STT Doubles with Large ΔM – Part VII: And Pisces Auriga

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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. Similar to the other objects covered so far several of the components show parameters quite different from the current WDS data.

1. Introduction

As follow up to our STT reports so far we continue in the constellations Andromeda, Pisces, and Auriga (see Table1.1). All values based on WDS data as of beginning of 2016.

With STT103 we have here again an object with a very bright primary making measurements difficult due to ADU values near CCD saturation.

2. Further Research

Following the procedure for the earlier parts 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 comparing with the existing data, and obtain as many images as possible suitable for photometry.

2.1 Historical Research and Catalog Comparisons

Several of the stars in this survey have notable aspects worth further investigation. Three main research sources were used for this section of this paper, the first of which was W.J. Hussey's *Micrometrical Observations of the Double Stars Discovered at Pulkowa*, published in 1901, which provided preliminary historical information on each of the stars. Hussey's book in-

Table 1. WDS Catalog Data at Beginning of 2016 for the Selected STT Objects

WDS ID	Name		RA	Dec	Sep	M1	M2	PA	Δ_M	Con
00439+3734	STT 19	AB	00:43:52.14	+37:33:38.0	9.7	8.54	11.40	115	2.86	And
01189+3958	STT 29	AB	01:18:53.15	+39:57:48.0	20.1	7.50	11.70	266	4.20	And
23486+3616	STT 506	AC	23:48:35.39	+36:16:28.4	21.1	7.37	10.80	80	3.43	And
00057+4549	STT 547	BP	00:05:41.00	+45:48:37.4	15.6	9.15	13.40	8	4.25	And
01256+3133	STT 30	AB	01:25:34.17	+31:33:01.9	4.6	8.09	11.80	245	3.71	Psc
01256+3133	STT 30	AD	01:25:34.17	+31:33:01.9	20.6	8.09	14.00	193	5.91	Psc
05074+5018	STT 94	AB	05:07:22.26	+50:18:20.2	17.9	7.44	11.10	305	3.66	Aur
05074+5018	STT 94	AC	05:07:22.26	+50:18:20.2	24.9	7.44	11.00	66	3.56	Aur
05091+4907	STT 96	AB	05:09:04.40	+49:07:18.8	20.6	6.67	11.10	105	4.43	Aur
05182+3322	STT 103	AB	05:18:10.56	+33:22:17.8	4.1	4.80	10.60	55	5.80	Aur
05232+4701	STT 104	AB	05:23:12.61	+47:01:17.9	7.1	4.80	11.10	190	4.00	Aur

cludes his observations and measures of all the stars originally listed in Otto Wilhelm Struve's 1845 Pulkovo 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 each of the three stars. In addition, Bill Hartkopf of the USNO graciously provided the text files for STT 30, STT 104, and STT 547.

Several of the stars in this survey were dropped from the second edition of Otto Struve's Pulkovo Catalogue (published in 1850) because the separations exceeded 16", which was the maximum catalog separation established for stars with companions fainter than ninth magnitude (Hussey, 1901, p. 16). The stars in this paper which were rejected are STT 29, STT 94, STT 96, and STT 506 AC. Fortunately, Hussey included all of the rejected stars in his 1901 book.

STT 30 (Psc). Hussey shows the first measures of the AB pair of STT 30 was made in 1843 by Otto Struve, although that measure is not listed in the WDS text file. Struve made two measures at that time (position angles of 227.8° and 234.6°, and separations of 4.39" and 4.53"), which are somewhat anomalous with the measures that have followed since. In general, the position angle of the AB pair has migrated from 238° (1869) to the most recent WDS reading of 244.8° (2004), and the separation has slowly increased from 4.3" to 4.6" over the same period.

Hussey (1901, p. 42) shows the AC pair was first measured by O. Struve in 1862 (105.0° and 56.98"), but the WDS text file shows Mädler preceded that with an 1843 measure (105.2° and 54"). The AC pair is remarkable for its lack of change since its discovery. There are a total of thirty-eight measures in the WDS for the pair, and there's very little difference between any of them. The most recent WDS (2011) measures are 105.7° and 56.78".

S.W. Burnham included a note on what is now the AD pair in his 1906 catalog entry on STT 30, although he didn't mention the year the observation was made (Burnham, 1906, Part II, p. 405). However the WDS text file shows he measured the pair in 1907 at 161.6° and 26.11", slightly different from his catalog estimate of 159° and 27". There's been a steady northward progression of the position angle and a narrowing of the separation since that time. The most recent WDS data goes back to 1998, which is 195.4° and 21.38". Those numbers are consistent with the change shown in the four measures in the years between 1907 and 1998, and are caused by a high rate of proper motion for the AB pair (as well as C) in contrast to very little motion for D (Figure 1).

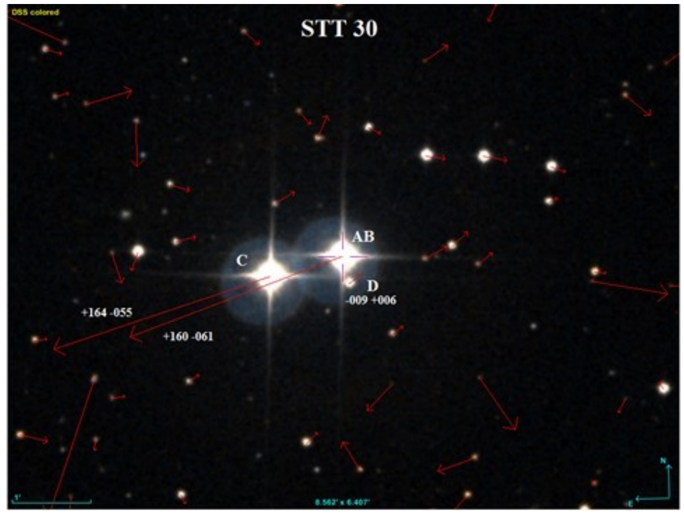
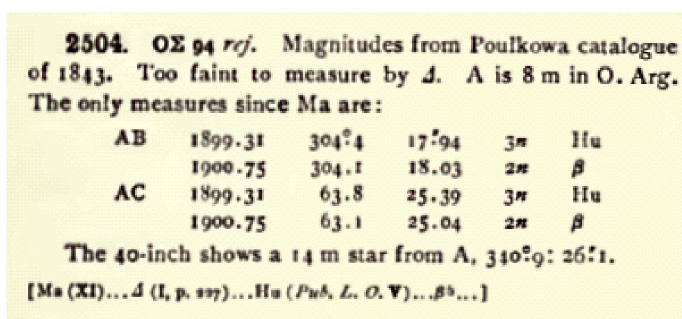


Figure 1. PM of STT 30 based on URAT1 data (Aladin image).

STT 94 (Aur). Hussey (1901, p. 65) shows Mädler was first with measures of both the AB and AC pairs. His 1843 measures for AB were 304.0° and 15.60"; for AC his measures were 63.3° and an estimated separation of 20". The most recent WDS measures (2011) are 305° and 17.9" for AB and 66° and 24.90" for AC. The AD pair was added in 1890 by S.W. Burnham (Figure 2). His measures were 340.9° and 26.1", and again little change is seen when compared with the most recent WDS measures (2002) of 344° and 26.3".



2504. OΣ 94 *rej.* Magnitudes from Poulkowa catalogue of 1843. Too faint to measure by Δ. A is 8 m in O. Arg. The only measures since Ma are:

AB	1899.31	304°.4	17".94	3n	Hu
	1900.75	304.1	18.03	2n	β
AC	1899.31	63.8	25.39	3n	Hu
	1900.75	63.1	25.04	2n	β

The 40-inch shows a 14 m star from A, 340°.9: 26".1.

[Ma (XI)... Δ (I, p. 197)... Hu (*Pub. L. O.* V)... β5...]

Figure 2. From Part II, p. 405, of Burnham's 1906 catalog.

STT 96 (Aur) Discovered in 1843 by Otto Struve, this is a difficult pair with a large ΔM between the primary and the secondary. The WDS shows magnitudes of 6.67 and 11.0 with a separation of 21.0" (PA 105°), which may explain why Otto Struve never provided a measure for it (Burnham, 1906, and Figure 3.).

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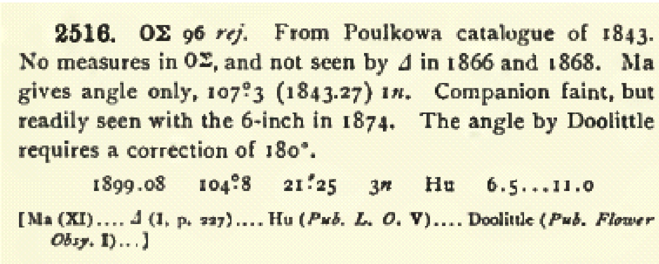
2516. OΣ 96 *rej.* From Poulkowa catalogue of 1843. No measures in OΣ, and not seen by Δ in 1866 and 1868. Ma gives angle only, 107°.3 (1843.27) 1*n*. Companion faint, but readily seen with the 6-inch in 1874. The angle by Doolittle requires a correction of 180°.

1899.08 104°.8 21″.25 3*n* Hu 6.5...11.0

[Ma (XI).... Δ (I, p. 227).... Hu (*Pub. L. O.* V).... Doolittle (*Pub. Flower Obsy.* I)...]

Figure 3. From p. 406 of Burnham's 1906 catalog, Part II.

Date	PA	Sep	Date	PA	Sep
1843.27	187.7		1911.55	190	18.42
1847.02	191.1	15.74	1911.895	190	18.12
1851.27	191.4	16.25	1958.18	189.8	19.62
1852.27	190.5		1996.918	189.1	20.74
1866.81	191.7	16.64	1999.78	189.4	20.73
1895.25	190.5	17.38	2002.846	189.9	20.579
1896.3	189.2	17.53	2007.655	190.15	21.092
1898.75	189.8	17.91	2011.29	189.2	20.87
1901.103	190.1	18.17	2012.938	189.8	21.18
1907.93	189	17.89	2014.85	190	21.4

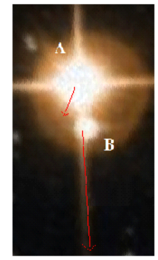

Figure 4. WDS text file data for STT 104 with Aladin image showing URAT1 proper motion arrows.

Burnham also mentions that Dembowski failed to see the secondary in 1866 and 1868. Both Burnham and Hussey (Hussey 1901, p. 65) include an 1843 observation by Mädler which lists a position angle (107.3°) but no separation. Hussey's three observations in 1898-1899 with the 36 inch Lick refractor average out to the numbers listed in Figure 2.2.3, 104.8° and 21.25". Our experience with this pair confirmed their visual difficulty.

STT 104 (Aur). This is another perplexing pair because it shows a surprising change in separation given the information available for it. As the data from the WDS text file in Figure 4 shows, the position angle has been remarkably consistent, while the separation has increased steadily. The most recent proper motion data from URAT1 for the pair shows the primary with a proper motion of +005.2 -013.5 and the secondary with proper motion of -003.6 -056, which give the secondary considerably more southerly motion than the primary. Simbad shows a distance for STT 104 A of 1929 light years, but no parallax for the secondary. Given the southerly motion in declination of the secondary relative to the primary, it's likely the fainter star is quite a bit closer to us than the primary, which would make this an optical pair

STT 547 (And). In his 1901 survey of Otto Struve's double stars, W.J. Hussey's first paragraph focused on a notable aspect of the AB pair of this multiple star: "Since discovery the angle has been increasing about three-fourths of a degree per year without appreciable change in distance. The angular motion is rapid for a binary of its distance and magnitudes" (Hussey, 1901, p. 215). With 398 observations of STT 547 AB in the WDS, that change has been documented in detail. A comparison of the first and last measurements clearly illustrates the dynamic nature of the pair, as well as confirming Hussey's description: 113.5° and 4.47" in 1876, and 189.30° and 6.030" in 2015. Our interest in STT 547 was primarily with the BP pair due to P's faint magnitude, but we quickly noticed the position angle of the pair in the Aladin photo didn't match the 2012 WDS position angle of 340° (Figure 2.2.5, top right). BP was added to the system in 1989, with an initial measure of 54.0° and 18.8", while the WDS 2012 data shows measures of 340° and 18.05". We were unable to find a date for the Aladin image, but it appears to have been made about 1989 since the positon angle in the photo is very close to 54°. As Figure 5 shows, P is virtually stationary (Simbad shows a proper motion of +000.1 +003.9 for P), while the AB pair is racing along at breakneck speed. Simbad's data shows identical proper motions for AB of +879 -154. Also shown in

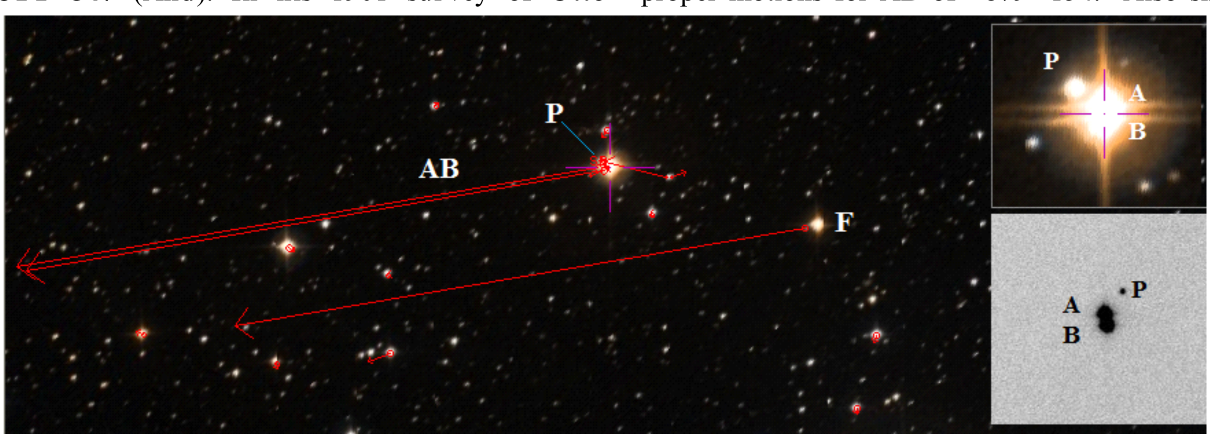

Figure 5. Aladin image with Simbad proper motion data shown for AB, F, and P. Inset at the right shows the change in the position angle of BP from about 1989 to our image taken late in 2015.

the image with a rapid pm is F, which Simbad lists at +870 -150.

2.2 Visual Observations

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

STT 19 (And): Knapp looked at STT 19 with a 140mm refractor and detected the secondary as a faint spot of light at 280x. It was still detectable with the aperture reduced to 110mm, suggesting the WDS magnitude of 11.40 is about right. John's observation with a six inch refractor at 152x found the secondary surprisingly difficult given the magnitude differential and separation. B appeared similar in brightness to a comparison star with a UCAC4 Vmag of 12.3, suggesting a fainter magnitude for B than the WDS value.

STT 29 (And): Nanson found several comparison stars for the secondary, all of which led to the conclusion the WDS magnitude of 11.7 is correct. Wilfried saw B as a faint spot of light in the 140mm refractor at 280x, which was still visible with the aperture reduced to 90mm, leading to the possibility the secondary is a bit brighter than the WDS magnitude.

STT 506 (And): Knapp's observation of STT 506 took place when it was low in altitude. At 280x in the 140mm refractor, C was faintly visible. With the aperture reduced to 60mm, it could still be seen, hinting it may be a bit brighter than the WDS magnitude of 10.80. At 84x in the six inch refractor, Nanson found C was similar in brightness to a comparison star with a UCAC4 Vmag of 11.9, suggesting a full magnitude of difference fainter than the WDS value.

STT 547 (And): The target for this complex multiple star was the BP pair, with WDS magnitudes of 9.15 and 13.40, separated by 18.10" per the WDS 2012 observation. In the six inch refractor at 152x, Nanson could see P with averted vision, indicating it may be as much as a full magnitude brighter than the WDS value, especially when the ninth magnitude glare of the AB pair is taken into consideration. Knapp was unable to resolve P in the 140mm refractor regardless of the magnification used, suggesting it's fainter than 13.0.

STT 94 (Aur): Knapp observed STT 94 with the 185mm refractor at 250x and was able to resolve B clearly and C only faintly. Using the masking device, the limit aperture for B was 140mm and for C 170mm, indicating the two components are fainter than the WDS magnitudes (11.10 for B, 11.0 for C), and also that C is fainter than B. John found both B and C were easily resolved in the six inch refractor at 152x, with B appearing a bit brighter than C. B appeared similar in magnitude to a comparison star with a UCAC4 Vmag of 11.9, suggesting that both B and C are fainter than the WDS values.

STT 96 (Aur): Using the six inch refractor, Nanson detected B at 152x, 190x, and 253x in the glare of the 6.7 magnitude primary. Given the 20.6" separation and the 11.1 magnitude for B currently listed in the WDS, it appears the WDS value for B is about right. On the first attempt, Knapp was unable to resolve B with the 185mm refractor under poor seeing conditions, which nevertheless hinted at a fainter magnitude for B than the WDS value. A second attempt resulted in faint resolution at 180x in the 185mm refractor. B could still be seen with the aperture reduced to 120mm at 250x, leading to the conclusion B is much fainter the WDS's 11.1 magnitude.

STT 103 (Aur): Knapp resolved B at 100x in the 185mm refractor, and could still see it with the aperture reduced to 140mm, suggesting the WDS magnitude of 10.6 is correct. Nanson needed magnifications of 487x and 607x in the six inch refractor in order to glimpse B, which led to the conclusion the WDS value for B is about right given the 4.1" separation and 5.8 magnitudes of difference between the primary and secondary.

STT 104 (Aur): Nanson resolved B at 152x in the six inch refractor and found it was similar in magnitude to a comparison star with a UCAC4 Vmag of 11.9, leading to the conclusion the WDS value of 11.1 is too bright. Knapp resolved B in the 185mm refractor at 100x and found it was still visible at 250x when the aperture was reduced to 90mm, suggesting the WDS value of 11.1 is correct.

STT 30 (Psc): Using the 140mm refractor at 280x, Knapp could detect a faint spot of light at the location of B for brief periods, suggesting it could be no brighter than the WDS value of 11.80. D, with a WDS magnitude of 14.0, was not seen. Nanson was able to detect B at 365x and 380x in the six inch refractor on two separate occasions, leading to the conclusion the WDS value for B is a likely a bit too bright. There was no hint of D, confirming Knapp's conclusion it's certainly fainter 13th magnitude. Not part of the survey, but nevertheless still an interesting observation, was Nanson's conclusion that C (WDS magnitude of 8.06) was distinctly brighter than A (WDS magnitude of 8.09), which was confirmed during the course of observations on two separate nights at several magnifications.

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 URAT1 refer-

ence stars with Vmags in the range 10.5 to 14.5mag. The RA/Dec coordinates resulting from plate solving with URAT1 reference stars in the 10.5 to 14.5mag range were used to calculate Sep and PA using the formula provided by R. Buchheim (2008). *Err_Sep* is calculated as
with *dRA* and *dDec* as average RA and Dec plate solv-

$$Err\_Sep = \sqrt{dRA^2 + dDec^2}$$

ing errors. *Err_PA* is the error estimation for PA calculated as
in degrees assuming the worst case that *Err_Sep* points

$$Err\_PA = \arctan\left(\frac{Err\_Sep}{Sep}\right)$$

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
with *dVmag* as the average Vmag error over all used

$$Err\_Mag = \sqrt{dVmag^2 + \left[2.5\log_{10}\left(1 + 1/SNR\right)\right]^2}$$

reference stars and *SNR* is the signal to noise ratio for the given star. The results are shown in Table 2.

3. Summary

Tables 3 and 4 compare the final results of our research with the WDS data that was current at the time we began working on our current group of stars.

In Table 3 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 3 and 4 to call attention to significant differences from the WDS data. With regard to Table 3, those magnitudes that differ by two tenths of a magnitude or more from the WDS values have been highlighted. In Table 4 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 in Table 5.

Acknowledgements:

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

- Washington Double Star Catalog as data source for the selected objects
- iTelescope: Images were taken with
  - iT24: 610mm CDK with 3962mm focal length. CCD: FLI-PL09000. Resolution 0.62 arcsec/pixel. V-filter. Located in Auberry, California. Elevation 1405m
  - iT11: 510mm CDK with 2280mm focal length. CCD: FLI ProLine PL11002M. Resolution 0.81 arcsec/pixel. B- and V-Filter. 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. Located in Nerpio, Spain. Elevation 1650m
  - iT21: 431mm CDK with 1940mm focal length. CCD: FLI-PL6303E. Resolution 0.96 arcsec/pixel. V-filter. Located in Mayhill, New Mexico. Elevation 2225m
- AAVSO VPhot for initial plate solving
- AAVSO APASS providing Vmags for faint reference stars (indirect via UCAC4)
- UCAC4 catalog (online via the University of Heidelberg website and Vizier and locally from USNO DVD) for counterchecks
- URAT1 catalog for high precision plate solving
- Aladin Sky Atlas v8.0 for counterchecks
- SIMBAD, VizieR for counterchecks
- 2MASS All Sky Catalog for counterchecks
- URAT1 Survey (preliminary) for counterchecks
- AstroPlanner v2.2 for object selection, session planning and for catalog based counterchecks
- MaxIm DL6 v6.08 for plate solving on base of the UCAC4 catalog
- Astrometrica v4.9.1.420 for astrometry and photometry measurements

(Continued on page 86)

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Table 2: Photometry and astrometry results for the selected STT objects. Date is the Bessel epoch and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with number of images and exposure time given (Specifications of the used telescopes: See Acknowledgements). The average results over all used images are given in the line below the individual stacks in 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 19	RA	Dec	dRA	dDec	Sep	ErrSep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
A	00 43 52.145	37 33 37.89	0.07	0.07	9.763	0.099	115.025	0.581	8.452	0.090	209.35	0.09	2015.785	5	1
B	00 43 52.889	37 33 33.76							11.437	0.092	54.01				
A	00 43 52.133	37 33 37.92	0.06	0.09	9.791	0.108	114.884	0.633	8.408	0.060	141.45	0.06	2015.807	5	1
B	00 43 52.880	37 33 33.80							11.438	0.065	41.93				
A	00 43 52.150	37 33 37.91	0.06	0.05	9.754	0.078	114.404	0.459	8.483	0.070	188.59	0.07	2015.774	5	2
B	00 43 52.897	37 33 33.88							11.500	0.071	80.33				
A	00 43 52.148	37 33 37.99	0.09	0.12	9.771	0.150	113.780	0.879	8.469	0.080	148.35	0.08	2015.779	5	2
B	00 43 52.900	37 33 34.05							11.504	0.083	46.69				
A	00 43 52.146	37 33 37.90	0.03	0.03	9.746	0.042	115.138	0.249	8.418	0.050	297.29	0.05	2015.782	5	2
B	00 43 52.888	37 33 33.76							11.410	0.051	98.11				
A	00 43 52.144	37 33 37.92	0.065	0.078	9.765	0.102	114.646	0.598	8.446	0.072			2015.785	25	3
B	00 43 52.891	37 33 33.85							11.458	0.074					
STT29	**RA**	**Dec**			**Sep**	**ErrSep**	**PA**	**ErrPA**	**Mag**	**ErrMag**	**SNR**	**DVmag**	**Date**	**N**	**Notes**
A	01 18 53.152	39 57 47.31	0.09	0.09	20.175	0.127	265.337	0.361	7.452	0.041	137.86	0.04	2015.779	5	1
B	01 18 51.403	39 57 45.67							11.838	0.051	34.46				
A	01 18 53.139	39 57 47.23	0.09	0.08	20.164	0.120	266.190	0.342	7.452	0.090	217.79	0.09	2015.785	5	1
B	01 18 51.389	39 57 45.89							11.808	0.093	42.51				
A	01 18 53.142	39 57 47.28	0.04	0.04	20.121	0.057	266.067	0.161	7.390	0.030	360.02	0.03	2015.774	5	2
B	01 18 51.396	39 57 45.90							11.762	0.033	82.82				
A	01 18 53.138	39 57 47.29	0.03	0.04	20.122	0.050	266.010	0.142	7.406	0.040	467.70	0.04	2015.782	5	2
B	01 18 51.392	39 57 45.89							11.768	0.042	87.00				
A	01 18 53.143	39 57 47.28	0.068	0.067	20.145	0.095	265.901	0.271	7.425	0.055			2015.780	20	3
B	01 18 51.395	39 57 45.84							11.794	0.059					
STT506	**RA**	**Dec**			**Sep**	**ErrSep**	**PA**	**ErrPA**	**Mag**	**ErrMag**	**SNR**	**DVmag**	**Date**	**N**	**Notes**
A	23 48 35.378	36 16 28.17	0.08	0.06	20.910	0.100	81.474	0.274	6.953	0.080	220.94	0.08	2015.785	5	1
C	23 48 37.088	36 16 31.27							11.002	0.082	60.81				
A	23 48 35.374	36 16 28.05	0.09	0.07	20.911	0.114	81.447	0.312	6.925	0.070	177.05	0.07	2015.807	5	1
C	23 48 37.084	36 16 31.16							10.986	0.073	56.161				
A	23 48 35.385	36 16 28.13	0.10	0.12	20.910	0.156	81.474	0.428	6.899	0.060	177.092	0.06	2015.779	5	1
C	23 48 37.095	36 16 31.23							10.962	0.063	54.572				
A	23 48 35.381	36 16 28.14	0.04	0.04	20.898	0.057	81.247	0.155	6.926	0.040	419.783	0.04	2015.774	5	2
C	23 48 37.089	36 16 31.32							10.994	0.041	113.77				
A	23 48 35.383	36 16 28.20	0.04	0.03	20.899	0.050	81.442	0.137	6.933	0.040	435.15	0.04	2015.782	5	2
C	23 48 37.092	36 16 31.31							10.973	0.041	120.27				
A	**23 48 35.380**	**36 16 28.14**	**0.074**	**0.071**	**20.906**	**0.103**	**81.417**	**0.282**	**6.927**	**0.060**			**2015.785**	**25**	**3**
C	23 48 37.090	36 16 31.26							10.983	0.062					

Table 2 continues on next page.

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Table 2 (continued). Photometry and astrometry results for the selected STT objects. Date is the Bessel epoch and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with number of images and exposure time given (Specifications of the used telescopes: See Acknowledgements). The average results over all used images are given in the line below the individual stacks in 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 547	RA	Dec	dRA	dDec	Sep	ErrSep	PA	ErrPA	Mag	ErrMag	SNR	dVmag	Date	N	
A	00 05 42.367	45 48 41.00	0.06	0.07	5.944	0.092	188.395	0.889	8.959	0.090	142.65	0.09	2015.785	5	4
B	00 05 42.284	45 48 35.12							9.070	0.090	127.32				
A	00 05 42.378	45 48 41.26	0.11	0.11	6.200	0.156	189.219	1.437	8.958	0.072	57.76	0.07	2015.807	5	4
B	00 05 42.283	45 48 35.14							9.037	0.073	54.26				
A	00 05 42.362	45 48 41.02	0.03	0.03	6.043	0.042	188.257	0.402	8.947	0.040	227.49	0.04	2015.774	5	5
B	00 05 42.279	45 48 35.04							9.031	0.040	214.25				
A	00 05 42.356	45 48 41.11	0.08	0.09	6.126	0.120	187.058	1.126	8.959	0.071	121.68	0.07	2015.779	5	5
B	00 05 42.284	45 48 35.03							9.040	0.071	112.05				
A	00 05 42.363	45 48 41.11	0.06	0.06	6.112	0.085	188.163	0.795	8.931	0.050	201.98	0.05	2015.782	5	5
B	00 05 42.280	45 48 35.06							9.017	0.051	149.06				
A	00 05 42.365	45 48 41.10	0.073	0.077	6.085	0.106	188.220	0.998	8.951	0.067			2015.785	25	6
B	00 05 42.282	45 48 35.08							9.039	0.067					
STT 547	**RA**	**Dec**	**dRA**	**dDec**	**Sep**	**ErrSep**	**PA**	**ErrPA**	**Mag**	**ErrMag**	**SNR**	**dVmag**	**Date**	**N**	
B	00 05 42.284	45 48 35.12	0.06	0.07	19.704	0.092	332.643	0.268	9.070	0.090	127.32	0.09	2015.785	5	7
P	00 05 41.418	45 48 52.62							13.116	0.100	24.40				
B	00 05 42.283	45 48 35.14	0.11	0.11	19.951	0.156	333.212	0.447	9.037	0.073	54.26	0.07	2015.807	5	8
P	00 05 41.423	45 48 52.95							13.163	0.097	15.649				
B	00 05 42.279	45 48 35.04	0.03	0.03	19.681	0.042	333.156	0.124	9.031	0.040	214.259	0.04	2015.774	5	9
P	00 05 41.429	45 48 52.60							13.030	0.046	47.2910				
B	00 05 42.284	45 48 35.03	0.08	0.09	19.758	0.120	332.588	0.349	9.040	0.071	112.05	0.07	2015.779	5	9
P	00 05 41.414	45 48 52.57							13.087	0.086	21.17				
B	00 05 42.280	45 48 35.06	0.06	0.06	19.672	0.085	333.142	0.247	9.017	0.051	149.06	0.05	2015.782	5	9
P	00 05 41.430	45 48 52.61							13.036	0.056	43.71				
B	00 05 42.282	45 48 35.08	0.073	0.077	19.753	0.106	332.949	0.308	9.039	0.067			2015.785	25	10
P	00 05 41.423	45 48 52.67							13.086	0.080					
STT 30	**RA**	**Dec**	**dRA**	**dDec**	**Sep**	**ErrSep**	**PA**	**ErrPA**	**Mag**	**ErrMag**	**SNR**	**dVmag**	**Date**	**N**	
A	01 25 34.468	31 33 00.73	0.06	0.05	4.267	0.078	245.196	1.049	8.036	0.050	336.30	0.05	2015.782	1	11
B	01 25 34.165	31 32 58.94	0.06	0.05	4.267	0.078	245.196	1.049	11.540	0.053	57.36	0.05	2015.782	1	11
A	01 25 34.463	31 33 00.84	0.10	0.07	4.412	0.122	245.067	1.585	8.042	0.080	181.15	0.08	2015.785	5	12
B	01 25 34.150	31 32 58.98	0.10	0.07	4.412	0.122	245.067	1.585	11.567	0.111	13.72	0.08	2015.785	5	12
A	01 25 34.466	31 33 00.73	0.02	0.04	4.521	0.045	245.567	0.567	8.023	0.040	357.32	0.04	2015.774	5	13
B	01 25 34.144	31 32 58.86	0.02	0.04	4.521	0.045	245.567	0.567	11.599	0.051	34.32	0.04	2015.774	5	13
A	01 25 34.471	31 33 00.68	0.07	0.11	4.245	0.130	244.611	1.759	8.015	0.070	193.11	0.07	2015.779	5	13
B	01 25 34.171	31 32 58.86	0.07	0.11	4.245	0.130	244.611	1.759	11.341	0.076	34.71	0.07	2015.779	5	13
A	01 25 34.467	31 33 00.75	0.069	0.073	4.361	0.100	245.117	1.314	8.029	0.062			2015.780	16	14
B	01 25 34.157	31 32 58.91	0.069	0.073	4.361	0.100	245.117	1.314	11.512	0.077			2015.780	16	14

Table 2 continues on next page.

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Table 2 (continued). Photometry and astrometry results for the selected STT objects. Date is the Bessel epoch and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with number of images and exposure time given (Specifications of the used telescopes: See Acknowledgements). The average results over all used images are given in the line below the individual stacks in 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 30	RA	Dec	dRA	dDec	Sep	ErrSep	PA	ErrPA	Mag	ErrMag	SNR	dVmag	Date	N	Notes
A	01 25 34.468	31 33 00.73	0.06	0.05	56.689	0.078	105.668	0.079	8.036	0.050	336.30	0.05	2015.782	1	15
C	01 25 38.738	31 32 45.42							8.010	0.050	373.63				
A	01 25 34.463	31 33 00.84	0.10	0.07	56.518	0.122	105.675	0.124	8.042	0.080	181.15	0.08	2015.785	5	16
C	01 25 38.720	31 32 45.57							8.004	0.080	179.40				
A	01 25 34.466	31 33 00.73	0.02	0.04	56.707	0.045	105.684	0.045	8.023	0.040	357.32	0.04	2015.774	5	17
C	01 25 38.737	31 32 45.40							7.998	0.040	393.43				
A	01 25 34.471	31 33 00.68	0.07	0.11	56.681	0.130	105.639	0.132	8.015	0.070	193.11	0.07	2015.779	5	17
C	01 25 38.741	31 32 45.40							7.993	0.070	212.13				
A	**01 25 34.467**	**31 33 00.75**	**0.069**	**0.073**	**56.648**	**0.100**	**105.667**	**0.101**	**8.029**	**0.062**			**2015.780**	**16**	**18**
C	**01 25 38.734**	**31 32 45.45**							**8.001**	**0.062**					

STT 30	RA	Dec	dRA	dDec	Sep	ErrSep	PA	ErrPA	Mag	ErrMag	SNR	dVmag	Date	N	Notes
A	01 25 34.468	31 33 00.73	0.06	0.05	21.421	0.078	203.865	0.209	8.036	0.050	336.30	0.05	2015.782	1	19
D	01 25 33.790	31 32 41.14							14.207	0.076	18.37				
A	01 25 34.463	31 33 00.84	0.10	0.07	21.535	0.122	202.400	0.325	8.042	0.080	181.15	0.08	2015.785	5	20
D	01 25 33.821	31 32 40.93							14.567	0.162	7.20				
A	01 25 34.466	31 33 00.73	0.02	0.04	21.241	0.045	203.967	0.121	8.023	0.040	357.32	0.04	2015.774	5	21
D	01 25 33.791	31 32 41.32							14.360	0.059	24.28				
A	01 25 34.471	31 33 00.68	0.07	0.11	21.279	0.130	203.997	0.351	8.015	0.070	193.11	0.07	2015.779	5	22
D	01 25 33.794	31 32 41.24							14.247	0.134	8.97				
A	**01 25 34.467**	**31 33 00.75**	**0.069**	**0.073**	**21.368**	**0.100**	**203.554**	**0.268**	**8.029**	**0.062**			**2015.780**	**16**	**23**
D	**01 25 33.799**	**31 32 41.16**							**14.345**	**0.116**					

STT 94	RA	Dec	dRA	dDec	Sep	ErrSep	PA	ErrPA	Mag	ErrMag	SNR	dVmag	Date	N	Notes
A	05 07 22.261	50 18 20.27	0.09	0.07	17.889	0.114	305.192	0.365	7.359	0.070	153.76	0.07	2016.093	5	24
B	05 07 20.735	50 18 30.58							11.640	0.089	19.52				
A	05 07 22.267	50 18 20.25	0.05	0.07	17.887	0.086	305.394	0.276	7.375	0.090	197.24	0.09	2016.107	5	25
B	05 07 20.745	50 18 30.61							11.636	0.101	23.37				
A	05 07 22.287	50 18 19.44	0.12	0.10	18.006	0.156	304.815	0.497	7.373	0.123	40.17	0.12	2016.108	5	26
B	05 07 20.744	50 18 29.72							11.552	0.125	30.85				
A	05 07 22.269	50 18 19.88	0.10	0.12	17.988	0.156	304.894	0.498	7.255	0.110	190.96	0.11	2016.119	5	26
B	05 07 20.729	50 18 30.17							11.434	0.111	63.99				
A	**05 07 22.271**	**50 18 19.96**	**0.094**	**0.092**	**17.942**	**0.132**	**305.073**	**0.420**	**7.341**	**0.100**			**2016.107**	**20**	**3**
B	**05 07 20.738**	**50 18 30.27**							**11.566**	**0.107**					

STT 94	RA	Dec	dRA	dDec	Sep	ErrSep	PA	ErrPA	Mag	ErrMag	SNR	dVmag	Date	N	Notes
A	05 07 22.261	50 18 20.27	0.09	0.07	25.403	0.114	65.931	0.257	7.359	0.070	153.76	0.07	2016.093	5	27
C	05 07 24.682	50 18 30.63							12.121	0.099	14.95				
A	05 07 22.267	50 18 20.25	0.05	0.07	25.354	0.086	65.858	0.194	7.375	0.090	197.24	0.09	2016.107	5	27
C	05 07 24.682	50 18 30.62							12.288	0.122	12.61				
A	05 07 22.287	50 18 19.44	0.12	0.10	25.396	0.156	65.081	0.352	7.373	0.123	40.17	0.12	2016.108	5	28
C	05 07 24.691	50 18 30.14							12.012	0.127	24.71				
A	05 07 22.269	50 18 19.88	0.10	0.12	25.291	0.156	66.017	0.354	7.255	0.110	190.96	0.11	2016.119	5	28
C	05 07 24.681	50 18 30.16							12.035	0.113	44.52				
A	**05 07 22.271**	**50 18 19.96**	**0.094**	**0.092**	**25.360**	**0.132**	**65.722**	**0.297**	**7.341**	**0.100**			**2016.107**	**20**	**3**
C	**05 07 24.684**	**50 18 30.39**							**12.114**	**0.116**					

Table 2 concludes on next page.

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Table 2 (conclusion). Photometry and astrometry results for the selected STT objects. Date is the Bessel epoch and N is the number of images used for the reported values. iT in the Notes column indicates the telescope used with number of images and exposure time given (Specifications of the used telescopes: See Acknowledgements). The average results over all used images are given in the line below the individual stacks in 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 96	RA	Dec	dRA	dDec	Sep	ErrSep	PA	ErrPA	Mag	ErrMag	SNR	dVmag	Date	N	Notes
A	05 09 04.370	49 07 19.02	0.07	0.08	20.727	0.106	105.044	0.294	6.572	0.110	229.24	0.11	2016.093	4	29
B	05 09 06.409	49 07 13.64							12.043	0.128	15.96				
A	05 09 04.363	49 07 18.95	0.08	0.06	20.688	0.100	104.959	0.277	6.593	0.100	261.81	0.10	2016.107	5	30
B	05 09 06.399	49 07 13.61							12.142	0.131	12.29				
A	05 09 04.405	49 07 18.15	0.12	0.12	20.385	0.170	104.431	0.477	6.640	0.121	60.25	0.12	2016.108	5	31
B	05 09 06.416	49 07 13.07							12.143	0.127	25.26				
A	05 09 04.383	49 07 18.73	0.10	0.12	20.542	0.156	104.490	0.436	6.538	0.070	186.00	0.07	2016.119	5	31
B	05 09 06.409	49 07 13.59							12.209	0.073	48.83				
A	05 09 04.380	49 07 18.71	0.094	0.098	20.585	0.136	104.733	0.380	6.586	0.102			2016.107	19	3
B	05 09 06.408	49 07 13.48							12.134	0.118					
STT 103	**RA**	**Dec**	**dRA**	**dDec**	**Sep**	**ErrSep**	**PA**	**ErrPA**	**Mag**	**ErrMag**	**SNR**	**dVmag**	**Date**	**N**	**Notes**
A	05 18 10.599	33 22 15.11	0.10	0.12	3.929	0.156	56.994	2.277	4.573	0.100	416.07	0.10	2016.107	5	32
B	05 18 10.862	33 22 17.25							9.831	0.118	16.88				
A	05 18 10.599	33 22 14.94	0.11	0.12	3.603	0.163	53.762	2.587	4.552	0.120	340.72	0.12	2016.093	1	33
B	05 18 10.831	33 22 17.07							9.497	0.142	13.73				
A	05 18 10.599	33 22 15.02	0.105	0.120	3.764	0.160	55.448	2.427	4.563	0.110			2016.100	6	34
B	05 18 10.847	33 22 17.16							9.664	0.131					
STT 104	**RA**	**Dec**	**dRA**	**dDec**	**Sep**	**ErrSep**	**PA**	**ErrPA**	**Mag**	**ErrMag**	**SNR**	**dVmag**	**Date**	**N**	
A	05 23 12.642	47 01 17.59	0.11	0.09	21.371	0.142	189.307	0.381	6.849	0.110	204.77	0.11	2016.093	3	35
B	05 23 12.304	47 00 56.50							11.730	0.123	19.15				
A	05 23 12.644	47 01 17.55	0.07	0.06	21.427	0.092	189.227	0.247	6.837	0.090	227.72	0.09	2016.107	5	36
B	05 23 12.308	47 00 56.40							11.723	0.105	19.64				
A	05 23 12.666	47 01 17.29	0.12	0.08	21.325	0.144	189.857	0.387	6.644	0.071	80.81	0.07	2016.108	5	37
B	05 23 12.309	47 00 56.28							11.637	0.075	38.85				
A	05 23 12.647	47 01 17.44	0.10	0.11	21.195	0.149	189.077	0.402	6.721	0.070	210.90	0.07	2016.119	5	37
B	05 23 12.320	47 00 56.51							11.720	0.072	62.61				
A	05 23 12.650	47 01 17.47	0.102	0.087	21.329	0.134	189.367	0.359	6.763	0.087			2016.107	18	3
B	05 23 12.310	47 00 56.42							11.703	0.096					

Notes to Table 2

1. iT24 stack 5x1s. A too bright for reliable photometry
2. iT24 stack 5x3s. A too bright for reliable photometry
3. A too bright for reliable photometry
4. iT24 stack 5x1s. A and B too bright for reliable photometry
5. iT24 stack 5x3s. A and B too bright for reliable photometry
6. A and B too bright for reliable photometry
7. iT24 stack 5x1s. B too bright for reliable photometry
8. iT24 stack 5x1s. B too bright for reliable photometry. SNR P <20
9. iT24 stack 5x3s. B too bright for reliable photometry
10. B too bright for reliable photometry
11. iT24 1x3s. A too bright for reliable photometry. Touching star disks
12. iT24 stack 5x1s. A too bright for reliable photometry. Overlapping star disks. SNR B <20
13. iT24 stack 5x3s. A too bright for reliable photometry. Overlapping star disks
14. A too bright for reliable photometry
15. iT24 1x3s. A and B too bright for reliable photometry
16. iT24 stack 5x1s. A and C too bright for reliable photometry
17. iT24 stack 5x3s. A and C too bright for reliable photometry
18. A and C too bright for reliable photometry
19. iT24 1x3s. A too bright for reliable photometry. SNR D<20
20. iT24 stack 5x1s. A too bright for reliable photometry. SNR D<10
21. iT24 stack 5x3s. A too bright for reliable photometry
22. iT24 stack 5x3s. A too bright for reliable photometry. SNR D<10
23. A too bright for reliable photometry. SNR D<20
24. iT18 stack 5x3s. A too bright for reliable photometry. SNR B<20
25. iT18 stack 5x3s. A too bright for reliable photometry
26. iT24 stack 5x3s. Image quality rather low. A too bright for reliable photometry
27. iT18 stack 5x3s. A too bright for reliable photometry. SNR C<20
28. iT24 stack 5x3s. Image quality rather low. A too bright for reliable photometry
29. iT18 stack 4x3s. A too bright for reliable photometry. SNR B<20
30. iT18 stack 5x3s. A too bright for reliable photometry. SNR B<20
31. iT24 stack 5x3s. Image quality rather low. A too bright for reliable photometry
32. iT18 stack 5x1s. Heavily overlapping star disks. SNR B<20
33. iT18 1x1s. Heavily overlapping star disks. SNR B<20
34. A and B too bright for reliable photometry. A too bright for reliable astrometry
35. iT18 stack 3x3s. A too bright for reliable photometry. SNR B<20
36. iT18 stack 5x3s. A too bright for reliable photometry. SNR B<20
37. iT24 stack 5x3s. A too bright for reliable photometry
38. iT24 stack 5x3s. A too bright for reliable photometry

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Table 3. 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 19 B	**11.40**	-	-	**11.247**	**11.458**	One observation that WDS magnitude is about right and one suggesting as faint as 12.3
STT 29 B	**11.70**	**11.570**	-	**11.746**	**11.794**	**One observation suggesting WDS magnitude is correct and one suggesting a bit brighter**
STT 506 C	**10.80**	**10.830**	-	**10.969**	**10.983**	**One observation suggesting C to be a bit brighter than WDS value, one suggesting a magnitude of about 11.9**
STT 547 B	**9.15**	-	**9.096**	-	**9.039**	**No estimations made of magnitude**
STT 547 P	**13.40**	-	-	**13.134**	**13.086**	**One observation that P is brighter than WDS value, one that B is fainter than 13.0**
STT 30 B	**11.80**	**12.864**	-	-	**11.512**	**One observation suggesting B could be no brighter than the WDS value,one observation suggesting the WDS value is a bit too bright.**
STT 30 C	**8.06**	**7.986**	**8.923**	**8.715**	**8.001**	**Two observations that C is brigher than A (WDS magnitude of 8.09)**
STT 30 D	**14.00**	**15.730**	-	**14.376**	**14.345**	**Not seen by either of the two observers**
STT 94 B	**11.10**	-	-	**11.367**	**11.566**	**Two observations that B is fainter than the WDS value**
STT 94 C	**11.00**	**12.310**	-	**11.702**	**12.114**	**Two observations that C is fainter than B**
STT 96 B	**11.10**	-	-	**11.978**	**12.134**	**One observation that the WDS value for B is about right based on visual difficulty, one that B is much fainter than the WDS value**
STT 103 B	**10.60**	-	-	-	**9.664**	**Two observations that the WDS value for B is about right 1)**
STT 104 B	**11.10**	**9.070**	-	**11.879**	**11.703**	**One observation suggesting a magnitude of about 11.9 for B, one observation that the WDS value is about right**

Table 4. Astrometry Results Compared to WDS

	WDS Coordinates	WDS Sep	WDS PA	Astrometry Coordinates	Astrometry Sep	Astrometry PA
STT 19 AB	00:43:52.14 +37:33:38.0	9.70	115	00 43 52.144 +37 33 37.92	9.765	114.646
STT 29 AB	01:18:53.15 +39:57:48.0	20.10	266	01 18 53.143 +39 57 47.28	20.145	265.901
STT 506 AC	23:48:35.39 +36:16:28.4	21.10	80	23 48 35.380 +36 16 28.14	20.906	**81.417**
STT 547 AB	00:05:41.00 +45:48:37.4	6.0	187	00 05 42.365 +45 48 41.10	6.085	**188.220**
STT 547 BP	00:05:41.00 +45:48:37.4	18.10	340	00 05 42.365 +45 48 41.10	**19.753**	**332.949**
STT 30 AB	01:25:34.17 +31:33:01.9	4.60	245	01 25 34.467 +31 33 00.75	**4.361**	245.117
STT 30 AC	01:25:34.17 +31:33:01.9	57.20	106	01 25 34.467 +31 33 00.75	**56.648**	105.667
STT 30 AD	01:25:34.17 +31:33:01.9	21.40	195	01 25 34.467 +31 33 00.75	21.368	**203.554**
STT 94 AB	05:07:22.26 +50:18:20.2	17.90	305	05 07 22.271 +50 18 19.96	17.942	305.073
STT 94 AC	05:07:22.26 +50:18:20.2	24.90	66	05 07 22.271 +50 18 19.96	**25.360**	65.722
STT 96 AB	05:09:04.40 +49:07:18.8	20.60	105	05 09 04.380 +49 07 18.71	20.585	104.733
STT 103 AB *1)*	05:18:10.56 +33:22:17.8	4.10	55	05 18 10.599 +33 22 15.02	**3.764**	55.448
STT 104 AB	05:23:12.61 +47:01:17.9	21.40	190	05 23 12.650 +47 01 17.47	21.329	189.367

1) These results have to be taken with caution due to photometry and astrometry issues with the too bright primary (CCD saturation and overlapping star disks.

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Table 3.3: 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 19 AB	9.771	9.765	0.102	Yes	115.116	114.646	0.598	Yes
STT 29 AB	20.134	20.145	0.095	Yes	266.040	265.901	0.271	Yes
STT 506 AC	20.794	20.906	0.103	No	81.410	81.417	0.282	Yes
STT 547 AB	6.046	6.085	0.106	Yes	187.231	188.220	0.998	Yes
STT 547 BP 1)	18.752	19.753	0.106	No	337.258	332.949	0.308	No
STT 30 AC 2)	56.754	56.648	0.100	No	105.642	105.667	0.101	Yes
STT 30 AD 2)	21.261	21.368	0.100	No	203.050	203.554	0.268	No
STT 94 AB	17.883	17.942	0.132	Yes	305.126	305.073	0.420	Yes
STT 94 AC	25.357	25.360	0.132	Yes	65.729	65.722	0.297	Yes
STT 96 AB	20.757	20.580	0.136	No	104.970	104.733	0.380	Yes
STT 104 AB	21.328	21.329	0.134	Yes	189.508	189.367	0.359	Yes

1) "Negative" quality control result due to the high proper motion of STT 547 B; the given values for separation and PA of STT 547 BP should be quite correct for the given observation date.

2) "Negative" quality control result probably also due to the high proper motion of most but not all components of STT 30

(Continued from page 79)

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$$sep = \sqrt{\left[\left(RA_2 - RA_1\right)\cos\left(Dec_1\right)\right]^2 + \left(Dec_2 - Dec_1\right)^2}$$

in radians and .

$$PA = \arctan\left(\frac{RA_2 - RA_1 \cos(Dec_1)}{Dec_2 - Dec_1}\right)$$

in radians depending on quadrant

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