Visual Observation and Measurements of Some Tycho Double Stars

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Abstract: No humble human visual observer would dare to challenge a robotic telescope – yet many Tycho based results are highly questionable to utterly wrong as is shown on several examples.

1. Introduction

Several years ago I observed mostly STF doubles as these objects have a record with many observations, are well documented, and reasonable targets for small amateur telescopes. Session planning based on the current WDS catalog data at the time of the observations assumed that recent measurements would provide most precise data. One of the selected objects was STF442, with 2.5” separation and magnitudes 10.06 and 13.0 (WDS values per end of 2014) – obviously not suited for a 120mm refractor, so it took me some time to give it a try in a night with excellent seeing. To my surprise resolution was easy and both components were rather equal bright. I checked then the STF catalog directly and found that F. Struve estimated the components had magnitudes 9.9 and 10.4. I then contacted Brian Mason at the USNO and it was determined that the 13 magnitude for the companion was based on Tycho, but obviously wrong, and the WDS catalog entry was accordingly changed to 10.5 magnitude for the secondary to keep the original Δm. This was my first experience with incorrect Tycho data; anecdotal evidence and no reason for a follow up.

But recently I selected objects from the WDS catalog double stars suited for observation with telescopes in the 150 to 200 mm aperture range in Cygnus. This resulted in several hundred doubles with different discoverer designations, but a good part were TDS and TDT objects in the range of 1.5 to 2.5” separation and brightness in the 11 to 12 magnitude range. First, visual observation results were not very convincing, so I checked the data on these objects in more detail. I noticed for the first time that most of these objects showed only one first/last observation indicating that Tycho was not only the “discoverer” of these doubles, but that so far no other observations were available to confirm these “discoveries”.

I then checked directly the Tycho Double Star catalog and found about 98,000 objects meaning about 49,000 doubles as all components were listed separately. About 80% of these objects show a WDS ID indicating that they are included in the WDS catalog, but mostly with well-known discoverer designations. Why the rest is not included in the WDS catalog is not entirely clear to me, but I assume the data for these objects is suspect from the first impression.

I then checked the WDS catalog and found about 9,800 objects with a TDS designation and about 4,200 objects with a TDT designation, so we have in total about 14,000 WDS objects with Tycho as discoverer (most or all of them obviously based on the report of Fabricius *et al.*, 2002) As mentioned before, most of them are without a confirming second observation. The vast majority of these objects are in the range of less than 1” separation with quite faint components. So they are not really suited for visual amateur observation and certainly also quite difficult for imaging unless perhaps with speckle interferometry. From the less than 3000 TDS objects with separation 1.5” or larger only about 600 show at least a second confirming observation and about 200 are listed with “X” in the notes section marking bogus doubles giving a ratio from 3:1 for confirmations against bogus.

I then selected a few of TDS and TDT objects in Cygnus in the 1.5” or larger separation range with only one observation to give it a try with the best suited iTelescope equipment available to me. Images with 3 second exposure time taken with remote telescope iT24 (for specifications see Acknowledgements) should, according to my experience, provide at least significant elongations if not clear separation of such objects, depending on the magnitudes of the components. Table 1 lists the WDS values for these selected objects.

2. Further Research

One image was taken for the selected objects with iT24 with 3 s exposure time; at least this was the intention, because the weather did not cooperate for an extended period, I missed several of the planned objects. The conditions for visual observations were even worse so that I managed this for only a small part of the list. The images I got were initially plate solved with AAVSO VPhot and then processed with Astrometrica with the results given in Table 2 with missed objects not listed.

In the Table 2 headings, "M1(2) new" means photometry result with V-filter for primary and secondary;

$$\mathrm{ErrM1(2)} = \sqrt{dV_{mag}^2 + Err(SNR)^2}$$

"Err M1(2)" stands for the calculated error estimation where dVmag is the average magnitude error from plate solving and SNR is the signal to noise ratio (not reported here). Date is Bessel epoch of observation.

Counter Check

As these results with only one confirmation out of (not counting the one declared bogus) 16 measured objects were not positive, I decided to have a look at Tycho doubles in another constellation high in altitude from a location in Australia. This allowed me to use the iTelescope iT27 with a somewhat better 0.53"/pixel resolution in Siding Spring and to invite Ross Gould to contribute visual observations. The obvious choice was the constellation Phoenix with the unconfirmed TDS/ TDT objects selected by separation larger than 1.5 arcseconds (including RST38 suggested by Ross as reference object with similar data but several confirming observations) shown in Table 3.

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Table 1: WDS values per beginning of 2016 for the selected unconfirmed TDS/TDT objects in Cygnus with separation larger than 1.5 arcseconds

Name	Comp	WDS ID	RA	Dec	Sep	M1	M2	PA
TDS1066	AB	20230+3752	20:23:00.563	+37:51:51.507	1.6	11.08	12.15	269
TDS1070	AB	20243+3811	20:24:18.572	+38:10:30.904	1.9	10.53	11.97	203
TDT2234	AB	20236+3817	20:23:38.850	+38:17:03.596	1.9	11.97	12.06	230
TDT3230	AB	21545+4052	21:54:30.980	+40:52:16.198	2.0	12.14	12.23	222
TDT3234	AB	21548+4310	21:54:50.817	+43:09:55.006	2.0	11.34	12.42	343
TDT3212	AB	21525+4332	21:52:31.463	+43:32:11.506	1.7	10.81	12.27	41
TDT3195	AB	21513+4428	21:51:19.262	+44:27:42.396	1.9	11.09	11.98	203
TDT3301	AB	22022+4510	22:02:09.220	+45:09:47.700	1.6	10.93	11.78	121
TDT3131	AB	21448+4534	21:44:48.581	+45:33:32.997	1.7	10.10	12.05	106
TDT3240	AB	21552+4700	21:55:11.829	+47:00:05.905	1.7	11.66	12.10	7
TDT3002	AB	21304+4926	21:30:21.980	+49:26:14.094	2.0	11.30	11.75	295
TDT3180	AB	21495+5019	21:49:32.942	+50:18:44.904	1.9	11.21	12.12	71
TDT3128	AB	21443+5024	21:44:15.801	+50:23:31.702	1.7	11.54	11.99	198
TDT3087	AB	21396+5025	21:39:37.778	+50:25:18.805	1.9	11.31	11.80	126
TDT3281	AB	21599+5116	21:59:51.541	+51:16:26.998	1.9	10.46	12.35	284
TDT3161	AB	21481+5156	21:48:07.138	+51:55:36.795	2.5	10.76	12.38	223
TDT3065	AB	21375+5157	21:37:28.180	+51:57:28.402	1.9	11.72	12.24	88
TDT3015	AB	21322+5336	21:32:09.137	+53:36:10.500	1.9	11.95	12.17	300
TDT3099	AB	21403+5338	21:40:20.439	+53:37:34.106	2.1	11.43	12.27	259
TDT3181	AB	21496+5350	21:49:33.491	+53:50:03.195	1.6	11.63	12.13	265
TDT3135	AB	21451+5432	21:45:08.569	+54:31:40.896	2.2	11.57	12.25	194
TDT3252	AB	21568+5506	21:56:47.059	+55:05:38.200	2.1	11.25	12.35	18

Table 2. Photometry results for the selected TDS/TDT components in Cygnus.

Name	WDS ID	M1 new	Err M1	M2 new	Err M2	Date	Notes
TDS1066	20230+3752	11.065	0.071	-	-	2015.886	No resolution, not even an elongation. Visual observation with 185mm refractor: Only faint single star, no resolution. WDS listed as Bogus and as such confirmed
TDS1070	20243+3811	10.382	0.080	-	-	2015.886	No resolution, not even an elongation. Same result with visual observation with 185mm refractor. Dec position error ~0.6". Bogus assumed
TDT2234	20236+3817	12.284	0.082	-	-	2015.886	No resolution, not even an elongation. Same result with visual observation with 185mm refractor. Bogus assumed
TDT3015	21322+5336	11.812	0.061	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3065	21375+5157	11.764	0.081	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3087	21396+5025	11.276	0.091	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3099	21403+5338	11.689	0.081	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3131	21448+4534	9.985	0.100	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3161	21481+5156	10.438	0.090	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3181	21496+5350	11.604	0.081	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3195	21513+4428	10.950	0.091	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3212	21525+4332	10.675	0.081	11.296	0.081	2015.847	Clear elongation with overlapping star disks - border case for separated photometry but possible. Visual observation with 185mm refractor positive - resolution in moments of good seeing
TDT3230	21545+4052	12.098	0.062	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3234	21548+4310	11.198	0.071	-	-	2015.847	No resolution, not even an elongation. Visual observation with 185mm refractor: Only faint single star, no resolution. Bogus assumed
TDT3240	21552+4700	11.429	0.091	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed
TDT3281	21599+5116	10.284	0.100	-	-	2015.847	No resolution, hint of an elongation but with wrong PA. No visual observation. Bogus assumed
TDT3301	22022+4510	10.711	0.080	-	-	2015.847	No resolution, not even an elongation. No visual observation. Bogus assumed

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Photometry and Astrometry in Phoenix

For each selected object, one 3 s image was taken with iT27 and, after the initial plate solving with AAVSO, was VPhot processed with Astrometrica. With the exception of TDT4192 all results listed in Table 4 were instantly obvious. Ross had bad luck with the weather making conclusive visual observation results impossible so we got here only a few hints (see Notes column).

Astrometry results are based on the formulae provided by R. Buchheim (2008) for calculating Sep and PA. Sep is separation and is calculated as

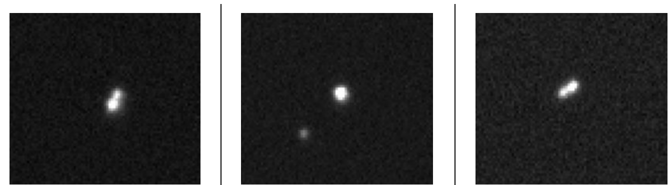
$$\text{Sep} = \sqrt{\left[\left(RA_2 - RA_1\right)\cos(Dec1)\right]^2 + \left(Dec_2 - Dec_1\right)^2}$$

in radians. Err Sep is the error estimation for Sep calculated as

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

ErrMag is the error estimation for Vmag results calculated as

$$ErrMag = \sqrt{dV_{mag}^2 + ErrSNR^2}$$



TDT 4218 – 2.3” TDT 4192 – 2.3” Bogus RST 38 – 2.4”

Figure 1. Images of three measured doubles.

with Err_SNR calculated as $2.5*\text{Log}_{10}(1+1/\text{SNR})$.

PA is calculated as

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

in radians and Err_PA is the error estimation for PA calculated as arctan(Err_Sep/Sep) in degrees, assuming the worst case that dSep points in the right angle to the direction of the separation means perpendicular to the separation vector

Just for visual comparison, Figure 1 shows three images side by side.

Additional Research

This again rather meager result in terms of confirming WDS Tycho Double Stars with only 1 positive

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Table 3: WDS values per beginning of 2016 for the selected TDS/TDT components in Phe plus RST38

WDS ID	Name	RA	Dec	Sep	M1	M2	PA
00065-5200	TDS1294	00:06:31.770	-52:00:17.303	2.3	12.20	13.42	224
00071-4152	TDS1299	00:07:05.950	-41:52:26.896	1.7	12.02	12.13	269
00087-4057	TDS1311	00:08:39.600	-40:56:32.194	2.3	11.56	12.82	137
00166-4347	TDS1376	00:16:34.590	-43:47:25.294	2.9	11.49	13.02	115
00171-5039	TDS1382	00:17:04.210	-50:38:35.794	2.1	11.92	12.97	119
00409-4743	TDS1564	00:40:53.840	-47:42:32.605	1.7	12.75	12.90	251
00467-4805	TDS1608	00:46:43.780	-48:05:18.604	2.3	11.96	13.15	232
01297-4023	TDS1893	01:29:43.220	-40:23:17.200	2.3	11.63	13.31	313
01322-4006	TDS1904	01:32:13.350	-40:05:43.103	1.8	12.35	12.87	69
01440-4538	TDS1973	01:43:57.830	-45:37:54.403	2.5	12.41	12.81	215
01496-4352	TDS2016	01:49:34.610	-43:51:47.799	2.1	11.85	12.25	222
23469-4150	TDT4189	23:46:54.670	-41:50:19.400	2.6	11.79	12.35	211
23472-4204	TDT4192	23:47:13.848	-42:04:22.299	2.3	11.61	12.23	209
23495-3927	TDT4218	23:49:30.992	-39:26:33.196	2.5	11.88	12.38	325
01425-4637	RST38	01:42:32.580	-46:37:04.196	2.4	12.30	12.70	112

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Table 4. Photometry and Astrometry Results for the Selected TDS Objects in Phoenix.

Name		RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date	N	Notes
TDS1294	A	00 06 31.835	-52 00 17.58	-	0.205	-	-	12.483	0.083	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDS1299	A	00 07 06.016	-41 52 26.86	-	0.206	-	-	12.098	0.064	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDS1311	A	00 08 39.625	-40 56 32.16	-	0.242	-	-	11.704	0.062	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDS1376	A	00 16 34.618	-43 47 24.98	-	0.184	-	-	11.970	0.082	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Visual impression also rather single star. Bogus assumed
	B							-	-			
TDS1382	A	00 17 04.260	-50 38 36.15	-	0.178	-	-	11.994	0.092	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDS1564	A	00 40 53.893	-47 42 32.70	-	0.304	-	-	12.547	0.062	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDS1608	A	00 46 43.812	-48 05 18.69	-	0.170	-	-	11.988	0.072	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDS1893	A	01 29 43.261	-40 23 17.39	-	0.186	-	-	11.501	0.072	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDS1904	A	01 32 13.359	-40 05 43.03	-	0.198	-	-	12.232	0.093	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDS1973	A	01 43 57.811	-45 37 54.62	-	0.269	-	-	12.394	0.083	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDS2016	A	01 49 34.639	-43 51 48.07	-	0.258	-	-	12.226	0.083	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
	B							-	-			
TDT4189	A	23 46 54.673	-41 50 19.96	-	0.227	-	-	11.610	0.093	2015.908	1	iT27 1x3s. No resolution, not even a hint for an elongation. Visual impression probably single. Bogus assumed
	B							-	-			
TDT4192	A	23 47 13.909	-42 04 21.92	-	0.264	-	-	11.574	0.095	2015.908	1	iT27 1x3s. First image suggested hint of elongation - but not confirmed by additional images. Visual impression not conclusive. Bogus assumed
	B							-	-			
TDT4218	A	23 49 31.014	-39 26 33.53	2.295	0.192	324.154	4.785	12.028	0.089	2015.908	1	iT27 1x3s. Touching star disks but rather clear resolution. SNR for B <20. Visual impression also double
	B	23 49 30.898	-39 26 31.67					12.521	0.101			
RST 38	A	01 42 32.548	-46 37 04.20	2.401	0.256	113.310	6.090	12.519	0.085	2015.911	1	iT27 1x3s. Touching star disks. Visual resolution
	B	01 42 32.762	-46 37 05.15					12.891	0.088			

Table 5. Photometry and Astrometry Results for the Selected TDS Objects.

Name		RA	Dec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	Date	N	Notes
TDS2046	A	01 53 51.895	-24 55 11.10	-	0.425	-	-	11.319	0.143	2016.026	1	1
	B								-			
TDS2074	A	01 58 21.221	-30 46 58.76	-	0.228	-	-	12.295	0.062	2016.026	1	2
	B								-			
TDS2106	A	02 05 15.934	-33 54 02.81	-	0.298	-	-	12.184	0.081	2016.026	1	2
	B								-			
TDS2146	A	02 10 45.190	-38 04 56.83	-	0.270	-	-	11.343	0.131	2016.026	1	2
	B								-			
TDS2177	A	02 15 23.165	-24 54 47.45	1.906	0.439	116.827	12.976	11.547	0.072	2016.026	1	3
	B	02 15 23.290	-24 54 48.31					11.769	0.072			
TDS2221	A	02 21 18.345	-38 10 28.25	-	0.286	-	-	11.337	0.100	2016.026	1	2
	B								-			
TDS2264	A	02 29 01.718	-37 16 35.91	1.588	0.248	63.441	8.891	11.700	0.111	2016.026	1	4
	B	02 29 01.837	-37 16 35.20					11.740	0.111			
TDS2447	A	03 06 48.102	-38 09 59.73	-	0.233	-	-	11.105	0.051	2015.999	2	5
	B								-			
TDS2481	A	03 13 08.226	-35 01 08.77	-	0.226	-	-	12.128	0.051	2016.026	1	2
	B								-			
TDS2511	A	03 16 28.792	-32 42 55.90	-	0.177	-	-	11.618	0.061	2016.026	1	2
	B								-			
TDS2543	A	03 25 15.801	-25 00 46.40	-	0.258	-	-	12.566	0.081	2016.026	1	2
	B								-			
TDS2593	A	03 35 21.415	-29 26 38.63	-	0.153	-	-	12.246	0.061	2016.026	1	2
	B								-			

Notes to Table 5.

1. iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
2. iT27 1x3s. No resolution, not even a hint for an elongation. Bogus assumed
3. iT27 1x3s. Overlapping star disks, clear elongation. Confirmed
4. iT27 1x3s. Overlapping star disks, clear elongation. Confirmed. A and B seem equally bright
5. iT27 1x3s. No resolution, not even a hint for an elongation. Same result with a second image. Bogus assumed

out of 14 objects called for just another attempt for a counter check. Beginning of 2016 the constellation For was reasonably high for imaging from Australia so just another set of images with the same selection criterion separation 1.5" or larger was taken with the following results in Table 5. Table headings in Table 5 were calculated as described for Table 4 earlier in this article.

Additional Research

With 2 confirmations out of 12 objects the wider TDS objects in Fornax fared a bit better than in Cygnus and Phoenix. To eliminate all potential doubts in terms of image resolution, I decided to have a look at objects far beyond any such questions in Puppis with 9 already confirmed objects with a separation of at least 2.6 arcseconds.

All these objects were confirmed again with our own measurements. Sep and PA in most cases were within the given error range compared with the values listed in the WDS catalog (in two cases with change of the components A and B according to the magnitude measurement). For the few cases outside the error range a counter check with URAT1 would be helpful for detecting potential proper motion issues, but URAT1 is currently not available for the southern sky.

Surprisingly all of the selected unconfirmed objects with rather comfortable separation have to be assumed bogus. To visualize these results some cut outs from the center of the used images are given in Figure 2.

Closing the Circle

In the final stage of writing this report I got the hint

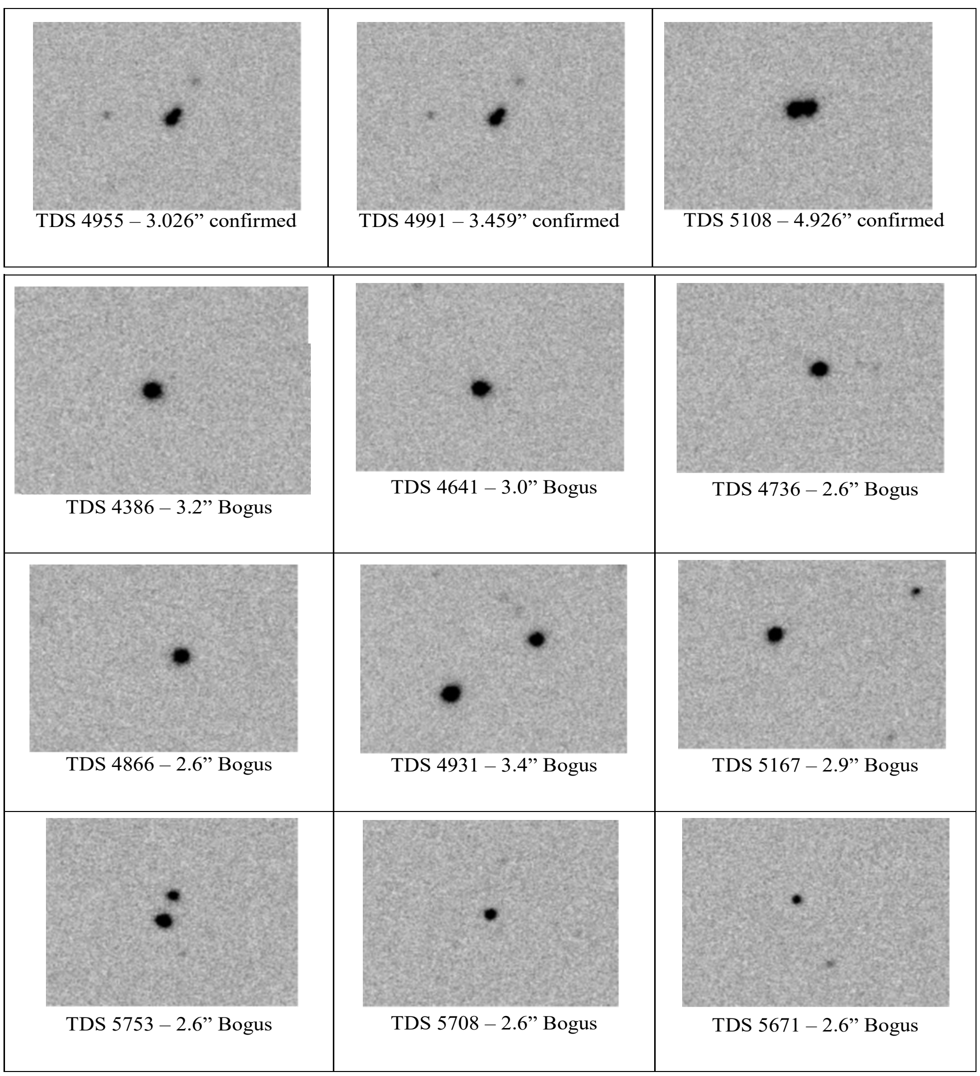

Figure 3. Image examples for the selected TDS objects in Pup showing confirmed objects versus obvious bogus

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Table 6. Measurement Results for HJ348

Name		RA	Dec	Sep	Err Sep	PA	Err PA	Vmag	Err Vmag	Date
HJ348	A	04 43 04.967	33 55 47.08	30.262	0.318	285.329	0.603	7.315	0.140	2016.085
	B	04 43 02.622	33 55 55.08					11.360	0.149	

that HJ348 (WDS04431+3356 with Sep 30.6" +7.42/9.5mag 286° PA) in Auriga might be listed with a far too bright magnitude for the companion. Measurements based on a stack of 6x1s images taken with iT18 resulted in the following values given in Table 6. This means that the companion is nearly 2 magnitudes fainter than currently listed in the WDS catalog. Checking HJ348 for synonyms I found that this pair is also included in the Tycho Double Star catalog being the source of the wrong magnitude for the companion – similar situation to STF442.

Historical Background to the Tycho Double Star Catalog (by Ross Gould)

The ESA Hipparcos satellite included the Tycho star mapper, which produced a catalogue of single stars, initially (Tycho-I) including just over 1 million stars to magnitude 11.5, with positional and photometric data. The material was re-processed later to yield the Tycho-II catalogue of 2.5 million stars. From this, an initial analysis for double stars produced over 12,000 double star measures including 1234 new double star systems (Mason et al, AJ, 2000 December). Following this, a "dedicated re-reduction of the Tycho data" produced a total of 13,251 discoveries (Hoeg, Fabricius, et al, A&A, 2002 March).

When the Hipparcos double star data had been released effort was made to confirm a good number of the claimed new pairs. This was done by speckle interferometry, these days a 'gold standard' for measures of doubles. Papers by Mason et al in 1999 and 2001 detailed this work (Mason et al, AJ 1999 and 2001). The conclusion, based on "only a subset of the new doubles" was that "most new Hipparcos doubles are bona fide double stars...", despite problems with verification of some of the list, using the McDonald Observatory 2.1metre telescope.

Fast forward a short time, and the new and greatly expanded Tycho Double Star Catalogue is announced, with over ten times as many new doubles as its predecessor, 13,251. The Fabricius 2002 paper provides details of the new analysis. Most of the added objects compared to the first catalogue "have separations between 0.3 and 1.0 arcsec".

The doubles were generated from single star results in combination. Proximity of positions was the criterion, and the separation and angle were calculated from the relative positions. Delta-m was typically no more than 2. Various methods were used in attempting to eliminate spurious detections. There was acknowledgement that the new analysis involved the risk of more spurious detections or of errors in rho and theta.

Because of the generally dim magnitudes of the stars, mostly of 11th and 12th magnitude, these are not easy pairs for re-observing to confirm their reality. Thus, a suggestion made in the Mason 2001 Hipparcos paper was useful, that is, using CCD imaging, as the Tycho doubles are not so close as to require interferometry on large telescopes. That the dim magnitudes are bordering on the practical limits for speckle work, regardless of aperture, also recommends imaging as the best technique. Mason (1999) noted that telescopes larger than the USNO 26-inch (0.7m) refractor did little to increase the magnitude limit but instead reached the same signal-to-noise ratio in less time. Other changes, such as longer exposures, broader waveband filters, or less magnification resulting in less resolution, were unhelpful.

The sheer number of objects listed in the Tycho Double Star Catalogue appears to have discouraged extensive follow-ups on these objects. There are many non-Tycho recorded doubles that are brighter and will therefore attract attention first. Despite the extended TDS Catalogue being available in 2002, the great majority of objects in it have not as yet been confirmed. As of January 2016, Dr. Brian Mason/USNO said that from the total of 14,175 TDS and TDT pairs, 226 appear to be not real, 965 have been confirmed by something other than Hipparcos, and 12,984 are still of unconfirmed status.

The work recorded in the present paper, on some of the easier because wider Tycho doubles, has a much higher rate of bogus doubles than the above numbers. The objects assessed here were chosen from those with only a 1991 observation merely by their separation. Because these are the wider pairs, and much wider than the nominal resolution of Tycho - 0.8" - it is surprising that so few appear to match the Tycho data. A high proportion appear to be bogus doubles in this modest sample. Ongoing work will indicate how representative this sample is, at least for separations above 1.5 arcseconds. The many Tycho doubles that are closer will require for their verification more resolution capability than was used for this study.

Summary

The results based on image processing and a few visual observations show a not positive record for the validity of the WDS catalog data for non-confirmed Tycho Double Stars – less than 10% of the by random selected TDS/TDT objects with separation larger than 1.5 arcseconds were confirmed as double stars and the rest was assumed being bogus without a regular pattern as for example a bright star nearby as is sometimes discussed. There seems to be no reason to consider the huge number of such objects with smaller separation being more reliable. This means that any TDS/TDT object with so far no confirming additional observation is to be considered with a rather high probability as potential bogus and that objects with other designations with Tycho based magnitudes might be better checked for the validity of at least the magnitude of the companion.

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. Ross is also working on checking wide TDS objects with Sky Survey images as at least a distinctive elongation is to be expected here for existing pairs.

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- 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
    - iT27: 700mm CDK with 4531mm focal length. CCD: FLI PL09000. Resolution 0.53 arcsec/pixel. V-filter. Located in Siding Spring, Australia. Elevation 1122m
    - iT18: 318mm CDK with 2541mm focal length. CCD: SBIG-STXL-6303E. Resolution 0.73 arcsec/pixel. V-filter. Located in Nerpio, Spain. Elevation 1650m
- 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

Special thanks to Brian Mason of the USNO for providing the precise numbers of TDS/TDT objects in the WDS catalog. As of 2016 out of a total 14,175 TDS and TDT pairs, 226 appear not to be real, 965 have been confirmed by something other than Hipparcos, and 12,984 are still unknown.

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