Measurements of Some VizieR I/330 Objects

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Abstract: Data Mining is a contemporary form of double star detection – software running over a star catalog with proper motion data producing long lists of newly detected pairs, most of them rather wide and faint and thus of little interest for the visual observer. For evaluation of such an approach I measured a random sample (selected by altitude suitable for imaging) of objects from the VizieR I/330 "Binary star discoveries in the URAT1 catalog" (Nicholson, 2015). Without exception the astrometry results were rather close to the I/330 catalog values proving the reliability of the provided data but in total several questions arose regarding the validity of Nicholson study.

Report

Martin P. Nicholson published 2015 at Amazon.com his work "Binary star discoveries in the URAT1 catalog - separation under 60 arc sec" presenting 9450 common proper motion binary star systems found in the first U.S. Naval Observatory Astrometric Robotic Telescope Catalog (URAT1) and this work was included in the VizieR database of star catalogs as I/330. The reported objects are accordingly to the author newly discovered pairs but are so far (begin of 2016) not included in the WDS catalog as USNO considers URAT1 as preliminary and this work of Nicholson as published without peer review. A first look into the printed version made me curious because the given separation and position angles did not match precisely with the given RA Dec position data. For this reason and also for a general countercheck for the delivered overall data quality I selected a few objects in the Boo constellation rather high in the northern skies at the time of this research with separation and magnitudes suitable for resolution with remote telescope iT18 (see specifications in the acknowledgements). In one case the components were much fainter than expected so I had to resort to remote telescope iT24 with larger aperture (see specifications in the acknowledgements). The

Table 1: VizieR I/330 Catalog Values per Beginning of 2016 for the Selected I/330 Objects Intended for Measurement

I/330#		RA	Dec	Sep	fmag1	fmag2	PA
4868	AB	14:09:46.200	+44:53:41.6	4.73	12.56	13.28	245
4969	AB	14:19:13.464	+42:23:19.3	7.59	10.02	10.46	130
4983	AB	14:20:56.904	+34:59:51.4	28.03	9.61	11.04	278
4986	AB	14:21:05.448	+49:42:18.7	9.64	11.57	12.41	316
5003	AB	14:23:46.032	+47:01:10.9	5.18	12.51	13.08	92
5204	AB	14:48:45.360	+32:32:23.3	10.67	11.41	12.74	42
5211	AB	14:49:27.936	+45:16:50.2	7.32	10.3	11.6	180
5229	AB	14:52:12.672	+31:02:07.8	12.04	11.87	13.44	187
5241	AB	14:53:32.208	+42:04:12.4	48.27	10.66	12.08	357
5359	AB	15:09:41.592	+49:41:46.0	25.13	11.01	11.43	65
5368	AB	15:10:15.840	+30:44:08.2	10.83	11.99	12.44	349
5398	AB	15:13:28.296	+38:59:50.3	9.70	13.13	13.41	272
5399	AB	15:13:39.528	+42:14:46.7	30.69	11.54	12.37	232
5447	AB	15:18:46.152	+43:13:50.9	16.19	12.81	13.12	27
5467	AB	15:20:58.704	+50:46:29.3	17.26	10.57	12.63	292

weather was not very cooperative so it took some time to get all images and in some cases I had to settle with less than 5 images for stacking. The star fields are mostly rather modest populated so the number of available reference stars for plate solving was also rather limited.

The current (begin of 2016) I/330 catalog data for these objects is listed in Table 1.

The measurement results are given in Table 2. The RA/Dec coordinates resulting from plate solving with URAT1 reference stars in the 10.5 to 14.5 magnitude range were used to calculate Sep and PA 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

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

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 URAT1 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* the signal to noise ratio for the given star. Date is the Bessel epoch of the observation and N is the number of images used for the reported values. The Notes column provides additional information about the used image:

In total, most astrometry results agree very well with the given separation and position angle. The photometry results differ from the given fmags for good reasons significantly and are at least for several components the first measurements with V-filter – for many components APASS Vmags were already available. I then checked the availability of CPM suggesting proper motion data in the UCAC4 catalog and found that in most cases this data was already given. Some examples are given in Figures 1 through 3.

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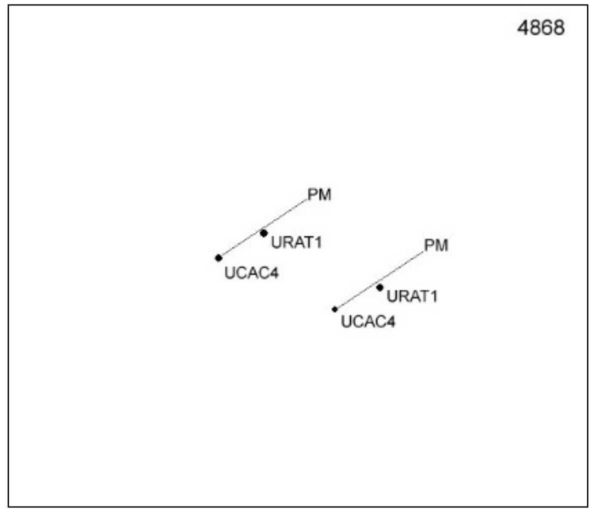

Figure 1. I/330 object 4868 - comparison UCAC4 with URAT1 positions with proper motion UCAC4 vector.

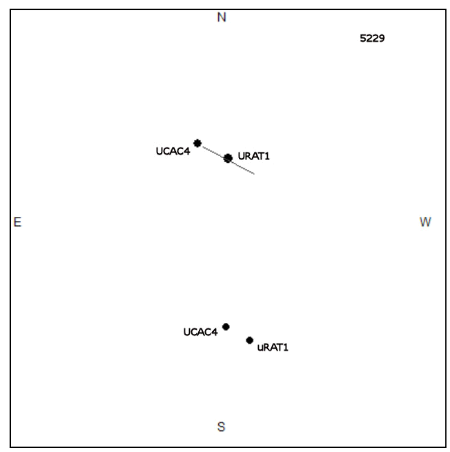

Figure 2. I/330 object 5229 - comparison UCAC4 with URAT1 positions with proper motion UCAC4 vector for only one component.

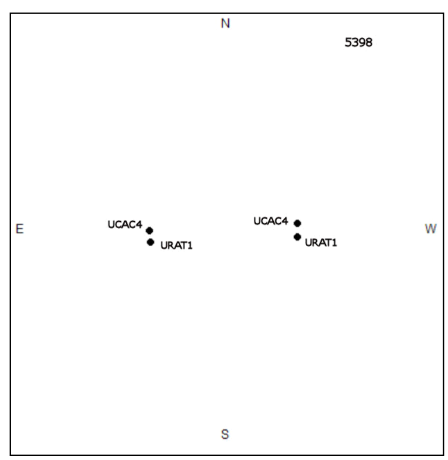

Image 3: I/330 object 5398 - comparison UCAC4 with URAT1 positions with no proper motion UCAC4 vector for both components but obvious movement between UCAC4 and URAT1 observations

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Table 2: Photometry and Astrometry Results for the Selected Objects

		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
MPN 4868	A	14 09 46.176	44 53 41.61	0.08	0.06	4.623	0.100	248.560	1.239	14.085	0.047	44.75	0.04	2016.319	5	iT24 stack 5x6s
	B	14 09 45.771	44 53 39.92							15.073	0.057	26.24				
MPN 4869	A	14 19 13.464	42 23 19.42	0.14	0.13	7.548	0.191	130.379	1.450	10.319	0.092	53.51	0.09	2016.266	2	iT18 stack 2x3s
	B	14 19 13.983	42 23 14.53							10.714	0.093	45.08				
MPN 4983	A	14 20 56.888	34 59 51.29	0.09	0.04	28.029	0.098	277.978	0.201	10.053	0.072	61.00	0.07	2016.266	4	iT18 stack 4x3s
	B	14 20 54.629	34 59 55.18							12.004	0.083	24.00				
MPN 4986	A	14 21 05.448	49 42 18.83	0.11	0.20	9.897	0.228	316.676	1.321	12.025	0.077	21.78	0.06	2016.266	3	iT18 stack 3x3s. SNR B<20
	B	14 21 04.748	49 42 26.03							13.438	0.119	10.08				
MPN 5003	A	14 23 45.987	47 01 10.65	0.10	0.09	4.765	0.135	89.760	1.617	14.065	0.157	7.00	0.06	2016.266	5	iT18 stack 5x3s. SNR A and B<10
	B	14 23 46.453	47 01 10.67							14.632	0.200	5.20				
MPN 5204	A	14 48 45.340	32 32 23.30	0.08	0.08	10.724	0.113	42.233	0.604	11.699	0.088	29.56	0.08	2016.266	4	iT18 stack 4x3s. SNR B<10
	B	14 48 45.910	32 32 31.24							13.519	0.133	9.72				
MPN 5211	A	14 49 27.895	45 16 50.26	0.08	0.05	7.324	0.094	181.899	0.738	10.962	0.084	40.86	0.08	2016.266	3	iT18 stack 3x3s. SNR B<20
	B	14 49 27.872	45 16 42.94							12.718	0.104	15.66				
MPN 5229	A	14 52 12.652	31 02 07.95	0.10	0.09	11.956	0.135	186.481	0.645	12.226	0.094	21.53	0.08	2016.266	4	iT18 stack 4x3s. SNR B<5
	B	14 52 12.547	31 01 56.07							14.962	0.317	3.06				
MPN 5241	A	14 53 32.177	42 04 12.31	0.07	0.06	48.280	0.092	357.383	0.109	11.104	0.085	37.87	0.08	2016.266	5	iT18 stack 5x3s. SNR B<20
	B	14 53 31.979	42 05 00.54							12.920	0.104	15.84				
MPN 5359	A	15 09 41.598	49 41 45.31	0.12	0.09	25.128	0.150	65.951	0.342	11.604	0.079	29.04	0.07	2016.266	3	iT18 stack 3x3s. SNR B<20
	B	15 09 43.963	49 41 55.55							12.362	0.089	19.50				
MPN 5368	A	15 10 15.819	30 44 08.68	0.05	0.13	10.645	0.139	349.603	0.750	12.381	0.087	16.92	0.06	2016.266	2	iT18 stack 2x3s. SNR A and B<20
	B	15 10 15.670	30 44 19.15							12.766	0.095	14.19				
MPN 5398	A	15 13 28.273	38 59 49.46	0.11	0.12	9.596	0.163	278.993	0.972	13.825	0.166	6.71	0.07	2016.266	3	iT18 stack 3x3s. SNR A and B<10
	B	15 13 27.460	38 59 50.96							14.093	0.163	6.86				
MPN 5399	A	15 13 39.547	42 14 46.34	0.12	0.09	30.705	0.150	232.951	0.280	11.828	0.099	26.02	0.09	2016.266	3	iT18 stack 3x3s. SNR B<20
	B	15 13 37.340	42 14 27.84							12.780	0.113	15.32				
MPN 5447	A	15 18 46.136	43 13 50.64	0.04	0.05	16.266	0.064	26.712	0.226	14.050	0.157	7.54	0.08	2016.266	5	iT18 stack 5x3s. SNR A and B <10
	B	15 18 46.805	43 14 05.17							14.100	0.174	6.53				
MPN 5467	A	15 20 58.680	50 46 29.50	0.06	0.04	16.961	0.072	291.732	0.244	10.779	37.620	43.74	0.07	2016.266	2	iT18 stack 2x3s. SNR B <10
	B	15 20 57.019	50 46 35.78							13.389	29.720	9.49				

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Summary

As already mentioned: A first look into the printed version of the Nicholson 2015 study made me curious because the given separation and position angles did not match precisely with the given RA Dec position numbers – only when comparing these numbers with the online VizieR I/330 data I found that this was due to the limited number of digits after the decimal point given in the printed version. Another point to be aware of is the mismatch of object numbers between the printed version and the VizieR I/330 online catalog – the reason for this is probably the fact that the online catalog includes more objects (9450 objects vs. 9590 objects).

Regrettable is the disregard for many objects existing APASS Vmags; repeating given fmags from the URAT1 catalog is not valuable information. Just running software over one single open source star catalog and presenting the results without extensive further counterchecks with other catalogs (besides the WDS catalog for eliminating already included objects) or other individual work looks like a very limited approach. Curious also is the fact that URAT1 would not have been necessary for this data mining project – the required proper motion data was already available in UCAC4 for most of the listed objects.

The criteria used for the detection of common proper motion pairs are not described in full detail in the form of formulas according to, for example, Halbwachs 1986. Nicholson gives in his printed Amazon.com study as minimum CPM requirement a proper motion of 60 mas/yr (opposed to the usual accepted 50 mas/yr – may be to make sure to fulfill the Halbwachs 1986 criterion separation/pm<1000 up to 60" separation) and excludes all stars with a difference in pm in either Dec or RA greater than the given URAT1 errors. As countercheck, I decided to try a new approach by comparing the UCAC4 and URAT1 positions directly. Only if the position change between these two observation epochs has the same direction and same distance for both components within the average UCAC4 position error of ~0.05" then CPM is considered as confirmed.

Nicholson claims to have done a countercheck with the WDS catalog to reduce his list to newly "discovered" pairs but obviously several objects slipped through this control as I found most objects listed here already present in the WDS catalog as described in Table 3.

For counter counterchecking I also looked at the Nicholson 2006 JDSO paper on CPM pairs and immediately the first newly discovered reported object is included in the WDS catalog as LEP2 discovered 1902.

Table 4: Cross-reference I/330 with WDS Catalog for the first 100 I/330 objects

VizieR I/330#	WDS object
6	CBL 556
22	SKF2456
25	CBL 560
33	CBL 562
40	CBL 563
47	CBL 566
60	CBL 567
66	CBL 568
97	CBL 574
98	CBL 575

So there seems to be a systematic error in Nicholson's process of filtering out the already known WDS pairs.

As an additional check I looked at the first 100 objects in the I/330 catalog and found 10 of them already present in the WDS catalog. A cross-reference of these 10 objects is given in Table 4.

Addendum

I contacted Martin Nicholson by email asking for a comment to my findings and his statement was "I think perhaps you have misunderstood the scope of the listing - nowhere does it say they are all new discoveries. In fact it quite clearly says they are not". This is a somewhat contradicting statement to the printed version Nicholson 2015 describing his procedure finishing with his last step at page 6: "Cross reference the results obtained with the latest on-line version of the WDS catalogue so that all the known double stars could be removed from the output file leaving only the new discoveries to be presented in this paper". In a second email he then stated that there is a difference between the printed and the online version of his catalog and that the printed version is cross checked with WDS and the online version not. A final countercheck for the in Table 4 listed objects then showed that the printed version includes also very well all of the above indicated WDS CPM pairs.

Acknowledgements

The following tools and resources have been used

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Table 3: Cross-reference between WDS catalog with VizieR I/330 – 11 out of 15 objects are already known as WDS objects. In the Notes column additional data for each object from APASS, UCAC4 and URAT1 is given if available. "CPM confirmed by comparison URAT1 and UCAC4 positions" in the Notes column means that by comparing UCAC4 and URAT1 positions both angular distance and direction are (within the average UCAC4 position error of ~0.05") ident for both components. WDS objects with both components included in UCAC4 catalog are also listed in the VizieR catalog J/AJ/146/76 Astrometry and photometry of UCAC4 double stars (Hartkopf+, 2013). The column WDS Code V (CPM) indicates with "Yes" if this objects is already marked as CPM pair in the WDS catalog

MPN		WDS ID	WDS Name	WDS RA	WDS Dec	WDS Sep	WDS M1	WDS M2	WDS PA	Notes	WDS Code V (CPM)
4868	AB	14098+4454	UC2692	14:09:46.361	+44:53:40.7	4.7	13.50	13.70	245	1	**Yes**
4969	AB	14192+4223	AG193	14:19:13.599	+42:23:19.3	7.6	10.28	10.95	130	2	**Yes**
4983	AB	14209+3500	HJ547	14:20:56.949	+34:59:52.4	28.2	10.43	11.98	293	3	-
4986	AB	14211+4942	UC193	14:21:05.501	+49:42:19.9	9.6	12.22	12.80	317	4	**Yes**
5003	AB	-	-	-	-	-	-	-	-	5	-
5204	AB	-	-	-	-	-	-	-	-	6	-
5211	AB	14495+4517	HDS2093	14:49:28.139	+45:16:50.1	7.4	11.06	13.06	181	7	**Yes**
5229	AB	14522+3101	LDS969	14:52:12.820	+31:02:08.5	12.0	12.39	14.90	187	8	-
5241	AB	-	-	-	-	-	-	-	-	9	-
5359	AB	15097+4942	BEM16	15:09:41.541	+49:41:47.5	25.1	11.58	12.31	66	10	-
5368	AB	15103+3044	LDS972	15:10:15.911	+30:44:07.2	10.8	12.90	13.30	350	11	-
5398	AB	-	-	-	-	-	-	-	-	12	-
5399	AB	15136+4215	LDS4537	15:13:39.570	+42:14:48.3	30.7	11.84	12.74	233	13	-
5447	AB	15188+4314	UC203	15:18:46.239	+43:13:51.9	16.1	13.51	13.90	28	14	**Yes**
5467	AB	15210+5046	UC2988	15:20:58.800	+50:46:28.7	17.3	10.70	13.00	292	15	**Yes**

Table 3 Notes

1. APASS 13.67 Vmag for A. Proper motion data already in UCAC4 available and CPM confirmed by comparison URAT1 and UCAC4 positions.
2. No APASS Vmag. Proper motion data already in UCAC4 available and CPM confirmed by comparison URAT1 and UCAC4 positions. WDS cross reference with CPM pair HJL 201.
3. No APASS Vmag. Proper motion data already in UCAC4 available and CPM confirmed by comparison URAT1 and UCAC4 positions.
4. APASS 12.00 Vmag for A. Proper motion data already in UCAC4 available and CPM confirmed by comparison URAT1 and UCAC4 positions.
5. APASS 13.45 Vmag for A. No WDS catalog object. No proper motion data in UCAC4 for A. Position comparison between UCAC4 and URAT1 results in proper motion with same direction and distance even if slightly outside the UCAC4 measurement error – CPM rather confirmed.
6. APASS 11.66 Vmag for A. No WDS catalog object. No proper motion data in UCAC4 for B. Position comparison between UCAC4 and URAT1 results in proper motion with same direction but different distance outside the UCAC4 measurement error range. Difference might be explained by the fact that UCAC4 for A is epoch 1991.675 while 2001.55 for B but also the difference per year remains significant - CPM not confirmed.
7. APASS 10.84 Vmag for A. Proper motion data already in UCAC4 available and CPM confirmed by comparison URAT1 and UCAC4 positions.
8. APASS 12.20 Vmag for A. No proper motion data in UCAC4 for B. Position comparison between UCAC4 and URAT1 results in proper motion with same vector direction but different vector length outside the UCAC4 measurement error range. Difference might be explained by the fact that UCAC4 for A is epoch 1986.41 while 2002.14 for B but also the difference per year remains significant - CPM not confirmed.
9. APASS 11.08/12.02 Vmag. No WDS catalog object. Proper motion data already in UCAC4 available and CPM confirmed by comparison URAT1 and UCAC4 positions.
10. APASS 11.58/12.31 Vmag. Proper motion data already in UCAC4 available and CPM confirmed by comparison URAT1 and UCAC4 positions.
11. APASS in between the two components 12.14 Vmag. Proper motion data already available in UCAC4. CPM confirmed by comparison URAT1 and UCAC4 positions.
12. APASS in between the components 13.67 Vmag. No WDS catalog object. Variable star VSX284415 for B. No proper motion data in UCAC4. CPM confirmed by comparison URAT1 and UCAC4 positions.
13. APASS 11.84/12.74 Vmag. Proper motion data already in UCAC4 available. CPM confirmed by comparison URAT1 and UCAC4 positions.
14. No APASS value. Proper motion data already in UCAC4 available and CPM confirmed by comparison URAT1 and UCAC4 positions.
15. APASS 10.74 Vmag for A. Proper motion data already in UCAC4 available and CPM confirmed by comparison URAT1 and UCAC4 positions.

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for this research:

- Washington Double Star Catalog as data source for the selected objects
- iTelescope: Images were taken with
- iT18: 318mm CDK with 2541mm focal length. CCD: SBIG-STXL-6303E. Resolution 0.73 arcsec/pixel. V-filter. Located in Nerpio, Spain. Elevation 1650m
- iT24: 610mm CDK with 3962mm focal length. CCD: FLI-PL09000. Resolution 0.62 arcsec/pixel. V-filter. Located in Auberry, California. Elevation 1405m
- AAVSO VPhot for initial plate solving and stacking
- AAVSO APASS providing Vmags
- 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 Survey Images for counterchecks
- AstroPlanner v2.2 for object selection, session planning and for catalog based counterchecks
- Astrometrica v4.9.1.420 for astrometry and photometry measurements

Special thanks to Paul Rodman (author of AstroPlanner) for providing me the current APASS catalog for local use with AstroPlanner

References

Buchheim, Robert, 2008, "CCD Double-Star Measurements at Altimira Observatory in 2007", *Journal of Double Star Observations*, **4**, 28-32.

Halbwachs, J.L., 1986, "Common proper motion stars in the AGK3", *Astronomy and Astrophysics Supplement Series,* **66**, 131-148.

Nicholson, Martin P., 2015, "Binary star discoveries in the URAT1 catalog - separation under 60 arc sec, Amazon.com. Abstract: Data mining using the recently published First U.S. Naval Observatory Astrometric Robotic Telescope Catalog (URAT1) has allowed the identification over 9400 common proper motion binary star systems many of which appear to be new discoveries

Nicholson, Martin P., 2006, "Unreported High Proper Motion Northern Double Stars in the LSPM Catalog", *Journal of Double Star Observations*, **2**, 68-73.