Double Star Measurements at the *Internationale Amateur Sternwarte* (IAS) in Namibia in 2008 and 2009

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Abstract: A 40-cm-Cassegrain telescope in Namibia was used for observing double and multiple systems in the southern sky. Digital images were recorded with a CCD camera at high frame rates via a firewire interface directly in a computer. Measurements of 34 double and multiple systems are presented and compared with literature data. Some noteworthy objects are discussed in more detail.

Introduction

For several years I have been using the technique of “lucky imaging” for recording and measuring double stars. In short, it means short exposure times to “freeze” the moments of good seeing, and pick out the best frames for superposition in a computer. In an earlier article in this Journal, I have addressed the accuracy and reproducibility of measurements in images thus obtained with telescopes of 40 cm and 50 cm aperture and a fast CCD camera [1]. As a result, the resolution can be pushed to the theoretical limit, but the accuracy of position measurements can even be one order of magnitude better than this. Standard deviations of separation measurements were typically below +/-0.05".

Among the 34 investigated systems, 18 are binaries. Most of the stars are brighter than 9 mag. Nevertheless, for many cases there are only few data listed in the literature. For some systems, deviations from predicted movements could be manifested. Systems, for which trustworthy literature data exist, are used for calibration of the image scale.

Instrumental

During two weeks in September 2008 and again in September 2009, I used the 40-cm-Cassegrain at the *Internationale Amateur Sternwarte* (IAS) in Namibia [2]. The nominal focal length is 6.3 m, which results in a resolution of about 0.19”/pixel with my b/w-CCD camera (DMK21AF04, *The Imaging Source*) with pixel size 5.6 µm square. Several recordings were also made with a 2x-Barlow lens inserted, combined with a red filter. A filter is necessary because of the chromatic aberration of the lens. It also helps to reduce the atmospheric spectrum. Exposure times were from 0.5 µsec up to 0.1 sec, depending on the star brightness and the seeing. The stream of digital images is transferred with rates up to 15/sec via a firewire interface into my notebook. To get the most out of the recordings, I usually select the best frames by visual inspection. The typical yield is about 50 to 150 useful frames out of a few thousand. These are one- or two-times re-sampled, and aligned with the program *Registax*, often with the option “manual”, and finally automatically stacked. Resampling results in rather smooth intensity profiles, and in position measurements with sub-pixel accuracy.

Calibration and Measurements

As calculation of the image scale from the focal length and pixel size is not sufficiently accurate, especially when using the Barlow, I do the calibration in an iterative way by measuring a number of doubles with well known separation. All systems are suitable, for which literature data can unambiguously be ex-

Table 1: List of measurements without Barlow. Systems used for calibration are marked by shaded lines. System names, positions and magnitudes are taken from the WDS. The two columns before the last one show the differences D of measured position angles (P.A.) and separations (rho) minus reference data. N is the number of measurements at different nights, or with different camera settings.

pair	RA + DEC	mags	P.A. meas.	rho meas.	date	N	D P.A.	D rho	notes
LCL 119 AC	00315 -6257	4.28 4.51	168.2	27.01	2008.738	1	~0	-0.03	1
			168.4	27.05	2009.710	3	+0.2	+0.01	
HDO 182	00427 -3828	6.60 7.01	21.0	0.69	2008.732	2	+1.0	-0.01	2
HJ 3416 AB	01033 -6006	7.58 7.67	129.1	5.15	2008.740	1	+0.1	+0.05	3
			129.4	5.07	2009.718	1	+0.4	-0.03	
SLR 1 AB	01061 -4643	4.10 4.19	117.4	0.39	2008.746	1	-0.3	-0.01	4
			112.8	0.42	2009.693	1	+0.3	+0.01	
HJ 3423 AB	01158 -6853	5.00 7.74	318.2	4.80	2008.740	1	-0.8	-0.18	5
			318.9	4.75	2009.718	1	~0	-0.28	
I 27 CD	01158 -6853	7.84 8.44	308.7	1.00	2008.740	1	+0.2	-0.04	6
HJ 3447	01361 -2954	5.97 7.35	182.5	0.75	2008.732	2	+0.5	-0.03	7
STF 186	01559 +0151	6.79 6.84	66.7	0.83	2008.732	1	~0	-0.03	8
BU 738	02232 -2952	7.60 7.97	212.3	1.79	2008.732	1	+0.5	-0.02	9
BU 739	02248 -2952	8.69 8.90	259.1	1.75	2008.732	1	-0.4	-0.02	10
HJ 3506	02338 -2814	4.95 7.71	245.1	10.63	2008.732	1	+0.1	-0.1	11
			245.0	10.80	2009.718	1	~0	+0.1	
BU 741 AB	02572 -2458	8.06 8.20	342.9	0.91	2008.732	1	+1.3	-0.03	12
S 423 AC	02572 -2458	8.06 7.86	225.8	28.93	2008.732	1	-0.2	-0.05	12
HJ 3555	03121 -2859	3.98 7.19	300.6	5.17	2008.732	1	+0.8	-0.02	13
HJ 3596	03485 -3147	8.27 8.54	137.7	9.34	2008.732	1	-0.3	-0.01	14
DUN 16	03486 -3737	4.72 5.25	215.8	8.23	2008.732	1	-0.3	~0	15
BU 1004 AB	04021 -3429	7.26 7.94	61.8	1.24	2008.732	1	+8.5	+0.43	16
I 152 AB	04049 -3527	8.37 8.65	79.6	1.03	2008.732	1	+0.4	+0.02	17
BU 311	04269 -2405	6.67 7.09	150.5	0.41	2008.732	1	+2.1	-0.03	18
I 154	04313 -3546	8.52 8.21	134.6	0.48	2008.732	1	-0.4	-0.01	19
AGC 1 AB	06451 -1643	-1.46 8.5	95.1	8.73	2008.740	1	-0.4	+0.02	20
			89.8	8.78	2009.721	2	-0.2	-0.05	
BU 332 AB	07279 -1133	6.22 7.35	172.9	0.71	2008.740	1	+1.9	-0.01	21
STF1097 AC		6.0 8.5	313.3	20.07	2008.740	2	+0.3	+0.27	
BU 332 AD		6.0 9.5	156.8	22.86	2008.740	1	-0.2	+0.06	
BU 332 AE		6.0 12.2	43.3	32.76	2008.740	1	+0.3	+0.56	
HJ 608 AB	20181 -1233	3.8 11.2	192.0	6.51	2008.732	2	-	-	22
HJ 608 AC		3.8 11.5	199.1	7.39	2008.732	2	-	-	
AGC 12 BC		11.2 11.5	240.1	1.24	1959	2	+0.1	-0.06	
HJ 5319	22120 -3818	7.65 7.66	314.5	2.08	2008.740	1	+0.5	-0.03	23
H N 56 AB	22143 -2104	5.63 6.72	112.1	5.25	2008.738	1	+0.4	+0.05	24
BU 172 AB	22241 -0450	6.45 6.63	42.5	0.41	2008.732	1	+0.9	+0.01	25
SHJ 345 AB	22266 -1645	6.29 6.39	34.7	1.35	2008.732	1	+0.7	+0.02	26
STF 2909	22288 -0001	4.34 4.49	171.3	2.04	2008.732	1	-1.6	-0.06	27
PZ 7	22315 -3221	4.28 7.12	172.4	30.35	2008.738	1	-0.1	+0.05	28

trapolated to the actual date. Main sources are the *WDS* [3], and the *4th Catalog of Interferometric Measurements of Binary Stars* [4]. Results for binaries are also compared with data from the *Sixth Catalog of Orbits of Visual Binary Stars* [5]. In the tables below, systems taken for reference are marked with shaded lines. The scale factors were adjusted such to obtain minimum mean values of the residuals, as well as of the standard deviations (sd). The results were 0.187”/pix without Barlow, and 0.097”/pix with Barlow, with sd-values of +/-0.05” and +/-0.04”, respectively, and total error margins of about +/-0.5%. The accuracy of separation measurements does not depend on separation, because of the fixed lateral resolution, except for very close systems with overlapping intensity profiles. Difficulties may also arise for pairs with large differences in brightness, such that the brighter one becomes overexposed. In such cases, the diffraction spikes from the holder of the secondary mirror help to determine its position.

For measuring the position angle, the east-west-direction was obtained by superposing series of images recorded while the telescope drive was switched off. The error margin is about +/-0.1°, but the total error is greater, and depends on the separation, because of the limited lateral resolution of the camera. For pairs with separations close to the resolution limit of the telescope, deviations of the P.A. can be up to a few degrees.

Measurements are listed in two tables below, Table 1 for those obtained without Barlow lens, and Table 2 for those with Barlow. Several systems were recorded in both configurations, and in both years 2008 and 2009. Use of the Barlow especially reduces the error margins for very close systems. Individual notes are given following the tables. Some of the notes refer to both tables.

(Continued on page 137)

Table 2: List for Measurements with Barlow.

pair	RA + DEC	mags	P.A. meas.	rho meas.	date	N	D P.A.	D rho	notes
SLR 1AB	01061 -4643	4.10 4.19	119.2	0.39	2008.740	1	+1.5	-0.02	4
			112.7	0.44	2009.710	5	+0.2	+0.02	
I 264 AB	01316 -5322	8.36 8.84	31.6	0.84	2008.735	1	~0	+0.03	29
			32.0	0.76	2009.732	1	+0.5	-0.05	
DUN 5	01398 -5612	5.78 5.90	188.4	11.46	2008.735	1	~0	-0.06	30
			188.0	11.58	2009.710	2	-0.4	+0.06	
HJ 3527	02433 -4032	6.97 7.20	40.1	2.28	2008.735	1	-0.7	+0.04	31
			40.7	2.28	2009.723	1	-0.2	+0.04	
Pz 2	02583 -4018	3.20 4.12	90.6	8.47	2008.740	1	~0	+0.07	32
			90.5	8.39	2009.723	1	~0	-0.01	
Jc 8 AB	03124 -4425	6.42 7.36	162.4	0.68	2008.740	2	+0.6	-0.02	33
			160.8	0.65	2009.710	4	~0	-0.01	
HJ 3556 AC		6.42 8.76	189.5	3.89	2008.740	2	-	-	
			189.5	3.88	2009.726	4	-	-	
DUN 16	03486 -3737	4.72 5.25	215.9	8.36	2008.735	1	-0.3	~0	15
			216.2	8.39	2009.723	1	~0	~0	
BU 1004 AB	04021 -3429	7.26 7.94	61.4	1.17	2008.735	1	+8.1	+0.4	16
			60.4	1.22	2009.715	3	+10.2	+0.45	
I 152 AB	04049 -3527	8.37 8.65	77.8	1.04	2008.735	1	-0.3	+0.02	17
BU 311	04269 -2405	6.67 7.09	149.9	0.44	2009.721	1	+1.5	-0.01	18
STF 2744AB	21031+0132	6.76 7.33	112.9	1.27	2008.735	1	-0.4	+0.03	34
			111.9	1.29	2009.696	1	-0.9	+0.05	
HJ 5319	22120 -3818	7.65 7.66	314.5	2.09	2009.723	1	+0.5	-0.02	23
SHJ 345 AB	22266 -1645	6.29 6.39	35.3	1.33	2008.738	2	+0.6	~0	26
			39.3	1.33	2009.704	1	~0	~0	
STF 2909	22288 -0001	4.34 4.49	170.6	2.10	2008.74	2	-2.3	~0	27
			169.8	2.18	2009.71	5	-1.8	+0.05	

Notes to Tables 1 and 2:

1. β Tuc, rho virtually fixed, PA slowly decreasing.
2. λ Scl, PA increasing.
3. in Tucana, relfix.
4. β Phe, binary, neglected between 2000 and 2008. Residuals refer to a newly calculated ephemeris with P=168y (see also the data in Table 2, Figure 1, and the discussion below).
5. κ Tuc AB, binary, P=857y, no recent literature data, both measurements in 2008 and 2009 markedly deviate from ephemeris.
6. κ Tuc CD, binary, P=85.2y.
7. τ Scl, binary, P~1504y. PA increasing, rho decreasing.
8. in Cetus, binary, P=165.7y, many speckle data listed, PA increasing, rho decreasing.
9. in Fornax, binary, P=560y, orbit highly tilted.
10. in Fornax, few data, PA decreasing, rho slowly increasing?
11. ω For, few data, rho fixed.
12. in Fornax, AB binary, P=137y, large deviation from ephemeris, also of recent speckle data. Residuals refer to the latter. Forms triple with S 432. Literature data only listed for AB-C. PA and rho slowly increasing. Residuals for AC estimated. See Figure 2.
13. α For, binary, P=269y, no recent literature data.
14. in Fornax, relfix, few data, residuals ambiguous.
15. f Eri, PA & rho slowly increasing, although no recent data are listed, extrapolation appears trustworthy. See also data in Table 2.
16. in Eridanus, binary, P=282y (?), significant residuals, also of recent speckle data, as referred to ephemeris. See also data in Table 2 and Figure 3.
17. in Eridanus, triple system, AC not resolved (rho~0.1”). Pair AB was termed as relfix by Burnham [6], but PA & rho are now increasing.
18. in Eridanus, binary, P=176y. See also data in Table 2. Residuals refer to speckle data of 2008.
19. in Eridanus, no recent data listed, good agreement with interferometric data of 1991.
20. α CMa, Sirius, binary, P=50y. PA decreased by 5° within one year. See Figure 4.
21. in Canis Maior, multiple system, few literature data. Residuals refer to last entries in WDS: for AB, AC from 2003, for AD, AE from 1998. See Figure 5.
22. α^2 Cap, optical triple, PA of close pair BC increasing. Residuals for BC refer to last entry in WDS from1959. No residuals given for AB and AC, as only data for A-BC from 1959 are listed in WDS. See Figure 6.
23. in Grus, PA increasing.
24. 41 Aquarii, slight PA decreasing, few data with large scatter. Residuals ambiguous.
25. in Aquarius, binary, P~149y, measurement fits well the trend of many speckle data with small scatter.
26. 53 Aquarii, binary. P=3500y, PA is rapidly increasing, with about constant rho.
27. ζ Aquarii, binary, P=760y, companion deviates periodically from orbit, and is currently moving towards it. See also data in Table 2, Figure 7, and the discussion below.
28. β Piscis Austrini, relfix, common proper motion. Few data, but relatively small scatter.
29. in Eridanus, binary, P=250y. Residuals referred to speckle data of 2008.
30. p Eridani, binary, P=483.7y. Few data, but relatively small scatter.
31. in Eridanus, Burnham states “no certain change” [6], but rho is slowly increasing.
32. θ Eridani, cpm, PA slowly increasing, few data with large scatter. Residuals for rho are somewhat ambiguous.
33. in Eridanus, triple system, AB binary, P=45.2y. No residuals given for AC, as only data for AB-C are listed in WDS.
34. in Aquarius, binary, P=1532y according to a “premature orbit” [5]. Recent measurements deviate from ephemeris. Residuals refer to exrapolation from many speckle data.

Discussion

A number of systems deserve special attention, and this is not limited to those with conspicuous residuals.

SLR1, or β Phoenicis (note #4), had in 2008 also been measured four times with a 50 cm Cassegrain. The resulting average values, combined with the results listed here, were 119.4º and 0.39", with standard deviations of about +/-1.1º and +/-0.01". This data strongly deviated from the ephemeris, as was discussed in a previous paper in this Journal [1], but was confirmed within the error limits by speckle measurements by Tokovinin with average date 2008.56 [4]. This led to re-calculation of the orbit by Alzner, et al. [7]. See Figure 1.

For κ Tucanae AB (note #5), the two measured separation values are significantly smaller than expected from the ephemeris and from a simple extrapolation of literature data. This remains unexplained at present. More measurements should be done.

The close companion of BU 741 AB in Fornax (note #12) apparently has earlier returned from its northernmost elongation than expected from the ephemeris, see Figure 2.

For BU 1004 AB in Eridanus (note #16), deviations from the current ephemeris became noticeable in speckle data at least since 2000, and have further increased. My recent measurements of 2008 and 2009 closely agree with speckle data of 2008. See Figure 3.

The system I 152 in Eridanus (note #17) is remarkable, as it has long been deemed as "relfix", as both PA and rho were about fixed for decades until the 1950's. However, since about 1990, both are rapidly increasing. The system also is triple, although AC with a currently assumed separation of about 0.1" could not be resolved.

The binary 53 Aquarii is interesting, as it is currently rapidly moving near periastron, while its period of 3500 y is assumed rather long. Thereby, rho remains almost constant.

Zeta Aquarii (note #27) is a special case, as the B component exhibits a wobble on its orbit with period of about 25 years, which is caused by an unseen companion. I have made several additional measurements in 2008 with a 50-cm-Cassegrain, and all data of 2008 are discussed in reference [1]. The result was a significant deviation from the currently assumed orbit for AB. The averaged data of five measurements done in 2009 with the 40-cm scope, which are listed in Table 2, indicate a return to the orbit, although the residuals are not really reduced. This is illustrated in the plot of the orbit in Figure 7.

Conclusion

The technique of lucky imaging not only pushes the resolution towards the theoretical limit of the telescope, but also increases the accuracy of position measurements by about one order of magnitude. This has already been discussed in more detail in an earlier article. Out of 66 measurements presented here, 11 residuals of the position angle exceed +/-1º, and 6 residuals of separation exceed +/- 0.1". For very close pairs, larger deviations of the P.A. could be due to the reduction of angular resolution, deviations of rho above 0.1" are clearly greater than the error margins. While some residuals appear more or less ambiguous, because of too few data in the literature, systems with definitely too large residuals have been discussed in more detail. At least for these, more attention should be paid in the near future.

References

[1] Anton, R., 2009, Journal of Double Star Observations, vol. 5 (1), 65-71.

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

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[5] Hartkopf, W.I. et al., Sixth Catalog of Orbits of Visual Binary Stars, online version, U.S. Naval Observatory.

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

[7] A. Alzner, R. Argyle, R. Anton, IAU Commission 26 (Double & Multiple Stars), Information Circular No. 169, October 2009.

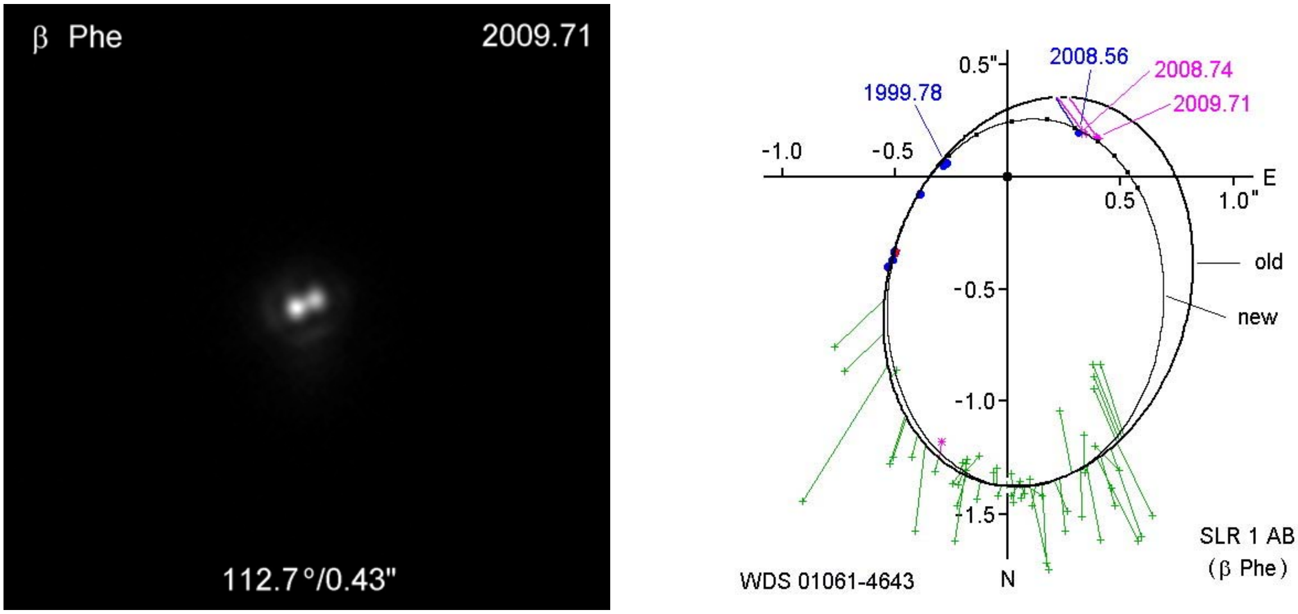


Figure 1: beta Phoenicis. Left: Superposition of 50 frames x 3 msec recorded with a 40cm-Cassegrain, with Barlow and red filter. The position given at the bottom is the average of 6 measurements around the date indicated at upper right. North is down, east is right, as in all other images. Right: Plot of the old and new orbit (modified from the 6th Catalog of Orbits of Binary Stars [5]). Visual measurements are marked in green, interferometric in blue, and my own in magenta with indicated dates. The latter represent six measurements each around both dates (see text). Ticks on the new orbit mark dates from 2000 to 2016 in 2-years steps. The lines connecting to the old orbit indicate the old ephemeris.

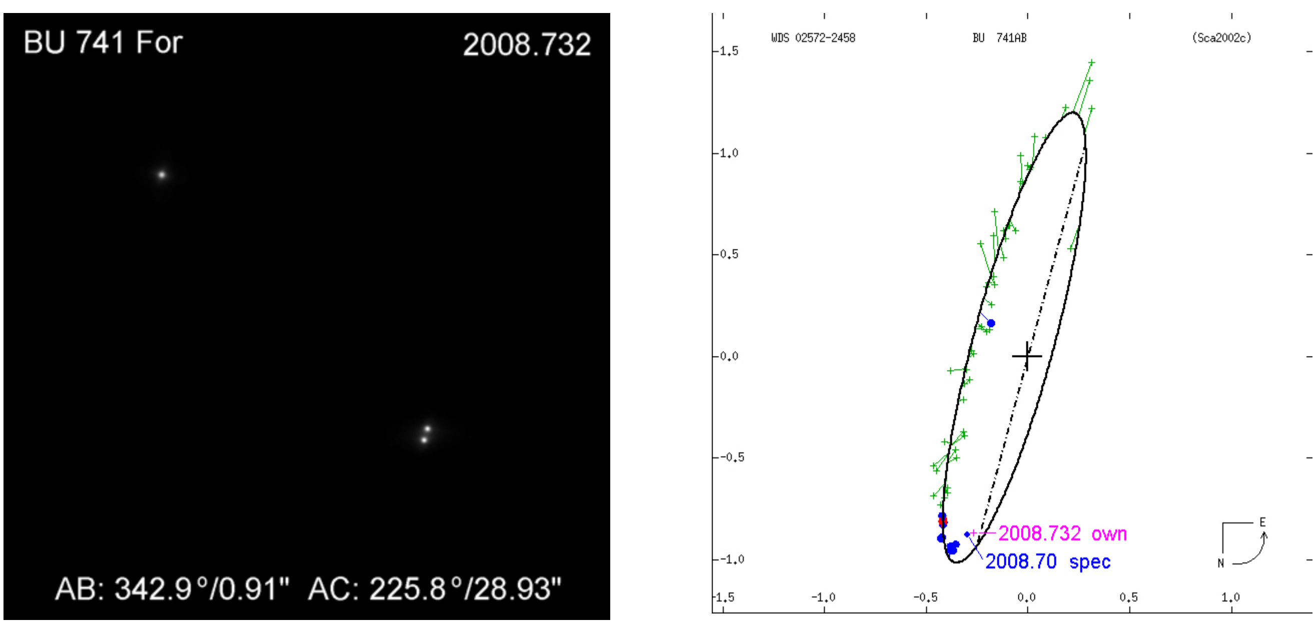
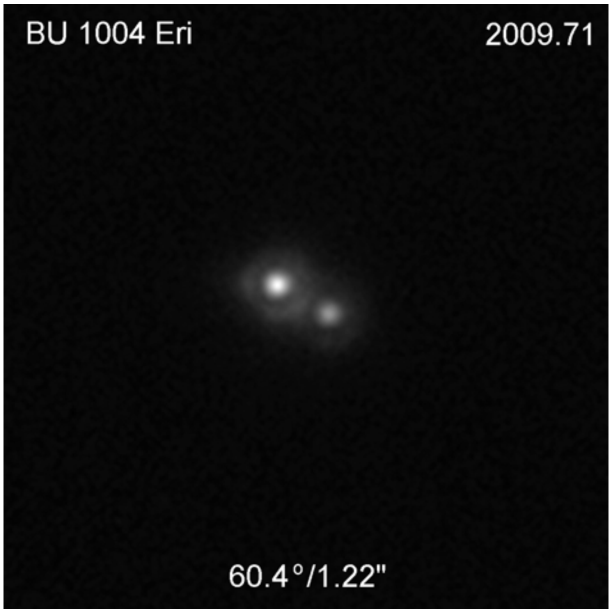


Figure 2: Left: The triple system BU 741 AB/S 423 AB-C in Fornax (52 frames x 16 msec). Right: The orbit of AB (modified from [5]). Recent position measurements with speckle interferometry (blue) and my own (magenta) deviate from the currently assumed orbit beyond the error margins.



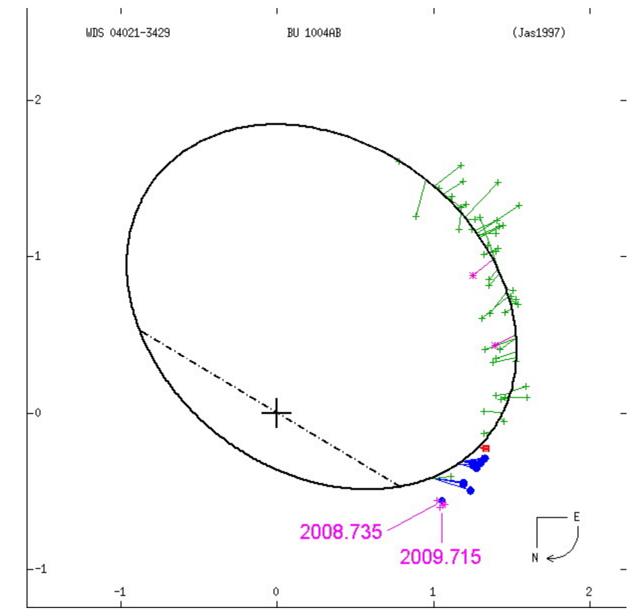
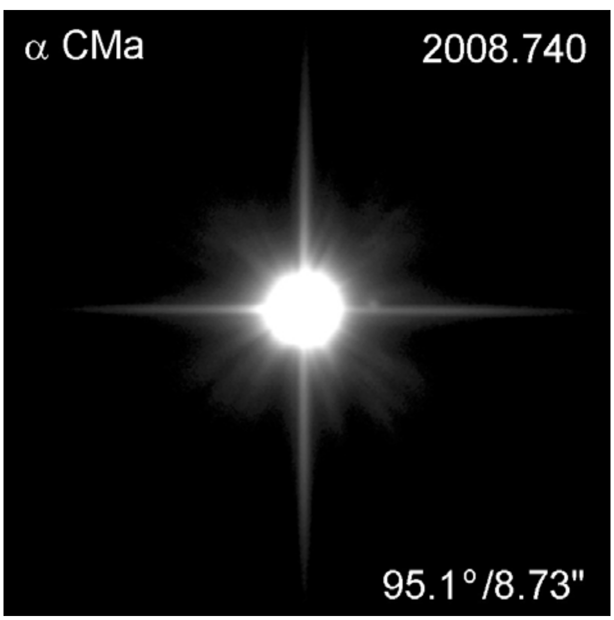


Figure 3: Left: The binary BU 1004 AB in Eridanus (88 frames x 33 msec). The position given at the bottom is the average of 3 measurements around the date indicated at upper right. Right: The orbit of AB (modified from [5]). Recent position measurements with speckle interferometry (blue) and my own (magenta) strongly deviate from the currently assumed orbit.



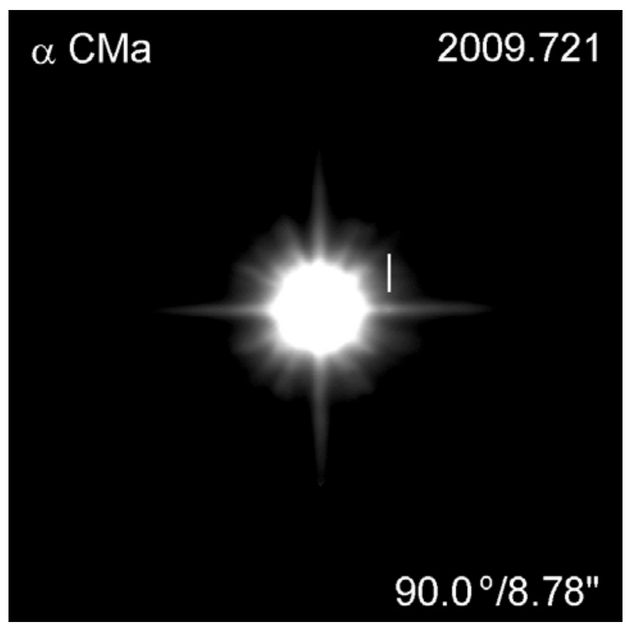


Figure 4: Sirius. The faint companion has moved from 2008 to 2009 by about 5°. Left image: 66 frames x 12 msec, right image: 36 x 12 msec. In 2009, it coincides with the diffraction spike from the spider of the secondary mirror (as is marked with a white line). Both images were recorded with the same configuration (without Barlow and filter), only the seeing was far from optimum in 2009.

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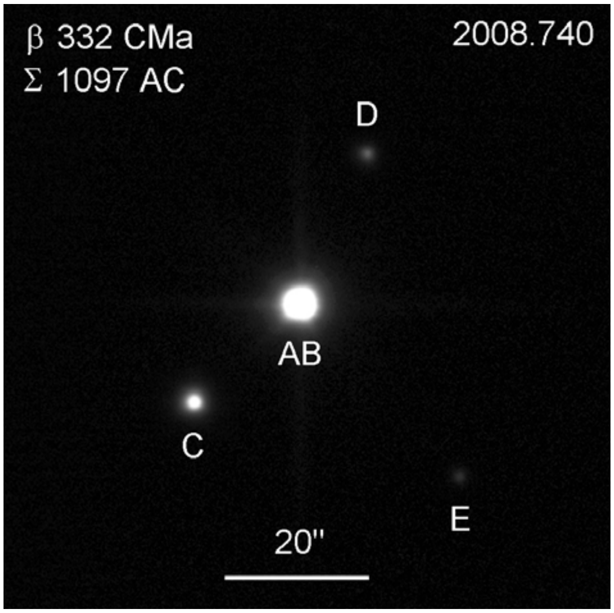


Figure 5: Wide field image of the multiple system BU 332 in Canis Maior (32 frames x 0.5 sec). The close pair AB is not resolved here because of overexposure, but it had been separately recorded with shorter exposure times.

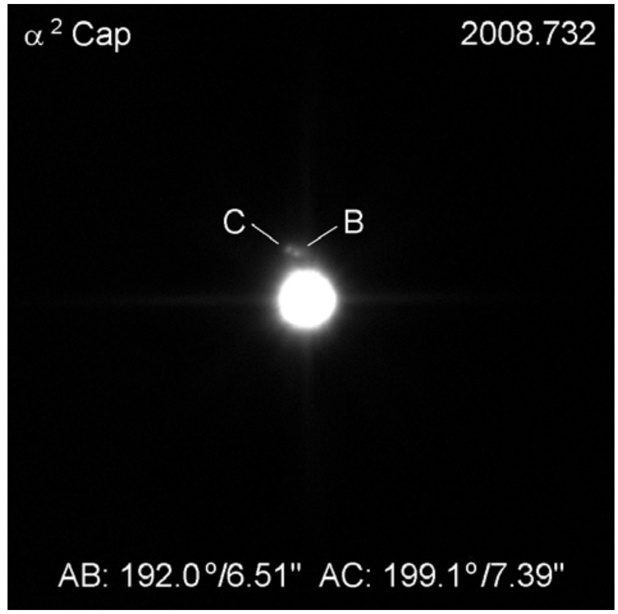
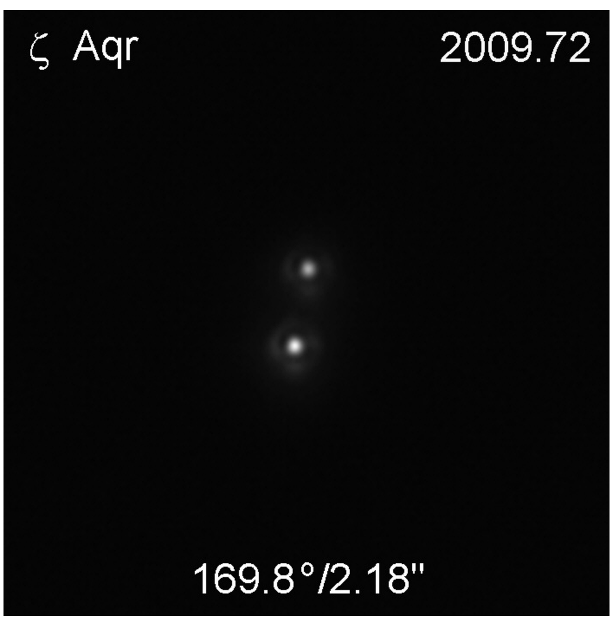


Figure 6: The optical system alpha2 Capricorni (46 frames x 0.5 sec). The close pair BC seems to slowly pass by the bright star in left direction (west).



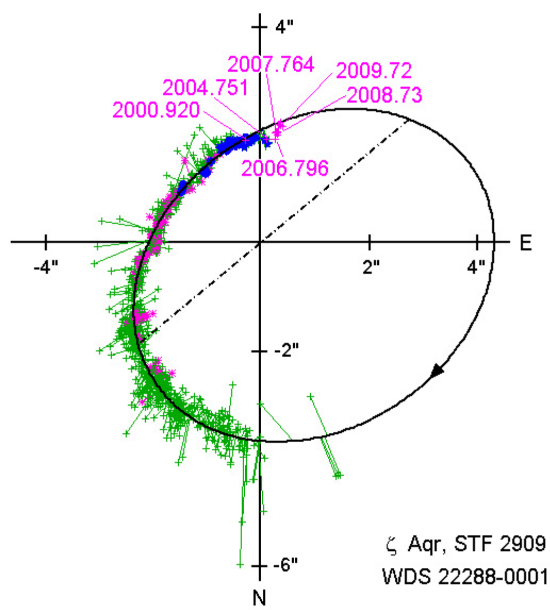


Figure 7: Left: The binary zeta Aquarii. Composite image from 5 recordings around the date indicated at upper right. Exposure times varied from 4 to 12 msec, all with Barlow and red filter. Right: The orbit with indicated own measurements from 2000 to 2009 (modified from [5]). Markings with date 2008.73 represent six measurements around that date, those at 2009.72 five measurements.