A&A 368, 572–579 (2001)
DOI: 10.1051/0004-6361:20010024

Astronomy & Astrophysics

Multicolour observations of nearby visual double stars. New CCD measurements and orbits

P. Lampens[1] and A. Strigachev[1,2]

[1] Royal Observatory of Belgium, Av. Circulaire 3, 1180 Brussels, Belgium
[2] Institute of Astronomy, Bulgarian Academy of Sciences, 72 Tsarigradsko Chausse Blvd., 1784 Sofia, Bulgaria
e-mail: `Anton.Strigachev@oma.be`

Received 20 September 2000 / Accepted 15 December 2000

Abstract. We present multicolour CCD observations of nine nearby visual double stars obtained in August and September 1999 with the 1.3-m telescope at Skinakas Observatory*. The results consist of relative positions (epochs, angular separations and position angles) and differential *BVRI* photometry. We confirm the physical association in eight cases. Previously known orbits do not match the new data for three systems. Orbits have been recalculated when sufficient data were available. We principally improve the precision of the known orbits for three binaries and show the acute lack of precision in two other cases. In one case, the components are shown to move apart with a linear relative speed of 0.050″/yr.

Key words. stars: binaries: visual – stars: fundamental parameters – stars: nearby – techniques: photometric – astrometry

1. Introduction

A major contribution of the Hipparcos mission in the field of double star research is the improved census, result of a systematic and repeated scrutiny of all 118 000 programme stars leading to a high number of new detections with small angular separations (Lindegren et al. 1997). Likewise, the results of Hipparcos have also brought a dramatic revision of the contents of the Catalogue of Nearby Stars in the sense that many "nearby" systems are further away than previously thought (Jahreiss & Wielen 1997). As a consequence, the sample of double and multiple stars within a distance of 25 pc from the Sun has changed significantly and merits to be studied as such since it is based on a more complete and more reliable survey than was previously possible.

The context of this research is to try to determine with some accuracy the distribution functions of the true separations, relative motions, mass and luminosity ratios as well as temperature differences of the binaries in the immediate solar neighbourhood. Such knowledge may provide observational constraints to the scenarios of binary star formation. For this, we need the fundamental data on the binaries as well as the individual properties of the components such as the magnitudes and the colour indices in addition to the astrometric parameters of each component.

Our programme stars belong to the intersection of the Catalogue of Nearby Stars (GJ, Gliese & Jahreiss 1991) and the Hipparcos Catalogue (ESA 1997) having parallaxes larger than 0.04″, so they are part of the newly defined sample of nearby double and multiple stars. They have been furthermore chosen among the systems with "intermediate" angular separation (between 1″and 15″) for which CCD observations can provide both accurate and complementary data on each of the components. They are generally listed in the "Double and Multiple Systems Annex - Components" (DMSA/C) section of the Hipparcos Catalogue. However, this does not always mean that all astrometric parameters have been derived independently. In most cases some similitude between parallaxes or between parallaxes and proper motions has been adopted. Additional ground-based data of comparable relative accuracy are necessary to verify the underlying assumption.

In addition, due to the limiting magnitude of the Hipparcos Catalogue, some of the faintest but nearby double stars have not been included or are at the limit of the

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Send offprint requests to: P. Lampens,
e-mail: `Patricia.Lampens@oma.be`

[*] Skinakas Observatory is a collaborate project of the University of Crete, the Foundation for Research and Technology - Hellas, and the Max-Planck-Institut für Extraterrestrische Physik.

satellite's possibilities. In this paper, we are focusing on nine fainter visual binaries in the sample, some of which are of specific interest since they also show orbital motion and therefore need accurate monitoring on a time scale longer than a few years. Two of these form part of the sample having component masses accurate within 15% used to re-assess the mass-luminosity relation based on the Hipparcos parallaxes (Lampens et al. 1998).

2. Observations

2.1. Instrumentation, limitations and primary data reduction

The observations were performed at the Skinakas Observatory of the Institute of Astronomy, University of Creta (Greece) using the 1.3-m telescope equipped with a CCD camera. The telescope is of type f/7.7 Ritchey-Chrétien. The CCD is a 1024 × 1024 SITe SI003B with 24 μm pixels (corresponding to $\approx 0.5''$ on the sky) and a field of view of about $8.5' \times 8.5'$.

The programme stars are listed in Table 1. Angular separations range from 1 to $6''$ while differential V magnitudes are smaller than 3 mag. The frames were taken on 30, 31 August and 4 September 1999 through standard $BVRI$ filters (Hatzidimitriou et al. 1999). Exposure times were adjusted so as to get as high as possible counts for the primary components; they were normally a few seconds long. We did not use a binning factor. The seeing during observations was approximately $1.8 \pm 0.2''$. The ambient temperature was 11−12°, the humidity 25−30%, the wind speed 50–60 km/h. Since we used such short exposures guiding was not needed. Overscans were automatically included on each frame. We took the flatfields at twilight in the evenings before starting the observations.

Bias and flat-field reductions were done using the ESO-MIDAS software package. The mean value of the overscans was subtracted from every image. Only the best flats were used and separately averaged for each colour band. Next each science frame was divided by its corresponding normalized flatfield.

2.2. Astrometry and relative photometry measurements

We measured the angular separations, the position angles and the differential magnitudes in the different filters of the components of the double stars. For this we used a specific two-dimensional profile fitting method developed within the ESO-MIDAS environment described in detail by Cuypers (1997). This method is well-suited to extract the photometric and astrometric content of close stellar profiles from small-field CCD images on which usually no single well-exposed PSF reference object exists. The method also works when the stellar profiles partially overlap (in the case of a small angular separation). It makes use of direct profile fitting with a modified Moffat (1982) profile corrected for ellipticity. Sky subtraction is done by taking the median of the three closest values in the corners of the subframe. The output gives the angular separation (ρ), the position angle (θ) and the difference in magnitude between the components in the sense (faintest minus brightest component) (Δm). We next converted the angular separations and position angles into absolute units after having carried out the astrometric calibration.

2.3. Astrometric calibration

We used the Landolt standard area PG0231+051 with equatorial coordinates specified for equinox 2000 (Landolt 1992) for the astrometric calibration. The field was taken on September 5, 1999 with the same instrumentation in the exact same configuration as before. We accurately measured the (x, y) positions of five stars from this field with standard MIDAS routines. A multilinear regression fit was then applied to the data. The correlation coefficients were 0.9985 ± 0.00191 for x and 0.9999 ± 0.00006 for y. We next calculated the scale ($0.494 \pm 0.005''$/pixel) and the orientation ($2.965 \pm 1°$ counted from North to West) of the CCD chip. Our value is close to the one computed from the specifications of the telescope and the camera (see Sect. 2.1). Angular separations and position angles were respectively corrected with these scale and zero-point offset.

3. Results and discussion

3.1. Astrometric and photometric results

Our results are presented in Table 2. The first column is the Hipparcos indentification number, the second is the epoch (in Bessel year), followed by the filter, the exposure time (in seconds) and the number of snapshots. Next we give the angular separation (ρ), the position angle (θ) and the magnitude difference (Δm) with their respective internal errors ($\sigma(\rho)$, $\sigma(\theta)$). These errors do *not* include the contribution of the errors of the astrometric calibration. The last column gives the difference of the magnitude differences between the primary and the secondary components (e.g. ($\Delta B - \Delta V$)). We consider the difference between these values and the colour difference of the components (e.g. $\Delta(B - V)$) to be insignificant.

Table 3 shows our relative positions compared with those of the Hipparcos Catalogue and those of the CCDM ("Catalogue of Components of Double and Multiple Stars", Dommanget & Nys 1994). The epoch, mean position angle and angular separation of each object are listed. Note that the errors ($\sigma(\rho)$, $\sigma(\theta)$ listed here include the contribution of the errors of the astrometric calibration. In Table 4 we give the "raw" difference in angular separation in position angle and in relative position in the sense (observed minus Hipparcos), i.e. without considering the difference in epoch of 8 years. Inspection of these values shows only one case where the difference in relative position is less than $0.1''$, i.e. the configuration of the system remained relatively stable over this period (HIP 86282).

Table 1. General information on the observed nearby double stars

HIP	GJ	BD/HD	RA$^{(1)}$	Dec$^{(1)}$	$V_{AB}^{(2)}$	Sp$_A^{(2)}$	Sp$_B^{(2)}$	$\Delta m^{(3)}$	$\pi^{(1)}$	$\frac{\sigma\pi}{\pi}$
Nr	Nr	Nr	2000	2000	(mag)			(mag)	(mas)	%
2552	22	+66 34	00 32 30.07	+67 14 07.6	10.29	M2	M3	2.5	98.74	3.4
4927	-	-	01 03 14.09	+20 05 51.5	12.40	M$^{(1)}$	-	1.9	61.23	8.6
15220	130.1	-	03 16 13.42	+58 10 10.6	10.53	M2	M2	0.3	74.29	8.5
80725	627	148653	16 28 52.88	+18 24 47.2	7.02	K3V	K3V	0.17	51.20	2.9
86282	9596	+23 3151	17 37 48.65	+22 57 17.3	9.89	K5	K5	0.3	45.17	9.8
97222	765.4	186858	19 45 33.52	+33 36 11.0	7.68	K3V	K3V	0.19	49.09	2.9
97292	767	331161	19 46 24.05	+32 00 59.3	10.28	M1	M2	1.0	74.90	3.9
110893	860	239960	22 27 00.42	+57 41 49.3	9.59	M3	M4	1.5	249.53	1.2
116132	896	+19 5116	23 31 52.24	+19 56 15.0	10.32	M3.5	M4.5	2.5	160.06	1.8

$^{(1)}$ Source is the Hipparcos Catalogue (ESA 1997), $^{(2)}$ Source is the Simbad Database, $^{(3)}$ Source is the CCDM (Dommanget & Nys 1994).

In all other cases significant relative motions are detected. A remark illustrates the type of the observed mean motion: values range from more than 4°/yr (HIP 110893) to 0.4°/yr (HIP 15220). For HIP 97292 a linear relative motion of about 0.035″/yr can be easily deduced from a comparison with the data in the CCDM catalogue. We also list in Table 4 the difference in angular separation and in relative position in the sense (ours minus the corresponding ephemeris) for five binaries based on orbits found in the literature, i.e. also taking the epoch difference into account. The orbital elements of these orbits are given in Table 7. With 0.1″ as an upper limit, we see that the match is good in two cases (HIP 97222, HIP 110893) while discrepancies are evident for another three systems. This lead us to (re)determine the orbits whenever sufficient data for these binaries could be found.

3.2. New orbit computations

To compute the orbits we made use of the astrometric data from the Washington Double Star Catalog of Observations (WDS, Worley & Douglass 1997), kindly supplied by Dr. Mason, supplemented by the new data. The general characteristics of these data in the WDS are shown in Table 5. We used the orbit determination code developed by Pourbaix (1994). The method is one of the type trial-and-error based on simulated annealing (Metropolis 1953) followed by a local least-squares minimization. The resulting sets of orbital elements are presented in Tables 6 and 7 and illustrated in Figs. 1–3. In these figures the new data are marked as large dots. The standard deviations for each orbital element computed from the variance-covariance matrix are also mentioned. They are helpful to assess the quality of the orbits but we must be aware that these classically computed errors underestimate the true errors in many occasions (Ruymaekers 1999).

3.3. Discussion on individual binaries

HIP 2552. This is probably the most interesting case in our study. Also known as BD +66°34, this M-dwarf visual binary is really a triple system – the primary of which is an astrometric binary (with components *Aa*). Hershey (1973) reported orbits for both pairs, the one for the *AB* pair that is the subject of our analysis is listed in Table 7. We found an orbital solution very close to the one derived by Hershey (1973). He assumed $e = 0$ for the orbit of *AB* supposing that the orbits of both components (*Aa* and *AB*) are co-planar and co-revolving. We actually confirm this assumption and the old orbit. However, the orbital elements are very poorly determined since the corresponding errors are extremely large. Moreover, there is another solution with very high eccentricity ($e = 0.999$) and very large major axis ($a = 290''$) that fits the data almost equally well. In Fig. 1 we can see that the coverage of the orbital arc is less than one quarter, this explains the ambiguity in the solution. Because of these extreme values we conclude that the latter solution is improbable. At the distance of 10 pc, the true separation would be of order 2900 AU and the system would be a very wide and massive one, in conflict with its spectral type. Anyway, more observations in the future would be necessary to be able to determine a reliable orbit for this pair in a nearby triple system.

The situation for the astrometric pair with components *Aa* (Mcy 1) looks much better: Söderhjelm (1999) determined an improved orbit based on the combination of ground-based IR speckle and Hipparcos Transit data with a periodicity of ≈15 yr and a relative total mass

Table 2. Results of the CCD observations of nearby visual double stars (N - number of frames)

HIP Nr	Epoch (year)	Filter	Exp. time (s)	N	ρ ($''$)	$\sigma(\rho)$ ($''$)	θ ($^\circ$)	$\sigma(\theta)$ ($^\circ$)	Δm (mag)	$\sigma(\Delta m)$ (mag)	$\Delta B-\Delta V$ $\Delta V-\Delta R$ $\Delta V-\Delta I$ $\Delta R-\Delta I$
2552	1999.6769	B	80	11	4.0868	0.0124	170.9264	0.1318	1.8552	0.0113	0.0579
2552		V	20	11	4.1023	0.0028	171.1469	0.0164	1.7973	0.0058	0.0836
2552		R	8	11	4.1026	0.0029	171.1608	0.0152	1.7137	0.0027	0.3245
2552		I	4	11	4.1082	0.0044	170.8997	0.0393	1.4728	0.0028	0.2409
4927	1999.6634	B	60	6	2.6218	0.0034	48.3851	0.0332	1.4653	0.0070	0.0640
4927		V	30	6	2.6202	0.0017	48.1804	0.0178	1.4013	0.0035	0.1785
4927		R	12	6	2.6104	0.0026	48.1491	0.0181	1.2228	0.0054	0.5300
4927		I	6	6	2.6196	0.0043	48.1765	0.0439	0.8713	0.0053	0.3515
15220	1999.6634	B	15	2	4.9098	0.0000	6.9115	0.0136	0.2190	0.0055	–0.0042
15220		V	6	2	4.9112	0.0001	6.8356	0.0649	0.2232	0.0041	0.0244
15220		R	3	2	4.9122	0.0040	6.8324	0.0711	0.1988	0.0064	0.0599
15220		I	1	2	4.8988	0.0027	6.9048	0.0325	0.1633	0.0035	0.0355
80725	1999.6653	B	4	2	1.9706	0.0218	123.9432	0.1428	0.1987	0.0095	0.0013
80725		V	1	2	1.9878	0.0044	124.2434	0.0189	0.1974	0.0303	0.0768
80725		R	1	2	1.9832	0.0082	124.6272	0.1019	0.1206	0.0197	0.0664
80725		I	1	2	1.9865	0.0132	124.0621	0.1886	0.1310	0.0378	–0.0104
86282	1999.6652	B	30	2	4.2308	0.0007	186.1771	0.0046	0.2789	0.0032	0.0137
86282		V	12	2	4.2261	0.0023	186.2256	0.1085	0.2652	0.0008	0.0679
86282		R	3	2	4.2316	0.0036	186.1537	0.0600	0.1973	0.0254	0.1056
86282		I	2	2	4.2267	0.0018	186.2147	0.0108	0.1596	0.0014	0.0377
97222	1999.6631	B	5	2	2.6653	0.0006	163.9374	0.0104	0.1638	0.0001	0.0128
97222		V	2	2	2.6736	0.0059	163.8987	0.0291	0.1510	0.0006	0.0111
97222		R	1	2	2.6628	0.0127	163.8198	0.2107	0.1399	0.0068	0.0433
97222		I	1	2	2.6651	0.0084	163.7241	0.1722	0.1077	0.0134	0.0322
97292	1999.6656	B	30	3	5.1231	0.0016	133.7835	0.0358	1.0514	0.0021	–0.0128
97292		V	9	3	5.1172	0.0023	133.7664	0.0094	1.0642	0.0186	0.0743
97292		R	5	3	5.1278	0.0003	133.7560	0.0357	0.9899	0.0097	-
97292		I	2	3	-	-	-	-	-	-	-
110893	1999.6631	B	30	5	-	-	-	-	-	-	-
110893		V	6	5	3.0865	0.0032	95.5027	0.0477	1.6983	0.0038	0.1880
110893		R	2	5	3.0817	0.0038	95.5376	0.1064	1.5103	0.0148	0.5091
110893		I	1	5	3.0797	0.0064	95.5189	0.0737	1.1892	0.0134	0.3211
116132	1999.6605	B	60	11	5.2083	0.0012	91.8059	0.0151	2.3183	0.0053	0.1141
116132		V	12	11	5.2115	0.0028	91.6998	0.0151	2.2042	0.0041	0.1869
116132		R	5	11	5.2045	0.0037	91.8245	0.0235	2.0173	0.0053	0.5433
116132		I	2	11	5.1951	0.0129	92.0582	0.3079	1.6609	0.0183	0.3564

error of 23% (see his Table 4). He also derived an improved parallax of $0.097 \pm 0.002''$. McCarthy et al. (1991) have succesfully imaged the astrometric companion using 2D infrared speckle interferometry and derived a fractional mass $\beta = 0.254$. They report masses accurate within 10% for each of the three components. Bearing in mind the acute lack of precision on the orbital elements of the visual pair AB, we cannot support this conclusion. More observations of this hierarchical triple system are certainly worthwhile to obtain better orbits and thus accurate masses.

HIP 80726, HIP 97222 and HIP 110893. Orbits for these three binaries can be found in the literature (see Table 7). Our solutions are not very different and basically confirm the known orbits. However we also quote the standard errors of each orbital element. We present the data and the revised orbits in Figs. 1–3 respectively. Clearly, the coverage of the orbital arcs is much better in these cases (it is complete for HIP 110893 with a period of 45 yr) and the orbits are well defined. With the additional data we have improved the precision of the elements somewhat as can be seen from the comparison of the sum of squared residuals for the previous and the revised orbit solutions.

HIP 97292. This is another interesting case. The best orbital solution has a high eccentricity combined with huge errors so we believe it should be rejected. Alternatively, this is an optical double system and the components are moving apart from each other. In Fig. 2 both fits are hardly distinguishable.

We address the question about the statistical relevance of orbital versus rectilinear motion. For this, we computed

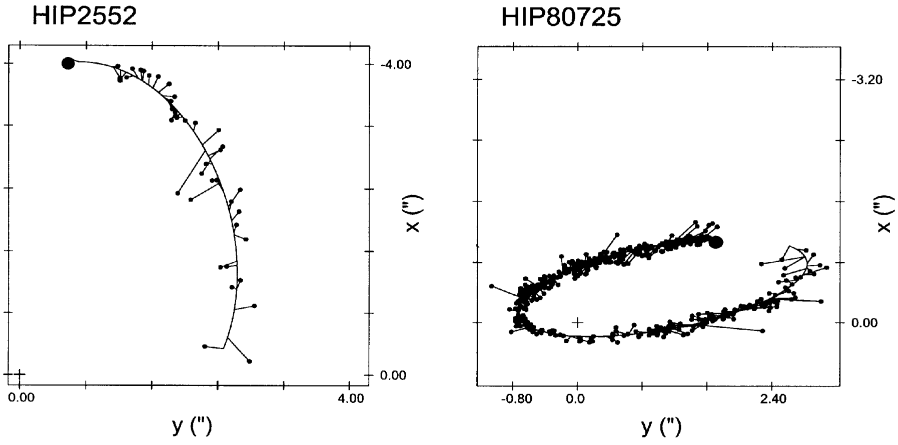

Fig. 1. Computed orbits for HIP 2552 and HIP 80725

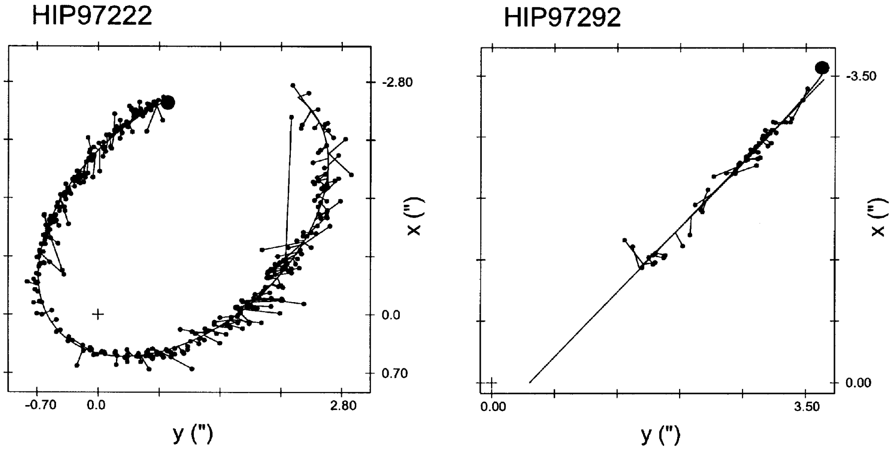

Fig. 2. Computed orbit for HIP 97222 and linear motion fit for HIP 97292

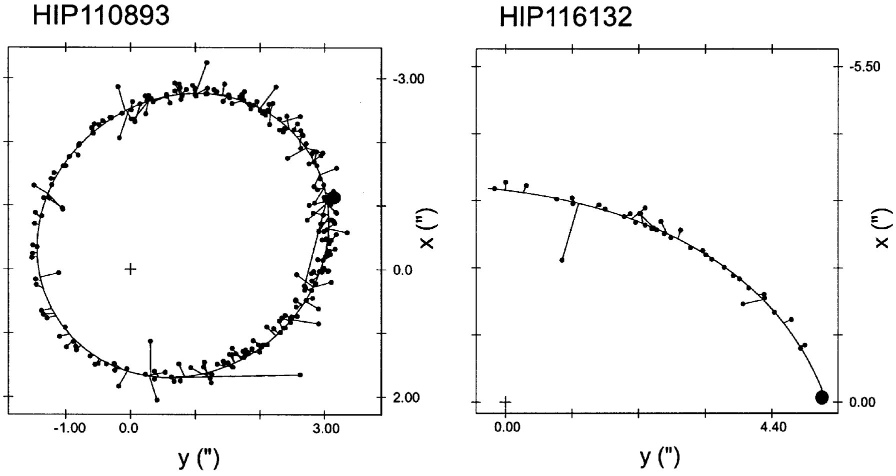

Fig. 3. Computed orbits for HIP 110893 and HIP 116132

the least squares fit of a uniform relative motion using the formula:

$$x_i = x_0 + x' * (t - t_0),$$
$$y_i = y_0 + y' * (t - t_0),$$

and found ($t_0 = 1963.483, x_0 = -2.418, y_0 = 2.694$) for the gravity centre of the data, and ($x' = -0.036, y' = 0.034$) for the velocity vector. Thus a relative speed of 0.050″/yr is found in the direction of 137° (counted from North to East). The weighted sum of squared residuals, χ_1^2 is equal to 0.03174.

Table 3. Comparison between the relative astrometric data at different epochs (for our data: with errors including astrometric calibration)

HIP	This paper			Hipparcos			CCDM		
Nr	Epoch	θ (°)	ρ ($''$)	Epoch	θ (°)	ρ ($''$)	Epoch	θ (°)	ρ ($''$)
2552	1999.7	171.03 (1.0)	4.10 (0.02)	1991.3	163.4	4.147	1959	140	3.8
4927	1999.7	48.22 (1.0)	2.62 (0.01)	1991.3	45.2	2.745	1936	23	3.0
15220	1999.7	6.87 (1.0)	4.91 (0.02)	1991.3	10.6	4.883	1960	23	4.7
80725	1999.7	124.22 (1.0)	1.98 (0.01)	1991.3	128.1	1.789	-	128	1.8
86282	1999.7	186.19 (1.0)	4.23 (0.02)	1991.3	185.5	4.265	1959	181	4.3
97222	1999.7	163.85 (1.0)	2.67 (0.01)	1991.3	169.2	2.459	-	169	2.5
97292	1999.7	133.77 (1.0)	5.12 (0.03)	1991.3	133.7	4.866	1959	132	3.7
110893	1999.7	95.52 (1.0)	3.08 (0.02)	1991.3	128.3	3.400	-	128	3.4
116132	1999.7	91.85 (1.0)	5.21 (0.03)	1991.3	100.7	5.029	1959	144	3.6

Table 4. Differences in relative position (ΔPos)

HIP Nr	$\Delta\rho''$	$\Delta\theta^\circ$	$\Delta\text{Pos}''^{a}$	Remark	$\Delta\rho''$	$\Delta\theta^\circ$	$\Delta\text{Pos}''^{b}$
2552	–0.047	7.633	0.551	orbital (31°/40 yr)	0.061	–1.707	0.136
4927	–0.127	3.023	0.190	motion (25°/63 yr)	-	-	-
15220	0.025	–3.729	0.320	motion (–17°/40 yr)	-	-	-
80725	0.193	–3.881	0.231	orbital (–0.5°/yr)	–0.020	–6.521	0.227
86282	–0.037	0.692	0.063	stable (<0.1″)	-	-	-
97222	0.207	–5.355	0.316	orbital (–0.6°/yr)	–0.036	–0.885	0.055
97292	0.256	0.068	0.256	lin. motion (1.4″/40 yr)	-	-	-
110893	–0.320	–32.781	1.854	orbital (–4.1°/yr)	0.024	–0.941	0.056
116132	0.176	–8.853	0.809	orbital (–52°/40 yr)	–0.112	–0.863	0.137

[a] Ours relative to Hipparcos. Also based on the data in the CCDM catalogue.
[b] Comparison with ephemerides from the literature.

Table 5. Information from the Washington Double Star Catalogue (Worley & Douglass 1997)

HIP Nr	WDS Nr	Disc. name	Comp.	Date(first)	Date(last)	No Obs.
2552	00321+6715	VYS 2	Aa-B	1924	1991	42
4927	01032+2006	LDS 873		1940	1991	12
15220	03162+5810	MLB 115		1914	1994	49
80725	16289+1825	STF 2052	AB	1822	1999	>99
86282	17378+2257	AG 210		1894	1998	32
97222	19456+3337	STF 2576	AB	1831	1999	>99
97292	19464+3201	KAM 3		1935	1991	52
110893	22280+5742	KR 60	AB	1890	1995	>99
116132	23317+1956	WIR 1		1941	1991	37

A two-sided F-test was used for testing whether the ratio χ_1^2/χ_2^2 is statistically equal to 1. We reject this hypothesis at the significance level α if F exceeds the tabulated value $F^{\rm t}_{\alpha/2}(n-4, n-6)$. Since χ_1^2 is necessarily at least equal to or larger than χ_2^2 (in this case, χ_2^2 is 0.02032), the rejection region with F smaller than the tabulated value $F^{\rm t}_{1-\alpha/2}$ need not be considered. We have that:

$$F = \frac{(55.0 * \chi_1^2/(n-4))}{(55.0 * \chi_2^2/(n-6))} = 1.444,$$

with 55.0 the total sum of assigned weights. From tabulated F distributions we find $F^{\rm t}_{0.025}(51, 49) = 1.60$ (Crow et al. 1960). So, we fail to reject the hypothesis at the 5% level, meaning that the orbital solution is not a better representation of the data than a linear motion. We thus can adopt the model of uniform relative motion with a risk factor of only 5% that it does not hold (type II error).

HIP 116132. The orbital elements have large errors and are badly determined as in the case of HIP 2552. This is because the coverage of the orbital arc is insufficient for a precise determination (Fig. 3). Our solution and the one from the literature are given in Table 7. The orbits are different so more observations are needed in the future.

Table 6. The Thiele-Innes elements for the computed orbits. ($\sigma(\theta)$ and $\sigma(\rho)$ - the standard deviations of the residuals)

HIP Nr	A (″)	B (″)	F (″)	G (″)	$\sigma(\theta)$ (°)	$\sigma(\rho)$ (″)
2552	1.6809	–2.5808	3.6185	0.4194	0.028	0.180
80725	0.6105	–1.3703	–0.3540	–1.7772	0.028	0.180
97222	1.4937	–1.2692	–1.1265	–1.6895	0.056	0.132
110893	1.2851	–1.9571	–2.0017	–1.2271	0.058	0.162
116132	–3.9631	5.1547	3.3131	5.6260	0.021	0.179

Table 7. Classical (Campbell) orbital parameters and standard deviations for the computed orbits (1st and possibly 2nd rows). The next row gives the orbital parameters as quoted in the literature (R.S.S. - sum of squared residuals)

HIP	a	i	e	Ω	ω	P	T	a^3/P^2	R.S.S.	Reference
	$\sigma(a)$	$\sigma(i)$	$\sigma(e)$	$\sigma(\Omega)$	$\sigma(\omega)$	$\sigma(P)$	$\sigma(T)$	$\sigma(a^3/P^2)$		
Nr	(″)	(°)		(°)	(°)	(yr)		(″^{3}yr^{-2})		
2552	4.09	53	0.0	164	125	320	1782	0.000668	9.87777e-03	This paper
	4.06	±51	0.0[1]	168	0.0	320	1993		1.31622e-02	Hershey (1973)
80725	2.246	108.131	0.7609	92.611	128.447	221.809	1921.033	0.000230	3.70021e-03	This paper
	0.017	0.167	0.0033	0.210	0.362	2.510	0.115	0.000004		
	2.28	108.25	0.764	93.93	131.06	237.37	1921.11		4.02943e-03	Scardia (1984)
97222	2.113	152.291	0.7718	89.561	126.526	232.277	1945.304	0.000175	6.69088e-03	This paper
	0.013	1.035	0.0036	2.323	2.322	2.681	0.114	0.000004		
	2.092	157.55	0.774	89.45	126.78	238.79	1945.285		7.04738e-03	Scardia (1981)
110893	2.381	165.763	0.4150	169.987	227.588	44.780	1925.668	0.00673	1.18845e-02	This paper
	0.014	2.145	0.0035	8.795	8.758	0.059	0.069	0.000116		
	2.383	167.2	0.410	154.5	211.0	44.67	1970.22		1.22147e-02	Heintz (1986)
116132	7.6	132.5	0.38	273.3	134.7	514.0	1970.0	0.001686	9.49197e-03	This paper
	6.87	123.5	0.20	82.1	354.0	359.0	2008.0		1.04659e-02	Heintz (1984)

[1] By assumption.

3.4. Determination of the component masses

From the colour differences presented in Table 2 and the joint photometry of the systems in the UBV photometric system (GCPD, Mermilliod et al. 1998), applying Eq. (3) of Mermilliod et al. (1992), we could derive the difference in bolometric correction between the components determined by Flower (1996) from their colours, and thus $\Delta M_{\rm Bol}$ (Table 8). We have then estimated the fractional masses, $\beta = M_B/M_{A+B}$, using the following relation:

$$\beta = 1/(1 + 10^{\Delta M_{\rm Bol}/(2.5\,K)}).$$

For this we have made use of a mass-luminosity relation based on the new Hipparcos parallaxes with slope $K = 3.82 \pm 0.07$ (Lampens et al. 1998). For binaries on the lower part of the main sequence ($0.18\ M_\odot < M_{A+B} < 0.5\ M_\odot$), we have used the slope of 1.59 as derived by Henry & McCarthy (1993). In the case where we have reliable orbits and parallaxes, these β-values allow us to determine the component masses. We present the fractional and the component masses with their errors as computed from the law of propagation of errors in Table 9 for the reliable cases only (i.e. with relative errors below 10%). HIP 97292 is not included because we do not consider it as a gravitationally bound system.

Table 8. Global and component colour information

HIP Nr	$(B-V)_{AB}$ (mag)	$(B-V)_B$ (mag)	$(B-V)_A$ (mag)	$\Delta\,BC$ (mag)	$\Delta M_{\rm Bol}$ (mag)
2552	1.597	1.646	1.588	–0.376	1.421
4927	1.61	1.66	1.60	–0.47	0.936
15220	1.54	1.54	1.54	+0.01	0.237
80725	0.86	0.86	0.86	–0.00	0.195
86282	1.57	1.58	1.56	–0.06	0.204
97222	1.036	1.043	1.030	–0.015	0.136
116132	1.61	1.71	1.60	–1.10	1.104
HIP Nr	$(R-I)_{AB}$ (mag)	$(R-I)_B$ (mag)	$(R-I)_A$ (mag)	$\Delta\,BC$ (mag)	$\Delta M_{\rm Bol}$ (mag)
110893	1.55*	1.83*	1.47*	–0.68*	1.02

(*) Based on the (ΔR, ΔI) colour differences and Lang (1992).

Table 9. Fractional and component masses (with errors in the reliable cases)

HIP Nr	β	M_{A+B} ($M_\odot$)	M_A ($M_\odot$)	M_B ($M_\odot$)
2552	0.415	0.69	0.40	0.29
4927	0.444	-	-	-
15220	0.486	-	-	-
80725	0.488	1.716 (0.153)	0.878 (0.078)	0.838 (0.075)
86282	0.488	-	-	-
97222	0.492	1.478 (0.133)	0.751 (0.067)	0.727 (0.065)
110893	0.356	0.433 (0.017)	0.279 (0.012)	0.154 (0.007)
116132	0.345	0.41	0.27	0.14

4. Conclusions

The following conclusions can be drawn:

1. We have obtained accurate new relative positions of nine nearby visual double stars from CCD observations performed at the Observatory of Skinakas;
2. When sufficient data were available, we recomputed the orbits. Principally we confirm the previously known ones but with a higher accuracy. In addition we quote the errors of the orbital elements;
3. Accurate differential *BVRI* magnitudes as well as colour differences for the components of these double stars have also been determined. New fundamental data, i.e. individual colours and masses, have been derived from these data;
4. The orbit of HIP 2552 AB still has very large errors and more data of the wide pair are definitely needed to obtain accurate masses for this interesting triple system. The orbit of HIP 116132 also lacks data;
5. In the case of HIP 97292 we conclude that the components move apart with a relative speed of $0.050''$/yr. It is most probably an optical double star.

Acknowledgements. We thank the Director of Skinakas Observatory Prof. I. Papamastorakis and I. Papadakis for the telescope time. We are grateful to Dr. B. Mason for providing the astrometric data from the Washington Double Star Catalog of Observations (USNO, Washington) and to Dr. D. Pourbaix for sending the code for orbit determination of visual binaries. We thank the referee, Dr. N. Turner, for useful comments and suggestions. A. Strigachev gratefully acknowledges a grant from the Belgian Federal Office for Scientific, Federal and Cultural Affairs (OSTC) in the frame of the project "Multicolour photometry and astrometry of double and multiple stars". This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France.

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