Radial Velocity Studies of Southern Close Binary Stars. I

Slavek M. Rucinski

David Dunlap Observatory, University of Toronto
P.O. Box 360, Richmond Hill, Ontario, Canada L4C 4Y6

rucinski@astro.utoronto.ca

and

Hilmar Duerbeck

WE/OBSS, Vrije Universiteit Brussel, Pleinlaan 2, B-1150 Brussels, Belgium

hduerbec@vub.ac.be

ABSTRACT

Radial-velocity measurements and sine-curve fits to the orbital velocity variations are presented for nine contact binaries, V1464 Aql, V759 Cen, DE Oct, MW Pav, BQ Phe, EL Aqr, SX Crv, VZ Lib, GR Vir; for the first five among these, our observations are the first available radial velocity data. Among three remaining radial velocity variables, CE Hyi is a known visual binary, while CL Cet and V1084 Sco are suspected to be multiple systems where the contact binary is spectrally dominated by its companion (which itself is a binary in V1084 Sco). Five additional variables, V872 Ara, BD Cap, HIP 69300, BX Ind, V388 Pav, are of unknown type, but most are pulsating stars; we give their mean radial velocities and $V \sin i$.

Subject headings: stars: close binaries - stars: eclipsing binaries – stars: variable stars

1. INTRODUCTION

The origins of this paper are related to those of the series of radial velocity studies of short period binaries currently conducted at the David Dunlap Observatory (DDO papers 1 – 10) (Lu & Rucinski 1999; Rucinski & Lu 1999; Rucinski, Lu, & Mochnacki 2000; Lu et al. 2001; Rucinski et al. 2001, 2002, 2003; Pych et al. 2004; Rucinski et al. 2005). Both authors realized in the 1990’s that with availability of good Hipparcos parallaxes (ESA 1997), the limiting factor in gathering spatial

---

1Based on the data obtained at the European Southern Observatory.
velocities of contact binaries would be radial velocities (RV). While the DDO studies have since succeeded in obtaining RV data for now over one hundred of northern binaries, for many reasons the data presented in this paper are so far the only effort for the southern binaries. We present these results because chances of continuation of these observations is basically nil: the telescope has been retired, and the remaining ESO telescopes are assigned for technically more demanding tasks.

The observations reported in this paper have been collected on 4 nights of August 8 – 11, 1998. To optimize on the returns from such a short survey, the 17 targets were selected to be a mixture of contact binaries possibly offering reasonable orbital solutions with a selection of variables suspected to be contact binaries (Duerbeck 1997). The next paper will contain similar results for Spring southern targets.

In this paper, we attempt to stay close to the format of the DDO series. In particular, we use the same data extraction procedures through the Broadening Function (BF) approach, as described in the DDO interim summary paper Rucinski (2002a, DDO-7). Of 17 stars discussed in this paper, four contact binaries (EL Aqr, SX Crv, VZ Lib, GR Vir) in the meantime have been observed during the DDO program resulting in good RV orbits; we include these systems here to report the Southern observations as a check of consistency. The remaining stars have been observed by us for radial-velocity variations for the first time. We have derived the radial velocities in the same way as described in the DDO papers; see the DDO-7 paper for a discussion of the broadening-function technique 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-primary-eclipse epoch, $T_0$. The primary radial velocity standard used to determine the BF’s as well as to find radial velocities was 6 Cet (F5V) assumed to have the velocity of $+14.9 \text{ km s}^{-1}$ (Simbad). This was the only sufficiently well observed standard which could be used as the BF template, but appeared to serve well for the whole range of the spectral types from mid-A to mid-G; the disparity of the spectral types manifested itself mostly in the broadening function intensities which would not normalize to unity as expected for perfect spectral matches.

We describe our results in the context of the existing photometric data from the literature and the Hipparcos project. We also utilize the mean $(B - V)$ color indexes taken from the Tycho-2 catalog (Høg et al. 2000) and the photometric estimates of the spectral types using the relations published by Bessell (1979). The spectral types are taken uniformly from the 5 volumes of the Michigan Catalogue of HD Stars (Houk et al. 1975–1999); from now on called HDH. Because the high incidence of companions to contact binary stars (Pribulla & Rucinski 2006), we checked all stars for possible membership in visual systems using the Washington Double Star Catalog (WDS)$^2$. DE Oct and CE Hyi have been identified as members of already known visual binaries. VZ Lib is a previously recognized (Lu et al. 2001, DDO-4) spectroscopic triple system.

\[http://ad.usno.navy.mil/wds/\]
The observations were carried with the ESO 1.52-m telescope at ESO La Silla, equipped with a Boller & Chivens Cassegrain spectrograph. Holographic grating No. 32 (2400 lines/mm) was used in combination with Loral CCD No. 39 (2048 × 2048 pix). The slit width was set to 220 μm. The broadening functions were extracted from the wavelength region of 401.6 – 499.8 nm. Thus, compared with the DDO results based on the Mg I triplet at 518.4 nm, with the window of about 25 – 30 nm, the ESO spectra are longer and more blue. They also have a lower resolution: While for the DDO spectra, the broadening functions have a resolution of typically $\sigma \simeq 13 – 18$ km s$^{-1}$, the spectra described here have the BF resolution of typically $\sigma \simeq 23 – 27$ km s$^{-1}$. Stellar exposure times ranged between 10 and 20 min, depending on the brightness of the object; each exposure was followed by the exposure of a He-Ar spectrum. Spectrum extraction and wavelength calibration was carried out using the ESO MIDAS software system$^3$.

This paper is structured in a way similar to the DDO series. We comment on individual contact binary systems in Section 2. Three additional variables which may be members of multiple systems with a dominating third component are described in Section 3, while additional five stars of mostly unknown types are described in Section 4. In each section, the stars appear in the constellation order. The individual measurements are listed in Tables 1 and 2, while Table 3 gives parameters of spectroscopic orbits derived for 9 binary stars discussed in Section 2. The broadening functions for selected phases of the 9 contact binaries are shown in Figure 1, while radial velocity orbital solutions for these stars are shown in Figure 2. We show the broadening functions for single stars or binaries without orbital solutions in Figure 3. The conclusions of the paper are summarized in Section 5.

2. CONTACT BINARY SYSTEMS

2.1. V1464 Aql

The variable star V1464 Aql (HIP 97600, HD 187438) was suggested to be a contact binary by Duerbeck (1997) (hereinafter D97) on the basis of the low-amplitude Hipparcos light curve. We found that the star is indeed a close binary and our six observations confirm that the period is two times longer than the original Hipparcos period and is equal to 0.697822 days. The SB1 orbit is shown in Figure 2 while the orbital elements are given in Table 3, together with the remaining binary stars. The RV data are in Table 2, together with the other stars showing single-lined spectra.

A search for the presence of the signature of the secondary star in the BF was unsuccessful. The visible component shows a relatively large broadening of its spectral lines with $V \sin i = 94 \pm 4$ km s$^{-1}$ (Figure 1). The star is bright, $V_{\text{max}} = 8.6$. The Tycho-2 color index $B - V = 0.237$ suggests, with no reddening, the spectral type of A8 – F0, much later than given in HDH, A2 V.

$^3$http://www.eso.org/projects/esomidas
The Hipparcos parallax of 7.16 ± 1.26 mas suggests $M_V = 2.9$ at the light maximum, which corresponds to F1/2V rather than early A. We do not have sufficiently many spectral standards to attempt our own classification, but the general appearance of our spectra for V1464 Aql indeed supports an early F spectral type.

2.2. EL Aqr

EL Aqr (HIP 117317) was the subject of a previous DDO study (Rucinski et al. 2001, DDO-5) where the orbital coverage was good, but the reported final elements had a larger scatter than for most of the DDO systems, probably because of typically large zenith distances and of a relative faintness of the system at $V_{max} = 10.35$. The $B - V$ given in DDO-5 was incorrect; the value of $B - V = 0.47$ better agrees with the DDO spectral type of F3V, but still suggests some amount of interstellar reddening. The spectral type is not available in HDH. For more information about the system, please consult DDO-5.

Our 15 observations are concentrated in the first half of the orbit. They confirm the DDO results, but the $K_2$ semi-amplitude is significantly smaller. This may be an indication of an insufficient spectral resolution, although the peaks in the BF's are quite well separated (Figure 1). The primary eclipse prediction of $T_0$ from the DDO observations served well the new observations and was adopted here without a change.

2.3. V759 Cen

The bright contact binary V759 Cen (HIP 69256, HD 123732) was discovered by Bond (1970). In spite of its brightness of $V_{max} \approx 7.45$, it has not been much observed since then with only sporadic photometric observations for eclipse timing. The color $b - y = 0.39$ and the spectral type F8 (Bond 1970) or G0V (HDH) and the period of 0.394 days suggest a typical contact binary.

The binary was observed 6 times within our program and these were its first RV observations. The phase distribution of the observations was far from optimal so that the orbital elements must be treated as preliminary. As can be seen in Figure 1, the spectral resolution was insufficient for this binary which is probably visible at a low inclination angle.

The Cracow database consulted in April 2006 provided an ephemeris used for our observations, as given in Table 3. Our bootstrap estimated errors are very large because of the insufficient number of observations. The mass ratio is probably close to $q \approx 0.2$. 
2.4. SX Crv

The very interesting and important contact binary SX Crv (HIP 61825, HD 110139) with the currently smallest known mass ratio of $q \simeq 0.07$ (Rucinski et al. 2001, DDO-5) was observed 8 times. The BF’s show the faint peak of the secondary component quite well although the DDO-5 elements are definitely better established as they were based on 49 best observations selected from among 96 available ones. As may be expected for a lower spectral resolution, the current observations give a smaller $K_2$, but the center of mass velocity appears to be also different; the latter effect may be due to the uneven phase distribution of the observations.

For more information about SX Crv, please consult DDO-5. Note the incorrect value of $B - V$ in that paper which should be 0.44. The HDH spectral type is F7V.

2.5. VZ Lib

The spectroscopically triple system VZ Lib (HIP 76050) was analyzed in Lu et al. (2001, DDO-4). The current observations show all three components, but the lower spectral resolution results in a much stronger merging of the primary and tertiary peaks in the BF. As observed for other binaries, the value of the semi-amplitude $K_2$ is again smaller for the current observations. For more information about VZ Lib, please consult DDO-4.

In DDO-4, a continuous change of the radial velocity of the companion in four seasons was noted. The current observations with the mean value $V_3 = -36.7 \pm 2.9$ at JD 2,451,034 (see Table 2 for individual observations) confirm the $V_3$ variability within the combined span of 4 years very well. The “kink” in $V_3$ visible in Figure 5 in DDO-4 is apparently real so that the orbital period of the triple system is probably quite short, of the order of a few years. It may be necessary to look for systematic changes in the center of mass data for the binary VZ Lib itself to confirm its motion. The fact that no obvious changes of $V_0$ have been noted so far suggests that the third component is probably much less massive than the binary.

2.6. DE Oct

DE Oct (HIP 100187, HD 191803) was observed spectroscopically for the first time within this program. D97 had suggested that this is a contact binary with the orbital period twice as long as the Hipparcos discovery period, $2 \times P = 0.5555922$ days. With this period, our 3 observations cannot properly define an orbit and no estimates of element uncertainties could be determined. However, we can exclude applicability to our observations of the Hipparcos conjunction time at $T_0 = 2,448,500.157$; the new value of $T_0$ is given in Table 3. The BF’s are poorly resolved so that the measured velocities, particularly of the secondary component, are very tentative.
DE Oct is a visual binary with the angular separation of 22.9 arcsec at the position angle 129° and the magnitude difference between the visual components of 2.85 (WDS 20194-7608). The secondary was far enough not to be included in the spectrograph slit.

The Tycho-2 color index $B - V = 0.319$ suggests a spectral type F1/2V, while the HDH spectral type is A9IV. The star is relatively bright, $V_{\text{max}} = 9.15$.

### 2.7. MW Pav

MW Pav (HIP 102508, HD 197070) was observed within our program for the first time and was the best observed star of this series with 18 observations defining a good radial velocity orbit. The spectral signatures are well separated in the BF’s, although one must take into account the warning signs from the other binaries that $K_2$ might be systematically underestimated at the available resolution. We assumed the value of the period from the Hipparcos results.

MW Pav is a well known southern contact binary with $V_{\text{max}} = 8.80$, $B - V = 0.33$ (Tycho-2), the spectral type F3IV/V (HDH) and a relatively long orbital period of 0.795 day. It was discovered by Eggen (1968) and initially designated as BV 894. A light curve solution was presented by Lapasset (1980). The secondary eclipse seemed to be total, so that evaluation of the mass ratio appeared to be possible. However, $q_{\text{phot}} = 0.122 \pm 0.003$, disagrees with our spectroscopic determination, $q_{\text{sp}} = 0.228 \pm 0.008$, even if we consider a possibility of a probable systematic underestimate of $K_2$ by (at most) 10%. Our spectroscopic observation should permit a combined solution of the parameters of this binary.

### 2.8. BQ Phe

BQ Phe (HIP 2005, HD 2145) was suggested by D97 to be a contact binary with the period twice longer than given by the Hipparcos discovery observations, $2 \times P = 0.437$ days. We confirm that BQ Phe is a contact binary, but with only 4 observations our orbital solution is indicative rather than definitive and the formal errors are very large. We assumed both the $T_0$ and the double Hipparcos period (see Table 3).

The star was a bit faint for this program, $V_{\text{max}} = 10.4$. Its spectral type F3/5V (HDH) agrees with $B - V = 0.51$ (Tycho-2).

### 2.9. GR Vir

GR Vir (HIP 72138) was analyzed for radial velocity variations by Rucinski & Lu (1999, DDO-2) where a good orbital solution was presented. With only 5 new observations we can only say that
we fully confirm the DDO-2 solution. We assumed both the $T_0$ and the period from the DDO-2 results.

For more information about GR Vir, please consult DDO-2. As for other systems observed before, we see that our value of $K_2$ is slightly lower than that observed at DDO.

3. POSSIBLE BINARY MEMBERS OF MULTIPLE SYSTEMS

3.1. CL Cet

CL Cet (HIP 2274, HD 2554) was suggested in D97 to be a contact binary with a period twice longer than the Hipparcos discovery result, $2 \times P = 0.6216$ days. The star has $V_{\text{max}} = 9.9$ and the Tycho-2 color index $B - V = 0.313$; the latter agrees with the spectral type of F2V (HDH).

Our spectroscopic observations do not have sufficient resolution to analyze apparent changes in the single-peaked, wide broadening function (Figure 3). It is possible that the binary signature is masked by a relatively rapidly rotating companion with $V \sin i = 135 \pm 8$ km s$^{-1}$. The single peak in the BF has the velocity $V = -18.9 \pm 1.2$ km s$^{-1}$. However, a significant shift by 10 km s$^{-1}$ from the average was observed for the last of our four observations. The case for a complex blending of three components in this system is the weakest one among the three cases discussed here; the star may be in fact a pulsating one.

3.2. CE Hyi

CE Hyi (HIP 7682, HD 10270) is another case suggested to be a contact binary by D97. Again, the orbital period suggested was $2 \times P = 0.4408$ days.

The star is known as a visual double star WDS 01389-5835 (HU 1553) with the angular separation of 1.9 arcsec at the position angle of 10$^\circ$ and a small magnitude difference of only 0.24. Our 3 observations show very clearly that the spectrum is dominated by a slowly rotating companion, while the close, low-inclination, contact binary is visible only in the base of the combined BF profile. Hipparcos and Tycho photometry of individual components shows that it is the fainter star (B) which is the photometric variable and thus the contact binary.

The comparable light contribution of both components to the combined spectrum is visible in the BF where the sharp-lined star shows the peak with $V \sin i$ which is un-measurably low, below the spectral resolution of our observations, while the contact binary light is distributed in the velocity domain within $\pm 200$ km s$^{-1}$ (Figure 3). The radial velocity of the slowly rotating companion is $V_3 = 9.00 \pm 0.33$ km s$^{-1}$.

The observed $V_{\text{max}} \approx 8.3$ is for the combined light of both visual components. The Tycho-2 catalog gives $V_A = 9.08$, $V_B = 9.29$ and $(B - V)_A = 0.333$, $(B - V)_B = 0.497$, respectively. The
Simbad database gives $B - V = 0.49$ and F5V for CE Hyi. The spectral type is after HDH.

### 3.3. V1084 Sco

V1084 Sco (HIP 86294, HD 159705) was suggested by D97 to be a contact binary with the period twice the Hipparcos period, $2 \times P = 0.3003$ days.

We have only 3 observations which show that system is a complex one: It appears to be a quadruple system consisting of a detached binary giving two sharp peaks in the BF (see Figure 3), and of a slightly fainter contact binary responsible for the short-period photometric variability. The contact binary – because of the stronger line broadening – is just barely detectable at the base of the BF. The radial velocities of the sharp-line binary components (designated as “3” and “4” in Table 2) varied during the 3 days of observations between $-19$ and $-31$ km s$^{-1}$ for the stronger component and $+77$ and $+83$ km s$^{-1}$ for the fainter component. Thus, the detached binary must be also relatively compact, but our observations were insufficient to determine any parameters of the radial velocity orbit. The star was included in the major radial velocity survey of Nordstrom et al. (2004) where it appears with the average radial velocity of $+21.3$ km s$^{-1}$.

This star is a very interesting object for further studies, particularly if the mutual period of revolution of the two binaries turns out moderately short to be observable. The star is relatively bright, $V_{\text{max}} = 9.0$, while the color and the spectral type given in Simbad are late, $B - V = 0.76$ and G6V (HDH). The Tycho-2 catalog is in agreement with $B - V = 0.73$.

### 4. RADIAL VELOCITY VARIABLES OF UNKNOWN TYPE

#### 4.1. V872 Ara

This star, at that time identified as HIP 81650 (HD 149989) was suspected in D97 to be a contact binary with the orbital period of 0.8532 days. Very little can be said on the basis of its light variations which are very small (0.02 mag.). Three observations obtained here show a wide, rotationally broadened profile with the average $V \sin i = 142 \pm 6$ km s$^{-1}$. The mean velocity is constant at $+42.1 \pm 2.4$ km s$^{-1}$, but the variation between $+37$ and $+45$ km s$^{-1}$ is larger than the measurement error of about $\pm 1.2$ km s$^{-1}$ so that some small variability may be present.

Our results are fully consistent with the recent study of de Cat et al. (2006) which explains the variability of V872 Ara by $\gamma$ Dor-type pulsations with the originally suggested period of 0.42658 days. The measured value of $V \sin i = 134 \pm 3$ km s$^{-1}$ is consistent within the combined errors with our estimate. We refer the reader to the paper of de Cat et al. (2006) for more information on this star. The spectral type is A8/F0V (HDH).
4.2. BD Cap

BD Cap (HIP 99365, HD 191301) was suggested by D97 to be a contact binary with the period twice as long as the one given by the Hipparcos project, \( 2 \times P = 0.3204 \) days. Our three spectra show a very broad BF with \( V \sin i = 133 \pm 10 \) km s\(^{-1}\). The mean velocity is practically constant at \( +9.7 \pm 1.0 \) km s\(^{-1}\). We cannot say more about this star except we note that it was included in the catalog of suspected and confirmed \( \delta \) Sct pulsating stars (Rodrigez et al. 2000) as well as in the survey of spatial velocities of nearby stars (Nordstrom et al. 2004). The spectral type is A9III (HDH).

4.3. Anon Cen = HIP 69300

HIP 69300 (HD 123720) was another suggestion of D97 to be a contact binary. Our two observations substantially differ in radial velocity of the star, \(-94.6\) and \(-25.9\) km s\(^{-1}\), but the broadening profile has the same \( V \sin i = 116 \pm 7 \) km s\(^{-1}\). The star does not have an entry in the General Catalog of Variable Stars\(^4\) and no variable star name has been assigned to it yet, but it is definitely a radial velocity variable. The spectral type is A4V (HDH).

4.4. BX Ind

BX Ind (HIP 108741, HD 208999), another candidate of D97, appears to be a slowly rotating star. Our seven observations all show a BF peak consistent with no rotation. Some small radial velocity changes within \(-32\) and \(-20\) km s\(^{-1}\) appear to be present with the mean value \(-27.6 \pm 1.7\) km s\(^{-1}\). This is definitely not a close binary star. It is listed in the Catalog of Delta Scuti stars of Rodrigez et al. (2000). The spectral type is F2V (HDH).

4.5. V388 Pav

We have only two observations of V388 Pav (HIP 103803, HD 199434), another candidate of D97. The radial velocity may be constant at the mean of \(+5.6 \pm 1.2\) km s\(^{-1}\), while the BF’s indicate a mild broadening of \( V \sin i = 45 \pm 7 \) km s\(^{-1}\). It is not a close binary star. It is listed in the Catalog of Delta Scuti stars of Rodrigez et al. (2000). The spectral type is F5II (HDH).

\(^4\)http://www.sai.msu.su/groups/cluster/gcvs/, the most recent electronic version 4.2.
5. SUMMARY

This program of radial velocity measurements of known and suspected southern contact binary stars was performed to fill the growing disparity in the available RV data for northern and southern hemispheres. With only four successive nights, the program could not achieve the same goals as the current David Dunlap Observatory survey. Still, some useful results have been obtained for 17 targets of the Fall southern sky.

We have confirmed the suggestion of Duerbeck (1997) (D97) that V1464 Aql, DE Oct, BQ Phe are contact binaries and obtained the first preliminary orbital data for these systems; V1464 Aql is a single-lined binary (SB1) while the rest are double-lined systems. We obtained the first radial velocity orbital data (SB2) for the well-known southern systems V759 Cen and MW Pav. We confirmed the David Dunlap Observatory results for the double-lined binaries EL Aqr, SX Crv, VZ Lib, GR Vir, but we noticed that in all these systems the secondary star semi-amplitude $K_2$ is by a few percent smaller than observed at DDO which may be a result of the lower spectral resolution.

Three systems could not be analyzed because of the presence of companions. In the case of CE Hyi, a visual companion had been known, but we see spectral signatures of a binary companion in V1084 Sco (so that the system is a quadruple one) and suspect a presence of a companion in CL Cet. We are not able to say much about other variables suggested in D97: V872 Ara, BD Cap, HIP 69300, BX Ind, V388 Pav, but most appear to be pulsating stars and have been included in catalogs of such objects; we give their mean radial velocities and $V \sin i$.

Thanks are due to George Conidis for participation in reductions of the data used in this paper. Thanks are also due to the reviewer, Dr. Vakhtang S. Tamazian, for a few very pointed suggestions on the improvement of the paper.

Support from the Natural Sciences and Engineering Council of Canada to SMR is acknowledged with gratitude. The research 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. This research made also use of the Washington Double Star (WDS) Catalog maintained at the U.S. Naval Observatory and the General Catalog of Variable Stars maintained at the Sternberg Astronomical Institute, Moscow, Russia.

REFERENCES

Bessell, M. S. 1979, PASP, 91, 589


Rucinski, S. M 2002b, PASP, 114, 1124


Captions to figures:

Fig. 1.— Broadening functions for 9 contact binary systems discussed in Section 2. The orbital phase is given in the right side of each panel. The last panel gives the BF representing the nominal resolution of the method.

Fig. 2.— The orbital solutions for 9 contact systems discussed in Section 2. Observations of lower quality are marked by open symbols. Dashes at the bottom mark orbital phases when signatures of the components were unresolved. The sine curve solutions based on DDO data are shown by broken lines. Note that present solutions give systematically smaller values of $K_2$. V1464 Aql is the only single lined binary (SB1) in this group of stars.

Fig. 3.— The 3 first panels show broadening functions for multiple systems discussed in Section 3, while the next 5 panels show the respective functions for radial velocity variables of mostly unknown type, as discussed in Section 4. Note that “strengths or “intensities” of the BF’s have different vertical scales for different stars. This is because the BF’s depend not only on the geometric (rotational) broadening, but also on how well spectral types of the template and of the program star match. For a perfect fit, the integral of the BF should give unity. The Y-axis units correspond to the BF sampling at 12.5 km s$^{-1}$ per point.
Table 1. Radial velocity observations of double lined binaries (the full table is available in electronic form)

<table>
<thead>
<tr>
<th>Star</th>
<th>HelJD</th>
<th>RV1</th>
<th>W1</th>
<th>RV2</th>
<th>W2</th>
</tr>
</thead>
<tbody>
<tr>
<td>EL Aqr</td>
<td>2451033.7239</td>
<td>20.84</td>
<td>1.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>EL Aqr</td>
<td>2451033.7474</td>
<td>11.39</td>
<td>1.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>EL Aqr</td>
<td>2451033.8103</td>
<td>-27.96</td>
<td>1.0</td>
<td>187.98</td>
<td>1.0</td>
</tr>
<tr>
<td>EL Aqr</td>
<td>2451033.8556</td>
<td>-40.11</td>
<td>1.0</td>
<td>239.22</td>
<td>1.0</td>
</tr>
<tr>
<td>EL Aqr</td>
<td>2451033.8732</td>
<td>-43.90</td>
<td>1.0</td>
<td>238.97</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Note. — The table gives the radial velocities $RV_i$ and associated weights $W_i$ for observations of 8 stars described in Section 2. The velocities are expressed in km s$^{-1}$. The weights $W_i$ were used in the orbital solutions and can take values of 1.0, 0.5 or 0; the zero weight observations may be eventually used in more extensive modeling of broadening functions.

Table 2. Radial velocity observations of single lined stars (the full table is available in electronic form)

<table>
<thead>
<tr>
<th>Star</th>
<th>HelJD</th>
<th>RV</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1464 Aql</td>
<td>2451033.6816</td>
<td>9.13</td>
</tr>
<tr>
<td>V1464 Aql</td>
<td>2451033.7740</td>
<td>32.03</td>
</tr>
<tr>
<td>V1464 Aql</td>
<td>2451034.7799</td>
<td>6.90</td>
</tr>
<tr>
<td>V1464 Aql</td>
<td>2451035.7022</td>
<td>-4.92</td>
</tr>
<tr>
<td>V1464 Aql</td>
<td>2451036.7050</td>
<td>47.12</td>
</tr>
</tbody>
</table>

Note. — The table gives the radial velocities $RV$ for observations of stars described in Sections 2 and 3. The velocities are expressed in km s$^{-1}$. 
Table 3. Spectroscopic orbital elements for 9 contact binaries

<table>
<thead>
<tr>
<th>Name</th>
<th>DDO</th>
<th>n_{obs}</th>
<th>n_{used}</th>
<th>V0</th>
<th>σV0</th>
<th>K1</th>
<th>σK1</th>
<th>K2</th>
<th>σK2</th>
<th>T0 − 2,400,000</th>
<th>σT0</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1464 Aql</td>
<td>new</td>
<td>6</td>
<td>6</td>
<td>+16.61</td>
<td>1.58</td>
<td>30.62</td>
<td>2.35</td>
<td>48,500.2642</td>
<td>0.0069</td>
<td>[0.697822]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EL Aqr</td>
<td>5</td>
<td>41</td>
<td>31</td>
<td>+12.51</td>
<td>2.08</td>
<td>53.38</td>
<td>1.53</td>
<td>263.34</td>
<td>4.38</td>
<td>51,109.3334</td>
<td>0.0032</td>
<td>[0.481410]</td>
</tr>
<tr>
<td>V759 Cen</td>
<td>new</td>
<td>6</td>
<td>6</td>
<td>+23.4</td>
<td>10.7</td>
<td>42.5</td>
<td>8.5</td>
<td>207.2</td>
<td>42.5</td>
<td>[52,500.368]</td>
<td>⋯</td>
<td>[0.393999]</td>
</tr>
<tr>
<td>SX Crv</td>
<td>5</td>
<td>96</td>
<td>49</td>
<td>+8.71</td>
<td>0.94</td>
<td>18.28</td>
<td>0.74</td>
<td>278.70</td>
<td>2.43</td>
<td>51,070.8192</td>
<td>0.0010</td>
<td>[0.316022]</td>
</tr>
<tr>
<td>VZ Lib</td>
<td>4</td>
<td>61</td>
<td>38</td>
<td>−31.11</td>
<td>2.30</td>
<td>68.54</td>
<td>3.84</td>
<td>289.25</td>
<td>4.55</td>
<td>51,091.4297</td>
<td>0.0015</td>
<td>[0.358263]</td>
</tr>
<tr>
<td>DE Oct</td>
<td>new</td>
<td>3</td>
<td>3</td>
<td>+17.86</td>
<td>0.96</td>
<td>15.42</td>
<td>1.30</td>
<td>172.55</td>
<td>1.19</td>
<td>48,500.026</td>
<td>0.020</td>
<td>[0.5555922]</td>
</tr>
<tr>
<td>MW Pav</td>
<td>new</td>
<td>18</td>
<td>18</td>
<td>−42.75</td>
<td>1.38</td>
<td>52.35</td>
<td>1.15</td>
<td>229.34</td>
<td>3.52</td>
<td>48,500.098</td>
<td>0.020</td>
<td>[0.7949810]</td>
</tr>
<tr>
<td>BQ Phe</td>
<td>new</td>
<td>4</td>
<td>4</td>
<td>+36.52</td>
<td>8.6</td>
<td>34.44</td>
<td>5.6</td>
<td>230.9</td>
<td>80.1</td>
<td>[48,500.085]</td>
<td>⋯</td>
<td>[0.436968]</td>
</tr>
<tr>
<td>GR Vir</td>
<td>2</td>
<td>43</td>
<td>37</td>
<td>−71.72</td>
<td>0.89</td>
<td>37.78</td>
<td>1.00</td>
<td>308.81</td>
<td>1.96</td>
<td>50,541.9582</td>
<td>0.0008</td>
<td>[0.346979]</td>
</tr>
<tr>
<td></td>
<td>new</td>
<td>5</td>
<td>5</td>
<td>−78.26</td>
<td>1.39</td>
<td>35.39</td>
<td>2.27</td>
<td>286.55</td>
<td>2.39</td>
<td>[same]</td>
<td>⋯</td>
<td>[same]</td>
</tr>
</tbody>
</table>

Note. — The column DDO gives the number of the DDO paper or “new” for this paper. n_{obs} and n_{used} give the number of available and used RV measurements, respectively. The radial velocity parameters V0, K1 and K2 and their rms errors are in km s\(^{-1}\). T0 is the heliocentric Julian Day of the superior conjunction (eclipse). The period P is in days. The assumed and fixed quantities are in square brackets.