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James A Daley

In the Spring 2006 issue, Jim Daley had an article describing his successful search for the C & D companions of Polaris. His images of the dim companions got the attention of professional astronomers. In this issue, Mr. Daley tells us about how he has improved on the technique he used and describes it in some detail so that others can try it out.

The picture is of the coronograph tube described by Mr. Daley in "A Method of Observing High Delta m Double Stars."

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Inside this issue:

Divinus Lux Observatory Bulletin: Report #11

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Abstract: This report contains theta/rho measurements from 93 different double star systems. The time period spans from 2007.282 to 2007.518. Measurements were obtained using a 20-cm Schmidt-Cassegrain telescope and an illuminated reticle micrometer. This report represents a portion of the work that is currently being conducted in double star astronomy at Divinus Lux Observatory in Flagstaff, Arizona.

A few years ago, when I was writing articles for publication in the *Double Star Observer*, I submitted two reports dealing with statistical studies that I had made regarding the nature of double star systems. The data used in these studies came from catalogs that were available at the time. Because this type of work has always been of interest to me, I was especially drawn to some similar research that was reported by Charles Lada, from the Harvard-Smithsonian Center for Astrophysics, in early 2006.

In his article, “Stellar Multiplicity and the IMF: Most Stars are Single,” published in the *Astrophysical Journal Letters*, Dr. Lada suggests that there exists a low binary star fraction for late type stars. In essence, stars of spectral type M, L, and T are far less likely to be binary in nature than are O, B, A, F, and G stars, indicating that there could be a relationship between spectral type and the percentage of stars that are single. The studies that Lada refer to indicate that 43% of G stars are single, while the percentage jumps to 74% for M stars. The percentages appear to be even higher as one moves to the right on the scale towards L and T stars. Because late type stars are far more numerous in the main sequence, Lada concludes that two thirds of all main sequence primary stars, which currently reside in the galactic disk, are single stars.

Therefore, Lada’s paper seems to challenge earlier articles on this subject which, for example, suggested a binary frequency rate of as much as 70 – 80% for F and G stars. While some of the research that Lada cites in his report is, admittedly, uncertain because of small sample size, studies utilizing the results of volume complete searches within a few parsecs of the Sun are also referenced. Perhaps previous conclusions regarding the frequency of binary systems will now need to be reexamined. For those who would like to study Lada’s article in depth, it may be accessed from his personal website. I have chosen to give this brief summary of Lada’s work, in my article, for the benefit of the reader who may also have an interest in this subject, but who may have been unaware of this recent research.

As has been done in previous articles, the selected double star systems, which appear in this report, have been taken from the 2001.0 version of the Washington Double Star Catalog, with published measurements that are no more recent than ten years ago. Beginning with this report, additional systems have also been selected from the 2006.5 W.D.S. Catalog. There are also some noteworthy items that are discussed pertaining to the following table.

First of all, several double stars are being mentioned for having significant theta/rho shifts because of proper motion from one or both of the components. In this regard, H 90 is a noteworthy example. Because of a large proper motion by the reference point star, the rho value, for this system, has increased by 23” since 1991. Proper motion by the reference point star, for SLE 687 AB-E, is also responsible for a rho value increase of 3.3” and a theta value increase of 4.9

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degrees since 1991. Proper motion by the companion star, in regards to SKF 10, is the cause for 6.3 degrees decrease in the theta value and a 9% decrease in the rho value since 1981.

In addition, ENG 60 Aa-B has shown an increase of 8.4 degrees in the theta value and a decrease of 9.4" in the rho value since 1910. Proper motion by "Aa," relative to "B," plus the passage of almost 100 years since the last published measurements are responsible for these large shifts. Proper motions by both components, for SLE 4, have caused a huge increase in the theta value, amounting to about 63.7 degrees. since 1982. During the same time period, the rho value has decreased by almost 8".0.

Regarding STF 2523 AC, a theta value of 146.9 degrees is being reported, which does not appear to be supported by the WDS or the Hipparcos/Tycho Catalogs. While a value of 144 degrees is commonly listed, I was not able to obtain such a measurement even after recalibration of the micrometer. The theta parameter for this system probably needs additional measurements from others in order to determine which value is more accurate.

Also worthy of mention are the measurements that are being reported for the visual binary star STF 2021 Aa-B. While the orbit for this binary is listed as "grade 5" in the visual binary stars section of Sky Catalog 2000.0, the theta/rho measurements appearing in the table match up well with those that are generated using the orbital elements that are currently recorded for this system. In addition, both sets of these theta/rho values agree closely with the values listed in the WDS Catalog.

Another double star, STF 2727, also appears to have displayed theta/rho shifts because of orbital motion. While not listed as a visual binary in Sky Catalog 2000.0, this common proper motion pair has displayed decreases of 2 degrees in the theta value and 3% in the rho value since 1997. This pair is also known as Gamma or 12 Delphinus.

As has appeared in previous reports, this one contains listings for possible common proper motion pairs, bearing the ARN prefix, which do not appear to have been previously recorded. The first one, ARN 95 (18516-0724), is located in Scutum near STF 2405. The theta/rho values are 105.5 degrees and 30.12 arc seconds. Secondly, a "C" component has been added to A 281 (20106+3452), labeled as ARN 96 AC. With theta/rho measurements of 313.5 degrees and 63.69 arc seconds, this star appears to share a common proper motion with the "AB" components. Finally, ARN 97 (20171+4127) is located in Cygnus near ES 1674. The theta/rho values for this possible common proper motion pair are 219.9 degrees and 12.84 arc seconds.

A possible correction is being noted for the WDS Catalog. In regards to HJ 1431 AC, the Catalog coordinates are listed as 19412+4126, but the current location of this double star appears more closely to 19406+4129. If other researchers had difficulty locating this pair, as a result, this might explain why the last published measurements were in 1912, with only one set of measurements being reported. The "B" component, which was last measured in 1914, appears to be entirely absent from current star charts.

NAME	RA DEC	MAGS	PA	SEP	DATE	N	NOTES
H 90	13184-1819	4.7 10.7	36.9	376.24	2007.282	1n	1
STF1764 AB	13377+0223	6.7 8.5	30.9	15.80	2007.282	1n	2
STF1764 AC	13377+0223	6.7 10.4	139.3	171.83	2007.282	1n	2
STF1795	13589+5306	6.9 9.8	2.4	7.90	2007.282	1n	3
STF1803	14064+3825	8.0 10.3	42.6	17.78	2007.282	1n	4
STF1804	14083+2112	8.1 9.2	13.8	4.94	2007.282	1n	5
STF1843 AB	14246+4750	7.6 9.2	186.5	19.75	2007.282	1n	6
STF1843 AC	14246+4750	7.6 9.7	63.7	98.75	2007.282	1n	6
STF1910	15075+0914	7.3 7.5	212.1	3.95	2007.351	1n	7

Table continued on next page.

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NAME	RA DEC	MAGS	PA	SEP	DATE	N	NOTES
SKF 10	15111+4424	10.1 10.7	284.7	13.83	2007.351	1n	8
STF1934 AB	15174+4348	9.3 9.5	13.7	9.38	2007.301	1n	9
STF1942	15261+2128	9.4 10.6	91.7	9.88	2007.301	1n	10
STF1950	15300+2530	7.9 9.1	93.3	3.46	2007.301	1n	11
STF1973	15464+3627	7.6 8.7	320.9	30.61	2007.351	1n	12
STF1990 AB	15589+2147	8.5 9.2	62.1	55.79	2007.301	1n	13
STF1990 AC	15589+2147	8.5 9.3	59.8	59.25	2007.301	1n	13
STF1990 BC	15589+2147	9.2 9.3	26.5	3.95	2007.301	1n	13
STF2021 Aa-B	16133+1332	7.3 7.4	355.6	4.44	2007.351	1n	14
BU 815 AD	16271+4255	8.7 9.8	86.1	435.49	2007.301	1n	15
BUP 170 Aa-B	16302+2129	2.8 10.6	274.7	245.89	2007.301	1n	16
STF2063	16318+4536	5.7 8.6	195.8	16.29	2007.351	1n	17
STF2078 AB	16362+5255	5.4 6.4	106.0	2.96	2007.351	1n	18
STF 30 AC	16362+5255	5.4 5.5	192.8	89.37	2007.351	1n	18
STF2080 AD	16386+3820	8.8 7.4*	80.3	397.96	2007.301	1n	19
STF2079	16396+2300	7.5 8.1	90.5	16.79	2007.351	1n	20
SLE 687 AB-E	16555-0820	9.0 10.2	323.9	295.26	2007.351	1n	21
SLE 4	17003+1958	10.7 10.7	281.7	11.85	2007.477	1n	22
FOX 281 AC	17047+1936	6.2 10.3	133.1	106.65	2007.400	1n	23
ENG 60 Aa-B	17200-0801	7.9 10.5	231.4	90.85	2007.477	1n	24
STT 329 AB	17245+3657	6.3 9.8	13.1	33.08	2007.397	1n	25
STF2181 AB	17317+3019	6.9 10.5	326.4	32.59	2007.397	1n	26
STF2186	17358+0100	8.2 8.4	79.4	2.96	2007.400	1n	27
STF2213	17449+3108	8.1 8.9	327.8	4.94	2007.397	1n	28
STF2225 AC	17452+5157	8.9 10.1	244.5	229.10	2007.397	1n	29
STF2225 CD	17452+5157	10.1 10.5	298.3	8.89	2007.397	1n	29
STF2252 AB	17590+0202	8.6 8.9	23.5	3.95	2007.400	1n	30
STF2252 AC	17590+0202	8.6 8.9	164.5	94.80	2007.400	1n	30
STF2271 AB	18003+5251	8.1 9.2	268.6	3.46	2007.400	1n	31
STF2265	18041+0628	9.8 10.5	281.7	23.70	2007.400	1n	32
STF2279	18046+5053	9.8 10.2	180.0	13.33	2007.400	1n	33
STT 346	18154+1946	8.3 9.0	329.5	5.43	2007.400	1n	34
STF2316 Aa-B	18272+0012	5.3 7.6	319.1	3.95	2007.400	1n	35

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NAME	RA DEC	MAGS	PA	SEP	DATE	N	NOTES
STF2333 AB	18311+3215	7.8 8.6	333.3	6.42	2007.400	1n	36
STF2329	18314+0628	8.2 9.4	43.0	4.44	2007.477	1n	37
STF2362	18384+3603	7.5 8.7	189.5	3.95	2007.400	1n	38
H 37 Aa-C	18426+5532	5.0 8.1	340.4	330.81	2007.400	1n	39
STF2398 AB	18428+5938	8.9 9.8	175.1	12.34	2007.479	1n	40
STF2373	18459-1030	7.3 8.3	336.9	4.44	2007.400	1n	41
ARN 95**	18516-0724	10.2 10.7	105.5	30.12	2007.477	1n	42
STF2405 AC	18521-0716	8.0 10.7	302.5	25.18	2007.477	1n	43
STF2417 AB	18562+0412	4.6 4.9	104.2	22.71	2007.477	1n	44
STF2417 AC	18562+0412	4.6 6.7	59.5	421.66	2007.477	1n	44
ENG 66 Aa-B	19080+1651	6.1 10.7	287.8	132.33	2007.455	1n	45
STF2470	19088+3446	7.1 8.4	268.5	13.83	2007.477	1n	46
STF2474Aa-B	19091+3436	6.7 7.8	263.1	15.80	2007.477	1n	47
STF2480	19118+2615	7.7 10.1	22.8	15.31	2007.455	1n	48
STF2486 AB	19121+4951	6.5 6.6	206.4	7.41	2007.477	1n	49
HJ 1380	19127+4746	9.4 9.9	226.2	5.43	2007.455	1n	50
STT 371 AB-C	19159+2727	7.1 9.7	270.5	47.40	2007.479	1n	51
H 48	19264+0149	8.1 10.6	172.9	152.08	2007.455	1n	52
STF2524	19266+2530	9.1 9.5	83.9	5.43	2007.455	1n	53
STF2523 AB	19268+2110	8.0 8.0	147.7	6.42	2007.479	1n	54
STF2523 AC	19268+2110	8.0 7.2*	146.9	250.83	2007.479	1n	54
HU 1194 AC	19281+3521	9.8 10.7	207.6	29.13	2007.455	1n	55
BLL 40	19368+5012	10.3 9.9*	13.4	91.34	2007.455	1n	56
STF2551 AB	19374+2249	9.6 10.5	41.3	6.91	2007.455	1n	57
STF2552	19379+1922	8.5 9.1	195.0	5.43	2007.455	1n	58
HJ 1431 AC	19406+4129	10.6 10.6	157.7	13.83	2007.455	1n	59
SEI 696 AC	19508+3430	10.2 10.0*	309.3	19.26	2007.455	1n	60
STT 388 AB	19524+2551	8.3 8.5	138.0	3.95	2007.479	1n	61
STT 388 AC	19524+2551	8.3 9.5	129.5	31.60	2007.479	1n	61
STF2589	19525+0039	8.5 8.8	294.2	4.94	2007.455	1n	62
ES 1970 AB	19591+3942	9.9 10.4	149.5	17.78	2007.455	1n	63
SCJ 24	19596+1153	9.0 10.6	6.5	38.51	2007.455	1n	64
HJ 1468	20015+4018	7.9 10.3	281.5	11.85	2007.482	1n	65

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NAME	RA DEC	MAGS	PA	SEP	DATE	N	NOTES
HJ 2918	20019-1733	8.0 8.3	134.8	15.80	2007.518	1n	66
STF2639 AB	20093+3529	7.8 8.7	301.8	5.93	2007.482	1n	67
TOB 50	20105+3323	9.0 10.1	268.9	31.60	2007.482	1n	68
A 281	20106+3452	9.0 9.4	173.0	4.44	2007.518	1n	69
ARN 96 AC**	20106+3452	9.0 9.7	313.5	63.69	2007.518	1n	69
STT 203	20131+3411	8.3 9.1	37.0	88.88	2007.482	1n	70
STT2663	20168+3942	8.2 8.7	321.8	5.43	2007.518	1n	71
ARN 97**	20171+4127	9.9 10.6	219.9	12.84	2007.518	1n	72
STF2671 AB	20184+5524	6.0 7.5	338.0	3.95	2007.518	1n	73
STT 205	20197+4108	7.2 8.9	320.0	45.43	2007.482	1n	74
STT 206 AB	20230+3913	6.7 8.5	254.7	43.45	2007.518	1n	75
AG 404	20241+2823	9.9 10.7	247.4	34.07	2007.482	1n	76
SEI1160 AB	20327+3916	8.2 10.3	49.9	14.32	2007.482	1n	77
HJ 2987	20410+2001	10.5 10.7	115.9	10.86	2007.518	1n	78
STF2715	20418+1231	7.8 10.1	2.0	12.34	2007.482	1n	79
HJ 1565	20433+2300	8.7 9.0	66.8	16.79	2007.482	1n	80
STF2725	20462+1554	7.5 8.1	11.2	6.42	2007.518	1n	81
STF2727	20467+1607	4.2 5.0	266.1	8.89	2007.518	1n	82
STF2728 AB	20482+2624	7.7 10.3	24.2	9.88	2007.482	1n	83
STF2742	21022+0711	7.4 7.6	215.5	2.96	2007.499	1n	84
STF2747	21024+3739	8.4 8.6	266.2	4.44	2007.518	1n	85
ES 2704 AB	21036+5358	8.5 8.9	96.8	54.31	2007.499	1n	86
STF2762 AC	21086+3012	5.7 10.1	229.3	59.25	2007.518	1n	87
ES 1453	21100+4326	8.9 9.9	68.4	5.43	2007.499	1n	88
AG 270	21189+3909	9.2 10.2	111.8	5.93	2007.499	1n	89
COU 132	21220+2350	8.8 10.3	201.4	13.33	2007.499	1n	90
STF2802	21318+3349	8.6 8.7	9.0	3.95	2007.518	1n	91
BLL 55 Aa-B	21432+3801	7.9 10.7	116.9	142.20	2007.499	1n	92
STF2848	21580+0556	7.2 7.7	56.9	10.86	2007.518	1n	93

* Companion star is the brighter component.
** Not listed in the WDS CATALOG.

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Notes

1. 61 Virginis. Separation increasing. Spect. G6V.
2. In Virgo. AB & AC = relatively fixed. Spect. K2III.
3. In Ursa Major. Relatively fixed. Spect. A2, A2.
4. In Canes Venatici. Position angle decreasing. Spect. K0.
5. In Bootes. Common proper motion; p.a. decreasing. Spect. F8, F8.
6. In Bootes. AB = relfix; cpm. AC = sep inc; p.a. dec. Spect. F4V, F5, G5.
7. In Bootes. Common proper motion; p.a. increasing. Spect. G2V, G3V.
8. In Bootes. Sep. & p.a. decreasing. Spect. K4, K.
9. In Bootes. Sep. increasing; p.a. decreasing. Spect. G5, G5.
10. In Serpens. Relatively fixed. Common proper motion. Spect. G5, G5.
11. In Serpens. Separation increasing. Spect. K4III, K4III.
12. In Corona Borealis. Common proper motion; p.a. slightly dec. Spect. F5, G0.
13. In Serpens. AB & AC = sep. dec. BC = relfix; cpm. Spect. K2, A2, A2.
14. In Hercules. Sep. & p.a. increasing; cpm. Spect. G8V, G8V.
15. In Hercules. Separation decreasing. Spect. G5, K0.
16. Beta or 27 Herculis. Separation decreasing. Spect. G7III.
17. In Hercules. Relatively fixed. Common proper motion. Spect. A2V, A0.
18. 17 Draconis. AB & AC = sep. & p.a. dec.; cpm. Spect. B9V, B9V, B9.5V.
19. In Hercules. Separation slightly decreasing. Spect. K0, A2.
20. In Hercules. Relatively fixed. Common proper motion. Spect. F0, A5.
21. In Ophiuchus. Sep. & p.a. increasing. Spect. M3V.
22. In Hercules. Sep. decreasing; p.a. increasing.
23. In Hercules. Separation slightly decreasing. Spect. A0IV.
24. In Ophiuchus. Sep. decreasing; p.a. increasing. Spect. G2V.
25. In Hercules. Relatively fixed. Spect. G5III, F0V.
26. In Hercules. Sep. & p.a. increasing. Spect. K0.
27. In Ophiuchus. Common proper motion; p.a. decreasing. Spect. B8IV, B8.
28. In Hercules. Common proper motion; p.a. decreasing. Spect. F8, F8.
29. In Draco. AC = relfix. CD = sep. & p.a. decreasing. Spect. K2, G5, K8.
30. In Ophiuchus. AB & AC = relatively fixed. Spect. A2, A2, K.
31. In Draco. Common proper motion; sep. & p.a. increasing. Spect. G0, G0.
32. In Ophiuchus. Sep. & p.a. slightly decreasing. Spect. G5III, F0.
33. In Draco. Common proper motion; p.a. decreasing. Spect. F8.
34. In Hercules. Relatively fixed. Common proper motion. Spect. F2, F2.
35. 59 Serpentis. Common proper motion; p.a. increasing. Spect. G0III, G0III.
36. In Lyra. Common proper motion; p.a. slightly decreasing. Spect. B9IV, A0.
37. In Ophiuchus. Relatively fixed. Common proper motion. Spect. B9IV, B9V.
38. In Lyra. Common proper motion; p.a. increasing. Spect. A5, A5.

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39. 46 Draconis. Sep. & p.a. slightly decreasing. Spect. B9.5, K0.
40. In Draco. Common proper motion; p.a. increasing. Spect. M4, M5.
41. In Scutum. Common proper motion; p.a. decreasing. Spect. F2, F2.
42. In Scutum. Common proper motion. Near STF 2405.
43. In Scutum. Slight increase in position angle. Spect. B9.
44. Theta or 63 Serpentis. AB = relfix; cpm. AC = sep. dec. Spect. A5V, A5V, G5.
45. In Sagitta. Sep. & p.a. increasing. Spect. G5V.
46. In Lyra. Sep. inc.; p.a. dec. Common proper motion. Spect. B3V, A2.
47. In Lyra. Sep. dec; p.a. inc. Common proper motion. Spect. G1V, G5.
48. In Lyra. Relatively fixed. Common proper motion. Spect. A9III, F0IV.
49. In Cygnus. Sep. & p.a. decreasing. Common proper motion. Spect. G5, G4V.
50. In Cygnus. Relatively fixed. Spect. A0.
51. In Lyra. Position angle increasing. Spect. B8V, F5.
52. In Aquila. Sep. & p.a. slightly decreasing. Spect. K2.
53. In Vulpecula. Sep. & p.a. decreasing. Spect. A2, A2.
54. In Vulpecula. AB = sep. dec. AC = relatively fixed. Spect. B7V, B7V, B5.
55. In Cygnus. Separation slightly decreasing. Spect. A0.
56. In Cygnus. Relatively fixed. Spect. S, A5.
57. In Vulpecula. Relatively fixed. Common proper motion. Spect. F5.
58. In Sagitta. Relatively fixed. Common proper motion. Spect. A2, A2.
59. In Cygnus. Relatively fixed.
60. In Cygnus. Relatively fixed. Common proper motion.
61. In Vulpecula. AB = p.a. dec.; cpm. AC = p.a. dec. Spect. A0, A0, A5.
62. In Aquila. Common proper motion; p.a. slightly decreasing. Spect. A0, A0.
63. In Cygnus. Separation slightly decreasing.
64. In Aquila. Sep. & p.a. increasing. Spect. A0V.
65. In Cygnus. Position angle increasing. Spect. A0.
66. In Sagittarius. Position angle slightly decreasing. Spect. A3V.
67. In Cygnus. Slight decrease in p.a. Spect. B.5IV, B.5IV.
68. In Cygnus. Sep. increasing; p.a. decreasing. Spect. A0, A0.
69. In Cygnus. AB = sep. inc. A, B, & C = common proper motion. Spect. F7V.
70. In Cygnus. Separation slightly decreasing. Spect. A2V, A0.
71. In Cygnus. Position angle decreasing. Spect. A0II, B9V.
72. In Cygnus. Common proper motion. Near ES 1674. Spect. B.
73. In Cygnus. Sep. inc; p.a. dec; common proper motion. Spect. A2V, A2V.
74. In Cygnus. Relatively fixed. Spect. B9V, A5.
75. In Cygnus. Position angle slightly decreasing. Spect. B9, B.
76. In Vulpecula. Sep. increasing; p.a. decreasing. Spect. G0, F8.
77. In Cygnus. Common proper motion; p.a. decreasing. Spect. B9, B9.

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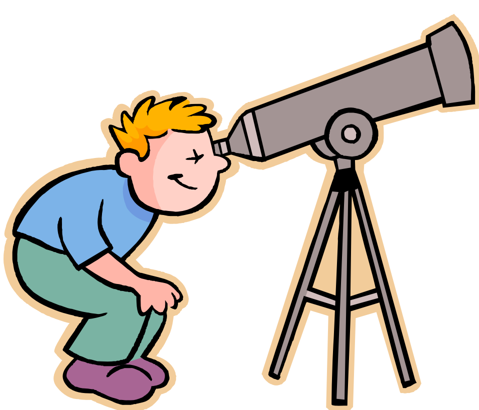
78. In Delphinus. Separation slightly decreasing. Spect. F8.
79. In Delphinus. Relatively fixed. Common proper motion. Spect. F8.
80. In Vulpecula. Sep. & p.a. decreasing. Spect. A2.
81. In Delphinus. Sep. & p.a. inc.; cpm. Spect. K0, K0.
82. Gamma or 12 Delphini. Sep. & p.a. dec; cpm. Spect. K1V, F7V.
83. In Vulpecula. Separation increasing. Spect. K5III.
84. In Equuleus. Position angle decreasing. Spect. F8, F8.
85. In Cygnus. Common proper motion; p.a. increasing. Spect. G5, G5.
86. In Cygnus. Separation slightly decreasing. Spect. A2, A0.
87. In Cygnus. Sep. & p.a. increasing. Spect. B9V.
88. In Cygnus. Common proper motion. Position angle decreasing.
89. In Cygnus. Sep. increasing; p.a. decreasing. Spect. F0.
90. In Pegasus. Position angle slightly decreasing. Spect. A3.
91. In Cygnus. Relatively fixed. Common proper motion. Spect. A5, A5.
92. In Cygnus. Separation slightly increasing. Spect. C6II.
93. In Pegasus. Relatively fixed. Common proper motion. Spect. A2, F2V.

Dave Arnold has been involved in the current double star measuring program since April 2001. He has previously published 23 double star research reprts in the Double Star Observer *as well as 10 previous reports in the* Journal of Double Star Observations. *During this time, several new double star systems, or additional components for existing double star systems, have been discovered.*



Measurements of the Visual Double Star STF 2079

Jolyon M. Johnson[1] and Russell M. Genet[1, 2]

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Abstract: With an astrometric eyepiece and self-made protractor-pointer mounted on a 12-inch aperture telescope, two first-time observers, during a physics research seminar at Cuesta College, determined the linear scale factor of the eyepiece using the drift-timing method. The separation and position angle of two well-known visual binary stars and one neglected visual binary star, STF 2079, were then measured. Measurement errors were calculated, and the observational results were found to agree with previous measurements with an accuracy consistent with the calculated errors. Both the separation and position angle of STF 2079 seem to be decreasing.

Introduction

Because many double stars can be seen through small telescopes and quantitatively measured with an inexpensive laser-etched eyepiece and self-made protractor-pointer, double star measurements make ideal astronomical research projects for those with modest means. By repeatedly measuring binary star separations and position angles over many decades—even centuries—their orbits and periods can be established. Newton's form of Kepler's third law (mass1 + mass2 = semi-major axis ^ 3 / period ^ 2) can then be applied to determine their masses, a key astrophysical parameter. Observing a double star can be a multi-generational effort, with individual observers patiently contributing their meticulous observations until, eventually, enough observations have accumulated to derive the binary's orbital parameters and hence its mass.

This project was a joint Cuesta College student/instructor effort during a physics research seminar. Neither author had previously observed double stars. The purpose of the project was threefold: (1) to learn one set of techniques for measuring double stars, (2) to practice these techniques on two well known stars (Zeta Ursae Majoris and Pi Bootis), and (3) to contribute observations of the neglected double star STF 2079.

The Orion Observatory, where all observations were made, is located on California's central coast, fifteen miles east of San Luis Obispo. Observations were made with a twelve-inch Meade LX-200 f/10 telescope using a Meade illuminated astrometric eyepiece. To measure the position angle of the double stars, Johnson built a protractor-pointer out of foam board, duct tape, an indicator pin, and a six-inch diameter plastic 360° protractor. The Sky 6.0 was used to locate the stars. All observations were made June 19-26, 2007.

Scale Factor Calibration

To determine the eyepiece's scale factor in arc-seconds per division, we set a bright star with a known declination on the eastern-most division of the eyepiece's horizontal scale. The right-ascension tracking was turned off. Using the drift time method, the time required for the star to drift to the western-most division was recorded. Twenty of these drift timings were obtained. After finding the average, standard deviation, and mean error of these drift times, we applied the following equation (Argyle, 2004, 152).

$$z = \frac{15.0411t + \cos(d)}{D}$$

Where z is the scale factor in arc-seconds per

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Star Name	RA	Dec	Pri Mag	Sec Mag
Zeta UMa (Mizar)	13h 23.9m	+54° 56m	2.2	3.9
Pi Boo	14h 40.7m	+16° 25m	4.9	5.8

Table 1: The positions and magnitudes of the two well-known visual doubles used to evaluate the precision and accuracy of our measurements.

eyepiece division, 15.0411 is arc-seconds per seconds of time that the Earth rotates, t is the average time for the star to drift across the entire scale in seconds, d is declination in degrees, and D is the number of divisions on the scale (50 for the Meade eyepiece)

We obtained twenty full-scale drift timings of Alpha Bootis (Arcturus), with a declination of +19° 11', and found the average time to be 28.0 seconds with a one-sigma standard deviation of ± 0.4 seconds. The mean error (standard deviation divided by the square root of n) was 0.1 seconds. Using the scale factor equation above, we determined there were 7.9 ± 0.02 arc-seconds per scalar division.

Procedures for Determining Separation and Position Angles

Separation was determined by centering the primary star in the eyepiece and adjusting the eyepiece's rotation so that the scale passed through the center of both stars. The number of divisions between the two stars was estimated and multiplied by the scale factor, z.

Position angle was determined by aligning the eyepiece so that the primary star moved straight along the scale with minimum deviation as the telescope swung east and west. The pin pointer was aligned parallel with the linear scale on the eyepiece. The protractor was then set so the pin pointed to 90.0°. The eyepiece was then rotated until the scale passed through the centers of both stars. The angular reading of the pointer was then estimated as the position angle to the nearest 0.1°. While we did not apply the protractor correction procedure, we did carefully center the protractor on the eyepiece (Argyle, 2004, 146-147).

Observational Results

We used two known double stars (Table 1) to practice measuring separations and position angles. They were selected from *Double Stars for Small Telescopes* (Haas 2006) based on magnitude, separation, and location in the sky.

These two stars were repeatedly observed. The mean error of the separation for these two stars, ±2.29" and ±1.07" respectively, were greater than anticipated. We attribute this to poor seeing, less than optimum alignment of telescope optics, and five first-time observers (three observers besides the authors contributed observations). Three observers besides the authors contributed observations. The observational results are displayed in Table 2 below.

The separation and position angle measured by Johnson, as shown in Table 3, provide the calendar and Besselian dates and the observations including mean errors. While the separations recorded on both nights agreed within the mean error, the position angles differed significantly, suggesting a small, systematic calibration difference between the two nights.

Analysis

The separations and position angles from past observations are shown in Table 4 as a comparison to those recorded by the authors.

As illustrated in Figure 1 below, it would appear

Star Name	Separation			Position Angle		
	# Obs	Result	Haas	# Obs	Result	Haas
Zeta UMa (Mizar)	6	15.6″ ± 2.29	14.3″	4	152.1° ± 0.61	153°
Pi Boo	5	7.5″ ± 1.07	5.5″	3	109.3° ± 0.41	111°

Table 2: Results from observing the two well-known stars. The mean errors of the observations were calculated as an estimate of the precision of the measurements.

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Date	Epoch	# Obs Sep	# Obs PA	Separation	Position Angle
6/25/07	B2007.482	10	10	17.0″ ± 0.12	90.5° ± 0.12
6/26/07	B2007.485	6	5	16.7″ ± 0.25	90.1° ± 0.05
Total		16	15	16.9″ ± 0.15	90.4° ± 0.10

Table 3: Observations of the neglected visual double star STF 2079 made by the authors.

Year	Separation	Position Angle	Source
1830	18.0″	91.0°	Mason
1997	17.2″	92.0°	Morlet
2000	17.2″	91.0°	Haas
2002	16.9″	91.0°	Mason
2007	16.9″	90.4°	Johnson and Genet

Table 4: Five measurements of STF 2079

that the separation has decreased by approximately 0.3" and the position angle has decreased by approximately 1.5° in the last ten years.

The latest *Washington Double Star Catalogue* (WDS, Mason 2007) entry for STF 2079 gives a separation of 16.79" and a position angle of 90.5°. The separation measured by the authors differed from the latest *WDS* records by only 0.11", and the position angle differed by only 0.1°, both within the estimated error.

Conclusions

With this project we learned, practiced, and applied a technique for measuring the separations and position angles of double stars. After calibrating our system's scale factor, we applied this technique to two known stars to practice and refine our methods.

We then used the same technique on STF 2079 to contribute a new measurement of a visual double star to the astronomical community. We concluded that, within our measurement error, there had been a

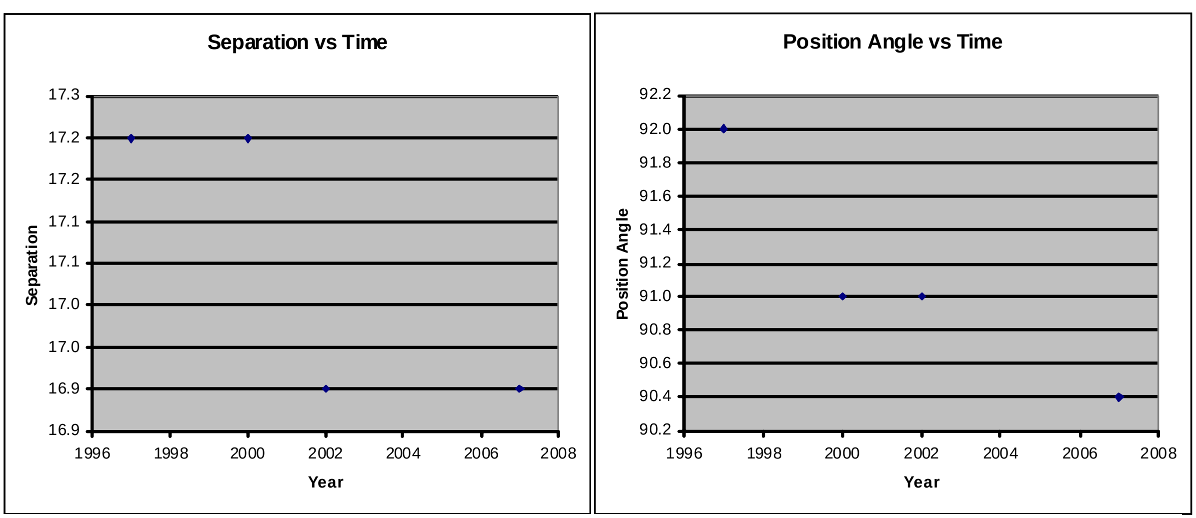

Figure 1: Separation and position angle have decreased since 1997

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significant change in the separation and position angle of STF 2079 since 1997.

To obtain more precise results in the future, we may use the bisecting method for measuring position angle (Argyle, 2004, 154). We recently purchased a Celestron Micro-guide astrometric eyepiece. As compared with the Meade eyepiece, there are more divisions on its scale, a reverse 360° protractor, and the scale has a space down the center so the divisions do not cover the stars, perhaps allowing fainter stars to be observed. Finally, greater precision may be achieved if we employ fewer, more experienced observers.

Acknowledgements

We thank David Arnold, a highly experienced visual binary star observer in Flagstaff, Arizona, for suggesting a neglected star to observe, for reviewing this paper, and for providing advice on the construction of the protractor-pointer; Darrell Grisham for measurement demonstrations and several observations; and Morgan Spangle for a one-hour speakerphone tutorial on measuring double stars. We also thank Noll Roberts and Dan Pemberton for contributing a few observations of the known stars. We thank Brittany McCrigler for loaning us her LX-200 telescope, and the Orion Observatory for the use of its pier, power, etc. Finally, we thank Robert Buchheim, Tom Frey, Tom Smith, and Kent Clark for their helpful reviews of this paper.

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Jolyon Johnson is starting his second year as a student at Cuesta College. He has been studying astronomy intensely for over a year, and is enrolled in the physics research seminar at Cuesta College. Russell Genet is a Professor of Astronomy at Cuesta College and instructs the physics research seminar. He is also a Research Scholar in Residence at California Polytechnic State University, and the Director of the Orion Observatory, www.OrionObservatory.org.

Christian Mayer's Double Star Catalog of 1779

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Abstract: I discuss modern reviews of the first double star catalog in the history of astronomy by comparing the historical data set with current values or ephemeris.

Christian Mayer was a German astronomer, who initiated the construction of an astronomical observatory in the city of Mannheim in 1771. His observatory was completed in 1775 and Mayer began his observations in January 1776 with a 2.5 inch achromatic telescope made by Peter Dollond in England. The focal length was about 8 feet and 1 inch. For his observations he used a power of 85. The telescope was mounted on an 8 foot mural quadrant made by John Bird also in England. It was Bird's last mural quadrant, see Figure 1. Figure 2 shows a part of Mayer's observation notes from January 24 and 25, 1776 after mounting the mural quadrant.

Mayer's interest was the study of the proper motion of the stars. During his observations, he often remarked on the stars that stood close together. During the time from 1776 to 1777 he found about 100 such close systems. He gives an account of his observations in the academy in Mannheim in 1777. Mayer believed in the physical togetherness of such systems, called "Doppel(t)sterne". His account was published in newspapers in different countries (Mayer, 1778).

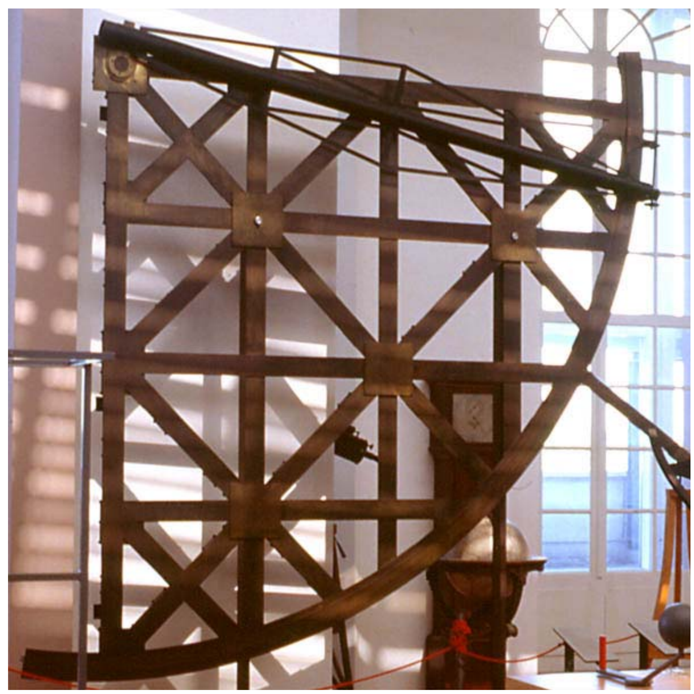

Figure 1: Mayer's mural quadrant from 1776. Photo: J.S. Schlimmer, 2005

Much criticism came from Maximilian Hell, a well known astronomer, who lived in Vienna. It came to a public dispute between them, published in the news paper in Mannheim and Vienna. Hell's opinion was that the faint companions are background stars and not physically connected with the brighter primary stars (Mayer, 1778). At the end of their dispute, Hell said, "Mayer shall compile a table with his double stars, so every astronomer can observe them when he wants." Hell's demand for a table of Mayer's double stars was Mayer's motive for publishing the first double star catalog in history of astronomy.

In its first version in 1779, the catalog included 72 double stars (Mayer, 1779). Two years later, Mayer's catalog was published in an astronomical circular by the Berlin astronomer Johann Elert Bode, who added 8 more well known double stars (Bode, 1781). In the

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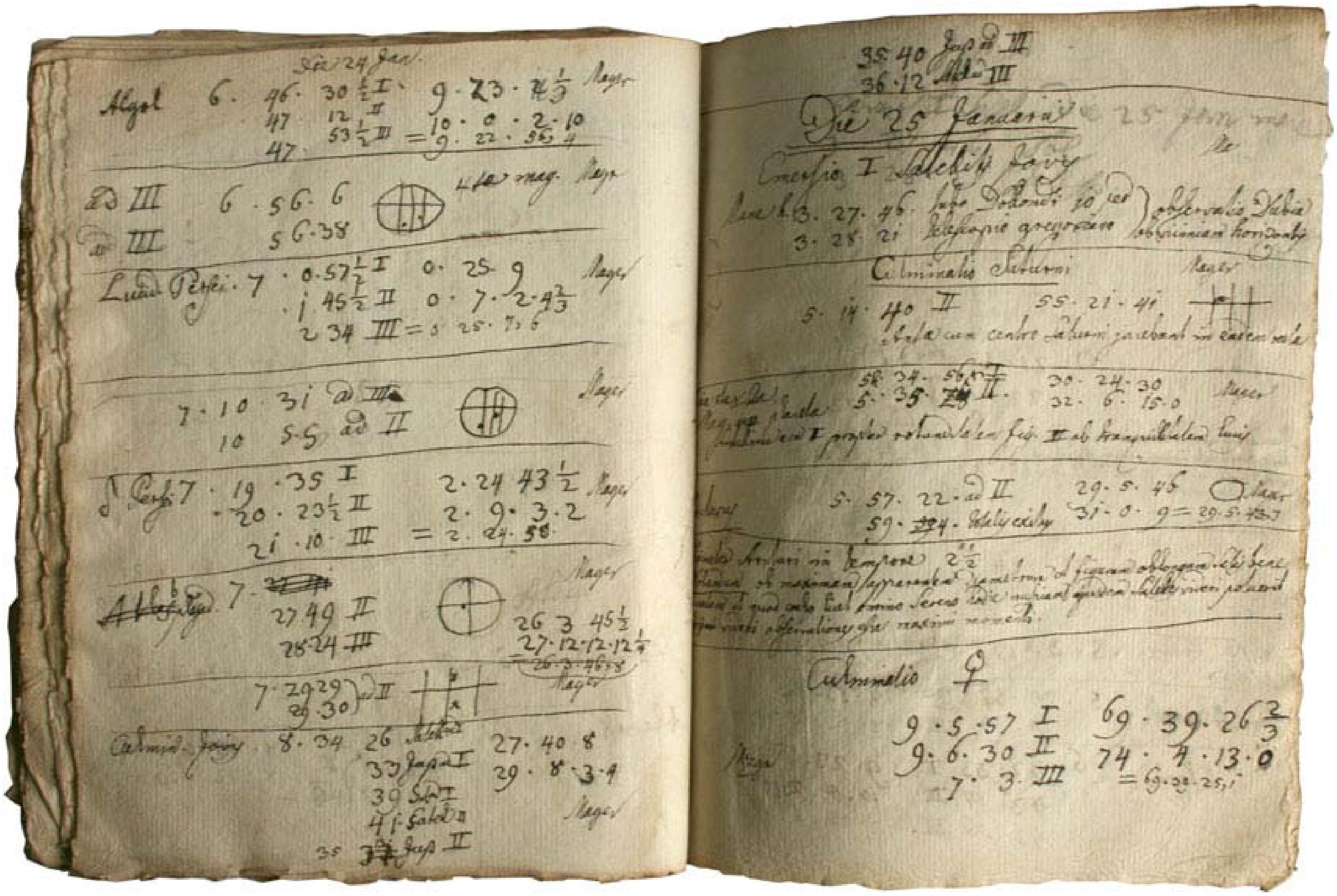

Figure 2: Mayer's observation notes from January 24 and 25· 1776, photo: J. S. Schlimmer 2007

1781 version, the catalog included 80 double stars. The closest system was 5 epsilon Lyrae with a separation of 2.9 arc seconds. It gives us a good impression of the quality of Mayer's telescope. The minimum separation of a perfect 2.5 inch reflector is about 1.7".

William Herschel heard in 1779 about Mayer's work and started his own observations of double stars. His intention was not to study the proper motion, he wanted to measure parallax (Herschel, 1782). Their method of operation in making their measurements was very different. With a mural quadrant, differences in declination were pick up directly, the differences in right ascension were measured with help of an astronomical pendulum clock (Mayer, 1778). With a declination of 0 degree, a star moves 15 arc second in one time second. In this way measurements were done in Cartesian coordinates. In opposition to Mayer Herschel measured the separation and the position angle directly in polar coordinates by comparing his observation with the placement of his lamp micrometer. In 1782 Herschel published his first double star catalog in the Philosophical Transactions.

In Mayer's catalog, often the stars had no name, but the coordinates for the year of his observations 1777 and 1778 are described. Because the precession of the earth's axis, the coordinates are obsolete. For example, gamma Arietis has moved 12 arc minutes in right ascension and 1 degree in declination. The first step of my review of Mayer's catalog was to calculate the current coordinates. With the, new coordinates many unnamed doubles could be identified.

The second step of my review was to transform Mayer's Cartesian coordinates into polar coordinates. Because the way a star moves in time depends on its

Christian Mayer's Double Star Catalog of 1779

declination, the calculations were done by the individual declinations of 1778.

Mayer's observation results could then be checked by comparison with current values of separation and angular position. Often there is no movement between the companions and separation and position angle are the same as in 1778. However, for some double star systems there is an orbit. With known orbital elements the position angle and separation can be calculated for 1778 and used for comparison. In some cases of components with equal brightness the position angles disagree by about 180 degrees.

By checking Mayer's values with data sets of The Washington Double Star Catalog, I often found entries for 1777 with equal or similar values cited by Herschel, Lewis and Strand (Mason, et al. 2007).

In the following table you'll find my calculations based on Mayer's observations of 1778 described in detail in his "Tabula Nova Stellarum Duplicium" (Mayer, 1779). Mayer 8, Mayer 10, Mayer 15, Mayer 32, Mayer 37, Mayer 48, Mayer 51 and Mayer 63 were not included in Mayer's first catalogue of 1779. The value of those stars were in the astronomical circular of Bode in 1781.

In some cases, I couldn't identify Mayer's observations. For Mayer 10, Mayer 16, Mayer 26, Mayer 27, Mayer 45, Mayer 53, Mayer 63, Mayer 69, Mayer 71, Mayer 74 and Mayer 78 I give the double stars which best match Mayer's transformed coordinates. In other cases like alpha Arietis or omega Piscis, the stars are not visual double stars.

Figure 3 represents the relative error of Mayers distance measurements. In 12 cases the error is under 5%, in 7 cases the error lies between 5 and 10%, and in a further 14 cases the error lies between 10 and 20%. In some cases the relative error is explained by the independent movement of the components e.g. with Mayer 36. In other cases, for example with Castor (Mayer 21), incorrect time measurement of the distance in right ascension significantly affects the results.

With a relative error of nearly 300%, Mayers measurements of 54 Virginis (Mayer 35) are the worst. Out of 57 measurements between 1777 and 2006 it follows that neither distance nor position angle has changed.

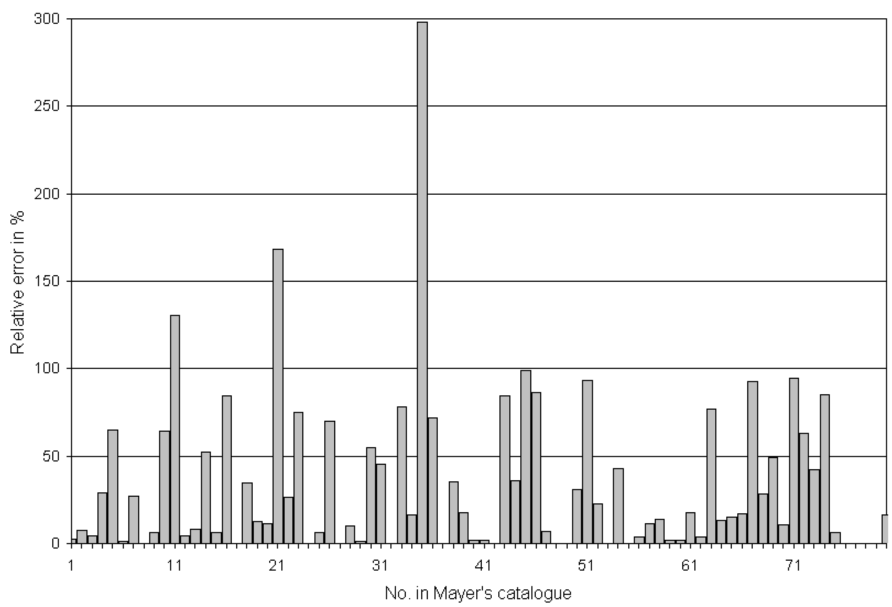

Figure 3: Relative error for Mayers' distance measurements for each double star system in his catalog.

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Description of a Lamp-Micrometer, and the Method of using it, William Herschel, Philosophical Transac-

(Continued on page 158)

Christian Mayer's Double Star Catalog of 1779

No.	Mayer's Description	Current Description	Code	WDS Identifier	Sep. 1778	Sep. 2007	Sep. Diff.	pa 1778	pa 2007	pa diff	mag. WDS	note
Mayer 1	Andromeda	HIP3617	STFA 1	00464+3057	45.9	47.1	-1.2	238	46	192	7.25,7.43	
Mayer 2	Androm.	74 ψ Pisces	STF 88AB	01057+2128	32.5	30.3	2.2	154	159	-5	5.27,5.45	
Mayer 3	zeta Fische	ζ Piscis	STF 100AB	01137+0735	24.3	23.3	1.0	67	63	4	5.22,6.15	
Mayer 4	bei my Fische	BSC 419	STF 122	01269+0332	4.2	5.9	-1.7	180	328	-148	6.65,9.51	
Mayer 5	Gamma Widder	γ Arietis	STF 180AB	01535+1918	12.5	7.6	4.9	193	0	193	4.52,4.58	
Mayer 6	Lambda Widder	λ Arietis	H 5 12AB	01579+2336	38.7	38.2	0.5	46	47	-1	4.80,6.65	
Mayer 7	Gamma Andromeda	γ Andromedae	STF 205A-BC	02039+4220	12.2	9.6	2.6	62	63	-1	2.31,5.02	
Mayer 8	Alpha Widder	α Arietis	-	-	-	-	-	-	-	-	2.0	1,2
Mayer 9	30 Widder	30 Arietis	STFA 5	02370+2439	41.4	39.0	2.4	276	275	1	6.50,7.02	
Mayer 10	Wahlfisch	BSC 587	HJ 3476AB	02004-0831	22.2	62.6	-40.4	98	200	-102	5.5,9.8	1
Mayer 11	Stier	BSC 1065	STF 401	03313+2734	26.7	11.6	15.1	90	270	-180	6.58,6.93	
Mayer 12	tau Stier	τ 94 Taurus	S 455Aa-B	04422+2257	60.3	63.0	-2.7	210	214	-4	4.24,7.02	
Mayer 13	Stier	BSC 1600	SHJ 49AB	04590+1433	43.6	40.3	3.3	303	305	-2	6.06,7.43	
Mayer 14	Orion	σ Orionis	STF 762AB,C	05387-0236	25.8	13.4	12.4	36	84	-49	3.76,6.56	
		σ Orionis	STF 762AB,E	05387-0236	36.6	41.5	-4.9	55	62	-7	3.76,6.34	
Mayer 15	Delta Orion	δ Orionis	STFA 14Aa-C	05320-0018	50.0	53.3	-3.3	0	1	-1	2.41,6.83	1
Mayer 16	bei Zeta Orion	TYC 4771-01005-1	A 291.8A-BC	05441-0229	15.0	94.8	-79.8	90	316	-226	9.43,9.77	
Mayer 17	Zwillinge	-	-	-	72.9	-	-	310	-	-	-	2
Mayer 18	Or. (11 Einh.)	Or. (11 Einh.)	STF 919AB	06288-0702	9.6	7.1	2.5	322	133	189	4.62,5.00	
Mayer 19	30 Zwillinge	HIP 31158	STF 924AB	06323+1747	22.2	19.7	2.5	211	211	0	6.31,6.88	
Mayer 20	Zwillinge	HIP 31323	S 524AB	06341+2207	47.0	53	-6.0	62	244	-182	7.17,7.41	
Mayer 21	Castor	α Gemini	STF1110AB	07346+3153	9.6	3.6	6.0	293	310	-17	1.93,2.97	3
Mayer 22	Zeta Krebs	ζ Cancri	STF1196AB-C	08122+1739	7.7	6.1	1.6	180	181	-1	5.05,6.20	
Mayer 23	2. Phi Krebs	2 Phi Can-ceri	STF1223	08268+2656	8.8	5.0	3.8	131	215	.-84	6.16,6.21	11

Table continued on next page.

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No.	Mayer's Description	Current Description	Code	WDS Identifier	Sep. 1778	Sep. 2007	Sep. Diff.	pa 1778	pa 2007	pa diff	mag. WDS	note
Mayer 24	Krebs, dunkel	24 Canceri	STF1224A-BC	08267+2432		5.4	-5.4		50	-50	6.92,7.53	
Mayer 25	iota Krebs	ι Canceri	STF1268	08467+2846	32.6	30.7	1.9	307	308	-1	4.13,5.99	
Mayer 26	bei pi Krebs	TYC0825-01529-1	STT 569Aa-C	09123+1500	6.0	20	-14.0	0	216	-216	6.56,10.40	
Mayer 27	bei pi Krebs	-	-	-	-	-	-	-	-	-	-	2
Mayer 28	54 Löwe	54 Leonis	STF1487	10556+2445	7.2	6.5	0.7	110	112	-2	4.48,6.30	
Mayer 29	bei tau Löwe Nr. 83	83 Leonis	STF1540AB	11268+0301	28.9	28.6	0.3	51	150	-99	6.55,7.50	
Mayer 30	tau Löwe	τ Leonis	STFA 19AB	11279+0251	39.9	88.9	-49.0	158	181	-23	5.05,7.47	
Mayer 31	a Wasserschlange	BSC4443	H 3 96	11323-2916	13.6	9.4	4.2	137	210	-73	5.64,5.73	
Mayer 32	Haar der Berenike	BSC4698	STF1633	12207+2703	-	8.9	-	-	245	-	7.04,7.13	1
Mayer 33	gamma Jungfrau	γ Virginis	STF1670AB	12417-0127	9.8	5.5	4.3	130	314	-184	3.48,3.53	4
Mayer 34	12 Jagdhunde	α Canis Venatici	STF1692	12560+3819	22.4	19.3	3.1	226	229	-3	2.85,5.52	
Mayer 35	54 Jungfrau	54 Virginis	SHJ 151	13134-1850	21.5	5.4	16.1	266	34	232	6.78,7.19	
Mayer 36	Jungfrau	HIP64638	SHJ 162Aa-B	13149-1122	30.3	107.6	-	77	-	-	7.11,8.18	5
Mayer 37	Zeta gr. Bären *)	ζ Ursa Majoris	STF1744AB	13239+5456	0.0	13.9	-13.9		153	-153	2.23,3.88	1
Mayer 38	Pi Bootes	π 29 Bootes	STF1864AB	14407+1625	7.4	5.5	1.9	106	111	-5	4.88,5.79	
Mayer 39	Beta Scorpion	β Scorpii	H 3 7AC	16054-1948	15.4	13.1	2.3	40	24	16	2.59,4.52	
Mayer 40	Ny Scorpion	ν Scorpii	H 5 6Aa-C	16120-1928	42.0	41.2	0.8	336	338	-2	4.35,5.31	
Mayer 41	12 im Herkules	36 Hercules	STFA 31Aa-B	16406+0413	70.3	69.1	1.2	228	229	1	5.76,6.92	
Mayer 42	alpha Ophiuch.	α Ophiuchi	-	-	13.2	-	-	180	-	-	-	2
Mayer 43	alpha Herkules	α Hercules	STF2140Aa-B	17146+1423	8.7	4.7	4.0	118	105	13	3.48,5.40	
Mayer 44	39 Ophiuch.	39 Ophiuchi	H 3 25	17180-2417	14.0	10.3	3.7	180	352	-172	5.23,6.64	
Mayer 45	71 Herkules	70 (!) Hercules	S 687AB	17209+2430	2.4	224.7	-222.3	90	56	34	5.12,9.33	
Mayer 46	roh Herkules	ρ Hercules	STF2161Aa-B	17237+3709	7.6	4.1	3.5	291	319	-28	4.50,5.40	
Mayer 47	61 Ophiuch.	61 Ophiuchi	STF2202AB	17446+0235	19.9	21.3	-1.4	102	93	9	6.13,6.47	

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No.	Mayer's Description	Current Description	Code	WDS Identifier	Sep. 1778	Sep. 2007	Sep. Diff.	pa 1778	pa 2007	pa diff	mag. WDS	note
Mayer 48	b Schützen	β Sagittarius	DUN 226	19226-4428	-	28.6	-	-	76	-	3.98,7.21	1
Mayer 49	beim Oph.	-	-	-	1.4	-	-	90	-	-	-	2
Mayer 50	Herkul.	95 Her	STF2264	18015+2136	8.5	6.5	2.0	260	257	3	4.85,5.20	
Mayer 51	rho Ophiuchi	ρ Ophiuchi	H 2 19AB	16256-2327	7.6	3.1	2.9	90	340	-250	5.07,5.74	1
Mayer 52	Herkules	100 Her	STF2280Aa-B	18078+2606	17.5	14.3	3.2	180	183	-3	5.81,5.84	
Mayer 53	Schlange	HIP89489	STF2296	18157-0321	0.0	3.3	-3.3	90	6	84	7.48,10.22	
Mayer 54	Schütze	BSC6848	SHJ 264AB-C	18187-1837	9.9	17.5	-7.6		51	-51	6.86,7.63	
Mayer 55	Ophiuchus	61 Serpentis	-	-	2.0	-	-	0	-	-	-	2
Mayer 56	zeta Leyer	ζ Lyrae	STFA 38AD	18448+3736	45.3	43.6	1.7	148	150	-2	4.34,5.62	
Mayer 57	epsilon Leyer	4 ε Lyrae	STF2382AB	18443+3940	3.8	3.4	0.4	38	31	7	5.15,6.10	6
Mayer 58	5. Leyer	5 ε Lyrae	STF2383Cc-D	18443+3940	2.5	2.9	-0.4	180	155	25	5.25,5.38	7
Mayer 59	beta Leyer	β Lyrae	STF 39AB	18501+3322	48.4	47.4	1.0	151	149	2	3.63,6.69	
Mayer 60	theta Schlange	θ Serpentis	STF2417AB	18562+0412	23.4	23.0	0.4	106	104	2	4.59,4.93	
Mayer 61	eta Leyer	η Lyrae	STF2487AB	19138+3909	23.5	28.6	-5.1	90	81	9	4.38,8.58	
Mayer 62	beta Schwan	β Lyrae	STFA 43Aa-B	19307+2758	33.9	35.3	-1.4	54	54	0	3.19,4.68	
Mayer 63	bei gamma Schwan	HIP104064	STF2753	21050+3526	7.0	29.9	-22.9	180	336	-156	7.38,10.74	1
Mayer 64	omega Steinbock	ω Capricor-nus	SHJ 324	20299-1835	25.6	22.6	3.0	242	239	3	5.91,6.68	
Mayer 65	Delphin	BSC7840	STF2690Aa-BC	20312+1116	15.2	17.8	-2.6	103	255	-152	7.12,7.39	
Mayer 66	über beta Del-phin	HIP101698	STF2703AB	20368+1444	29.5	25.2	4.3	249	290	-41	8.35,8.42	
Mayer 67	gamma Delphin	γ Delphinus	STF2727	20467+1607	17.5	9.1	8.4	278	266	12	4.36,5.03	
Mayer 68	beim Füllen	ε Equuleus	STF2737AB-C	20591+0418	13.8	10.7	3.1	78	67	11	5.30,7.05	
Mayer 69	Schwan	HIP104064	STF2753	21050+3526	15.3	29.9	-14.6	126	336	-210	7.38,10.74	
Mayer 70	Schwan	61 Cygni	STF2758AB	21069+3845	15.3	13.8	1.5	51	48	3	5.35,6.10	8
Mayer 71	Schwan	HIP104417	S 779	21091+3844	6.0	111.6	-105.6	180	11	169	7.61,9.57	

Table continued on next page.

Christian Mayer's Double Star Catalog of 1779

No.	Mayer's Description	Current Description	Code	WDS Identifier	Sep. 1778	Sep. 2007	Sep. Diff.	pa 1778	pa 2007	pa diff	mag. WDS	note
Mayer 72	my Schwan	μ Cygni	STF2822AB	21441+2845	11.2	6.9	4.3	109	109	0	4.75,6.18	9
Mayer 73	Wassermann	HD 208718	STF2848	21580+0556	15.5	10.9	4.6	75	57	18	7.21,7.73	
Mayer 74	Zeta Wassermann	74 ψ Pisces	STF 88AB	01057+2128	4.6	30.3	-25.7	221	156	65	5.27,5.45	
Mayer 75	Wassermann	HIP114702	STF2993AB	23141-0855	26.0	24.4	1.6	180	177	3	7.60,8.17	
Mayer 76	Wassermann	HD 220436	STF3008	23238-0828	-	6.3	-	-	151	-	7.21,7.67	
Mayer 77	Fische	HIP116035	STF3019	23307+0515	-	10.4	-	-	184	-	7.77,8.37	
Mayer 78	Andromeda	TYC2772-00004-1	SHJ 358	23543+3154	0.0	36.5	-	-	334	-	8.25,10.37	
Mayer 79	omega Fische	ω Piscis	-	-	-	-	-	-	-	-	-	2
Mayer 80	Andromeda	BSC9075	STF3050	23595+3343	4.3	3.7	0.6	180	179	1	6.46,6.72	10

Description :

Column 1 : Number from (Bode, 1781)

Column 2 : Mayer's Description from (Bode, 1781)

Column 3 : Current Description from (Hoffleit, 1991) and Redshift 5

Column 4 : Code from Washington Double Star Catalog

Column 5 : Separation for 1778 from (Mayer,1779) except note 1

Column 6 : Current separation from Washington Double Star Catalog except note 3,4,6-10,11

Column 7 : Separation differences = Column 5 – Column 6

Column 8 : Position angle for 1778 from (Mayer, 1779), except note 1

Column 9 : Current position angle from Washington Double Star Catalog, except note 3,4,6-10,11

Column 10: Position angle differences = Column 8 – Column 9

Column 11: Brightness from Washington Double Star Catalog

Column 12: Notes

Notes:

1. Published first in Bode's astronomical yearbook in 1781
2. No double star
3. Ephemeris for 1778, Doc1985
4. Ephemeris for 1778, Sca2006b
5. The proper motion is 0.37"/year
6. Ephemeris for 1778, Nov.2006e
7. Ephemeris for 1778, Doc1984b
8. Ephemeris for 1778, Kis1997
9. Ephemeris for 1778, Hei1995
10. Ephemeris for 1778, Sta1977b
11. Ephemeris for 1778, Hei1996b

Christian Mayer's Double Star Catalog of 1779

(Continued from page 153)

tions of the Royal Society of London, 1782 Vol. 72

Bright Star Catalogue, 5th Revised Ed. (Preliminary Version), Hoffleit+, 1991, Yale University Observatory, http://www.alcyone.de/SIT/bsc/index.html

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Redshift 5, Maris Technologies, United Soft Media GmbH, http://www.redshift.de/us/_main/index.htm

A Method of Measuring High Delta m Doubles

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Abstract: This paper describes a method of precisely measuring theta and rho for pairs in which the difference in stellar magnitude (delta m) is in the range of 8 to 12 . The instrumentation takes the form of a stellar coronagraph where, in this design, a highly attenuating foil strip is substituted for the normal opaque occultor, thus giving a sharp, well exposed and well defined position for the bright primary, along with faint and sometimes numerous components lying clear of the foil. Many WDS listed high dm components are unconfirmed providing an additional challenge in their recovery. Although many components are optical, good measures of these objects can be of some value in various proper motion studies. The instruments optical/mechanical design is described in sufficient detail such that other observers may assemble a similar device from their optics collection. CCD images of a few program stars are also shown.

Introduction

Measuring high delta m pairs with a CCD detector presents special difficulties due to detector saturation. Even in the case of wide pairs, where the faint secondary is well imaged outside this saturated region, calculating the centroid of the overexposed primary is practically hopeless. As similar but increasingly closer pairs are imaged, there comes a separation where the faint component is impossibly buried in the "glare" of the primary, just as in visual work, only worse! Overcoming this limitation has fascinated the writer for years and recently, spurred on by a challenge of Brian Mason's, some progress was made in this area with the recovery and measurement of Burnham's faint "C" & "D" components of Polaris. These results were reported in the Spring 2006 issue of this journal. The instrumentation described here moves away from the somewhat makeshift arrangement used in the Polaris measures and, instead, follows along the lines of a true stellar coronagraph. In this report the word "occultor" is usually used when referring to the highly attenuating foil strip.

Sources of Scattered Light

Light is scattered passing through the atmosphere and again in the telescope optics. Depending on sky conditions, one or the other can be the dominant contributor. Sky transparency, as with a solar coronagraph, governs the strength of atmospherically scattered light. Atmospheric dust, haze, mist, fog, ice crystals and forest fire smoke produce an aureole or light glow around each star image. Typically this aureole extends only a short angular distance from the star, fading asymptotically away and typically going below the detection threshold (for the required program exposures) within a few arc minutes. In very clear conditions at high altitude sites, this attendant glow is very weak with a total integrated brightness perhaps one or two millionths of the observed star. With just the slightest haze, the atmospheric scatter begins to compete with the telescope's optical scatter. Determining the exact level or strength of instrumental scatter is not straightforward but needless to say systems with a minimum number of surfaces are favored. It is assumed by the writer that, on the clearest nights, the observed aureole surrounding a bright occulted star in the LSO telescope images is primarily instrumental in nature. In any case, the scatter clearly originates before the occultor and coronagraph lenses as can be seen by the blackness of the field covered by the occultor (see Figure 1).

The effects of this surrounding diffuse glow become apparent when detecting and measuring close-in faint components of the brightest primaries. The harmfulness of this glow can be reduced by digitally dividing an image of the program star by a control star of similar brightness and sky location. Here the control star (which can be the program star itself) must be positioned behind the occultor in nearly the same frame position as the program star (a slight displacement is required to extract the attenuated primary). Field information common to both images is thus subtracted out by division, the same as in the normal process of flat fielding an image. Esthetically, the results are hardly pleasing as artifacts from imperfect registration always remain, however, from a scientific viewpoint, beneficial canceling of the scattered light is achieved. Thankfully, most high delta m measures do not require this extremely sensitive and tedious operation.

The Tailpiece Coronagraph

The instrument is located at the final focus of the writer's 9-inch Schupmann medial telescope. It consists of a 24-mm focal length microscope eyepiece used as a magnifying relay providing an effective system focal length of 164.8-inches. The relay lens is mounted approximately midway inside an old empty Barlow tube into which the ST-7 CCD is plugged. In the initial design the attenuating “occultor” was taped to a thin support window at the entrance to the tube, the occultor and stars alike focused on the CCD via the relay lens set. The occultor is a 1-mm wide strip cut with a razor blade from a sheet of 1Baader solar film. It extends well outside the CCD field in the long dimension and subtends 40 seconds of arc in width. The film (foil) employed is designed for visual solar work and attenuates the light by 10 magnitudes or 10,000 times in intensity. Because the film is extremely thin, just a few ten thousandths of an inch, the focus for the occulted star and the unocculted star (s) are, for practical purposes, identical and all sharply imaged.

First Star Tests and Design Refinements

Imaging tests of the device were very encouraging until calibrations to determine the effective focal length were begun. A 38 arc seconds pair (STF 5 app) was chosen to obtain an initial calibration and to also determine if the magnification or plate scale was uniform throughout the field. It became apparent almost immediately that there was significant field distortion, as the separation values varied about 0.6 arcseconds, center to edge, of the 5.7 x 3.8 arcminute field. Optical distortion in any relay system can be reduced to

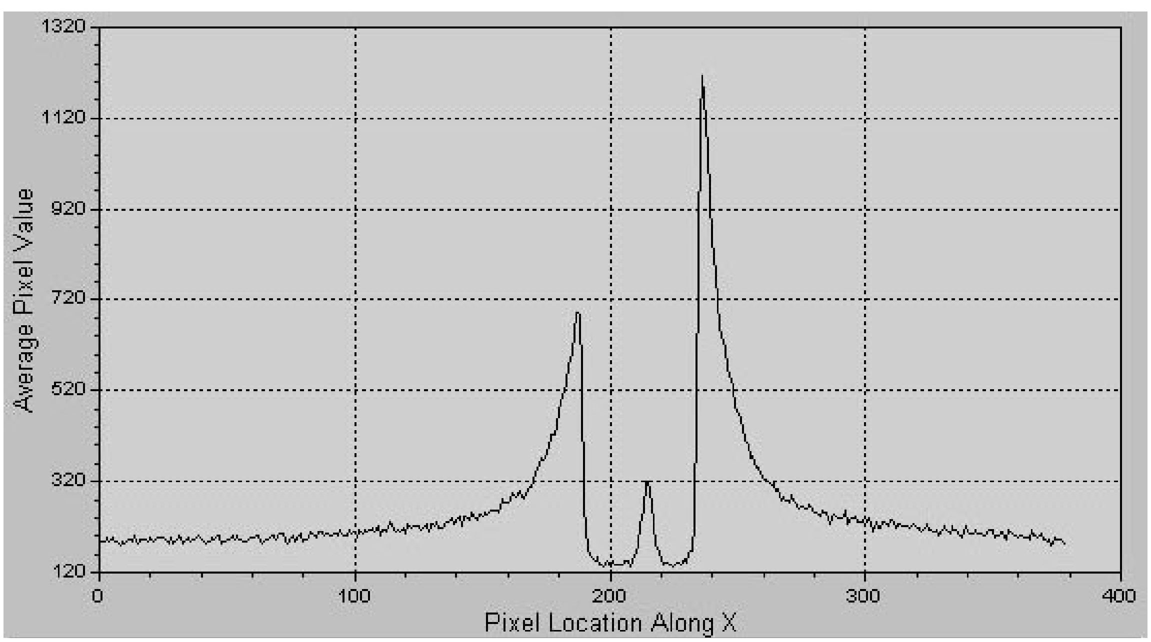

Figure 1: This graph shows a line intensity scan perpendicular to the occulting strip and through the occulted image of Spica. The sharp, highly attenuated image of the primary is clearly seen thus permitting accurate centroid determination. Scattered light outside the occultor tapers away to near sky background levels. Figure 5 shows the CCD image used for the scan and includes additional details.

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near zero if a pupil is imaged at an appropriate place within its lens elements. This is done by providing a field lens at the first focus of the relay. This field lens images the Schupmann corrector of the author's telescope, itself an intermediate pupil, onto the relay elements. A plano convex field lens at that location would, as with the previous window, provide a convenient mounting surface for the foil strip against its plano surface. The price one pays for correcting distortion is an increase in field curvature, the field lens here adding to that of the relay lens.

The optical system was first ray traced in OSLO (a free downloadable student ray trace program) without a field lens confirming the distortion observation, the trace predicting about 2% distortion at the field edge. Next a field lens was entered in the optical prescription and located at the first focus such that the plano surface faced the incoming light. This is important so that the occultor, which is simply Scotch taped to the plano surface, blocks all the relay elements, including the field lens itself, of bright light. The convex curvature of the field lens was varied using OSLO's slide-bar feature until the distortion went to near zero (less than 0.05 %). This placed the pupil nearly coincident, but just 1mm skyward of the last element's surface at the chosen relay magnification of 1.65, thus providing an accessible location for the possible inclusion of a Lyot stop. A Lyot stop is a circular aperture located at a pupil after an occultor and blocks the bright diffraction ring originating at the telescope's aperture. In operation this stop reduces and defines the final or effective aperture.

A plano convex lens of 45 mm FL was found that closely matched that of the prescription. It was mounted in the same threaded cell that previously held the window and which screws into the nose of the old Barlow tube. Adding the field lens steepened the field curvature (Petzval radius) from 35.8 mm to 25.8 mm, just barely acceptable for maintaining focus across the ST-7 chip at the working f-ratio of 18. The microscope eyepiece is held in the tube with setscrews through the side of the tube. Figures 2, 3, and 4 show photographs of the device.

Final Star Tests

First an observing run was made, again on STF 5 app, to verify the ray trace work and to get an initial measure of the telescope's effective focal length. The results of this test were very encouraging with distortion now greatly reduced. Measured separations of STF 5 app for 3 field positions gave the following results: Field center 37.989" sd = 0.065", 50% field 37.987 sd =0.069", and field edge 38.025" sd = 0.081". The field positions measured are located along the wide axis of the CCD. The effective FL based on this double was determined to be 164.8 inches. Next an independent measurement of EFL was performed with a coarse objective grating which closely confirmed the value, the grating being the final arbiter.

Figure 2: Coronograph tube

Figure 3: Closeup of Occulting Strip Taped to Field Lens.

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Figure 4: Coronagraph Attached to ST-7 CCD.

Operational Bounds

In order to set up an observing program, it was necessary to determine the faintest primary that could be reliably imaged through the foil optical attenuator. Past experience at LSO showed that a 30 second exposure is just about the limit before image motion and, to some extent, atmospheric blurring becomes ruinous to faint double star work (this limit is somewhat extended at higher declinations). Given this, a few 30 second test exposures showed that primaries no fainter than 4.5 magnitude could be usefully imaged through the foil in 3x3 binned mode and that primaries around 3.5 are well imaged in full resolution (no binning) on perfect nights. Experience with the finished system shows 2x2 binning the more usual for most work. The magnitude limit for secondaries fall out of the 30 second limit and run roughly in the range of magnitude 14 to 16. Component separation limits are, of course, delta m dependent.

Based on the above constraints along with limiting the observations to declinations between the pole and minus 15 degrees, Brian Mason generated an observing list of about 222 objects. This list forms the basis of LSO's high delta m observing program.

First Impressions

Not surprisingly, a great number of unlisted stars are found around many of the primaries. As CCD's are red sensitive and as no optical (bandpass) filtering is employed for most of this work, red stars are detected which appear brighter than the WDS listed components. My rule on this is simple, if a star as close or closer and similarly bright as the listed closest program star is discovered, then I will assign it a designation. CCD images are always available to investigators for further study in any case.

Operational Procedure

The program stars are all bright and easy to find using the handy *Norton's Star Atlas* or similar charts. This is quite a relaxing change from recent work on faint doubles such as Stein's photographic pairs! Once the primary is roughly centered using a special cross hair eyepiece, the remaining task is to rotate the coronagraph tube so that the last measured position angle is approximately perpendicular to the long axis of the occulting strip. Often the faint companion can be visually spotted at this point. Next the bright primary is centered behind the "occultor" and the CCD installed. Usually the faint companion(s) show well with a 10 second exposure and, for the brighter primaries, is the most often used exposure time.

Sample Images

The following sample images are unfiltered, the bandwidth determined primarily by the ST-7 CCD color response. This favors the red region tending to accentuate K and M stars. The images are oriented with north up and east to the left.

In Figure 5 we see the occulted image of Spica, the primary of BUP 150 AB. This 10 second exposure in 2x2 binned mode through a thick atmosphere easily captures the 12th magnitude "B" component seen in upper left. A very faint closer star is also just revealed. Note the CCD "burn-in" spot where Spica was inadvertently exposed outside of the occultor. These desensitized spots disappear by the next night.

Figure 6 shows Gamma Draco and some of Burnham's many faint components, a few of which lie well outside the field.

Lastly, the star Vega is seen in Figure 7. The STF component "D" is, interestingly, measured from "C"

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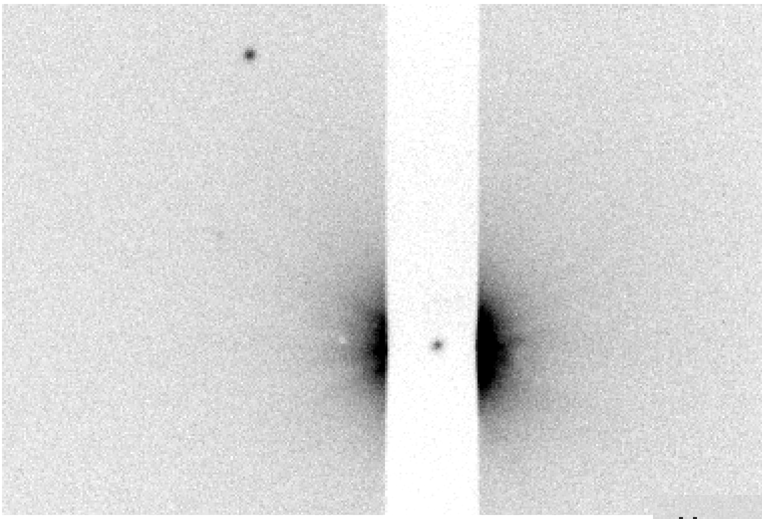

Figure 5: Spica, 10 sec exp, 2x2 binned.

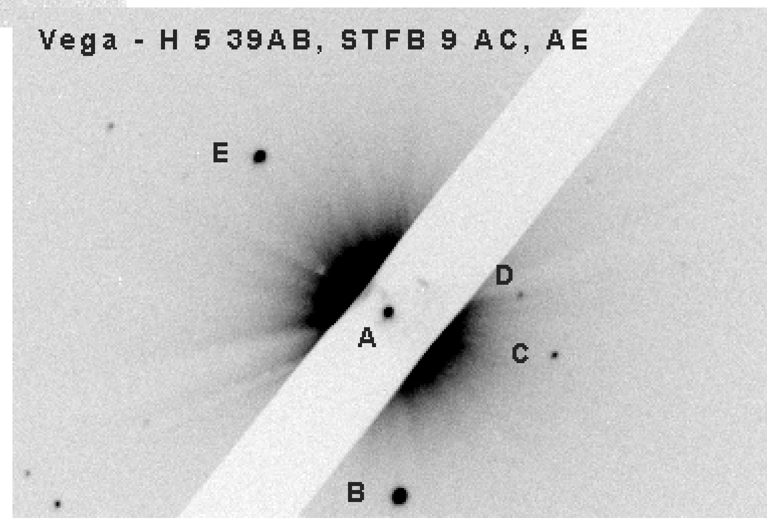

Figure 7: Vega, 20 sec exp, 2x2 binned.

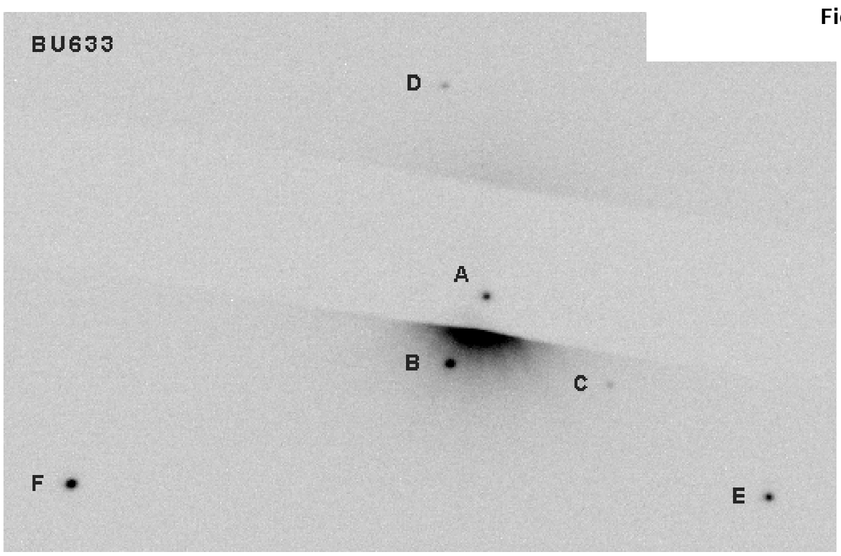

Figure 6: Gamma Draco, 10 sec exp, no binning, cropped.

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(Continued from page 162)

but not from "A". Note the closer faint unlisted component at the LSO measured values of 277 degrees and 29.27 arcseconds separation and the neat double at lower left.

Summary

A method of measuring high delta m pairs with a CCD sensor has been presented. The device implementation is described and sample images shown. The device is currently employed in an ongoing measurement program of these difficult stellar objects. Filters such as the Baader photographic foil of density 3.5 may be tried to cover an intermediate delta m range. Measurements of many of the program's high delta m doubles will be submitted to this journal in the near future.

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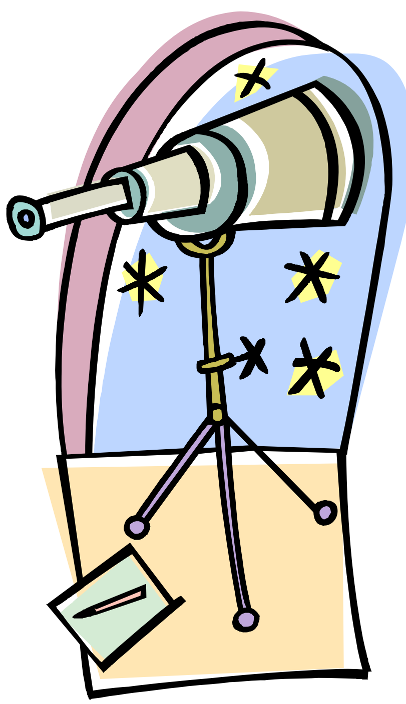

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Questions, comments, or submissions may be directed to rkentclark@jaguar1.usouthal.edu or to rmollise@bellsouth.net

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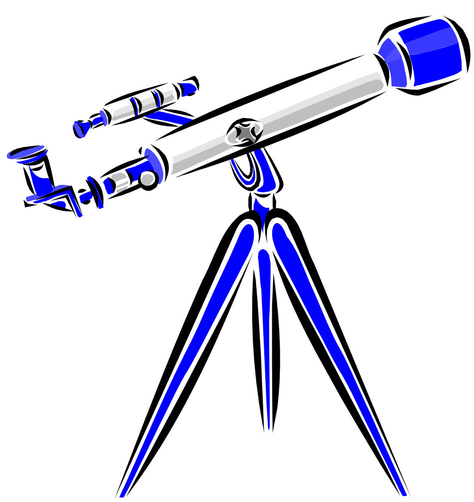

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