Visual Observation and Measurements of 33 so far Unconfirmed Tycho Double Stars in Cygnus with 2 Arcseconds Separation

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Abstract: As already reported (Knapp and Gould 2016), most Tycho Double Star objects in the WDS catalog are unconfirmed. From the huge number of in total nearly 1000 TDS/TDT objects in the Cygnus constellation, all unconfirmed pairs (per beginning of 2016) listed with 2" separation were visually observed and measured based on CCD images.

Introduction

A short holiday trip into the Austrian mountains offered the possibility of using a hotel-owned observatory at an altitude of about 1900 m equipped with a 17 inch Planewave f/6.8 CDK telescope for visual observations for two consecutive nights. Despite the full moon at the date in question I used this opportunity for just another check of Tycho Double Stars as resolution of double star observation is not this sensitive to light polluted skies. But to be on the safe side, I decided to restrict the targets to objects near the zenith with a separation of 2", as resolution with a 17 inch telescope should then be easy even under these imperfect conditions. From a total of about 1000 TDS/TDT objects in Cygnus, there remained 33 pairs with a separation of 2". For counter-checking, I selected 5 already confirmed pairs also in Cygnus with similar 2" separation and magnitude range about 11-12 mag.

Visual Observations

The first session was to some degree spent with getting familiar with the telescope and the GoTo mount with some difficulties with the latter – the number of observed objects was therefore rather small. Things went much smoother in the second session especially after several resynchronizations of the GoTo system. In addition to the GoTo system, very detailed star maps were used to be sure to look at the correct objects. The results are shown in the Table 1.

Measurements based on CCD imaging

Five images with exposure time of 3 seconds were taken per object with remote telescope iT24 (for specifications see Acknowledgements). The images were stacked with VPhot and plate solved with Astrometrica with URAT1 reference stars with Vmags in the range 10.5 to 14.5mag. The RA/Dec coordinates resulting from plate solving were used to calculate Sep and PA using the formula provided by R. Buchheim 2008 (see References). *Err_PA* is the error estimation for PA in degrees calculated as arctan(*Err_Sep*/*Sep*), assuming the worst case that *Err_Sep* points perpendicular to the separation vector. *Mag* is the photometry result based on URAT1 reference stars with Vmags between 10.5 and 14.5mag. *Err_Mag* is calculated as

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

with dVmag as the average Vmag error over all used reference stars and SNR as the signal to noise ratio for the given star. Date is the Bessel epoch and N is the number of images used for the reported values. The results are shown in Table 2.

Summary

The comparison of imaging and visual observation results plus the additional check of 2MASS images

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Table 1: Observation results for all TDS objects in Cyg with 2" separation so far not confirmed plus 5 already confirmed non TDS objects for counter-checking with their WDS data per begin of 2016. Method of observation = V (visual estimate) and aperture = 0.425m

WDS ID	Name	RA	Dec	Sep	M1	M2	PA	Date	Observation notes
21442+3453	HO605	21:44:07.293	+34:52:33.8	2.0	11.34	12.11	340	2016.553	With a magnification of x230 resolution at ~345° with estimated separation ~2"
21545+4052	TDT3230	21:54:30.980	+40:52:16.2	2.0	12.14	12.23	222	2016.553	No resolution
21466+3815	COU1639	21:46:34.778	+38:14:43.4	2.0	11.27	11.56	211	2016.553	With a magnification of x230 resolution at ~210° with estimated separation ~2"
21212+3044	TDT2914	21:21:14.751	+30:44:12.3	2.0	10.86	12.66	17	2016.553	No resolution
21548+4310	TDT3234	21:54:50.817	+43:09:55.0	2.0	11.34	12.42	343	2016.553	No resolution
21279+3439	TDT2980	21:27:56.960	+34:39:10.8	2.0	12.12	12.63	121	2016.553	No resolution
21300+3549	TDT2998	21:30:00.117	+35:49:04.2	2.0	11.53	13.28	209	2016.553	No resolution
21158+3159	TDT2868	21:15:50.729	+31:59:22.6	2.0	11.63	12.58	185	2016.553	No resolution
21245+3632	ES2125	21:24:29.222	+36:31:30.9	2.0	10.41	11.82	36	2016.553	With a magnification of x230 resolution at ~45° with estimated separation ~2"
21195+3745	TDT2904	21:19:32.118	+37:45:29.7	2.0	11.55	13.12	216	2016.553	No resolution
21107+3515	TDS1120	21:10:43.050	+35:15:15.5	2.0	10.18	12.43	244	2016.553	No resolution
21095+3506	TDT2791	21:09:29.133	+35:05:30.9	2.0	11.76	12.61	252	2016.553	No resolution
20592+3231	TDT2675	20:59:14.778	+32:31:29.4	2.0	11.62	12.56	207	2016.553	No resolution
21070+3724	TDT2763	21:07:00.529	+37:24:24.0	2.0	11.35	12.68	215	2016.553	No resolution
21282+4607	TDT2981	21:28:11.977	+46:06:34.7	2.0	11.64	12.07	101	2016.553	No resolution
21068+3834	TDT2758	21:06:49.969	+38:33:32.0	2.0	11.85	12.24	236	2016.553	No resolution
21304+4926	TDT3002	21:30:21.980	+49:26:14.1	2.0	11.30	11.75	295	2016.553	With a magnification of x230 resolution at ~300° with estimated separation 2"
21037+4616	TDT2719	21:03:40.853	+46:16:09.7	2.0	11.87	12.14	220	2016.553	No resolution
20152+3006	TDT2121	20:15:12.978	+30:06:07.6	2.0	11.92	12.18	11	2016.553	No resolution
20107+3015	TDT2051	20:10:43.449	+30:14:40.6	2.0	11.90	12.27	242	2016.553	No resolution
20449+4332	ES1448	20:44:52.852	+43:31:51.6	2.0	10.39	10.80	142	2016.553	With magnification of x230 resolution at about 140° with estimated separation of ~2"
20160+3751	TDT2130	20:15:58.427	+37:50:35.2	2.0	11.28	11.82	236	2016.553	No resolution
20275+4307	TDT2289	20:27:28.320	+43:07:07.3	2.0	11.69	12.24	346	2016.553	No resolution
20330+5922	TDT2359	20:33:00.231	+59:21:55.4	2.0	10.17	12.79	113	2016.553	No resolution
20258+5938	TDT2261	20:25:50.823	+59:37:50.1	2.0	10.08	11.77	134	2016.553	No resolution
19447+3204	TDT1697	19:44:40.740	+32:04:17.0	2.0	12.12	12.45	297	2016.553	No resolution
19466+3243	TDT1729	19:46:34.530	+32:43:16.9	2.0	10.22	12.44	111	2016.553	No resolution
20209+5511	TDT2197	20:20:56.891	+55:10:55.8	2.0	10.81	13.32	241	2016.553	No resolution
19511+3643	ES242	19:51:02.020	+36:42:42.8	2.0	11.00	11.50	30	2016.551	With a magnification of x230 resolution at ~30° with a separation of ~2"
20153+5428	TDT2123	20:15:20.098	+54:27:40.3	2.0	11.27	11.84	328	2016.551	No resolution
20056+5821	TDT1965	20:05:38.448	+58:21:04.6	2.0	11.63	12.41	160	2016.551	No resolution
20071+5431	TDT1991	20:07:05.459	+54:31:00.4	2.0	10.64	12.23	333	2016.551	No resolution
19438+3738	TDT1680	19:43:45.513	+37:38:17.0	2.0	11.86	11.95	273	2016.551	No resolution
19290+3508	POP135	19:28:56.513	+35:06:44.7	2.0	11.11	12.11	35	2016.551	With a magnification of x230 hint of companion at ~40° with a separation of ~2"
19326+4839	TDT1533	19:32:38.038	+48:39:06.2	2.0	11.99	12.01	215	2016.551	No resolution
19209+4710	TDT1391	19:20:56.328	+47:10:09.1	2.0	11.74	12.27	2	2016.551	No resolution
19178+4759	TDT1358	19:17:48.420	+47:59:17.6	2.0	11.40	12.12	234	2016.551	No resolution
19095+4828	TDT1259	19:09:29.552	+48:27:57.0	2.0	11.98	12.00	216	2016.551	With a magnification of x420 resolution at a position angle of ~215° and a separation of ~2"

Table 2. Measurement results for all TDS objects in Cyg with 2" separation so far not confirmed plus 5 already confirmed non TDS objects for counter-checking based on iT24 images (plus one by chance found additional double star). Method of observations = C (CCD or other two-dimensional electronic imaging) and aperture = 0.61m

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
HO 605	A	21 44 07.265	34 52 34.08	0.05	0.06	1.864	0.078	340.730	2.399	11.097	0.062	73.94	0.06	2016.587	5	1
	B	21 44 07.215	34 52 35.84							11.326	0.061	80.61				
TDT3230	A	21 54 30.978	40 52 16.06	0.05	0.05	-	0.071	-	-	12.048	0.062	64.21	0.06	2016.587	5	2
	B										-					
COU1639	A	21 46 34.779	38 14 43.75	0.03	0.04	1.754	0.050	204.186	1.633	11.000	0.041	105.02	0.04	2016.587	5	1
	B	21 46 34.718	38 14 42.15							11.290	0.042	91.33				
TDT2914	A	21 21 14.766	30 44 12.24	0.03	0.03	-	0.042	-	-	10.814	0.041	111.80	0.04	2016.587	5	2
	B										-					
TDT3234	A	21 54 50.873	43 09 55.07	0.03	0.04	-	0.050	-	-	11.250	0.071	96.43	0.07	2016.587	5	2
	B										-					
TDT2980	A	21 27 56.985	34 39 10.89	0.03	0.04	-	0.050	-	-	11.917	0.062	69.82	0.06	2016.587	5	2
	B										-					
TDT2998	A	21 30 00.125	35 49 04.03	0.03	0.04	-	0.050	-	-	11.444	0.052	75.82	0.05	2016.587	5	2
	B										-					
TDT2868	A	21 15 50.764	31 59 22.51	0.03	0.04	-	0.050	-	-	11.666	0.062	76.98	0.06	2016.587	5	2
	B										-					
ES 2125	A	21 24 29.230	36 31 31.12	0.04	0.04	2.005	0.057	33.586	1.616	10.360	0.072	66.09	0.07	2016.587	5	1
	B	21 24 29.322	36 31 32.79							11.193	0.071	84.73				
TDT2904	A	21 19 32.121	37 45 29.49	0.03	0.03	-	0.042	-	-	11.709	0.052	82.76	0.05	2016.587	5	2
	B										-					
TDS1120	A	21 10 43.074	35 15 15.38	0.04	0.04	-	0.057	-	-	10.061	0.051	128.41	0.05	2016.587	5	2
	B										-					
TDT2791	A	21 09 29.115	35 05 30.89	0.04	0.04	-	0.057	-	-	11.997	0.062	63.05	0.06	2016.587	5	2
	B										-					
TDT2675	A	20 59 14.781	32 31 29.21	0.03	0.05	-	0.058	-	-	12.186	0.053	58.08	0.05	2016.587	5	2
	B										-					
TDT2763	A	21 07 00.484	37 24 23.36	0.03	0.04	-	0.050	-	-	11.197	0.061	91.60	0.06	2016.587	5	2
	B										-					
TDT2981	A	21 28 11.981	46 06 34.77	0.03	0.04	-	0.050	-	-	11.648	0.061	82.05	0.06	2016.587	5	2
	B										-					
TDT2758	A	21 06 49.966	38 33 32.18	0.03	0.04	-	0.050	-	-	11.851	0.052	77.63	0.05	2016.587	5	2
	B										-					
TDT3002	A	21 30 21.931	49 26 14.27	0.04	0.04	1.664	0.057	311.381	1.947	11.013	0.072	64.96	0.07	2016.587	5	1
	B	21 30 21.803	49 26 15.37							11.608	0.072	65.42				
TDT2719	A	21 03 40.854	46 16 09.61	0.04	0.04	-	0.057	-	-	12.211	0.062	65.15	0.06	2016.587	5	2
	B										-					
TDT2121	A	20 15 12.962	30 06 07.82	0.06	0.07	-	0.092	-	-	12.153	0.111	60.28	0.11	2016.587	5	2
	B										-					
TDT2051	A	20 10 43.433	30 14 40.55	0.06	0.06	-	0.085	-	-	11.050	0.061	105.25	0.06	2016.587	5	2
	B										-					

Table 2 concludes on next page.

Visual Observation and Measurements of 33 so far Unconfirmed Tycho Double Stars in Cygnus ...

Table 2 (conclusion). Measurement results for all TDS objects in Cyg with 2" separation so far not confirmed plus 5 already confirmed non TDS objects for counter-checking based on iT24 images (plus one by chance found additional double star). Method of observations = C (CCD or other two-dimensional electronic imaging) and aperture = 0.61m

Name		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
ES 1448	A	20 44 52.839	43 31 51.96	0.05	0.06	1.881	0.078	140.927	2.378	10.239	0.062	74.41	0.06	2016.587	5	1
	B	20 44 52.948	43 31 50.50							10.593	0.061	102.48				
TDT2130	A	20 15 58.445	37 50 35.19	0.06	0.09	-	0.108	-	-	11.587	0.081	73.08	0.08	2016.587	5	2
	B										-					
TDT2289	A	20 27 28.319	43 07 06.90	0.05	0.06	-	0.078	-	-	11.878	0.072	67.63	0.07	2016.587	5	2
	B										-					
TDT2359	A	20 33 00.211	59 21 55.17	0.05	0.07	-	0.086	-	-	10.074	0.051	140.73	0.05	2016.587	5	2
	B										-					
TDT2261	A	20 25 50.823	59 37 50.29	0.07	0.08	-	0.106	-	-	9.921	0.070	132.76	0.07	2016.587	5	2
	B										-					
TDT1697	A	19 44 40.606	32 04 18.18	0.07	0.07	-	0.099	-	-	12.279	0.092	54.42	0.09	2016.587	5	2
	B										-					
TDT1729	A	19 46 34.516	32 43 16.83	0.06	0.07	-	0.092	-	-	10.045	0.080	152.78	0.08	2016.587	5	2
	B										-					
TDT2197	A	20 20 56.897	55 10 55.79	0.06	0.06	-	0.085	-	-	10.677	0.061	118.95	0.06	2016.587	5	2
	B										-					
ES 242	A	19 51 02.024	36 42 42.93	0.06	0.05	1.844	0.078	31.016	2.426	11.088	0.072	68.29	0.07	2016.587	5	1
	B	19 51 02.103	36 42 44.51							11.369	0.073	56.69				
TDT2123	A	20 15 20.106	54 27 40.39	0.05	0.06	-	0.078	-	-	11.459	0.061	81.42	0.06	2016.587	5	2
	B										-					
TDT1965	A	20 05 38.479	58 21 04.77	0.05	0.07	-	0.086	-	-	11.962	0.073	55.29	0.07	2016.587	5	2
	B										-					
TYC3948-01545-1	A	20 05 29.946	58 21 06.72	0.05	0.07	2.651	0.086	78.467	1.859	11.372	0.073	54.85	0.07	2016.587	5	3
	B	20 05 30.276	58 21 07.25							12.963	0.091	18.11				
TDT1991	A	20 07 05.472	54 31 00.36	0.05	0.07	-	0.086	-	-	10.598	0.081	111.35	0.08	2016.587	5	2
	B										-					
TDT1680	A	19 43 45.493	37 38 17.23	0.06	0.06	-	0.085	-	-	11.436	0.061	91.56	0.06	2016.587	5	2
	B										-					
POP 135	A	19 28 56.516	35 06 44.99	0.04	0.05	1.846	0.064	37.220	1.987	11.106	0.062	71.36	0.06	2016.587	5	1
	B	19 28 56.607	35 06 46.46							11.743	0.062	73.08				
TDT1533	A	19 32 38.027	48 39 06.14	0.03	0.03	-	0.042	-	-	11.946	0.053	65.20	0.05	2016.587	5	2
	B										-					
TDT1391	A	19 20 56.331	47 10 09.47	0.03	0.04	2.064	0.050	3.682	1.388	11.821	0.044	55.67	0.04	2016.587	5	1
	B	19 20 56.344	47 10 11.53							12.098	0.045	53.86				
TDT1358	A	19 17 48.423	47 59 17.77	0.03	0.03	-	0.042	-	-	11.456	0.052	78.70	0.05	2016.587	5	2
	B										-					
TDT1259	A	19 09 29.515	48 27 57.21	0.06	0.08	2.275	0.100	204.535	2.516	12.073	0.112	48.54	0.11	2016.587	5	1
	B	19 09 29.420	48 27 55.14							11.957	0.111	60.02				

Table 2 notes:

1. Touching/overlapping star disks
2. Appears as a single star
3. Same image as TDT 1965. Double star confirmed by elongation in 2MASS images, yet no 2MASS catalog entry exists for B nor in any other catalog

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(SDSS images are currently not available for Cyg) should allow for very conclusive assessments per object if bogus or not. The results of this comparison are shown in Table 3.

From 33 so far unconfirmed 2" TDS objects in Cyg only 3 are confirmed as double stars while for the rest we cannot confirm, while from the 5 selected additional 2" double stars in Cygnus all 5 have been fully confirmed.

Potential further research

As the number of so far unconfirmed Tycho Double Stars is huge the field for further research seems also huge. The effort to eliminate all bogus TDS/TDT objects from the WDS catalog is probably much higher than adding them initially especially if we go down in separation far below 2 arcseconds. Counterchecking with SDSS images with much better resolution than 2MASS offers a possibility with reasonable effort down to separations of somewhat less than 1.5" but then things get difficult. It seems out of the question to counter-check the huge number of so far not confirmed TDS objects with visual observation (anyway a rather frustrating task – looking at single stars proposed to be doubles) and taking dedicated images for this purpose especially for separations smaller than 1.5" – the effort would be huge and obviously a waste of time and equipment. The meager ratio of confirmed to bogus from the so far counter-checked TDS objects suggests a crude resolution: All so far not confirmed TDS objects are to be considered suspect with a high probability of at least 85% of being bogus.

Acknowledgements

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

- Washington Double Star Catalog as data source for the selected objects
- CCD imaging: Images were taken with iTelescope iT24: 610mm CDK with 3962mm focal length. CCD: FLI-PL09000. Resolution 0.62 arcsec/pixel. V-filter. Located in Auberry, California. Elevation 1405m
- Visual observations: 425mm CDK with focal length 2940mm. Located at Gerlitzen, Austria. Elevation 1900m
- Aladin Sky Atlas v9.0 (2MASS and POSS images)
- SIMBAD, VizieR
- 2MASS All Sky Catalog
- AstroPlanner v2.2 for object selection

References

Buchheim, Robert, 2008, "CCD Double-Star Measurements at Altimira Observatory in 2007", *Journal of Double Star Observations*, **4**, 27-31. Formulas for calculating Separation and Position Angle from the RA Dec coordinates given as

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

in radians and

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

in radians depending on quadrant

Knapp, Wilfried; Gould, Ross, 2016, "Visual Observation and Measurements of some Tycho Double Stars", *Journal of Double Star Observations*, **12**, 427 - 436

Table 3 Overall assessment for all TDS objects in Cyg with 2" separation so far not confirmed plus 5 already confirmed non TDS objects for counter-checking based on iT24 images, visual observation and counter-checking 2MASS and POSS images

Name	Imaging	Visual observation	Aladin images	Overall conclusion
HO 605	Touching/overlapping star disks	With a magnification of x230 resolution at ~345° with estimated separation 2"	2MASS and POSS images suggest elongation	Object as double star confirmed
TDT 3230	Obviously single star	No resolution	2MASS images without hint of elongation	Bogus
COU 1639	Touching/overlapping star disks	With a magnification of x230 resolution at ~210° with estimated separation 2"	2MASS images suggest elongation	Object as double star confirmed
TDT 2914	Obviously single star	No resolution	2MASS images no hint of elongation	Bogus
TDT 3234	Obviously single star	No resolution	2MASS no hint of elongation	Bogus
TDT 2980	Obviously single star	No resolution	2MASS images no hint of elongation	Bogus
TDT 2998	Obviously single star	No resolution	2MASS images no hint of elongation	Bogus
TDT 2868	Obviously single star	No resolution	2MASS images no hint of elongation	Bogus
ES 2125	Touching/overlapping star disks	With a magnification of x230 resolution at ~45° with estimated separation 2"	2MASS and POSS images suggest elongation	Object as double star confirmed
TDT 2904	Obviously single star	No resolution	2MASS images no hint of elongation	Bogus
TDS 1120	Obviously single star	No resolution	**2MASS images slight hint of elongation**	Probably bogus (after rather negative re-checking of 2MASS and POSS images)
TDT 2791	Obviously single star	No resolution	2MASS images no hint of elongation	Bogus
TDT 2675	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus
TDT 2763	Obviously single star	No resolution	2MASS images slight hint of elongation	Bogus
TDT 2981	Obviously single star	No resolution	2MASS images no hint of elongation	Bogus
TDT 2758	Obviously single star	No resolution	2MASS images no hint of elongation	Bogus
TDT 3002	Touching/overlapping star disks	With a magnification of x230 resolution at ~300° with estimated separation 2"	2MASS no hint of elongation but POSS images show hint of elongation	Object as double star confirmed
TDT 2719	Obviously single star	No resolution	2MASS images no hint of elongation	Bogus
TDT 2121	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus
TDT 2051	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus

Table 3 concludes on next page.

Table 3 (conclusion). Overall assessment for all TDS objects in Cyg with 2" separation so far not confirmed plus 5 already confirmed non TDS objects for counter-checking based on iT24 images, visual observation and counter-checking 2MASS and POSS images

Name	Imaging	Visual observation	Aladin images	Overall conclusion
ES 1448	Touching/overlapping star disks	With magnification of x230 resolution at about 140° with estimated separation of 2"	2MASS and POSS images suggest elongation	Object as double star confirmed
TDT 2130	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus
TDT 2289	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus
TDT 2359	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus
TDT 2261	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus
TDT 1697	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus
TDT 1729	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus
TDT 2197	Obviously single star	No resolution	2MASS J no hint of elongation	Bogus
ES 242	Touching/overlapping star disks	With a magnification of x230 resolution at ~30° with a separation of ~2"	2MASS and POSS images suggest elongation	Object as double star confirmed
TDT 2123	Obviously single star	No resolution	2MASS no hint of elongation	Bogus
TDT 1965	Obviously single star	No resolution	2MASS no hint of elongation	Bogus
TDT 1991	Obviously single star	No resolution	2MASS no hint of elongation	Bogus
TDT 1680	Obviously single star	No resolution	2MASS no hint of elongation	Bogus
POP 135	Touching/overlapping star disks	With a magnification of x230 hint of companion at ~40° with a separation of ~2"	2MASS and POSS images suggest elongation	Object as double star confirmed
TDT 1533	Obviously single star	No resolution	2MASS no hint of elongation	Bogus
TDT 1391	Touching/overlapping star disks	**No resolution**	2MASS image suggest hint of elongation	Object as double star confirmed (negative visual observation probably due to observing the wrong object because of initial problems with the GoTo mount)
TDT 1358	Obviously single star	No resolution	2MASS no hint of elongation	Bogus
TDT 1259	Touching/overlapping star disks	With a magnification of x420 resolution at a position angle of ~215° and a separation of ~2"	2MASS images suggest elongation	Object as double star confirmed