Double and Multiple Star Measurements in the Northern Sky with a 10” Newtonian and a Fast CCD Camera in 2006 through 2009

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Abstract: Using a 10” Newtonian and a fast CCD camera, recordings of double and multiple stars were made at high frame rates with a notebook computer. From superpositions of “lucky images”, measurements of 139 systems were obtained and compared with literature data. B/w and color images of some noteworthy systems are also presented.

Introduction

By using the technique of “lucky imaging”, seeing effects can strongly be reduced, and not only the resolution of a given telescope can be pushed to its limits, but also the accuracy of position measurements can be better than this by about one order of magnitude. This has already been demonstrated in earlier papers in this journal [1-3]. Standard deviations of separation measurements of less than +/- 0.05 msec were routinely obtained with telescopes of 40 or 50 cm aperture, even under non-optimum seeing conditions. In this report, similar measurements are described, which I obtained with my 10” Newtonian (~25 cm) at home during the course of more than three years, always with the same camera setup. In 139 investigated double and multiple systems, a total of 169 pairs were measured, often several times. Among these, 54 pairs are more or less well known binaries. 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 of Newtonian type with aperture 10” (~25 cm) and a focal ratio of f/6. In all recordings, I used a 2x Barlow lens (*Televue*), which extends the effective focal length of 3 m. With my b/w-CCD camera (DMK21AF04, *The Imaging Source*) with pixel size 5.6 µm square, this results in a resolution of about 0.19 arcsec/pix. An exact calibration was obtained by an iterative method by measuring well documented double stars, as will be described in the next section. Generally, I used a red filter to cope with chromatic aberration of the Barlow lens, as well as to reduce the atmospheric spectrum. For systems with pronounced color contrast, I also made recordings with near-IR, green and blue filters in order to produce composite images. This setup was the same as I used with telescopes under the southern sky, and as I have described previously [1-3]. Exposure times varied between 0.5 msec and 100 msec, depending on the star brightness, and on the seeing. The procedure of image processing was essentially the same as reported earlier. The best “lucky” frames, out of recordings of a few thousands, were usually selected by visual inspection with the program *VirtualDub*. The typical yield was from several tens to more than a hundred frames, which were then re-sampled, and registered (often manually), and finally automatically stacked. Both registering and stacking was performed with the program *Registax*. This process resulted in smooth intensity profiles, and in position measurements with subpixel accuracy.

Calibration

I calibrated the image scale by measuring a number of double stars with sufficiently well known separations. These are mainly selected from the WDS [4], and the so-called speckle catalog [5]. Criterion was that literature data could unambiguously be extrapolated to the actual date. This may even include binaries. In total, 153 measurements of 58 such systems were obtained, which are contained in the table below, and are marked with shaded lines. The residuals of the separations (rho) are plotted in Figure 1. The calibration constant was adjusted such that the sum of the residuals as well as the standard deviation assumed minimum values. Statistical analysis resulted in a value of 0.194 ± 0.001 arcsec/pix, or ± 0.5 %. The standard deviation of the residuals (of the pairs used for calibration) is 0.03 arcsec, with range between maximum and minimum of 0.1 arcsec. The absolute total error margin is the sum of both contributions, which is also plotted in Fig. 1. Clearly, it increases with separation.

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 error margin was of the order of ±0.1 degree. The residuals of the position angles (PA) are plotted versus the separation rho in Figure 2. Statistics yielded a standard deviation of 0.83 degrees with range between maximum and minimum of +3.5 and -3.1 degrees, respectively. Deviations increase with decreasing separation, mainly because the lateral resolution is fixed by the pixel size. The largest deviations were observed for separations below 1 arcsec.

Results

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 of PA and rho, and the number referring to individual notes, which follow the table. Asterisks denote systems, for which images are shown below. Systems used for calibration of the image scale are marked with shaded lines.

The accompanying images are chosen for different reasons. In general, they show the image quality, which can be obtained with lucky imaging, which is often apparent by the diffraction rings. Images of close systems (Figure 4) demonstrate the resolving power, which is close to the theoretical limit. Other images depict interesting multiple systems. RGB composites are presented of pairs with marked color contrast (Figures 14, 15). In all images, north is down, and east is right. At the bottom, position angles and separations are indicated as measured from the respective image.

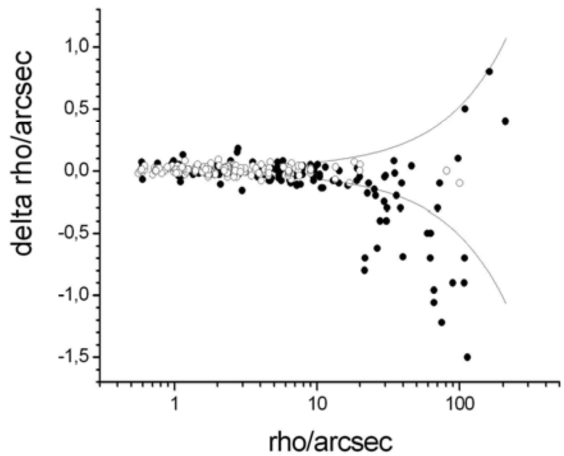

Figure 1: Plot of the residuals of rho versus rho. Semi-logarithmic scale. Open circles represent systems, which have been used for calibration of the image scale, full circles denote all others. The curves mark the total statistical error limits. See text.

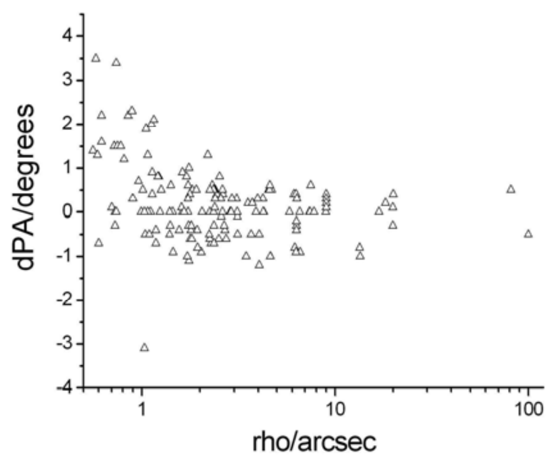

Figure 2: Plot of the residuals of the position angle versus rho. Only systems used for calibration are included here. The increase of scatter towards small separations is mainly caused by the fixed image resolution.

(Continued on page 196)

Double and Multiple Star Measurements in the Northern Sky with a 10" Newtonian ...

PAIR	RA + DEC	MAGS	PA meas.	rho meas.	DATE	N	D PA	D rho	NOTES
HJ 1947 AB	00 16.4 +43 36	6.16 9.83	73.9	8.97	2007.797	1	-0.6	+0.05	1
STF 22 AB-C	00 17.4 +08 53	7.13 7.77	234.1	4.00	2008.661	1	-0.4	+0.02	2
STF 24	00 18.5 +26 08	7.79 8.44	248.1 246.8	5.27 5.21	2006.792 2007.797	1 1	+0.2 -1.1?	+0.07 +0.01	3
AC 1	00 20.9 +32 59	7.27 8.26	288.1 287.4	1.89 1.84	2006.792 2007.797	1 1	~0 -0.2	+0.04 -0.01	4
STF 46	00 39.9 +21 26	5.56 8.49	196.0	6.51	2007.764	4	+0.5	-0.10	5
STF 60AB	00 49.1 +57 49	3.52 7.36	320.7 321.3	12.92 13.00	2007.784 2009.789	4 4	~0 ~0	-0.08 -0.08	6*
STF 60AE		3.52 10.15	124.5	81.1	2009.789	1	+0.5	~0	
STF 61	00 49.9 +27 43	6.33 6.34	295.4 295.6 295.3	4.27 4.24 4.26	2007.764 2008.661 2009.803	1 1 1	~0 +0.3 ~0	+0.02 -0.01 0.01	7
STF 73AB	00 55.0 +23 38	6.12 6.54	318.3 323.4	1.04 1.06	2007.756 2009.789	1 1	-0.5 -0.3	+0.01 ~0	8
STF 79	01 00.1 +44 43	6.04 6.77	193.7	7.80	2007.756	1	+0.1	~0	9
STT 21	01 03.0 +47 23	6.76 8.07	174.0 176.4	1.18 1.22	2007.756 2009.647	1 1	-0.7 +0.8	-0.03 -0.01	10
STF 88AB	01 05.7 +21 28	5.27 5.45	159.3 158.4	29.65 29.45	2007.784 2007.808	1 1	-0.3 -1.1	-0.05 -0.25	11
BU 303	01 09.7 +23 48	7.32 7.56	291.6	0.60	2009.803	1	-0.7	-0.01	12
BU 398	01 11.9 +47 48	9.31 9.38	44.3	1.82	2007.756	1	+0.5	0.01	13
STF 100AB	01 13.7 +07 35	5.22 6.15	63.3	22.50	2007.784	1	+0.5	-0.18	14
STF 174	01 50.1 +22 17	6.33 7.21	164.8 164.2	2.81 2.82	2007.764 2009.803	4 4	+0.4 ~0	-0.03 -0.02	15*
STF 180AB	01 53.5 +19 18	4.52 4.58	0.7 0.8	7.38 7.40	2007.808 2009.803	1 1	~0 ~0	~0 +0.04	16
STF 185AB	02 02.2 +75 30	6.77 8.58	8.5	1.14	2007.808	1	-1.0	+0.01	17
STF 208AB	02 03.7 +25 56	5.82 7.87	340.4	1.26	2007.808	1	+0.5	+0.01	18
STF 205	02 03.9 +42 20	2.31 5.02	63.0 62.7 63.3 62.2 62.9	9.53 9.42 9.45 9.52 9.48	2006.794 2007.753 2007.844 2009.647 2009.789	3 4 4 1 4	~0 -0.3 +0.2 -0.6 ~0	+0.02 -0.08 -0.05 +0.03 ~0	19*
STF 222	02 10.9 +39 02	6.05 6.71	35.1	16.46	2007.753	2	-0.6	-0.12	20
STF 227	02 12.4 +30 18	5.26 6.67	69.5 67.2	3.90 3.83	2007.784 2009.803	1 1	+0.9 -1.4	+0.02 -0.05	21
STF 228	02 14.0 +47 29	6.56 7.21	291.1 294.6 293.6	0.90 0.85 0.81	2007.756 2009.647 2009.789	1 1 1	+0.3 +2.2 +1.2	+0.02 ~0 -0.02	22*
STF 232	02 14.7 +30 24	7.82 7.90	66.8	6.53	2007.784	1	+0.9	-0.07	23
STF 245AB	02 18.6 +40 17	7.26 8.03	292.7	10.96	2007.753	4	-0.8	-0.14	24
STF 262Aa-B	02 29.1 +67 24	4.63 6.92	229.6 230.4	2.74 2.78	2007.784 2009.789	1 3	+0.1 +1.2	+0.15 +0.18	25*
STF 262Aa-C		4.63 9.05	115.7 116.1	7.20 7.19	2007.784 2009.789	1 3	-0.3 +0.1	-0.11 -0.12	
STF 262BC		6.92 9.05	98.9 99.0	8.67 8.67	2007.784 2009.789	1 3	- -	- -	

Double and Multiple Star Measurements in the Northern Sky with a 10" Newtonian ...

PAIR	RA + DEC	MAGS	PA	rho	DATE	N	D PA	D rho	NOTES
STF 93	02 31.8 +89 16	2.1 9.1	233.2	18.29	2007.808	1	+0.2	+0.07	26*
STF 305AB	02 47.5 +19 22	7.52 8.25	306.6	3.67	2007.808	1	-0.5	~0	27
STF 333AB	02 59.2 +21 20	5.17 5.57	209.9 208.9 209.6	1.41 1.39 1.39	2007.808 2007.860 2009.803	1 1 1	+0.6 -0.5 ~0	+0.03 +0.01 +0.01	28*
STT 531AB	04 07.6 +38 04	7.32 9.69	356.6 357.0	2.44 2.53	2007.808 2007.844	1 1	+0.4 +0.8	+0.05 -0.03	29
STF 494	04 08.9 +23 06	7.53 7.65	187.8	5.26	2008.967	1	-0.2	+0.03	30
STT 81AB	04 24.6 +33 58	5.84 9.25	15.8	4.29	2007.844	1	-0.6	-0.03	31
STF 616	04 59.3 +37 53	5.00 8.21	2.4	4.75	2008.112	1	-0.6	+0.02	32
STT 92AB	05 00.3 +39 24	6.02 9.50	278.8	4.05	2008.112	1	-1.2	-0.08	33
STF 644AB	05 10.3 +37 18	6.96 6.78	224.2 222.6	1.59 1.59	2007.844 2008.112	3 4	+1.6 ~0	~0 ~0	34*
VBS 10AC	05 10.3 +37 18	6.96 10.48	191.6	72.4	2008.112	1	-0.6	+0.37	34*
STF 681	05 20.7 +46 58	6.61 9.21	180.1	23.0	2008.112	1	-0.6	-0.1	35
STF 718AB	05 32.3 +49 24	7.47 7.54	72.8	7.66	2008.112	1	-0.5	-0.11	36
STF 764	05 41.3 +29 29	6.38 7.08	14.1	25.7	2008.112	1	~0	-0.2	37
STF 845AB	06 11.6 +48 43	6.16 6.86	358.4	7.47	2008.112	1	+0.6	-0.04	38
STF 918AB	06 34.0 +52 28	7.26 8.19	334.5	4.77	2008.112	1	-0.2	-0.06	39
STT 152	06 39.6 +28 16	6.21 7.85	37.2	0.92	2008.112	1	+1.4	+0.03	40
STF1110AB	07 34.6 +31 53	1.93 2.97	58.2 163.7	4.52 70.1	2009.227	1 1	+0.5 -0.3	~0 -0.3	41*
STF1177	08 05.6 +27 32	6.69 7.41	350.2	3.52	2008.128	1	-0.4	+0.07	42
STF1196AB AC	08 12.2 +17 39	5.30 6.25 " 5.85	47.8 44.8 43.1 69.0 68.6 67.8	0.99 1.03 1.07 6.60 6.55 6.57	2007.121 2008.128 2009.208 2007.121 2008.128 2009.208	1 1 1 1 1 1	~0 ~0 +1.3 -0.9 ~0 ~0	-0.01 ~0 +0.02 +0.06 -0.03 -0.07	43*
STF 1223	08 26.8 +26 56	6.16 6.21	218.0	5.15	2008.128	1	~0	+0.01	44
STF 1245 AB AC AD AE Ax Ay	08 35.8 +06 37	5.98 7.16 - 10.70 - 12.0 - 9.6	24.2 109.3 290.1 206.2 71.4 210.6	10.05 97.6 108.3 113.3 46.0 118.8	2008.128 " " " " "	3 2 2 1 2 1	-1 -0.8 -0.3 -0.8 -1.2 -	+0.05 +0.1 -0.7 -1.5 +0.04 -	45
STF1268 AB	08 46.7 +28 46	4.13 5.99	307.5	30.2	2008.128	4	~0	-0.04	46*
STF1291 AB	08 54.2 +30 35	6.09 6.37	310.2 310.5	1.48 1.52	2008.128 2008.273	1 1	-0.3 ~0	-0.02 +0.02	47
STF1298 AB	09 01.4 +32 15	5.95 8.56	135.3	4.42	2008.128	1	+0.4	-0.01	48
STF1311 AB	09 07.4 +22 59	6.92 7.13 "	199.3 116.5	7.54 27.6	2008.128	3 1	+0.4 -0.5	-0.02 -0.4	49
STF1321 AB	09 14.4 +52 41	7.79 7.88	95.8	16.9	2009.296	1	~0	-0.10	50
STF3121	09 17.9 +28 34	7.9 8.0	220.9	0.60	2008.128	1	+11?	-0.07	51
STF1333	09 18.4 +35 22	6.63 6.69	48.8	1.92	2009.260	1	~0	+0.01	52

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PAIR	RA + DEC	MAGS	PA meas.	rho meas.	DATE	N	D PA	D rho	NOTES
STF1334AB	09 18.8 +36 48	3.92 6.09	224.9	2.62	2009.260	1	+0.4	-0.01	53
STF1338AB	09 21.0 +38 11	6.27 7.08	300.5	1.07	2009.304	1	-1.5	+0.05	54
AC		6.12 11.4	166.5	142.9		1	-	-	
STF1356	09 28.5 +09 03	5.69 7.28	103.1	0.72	2008.128	2	+1.5	+0.02	55
			103.2	0.75	2009.260	3	+1.5	+0.02	
			101.4	0.73	2009.299	1	-0.3	0.0	
			101.8	0.70	2009.301	2	+0.1	-0.03	
			105.3	0.74	2009.304	1	+3.4	+0.01	
STT215	10 16.3 +17 44	7.25 7.46	178.5	1.44	2009.299	1	~0	+0.01	56
STF1424AB	10 20.0 +19 50	2.37 3.64	126.0	4.70	2007.121	1	+0.5	+0.07	57
			124.4	4.63	2008.128	1	-1?	+0.02	
			124.8	4.62	2008.270	5	-1?	+0.02	
			126.2	4.57	2009.244	1	+0.5	-0.04	
			126.4	4.60	2009.301	1	+0.6	-0.02	
STF1426AB	10 20.5 +06 26	7.99 8.30	311.7	0.96	2009.301	2	+0.7	+0.04	58
AC		" 9.43	8.5	7.77		2	~0	+0.04	
STT 217	10 26.9 +17 13	7.85 8.58	149.7	0.78	2009.301	1	+1.5	+0.02	59
STF1450AB	10 35.0 +08 39	5.80 7.90	157.2	2.10	2009.252	1	+0.7	+0.01	60
STF1487	10 55.6 +24 45	4.48 6.30	113.5	6.51	2008.273	1	+1.1	-0.02	61
			112.4	6.45	2009.244	1	~0	-0.08	
STF1523AB	11 18.2 +31 32	4.33 4.80	223.7	1.62	2008.276	2	~0	-0.01	62
			224.6	1.62	2008.311	1	+0.9	-0.01	
			216.9	1.62	2009.244	1	~0	+0.01	
STF1536AB	11 23.9 +10 32	4.06 6.71	102.5	1.91	2008.270	2	+0.5	-0.03	63
			101.1	2.03	2008.273	1	-0.9	+0.09	
			99.9	1.94	2009.244	2	-0.8	-0.02	
			101.1	1.93	2009.301	1	-0.4	-0.03	
STF1543AB	11 29.1 +39 20	5.35 10.67	353.4	5.40	2008.276	1	-0.5	-0.04	64
			354.6	5.38	2009.252	1	+0.7	-0.06	
STF1552AB	11 34.7 +16 48	6.26 7.31	206.9	3.46	2008.270	1	-1	-0.04	65
			208.6	3.54	2009.244	2	+0.2	+0.04	
AC		6.26 9.77	234.0	62.3	2008.270	1	-1	-0.5	
			235.2	62.3	2009.244	2	~0	-0.7	
BC		7.4 8.8?	235.6	59.2	2008.270	1	-1	-0.5	
STF1555AB	11 36.3 +27 47	6.41 6.78	148.1	0.73	2009.299	1	~0	~0	66
			148.3	0.74	2009.304	1	~0	~0	
STF1555AB-C		5.83 11.17	155.8	21.5	2009.299	1	-0.1	-0.8	
			156.5	21.7	2009.304	1	+0.6	-0.7	
STF1561AB	11 38.7 +45 07	6.53 8.23	247.4	8.98	2009.296	1	~0	-0.02	67
STF1579AB-C	11 55.1 +46 29	6.68 8.32	41.6	3.86	2009.296	1	~0	+0.02	68
AB-D		6.68 6.97	113.5	62.5		1	-0.3	-0.5	
STF1596	12 04.3 +21 28	6.18 7.48	235.7	3.73	2008.273	1	+0.2	+0.02	69
STF1622AB	12 16.1 +40 40	5.86 8.71	259.0	11.43	2008.273	4	-0.5	+0.03	70
STF1639AB	12 24.4 +25 35	6.74 7.83	322.7	1.75	2008.276	1	-1.1	-0.03	71
			323.0	1.78	2009.244	1	-0.6	+0.01	
			323.2	1.79	2009.260	1	-0.4	+0.01	
STF1657	12 35.1 +18 23	5.11 6.33	269.8	19.9	2008.273	4	-0.3	-0.05	72
			270.5	20.0	2009.252	4	+0.4	+0.05	
			270.2	19.9	2009.260	1	+0.1	-0.05	
STF1670 AB	12 41.7 -01 27	3.48	38.5	1.01	2008.311	1	+0.5	+0.01	73
		3.53	39.9	1.05	2008.342	1	+1.9	+0.04	
			33.7	1.03	2008.369	1	-3.1?	+0.01	
			30.4	1.21	2009.252	1	+0.8	-0.01	
			28.6	1.24	2009.260	1	~0	+0.01	
			28.6	1.24	2009.296	1	~0	+0.01	

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PAIR	RA + DEC	MAGS	PA meas.	rho meas.	DATE	N	D PA	D rho	NOTES
STF1687 AB	12 53.3 +21 15	5.15 7.08	194.9 196.2 196.5 194.0 193.6	1.13 1.12 1.15 1.11 1.18	2008.276 2009.208 2009.244 2009.260 2009.299	1 1 2 2 2	+0.9 +2.0 +2.1 ~0 -0.4	+0.03 +0.02 +0.01 +0.01 +0.08	74*
STF1687 AC		5.15 9.76	126.5 127.4 127.3 127.2 127.7	28.3 28.4 28.2 28.3 28.3	2008.276 2009.208 2009.244 2009.260 2009.299	1 1 2 2 2	- - - - -	- - - - -	
STF1692	12 56.0 +38 19	2.85 5.52	227.9 229.1	19.0 19.1	2008.273 2009.244	4 4	-0.7 +0.5	-0.08 +0.02	75
BU1082	13 00.7 +56 22	5.02 7.88	100.7 99.1	1.12 1.13	2008.311 2009.244	2 1	+3.6 +0.1	-0.04 -0.02	76
COU 11Aa-B	13 06.4 +21 09	6.10 8.75	314.7 314.2	1.69 1.73	2008.276 2009.260	2 1	-0.8 -1.5?	-0.03 -0.03	77
STT261	13 12.0 +32 05	7.40 7.64	338.3 338.8 339.2	2.50 2.57 2.56	2008.273 2009.244 2009.260	1 1 1	-0.6 -0.1 +0.3	~0 +0.05 +0.04	78
STF1744 AB	13 23.9 +54 56	2.23 3.88	152.7 152.9	14.2 14.3	2008.311 2009.208	3 1	+0.2 -0.6	-0.10 ~0	79
STF1768 AB	13 37.5 +36 18	4.98 6.95	96.7 97.7 97.3 97.1	1.74 1.75 1.73 1.77	2008.273 2009.208 2009.244 2009.260	1 1 1 1	-0.3 +1.0 +0.6 +0.4	-0.04 +0.02 ~0 +0.04	80
STF1772 AB	13 40.7 +19 57	5.76 9.60	132.5	4.58	2008.276	1	-0.8	-0.08	81
STF1770	13 43.1 +03 32	5.55 8.31	226.6	2.73	2008.369	1	-0.6	-0.05	82
STF1785	13 49.1 +26 59	7.36 8.15	179.0 180.5 180.9	3.13 3.12 3.09	2008.276 2009.244 2009.299	1 1 1	-0.5 -0.1 +0.3	-0.01 ~0 -0.01	83
STF1821 AB	14 13.5 +51 47	4.53 6.62	234.4 234.2	13.4 13.5	2008.276 2008.344	1 1	-0.8 -1.0	-0.07 +0.03	84
STFA 26 AB	14 16.2 +51 22	4.76 7.39	32.0	38.4	2008.344	1	-0.4	-0.30	85
STF1834	14 20.3 +48 30	8.09 8.29	103.1 102.6	1.56 1.60	2008.276 2009.252	1 1	-0.4 +0.1	-0.01 +0.03	86
STF1850 AB	14 28.6 +28 17	7.11 7.56	261.0	25.2	2008.276	1	-0.2	-0.15	87
STF1864 AB	14 40.7 +16 25	4.88 5.79	109.7	5.52	2008.276	1	-0.8	~0	88
STF1865 AB	14 41.1 +13 44	4.46 4.55	298.2 297.4 298.5 296.6 296.3	0.62 0.56 0.58 0.62 0.59	2008.317 2008.344 2009.252 2009.260 2009.301	1 1 1 1 1	+2.2 +1.4 +3.5 +1.6 +1.3	+0.01 -0.02 ~0 +0.04 +0.01	89*
STF 1877 AB	14 45.0 +27 04	2.58 4.81	343.3	2.86	2009.304	4	~0	+0.01	90
STF 1884	14 48.4 +24 22	6.58 7.48	55.8	2.17	2008.342	1	-	-	91
STF 1890	14 49.7 +48 43	6.31 6.67	45.2	2.69	2008.276	1	-0.4	+0.04	92
STF1888 AB	14 51.4 +19 06	4.76 6.95	309.0 309.7	6.18 6.13	2008.276 2009.208	1 1	-0.8 +0.4	+0.01 +0.03	93*
STF1888AC		4.76 12.6	340.4	71.6	2008.311	1	-	-	
STF1888AD		4.76 9.6	286.0	161.1	2008.311	1	~0	+0.8	
ARN11 AE		4.76 8.65	98.3	271.6	2008.311	1	-	-	
STT288	14 53.4 +15 42	6.89 7.55	161.5	1.09	2008.276	1	-0.5	+0.01	94

Double and Multiple Star Measurements in the Northern Sky with a 10" Newtonian ...

PAIR	RA + DEC	MAGS	PA meas.	rho meas.	DATE	N	D PA	D rho	NOTES
STF1909	15 03.8 +47 39	5.20 6.10	57.0	1.72	2008.276	1	-1.0	-0.05	95
			58.6	1.73	2008.383	1	+0.3	-0.03	
			60.1	1.70	2009.299	1	+0.8	+0.03	
STFA 28AB	15 24.5 +37 23	4.33 7.09	169.9	107.4	2008.276	1	-1.1	-0.9	96
			170.0	108.7	2008.311	1	-1.0	+0.5	
			170.8	107.4	2009.299	1	-0.2	-0.9	
STF1938BC		7.09 7.63	5.1	2.28	2008.276	1	-0.7	+0.03	97
			5.2	2.25	2008.311	1	-0.6	~0	
			5.4	2.25	2009.299	1	~0	~0	
STF1954AB	15 34.8 +10 32	4.17 5.16	172.2	4.05	2008.342	1	-0.5	+0.05	98
			173.1	3.97	2008.383	1	+0.3	-0.03	
STF1965AB	15 39.4 +36 38	4.96 5.91	304.5	6.27	2008.342	1	-0.9	-0.04	99
			305.9	6.29	2009.252	1	+0.4	-0.02	
			305.2	6.31	2009.260	1	-0.3	~0	
STF1967	15 42.7 +26 18	4.04 5.60	114.7	0.76	2009.260	1	+4.7	+0.06	100
STF1970AB	15 46.2 +15 25	3.66 9.96	263.9	30.5	2008.383	1	~0	-0.4	101
STF2032AB	16 14.7 +33 52	5.62 6.49	236.1	7.03	2008.342	1	-0.1	-0.04	102
STF2054AB	16 23.8 +61 42	6.15 7.09	349.7	1.02	2009.304	2	-1.3	+0.03	103
STF2078AB	16 36.2 +52 55	5.38 6.42	104.2	3.11	2009.304	1	~0	+0.02	104*
STFA 30AC		5.38 5.50	193.3	89.4		1	+0.3	-0.9	
STF2084	16 41.3 +31 36	2.95 5.40	193.3	1.07	2008.369	1	~0	-0.02	105
STF2118AB	16 56.4 +65 02	7.07 7.30	66.9	1.03	2009.304	1	~0	-0.02	106
STF2130AB	17 05.3 +54 28	5.66 5.69	9.8	2.35	2008.369	1	~0	-0.05	107
			9.2	2.36	2008.383	2	-0.7	+0.01	
			10.1	2.39	2008.388	1	+0.3	+0.04	
			9.2	2.39	2009.304	1	+0.5	+0.03	
STF2140AB	17 14.6 +14 23	3.48 5.40	103.1	4.69	2008.369	1	-0.4	-0.08	108
STF2161AB	17 23.7 +37 09	4.50 5.40	318.3	4.01	2008.344	4	-0.5	~0	109
BU 962AB	17 35.0 +61 53	5.28 8.54	320.7	1.10	2008.383	1	~0	-0.09	110
STF2199	17 38.6 +55 46	8.03 8.60	56.8	2.05	2009.304	1	~0	+0.04	111
STF2220A-BC	17 46.5 +27 43	3.42 9.78	248.1	35.1	2008.344	1	-0.6	-0.02	112*
AC 7BC		10.2 10.7	236.4	1.06	2008.344	1	-0.6	-0.04	
			237.4	1.13	2008.369	1	+0.4	+0.03	
STF2264	18 01.5 +21 36	4.85 5.20	257.5	6.34	2007.545	11	+0.3	+0.01	113
			257.0	6.31	2008.344	1	-0.2	-0.01	
			256.4	6.32	2009.647		-0.4	~0	
STF2383AB	18 44.3 +39 40	5.01 6.10	348.6	2.38	2008.383	2	+0.1	+0.03	114*
			349.1	2.36	2008.388	1	+0.5	+0.01	
			348.6	2.31	2009.647	1	+0.6	-0.02	
STF2383CD		5.25 5.38	79.8	2.37	2008.383	2	+0.5	+0.01	114*
			79.1	2.36	2008.388	1	-0.3	-0.01	
			79.3	2.35	2009.647	1	+0.5	-0.02	
STF2383AD		5.01 5.38	172.3	208.3	2008.388	1	+0.3	+0.4	114*
Es 2028AB	18 54.5 +36 54	4.3 11.2	349.4	86.5	2008.369	1	-	-	115
AC		11.2 11.6	134.8	2.09	〃	1	-1.6	-0.11	
STFA 43AB	19 30.7 +27 58	3.37 4.68	55.3	34.5	2007.518	1	+0.3	+0.08	116*
STFA 46Aa-B	19 41.8 +50 32	6.00 6.23	133.3	39.2	2007.521	1	-0.1	-0.10	117
STF2579AB	19 45.0 +45 08	2.89 6.27	220.6	2.61	2007.545	1	~0	-0.04	118
			220.7	2.61	2008.383	1	+0.5	-0.05	
			219.9	2.66	2008.560	1	-0.3	~0	

Double and Multiple Star Measurements in the Northern Sky with a 10" Newtonian ...

PAIR	RA + DEC	MAGS	PA meas.	rho meas.	DATE	N	D PA	D rho	NOTES
STF2583AB	19 48.7 +11 49	6.34 6.75	104.4 105.3 104.9	1.45 1.39 1.40	2008.560 2008.661 2009.647	1 1 1	-0.9 ~0 -0.3	+0.05 -0.01 ~0	119
STF2605AB	19 55.6 +52 26	5.03 7.52	175.7 175.4	2.92 2.89	2007.521 2007.715	1 2	+0.3 ~0	+0.02 -0.01	120
STF2628	20 07.8 +09 24	6.60 8.66	338.3 337.8	2.98 2.97	2008.661 2009.647	1 1	-0.6 -1.1	-0.16 -0.16	121
STF2727	20 46.7 +16 07	4.36 5.03	266.1 266.0 265.8 265.7	9.02 9.00 9.00 8.99	2007.545 2007.715 2008.560 2008.661	41 4 4	+0.4 +0.3 +0.2 +0.1	+0.02 ~0 +0.02 +0.01	122*
STT 413	20 47.4 +36 29	4.73 6.26	8.6 7.1	0.98 0.96	2008.560 2009.647	1 2	+4.2 +3.1	+0.08 +0.06	123
STF2729AB	20 51.4 -05 38	6.40 7.43	27.5	0.89	2007.764	1	+2.3	+0.03	124
STF2737AB	20 59.1 +04 18	5.96 6.31	282.9 287.0	0.60 0.59	2008.661 2009.647	1 1	-1.1 +3.0	+0.04 +0.07	125
STF2737AC AB-C		5.96 7.05 5.30 7.05	67.5 66.9	10.42 10.38	2008.661 2009.647	1 1	+0.4 -0.1	-0.03 -0.05	125
STT 426	21 01.2 +46 09	5.4 9.6	160.5	2.85	2008.560	1	~0	~0	126
STF2745AB	21 04.1 -05 49	5.80 7.50	196.3	2.47	2007.764	1	+0.4	+0.08	127
STF2758AB	21 06.9 +38 45	5.35 6.10	151.2 151.6	30.7 30.9	2007.521 2009.647	1 1	-0.5 +0.5	-0.4 -0.3	128
STFB 11AB	21 22.1 +19 48	4.20 7.56	311.1	35.9	2007.715	2	-0.4	-0.2	129
STF2822	21 44.1 +28 45	4.75 6.18	311.4 312.3 313.3	1.81 1.80 1.73	2007.545 2008.560 2009.647	1 1 1	-0.6 -0.3 ~0	+0.05 +0.06 +0.01	130
STF2863AB	22 03.8 +64 38	4.45 6.40	275.6 273.8 274.7	7.89 7.96 7.85	2007.525 2007.545 2009.647	4 1 1	+0.8 -0.9 ~0	-0.03 +0.04 +0.01	131
STF2854	22 04.4 +13 39	7.77 7.89	83.4	1.65	2009.647	1	~0	+0.01	132
STF2909AB	22 28.8 -00 01	4.34 4.49	171.3 170.6	2.06 2.07	2007.753 2007.764	1 1	+1.0 +0	-0.03 -0.02	133
STF2958	22 56.9 +11 51	6.63 9.09	14.5	3.90	2008.661	1	~0	-0.02	134
STF3007AB AC	23 22.8 +20 34	6.74 9.78 10.86	91.0 304.9	5.80 99.8	2007.545 "	1 1	~0 -0.5	+0.03 -0.1	135
STT 496AB HJ 355AC HJ 1888AE HJ 1888AF HJ 1888AG DA 2CD HJ 1886CH HJ 1887FG	23 30.0 +58 33	4.9 9.3 4.87 7.23 4.9 11.28 4.87 10.59 4.9 11.11 7.23 9.06 7.1 12.9 8.9 9.1	- 268.7 116.9 338.4 347.7 215.4 338.1 73.3	- 74.7 39.9 66.0 66.0 1.35 26.4 10.66	2008.560 " " " " " " "	1 1 1 1 1 1 1 1	- ~0 ~0 ~0 -0.3 +0.4 +1.0 +0.3	- -1.22 -0.69 -0.96 -1.06 -0.03 -0.62 -0.14	136
STF3042	23 51.9 +37 53	7.62 7.75	86.9 86.6	5.76 5.61	2006.792 2007.797	1 1	+0.9 +0.2	+0.08 -0.08	137
BU 728	23 52.2 +43 31	8.69 8.94	9.6	1.22	2007.797	1	+0.3	+0.01	138
STF3050	23 59.5 +33 43	6.46 6.72	335.6 336.2 335.4	2.19 2.25 2.23	2007.797 2009.647 2009.789	1 1 1	+1.3 +0.5 -0.5	+0.02 +0.02 ~0	139*

Notes:

1. in Andromeda, cpm, relfix.
2. 38 Piscium, large scatter of literature data, AB (0.1”) not resolved.
3. theta And, relfix, cpm, reference data ambiguous.
4. in Andromeda, rho and PA slowly increasing.
5. 55 Piscium, yellow-blue color contrast, PA increasing, few data.
6. eta Cas, AB binary, P= 480 y, yellow-red color contrast, spectra G0V/dM0. AE: PA increasing, but only few data. Linear decrease of rho allows for trustworthy extrapolation. Another somewhat dimmer component seen at 74.3o/99.5”, which also appears on POSS plate from1995 at 78.7o/106.1”. This is not listed in WDS. See fig. 5.
7. 65 Piscium, relfix, cpm, rho has slightly increased since the 18th century until the 1950's, then decreased, while PA seems to slowly decrease.
8. 36 Andromedae, binary, P=168 y, many interferometric data with small scatter.
9. in Andromeda, cpm, relfix.
10. in Andromeda, binary, P=450 y, orbit highly tilted, measured separation closely follows trend of speckle data, but is off from ephemeris by about +0.1”.
11. psi (74) Piscium, AB relfix, cpm, AC: 11.m2 in ~91 “.
12. in Pisces, rho decreasing.
13. in Andromeda, few literature data with large scatter, large deviation of PA.
14. zeta Piscium, relfix, P.A. (and rho?) decreasing, BC: 12m.2 in 1.8 “.
15. 1 Arietis, cpm, literature data exhibit large scatter. Color contrast yellow-blue, spectra G3 – A, see fig. 15.
16. gamma Arietis, PA increasing, rho decreasing.
17. in Cassiopeia, cpm, AC distance ~120 “, few literature data.
18. 10 Arietis, binary, P=309 y, significant deviation from ephemeris, no recent data.
19. gamma Andromedae, rho decreasing, colors yellow-blue, spectra K3 – B/A. Gamma b binary, P=56 y, rho < 0.3”, not resolved here. See fig. 15.
20. 59 Andromedae, relfix.
21. iota Trianguli, cpm, PA decreasing.
22. in Andromeda, binary, P=144 y. See fig. 4.
23. in Triangulum, cpm, relfix.
24. in Andromeda, relfix, colors yellow-blue? not verified in RGBIR-images. Few data.
25. iota Cassiopeiae, multiple, AB binary, P=840 y, literature data exhibit periodic deviations from calculated orbit, which seems to be caused by an unseen companion. Residuals refer to ephemeris. Aa distance ~0.5 “(8.m48). BC: rho seems to rapidly decrease, extrapolation ambiguous. See fig. 6.
26. alpha UMi, Polaris, residuals ambiguous because of too few data. See fig. 6.
27. in Aries, binary, “premature orbit”, P=720 y, own measurement of separation as well as speckle data deviate from calculated orbit by about -0.05” to -0.10”.
28. epsilon Ari, AB PA slowly increasing, many speckle data. See fig. 4.
29. in Perseus, binary, “premature orbit”, P=700 y, both PA and rho deviate from calculated orbit, in accordance with speckle data.
30. in Taurus, relfix, cpm.
31. 56 Persei, cpm, few data.
32. omega Aurigae, PA slowly increasing, rho decreasing, few data.
33. 5 Aurigae, binary, P=1598 y (?), PA and rho increasing.
34. in Auriga, AB relfix, cpm, nice yellow-blue color contrast, large scatter of PA data in the literature. VBS 10 AC: P.A. slowly decreasing ? See fig. 14.
35. in Auriga, relfix, few data with large scatter.
36. in Auriga, relfix.
37. in Auriga, relfix, cpm.
38. 41 Aurigae, relfix, cpm.
39. in Auriga, cpm, PA inc.
40. 54 Aurigae.
41. alpha Geminorum, “Castor”, AB binary, P=467 y. AC: in literature only few data with large scatter. See fig. 7.
42. in Cancer, relfix, cpm, large scatter of literature data.
43. zeta Cancri, famous triple system, AB binary, P=59.7 y, AB-C “binary”, P=1115 y, C has an invisible companion, which causes periodic deviations from orbit (currently ~0.1”). See fig. 8.
44. phi 2 Cancri, cpm, PA slow inc.

45. in Cancer, multiple system, few data, AB relfix, AC: PA dec, rho inc, AD: PA inc, rho dec, AE: PA dec, rho dec. x, y not listed in WDS, but present in POSS plates, AX: PA dec, rho inc, estimated magnitudes ~13m and ~12.3m, respectively. D appears brighter by ~1m than listed (12m.0).
46. iota Cancri, relfix, cpm, nice yellow-blue color contrast. See fig. 15.
47. iota2 (57) Cancri, cpm, PA slow dec, no third component seen.
48. 66 Cancri, relfix, few data, large scatter.
49. in Cancer, relfix, cpm, residuals ambiguous because of too few literature data.
50. in Ursa Major, binary, P= 975 y.
51. in Cancer, binary, P=34.2 y. Residuals ambiguous, because both PA and rho rapidly change.
52. in Lynx, PA & rho inc, large scatter of literature data.
53. 38 Lyncis, PA slow dec.
54. in Lynx, AB binary, P=390 y, PA inc, few data for AB-C.
55. omega (2) Leonis, binary, P=117 y, many interferometric data. See fig. 4.
56. in Leo, binary, P=670 y, own measurement of rho as well as recent speckle data deviate from the ephemeris by -0.1".
57. gamma Leonis, AB binary, P=619 y, color contrast, relatively large scatter of literature data.
58. in Leo, triple system, AB binary, orbit preliminary. See fig. 8.
59. in Leo, binary, P=140 y. See fig. 4.
60. TX (49) Leonis, relfix, cpm, few data in the literature, PA and rho slowly decreasing ?
61. 54 Leonis, cpm, large scatter of literature data, colors?
62. xi Ursae Majoris, binary, well documented orbit, P=59.8 y.
63. iota Leonis, binary, P=183 y, PA decreasing.
64. 57 Ursae Majoris, AB cpm, PA dec, few data in literature.
65. 90 Leonis, triple, AB cpm, relfix, few data with large scatter in literature. See fig. 9.
66. in Leo, AB binary, "premature orbit", P=916 yr, highly inclined. Own measurements of rho, as well as speckle data, deviate from calculated ephemeris. AB-C: few data in literature.
67. in UMa, binary, orbit preliminary, P=2050 y (?).
68. 65 Ursae Majoris, quadruple (AB: ~0.1", not resolved). See fig. 9.
69. zeta (2) Comae Berenices, relfix, scatter of literature data.
70. 2 Canum Venaticorum, relfix, colors.
71. in Coma Berenices, binary, P=678 y.
72. 24 Comae Berenices, relfix, cpm, spectra K2III - ?, colors yellow-bluish. See fig. 15.
73. gamma Virginis, binary, P=169 y. See fig. 4.
74. 35 Comae Berenices, triple, AB binary, P=510 y, all cpm, rho seems to slightly increase and deviate from ephemeris. AC: no residuals because of too few data in the literature. See fig. 10.
75. alpha Canum Venaticorum, cpm, relfix, description of color contrast in literature varies from white - bluish to yellow – reddish. Own RGB composite corresponds to the latter.
76. 78 Ursae Majoris, binary, P=107 y, difficult, residuals ambiguous because of few data.
77. 39 Comae Berenices, relatively large scatter of literature data, PA dec, rho inc.
78. in Canes Venatici, PA dec, r slow inc.
79. zeta Ursae Majoris, "Mizar", PA slow inc, some scatter of literature data.
80. 25 Canum Venaticorum, binary, P=240 y.
81. 1 Bootis, PA dec, few data in literature, large scatter.
82. 84 Virginis, PA slight dec.
83. in Bootes, binary, P=156 y.
84. kappa Bootis, Burnham: "relfix", USNO: binary, P=6101 (6675) y, orbit questionable.
85. iota Bootis, relfix, cpm, few data, large scatter.
86. in Bootes, binary, P=321 y.
87. in Bootes, relfix.
88. pi Bootis, PA slow inc.
89. zeta Bootis, binary, P=123 y. See fig. 4. Five measurements in 2008 and 2009 resulted in a standard deviation of only +/-0.03 ", which compares well with speckle data.
90. epsilon Bootis, yellow-blue color contrast.
91. in Bootes, cpm, large scatter of literature data.
92. 39 Bootis, relfix.
93. xi Bootis, multiple, AB binary, P=151.5 y. AC: PA dec, rho inc, AD: PA about constant in the last 50 years, rho slow inc, AE: rho dec, only

few data. No residuals given for AC and AE, because of too few data. See fig. 11.

94. in Bootes, binary, P=210 y.
95. 44 Bootis, binary, P=225 y, orbit highly inclined.
96. mu Bootis, spectra F2IVa/G0V, cpm, few data in the literature, residuals ambiguous.
97. mu b Bootis, binary, P=246 y.
98. delta Serpentis, binary, "premature orbit", P=1038 y.
99. zeta Coronae Borealis, relfix.
100. gamma Coronae Borealis, binary, P=93 y. Orbit highly inclined.
101. beta Serpentis, cpm, residuals ambiguous because of too few data.
102. sigma Coronae Borealis, binary, P=1000 y, new orbit rotated by 180 degrees (?).
103. in Draco, PA and rho slow dec.
104. AB: 17 Draconis, PA and rho slow dec. AC: 16 Draconis, cpm, relfix. See fig. 12.
105. zeta Her, binary, P=34.5 y, PA dec.
106. 20 Draconis, binary, "premature orbit", highly inclined, P=422 y. Recent measurements of rho are smaller than ephemeris data by about -0.1".
107. mu Draconis, binary, P=672 y, ABC cpm.
108. alpha Herculis, binary, premature orbit, orange-blue color contrast, spectra M5-G5. Descriptions in literature vary: red/greenish, or orange/blue-turquoise.
109. rho Herculis, PA slow inc.
110. 26 Draconis, binary, P=76 y, few data in the literature, difficult, because faint companion on diffraction ring.
111. in Draco, binary, "premature orbit", P=1298 y (?). Both rho and PA deviate from the calculated ephemeris, which is based on only a small section of the orbit.
112. mu Herculis, PA and rho inc, BC binary, P=43.2 y, few data. See fig. 12.
113. 95 Herculis, cpm, relfix.
114. epsilon Lyrae, "double-double", AB (epsilon 1): "premature orbit", P= 1175..1804 y (?), CcD (epsilon 2): P= 724 y, no residuals given for AD, because of too few data. See fig. 13.
115. delta 2 Lyrae, A-BC probably optical, few data in the literature, residuals ambiguous.
116. beta Cygni, Albireo, colours orange-blue, large scatter of literature data. See fig. 15.
117. 16 Cygni, suspected binary, very preliminary orbit.
118. delta Cygni, binary, P=780 y.
119. pi Aquilae, P.A. decreasing, rho: large scatter of literature data.
120. psi Cygni, PA & rho decreasing, few data in literature.
121. in Aquila, PA & rho decreasing, few data.
122. gamma Delphini, PA & rho slowly decreasing, color contrast, spectra K1IV/F7V. See fig. 15.
123. lambda Cygni, binary, P=391 y.
124. 4 Aquarii, binary, P=194 y.
125. epsilon Equuli, triple, all cpm, AB binary, P=101.5 y, highly inclined orbit, C physical.
126. 60 Cygni, in literature few data with large scatter.
127. 12 Aquarii, denoted as cpm, relfix in Burnham´s Celestial Handbook [7], but PA is increasing, rho decreasing. Literature data exhibit large scatter.
128. 61 Cygni, binary, P=653.3 y, large proper motion.
129. 1 Pegasi, AB cpm, relfix.
130. mu Cygni, binary, P=789 y.
131. xi (17) Cephei, cpm, binary, P=3800 y (?). Colors white-blue listed in literature, but own measurements of delta mag at different colors do not significantly vary: near IR (-1.5 mag), red (-1.3), green (-1.5), blue (-1.5).
132. in Pegasus, rho decreasing.
133. zeta (55) Aquarii AB, binary, P=760 y. B has an unseen companion b with period of 25.7 y, which causes wobble on orbit. Residuals refer to currently assumed ephemeris. See ref. [2].
134. in Pegasus, cpm, PA inc, large scatter of literature data for rho.
135. in Pegasus, AB: cpm, rho seems to decrease after increasing for more than a century, PA increasing; AC: rho increasing, PA decreasing, few data in literature.
136. AR Cassiopeiae, multiple, AB not resolved.
137. in Andromeda, rho slightly increasing, P.A. decreasing.
138. in Andromeda, large scatter of literature data.
139. in Andromeda, binary, P=320 y (?), many data in literature, deviation from currently assumed orbit, residuals refer to extrapolated literature data. See fig 3.

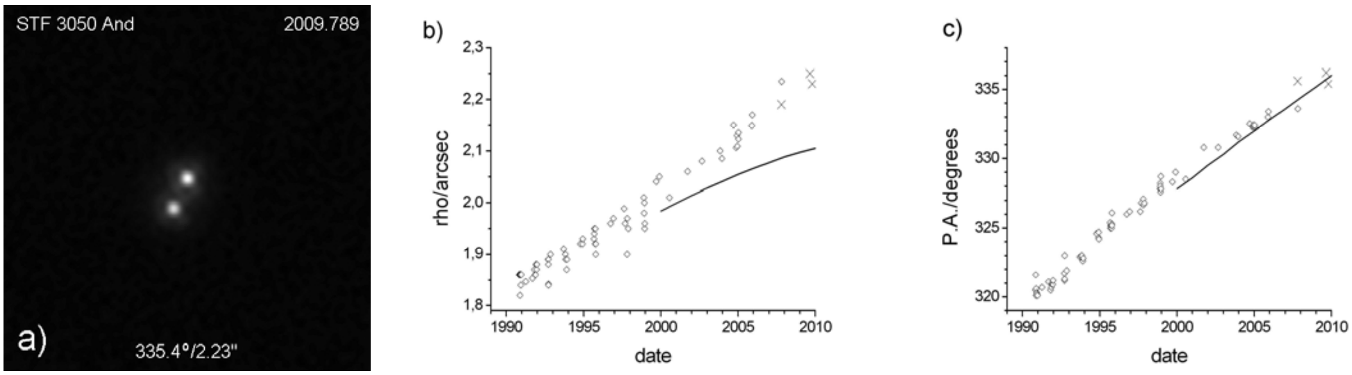

Figure 3: (a) The binary STF 3050 in Andromeda (135 frames x 12 msec). Measurements of P.A. and rho are indicated at the bottom. Note the faint diffraction rings around both components. These are generally more or less well developed depending on the seeing conditions. North is down, east is right, as in all other images. **(b, c)** Separation rho (b), and position angle P.A. (c) of the binary STF 3050 versus date. Open diamonds mark speckle data, crosses own measurements. Curves represent the currently assumed ephemeris, taken from ref. [6].

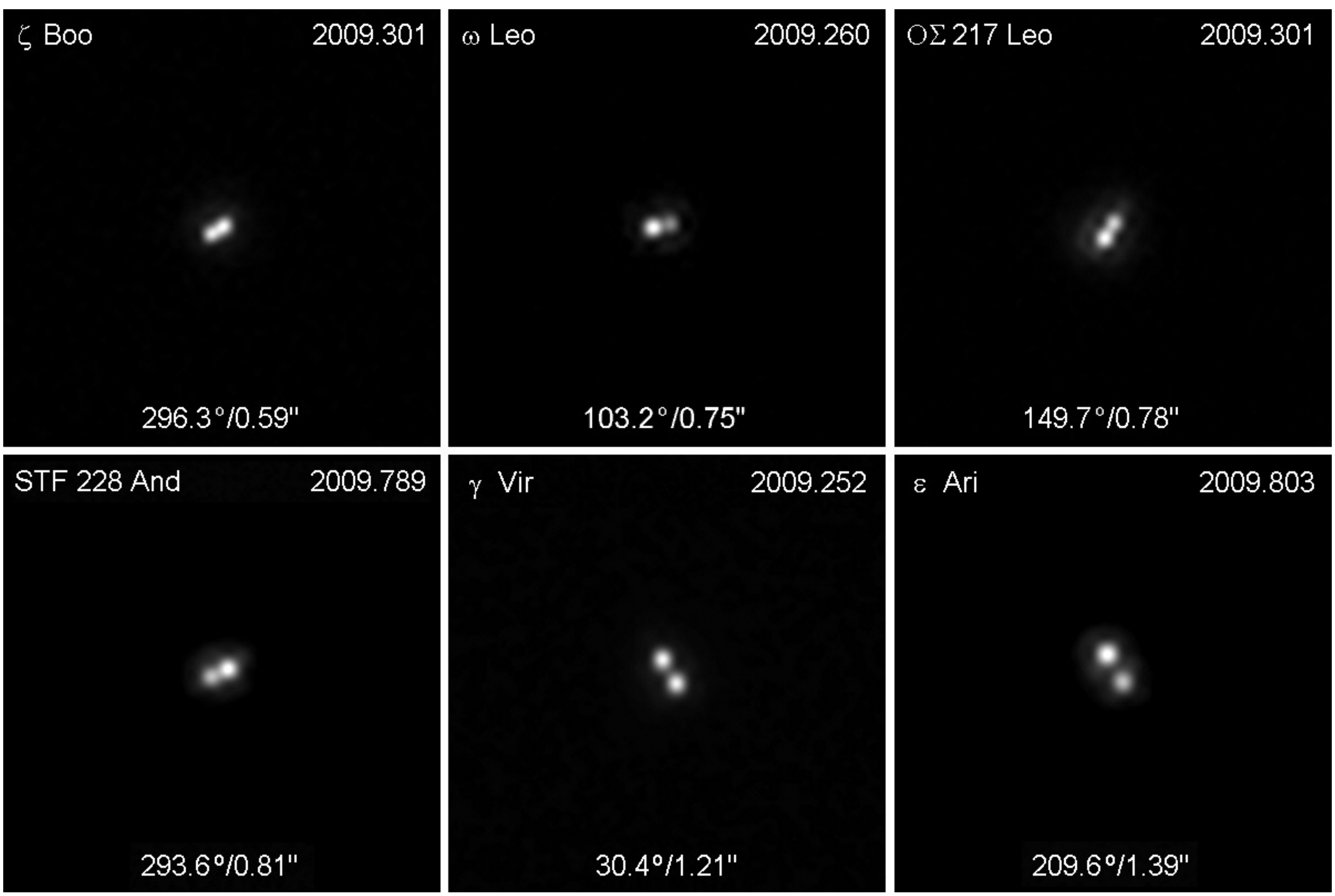

Figure 4: Close pairs: Top row, left: zeta Bootis, binary, period 123 y (93 x 3 msec), middle: omega Leonis, binary, 117 y (240 x 4 msec), right: STT 217 in Leo, binary, 140 y (113 x 63 msec). Bottom row, left: STF 288 in Andromeda, binary, 144 y (82 x 26 msec), middle: gamma Virginis, binary, 169 y (59 x 2 msec), right: epsilon Arietis, (69 x 11 msec). All images are to scale.

Double and Multiple Star Measurements in the Northern Sky with a 10" Newtonian ...

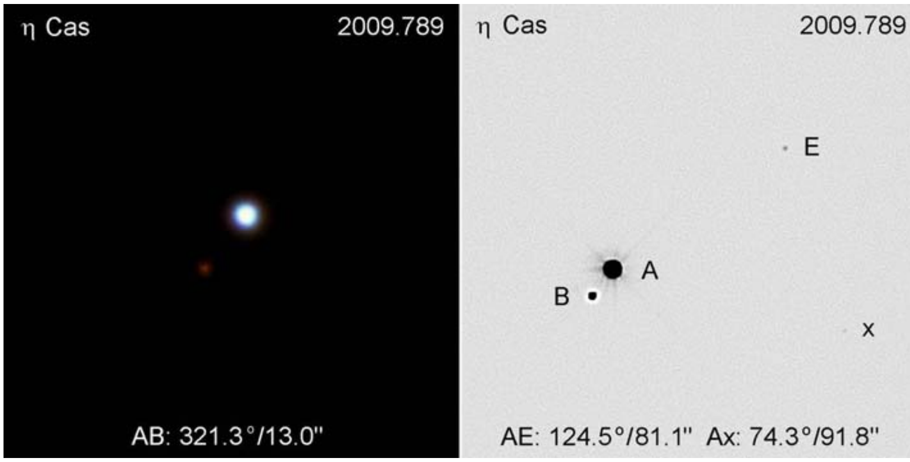

Figure 5: Eta Cassiopeiae. Left: RGB composite of AB. Spectral classes are G - M. (Exposures: R, 126 x 20 msec; G, 98 x 33 msec; B, 129 x 48 msec). Right: Wide field, with components E (~10 mag) and x. The latter is of estimated 11 mag and not listed in WDS (red filter, 32 x 250 msec).

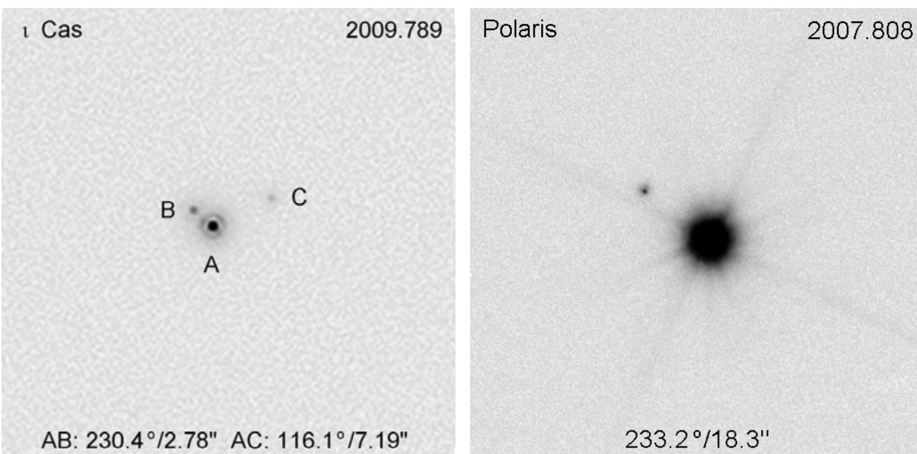

Figure 6: Left: The triple system iota Cas. (102 x 20 msec). AB is a binary with period 840 y. Right: alpha UMi, "Polaris" (32 x 100 msec). In both images, the contrast was strongly enhanced in order to show the dim companions and/or the diffraction spikes.

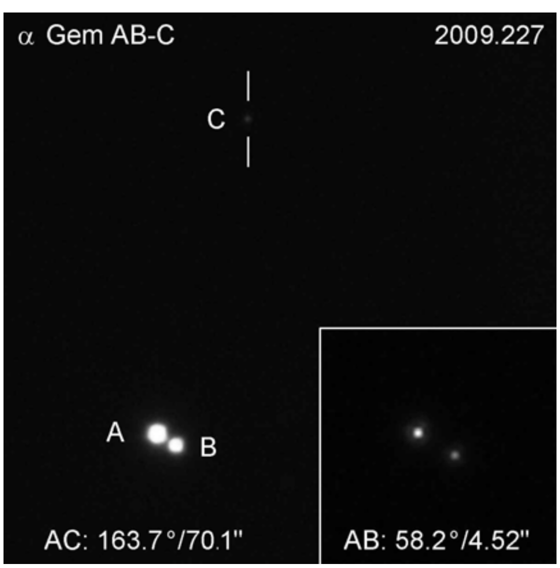

Figure 7: The multiple alpha Geminorum, "Castor" (32 x 33 msec). The inset shows a close-up of the binary AB, recorded with shorter exposure time (82 x 0.5 msec).

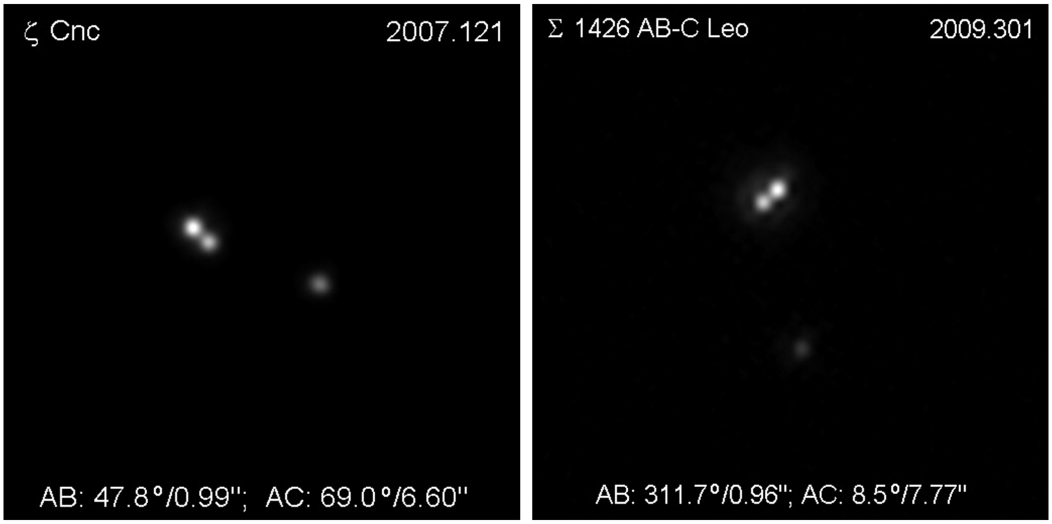

Figure 8: Two similarly looking triple systems: In zeta Cancri (left), B is orbiting A with period of about 60 y, and C orbits AB with period 1115 y (64 x 10 msec). For STF 1426 in Leo (right), a preliminary orbit has only been computed for AB with period 662 y (233 x 48 msec).

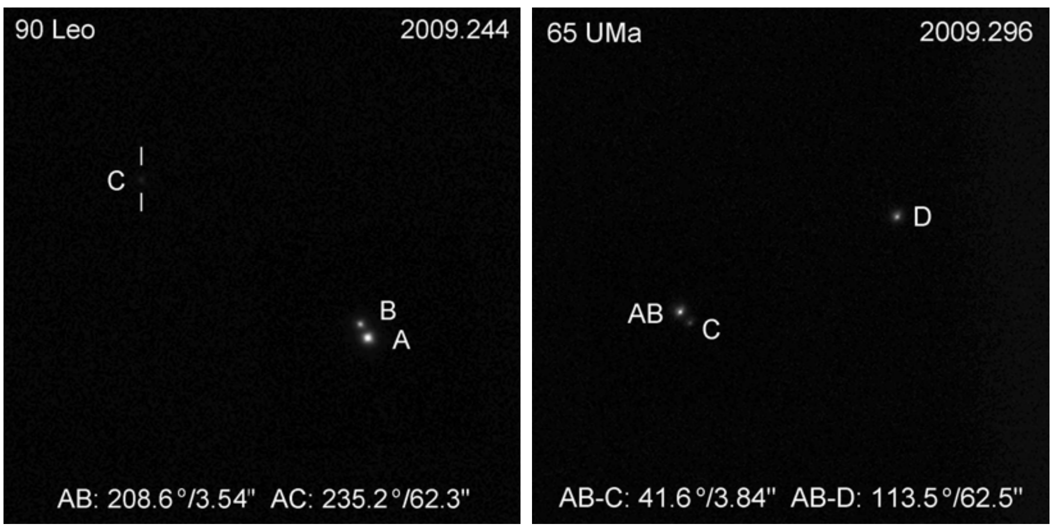

Figure 9: Left: 90 Leonis, AB likely binary (33 x 200 msec), Right: 65 Ursae Majoris, AB very close binary, not resolved (99 x 33 msec).

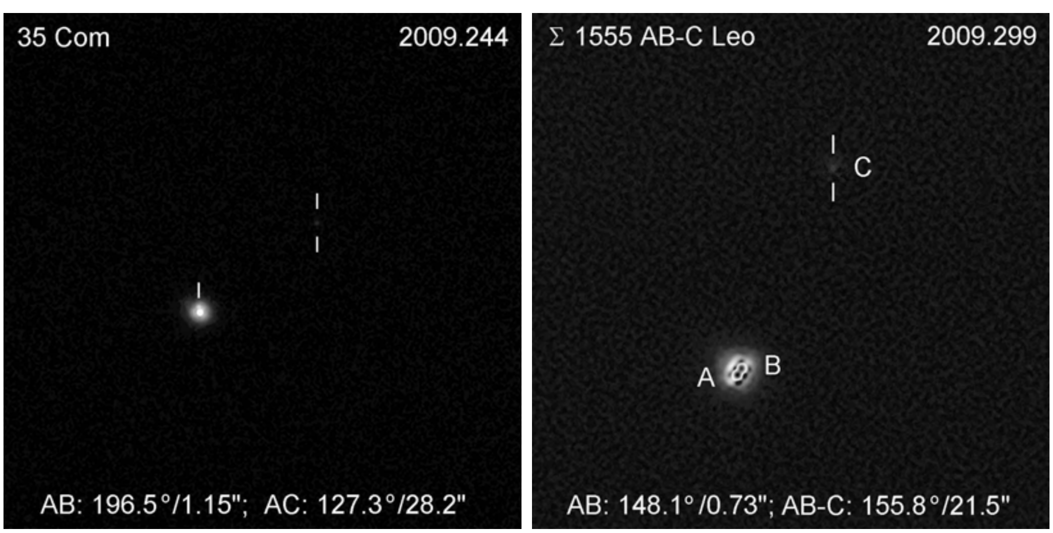

Figure 10: Left: The triple 35 Com. Imaging of AB is difficult, because the rather dim companion coincides with the diffraction ring of A (67 x 33 msec). Right: STF 1555 in Leo. The wide field image is a superposition of 136 frames at 14 msec. The pair AB has been separately recorded with 123 frames at 12 msec. This image is superimposed as a negative.

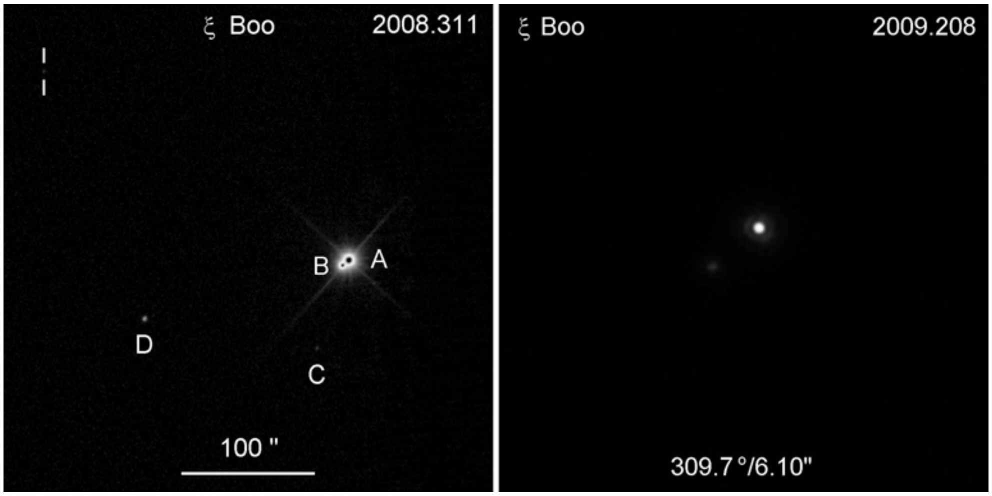

Figure 11: The multiple system xi Bootis. Left: Wide field view with superimposed negative image of AB (42 x 100 msec). The faint star at upper left is not listed in the WDS. Component E is out of the field at right. Right: Close-up of AB (74 x 8.3 msec).

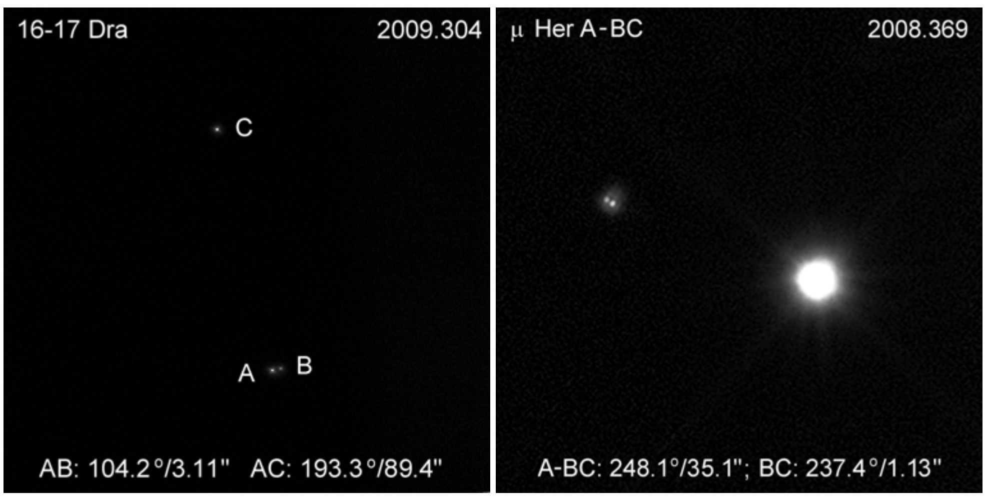

Figure 12: Left: The system 16 (C) - 17 (AB) in Draco (147 x 8.3 msec). Right: Mu Herculis. BC is a binary of faint red dwarfs with period 43.2 y (78 x 100 msec).

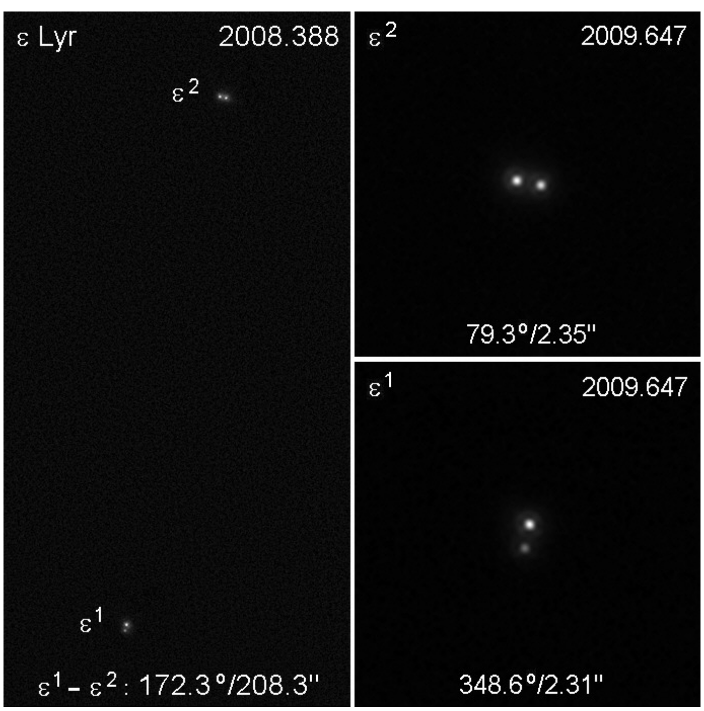

Figure 13: The "double-double" epsilon Lyrae. Left: Wide field view (no composite) obtained at fairly steady seeing (111 x 8.3 msec). Right: Close-ups of epsilon 1 and epsilon 2 recorded about a year later (143 x 8.3 msec, and 79 x 8.3 msec, respectively). Both are binaries, but only small fractions of their orbits are documented. Periods are estimated from 1175 to 1804 y for epsilon[1], and 724 y for epsilon[2].

Double and Multiple Star Measurements in the Northern Sky with a 10" Newtonian ...

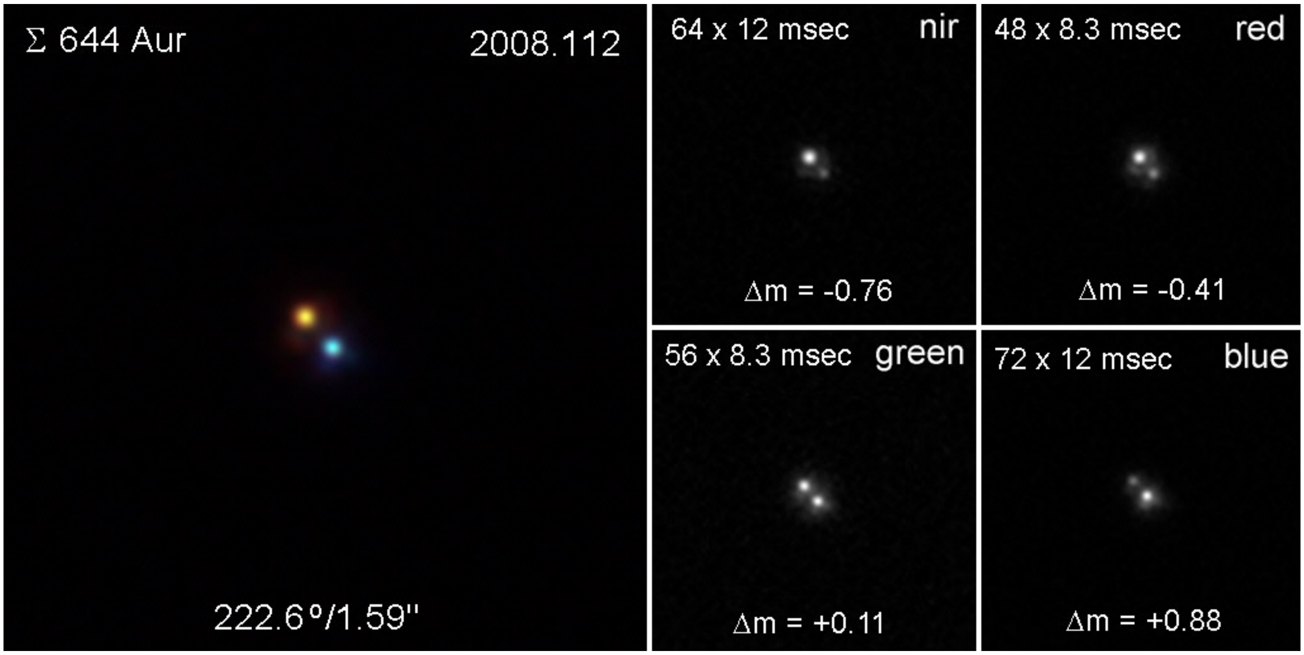

Figure 14: STF 644 Aurigae, left: RGB composite, right: filtered images as indicated. Note smaller scale. Numbers and exposure times of the respective frames are also given. In this rare case, the brightness of the components is about equal in the visible, despite the strong color contrast. Spectra are B2- K3. The blue star is designated as main component of the system. In the WDS, the difference in magnitude Δ(delta)m is given as +0.18, which roughly corresponds to the value measured here in green light.

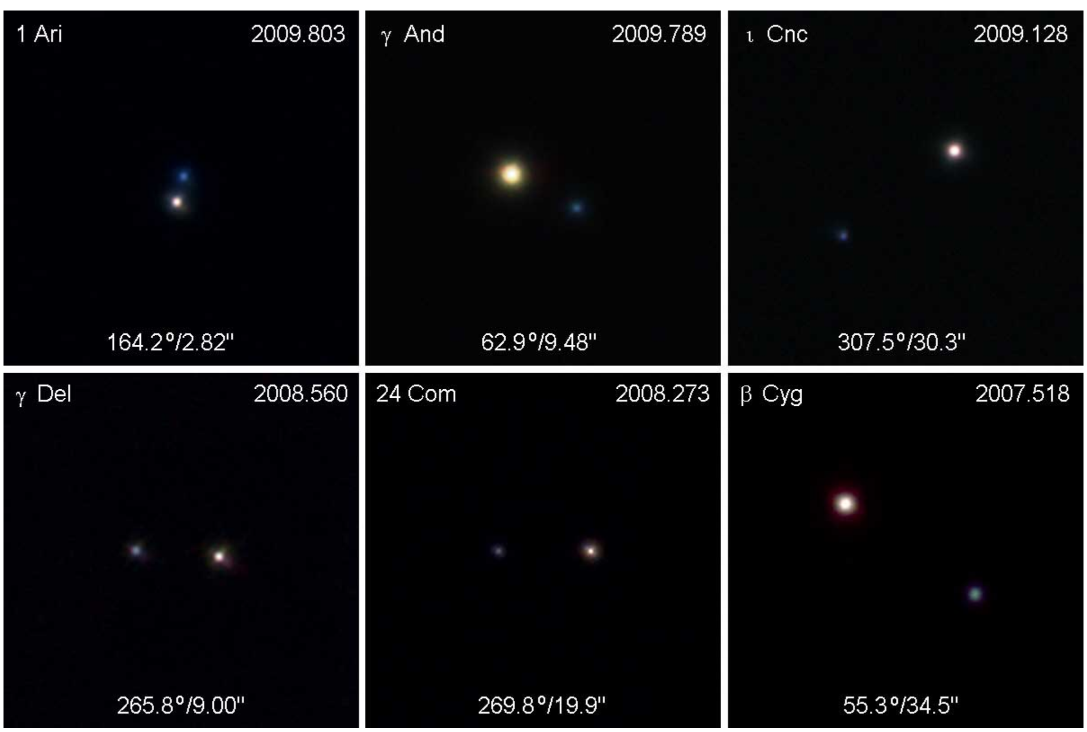

Figure 15: RGB composites. Upper row, left: 1 Arietis, spectra G3- A. Middle: gamma Andromedae, spectra K3 –B/ A. The blue companion is a close double, but not resolved here. Right: iota Cancri, spectra G7.5 – ?. Bottom row, left: gamma Delphini, spectra K1 – F7. Middle: 24 Comae, spectra K2 - ?. Right: beta Cygni, "Albireo", spectra K3 – B0. Images are not to scale.

Double and Multiple Star Measurements in the Northern Sky with a 10" Newtonian ...

(Continued from page 181)

Discussion and Conclusion

In this survey, most double and multiple star systems are well known, while the brightness of even the dimmer components is rarely below 10 mag. Nevertheless, in many cases, there are only few data found in the literature, and these often exhibit large scatter. This is especially true for pairs with larger separation, for which mainly visual measurements are listed in the catalogs, and the accuracy is usually not known. Therefore, extrapolation of position data is often somewhat ambiguous. This may be one reason for the scatter of the residuals, as illustrated in Figure 1. In any case, it makes sense to pay attention also to such systems.

On the other hand, pairs with medium to small separations, in particular binaries, are mostly thoroughly investigated with both visual and interferometric methods, and the accuracy can be estimated from the scatter. Among these, numerous systems are suitable for calibration of the image scale. Comparing the scatter of speckle data and that from lucky imaging, the accuracy of the latter at least comes close, and also comes close to the theoretical limit of resolution of the 10" telescope. One example is the pair zeta Bootis with separation 0.6", which is shown in fig. 4. Therefore, lucky imaging appears to be a suitable complement to speckle measurements for medium sized amateur telescopes.

In several cases, systematic deviations from predicted positions became apparent, which are also documented by recent measurements from other authors, especially in the speckle catalog [5]. A striking example is STF 3050 in Andromeda (note #139), which is illustrated in fig. 3. Currently, the separation increases faster than expected from the ephemeris. The difference has now grown to greater than +0.1", which is much larger than the error margin of both speckle data and results from lucky imaging. Other binary systems with obvious deviations from calculated orbits are the following:

- STT 21 in Andromeda (note #10),
- iota Cassiopeiae AB (note #25, see fig. 7),
- STF 305 in Aries (note #27),
- STT 531 in Perseus (note #29),
- zeta Cancri AB-C (note #43, see fig. 9),
- STT 215 in Leo (note #56),
- STF 1555 AB (note #66),
- 35 Comae AB (note #74, see fig. 11),
- kappa Bootis (note #84),
- 20 Draconis (note #106),
- STF 2199 in Draco (note #111),
- zeta Aquarii AB (note #133, see also a more detailed discussion in an earlier paper in this Journal [2]).

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[4] Mason, B.D. et al., *The Washington Double Star Catalog (WDS)*, U.S. Naval Observatory, online access Dec. 2009.

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[7] R. Burnham, *Burnham´s Celestial Handbook,* Dover Publications, New York 1978.

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