Assessment of 26,840 WDS Objects for being Common Proper Motion Pairs

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Abstract: The WDS catalog contains (as of August 2017) more than 100,000 objects which are currently not considered to be physical. For 26,840 of these objects both components were identified in the UCAC5 catalog and checked with UCAC5 proper motion data using a common proper motion (CPM) assessment scheme according to Knapp and Nanson 2017 with extensions. A surprisingly large number of these pairs seem to be physical. Additionally, GAIA DR1 positions are given for all components, and precise separation and position angle based on GAIA DR1 coordinates were calculated for all of the 26,840 pairs.

1. Introduction

The WDS catalog contains (per the August 2017 release) more than 100,000 double stars listed without "V" or other code declaring them as possibly physical pairs. The most recently available precise proper motion data in the GAIA DR1 catalog allows for a very reliable counter-check of this assumption, but the TGAS subset of GAIA DR1 with only about 2,000,000 stars covers only a small number of the WDS stars. The next reliable source of precise proper motion data is (with some caveats – see paragraph 4) the UCAC5 catalog, as it contains data for more than 100,000,000 stars based on re-reduction of the UCAC images using TGAS objects as reference stars and comparing the UCAC5 positions with those in the GAIA DR1. This gave us a huge increase in the number of objects available to check against the selected WDS objects.

2. Selection and Identification of the Objects

A program was written that parsed the wds_precise.txt catalog and found all binaries that did not have a "V" or other designation in their notes column indicating a physical pair. This list was then searched by a second program for UCAC5 stars that corresponded to the WDS pair. The UCAC5 star needed to be within 4 arc seconds and not brighter than a magnitude (visual bandpass) and no fainter than two magnitudes of the WDS star. If both members of a UCAC5 pair were found, the position angle of the UCAC5 stars needed to be within 4 degrees of the most recent WDS observation. The results of this search formed the basis for our subsequent analysis, reported in this paper.

There is the question of possible false positives in our survey. We did a counter-check by selecting the objects with the largest difference in separation and position angle between WDS and GAIA DR1 as such differences are either the result of very different proper motions as reported by the WDS and UCAC5 or the consequence of a misidentification. The most suspect objects we checked here were WDS discoverer designations B 184 AB, HDS 2154 and 2857, KUI 100 AB and AC, LDS 352 and 372, LMP 35 AC, HDS 2857, ENO 3, OSO 68 AC, RSS 409 and 426, STI1 318 and WNO 24. In all cases the explanation was that one component had an extremely fast proper motion leading to a quick change in separation and position angle and none of these objects proved to be an incorrect identification. This does certainly not mean that we can be sure that there are no false positives in our data set at all but we are confident that the number of misidentifications is certainly less than one in a thousand.

3. Results

The table with the results is far too large to be given here in print so we list here only a selection of columns for the first 25 objects sorted by WDS ID. The full table with data for all of the objects including content description can be downloaded as a spreadsheet from the JDSO website as “WDSvsUCAC5 II”.

The programs used to select pairs in the WDS, and then match those stars with ones in the UCAC5, and then check for misidentifications are posted here: https://sourceforge.net/projects/codefromwdsvsucac5/files/?source=navbar.

During the work on this report it became evident that there is a difference between assessing double stars for being potential common proper motion pairs and counter-checking assumed CPM pairs – in the latter case we have large proper motion data values and rarely objects with very small proper motion values. In the former case a good number of the objects have, for both objects, proper motion values far too small to be significant. For this reason the CPM assessment scheme was extended to reflect this fact (A planned extension of the letter based CPM rating scheme – Knapp 2018, is in preparation). We also suggest the introduction of a new WDS catalog note code indicating “Tested for common proper motion – most probably optical, but undecidable with given proper motion data” to avoid a simply undefined state in this regard.

The following data is given in Table 1.

- WDS ID.
- Name = Discoverer ID.
- GAIA DR1 coordinates for the primary (observation epoch 2015) in degrees.
- Separation and position angle calculated from the GAIA DR1 positions for primary and secondary.
- Proper motion vector direction for both components calculated from UCAC5 proper motion data in degrees.
- Proper motion vector length for both components calculated from UCAC5 proper motion data in mas/yr.
- CPM rating and score (see Appendix A).
- Notes with comments.

The full data set available for download also contains additional columns to provide full information on all checked objects.

4. Reliability of UCAC5 Proper Motion Data

The UCAC5 RA and Dec proper motion errors are about 1-2 mas for most objects (see Zacharias et al. 2017), but some of the UCAC5 objects have e_pm values larger than 6 mas (see Knapp and Bryant 2018). This seems somewhat surprising as this is the error range one gets usually when comparing 2MASS to GAIA DR1 positions and why a proper motion catalog like UCAC5 based on plate solving with TGAS refer-

(Text continues on page 430)

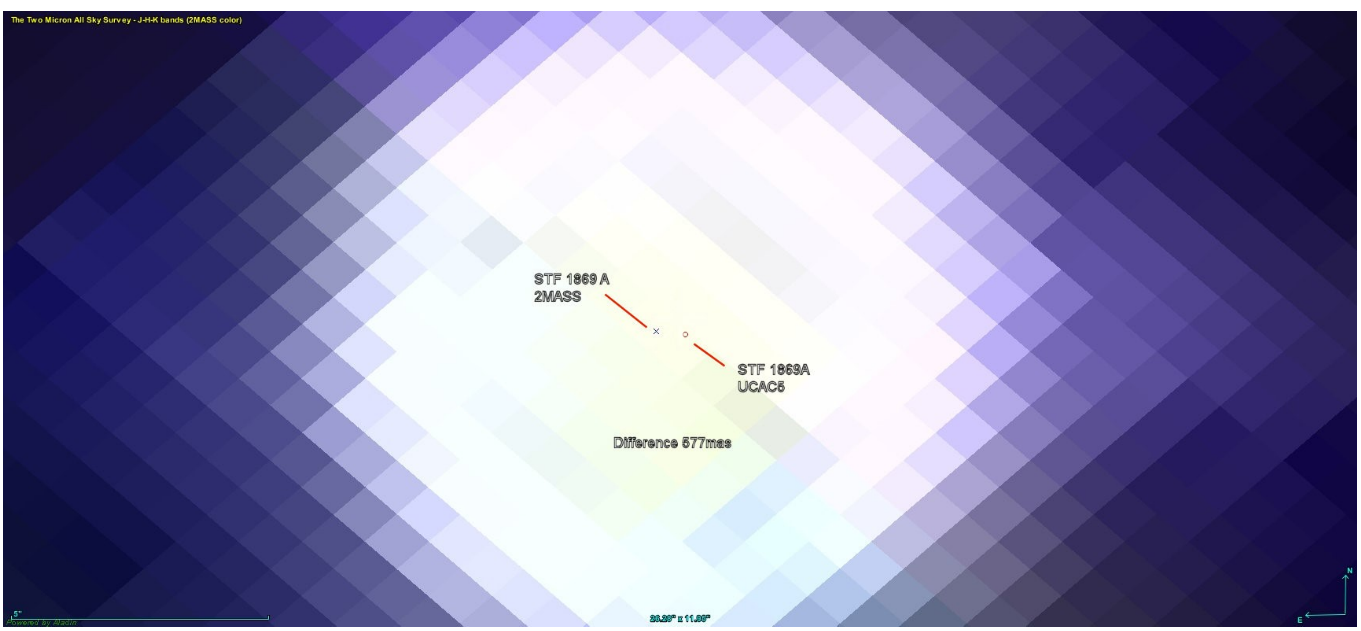

Figure1 . 2MASS image of STF1869 A showing the 2MASS position as well as the UCAC5 position (both are J2000 coordinates) with a “separation” of 577mas.

Table 1: The first 25 objects from the data set

WDS ID	Discoverer	RA A	DE A	GAIA Sep	GAIA PA	PMVD° A	PMVD° B	PMVL A	PMVL B	CPM Rat	CPM %	Notes
00000+4004	ES 2543AB	0.01523167	40.0887	4.40849735	253.392628	192.724356	84.2176077	3.17804972	7.94040301	DDDB	0	Almost certainly optical
00000+4004	ES 2543AC	0.01523167	40.0887	14.4093727	66.12538	192.724356	27.897271	3.17804972	1.92353841	DDDC	0	Almost certainly optical, but un-decidable with given PM data
00002-2519	COO 273	0.04049278	-25.32484	8.45825739	10.5231357	163.767649	175.648922	8.22800097	9.226592	DCDB	0	Almost certainly optical
00003+1642	HJ 318	0.05755306	16.6824	25.9639314	61.0594363	92.8271246	220.815084	40.5493526	8.72066511	DDCC	0	Almost certainly optical
00004+7305	HJ 3231AB	0.09393861	73.08223	23.4073126	281.803243	95.0764016	5.44033203	39.5551514	8.43800924	DDCB	0	Almost certainly optical
00004+7305	HJ 3231AC	0.09393861	73.08223	44.8251933	296.059643	95.0764016	76.2392149	39.5551514	15.1343979	DDCC	0	Almost certainly optical
00004+5044	HJ 1923	0.09845889	50.73895	11.5190279	279.171401	152.684392	158.101807	10.2420701	10.9931797	BBDC	40	Weak CPM candidate
00004+6026	STI1248	0.1034603	60.42536	12.2762989	48.0404786	65.8312096	65.9832879	31.0190264	32.1864878	AABB	92	Solid CPM candidate
00005+5457	STI3076	0.1263411	54.95593	8.41802669	276.877272	110.282559	110.224859	29.4244796	2.02484567	ADCB	4	Almost certainly optical
00005+5902	STI3079AB	0.1358408	59.04433	14.3122733	123.598601	86.9872125	98.426969	1.90262976	5.45893763	DDDC	0	Almost certainly optical, but un-decidable with given PM data
00005+5609	STI3078	0.1367186	56.15967	13.7100953	194.321946	235.713123	241.431592	5.32541078	21.7478735	BDCC	3	Almost certainly optical
00007+6103	NVL 8AC	0.1789797	61.05733	20.647747	221.433992	74.3289085	75.3094859	91.8128531	93.4550694	AAAB	97	Solid CPM candidate
00008+0630	GWP 2	0.1878367	6.494974	10.1284573	290.471856	169.637541	174.393515	106.740995	109.523924	BABA	76	Good CPM candidate
00008+3647	ES 221	0.2068961	36.78001	15.3941646	233.725619	230.520733	228.676602	38.2196285	35.2865413	ABBB	74	Good CPM candidate
00009+5915	STI3081	0.2138639	59.25523	4.62180907	87.3213091	88.72697	265.840358	4.50111097	5.51452627	DDDB	0	Almost certainly optical
00009+6023	MRI 4	0.2150719	60.38517	21.351826	358.915329	85.8447862	343.300756	23.4616709	1.04403065	DDCC	0	Almost certainly optical
00010-4234	I 1088AC	0.2567086	-42.57131	17.5733238	140.746637	135.410715	124.35078	39.4575722	16.8362704	DDBB	0	Almost certainly optical
00011+6336	MLB 240	0.2815872	63.60294	5.96386584	42.0576288	201.09234	167.005383	7.50266619	8.00499844	DBDB	1	Almost certainly optical, but un-decidable with given PM data
00012+1357	WNO 12AB	0.3050503	13.9757	11.6503093	203.843386	9.21602268	10.2710037	152.974671	151.42655	BAAA	80	Good CPM candidate
00013+6021	STTA254AB	0.3161597	60.35526	57.5660031	89.2833611	16.0029989	123.690068	40.988413	2.16333077	DDCC	0	Almost certainly optical
00013-7012	GLI 290AB	0.3233872	-70.18659	28.1889096	118.281465	101.445064	101.848854	66.5227781	66.7216607	AAAB	97	Solid CPM candidate
00013+0742	BU 9023CD	0.32682	7.747532	9.7556702	51.4988555	213.690068	224.409343	6.12943717	6.85930026	DCDC	0	Almost certainly optical
00013+5604	HJ 1925	0.3730181	56.05581	19.223537	341.706496	195.427609	217.528441	34.9596911	8.70057469	DDCB	0	Almost certainly optical
00016+6107	STI1253	0.3888058	61.1176	6.89152698	149.533752	89.9939689	270.023873	9.50000005	2.40000021	DDDC	0	Almost certainly optical
00016+3714	ES 2444	0.4071675	37.24546	9.3121169	249.402567	126.253838	217.275982	7.4404301	31.0407796	DDCB	0	Almost certainly optical

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ence stars should deliver data with such large errors is unknown. This puzzle led to the examination of some of the UCAC5 objects with the largest pm error values in our sample and to our surprise we found at least some of these objects are listed with sizable (greater than 60 mas in RA and Dec) position errors when compared with 2MASS. For example STF 1869 - the 2MASS image in Figure 1 shows the 2MASS position as well as the UCAC5 position (both are J2000 coordinates) with a "separation" of 577mas. This difference is difficult to explain based on usual measurement errors or with proper motion between the observation epochs with a time delta of only about one year. Due to this difference our UCAC5 based CPM assessment in this case is "almost certainly optical" while the 2MASS to GAIA DR1 position comparison results in a "good CPM candidate".

So far we have no explanation for this odd situation rendering UCAC5 a much less reliable proper motion and especially position data source than expected. Zacharias et al. 2017 suggest larger e_pm numbers may be expected for stars fainter than 15mag but while many of the suspect objects are indeed rather faint there are also many objects far brighter than 15mag. We intend to investigate this issue more in detail in a separate report which is in preparation.

5. Summary

Out of 26,840 counter-checked V-coded WDS objects:

- 302 objects were flagged due to proper motion error values considered to be too large for reliable CPM assessment – this is in comparison to our report on counter-checking WDS V-coded objects with 290 out of 4.937 objects (Knapp and Bryant 2018) a significantly smaller number
- 176 qualified as perfect AAAA CPM candidates with (within the given error range) ident proper motion vector direction and length, PM error size of less than 5% of PM vector length and a relationship of angular separation to PM speed of less than 100 years. This means these pairs are almost certainly physical.
- 2,092 qualified as solid CPM candidates with (within the given error range) ident proper motion vector direction and length but with minor issues regarding PM error size and relationship of angular separation to PM speed. These are also to consider as almost certainly physical.
- 2,465 qualified as good CPM candidates with proper motion vector direction and length differences within twice the given error range and with only minor issues regarding the PM error size and relationship of their angular separation to PM speed. Some differences in PM vector length and direction might be caused by an orbit depending on the plane of the orbit with respect to the sky so this class of objects might contain a few doubles with orbits.
- 812 objects qualified as weak CPM candidates with a rather small probability for being physical with the caveat of insignificant pm data for a few of them.
- 966 objects are probably optical as their proper motion vector direction is beyond twice but within triple the given error range, as well as showing some PM vector length differences again with the caveat of insignificant pm data for a few of them.
- 16,659 of the remaining 20,027 objects are almost certainly optical pairs.
- The remaining 3,368 objects are also almost certainly optical but the proper motion values are far too small to be considered definitive.

These results show the need for a systematic check of all WDS objects for being potential physical or not.

Statistics for a few selected double star discoverer ID's: Perfect to good CPM candidates are

- A: 14 out of 125 objects
- B: 86 out of 415 objects
- BAL: 206 out of 1,257 objects
- BRT: 306 out of 1,125 objects
- DAM: 80 out of 528 objects
- ES: 166 out of 867 objects
- GRV: 390 out of 705 objects
- HJ: 721 out of 3,334 objects
- J: 194 out of 1,097 objects
- LDS: 284 out of 418 objects
- POU: 166 out of 2,956 objects
- SKF: 99 out of 251 objects
- STF: 269 out of 1,190 objects
- STI: 144 out of 1,174 objects
- TDS/TDT: 35 out of 127 objects

Acknowledgements:

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

- Washington Double Star Catalog as data source for the selected objects
- UCAC5 catalog
- GAIA DR1 catalog
- Aladin Sky Atlas v8.0 for counterchecks
- 2MASS All Sky Survey Images for counterchecks
- Sourceforge Software Repository

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Appendix A

Description of the CPM Rating procedure (Knapp and Nanson 2017) with Extensions (Knapp 2018, paper in preparation)

Four rating factors are used: Proper motion vector direction, proper motion vector length, size of the position error in relation to the proper motion vector length according to Knapp and Nanson, with an extension for relating separation to proper motion speed

- Proper motion vector direction ratings: “A” for identical direction within the error range (calculated by assuming the worst case of the position error pointing in the right angle to the PM vector), “B” for similar direction within the double error range, “C” for similar direction within the triple error range, and “D” for outside the triple error range.
- Proper motion vector length ratings: “A” for identical length within the error range (calculated by assuming the worst case of the position error pointing in the direction of the PM vector), “B” for similar length within the double error range, “C” for similar length within the triple error range, and “D” for errors outside of this.
- Error size ratings: “A” for an error size of less than 5% of the proper motion vector length, “B” for less than 10%, “C” for less than 15%, and “D” for an error size larger than 15%.
- Relation of separation to proper motion speed: "A" for less than 100 years, "B" for less than 1,000 years, "C" for less than 10,000 years, and "D" for greater than 10,000 years.

To compensate for excessively large position errors resulting in an “A” rating despite high deviations proper motion direction and/or angle, an absolute upper limit is applied regardless of the calculated error size:

- Proper motion vector direction: Upper limit 2.86° difference for an “A”.
- Proper motion vector length: Upper limit 5% difference for an “A”.

To make the letter based assessment results easier to understand a transformation into a probability percentage for being physical with a corresponding verbal description is added.

Additionally the relationship of proper motion error size to proper motion vector length is checked (by RMS over all e_pm values larger than sum of PMVL*0.3) for being too large to allow for reasonable CPM assessment – in these cases the verbal description “but undecidable with given PM data” is added.