STT Doubles with Large Δ M – Part I: Gem

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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 indeed most of the selected objects show parameters quite different from the current WDS data.

1. Introduction

Systematic visual double star observing sessions covering many constellations usually include some STT objects. Over time, experience results in the ability to reach conclusions in regard to how much aperture might be necessary to resolve a double star with given parameters. Because many STT objects were much harder to resolve than the WDS catalog data suggests, we decided to have a closer look.

As background, in 1843 Otto Wilhelm Struve published a catalog of double star discoveries which is commonly referred to as the Pulkovo Catalog. It was divided into two parts, the first part containing 514 stars, and the second part 256 stars. The separation limit for the 514 stars in the first part of the catalog was set at 32”, except in the case of components fainter than ninth magnitude, in which case the limit was set at 16”. That group of stars was assigned the prefix OΣ, which in the WDS catalog is referred to with a prefix of STT. As a consequence of the 16” separation limit for components fainter than ninth magnitude, many of the stars have a high delta_M, which makes them difficult objects for observation.

For our study we selected STT doubles from the WDS catalog with the following criteria:

- Constellation in the northern hemisphere
- Separation larger than 2" but less than 30"
- Delta_M larger 2
- M2 fainter than +10mag given with only single digit precision, indicating an estimate rather than a precise measurement.

We added STT 179 to our list despite a companion listed brighter +10mag as from previous observations we suspected the companion of being far fainter than

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Table 1. WDS 2114.96 values for the selected STT objects in Gem

Name	WDS ID	RA	Dec	Sep	PA	M1	M2	Delta_M
STT 143AB	WDS06312+1656	06:31:09.990	+16:56:19.003	7.6	103	6.20	10.4	4.20
STT 151AC	WDS06389+2748	06:38:53.620	+27:48:15.502	27.4	237	7.35	13.5	6.15
STT 153AB	WDS06422+2528	06:42:11.961	+25:28:06.800	19	92	7.80	11.8	4.00
STT 162AB,C	WDS06598+1556	06:59:50.480	+15:56:27.899	22.8	155	7.00	10.0	3.00
STT 164AB	WDS07062+2452	07:06:11.590	+24:51:36.600	6.3	75	7.10	11.1	4.00
STT 165AB	WDS07084+1556	07:08:22.039	+15:55:51.300	13.3	8	5.44	11.3	5.86
STT 166AC	WDS07128+2713	07:12:49.081	+27:13:30.201	14.1	78	7.24	12.7	5.46
STT 172AB	WDS07295+3448	07:29:27.070	+34:48:12.000	15	253	8.00	11.9	3.90
STT 173AC	WDS07344+3307	07:34:24.690	+33:07:21.197	18.8	234	7.95	12.8	4.85
STT 179AB	WDS07444+2424	07:44:26.869	+24:23:53.297	7.5	242	3.70	8.2	4.50
STT 181AB	WDS07457+3433	07:45:41.389	+34:33:19.402	6.8	262	8.00	12.3	4.30
STT 183AB	WDS07540+1602	07:53:57.611	+16:02:10.401	17.1	34	7.10	11.1	4.00
STT 519AB	WDS06313+1544	06:31:17.740	+15:44:14.400	8.4	79	8.36	10.7	2.34

the records would indicate. This resulted in a total of 93 objects in our sample. We decided to begin our project in the constellation of Gemini which contained 13 objects from our list (see Table1) and was then conveniently located near zenith. All values based on WDS data as of the end of 2014 are shown in Table 1.

2. Further Research

To investigate further we concluded 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 Difficulty and Beauty of observing and imaging double stars with large delta_M

It is common knowledge that double stars with a large difference in magnitude between the components are harder to resolve visually than binaries with equally bright components and the same is true when it comes to imaging them. In both cases the brightness of the primary is the main problem, making a faint companion quickly invisible. For the human eye the contrast might get too extreme for resolution, and for the camera the radius of the star disk of the primary gets quickly larger even if there is an otherwise comfortable separation. For this project where the targets were by design chosen for this attribute, it was necessary to keep the exposure times relatively short to prevent the primary from overwhelming the much fainter companion, but this was at the expense of recording relatively fewer comparison stars which are required for the calculation of magnitudes.

Besides these technical aspects we consider the visual observation of wide and faint double stars with large delta_M as very rewarding even when compared with difficult-to-resolve close and equally bright binaries. There often exists a quiet quality unique to these objects, giving the impression of complete silence and calmness. Sometimes these objects seem to wander in isolation with few stars in the field of view while others live in a densely populated field amid star patterns of asterism like quality.

That the imaging of double stars can be a very rewarding activity is demonstrated by the numerous images displayed on the Yahoo Double Star Imaging Group website. For our project Steve Smith took over the task of making aesthetically appealing color images of many of our objects in contrast to the monochrome, V-filtered science images. For the most challenging objects on our list , such as STT179, his images had the side benefit of allowing, if not precise photometry measures, at least facilitating well founded magnitude estimations for the companions. Steve used an ES127mm f 7.5 refractor, at times fitted with a Televue 2.5x Powermate giving an effective focal ratio of f19. Coupled with an Olympus E-PL1 camera the system has a photographic resolution of 0.38 arc-sec/pixel suitable for clearly recording separations down to approximately 3 arc-sec. Two example images are shown in Figures 1 and 2. Other images are shown in the appendix.

2.2 Historical Research and Catalog Comparisons

A review of the preliminary data for the thirteen selected STT doubles in Gemini led to a request for the

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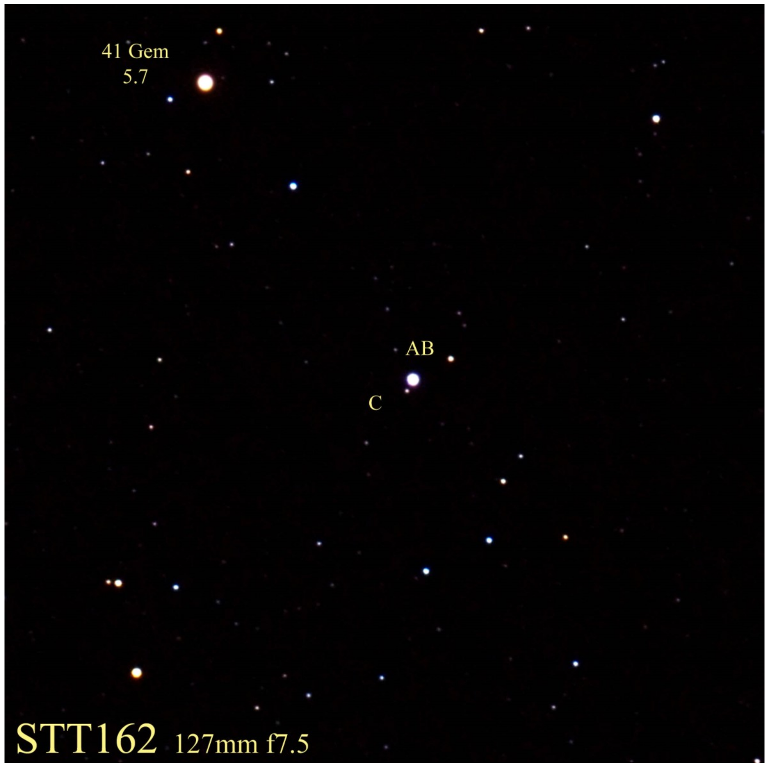

Figure 1: STT 162 Located in a particularly rich and beautiful star field providing numerous targets for comparison

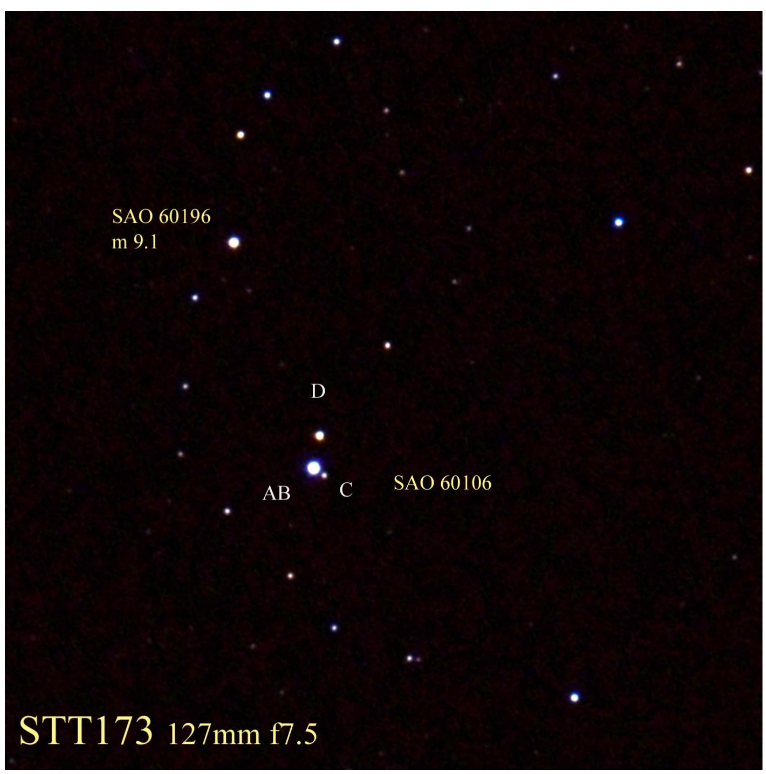

Figure 2: STT173 and neighbors - Reminiscent of the "Beach Umbrella" asterism in Orion

WDS text files on STT 143, STT 153, and STT 164. (For those not familiar with their contents, the WDS text files include all of the known measures for a particular star, along with the source of the original publication).

STT 143: The WDS text file for this pair was requested because of a possible magnitude issue with the B component. The WDS magnitude is listed at 10.40 (2009), but a check of both the NOMAD-1 and UCAC4 catalogs showed no visual magnitudes, and in fact, UCAC4 has no data at all on B. Thus, the only source of comparison with the current WDS value was the text file.

A review of the magnitudes in the text file (Table 2.) shows the magnitude assigned to B has varied from a high of 9.2 (1956) to a low of 11.9 (1924), with the final three values in the file being the 2MASS J, H, and K magnitudes

STT 153: A review of Aladin photos showed an obvious contradiction in position angle with the WDS data, as well as a possible error in separation. The WDS data listed at the time of the research in March, 2015, showed a PA of 92° and 19.00" (1998), but it was clear from the Aladin images the PA was considerably north of 92°. Preliminary measures using the Aladin tools showed a PA of 72° and a separation of 20". A review of the text file data (Table 3) turned up a totally unexpected result: the most recent measure was made in 2004, not 1998. In fact, the position angle shown in 2004 is closer to the actual PA, while the 2004 separation is considerably in error. On the other hand, the 1998 measure of the PA is obviously in error, while the separation is reasonably close. So we have a case in which one of the two parts of each of the two most recent measures in the WDS text file conflict quite noticeably with all the prior measures.

STT 164: This was the greatest puzzle of all. The position angle and separations in the first and last data in the WDS contrasted considerably, with the PA jumping from 47.8° in 1843 to 75.3° in 2011, and the separation fluctuating from 9.09" in 1843 to 6.34" in 2011. The data in the WDS text file revealed a wide range of position angles and separations, as can be seen in Table 4. Also puzzling was the magnitude of the B component, shown as 11.10 in the WDS (2011), but not listed in the text file. The NOMAD-1 catalog showed no visual magnitude for B, and again UCAC4 had no data whatever on that component. Using NOMAD-1's J and K magnitudes to produce a visual magnitude for B (according to Warner 2007) resulted in a rather unlikely value of 13.983 when compared with

Table 2. STT 143 B

Mag	Date	Source
10.2	1867	Dembowski
10.1	1884	J. Perrotin
10.3	1921	G. Abetti
11.9	1924	E. Opik
9.2	1956	C.E. Worley
9.3	1958.08	W.H. van den Boss
10.4	1958.19	W. H. van den Boss
9.4	1980	J.L. Comellas
8.263	1997.8	2MASS J Mag
7.948	1997.8	2MASS H Mag
8.428	1997.8	2MASS K Mag

Table 3. STT 153 AB

PA	Sep	Date	Source
70.8°	20.00"	1843	Mädler
70.9°	19.552"	1897	Wycoff 1998 photo
71.1°	20.35"	1898	E. Doolittle
70.7°	20.10"	1899.035	W.J. Hussey
71.4°	20.27"	1899.256	W.J. Hussey
71.3°	19.538"	1900	Wycoff 1998 photo
71.8°	20.140"	1905	Wycoff 1998 photo
70.9°	19.78"	1917	F.L. Brown
73.4°	20.25"	1963	P. Couteau
71.2°	20.40"	1975	C.E. Worley
91.8°	19.00"	1998	W.L. Sanders
70.6	34.60"	2004	W.L. Sanders

Table 4. STT 164 AB

PA	Sep	Mag.	Date	Source
47.8°	9.09		1843	Madler
51.0°	13.98		1899	W.J. Hussey
50.4°	14.36		1899	W.J Hussey
50.2°	13.55	7.3, 11.2	1901	S.W. Burnham
51.5°	13.5		1905	S.G. Barton
52.3°	13.637		1905	Wycoff 1998 photo
66.0°	13.8	8.0, 11.6	1906	M.A. Pourteau
44.3°	4.56		1908	E.D. Roe
54.3°	12.05		1930	G. Struve
63.0°	9.76	6.5, 10.5	1963	P. Couteau
		7.02	1991	Hipparcos
75.3°	6.34		2011	J. Serot

the WDS value, as well as with the 10.5 to 11.6 magnitude range shown in the text file. The A component also showed a fluctuation in magnitude in the text file, ranging from 6.5 to 8.0.

2.2 Visual Observations

John Nanson made visual observations of all the Gemini stars listed in Table 1 using a six inch f/10 refractor, and Wilfried Knapp observed most of them, using apertures of 140mm and 185mm.

STT 143: Visual observation by John confirmed about four magnitudes of difference between A and B, indicating the WDS 10.40 magnitude is reasonably close.

STT 151: There are two companions to the primary of STT 151, with the WDS showing B at a magnitude of 10.48 and C at a magnitude of 13.50. John had no problem seeing B and felt the three magnitudes of difference between it and the primary were reasonably close, but was unable to catch C visually. Wilfried was unable to see either B or C.

STT 153: Visual observations by both Wilfried and John confirmed the correct position angle of the AB pair is in the vicinity of seventy degrees. There were no issues with the magnitudes.

STT 162: The WDS lists the C component at a magnitude of 10, but visual observations by both John and Wilfried confirmed it's at least two magnitudes fainter than that. Two stars were used for comparison to C, both of which appeared very similar in magnitude: UCAC4 530-036804, with a Vmag of 12.463 (located 5.4' south and slightly east of STT 162), and UCAC4 530-036708, with a Vmag of 12.265 (located 3.8' southwest of STT 162).

STT 164: Visual observations by John and Wilfried indicated B was fainter than the WDS figure of 11.10. Wilfried felt B was as faint as 12.5, while John's observation was not only that B was fainter than the WDS value, but that a difference of five magnitudes existed between A and B (as opposed to the WDS difference of four), some of which might be attributable to the WDS 7.10 magnitude for A being too faint. Separation was difficult to gauge visually, but the PA of 75.3° in the WDS seemed reasonably close.

STT 165: The WDS lists B with a magnitude of 11.30 at a distance of 13.30". John found B was right at the edge of averted vision in his six inch refractor, indicating B is fainter than the WDS value. B was compared to UCAC4 530-038653 (Vmag of 12.023, located 3.7' northwest of STT 165), which was very similar in brightness, and UCAC4 530-038629 (Vmag of 11.381, located 6.3' west and slightly north of STT 165), which was slightly brighter than B. The C component, listed in the WDS at a magnitude of 13.49, was mainly an averted vision object in the six inch refractor, but was nonetheless easily detectable, suggesting it may be slightly brighter than 13.49.

STT 166: The C component is shown at a magnitude of 12.70 in the WDS, at a distance of 14.10" from the 7.24 magnitude primary. John found C was very elusive, but expected that would be the case given the delta_M of 5.46 between the two stars. Wilfried found no trace of C in the 185mm scope.

STT 172: The WDS shows a magnitude of 11.9 for the B component with a separation of 15". John found B difficult to hold in view with averted vision in the six inch f/10 refractor, which would indicate it's at least a magnitude fainter than 11.9, especially when the 15" separation is taken into account. Wilfried also found B was fainter than expected using a 140mm refractor, suggesting a magnitude in the 12.8 range.

STT 173: Two comparison stars were used to estimate the magnitude of the C component, shown in the WDS at a magnitude of 12.80. UCAC4 616-041369 is listed with a Vmag of 12.267 (located 2.2' southeast of the STT 173 primary), and UCAC4 616-041358 is listed with a Vmag of 12.407 (located 2.6' south and slightly east of STT 173). Both of those stars appeared slightly brighter than C to both John and Wilfried, indicating the WDS magnitude is reasonably close.

STT 179 (Kappa Geminorum): The WDS shows the B component at a magnitude of 8.2, but visual observation by both John and Wilfred indicated it's significantly fainter than that. Two comparison stars were used. The first, UCAC4 572-041577 (located 8.1' southeast of STT 179) is listed with a Vmag of 8.90, and B was very clearly fainter than that. The second star, which was the one in the field of view most similar in magnitude to B, was UCAC4 573-041706 (located 14' west and slightly north of STT 179). It's listed with a Vmag of 11.738, which was noticeably fainter than B, suggesting the magnitude of B is in the range of 10.0 to 10.5.

STT 181: The WDS shows B at a magnitude of 12.3, separated from the magnitude 8 primary by 6.8".

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John had difficulty at first with B, but after seeing it at 253x was able to see it with averted vision at 152x. Wilfried saw B as extremely faint with an aperture of 140mm. Their observations are pretty much in accord with a delta_M of 4.3 for the two stars.

STT 183: The magnitude listed in the WDS for the B component is 11.1, but again, visual observation indicated it was considerably fainter than that. John was able to catch it with averted vision in the six inch refractor, and Wilfred didn't see it at all in the 140mm scope. John compared B with three other stars: UCAC4 532-043525 (located 12.5' north and slightly west of STT 183) with a Vmag of 13.100; UCAC4 531 -043997 (located 6.3' north and slightly west of STT 183) with a Vmag of 13.405; and UCAC4 531-043967 (located 7.8' northwest of STT 183) with a Vmag of 12.517. Evaluation was difficult because B was an averted vision object only, but all three comparison stars appeared similar to B, indicating a magnitude in the 12.6 to 13.0 range.

STT 519: The WDS shows B at a magnitude of 10.7. Both John and Wilfried made visual observations which indicated B is slightly fainter than that. Wilfried found B was similar in brightness to UCAC4 529-027814 (located 2' east of STT 519) which has a Vmag of 12.109. John found UCAC4 529-027813 (located 2.5' southeast of STT 519), with a Vmag of 11.349, appeared to be a close match for B, and possibly slightly fainter. A better magnitude appears to be in the 11.2 to 11.5 range.

3. Photometry and Astrometry

3.1 Photometry Results

Several hundred images were taken with iTelescope remote telescopes and used (with a few exceptions) in stacks of 5 images with 1s exposure time. Photometry was performed with AAVSO VPhot, and in one case with Astrometrica, using UCAC4 catalog stars with Vmags within the field of the double star. The resulting photometry reports could have been used to calculate average results for all existing stacks from different telescopes and different imaging dates but we preferred to submit the different reports per object sep-

(Continued on page 398)

Table 5: Photometry results for the selected STT objects in Gem

Name	WDS ID	Mag2	Err	Std	Err(SNR)	SNR	Date	N	Notes
STT143 AB	06312+1656	10.136	0.012	0.040	0.011	99	2015.281	5	iT24
		9.948	0.038	0.036	0.013	86	2015.302	5	iT21
		10.029	0.065	0.064	0.013	81	2015.297	5	iT21
		9.984	0.022	0.007	0.021	52	2015.253	5	iT21
		10.201	0.030	0.023	0.019	55	2015.299	4	iT18
STT151 AC	06389+2748	13.775	0.079	0.047	0.064	17	2015.308	10	1)
STT153 AB	06422+2528	11.728	0.029	0.004	0.029	37	2015.281	5	iT24
		11.811	0.051	0.015	0.049	22	2015.302	5	iT21
		11.724	0.110	0.024	0.107	10	2015.253	5	iT21
		11.993	0.066	0.007	0.065	16	2015.297	4	iT21
		11.712	0.057	0.030	0.049	22	2015.299	5	iT18
STT162 AB,C	06598+1556	12.264	0.032	0.014	0.029	37	2014.994	1	2)
		12.189	0.044	0.009	0.043	24	2015.281	5	iT24
		12.307	0.063	0.005	0.063	17	2015.297	5	iT21
		12.332	0.068	0.006	0.068	16	2015.253	5	iT21
		12.155	0.095	0.056	0.077	14	2015.299	4	iT18
STT164 AB	07062+2452	11.583	0.106	0.084	0.064	16	2015.299	2	iT18
		11.729	0.061	0.030	0.053	20	2015.253	5	iT21
		11.723	0.073	0.029	0.067	16	2015.291	5	iT21
		11.654	0.042	0.015	0.039	27	2015.297	5	iT21
		11.783	0.044	0.030	0.032	33	2015.281	5	iT24

Table 5 continues on next page.

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Table 5 (continued): Photometry results for the selected STT objects in Gem

Name	WDS ID	Mag2	Err	Std	Err(SNR)	SNR	Date	N	Notes
STT165 AB	07084+1556	10.954	0.031	0.025	0.018	61	2015.281	5	iT24
		10.934	0.040	0.033	0.023	46	2015.297	5	iT21
		10.924	0.021	0.008	0.019	56	2015.253	5	iT21
		10.915	0.052	0.043	0.030	36	2015.299	4	iT18
STT166 AC	07128+2713	12.827	0.089	0.039	0.081	13	2015.281	5	3)
STT172 AB	07295+3448	12.674	0.057	0.007	0.057	19	2015.281	5	4)
STT173 AC	07344+3307	12.253	0.053	0.025	0.046	23	2015.281	5	iT24
		12.287	0.068	0.023	0.064	16	2015.297	5	iT21
		12.230	0.131	0.089	0.096	11	2015.291	5	iT21
STT179 AB	07444+2424	9.986	-	0.217	-	-	2015.237	2	5)
STT181 AB	07457+3433	11.731	0.044	0.007	0.043	25	2015.281	1	iT24
		11.698	0.079	0.046	0.065	16	2015.292	4	iT21
		11.452	0.047	0.027	0.039	27	2015.297	5	iT21
STT183 AB	07540+1602	12.836	0.083	0.056	0.061	17	2015.281	5	iT24
		12.793	0.097	0.053	0.081	13	2015.253	5	iT21
STT519 AB	06313+1544	10.905	0.041	0.037	0.018	61	2015.281	5	iT24
		10.846	0.030	0.017	0.024	45	2015.302	5	iT21
		10.951	0.085	0.081	0.027	40	2015.297	5	iT21
		10.912	0.026	0.014	0.022	49	2015.253	5	iT21

*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. Notes indicate the telescope used or refer to a note number.*

Table 5 Notes:

1. Stack of 10 images taken with iT21 with 5s exposure time. Other images were taken with 1s exposure time but these turned out to be of little use for photometry for a component this faint
2. One iT24 image with 3s exposure time
3. Images taken with iT24. Other images were taken with iT21 and iT18 as well but with SNR below 10 so with less reliability for photometry
4. Images taken with iT24. Another stack of images taken with iT21 was with SNR below 10 of no good use for photometry
5. Due to the brightness of the primary of this object it was impossible to take images with the iTelescope equipment that was used which were suitable for photometry of B as the star disks of A and B were completely overlapping. Any attempt to use combined magnitude according to M. Greaney (2012) ended without success due to the low influence of B on the total value. Thus we had to use the images of Steve Smith, which showed the secondary quite well but were taken without a V-filter, in order to get at least well founded estimations. For this purpose we used MaxIm DL6 to convert the JPG color images to mono color FITS and used this image for plate solving, with Astrometrica also providing photometrical estimates. The resulting estimates were then averaged and the standard deviation calculated (listed in the Std column)

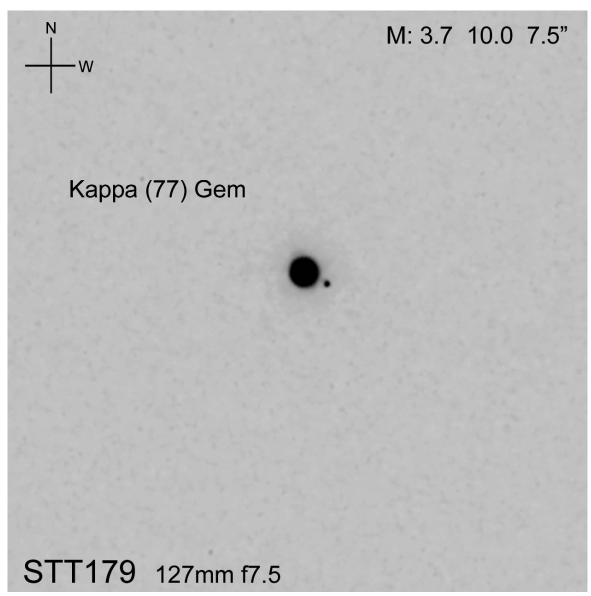

Figure 3: STT179 - Very difficult because of the brightness of the primary, yet good resolution of B - despite the lack of direct comparison stars obviously much fainter than previously recorded. The +10mag for the secondary indicated in the image is our estimation based on photometry without V-filter and visual observation

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Table 6: Astrometry results for the selected STT objects in Gem. Sep means separation in arcseconds and PA means position angle in degrees

Name	Comp	WDS ID	RA	Dec	Sep	PA	Date	Notes
STT153	A	06422+2528	06:42:11.956	25:28:06.720	20.5	71.1	2015.287	1)
	B		06:42:13.388	25:28:13.360				
STT162	AB	06598+1556	06:59:50.484	15:56:28.060	22.6	154	2015.225	2)
	C		06:59:51.170	15:56:07.760				
STT164	A	07062+2452	07:06:11.602	24:51:36.420	7.3	77.3	2015.284	3)
	B		07:06:12.123	24:51:38.025				
STT165	A	07084+1556	07:08:22.025	15:55:48.920	16	5.9	2015.282	4)
	B		07:08:22.140	15:56:04.850				
STT166	A	07128+2713	07:12:49.081	27:13:30.201	13.8	76.6	2015.281	5)
	C		07:12:50.090	27:13:33.400				
STT183	A	07540+1602	07:53:57.600	16:02:10.400	16.9	34.8	2015.267	6)
	B		07:53:58.270	16:02:24.300				
STT519	A	06313+1544	06:31:17.755	15:44:14.150	8.4	78	2015.283	7)
	B		06:31:18.325	15:44:15.900				

Table 6 Notes:

1. As the coordinates for the UCAC4 objects 578-033195 and 578-033189 are very close to identical, additional PA and Sep calculation with these values as counter check wasn't felt to be necessary
2. Counter check with the coordinates for the UCAC4 objects 530-036757 and 530-036763 results in 22.44" for Sep and 154.16° for PA
3. No UCAC4 object for B available
4. No UCAC4 object for B available
5. The coordinates measured for STT166A with 07:12:49.07 +27:13:28.70 are for the overlapping star disks of STF1037AB and thus less precise than desired – as the position of A given for STF1037A and STT166A is identical, we adopted those parameters of A to calculate the Sep and PA for STT 166 AC. But the measured position is quite different at about 2 arcsec south of the WDS average of A+B, so this is a bit curious. We repeated our measurement with MaxIm DL6 and UCAC4 based plate solving with confirmation of this result. A counter check with the coordinates of other stars in the images used showed a good match with the UCAC4 coordinates so this calls for further research. STF1037 is also listed as Tycho Double star TYC1904-01418-1/2 but with identical coordinates 07:12:49.057 +27:13:29.761 for both stars. Further the WDS data situation is a bit confusing for this object as the parameters for STF1037AB differ heavily from STT166B as can be seen in Figure 4,

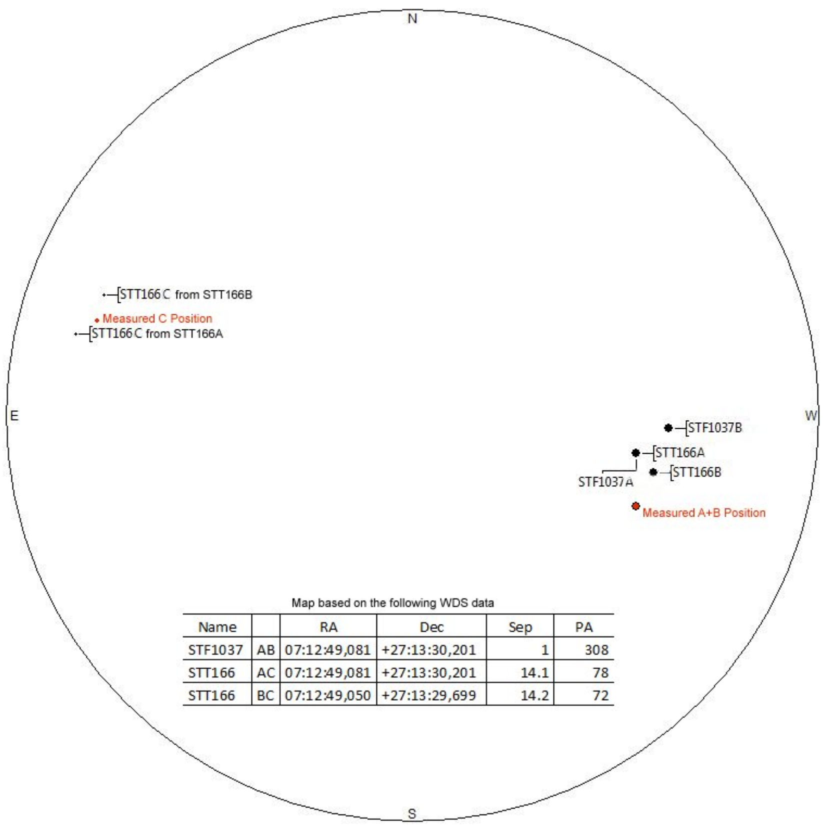

Figure 4: Star map for STT166 based on latest WDS data (2014

made on the basis of the mentioned WDS parameters.

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The fact that STT166 A and B have a known grade 2 Orbit (thanks to Ross Gould for this hint on the Cloudy Nights DSO forum) might be a reason that the centroid of the combined star disks has to move over time but seems no sufficient reason for catalog differences this large. On the other hand the coordinates of STT166B are quite identical to these of TYC1904-01418-2. UCAC4 is not of much help here, as no objects for B and C exist. This situation calls at least for a correction of the coordinates of STT 166 BC to match with the data of STF1037 AB as the calculation of PA and Sep based on the STT 166 coordinates would result in 219.48° and 0.65", which is very different from the values for STF1037 and most probably wrong. Calculated on basis of the STF1037 data the RA/Dec coordinates for B would be 07:12:49,021 +27:13:30.826

6. Counter check with the coordinates for the UCAC4 objects 531-044007 and 531-044009 results in 17.01" for Sep and 34.14° for PA
7. Counter check with the coordinates for the UCAC4 objects 529-027767 and 529-027771 results in 8.56" for Sep and 78.37° for PA

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arately. Results are shown in Table 5.

Specifications of the telescopes that were used are as follows:

- 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. 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
- Steve Smith: 127mm refractor with 939mm focal length. Photographic esolution 0.98 arcsec/pixel. No filter. No transformation coefficients available. Located in Castle Rock, Colorado. Elevation 1980m.

3.2 Astrometry Results

Astrometric calculations were done only for objects with position issues assumed. 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 as tool to determine the RA/Dec coordinates for all needed components based on the GSC catalog. The resulting RA/Dec coordinates based on this approach were used to calculate the Sep and PA listed in Table 6. If UCAC4 coordinates were available (which are assumed to be the most precise coordinates available) they were used for a counter check in the Notes section.

Summary

Tables 7 and 8 compare the final results of our research with the WDS data that was current at the time we began working on the thirteen STT stars in Gemini.

In Table 7, the results of our photometry have been averaged for the stars with multiple photometry readings. 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 7 is the large number of instances in which there is an absence of Vmag values in the two catalogs, as was also the case with the UCAC4 fit model magnitudes (f.mag), pointing to the difficulties in magnitude determinations of high delta_M pairs.

For the most part, the visual observations of these difficult pairs were in reasonable agreement with the photometry, with the exception of STT 165 B. That star was looked at closely twice and in each case estimated to be approximately a magnitude fainter than the WDS value, while our photometry indicated it's slightly brighter than the WDS value. The reason for this remains unclear and might have something to do with the color hues of the components.

For the purpose of suggesting appropriate changes to the current WDS data, we've used bold type in Tables 7 and 8 to call attention to significant differences. With regard to Table 7, those magnitudes that differ by

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Table 7: Photometry and Visual Results Compared to WDS

Disc. Code	WDS Mag	NOMAD-1 VMag	UCAC4 VMag	UAC4 f. mag	Average of Photometry Measures	Results of Visual Observations
STT 143 B	10.40	-	-	-	**10.060**	B reasonably close to WDS value
STT 151 C	13.50	13.030	-	13.546	**13.775**	C not visible
STT 153 B	11.80	11.720	12.028	11.744	11.794	B reasonably close to WDS value
STT 162 C	10.00	-	-	11.981	**12.249**	C estimated at 12.3 based on comparison stars
STT 164 B	11.10	-	-	-	**11.694**	B half a magnitude fainter than WDS
STT 165 B	11.30	-	-	-	**10.932**	B appeared to be in the 12.0 to 12.5 range
STT 166 C	12.70	-	-	-	12.827	C reasonably close to WDS value
STT 172 B	11.90	-	-	12.519	**12.674**	B estimated at close to the UCAC4 f.mag of12.519
STT 173 C	12.80	-	-	12.138	**12.257**	C appeared close to WDS value of 12.8
STT 179 B	8.20	-	-	-	**9.986**	B appeared to be in the 10.0 to 10.5 range
STT 181 B	12.30	-	-	11.733	**11.627**	B reasonably close to WDS value
STT 183 B	11.10	17.970	-	12.851	**12.815**	B about 1.5 magnitudes fainter than WDS value
STT 519 B	10.70	-	10.645	10.743	**10.904**	B estimated in the 11.2 to 11.5 range

Table 8: Astrometry Results Compared to WDS

Disc. Code	WDS Sep	WDS PA	Astrometry Sep	Astrometry PA
STT 153 AB	19.0	92°	**20.5**	**71.1°**
STT 162 AB,C	22.8	155°	22.6	**154.0°**
STT 164 AB	6.3	75°	**7.3**	**77.3°**
STT 165 AB	13.3	8°	**16.0**	**5.9°**
STT 166 AC	14.1	78°	**13.8**	**76.6°**
STT 183 AB	17.1	34°	16.9	**34.8°**
STT 519 AB	8.4	79°	8.4	**78.0°**

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two tenths of a magnitude or more from the WDS values have been highlighted in bold. In Table 8, differences in separation in excess of 0.2 arc seconds are highlighted; all the position angles differ by more than a degree, so all are highlighted in bold.

References:

Buchheim, Robert, 2008, CCD Double-Star Measurements at Altimira Observatory in 2007, Journal of Double Star Observations, Vol. 4 No. 1 Page 28

Greaney, Michael, 2012, "Some Useful Formulae" in R.W. Argyle, Observing and Measuring Visual Double Stars, 2nd Edition 2012, Chapter 25, Page 359

Hussey, W.J., 1901, "Micrometrical Observations of the Double Stars Discovered at Pulkowa Made with the Thirty-Six-Inch and Twelve-Inch Refractors of Lick Observatory", pp. 14-16. A.J. Johnston, Sacramento

Warner, Brian D., 2007, Initial Results from a Dedicated H-G Project, Minor Planet Bulletin 34, Page 114 "Converting 2MASS J-K Magnitudes to the BV(RI)c System"

Acknowledgements:

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

- 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
- AstroPlanner v2.2
- MaxIm DL6 v6.08
- Astrometrica v4.8.2.405

Appendix: Additional Images for Visualization

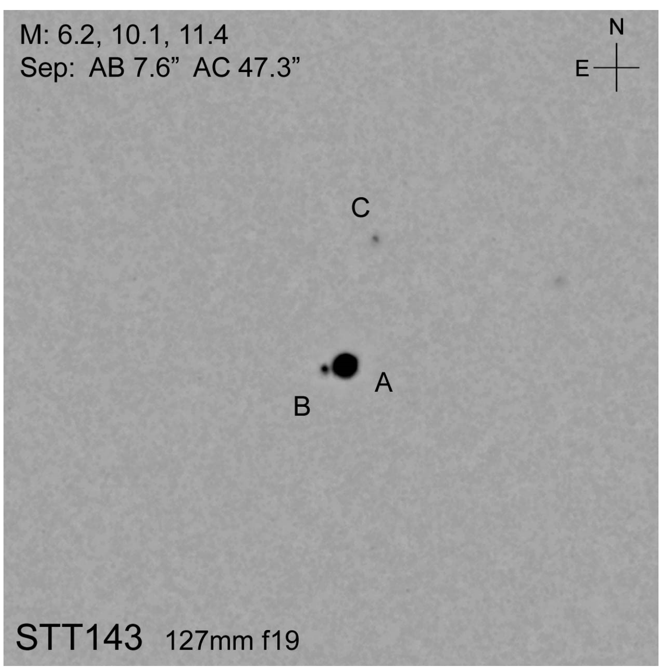

Figure 5. STT143 - Nice triple. The given mag for B is our photometry result

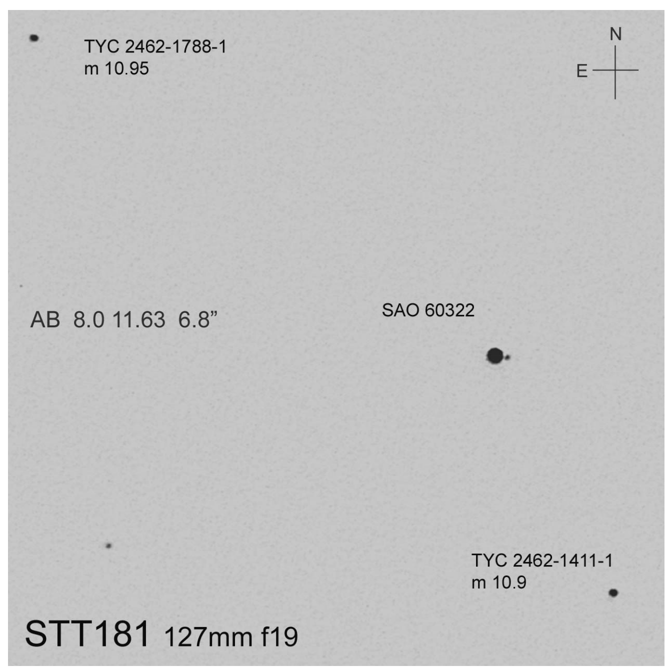

Figure 6. STT181 - Solid resolution of faint companion. The given mag for B is our photometry result

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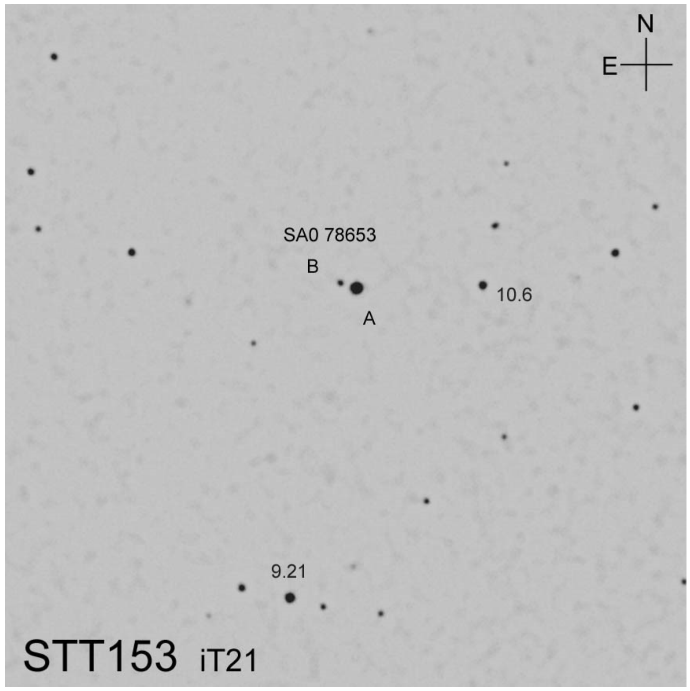

Figure 7. STT 153 in a rich star field

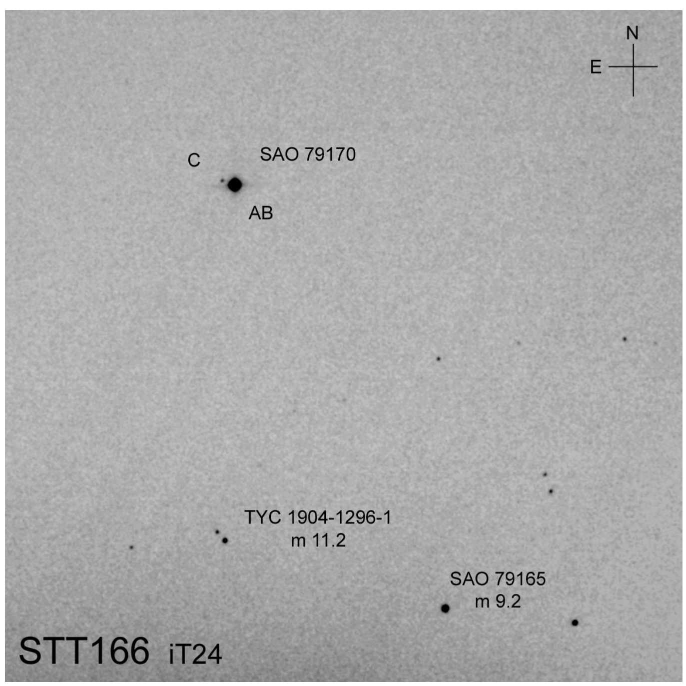

Figure 8. STT 166 – coordinates riddle