An Investigation on the Relative Proper Motion of Some Optical Double Stars

Joerg S. Schlimmer

Seeheim-Jugenheim, Hessen, Germany

Email: js@epsilon-lyrae.de

Abstract: I report on the measurements of some well known and neglected optical double stars. From measurements listed in the WDS catalog the relative proper motion were calculated and compared with Hipparcos or WDS data. Two historical measurements of STF1424AC (Algieba/AD Leo) which not listed in the WDS catalog are introduced. The quality of these measurements will be point out.

For my observations, I use a small 8 inch Newtonian telescope with a standard webcam described in my reports of 2007 and 2008 (Schlimmer 2007a, Schlimmer 2008b). In 2008 my attention applies more and more to the double stars from the neglected list. Some of these double stars are not physically attached by gravitation. In some cases there is a proper motion of one or both of the components. Because this relative motion is linear, it is easy to calculate a linear fit, residuals and ephemeris.

To calculate the relative proper motion, normally the complete data set of the measurements from the WDS (Mason et al., 2008) and the current measurement of the author are used. The different measurements will not be weighted. Mavericks will be eliminated before calculation. For plotting the relative proper motion the measurements will be transformed from polar to Cartesian coordinates by following formula:

$$x = d \sin(PA)$$
$$y = d \cos(PA)$$

in which d is the distance or separation in arc seconds and PA is the position angle. A linear fit will be calculated with the Gaussian method of least squares. The x value of the proper motion, which represents the motion in right ascension, will be taken directly from Cartesian coordinates. To calculate the y value of the proper motion, which represents the motion in declination, the y value from linear fit ($y = mx + b$) will be used. The calculation of the residuals (for example observed separation – calculated separation) is at least a good method to check the quality of one's own and also other astronomer's observations.

1. WDS 05284-0330, (BUP 80, HIP 25623)

WDS 05284-0330, (BUP 80, HIP 25623) is a double star from the neglected list. Since its discovery in 1907 just 4 measurements were made. With a proper motion of -306.66 mas in right ascension and -797.19 mas in declination BUP 80 is a high proper motion star. Its parallax is 77.03 mas and its distance is about 550 light years. Its brightness is 7.64 and 10.1 (WDS) or fainter. In my opinion the brightness is about magnitude 11.0. I observed BUP 80 in three different nights in February 2008. The values of distance and position angle in Table 1 are averaged. The signal to noise ratio of a single frame is too low to determine the companion. Therefore 50 up to 100 frames of the video record were stacked automatically. As result we get a frame with a very uniform noise that could be analyzed.

Because of the high quality of the measurements, a linear fit can be calculated with low residuals, which are given in Table 1. Figure 1 shows the linear fit and Table 2 gives the ephemeris for the pair.

An Investigation on the Relative Proper Motion of Some Optical Double Stars

Discoverer Code	Date	PA Observed	PA Calculated	PA Residuals	Distance Observed	Distance Calculated	Distance Residuals
Bu_1913	1907.l78	202.1	202.2	-0.08	134.29	133.95	0.44
Bu_1913	1911.13	202.2	202.2	-0.02	131.18	131.06	0.12
Hsw2004	1984.897	205	204.2	0.81	67.2	69.31	-2.11
Schlimmer	2008.102	205.28	204.2	-0.90	48.546	47.00	1.55

Table 1: Measurements, linear fit and residuals (observed-calculated)

Results

Polar coordinates for closest approach:
s = 5.04”
pa= 290.0°
Time of closest approach:
T_0 = 2061.96

Proper motion:
μx = -297.0 mas/yr [HIP -306.7 mas, WDS -309 mas]
μy = -815.1 mas/yr [HIP -797.2 mas, WDS -806 mas
μ = -867.6 mas/yr

Date	Distance	PA
2020	38.28	206.7
2040	21.14	212.2
2060	5.55	253.3
2080	14.72	357.6
2100	31.70	11.9

Table 2: Ephemeris for BUP 80

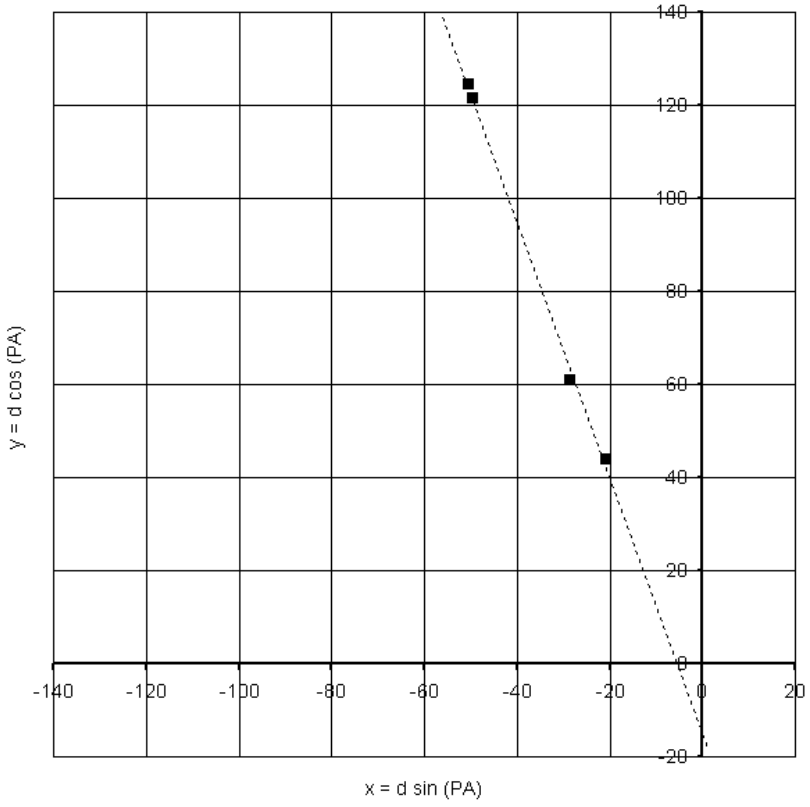

Figure 1: Measurements and linear fit of BUP 80 (WDS 05284-0330)

WDS 10200+1950 (STF1424AC) Algieba / AD Leo

Algieba is a famous double star. Its physical B companion is well known and often observed. Algieba has two further optical components C and D. The companion C was first discovered by John Flamsteed in 1690 (Mayer, 1779) and also often observed by the astronomer Christian Mayer in 1777/1778 (Mayer 1778, Mayer 1779) and William Herschel in 1782 (Herschel 1785). C is also known as AD Leo. Mayer described C as a star of 6th magnitude Herschel described only its relative position to the primary component A. Currently the magnitude is 9.64. This is a big difference to Mayer's estimation and Mayer wouldn't able to observe a star of this magnitude with his 3-inch telescope. Because of this fact, we may assume that AD Leo was much brighter in the 17th and 18th century as today. The measurements and the residuals of Mayer's and Herschel's observations are shown in Table 3.

Because of the high values of the residuals of Mayer's and Herschel's results, both measurements weren't used to calculate a linear fit. The linear fit in Figure 2 is extrapolated to Mayer's and Herschel's measurements. Below the results of the relative proper motion are shown. In WDS catalog the proper motion for primary and secondary component is given. Because both components have a proper motion in different directions, the relative proper motion is the sum of the differences.

μx = -794.5 mas/yr [WDS +311 -502 mas, result -813 mas]
μy = -121.5 mas/yr [WDS -153 -43 mas, result -110 mas]
μ = -803.8 mas/yr

Astronomer	Date	PA Observed	PA Calculated	PA Residuals	Distance Observed	Distance Calculated	Distance Residuals
Christian Mayer	1778	316.7	314.43	2.27	97.8	93.9	3.9
William Herschel	1782	301	306.36	-5.36	121	118.2	-7.2

Table. 3: Historical measurements of STF1424AC (AD Leo)

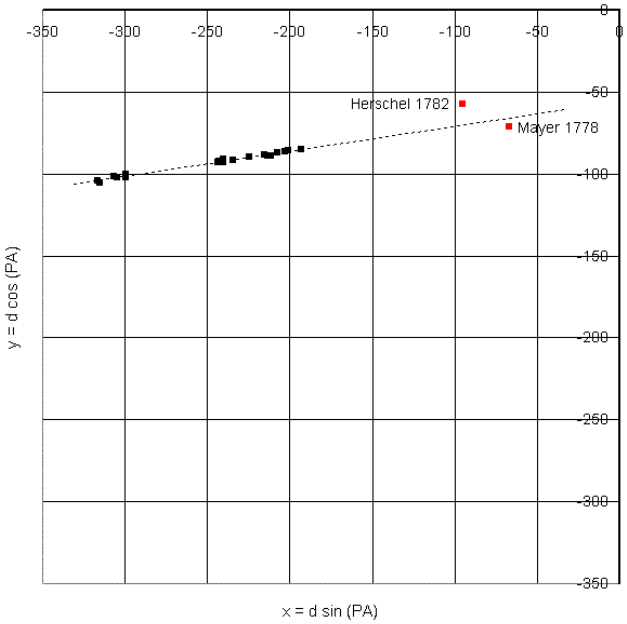

Figure 2: Plot of the measurements of STF1424 AC. Two historical observations of Christian Mayer and William Herschel which are not listed in WDS are marked in red.

WDS 13149-1122 (SHJ 162Aa-B)

WDS 13149-1122 in the constellation Virgo was first observed in 1777 by Christian Mayer. He added this star to his double star catalog of 1779 at position 36 (Schlimmer, 2007b). The relative proper motion of this star is easy to observe and well known. The plot of the measurements point out that Mayer's observation results were very good. Figure 3 shows the measurements of this pair. Below are the results of the proper motion from the measurement from the WDS:

μx = -211 mas/yr [Hip -208 mas]
μy = -313 mas/yr [Hip -316 mas]
μ = -378 mas/yr [HIP -378 mas]

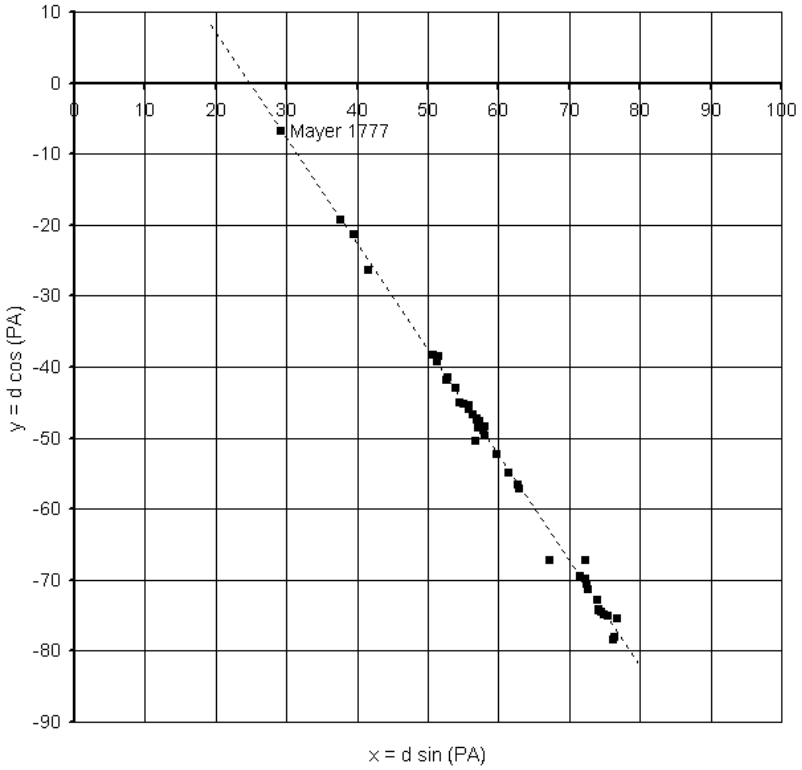

Figure 3: Plot of the measurements of SHJ 162Aa-B

An Investigation on the Relative Proper Motion of Some Optical Double Stars

WDS 14463+0939 (STF1879)

WDS 14463+0939 (STF1879) was discovered in 1827. The orbit of AB is well determined. A further component, D, is an optical companion. Only four measurements are listed in the WDS catalog (Table 4). With these values and an additional 5th measurement made by the author it is easy to calculate a linear fit with low residuals (Figure 4). The residuals are listed in Table 4. Table 5 gives the ephemeris for STF1879.

Results:

Polar coordinates for closest approach:
s = 109.85”
pa= 252.4°

Time of closest approach:
T_0 = 2204.8

Proper motion:
μx = 77.6 mas/yr [WDS 71 mas]
μy =-245.1 mas/yr [WDS -266 mas]
μ = 257.0 mas/yr

Discoverer Code	Date	PA Observed	PA Calculated	PA Residuals	Distance Observed	Distance Calculated	Distance Residuals
Bu_1913	1910.360	218.10	218.57	-0.47	133.670	133.324	0.35
WFC1998	1923.430	219.10	219.07	0.03	131.434	131.456	-0.02
Opi1927	1925.260	219.40	218.91	0.49	130.390	130.745	-0.36
TMA2003	2000.310	227.20	227.48	-0.28	121.700	121.515	0.19
Schlimmer	2008.363	227.99	227.74	0.25	120.430	120.594	-0.16

Table 4: Measurements, linear fit and residues (observed-calculated)

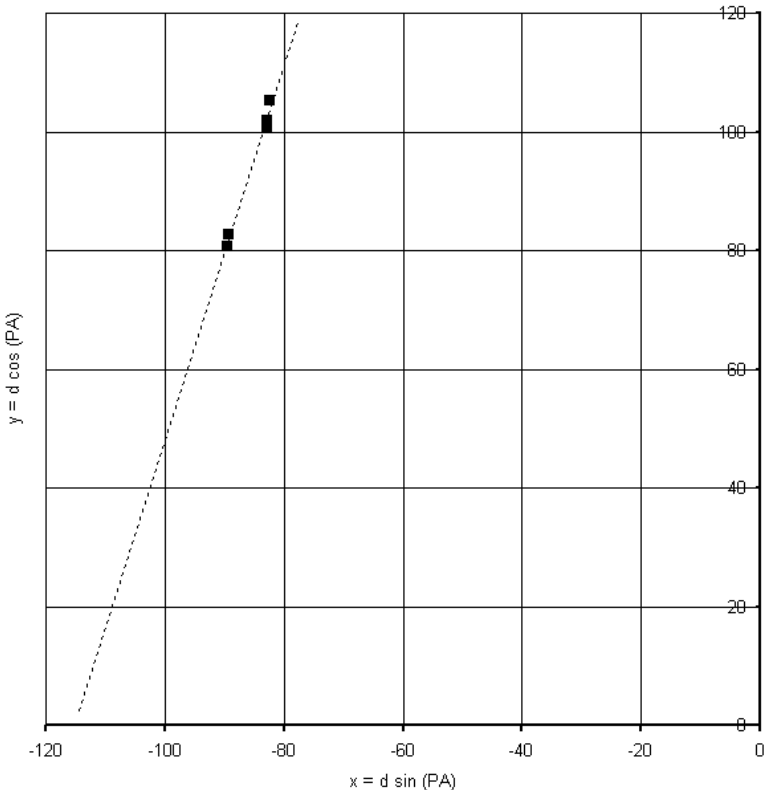

Figure 4: Plot of the measurements and linear fit of STF1879AB-D (WDS 14463+0939)

Date	Distance	PA
2050	116.8	227.7
2100	113.1	238.7
2150	110.8	245.1
2200	109.9	251.8
2250	110.5	258.5

Table 5: Ephemeris for STF1879AB-D

An Investigation on the Relative Proper Motion of Some Optical Double Stars

WDS 18369+3846 (Vega)

Vega is the brightest star in summer. There are two optical companions. AB was discovered by William Herschel in 1781 (Herschel, 1782) and is known as H 5 39AB. AE was discovered by John Herschel in 1831 and is known as STFB 9AE. Both companions can be easily observed with an 8-inch Newtonian telescope. While AB was often observed (69 times), AE was only observed 12 times. Because time of closest approach for AB is past, we discussed only the relative proper motion between AE. Figure 5 shows a plot of these measurements. The calculation of the linear fit points out, that Vega moves directly to companion E. Ephemeris for Vega is in Table 6.

Results

Polar coordinates for closest approach:
s = 2.16”
pa= 310.3°

Time of closest approach:
T0 = 2261.2

Proper motion:
μx = 227 mas/yr [HIP 201 mas]
μy = 268 mas/yr [HIP 287 mas]
μ = 351 mas/yr

Date	Distance	PA
2050	74.2	38.7
2100	56.7	38.2
2150	39.1	37.2
2200	21.6	34.6
2250	4.5	11.6
2300	13.8	220.6

Table 6: Vega

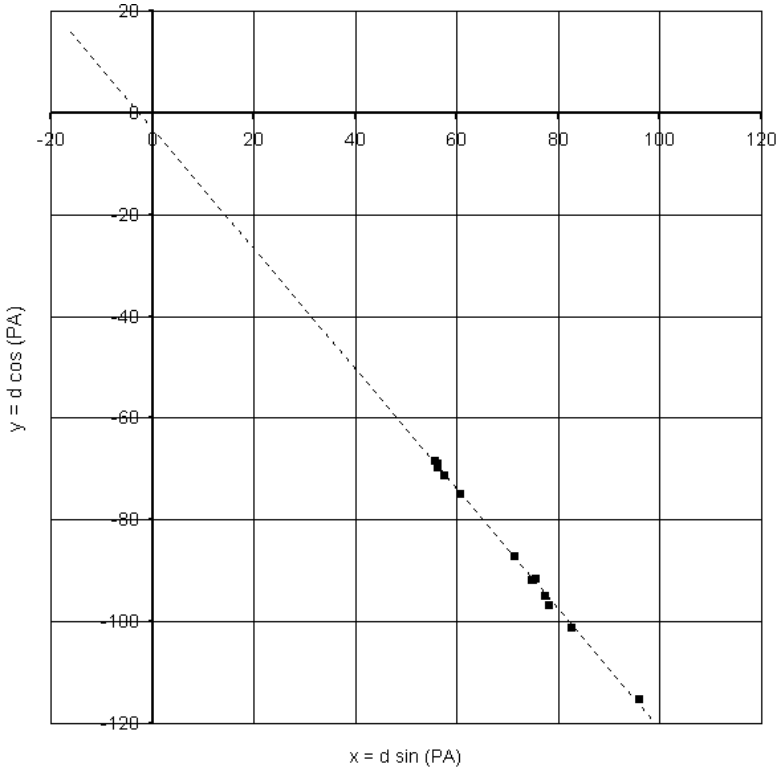

Figure 5: Plot of the measurements and linear fit of STFB 9AE

An Investigation on the Relative Proper Motion of Some Optical Double Stars

WDS 18073+1557 (LDS1005 AB)

WDS 18073+1557 has two components, LDS1005 AB and TOB 271 AC. Because of its brightness of 6.82, 8.70 for AB and 6.82, 8.31 for AC all components are easy to observe. Since its discovery in 1896 LDS1005 AB was observed 12 times. The relative proper motion is mostly in declination (Figure 6).

Proper motion:
μx = -9 mas/yr [WDS -7 mas]
μy = -146 mas/yr [WDS -144 mas]
μ = -147 mas/yr

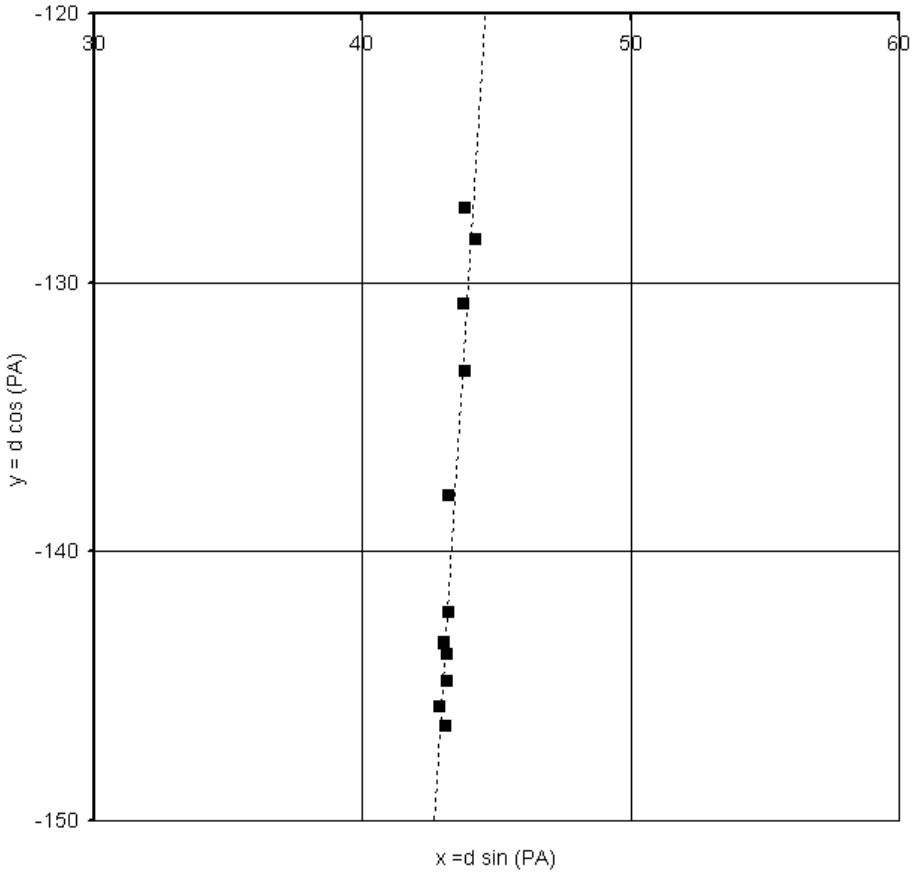

Figure 6: Plot of the measurements and linear fit of LDS1005 AB

WDS 14527+0746 (HLD 120AB)

HLD 120AB was described in detail by the author (Schlimmer, 2008a). In springtime, a new measurement was done. A further calculation with that new value shows no significant changes in the calculation results.

Polar coordinates for closest approach:
s = 1.384”
pa= 309.5°

Time of closest approach:
T_0 = 2232.8

Proper motion:
μx = -45.21 mas/yr [Schlimmer 2008a : -45.71 mas/yr]
μy = -54.94 mas/yr [Schlimmer 2008a : -55.98 mas/yr]
μ = -71.15 mas/yr [Schlimmer 2008a : -72.27 mas/yr]

Summary

The comparison of the relative proper motion, calculated by the author, with values from the Hipparcos or WDS catalogs shows differences in most cases. There are two major reasons for these differences. First, the result depends on the selected measurements. Residuals are used to check the quality of the measurements. For calculation, measurements with low residuals will be taken. Different datasets provide different results. Second, Hipparcos values point out only the proper motion of the primary companion not the relative motion between both components.

Measurements made by the author of the doubles stars discussed in this paper are given in Table 7.

References

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NAME	RA+DEC	MAGS	PA	SEP	DATE	N	NOTES
BUP 80	05284-0330	7.64 10.1	205.3	48.55	2008.102	3	
STF1424 AC	10200+1950	2.37 9.64	288.5	332.61	2008.319	78	Algieba
SHJ 162 Aa-B	13149-1122	7.11 8.18	44.2	109.34	2008.319	39	Mayer 36
STF1879 AB-D	14463+0939	7.32 10.8	228.0	120.43	2008.363	1	
HLD 120 AB	14527+0746	8.3 9.9	224.2	16.09	2008.357	20	
LDS1005 AB	18073+1557	6.82 8.31	16.4	151.95	2008.653	45	
STFB 9 AE	18369+3846	0.02 9.5	39.2	88.27	2008.497	1	Vega

Table 7: Measurements made by the author