Measurements of some Tycho Double Stars – Follow Up Canis Minor and Columba

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Abstract: As follow up to our report "Visual Observation and Measurements of some Tycho Double Stars" we decided to have a look at some more wider TDS objects in other constellations but to replace the hapless visual observation task by counterchecking with existing Sky Survey images

Introduction

So far unconfirmed TDS objects are to be found in all constellations so the selected objects are more or less a random choice based on reasonable altitude for imaging with a remote telescope located in Australia. All the selected objects are in the constellations Canis Minor (CMi) or Columba (Col).

Further Research

One image was taken for the selected objects with iT27 with 3s exposure time. The RA/Dec coordinates resulting from plate solving with UCAC4 reference stars in the 10.5 to 14.5 magnitude range were used to calculate separation and postion angle using the formula provided by R. Buchheim (2008). *Err_Sep* is calculated as

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

with *dRA* and *dDec* as average RA and Dec plate solving errors. *Err_PA* is the error estimation for PA calculated as arctan(*Err_Sep/Sep*) in degrees assuming the worst case that *Err_Sep* points in the right angle to the direction of the separation means perpendicular to the separation vector. *Mag* is the photometry result based on UCAC4 reference stars with Vmags between 10.5 and 14.5mag. *Err_Mag* is calculated as

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

with *dVmag* as the average Vmag error over all used reference stars and *SNR* is the signal to noise ratio for the given star. The results are shown in Table 2.

Counter Check

All these results were visually counterchecked using Sky Survey images as described in Table 3.

An account of the methodology used for 2MASS Sky Survey images, its usefulness and limitations, will be given in a separate short article to appear in JDSO. It was found that, whereas the usual deep magnitude sky survey plates are limited to 5 arcseconds or wider in showing double stars, the IR images of 2MASS, taken in 1997-1999, can show double stars as elongated images down to about 1.5 arcseconds separation with moderate Δm (in IR). AladinLite shows a combined set of 2MASS images, which gives a first assessment. In Figures 1 through 10 are reproduced the J-band 2MASS images or sometimes K-band. Both J-band and K-band

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Table 1. WDS values per begin of 2016 for the selected unconfirmed TDS/TDT objects in Canis Minor and Columba with separation larger than 1.5 arcseconds

Name	Comp	WDS ID	RA	Dec	Sep	M1	M2	PA	Con
TDS360	AB	07212+0511	07:21:09.941	+05:11:19.2	1.5	11.33	11.52	148	CMi
TDS403	AB	07437+0743	07:43:40.900	+07:42:40.8	1.5	10.39	11.69	130	CMi
TDS4528	AB	07095+0247	07:09:28.400	+02:47:07.7	1.5	11.22	11.77	256	CMi
TDS4547	AB	07105+0434	07:10:30.830	+04:34:06.2	2.3	11.32	12.70	4	CMi
TDS4690	AB	07182+0906	07:18:09.119	+09:05:32.0	1.6	11.56	11.92	184	CMi
TDS4767	AB	07240+0638	07:24:00.340	+06:38:16.8	3.7	12.49	12.57	207	CMi
TDS4828	AB	07279+0013	07:27:53.050	+00:12:45.7	1.5	11.59	12.13	229	CMi
TDS4900	AB	07319+0004	07:31:55.950	+00:04:06.9	1.8	11.20	12.36	259	CMi
TDS4967	AB	07355+0256	07:35:30.270	+02:56:19.7	2.3	10.85	12.02	146	CMi
TDS5012	AB	07388+0626	07:38:48.360	+06:25:44.4	2.4	11.52	12.68	156	CMi
TDS5052	AB	07409+1108	07:40:54.989	+11:08:27.8	1.9	11.70	12.03	255	CMi
TDS5065	AB	07413+0452	07:41:16.051	+04:52:02.4	1.5	11.32	12.13	34	CMi
TDS5087	AB	07422+0431	07:42:09.370	+04:31:17.4	2.2	11.36	12.50	179	CMi
TDS5571	AB	08091+0212	08:09:06.021	+02:12:08.7	1.6	10.75	11.95	305	CMi
TDS3063	AB	05061-4152	05:06:03.931	-41:51:52.1	2.0	10.09	12.09	326	Col
TDS3113	AB	05132-4152	05:13:10.791	-41:52:03.2	1.5	11.62	11.92	36	Col
TDS3176	AB	05240-3719	05:24:02.210	-37:19:05.9	1.5	11.37	12.11	216	Col
TDS3297	AB	05428-2919	05:42:47.701	-29:18:33.5	2.0	10.19	12.36	144	Col
TDS3391	AB	05525-4012	05:52:28.400	-40:11:44.8	2.0	11.55	12.34	203	Col
TDS3529	AB	06038-3307	06:03:50.440	-33:06:38.2	2.5	11.75	12.01	160	Col
TDS3586	AB	06088-2806	06:08:48.569	-28:05:30.0	2.2	11.15	12.69	128	Col
TDS3614	AB	06115-4151	06:11:31.110	-41:50:49.8	1.7	11.45	13.26	296	Col
TDS3731	AB	06194-3322	06:19:26.080	-33:22:18.4	2.3	11.22	12.76	335	Col
TDS3846	AB	06277-3316	06:27:43.730	-33:15:51.6	1.8	11.36	13.04	224	Col
TDS3852	AB	06279-4140	06:27:56.030	-41:40:07.8	1.8	11.48	12.17	227	Col
TDS3891	AB	06313-3438	06:31:19.950	-34:37:44.5	2.1	11.49	12.24	272	Col

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Table 2. Astrometry and photometry results for the selected TDS/TDT components in CMi and Col. Date is the Bessel epoch of the observation and N is the number of images used for the reported values. iT27 in the Notes column indicates the telescope used with number of images and exposure time given (Specifications of iT27: See Acknowledgements).

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
TDS 360	A	07 21 09.888	05 11 20.11							10.856	0.111	63.65				iT27 1x3s. Overlapping star disks, photometry results questionable besides being similar bright. Astrometry result plausible
				0.21	0.19	2.033	0.283	136.311	7.931				0.11	2016.117	1	
	B	07 21 09.982	05 11 18.64							10.891	0.111	82.11				
TDS 403	A	07 43 40.834	07 42 41.50							10.639	0.080	141.59				iT27 1x3s. Overlapping star disks, photometry results questionable besides being similar bright. Astrometry result plausible
				0.18	0.18	2.223	0.255	132.084	6.532				0.08	2016.117	1	
	B	07 43 40.945	07 42 40.01							10.742	0.080	150.94				
TDS 4528	A	07 09 28.395	02 47 07.57							11.227	0.101	105.45				iT27 1x3s. No hint of elongation, bogus assumed
				0.20	0.17	-	0.262	-	-				0.10	2016.117	1	
	B	-	-							-	-	-				
TDS 4547	A	07 10 30.803	04 34 06.30							11.460	0.071	114.12				iT27 1x3s. Smallest hint of elongation, but not conclusive. Bogus assumed or at least far smaller separation than 2.3"
				0.21	0.18	-	0.277	-	-				0.07	2016.117	1	
	B	-	-							-	-	-				
TDS 4690	A	07 18 09.096	09 05 31.97							11.814	0.112	58.84				iT27 1x3s. Hint of elongation, but of unequal bright pair
				0.11	0.11	1.600	0.156	181.061	5.552				0.11	2016.237	1	
	B	07 18 09.094	09 05 30.37							12.554	0.117	25.94				
TDS 4767	A	07 24 00.338	06 38 16.82							12.012	0.081	91.98				iT27 1x3s. Only "primary" resolved, no trace of a 3.7" companion, bogus assumed. Nearby UCAC4-484-036641 optical pair
				0.17	0.16	-	0.233	-	-				0.08	2016.117	1	
	B	-	-							-	-	-				
UCAC4-484-036641	A	07 24 21.012	06 40 32.06							10.762	0.081	115.04				iT27 1x3s. Optical pair near TDS4767
				0.17	0.16	3.280	0.233	245.308	4.072				0.08	2016.117	1	
	B	07 24 20.812	06 40 30.69							12.578	0.089	26.82				
TDS 4828	A	07 27 53.039	00 12 45.56							11.716	0.101	70.53				iT27 1x3s. No hint of elongation, bogus assumed
				0.18	0.16	-	0.241	-	-				0.10	2016.117	1	
	B	-	-							-	-	-				
TDS 4900	A	07 31 55.935	00 04 06.90							11.289	0.071	83.70				iT27 1x3s. No hint of elongation, bogus assumed
				0.18	0.18	-	0.255	-	-				0.07	2016.117	1	
	B	-	-							-	-	-				

Table 2(continued) . Astrometry and photometry results for the selected TDS/TDT components in CMi and Col. Date is the Bessel epoch of the observation and N is the number of images used for the reported values. iT27 in the Notes column indicates the telescope used with number of images and exposure time given (Specifications of iT27: See Acknowledgements).

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
TDS 4967	A	07 35 30.254	02 56 19.58	0.18	0.16	-	0.241	-	-	10.919	0.071	127.10	0.07	2016.117	1	iT27 1x3s. No hint of elongation, bogus assumed
	B	-	-							-	-	-				
TDS 5012	A	07 38 48.376	06 25 43.95	0.10	0.10	2.250	0.141	146.195	3.596	11.258	0.111	60.71	0.11	2016.234	1	iT27 1x3s. Distinct elongation, touching/ overlapping star disks
	B	07 38 48.460	06 25 42.08							12.512	0.116	29.91				
TDS 5052	A	07 40 54.980	11 08 27.88	0.10	0.12	-	0.156	-	-	12.335	0.081	72.30	0.08	2016.234	1	iT27 1x3s. No hint of elongation, bogus assumed
	B	-	-							-	-	-				
TDS 5065	A	07 41 16.052	04 52 02.50	0.17	0.16	-	0.233	-	-	11.284	0.070	136.22	0.07	2016.117	1	iT27 1x3s. No hint of elongation, bogus assumed
	B	-	-							-	-	-				
TDS 5087	A	07 42 09.378	04 31 17.20	0.18	0.14	-	0.228	-	-	11.099	0.090	131.96	0.09	2016.117	1	iT27 1x3s. No hint of elongation, bogus assumed
	B	-	-							-	-	-				
TDS 5571	A	08 09 06.028	02 12 08.63	0.09	0.12	-	0.150	-	-	10.695	0.051	128.19	0.05	2016.234	1	iT27 1x3s. Hint of elongation in the right direction - but this is the case with all stars in the image, obviously tracking error. Bogus assumed
	B	-	-							-	-	-				
TDS 3063	A	05 06 03.975	-41 51 52.12	0.21	0.12	-	0.242	-	-	9.976	0.091	83.75	0.09	2016.120	1	iT27 1x3s. No resolution, not even a hint of an elongation. Bogus assumed
	B	-	-							-	-	-				
TDS 3113	A	05 13 10.767	-41 52 02.91	0.19	0.18	1.466	0.262	47.000	10.121	11.154	0.151	79.24	0.15	2016.120	1	iT27 1x3s. Elongation not very distinctive but measurement seems with the exception of PA rather a confirmation of the current WDS catalog data
	B	05 13 10.863	-41 52 01.91							11.168	0.151	83.89				
TDS 3176	A	05 24 02.211	-37 19 05.74	0.20	0.20	1.964	0.283	209.469	8.195	11.140	0.111	71.84	0.11	2016.120	1	iT27 1x3s. Elongation not very distinctive but measurement seems with the exception of mag B rather a confirmation of the current WDS catalog data
	B	05 24 02.130	-37 19 07.45							11.147	0.112	57.10				

Table 2(conclusion) . Astrometry and photometry results for the selected TDS/TDT components in CMi and Col. Date is the Bessel epoch of the observation and N is the number of images used for the reported values. iT27 in the Notes column indicates the telescope used with number of images and exposure time given (Specifications of iT27: See Acknowledgements).

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
TDS 3297	A	05 42 47.667	-29 18 33.73	0.17	0.16	-	0.233	-	-	10.082	0.091	89.68	0.09	2016.120	1	iT27 1x3s. No resolution, not even a hint of an elongation. Bogus assumed
	B	-	-							-	-	-				
TDS 3391	A	05 52 28.378	-40 11 44.43	0.19	0.22	-	0.291	-	-	11.796	0.092	58.21	0.09	2016.120	1	iT27 1x3s. No resolution, not even a hint of an elongation. Bogus assumed
	B	-	-							-	-	-				
TDS 3529	A	06 03 50.378	-33 06 37.28	0.21	0.16	2.374	0.264	153.263	6.346	11.402	0.121	60.59	0.12	2016.120	1	iT27 1x3s. Touching star disks. With the exception of mags A and B rather a confirmation of the current WDS catalog data
	B	06 03 50.463	-33 06 39.40							11.566	0.122	51.89				
TDS 3586	A	06 08 48.560	-28 05 29.69	0.22	0.27	-	0.348	-	-	11.193	0.103	42.37	0.10	2016.120	1	iT27 1x3s. No resolution, not even a hint of an elongation. Bogus assumed
	B	-	-							-	-	-				
TDS 3614	A	06 11 31.087	-41 50 49.69	0.16	0.15	-	0.219	-	-	11.192	0.071	93.77	0.07	2016.120	1	iT27 1x3s. No resolution, not even a hint of an elongation. Bogus assumed
	B	-	-							-	-	-				
TDS 3731	A	06 19 26.077	-33 22 18.50	0.14	0.17	-	0.220	-	-	11.124	0.071	113.21	0.07	2016.120	1	iT27 1x3s. No resolution, not even a hint of an elongation. Bogus assumed
	B	-	-							-	-	-				
TDS 3846	A	06 27 43.725	-33 15 51.33	0.17	0.15	-	0.227	-	-	11.381	0.061	94.77	0.06	2016.120	1	iT27 1x3s. No resolution, not even a hint of an elongation. Bogus assumed
	B	-	-							-	-	-				
TDS 3852	A	06 27 56.016	-41 40 07.80	0.20	0.24	-	0.312	-	-	11.567	0.081	88.78	0.08	2016.120	1	iT27 1x3s. No resolution, not even a hint of an elongation. Bogus assumed
	B	-	-							-	-	-				
TDS 3891	A	06 31 19.940	-34 37 44.23	0.20	0.15	-	0.250	-	-	12.239	0.062	70.88	0.06	2016.120	1	iT27 1x3s. No resolution, not even a hint of an elongation. Bogus assumed
	B	-	-							-	-	-				

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Table 3. Results countercheck TDS objects in CMi and Col by Sky Survey images

Name		WDS ID	Notes
TDS360	AB	07212+0511	AladinLite 2MASS elongated image, out of round in PA ~150/330. 2MASS J 1999 clear elongation in approx PA of Tycho. **Double.**
TDS403	AB	07437+0743	AladinLite 2MASS rather lumpy artefacted image; not useful. 2MASS J 1999 fairly neat symmetrical single image. Some extension to West? 2MASS K 1999 slightly different from J image, but pretty symmetrical. Slight impression of E-W extension. **Likely single. Does not fit Tycho numbers; image is overexposed.**
TDS4528	AB	07095+0247	AladinLite 2MASS fairly round image, no E-W elongation. 2MASS J 1999 pretty regular symmetrical image. Pixels slightly brighter E than W. However, does not show elongation as well, so **probably single.**
TDS4547	AB	07105+0434	AladinLite 2MASS slightly out of round but more E-W; likely single. 2MASS J 1999 neat symmetrical single star; no extension; pixels of pretty regular brightness symmetrically. **Single.**
TDS4690	AB	07182+0906	AladinLite 2MASS slight elongation offset a little from N-S; PA ~200. 2MASS J 1999 Somewhat asymmetrical extended image slightly off N-S line; image suggests PA nearer to ~200. **Double.** K-band image: Some elongation, PA larger than Tycho, ~190+.
TDS4767	AB	07240+0638	AladinLite 2MASS adjoining star to SSE. Both stars neatly single, nicely round. 2MASS J 1999 Two regular single star images (8.5" pair). Single regular image for TDS4767. **Clearly single.**
TDS4828	AB	07279+0013	AladinLite 2MASS single nicely round star 2MASS J 1999 pretty regular symmetrical single image; slight variations in pixel brightness, no sign of elongation. **Single.**
TDS4900	AB	07319+0004	AladinLite 2MASS neat symmetrical round single star. 2MASS J 1998 regular quite symmetrical single image. Some pixel brightness variation. 2MASS K 1998 fairly symmetrical image, some pixel brightness variations. Any extension hinted at is N-S, not E-W. **Single.**
TDS4967	AB	07355+0256	AladinLite 2MASS quite neat and symmetrical round star image. 2MASS J 1999 pretty regular single-looking image. Slight variations in pixel brightness, but no sign of elongation. 2MASS K 1999 Similar to J image, but pixel brightness more regular. No elongation anywhere. Clearly **single.**
TDS5012	AB	07388+0626	AladinLite 2MASS clearly elongated slightly unequal double overlapped. 2MASS J 1999 clearly elongated double in Tycho PA..... **Double.**
TDS5052	AB	07409+1108	AladinLite 2MASS v slightly out of round star, but not in PA ~255; perhaps ~320/330. 2MASS J 1999 fairly regular, symmetrical single-looking image. 2MASS K 1999 slightly different pattern of pixel brightness; but not a good fit for Tycho. **Likely single.**
TDS5065	AB	07413+0452	AladinLite 2MASS pretty round symmetrical single image. 2MASS J 1999 fairly symmetrical image, slight hint of elongation E-W (not in Tycho PA). 2MASS K 1999 fairly regular symmetrical image, likely single; slightly different from J. **Likely single.**
TDS5087	AB	07422+0431	AladinLite 2MASS fairly good symmetrical single image. 2MASS J 1999 fairly symmetrical single image. K-band image similar. **Likely single.**
TDS5571	AB	08091+0212	AladinLite 2MASS pretty good round star. 2MASS J 1997 quite symmetrical single image. K-band image similar, looks single. **Likely single.**
TDS3063	AB	05061-4152	AladinLite 2MASS nearly circular star image. 2MASS J 1998 fairly regular (symmetrical) image, **single.**
TDS3113	AB	05132-4152	AladinLite 2MASS slight elongation in PA ~40/220. 2MASS J 1998 some elongation clearly present; K band similar. **Probably double,** though near the limit of detectability.

Table 3 concludes on next page.

Table 3 (conclusion). Results countercheck TDS objects in CMi and Col by Sky Survey images

Name		WDS ID	Notes
TDS3113	AB	05132-4152	AladinLite 2MASS slight elongation in PA ~40/220. 2MASS J 1998 some elongation clearly present; K band similar. **Probably double,** though near the limit of detectability.
TDS3176	AB	05240-3719	AladinLite 2MASS slightly out of round/oval in PA ~210/030 2MASS J 1999 clear elongation NW/SE. **Double.**
TDS3297	AB	05428-2919	AladinLite DSS 2MASS no sign of double; round. 2MASS J 1998 quite regular symmetrical image. Appears **single.**
TDS3391	AB	05525-4012	AladinLite 2MASS fairly circular image. 2MASS J 1999 Image roughly symmetrical, but brighter to N and E. K-band image similar. **Likely single.** **Also:** Star nearby SSW is marked double by UCAC. It shows asymmetry in K band image. Perhaps 2.0" in PA ~125/305. It is TYC 7602-931-1: on AladinLite 2MASS hint only of elongation. Does this suggest an ID problem? - a need to establish which is meant to be the double? However this ucac4 double does not fit the Tycho PA.
TDS3529	AB	06038-3307	AladinLite DSS 2MASS some elongation (egg shape) in PA ~150. 2MASS J 1999 distinct elongation in PA ~160; obvious contrast with nearby star to SE which is single. **Double.**
TDS3586	AB	06088-2806	AladinLite 2MASS near-circular image, faint hint of elongation N-S? 2MASS J 1999 symmetrical image but with slight brightness variation suggests slight E-W asymmetry. K band similar. Assessed **single.**
TDS3614	AB	06115-4151	AladinLite 2MASS fairly regular round image. 2MASS J 1997 image pretty symmetrical. **Likely single.**
TDS3731	AB	06194-3322	AladinLite 2MASS fairly round single. 2MASS J 1999 Reasonably symmetrical image; slightly brighter pixels to West. K image also symmetrical and less pixel brightness variation. **Probably single.**
TDS3846	AB	06277-3316	AladinLite 2MASS circular single. 2MASS J 1999 Symmetrical, but hint of N-S elongation on brightness only, which does not fit Tycho PA. **Likely single.**
TDS3852	AB	06279-4140	AladinLite 2MASS circular disc, single. 2MASS J 1999 looks single, though with slight N-S asymmetry of pixel brightness that does not fit Tycho PA. No elongation as such. K image similar to J. **Single.**
TDS3891	AB	06313-3438	AladinLite 2MASS nicely round star. 2MASS J 1999 Symmetrical image, but impression of brightness pattern N-S brighter, E-W dimmer (does not fit Tycho PA). K band image similar to J. **Likely single.**

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Images from 2MASS survey: data is from Tycho in WDS for ~1991. First, some genuine pairs, including one long known, RST 1289, of similar magnitudes (10.98, 11.98) to many Tycho pairs.

Figure 1. RST 1289 1.9″ PA 111

Figure 2: TDS 360 1.5″ PA 148

Figure 3: TDS3113 1.5″ PA 036

Figure 4: TDS3176 1.5″ PA 216

Then, some of the pairs assumed bogus from image examination, plus TDS4547 where there was ambiguity in the new image. These are 2MASS J images.

Figure 5: TDS4547 2.3″ PA 004

Figure 6: TDS4767 3.7″ PA 207

Figure 7: TDS5052 1.9″ PA 255

Figure 8: TDS3586 2.2″ PA 128

And one TDS object where there was uncertainty between the new image and the 2MASS images: TDS403. Tycho lists 1.5", PA 130, mags 10.39 and 11.69.

Figure 9: TDS403 2MASS J

Image 10: TDS403 2MASS K

(Continued from page 547)

were always examined, and sometimes H-band as well. The conclusions given are from comparing the Tycho Position Angle and Separation with the images, within the limits of resolution possible from 2MASS.

Summary

Overall in most cases the measurement results based on own images are well confirmed by the impressions based on 2MASS Sky Survey images and vice versa: 6 confirmations out of 26 objects, a non-conclusive result for TDS403, a small probability for TDS4547 not being bogus but simply wrong in separation and 18 most probably bogus.

The results obtained here, and in our previous paper, raise questions as to the reliability of the methodology and algorithms used for the much enlarged second version of the Tycho Double Star Catalogue. If only a minority of objects prove to be double, or even if many of them are double but do not fit the published measures, we have a significant problem of analytic methodology on the part of the catalogue creators. And if the same or similar methodologies are to be used for interpreting Gaia data, this will create huge problems of confirmation as many of the Gaia objects will not be accessible by other means.

We intend to produce future papers like this one. Increasing the survey of TDS/TDT objects should improve the statistical base and be of help for analytical treatment of possible patterns in the errors. The limitation the present authors have is inadequate equipment for studying the large number of Tycho objects with less than about 1.5" claimed separation. An attempt will be made to rectify that. But, in the meantime, it should be a matter of concern that a high proportion of the wider objects in the TDS/TDT catalogue appear to be bogus. These are objects well within the assessed capability of the system used. Most Tycho doubles have closer listed separations than we can access, and many of them are closer than the original assessed capability of Tycho, which suggests that the proportion of bogus objects could be even larger among the closer listings.

Potential Further Research

Besides continuing to observe and image TDS objects wide enough to be resolved with the given equipment it might be of interest to image also rather close pairs for measurement of the combined magnitude and to compare this value with the calculated combined magnitude based on the current WDS catalog data – crass differences here should indicate questionable objects.

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- Washington Double Star Catalog as data source for the selected objects
- iTelescope: Images were taken with iT27: 700mm CDK with 4531mm focal length. CCD: FLI PL09000. Resolution 0.53 arcsec/pixel. V-filter. Located in Siding Spring, Australia. Elevation 1122m
- 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 and for high precision plate solving
- Tycho Double Star catalog for counterchecks
- 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 v4.8.2.405 for astrometry and photometry measurements

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