The Astronomical Journal, 120:1133–1139, 2000 August

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

Slavek M. Rucinski, Wenxian Lu, and Stefan W. Mochnacki
David Dunlap Observatory, University of Toronto, P.O. Box 360, Richmond Hill, ON L4C 4Y6, Canada; rucinski@astro.utoronto.ca, lu@astro.utoronto.ca, mochnacki@astro.utoronto.ca
Received 2000 February 3; accepted 2000 April 5

ABSTRACT

Radial velocity measurements and simple sine-curve fits to the orbital velocity variations are presented for the third set of 10 close binary systems: CN And, HV Aqr, AO Cam, YY CrB, FU Dra, RZ Dra, UX Eri, RT LMi, V753 Mon, and OU Ser. All systems except two (CN And and RZ Dra) are contact, double-line spectroscopic binaries, with four of them (YY CrB, FU Dra, V753 Mon, and OU Ser) being the recent discoveries of the *Hipparcos* satellite project. The most interesting object is V753 Mon with the mass ratio closest to unity among all contact systems ($q = 0.970 \pm 0.003$) and large total mass [$(M_1 + M_2)\sin^3 i = 2.93 \pm 0.06$]. 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

1. INTRODUCTION

This paper is a continuation of the radial velocity studies of close binary stars, Lu & Rucinski (1999, hereafter Paper I) and Rucinski & Lu (1999, hereafter Paper II). The main goals and motivations are described in these papers. In short, we attempt to obtain modern radial velocity data for close binary systems which are accessible to the 1.8 m–class telescopes at medium spectral resolution of about $R = 10{,}000$–$15{,}000$. Selection of the objects is quasi-random in the sense that we started with shortest period contact binaries. The intention is to publish the results in groups of 10 systems as soon as reasonable orbital elements can be obtained from measurements evenly distributed in orbital phases. We are currently observing a few dozen such systems. The rate of progress may slow down, as we move into the domain of long-period systems.

This paper is structured in the same way as Papers I and II in that it consists of two tables containing the radial velocity measurements (Table 1) and their sine-curve solutions (Table 2) and of brief summaries of previous studies for individual systems. The reader is referred to the previous papers for technical details of the program. In short, all observations described here were made with the 1.88 m telescope of the David Dunlap Observatory (DDO) of the University of Toronto. The Cassegrain spectrograph giving the scale of 0.2 Å pixel^{-1}, or about 12 km s^{-1} pixel^{-1}, was used; the pixel size of the CCD was 19 μm. A relatively wide spectrograph slit of 300 μm corresponded to the angular size on the sky of 1.″8 and the projected width of 4 pixels. The spectra were centered at 5185 Å with the spectral coverage of 210 Å. The exposure times were typically 10–15 minutes long. The observations have been collected between 1996 December and 1999 December; the ranges of dates for individual systems can be found in Table 1.

The data in Table 2 are organized in approximately the same manner as in Paper II. 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, in the first column after the star name, our new spectral classifications of the program objects. The classification spectra were obtained with a grating giving a dispersion of 0.62 Å pixel^{-1} in the range 3850–4450 Å. The program star spectra were "interpolated" between spectra of standard stars in terms of relative strengths of lines known as reliable classification criteria.

In the radial velocity solutions of the orbits, the data have been assigned weights on the basis of our ability to resolve the components and to fit independent Gaussians to each of the broadening function peaks. Weight equal to zero in Table 1 means that an observation was not used in our orbital solutions; however, these observations may be utilized in detailed modeling of broadening functions, if such are undertaken for the available material. The full-weight points are marked in the figures by filled symbols while half-weight points are marked by open symbols. Phases of the observations with zero weights are shown by short markers in the lower parts of the figures; they were usually obtained close to the phases of orbital conjunctions.

All systems discussed in this paper except one have been observed for radial velocities for the first time. The only exception is RZ Dra, for which an SB1 orbit solution was obtained by Struve (1946). The solutions presented in Table 2 for the four circular-orbit parameters, γ, K_1, K_2, and T_0, have been obtained iteratively, with fixed values of the orbital period. First, two independent least-squares solutions for each star were made using the same programs as described in Papers I and II. Then, one combined solution for both amplitudes and the common γ was made with the fixed mean value of T_0. Next, differential corrections for γ, K_1, K_2, and T_0 were determined, providing best values of the four parameters. These values are given in Table 2. The corrections to γ, K_1, K_2, and T_0 were finally subject to a bootstrap process (several thousand solutions with randomly drawn data with repetitions) to provide the median values and ranges of the parameters. We have adopted them as measures of uncertainty of parameters in Table 2.

Throughout the paper, when the errors are not written otherwise, we express standard mean errors in terms of the last quoted digits; e.g., the number 0.349 (29) should be interpreted as 0.349 ± 0.029.

[1] Based on data obtained at the David Dunlap Observatory, University of Toronto.

TABLE 1

DDO Observations of the Third Group of 10 Close Binary Systems

HJD (2,400,000)	Phase	V_1	ΔV_1	V_2	ΔV_2
CN And:					
50,615.7873......	0.3120	−107.6	−1.8	178.0	−4.7
50,615.7986......	0.3364	−105.5	−5.7	154.6	−12.6
50,615.8112......	0.3636	−91.3	−0.3	133.3	−11.4
50,615.8222......	0.3874	−73.2	8.6	92.0	−28.9
50,615.8339......	0.4127	−52.5	18.0	...	...

Note.—Velocities are expressed in km s^{-1}. Observations leading to entirely unseparable broadening and correlation function peaks are marked by ellipses; these observations may be eventually used in more extensive modeling of broadening functions. 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.

2. RESULTS FOR INDIVIDUAL SYSTEMS

2.1. *CN And*

The variability of CN And was discovered by Hoffmeister (1949). Modern light curves were presented by Kałużny (1983), Rafert, Markworth, & Michaels (1985), Keskin (1989), and Samec et al. (1998). The light curve is of the EB type, with unequally deep eclipses. From the eclipse timing, there exists a clear indication of a continuous period decrease. We used the determination of the primary eclipse time, T_0, by Samec et al. (1998), which was almost contemporary with our observations; the period was from the same source. The radial velocity curve of the secondary component (see Fig. 1) shows some asymmetry in the first half of the orbital period, which may explain why our T_0 is shifted by −0.014 days to earlier phases. From the radial velocity point of view, the system looks like a typical A-type contact binary, but it could also be a very close semidetached system.

Two groups of investigators attempted solutions of the light curves for orbital parameters, disregarding the lack of any information on the spectroscopic mass ratio. Our $q_{sp} = 0.39 \pm 0.03$ differs rather drastically from these photometric estimates. Kałużny (1983) expected the mass ratio to be within $0.55 < q_{ph} < 0.85$. Rafert et al. (1985) found the most likely interval to be $0.5 < q_{ph} < 0.8$; they saw indications of a strong contact. The matter of the contact or semidetached nature of the system should be revisited in view of the discrepancy between our q_{sp} and the previous estimates of q_{ph}.

The photometric data at maximum light were published by Kałużny (1983): $V = 9.62$, $B-V = 0.45$. The system is apparently a moderately strong X-ray source (Shaw, Caillault, & Schmitt 1996).

2.2. *HV Aqr*

The variability of HV Aqr was discovered relatively recently by Hutton (1992). The type of variability was identified by Schirmer (1992) and a preliminary, but thorough study was presented by Robb (1992). The system shows total eclipses at the shallower of the two minima, so it is definitely an A-type one. This circumstance is important to our results because neither available ephemerides of Schirmer and Robb predict the primary minimum correctly, and we are not sure how our radial velocity (Fig. 1) observations relate to the photometric observations: our T_0 falls at phase 0.47 for the former and at 0.70 for the latter. Probably the

TABLE 2

Spectroscopic Orbital Elements of the Third Group of 10 Close Binary Systems

Name, Type	Type	Other Names	γ	K_1 / K_2	ϵ_1 / ϵ_2	$T_0 - 2{,}400{,}000$ / $O-C$ and [E]	P (days) / $(M_1 + M_2)\sin^3 i$	$q = m_2/m_1$
CN And, F5 V	A/EB	BD +39°59	−24.86 (1.45)	87.53 (1.11)	6.10	50,850.2790 (22)	0.462793	0.390 (33)
				224.35 (2.84)	18.03	−0.0137 [327]	1.458 (55)	
HV Aqr, F5 V..........	A	BD −3°5183	−3.77 (1.25)	42.41 (1.44)	4.83	50,859.3453 (8)	0.374460	0.145 (50)
				293.35 (2.11)	11.46	[a]	1.472 (47)	
AO Cam, G0 V	W	BD +52°826	−13.17 (0.83)	250.50 (1.05)	6.47	50,960.1131 (5)	0.329905	2.420 (11)
				103.51 (1.28)	5.50	−0.0121 [13732]	1.520 (30)	$1/q = 0.413$
YY CrB, F8 V..........	A	HD 141990	−4.58 (1.02)	68.07 (1.54)	7.79	50,955.8711 (6)	0.376565	0.243 (23)
		HIP 77598		279.85 (1.55)	14.13	−0.0053 [6521]	1.647 (44)	0.243 (23)
FU Dra, F8 V..........	W	HIP 76272	−11.38 (1.14)	280.76 (2.09)	8.68	50,866.2777 (8)	0.306718	3.989 (30)
				70.38 (1.84)	7.51	−0.0086 [7714]	1.379 (46)	$1/q = 0.251$
RZ Dra, A6 V..........	A/EB	HIP 90092	10.68 (1.76)	96.85 (1.72)	7.53	51,035.4103 (28)	0.550876	0.396 (37)
				244.47 (3.54)	22.22	−0.0165 [39186]	2.28 (10)	
UX Eri, F9 V..........	A	BD −7°553	12.79 (1.09)	91.75 (1.55)	6.81	50,416.5587 (14)	0.445279	0.373 (21)
		HIP 14699		245.76 (1.86)	10.09	+0.0030 [−78]	1.798 (54)	0.373 (21)
RT LMi, F7 V	A		−10.30 (1.74)	95.34 (1.67)	7.28	51,261.1008 (16)	0.374918	
				260.17 (3.59)	15.68	−0.0016 [41056]	1.749 (78)	
V753 Mon, A8 V	W	HD 54975	38.58 (0.83)	176.07 (0.97)	8.84	51,188.0809 (15)	0.677049	1.031 (9)
		HIP 34684		170.76 (0.97)	6.80	−0.0249 [3970]	2.933 (56)	$1/q = 0.970$
OU Ser, F9/G0 V......	A	HD 136924	−64.08 (0.41)	40.59 (0.59)	3.80	50,901.9916 (3)	0.296764	0.173 (17)
		HIP 75269		234.24 (0.69)	5.97	+0.0026 [8093]	0.640 (9)	

Note.—The convention of naming the components is that the subscript 1 designates the component that is eclipsed at the deeper minimum and is therefore the hotter one. 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 q, 0.173 (17) should be interpreted as 0.173 ± 0.017. The average radial velocities (γ), the velocity amplitudes (K_i) and the standard unit-weight errors of the solutions (ϵ) are expressed in km s^{-1}. The observed moments of primary minima are given by T_0 while their $O-C$ 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].

[a] The two available ephemerides for moments of primary minima of HV Aqr give discordant results and do not provide a clear guidance to which eclipse our T_0 applies. It has been assumed that the system is A type on the basis of the light curve data; see text.

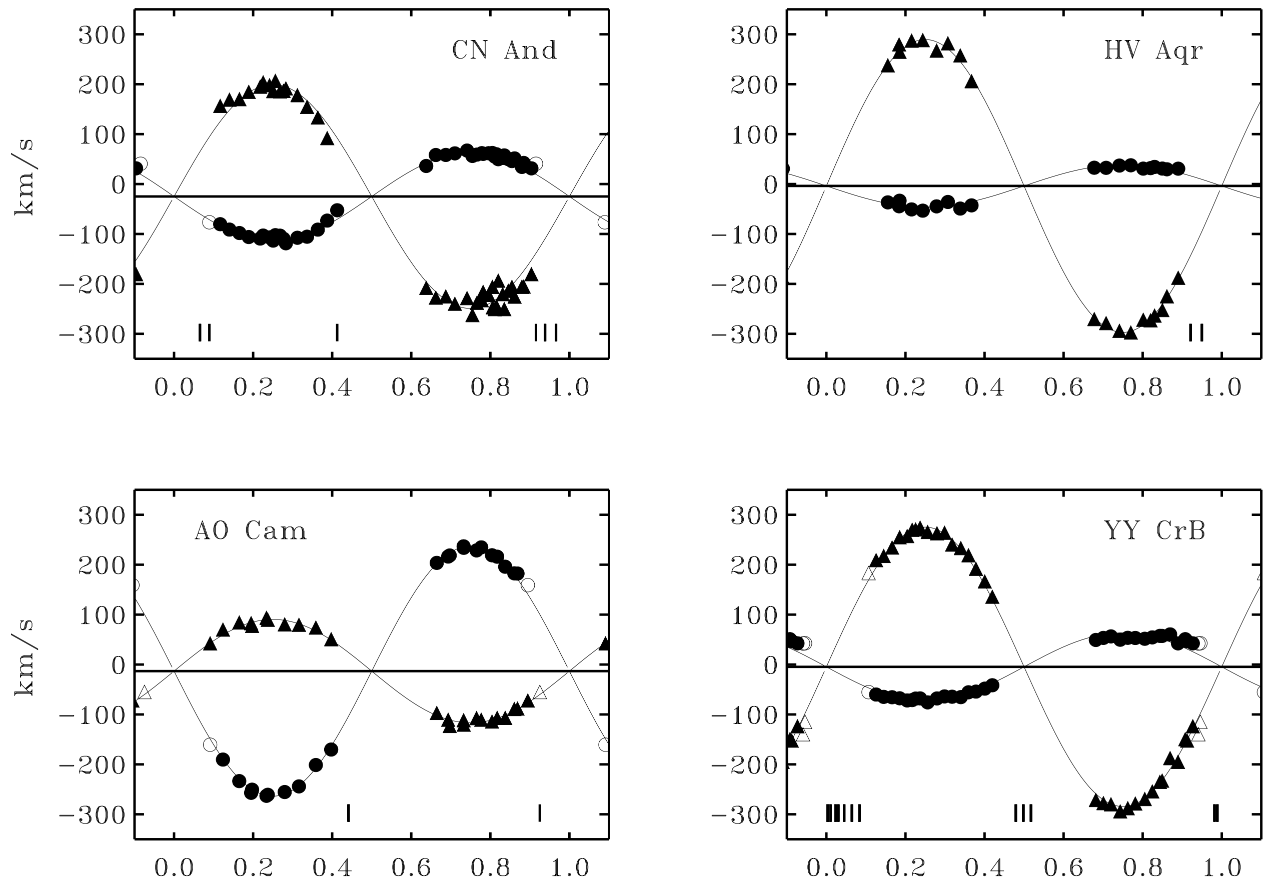

FIG. 1.—Radial velocities of the systems CN And, HV Aqr, AO Cam, and YY CrB plotted in individual panels vs. orbital phases. The thin lines give the respective circular-orbit (sine-curve) fits to the radial velocities. Note that AO Cam is a W-type system while the rest are A-type systems. Short marks in the lower parts of the panels show phases of available observations which were not used in the solutions because of the blending of lines. Open symbols in this and the next two figures indicate observations given half-weights in the solutions. All panels have the same vertical scales.

values of the orbital period are slightly incorrect for both ephemerides. We used the period of 0.374460 days, following Schirmer (1992); if this is incorrect, then part of the scatter in our data may be due to the incorrect phasing over the span of 450 days of our observations.

The mass ratio of HV Aqr is small, $q_{\rm sp} = 0.145 \pm 0.05$. It agrees perfectly with the photometric solution of Robb (1992) of $q_{\rm ph} = 0.146$, which confirms the validity of the photometric approach for totally eclipsing systems, in contrast with the typical lack of agreement for partially eclipsing systems.

Our spectral type of F5 V does not agree with the observed color index $B-V = 0.63$–0.78 for the reddening of $E_{B-V} = 0.08$ as suggested by Robb (1992; using the spectral type vs. color relation of Popper 1980). For agreement, the reddening should be $E_{B-V} \simeq 0.2$. The system is bright, with $V = 9.80$, and it is potentially one of the best for a combined spectroscopic-photometric solution.

2.3. *AO Cam*

The variability of AO Cam was discovered by Hoffmeister (1966). Milone, Piggott, & Morris (1982) analyzed their photometric observations in a simplified way. Subsequent photometric solution by Evans, Grossoehme, & Moyer (1985) and even the sophisticated work of Barone et al. (1993) did not bring much progress in view of the partial eclipses and total lack of any information on the mass ratio. Barone et al. (1993) stated that AO Cam is definitely a W-type system; they estimated the photometric mass ratio at $q_{\rm ph} = 1.71 \pm 0.04$ or $1/q = 0.585$. This value is very different from our spectroscopic result, $q_{\rm sp} = 0.413 \pm 0.011$, but we do confirm the W type of the system.

AO Cam does not have any *UBV* data. Our spectral classification is G0 V. In view of its considerable brightness of $V = 9.50$ at maxima, it appears to be a somewhat neglected system.

To predict the moment of the primary eclipse T_0, we used the ephemeris based on the period of Evans et al. (1985) and the observations of the *secondary eclipses* by Faulkner (1986). The $O-C$ deviation is relatively small, despite many orbital periods having elapsed since Faulkner's observations.

2.4. *YY CrB*

YY CrB is one of the variable stars discovered by the *Hipparcos* satellite mission (ESA 1997). The only available light curve comes from this satellite; the star has not been studied in any other way. There are no obvious indications of total eclipses, but the coverage of eclipses is relatively poor, so that it is possible that the minimum identified as the primary is not the deeper one. We used the primary minimum ephemeris of *Hipparcos*, and this results in a contact system of type A, that is, one with the more massive and hotter component eclipsed at this minimum.

The system is bright, $V_{\rm max} = 8.64$, and its *Hipparcos* parallax is relatively large and well determined,

$p = 11.36 \pm 0.85$ mas, giving a good estimate of the absolute magnitude of the system, $M_V = 3.92 \pm 0.16$. With $B-V = 0.62 \pm 0.02$ from the *Hipparcos* database, the $M_V(\log P, B-V)$ calibration (Rucinski & Duerbeck 1997) gives $M_V^{\rm cal} = 3.88$, so that the agreement is perfect. Our spectral classification of F8 V agrees with the $B-V$ color index.

With the very good parallax and the new radial velocity data (Fig. 1), YY CrB is one of the systems with a great potential for providing an excellent combined photometric and spectroscopic solution.

2.5. *FU Dra*

FU Dra is another *Hipparcos* discovery. Again, we assumed the primary eclipse identification and its ephemeris as in the *Hipparcos* publication (ESA 1997). With these assumptions, the system appears to belong to the W-type systems. The mass ratio is somewhat small for such systems, $q_{\rm sp} = 0.25 \pm 0.03$.

The system is bright, $V_{\rm max} = 10.55$, but its *Hipparcos* parallax is only moderately well determined, $p = 6.25 \pm 1.09$ mas, resulting in the absolute magnitude $M_V = 4.53 \pm 0.38$. The system was measured by the *Hipparcos* project to have a relatively large tangential motion, $\mu_{\rm RA} = -255.85 \pm 1.18$ mas and $\mu_{\rm decl} = 16.61 \pm 1.18$ mas. The large proper motion had been noticed before (Lee 1984a, 1984b, star number G224-73), but the spatial velocity was then estimated assuming an uncertain spectroscopic parallax. Using the *Hipparcos* data one obtains the two tangential components, $V_{\rm RA} = -194$ km s^{-1} and $V_{\rm decl} = 13$ km s^{-1}. The radial velocity $\gamma = -11$ km s^{-1} is moderate (see Fig. 2), so that only the right ascension component of the spatial tangential velocity is very large.

The color index in the *Hipparcos* Catalogue, $B-V = 0.59$, would imply some amount of reddening when compared with our classification of F8 V. However, we estimate that our classification is uncertain at the level of at least 1 spectral subtype. A change from F8 V to F9 V would imply a change in $B-V$ from 0.53 to 0.56. Lee (1984b) gave G0: as a somewhat uncertain estimate of the spectral type.

2.6. *RZ Dra*

RZ Dra has been frequently photometrically observed since the discovery by Ceraski (1907). The most recent extensive analysis of the system was by Kreiner et al. (1994). It utilized the only extant set of spectroscopic observations by Struve (1946) which led to a detection of one, brighter component. Our data confirm the primary amplitude $K_1 = 100$ km s^{-1}, but we have been also able to detect the secondary component and measure K_2. We found, however, that the systemic velocity is different than the one given by Struve. He determined $\gamma = -16$ km s^{-1} whereas ours is $\gamma = +11$ km s^{-1}.

The system of RZ Dra consists of components considerably differing in the effective temperature, and thus is classified as an EB-type binary. Spectroscopically, one sees a more massive component eclipsed at the deeper minimum so that it can be an Algol semidetached binary or an A-type contact system in poor thermal contact. The analysis of Kreiner et al. (1994) was made under the assumption of the

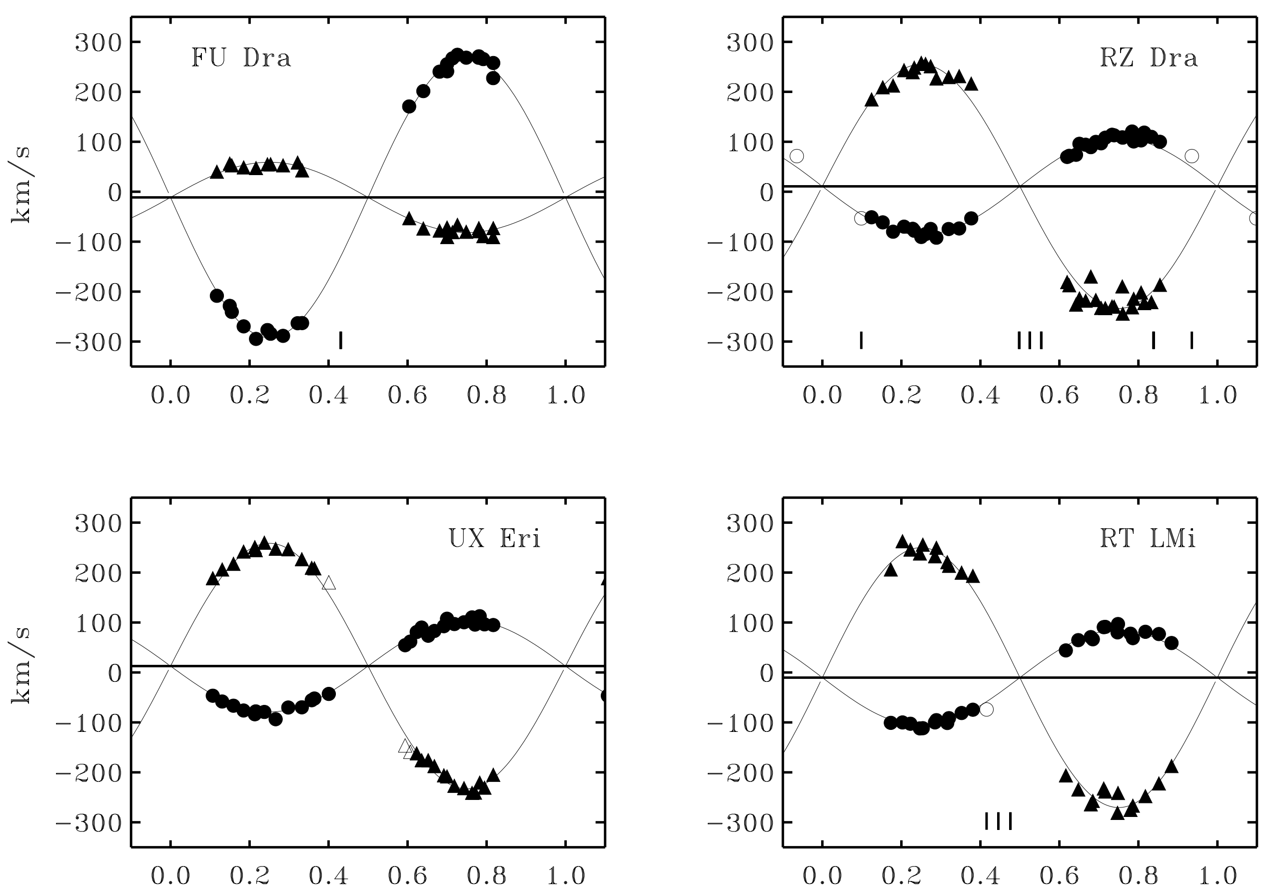

FIG. 2.—Radial velocities of the systems FU Dra, RZ Dra, UX Eri, and RT LMi

semidetached configuration. They found the photometric mass ratio $q_{ph} \simeq 0.45$, but some solutions suggested $q_{ph} \simeq 0.55$. Our relatively well defined solution for both components gives $q_{sp} = 0.40 \pm 0.04$. The same investigation of Kreiner et al. provided the starting value of T_0 and the value of the orbital period. Despite indications that the period may be variable and that many epochs elapsed since the study by Kreiner et al., the observed shift in the primary eclipse time is relatively small.

The spectral type that we observed, A6 V, most probably applies to the primary component which is much hotter than its companion (we have not attempted to separate the spectra in terms of spectral types). The *Hipparcos* parallax of the system, $p = 1.81 \pm 1.01$ mas, is too poor for an more extensive analysis of the absolute magnitude of the system. RZ Dra appears to be a relatively short-period (0.55 days) semidetached Algol with both components accessible to spectroscopic observations.

2.7. *UX Eri*

UX Eri is a contact binary which was extensively photometrically observed since its discovery by Soloviev (1937). The first modern contact model solutions, which gave surprisingly good agreement with our spectroscopic mass ratio, $q_{sp} = 0.37 \pm 0.02$, was presented by Mauder (1972) almost a quarter of a century ago; it utilized the light curve of Binnendijk (1967) and arrived at $q_{ph} = 0.42$.

Our observations have been supplemented by four observations obtained at the same time by H. Duerbeck at the European Southern Observatory with a 1.52 m telescope and a Cassegrain spectrograph. As a starting point of our solution, we used the moment of the primary minimum T_0 as predicted on the basis of observations by Agerer & Huebscher (1998a, 1998b); both took place actually slightly after our spectroscopic observations. The orbital period was taken from the General Catalogue of Variable Stars.

UX Eri appears to be an A-type contact binary. The $B-V$ color index is not available for this star (it has also not been measured by *Hipparcos*), so we have not been able to relate it to our spectral classification of F9 V. The *Hipparcos* parallax $p = 6.57 \pm 2.84$ mas provides a relatively poor estimate of the absolute magnitude: for the maximum brightness of $V_{max} = 10.59$, $M_V = 4.7 \pm 0.9$.

2.8. *RT LMi*

RT LMi was discovered as a variable star by Hoffmeister (1949). The most recent analysis, from which we took the time of the primary eclipse, T_0 and the period, is by Niarchos, Hoffmann, & Duerbeck (1994). The system has been characterized in this study as a W-type contact binary of spectral type G0 V with photospheric spots. Our spectral classification is based on poor spectra, but they indicate a slightly earlier spectral type, of approximately F7 V. As Niarchos et al. (1994) pointed out, the minima were observed to be of almost equal depth. Our spectroscopic orbit gives an A type, so that the minimum selected by the authors as the primary corresponds to the eclipse of the more massive component (the temporal shift is very small despite many elapsed epochs). The photometric solution of Niarchos et al. (1994) assuming the W type appears therefore to be invalid. The system is otherwise quite an inconspicuous contact binary. It lacks even the most essential photometric data. SIMBAD gives $V_{max} = 11.4$, but the source of this value is not cited.

2.9. *V753 Mon*

V753 Mon is a new discovery of the *Hipparcos* mission. It is probably one of the most interesting new close binaries recently discovered. V753 Mon has not been studied before. The only published photometric data come from the *uvby* survey of Olsen (1994), who found $b-y = 0.214 \pm 0.008$, $m_1 = 0.160 \pm 0.003$, and $c_1 = 0.693 \pm 0.023$. The $b-y$ color index color corresponds to $B-V \simeq 0.34$ or the spectral type F2 V. Our spectral classification is A8 V, which does not agree with these estimates and with $B-V = 0.36$ in the *Hipparcos* Catalogue, unless there is considerable reddening of about $E_{B-V} \simeq 0.12$. However, the early type would be in a better accord with the large masses indicated by the radial velocity solution (see Fig. 3). The brightness data in the Olsen measurements indicated quite appreciable variability, $V = 8.46 \pm 0.34$, but this indication has been apparently overlooked. The *Hipparcos* mission database treats it as a new discovery.

The two features distinguish V753 Mon as a particularly interesting system: the mass ratio close to unity and the large amplitudes of radial velocity variations indicating a large total mass. The mass ratio $q_{sp} = 0.970 \pm 0.009$ is the closest to unity of all known contact binaries. Note that the currently largest mass ratios are $q = 0.80$ for VZ Psc (Hrivnak, Guinan, & Lu 1995) and SW Lac (Zhai & Lu 1989) and $q = 0.84$ for OO Aql (Hrivnak 1989). Since contact systems with $q \simeq 1$ are not observed, but are

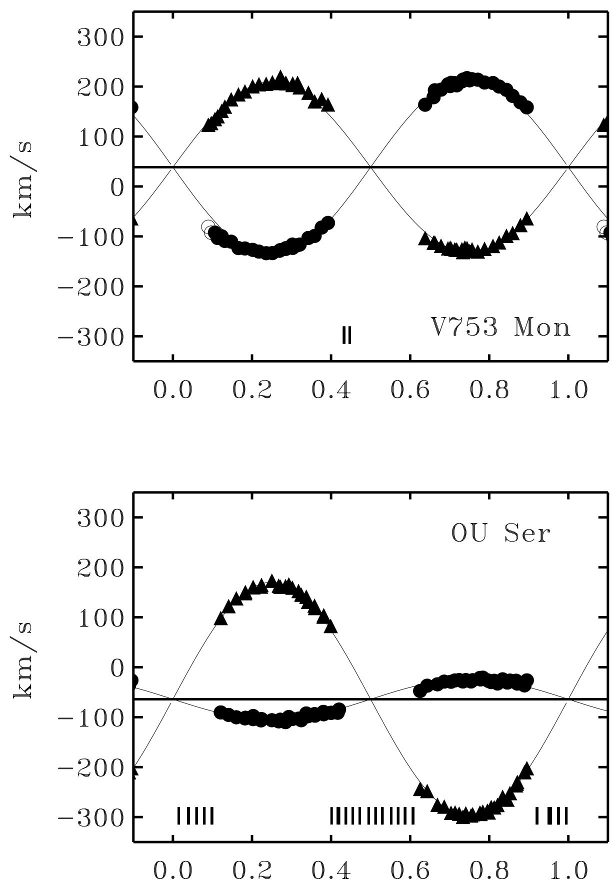

FIG. 3.—Radial velocities of the systems V753 Mon and OU Ser. While both of these recently discovered systems are very interesting, V753 Mon is exceptional in having a mass ratio very close to unity and in showing very large radial velocity amplitudes.

expected to experience *strong favorable observational biases for their detection and ease in analysis*, it is generally thought that contact configurations avoid this particular mass ratio. The summed amplitudes of the radial velocity variations for V753 Mon give the total mass of the system, $(M_1 + M_2)\sin^3 i = 2.93 \pm 0.06$. This is in perfect agreement with the expected masses of two main-sequence stars of the spectral type F2 V seen on an orbit exactly perpendicular to the plane of the sky. The light variation is about 0.52 mag, in place of the expected about 1.0 mag for a contact system with $q \simeq 1$; therefore, the total mass for $i < 90°$ may turn out to be substantially larger. For the spectral type estimated by us the individual masses should be close to 1.7 $M_\odot$.

Our radial velocity data show that with the ephemeris based on the *Hipparcos* data, the system belongs to the W-type contact systems. Apparently, the eclipses are of almost the same depth, as expected for $q \simeq 1$. However, the light curve from *Hipparcos* is poorly covered around the secondary minimum, so that the identification of the eclipses is uncertain. Obviously, the distinction between A-type and W-type systems becomes immaterial for $q \rightarrow 1$.

The system is begging a new light curve and an extensive analysis, not only because of the unusual properties, but also because it is bright, $V_{max} = 8.34$, and has a moderately well determined *Hipparcos* parallax: $p = 5.23 \pm 1.04$, resulting in $M_V = 1.93 \pm 0.43$. This is in perfect agreement with the $M_V(\log P, B-V)$ calibration, which gives $M_V^{cal} = 1.90$ for the assumed $B-V = 0.34$. The agreement would not be that good if the color index were smaller, say 0.22, then one would obtain $M_V^{cal} = 1.54$, which is still within the uncertainty of the parallax. Further investigations of V753 Mon will therefore contribute to the absolute magnitude calibration, which is rather moderately well defined for contact binaries with periods longer than about 0.5 days (Rucinski & Duerbeck 1997).

2.10. *OU Ser*

OU Ser is the fourth *Hipparcos* mission discovery in this group of systems. The light curve shows almost equally deep minima. With the *Hipparcos* ephemeris, the system appears to be an A-type one with a small mass ratio $q_{sp} = 0.173 \pm 0.017$. Our spectral classification of the system indicates the spectral type F9/G0 V.

The distinguishing properties of OU Ser in the *Hipparcos* database are its large proper motion and a well-measured parallax. The tangential components of the proper motion are $\mu_{RA} = -387.5 \pm 0.9$ mas and $\mu_{decl} = 2.8 \pm 0.8$ mas. With the parallax of $p = 17.3 \pm 1.0$ mas, this translates into the spatial components $V_{RA} = -106$ km s^{-1} and $V_{decl} = 1$ km s^{-1}. The mean radial velocity of the system is $\gamma = -64.08 \pm 0.41$ km s^{-1} (Fig. 3). Thus, the right ascension and the radial velocity components indicate a high-velocity star.

The large proper motion of the star had been the reason for its inclusion in the survey by Carney et al. (1994). They noted also the broad lines indicating short-period binarity and the possibility of light variations. Their photometric data, $V = 8.27$, $B-V = 0.62$, and $U-B = 0.08$, agree with our spectral classification, F9/G0 V. The *ubvy* survey of Olsen (1994) suggests a slightly larger $B-V \simeq 0.66$ on the basis of the $b-y = 0.411 \pm 0.003$, hence a spectral type around G1/G2 V. The difference in the classification may be due to the apparently low metallicity of the system as judged by its low index, $m_1 = 0.168 \pm 0.004$ (provided this index is not confused by any chromospheric activity). The other data of Olsen are $V = 8.278 \pm 0.005$ and $c_1 = 0.281 \pm 0.006$.

Assuming $V_{max} = 8.25$ and the parallax $p = 17.3 \pm 1.0$ mas, one obtains $M_V = 4.44 \pm 0.12$. This again agrees very well with the absolute magnitude derived from the $M_V(\log P, B-V)$ calibration of Rucinski & Duerbeck (1997): for $B-V = 0.62$, $M_V^{cal} = 4.32$, while for $B-V = 0.66$, $M_V^{cal} = 4.46$.

With the excellent parallax data and its properties of a high-velocity star, OU Ser deserves a combined photometric-spectroscopic solution.

3. SUMMARY

This paper provides radial velocity data for the third group of 10 close binary systems that we observed at the David Dunlap Observatory. All, except RZ Dra (which had SB1 radial velocity data), have never been observed spectroscopically; all 10 are binaries with both components clearly detected, so that they can be called SB2. All systems, except CN And and RZ Dra, which may be very close semidetached systems, are contact binaries. We describe the special features of the individual systems in the descriptions in § 2. We note that again about half of the system are A-type contact binaries; the likely reasons why we tend to select them over the W-type systems in our randomly drawn sample are given in the conclusions to Paper II. We also classified two binaries as EB systems, CN And and RZ Dra; they are most probably semidetached binaries.

We give the values of $(M_1 + M_2)\sin^3 i = 1.0385 \times 10^{-7} (K_1 + K_2)^3 P(\text{days})\ M_\odot$ in Table 2. We have not converted them into the sums of masses, because in most cases the inclination angles are either unknown or not trustworthy. However, one case is very interesting here: the total mass of components of the system V753 Mon is very large, $M_1 + M_2 > 2.93\ M_\odot$. Since very large velocity amplitudes—larger than expected—are a rare phenomenon in the world of contact systems, this system requires special attention of the observers. The binary is also unique in having its mass ratio exceptionally close to unity, $q_{sp} = 0.970 \pm 0.009$. Two other systems discovered by the *Hipparcos* mission are also very important and promise excellent combined solutions, YY CrB and OU Ser. They are important because both are high-velocity stars and have excellent parallaxes. Finally, the recently discovered system HV Aqr offers an excellent solution in view of the total, well-defined eclipses and very good radial velocity data.

The authors would like to thank Jim Thomson for help with observations and to Hilmar Duerbeck for a permission to use his observations of UX Eri. We would also like to thank the anonymous referee for providing an exceptionally careful and useful review of the paper. The research has made use of the SIMBAD database, operated at the CDS, Strasbourg, France, and accessible through the Canadian Astronomy Data Centre, which is operated by the Herzberg Institute of Astrophysics, National Research Council of Canada.

REFERENCES

Agerer, F., & Huebscher, J. 1998a, Inf. Bull. Variable Stars, No. 4562
———. 1998b, Inf. Bull. Variable Stars, No. 4606
Barone, F., Di Fiore, L., Milano, L., & Russo, G. 1993, ApJ, 407, 237
Binnendijk, L. 1967, AJ, 72, 82
Carney, B. W., Latham, D. W., Laird, J. B., & Aguilar, L. A. 1994, AJ, 107, 2240
Ceraski, W. 1907, Astron. Nachr., 174, 265
ESA. 1997, The Hipparcos and Tycho Catalogues (ESA SP-1200) (Noordwijk: ESA)
Evans, E., III, Grossoehme, D. H., & Moyer, E. J., Jr. 1985, PASP, 97, 648
Faulkner, D. R. 1986, PASP, 98, 690
Hoffmeister, C. 1949, Astr. Abh. Astron. Nachr., 12, 1
———. 1966, Astron. Nachr., 289, 1
Hrivnak, B. J. 1989, ApJ, 340, 458
Hrivnak, B. J., Guinan, E. F., & Lu, W. 1995, ApJ, 455, 300
Hutton, R. G. 1992, Inf. Bull. Variable Stars, No. 3723
Kałużny, J. 1983, Acta Astron., 33, 345
Keskin, V. 1989, Ap&SS, 153, 191
Kreiner, J. M., Pajdosz, G., Tremko, J., & Zola, S. 1994, A&A, 285, 459
Lee, S.-G. 1984a, AJ, 89, 702
Lee, S.-G. 1984b, AJ, 89, 720
Lu, W., & Rucinski, S. M. 1999, AJ, 118, 515 (Paper I)
Mauder, H. 1972, A&A, 17, 1
Milone, E. F., Piggott, D. H., & Morris, S. L. 1982, JRASC, 76, 90
Niarchos, P. G., Hoffmann, M., & Duerbeck, H. W. 1994, A&AS, 103, 39
Olsen, E. H. 1994, A&AS, 106, 257
Popper, D. M. 1980, ARA&A, 18, 115
Rafert, J. B., Markworth, N. L., & Michaels, E. J. 1985, PASP, 97, 310
Robb, R. M. 1992, Inf. Bull. Variable Stars, No. 3798
Rucinski, S. M., & Duerbeck, H. W. 1997, PASP, 109, 1340
Rucinski, S. M., & Lu, W. 1999, AJ, 118, 2451 (Paper II)
Samec, R. G., Laird, H., Mutzke, M., & Faulkner, D. R. 1998, Inf. Bull. Variable Stars, No. 4616
Schirmer, J. 1992, Inf. Bull. Variable Stars, No. 3785
Shaw, J. S., Caillault, J.-P., & Schmitt, J. H. M. M. 1996, ApJ, 461, 951
Soloviev, A. 1937, Tadjik Obs. Circ., No. 27, 7
Struve, O. 1946, ApJ, 103, 76
Zhai, D. S., & Lu, W. X. 1989, Acta Astron. Sinica, 9, 208 (English transl. Chinese Astron. Astrophys., 13, 350)