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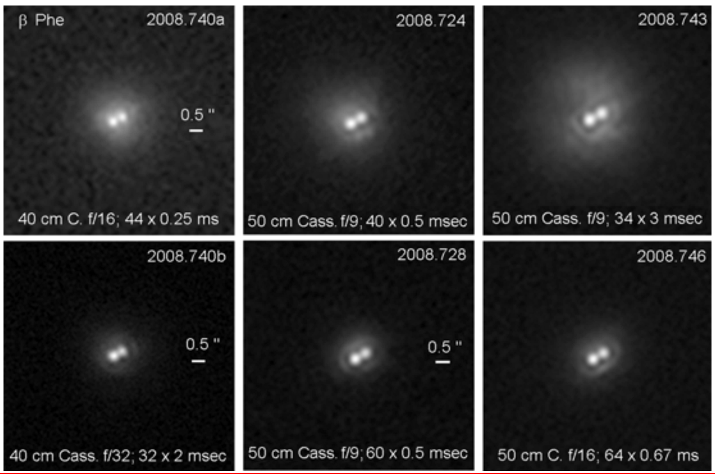

Image from "On the Accuracy of Double Star Measurements from "Lucky" Images ..." by Rainer Anton. on page 65 ff.

Inside this issue:

Divinus Lux Observatory: Report #16

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Abstract: This report contains theta/rho measurements from 97 different double star systems. The time period spans from 2008.432 to 2008.721. Measurements were obtained using a 20-cm Schmidt-Cassegrain telescope and an illuminated reticle micrometer. This report represents a portion of the work that is currently being conducted in double star astronomy at Divinus Lux Observatory in Flagstaff, Arizona.

Occasionally, when the researcher is making rho measurements of known visual binary stars, the desire may emerge to convert the arc second measurements into astronomical units, so that the apparent separation of the binary can be visualized. Fortunately, if the distance to the binary is known with a fair amount of certainty, some algebraic equations exist that can serve as conversion tools, thereby allowing one to obtain a good approximation. As an example of this process, the apparent separation in astronomical units, for STF 1321 AB (09144+5241), will be calculated using a 20.32 cm aperture telescope.

To begin with, the formula $A_{au} \approx 15r/D$ (Couteau 1981) is applied, in which r = the distance to the system in parsecs and D = the aperture of the telescope in centimeters. Performing the calculation using the value of 6.19 parsecs from the Hipparcos catalog, and 20.32 centimeters for the aperture, a value of 4.57 astronomical units is obtained. This value represents an approximation of the resolving power of the telescope at the distance of 6.19 parsecs.

Tanguay (1998) states that the true resolving power of a telescope is actually represented when the edges of the two Airy disks are in contact, which yields a resolving power value of .75" for a 20 cm telescope. Hence, if one applies the formula $AU = \rho/R \times A_{au}$ to the current WDS catalog rho value of 17.1" for STF 1321 AB, a value of 104.2 au will be obtained. In this formula, ρ = the rho value (17.1"), R = the resolving power of the telescope (.75"), and A_{au} = 4.57.

If the researcher substitutes the semi major axis value of 16.73" as presented in Sky Catalog 2000.0 in place of the listed 17.1" rho value, the calculation yields a value of 101.9 au. By utilizing this semi major axis value, along with the listed period of 975 years, and inserting these into the well known formula $M_1 + M_2 = a^3/p^2$ (Newton's form of Kepler's third law), the combined masses of STF 1321 AB can be calculated as 1.11 solar masses. For the sake of comparison, www.solstation.com lists a mass range for this pair at 1.03 to 1.33 solar masses.

In essence, by making some basic calculations like those presented above, the researcher is able to add depth to the data that is being worked with. Even though the researcher could probably locate this information in a publication without having to make the above calculations, this could be one way for making binary star research more fun and interesting. By working through such calculations as these for oneself, a greater appreciation can be gained for some of the methodology that is employed when this type of information does appear in published form.

As has been done in previous articles, the selected double star systems, which appear in this report, have been taken from the 2001.0 version of the Washington Double Star (WDS) Catalog, with published measure-

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ments that are no more recent than ten years ago. Several systems are included from the 2006.5 version of the WDS Catalog as well. While almost all of the theta/rho measurements, in this report, were right in line with catalog values, there were 2 double stars that displayed noteworthy shifts, which appear in the following table.

First of all, disparate proper motions, by both components of HJ 931, are responsible for decreases of 4% in the rho value and almost 2 degrees for the theta

(Continued on page 9)

NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
STF2336	18328+1349	9.1 10.2	8.1	6.91	2008.432	1
STF 37 AB-CD	18443+3940	5.0 5.2	173.5	209.35	2008.432	2
STF 37 AI	18443+3940	5.0 10.4	137.9	150.10	2008.432	2
STF 39 AB	18501+3322	3.6 6.7	149.9	45.43	2008.432	3
BU 293 AE	18501+3322	3.6 10.1	317.4	67.15	2008.432	3
BU 293 AF	18501+3322	3.6 10.6	18.3	85.91	2008.432	3
BU 52 AB	19038+2602	7.8 10.2	297.8	51.35	2008.432	4
STF2522	19258+2846	7.7 8.8	339.0	4.44	2008.432	5
AG 231	19296+1800	9.9 10.0	242.0	4.44	2008.489	6
STF2619 AB	20011+4816	8.8 8.8	239.0	3.95	2008.432	7
STF 50 Aa-C	20136+4644	3.8 7.0	174.1	106.65	2008.432	8
STF 50 Aa-D	20136+4644	3.8 4.8	324.6	333.78	2008.432	8
AG 255	20263+3728	10.0 10.5	286.0	4.94	2008.489	9
STF2697	20344-0029	7.6 9.8	356.8	29.63	2008.489	10
STF2705 AB	20377+3322	7.4 8.0	262.0	2.96	2008.432	11
HJ 1601	20596+3703	10.0 10.4	143.2	6.42	2008.489	12
STF2753	21050+3526	7.4 10.7	335.6	29.63	2008.454	13
HJ 275	21072+1524	8.2 10.5	337.4	22.22	2008.454	14
H 47	21124-1500	8.2 8.2	309.5	3.95	2008.587	15
HJ 931	21174+3203	9.4 10.6	358.3	9.88	2008.587	16
STF 433 AC	21179+3454	4.4 10.0	183.8	21.73	2008.454	17
FOX 259	21195+4253	9.9 10.5	305.9	12.34	2008.587	18
S 786	21197+5303	6.8 9.1	299.5	47.89	2008.454	19
STF2789 AB	21200+5259	7.6 7.9	113.9	6.42	2008.587	20

Table continued on next page.

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NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
STF2793 AB-C	21251+0923	7.4 9.0	241.7	26.66	2005.454	21
WAL 139 AC	21290+3224	9.5 10.3	250.9	41.48	2008.454	22
A 770 AB-E	21308+4827	8.7 10.6	14.4	98.26	2008.454	23
KU 132 Aa-B	21334+3058	10.1 10.6	256.7	53.82	2008.454	24
HO 164 AB	21410+3504	9.4 9.7	70.0	4.44	2008.587	25
SCA 92 AC	21464-0505	10.7 10.7	252.8	82.46	2008.454	26
STT 455	21567+1607	8.5 10.2	270.9	9.88	2008.454	27
STF2872 A-BC	22086+5917	7.2 8.0	315.5	21.73	2008.508	28
STF2867 AB	22100+0757	8.2 9.3	208.6	10.37	2008.508	29
HJ 1741 AB	22112+5049	5.4 10.4	285.6	36.04	2008.587	30
HJ 1741 AD	22112+5049	5.4 9.9	270.9	73.57	2008.587	30
SCA 125	22206-0031	9.4 10.7	70.9	103.43	2008.495	31
SCA 126	22218-0150	9.7 10.6	331.3	83.44	2008.495	32
HJ 965	22290+3432	8.9 10.1	146.2	34.07	2008.587	33
FRK 11	22301+4921	6.4 10.6	90.1	66.66	2008.495	34
STF2917 AB	22306+5332	8.2 8.5	70.0	4.44	2008.508	35
ES 1468	22342+4341	9.2 10.5	327.6	5.93	2008.495	36
AG 284	22387+3718	9.8 9.9	230.1	26.17	2008.495	37
CHE 366	22416+2947	10.0 10.2	6.9	21.73	2008.495	38
HJ 1806	22451+4449	9.2 10.3	334.7	6.91	2008.495	39
HDS3229	22451+3841	8.6 10.6	330.3	20.24	2008.495	40
HJ 969	22459+3358	9.7 10.6	25.6	5.93	2008.508	41
STT 480	22461+5804	7.6 8.6	116.5	30.61	2008.508	42
BU 1518	22496-1059	10.3 10.4	204.0	6.42	2008.587	43
STT 597 AB	22514+1358	8.3 10.6	327.7	201.45	2008.508	44
STF2949	22519+3002	9.6 10.6	182.9	11.36	2008.508	45
HJ 972	22530+3140	9.6 10.7	207.0	28.14	2008.508	46
STF2696	23010+2646	8.4 9.7	36.0	3.95	2008.585	47
HDS3286	23035+4123	9.2 10.4	353.0	17.78	2008.585	48

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NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
STT 242	23065+4655	7.8 8.6	31.0	79.99	2008.585	49
HJ 979	23083+2207	8.8 10.7	217.3	18.27	2008.585	50
BU 717 AC	23177+4901	4.8 10.7	131.4	217.25	2008.585	51
STT 498 AB	23313+5225	7.6 10.2	244.1	17.28	2008.587	52
STF3024	23320+4349	8.6 9.3	309.0	4.94	2008.587	53
BGH 72	23323-1337	8.6 9.1	154.5	120.97	2008.585	54
HJ 1892	23341+5947	9.6 10.4	94.7	6.91	2008.585	55
HJ 1893	23350+4731	9.6 9.9	249.2	4.94	2008.585	56
ES 859 AB	23375+4832	8.3 10.6	217.5	88.88	2008.585	57
AG 429	23527+2920	9.4 10.3	270.5	6.42	2008.587	58
AG 296	23557+3830	10.1 10.2	55.2	5.93	2008.585	59
HJ 5435 AB	23574-1606	9.4 10.7	8.2	14.81	2008.585	60
STF3049 AC	23590+5545	5.0 10.3	66.1	106.16	2008.585	61
HJ 1929 AB-C	00039+2759	8.7 9.5	287.4	5.43	2008.607	62
STF3056 AB-C	00047+3416	7.1 9.5	3.3	25.68	2008.607	63
STF3056 AB-D	00047+3416	7.1 10.5	238.2	95.29	2008.607	63
STF 4	00099+0827	9.4 9.5	275.5	5.43	2008.607	64
STF 3	00100+4623	7.8 9.0	83.0	4.94	2008.607	65
STF 22 AB-C	00174+0853	7.1 7.6	234.4	3.95	2008.607	66
STF 78	00591+0523	10.2 10.4	243.1	4.94	2008.607	67
STT 11 AB-C	01072+3839	7.6 8.7	164.1	59.74	2008.609	68
STF 101	01139-0737	7.5 10.2	346.5	20.74	2008.607	69
ES 119 AC	01180+5355	8.2 10.7	276.8	44.44	2008.607	70
STI1560	01192+5821	9.9 10.2	324.8	13.83	2008.609	71
BU 1102 A-BC	01274+6017	7.9 10.6	264.9	63.20	2008.609	72
EGB 1	01397+4602	9.5 10.4	144.6	5.93	2008.609	73
STF 155 AB	01443+0929	7.8 8.0	326.0	4.94	2008.609	74
KPR 1 AC	01443+0929	7.8 8.4	283.9	191.58	2008.609	74
STF 180 AB	01535+1918	4.5 4.6	0.4	7.41	2008.609	75

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NAME	RA DEC	MAGS	PA	SEP	DATE	NOTES
STF 180 AC	01535+1918	4.5 8.5	81.6	216.26	2008.609	75
HDS 259	01545+5954	8.3 10.1	211.8	16.79	2008.609	76
ES 2144	01567+3505	10.1 10.6	143.2	6.42	2008.609	77
STI1786	02088+5823	9.9 10.7	321.4	15.80	2008.626	78
STF 225 AC	02132+5412	8.1 10.4	160.5	152.57	2008.626	79
ES 764 AB	02249+5153	9.6 10.6	62.6	35.55	2008.626	80
STF 293 AD	02443+5704	9.3 8.7*	343.6	187.63	2008.626	81
HJ 655	02476+1014	9.1 10.2	308.5	23.70	2008.626	82
STF 304	02488+4911	7.5 10.7	289.2	26.17	2008.626	83
AG 55 AB-C	02502+0641	9.9 10.3	178.1	45.92	2008.626	84
A 2341 AD	02544+0946	9.6 10.6	308.3	126.40	2008.626	85
HJ 2162 AB	02548+4332	10.5 10.7	39.5	12.84	2008.626	86
ES 464	03213+4743	10.1 10.6	67.4	6.91	2008.626	87
ARG 55 AB	03247+4417	9.4 10.7	199.2	26.17	2008.721	88
SMA 38	03348+4408	10.2 10.7	68.3	21.67	2008.721	89
STF 400 AB-C	03350+6002	6.8 10.7	235.8	92.33	2008.721	90
A 1707 AC	03419+4331	7.6 10.4	144.9	64.68	2008.721	91
AG 72	03428+3016	10.4 10.7	281.5	6.42	2008.721	92
HL 7 AE	03449+2407	3.7 10.6	345.5	186.14	2008.721	93
ES 770 AB	03494+5214	10.2 10.4	232.5	69.62	2008.721	94
HDS 486	03530+4557	8.5 10.2	311.1	16.75	2008.721	95
S 440 AB	03566+5042	5.3 10.5	30.7	75.54	2008.721	96
STT 68 AB	03597+4809	7.8 9.2	176.1	39.00	2008.721	97

* Companion star is the brighter component.

Table Notes

1. In Hercules. Separation slightly increasing. Spect. F0.
2. Epsilon Lyrae. AB-CD = sep. inc.; common proper mot. Spect. F1V, A4V.
3. Beta Lyrae. AB, AE, AF = relatively fixed. Spect. AB = B7V, B3.
4. In Lyra. Sep. increasing; p.a. decreasing. Spect. A0.
5. In Cygnus. Relatively fixed. Spect. A0, A0.
6. In Sagitta. Sep. & p.a. increasing. Spect. F8.
7. In Cygnus. Common proper motion; p.a. decreasing. Spect. G5, G5.

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8. 31 Cygni. Aa-C = relatively fixed. Aa-D = p.a. inc. Spect. K0, B9, A2.
9. In Cygnus. Separation slightly decreasing.
10. In Aquila. Sep. & p.a. decreasing. Spect. K2.
11. In Cygnus. Relatively fixed. Common proper motion. Spect. K0.
12. In Cygnus. Separation decreasing. Spect. A2.
13. In Cygnus. Sep. & p.a. decreasing. Spect. F0.
14. In Delphinus. Sep. & p.a. decreasing. Spect. F2II.
15. In Capricornus. Sep. increasing; p.a. decreasing. Spect. G3IV, G3V.
16. In Cygnus. Sep. & p.a. decreasing. Spect. G0, G0.
17. Nu or 66 Cygni. Sep. & p.a. increasing. Spect. B2V
18. In Cygnus. Relatively fixed.
19. In Cygnus. Sep. & p.a. slightly decreasing. Spect. K2, A0.
20. In Cygnus. Common proper motion; separation increasing. Spect. F8V, G5.
21. In Equuleus. Relatively fixed. Common proper motion. Spect. A5IV, F0.
22. In Cygnus. Separation slightly increasing. Spect. A2.
23. In Cygnus. Sep. increasing; p.a. decreasing. Spect. K0.
24. In Cygnus. Relatively fixed. Common proper motion. Spect. F8, G0.
25. In Cygnus. Sep. & p.a. increasing. Spect. K0.
26. In Aquarius. Separation increasing.
27. In Pegasus. Relatively fixed. Common proper motion. Spect. F8, F8.
28. In Cepheus. Relatively fixed. Common proper motion. Spect. B9.5V, A0.
29. In Pegasus. Relatively fixed. Common proper motion. Spect. G5III, G0.
30. In Lacerta. AB & AD = sep. increasing; p.a. decreasing. Spect. AD = A5V, K0.
31. In Aquarius. Position angle decreasing. Spect. K2.
32. In Aquarius. Relatively fixed. Common proper motion.
33. In Pegasus. Sep. & p.a. increasing. Spect. G5.
34. In Lacerta. Sep. increasing; p.a. decreasing. Spect. K2III.
35. In Lacerta. Relatively fixed. Common proper motion. Spect. F0IV, F0IV.
36. In Lacerta. Separation increasing. Spect. A3.
37. In Lacerta. Relatively fixed. Spect. A0, A0.
38. In Pegasus. Position angle decreasing. Spect. G5, F8.
39. In Lacerta. Common proper motion; p.a. decreasing. Spect. F8.
40. In Lacerta. Common proper motion; p.a. decreasing. Spect. A2V, A2V.
41. In Pegasus. Relatively fixed. Common proper motion.
42. In Cepheus. Relatively fixed. Common proper motion. Spect. F8, G0.
43. In Aquarius. Relatively fixed. Spect. F8.
44. In Pegasus. Sep. increasing; p.a. decreasing. Spect. K0.
45. In Pegasus. Relatively fixed. Common proper motion. Spect. F8.
46. In Pegasus. Sep. & p.a. increasing. Spect. F8.
47. In Pegasus. Relatively fixed. Common proper motion. Spect. A5, A5.
48. In Andromeda. Relatively fixed. Common proper motion. Spect. A2, A2.
49. In Andromeda. Relatively fixed. Spect. B3, B9.
50. In Pegasus. Relatively fixed. Common proper motion. Spect. K0, G.
51. 8 Andromedae. Separation slightly decreasing. Spect. M2III.
52. In Cassiopeia. Relatively fixed. Spect. F6V.

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53. In Andromeda. Common proper motion; p.a. decreasing. Spect. A0, A0.
54. In Aquarius. Relatively fixed. Common proper motion. Spect. G5, G0.
55. In Cassiopeia. Separation slightly increasing. Spect. A4I.
56. In Andromeda. Common proper motion; sep. & p.a. increasing. Spect. F0.
57. In Andromeda. Separation slightly decreasing. Spect. K0.
58. In Pegasus. Separation slightly increasing. Spect. F0.
59. In Andromeda. Common proper motion; separation slightly increasing.
60. In Cetus. Relatively fixed. Common proper motion. Spect. G0V.
61. Sigma or 8 Cassiopeiae. Separation decreasing. Spect. B1V.
62. In Pegasus. Sep. increasing; p.a. decreasing. Spect. F8.
63. In Andromeda. AB-C = sep. & p.a. inc. AB-D = sep. dec. Spect. K0.
64. In Pisces. Common proper motion. Sep. dec.; p.a. inc. Spect. G5, G5.
65. In Andromeda. Sep. increasing; p.a. decreasing. Spect. A4V, A3+.
66. In Pisces. Sep. & p.a. slightly decreasing. Spect. F5, F5.
67. In Pisces. Common proper motion; p.a. decreasing. Spect. F8, F8.
68. In Andromeda. Sep. decreasing; p.a. increasing. Spect. F8, A5.
69. In Cetus. Common proper motion; p.a. increasing. Spect. G5.
70. In Cassiopeia. Separation increasing. Spect. A2.
71. In NGC 457 star cluster in Cassiopeia. Increasing p.a. Spect. B2.
72. In Cassiopeia. Separation increasing. Spect. B3I.
73. In Andromeda. Relatively fixed.
74. In Pisces. AB = p.a. dec.; c.p.m. AC = sep. inc. Spect. F2, F5, F0.
75. 5 or γ Arietis. AB = p.a. inc.; sep. dec; c.p.m. AC = sep. dec. Spect. A, B9V, K.
76. In Cassiopeia. Separation increasing. Spect. B9IV, B9IV.
77. In Triangulum. Relatively fixed. Common proper motion.
78. In Perseus. Sep. & p.a. increasing. Spect. B6V.
79. In Perseus. Separation increasing. Spect. A0, G0.
80. In Perseus. Separation slightly decreasing. Spect. B8.
81. In Perseus. Sep. decreasing; p.a. increasing. Spect. K0, A2.
82. In Cetus. Relatively fixed. Common proper motion. Spect. F5.
83. In Perseus. Separation increasing. Spect. A0V.
84. In Cetus. Sep. decreasing; p.a. increasing. Spect. G0.
85. In Cetus. Separation slightly increasing. Spect. G5.
86. In Perseus. Position angle increasing.
87. In Perseus. Relatively fixed. Common proper motion.
88. In Perseus. Relatively fixed. Common proper motion. Spect. F5.
89. In Perseus. Relatively fixed. Common proper motion.
90. In Camelopardus. Relatively fixed. Spect. F3V.
91. In Perseus. Separation decreasing. Spect. G5.
92. In Taurus. Common proper motion; p.a. decreasing. Spect. F8.
93. 17 Tauri. Separation increasing. Spect. B5.
94. In Perseus. Position angle increasing.
95. In Perseus. Sep. increasing; p.a. decreasing. Spect. B9, B9.
96. 43 Persei. Relatively fixed. Common proper motion. Spect. F5IV.
97. In Perseus. Relatively fixed. Common proper motion. Spect. B9.

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value during the past 10 years. Secondly, a decrease in the theta value is also being noted for HJ 1741 AB. Since 1998, a 2.4 degrees shift has occurred because of proper motion by the "A" component.

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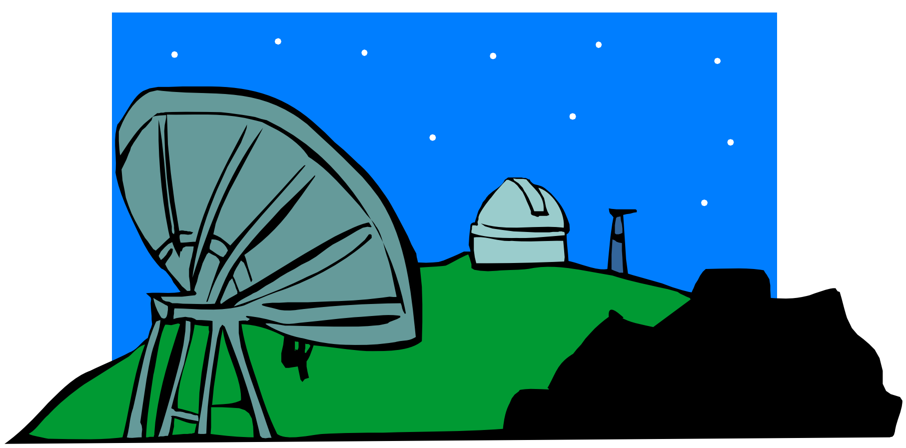

An Investigation on the Relative Proper Motion of Some Optical Double Stars

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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	1907.178	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

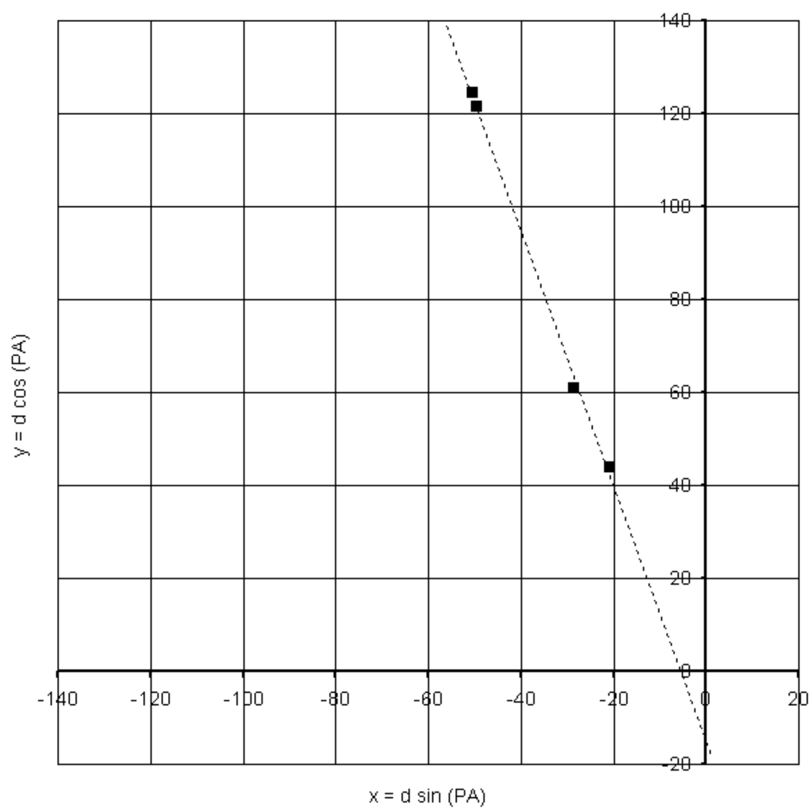

Figure 1: Measurements and linear fit of BUP 80 (WDS 05284-0330)

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)

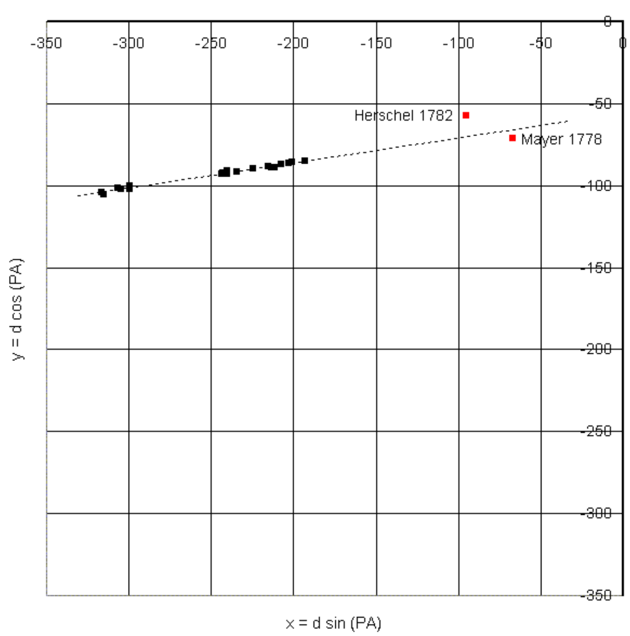

Figure 2: Plot of the measurements of STF1424 AC. Two historical observations of Christian Mayer and William Herschel which are not listed in WDS are marked in red.

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]

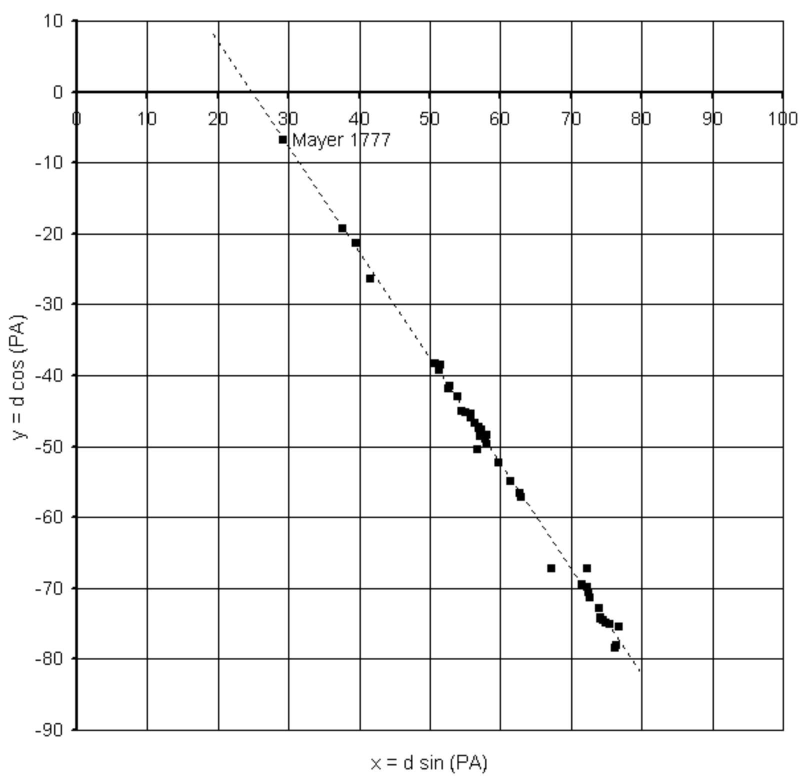

Figure 3: Plot of the measurements of SHJ 162Aa-B

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)

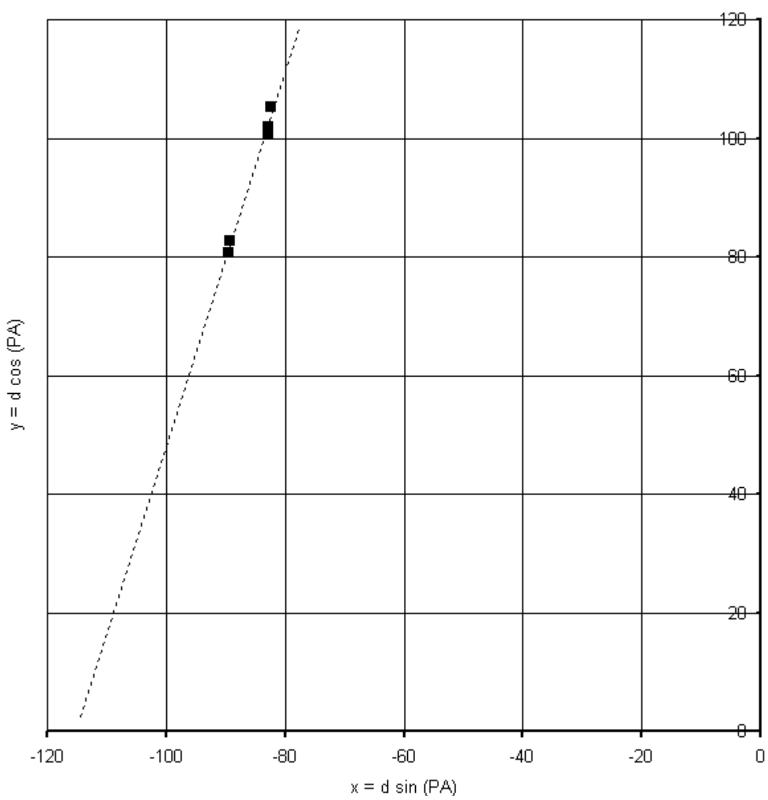

Figure 4: Plot of the measurements and linear fit of STF1879AB-D (WDS 14463+0939)

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

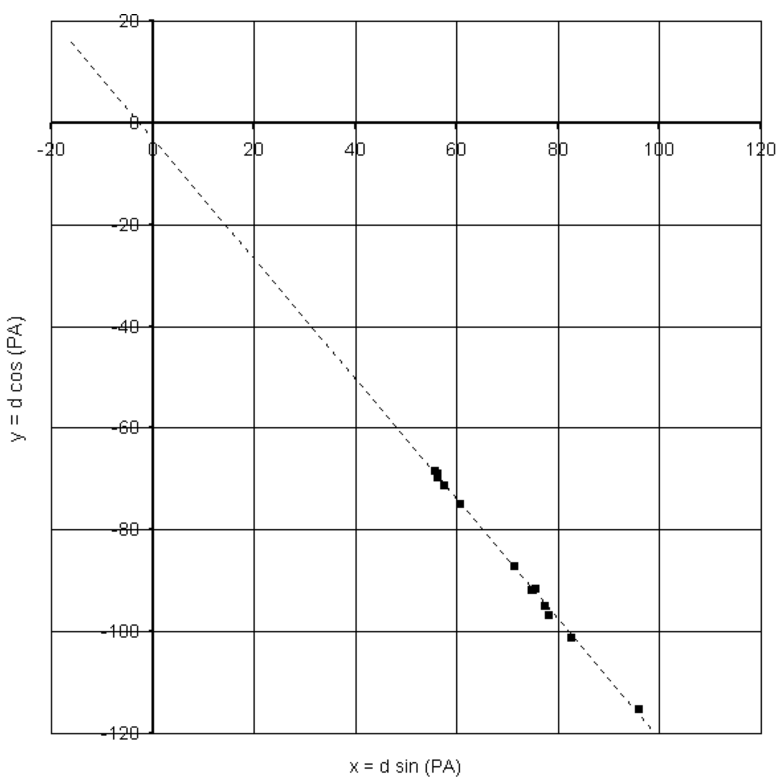

Figure 5: Plot of the measurements and linear fit of STFB 9AE

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

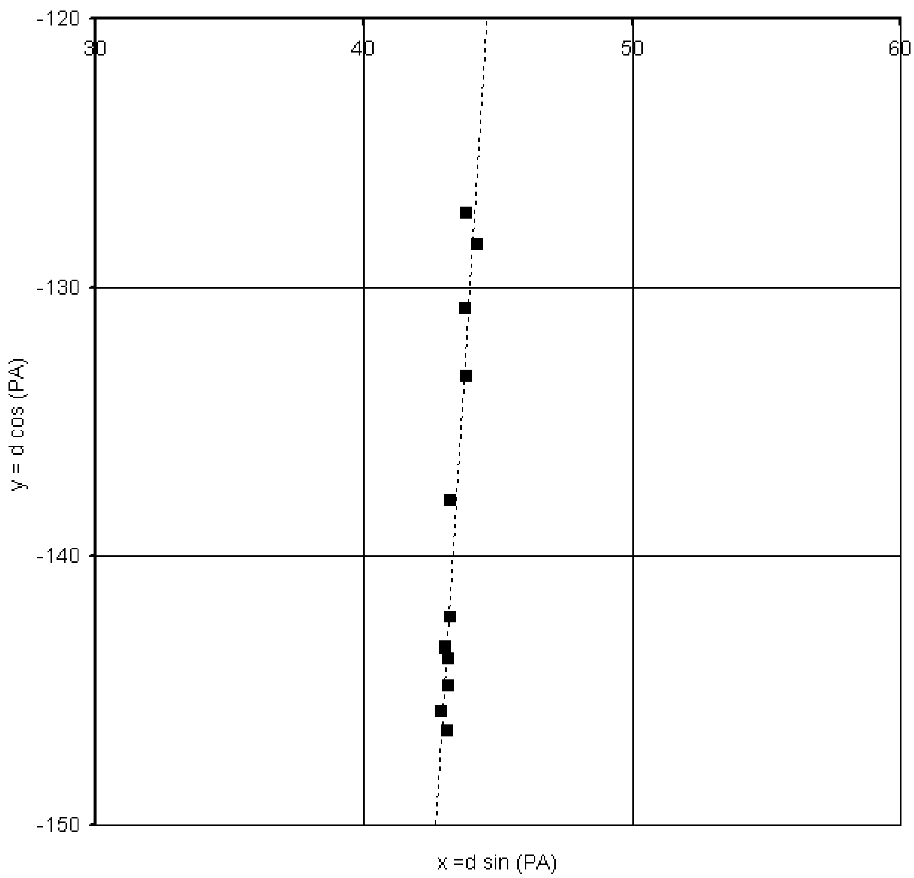

Figure 6: Plot of the measurements and linear fit of LDS1005 AB

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

Christian Mayer, "Gründliche Vertheidigung neuer Beobachtungen von Fixsterntrabanten welche zu Mannheim auf der kurfürstlichen Sternwarte entdeckt worden sind" [Defense of new Observations of Fixed Star Satellites], Mannheim 1778

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Schlimmer 2007b, "Christian Mayer’s Double Star Catalog of 1779", *Journal of Double Star Observations*, Vol. 3 No. 4, 151-158

Schlimmer 2008a, "The Relative Proper Motion of HLD 120AB (WDS14527+0746)", *Journal of Double Star Observations*, Vol. 4 No. 2, 56-58

Schlimmer 2008b, "Double Star Measurements Using a Webcam: Annual Report of 2007", *Journal of Double Star Observations*, Vol. 4 No. 2, 81-83

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

CCD Double-Star Measurements at Observatorio Astronómico Camino de Palomares (OACP): First Series

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Abstract: In this paper we present the results of CCD Theta/Rho measurements for 116 double and multiple stars (223 pairs) in 2007. The residuals in angular separation and position angle are computed for binaries with known orbit. Also, studies about the nature of three new pairs are reported. This first series of measurements is integrated in the observational programs that Syrma-MED is developing at present.

Introduction

The measurements reported in this work were carried out by CCD imaging at the Observatorio Astronómico Camino de Palomares (hereafter OACP, Latitude: 41º 39' 59.53296 N; Longitude: 4º 41' 42.15818 W; Altitude: 694.651 m, Valladolid, Spain), during the months July, August and September, 2007. The observation period was of 27 nights on the whole. The measurements reported here were made by using a CCD for the first time, and it is expected that there will be more of them in the future. Because of the experimental nature of this first series, the selections of the pairs that are measured have not followed a specific criterion. The main interest of the work is to calibrate the Meade DSI Pro CCD camera. Our intention is to verify the response of the equipment in the measurement of visual double stars. This is the reason why pairs of all kinds were chosen: close and wide pairs (the angular separation measured ranging from 2.5" to 421"), systems with great Delta-M, and others of equal magnitudes. The residuals in angular separation and position angle are computed for three binaries with known orbit. In addition to this, fixed and relatively fixed systems were measured for calibration purposes. We include pairs measured recently (2006), others relatively neglected (last measurement in the 1990's) as well as a few others with a unique official measure, so they have been, finally, confirmed. During the data reduction process, we found three uncataloged pairs near well-known ones. They have been evaluated for binarity with regular methods which were used before in previous articles (Masa, 2007) and we propose they be included in WDS.

No filter was used for the observations.

The Telescope

The main instrument of the OACP is a Newtonian telescope (D = 200 mm; F = 1,000 mm) mounted equatorially. It has been used at the prime focus as well as by attaching Barlow lens: Takahashi 2x and Meade Telenegative 3x. The mounting of the telescope does not have a GOTO system. For this reason, the pairs were located by using the settings circles. A refractor telescope (D = 70 mm; F = 700 mm) in parallel with the reflector and an illuminated reticle eyepiece were used to help in centering the desired object. This auxiliary element made locating tasks on the computer screen easier. At the same time, the software Guide 8.0 showed the expected stellar

Figure 1: The OACP Observatory is operative since October 2002.

field of the target area. Figure 1 shows the observatory building and the main telescope.

The Camera and the Image Acquisition Software

The camera, a Meade DSI Pro, incorporates the CCD monochrome image sensor, the Sony ICX254AL with EXview HAD CCD™ technology (Hole Accumulation Diode). The geometrical features of this sensor are shown in Table 1.

The raw frames have a resolution of 508 x 489 pixels. Nevertheless, this format was not used for the measurements. The image acquisition software provided by Meade (*Envisage*) allows resampling the raw image in real time. The geometrical correction is made internally by *Envisage* and gives a definitive image of 648 x 488 pixels, emulating square pixels of 7.5 x 7.5 µm size.

Envisage is powerful and versatile software capable of integrating hundreds of images into only one final image in real time. Generally, this composite image has a good signal to noise ratio. The real power of this algorithm, similar to *Lucky Imaging* techniques, consists of the addition of many short-exposure images. By doing this, the effects of the atmospheric turbulence are worked out, by means of "freezing" the seeing practically. We have been able to obtain good results on especially turbulent nights under very poor seeing conditions. Despite the live image continuously "dancing", the software could make a final composite image which was perfectly measurable. To obtain this digital frame, the main requirement is that the exposure times be as short as possible. The typical exposure times ranked from 0.02 to 1 second, depending on the stellar magnitudes and the quality of the sky. To align and to combine the images of the series, it is useful to select a star from the field (the main component, normally) which can serve as the reference. Only the images of high enough quality are used. They are evaluated continuously by *Envisage* in every partial frame. In general, the combined image was the result of adding at least 50 partial images and the total exposure time was around 25 seconds. The eventual polar misalignments and/or tracking errors are not critical factors and this is another advantage of this technique. Finally, another interesting feature of the software is that it allows the images to be pre-processed automatically beforehand. In this way, if the exposure time is set to one second, then the software will subtract the dark frames (which are taken at the

Image size	Diagonal 6 mm (Type 1/3)
No. of effective pixels	510 (H) × 492 (V) ≈ 250K pixels
Total number of pixels	537 (H) × 505 (V) ≈ 270K pixels
Chip size	6.00 mm (H) × 4.96 mm (V)
Image area size	4.8 mm (H) × 3.6 mm (V)
Unit cell size	9.6µm (H) × 7.5µm (V)

Table 1: Geometry of the Sony ICX254AL CCD sensor

beginning of the session). The image obtained after this action is the definitive one and, ordinarily, will be used to in making the measurements.

For the correct focusing of the stars we used a Hartman's mask with three triangular holes.

Instrumental constants

For each optical train, the "instrumental constants", that is, the image scale in arsec/pixel and the orientation of the CCD sensor with regard to the sky's cardinal points, was determined by several methods:

i) The *Astrometrica* software (version 4.4.2.366) by Herbert Raab was used (when the images contained enough number of reference stars) jointly with the UCAC2 as reference star catalog. We obtained the scale and the orientation with this early reduction.

ii) We have measured several calibration pairs. They have been extracted from a list compiled by three members of The Double Star Commission of the French Astronomical Society (SAF): Guy Morlet and Florence and Pascal Mauroy (available for downloading at http://saf.etoilesdoubles.free.fr/). Thirty-two stable pairs made up this list and it is based on the results of the Hipparcos satellite. Whenever possible, two different reference pairs were registered every night; one at the beginning and another at the end of the observation.

iii) The new *Catalog of Rectilinear Elements* (http://ad.usno.navy.mil/wds/lin1.html) was used. Many systems in the Washington Double Star Catalog have shown significant relative motion since their discovery. The *Catalog of Rectilinear Elements* provides linear fits for those systems whose motion does not appear to be Keplerian. While a few of these may in fact be very long-period physical pairs whose orbital motion is not yet apparent, most are probably optical pairs. These linear fits, then, describe the relative proper motions between these pairs of stars and this property is very useful for CCD calibration. The predicted positions for the observation date were calculated by using a linear regression over the ephemerides of the catalog. Those values were compared to our measurements.

iv) Another auxiliary method was used for the orientation of the CCD chip. It made use of a function implemented in *Reduc* (the software of reduction; see next section), which was specifically designed for this purpose. First, with tracking turned off, a series of star trails in right ascension were recorded. Drift analysis is then carried out by reduction software after knowing the theoretical orientation of the transit frame (i.e., where the North/East cardinal points were). As a rule, four-trail measurements give an average final value of the sensor orientation. This procedure has yielded excellent results so far. Typically, the values of rotation of the sensor in relation to the sky never exceeded ± 1º. This was feasible because the camera was oriented as exactly as possible with the East/West line at the beginning of the observation.

The figures obtained by these four methods were equivalent for the same field. The calibration results for each different optical configuration are shown in Table 2.

Optical train	Escale (a.s./pixel)	Effective Focal Length (mm)	Focal Ratio (f/)	FOV (arcminutes)
Prime focus	1.55	1,000	5	12.6 x 16.7
Barlow 2x (2.26)	0.68	2,260	11.3	5.6 x 7.4
Barlow 3x (3.48)	0.44	3,480	17.4	3.6 x 4.8

Table 2. Instrumental constants

Reduction Software

Florent Losse's *Reduc* software (version 3.80) was used to measure theta and rho from the CCD images. Lately, this software has spread impressively at an international level. More and more followers are using this tool in double star astronomy. It is undoubtedly, a fundamental piece, as well as an irreplaceable tool for relative astrometry tasks. The software has many features. Perhaps the most important feature is that *Reduc* is developed especially to measure double stars from images from webcams and CCD imagers. *Reduc* has an intuitive and friendly interface. The calculations are mostly made in an automatic way and it has an excellent set of tools. Among its special features, its power is the most noteworthy one: it is able to measure correctly over images with very saturated stars and over pairs with defective signal to noise ratio. *Reduc* can make a successful measurement for pairs whose magnitudes are very different. In such cases, almost unfailingly, it is necessary to either saturate or overexpose the main component so the dim component of the pair can be registered. This is one of the most important handicaps that appear while working with CCD images. We have been able to use observations made on the systems whose main star appears so saturated that even a "cross" is visible. These four orthogonal spikes (in our case) are produced by the diffraction of the spider vanes supporting the small secondary mirror, whereas the weak component disguised by the principal's glare is hardly seen. Even in such extreme cases the algorithms of *Reduc* are able to find the centroids successfully.

Reduc is developed continuously by its author. In the last version (3.82) Florent Losse has introduced new and interesting functions. Among them, reading FITS images of 8, 16 and 32 bit integers; FITS 32 bit real, BMP, AVI-BMP conversion; darks and bias pre-processing; crop images; drift calibration; shift and add features; binning x2; Multilanguage platform (French, English, Spanish, and Italian).

Reduc, also includes Surface which is another powerful measurement algorithm, based in the adjustment of a three-dimensional surface. This feature uses the surface algorithm especially designed to measure very tight stars. Developed by Guy Morlet and Pierre Bacchus to measure the images acquired on the 50 cm refractor at the Nice Observatory, it was reserved for the private usage of the members of the SAF. Now, it is integrated in *Reduc* with the authorization and by courtesy of the authors.

Finally, *Reduc* works well under Windows, Linux and Wine, and the author provides the latest version for free at florent_losse@yahoo.fr.

To obtain further information about *Reduc* visit http://www.astrosurf.com/hfosaf/

The Measures

The results of measurements are presented in Table 3. A total of 223 measurements are listed. They belong to 116 double or multiple systems. The data structure in the table is as follows:

Columns 1 and 2: Identifier of the WDS catalog and name of the system. Note: the new pairs are labeled in Column 1 as "uncat". The precise coordinates (J2000) for the main star are reported in the section Discoveries.

Columns 3 and 4: Magnitudes for each component, given in WDS catalog. Note: the V magnitudes that we have calculated in this work are highlighted with boldface type.

Column 5: The epoch of the observation, given in fractional Besselian year.

Column 6: Position Angle.

Column 7: Angular Separation.

Column 8: Number of composite images measured for each pair.

Column 9: Number of nights.

Column 10: Notes.

The mean internal uncertainties for Theta and Rho (given as the average of standard deviation of all measurements) were 0.12º and 0.08" respectively (Figures 2 and 3).

Three reference patterns were used in order to evaluate the accuracy of our measurements: three orbital pairs, 10 stable pairs based upon the results of Hipparcos mission and 10 pairs included in the Catalog of Rectilinear Elements. In all the cases the residuals (O-C) were calculated between the observed positions and the calculated ones. Two of the three orbital systems measured are of grade 5, so that (due to the imprecision of the orbit solution) the residuals are more marked. The residuals are shown in Tables 4, 5 and 6.

A comparative review of the residuals in Tables 5 and 6 was made. We calculated the Root Mean Square (RMS) of the residuals or Quadratic Mean by using Theta/Rho residuals of the two former tables. The

(Continued on page 30)

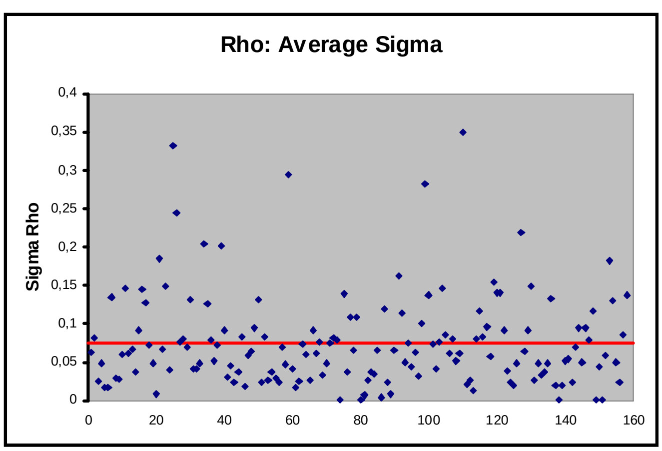

Figure 2: Internal errors in Position Angle.

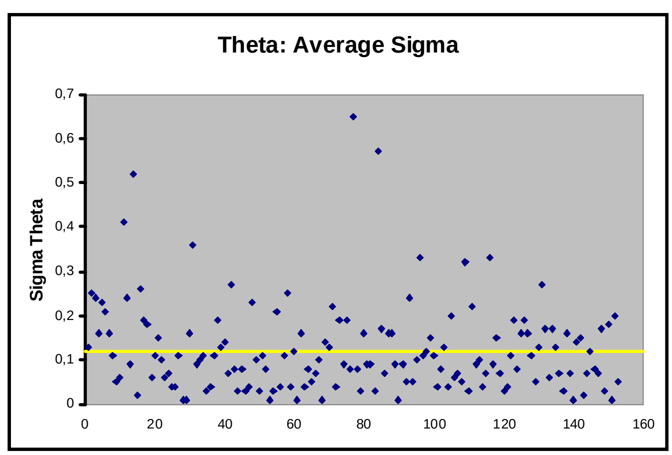

Figure 3: Internal errors in Separation.

CCD Double-Star Measurements at Observatorio Astronómico Camino de Palomares ...

WDS Id.	Discoverer	WDS Mag. 1	WDS Mag. 2	Epoch	Theta (deg)	Rho (a.s.)	N img.	Nights	Notes
00013+6021	STTA254AB	7.40	8.33	2007.6386	89.67	56.991	4	1	1
00013+6021	STTA254AC	7.40	9.56	2007.6386	323.87	155.535	3	1	1
00013+6021	STTA254AD	7.40	10.35	2007.6386	118.07	181.467	4	1	1
00013+6021	STTA254BD	8.33	10.35	2007.6386	129.71	134.153	4	1	1
Uncat	MRI 4	**11.99**	**12.31**	2007.6386	359.78	21.375	2	1	2
00056+7617	HJ 3237	8.93	12.15	2007.6688	308.89	48.982	2	1	3
00084+2905	H 5 32Aa-B	2.22	11.11	2007.5703	283.86	90.625	1	1	4
00116+5945	BU 254AB	8.00	12.00	2007.6426	239.34	7.714	7	2	5
00116+5945	BU 254AC	8.00	12.70	2007.6426	240.78	37.240	5	2	5
00141+7601	STTA 1	7.39	7.81	2007.6688	103.86	73.430	3	1	6
00152+5947	HJ 1008AB	8.12	11.31	2007.6385	125.29	21.698	3	1	7
00152+5947	ABH 2AD	8.06	13.08	2007.6385	147.07	78.852	3	1	7
00152+5947	ABH 2AE	8.06	14.20	2007.6385	58.27	106.226	4	1	7
00152+5947	ABH 2AF	8.06	14.10	2007.6385	340.60	58.698	3	1	7
00152+5947	ES 1BC	11.60	13.30	2007.6385	226.52	10.140	4	1	7
00152+7801	STF 11	8.48	10.14	2007.6689	192.84	8.155	3	1	8
00170+6132	BU 392	5.73	12.48	2007.6659	71.07	19.450	2	1	9
00327+2312	BU 1310AC	6.80	12.50	2007.6880	276.26	27.217	6	1	10
00327+2312	BU 1310AD	7.10	9.20	2007.6880	154.83	94.376	5	1	10
00355+5841	STF 38	8.66	8.97	2007.6740	144.53	17.045	5	1	11
00362+2402	HO 623	7.30	12.30	2007.6880	155.24	9.067	4	1	12
00393+3052	BU 491AB	3.25	12.44	2007.6878	298.04	28.936	4	1	13
00399+2126	STF 46	5.56	8.49	2007.6881	194.98	6.568	5	1	14
00400+7652	STTA 5	6.86	8.78	2007.6689	141.90	118.027	3	1	15
00403+2403	STF 47AB	7.25	8.82	2007.6879	205.37	16.650	7	1	16
00403+2403	BU 1348AC	7.21	11.10	2007.6879	232.84	46.706	4	1	16
00403+2403	BU 1348BC	9.51	11.10	2007.6879	246.48	32.924	3	1	16
00405+5632	H 5 18AD	2.35	8.98	2007.6795	282.23	70.490	3	1	17
00444+7713	STF 50	8.01	10.62	2007.6690	95.74	22.104	3	1	18

Table 3: Relative astrometry of the observed pairs.

Table continued on next page.

WDS Id.	Discoverer	WDS Mag. 1	WDS Mag. 2	Epoch	Theta (deg)	Rho (a.s.)	N img.	Nights	Notes
00464+3057	STFA 1	7.25	7.43	2007.6879	46.79	47.594	4	1	19
00491+5749	STF 60AB	3.52	7.36	2007.6768	320.39	12.965	6	2	20
01170+3828	STF 104	8.03	9.83	2007.6851	322.87	13.822	4	1	21
01188+3724	STF 108	6.52	9.57	2007.6850	63.75	6.350	3	1	22
01201+3639	WEI 3	8.93	9.82	2007.6850	187.29	4.912	4	1	23
01317+6103	STF 128	7.80	9.50	2007.6414	309.17	11.283	3	1	24
01317+6101	STI 228	12.60	13.50	2007.6414	333.43	5.970	3	1	25
01321+1657	STF 132AB	6.88	10.61	2007.6304	342.12	61.993	8	1	26
01321+1657	STF 132AC	6.80	10.90	2007.6304	247.87	67.752	4	1	26
01321+1657	STF 132AD	6.90	10.00	2007.6304	109.42	115.662	3	1	26
01321+1657	STF 132DF	10.00	10.60	2007.6304	288.87	5.053	2	1	26
01332+6041	STF 131AB	7.30	9.90	2007.6415	143.15	13.870	2	1	27
01332+6041	STF 131AC	7.23	11.80	2007.6415	145.42	28.030	3	1	27
01332+6041	STF 131BC	9.90	11.80	2007.6415	147.63	14.181	2	1	27
01332+6041	FLE 2AD	7.23	11.74	2007.6415	120.90	46.300	2	1	27
01332+6041	FLE 2AE	7.30	10.62	2007.6415	135.97	82.161	2	1	27
01349+1234	STF 136AB	7.33	8.33	2007.6306	77.30	15.510	4	1	28
01535+1918	STF 180AB	4.52	4.58	2007.6374	0.20	7.423	9	2	29
01535+1918	STF 180AC	4.52	8.63	2007.6374	80.63	217.590	3	2	29
01535+1918	STF 180BC	4.58	8.63	2007.6374	82.49	216.512	3	2	29
01581+4123	S 404AB	7.64	7.64	2007.6307	83.67	28.992	2	1	30
01581+4123	S 404BC	9.60	12.50	2007.6307	100.92	83.471	4	1	30
02011+3518	STF 197AB	8.21	9.30	2007.6184	232.68	36.943	2	1	31
02011+3518	STF 197AC	8.10	14.00	2007.6184	73.71	40.749	2	1	31
02039+4220	STF 205A-BC	2.31	5.02	2007.6442	62.48	9.107	6	2	32
02103+3322	STF 219	8.03	8.89	2007.6183	183.09	11.582	3	1	33
02109+3902	STF 222	6.05	6.71	2007.6442	36.00	16.692	7	2	34
02187+3429	STF 246	7.82	9.26	2007.6447	123.33	9.825	9	3	35
02336+3125	HJ 653	7.40	11.10	2007.6416	42.67	23.142	2	1	36

Table continued on next page.

CCD Double-Star Measurements at Observatorio Astronómico Camino de Palomares ...

WDS Id.	Discoverer	WDS Mag. 1	WDS Mag. 2	Epoch	Theta (deg)	Rho (a.s.)	N img.	Nights	Notes
02390+6235	STTA 28	6.65	7.56	2007.666	147.71	67.887	3	1	37
02420+4248	HJ 1123	8.39	8.46	2007.6199	248.67	20.059	3	1	38
02425+4016	STF 292	7.56	8.23	2007.6252	211.92	23.121	3	1	39
02451+5708	STI1936	8.20	12.80	2007.6253	217.85	9.927	2	1	40
02454+5634	STF 297Aa-B	8.55	8.87	2007.6553	278.28	15.884	10	2	41
02454+5634	STF 297Aa-C	7.80	10.40	2007.6553	108.01	28.779	10	2	41
02454+5634	STF 297BC	7.80	10.40	2007.6553	104.48	44.503	10	2	41
02456+5709	STI1937	12.20	12.80	2007.6253	30.51	5.813	4	1	42
02476+5357	STF 301	7.85	8.70	2007.6854	16.38	8.278	3	1	43
02507+5554	STF 307AB	3.76	8.50	2007.6471	300.46	28.750	8	2	44
02507+5554	STF 307AC	3.76	9.90	2007.6471	270.22	68.877	8	2	44
02507+5554	WAL 19AF	3.76	11.44	2007.6471	24.72	57.473	6	2	44
02507+5554	WAR 1CD	9.90	10.40	2007.6089	116.01	5.139	3	1	44
02507+6249	STI 396AB	8.70	10.80	2007.6661	148.22	11.504	5	1	45
02507+6249	SIN 5AD	8.70	13.00	2007.6661	95.01	39.365	4	1	45
02507+6249	SIN 5AF	8.70	12.80	2007.6661	267.15	92.169	4	1	45
02507+6249	SIN 5AG	8.70	14.40	2007.6661	262.18	128.845	2	1	45
03068+4545	ES 558	7.65	10.62	2007.6363	0.12	8.252	4	1	46
03136+3909	STF 364	8.73	8.92	2007.6293	310.82	11.742	2	1	47
03215+4523	HO 319AB	7.50	11.80	2007.6362	47.42	11.574	2	1	48
03215+4523	HO 319AC	7.50	14.50	2007.6362	302.92	9.994	2	1	48
Uncat	MRI 3AD	7.50	12.01	2007.6362	267.10	155.649	3	1	48
03293+4503	STF 391	7.60	8.32	2007.6362	95.04	4.312	2	1	49
03294+4656	STT 55AB	6.24	10.80	2007.6361	295.38	31.053	3	1	50
03294+4656	A 982BC	10.80	13.80	2007.6361	238.67	3.651	3	1	50
03294+4656	A 982BD	10.80	14.50	2007.6361	301.98	21.187	2	1	50
03294+4656	A 982BE	10.80	14.00	2007.6361	273.80	44.724	2	1	50
03294+4656	A 982EF	14.00	14.70	2007.6361	307.77	2.632	2	1	50
03316+4752	STT 56AB	6.76	10.67	2007.6361	352.43	32.675	2	1	51

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WDS Id.	Discoverer	WDS Mag. 1	WDS Mag. 2	Epoch	Theta (deg)	Rho (a.s.)	N img.	Nights	Notes
03316+4752	WAL 23AC	6.76	12.51	2007.6361	47.29	45.824	4	1	51
03332+4615	ES 560	8.33	11.29	2007.6362	142.45	9.633	3	1	52
03541+3153	STF 464AB	2.85	9.16	2007.6171	208.03	12.818	2	1	53
03541+3153	STF 464AC	2.85	11.24	2007.6171	287.07	32.713	4	1	53
03541+3153	STF 464AD	2.86	10.44	2007.6171	195.41	98.317	2	1	53
03541+3153	STF 464AE	2.86	9.96	2007.6171	185.61	119.972	2	1	53
03541+3153	STF 464CD	11.24	9.90	2007.6171	177.16	104.450	2	1	53
03541+3153	STF 464CE	11.24	9.90	2007.6171	171.38	130.454	2	1	53
03541+3153	STF 464DE	10.44	9.96	2007.6171	149.67	28.518	2	1	53
03541+3153	SLV 2BC	9.16	11.24	2007.6171	309.61	32.775	2	1	53
03541+3153	SLV 2BD	9.16	10.44	2007.6171	193.54	85.855	2	1	53
03573+4153	STF 469	6.90	9.92	2007.6389	145.57	9.060	4	1	54
04009+2312	STF 479AB	6.92	7.76	2007.6855	127.02	7.510	4	1	55
04009+2312	STF 479AC	6.92	9.45	2007.6855	241.31	58.320	5	1	55
04078+6220	STF 485AC	6.91	10.39	2007.6664	0.03	11.032	3	1	56
04078+6220	STF 485AD	6.91	14.10	2007.6664	132.05	14.398	2	1	56
04078+6220	STF 485AE	6.91	6.94	2007.6664	305.01	17.871	2	1	56
04078+6220	STF 485AF	6.91	12.20	2007.6664	320.05	36.294	4	1	56
04078+6220	STF 484AG	6.91	9.63	2007.6664	260.59	60.142	2	1	56
04078+6220	STF 484AH	6.91	10.50	2007.6664	256.71	57.120	3	1	56
04078+6220	STF 484AI	6.91	9.81	2007.6664	278.94	69.564	3	1	56
04078+6220	STF 485AL	6.91	10.40	2007.6664	71.47	98.401	2	1	56
04078+6220	STF 485AO	6.91	9.40	2007.6664	77.81	138.788	2	1	56
04078+6220	HZG 2AN	6.91	9.62	2007.6664	206.22	116.186	2	1	56
04078+6220	WSI 20AQ	6.91	13.20	2007.6664	324.56	45.623	3	1	56
04078+6220	STF 485EC	6.94	11.70	2007.6664	87.13	14.642	2	1	56
04078+6220	STF 485EF	6.94	11.90	2007.6664	333.78	19.581	2	1	56
04078+6220	STF 485EG	6.94	9.63	2007.6664	245.79	49.004	2	1	56
04078+6220	STF 484EH	6.94	10.50	2007.6664	240.23	47.165	3	1	56

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WDS Id.	Discoverer	WDS Mag. 1	WDS Mag. 2	Epoch	Theta (deg)	Rho (a.s.)	N img.	Nights	Notes
04078+6220	STF 484EI	6.94	9.81	2007.6664	270.62	54.062	3	1	56
04078+6220	WSI 20EQ	6.94	---	2007.6664	336.4	29.407	4	1	56
04078+6220	WSI 20FQ	12.20	13.20	2007.6664	342.12	9.842	2	1	56
04078+6220	STF 484GH	9.63	10.50	2007.6664	131.88	5.494	2	1	56
04078+6220	STF 484GI	9.63	9.81	2007.6664	335.73	22.688	2	1	56
04078+6220	STF 484HI	10.50	9.81	2007.6664	331.25	27.371	5	1	56
04078+6220	HZG 2IJ	9.81	12.00	2007.6664	155.89	60.388	2	1	56
04078+6220	HLM 3LM	10.40	11.40	2007.6664	215.55	5.401	4	1	56
04078+6220	HZG 2LO	10.40	9.40	2007.6664	92.64	42.425	5	1	56
04078+6220	HZG 2OP	9.40	---	2007.6664	228.79	17.292	5	1	56
04089+2306	STF 494	7.53	7.65	2007.6855	188.65	5.321	2	1	57
04198+2344	STF 523AB	7.58	9.86	2007.6854	163.30	10.471	6	1	58
04198+2344	STF 523AC	7.58	8.92	2007.6854	49.83	109.427	4	1	58
04240+2418	STF 534AB	6.36	7.94	2007.6854	290.56	29.213	5	1	59
04335+1801	STF 559	6.97	7.02	2007.6692	277.02	2.812	2	1	60
04588+4408	STF 613AB	8.59	9.58	2007.6445	99.65	11.859	3	1	61
04588+4408	STF 613AC	8.59	10.90	2007.6445	51.62	21.158	3	1	61
04588+4408	STF 613BC	9.90	10.90	2007.6445	17.67	15.872	2	1	61
05003+3924	STT 92AB	6.02	9.50	2007.6691	281.64	4.045	3	1	62
05091+4907	STT 96	6.67	11.10	2007.6554	105.11	21.171	8	2	63
05138+4658	STT 101	7.59	10.64	2007.6663	184.02	5.961	3	1	64
05167+1826	STF 670A-Bb	7.72	8.28	2007.6883	165.28	2.499	3	1	65
05175+2008	STF 674	6.82	9.68	2007.6882	148.33	10.081	4	1	66
05185+1800	J 1818	9.00	10.50	2007.6883	354.02	6.121	5	1	67
05189+4515	STF 669	8.44	8.97	2007.6445	278.38	9.878	3	1	68
05192+2008	STF 680	6.22	9.66	2007.6882	203.82	9.107	6	1	69
05207+4658	STF 681	6.61	9.21	2007.6553	182.34	23.325	7	2	70
05232+4701	STT 104	7.10	11.10	2007.6554	190.15	21.092	10	2	71
05243+2008	HU 447	8.40	12.90	2007.6882	210.60	4.944	7	1	72

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CCD Double-Star Measurements at Observatorio Astronómico Camino de Palomares ...

WDS Id.	Discoverer	WDS Mag. 1	WDS Mag. 2	Epoch	Theta (deg)	Rho (a.s.)	N img.	Nights	Notes
05323+4924	STF 718AB	7.47	7.54	2007.6444	73.45	7.785	2	1	73
05323+4924	STF 718AC	7.47	11.22	2007.6444	186.41	117.867	3	1	73
05351+0956	STF 738AB	3.51	5.45	2007.6882	43.97	4.206	3	1	74
05364+2200	STF 742	7.09	7.47	2007.6884	274.04	4.056	6	1	75
05413+2929	STF 764	6.38	7.08	2007.6856	14.01	26.071	4	1	76
05425+2951	BU 14	7.30	10.50	2007.6856	192.26	5.025	7	1	77
12492+8325	STF1694AB	5.29	5.74	2007.5729	326.31	21.397	1	1	78
12492+8325	WAL 63AC	5.29	11.50	2007.5729	222.67	73.323	1	1	78
13126+5827	STF1732AB	8.68	10.42	2007.6303	127.16	25.845	2	1	79
13239+5456	STF1744AB	2.23	3.88	2007.6167	152.96	14.419	8	2	80
14286+2817	STF1850	7.11	7.56	2007.6068	261.78	25.440	4	1	81
14318+3022	HJ 2728	3.58	11.50	2007.6084	345.10	35.045	2	1	82
14596+5352	SHJ 191	6.86	7.57	2007.6031	341.55	40.311	4	1	83
16460+8202	HDO 143	4.23	11.20	2007.6029	0.89	77.410	2	1	84
Uncat	MRI 2	**13.74**	**13.93**	2007.6032	177.44	17.715	5	1	85
17322+5511	STFA 35	4.87	4.90	2007.6032	311.11	62.175	2	1	86
18448+3736	STFA 38AD	4.34	5.62	2007.6155	149.88	43.705	2	1	87
18448+3736	BU 968AC	4.30	13.30	2007.6155	270.18	48.460	3	1	87
18448+3736	BU 968AE	4.30	11.50	2007.6155	298.30	62.026	3	1	87
18501+3322	STFA 39AB	3.63	6.69	2007.6006	148.03	45.615	5	1	88
18501+3322	BU 293AE	3.63	10.14	2007.6006	317.84	67.372	4	1	88
18501+3322	BU 293AF	3.63	10.62	2007.6006	18.43	86.516	5	1	88
18501+3322	BU 293BE	6.69	10.14	2007.6006	321.97	112.500	5	1	88
18501+3322	BU 293BF	6.69	10.62	2007.6006	1.53	120.776	4	1	88
18501+3322	BU 293EF	10.14	10.62	2007.6006	66.08	79.349	5	1	88
18562+0412	STF2417AB	4.59	4.93	2007.6686	103.59	22.411	6	1	89
18562+0412	STF2417AC	4.59	6.78	2007.6686	58.10	420.965	3	1	89
18562+0412	STF2417BC	4.93	6.78	2007.6686	55.84	405.583	4	1	89
19171+0920	STT 370AB	8.34	8.71	2007.6687	14.07	19.686	7	1	90

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CCD Double-Star Measurements at Observatorio Astronómico Camino de Palomares ...

WDS Id.	Discoverer	WDS Mag. 1	WDS Mag. 2	Epoch	Theta (deg)	Rho (a.s.)	N img.	Nights	Notes
19171+0920	STT 370AC	8.34	----	2007.6687	77.45	22.653	6	1	90
19171+0920	STT 370BC	9.10	----	2007.6687	129.43	22.406	5	1	90
19307+2758	STFA 43Aa-B	3.19	4.68	2007.5895	54.30	34.546	5	1	91
19307+2758	WAL 114Aa-C	3.19	10.99	2007.5950	340.25	65.030	7	2	91
19369+1116	J 133AB	6.07	14.00	2007.6359	57.58	14.802	2	1	92
19369+1116	J 133AC	6.07	12.50	2007.6359	310.27	20.389	2	1	92
19369+1116	WAL 115AD	6.07	11.25	2007.6359	51.09	63.884	3	1	92
19411+1041	STF2558	8.00	10.50	2007.6358	307.16	27.793	2	1	93
19441+1222	STF2567	7.93	9.96	2007.6344	309.96	17.902	5	1	94
19487+1149	STF2583AC	5.70	12.20	2007.6357	296.56	36.092	3	1	95
19523+1021	STF2590AB	6.50	10.31	2007.6058	308.54	13.517	3	1	96
19523+1021	STF2590CD	11.60	12.20	2007.6058	271.94	8.279	5	1	96
19533+1150	STF2593AB	8.70	10.10	2007.6358	242.99	12.182	3	1	97
19533+1150	STF2593BC	10.10	11.40	2007.6358	309.38	3.550	3	1	97
20391+1550	BU 288AC	5.90	10.80	2007.5923	123.80	39.956	3	1	98
20391+1550	BU 288AD	5.90	14.30	2007.5923	147.11	29.268	2	1	98
20391+1550	BU 288AE	5.90	14.30	2007.5923	32.51	21.661	2	1	98
21287+7034	STF2806Aa-B	3.17	8.63	2007.6440	249.10	13.131	3	1	99
22106+7008	STF2883	5.56	8.56	2007.6440	252.06	14.489	5	1	100
22284+5825	H 4 31AB	8.54	10.52	2007.6468	3.74	25.082	4	1	101
22284+5825	ARN 79AC	8.54	9.46	2007.6468	320.21	78.747	3	1	101
22292+5825	BU 702AB	4.21	13.00	2007.6467	284.24	20.918	2	1	102
22292+5825	STFA 58AC	4.21	6.11	2007.6467	191.37	40.798	5	1	102
22330+6955	STF2924AB-C	6.00	10.50	2007.6441	196.73	124.403	3	1	103
22330+6955	STF2924AB-D	6.00	10.20	2007.6441	196.90	187.828	3	1	103
22331+6830	BU 706AC	7.77	10.98	2007.6441	251.03	31.069	3	1	104
22332+7022	STF2923AB	6.32	9.24	2007.6440	47.45	9.681	3	1	105
22332+7022	STF2923AC	6.30	11.30	2007.6440	148.22	96.243	3	1	105
22403+6830	BU 845AB	8.10	12.10	2007.6442	203.36	6.743	2	1	106

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CCD Double-Star Measurements at Observatorio Astronómico Camino de Palomares ...

WDS Id.	Discoverer	WDS Mag. 1	WDS Mag. 2	Epoch	Theta (deg)	Rho (a.s.)	N img.	Nights	Notes
22403+6830	BU 845AC	8.10	13.20	2007.6442	16.36	16.495	2	1	106
22403+6830	FOX 269AD	8.10	13.30	2007.6442	96.78	44.754	3	1	106
22450+6808	STT 529AB	9.08	9.89	2007.6445	200.42	3.765	2	1	107
22450+6808	STT 529AC	9.08	10.81	2007.6445	219.21	20.467	3	1	107
23100+4758	STF2985	7.21	8.02	2007.6808	256.07	15.804	5	1	108
23104+4901	STF2987	7.42	10.41	2007.6823	150.03	4.374	1	1	109
23144+2943	HJ 1858	8.68	11.09	2007.6085	81.90	20.401	2	1	110
23144+2946	HJ 1859	6.41	9.90	2007.6085	122.23	33.923	2	1	111
23144+2946	ARN 26AC	6.45	8.68	2007.6085	181.30	190.888	3	1	111
23177+4901	FOX 273AD	5.01	11.60	2007.6823	233.06	58.569	4	1	112
23461+6028	STF3037AC	7.39	9.53	2007.6388	188.71	29.146	3	1	113
23461+6028	STF3037AD	7.35	10.86	2007.6388	232.76	52.585	3	1	113
23461+6028	STF3037AE	7.35	9.70	2007.6388	62.85	109.943	2	1	113
23461+6028	STF3037AF	7.35	11.13	2007.6388	147.20	123.461	2	1	113
23496+6052	STI1222	9.16	9.57	2007.6373	21.56	11.975	5	1	114
23527+6042	BU 1153AB-C	11.14	12.25	2007.6387	336.24	14.004	4	1	115
23527+6042	BU 1153AB-D	11.14	6.89	2007.6387	66.09	176.945	2	1	115
23531+6042	STT 511AB	6.89	10.58	2007.6387	34.24	9.819	4	1	116
23531+6042	STT 511AC	6.90	14.10	2007.6387	39.71	35.788	3	1	116
23531+6042	STT 511AD	6.90	10.34	2007.6387	130.52	68.322	3	1	116

Table 3 concluded. Notes begin on page 36

WDS Id.	Discoverer	Grade	Reference	Residual (O-C)	
				Theta (°)	Rho (")
00491+5749	STF 60AB	3	Str1969a	-0.08	-0.155
05003+3924	STT 92AB	5	Cve2006e	+0.76	-0.022
05364+2200	STF 742	5	Hop1973b	-0.57	-0.064

Table 4. Residuals of orbital systems measures in this series

WDS Id.	Discoverer	Epoch	Observation (O)		Ephemerides (C)		Residual (O-C)	
			Theta	Rho	Theta	Rho	Theta	Rho
00355+5841	STF 38	2007.6740	144.53	17.045	144.26	16.93	+0.27	+0.115
01349+1234	STF 136AB	2007.6306	77.30	15.510	77.10	15.54	+0.20	-0.030
02109+3902	STF 222	2007.6442	36.00	16.692	35.90	16.69	+0.10	+0.002
02425+4016	STF 292	2007.6252	211.92	23.121	211.57	23.05	+0.35	+0.071
02454+5634	STF 297Aa-B	2007.6553	278.28	15.884	278.64	15.81	-0.36	+0.074
04078+6220	STF 485AE	2007.6664	305.01	17.871	304.73	17.91	+0.28	-0.039
04240+2418	STF 534AB	2007.6854	290.56	29.213	290.74	29.08	-0.18	+0.133
05413+2929	STF 764	2007.6856	14.01	26.071	13.96	26.01	+0.05	+0.061
19171+0920	STT 370AB	2007.6687	14.07	19.686	13.56	19.52	+0.51	+0.166
23100+4758	STF2985	2007.6808	256.07	15.804	256.51	15.61	-0.44	+0.194

Table 5: Residuals of the stable pairs based upon the results of Hipparcos mission (extracted from Morlet-Mauroy's list) o f

WDS Id.	Discoverer	Epoch	Observation (O)		Ephemerides (C)		Residual (O-C)	
			Theta	Rho	Theta	Rho	Theta	Rho
00084+2905	H 5 32Aa-B	2007.5703	283.86	90.625	284.078	90.278	-0.218	+0.347
00444+7713	STF 50	2007.6690	95.74	22.104	95.541	21.937	+0.199	+0.167
00464+3057	STFA 1	2007.6879	46.79	47.594	46.636	47.288	+0.154	+0.306
01321+1657	STF 132AB	2007.6304	342.12	61.993	341.939	62.157	+0.181	-0.164
01581+4123	S 404AB	2007.6307	83.67	28.992	83.358	28.872	+0.312	+0.120
02011+3518	STF 197AB	2007.6184	232.68	36.943	232.556	37.461	+0.124	-0.518
03316+4752	STT 56AB	2007.6361	352.43	32.675	352.300	32.716	+0.130	-0.041
04588+4408	STF 613AB	2007.6445	99.65	11.859	99.286	11.931	+0.364	-0.072
05232+4701	STT 104	2007.6554	190.15	21.092	189.194	21.015	+0.956	+0.077
23144+2943	HJ 1858	2007.6085	81.90	20.401	81.776	20.128	+0.124	+0.273

Table 6: Residuals of the pairs included in the Catalog of Rectilinear Elements

(Continued from page 21)

results (Table 7) showed a great coherency. The RMS values are very similar, either in Theta or in Rho, demonstrating two important statements: 1) the reliability of the ephemerides in both samples, in spite of being small ones and chosen at random; and 2) the regularity and linearity of our procedure of measurement.

Discoveries

Three new pairs were found. These pairs are uncataloged as well as likely true binary systems. One them is a new companion for a known system. They are listed in order of increasing right ascension.

Because all the new components are located near the galactic plane, we have derived the interstellar reddening for each of them. The total line-of-sight interstellar reddening (hereafter denoted by the suffix "∞") was obtained from the Schlegel *et al.* (1998) maps, using the NED database extinction calculator. This tool is available on-line at the web site http://nedwww.ipac.caltech.edu/forms/calculator.html

This previous reddening was reduced by the expo-

Sample	RMS Theta	RMS Rho
Stable pairs Hipparcos (Morlet-Mauroy)	0.30692019	0.10619275
Catalog of Rectilinear Elements	0.36538062	0.25276016

Table 7: RMS residuals for the two samples

nential law derived by Anthony-Twarog & Twarog (1994), which takes into account the galactic latitude and the distance. The reduction fraction (*f*) is given by the expression:

$$f = 1 - \exp(-Hr \sin b),$$

where r is the star's distance, b is the galactic latitude, and H is an observational constant equal to 0.008 pc^{-1}.

Using the same methods as used previously (Masa, 2007) in order to analyze data found in the literature, the following conclusions were drawn:

MRI 4

This uncataloged pair is located in the vicinity of STTA254. The main star is in position (J2000) RA = 00h 00m 51.56s and Dec = +60º 23' 06.6". The optical photometry in the literature is not reliable. The Tycho-2 catalog only gives VT magnitude for the principal star, so our study is based on the NIR photometry of 2MASS. For both components, the 2MASS`s quality flag, labeled "AAA", indicates the best quality grade of the JHK magnitudes. First, working with the reddened JHK magnitudes, we derived the preliminary spectral types, those derived by energy distribution, and a crude estimation of the photometric distances, as well. Several standard tables to assign intrinsic V magnitudes and (B – V) and (V – I) color indexes were consulted. The M_{Ks} absolute magnitude of each component by means (V – K_S) color, according to the procedure of Henry *et al.* (2004) was derived (see below). The M_V absolute magnitude came from $M_V = M_{Ks} + (V - K_S)$. In the next step, using the preliminary distances, we corrected the NIR photometry by reddening and extinction (the components are placed near the galactic plane (A: b = -1.875º; B: b = -1.869º). The new set of distance values was used to calculate a more reliable value of reddening. Lastly, in this second iteration of the recursive method, the definitive color excess values are $E(B - V)_0 = 0.025$ and $E(B - V)_0 = 0.023$ for A and B components respectively. The total absorption for the 2MASS magnitudes came from the equations of Fiorucci & Munari (2003):

$$A_J = 0.887\, E(B - V)$$
$$A_H = 0.565\, E(B - V)$$
$$A_{Ks} = 0.382\, E(B - V)$$

We present the results of our reddening study in Table 8.

With the corrected JHK magnitudes, the de-reddened optical magnitudes and the colors in the BVRI Johnson-Cousins photometric system were obtained. We used the color transformations presented by Bilir *et al.* (2008) in a recent work. The $(B - V)_0$ and $(R - I_C)_0$ colors are calculated as a function of $(J - H)_0$ and $(H - K_S)_0$ by the equations:

$$(B - V)_0 = 1.622\,(J - H)_0 + 0.912\,(H - K_S)_0 + 0.044$$
$$(R - I)_0 = 0.954\,(J - H)_0 + 0.593\,(H - K_S)_0 + 0.025$$

The average of the results obtained with the following formulae give us the standard V magnitude:

$$(V - J)_0 = 1.210\,(B - V)_0 + 1.295\,(R - I)_0 - 0.046$$
$$(V - H)_0 = 1.816\,(B - V)_0 + 1.035\,(R - I)_0 + 0.016$$
$$(V - K_S)_0 = 1.896\,(B - V)_0 + 1.131\,(R - I)_0 - 0.004$$

Note: the numerical values of the coefficients of the above five transformations are related with the total sample of stars studied by Bilir *et al.*, without taking into account the metallicity.

Next, the $(V - I_C)_0$ color index is derived by means of the Dough West's transformation as a function of the $(J - K_S)_0$ color index (http://members.aol.com/dwest61506/page72.html). This formula assumes an error of 0.05 mag. and is valid in the range [$-0.1 < (J - K_S) < 0.8$]:

	2MASS original data			Colour excess and total absorption							De-reddened 2MASS photometry		
Star	J	H	K_S	b	$E(B-V)_\infty$	$E(B-V)_0$	A_V	A_J	A_H	A_{Ks}	J_0	H_0	$(K_S)_0$
A	9.950	9.410	9.227	+1.875	1.076	0.025	0.079	0.022	0.014	0.010	9.928	9.396	9.217
B	10.037	9.447	9.227	+1.869	1.084	0.023	0.071	0.020	0.013	0.009	10.017	9.434	9.218

Table 8: Colour excess and total absorption for MRI 4

Star	$(B-V)_0$	$(R-I)_0$	$(V-I_C)_0$	$(J-H)_0$	$(H-K_S)_0$	$(J-K_S)_0$	V_0	B_0	$(I_C)_0$	M_{Ks}	M_V	$V-M_V$	d	SpT
A	1.070	0.638	1.210	0.532	0.178	0.710	11.994	13.063	13.204	4.419	7.199	4.745	91	K4V
B	1.186	0.709	1.351	0.583	0.216	0.798	12.308	13.494	13.660	4.679	7.769	4.539	81	K6V

Table 9: Results of the photometric study of MRI 4

$(V-I_C)_0 = 1.6032\,(J-K_S)_0 + 0.0715$

Lastly, we calculate the absolute magnitude, M_{KS}, according to the equation of Henry *et al.* (2004), which is useful for an $(V-K_S)$ applicable range of 2.24-9.27:

$M_{KS} = 0.00959\,(V-K_S)^4 - 0.23953\,(V-K_S)^3 + 2.05071\,(V-K_S)^2 - 5.9823\,(V-K_S) + 9.77683$

In a last step, the definitive photometric distances and the spectral types (spectral distribution of energy in BVIJHK bands) are derived. We have summarized the photometric results of our study in Table 9.

Because no proper motions were found in the literature, a preliminary estimation was carried out. Using old positions measured over a DSS plate (epoch 1954.747) and those from the Two Micron All Sky Survey (2MASS) (epoch 1999.737), the proper motions of the components were estimated. The DSS plate was measured using the *fv* software provided by HEARSAC. The temporal baseline between the two positions expands 44.9901 years on the whole and the results are very similar for both components. The values we have obtained are listed in Table 10. In addition, the joint shift of the two components in the expected position angle was corroborated visually by means of the blink feature provided by Aladin. According to this, if our estimation is correct, the applied characterization criteria indicates that MRI 4 has a 73% probability of being a physical pair.

MRI 3AD

This is a star of magnitude V = 12.011 that could be a new distant component for the HO 319 triple system. Its position (J2000) is RA = 03h 21m 15.04s and Dec = +45º 23' 05.5" and is separated 155" from the A component (V = 7.41). Aladin seemed to indicate the D component has a proper motion very similar to that of the main star. Fortunately, values of proper motions appear in the literature. These values are all very similar. They are also within the range of the errors (Table 11). The AD pair, as can be gathered from the other three sets of relative astrometric measurements for several epochs (along a baseline of 111.56 years) has remained stable (Table 12). This is as expected for a common proper motion pair. The system is very close to the galactic plane (A: *b* = -9.857; B: *b* = -9.883º) so the photometry of the components was corrected by reddening and extinction [A component: $E(B-V)_o = 0.115$ and Av = 0.36; D component: $E(B-V)_o = 0.108$ and Av = 0.33].

After this step, we obtained spectral types B9III and F4V for A and D components by means of the spectral distribution of energy in BVIJHK bands. In accordance with several sources in literature, the A component is a B8 star. Other more modern refer-

Source	Epoch		RA (°)	Dec (°)	μα (mas·yr^{-1})	μδ (mas·yr^{-1})	θ	ρ
DSS	1954.747	A	0.21402	60.3856819	+64	-42	0.400	21.251
		B	0.2141	60.3915847				
2MASS	1999.737	A	0.214822	60.385159	+57	-40	359.975	21.352
		B	0.214817	60.391090				
OACP	2007.6386	CCD measures					359.78	21.375

Table 10: Proper motions and relative astrometry of MRI 4

Source / Component		μα (mas·yr-1)	σ(μα) ±	μδ (mas·yr-1)	σ(μδ) ±
Tycho-2	**A**	-4.1	0.9	-1.5	0.9
	D	-4.3	3.1	-1.9	2.9
USNOB-1.0	**A**	-6	--	-2	--
	D	-6	--	-2	--
ASCC-2.5	**A**	-3.62	1.16	-1.22	0.98
	D	-4.31	3	-1.79	2.89
UCAC-2	**A**	-4.33	0.89	-2.52	0.8
	D	-5.1	0.7	-1.5	0.7

Table 11: Proper motions of MRI 3AD from the literature

ences indicate A is a B9.5 Ib-II star (Abt, 1985; Reed, 2005; Skiff, 2007), though. In any case its giant character is confirmed.

Hipparcos recorded a parallax of moderate precision for HO 319A, π= 2.29 ± 1.05 mas, placing it at a distance of about 440 parsec. Within the errors, this value is consistent with the 517.6 parsec obtained photometrically in our study. For the D component, we have found a photometric distance of about 487.5 parsecs. Judging from the distance modulus, the probability for the two stars to be at the same distance from us rises to 99%. Though not definite, our results indicate there could be a high probability of a physical relation between the new component and the main system.

MRI 2

MRI 2 was found near STT 312 (eta Dra). The main component is in position (J2000) RA = 16h 23m 30.84s and Dec = +61º 31' 37.8". The V magnitudes of the components were extracted from the NOMAD database (source Yb6, which is not yet published by USNO). They are 13.660 and 13.940 for A and B respectively. NOMAD also offers photometric data in the B and R bands (USNO-B1.0). The infrared photometry measured by 2MASS gives magnitudes A: J-H-K = 12.754-12.458-12.449 and B: J-H-K = 12.968-12.698-12.645. Nevertheless, we decided to use the same procedure carried out with MRI 4, that is, to calculate the visual photometry on the basis of the NIR photometry of 2MASS.

The same reddening [$E(B–V)_o$ = 0.019 and Av = 0.06] for the two stars was obtained. An identical spectrum F7V was derived for both stars. The luminosity classes were verified by means of JH/HK double-color diagrams as well as Reduced-Proper-Motion diagrams.

According to the procedure given by Reid & Murray (1992), the absolute visual magnitudes (M_V) were derived:

$$M_V = 0.427 + 8.121(B - V) - 1.777(B - V)^2$$

The results obtained are consistent with the theoretical value (M_V = 3.8) for an F7V spectrum found in the standard conversion tables for spectrum-magnitude. Our values are: A component, M_V = 4.17

Source	Epoch		RA HH MM SS.S	RA (°)	Dec ° ' "	Dec (°)	θ	ρ
AC2000.2	1896.0745	**A**	03 21 29.838	50.37433	+45 23 13.44	+45.380667	267.263	155.422
		D	03 21 15.102	50.31293	+45 23 05.96	+45.3849889		
ASCC-2.5	1991.25	**A**	03 21 29.80431	50.37418461	+45 23 13.40272	+45.38705631	267.177	155.467
		D	03 21 15.06522	50.31277176	+45 23 05.68673	+45.38491298		
2MASS	1999.8740	**A**	03 21 29.79336	50.374139	+45 23 13.2576	+45.387016	267.165	155.631
		D	03 21 15.03888	50.312662	+45 23 05.4996	+45.384861		
OACP	2007.6362	**CCD measures**					267.100	155.649

Table 12. Additional relative astrometry of MRI 3AD.

	2MASS original data			Colour excess and total absorption							De-reddened 2MASS photometry		
Star	J	H	K_S	b	$E(B-V)_\infty$	$E(B-V)_0$	A_V	A_J	A_H	A_{Ks}	J_0	H_0	$(K_S)_0$
A	12.754	12.458	12.449	+41.0004	0.019	0.018	0.06	0.017	0.011	0.007	12.737	12.447	12.442
B	12.968	12.698	12.645	+41.0018	0.019	0.018	0.06	0.017	0.011	0.011	12.951	12.687	12.638

Table 13: Colour excess and total absorption for MRI 2

Star	$(B-V)_0$	$(R-I)_0$	$(V-I_C)_0$	$(J-H)_0$	$(H-K_S)_0$	$(J-K_S)_0$	V_0	B_0	$(I_C)_0$	M_{Ks}	M_V	$V-M_V$	d	SpT
A	0.519	0.308	0.552	0.290	0.005	0.295	13.74	14.26	13.19	2.872	4.17	9.57	591.6	K7V
B	0.511	0.302	0.568	0.264	0.049	0.313	13.93	14.44	13.36	2.818	4.11	9.82	619.4	K7V

Table 14: Results of the photometric study of MRI 2

and B component, M_V = 4.11. These figures place both stars at practically the same distance from the Sun: 591.6 pc and 619.4 pc, in that order, for A and B components. See Tables 13 and 14 for details.

Another two pairs of theta/rho measurements were obtained by using the positions of APM and 2MASS catalogs for epochs 1954.491 and 1999.3182 (Table 15). These measurements are congruent with the one we have carried out in the OACP and show the pair has been stable during the 52 years that have passed. This fact seems to indicate the components are moving together in the space and may have a common origin.

The annual relative proper motion of the B component with regard to the primary star was calculated by means of these three sets of Theta/Rho. The result of this calculation was 6 mas·year^{-1}. In addition to this, the proper motions of both components were estimated by using the positions of 1954 and 1999 (A: $\mu\alpha$ = 16 mas·year^{-1} and $\mu\delta$ = -4 mas·year^{-1}; B: $\mu\alpha$ = 9 mas·year^{-1} and $\mu\delta$ = -0.001 mas·year^{-1}). The small motions in RA and Dec (in the same order of magnitude for both components) show they move together in the same direction and at comparable speeds. Moreover, the relative motion of this system is also consistent with these values, being within the margins of error, thus showing how good the estimation is.

Finally, the characterization criteria indicate a moderate probability of 50% of physical relation due to the small differences in the estimated proper motions. Nevertheless, other empirical criteria cause us to consider the system as physical. In order to check

Source	Epoch		RA HH MM SS.S	RA (°)	Dec ° ' "	Dec (°)	θ	ρ
APM	1954.4910	A	16 23 30.789	245.878287	+61 31 38.4	+61.527234	177.176	18.002
		B	16 23 30.913	245.878806	+61 31 20.06	+61.522239		
2MASS	1999.3182	A	16 23 30.83808	245.878492	+61 31 37.848	+61.527180	177.675	17.856
		B	16 23 30.93936	245.878914	+61 31 20.0064	+61.522224		
OACP	2007.6032	CCD measures					177.440	17.715

Table 15: Additional relative astrometry for MRI 2

the evolution of this system in the future, more measures of relative astrometry are needed.

The three new pairs are shown in Figures 4, 5 and 6.

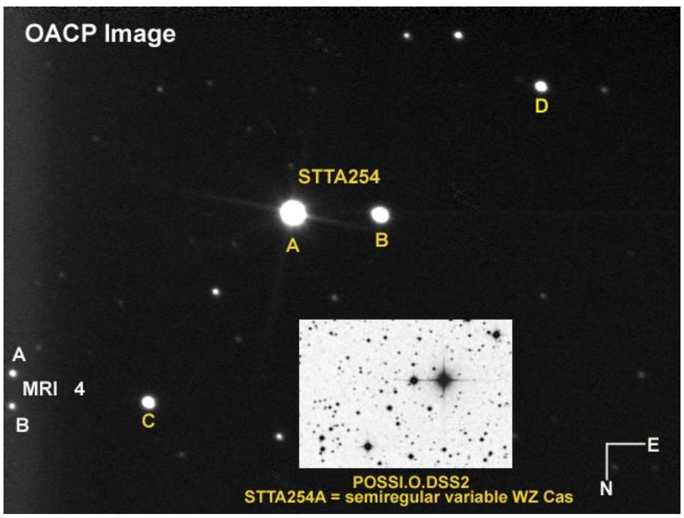

Figure 4. MRI 4. New pair in the vicinity of STTA254. As a curiosity, the superimposed diagram from a DSS plate shows the variability of STTA254A (at minimum).

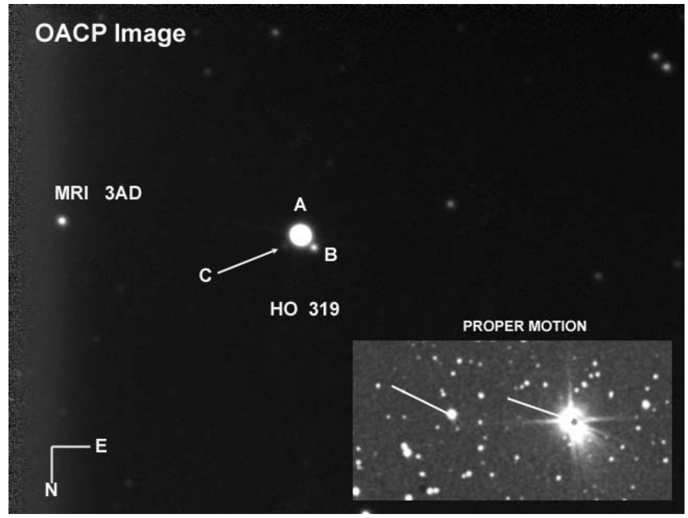

Figure 5. MRI 3AD. A new distant CPM companion for the triple system HO 319. The superimposed diagram represents the proper motion vectors for 10,000 years. Note: also, the pair located at the right top corner has been studied by us and it is optical.

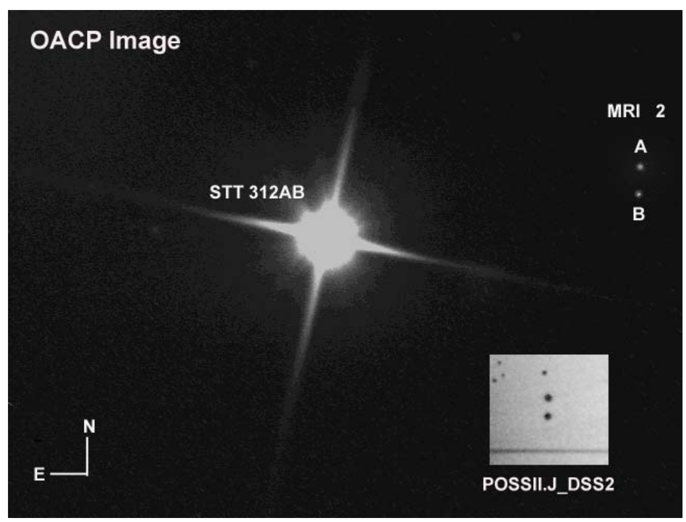

Figure 6. MRI 2. New pair located nearby of STT 321AB.

Notes

In the following, the acronyms "CPM" and "Relfix" mean Common Proper Motion and Relatively Fixed.

1. STTA254AB. In Cas. Similar proper motions. Relfix. A component (WZ Cas) is a semiregular variable type SRb, P = 186 days.
   STTA254AC: Similar proper motions. Relfix.
   STTA254AD: Incompatible proper motions. Optical pair.
   STTA254BD: Incompatible proper motions. Optical pair.
2. MRI 4. In Cas. New pair. Nearby of STTA254. See "Discoveries" and Figure 4.
3. HJ 3237. In Cep. Incompatible proper motions. Optical pair.
4. H 5 32Aa-B. In And (alpha And). A is a spectroscopic binary, P = 96.7 days. Incompatible proper motions. Optical pair. Included in the *Catalog of Rectilinear Elements*.
5. BU 254AB. In Cas. Theta: dispersion in the historical measures but the tendency is stable. Rho stable.
   BU 254AC: Theta and Rho slightly decreasing.
6. STTA 1. In Cep. Incompatible proper motions. Optical pair.
7. HJ 1008AB. In Cas. Relfix.
   ABH 2AD: Theta slightly decreasing. Rho slightly increasing.
   ABH 2AE: Only three official measures. Relfix.
   ABH 2AF: Only three official measures. Relfix.
   ES 1BC: Relfix.
8. STF 11. In Cep. CPM. Stable pair.
9. BU 392. In Cas. Relfix.
10. BU 1310AC. In And. High proper motion of A component. Theta decreasing. Rho increasing.

BU 1310AD: Theta increasing. Rho decreasing.

11. STF 38. In Cas. CPM. Calibration pair.
12. HO 623. In And. Relfix. Rho slightly decreasing.
13. BU 491AB. In And (delta And). A is a spectroscopic binary.
14. STF 46. In Psc (55 Psc). CPM.
15. STTA 5. In Cas. Incompatible proper motions. Optical pair.
16. STF 47AB. In And. CPM.
    BU 1348AC: Theta and Rho increasing.
    BU 1348BC: Theta and Rho increasing.
17. H5 18AD. In Cas. Subsystem of BU 1349 (alpha Cas). Also HJ 1993. Theta and Rho increasing. Incompatible proper motions. Optical pair.
18. STF 50. In Cas. Incompatible proper motions. Optical pair. Included in the *Catalog of Rectilinear Elements*.
19. STFA 1. In And. Optical pair. Included in the *Catalog of Rectilinear Elements*.
20. STF60AB. In Cas. (eta Cas). Orbital pair. See Table 4 for residuals.
21. STF 104. In And. Similar proper motions. Relfix. Rho slowly increasing.
22. STF 108. In And. Similar proper motions. Relfix. A is a spectroscopic binary.
23. WEI 3. In And. High CPM. Relfix. Theta and Rho slightly increasing.
24. STF 128. In Cas. Also STI 227. Theta increasing. Rho decreasing.
25. STI 228. In Cas. Only three official measures. Relfix.
26. STF 132AB. In Psc. High proper motion of A component. A is a spectroscopic binary, P = 36.6 days. Optical pair. Included in the *Catalog of Rectilinear Elements*.
    STF 132AC: Theta increasing. Rho decreasing. Optical pair.
    STF 132AD: Theta and Rho decreasing. Optical pair.
    STF 132DF: Only four official measures. Relfix.
27. STF 131AB. In Cas. Inside of M 103. CPM. Fixed.
    STF 131AC: Theta stable. Rho very slightly decreasing.
    STF 131BC: Theta increasing and Rho decreasing.
    FLE 2AD: Only three official measures. The first measure by the discoverer disagrees. Since 1996 the pair appears to be stable.
    FLE 2AE: Fixed.
28. STF 136AB. In Psc. Similar proper motions. Calibration pair. Relfix.
29. STF 180AB. In Ari (gamma Ari). CPM. A is a variable of the Alpha CVn type.
    STF 180AC: Incompatible proper motions. Optical pair.
    STF 180BC: Incompatible proper motions. Optical pair.
30. S 404AB. In And. Incompatible proper motions. Optical pair. Included in the *Catalog of Rectilinear Elements*.
    S 404BC: Only two official measures. Rho increasing.
31. STF 197AB. In Tri. Incompatible proper motions. Optical pair. Included in the *Catalog of Rectilinear Elements*.
    STF 197AC: only one official measure (1909). Confirmed. Due to de high proper motion of A component Theta and Rho increasing (6° and 10").

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Optical pair.

32. STF 205 A-BC. In And (gamma And). CPM. BC pair is the orbital system STT 38BC, not split by our instrument. Also, B is a spectroscopic binary.
33. STF 219. In tri. CPM.
34. STF 222. In And (55 And). Calibration pair. Stable.
35. STF 246. In Tri. High CPM.
36. HJ 653. In Tri. Rho increasing.
37. STTA28. In Cas. CPM.
38. HJ 1123. In Per. Inside of M34. Theta decreasing. Rho increasing.
39. STF 292. In Per. CPM. Calibration pair.
40. STI1936. In Per. Theta increasing. Rho decreasing.
41. STF 297Aa-B. In Per. Calibration pair.

STF 297Aa-C: Relfix.

STF 297BC: Relfix.

42. STI1937. In Per. Only two official measures. Relfix. In the same field of STI1936.
43. STF301. In Per. CPM. A is a long-period spectroscopic binary, P = 675 days.
44. STF 307AB. In Per (eta Per). CPM. A is a spectroscopic binary.
    STF 307AC: Relfix.
    WAL 19AF: only one official measure. Confirmed? The most probable candidate for F component is located at (J2000) 025044.71 +555435.8 (Vmag 10.82 from NOMAD). According to this, Theta has decreased 15.3º since the first measure by Wallenquist in 1944. Our Rho measure is very similar to the original one. A blink with Aladin by using DSS and 2MASS plates do not confirm this great shift of Theta. We have not consulted the catalog where the author published his measure; because of it we think that is a mistake of the discoverer or of transcription.
    WAR 1CD: Relfix.
45. STI 396AB. In Cas. Relfix.
    SIN 5AD: Only two official measures. Stable.
    SIN 5AF: Only one official measure. Confirmed. Our Rho measure is 13" smaller than the original one. Theta is stable.
    SIN 5AG: Only two official measures. Stable pair.
46. ES 558. In Per. CPM. Stable pair.
47. STF 364. In Per. CPM. Physical pair.
48. HO 319AB. In Per. Relfix.
    HO 319AC: Only one official measure (1914). Confirmed. Change in angle (decreasing): 5º. Change in distance (decreasing): 8".
    MRI 3AD: New component. See *"Discoveries"* and Figure 5. D is TYC 3311 2401.
49. STF 391. In Per. Relfix.
50. STT 55AB. In Per. Theta and Rho increasing.
    A 982BC: Difficult. Elongated shape. Our Theta measure is about 6º greater than the last official measure from 2MASS (1999)! Rho matches well.
    A 982BD: Only two official measures. Relfix.
    A 982BE: Only one official measure (1916). Confirmed. Relfix.
    A 982EF: Only one official measure (1916). Confirmed. Relfix.
51. STT 56AB. In Per. Incompatible proper motions. Optical pair. Included in *Catalog of Rectilinear Elements*.
    WAL 23AC: Only two official measures. Discrepancy between the three measures. By means of Aladin, our conclusion is that the last measure (1999) corresponds surely to a weak star (V=16.76, GSG 2.3 NCC8056318) nearby to the real C component. According UCAC-2 catalog, the proper motion of C component is pmRA = 44.1 and pmDec = -3.5 (mas). These values are incompatible with those of the primary, so the AC pair may be optical, too.
52. ES 560. In Per. CPM. Physical pair.
53. STF 464AB. In Per (zeta Per). A is a spectroscopic binary. Relfix.
    STF 464AC: Relfix.
    STF 464AD: Rho increasing.
    STF 464AE: Relfix.
    STF 464CD: Rho increasing.
    STF 464CE: Relfix.
    STF 464DE: High proper motion of D component: the stars are approaching.
    SLV 2BC: Slow approximation.
    SLV 2BD: Theta decreasing. Rho increasing.
54. STF 469. In Per. CPM.
55. STF479AB. In Tau. CPM.
    STF 479AC: Incompatible proper motions. Optical pair.
56. STF 485(*). In Cam. Inside NGC 1502. A complex multiple system with many historical errors. See WDS Notes for details. There are 28 pairs with the same WDS identifier. We reported measures for 25 pairs on the whole. The others three unreported pairs are: ES 2603AB, great Delta-M, overlapping; CHR 209Aa, too close and HZG 2JK, the K component not have been identified in our images. This pair has only two official measures. The last of them came from 2MASS (1999).

Our image of the field in Aladin does not show any possible candidate around the J star. We think the measure of 2MASS is erroneous and the K component is not identified. See image below for identification of the components (Figure 7).

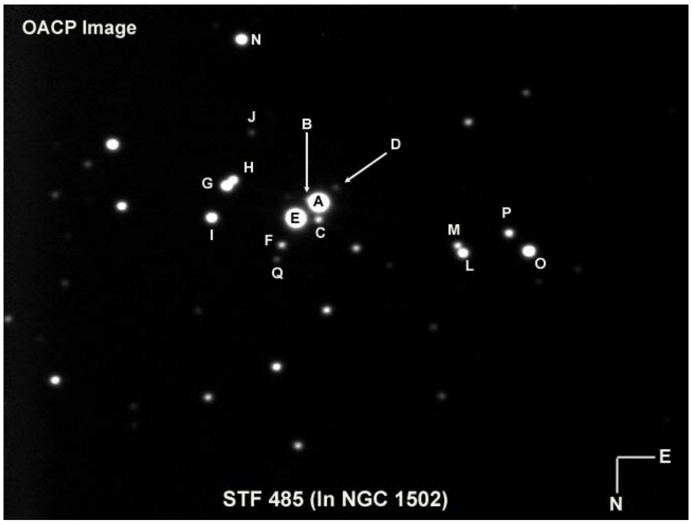

Figure 7. In this OACP image are labeled all the components of this complex multiple system. An exception: we have not found the component K in the surroundings of the J component.

The comments about our measures are the following:

STF 485AC: Relfix.
STF 485AD: Theta increasing. Rho stable.
STF 485AE: Calibration pair. Twins BOIII. Stable with slightly increasing of Theta.
STF 485AF: Relfix.
STF 484AG: Relfix.
STF 484AH: Neglected. Not measured since 1908. Rho decreasing. Theta increasing.
STF 484AI: Rho slightly decreasing. Theta slightly increasing.
STF 485AL: Only one official measure (1902). Confirmed. Rho increasing (8.5").
STF 485AO: Stable.
HZG 2AN: Relfix.
WSI 20AQ: Only three official measures. Relfix.
STF 485EC: Theta and Rho slightly increasing.
STF 485EF: Relfix.
STF 485EG: Relfix.
STF 484EH: Relfix.
STF 484EI: Relfix.
WSI 20EQ: Only three official measures. Relfix.
WSI 20FQ: Only three official measures. Relfix.
STF 484GH: Relfix.
STF 484GI: Theta slightly increasing.
STF 484HI: Theta stable. Rho decreasing. Great dispersion in the historical measures.
HZG 2IJ: Only two official measures. Stable since 1999 (measure of 2MASS).
HLM 3LM: Theta slightly increasing.
HZG 2LO: Relfix.
HZG 2OP: Relfix.

57. STF 494. In Tau. Twins A8IV. Stable.
58. STF 523AB. In Tau. Relfix.
    STF 523AC: Incompatible proper motions. Optical pair.
59. STF 534AB. In Tau (62 Tau). CPM. Calibration pair. B is the close double BAG 13Ba,Bb.
60. STF 559. In Tau. Incompatible proper motions but the system is stable.
61. STF 613AB. In Aur. Incompatible proper motions. Optical pair. Included in the *Catalog of Rectilinear Elements*.
    STF 613AC: Theta and Rho decreasing.
    STF 613BC: Relfix.
62. STT 92AB. In Aur. Orbital. See Table 4 for residuals.
63. STT 96. In Aur. Only five measures but appear to be stable.
64. STT 101. In Aur. Difficult, great Delta-M. Relfix.
65. STF 670Aa-Bb. In Tau. Difficult. Relfix.
66. STF 674. In Tau. CPM. A is the Algol-type binary CD Tau, P = 3.44 days.
67. J 1818. In Tau. Relfix.
68. STF 669. In Aur. Similar proper motions. Relfix.
69. STF 680. In Aur. CPM. WDS Note: Spectrum composite; G8II-III+G1IV-V (BSC).
70. STF 681. In Aur. The system is stable. The proper motion of B is surely erroneous. More details about this system coming soon.
71. STT 104. In Aur. Optical pair. Included in the *Catalog of Rectilinear Elements*.
72. HU 447. In Tau. Great dispersion in Theta (historical measures). Rho slowly increasing.
73. STF 718. In Aur. CPM.
    STF 718AC: Probably optical.
74. STF 738AB. In Ori (lambda Ori). CPM.
75. STF 742. In Tau. Orbital. See Table 4 for residuals.
76. STF 764. In Aur. CPM. Calibration pair. A is a spectroscopic binary.
77. BU 14. In Aur. Difficult, great Delta-M. Theta decreasing.
78. STF1694AB. In Cam. Similar proper motions.

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Relfix. B is a spectroscopic binary, spectrum A0V+A2V.
WAL 63AC: Only two official measures. Theta and Rho decreasing.

79. STF 1732AB. In UMa. CPM. B is the close double BU 1434BC.
80. STF1744AB. In UMa (Mizar). CPM.
81. STF1850. In Boo. CPM. B is a spectroscopic binary.
82. HJ 2728. In Boo (rho Boo). Theta increasing. Rho decreasing. Incompatible proper motions. Optical pair. Included in the *Catalog of Rectilinear Elements*.
83. SHJ 191. In Boo. CPM. Physical.
84. HDO 143. In UMi (epsilon UMi). A is an Algol-type system. Neglected pair (last measure 1959). Theta decreasing.
85. MRI 2. In Dra. New pair. See *"Discoveries"* and Figure 6.
86. STFA 35. In Dra (nu Dra). High CPM. Physical pair.
87. STFA 38AD. In Lyr (zeta 2 Lyr). Similar proper motions. Fixed. Physical.
    BU 968AC: Theta decreasing. Rho increasing.
    BU 968AE: Theta Decreasing. Rho slowly increasing.
88. STFA 39AB. In Lyr (beta Lyr). A is the prototype variable of its class. Relfix.
    BU 293AE: Relfix.
    BU 293AF: Relfix.
    BU 293BE: Relfix.
    BU 293BF: Theta very slowly decreasing. Rho relfix.
    BU 293EF: Only one official measure (without data for Theta). Confirmed.
89. STF2417AB. In Ser (theta Ser). Similar proper motions. Relfix.
    STF2417AC: Relfix. Surely Physical.
    STF2417BC: Relfix.
90. STT 370AB. In Aql. Similar proper motions. Calibration pair. B is the Algol-type system V342 Aql. Surely Physical.
    STT 370AC: Only two official measures. Relfix.
    STT 370BC: Only two official measures. Relfix.
91. STFA 43Aa-B. In Cyg (Albireo). Similar proper motions. Surely physical.
    WAL 114Aa-C: Only one official measure (1944). Confirmed. Theta stable. Rho increasing (15").
92. J 133AB. In Aql. Neglected pair (last measure 1959). Poor signal in our images. Rho decreasing.
    J 133AC: Theta and Rho decreasing.
    WAL 115AD: Only one official measure. Confirmed. Incompatible proper motions. Theta increasing and Rho notably decreasing. Optical pair. *Note:* B component is KUI 92BE. (E component mag 14.5). This pair has only one official measure (1934) and it is registered in the OACP's images with a bad resolution and poor signal. Hence the pair not was measured. Confirmed visually but not measured.
93. STF2558. In Aql. Relfix.
94. STF2567. In Aql. CPM. Same as STF2568. Rho decreasing.
95. STF2583AC. In Aql. The close pair AB is pi Aql. We have measured the AB-C pair. Theta decreasing. Rho increasing.
96. STF2590AB. In Aql. CPM. Relfix. A is variable of BE type.
    STF2590CD: Only one official measure (1909). Confirmed. Rho increasing. Our measure is congruent with other one derived by means of the astrometry from CMC14 (epoch 2001.4816): 271.903º and 8.348".
97. STF2593AB. In Aql. Theta increasing.
    STF2593BC: Relfix. Our Theta measure is uncertain and discordant. Rho is congruent.
98. BU 288AC. In Del. Theta and Rho decreasing.
    BU 288AD: Relfix with only three official measures.
    BU 288AE: Relfix with only three official measures.
99. STF2806Aa-B. In Cep (beta Cep). A is a close double. Rho decreasing.
100. STF2883. In Cep. CPM. Physical.
101. H 4 31AB. In Cep. Incompatible proper motions. Optical pair.
    ARN 79AC: CPM.
102. BU 702AB. In Cep (delta Cep). Prototype of the Cepheid variables P = 5.36 days. Neglected pair (last measure 1961). Great Delta-M: 7.3 in our images. Stable.
    STFA 58AC: CPM. Physical.
103. STF2924AB-C. In Cep. AB close double of high CPM and orbital. Only two official measures. Theta and Rho increasing. Optical pair.
    STF2924AB-D: Theta and Rho increasing. Optical pair.
104. BU 706AC. In Cep. Theta decreasing. Rho increasing.
105. STF2923AB. In Cep. CPM. Relfix.
    STF2923AC: Only two official measures. Relfix.
106. BU 845AB. In Cep. Theta and Rho increasing.

BU 845AC: Theta and Rho increasing.
FOX 269AD: Only two official measures. Rho decreasing.

107. STT 529AB. In Cep. A is the Algol-type system ZZ Cep. Incompatible proper motions. Optical pair.
STT 529AC: CPM. Fixed.
108. STF2985. In And. Calibration pair. B is a BY Dra-type variable, and a double-lined spectroscopic binary, P = 3.03 days. Physical.
109. STF2987. In And. High CPM. Difficult, great Delta-M. Physical.
110. HJ 1858. In Peg. Incompatible proper motions. Optical pair. Included in the *Catalog of Rectilinear Elements*.
111. HJ 1859. In Peg. Relfix.
ARN 26AC: Relfix but incompatible proper motions. Optical pair. A curious case: two systems have been merged. The C component of ARN 26 is the A component of HJ 1858 which is located in the vicinity of HJ 1859. See image below (Figure 8).

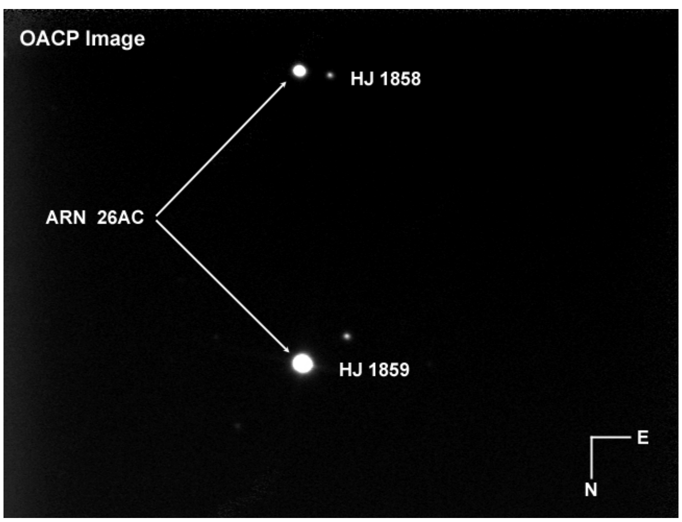

Figure 8. Merged systems: the C component of ARN 26 is the A component of HJ 1858

112. FOX 273AD. In And. Subsystem of BU 717 (8 And). Only two official measures. Theta stable. Rho increasing.
113. STF3037AC. In Cas. Because de AB pair in not split by our instrument the measure reported correspond to AB-C. Similar proper motions. Relfix.
STF3037AD: Theta increasing. Rho slowly increasing.
STF3037AE: Relfix.
STF3037AF: Theta slowly increasing. Rho slowly decreasing.
114. STI1222. In Cas CPM. Fixed.
115. BU 1153AB-C. In Cas. In the same field of STT511. The A component is a close double. Theta fastly decreasing.
BU 1153AD. D component is the A component of STT 511. Fixed.
116. STT 511AB. In Cas. Relfix.
STT 511AC. Only two official measures. Fixed.
STT 511AD: Only five official measures. Relfix.

Conclusions

The results obtained in this first series of Theta/Rho measurements show that the equipment and the techniques used are suitable for this task. We have verified that our measurements match very well with those from 2MASS (1999) as well as those of Tycho-2 (1991) (logically in the case of pairs fixed or relfix). This fact is a clear indication of the reliability of our procedure.

We have confirmed the existence of 12 pairs that previously had only the discovery measurement. In addition, we have reported measures for 16 pairs with two official measures and for others nine pairs with three official measures, which will serve to check the tendency of the components. Also, a number of neglected pairs have been included.

Acknowledgements

This research has made use of the Washington Double Star Catalog (WDS), the *Catalog of Rectilinear Elements*, the *Sixth Catalog of Orbits of Visual Binary Stars*, the USNO-B1.0 and the UCAC2 maintained at the U.S. Naval Observatory.

This research has made use of The Naval Observatory Merged Astrometric Dataset (NOMAD) at http://www.nofs.navy.mil/nomad/. NOMAD is a simple merge of data from the Hipparcos, Tycho-2, UCAC-2 and USNO-B1 catalogs, supplemented by photometric information from the 2MASS final release point source catalog. The primary aim of NOMAD is to help users retrieve the best currently available astrometric data for any star in the sky by providing these data in one place.

This research has made use of The APM-North Catalog. http://www.ast.cam.ac.uk/~apmcat/.

This research has made use of the All-sky Compiled Catalog of 2.5 million stars (ASCC-2.5, 2nd version) at http://webviz.u-strasbg.fr/viz-bin/VizieR?-source=I/280A.

This research has made use of the AC 2000.2: The Astrographic Catalogue on The Hipparcos System. Catalogue of Positions Derived from the Astrographic Catalogue Measures. Positions are from the Hipparcos System (HCRS, J2000.0) at the Mean Epochs of Observation. (http://webviz.u-strasbg.fr/viz-bin/VizieR?-source=I/275).

This research has made use of the Carlsberg Meridian Catalog 14 (CMC14) (http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=I/304).

This research has made use of the Astrophysics Data System (ADS) in order to consult several professional works. Web Site: http://adswww.harvard.edu/index.html

This research has made use of data products from the Two Micron All Sky Survey (2MASS), which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

This research has made use of DSS. The Digitized Sky Survey was produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present compressed digital form with the permission of these institutions.

This research has made use of Aladin, an interactive software sky atlas allowing the user to visualize digitized images of any part of the sky, to superimpose entries from astronomical catalogs or personal user data files, and to interactively access related data and information from the *SIMBAD*, *NED*, *VizieR*, or other archives for all known objects in the field. Aladin is particularly useful for multi-spectral cross-identifications of astronomical sources, observation preparation and quality control of new data sets (by comparison with standard catalogues covering the same region of sky). Available at http://aladin.u-strasbg.fr/

This research has made use of the *fv* software, a tool for viewing and editing any FITS format image or table. It is provided by the High Energy Astrophysics Science Archive Research Center (HEARSAC) at NASA/GSFC. The package is available in: http://heasarc.gsfc.nasa.gov/docs/software/ftools/fv/

This research has made use of Guide 8.0 astronomical software of Project Pluto. Internet site: http://www.projectpluto.com/

This research has made use of *Astrometrica*, an interactive software tool for scientific grade astrometric data reduction of CCD images. The author: Herbert Raab. Internet site: http.//www.astrometrica.at/

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Measurement of Neglected Double Stars with a Mintron Video Camera

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Abstract: This report contains the theta/rho measurements from 60 neglected double stars systems. For this I used a 28-cm Schmidt-Cassegrain telescope and a Mintron video camera. To use this camera for astronomical intentions first it was necessary to adapt the software to the special size of his detector.

At the beginning of 2007 I decided to do a specific program of doubles that needed updates. To do this, I downloaded the latest version of the Washington Double Star catalog (WDS) and filtered it to show systems with an angular separation greater than 1" and less than 15", that had not been measured since 1991; that is, they had been studied neither by the Hipparcos mission nor by Tycho. A little over fourteen thousand entries were selected; that would be my new observational program.

I used an f/10 Schmidt-Cassegrain telescope with a 28 cm aperture and a Mintron video camera. The video camera uses a Sony ICX249AL monochrome (black-and-white) sensor, and is very sensitive. The maximum exposure time was 2.56 seconds, though depending on the magnitude of each system, shorter exposure times were sometimes used. A video capture (frame grabber) card was used with the camera to produce 768 x 576 pixel still images. Unfortunately, this combination of the 795 x 596 pixel sensor and the 768 x 576 pixel frame - grabber produces a rescaled image This rescaling must be corrected for using post processing in order for measurements to be correct.

The capture of images was first produced at the primary focus, which yielded a resolution of 0.65 as/pixel. Also, in most of the cases, images were taken with a 2X Barlow. This configuration resulted in a focal length of 5870mm at a resolution of .30 arc-seconds/pixel.

For the reduction of information I primarily used *Astrometrica* version 4.4. With this program, using the UCAC2 catalog when possible, I calculated the absolute astrometry of each star. Later, the program *Dobles*, developed by Julio Castellano, calculated theta and rho depending on the absolute astrometry. In addition, *Astrometrica* also calculated the resolution per pixel and the orientation of the image, both necessary in order to perform measurements with the Reduc software. Due to the fact that there were not always sufficient stars to refer to, not all the systems were measured using this method. In these cases, *Reduc* turned out to be a fundamental tool. However, when possible, every system was measured using both types of software. I want to express my gratitude for the work Florent Losse carried out to make *Reduc* work despite the re-scaling previously mentioned.

Description of the Table

When the magnitude appears with two decimals, it is extracted from catalogs, principally from the Tycho-2 Catalog, although I have also used Nomad Catalog, and on occasions I have transformed the aerial map-making of the photometry of the US-NOB1.0 to magnitude V. The others, included only for orientation, are calculated by *Astrometrica* according to the images measured on the basis of the USNOA2.0 catalog in R band without any filter.

The number of the Tycho catalog or GSC is given, as well as the coordinates in J2000.0 epoch, calculated with *Astrometrica* for the main star.

The spectral classes were calculated primarily on the basis of JHK photometry of the 2MASS catalog, according to a routine developed by Francisco M. Rica. In many cases, the spectrum is given depending on whether the stars are presumed to be giants or on the main sequence.

All the systems were observed on one single night.

Acknowledgments

I thank Florent Losse for his work on the *Reduc* software. Thanks also to Francisco M. Rica Romero for his help. I also want to thank Juan Luis González Carballo for his help in the translation of this article and his constant encouragement.

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www.projectpluto.com

http://webviz.u-strasbg.fr/viz-bin/VizieR

WDS	Designa-tion	Mag A	Mag B	Tycho/GSC A	Tycho/GSC B	PA	Sep	Epoch	Coordinates	Notes
00016+3714	ALI 472	12.2	12.2	2271 1913		249.6	9.04	2007.764	00 01 37.01 +37 14 40.7	1
00118+3608	BU 1340	10.22	13.5	2272 1536 1		232.7	5.06	2007.764	00 11 56.47 +36 08 54.8	2
00139+6023	STI 25	13.0	13.9	4014 1173		218.8	3.42	2007.737	00 13 54.73 +60 23 19.3	
00156+5910	STI1308	11.41	12.9	3665 326 1		223.6	3.41	2007.737	00 15 40.13 +59 10 15.6	3
00163+1537	J 1321	11.02		1179 1731 1		105.8	2.63	2007.795		4
00214+6135	ES 1937	9.90	16	4015 32 1		314.0	5.52	2007.737	00 21 21.43 +61 33 30.1	5
00248+6114	STI 53	13.0	12.9	4015 1342		119.5	6.07	2007.737	00 24 50.19 +61 14 25.3	6
00530+6358	STI 135	11.00	14.8	4025 1466 1		162.0	4.13	2007.740	00 53 00.32 +63 57 33.2	7
00581+3944	MLB 972	13.3	14.5	2802 1074		286.2	5.41	2007.732	00 58 03.05 +39 44 55.4	8
01013+3704	TDS1720	11.55	11.63	2289 342 1		244.9	2.48	2007.732		9
01024+3958	MLB 811	12.52	13.3	2803 1842		202.1	7.18	2007.732		10
01040+6325	STI 170	11.87	13.9	4021 989 1		184.9	7.72	2007.740	01 03 56.32 +63 25 17.5	11
01051+3814	J 1804	11.06	12.8	2799 1018 1		309.7	5.22	2007.732	01 05 05.95 +38 14 27.4	12
01076+2354	POU 102AB	11.85		1747 648		110.8	4.37	2007.833		13
01185+4018	MLB 736	12.95	14.2	2804 1875		65.6	8.10	2007.923	01 18 31.28 +40 17 46.0	14
01248+6222	STI 211	12.2	12.24		4034 1444 1	279.0	13.13	2007.740	01 24 42.15 +62 22 27.4	15
01254+3938	MLB 812AB	12.64	13	2817 1107		237.5	5.34	2007.923	01 25 25.29 +39 37 37.9	16
01270+3742	ES 2449	11.74	13	2813 1132		186.1	6.56	2007.923	01 27 02.72 +37 43 06.7	17
01288+6318	MLB 328	11.94	13.5	4035 785 1		109.0	2.94	2007.740	01 28 48.08 +63 18 22.6	18
01295+6317	MLB 329AB	11.46	12.5	4035 571		347.1	3.10	2007.740	01 29 23.04 +63 16 58.8	
02045+3137	SEI 23	12.78	13.15	2308 151 1		255.8	28.08	2007.765	02 04 40.50 +31 38 09.9	19
02115+3102	MLB1034	10.80	13.7	2309 1093 1		285.2	11.56	2007.765	02 11 28.98 +31 02 37.7	20

Table continued on next page.

Measurement of Neglected Double Stars with a Mintron Video Camera

WDS	Designa-tion	Mag A	Mag B	Tycho/GSC A	Tycho/GSC B	PA	Sep	Epoch	Coordinates	Notes
02157+2957	MLB 738	11.56	13.8	1777 447 1		274.1	8.83	2007.765	02 15 40.91 +29 57 00.0	21
02160+2940	MLB 740	11.71	14.0	1777 1458 1		338.3	6.39	2007.765	02 16 01.65 +29 40 06.7	22
02160+3044	MLB 739	11.58	13.1	2310 1354 1		129.7	15.36	2007.765	02 16 01.64 +30 44 06.6	23
03068+3918	MLB 818	12.70	14.5	2847 450		328.6	6.71	2007.926	03 06 47.24 +39 18 37.1	24
03074+4004	MLB1027	11.63	14.5	2851 534		14.0	7.35	2007.926	03 07 21.98 +40 04 45.0	25
03084+4020	BRT2204	12.07		2851 1928		190.5	3.86	2007.926	03 08 22.83 +40 19 53.8	26
03381+2503	POU 299	11.88		1803 226		69.8	6.72	2007.937	03 38 03.17 +25 02 27.7	27
03482+2235	LOH 1	10.97	12.49	1800 2103		131.8	9.33	2007.937	03 48 08.10 +22 33 31.9	28
03562+2415	POU 323	12.3	13.2	1813 35		346.7	4.41	2007.803	03 56 11.29 +24 14 22.6	29
03570+2359	POU 326	13.0	13.3	1813 309		153.6	5.73	2007.803	03 57 00.43 +23 59 10.8	30
03579+2322	POU 333	13.13	14.6	1813 871		230.2	3.99	2007.803	03 57 59.31 +23 22 09.2	31
04015+2443	POU 345	12.74	13.26	1817 527	1817 497	214.4	14.48	2007.929	04 01 33.14 +24 42 26.9	32
04019+2358	POU 350	13.96	14.6	1813 173	1813 220	31.8	3.86	2007.929	04 01 53.69 +23 57 50.3	33
05350+3648	SEI 338		12.39	2416 1034	2416 1111	62.5	7.07	2007.943	05 34 59.04 +36 47 39.9	34
05464+3659	MLB 824	13.08	14.44	2417 1102		15.8	9.29	2007.937	05 46 27.21 +36 59 25.6	35
05468+3606	COU1730	11.53		2417 771		174.6	1.84	2007.937		36
05468+3658	MLB 825	11.64	13.6	2417 726		97.6	6.16	2007.937	05 46 45.50 +36 57 46.0	37
18463+3745	ES 2484	13.1	12.7			332.4	6.65	2007.663	18 46 17.10 +37 45 40.9	38
18466+3853	ES 2021AB	11.22	12.6	3118 1777 1		253.94	20.49	2007.663	18 46 37.26 +38 52 24.2	39
18466+3853	ES 2021BC	12.7	13.8	3118 1743		297.9	3.66	2007.663	18 46 35.58 +38 52 18.6	40
18477+4159	ES 1560	10.46	12.9	3126 1088 1		346	9.88	2007.663	18 47 03.01 +41 55 24.1	41
18484+3612	ES 2023	8.64	12.5	2650 1010		244.4	6.17	2007.663	18 48 24.10 +36 11 41.9	
18546+3656	ELS 7AB	13.0	13.1			338.9	8.51	2007.663	18 54 37.56 +36 55 48.5	
18546+3656	ELS 7AC	13.0	15.5			120.1	10.09	2007.663	18 54 37.56 +36 55 48.5	
20212+3304	MLB 772	12.71	14.17	2676 865		133.3	8.32	2007.671	20 21 12.00 +33 04 06.7	42
20242+3456	POP 94	11.81		2693 994 1		150.4	2.69	2007.671	20 24 12.18 +34 56 58.4	
20243+3507	POP 80	12.6	13.8	2693 702		328.3	2.81	2007.671	20 24 16.37 +35 08 08.0	43
21285+3636	ALI 443	11.40	13.0	2716 1139		298.1	4.27	2007.642	21 28 31.74 +36 36 29.0	44
21296+3625	ES 258AB	10.84	11.08	2716 2656 1	2716 1017 1	33.7	10.94	2007.643	21 29 35.76 +36 26 09.0	45
21296+3625	ES 258BC	11.08	12.3	2716 1017 1		9.7	18.44	2007.643	21 29 36.26 +36 26 18.0	46

Table continued on next page.

Measurement of Neglected Double Stars with a Mintron Video Camera

WDS	Desig-nation	Mag A	Mag B	Tycho/GSC A	Tycho/GSC B	PA	Sep	Epoch	Coordinates	Notes
21400+3605	ES 2129	12	11.60	2729 1268		311.2	5.14	2007.643	21 40 18.97 +36 02 53.5	47
21407+3612	ES 2130	12.5	13.5	2729 1208		120	3.17	2007.643	21 40 42.99 +36 12 48.3	48
22156+3811	ES 2530	11.09	12.1	3199 364 1		304.7	5.22	2007.732	22 15 34.15 +38 10 58.7	49
22178+3857	MLB 795	11.48	13.1	3199 629		81.1	6.72	2007.732	22 17 46.89 +38 57 07.5	50
22189+3807	ALI 701	11.6	11.27	3199 1581	3199 2167 1	13.7	14.13	2007.732	22 18 48.57 +38 06 51.2	51
23298+2451	POU5816	12.59		2250 154		209.9	3.22	2007.923		52
23358+2432	POU5828	13.42	13.79	2250 824	2250 560	55.3	11.02	2007.828	23 35 46.07 +24 32 27.8	53
23583+0132	BVD 10	12.29	12.40	587 699		249.5	7.58	2007.836	23 58 20.43 +01 32 07.0	54

Table Notes

1. Spect. G7 V/G1 III and A7 V. Different proper motion of each component. Optical double star.
2. A-component Spect. F7 V.
3. A-component Spect. F1 V.
4. Only measured with Reduc. Primary, with F7 V Spect., has proper motion in RA: 40.3 mas/yr and in Dec: -43.3 mas/yr. Practically without movement in all the 20th century, so they must have some physical relation.
5. Spect. G5 V and G1 V/F9 III. Small proper motions.
6. Spect. A6 V and G6 V. I see slightly bright the B component.
7. Spect. A9 V and F4 V. Sep. increasing.
8. Spect. F9 V and G3 V.
9. Only measured with Reduc. A-component Spect. K3 V/ K0 III and it has a proper motion in RA: -10.9 mas/yr and in DEC: -21.7 mas/yr.
10. A-component have Spect. M4 III and it has a proper motion in RA: 21.8 mas/yr and in Dec: 2.7 mas/yr. B component is F9 V. Sep. increasing.
11. Very similar Spect., both G7 V/G1 III. Sep. decreasing.
12. A-component's Spect. G1 V/ F9 III and it has a proper motion in RA: -20.6 mas/yr and in Dec: -13.4 mas/yr. B component's Spect. G9 V/ G3 III.
13. Only measured with Reduc. A-component's Spect. K1 V/G5 III and it has a proper motion in RA: 0.0 mas/yr and in Dec: -9.5 mas/yr.
14. Spect.: A-component K3 V / G9 III and B component G5 V/ F9 III.
15. Spect. F3 V and F1 V. In this case Theta should have an inverse character, B component must be brighter.
16. Red stars, Spect. M4 III and K2 V/G9 III respectively.
17. Optical system. Spect. G6 V and F8 V respectively.
18. A-component has the next proper motion: -8.8 mas/yr and in Dec: -5.4 mas/yr.
19. Evident optical system. In UCAC2 catalogue proper motion of A-component in RA is -11.4 mas/yr and in Dec -7.8 mas/yr. B component has proper motion in RA -3.1 mas/yr and in Dec -3.8 mas/yr. Spect. F9 V/ F8 III and G7 V/G0 III respectively.
20. Optical couple, they split each other. A-component has a proper motion in RA 21.2 mas/yr and in Dec -7.9 mas/yr. Spect. K4 V/ K1 III and G1 V/F8 III respectively.
21. Optical double star. A-component has a proper motion in RA 26.6 mas/yr and in Dec -34.9 mas/yr. Spect. G5 V/ F9 III and K1 V/ G4 III respectively.
22. Spect. F6 V and G6 V.

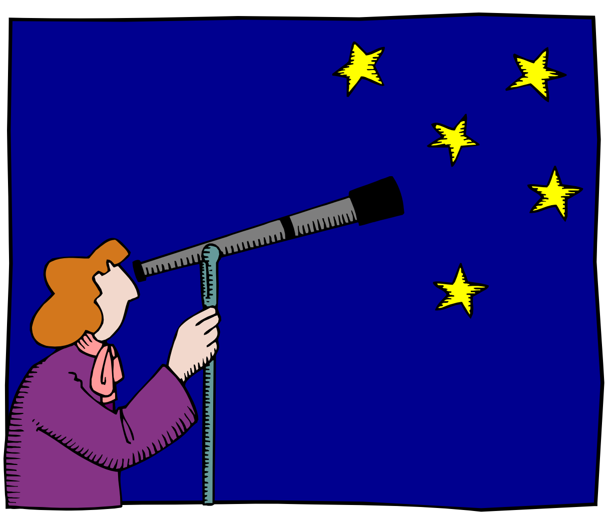
Measurement of Neglected Double Stars with a Mintron Video Camera

23. Optical pair, the split each other quickly. A-component has a proper motion in RA 14.4 mas/yr and in Dec -0.3 mas/y and Spect. F3 V. Deducing: B component, a red star (Spect. M3 V/ K4 III), presents a bigger proper motion.
24. Spect. G5 V/ F9 III and G0 V /F8 III.
25. Spect. K3 V/ K0 III and F6 V.
26. Spect. F9 V and F8 V.
27. Similar Spect.: G7 V / G1 III.
28. Proper motions according to the UCAC2 catalogue: A-component in RA: -33.6 mas/yr and in Dec: -18.4 mas/yr, and B: in RA: -35.1 mas/yr and in Dec: -19.9 mas/yr. Common proper motion stars. Spect. F7 V and G6 V.
29. Proper motion of A-component according UCAC2: RA: 11.7 mas/yr and Dec: -63.1 mas/yr. Spect.: G9 V/ G2 III and K1 V/ G5 III.
30. Spect.: G8 V/ G2 III and K1 V/ G5 III.
31. Proper motion of A-component according to UCAC2: RA 32.7 mas/yr and Dec: 24.5 mas/yr. Spect.: G5 V/ F9 III and K0 V/ G3 III.
32. Optical pair, probably. Spect.: G7 V/ G1 III and K6 V/ K2 III.
33. Spect.: F8 V and G3 V. Insignificant proper motions.
34. Spect.: F6 V and F4 V. Different proper motions. Optical pair.
35. Spect.: F6 V and M0 V/ K4 III.
36. According to Tycho-2, proper motion of A-component: RA: -20.1 mas/yr and Dec: -67.8 mas/yr. Spect.: K0 V. Physical system.
37. The A-component has the next proper motion: RA: 6.8 mas/yr and en Dec: -10.6 mas/yr. Spect.: G3 V/ F9 III.
38. AP should be invert. According Nomad Catalog the proper motion of B component is: RA: -45.8 mas/yr and Dec: 85.1 mas/yr.; Spect.: G9 V/ G2 III. A-component Spect.: G0 V/ F8 III.
39. Proper motions very different, optical double star. Spect.: F6 V and F9 V.
40. According to UCAC2 catalogue, proper motion of A-component is 32.4 mas/yr and Dec: -2.7 mas/yr, Spect. F9 V.
41. Main component Spect.: K9 V with the next proper motion: RA 1.2 mas/yr and Dec: -11.3 (Tycho 2). B component Spect.: G5 V/ G0 III.
42. A-component Spect.: G4 V/ F9 III and has the next proper motion: RA: -4.5 mas/yr and Dec: -6.1 mas/yr. B component Spect.: K1 V/G5 III.
43. A-component has proper motion: RA: -0.2 mas/yr and Dec: -9.2 mas/yr.
44. Spect.: K1 III and F3 V respectively. A-component proper motion: RA 51.1 mas/yr and Dec: -32.8 mas/yr. The B component should have the same p.m. Probably physical system.
45. Spect.: F1 V and K0 V. Optical couple.
46. Proper motion of A-component: RA: -36.0 mas/yr and Dec: -157.3 mas/yr. Proper motion of B component: RA: 5.1 mas/yr and en Dec: 87.4 mas/yr. Optical double star with high displacement. Spect.: K0 V and G3 V respectively.
47. AP should be invert. Spect.: K and K5 III. Proper motion of B component: RA: 3.6 mas/yr and Dec: 12 mas/yr.
48. Proper motion: RA: 20.8 mas/yr and Dec: 1.2 mas/yr.
49. Spect.: F3 V and G5 V. Proper motion of A-component: RA: 9.7 mas/yr and Dec: -10.3 mas/yr.
50. Spect.: F7 V and G2 V. A-component has the next p.m.: RA: -10.2 mas/yr and Dec: -1.2 mas/yr.
51. Different proper motions, optical double star. A-component = RA: 4.5 mas/yr and Dec: -1.7 mas/yr. B-component: RA: 9.6 mas/yr and en Dec: -5.7 mas/yr. AP should be invert.
52. A-component Spect. K has proper motion: RA: 20.4 mas/yr and Dec: 29.1 mas/yr.

Measurement of Neglected Double Stars with a Mintron Video Camera

53. Optical pair. A-component Spect. G and has p.m.: RA: -8.2 mas/yr and Dec: -31.1 mas/yr. B component has Spect.: K.
54. Not cataloged in WDS. Spect. G6 V (both). Possibility that it's a physical system.

The author is an active observer of double stars, comets and asteroids who is working from home in Spain. He is also a member of the LIADA's Double Star Section.



Double Star Measures Using a DSLR Camera #2

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Abstract: This article contains measures made with a DSLR camera. The images used for the measures were taken in the period between 2007.249—2007.268. The result is 190 positive and 3 negative measures.

Continuing the measures of my photos taken in 2007, the next results to come are from the measuring period between 1 Apr – 8 Apr 2007. The photographic equipment used and the processing and measuring methods are the same as those detailed in my previous article (Berko, 2008). Therefore, I would only like to note that I was working with a Canon 350D digital camera with a 35.5 cm Newtonian telescope at a focal length of 4200 mm. The pictures were measured with Florent Losse's program (Reduc 3.62). I used approximately 1424 photos for the present publication. My results include the data of 2022 independent measures of 193 pairs.

A table contains the results of the measures, followed by the notes. In the first three columns of the table, the WDS coordinates and names of the doubles as well as the components' brightness can be found. I determined the brightness of the components on the basis of WDS, although it seems contradictory sometimes. When there is an Anon. component, I gave the GSC or USNO "R" brightness or, if not available, I provided the brightness I estimated on the basis of the photo.

This is followed by the position angle (PA) and the separation (Sep) measured and calculated by me. In both cases, the value of the standard deviation is also indicated (+/-).The column (epoch) gives the times the images were taken. Finally, in every row, the number of individual measures (n.), the reference number to the description (notes), and the reference number of the image belonging to the measures (img) can be seen.

In the descriptions (notes), is found the GSC number of the primary star of those doubles I measured; in case it appears in the GSC catalogue. Also, my personal notes about the given double starts can be read here. One problem encountered was the 10-character identification coordinates of WDS. In many cases it is different from the real position of the double. Although WDS contains more precise coordinates for most of the pairs, at times the double cannot be found at these locations. For the doubles measured by me, I give suggestions regarding these closest coordinates in the form of (xxxxx+xxxx!).

I have also attached images of some of the doubles I measured, with captions provided. The complete image archive of the article and the table referring to the photos can be accessed at http://csillag.bacska.hu/dcam/JDSO/2009_1/.

Acknowledgements

I would especially like to thank Ágnes Kiricsi, who has helped a lot in this publication with the English translations and the correspondence.

References

Berko, Erno, "Double Star Measures Using a DSLR Camera", *JDSO*, **4**, 144-155, 2008.

Double Star Measures Using a DSLR Camera #2

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Image
05136+3542	DOO 32	8.36	12.17	173.67	0.05	22.05	0.02	2007.249	12	1	1
05175+3630	SEI 153	11.0	11.0	54.76	0.12	27.9	0.04	2007.249	12	2	
05176+3629	SEI 157	10.0	11.0	320.85	0.26	7.38	0.05	2007.249	12	3	
05177+3628	Anon. 1	13.0	13.5	105.86	0.13	8.68	0.1	2007.249	4	4	
05182+3602	SEI 166	11.46	12.13	156.47	0.09	27.94	0.05	2007.249	15	5	
05187+3624	SEI 175	11.0	11.0	91.63	0.11	27.23	0.06	2007.249	10	6	
05189+3612	SEI 178	8.3	11.7	199.34	0.2	25.59	0.04	2007.249	10	7	
05192+3549	Anon. 2	12.0	12.5	334.11	0.34	6.25	0.05	2007.249	12	8	
05192+3548	SEI 179	9.20	9.2	222.49	0.11	24.74	0.05	2007.249	11	9	
05194+3550	Anon. 3	11.9	13.0	233.85	0.27	12.68	0.06	2007.249	10	10	
05198+3546	SEI 191	10.3	12.0	65.79	0.11	22.73	0.06	2007.249	5	11	
05199+3624	SEI 192	10.5	11.0	145.04	0.24	28.4	0.09	2007.249	5	12	
05199+3545	Anon. 4	12.7	13.1	143.54	0.37	8.89	0.05	2007.249	7	13	
05210+3620	SEI 204	10.4	10.8	65.91	0.13	14.77	0.05	2007.249	12	14	
05219+3416	TOB 29	11.8	11.9	226.42	0.17	18.65	0.05	2007.249	12	15	
05375+3147	WZ 10	9.75	11.04	255.66	0.27	9.45	0.03	2007.254	11	16	2
05380+3145	SEI 359	10.5	11.0	42.87	0.18	17.3	0.06	2007.254	15	17	
05387+3229	ARA2323	8.02	10.80	260.59	0.15	51.68	0.07	2007.254	11	18	
05391+3239	SEI 365	10.71	10.88	322.45	0.12	30.58	0.04	2007.254	14	19	
05401+3722	Anon. 5	12.8	13.6	120.56	0.34	9.74	0.06	2007.268	10	20	
05403+3721	SEI 366 AB	10.5	11.0	228.27	0.14	28.38	0.08	2007.268	16	21	
05403+3721	Anon. 6 Ax	10.5	14.0	71.38	0.28	6.9	0.06	2007.268	5	21	
05406+3544	SEI 368	10.4	12.1	284.61	0.38	16.52	0.06	2007.268	10	22	
05409+3734	SEI 369	11.8	12.3	69.43	0.37	5.75	0.07	2007.268	11	23	
05413+2929	STF 764	6.38	7.08	13.93	0.11	26.04	0.05	2007.254	18	24	
05414+3223	SEI 372	11.90	11.73	112.47	0.21	15.18	0.05	2007.254	13	25	
05418+3727	SEI 373	11.3	11.6	179.48	0.15	5.28	0.06	2007.268	12	26	
05421+3245	HJ 369	10.5	12.0	326.37	0.32	15.44	0.06	2007.254	13	27	2
05423+3247	HJ 370	11.08	11.74	258.95	0.19	12.88	0.05	2007.254	14	28	2
05427+3735	SEI 379	11.0	11.0	46.95	0.14	24.16	0.05	2007.268	16	29	
05428+3322	STF 773 AB	9.2	10.7	219.47	0.06	27.17	0.02	2007.254	10	30	
05428+3322	STF 773 AC	9.2	12.4	256.39	0.31	18.83	0.07	2007.254	7	30	
05430+3319	HO 509	6.8	11.8	203.78	0.65	8.22	0.06	2007.254	3	31	
05434+3334	SEI 380	8.8	11.3	51.99	0.21	28.92	0.07	2007.254	10	32	
05446+3234	SEI 381	10.5	11.0	53.6	0.08	28.05	0.05	2007.268	20	33	
05450+3618	SEI 382	11.0	11.0	134.25	0.35	7.03	0.03	2007.268	17	34	
05453+3224	STF 781	9.23	10.4	121.38	0.16	15.23	0.07	2007.268	13	35	
05458+3149	Anon. 7 AB	13.2	13.3	258.88	0.31	14.91	0.06	2007.254	8	36	
05458+3149	Anon. 7 BC	13.3	13.3	317.84	0.44	5.23	0.05	2007.254	6	37	

Table continued on next page.

Double Star Measures Using a DSLR Camera #2

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Image
05459+3726	SEI 383	8.95	12.29	241.32	0.18	24.83	0.06	2007.268	17	38	
05460+3717	BLL 16	7.36	11.0	89.82	0.11	72.24	0.04	2007.268	6	39	4
05463+3152	SEI 384	10.0	10.7	354.42	0.28	13.92	0.06	2007.254	12	40	
05464+3659	MLB 824	10.0	11.0	14.68	0.23	9.15	0.06	2007.268	13	41	
05467+3153	Anon. 8	11.2	12.0	317.71	0.16	16.51	0.05	2007.254	11	42	
05468+3700	ALI 309	11.7	11.8	338.71	0.25	6.7	0.02	2007.268	16	43	
05468+3658	MLB 825	11.69	11.8	97.31	0.25	5.63	0.1	2007.268	8	44	
05476+2155	Anon. 9	13.2	13.5	224.37	0.39	5.36	0.06	2007.263	9	45	
05476+2155	Anon.10	14.0	14.2	103.73		3.21		2007.263	1	46	
05477+2157	SLE 280	10.8	11.9	231.4	0.15	11.85	0.06	2007.263	14	47	
05478+2156	Anon.11	13.5	14.1	157.31	0.28	10.49	0.07	2007.263	10	48	
05496+3128	Anon.12	10.5	11.5	154.64	0.42	9.12	0.07	2007.254	11	49	
05497+3146	SEI 390 AB	9.0	9.8	224.25	0.31	5.52	0.06	2007.254	14	50	
05497+3146	SEI 391 AC	9.0	10.2	140.56	0.08	27.53	0.04	2007.254	18	50	
05498+3258	S 500	8.57	8.85	90.26	0.05	60.18	0.05	2007.254	13	51	
05498+3127	SEI 392	9.2	10.5	308.19	0.27	8.77	0.06	2007.254	13	52	
05499+3147	STF 796 AB	7.24	8.23					2007.254		53	
05499+3147	STF 796 AC	7.24	10.20	324.91	0.07	209.93	0.06	2007.254	9	54	
05501+3258	Anon.13	11.5	12.0	202.64		4.12		2007.254	1	55	
05514+3306	SEI 395	10.20	11.16	167.48	0.24	19.09	0.05	2007.254	10	56	
05518+2827	STF 805	8.41	8.87	49.41	0.13	12.13	0.06	2007.268	16	57	
05520+3750	SEI 397	8.1	10.6	120.24	0.04	9.29	0.07	2007.268	2	58	5
05520+3137	SEI 400 AB	11.24	11.86	10.66	0.17	12.81	0.02	2007.254	15	59	
05520+3137	SEI 400 AC	11.24	12.16	30.17	0.07	29.48	0.03	2007.254	15	59	
05520+3137	ABH 32 AD	11.61	12.29	44.78	0.04	49.51	0.03	2007.254	15	59	
05520+3137	ABH 32 AE	11.61	13.87	254.85	0.05	44.54	0.07	2007.254	13	59	
05520+3137	ABH 32 AF	11.61	12.16	178.66	0.03	97.96	0.04	2007.254	15	60	
05520+3137	SEI 400 BC	11.86	12.16	43.98	0.1	17.93	0.03	2007.254	15	59	
05520+3136	Anon.14	11.25	11.9	297.42	0.03	83.43	0.04	2007.254	15	61	
05524+3752	SEI 402	11.3	12.0	180.37	0.1	7.03	0.06	2007.268	5	62	5
05535+3217	SEI 431 AB	9.3	10.5	199.29	0.15	20.79	0.05	2007.254	15	63	
05535+3217	Anon.15 Bx	11.0	12.0	156.21	0.23	19.99	0.07	2007.254	15	64	
05539+3027	TOB 41 AB	10.22	11.34	102.4	0.07	18.23	0.03	2007.263	14	65	
05539+3027	TOB 41 AC	10.22	11.06	66.67	0.06	33.29	0.04	2007.263	14	65	
05542+3029	STF 811	8.0	9.3	234.05	0.23	4.7	0.05	2007.263	12	66	
05558+3708	SEI 438	10.5	11.0	118.55	0.28	13.05	0.06	2007.268	15	67	
05559+3104	SEI 442	9.5	10.5	186.24	0.1	25.21	0.04	2007.263	14	68	
05561+3719	SEI 441	11.0	12.37	213.03	0.25	11.15	0.04	2007.268	17	69	
05565+3707	SEI 443	11.0	11.0	74.69	0.19	26.19	0.07	2007.268	14	70	

Table continued on next page.

Double Star Measures Using a DSLR Camera #2

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Image
05567+3711	Anon.16	14.3	14.9	185.97	0.28	9.64	0.08	2007.268	6	71	
05568+3710	SEI 446	10.5	11.0	123.4	0.25	15.69	0.05	2007.268	14	72	
06046+3014	STF 834	8.61	9.38	308.65	0.11	22.88	0.03	2007.249	15	73	
06051+3016	Anon.17	12.0	12.5	176.39		11.77		2007.249	1	74	
06064+2931	STT 129	6.24	10.49	208.7	1.24	9.4	0.44	2007.249	10	75	6
06592+1843	BU 899 AB	9.03	9.85					2007.268		76	
06592+1843	BU 899 AC	8.7	9.7	175.41	0.14	24.18	0.06	2007.268	17	77	
06592+1843	BU 899 AD	8.76	9.21	45.77	0.06	41.75	0.06	2007.268	17	77	
06592+1843	ABH 55 AE	8.55	13.83	92.25	0.06	109.34	0.08	2007.268	7	77	
07039+2122	SLE 395	10.72	11.02	343.55	0.32	11.27	0.05	2007.265	12	78	
07043+2102	SLE 397	10.9	11.8	15.83	0.24	13.67	0.07	2007.265	12	79	
07045+2122	SMA 71							2007.265		80	
07046+2117	J 1989 AB	11.4	11.6	256.02	0.23	38.56	0.05	2007.265	11	81	
07046+2117	BRT2368 BC	11.6	11.6	106.2		4.3		2007.265	1	81	
07053+2102	SLE 399	10.8	12.0	231.56	0.26	11.88	0.06	2007.265	8	82	
07072+1650	STF1017	9.32	10.25	254.15	0.26	12.72	0.04	2007.268	15	83	
07081+2016	SLE 401	11.0	11.9	212.51	0.17	11.23	0.1	2007.268	6	84	
07081-0146	BAL 408	9.0	11.2	339.16	0.92	5.72	0.09	2007.265	3	85	
07082-0151	J 2781 AB	10.0	10.2	9.1	0.2	25.79	0.07	2007.265	3	86	
07082-0151	BAL 409 BC	10.3	10.9	267.01	0.29	5.08	0.15	2007.265	3	86	
07083-0120	BAL 410	11.2	11.2	166	0.32	10.88	0.07	2007.263	9	87	
07084-0119	BAL 411	11.2	11.5	252.87	0.19	17.78	0.06	2007.263	10	88	
07084-0119	BAL 412 AB	13.54	12.9	198.62	0.22	15.59	0.07	2007.263	9	89	
07084-0119	BKO 23 AC	13.54	13.84	227.84	0.14	29.73	0.06	2007.263	8	89	
07085-0125	BAL 414	11.2	11.4	7.3	0.3	13.09	0.06	2007.263	8	90	7
07085-0144	BAL 413	12.2	14.0	82.52	0.29	18.96	0.06	2007.265	8	91	
07088+1655	STF1027	8.47	8.69	356.02	0.33	6.5	0.08	2007.265	10	92	
07092-0142	BAL 415 AB	11.2	11.5	165.09	0.32	17.1	0.07	2007.263	12	93	
07092-0142	Anon.18 Bx	11.5	13.5	90.56		5.03		2007.263	1	94	
07095-0139	BAL 416	11.1	11.5	81.56	0.26	15.93	0.06	2007.263	12	95	
07095-0140	Anon.19	13.7	15.0	85.67	0.45	10.5	0.07	2007.263	11	96	
07096-0132	BAL 418	11.3	11.4	295.6	0.37	10.33	0.05	2007.263	12	97	
07096-0137	BAL 417	8.9	11.5	247.96	0.2	20.63	0.05	2007.263	12	98	
07098-0127	BAL 419	11.0	11.0	132.7	0.25	15.88	0.04	2007.263	16	99	
07098-0135	BAL 420	11.3	11.4	60.16	0.23	16.93	0.05	2007.263	11	100	
07108-0135	BAL 427	10.6	11.4	161.71	0.37	10.65	0.08	2007.265	8	101	

Table continued on next page.

Double Star Measures Using a DSLR Camera #2

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Image
07108-0144	BAL 428	11.4	11.4	150.66	0.35	9.52	0.04	2007.265	10	102	
07109-0027	BAL 771	11.2	11.5	357.93	0.31	8.89	0.06	2007.263	7	103	
07109-0201	BAL 430	12.83	12.84	99.65	0.34	8.14	0.07	2007.265	9	104	8
07110-0200	BAL 431	9.8	11.4	132.86	0.3	16.16	0.05	2007.265	11	105	8
07111+2132	FAL 19	9.08	12.38	218.18	0.21	10.5	0.08	2007.268	8	106	
07111-0139	BAL 432	11.2	11.3	54.88	0.47	4.09	0.07	2007.265	3	107	
07111-0207	BAL 434	11.1	11.5	21.87	0.35	17.59	0.06	2007.263	8	108	
07112-0136	BAL 433	10.7	11.5	58.77	0.12	15.28	0.05	2007.265	13	109	
07112-0208	BAL 436	11.4	11.5	33.38	0.24	18.19	0.07	2007.263	11	110	
07112-0209	BAL 435	9.96	11.15	302.93	0.15	20.79	0.03	2007.263	14	111	
07114-0035	BAL 773	11.3	11.3	155.65	0.16	16.59	0.03	2007.263	12	112	
07115-0025	BAL 774	10.0	11.3	252.41	0.34	9.69	0.06	2007.263	10	113	
07116-0132	BAL 439	11.4	11.5	288.95	0.29	19.1	0.04	2007.265	5	114	
07116-0158	BAL 438	9.74	11.15	74.91	0.35	11.29	0.07	2007.265	5	115	
07116-0211	BAL 153	11.3	11.4	254.49	0.32	17.29	0.07	2007.263	9	116	
07117-0206	BAL 440	10.4	10.8	195.56	0.14	15.64	0.05	2007.263	14	117	
07118-0130	Anon.20	13.9	14.0	106.16	0.29	9.44	0.04	2007.265	6	118	
07119-0130	BAL 441	8.8	9.5	33.44	0.12	14.34	0.04	2007.265	16	119	
07119-0132	Anon.21	14.0	14.4	171.27	0.42	5.87	0.05	2007.265	4	120	
07119-0207	BAL 443	10.0	11.2	227.8	0.2	16.55	0.04	2007.263	4	121	
07122-0205	BAL 444	9.6	11.2	299.43	0.18	14.08	0.05	2007.263	14	122	
07123-0029	BAL 776 AB	10.8	11.3	236.08	0.11	17.25	0.04	2007.263	12	123	
07123-0029	BKO 24 AC	10.8	11.0	203.78	0.02	110.55	0.05	2007.263	12	123	
07123-0029	BKO 24 CD	11.0	11.5	72.58	0.32	8.45	0.05	2007.263	12	123	
07124-0139	Anon.22	13.6	13.8	273.97	0.37	8.48	0.07	2007.265	10	124	
07125-0141	BAL 445	10.6	11.5	41.7	0.21	20.37	0.07	2007.265	13	125	
07125-0204	BAL 446	11.2	11.3	126.06	0.15	17.37	0.04	2007.263	15	126	
07126-0147	BAL 448	10.8	11.0	224.6		3.84		2007.265	1	127	
07128-0204	BAL 450	11.2	11.3	98.83	0.35	12.66	0.04	2007.263	6	128	
07138+1746	STF1041	9.1	12.1	266.26	0.08	25.92	0.04	2007.268	12	129	
07160+1644	DUF 2	9.24	9.34	112.51	0.11	41.39	0.05	2007.265	14	130	
07247+2019	Anon.23 AB	10.85	12.0	27.64	0.32	13.33	0.04	2007.263	16	131	
07247+2019	Anon.23 BC	12.0	13.0	294.8		3.12		2007.263	1	131	
07247+2008	Anon.24	13.5	14.5	155.09	0.24	9.52	0.06	2007.263	7	132	
07248+2003	Anon.25	12.5	12.6	241.37	0.16	10.34	0.05	2007.263	17	133	
07255+2016	Anon.26	12.7	12.9	159.78	0.27	7.14	0.06	2007.263	14	134	

Table continued on next page.

Double Star Measures Using a DSLR Camera #2

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Image
07256+2030	STF1083	7.32	8.13	45.01	0.2	6.34	0.05	2007.263	14	135	
07265+1831	STF1090 AB	7.27	8.17	97.84	0.07	60.88	0.05	2007.263	16	136	
07265+1831	STF1090 AC	7.27	9.48	79.22	0.12	49.96	0.05	2007.263	14	136	
07266+1834	XMI 62 AB	11.53	12.15	273.68	0.2	14.62	0.04	2007.263	16	137	
07266+1834	Anon.27 Ax	11.53	14.0	73.86	0.17	13.44	0.08	2007.263	8	137	
07273+2017	GRV 734	10.33	11.39	48.12	0.05	36.39	0.03	2007.263	16	138	
07375+1728	SLE 431	11.8	12.1	54.76	0.3	11.89	0.06	2007.263	11	139	
07382+1752	HJ 2404 AB	10.0	11.0	56.48	0.36	15.09	0.08	2007.263	6	140	
07382+1752	HJ 2404 AC	9.82	9.36	186.9	0.06	48.67	0.03	2007.263	9	140	
07382+1752	HJ 2404 AD	10.0	13.5	56.94	0.04	41.98	0.01	2007.263	2	140	
07382+1752	SLE 433 AE	10.0	11.8	318.35	0.09	143.73	0.04	2007.263	4	141	
07585+3215	SEI 484	10.4	11.7	257.11	0.17	26.53	0.04	2007.265	7	142	
07596+3211	SEI 485	10.71	11.07	88.7	0.1	20.7	0.02	2007.265	16	143	
08097+2533	WRH 27	7.61	8.69	97.41	0.09	29.06	0.06	2007.265	15	144	
08100+3017	Anon.28	11.0	11.6	86.42	0.16	18.99	0.05	2007.263	14	145	
08102+2551	BUP 111 AB	6.58	9.32	48.47	0.04	81.13	0.07	2007.265	8	146	
08102+2551	ARN 2 AC	6.6	8.0	21.67	0.04	188.68	0.05	2007.265	9	147	
08511+1153	BKO 35	12.0	13.5	144.24	0.31	6.97	0.05	2007.265	6	148	9
08512+1149	CHE 118 AB	9.80	10.52	62.09	0.35	23.84	0.07	2007.265	13	149	
08512+1149	BKO 36 AC	9.8	14.2	29.66	0.06	32.6	0.05	2007.265	8	149	
08513+1151	BKO 37	11.0	13.0	206.13	0.22	8.1	0.06	2007.265	4	150	
08513+1149	BKO 38	12.2	14.5	74.52	0.16	10.37	0.1	2007.265	5	151	
08513+1148	BKO 39	11.9	13.2	233.77	0.19	12.62	0.04	2007.265	8	152	
08513+1146	CHE 119 AB	9.45	10.48	300.61	0.23	13.38	0.03	2007.265	13	153	
08513+1146	CHE 119 AC	9.45	10.65	13.47	0.07	32.54	0.1	2007.265	10	153	
08513+1146	BKO 40 AD	9.45	14.9	334.61	0.14	21.61	0.05	2007.265	6	153	
08514+1147	BKO 41 A-BC	13.0	13.0	144.52	0.23	7.24	0.04	2007.265	6	154	
08515+1154	CHE 120	9.70	10.56	144.65	0.23	31.41	0.06	2007.265	10	155	
08515+1152	CHE 121 AB	9.33	10.54	37.39	0.05	31.17	0.07	2007.265	17	156	
08515+1152	CHE 121 AC	9.3	11.0	74.69	0.09	27.23	0.07	2007.265	16	156	
08515+1152	BKO 42 AD	9.3	13.0	118.77	0.21	14.29	0.06	2007.265	4	156	
08515+1149	BKO 43	11.0	11.0	95.39	0.13	9.24	0.05	2007.265	8	157	
08515+1149	BKO 44	11.5	13.0	155.43		3.88		2007.265	1	158	
08515+1148	BKO 45	12.0	12.0	355.77	0.21	8.8	0.05	2007.265	8	159	
08516+1152	CHE 123 AB	9.59	10.48	220.61	0.04	39.45	0.03	2007.265	12	160	
08516+1152	BKO 46 AC	9.59	12.5	183.79	0.13	16.24	0.08	2007.265	7	160	

Table continued on next page.

Double Star Measures Using a DSLR Camera #2

WDS	Discoverer	m1	m2	PA	+/-	Sep	+/-	Epoch	n	Notes	Image
08517+1151	CHE 124	10.43	10.67	273.09	0.13	26.91	0.05	2007.265	19	161	
08517+1151	CHE 125	10.37	10.68	174.34	0.25	15.84	0.07	2007.265	16	162	
08517+1147	CHE 126 AB	10.39	10.83	121.67	0.19	22.95	0.07	2007.265	15	163	
08517+1147	BKO 47 AC	10.39	10.70	72.74	0.08	31.75	0.05	2007.265	14	163	
08518+1150	CHE 127 AB	9.31	10.45	51.17	0.15	24.65	0.08	2007.265	11	164	
08518+1150	CHE 127 AC	9.31	10.70	14.74	0.12	28.84	0.07	2007.265	15	164	
10285+1309	STF1438 AB	9.5	11.1	244.84	0.32	9.81	0.05	2007.263	18	165	

Table Notes

1. A=GSC 2401 1002 (05141+3541!). Far from the specified location (6,5'). Only GSC shows it in the given location, DSS does not.
2. A=GSC 2402 646
3. A=GSC 2402 474 (05177+3628!).
4. (051742+362731), A, B do appear in USNO.
5. A=GSC 2402 1162 (05182+3601!).
6. A=GSC 2402 1266
7. A=GSC 2402 94
8. AB=GSC 2402 992 non star.
9. A=GSC 2402 756
10. A=GSC 2402 1336
11. A=GSC 2402 1094
12. A=GSC 2402 868
13. A=GSC 2402 766 non star.
14. A=GSC 2402 690 (05211+3620!).
15. A=GSC 2398 1490
16. A=GSC 2404 775 1
17. A=GSC 2404 695
18. A=GSC 2408 1103. The difference is significant compared to the previous measure.
19. A=GSC 2408 875
20. A, B do appear in USNO. (054009+372211).
21. Ax=GSC 2416 218 non star (05402+3721!).
22. A=GSC 2416 857 (05407+3550!). Far from the specified location (6').
23. AB=GSC 2911 1626 non star.
24. A=GSC 1873 934
25. A=GSC 2408 585
26. A=GSC 2416 468
27. A=GSC 2409 1003
28. A=GSC 2409 792 (05422+3247!).
29. A=GSC 2911 1592
30. A=GSC 2409 1637 (05435+3317!). Far from the specified location (10').
31. A=GSC 2409 1929. Uncertain measures due to DM.
32. A=GSC 2409 1645
33. A=GSC 2405 91 (05446+3133!).

Double Star Measures Using a DSLR Camera #2

34. A=GSC 2417 409 non star (05446+3623!). Far from the specified location (7').
35. A=GSC 2409 1327
36. A=GSC 2405 1793
37. BC=GSC 2405 645 non star.
38. A=GSC 2417 1044
39. A=GSC 2417 368 The primary star has significant proper motion according to the Hipparcos catalog: pmRA: 488,1 mas/y; pmD: -509,5 mas/y. At my request, György Vaskúti made calculations on the basis of the double's available measures (1880; 1908; 1954; 1991; 2007). He determined there's a systematic difference between the calculated and the measured values, therefore it can be supposed that the B component has its own proper motion. On the basis of the first and the last measures, its value is pmRA: -11 mas/y; pmD: -33 mas/y.
40. GSC 2405 179
41. A=GSC 2417 1102 non star (05465+3659!).
42. A=GSC 2409 425
43. AB=GSC 2417 854 non star.
44. AB=GSC 2417 726 non star.
45. A=GSC 1311 1823 non star.
46. A=GSC 1311 1761 non star.
47. A=GSC 1311 51 non star. The difference is significant compared to the previous measure.
48. A=GSC 1311 2030 non star.
49. AB=GSC 2405 1889 non star.
50. A=GSC 2405 471 (05497+3147!).
51. A=GSC 2409 154
52. AB=GSC 2405 417 non star.
53. A=GSC 2405 1905 1. AB is visible but cannot be measured.
54. A=GSC 2405 1905 1
55. AB=GSC 2409 110 non star.
56. A=GSC 2410 157
57. A=GSC 1875 2587
58. A=GSC 2912 1185. Uncertain measures. Significant difference compared to the previous measures and GSC. Measuring the DSS image also showed different values.
59. A=GSC 2406 1020 (05520+3136!).
60. A=GSC 2406 1020 (05520+3136!). Only this star can be found in the given direction. The difference from the values indicated is significant.
61. A=GSC 2406 1020. Similar parameters to ABH 32 AF, but with a 90 degree difference.
62. A=GSC 2912 1667
63. A=GSC 2410 719
64. B=GSC 2410 1722 non star. Could this be the original SEI 431 AB?
65. A=GSC 2406 2086
66. A=GSC 2406 1864 1 (05542+3030!).
67. A=GSC 2418 520 (05558+3707!).
68. A=GSC 2406 1175
69. A=GSC 2418 773 non star (05562+3719!).
70. A=GSC 2418 562
71. A=GSC 2418 808
72. A=GSC 2418 1004

73. A=GSC 2419 1293
74. A=GSC 2419 1127
75. A=GSC 1876 1774. Uncertain measures due to DM.
76. AB=GSC 1348 3. AB are not separated.
77. AB=GSC 1348 3
78. A=GSC 1356 1898
79. A=GSC 1357 467
80. According to its data, it is the same as BRT 2368. There is no other similar double in the vicinity.
81. A=GSC 1357 1093
82. A=GSC 1357 1859
83. A=GSC 1345 1966
84. A=GSC 1353 127 (07084+2013!). The difference is significant, but there is nothing else nearby.
85. A=GSC 4815 2707 (07080-0146!).
86. A=GSC 4815 2431 (07082-0152!).
87. A=GSC 4815 3231 non star (07083-0121!).
88. A=GSC 4815 3235 (07084-0120!). = BAL 412 BC.
89. A=GSC 4815 3111 (07084-0120!).
90. A=GSC 4815 3750
91. A=GSC 4815 3019 non star (07086-0145!).
92. A=GSC 1349 488 1
93. A=GSC 4815 2777 (07091-0141!).
94. x=GSC 4815 2211 blended object.
95. A=GSC 4815 2521
96. A=GSC 4815 2929
97. A=GSC 4815 2911 non star.
98. A=GSC 4815 2885
99. A=GSC 4815 2467 non star (07097-0127!).
100. A=GSC 4815 3025 (07097-0134!).
101. A=GSC 4815 1208 non star (07108-0134!).
102. A=GSC 4815 1740 non star.
103. A=GSC 4815 1561 blended object.
104. A=GSC 4819 3768 blended object.
105. A=GSC 4819 3487
106. A=GSC 1357 2052
107. AB=GSC 4815 982 non star (07110-0139!).
108. A=GSC 4819 2738
109. A=GSC 4815 889 (07111-0136!).
110. A=GSC 4819 3250 (07113-0208!). Could the 1998 measure be BAL 434?
111. A=GSC 4819 2836
112. A=GSC 4815 1389 (07114-0034!).
113. A=GSC 4815 182 blended object.
114. A=GSC 4815 2345 non star.
115. A=GSC 4819 3734 (07115-0158!).
116. A=GSC 4819 3472
117. A=GSC 4819 2876

Double Star Measures Using a DSLR Camera #2

118.A=GSC 4815 1464 non star.
119.A=GSC 4815 988 non star (07119-0129!).
120.AB=GSC 4815 1536
121.A=GSC 4819 3526
122.A=GSC 4819 2776 non star.
123.A=GSC 4815 419 (07123-0030!).
124.A=GSC 4815 970 non star.
125.A=GSC 4815 568 (07124-0141!).
126.A=GSC 4819 3172 non star.
127.A=GSC 4815 1612
128.A=GSC 4819 3038
129.A=GSC 1350 740
130.A=GSC 1346 253
131.A=GSC 1355 1102
132.(072442+200750), A does appear in USNO.
133.A=GSC 1355 836. Since the beginning of the 1980s, amateur astronomer György Vaskúti has been taking notes on all the doubles he visually observes and which do not appear in public catalogs. His list contains nearly 300 double stars. In the meantime, a greater portion of these doubles has been catalogued in WDS on the basis of other astronomers' measures. This double star cannot be found in WDS yet; György Vaskúti found it in 1990, and it appears in his list by his own "VGY 215" marking.
134.A=GSC 1355 444 non star.
135.A=GSC 1355 162 1
136.A=GSC 1351 1053
137.A=GSC 1351 238
138.A=GSC 1355 744
139.A=GSC 1365 960 non star.
140.A=GSC 1365 968
141.A=GSC 1365 968. Very different data, but there is no better star in the vicinity.
142.A=GSC 2472 393 (07585+3214!).
143.A=GSC 2472 538 (07596+3210!).
144.A=GSC 1931 841 (08097+2543!).
145.A=GSC 2469 550. This double star cannot be found in WDS yet; György Vaskúti found it in 1990, and it appears in his list by his own "VGY 88" marking.
146.A=GSC 1931 1927
147.A=GSC 1931 1927. The difference is significant, the DSS image shows a PA of about 21 degrees, too.
148.AB=GSC 814 1351 non star.
149.A=GSC 814 1769 (08511+1148!).
150.A=GSC 814 1763
151.A=GSC 814 1323
152.A=GSC 814 1647 non star.
153.A=GSC 814 2331 (08513+1145!).
154.A=GSC 814 1527 non star. BC is visible but cannot be measured.
155.A=GSC 814 1025 (08514+1154!).
156.A=GSC 814 1205
157.A=GSC 814 2089
158.A=GSC 814 2079

Double Star Measures Using a DSLR Camera #2

159.A=GSC 814 1537 non star.
160.A=GSC 814 1315 (08516+1151!).
161.A=GSC 814 1981 (08517+1150!).
162.A=GSC 814 1007 (08517+1150!).
163.A=GSC 814 1737
164.A=GSC 814 2047 (08518+1149!)
165.A=GSC 844 681 (10292+1309!). Far from the specified location (10,6').

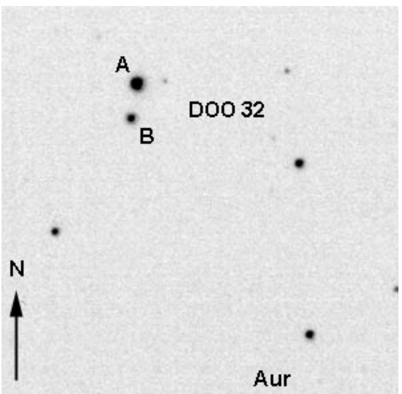

Figure 1: DOO 32

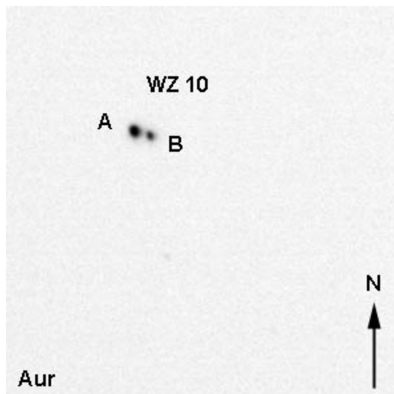

Figure 2: WZ 10

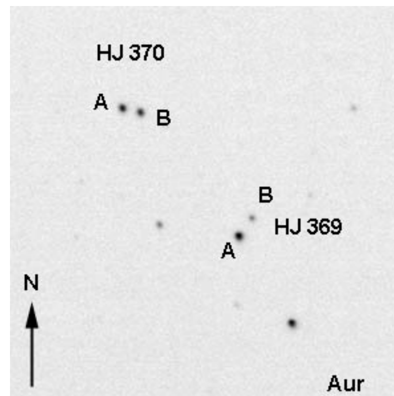

Figure 3: HJ 370 and HJ 369

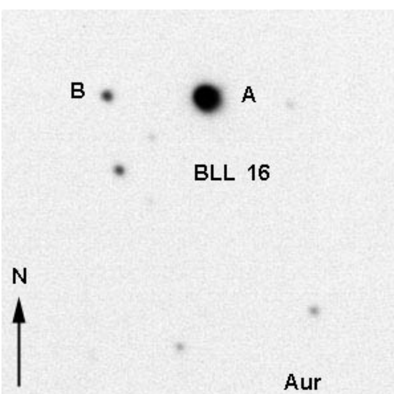

Figure 4: BLL 16

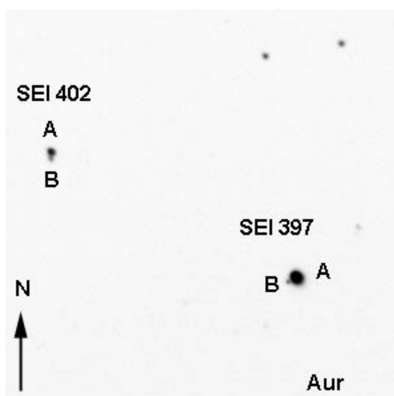

Figure 5: SEI 402 and SEI 397

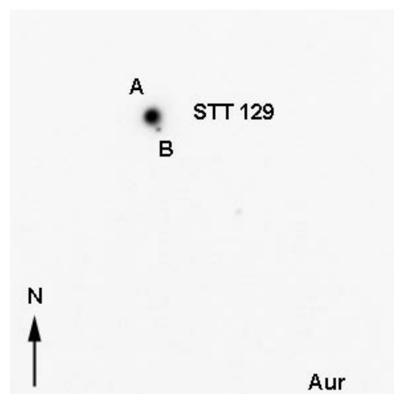

Figure 6: STT 129

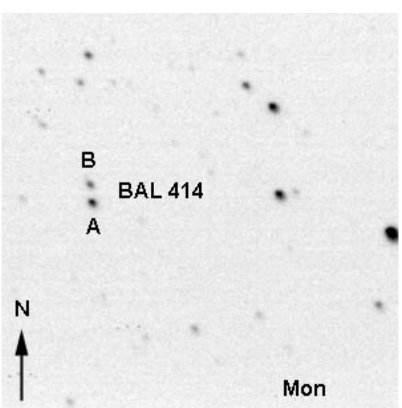

Figure 7: BAL 414

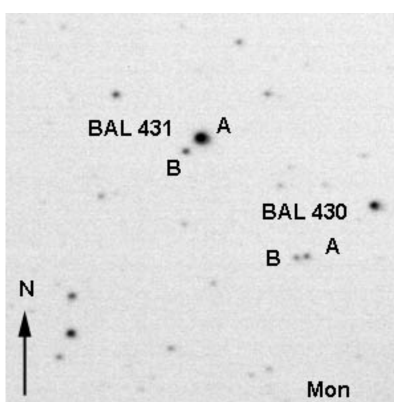

Figure 8: BAL 431 and BAL 430

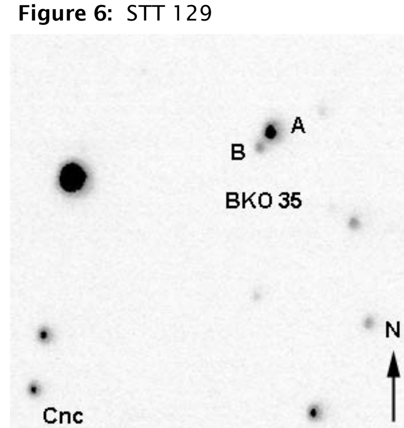

Figure 9: BKO 35

A Comparison of the Astrometric Precision and Accuracy of Double Star Observations with Two Telescopes

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Abstract: Using a manual Meade 6” Newtonian telescope and a computerized Meade 10” Schmidt-Cassegrain telescope, students from Arroyo Grande High School measured the well-known separation and position angle of the bright visual double star Albireo. The precision and accuracy of the observations from the two telescopes were compared to each other and to published values of Albireo taken as the standard. It was hypothesized that the larger, computerized telescope would be both more precise and more accurate.

Introduction

The objective of this project was to compare the precision and accuracy of visual astrometric observations of a double star made with two different telescopes. Precision is the repeatability (reliability) of the observations, i.e. how well the observers agree among themselves. Accuracy, on the other hand, is agreement with some already well-established value. Highly precise and accurate astrometric measurements are desired because they will be more strongly weighted in later analyses of a binary system. Since our objective was to evaluate both the precision and accuracy of our astrometric observations, as opposed to obtaining new values on a neglected or rapidly changing double star, we chose the double star Albireo because it has a well established separation and position angle that change only slowly over time.

This project was part of the Fall 2008 Physics Research Seminar at Cuesta College’s South Campus in Arroyo Grande, California. As suggested by Johnson (2007), visual observations of double stars are well suited to one semester research seminars. Ten student first time observers attending Arroyo Grande High School met with experienced observers Genet, Johnson, and White on September 19th, 2008 (B2008.718) at the Marble residence in Arroyo Grande to observe Albireo (Marble et al, 2008).

The observers were divided into two teams: Alvarez, Kight, Navarro, Schachter, Summers, Weise, Mires and Genet used a manual 6”, f/6 Newtonian telescope with a clock drive; Fishbein, Hyland, Lopez, Rosas, Johnson, and White used a computer controlled 10”, f/10 Meade LX200 Schmidt-Cassegrain telescope. A 12 mm Meade astrometric eyepiece was used with the 6” telescope while a 12.5 mm Celestron Micro Guide eyepiece was used with the 10” telescope. Stopwatches that read out to the nearest 0.01 second were used in the calibration of the linear scales of both eyepieces.

Prior to the observations, the authors hypothesized that with a longer focal length (100” versus 36”) and larger aperture (10” versus 6”), the separations

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Figure 1: Aubrey Schachter (right) watches Vega drift across the field of view of the 6" Newtonian telescope, while Molly Summers (center) times the drift with a stopwatch, and Cheyne Kight (left) records the time.

and position angles would be easier to see through the larger 10" telescope and hence would be more precisely and accurately recorded. Furthermore, the 10" telescope was on a much sturdier mount, computer controlled, and operated by an experienced operator, all factors which could lead to greater precision and accuracy. Specifically, we hypothesized that the variance of both the separation and position angle measurements would be significantly greater for the 6" than for the 10" telescope while the accuracy would be significantly higher on the 10" than the 6".

Mathematically, our hypothesis for precision was H_1: $\varsigma_{10}^2 < \varsigma_6^2$ (statistically significant at 95%), while the null hypothesis was H_o: $\varsigma_{10}^2 = \varsigma_6^2$ (not statistically significant at 95%); where H_1 was our hypothesis, H_o was the null hypothesis, ς was the standard deviation, and ς_x^2 was the variance of the data set. Our hypothesis for accuracy was H_1: $\delta_{10} < \delta_6$, while the null hypothesis was H_o: $\delta_{10} = \delta_6$; where H_1 was our hypothesis, H_o was the null hypothesis, and δ was the accuracy of the data set.

Calibrations

To calculate the scale constants for the two telescopes in arc seconds per division, the observers determined the time it took for stars with a known declination to drift across the linear scale of each eyepiece (Teague, 2004). Each star was aligned so the linear scale passed through the center of the calibration star. The eyepiece was then rotated until the star followed the ruler with minimal deviation as the telescope was slewed east and west. The star was then placed on the outer protractor and the right ascension motor turned off. When the star passed over the beginning of the ruler, the stopwatch was started, and then stopped as the star crossed the other end of the ruler. The displayed time was recorded to the nearest 0.01 second. This procedure was repeated five times on the 6" and nine times on the 10". The observers on the 6" telescope did not make as many observations because their telescope was not computerized, so re-aligning the star before each drift was more time consuming. One random outlier from the 10" observations was not included in the final analysis.

The mean drift time for each telescope was used to calculate the scale constant for each eyepiece using the following equation (Teague, 2004):

$$Z = \frac{15.0411 t \cos(d)}{D}$$

where Z is the scale constant in arc seconds per division; 15.0411 is the number of arc seconds per second that the Earth rotates; t is the average drift time; d is the declination of the star; and D is the number of divisions on the linear scale (50 for the Meade eyepiece and 60 for the Celestron eyepiece).

Each team observed a different star for calibration, Vega for the 6" and Beta Andromeda for the 10". Using the calibration equation above, the 6" team determined their scale constant to be 32.0 ± 0.06"/division. The 10" team calculated a scale constant of 7.07 ± 0.01"/division. Table 1 shows the declinations of both stars (Epoch 2000), the number of observations, mean drift times, standard deviations, and standard errors of the mean.

	6" Telescope	10" Telescope
Star Observed	Vega	Beta And
Star Declination	+38° 47' 01"	+35° 47' 14"
Number of Observation	5	8
Mean Drift Time	136.47s	34.74s
Standard Deviation	0.55s	0.41s
Standard Error of the Mean	0.25s	0.14s

Table 1: Comparison of Calibration Drift Times

Separation and Position Angle Observations

The distance between the two stars was estimated by each observer to the nearest 0.1 division. The double star was moved between each observation to different parts of the linear scale to avoid observational bias. The angular separation in arc seconds for each telescope was then determined by multiplying the average number of divisions separating the two stars on the linear scale by the appropriate scale constant.

The position angle was determined by placing the brighter star at the center of the eyepiece and rotating the eyepiece so that the linear scale bisected both stars. The right ascension motor was then turned off. The position angle was determined by estimating which degree marking the star crossed the outer protractor of the eyepiece (Teague, 2004). This step was repeated three times on the 6” and four times on the 10”. Atmospheric conditions and the rising moon did not allow for further observations. For each measurement, team members privately recorded their results to avoid influencing the other observers.

To compare the astrometric precision of the two telescopes, the students aimed both telescopes at the well documented, slowly revolving double star, Albireo. Each team measured its separation and position angle. Table 2 shows the means, standard deviations, and standard errors of the mean for both telescopes' measurements of separation and position angle. The students used *Microsoft Excel* for the calculations.

	Separation		Position Angle	
	6″ Telescope	10″ Telescope	6″ Telescope	10″ Telescope
Mean	37.12″	32.45″	56.3°	54.0°
St. Dev.	6.08″	1.2″	0.6°	0.8°
St. Err.	0.64″	0.14″	0.1°	0.2°

Table 2: Comparison of Separation and Position Angle of Albireo

Analysis

Were the 10” separation and position angle observations more precise than the 6” observations as the authors hypothesized? Table 3 shows the separation variance for both telescopes.

	# of Obs.	St. Dev.	Variance
6″ Telescope	5	6.8″	46.2
10″ Telescope	8	1.2″	1.4

Table 3: Separation Variance for two telescopes

The critical f-ratio (95%) was 4.12 from tables for 4 degrees of freedom for the numerator (5-1 = 4) and 7 degrees of freedom for the denominator (8-1 = 7). The observed variance ratio of 33 (46.2/1.4) was 8 times the critical F ratio value from the table, so the null hypothesis was rejected while the hypothesis that the 10” observations of the separation would be more precise was accepted.

Table 4 shows the position angle variance comparison for the precision of both telescopes.

	# of Obs.	St. Dev.	Variance
6″ Telescope	3	0.6°	0.36
10″ Telescope	5	0.8°	0.64

Table 4: Data for Position Angle Variance Comparison

The critical f-ratio (95%) was 19.2 from tables for 4 degrees of freedom for the numerator (5 -1 = 4) and 2 degrees of freedom for the denominator (3-1 = 2). The variance ratio of 1.8 (0.64/0.36) was more than 10.7 times less than the critical F ratio from the table, so the null hypothesis could not be rejected and the hypothesis that the 10” position angle observations would be more precise was not accepted.

Were observations made on the 10” more accurate than those on the 6”? Table 5 compares the observed separations and position angles for both telescopes to literature values of Albireo (STFA 43Aa-B) from the Washington Double Star (WDS) Catalog (Mason, 2006).

While the separation measured on the 6” was approximately 3% more accurate than on the 10”, the position angle measured on the 10” was identical to the literature value. According to Ron Tanguay (1998), who is highly experienced in astrometry with eyepiece reticle micrometers, “With a well calibrated reticle micrometer, we may expect measurements to average about +/- 1 degree in the position angle and +/- 2% in separation from the data listed in the WDS Catalog.”

Based on Tanguay's criteria, observations on both telescopes were reasonably accurate in their separation and position angle measurements. However, neither set of observations were definitively more accurate than the other. Therefore, the hypothesis that the larger telescope would make more accurate measurements could not be accepted.

Discussions and Conclusions

The students concluded that the larger telescope was more precise than the smaller one when measuring the angular separation of a double star because the separation measurements made with the 10” telescope were about five times more precise than those made with the 6” telescope. A likely cause is that the stars were separated by about one division in the 6” while they were separated by several divisions

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	Separation				Position Angle			
	Obs.	Lit.	Diff.	% Diff.	Obs.	Lit.	Diff.	% Diff.
6″ telescope	37.12″	35.3″	1.82″	5%	56.3°	54.0°	2.3°	4%
10″ telescope	32.45″	35.3″	2.85″	8%	54.0°	54.0°	0.0°	0%

Table 5: Comparison of Observed Values for Albireo on the 6” and 10” Telescopes to Literature Values

in the larger telescope. Thus the stars didn’t appear to blur together.

It was suggested by a reviewer that the apparent difference in precision could also have been due to the different eyepieces used in each telescope. The Celestron Micro Guide eyepiece has 60 divisions on its linear scale while the Meade Astrometric eyepiece has only 50. With more divisions on the linear scale, one might expect a more precise result from the Celestron eyepiece regardless of the telescope used. However, our difference in precision was probably not primarily due to the different eyepieces alone since the observed variance ratio was 8 times the critical f-ratio. Perhaps it was a combination of a larger telescope and an eyepiece with more linear scale divisions that produced the more precise result on the 10” telescope. Future evaluations, however, might consider controlling this variable by using the same eyepiece in both telescopes.

It was suggested by another reviewer that the observers who used the 10” telescope might have made more precise measurements because they were either more organized or more careful and meticulous than those who used the 6” telescope. This reviewer suggested that this possibility could be evaluated in any future assessments by having teams exchange telescopes and make a second set of observations.

The most surprising result from the comparison, however, was that the position angle measurements were no more precise on the 10” than on the 6”. In fact, the 10” observations were slightly less precise (although the difference was not statistically signifi-

Figure 2: Several of the students analyzed the data with Russ Genet and Jo Johnson at the Marbles’ home in Arroyo Grande, California. Left to right: Hairold Lopez, Jolyon Johnson, Mike Hyland, Carlos Rosas, Amos Fishbein, Aubrey Schachter, Molly Summers, and Russ Genet.

cant). This lack of difference may be because it does not matter how magnified an object was in the eyepiece when making position angle measurements. The authors suggest that since the protractor itself was not magnified, it could not be viewed more precisely. Furthermore, with the longer focal length of the 10" telescope and correspondingly smaller field of view, the star drifted faster across its field of view, including the protractor, and thus may actually have been more difficult to observe. On the other hand, with twice the magnification and brighter stars on the 10", one would have expected that the ruler could have been set to more accurately bisect the two stars prior to commencing the positional angle drift.

It might be noted that Darrell Grisham (2008), an experienced astronomer in California Valley, made very accurate measurements of bright visual double stars during the fall 2007 research seminar with a three inch Tasco telescope. His separation measurements were approximately 0.8% different from the literature values (ours were 5% for the 6" and 8% for the 10") and his position angle measurements were approximately 3% different (ours were 4% for the 6" and 0% for the 10"). For smaller telescopes, accuracy might be more dependent upon the experience of the observer than telescope aperture or focal length.

Acknowledgments

The authors thank John and Chrissie Marble for the use of their home for the observations. We also thank the now retired Arroyo Grande High School physics teacher, John Baxter, for recommending the research seminar to the students. The authors also thank the Central Coast Astronomical Society for loaning us the 6" Equatorial Newtonian telescope. Lastly, the authors thank external reviewers David Arnold, Robert Buchheim, Tom Smith, and Vera Wallen for their helpful suggestions.

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Pablo Alvarez, Amos E. Fishbein, Michael W. Hyland, Cheyne L. Kight, Hairold Lopez, Tanya Navarro, Carlos A. Rosas, Aubrey E. Schachter, Molly A. Summers, and Eric D. Weise are students at Arroyo Grande High School and were members of the fall 2008 Physics 193A Research Seminar at Cuesta College. Megan A. Hoffman and Robert C. Mires were also members of the research seminar and are students at Cuesta College. Jolyon M. Johnson is a student at Cuesta College and the Science Advisor for the research seminar and the Orion Observatory, www.OrionObservatory.org. Russell M. Genet is a Professor of Astronomy at Cuesta College and led the research seminar. He is also a Research Scholar in Residence at California Polytechnic State University and Director of the Orion Observatory. Robin White, the Observatory Assistant at Cuesta College, is a highly experienced observer and provided the 10" telescope.

On the Accuracy of Double Star Measurements from "Lucky" Images, a Case Study of Zeta Aqr and Beta Phe

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Abstract: The accuracy and reproducibility of measuring double stars from "lucky" images was tested by repeated recordings at consecutive nights of two systems, zeta Aquarii (STF 2909) and beta Phoenicis (SLR1 AB), with current separations of about 2 arcsec and 0.4 arcsec, respectively, using a fast CCD camera at two telescopes (40 cm and 50 cm Cassegrain). By careful selection and superposition of only the best images out of longer sequences, error margins of position measurements were significantly reduced. Standard deviations for the separation of the order of +/-0.01 arcsec were obtained, even under non-optimum seeing conditions.

Introduction

High-resolution imaging of celestial objects is limited by seeing effects. Even under good seeing conditions, the size of the seeing disc is rarely smaller than 1 arcsec, which is larger than the Airy diffraction disc of modest amateur telescopes. The theoretical resolution is usually referred to as Rayleigh or Dawes limits, which only depend, besides the wavelength, on aperture. Both are somewhat arbitrary, as they are calculated under the assumption that two overlapping Airy peaks can be split, when the drop of the light intensity in between is 25%, or 3%, respectively, which may or may not be detected by visual observers. As an example, an aperture of 50 cm would produce an Airy disc with total diameter 0.55 arcsec, with a full-width at half-maximum (FWHM) of 0.23 arcsec, at a wavelength of 550 nm, and the resolution limits are 0.28 or 0.23 arcsec, respectively. In reality, when observing close double stars, blurring of the Airy discs by seeing effects, if not optical or other defects, reduces the resolution accordingly, in particular, when taking images with long exposure times.

While these limits are of interest for estimating the splitting power of a telescope, angular resolution is not the only criterion for the accuracy of double star measurements. In fact, most important is the accuracy of determining the positions of the centroids of the seeing discs of the components. Provided that both are symmetric or at least similar, this is a matter of resolution of the image itself, i.e. the size of the pixels of the CCD camera in relation to the focal length of the telescope. In this respect, relatively long exposure times help in averaging image distortions by seeing effects. The improvement by using lucky imaging techniques, which means using exposure times down to the order of milliseconds and registering and stacking only the best images out of longer sequences, consists in a significant reduction of the effective size of the seeing disc, with particular benefit for splitting and measuring close pairs. In the following, the reproducibility and accuracy of this technique is evaluated for two representative systems, zeta Aqr (STF 2909, WDS 22288-0001) and beta Phoenicis (SLR1 AB, WDS 01061-4643), with current separations of 2 and 0.4 arcsec, respectively. These were mainly selected because of their brightness (~ 4 mag), with about equal values of the components, which allows for short exposure times. They are also interesting for other reasons. Both are binaries with assumed periods of 587 and 195 years, respectively, but recent measurements, also by other authors, deviate from published orbits. Closer looks appear to be worthwhile.

Instrumental

Recordings were done during several nights during one week in September 2008 with two telescopes at the International Amateur Sternwarte (IAS) in Namibia [1]. Seeing conditions are generally good at this location. The telescopes were of Cassegrain type with apertures 40 cm and 50 cm, and focal lengths of 6.3 m and 4.5 m, respectively. In most cases, the latter were effectively doubled with a Barlow lens, which, however, required insertion of a band filter to reduce chromatic aberrations of the lens. A red filter was used (Edmund Scientific Co.), which, combined with the spectral sensitivity of the camera chip, resulted in maximum response at wavelengths between 600 and 750 nm.

Digital images were recorded at high frequencies with a b/w-CCD camera (DMK21AF04, The Imaging Source) via a firewire interface as bitmaps into a computer. The chip contains 640x480 square pixels with a size of 5.6 µm, which results in image scales of nominally 0.18 arcsecond/pixel for the 40 cm telescope, and 0.26 arcsecond/pixel for the 50 cm. These values are halved when using the Barlow lens. More exact calibrations were obtained in an iterative way by measuring systems with well known and predictable separations. This procedure was the same as was described in earlier articles [2,3]. The results are listed in Table 1. Error limits are estimated to +/- 1 percent.

telescope	without Barlow	with Barlow
40 cm Cass.	0.187	0.097
50 cm Cass.	n/a	0.132

Table 1: Calibration factors in arcsec/pixel as determined from reference systems

Exposure times were chosen to obtain decent signal-to-noise ratios, but to avoid saturation of pixels, and ranged from 0.25 milliseconds per frame (beta Phe, 40 cm without Barlow) up to 12 milliseconds (zeta Aqr, 50 cm with Barlow and red filter). Seeing conditions varied between mean and very good, partly due to different zenith distances of the stars ranging from 20 to about 60 degrees.

Sequences of about 2000 frames were recorded within a couple of minutes, out of which the best were later selected by visual inspection for further evaluation. However, even under good seeing, the so called lucky image is virtually never perfect. Moreover, it is sometimes difficult to decide whether an image is useful or not, especially, when anisoplanatic effects occur. For the close pairs investigated here, this was luckily rarely the case. A simple estimate of image quality by measuring the Strehl ratio is often not sufficient. Rather, the more or less distorted profile of the star image, including the diffraction rings, which may fluctuate in shape and intensity, has to be taken into account. A good strategy is to select good images when they come in bunches, although not necessarily consecutively, at moments of steadier seeing than average. The yield of useful images was generally of the order of only a few percent. These were resampled, i.e. the images were recalculated by doubling the number of pixels in x- and y-direction, up to three times, and stacked with sub-pixel accuracy, referred to the original pixel size. This procedure results in rather smooth intensity profiles and in an accordingly more accurate definition of the peak centroids. For measuring the position angle, the east-west direction was determined from superposed images recorded while the telescope drive was temporarily switched off. This was done for each individual recording of any system, resulting in an average error margin of +/-0.2 degrees.

Results

A) Zeta Aquarii

Figure 1 shows images of ζ Aqr (WDS 22288-0001) produced from recordings with both telescopes at different nights, under different conditions, as indicated in the images and in the caption. While the seeing varied (qualitative estimates are listed in Table 2 below), the Airy diffraction rings could be resolved in all cases. Slightly asymmetrical brightness may be caused by minor changes of telescope collimation, possibly by varying tilt angles and/or temperature. Collimation was not re-adjusted, as such variations are not thought to influence the accuracy of position measurements. The image of date 2008.732 suffers most from only mediocre seeing, which resulted in somewhat enlarged seeing discs and in an inhomogeneous background. Moreover, as it was obtained without Barlow, it had to be enlarged by a factor of two to adapt to the scale of the images with Barlow. Nevertheless, the image quality is sufficient to determine the peak centroids with sub-pixel accuracy, as in all other cases.

A representative line scan of the peak profiles is shown in Figure 2. A full-width at half-height

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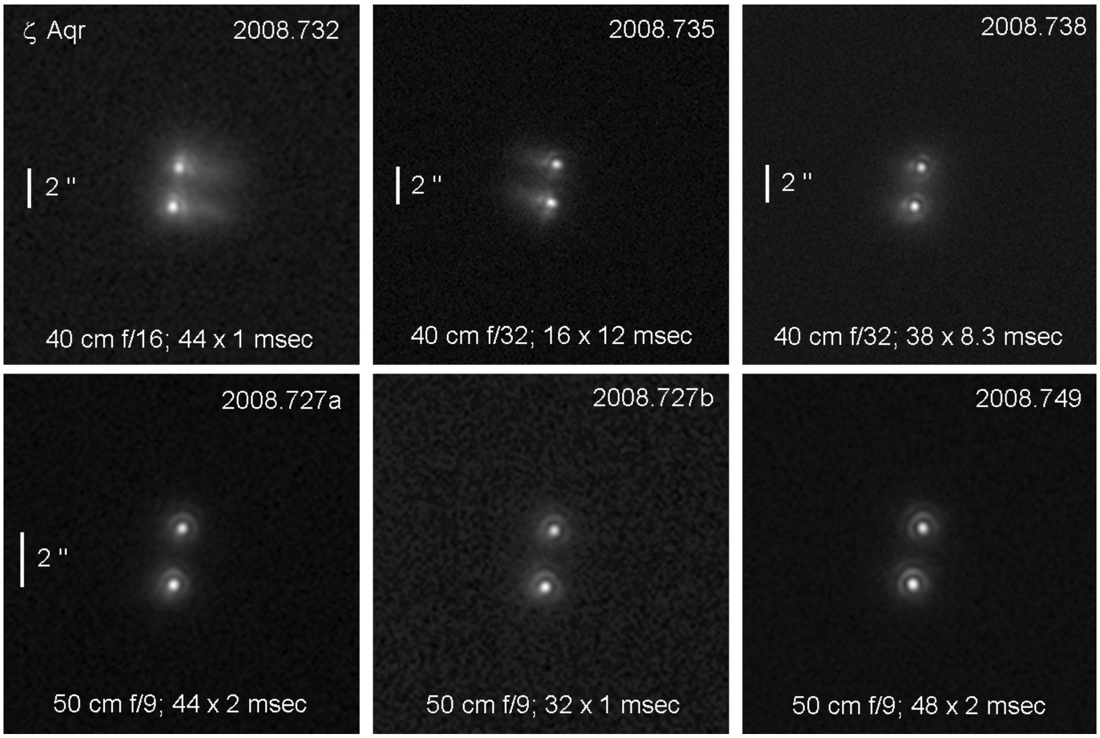

Figure 1: Images of zeta Aquarii, obtained with a 40 cm scope (upper row), and with a 50 cm scope (bottom row) at the indicated dates, with partly varying f-settings. Recording at 2008.732 (upper left) was done without Barlow and filter, all others with Barlow and with red filter. Recordings at 2008.727 a and b were consecutively made and only differ by exposure time. At bottom right, the numbers of superposed frames and exposure times are indicated

(FWHM) of 0.39 arcsec was obtained, which is much smaller than the blurred seeing disc (~ 1 arcsec) resulting from longer exposures, although it does not reach the theoretical value of 0.23 arcsec for a 50 cm scope. This may have two reasons. First, the theoretical limit is derived for a non-obstructed light path, which does not apply here, and second, seeing effects can not completely be eliminated. It should be noted that in any case no further smoothing or non-linear stretching of the grey levels had been applied during image processing. It is also noteworthy that relatively small numbers of superposed frames already lead to rather well defined profiles. This is a consequence of carefully selecting "lucky" images.

In Table 2, the results of position measurements are listed, together with measurements of the brightness differences of the components, and with qualitative estimates of the seeing. The mean value of the position angle is 170.5 degrees, with range 1.5 degrees, and standard deviation +/-0.55 degrees. The mean of separation is 2.094 arcsec, with range 0.037 arcsec, and standard deviation +/-0.014 arcsec.

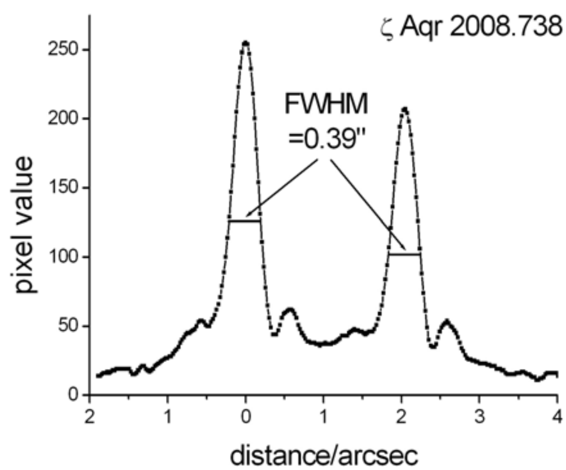

Figure 2: Line scan of the intensity profiles in fig. 1, top right (40 cm Cass.). A full-width at half-height (FWHM) of 0.39 arcsec was obtained. While the Airy diffraction rings are clearly visible, although not quite symmetrical, the relatively increased background at and around the peaks is caused by residual seeing effects.

telescope	date	P.A./degrees	rho/arcsec	I_A/I_B **	Δ mag **	seeing
40cm Cass. f/16 *	2008.732	171.3	2.085	1.031	-0.033	mean
" f/32	2008.735	170.9	2.076	1.196	-0.194	mean
" "	2008.738	170.2	2.113	1.192	-0.191	fair
50cm Cass. f/9	2008.727 a	170.5	2.089	1.192	-0.191	good
"	2008.727 b	170.1	2.108	1.203	-0.201	good
"	2008.749	169.8	2.090	1.171	-0.171	very good
	mean:	170.5	2.094	1.191	-0.190	
	std.dev.:	+/- 0.55	+/-0.014	0.012	0.011	

Table 2: Measurements of position angles (P.A.), separations (rho), intensity ratios (I_A/I_B), and magnitude differences (Δ mag) of the components in the system zeta Aquarii, obtained with two telescopes and at different nights. Qualitative estimates of the seeing are also listed. The total mean values of position and intensity data, as well as their standard deviations are given in the last two lines.

**: Recording without Barlow and filter, all others were made with Barlow and red filter.*
***: For statistical analysis of the intensity data, the measurement without Barlow and filter*

Measurements of the intensity ratios I_A/I_B of the components were done for testing the reproducibility with regard to variable seeing. From the ratios, the differences in magnitude were calculated according to $\Delta mag = -2.5 \log(I_A/I_B)$. Intensities were measured by integrating the pixel values in the peaks, and subtraction of the background in the surroundings. Although the DMK camera is not particularly suited for intensity measurements, as the output only delivers 256 grey levels (although the internal resolution is 10 bits), standard deviations of I_A/I_B and of Δmag were in the range of only one percent. The mean value of Δmag = -0.19 is slightly greater than expected from the visual magnitudes, which are listed as $4.^m34$ and $4.^m49$ (difference $-0.^m15$) in the *Washington Double Star Catalog* [4]. With a standard deviation of my own measurement of the order of $0.^m01$, the difference of $0.^m04$ with respect to the WDS entry appears to be real, and may be due to the different wavelengths at which the measurements were done (red filter – visual), although the spectra of the components, F3IV - F3V, do not seem to be very different.

The position measurements were compared with literature data. For doing this, an additional error of the image scale of +/- 1 percent has to be taken into account, which leads to a total error margin of the separation of about +/- 0.03 arcsec. In Table 3, data from other authors, as well as from my own, which I had obtained with my 10-inch Newtonian at home, are listed. The last row contains the actual entry in the WDS, which probably is the rounded version of the data from refs. [6] and [7]. My present data seem to fit rather well into this trend.

The data in Table 3 reflect orbital motion in that the position angle decreases, while the separation increases. However, deviations from the currently assumed orbit have increased in the last few years beyond the error margins. Figure 3 is adopted from the *6th Catalog of Orbits of Binary Stars* (USNO, [5]) and shows the orbit with markings of own recent measurements. Some more or less obvious, and apparently periodic deviations had also been observed earlier, and led to the assumption of distortions by a third, unseen component with period of about 25

author	date	P.A./ degrees	rho/arcsec
own *	2004.751	177.5	1.88
A. Alzner [6]	2006.79	172.4	1.95
own *	2006.792	171.2	1.91
R. Argyle [7]	2006.810	171.6	2.04
own *	2007.753	171.3	2.05
own *	2007.764	170.6	2.06
R. Argyle [8]	2007.835	170.4	2.11
WDS [4]	2007	172	2.0

Table 3: List of other recent measurements of zeta Aqr.

*: *own measurements with a 10-inch Newton at f/12 at home, unpublished.*

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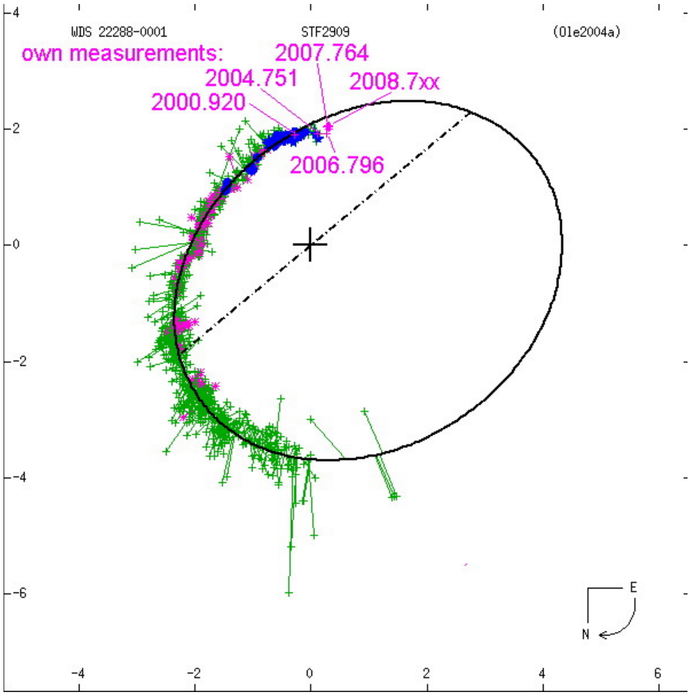

Figure 3: Orbit of zeta Aqr, adopted from the 6th Catalog of Orbits of Binary Stars (USNO). Own measurements are marked with dates. Dates 2008.7xx range from xx = 27 to 49. Error margins are of the order of the symbol size. Deviations from the calculated orbit, as were also seen by other authors, have increased in the last few years.

years, as is described in *Burnham´s Celestial Handbook* [9]. While other authors have suspected this to be an over interpretation with regard to the error limits, the trend of the recent observations seems to support the theory.

B) Beta Phoenicis

Six recordings were also made of the system β Phe (WDS01061-4643), and the resulting images are collected in Figure 4. Exposure times of single frames ranged from 0.25 to 3 milliseconds, and between 40 and 60 best frames were superposed. In all cases, the pair is clearly split, and the Airy diffraction rings are resolved, but they partly coincide with the peaks of the other component. Variations of the seeing conditions are mainly visible in the background.

Figure 5 shows a representative line scan across the peaks of the components. Again, no additional smoothing or non-linear stretching of the grey levels was applied. Decomposition of the profiles resulted in a FWHM of 0.32 arcsec of the individual peaks, which is smaller than in the case of zeta Aqr, due to better seeing. For demonstrating the gain in resolution by lucky imaging, a simulated profile is also plottted, which was obtained by superposing 500 unselected frames, and simulates an exposure of 1/3 second. The

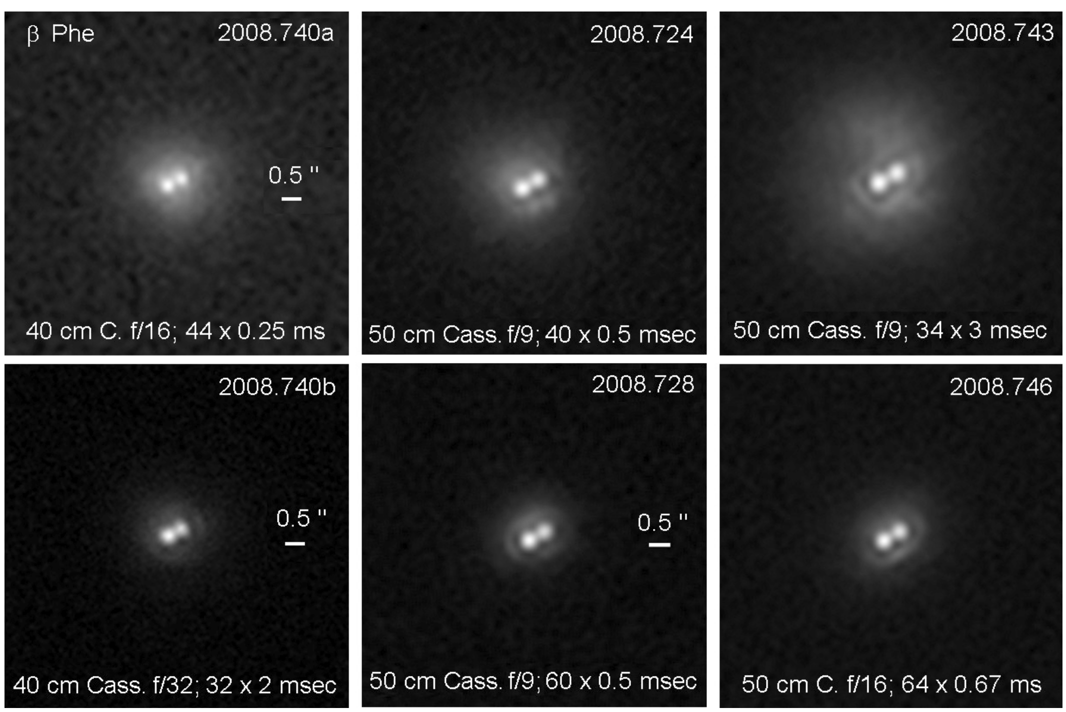

Fig. 4: Images of beta Phe, obtained with the 40 cm Cassegrain, and with the 50 cm Cassegrain at the indicated dates, with partly varying f-settings. Recording at 2008.740 (upper left) was done without Barlow and filter, all others with Barlow and with red filter. Figures at bottom right indicate numbers of superposed frames and exposure times.

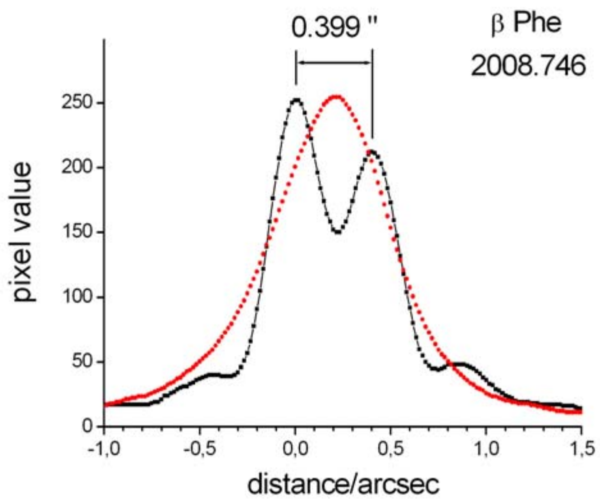

Figure 5: Line scan of the pixel values along the line crossing the peak centroids of both components (black line and data points), taken from the image in fig. 4, bottom right (50 cm telescope). The profile dotted in red is from a superposition of 500 unselected frames (exposure time 0.67 milliseconds), and represents an exposure of 1/3 second.

peaks and diffraction rings are completely smeared out. In Table 4, the results of the individual measurements are listed and analyzed. The range of position angles is 3.3 degrees, with a mean value of 119.4 degrees, and a standard deviation of +/- 1.1 degrees. The range of separation values of 0.014 arcsec, at a mean value of 0.390 arcsec, and the standard deviation of +/- 0.007 arcsec are surprisingly low. However, the total error margin may be somewhat greater for two reasons. First, the error of the calibration constant of about 1 percent has to be added. Second, the peak profiles are slightly distorted by partly overlapping. This effect was analyzed by decomposition and revealed an apparent inward shift of the centroids by about 0.01 arcsec in an average. Thus, the end result of the separation is shifted to 0.40 arcsec, with an estimated total error limit of +/- 0.02 arcsec. These profiles were also analyzed with regard to the resolution limit under the actual seeing conditions. It turned out that Rayleigh´s limit would be reached at separations of about 0.35 arcsec, which is determined by the seeing, not by the telescope.

Unfortunately, no recent data of this system are available in the literature to compare with [10]. An orbit has been calculated in 2001, and the interpolated ephemeris for the date 2008.74 would be 147.7 degrees and 0.420 arcsec [5]. An image of the orbit, adopted from the *6th Catalog of Orbits of Binary Stars*, is shown in fig. 6 [5]. The deviation of my measurements is greater than the error limits. The last entry in the *4th Catalog of Interferometric Measurements of Binary Stars* with date 2001.862 only gives an upper limit of separation of 0.266 arcsec, but no value for the position angle [11]. While the orbit is of grade 5, more measurements in the near future, becoming more feasible with further increasing separation, should reduce ambiguities.

Summary

The technique of so called lucky imaging with

telescope	date	P.A./degrees	rho/arcsec	seeing
40cm Cass. f/16*	2008.740a	117.4	0.398	good
„ f/32	2008.740b	119.2	0.387	very good
50cm Cass. f/9	2008.724	119.4	0.385	mean
„	2008.728	119.8	0.392	very good
„	2008.743	120.7	0.381	mean
„	2008.746	119.7	0.399	very good
	mean:	119.4	0.390	
	std.dev.:	+/- 1.09	+/-0.007	

Table 4: Measurements of position angles (P.A.) and separations (rho) of the system beta Phoenicis. Qualitative characterizations of the seeing conditions are also listed. The total mean values, as well as their standard deviations are given in the bottom two lines.

**: without Barlow, all other recordings were made with Barlow.*

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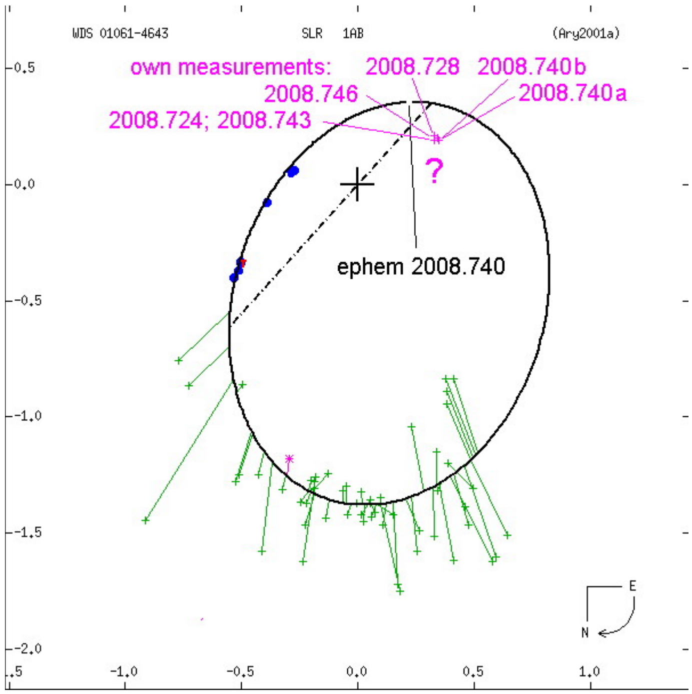

Figure 6: Orbit of beta Phe, adopted from the 6th Catalog of Orbits of Binary Stars, USNO. The expected position, as interpolated from the ephemeris, and my own measurements are marked with dates.

careful selection of only the best images was shown to significantly reduce the size of the seeing disk, and to obtain diffraction limited images almost routinely. However, seeing effects could not completely be eliminated, and the theoretical values of the angular resolution could not quite be reached. Nevertheless, the system beta Phe, with separation 0.40 arcsec, was clearly resolved with both telesopes, and resolution limits according to Rayleigh´s criterion, but affected by the seeing, were estimated to about 0.35 arcsec.

On the other hand, the reproducibility and accuracy of determining peak centroids with standard deviations of the order of +/- 0.01 arcsec is much better than would be expected from the theoretical resolution limits. This scatter is expected to virtually not depend on separation, if not seeing effects like anisoplanatic variations play a role. The total error margin, however, has to include that of the scaling factor of about one percent. In addition, a correction had to be applied in the case of beta Phe, due to partly overlapping peaks, which resulted in the value given above. Clearly, the error margins of the position angle, i.e. +/- 1.1 degrees for beta Phe, and +/- 0.6 degrees for zeta Aqr, with separation 2.09 arcsec, depend on separation, because the resolution in the image is fixed by the pixel size.

The results were compared with literature data, as far as possible. In the case of zeta Aqr, deviations from the currently assumed orbit, which have also been observed by other authors, support the assumption of the existence of a third component, which produces a periodic wobble on the orbit, not only recently. The system beta Phe seems to have been neglected in recent years, and no actual data exist to compare with. My own measurements deviate from the currently assumed orbit by more than the error limits. Provided that this will be confirmed in the future, the ephemeris could possibly be upgraded.

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The author is a retired physicist from Hamburg University, Germany, and has worked on double stars with fast cameras since 1995 at home, and sometimes in Namibia.

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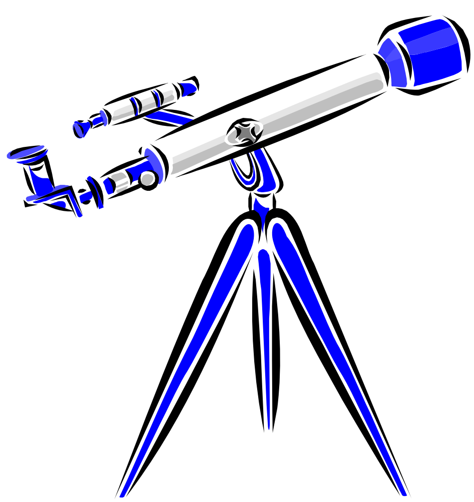

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