HIGH VELOCITY SPECTROSCOPIC BINARY ORBITS FROM PHOTOELECTRIC RADIAL VELOCITIES: BD +82 565 A

A. Bartkevičius\textsuperscript{1,3} and J. Sperauskas\textsuperscript{1,2}

\textsuperscript{1} Institute of Theoretical Physics and Astronomy, Vilnius University, Goštauto 12, Vilnius, LT-01108, Lithuania

\textsuperscript{2} Vilnius University Observatory, Ėiurlionio 29, Vilnius, LT-03100, Lithuania

\textsuperscript{3} Department of Theoretical Physics, Vilnius Pedagogical University, Studenty 39, Vilnius, LT-08106, Lithuania

Received 2005 November 21

Abstract. The spectroscopic orbit of a circumpolar high proper motion visual binary BD +82 565 A component is determined from 57 CORAVEL radial velocity measurements. A short period $P = 12.69$ d and a moderate eccentricity $e = 0.30$ are obtained. The visual system AB has a projected spatial separation $\sim 830$ AU. The system’s barycenter velocity $V_0 = -86.7$ km/s, the transverse velocity $V_t = 118.7$ km/s and the Galactic spatial velocity components $U = -62.6$ km/s, $V = -84.1$ km/s and $W = -84.2$ km/s give evidence that it belongs to the thick disk of the Galaxy.

Key words: stars: binaries: spectroscopic, visual, individual: BD +82 565

1. INTRODUCTION

In 1988 we initiated a program of photoelectric radial velocity measurements of Population II single and binary stars (Bartkevičius & Sperauskas 1990, 1994, 1999, 2005; Bartkevičius et al. 1992; Sperauskas & Bartkevičius 2002). The analysis of the results have led to the discovery of some new radial velocity variables. With this publication we start to publish spectroscopic orbits of the newly discovered binaries.

As a high proper motion star ($\mu = 0.37''$ per year), BD +82 565 was first mentioned in 1916 (communicated by the Astronomer Royal, MNRAS, 76, 585). Its proper motion was determined by comparing the coordinates given in vol. III of the Greenwich Astrographic Catalogue with the coordinates from the Circumpolar Stars Catalogue (Carrington 1857). Luyten included this star in his high proper motion catalogs LTT (Luyten 1961) and NLTT (Luyten 1979). The star is also included in the Lowell Observatory high proper motion survey as G 259-37, and there a very good identification chart is given (Giclas et al. 1970). As a double common proper motion star, it was discovered by Luyten (1966). Slightly different data are given in subsequent Luyten’s publications (Luyten 1967, 1968). The star is also included in the original Luyten publication of Double Stars with Common Proper Motion (LDS) as LDS 1894 (Luyten 1969). In NLTT Luyten gives the angular distance $d = 12.0''$ and $PA = 81.0^\circ$ between the A and B components. Salim & Gould (2003) in the Revised NLTT Catalogue presents slightly
different values for the AB system: \( d = 11.5'' \) and \( PA = 87.9^\circ \) for J2000.0. Our estimates using the CDS ALADIN interactive sky atlas are: \( d = 11.2\pm0.2'' \), \( PA = 79.5\pm0.7^\circ \) for J1950.0 and \( d = 11.4\pm0.1'' \) \( PA = 82.9\pm0.3^\circ \) for J2000.0. To our knowledge, no other measurements of angular distance and position angle between the components are known.

2. IDENTIFICATION

Equatorial coordinates of the A component of the binary are \( \alpha(2000.0) = 18^h47^m02.6389^s \), \( \delta(2000.0) = +82^\circ43'30.260'' \). Five stars are seen in one arcmin field of the first Palomar Observatory Sky Survey (POSS I) (Figure 1). In the second-epoch Palomar survey the third star is blended by the binary due to its high proper motion (Figure 2). Identification of the stars taken from the CDS Simbad is presented in Table 1. Stars 3, 4 and 5 are optical components.

![Identification chart from the first Palomar Observatory Sky Survey (POSS I.O).](image1)

![Identification chart for epoch 2000.0. Proper motion for star 3 is unknown, its position is for the epoch 1953.7.](image2)

**Table 1.** Identification of binary components and nearby stars.

| Component A | Component B |
|-------------|-------------|
| BD +82 565, AGK3 +82 545, HIP 92162, PLX 4424, CCDM J18471+8244, WDS J18470+8244, IDS 18587+8236, PPM 3296, SAO 3127, G 259-37, LTT 15562, LDS 1894, TYC 4648 474 1, USNO-A2.0 1725-006000458, GSC2.2 N01001337626, 2MASS 18470262+8243300 | LP 10-124, LP 9-323, 2MASS 18470873+8243320 |
| Star 3 | Star 4 |
| USNO-A2.0 1725-00600531 | USNO-A2.0 1725-005000574, GSC2.2 N01001337627, APM-N EO0802-0246683, 2MASS 18471195+8243116 |
| Star 5 | Star 5 |
| USNO-A2.0 1725-00500367, APM-N EO0802-0246181, GSC2.2 N01001337628 |
3. PHOTOMETRY AND SPECTRAL TYPES

From the Kharchenko (2001) ASCC-2.5 catalog the magnitude and color index of the A component are: $V = 9.32 \pm 0.02$ and $B-V = 0.67 \pm 0.04$. The B component and other three field stars have only photographic magnitudes in the systems similar to $B$ and $R$, and they are presented in Table 2. The infrared 2MASS photometry results available for three stars are also given.

Table 2. Photometry of stars in the vicinity of BD +82 565.

| Comp. | $B$     | $\sigma_B$ | $R$     | $\sigma_R$ | $B-R$ | $\sigma_{(B-R)}$ | Source                           |
|-------|---------|------------|---------|------------|-------|-----------------|----------------------------------|
| A     | 9.99    | 0.03       | 8.81    | 0.41       | 1.18  | 0.41            | ASCC-2.5, GSC2.2                 |
| B     | 16.0    | 14.5       | 1.5     | 0.41       | 1.3   | NLTT            |                                  |
| 3     | 16.0    | 14.7       | 1.3     | 0.59       | 0.59  | GSC2.2          |                                  |
| 4     | 17.12   | 0.41       | 15.29   | 0.42       | 1.91  | 0.59            |                                  |
| 5     | 17.60   | 0.41       | 17.15   | 0.42       | 0.45  | 0.59            |                                  |

Three discrepant one-dimension spectral types for the A component are known. Petersson (1927) in 1924 classified the star as F8 using 264 Å/mm dispersion objective prism spectra obtained at the Uppsala Observatory. This type is given in the Skiff (2003) Catalogue of Stellar Spectral Classifications. G. P. Kuiper obtained a considerably later spectral type, K0 (published by Bidelman (1985) in the article “G. P. Kuiper’s spectral classifications of proper-motion stars”). A decade earlier Bidelman & Lee (1975) presented Kuiper’s spectral type in a compilation of spectral types for proper motion stars pointing Jenkins (1952) Catalogue of Trigonometric Parallaxes as the literature source. In the van Altena et al. (1995) catalog of trigonometric parallaxes a dK0 spectral class is given, quoting Bidelman as the literature source, so the origin of the dwarf classification is not clear. The third spectral class, G0, was estimated by Balz (1958) from the McCormick Observatory 300 Å/mm spectra, and quoted also in the AGK3 catalog and in many other sources including the SIMBAD database. Intrinsic color index $(B-V)_0 = 0.65$ corresponds to the G2/G5 V spectral type. For the B component Luyten presented different color classes: from k, k-m to m. 2MASS colors correspond to a dwarf of K5–K7 spectral type.

4. DISTANCE, ABSOLUTE MAGNITUDE AND KINEMATICS

*Hipparcos* recorded a good precision (6%) parallax $\pi = 13.78 \pm 0.81$ mas. This corresponds to a distance $d = 72.6 \pm 4.3$ pc. Only one useless ground-based parallax, $\pi = 0.0017 \pm 0.0133$ mas, measured with the Greenwich Observatory Thompson 66 cm refractor (Dyson 1925) is included in Jenkins (1952) and van Altena et al. (1995) Yale General Parallax Catalogues. The *Tycho* program obtained a very negative parallax, $\pi = -9.90 \pm 11.20$ mas. Kharchenko (2001), following a questionable method to average *Hipparcos* and *Tycho* parallax determinations, has presented $\pi = 13.65 \pm 0.81$ mas. From Schlegel et al. (1998) interstellar reddening
maps for the binary at $\ell = 114.8^\circ$ and $b = 27.0^\circ$ the total line-of-sight interstellar reddening is $E_{B-V} = 0.07$. Taking into account a distance to the binary of 72.6 pc (from the Hipparcos parallax), the true $E_{B-V} = 0.02$ and $A_V = 0.07$ are calculated (Anthony-Twarog & Twarog 1994).

The absolute magnitude of component A from the Hipparcos parallax and the above-mentioned $V$ and $A_V$ is $M_V = 4.95 \pm 0.13$ mag. In the $M_V$ vs. $(B - V)_0$ plot the A component is situated within the main-sequence band. The reduced proper-motion diagram $H_V$, $B-V$ places the star at the subdwarf-main sequence border. The B component in the blue spectral region is fainter by 6 mag, in the red – by 5.7 mag, and this corresponds to a M3/4 dwarf. However, the infrared 2MASS photometry of the star is consistent with an earlier K5/7 dwarf.

The Hipparcos parallax, the Tycho 2 proper motion components and our value of spectroscopic binary barycenter radial velocity are used to calculate kinematical parameters of the system. The procedure of computation is the same as in Bartkevičius & Gudas (2001, 2002). The velocity component $U$ is directed to the Galactic center, $V$ – to the direction of Galactic rotation and $W$ – to the North Galactic Pole. They have been corrected due to the solar motion with respect to the Local Standard of Rest $U = 10.0 \pm 0.4$ km/s, $V = 5.2 \pm 0.6$ km/s and $W = 7.2 \pm 0.4$ km/s (Binney & Merrifield 1998). Evidently, the binary belongs to the thick disk population.

5. RADIAL VELOCITY MEASUREMENTS

Radial velocity measurements were made by J. Sperauskas with a CORAVEL-type spectrometer constructed at the Vilnius University Observatory. A description of the measurements and data reduction procedures are presented in Upgren, Sperauskas & Boyle (2002). 57 individual radial velocities for BD +82 565 A were obtained at the Molėtai Observatory with the 0.63 m and 1.65 m telescopes. These measurements were spread over the period of 619 days starting in 2000 August 28. Standard single-measurement errors range from 0.7 to 1.0 km/s with the mean value of 0.8 km/s. Individual radial velocity measurements are listed in Table 4 together with the Heliocentric Julian Days and phases calculated from the orbital elements, measurement errors and residuals.

6. ORBITAL SOLUTION

The obtained radial velocity curve is plotted in Figure 3. The calculated orbital elements are given in Table 5. The system has a high center of mass radial velocity and moderate orbit eccentricity.
Table 3. Kinematical parameters.

| Parameter | Value        |
|-----------|--------------|
| \( \ell \) | 114.8        |
| \( b \)   | 27.0         |
| \( \mu_\alpha \) | 183.3 |
| \( \sigma_{\mu_\alpha} \) | 1.5     |
| \( \mu_\delta \) | 292.3 |
| \( \sigma_{\mu_\delta} \) | 1.5     |
| \( V_r \) | \(-86.70\) |
| \( \sigma_{V_r} \) | 0.07   |
| \( V_t \) | 118.7       |

Table 4. Radial velocity measurements.

| HJD     | Phase | \( V_r \) | \( \sigma_{V_r} \) | \( O - C \) |
|---------|-------|-----------|-----------------|-----------|
| 51785.320 | 0.486205 | 99.2 | 0.7 | -0.195 |
| 51794.348 | 0.197961 | -109.8 | 0.8 | -0.826 |
| 51999.586 | 0.369176 | -65.1 | 0.9 | 0.342 |
| 52003.557 | 0.628060 | -77.8 | 0.9 | 0.791 |
| 52004.561 | 0.761169 | -67.9 | 0.7 | 0.268 |
| 52005.564 | 0.922578 | -64.4 | 0.8 | 0.755 |
| 52006.569 | 0.998183 | -66.1 | 0.8 | -0.826 |
| 52007.576 | 0.998735 | -65.1 | 0.9 | 0.342 |
| 52008.580 | 0.078081 | -90.7 | 0.9 | 0.818 |
| 52008.580 | 0.078553 | -92.2 | 1.1 | -0.546 |
| 52009.580 | 0.079656 | -92.0 | 0.9 | -0.033 |
| 52010.580 | 0.080129 | -91.9 | 0.9 | 0.201 |
| 52011.580 | 0.080629 | -91.0 | 0.8 | -0.033 |
| 52012.580 | 0.081129 | -90.0 | 0.8 | -0.826 |
| 52013.580 | 0.081629 | -89.1 | 0.8 | -0.826 |
| 52014.580 | 0.082129 | -88.2 | 0.8 | -0.826 |
| 52015.580 | 0.082629 | -87.3 | 0.8 | -0.826 |

Table 5. Orbital elements of BD +82 565 A.

| Parameter                          | Value                          |
|------------------------------------|--------------------------------|
| Orbital period                     | \( P = 12.6913 \pm 0.0009 \text{ days} \) |
| Center-of-mass velocity            | \( V_0 = -86.70 \pm 0.07 \text{ km/s} \) |
| Half-amplitude                     | \( K = 29.55 \pm 0.10 \text{ km/s} \) |
| Eccentricity                       | \( e = 0.305 \pm 0.003 \) |
| Longitude of periastron            | \( \omega = (57.3 \pm 0.6) \text{ deg} \) |
| Date of conjunction                | \( T_{\text{con}} = 2452401.021 \pm 0.022 \text{ HJD} \) |
| Projected semimajor axis           | \( a \sin i = (4.91 \pm 0.02) \text{ 10^6 km} \) |
| Function of the mass               | \( f(m) = 0.0294 \pm 0.0004 \text{ M}_\odot \) |
| Mean square error of one observation | \( \sigma(O-C) = \pm 0.44 \text{ km/s} \) |
7. VISUAL SUBSYSTEM PARAMETERS

The period of the AB subsystem of almost 17,000 years is estimated using Kepler’s third law, assuming circular face-on orbit, apparent separation $d = 11.5''$, parallax $\pi = 13.78$ mas and total mass $1.8 \, M_\odot$, adopting for a spectroscopic binary A the main component $M = 1 \, M_\odot$ (according to its spectral class) and for the secondary component $0.5 \, M_\odot$ (from the spectroscopic mass function $f(m)$ taking $\sin^3 i = 2/3$). For the visual B component we adopted $0.3 \, M_\odot$ (from the mass-luminosity relation). From the Palomar first and second epoch Sky Surveys and 2MASS survey crude estimates of the angular separation and position angle were made for two epochs. For $E_{\text{mean}} = 1953.7$ we obtain: $d_{\text{mean}} = (11.18 \pm 0.21)''$ and $PA_{\text{mean}} = (79.65 \pm 0.69)^\circ$ and for $E_{\text{mean}} = 1998.1$ we obtain $d_{\text{mean}} = (11.46 \pm 0.07)''$ and $PA_{\text{mean}} = (83.07 \pm 0.33)^\circ$. Evidently, during 44 years the angular separation practically did not change. Only the change of the position angle of $0.077^\circ$ per year may be real. In case of the circular orbit, this change of $PA$ corresponds to a period of about 4700 years which is almost four times smaller than that calculated from the third Kepler law.

The minimum spatial distance between components A and B, adopting the projected spatial distance from the mean angular separation $d = 11.4''$ and a distance of 72.6 pc, is $\sim 830$ AU.

8. CONCLUSIONS

A short-period ($P = 12.69$ d) and moderate eccentricity ($e = 0.30$) spectroscopic orbit of the A component of a high velocity ($v_{\text{tot}} = 147.0$ km/s) visual binary system BD $+82$ 565 is determined from 57 CORAVEL-type radial velocity measurements. The projected spatial separation of components of the visual binary AB is $\sim 830$ AU.

ACKNOWLEDGMENTS. We are indebted to V.-D. Bartkevičienė for preparation of the manuscript to publication. In this investigation the information from the Strasbourg Stellar Data Center (CDS), NASA Bibliographic Data Center (ADS), Astrophysics preprint archive and the Washington Visual Double Stars Catalog (WDS) were used. Radial velocity observations were obtained with the 0.63 m and 1.65 m telescopes of the Molėtai Observatory, Lithuania.

REFERENCES

Anthony-Twarog B. J., Twarog B. A. 1994, AJ, 107, 1577
Balz A. G. A. 1958, Publ. McCormick Obs., 13, 1
Bartkevičius A., Gudas A. 2001, Baltic Astronomy, 10, 481
Bartkevičius A., Gudas A. 2002, Baltic Astronomy, 11, 153
Bartkevičius A., Sperauskas J. 1990, in Proceedings of the Nordic – Baltic Astronomy Meeting, eds. C.-I. Lagerkvist, D. Kiselman & M. Lindgren, Astronomical Observatory of the Uppsala University, p. 45
Bartkevičius A., Sperauskas J. 1994, Baltic Astronomy, 3, 49
Bartkevičius A., Sperauskas J. 1999, Baltic Astronomy, 8, 325
Bartkevičius A., Sperauskas J. 2005, Baltic Astronomy, 14, 511 (this issue)
High velocity spectroscopic binary orbits: BD +82 565 A

Bartkevičius A., Sperauskas J., Rastorguev A. S., Tokovinin A. A. 1992, Baltic Astronomy, 1, 47
Bidelman W. P. 1985. *G. P. Kuiper’s Spectral Classifications of Proper-motion Stars*, ApJS, 59, 197
Bidelman W. P., Lee S.-G. 1975, AJ, 80, 239
Binney J., Merrifield M. 1998 *Galactic Astronomy*, Princeton University Press, Princeton
Carrington R. C. 1857, *A Catalogue of 3735 Circumpolar Stars, observed at Redhill in the Years 1854, 1855, and 1856, and reduced to Mean Positions for 1855.0*, London
Dyson F. 1925, *Greenwich Observations of Stellar Parallaxes*
Giclas H. L., Burnham R., Thomas N. G. 1970, Bull. Lowell Obs., 8 (No. 152), 165
Jenkins L. F. 1952, *General Catalogue of Trigonometric Stellar Parallaxes*, Yale University Observatory, New Haven
Kharchenko N. V. 2001, *All-sky Compiled Catalogue of 2.5 Million Stars*, Kinematics and Physics of Celestial Bodies, Kiev, 17, 409; CDS Catalog No.1/280A
Luyten W. J. 1961. *A Catalogue of 7127 Stars in the Northern Hemisphere with Proper Motions Exceeding 0.2″ Annually*, Minneapolis
Luyten W. J. 1966, Publ. Minnesota Obs., No. 17
Luyten W. J. 1967, *Proper Motion Survey with the 48-inch Schmidt Telescope. XII*, Minnesota University Observatory, Minneapolis
Luyten W. J. 1968, *Proper Motion Survey with the 48-inch Schmidt Telescope. XIV*, Minnesota University Observatory, Minneapolis
Luyten W. J. 1969. *Proper Motion Survey with the 48-inch Schmidt Telescope. XXI*, Minnesota University Observatory, Minneapolis; CDS Catalog No. I/130
Luyten W. J. 1979. *NLTT Catalogue. Vol. I. +90 to +30*, University of Minnesota, Minneapolis; CDS Catalog No. I/98A
Udry S., Mayor M., Maurice E., Andersen J., Imbert M., Mermilliod J. C. 1999, in *Precise Stellar Radial Velocities*, eds. J. B. Hearnshaw & C. D. Scarfe, ASP Conf. Ser., 185, 383 (IAU Colloq. No. 170)
Upgren A. R., Sperauskas J., Boyle R. P. 2002, Baltic Astronomy, 11, 91
Petersson J. H. 1927, Medd. Uppsala Obs., 29, 1
Salim S., Gould A. 2003, ApJ, 582, 1011; CDS Catalog No. J/ApJ/582/1011
Schlegel D. J., Finkbeiner D. P., Davis M. 1998, ApJ, 500, 525
Skiff B. A. 2003. *Catalogue of Stellar Spectral Classifications*, Lowell Observatory, CDS Catalog No. III/233
Sperauskas J., Bartkevičius A. 2002, AN, 323, 139
van Altena W. F., Lee J. T., Hoffleit E. D. 1995, *The General Catalogue of Trigonometric Stellar Parallaxes*, 4th edition, Yale University Observatory