

# Double Star Measurements at the Southern Sky with a 50 cm Reflector and a Fast CCD Camera in 2014

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**Abstract:** A Ritchey-Chrétien reflector with 50 cm aperture was used in Namibia for recordings of double stars with a fast CCD camera and a notebook computer. From superposition of “lucky images”, measurements of 91 pairings in 79 double and multiple systems were obtained and compared with literature data. Occasional deviations are discussed. Some images of noteworthy systems are also presented.

## Introduction

As in earlier work, the technique of “lucky imaging” was applied to reduce seeing effects in recordings of double star images by using short exposure times. With only the best frames being registered and stacked, the resolution can approach the theoretical limit of the telescope, and the accuracy of position measurements can even be better than this by about one order of magnitude. More details of the technique are, for example, described in reference [1]. In this paper, measurements on double and multiple systems, made in March/April 2014 in Namibia, are reported. Some are well documented in the literature, such that extrapolations are reasonable and can be used for calibration. For many others, however, only few data exist, and often with large scatter. The present results may help to improve the statistics.

## Instrumental

Recordings were made with a 50 cm telescope of Ritchey-Chrétien type (*Alluna*, Germany) at the *Internationale Amateur-Sternwarte* (IAS) in Namibia, which I had already used in 2012 [2, 3]. The focal length is 4.1 m. Imaging was done with a b/w-CCD camera of type “Chameleon” (*Point Grey*). Its small pixel size of 3.75  $\mu\text{m}$  square results in a nominal resolution of 0.19 arcseconds per pixel. This was about halved with a Barlow lens, with only one exception (*Acrux*). A more ex-

act scaling factor was obtained with calibration stars (see Table 1 and discussion below).

Recordings were made with red or near-infrared filters to reduce seeing effects and the atmospheric spectrum, and especially when using the Barlow lens, to reduce chromatic aberration. Exposure times were varied between 0.1 msec and 350 msec, depending on the brightness and on the seeing conditions. The best frames, typically several tens up to more than one hundred, were later selected and stacked, as described earlier.

Position angles were obtained as usual by recording trails in an east-west direction, while the telescope drive was temporarily switched off.

## Results

All measurements are listed in Table 1, which is followed by individual notes. Numbering of the notes (last column at right) is with R.A. values. Names, position, and magnitude data are adopted from the *WDS* [4]. *N* is the total number of recordings. Shaded lines denote systems which were used for calibration of the image scale (see below). The residuals, delta P.A. and delta rho, refer to the trends of literature data, if sufficiently available, or for binaries, to the currently assumed ephemeris, if not otherwise stated. Main sources are the *Fourth Catalog of Interferometric Measurements of Binary Stars* (“speckle catalog”) [5], and the *Sixth*

(Continued on page 87)

**Double Star Measurements at the Southern Sky with a 50 cm Reflector ...**

*Table 1: List of measurements. Systems used for calibration of the image scale are marked by shaded lines. Position angles (P.A.) are in degrees, separations (rho) in arcseconds. N is the number of different recordings. Residuals delta P.A. and/or delta rho are given, when extrapolations of literature data appear reasonable. Notes with asterisks refer to figures shown below.*

PAIR	RA + DEC	MAGS	P.A. meas.	$\rho$ meas.	DATE	N	$\Delta$ P.A.	$\Delta$ rho	NOTES
STT 517 AB	05 13.5 +01 58	6.79 6.99	243.1	0.69	2014.243	1	1.6	0.01	05135
STF 668 A,BC	05 14.5 -08 12	0.3 6.8	202.0	9.52	2014.243	2	-	-	05145
DUN 23	06 04.8 -48 28	7.30 7.69	127.1	2.59	2014.248	1	0.2	-0.01	06048
R 65 AB	06 29.8 -50 14	5.97 6.15	256.9	0.46	2014.248	1	0.8	-0.01	06298
DUN 30 AC		5.97 7.98	311.1	12.03	2014.248	1	-	-	
HDO 195 CD		7.98 8.73	184.2	0.37	2014.248	1	4.2	-0.02	
DUN 32	06 42.3 -38 24	6.59 7.73	277.1	7.95	2014.249	1	0.1	0.02	06423
HU 112	07 01.8 -11 18	7.03 7.70	197.3	0.62	2014.249	2	-1.3	-0.01	07018
I 7	07 17.5 -46 59	7.10 8.35	202.0	0.68	2014.246	2	-0.8	-0.01	07175
STF1104 AB	07 29.4 -15 00	6.39 7.60	36.3	1.79	2014.246	2	-0.7	-0.02	07294
HU 710	07 43.0 -17 04	7.00 7.95	62.7	0.48	2014.243	1	0.7	0.01	07430
STF1146	07 47.9 -12 12	5.73 7.32	341.0	1.07	2014.244	1	0.3	-0.03	07479
HJ 4087	08 22.1 -40 69	7.58 7.98	254.4	1.47	2014.247	1	1.0	0.02	08221
SLR 8	08 32.1 -53 13	6.13 7.08	281.3	0.81	2014.255	1	0	0.01	08321*
BU 205	08 33.1 -24 36	7.14 6.84	290.2	0.54	2014.247	1	2.8	-0.05	08331*
BU 208	08 39.1 -22 40	5.37 6.81	41.8	0.91	2014.247	1	-6.5	+0.18	08391*
I 314	08 39.4 -36 36	6.4 7.9	242.6	0.82	2014.248	2	0.4	0.02	08394
HJ 4188 AB	09 12.5 -43 37	5.96 6.76	281.0	2.88	2014.255	1	0.5	0	09125
COP 1	09 30.7 -40 28	3.91 5.12	115.2	0.99	2014.251	2	-2.6	-0.10	09307*
R 123	09 33.3 -57 58	7.50 7.61	32.7	1.87	2014.256	1	-0.5	-0.01	09333
SEE 115	09 37.2 -53 40	6.12 6.28	9.9	0.68	2014.255	1	0	-0.03	09372
HRG 47	10 03.6 -61 53	6.34 7.93	353.4	1.14	2014.256	1	0.9	-0.02	10036
I 173	10 06.2 -47 22	5.32 7.10	9.3	0.96	2014.251	2	0.6	-0.01	10062*
DUN 89 AB	10 33.3 -55 23	6.79 7.76	31.0	25.93	2014.256	1	-	-	10333
HLD 106 BC		7.76 8.14	255.1	1.41	2014.256	1	-	-	
BU 411	10 36.1 -26 41	6.68 7.77	305.5	1.33	2014.247	1	0.3	0	10361
SEE 119	10 37.3 -48 14	4.13 5.76	259.8	0.46	2014.251	2	2.8	0.03	10373*
R 155 $\mu$ Vel	10 46.8 -49 25	2.82 5.65	56.8	2.32	2014.250	2	0.7	-0.04	10468
HJ 4383	10 53.7 -70 43	6.38 7.09	288.6	1.55	2014.256	1	0	0.04	10537
HJ 4432	11 23.4 -64 57	5.37 6.56	309.8	2.53	2014.256	1	-	-	11234
BSO 5	11 24.7 -61 39	7.68 8.76	248.3	7.49	2014.245	1	0.4	0.02	11247
I 885 Aa,Ab	11 28.6 -45 08	7.98 9.90	146.3	0.58	2014.245	1	5.1	0.06	11286
HJ 4455 AB	11 36.6 -33 34	6.01 7.77	241.1	3.49	2014.256	1	-	-	11366
HLD 114	11 55.0 -56 06	7.36 7.81	169.2	3.82	2014.245	1	1.1	0.74	11550
SEE 143	12 03.6 -39 01	7.05 7.65	25.0	0.49	2014.248	2	0.7	0.01	12036*
DUN 117 AB	12 04.8 -62 00	7.40 7.83	149.4	23.56	2014.232	2	-	-	12048*
DUN 117 AC		7.40 10.0	18.5	25.67	2014.232	2	-	-	
DUN 117 AX		7.40 13?	115.5	3.24	2014.232	1	-	-	
BU 920	12 15.8 -23 21	6.86 8.22	306.3	1.91	2014.244	1	-0.7	0.01	12158
BSO 8	12 24.9 -58 07	7.84 7.98	334.5	5.42	2014.232	1	-	-	12249

*Table 1 continues on next page.*

### Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

Table 1 (continued): List of measurements. Systems used for calibration of the image scale are marked by shaded lines. Position angles (P.A.) are in degrees, separations ( $\rho$ ) in arcseconds.  $N$  is the number of different recordings. Residuals  $\Delta P.A.$  and/or  $\Delta \rho$  are given, when extrapolations of literature data appear reasonable. Notes with asterisks refer to figures shown below.

PAIR	RA + DEC	MAGS	P.A. meas.	$\rho$ meas.	DATE	N	$\Delta P.A.$	$\Delta \rho$	NOTES
BU 606	12 26.0 -14 57	7.42 9.39	289.3	0.54	2014.244	1	1.0	-0.03	12260
DUN 252 AB	12 26.6 -63 06 1	1.25 1.55	112.3	4.00	2014.232	1	-	-	12266
DUN 252 AC		1.25 4.80	202.0	91.8	2014.240	2	-	-	
ANT 1 AG		1.25 10?	145.3	58.7	2014.268	2	-	-	
CPO 12 A,BC	12 28.3 -61 46	7.32 8.24	187.6	2.08	2014.240	1	-1.2	-0.03	12283
R 207	12 46.3 -68 07	3.52 3.98	51.4	0.98	2014.237	3	-6.4	0.08	12463
I 83	12 56.7 -47 41	7.39 7.68	235.6	0.85	2014.248	2	0.3	-0.01	12567
BU 341	13 03.8 -20 35	6.25 6.51	131.7	0.47	2014.246	2	-0.3	0.01	13038
I 917	13 06.6 -46 02	8.13 8.37	277.5	1.39	2014.251	1	1.5	0.03	13066
R 213	13 07.4 -59 52	6.59 7.04	21.5	0.66	2014.251	1	0	-0.01	13074
RST3829	13 14.9 -11 22	7.35 9.14	154.8	0.53	2014.246	2	-1.2	-0.03	13149
I 298	13 32.5 -69 14	7.36 8.54	150.5	0.53	2014.245	1	-1.8	-0.03	13325
HWE 95 AB	13 43.8 -40 11	7.51 7.85	185.1	0.89	2014.256	1	0	-0.03	13438
BU 343	13 52.0 -31 37	6.26 8.91	202.4	0.66	2014.246	2	1.7	-0.03	13520
HWE 28 AB	13 53.5 -35 40	6.27 6.38	314.2	1.00	2014.242	3	0.3	0.06	13535*
SLR 19	14 07.7 -49 52	7.14 7.38	326.7	1.12	2014.243	3	-0.1	-0.03	14077
HJ 4672	14 20.2 -43 04	5.77 7.94	300.8	3.46	2014.256	1	0	0.05	14202
RHD 1 AB	14 39.6 -60 50	0.14 1.24	279.2	4.33	2014.241	5	0.2	-0.01	14396
NZO 52	14 40.8 -66 57	7.87 8.54	59.5	2.21	2014.256	1	-	-	14408
HJ 4707	14 54.2 -66 25	7.53 8.09	271.2	1.13	2014.245	1	0.1	-0.03	14542
I 227 AB	14 56.5 -34 38	8.06 8.39	99.6	0.44	2014.251	1	0.5	0.01	14565a
HJ 4715	14 56.5 -47 53	5.98 6.82	277.9	2.08	2014.256	1	0	0.01	14565b
HN 28 AB	14 57.5 -21 25	5.88 8.18	306.4	25.69	2014.253	2	-0.4	0.01	14575
BU 239	14 58.7 -27 39	6.17 6.79	12.4	0.47	2014.248	1	-0.8	0	14587*
HJ 4728 AB	15 05.1 -47 03	4.56 4.60	64.4	1.64	2014.256	1	0	-0.03	15051
I 228	15 14.0 -43 48	7.98 8.24	12.0	1.34	2014.269	1	0	0.01	15140
STF3091 AB	15 16.0 -04 54	7.74 8.48	228.5	0.51	2014.256	1	3.1	-0.03	15160
BU 227 AB		7.53 8.64	158.9	1.82	2014.249	1	0	-0.01	
HJ 4757	15 23.4 -59 19	4.94 5.73	179.4	0.79	2014.250	2	2.1	-0.03	15234
CPO 16 AB	15 29.5 -58 21	7.03 7.98	33.9	2.48	2014.269	1	0	0.04	15295
B 2036 AB	15 31.3 -33 49	7.7 7.9	1.6	0.38	2014.250	2	0.5	0	15313*
HWE 78 AC	15 31.3 -33 49	7.7 9.11	119.7	1.46	2014.250	2	0	-0.01	15313*
HJ 4786 AB	15 35.1 -41 10	2.95 4.45	275.9	0.83	2014.242	2	-0.7	0	15351*
BU 36	15 53.6 -25 20	4.69 6.98	267.8	1.98	2014.269	1	0	0.01	15536
I 977	15 55.7 -26 45	7.99 8.48	256.3	0.52	2014.250	1	-1.0	-0.02	15557
PZ 4	15 56.9 -33 58	5.09 5.56	49.3	10.18	2014.233	1	0	0.03	15569
SEE 258 AB	16 03.5 -57 47	5.20 5.76	190.0	0.26	2014.233	1	-0.4	-0.01	16035*
HJ 4825 AB,C		4.64 8.02	242.1	11.04	2014.233	1	0.3	-0.01	
HWE 82	16 03.8 -33 04	7.71 7.86	344.7	2.31	2014.269	1	-	-	16038
STF1998 AB	16 04.4 -11 22	5.16 4.87	3.0	1.05	2014.252	2	0.3	0	16044
STF1998 AC		5.16 7.30	42.0	7.97	2014.252	2	-1.8	0.43	

Table 1 concludes on next page.

## Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

*Table 1 (conclusion): List of measurements. Systems used for calibration of the image scale are marked by shaded lines. Position angles (P.A.) are in degrees, separations ( $\rho$ ) in arcseconds.  $N$  is the number of different recordings. Residuals  $\Delta P.A.$  and/or  $\Delta \rho$  are given, when extrapolations of literature data appear reasonable. Notes with asterisks refer to figures shown below.*

PAIR	RA + DEC	MAGS	P.A. meas.	$\rho$ meas.	DATE	N	DP.A.	Drho	NOTES
BU 120 AB	16 12.0 -19 28	4.35 5.31	2.0	1.32	2014.251	1	0	-0.01	16120
MTL 2 CD		6.60 7.23	55.5	2.38	2014.251	1	0	0.04	
H 5 6 AC		4.35 6.60	335.6	41.58	2014.251	1	-	-	
GNT 1 AB	16 29.4 -26 26	0.96 5.4	276.6	2.57	2014.251	1	-0.4	-0.03	16294
R 283	16 42.5 -37 05	6.98 7.83	246.9	0.81	2014.251	2	1.6	0	16425
BU 1118 AB	17 10.4 -15 44	3.05 3.27	232.3	0.55	2014.250	1	0	-0.02	17104
SHJ 243 AB	17 15.3 -26 36	5.12 5.12	141.1	5.06	2014.251	1	0	0.05	17153
MLO 4	17 19.0 -34 59	6.37 7.38	152.5	1.23	2014.251	1	-0.9	0.04	17190
HDO 275	17 44.3 -72 13	6.85 8.11	76.5	0.68	2014.251	1	0	-0.04	17443
HJ 5014	18 06.8 -43 25	5.65 5.68	1.8	1.78	2014.233	1	-0.6	0.02	18068

### Table Notes:

Terms "cpm" (common proper motion) and "relfix" (relatively fixed) refer to Burnham [7].

Asterisks in column "notes" refer to figures shown below.

05135: in Orion, binary,  $P = 312$  y, many speckle data.

05145:  $\beta$  Orionis, "Rigel", measurement difficult, because of large difference in brightness of the components, large scatter of literature data, residuals ambiguous,  $\rho$  seems to slowly increase.

05308: 32 Orionis, binary in doubt,  $P = 586$  y ?, "motion about rectilinear", many speckle data.

06048: in Puppis, binary,  $P = 464$  y.

06298: in Puppis, two binaries, AB:  $P = 52.9$  y, many speckle data, CD:  $P = 101$  y. Few data for AB-CD, residuals ambiguous.

06423: in Puppis, few data, residuals refer to last entry in speckle catalog from 1991.

07018: in Canis major, few data with some scatter, PA increasing.

07175: in Puppis, binary,  $P = 82$  y, large excentricity, many speckle data.

07294: in Puppis, binary,  $P = 729$  y ?, "premature orbit".

07430: in Puppis, binary,  $P = 138$  y, many recent speckle data.

07479: in Puppis, binary,  $P = 1332$  y ?, own measure follows recent speckle data, being close to the re-

cently revised orbit (which much longer period than previously assumed).

08221: in Puppis, binary,  $P = 880$  y ?, few data, only small portion of orbit documented.

08321: in Vela, few data, PA decreasing,  $\rho$  about constant at least since decades. See fig. 3.

08331: in Pyxis, binary,  $P = 136$  y, apparent orbit almost circular, many speckle data, measured position deviates from ephemeris, but fits better to the trend of recent speckle data. See figs. 3 and 4.

08391: in Pyxis, binary,  $P = 123$  y, orbit highly inclined, many speckle data with only small scatter, but significant deviations from ephemeris. Own measure closely follows trend of recent speckle data. Residuals refer to ephemeris.

08394: in Pyxis, binary,  $P = 66$  y, few data.

09125: in Vela, few data, PA decreasing,  $\rho$  increasing.

09307:  $\psi$  Velorum, binary,  $P = 34$  y, own measure deviates from ephemeris, but follows the trend of recent speckle data. See fig. 6.

09333: in Carina, "neglected".

09372: in Vela, PA increasing.

10036: in Carina, "neglected", few data,  $\rho$  virtually constant since about a hundred years, PA increasing?

(Continued on page 85)

## Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

- 10062: in Vela, binary,  $P = 232$  y, few data. See fig. 3.
- 10333: in Vela, tripel, too few data, residuals ambiguous, PA(BC) increasing.
- 10361: in Hydra, binary,  $P = 210$  y, orbit well documented, recent speckle data with only small scatter suggest fairly accurate extrapolation.
- 10373: in Vela, close and fast binary,  $P = 16$  y, although measurement difficult, because companion on diffraction ring, position seems to deviate from the ephemeris, and to follow the trend of recent speckle measurements. See fig. 3.
- 10468:  $\mu$  Velorum, binary,  $P = 138$  y, few data, own measure of  $\rho$  as well as recent speckle data fit quite well to the recently revised orbit.
- 10537: in Carina, few data, residuals refer to last entry in speckle catalog from 1991.
- 11234: in Musca, few data, residuals ambiguous.
- 11247: in Centaurus, binary,  $P = 421$  y, few speckle data.
- 11286: in Centaurus, binary,  $P = 650$  y ?, only small portion of orbit covered, own measure follow speckle data, all deviate from ephemeris.
- 11366: in Hydra, relfix, cpm, few data, residuals ambiguous.
- 11550: in Centaurus, binary,  $P = 930$  y ?, orbit highly inclined, only small portion documented, measured position is far off from ephemeris.
- 12036: in Centaurus, binary,  $P = 109$  y, small scatter of recent speckle data, PA and  $\rho$  rapidly decreasing.
- 12048: in Crux, relfix, few data, dim companion x near A (~13 mag?) not listed in the WDS. See fig. 10.
- 12158: in Corvus, binary,  $P = 873$  y ?, orbit is preliminary, but recent speckle data with relatively small scatter let short term extrapolation appear reasonable.
- 12249: in Crux, few data, residuals ambiguous.
- 12260: in Corvus, binary,  $P = 707.6$  y ?, orbit ambiguous, highly inclined, few data.
- 12266: alpha Crucis, AB binary, no closed orbit determined, few data, even fewer for AC, residuals ambiguous. Separations of both AC and AG have increased by 2.2" or 2.3", respectively, since my last measurements in 2012, while the PA's were about the same. Imaging of component G was done without Barlow, and of distant C even with a reducer to increase the field of view. The corresponding scaling factors were calculated on the basis of images of AB, taken with Barlow.
- 12283: in Crux, binary,  $P = 2520$  y ?, orbit preliminary, few data, PA decreasing. BC not resolved.
- 12463: beta Muscae, binary,  $P = 383$  y, measured position is lying exactly on the orbit, but deviates from the ephemeris. This seems to be shifted by about 5 years. See figs. 5a and 5b.
- 12567: in Centaurus, binary,  $P = 294$  y, measured position is close to recently revised orbit.
- 13038: in Virgo, binary,  $P = 59$  y ?, orbit almost directly edge-on.
- 13066: in Centaurus, "neglected", PA decreasing,  $\rho$  slowly increasing.
- 13074: in Centaurus, relfix, PA decreasing, own measure seems to follow the long time trend, despite large scatter of recent speckle data,  $\rho$  decreasing since about 1950.
- 13149: in Virgo, binary, orbit revised in 2014,  $P = 122.7$  y, few data.
- 13325: in Musca, binary,  $P = 590$  y, few data,  $\rho$  deviates from ephemeris, in accordance with recent speckle data.
- 13438: in Centaurus, few data, PA and  $\rho$  decreasing.
- 13520: in Centaurus, binary, newly revised orbit,  $P = 280$  y, PA decreasing,  $\rho$  rapidly increasing.
- 13535: in Centaurus, binary,  $P = 258$  y, few data, measured position deviates from ephemeris, similar to recent speckle data. See figs. 7a and 7b.
- 14077: in Centaurus, binary,  $P = 233$  y, measured position reasonably fits to recently revised ephemeris.
- 14202: in Lupus, few data,  $\rho$  seems to be slowly decreasing, residuals ambiguous.
- 14396: alpha Centauri, AB binary,  $P = 79.9$  y, well documented.
- 14408: in Circinus, "neglected", few data,  $\rho$  seems to be increasing, residuals ambiguous.
- 14542: in Circinus, binary,  $P = 288$  y, few data, own measure close to ephemeris.
- 14565a: in Centaurus, binary,  $P = 40$  y, own measure close to ephemeris.
- 14565b: also known as DUN 174, in Lupus, although denoted as relfix by Burnham,  $\rho$  has decreased since 1826, while the PA stays about constant in the last hundred years.
- 14575: also known as 33 Librae, AB binary,  $P = 2130$  y (?), only a small portion of the orbit is documented, but this is on a long stretch, which can fairly accurately be extrapolated to the near future.
- 14587: also known as 59 Hydrae, binary,  $P = 429$  y, measured position fits well both the ephemeris and the trend of recent speckle data. See fig. 3.
- 15051: pi Lupi, PA slowly decreasing.
- 15140: in Lupus, "neglected", PA decreasing, while  $\rho$  about constant.

(Continued on page 86)

**Double Star Measurements at the Southern Sky with a 50 cm Reflector ...**

- 15160: in Libra, binary,  $P = 156$  y, large scatter of recent PA (speckle) data.
- 15192: in Libra, few data, PA decreasing.
- 15234: gamma Circini, binary,  $P = 270$  y, while the measured PA is close to the newly revised ephemeris, rho is slightly off.
- 15295: in Circinus, "neglected", PA increasing.
- 15313: in Lupus, triple, AB: binary,  $P = 227.8$  y, orbit almost directly edge-on, rho is rapidly increasing. C is orbiting around AB,  $P = 1258$  y ?, few data. See fig. 3.
- 15351: gamma Lupi, binary,  $P = 190$  y, orbit highly inclined, but reasonably well documented. See fig. 3.
- 15536: in Scorpius, PA and rho decreasing.
- 15557: in Scorpius, binary,  $P = 158$  y, two orbits calculated by Scardia [6], own measure seems to better fit to the first one.
- 15569: xi Lupi, reifix, "splendid".
- 16035: jota<sup>1</sup> Normae, triple, all cpm, AB binary,  $P = 26.9$  y, PA and rho rapidly decreasing, AB-C: few data, PA decreasing. See fig 3.
- 16038: in Lupus, "neglected", although deemed reifix by Burnham, PA and rho are slowly decreasing.
- 16044: xi Scorpil, interesting triple, AB: binary,  $P = 45.8$  y, many speckle data. Own measure fits well to both ephemeris and literature data. AC:  $P = ?$  y, only small portion of orbit covered. Residuals refer to the ephemeris. PA and rho data exhibit large scatter, possibly due to confusion as to which to refer, A or AB. See fig. 9.
- 16120: nu Scorpil, "double-double", but no orbits determined, rho(AB) slowly increasing, PA(CD) slowly increasing.
- 16294: alpha Scorpil, "Antares", binary, preliminary orbit,  $P = 1218$  y, only few recent data, own measure close to ephemeris, although difficult because of large difference of brightness of the components.
- 16425: in Scorpius, binary, "premature orbit", own measure close to ephemeris.
- 17104: eta Ophiuchi, binary,  $P = 88$  y, many speckle data with small scatter. See fig. 3.
- 17153: also known as 36 Ophiuchi, binary,  $P = 550$  y (?), "premature orbit".
- 17190: in Scorpius, binary,  $P = 42.1$  y, PA and rho rapidly decreasing.
- 17443: in Apus, binary,  $P = 101$ y, few data, PA decreasing, rho increasing.
- 18068: in Corona Australis, binary,  $P = 191$  y, own measures deviate from ephemeris, in accordance with the trend of speckle data.

## Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

(Continued from page 81)

*Catalog of Orbits of Visual Binary Stars* [6]. Data available up to December 2014 are taken into account, as of writing this article. In several cases, larger deviations were found, which often agree with trends of literature data. These will be discussed in more detail below. In other cases, literature data are so scarce and/or exhibit so large a scatter that no reasonable residuals can be given.

Systems used for calibration of the image scale were carefully selected. In Table 1, these are marked with shaded lines. Criterion was a well documented history of literature data, i. e. many data with small scatter, generally from the speckle catalog [5], such that extrapolation to the current date was unambiguous. Statistical analysis with 16 pairs resulted in a calibration factor of 0.0967 arcsec/pixel (with Barlow) with an error margin of  $\pm 0.3$  percent. Maximum error margins for separation measurements are expected to be of the order of  $\pm 0.02$  arcsec for the range of relatively small separations considered here.

Generally, residuals were calculated as differences against extrapolated literature data, mainly from the speckle catalog, and for binaries against ephemeris data [6]. In some cases, no reasonable residuals could be given, because of too few data and/or too large a scatter. Some systems exhibit significant deviations which are discussed in the notes or below. Residuals of PA and rho values are plotted versus the measured separation in Figures 1 and 2, respectively.

As can be seen in Figure 1, several residuals are greater than the error limits. As they are usually calculated with respect to the current ephemeris, deviations may indicate that this should sooner or later be revised. In fact, in many cases, residuals against the trend of recent measurements are found much smaller. Examples are shown in Figures 4 and 6 - 8 below.

The error margins of measurements of the position angle are expected to be of the order of about  $\pm 0.2$  degrees for large separations, but to increase toward small separations, and can reach several degrees for very close pairs. The reason is the fixed resolution in the images. In fact, this is apparent in the plot in Fig. 2. However, a number of pairs seem to stand out more than this, in particular binaries with not well known orbits.

Some images of double and multiple systems are presented in the following figures. Fig. 3 is a selection of close binaries with sub-arcsec separations.

### Concluding remarks

For many of the doubles investigated here there are only few data found in the literature, and often with

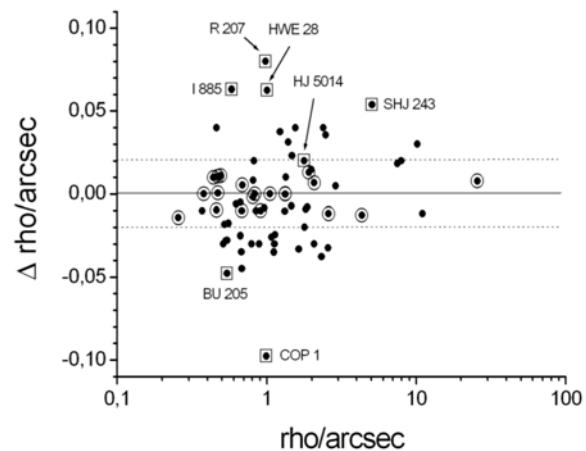


Figure 1. Plot of the residuals of rho versus rho. Semi-logarithmic scale. Pairs used for calibration are marked with superposed open circles. Some systems with large deviations are marked with their names. Symbols with squares denote binaries with significant deviations from ephemeris data. See also notes.

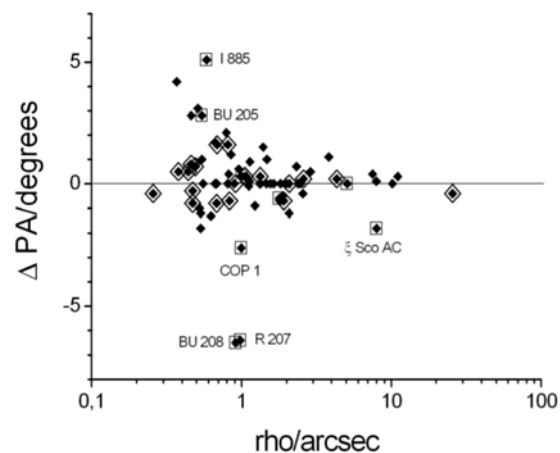


Figure 2. Plot of the residuals of the P.A. versus rho. Semi-logarithmic scale. Pairs used for calibration of the image scale are marked with superposed open rhombs. Some systems with large deviations are marked with their names. See also notes.

(Continued on page 90)

Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

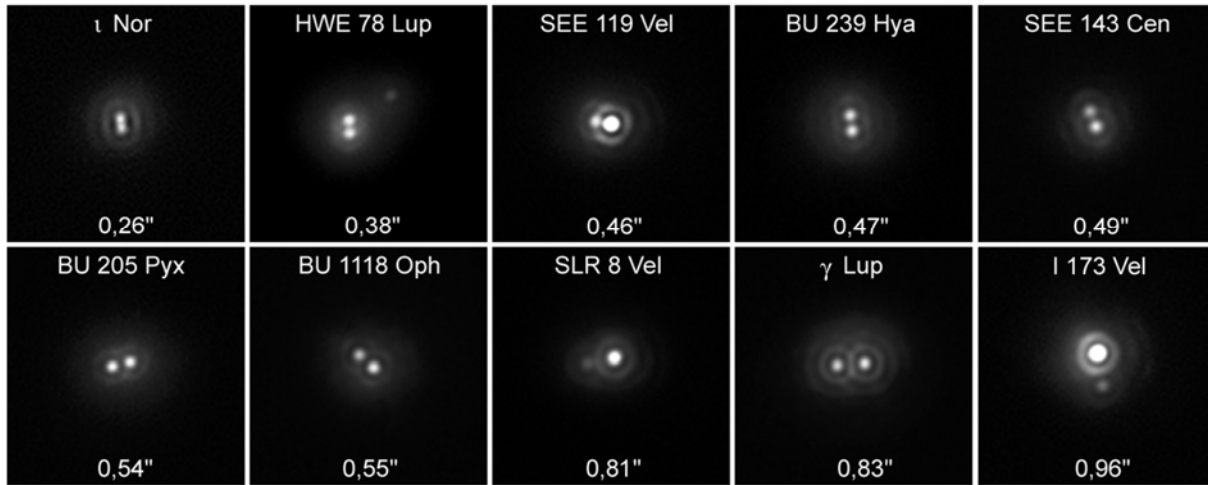


Figure 3. A selection of close binaries. North is down, and east is right, as in all other star images. See also notes 16035, 15313, 10373, 14587, 12036, 08331, 17104, 08321, 15351, 10062, respectively.

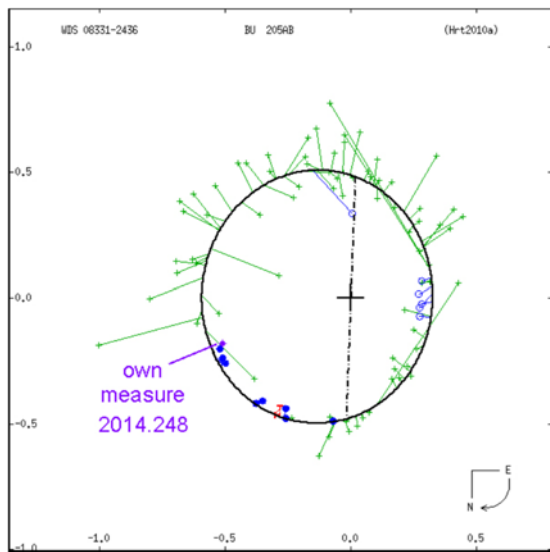


Fig. 4: The orbit of BU 205 AB in Pyxis (WDS 08331-2436). Adopted from reference [6]. Recent speckle data (blue), as well as my own measurement (purple) tend to deviate from the ephemeris. See Fig. 3 and note 08331.

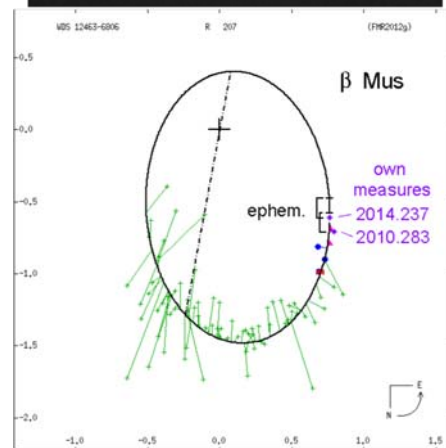
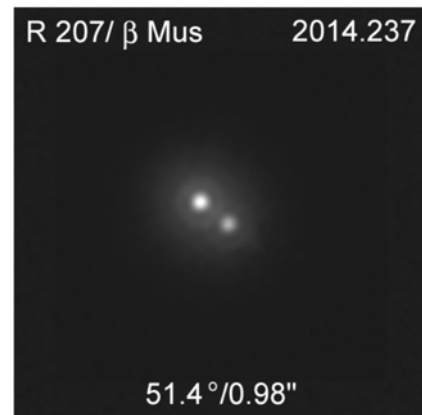


Figure 5a: (Top) The binary R 207/beta Muscae (WDS 12463-6807). Composite of two imaging series recorded on different dates. See also note 12463.

Figure 5b: (Bottom) The orbit of beta Muscae. Adopted from reference [6]. Positions measured in 2012 and 2014 (purple) are on or close to the orbit, but the ephemeris for the respective dates systematically deviate, as indicated. Blue symbols indicate recent speckle data. See also note 12463.



Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

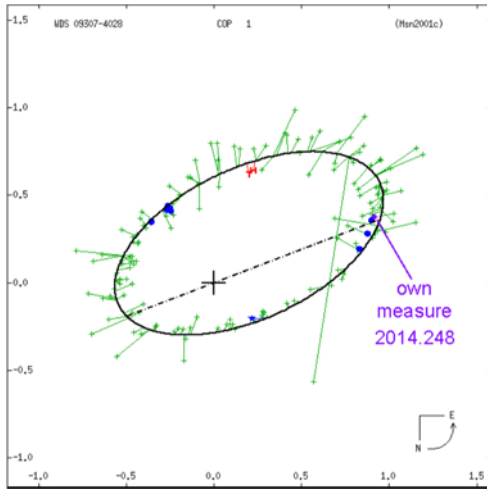


Figure 6. The orbit of COP 1 (WDS 09307-4028,  $\psi$  Vel). Adopted from reference [6]. The measured position (purple) deviates from the orbit, but follows the trend of recent speckle data (blue). See also note 09307.

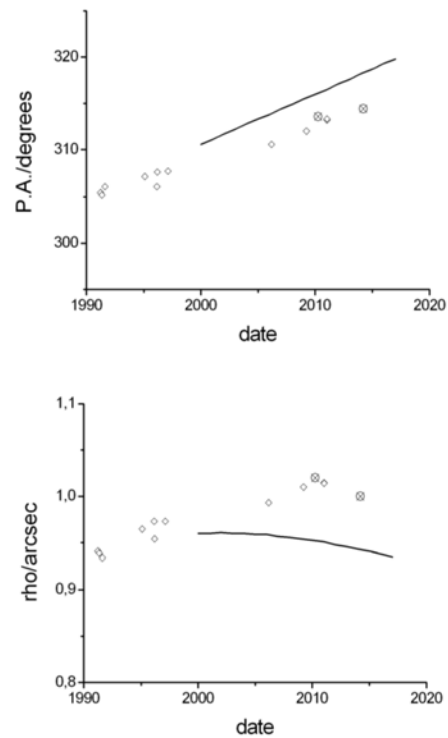


Figure 7a. (Top) Plot of the position angle versus date of the binary of HWE 28 AB in Centaurus (WDS 13535-3540). Open squares are speckle data [5], circles with crosses are own measurements of 2012 and 2014. The solid line is the ephemeris (Lin1998a).

Figure 7b. (Bottom) Plot of the separation  $\rho$  of HWE 28 AB versus date. The meaning of the symbols is as in Fig. 7a. Deviations from the ephemeris are clearly greater than the error margins of the measurements.

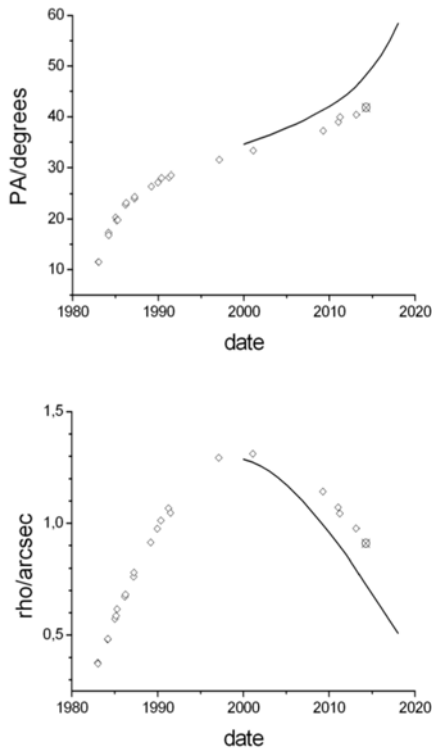


Figure 8a. (Top) Plot of the position angle versus date of the binary of BU 208 AB in Pyxis (WDS 08391-2240). Open squares indicate speckle data [5], the circle with cross is my measurement of 2014. The solid line is the ephemeris (Hei1990c).

Figure 8b. (Bottom) Plot of the separation  $\rho$  of BU 208 AB versus date. The meaning of the symbols is as above. Deviations from the ephemeris are clearly greater than the error margins of the measurements.

Double Star Measurements at the Southern Sky with a 50 cm Reflector ...

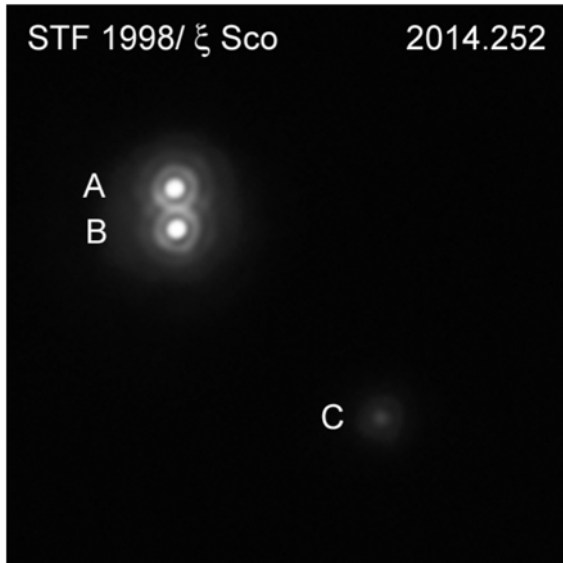


Figure 9. The triple xi Scorpii (STF 1998, WDS 16044-1122). The period of binary AB is about 46 years, while the orbit of C around AB is still not well known. See note 16044.

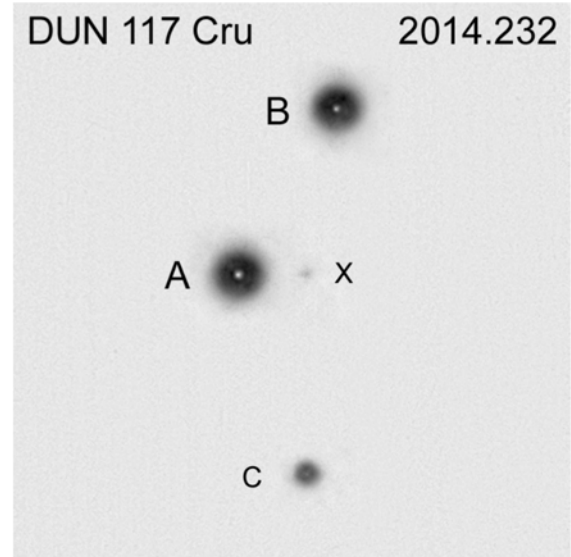


Figure 10. The multiple DUN 117 in Crux (WDS 12048-6200). Composite of a short exposure (specs in the centers of components A, B, and C), and a longer exposure as a negative, in order to show the dim companion x. See note 12048.

(Continued from page 87)

large scatter, although most systems are fairly bright, and easily accessible. The accuracy of my own measurements is checked by comparing with mainly speckle data of systems, which have frequently been measured. Generally, the scatter is of comparable magnitude. As a result of this work, several double star systems were found, which should more often be measured, in order to improve the knowledge about their status, or of their orbits, respectively. In particular, the following systems seem to be interesting:

WDS Ident.	Name
08331-2436	BU 205 Pyx
08391-2240	BU 208 Pyx
08394-3636	I 314 Pyx
09307-4028	COP 1, ψ Vel
10373-4814	SEE 119 Vel
11286-4508	I 885 Cen
11550-5606	HLD 114 Cen
12463-6807	R 207, β Mus
13325-6914	I 298 Mus
13535-3540	HWE 28 Cen
16044-1122	STF 1998 AC, ξ Sco
18068-4325	HJ 5014 CrA

**Acknowledgement**

I have made extensive use of the double star catalogs available online at the USNO website. Special

thanks are due to Brian Mason for directing my attention to a number of less frequently observed and “neglected” doubles.

**References**

- [1] Anton, R., Lucky imaging. In *Observing and Measuring Visual Double Stars, 2nd Edition*, Robert Argyle, ed., Springer, New York, 2012
- [2] IAS, <http://www.ias-observatory.org>
- [3] Anton, R., 2010, *Journal of Double Star Observations*, vol. 6 (2), 133-140.
- [4] Mason, B.D. et al., *The Washington Double Star Catalog (WDS)*, U.S. Naval Observatory, online access Dec. 2014.
- [5] Hartkopf, W.I. et al., *Fourth Catalog of Interferometric Measurements of Binary Stars*, U.S. Naval Observatory, online access Dec. 2014.
- [6] Hartkopf, W.I. et al., *Sixth Catalog of Orbits of Visual Binary Stars*, U.S. Naval Observatory, online access Dec. 2014.
- [7] Burnham, R., Jr., 1978, *Burnham’s Celestial Handbook*, Dover Publications, New York, 1978.