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RADIAL VELOCITY STUDIES OF CLOSE BINARY STARS. VIII.[1]

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ABSTRACT

Radial velocity measurements and sine-curve fits to the orbital velocity variations are presented for the seventh set of 10 close binary systems: V410 Aur, V523 Cas, QW Gem, V921 Her, V2357 Oph, V1130 Tau, HN UMa, HX UMa, HD 93917, and NSV 223. All systems but three (V523 Cas, HD 93917, NSV 223) were discovered photometrically by the *Hipparcos* mission. All systems are double-lined (SB2) binaries, and all but the detached, very close system V1130 Tau are contact binaries. The broadening function permitted improvement of the orbital elements for V523 Cas, which was the only system observed before for radial velocity variations. Spectroscopic/visual companions were detected for V410 Aur and HX UMa. Several of the studied systems are prime candidates for combined light and radial velocity synthesis solutions.

Key word: binaries: close — binaries: eclipsing — stars: variables: general

On-line material: machine-readable tables

1. INTRODUCTION

This paper is a continuation of a series of papers on radial velocity studies of close binary stars (Lu & Rucinski 1999; Rucinski & Lu 1999; Rucinski, Lu, & Mochnacki 2000; Rucinski et al. 2001, 2002; Lu, Rucinski, & Ogłoza 2001) and presents data for the seventh group of 10 close binary stars observed at the David Dunlap Observatory. Selection of the targets is quasi-random: at a given time, we observe a few dozen close binary systems with periods shorter than 1 day, brighter than 11 mag, and with declinations greater than $-20°$; we publish the results in groups of 10 systems as soon as reasonable orbital elements are obtained from measurements evenly distributed in orbital phases. For technical details and conventions, and for preliminary estimates of errors and uncertainties, see the interim summary paper Rucinski (2002a, hereafter Paper VII).

This paper is structured in the same way as the previous papers in that most of the data for the observed binaries are in two tables consisting of the radial velocity measurements (Table 1) and their sine-curve solutions (Table 2). Section 2 of the paper contains brief summaries of previous studies of individual systems and comments on the new data. Figures 1–3 show the radial velocity data and solutions. While in the previous papers we showed only some of the most interesting broadening functions (BFs), Figure 4 of this paper shows the BFs for all systems; the functions have been selected from among the best-defined ones around the orbital phase of 0.25.

The observations reported in this paper were collected between 2000 March and 2002 April; the range of dates for individual systems can be found in Table 1. All systems discussed in this paper, except V523 Cas, have been observed for radial velocity variations for the first time. We have derived the radial velocities in the same way as described in previous papers; see Paper VII for a discussion of the broadening function approach used in the derivation of the radial velocity orbit parameters: the amplitudes K_i, the center-of-mass velocity V_0, and the time-of-eclipse epoch T_0.

The data in Table 2 are organized in the same manner as in previous papers. In addition to the parameters of spectroscopic orbits, the table provides information about the relation between the spectroscopically observed epoch of the primary-eclipse T_0 and the recent photometric determinations in the form of the $O-C$ deviations for the number of elapsed periods E. It also contains our new spectral classifications of the program objects.

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TABLE 1
DDO Observations of the Seventh Group of 10 Close Binary Systems

HJD (2,400,000)	Phase	V_1 (km s^{-1})	ΔV_1 (km s^{-1})	V_2 (km s^{-1})	ΔV_2 (km s^{-1})
V410 Aur					
51849.7638.......	0.0961	−2.0	−15.0	225.5	22.9
51849.7723.......	0.1193	−1.7	−9.9	248.6	12.9
51849.7810.......	0.1430	−5.9	−9.8	270.9	5.7
51849.7912.......	0.1710	−16.0	−15.9	269.7	−23.7
51849.8002.......	0.1954	2.3	5.0	328.8	17.1

Notes.—The deviations ΔV_i are relative to the simple sine-curve fits to the radial velocity data. Observations leading to entirely inseparable broadening and correlation function peaks are left empty; these observations may eventually be used in more extensive modeling of BFs. The radial velocities designated as V_1 correspond to the component that was stronger and easier to measure in the analysis of the BFs; it is not always the component eclipsed during the primary minimum at the epoch T_0 (see Table 2). Figs. 1–3 should help in identifying which star is which. Table 1 is presented in its entirety in the electronic edition of the Astronomical Journal. A portion is shown here for guidance regarding its form and content.

[a] Given 0.5 weight in the orbital solution.

[b] Given 0.25 weight in the orbital solution.

2. RESULTS FOR INDIVIDUAL SYSTEMS

2.1. *V410 Aur*

V410 Aur was discovered by the *Hipparcos* satellite. The somewhat sparsely covered *Hipparcos* light curve is rather typical for a W UMa type system; it has an amplitude of about 0.33 mag. Total eclipses are entirely possible, given the large semiamplitudes K_i of our solution, suggesting an orbital inclination $i \simeq 90°$. The system is a spectroscopic triple, with the third component having relative brightness of $L_3/(L_1 + L_2) = 0.26 \pm 0.01$. The photometric amplitude corrected for the third light is 0.43 mag, which actually is large and inconsistent with the mass ratio $q_{\rm sp} = 0.14$; the maximum amplitude for the inclination of $i = 90°$ is expected to be around 0.33–0.38 mag (Rucinski 2001).

The individual velocities of the third component did not show any trace of " cross talk " (i.e., it did not correlate with the binary phase), although the third-star peak in the BF was strong and always projected into the BF signature of the primary component (see Fig. 4), making the orbital solution somewhat poorer than for similar systems without companions (see Fig. 1). The radial velocity observations of the third component are given in Table 3. Our observations were made in two groups, around HJD 2,451,870 and HJD 2,452,280. The average velocities of the third component for these groups were $V_3 = 48.38 \pm 0.30$ and 43.90 ± 0.43 km s^{-1}; both differ significantly from the mean velocity of the close binary, $V_0 = 36.94 \pm 3.10$ km s^{-1}. Unfortunately, we do not have enough observations and they are not accurate

TABLE 2
Spectroscopic Orbital Elements

Name	Type, Spectral Type	Other Names	V_0	K_1, K_2	ϵ_1, ϵ_2	$T_0 - 2{,}400{,}000$, $(O-C)$ (days) [E]	P (days), $(M_1 + M_2) \sin^3 i$	q
V410 Aur	EW/A	HD 280332	+36.94(3.10)	42.14(3.73)	11.53	52,061.1068(22)	0.366340	0.144(13)
	G0/2 V	HIP 23337		291.68(4.50)	22.19	+0.1060 [9720]	1.42(10)	
V523 Cas..........	EW/W		−2.54(0.90)	121.64(1.14)	7.82	52,104.0295(4)	0.233693	0.516(7)
	K4 V			235.95(1.41)	10.37	+0.0027 [1205]	1.110(24)	
QW Gem..........	EW/W	HD 264672	−0.90(1.39)	89.17(1.84)	7.79	51,961.2357(11)	0.358127	0.334(9)
	F8 V	HIP 32845		267.30(2.52)	12.14	−0.0096 [9664]	1.685(62)	
V921 Her	EW/A	HD 152172	−79.04(1.05)	51.45(0.89)	4.06	51,979.8304(62)	0.877366	0.226(5)
	A7 IV:	HIP 82344		227.17(1.97)	17.37	+0.0718 [3966]	1.971(61)	
V2357 Oph.......	EW/A	HIP 82967	−19.12(1.64)	44.12(1.63)	7.37	52,050.2364(22)	0.415568[a]	0.231(10)
	G5 V			190.93(2.90)	9.93	−0.0061 [8543]	0.560(32)	
V1130 Tau	EA	HD 24133	−12.74(0.46)	147.21(0.63)	3.39	52,097.6133(11)	0.798871	0.919(7)
	F3 V	HIP 17988		160.11(0.74)	4.26	−0.0218 [4503]	2.408(32)	
HN UMa	EW/A	BD +38°2220	−37.11(0.63)	29.65(0.76)	3.02	52,049.9590(8)	0.382608	0.140(4)
	F8 V	HIP 55030		212.22(0.96)	4.42	+0.0439 [9278]	0.562(12)	
HX UMa	EW/A	HD 104425	−19.88(1.11)	60.80(1.45)	6.16	51,835.0458(13)	0.379156	0.291(9)
	F4 V	HIP 58648		209.18(2.07)	9.53	−0.0032 [8795]	0.775(30)	
HD 93917	EW/W	BD −1°2452[b]	+17.47(0.79)	74.33(0.91)	4.12	52,374.6151(8)	0.443420	0.313(5)
	F9.5			237.30(1.32)	6.12	+0.0095 [810]	1.394(30)	
NSV 223	EW/A	BD +20°75	−21.66(2.15)	40.39(2.64)	9.02	50,748.8907(18)	0.366128	0.136(10)
	F7 V			297.98(4.18)	14.43	−0.0053 [2941]	1.47(9)	

Notes.—The spectral types given in the second column are all new and relate to the combined spectral type of all components in a system. The convention of naming the binary components in this table is that the more massive star is marked by the subscript " 1," so that the mass ratio is defined to be always $q \leq 1$. Figs. 1–3 should help identify which component is eclipsed at the primary minimum. The standard errors of the circular solutions in the table are expressed in units of the last decimal places quoted; they are given in parentheses after each value. The center-of-mass velocities (V_0), the velocity amplitudes (K_i), and the standard unit-weight errors of the solutions (ϵ) are all expressed in km s^{-1}. The spectroscopically determined moments of primary minima are given by T_0; the corresponding $O-C$ deviations (in days) have been calculated from the most recent available ephemerides, as given in the text, using the assumed periods and the number of epochs given by [E]. The values of $(M_1 + M_2) \sin^3 i$ are in solar mass units.

[a] The period is twice as long as in the *Hipparcos* Catalogue (ESA 1997), where the star was classified as a pulsating one. The T_0 has been adjusted from the maximum to the minimum of light, as described in the text.

[b] The variability discovery paper gives BD −1°2448, while SIMBAD gives BD −1°2452.

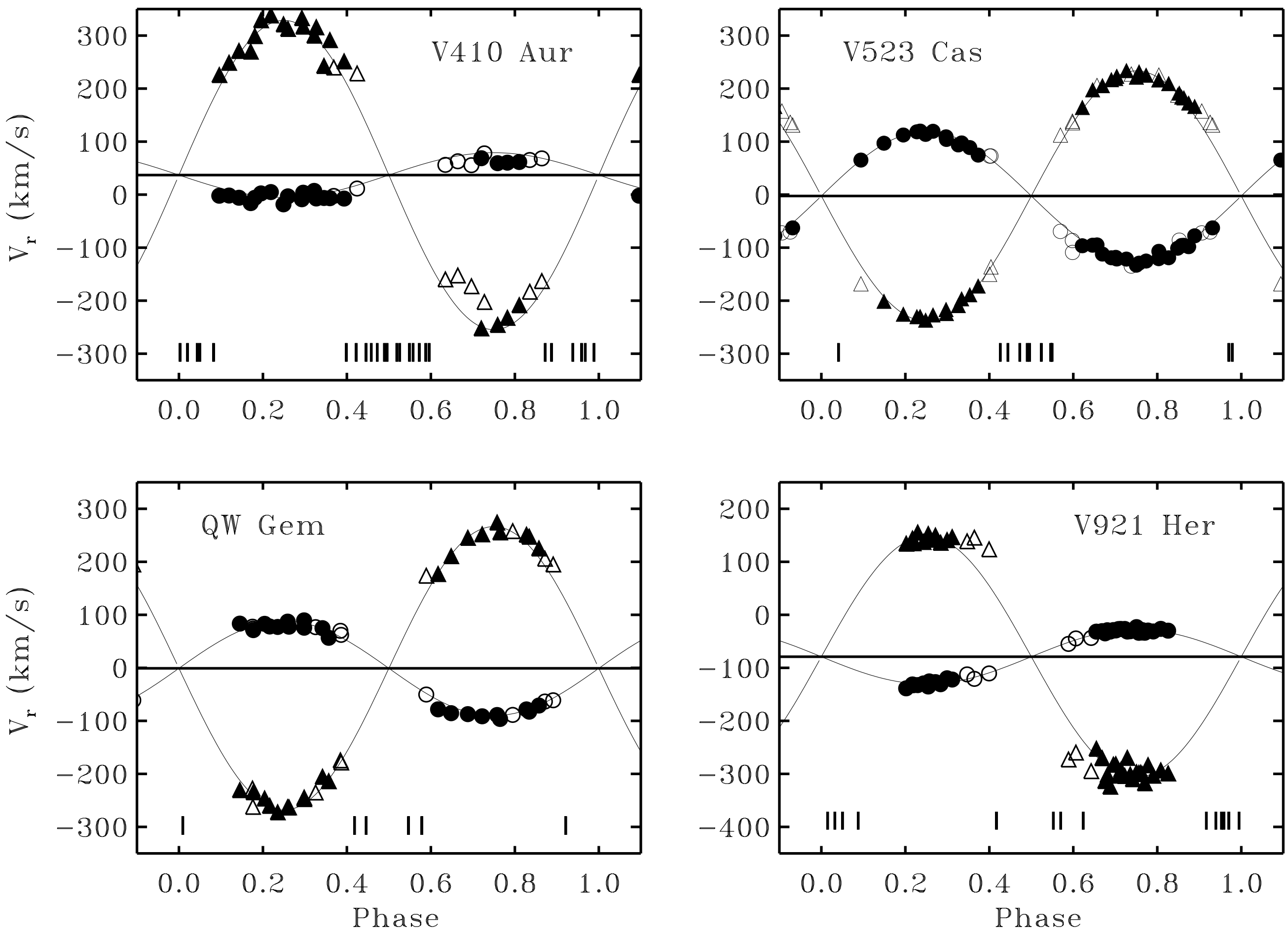

FIG. 1.—Radial velocities of the systems V410 Aur, V523 Cas, QW Gem, and V921 Her vs. the orbital phases. The lines give the respective circular orbit (sine-curve) fits to the radial velocities. All four systems are contact binaries. V410 Aur and V921 Her are A-type contact systems, while V523 Cas and QW Gem are W-type contact systems. V410 Aur has a fainter spectroscopic companion whose presence lowered the quality of the measurements and of the solution. Shown are components with velocities V_1 (*circles*) and V_2 (*triangles*), as listed in Table 1. The component eclipsed at the minimum corresponding to T_0 (as given in Table 2) is the one that shows negative velocities for the phase interval 0.0–0.5. Open symbols indicate observations contributing half-weight data in the solutions. Short marks in the lower parts of the panels show phases of available observations that were not used in the solutions because of the blending of lines. All panels have the same vertical range, -350 to 350 km s^{-1}, but the display is vertically shifted for V921 Her.

enough to check if the difference in the average V_3 is reflected in a change of the binary center-of-mass velocity V_0; our solution for the binary uses one constant value for V_0.

The orbital ephemeris based on the *Hipparcos* data shows a large $O-C$ deviation of 0.10 days. We arbitrarily reduced the $O-C$ by shifting the time of the primary eclipse by that amount under the assumption that V410 Aur is a contact binary of the A type (i.e., that the hotter component is the more massive one).

The third body in the system was probably the reason for the large error in the *Hipparcos* parallax, 4.77 ± 5.39 mas, so that we have no distance estimate for the system. There is a discrepancy between the $V_{\max}$ estimated from the *Hipparcos* $H_p = 9.98$ and from the Tycho-2 (Høg et al. 2000) photometry, $V_{\max} = 10.18$ (transformed from V_T). Our estimate of the spectral type, G0/G2 V, is consistent with the average $B-V = 0.56$ from Tycho-2.

2.2. *V523 Cas*

V523 Cas is the only system in this group that was observed spectroscopically before our observations (Milone et al. 1985). The system is an interesting one because—with its very short orbital period of 0.237 days, right next to CC Com at 0.221 days—it is very close to the still-unexplained abrupt cutoff in the orbital period distribution of contact binaries. Several photometric studies of V523 Cas have recently been rediscussed by Lister et al. (2000), where all previous references are given. The photometric solutions encountered the common problem of a featureless light curve poorly constraining the geometric parameters, with the crucial parameter of the mass ratio taking a large range of values, with the photometric ones usually above the value determined by Milone et al. 1985 of $q_{\rm sp} = 0.42 \pm 0.02$.

Our radial velocity results are well defined (Fig. 1). The BF (Fig. 4) very clearly shows the more compact and slightly hotter (or having a higher surface brightness) less massive component. The disparity of the component shapes is quite striking in the BF; it seems as if the secondary were a detached component (but still quite large) in a semidetached binary. Our spectroscopic mass ratio, $q_{\rm sp} = 0.516 \pm 0.008$, is very close to the photometric value determined most recently by Lister et al. (2000), $q_{\rm ph} = 0.53 \pm 0.02$, hopefully ending the long dispute about the $q_{\rm sp}$ versus $q_{\rm ph}$ disparity (Maceroni 1986).

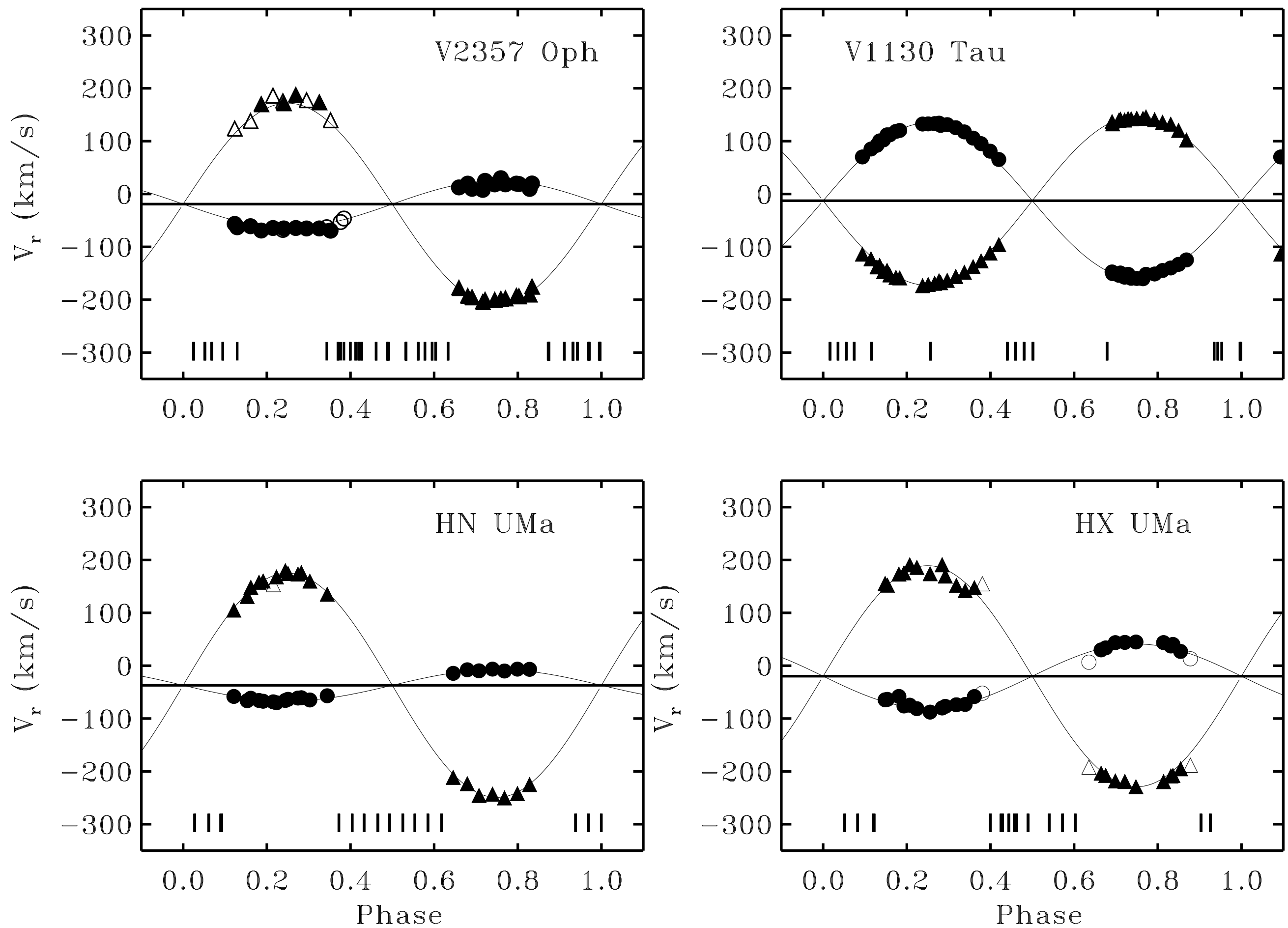

FIG. 2.—Same as for Fig. 1, but for the systems V2357 Oph, V1130 Tau, HN UMa, and HX UMa. All systems except V1130 Tau, which is a close detached system, are contact systems of the A type. HX UMa has a faint companion.

The ephemeris used to phase the observations was based on two sources: the period as given in Table 2 is from Nelson (2001), while the initial epoch, $T_0 = 2,451,822.4267$, was taken from Pribulla et al. (2001).

V523 Cas does not have a trigonometric parallax and was apparently too faint to be included in the Tycho-2 project. Thus, we refrain from a full discussion of its parameters, noting only that our spectral type, K4 V, confirms previous classifications and agrees with $B-V = 1.07$ measured by Bradstreet (1981); in that work $V_{\max} = 10.59$. The (extrapolated) calibration of Rucinski & Duerbeck (1997, hereafter RD97) gives $M_V = 6.15$, so that V523 Cas is one of the faintest known contact binaries. This gives a rather small distance to the binary, about 77 pc.

2.3. *QW Gem*

This contact system has been discovered by *Hipparcos*. It is somewhat faint for our telescope, so that the individual BFs are noisy, but the orbital solution is well defined (Fig. 1). This contact system is of the W type when the *Hipparcos* ephemeris is used; this ephemeris gives a very small $O-C$ deviation. The light curve has a moderately large amplitude of 0.41 mag.

The maximum light brightness, $V_{\max} = 10.3 \pm 0.1$, is estimated from the transformed H_p data and the Tycho-2 average data; this estimate is very approximate. The *Hipparcos* parallax has a large error, 4.09 ± 5.42, which may indicate some undiscovered companions or just reflect the relative faintness of the star. Our spectral type, F8 V, is consistent with the Tycho-2 average $B-V = 0.48$. $M_V = 3.36$ determined from the very uncertain parallax is in agreement with $M_V(\mathrm{cal}) = 3.55$ derived using the RD97 calibration.

2.4. *V921 Her*

V921 Her is another *Hipparcos* discovery. This contact system is of the A type, with the more massive component eclipsed during the deeper minimum. The *Hipparcos* light curve is well defined, with an amplitude of 0.36 mag. The system is interesting in that it has a relatively long period of 0.877 days, which is rather infrequent among contact binaries. The color index estimated from the Tycho-2 data, $B-V = 0.27$, points to a spectral type slightly later than our new classification, A7 IV (the SIMBAD type is an even earlier A5), but there may be some interstellar reddening. The *Hipparcos* parallax, 2.39 ± 0.97 mas, and $V_{\max} = 9.37$, with an assumption of no reddening, give $M_V = 1.3 \pm 0.9$, which is consistent with the extrapolated RD97 calibration, $M_V(\mathrm{cal}) = 1.1$. This is one of the most luminous contact systems with $P < 1$ day.

The components are only barely resolved in the BF, which may indicate a low orbital inclination (a small sin *i*). The orbit is moderately well defined (Fig. 1), partly because of the early spectral type and dearth of lines; both factors tend to increase the velocity errors. An interesting feature is

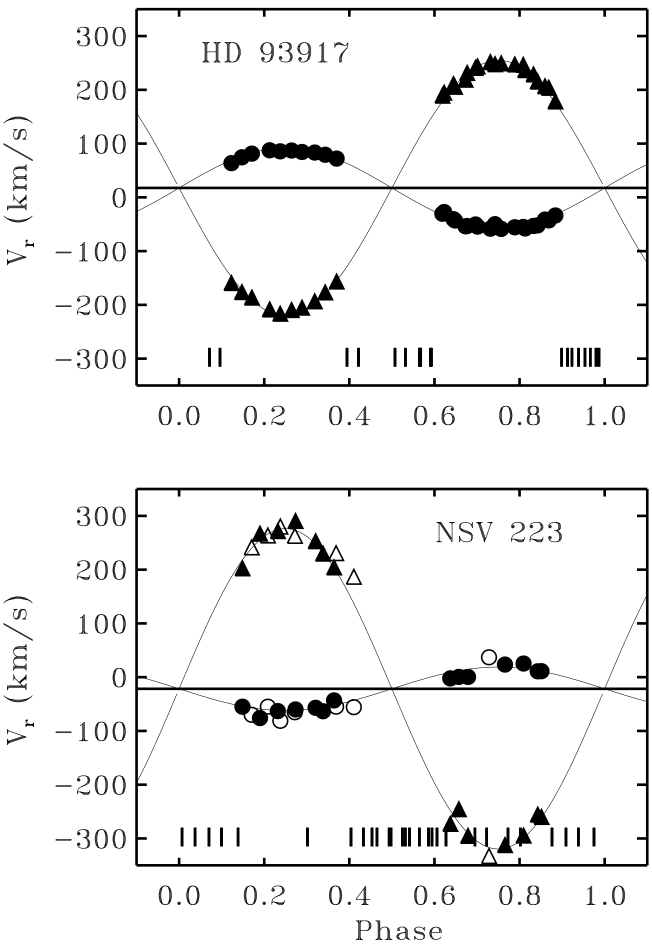

FIG. 3.—Same as for Fig. 1, but for the systems HD 93917 and NSV 223. The former is a contact binary of the W type, while the latter is of the A type.

a relatively large (in the absolute sense) mean systemic velocity of $V_0 = -79$ km s^{-1}; the *Hipparcos* tangential velocities are small, so that the large radial velocity is the main contributor to the spatial velocity of 81 km s^{-1}.

2.5. *V2357 Oph*

The variable V2357 Oph was discovered by *Hipparcos*. It was classified as a pulsating star with a period of 0.208 days, which is 2 times shorter than the actual orbital period. The *Hipparcos* ephemeris was for the maximum light. Assuming that the *Hipparcos* initial epoch corresponded to the minimum just before the maximum used in the ephemeris ($T_0 = 2,448,500.0451$), the resulting $O-C$ is quite small (see Table 2).

The orbit is only moderately well defined (Fig. 2), partly because the system is a bit faint for our instrumentation and partly because of the small separation of the components in the BFs. The small radial velocity semiamplitudes K_i and the small photometric amplitude of 0.12 mag are all consistent with the low orbital inclination.

The *Hipparcos* parallax, 5.37 ± 2.01 mas, and $V_{\rm max} = 10.43$ lead to $M_V = 4.08 \pm 0.82$, while $M_V({\rm cal}) = 4.23$ (RD97) for the average $B-V = 0.80$, as indicated by the Tycho-2 data. This color index is approximately consistent with our spectral type, G5 V.

2.6. *V1130 Tau*

The bright ($V_{\rm max} = 6.56$) system V1130 Tau was discovered by *Hipparcos*. It is the only noncontact system in this group of 10 binaries. The BFs are exceptionally well defined and show (Fig. 4) two large but detached components of similar size and brightness. The mass ratio resulting from our orbit (Fig. 2) is $q = 0.919 \pm 0.008$. The photometric variations observed by *Hipparcos* define a very nice light curve with rounded maxima and an amplitude of 0.38 mag. The distinction of which component is the hotter one and thus which of the minima should be called the primary minimum is not well established from the *Hipparcos* light curve. The BFs show the fainter component eclipsed during the *Hipparcos* primary minimum, which may indicate that the identification of the eclipses is actually incorrect.

The system begs to be analyzed in detail, since it is one of the shortest period detached systems with the spectral type F3 V. This spectral type is in agreement with the average $B-V = 0.34$, as derived from the Tycho-2 data. The *Hipparcos* parallax is relatively large (in fact the largest in this group of binaries) and well determined, 15.35 ± 0.78 mas, leading to $M_V = 2.49 \pm 0.12$. The contact binary calibration of RD97 obviously does not apply in this case; we can only note that the combined brightness corresponds to some 0.6 mag above the main sequence, which simply reflects the detached binary nature of two similar stars. We note that $(M_1 + M_2) \sin^3 i = 2.41 \pm 0.03\ M_\odot$ for V1130 Tau is relatively large, so that the orbital inclination must be close to 90°.

2.7. *HN UMa*

Another *Hipparcos* discovery, HN UMa is a rather common-looking contact system seen at moderately low orbital inclination because both the photometric variations (0.12 mag) and the radial velocity semiamplitudes, K_i, are rather small (Fig. 2). The spectral type of F8 V is somewhat early for the average $B-V = 0.46$ derived from the Tycho-2 data. The *Hipparcos* parallax, 5.81 ± 1.39 mas, with the adopted $V_{\rm max} = 9.80$, gives $M_V = 3.62 \pm 0.53$, while $M_V({\rm cal}) = 3.36$ (RD97). The proper motion of the system (Tycho-2 data) is comparatively large, $\mu_\alpha \cos\delta = +54.0 \pm 1.9$ mas and $\mu_\delta = -36.9 \pm 1.8$ mas, which together with $V_0 = -37.1$ km s^{-1} result in a relatively large spatial velocity of 65.0 km s^{-1}.

TABLE 3

OBSERVATIONS OF THE SPECTROSCOPIC COMPANIONS

HJD (2,450,000)	V_r (km s^{-1})
V410 Aur B	
1849.7638	46.9
1849.7723	48.7
1849.7810	51.0
1849.7912	50.8

NOTES.—Table 3 is presented in its entirety in the electronic edition of the Astronomical Journal. A portion is shown here for guidance regarding its form and content.

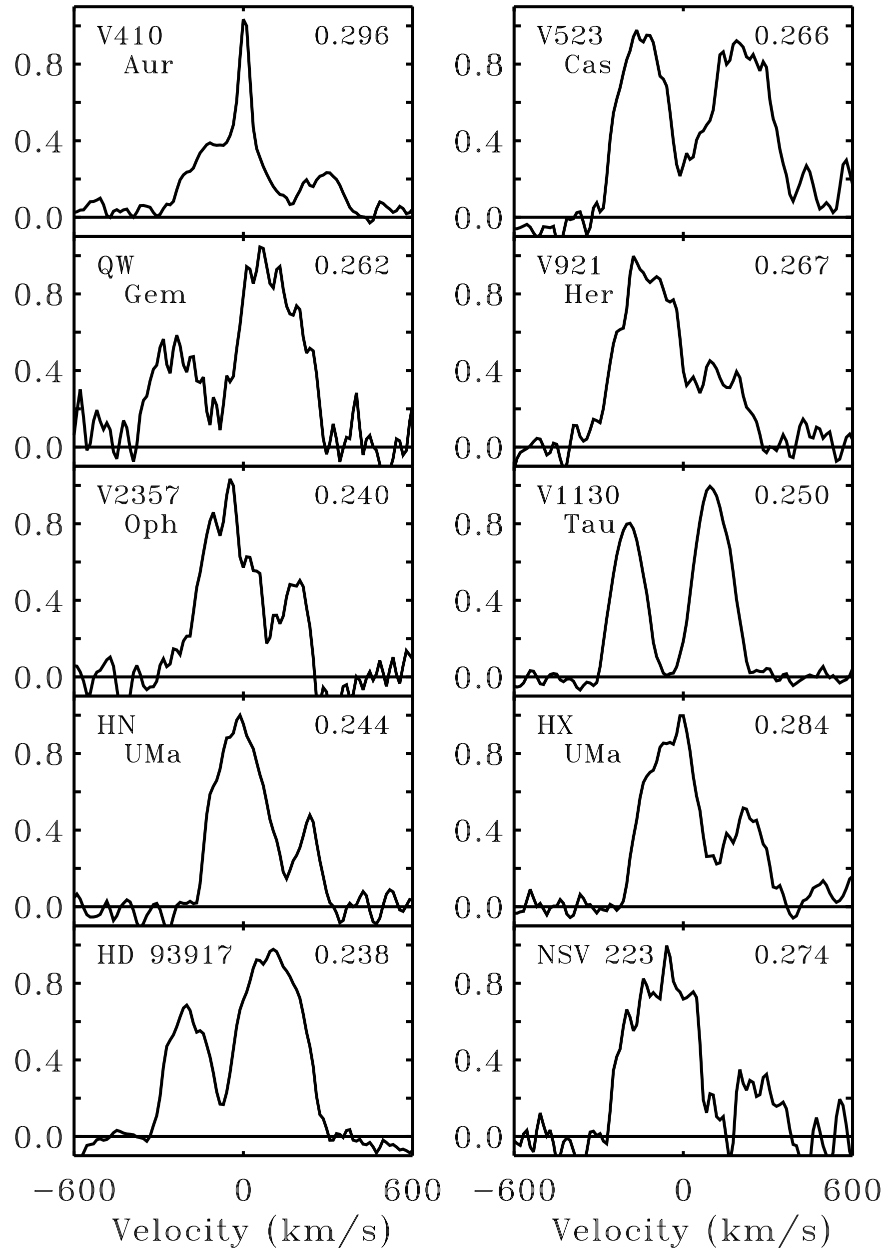

FIG. 4.—Broadening functions for all binary systems of this group, all for orbital phases around 0.25, as in similar figures in the previous papers. V410 Aur has a well-defined, slowly rotating companion. A tiny third-body feature in the BF of HX UMa could easily be taken for a small error fluctuation (as in poorly determined cases of fainter systems, such as NSV 223), if not for its persistence throughout all the phases.

2.8. *HX UMa*

The variability of HX UMa was discovered by *Hipparcos*. The light curve is of a typical W UMa type system with an amplitude of 0.17 mag. Apparently, the ephemeris of *Hipparcos* predicts the photometric minima quite well with a very small $O-C$ shift; the deeper one corresponds to the eclipse of the more massive star.

A close companion at the distance of 0$''$.63 was discovered by *Hipparcos*. The redetermination by Fabricius & Makarov (2000) gave an average magnitude difference between the components of 3.00 mag in the H_p system; our determination of a weak third-light peak in the BF gives $L_3/(L_1 + L_2) = 0.049 \pm 0.004$, or $\Delta m = 3.27 \pm 0.10$ at the bandpass of our spectroscopy at 5184 Å. The signature of the third body was just barely detectable (Fig. 4), and if not for the persistence through the orbital phases of the binary, it could easily be taken for noise in the BF. The radial velocity data for the third component are given in Table 3. The average velocity, $V_3 = -23.59 \pm 0.77$ km s^{-1}, is slightly different from the center-of-mass velocity of the binary, $V_0 = -19.88 \pm 0.39$ km s^{-1}, but the difference may be of no significance, as we cannot exclude any systematic bias in the measurements of V_3 on top of the much stronger feature of the close binary system. We do not see any cross talk in the velocity determinations, in the sense that V_3 does not depend on the orbital phase of the close binary (see Paper VII for a discussion of cases in which such a dependence is observed). Our observations were made in two groups, centered on HJD 2,451,697.4 and 2,451,986.9 (see Table 3).

We do not see any significant change in V_3 between these epochs, with the average values of -22.95 ± 1.12 and -24.56 ± 1.00 km s^{-1}.

The spectral type, F8 V, is consistent with $B-V = 0.44$ derived from the Tycho-2 data. The *Hipparcos* parallax is poorly determined, 6.68 ± 3.01 mas, possibly reflecting the visual binary nature of the system, so it cannot be meaningfully compared with the RD97 calibration, which predicts $M_V(\mathrm{cal}) = 3.32$.

It was noted by Bartkevičius & Lazauskaitė (1997) that HX UMa is not physically related to the nearby variable star DP UMa (HD 104513).

2.9. *HD 93917*

The W UMa type variability of HD 93917 was recently discovered by Lasala-Garcia (2001); we used the timing data from that work for the values of T_0 and P. The amplitude of light variations is 0.34 mag, so it is rather curious that the variability of this bright ($V_{\max} = 9.02$) star went undetected for such a long time. There are more curious circumstances around this star: It is one of very few HD stars not observed by the main *Hipparcos* project (but it was observed by Tycho). Also, there existed a large discrepancy between the $B-V = 0.55$ color index, as given in the SIMBAD database and confirmed by Tycho-2, and the SIMBAD spectral type of K0. We found that the spectral type is F9.5 V, which agrees very well with the color index. The predicted $M_V(\mathrm{cal}) = 3.35$ (RD97) cannot be checked because the Tycho parallax is poor, 14.9 ± 11.4 mas.

Our observations define a very good spectroscopic orbit without any peculiarities (Fig. 3). The system belongs to the W type of contact binaries; i.e., it has a hotter less massive component. There is absolutely nothing peculiar in the system except for the very fact that, being so bright, its variability remained undetected for such a long time. We note that Rucinski (2002b, §§ 8 and 12) estimated that even among brights stars within the interval $7.5 < V < 8.5$, perhaps as many as 45 contact systems still remain to be discovered.

2.10. *NSV 223*

The variability of NSV 223 has been known since its discovery by Strohmeier et al. (1956). Recently, Verrot & Van Cauteren (2000) obtained a light curve showing a total, long-duration eclipse in the secondary minimum, which suggests that the mass ratio is small. Our radial velocity data (Fig. 3) fully confirm these predictions: the contact system is indeed of the A type and the mass ratio is small, $q = 0.136 \pm 0.011$. The large semiamplitudes, K_i, suggest that the orbital inclination is close to 90°. In spite of those properties promising a very good combined solution, the system is poorly known. What is known is $V_{\max} = 10.86$ from Verrot & Van Cauteren (2000); also, our spectral type is F7 V. The ephemeris given by the discoverers holds quite well (see Table 2).

3. SUMMARY

This paper presents radial velocity data and orbital solutions for the seventh group of 10 close binary systems observed at the David Dunlap Observatory. In this series, only V523 Cas has a history of previous radial velocity studies. Seven systems were discovered photometrically by the *Hipparcos* satellite mission, while two binary systems, HD 93917 and NSV 223, have been identified as contact systems only very recently.

All systems of this group, with the exception of the detached binary V1130 Tau, are contact binaries of the W UMa type. All systems are double-lined (SB2) binaries with visible spectral lines of both components. V1130 Tau is interesting because it is very close yet detached, consisting of two almost identical F3 V stars on a tight orbit with $P = 0.799$ days. In contrast, the early-type (A7) contact binary V921 Her has a relatively long period of $P = 0.877$ days. A bright (9 mag), recently discovered contact system, HD 93917, is rather inconspicuous in its properties except for the fact that it remained undiscovered for such a long time; this confirms the prediction that many close binary systems still remain to be discovered among bright stars. V410 Aur and HX UMa have fainter companions detected spectroscopically.

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REFERENCES

Bartkevičius, A., & Lazauskaitė, R. 1997, Baltic Astron., 6, 499
Bradstreet, D. H. 1981, AJ, 86, 98
ESA. 1997, The Hipparcos and Tycho Catalogues (ESA SP-1200) (Noordwijk: ESA)
Fabricius, C., & Makarov, V. V. 2000, A&A, 356, 141
Høg, E., Fabricius, C., Makarov, V. V., Urban, S., Corbin, T., Wycoff, G., Bastian, U., Schwekendiek, P., & Wicenec, A. 2000, A&A, 355, L27
Lasala-Garcia, A. 2001, Inf. Bull. Variable Stars, No. 5075
Lister, T. A., McDermid, R. M., & Hilditch, R. W. 2000, MNRAS, 317, 111
Lu, W., & Rucinski, S. M. 1999, AJ, 118, 515
Lu, W., Rucinski, S. M., & Ogłoza, W. 2001, AJ, 122, 402
Maceroni, C. 1986, A&A, 170, 43
Milone, E. F., Hrivnak, B. J., & Fisher, W. A. 1985, AJ, 90, 354
Nelson, R. H. 2001, Inf. Bull. Variable Stars, No. 5040
Pribulla, T., Vaňko, M., Parimucha, Š, & Chochol, D. 2001, Inf. Bull. Variable Stars, No. 5056
Rucinski, S. M. 2001, AJ, 122, 1007
———. 2002a, AJ, 124, 1746 (Paper VII)
———. 2002b, PASP, 114, 1124
Rucinski, S. M., & Duerbeck, H. W. 1997, PASP, 109, 1340 (RD97)
Rucinski, S. M., & Lu, W. 1999, AJ, 118, 2451
Rucinski, S. M., Lu, W., Capobianco, C. C., Mochnacki, S. W., Blake, R. M., Thomson, J. R., Ogłoza, W., & Stachowski, G. 2002, AJ, 124, 1738
Rucinski, S. M., Lu, W., & Mochnacki, S. W. 2000, AJ, 120, 1133
Rucinski, S. M., Lu, W., Mochnacki, S. W., Ogłoza, W., & Stachowski, G. 2001, AJ, 122, 1974
Strohmeier, W., Kippenhahn, R., & Geyer, E. 1956, Kleine Veröff. Remeis-Sternw. Bamberg, No. 15
Verrot, J. P., & Van Cauteren, P. 2000, Inf. Bull. Variable Stars, No. 4910