Double and Multiple Star Measurements at the Northern Sky with a 10”-Newtonian and a Fast CCD Camera in 2010

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Abstract: 62 double and multiple star systems were recorded with a 10”-Newtonian and a fast CCD camera, using the technique of “lucky imaging”. Measurements were compared with literature data, and particular deviations are discussed. B/w and color images of some noteworthy examples are also presented.

Introduction

This is a continuation of earlier work, which has been reported in this journal [1-3]. As has been demonstrated, seeing effects can effectively be reduced by using the technique of “lucky imaging”, and the resolution and accuracy of measurements can be pushed to their limits, given mainly by the size of the telescope. In this report, measurements are described, which I obtained with my 10”-Newtonian at home in 2010. Only the camera was replaced by a type with higher resolution, which helps to measure especially close pairs more accurately. 62 double and multiple systems were investigated, often more than once, and a total of 101 measurements on 72 pairs were obtained and compared with literature data. Although in most cases stars are brighter than 10 mag, data are often scarce, and exhibit large scatter. 41 pairs are binaries with more or less well known orbits. In some cases, deviations from ephemeris data were found, in accordance with measurements from other authors. These will be discussed in more detail.

Instrumental

The telescope is a Newtonian with 10 inch (~25 cm) aperture and a focal ratio of f/6. Recordings were all made with a 2x Barlow lens. A red filter was used, which reduces its chromatic aberration in the infrared, as well as the atmospheric spectrum. Additional recordings were done with near infrared, green and blue filters, in order to produce RGB-composites. The new camera was the b/w-version of the DMK31AF03.AS (*The Imaging Source*) with pixel size 4.65 µm square, which results in an approximate resolution of about 0.16 arcsec/pix. A more exact calibration was obtained by an iterative method by measuring well documented double stars, as has been described in earlier work. All other parameters were the same as before. Exposure times ranged from a few milliseconds to 0.5 sec, depending on the star brightness and on the seeing. Recordings comprised between 500 and 3000 frames, of which the 50 to 100 best ones were used for further processing, which included re-sampling, registering, and stacking.

Calibration

Of the 72 pairs, 25 were found to be suitable as reference for calibration of the image scale, as they are sufficiently well documented in the literature, and data can unambiguously be extrapolated to the actual date. Sources are the WDS [4], and, preferably, the so-called speckle catalog [5]. These pairs are marked by shaded lines in the table below, which contains all measurements. The calibration constant was adjusted such that the sum of the residuals of the separation ($\rho_{meas.} - \rho_{lit.}$), as well as the standard deviation assumed minimum values. This resulted in a value of 0.162 ± 0.001 arcsec/pix, corresponding to

±0.6 %. The standard deviation of the residuals is ±0.03 arcsec, with range between -0.1 and +0.05 arcsec. The final residuals are plotted in Figure 1. The total error margin, in absolute terms, is taken as the sum of the statistical error, and that of the calibration constant. This is also plotted in Figure 1. While the former is a constant, the latter increases with separation. It should be noted that scatter can also be caused by errors of the literature data, which are often difficult to estimate. The large residuals of #8 (iota Cas), #61 (STT 513 in And), and #62 (STF3050 in And) are more or less due to unexpected deviations from trends or from calculated orbits, respectively. A general problem arises for separations around 1”, because of interference with the diffraction ring of the main star, in particular, when the companion is significantly dimmer. This seems to affect #37, as well as #19 and #27 in Figure 2 below.

Position angles were measured by referring to star trails in east-west direction, which were obtained by superposing frames with short exposures, while the system was drifting across the field with the telescope drive shut off. This was done for every recording of any system in order to avoid errors, which may occur by slight misalignment of the mounting. The residuals of the position angles (P.A.) are plotted versus the separation rho in Figure 2. When taking into account only the reference systems, statistics yields a standard deviation of ±0.46 degrees with range between -1.1 and +1.1 degrees. Deviations increase with decreasing separation, because the lateral resolution is fixed by the pixel size.

Measurements

All measurements are listed in the following table, which contains the name of the system, the position in right ascension and declination, the magnitudes of the components (all taken from the WDS), the measured position angles (PA) in degrees, and separations (rho) in arcsec, the date, the number of recordings, the residuals in PA and in rho, and the number of individual notes, which follow the table. Systems used for calibration of the image scale are marked with shaded lines. In some cases, residuals are referred to the ephemeris, which is taken from the *Sixth Catalog of Orbits of Visual Binary Stars* [6].

Discussion and Conclusion

Most of the double and multiple star systems investigated here are well known. Nevertheless, in many cases, there are only few data found in the literature, and these often exhibit large scatter. As one can see from Figures 1 and 2, and from the table notes, there are a number of systems with residuals which exceed the error limits of the measurements for

(Continued on page 85)

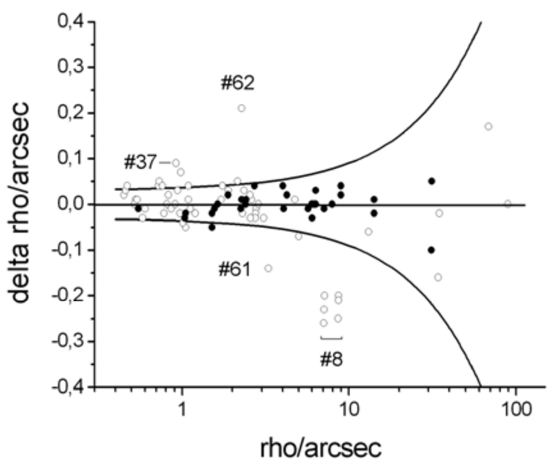

Figure 1: Plot of the residuals of rho versus rho. Semi-logarithmic scale. Full circles denote systems, which have been used for calibration of the image scale, open circles all others. The curves represent the total statistical error limits. Pairs with particular deviations are marked with their note numbers.

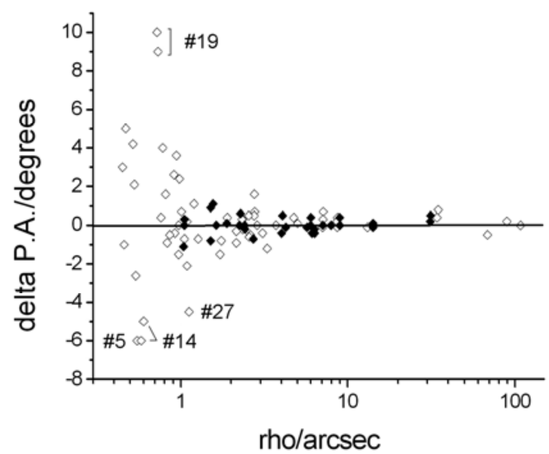

Figure 2: Plot of the residuals of the position angle versus rho. Full rhombs represent reference systems, open symbols all others. The increase of scatter towards small separations is mainly caused by the fixed image resolution. Some pairs with large deviations are marked with their note numbers.

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PAIR	RA + DEC	MAGS	PA meas.	rho meas.	DATE	N	delta PA	delta rho	NOTES
STT 547 AB	00 05.7 +45 49	8.98 9.15	186.4	6.01	2010.723	1	+0.4	-0.03	1
STF 3062	00 06.3 +58 26	6.42 7.32	349.2	1.51	2010.796	1	+0.9	-0.02	2
STF 60 AB	00 49.1 +57 49	3.52 7.36	322.0	13.15	2010.774	4	-0.1	-0.06	3
STF 61	00 49.9 +27 43	6.33 6.34	115.2	4.25	2010.796	1	-0.1	+0.02	4
STT 20 AB	00 54.6 +19 11	6.12 7.19	~175	0.55	2010.796	1	~-6	-0.01	5
STF 73 AB	00 55.0 +23 38	6.12 6.54	323.1 324.5	1.04 1.05	2010.725 2010.774	1 1	-1.1 +0.3	-0.03 -0.02	6
STF 228	02 14.0 +47 29	6.56 7.21	296.7	0.78	2010.777	1	+4?	-0.02	7
STF 262 AB		4.63 6.92	230.8 231.7 230.6	2.77 2.76 2.75	2010.774 2010.777 2010.796	1 1 1	+1.8 +2.7 +1.6	+0.17 +0.16 +0.15	
STF 262 AC	02 29.1 +67 24	4.63 9.05	116.2 115.4 115.8	7.14 7.08 7.11	2010.774 2010.777 2010.796	1 1 1	+0.7 -0.1 +0.3	-0.20 -0.26 -0.23	8
STF 262 BC		7.6 8.6	99.3 98.8 99.1	8.67 8.66 8.62	2010.774 2010.777 2010.769	1 1 1	+0.4 -0.1 +0.2	-0.20 -0.21 -0.25	
STF 1865 AB	14 41.1 +13 44	4.46 4.55	295.8 297.9	0.53 0.52	2010.419 2010.422	11	+2.1 +4.2	+0.01 ~0	9
STF 1888 AB	14 51.4 +19 06	4.76 6.95	307.8	6.00	2010.422	1	~0	~0	10
STT 288	14 53.4 +15 42	6.89 7.55	161.0	1.05	2010.419	1	~0	-0.02	11
STF 1909	15 03.8 +47 39	5.20 6.10	59.3	1.51	2010.419	1	-0.8	-0.05	12
STF 1932 AB	15 18.3 +26 50	7.32 7.41	263.9	1.63	2010.456	1	~0	~0	13
STF 1937 AB	15 23.2 +30 17	5.64 5.95	~167 ~166	0.60 0.58	2010.419 2010.456	1 1	~-5 ~-6	-0.01 -0.03	14
STF 28 AB	15 24.5 +37 23	4.33 7.09	170.7	107.7	2010.419	1	~0	?	15
STF1938 Ba-Bb		7.09 7.63	6.6	2.28	2010.419	2	+0.6	+0.01	
STF 1954 AB	15 34.8 +10 32	4.17 5.16	172.2	4.02	2010.419	1	-0.4	+0.04	16
STT 298 AB	15 36.0 +39 48	7.16 8.44	178.0	1.05	2010.419	1	-0.7	-0.05	17
STF 1965	15 39.4 +36 38	4.96 5.91	305.4	6.31	2010.456	1	-0.2	~0	18
STF 1967	15 42.7 +26 18	4.04 5.60	~121 ~120	0.72 0.73	2010.419 2010.456	1 1	+10? +9?	+0.04 +0.05	19
STF 1988	15 56.8 +12 29	7.59 7.84	250.2	1.89	2010.459	1	+0.1	+0.02	20
STT 303 AB	16 00.9 +13 16	7.69 8.06	173.6	1.56	2010.459	1	+1.1	-0.01	21
STF 2021 AB	16 13.3 +13 32	7.43 7.48	356.3	4.07	2010.459	1	+0.5	-0.01	22
STF 2032 AB	16 14.7 +33 52	5.62 6.49	237.4	7.10	2010.456	1	~0	-0.01	23
STF 2054 AB	16 23.8 +61 42	6.15 7.09	349.4	0.97	2010.419	1	-1.5	-0.02	24
STF 2052 AB	16 28.9 +18 25	7.69 7.91	120.1	2.25	2010.459	1	~0	-0.01	25
STF 2078 AB	16 36.2 +52 55	5.38 6.42	104.0	3.09	2010.419	1	-0.4	-0.03	26
STF 2078 AC		5.38 5.50	193.1	89.4	2010.419	1	+0.2	0	
STF 2084	16 41.3 +31 36	2.95 5.40	~170	1.12	2010.419	1	~-4.5	-0.01	27
STF 2118 AB	16 56.4 +65 02	7.07 7.30	67.7 64.9	1.01 1.09	2010.419 2010.459	1 1	+0.7 -2.1	-0.04 +0.04	28
STF 2130 AB	17 05.3 +54 28	5.66 5.69	7.5 7.3	2.41 2.42	2010.459 2010.723	1 1	~0 -0.2	~0 +0.01	29

Table continued on next page.

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PAIR	RA + DEC	MAGS	PA meas.	rho meas.	DATE	N	delta PA	delta rho	NOTES
STF 2140 AB	17 14.6 +14 23	3.48 5.40	102.9	4.75	2010.459	4	+0.4	+0.01	30
STF 2220 A-BC	17 46.5 +27 43	3.49 9.78	248.8	34.88	2010.681	1	+0.8	-0.02	31
AC 7 BC		10.2 10.7	244.9	1.09	2010.681	1	+0.2	+0.01	
STT 338 AB	17 52.0 +15 20	7.21 7.38	164.1 161.6	0.81 0.83	2010.459 2010.681	1 1	+1.6? -0.9	~0 +0.02	32
STF 2245 AB	17 56.4 +18 20	7.43 7.55	290.5 290.4	2.61 2.57	2010.459 2010.681	1 1	-0.5 -0.6	+0.01 -0.03	33
STF 2264	18 01.5 +21 36	4.85 5.20	256.7 256.7	6.33 6.30	2010.456 2010.681	1 1	-0.4 -0.4	+0.03 ~0	34
STF 2280 AB	18 07.8 +26 06	5.81 5.84	183.1 182.9	14.21 14.18	2010.459 2010.681	1 1	+0.1 -0.1	+0.01 -0.02	35
STF 2289	18 10.1 +16 29	6.65 7.21	220.4	1.20	2010.459	1	+1.1	-0.02	36
AC 11	18 25.0 -01 35	6.71 7.21	354.2	0.92	2010.459	1	-0.4	+0.09	37
STF 2316 AB	18 27.2 +00 12	5.38 7.62	320.3	3.72	2010.459	4	~0	?	38
STF 2351	18 36.2 +41 17	7.60 7.64	160.1	5.00	2010.681	1	+0.1	-0.07	39
STF 2382 AB	18 44.3 +39 40	5.15 6.10	347.1 347.4	2.35 2.30	2010.456 2010.681	1 1	-0.2 +0.1	+0.03 -0.02	40
STF 2383 CD		5.25 5.38	78.1 78.1	2.34 2.33	2010.456 2010.681	1 1	+0.3 +0.3	- -	
STFA 37 AD		5.15 5.38	171.9 172.0	206.6 206.7	2010.456 2010.681	1 1	<1 <1	-1.4? -1.3?	
STF 2375 AB	18 45.5 +05 30	6.34 6.73	119.7	2.55	2010.459	1	+0.5	+0.02	41
STFA 43 AB	19 30.7 +27 57	3.19 4.68	53.9	34.27	2010.681	4	+0.4	-0,16	42
STF 2579 AB	19 45.0 +45 08	2.89 6.27	219.5	2.72	2010.723	1	-0.7	+0.04	43
STT 410 AB	20 39.6 +40 35	6.73 6.83	3.0	0.86	2010.681	1	-0.5	-0.01	44
STT 410 AB-C		6.76 8.72	68.5	68.27	2010.681	1	-0.5	+0.17	
STF 2725 AB	20 46.2 +15 54	7.54 8.20	10.5	6.11	2010.774	1	-0.4	~0	45
STF 2727 AB	20 46.7 +16 07	4.36 5.03	265.9 265.5	8.96 8.98	2010.672 2010.774	1 1	+0.4 ~0	+0.02 +0.04	46
STT 413 AB	20 47.4 +36 29	4.73 6.26	5.7 4.5 4.7	0.94 0.98 0.91	2010.681 2010.723 2010.777	1 1 1	+3.6 +2.4 +2.6	+0.03 +0.07 ~0	47
STF 2737 AB	20 59.1 +04 18	5.96 6.31	~289 ~285 ~291	0.45 0.46 0.47	2010.681 2010.723 2010.724	1 1 1	+3 -1 +5	+0.02 +0.03 +0.04	48
STF 2737 AB-C		5.30 7.05	66.2 66.2 68.4	10.34 10.40 10.32	2010.681 2010.723 2010.724	1 1 1	- - -	- - -	
STF 2742	21 02.2 +07 11	7.41 7.64	213.9	2.87	2010.681	1	~0?	~0?	49
STF 2758 AB	21 06.9 +38 45	5.20 6.05	151.3 151.6	31.20 31.35	2010.774 2010.777	1 1	+0.2 +0.5	-0.10 +0.05	50
AGC 13 AB	21 14.8 +38 03	3.83 6.57	229.1 224.2	0.97 0.91	2010.673 2010.723	1 2	- -	- -	51
STF 2799	21 28.9 +11 05	7.37 7.44	261.3	1.90	2010.777	1	+0.4	+0.03	52
STF 2822 AB	21 44.1 +28 45	4.75 6.18	313.2 312.5	1.75 1.72	2010.673 2010.777	1 1	-0.8 -1.5	+0.04 +0.01	53
STF 2843 AB	21 51.6 +65 45	7.01 7.28	150.2	1.22	2010.774	1	-	-	54
STF 2863 AB	22 03.8 +64 38	4.45 6.40	274.6	7.95	2010.774	1	~0	~0	55
STF 2909	22 28.8 -00 01	4.34 4.49	168.1 168.6	2.15 2.15	2010.673 2010.681	1 1	-0.9 -0.3	+0.05 +0.05	56
BU 720	23 34.0 +31 20	5.67 6.11	101.9	0.54	2010.777	1	-2.6	+0.01	57
STT 507	23 48.7 +64 53	6.76 7.76	316.3	0.76	2010.777	1	+0.4	+0.04	58
STF 3042	23 51.9 +37 53	7.62 7.75	86.3	5.70	2010.723	1	-0.1	-0.01	59
BU 728 AB	23 52.2 +43 31	8.69 8.94	8.6	1.27	2010.723	1	-0.7	-	60
STT 513	23 58.4 +35 01	6.82 9.34	16.3	3.24	2010.723	1	-1.2	-0.16	61
STF 3050	23 59.5 +33 43	6.46 6.72	336.7	2.28	2010.723	1	+0.6	+0.21	62

Notes:

Terms "cpm" (common proper motion), and "relfix" are taken from Burnham [7].

1. in Andromeda, binary, P=360 y, „premature“ orbit.
2. in Cassiopeia, binary, P=107 y, many speckle data.
3. eta Cassiopeiae, binary, P=480 y, color contrast.
4. 65 Piscium, cpm, deemed relfix, but rho seems to slowly decrease.
5. 66 Piscium, binary, P=360 y, many speckle data, large residual of P.A. because of close distance.
6. 36 Andromedae, binary, P=168 y, many speckle data.
7. in Andromeda, binary, P=144 y.
8. ι Cassiopeiae, triple, AB binary, P=841 y, B shows periodic deviations from orbit, and seems to be in a phase of large deviation from the calculated orbit. The measured position agrees reasonably well with recent speckle data, residuals referred to speckle data. Both separations of AC and BC appear to rapidly decrease. Residuals given against speckle data of 2005.
9. ζ Bootis, binary, P=123 y, rho is close to resolution limit, nevertheless the measured position fits to the ephemeris within the error margin. Some recent speckle data significantly deviate. See fig. 3 and ref. [3].
10. ξ Bootis, binary, P=151.5 y.
11. in Bootes, binary, P=210 y.
12. 44 Bootis, binary, P=225 y, orbit highly inclined.
13. in Corona Borealis, binary, P=203 y.
14. η Coronae Borealis, binary, P=41.6 y, separation close to resolution limit, residuals against ephemeris. See fig. 3.
15. μ - μb Bootis, residuals ambiguous, because of too few data with large scatter. μb binary, P=246 y. See fig. 4.
16. δ Serpentis, binary, “premature” orbit, P=1038 y?
17. in Bootes, binary, P=55.6 y.
18. ζ Coronae Borealis, relfix.
19. γ Coronae Borealis, binary, P=93 y, orbit

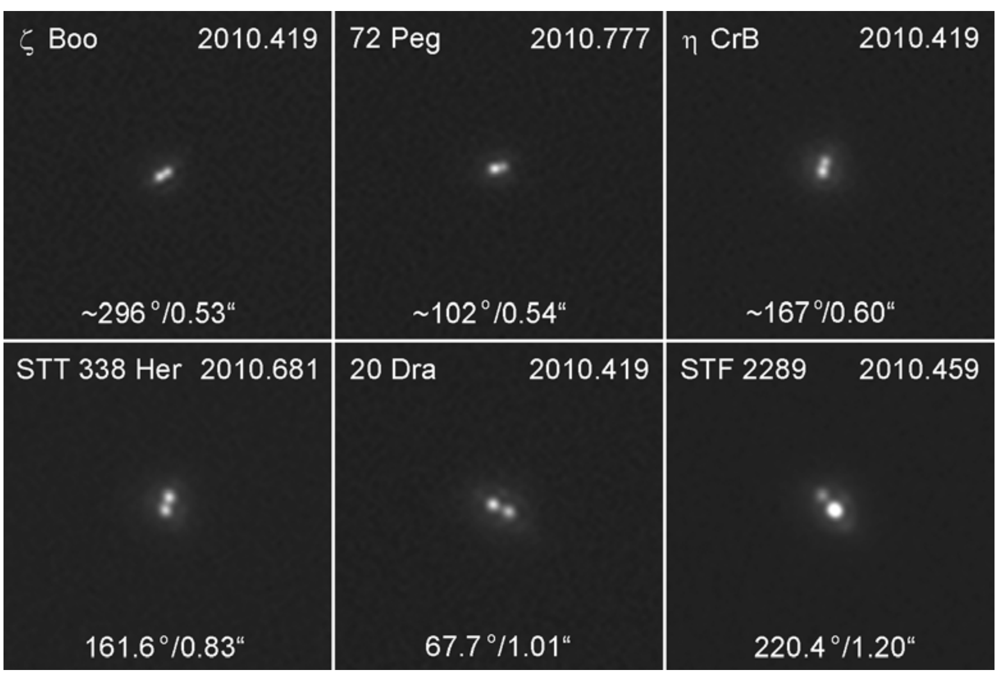

Figure 3: Some close pairs, partly at the resolution limit. All are binaries with more or less definite orbits, except STT 338, for which orbital motion is not yet obvious. All images are to scale. See also notes #9, 57, 14, 32, 28, and 36 (from top left to bottom right).

highly inclined, difficult, because of dim companion on diffraction ring of main star, estimated P.A. ambiguous.

20. in Serpens, P.A. and rho slowly decreasing.
21. in Serpens, rho slowly increasing.
22. 49 Herculis, P.A slowly increasing.
23. σ Coronae Borealis, binary, P=1000 y.
24. in Draco, P.A. and rho decreasing.
25. in Hercules, binary, P=257 y.
26. 16 –17 Draconis, triple, cpm. AB: P.A. and rho dec, AC: P.A. dec, few data with large scatter, residuals against last entry in WDS.
27. ζ Herculis, binary, P=34.5 y, difficult, because dim companion on diffraction ring of main star. Nevertheless, estimated position fits well to ephemeris.
28. 20 Draconis, binary, “premature” orbit, highly inclined, P=422 y. See fig. 3.
29. μ Draconis, binary, P=672 y, own measures closely continue on the trend of speckle data, but all deviate from calculated orbit.
30. α Herculis, binary, premature orbit, considerable scatter of literature data for rho. Color contrast. See fig. 6.
31. μ Herculis, P.A. and rho inc, BC binary, P=43.2 y. Residuals against last entry in WDS.
32. in Hercules, P.A. dec. Although close, orbital movement not obvious. See fig. 3.
33. in Hercules, relfix, cpm, P.A. slowly decreasing.
34. 95 Herculis, relfix, cpm, P.A. slowly decreasing.
35. 100 Herculis, relfix, cpm.
36. in Hercules, binary, “premature” orbit, P=3040 y, measured position deviates from ephemeris, in accordance with most recent speckle data. See fig. 3.
37. in Serpens, binary, P=240 y, orbit highly inclined, recent rho data tend to deviate from calculated ephemeris.
38. 59 Serpentis, cpm, large scatter of rho data in literature. Weak color contrast.
39. in Lyra, relfix.
40. ε Lyrae, both binaries, ε1 (AB) “premature” orbit, ε (CcD) P=724 y. Residuals for AD ambiguous, because of too few data with large scatter.
41. in Serpens, quadruple system, Aa, Bb not resolved here. Residuals against speckle data of 2007.
42. β Cygni, large scatter of literature data, residuals against speckle data of 2003. Color contrast. See fig. 6.

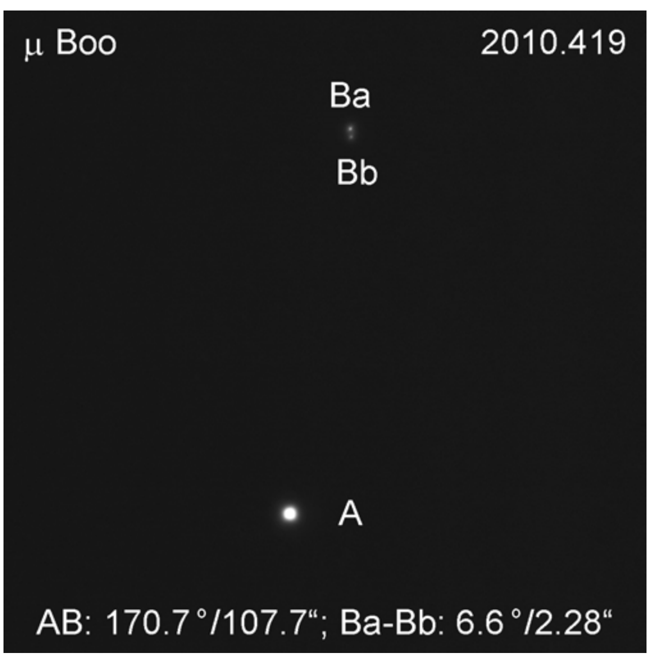

Fig. 4: The triple mu Bootis. The pair Ba-Bb (mu^2) is a binary with period 246 years, and seems to be physically connected to A. See also note #15.

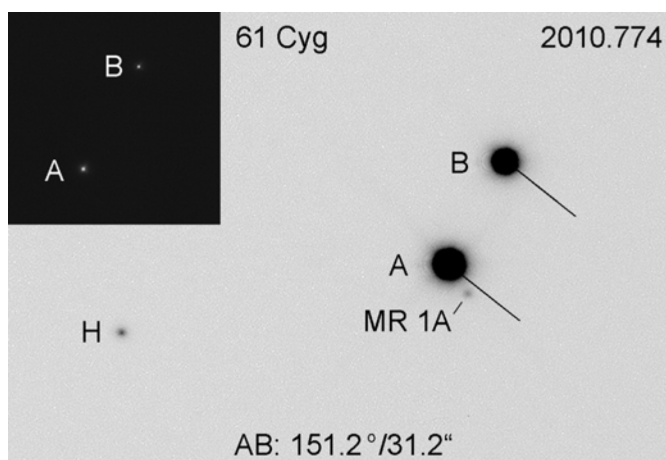

Fig. 5: The famous binary 61 Cygni forms a temporary triple by passing near the faint background star MR 1A of about 10th magnitude. The current distance is about 9.5” from A. H is another background star at distance 89”. The straight lines indicate the proper motion of A and B (about 5”/y) within the next five years. 131 frames at 0.5 sec. The inset shows the pair recorded with exposure time 17 msec (128 frames). See also note #50.

43. δ Cygni, binary, P=780 y.
44. in Cygnus, triple, AB: P.A. dec, rho slow inc, AC virtually fixed.
45. in Delphinus, binary, “premature” orbit, P=2815 y(?).
46. γ Delphini, P.A. and rho decreasing.
47. λ Cygni, binary, P=391y, periodic deviations from orbit.
48. ε Equulei, AB binary, P=101.4 y, orbit almost edge-on. While AB has been clearly resolved at 0.6” in 2009 [3], it only appears elongated here, as rho has decreased to below 0.5”. Position and residuals estimated. Rho data fit well to ephemeris, but P.A. significantly deviates. AC: P.A. possibly slowly decreasing.
49. λ Equulei, P.A. dec, rho slow inc.
50. 61 Cygni, binary, P=653 y, large proper motion. Main component currently close to faint background star. See fig. 5.
51. τ (65) Cygni, binary, P=49.8 y, difficult, because faint companion on diffraction ring of main star. Position estimated, no residuals given.
52. in Pegasus, binary, P=618 y, both recent speckle data as well as own measures deviate from calculated orbit.
53. μ Cygni, binary, P=789 y, many speckle data.
54. in Cepheus, P.A. increasing, rho decreasing, extrapolation of literature data ambiguous, no residuals given.
55. ξ Cephei, P.A. decreasing, rho increasing.
56. ζ Aquarii, binary, currently assumed orbital period is 487 y, wobble on orbit with period of about 25 years is caused by unseen companion of B. After deviating for more than 6 years, B has returned to the calculated orbit in 2009/2010.
57. 72 Pegasi, binary, P=241 y, speckle measures of separation exhibit peculiar scatter from 1990 to 1995, while the P.A. monotonically increased. Currently slight deviation from orbit. See fig. 3.
58. in Cassiopeia, binary, P=566 y, no recent speckle data.
59. in Andromeda, P.A. decreasing, rho increasing.
60. in Andromeda, large scatter of speckle data for rho, no residuals given.
61. in Andromeda, relfix, few data. Residuals against speckle data of 2005.
62. in Andromeda, binary, P=320 y(?), rho continues to increasingly deviate from calculated orbit. Residuals refer to ephemeris. See also ref. [3].

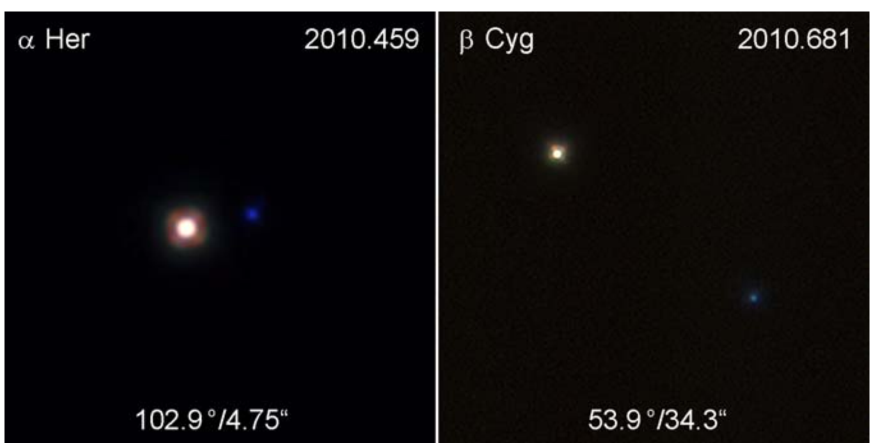

Fig. 6: RGB composites. In alpha Herculis (left), the main component is of spectral class M5, while the companion seems to be itself double, showing a composite spectrum F/G. This would not suggest the very blue color produced here, but nevertheless, reports of visual observers range from vivid bluish-turquoise to bluish-green. Spectra of the components of beta Cygni (right) are K3 and B0. Visual perception ranges from golden-yellow or orange to vivid blue or “sapphire”. Images are not to scale. See also notes #30 and 42, respectively.

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various reasons. Most often, this appears to be caused by ambiguous extrapolation of position data due to scarce literature data. In particular, this applies to pairs with large separations. Such systems are not often measured with interferometric methods, and literature data are mainly visual with large scatter. In several cases, however, deviations from predicted positions follow trends, which are also documented by recent measurements from other authors, especially in the speckle catalog [5]. In particular, close binaries are more frequently investigated with interferometry for obvious reasons. As a general remark, error margins of separation measurements presented here are relatively small, even for close pairs near the resolution limit. However, just for these pairs, errors of P.A. measurements can be quite large. In any case, systems which exhibit significant deviations from calculated orbits, and which deserve special attention, are the following:

- ι Cassiopeiae AB (note #8), component B deviates from the calculated orbit with period of about 52 years, and literature data show large scatter. Currently, rho(BC) seems to rapidly decrease.
- AC 11 in Serpens (note #37), orbit highly inclined, recent rho data tend to deviate from calculated epemeris.
- λ Cygni (note #47), periodic deviations from orbit.
- STF 2799 in Pegasus (note #52), both recent speckle data as well as own measures deviate from calculated orbit.
- ζ Aquarii AB (note #56, see also a more detailed discussion in an earlier paper in this Journal [2]), B has now returned to the calculated orbit.
- 72 Pegasi (note #57), speckle measures of separation exhibit peculiar scatter from 1990 to 1995, while the P.A. monotonically increased. Currently slight deviation from orbit.
- STF 3050 in Andromeda (note #62), the separation continues to deviate from the calculated orbit.

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