Spectroscopic orbits of nearby solar-type dwarfs. II.

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ABSTRACT

Several nearby solar-type dwarfs with variable radial velocity were monitored to find their spectroscopic orbits. First orbital elements of 15 binaries (HIP 12144, 17895, 27970, 32329, 38636, 39072, 40479, 43004, 73700, 79234, 84696, 92140, 88656, 104514, and 112222) are determined. The previously known orbits of HIP 5276, 21443, 28678, and 41214 are confirmed and updated. The orbital periods range from 2 days to 4 years. There are 8 hierarchical systems with additional distant companions among those 19 stars. The outer visual orbit of the triple system HIP 17895 is updated and the masses of all its components are estimated. We provide radial velocities of another 16 Hipparcos stars without orbital solutions, some of those with long periods or false claims of variability.

Key words: binaries: spectroscopic; stars: solar-type

1 INTRODUCTION

This paper continues the work on spectroscopic orbits of nearby solar-type stars introduced in our previous publication (Gorynya & Tokovinin 2014, hereafter GT14). Stars with variable radial velocity (RV) and unknown orbits that belong to the 67-pc sample (Tokovinin 2014) were selected for monitoring. Many of those spectroscopic binaries (SBs) were discovered by the Geneva-Copenhagen Survey, GCS (Nordström et al. 2004). Their unknown periods and mass ratios prevent detailed statistical study of this important volume-limited sample. A large number of such binaries were followed by D. Latham at Center for Astrophysics, leading to hundreds of orbital solutions (D. Latham, in preparation). Still, not all spectroscopic binaries are covered.

As in GT14, our aim is to complement the existing work and to determine, whenever possible, spectroscopic orbits. The objects covered in this study are listed in Table I where visual magnitudes and spectral types are taken from SIMBAD, trigonometric parallaxes \( p \) from the Hipparcos-2 (van Leeuwen 2007) or Gaia (Gaia collaboration 2016) catalogues (the latter are marked by asterisks), and the masses are estimated from the absolute magnitudes (Tokovinin 2014). All stars are bright; their spectral types range from F3V to G8V. The last column resumes our results by indicating the orbital periods or RV variability; astrometric acceleration detected by Hipparcos is noted as well.

2 OBSERVATIONS

The observations were started in 2012 at the 1-m telescope of the Crimean Astrophysical Observatory sited in Simeiz, Crimea. The last observing season used in this work was in October 2017. Radial velocities were measured by the CORAVEL-type echelle spectrometer, the Radial Velocity Meter (RVM). This instrument is based on analogue correlation of spectrum with a physical mask, where slits correspond to the spectral lines (Tokovinin 1987). The RVs are measured by fitting Gaussian curves to the observed correlation dips, with the velocity zero point determined from observations of RV standards. Further information on the observing method and its limitations can be found e.g. in (Tokovinin & Gorynya 2001). The RV precision reaches 0.3 km s\(^{-1}\), but it is worse for stars with shallow correlation dips and/or fast axial rotation.

For some stars, additional RVs were measured with the fiber echelle and the CHIRON spectrometers (Tokovinin et al. 2013) at the CTIO 1.5-m telescope. The reader should refer to (Tokovinin et al. 2015, Tokovinin 2015) for information on those instruments and the data reduction methods. The RVs are derived from the fiber echelle and CHIRON spectra by cross-correlation with the mask based on the solar spectrum and therefore do not require zero-point adjustment. Indeed, we see no systematic difference with the RVM velocities.

3 NEW ORBITS

Identifications and basic parameters of stars with orbital solutions are given in Table I. The orbital elements and their errors are listed in Table II in standard notation. Its last columns contain the total number \( N \) of the RV measurements, the rms resid-
Table 1. List of 35 observed stars

| HIP   | HD     | V mag | Spectral type | p mas | M1 M⊙ | Note          |
|-------|--------|-------|---------------|-------|-------|---------------|
| 5276  | 6611   | 7.24  | F5            | 19.4  | 1.29  | SB1, 74d      |
| 12444 | 16673  | 5.79  | F8V           | 46.0  | 1.20  | SB1, 37d      |
| 17895 | 24031  | 7.23  | F8V           | 19.6  | 1.14  | SB3, 251d     |
| 20693 | 28069  | 7.36  | F7V           | 21.3* | 1.26  | Const.        |
| 21443 | 28907  | 8.61  | G5            | 15.5  | 1.11  | SB1, 2.1d     |
| 24076 | 33507  | 7.42  | F6V           | 17.4  | 1.14  | Const.        |
| 26444 | 37271  | 7.64  | F5            | 20.4* | 1.20  | Const.        |
| 27878 | 39570  | 7.76  | G2            | 18.7  | 1.20  | Const.        |
| 27970 | 39899  | 7.73  | F5V           | 16.0  | 1.27  | SB1, 15d      |
| 28687 | 42155  | 7.49  | F9            | 15.8  | 1.19  | SB2, 148d     |
| 31480 | 46871  | 7.51  | G0V           | 14.0* | 1.35  | Trend, acc.   |
| 32329 | 48565  | 7.18  | F8            | 20.3  | 1.28  | SB1, 73d      |
| 36836 | 60552  | 6.71  | F7III         | 22.5  | 1.34  | Trend, acc.   |
| 38636 | 64273  | 8.36  | G3            | 16.5  | 1.12  | SB1, 66d      |
| 39072 | 65156  | 8.67  | G0            | 15.6  | 1.09  | SB1, 22d      |
| 40479 | 69151  | 8.16  | F6V           | 15.9  | 1.18  | SB1, 58d      |
| 41214 | 70937  | 6.03  | F2V           | 15.8  | 1.61  | SB2, 28d      |
| 43006 | 74685  | 7.59  | F8            | 18.4  | 1.24  | SB1, 70d      |
| 43393 | 75530  | 9.18  | G8V           | 20.0* | 0.94  | Var, slow     |
| 48391 | 85238  | 7.60  | G0            | 22.0  | 1.11  | Const.        |
| 5276  | 99739  | 7.24  | F6V           | 20.4* | 1.29  | Var, 35d?     |
| 56282 | 100269 | 8.09  | F9V           | 15.5* | 1.19  | Var, 122d?    |
| 66290 | 124086 | 8.29  | G9            | 15.2  | 1.18  | Trend, acc.   |
| 73700 | 133460 | 7.28  | F8V           | 15.2  | 1.42  | SB1, 200d     |
| 73765 | 133725 | 7.49  | F8            | 19.5* | 1.21  | Var, 15d?     |
| 79234 | 145605 | 7.72  | F5            | 18.3  | 1.21  | SB1, 9d       |
| 81312 | 149890 | 7.10  | F8V           | 26.0* | 1.19  | Const.        |
| 84696 | 156635 | 6.66  | F7V           | 24.8  | 1.30  | SB1, 3.6yr    |
| 85963 | 159307 | 7.40  | F3V           | 15.3  | 1.37  | Var, acc.     |
| 88656 | 163560 | 7.09  | F8V           | 18.3* | 1.25  | SB2, 4.3d     |
| 92140 | 173614 | 7.00  | F5V           | 18.4  | 1.31  | SB1, 58d      |
| 104514| 201639 | 8.14  | F8            | 15.5  | 1.20  | SB1, 26d      |
| 109122| 207967 | 7.12  | F3V           | 16.9  | 1.40  | Var, 154d?    |
| 112222| 215243 | 6.51  | G8 IV          | 23.6  | 1.37  | SB1, 4.5yr    |

Note: See Section 1 for the description of the columns.

except the triple-lined system HIP 17895 which is deferred to the following Section. The masses of the primary components are derived from their apparent V magnitudes and trigonometric parallaxes using standard relations for main sequence dwarfs (Tokovinin 2014), corrections are made for the magnitudes of double-lined binaries. The existence of additional (tertiary) visual components is noted.

HIP 5276 was discussed in GT14. Its preliminary 74-day orbit is now definitive. This is a triple system with the physical visual companion B at 6.2 (Roberts et al. 2013).

HIP 12444 has now a well-defined 37-day nearly circular orbit. The minimum secondary mass is 0.2 M⊙. This star, located at 21.7 pc, has attracted considerable attention (194 references in SIMBAD), and it is surprising that since its identification as a spectroscopic binary in the GCS no orbit has been determined despite spectroscopic surveys like those of Fuhrmann et al. (2017).

HIP 21443 has a 2-day period was presented in GT14. The orbit is now strengthened by additional measurements. This is a triple system with the physical companion at 5°7 discovered by Riddle et al. (2015).

HIP 27970 is a Hipparcos acceleration binary with a variable RV detected by the GCS. The 15-day orbit determined here implies that the system is triple, as the spectroscopic period is too short to cause any detectable acceleration; the period of the tertiary companion remains unknown. The astrometric binary was not resolved by speckle interferometry at the Southern Astrophysical Research Telescope, SOAR (Tokovinin et al. 2016, and references therein), placing an upper limit on its separation and mass. The centre-of-mass velocity, −9.5 km s⁻¹, is very close to the mean velocity of −9.6 km s⁻¹ given in the GCS (no long-term RV trend).

HIP 28678 is a double-lined binary with nearly equal components for which a tentative 163-day orbit was proposed in GT14. The period is now revised to 148 days, and the new RV curve is shown in Fig. 4. The semimajor axis is 11 mas. The spectroscopic masses are two times less than the masses estimated from the luminosity, hence the orbital inclination should be around 53°. The binary can be resolved by speckle interferometry at 8-m telescopes.

HIP 32329 has a preliminary orbit with P = 73 days. A similar period has been determined by D. Latham (2015, private communication), lending independent verification of our tentative orbit. Latham noted that the system is triple, and, indeed, it is an acceleration binary in Hipparcos. The outer period is not known and the companion has not been resolved by speckle interferometry and adaptive optics. This is a barium star (Allen & Barbuy 2000), suggesting that the spectroscopic companion is most likely a white dwarf; its minimum mass is 0.25 M⊙. The relatively large eccentricity of the inner orbit, e = 0.26, is at odds with the suggested nature of the companion (a nearly circular orbit is expected). However, the eccentricity could be pumped up by the tertiary companion.

HIP 38636 has a variable RV according to the CGS. Now its 66.5-day orbit is determined. This is a triple system with a common proper motion (CPM) companion at 98°.

HIP 39072, like the previous object, is a spectroscopic binary detected by the GCS which now has a 22.5-day orbit. No visual components are known.

HIP 40479 has a 58-day orbit. The visual companion at 31°2 noted by Riddle et al. (2015) is likely optical because its position in 2MASS is not the same. No close visual companions were detected by speckle interferometry at SOAR.

HIP 41214 is a 28-day double-lined binary. Its preliminary orbit presented in GT14 is now definitive. However, the periastron
is still not covered by the observations. Speckle interferometry at SOAR has not revealed any additional companions.

HIP 43004 has an orbital period of 70 days, although the orbit is still provisional. No other companions have been found at SOAR.

HIP 73700 has a variable RV. An orbit with \( P = 200 \) days is fitted to the data.

HIP 79234 is a single-lined binary with a period of 9.07 days, without additional companions.

HIP 84696 is an acceleration binary for which Goldin & Makarov (2007) determined a 4-year astrometric orbit with an axis of 23.8 mas. Our spectroscopic period of 3.55 years, as well as other elements in common, match that orbit within errors. The astrometric inclination of 120° and the RV amplitude lead to the secondary mass of 0.54 \( M_\odot \). The semimajor axis is 70 mas, and the estimated astrometric axis is 20 mas, in agreement with the Hipparcos orbit. This system is not triple, as far as we know.

HIP 88656 has a double-lined orbit with \( P = 4.27 \) days. Five observations with CHIRON are used. Note the non-zero eccentricity, unusual at such short periods. The ratio of the dip areas corresponds to the flux ratio of 0.27, hence the individual V magnitudes of the components Aa and Ab are 7.37 and 8.79 mag, respectively. The masses of the components Aa and Ab, estimated from their absolute magnitudes and the standard relations, are 1.25 and 0.82 \( M_\odot \), matching the spectroscopic mass ratio of 0.71. On the other hand, the “spectroscopic” masses \( M \sin^3 i \) are 0.73 and 0.32 \( M_\odot \) and imply the orbital inclination of \( i = 57° \). The widths of the correlation dips measured with CHIRON correspond to the approximate rotational velocities \( V \sin i \) of 13.6 and 7.8 km s\(^{-1}\) for Aa and Ab that match the expected synchronous velocities reasonably well (a star of one solar radius synchronized and aligned with the orbit would have \( V \sin i = 9.8 \) km s\(^{-1}\)).

There is a faint (\( V = 13.8 \) mag) visual companion B (A 2595 AB) at 3°0, known since 1913 and measured for the last time in 1972. Despite the cloud sky in this area, the companion is physical because it keeps a nearly fixed relative position, while the proper motion is moderately fast. The projected separation between A and B corresponds to the orbital period of the order of 1.3 kyr;
Figure 1. Radial velocity curves. Each panel plots the orbital phase on the horizontal axis and the RV (in km s$^{-1}$) on the vertical axis. The measurements are plotted as squares and triangles for the primary and secondary components, respectively. The full and dashed lines mark the RV curves, the horizontal dotted line corresponds to the centre-of-mass velocity. The crosses mark less accurate RVs that were given a low weight.

Figure 2. Radial velocity curves for tentative orbital solutions. The crosses mark RVs that were given low weights.

No RV trend is noted. The star is on the Lick planet-search program (Fischer et al. 2014); however, the 5 RVs given in that paper do not match the orbit, possibly because the double-lined spectrum was not accounted for in their data reduction.

HIP 92140 has been observed also with the fiber echelle at the CTIO 1.5 m telescope (Tokovinin et al. 2015). We combine the RVM and the echelle RVs in an orbit with $P = 588$ days. The crosses in Fig. 1 denote the RVM velocities, the squares are the fiber echelle RVs. The orbit can still be improved, but its long period requires monitoring for several more years. This is a triple system with the visual companion at 5′.8, four magnitudes fainter...
than the spectroscopic pair. The orbital period of the visual binary is of the order of 4 kyr.

HIP 104514 has a slow RV variation with a 266 day period and a small amplitude. The tertiary companion at 3′.3 has been discovered with Robo-AO (Riddle et al. 2015) and later shown to be physical (co-moving) by Roberts et al. (2015).

HIP 112222 is a bright Hipparcos acceleration binary with slow RV variability. Monitoring during 5 years has covered one full orbital cycle of 1634±20 days, allowing us to determine the preliminary elements. The minimum secondary mass is 0.34 solar. The semimajor axis is 77 mas, while the predicted astrometric axis is 15 mas. No astrometric orbit has been derived so far, but this should be an easy task for Gaia.

No additional companions to this star are known. However, Shaya & Olling (2011) noted that the K2V star HIP 112354 has a common proper motion and distance. Its RV of 1.9 km s\(^{-1}\) also roughly matches the centre-of-mass velocity of our binary, \(-2.9 \text{ km s}^{-1}\). This CPM companion is itself a visual binary BU 711 with a known orbit \((P = 800 \text{ yr})\). The projected distance between those two binaries is 0.4 pc, too large for a gravitationally bound pair. However, they could be a young co-moving pair of binaries with a common origin.

Among the 19 stars of this Section, 8 have additional components (they are at least triple). Partly the large fraction of hierarchies can be explained by the efforts of observers to look for additional companions around spectroscopic binaries within 67 pc (e.g. Riddle et al. 2015).

### 4 THE TRIPLE SYSTEM HIP 17895

HIP 17895 is a nearby solar-type dwarf with the HIP2 parallax of 19.63±0.66 mas. Double lines were detected by the GCS and the mass ratio of 0.577±0.109 was estimated. At the same time, this is a visual binary YR 23 (WDS J03496−0220), first resolved by Horch et al. (2002) in 2000.76 at 0′.28 separation. Such a binary would normally be resolved by Hipparcos, but its duplicity has not been recognized by that experiment. However, Hipparcos identified the object as an astrometric binary. It was not known whether the double lines were produced by the visual/astrometric binary itself or whether the system is triple.

The object has been observed with the CHIRON spectrograph at the 1.5-m telescope at CTIO in the second half of 2015 and in 2017. The spectra and the RV measurement by cross-correlation are described in Tocovani (2013, 2014). The first spectrum has clearly shown triple lines (Fig. 3). The broad central feature with the largest equivalent width belongs to the visual primary component A, the two flanking narrow dips correspond to the spectroscopic subsystem Ba,Bb. The narrow lines moved on the time scale of months, while the central line remained stationary. The CHIRON data cover 145 days in 2015, slightly more than half of the orbital cycle.

We placed this star on the RVM observing programme in 2012. These observations are used in the orbit calculation to extend the time coverage and constrain the orbital period. However, the lower spectral resolution of the RVM, its lower sensitivity, and the triple-lined nature of the spectrum all lead to the relatively large errors of the RVM velocities. The elements of the double-lined orbit of Ba,Bb are given in Table 2: the RV curve is given in Fig. 4. In the final least-squares adjustment, the errors of the CHIRON RVs (and the corresponding weights) were set to 0.3 km s\(^{-1}\), while the errors of the RVM velocities were increased artificially to reflect their lower accuracy.

Although the measurements of the visual pair A,B in 2001–2014 cover only a small fraction of its orbit, its preliminary elements with \(P = 54 \text{ yr}\) were determined by Riddle et al. (2015). Here this orbit is updated by using the latest data, a different set of weights, and a fixed eccentricity of 0.6. As the orbit is poorly constrained anyway, this is acceptable. A larger eccentricity corresponds to the larger mass sum. By choosing \(e = 0.6\), we get the expected mass sum of 2.9 \(\text{M}_\odot\). The orbit implies a separation of 0′.22 in 1991.25, so the non-resolution by Hipparcos is still difficult to explain. If we adopt a shorter period (meaning a closer separation in 1991), the mass sum becomes too large (e.g. 11 \(\text{M}_\odot\) for \(P = 40 \text{ yr}\)). The new orbital elements of A,B are: \(P = 51.1 \text{ yr}\), \(T_0 = 1988.3\), \(e = 0.6\), \(a = 0′.383\), \(\Omega_A = 68°\), \(\omega = 286°\), \(i = 121°\).

The visual elements and the expected mass sum correspond to the RV amplitudes in the outer orbit of \(K_A + K_B = 14 \text{ km s}^{-1}\) and match the RV difference of \(\sim 2 \text{ km s}^{-1}\) between A and B measured in 2015 (the RVs of A measured from the well-resolved profiles are 4.8, 5.4, and 5.0 km s\(^{-1}\) on JD 2457257, 2457276, and 2457277,

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**Figure 3.** Cross-correlation function of HIP 17895 recorded with CHIRON on JD 2457257.

**Figure 4.** The RV curve of HIP 17895 Ba,Bb. The squares and triangles stand for the RVs of the primary (Ba) and secondary (Bb) components, respectively, measured with CHIRON. The large and small crosses correspond to the RVM data of lower accuracy.
respectively). This means that the true ascending node of the visual orbit is already known. Small orbital coverage prevents us from measuring the masses and orbital parallaxes from the combined visual/spectroscopic orbit of the outer pair A,B. Large variations of the RV are predicted to occur at the time of the next periastron passage around 2040.

Individual magnitudes and masses of all three components can be deduced from the available data. The speckle interferometry at SOAR yields the relative photometry of the A,B pair: \( \Delta y = 0.78 \) mag (two measures) and \( \Delta I = 0.57 \) mag (one measure). The latter matches \( \Delta I = 0.56 \) mag given by [Horch et al. (2002)]. On the other hand, the equivalent width of the individual details in the cross-correlation (Fig. 3) is 0.90, 0.32, and 0.11 km s\(^{-1}\) for A, Ba, and Bb, respectively. The flux ratio between A and B is thus 0.48±0.05 or 0.80 mag, in good agreement with the speckle photometry. So, the individual V magnitudes of A, Ba, and Bb are estimated to be 7.67, 8.74, and 9.92 mag, respectively. Standard relations for main sequence stars and the Hipparcos parallax lead to the masses of 1.14, 0.96, and 0.80 \( \text{M}_\odot \), or the mass sum of 2.9 \( \text{M}_\odot \). These estimates agree with the directly measured mass ratio in the inner binary, \( q_{\text{Ba,Bb}} = 0.85 \). All three stars in this triple system apparently match the standard main-sequence relation between mass and absolute magnitude.

The spectroscopic mass sum in the inner subsystem \( (M_{\text{Ba}} + M_{\text{Bb}}) \sin^3 i = 1.72 \text{M}_\odot \) is just slightly less than the estimated mass sum of 1.76 \( \text{M}_\odot \). This means that the orbit of Ba,Bb has a high inclination \( i_{\text{Ba,Bb}} \approx 80^\circ \) or \( q_{\text{Ba,Bb}} \approx 100^\circ \). The inclination of the outer orbit is \( i_{\text{A,B}} = 121^\circ \). Therefore, the inner and outer orbits possibly have small mutual inclination.

The semimajor axis of the inner orbit is 18.5 mas. Knowing the inclination, we can compute the separation between Ba and Bb. At the moment of the SOAR observation in 2011.04 it was 15 mas, just below the diffraction limit. There is a hint that the inner pair was indeed partially resolved, but no reliable measure can be extracted. The maximum separation of about 26 mas and \( \Delta V = 1.2 \) mag mean that the subsystem Ba,Bb can be resolved at 4-m telescopes and certainly at 8-m ones and with long-baseline interferometers like CHARA. Several resolved observation of Ba,Bb would establish its visual orbit and the mutual inclination in this triple system. The 250-day motion of the photo-centre caused by the subsystem is large enough to be detectable by Gaia or by the residuals in the outer orbit.

The spectral lines of the component A are broadened by the axial rotation of \( V \sin i \approx 24 \text{ km s}^{-1} \) corresponding to the rotational period of \(<2.6\) days. According to the age-rotation relation proposed by [Barnes (2007)], the age might be less than 200 Myr. The large \( V \sin i \) also suggests a high inclination of the rotation axis, matching in this respect the highly inclined orbits. Coronal X-ray emission from this multiple system was detected by ROSAT (RX J0349.6–0219).

### 5 STARS WITHOUT ORBITS

Table 3 reports on the 16 stars observed in this programme with RVM but lacking orbits. It gives the total number of RVs \( N \), the average RV, the unweighted r.m.s. scatter of the velocities \( \sigma \), and the total time span of the observations \( \Delta T \) in days. The individual RVs are provided in the Supplementary material, Table 5.

According to the GCS, all those stars are spectroscopic binaries. However, some of them turned out to have a constant RV (HIP 20693, 26444, 27878, 48391, 81312). The spurious detection of variability in the GCS could have been caused by an outlying measure or by pointing a wrong star. Another group of stars show only a slow RV variation (e.g. linear trends) indicative of long orbital periods; for some of those an astrometric acceleration was also detected by Hipparcos (HIP 31480, 36836, 43393, 66290, 69238, 85963). The plots of RV vs. time for these stars are given in Fig. 5. The remaining objects are spectroscopic binaries for which our data do not yet allow orbit calculation. Individual comments are provided below. All periods proposed below are tentative.

#### Table 3. Average RVs of stars without orbits

| HIP    | \( N \) | \( \langle \text{RV} \rangle \) \( \text{km s}^{-1} \) | \( \sigma \) \( \text{km s}^{-1} \) | \( \Delta T \) \( \text{days} \) |
|-------|-------|----------------|-------------|---------|
| 20693 | 27    | 31.51          | 1.66        | 1483    |
| 24076 | 22    | 6.87           | 1.14        | 1482    |
| 26444 | 11    | 47.41          | 0.85        | 1102    |
| 27878 | 19    | 32.70          | 1.04        | 1481    |
| 31480 | 10    | 19.45          | 1.61        | 1252    |
| 36836 | 10    | 9.88           | 3.43        | 1622    |
| 43393 | 12    | 31.60          | 2.41        | 1645    |
| 48391 | 15    | −12.09         | 1.04        | 390     |
| 55982 | 14    | 8.68           | 4.94        | 389     |
| 56282 | 12    | 9.53           | 6.59        | 388     |
| 66290 | 14    | −17.95         | 1.82        | 521     |
| 69238 | 10    | −17.88         | 2.66        | 389     |
| 73765 | 23    | −12.10         | 9.20        | 1341    |
| 81312 | 33    | −5.31          | 0.50        | 1128    |
| 85963 | 13    | −11.29         | 17.20       | 1111    |
| 109122| 61    | −6.10          | 6.31        | 1433    |
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Figure 5. Plots of RV vs. time for six stars with slow RV variation. The Hipparcos numbers are indicated in the plots.

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REFERENCES

Allen, D. M. & Barbuy, B. 2006, A&A, 454, 895
Barnes, S. A. 2007, ApJ, 669, 1167
Fischer, D. A., Marcy, G. W., & Sromonck, J. F. P. 2014, ApJS, 210, 5
Fuhrmann, K., Chini, R., Karenhandt, L & Chen, Z. 2017, ApJ, 836, 139
Gaia Collaboration, Brown, A. G. A., Vallenari, A., Prusti, T. et al. 2016, A&A, 595, 2
Goldin, A. & Makarov, V. V. 2007, ApJS, 173, 137
Gorynya, N. A. & Tokovinin, A. A. 2014, MNRAS, 441, 2316 (GT14)
Horch, E. P., Robinson, S. E., Ninkov, Z. et al. 2002, AJ, 124, 2245
Latham, D. W., Stefanik, R. P., Torres, G. et al. 2002, AJ, 124, 1144
Nordström, B., Mayor, M., Andersen, J. et al. 2004, A&A, 418, 989 (GCS)
Riddle, R., Tokovinin, A., Mason, B. D. et al. 2015, ApJ, 799, 4
Roberts, L. C., Jr., Tokovinin, A., Mason, B. D. et al. 2015, AJ, 150, 130
Shaya, E. J. & Olling, R. P. 2011, ApJS, 192, 2
Tokovinin, A. A. 1987, AZh, 64, 196 (SvA, 31, 98)
Tokovinin, A. A. & Gorynya, N. A. 2001, A&A, 374, 227
Tokovinin, A., Fischer, D.A., Bonati, M. et al. 2013, PASP, 125, 1336
Tokovinin, A. 2014, AJ, 147, 86ar.gz atokovin@ctiowa
Tokovinin, A., Pribulla, T., & Fischer, D. 2015, AJ, 149, 8
Tokovinin, A. 2015, AJ, 150, 177
Tokovinin, A., Mason, B. D., Hartkopf, W. I. et al. 2016, AJ, 151, 153
Tokovinin, A. 2016, AJ, 152, 11
Tokovinin, A. 2017, AJ, 154, 110
van Leeuwen, F. 2007, A&A, 474, 653 (HIP2)

6 SUPPLEMENTARY MATERIAL

Table 4 gives the individual RVs and residuals to the orbits. Its columns contain the Hipparcos number, the heliocentric Julian date of observation minus 2400000, the RV, its error, and the residual to the orbit, all in km s\(^{-1}\). The last column of Table 4 contains the flag denoting the component (a for the primary and b for the secondary). Letters F or C are added to the component flag to mark the RVs measured with the fiber echelle and CHIRON, respectively. Table 5 gives the individual RVs of stars without orbits, in the same form except that there are no columns with the residuals and the component flag. All RVs listed in Table 5 are measured with the RVM.