Ludwig Schupmann Observatory Measures of Large Δm Pairs - Part Three

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Abstract: This is the final report of a three part series devoted to the measurement of double stars having a large difference in stellar magnitude. Results are given in theta and rho space for 100 components lying in 47 systems. A comparatively small number of these pairs are physical, however, due to the typically large elapsed time since discovery, the cataloged proper motion values of their bright primaries may, in many objects, be further honed. A few measures of more usual pairs associated with these systems are also given such as the close, fast-moving binary pair called "Capella H".

Introduction

One may get an idea of the difficulties encountered in measuring large Δm pairs by reading the author's article in the Fall 2007 issue of the JDSO (Daley 2007). A description of the special tailpiece instrumentation employed to carry out these observation is also described there.

The visual discovery of these faint components is just amazing and shows just how keen-sighted these early observers were.

The Measures

The following data is listed in the conventional way. From left to right: the discoverer's designation, WDS identifier (Epoch 2000 RA & Dec), WDS mags rounded off to the first place (LSO unfiltered CCD "red" magnitudes in bold italics are Δm inferred from known stars in the system), LSO position angle in degrees, LSO separation in seconds of arc, decimal date of observation (note that these observations span mid October 2008 through late March 2009), number of nights observed and a notes column. In the notes column "neglected pair" entries such as "8m84" signifies 8 previous measures, the last being 84 years ago. Other self explanatory items, perhaps of interest, appear in this column. Extensive notes are also indicated in the notes column and appear at the end of the article. Most measures are the mean of at least 12 CCD frames. Images made with the stellar coronograph of some of the doubles are at the end of this article.

Future Plans

Development of a more powerful stellar coronagraph is underway at LSO. The chief aim being to measure much closer pairs, such as Procyon AB and similar difficult objects. This new instrumentation will be part of a 14-inch Schupmann medial, now nearing completion. In the meantime, the present telescopic system, a 9-inch Schupmann medial, will be used to image the few remaining large Δm systems in the original obs list that was kindly provided by Dr. Brian Mason of the USNO. These results will be worked into upcoming reports of mostly "normal" systems.

Epilogue

With 1,000 plus measures published, I enter my 11th year of double star observations. Now and then I have pondered dreamily: will the future of amateur double star work lean toward specialized observations as more and more powerful astrometric satellites record nearly every double in the sky to accuracies unimaginable? Will we all become "data miners" (many already have)? What is the future of earth-based visual double star astrometry? Even the data miners could go extinct as doubles are machine analyzed, automatically computing orbits, spectral classes and component masses by the millions! From this the astrophysicists will benefit tremendously, surprising us with crisper theories of galactic formation and evolution.

My guess is that, with professional guidance, we who love observing under the stars will find a place to fit in meaningfully for a long time to come.

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Table 1: Measures made at Ludwig Schupmann Observatory

Discoverer	RA+DEC	Mags	PA	Sep	Date	n	Notes
BUP 3 AB	**00132+1511**	**2.8 11.8**	**285.1**	**163.57**	**2008.915**	**1**	**Gamma Peg**
BUP 3 BC	00132+1511	11.8 12.4	195.2	20.08	2008.915	1	
HJ 1953 AB	00194-0849	3.5 12.9	18.0	68.37	2008.915	1	Iota Cet
HJ 1953 AC	00194-0849	3.8 8.6	191.0	106.25	2008.915	1	
BU 499 AC	00567+6043	2.2 12.9	345.3	53.35	2009.055	1	Gamma Cas
BU 505	01240-0811	3.6 14.8	49.3	78.93	2009.057	1	8m85, Theta Cet
BUP 19	01258+6014	2.7 11.5	59.2	110.33	2009.055	1	2m84, Delta Cas
STF 93 AB	02318+8916	2.1 9.1	231.5	18.19	2009.208	1	Polaris
STF 93 AC	02318+8916	2.1 13.8	97.6	38.73	2009.208	1	
STF 93 AD	02318+8916	2.1 13.0	188.5	82.09	2009.208	1	
BUP 34 AB	02506+3819	4.3 12.8	122.6	76.66	2009.085	1	16 Per
EDG 1 Aa-B	02543+5246	4.0 12.3	107.3	51.58	2009.057	1	Tau Per
BU 1376 Aa-C	02543+5246	4.0 12.7	106.4	55.46	2009.057	1	1m131
BU 1376 BC	02543+5246	10.7 11.8	86.4	4.17	2009.057	1	2m89
BU 526 Aa-B	03082+4057	2.0 12.7	155.5	58.51	2009.071	1	Algol
BU 526 Aa-C	03082+4057	2.0 12.5	146.3	67.72	2009.071	1	
BU 526 Aa-D	03082+4057	2.0 10.5	192.9	81.67	2009.071	1	
BU 526 Aa-E	03082+4057	2.0 12.5	185.9	85.52	2009.071	1	
DAL 46 Aa-F	03082+4057	2.0 13.7	111.2	93.23	2009.071	1	new component
DAL 46 FG	03082+4057	13.7 14.7	283.4	6.19	2009.071	1	CCD pair
ES 2596	03095+4451	4.0 13.5	318.8	44.06	2009.088	1	3m76, Kappa Per
HL 7 AB	03449+2407	3.7 13.	143.7	99.52	2009.079	1	Electra
HL 7 AC	03449+2407	3.7 13.	121.5	142.72	2009.079	1	
ES 2601 AB	03452+4235	3.8 11.9	49.9	31.56	2009.088	1	Nu Per
STG 3 AC	03452+4235	3.8 13.0	185.8	55.67	2009.088	1	1m85
DAL 47 Aa	03452+4235	3.8 13.8	71.9	22.77	2009.088	1	new component
DAL 47 Bb	03452+4235	11.9 14.3	267.6	7.74	2009.088	1	new component
HJ 3251 AB	03452+2428	4.3 8.1	329.0	71.50	2009.104	1	Taygeta
HL 9 AC	03452+2428	4.3 14.	53.9	52.08	2009.104	1	
HL 11	03458+2422	3.9 13.	73.3	112.43	2009.104	1	Maia

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Table 1, continued: Measures made at Ludwig Schupmann Observatory

Discoverer	RA+DEC	Mags	PA	Sep	Date	n	Notes
HL 29 Aa-B	03492+2403	2.9 13.	285.1	94.53	2009.111	1	Atlas
HL 29 Aa-C	03492+2303	2.9 15.	37.2	48.78	2009.111	1	
HL 29 Aa-D	03492+2303	2.9 14.	61.3	111.59	2009.111	1	1m124
DAL 48 DE	03492+2303	14. ***14.7***	122.5	5.41	2009.111	1	new component, see note 1
STF 464 AB	03541+3153	2.8 9.2	207.7	13.33	2009.111	1	Zeta Per, physical
STF 464 AC	03541+3153	2.8 11.2	286.3	32.83	2009.111	1	
STF 464 AD	03541+3153	2.8 10.4	195.3	98.28	2009.111	1	
STF 464 AE	03541+3153	2.8 10.0	185.5	119.95	2009.111	1	physical
SLV 2 BC	03541+3153	9.2 11.2	309.5	33.09	2009.111	1	
SLV 2 BD	03541+3153	9.2 10.4	193.4	85.44	2009.111	1	
STF 464 CD	03541+3153	11.2 9.9	177.0	104.24	2009.111	1	
STF 464 CE	03451+3153	11.2 9.9	171.2	130.26	2009.111	1	
STF 464 DE	03541+3153	10.4 10.0	149.5	28.59	2009.111	1	
STF 471 AC	03579+4001	3.0 13.9	10.3	79.94	2009.131	1	Epsilon Per
HJ 3608 AB	03580-1331	3.2 14.4	284.0	36.43	2009.129	1	Zaurak, see note 2
HJ 3608 AC	03580-1331	3.2 12.7	253.7	56.11	2009.129	1	
STT 73 AB	04149+4825	4.2 10.3	350.6	14.68	2009.123	1	9m29 Mu Per, see note 3
H 6 20 AC	04149+4825	4.2 10.4	233.8	83.27	2009.123	1	
STT 73 Ab	04149+4825	4.3 12.6	122.7	48.06	2009.123	1	
BUP 55 Aa-B	04230+1732	3.8 12.6	336.3	111.82	2009.131	1	Delta 1 Tau
STT 560 AB	04498+0658	3.2 11.3	168.5	73.90	2009.142	1	Pi 3 Ori
DAL 50 Aa	04498+0658	3.2 ***13.1***	5.3	22.15	2009.142	1	new component
BUP 74	05078-0505	2.8 10.9	136.5	116.82	2009.142	1	Beta Eri
BAR 25 AB	05167+4600	2.1 ***13.7***	6.7	89.83	2009.153	1	1m111, Capella, see note 4
BU 1392 AC	05167+4600	2.1 15.1	331.9	130.51	2009.153	1	1m131
BU 1392 AD	05167+4600	2.1 13.6	193.6	73.23	2009.153	1	1m131,
BU1392 AE	05167+4600	2.1 12.1	325.7	191.15	2009.173	1	2m101
HJ 2256 AF	05167+4600	0.2 10.2	135.7	109.19	2009.153	1	19m10
ST 3 HL	05165+4600	10.5 13.7	171.4	3.27	2009.173	1	18m10, “Capella H”
BUP 78	05251+0621	1.6 12.2	144.2	178.00	2009.194	1	Bellatrix

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Table 1, continued: Measures made at Ludwig Schupmann Observatory

Discoverer	RA+DEC	Mags	PA	Sep	Date	n	Notes
BUP 90 AB	06377+1624	1.9 11.2	296.4	140.50	2009.203	1	Gamma Gem
BUP 90 AC	06377+1624	1.9 10.9	334.8	148.05	2009.203	1	2m102
AGC 1 AB	06451-1643	-1.5 8.5	94.8	8.44	2009.197	1	Sirius, see note 5
DIC 1 AD	07393+0514	0.4	322.8	115.43	2009.216	1	17m25, Procyon
BU 580 AB	07453+2802	1.1 13.7	75.7	39.82	2009.208	1	6m109, Pollux
BU 580 AG	07453+2802	1.3 11.3	352.0	151.83	2009.208	1	
BUP 182 Aa-B	18211+7244	3.6 11.8	356.9	177.78	2008.792	1	3m94, Chi Dra
BUP 182 BC	18211+7244	11.8 13.3	303.0	9.30	2008.792	1	1m100, possible binary
BUP 198 AB	19463+1037	2.7 10.8	256.5	134.19	2008.800	1	Gamma Aql
DAL 44 AC	19463+1037	2.7 ***10.9***	329.1	65.61	2008.800	1	new component
DAL 44 AD	19463+1037	2.7 ***11.4***	267.3	53.54	2008.800	1	new component
DAL 27 AD	19508+0852	0.8 11.7	98.1	31.20	2008.800	1	Altair
H 6 27 Aa-B	20113-0049	2.2 13.0	259.3	115.80	2008.803	1	Theta Aql
BU 295 AB	20176-1230	4.2 14.1	211.9	53.19	2008.803	1	Alpha Cap
BU 298 Aa-B	20396+1555	3.9 13.4	231.5	35.28	2008.803	1	Alpha Del
HJ 1554 Aa-C	20396+1555	3.9 11.9	277.3	47.79	2008.803	1	
BU 298 Aa-D	20396+1555	3.9 12.9	159.5	45.55	2008.803	1	
BU 298 Aa-E	20396+1555	3.9 12.6	303.2	56.49	2008.803	1	
BU 298 Aa-F	20396+1555	3.9 10.7	117.7	72.62	2008.803	1	
H N 73	20414+4517	1.2 11.7	105.0	75.55	2008.803	1	Deneb
BUP 227 AB	21129+3014	3.2 11.6	205.3	65.57	2008.814	1	Zeta Cyg
BUP 227 AC	21129+3014	3.2 11.3	299.5	91.49	2008.814	1	
BUP 227 AD	21129+3014	3.2 12.6	62.8	104.61	2008.814	1	4m101
BU 1502 AB	21186+6235	2.5 11.5	17.6	197.21	2008.822	1	Alpha Cep
BU 1502 B-CD	21186+6235	10.4	164.5	21.94	2008.822	1	1m101
H 5 76 AB	21316-0534	2.9 11.0	318.6	37.01	2008.822	1	Beta Aqr
BU 73 AC	21316-0534	2.9 11.6	187.9	60.48	2008.822	1	
S 798 AB	21442+0953	2.4 12.7	322.3	82.73	2008.822	1	Epsilon Peg
BUP 232	22058-0019	3.0 12.2	39.8	109.96	2008.822	1	Alpha Aqr
HJ 3106	22217-0123	3.8 12.2	149.5	33.29	2008.822	1	Gamma Aqr

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Table 1, continued: Measures made at Ludwig Schupmann Observatory

Discoverer	RA+DEC	Mags	PA	Sep	Date	n	Notes
BU 702 AB	22292+5825	4.2 13.0	281.5	21.20	2008.882	1	6m47, Delta Cep
STF 58 AC	22292+5825	4.2 6.3	191.0	40.75	2008.882	1	Cal check, see note 6
DAL 45 AD	22292+5825	4.2 ***13.9***	38.3	108.48	2008.882	1	new component
DAL 45 DE	22292+5825	***13.9 14.0***	22.7	1.39	2008.882	1	neat close pair for a CCD
BU 703	22313+5017	3.8 11.8	286.2	45.83	2008.882	1	Alpha Lac
HJ 1842 AB	23038+2805	2.4 11.8	213.5	126.62	2008.882	1	Beta Peg
STF 12 A-BC	23159-0905	4.2 9.2	311.9	49.93	2008.833	1	Psi 1 Aqr, fixed
BU 1220 AD	23159-0905	3.2 13.5	273.4	110.07	2008.833	1	6m84, flying apart
BU 1220 BC-E	23159-0905	9.2 14.3	293.5	42.32	2008.833	1	6m84, flying apart
BUP 240 AB	23399+0538	4.1 13	305.4	122.59	2008.882	1	Iota Psc

Table Notes

1) DAL 48 DE forms a fairly close double, the primary of which is Asaph Hall's "D" component of Atlas. Somewhat surprisingly, Hall, the elder I presume, did not spot it but then again if "E" is a red star that would explain it. Figure 1 shows the system as imaged at LSO with the exposure best for the new pair's measure.

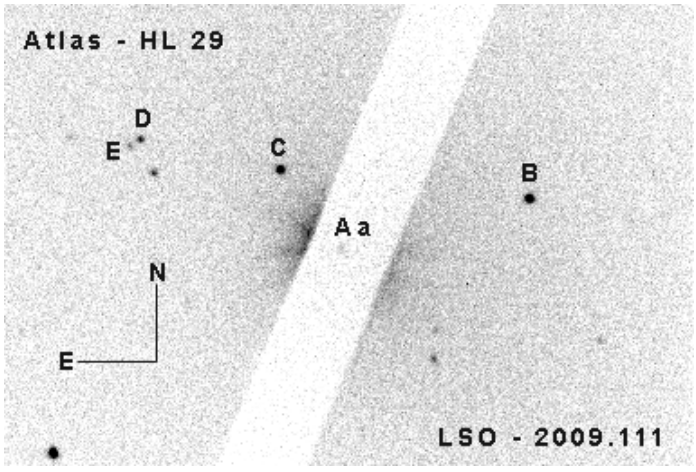

Figure 1

2) A faint component was found while measuring HJ 3608. Interestingly, it is very close to Herschel's original position for the secondary of PA 286 degrees and 30.0" separation. The fainter component is easily seen in the CCD image shown in Figure 2. The motion of the currently cataloged and well measured secondary is such that it could never have occupied the position of the original HJ 3608 measure. It therefore appears that the fainter component's position confirms John Herschel's original discovery and is in all probability cpm with the primary. Much later other observers picked up the more distant but brighter component providing a string of measures that show a linear apparent motion of 19.5" parallel to and agreeing with, the proper motion of the primary. Thus we now have HJ 3608 AB and AC.

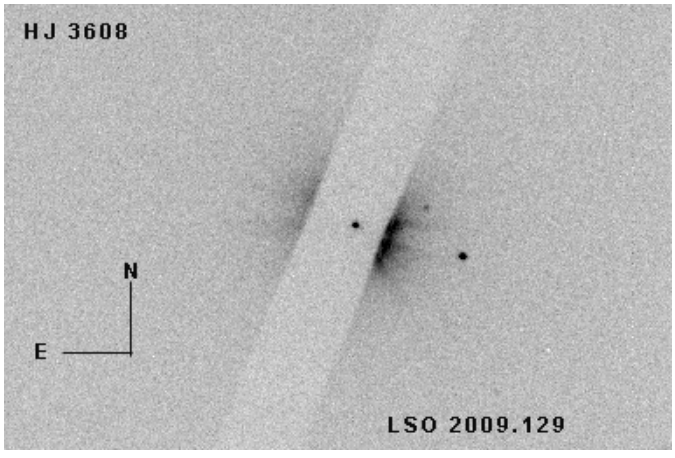

Figure 2

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3) STT 73 AB is a common proper motion (cpm) pair. The LSO determination indicates that the position angle has changed little since the 1851 discovery; showing about a 1 degree increase. On the face of it the separation shows a small closing on the order of 0.3 arc seconds, however the measurement errors compete with this value as is also the case for PA but of a lesser extent (see below). The orbital period of the AB pair may be many thousands of years. It is nearly impossible to show A and B well in a single image range setting. In the actual measurment process it's easy to visually position the analysis box and set the area to determine individual component centroids by using the digital range and background adjustments in CCDOPS. I have therefore presented the image at two settings to give the reader not familiar with the process a fuller understanding of the operation I customarily use for these very difficult pairs. These adjustments do not affect the actual centroid calculations.

The CCD image in Figures 3a and 3b also shows the additional two WDS listed components whose individual motions are not clearly parallel to the primary's cataloged proper motion vector. The standard deviation of the mean of my 11-plate measure of AB is 0.46 deg in PA and 0.26" in separation. This fascinating system may take another 100 years to sort out!

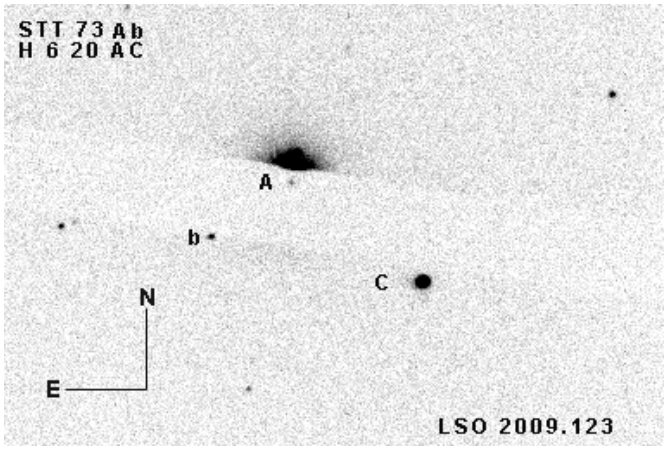

Figure 3A: STT 73

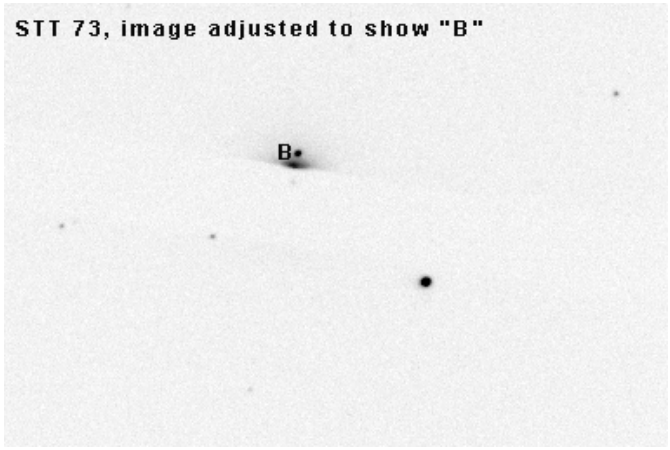

Figure 3B

4) Capella, only 42 ly distant, is a most fascinating multiple star. In 1899 Campbell discovered Capella to be a double-lined spectroscopic binary from his observations at Lick Observatory and almost simultaneously and independently by Newall at University Observatory, Cambridge, England. Subsequent interferometric resolution by J.A. Anderson in 1919-20 with his tiny visual interferometer (Candler 1951) located just 2-feet inside focus of the 100-inch Hooker reflector, is a delightful and scientifically powerful story.

All but one of the cataloged faint companions are, without doubt, optical. The one exception is the most distant component, "Capella H". Discovered by R. Furuhjelm in 1895, this red dwarf is WDS listed as FRH 1AH and lies a full 12' from Capella with both apparently exhibiting the same space motion. Capella H lies well outside my camera's FOV so AH could not be measured, thus preventing a confirmation of Furuhjelm's single measure (nice project for data-miners).

In 1935 "H" was split by Charles L. Stearns (ST 3 HL) and this close pair has shown rapid orbital motion over the ensuing years. The primary of ST 3 HL is a relatively bright 10.2 magnitude class M1V and its rather faint secondary a class M5Vof 13.7magnitude. These visual magnitude estimates are by Charles E. Worley as mentioned in Burnham's Celestial Handbook.

Great care was taken in determining the theta and rho values for ST 3 HL reported here. Only the sharpest eleven images from a string of at least 100 CCD frames were measured for determining the mean, yielding a standard deviation for theta of 1.2º and 0.07" for rho. The eleven selected images were photometrically measured as well, giving an unfiltered delta m value of 2.27 ± 0.1. Being essentially an R-band measure of what are very red stars, I expect and do see a smaller delta m than the visual estimate.

Figure 4 is a cropped CCD image of Capella H and a neat close-by field star, the proper motion of which is on the order of 1 mas/yr. The field star's relative posi-

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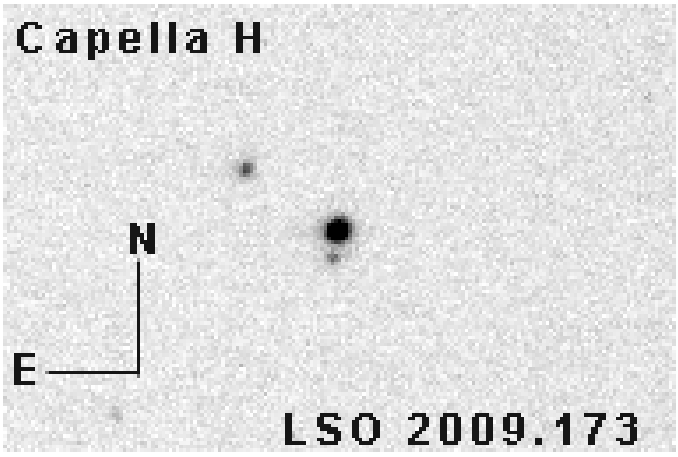

Figure 4

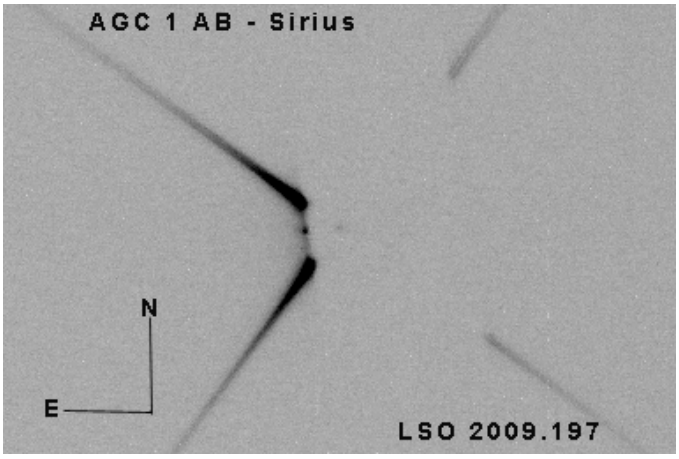

Figure 5

tion is PA = 56.1º and separation = 13.65" 2009.173). For various astrometric purposes, it may be useful to include this handy field star in future measures. Capella H is a great target for small CCD equipped telescopes. The position angle is presently changing about one half degree per year and the separation may have past its greatest extent so careful measures every few years should be interesting and rather valuable too.

A few words on Capella's optical components, three of which are LSO confirmations: using the first cataloged measures and the LSO measures reported here, the optical components AB and AE show a position shift parallel with the proper motion of Capella. Component AC is in slightly less agreement and for objects AD and AF even greater misalignment is observed. The problem may simply be the quality of the first measures, likely the 20 measures of AF, when plotted will give a better fit. The possibility of distinct proper motion of some of these faint components may also factor in.

5) AGC 1 AB - Measuring Sirius is usually tedious, primarily due to seeing conditions for such a low lying object as viewed from LSO. On the night of this measurement the seeing was superb for a short while and the "Pup" was a fine visual white dot steadily in view with the primary hidden behind the occulting filter. In an absolute panic, images were taken using the fast framing "focus mode", saving the best as they appeared. Finally 13 of the saved images were selected and used for analysis. Figure 5 shows a typical CCD image used for measurement. The exposure time was 0.25 seconds. A square aperture mask measuring 5.4-inches on a side was employed in conjunction with the stellar coronagraph for this and all other exposures of Sirius. The square aperture mask could have been rotated slightly to a more favorable angle in this example image but there was no time to lower the scope, make the adjustment, and get back on target before the seeing possibly degraded, which it did shortly after the data collection phase.

6) STF 58 AC is a cpm pair the primary of which is Delta Cephei, the classic (prototype) Cepheid variable. Over 58 measurements of the bright AC pair have been made over the years, thus a reasonably accurate relative position can be determined. The reason for including this measure in a large dm program is to afford the user a way of judging the general accuracy of the rarely observed large dm objects reported here. The pair is nearly fixed and plenty wide for the purpose. My listed separation measure, with a standard deviation of 0.132", is in good agreement with Hipparcos catalog data where a separation of 40.756" is calculated. Regarding position angles: all position angles in this range of separation are accurate to ± 0.1 degrees and are verified by performing full frame width drift calibrations for each system.

References

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Candler C., 1951, Modern Interferometers, Hilger & Watts Ltd., Hilger Division, pp 238-239.