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

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ABSTRACT

Radial velocity measurements and sine-curve fits to the orbital velocity variations are presented for the fifth set of 10 close binary systems: V376 And, EL Aqr, EF Boo, DN Cam, FN Cam, V776 Cas, SX Crv, V351 Peg, EQ Tau, and KZ Vir. All systems are double-lined, spectroscopic contact binaries (KZ Vir may be a low-inclination, close, noncontact binary), with seven (all except EL Aqr, SX Crv, and EQ Tau) being the recent photometric discoveries of the *Hipparcos* project. The most interesting object is SX Crv, a contact system with an unprecedented low mass ratio, $q = 0.066 \pm 0.003$, whose existence challenges the current theory of tidal stability of contact systems. Several of the studied systems are prime candidates for combined light and radial velocity synthesis solutions.

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

On-line material: machine-readable table

1. INTRODUCTION

This paper is a continuation of the radial velocity studies of close binary stars by Lu & Rucinski (1999, hereafter Paper I), Rucinski & Lu (1999, hereafter Paper II), Rucinski, Lu, & Mochnacki (2000, hereafter Paper III), and Lu, Rucinski, & Ogłoza (2001, hereafter Paper IV). The main goals and motivations are described in these papers. In short, we attempt to obtain radial velocity data for close binary systems that are accessible to 1.8 m class telescopes at a medium spectral resolution of about $R = 10{,}000$–$15{,}000$. Selection of the objects is quasi-random, in the sense that we have started with short-period (mostly contact) binaries and we attempt to slowly progress to longer periods as the project continues. We publish the results in groups of 10 systems as soon as reasonable orbital elements are obtained from measurements evenly distributed in orbital phases.

This paper is structured in the same way as Papers I–IV, in that most of the data for the observed binaries are in two tables with the radial velocity measurements (Table 1) and their sine-curve solutions (Table 2). Section 2 of the paper contains brief summaries of previous studies for individual systems. The observations reported in this paper have been collected between 1996 October and 2001 February; the ranges of dates for individual systems can be found in Table 1. All systems discussed in this paper 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, in particular, Paper IV for a discussion of the broadening function approach used in the derivation of the velocity amplitudes, K_i, and the center-of-mass velocity, V_0.

The data in Table 2 are organized in the same manner as before. 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. For further technical details and conventions used in the paper, please refer to Papers I–IV of this series.

2. RESULTS FOR INDIVIDUAL SYSTEMS

2.1. *V376 And*

V376 And is one of the new eclipsing binary systems discovered by the *Hipparcos* mission (ESA 1997, hereafter HIP). The early spectral type of the binary is its distinguishing feature. Our estimate is A4 V, not as early as the previous estimates (A0, as given in SIMBAD), yet early enough to be unusual, in that the system looks like a perfect contact binary of the W UMa type. There are very few systems with such an early spectral type among W UMa–type binaries. The relatively long period, 0.799 days, is consistent with the spectral type.

The light curve shows two equally deep minima, so that the choice of the contact binary type is somewhat arbitrary. We chose to use the original ESA (1997) ephemeris, which then leads to the A-type system (the more massive, hotter star eclipsed at minimum corresponding to our T_0). Note, however, that $T_0 = 2{,}451{,}510.5416$, determined by Keskin, Yasarsoy, & Sipahi (2000) from photometric observations obtained during the span of our spectroscopic observations, must then refer to the secondary minimum. These observations are in excellent agreement with our observations in terms of the initial epoch, if allowance of a half-period is made.

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TABLE 1

DDO OBSERVATIONS OF THE FIFTH GROUP OF 10 CLOSE BINARY SYSTEMS

HJD −2,400,000	Phase	V_1	ΔV_1	V_2	ΔV_2
V376 And:					
51,381.8046......	0.3071	−43.2	−0.5	243.5	5.6
51,381.8118......	0.3161	−44.2	−3.0	239.4	6.4
51,381.8195......	0.3257	−42.2	−2.8	221.4	−5.6
51,381.8287......	0.3372	−33.5	3.4	231.8	13.0
51,381.8361......	0.3465	−33.8	0.9	224.7	13.2

NOTES.—Table 1 is available in its entirety in the electronic edition of the Astronomical Journal. A portion is shown here for guidance regarding its form and content. Velocities are expressed in kilometers per second. 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 marked by ellipses; these observations may be eventually used in more extensive modeling of broadening functions. The radial velocities designated as V_1 correspond to the component eclipsed during the primary minimum at the epoch given as T_0 in Table 2.

The average $B-V = 0.28$ estimated from Tycho-2 project data (Hog et al. 2000, hereafter TYC2) agrees with our spectral type if some reddening of $E_{B-V} = 0.1$ is assumed. Then the maximum-light magnitude[4] $V_{\rm max} \simeq 7.63$ and the HIP parallax $p = 5.07 \pm 0.89$ mas lead to $M_V = 0.85 \pm 0.40$, including a correction for interstellar absorption based on the reddening of $E_{B-V} = 0.1$. The period-luminosity-color relation calibrated by Rucinski & Duerbeck (1997, hereafter RD97) gives $M_V = 1.1$. At the large distance of almost 200 pc, the reddening of $E_{B-V} = 0.1$ is entirely possible. The system is apparently one of the intrinsically brightest and bluest contact binaries for which the RD97 calibration appears to apply; the nominal range of the calibration is $0.26 < (B-V)_0 < 1.14$.

Our radial velocity data are of good quality (Fig. 1). The system deserves a combined spectroscopic and photometric analysis because it is an early-type binary that possesses the characteristic properties of a W UMa–type system (equal effective temperatures of components, while the masses are very different, $q = 0.305 \pm 0.005$). The existence of V376 And tells us directly that an outer convective envelope is not a necessary condition for a good thermal contact between components.

2.2. *EL Aqr*

EL Aqr was discovered as a variable star by Hoffmeister (1933) and then rediscovered by Stepien (1968), who correctly identified it as a contact binary system. He determined the period and gave $V_{\rm max} = 10.35$ and $B-V = 0.40$. While $V_{\rm max}$ agrees with estimates based on the HIP and TYC2 data, the latter suggest $B-V = 0.55$, which would not agree well with our estimate of the spectral type, F3 V, unless the system suffers a moderately large reddening of $E_{B-V} \simeq 0.15$. The HIP parallax is small and has a large error, $p = 4.7 \pm 1.9$ mas, so that the absolute magnitude is poorly determined.

Because of the relative faintness of EL Aqr and large zenith distance as seen from the David Dunlap Observatory (DDO), our radial velocity observations have relatively large scatter (Fig. 1). The system is of the A type and has a small mass ratio, $q = 0.203 \pm 0.008$. The ephemeris of Agerer & Hübscher (1999), based on photometric observations obtained during our observations ($T_0 = 2{,}451{,}080.4443$), agrees very well with our determination of T_0.

2.3. *EF Boo*

EF Boo is also a new eclipsing system discovered by the *Hipparcos* mission (ESA 1997). Our radial velocity orbit solution is well defined (Fig. 1) and shows a typical W-type system (the less massive, yet slightly hotter component eclipsed at the primary minimum), albeit of a rather long orbital period of 0.4205 days. The mass ratio is large, $q = 0.512 \pm 0.008$, as is common for W-type systems. The only peculiarity is the spectral type, which shows a complex spectrum consisting of an F5 component and of signatures of a late-G type. We have not been able to detect a third component in the broadening functions, which is surprising in view of the well-defined signatures of two different components in the classification spectrum. The mean $B-V = 0.57$ from TYC2 is in fact consistent with a spectral type half-way between F5 and late G. The HIP parallax, $p = 6.00 \pm 1.06$ mas, is rather small, but the resulting $M_V = 3.15 \pm 0.40$, based on $V_{\rm max} = 9.26$, agrees with the RD97 calibration, $M_V = 3.47$, under an assumption of no reddening.

EF Boo was observed photometrically during our observations (Ozdemir et al. 2001). The closest primary eclipse time $T_0 = 2{,}451{,}719.330$ agrees perfectly with our determination.

2.4. *DN Cam*

DN Cam is another eclipsing binary system discovered by the *Hipparcos* mission. It is similar to the one described above, but it is 1 mag brighter, $V_{\rm max} = 8.14$. As a result, our observations show very little scatter (Fig. 1). The system appears to be an uncomplicated W-type system, again of a rather long orbital period for W type, 0.4983 days. Our spectral type, F2 V, is based on only one spectrum, but it does agree with the TYC2 average, $B-V = 0.36$, if there is no reddening. The parallax is small, $p = 4.49 \pm 0.89$ mas, so that the larger apparent brightness than for EF Boo must be due to a larger intrinsic luminosity. From the parallax, $M_V = 1.4 \pm 0.4$, while the RD97 calibration gives $M_V({\rm cal}) = 2.6$, so that there appears some discrepancy here.

DN Cam has not been observed photometrically since the discovery by *Hipparcos*. Our determination of T_0 is fully consistent with the original ephemeris, $T_0 = 2{,}448{,}500.488$. It should be noted that the HIP light curve shows practically equally deep eclipses, so that the matter of the type of the system (A or W) is uncertain and awaits detailed modeling.

2.5. *FN Cam*

FN Cam is another *Hipparcos* discovery. It is an A-type system (Fig. 2) with a well-defined radial velocity orbital solution and a moderately long period, 0.6771 days. The original HIP epoch, $T_0 = 2{,}448{,}500.427$, agrees well with our determination of T_0. Again, the eclipses are almost equally deep in this case.

[4] The maximum-light magnitude for this and subsequent stars has been estimated in two ways, with the average value adopted: (1) on the basis of maximum magnitude, $H_p(5\%)$ (the upper fifth percentile), using a linear fit, $(V-H_p) = -0.03 + 0.155(B-V)$, which has been determined on the basis of the ESA (1997) data and is applicable in the range $0.1 < (B-V) < 0.8$ (both $H_p(5\%)$ and $V-H_p$ are described in ESA 1997); (2) from the average V in TYC2, corrected by one-half of the photometric amplitude.

TABLE 2

SPECTROSCOPIC ORBITAL ELEMENTS OF THE FIFTH SET OF 10 CLOSE BINARY SYSTEMS

Name (1)	Type, Spectral Type (2)	Other Names (3)	V_0 (4)	K_1, K_2 (5)	ϵ_1, ϵ_2 (6)	T_0 −2,400,000, $(O-C)$, [E] (7)	P (days), $(M_1+M_2)\sin^3 i$ (8)	q (9)
V376 And...........	EW/A	HD 15922	+22.83 (0.89)	70.00 (0.67)	4.17	51,644.3215 (24)	0.798669	0.305 (5)
	A4 V	HIP 12039	...	229.67 (1.78)	13.20	+0.0028 [167.5]	2.232 (55)	...
EL Aqr	EW/A	BD −08°6189	+12.51 (2.08)	53.38 (1.53)	8.88	51,109.3334 (32)	0.481410	0.203 (8)
	F3 V	HIP 117317	...	263.34 (4.38)	23.49	+0.0049 [60]	1.588 (89)	...
EF Boo	EW/W	HD 234150	−13.16 (1.07)	122.84 (1.10)	5.28	51,725.2174 (12)	0.429512	0.512 (8)
	F5+late G:	HIP 71107	...	239.90 (2.25)	11.67	+0.0003 [14]	2.129 (59)	...
DN Cam............	EW/W	HD 29213	+6.04 (0.98)	105.45 (0.65)	4.13	51,679.6954 (12)	0.498312	0.421 (6)
	F2 V:	HIP 21913	...	250.62 (1.91)	13.04	−0.0232 [6380]	2.336 (50)	...
FN Cam	EW/A	HD 79886	+12.96 (1.11)	59.62 (0.93)	5.20	51,351.1554 (24)	0.677128	0.222 (5)
	A9, F2	HIP 46005	...	269.01 (2.10)	11.50	+0.0195 [4210]	2.496 (69)	...
V776 Cas	EW/A	BD +69°121	−24.71 (0.69)	31.97 (0.64)	2.58	51,788.2184 (8)	0.440413	0.130 (4)
	F2V	HIP 8821	...	245.31 (1.83)	12.04	+0.0099 [2210][a]	0.975 (26)	...
SX Crv...............	EW/A	HD 110139	+8.71 (0.94)	18.28 (0.74)	3.98	51,070.8192 (10)	0.316622	0.066 (3)
	F6 V, F7 V	HIP 61825	...	278.70 (2.43)	21.44	+0.0129 [8119]	0.861 (28)	...
V351 Peg	EW/W	HD 220659	−8.08 (0.89)	87.37 (0.83)	3.83	51,418.3205 (15)	0.593297	0.360 (6)
	A8 V	HIP 115627	...	242.62 (1.99)	16.89	−0.0091 [1173][b]	2.214 (57)	...
EQ Tau	EW/A	...	+71.95 (1.22)	112.41 (1.43)	7.46	51,183.9030 (9)	0.341348	0.442 (7)
	G2:	...	...	254.38 (2.42)	13.15	+0.0023 [2305]	1.749 (55)	...
KZ Vir...............	EW/A	HD 114726	−4.50 (0.48)	111.40 (0.77)	3.10	51,414.7848 (11)	1.131820	0.848 (8)
	F7 V	HIP 64433	...	131.34 (0.87)	3.82	+0.0318 [2575]	1.681 (34)	...

NOTES.—The spectral types given in column (2) are all new. The convention of naming the binary components is that the subscript 1 designates the component that is more massive so that the mass ratio is defined to be always $q \leq 1$. The standard errors of the circular solutions in the table are expressed in units of last decimal places quoted; they are given in parentheses after each value. For example, the last table entry for the mass ratio q, 0.848(8), should be interpreted as $q = 0.848 \pm 0.008$. The center-of-mass velocities (V_0), the velocity amplitudes (K_i), and the standard unit-weight errors of the solutions (ϵ) are expressed in kilometers per second. 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] V776 Cas: T_0 has been advanced from the published time to the mean time of observations, HJD = 2,450,814.8957.

[b] V351 Peg: Same as for V776 Cas, HJD = 2,450,722.3918.

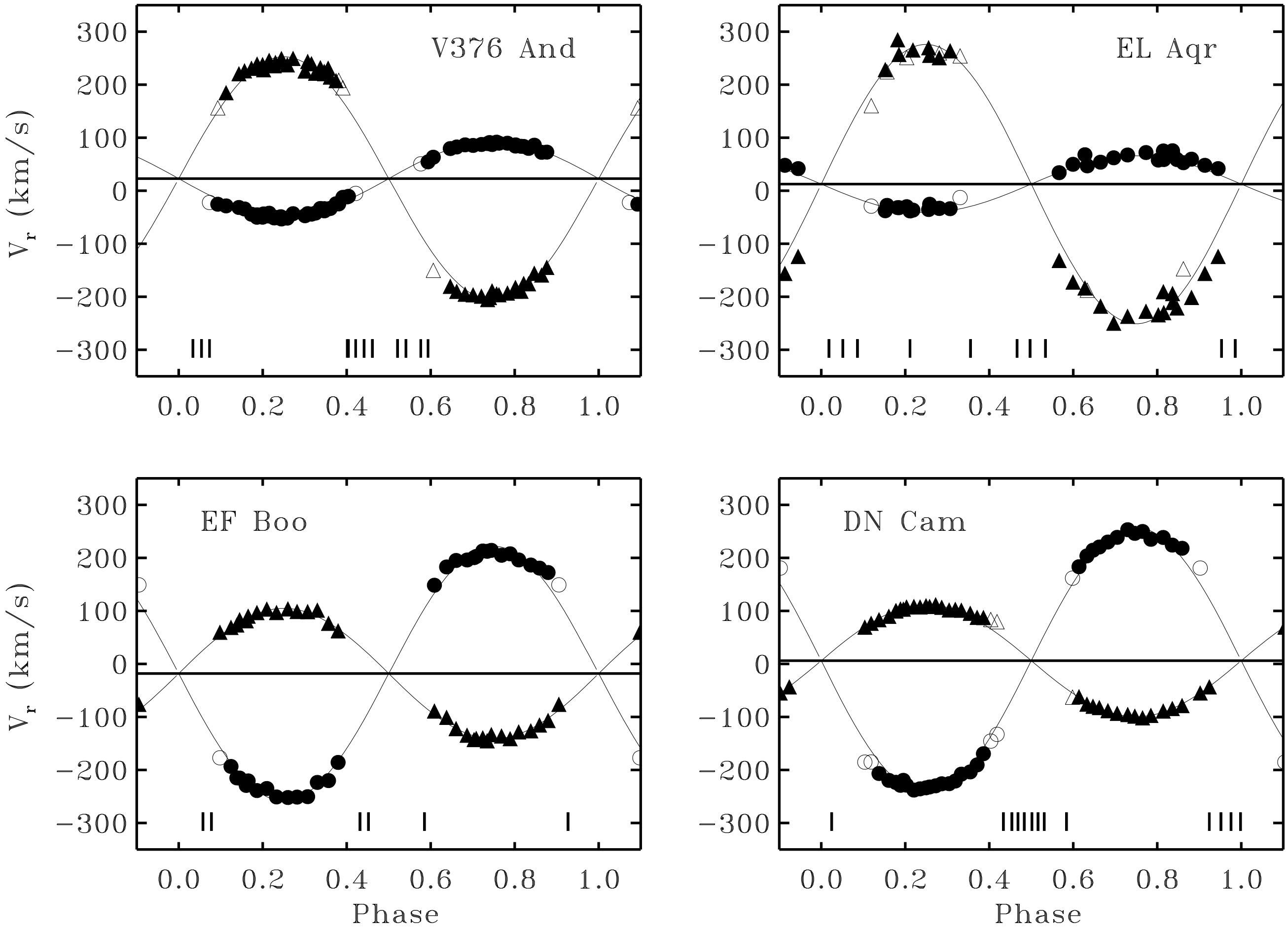

FIG. 1.—Radial velocities of the systems V376 And, EL Aqr, EF Boo, and DN Cam are plotted in individual panels vs. orbital phases. The lines give the respective circular-orbit (sine-curve) fits to the radial velocities. V376 And and EL Aqr are A-type systems, while EF Boo and DN Cam are W-type systems. The circles and triangles in this and the next two figures correspond respectively to components eclipsed at the minimum corresponding to T_0 (as given in Table 2) or half a period later, while 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 ranges, -350 to $+350$ km s^{-1}.

Our independent estimates of the spectral type are not entirely consistent, A9 and F2, but agree with the spectral type estimated before (F2 in SIMBAD). The TYC2 value of $B-V = 0.41$ would be consistent with the spectral type only if some reddening of about $E_{B-V} = 0.05$ was present. For $V_{\max} = 8.47$, $p = 3.62 \pm 0.95$ mas, $M_V = 1.1 \pm 0.6$, while $M_V(\text{cal}) = 2.0$. FN Cam has the largest value of $(M_1 + M_2) \sin^3 i = 2.50 \pm 0.07\ M_\odot$ among the binary systems of this group.

2.6. *V776 Cas*

V776 Cas was discovered as an eclipsing binary by the *Hipparcos* mission. It appeared in Duerbeck (1997) as V778 Cas with the period 2 times longer than the actual period of the binary. The binary is a contact, A-type system of a very small mass ratio, $q = 0.130 \pm 0.004$. The HIP light curve has a small amplitude, which is consistent with the relatively small $(M_1 + M_2) \sin^3 i = 0.975 \pm 0.026\ M_\odot$, both most probably due to a low orbital inclination.

The star was observed photometrically after the HIP discovery by Gomez-Forrellad et al. (1999). They did not publish their original eclipse times but reduced them to the HIP moments. The restored time for the time of their observations, as given in Table 2, $T_0 = 2{,}450{,}814.8957$, agrees very well with our determination.

Our spectral type, F2 V, would agree with the TYC2 average $B-V = 0.47$ if some reddening of about $E_{B-V} = 0.1$ were present. With $V_{\max} = 8.92$ and $p = 4.86 \pm 1.56$, $M_V = 2.0 \pm 0.7$, while the RD97 calibration predicts $M_V(\text{cal}) = 2.8$.

V776 Cas is the brighter member of the visual binary ADS 1485. The companion, at a separation of 5″.38, is 2 mag fainter than the contact binary. We avoided the companion in our radial velocity observations of V776 Cas but observed its velocity on two occasions with the following results: HJD = 2,451,769.800, $V_r = -26.4$ km s^{-1} and HJD = 2,451,806.715, $V_r = -27.4$ km s^{-1}.

2.7. *SX Crv*

This is definitely the most interesting among this group of binaries because of the extremely small mass ratio that we found, $q = 0.066 \pm 0.003$. This is not only a new "record" for a contact binary, surpassing the well-known case of AW UMa with $q = 0.075$, but also a bit of an embarrassment for the theory that currently predicts a cutoff at about $q = 0.09$ (Rasio 1995). The binary is similar to AW UMa in being the

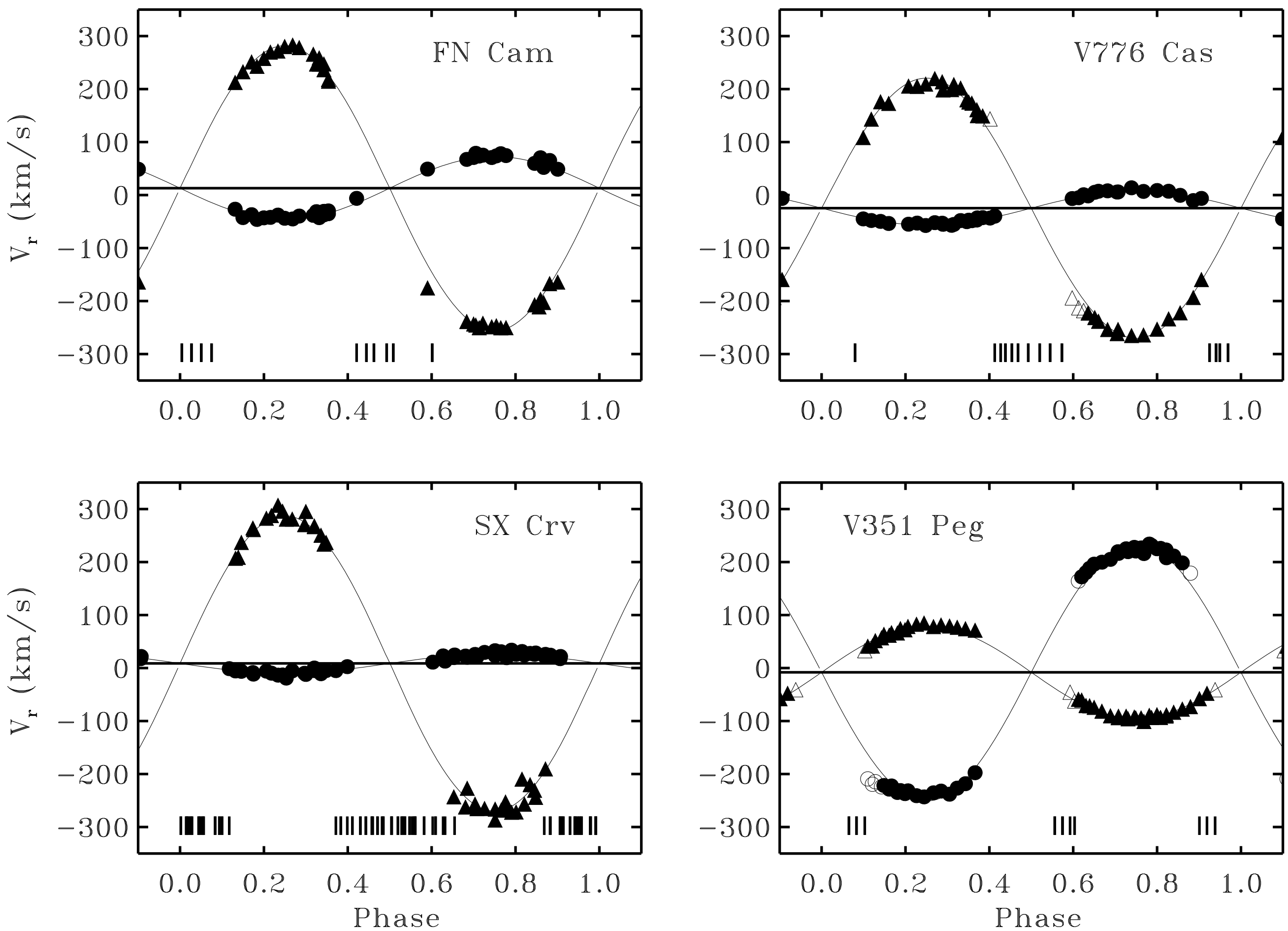

FIG. 2.—Same as for Fig. 1, but with the radial velocity orbits for the systems FN Cam, V776 Cas, SX Crv, and V351 Peg. Only V351 Peg is a W-type system, the others are A-type systems. SX Crv is a new record holder with a mass ratio of only $q = 0.066 \pm 0.003$.

extreme mass ratio A-type system, but its spectral type is slightly later, F6/7 V and the period is shorter, 0.3166 days, compared with F0/2 V and 0.4387 for AW UMa.

The discovery of spectral signatures of the secondary component in SX Crv was not easy. In fact, without any new photometric data, we unnecessarily collected many observations during conjunctions, assigning our initial inability to detect the secondary to a possible problem with the initial epoch and/or to a variable period. Only later on did we realize that a weak signature of the secondary was detectable in our broadening functions, in spite of the large ratio of masses of 15:1. To calculate the orbital phases, we used the HIP data on the period and the initial epoch (T_0 = 2,448,500.1539).

The binary was discovered by Sunwal et al. (1974). Photometry of Scaltriti & Busso (1984) showed a shallow light curve with an amplitude of about 0.2 mag and $V_{\rm max} \simeq 8.95$. Our estimate is slightly fainter, $V_{\rm max} = 8.99$. The TYC2 color index, $B-V = 0.52$, agrees with our spectral type, F6/7 V. The HIP parallax is the largest for this group of binaries, $p = 10.90 \pm 1.21$ mas, leading to $M_V = 4.18$ 0.25, which is consistent with the RD97 calibration, M_V(cal) = 3.91.

The HIP light curve is rather poorly covered, so it is difficult to say if the secondary eclipse of SX Crv is total. It may be actually the case because—for a small q—total eclipses take place over a wide range of the inclinations; also, an amplitude as "large" as the observed 0.2 mag is not easy to obtain for such a small mass ratio without the inclination being sufficiently large to produce total eclipses. When related to the expected mass for the spectral type of F6/7 V, $(M_1 + M_2)\sin^3 i = 0.861 \pm 0.028\ M_\odot$ is small; this suggests a moderately low inclination angle, $i \simeq 60°$–$70°$. Figure 3 in Mochnacki & Doughty (1972) gives the angle of the internal contact for total eclipses. With $q = 0.066$, no total secondary eclipses are expected for $i < 66^\circ\!.5$, but for inclinations larger than this angle, the internal contact angle sensitively depends on i. For $i = 70°$ and $q = 0.066$, the internal contact angle already reaches a rather easy to detect value of $\psi_i \simeq 14°$. Thus, detection of totality in the secondary eclipses will provide a powerful check on our spectroscopic determination and a very good opportunity to determine an accurate total mass of the system.

SX Crv deserves a full combined spectroscopic and photometric solution based on modern, accurate photometric observations. It is one of the most interesting close binary systems currently known and has a potential of increasing our knowledge of the critical, perhaps final, stages in contact of very close binary systems.

2.8. *V351 Peg*

V351 Peg was discovered to be an eclipsing binary by the *Hipparcos* mission. It is listed in the HIP catalog with the period equal to one-half of the actual one (0.5933 days),

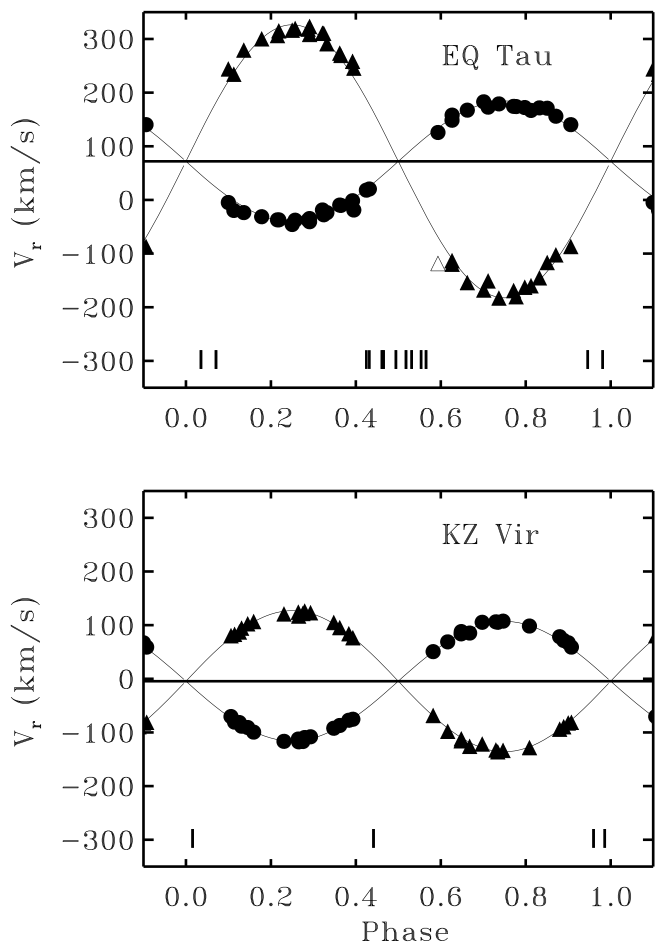

FIG. 3.—Same as for Fig. 1, for the systems EQ Tau and KZ Vir. EQ Tau is a relatively inconspicuous system close in the sky to the Pleiades. It is most likely behind the cluster and appears to have an exceptionally large spatial velocity. This is indicated also by the large center-of-mass velocity, V_0, as shown in the figure. KZ Vir is probably a close but noncontact system of two similar, distorted stars.

apparently due to the identical depths of the eclipses. We used a period 2 times longer than in the HIP catalog but kept the original initial epoch for consistency with these observations; then the system is of the W type. The system was subsequently photometrically observed by Gomez-Forrellad et al. (1999). Their published value, advanced to the actual time of the observations, is $T_0 = 2{,}450{,}722.3918$. Our determination is fully consistent with this determination.

V351 Peg is a bright star, $V_{max} = 7.92$, but its HIP parallax is only moderately large, $p = 7.34 \pm 0.92$ mas. The average TYC2 color index, $B-V = 0.32$, requires some reddening of $E_{B-V} = 0.05$ to reconcile with our spectral type, A8 V (the previous spectral type was A9 III, quoted in SIMBAD). With these data, $M_V = 2.09 \pm 0.28$, while $M_V(\mathrm{cal}) = 1.94$. Thus, the star is not as blue and luminous as V376 And described at the beginning of this section, but is nevertheless one of the good examples of an early-type, genuine-contact, unequal component-mass system.

2.9. *EQ Tau*

EQ Tau is the only system in this group that was not observed by *Hipparcos*. It is best known for the fact that it is located in the area of Pleiades and sometimes is mentioned in this context (Popova & Kraicheva 1984). However, a note in the General Catalogue of Variable Stars (Kholopov et al. 1985–1988) specifically mentions that the system is not a member of Pleiades, probably on the basis that it is too faint to be located on or above the main sequence of the cluster.

The binary was discovered and observed by Tsesevich (1954). New photometric observations were obtained by Benbow & Mutel (1995) and Buckner, Nellermoe, & Mutel (1998). We have used the more recent of these eclipse time predictions, $T_0 = 2{,}450{,}396.925$, with $P = 0.3413471$ days, which served our spectroscopic observations very well.

EQ Tau is too faint to be included in the HIP catalog but appears in TYC2 with the average $V = 11.28$, $B-V = 0.98$. The color index is much redder than implied by our spectral type, G2, although this estimate is uncertain. It is possible that the star is reddened by the interstellar matter in the Pleiades cluster. The proper motion of the star is exceptionally large, in fact the largest among stars of this group, $\mu_\alpha \cos(\delta) = +68.4 \pm 1.4$ mas, $\mu_\delta = -29.6 \pm 1.5$ mas. If we assume that the star is at the distance of the Pleiades and use the Pleiades' parallax following van Leeuwen (1999), $p = 8.45 \pm 0.25$ mas (118 pc), then $V_\alpha = +38$ km s^{-1}, $V_\delta = -17$ km s^{-1}, and $M_V \simeq 5.5$. For an assumed larger, arbitrary, but plausible, distance of 200 pc ($p = 5$ mas), $V_\alpha = +65$ km s^{-1}, $V_\delta = -28$ km s^{-1}, and $M_V \simeq 4.3$. The large spatial velocity is certainly strongly indicated by our center-of-mass velocity, $V_0 = +72$ km s^{-1}. Thus, the star, even if not a member of the Pleiades, is very interesting as a large spatial motion object. Despite the relative faintness of EQ Tau for our telescope, its spectroscopic orbit is relatively well defined (Fig. 3).

2.10. *KZ Vir*

KZ Vir is another *Hipparcos* eclipsing binary discovery that apparently has not been observed photometrically since; for that reason we used $T_0 = 2{,}448{,}500.3165$ from the HIP catalog. KZ Vir has been included in our program mostly because of its large apparent brightness ($V_{max} = 8.36$). It is an interesting object: If it is a contact binary, then it has a surprisingly late spectral type, F7, for its relatively long orbital period of 1.13 days. The mass ratio is not typical for the majority of contact binaries, $q = 0.85$, but such rare systems occasionally exist.

The average TYC2 value of $B-V = 0.48$ agrees with the spectral type of F7. The HIP parallax, $p = 6.53 \pm 0.93$, with no reddening gives $M_V = 2.43 \pm 0.32$. This luminosity estimate is in some conflict with the RD97 contact binary calibration, which predicts a much larger brightness, $M_V(\mathrm{cal}) = 1.33$. This is a strong indication that the system has much less radiating area than a contact system and is a close, but detached binary.

The velocity amplitudes are relatively small, which would be consistent with the small photometric amplitude (0.07 mag), both probably caused by a low orbital inclination. The small photometric amplitude could also result from a moderate distortion of its detached components.

3. SUMMARY

The paper presents radial velocity data and orbital solutions for the fifth group of 10 close binary systems, which we observed at the DDO. None were observed spectroscopically before. All systems are double-lined (SB2) binaries with visible spectral lines of both components. All, with the possible exception of KZ Vir with the period of 1.13 days, are contact binaries. The values of $(M_1 + M_2) \sin^3 i = 1.0385 \times 10^{-7}(K_1 + K_2)^3 P(\text{days})\ M_\odot$ are given in Table 2.

Although our selection of targets is quite unsystematic, we keep discovering very interesting objects. Seven of the systems are new photometric discoveries of the *Hipparcos* project. The magnitude-limited nature of the HIP survey has led to an emphasis on relatively luminous, massive, early-type (mid-A to early-F) systems. V376 And, DN Cam, FN Cam, V776 Cas, and V351 Peg are such binaries; they have typical properties of contact systems, with the mass ratio far from unity.

The most interesting discovery of this series is undoubtedly the very small mass ratio of SX Crv, $q = 0.066 \pm 0.003$. This becomes now the smallest known mass ratio among contact binaries, taking the record from the well-known AW UMa. The detection of the low-mass companion was possible mostly thanks to the superior capabilities of the broadening function approach (Rucinski 1999). Together with $q = 0.970 \pm 0.003$ determined in Paper III for V753 Mon, our spectroscopic observations have resulted in determinations of the most extreme values of the mass ratio observed in contact binaries. The very small mass ratio for SX Crv strongly suggests that AW UMa is not an exception, and that mass ratios smaller than the theoretically predicted lower limit of $q_{\min} \simeq 0.09$ (Rasio 1995) certainly exist.

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