STT Doubles with Large ΔM – Part IV: Ophiuchus and Hercules

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Abstract: The results of visual double star observing sessions suggested a pattern for STT doubles with large ΔM of being harder to resolve than would be expected based on the WDS catalog data. It was felt this might be a problem with expectations on one hand, and on the other might be an indication of a need for new precise measurements, so we decided to take a closer look at a selected sample of STT doubles and do some research. We found that like in the other constellations covered so far (Gem, Leo, UMa, etc.) at least several of the selected objects in Ophiuchus and Hercules show parameters quite different from the current WDS data.

1. Introduction

As follow up to our reports "STT Doubles with Large delta_M – Part I, II and III" we continued in the constellations of Ophiuchus (Oph) and Hercules (Her), which contained 9 objects from our list (see Table 1) conveniently located with reasonable altitude at the time of observation. All values are from the WDS data as of the end of 2014.

2. Further Research

Following the procedure for parts I, II, and III of our report we concluded again that the best approach would be to check historical data on all objects, observe them visually with the target of comparing with the existing data and obtain as many images as possible suitable for photometry.

2.1 Historical Research and Catalog Comparisons

Of the nine stars in this survey, five of them have notable aspects worth further investigation. Three main research sources were used for this section of the paper, the first of which was W.J. Hussey's *Micrometrical Observations of the Double Stars Discovered at Pulkovo*, published in 1901, which provided preliminary historical information on each of the stars. Hussey's book includes his observations and measures of all the stars originally listed in Otto Wilhelm Struve's 1845 Pulko-

Table 1. WDS 2014.96 values for the selected STT objects in Oph and Her

Name	Comp	ID	RA	Dec	Con	Sep	PA	M1	M2	ΔM
STT 326	AB	17183+0931	17:18:15.811	+09:31:03.899	Oph	17.9	223	8.10	12.40	4.30
STT 342	AB	18073+0934	18:07:21.019	+09:33:49.199	Oph	24.8	298	3.73	14.00	10.27
STT 310	AB	16254+3755	16:25:25.459	+37:54:36.796	Her	3.0	226	8.40	11.00	2.60
STT 314	AB	16389+2028	16:38:51.498	+20:27:57.599	Her	3.8	234	8.80	11.70	2.90
STT 317	AB	16530+4424	16:52:57.219	+44:24:08.000	Her	24.8	200	8.21	12.00	3.79
STT 324	AB	17080+3112	17:08:00.700	+31:12:22.497	Her	3.5	220	6.60	11.10	4.50
STT 328	AB	17173+3306	17:17:19.568	+33:06:00.406	Her	4.2	59	4.80	10.20	5.40
STT 338	AC	17520+1520	17:51:58.462	+15:19:34.899	Her	32.8	201	7.21	13.60	6.39
STT 585	BP	16450+0605	16:44:57.961	+06:02:37.099	Her	77.4	3	10.4	13.10	2.70

vo Catalog, as well as data beginning with the date of first measure and continuing through the following years up to 1900. That data, plus inclusion of the background for the Pulkovo Catalog, makes Hussey's book a valuable source of reference. Also consulted was S.W. Burnham's *A General Catalogue of Double Stars Within 121° of the North Pole, Part II*, for information on STT 585. In addition, Bill Hartkopf of the USNO graciously supplied text files for STT 324, 326, 338, 342, and 585, as well as other information.

STT 317 (Her) stood out immediately as a star worth further investigation because of the very noticeable changes in position angle and separation of the AB pair. According to Hussey's data (Hussey, 1910, p. 137), Johann Heinrich Mädler made the first measurements of STT 317 AB in 1843, which were 234.1° and 15.39". The most recent WDS data (dated 2013) at the time we made observations of STT 317 showed a position angle of 200° and a separation of 24.80". That considerable change in PA and separation is due to the two stars moving in opposite directions, which is shown in Figure 2. Also notable in the image is the high proper motion of the C component relative to A and B. However, there is less change between the first AC measures in 1874 (318.1° and 113.40") and the 2013 WDS measures (316° and 130.40") due to the two stars moving in similar directions.

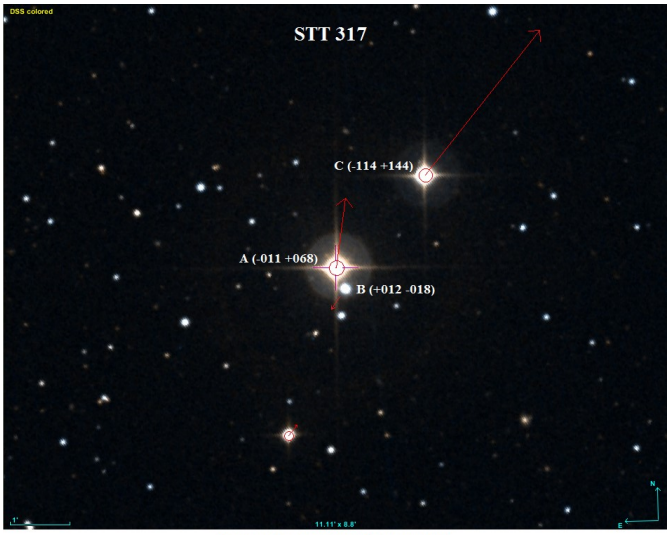

Figure 1. Proper Motion of STT 317 Components

STT 324 (Her) shows measurements changing from 213.6° and 3.8" in 1848 to 219.9° and 3.5" in 2000, the date of the most recent measures in the WDS. We requested the text file to see what changes had taken place in the 152 years between those two dates and found almost all of the fourteen measures between 1867 and 2000 (Table 2) showed a position angle in the range of 219° to 221°. The separations are more erratic, ranging from a high of 4.05" in 1869 by Dembowski to a low of 3.5" in 2000. Hussey (1901, p. 139) shows the first measures of STT 324 in 1848 were made by Otto Struve, and he also shows a follow-up measure of 218.5° and 3.87" by Struve in 1853 which is not listed in the WDS text file. So in general, it appears the position angle of this pair has been rather consistently in the 220° range, while the separation has fluctuated somewhat, averaging out to 3.79".

Table 2. Data from WDS Text File for STT 324

STT 324

Year	PA	Sep
1848.52	213.6	3.80
1867.12	219.93	3.987
1868.61	215.3	3.61
1869.22	220.1	4.05
1897.690	220.6	3.89
1898.52	220.4	3.78
1899.54	220.8	3.80
1901.539	223.4	3.90
1903.51	221.7	4.00
1923.46	221.2	3.65
1923.546	219.1	3.65
1937.04	220.6	3.64
1945.58	220.1	3.72
1972.567	220.4	3.97
1990.340	220.1	3.71
2001.552	219.9	3.50

STT 326 (Oph) stood out because of a consistent change in position angle and separation, which is a result of the two stars moving away from each other. The WDS proper motion numbers show the primary is moving east and south at a relatively slow rate of +027 -020, while the secondary is moving west and south at similar rate, -015 -021. When the 139 years of data of shown in the WDS is plotted, the consistent trend is very obvious, see Figure 2.

STT 342 (Oph) has a strange history which began with Otto Struve's 1841 observation of a companion at an estimated distance of 1.5". He recorded eight additional observations (Figure 3) of what he identified as an eighth magnitude companion, several of which described it as "suspect." (Hussey, 1901, pp. 144-45).

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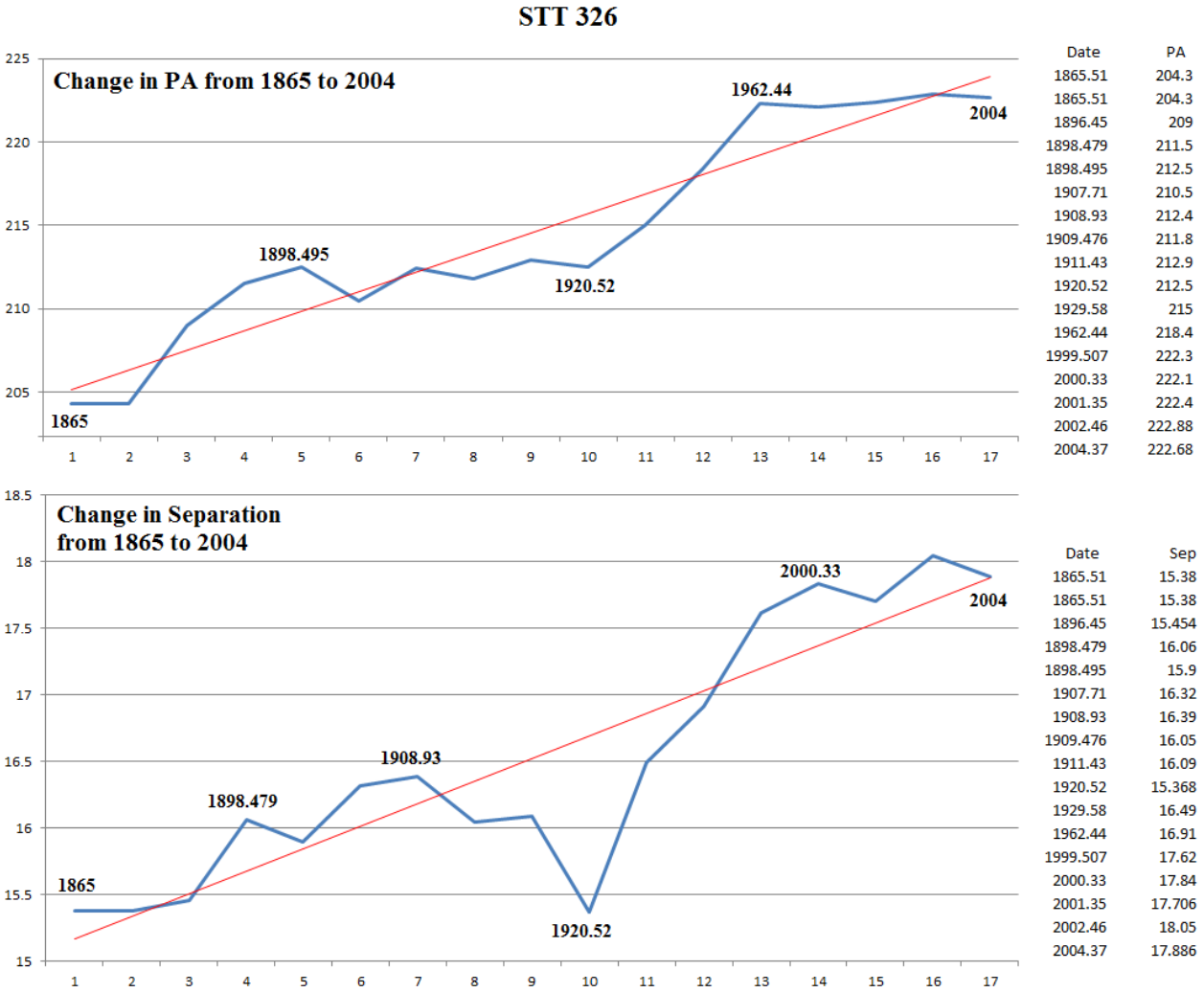

Date	PA
1865.51	204.3
1865.51	204.3
1896.45	209
1898.479	211.5
1898.495	212.5
1907.71	210.5
1908.93	212.4
1909.476	211.8
1911.43	212.9
1920.52	212.5
1929.58	215
1962.44	218.4
1999.507	222.3
2000.33	222.1
2001.35	222.4
2002.46	222.88
2004.37	222.68

Date	Sep
1865.51	15.38
1865.51	15.38
1896.45	15.454
1898.479	16.06
1898.495	15.9
1907.71	16.32
1908.93	16.39
1909.476	16.05
1911.43	16.09
1920.52	15.368
1929.58	16.49
1962.44	16.91
1999.507	17.62
2000.33	17.84
2001.35	17.706
2002.46	18.05
2004.37	17.886

Figure 2. STT 326 Measures from WDS Text File

1841.83	Estimated distance 1½″.
1842.72	160°.3 154°.3 1″.30 1″.21
1844.85	Suspected elongation of bright star in 63°.
1846.69	Perhaps slightly elongated or wedged in 87°.
1847.59	166°.3 163°.0 1″.59 1″.68 Not certain that the object observed may not be an optical illusion, but I think not.
1847.70	170°.7 169°.6 1″.2± 1″.27± I think it is certainly double, but the images are not very good.
1851.67	169°.6 167°.3 1″.44 1″.55 This is only an optical deception.
1876.67	157°.8 154°.5 1″.59 1″.60 Companion seen at once.
1877.56	Companion suspected in 158° at distance of 1″.4.

Figure 3. Otto Struve's Observations of Close Companion of STT 342 (from Hussey, 1901, p. 145).

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But as Hussey states, Struve also recorded another eight observations in which he failed to see the companion. Although other observers also reported measures between 1845 and 1884, no one reported the sighting of the companion when using large refractors, specifically the 26 inch at the USNO and the 36 inch at Lick. Hussey, S.W. Burnham, and R.G. Aitken each used the 36 inch Lick Refractor with no success during the period 1889 to 1898, which seems to have effectively decided the matter.

Burnham credits Simon Newcomb with the first measure of the star now identified as B, which surprisingly didn't occur until 1890, perhaps because of all the attention focused on the spurious close companion. The star now identified as C was discovered by John Herschel in 1827, which he cataloged as H 5943.

STT 585 (Her) is included here because of its anomalous numbering. When Otto Struve published his first Dorpat catalog in 1845, it ended at number 514. That catalog also was restricted to pairs with separations of 16" or less for companions fainter than ninth magnitude. All of the components of STT 585 are well over that limit, and all are fainter than tenth magnitude. The pairs wider than 16" of separation were added to Struve's appendix, which included a total of 254 stars.

So STT 585 stands out as being peculiarly numbered, which is significant also because the first measures of it weren't made until 1854. Research in Burnham's 1906 General Catalog (Burnham, 1901, p. 725) shows STT 585 is referred to only as 41 Herculis, and a 1996 copy of the WDS shows the star and its components referred to only as STT, with no number attached. However, a look at a 2001 copy of the WDS found the system had been designated as STT 585. A request to Bill Hartkopf at the WDS for background on the numbering provided information that stars such as this, which were not numbered in the IDS catalog (the predecessor to the WDS), were later given designations by Brian Mason of the WDS.

2.2 Visual Observations

Both Nanson and Knapp made visual observations of the stars included in this report. Nanson used a 152 mm f/10 refractor and a 235 mm SCT, while Knapp utilized 140 mm and 185 mm refractors and a 235 mm SCT, as well as a masking device to evaluate what could be seen at lesser apertures.

STT 310 (Her): This was a difficult pair with a magnitude differential of 2.4 and a separation of 3" according to the WDS data. Nanson observed it at the meridian with a six inch f/10 refractor and detected a definite elongation at 380x, and had a brief glimpse of a dot of light at the correct PA. Given the difficulty, he estimated the secondary was slightly fainter than the WDS magnitude of 11.0. Knapp observed the secondary at 200x in a 140 mm refractor and could still see it when the aperture was reduced to 110 mm, suggesting a magnitude slightly brighter than 11.0.

STT 314 (Her): Knapp observed this pair twice with a 185 mm refractor and resolved the secondary at 250x and 360x. He noticed a comparison star with a Vmag of 13.021 (UCAC4 553-056558) was a bit fainter than the secondary, but since he could still see the secondary with averted vision when the aperture was reduced to 130mm, he concluded the WDS magnitude of 11.7 was correct. Nanson used the same comparison star and concluded the secondary was just slightly brighter, but also felt the Vmag of 13.021 for the comparison star was too faint. He estimated the secondary to be of about 12.5 magnitude, which was in line with the difficulty he had in resolving it.

STT 317 (Her): Nanson resolved the B component at 109x and 152x in the six inch refractor, and concluded it was definitely fainter than the WDS magnitude of 12.0. It appeared to be slightly fainter than a 12.340 magnitude comparison star, suggesting the WDS magnitude is a bit too bright. Knapp resolved B in the 140 mm refractor with averted vision at a magnification of 280x, and could still detect it with the aperture reduced to 100 mm, which he concluded confirmed the WDS magnitude.

STT 324 (Her): Knapp resolved the secondary in a 185 mm refractor at 100x and could still detect it at 180x with the aperture reduced to 170 mm. Comparison stars with Vmags of 11.635 and 11.812 appeared to be similar in brightness to the secondary, suggesting it's slightly fainter than the WDS magnitude of 11.1. Nanson attempted this pair twice with the six inch refractor, but seeing conditions were too poor each time to allow visual detection.

STT 326 (Oph): Nanson observed this pair once with a 235 mm SCT and resolved the secondary at 136x. It appeared to be similar in magnitude to a comparison star with a Vmag of 12.660, suggesting the WDS magnitude of 12.4 for B is about right. Knapp observed STT 326 twice, catching a glimpse of it through a thin veil of clouds in the 140mm refractor at 180x, and during the next observation detected it at 40x in the 185 mm refractor, with confirmations at 100x, 180x, and 250x. He could still detect the secondary with averted vision when the aperture was reduced to 110mm, suggesting the secondary is brighter (about 11.8) than the WDS's 12.4. A comparison star with a Vmag of 13.477 seemed somewhat fainter than the secondary.

STT 328 (Her): Knapp resolved the secondary

at 140x and 200x in the 140 mm refractor, and could still detect it with the aperture reduced to 115 mm, which seems to confirm the WDS magnitude of 10.2. Nanson observed this pair twice with the six inch refractor, finding the secondary easier to resolve each time than would be expected for a pair with a ΔM of 5.4 and a separation of 4.2". No comparison stars were available, but based on both his experience and Knapp's, it's possible that either the separation is wider than 4.2" or the magnitude of the secondary is brighter than the WDS's 10.2

STT 338 (Her): Using a 235 mm SCT at 196x Nanson found C was slightly fainter than a comparison star with a Vmag of 12.951, suggesting it may be a bit brighter than the WDS magnitude of 13.60. Knapp came to the same conclusion using a 185mm refractor at 180x, but found the limit aperture for resolution was 150 mm, which would seem to suggest a magnitude for C of 12.4. A second observation with the same refractor resulted in a limiting aperture of 160 mm, which still suggests C is brighter than the WDS's 13.60 magnitude.

STT 342 (Oph): Knapp was unable to resolve B using 140 mm and 180 mm refractors. C was resolved with the 185 mm refractor at 180x, but was more difficult than expected based on the data. A comparison star with a Vmag of 11.934 was similar in brightness to C, suggesting the WDS magnitude for it of 11.48 is close. However, a limiting aperture for C of 130mm suggests C may be slightly fainter than 11.48. Nanson found B very difficult with a 235 mm SCT, but finally got a glimpse of it at 408x. Further attempts to see it failed, but based on the one observation, it's likely that B is a bit brighter than the 14.0 magnitude listed for it in the WDS. Using the same comparison star for C that Knapp used, he also found the two to be similar in magnitude.

STT 585 (Her): Using a 235 mm SCT and two comparison stars, Nanson found P was obviously brighter than the WDS magnitude of 13.10, perhaps by as much as half a magnitude. Knapp observed P twice, resolving it at 100x in the 185mm refractor on the first observation. Based on a limiting aperture of 170 mm for P, he estimated its magnitude in the 12.5 to 12.6 range. A second observation with the 185 mm refractor resulted in a limiting aperture of 120 mm, again pointing toward P being brighter than the WDS's 13.

2.3 Photometry and Astrometry Results

Several hundred images taken with iTelescope remote telescopes were in a first step plate solved and stacked with AAVSO VPhot. The stacked images were then plate solved with Astrometrica with UCAC4 reference stars with Vmags in the range 10.5 to 14.5mag. The RA/Dec coordinates resulting from plate solving were used to calculate Sep and PA using the formula provided by R. Buchheim (2008). Photometry was also performed with Astrometrica based on the Vmags of the UCAC4 reference stars used for plate solving. The results are shown in Table 3.

3. Summary

Tables 4 and 5 below compare the final results of our research with the WDS data that was current at the time we began working on the group of stars in Oph and Her.

In Table 4 the results of our photometry have been averaged for each star. Because we're aware that both the NOMAD-1 and the UCAC4 catalogs are frequently consulted when making WDS evaluations of magnitudes changes, the data from those catalogs has also been included for each of the stars.

Red type has been used in Tables 4 and 5 to call attention to significant differences from the WDS data. With regard to Table 4, those magnitudes that differ by two tenths of a magnitude or more from the WDS values have been highlighted. In Table 5 differences in separation in excess of two-tenths of an arc second are highlighted, as are all position angles which differ by more than a degree.

Subsequent to our measures, as a quality check for our astrometry results we turned to the URAT1 catalog for the most recent precise professional measurements available. We used its coordinates to calculate the Sep and PA for all objects in this report for which URAT1 data was available and compared these values with our results, which are shown below in Table 6.

With the exception of STT 585 BP, the Sep results are all within the given error range, so this comparison can be considered as confirmation for the reported results. In the case of STT 585 BP, a rather high rate of proper motion for B (GAIA shows a PM of -219 -255) seems to be the cause of the discrepancy. We calculated a 0.3" shift in position of B between the 2013.735 URAT1 data and the 2015.497 date of our measure.

With regard to the use of URAT1 as a quality check on our astrometry, we contacted Norbert Zacharias at the USNO, who was closely involved in the URAT1 project. He referred us to a paper on which he was lead author which contains this information: "URAT1 can serve as accurate reference star catalog before Gaia data become available. The position accuracy of URAT1 is about 4 times higher than for UCAC4 data at its faint end and the sky density of URAT1 is about 4 times larger than that of UCAC4, similar to the sky density of 2MASS." (Zacharias, 2015, p. 11).

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*Table 3: Photometry and astrometry results for the selected STT objects in Oph and Her. RA and Dec are the coordinates based on plate solving with UCAC4 reference stars in the 10.5 to 14.5mag range. Sep is separation calculated as SQRT (((RA2-RA1)*cos(Dec1))^2+(Dec2-Dec1)^2) in radians. Err_Sep is calculated as SQRT(dRA^2+dSep^2) with dRA and dDec as average RA and Dec plate solving errors. PA is calculated as arctan((RA2-RA1)*cos(Dec1))/(Dec2-Dec1)) in radians depending on quadrant and Err_PA is the error estimation for PA calculated as arctan(Err_Sep/Sep) in degrees assuming the worst case that Err_Sep points in the right angle to the direction of the separation means perpendicular to the separation vector. Mag is the photometry result based on UCAC4 reference stars with Vmags between 10.5 and 14.5mag. Err_Mag is calculated as square root of (dVmag^2 + (2.5*Log10(1+1/SNR))^2) with dVmag as the average Vmag error over all used reference stars and SNR is the signal to noise ratio for the given star. Date is the Bessel epoch in 2015 and N is the number of images (usually with 1s exposure time) used for the reported values. iT in the Notes column indicates the telescope used with number of images and exposure time given.*

The average results over all used images are given in the line below the individual stacks in red and bold. The error estimation over all used images is calculated as root mean square over the individual Err values. The N column in the summary line gives the total number of images used and Date the average Bessel epoch.

STT 326	RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date 2015	N	Notes
A	17 18 15.842	09 31 03.51	18.038	0.233	223.934	0.741	8.036	0.120	519	5	iT11 stack 5x1s
B	17 18 14.996	09 30 50.52					12.190	0.127			
A	17 18 15.863	09 31 03.35	18.143	0.234	224.004	0.740	7.979	0.110	478	2	iT24 stack 2x1s
B	17 18 15.011	09 30 50.30					12.034	0.113			
A	17 18 15.844	09 31 03.33	18.170	0.234	224.182	0.739	7.934	0.110	476	5	iT24 stack 5x1s
B	17 18 14.988	09 30 50.30					11.983	0.114			
A	17 18 15.845	09 31 03.49	18.029	0.163	223.766	0.517	8.013	0.060	511	5	iT24 stack 5x1s_2
B	17 18 15.002	09 30 50.47					12.088	0.064			
A	17 18 15.849	09 31 03.52	18.099	0.156	223.814	0.492	7.999	0.090	522	5	iT24 stack 5x1s_3
B	17 18 15.002	09 30 50.46					12.039	0.093			
A	17 18 15.853	09 31 03.53	18.187	0.276	223.419	0.869	8.074	0.151	516	5	iT24 stack 5x1s_4
B	17 18 15.008	09 30 50.32					12.143	0.155			
A	17 18 15.848	09 31 03.57	18.077	0.198	223.880	0.629	7.993	0.080	524	5	iT24 stack 5x1s_5
B	17 18 15.001	09 30 50.54					12.071	0.085			
A	17 18 15.849	09 31 03.471	18.106	0.217	223.857	0.688	8.004	0.107	507	32	Summary line
B	17 18 15.001	09 30 50.416					12.078	0.111			
STT342	**RA**	**Dec**	**Sep**	**Err Sep**	**PA**	**Err PA**	**Mag**	**Err Mag**	**Date 2015**	**N**	**Notes**
A	18 07 20.934	09 33 51.60	24.941	0.270	295.965	0.621	4.658	0.131	519	4	iT24 stack 4x1s. SNR for B <20
B	18 07 19.418	09 34 02.52					13.780	0.152			
A	18 07 20.917	09 33 51.28	24.659	0.212	297.405	0.493	4.707	0.190	524	5	iT24 stack 5x1s. SNR for B <20
B	18 07 19.437	09 34 02.63					14.003	0.211			
A	18 07 20.943	09 33 51.36	25.129	0.184	297.055	0.419	5.021	0.140	511	5	iT24 stack 5x1s_2. SNR for B <20
B	18 07 19.430	09 34 02.79					13.864	0.154			
A	18 07 20.932	09 33 50.90	25.397	0.234	298.427	0.529	4.569	0.120	628	5	iT24 stack 5x3s
B	18 07 19.422	09 34 02.99					13.868	0.130			
A	18 07 20.930	09 33 50.57	25.326	0.213	298.411	0.481	4.969	0.120	628	5	iT24 stack 5x6s
B	18 07 19.424	09 34 02.62					13.903	0.126			
A	18 07 20.918	09 33 50.75	25.249	0.198	298.299	0.449	5.054	0.120	628	5	iT24 stack 5x9s
B	18 07 19.415	09 34 02.72					13.799	0.124			
A	18 07 20.916	09 33 51.54	24.698	0.191	297.358	0.443	4.060	0.140	522	6	iT24 stack 6x1s. SNR for B <20
B	18 07 19.433	09 34 02.89					13.822	0.157			
A	18 07 20.927	09 33 51.143	25.055	0.216	297.565	0.495	4.720	0.139	566	35	SNR for B in some images <20. A too bright for reliable photometry
B	18 7 19.426	09 34 02.737					13.863	0.153			

Table 3 continues on next page.

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Table 3 (continued). Photometry and astrometry results for the selected STT objects in Oph and Her. RA and Dec are the co-ordinates based on plate solving with UCAC4 reference stars in the 10.5 to 14.5mag range. ...

STT 310	RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date 2015	N	Notes
A	16 25 25.445	37 54 36.33	2.936	0.150	222.629	2.925	8.230	0.080	467	5	iT24 stack 5x1s
B	16 25 25.277	37 54 34.17					11.123	0.085			
A	16 25 25.445	37 54 36.31	3.064	0.184	221.634	3.444	8.215	0.070	522	5	iT24 stack 5x1s_2
B	16 25 25.273	37 54 34.02					11.081	0.074			
A	16 25 25.446	37 54 36.22	3.432	0.184	222.257	3.066	8.209	0.080	516	5	iT24 stack 5x1s_3
B	16 25 25.251	37 54 33.68					11.325	0.084			
A	16 25 25.445	37 54 36.37	3.209	0.163	221.869	2.904	8.209	0.070	525	5	iT24 stack 5x1s_4
B	16 25 25.264	37 54 33.98					11.066	0.073			
A	16 25 25.445	37 54 36.307	3.160	0.171	222.094	3.095	8.216	0.075	507	20	Touching/ overlapping star disks
B	16 25 25.266	37 54 33.962					11.149	0.079			
STT 314	**RA**	**Dec**	**Sep**	**Err Sep**	**PA**	**Err PA**	**Mag**	**Err Mag**	**Date 2015**	**N**	**Notes**
A	16 38 51.508	20 27 57.45	3.576	0.277	235.218	4.423	8.313	0.100	472	5	iT11 stack 5x1s
B	16 38 51.299	20 27 55.41					11.139	0.104			
A	16 38 51.497	20 27 57.43	3.639	0.213	234.950	3.343	8.278	0.100	521	5	iT18 stack 5x1s
B	16 38 51.285	20 27 55.34					11.301	0.109			
A	16 38 51.492	20 27 57.64	3.729	0.198	232.311	3.039	8.123	0.100	470	5	iT21 stack 5x1s
B	16 38 51.282	20 27 55.36					11.110	0.111			
A	16 38 51.492	20 27 57.29	3.557	0.170	232.202	2.732	8.223	0.070	473	5	iT24 stack 5x1s
B	16 38 51.292	20 27 55.11					11.278	0.073			
A	16 38 51.497	20 27 57.35	3.393	0.194	228.915	3.275	8.236	0.070	478	5	iT24 stack 5x1s_2
B	16 38 51.315	20 27 55.12					10.979	0.075			
A	16 38 51.494	20 27 57.35	3.740	0.261	231.068	3.989	8.234	0.061	476	5	iT24 stack 5x1s_3
B	16 38 51.287	20 27 55.00					11.019	0.070			
A	16 38 51.499	20 27 57.28	3.720	0.172	229.412	2.648	8.206	0.070	524	5	iT24 stack 5x1s_4
B	16 38 51.298	20 27 54.86					11.254	0.073			
A	16 38 51.495	20 27 57.05	3.530	0.248	235.094	4.012	8.280	0.100	516	5	iT24 stack 5x1s_5
B	16 38 51.289	20 27 55.03					11.430	0.111			
A	16 38 51.499	20 27 57.28	3.720	0.172	229.412	2.648	8.206	0.070	524	5	iT24 stack 5x1s_6
B	16 38 51.298	20 27 54.86					11.254	0.073			
A	16 38 51.497	20 27 57.347	3.619	0.215	232.056	3.399	**8.233**	**0.084**	**495**	**45**	**Summary line**
B	16 38 51.294	20 27 55.121					**11.196**	**0.091**			

Table 3 continues on next page.

STT Doubles with Large ΔM – Part IV: Ophiuchus and Hercules

Table 3 (continued). Photometry and astrometry results for the selected STT objects in Oph and Her. RA and Dec are the co-ordinates based on plate solving with UCAC4 reference stars in the 10.5 to 14.5mag range. ...

STT 317	RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date	N	Notes
A	16 52 57.208	44 24 09.33	24.713	0.355	199.744	0.823	7.900	0.070	530	4	iT21 stack 4x1s. SNR B<20
B	16 52 56.429	44 23 46.07					12.677	0.103			
A	16 52 57.196	44 24 09.67	24.808	0.141	200.349	0.327	8.030	0.070	476	3	iT24 stack 3x1s
B	16 52 56.391	44 23 46.41					12.517	0.078			
A	16 52 57.187	44 24 09.81	24.852	0.178	200.154	0.410	7.757	0.060	467	5	iT24 stack 5x1s
B	16 52 56.388	44 23 46.48					12.471	0.068			
A	16 52 57.189	44 24 09.83	24.925	0.164	200.276	0.377	7.822	0.050	473	5	iT24 stack 5x1s_2
B	16 52 56.383	44 23 46.45					12.472	0.057			
A	16 52 57.200	44 24 09.60	24.760	0.149	200.444	0.344	7.769	0.070	511	5	iT24 stack 5x1s_3
B	16 52 56.393	44 23 46.40					12.499	0.076			
A	16 52 57.195	44 24 09.60	24.713	0.163	200.485	0.377	7.850	0.060	522	5	iT24 stack 5x1s_4
B	16 52 56.388	44 23 46.45					12.501	0.067			
A	16 52 57.194	44 24 09.63	24.741	0.163	200.460	0.377	7.852	0.080	516	5	iT24 stack 5x1s_5
B	16 52 56.387	44 23 46.45					12.484	0.087			
A	16 52 57.196	44 24 09.639	24.787	0.200	200.273	0.462	7.854	0.066	499	32	Summary line
B	16 52 56.394	44 23 46.387					12.517	0.078			
STT 324	RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date	N	Notes
A	17 08 00.683	31 12 22.06	2.974	0.191	218.411	3.676	6.098	0.070	473	5	iT24 stack 5x1s. Overlapping star disks. SNR for B<20
B	17 08 00.539	31 12 19.73					10.530	0.095			
A	17 08 00.682	31 12 22.08	3.550	0.212	221.957	3.420	6.039	0.070	473	5	iT24 stack 5x1s_2. Overlapping star disks. SNR for B<20
B	17 08 00.497	31 12 19.44					10.883	0.095			
A	17 08 00.691	31 12 21.72	3.669	0.177	227.256	2.761	5.953	0.090	478	5	iT24 stack 5x1s_3. Overlapping star disks
B	17 08 00.481	31 12 19.23					10.657	0.102			
A	17 08 00.678	31 12 21.98	3.676	0.205	219.173	3.195	5.820	0.090	476	5	iT24 stack 5x1s_4. Overlapping star disks
B	17 08 00.497	31 12 19.13					10.039	0.102			
A	17 08 00.685	31 12 22.11	3.786	0.200	218.081	3.024	6.130	0.080	511	5	iT24 stack 5x1s_5. Overlapping star disks
B	17 08 00.503	31 12 19.13					11.197	0.094			
A	17 08 00.670	31 12 22.41	3.084	0.212	205.639	3.935	5.801	0.120	516	5	iT24 stack 5x1s_6. Overlapping star disks
B	17 08 00.566	31 12 19.63					10.180	0.127			
A	17 08 00.683	31 12 22.21	3.612	0.184	217.395	2.922	6.076	0.080	525	5	iT24 stack 5x1s_7. Overlapping star disks
B	17 08 00.512	31 12 19.34					10.980	0.090			
A	17 08 00.683	31 12 22.21	4.196	0.184	218.366	2.516	6.085	0.080	525	5	iT24 stack 5x1s_8. Overlapping star disks
B	17 08 00.480	31 12 18.92					11.523	0.089			
A	17 08 00.682	31 12 22.097	3.552	0.196	218.535	3.161	6.000	0.086	497	40	Summary line
B	17 08 00.509	31 12 19.319					10.749	0.100			

Table 3 continues on next page.

STT Doubles with Large ΔM – Part IV: Ophiuchus and Hercules

Table 3 (continued). Photometry and astrometry results for the selected STT objects in Oph and Her. RA and Dec are the co-ordinates based on plate solving with UCAC4 reference stars in the 10.5 to 14.5mag range. ...

STF2127	RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date	N	Notes
A	17 07 04.412	31 05 34.78	15.127	0.191	280.475	0.724	8.423	0.070	473	5	iT24 stack 5x1s
B	17 07 03.254	31 05 37.53					11.555	0.072			
A	17 07 04.417	31 05 34.74	15.163	0.212	280.411	0.802	8.404	0.070	473	5	iT24 stack 5x1s_2
B	17 07 03.256	31 05 37.48					11.569	0.072			
A	17 07 04.424	31 05 34.47	15.301	0.177	281.574	0.662	8.356	0.090	478	5	iT24 stack 5x1s_3
B	17 07 03.257	31 05 37.54					11.615	0.092			
A	17 07 04.407	31 05 34.56	15.056	0.205	281.144	0.781	8.217	0.090	476	5	iT24 stack 5x1s_4
B	17 07 03.257	31 05 37.47					11.669	0.094			
A	17 07 04.420	31 05 34.81	15.213	0.200	280.376	0.753	8.453	0.080	511	5	iT24 stack 5x1s_5
B	17 07 03.255	31 05 37.55					11.528	0.082			
A	17 07 04.403	31 05 35.10	14.955	0.212	279.585	0.813	8.186	0.120	516	5	iT24 stack 5x1s_6
B	17 07 03.255	31 05 37.59					11.521	0.122			
A	17 07 04.409	31 05 34.86	15.148	0.184	280.113	0.697	8.424	0.080	525	5	iT24 stack 5x1s_7
B	17 07 03.248	31 05 37.52					11.528	0.082			
A	17 07 04.413	31 05 34.760	15.137	0.198	280.528	0.749	8.352	0.087	493	35	Summary line
B	17 07 03.255	31 05 37.526					11.569	0.089			
STT 328	RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date	N	Notes
A	17 17 19.563	33 06 00.05	4.549	0.184	57.708	2.321	4.808	0.070	470	4	iT24 stack 4x1s. Overlapping star disks. SNR for B<20
B	17 17 19.869	33 06 02.48					10.328	0.112			
A	17 17 19.559	33 06 00.36	4.694	0.219	61.082	2.675	4.848	0.080	473	5	iT24 stack 5x1s. Overlapping star disks, SNR for B<20
B	17 17 19.886	33 06 02.63					10.461	0.117			
A	17 17 19.565	33 06 00.38	4.533	0.214	57.730	2.703	4.837	0.080	478	5	iT24 stack 5x1s_2. Overlapping star disks, SNR for B<20
B	17 17 19.870	33 06 02.80					10.147	0.122			
A	17 17 19.556	33 06 00.46	4.326	0.198	60.960	2.627	4.096	0.080	516	5	iT24 stack 5x1s_3. Overlapping star disks, SNR for B<20
B	17 17 19.857	33 06 02.56					10.118	0.097			
A	17 17 19.563	33 06 00.42	4.508	0.163	59.469	2.068	4.810	0.080	522	5	iT24 stack 5x1s_4. Overlapping star disks, SNR for B<20
B	17 17 19.872	33 06 02.71					10.301	0.109			
A	17 17 19.561	33 06 00.334	4.520	0.197	59.386	2.494	4.680	0.078	492	24	Summary line
B	17 17 19.871	33 06 02.636					10.271	0.112			

Table 3 continues on next page.

STT Doubles with Large ΔM – Part IV: Ophiuchus and Hercules

Table 3 (continued). Photometry and astrometry results for the selected STT objects in Oph and Her. RA and Dec are the co-ordinates based on plate solving with UCAC4 reference stars in the 10.5 to 14.5mag range. ...

STT338	RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date	N	Notes
AB	17 51 58.466	15 19 35.28	32.525	0.250	202.077	0.440	6.363	0.150	472	5	iT11 stack 5x1s. SNR for B<20
C	17 51 57.621	15 19 05.14					13.239	0.169			
AB	17 51 58.470	15 19 34.96	32.617	0.262	202.148	0.460	6.309	0.090	521	4	iT18 stack 4x1s. SNR for C<10
C	17 51 57.620	15 19 04.75					13.157	0.143			
AB	17 51 58.461	15 19 34.91	32.648	0.184	202.236	0.323	5.985	0.140	470	5	iT21 stack 5x1s. SNR for C<20
C	17 51 57.607	15 19 04.69					13.033	0.167			
AB	17 51 58.461	15 19 35.15	32.789	0.191	202.053	0.334	6.091	0.080	473	5	iT24 stack 5x1s
C	17 51 57.610	15 19 04.76					13.022	0.088			
AB	17 51 58.453	15 19 35.22	32.649	0.227	201.961	0.398	6.062	0.080	467	5	iT24 stack 5x1s_2
C	17 51 57.609	15 19 04.94					13.041	0.089			
AB	17 51 58.451	15 19 35.02	32.270	0.226	202.094	0.402	6.005	0.080	478	5	iT24 stack 5x1s_3
C	17 51 57.612	15 19 05.12					12.988	0.089			
AB	17 51 58.458	15 19 35.24	32.660	0.191	202.008	0.335	6.215	0.070	511	5	iT24 stack 5x1s_4
C	17 51 57.612	15 19 04.96					13.124	0.079			
AB	17 51 58.449	15 19 35.30	32.885	0.226	201.388	0.394	6.101	0.090	516	5	iT24 stack 5x1s_5
C	17 51 57.620	15 19 04.68					13.176	0.099			
AB	17 51 58.448	15 19 35.34	32.726	0.212	202.015	0.371	6.073	0.080	522	5	iT24 stack 5x1s_6
C	17 51 57.600	15 19 05.00					13.037	0.089			
AB	17 51 58.457	15 19 35.158	32.641	0.220	201.997	0.387	6.134	0.099	492	44	Summary line
C	17 51 57.612	15 19 04.893					13.091	0.117			
STT338	RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date	N	Notes
AB	17 51 58.466	15 19 35.28	96.303	0.250	246.786	0.149	6.363	0.150	472	5	iT11 stack 5x1s
D	17 51 52.348	15 18 57.32					11.834	0.154			
AB	17 51 58.470	15 19 34.96	96.338	0.262	246.846	0.156	6.309	0.090	521	4	iT18 stack 4x1s
D	17 51 52.347	15 18 57.08					11.819	0.104			
AB	17 51 58.461	15 19 34.91	96.291	0.184	246.847	0.109	5.985	0.140	530	5	iT21 stack 5x1s
D	17 51 52.341	15 18 57.05					11.110	0.148			
AB	17 51 58.461	15 19 35.15	96.367	0.191	246.828	0.114	6.091	0.080	473	5	iT24 stack 5x1s
D	17 51 52.337	15 18 57.23					11.666	0.082			
AB	17 51 58.453	15 19 35.22	96.288	0.227	246.762	0.135	6.062	0.080	467	5	iT24 stack 5x1s_2
D	17 51 52.337	15 18 57.23					11.650	0.082			
AB	17 51 58.451	15 19 35.02	96.251	0.226	246.837	0.135	6.005	0.080	478	5	iT24 stack 5x1s_3
D	17 51 52.334	15 18 57.16					11.019	0.087			
AB	17 51 58.458	15 19 35.24	96.328	0.191	246.773	0.114	6.215	0.070	511	5	iT24 stack 5x1s_4
D	17 51 52.339	15 18 57.25					11.660	0.072			
AB	17 51 58.449	15 19 35.30	96.131	0.226	246.631	0.135	6.101	0.090	516	5	iT24 stack 5x1s_5
D	17 51 52.349	15 18 57.17					11.734	0.092			
AB	17 51 58.448	15 19 35.34	96.329	0.212	246.728	0.126	6.073	0.080	522	5	iT24 stack 5x1s_6
D	17 51 52.331	15 18 57.28					11.633	0.082			
AB	17 51 58.457	15 19 35.158	96.292	0.220	246.782	0.131	6.134	0.099	499	44	Summary line
D	17 51 52.34	15 18 57.197					11.569	0.104			

Table 3 concludes on next page.

STT Doubles with Large ΔM – Part IV: Ophiuchus and Hercules

Table 3 (conclusion). Photometry and astrometry results for the selected STT objects in Oph and Her. RA and Dec are the coordinates based on plate solving with UCAC4 reference stars in the 10.5 to 14.5mag range. ...

STT 585	RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date	N	Notes
B	16 44 57.753	06 02 33.08	89.669	0.255	5.202	0.163	10.369	0.092	472	5	iT11 stack 5x1s. SNR for P<20
P	16 44 58.298	06 04 02.38					12.940	0.113			
B	16 44 57.734	06 02 33.16	89.754	0.228	5.092	0.146	10.321	0.113	515	2	iT18 stack 5x1s. SNR for P<10
P	16 44 58.268	06 04 02.56					13.125	0.169			
B	16 44 57.726	06 02 33.22	89.801	0.333	5.414	0.212	9.887	0.161	515	9	iT21 stack 5x1s. SNR for P<20
P	16 44 58.294	06 04 02.62					12.544	0.174			
B	16 44 57.733	06 02 33.14	89.624	0.177	5.233	0.113	10.272	0.160	473	5	iT24 stack 5x1s
P	16 44 58.281	06 04 02.39					12.742	0.163			
B	16 44 57.731	06 02 33.19	89.640	0.205	5.280	0.131	10.259	0.081	467	5	iT24 stack 5x1s_2
P	16 44 58.284	06 04 02.45					12.783	0.086			
B	16 44 57.735	06 02 33.24	89.565	0.177	5.246	0.113	10.263	0.071	476	5	iT24 stack 5x1s_3
P	16 44 58.284	06 04 02.43					12.749	0.081			
B	16 44 57.733	06 02 33.11	89.666	0.205	5.250	0.131	10.275	0.071	511	5	iT24 stack 5x1s_4
P	16 44 58.283	06 04 02.40					12.763	0.076			
B	16 44 57.741	06 02 32.98	89.615	0.248	5.243	0.159	10.326	0.121	516	5	iT24 stack 5x1s_5
P	16 44 58.290	06 04 02.22					12.876	0.126			
B	16 44 57.736	06 02 33.10	89.929	0.227	5.263	0.144	10.303	0.120	524	5	iT24 stack 5x1s_6
P	16 44 58.289	06 04 02.65					12.838	0.125			
B	16 44 57.736	06 02 33.136	89.696	0.233	5.247	0.149	10.253	0.115	497	46	Summary line
P	16 44 58.286	06 04 02.456					12.818	0.129			

Specifications of the used telescopes:

- iT11: 510mm CDK with 2280mm focal length. CCD: FLI ProLine PL11002M. Resolution 0.81 arcsec/pixel. B- and V-Filter. Transformation coefficients B-V available. Located in Mayhill, New Mexico. Elevation 2225m
- iT18: 318mm CDK with 2541mm focal length. CCD: SBIG-STXL-6303E. Resolution 0.73 arcsec/pixel. V-filter. No transformation coefficients available. Located in Nerpio, Spain. Elevation 1650m
- iT21: 431mm CDK with 1940mm focal length. CCD: FLI-PL6303E. Resolution 0.96 arcsec/pixel. V-filter. Transformation coefficients V-R available, but not used. Located in Mayhill, New Mexico. Elevation 2225m
- iT24: 610mm CDK with 3962mm focal length. CCD: FLI-PL09000. Resolution 0.62 arcsec/pixel. V-filter. No transformation coefficients available. Located in Auberry, California. Elevation 1405m

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Table 4. Photometry and Visual Results Compared to WDS

	WDS Mag	NOMAD-1 VMag	UCAC4 VMa	UCAC4 f. mag	Average of Photometry Measures	Results of Visual Observations
STT 326 B	12.40	12.060	-	12.307	12.078	Three observations: one concluded B was slightly brighter, one that it was close to the WDS value, and one that it was fainter.
STT 342 B	14.00	-	-	13.711	13.863	One observation of B found it was slightly brighter than the WDS value.
STT 310 B	11.00	-	-	-	11.149	Two observations: one found B slightly brighter, one estimated it to be slightly fainter than the WDS value.
STT 314 B	11.70	-	-	-	11.196	Two observations: one found the WDS magnitude to be about right, one estimated B at 12.5.
STT 317 B	12.00	12.220	-	12.475	12.517	Two observations: one found the WDS magnitude to be about right, the other concluded B was a bit fainter than the WDS value.
STT 324 B	11.10	-	-	-	10.749	One observation suggested B was slightly fainter than the WDS magnitude.
STF 2127 B	12.30	11.030	-	11.342	11.569	No visual observations made.
STT 328 B	10.20	-	-	-	10.271	One observation tended to confirm the WDS magnitude; the other felt B was either brighter than the WDS magnitude or the separation was slightly wider than the WDS value.
STT 338 C	13.60	13.80	-	12.746	13.091	Three observations indicated C was brighter than the WDS value.
STT 338 D	10.60	11.950	11.671	11.289	11.569	No visual estimates made.
STT 585 P	13.10	11.960	12.799	12.812	12.818	Three observations, all indicating P was brighter than the WDS magnitude.

Table 5. Astrometry Results Compared to WDS

	WDS Coordinates	WDS Sep	WDS PA	Astrometry Coordinates	Astrometry Sep	Astrometry PA
STT 326 AB	**17 18 15.81 +09 31 03.9**	17.90"	223°	17 18 15.849 +09 31 03.471	18.106"	223.857°
STT 342 AB	**18 07 21.02 +09 33 49.2**	24.90"	298°	18 07 20.927 +09 33 51.143	25.055"	297.565°
STT 310 AB	**16 25 25.46 +37 54 36.8**	3.00"	226°	16 25 25.445 +37 54 36.307	3.160"	222.094°
STT 314 AB	**16 38 51.50 +20 27 57.6**	3.80"	234°	16 38 51.497 +20 27 57.347	3.619"	232.056°
STT 317 AB	**16 52 57.22 +44 24 08.0**	24.80"	200°	16 52 57.196 +44 24 09.639	24.787"	200.273°
STT 324 AB	17 08 00.70 +31 12 22.5	3.50"	220°	17 08 00.682 +31 12 22.097	3.552"	218.535°
STF 2127 AB	**17 07 04.42 +31 05 35.1**	14.80"	276°	17 07 04.413 +31 05 34.760	15.137"	280.528°
STT 328 AB	**17 17 19.57 +33 06 00.4**	4.20"	59°	17 17 19.561 +33 06 00.334	4.520"	59.386°
STT 338 AB-C	**17 51 58.46 +15 19 34.9**	32.80"	201°	17 51 58.457 +15 19 35.158	32.641"	201.997°
STT 338 AB-D	**17 51 58.46 +15 19 34.9**	95.60"	247°	17 51 58.457 +15 19 35.158	96.292"	246.782°
STT 585 BP**	**16 44 57.96 +06 02 37.1**	85.90"	3°	16 44 57.736 +06 02 33.136	89.696"	5.247°

** At the time we first pulled data from the WDS for STT 585 BP, it listed the 2001 (most recent) separation as 77.40". However, a look at the text file for that pair of stars showed a separation of 85.858" for the 2001 measure. That error is now corrected in the current WDS listing of STT 585 BP.

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Table 6. Astrometry Results Compared with URAT1 Coordinates

Object	URAT1 Sep	iTelescope Sep	Err Sep	Within Error Range?	URAT1 PA	iTelescope PA	Err PA	Within Error Range?
STT 326 AB	18.031"	18.106"	0.217	Yes	223.648°	223.857°	0.688	Yes
STT 342 AB	25.040"	25.055"	0.216	Yes	297.562°	297.565°	0.495	Yes
STT 317 AB	24.710"	24.787"	0.200	Yes	200.574°	200.273°	0.462	Yes
STF 2127 AB	15.219"	15.137"	0.198	Yes	280.579°	280.528°	0.749	Yes
STT 338 AB-C	32.588"	32.641"	0.220	Yes	202.149°	201.997°	0.387	Yes
STT 338 AB-D	96.349"	96.292°	0.220	Yes	246.862°	246.782°	0.131	Yes
STT 585 BP	89.254"	89.696°	0.233	No	5.033°	5.247°	0.149	No

(Continued from page 365)

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- Washington Double Star Catalog
- iTelescope
- AAVSO VPhot
- AAVSO APASS
- UCAC4 catalog via the University of Heidelberg website and directly from USNO DVD
- Aladin Sky Atlas v8.0
- SIMBAD, VizieR
- 2MASS All Sky Catalog
- URAT1 Survey
- AstroPlanner v2.2
- MaxIm DL6 v6.08
- Astrometrica v4.8.2.405