

Astronomical Association of Queensland Program of Measurement of Nine Neglected Southern Multiple Stars

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Abstract: Through the first half of 2015 measurements were completed for the following nine southern multiple stars as listed in the Washington Double Star Catalog. Using a 400mm F4.5 Newtonian reflector fitted with a Meade DSI 2 camera and software programme Astro-Planner V2.1 (Rodman) the obtained images were analyzed using Losse's REDUC software.

Introduction

These latest results are a continuation of the Astronomical Association of Queensland's program of measuring neglected southern multiple stars. Observed from an approximate latitude of 27°S, target stars were selected from the WDSC that met the criteria of a minimum of fifteen years since the last measure and preferably with very few previous observations.

Method

All images were obtained using a Meade DSI 2 CCD camera coupled to an equatorially mounted 400mm F4.5 Newtonian reflector. Separations and position angles were measured using the software program REDUC (Losse), which is specifically designed to measure double stars, using appropriate images of the target pairs together with images of calibration pairs of known separation and PA; Argyle's list of calibration pairs was used for this purpose (Argyle, 2004). For this optical/camera (Sony ICX429 752x582 pixel sensor) combination a FOV of approximately 0.2° was calculated using Argyle's list. The use of REDUC requires input of the image scale of the particular camera/scope combination. By using the same information from the calibration pairs, the image scale mean can be calculated over a number of nights. In this case 10 images themselves consisting of 10 stacked images per night over 7 nights provided the necessary information to calculate the mean. Using this optical

assembly to image calibration pairs Beta Tucanae, Theta Serpens, and Omicron Capricorni, raw image scales varied from 0.940 to 0.978, with a mean figure of 0.96260" per pixel. This figure is then used in REDUC for all the target star reductions. The imaging and reduction methods were described in detail in Napier-Munn & Jenkinson 2009.

In order to obtain statistically viable results, the DSI software is used to stack a minimum of 10 individual good quality images as they are acquired, to generate one image for measuring. About 10 such images are obtained per pair per night, plus 3 trailed images with the tracking switched off in order to calibrate the E-W axis in the images. The REDUC software is then used to generate a single average measure for the 10 images. This process is repeated on 6-7 separate nights, generating mean separations and position angles together with standard deviations from which a confidence interval for the measurement can be calculated and a decision made as to whether there has been a statistically significant change in PA or separation.

Results

The results are presented below, in order of increasing RA. For each system, the current WDSC information is first reproduced, including the epoch 2000 position, magnitudes (if known), PA, separation, and year of last measure. The new measures are then given

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in tabular form, including the date of measurement, mean, standard deviation, and 95% confidence limits (from the formula st_{α}/\sqrt{n} , where t_{α} is the value of t for a 2-sided probability level α (in this case $\alpha = 0.05$), s is the sample standard deviation, and n is the number of observations). An example of a relevant image used in the measures is included.

A conclusion is then given as to whether the pair has moved or not. This is based on judicious interpretation of three criteria in terms of both PA and separation:

1. t-tests for a single sample mean comparing the new mean PA and separation values with the single values given in the WDSC; $P \leq 0.05$ was taken as evidence of movement (that is, the new mean is significantly different to the single value reported in the WDSC, with 95% or more confidence).
2. Whether the last measure as recorded in the WDSC lies within the 95% confidence interval of our new measure (suggesting no movement) or not (suggesting movement).
3. The absolute size of the change; a statistically significant change that is very small is still very small and may not be of practical significance.

Note that in a separate paper (Napier-Munn & Jenkinson 2014) we have shown that the uncertainty in PA increases with decrease in separation, and the uncertainty in separation increases with increase in separation, for reasons discussed in that paper. ‘Uncertainty’ here is defined as the standard deviation of repeated

measures.

The mean 95% confidence intervals for the new measures were $\pm 0.589^{\circ}$ in PA and $\pm 0.134''$ in separation. The results are given in Table 1.

Details of each measure are given in Tables 2 through 10 with examples of the measured images.

Acknowledgements

This research has made use of the Washington Double Star Catalogue maintained at the U.S. Naval Observatory.

References

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Table 1. Summary of Measurements of Nine Multiple Stars.

System	Last listed measure			New measure			Comment
	PA °	Sep. "	Epoch	PA °	Sep. "	Epoch*	
BU1419BC Puppis	300.0	7.8	1903	297.08	8.00	2015.083	Possible small PA change
SEE98 Puppis	67.0	5.9	1928	66.35	5.08	2015.043	Little evident movement
B2659 Pyxis	265.0	8.0	1932	172.79	18.61	2015.099	Large apparent movement
B2263 Vela	315.0	7.0	1932	21.63	12.38	2015.099	Considerable movement
CPO327 Centaurus	321.0	7.6	1930	324.34	6.55	2015.178	Movement
RST3746AB Cen	317.0	16.0	1944	325.97	14.81	2015.178	Clear movement
ARA1790 Corvus	184.0	11.3	1922	151.60	47.63	2015.303	Questionable Sep. change
RSS370 Lupus	148.0	7.2	1976	149.64	7.52	2015.308	Possible small PA
RSS386 TrA	270.0	10.3	1974	14.63	10.31	2015.308	Questionable PA change

* Epochs of new measures given in Besselian years as the average of the observations making up the measure.

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Table 2. Measurements of BU 1419 BC.

BU1419BC Puppis	RA. 08 08.5 MAG. 7.55 & 13.0	DEC. -19 52 PA. 300.0°	Last Measure 1903 SEP. 7.8"
Date	No. images	PA°	Sep"
16 January 2015	11	298.440	8.034
17 January 2015	10	297.130	8.113
30 January 2015	10	295.310	7.915
31 January 2015	9	298.250	7.777
6 February 2015	11	296.550	8.125
14 February 2015	10	297.380	8.131
15 February 2015	10	296.520	7.924
Mean		297.083	8.003
Standard dev.		1.083	0.135
95% CI +/-		1.002	0.125
P(t) movement		0.000	0.007
COMMENTS: Possible slight movement in PA over the last 112 years.			

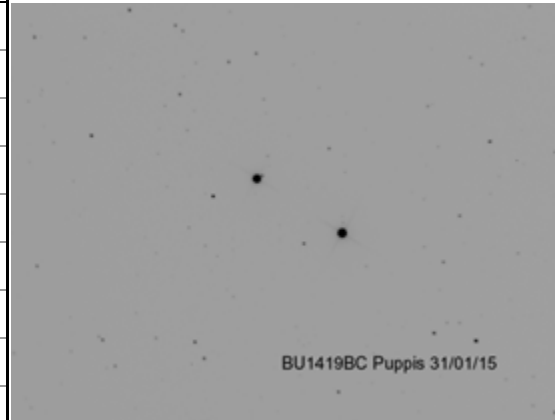


Table 3. Measurements of HO 554 AC.

SEE98 Puppis	RA. 08 14.9 MAG. 6.7 & 12.7	DEC. -35 41 PA. 67°	Last Measure 1928 SEP. 5.9"
Date	No. images	PA°	Sep"
6 January 2015	10	66.540	5.125
7 January 2015	10	66.380	5.134
8 January 2015	10	67.220	5.275
16 January 2015	10	66.750	5.612
17 January 2015	10	65.690	4.835
30 January 2015	10	65.620	4.789
31 January 2015	10	66.220	4.787
Mean		66.346	5.080
Standard dev.		0.569	0.305
95% CI +/-		0.526	0.282
P(t) movement		0.000	0.000
COMMENTS: Little movement evident since 1929.			



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Table 4. Measurements of B 2659.

B2659 Pyxis	RA. 08 29.5	DEC. -18 45	Last Measure 1932
	MAG. 7.7 & 13.2	PA. 265.0°	SEP. 8.0"
Date	No. images	PA°	Sep"
17 January 2015	10	172.440	18.464
30 January 2015	10	172.940	18.639
31 January 2015	11	172.270	18.564
6 February 2015	10	173.220	18.625
14 February 2015	10	172.700	18.746
23 February 2015	10	173.020	18.607
24 February 2015	10	172.910	18.612
Mean		172.786	18.608
Standard dev.		0.336	0.085
95% CI +/-		0.310	0.078
P(t) movement		0.000	0.000
COMMENTS: Large apparent movement in both axes since the only previous measurement in 1932 warrants further investigation.			



Table 5. Measurements of B 2263.

B2263 Vela	RA. 11 03.2	DEC. -51 00	Last Measure 1932
	MAG. 7.8 & 13.0	PA. 315.0°	SEP. 7.0"
Date	No. images	PA°	Sep"
17 January 2015	10	21.660	12.232
30 January 2015	10	21.870	12.184
6 February 2015	10	21.000	12.407
14 February 2015	10	21.040	12.346
21 February 2015	10	23.330	12.143
23 February 2015	10	22.330	12.594
24 February 2015	9	21.880	12.497
Mean		21.630	12.377
Standard dev.		0.521	0.156
95% CI +/-		0.547	0.164
P(t) movement		0.000	0.000
COMMENTS: Poor seeing on 21 February 2015 - results deleted from calculation of mean. Considerable movement apparent since the only previous measure in 1932.			



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Table 6. Measurements of CPO 327.

CPO327 Centaurus	RA. 11 31.1 MAG. 8.0 & 12.8	DEC. -43 33 PA. 321.0°	Last Measure 1930 SEP. 7.6"
Date	No. images	PA°	Sep"
21 February 2015	10	324.540	6.245
27 February 2015	10	325.720	6.348
7 March 2015	10	322.320	6.667
12 March 2015	10	323.680	6.532
14 March 2015	10	323.980	6.538
17 March 2015	10	325.640	6.710
19 March 2015	10	324.500	6.796
Mean		324.340	6.548
Standard dev.		1.177	0.198
95% CI +/-		1.088	0.183
P(t) movement		0.000	0.000
COMMENTS: Increase in PA and decrease in separation appear consistent with the two previous measures in 1902 and 1930.			

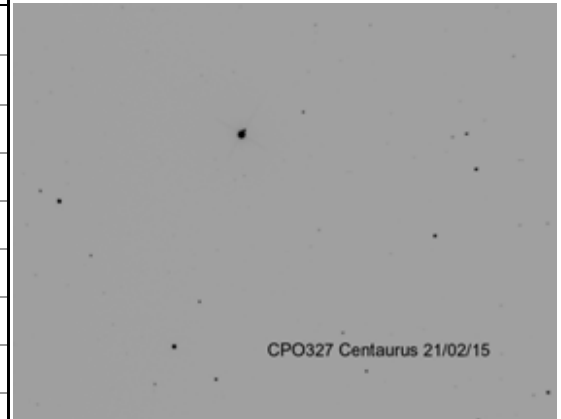
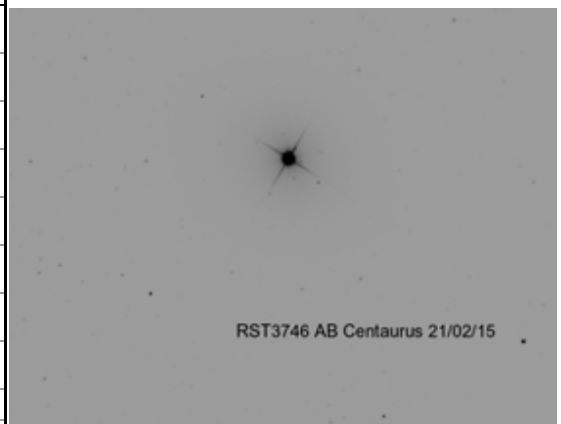


Table 7. Measurements of RST 3746 AB.

RST3746AB CENTAURUS	RA. 11 35.8 MAG. 3.12 & 11.5	DEC. -63 01 PA. 317.0°	Last Measure 1944 SEP. 16.0"
Date	No. images	PA°	Sep"
21 February 2015	10	326.260	14.684
27 February 2015	10	326.310	14.882
7 March 2015	10	325.880	14.774
12 March 2015	10	325.650	14.998
13 March 2015	10	326.020	14.510
14 March 2015	10	325.830	15.163
17 March 2015	10	325.830	14.640
Mean		325.969	14.807
Standard dev.		0.242	0.224
95% CI +/-		0.224	0.207
P(t) movement		0.000	0.063
COMMENTS: Changes in PA & separation consistent with two previous measures in 1937 & 1944.			



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Table 8. Measurements of ARA 1790.

ARA 1790 Corvus	RA. 12 06.2 MAG. 8.8 & 11.1	DEC. -22 47 PA. 184.0°	Last Measure 1922 SEP. 11.3"
Date	No. images	PA°	Sep"
16 April 2015	10	151.660	47.566
17 April 2015	10	151.720	47.724
22 April 2015	10	151.680	47.550
24 April 2015	10	151.680	47.479
26 April 2015	10	151.150	47.511
28 April 2015	10	151.510	47.773
29 April 2015	10	151.790	47.781
Mean		151.599	47.626
Standard dev.		0.215	0.129
95% CI +/-		0.199	0.119
P(t) movement		0.000	0.000
COMMENTS: Large increase in separation over 93 years. Change in PA relative to separation change seems viable.			

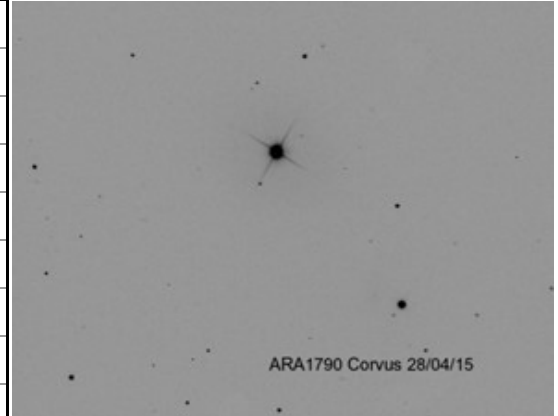
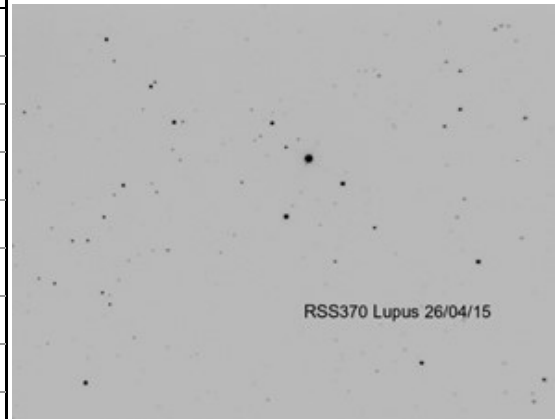


Table 9. Measurements of RSS 370.

RSS 370 Lupus	RA. 15 17.0 MAG. 8.64 & --	DEC. -39 57 PA. 148.0°	Last Measure 1976 SEP. 7.2"
Date	No. images	PA°	Sep"
14 April 2015	11	150.100	7.498
17 April 2015	10	150.230	7.520
18 April 2015	10	149.740	7.559
24 April 2015	10	151.040	7.587
26 April 2015	10	149.240	7.504
04 May 2015	10	148.840	7.615
05 May 2015	10	148.290	7.394
Mean		149.640	7.525
Standard dev.		0.927	0.072
95% CI +/-		0.857	0.067
P(t) movement		0.003	0.000
COMMENTS: Possible small increase in PA since the only previous measure in 1976.			



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Table 10. Measurements of RSS 386.

RSS 386	RA. 15 48.6	DEC. -65 14	Last Measure 1974
Triangulum Aust.	MAG. 8.6 & 12.0	PA. 270°	SEP. 10.3"
Date	No. images	PA°	Sep"
16 April 2015	10	14.460	10.246
17 April 2015	10	14.330	10.388
18 April 2015	10	13.590	10.285
24 April 2015	10	15.140	10.159
04 May 2015	10	14.870	10.378
05 May 2015	10	15.400	10.319
08 May 2015	10	14.610	10.364
Mean		14.629	10.306
Standard dev.		0.593	0.083
95% CI +/-		0.549	0.077
P(t) movement		0.000	0.864
COMMENTS: No change in separation makes large change in PA questionable over the last 41 years.			

