STT Doubles with Large ΔM – Part II: Leo and UMa

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Abstract: The results of visual double star observing sessions suggested a pattern for STT doubles with large ΔM 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 also in Leo and Uma at least several of the selected objects show parameters quite different from the current WDS data.

1. Introduction

As follow up to our report "STT Doubles with Large delta_M – Part I: Gem" (Knapp, Nanson, and Smith 2015) we continued in the constellations of Leo and Uma which contained 10 objects from our list (see Table 1.1) then conveniently located near zenith. All values are based on WDS data as of the end of 2014.

2. Further Research

Following the procedure for Part I 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 Challenges of imaging double stars with large ΔM

In Part I the challenges and difficulties of observing and photographing unequal double stars were discussed in a general way. Those systems had separations greater than 6.8" and were in a sense relatively easy to resolve. Looking at the data in Table 1.1 shows three systems which have separations considerably smaller than dealt with earlier and in particular STT222 with a separation of 4" and ΔM = 4 will obviously present the greatest challenge for both visual and photographic observations in this installment.

This poses the general question: which conditions have to be fulfilled to be able to resolve a double star by imaging? For visual resolution of equal bright doubles, criteria such as Rayleigh, Dawes etc., are fairly straightforward and for imaging we can apply the Nyquist Sampling Criterion (Nyquist 1928) that states that the sampling rate should be twice the highest frequency being measured or in the case of resolving objects or imaging, the angular resolution per pixel should be at least half the angular resolution of the object you are trying to resolve to get all or most of the details the telescope can offer. Or the other way around: If we need to image objects with a separation of "n" arcseconds we would need a telescope/camera combination capable of resolutions to half this value. But even then we might not get all the details in an image that we can easily observe visually – for example diffraction

Table 1.1. WDS 2014.96 values for the selected STT objects in Leo and UMa

Name	Comp	WDS ID	RA	Dec	Con	Sep	PA	M1	M2	ΔM
STT204	AB	09388+1047	09:38:45.689	+10:46:39.800	Leo	7.8	99	6.70	11.60	4.90
STT207	AB	09499+1650	09:49:52.830	+16:50:18.597	Leo	23.9	320	8.00	11.10	3.10
STT523	AB	10172+2306	10:17:14.799	+23:06:23.203	Leo	7.7	299	5.80	11.40	5.60
STT199	AB	09207+5116	09:20:43.759	+51:15:57.802	UMa	5.6	138	6.19	10.00	3.81
STT219	AB	10302+5100	10:30:11.491	+50:59:36.201	UMa	13.3	297	7.60	11.20	3.60
STT222	AB	10383+6007	10:38:19.892	+60:07:30.096	UMa	4	339	7.00	11.00	4.00
STT226	AB	10408+4132	10:40:46.120	+41:31:36.295	UMa	18.2	61	7.90	12.70	4.80
STT233	AB	11188+6641	11:18:46.751	+66:41:03.300	UMa	4.7	333	7.20	10.10	2.90
STT521	AB	09510+5902	09:50:59.689	+59:02:20.804	UMa	11.8	296	3.80	11.50	7.70
STT522	AB	09539+6447	09:53:54.039	+64:47:20.213	UMa	14.4	123	7.50	11.20	3.70

rings – but this topic will be discussed more in detail in a later report.

In the case of STT222 with a 4” separation assuming equally bright components in the +6mag range we would then be on the safe side with an imaging setup capable of 2 arc-seconds per pixel. This would seem to be not at all difficult to achieve using the iTelescope equipment which have far better resolution (for example iT24 with a resolution of 0.625 arc-seconds/pixel). But it proved impossible to clearly resolve STT222 – the reason for this is the unequal brightness of the components. Even a rather short exposure time of 1 second causes the image of the primary due to the large aperture to be overexposed (star bloat) which drowns out the fainter secondary.

Criteria that predict the ability to visually resolve unequal doubles like the Rule-of-Thumb (RoT) models from Lord (1994) or Munn-Napier (2008) involves a more subtle interplay of the aperture, magnitudes, ΔM, and separation for a given system. The predictive power of these RoT’s might be limited but they certainly imply that larger apertures are required for visual and photographic resolution of unequal doubles compared to doubles with equally bright components. Ignoring the fact that we consider the current magnitude for STT222B as suspect we can apply the Napier-Munn algorithm to the parameters of STT222 which concludes that for a 50% probability of a successful visual resolution, a minimum 130mm of aperture is required. This aperture is typically capable of ~0.9 arc-sec resolution so when we apply the Nyquist sampling criterion an image resolution of 0.45 arc-secs per pixel is the suggested minimum for successfully imaging this pair. The application of these criteria seems to predict that a camera/telescope system capable of resolving 0.625 arc-sec/pixel will, regardless of size of aperture, not be sufficient to image STT222 which seems to confirm our negative result using the iT24 telescope. On the other hand we were able to clearly resolve STT222 using a 127mm aperture and a camera system capable of 0.326 arc-sec/pixel resolution. These results seem to show that the application of visual RoT’s in conjunction with the Nyquist criteria can provide a reasonable guideline for predicting the successful photographic resolution of unequal double stars.

From an aesthetical point of view none of the objects of this installment reside in particularly rich star fields but several of them are multiple systems and should be attractive targets for the visual observer - images of all the objects can be found in the Appendix at the end of this paper.

2.2 Historical Research and Catalog Comparisons

In 1901 W.J. Hussey published *Micrometrical Observations of the Double Stars Discovered at Pulkovo*, which was a survey of all 514 of the stars listed in Otto Wilhelm Struve’s 1843 Pulkovo Catalog (those stars carry the WDS prefix of STT). Two of the stars in our list, STT 207 in Leo and STT 226 in UMa, were rejected in the second edition of the Pulkovo Catalog because their separation exceeded the 16” separation limit established for the stars in the catalog with companions fainter than ninth magnitude. STT 207 was measured at 16.05” in 1843. No measurement of separation was made in 1843 when STT 226 was discovered, but it was dropped from the catalog when later measures showed it exceeded the 16” limit. Fortunately, Hussey's study includes all of the stars later rejected by Struve.

Among the information included in Hussey's book are all known measures of the Pulkovo Catalog stars from their date of discovery up through 1898 to 1900, making it a valuable source of reference for the history of the stars discussed in this paper. The data listed in the book for three of our ten stars was interesting enough to prompt requests for the WDS text files in order to obtain the additional measures made between 1898 and the most recent WDS data, as well as a history of magnitudes.

In reviewing the data for STT 204 (Leo), it was discovered that the earliest measured position angles and separations were essentially the same as the most recent measurements in the WDS, despite significant changes in the intervening years (Figure 2.2.1). STT 204 has not been identified as an orbital pair.

In the case of STT 199 (UMa), the position angle shows a reasonably smooth progression from 113° to 138°, while the separation shows a series of erratic changes. Surprisingly, the first (1847) and most recent (1998) measures are within .02" of each other (Figure 2.2.2). The AB pair of STT 199 also has not been identified as orbital.

More than likely the two graphs represent the difficulties associated with micrometer measurements of close pairs of stars with high magnitude differentials, as opposed to physical interaction between the components.

The text file for STT 522 (UMa) was requested in order to look at the magnitude history of STT 522B. Apart from the 1999 2MASS data (J, H, and K magnitudes), only three magnitudes are listed: 11.0 (1907), 11.2 (1963), and 12.18 (2003). The bibliographic reference for the 12.18 magnitude refers to a 2013 paper (Hartkopf, *et al*, 2013), indicating the 12.18 magnitude is more recent than the 2003 date listed in the text file. However, the current magnitude for STT 522B in the WDS catalog is the 1963 value of 11.2.

2.3 Visual Observations

Both John Nanson and Wilfried Knapp made visual observations of the stars in Ursa Major and Leo which are listed in Table 1.1. Nanson used a 152mm f/10 refractor and Wilfried Knapp utilized apertures of 140mm and 185mm.

STT 204 (Leo): Nanson looked at STT 204B twice, found it very difficult, and was only able to catch glimpses of it each time – observations were made at 120x, 127x, 160x, and 253x. Knapp found it very faint at 360x. Nanson was unable to find a good comparison star, so attempted to compare B and C but found it wasn't possible because B was so elusive. Knapp found B to be somewhat similar to UCAC4 504-050613 with a 12.567 Vmag. Taking into consideration the 4.9 magnitudes of difference between A and B, as well as the 7.80" separation, Nanson considered it unlikely that B could be any fainter than the WDS value of 11.60.

Whereas both observers found the estimation of a magnitude for B to be difficult, Nanson found C was much easier. A comparison star for C was found, UCAC4 504-050609, which is listed with a Vmag of 11.903. John found C appeared to be slightly brighter than that star, indicating C may be about half a magnitude fainter than the 10.65 magnitude listed in the WDS.

STT 207 (Leo): Knapp observed STT 207B at 180x and found nearby UCAC4 535-050345 with a Vmag of 10.665 to be much brighter than B. Nanson observed STT 207B twice and found B was about equal in magnitude to UCAC4 535-050362, which is listed with a Vmag of 12.295.

STT 523 (Leo): The primary is a bright, beautiful yellow, located in a dazzling field. Nanson found B was very difficult, a mere speck of light (if that), and extremely hard to pick out next to the primary, but when it could be seen, it was easier to see with direct vision than averted vision. It was best seen at 76x since that magnification reduced the primary to a tight, round, smooth dot of light. At 253x, it was a very difficult object. Knapp also found the primary very bright and was unable to resolve the secondary due to its low altitude and a very unstable atmosphere. No comparison star could be found by either observer. Given the difference in magnitudes of 5.6 and the WDS separation of 7.7", John found it very unlikely B could be fainter than the WDS value of 11.4.

STT 199 (UMa): Knapp observed STT 199 on three occasions and was able to resolve B during the last two observations. At a magnification of 250x, B appeared as a fuzzy speck, similar in brightness to nearby UCAC4 707-048231 with a Vmag of 12.491. At 200x during the third observation, B was seen with averted vision. The aperture could then be reduced to 120mm indicating together with the other parameters of STT207 a magnitude for B of ~10.8. Nanson observed STT 199 once and found B was visible only with averted vision. Numerous glimpses were had at 109x, 127x, and 152x, but it was lost completely at 203x. Both observers concluded B was likely a bit fainter than the 10.66 magnitude shown for it in the WDS. Both observers also found C was an easy object.

STT 219 (UMa): Nanson observed STT 219 once at magnifications of 109x and 152x, and found B easy to pick out of the glare of the primary. As a result, he felt the WDS magnitude of 11.2 was reasonable

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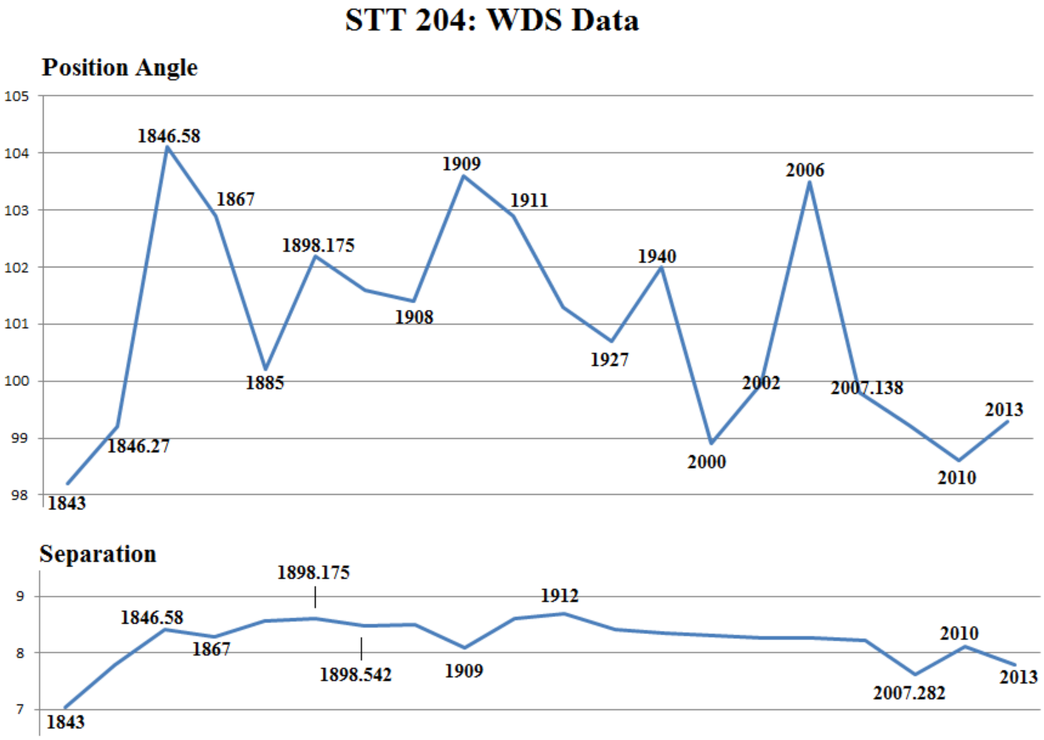
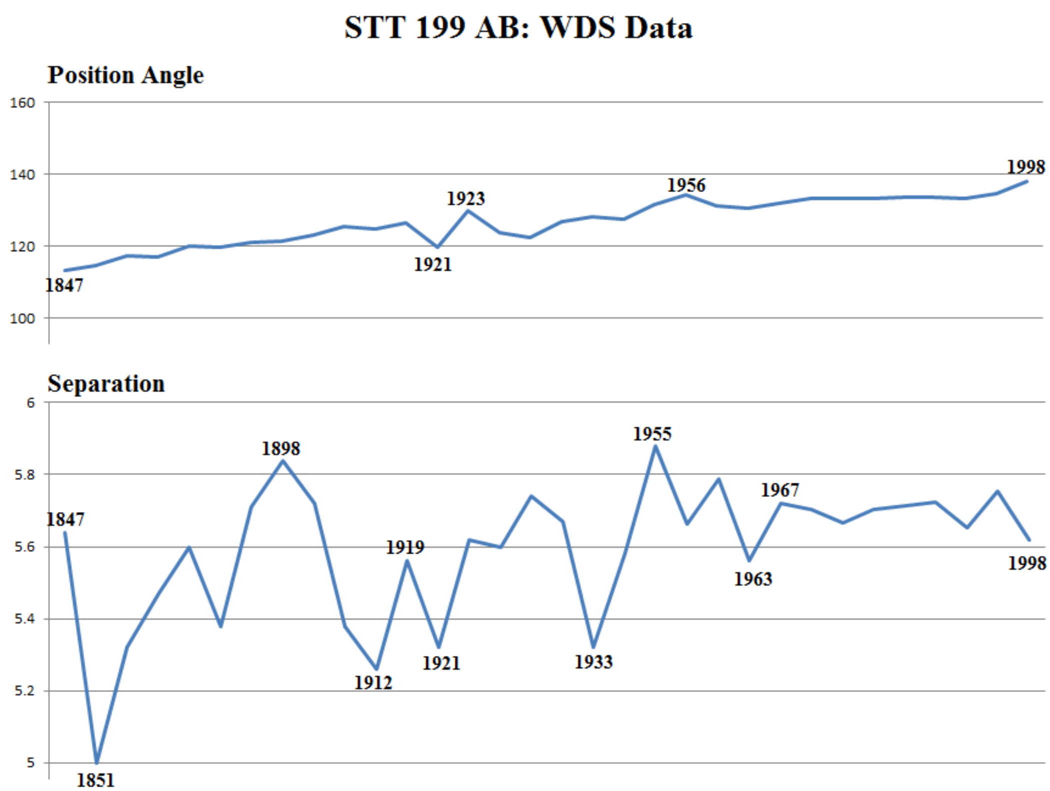


Year	PA	Sep
1843.22	98.2	7.04
1846.27	99.2	7.8
1846.58	104.1	8.42
1867.37	102.9	8.29
1885.2	100.2	8.57
1898.175	102.2	8.6
1898.542	101.6	8.48
1908.25	101.4	8.5
1909.27	103.6	8.098
1911.26	102.9	8.601
1912.07	101.3	8.69
1927.12	100.7	8.42
1940.57	102	8.36
2000.9	98.9	8.31
2002.2	99.96	8.26
2006.181	103.5	8.27
2007.138	99.8	8.22
2007.282	99.23	7.61
2010.293	98.6	8.11
2013.14	99.3	7.8

Figure 2.2.1. STT 204 Position Angles and Separations, 1843 through 2013; WDS text file data shown at right.



Year	PA	Sep
1847.02	113.2	5.64
1851.32	114.5	5
1868.11	117.17	5.32
1870.3	117	5.47
1892.235	120.15	5.6
1893.34	119.7	5.38
1897.731	120.9	5.71
1898.31	121.3	5.84
1903.27	123.2	5.72
1909.3	125.5	5.38
1912.92	124.9	5.26
1919.22	126.3	5.56
1921.24	119.8	5.32
1923.31	130	5.62
1923.39	123.9	5.6
1924.107	122.5	5.74
1925.34	126.9	5.67
1933.63	128.1	5.32
1934.23	127.4	5.58
1955.11	131.6	5.88
1956.216	134.14	5.662
1960.254	131.16	5.788
1963.25	130.6	5.56
1967.651	132	5.72
1972.112	133.26	5.703
1972.112	133.14	5.666
1973.048	133.15	5.704
1973.119	133.5	5.714
1973.133	133.54	5.722
1973.228	133.33	5.651
1983.288	134.67	5.753
1998.93	138	5.62

Figure 2.2.2. STT 199 Position Angles and Separations, 1847 to 1998; WDS text file data shown at right.

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considering the 3.6 magnitudes of difference between it and the primary. Knapp observed STT 219 three times and was able to resolve B at 180x, and 200x. Nearby UCAC4 705-049593, with a Vmag of 12.964, seemed a bit brighter than B. He concluded from the limit aperture for resolution of 105mm that B was likely to be somewhat fainter than the 11.2 WDS magnitude.

STT 222 (UMa): Knapp viewed STT 222 three times and was unable to resolve B. Nanson made one observation and found B to be a very difficult averted vision object at magnifications of 152x, 203x, and 253x. In consideration of the four magnitude difference between the primary and secondary, as well as the 4" separation, he concluded B was likely to be half a magnitude fainter than the WDS value of 11.

STT 226 (UMa): Nanson made one observation of B at 152x and found it was very tough to see in the glare of the primary, visible only with averted vision. Given the difference in magnitude between A and B of 4.8, plus the 18.2" separation, that was a bit of a surprise. B was found to be slightly fainter than UCAC4 658-054237, which is shown with a Vmag of 12.083.

Knapp made three observations of B. During the first one, B wasn't visible until reaching 360x, but having seen it, he was able to go back to 250x and also see it. During the second one B was rather fuzzy at 250x. Nearby UCAC4 659-053473, with a Vmag of 12.236, appeared similar in magnitude to B. During the third observation it was very faint at 280x, but the aperture needed for resolution could be reduced to 125mm indicating together with the other parameters of STT226 a magnitude for B of about 12.3.

STT 233 (UMa): Knapp made three observations of STT 233. During the first one, B appeared quite faint at 100x. Nearby UCAC4 784-021844, with a Vmag of 12.419, seemed a bit brighter than B. An aperture mask was used at 180x to reduce the 185mm aperture to 150mm, but any lower reduction resulted in the loss of B, suggesting it to be much fainter than the WDS magnitude of 10.1. On the second observation, B was seen at 250x, and compared again with UCAC4 784-021844, and again seemed a bit brighter than B. The third observation, with a 140mm refractor, resolved B at 140x. A limiting aperture of 95mm suggested that B may only a bit fainter than the WDS value of 10.1, if at all.

Nanson made one observation of STT 233 at 152x and 253x and found B easier to see than expected. The fact that it could be seen with direct vision (as opposed to averted vision) suggested it might be as much as a half magnitude brighter than the 10.1 magnitude listed in the WDS. C was compared with UCAC4 784-021832, shown with a Vmag of 13.449, and found to be slightly brighter, suggesting the WDS value of 12.90 is correct.

STT 521 (UMa): Nanson observed STT 521, and tried several magnifications (84x, 109x, 127x, 152x, 203x, 253x) and was unable to see B. Knapp made three visits to STT 521 and also was unable to resolve B.

STT 522 (UMa): Knapp's first attempt to see STT 522B was unsuccessful, but a second observation resulted in its appearance at 180x. Nearby UCAC4 775-029678, with a Vmag of 12.089, appeared to be a bit brighter. A third observation, with a 140mm refractor, resulted in B being seen at 280x with averted vision. A limiting aperture of 100mm indicated B may be slightly fainter than the WDS magnitude of 11.2.

Nanson was able to see B at 152x and 203x with averted vision, and glimpsed it a few times with direct vision. He used the same star as Wilfried for comparison and found it similar in magnitude to B, again suggesting a value fainter than the 11.2 in the WDS.

2.4 Photometry and Astrometry

2.4.1 Photometry Results with iTelescope images

Several hundred images were taken with iTelescope remote telescopes but photometry proved this time rather difficult, as plate solving failed for most images with the iTelescope equipment. This might have several reasons like moon light causing less than perfect images, few reference stars etc. However the visual impression of the images was quite good so when plate solving with MaxIm DL6/PinPoint and Astrometrica with latest software versions, most images were positive plate solved without any problems and then uploaded to AAVSO VPhot again.

Then photometry was performed with AAVSO VPhot with the same sequence for the different image stacks (mostly of 5 images with 1s exposure time) and in case of STT222 with a VPhot emulating spreadsheet using Astrometrica SNR and Flux data. The resulting photometry reports are shown in Table 2.4.1.1.

Specifications of the used telescopes:

- iT11: 510mm CDK with 2280mm focal length. Resolution 0.81 arcsec/pixel. V-Filter. Transformation coefficients B-V available, but not used. Located in Mayhill, New Mexico. Elevation 2225m
- iT18: 318mm CDK with 2541mm focal length. Resolution 0.73 arcsec/pixel. V-filter. No transformation coefficients available. Located in Nerpio, Spain. Elevation 1650m
- iT21: 431mm CDK with 1940mm focal length. Resolution 0.96 arcsec/pixel. V-filter. Transformation coefficients V-R available, but not used.

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*Table 2.4.1.1. Photometry results for the selected STT objects in Leo and Uma. Mag2 means magnitude for secondary. SNR stands for Signal to Noise Ratio. Err(SNR) is calculated as 2.5*Log10(1+1/SNR). Std is the standard deviation calculated in relation to the used comparison stars. Err is calculated as square root of (Std^2 + Err(SNR)^2). N is the number of images (usually with 1s exposure time) used for the reported values. Date is the Bessel epoch of the observation. Scope indicates the telescope used and Notes refer to a note number.*

Name	Comp	Mag2	Err	Std	Err(SNR)	SNR	Date	N	Scope	Notes
STT204	B	10.875	0.062	0.059	0.020	55	2015.346	4	iT11	
		10.505	0.059	0.059	0.007	151	2015.376	5	iT11	
		10.821	0.065	0.058	0.030	36	2015.357	5	iT18	
		10.729	0.067	0.063	0.024	46	2015.327	2	iT21	
		10.439	0.081	0.079	0.017	63	2015.382	5	iT21	
		10.802	0.015	0.009	0.012	88	2015.379	5	iT24	
		10.737	0.032	0.029	0.013	81	2015.382	5	iT24	
STT207	B	11.530	0.033	0.030	0.014	75	2015.376	5	iT11	
		11.495	0.022	0.016	0.015	72	2015.370	5	iT18	
		11.601	0.047	0.001	0.047	23	2015.382	3	iT24	
		11.495	0.031	0.022	0.022	49	2015.382	5	iT24	
		11.506	0.032	0.027	0.018	60	2015.379	5	iT24	
		11.520	0.052	0.048	0.019	57	2015.360	5	iT24	
STT523	B	11.245	0.046	0.035	0.031	35	2015.346	2	iT11	
		11.282	0.018	-	0.013	85	2015.370	5	iT18	
		11.393	0.026	-	0.018	60	2015.379	3	iT24	
		11.312	0.087	0.085	0.016	65	2015.382	5	iT24	
STT199	B	10.461	0.028	0.023	0.017	65	2015.363	5	iT24	
		10.118	0.016	0.013	0.010	107	2015.379	5	iT24	
		10.034	0.017	0.013	0.011	101	2015.382	5	iT24	
STT219	B	11.823	0.091	0.088	0.024	45	2015.376	5	iT11	
		11.671	0.018	0.002	0.018	61	2015.370	5	iT18	
		11.658	0.058	0.044	0.038	28	2015.380	2	iT24	
		11.806	0.070	0.062	0.032	34	2015.382	3	iT24	
		11.666	0.070	0.067	0.021	52	2015.360	5	iT24	
STT222	B	11.678	0.072	0.028	0.066	16	2015.380	5	iT24	1)
		11.834	0.063	0.030	0.056	19	2015.380	5	iT24	
STT226	B	12.631	0.050	0.039	0.032	34	2015.377	5	iT11	
		12.683	0.034	0.010	0.032	33	2015.370	3	iT18	
		12.568	0.104	0.089	0.053	20	2015.380	4	iT24	
		12.622	0.073	0.056	0.047	23	2015.382	5	iT24	
		12.605	0.036	0.006	0.035	31	2015.360	5	iT24	
STT233	B	10.494	0.008	0.002	0.008	142	2015.376	5	iT11	
		9.953	0.035	0.034	0.006	168	2015.370	5	iT18	
		10.238	0.162	0.162	0.011	100	2015.380	1	iT24	
		10.152	0.013	0.009	0.009	122	2015.382	5	iT24	
		10.045	0.059	0.059	0.008	143	2015.360	5	iT24	
STT521	B	11.244	0.031	0.024	0.019	56	2015.370	1	iT18	
		11.142	0.018	0.003	0.018	60	2015.382	4	iT24	
		11.319	0.023	0.014	0.018	60	2015.379	5	iT24	
		11.362	0.019	0.006	0.018	61	2015.360	5	iT24	
STT522	B	12.117	0.083	0.037	0.074	14	2015.366	3	iT11	
		12.183	0.026	0.010	0.024	45	2015.376	5	iT11	
		12.155	0.023	0.008	0.021	51	2015.370	5	iT18	
		12.141	0.030	0.014	0.026	41	2015.360	5	iT24	
		12.093	0.031	0.013	0.028	38	2015.379	5	iT24	
		12.195	0.034	0.007	0.033	33	2015.382	5	iT24	

Table 2.4.1.1 Note:

1. In case of STT222 the iTelescope equipment used was insufficient to get resolution of B good enough to allow VPhot photometry due to overlapping star disks. By a chance experiment we found that changing the background and range parameters when viewing the iT24 image stacks in Astrometrica made it possible to identify B even with a somewhat overlapping star disk with A (see Figure 2.4.1.1 below). With an aperture of 2 pixels in this very spot in the image we got despite the low SNR of 16 and 19 an estimation for B based on images made with V-filter based on Flux and SNR data from Astrometrica. With a spreadsheet based on formulae provided by Beck/Henden/Templeton (2015) and Raab (2002) we emulated the VPhot procedure to get comparable results. To countercheck these results we made also magnitude estimations with Astrometica based on the images taken by Steve Smith without using a V-filter (see section 2.4.2).

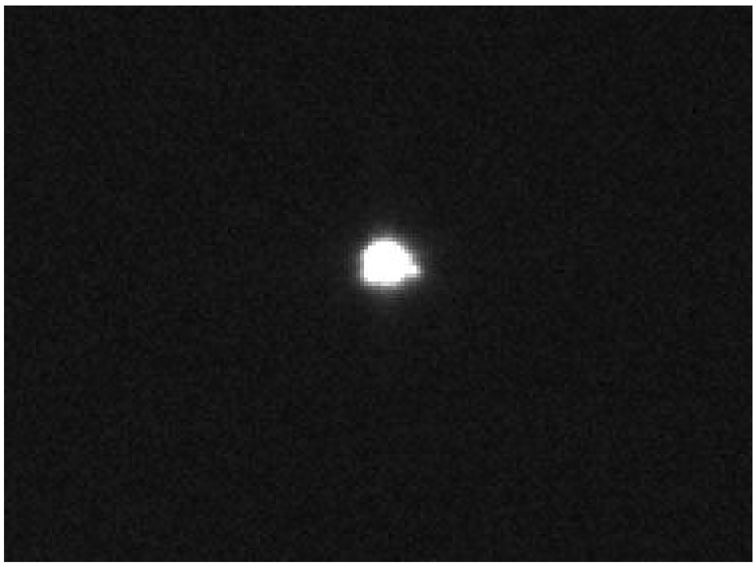

Figure 2.4.1.1. STT222 iT24 image with changed parameters for background and pixel range shows a hint of B

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Located in Mayhill, New Mexico. Elevation 2225m

- iT24: 610mm CDK with 3962mm focal length. Resolution 0.62 arcsec/pixel. V-filter. No transformation coefficients available. Located in Auberry, California. Elevation 1405m

2.4.2 Magnitude Estimates of STT222B using Astrometrica

Using the 127mm scope we were able to obtain images clearly resolving the components of STT222B. The unfiltered JPEG images were imported into AstroImageJ, de-bayered and only the green channel used to approximate a V-Filtered image. The images were then plate solved, and saved in FITS format and imported into Astrometrica, where the program selected reference stars and used UCAC4 V band magnitudes as a basis for calculating the magnitude of STT222B.

Due to the proximity of the much brighter primary it was critical to size the measurement aperture to effectively measure the flux from the secondary while rejecting unwanted illumination from the primary, as can be seen in the image below which shows the Object Selection Window used in Astrometrica (Figure 2.4.2.1). By plotting Flux vs Aperture for various radii we determined a radius of 3 to 4 pixels to be optimal for our particular image scale.

The three best frames were selected from several nights of imaging and each was calibrated with dark and bias frames applied. The calculated magnitude of STT222B for each frame is shown in Table 2.4.2.1. The results of each frame were combined using the weighted standard deviation. The average calculated magnitude of STT222B for both calibrated and uncalibrated frames is 11.69 ± 0.14 which is fainter than the current value of 11.0. The value seems to roughly agree with a visual impression in Figure 2.4.2.2.

Specifications for Steve Smith's telescope are as follows: ES127ED refractor 127mm and x2.5 Televue Powermate - 2338mm focal length. Photographic reso-

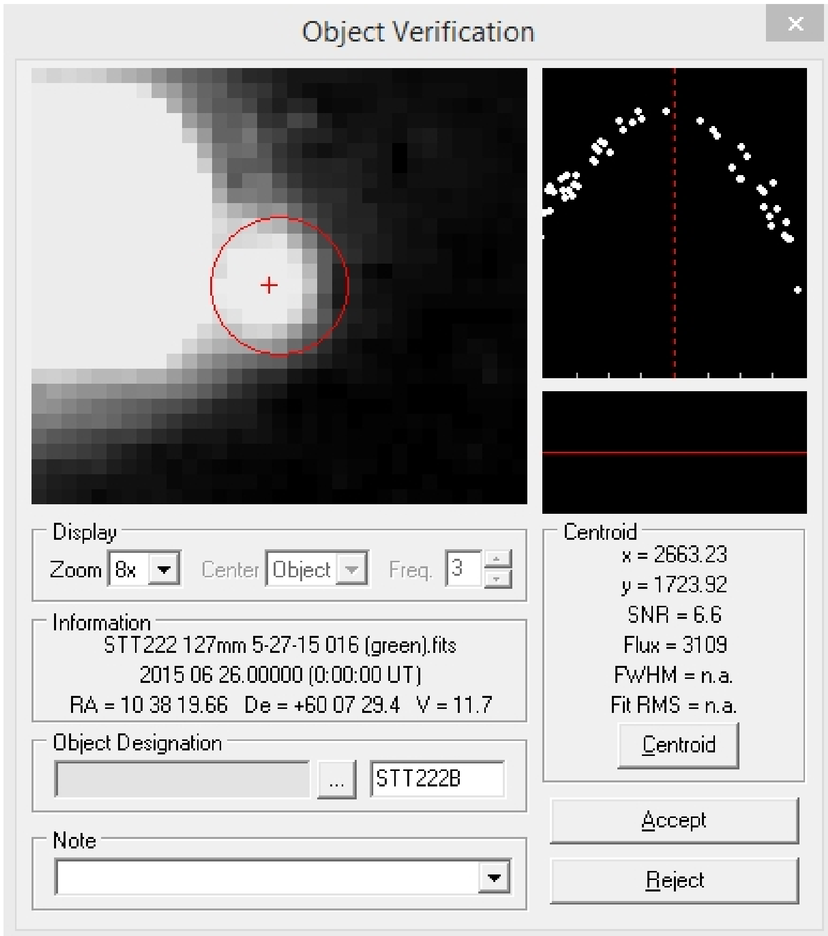

Figure 2.4.2.1. Astrometrica Photometry Windows for Frame #16 showing STT222B and how critical it is to size and place the photometric aperture. The flux profile for the chosen aperture is shown on the right.

lution 0.326 arc-sec/pixel. No filter. No transformation coefficients available. Located in Castle Rock, Colorado. Elevation 1980m.

2.4.3 Astrometry Results with iTelescope images

Astrometric calculations were done only for objects with position issues assumed and as a counter check also for one random chosen object with no such issue. In cases with questionable RA/Dec coordinates or position angles, new separations and position angles were calculated using the formula provided by R. Buchheim (2008). While for photometry we reported the results per image stack separately, the astrometry results are based on the average coordinates of all image stacks available per object. We used MaxIm DL6

*Table 2.4.2.1. Magnitude measurements of STT222B using Astrometrica. SNR stands for Signal to Noise Ratio. Err(SNR) is calculated as (1+1/SNR)/ 2.5*Log10. Total Error calculated using SRSS. Date is the Bessel epoch of the observation.*

Frame	Date	# Comp Stars	STT222B Mag	Std Dev	SNR	Error SNR +/-	TOT Error +/-
#15	2015.404	11	11.65	0.09	33.9	0.03	0.10
#16	2015.404	14	11.76	0.10	33.9	0.03	0.10
#22	2015.404	6	11.65	0.23	22.14	0.05	0.24
			11.69	+/-	0.14		

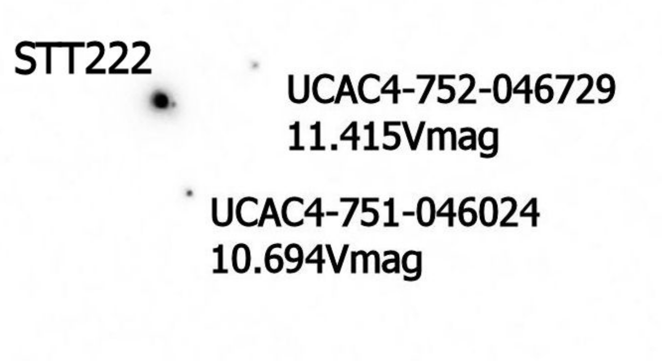

Figure 2.4.2.2. Visual comparison of STT222B with UCAC4 stars – Note: Actual positions of UCAC4 stars have been altered to aid comparison.

as a tool to determine the RA/Dec coordinates for all needed components based on the UCAC4 catalog and for STT222B Astrometrica with online Vizier access for plate solving was used. The average plate solving error was in all cases between 0.1 and 0.4 arcseconds. The resulting RA/Dec coordinates based on this approach were used to calculate the Sep and PA listed in Table 2.4.3.1. To counter check the validity of our results we checked also the position data for other stars in the field of the images and compared this with the catalog values of these stars.

Summary

Tables 3.1 and 3.2 below compare the final results of our research with the WDS data that was current at the time we began working on the three stars in Leo and the seven in Ursa Major.

In Table 3.1 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. One thing that stands out on first glance at Table 3.1 is the absence of NOMAD-1 and UCAC4 data, especially with regard to the UCAC4 Vmags. As we observed in our first paper in this series, the lack of data appears to be confirmation of the difficulties associated with magnitude determinations of high delta_M pairs.

Another issue is obvious in the NOMAD-1 Vmag column with regard to STT 199B and STT 222B. It appears distinct resolution of the secondary for each of those stars was a problem, something we also experienced, particularly in regard to STT 222B (see Note 1 under Table 2.4.1.1), and to a lesser extent with STT 199B. Also note there are two entries in Table 3.1 for STT 222, one based on the data from Table 2.4.1.1 in section 2.4.1 and one based on the data from Table 2.4.2.1 in section 2.4.2. See the discussions in Note 1 under Table 2.4.1.1 as well as in section 2.4.2.

For the most part, the visual observations of these difficult pairs were in reasonable agreement with the photometry, but two exceptions stand out. Our observations of STT 207B appeared to confirm the NOMAD-1 Vmag, but our photometric results indicated the star was .6 of a magnitude brighter than the observations. With regard to STT 233B, our three observations essentially bracketed the WDS data. It's possible perception of the colors and hues of the stars had an effect on those results.

For the purpose of suggesting appropriate changes to the current WDS data, we've used bold red type in Tables 3.1 and 3.2 to call attention to significant differences. With regard to Table 3.1, those magnitudes that differ by two tenths of a magnitude or more from the WDS values have been highlighted. Note that four of the ten WDS magnitudes match up well with our photometry results. In Table 3.2 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. All of the declination coordinates are significantly different, so all have been highlighted in red.

Acknowledgements

The following tools and resources have been used for this research:

- 2MASS All Sky Catalog
- AAVSO APASS
- AAVSO VPhot
- Aladin Sky Atlas v8.0
- AstroImageJ v3.0.0
- Astrometrica v4.8.2.405
- AstroPlanner v2.2
- iTelescope
- MaxIm DL6 v6.08
- SIMBAD, VizieR
- URAT1 catalog via Vizier
- UCAC4 catalog via the University of Heidelberg website and directly from USNO DVD
- Washington Double Star Catalog

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STT Doubles with Large ΔM – Part II: Leo and UMa

Table 2.4.3.1. Astrometry results for the selected STT objects in Leo and UMa. Sep means separation in arcseconds and PA means position angle in degrees

Name	Comp	WDS ID	RA	Dec	Sep	PA	Date	Notes
STT523	A	10172+2306	10:17:14.07	23:06:20.90	6.7	307	2015.369	1)
	B		10:17:13.68	23:06:24.93				
STT222	A	10383+6007	10:38:19.83	60:07:25.15	4.3	336	2015.366	2)
	B		10:38:19.60	60:07:29.10				
STT521	A	09510+5902	09:50:58.77	59:02:16.85	12.1	298	2015.373	3)
	B		09:50:57.38	59:02:22.45				
STT204	A	09388+1047	09:38:45.62	10:46:38.76	8.2	99	2015.364	4)
	B		09:38:46.17	10:46:37.54				

Notes:

1. Astrometry based on plate solving with MaxIm DL6 based on UCAC4. Position results counterchecked with Astrometrica with quite similar values. Countercheck with TYC1969-00976-1 and TYC1969-00881-1 positions gave results corresponding very well with the Tycho2 catalog values thus quite confirming our research.

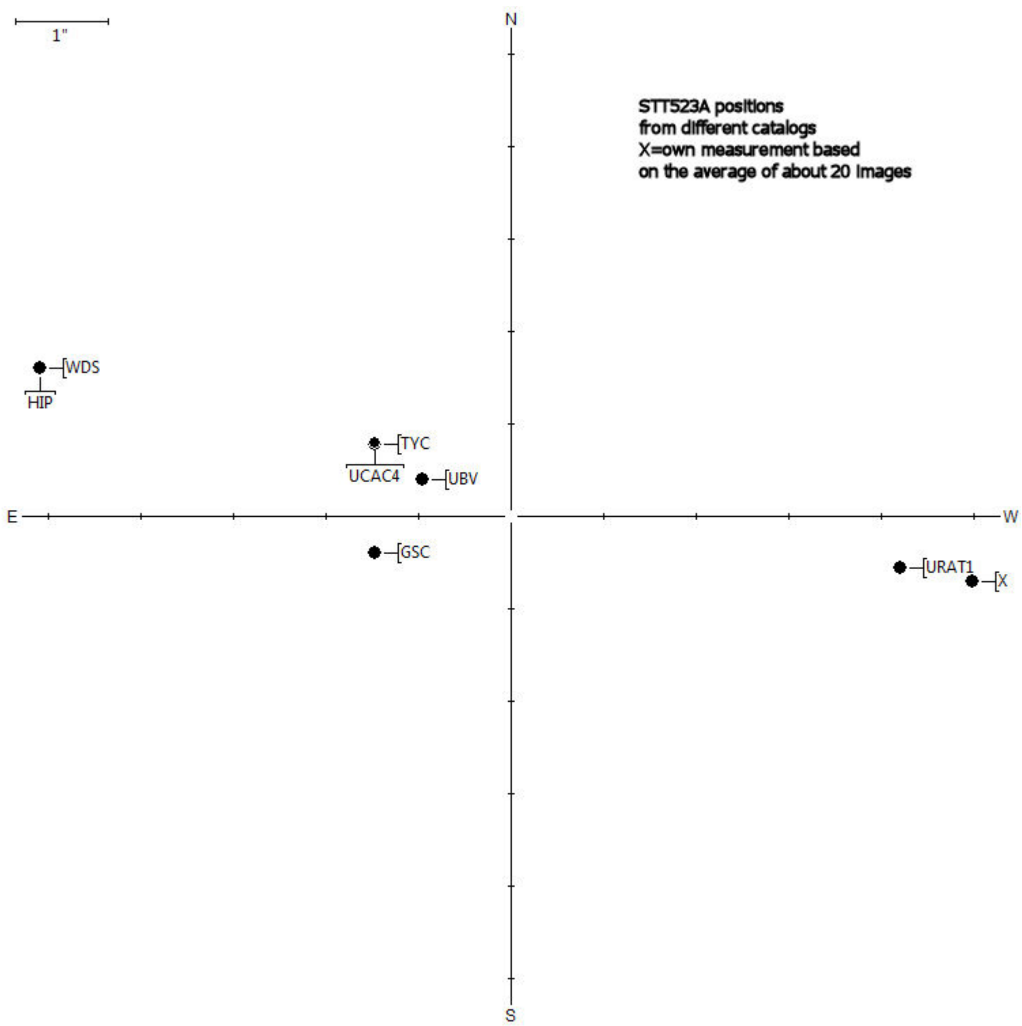

Figure 2.4.3.1. STT523 - STT523A star map with coordinates from different catalogs.

STT Doubles with Large ΔM – Part II: Leo and UMa

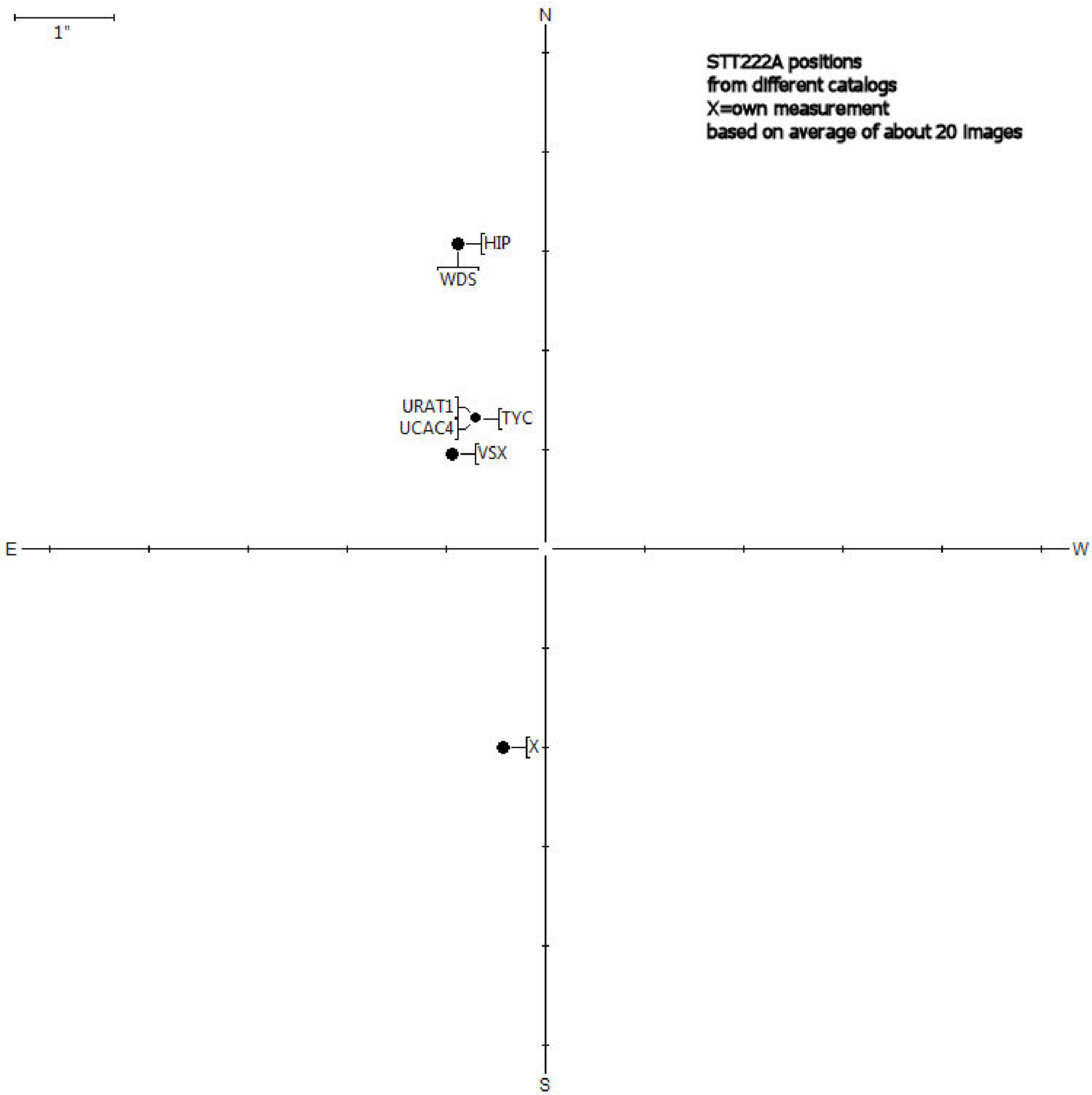

Figure 2.4.3.2. STT222 - STT222A star map with coordinates from different catalogs

2. The results shown here are a mix of data for A from MaxIm DL6 based on UCAC4 and counterchecked with Astrometrica and data for B based on results from Astrometrica from the iT24 images showing the position of B very clearly after raising the pixel range parameter to 574. Countercheck with TYC4144-00894-1, TYC4144-00364-1, and TYC4144-01457-1 positions gave results corresponding very well with the Tycho2 catalog values thus quite confirming our research.

STT Doubles with Large ΔM – Part II: Leo and UMa

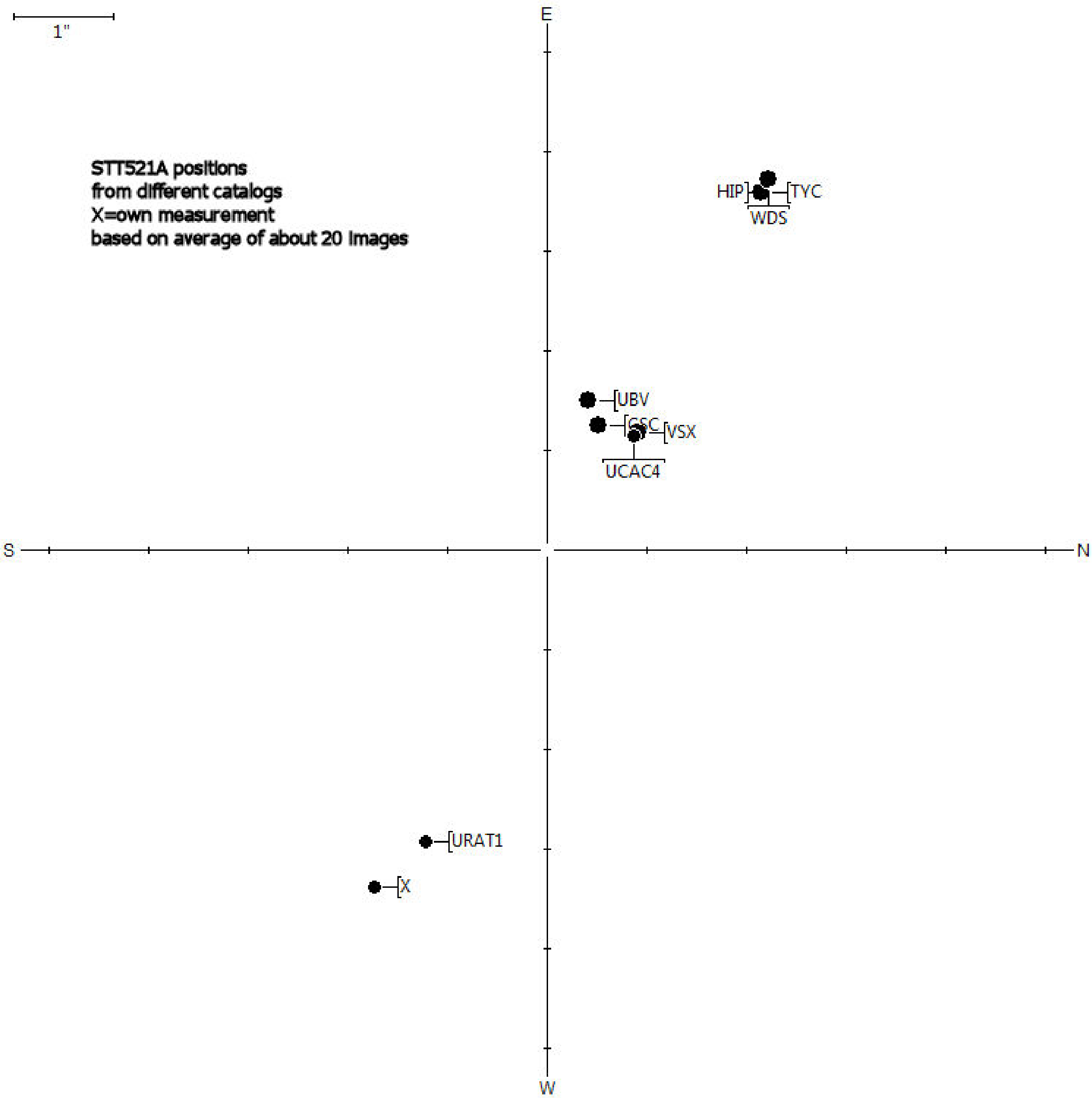

Figure 2.4.3.3: STT521 - STT521A star map with oordinates from different catalogs

3. Astrometry based on plate solving with MaxIm DL6 based on UCAC4. Position results counterchecked with Astrometrica with quite similar values. Countercheck with TYC1969-00976-1 and TYC1969-00881-1 positions gave results corresponding very well with the Tycho2 catalog values thus quite confirming our research.

4. For comparison astrometry results for an object with no suspect position data again done with MaxIm DL6 based on UCAC4 and counterchecked with Astrometrica. Comparison with WDS position data resulted in small differences well within the resolution limits of the equipment used – but it may be also that Dec and separation for A need a small correction as the new URAT1 catalog is quite close to our measurement which might be considered as confirmation for our results.

STT Doubles with Large ΔM – Part II: Leo and UMa

(Continued from page 119)

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Table 3.1: Photometry and Visual Results Compared to WDS

	WDS Mag	NOMAD-1 VMag	UCAC4 VMag	UCAC4 f. mag	Average of Photometry Measures	Results of Visual Observations
STT 204 B	11.60	-	-	-	10.701	B unlikely to be fainter than WDS value given delta_M of 4.89 and 3.7″ separation, although one observation found B was somewhat similar to a 12.6 magnitude star
STT 207 B	11.10	12.140	-	11.296	11.525	Three observations indicated B was in the 12.1 to 12.3 range.
STT 523 B	11.40	-	-	-	11.308	B unlikely to be fainter than WDS given delta_M of 5.6 and 7.7″ separation
STT 199 B	10.00	6.210	-	-	10.204	Two of three observations concluded B was likely a bit fainter than the WDS magnitude of 10.0
STT 219 B	11.20	-	-	11.335	11.725	One observation estimated B to be about equal to the WDS magnitude of 11.2, one estimated B to be slightly fainter than WDS value.
STT 222 B (Section 2.4.1)	11.00	7.060	-	-	11.756	B estimated to be about half a magnitude fainter than WDS value of 11.0
STT 222 B (Section 2.4.2)	11.00	7.060	-	-	11.69	
STT 226 B	12.70	11.960	-	12.489	12.622	Three observations suggested B was in the 12.2 to 12.3 range.
STT 233 B	10.10	-	10.307	-	10.176	B estimated to be about half a magnitude brighter than WDS value, a bit fainter than WDS, and much fainter than WDS value.
STT 521 B	11.50	-	-	-	11.267	Unable to resolve B during four separate observations.
STT 522 B	11.20	-	-	12.264	12.147	Three observations found B was noticeably fainter than WDS magnitude of 11.2

Table 3.2: Astrometry Results Compared to WDS

	WDS Coordinates	WDS Sep	WDS PA	Photometry Coordinates	Astrometry Sep	Astrometry PA
STT 523 AB	10:17:14.80 +23:06:23.20	7.70	299°	10:17:14.07 +23:06:20.90	6.7"	307°
STT 222 AB	10:38:19.89 +60:07:30.10	4.00	339°	10:38:19.83 +60:07:25.15	4.3"	336°
STT 521 AB	09:50:59.69 +59:02:20.80	11.80	296°	09:50:58.77 +59:02:16.85	12.1"	298°
STT 204 AB	09:38:45.69 +10:46:39.80	7.80	99°	09:38:45.62 +10:46:38.76	8.2"	99°

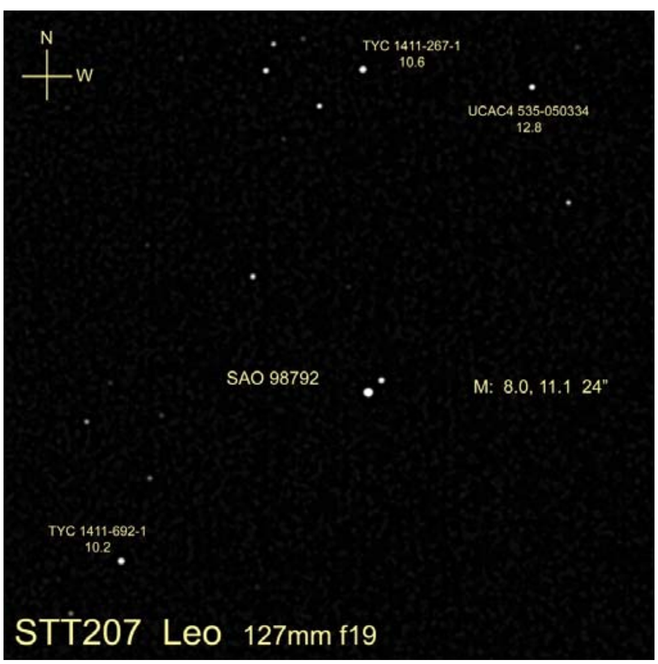
and Comets in Europe, 2002, May 17-19, Visnjan, Croatia. Page 15, Formula (6) http://www.astro.hr/mace2002/Report/MACE2002_final.PDF

STT Doubles with Large ΔM – Part II: Leo and UMa

Appendix

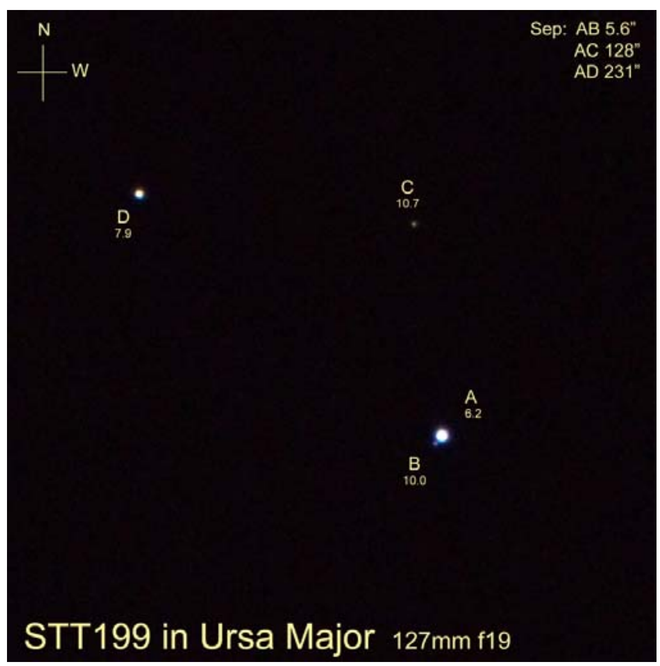
Below are selected images of the STT systems investigated in this report. Unless noted all data is from the WDS as of December. All images have been cropped unless noted.

STT204: The visual impression is that B & C are of similar brightness. Our Photometry results confirm this with a measured magnitude of 10.7 for B



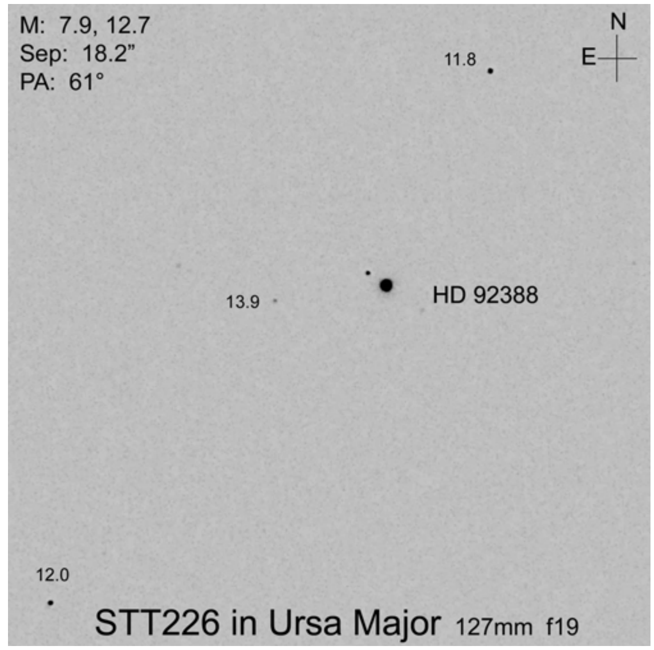
STT207: In this image B appears fainter than 10.6mag TYC1411-002671, but a bit brighter than the 12.28 magnitude of UCAC4-535-050334

STT523: Our measures confirm the WDS magnitude but suggest that corrections in Declination, Separation and Position Angle may be warranted.



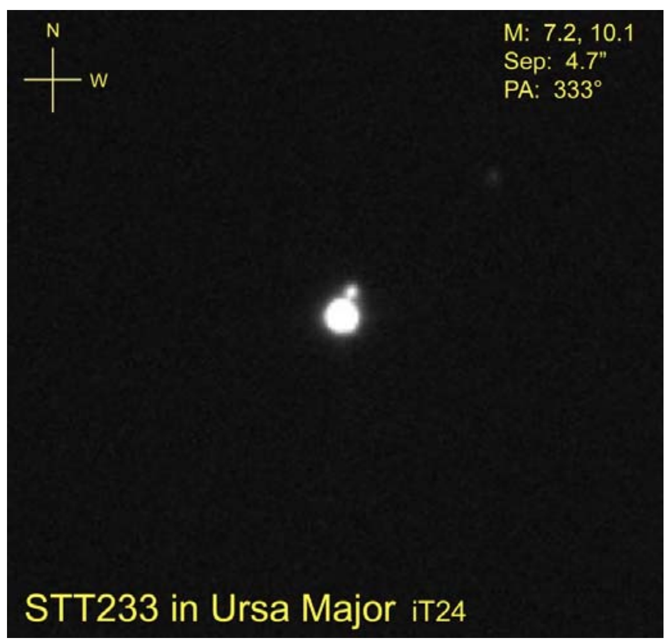
STT199: Comparison with C suggests that B might be a bit fainter than the 10.0 mag WDS value but our photometry results of 10.2mag are within the margin of error and cannot be considered as significantly different.

STT219: Of interest in this photo is the deep red tint of the companion. Neither DSS nor 2MASS images show a similar tint for STT219B.



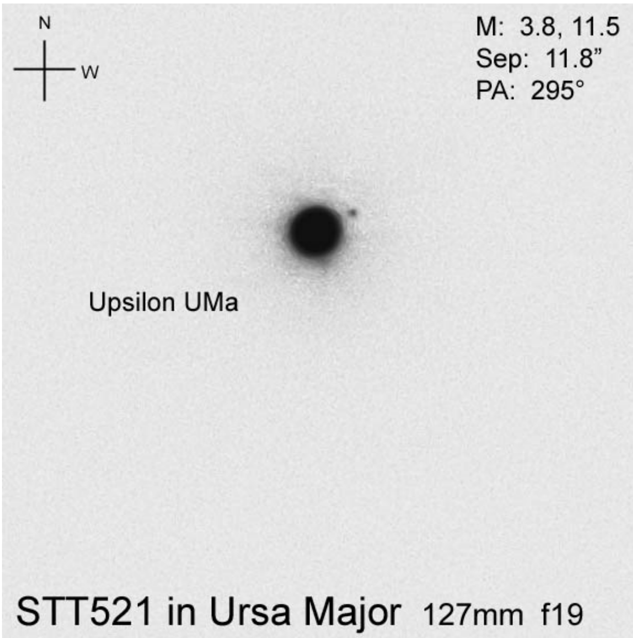
STT226: The image suggests B to be nearly equal to the nearby 11.8 and 12.0 mag stars but our photometry results show close agreement with the WDS value of 12.7

STT222: A long focal length refractor with a photographic resolution of 0.33 arc-sec/pixel was required to capture a clean separation of this system, the most difficult object in this sample. Our magnitude measures of the secondary yielded values considerably dimmer than the current WDS listing.



STT233: Our measurements confirm the 10.1mag from WDS.

STT Doubles with Large ΔM – Part II: Leo and UMa



STT521: The rather comfortable separation of 11.8" allowed the resolution of this pair despite the extraordinary ΔM of 7.7.

STT522: In this image the B component appears similar in brightness to UCAC4 77-029678 at 12.09 mag which is supported by our photometry results and is a significant departure from the WDS value of 11.2.