Double Star Measurements at the International Amateur Sternwarte (IAS) in Namibia in 2007

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Abstract: A 50cm-Cassegrain and an 11-inch Schmidt Cassegrain at the Internationale Amateursternwarte (IAS) in Namibia was used for observing double and multiple systems at 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 55 pairs in 39 systems are presented and compared with literature data.

Introduction

Usually, seeing limits the resolution of the telescope. However, diffraction limited images of double stars – and of other celestial objects - can be obtained by a method, which is sometimes called "lucky imaging". By using short exposure times and high frame rates, the moments of good seeing can be "frozen" and the best images selected for superposition. I have used this technique now for more than ten years with CCD-video cameras, and found that the error margin in double star positions can be as small as 0.1 arcsec, even with modest amateur telescopes and even under non-optimum seeing conditions [1-3]. The video camera is now replaced by a high-resolution CCD-firewire camera, which delivers a significantly better image quality at relatively high frames rates. In 2002 and 2003, I measured several double star systems in the southern sky. The recent stay in Namibia was also intended to repeat some earlier measurements, which appeared questionable because of significant deviations from older literature data.

Equipment and Image Processing

The *Internationale Amateursternwarte* (IAS, www.ias-observatory.org) is based in Germany and maintains and develops observatories at a guest farm and on the Gamsberg in Namibia, approximately 160 km south-west of Windhuk, the capital of the country. As a member of the IAS, I obtained observing time for one week in May 2007 at a 50cm-Cassegrain and an 11 inch SCT located at the guest farm. At a height of 1880 m above sea level, the seeing conditions were quite good for most of the time, although not optimum.

Digital images were recorded with a b/w-CCD firewire camera (DMK21AF04, The Imaging Source) and stored as bitmaps directly in the computer, without conversion into video signals. The chip contains 640x480 square pixels with size 5.6 µm, which results in an image scale of 0.42 arcsec/pix with the C11 (f = 2.8 m), and 0.26 arcsec/pix with the 50 cm Cassegrain (f = 4.5m). These values are about halved when using a Barlow lens. However, the exact calibration of the image scale was obtained by imaging double stars with well known separations. This will be explained in more detail in section III. At short exposure times down to 0.1 msec, I could obtain an image frequency of about 10 to 15 frames per sec with my notebook. This can be somewhat increased, and the amount of data reduced, by limiting the image size to the "region of interest".

When using a Barlow lens, the high sensitivity of the chip at near infrared wavelengths together with the not sufficient chromatic correction requires insertion of a band filter. This reduces the sensitivity by about 2 magnitudes. As an example, a minimum exposure time of about 0.2 msec is needed for a star of mag 1.0 with the C11, or 0.1 msec with the 50 cm Cassegrain. The actual exposure time is chosen as a compromise between signal-to-noise ratio and pixel

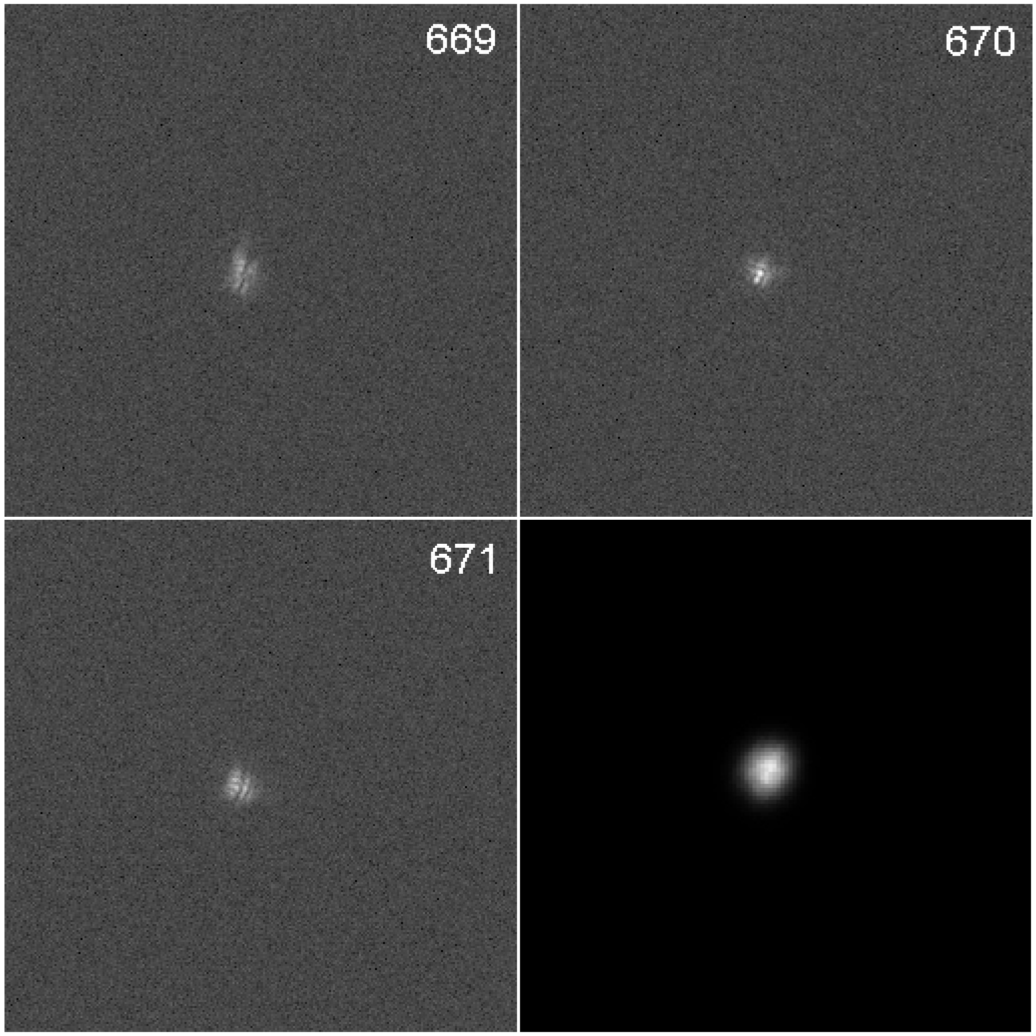

Figure 1: Three consecutive original frames of g Centauri (with numbers at upper right, exposure time 4 msec, time lapse 80 msec), obtained with the 50cm-Cassegrain with Barlow lens and near-IR filter. The image at lower right is an enlarged view of the superposition of 500 unselected frames (without resampling), corresponding to an exposure time of 2 sec. While there exist some nearly perfect images like no. 670, the superposition produces rather diffuse, overlapping seeing discs.

saturation. Generally, a well defined star image should comprise just a couple of pixels. With a set of 4 filters (near infrared, red, green, blue), I also produce composite images of double stars with color contrast.

Depending on the seeing, the yield of useful images is typically not more than a few percent. Usually, I choose the best frames by visual inspection and superpose them manually in the computer. While there exist programs for doing this automatically, I encountered difficulties when dealing with image distortions like, for example, unevenly illuminated diffraction rings around the central Airy disc, which can be caused by a slight misalignment of the telescope (coma) combined with seeing effects (see Figure 1).

In order to obtain sufficiently well defined images, I choose between 32 and 128 best frames, which are then resampled (often two times), registered and superposed. This results in rather smooth intensity profiles of star images and allows accurate determination of the peak centroid. This is shown in Figure 2 for the system γ (gamma) Centauri and the accompanying line scan of the intensity profile. The image scale was calibrated with two “neighboring” systems: the relfix

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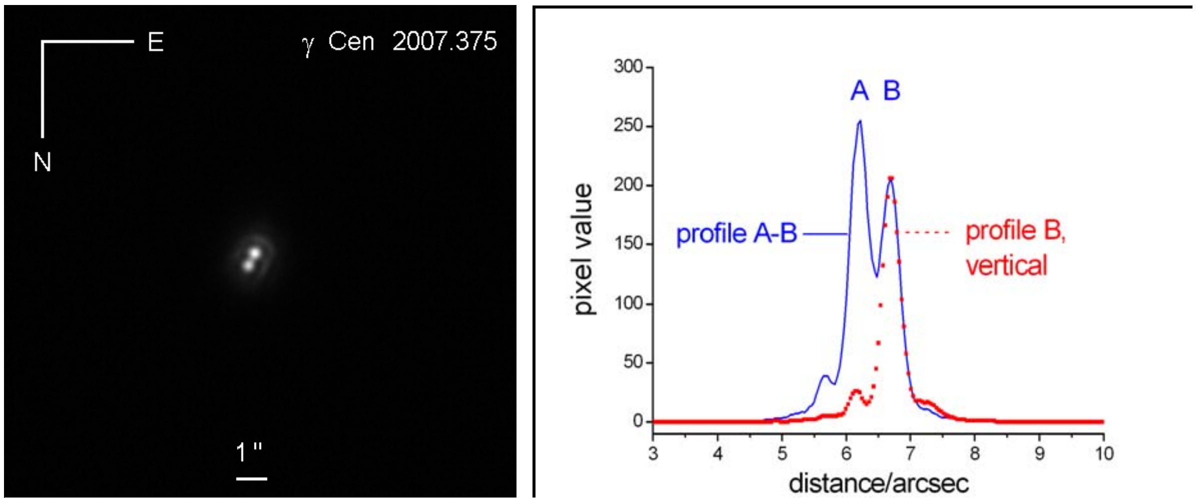

Figure 2: Left: Superposition of 32 best frames out of 1500 (similar to no. 670 in fig. 1) after two times resampling. The slightly asymmetric diffraction rings may indicate some coma, which however, does not impair the accuracy of determining the peak centroids. Right: intensity profiles in line of the components A-B (blue) and vertically across component B red, dotted). The peak widths at half height of the components are about 0.5 arcsec, the measured separation is 0.47 arcsec with an estimated error margin of +/- 0.03 arcsec.

pair DUN117 in Crux, separation 22.7 arcsec, and alpha Crucis AB, separation 4.0 arcsec, which were imaged under the same conditions.

Calibration and Measurements

The image scale can in principal be calculated from the pixel and chip dimensions and the focal length of the telescope, as was already mentioned before. However, when using a Barlow lens, the effective focal length depends on its exact distance to the chip. This must be fixed. Therefore, I have done the calibration independently, in the same way as I have described in my earlier papers, namely by measuring a number of systems with well known separations, including but not limited to systems denoted as relatively fixed ("relfix") in the literature. Only those systems were considered for reference, which exhibit either negligible or well predictable movements based on not too few data. In these cases positions have been extrapolated to the epoch 2007.35. Main sources were the WDS [4], the 4th Catalog of Interferometric Measurements of Binary Stars [5], the 6th Catalog of Orbits of Visual Binary Stars [6], the Sky Catalog 2000.0 [7], and Burnham´s Celestial Handbook [8]. All measurements are listed in Table 1 below. Individual remarks are given following the table. Systems included for calibration are marked by shaded lines. The image scale was adjusted such that the average difference between measured and (extrapolated) literature data of these systems became virtually zero. This is also illustrated in Figure 3 below, where the residuals of all measurements are plotted. The resulting image scales (with Barlow) are 0.2204 +/- 0.005 arcsec/pixel for the C11, and 0.132 +/- 0.002 arcsec/pixel for the 50 cm Cassegrain. The latter value is based on only two systems, DUN117 and alpha Crucis AB, as was already mentioned in section II, but appears as rather reliable.

Discussion and Conclusion

It is apparent that diffraction limited images of double stars can almost routinely be obtained by employing the technique of selecting and superposing only the best frames out of longer sequences. In particular, the firewire camera delivers a significantly improved image quality when compared with video. It is remarkable that 28 out of 55 measured separations deviate less than +/- 0.1 arcsec from the corresponding extrapolated literature data. It turns out that among these 28 there are only three relfix systems, but mainly others, which apparently exhibit predictable

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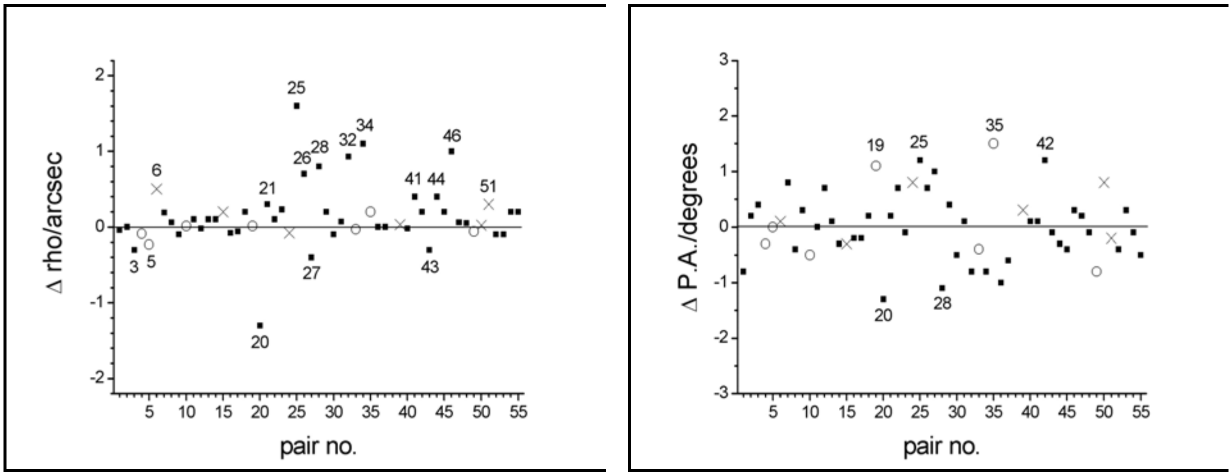

Figure 3: left: Differences Δ rho of measured separations minus extrapolated reference data (residuals) of pairs listed in table 1. Open circles mark binaries, crosses systems denoted as relfix in the literature. Pairs with measured deviations greater than +/- 0.2 arcsec are marked by their numbers. Right: same for the position angles. Pairs with deviations greater than +/- 1 degree are marked by their numbers. Generally, deviations may have various reasons as explained in the notes to table 1. In addition, the error margin for P.A. increases with decreasing separation, due to the limited resolution in the images. Note: For nos. 1 and 2, average values from table 1 are plotted.

PAIR	RA + DEC	MAGS	PA meas.	rho meas.	DATE	N	D PA	D rho	NOTES
DUN 252AB	12 26.6 -63 06	1.25 1.55	113.5	3.96	2007.375	2	+0.5	-0.08	1a*
DUN 252AB	12 26.6 -63 06	1.25 1.55	112.5	4.04	2007.364	2	-0.5	0.0	1b
DUN 252AC	12 26.6 -63 06	1.25 4.8	202.5	90.2	2007.375	1	+0.5	+0.2	2a*
DUN 252AC	12 26.6 -63 06	1.25 4.8	202.2	90.0	2007.364	2	+0.2	0.0	2b
DON 541AB	12 37.2 -69 08	2.69 13.0	321.4	28.8	2007.373	1	+0.4	-0.3	3
HJ 4539AB	12 41.5 -48 58	2.82 2.88	335.2	0.47	2007.375	1	-0.3	-0.09	4*
R 207	12 46.3 -68 06	3.52 3.98	48.1	1.04	2007.373	1	0	-0.23	5
DUN 126AB	12 54.6 -57 11	3.94 4.95	17.1	34.6	2007.370	1	+0.1	-0.2	6
DUN 128	13 06.9 -49 54	4.23 10.1	99.8	25.2	2007.373	1	+0.8	+0.2	7
RMK 16AB	13 08.1 -65 18	5.65 7.55	186.6	5.36	2007.373	1	-0.4	+0.06	8
DUN 146	13 49.3 -40 31	6.95 7.45	86.7	67.5	2007.373	1	+0.3	-0.1	9
RHD 1AB	14 39.6 -60 50	0.14 1.24	235.7	8.78	2007.367	2	-0.5	+0.01	10
CPO 62	14 58.5 -47 26	7.37 8.36	164.0	24.6	2007.373	1	0.0	+0.1	11

Table 1: List of all measurements. Systems used for calibration are marked by shaded lines. Asterisks denote measurements with the 50 cm Cassegrain. System names, positions and magnitudes are taken from the WDS 2006.5. The two columns before the last one show the differences Δ (delta) of measured position angles (PA) and separations (rho) minus reference data (see text). These are also plotted in Figure 3. N is the number of measurements at different nights, with different camera settings and/or filters.

Table continued on next page.

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PAIR	RA + DEC	MAGS	PA meas.	rho meas.	DATE	N	D PA	D rho	NOTES
HJ 4728	15 05.1 -47 03	4.56 4.60	66.7	1.68	2007.367	1	+0.7	-0.02	12
CPO 415	15 10.7 -43 44	7.07 7.66	20.5	49.9	2007.373	1	+0.1	+0.1	13
DUN 178AC	15 11.6 -45 17	6.53 7.31	257.4	30.78	2007,373	1	-0.3	+0.1	14
DUN 177	15 11.9 -48 44	3.83 5.52	142.5	26.46	2007.373	1	-0.3	+0.2	15
DUN 176	15 12.3 -52 06	3.50 6.74	248.8	71.72	2007.373	1	-0.2	-0.1	16
HJ 4753AB	15 18.5 -47 53	4.99 4.93	307.8	0.94	2007.373	1	-0.2	-0.06	17
DUN 180AC	15 18.5 -47 53	4.99 6.34	129.2	23.17	2007.373	1	+0.2	+0.2	18
HJ 4786	15 35.1 -41 10	2.95 4.45	278.4	0.83	2007.367	1	+1.1	+0.01	19
HDO 250	15 38.1 -42 34	4.33 11.2	28.7	11.43	2007.373	1	-1.3	-1.3	20
ARG 28AB	15 41.9 -30 09	7.86 10.1	24.2	35.4	2007.373	1	+0.2	+0.3	21
ARG 28AC	15 41.9 -30 09	7.86 10.4	331.7	35.7	2007.373	1	+0.7	+0.1	22
ARG 28AD	15 41.9 -30 09	7.86 10.5	323.9	88.7	2007.373	1	-0.1	+0.2	23
PZ 4	15 56.9 -33 58	5.09 5.56	49.5	10.32	2007.373	1	+0.5	-0.08	24
B 2372AB	15 59.5 -71 07	7.8 14.?	241.2	9.6	2007.373	1	+1.2	+1.6	25
BSO 21AC	15 59.5 -71 07	7.8 8.65	319.7	37.7	2007.373	1	+0.7	+0.7	26
RMK 21AB	16 00.1 -38 24	3.37 7.50	20.3	14.43	2007.373	1	+1.0	-0.4	27
RMK 21AC	16 00.1 -38 24	3.37 9.27	247.7	115.8	2007.373	1	-1.1	+0.8	28
BU 120Aa-B	16 12.0 -19 28	4.35 5.31	2.4	1.38	2007.375	1	+0.4	+0.2	29
H 5 6Aa-C	16 12.0 -19 28	4.21 6.60	336.1	41.52	2007.375	1	-0.5	-0.1	30
MTL 2CD	16 12.0 -19 28	6.60 7.23	54.5	2.51	2007.375	2	+0.1	+0.07	31
DUN 214	17 13.3 -67 12	5.99 8.78	16.2	39.03	2007.373	4	-0.8	+0.93	32
MLO 4AB	17 19.0 -34 59	6.37 7.38	206.3	1.48	2007.375	2	-0,4	-0.03	33
HJ 4935A-C	17 19.0 -34 59	6.01 10.8	141.3	32.98	2007.375	1	-0.8	+1.1	34
BSO 13AB	17 19.1 -46 38	5.61 8.88	256.9	9.90	2007.373	4	+1.5	+0.2	35
HJ 4949AB	17 26.9 -45 51	5.63 6.46	251.5	2.12	2007.373	1	-1.0	0.0	36
HJ 4970AB	17 42.2 -48 39	8.16 9.13	68.4	8.20	2007.373	1	-0.6	0.0	37
HJ 4970AC	17 42.2 -48 39	8.16 10.5	234.5	20.57	2007.373	1	+0.5	+0.3	38
BU 245	18 10.1 -30 44	5.77 7.99	352.2	4.10	2007.378	1	+0.3	+0.03	39
BU 132	18 11.2 -19 51	7.01 7.13	189.1	1.38	2007.378	1	+0.1	-0.02	40

Table 1: List of all measurements. Systems used for calibration are marked by shaded lines. Asterisks denote measurements with the 50 cm Cassegrain. System names, positions and magnitudes are taken from the WDS 2006.5. The two columns before the last one show the differences Δ (delta) of measured position angles (PA) and separations (rho) minus reference data (see text). These are also plotted in Figure 3. N is the number of measurements at different nights, with different camera settings and/or filters.

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H 5 7AB	18 13.8 -21 04	3.85 10.5	258.1	17.0	2007.368	2	+0.1	+0.4	41
BU 292AC	18 13.8 -21 04	3.85 13.5	119.2	25.8	2007.368	2	+1.2	+0.2	42
HJ 2822AD	18 13.8 -21 04	3.85 9.96	311.9	48.2	2007.368	2	-0.1	-0.3	43
HJ 2822AE	18 13.8 -21 04	3.85 9.22	114.7	50.6	2007.368	2	-0.3	+0.4	44
BU 760AC	18 17.6 -36 46	3.2 13.0	320.6	28.4	2007.364	1	-0.4	+0.2	45
BU 760AD	18 17.6 -36 46	3.2 10.0	319.3	93.9	2007.364	1	+0.3	+1.0	46
STN 62	18 34.5 -34 49	7.57 7.77	132.2	2.34	2007.375	1	+0.2	+0.06	47
HJ 5075	19 04.1 -63 47	7.68 7.69	112.9	1.75	2007.373	1	-0.1	+0.05	48
H N 126	19 04.3 -21 32	7.87 8.06	188.5	1.18	2007.375	1	-0.8	-0.06	49
S 715	19 17.7 -15 58	7.07 7.90	16.8	8.42	2007.373	1	+0.8	+0.02	50
DUN 226	19 22.6 -44 28	3.98 7.21	75.8	28.9	2007.371	1	-0.2	+0.3	51
HJ 2866AB	19 23.4 -18 00	8.69 8.65	52.6	23.6	2007.370	1	-0.4	-0.1	52
HJ 2866AC	19 23.4 -18 00	8.69 9.57	104.3	35.5	2007.370	1	+0.3	-0.1	53
HJ 2866BC	19 23.4 -18 00	8.65 9.57	145.9	27.9	2007.370	1	-0.1	+0.2	54
RMK 25	20.14.9 -56 59	7.97 8.02	28.5	7.42	2007.370	1	-0.5	+0.2	55

Notes

1a*, 1b: α Cru AB, 1a* measured with 50cm-Cassegrain, 1b with the C11.

2a*, 2b: α Cru AC, 2a* measured with 50cm-Cassegrain, 2b with the C11. The 50cm shows at 100msec a fourth component of about 7.5 mag at 146°/56.7”, a fifth of estimated 12th mag at 167°/47.4”, and a sixth, also very faint, at 227°/63.9”. All these are not listed in the WDS (see fig. 4).

3: α Mus AB.

4*: γ Cen AB, binary, P ~ 85 a, imaged with 50cm-Cassegrain, see fig. 2.

5: β Mus, binary, P = 383a (?), rho deviates from interpolated ephemeris, a similar deviation was already noted in an earlier measurement at 2002.685: 44.1°/1.11”[3]. This data seem to follow a trend also seen by other authors. The published orbit may be based on too few measurements. See fig. 5.

6: μ Cru AB, relfix, only few data in the literature, see fig. 6.

7: ξ^2 Cen, common proper motion.

8: θ Mus AB, relfix, few data, see fig. 6.

9: in Centaurus, rho increasing since 1826, few data.

10: α Cen: binary, P ~ 80 a, average data from two measurements on subsequent nights, already measured in 2000 and 2002, all data correspond well to published orbit. See fig. 7.

11: in Lupus, rho virtually fixed.

12: π Lup, already measured in 2002: 66°/1.7 arcsec. Literature data, including interferometric, show relatively small scatter, see fig. 8.

13: in Lupus, common proper motion, relatively fixed since more than 100 years.

14: in Lupus, optical. The close and faint component B (9.6 mag at 1.2”) was not detected in the wide field image at short exposure times. C fits well to rectilinear elements [9].

15: κ Lup, common proper motion. Denoted as relfix in Burnham´s Celestial Handbook, but PA and rho have noticeably decreased since 1826.

16: ζ Lup, virtually no change since decades, only small scatter of literature data.

17, 18: μ Lup: all common proper motion, confusion in WDS on which is A, which B. See fig. 8.

19: γ Lup, binary, measured position close to published orbit. See fig. 8.

20: ω Lup, only few data in the literature. Already measured in 2002 [3], but recent result appears more reliable due to better image quality. See fig. 8.

21-23: multiple system in Lupus. AB no significant change since 1880. AC reference taken from 1960, as data from 1991 in WDS appear doubtful, rho AC decreased since 1880. AD virtually no change since 1880. Brightness of C significantly lower than of D in the red band, although listed as about equal (10.40/10.46 mag, respectively) in the WDS. Component C is listed with 11.4 mag in Sky Catalog 2000.0. See fig. 8.

24: ξ Lup, relfix, also measured in 2002: 49°/10.4”. Only small scatter of literature data.

25, 26: in Apus, AB reference last entry in WDS2006.5 from 1931. Own measure possibly inaccurate due to very low brightness of B. AC PA and rho increasing, color contrast yellow-blue. See fig. 9.

27, 28: η Lup, also known as DUN197, relfix, common proper motion. Only few data in the literature with large scatter. Virtually no change of B and C since 1919. Already measured in 2002, but recent data appear more reliable due to better image quality. Fourth component with estimated 10 mag at 293.3°/135.5 arcsec not listed in WDS. See fig. 8.

29-31: ν Sco, "double double“, all common proper motion, AB rho increasing, AC virtually fixed for more than 100 years, CD rho and PA increasing. See fig. 10.

32: in Ara, optical, PA and rho increasing, components exhibit different proper motions, extrapolation of literature data doubtful. Color contrast orange-blue.

33, 34: in Scorpius, also known as BU416, AB binary, already measured in 2002, both positions fit well to published orbit. AC only few data, PA and rho increasing.

35: L7194, in Ara, binary, also measured in 2002, recent measurement appears more accurate. There exist at least two published ephemeris data. Color contrast (G8V/M0V). See fig. 10.

36: in Ara, PA decreasing.

37, 38: in Ara, AB: virtually no change in the last 80 years. AC: PA and rho increasing. A fourth star is at 270.8°/52.57 arcsec (9.4 mag), which is plotted in Guide 8.0 [10], but not listed in WDS. A fifth star with estimated 10 mag is at 150.5°/13.25 arcsec, which is neither plotted in Guide 8.0 nor listed in WDS.

39: in Sagittarius, relfix, only few data in the literature.

40: in Sagittarius, PA decreasing, rho increasing.

41-44: μ Sgr, multiple system, rho (AB, AC, AD) have increased since 1830, otherwise only slight changes since decades. Error margins may be increased by overexposure of component A. See fig. 11.

45, 46: η Sgr: already measured in 2002.688: AC: 321°/28.2 arcsec, PA increased, rho decreased since 1896; AD: 319°/92.9 arcsec, PA slightly increased, rho data scattered. Component B (3.6 arcsec from A, 7.8 mag) not detected in the glare of A. See fig.11.

47: in Sagittarius, PA slowly decreasing. Only few data.

48: in Pavo, only little change since 1835. Only few data.

49: HU261, in Sagittarius, binary, measured position very close to published orbit.

50: in Sagittarius, relfix.

51: β Sgr, relfix, common proper motion, few data in the literature.

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52-54: in Sagittarius, nice triangle with components of about equal brightness, C probably optical, because of much larger parallax than A and B. See fig. 10. BC very close to rectilinear elements [9].

55: HJ5177, in Pavo, only few data in the literature. Fits rectilinear elements [9].

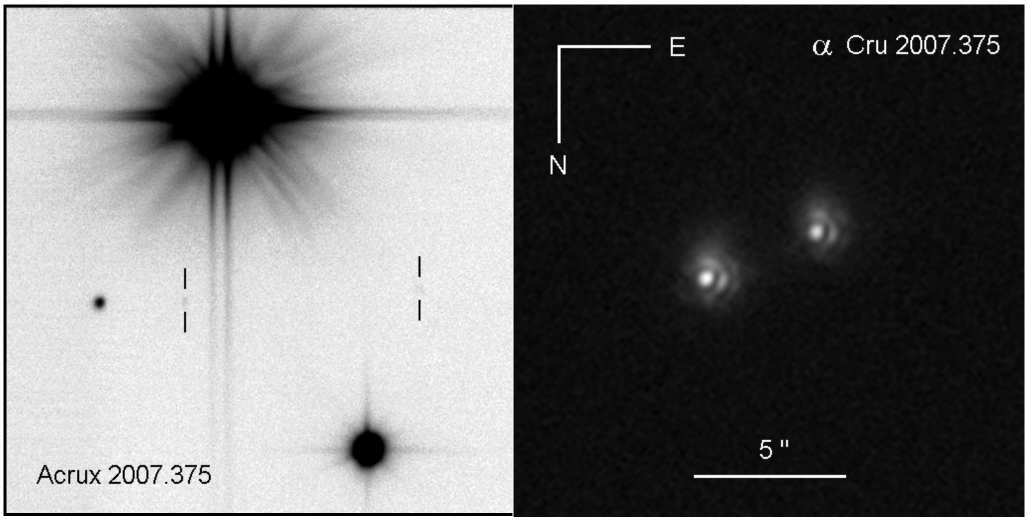

Figure 4: Acrux imaged with the 50cm-Cassegrain. Left: without Barlow, 32 frames, 100msec. AB and C are overexposed. Separations AB and AC were measured using the diffraction spikes. Note the faint component at left. Two other even fainter components are marked by vertical lines. In this image, north is up and east is left. Right: AB with Barlow, NIR filter, 32 frames, 2 msec.

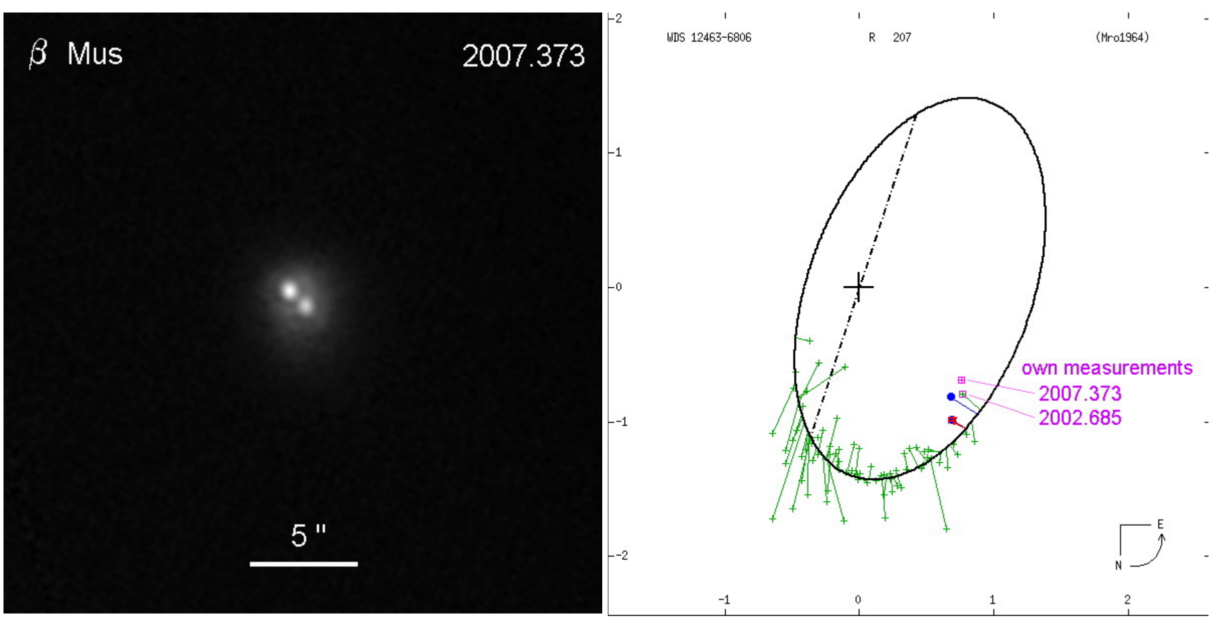

Figure 5: The binary R207 or β Muscae imaged with the C11, 32 frames, 8.3 msec, Barlow, red filter. This system has also been measured in 2002, and both positions are plotted in the graph at right, adopted from the 6th Catalog of Orbits of Binary Stars, USNO. It seems that recent measurements by other authors deviate in similar direction from the calculated orbit.

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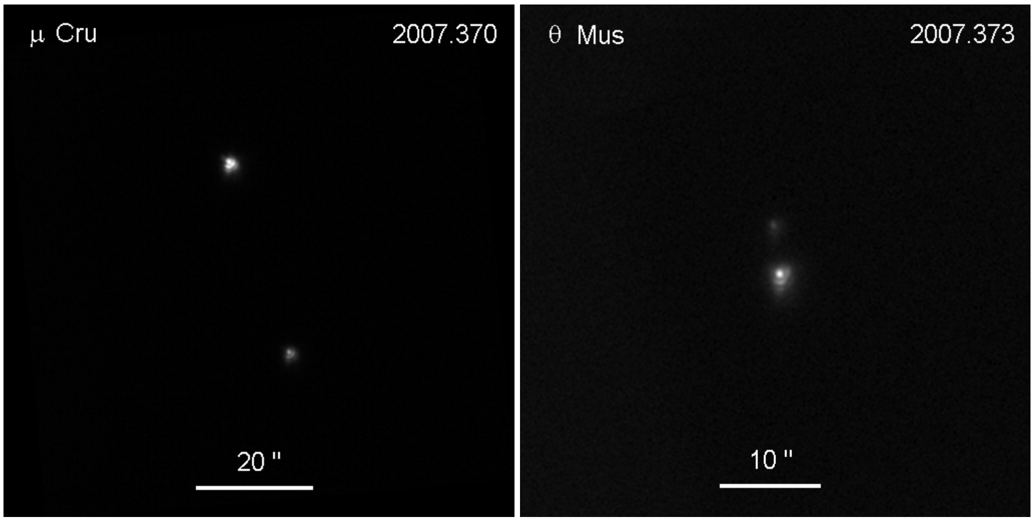

Figure 6: C11 images of "relfix" systems μ Crucis (w/o Barlow, 32 frames, 8.3 msec) and θ Muscae (Barlow, red filter, 64 frames, 33 msec). North is down, east is right, as in all following images.

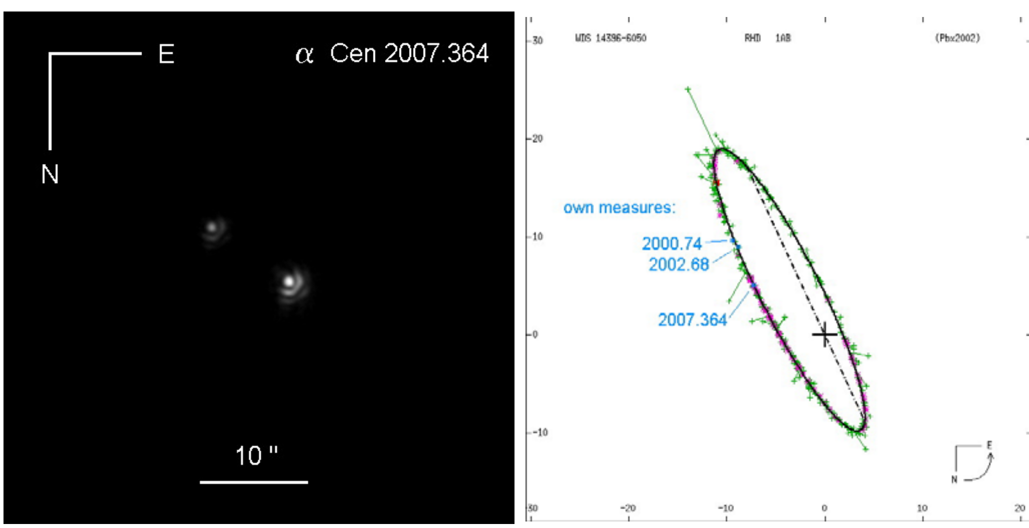

Figure 7: Left: Alpha Centauri, C11 image, Barlow, NIR filter, 1 msec. Right: This system was also measured in 2000 and 2002 with a C8-SCT. All three positions are plotted and fit well to the published orbit, adopted from the 6th Catalog of Orbits of Binary Stars, USNO.

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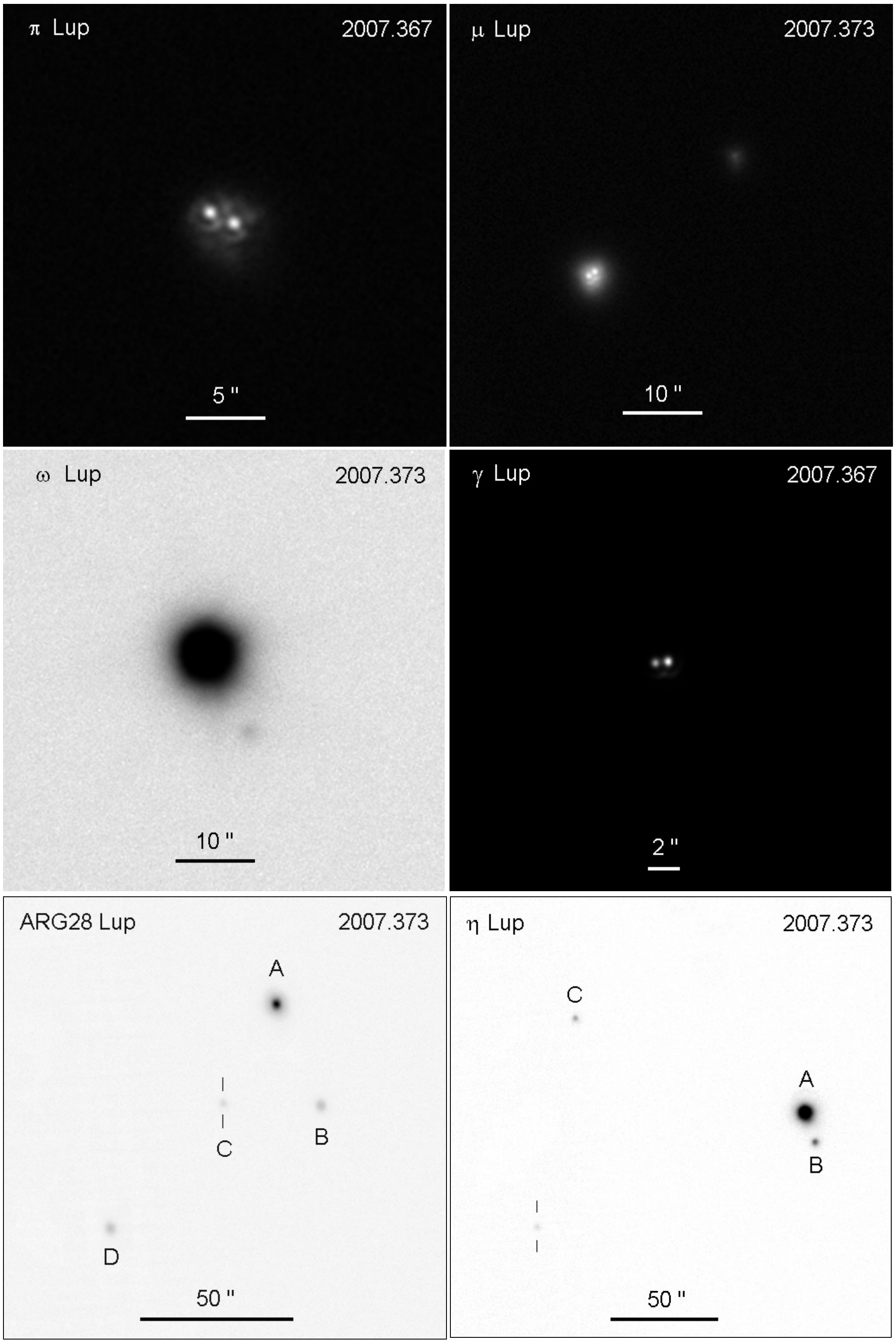

Figure 8: Double and multiple systems in Lupus. C11 images; π, μ, ω, γ with Barlow, ARG28 and η w/o Barlow, all with red filter. Exposures: π, 32 frames, 20 msec; μ, 64 frames, 48 msec; ω, 32 frames, 0.5 sec; γ, 32 frames, 8.3 msec; ARG28, 250 frames, 0.1 sec; η, 32 frames, 0.1 sec.

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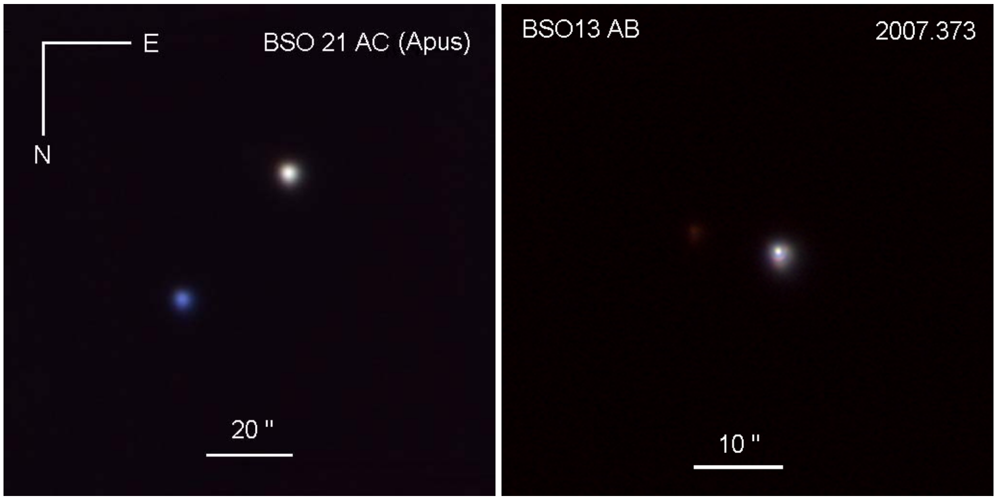

Figure 9: RGB-composites of BSO 21AC in Apus (left) and BSO 13AB in Ara (right). Spectra are classified as G5/? and G8V/MoV, respectively. C11 images.

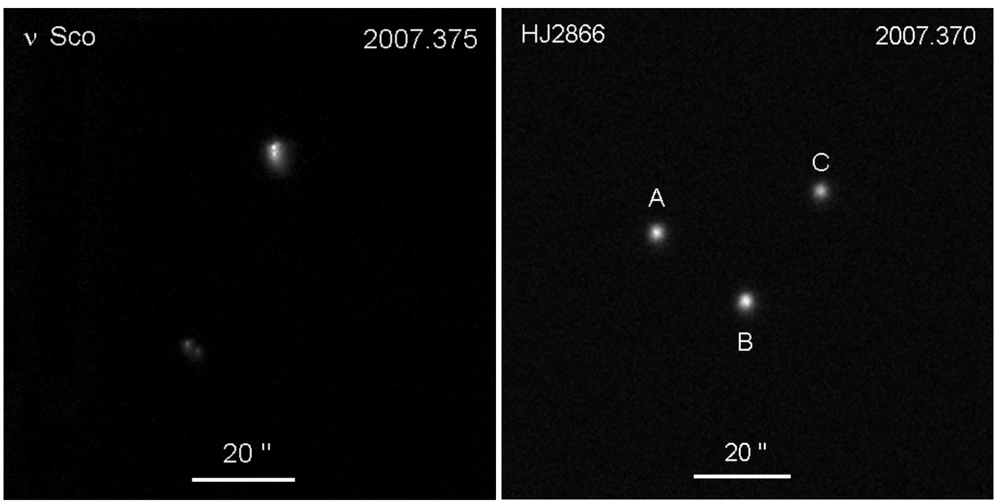

Figure 10: The “double-double” ν Scorpii (left), and the triple system HJ2866 in Sagittarius. C11 images. See notes.

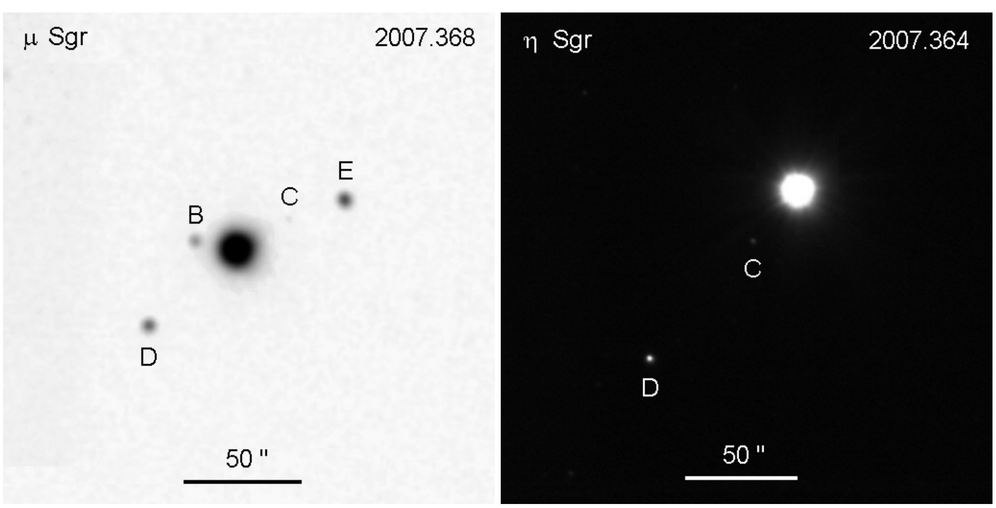

Figure 11: Wide field images of multiple systems μ and η in Sagittarius. C11 images, in both cases 32 frames/0.5 sec w/o Barlow. See notes.

Double Star Measurements at the International Amateur Sternwarte (IAS) in Namibia in 2007

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movements, and even five binaries with well known orbits. On the other hand, there are three relfix systems with larger deviations. Generally, this is caused by too few literature data or too much scatter or both. In this respect, the recent measurements may generally help to improve the statistics of positional data.

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