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New spectroscopic binaries among classical Cepheids. II.

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Abstract. Radial velocity measurements of classical Cepheids obtained by the CORAVEL and ELODIE spectrographs have been analysed. The comparison with earlier radial velocity data resulted in the discovery of eight new spectroscopic binaries (in the $9\overset{\mathrm{m}}{.}7 - 12\overset{\mathrm{m}}{.}4$ interval of mean V-brightness). An updated value of the pulsation period is also determined for the new SB-Cepheids.

Key words: Cepheids — binaries: spectroscopic

1. Introduction

Cepheid variables have been targets of numerous extensive (multicolour) photometric studies in view of their key-rôle in determining stellar structure and evolution as well as the cosmic distance scale through the regular pulsation of these variable stars. Unlike photometric data, there are only few projects aimed at measuring radial velocities of large numbers of Cepheids because such projects are more time-consuming than the photometric ones.

Radial velocity data are, however, indispensable in several respects. Their traditional use is for deriving radius variations via the Baade–Wesselink method from which the stellar radius can be derived as well as the luminosity and distance of the individual Cepheids (Gieren et al. 1993). With the advent of sensitive and precise radial velocity spectrometers (e.g. CORAVEL, ELODIE – Baranne et al. 1979, 1996), radial velocity of faint Cepheids can also be studied, allowing the analysis of Galactic kinematics and rotation parameters (Pont et al. 1997). The third major field of research where radial velocity data offer a significant contribution is the study of binary nature of Cepheids. Szabados (1995) pointed out the existence of a selection effect which hinders the discovery of duplicity among fainter Cepheids. As a matter of fact, the incidence of binaries among classical Cepheids exceeds 50 per cent.

Therefore, it is not surprising that new spectroscopic binaries involving a Cepheid component have been amply found from the data of extensive radial velocity projects. Such projects include: the observational campaigns of the Geneva group (Bersier et al. 1994; Pont et al. 1994, 1997) using the CORAVEL and more recently the ELODIE spectrographs, and those of the Moscow group (Gorynya et al. 1996 and the references therein), the latter group using a CORAVEL-type equipment. It is worth mentioning that spectroscopic binaries have been found even among Cepheids in the Magellanic Clouds (Imbert 1994), also with the help of the CORAVEL spectrograph.

The observational efforts of these teams have resulted in a unique data-base containing an unprecedented number of precise and homogeneous radial velocity measurements on classical Cepheids. The extended temporal coverage was a major contribution to help discover new SB-systems among Cepheids. Thus variations in the γ-velocity (i.e. the mean radial velocity averaged over a whole pulsational cycle) were reported e.g. in the case of BY Cas, AC Mon, UZ Sct, VY Sgr (Pont et al. 1994), MW Cyg (Gorynya et al. 1992b; Samus et al. 1993), and independently for BY Cas (Gorynya et al. 1994). Even the intercomparison of the data for Cepheids common in both samples allowed the discovery of SB-nature of such bright Cepheids as U Vul and SV Vul (Szabados 1996). (Later on, when supplementing with his own data, Imbert (1996) was able to determine the orbital elements for both the U Vul and MW Cyg systems.)

In addition to those recent datasets, there is a former project on Cepheid radial velocities performed as early as in the 1920-1930-es (Joy 1937). When comparing Joy's data with the recent ones, it turned out that many unrecognized SB-systems can be revealed even with the help of those historic data of limited accuracy (Szabados 1996).

The aim of this paper is similar: comparing the early radial velocity data with those reported by Pont et al. (1997). Because in their recent paper Pont et al. concentrated on the determination of the rotation of the Galactic

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Send offprint requests to: L. Szabados disk, searching for effects of binary companions in the radial velocity data was not a main issue in that study. Nevertheless, using only their own high-precision data, CI Per is suspected to belong to a binary system. However, no attempt was made to compare the new data with the available previous radial velocity measurements. Their sample involved 48 remote, quite faint Cepheids. This is the reason why Pont et al.'s (1997) measurements form the first epoch radial velocity dataset for most of their programme stars. There have been, however, prior radial velocity data for 16 Cepheids in that sample – mostly obtained by Joy (1937) – allowing a comparison to be made between the mean values for the two epochs.

It turned out that eight Cepheids in that sample belong to spectroscopic binary systems unrecognized before. Following a brief description of the method of the analysis (Sect. 2), the available information on the new SB-Cepheids is published (Sect. 3), while Sect. 4 contains some concluding remarks.

2. Method of the analysis

When searching for changes in the γ-velocity caused by the orbital motion of the Cepheid around the common mass centre of the binary system, extreme care has to be taken not to mix spurious effects with the intrinsic radial velocity variation.

At first, the pulsational radial velocity curve has to be determined which necessitates knowledge of the pulsation period as accurately as possible. Use of inaccurate pulsation period causes a phase mismatch in the radial velocity curve which can give rise to increased scatter in the radial velocity curve. This, however, must not be interpreted as an orbital effect even though it appears as a vertical shift in the annual γ-velocity. Another negative consequence of the use of improper pulsation period is that it can smear any low amplitude orbital effect. The case of SV Vul clearly shows that even minor orbital γ-velocity variation can be detected if allowance is made for the continuously changing pulsation period (Szabados 1996).

If properly phased normal curves representing two different epochs are compared, only vertical shift can occur between the two curves, and this refers to the change in the mean radial velocity, i.e. to the orbital motion. This is, however, an idealistic case. In reality, the value of the radial velocity determined from the spectrum depends on both the circumstances in the stellar atmosphere having various impacts on the line profile (asymmetry, broadening, occasional emission – see e.g. Albrow & Cottrell 1996; Butler 1993; Sabbey et al. 1995), and the method of determination of the radial velocity (Vinkó et al. 1998). Coupled with the problem of uncertainty in the early radial velocities (such as Joy's 1937, pioneering work), a reasonable lower limit of γ-velocity variation that can be attributed to the membership of the Cepheid in a binary system is four km s^{-1} (Szabados 1996). Based on a homogeneous and precise dataset, this lower limit can be decreased considerably, see e.g. the case of SV Vul (Szabados 1996) again, and the remark on VW Pup, later on in this paper.

In order to determine the correct value of the pulsation period, the O−C-method was applied using the photometric data which are usually more accurate and available more frequently than radial velocity observations. The O−C-diagrams have been constructed for seven Cepheids in this sample (the only exception is V495 Mon). The commonly used method of O−C-diagram need not be introduced here, as to its details, the reader is referred to Willson (1986) (general information) and Szabados (1977) (application to Cepheids).

As to the other Cepheids for which the comparison of the recent radial velocity data with the first epoch values did not indicate noticeable change in the γ-velocity, the behaviour of the pulsation period was not studied during this project.

In all seven cases for which new pulsation period was determined, the new value only slightly differs from the catalogued period. The linear elements determined by the weighted least squares fit to the moments of the photometric normal maxima are indicated in the next section. Since no period change has been detected, nor assumed for the Cepheids under study, the O−C graphs are not published here. Nevertheless, the normal maxima and the O−C-residuals utilized for the determination of the precise value of the pulsation period are given in tabular form (see Tables 2–8). These data, along with the bibliographic references may be useful for later studies and revisions of the pulsation period, keeping in mind that classical Cepheids undergo period changes of various origin (evolutionary, duplicity related, and erratic – see Szabados 1994).

The subsequent columns in the tables summarising the O−C-residuals contain the following data:
1. Moment of normal maximum; 2. Epoch as counted from the final ephemeris given among the remarks on individual variables in Sect. 3; 3. O−C-residual also calculated from the same ephemeris; 4. Weight assigned to the given photometric series when performing the least squares fit for the period determination; 5. Type of the photometric data (vis: visual; pg: photographic; pe: photoelectric); 6. Reference to the observational data.

In most cases, photographic and visual have been taken into account in order to incorporate those epochs when the first radial velocity series (Joy 1937) was obtained.

The list of the newly discovered SB-Cepheids is given in Table 1 which also contains the logarithm of the pulsation period (the precise value can be found as a remark at the respective Cepheid), the mean V-brightness and the difference between the mean values of the radial velocity determined from Joy's (1937) and the recent data (absolute value in km s^{-1}). This latter difference gives a qualitative estimate for the orbital effect and it is by no

Table 1. List of the newly discovered SB-Cepheids

Cepheid	log$P$	$\langle V\rangle$	Δv_γ
YZ Aur	1.260	10.4	10.6
AS Aur	0.502	11.9	8.2
AA Gem	1.053	9.7	14.2
TX Mon	0.940	11.0	7.0
V495 Mon	0.612	12.4	?
CS Ori	0.590	11.4	26.7
UX Per	0.660	11.6	14.6
VW Pup	0.632	11.4	29.4

means the amplitude of the orbital radial velocity variation. Because of the limited number of Joy's data, the arithmetic average of the radial velocities is not strictly equal to the γ-velocity but it serves as an approximation (see Pont et al. 1994b on the goodness of γ-velocity determinations from a few data points). For V495 Mon the available data are far too small to estimate the orbital effect but in view of the homogeneity of the data-set the variation in the γ-velocity is probably real.

The Cepheids involved in this sample can be commonly characterised as neglected from an observational point of view but fortunately the distribution of the available data allows the precise determination of the pulsation period. The much less numerous radial velocity data are only sufficient for revealing the variability in the γ-velocity, the orbital elements can be determined if more radial velocity data are available.

3. Remarks on the individual Cepheids

YZ Aurigae

The presence of a photometric companion has already been suspected by Madore (1977) and Madore & Fernie (1980). The additional light from a blue companion star has been confirmed by Szabados (1998) based on the wavelength dependence of the photometric amplitudes in U, B, V and R bands.

The radial velocity of YZ Aur was measured at two epochs (Joy 1937, and present paper) separated by an interval longer than 20 000 days. (In addition, there are two recent data published by Gorynya et al. 1992a). Although the descending branch of the radial velocity phase curve is not covered by recent data (see Fig. 1), the systematic shift in the γ-velocity is obvious between the two data series.

The new value of the pulsation period has been determined from the data collected in Table 2. The revised elements for the normal maxima are as follows:

$$\begin{aligned} C = \mathrm{JD}\,2\,443\,816.417 &+ 18\overset{\mathrm{d}}{.}192\,830 \times E \\ \pm.030 \qquad &\pm.000\,043. \end{aligned}$$

The radial velocity phase curve is shown plotted in Fig. 1 using this revised value of the pulsation period.

Table 2. O−C residuals for YZ Aur

JD 2 400 000+	E	O−C [d]	w	type	Reference
16 290.613	−1513	−0.052	1	pg	Yakimov (1962)
17 509.537	−1446	−0.048	1	vis	Williams (1918)
21 548.525	−1224	0.132	1	vis	Williams (1918)
25 241.720	−1021	0.182	1	vis	Beyer (1930)
26 315.010	−962	0.095	1	vis	Kukarkin (1940)
26 751.640	−938	0.098	1	vis	Detre (1935)
27 424.795	−901	0.118	1	vis	Detre (1935)
29 170.930	−805	−0.259	1	pg	Yakimov (1962)
32 846.025	−603	−0.116	1	pg	Filatov (1958)
32 973.338	−596	−0.152	1	pg	Yakimov (1962)
36 830.288	−384	−0.082	2	pe	Weaver et al. (1960)
43 816.489	0	0.072	3	pe	Szabados (1981)
45 690.164	103	−0.114	3	pe	Berdnikov (1986)
47 418.555	198	−0.042	3	pe	Berdnikov (1992a)
48 510.312	258	0.145	3	pe	Berdnikov (1992b)

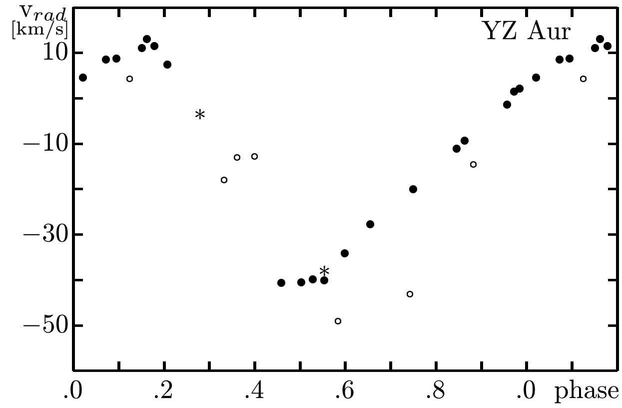

Fig. 1. Radial velocity curve of YZ Aur using the revised pulsation period of 18.192830 days. Zero phase was arbitrarily chosen at JD 2 400 000 for each radial velocity phase curve presented in this paper. Open circles denote Joy's (1937) data, asterisks mean Gorynya et al.'s (1992a) observations, while filled circles are used for showing data listed in the present paper

AS Aurigae

As to the photometric data, this Cepheid has been very much neglected (see Table 3) but fortunately there are two radial velocity measurement series widely separated in time (Joy 1937, and present paper) showing discordant γ-velocity values (see Fig. 2). Because the photometric observational material also spans a time interval longer than half a century, the phase matching can be considered as reliable when using the revised pulsation period. The scanty photometric data led to the following elements for the moments of brightness maxima:

$$\begin{aligned} C = \mathrm{JD}\,2\,447\,648.646 &+ 3\overset{\mathrm{d}}{.}175\,001 \times E \\ \pm.007 \qquad &\pm.000\,002. \end{aligned}$$

AA Geminorum

Being the brightest Cepheid in this sample, AA Gem has

Table 3. O−C residuals for AS Aur

JD 2 400 000+	E	O−C [d]	w	type	Reference
26 325.338	−6716	−0.001	1	vis	Tsessevich (1952)
47 648.634	0	−0.012	3	CCD	Henden (1996)
48 588.463	296	0.017	2	CCD	Schmidt & Reiswig (1993)

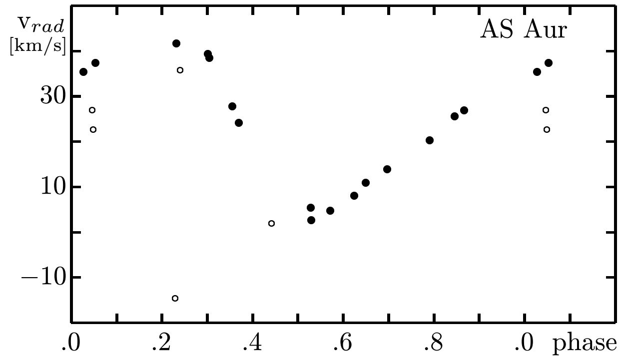

Fig. 2. Radial velocity curve of AS Aur folded on the revised pulsation period of 3.175001 days. Open circles: Joy's (1937) data, filled circles: present paper

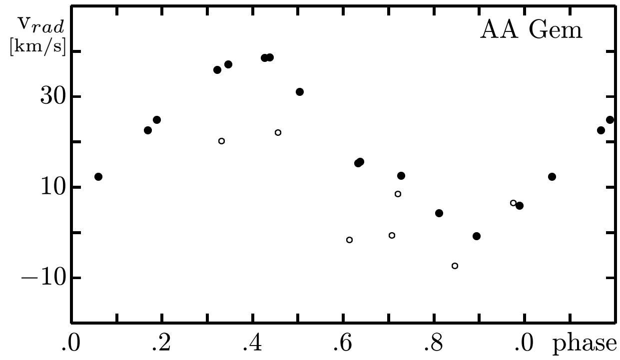

Fig. 3. Radial velocity curve of AA Gem using the revised pulsation period of 11.302450 days. Symbols are the same as in Fig. 2

a long record of photometric observations (see Table 4), therefore the new ephemeris is very reliable:

$$C = \mathrm{JD}\,2\,443\,737.759 \;+\; 11\overset{\mathrm{d}}{.}302\,450 \times E$$
$$\pm.030 \qquad \pm.000\,036.$$

The photometric duplicity indicators led to controversial results: Madore's (1977) loop-method does not indicate a (blue) companion while the phase-method (Madore & Fernie 1980) refers to a photometric companion. In their recent study, Evans & Udalski (1994) conclude that the two faint companions are only optical, i.e. physically unrelated to AA Gem. The available two radial velocity datasets, however, result in significantly discordant γ-velocities (see Fig. 3): Joy's (1937) velocity data fall below the recent data by more than 10 km s^{-1} on the average.

Table 4. O−C residuals for AA Gem

JD 2 400 000+	E	O−C [d]	w	type	Reference
25 133.785	−1646	−0.141	1	pg	Prager (1929)
25 348.970	−1627	0.297	1	vis	Kukarkin (1940)
26 015.515	−1568	−0.002	1	vis	Beyer (1934)
27 055.602	−1476	0.259	1	vis	Beyer (1934)
28 061.251	−1387	−0.010	1	vis	Martynov (1951)
28 683.197	−1332	0.301	1	vis	Martynov (1951)
28 953.877	−1308	−0.277	1	pg	Koshkina (1963)
29 157.579	−1290	−0.020	1	pg	Chudovicheva (1952)
29 439.991	−1265	−0.169	1	vis	Martynov (1951)
29 530.500	−1257	−0.079	1	pg	Koshkina (1963)
30 118.358	−1205	0.051	1	vis	Martynov (1951)
30 785.592	−1146	0.441	1	vis	Martynov (1951)
31 135.468	−1115	−0.059	1	pg	Chudovicheva (1952)
32 446.439	−999	−0.172	1	pg	Chudovicheva (1952)
33 543.332	−902	0.383	1	pg	Chudovicheva (1952)
33 599.199	−897	−0.262	1	pg	Satyvoldiev (1970)
33 972.437	−864	−0.005	1	pg	Rosino & Nobili (1955)
34 029.050	−859	0.096	1	pg	Koshkina (1963)
34 537.701	−814	0.136	1	pg	Rosino & Nobili (1955)
36 504.096	−640	−0.095	1	pg	Satyvoldiev (1970)
36 831.705	−611	−0.257	2	pe	Weaver et al. (1960)
37 634.342	−540	−0.094	2	pe	Mitchell et al. (1964)
38 436.673	−469	−0.237	1	pg	Satyvoldiev (1970)
39 250.725	−397	0.039	2	pe	Takase (1969)
43 737.679	0	−0.080	2	pe	Szabados (1981)
44 404.529	59	−0.075	3	pe	Moffett & Barnes (1984)
44 980.992	110	−0.037	3	pe	Moffett & Barnes (1984)
45 693.028	173	−0.055	3	pe	Berdnikov (1986)
47 422.431	326	0.073	3	pe	Berdnikov (1992a)
47 987.378	376	−0.102	2	pe	Evans & Udalski (1994)
48 518.746	423	0.051	3	pe	Berdnikov (1992b)
50 010.958	555	0.339	2	pe	Berdnikov et al. (1997)

TX Monocerotis

Pel's (1978) multicolour photometry indicated the presence of a companion but no detailed spectroscopic study of this Cepheid has been performed yet. Vinkó (1991) searched for evidence of a companion in the O−C diagram of TX Mon but the scatter due to inaccuracy of the early photometric data do not allow to reveal the light-time effect, if any. He approximated the O−C graph by a parabola assuming a continuous minor increase in the pulsation period. Here the pulsation period is assumed to be constant and the resulting linear ephemeris (determined from the data in Table 5)

$$C = \mathrm{JD}\,2\,444\,982.854 \;+\; 8\overset{\mathrm{d}}{.}701\,903 \times E$$
$$\pm.092 \qquad \pm.000\,078.$$

is as acceptable as Vinkó's parabolic one.

The available radial velocity data, however, clearly show the effect of a physical companion (see Fig. 4). Not only are Joy's (1937) velocity values systematically smaller than the "normal" value of the corresponding phase of the

Table 5. O$-$C residuals for TX Mon

JD 2 400 000+	E	O$-$C [d]	w	type	Reference
18 909.53	-2893	1.28	1	pg	Fatkina (1950)
27 048.309	-2061	0.077	1	vis	Florya & Kukarkina (1953)
28 596.57	-1883	-0.60	1	pg	Fatkina (1950)
29 283.59	-1804	-1.03	1	pg	Fatkina (1950)
29 719.899	-1754	0.184	1	pg	Erleksova (1960)
30 641.927	-1648	-0.191	1	pg	Erleksova (1960)
32 973.997	-1380	-0.231	1	pg	Erleksova (1960)
33 600.434	-1308	-0.331	1	pg	Erleksova (1960)
35 549.796	-1084	-0.195	1	pg	Erleksova (1960)
35 558.914	-1083	0.221	3	pe	Walraven et al. (1958)
36 246.019	-1004	-0.124	1	pg	Erleksova (1960)
36 837.767	-936	-0.106	3	pe	Mitchell et al. (1964)
40 832.092	-477	0.046	3	pe	Pel (1976)
44 982.890	0	0.036	3	pe	Moffett & Barnes (1984)
48 515.927	406	0.100	3	pe	Berdnikov (1992b)
49 812.500	555	0.090	3	pe	Berdnikov & Turner (1995)

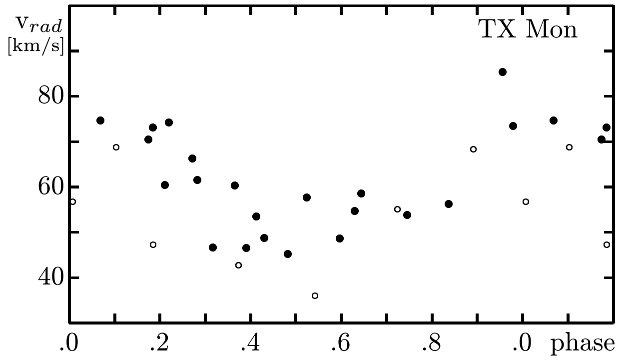

Fig. 4. Radial velocity curve of TX Mon folded on the revised pulsation period of 8.701903 days. Symbols are the same as in Fig. 2

second-epoch radial velocity curve but the recent high-precision data collected during a time interval as short as four years show a wide scatter, indicating variations in the γ-velocity due to orbital motion. The number of the available data points justified that a search for periodicity be performed, in order to obtain a preliminary value of the orbital period. A Lafler–Kinman-type algorithm (Lafler & Kinman 1965) indicates that the orbital period is near 470 days (the uncertainty being as large as ±30 days), and longer periods can be excluded. This means that TX Mon is a classical Cepheid with one of the shortest known orbital period. A Fourier-type algorithm (Deeming 1975), however, could not confirm this preliminary value but no other value for the orbital periodicity could be guessed.

V495 Monocerotis

The faintest Cepheid in this sample has only a brief history of observations. Even the pulsation period could not be improved based on the available photometric data covering only a decade, so the value of 4.096 583 days, published in the GCVS, has been used.

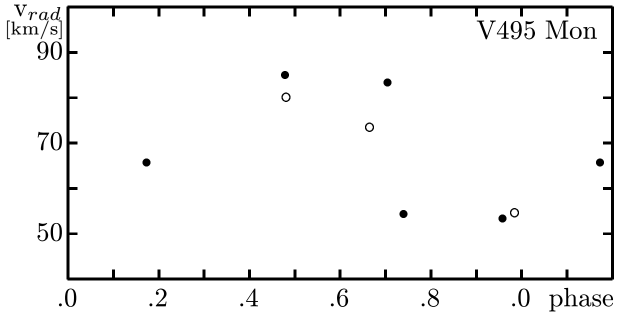

Fig. 5. Radial velocity curve of V495 Mon folded on the pulsation period of 4.096583 days. All observations were obtained by Pont et al. (1997). Filled circles denote radial velocity data taken in Nov. 1993/Mar. 1994, open circles are the data from Dec. 1994–Jan. 1995

The radial velocity data obtained by the ELODIE-spectrograph (Pont et al. 1997) are plotted in Fig. 5. It is clearly seen that the data show an annual shift, indicative of the orbital motion of the Cepheid around the mass centre of a binary system. Since these data were acquired within two consecutive observational seasons, any subtle error in the pulsation period cannot modify this conclusion. Duplicity of V495 Mon, however, has to be confirmed by further radial velocity data because the present data have been obtained at the brightness limit for the ELODIE, and the correlation functions sometimes were not very clean.

CS Orionis

The updated ephemeris determined from the data listed in Table 6 is as follows:

$$\begin{array}{lll} C = \mathrm{JD}\,2\,443\,609.046 & + & 3\overset{\mathrm{d}}{.}889\,281 \times E \\ \qquad\qquad\quad \pm.039 & & \pm.000\,014. \end{array}$$

The photometric amplitudes in U, B, V, and R bands indicate the presence of a blue companion (Szabados 1998).

This companion may be responsible for the orbital effect detectable in the radial velocity data (see Fig. 6). The difference between the mean velocity averaged over one pulsational cycle exceeds 20 km s^{-1}, if Joy's (1937) and the recent data are compared.

UX Persei

The revised ephemeris determined from the data appearing in Table 7 is as follows:

$$\begin{array}{lll} C = \mathrm{JD}\,2\,448\,981.686 & + & 4\overset{\mathrm{d}}{.}565\,733 \times E \\ \qquad\qquad\quad \pm.027 & & \pm.000\,011. \end{array}$$

Although Madore's (1977) loop-method, based on the $U-B$ and $B-V$ colour indices, does not indicate the presence of a secondary star, UX Per seems to have a photometric companion based on the phase-method (Madore & Fernie 1980).

Table 6. O−C residuals for CS Ori

JD 2 400 000+	E	O−C [d]	w	type	Reference
16 099.830	−7073	−0.331	1	pg	Parenago (1933)
22 299.689	−5479	0.014	1	pg	Parenago (1933)
29 281.125	−3684	0.190	1	pg	Kukarkina (1954)
33 948.296	−2484	0.224	1	pg	Kukarkina (1954)
37 499.083	−1571	0.097	2	pe	Mitchell et al. (1964)
43 609.113	0	0.067	3	pe	Henden (1980)
48 672.803	1302	−0.087	3	CCD	Schmidt et al. (1995)
49 800.706	1592	−0.075	3	pe	Pont et al. (1997)

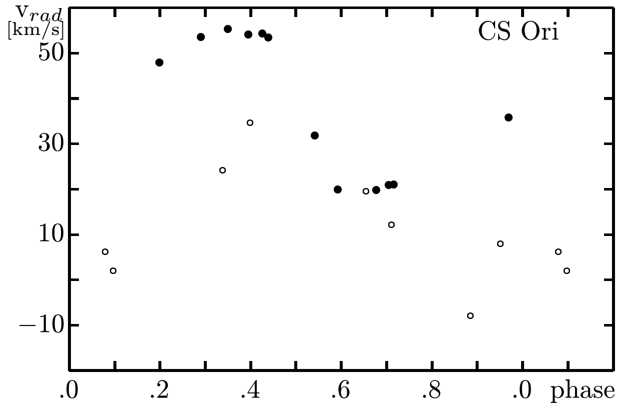

Fig. 6. Radial velocity curve of CS Ori folded on the revised pulsation period of 3.889281 days. Symbols are the same as in Fig. 2

Table 7. O−C residuals for UX Per

JD 2 400 000+	E	O−C [d]	w	type	Reference
26 449.789	−4935	−0.005	1	vis	Kukarkin (1932)
29 280.471	−4315	−0.077	1	pg	Lesyunina (1963)
34 695.747	−3129	0.240	1	pg	Lesyunina (1963)
36 882.452	−2650	−0.042	3	pe	Bahner et al. (1962)
37 631.265	−2486	−0.009	3	pe	Mitchell et al. (1964)
49 981.675	0	−0.011	3	CCD	Schmidt & Seth (1996)
49 990.720	221	0.008	3	pe	Berdnikov et al. (1997)

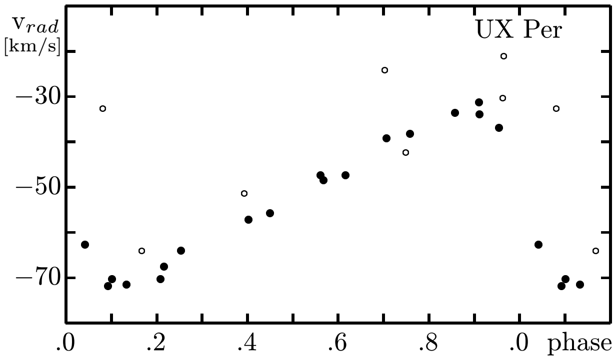

Fig. 7. Radial velocity curve of UX Per folded on the revised pulsation period of 4.565733 days. Symbols are the same as in Fig. 2

Table 8. O−C residuals for VW Pup

JD 2 400 000+	E	O−C [d]	w	type	Reference
25 403.066	−4242	0.059	1	pg	Oosterhoff (1935)
35 241.932	−1946	−0.119	1	pe	Irwin (1961), Walraven et al. (1958)
41 010.065	−600	0.003	3	pe	Pel (1976)
43 581.249	0	0.008	3	pe	Barrell (1982)
49 739.223	1437	0.009	3	pe	Pont et al. (1997)

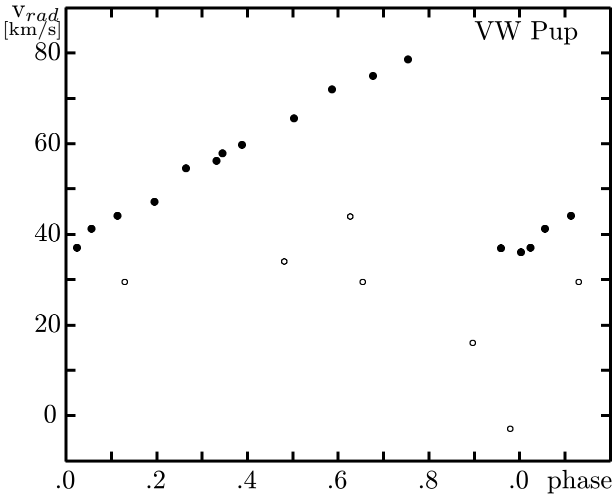

Fig. 8. Radial velocity curve of VW Pup folded on the revised pulsation period of 4.285298 days. Symbols are the same as in Fig. 2

The radial velocity data clearly indicate a spectroscopic companion (see Fig. 7): Joy's (1937) data are systematically less negative (but a single point) than the CORAVEL-measurements, the difference being significant, about 15 km s^{-1}.

VW Puppis

The revised ephemeris based on the photometric data (see Table 8) is quite precise:

$$C = \mathrm{JD}\,2\,443\,581.241 \;+\; 4\overset{\mathrm{d}}{.}285\,298 \times E$$
$$\pm.014 \qquad \pm.000\,009.$$

The variation in the γ-velocity caused by the orbital motion is the largest in this sample (see Fig. 8): the difference between Joy's (1937) and the CORAVEL-data of the corresponding phase is about 25 km s^{-1}. A closer inspection of the CORAVEL-data reveals that even an annual shift is noticeable: an increase of about 1 km s^{-1} in the γ-velocity is observed in this homogeneous dataset.

Table 9. Radial velocity data for the programme stars (for V495 Mon: ELODIE-data, for the other seven Cepheids: CORAVEL-data)

JD 2 400 000+	v_{rad} [km s^{-1}]	σ [km s^{-1}]
YZ Aur		
49639.637	−39.81	0.61
49656.571	−40.69	0.85
49663.626	−11.09	0.58
49684.321	2.06	0.55
49687.558	13.12	0.77
49768.293	−34.19	0.53
49769.299	−27.73	0.60
49777.299	8.76	0.76
49778.321	11.11	0.97
49779.354	7.42	0.91
50130.388	−40.51	0.70
50131.309	−40.09	0.87
50393.635	1.52	0.69
50394.530	4.58	0.60
50462.342	−20.01	0.43
50464.411	−9.32	0.58
50484.315	−1.47	0.61
50486.410	8.61	0.70
50488.362	11.47	0.80
AS Aur		
49639.649	2.70	0.87
49656.591	26.89	0.58
49681.454	13.90	0.54
49682.500	35.39	0.50
49753.394	27.81	0.75
49756.410	38.47	0.76
49768.309	37.33	0.58
49769.311	24.22	0.80
49779.341	5.37	1.06
50395.597	8.08	0.77
50462.356	10.91	0.78
50464.422	39.39	0.80
50484.330	4.79	0.71
50486.428	41.71	0.73
50488.376	25.59	0.60
50491.378	20.30	0.59
AA Gem		
49656.600	38.70	0.49
49663.638	12.28	0.39
49681.426	15.22	0.38
49682.485	12.58	0.39
49684.375	−0.79	0.40
49721.602	24.89	0.46
49768.328	35.83	0.39
49770.381	31.09	0.49
50438.744	15.68	0.46
50440.694	4.27	0.44
50442.707	5.85	0.39
50444.739	22.54	0.46
50446.741	37.10	0.43
50447.665	38.54	0.51
TX Mon		
49364.473	56.24	0.57
49366.487	74.66	0.48
49422.298	45.25	0.60
49423.292	48.65	0.66
49639.686	66.79	0.49
49656.623	66.35	0.51
49663.670	74.28	0.74
49681.520	66.26	0.46
49769.360	60.28	0.54
49777.335	61.53	0.73
49809.311	85.39	0.58
50098.464	73.07	0.69
50100.445	53.54	0.64
50101.412	57.70	0.51
50102.459	58.55	0.47
50135.406	48.73	0.33
50437.748	70.47	0.70
50439.635	46.57	0.41
50441.713	54.68	0.47
50442.712	53.82	0.43
50444.752	73.47	0.60
50446.761	60.45	0.57
50447.681	46.69	0.51
V495 Mon		
49317.694	54.348	0.403
49318.591	53.426	0.132
49319.472	65.686	0.137
49320.721	85.030	0.995
49415.868	83.314	0.658
49695.582	54.607	0.181
49697.616	80.000	0.168
49739.339	73.370	0.482
CS Ori		
49681.555	35.87	0.42
49684.419	20.96	0.66
49749.501	53.50	0.68
49768.369	53.53	0.53
49769.346	31.88	0.69
49776.374	55.36	0.56
49777.319	19.87	1.03
50437.730	54.12	0.66
50441.744	54.31	0.49
50442.720	19.82	0.68
50444.745	48.01	0.77
50446.754	21.07	0.68
UX Per		
49364.296	−31.32	0.73
49365.312	−71.48	0.88
49367.299	−48.47	0.56
49374.255	−71.80	1.32
49419.282	−36.92	1.52
49422.308	−47.36	0.82
49639.598	−70.32	0.77
49655.571	−39.13	0.75
49656.512	−33.85	0.76
49663.531	−55.75	0.74
49812.338	−62.73	1.08
49813.307	−64.03	0.97
50394.556	−47.42	0.42
50462.316	−57.12	0.60
50464.392	−33.60	0.83
50484.294	−67.58	0.85
50488.337	−70.33	1.18
50491.335	−38.20	0.66
VW Pup		
49656.650	74.90	0.71
49681.617	65.63	0.60
49684.582	47.21	0.46
49768.396	78.62	0.62
49796.587	56.21	0.53
49799.552	37.13	0.93
49812.315	36.11	0.69
50437.783	36.90	0.68
50439.619	59.76	0.39
50442.727	44.08	0.59
50443.720	57.84	0.53
50444.757	71.94	0.62
50446.767	41.22	0.58

4. Conclusion

The discovery that eight more classical Cepheids have spectroscopic companion, also supports the facts (Szabados 1995) that the incidence of binaries among classical Cepheids is larger than 50 per cent, and there are lots of spectroscopic binaries among Cepheids fainter than 8th magnitude whose duplicity remains to be discovered.

The modern radial velocity spectrometers (CORAVEL, ELODIE, etc.) attached to a telescope of about 1m diameter are capable of measuring stars of 12–13th magnitude within a reasonably short time, and the precision of the radial velocity determination allows the detection of very small orbital effects (less than one km s^{-1} change in the γ-velocity), if homogeneous datasets covering several seasons are available. The shortest known orbital period for classical Cepheids is slightly longer than one year (Szabados 1992), while the other extremum, the longest still detectable orbital period is as long as several decades (T Mon).

The earlier radial velocity data of limited precision are useful for revealing the orbital motion if there is only a short dataset of recent radial velocity values, which is the case for the stars discussed in the present paper. The next step, then, is the extensive study of these newly recognized spectroscopic binaries. For the time being, none of the orbital elements can be determined from the available data. There are, however, several pieces of information that can be deduced from the pattern of the γ-velocity change, such as the short orbital period of TX Mon and the several-year-long orbital period is adequate to the observations of VW Pup. All Cepheids whose binary nature is reported here show considerable amplitude of γ-velocity variation (only V495 Mon may be an exception). For the sake of information, the new radial velocity data on the eight new SB-Cepheids obtained by the CORAVEL and ELODIE spectrographs are listed in Table 9.

The detection of numerous spectroscopic binaries among Cepheids justifies that the time-consuming project of collecting radial velocity data of Cepheids is an observational programme worthy to be carried out because binary Cepheids are key-objects for both astrophysics (stellar evolution) and cosmology (distance scale).

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