36639.347	-704	-0.439	1	Azarnova (1960a)
37004.583	-668	-0.606	1	Mayall (1964)
37258.567	-643	-0.373	1	Mitchell et al. (1964)
37979.154	-572	-0.442	2	Williams (1966)
38527.582	-518	-0.118	3	Wisniewski & Johnson (1968)
39420.773	-430	-0.133	3	Takase (1969)
39765.870	-396	-0.139	2	Sudzius (1969)
39796.556	-393	0.097	3	Szabados (1981)
40892.664*	-285	-0.003	2	Feltz & McNamara (1980)

Table 62. (cont.)

Norm.max. JD2400000+	E	O-C	W	Reference
41004.565	-274	0.247	2	Evans (1976)
42354.510	-141	0.232	1	Scarfe (1976)
42465.897	-130	-0.031	3	Depenchuk (1980)
43552.060*	-23	0.074	3	Moffett & Barnes (1984)
43785.473	0	0.035	3	Szabados (1981)
43805.927	2	0.189	2	Depenchuk (1980)
44039.297*	25	0.107	3	Moffett & Barnes (1984)
44140.727*	35	0.036	1	Schmidt & Parsons (1982)
44709.348*	91	0.253	1	Ridgway et al. (1982)

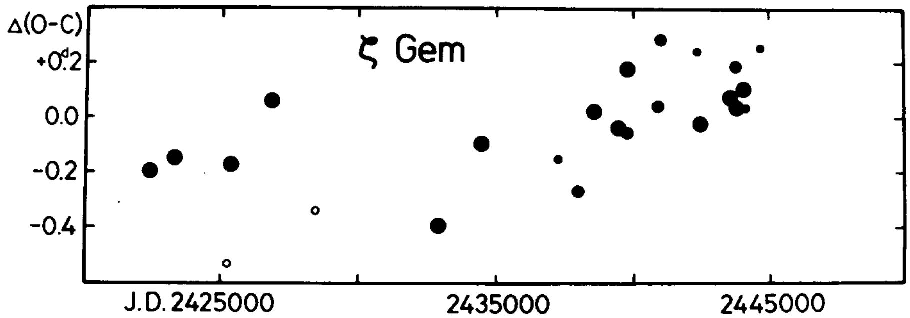

Figure 42. Δ(O-C) diagram of ζ Gem

The old visual observations have also been taken into account during the re-discussion of the O-C diagram, because the previous study (see Paper III) revealed some shorter time-scale deviations superimposed on the general parabolic trend of the O-C diagram. In order to obtain the value of the period decrease as accurately as possible, a long time-base data set is necessary. The currently used ephemeris is deduced from the best parabolic fit (see Table 62 and Figure 41):

$$C = \underset{\pm .053}{2443785.438} + \underset{\pm .000053}{10^{d}.150074} \cdot E \qquad (46)$$

while the continuous period decrease is as follows:

$$P = \underset{\pm .000053}{10^{d}.150074} - \underset{\pm .23}{10^{d}.76} \cdot 10^{-7} \cdot E \qquad (47)$$

The deviations from the least squares fitted parabola are shown on the Δ (O-C) diagram in Figure 42. Here only the photoelectric and the photographic O-C residuals have been taken into account. The trend of the deviations resembles the phase jump appearing in the O-C diagram of a number of Cepheids. In most cases, however, the O-C diagrams are linear, and ζ Gem would be the first case when a phase jump occurs on a parabolic O-C diagram. It cannot be excluded that this phase shift is not the commonly appearing one in binary Cepheids, but its origin can be explained

Table 63. γ-velocities of ζ Gem

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
14419	170	13.5	0.8	15	Henroteau (1925)
14650	39	6.0	2.1	3	Campbell (1899)
14851	158	7.1	0.5	44	Henroteau (1925)
19799	1312	11.3	2.1	3	Spencer Jones (1928)
21014	417	7.4	0.5	42	Hase (1929)
21592	1	12.2	2.0	1	Abt (1970)
22606	188	5.1	0.6	23	Hase (1929)
23541	80	6.3	0.7	22	Jacobsen (1926)
23837	21	6.9	0.5	43	Henroteau (1925)
24664	496	5.6	0.6	25	Hase (1929)
27413	86	1.6	2.0	2	Abt (1970)
29028	393	6.5	0.9	6	Abt (1970)
30368	408	7.1	0.1	13	Scarfe (1976)
40506	636	7.8	0.1	15	Abt & Levy (1974)
40625	224	6.5	0.1	12	Scarfe (1976)
40990	21	6.2	0.3	6	Evans (1976)
43463	57	4.4	1.2	12	Wilson et al. (1989)
43619	135	5.7	0.5	4	Beavers & Eitter (1986)
43934	218	5.0	0.8	21	Barnes et al. (1987)
44313	540	4.8	0.4	19	Jacobsen & Wallerstein (1982)
44916	8	5.4	0.3	7	Beavers & Eitter (1986)
46951	296	6.7	0.4	10	Samus (1990)

in terms of the stellar activity (see *Hall*, 1990, and the general remarks in this paper, on page 233).

The γ-velocities determined from the available radial velocity data (see Table 63 and the lower panel of Figure 41) do not show a clear variation but changes up to 4-5 km/s cannot be excluded. Even in this latter case, no observable light-time effect is expected in the O-C diagram. A long series of homogeneous radial velocity observations will hopefully solve the problem of duplicity of ζ Gem.

V Lacertae

The photographic and photoelectric O-C residuals listed in Paper I have been supplemented with the more recent photoelectric data. The O-C diagram continues to be parabolic (see Figure 43). During the present analysis the O-C residuals (listed in Table 64) have been calculated using the elements:

$$C = \underset{\pm.006}{2441907.706} + \underset{\pm.000003}{4\overset{d}{.}983179} \cdot E \tag{48}$$

The continuous decrease in the period can be characterized as follows:

$$P = \underset{\pm.000003}{4\overset{d}{.}983179} - \underset{\pm.02}{1\overset{d}{.}09} \cdot 10^{-7} \cdot E \tag{49}$$

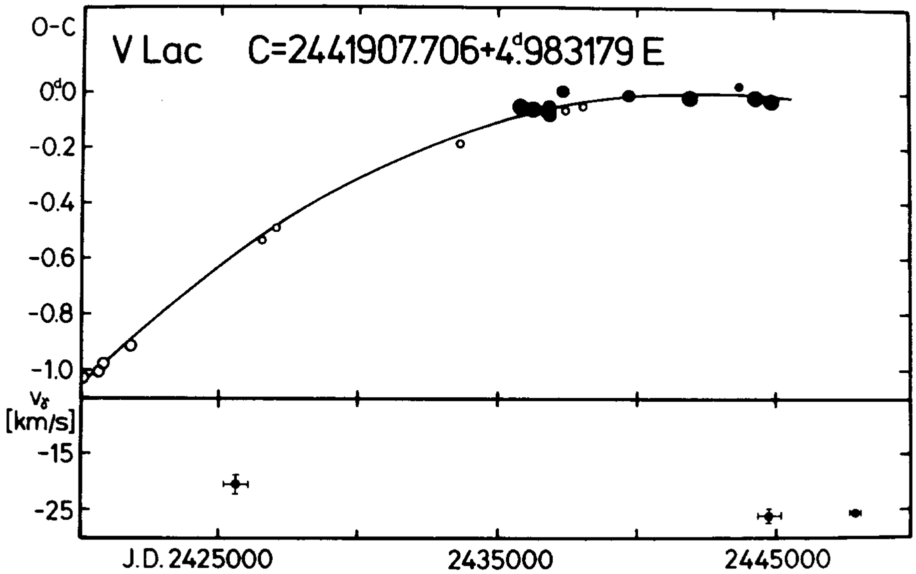

Figure 43. Upper panel: O-C diagram of V Lac
Lower panel: γ-velocities for the same Cepheid

Table 64. O-C residuals for V Lac

Norm.max. JD2400000+	E	O-C	W	Reference
19716.574	-4453	-1.036	1	Martin & Plummer (1916)
20070.390	-4382	-1.026	2	Martin & Plummer (1916)
20633.512	-4269	-1.003	2	Martin & Plummer (1916)
20817.920	-4232	-0.972	2	Hertzsprung (1922)
21844.515	-4026	-0.912	2	Jordan (1929)
26558.980	-3080	-0.535	1	Zonn (1933)
27092.226	-2973	-0.489	1	Zonn (1933)
33635.445	-1660	-0.184	1	Solov'yov (1952)
35788.311*	-1228	-0.051	3	Bahner & Mavridis (1977)
36266.691*	-1132	-0.056	3	Bahner & Mavridis (1977)
36794.894	-1026	-0.070	3	Weaver et al. (1960)
36809.829	-1023	-0.085	2	Oosterhoff (1960)
36834.777	-1018	-0.053	2	Bahner et al. (1962)
37348.104	-915	0.007	2	Mitchell et al. (1964)
37422.781	-900	-0.064	1	Golovatyj (1964)
38070.607	-770	-0.051	1	Golovatyj (1964)
39754.969	-432	-0.004	2	Szabados (1977)
41907.688	0	-0.018	3	Szabados (1977)
43711.644*	362	0.027	1	Henden (1979)
44329.517*	486	-0.014	3	Moffett & Barnes (1984)
44957.385*	612	-0.027	3	Moffett & Barnes (1984)

Because traces of a wave-like distorsion are apparently superimposed on the fitted parabola, light-time effect was also searched for. Two possible periods could be deduced in this way: 4020 and 8040 days. It is, however, improbable that either of these values corresponds to the orbital period

Table 65. γ-velocities of V Lac

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25632	440	-20.4	1.6	9	Joy (1937)
44771	427	-26.0	1.3	11	Barnes et al. (1987)
47970	164	-25.7	0.7	8	Samus (1990)

because the waves caused by these periods are not compatible with the γ-velocity changes to be discussed below.

The γ-velocities derived from the available radial velocity data are listed in Table 65 (see also the lower panel of Figure 43). The discrepancy noted by *Moffett* and *Barnes* (1987) is clearly seen between *Joy*'s (1937) and the more recent data. Nevertheless, additional radial velocity measurements are needed to confirm the spectroscopic binary nature of V Lac. As a matter of fact, *Oosterhoff* (1960) assumed a blue photometric companion, but the spectrophotometric study performed by *Miller* and *Preston* (1964a) does not support the existence of a blue secondary star.

X Lacertae

The recent photoelectric data imply that the O-C diagram of X Lac can be properly interpreted in terms of phase jumps (see Figure 44). A new

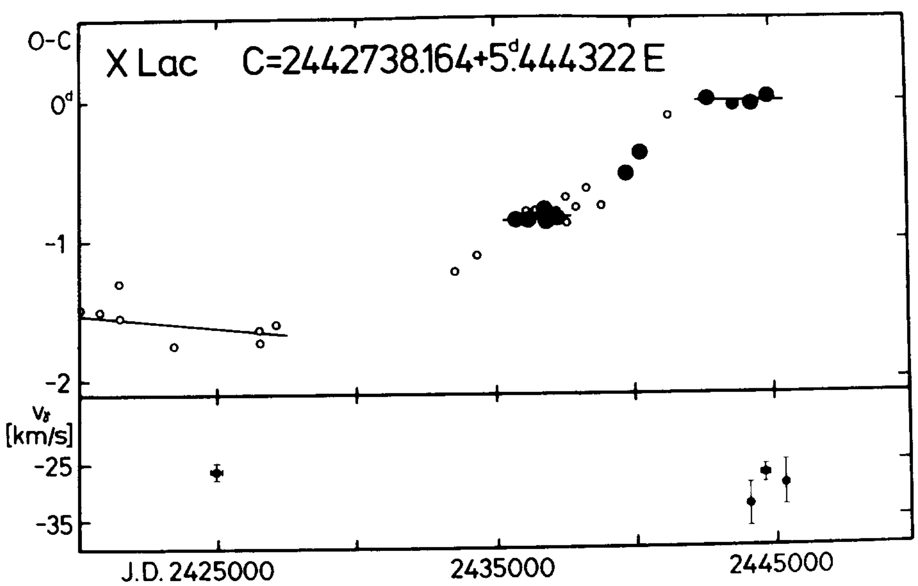

Figure 44. Upper panel: O-C diagram of X Lac
Lower panel: γ-velocities for the same Cepheid

Table 66. O-C residuals for X Lac

Norm.max. JD2400000+	E	O-C	W	Reference
17551.212	-4626	-1.518	1	Seares (1906, 1907)
19870.408	-4200	-1.604	1	Martin & Plummer (1916)
20012.081	-4174	-1.483	1	Hertzsprung (1922)
20741.601	-4040	-1.502	1	Martin & Plummer (1916)
21460.459	-3908	-1.295	1	Hertzsprung (1922)
21487.423	-3903	-1.552	1	Jordan (1929)
23458.068	-3541	-1.752	1	Doberck (1924)
26539.666	-2975	-1.640	1	Kukarkin (1940)
26550.469	-2973	-1.726	1	Zonn (1933)
27105.928	-2871	-1.598	1	Zonn (1933)
33536.037	-1690	-1.223	1	Solov'yov (1952)
34358.247	-1539	-1.105	1	Romano (1955)
35757.696	-1282	-0.847	3	Bahner & Mavridis (1971)
36122.521	-1215	-0.792	1	Makarenko (1969)
36193.241	-1202	-0.848	3	Bahner & Mavridis (1971)
36487.298	-1148	-0.784	1	Makarenko (1969)
36786.745	-1093	-0.775	3	Weaver et al. (1960)
36797.603	-1091	-0.806	3	Oosterhoff (1960)
36835.657	-1084	-0.862	3	Bahner et al. (1962)
36841.091	-1083	-0.872	1	Makarenko (1969)
37200.493	-1017	-0.796	1	Makarenko (1969)
37216.790	-1014	-0.831	3	Mitchell et al. (1964)
37576.258	-948	-0.689	1	Makarenko (1969)
37635.956	-937	-0.878	1	Golovatyj (1964)
37946.397	-880	-0.764	1	Makarenko (1969)
38305.854	-814	-0.632	1	Makarenko (1969)
38866.704	-711	-0.754	1	Makarenko (1969)
39743.265	-550	-0.522	3	Szabados (1980)
40195.303	-467	-0.363	3	Asteriadis et al. (1977)
41333.418*	-258	-0.111	1	Feltz & McNamara (1980)
42738.184	0	0.020	3	Szabados (1980)
43696.330	176	-0.034	2	Henden (1979)
44327.880*	292	-0.026	3	Moffett & Barnes (1984)
44948.587*	406	0.028	3	Moffett & Barnes (1984)

normal light curve was used during this study, and the O-C residuals listed in Table 66 have been calculated according to the ephemeris:

$$C = \underset{\pm .015}{2442738.164} + \underset{\pm .000057}{5\overset{d}{.}444322} \cdot E \qquad (50)$$

The three intervals during which the pulsation period was nearly the same are listed below:

between J.D. 2417550 and 2427100 P = 5.444212 ± 0.000066 days

between J.D. 2435750 and 2437200 P = 5.444403 ± 0.000080 days

after J.D. 2442700 P = 5.444322 ± 0.000057 days.

The pulsation period valid during the intermediate intervals cannot be determined reliably. The value of the phase jump was about 0.18 day (≈0.15 cycle) in both cases.

The variation in the γ-velocity can be suspected on the basis of the radial velocity data (see Table 67 and the lower panel of Figure 44).

Table 67. γ-velocities of X Lac

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
24959	201	-26.2	1.5	10	Joy (1937)
44061	1	-32.6	4.0	1	Barnes et al. (1988)
44608	175	-27.1	1.5	8	Barnes et al. (1988)
45340	2	-28.9	4.0	2	Barnes et al. (1988)

Moffett and *Barnes* (1987) also mentioned this discrepancy. There are, however, other pieces of evidence for the binary nature of X Lac: the method of *Madore* and *Fernie* (1980) indicated a blue photometric companion, while *Usenko* (1990b) assumes a B7 companion from the two-colour diagram. In addition, the phase jumps seen in the O-C diagram give an independent evidence for duplicity of X Lacertae.

Y Lacertae

The new photoelectric O-C residuals confirm the earlier conclusion about the constancy of the pulsation period of Y Lac. The new ephemeris used for computing the O-C residuals listed in Table 68 is as follows:

$$C = 2441746.722 + 4\overset{d}{.}323769 \cdot E \qquad (51)$$
$$\pm.004 \quad \pm.000003$$

The plot of the residuals in Figure 45, however, shows hints of a wave-like pattern with a cycle-length of more than ten thousand days. Obviously, more observations are needed to decide whether these deviations from the straight line can be attributed to the light-time effect or not.

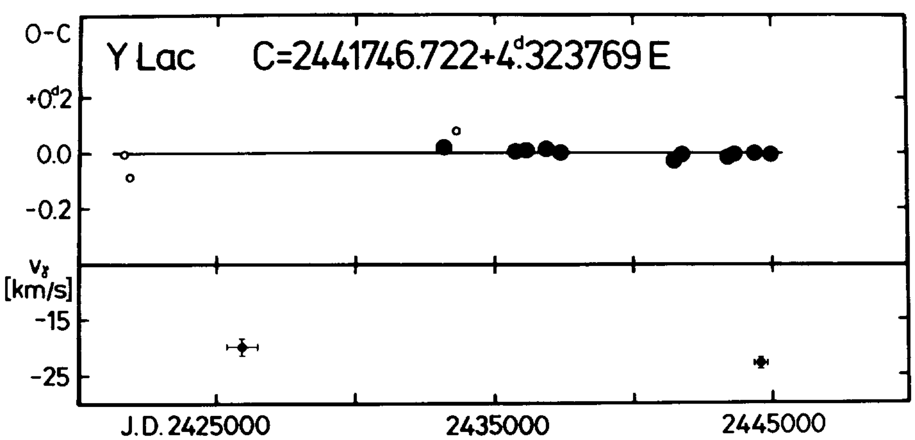

Figure 45. Upper panel: O-C diagram of Y Lac
Lower panel: γ-velocities for the same Cepheid

Table 68. O-C residuals for Y Lac

Norm.max. JD2400000+	E	O-C	W	Reference
21658.488	-4646	-0.003	1	Jordan (1929)
21818.386	-4609	-0.085	1	Martin & Plummer (1919)
33125.147	-1994	0.020	3	Eggen (1951)
33609.468	-1882	0.079	1	Solov'yov (1952)
35710.744*	-1396	0.004	3	Bahner & Mavridis (1977)
36112.859*	-1303	0.008	3	Bahner & Mavridis (1977)
36834.936	-1136	0.016	3	Bahner et al. (1962)
37366.745	-1013	0.001	3	Mitchell et al. (1964)
41431.062*	-73	-0.025	3	Feltz & McNamara (1980)
41746.720	0	-0.002	3	Szabados (1977)
43039.515*	299	-0.014	3	Chekhanikhina (1982)
43683.766*	448	-0.005	3	Henden (1979)
44349.632*	602	0.001	3	Moffett & Barnes (1984)
44457.722*	627	-0.003	1	present paper
44924.690*	735	-0.002	3	Moffett & Barnes (1984)

Table 69. γ-velocities of Y Lac

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25943	564	-19.8	1.5	10	Joy (1937)
44576	225	-22.7	0.9	21	Barnes et al. (1988)

The two γ-velocities determined from the available radial velocity data (see Table 69) deviate from each other. This discrepancy has been already noted by *Moffett* and *Barnes* (1987). An A0V companion has been discovered in an IUE spectrum (*Evans* et al., 1990a), thus confirming *Madore*'s (1977) earlier suggestion concerning the existence of a blue companion to Y Lac. The spectroscopic binary nature of this Cepheid, however, has to be studied further.

Z Lacertae

The recent O-C residuals confirm the parabolic shape of the O-C diagram (see Table 70 and Figure 46). The ephemeris is slightly modified as compared with that determined in Paper III. When constructing the present O-C diagram, the following ephemeris was used:

$$C = \underset{\pm .007}{2442827.136} + \underset{\pm .000021}{10\overset{d}{.}885642} \cdot E \qquad (52)$$

The decrease of the pulsation period is as follows:

$$P = \underset{\pm .000021}{10\overset{d}{.}885642} - \underset{\pm 2.8}{6\overset{d}{.}4} \cdot 10^{-8} \cdot E \qquad (53)$$

Because Z Lac is a member in a newly discovered spectroscopic binary (*Moffett* and *Barnes*, 1987; *Gieren*, 1989a) an attempt was made to search for a light-time effect in the O-C diagram. The only reasonable fit

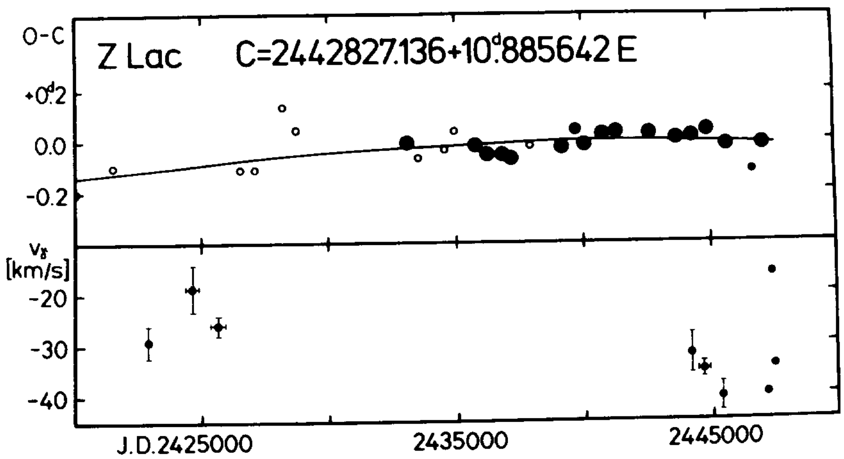

Figure 46. Upper panel: O-C diagram of Z Lac
Lower panel: γ-velocities for the same Cepheid

Table 70. O-C residuals for Z Lac

Norm.max. JD2400000+	E	O-C	W	Reference
20108.601	-2087	-0.200	1	Hertzsprung (1922)
21534.721	-1956	-0.099	1	Hertzsprung (1922)
26542.105	-1496	-0.111	1	Zonn (1933)
27108.157	-1444	-0.112	1	Zonn (1933)
28229.624	-1341	0.134	1	Gur'yev (1937)
28741.160	-1294	0.045	1	Gur'yev (1938)
33084.478	-895	-0.008	3	Eggen (1951)
33519.846	-855	-0.066	1	Solov'yov (1952)
34575.782	-758	-0.037	1	Chuprina (1954a)
34967.738	-722	0.036	1	Chuprina (1956)
35751.452	-650	-0.017	3	Bahner & Mavridis (1971)
36230.385	-606	-0.052	3	Bahner & Mavridis (1971)
36829.095	-551	-0.052	3	Bahner et al. (1962)
37199.191	-517	-0.068	3	Mitchell et al. (1964)
37928.575	-450	-0.022	1	Girnyak (1964)
39180.423	-335	-0.023	3	Takase (1969)
39768.312	-281	0.041	2	Szabados (1981)
40083.936	-252	-0.018	3	Asteriadis et al. (1977)
40791.548	-187	0.027	3	Asteriadis et al. (1977)
41324.953*	-138	0.036	3	Feltz & McNamara (1980)
42674.769*	-14	0.032	3	Szabados (1977)
43708.881*	81	0.008	3	Szabados (1977)
44318.486*	137	0.017	3	Moffett & Barnes (1984)
44938.988*	194	0.037	3	Moffett & Barnes (1984)
45679.155*	262	-0.019	3	Berdnikov (1986)
46702.305*	356	-0.120	1	"Carlsberg" (1989)
47126.952*	395	-0.013	3	Gieren (1989a)

results in a period of about, 8700 days but a period as long as this can hardly correspond to the orbital period of the system because the variation in the γ-velocity suggests a much shorter value.

Table 71. γ-velocities of Z Lac

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
22936	15	-29.1	3.2	3	Joy (1937)
24613	277	-18.7	4.5	2	Joy (1937)
25665	282	-26.0	2.0	6	Joy (1937)
44131	95	-31.7	4.0	2	Barnes et al. (1988)
44613	188	-35.0	1.6	7	Barnes et al. (1988)
45343	1	-40.4	2.8	3	Barnes et al. (1988)
47134	7	-39.9	0.3	7	Gieren (1989a)
47373	1	-16.4	0.5	1	Samus (1990)
47472	1	-34.5	0.7	1	Samus (1990)

The γ-velocities of Z Lac are listed in Table 71. As is clearly seen from the lower panel of Figure 46, the orbital period is much shorter than 8700 days, perhaps it can be as short as one year. Further speculation on the value of the orbital period is untimely yet.

RR Lacertae

A new normal light curve based on *Moffett* and *Barnes'* (1984) observations was used when studying the period changes of RR Lac. As a consequence, a systematic correction of -0.026 day has been applied to the normal maxima taken from Paper II. The new values of the O-C residuals (see Table 72) have been computed with the formula:

$$C = \underset{\pm.006}{2442776.681} + \underset{\pm.000011}{6^{\mathrm{d}}.416289} \cdot E \qquad (54)$$

The best representation of the O-C plot is the approximation with a

Table 72. O-C residuals for RR Lac

Norm.max. JD2400000+	E	O-C	W	Reference
20005.526	-3549	0.255	2	Hertzsprung (1922)
21429.895	-3327	0.208	2	Hertzsprung (1922)
21667.339	-3290	0.249	1	Jordan (1929)
26537.195	-2531	0.141	1	Zonn (1933)
27095.442	-2444	0.171	1	Zonn (1933)
32998.324	-1524	0.067	3	Eggen (1951)
33537.290	-1440	0.065	1	Solov'yov (1952)
34968.107	-1217	0.050	1	Azarnova (1957)
36033.188	-1051	0.027	3	Bahner & Mavridis (1971)
36835.212	-926	0.015	3	Bahner et al. (1962)
37213.735	-867	-0.023	3	Mitchell et al. (1964)
37579.554	-810	0.067	1	Girnyak (1964)
38240.312	-707	-0.053	1	Girnyak (1964)
40582.324	-342	0.014	3	Asteriadis et al. (1977)
42776.694	0	0.013	3	Szabados (1980)
44335.840*	243	0.001	3	Moffett & Barnes (1984)
44932.557*	336	0.003	3	Moffett & Barnes (1984)

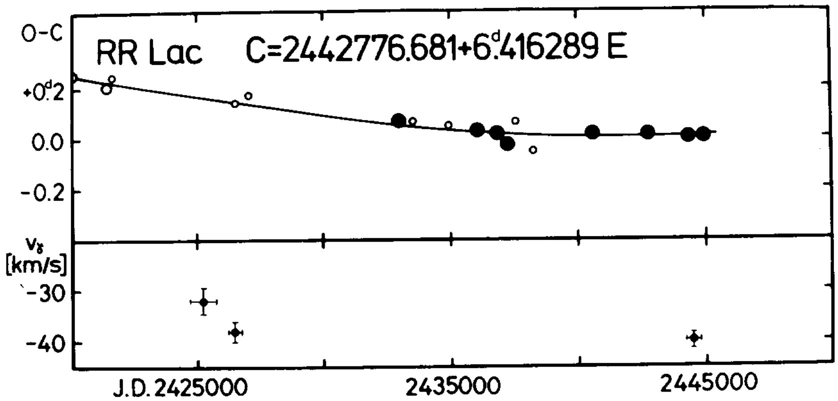

Figure 47. Upper panel: O-C diagram of RR Lac
Lower panel: γ-velocities for the same Cepheid

Table 73. γ-velocities of RR Lac

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25244	526	-31.9	2.6	4	Joy (1937)
26502	255	-37.9	2.0	6	Joy (1937)
44510	288	-39.8	1.5	8	Barnes et al. (1987)

parabola (see Figure 47) indicating a continuously increasing pulsation period:

$$P = 6\overset{d}{.}416289 + 4\overset{d}{.}1\cdot10^{-8}\cdot E \qquad (55)$$
$$\pm.000011 \quad \pm0.6$$

There are three values of the γ-velocity that can be deduced from the published radial velocity measurements (see Table 73). These data indicate that the γ-velocity of RR Lac possibly varies, in accordance with the study performed by *Moffett* and *Barnes* (1987) who also noticed the discordant γ-velocities. Further radial velocity observations would be very important.

BG Lacertae

BG Lac keeps its constant pulsation period. The new value based on solely photoelectric data (see Table 74) only slightly differs from that determined in Paper II. The O-C residuals plotted in Figure 48 have been approximated with the line:

$$C = 2442673.187 + 5\overset{d}{.}331902\cdot E \qquad (56)$$
$$\pm.009 \quad \pm.000010$$

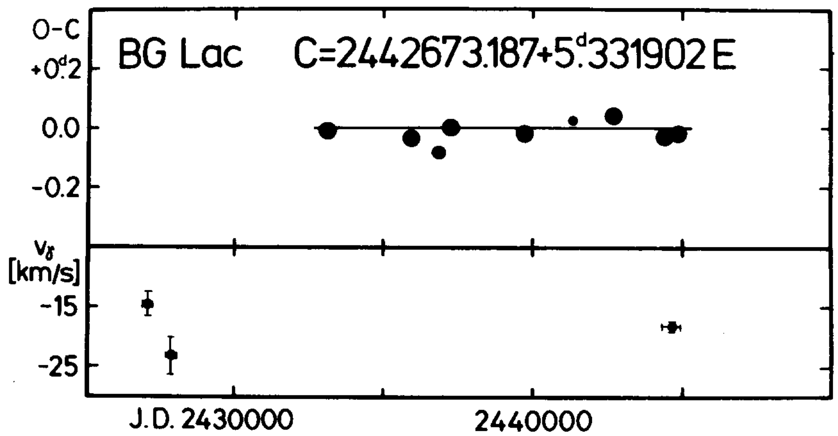

Figure 48. Upper panel: O-C diagram of BG Lac
Lower panel: γ-velocities for the same Cepheid

Table 74. O-C residuals for BG Lac

Norm.max. JD2400000+	E	O-C	W	Reference
33129.068	-1790	-0.014	3	Eggen (1951)
35938.962	-1263	-0.033	3	Bahner & Mavridis (1977)
36834.834	-1095	-0.080	2	Bahner et al. (1962)
37261.307	-1015	0.001	3	Mitchell et al. (1964)
39772.614	-544	-0.018	3	Szabados (1980)
41361.567*	-246	0.028	1	Feltz & McNamara (1980)
42673.231	0	0.044	3	Szabados (1980)
44400.699*	324	-0.024	3	Moffett & Barnes (1984)
44896.574*	417	-0.016	3	Moffett & Barnes (1984)

Table 75. γ-velocities of BG Lac

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
27048	180	-14.5	2.0	6	Joy (1937)
27868	195	-23.1	3.2	3	Joy (1937)
44640	309	-18.0	0.9	23	Barnes et al. (1988)

As to the duplicity of BG Lac, *Madore* (1977) assumed a B8 type photometric companion. No blue companion star was, however, found during the IUE-study of this Cepheid (*Böhm-Vitense* and *Proffitt*, 1985). Nevertheless, the γ-velocity seems to be variable judging from the data listed in Table 75. Further radial velocity measurements are necessary to point out the possible orbital effect more clearly.

T Monocerotis

The O-C diagram of T Mon published in Paper III clearly showed a continuous period increase during an interval of more than one century. A

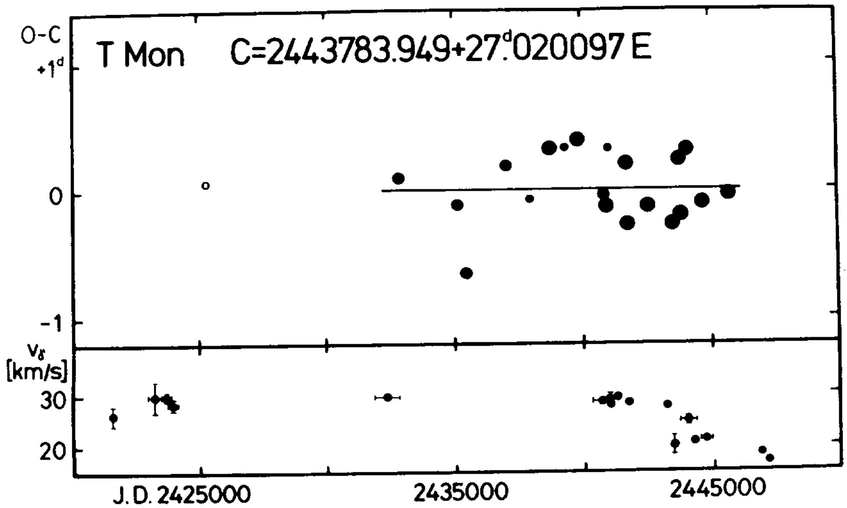

Figure 49. Upper panel: O-C diagram of T Mon
Lower panel: γ-velocities for the same Cepheid

Table 76. O-C residuals for T Mon

Norm.max. JD2400000+	E	O-C	W	Reference
25302.270	-684	0.067		Hellerich (1935)
32840.908	-405	0.098	2	Eggen (1951)
35191.449	-318	-0.109	2	Irwin (1961)
35488.134	-307	-0.645	2	Walraven et al. (1958)
37056.133	-249	0.188	2	Mitchell et al. (1964)
37974.560	-215	-0.068	1	Williams (1966)
38758.533	-186	0.322	3	Wisniewski & Johnson (1968)
39352.984	-164	0.331	1	Takase (1969)
39812.386	-147	0.391	3	Szabados (1981)
40892.759*	-107	-0.040	2	Feltz & McNamara (1980)
40919.687	-106	-0.132	3	Pel (1976)
41001.207	-103	0.328	1	Evans (1976)
41730.626	-76	0.204	3	Landis (1976)
41757.170*	-75	-0.272	3	Dean et al. (1977)
42567.909*	-45	-0.136	3	Dean et al. (1977)
43513.475*	-10	-0.273	3	Dean (1981)
43784.184	0	0.235	3	Szabados (1981)
43810.773*	1	-0.196	3	Moffett & Barnes (1984)
44081.479*	11	0.309	3	Eggen (1983b)
44702.532*	34	-0.100	3	Coulson & Caldwell (1985)
45702.336*	71	-0.040	3	Berdnikov (1986)

closer look at the O-C residuals revealed deviations from the uniform period decrease (see Figure 53 in Paper III). These deviations are much too large to be explained by the light-time effect. Because the photoelectric O-C residuals fall on a branch of such systematic deviation,

Table 77. γ-velocities of T Mon

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
17174	21	22.1	2.1	3	Frost (1906)
21580	30	26.2	2.0	5	Sanford (1927)
23262	268	30.0	3.0	2	Harper (1934)
23698	181	30.1	0.8	27	Sanford (1927)
23934	195	28.4	1.1	15	Sanford (1927)
32327	575	29.8	0.5	20	Sanford (1956)
40682	364	28.7	0.3	25	Wallerstein (1972)
40984	11	29.2	1.1	3	Schmidt (1974)
41006	15	28.1	0.3	4	Evans (1976)
41285	8	29.6	0.2	8	Coulson (1983)
41713	52	28.6	0.2	14	Coulson (1983)
43204	1	28.0	0.6	1	Coulson (1983)
43435	60	20.2	1.6	7	Wilson et al. (1989)
44023	314	25.0	0.8	25	Barnes et al. (1987)
44266	61	21.0	0.6	27	Coulson (1983)
44723	150	21.4	0.5	31	Coulson (1983)
46862	7	18.7	0.6	3	Samus (1990)
47134	7	17.0	0.2	13	Gieren (1989b)

the O-C diagram covering the last forty years cannot be approximated with a parabola. Instead, a constant period has been assumed here, when constructing the O-C diagram from the data points listed in Table 76 (and shown plotted in Figure 49):

$$C = 2443783.949 + 27\overset{d}{.}020097 \cdot E \qquad (57)$$
$$\pm.048 \qquad \pm.000305$$

Note that this ephemeris is not valid before J.D. 2425000, and the reality of predicting future maxima using Eq. (57) may be doubted.

The duplicity of T Mon was frequently discussed in the last decade. In the most recent detailed study *Gieren* (1989b) concludes that the orbital period is about 175 years. The γ-velocities have been redetermined in the present study, supplemented with the results obtained from the recently published radial velocity measurements (see Table 77 and the lower panel of Figure 49). The new values of the γ-velocity also confirm *Gieren*'s conclusion concerning the long orbital period. Although the orbital motion of this Cepheid causes a light-time effect with a full amplitude exceeding 0.1 day, the effect cannot be pointed out in the O-C diagram because of the wide scatter due to the long pulsation period of T Mon.

Being a possible member in the Mon OB2 association (*Gieren*, 1988), T Mon can be an important calibrating Cepheid.

SV Monocerotis

The new value of the pulsation period determined only from photoelectric data (see Table 78 and Figure 50) is somewhat shorter than that determined in Paper III. The O-C residuals have been calculated using the elements:

$$C = 2443794.249 + 15\overset{d}{.}232582 \cdot E \qquad (58)$$
$$\pm.019 \qquad \pm.000073$$

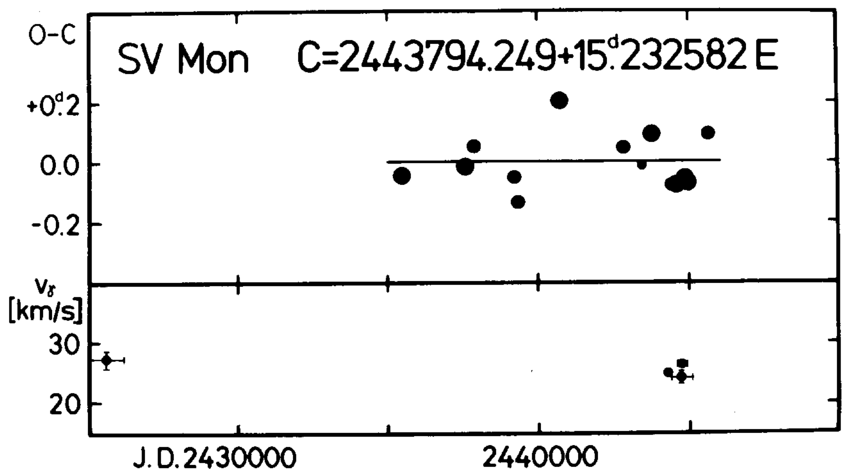

Figure 50. Upper panel: O-C diagram of SV Mon
Lower panel: γ-velocities for the same Cepheid

Table 78. O-C residuals for SV Mon

Norm.max. JD2400000+	E	O-C	W	Reference
35477.219	-546	-0.040	3	Walraven et al. (1958)
37564.109	-409	-0.014	3	Mitchell et al. (1964)
37899.291	-387	0.051	2	Eggen (1969)
39209.191	-301	-0.051	2	Wamsteker (1972)
39346.203	-292	-0.132	2	Takase (1969)
40732.705	-201	0.205	3	Pel (1976)
42865.108	-61	0.047	2	Dean (1977)
43489.586*	-20	-0.011	1	Dean (1981)
43794.342	0	0.093	3	Szabados (1981)
44449.175*	43	-0.075	2	Eggen (1983b)
44525.339*	48	-0.074	3	Coulson & Caldwell (1985)
44890.941*	72	-0.054	3	Moffett & Barnes (1984)
44967.090*	77	-0.068	3	Coulson & Caldwell (1985)
45683.183*	124	0.094	2	Berdnikov (1986)

Table 79. γ-velocities of SV Mon

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25581	625	27.3	1.5	10	Joy (1937)
44264	64	24.9	0.2	26	Coulson & Caldwell (1985)
44705	370	24.2	0.9	19	Barnes et al. (1988)
44723	150	26.5	0.2	31	Coulson & Caldwell (1985)

There is no evidence for duplicity of SV Mon published in the literature, and correspondingly, the γ-velocities listed in Table 79 show no sign of variability.

CV Monocerotis

Considerable attention has been paid to this not very bright Cepheid, because it is a suspected member of an anonymous open cluster (see *Walker*, 1987 and the references therein). *Turner*'s (1978) photometric data were used for determining a new normal light curve. The earlier (partly photographic) observations have been analysed again because of the existence of the phase jump pointed out in Paper II. The O–C residuals listed in Table 80 have been obtained using the ephemeris:

$$C = \underset{\pm .013}{2442773.064} + \underset{\pm .000026}{5\overset{d}{.}378804} \cdot E \qquad (59)$$

The O–C diagram in Figure 51 confirms the occurrence of the phase jump at about J.D. 2436000. The shift between the two almost parallel sections is about −0.34 day. Before J.D. 2436000 the pulsation period was 5.378757 ± 0.000011 days, i.e. practically the same value as given in the current ephemeris (Eq. 59).

Unfortunately the observational efforts have not been extended towards the spectroscopy of CV Mon. Only one set of radial velocity data is available in the literature (*Barnes* et al., 1988). A second epoch radial velocity observation would be extremely valuable for pointing out the spectroscopic binary nature of this Cepheid. The companion is expected to be a B7 star (*Madore*, 1977), or at least a blue one (*Pel*, 1978).

Table 80. O–C residuals for CV Mon

Norm.max. JD2400000+	E	O–C	W	Reference
29805.169	-2411	0.401	1	Teplitskaya (1951)
30778.710	-2230	0.379	1	Teplitskaya (1951)
31908.250	-2020	0.371	1	Filatov (1961)
35447.480	-1362	0.347	1	Filatov (1961)
36571.216	-1153	-0.087	2	Arp (1960)
41035.782	-323	0.072	3	Pel (1976)
42773.133	0	0.069	3	Szabados (1980)
42842.984	13	-0.004	3	Turner (1978)
43886.453*	207	-0.023	2	Dean (1981)
44499.642*	321	-0.018	2	Moffett & Barnes (1984)
44951.475*	405	-0.005	3	Moffett & Barnes (1984)
45962.734*	593	0.039	1	Visvanathan (1989)
46468.211*	687	-0.091	2	present paper

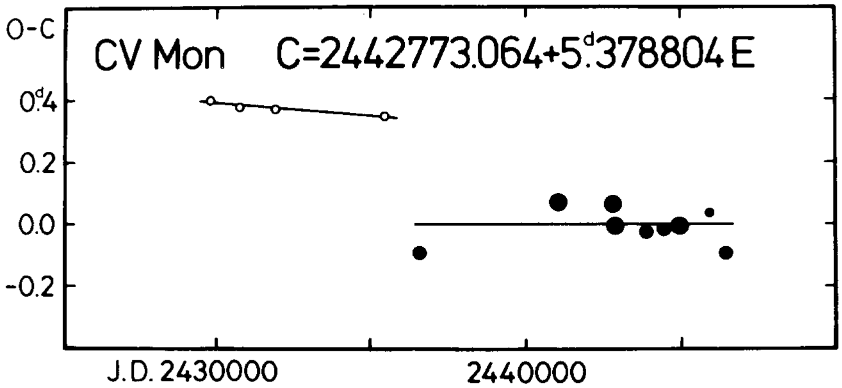

Figure 51. O-C diagram of CV Mon

V465 Monocerotis

There are only four photoelectric maxima determined for V465 Mon (see Table 81 and Figure 52). The weighted least squares fit resulted in the ephemeris:

$$C = 2441698.707 + 2\overset{d}{.}713006 \cdot E \qquad (60)$$
$$\pm.028 \quad \pm.000048$$

The behaviour of the pulsation period prior to J.D. 2441000 is poorly known. As is seen in the previous O-C diagram (in Paper I), the period has not been constant since the discovery of light variability. V465 Mon deserves more attention. Further photometric data will hopefully explain and remove the zero point difference between the magnitude scales used by the three observers involved in Table 81.

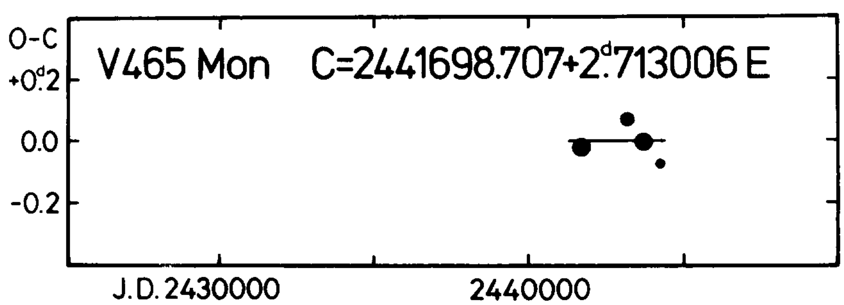

Figure 52. O-C diagram of V465 Mon

Table 81. O-C residuals for V465 Mon

Norm.max. JD2400000+	E	O-C	W	Reference
41698.687	0	-0.020	3	Szabados (1977)
43166.515	541	0.072	2	Szabados (1977)
43676.484*	729	-0.004	3	Henden (1979)
44235.292*	935	-0.076	1	Diethelm & Tammann (1982)

According to *Burki* (1985) V465 Mon is a component in a spectroscopic binary system. Unfortunately the radial velocity data have not been published yet.

RS Orionis

The O-C diagram of RS Ori is very interesting: possibly shows both a light-time effect and a phase jump. The photoelectric and the reliable earlier photographic observations have been converted into O-C residuals (see Table 82) using the ephemeris:

$$C = 2442820.769 + 7\overset{d}{.}566841 \cdot E \qquad (61)$$
$$\pm.009 \quad \pm.000014$$

Table 82. O-C residuals for RS Ori

Norm.max. JD2400000+	E	O-C	W	Reference
16533.795	-3474	0.232	1	Kukarkina (1955)
21936.353	-2760	0.145	1	Jordan (1929)
25326.322	-2312	0.089	1	Puchinskas (1962)
26393.242	-2171	0.085	1	Martynov (1951)
27233.264	-2060	0.187	1	Martynov (1951)
27581.209	-2014	0.058	1	Puchinskas (1962)
27982.333	-1961	0.139	1	Martynov (1951)
28565.060	-1884	0.219	1	Martynov (1951)
29064.379	-1818	0.127	1	Martynov (1951)
29306.578	-1786	0.187	1	Koshkina (1963)
29798.322	-1721	0.086	1	Martynov (1951)
30751.793	-1595	0.135	1	Martynov (1951)
31039.385	-1557	0.187	1	Kukarkina (1955)
33892.019	-1180	0.122	1	Koshkina (1963)
33960.037	-1171	0.039	1	Solov'yov (1956)
35178.286	-1010	0.026	2	Irwin (1961)
35208.500	-1006	-0.027	2	Walraven et al. (1958)
36192.193	-876	-0.023	3	Bahner et al. (1977)
36282.987	-864	-0.031	1	Puchinskas (1962)
36835.395	-791	-0.003	3	Weaver et al. (1960)
37047.280	-763	0.011	3	Mitchell et al. (1964)
38076.401	-627	0.041	1	Fridel' (1971)
40777.748	-270	0.026	3	Pel (1976)
42820.794	0	0.025	3	Szabados (1980)
44440.057*	214	-0.016	3	Moffett & Barnes (1984)
44644.241*	241	-0.137	1	present paper
44795.791*	261	0.076	1	Eggen (1985)
44969.752*	284	0.000	3	Moffett & Barnes (1984)

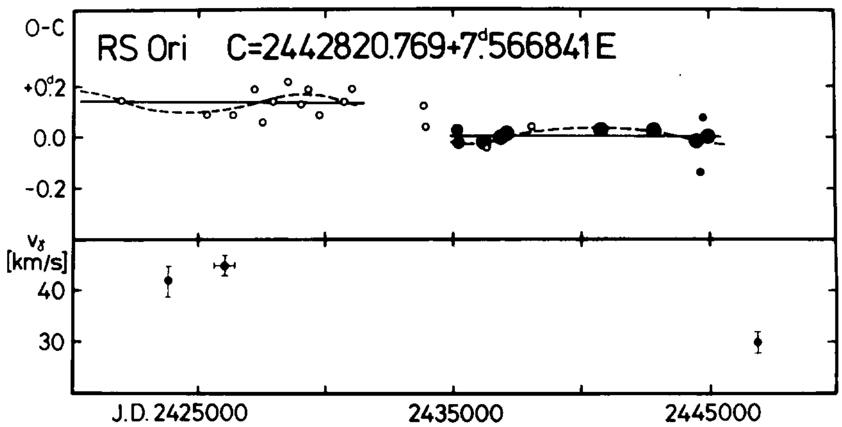

Figure 53. Upper panel: O-C diagram of RS Ori
Lower panel: γ-velocities for the same Cepheid

Table 83. γ-velocities of RS Ori

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
23814	66	42	3	5	Joy (1937)
26029	400	45	2	8	Joy (1937)
46866	1	30	2	2	Samus (1990)

The O-C graph in Figure 53 shows a phase jump between J.D. 2431000 and 2435000 (as already noted in Paper II). In addition to this phase shift (of -0.13 day) a long-term sinusoidal pattern of the O-C residuals is also suspected (see the free-hand dashed lines in Figure 53). If these waves are attributed to the orbital motion of the Cepheid component, the phasing of the γ-velocity variations (see Table 83 and the lower panel of Figure 53) is in accord with the expected tendency. The wave and the rejump to the earlier pulsation period has to be confirmed. Before J.D. 2431000 the period was 7.566830 ± 0.000034 days. An attempt was made to approximate the whole interval of observations with a single line. In that case, however, the amplitude of the sinusoidal term would be too large, therefore incompatible with the light-time interpretation.

The γ-velocities determined for RS Ori are not accurate enough, because no well covered pulsational radial velocity curve has been obtained yet. Nevertheless, the variability of the γ-velocity cannot be doubted. Duplicity of RS Ori has been confirmed by recent IUE observations (*Evans* et al., 1990a), the spectral type of the companion being B8V - B9V. RS Orionis is a very promising target for the observers.

GQ Orionis

Using the photoelectric observations published in the last decade, the pulsation period of GQ Ori can be refined. The O-C residuals listed in Table 84 (see also Figure 54) have been obtained with the help of the following ephemeris:

$$C = \underset{\pm .011}{2442798.377} + \underset{\pm .000058}{8^{d}.616283} \cdot E \qquad (62)$$

The only available series of radial velocity observations (*Barnes* et al., 1988) is not enough for studying the duplicity of GQ Ori.

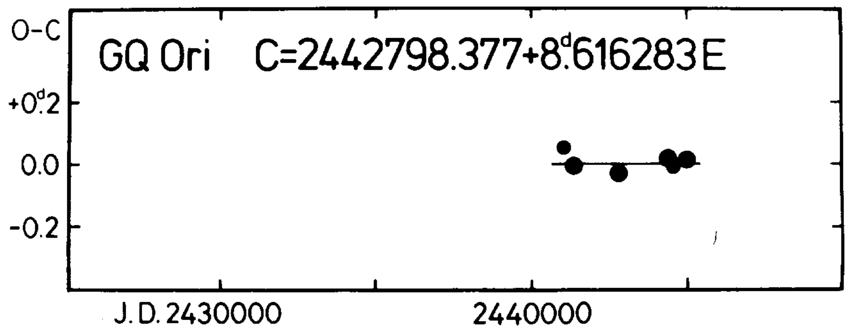

Figure 54. O-C diagram of GQ Ori

Table 84. O-C residuals for GQ Ori

Norm.max. JD2400000+	E	O-C	W	Reference
41066.557	-201	0.053	2	Pel (1976)
41368.070	-166	-0.004	3	Wachmann (1976)
42798.348	0	-0.029	3	Szabados (1980)
44392.411*	185	0.022	3	Moffett & Barnes (1984)
44599.171*	209	-0.009	2	Eggen (1985)
44986.928*	254	0.015	3	Moffett & Barnes (1984)

SV Persei

The O-C residuals listed in Table 85 have been computed with the elements:

$$C = \underset{\pm .008}{2443839.303} + \underset{\pm .000019}{11^{d}.129319} \cdot E \qquad (63)$$

The plot of the O-C residuals in Figure 55 shows that a phase shift might have occurred. This has been already pointed out in Paper III. The pulsation period was 11.129027 ± 0.000183 days before J.D. 2426000, and a

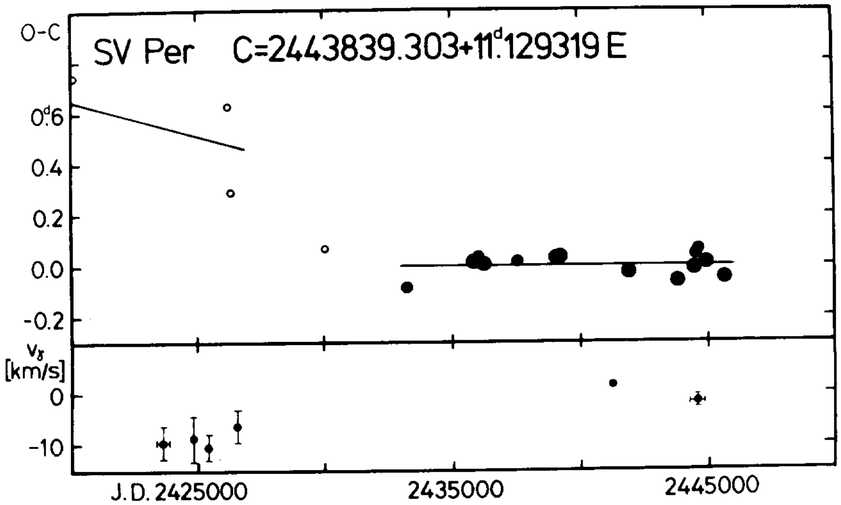

Figure 55. Upper panel: O-C diagram of SV Per
Lower panel: γ-velocities for the same Cepheid

Table 85. O-C residuals for SV Per

Norm.max. JD2400000+	E	O-C	W	Reference
17930.893	-2328	0.645	1	Enebo (1908)
18298.108	-2295	0.592	1	Enebo (1909)
18977.140	-2234	0.736	1	Enebo (1914)
20112.339	-2132	0.744	1	Enebo (1914)
26288.996	-1577	0.629	1	Kukarkin (1940)
26377.692	-1569	0.291	1	Rügemer (1932)
30027.889	-1241	0.071		Mergentaler (1948)
33232.980	-953	-0.082	2	Eggen et al. (1957)
35848.470	-718	0.018	3	Bahner & Mavridis (1977)
36260.245	-681	0.008	3	Bahner & Mavridis (1977)
37595.773	-561	0.018	2	Mitchell et al. (1964)
39075.985	-428	0.030	3	Takase (1969)
39209.541	-416	0.035	3	Wamsteker (1972)
41913.906	-173	-0.025	3	Vasil'yanovskaya (1977)
43839.246	0	-0.057	3	Szabados (1981)
44473.663*	57	-0.011	3	Moffett & Barnes (1984)
44529.365*	62	0.044	2	Eggen (1983b)
44651.810*	73	0.067	2	present paper
44963.375*	101	0.011	3	Moffett & Barnes (1984)
45686.725*	166	-0.045	3	Berdnikov (1986)

phase shift of about -0.3 day might occur between J.D. 2426000 and 2430000. Since most of the early O-C residuals are based on visual observations, the phase jump cannot be determined as clearly as in the cases when more accurate observations are also available.

Table 86. γ-velocities of SV Per

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
23635	264	-9.4	3.2	3	Joy (1937)
24822	18	-8.6	4.5	2	Joy (1937)
25413	157	-10.3	2.6	4	Joy (1937)
26572	30	-6.3	3.2	3	Joy (1937)
41252	1	1.8	0.1	3	Lloyd Evans (1984)
44586	290	-1.7	0.9	20	Barnes et al. (1988)

The γ-velocities listed in Table 86 confirm the previous conclusion drawn by *Lloyd Evans* (1984) about the spectroscopic binary nature of SV Per. The blue companion suspected from photometry (*Madore*, 1977) has been discovered in the ultraviolet spectrum of this Cepheid (*Böhm-Vitense* and *Proffitt*, 1985). The orbital period might not be very short, because *Gieren* and *Brieva* (1990) found no evidence for variable γ-velocity between 1971 and 1987.

VX Persei

The old O-C residuals corrected according to the new normal curve, supplemented with the more recent residuals (see Table 87) indicate a changing period (see Figure 56). The new ephemeris used in the present study is as follows:

$$C = 2443759.184 + 10^{d}.886972 \cdot E \qquad (64)$$
$$\pm.017 \qquad \pm.000142$$

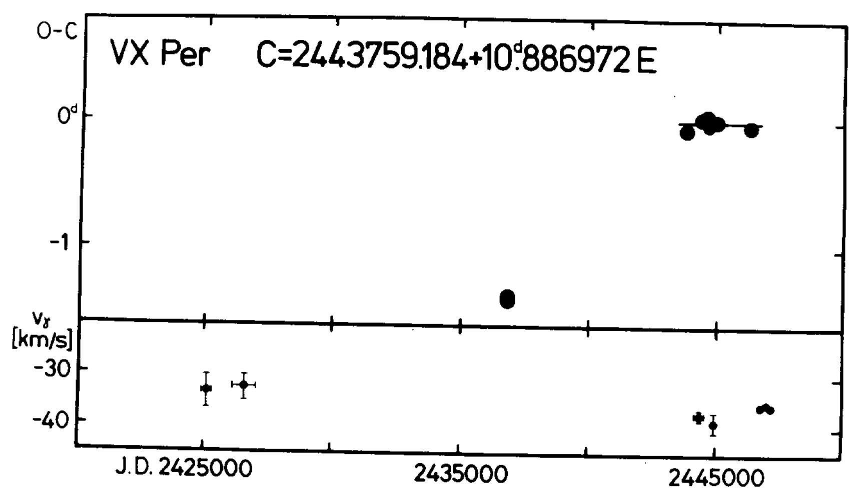

Figure 56. Upper panel: O-C diagram of VX Per
Lower panel: γ-velocities for the same Cepheid

Table 87. O-C residuals for VX Per

Norm.max. JD2400000+	E	O-C	W	Reference
36811.935	-638	-1.361	3	Oosterhoff (1960)
36822.785	-637	-1.398	3	Weaver et al. (1960)
43759.125	0	-0.059	3	Szabados (1981)
44358.001*	55	0.034	3	Moffett & Barnes (1984)
44532.214*	71	0.055	3	Eggen (1983b)
44651.885*	82	-0.031	2	present paper
44956.767*	110	0.016	3	Moffett & Barnes (1984)
46284.936*	232	-0.026	3	Berdnikov (1987)

Table 88. γ-velocities of VX Per

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25113	193	-33.3	3.2	3	Joy (1937)
26626	477	-32.4	2.6	4	Joy (1937)
44386	178	-37.0	1.0	18	Barnes et al. (1988)
44948	57	-38.4	2.0	5	Barnes et al. (1988)
46767	64	-35.3	0.1	56	Coker et al. (1989)
47004	15	-34.8	0.3	7	Metzger et al. (1990)
47124	63	-35.4	0.2	6	Coker et al. (1989)

Before J.D. 2443000 the pulsation period was longer, but an accurate value of the period for the previous epochs cannot be determined due to the paucity of data. A parabolic O-C graph, i.e. a continuously decreasing period is also possible, and photometric observations to be obtained in the near future will give a definitive answer for this problem.

The γ-velocity of VX Per can be considered as stable (see the values listed in Table 88). No other evidence exists for the duplicity of this Cepheid.

AS Persei

The recent high quality photoelectric observations (especially those obtained by *Moffett* and *Barnes*, 1984) do not support the hypothesis raised in Paper I concerning the changing pulsational amplitude of AS Per. The O-C residuals listed in Table 89 (see also Figure 57) have been obtained using the elements:

$$C = \underset{\pm .004}{2441723.941} + \underset{\pm .000007}{4\overset{d}{.}972540} \cdot E \qquad (65)$$

The pulsation period of AS Per has remained constant since the beginning of the photoelectric observations.

The available radial velocity observations (*Joy*, 1937) are not sufficient for the reliable determination of the γ-velocity, therefore new radial velocity observations would be valuable.

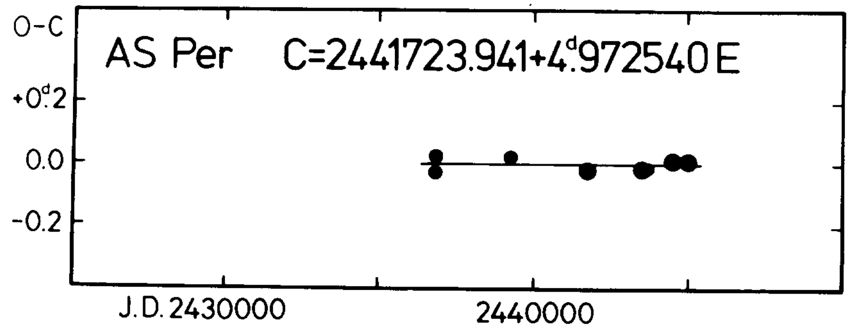

Figure 57. O-C diagram of AS Per

Table 89. O-C residuals for AS Per

Norm.max. JD2400000+	E	O-C	W	Reference
36816.019	-987	-0.025	2	Weaver et al. (1960)
36821.041	-986	0.024	2	Oosterhoff (1960)
39252.614	-497	0.025	2	Takase (1969)
41723.922	0	-0.019	3	Szabados (1977)
43484.207*	354	-0.013	3	present paper
43688.080*	395	-0.014	2	Henden (1979)
44473.768*	553	0.012	3	Moffett & Barnes (1984)
44971.024*	653	0.014	3	Moffett & Barnes (1984)

AW Persei

This Cepheid, belonging to a wide binary system, has become a popular object among the observers. The behaviour of AW Per is best described by

Table 90. O-C residuals for AW Per

Norm.max. JD2400000+	E	O-C	W	Reference
29070.812	-2110	-0.021	1	Opolski (1948)
32865.073	-1523	0.094	1	Erleksova (1961)
35463.438	-1121	0.083	1	Erleksova (1961)
36109.735	-1021	0.018	3	Bahner & Mavridis (1977)
36426.431	-972	-0.003	1	Erleksova (1961)
36820.711	-911	-0.004	3	Oosterhoff (1960)
36827.181	-910	0.002	3	Weaver et al. (1960)
39503.063	-496	-0.055	3	Wamsteker (1972)
40155.863*	-395	-0.081	1	Feltz & McNamara (1980)
40996.175*	-265	-0.040	2	Feltz & McNamara (1980)
40996.204	-265	-0.011	2	Evans (1976)
42709.062	0	-0.013	3	Szabados (1980)
43704.490*	154	0.017	3	Moffett & Barnes (1984)
44079.371*	212	0.008	3	Moffett & Barnes (1984)
44641.665*	299	-0.033	1	present paper
46477.402*	583	0.035	2	present paper
47311.211*	712	0.037	2	present paper

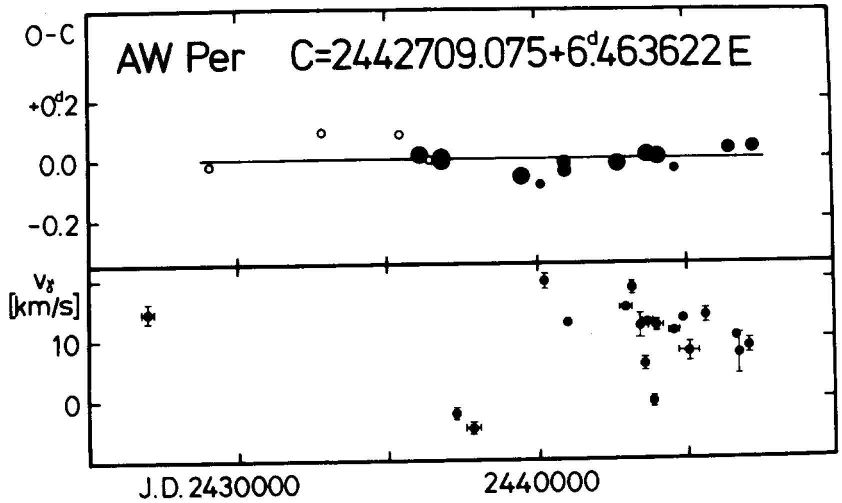

Figure 58. Upper panel: O-C diagram of AW Per
Lower panel: γ-velocities for the same Cepheid

Table 91. γ-velocities of AW Per

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
26981	188	14.8	1.6	9	Joy (1937)
37247	33	-2.1	0.9	8	Miller & Preston (1964b)
37798	223	-4.5	0.9	9	Miller & Preston (1964b)
40214	43	19.7	1.2	2	Welch & Evans (1989)
40971	4	12.9	0.4	3	Evans (1976)
42989	188	15.3	0.2	7	Griffin (1982) *
43155	2	18.5	1.0	2	McNamara & Chapman (1977)
43408	49	12.3	2.0	5	Wilson et al. (1989)
43559	15	6.0	1.0	2	Evans (1983)
43639	179	12.9	0.2	11	Griffin (1982) *
43821	1	-0.3	0.8	1	Beavers & Eitter (1986)
43962	220	12.3	0.8	25	Barnes et al. (1987)
44549	169	11.5	0.2	14	Griffin (1982) *
44836	159	13.4	0.4	5	Evans (1983)
45036	373	8.0	1.6	6	Barnes et al. (1987)
45610	1	13.9	1.2	1	Welch & Evans (1989)
46639	118	10.5	0.4	12	Welch & Evans (1989)
46727	1	7.5	3.4	2	present paper
47091	4	8.8	1.2	2	Welch & Evans (1989)

* Observer: T. Lloyd Evans

Welch and *Evans* (1989), and the additional photometric and spectroscopic data analysed here confirm their results. The O-C residuals listed in Table 90 have been calculated with the formula:

$$C = 2442709.075 + 6.^{d}463622 \cdot E \qquad (66)$$
$$\pm.007 \quad \pm.000009$$

The plot of the O-C residuals in Figure 58 clearly shows the wave-like pattern due to the orbital motion. The light-time effect keeps on being consistent with the phase of the γ-velocity variation.

In addition to the radial velocity data analysed by *Welch* and *Evans* (1989), Table 91 also lists some other γ-velocity values that have not been used for deriving the orbit of AW Persei, including that obtained from *Lloyd Evans'* radial velocity measurements (*Griffin*, 1982), and from the two spectra taken by the author at Rozhen Observatory (see Table 109). The γ-velocity values plotted in the lower panel of Figure 58 well demonstrate the long orbital period: 13100 $\pm$ 100 days, as determined by *Welch* and *Evans* (1989).

In view of its importance, regular photometric observations of AW Per will continue at Konkoly.

V440 Persei

Due to the short time-base of the available photometric observations, the shape of the O-C graph cannot be determined reliably. The O-C residuals listed in Table 92 have been obtained using the linear ephemeris:

$$C = \underset{\pm .014}{2444551.137} + \underset{\pm .000074}{7^{d}.572498} \cdot E \qquad (67)$$

Further observations are necessary to decide whether an additional parabolic term would give a better fit when predicting the forthcoming light maxima (cf. Figure 59).

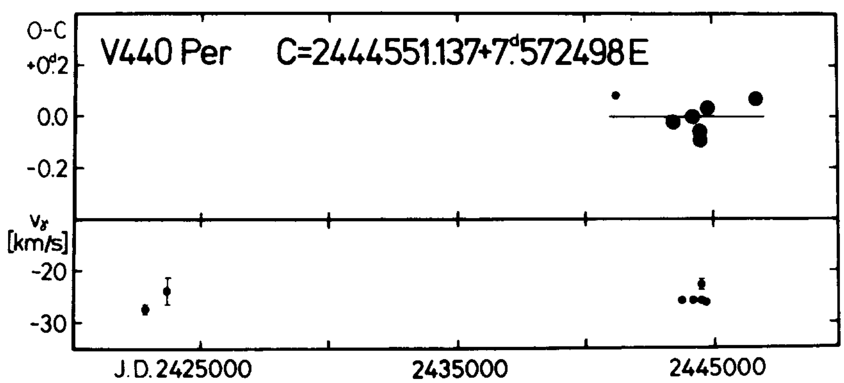

Figure 59. Upper panel: O-C diagram of V440 Per
Lower panel: γ-velocities for the same Cepheid

Table 92. O-C residuals for V440 Per

Norm.max. JD2400000+	E	O-C	W	Reference
41219.322*	-440	0.084	2	Burki & Benz (1982)
43483.394	-141	-0.021	3	Szabados (1980)
44240.668*	-41	0.003	3	Burki & Benz (1982)
44528.363*	-3	-0.057	3	Eggen (1985)
44551.047*	0	-0.090	3	Burki & Benz (1982)
44869.217*	42	0.035	3	Arellano Ferro (1984)
46724.514*	287	0.070	3	Arellano Ferro et al. (1987)

Table 93. γ-velocities of V440 Per

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
22863	107	-27.4	0.9	6	Abt (1970)
23699	28	-23.7	2.5	2	Plaskett (1934)
43796	126	-25.6	0.1	18	Burki & Benz (1982)
44202	24	-25.6	0.1	23	Burki & Benz (1982)
44525	1	-22.4	0.8	2	Beavers & Eitter (1986)
44559	67	-25.6	0.1	19	Burki & Benz (1982)
44712	136	-25.8	0.4	15	Arellano Ferro (1984)

The γ-velocities of V440 Per are listed in Table 93. Although the γ-velocity seems to be constant, the variable star may have a companion, but the inclination of the orbit is unfavourable for detecting the orbital motion. In addition to the fact that *Usenko* (1990b) assumes a B8 type photometric companion, the suspicion supporting the existence of the companion is based on the relatively large radial velocity amplitude, as compared with the amplitude of the light variation. It is obvious that a companion star tends to diminish the photometric amplitude of the variable, and does not influence the pulsational radial velocity amplitude (i.e. having removed the orbital effect). The binary Cepheids usually have a larger ratio of radial velocity amplitude per light variation amplitude (*Szabados*, unpublished). A detailed analysis of this effect is in progress.

S Sagittae

The reliable earlier O-C residuals taken from Paper II have been supplemented with the O-C values derived from the more recently published photoelectric observations (see Table 94). The O-C residuals (partly plotted in Figure 60) have been approximated with a parabola instead of two intersecting straight lines, as suggested in Paper II. The O-C residuals in Table 94 have been computed with the formula:

$$C = \underset{\pm .021}{2442678.821} + \underset{\pm .000029}{8^{d}\!.382146} \cdot E \qquad (68)$$

Table 94. O–C residuals for S Sge

Norm.max. JD2400000+	E	O–C	W	Reference
09829.793	-3919	0.602	1	Gore (1886)
09888.258	-3912	0.392	1	Gore (1886)
10164.999	-3879	0.522	1	Gore (1887)
10567.248	-3831	0.428	1	Gore (1888)
11263.052	-3748	0.514	1	Gore (1890)
11615.078	-3706	0.490	1	Gore (1891)
11975.160	-3663	0.140	1	Markwick (1892)
14196.461	-3398	0.172	1	Pickering (1904)
14934.134	-3310	0.216	1	Prittwitz (1901)
16082.542	-3173	0.270	1	Tass (1925)
16761.439	-3092	0.213	1	Lau (1907)
16803.375	-3087	0.239	1	Tass (1925)
17062.887	-3056	-0.096	1	Wilkens (1906)
17632.674	-2988	-0.295	1	Jordan (1919)
17850.862	-2962	-0.043	1	Hertzsprung (1909)
17851.029	-2962	0.124	1	Nijland (1923)
17851.054	-2962	0.149	1	Zeipel (1908)
18035.437	-2940	0.125	1	Tass (1925)
18152.813	-2926	0.151	1	Nijland (1923)
18521.561	-2882	0.085	1	Nijland (1923)
18806.555	-2848	0.086	1	Nijland (1923)
18957.443	-2830	0.095	2	Hertzsprung (1917)
19317.859	-2787	0.079	2	Hertzsprung (1917)
21061.385	-2579	0.119	1	Luyten (1922)
21488.867	-2528	0.111	1	Lacchini (1921)
21748.891	-2497	0.289	1	Luyten (1922)
22192.987	-2444	0.131	1	Leiner (1926)
22897.156	-2360	0.200	1	Eaton (1920, 1921, 1922) & Walker (1921, 1922)
23316.013	-2310	-0.051	1	Nielsen (1927c)
23333.038	-2308	0.210	1	AFOEV (1922, 1923)
24213.006	-2203	0.053	1	Parenago (1938)
24690.941	-2146	0.205	1	Leiner (1938)
24774.587	-2136	0.030	1	Kukarkin (1940)
25134.962	-2093	-0.027	1	Hellerich (1935)
25386.645	-2063	0.191	1	Leiner (1938)
25445.085	-2056	-0.044	1	Zverev (1936)
25453.702	-2055	0.191	1	Kukarkin (1940)
25797.187	-2014	0.008	1	Zverev (1936)
25847.689	-2008	0.217	1	Leiner (1938)
26182.943	-1968	0.185	1	Leiner (1938)
26384.157	-1944	0.228	1	Parenago (1938)
26451.214	-1936	0.228	1	Kukarkin (1940)
26476.126	-1933	-0.007	1	Zverev (1936)
26794.741	-1895	0.087	1	Kox (1935)
26920.633	-1880	0.246	1	Florya & Kukarkina (1953)
27591.056	-1800	0.010	1	Krebs (1935)
28001.975	-1751	0.292	1	Krebs (1936)
29091.599	-1621	0.237	1	Leiner (1938)
29141.833	-1615	0.178	3	Bennett (1939)
33131.605	-1139	0.048	3	Eggen (1951)
33198.520	-1131	-0.094	1	Solov'yov (1959)
34036.880	-1031	0.052	1	Solov'yov (1959)
34598.351	-964	-0.081	1	Solov'yov (1959)

Table 94. (cont.)

Norm.max. JD2400000+	E	O-C	W	Reference
34615.241	-962	0.044	3	Szabados (1980)
35285.815	-882	0.047	2	Irwin (1961)
35403.191	-868	0.073	1	Solov'yov (1959)
35730.121	-829	0.099	3	Prokof'yeva (1961)
35730.154	-829	0.132	1	Solov'yov (1959)
36048.551	-791	0.007	1	Solov'yov (1959)
36190.964	-774	-0.076	1	Latyshev (1969)
36207.768	-772	-0.036	1	Svolopoulos (1960)
36450.962	-743	0.075	1	Solov'yov (1959)
36459.445	-742	0.176	1	Solov'yov (1959)
36509.621	-736	0.059	3	Walraven et al. (1958)
36718.940	-711	-0.175	1	Azarnova (1960b)
37213.656	-652	-0.006	3	Mitchell et al. (1964)
37917.700	-568	-0.062	3	Walraven et al. (1964)
39040.928	-434	-0.042	3	Wisniewski & Johnson (1968)
40440.802*	-267	0.014	3	Feltz & McNamara (1980)
40834.696	-220	-0.053	2	Evans (1976)
41220.269*	-174	-0.059	2	Feltz & McNamara (1980)
42595.144	-10	0.144	1	Berdnikov (1977)
42678.783	0	-0.038	3	Szabados (1980)
43340.987*	79	-0.024	3	Moffett & Barnes (1984)
43835.505*	138	-0.052	3	Moffett & Barnes (1984)
44808.023*	254	0.137	1	present paper
46643.574*	473	-0.002	2	present paper

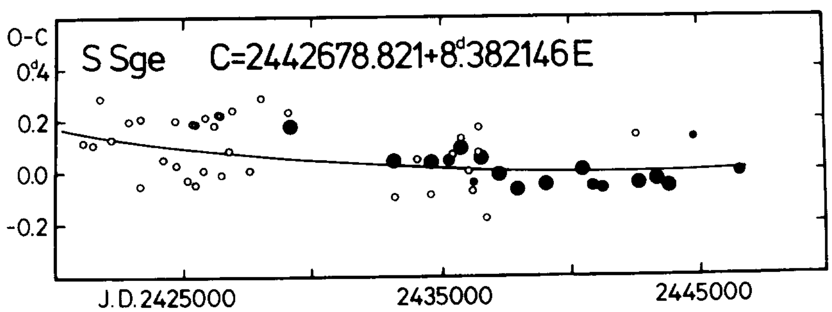

Figure 60. O-C diagram of S Sge

The continuous period increase is given by the equation:

$$P = 8^d\!.382146 + 4^d\!.4\cdot 10^{-8}\cdot E \qquad (69)$$
$$\pm.000029 \quad \pm 1.6$$

Future photoelectric observations are needed to decide whether the deviations from the parabola are systematic or random. It is clear, however, that the light-time effect expected from the orbital motion is much less than the detection limit.

S Sge is one of the best studied binary Cepheids, therefore no attempt was made here for determining the orbital elements. A single new radial velocity value obtained with the 2m telescope in Rozhen is, however, listed in Table 109. The most recent results concerning the duplicity of S Sge are published by *Slovak* and *Barnes* (1987) (P_{orb} = 676.2 days), *Evans* et al. (1989), and *Slovak* et al. (1989). The two latter papers put forward evidence for a third component in the system, what makes S Sge an even more interesting object for future observations.

SW Tauri

The previously determined O-C residuals (see Paper I) have been corrected according to the new normal light curve based on the superior observations made by *Moffett* and *Barnes* (1984). The corrected and the newly determined O-C residuals are all listed in Table 95. The plot of these residuals in Figure 61 shows a parabolic shape instead of the occurrence of a single period change suggested in Paper I. The new ephemeris used when determining the O-C values is as follows:

$$C = \underset{\pm .003}{2441687.762} + \underset{\pm .000001}{1\overset{d}{.}583577} \cdot E \qquad (70)$$

The continuous period decrease can be computed from the formula:

$$P = \underset{\pm .000001}{1\overset{d}{.}583577} - \underset{\pm .54}{7\overset{d}{.}13} \cdot 10^{-9} \cdot E \qquad (71)$$

This slight and smooth period change is atypical of the short period Population II Cepheids.

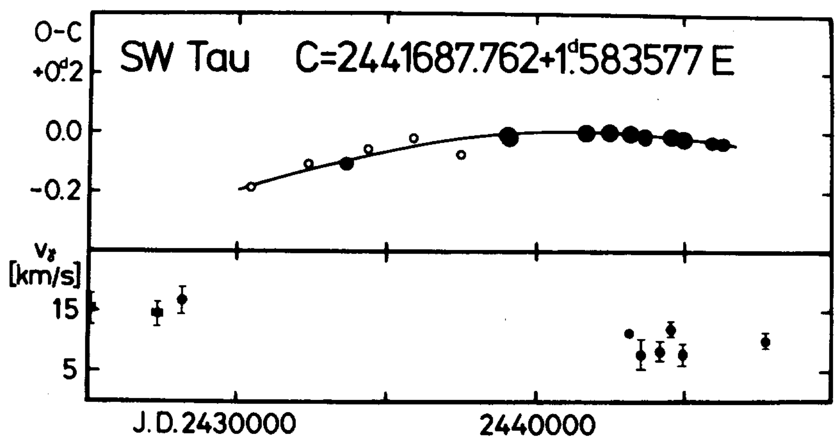

Figure 61. Upper panel: O-C diagram of SW Tau
Lower panel: γ-velocities for the same Cepheid

Table 95. O-C residuals for SW Tau

Norm.max. JD2400000+	E	O-C	W	Reference
30434.681	-7106	-0.183	1	Solov'yov (1957)
32354.052	-5894	-0.107	1	Borzdyko (1965)
33638.337	-5083	-0.103	2	Eggen et al. (1957)
34377.911	-4616	-0.059	1	Borzdyko (1965)
35879.185	-3668	-0.017	1	Borzdyko (1965)
37465.873	-2666	-0.073	1	Mandel' (1970)
39059.018	-1660	-0.006	3	Milone (1970)
39078.014	-1648	-0.013	3	Wamsteker (1972)
41687.762	0	0.000	3	Szabados (1977)
42455.800*	485	0.003	3	Dean et al. (1977)
43166.821*	934	-0.002	3	Stobie & Balona (1979)
43176.324	940	0.000	2	Szabados (1977)
43630.795*	1227	-0.016	2	Henden (1979)
43675.141*	1255	-0.010	2	Diethelm & Tammann (1982)
44519.188*	1788	-0.010	3	Moffett & Barnes (1984)
44994.253*	2088	-0.018	3	Moffett & Barnes (1984)
45966.558*	2702	-0.029	2	Diethelm (1986)
46337.110*	2936	-0.034	2	Wallerstein (1987)

Table 96. γ-velocities of SW Tau

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
24993	176	15.3	2.6	4	Joy (1937)
27343	174	14.6	2.0	6	Joy (1937)
28175	59	16.8	2.3	5	Joy (1937)
43139	26	11.5	0.6	17	Stobie & Balona (1979)
43526	1	8.0	2.5	1	Stobie & Balona (1979)
44187	29	8.6	1.6	7	Barnes et al. (1988)
44555	49	12.2	1.3	10	Barnes et al. (1988)
44948	51	8.0	1.8	6	Barnes et al. (1988)
47793	1	10.4	1.2	1	Samus (1990)

The γ-velocity of SW Tau seems to be variable (see Table 96 and the lower panel of Figure 61). Nevertheless, further radial velocity observations are necessary to confirm the duplicity of this variable star.

SZ Tauri

A rejump to an earlier pulsation period was reported in Paper I. Since then a new period change has occurred (*Trammell*, 1987), and interestingly enough, the new period is almost identical with that valid during the interval 1920 - 1960. The photoelectric O-C residuals listed in Table 97 confirm the new phase jump, though this event took place so slowly that the intermediate period can well be determined (see Figure 62). The current ephemeris used for calculating the O-C residuals is as follows:

$$C = \underset{\pm.032}{2441659.262} + \underset{\pm.000043}{3\overset{d}{.}149138}\cdot E \qquad (72)$$

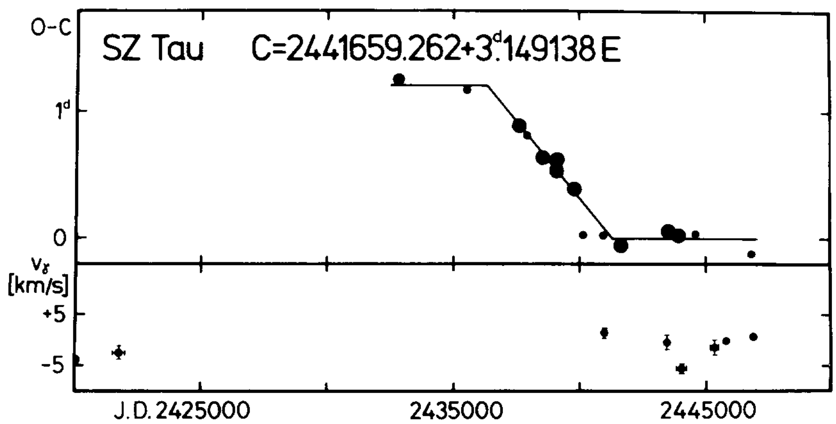

Figure 62. Upper panel: O-C diagram of SZ Tau
Lower panel: γ-velocities for the same Cepheid

Table 97. O-C residuals for SZ Tau

Norm.max. JD2400000+	E	O-C	W	Reference
32852.379	-2797	1.256	2	Eggen (1951)
35541.659	-1943	1.172	1	Walraven et al. (1958)
37619.809	-1283	0.891	3	Mitchell et al. (1964)
37962.988	-1174	0.814	1	Williams (1966)
38529.659	-994	0.640	3	Wisniewski & Johnson (1968)
39055.461	-827	0.536	3	Milone (1970)
39077.600	-820	0.631	3	Wamsteker (1972)
39807.965	-588	0.396	3	Szabados (1977)
40147.996*	-480	0.032	1	Feltz & McNamara (1980)
40991.677*	-212	0.032	1	Feltz & McNamara (1980)
41659.204	0	-0.058	3	Szabados (1977)
43520.462*	591	0.059	3	Moffett & Barnes (1984)
43926.666*	720	0.025	3	Moffett & Barnes (1984)
44647.837*	949	0.043	1	present paper
46845.772*	1647	-0.120	1	Trammell (1987)

The earlier values of the pulsation period have not been determined again, these values are taken from Paper I:

before J.D. 2418500	P = 3.14839 days,
between J.D. 2425500 and 2436300	P = 3.149057 days,
between J.D. 2436300 and 2441300	P = 3.148380 days,
after J.D. 2441300	P = 3.149138 days.

Because of the stepwise O-C graph, i.e. the phenomenon of the phase jump, SZ Tau probably belongs to a binary system, as well. The existence of a bright blue companion is, however, doubtful (see *Leonard* and *Turner*, 1986, and the references therein). As can be seen in the lower panel of

Table 98. γ-velocities of SZ Tau

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
20095	49	-3.7	0.6	30	Haynes (1914)
21784	236	-2.5	1.2	4	Abt (1970)
40972	10	1.4	0.8	5	Schmidt (1974)
43449	59	-0.3	1.4	9	Wilson et al. (1989)
44011	220	-5.5	0.8	25	Barnes et al. (1987)
45311	147	-1.3	1.5	8	Barnes et al. (1987)
45721	8	-0.1	0.1	36	Gieren (1985)
46866	1	0.9	0.5	2	Samus (1990)

Figure 62, and in the data listed in Table 98, the γ-velocity of SZ Tau might be variable. The spectroscopic binary nature of SZ Tau, however, needs confirmation.

SZ Tau is an important object because of one more reason, viz. its possible membership in the open cluster NGC 1647 (*Walker*, 1987; *Gieren*, 1988).

S Vulpeculae

S Vul is one of the longest period Cepheids in our Galaxy. Its pulsation period has been strongly varying (*Mahmoud* and *Szabados*, 1980), and the latest period change just noticeable in 1980 now can be traced. The O-C residuals listed in Table 99, and shown plotted in Figure 63 have been obtained with the elements:

$$C = 2444147.692 + 68^{d}.500 \cdot E \qquad (73)$$
$$\pm.518 \qquad \pm.027$$

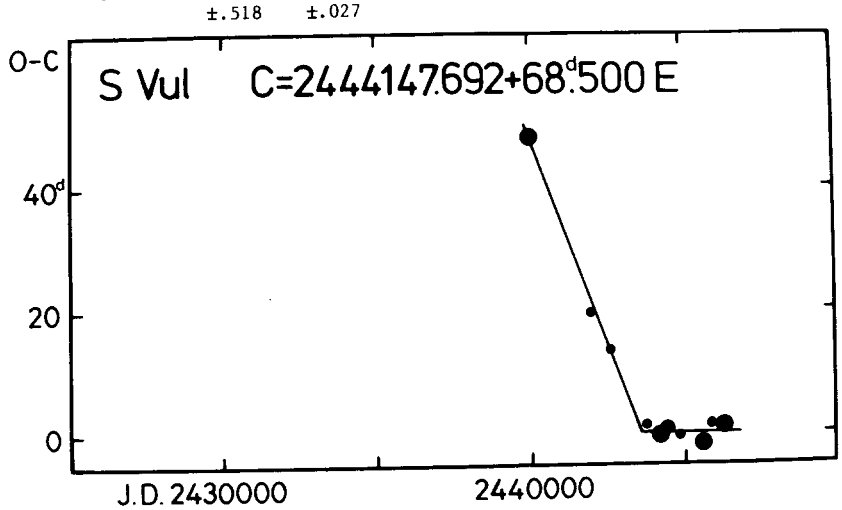

Figure 63. O-C diagram of S Vul

Table 99. O-C residuals for S Vul

Norm.max. JD2400000+	E	O-C	W	Reference
40017.349	-61	48.157	3	Fernie (1970)
41975.061*	-32	19.369	1	Schmidt (1976)
42585.601*	-23	13.409	1	Dawson (1979)
43738.161	-6	1.469	1	Turner (1980)
44147.253	0	-0.439	3	Mahmoud & Szabados (1980)
44422.573	4	0.881	2	Mahmoud & Szabados (1980)
44832.141*	10	-0.551	1	present paper
45584.257*	21	-1.935	3	Berdnikov & Ivanov (1986)
45861.682*	25	1.490	1	Berdnikov & Ivanov (1986)
46272.203*	31	1.011	3	Berdnikov & Ivanov (1986)

The available radial velocity data do not permit even the reliable determination of the γ-velocity, but as a matter of fact, no evidence can be found in the literature regarding the duplicity of S Vul.

T Vulpeculae

A new normal light curve has been determined on the basis of the photoelectric observations made by *Moffett* and *Barnes* (1984). The new O-C residuals (listed in Table 100) have been determined with the help of this normal curve, and the O-C residuals published earlier in Paper I have been corrected accordingly. The best linear fit to the data points after J.D. 2434500 is as follows:

$$C = \underset{\pm.007}{2441705.127} + \underset{\pm.000009}{4\overset{d}{.}435453} \cdot E \qquad (74)$$

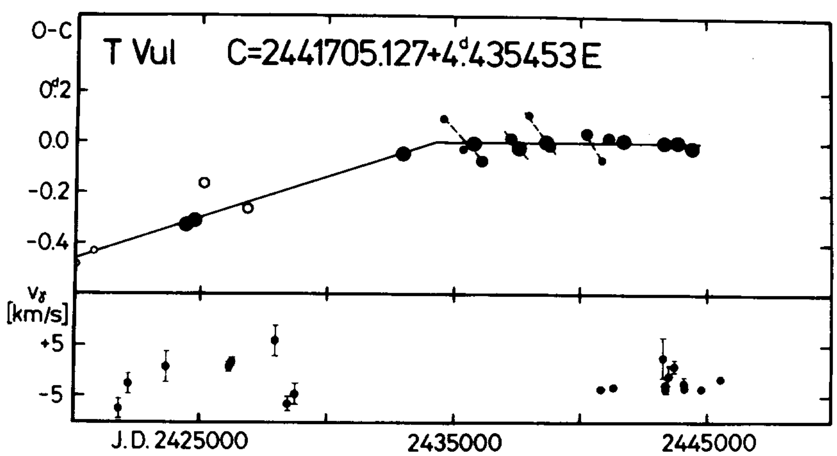

Figure 64. Upper panel: O-C diagram of T Vul
Lower panel: γ-velocities for the same Cepheid

Table 100. O-C residuals for T Vul

Norm.max. JD2400000+	E	O-C	W	Reference
20001.972	-4893	-0.483		Hertzsprung (1919)
20747.181	-4725	-0.431		Hertzsprung (1919)
24375.483	-3907	-0.329		Huffer (1928a)
24721.463	-3829	-0.314		Huffer (1928a)
25116.367	-3740	-0.166		Hellerich (1935)
26859.398	-3347	-0.268		Kox (1935)
32967.242	-1970	-0.043		Eggen (1951)
34595.189	-1603	0.093	1	Szabados (1977)
35362.401	-1430	-0.028	1	Walraven et al. (1958)
35757.181	-1341	-0.004	3	Prokof'yeva (1961)
36098.640	-1264	-0.074	2	Svolopoulos (1960)
37212.028	-1013	0.015	2	Mitchell et al. (1964)
37562.390	-934	-0.024	3	Johansen (1971)
37939.534	-849	0.107	1	Williams (1966)
38649.098	-689	-0.002	3	Johansen (1971)
38733.365	-670	-0.008	2	Wisniewski & Johnson (1968)
40254.769*	-327	0.035	2	Feltz & McNamara (1980)
40853.449*	-192	-0.071	1	Evans (1976)
41128.537*	-130	0.019	2	Feltz & McNamara (1980)
41705.136	0	0.009	3	Szabados (1977)
43359.552*	373	0.001	3	Moffett & Barnes (1984)
43874.070*	489	0.006	3	Moffett & Barnes (1984)
44472.831*	624	-0.019	3	Berdnikov & Bogdanov (1987)

Table 101. γ-velocities of T Vul

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
16683	2	9.0	3.0	2	Frost (1904)
16699	19	-1.5	1.5	5	Albrecht (1907)
16765	11	-3.8	3.0	2	Albrecht (1907)
17093	18	1.0	1.5	5	Albrecht (1907)
17151	19	-1.4	0.6	24	Albrecht (1907)
17214	3	-3.5	3.0	2	Albrecht (1907)
17438	7	-0.8	0.8	14	Albrecht (1907)
21796	2	-7.5	2.0	2	Abt (1973)
22166	68	-2.5	2.0	2	Abt (1973)
23622	11	0.8	3.0	2	Harper (1934)
26179	10	0.9	0.9	12	Lüst-Kulka (1954)
26220	14	1.8	0.8	16	Lüst-Kulka (1954)
27995	1	5.8	3.0	1	Young (1939)
28450	1	-6.4	1.4	3	Abt (1973)
28760	32	-4.5	2.1	3	Young (1939)
40825	24	-3.2	0.3	4	Evans (1976)
41336	11	-2.8	0.4	3	Evans (1976)
43293	1	2.8	4.0	2	Wilson et al. (1989)
43327	33	-2.4	0.3	3	Evans & Lyons (1986)
43377	46	-3.2	0.4	5	Beavers & Eitter (1986)
43382	4	-3.2	0.9	21	Wilson et al. (1989)
43500	5	-0.7	2.0	5	Wilson et al. (1989)
43735	69	1.1	1.2	11	Barnes et al. (1987)
44134	81	-2.2	1.1	12	Barnes et al. (1987)
44136	36	-2.8	0.2	4	Evans & Lyons (1986)
44811	1	-3.2	0.4	1	Evans & Lyons (1986)
45539	24	-1.6	0.2	4	Evans & Lyons (1986)

Before J.D. 2434500 the pulsation period was somewhat longer (see Figure 64): P = 4.435589 days, as determined in Paper I. Moreover, it cannot be excluded that the period of pulsation before J.D. 2419000 practically coincided with the recent value, i.e. a phase slide occurred between J.D. 2419000 and 2434500. This phenomenon cannot be followed in Figure 64, because the early visual observations have not been analysed here. Another kind of phase jump can, however, be suspected in the recent part of the O-C graph. In Figure 64 dashed lines indicate these assumed phase jumps. The quasi-period in the recurrence of these jumps is the same as the value of the orbital period of T Vul discussed below. This phenomenon is similar to that observed in Y Oph (see Paper IV, p. 39).

The variation in the γ-velocity exceeds the limit that could be attributed to the observational uncertainty. The considerably large number of the γ-velocities listed in Table 101 (and partly plotted in the lower panel of Figure 64) has been analysed for the possible periodicity. A reasonably good "orbital" radial velocity curve could be obtained at a period of 1745 days. This phase diagram is plotted in Figure 65. The only strongly deviating γ-velocity is the point determined from *Frost*'s (1904) two radial velocity measurements, being the earliest velocity data for T Vul. Interestingly enough, *Kovács* et al. (1990) also found a long periodicity in the radial velocity data (their sample was a subset of the data studied here), but the period of 738 days discovered by them cannot be revealed from the present sample. The strong coincidence of the 1745 day period with the cycle length of the subtle phase jumps in the O-C diagram

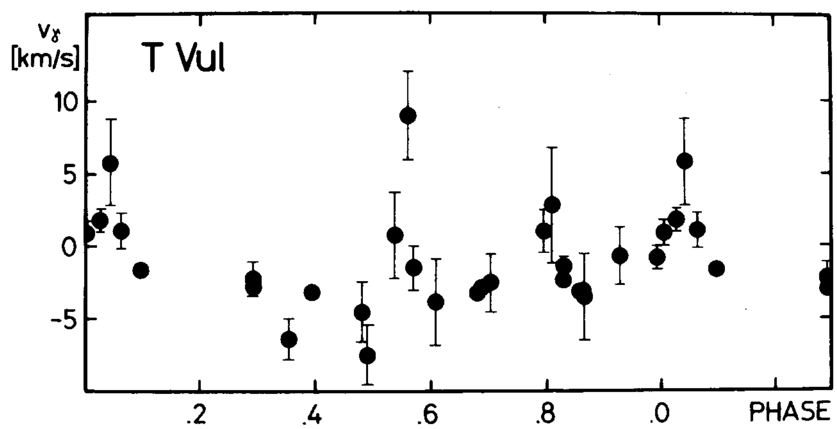

Figure 65. γ-velocity values of T Vul folded with the 1745 day period

confirm the author's belief that this longer period represents the orbital period of the binary system containing T Vul. The presence of a companion star has already been suspected by *Kurochkin* (1966).

Extensive photometric and spectroscopic observations would be necessary to obtain a more reliable picture on the duplicity of T Vul.

U Vulpeculae

The O-C diagram covering almost a century was approximated with a single straight line in Paper II. The photoelectric O-C residuals supplemented with some more data published in the eighties (see Table 102 and Figure 66) are better represented by two linear sections. It has to be noted that the extrapolation of this alternating period change towards the earlier visual observations also gives a reasonably good fit to the O-C residuals. The O-C residuals listed in Table 102 have been obtained with the elements:

$$C = 2442526.312 + 7^{d}.990821 \cdot E \qquad (75)$$
$$\pm.006 \quad \pm.000026$$

The γ-velocities of U Vul show an intrinsic variation (see Table 103 and the lower panel of Figure 66) which can be explained with the duplicity of U Vul. The existence of a companion was already suspected by *Kurochkin* (1966). The γ-velocities derived from *Sanford*'s (1928) radial velocity data indicate that the orbital period might not be too long (i.e. much longer than 1000 days). The formal period search routine applied to

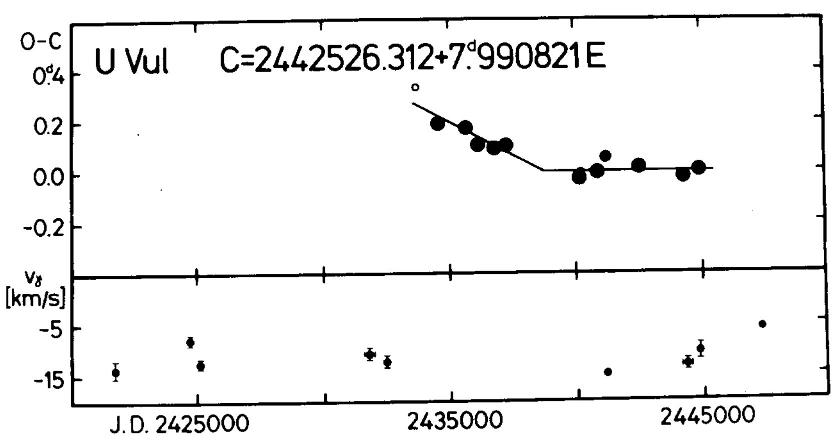

Figure 66. Upper panel: O-C diagram of U Vul
Lower panel: γ-velocities for the same Cepheid

Table 102. O-C residuals for U Vul

Norm.max. JD2400000+	E	O-C	W	Reference
33704.781	-1104	0.335	1	Chuprina (1952)
34591.618	-993	0.191	3	Szabados (1980)
35638.397	-862	0.173	3	Walraven et al. (1958)
36125.772	-801	0.108	3	Bahner & Mavridis (1971)
36781.008	-719	0.096	3	Weaver et al. (1960)
37244.483	-661	0.104	3	Mitchell et al. (1964)
40121.046	-301	-0.029	3	Asteriadis et al. (1977)
40208.971*	-290	-0.003	1	Feltz & McNamara (1980)
40840.247	-211	-0.002	3	Evans (1976)
41199.889*	-166	0.053	2	Feltz & McNamara (1980)
42526.328	0	0.016	3	Szabados (1980)
44292.262*	221	-0.021	3	Moffett & Barnes (1984)
44923.562*	300	0.004	3	Moffett & Barnes (1984)

Table 103. γ-velocities of U Vul

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
21759	28	-13.5	1.7	4	Sanford (1928)
24745	39	-7.9	0.9	13	Sanford (1928)
25111	48	-12.5	0.9	13	Sanford (1928)
31776	185	-10.5	1.2	7	Sanford (1951)
32494	128	-12.1	1.2	7	Sanford (1951)
41067	116	-14.7	0.3	6	Evans (1976)
44369	219	-13.0	1.1	15	Barnes et al. (1988)
44877	76	-10.5	1.6	7	Barnes et al. (1988)
47365	1	-6.1	0.4	1	Samus (1990)

the γ-velocity values of U Vul resulted in the orbital period of 868 days. This value, however, cannot be accepted without reservation. The determination of the true value of the orbital period is not possible without performing new radial velocity measurements. Photometric observations would be necessary, as well, in order to study whether the alternating period changes represent a kind of phase jump (or phase slide) characteristic of binary Cepheids. It is clear, however, that the alternating period changes cannot be replaced with a sinusoidal wave caused by the light-time effect, because the γ-velocity data indicate an oscillation in the O-C diagram that would hardly be detected.

X Vulpeculae

The O-C residuals of X Vul listed in Table 104 have been obtained using the ephemeris:

$$C = \underset{\pm .012}{2442665.932} + \underset{\pm .000022}{6\overset{d}{.}319490}\cdot E \tag{76}$$

Instead of a single straight line, the O-C plot has been approximated with two sections and a phase jump in between (see Figure 67). This phase jump, however, has to be confirmed.

The γ-velocity of X Vul varies, and this Cepheid probably belongs to a long period spectroscopic binary (see Table 105 and the lower panel of Figure 67). *Moffett* and *Barnes* (1987) also noted the discrepancy between the γ-velocity values determined at two epochs, while *Janot-Pacheco* (1976) suspected a photometric companion.

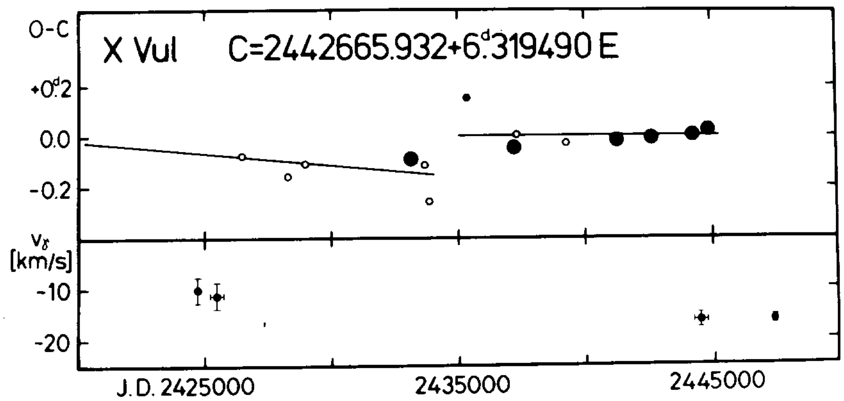

Figure 67. Upper panel: O-C diagram of X Vul
Lower panel: γ-velocities for the same Cepheid

Table 104. O-C residuals for X Vul

Norm.max. JD2400000+	E	O-C	W	Reference
17470.166	-3987	0.041	1	Luizet (1907)
26481.643	-2561	-0.075	1	Kukarkin (1940)
28314.212	-2271	-0.158	1	Azhusenis (1956)
28984.128	-2165	-0.108	1	Azhusenis (1956)
33117.093	-1511	-0.090	3	Eggen (1951)
33692.141	-1420	-0.115	1	Chuprina (1954b)
33868.946	-1392	-0.256	1	Chuprina (1954b)
35354.434	-1157	0.152	1	Walraven et al. (1958)
37205.847	-864	-0.046	3	Mitchell et al. (1964)
37357.564	-840	0.004	1	Boyko (1970)
39291.295	-534	-0.029	1	Boyko (1970)
41294.584*	-217	-0.019	3	Feltz & McNamara (1980)
42665.923	0	-0.009	3	Szabados (1980)
44296.367*	258	0.007	3	Moffett & Barnes (1984)
44909.375*	355	0.024	3	Moffett & Barnes (1984)

Table 105. γ-velocities of X Vul

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
24748	2	-10.1	2.6	4	Joy (1937)
25490	233	-11.2	2.6	4	Joy (1937)
44504	273	-16.2	1.4	9	Barnes et al. (1988)
47361	1	-16.2	0.8	1	Samus (1990)

SV Vulpeculae

SV Vul is a very important Cepheid because of several reasons. Not only is SV Vul one of the longest period Cepheids in our Galaxy, but it is a possible member of the Vul OB1 association (see *Walker*, 1987 and the references therein).

Table 106. O-C residuals for SV Vul

Norm.max. JD2400000+	E	O-C	W	Reference
23244.975	-454	-38.321	1	Kristensen (1923, 1924)
23470.600	-449	-37.730	1	Leiner (1924)
23651.731	-445	-36.626	1	Zakharov (1924a, 1924b)
23877.517	-440	-35.874	1	Kristensen (1926)
23923.562	-439	-34.836	1	Beyer (1930)
23967.607	-438	-35.798	1	Ahnert (1931)
24013.407	-437	-35.004	1	Zakharov (1928)
24148.197	-434	-35.235	1	Leiner (1929)
24329.463	-430	-33.996	1	Zakharov (1928)
24374.633	-429	-33.833	1	Beyer (1930)
24419.533	-428	-33.940	1	Nielsen (1927b)
24511.449	-426	-32.037	1	Ahnert (1931)
24736.039	-421	-32.481	1	Leiner (1929)
24736.624	-421	-31.896	1	Beyer (1930)
24781.299	-420	-31.228	1	Zakharov (1928)
25142.885	-412	-30.696	1	Beyer (1930)
25143.425	-412	-30.156	1	Ahnert (1931)
25369.366	-407	-29.249	1	Leiner (1929)
25550.091	-403	-28.552	1	Beyer (1930)
25865.787	-396	-27.903	1	Ahnert (1931)
25866.102	-396	-27.588	1	Kukarkin (1940)
25955.541	-394	-28.163	1	Zakharov (1954)
26180.987	-389	-27.751	1	Ahnert (1931)
26406.522	-384	-27.250	1	Zverev (1936)
26453.088	-383	-25.691	1	Terkán (1935)
26677.903	-378	-25.910	1	Kukarkin (1940)
26904.924	-373	-23.923	1	Florya & Kukarkina (1953)
27265.565	-365	-23.336	1	Florya & Kukarkina (1953)
28077.230	-347	-21.793	1	Nassau & Ashbrook (1942)
28754.097	-332	-20.028	1	Dziewulski & Iwanowska (1946)
32948.126	-239	-11.632	3	Eggen (1951)
33535.518	-226	-9.328	1	Chuprina (1953)
35340.791	-186	-4.327	1	Walraven et al. (1958)
37232.711	-144	-2.693	3	Mitchell et al. (1964)
37952.866	-128	-2.647	1	Williams (1966)
38268.336	-121	-2.224	3	Fernie et al. (1965)
40654.719*	-68	-1.202	2	Feltz & McNamara (1980)
41329.910*	-53	-1.113	2	Feltz & McNamara (1980)
43085.550	-14	-0.738	3	Fernie (1979a)
43625.769*	-2	-0.600	3	Moffett & Barnes (1984)
43715.229	0	-1.154	3	Szabados (1981)
44075.401*	8	-1.036	3	Moffett & Barnes (1984)
44480.354*	17	-1.145	1	present paper
44525.619*	18	-0.886	2	Eggen (1983b)
45652.558*	43	0.883	3	Berdnikov (1986)
46283.295*	57	1.524	3	Berdnikov (1987)

The behaviour of the period changes of this classical Cepheid continues to be very interesting. As it was pointed out in Paper III, erratic changes appear superimposed on the general parabolic trend of the O-C diagram. The new O-C residuals, as well as the earlier ones (corrected according to the new normal light curve) are listed in Table 106. The plot of these residuals shown in Figure 68 has been obtained with the elements:

$$C = \underset{\pm.181}{2443716.383} + \underset{\pm.0026}{45\overset{d}{.}0068} \cdot E \tag{77}$$

The parabolic fit, also shown in Figure 68 corresponds to the continuous period decrease:

$$P = \underset{\pm.0026}{45\overset{d}{.}0068} - \underset{\pm.12}{3\overset{d}{.}64} \cdot 10^{-4} \cdot E \tag{78}$$

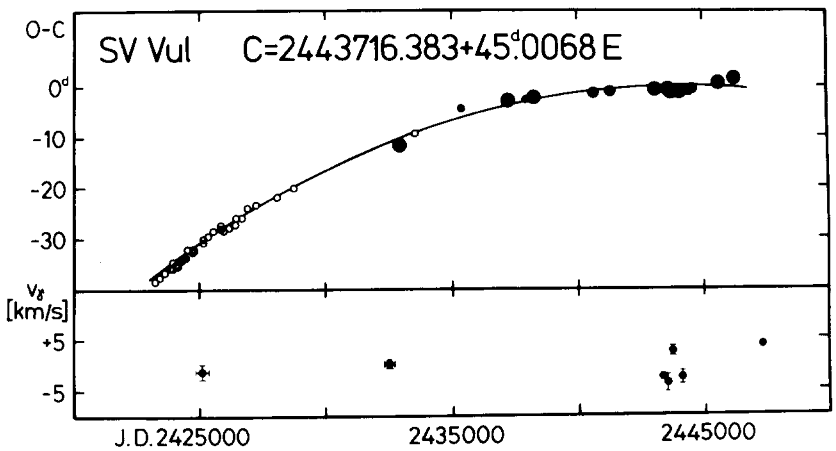

Figure 68. Upper panel: O-C diagram of SV Vul
Lower panel: γ-velocities for the same Cepheid

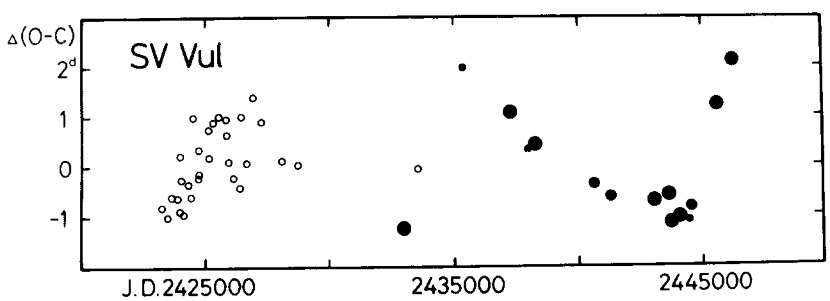

Figure 69. Δ(O-C) diagram of SV Vul

Table 107. γ-velocities of SV Vul

J.D. 2400000+	σ [d]	v_γ [km/s]	σ [km/s]	n	Reference
25121	249	-1.2	1.4	11	Joy (1937)
32503	181	0.4	0.8	15	Sanford (1956)
43336	63	-2.4	0.3	5	Fernie (1979a)
43502	5	-3.6	1.6	7	Wilson et al. (1989)
43709	75	2.7	1.0	15	Barnes et al. (1987)
44110	67	-2.5	1.2	11	Barnes et al. (1987)
47311	1	4.0	0.6	2	Samus (1990)

The deviation of the individual O-C residuals from this parabola, i.e. the Δ (O-C) diagram is shown in Figure 69. Figures 68 and 69 clearly indicate the commencement of a new positive deviation in the mid-eighties. The oscillation about the parabola seems to be cyclic with a cycle-length of slightly longer than ten thousand days (see also *Schröder*, 1978). The amplitude of this oscillation is considerable: it reaches 0.03 pulsation phase, and by no means is caused by the light-time effect. Since the recent deviation has not been taken into account in calculating the forthcoming maxima, the numerical data for SV Vul in Table 110 may be in error. Regular photometric study of SV Vul is desirable.

The γ-velocity values determined for SV Vul are collected in Table 107. Although the extreme values differ from each other by more than 7 km/s, the variability in the γ-velocity cannot be stated, because the extreme values have been determined from radial velocity data, either of poor quality or small in number.

GENERAL REMARKS

A considerable fraction of the Cepheids in this sample has been known to exhibit characteristic period changes. In order to achieve a more complete coverage in the O-C diagram, selected programme stars have been observed with the 50 cm Cassegrain telescope at Piszkéstető Mountain Station of Konkoly Observatory. This telescope is equipped with an integrating photoelectric photometer (containing an EMI 9058QB type multiplier) and standard UBV filters. The individual observational data are listed in Table 108. The mean error of these new photometric measurements is about $0^m.01$ in V and B, and somewhat larger in U. The observations have been transformed into the standard UBV system, but the data on V636 Cas are only differential magnitudes with respect to the comparison star BD+62°259.

Table 108. New photoelectric observations of selected Cepheids

FF Aql

J.D.Hel. 2440000+	V	B-V	U-B
3287.491	5.45	0.79	
3304.438	5.56	0.78	
3337.388	5.29	0.69	
3382.375	5.22	0.68	
3385.336	5.51	0.83	
3386.312	5.36	0.74	
3388.350	5.41	0.78	
3401.363	5.33	0.73	
3438.255	5.50	0.81	
3599.595	5.52	0.84	
3647.441	5.39	0.75	
3737.333	5.44	0.80	
3739.338	5.39	0.74	
3743.424	5.47	0.80	
3765.345	5.51	0.82	
3772.280	5.32	0.71	
3789.305	5.20	0.65	
3800.218	5.49	0.80	
6597.372	5.23	0.66	0.46
6612.424	5.50	0.80	0.47
6614.374	5.36	0.72	0.50
6652.382	5.45	0.79	0.64
6653.339	5.54	0.80	0.52

RW Cam

J.D.Hel. 2440000+	V	B-V	U-B
6466.268	8.32	1.21	0.90
6467.275	8.16	1.19	0.95
6489.364	8.67	1.48	1.02
6490.360	8.76	1.49	0.93
7174.467	8.28	1.29	0.95
7175.473	8.35	1.39	0.98
7443.581	8.84	1.51	0.92
7444.530	8.93	1.49	0.87

BY Cas

J.D.Hel. 2440000+	V	B-V	U-B
3382.524	10.13	1.23	
3420.472	10.36	1.21	
3425.456	10.48	1.36	
3426.433	10.48	1.33	
3437.474	10.23	1.12	
3489.328	10.26	1.30	
3490.319	10.59	1.37	
3572.247	10.24	1.25	
4108.530	10.51:	1.20:	
4143.422	10.29	1.21	
4157.406	10.62	1.31	
4159.392	10.37	1.10	

(BY Cas)

J.D.Hel. 2440000+	V	B-V	U-B
4162.493	10.24	1.19	
4166.325	10.43	1.28	
4167.490	10.61	1.30	
4203.302	10.54	1.19	
4251.285	10.62	1.30	

DD Cas

J.D.Hel. 2440000+	V	B-V	U-B
4874.397	10.26:	1.35:	
4972.244	10.09	1.34	
5229.432	10.25	1.30	
5259.352	10.15	1.30	
5294.352	9.91	1.21	

V636 Cas

J.D.Hel. 2440000+	ΔV	Δ(B-V)
5200.515	-0.322	0.832
5229.408	-0.293	0.800
5259.464	-0.311	0.823
7791.437	-0.294	0.896

IR Cep

J.D.Hel. 2440000+	V	B-V	U-B
7316.500	7.80	0.82	0.48
7387.529	7.65	0.75	0.51
7388.462	7.85	0.86	0.55
7438.233	7.65:	0.71:	0.46:
7438.385	7.62	0.73	0.52
7439.360	7.90	0.88	0.56
7439.439	7.91	0.89	0.53
7440.268	7.71	0.78	0.49
7441.236	7.82	0.84	0.55

SU Cyg

J.D.Hel. 2440000+	V	B-V	U-B
3304.451	7.15	0.69	
3337.375	6.73	0.58	
3351.527	6.65	0.49	
3363.513	6.45	0.42	
3375.464	6.66	0.48	
3388.415	7.03	0.68	
3401.387	6.84	0.54	
3403.325	6.98	0.65	
3424.256	7.05	0.61	
3440.234	6.46	0.41	
4372.461	7.01	0.63	

Table 108. (cont.)

J.D.Hel. 2440000+	V	B-V	U-B
		(SU Cyg)	
4402.459	6.73	0.55	
4455.393	6.45	0.41	
4458.535	7.16	0.63	
4811.391	7.15	0.67	
4822.436	7.01	0.63	
4840.386	6.54	0.46	
4862.346	7.18	0.61	
4870.303	6.96	0.58	
4874.308	6.75	0.51	
5200.451	7.19	0.70	
5224.376	6.59	0.44	
5229.331	6.76	0.55	
5259.286	6.46	0.40	
5294.273	6.58	0.47	
6222.490	7.06	0.70	0.46
6266.455	6.70	0.52	0.44
6268.445	7.02	0.69	0.45
6271.433	6.74	0.56	0.45
6387.241	6.90	0.64	0.45
6597.429	6.46	0.40	0.47
6652.413	6.84	0.63	0.49
6653.372	7.11	0.70	0.48
7791.361	7.05	0.69	0.43
7792.321	7.19	0.71	0.44

J.D.Hel. 2440000+	V	B-V	U-B
		DT Cyg	
3351.538	5.83	0.48	
3363.538	5.92	0.55	
3375.426	5.82	0.49	
3382.359	5.68	0.45	
3382.477	5.70	0.44	
3386.349	5.90	0.53	
3388.452	5.93	0.55	
3403.312	5.94	0.56	
3437.229	5.69	0.44	
3440.248	5.75	0.49	
3489.228	5.74	0.46	
3714.543	5.72	0.38	
3722.566	5.78	0.47	
3736.444	5.83	0.49	
3743.463	5.90	0.54	
3765.357	5.86	0.54	
3772.433	5.73	0.47	
3789.372	5.63	0.44	
3798.260	5.98	0.54	
4108.449	5.91	0.52	
4111.473	5.73	0.47	
4129.387	5.67	0.42	
4157.326	5.75	0.47	

J.D.Hel. 2440000+	V	B-V	U-B
		(DT Cyg)	
4159.271	5.66	0.42	
4166.277	5.80	0.50	
4215.191	5.83	0.50	
4458.423	5.92	0.51	
4486.328	5.76	0.44	
4811.473	5.71	0.42	
4822.468	5.86	0.51	
4840.417	5.93	0.55	

J.D.Hel. 2440000+	V	B-V	U-B
		V532 Cyg	
3353.552	9.23	1.14	
3375.562	9.08	1.12	
3382.460	9.18	1.14	
3388.498	9.05	1.09	
3401.451	8.96	1.06	
3403.349	9.11	1.08	
3437.297	8.92	0.99	
3440.262	8.94	0.99	
3476.218	8.88	1.01	
3481.227	9.25	1.14	
3489.218	8.97	1.02	
4108.486	9.30	1.19	
4111.589	9.23	1.18	
4113.401	8.91	1.06	
4157.350	9.15	1.15	
4162.418	9.02	1.07	
4166.338	8.94	1.06	
4173.267	9.05	1.10	
4203.267	9.30:	1.05:	
4811.503	9.25	1.15	
4822.498	8.90	1.05	
4840.439	9.23	1.14	
4862.391	9.02	1.07	
4870.347	9.27	1.17	
4874.347	9.14	1.16	
5224.403	9.19	1.19	
5229.359	8.94	1.08	
5259.316	8.93	1.06	
5294.318	9.22	1.12	
6268.511	9.14	1.12	
6387.309	9.26	1.15	
6652.496	9.10	1.13	
6653.475	9.24	1.17	
7388.421	9.20	1.15	
7438.346	9.25	1.14	
7439.405	8.93	1.01	
7443.435	8.99	1.04	
7444.328	9.21	1.17	
7791.339	8.94	1.04	
7792.353	9.20	1.17	

Table 108. (cont.)

J.D.Hel. 2440000+	V	B-V	U-B
			TX Del
4458.468	8.98	0.62	
4462.399	9.33	0.82	

J.D.Hel. 2440000+	V	B-V	U-B
			Y Lac
4458.516	8.99	0.68	

J.D.Hel. 2440000+	V	B-V	U-B
			CV Mon
6466.360	10.54	1.46	
6467.353	10.45	1.37	

J.D.Hel. 2440000+	V	B-V	U-B
			RS Ori
4633.470	8.69	1.14	
4637.453	8.11	0.87	
4661.392	8.23	0.96	

J.D.Hel. 2440000+	V	B-V	U-B
			SV Per
4633.448	8.99	1.19	
4661.358	9.04	1.02	

J.D.Hel. 2440000+	V	B-V	U-B
			VX Per
4638.304	9.07	1.18	
4661.299	9.11	1.13	

J.D.Hel. 2440000+	V	B-V	U-B
			AS Per
3385.570	9.33	1.45	
3420.592	9.47	1.44	
3423.588	9.93	1.61	
3424.576	9.12	1.28	
3437.460	9.85	1.67	
3458.651	9.70	1.56	
3481.315	9.72	1.56	
3490.492	9.49	1.52	
3546.247	9.79	1.55	
3560.415	9.54	1.58	
3572.261	9.98	1.72	
3598.293	9.28	1.36	

J.D.Hel. 2440000+	V	B-V	U-B
			AW Per
4633.429	7.86	1.22	
4637.427	7.42	1.14	
4661.337	7.07	0.93	
6466.321	7.41	1.09	0.73
6467.326	7.56	1.15	0.75
6489.403	7.63	1.09	0.68
6490.400	7.06	0.89	0.68
7174.389	7.73	1.13	0.71
7175.407	7.06	0.87	0.71
7443.568	7.64	1.18	0.79
7444.574	7.80	1.21	0.78

J.D.Hel. 2440000+	V	B-V	U-B
			S Sge
4811.440	5.65	0.86	
6597.447	5.74	0.93	0.78
6614.423	5.82	0.91	0.84
6652.399	5.32	0.61	0.53
6653.356	5.38	0.69	0.53
6691.254	5.98	0.98	0.83

J.D.Hel. 2440000+	V	B-V	U-B
			SZ Tau
4633.409	6.66	0.90	
4661.261	6.52	0.84	

J.D.Hel. 2440000+	V	B-V	U-B
			S Vul
4811.458	9.44	1.73	
4822.451	9.14	1.56	
4840.400	8.96	1.57	
4870.318	9.31	1.83	
4874.327	9.40	1.77	

J.D.Hel. 2440000+	V	B-V	U-B
			SV Vul
4455.426	7.32	1.70	
4458.550	7.41	1.72	

Table 109. New radial velocity measurements of selected Cepheids

Cepheid	J.D.Hel. 2440000+	radial velocity	σ [km/s]	number of lines	dispersion (Å/mm)
FF Aql	6727.269	-23.8 km/s	1.6	17	9
DT Cyg	5270.297	1.9	2.3	17	9
AW Per	6726.512	9.7	3.9	21	18
AW Per	6727.498	19.7	2.9	18	18
S Sge	6726.281	-12.9	2.4	22	9

Several spectrograms of binary Cepheids were also taken with the coudé spectrograph attached to the 2 m telescope of Rozhen Observatory (Bulgaria). The spectra were obtained at a dispersion of either 9 Å/mm or 18 Å/mm at H_{γ}. The individual radial velocity values are listed in Table 109.

A brief summary on the period, period changes and γ-velocity variations is compiled in Table 110. The subsequent columns of this table contain the following data:

1. Name of the Cepheid,
2. Moment of the normal maximum just following J.D. 2450000,
3. Pulsation period expected at J.D. 2450000. This value is calculated with the help of the corresponding (linear or parabolic) ephemeris published in the previous discussion on the given star,
4. Characteristic features in the O-C diagram,
5. Variability in the γ-velocity,
6. Value of the orbital period,
7. Reference to the paper where the value cited in the previous column has been published.

The use of J.D. 2450000 seems to be a reasonable compromise, because the extrapolation of the current elements for 1995 is not hazardous in the overwhelming majority of the cases. There are only eight stars (V572 Aql, BY Cas, DT Cyg, DX Gem, T Mon, VX Per, V440 Per, and SV Vul) in this sample, exhibiting either a quite recent period change or a deviation from the parabolic fit, that may cause some uncertainty in the prediction of the ephemeris.

The extension of the O-C diagrams to a larger time-base and the use of more accurate observations resulted in a different from the previous interpretation of the period changes in a number of cases. Instead of a single sudden period change (i.e. two linear sections in the O-C diagram) a continuous change in the period (i.e. parabolic O-C graph) is suggested for VZ Cyg, W Gem, RZ Gem, RR Lac, S Sge, and SW Tau.

The phase jump interpretation proposed in Papers I-III has been confirmed in most cases, and in additon, this phenomenon seems to have happened to some more Cepheids. The list of the northern Cepheids showing a phase jump in their pulsation is as follows: FF Aql, BY Cas, DD Cas, DL Cas, X Cyg, SU Cyg, SZ Cyg, DT Cyg, V532 Cyg, V924 Cyg, TX Del, DX Gem, X Lac, CV Mon, RS Ori, SV Per, SZ Tau, T Vul, X Vul. The phase jump appears most clearly in the case of FF Aql and SU Cyg, while its occurrence has to be confirmed in the case of some stars listed above (see Table 110). For FF Aql the phase shift has also been detected in the radial velocity data (*Evans* et al. 1990b). SU Cyg is unique in the respect that the phase jump was accompanied with a noticeable change in the shape of the light curve.

The phenomenon of the phase shift is a feature occurring in binary Cepheids, and its repeated occurrence in the same star (Y Oph in Paper IV, TX Del and T Vul in this paper) suggests that the jump is triggered by the orbital motion.

The orbital motion itself can be followed in the O-C diagram via the light-time effect. This phenomenon is best seen in AW Per, but may also be present in the O-C plot of FM Aql, RW Cam, Y Lac, and RS Ori. This latter Cepheid is especially important because RS Ori might be the first case of exhibiting a phase jump and the light-time effect in the same O-C diagram.

The alternating period changes on a time-scale of several years or decades can be attributed to solar type activity cycles (*Hall*, 1990). The present sample contains several Cepheids showing quasi-cyclic changes in the pulsation period, viz. ζ Gem, T Mon, S Vul, and SV Vul. Although the number of Cepheids forming this group is small, it may be significant that the shortest pulsation period for a member is longer than 10 days. A problem to be solved in the future is the differentiation between the phase slip (a slower or more gradual phase jump) and the alternate period changes due to magnetic effects. The solar type activity cycle does not necessitate the duplicity of the star involved, although a companion star usually strengthens the activity.

The analysis of the radial velocity observations has resulted in revealing a number of new spectroscopic binary Cepheids or candidates. The most promising cases are: KL Aql, η Aql, SU Cas, V636 Cas, BZ Cyg, MW Cyg, V386 Cyg, W Gem, RZ Gem, AD Gem, RS Ori, SV Per, SW Tau, T Vul, U Vul. An attempt was made to find the value of the orbital period for Cepheids with ample radial velocity data, but each spectroscopic period derived here has to be confirmed with the help of additional measurements.

Table 110. Summary on the periods, period changes and duplicity

Cepheid	Norm.max. 2400000+	Period [d]	O-C graph	v_{γ}	P_{orb} [d]	Source
SZ Aql	50012.262	17.141745	parabolic (+)	?		
TT Aql	50000.687	13.754954	linear	var.?		
FF Aql	50004.063	4.470936	lin. with PHJ	var.	1430	Evans et al. (1990)
FM Aql	50003.142	6.114265	linear (+LTE?)	const.?	2800 ?	this paper
KL Aql	50002.539	6.108015	linear	var.	short	this paper
V 572 Aql	50000.287	3.768001	linear (?)	-		
V 1344 Aql	50000.187	7.476787	linear	var.?		
η Aql	50000.175	7.176758	parabolic (+)	var.	926 ?	this paper
RT Aur	50000.279	3.728198	linear	const.		
AN Aur	50003.628	10.289563	linear	var.		
RW Cam	50012.740	16.415015	lin. with LTE or PHJ	var.	7000 ?	this paper
SU Cas	50000.720	1.949325	linear	var.	462.5 ?	this paper
SZ Cas	50009.120	13.645356	parabolic (+)	var.?		
BY Cas	50000.908	3.222199	lin. with PHJ	?		
DD Cas	50001.805	9.811656	lin. (+ PHJ?)	var.?		
DL Cas	50004.712	8.000598	lin. with PHJ	var.	688.0	Harris et al. (1987)
IX Cas	50003.203	9.154549	irregular	var.	110.29	Harris and Welch (1989)
V 636 Cas	50005.366	8.375735	linear	var.		
IR Cep	50000.719	2.114088	linear (+EPCH)	one		
V 351 Cep	50000.179	2.806052	linear (+EPCH)	-		
X Cyg	50007.657	16.385692	lin. with PHJ	var.?		
SU Cyg	50000.682	3.845512	lin. with PHJ	var.	549.16	Evans (1988)
SZ Cyg	50000.868	15.110228	lin. with PHJ	var.		
TX Cyg	50003.317	14.711635	linear (+EPCH)	var.?		
VZ Cyg	50004.454	4.864372	parabolic (-)	var.?		
BZ Cyg	50001.523	10.142222	linear	var.		
DT Cyg	50002.270	2.499086	lin. with PHJ	var.		
MW Cyg	50004.005	5.954666	linear	var.		
V 386 Cyg	50001.131	5.257635	linear	var.		
V 532 Cyg	50000.792	3.283494	lin. with PHJ	var.?		
V 924 Cyg	50002.268	5.571305	lin. with PHJ	-		
V 1334 Cyg	50002.920	3.332804	linear	var.	<1240	this paper
V 1726 Cyg	50003.570	4.236978		one		
TX Del	50000.932	6.165904	lin. (+ PHJ?)	var.	133.15	Harris and Welch (1989)

Table 110. (cont.)

Cepheid	Norm.max. 2400000+	Period [d]	O-C graph	v_γ	P_{orb} [d]	Source
W Gem	50003.897	7.913277	parabolic (-)	var.		
RZ Gem	50002.248	5.528942	parabolic (-)	var.	886 ?	this paper
AD Gem	50002.061	3.787990	linear	var.		
DX Gem	50001.290	3.136779	lin. with PHJ	var.?		Burki (1985)
ζ Gem	50007.231	10.149414	parabolic (-)	var.?		
V Lac	50000.245	4.983002	parabolic (-)	var.?		
X Lac	50000.890	5.444322	lin. with PHJ	var.?		
Y Lac	50000.797	4.323769	linear	var.?		
Z Lac	50000.760	10.885600	parabolic (-)	var.	short	this paper
RR Lac	50001.448	6.416335	parabolic (+)	var.		
BG Lac	50004.552	5.331902	linear	var.?		
T Mon	50025.601	27.020097	lin. on par. (+)	var.	very long	Gieren (1989b)
SV Mon	50009.142	15.232582	linear	const.		
CV Mon	50002.177	5.378804	lin. with PHJ	one		
V 465 Mon	50000.505	2.713006	linear (+EPCH)	var.		Burki (1985)
RS Ori	50001.701	7.566841	lin. with LTE and PHJ	var.	long ?	this paper
GQ Ori	50001.590	8.616283	linear	one		
SV Per	50004.946	11.129319	lin. (+ PHJ?)	var.		
VX Per	50008.306	10.886972	linear (+EPCH)	const.		
AS Per	50003.220	4.972540	linear	one		
AW Per	50000.041	6.463622	lin. with LTE	var.	13100	Welch and Evans (1989)
V 440 Per	50003.336	7.572498	linear (?)	const.		
S Sge	50004.834	8.382184	parabolic (+)	var.	676.2	Slovak and Barnes (1987)
SW Tau	50001.443	1.583540	parabolic (-)	var.		
SZ Tau	50001.329	3.149138	lin. with PHJ	var.?		
S Vul	50038.692	68.500	lin. sections	?		
T Vul	50003.860	4.435453	lin. with PHJ	var.	1745	this paper
U Vul	50005.698	7.990821	linear (+EPCH)	var.	868 ?	this paper
X Vul	50002.860	6.319490	lin. (+ PHJ?)	var.		
SV Vul	50013.768	44.9558	parabolic (-)	const.?		

Legend: LTE : light-time effect
PHJ : phase jump(s)
EPCH : earlier period change(s)
one : only one series of radial velocity data
(+) and (-) : continuous period increase or decrease
? : poorly covered radial velocity curve, the γ-velocity cannot be determined
- : radial velocity observations have not been made

A new method, independent from the previously used ones, has been proposed for revealing the presence of a companion. This evidence is based on the amplitude ratio of the light and radial velocity variability (see V440 Per).

The new discoveries and uncertainties confirm the fact that there is a huge number of Cepheid variables deserving regular attention (photometric and radial velocity studies), and/or occasional close inspection in the form of a detailed spectroscopic analysis.

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Abstract

Photoelectric photometry of RU Cam was carried out at Konkoly Observatory on 1343 nights between 1966 and 1982. 1453 observations both in V and B and 30 observations in U have been published. Using all available data the period and light curve changes of the star have been investigated. A slight continuous period decrease took place between 1907 (P = 22.19 days) and 1965 (P = 22.07 days). After 1965 the period has become very unstable and fluctuated between 17.4 and 26.6 days. It happened several times (probably at irregular time intervals) that after a short-lived recovery phase the amplitude decreased again and the light variation almost disappeared. The light curve also showed that there were time intervals when the light varied irregularly and the count of epoch numbers became very uncertain.

The photoelectric data obtained in the years 1965–1982 have been Fourier-analysed. There was no indication for modulation effects. A number of peaks appeared in the spectrum around f = 0.046 cycle/day suggesting that stochastic or chaotic characters have become dominant in the star's pulsation.

1. Introduction

Although the peculiar behaviour of RU Camelopardalis was known before 1966, it was regarded as a normal Population II Cepheid. The only strikingly abnormal characteristics in its spectrum discovered as early as in 1919 (*Joy*, 1919, *Cannon*, 1920) was that the carbon features were clearly marked. Its spectral type at minimum light was R0 (*Sanford*, 1927, 1928) or $C6_2$ (*Keenan and Morgan*, 1941) or $C3_2e$ (*Bidelman*, 1954), while at maximum light it was close to K0. The hydrogen lines were in emission near median magnitude on the rising branch of the light curve and at velocity maximum between the 3^{rd} and 6^{th} days after minimum light (*Sanford*, 1928; *Jehoulet*, 1954; *Climenhaga*, 1960). The radial velocity measurements showed evidence of stratification effects and the presence of an expanding chromosphere was indicated by the high negative velocity of the emission components of CaII H and K (*Faraggiana and Hack*, 1967a, b). In spite of the fact that RU Cam is a Population II star, it is not metal poor, the metal abundance is almost normal, with a slight excess of a factor of 2 or 3 for Ca, Ti, V, Ni and the rare earths with respect to Fe. The star is not H poor either and the excess of carbon is not larger than 2 or 3 (*Faraggiana and Hack*, 1967b). The high abundance of C^{13} (relative to C^{12}) (*Faraggiana and Hack*, 1967b; *Climenhaga*, 1960) produced by the carbon cycle indicates that RU Cam is in an advanced evolutionary state.

In the beginning of 1966 *Demers and Fernie* (1966) reported that they were unable to detect light variations in RU Cam exceeding 0.1-0.2 mag but the star was apparently still unstable with irregular fluctuations of the order of 0.2 mag. This observation initiated a series of speculations about ceasing pulsation in RU Cam. Since the star showed strong irregular changes in the past, too, there was some suspicion that the star did not stop pulsating, only the amplitude of its light variation decreased temporarily. *Detre* (1966) even suggested cyclic amplitude variations and predicted the increase of amplitude. Following *Demers and Fernie*'s announcement photoelectric photometry of RU Cam was commenced at some observatories (*Wamsteker*, 1966, 1968; *Cester*, 1967, 1968, 1969; *Broglia*, 1967, 1969; *Broglia and Guerrero*, 1969a, b, 1971, 1972a, b, 1973; *Broglia et al.*, 1978, *Fernie and Watt*, 1967; *Fernie*, 1968; *Zaitseva*, 1967, 1968; *Zaitseva and Ljutiy*, 1969, 1971, 1978; *Zaitseva et al.*, 1973, *Kovalenko*, 1974), in order to investigate the peculiar behaviour of the star. The photoelectric observations at Konkoly Observatory were started in August, 1966.

As to a brief historical overview, the light variability of RU Cam (BD +69°417 (8.5) = HD 56167 (K0) = 2.1907) was discovered by *Mme L. Ceraski* on *Blazhko*'s plate collection obtained between 1899-1906 (*Ceraski*, 1907). Using his visual estimates of 1907 and photographic observations obtained in the years 1904-1906, *Blazhko* (1907) determined the period of light variation and gave the elements for maximum light:

$$\text{Max.} = \text{J.D. } 2417620.0 + 22\overset{d}{.}27 \times \text{E}.$$

Luizet (1907, 1912), *Ichinohe* (1909), *Shapley* (1913), *Silva* (1922), *Leiner* (1923, 1929), *Haas* (1923), *Edelberg* (1932), *Florja and Kukarkina* (1953), published visual or photographic estimates, while *Lenouvel and Jehoulet* (1953), *Lenouvel and Dagouillon* (1954), *Eggen et al.* (1957), *Lenouvel and Fiogère* (1957), *Delsemme and Delsemme-Jehoulet* (1958), *Michalowska-Smak and Smak* (1965), *Mitchell et al.* (1964), *Williams* (1966) and *Smak* (1966) published photoelectric observations of RU Cam obtained prior to *Demers and Fernie*'s announcement.

Leiner (1923) already suspected that the light curve of RU Camelopardalis varied from cycle to cycle and the period of the star was also changing. Further investigations (*Haas*, 1923; *Leiner*, 1929; *Edelberg*, 1932; *Nielsen and Sjögren*, 1943) confirmed this suspicion.

Although the star was included in the general list of Cepheid variables, *Robinson* (1933) called the attention to the peculiarities of RU Cam in its spectrum, light curve, period and radial velocity. He supposed that between these peculiarities certain interrelationships existed but did not see any reason to exclude this star from the list of Cepheids. *Payne-Gaposchkin* (1941) noted that W Virginis resembled RU Cam in the shape of light curve, the variation of period, the correspondence between light and velocity curves, and the occurrence of bright lines at and following the minima.

The complex character of the variability of RU Cam during the 50's and early 60's was traced back on Sonneberg archival plates (*Huth and Wenzel*, 1966; *Huth*, 1966, 1967) and *Huth* ascertained that the light amplitude of the star might undergo considerable changes within several months. The large irregularities in the light variation of this object were obvious from a mere visual inspection of the time series of its luminosity, and it was also clear that the cycle length was also undergoing irregular fluctuations.

Parallel with the irregular behaviour of the light variation the radial velocity changes of the star showed complex character (*Demers and Crampton*, 1966; *Wallerstein and Crampton*, 1967). During the period when the amplitude was smaller than 0.05 mag, no emission lines were visible in the spectrum of the star and its radial velocity seemed to be constant and approximately equal to *Sanford*'s gamma velocity (*Sanford*, 1928). *Wallerstein* (1968) investigated the atmospheric parameters of the star during this "quiescent" period in the early 1965. *Lloyd Evans* (1983) suggested that there might be a possible connection between extreme irregularity and the occurrence of an overabundance of carbon in RU Cam.

2. Observations

The photoelectric photometry of RU Camelopardalis was started by *L. Detre* and one of the authors of the present paper (*Detre and Szeidl*, 1967) at Konkoly Observatory on August 10, 1966. The observations were carried out by the observatory's 24 in. telescope at Budapest and by the 20 in. telescope at Piszkéstető Mountain Station.

At Budapest the photometer was equipped with an unrefrigerated EMI 9502B photomultiplier and Schott filters UG1 for the U, BG12+GG13 for the B and GG11 for the V band and was placed at the Newtonian focus (f/6) of the 24 in. telescope. Since 1972 photoelectric observations have also been obtained by the 20 in. Cassegrain telescope (f/15) at Piszkéstető. At this location we used an integrating photometer equipped with an unrefrigerated EMI 9058QB photomultiplier and the following Schott filters: UG2 in U, BG12+GG13 in B and GG11 in V.

BD +70°448 was used as the main comparison star. Several other stars were also observed in order to check the constancy of the main comparison and to determine the transformation coefficients. Tie-in observations of the comparison stars were made on six nights and Table 1 presents the results of these observations. Their errors are about 0.01 mag in V and B and 0.03 mag in U.

Table 1

Brightness and colours of the comparison stars

star	V	$B-V$	$U-B$
BD +69°420 = HD 57201 (F8)	8.906	+0.506	+0.055
BD +69°422 = HD 57308 (G0)	8.021	+0.801	+0.487
BD +70°447 = HD 56323 (F5)	9.056	+0.326	+0.072
BD +70°448	9.059	+1.090	+0.934

In order to get a judgement about the accuracy of the brightness and colours of the main comparison star all these values obtained by different observers for BD +70°448 are collected in Table 2. The agreement between the different observers is fairly good.

During 1343 nights 119, 7597 and 7597 observations were made in U, B and V, respectively at Konkoly Observatory. The observations have been corrected for atmospheric extinction and transformed into the UBV system in the traditional way. Each observing run mostly consisted of six observations which were composed into normal values. In this way 30 normal points were obtained in U and 1453 normal values in both B and V.

Table 2

Magnitudes and colours of BD +70°448 in other studies

V	$B-V$	$U-B$	source
9.09	+1.10	+0.98	Lenouvel & Fiogère, 1957
9.058	+1.092	+0.972	Michalowska-Smak & Smak, 1965
9.09	+1.09		Cester, 1967
9.083	+1.077	+0.957	Fernie & Watt, 1967
9.090	+1.089		Cester, 1968

The B and V normal values are given in Table 3 and the U values in Table 4 (see on pages 273–300). The Julian Dates of the observations obtained at Piszkéstető are marked by asterisks. Tables 3 and 4 also present the number of observations (n), the r.m.s. errors, the $B-V$ colour indices and the average zenith distance at the observations. In order to cover the light curve of RU Camelopardalis as fully as possible, the star was observed during the nights of poor quality, as well, and this circumstance explains the lower precision of some of the normals.

During the period of our observations (J.D.2439348 – 2445260) photoelectric photometry of RU Cam was carried out at other observatories, as well. Since there are a number of common nights of observation our photometry can be compared with that of others. While comparing the observations we supposed that the changes in brightness of RU Cam during a night may be neglected.

We have 243 common nights of observation in V and 204 in B with *Broglia et al.*, (*Broglia*, 1969; *Broglia and Guerrero*, 1969b, 1972a, 1973; *Broglia, Conconi and Guerrero*, 1978). They used the same comparison star as we did but they accepted *Lenouvel and Fiogère*'s (1957) magnitudes and colours for it. Taking into account the differences in the accepted magnitudes of the comparison star we came to the conclusion that the average systematic differences (zero point shifts) between *Broglia et al.*'s and our observations in V and B are:

$$\overline{\Delta V} = n^{-1}\sum \Delta V_i = -0.0002 \text{ mag}, \qquad \sigma(V) = \sqrt{(n-1)^{-1}\sum(\Delta V_i)^2} = 0.0125,$$

$$\overline{\Delta B} = n^{-1}\sum \Delta B_i = 0.0000 \text{ mag}, \qquad \sigma(B) = \sqrt{(n-1)^{-1}\sum(\Delta B_i)^2} = 0.0147.$$

The distributions of the ΔV_i and ΔB_i values are nearly normal and are shown in Figure 1. The above results indicate that our observations fit in well with that of *Broglia et al.*

A comparison with *Cester*'s (1968, 1969) observations led to a similar result. There were 38 and 39 common nights of observation in V and B, respectively. The zero point shifts between his and our V and B are:

$$\overline{\Delta V} = +0.0007 \text{ mag}, \quad \sigma(V) = 0.0148,$$

$$\overline{\Delta B} = +0.0038 \text{ mag}, \quad \sigma(B) = 0.0212.$$

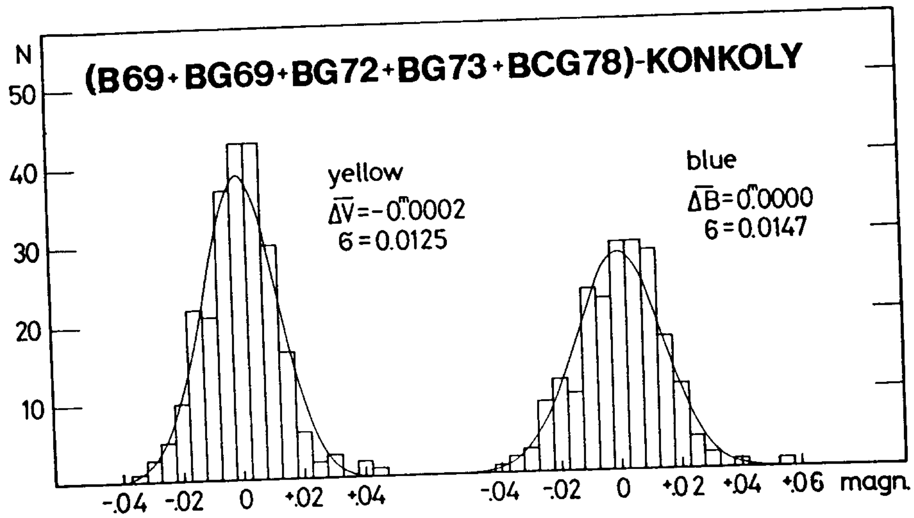

Figure 1. The distribution of the ΔV_i and ΔB_i values

The conformity between *Cester*'s and our observations in V is also good, however in B it is not quite satisfactory, but still acceptable. The comparison of *Cester*'s and *Broglia et al.*'s observations resulted in the same conclusion.

Wamsteker (1968) observed the star only in yellow light and had 11 common nights of observation with us. Comparing his observations to ours an average difference of:

$$\overline{\Delta V} = -0.0035 \text{ mag}, \qquad \sigma(V) = 0.0061$$

can be deduced in the characteristic parameters. These values indicate that *Wamsteker*'s photometric system is close to ours.

Fernie (1968) published 50 observations in V, and 49 ones in B (one of them, on J.D. 2439646 may be misprinted in his Table). There were 14 common nights of observation in V and 13 in B. The comparison to our observations gave the following results:

$$\overline{\Delta V} = +0.0091 \text{ mag}, \qquad \sigma(V) = 0.0204,$$

$$\overline{\Delta B} = -0.0137 \text{ mag}, \qquad \sigma(B) = 0.0263.$$

The difference between *Fernie*'s and our photometric systems is significant, although the discrepancy can partly be attributed to the fact that the times of observation of the common nights usually differed by more than eight hours.

Zaitseva and Ljutiy (*Zaitseva*, 1967, 1968, *Zaitseva and Ljutiy*, 1969, 1971, 1978) observed the star between 1966 May and 1975 May on 206 nights of which 95 were common with ours. The comparison of the observations of the common nights resulted in:

$$\overline{\Delta V} = +0.0154 \text{ mag}, \quad \sigma(V) = 0.0209,$$

$$\overline{\Delta B} = -0.0025 \text{ mag}, \quad \sigma(B) = 0.0230.$$

The differences between the two photometries are rather large, both significant systematic and large random differences occur.

To sum up the discussion about the photometries carried out during the time interval covered by our observations we conclude that *Broglia et al.*'s, *Cester*'s and *Wamsteker*'s photometry is in accord with ours, while *Fernie*'s (and co-workers') as well as *Zaitseva and Ljutiy*'s photometry differs from ours rather significantly. Therefore the latter two photometries are only used in the further discussion for lack of other photoelectric observations. Figure 2a-i presents our V observations (dots) and those of *Broglia* et al., *Cester and Wamsteker* (crosses).

3. Period changes and discussion

Since the discovery of the variability of RU Cam a great number of visual, photographic and photoelectric observations have been collected for the star. As the light minima are sharp and usually well-defined unlike the light maxima which are broad and blunt, the period changes of the star can be examined more exactly from the times of minima. Table 5 contains all the available times of minima prior to the remarkable amplitude decrease in early 1965. The $\mathrm{O}-\mathrm{C}_1$ values are computed by the formula:

$$\mathrm{C}_1 = \mathrm{J.D.}\ 2417610.5 + 22\overset{\mathrm{d}}{.}16 \times \mathrm{E}_1.$$

Although changes in the period (either abrupt or smooth) occurred several times, but on the average, the period P = 22.16 days held on during the time interval J.D. 2412868 – J.D. 2438680 (1874 February - 1964 October). The $\mathrm{O}-\mathrm{C}_1$ residuals are plotted against time in Figure 3. The abrupt changes in the period might occur at around J.D. 2421000, J.D. 2423000, J.D. 2426300, J.D.2434500 and J.D. 2437000 (see the study of period changes in detail by *Huth*, 1967), though continuous and/or erratic changes cannot be excluded. Moreover, *Leiner* (1929) found jumps in the phase of minima. He observed a phase shift of 1 1/2 days at the end of 1922. If we assume that the period fluctuations $(P_i - \overline{P})$ may be regarded as random variables with zero mean and that the stochastic process is stationary, the O−C diagram consisting of cycles of different lengths and amplitudes can take its origin from the accumulation of random fluctuations in the period (e.g. *Sterne*, 1934, or *Balázs-Detre and Detre*, 1966). By all means, however, a systematic period decrease can be presumed from 1907 (P = 22.19 days) till 1965 (P = 22.07 days).

The photoelectric observations made at Konkoly Observatory and those available in the literature were used to determine the moments and magnitudes of light minima and maxima for the V band. In order to derive the times and magnitude values as accurately as possible, parabolas were fitted to the observations around minima and maxima. The results are given in Table 6 and Table 7, respectively.

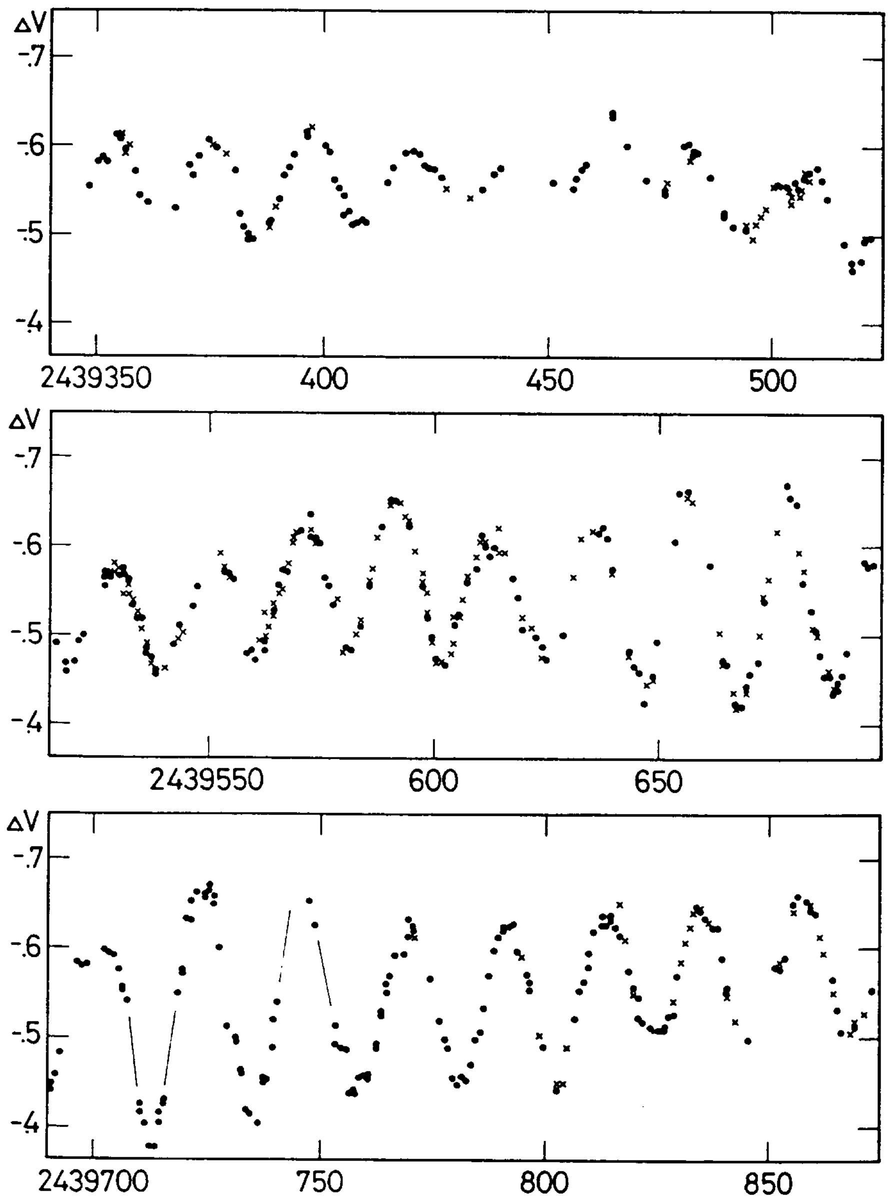

Figure 2a. Photoelectric V observations (dots: Konkoly observations)

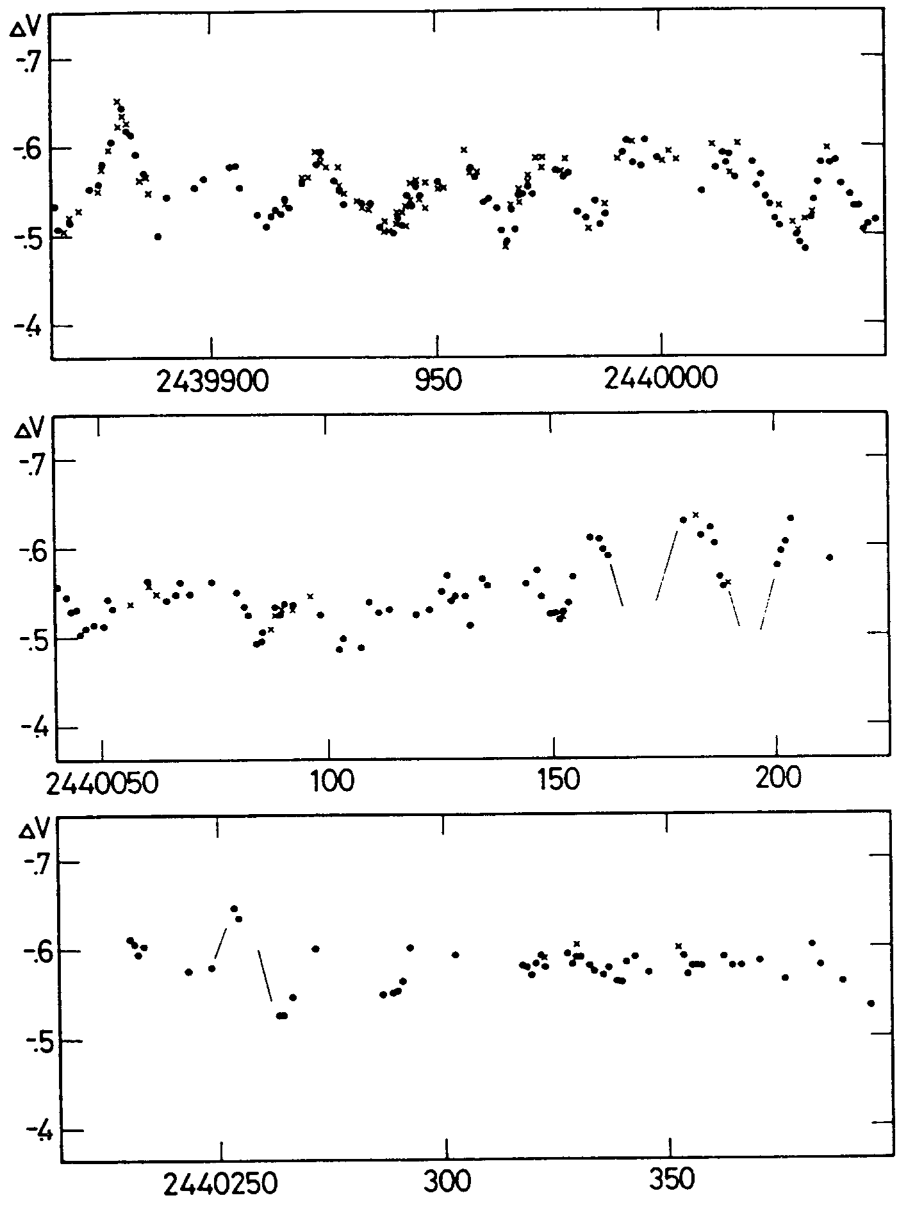

Figure 2b. The same as Fig. 2a.

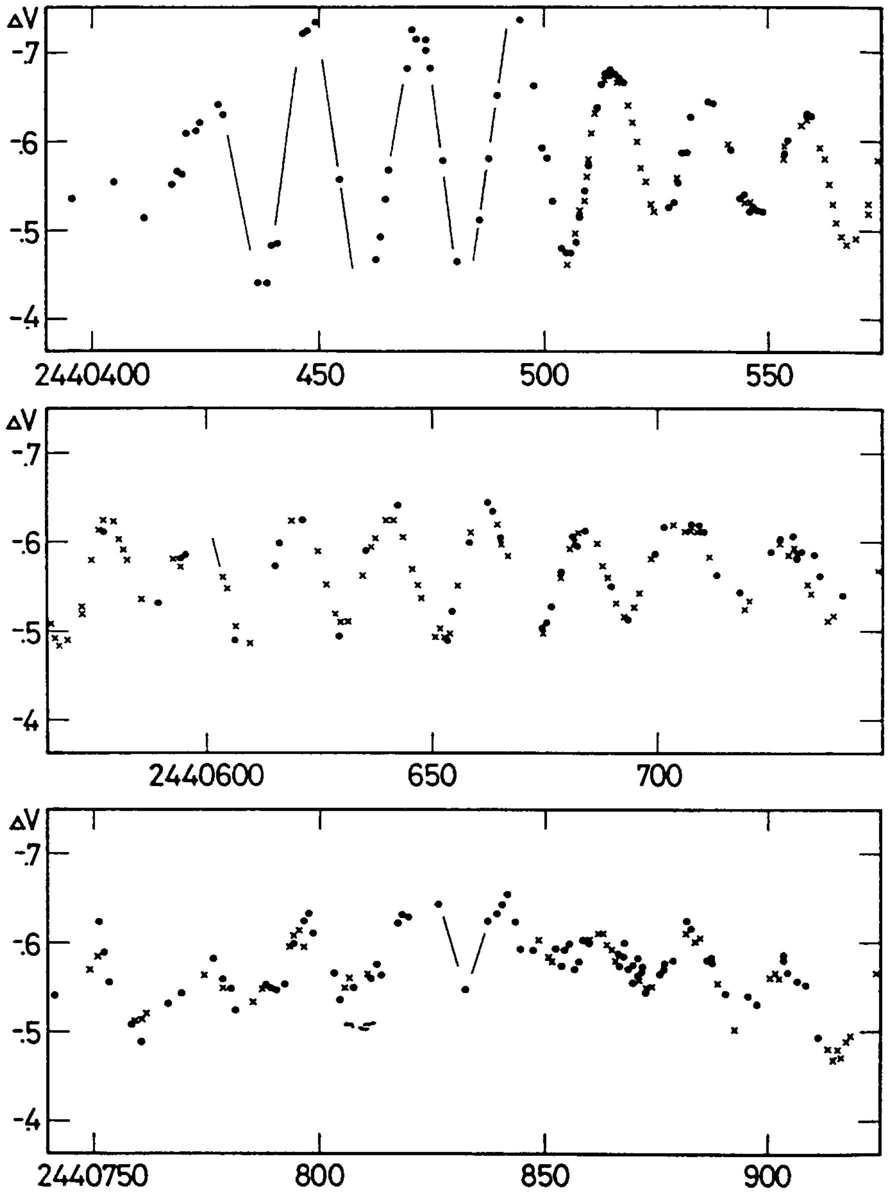

Figure 2c. The same as Fig. 2a.

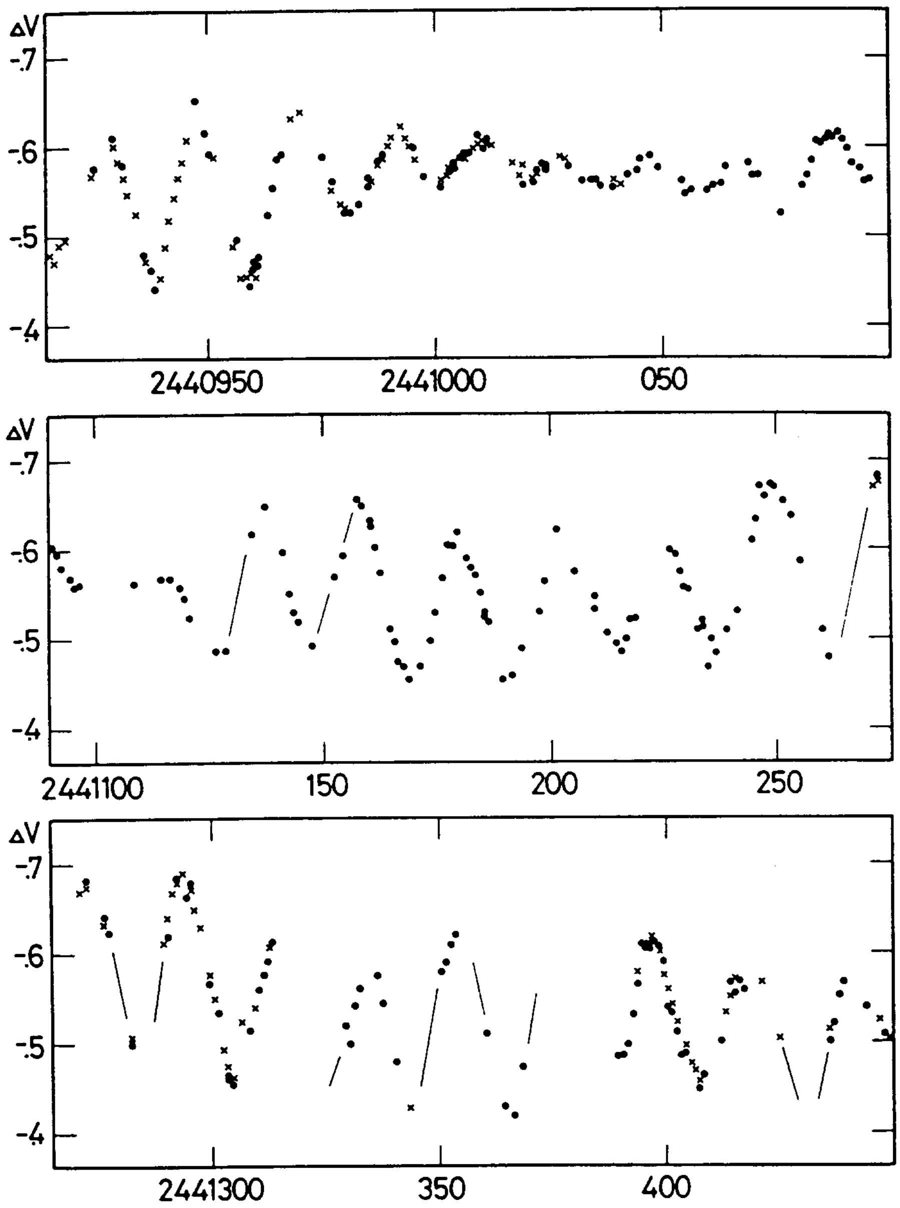

Figure 2d. The same as Fig. 2a.

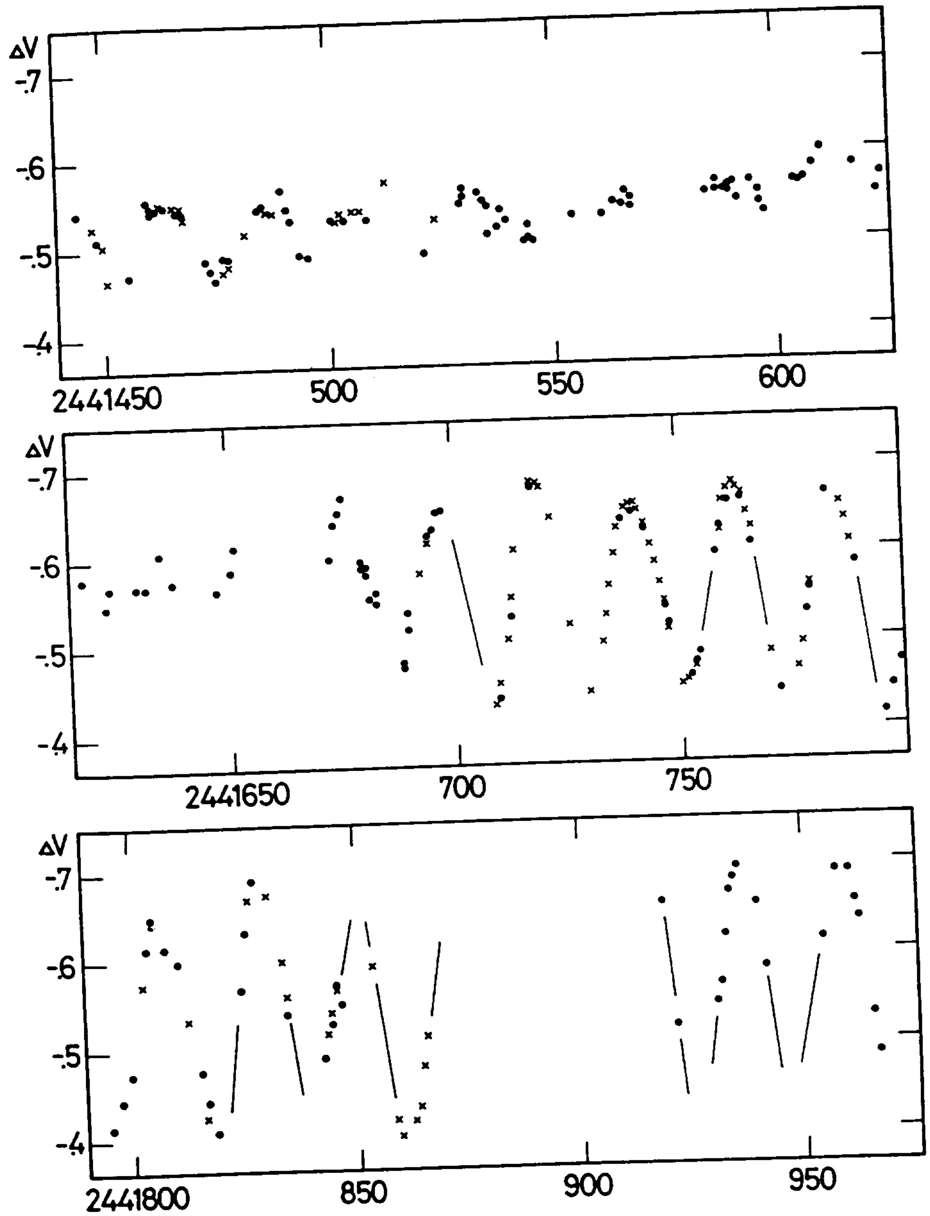

Figure 2e. The same as Fig. 2a.

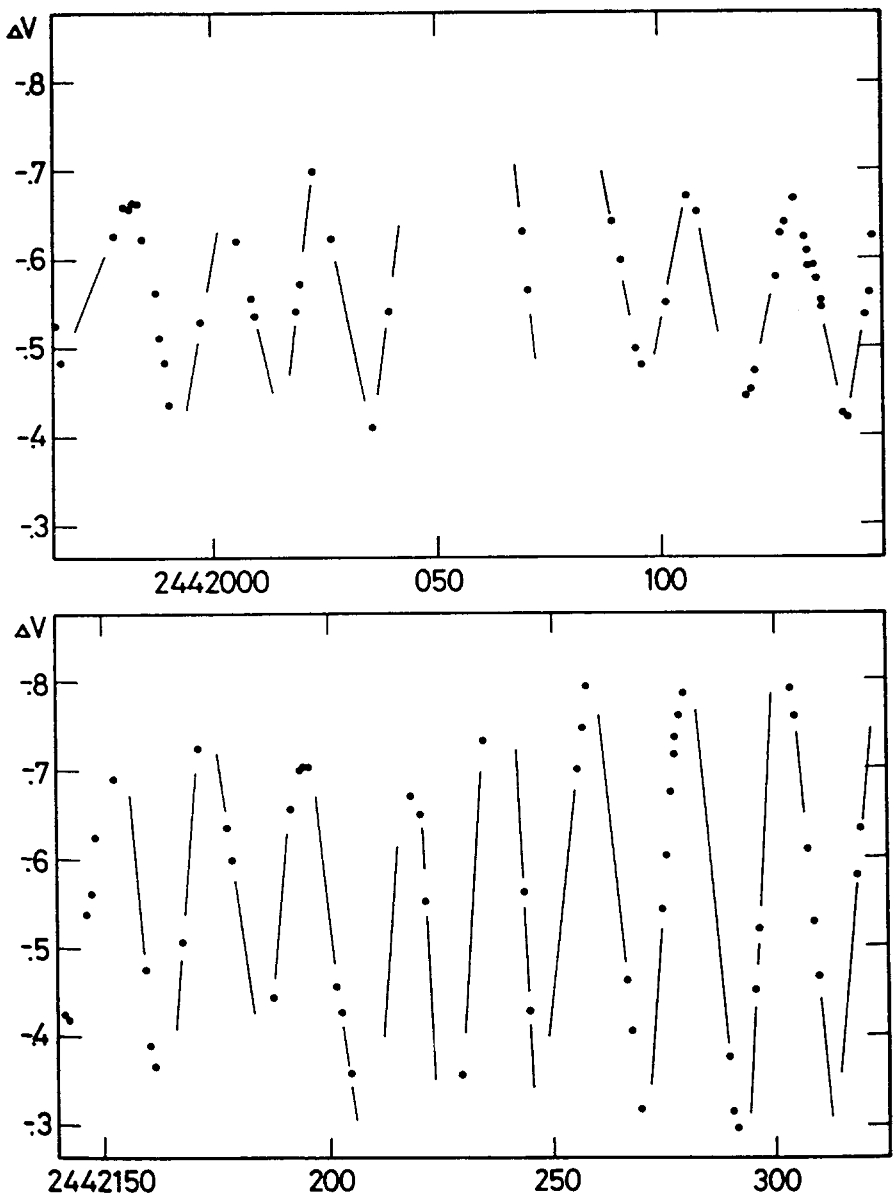

Figure 2f. The same as Fig. 2a.

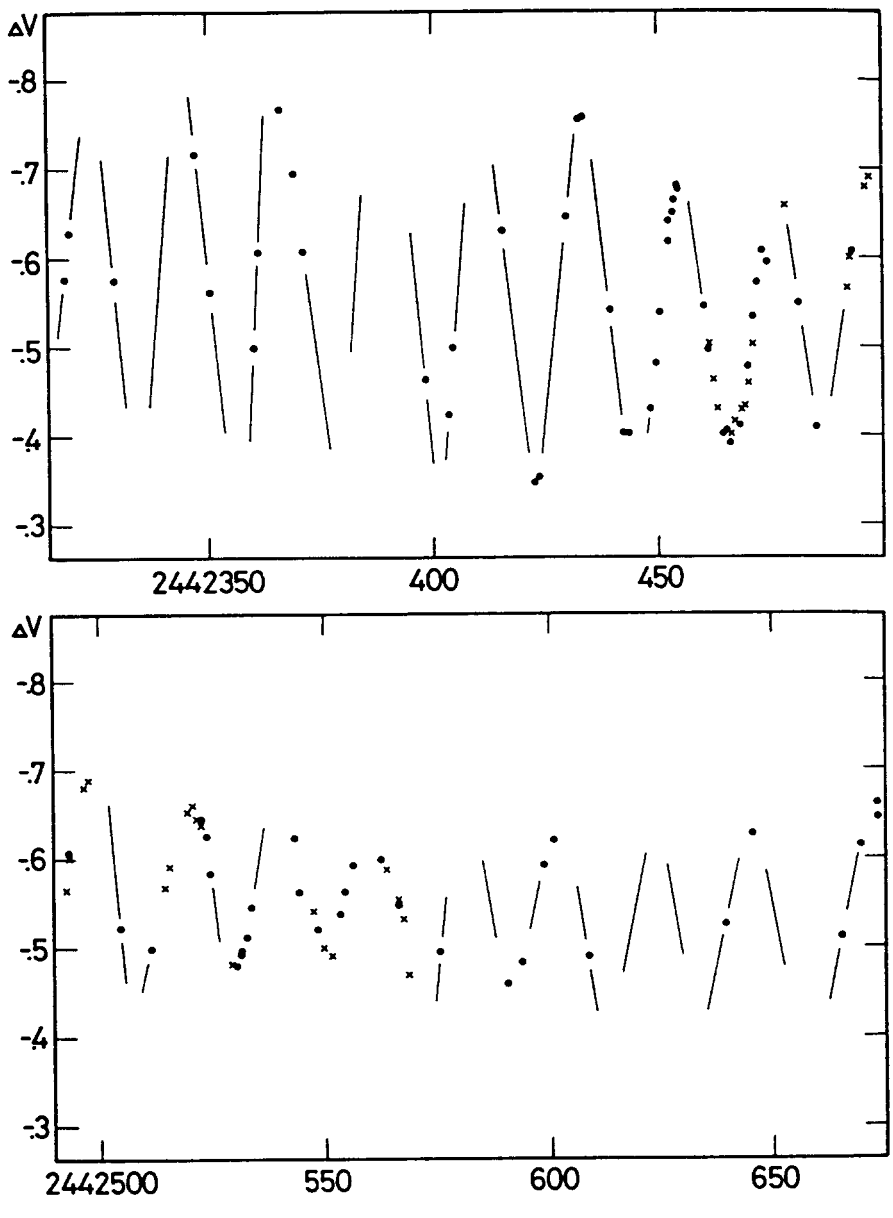

Figure 2g. The same as Fig. 2a.

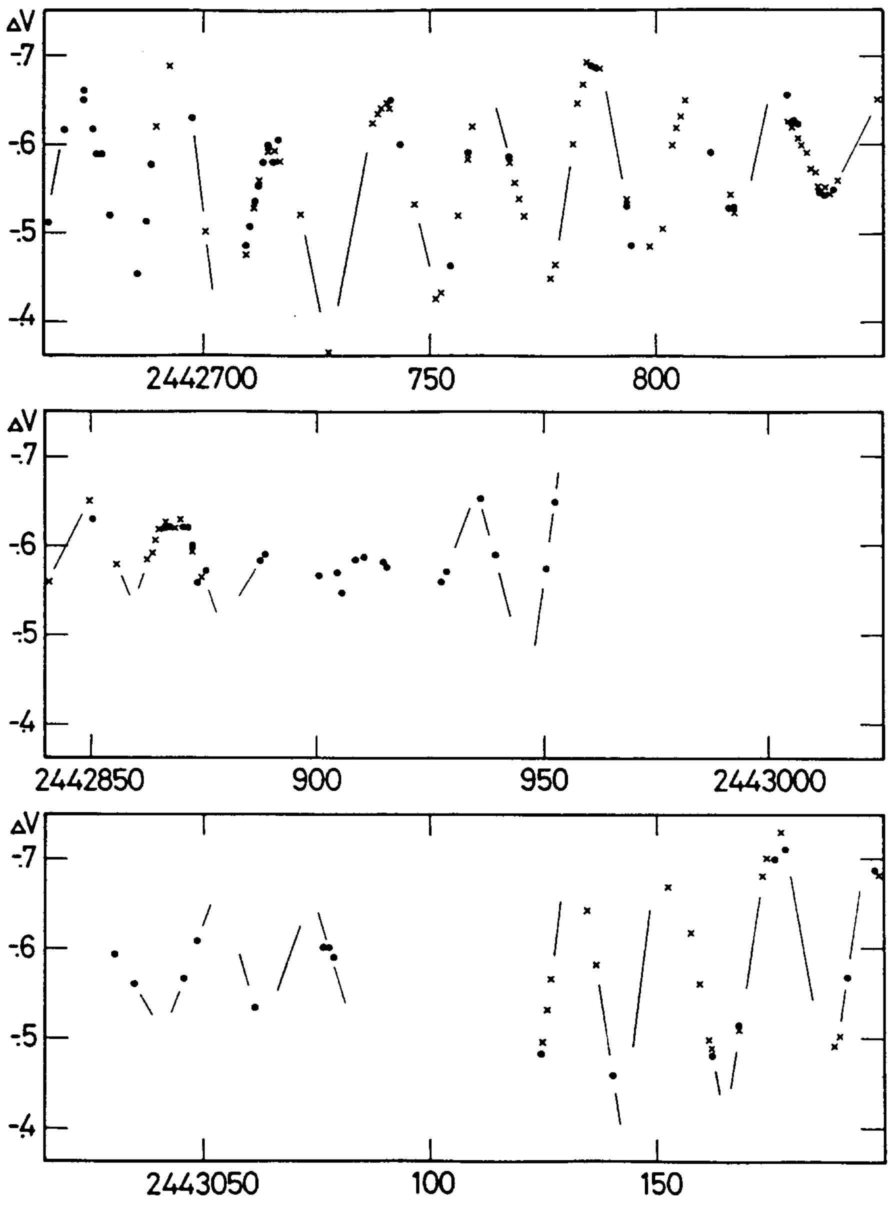

Figure 2h. The same as Fig. 2a.

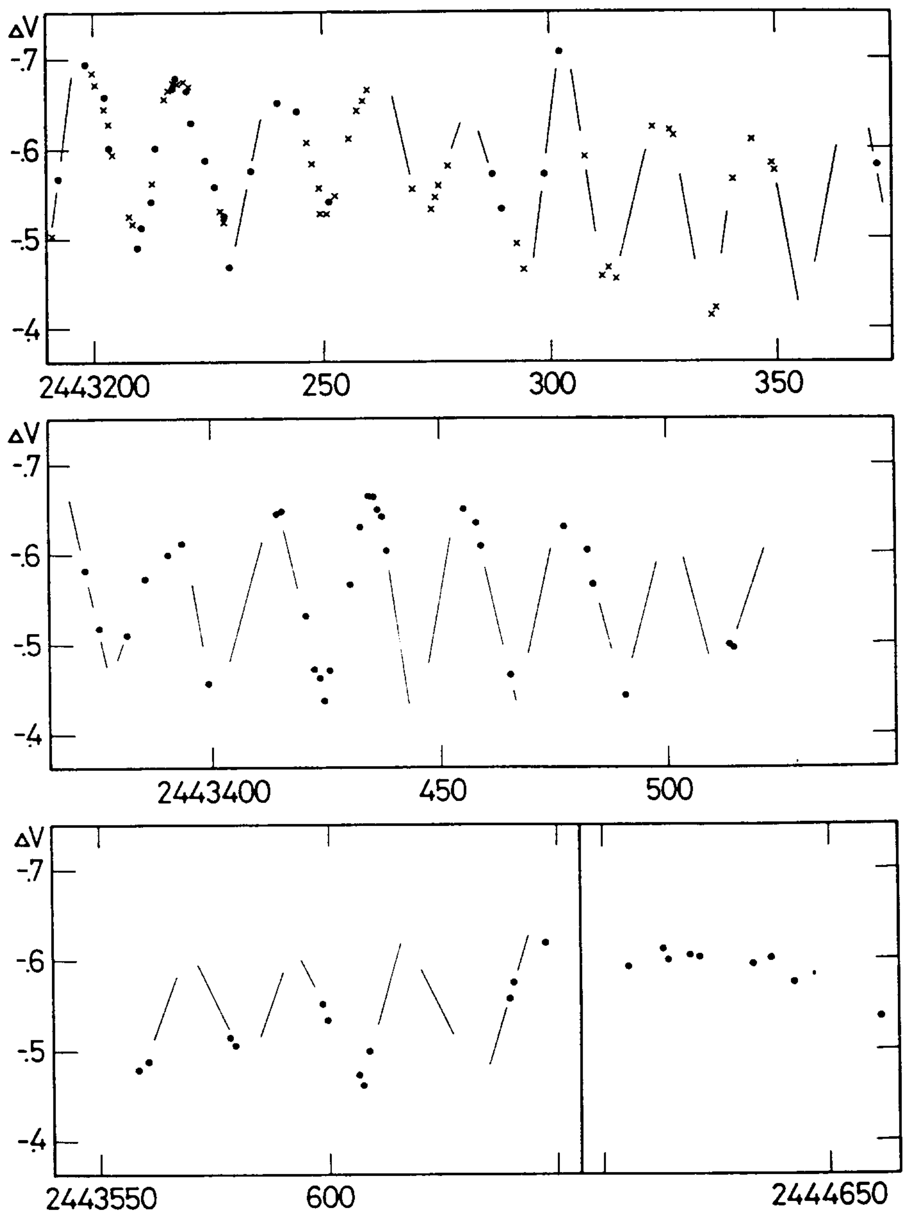

Figure 2i. The same as Fig. 2a.

Table 5

Times of minima prior to the amplitude decrease of 1965

t_{min} 2400000+		E_1	$O-C_1$	References
12868	v	−214	−0.3	K07
13601	v	−181	1.5	K07
17610.5	v	0	0.0	B07
17655.2	v	+2	0.4	L07; L12; I09
17676.5	v	3	−0.5	I09; S13 (E.S. Haynes)
17699.1	v	4	0.0	L07; L12; S13 (E.S. Haynes)
17722.0	v	5	0.7	I09; S13 (E.S. Haynes)
17743.9	v	6	0.4	L07; L12; I09
17766.7	v	7	1.1	L07; L12; S13 (E.S. Haynes)
17788.2	v	8	0.4	S13 (E.S. Haynes)
17831.9	v	10	−0.2	I09 (N36)
17855.1	v	11	0.8	S13 (E.S. Haynes)
17943.6	v	15	0.7	S13 (E.S. Haynes)
17966.0	v	16	0.9	I09; S13 (E.S. Haynes)
18010.8	v	18	1.4	S13 (E.S. Haynes)
18032.1	v	19	0.6	S13 (E.S. Haynes)
18054.3	v	20	0.6	S13 (E.S. Haynes)
18077.0	v	21	1.1	S13 (E.S. Haynes & F.H. Seares)
18099.0	v	22	1.0	S13 (E.S. Haynes & F.H. Seares)
18121.2	v	23	1.0	L12; S13 (E.S. Haynes & F.H. Seares)
18143.8	v	24	1.5	L12; S13 (E.S. Haynes & F.H. Seares)
18232.0	v	28	1.0	L12
18364.5	v	34	0.6	L12; S13 (E.S. Haynes)
18387.4	v	35	1.3	S13 (E.H.Haynes)
18519.0	v	41	−0.1	L12
18586.7	v	44	1.2	L12
18651		47	−1.0	Y16
18719.5	v	50	1.0	L12 (N36)
18741.9	v	51	1.2	L12
18763.2	v	52	0.4	L12
18786.9	v	53	1.9	L12
18940.0	v	60	−0.1	L12
18963.0	v	61	0.7	L12
19051.9	v	65	1.0	L12
19074.8	v	66	1.7	L12
19140.7	v	69	1.2	L12
19229.6	v	73	1.4	L12
19252.0	v	74	1.7	L12
19339.8	v	78	0.8	L12
19450.4	v	83	0.6	L12
19474.4	v	84	2.5	L12
19496.9	v	85	2.8	L12
19539.7	v	87	1.3	L12
20117.6	v	113	3.0	S22
20428.7	v	127	3.9	S22
20494.3	v	130	3.0	S22
20561		133	3.2	Y16
20958.4	v	151	1.7	S22
22178.0	v	206	2.5	L23
22266.5	v	210	2.4	L23

Table 5 (cont.)

t_{min}		E_1	$O-C_1$	References	t_{min}		E_1	$O-C_1$	References
22355.3	v	214	2.6	L23	26748.4	pg	412	8.0	H67
22443.3	v	218	1.9	L23	27081.2	v	427	8.4	P56
22487.4	v	220	1.7	L23 (S28)	27214.7	pg	433	8.9	H67
22531.5	v	222	1.5	L23	28076.4	v	472	6.4	L38
22576.4	v	224	2.1	L23 (S28)	28519.4	v	492	6.2	K37
22619.8	v	226	1.1	L23	29382.4	v	531	4.9	NS41
22641.8	v	227	1.0	L23 (S28)	30002.9	v	559	5.0	N52
22708.6	v	230	1.3	L23 (N36)	30201.8	v	568	4.4	NS43
22797.2	v	234	1.3	L23	30314.3	v	573	6.1	M64
22818.6	v	235	0.5	L23 (S28)	30334.3	v	574	4.0	M64
22841.7	v	236	1.4	L23 (S28)	30623.4	v	587	5.0	M64
22885.6	v	238	1.0	L23	30645.3	v	588	4.7	M64
22907.8	v	239	1.1	L23 (S28)	31044.1	v	606	4.6	N52
22930.1	v	240	1.2	L23 (S28)	31996.3	v	649	4.0	N52
22974.4	v	242	1.2	L23	32217.8	v	659	3.9	LJ53 (P. Ledoux)
23085.1	v	247	1.1	L23	32771.0	v	684	3.1	N55
23129.4	v	249	1.1	L23 (S28)	32859.7	pe	688	3.1	E57
23173.4	v	251	0.7	L23	32968.3	pg	693	0.9	H67
23240.2	v	254	1.1	L23	33568.2	pg	720	2.5	H67
23261.9	v	255	0.6	H23 (S28; N36)	33656.1	pg	724	1.8	H67
23283.4	v	256	−0.1	L23 (S28)	33678.5	pg	725	2.0	LJ53 (B.S.Whitney)
23328.7	v	258	0.9	L23	33744.8	v	728	1.8	N55
23440.9	v	263	2.3	L29	34010.4	v	740	1.5	N55
23529.4	v	267	2.2	L29	34076.4	pe	743	1.0	LJ53
23618.1	v	271	2.2	L29	34298.7	pg	753	1.7	H67
23706.6	v	275	2.1	L29	34430.8	pe	759	0.9	LD54
23750.7	v	277	1.9	L29 (N36)	34652.5	pg	769	1.0	H67
23839.7	v	281	2.2	L29	34696.5	pe	771	0.6	LD54
24105.5	v	293	2.1	L29	35052.6	pg	787	2.2	H67
24282.3	v	301	1.6	L29	35362.8	pg	801	2.1	H67
24616.8	v	316	3.7	L29	35539.8	pe	809	1.9	LF57
24683.3	v	319	3.8	L29	35605.0	pg	812	0.6	H67
24772.5	v	323	4.3	L29	35895.0	pe	825	2.5	DJ58
25039.6	v	335	5.5	L29 (N36)	35917.2	pe	826	2.5	DJ58
25173.5	v	341	6.4	L29	36005	v	830	1.7	AAVSO (N.O. Hutchings)
25306.1	v	347	6.1	L29	36073	v	833	3.2	AAVSO (N.O. Hutchings)
25417.2	v	352	6.4	L29	36161.0	pg	837	2.6	H67
25461.9	v	354	6.8	L29	36227.2	pg	840	2.3	H67
25484.3	v	355	7.0	L29	36316	v	844	2.5	AAVSO (N.O. Hutchings)
25506.3	v	356	6.8	E32	36603.4	pg	857	1.8	H67
25528.1	v	357	6.5	E32	36958.2	pg	873	2.0	H67
25617.2	v	361	6.9	E32	37024.5	pe	876	1.8	Mi64
25683.3	v	364	6.6	N30	37401.2	pg	893	1.8	H67
25706.0	v	365	7.1	E32	37577.4	pg	901	0.7	H67
25862.1	v	372	8.1	E32	37731.6	pg	908	−0.2	H67
25884.2	pg	373	8.0	H67	37775.5	pe	910	−0.6	MS65
25994.3	v	378	7.3	E32	37886.5	pg	915	−0.4	H67
26040.6	pg	380	9.3	H67	38085.6	pg	924	−0.7	H67
26416.5	pg	397	8.5	H67	38284.3	pg	933	−1.5	H67
26439.0	v	398	8.8	E32	38415.5	pg	939	−3.2	H67
26483.0	v	400	8.5	E32	38504.4	pg	943	−3.0	H67
26571.3	v	404	8.2	E32	38680.4	pg	951	−4.3	H67
26594.5	v	405	9.2	E32					

References: K07 = Kreutz 1907; B07 = Blazhko 1907; L07 = Luizet 1907; L12 = Luizet 1912; I09 = Ichinohe 1909; S13 = Shapley 1913; Y16 = Yendell 1916; S22 = Silva 1922; L23 = Leiner 1923; L29 = Leiner 1929; H23 = Haas 1923; S28 = Sanford 1928; N30 = Nielsen 1930; N36 = Nielsen 1936; N52 = Nielsen 1952; N55 = Nielsen 1955; E32 = Edelberg 1932; K37 = Krebs 1937; L38 = Larson 1938; NS41 = Nielsen & Sjögren 1941; NS43 = Nielsen & Sjögren 1943; LJ = Lenouvel & Jehoulet 1953; LD54 = Lenouvel & Daguillon 1954; E57 = Eggen et al. 1957; LF57 = Lenouvel & Fiogère 1957; DJ58 = Delsemme & Delsemme-Jehoulet 1958; P56 = Parenago 1956; M64 = Model 1964; Mi64 = Mitchell et al. 1964; MS65 = Michalowska-Smak & Smak 1965; H67 = Huth 1967

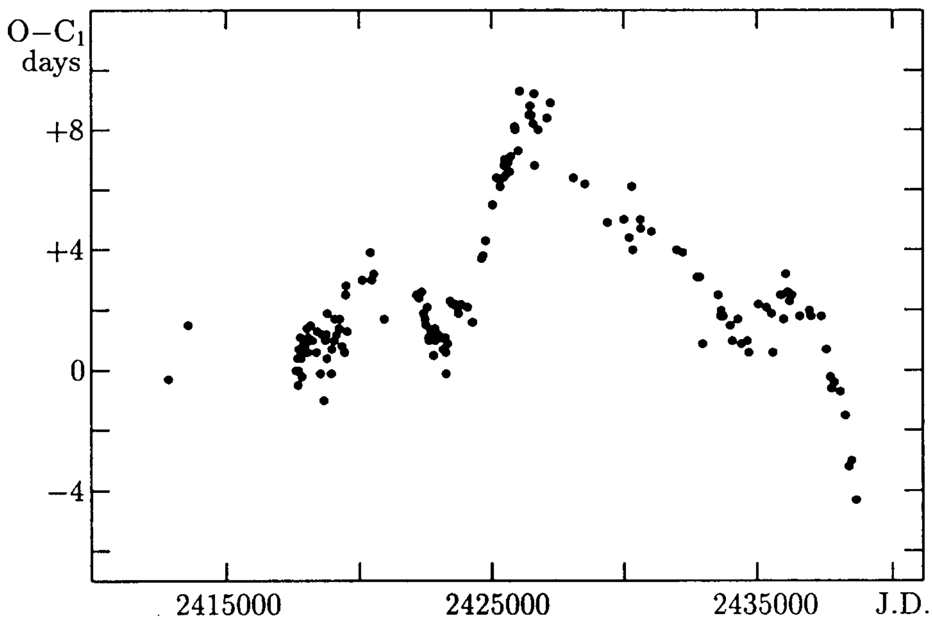

Figure 3. $O - C_1$ diagram of RU Cam

Although most observers took note of light curve changes of RU Cam, especially in the depth of the light minima (sometimes it reached 0.5 mag.) and called attention to the peculiarities of RU Cam (*Silva*, 1922; *Leiner*, 1923, 1929; *Haas*, 1923; *Edelberg*, 1932, *Robinson*, 1933; *Nielsen and Sjögren*, 1943) no one realized the star's extreme nature until the announcement of *Demers and Fernie* (1966). They observed the unprecedented amplitude decrease of the star in 1965.

After the 1965 event the period of the star has become very unstable and fluctuated between 17.4 and 26.6 days. Figure 4 presents the frequency distribution of the observed $P_i = t^{min}_{i+1} - t^{min}_i$ periods since 1965. The values of the period usually fell into the 20-24 day time interval with an average value of 21.75 days. After 1965 the O−C residuals have been computed by the formula:

$$C_2 = \text{J.D. } 2439079.6 + 21^{d}.75 \times E_2$$

where $E_2 = E_1 - 969$. The O−C_2 diagram (Figure 5) also shows that the period underwent large fluctuations, especially during the times when the amplitude of the light variation

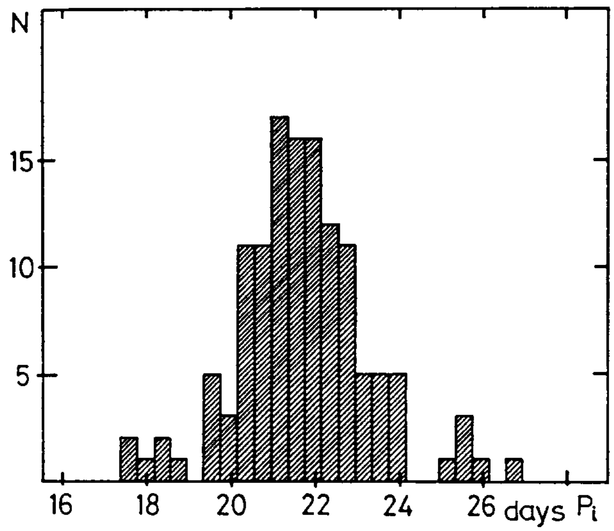

Figure 4. Frequency distribution of the observed P_i periods since 1966

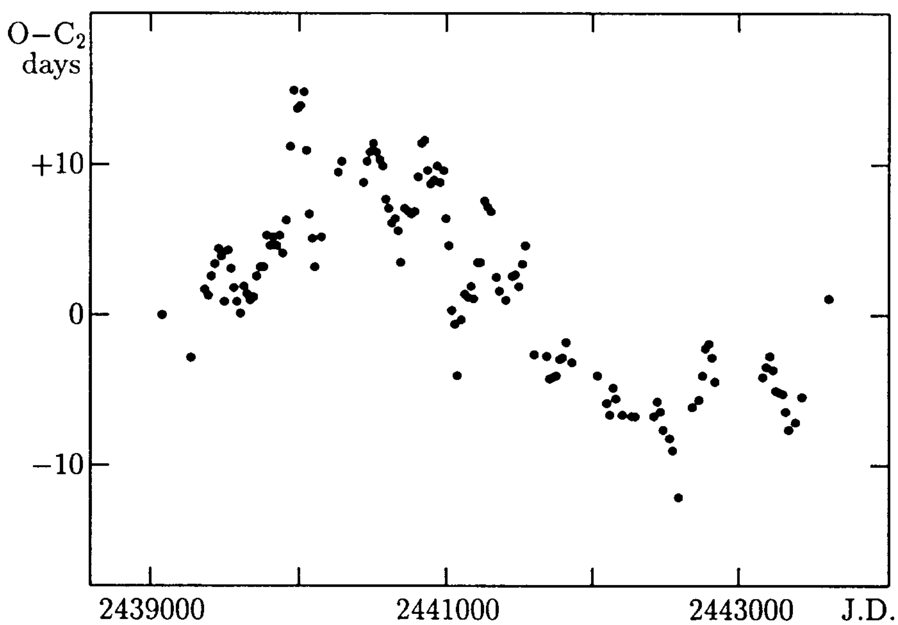

Figure 5. $O - C_2$ diagram of RU Cam

Table 6

Times and brightness of minima from photoelectric V observations

t_{min} 2400000+	m_V^{min}	E_2	$O-C_2$	References
32859.7	9.09	−281	$-108^{d}.2$	E57
34076.4	9.15	−226	−87.7	LJ53
34430.8	9.27	−210	−81.3	LD54
34696.5	9.26	−198	−76.6	LD54
35539.8	9.17	−160	−59.8	LF57
35895.0	9.58	−144	−52.6	DJ58
35917.2	9.60	−143	−52.1	DJ58
37024.5	9.11	−93	−32.3	M64
37775.5	9.77	−59	−20.9	MS65
39079.6	8.61	0	0.0	W66
39272.6	8.55	9	−2.8	Z67
39364	8.55	13	1.7	Pp
39385.4	8.568	14	1.3	Pp
39408.4	8.548	15	2.6	Pp
39431	8.52	16	3.4	W68
39453.7	8.514	17	4.4	Pp
39475	8.52	18	3.9	Pp; B69
39493.7	8.559	19	0.9	Pp; C68
39518.9	8.595	20	4.3	Pp
39539.4	8.602	21	3.1	Pp; B69
39559.9	8.582	22	1.8	Pp
39580.8	8.581	23	0.9	Pp; B69
39601.7	8.593	24	0.1	Pp; C68; B69
39625.3	8.589	25	1.9	Pp; B69
39646.5	8.628	26	1.4	Pp
39667.9	8.639	27	1.0	Pp; B69
39689.8	8.620	28	1.2	Pp; B69
39712.9	8.685	29	2.6	Pp
39735.3	8.666	30	3.2	Pp
39757.0	8.624	31	3.2	Pp
39780.9	8.613	32	5.3	Pp
39802.0	8.615	33	4.6	Pp; W68
39824.3	8.552	34	5.2	Pp; BG69
39845.5	8.559	35	4.6	Pp
39867.9	8.554	36	5.3	Pp; BG69
39888.4	8.562	37	4.1	Pp
39912.4	8.543	38	6.3	Pp; BG69
39939.0	8.558	39	11.2	Pp; C69; BG69
39964.5	8.563	40	14.9	Pp; C69; BG69
39985.0	8.548	41	13.7	Pp; BG69
40007	8.53	42	13.9	Pp
40029.7	8.570	43	14.8	Pp; BG69
40047.5	8.550	44	10.9	Pp
40065[i)]	8.51	45	6.7	Pp
40085.2	8.562	46	5.1	Pp
40105[ii)]	8.57	47	3.2	Pp
40150.5	8.54	49	5.2	Pp; C69
40263.6	8.530	54	9.5	Pp
40286[iii)]	8.51	55	10.2	Pp
40436.9	8.624	62	8.8	Pp
40460	8.62	63	$10^{d}.2$	Pp
40482.4	8.603	64	10.8	Pp
40504.8	8.591	65	11.4	Pp; BG72
40525.9	8.550	66	10.8	Pp; BG72
40547.1	8.540	67	10.3	Pp
40568.5	8.578	68	9.9	BG72
40588	8.53	69	7.7	Pp; BG72
40609.2	8.574	70	7.1	Pp; BG72
40629.9	8.555	71	6.1	Pp; BG72
40652.0	8.567	72	6.4	Pp; BG72
40673	8.56	73	5.6	BG72
40692.6	8.546	74	3.5	Pp; BG72
40718.0	8.526	75	7.1	Pp; BG72
40739.5	8.544	76	6.9	BG72
40761.0	8.550	77	6.7	Pp; BG72
40783	8.54	78	6.9	Pp; BG72
40807	8.51	79	9.2	Pp; BG72
40831	8.51	80	11.4	Pp
40853.0	8.476	81	11.6	Pp; BG73
40872.7	8.506	82	9.6	Pp; BG73
40893.6	8.554	83	8.7	Pp; BG73
40915.6	8.588	84	9.0	BG73
40938.3	8.611	85	9.9	Pp; BG73
40958.9	8.610	86	8.8	Pp; BG73
40981.5	8.533	87	9.6	Pp; BG73
41000.0	8.504	88	6.4	Pp; BG73
41020.0	8.503	89	4.6	Pp; BG73
41037.4	8.504	90	0.3	Pp; BG73
41058.3	8.516	91	−0.6	Pp
41076.6	8.539	92	−4.0	Pp
41102	8.53	93	−0.3	ZL78
41125.5	8.580	94	1.4	Pp
41147.1	8.565	95	1.2	Pp
41169.5	8.607	96	1.9	Pp
41190.5	8.606	97	1.1	Pp
41214.6	8.568	98	3.5	Pp
41236.3	8.575	99	3.5	Pp
41262.2	8.574	100	7.6	Pp
41283.6	8.561	101	7.2	Pp; BG73
41305.0	8.604	102	6.9	Pp; BG73
41344.1	8.635	104	2.5	BG73
41364.9	8.639	105	1.6	Pp
41407.8	8.604	107	1.0	Pp; BG73
41452.9	8.606	109	2.6	Pp; BG73
41474.8	8.593	110	2.7	Pp; BG73
41495.7	8.576	111	1.9	Pp
41519	8.58	112	3.4	Pp
41542[iv)]	8.56	113	4.6	Pp
41600	8.53	116	−2.6	Pp
41686.9	8.590	120	−2.7	Pp

Table 6 (cont.)

t_{min} 2400000+	m_V^{min}	E_2	O−C_2	References	t_{min} 2400000+	m_V^{min}	E_2	O−C_2	References
41707.2	8.63	121	$-4^d.2$	B78	42591	8.60	162	$-12^d.1$	Pp
41729.0	8.618	122	−4.1	B78	42684	8.63	166	−6.1	Pp
41750.9	8.609	123	−4.0	Pp; B78	42728	8.72	168	−5.6	B78
41773.7	8.627	124	−2.9	Pp; B78	42751.4	8.633	169	−4.0	B78
41795.6	8.644	125	−2.8	Pp	42774.9	8.623	170	−2.2	B78
41818.3	8.651	126	−1.8	Pp; B78	42797	8.59	171	−1.9	Pp; B78
41860.5	8.661	128	−3.1	B78	42817.8	8.534	172	−2.8	Pp; B78
42033.6	8.663	136	−4.0	Pp	42837.9	8.515	173	−4.4	Pp; B78
42097	8.60	139	−5.8	Pp	43164.5	8.595	188	−4.1	Pp; B78
42118	8.62	140	−6.6	Pp	43187	8.59	189	−3.4	B78
42141.5	8.637	141	−4.8	Pp	43209.4	8.571	190	−2.7	Pp
42162.6	8.701	142	−5.5	Pp	43230.3	8.592	191	−3.6	Pp
42205	8.71	144	−6.6	Pp	43250.6	8.533	192	−5.0	B78
42270.1	8.744	147	−6.7	Pp	43272.2	8.529	193	−5.1	B78
42291.9	8.770	148	−6.7	Pp	43293.9	8.593	194	−5.2	B78
42422.4	8.713	154	−6.7	Pp	43314.4	8.608	195	−6.4	B78
42445.1	8.679	155	−5.7	Pp	43335.0	8.647	196	−7.6	B78
42466.2	8.663	156	−6.4	Pp; B78	43379	8.59	198	−7.1	Pp
42486.7	8.660	157	−7.6	Pp	43424.2	8.617	200	−5.4	Pp
42529.6	8.580	159	−8.2	Pp; B78	43604.7	8.610	208	1.1	Pp
42550.6	8.569	160	−9.0	B78	45254	8.62	284:	−2.6	Pp

References: LJ53 = Lenouvel and Jehoulet, 1953; LD54 = Lenouvel and Daguillon, 1954; LF57 = Lenouvel and Fiogère, 1957; E57 = Eggen et al., 1957, DJ58 = Delsemme and Delsemme-Jehoulet, 1958; M64 = Mitchell et al., 1964; MS65 = Michalowska-Smak and Smak, 1965; W66 = Wamsteker, 1966; Z67 = Zaitseva, 1967; W68 = Wamsteker, 1968; C68 = Cester, 1968; C69 = Cester, 1969; B69 = Broglia, 1969; BG69 = Broglia and Guerrero, 1969b; BG72 = Broglia and Guerrero, 1972a; BG73 = Broglia and Guerrero, 1973; B78 = Broglia et al., 1978; ZL = Zaitseva and Ljutiy, 1978; Pp = Present paper

Remarks:
i) The brightness of the star hardly varies.
ii) Nearly constant, irregular light variation between J.D. 2440110 and 2440145 ($m_V \approx 8.52$).
iii) The star's brightness is nearly constant between J.D. 2440310 and 2440380 ($m_V \approx 8.48$).
iv) From this time a slow increase occurs in brightness until J.D.2441595, no minimum during this time period.

became very small. Figure 6 presents the brightness of maxima and minima between J.D. 2439000 and J.D. 2443640. It can be seen from this figure that it happened several times that after a short-lived recovery phase the amplitude decreased again and the light variation almost disappeared (e.g. around J.D. 2439450, J.D. 2440100, J.D. 2440850 etc.). From the light curve (Figure 2) it is evident that the brightness of the star varied non-periodically between J.D. 2440050 and J.D. 2440150 as well as between J.D. 2440320 and J.D. 2440380. The light was almost constant during this latter time period. Between J.D. 2441540 and J.D. 2441595 there were neither minima nor maxima and the stellar brightness was slowly increasing. During these time intervals the count of epoch numbers is, of course, very uncertain and jumps in phase could occur. In fact, such kind of jumps had already been observed (e.g. *Leiner*, 1929).

Table 7

Times and brightness of maxima from photoelectric V observations

t_{max} 2400000+	m_V^{max}	E_2	$O-C_2$	References
32824.2	8.28	-283	$-100\overset{d}{.}2$	E57
34064.7	8.24	-227	-77.6	LJ53
34421.2	8.15	-211	-69.1	LD54
35905.2	8.13	-144	-42.4	DJ58
37012.2	8.18	-94	-22.9	M64
37698.0	8.20	-63	-11.3	MS65
37964.0	8.22	-51	-6.3	Wi66
39025.5	8.47	-3	11.2	W66
39354.9	8.452	12	14.3	Pp; W66
39375.7	8.459	13	13.3	Pp; W66
39397.5	8.443	14	13.4	Pp; W66
39419.6	8.468	15	13.8	Pp
39443	8.47	16	15.4	Z67
39463.6	8.422	17	14.2	Pp
39481.9	8.465	18	10.8	Pp; C68
39509.4[i)]	8.485	19	16.6	Pp
39529.6	8.485	20	15.0	Pp; C68; B69
39551.1	8.464	21	14.8	B69
39571.3	8.430	22	13.2	Pp; C68; B69
39591.4	8.407	23	11.5	Pp; W68; B69
39612.6	8.452	24	11.0	Pp; W68; B69
39635	8.43	25	11.6	Pp; B69
39656.4	8.399	26	11.3	Pp; B69
39678.5	8.391	27	11.6	Pp
39701.9[ii)]	8.459	28	13.3	Pp
39723.9	8.389	29	13.6	Pp
39745	8.38	30	12.9	Pp
39769.9	8.434	31	16.0	Pp; C69
39791.2	8.434	32	15.6	Pp
39813.6	8.423	33	16.3	Pp
39834.0[iii)]	8.412	34	14.9	Pp; Z68; BG69
39857.2	8.400	35	16.4	Pp
39880.2	8.424	36	17.6	Pp; BG69
39902	8.48	37	17.6	Pp
39924.3[iii)]	8.475	38	18.2	Pp; C69; BG69
39955[ii)]	8.47	39	27.1	C69
39974.6[iii)]	8.481	40	25.0	Pp; C69; BG69
39996.7	8.458	41	25.3	Pp; BG69
40015.6[iv)]	8.47	42	22.5	Pp; BG69
40037.9	8.468	43	23.0	Pp; BG69
40060	8.50	44	23.4	Pp; BG69
40074	8.50	45	15.7	Pp
40093.9[v)]	8.519	46	13.8	Pp; BG69
40159.3	8.449	49	13.9	Pp
40181.6	8.424	50	14.5	Pp; BG69
40206	8.42	51	17.2	Pp
40252.5[vi)]	8.410	53	20.1	Pp
40426.5	8.420	61	20.1	Pp
40448.2	8.328	62	20.1	Pp
40471.7	8.344	63	21.8	Pp
40493.7	8.320	64	$22\overset{d}{.}1$	Pp
40515.1	8.382	65	21.8	Pp; BG72
40536.2	8.415	66	21.1	Pp
40557.8	8.435	67	20.9	Pp; BG72
40578.2	8.438	68	19.6	Pp; BG72
40619.8	8.430	70	17.7	Pp; BG72
40640.8	8.429	71	16.9	Pp; BG72
40661.9	8.415	72	16.3	Pp
40683.5	8.448	73	16.2	Pp; BG72
40705.4	8.438	74	16.3	Pp; BG72
40728.8	8.463	75	18.0	Pp; BG72
40749	8.47	76	16.4	Pp; BG72
40774	8.48	77	19.7	Pp; BG72
40797.7[vii)]	8.442	78	21.6	Pp; BG72
40819.3	8.425	79	21.5	Pp
40840.7	8.409	80	21.1	Pp
40861.0	8.450	81	19.7	Pp; BG73
40881.6	8.444	82	18.5	Pp; BG73
40903.0	8.484	83	18.2	Pp; BG73
40928.4	8.449	84	21.8	Pp; BG73
40947.6	8.410	85	19.2	Pp
40970.7	8.421	86	20.6	BG73
40991.9	8.441	87	20.0	BG73
41011.0	8.456	88	17.4	Pp; BG73
41026.7	8.475	89	11.3	Pp; BG73
41047.7	8.477	90	10.6	Pp
41067.5	8.472	91	8.7	Pp
41087.8	8.446	92	7.2	Pp
41113	8.48	93	10.6	Pp
41137.6	8.409	94	13.5	Pp
41158.0	8.403	95	12.2	Pp
41179.8	8.443	96	12.2	Pp
41202.0	8.439	97	12.7	Pp
41225.1	8.462	98	14.0	Pp
41249.4	8.384	99	16.6	Pp
41272.3	8.380	100	17.7	Pp; BG73
41293.7	8.372	101	17.3	Pp; BG73
41314.8	8.439	102	16.7	Pp
41334.5	8.479	103	14.6	Pp
41354.3	8.436	104	12.7	Pp
41396.5	8.445	106	11.4	Pp; BG73
41418.3	8.484	107	11.5	Pp; BG73
41441.1	8.485	108	12.5	Pp
41464.0	8.505	109	13.6	Pp; BG73
41487.6	8.510	110	15.5	Pp; BG73
41512[viii)]	8.49	111	18.2	BG73
41532.0[ix)]	8.496	112	16.4	Pp
41613	8.46	116	10.4	Pp
41634.1	8.454	117	9.8	Pp
41654.4	8.420	118	8.3	ZL78

Table 7 (cont.)

t_{max} 2400000+	m_V^{max}	E_2	O−C_2	References	t_{max} 2400000+	m_V^{max}	E_2	O−C_2	References
41675.6	8.394	119	$7\overset{\mathrm{d}}{.}7$	Pp	42519.5	8.400	158	$3\overset{\mathrm{d}}{.}4$	B78
41698.5	8.405	120	8.9	Pp	42560.1	8.454	160	0.5	Pp
41718.1	8.379	121	6.7	Pp; B78	42672.6	8.399	165	4.3	Pp
41739.5	8.406	122	6.4	Pp; B78	42694	8.37	166	3.9	B78
41762.3	8.386	123	7.4	B78	42716.0	8.466	167	4.2	Pp; B78
41784.5	8.393	124	7.9	Pp; B78	42740.2	8.411	168	6.6	Pp; B78
41806	8.38	125	7.6	Pp	42786.1	8.370	170	9.0	Pp; B78
41828.5	8.360	126	8.4	Pp; B78	42807.7	8.409	171	8.9	B78
41936.3	8.364	131	7.4	Pp	$42868^{x)}$	8.44	174	3.9	Pp; B78
41958.7	8.362	132	8.1	Pp	43131.5	8.41	186	6.4	B78
41981.6	8.392	133	9.3	Pp	43151.7	8.390	187	4.8	B78
42023.2	8.361	135	7.3	Pp	43177.0	8.342	188	8.4	Pp; B78
42106.4	8.388	139	3.6	Pp	43198.9	8.376	189	8.5	Pp; B78
42129.9	8.391	140	5.3	Pp	43218.1	8.382	190	6.0	Pp; B78
42152.2	8.368	141	5.8	Pp	43241	8.40	191	7.1	Pp
42173	8.33	142	4.9	Pp	43261	8.39	192	5.4	B78
42194.5	8.352	143	4.6	Pp	43303.0	8.351	194	3.9	Pp
42259	8.25	146	3.9	Pp	43325	8.42	195	4.2	B78
42281.1	8.260	147	4.3	Pp	43344.9	8.451	196	2.3	B78
42302.4	8.259	148	3.8	Pp	43415.2	8.410	199	7.3	Pp
42366.3	8.292	151	2.5	Pp	43435.2	8.396	200	5.6	Pp
42433.6	8.299	154	4.5	Pp	43456.7	8.403	201	5.3	Pp
42455.5	8.374	155	4.6	Pp	43640	8.43	209	14.6	Pp
42477	8.39	156	4.4	B78	45222.1	8.350	282:	9.0	Pp
42498.0	8.369	157	3.7	B78					

References: The same as in Table 6 and Wi66=Williams 1966; Z68=Zaitseva 1968.

Remarks:
i) large hump before maximum
ii) hump before maximum
iii) hump after maximum
iv) large scatter in maximum
v) nearly constant, irregular light variation between J.D. 2440110 and 2440145 (m_v~8.52)
vi) nearly constant between J.D. 2440310 and 2440380 (m_v~8.48)
vii) hump on the ascending branch
viii) long (9 days) stillstand on the ascending branch
ix) slow, continuous increase in brightness between J.D. 2441540 and 2441595
x) maximum light was constant during five days ($m_v^{max} \approx 8.44$)

The fluctuations in other parameters have also increased after 1965. For example, the length of the ascending branch, $M-m$, fluctuated between 9.3 and 10.1 days before 1965, while the fluctuations were between 6.7 and 16.3 days, with a mean $\overline{M-m} = 10.91$ days after 1965.

Huth (1967) suspected a connection between the changes of the period and the light amplitude, while *Broglia and Guerrero* (1973) and *Broglia et al.* (1978) denied the existence of such a correlation. They found, however, a correlation between the amplitude (sine fitting) and the period (sine fitting). Our investigations do not support the existence

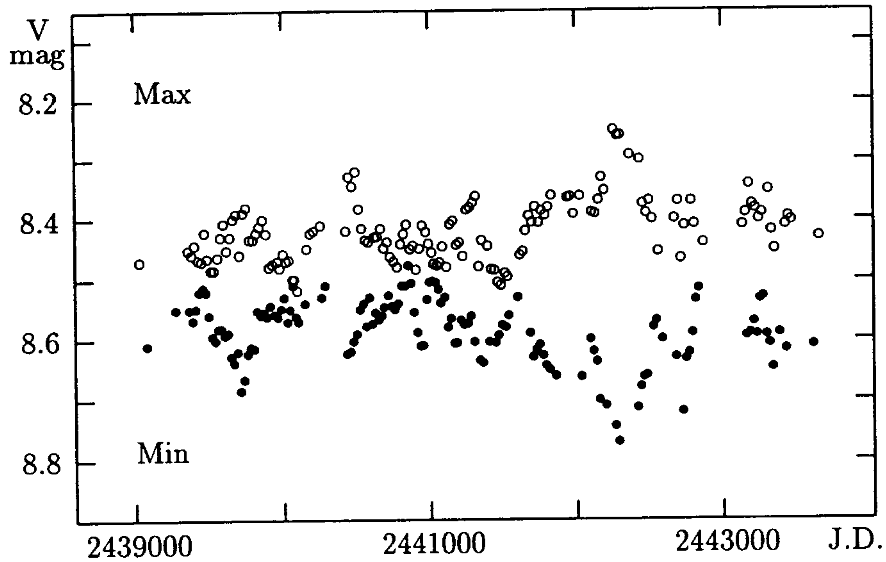

Figure 6. The observed photoelectric maxima (circles) and minima (dots) since 1965

of either the correlation between the variation of the period and the changes of the light curve amplitude or the correlation between the amplitude and period.

As it was pointed out by *Broglia and Guerrero* (1973) and *Broglia et al.* (1978) the mean luminosity of RU Cam did not vary significantly, consequently the energy production of the star was the same after 1965 as before. This means that the outer layers of the star are responsible for its irregular behaviour.

The photometric data obtained in the years 1965-1982 were Fourier analysed, but there were no indications for a modulation effect; instead of some separate peaks a bunch of peaks appeared in the spectrum around the frequency f = 0.046 cycle/day suggesting that the star might pulsate rather in chaotic or stochastic way (see a more detailed discussion in a forthcoming paper of *Kolláth and Szeidl*, 1993).

The unique behaviour of RU Cam – as it was pointed out by *Wallerstein* (1968) – may be associated with the processes of mass loss and mixing which modify the pulsational conditions in the outer layers of the star. Nevertheless, the problem is still unsolved how the more or less regular pulsation of RU Cam ceased in a very short time interval (within one year) and gave place to an oscillation in which the erratic component is sometimes dominant (*Broglia and Guerrero*, 1972a) or which has become chaotic (*Perdang*, 1985).

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Table 3

Photoelectric V and B observations of RU Cam
(variable – BD +70°448)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
39348.576	–.552±008	–.456±013	.096	3	51
39350.572	–.581±004	–.500±006	.081	3	51
39351.569	–.584±002	–.517±002	.067	5	50
39352.584	–.580±004	–.516±010	.064	4	48
39354.583	–.612±005	–.541±009	.071	6	48
39355.572	–.607±003	–.525±005	.082	6	49
39356.573	–.595±005	–.531±008	.064	6	48
39358.555	–.570±002	–.509±006	.061	4	50
39359.585	–.543±003	–.441±006	.102	2	46
39361.577	–.537±002	–.447±007	.090	3	46
39367.557	–.531±005	–.442±002	.089	4	47
39370.569	–.577±001	–.505±005	.072	6	44
39371.564	–.566±005	–.498±007	.068	4	45
39372.564	–.588±004	–.510±006	.078	3	45
39374.577	–.606±002	–.548±004	.058	5	42
39376.567	–.598±004	–.537±005	.061	5	43
39380.572	–.572±006	–.477±018	.095	4	41
39381.553	–.520±004	–.441±012	.079	5	43
39382.515	–.509±004	–.418±003	.091	4	47
39383.511	–.501±003	–.427±005	.074	5	47
39383.611	–.493±006	–.418±002	.075	2	35
39384.615	–.495±002	–.398±008	.097	3	34
39388.495	–.513±002	–.402±014	.111	3	47
39388.575	–.512±001	–.401±002	.111	3	38
39390.564	–.539±003	–.451±005	.088	5	39
39391.585	–.567±006	–.482±003	.085	3	35
39392.544	–.572±003	–.486±004	.086	5	40
39393.528	–.590±005	–.515±003	.075	6	42
39396.367	–.616±004	–.537±007	.079	5	58
39396.534	–.608±003	–.568±007	.040	5	40
39400.591	–.599±006	–.541±007	.058	3	32
39401.494	–.591±002	–.534±003	.057	5	43
39402.533	–.562±004	–.489±006	.073	5	39
39403.503	–.552±004	–.462±009	.090	6	41
39404.529	–.520±004	–.434±008	.086	7	38
39404.611	–.544±001	–.433±003	.111	6	29
39405.515	–.525±002	–.421±006	.104	8	39
39406.583	–.511±007	–.424±001	.087	3	31
39407.468	–.513±005	–.423±006	.090	3	45
39408.490	–.516±004	–.411±003	.105	8	42
39409.564	–.513±004	–.404±006	.109	4	32
39414.499	–.558±007	–.516±016	.042	5	38
39415.497	–.575±007	–.519±016	.056	6	38
39418.491	–.591±002	–.527±003	.064	3	38
39420.621	–.593±004	–.518±005	.075	4	24
39421.507	–.590±004	–.527±006	.063	4	35
39422.499	–.576±001	–.523±008	.053	5	36
39423.641	–.574±003	–.505±028	.069	2	22
39424.658	–.574±002	–.503±008	.071	4	22
39426.605	–.564±001	–.475±003	.089	6	24
39435.399	–.549±005	–.447±004	.102	2	44
39438.458	–.567±003	–.496±004	.071	6	36

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
39439.477	−.571±004	−.520±004	.051	7	33
39451.445	−.558±002	−.469±004	.089	6	33
39455.558	−.552±005	−.455±010	.097	7	22
39456.461	−.563±003	−.467±009	.096	7	29
39457.422	−.573±003	−.488±005	.085	7	33
39458.419	−.581±001	−.511±002	.070	7	34
39464.420	−.632±003	−.569±008	.063	2	31
39464.550	−.637±001	−.569±002	.068	6	22
39467.594	−.598±002	−.538±005	.060	7	24
39471.442	−.562±005	−.485±004	.077	3	27
39476.345	−.546±003	−.465±006	.081	4	37
39476.451	−.551±006	−.452±007	.099	4	25
39480.655	−.600±004	−.525±006	.075	7	34
39481.405	−.602±001	−.532±006	.070	6	28
39482.363	−.594±004	−.521±007	.073	7	32
39482.607	−.588±003	−.517±006	.071	5	29
39483.366	−.591±001	−.525±007	.066	6	32
39486.587	−.565±006	−.490±005	.075	5	28
39489.321	−.519±001	−.425±006	.094	6	35
39489.497	−.524±001	−.404±003	.120	6	22
39491.211	−.509±006	−.411±010	.098	6	48
39494.281	−.505±003	−.402±004	.103	6	38
39501.461	−.556±002	−.463±004	.093	7	22
39503.326	−.554±001	−.473±006	.081	7	30
39505.503	−.560±001	−.452±002	.108	7	25
39506.519	−.552±001	−.472±001	.080	7	27
39507.573	−.566±002	−.472±007	.094	5	33
39508.265	−.570±001	−.471±005	.099	6	36
39510.248	−.575±003	−.470±003	.105	5	37
39511.316	−.562±003	−.447±007	.115	6	29
39512.649	−.541±004	−.429±009	.112	2	44
39516.262	−.491±004	−.369±004	.122	6	33
39518.364	−.460±002	−.350±004	.110	7	23
39518.643	−.470±004	−.364±003	.106	5	46
39520.360	−.472±001	−.360±004	.112	7	23
39521.242	−.494±006	−.379±015	.115	5	34
39522.280	−.498±005	−.383±013	.115	4	29
39527.286	−.565±003	−.483±004	.082	5	27
39527.395	−.555±001	−.485±003	.070	6	22
39527.584	−.572±006	−.481±006	.091	6	41
39528.267	−.565±002	−.483±002	.082	6	29
39528.545	−.564±001	−.486±003	.078	6	37
39530.272	−.567±002	−.488±005	.079	6	28
39531.284	−.575±003	−.466±003	.109	5	26
39531.464	−.568±001	−.473±004	.095	6	28
39531.613	−.576±003	−.465±006	.111	6	46
39532.318	−.562±002	−.450±007	.112	10	24
39533.557	−.536±003	−.434±003	.102	9	40
39534.347	−.520±002	−.407±004	.113	8	22
39535.281	−.520±002	−.374±006	.146	6	26
39536.363	−.480±002	−.365±008	.115	6	22
39536.592	−.485±002	−.350±006	.135	7	45
39537.274	−.474±002	−.343±006	.131	6	26
39538.270	−.461±003	−.342±002	.119	6	26

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
39538.575	–.458±005	–.358±005	.100	5	44
39542.485	–.491±002	–.400±008	.091	6	34
39544.330	–.512±003	–.439±002	.073	6	22
39546.304	–.532±003	–.478±006	.054	6	22
39547.319	–.555±003	–.475±004	.080	6	22
39553.525	–.571±016	–.494±008	.077	2	43
39554.349	–.570±004	–.470±007	.100	5	24
39555.284	–.563±009	–.475±009	.088	3	22
39558.527	–.479±004	–.371±012	.108	6	45
39559.629	–.483±006	–.359±006	.124	5	56
39560.321	–.472±002	–.360±004	.112	6	23
39562.284	–.483±005	–.392±003	.091	5	22
39562.484	–.493±002	–.387±006	.106	4	41
39564.295	–.528±003	–.444±002	.084	6	23
39565.535	–.556±003	–.490±006	.066	4	48
39566.622	–.574±002	–.518±005	.056	5	57
39567.308	–.572±004	–.510±009	.062	4	23
39570.304	–.618±003	–.565±003	.053	6	24
39572.310	–.638±003	–.541±003	.097	5	24
39572.515	–.609±007	–.531±009	.078	5	48
39573.338	–.609±002	–.521±006	.088	2	27
39574.288	–.603±002	–.501±003	.102	6	23
39575.365	–.564±002	–.467±002	.097	5	30
39576.301	–.556±004	–.452±002	.104	5	25
39577.566	–.535±008	–.409±006	.126	5	54
39580.357	–.487±004	–.365±006	.122	6	31
39581.320	–.485±001	–.365±004	.120	6	27
39583.323	–.510±004	–.433±003	.077	6	28
39585.325	–.555±002	–.502±003	.053	6	29
39588.304	–.622±002	–.606±004	.016	5	28
39590.302	–.653±002	–.625±004	.028	6	28
39591.367	–.651±005	–.611±011	.040	5	36
39594.523	–.622±006	–.527±004	.095	6	55
39597.316	–.555±003	–.436±004	.119	6	32
39598.324	–.519±002	–.396±003	.123	6	33
39599.534	–.499±003	–.376±005	.123	5	57
39600.307	–.473±003	–.361±006	.112	6	32
39602.313	–.468±005	–.360±005	.108	5	33
39604.337	–.512±003	–.425±005	.087	6	37
39605.347	–.524±003	–.444±004	.080	6	38
39607.556	–.560±006	–.503±005	.057	6	60
39609.494	–.575±003	–.499±003	.076	6	56
39610.365	–.610±003	–.567±002	.039	7	42
39611.343	–.600±003	–.560±002	.040	6	40
39612.575	–.590±002	–.515±004	.075	6	61
39613.558	–.599±002	–.548±002	.051	6	61
39617.341	–.565±002	–.468±003	.097	6	41
39618.343	–.543±003	–.441±004	.102	6	42
39619.513	–.508±003	–.398±008	.110	6	59
39622.455	–.498±005	–.363±007	.135	6	55
39623.350	–.488±003	–.356±007	.132	6	45
39624.371	–.471±002	–.357±007	.114	5	47
39628.432	–.501±005	–.417±006	.084	9	55
39636.382	–.616±004	–.588±007	.028	6	52

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
39637.372	–.623±003	–.555±006	.068	6	51
39638.357	–.611±003	–.522±004	.089	6	50
39639.361	–.575±002	–.507±004	.068	6	51
39643.494	–.484±008	–.375±008	.109	2	61
39644.384	–.466±005	–.335±005	.131	3	54
39645.372	–.459±003	–.302±007	.157	5	54
39646.378	–.425±003	–.310±004	.115	6	55
39648.372	–.456±003	–.349±006	.107	6	54
39648.518	–.454±005	–.361±007	.093	6	63
39649.432	–.493±004	–.423±005	.070	3	59
39653.426	–.606±003	–.612±002	–.006	5	60
39654.376	–.661±005	–.636±005	.025	6	56
39656.533	–.664±004	–.660±002	.004	2	63
39661.473	–.580±004	–.486±004	.094	6	62
39664.397	–.473±003	–.360±004	.113	5	60
39665.389	–.468±006	–.335±005	.133	6	59
39667.392	–.425±004	–.313±006	.112	6	60
39668.402	–.422±003	–.321±009	.101	5	61
39669.389	–.444±005	–.356±006	.088	6	60
39670.416	–.458±007	–.366±002	.092	4	61
39672.385	–.471±004	–.431±007	.040	6	60
39673.397	–.539±004	–.496±002	.043	6	61
39678.510	–.670±005	–.623±003	.047	6	62
39679.490	–.656±003	–.637±005	.019	6	63
39680.467	–.649±005	–.553±005	.096	6	63
39682.412	–.560±005	–.520±005	.040	6	62
39684.516	–.529±005	–.426±004	.103	3	61
39685.529	–.507±004	–.415±015	.092	6	61
39686.529	–.480±007	–.377±006	.103	5	61
39687.529	–.456±009	–.347±019	.109	3	60
39688.528	–.456±006	–.323±011	.133	7	60
39689.533	–.436±003	–.328±013	.108	7	60
39690.377	–.448±010	–.329±009	.119	6	62
39690.527	–.439±008	–.326±011	.113	9	60
39691.525	–.458±009	–.314±013	.144	6	60
39692.533	–.483±006	–.361±003	.122	3	59
39696.374	–.583±002	–.498±009	.085	6	62
39697.479	–.579±007	–.513±012	.066	4	61
39698.407	–.580±004	–.550±006	.030	6	63
39702.439	–.598±002	–.546±009	.052	6	62
39703.449	–.595±013	–.518±015	.077	5	62
39704.549	–.593±005	–.493±009	.100	5	56
39705.552	–.575±008	–.476±011	.099	6	55
39706.381	–.556±004	–.459±005	.097	6	63
39706.552	–.553±005	–.456±007	.097	4	55
39707.468	–.541±005	–.401±009	.140	6	61
39710.369	–.418±003	–.302±005	.116	6	63
39710.550	–.427±002	–.291±009	.136	5	54
39711.551	–.404±005	–.267±003	.137	7	54
39712.483	–.377±006	–.233±009	.144	6	59
39713.370	–.378±005	–.254±009	.124	3	63
39714.353	–.405±003	–.272±005	.133	6	63
39714.553	–.418±003	–.255±005	.163	6	53
39715.391	–.432±010	–.330±012	.102	4	63

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
39715.552	–.426±005	–.331±001	.095	5	53
39718.560	–.550±002	–.478±003	.072	6	51
39719.382	–.575±002	–.512±004	.063	6	62
39719.563	–.571±001	–.531±001	.040	6	50
39720.471	–.633±004	–.576±004	.057	4	58
39721.363	–.630±002	–.589±006	.041	6	63
39721.568	–.654±003	–.588±004	.066	6	49
39722.560	–.662±005	–.620±004	.042	6	50
39724.390	–.661±005	–.631±005	.030	6	62
39724.560	–.657±001	–.602±003	.055	5	49
39725.333	–.664±003	–.599±006	.065	6	63
39725.542	–.670±003	–.589±004	.081	6	51
39726.344	–.657±008	–.577±007	.080	5	63
39726.563	–.646±006	–.571±010	.075	6	48
39727.403	–.598±003	–.529±016	.069	6	61
39729.530	–.513±002	–.385±016	.128	2	51
39731.426	–.495±005	–.366±011	.129	7	59
39731.546	–.500±006	–.357±012	.143	5	49
39732.319	–.461±003	–.351±005	.110	8	63
39732.567	–.467±003	–.323±004	.144	5	46
39733.481	–.419±002	–.312±015	.107	5	55
39734.432	–.415±003	–.285±009	.130	10	58
39736.331	–.405±004	–.326±004	.079	4	63
39737.393	–.456±005	–.347±002	.109	6	60
39737.587	–.448±001	–.348±005	.100	6	42
39738.298	–.453±002	–.352±003	.101	4	63
39739.321	–.489±005	–.391±006	.098	6	63
39739.581	–.520±004	–.410±005	.110	6	42
39740.372	–.539±005	–.481±002	.058	6	61
39747.592	–.653±003	–.620±001	.033	2	38
39748.343	–.628±003	–.560±008	.068	4	61
39753.280	–.514±003	–.378±006	.136	6	63
39753.607	–.493±002	–.381±007	.112	4	34
39754.457	–.489±006	–.363±014	.126	3	51
39755.373	–.489±004	–.375±011	.114	6	59
39756.568	–.435±002	–.338±004	.097	6	38
39757.286	–.435±006	–.351±004	.084	6	62
39757.623	–.440±001	–.353±004	.087	6	31
39758.522	–.456±002	–.332±003	.124	5	43
39759.320	–.458±002	–.352±004	.106	5	61
39760.387	–.459±009	–.381±010	.078	4	56
39760.606	–.455±005	–.374±003	.081	2	32
39762.427	–.493±004	–.425±002	.068	6	52
39762.620	–.488±001	–.429±004	.059	6	29
39763.284	–.530±006	–.466±006	.064	6	62
39763.600	–.524±001	–.453±002	.071	6	31
39764.287	–.550±004	–.489±007	.061	6	62
39764.559	–.562±003	–.500±009	.062	6	36
39765.406	–.569±003	–.519±003	.050	8	54
39766.295	–.592±002	–.532±006	.060	6	61
39768.266	–.592±003	–.558±007	.034	4	62
39769.285	–.616±003	–.549±006	.067	5	61
39769.562	–.634±002	–.558±003	.076	6	34
39770.373	–.626±004	–.548±007	.078	6	55

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
39770.640	–.620±002	–.533±002	.087	6	25
39774.416	–.567±004	–.458±004	.109	5	50
39776.436	–.520±004	–.423±007	.097	7	47
39777.407	–.500±004	–.404±006	.096	6	50
39778.417	–.489±006	–.389±006	.100	5	49
39779.337	–.456±002	–.368±004	.088	2	56
39779.557	–.458±002	–.358±006	.100	5	31
39780.454	–.448±005	–.356±009	.092	6	44
39780.545	–.446±001	–.351±004	.095	5	32
39781.514	–.458±006	–.386±004	.072	6	36
39782.457	–.454±003	–.372±004	.082	6	43
39783.478	–.471±002	–.389±002	.082	6	40
39784.461	–.499±001	–.412±003	.087	6	42
39785.283	–.507±003	–.442±006	.065	6	59
39786.423	–.535±001	–.470±003	.065	6	46
39787.448	–.571±003	–.488±002	.083	6	42
39788.329	–.598±005	–.519±003	.079	6	55
39789.287	–.614±001	–.521±006	.093	6	58
39790.374	–.625±004	–.548±009	.077	6	50
39790.518	–.619±003	–.534±006	.085	6	32
39791.261	–.625±005	–.551±007	.074	6	59
39792.344	–.628±003	–.540±006	.088	6	52
39793.591	–.597±002	–.513±007	.084	5	24
39795.289	–.570±004	–.476±006	.094	5	57
39795.497	–.571±004	–.474±006	.097	6	33
39796.227	–.562±003	–.450±003	.112	6	61
39796.439	–.552±003	–.443±004	.109	6	40
39799.231	–.492±003	–.388±011	.104	6	60
39802.392	–.443±009	–.355±009	.088	6	44
39806.230	–.523±008	–.490±006	.033	4	59
39807.482	–.555±008	–.513±013	.042	5	31
39808.294	–.564±003	–.518±002	.046	6	53
39809.373	–.582±007	–.538±005	.044	6	44
39809.509	–.597±003	–.561±005	.036	6	28
39810.510	–.619±003	–.555±002	.064	6	27
39812.254	–.638±005	–.583±010	.055	6	56
39812.420	–.628±003	–.581±009	.047	5	37
39813.335	–.627±003	–.584±007	.043	5	47
39814.219	–.639±004	–.541±004	.098	6	58
39814.577	–.632±003	–.524±004	.108	5	22
39815.459	–.624±006	–.523±008	.101	6	31
39816.451	–.615±008	–.506±004	.109	6	32
39818.317	–.575±003	–.488±005	.087	6	48
39819.551	–.557±002	–.446±007	.111	6	23
39820.432	–.547±001	–.413±001	.134	6	33
39820.601	–.521±004	–.420±004	.101	6	23
39821.236	–.518±005	–.423±015	.095	5	55
39823.411	–.512±002	–.415±003	.097	2	35
39825.540	–.510±001	–.423±002	.087	6	23
39826.208	–.509±003	–.422±009	.087	5	56
39826.660	–.514±005	–.431±003	.083	6	29
39827.503	–.525±002	–.448±003	.077	6	24
39828.255	–.528±004	–.472±002	.056	5	52
39829.671	–.569	–.523	.046	1	31

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
39833.296	−.647±005	−.566±005	.081	6	45
39834.454	−.641±001	−.584±010	.057	2	26
39835.262	−.634±005	−.577±005	.057	6	49
39837.422	−.623±003	−.564±002	.059	6	29
39838.358	−.623±002	−.516±003	.107	5	36
39839.248	−.589±001	−.507±009	.082	4	49
39840.309	−.552±006	−.491±005	.061	6	42
39840.625	−.555±004	−.479±003	.076	5	29
39845.302	−.499±003	−.389±002	.110	6	41
39851.394	−.581±002	−.518±001	.063	2	28
39852.200	−.579±004	−.526±003	.053	6	50
39853.204	−.592±005	−.533±002	.059	6	50
39855.507	−.652	−.590	.062	1	23
39856.205	−.660±004	−.608±004	.052	6	49
39858.220	−.653±002	−.594±004	.059	6	46
39859.443	−.645±001	−.582±001	.063	6	23
39860.705	−.640±007	−.530±005	.110	5	45
39864.231	−.567±006	−.458±008	.109	7	43
39865.227	−.533±004	−.424±006	.109	6	43
39866.468	−.507±004	−.405±005	.102	6	23
39869.203	−.513±003	−.382±005	.131	7	45
39873.221	−.553	−.439	.114	1	41
39875.355	−.558±003	−.494±002	.064	6	25
39876.225	−.582±004	−.494±003	.088	6	39
39878.235	−.606±002	−.550±004	.056	7	38
39880.512	−.642±001	−.526±001	.116	6	29
39881.325	−.617±002	−.538±004	.079	6	27
39882.275	−.615±001	−.533±001	.082	2	32
39883.248	−.590±001	−.514±001	.076	6	35
39885.249	−.569±004	−.479±004	.090	2	34
39888.254	−.497±003	−.401±003	.096	6	32
39890.372	−.542±004	−.416±009	.126	5	22
39896.251	−.552±004	−.481±005	.071	6	30
39898.243	−.563±002	−.517±002	.046	6	30
39904.245	−.576	−.488	.088	1	28
39905.249	−.577±004	−.489±003	.088	5	27
39906.291	−.552±003	−.440±007	.112	6	24
39910.453	−.519±002	−.407±007	.112	6	31
39912.253	−.509	−.401	.108	1	25
39913.459	−.519±002	−.429±005	.090	5	33
39914.253	−.527±001	−.431±006	.096	5	25
39915.297	−.522±005	−.429±003	.093	5	22
39916.636	−.541±002	−.447±003	.094	6	54
39917.375	−.530±002	−.460±003	.070	6	25
39920.449	−.557±003	−.465±005	.092	4	34
39923.332	−.579±001	−.483±005	.096	6	23
39924.344	−.593±003	−.486±007	.107	4	24
39927.494	−.560±002	−.476±006	.084	6	42
39928.293	−.548±003	−.469±003	.079	6	22
39929.636	−.534±003	−.477±006	.057	5	57
39933.302	−.535±002	−.427±005	.108	6	23
39935.286	−.534±002	−.418±003	.116	6	23
39937.402	−.507±006	−.411±007	.096	8	34
39940.297	−.501±002	−.440±008	.061	5	24

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B−V)	n	Z
39941.309	−.518±002	−.441±005	.077	6	25
39942.308	−.509±001	−.422±002	.087	6	25
39943.301	−.543±005	−.434±007	.109	8	25
39944.305	−.531±003	−.442±002	.089	6	25
39945.318	−.552±001	−.435±003	.117	6	27
39946.300	−.544±003	−.441±003	.103	7	26
39951.347	−.557±008	−.445±009	.112	6	32
39957.339	−.574±002	−.497±002	.077	7	33
39958.316	−.564±005	−.491±005	.073	6	30
39960.321	−.535±002	−.443±002	.092	2	32
39961.326	−.540±005	−.441±010	.099	5	32
39963.436	−.531±009	−.448±011	.083	6	47
39964.389	−.501±006	−.369±005	.132	6	42
39965.488	−.491±002	−.424±002	.067	6	53
39966.377	−.527±001	−.416±003	.111	6	41
39967.338	−.504±003	−.429±002	.075	6	36
39968.335	−.543±001	−.448±002	.095	6	36
39969.343	−.545±003	−.440±005	.105	10	37
39969.372	−.544±004	−.456±004	.088	8	41
39969.401	−.543±003	−.451±005	.092	8	45
39970.446	−.553±002	−.503±003	.050	8	50
39971.547	−.545±003	−.502±005	.043	6	59
39976.352	−.569±002	−.477±003	.092	6	41
39978.333	−.564±004	−.456±005	.108	6	39
39979.376	−.568±006	−.466±001	.102	2	45
39981.520	−.523±010	−.448±010	.075	3	59
39983.372	−.517±002	−.439±003	.078	6	45
39985.432	−.536±001	−.441±002	.095	6	53
39986.368	−.508±001	−.432±002	.076	6	46
39987.362	−.521±002	−.456±006	.065	6	46
39991.381	−.591±007	−.520±010	.071	9	49
39992.433	−.605±004	−.496±005	.109	5	55
39993.435	−.580±004	−.527±007	.053	6	55
39995.424	−.576±003	−.490±004	.086	6	55
39996.427	−.605±003	−.500±004	.105	6	55
39999.375	−.585±003	−.542±004	.043	6	51
40009.356	−.547±008	−.480±009	.067	4	52
40012.363	−.573±008	−.510±006	.063	6	53
40013.438	−.590±005	−.528±008	.062	6	59
40014.378	−.580±002	−.531±004	.049	6	55
40015.392	−.588±002	−.489±002	.099	6	56
40016.375	−.562±003	−.482±003	.080	6	55
40020.380	−.580±004	−.469±005	.111	6	57
40021.424	−.553±006	−.444±006	.109	6	60
40022.422	−.566±009	−.481±009	.085	5	60
40023.381	−.539±004	−.494±007	.045	6	58
40024.432	−.532±009	−.479±012	.053	5	61
40025.482	−.515±009	−.464±012	.051	6	62
40026.472	−.509±006	−.390±002	.119	5	62
40030.379	−.497±010	−.381±008	.116	6	59
40031.395	−.488±010	−.392±007	.096	4	60
40032.398	−.484±010	−.402±014	.082	6	60
40033.496	−.518±007	−.427±012	.091	6	63
40034.401	−.538±004	−.457±009	.081	6	61

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
40035.379	−.558±006	−.502±004	.056	6	59
40036.435	−.582±004	−.517±006	.065	8	62
40038.377	−.580±003	−.506±004	.074	6	60
40039.489	−.584±002	−.510±002	.074	6	63
40040.510	−.556±002	−.511±005	.045	6	62
40042.382	−.542±009	−.464±005	.078	4	61
40043.490	−.530±005	−.429±004	.101	6	63
40044.379	−.532±002	−.404±003	.128	6	61
40045.381	−.504±002	−.400±002	.104	6	61
40046.434	−.510±002	−.424±005	.086	6	63
40048.531	−.515±003	−.444±006	.071	6	61
40050.385	−.513±004	−.411±005	.102	6	62
40051.497	−.543±003	−.467±006	.076	6	62
40052.377	−.532±005	−.459±008	.073	4	62
40060.532	−.562±004	−.478±002	.084	6	59
40064.377	−.541±005	−.436±009	.105	6	63
40066.425	−.547±004	−.437±002	.110	3	63
40067.488	−.562±004	−.452±010	.110	4	60
40069.550	−.548±008	−.442±005	.106	6	56
40074.377	−.563±006	−.460±015	.103	5	63
40080.442	−.551±006	−.462±012	.089	6	61
40081.580	−.533±004	−.476±008	.057	6	50
40082.576	−.525±005	−.455±007	.070	6	50
40084.353	−.492±003	−.393±009	.099	6	63
40085.402	−.505±002	−.382±008	.123	6	62
40085.553	−.495	−.377	.118	1	51
40088.513	−.533±004	−.436±006	.097	12	54
40089.474	−.525±002	−.466±008	.059	6	57
40090.492	−.536±006	−.436±008	.100	6	56
40092.504	−.536±003	−.469±006	.067	5	54
40098.605	−.525±005	−.442±001	.083	2	41
40102.348	−.486±003	−.437±002	.049	4	62
40103.424	−.497±004	−.390±010	.107	6	58
40107.426	−.487±009	−.390±012	.097	5	57
40109.564	−.538±004	−.428±008	.110	5	43
40111.485	−.529±004	−.448±008	.081	6	51
40113.496	−.532±004	−.463±004	.069	6	49
40119.574	−.526±004	−.442±004	.084	5	38
40122.559	−.530±002	−.466±003	.064	6	39
40125.454	−.550±004	−.466±004	.084	6	50
40126.452	−.569±004	−.463±010	.106	6	50
40127.432	−.540±003	−.470±008	.070	5	52
40128.516	−.544±003	−.450±009	.094	5	42
40130.405	−.545±003	−.428±005	.117	7	54
40131.392	−.513±006	−.460±006	.053	10	55
40134.586	−.565±007	−.473±007	.092	3	31
40135.454	−.558±004	−.451±005	.107	6	47
40144.391	−.559±002	−.508±004	.051	6	51
40146.634	−.574±002	−.478±002	.096	5	24
40147.352	−.543±002	−.473±005	.070	9	54
40149.356	−.525±001	−.423±003	.102	6	53
40150.335	−.524±004	−.430±005	.094	6	55
40151.348	−.517±006	−.425±003	.092	7	54
40152.474	−.528±004	−.459±002	.069	6	39

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
40153.376	−.546±006	−.483±004	.063	9	50
40154.636	−.566±001	−.505±002	.061	6	23
40158.640	−.610±003	−.549±002	.061	6	22
40160.540	−.608±003	−.530±003	.078	6	29
40161.410	−.596±005	−.559±007	.037	5	44
40162.624	−.590±001	−.544±003	.046	6	22
40179.484	−.629±002	−.579±002	.050	7	29
40183.252	−.613±002	−.559±007	.054	6	54
40185.569	−.620±003	−.507±002	.113	6	22
40186.239	−.603±002	−.560±001	.043	6	55
40187.262	−.565±003	−.512±007	.053	7	52
40188.509	−.555±003	−.469±003	.086	6	24
40200.296	−.580±003	−.488±002	.092	6	45
40201.569	−.597±003	−.523±004	.074	5	23
40202.425	−.604±003	−.559±006	.045	6	28
40203.457	−.631±001	−.586±004	.045	6	25
40212.229	−.587±002	−.500±008	.087	3	49
40230.242	−.612±001	−.548±002	.064	5	41
40231.219	−.606±003	−.525±004	.081	6	44
40232.250	−.594±002	−.538±004	.056	6	40
40233.247	−.604±004	−.527±003	.077	6	40
40243.233	−.576±003	−.500±003	.076	6	38
40248.493	−.580±002	−.505±004	.075	5	27
40253.327	−.647±002	−.563±003	.084	5	25
40254.299	−.636±006	−.534±008	.102	6	27
40263.266	−.526±004	−.446±002	.080	6	28
40264.258	−.527±003	−.438±003	.089	6	28
40266.417	−.547±004	−.471±003	.076	6	25
40271.285	−.600±003	−.545±002	.055	6	24
40286.386	−.548±004	−.452±002	.096	6	27
40288.309	−.552±006	−.472±004	.080	5	22
40289.320	−.556±004	−.469±003	.087	6	23
40290.311	−.564±008	−.493±008	.071	7	23
40292.454	−.601±004	−.516±007	.085	6	37
40302.368	−.592±003	−.529±005	.063	5	30
40317.341	−.582±003	−.495±004	.087	6	31
40318.354	−.579±001	−.506±003	.073	6	33
40319.376	−.570±002	−.476±002	.094	6	36
40320.440	−.586±002	−.495±004	.091	6	45
40321.343	−.593±002	−.505±003	.088	6	33
40322.340	−.579±002	−.495±005	.084	6	33
40327.393	−.593±002	−.520±004	.073	6	41
40328.439	−.584±005	−.511±005	.073	6	47
40329.407	−.591±002	−.516±001	.075	3	43
40330.439	−.589±003	−.513±003	.076	7	47
40332.384	−.582±004	−.494±002	.088	6	42
40333.379	−.573±001	−.512±002	.061	6	41
40335.330	−.569±006	−.492±007	.077	6	36
40336.338	−.578±010	−.487±010	.091	5	38
40338.337	−.564±002	−.478±002	.086	6	38
40339.415	−.563±001	−.496±002	.067	6	48
40340.358	−.585±004	−.487±004	.098	6	41
40342.358	−.589±003	−.517±001	.072	6	42
40345.341	−.572±006	−.476±003	.096	4	41

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B−V)	n	Z
40353.359	−.591±003	−.508±001	.083	6	46
40354.356	−.571±003	−.509±003	.062	6	46
40355.356	−.580±007	−.494±010	.086	6	46
40356.349	−.580±007	−.492±009	.088	6	45
40357.351	−.580±003	−.503±004	.077	6	46
40362.360	−.589±004	−.513±006	.076	6	48
40364.376	−.580±011	−.500±012	.080	8	51
40366.372	−.579±004	−.484±005	.095	6	51
40370.469	−.586±004	−.495±008	.091	6	60
40376.380	−.562±006	−.491±009	.071	6	54
40382.389	−.604±003	−.516±005	.088	6	57
40384.416	−.581±003	−.512±007	.069	6	59
40389.393	−.562±003	−.472±005	.090	5	59
40395.476	−.535±009	−.472±012	.063	5	63
40404.513	−.553±007	−.528±005	.025	6	62
40411.443	−.513±001	−.326±016	.187	2	63
40417.391	−.549±004	−.449±007	.100	6	62
40418.400	−.566±001	−.477±005	.089	6	62
40419.444	−.561±006	−.508±006	.053	6	63
40420.511	−.607±004	−.529±004	.078	6	61
40422.543	−.610±002	−.556±004	.054	6	59
40423.547	−.619±008	−.590±013	.029	7	58
40427.501	−.641±005	−.607±005	.034	7	60
40428.521	−.628±004	−.588±005	.040	6	59
40436.501	−.441±003	−.329±007	.112	6	59
40438.559	−.440±007	−.320±010	.120	8	54
40439.555	−.484±002	−.335±006	.149	6	54
40440.482	−.486±006	−.382±007	.104	5	60
40446.545	−.722±006	−.630±008	.092	8	53
40447.551	−.727±010	−.697±009	.030	3	52
40449.501	−.735±003	−.693±005	.042	6	56
40454.552	−.555±005	−.473±005	.082	7	50
40462.586	−.466±005	−.384±006	.082	6	44
40463.583	−.490±002	−.374±008	.116	6	44
40464.499	−.533±002	−.418±005	.115	6	53
40465.563	−.565±004	−.469±004	.096	6	46
40469.362	−.680±005	−.661±014	.019	3	61
40470.557	−.723±005	−.672±007	.051	6	44
40471.316	−.712±002	−.700±001	.012	3	63
40471.496	−.711±003	−.708±005	.003	6	51
40473.430	−.712±008	−.677±009	.035	3	57
40473.590	−.700±005	−.664±004	.036	6	40
40474.546	−.679±003	−.610±003	.069	6	45
40477.567	−.576±003	−.486±006	.090	6	41
40480.573	−.464±007	−.360±005	.104	4	39
40485.328	−.508±006	−.429±006	.079	6	61
40487.567	−.578±003	−.514±007	.064	6	38
40489.556	−.649±004	−.633±004	.016	5	39
40494.329	−.736±001	−.671±006	.065	3	60
40494.454	−.737±006	−.680±005	.057	6	49
40497.592	−.660±005	−.595±004	.065	4	31
40499.561	−.590±008	−.519±009	.071	4	34
40500.467	−.580±006	−.467±006	.113	6	45
40501.505	−.533±002	−.423±004	.110	6	41

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
40503.577	–.480±004	–.367±006	.113	5	31
40504.443	–.476±005	–.368±003	.108	5	47
40505.477	–.474±007	–.365±003	.109	5	43
40506.398	–.485±002	–.415±001	.070	5	51
40507.558	–.513±002	–.466±002	.047	6	32
40508.569	–.543±002	–.484±003	.059	6	30
40509.487	–.572	–.528	.044	1	40
40511.353	–.636±006	–.588±007	.048	6	55
40512.596	–.663±003	–.622±003	.041	6	26
40513.407	–.675±006	–.641±005	.034	6	49
40513.613	–.673±002	–.644±003	.029	6	25
40514.314	–.679±004	–.637±005	.042	5	57
40514.580	–.673±002	–.630±002	.043	6	28
40515.451	–.672±003	–.622±002	.050	6	43
40516.362	–.667±001	–.605±004	.062	5	52
40516.568	–.670±002	–.612±002	.058	6	28
40517.523	–.665±002	–.581±003	.084	6	33
40527.635	–.515±004	–.445±003	.070	6	22
40528.573	–.531±001	–.470±003	.061	6	25
40529.625	–.553±001	–.512±002	.041	6	22
40530.390	–.586±002	–.540±005	.046	6	45
40531.431	–.586±002	–.566±003	.020	6	40
40532.639	–.628±003	–.595±004	.033	7	22
40536.655	–.644±002	–.587±005	.057	6	24
40537.280	–.641±003	–.572±004	.069	6	55
40541.416	–.590±002	–.495±002	.095	6	38
40543.299	–.535±005	–.447±008	.088	3	51
40544.460	–.540±002	–.430±003	.110	5	32
40545.676	–.521±005	–.429±004	.092	5	27
40546.529	–.524±003	–.435±008	.089	6	24
40547.521	–.521±005	–.452±004	.069	6	25
40548.533	–.521±004	–.428±003	.093	5	24
40553.407	–.586±005	–.522±004	.064	6	35
40554.608	–.599±002	–.552±003	.047	6	24
40558.589	–.630±002	–.534±004	.096	5	23
40559.413	–.626±006	–.519±008	.107	3	32
40577.675	–.612±001	–.557±017	.055	2	37
40589.235	–.533±002	–.440±005	.093	6	44
40594.588	–.582±005	–.515±006	.067	6	32
40595.225	–.588±004	–.527±004	.061	6	43
40606.610	–.490±004	–.392±003	.098	6	39
40615.260	–.574±002	–.529±001	.045	6	32
40616.249	–.599±004	–.544±007	.055	7	33
40621.475	–.624±003	–.568±004	.056	6	28
40629.650	–.494±005	–.422±005	.072	6	51
40635.452	–.591±012	–.539±012	.052	6	29
40642.482	–.642±008	–.541±022	.101	6	35
40653.429	–.491±006	–.408±007	.083	6	32
40654.384	–.521±004	–.447±004	.074	6	27
40658.494	–.601±003	–.562±008	.039	7	42
40662.286	–.645±006	–.572±007	.073	5	22
40663.345	–.636±007	–.571±007	.065	6	26
40665.480	–.606±006	–.519±013	.087	6	43
40674.301	–.504±004	–.392±006	.112	6	25

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
40675.326	−.509±005	−.407±002	.102	6	27
40676.389	−.528±004	−.425±011	.103	6	35
40678.457	−.568±005	−.468±006	.100	6	44
40681.489	−.607±004	−.538±003	.069	6	49
40682.586	−.597±004	−.539±003	.058	6	58
40683.400	−.613±005	−.552±012	.061	6	39
40689.361	−.549±005	−.459±005	.090	6	36
40693.327	−.514±006	−.427±013	.087	3	33
40699.531	−.587±005	−.524±007	.063	4	58
40701.516	−.617±006	−.541±004	.076	6	57
40707.367	−.620±006	−.528±006	.092	6	43
40709.358	−.618±003	−.516±008	.102	6	43
40710.353	−.612±003	−.504±003	.108	6	42
40713.434	−.564±005	−.475±003	.089	10	52
40718.430	−.544±010	−.457±004	.087	2	53
40725.359	−.589±007	−.539±005	.050	6	48
40727.339	−.604±009	−.546±006	.058	6	46
40730.402	−.608±006	−.527±007	.081	6	54
40731.431	−.582±005	−.514±005	.068	6	56
40732.454	−.591±006	−.494±007	.097	18	58
40735.538	−.586±002	−.419±005	.167	6	63
40736.480	−.562±009	−.446±010	.116	6	61
40741.508	−.542±009	−.435±006	.107	5	62
40751.473	−.624±004	−.520±009	.104	6	62
40752.385	−.585±007	−.517±008	.068	6	58
40753.396	−.556±006	−.463±008	.093	4	58
40758.434	−.509±005	−.412±010	.097	6	61
40760.374	−.491±010	−.379±011	.112	4	58
40766.470	−.532±005	−.477±012	.055	6	63
40769.384	−.544±002	−.476±002	.068	6	60
40776.468	−.583±005	−.488±009	.095	5	63
40778.408	−.560±004	−.474±008	.086	4	62
40780.406	−.548±002	−.447±010	.101	6	62
40781.511	−.524±004	−.411±004	.113	6	61
40788.412	−.555±008	−.464±010	.091	8	63
40789.547	−.550	−.459	.091	1	58
40790.375	−.548	−.502	.046	1	62
40792.382	−.555±003	−.564±013	−.009	6	63
40794.510	−.599±001	−.596±003	.003	6	60
40796.383	−.626±004	−.614±006	.012	7	63
40797.390	−.634±003	−.575±011	.059	6	63
40798.473	−.611±007	−.572±009	.039	7	61
40803.436	−.567±005	−.509±003	.058	10	62
40804.524	−.537±006	−.507±007	.030	6	57
40807.458	−.551±001	−.438±004	.113	6	61
40811.513	−.560±001	−.489±003	.071	5	56
40812.424	−.576±009	−.501±007	.075	6	61
40813.433	−.564±006	−.468±008	.096	6	61
40817.363	−.622±008	−.538±007	.084	4	63
40818.380	−.632±008	−.540±011	.092	4	62
40819.529	−.629±007	−.557±003	.072	6	53
40826.475	−.643±004	−.553±010	.090	5	56
40832.361	−.547±008	−.527±007	.020	6	62
40837.315	−.624±008	−.580±007	.044	5	63

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
40839.392	−.634±006	−.613±010	.021	5	59
40840.335	−.646±007	−.557±008	.089	5	62
40841.311	−.656±005	−.556±006	.100	6	62
40843.376	−.624±007	−.583±008	.041	7	60
40844.587	−.592±005	−.537±004	.055	6	38
40847.504	−.591±003	−.584±003	.007	6	47
40852.347	−.592±004	−.509±011	.083	6	60
40852.486	−.592±003	−.527±007	.065	6	48
40853.308	−.575±002	−.505±005	.070	5	62
40854.361	−.592±003	−.510±007	.082	6	59
40855.567	−.599±004	−.521±012	.078	5	37
40856.334	−.570±004	−.537±006	.033	6	60
40857.283	−.580±002	−.533±010	.047	4	62
40857.550	−.582±008	−.523±007	.059	6	38
40858.295	−.604±012	−.534±017	.070	6	62
40859.287	−.598±002	−.550±006	.048	5	62
40859.611	−.599±003	−.549±002	.050	6	30
40866.274	−.588±004	−.503±010	.085	6	62
40866.616	−.575±004	−.496±005	.079	6	27
40867.281	−.601±006	−.488±006	.113	5	61
40867.606	−.585±003	−.454±002	.131	6	28
40868.527	−.568±004	−.481±008	.087	6	37
40869.286	−.574±004	−.489±003	.085	4	61
40869.500	−.554±002	−.477±002	.077	6	40
40870.276	−.584±002	−.450±005	.134	5	61
40870.491	−.563±003	−.464±004	.099	6	41
40871.382	−.571±003	−.470±006	.101	3	53
40871.573	−.567±006	−.474±007	.093	6	31
40872.523	−.544±002	−.448±002	.096	6	36
40875.588	−.565±005	−.521±003	.044	2	28
40876.565	−.577±004	−.505±007	.072	6	30
40877.353	−.594±003	−.517±005	.077	5	54
40877.527	−.569±005	−.487±004	.082	6	34
40878.537	−.579±006	−.538±006	.041	6	33
40881.315	−.623±003	−.547±006	.076	4	57
40882.455	−.616±002	−.553±009	.063	6	42
40886.450	−.580±002	−.511±004	.069	2	41
40887.253	−.578±004	−.507±002	.071	3	60
40887.409	−.583±007	−.500±009	.083	5	45
40890.373	−.542±003	−.434±003	.108	5	49
40895.352	−.540±004	−.454±010	.086	5	50
40897.428	−.533±003	−.470±007	.063	6	40
40903.236	−.586±009	−.512±009	.074	5	58
40903.556	−.579±004	−.512±005	.067	6	24
40904.543	−.567±010	−.492±008	.075	4	25
40906.360	−.558±002	−.490±010	.068	6	45
40908.599	−.554±004	−.457±009	.097	6	22
40911.635	−.496±001	−.402±003	.094	6	24
40925.489	−.578±004	−.490±003	.088	6	25
40929.307	−.610±003	−.522±003	.088	6	44
40931.421	−.581±003	−.476±003	.105	6	29
40936.419	−.479±005	−.353±009	.126	5	28
40937.351	−.462±002	−.337±002	.125	6	36
40938.347	−.441±004	−.337±006	.104	6	36

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
40947.284	−.652±003	−.546±003	.106	5	41
40949.503	−.615±002	−.585±001	.030	6	23
40949.601	−.617±005	−.581±001	.036	4	30
40950.585	−.591±004	−.541±008	.050	3	29
40956.235	−.495±006	−.378±003	.117	6	44
40959.291	−.443±011	−.351±018	.092	8	36
40960.239	−.469±007	−.333±004	.136	6	42
40960.272	−.462±002	−.337±003	.125	6	38
40961.247	−.466±004	−.375±005	.091	6	41
40961.281	−.475±001	−.367±003	.108	5	36
40963.270	−.522±003	−.438±003	.084	6	37
40964.485	−.553±003	−.499±003	.054	12	23
40965.508	−.587±006	−.533±007	.054	6	25
40966.247	−.591±005	−.565±005	.026	6	39
40966.513	−.593±005	−.569±005	.024	3	26
40975.252	−.588±003	−.507±004	.081	6	35
40977.664	−.560±007	−.454±013	.106	5	47
40980.246	−.525±004	−.433±003	.092	7	34
40981.265	−.525±003	−.435±001	.090	6	32
40983.445	−.536±003	−.440±008	.096	6	24
40985.462	−.564±002	−.475±002	.089	6	26
40985.493	−.554±001	−.486±004	.068	6	29
40987.462	−.583±002	−.546±004	.037	5	27
40988.388	−.590±007	−.539±007	.051	12	22
40995.319	−.597±001	−.508±015	.089	2	23
40997.255	−.566±002	−.450±002	.116	6	28
40997.283	−.567±003	−.459±002	.108	5	25
41001.259	−.554±002	−.444±005	.110	6	27
41003.377	−.570±006	−.471±002	.099	6	24
41004.250	−.576±004	−.479±010	.097	6	26
41004.323	−.582±005	−.470±005	.112	6	22
41005.399	−.587±004	−.487±006	.100	6	25
41006.497	−.590±006	−.514±007	.076	6	36
41007.279	−.590±002	−.529±007	.061	12	24
41009.278	−.611±003	−.542±004	.069	10	23
41010.273	−.595±004	−.549±006	.046	6	23
41011.461	−.607±004	−.537±006	.070	6	34
41019.341	−.554±008	−.446±007	.108	6	24
41021.275	−.558±005	−.446±006	.112	6	22
41022.293	−.572±007	−.449±003	.123	5	22
41023.276	−.581±002	−.480±006	.101	6	22
41023.310	−.579±003	−.483±002	.096	6	23
41024.332	−.571±001	−.502±003	.069	6	24
41024.365	−.579±002	−.503±004	.076	6	27
41029.294	−.576±004	−.497±004	.079	8	23
41032.301	−.561±004	−.486±009	.075	3	24
41034.378	−.561±009	−.479±008	.082	6	31
41035.288	−.560±003	−.468±002	.092	6	23
41036.356	−.554±004	−.481±007	.073	6	29
41039.318	−.553±004	−.464±007	.089	6	26
41042.302	−.568±003	−.478±003	.090	6	26
41044.394	−.570±002	−.496±005	.074	6	37
41045.593	−.584±001	−.538±002	.046	2	58
41047.348	−.588±004	−.515±003	.073	6	32

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B-V)	n	Z
41049.347	−.575±004	−.500±003	.075	6	33
41054.308	−.560±002	−.468±002	.092	6	30
41055.361	−.545±006	−.471±009	.074	4	36
41056.313	−.548±002	−.475±003	.073	6	31
41060.325	−.548±003	−.451±006	.097	5	33
41061.328	−.554±003	−.465±004	.089	6	34
41063.432	−.558±005	−.467±006	.091	6	48
41064.325	−.576±009	−.486±009	.090	5	35
41069.350	−.581±005	−.486±004	.095	5	40
41070.379	−.567±007	−.498±007	.069	6	44
41071.356	−.568±003	−.474±003	.094	6	41
41076.435	−.522±007	−.458±005	.064	6	52
41081.340	−.555±007	−.481±009	.074	6	42
41082.399	−.566±003	−.488±008	.078	6	50
41083.346	−.584±004	−.507±006	.077	6	44
41084.353	−.605±005	−.519±008	.086	6	45
41085.348	−.602±004	−.542±008	.060	6	45
41086.360	−.609±005	−.537±005	.072	7	46
41087.348	−.613±015	−.542±016	.071	5	45
41088.352	−.610±002	−.560±008	.050	6	46
41089.375	−.615±011	−.547±007	.068	6	49
41090.362	−.605±004	−.563±007	.042	6	48
41091.367	−.596±004	−.531±013	.065	4	49
41092.363	−.581±004	−.531±008	.050	6	49
41094.437	−.578±006	−.505±004	.073	6	57
41095.358	−.560±004	−.485±004	.075	5	49
41096.365	−.562±002	−.473±003	.089	6	50
41108.374	−.563±002	−.501±003	.062	5	54
41114.447	−.576±001	−.510±002	.066	4	61
41116.445	−.576±003	−.483±004	.093	3	61
41118.448	−.558±005	−.469±007	.089	6	61
41119.383	−.546±003	−.454±005	.092	6	58
41120.381	−.523±003	−.441±010	.082	5	58
41126.381	−.487±008	−.423±010	.064	6	59
41128.455	−.488±007	−.409±010	.079	5	62
41134.413	−.617±007	−.604±005	.013	5	62
41137.383	−.650±006	−.608±009	.042	6	61
41141.515	−.598±002	−.494±005	.104	5	62
41142.384	−.549±005	−.464±003	.085	5	61
41143.425	−.531±005	−.430±012	.101	5	63
41144.392	−.519±010	−.412±015	.107	5	62
41147.380	−.493±004	−.366±002	.127	5	62
41152.540	−.569±010	−.488±013	.081	4	59
41154.525	−.595±005	−.535±005	.060	5	60
41157.539	−.658±010	−.594±003	.064	4	58
41158.537	−.651±009	−.606±004	.045	4	58
41160.361	−.628±007	−.562±013	.066	4	62
41160.544	−.633±005	−.561±011	.072	5	57
41161.355	−.603±006	−.512±006	.091	4	62
41162.417	−.575±005	−.503±003	.072	6	63
41164.450	−.511±004	−.419±007	.092	5	62
41165.536	−.497±002	−.370±010	.127	6	57
41166.549	−.475±005	−.360±006	.115	6	55
41167.555	−.469±009	−.318±013	.151	6	55

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
41168.560	−.455±013	−.281±017	.174	4	54
41171.548	−.469±009	−.346±004	.123	6	54
41173.544	−.498±004	−.399±008	.099	6	54
41174.553	−.530±003	−.436±007	.094	6	53
41176.554	−.568±004	−.501±008	.067	6	52
41177.561	−.606±003	−.507±003	.099	6	51
41178.568	−.606±007	−.547±003	.059	6	51
41179.555	−.619±010	−.566±006	.053	6	51
41181.565	−.590±011	−.535±006	.055	5	50
41182.564	−.580±006	−.510±007	.070	6	50
41183.563	−.572±003	−.486±004	.086	5	50
41184.556	−.551±005	−.445±001	.106	5	50
41185.555	−.523±004	−.414±007	.109	5	50
41185.570	−.529±003	−.429±006	.100	5	48
41186.569	−.521±002	−.381±009	.140	2	48
41189.558	−.455±004	−.329±004	.126	5	48
41191.585	−.460±003	−.343±008	.117	4	44
41193.580	−.489±007	−.374±003	.115	4	45
41197.520	−.532±009	−.495±009	.037	3	50
41198.593	−.565±004	−.521±011	.044	5	41
41201.570	−.622±008	−.573±003	.049	4	43
41205.573	−.574±006	−.525±009	.049	5	41
41209.574	−.547±010	−.444±011	.103	5	40
41209.610	−.533±012	−.439±013	.094	4	35
41212.550	−.507±003	−.387±007	.120	6	42
41214.575	−.496±003	−.401±006	.095	6	38
41215.630	−.486±003	−.395±008	.091	5	31
41216.584	−.499±003	−.421±005	.078	6	36
41217.595	−.520±003	−.414±007	.106	6	35
41218.582	−.521±002	−.438±003	.083	6	36
41226.564	−.598±006	−.554±004	.044	6	35
41227.565	−.594±002	−.526±006	.068	6	35
41228.523	−.573±005	−.510±003	.063	6	40
41229.622	−.558±006	−.489±009	.069	5	28
41230.593	−.555±003	−.471±003	.084	6	30
41232.568	−.509±002	−.418±002	.091	6	33
41233.529	−.512±002	−.396±002	.116	6	37
41233.579	−.520±005	−.398±003	.122	6	31
41234.561	−.467±004	−.418±003	.049	6	33
41235.559	−.502±002	−.371±007	.131	6	33
41236.594	−.484±002	−.386±005	.098	6	29
41238.545	−.509±006	−.414±004	.095	6	33
41241.530	−.529±003	−.472±003	.057	6	34
41244.559	−.611±004	−.562±005	.049	6	30
41245.560	−.634±003	−.588±004	.046	4	30
41246.560	−.671±007	−.615±008	.056	6	29
41247.554	−.660±003	−.621±002	.039	6	29
41248.517	−.674±003	−.620±001	.054	6	34
41249.553	−.670±003	−.628±002	.042	6	29
41251.541	−.654±005	−.598±009	.056	6	30
41253.548	−.636±005	−.554±002	.082	8	29
41255.395	−.587±003	−.514±004	.073	6	46
41260.423	−.511±005	−.387±002	.124	6	41
41261.476	−.479±003	−.393±013	.086	6	34

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B−V)	n	Z
41272.430	−.683±004	−.632±004	.051	6	36
41276.599	−.642±004	−.559±008	.083	6	22
41277.269	−.625±009	−.524±008	.101	6	53
41282.541	−.500±002	−.393±005	.107	6	23
41290.218	−.621±009	−.559±004	.062	4	55
41292.349	−.685±005	−.617±003	.068	6	40
41294.207	−.664±007	−.622±003	.042	6	55
41295.209	−.681±003	−.616±003	.065	6	54
41299.539	−.567±009	−.470±009	.097	2	22
41301.198	−.535±002	−.413±003	.122	6	54
41303.206	−.465±007	−.362±010	.103	6	52
41303.458	−.460±007	−.355±007	.105	6	24
41304.217	−.456±002	−.354±002	.102	6	51
41308.447	−.515±009	−.407±011	.108	3	24
41310.201	−.560±008	−.491±003	.069	6	51
41311.305	−.578±004	−.523±004	.055	8	39
41312.230	−.592±006	−.534±007	.058	6	47
41313.619	−.613±009	−.531±010	.082	5	32
41329.409	−.521±006	−.419±005	.102	5	23
41330.224	−.500±008	−.446±007	.054	6	42
41331.311	−.542±002	−.458±004	.084	6	31
41332.340	−.561±005	−.473±010	.088	6	28
41336.246	−.573±008	−.477±018	.096	5	37
41337.511	−.544±003	−.434±001	.110	6	27
41340.311	−.480±004	−.399±002	.081	6	28
41350.608	−.581±003	−.483±003	.098	6	43
41351.229	−.591±009	−.509±005	.082	6	34
41352.243	−.610±005	−.538±003	.072	6	32
41353.248	−.619±003	−.557±002	.062	6	32
41360.358	−.511±007	−.402±006	.109	8	22
41364.321	−.431±004	−.304±004	.127	6	23
41366.247	−.420±010	−.311±009	.109	6	28
41368.257	−.476±003	−.361±009	.115	6	26
41389.319	−.486±008	−.360±005	.126	6	23
41390.272	−.487±001	−.378±004	.109	6	22
41391.279	−.498±002	−.415±004	.083	6	22
41392.275	−.532±002	−.458±001	.074	6	22
41393.278	−.565±003	−.493±006	.072	6	22
41394.285	−.609±004	−.510±004	.099	6	23
41395.281	−.606±005	−.534±006	.072	6	22
41396.328	−.604±004	−.544±004	.060	7	25
41397.432	−.613±005	−.552±002	.061	6	37
41398.515	−.608±006	−.539±006	.069	6	48
41399.289	−.590±012	−.507±004	.083	6	23
41400.593	−.539±009	−.471±007	.068	6	56
41401.288	−.534±002	−.453±002	.081	6	24
41402.306	−.511±002	−.443±003	.068	6	25
41403.303	−.488±003	−.406±005	.082	6	25
41404.486	−.489±003	−.389±005	.100	6	46
41407.477	−.448±010	−.343±011	.105	6	46
41408.353	−.465±003	−.340±004	.125	6	31
41412.331	−.503±002	−.405±005	.098	8	30
41414.389	−.568±003	−.461±005	.107	4	38
41415.304	−.556±002	−.488±002	.068	6	28

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
41416.332	–.566±003	–.501±001	.065	3	31
41417.591	–.559±006	–.530±003	.029	6	59
41436.340	–.503±006	–.389±006	.114	6	39
41437.349	–.522±002	–.438±004	.084	5	40
41438.329	–.554±002	–.464±005	.090	6	38
41439.326	–.567±006	–.486±003	.081	6	38
41444.572	–.541±005	–.488±004	.053	5	62
41448.356	–.509±006	–.418±007	.091	7	45
41455.346	–.471±003	–.356±003	.115	6	46
41459.420	–.556±005	–.431±010	.125	2	55
41460.359	–.541±012	–.439±009	.102	3	49
41460.548	–.548±008	–.432±010	.116	3	62
41461.354	–.547±003	–.469±007	.078	6	49
41463.379	–.548±002	–.454±005	.094	6	52
41466.361	–.543±004	–.439±005	.104	5	51
41467.392	–.540±004	–.457±002	.083	6	54
41472.419	–.487±006	–.371±007	.116	5	58
41473.540	–.473±005	–.383±005	.090	3	63
41474.363	–.465±004	–.359±012	.106	5	54
41476.385	–.490±003	–.372±007	.118	6	56
41477.374	–.489±006	–.372±009	.117	4	55
41484.366	–.544±002	–.422±010	.122	2	56
41485.493	–.548±007	–.447±006	.101	5	63
41489.461	–.565±004	–.458±003	.107	6	62
41490.384	–.541±002	–.461±004	.080	6	59
41491.393	–.531±003	–.483±005	.048	6	60
41493.519	–.493±008	–.462±008	.031	7	63
41495.377	–.486±004	–.434±014	.052	5	59
41500.373	–.532±003	–.449±008	.083	5	60
41503.373	–.531±011	–.447±014	.084	6	60
41508.536	–.532±005	–.433±008	.099	5	61
41521.543	–.491±011	–.423±009	.068	4	58
41529.557	–.545±005	–.457±008	.088	6	55
41530.367	–.555±004	–.456±006	.099	6	63
41530.547	–.563±006	–.454±006	.109	4	56
41533.377	–.558±005	–.471±006	.087	3	63
41534.386	–.548±008	–.461±001	.087	3	63
41535.357	–.540±005	–.484±007	.056	4	63
41535.570	–.510±005	–.438±005	.072	4	52
41537.350	–.517±004	–.448±007	.069	6	63
41538.562	–.537±011	–.443±006	.094	5	52
41539.478	–.525±006	–.452±008	.073	5	59
41543.547*	–.502±003	–.404±008	.098	5	52
41544.557	–.506±003	–.407±006	.099	6	51
41544.560*	–.520±009	–.397±005	.123	3	51
41545.545	–.502±005	–.394±007	.108	6	52
41545.548*	–.502±003	–.408±005	.094	5	52
41554.570	–.529±009	–.459±013	.070	6	47
41561.576	–.532±006	–.440±006	.092	6	44
41563.569	–.544±003	–.461±010	.083	6	44
41565.586	–.540±002	–.444±006	.096	5	41
41566.590	–.555±006	–.440±008	.115	6	41
41567.572*	–.537±004	–.435±004	.102	4	42

* observation made at Piszkéstető mountain station

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
41567.577	−.547±003	−.447±007	.100	6	42
41584.568	−.552±004	−.475±008	.077	3	37
41586.566	−.565±003	−.470±004	.095	6	36
41586.604*	−.554±004	−.494±004	.060	5	32
41588.553	−.556±002	−.505±002	.051	6	37
41589.447	−.554±005	−.482±012	.072	5	50
41589.607*	−.560±002	−.479±004	.081	5	30
41590.555	−.564±007	−.477±009	.087	6	37
41591.555	−.544±003	−.484±003	.060	6	36
41594.556	−.565±006	−.459±005	.106	6	35
41596.583	−.541±001	−.453±002	.088	6	31
41596.621*	−.553±004	−.443±006	.110	5	27
41597.370	−.531±004	−.451±005	.080	6	55
41604.614	−.564±004	−.506±003	.058	5	26
41605.550	−.562±001	−.504±001	.058	6	32
41606.556	−.565±001	−.503±001	.062	5	31
41608.525	−.584±002	−.518±004	.066	6	35
41610.492	−.597±004	−.514±004	.083	5	38
41617.508	−.581±010	−.474±010	.107	6	33
41622.409	−.549±007	−.479±003	.070	5	44
41623.547	−.569±002	−.456±004	.113	6	27
41629.499	−.571±002	−.492±003	.079	6	30
41631.455	−.570±005	−.515±005	.055	6	35
41634.472	−.608±002	−.502±003	.106	5	32
41637.589	−.574±005	−.506±003	.068	5	22
41647.383	−.565±004	−.465±004	.100	6	39
41650.415	−.586±001	−.540±002	.046	5	34
41651.455*	−.612±006	−.552±008	.060	6	29
41672.211	−.597±007	−.546±008	.051	6	51
41673.218	−.636±006	−.562±008	.074	5	50
41674.515	−.651±003	−.592±008	.059	6	22
41675.250	−.668±005	−.595±004	.073	5	46
41679.199	−.586±008	−.538±007	.048	6	50
41679.275*	−.595±003	−.502±008	.093	4	41
41680.248*	−.579±006	−.493±010	.086	4	44
41680.562	−.587±008	−.483±007	.104	6	26
41681.631*	−.552±002	−.457±009	.095	4	34
41682.208	−.560±005	−.420±008	.140	6	48
41682.277*	−.546	−.426	.120	1	40
41688.234	−.475±006	−.392±005	.083	6	43
41688.258*	−.482±014	−.381±014	.101	4	40
41689.280*	−.517±004	−.435±004	.082	5	37
41689.283	−.536±007	−.428±007	.108	6	37
41694.319	−.622±007	−.578±003	.044	5	31
41695.269	−.629±009	−.589±003	.040	6	37
41696.203	−.648±004	−.597±004	.051	6	44
41697.296	−.649±016	−.594±010	.055	6	33
41709.336	−.438±008	−.307±006	.131	6	25
41712.213	−.529±002	−.461±004	.068	3	38
41717.242	−.673±008	−.655±009	.018	5	33
41737.483	−.636±008	−.611±004	.025	4	35
41739.282	−.643±008	−.627±007	.016	5	23

* observation made at Piszkéstető mountain station

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
41742.361	−.624±004	−.569±005	.055	6	24
41746.283	−.536±002	−.430±004	.106	4	22
41747.403	−.517±002	−.381±004	.136	6	29
41752.473	−.460±003	−.318±003	.142	6	39
41753.358	−.475±012	−.348±011	.127	6	26
41754.282	−.484±004	−.417±005	.067	6	22
41758.335	−.597±006	−.549±009	.048	6	25
41759.273	−.628±003	−.573±007	.055	6	22
41761.292	−.655±002	−.640±001	.015	5	23
41764.285	−.657±005	−.616±004	.041	5	23
41766.291	−.608±006	−.551±006	.057	6	23
41772.285	−.441±005	−.311±007	.130	5	24
41778.338	−.530±004	−.453±005	.077	6	31
41779.353	−.554±008	−.503±005	.051	3	33
41783.408	−.662±002	−.613±003	.049	3	41
41789.473	−.583±006	−.434±007	.149	4	51
41795.306	−.415±005	−.267±008	.148	4	33
41795.320*	−.417±004	−.268±008	.149	4	34
41797.426*	−.445±004	−.332±001	.113	2	48
41799.320	−.472±007	−.403±005	.069	5	36
41803.337	−.615±004	−.583±009	.032	4	39
41804.344	−.651±007	−.616±007	.035	4	40
41807.339	−.616±006	−.570±018	.046	3	41
41810.347	−.601±005	−.507±010	.094	5	43
41815.381	−.477±008	−.294±002	.183	6	49
41816.492	−.443±004	−.278±003	.165	5	59
41818.350	−.408±004	−.281±013	.127	6	46
41824.389	−.568±007	−.539±002	.029	2	52
41825.411	−.634±001	−.620±003	.014	2	54
41827.461	−.690±010	−.654±004	.036	5	59
41834.391	−.540±011	−.463±015	.077	4	55
41842.376	−.490±004	−.387±009	.103	6	55
41844.379	−.528±004	−.471±006	.057	5	56
41845.373	−.572±009	−.497±007	.075	6	56
41846.378	−.549±006	−.580±002	−.031	4	57
41918.553*	−.656±008	−.609±005	.047	4	49
41921.557*	−.518±003	−.371±006	.147	4	47
41930.580	−.543±001	−.443±006	.100	4	42
41931.576	−.565±003	−.502±002	.063	3	43
41932.563	−.618±002	−.593±003	.025	4	44
41933.533	−.666±005	−.624±004	.042	6	47
41934.612	−.682±006	−.669±012	.013	5	37
41935.574	−.694±008	−.662±004	.032	5	41
41939.589	−.652±005	−.573±008	.079	4	38
41941.595	−.582±008	−.448±007	.134	4	37
41954.543	−.613±005	−.565±003	.048	4	39
41957.594	−.688±003	−.668±007	.020	4	31
41960.483	−.687±005	−.612±007	.075	4	44
41961.471	−.653±007	−.578±004	.075	5	45
41962.526	−.635±003	−.528±007	.107	5	38
41965.538	−.527±010	−.376±011	.151	5	35
41966.524	−.484±001	−.297±005	.187	4	37

* observation made at Piszkéstető mountain station

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
41978.484	−.629	−.578	.051	1	38
41980.418	−.660±009	−.611±009	.049	6	45
41981.532	−.659±007	−.576±006	.083	5	31
41982.448	−.665±008	−.582±001	.083	5	41
41983.587	−.668±006	−.555±005	.113	6	25
41984.428	−.623±006	−.526±005	.097	5	43
41987.622	−.563±006	−.424±007	.139	4	22
41988.637	−.512±005	−.354±002	.158	4	22
41989.467	−.483±008	−.332±003	.151	4	36
41990.432	−.437±004	−.333±013	.104	6	40
41997.451	−.539±004	−.486±013	.053	6	36
42005.463	−.620±009	−.510±009	.110	6	31
42008.573	−.557±010	−.411±003	.146	4	22
42009.468	−.536±004	−.428±005	.108	5	29
42018.596	−.541±002	−.456±005	.085	5	23
42019.311	−.570±007	−.519±008	.051	5	45
42022.465	−.697±008	−.652±010	.045	5	26
42026.313	−.623±007	−.554±005	.069	6	43
42035.356	−.409±004	−.307±009	.102	4	34
42039.453	−.540±010	−.469±010	.071	5	24
42069.268	−.632±008	−.505±004	.127	6	34
42070.302	−.565±005	−.466±007	.099	6	30
42089.450	−.642±005	−.550±002	.092	5	27
42091.625	−.598±008	−.474±002	.124	4	48
42094.605	−.497±003	−.365±004	.132	4	47
42095.311	−.478±006	−.353±008	.125	6	23
42101.374	−.550±009	−.443±008	.107	4	24
42106.248	−.671±005	−.616±011	.055	5	25
42108.351	−.653±007	−.631±009	.022	5	23
42119.273	−.445±004	−.361±006	.084	5	22
42120.317	−.455±008	−.354±005	.101	5	23
42121.282	−.472±002	−.386±004	.086	3	22
42126.336	−.580±007	−.522±009	.058	5	26
42127.429	−.628±009	−.564±006	.064	5	37
42128.318	−.642±006	−.620±008	.022	5	25
42130.416	−.668±001	−.574±001	.094	2	36
42132.483*	−.623±009	−.532±006	.091	5	45
42133.311	−.593±006	−.514±009	.079	4	26
42133.495*	−.610±006	−.517±009	.093	3	46
42134.320	−.593±005	−.509±007	.084	6	26
42135.304	−.578±004	−.406±006	.172	4	25
42136.302	−.545±007	−.396±013	.149	4	25
42136.473*	−.552±013	−.413±008	.139	4	45
42141.383	−.426±007	−.262±009	.164	5	36
42142.316	−.420±004	−.283±008	.137	4	28
42146.419	−.538±004	−.445±012	.093	5	42
42147.301	−.561±003	−.486±001	.075	5	28
42148.342	−.626±005	−.616±005	.010	5	33
42152.355	−.691±006	−.625±005	.066	5	36
42159.340	−.473±008	−.307±005	.166	5	36
42160.322	−.391±009	−.222±004	.169	3	34
42161.339	−.368±005	−.228±006	.140	5	37

* observation made at Piszkéstető mountain station

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
42167.502	–.507±007	–.452±005	.055	5	57
42171.323	–.724±010	–.649±015	.075	6	39
42177.397	–.636	–.529	.107	1	49
42178.341	–.598±008	–.458±002	.140	5	43
42187.523*	–.445±014	–.316±014	.129	4	61
42191.394	–.656±008	–.614±008	.042	5	53
42193.410	–.699±003	–.701±008	–.002	5	55
42194.357	–.705±006	–.677±011	.028	5	50
42195.359	–.706±003	–.684±007	.022	5	51
42201.357	–.456±006	–.362±007	.094	4	52
42202.346	–.429±006	–.287±007	.142	5	51
42204.360	–.359±009	–.225±012	.134	5	53
42218.372	–.670±008	–.660±008	.010	4	57
42220.376	–.648±007	–.548±014	.100	3	58
42221.448	–.552±007	–.480±013	.072	5	62
42229.361	–.358±008	–.281±007	.077	5	59
42234.386	–.733±006	–.768±013	–.035	5	61
42243.375	–.562±010	–.481±007	.081	5	62
42244.405	–.430±006	–.221±006	.209	4	62
42255.343	–.700±007	–.599±016	.101	5	62
42256.511	–.745±006	–.738±008	.007	5	59
42257.529	–.792±006	–.760±006	.032	4	58
42266.560	–.464±004	–.348±003	.116	5	53
42267.553	–.406±009	–.249±009	.157	5	54
42269.577	–.319±008	–.174±009	.145	6	51
42274.526	–.544±005	–.462±007	.082	3	54
42275.583	–.603±004	–.590±005	.013	5	48
42276.560	–.674±004	–.686±009	–.012	5	51
42277.551	–.736±004	–.733±003	.003	5	51
42277.559*	–.713±006	–.736±006	–.023	3	50
42278.544*	–.760±010	–.787±012	–.027	4	51
42279.575*	–.785±003	–.839±004	–.054	4	48
42289.562	–.377±012	–.204±017	.173	5	46
42290.541	–.316±010	–.131±012	.185	5	49
42291.449	–.297±008	–.133±007	.164	4	57
42295.524	–.452±007	–.354±003	.098	5	49
42296.559	–.521±005	–.483±007	.038	5	45
42303.496	–.790±007	–.759±006	.031	6	50
42304.589	–.761±005	–.703±004	.058	5	38
42307.565	–.609±004	–.484±004	.125	3	40
42308.600	–.528±011	–.384±009	.144	5	35
42309.555	–.467±007	–.312±005	.155	5	41
42318.515	–.581±005	–.475±005	.106	5	42
42319.433	–.633±004	–.610±002	.023	4	52
42329.420	–.576±005	–.434±003	.142	4	50
42347.297	–.717±005	–.680±010	.037	5	57
42350.493	–.563±007	–.436±013	.127	3	34
42360.557	–.501±002	–.424±013	.077	4	25
42361.636	–.607±001	–.552±002	.055	5	23
42366.614	–.766±005	–.776±007	–.010	5	22
42369.538	–.693±008	–.642±011	.051	5	24
42371.605	–.608±004	–.476±005	.132	5	22

* observation made at Piszkéstető mountain station

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
42398.597	−.462±013	−.207±011	.255	3	27
42403.375	−.423±007	−.278±008	.145	5	31
42404.615	−.498±009	−.416±004	.082	4	30
42415.295	−.631±010	−.536±013	.095	5	37
42422.432	−.347±004	−.177±006	.170	6	22
42423.612	−.354±004	−.194±004	.160	5	36
42429.588	−.644±009	−.626±007	.018	5	35
42432.456	−.754±005	−.738±007	.016	6	23
42433.486	−.757±003	−.757±006	.000	5	25
42439.255	−.541±002	−.400±011	.141	4	34
42442.606	−.403±005	−.246±004	.157	5	42
42443.320	−.403±010	−.228±009	.175	5	26
42448.595	−.430±009	−.383±012	.047	5	42
42449.497	−.479±010	−.428±003	.051	5	31
42450.461	−.537±002	−.483±006	.054	4	27
42452.283*	−.616±002	−.600±004	.016	4	26
42452.459	−.641±010	−.585±011	.056	5	28
42453.262*	−.649±004	−.626±005	.023	4	28
42453.557	−.661±005	−.629±004	.032	4	40
42454.256*	−.676±004	−.669±002	.007	4	28
42454.394	−.680±003	−.641±004	.039	4	23
42460.441	−.545±006	−.416±005	.129	5	28
42461.321	−.494±002	−.366±002	.128	4	23
42464.299	−.401±002	−.242±003	.159	4	23
42465.368	−.406±008	−.221±011	.185	5	23
42466.288	−.390±010	−.276±006	.114	5	23
42468.360	−.411±006	−.326±008	.085	5	23
42470.409	−.476±006	−.410±006	.066	4	27
42471.406	−.533±005	−.473±002	.060	4	27
42472.366	−.570±009	−.505±002	.065	4	24
42473.534	−.609±007	−.548±009	.061	4	43
42474.350	−.595±005	−.578±010	.017	5	24
42481.415	−.547±004	−.420±007	.127	6	31
42485.311	−.408±010	−.312±008	.096	5	23
42493.513	−.607±009	−.569±007	.038	5	47
42504.428*	−.522±006	−.382±005	.140	5	40
42511.365	−.499±007	−.436±007	.063	5	35
42522.328	−.645±008	−.526±004	.119	5	34
42523.367	−.625±006	−.469±008	.156	5	39
42524.330	−.584±007	−.431±008	.153	5	35
42530.410	−.481±006	−.353±008	.128	5	47
42531.353*	−.496±005	−.390±002	.106	3	40
42531.400	−.494±005	−.384±010	.110	5	46
42532.519*	−.511±004	−.411±013	.100	4	58
42533.318	−.545±007	−.447±006	.098	6	37
42543.408	−.623±010	−.508±009	.115	6	50
42544.342	−.564±008	−.463±009	.101	5	44
42548.363*	−.521±006	−.355±009	.166	5	47
42548.477	−.522±005	−.347±007	.175	5	58
42553.474	−.538±009	−.444±011	.094	4	59
42554.341	−.563±005	−.452±003	.111	3	46
42556.517	−.593±004	−.535±014	.058	5	61

* observation made at Piszkéstető mountain station

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
42562.409	–.598±008	–.547±008	.051	5	56
42566.384	–.547±006	–.471±014	.076	4	54
42575.460	–.495±004	–.412±013	.083	5	61
42590.380	–.460±005	–.340±007	.120	4	59
42593.410	–.483±005	–.354±012	.129	5	61
42598.386	–.592±010	–.498±007	.094	5	61
42600.506	–.620±009	–.541±008	.079	6	62
42608.384	–.491±009	–.376±004	.115	4	62
42639.551	–.526±006	–.436±010	.090	6	52
42645.578	–.630±007	–.572±009	.058	5	47
42665.588*	–.512±003	–.403±002	.109	3	39
42669.550*	–.615±006	–.572±009	.043	4	42
42673.517*	–.662±005	–.643±005	.019	4	45
42673.570	–.646±007	–.644±007	.002	5	39
42675.554	–.617±006	–.615±008	.002	4	40
42676.532	–.588±003	–.539±009	.049	4	43
42677.522	–.588±010	–.470±011	.118	5	44
42679.527	–.521±007	–.389±006	.132	5	42
42685.611	–.453±004	–.259±009	.194	5	30
42687.583	–.516±008	–.422±008	.094	4	33
42688.588	–.578±001	–.485±007	.093	5	32
42697.605*	–.631	–.550	.081	1	27
42709.568	–.486±005	–.395±006	.091	6	28
42710.617	–.507±005	–.430±005	.077	5	24
42711.608	–.536±003	–.486±006	.050	5	24
42712.470	–.554±007	–.506±002	.048	5	39
42713.614	–.580±002	–.536±008	.044	5	23
42714.568	–.598±011	–.558±009	.040	4	27
42715.652	–.579±004	–.554±010	.025	4	22
42716.574	–.604±002	–.514±003	.090	4	25
42741.630	–.648±004	–.604±004	.044	5	24
42743.626	–.601±001	–.546±009	.055	5	24
42754.353	–.463±005	–.333±005	.130	6	39
42758.379	–.591±009	–.559±009	.032	5	34
42767.447	–.586±008	–.521±001	.065	3	25
42785.470	–.687±005	–.646±008	.041	5	22
42786.621	–.686±009	–.641±004	.045	4	36
42793.417	–.532±009	–.430±004	.102	5	22
42794.311	–.486±008	–.433±010	.053	4	30
42812.266	–.589±009	–.521±009	.068	5	30
42816.564	–.527±004	–.414±007	.113	4	39
42817.456	–.529±004	–.438±006	.091	4	27
42829.457	–.656±006	–.530±004	.126	4	31
42830.514	–.624±002	–.536±001	.088	4	38
42831.364	–.622±002	–.511±001	.111	4	23
42836.410	–.546±007	–.423±008	.123	4	28
42837.352	–.544±006	–.455±005	.089	4	23
42839.251	–.549±003	–.427±005	.122	4	24
42850.357	–.630±005	–.577±003	.053	4	26
42866.349	–.620±006	–.578±008	.042	4	30
42867.314	–.622±005	–.571±018	.051	4	26
42870.465	–.622±010	–.574±006	.048	4	45

* observation made at Piszkéstető mountain station

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
42871.388	–.620±004	–.564±003	.056	4	36
42872.468	–.601±004	–.529±003	.072	4	46
42873.431	–.557±007	–.500±012	.057	4	42
42875.420	–.573±003	–.476±004	.097	4	42
42887.359	–.583±009	–.542±010	.041	5	38
42888.362	–.592±005	–.560±015	.032	5	39
42900.458	–.567±008	–.472±004	.095	3	53
42904.326	–.571±001	–.493±008	.078	4	39
42905.362	–.546±007	–.472±011	.074	5	45
42908.360	–.586±005	–.488±007	.098	5	45
42910.339	–.588±008	–.515±004	.073	5	43
42914.359	–.582±006	–.498±006	.084	2	47
42915.364	–.576±007	–.487±006	.089	4	48
42927.426	–.560±007	–.468±009	.092	4	57
42928.357	–.570±004	–.499±011	.071	4	51
42936.370	–.655±007	–.592±006	.063	3	55
42939.366	–.589±008	–.521±019	.068	4	55
42950.488	–.573±005	–.554±007	.019	5	63
42952.400	–.650±007	–.574±007	.076	3	60
43030.560	–.593±003	–.506±005	.087	4	43
43034.585	–.559±004	–.494±013	.065	4	39
43045.614	–.566±003	–.464±007	.102	4	32
43048.605	–.608±008	–.499±006	.109	4	32
43061.477	–.534±002	–.510±014	.024	5	43
43076.478	–.602±007	–.520±018	.082	5	38
43077.456	–.602±005	–.512±004	.090	5	40
43078.634	–.589±010	–.485±010	.104	5	23
43124.585	–.482±008	–.393±007	.089	3	25
43140.330	–.458±003	–.323±004	.135	4	35
43162.480	–.481±005	–.354±003	.127	4	24
43168.502	–.513±003	–.440±008	.073	6	28
43176.459	–.701±003	–.671±007	.030	5	26
43178.448	–.710±005	–.601±011	.109	4	25
43192.251	–.567±005	–.529±010	.038	5	27
43198.281	–.688±007	–.640±011	.048	5	24
43202.568	–.658±004	–.557±005	.101	4	47
43203.282	–.601±010	–.522±009	.079	5	23
43209.325	–.489±001	–.425±005	.064	4	23
43210.474	–.512±004	–.405±006	.107	4	38
43212.423	–.541±011	–.491±008	.050	4	32
43213.341	–.601±006	–.545±008	.056	4	24
43217.292	–.666±009	–.635±003	.031	3	23
43218.279	–.679±008	–.632±014	.047	3	22
43220.517	–.664±008	–.586±004	.078	4	46
43221.362	–.629±006	–.565±015	.064	4	28
43224.386	–.587±008	–.472±006	.115	4	32
43226.427	–.558±004	–.436±002	.122	4	37
43228.368	–.524±006	–.394±005	.130	5	31
43229.485	–.467±006	–.393±010	.074	5	46
43234.455	–.575±003	–.467±007	.108	3	44
43240.364	–.651±005	–.606±012	.045	4	34
43244.547	–.642±008	–.523±010	.119	5	56
43251.345	–.541±008	–.416±007	.125	4	36
43287.394	–.570±003	–.450±002	.120	4	53

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
43289.355	−.532±006	−.388±004	.144	5	50
43298.380	−.571±007	−.541±011	.030	4	54
43302.512	−.706±002	−.610±009	.096	4	63
43372.473	−.583±006	−.497±002	.086	3	58
43375.582	−.518±006	−.403±004	.115	3	47
43381.558	−.511±006	−.367±009	.144	3	48
43385.596	−.572±004	−.476±010	.096	3	42
43390.587	−.601±005	−.553±002	.048	3	42
43393.595	−.612±008	−.552±005	.060	3	40
43399.484	−.457±005	−.370±006	.087	3	51
43414.461	−.646±005	−.610±004	.036	3	49
43415.503	−.648±008	−.595±004	.053	3	43
43420.574	−.533±007	−.394±003	.139	3	33
43422.620	−.470±005	−.328±009	.142	3	27
43423.597	−.463±011	−.320±003	.143	3	29
43424.560	−.437±002	−.303±007	.134	3	34
43425.565	−.472±010	−.326±007	.146	3	32
43430.518	−.566±011	−.517±011	.049	5	36
43432.550	−.631±006	−.590±005	.041	4	32
43434.519	−.664±004	−.617±007	.047	4	35
43435.509	−.663±005	−.611±003	.052	3	36
43436.478	−.650±002	−.579±004	.071	3	40
43437.443	−.642±010	−.565±005	.077	4	44
43438.537	−.605±002	−.526±007	.079	3	32
43455.598	−.649±002	−.582±017	.067	3	23
43458.586	−.637±003	−.582±002	.055	3	23
43459.663	−.610±004	−.552±003	.058	3	24
43465.673	−.467±005	−.354±005	.113	4	26
43477.564	−.638±005	−.601±007	.037	3	22
43482.592	−.604±009	−.502±008	.102	4	24
43483.687	−.568±004	−.481±009	.087	3	33
43490.367	−.444±004	−.320±003	.124	3	35
43513.640	−.498±002	−.360±005	.138	9	38
43514.466	−.494±003	−.372±006	.122	5	22
43558.416	−.480±003	−.404±006	.076	4	26
43560.500	−.486±006	−.372±006	.114	4	36
43578.278	−.515±008	−.419±006	.096	5	22
43579.388	−.508±009	−.439±008	.069	5	29
43598.367	−.553±008	−.422±009	.131	4	32
43599.369	−.535±012	−.427±007	.108	3	33
43606.322	−.474±005	−.362±007	.112	3	30
43607.373	−.462±005	−.427±016	.035	4	36
43608.326	−.502±008	−.398±009	.104	6	31
43639.336	−.558±006	−.452±004	.106	3	42
43640.326	−.576±003	−.412±005	.164	3	41
43647.389	−.618±005	−.464±005	.154	4	51
44605.360	−.592±004	−.532±005	.060	4	30
44613.476	−.612±003	−.510±001	.102	4	23
44614.317	−.601±001	−.514±007	.087	3	32
44619.292	−.606±007	−.500±007	.106	4	33
44621.374	−.603±001	−.504±005	.099	4	24
44633.493	−.595±003	−.505±005	.090	4	28
44637.476	−.603±002	−.511±004	.092	4	27
44642.494	−.574±002	−.469±002	.105	4	31

Table 3. (cont.)

J.D.	ΔV	ΔB	Δ(B–V)	n	Z
44661.428	−.536±005	−.452±005	.084	5	29
45218.496	−.632±005	−.665±003	−.033	5	51
45221.507	−.696±006	−.642±003	.054	5	49
45223.519	−.707±007	−.624±009	.083	5	47
45224.511	−.667±009	−.560±005	.107	5	48
45225.552	−.630±007	−.516±007	.114	5	43
45226.526	−.590±005	−.459±007	.131	5	46
45251.545	−.464±002	−.312±008	.152	2	35
45259.526	−.529±001	−.481±002	.048	5	34
45260.540	−.565±007	−.522±007	.043	4	33

Table 4

Photoelectric U observations of RU Cam
(variable – BD +70°448)

J.D.	ΔU	n	J.D.	ΔU	n
39536.591	−.292±009	5	39617.358	−.313±008	3
39538.572	−.318±005	3	39618.359	−.370±006	4
39546.304	−.468±005	5	39623.371	−.365±014	4
39547.319	−.470±004	5	39639.381	−.306±019	3
39562.484	−.337±005	4	39664.420	−.326±011	4
39564.292	−.420±006	6	40449.513	−.714±011	4
39570.304	−.577±006	6	40807.471	−.437±006	3
39585.346	−.465±010	3	41634.484	−.545±003	5
39588.322	−.691±013	3	41637.604	−.506±006	5
39590.324	−.650±002	4	41650.430	−.574±006	5
39598.346	−.345±012	4	41679.275*	−.530±016	4
39600.326	−.287±011	3	41680.248*	−.469±010	4
39604.361	−.336±003	3	41682.277*	−.413	1
39610.392	−.624±009	4	42452.283*	−.644±009	4
39611.361	−.649±011	4	42453.262*	−.654±016	4

* observation made at Piszkéstető mountain station

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UBVRI PHOTOMETRY OF AE URSAE MAIORIS AT KONKOLY OBSERVATORY (1974-1998)

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Abstract

During the years 1974-1998 UBVRI differential photoelectric photometry of the large amplitude Delta Scuti star AE UMa was carried out at Konkoly Observatory and a total of 6575 observations were collected, 1198 in the U, 1947 in the B, 1935 in the V, 784 in the R and 711 in the I colours. The observations are given in Tables 3-7. From the Konkoly photometry 69 new epochs of maximum light were determined. These are listed in Table 2 together with the 59 times of maximum light found in the literature.

INTRODUCTION

The variability of AE Ursae Maioris (=BV92=GC 02998-01063, $\alpha_{2000} = 9^{\mathrm{h}}36^{\mathrm{m}}53^{\mathrm{s}}.2$, $\delta_{2000} = 44°04'00''$) was discovered by Geyer *et al.* (1955). Götz and Wenzel (1961) classified the star's spectral type as A9. Tsesevich (1956) and Filatov (1960) observed the star visually and photographically, but neither of them was able to determine the type and correct value of the period of the variability. Later Tsesevich (1973) observed the star again visually and pointed out that the star belonged to the class of dwarf cepheids and had a period of 0.086017055 day. Tsesevich (1973) reported strong cycle-to-cycle variation of the light curve. He also investigated the star's light variation on old Moscow (Sternberg Institute) archive plates and determined the earliest known epoch of maximum light for the year 1937.

During the past 25 years the star was extensively observed by Broglia and Conconi (1975) and Rodríguez *et al.* (1992). Several times of maximum light were reported by the BAV group (Braune *et al.* 1979, 1982; Huebscher *et al.* 1985, 1992 and Agerer *et al.* 1999). The results of a new series of CCD measurements were summarized and ten accurate times of maximum light were listed by Hintz *et al.* (1997). The star was also observed by the Hipparcos (AE UMa=HIP 47181).

In order to investigate the star's light curve variation and its period changes we commenced the observations of AE UMa in 1974 and the first results were published in a short note (Szeidl 1974).

THE OBSERVATIONS

On the whole, 6575 observations have been collected at Konkoly Observatory during 41 nights from 1974 until 1998.

In the years 1974-1977 all the observations were obtained with the 60 cm telescope at Svábhegy near Budapest with the exception of the observations of two nights: 1974 Jan. 14/15=JD. 2442062 and 1974 March 21/22=JD. 2442128. (These observations were made with the 50 cm telescope at Piszkéstető mountain station.) An uncooled UBV photometer was used at the Newtonian focus of the 60 cm telescope. The photometer employed an EMI 9052 B multiplier with Schott filters BG12+GG13 in B and GG11 in V.

Since the night sky near Budapest was too bright, the observations were limited only for the B and V bands.

The observations between 1981-1986 were carried out with the 50 cm Cassegrain telescope at Konkoly Observatory's Piszkéstető mountain station. At this telescope we used an integrating photometer equipped with an unrefrigerated EMI 9058 QB photomultiplier and the following Schott filters: UG2 in U, BG12+GG13 in B and GG11 in V.

In 1996-1998 the observations were made with the 1 m Ritchey-Chrétien telescope of the mountain station. A new photon-counting photometer was used, drawn up and constructed by G. Virághalmy. The EMI 9203 QB type multiplier was electronically cooled to -20 ± 0.1°C. The realized photometric system was close to the Cousins system. The type of filters and their thickness were: 1.5 mm UG1 + 0.8 mm UG5 + 1.5 mm BG38 for the U, 1.8 mm BG13 + 5 mm BG38 + 0.6 mm BG24 for the B, 1.8 mm GG14 + 3 mm BG38 for the V, 4 mm OG1 + 1 mm GG20 + 0.3 mm BG26 for the R and 0.5 mm UG3 + 3.2 mm RG8 + 1.5 mm RG9 for the I band. A detailed description of the photometer is given by Virághalmy (2000).

The star BD+44°1882 was used as comparison, and BD+44°1884 as check star. The brightness (V) and colour (B-V) of these stars are given in Broglia and Conconi (1975).

Several differential photometric observations were carried out between the comparison and the check stars. These runs indicated that the errors of the single observations were less than $0.^{m}01$ in B, V and R, and around $0.^{m}02$ in U and I on average nights.

The observations of the variable were reduced in the usual way. The UT times have been converted to heliocentric JD. The correction for atmospheric extinction was neglected since the comparison star was very close to the variable. (The distance between them is less then 15'.) The UBV observations have been transformed into the Johnson system in the traditional way. The R and I measurements are in the instrumental system. The journal of the observations is given in Tables 1. The individual observations of AE UMa are listed in Table 3-7 in the sense variable minus comparison.

THE OBSERVED MAXIMA

The light curves have the typical asymmetrical shape of the large amplitude δ Scuti stars. The large variation in the amplitude and shape of the light curves makes the determination of the times of light maximum difficult. The observations near the top of the light curves were fitted with third order polinomials and a least squares calculation provided the times of maximum. The results of course, depended on how many data points were involved in the calculation close to maximum light. Therefore several trials were made at each observed maximum. The most reliable results could be achieved when only 5-6 data points were taken into account. This procedure also gave an estimate of the error of the determination of the instant of maximum light: about ± 0.0004 day.

The epochs of maximum light reported here are the mean values obtained from the V and B light curves. (Although a phase lag between the times of maximum light in different colours may exist, this is less than the error of the determination of the epoch of maximum light.)

69 new times of maximum are listed in Table 2, together with those 59 reported in the literature. In Table 2 the O-C values and the epoch numbers are also given calculated by the following ephemeris:

$$C = 2442062.5824 + 0^{\rm d}.08601707 \times E$$

The detector used by the observers (vis=visual, pg=photographic, pe=photoelectric, CCD=CCD photometry) and the source of the data are also indicated in Table 2.

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Table 1. Journal of observations

Year	Filter	No. of nights	No. of obs.	Length of obs. in hours
1974	V	12	425	24.48
	B	12	432	24.50
1975	V	2	53	3.25
	B	2	54	3.24
1976	V	5	93	6.55
	B	5	97	6.60
1977	V	1	20	1.09
	B	1	21	1.09
1981	V	4	264	14.66
	B	4	264	14.66
	U	3	212	11.89
1982	V	1	15	0.76
	B	1	15	0.76
	U	1	15	0.76
1983	V	3	203	11.80
	B	3	202	11.80
	U	3	190	11.48
1986	V	1	67	4.47
	B	1	67	4.47
	U	1	64	4.47
1996	I	1	48	6.83
	R	2	90	10.92
	V	2	93	11.21
	B	2	93	11.21
	U	1	59	7.42
1997	I	3	58	3.94
	R	3	60	4.11
	V	3	61	4.11
	B	3	61	4.11
	U	3	42	2.46
1998	I	7	605	47.32
	R	7	634	48.57
	V	7	641	48.77
	B	7	641	48.75
	U	7	616	47.74

Table 1. Journal of observations (cont.)

Year	Filter	No. of nights	No. of obs.	Length of obs. in hours
All:	I	11	711	58.09
	R	12	784	63.60
	V	41	1935	131.15
	B	41	1947	131.16
	U	19	1198	86.22

Table 2. Times of maximum of AE UMa

Year	Max.time	Det.	Cycle	O-C	Source
	2400000+				
1937	28632.398	pg	-156134	+.0048	Tsesevich (1973)
1946	31875.122	pg	-118435	-.0287	Filatov (1960)
1950	33379.256	pg	-100949	+.0108	
1956	35601.188	pg	- 75118	+.0359	
	35604.337	vis	- 75081	+.0022	Tesevich (1973)
	35607.173	pg	- 75048	-.0003	Filatov (1960)
1957	35981.202	pg	- 70700	+.0264	
1963	38106.402	vis	- 45993	+.0027	Tsesevich (1973)
1971	41059.368	vis	- 11663	+.0027	
1973	41773.223	vis	- 3364	+.0020	
1974	42062.5832	pe	0	+.0008	Present paper
	42065.5959	pe	35	+.0029	Broglia et al. (1975)
	42065.6778	pe	36	-.0012	
	42068.3432	pe	67	-.0023	
	42068.4302	pe	68	-.0014	
	42068.5203	pe	69	+.0027	
	42068.6029	pe	70	-.0007	
	42068.6871	pe	71	-.0025	

Table 2. Times of maximum of AE UMa (cont.)

Year	Max.time	Det.	Cycle	O-C	Source
	2400000+				
1974	42069.3808	pe	79	+.0031	
	42069.4651	pe	80	+.0013	
	42069.5473	pe	81	-.0025	
	42069.6363	pe	82	+.0005	
	42086.4965	pe	278	+.0014	
	42086.5787	pe	279	-.0025	
	42069.5473	pe	81	-.0025	
	42069.6363	pe	82	+.0005	
	42086.4965	pe	278	+.0014	
	42086.5787	pe	279	-.0025	
	42087.4390	pe	289	-.0023	
	42087.5263	pe	290	-.0011	
	42087.6155	pe	291	+.0021	
	42095.5298	pe	383	+.0029	Present paper
	42095.6123	pe	384	-.0007	
	42103.3513	pe	474	-.0032	Broglia et al. (1975)
	42106.4523	pe	510	+.0012	Present paper
	42119.5252	pe	662	-.0005	
	42121.5025	pe	685	-.0016	
	42122.3628	pe	695	-.0015	Broglia et al. (1975)
	42122.4484	pe	696	-.0019	
	42128.2968	pe	764	-.0026	Present paper
	42128.3872	pe	765	+.0017	
	42128.4727	pe	766	+.0012	
	42128.5557	pe	767	-.0018	
	42133.4627	pe	824	+.0022	
	42133.5442	pe	825	-.0023	
	42134.4055	pe	835	-.0012	
	42147.3933	pe	986	-.0019	
	42148.4295	pe	998	+.0021	
	42148.5117	pe	999	-.0018	
	42159.4365	pe	1126	-.0011	
	42161.4145	pe	1149	-.0015	

Table 2. Times of maximum of AE UMa (cont.)

Year	Max.time	Det.	Cycle	O-C	Source
	2400000+				
1975	42453.5306	pe	4545	+.0006	
	42453.6137	pe	4546	-.0023	
	42460.4989	pe	4626	+.0015	
	42532.407	vis	5462	-.0006	Braune et al. (1979)
1976	42830.6280	pe	8929	-.0008	Present paper
	42837.5120	pe	9009	+.0018	
	42838.4591	pe	9020	+.0027	
	42866.496	vis	9346	-.0019	Braune et al. (1979)
	42869.3377	pe	9379	+.0012	Present paper
	42869.4205	pe	9380	-.0020	
1977	43162.5708	pe	12788	+.0021	
1981	44633.4626	pe	29888	+.0020	
	44633.5440	pe	29889	-.0026	
	44633.6309	pe	29890	-.0017	
	44634.4046	pe	29899	-.0022	
	44634.4902	pe	29900	-.0026	
	44634.5810	pe	29901	+.0022	
	44692.4709	pe	30574	+.0026	
	44696.343	vis	30619	+.0039	Braune et al. (1982)
	44696.426	vis	30620	+.0009	
	44696.520	vis	30621	+.0089	
1983	45355.4902	pe	38282	+.0023	Present paper
	45355.5727	pe	38283	-.0012	
	45382.3228	pe	38594	-.0024	
	45382.4104	pe	38595	-.0008	
	45382.4997	pe	38596	+.0025	
	45382.5807	pe	38597	-.0026	
1985	46114.332	vis	47104	+.0015	Huebscher et al. (1985)
1986	46468.4601	pe	51221	-.0026	Present paper
	46468.5468	pe	51222	-.0020	
1987	46855.6279	pe	55722	+.0023	Rodriguez et al. (1992)
	46856.5729	pe	55733	+.0011	
	46856.6561	pe	55734	-.0017	
	46857.6017	pe	55745	-.0023	

Table 2. Times of maximum of AE UMa (cont.)

Year	Max.time	Det.	Cycle	O-C	Source
	2400000+				
1987	46857.6925	pe	55746	+.0025	
	46858.6382	pe	55757	+.0020	
	46859.6666	pe	55769	-.0018	
	46878.4181	pe	55987	-.0020	
	46878.5064	pe	55988	+.0003	
	46878.5946	pe	55989	+.0025	
	46884.5262	pe	56058	-.0011	
	46884.6117	pe	56059	-.0016	
	46886.5907	pe	56082	-.0010	
1992	48683.317	vis	76970	+.0007	Huebscher et al. (1992)
1996	50151.4564	pe	94038	+.0008	Present paper
	50151.5384	pe	94039	-.0032	
	50152.3170	pe	94048	+.0012	
	50152.4862	pe	94050	-.0016	
	50152.5756	pe	94051	+.0017	
1997	50458.8815	CCD	97612	+.0009	Hintz et al. (1997)
	50458.9636	CCD	97613	-.0031	
	50459.8240	CCD	97623	-.0028	
	50459.9113	CCD	97624	-.0015	
	50467.7388	CCD	97715	-.0016	
	50467.8236	CCD	97716	-.0028	
	50490.3607	pe	97978	-.0022	Present paper
	50505.6697	CCD	98156	-.0042	Hintz et al. (1997)
	50505.7595	CCD	98157	-.0004	
	50505.8461	CCD	98158	+.0001	
	50516.7676	CCD	98285	-.0025	
	50554.4432	pe	98723	-.0024	Present paper
1998	50813.3550	pe	101733	-.0020	
	50813.4408	pe	101734	-.0022	
	50813.6151	pe	101736	+.0001	
	50813.6985	pe	101737	-.0026	
	50848.4540	pe	102141	+.0021	
	50848.5391	pe	102142	+.0011	
	50848.6212	pe	102143	-.0028	

Table 2. Times of maximum of AE UMa (cont.)

Year	Max.time	Det.	Cycle	O-C	Source
	2400000+				
1998	50849.4815	pe	102153	-.0026	
	50849.5688	pe	102154	-.0014	
	50862.3840	pe	102303	-.0027	Agerer et al. (1999)
	50872.2809	pe	102418	+.0022	Present paper
	50872.3634	pe	102419	-.0013	
	50872.4481	pe	102420	-.0026	
	50872.5394	pe	102421	+.0027	
	50899.3729	pe	102733	-.0012	
	50899.4570	pe	102734	-.0031	
	50902.2976	pe	102767	-.0010	
	50902.3819	pe	102768	-.0028	
	50903.3321	pe	102779	+.0013	
	50903.4192	pe	102780	+.0023	
	50903.5009	pe	102781	-.0020	

Table 3.
Differential U observations of AE UMa

2444633 +	0.5165 +1.306	0.6210 +1.009	0.4395 +1.195	0.5412 +1.281
0.4106 +1.214	0.5241 +1.305	0.6224 +0.978	0.4409 +1.211	0.5426 +1.278
0.4120 +1.223	0.5255 +1.275	0.6298 +0.794	0.4423 +1.222	0.5439 +1.277
0.4133 +1.227	0.5269 +1.263	0.6312 +0.802	0.4435 +1.234	0.5516 +1.261
0.4147 +1.238	0.5283 +1.269	0.6326 +0.817	0.4450 +1.238	0.5529 +1.268
0.4161 +1.236	0.5297 +1.194	0.6340 +0.837	0.4512 +1.265	0.5543 +1.246
0.4237 +1.302	0.5359 +0.954	0.6354 +0.837	0.4526 +1.289	0.5557 +1.243
0.4250 +1.301	0.5373 +0.874	0.6416 +0.913	0.4540 +1.292	0.5571 +1.233
0.4264 +1.308	0.5387 +0.798	0.6430 +0.936	0.4554 +1.276	0.5641 +1.147
0.4278 +1.308	0.5401 +0.710	0.6444 +0.952	0.4568 +1.279	0.5655 +1.133
0.4373 +1.288	0.5415 +0.648	0.6458 +0.973	0.4629 +1.289	0.5668 +1.093
0.4387 +1.276	0.5430 +0.625	0.6472 +0.987	0.4643 +1.296	0.5682 +1.080
0.4401 +1.294	0.5444 +0.637	0.6535 +1.080	0.4657 +1.281	0.5696 +1.001
0.4415 +1.289	0.5458 +0.639	0.6549 +1.084	0.4671 +1.258	0.5761 +0.837
0.4429 +1.282	0.5472 +0.655	0.6563 +1.102	0.4685 +1.260	0.5775 +0.816
0.4497 +1.079	0.5486 +0.687	0.6577 +1.130	0.4743 +1.179	0.5789 +0.811
0.4511 +1.050	0.5550 +0.822	0.6591 +1.142	0.4757 +1.166	0.5803 +0.813
0.4525 +0.965	0.5564 +0.862		0.4771 +1.097	0.5817 +0.809
0.4539 +0.922	0.5578 +0.889	2444634 +	0.4785 +1.050	0.5831 +0.815
0.4553 +0.849	0.5591 +0.899	0.3806 +1.305	0.4799 +1.019	0.5845 +0.820
0.4609 +0.687	0.5605 +0.938	0.3820 +1.279	0.4859 +0.808	0.5859 +0.825
0.4623 +0.679	0.5675 +1.055	0.3834 +1.286	0.4873 +0.751	0.5937 +0.976
0.4637 +0.710	0.5689 +1.078	0.3848 +1.273	0.4887 +0.747	0.5951 +0.976
0.4651 +0.725	0.5703 +1.076	0.3862 +1.276	0.4901 +0.750	0.5965 +1.000
0.4665 +0.731	0.5717 +1.098	0.3925 +1.113	0.4915 +0.758	0.5978 +1.001
0.4726 +0.856	0.5731 +1.123	0.3939 +1.101	0.4929 +0.785	0.6059 +1.094
0.4740 +0.894	0.5794 +1.181	0.3953 +1.008	0.4942 +0.789	0.6073 +1.108
0.4754 +0.896	0.5807 +1.202	0.3967 +0.939	0.5007 +0.881	0.6088 +1.125
0.4768 +0.909	0.5821 +1.211	0.3981 +0.847	0.5021 +0.908	0.6101 +1.135
0.4782 +0.936	0.5835 +1.228	0.4037 +0.563	0.5035 +0.942	0.6115 +1.150
0.4853 +1.047	0.5849 +1.228	0.4050 +0.567	0.5049 +0.942	0.4318 +1.075
0.4866 +1.047	0.5910 +1.266	0.4064 +0.575	0.5063 +0.975	0.4331 +1.093
0.4880 +1.093	0.5924 +1.292	0.4078 +0.613	0.5143 +1.084	0.4345 +1.103
0.4894 +1.113	0.5938 +1.290	0.4092 +0.657	0.5157 +1.089	0.4359 +1.109
0.4908 +1.136	0.5952 +1.292	0.4153 +0.828	0.5171 +1.103	0.4373 +1.140
0.4988 +1.276	0.5966 +1.294	0.4167 +0.855	0.5185 +1.118	0.4478 +1.200
0.5001 +1.275	0.6042 +1.307	0.4181 +0.879	0.5199 +1.129	0.4492 +1.207
0.5015 +1.303	0.6056 +1.295	0.4194 +0.912	0.5269 +1.203	0.4506 +1.241
0.5028 +1.287	0.6069 +1.291	0.4208 +0.954	0.5283 +1.222	0.4520 +1.245
0.5042 +1.308	0.6083 +1.257	0.4270 +1.054	0.5297 +1.227	0.4534 +1.255
0.5109 +1.308	0.6097 +1.252	0.4284 +1.076	0.5311 +1.221	0.4644 +1.253
0.5123 +1.302	0.6168 +1.112	0.4298 +1.061	0.5324 +1.241	0.4658 +1.261
0.5137 +1.300	0.6182 +1.083	0.4312 +1.083	0.5385 +1.261	0.4672 +1.253
0.5151 +1.283	0.6196 +1.039	0.4326 +1.116	0.5399 +1.263	0.4686 +1.241

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0.5099 +0.859
0.5113 +0.903
0.5126 +0.942
0.5140 +0.968
0.5154 +0.985

0.5215 +1.022	0.4319 +1.297	0.5723 +1.144	0.5289 +1.199	0.4103 +1.307
0.5228 +1.049	0.4334 +1.300	0.5738 +1.144	0.5392 +1.224	0.4116 +1.280
0.5242 +1.077	0.4349 +1.310		0.5412 +1.225	0.4130 +1.310
0.5256 +1.098	0.4364 +1.312	2450152 +	0.5431 +1.263	0.4180 +1.303
0.5270 +1.119	0.4465 +1.195	0.2874 +1.255	0.5530 +1.245	0.4194 +1.316
0.5330 +1.170	0.4480 +1.132	0.2893 +1.252	0.5550 +1.152	0.4207 +1.280
0.5358 +1.196	0.4494 +1.061	0.2913 +1.220	0.5569 +1.150	
0.5371 +1.199	0.4510 +0.994	0.2996 +1.144	0.5661 +0.945	2450554 +
0.5385 +1.208	0.4525 +0.886	0.3015 +1.201	0.5681 +0.923	0.4295 +1.168
0.5469 +1.291	0.4588 +0.592	0.3035 +1.139	0.5700 +0.894	0.4308 +1.101
0.5483 +1.283	0.4603 +0.570	0.3122 +0.695	0.5789 +0.708	0.4321 +1.054
0.5497 +1.283	0.4618 +0.616	0.3141 +0.678	0.5809 +0.731	0.4372 +0.759
0.5511 +1.284	0.4633 +0.642	0.3161 +0.616	0.5828 +0.792	0.4385 +0.786
0.5574 +1.265	0.4648 +0.712	0.3251 +0.735	0.5926 +0.941	0.4398 +0.708
0.5588 +1.272	0.4865 +1.111	0.3271 +0.759	0.5946 +0.961	0.4451 +0.744
0.5602 +1.282	0.4879 +1.116	0.3290 +0.817	0.5965 +1.021	0.4464 +0.775
0.5616 +1.284	0.4894 +1.118	0.3373 +0.952		0.4477 +0.774
0.5630 +1.261	0.4909 +1.145	0.3393 +1.020	2450487 +	
0.5714 +1.052	0.4930 +1.174	0.3412 +1.060	0.4251 +1.044	2450813 +
0.5727 +0.966	0.5002 +1.203	0.3491 +1.182	0.4264 +0.954	0.3436 +1.049
0.5741 +0.941	0.5016 +1.224	0.3510 +1.163	0.4277 +0.958	0.3449 +0.967
0.5755 +0.835	0.5031 +1.252	0.3530 +1.178	0.4335 +0.597	0.3462 +0.942
0.5769 +0.708	0.5046 +1.240	0.3610 +1.298	0.4348 +0.635	0.3518 +0.589
0.5784 +0.643	0.5061 +1.245	0.3630 +1.245		0.3531 +0.621
0.5798 +0.596	0.5148 +1.292	0.3649 +1.281	2450490 +	0.3545 +0.658
0.5816 +0.587	0.5163 +1.289	0.3731 +1.314	0.3462 +1.292	0.3596 +0.619
0.5830 +0.631	0.5177 +1.300	0.3751 +1.299	0.3475 +1.167	0.3609 +0.672
0.5844 +0.669	0.5192 +1.261	0.3770 +1.309	0.3488 +1.118	0.3623 +0.683
0.5858 +0.701	0.5207 +1.271	0.4446 +1.248	0.3543 +0.824	0.3673 +0.824
0.5872 +0.729	0.5278 +1.213	0.4465 +1.269	0.3557 +0.696	0.3686 +0.856
	0.5292 +1.218	0.4485 +1.266	0.3570 +0.541	0.3699 +0.878
2446468 +	0.5307 +1.181	0.4568 +1.213	0.3622 +0.502	0.3783 +1.020
0.3877 +0.820	0.5322 +1.150	0.4588 +1.200	0.3635 +0.546	0.3796 +1.090
0.3891 +0.905	0.5337 +1.121	0.4607 +1.192	0.3648 +0.555	0.3809 +1.116
0.3907 +0.931	0.5409 +0.886	0.4743 +1.085	0.3714 +0.789	0.3951 +1.177
0.3928 +0.930	0.5424 +0.817	0.4763 +0.963	0.3727 +0.813	0.3964 +1.178
0.3937 +0.968	0.5438 +0.776	0.4782 +0.915	0.3782 +0.885	0.3977 +1.250
0.4018 +1.100	0.5452 +0.748	0.4878 +0.826	0.3795 +0.923	0.4119 +1.280
0.4033 +1.139	0.5468 +0.771	0.4897 +0.826	0.3808 +0.912	0.4132 +1.289
0.4048 +1.151	0.5536 +0.850	0.4986 +0.907	0.3859 +1.022	0.4145 +1.292
0.4078 +1.158	0.5551 +0.872	0.5005 +0.938	0.3872 +1.092	0.4199 +1.211
0.4162 +1.208	0.5566 +0.882	0.5025 +1.002	0.3885 +1.122	0.4212 +1.194
0.4177 +1.246	0.5581 +0.934	0.5115 +1.072	0.3941 +1.206	0.4225 +1.201
0.4191 +1.254	0.5596 +0.948	0.5134 +1.070	0.3954 +1.205	0.4280 +1.055
0.4206 +1.241	0.5678 +1.035	0.5154 +1.091	0.3967 +1.204	0.4293 +1.028
0.4221 +1.275	0.5693 +1.063	0.5250 +1.188	0.4021 +1.235	0.4306 +1.051
0.4304 +1.309	0.5708 +1.102	0.5270 +1.204	0.4034 +1.206	0.4364 +0.784

0.4377 +0.745	0.6252 +0.816	0.4543 +0.831	0.6207 +0.501	0.4687 +1.102
0.4390 +0.763	0.6265 +0.888	0.4599 +0.838	0.6220 +0.532	0.4742 +0.906
0.4451 +0.792	0.6333 +0.959	0.4612 +0.831	0.6276 +0.659	0.4755 +0.813
0.4464 +0.836	0.6346 +0.898	0.4625 +0.827	0.6289 +0.672	0.4768 +0.678
0.4477 +0.853	0.6359 +0.943	0.4681 +0.885	0.6303 +0.731	0.4822 +0.611
0.4551 +0.946	0.6421 +1.042	0.4694 +0.927	0.6365 +0.941	0.4835 +0.590
0.4563 +0.978	0.6434 +1.092	0.4707 +0.946	0.6378 +0.935	0.4848 +0.596
0.4577 +0.989	0.6447 +1.131	0.4765 +1.023	0.6391 +0.949	0.4907 +0.787
0.4637 +1.070	0.6503 +1.201	0.4778 +1.050	0.6449 +1.027	0.4920 +0.778
0.4651 +1.096	0.6517 +1.146	0.4792 +1.110	0.6462 +1.037	0.4933 +0.791
0.4664 +1.104	0.6530 +1.156	0.4863 +1.163	0.6475 +1.022	0.4990 +0.934
0.4809 +1.237	0.6600 +1.259	0.4876 +1.181	0.6531 +1.156	0.5003 +0.935
0.4835 +1.283	0.6614 +1.256	0.4889 +1.197	0.6544 +1.141	0.5016 +0.982
0.4899 +1.275	0.6676 +1.260	0.4951 +1.275	0.6557 +1.135	0.5069 +1.070
0.4912 +1.283	0.6690 +1.242	0.4964 +1.280	0.6617 +1.191	0.5083 +1.044
0.4925 +1.304	0.6786 +1.313	0.4977 +1.300	0.6630 +1.199	0.5096 +1.106
0.4982 +1.281	0.6852 +1.071	0.5031 +1.312	0.6643 +1.222	0.5152 +1.141
0.4995 +1.212	0.6865 +1.071	0.5045 +1.319		0.5165 +1.179
0.5008 +1.240	0.6879 +0.972	0.5058 +1.239	2450849 +	0.5178 +1.153
0.5374 +0.765	0.6936 +0.800	0.5114 +1.276	0.2828 +1.262	0.5232 +1.203
0.5387 +0.837	0.6949 +0.795	0.5127 +1.285	0.2850 +1.310	0.5245 +1.213
0.5400 +0.829	0.6962 +0.711	0.5140 +1.231	0.2872 +1.259	0.5258 +1.246
0.5454 +0.930	0.7019 +0.723	0.5199 +1.281	0.2982 +1.110	0.5317 +1.308
0.5467 +0.913	0.7032 +0.733	0.5212 +1.202	0.3004 +1.122	0.5330 +1.299
0.5480 +0.955	0.7046 +0.743	0.5225 +1.162	0.3195 +0.852	0.5343 +1.318
0.5539 +1.023		0.5286 +0.906	0.3216 +0.835	0.5402 +1.325
0.5552 +1.020	2450848 +	0.5299 +0.890	0.3238 +0.824	0.5415 +1.277
0.5565 +1.081	0.4026 +1.258	0.5312 +0.754	0.3345 +1.010	0.5428 +1.262
0.5623 +1.169	0.4039 +1.245	0.5371 +0.575	0.3339 +0.999	0.5488 +1.147
0.5636 +1.202	0.4052 +1.239	0.5384 +0.574	0.3361 +0.964	0.5501 +1.198
0.5649 +1.213	0.4108 +1.249	0.5397 +0.590	0.3482 +1.170	0.5514 +1.138
0.5713 +1.190	0.4121 +1.258	0.5457 +0.700	0.3585 +1.237	0.5588 +0.959
0.5727 +1.236	0.4134 +1.270	0.5470 +0.705	0.3580 +1.227	0.5601 +0.937
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0.5800 +1.259	0.4199 +1.264	0.5541 +0.857	0.3700 +1.250	0.5668 +0.810
0.5813 +1.238	0.4212 +1.292	0.5555 +0.909	0.3721 +1.275	0.5681 +0.735
0.5826 +1.314	0.4267 +1.310	0.5568 +0.965	0.3743 +1.256	0.5694 +0.815
0.5884 +1.290	0.4280 +1.294	0.5937 +1.261	0.3821 +1.299	0.5751 +0.841
0.5897 +1.291	0.4293 +1.326	0.5950 +1.221	0.3842 +1.282	0.5764 +0.912
0.5911 +1.309	0.4356 +1.144	0.5963 +1.281	0.4500 +1.252	0.5778 +0.892
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0.5980 +1.246	0.4383 +1.127	0.6038 +1.238	0.4527 +1.282	0.6170 +1.303
0.5993 +1.276	0.4436 +0.991	0.6051 +1.174	0.4580 +1.265	0.6183 +1.276
0.6066 +0.898	0.4450 +0.938	0.6112 +0.951	0.4593 +1.285	0.6239 +1.312
0.6079 +0.847	0.4463 +0.882	0.6125 +0.933	0.4606 +1.204	0.6252 +1.309
0.6092 +0.822	0.4517 +0.847	0.6138 +0.848	0.4660 +1.122	0.6265 +1.290
0.6239 +0.765	0.4530 +0.822	0.6193 +0.530	0.4673 +1.121	0.6328 +1.255

0.6341	+1.246
0.6354	+1.208
0.6409	+1.084
0.6422	+1.084
0.6435	+1.023
2450872 +	
0.2664	+1.166
0.2677	+1.096
0.2690	+1.039
0.2745	+0.800
0.2758	+0.772
0.2771	+0.695
0.2824	+0.700
0.2837	+0.686
0.2850	+0.697
0.2906	+0.859
0.2920	+0.878
0.2933	+0.934
0.2989	+0.985
0.3002	+0.960
0.3015	+1.022
0.3068	+1.094
0.3081	+1.077
0.3094	+1.078
0.3153	+1.182
0.3166	+1.173
0.3179	+1.153
0.3236	+1.254
0.3249	+1.325
0.3262	+1.337
0.3320	+1.284
0.3333	+1.298
0.3346	+1.286
0.3401	+1.250
0.3414	+1.227
0.3427	+1.225
0.3478	+1.217
0.3492	+1.140
0.3505	+1.071
0.3559	+0.828
0.3573	+0.697
0.3586	+0.637
0.3639	+0.525
0.3652	+0.583
0.3666	+0.648
0.3722	+0.771
0.3735	+0.789
0.3749	+0.881
0.3809	+0.934
0.3822	+0.984
0.3835	+0.994
0.3887	+1.091
0.3900	+1.109
0.3913	+1.100
0.3970	+1.186
0.3983	+1.123
0.3997	+1.168
0.4054	+1.294
0.4081	+1.282
0.4134	+1.307
0.4147	+1.247
0.4160	+1.315
0.4213	+1.312
0.4226	+1.296
0.4239	+1.255
0.4292	+1.176
0.4305	+1.210
0.4319	+1.164
0.4374	+1.016
0.4387	+0.978
0.4401	+0.894
0.4457	+0.716
0.4470	+0.747
0.4483	+0.774
0.4537	+0.762
0.4550	+0.816
0.4563	+0.792
0.4644	+0.918
0.4657	+0.973
0.4671	+1.038
0.4730	+1.083
0.4743	+1.105
0.4756	+1.110
0.4811	+1.150
0.4825	+1.133
0.4838	+1.182
0.4892	+1.216
0.4906	+1.181
0.4919	+1.263
0.4978	+1.260
0.4991	+1.234
0.5004	+1.222
0.5059	+1.234
0.5073	+1.242
0.5086	+1.230
0.5142	+1.276
0.5155	+1.238
0.5168	+1.278
0.5223	+1.267
0.5237	+1.200
0.5250	+1.146
0.5312	+0.932
0.5325	+0.935
0.5338	+0.899
0.5391	+0.718
0.5404	+0.723
0.5417	+0.783
0.5474	+0.862
0.5487	+0.831
0.5500	+0.810
0.5561	+0.927
0.5574	+0.971
0.5587	+1.006
0.5649	+1.110
0.5676	+1.136
0.5741	+1.191
0.5768	+1.251
0.5821	+1.271
0.5834	+1.237
0.5847	+1.308
0.5903	+1.290
0.5916	+1.292
0.5929	+1.327
0.5987	+1.274
0.6000	+1.310
0.6014	+1.310
0.6067	+1.251
0.6080	+1.190
0.6093	+1.149
2450899 +	
0.2904	+0.691
0.2917	+0.714
0.2930	+0.728
0.2988	+0.739
0.3001	+0.797
0.3015	+0.844
0.3070	+0.991
0.3083	+1.008
0.3151	+1.156
0.3164	+1.167
0.3177	+1.143
0.3235	+1.152
0.3248	+1.171
0.3261	+1.195
0.3324	+1.244
0.3337	+1.281
0.3351	+1.286
0.3379	+1.326
0.3423	+1.300
0.3436	+1.318
0.3489	+1.281
0.3502	+1.252
0.3515	+1.320
0.3568	+1.299
0.3581	+1.209
0.3594	+1.136
0.3649	+0.875
0.3662	+0.827
0.3675	+0.659
0.3727	+0.487
0.3740	+0.517
0.3753	+0.599
0.3805	+0.714
0.3818	+0.754
0.3832	+0.787
0.3890	+0.899
0.3903	+0.950
0.3917	+0.938
0.3975	+1.093
0.3989	+1.089
0.4002	+1.108
0.4055	+1.237
0.4068	+1.207
0.4081	+1.282
0.4169	+1.242
0.4182	+1.245
0.4195	+1.244
0.4247	+1.261
0.4260	+1.264
0.4273	+1.328
0.4543	+0.787
0.4556	+0.729
0.4569	+0.751
0.4621	+0.805
0.4634	+0.845
0.4647	+0.807
0.4698	+0.900
0.4712	+0.874
0.4725	+0.920
0.4780	+0.971
0.4794	+1.030
0.4807	+0.991
0.4923	+1.161
0.4980	+1.239
0.4993	+1.251
0.5007	+1.260
2450902 +	
0.2814	+1.249
0.2827	+1.152
0.2840	+1.140
0.2891	+0.899
0.2904	+0.824
0.2917	+0.753
0.2972	+0.581
0.2985	+0.564
0.2998	+0.602
0.3056	+0.659
0.3069	+0.781
0.3082	+0.771
0.3136	+0.902
0.3149	+0.951
0.3162	+0.934
0.3216	+1.101
0.3229	+1.087
0.3242	+1.181
0.3295	+1.234
0.3308	+1.203
0.3322	+1.203
0.3379	+1.192
0.3392	+1.258
0.3406	+1.227
0.3457	+1.266
0.3470	+1.286
0.3484	+1.321
0.3541	+1.311
0.3554	+1.301
0.3567	+1.263
0.3617	+1.206
0.3631	+1.137
0.3644	+1.115
0.3694	+1.074
0.3707	+1.060

0.3720 +1.018	0.4481 +1.219	0.3284 +0.866	0.3998 +1.194	0.4778 +1.260
0.3773 +0.765	0.4534 +1.251	0.3336 +0.844	0.4050 +1.110	0.4831 +1.242
0.3786 +0.742	0.4547 +1.254	0.3349 +0.854	0.4063 +1.064	0.4844 +1.250
0.3799 +0.745	0.4560 +1.239	0.3362 +0.851	0.4076 +1.021	0.4857 +1.199
0.3862 +0.769	0.4611 +1.036	0.3416 +0.884	0.4140 +0.745	0.4914 +0.995
0.3875 +0.733	0.4624 +1.010	0.3430 +0.932	0.4153 +0.688	0.4927 +0.960
0.3888 +0.751		0.3443 +0.918	0.4166 +0.624	0.4940 +0.851
0.3968 +0.885	2450903 +	0.3497 +1.031	0.4237 +0.686	0.4993 +0.594
0.3981 +0.876	0.2782 +1.228	0.3510 +1.069	0.4250 +0.687	0.5006 +0.586
0.3995 +0.881	0.2795 +1.210	0.3524 +1.117	0.4263 +0.739	0.5019 +0.582
0.4057 +1.021	0.2863 +1.240	0.3575 +1.107	0.4326 +0.907	0.5073 +0.715
0.4070 +1.084	0.2876 +1.328	0.3588 +1.112	0.4339 +0.898	0.5086 +0.785
0.4083 +1.071	0.2890 +1.284	0.3601 +1.174	0.4352 +0.905	0.5099 +0.794
0.4139 +1.197	0.2940 +1.248	0.3653 +1.157	0.4427 +1.043	0.5312 +1.133
0.4152 +1.241	0.2953 +1.318	0.3666 +1.209	0.4440 +1.100	0.5325 +1.181
0.4165 +1.207	0.2966 +1.285	0.3680 +1.223	0.4453 +1.100	0.5339 +1.195
0.4218 +1.231	0.3019 +1.324	0.3733 +1.225	0.4514 +1.147	0.5391 +1.187
0.4231 +1.233	0.3033 +1.332	0.3746 +1.198	0.4527 +1.226	0.5404 +1.228
0.4244 +1.185	0.3046 +1.274	0.3759 +1.222	0.4540 +1.271	0.5417 +1.222
0.4295 +1.272	0.3100 +1.214	0.3814 +1.256	0.4592 +1.282	0.5473 +1.285
0.4308 +1.259	0.3113 +1.225	0.3827 +1.282	0.4605 +1.279	0.5486 +1.268
0.4322 +1.241	0.3126 +1.135	0.3840 +1.250	0.4618 +1.215	0.5499 +1.304
0.4374 +1.216	0.3180 +1.041	0.3894 +1.284	0.4673 +1.271	
0.4387 +1.217	0.3193 +1.002	0.3907 +1.271	0.4686 +1.283	
0.4400 +1.304	0.3206 +1.008	0.3920 +1.263	0.4699 +1.280	
0.4454 +1.198	0.3258 +0.925	0.3972 +1.238	0.4751 +1.296	
0.4468 +1.283	0.3271 +0.847	0.3985 +1.252	0.4764 +1.233	

Table 4.

Differential B observations of AE UMa

2442062 +	0.5767 +0.879	0.4984 +1.301	0.5262 +0.770	0.5588 +1.165
0.5474 +1.264	0.5775 +0.852	0.5012 +1.294	0.5283 +0.722	0.5616 +1.215
0.5481 +1.258	0.5810 +0.794	0.5026 +1.291	0.5297 +0.703	0.5630 +1.230
0.5495 +1.274	0.5824 +0.780	0.5053 +1.266	0.5324 +0.736	0.5658 +1.257
0.5514 +1.291	0.5834 +0.773	0.5067 +1.260	0.5338 +0.762	0.5672 +1.268
0.5526 +1.291	0.5845 +0.773	0.5095 +1.226	0.5366 +0.800	0.5699 +1.288
0.5584 +1.245	0.5859 +0.781	0.5109 +1.228	0.5380 +0.822	0.5713 +1.288
0.5596 +1.237	0.5912 +0.827	0.5137 +1.171	0.5408 +0.868	0.5783 +1.296
0.5606 +1.234	0.5921 +0.840	0.5151 +1.125	0.5422 +0.895	0.5797 +1.294
0.5616 +1.220	0.5928 +0.843	0.5172 +1.091	0.5450 +0.943	0.5838 +1.308
0.5668 +1.148	0.5937 +0.847	0.5179 +1.052	0.5463 +0.959	0.5866 +1.293
0.5674 +1.118	0.5984 +0.910	0.5199 +0.991	0.5491 +0.999	0.5880 +1.307
0.5686 +1.085	0.5993 +0.916	0.5206 +0.947	0.5505 +1.015	0.5922 +1.287
0.5697 +1.078		0.5227 +0.887	0.5533 +1.071	0.5949 +1.277
0.5744 +0.929	2442095 +	0.5234 +0.853	0.5547 +1.083	0.5963 +1.246
0.5756 +0.899	0.4970 +1.315	0.5255 +0.806	0.5574 +1.136	0.5991 +1.170

0.6033 +0.963
0.6047 +0.898
0.6074 +0.694
0.6088 +0.659
0.6116 +0.533
0.6130 +0.554
0.6158 +0.576
0.6172 +0.635
0.6199 +0.706
0.6213 +0.736
0.6255 +0.849
0.6283 +0.916
0.6297 +0.943
0.6324 +0.979
0.6338 +0.999

2442106 +
0.4417 +1.010
0.4430 +0.957
0.4458 +0.809
0.4472 +0.731
0.4500 +0.590
0.4514 +0.557
0.4542 +0.577
0.4555 +0.603
0.4583 +0.658
0.4597 +0.688
0.4625 +0.743
0.4639 +0.770
0.4667 +0.822
0.4680 +0.866
0.4708 +0.941
0.4722 +0.956

2442119 +
0.5065 +1.170
0.5107 +1.071
0.5128 +1.015
0.5169 +0.882
0.5190 +0.832
0.5232 +0.729
0.5253 +0.730
0.5294 +0.760
0.5315 +0.794

2442121 +
0.4905 +1.087
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0.4953 +0.838
0.5009 +0.562
0.5043 +0.566
0.5057 +0.571
0.5085 +0.650
0.5099 +0.686
0.5134 +0.751
0.5148 +0.807
0.5189 +0.882
0.5203 +0.914

2442128 +
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0.2920 +0.746
0.2930 +0.722
0.2942 +0.676
0.2953 +0.655
0.2964 +0.643
0.2975 +0.637
0.2985 +0.650
0.2996 +0.667
0.3035 +0.730
0.3059 +0.761
0.3070 +0.781
0.3082 +0.786
0.3093 +0.803
0.3106 +0.835
0.3118 +0.860
0.3131 +0.874
0.3177 +0.965
0.3189 +0.984
0.3203 +0.999
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0.3517 +1.243
0.3527 +1.239
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0.3631 +1.274
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0.3791 +0.914
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0.3882 +0.776
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0.3920 +0.809
0.3948 +0.817
0.3962 +0.829
0.3981 +0.867
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0.4014 +0.888
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0.4217 +1.116
0.4231 +1.138
0.4244 +1.172
0.4256 +1.181
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0.4402 +1.275
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0.4439 +1.294
0.4456 +1.293
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0.4485 +1.279
0.4496 +1.278
0.4593 +1.125
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0.4733 +0.586
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0.4851 +0.804
0.4870 +0.852
0.4883 +0.867
0.4895 +0.888
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0.5625 +0.675
0.5636 +0.703
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0.5657 +0.752
0.5668 +0.766
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0.4170 +0.997

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0.4324 +0.729
0.4345 +0.688
0.4359 +0.683
0.4380 +0.666
0.4394 +0.683
0.4474 +0.816
0.4495 +0.836
0.4509 +0.854
0.4530 +0.873

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0.4140 +0.504
0.4151 +0.497
0.4179 +0.542
0.4189 +0.589
0.4214 +0.639

2442453 +
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0.5251 +0.754
0.5258 +0.684
0.5281 +0.590
0.5292 +0.558
0.5314 +0.557
0.5324 +0.583
0.5345 +0.610
0.5357 +0.628
0.5383 +0.695
0.5395 +0.725
0.5420 +0.771
0.5428 +0.805
0.5455 +0.850
0.5468 +0.894
0.5970 +1.269
0.5981 +1.232
0.6005 +1.113
0.6017 +1.078
0.6040 +0.990
0.6051 +0.948
0.6071 +0.824
0.6081 +0.758
0.6103 +0.653
0.6113 +0.612
0.6136 +0.577
0.6146 +0.610
0.6168 +0.618
0.6179 +0.636
0.6202 +0.682
0.6213 +0.712
0.6237 +0.776
0.6248 +0.794
0.6272 +0.820
0.6283 +0.872

2442460 +
0.4889 +0.994
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0.4922 +0.900
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0.4964 +0.775
0.4990 +0.757
0.5000 +0.750

0.5024 +0.777
0.5035 +0.797
0.5060 +0.825
0.5069 +0.828
0.5099 +0.857
0.5109 +0.860
0.5131 +0.905
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2444634 +
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0.4432 +1.195
0.4446 +1.216
0.4507 +1.254
0.4521 +1.270
0.4535 +1.285

0.4549 +1.284	0.5678 +1.061	0.4154 +1.136	0.4691 +1.253	0.5365 +1.263
0.4563 +1.293	0.5692 +1.031	0.4227 +1.196	0.4765 +1.253	0.5494 +1.289
0.4624 +1.295	0.5756 +0.786	0.4241 +1.220	0.4778 +1.261	0.5507 +1.288
0.4638 +1.289	0.5770 +0.766	0.4255 +1.228	0.4792 +1.239	0.5521 +1.277
0.4652 +1.288	0.5784 +0.746	0.4269 +1.232	0.4806 +1.245	0.5535 +1.273
0.4666 +1.284	0.5798 +0.739	0.4282 +1.237	0.4820 +1.238	0.5549 +1.255
0.4680 +1.272	0.5812 +0.739	0.4359 +1.266		0.5617 +1.031
0.4739 +1.170	0.5826 +0.740	0.4373 +1.278	2445355 +	0.5630 +0.945
0.4753 +1.145	0.5840 +0.751	0.4387 +1.273	0.4313 +1.096	0.5644 +0.846
0.4767 +1.125	0.5855 +0.761	0.4400 +1.283	0.4327 +1.108	0.5658 +0.737
0.4781 +1.073	0.5932 +0.868	0.4414 +1.281	0.4341 +1.120	0.5672 +0.640
0.4794 +1.026	0.5946 +0.901	0.4484 +1.267	0.4354 +1.136	0.5686 +0.561
0.4855 +0.757	0.5960 +0.917	0.4498 +1.258	0.4368 +1.141	0.5700 +0.524
0.4868 +0.707	0.5974 +0.936	0.4511 +1.278	0.4474 +1.197	0.5722 +0.503
0.4882 +0.694	0.5988 +0.979	0.4525 +1.241	0.4488 +1.215	0.5736 +0.495
0.4896 +0.672	0.6055 +1.070	0.4539 +1.225	0.4502 +1.230	0.5750 +0.515
0.4910 +0.677	0.6069 +1.080	0.4609 +0.957	0.4515 +1.228	0.5763 +0.526
0.4924 +0.692	0.6083 +1.103	0.4623 +0.902	0.4529 +1.247	
0.4938 +0.705	0.6096 +1.112	0.4636 +0.814	0.4640 +1.264	2445381 +
0.5003 +0.801	0.6111 +1.140	0.4650 +0.746	0.4654 +1.262	0.3049 +0.865
0.5017 +0.823		0.4664 +0.689	0.4668 +1.251	0.3063 +0.871
0.5031 +0.858	2444648 +	0.4684 +0.651	0.4681 +1.254	0.3076 +0.885
0.5045 +0.896	0.3526 +0.852	0.4697 +0.633	0.4695 +1.239	0.3090 +0.908
0.5058 +0.916	0.3540 +0.874	0.4711 +0.625	0.4766 +1.096	0.3104 +0.930
0.5139 +1.038	0.3554 +0.891	0.4725 +0.631	0.4780 +1.046	0.3181 +1.049
0.5152 +1.052	0.3568 +0.917	0.4739 +0.660	0.4794 +0.974	0.3195 +1.079
0.5166 +1.079	0.3581 +0.944	0.4831 +0.825	0.4807 +0.930	0.3209 +1.106
0.5180 +1.091	0.3646 +1.029	0.4845 +0.861	0.4821 +0.872	0.3223 +1.111
0.5194 +1.121	0.3660 +1.042	0.4859 +0.878	0.4888 +0.649	0.3236 +1.136
0.5265 +1.170	0.3674 +1.059	0.4873 +0.908	0.4902 +0.638	0.3322 +1.201
0.5278 +1.184	0.3688 +1.091	0.4886 +0.942	0.4916 +0.638	0.3377 +1.261
0.5292 +1.185		0.4957 +1.069	0.4930 +0.661	
0.5306 +1.204	2444692 +	0.4972 +1.084	0.5021 +0.805	2445382 +
0.5320 +1.203	0.3863 +0.792	0.4986 +1.088	0.5035 +0.832	0.2847 +1.286
0.5380 +1.247	0.3877 +0.794	0.4999 +1.116	0.5049 +0.858	0.2861 +1.283
0.5394 +1.250	0.3891 +0.809	0.5013 +1.144	0.5063 +0.890	0.2875 +1.285
0.5408 +1.249	0.3904 +0.830		0.5077 +0.921	0.2889 +1.287
0.5422 +1.262	0.3918 +0.854	2444987 +	0.5146 +1.062	0.2903 +1.272
0.5436 +1.263	0.3981 +0.934	0.4502 +1.133	0.5160 +1.087	0.2979 +1.278
0.5511 +1.268	0.3995 +0.960	0.4516 +1.147	0.5174 +1.093	0.2993 +1.280
0.5525 +1.252	0.4009 +0.975	0.4530 +1.151	0.5188 +1.121	0.3006 +1.280
0.5539 +1.256	0.4023 +0.999	0.4543 +1.172	0.5202 +1.153	0.3020 +1.269
0.5553 +1.244	0.4036 +1.014	0.4557 +1.174	0.5263 +1.198	0.3034 +1.255
0.5567 +1.242	0.4099 +1.087	0.4636 +1.221	0.5277 +1.220	0.3103 +1.106
0.5636 +1.179	0.4113 +1.107	0.4649 +1.243	0.5291 +1.227	0.3117 +1.035
0.5650 +1.136	0.4127 +1.130	0.4663 +1.243	0.5305 +1.241	0.3131 +0.991
0.5664 +1.106	0.4140 +1.133	0.4677 +1.257	0.5318 +1.245	0.3145 +0.890

0.3159 +0.815	0.4272 +0.945	0.5465 +1.259	0.4359 +1.300	0.5733 +1.086
0.3223 +0.512	0.4332 +1.039	0.5478 +1.268	0.4460 +1.208	
0.3237 +0.514	0.4346 +1.058	0.5492 +1.283	0.4475 +1.164	2450151 +
0.3251 +0.550	0.4360 +1.072	0.5506 +1.294	0.4490 +1.116	0.4440 +1.097
0.3264 +0.566	0.4374 +1.082	0.5570 +1.278	0.4505 +1.039	0.4460 +1.034
0.3278 +0.599	0.4387 +1.096	0.5584 +1.278	0.4520 +0.936	0.4479 +0.943
0.3357 +0.817	0.4481 +1.186	0.5597 +1.280	0.4583 +0.535	0.4603 +0.615
0.3371 +0.862	0.4495 +1.199	0.5611 +1.268	0.4598 +0.532	0.4622 +0.640
0.3384 +0.882	0.4508 +1.200	0.5625 +1.288	0.4613 +0.531	0.4642 +0.695
0.3398 +0.891	0.4522 +1.216	0.5709 +1.051	0.4628 +0.560	0.4802 +1.033
0.3412 +0.925	0.4536 +1.224	0.5723 +0.986	0.4643 +0.584	0.4821 +1.049
0.3503 +1.051	0.4602 +1.261	0.5737 +0.918	0.4760 +0.866	0.4841 +1.081
0.3517 +1.067	0.4616 +1.259	0.5750 +0.833	0.4775 +0.880	0.4958 +1.222
0.3531 +1.089	0.4629 +1.266	0.5764 +0.705	0.4860 +1.066	0.4978 +1.240
0.3545 +1.099	0.4643 +1.275	0.5779 +0.603	0.4874 +1.099	0.4998 +1.245
0.3559 +1.134	0.4657 +1.269	0.5793 +0.526	0.4889 +1.110	0.5112 +1.311
0.3631 +1.203	0.4733 +1.265	0.5812 +0.512	0.4904 +1.111	0.5132 +1.309
0.3645 +1.229	0.4747 +1.256	0.5825 +0.515	0.4920 +1.131	0.5151 +1.304
0.3659 +1.240	0.4761 +1.255	0.5839 +0.553	0.4996 +1.197	0.5247 +1.157
0.3673 +1.244	0.4774 +1.248	0.5853 +0.577	0.5011 +1.218	0.5266 +1.119
0.3687 +1.242	0.4788 +1.238	0.5867 +0.590	0.5026 +1.222	0.5286 +1.051
0.3751 +1.286	0.4871 +1.093	0.5931 +0.759	0.5041 +1.235	0.5399 +0.641
0.3765 +1.280	0.4885 +1.034	0.5945 +0.781	0.5056 +1.244	0.5419 +0.676
0.3779 +1.295	0.4899 +0.978	0.5959 +0.829	0.5143 +1.291	0.5438 +0.723
0.3792 +1.274	0.4913 +0.909	0.5973 +0.873	0.5158 +1.276	0.5590 +0.998
0.3806 +1.275	0.4927 +0.837	0.5986 +0.888	0.5172 +1.289	0.5610 +1.028
0.3879 +1.230	0.4981 +0.675		0.5187 +1.277	0.5629 +1.048
0.3893 +1.215	0.4995 +0.664	2446468 +	0.5202 +1.270	0.5718 +1.145
0.3907 +1.210	0.5009 +0.669	0.3872 +0.720	0.5273 +1.213	0.5738 +1.171
0.3921 +1.184	0.5023 +0.691	0.3885 +0.771	0.5287 +1.211	0.5758 +1.200
0.3934 +1.166	0.5037 +0.689	0.3902 +0.797	0.5302 +1.191	0.5850 +1.253
0.4004 +0.949	0.5094 +0.792	0.3917 +0.844	0.5317 +1.171	0.5870 +1.281
0.4018 +0.911	0.5108 +0.815	0.3932 +0.867	0.5332 +1.132	0.5889 +1.278
0.4031 +0.886	0.5122 +0.858	0.4014 +1.038	0.5404 +0.859	0.5980 +1.301
0.4045 +0.833	0.5136 +0.889	0.4028 +1.054	0.5419 +0.809	0.5999 +1.305
0.4059 +0.805	0.5149 +0.918	0.4043 +1.078	0.5433 +0.753	0.6019 +1.307
0.4073 +0.786	0.5210 +1.013	0.4058 +1.091	0.5447 +0.717	
0.4087 +0.766	0.5224 +1.031	0.4073 +1.107	0.5463 +0.730	2450152 +
0.4104 +0.741	0.5238 +1.054	0.4157 +1.191	0.5531 +0.778	0.2877 +1.286
0.4117 +0.755	0.5252 +1.071	0.4172 +1.209	0.5546 +0.796	0.2897 +1.293
0.4131 +0.769	0.5265 +1.103	0.4186 +1.231	0.5561 +0.823	0.2916 +1.284
0.4145 +0.793	0.5325 +1.165	0.4201 +1.248	0.5576 +0.848	0.3000 +1.211
0.4159 +0.806	0.5339 +1.181	0.4216 +1.245	0.5591 +0.880	0.3019 +1.189
0.4217 +0.857	0.5353 +1.179	0.4300 +1.303	0.5673 +1.015	0.3039 +1.149
0.4230 +0.882	0.5367 +1.195	0.4314 +1.299	0.5688 +1.033	0.3126 +0.698
0.4244 +0.903	0.5381 +1.197	0.4330 +1.303	0.5703 +1.052	0.3145 +0.630
0.4258 +0.920	0.5451 +1.248	0.4345 +1.304	0.5718 +1.070	0.3165 +0.613

0.3255 +0.744	0.5832 +0.751	0.4049 +1.255	0.4201 +1.233	0.5983 +1.244
0.3275 +0.790	0.5930 +0.938	0.4106 +1.280	0.4214 +1.215	0.5996 +1.219
0.3294 +0.848	0.5950 +0.952	0.4119 +1.303	0.4228 +1.201	0.6069 +0.927
0.3377 +0.985	0.5969 +1.016	0.4132 +1.320	0.4282 +1.061	0.6082 +0.848
0.3397 +1.027		0.4183 +1.281	0.4295 +1.014	0.6095 +0.831
0.3416 +1.044	2450487 +	0.4196 +1.245	0.4309 +1.032	0.6242 +0.781
0.3495 +1.160	0.3852 +1.198	0.4209 +1.272	0.4367 +0.806	0.6255 +0.857
0.3515 +1.170	0.3865 +1.200		0.4380 +0.784	0.6268 +0.863
0.3534 +1.185	0.3878 +1.216	2450554 +	0.4393 +0.785	0.6335 +0.935
0.3614 +1.247	0.4011 +1.253	0.4091 +1.294	0.4454 +0.791	0.6349 +0.941
0.3634 +1.273	0.4024 +1.292	0.4105 +1.304	0.4467 +0.829	0.6362 +0.951
0.3653 +1.276	0.4037 +1.287	0.4118 +1.283	0.4480 +0.843	0.6424 +1.145
0.3735 +1.297	0.4096 +1.295	0.4298 +1.141	0.4553 +0.930	0.6437 +1.158
0.3755 +1.299	0.4109 +1.307	0.4311 +1.109	0.4566 +0.955	0.6450 +1.173
0.3774 +1.288	0.4122 +1.299	0.4324 +1.042	0.4580 +0.963	0.6506 +1.179
0.4450 +1.257	0.4174 +1.277	0.4375 +0.848	0.4640 +1.025	0.6519 +1.203
0.4469 +1.265	0.4187 +1.288	0.4388 +0.780	0.4653 +1.056	0.6532 +1.193
0.4489 +1.252	0.4200 +1.267	0.4401 +0.763	0.4666 +1.057	0.6603 +1.255
0.4572 +1.291	0.4253 +1.077	0.4454 +0.736	0.4811 +1.225	0.6616 +1.263
0.4592 +1.266	0.4266 +0.988	0.4467 +0.767	0.4825 +1.233	0.6679 +1.246
0.4611 +1.276	0.4280 +0.924	0.4480 +0.774	0.4838 +1.288	0.6692 +1.249
0.4747 +1.050	0.4338 +0.617	0.4534 +0.852	0.4901 +1.279	0.6705 +1.264
0.4767 +0.998	0.4351 +0.620	0.4547 +0.860	0.4914 +1.285	0.6763 +1.300
0.4786 +0.946		0.4560 +0.898	0.4985 +1.240	0.6776 +1.343
0.4862 +0.793	2450490 +		0.4998 +1.231	0.6789 +1.315
0.4882 +0.806	0.3465 +1.174	2450813 +	0.5377 +0.751	0.6855 +1.093
0.4901 +0.804	0.3478 +1.131	0.3439 +1.062	0.5390 +0.770	0.6868 +1.040
0.4990 +0.908	0.3491 +1.082	0.3452 +1.010	0.5403 +0.803	0.6881 +1.027
0.5009 +0.946	0.3546 +0.785	0.3465 +0.946	0.5457 +0.879	0.6938 +0.762
0.5029 +0.965	0.3559 +0.664	0.3521 +0.646	0.5470 +0.919	0.6952 +0.724
0.5118 +1.076	0.3573 +0.571	0.3534 +0.659	0.5483 +0.952	0.6965 +0.681
0.5138 +1.102	0.3625 +0.549	0.3547 +0.661	0.5541 +1.021	0.7022 +0.705
0.5157 +1.110	0.3638 +0.572	0.3599 +0.679	0.5554 +1.044	0.7035 +0.745
0.5254 +1.202	0.3651 +0.600	0.3612 +0.701	0.5567 +1.066	0.7048 +0.751
0.5274 +1.201	0.3716 +0.747	0.3625 +0.725	0.5625 +1.154	0.7107 +0.872
0.5293 +1.210	0.3729 +0.784	0.3676 +0.840	0.5638 +1.215	0.7120 +0.907
0.5396 +1.246	0.3784 +0.921	0.3689 +0.878	0.5652 +1.224	0.7133 +0.936
0.5416 +1.254	0.3797 +0.953	0.3702 +0.894	0.5716 +1.233	
0.5435 +1.259	0.3811 +1.008	0.3786 +1.009	0.5729 +1.265	2450848 +
0.5534 +1.246	0.3861 +1.055	0.3799 +1.044	0.5742 +1.278	0.4028 +1.200
0.5554 +1.243	0.3875 +1.077	0.3812 +1.081	0.5802 +1.291	0.4042 +1.197
0.5573 +1.227	0.3888 +1.094	0.3954 +1.220	0.5816 +1.295	0.4055 +1.213
0.5665 +0.970	0.3943 +1.201	0.3967 +1.234	0.5829 +1.300	0.4110 +1.257
0.5685 +0.911	0.3956 +1.226	0.3980 +1.257	0.5887 +1.315	0.4123 +1.244
0.5704 +0.842	0.3969 +1.242	0.4122 +1.291	0.5900 +1.308	0.4137 +1.262
0.5793 +0.713	0.4023 +1.251	0.4135 +1.276	0.5913 +1.296	0.4189 +1.263
0.5813 +0.729	0.4036 +1.260	0.4148 +1.277	0.5970 +1.268	0.4202 +1.265

0.4215 +1.290	0.5557 +0.915	0.3704 +1.281	0.5617 +0.895	0.3265 +1.298
0.4270 +1.248	0.5570 +0.928	0.3726 +1.289	0.5671 +0.780	0.3323 +1.299
0.4283 +1.242	0.5940 +1.278	0.3747 +1.266	0.5684 +0.780	0.3336 +1.314
0.4296 +1.259	0.5953 +1.304	0.3803 +1.234	0.5697 +0.784	0.3349 +1.294
0.4359 +1.196	0.5966 +1.285	0.3825 +1.227	0.5754 +0.826	0.3403 +1.293
0.4372 +1.177	0.6028 +1.244	0.3847 +1.260	0.5767 +0.836	0.3416 +1.280
0.4385 +1.165	0.6041 +1.209	0.4503 +1.281	0.5780 +0.849	0.3430 +1.306
0.4439 +0.968	0.6054 +1.177	0.4516 +1.306	0.6159 +1.233	0.3481 +1.264
0.4452 +0.940	0.6115 +0.984	0.4529 +1.314	0.6172 +1.230	0.3494 +1.207
0.4465 +0.885	0.6128 +0.923	0.4583 +1.273	0.6185 +1.233	0.3507 +1.164
0.4519 +0.773	0.6141 +0.844	0.4596 +1.305	0.6241 +1.274	0.3562 +0.840
0.4532 +0.790	0.6196 +0.584	0.4609 +1.278	0.6254 +1.289	0.3575 +0.740
0.4545 +0.787	0.6209 +0.585	0.4663 +1.215	0.6268 +1.277	0.3588 +0.635
0.4602 +0.821	0.6222 +0.594	0.4676 +1.171	0.6330 +1.258	0.3642 +0.522
0.4615 +0.830	0.6279 +0.686	0.4689 +1.107	0.6343 +1.264	0.3655 +0.548
0.4628 +0.829	0.6292 +0.735	0.4745 +0.850	0.6356 +1.272	0.3668 +0.578
0.4684 +0.898	0.6305 +0.752	0.4758 +0.755	0.6412 +1.073	0.3725 +0.747
0.4697 +0.938	0.6367 +0.914	0.4771 +0.632	0.6425 +1.011	0.3738 +0.796
0.4710 +0.950	0.6380 +0.930	0.4825 +0.549	0.6438 +0.922	0.3751 +0.822
0.4768 +1.045	0.6393 +0.932	0.4838 +0.572	0.6662 +0.783	0.3811 +0.941
0.4781 +1.069	0.6451 +1.040	0.4851 +0.589	0.6676 +0.796	0.3825 +0.982
0.4794 +1.085	0.6464 +1.050	0.4909 +0.756	0.6689 +0.828	0.3838 +1.017
0.4866 +1.159	0.6478 +1.075	0.4922 +0.775		0.3890 +1.082
0.4879 +1.203	0.6533 +1.134	0.4936 +0.810	2450872 +	0.3903 +1.107
0.4892 +1.180	0.6546 +1.145	0.4992 +0.930	0.2666 +1.133	0.3916 +1.100
0.4954 +1.238	0.6559 +1.153	0.5006 +0.931	0.2679 +1.121	0.3973 +1.179
0.4967 +1.248	0.6619 +1.226	0.5019 +0.971	0.2693 +1.063	0.3986 +1.185
0.4980 +1.249	0.6632 +1.227	0.5072 +1.067	0.2747 +0.824	0.3999 +1.195
0.5034 +1.271	0.6646 +1.248	0.5085 +1.079	0.2760 +0.764	0.4057 +1.265
0.5047 +1.258		0.5098 +1.117	0.2773 +0.714	0.4070 +1.298
0.5060 +1.269	2450849 +	0.5154 +1.160	0.2826 +0.683	0.4083 +1.293
0.5117 +1.291	0.2832 +1.265	0.5167 +1.182	0.2839 +0.698	0.4137 +1.287
0.5130 +1.300	0.2854 +1.285	0.5180 +1.197	0.2853 +0.699	0.4150 +1.292
0.5143 +1.279	0.2876 +1.274	0.5234 +1.218	0.2909 +0.813	0.4163 +1.320
0.5202 +1.259	0.2964 +1.156	0.5247 +1.237	0.2922 +0.833	0.4216 +1.304
0.5215 +1.250	0.2986 +1.128	0.5260 +1.243	0.2935 +0.884	0.4229 +1.306
0.5228 +1.217	0.3008 +1.106	0.5320 +1.269	0.2991 +0.959	0.4242 +1.307
0.5289 +0.992	0.3199 +0.832	0.5333 +1.287	0.3005 +0.987	0.4295 +1.220
0.5302 +0.916	0.3221 +0.849	0.5346 +1.287	0.3018 +1.013	0.4308 +1.205
0.5315 +0.851	0.3242 +0.855	0.5404 +1.261	0.3071 +1.085	0.4321 +1.188
0.5373 +0.573	0.3322 +0.979	0.5418 +1.276	0.3084 +1.096	0.4376 +1.046
0.5386 +0.562	0.3343 +1.007	0.5431 +1.268	0.3097 +1.111	0.4390 +0.992
0.5400 +0.567	0.3365 +1.048	0.5491 +1.219	0.3155 +1.198	0.4403 +0.923
0.5460 +0.675	0.3486 +1.192	0.5504 +1.210	0.3169 +1.181	0.4459 +0.752
0.5473 +0.709	0.3589 +1.246	0.5517 +1.179	0.3182 +1.219	0.4472 +0.744
0.5486 +0.744	0.3584 +1.232	0.5591 +0.995	0.3238 +1.268	0.4485 +0.754
0.5544 +0.893	0.3605 +1.246	0.5604 +0.958	0.3251 +1.286	0.4540 +0.800

0.4553 +0.819	0.5906 +1.288	0.3893 +0.903	0.3001 +0.588	0.4311 +1.271
0.4566 +0.825	0.5919 +1.288	0.3906 +0.934	0.3058 +0.710	0.4324 +1.283
0.4647 +0.974	0.5932 +1.310	0.3919 +0.954	0.3071 +0.744	0.4376 +1.277
0.4660 +0.994	0.5990 +1.311	0.3978 +1.082	0.3085 +0.782	0.4390 +1.268
0.4673 +1.018	0.6003 +1.287	0.3991 +1.096	0.3138 +0.884	0.4403 +1.274
0.4732 +1.056	0.6016 +1.308	0.4004 +1.108	0.3151 +0.925	0.4457 +1.254
0.4745 +1.069	0.6069 +1.239	0.4058 +1.165	0.3165 +0.939	0.4470 +1.253
0.4758 +1.096	0.6082 +1.223	0.4071 +1.174	0.3219 +1.070	0.4483 +1.273
0.4814 +1.131	0.6096 +1.196	0.4084 +1.188	0.3232 +1.072	0.4536 +1.205
0.4827 +1.146		0.4171 +1.266	0.3245 +1.091	0.4550 +1.185
0.4840 +1.178	2450899 +	0.4184 +1.261	0.3298 +1.125	0.4563 +1.181
0.4895 +1.229	0.2907 +0.696	0.4198 +1.283	0.3311 +1.144	0.4614 +1.062
0.4908 +1.230	0.2920 +0.701	0.4249 +1.277	0.3324 +1.181	0.4627 +1.011
0.4922 +1.246	0.2933 +0.701	0.4263 +1.292	0.3382 +1.204	0.4640 +0.950
0.4981 +1.260	0.2991 +0.772	0.4276 +1.288	0.3395 +1.223	
0.4994 +1.269	0.3004 +0.802	0.4405 +1.185	0.3408 +1.239	2450903 +
0.5007 +1.260	0.3017 +0.829	0.4418 +1.168	0.3460 +1.283	0.2785 +1.169
0.5062 +1.254	0.3072 +0.940	0.4431 +1.153	0.3473 +1.297	0.2798 +1.170
0.5075 +1.270	0.3086 +0.964	0.4545 +0.732	0.3486 +1.296	0.2811 +1.185
0.5088 +1.278	0.3099 +0.987	0.4558 +0.729	0.3543 +1.298	0.2866 +1.236
0.5144 +1.255	0.3153 +1.049	0.4572 +0.713	0.3556 +1.308	0.2879 +1.269
0.5157 +1.236	0.3166 +1.069	0.4623 +0.775	0.3570 +1.291	0.2892 +1.283
0.5170 +1.228	0.3179 +1.098	0.4636 +0.796	0.3620 +1.250	0.2943 +1.289
0.5226 +1.166	0.3237 +1.138	0.4650 +0.811	0.3633 +1.232	0.2956 +1.302
0.5239 +1.160	0.3251 +1.157	0.4701 +0.876	0.3647 +1.217	0.2969 +1.277
0.5252 +1.107	0.3264 +1.178	0.4714 +0.900	0.3696 +1.095	0.3022 +1.278
0.5315 +0.925	0.3327 +1.246	0.4727 +0.918	0.3710 +1.041	0.3035 +1.275
0.5328 +0.882	0.3340 +1.226	0.4783 +0.996	0.3723 +1.010	0.3048 +1.264
0.5341 +0.856	0.3354 +1.257	0.4796 +1.005	0.3775 +0.744	0.3103 +1.222
0.5394 +0.749	0.3413 +1.287	0.4809 +1.042	0.3789 +0.709	0.3116 +1.232
0.5407 +0.745	0.3426 +1.310	0.4926 +1.162	0.3802 +0.694	0.3129 +1.206
0.5420 +0.763	0.3439 +1.292	0.4983 +1.203	0.3864 +0.728	0.3183 +1.073
0.5476 +0.837	0.3492 +1.296	0.4996 +1.216	0.3878 +0.741	0.3196 +1.043
0.5489 +0.850	0.3505 +1.290	0.5009 +1.240	0.3891 +0.755	0.3209 +0.992
0.5503 +0.872	0.3518 +1.299	0.5065 +1.263	0.3971 +0.888	0.3260 +0.859
0.5564 +0.956	0.3571 +1.238	0.5078 +1.288	0.3984 +0.905	0.3273 +0.849
0.5577 +0.981	0.3584 +1.192	0.5092 +1.276	0.3997 +0.937	0.3287 +0.829
0.5590 +1.004	0.3597 +1.170		0.4060 +1.039	0.3339 +0.822
0.5652 +1.099	0.3651 +0.871	2450902 +	0.4073 +1.046	0.3352 +0.827
0.5665 +1.111	0.3664 +0.784	0.2816 +1.231	0.4086 +1.087	0.3365 +0.854
0.5678 +1.139	0.3677 +0.681	0.2829 +1.207	0.4141 +1.156	0.3419 +0.883
0.5744 +1.178	0.3729 +0.533	0.2842 +1.164	0.4154 +1.173	0.3432 +0.891
0.5757 +1.196	0.3742 +0.539	0.2894 +0.948	0.4167 +1.183	0.3445 +0.918
0.5770 +1.208	0.3756 +0.555	0.2907 +0.860	0.4220 +1.248	0.3500 +0.996
0.5823 +1.247	0.3808 +0.694	0.2920 +0.750	0.4233 +1.251	0.3513 +1.016
0.5836 +1.257	0.3821 +0.736	0.2975 +0.553	0.4246 +1.238	0.3526 +1.028
0.5850 +1.266	0.3834 +0.765	0.2988 +0.556	0.4298 +1.248	0.3577 +1.103

0.3591 +1.097	0.3974 +1.239	0.4355 +0.925	0.4767 +1.308	0.5156 +0.843
0.3604 +1.106	0.3987 +1.240	0.4429 +1.043	0.4780 +1.320	0.5169 +0.882
0.3656 +1.142	0.4001 +1.228	0.4443 +1.065	0.4834 +1.283	0.5182 +0.905
0.3669 +1.172	0.4052 +1.144	0.4456 +1.094	0.4847 +1.261	0.5315 +1.135
0.3682 +1.167	0.4065 +1.093	0.4517 +1.135	0.4860 +1.236	0.5328 +1.151
0.3736 +1.229	0.4079 +1.063	0.4530 +1.151	0.4916 +0.982	0.5341 +1.170
0.3749 +1.237	0.4143 +0.731	0.4543 +1.178	0.4929 +0.884	0.5394 +1.199
0.3762 +1.251	0.4156 +0.689	0.4594 +1.212	0.4943 +0.804	0.5407 +1.206
0.3817 +1.256	0.4169 +0.644	0.4608 +1.242	0.4996 +0.552	0.5420 +1.225
0.3830 +1.279	0.4239 +0.683	0.4621 +1.246	0.5009 +0.547	0.5475 +1.274
0.3843 +1.285	0.4252 +0.676	0.4676 +1.295	0.5022 +0.564	0.5488 +1.269
0.3897 +1.279	0.4266 +0.715	0.4689 +1.279	0.5075 +0.683	0.5502 +1.285
0.3909 +1.293	0.4329 +0.821	0.4702 +1.299	0.5089 +0.705	
0.3923 +1.285	0.4342 +0.869	0.4754 +1.304	0.5102 +0.741	

Table 5.
Differential V observations of AE UMa

2442062 +		0.5540 +1.129	0.6262 +0.947	0.5239 +0.852
0.5470 +1.283	2442095 +	0.5553 +1.154	0.6290 +0.999	0.5260 +0.856
0.5477 +1.276	0.4977 +1.325	0.5595 +1.215	0.6331 +1.062	0.5301 +0.901
0.5486 +1.277	0.4991 +1.316	0.5623 +1.235	0.6345 +1.078	0.5322 +0.932
0.5502 +1.298	0.5033 +1.305	0.5637 +1.261		
0.5519 +1.295	0.5060 +1.303	0.5665 +1.270	2442106 +	2442121 +
0.5579 +1.292	0.5074 +1.292	0.5678 +1.282	0.4423 +1.083	0.4912 +1.108
0.5591 +1.269	0.5102 +1.279	0.5706 +1.290	0.4437 +1.034	0.4925 +1.067
0.5600 +1.253	0.5116 +1.258	0.5720 +1.302	0.4465 +0.938	0.4974 +0.880
0.5611 +1.254	0.5144 +1.223	0.5790 +1.311	0.4479 +0.850	0.5016 +0.752
0.5657 +1.201	0.5175 +1.151	0.5803 +1.318	0.4507 +0.768	0.5050 +0.720
0.5671 +1.169	0.5182 +1.140	0.5831 +1.321	0.4521 +0.753	0.5064 +0.749
0.5680 +1.159	0.5202 +1.064	0.5845 +1.315	0.4548 +0.776	0.5092 +0.802
0.5693 +1.138	0.5209 +1.036	0.5915 +1.319	0.4562 +0.788	0.5106 +0.821
0.5737 +1.043	0.5230 +0.969	0.5928 +1.314	0.4590 +0.811	0.5141 +0.936
0.5750 +1.023	0.5237 +0.963	0.5956 +1.289	0.4604 +0.832	0.5155 +0.971
0.5762 +0.988	0.5258 +0.905	0.5970 +1.275	0.4632 +0.866	0.5196 +1.056
0.5770 +0.981	0.5265 +0.889	0.5998 +1.226	0.4646 +0.892	0.5210 +1.065
0.5804 +0.905	0.5290 +0.865	0.6040 +1.023	0.4673 +0.935	
0.5820 +0.891	0.5304 +0.864	0.6053 +0.968	0.4687 +0.971	2442128 +
0.5828 +0.892	0.5331 +0.876	0.6081 +0.838	0.4715 +1.020	0.2884 +1.117
0.5839 +0.900	0.5345 +0.890	0.6095 +0.783	0.4729 +1.038	0.2896 +1.096
0.5852 +0.898	0.5373 +0.918	0.6123 +0.717		0.2913 +0.925
0.5907 +0.932	0.5387 +0.925	0.6137 +0.726	2442119 +	0.2927 +0.871
0.5918 +0.952	0.5429 +1.008	0.6165 +0.762	0.5072 +1.234	0.2936 +0.845
0.5924 +0.957	0.5457 +1.047	0.6178 +0.783	0.5114 +1.160	0.2947 +0.805
0.5934 +0.971	0.5470 +1.081	0.6206 +0.856	0.5135 +1.086	0.2958 +0.811
0.5978 +1.008	0.5498 +1.090	0.6220 +0.874	0.5176 +0.980	0.2969 +0.809
0.5988 +1.020	0.5512 +1.109	0.6248 +0.928	0.5197 +0.921	0.2979 +0.808

0.2991 +0.809	0.3838 +0.920	0.5025 +1.190	0.5292 +1.224	0.3886 +0.860
0.3029 +0.864	0.3877 +0.904	0.5037 +1.200	0.5313 +1.136	0.3899 +0.813
0.3042 +0.877	0.3896 +0.905	0.5118 +1.245	0.5362 +0.957	0.3959 +0.811
0.3066 +0.885	0.3914 +0.927	0.5381 +1.274	0.5376 +0.903	0.4004 +0.864
0.3076 +0.898	0.3927 +0.935	0.5394 +1.243	0.5410 +0.736	0.4018 +0.879
0.3088 +0.913	0.3955 +0.936	0.5406 +1.211	0.5427 +0.716	0.4087 +0.970
0.3100 +0.933	0.3968 +0.951	0.5417 +1.198	0.5459 +0.707	0.4108 +1.011
0.3111 +0.949	0.3992 +0.968	0.5427 +1.180	0.5473 +0.729	0.4163 +1.084
0.3124 +0.984	0.4008 +0.996	0.5445 +1.130	0.5508 +0.804	0.4177 +1.147
0.3170 +1.044	0.4197 +1.176	0.5456 +1.088	0.5522 +0.840	
0.3183 +1.070	0.4210 +1.172	0.5468 +1.058	0.5556 +0.873	2442148 +
0.3197 +1.078	0.4225 +1.198	0.5478 +1.008	0.5570 +0.908	0.3913 +1.278
0.3209 +1.106	0.4237 +1.197	0.5490 +0.956	0.5605 +0.992	0.3927 +1.290
0.3220 +1.104	0.4249 +1.215	0.5499 +0.904	0.5619 +1.029	0.3955 +1.302
0.3232 +1.132	0.4262 +1.213	0.5511 +0.848		0.3969 +1.305
0.3241 +1.131	0.4275 +1.242	0.5597 +0.774	2442134 +	0.3997 +1.303
0.3253 +1.148	0.4289 +1.241	0.5607 +0.799	0.3840 +1.273	0.4011 +1.293
0.3303 +1.199	0.4393 +1.292	0.5619 +0.820	0.3854 +1.288	0.4038 +1.280
0.3315 +1.204	0.4412 +1.285	0.5630 +0.855	0.3889 +1.251	0.4052 +1.291
0.3329 +1.216	0.4427 +1.289	0.5643 +0.857	0.3909 +1.215	0.4219 +0.985
0.3342 +1.214	0.4447 +1.295	0.5654 +0.879	0.3972 +0.999	0.4247 +0.866
0.3356 +1.218	0.4466 +1.294	0.5662 +0.923	0.4028 +0.794	0.4261 +0.783
0.3370 +1.219	0.4479 +1.290	0.5674 +0.945	0.4041 +0.753	0.4274 +0.770
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0.3395 +1.225	0.4583 +1.206	0.5765 +1.114	0.4097 +0.740	0.4302 +0.752
0.3437 +1.237	0.4599 +1.178		0.4125 +0.801	0.4330 +0.766
0.3448 +1.253	0.4612 +1.142	2442133 +	0.4139 +0.829	0.4344 +0.810
0.3459 +1.257	0.4621 +1.126	0.4410 +1.293	0.4173 +0.894	0.4372 +0.879
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0.3486 +1.258	0.4645 +1.041	0.4466 +1.229	0.4222 +0.981	0.4413 +0.939
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0.3576 +1.308	0.4702 +0.775	0.4570 +0.887	0.4312 +1.094	0.4511 +1.097
0.3591 +1.289	0.4713 +0.762	0.4619 +0.759	0.4326 +1.128	0.4524 +1.119
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0.3624 +1.303	0.4758 +0.801	0.4730 +0.881		0.4594 +1.193
0.3637 +1.282	0.4814 +0.856	0.4744 +0.902	2442147 +	0.4608 +1.193
0.3650 +1.262	0.4826 +0.868	0.5008 +1.262	0.3573 +1.302	0.4636 +1.211
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0.4868 +0.972	0.4898 +0.804	0.3232 +1.163	0.3902 +1.253	0.5005 +0.816
0.4882 +1.000	0.4911 +0.807	0.3318 +1.230	0.3916 +1.239	0.5018 +0.829

0.5032 +0.832	0.3897 +0.919	0.5297 +1.236	0.5854 +1.249	0.5122 +1.127
0.5090 +0.904	0.3911 +0.966	0.5312 +1.217	0.5874 +1.281	0.5142 +1.151
0.5103 +0.936	0.4009 +1.117	0.5327 +1.179	0.5893 +1.278	0.5161 +1.155
0.5117 +0.954	0.4023 +1.133	0.5399 +0.985	0.5984 +1.288	0.5258 +1.216
0.5131 +0.989	0.4038 +1.142	0.5414 +0.943	0.6003 +1.273	0.5278 +1.227
0.5145 +1.013	0.4052 +1.157	0.5429 +0.892	0.6023 +1.267	0.5297 +1.233
0.5206 +1.101	0.4068 +1.161	0.5443 +0.860		0.5400 +1.275
0.5219 +1.118	0.4152 +1.230	0.5458 +0.862	2450152 +	0.5420 +1.289
0.5233 +1.132	0.4167 +1.233	0.5526 +0.886	0.2881 +1.295	0.5439 +1.279
0.5247 +1.154	0.4180 +1.244	0.5541 +0.905	0.2901 +1.302	0.5538 +1.266
0.5261 +1.169	0.4196 +1.256	0.5556 +0.914	0.2920 +1.299	0.5557 +1.243
0.5321 +1.199	0.4212 +1.270	0.5571 +0.933	0.3004 +1.264	0.5577 +1.242
0.5335 +1.213	0.4295 +1.307	0.5586 +0.950	0.3023 +1.231	0.5669 +1.054
0.5348 +1.205	0.4310 +1.299	0.5669 +1.067	0.3043 +1.188	0.5688 +1.001
0.5362 +1.223	0.4326 +1.307	0.5683 +1.089	0.3130 +0.825	0.5708 +0.939
0.5376 +1.239	0.4340 +1.316	0.5699 +1.100	0.3149 +0.781	0.5797 +0.870
0.5446 +1.279	0.4354 +1.309	0.5713 +1.107	0.3169 +0.755	0.5816 +0.883
0.5460 +1.283	0.4455 +1.244	0.5728 +1.136	0.3259 +0.858	0.5836 +0.898
0.5474 +1.292	0.4470 +1.215		0.3279 +0.901	0.5934 +1.041
0.5488 +1.305	0.4485 +1.176	2450151 +	0.3298 +0.934	0.5954 +1.057
0.5502 +1.314	0.4500 +1.101	0.4444 +1.137	0.3381 +1.065	0.5973 +1.100
0.5565 +1.305	0.4515 +1.056	0.4464 +1.102	0.3401 +1.086	
0.5579 +1.298	0.4579 +0.727	0.4483 +1.003	0.3420 +1.111	2450487 +
0.5593 +1.294	0.4593 +0.700	0.4607 +0.788	0.3499 +1.198	0.3854 +1.175
0.5607 +1.299	0.4608 +0.714	0.4626 +0.822	0.3518 +1.210	0.3867 +1.188
0.5621 +1.300	0.4623 +0.730	0.4646 +0.845	0.3538 +1.221	0.3880 +1.201
0.5705 +1.139	0.4638 +0.769	0.4805 +1.109	0.3618 +1.276	0.4013 +1.261
0.5718 +1.092	0.4726 +0.959	0.4825 +1.131	0.3638 +1.290	0.4026 +1.318
0.5732 +1.035	0.4756 +1.005	0.4845 +1.162	0.3657 +1.296	0.4040 +1.320
0.5746 +0.971	0.4770 +1.022	0.4962 +1.243	0.3739 +1.304	0.4098 +1.322
0.5760 +0.887	0.4855 +1.129	0.4982 +1.249	0.3759 +1.309	0.4111 +1.321
0.5775 +0.815	0.4870 +1.142	0.5002 +1.289	0.3778 +1.306	0.4125 +1.311
0.5789 +0.755	0.4885 +1.144	0.5116 +1.306	0.4454 +1.280	0.4176 +1.281
0.5807 +0.696	0.4900 +1.156	0.5136 +1.313	0.4473 +1.268	0.4190 +1.298
0.5821 +0.710	0.4916 +1.171	0.5155 +1.314	0.4493 +1.277	0.4203 +1.279
0.5835 +0.723	0.4991 +1.234	0.5251 +1.197	0.4576 +1.282	0.4256 +1.127
0.5849 +0.751	0.5007 +1.245	0.5270 +1.171	0.4595 +1.277	0.4269 +1.054
0.5862 +0.764	0.5021 +1.255	0.5290 +1.103	0.4615 +1.277	0.4282 +0.995
0.5927 +0.882	0.5037 +1.258	0.5403 +0.786	0.4751 +1.104	0.4341 +0.745
0.5940 +0.914	0.5051 +1.269	0.5423 +0.810	0.4771 +1.046	0.4354 +0.750
0.5954 +0.932	0.5138 +1.293	0.5442 +0.844	0.4790 +1.015	
0.5968 +0.956	0.5153 +1.288	0.5594 +1.056	0.4866 +0.905	2450490 +
0.5982 +0.996	0.5168 +1.294	0.5614 +1.069	0.4885 +0.917	0.3467 +1.218
	0.5182 +1.288	0.5633 +1.123	0.4905 +0.933	0.3480 +1.176
2446468 +	0.5197 +1.286	0.5722 +1.198	0.4994 +1.011	0.3493 +1.146
0.3867 +0.843	0.5268 +1.264	0.5742 +1.207	0.5013 +1.031	0.3549 +0.862
0.3882 +0.895	0.5283 +1.255	0.5761 +1.223	0.5033 +1.047	0.3562 +0.778

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0.6648 +1.230

2450849 +	0.5157 +1.201	0.2829 +0.812	0.4086 +1.283	0.5409 +0.883
0.2836 +1.284	0.5170 +1.208	0.2842 +0.827	0.4139 +1.291	0.5423 +0.907
0.2858 +1.282	0.5183 +1.206	0.2855 +0.832	0.4152 +1.305	0.5479 +0.958
0.2880 +1.293	0.5237 +1.261	0.2912 +0.939	0.4166 +1.293	0.5492 +0.971
0.2969 +1.199	0.5250 +1.251	0.2925 +0.954	0.4218 +1.292	0.5505 +0.998
0.2991 +1.184	0.5263 +1.269	0.2938 +0.989	0.4231 +1.299	0.5566 +1.057
0.3013 +1.159	0.5322 +1.279	0.2994 +1.060	0.4244 +1.303	0.5579 +1.072
0.3203 +0.934	0.5335 +1.294	0.3007 +1.036	0.4297 +1.258	0.5593 +1.071
0.3225 +0.941	0.5349 +1.291	0.3020 +1.086	0.4311 +1.242	0.5655 +1.157
0.3246 +0.958	0.5407 +1.299	0.3073 +1.143	0.4324 +1.218	0.5668 +1.161
0.3326 +1.057	0.5420 +1.301	0.3087 +1.149	0.4379 +1.105	0.5681 +1.163
0.3348 +1.062	0.5433 +1.297	0.3100 +1.158	0.4392 +1.050	0.5746 +1.211
0.3369 +1.103	0.5493 +1.259	0.3158 +1.226	0.4405 +1.013	0.5760 +1.219
0.3491 +1.219	0.5506 +1.223	0.3171 +1.211	0.4462 +0.876	0.5773 +1.244
0.3593 +1.225	0.5520 +1.207	0.3184 +1.246	0.4475 +0.879	0.5826 +1.271
0.3588 +1.253	0.5593 +1.073	0.3241 +1.286	0.4488 +0.875	0.5839 +1.275
0.3610 +1.248	0.5606 +1.041	0.3254 +1.297	0.4542 +0.907	0.5852 +1.291
0.3708 +1.277	0.5620 +0.981	0.3267 +1.308	0.4556 +0.911	0.5908 +1.306
0.3730 +1.289	0.5673 +0.903	0.3325 +1.316	0.4569 +0.938	0.5921 +1.300
0.3751 +1.285	0.5686 +0.894	0.3339 +1.303	0.4649 +1.039	0.5934 +1.310
0.3808 +1.265	0.5700 +0.901	0.3352 +1.307	0.4663 +1.082	0.5993 +1.301
0.3829 +1.268	0.5756 +0.922	0.3406 +1.301	0.4676 +1.093	0.6006 +1.293
0.3851 +1.277	0.5770 +0.931	0.3419 +1.280	0.4735 +1.132	0.6019 +1.309
0.4506 +1.285	0.5783 +0.972	0.3432 +1.339	0.4748 +1.151	0.6072 +1.270
0.4519 +1.315	0.6162 +1.264	0.3484 +1.280	0.4761 +1.152	0.6085 +1.253
0.4532 +1.311	0.6175 +1.268	0.3497 +1.253	0.4817 +1.182	0.6098 +1.213
0.4586 +1.297	0.6188 +1.267	0.3510 +1.204	0.4830 +1.197	
0.4599 +1.296	0.6244 +1.303	0.3565 +0.940	0.4843 +1.215	2450899 +
0.4612 +1.298	0.6257 +1.305	0.3578 +0.869	0.4898 +1.257	0.2909 +0.830
0.4666 +1.213	0.6270 +1.305	0.3591 +0.792	0.4911 +1.252	0.2922 +0.831
0.4679 +1.196	0.6333 +1.292	0.3644 +0.708	0.4924 +1.259	0.2936 +0.831
0.4692 +1.167	0.6346 +1.282	0.3658 +0.710	0.4983 +1.287	0.2993 +0.903
0.4747 +0.939	0.6359 +1.281	0.3671 +0.744	0.4996 +1.286	0.3007 +0.912
0.4760 +0.855	0.6414 +1.169	0.3727 +0.862	0.5010 +1.294	0.3020 +0.934
0.4774 +0.783	0.6427 +1.148	0.3740 +0.897	0.5065 +1.302	0.3075 +1.007
0.4827 +0.717	0.6441 +1.094	0.3754 +0.927	0.5078 +1.295	0.3088 +1.034
0.4840 +0.746	0.6665 +0.866	0.3814 +1.036	0.5091 +1.294	0.3102 +1.040
0.4853 +0.746	0.6678 +0.893	0.3827 +1.043	0.5147 +1.268	0.3156 +1.118
0.4912 +0.861	0.6691 +0.919	0.3840 +1.072	0.5160 +1.260	0.3169 +1.116
0.4925 +0.899		0.3892 +1.138	0.5173 +1.254	0.3182 +1.137
0.4938 +0.914	2450872 +	0.3905 +1.165	0.5229 +1.199	0.3240 +1.183
0.4995 +1.027	0.2669 +1.180	0.3919 +1.182	0.5242 +1.187	0.3253 +1.196
0.5008 +1.023	0.2682 +1.148	0.3976 +1.225	0.5255 +1.158	0.3266 +1.208
0.5021 +1.057	0.2695 +1.115	0.3989 +1.230	0.5317 +1.022	0.3330 +1.255
0.5075 +1.116	0.2750 +0.914	0.4002 +1.245	0.5331 +0.984	0.3343 +1.271
0.5088 +1.129	0.2763 +0.859	0.4060 +1.295	0.5344 +0.956	0.3356 +1.274
0.5101 +1.139	0.2776 +0.818	0.4073 +1.283	0.5396 +0.888	0.3415 +1.295

0.3429 +1.300	0.4812 +1.098	0.3778 +0.861	0.3051 +1.275	0.4331 +0.946
0.3442 +1.315	0.4929 +1.187	0.3791 +0.842	0.3105 +1.239	0.4344 +0.990
0.3494 +1.298	0.4985 +1.224	0.3804 +0.822	0.3118 +1.226	0.4357 +0.998
0.3507 +1.290	0.4999 +1.241	0.3867 +0.847	0.3131 +1.220	0.4432 +1.117
0.3520 +1.302	0.5012 +1.244	0.3880 +0.855	0.3185 +1.129	0.4445 +1.126
0.3573 +1.260	0.5068 +1.281	0.3893 +0.879	0.3199 +1.103	0.4458 +1.137
0.3586 +1.229	0.5081 +1.281	0.3974 +0.988	0.3212 +1.076	0.4519 +1.176
0.3599 +1.200	0.5094 +1.267	0.3987 +1.005	0.3263 +0.970	0.4533 +1.191
0.3654 +0.965		0.4000 +1.024	0.3276 +0.952	0.4546 +1.208
0.3667 +0.884	2450902 +	0.4062 +1.109	0.3289 +0.934	0.4597 +1.267
0.3680 +0.801	0.2819 +1.250	0.4075 +1.126	0.3341 +0.922	0.4610 +1.270
0.3732 +0.698	0.2832 +1.215	0.4089 +1.157	0.3354 +0.923	0.4623 +1.282
0.3745 +0.712	0.2845 +1.216	0.4144 +1.210	0.3368 +0.943	0.4678 +1.287
0.3758 +0.726	0.2896 +1.004	0.4157 +1.201	0.3422 +0.989	0.4691 +1.293
0.3810 +0.834	0.2909 +0.944	0.4170 +1.194	0.3435 +1.003	0.4705 +1.287
0.3823 +0.868	0.2923 +0.841	0.4223 +1.256	0.3448 +1.013	0.4757 +1.301
0.3837 +0.882	0.2977 +0.709	0.4236 +1.255	0.3502 +1.065	0.4770 +1.289
0.3896 +1.000	0.2991 +0.750	0.4249 +1.268	0.3516 +1.085	0.4783 +1.299
0.3909 +1.003	0.3004 +0.767	0.4300 +1.272	0.3529 +1.094	0.4836 +1.263
0.3922 +1.035	0.3061 +0.856	0.4314 +1.297	0.3580 +1.149	0.4850 +1.252
0.3981 +1.114	0.3074 +0.892	0.4327 +1.292	0.3593 +1.167	0.4863 +1.233
0.3994 +1.135	0.3087 +0.913	0.4379 +1.266	0.3606 +1.169	0.4919 +1.040
0.4007 +1.133	0.3141 +0.980	0.4392 +1.261	0.3659 +1.202	0.4932 +0.991
0.4060 +1.197	0.3154 +1.006	0.4405 +1.263	0.3672 +1.203	0.4945 +0.908
0.4074 +1.202	0.3167 +1.020	0.4460 +1.264	0.3685 +1.215	0.4998 +0.704
0.4087 +1.221	0.3221 +1.115	0.4473 +1.266	0.3738 +1.240	0.5011 +0.720
0.4174 +1.284	0.3234 +1.122	0.4486 +1.292	0.3752 +1.254	0.5025 +0.718
0.4187 +1.288	0.3248 +1.125	0.4539 +1.206	0.3765 +1.261	0.5078 +0.827
0.4200 +1.298	0.3301 +1.175	0.4552 +1.225	0.3819 +1.268	0.5091 +0.843
0.4252 +1.293	0.3314 +1.202	0.4565 +1.227	0.3832 +1.285	0.5104 +0.862
0.4265 +1.311	0.3327 +1.202	0.4616 +1.130	0.3845 +1.286	0.5158 +0.963
0.4279 +1.315	0.3385 +1.248	0.4629 +1.096	0.3899 +1.297	0.5172 +0.975
0.4407 +1.228	0.3398 +1.260	0.4642 +1.064	0.3912 +1.291	0.5185 +1.002
0.4420 +1.219	0.3411 +1.259		0.3925 +1.281	0.5318 +1.170
0.4433 +1.185	0.3463 +1.301	2450903 +	0.3977 +1.268	0.5331 +1.171
0.4548 +0.876	0.3476 +1.290	0.2788 +1.194	0.3990 +1.254	0.5344 +1.191
0.4561 +0.866	0.3489 +1.305	0.2801 +1.201	0.4003 +1.260	0.5396 +1.213
0.4574 +0.847	0.3546 +1.287	0.2814 +1.224	0.4055 +1.187	0.5410 +1.237
0.4626 +0.899	0.3559 +1.298	0.2868 +1.250	0.4068 +1.149	0.5423 +1.240
0.4639 +0.902	0.3572 +1.292	0.2882 +1.294	0.4081 +1.123	0.5478 +1.286
0.4653 +0.924	0.3623 +1.271	0.2895 +1.289	0.4145 +0.871	0.5491 +1.267
0.4704 +0.984	0.3636 +1.260	0.2945 +1.277	0.4159 +0.829	0.5504 +1.262
0.4717 +1.004	0.3649 +1.253	0.2958 +1.293	0.4172 +0.804	
0.4730 +1.020	0.3699 +1.140	0.2972 +1.291	0.4242 +0.830	
0.4786 +1.069	0.3712 +1.123	0.3025 +1.281	0.4255 +0.835	
0.4799 +1.089	0.3725 +1.063	0.3038 +1.285	0.4268 +0.866	

Table 6.
Differential R observations of AE UMa

2450151 +	0.3302 +0.981	0.5820 +0.959	0.3975 +1.239	0.3985 +1.283
0.4448 +1.169	0.3385 +1.102	0.5840 +0.960	0.4028 +1.270	0.4127 +1.290
0.4468 +1.094	0.3405 +1.120	0.5938 +1.079	0.4041 +1.258	0.4140 +1.297
0.4487 +1.004	0.3424 +1.150	0.5958 +1.096	0.4055 +1.258	0.4153 +1.292
0.4611 +0.854	0.3503 +1.204	0.5977 +1.107	0.4111 +1.290	0.4207 +1.236
0.4630 +0.880	0.3522 +1.216		0.4124 +1.301	0.4220 +1.240
0.4650 +0.913	0.3542 +1.226	2450487 +	0.4138 +1.289	0.4287 +1.133
0.4810 +1.147	0.3622 +1.277	0.3857 +1.210	0.4188 +1.253	0.4301 +1.134
0.4829 +1.167	0.3642 +1.282	0.3870 +1.225	0.4201 +1.247	0.4372 +0.983
0.4849 +1.185	0.3661 +1.290	0.3883 +1.220	0.4214 +1.264	0.4385 +0.971
0.4966 +1.241	0.3743 +1.297	0.4016 +1.276		0.4398 +0.971
0.4986 +1.260	0.3762 +1.335	0.4029 +1.297	2450554 +	0.4459 +0.987
0.5005 +1.269	0.3782 +1.315	0.4042 +1.325	0.4097 +1.278	0.4472 +1.007
0.5120 +1.305	0.4458 +1.231	0.4101 +1.304	0.4110 +1.286	0.4485 +1.047
0.5140 +1.325	0.4477 +1.251	0.4114 +1.298	0.4123 +1.290	0.4558 +1.090
0.5159 +1.326	0.4497 +1.248	0.4127 +1.290	0.4303 +1.197	0.4571 +1.113
0.5255 +1.218	0.4580 +1.251	0.4179 +1.274	0.4316 +1.167	0.4585 +1.123
0.5274 +1.168	0.4599 +1.249	0.4192 +1.304	0.4329 +1.152	0.4645 +1.129
0.5294 +1.148	0.4519 +1.243	0.4206 +1.295	0.4380 +0.986	0.4658 +1.125
0.5407 +0.869	0.4755 +1.140	0.4259 +1.131	0.4393 +0.958	0.4672 +1.156
0.5427 +0.888	0.4775 +1.100	0.4272 +1.103	0.4406 +0.940	0.4817 +1.252
0.5446 +0.904	0.4794 +1.048	0.4285 +1.001	0.4459 +0.940	0.4830 +1.285
0.5598 +1.106	0.4870 +0.983	0.4343 +0.839	0.4472 +0.940	0.4843 +1.298
0.5618 +1.106	0.4890 +0.984	0.4356 +0.848	0.4485 +0.944	0.4906 +1.307
0.5637 +1.142	0.4909 +1.002		0.4539 +1.006	0.4920 +1.335
0.5626 +1.191	0.4997 +1.058	2450490 +	0.4552 +1.023	0.4990 +1.276
0.5746 +1.215	0.5017 +1.074	0.3470 +1.228	0.4565 +1.041	0.5003 +1.260
0.5765 +1.241	0.5037 +1.101	0.3483 +1.187		0.5382 +0.948
0.5858 +1.250	0.5126 +1.164	0.3496 +1.158	2450813 +	0.5395 +0.962
0.5877 +1.271	0.5146 +1.175	0.3552 +0.912	0.3444 +1.143	0.5408 +0.980
0.5897 +1.246	0.5165 +1.174	0.3565 +0.848	0.3457 +1.105	0.5462 +1.028
0.5998 +1.243	0.5262 +1.218	0.3578 +0.798	0.3470 +1.110	0.5475 +1.070
0.6007 +1.235	0.5282 +1.229	0.3630 +0.804	0.3526 +0.942	0.5488 +1.075
0.6027 +1.236	0.5301 +1.226	0.3643 +0.836	0.3604 +0.912	0.5546 +1.106
	0.5404 +1.272	0.3708 +0.947	0.3617 +0.949	0.5560 +1.121
2450152 +	0.5424 +1.301	0.3721 +0.977	0.3631 +0.998	0.5573 +1.125
0.3008 +1.228	0.5443 +1.301	0.3735 +0.980	0.3681 +1.006	0.5631 +1.207
0.3027 +1.200	0.5542 +1.289	0.3790 +1.092	0.3694 +1.015	0.5644 +1.254
0.3047 +1.161	0.5561 +1.278	0.3816 +1.122	0.3707 +1.074	0.5657 +1.254
0.3133 +0.888	0.5581 +1.257	0.3867 +1.171	0.3791 +1.051	0.5721 +1.266
0.3153 +0.855	0.5673 +1.090	0.3880 +1.185	0.3804 +1.073	0.5734 +1.285
0.3183 +0.848	0.5692 +1.039	0.3893 +1.197	0.3817 +1.126	0.5747 +1.287
0.3263 +0.935	0.5712 +0.998	0.3948 +1.237	0.3959 +1.233	0.5808 +1.277
0.3282 +0.973	0.5801 +0.936	0.3962 +1.254	0.3972 +1.280	0.5821 +1.299

0.5834 +1.311	0.4194 +1.287	0.5549 +1.035	0.3614 +1.286	0.5609 +1.068
0.5892 +1.333	0.4207 +1.274	0.5562 +1.055	0.3713 +1.320	0.5622 +1.030
0.5905 +1.324	0.4220 +1.296	0.5576 +1.075	0.3734 +1.302	0.5676 +0.980
0.5919 +1.326	0.4275 +1.278	0.5945 +1.297	0.3756 +1.292	0.5689 +0.965
0.5975 +1.285	0.4288 +1.286	0.5958 +1.294	0.3812 +1.269	0.5702 +0.971
0.5988 +1.271	0.4301 +1.264	0.5971 +1.301	0.3834 +1.280	0.5759 +0.986
0.6001 +1.276	0.4364 +1.223	0.6033 +1.279	0.3855 +1.291	0.5772 +1.016
0.6074 +1.046	0.4377 +1.189	0.6046 +1.241	0.4508 +1.326	0.5785 +1.017
0.6087 +1.001	0.4444 +1.114	0.6059 +1.228	0.4521 +1.310	0.6164 +1.259
0.6100 +0.999	0.4457 +1.074	0.6120 +1.102	0.4535 +1.324	0.6177 +1.271
0.6247 +0.971	0.4471 +1.050	0.6133 +1.044	0.4588 +1.321	0.6191 +1.270
0.6273 +0.976	0.4524 +0.981	0.6146 +0.992	0.4601 +1.317	0.6247 +1.289
0.6341 +1.061	0.4537 +0.980	0.6201 +0.829	0.4614 +1.287	0.6260 +1.296
0.6354 +1.088	0.4551 +0.955	0.6214 +0.818	0.4668 +1.258	0.6273 +1.304
0.6367 +1.133	0.4607 +0.990	0.6227 +0.825	0.4681 +1.230	0.6335 +1.307
0.6429 +1.163	0.4620 +1.005	0.6284 +0.911	0.4694 +1.182	0.6349 +1.298
0.6442 +1.174	0.4633 +1.003	0.6297 +0.941	0.4750 +0.985	0.6362 +1.277
0.6455 +1.207	0.4689 +1.066	0.6311 +0.952	0.4763 +0.925	0.6417 +1.224
0.6511 +1.191	0.4702 +1.080	0.6372 +1.060	0.4776 +0.855	0.6430 +1.216
0.6524 +1.190	0.4715 +1.089	0.6386 +1.067	0.4830 +0.815	0.6443 +1.183
0.6537 +1.226	0.4773 +1.140	0.6399 +1.065	0.4843 +0.832	0.6668 +0.938
0.6595 +1.269	0.4786 +1.168	0.6457 +1.143	0.4856 +0.855	0.6681 +0.959
0.6608 +1.250	0.4799 +1.165	0.6470 +1.153	0.4915 +0.947	0.6694 +0.976
0.6621 +1.282	0.4871 +1.218	0.6483 +1.148	0.4928 +0.965	
0.6684 +1.263	0.4884 +1.221	0.6538 +1.219	0.4941 +0.981	2450872 +
0.6697 +1.286	0.4897 +1.234	0.6551 +1.201	0.4998 +1.070	0.2672 +1.196
0.6710 +1.272	0.4959 +1.249	0.6565 +1.226	0.5011 +1.072	0.2685 +1.179
0.6768 +1.321	0.4972 +1.284	0.6625 +1.253	0.5024 +1.088	0.2698 +1.154
0.6781 +1.306	0.4985 +1.280	0.6638 +1.254	0.5077 +1.158	0.2752 +0.963
0.6794 +1.328	0.5039 +1.278	0.6651 +1.255	0.5090 +1.143	0.2765 +0.924
0.6860 +1.149	0.5052 +1.292		0.5104 +1.164	0.2779 +0.904
0.6873 +1.121	0.5065 +1.281	2450849 +	0.5159 +1.210	0.2832 +0.920
0.6886 +1.102	0.5122 +1.310	0.2841 +1.293	0.5173 +1.228	0.2845 +0.921
0.6944 +0.947	0.5135 +1.313	0.2863 +1.294	0.5186 +1.231	0.2858 +0.922
0.6957 +0.918	0.5148 +1.300	0.2885 +1.295	0.5240 +1.256	0.2914 +1.004
0.6970 +0.903	0.5207 +1.286	0.2973 +1.231	0.5253 +1.270	0.2928 +1.015
0.7027 +0.925	0.5220 +1.282	0.2995 +1.209	0.5266 +1.283	0.2941 +1.065
0.7040 +0.940	0.5233 +1.273	0.3017 +1.188	0.5325 +1.279	0.2997 +1.088
0.7053 +0.961	0.5294 +1.109	0.3208 +0.979	0.5338 +1.297	0.3010 +1.099
	0.5307 +1.041	0.3229 +0.990	0.5351 +1.296	0.3023 +1.113
2450848 +	0.5320 +1.001	0.3251 +0.996	0.5410 +1.303	0.3076 +1.178
0.4034 +1.247	0.5379 +0.822	0.3330 +1.083	0.5423 +1.307	0.3089 +1.180
0.4047 +1.255	0.5392 +0.816	0.3352 +1.107	0.5436 +1.284	0.3102 +1.178
0.4060 +1.258	0.5405 +0.815	0.3374 +1.138	0.5496 +1.266	0.3161 +1.252
0.4116 +1.279	0.5465 +0.904	0.3495 +1.217	0.5509 +1.248	0.3174 +1.227
0.4129 +1.280	0.5478 +0.932	0.3571 +1.249	0.5522 +1.225	0.3187 +1.254
0.4142 +1.265	0.5492 +0.952	0.3593 +1.268	0.5596 +1.091	0.3243 +1.297

0.3257 +1.306	0.4545 +0.979	0.5855 +1.289	0.3839 +0.965	0.2980 +0.809
0.3270 +1.303	0.4558 +1.000	0.5911 +1.308	0.3898 +1.046	0.2993 +0.853
0.3328 +1.308	0.4571 +1.011	0.5924 +1.307	0.3911 +1.061	0.3006 +0.850
0.3341 +1.313	0.4652 +1.095	0.5937 +1.325	0.3924 +1.070	0.3063 +0.941
0.3354 +1.329	0.4665 +1.100	0.5995 +1.299	0.3983 +1.144	0.3077 +0.961
0.3408 +1.288	0.4678 +1.128	0.6008 +1.308	0.3996 +1.154	0.3090 +0.979
0.3422 +1.274	0.4737 +1.150	0.6022 +1.313	0.4009 +1.175	0.3143 +1.018
0.3435 +1.310	0.4751 +1.160	0.6075 +1.274	0.4063 +1.224	0.3157 +1.045
0.3486 +1.282	0.4764 +1.164	0.6088 +1.262	0.4076 +1.221	0.3170 +1.065
0.3499 +1.234	0.4819 +1.203	0.6101 +1.236	0.4089 +1.242	0.3224 +1.156
0.3513 +1.182	0.4832 +1.200		0.4177 +1.277	0.3237 +1.155
0.3567 +0.989	0.4846 +1.220	2450899 +	0.4190 +1.282	0.3250 +1.158
0.3580 +0.939	0.4901 +1.269	0.2912 +0.899	0.4203 +1.292	0.3303 +1.203
0.3593 +0.893	0.4914 +1.257	0.2925 +0.911	0.4255 +1.297	0.3316 +1.230
0.3647 +0.809	0.4927 +1.283	0.2938 +0.913	0.4268 +1.308	0.3329 +1.209
0.3660 +0.819	0.4986 +1.282	0.2996 +0.956	0.4281 +1.316	0.3387 +1.256
0.3673 +0.836	0.4999 +1.295	0.3009 +0.979	0.4410 +1.264	0.3400 +1.251
0.3730 +0.947	0.5012 +1.283	0.3023 +0.994	0.4423 +1.228	0.3415 +1.258
0.3743 +0.976	0.5067 +1.286	0.3078 +1.054	0.4436 +1.211	0.3465 +1.292
0.3756 +1.006	0.5080 +1.282	0.3091 +1.074	0.4551 +0.933	0.3478 +1.288
0.3817 +1.078	0.5094 +1.290	0.3104 +1.097	0.4564 +0.943	0.3492 +1.296
0.3830 +1.095	0.5149 +1.286	0.3158 +1.121	0.4577 +0.931	0.3548 +1.312
0.3843 +1.095	0.5163 +1.284	0.3171 +1.145	0.4629 +0.984	0.3562 +1.297
0.3895 +1.151	0.5176 +1.277	0.3185 +1.154	0.4642 +0.978	0.3575 +1.291
0.3908 +1.163	0.5231 +1.218	0.3243 +1.193	0.4655 +0.992	0.3625 +1.278
0.3921 +1.182	0.5244 +1.210	0.3256 +1.218	0.4706 +1.030	0.3639 +1.266
0.3978 +1.232	0.5258 +1.191	0.3269 +1.224	0.4720 +1.053	0.3652 +1.254
0.3991 +1.224	0.5320 +1.046	0.3332 +1.248	0.4733 +1.056	0.3702 +1.170
0.4004 +1.222	0.5333 +1.024	0.3345 +1.263	0.4788 +1.103	0.3715 +1.141
0.4062 +1.290	0.5346 +1.011	0.3359 +1.274	0.4801 +1.127	0.3728 +1.101
0.4075 +1.299	0.5399 +0.942	0.3418 +1.307	0.4814 +1.133	0.3781 +0.939
0.4089 +1.284	0.5412 +0.947	0.3431 +1.313	0.4918 +1.198	0.3794 +0.923
0.4142 +1.308	0.5425 +0.980	0.3444 +1.275	0.4931 +1.213	0.3807 +0.901
0.4155 +1.311	0.5481 +1.003	0.3497 +1.315	0.4988 +1.233	0.3870 +0.928
0.4168 +1.314	0.5495 +1.036	0.3510 +1.304	0.5001 +1.254	0.3883 +0.943
0.4221 +1.309	0.5508 +1.039	0.3523 +1.316	0.5014 +1.270	0.3896 +0.963
0.4234 +1.316	0.5569 +1.093	0.3576 +1.287	0.5071 +1.291	0.3976 +1.031
0.4247 +1.310	0.5582 +1.113	0.3589 +1.256	0.5084 +1.295	0.3989 +1.050
0.4300 +1.271	0.5595 +1.127	0.3602 +1.211	0.5097 +1.278	0.4002 +1.071
0.4313 +1.248	0.5657 +1.188	0.3656 +1.019		0.4065 +1.146
0.4326 +1.218	0.5670 +1.183	0.3669 +0.947	2450902 +	0.4078 +1.155
0.4382 +1.129	0.5683 +1.203	0.3683 +0.880	0.2821 +1.245	0.4091 +1.180
0.4395 +1.088	0.5749 +1.226	0.3735 +0.793	0.2835 +1.239	0.4146 +1.211
0.4408 +1.043	0.5762 +1.227	0.3748 +0.810	0.2848 +1.226	0.4159 +1.218
0.4464 +0.954	0.5775 +1.261	0.3761 +0.827	0.2899 +1.062	0.4173 +1.216
0.4477 +0.940	0.5828 +1.264	0.3813 +0.916	0.2912 +0.981	0.4225 +1.265
0.4491 +0.953	0.5842 +1.277	0.3826 +0.942	0.2925 +0.926	0.4238 +1.281

0.4252 +1.269	0.2948 +1.281	0.3583 +1.169	0.4244 +0.905	0.4921 +1.084
0.4303 +1.281	0.2961 +1.280	0.3596 +1.192	0.4258 +0.911	0.4935 +1.016
0.4316 +1.283	0.2974 +1.286	0.3609 +1.193	0.4271 +0.935	0.4948 +0.950
0.4329 +1.304	0.3027 +1.301	0.3661 +1.216	0.4334 +1.009	0.5001 +0.801
0.4382 +1.272	0.3040 +1.293	0.3674 +1.214	0.4347 +1.048	0.5014 +0.812
0.4395 +1.263	0.3054 +1.302	0.3687 +1.223	0.4360 +1.062	0.5027 +0.825
0.4408 +1.288	0.3108 +1.264	0.3741 +1.240	0.4435 +1.130	0.5081 +0.911
0.4462 +1.253	0.3121 +1.253	0.3754 +1.246	0.4448 +1.153	0.5094 +0.932
0.4475 +1.264	0.3134 +1.243	0.3767 +1.258	0.4461 +1.174	0.5107 +0.944
0.4488 +1.280	0.3188 +1.162	0.3822 +1.268	0.4522 +1.194	0.5161 +1.019
0.4542 +1.238	0.3201 +1.130	0.3835 +1.290	0.4535 +1.217	0.5174 +1.040
0.4555 +1.238	0.3214 +1.112	0.3848 +1.301	0.4548 +1.207	0.5187 +1.041
0.4568 +1.233	0.3265 +1.014	0.3901 +1.295	0.4600 +1.251	0.5320 +1.155
0.4619 +1.146	0.3279 +1.005	0.3915 +1.298	0.4613 +1.255	0.5333 +1.190
0.4632 +1.083	0.3292 +1.009	0.3928 +1.275	0.4626 +1.270	0.5346 +1.223
0.4645 +1.090	0.3344 +0.990	0.3979 +1.279	0.4681 +1.293	0.5399 +1.227
	0.3357 +1.000	0.3993 +1.271	0.4694 +1.294	0.5412 +1.241
2450903 +	0.3370 +1.005	0.4006 +1.249	0.4707 +1.298	0.5425 +1.230
0.2790 +1.209	0.3424 +1.037	0.4058 +1.199	0.4759 +1.325	0.5479 +1.277
0.2803 +1.224	0.3438 +1.060	0.4071 +1.167	0.4772 +1.310	0.5494 +1.269
0.2816 +1.239	0.3451 +1.060	0.4084 +1.137	0.4785 +1.302	0.5507 +1.285
0.2871 +1.266	0.3505 +1.118	0.4148 +0.931	0.4839 +1.298	
0.2884 +1.286	0.3518 +1.117	0.4161 +0.887	0.4852 +1.261	
0.2897 +1.300	0.3531 +1.132	0.4174 +0.886	0.4865 +1.274	

Table 7.

Differential *I* observations of AE UMa

2450152 +	0.4759 +1.197	0.5565 +1.244	0.4103 +1.287	0.3711 +1.018
0.3137 +1.012	0.4778 +1.142	0.5585 +1.284	0.4117 +1.310	0.3724 +1.059
0.3157 +0.986	0.4798 +1.105	0.5677 +1.164	0.4130 +1.267	0.3737 +1.043
0.3177 +0.959	0.4874 +1.075	0.5696 +1.128	0.4182 +1.259	0.3792 +1.160
0.3267 +1.025	0.4893 +1.038	0.5716 +1.048	0.4195 +1.250	0.3805 +1.216
0.3286 +1.003	0.4913 +1.080	0.5805 +1.024	0.4208 +1.280	0.3818 +1.199
0.3306 +1.106	0.5001 +1.141	0.5824 +1.022	0.4261 +1.176	0.3869 +1.235
0.3389 +1.150	0.5021 +1.149	0.5844 +1.025	0.4274 +1.178	0.3882 +1.166
0.3408 +1.157	0.5040 +1.148	0.5942 +1.189	0.4287 +1.021	0.3895 +1.175
0.3428 +1.176	0.5130 +1.162	0.5961 +1.231		0.3951 +1.237
0.3506 +1.217	0.5150 +1.199	0.5981 +1.082	2450490 +	0.3964 +1.247
0.3526 +1.212	0.5169 +1.234		0.3472 +1.252	0.3977 +1.277
0.3546 +1.220	0.5266 +1.214	2450487 +	0.3486 +1.215	0.4031 +1.231
0.3626 +1.295	0.5285 +1.192	0.3859 +1.226	0.3499 +1.184	0.4044 +1.246
0.3645 +1.269	0.5305 +1.240	0.3873 +1.230	0.3554 +0.994	0.4057 +1.268
0.3665 +1.291	0.5408 +1.292	0.3886 +1.231	0.3567 +0.930	0.4114 +1.261
0.3747 +1.321	0.5427 +1.259	0.4019 +1.263	0.3581 +0.917	0.4127 +1.314
0.3766 +1.402	0.5447 +1.277	0.4032 +1.298	0.3633 +0.946	0.4140 +1.267
0.3786 +1.383	0.5546 +1.263	0.4045 +1.307	0.3646 +0.963	0.4191 +1.256

0.4204 +1.273	0.5006 +1.277	0.6876 +1.179	0.5124 +1.273	0.2845 +1.319
0.4217 +1.296	0.5385 +1.013	0.6889 +1.132	0.5138 +1.277	0.2867 +1.308
	0.5398 +1.017	0.6946 +1.049	0.5151 +1.270	0.2889 +1.285
2450554 +	0.5411 +1.063	0.6959 +1.008	0.5210 +1.291	0.2977 +1.213
0.4099 +1.290	0.5464 +1.106	0.6973 +1.007	0.5223 +1.296	0.2999 +1.213
0.4112 +1.303	0.5478 +1.114	0.7030 +1.000	0.5236 +1.295	0.3021 +1.218
0.4125 +1.297	0.5491 +1.102	0.7043 +1.013	0.5297 +1.179	0.3212 +1.062
0.4318 +1.212	0.5549 +1.093	0.7056 +1.046	0.5310 +1.093	0.3233 +1.058
0.4332 +1.195	0.5562 +1.114		0.5323 +1.101	0.3255 +1.101
0.4382 +1.084	0.5575 +1.138	2450848 +	0.5381 +0.950	0.3499 +1.217
0.4396 +1.043	0.5633 +1.223	0.4036 +1.184	0.5394 +0.905	0.3575 +1.293
0.4409 +1.054	0.5646 +1.240	0.4049 +1.224	0.5407 +0.955	0.3597 +1.303
0.4461 +1.052	0.5660 +1.253	0.4062 +1.263	0.5468 +1.021	0.3618 +1.285
0.4475 +1.034	0.5724 +1.310	0.4118 +1.282	0.5481 +1.014	0.3738 +1.284
0.4488 +1.010	0.5737 +1.315	0.4131 +1.266	0.5494 +1.039	0.3760 +1.301
0.4542 +1.065	0.5750 +1.310	0.4144 +1.320	0.5552 +1.109	0.3816 +1.269
0.4555 +1.077	0.5810 +1.296	0.4197 +1.320	0.5565 +1.100	0.3838 +1.314
0.4568 +1.094	0.5823 +1.289	0.4210 +1.257	0.5578 +1.112	0.3859 +1.311
	0.5836 +1.301	0.4278 +1.266	0.5947 +1.305	0.4511 +1.260
2450813 +	0.5895 +1.312	0.4291 +1.288	0.5961 +1.292	0.4524 +1.299
0.3962 +1.206	0.5908 +1.323	0.4304 +1.326	0.5974 +1.315	0.4537 +1.262
0.3975 +1.215	0.5921 +1.310	0.4367 +1.283	0.6036 +1.291	0.4591 +1.301
0.3988 +1.252	0.5977 +1.318	0.4380 +1.271	0.6049 +1.226	0.4604 +1.290
0.4130 +1.245	0.5991 +1.320	0.4447 +1.165	0.6062 +1.223	0.4617 +1.275
0.4143 +1.238	0.6004 +1.265	0.4460 +1.173	0.6122 +1.146	0.4671 +1.280
0.4156 +1.252	0.6076 +1.116	0.4473 +1.129	0.6136 +1.078	0.4684 +1.258
0.4209 +1.223	0.6089 +1.106	0.4527 +1.063	0.6149 +1.060	0.4697 +1.237
0.4222 +1.265	0.6103 +1.075	0.4540 +1.076	0.6204 +0.967	0.4753 +1.017
0.4290 +1.178	0.6249 +1.027	0.4553 +1.041	0.6217 +0.924	0.4766 +0.959
0.4303 +1.165	0.6262 +1.050	0.4609 +1.038	0.6230 +0.959	0.4779 +0.947
0.4375 +1.047	0.6276 +1.034	0.4623 +1.079	0.6287 +0.994	0.4833 +0.967
0.4388 +1.047	0.6343 +1.075	0.4636 +1.036	0.6300 +1.050	0.4846 +0.967
0.4401 +1.070	0.6357 +1.096	0.4692 +1.044	0.6313 +1.024	0.4859 +0.973
0.4461 +1.099	0.6370 +1.151	0.4705 +1.124	0.6375 +1.084	0.4917 +1.058
0.4474 +1.125	0.6432 +1.182	0.4718 +1.091	0.6388 +1.109	0.4930 +1.062
0.4488 +1.140	0.6445 +1.190	0.4776 +1.163	0.6401 +1.104	0.4944 +1.114
0.4561 +1.145	0.6458 +1.256	0.4789 +1.191	0.6459 +1.159	0.5000 +1.123
0.4574 +1.141	0.6514 +1.170	0.4802 +1.225	0.6472 +1.188	0.5013 +1.182
0.4587 +1.170	0.6527 +1.199	0.4873 +1.220	0.6485 +1.200	0.5027 +1.128
0.4648 +1.145	0.6540 +1.250	0.4887 +1.272	0.6541 +1.246	0.5080 +1.193
0.4661 +1.167	0.6598 +1.233	0.4900 +1.245	0.6554 +1.224	0.5093 +1.224
0.4674 +1.184	0.6624 +1.258	0.4961 +1.271	0.6567 +1.197	0.5106 +1.223
0.4819 +1.250	0.6687 +1.270	0.4975 +1.257	0.6627 +1.262	0.5162 +1.190
0.4832 +1.327	0.6700 +1.269	0.4988 +1.246	0.6640 +1.258	0.5175 +1.228
0.4909 +1.295	0.6713 +1.262	0.5042 +1.292	0.6654 +1.271	0.5188 +1.252
0.4922 +1.322	0.6784 +1.322	0.5055 +1.331		0.5242 +1.245
0.4993 +1.270	0.6863 +1.186	0.5068 +1.325	2450849 +	0.5255 +1.252

0.5268 +1.238	0.2943 +1.100	0.4237 +1.323	0.5571 +1.178	0.3659 +1.080
0.5327 +1.346	0.2999 +1.064	0.4250 +1.330	0.5585 +1.184	0.3672 +1.025
0.5340 +1.320	0.3012 +1.162	0.4303 +1.252	0.5598 +1.163	0.3685 +0.950
0.5353 +1.297	0.3026 +1.131	0.4316 +1.275	0.5660 +1.213	0.3737 +0.951
0.5412 +1.245	0.3079 +1.186	0.4329 +1.253	0.5673 +1.198	0.3750 +0.956
0.5425 +1.290	0.3092 +1.199	0.4384 +1.182	0.5686 +1.200	0.3764 +0.967
0.5438 +1.260	0.3105 +1.223	0.4398 +1.134	0.5752 +1.209	0.3815 +1.045
0.5499 +1.256	0.3163 +1.273	0.4411 +1.080	0.5765 +1.257	0.3829 +1.073
0.5512 +1.241	0.3176 +1.285	0.4467 +1.037	0.5778 +1.225	0.3842 +1.063
0.5525 +1.272	0.3190 +1.255	0.4480 +1.008	0.5831 +1.283	0.3901 +1.149
0.5599 +1.174	0.3246 +1.284	0.4493 +1.058	0.5844 +1.284	0.3914 +1.117
0.5612 +1.157	0.3259 +1.254	0.4548 +1.016	0.5857 +1.288	0.3927 +1.127
0.5625 +1.090	0.3272 +1.296	0.4561 +1.061	0.5913 +1.291	0.3986 +1.167
0.5679 +1.055	0.3331 +1.336	0.4574 +1.093	0.5927 +1.303	0.3999 +1.138
0.5692 +1.064	0.3344 +1.317	0.4655 +1.143	0.5940 +1.328	0.4012 +1.210
0.5705 +1.024	0.3357 +1.302	0.4668 +1.177	0.5998 +1.287	0.4066 +1.250
0.5762 +1.092	0.3411 +1.319	0.4681 +1.193	0.6011 +1.319	0.4079 +1.246
0.5775 +1.100	0.3424 +1.285	0.4740 +1.171	0.6024 +1.302	0.4092 +1.204
0.5788 +1.140	0.3437 +1.330	0.4753 +1.162	0.6077 +1.245	0.4179 +1.307
0.6167 +1.284	0.3489 +1.292	0.4766 +1.211	0.6090 +1.263	0.4192 +1.302
0.6180 +1.218	0.3502 +1.211	0.4822 +1.231	0.6104 +1.165	0.4206 +1.301
0.6193 +1.292	0.3515 +1.167	0.4835 +1.248		0.4257 +1.318
0.6249 +1.310	0.3570 +1.051	0.4848 +1.211	2450899 +	0.4271 +1.328
0.6263 +1.307	0.3583 +1.088	0.4903 +1.270	0.2915 +0.971	0.4412 +1.284
0.6276 +1.332	0.3596 +1.089	0.4916 +1.282	0.2928 +0.994	0.4426 +1.261
0.6338 +1.307	0.3650 +0.974	0.4930 +1.270	0.2941 +1.044	0.4439 +1.255
0.6351 +1.322	0.3663 +0.980	0.4989 +1.291	0.2999 +1.035	0.4553 +1.072
0.6364 +1.327	0.3676 +0.979	0.5002 +1.285	0.3012 +1.075	0.4566 +1.076
0.6420 +1.291	0.3733 +1.024	0.5015 +1.320	0.3025 +1.065	0.4580 +1.055
0.6433 +1.269	0.3746 +1.066	0.5070 +1.304	0.3081 +1.113	0.4631 +1.050
0.6446 +1.264	0.3759 +1.041	0.5083 +1.312	0.3161 +1.166	0.4645 +1.078
0.6670 +1.041	0.3819 +1.161	0.5096 +1.289	0.3174 +1.180	0.4658 +1.087
0.6683 +1.033	0.3832 +1.163	0.5152 +1.318	0.3187 +1.191	0.4709 +1.090
0.6697 +1.083	0.3846 +1.179	0.5165 +1.318	0.3258 +1.187	0.4722 +1.120
	0.3897 +1.190	0.5178 +1.262	0.3272 +1.193	0.4735 +1.094
2450872 +	0.3911 +1.194	0.5234 +1.246	0.3335 +1.265	0.4791 +1.153
0.2674 +1.205	0.3924 +1.195	0.5247 +1.213	0.3348 +1.283	0.4804 +1.143
0.2687 +1.220	0.3981 +1.201	0.5260 +1.239	0.3361 +1.281	0.4817 +1.207
0.2700 +1.184	0.3994 +1.220	0.5323 +1.099	0.3421 +1.306	0.4920 +1.225
0.2755 +1.078	0.4007 +1.288	0.5336 +1.101	0.3434 +1.288	0.4934 +1.233
0.2768 +1.043	0.4065 +1.312	0.5349 +1.098	0.3447 +1.326	0.4991 +1.223
0.2781 +1.055	0.4078 +1.291	0.5401 +1.018	0.3499 +1.296	0.5004 +1.234
0.2834 +1.017	0.4091 +1.268	0.5414 +1.036	0.3512 +1.318	0.5017 +1.259
0.2847 +1.004	0.4144 +1.268	0.5428 +1.009	0.3526 +1.266	0.5073 +1.284
0.2861 +1.023	0.4158 +1.327	0.5484 +1.095	0.3578 +1.257	0.5086 +1.266
0.2917 +1.054	0.4171 +1.347	0.5497 +1.084	0.3592 +1.291	0.5099 +1.308
0.2930 +1.060	0.4223 +1.337	0.5510 +1.129	0.3605 +1.275	

2450902 +	0.3717 +1.171	0.4648 +1.121	0.3677 +1.244	0.4629 +1.265
0.2824 +1.288	0.3731 +1.172		0.3690 +1.227	0.4684 +1.280
0.2837 +1.291	0.3783 +1.068	2450903 +	0.3744 +1.260	0.4697 +1.258
0.2850 +1.206	0.3796 +1.022	0.2793 +1.205	0.3757 +1.285	0.4710 +1.290
0.2902 +1.119	0.3810 +1.004	0.2806 +1.233	0.3770 +1.296	0.4762 +1.315
0.2915 +1.062	0.3872 +1.045	0.2819 +1.275	0.3824 +1.270	0.4775 +1.303
0.2928 +1.021	0.3885 +1.051	0.2874 +1.299	0.3838 +1.284	0.4788 +1.288
0.2983 +0.929	0.3899 +1.024	0.2887 +1.318	0.3851 +1.333	0.4842 +1.198
0.2996 +0.943	0.3979 +1.075	0.2900 +1.311	0.3904 +1.291	0.4855 +1.309
0.3009 +0.950	0.3992 +1.115	0.2950 +1.302	0.3917 +1.278	0.4868 +1.266
0.3066 +0.957	0.4005 +1.121	0.2964 +1.342	0.3930 +1.246	0.4924 +1.135
0.3079 +0.963	0.4068 +1.149	0.2977 +1.304	0.3982 +1.279	0.4937 +1.095
0.3092 +1.000	0.4081 +1.173	0.3030 +1.342	0.3995 +1.296	0.4950 +1.040
0.3146 +1.071	0.4094 +1.184	0.3043 +1.315	0.4008 +1.258	0.5003 +0.910
0.3172 +1.090	0.4149 +1.232	0.3056 +1.324	0.4060 +1.250	0.5017 +0.913
0.3227 +1.182	0.4162 +1.232	0.3191 +1.238	0.4073 +1.192	0.5030 +0.926
0.3240 +1.211	0.4175 +1.240	0.3204 +1.167	0.4086 +1.195	0.5083 +1.009
0.3253 +1.195	0.4228 +1.295	0.3217 +1.174	0.4151 +0.982	0.5097 +1.032
0.3306 +1.229	0.4241 +1.246	0.3268 +1.116	0.4164 +0.997	0.5110 +1.020
0.3319 +1.245	0.4254 +1.298	0.3281 +1.094	0.4177 +0.984	0.5164 +1.066
0.3332 +1.211	0.4306 +1.250	0.3294 +1.096	0.4247 +0.978	0.5177 +1.094
0.3390 +1.219	0.4319 +1.232	0.3346 +1.125	0.4260 +1.007	0.5190 +1.120
0.3403 +1.278	0.4332 +1.249	0.3360 +1.118	0.4273 +1.005	0.5323 +1.173
0.3416 +1.274	0.4384 +1.289	0.3373 +1.138	0.4336 +1.040	0.5336 +1.145
0.3468 +1.282	0.4397 +1.295	0.3427 +1.099	0.4350 +1.101	0.5349 +1.187
0.3481 +1.311	0.4411 +1.254	0.3440 +1.114	0.4363 +1.074	0.5402 +1.248
0.3494 +1.308	0.4465 +1.273	0.3453 +1.135	0.4437 +1.197	0.5415 +1.262
0.3551 +1.306	0.4478 +1.290	0.3508 +1.144	0.4450 +1.186	0.5428 +1.248
0.3564 +1.310	0.4491 +1.304	0.3521 +1.152	0.4464 +1.235	0.5483 +1.292
0.3578 +1.326	0.4544 +1.251	0.3534 +1.201	0.4525 +1.247	0.5496 +1.273
0.3628 +1.264	0.4557 +1.263	0.3585 +1.220	0.4538 +1.256	0.5509 +1.306
0.3641 +1.272	0.4570 +1.232	0.3598 +1.220	0.4551 +1.242	
0.3654 +1.242	0.4621 +1.187	0.3611 +1.194	0.4602 +1.245	
0.3704 +1.187	0.4635 +1.118	0.3664 +1.210	0.4615 +1.274	