A New Concept for Counter-Checking of Assumed CPM Pairs

It is always pleasant to have exact solutions in simple form at your disposal - Karl Schwarzschild, 1916

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Abstract: The inflation of "newly discovered" CPM pairs makes it necessary to develop an approach for a solid concept for counter-checking assumed CPM pairs with the target to identify false positives. Such a concept is presented in this report.

Introduction

Common proper motion pair means two stars moving through space in similar direction with similar speed. Such pairs are of interest because of their potential physical relationship in terms of common origin. Despite several attempts (especially from Halbwachs 1986) there exists no generally accepted set of criteria for identifying CPM pairs. Some often used criteria are:

- Minimum of pm/yr (most often 50mas following Halbwachs 1986)
- Maximum separation in terms of pm (separation/pm<1000 following Halbwachs 1986)
- 0.05 significance criterion ($[\mu_1 - \mu_2]^2 < -2\ [\sigma_1^2 + \sigma_2^2]\ \ln\ [0.05]$ with μ_1, μ^2 as the two proper motion vectors and σ_1, σ_2 as the corresponding mean error following Halbwachs 1986 or modified by Caballero et al 2010 as $(\mu_{11} - \mu_{21})^2 < -2\ \sigma_{12}\ \ln\ (0.05)$ plus $(\mu 12 - \mu 22)^2 < -2\ \sigma_{22}\ \ln\ (0.05)$
- Maximum delta in direction of the pm vectors (45° following Hartkopf 2013)
- Delta proper motion vector length less than given pm error.

All these criteria are pm number based with the usual problem that the pm data in the existing catalogs is often less than reliable as is easy to demonstrate by looking at pm numbers from different catalogs. So CPM pairs "discovered" using a single catalog violate a basic rule for astronomical data mining: never trust a single source. Yet even assuming the numbers are correct and the criteria for detecting CPM pairs are sufficient this is still not sufficient to assume a physical relationship in terms of a common origin – they might very well be fellow travelers by random. So some additional research seems necessary by checking as many sources as possible for hints of a physical relationship such as spectral type, color, radial velocity, distance, and so on. On the other hand stars with rather low proper motion might be candidates as physical pairs if color and magnitudes are similar as the probability that such a combination is given for close objects by random is rather very low.

The WDS catalog is by definition a compilation of trusted observations reports, which means usually published in peer reviewed journals. Thus many objects are included in the WDS catalog as CPM pairs based on such reports, which also means without applying a consistent set of criteria. As the number of CPM pair related reports is increasing rapidly we think there should be a simple but reliable concept for eliminating false CPM positives.

Description of the new concept

With the availability of new star catalogs with RA/Dec positions of high precision the obvious way for counter-checking assumed CPM pairs is the comparison of positions in such catalogs with some decades between the observation epochs. The procedure is straight forward:

- Calculating the distance and the position angle between the star positions in different epochs similar to calculating separation and position angle for double stars, including calculating corresponding error estimations
- Comparing the values for distance and position angle for the two components of an assumed CPM pair to check if the direction and the length of the proper motion vector is within the calculated error estimations
- To stay within a reasonable range of error estimations it is necessary to keep the relation of position error to the length of the proper motion vector rather small – else the resulting error estimation would allow results with absurdly high deviations to be considered as "similar"
- The same goes for the calculated proper motion vector length per year – the difference between the two values for the two components should be as small as possible to be reasonable
- As an historical reference we might also check if the pm vector is at least 50mas/yr according to Halbwachs 1986 – but in this context this seems not really important as we are not data mining but simply counter-checking.

In a first attempt the obvious catalog choice was for UCAC4 and URAT1 as the currently most precise catalogs used for plate solving. But here an unexpected issue arose – UCAC4 has different observations epochs for RA and Dec making it difficult to determine a reliable time frame between the UCAC4 and URAT1 observation epochs. To consolidate different RA/Dec epochs to a common mean epoch would be possible by applying the given pm data to the given coordinates – but this would mean using the existing pm data we wanted to avoid from the very beginning to keep our approach consistent. Simply averaging the RA/Dec epochs might have been a possibility for rather small differences of less than 1 year. But then the next issue arose: even in cases with very similar to identical UCAC4 RA/Dec epochs the counter-check results remained inconsistent as the resulting pm vector/yr values showed unexpectedly large deltas between the components of well-established CPM pairs. This led to the conclusion that there might be an observation epoch issue with UCAC4 we might not be able to resolve.

As an alternative for UCAC4 we looked at the Initial Gaia Source List created as starting point for the Gaia Initial Data Treatment. If IGSL is good enough to be used as starting point for the Gaia results then it should be good enough for our purpose. First checks showed promising results and for our purpose a very positive attribute of IGSL: a consistent observation epoch of 1983.89 giving a time frame of ~30 years when comparing positions with URAT1 – a time frame large enough to allow for significant proper motion results. One issue arose also with the use of IGSL positions as a starting point: the resulting proper motion vector lengths are consistently less than half of the given pm data values in IGSL or URAT1. A first idea was an error in our spreadsheet but using positions from POSS I 1954 and POSS II 1994 we got results similar to the current catalog values – this means our spreadsheet is working fine and that there must be some position issue either with the old plates or with the contemporary catalogs. We assumed the former but then additional issues arose with not very convincing results for several objects (for example STT30AC and SKF299CD). IGSL is a compilation catalog produced for the Gaia mission with combined data from the following catalogs: Tycho2, LQRF, UCAC4, SDSS-DR9, PPMXL, GSC23, GEPC, OGLE, Sky2000, 2MASS. According to the authors (Smart and Nicastro 2014) this catalog is reliable but includes unavoidable errors and the user should have in mind that it is to be used with care for individual objects – obviously we stumbled over this caveat.

We found then that such issues were easily resolved by using 2MASS as a reference catalog and that this setup also solved the issue with the pm/yr riddle given with UCAC4 and IGSL by providing reasonable pm values also per year. Using 2MASS instead of IGSL means in theory loss of about 15 years time distance between observation epochs but the results told us that this is an illusion as the IGSL mean epoch is obviously questionable. We then realized that URAT1 also uses 2MASS as reference for calculating pm values making our second reference catalog switch all the more understandable. However, the question of obvious observation epoch issues with UCAC4 and IGSL remains open and we can only hope that the evident shaky IGSL data quality will not have consequences for the future GAIA catalog data quality.

Finally another issue arose with the given quite small proper motion errors in URAT1 not matching very well with the pm error calculations we made based on the given 2MASS position errors. When investigating this further we found the cause is the use of a rather low estimated mean 2MASS position error for URAT1 with the consequence that any data mining based on URAT1 using the given e_pm value without any counter-checking is highly questionable.

Description of Details and Usage of the Check CPM spreadsheet

In the spreadsheet we developed for the CPM counter-check we use the following formulas and checks:

- Proper motion vector direction: Calculated from the RA Dec coordinates as arctan((RA2-RA1)*cos (Dec1))/(Dec2-Dec1)) in radians depending on quadrant (Buchheim 2008)
- Proper motion vector length: Calculated from the RA Dec coordinates as SQRT(((RA2-RA1)*cos (Dec1))^2+(Dec2-Dec1)^2) in radians (Buchheim 2008)
- Proper motion vector length error estimation e_PMVL: Calculated as SQRT(e_RA^2+e_Dec^2) with e_RA and e_Dec as given IGSL RA and Dec errors
- Proper motion vector direction error estimation e_PMVD: Calculated as arctan(e_PMVL/PMVL) in degrees assuming the worst case that e_PMVL points in the right angle to the direction of the proper motion vector means perpendicular
- Check for identical PMVD by comparison Δ PMVD with e_PMVD resulting in an "A" for being smaller, "B" for being larger but still smaller than 2*e_PMVD and "C" for being larger than that
- Check for identical PMVL by comparison Δ OMVL with e_PMVL resulting in an "A" for being smaller, "B" for being larger but still smaller than 2*e_PMVL and "C" for being larger than that
- Check relation of the position error to pm vector length: As both checks for identical PMVD and PMVL depend highly on the size of e_PMVL we check additionally the relationship between the size of e_PMVL to PMVL for both components resulting in an A if both e_PMVL are less than 5% of PMVL, in a "B" if at least one or both e_PMVL are less than 10% of PMVL and in a "C" if at least one e_PMVL is larger than 10% of PMVL. This check corresponds to some degree to the significance criterion according to Caballero et al 2010

The spreadsheet can be downloaded from http://www.sterngucker.eu/XLS/Check%20CPM%202MASS%20to%20URAT1.xlsx

Usage of the spreadsheet:

- Locate the object in Aladin V9
- Load the 2MASS catalog
- Load the URAT1 catalog
- Click on the primary to get the data for the "2 superimposed objects"
- Do the same for the secondary while pressing Upper Case to get the data for the additionally "2 superimposed objects"
- Right click on the data lines with "Copy all measurements (for Excel)"
- Copy into the spreadsheet with cell A7 marked
- Click the VizieR links in Aladin for 2MASS catalog entry details and enter 2MASS position errors and Julian observation date into the spreadsheet in lines 11 and 12 (usually identical except for very wide pairs)
- Enter the name of the object into cell D14
- Interpretation of the results

This procedure needs an additional step for Excel language versions using a decimal separator different from the decimal point – for example the decimal comma in the German version: in this case after copying the data into the spreadsheet you need to simply change all "." into "," for all fields marked after the copy command.

Interpretation of the result: The following is a kind of rating in form of A/B/C for the different criteria with a triple A for a perfect result.

- The first letter stands for the comparison of the pm vector direction: "A" means within the error range calculated from the given 2MASS position error but at least within 2.86°, "B" means within the double error range but at least within 5.72° and "C" means outside the double error range or outside 5.72°. An assumed CPM pair with a "B" would already need very good additional arguments like same spectral type of other physical attributes to be acceptable as assumed physical. And a "C" means clearly not CPM because moving in different directions. The requirement of less than 2.86° for an A is based on the assumption that two close stars within the same image should share a rather similar position error thus reducing the theoretical effect assumed in the error range calculation.
- The second letter stands for the comparison of the pm vector length: "A" means within the error range calculated from the given 2MASS position error and the vector length but at least within 5% of the pm vector length, "B" means within the double error range but at least within 10% of the pm vector

length and "C" means outside the double error range or outside 10%. An assumed CPM pair with a "B" would already need very good additional arguments like same spectral type of other physical attributes to be acceptable as assumed physical. And a "C" means clearly not CPM because of a too large delta in pm vector length. The requirement of less than 5% for an A is again based on the assumption that two close stars within the same image should share a rather similar position error so any delta should remain below this value.

- The third letter stands for the data quality in terms of the relation of the 2MASS position error to the length of the pm vector length: "A" stands for less than 5% allowing up to 2.86° delta in proper motion vector direction, "B" stands for less than 10% allowing up to 5.72° delta in proper motion vector direction and "C" stands for more than 5.72°. An assumed CPM pair with a "B" is thus already considered a bit shaky in terms of data quality and would already need very good additional arguments like same spectral type of other physical attributes to be acceptable as assumed physical. And a "C" means clearly not CPM because of a too large position error to pm vector length relation rendering such results as unreliable. This check is very important because it questions the results in the first two letters – in other words an "AA" followed by "B" or "C" indicates very similar pm direction and speed but with the possibility of a "lucky hit" within the given error range.
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We then selected assumed CPM objects from the different sources listed in references and acknowledgements and applied the CPM Check Spreadsheet.

First Impressions

After finishing the draft of our table with the CPM check results we did an initial statistical analysis with in total 139 objects:

- 125 are WDS objects
- 92 of them have V-Codes and one has an O code (for orbit), which equals a total of 93 marked as CPM if we take O as close to CPM
- of these 93 objects only 14 got a solid AAA, 23 got an AAB and 7 an AAC, making a total of 44 objects with confirmed CPM results, which is less than 50% of the V-coded objects
- of these 93 objects 7 have an ABA to ABC rating so things get a bit shaky here
- Next we have 5 pairs with similar direction but different speed. Interestingly the O-coded object is in this group. It would be worth checking if this result is in agreement with the calculated orbit (see summary)
- Next we have 15 objects with BAB to BCC, meaning objects with rather different pm direction
- Finally we have 22 objects with CAB to CCC rendering the V-code as highly suspect, which is equal to about 25% of the total
- In the next group we have 32 WDS objects without V-code
- 15 of them with AAA to AAC rating means solid CPM
- 5 of them BAA to BBC means potential CPM
- 12 more with BCC to CCC
- Finally we have 14 objects not included in the WDS catalog
- 9 of them AAA to AAC means solid CPM pairs
- 2 with ABA and BAC means potential CPM
- 3 with CAC means pm in different directions thus probably not CPM

The mentioned 32 WDS objects without V-code were selected from different sources as declared or suspected CPM candidates – about 50% of them are confirmed as serious CPM objects.

Most interesting are the 14 objects mentioned above which are not included in the WDS catalog with about 75% of them serious CPM candidates – all were selected because of clear hints for being CPM objects and most of them from the LSPM catalog. It seems that the LSPM catalog is still a good source for finding so far not cataloged CPM pairs. Amazingly most close LSPM objects show very similar pm direction and speed and qualify as components of a CPM pair.

Next step was to counter-check the last group of 22 suspect WDS V-coded objects with POSS images to get an impression if our results were in line with images of these objects with a time distance of ~40 years.

This quickly resulted in a slightly confusing situation in which an object with a small PM is rather unspectacular when blinking POSS images or making Aladin mosaics of them – so we had to learn that no noticeable pm here is a confirmation of our non-CPM results. A side result was the detection of a few WDS errors in form of typos or mismatch of components.

Most interesting here is the fact that a good part of these objects showed significant changes in the proper motion data from the UCAC4 catalog to the URAT1 catalog, probably making the difference between whether CPM was assumed or not. This demonstrates once more that there are some risks in relying solely on the PM numbers in one single catalog and that it is necessary to check the CPM status for objects of interest from time to time, especially when new position data is available.

Table 1 includes a selection of pairs that were evaluated as CCC by our Check CPM spreadsheet, in which we compare PM data from the UCAC4 and URAT1 catalogs. Those numbers which resulted in a noticeable change in relative motion between the components are highlighted in red in the table. In a few cases, such as GMC 13 DC and PNT 2, the change in data increased the possibility of shared proper motion. In addition, there were a few instances in which the data changes resulted in a change of direction of one of the components, such as PKO 5, SMR 67, and UC 306. However, in the majority of cases we looked at, the change from UCAC4 to URAT1 data resulted in an increased divergence of direction, making common proper motion less likely.

Some Examples

Table 2 shows the results of our CPM Check spreadsheet for CPM assumed objects from different sources indicated in the Notes column.

Summary

The approach presented here for checking assumed CPM pairs for validity is, as shown in the examples above, a useful tool to identify pairs with reliable data suggesting common proper motion in the sense of being within a reasonable error range for identical direction and speed. Such a check should in our opinion be applied on any object suggested to be a newly "discovered" CPM pair and over time also to all pairs currently in the WDS labeled with the V note code.

Table 1: Examples for Proper Motion Data Change from UCAC4 to URAT1 Catalogs

Disc. Code	Catalog	PM in RA Primary	PM in DEC Secondary
	UCAC4	+010.8 -003.8	-004.2 **-014.3**
GMC 13DC	URAT1	+009.1 -002.7	-003.5 **-004.2**
	UCAC4	**-001.3** +001.0	**-001.5** +000.2
PKO 5	URAT1	**+003.7** +001.5	**+001.6** +001.3
	UCAC4	+029.9 -079.7	+031.5 **-082.3**
PNT 2	URAT1	+026.8 -073.3	+027.2 **-074.4**
	UCAC4	-017.6 +018.6	**-017.8** +019.2
SHY 378	URAT1	-014.4 +020.1	**-022.7** +020.1
	UCAC4	-019.0 **+003.8**	-017.1 +004.7
SKF2325	URAT1	-020.7 **+007.1**	**-024.1** +005.5
	UCAC4	**+003.8** -007.0	+005.4 -007.4
SMR 16AC	URAT1	**+014.8** -000.4	+006.4 -005.7
	UCAC4	**+013.0 -015.5**	No data
SMR 66	URAT1	**+006.1 -000.2**	-008.8 -004.0
	UCAC4	-012.4 -023.1	**-014.9** -018.8
SMR 67	URAT1	-009.8 -024.3	+001.0 -017.8
	UCAC4	**-020.0 -014.0**	-012.8 **-006.4**
STI 117	URAT1	**-006.5 -005.6**	-007.5 **-011.8**
	UCAC4	**+061.1 -000.2**	+056.2 **-003.9**
UC 302	URAT1	**+053.0 +015.0**	+051.2 **+013.2**
	UCAC4	+071.2 **-004.3**	**+051.8** -022.5
UC 306	URAT1	+075.8 **+005.2**	**+061.1** -016.3

Known weaknesses of our approach and interesting side results of our study follow:

- URAT1 is available only for the northern skies – so our approach shares this limitation making it for example impossible to check AHD17 (Ahad 2013). Would have been of interest as the proper motion/yr of this pair is far below the Halbwachs 1986 criterion of 50mas.
- As already mentioned UCAC4 and IGSL seem to have serious data quality problems with the mean observation epoch as is shown by unrealistic low pm/yr values when dividing the calculated proper motion vector length by the time frame between the given observation dates.
- As already mentioned URAT1 provides rather optimistic pm error estimations by assuming a rather low average 2MASS position error of ~90mas resulting in modest ~6mas/yr with only minor variations due to the time difference in observation dates. As our research relies heavily on the effective given 2MASS position error we get rather often more than triple this value. This means that all CPM research relying exclusively on the URAT1 e_pm data (like for example Nicholson 2015) is rendered as highly suspect.
- While URAT1 was created with special considerations to include also brighter stars this can get complicated if proper motion is involved. Caveat in the "readme.urat1" file: "Stars with higher proper motions were not attempted to match for this release, neither were other catalogs used to improve the proper motions". An example for such a case is 61 Cyg mentioned by Aitken 1922 as special proper motion object or the WDS V-coded CPM pair OSV3. In the URAT1 catalog we have found objects corresponding with the 61 Cyg components are located far away from the corresponding star disks in images such as 2MASS due to the huge pm speed – it simply needs some time and patience to locate such objects.
- 61 Cyg shows also the limited value of our approach for very fast proper motion pairs. Based on our own measurement as a substitute for the URAT1 positions we were initially unable to find in the Aladin image of 61 Cyg, the result is a proper motion direction of ~52° with a delta of less than 0.5° and a proper motion vector length of amazing

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Table 2. CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
ADS1727	141.48	141.50	2.860	1,181.7	1,179.4	59.027	A	A	B	VD	Selected by random from Halbwachs 1986 (Table II). PM direction and speed very close, position error ~7% of pm vector length - solid AAB CPM rating.
ADS 191	104.26	101.94	2.860	1,260.1	1,239.2	62.481	A	A	B	VD	Selected by random from Halbwachs 1986. Relation position error to pm vector length ~8% so CPM confirmation not perfect.
ADS8108	66.79	68.44	2.860	2,534.3	2,415.6	123.748	A	A	B	VDZ	Selected by random from Halbwachs 1986. Relation position error to pm vector length ~6% so CPM confirmation just slightly not perfect.
ADS8168	170.72	173.55	2.860	1,276.0	1,292.7	64.216	A	A	B	VD	Selected by random from Halbwachs 1986. Relation position error to pm vector length ~7% so CPM confirmation not perfect.
AG 32AB	92.00	90.12	2.860	514.5	516.6	25.779	A	A	C	-	Picked at random from Harshaw, 2016. His results categorize AG 32 AB as CPM. Check CPM results good for vector direction and length, but position error in relation to PM vector length is slightly beyond the 10% cutoff for a B rating (16.5% for A, 16.4% for B). Simbad shows A as an F8 star, but doesn't provide a spectral class for B.
AG 193	282.19	283.24	2.860	1,648.2	1,608.3	81.414	A	A	B	VD	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). e_PMVL larger than 5% of PVML for B, yet Check CPM result seems rather positive. Listed also in Vizier I/330 as MPN 4969 "newly discovered" from Nicholson 2015.
ARG 5	211.33	191.42	2.860	61.1	83.4	3.612	C	C	C	-	Picked at random from Harshaw, 2016. His results categorize ARG 5 as CPM. The vector direction and length are outside the 2x error range, while the position error in relation to the PM vector is well outside the 10% cutoff (138.9% for A, 101.8% for B). Simbad shows the primary with a spectral class of B9, none listed for the secondary.
ARN 55AD (HJL 1011)	127.37	132.97	2.860	889.0	739.4	40.709	B	C	C	-	Picked at random from Halbwachs, 1986. Check CPM results show the pair is in the 2x error range for vector direction and outside the 2x the error range for vector length; position error in relation to PM vector length is at the outside edge of the B range for the A component (9.5%) and just outside the B range for the secondary (11.5%). Both Halbwachs and Simbad show A with a spectral class of A3 and D as G5.
BEM 16	162.39	164.65	2.860	1,732.5	1,717.2	86.244	A	A	B	-	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). B rating for only slightly above 5% position error ratio - looks like a good CPM confirmation. Listed in VizieR I/330 as "newly discovered pair" MPN 5359.
BGH 22	297.17	302.03	2.860	2,719.0	2,762.0	137.025	B	A	A	-	Picked at random from Benavides, et al, 2010. Check CPM results show the pair is in the 2x range for vector direction and within the error range for vector length; the position error in relation to the PM vector length is within the criteria for an A rating (4.3% for A, 4.2% for B).
BGH 35 (HJL 1064)	277.05	281.14	2.860	1,657.8	1,597.5	81.382	B	A	C	-	Picked at random from Halbwachs, 1986. Check CPM results show the pair is within the 2x error range for vector direction and within the error range for vector length; position error in relation to PM vector length is just inside the B range for the A component (9.2%) and outside the B range for the secondary (16.5%). Both Halbwachs and Simbad shows A with an F5 spectral class and B as G5.
BGH 1AB,C (HIP 190)	203.65	204.33	2.860	1,557.9	1,570.5	78.210	A	A	B	V	Selected from Shaya and Olling 2011. Solid AAB CPM rating, 2MASS position error ~6,5% of pm vector length.
BU 1442AB	144.34	144.36	0.683	16,395.2	16,477.9	196.469	A	A	A	VDP	Selected by random from the WDS catalog as V-coded object. Solid triple AAA CPM rating.

Table 2 continues on next page.

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Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
BVD 14	147.25	156.24	2.860	204.2	273.4	11.938	C	C	C	-	Picked at random from Benavides, et al, 2010. Check CPM results show the pair is outside the 2x error range for both the vector direction and length; position error in relation to PM vector length is well outside the error range (61.4% for A, 45.6% for B). Simbad shows the primary with a spectral class of F6 and the secondary as K3.
BVD 18	118.37	125.76	2.860	1,285.1	1,290.6	64.392	C	A	B	-	Picked at random from Benavides, et al, 2010. Check CPM results show the vector direction is outside the 2x range, while the vector length is within the error range; the position error in relation to the PM vector length is just inside the criteria for a B rating (6.6% for both components). Simbad shows the primary with a spectral class of G8 and the secondary as G7.
CBL 105	44.91	45.56	2.860	832.0	889.1	43.028	A	B	C	V	Picked at random from Caballero, 2009. Check CPM results show the pair is within the error range for vector direction, vector length is in the 2x error range; and the position error in relation to PM vector length is just at the fringe of being outside the B range (10.2% for A and 9.5% for B). Simbad doesn't show spectral classes for either star.
CBL 119	165.57	165.64	2.860	1,236.8	1,236.7	61.837	A	A	B	V	Picked at random from Caballero, 2010. Check CPM results show the pair is within the error range for vector direction and length; position error in relation to PM vector length is in the middle of the B range (7.5% for both A and B). Simbad doesn't show spectral classes for either star.
CBL 148	238.13	236.48	2.860	951.8	925.8	46.940	A	A	C	V	Picked at random from Caballero, 2010. Check CPM results show the pair is within the error range for vector direction and length; position error in relation to PM vector length is decidedly outside the B range (18.8% for A and 19.3% for B). Simbad doesn't show spectral classes for either star.
CBL 167	171.83	171.20	2.860	604.8	784.3	34.728	A	C	C	V	Picked at random from Caballero, 2010. Check CPM results show the pair is within the error range for vector direction but outside the 2x error range for length; position error in relation to PM vector length is a bit outside the B range (14.0% for A and 10.8% for B). Simbad shows both stars with a G5 spectral class.
CBL 181	116.72	126.92	2.860	1,274.7	1,265.1	63.495	C	A	B	V	Picked at random from Caballero, 2010. Check CPM results show the pair is outside the error range for vector direction and within the error range for vector length; position error in relation to PM vector length is just inside the B range (6.7% for both A and B). Simbad shows both stars with a K0 spectral class (HD 358326 and HD 358327). Blinking suitable 2MASS and SERC (in lack of POSS) images suggest somewhat similar pm direction and speed. Comparisons of pm data show some changes from UCAC4 to URAT1 suggesting CPM rather with UCAC4 but no longer with URAT1.
CBL 193	95.00	95.16	2.860	2,113.3	2,085.8	104.976	A	A	A	V	Picked at random from Caballero, 2010. Meets all three Check CPM criteria for CPM. Simbad has no spectral class for A, but lists B as K4/5.
CBL 21	75.03	75.86	2.860	1,874.4	1,881.8	93.905	A	A	A	V	Picked at random from Caballero, 2009. Meets all three Check CPM criteria for CPM. No spectral class shown in Simbad for either star.
CBL 53	277.83	278.94	2.860	1,207.8	1,221.3	60.725	A	A	B	V	Picked at random from Caballero, 2009. Check CPM results show the pair is within the error range for vector direction and length; position error in relation to PM vector length is in the middle of the B range (7.6% for both A and B). Simbad doesn't show spectral classes for either star.
CBL 70	280.52	278.93	2.860	1,084.3	1,057.2	53.539	A	A	B	V	Picked at random from Caballero, 2009. Check CPM results show the pair is within the error range for vector direction and length; position error in relation to PM vector length a bit past the middle of the B range (8.5% for A and 8.7% for B). Simbad doesn't show spectral classes for either star.

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
CBL 9	70.22	72.85	2.860	1,066.1	1,040.0	52.654	A	A	B	V	Picked at random from Caballero, 2009. Check CPM results show the pair is within the error range for vector direction and length; position error in relation to PM vector length is at the extreme edge of the B range (9.3% for A, 9.5% for B). Simbad doesn't show spectral classes for either star.
CBL 92	59.92	59.01	2.860	723.3	728.5	36.294	A	A	C	V	Picked at random from Caballero, 2009. Check CPM results show the pair is within the error range for vector direction and length; position error in relation to PM vector length is just beyond the B range (11.7% for A and 11.6% for B). Simbad doesn't show spectral classes for either star.
CLL 21AC	220.98	5.13	2.860	680.5	364.0	26.112	C	C	C	V	Obviously a WDS error regarding components should be BC and would then be ident with SKF 179 BC, which is shown below. Correspondence with Bill Hartkopf resulted in the V code being removed from CLL 21 AC after confirmation of error. That CLL 21 AC is not a CPM pair was confirmed also by counter-checking with blinking of POSS images.
CRB 8	86.06	85.62	2.695	2,770.1	2,754.8	130.384	A	A	A	V	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. Solid triple AAA CPM rating.
CRB 9	115.05	114.95	2.860	2,278.6	2,344.9	115.589	A	A	B	V	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. PM direction and speed very close, position error only for one component slightly above 5% of the pm vector length - very solid triple AAB CPM rating.
DAM 349	172.55	170.42	2.860	918.6	939.4	46.448	A	A	B	V	Selected by random from the WDS catalog as V-coded object. Relation position error to pm vector length slightly smaller than 10%, similar direction and speed thus considered a bit unreliable, otherwise CPM looks promising. Listed also in VizieR I/330 as MPN 5852 as "new discovery 2015."
DU 4 (HJL 325)	204.82	205.72	2.860	855.9	1,040.1	47.400	A	C	C	V	Picked at random from Halbwachs, 1986. Check CPM results show the pair is within the error range for vector direction and outside the 2x the error range for vector length; position error in relation to PM vector length is a bit outside the B range for the A component (11.6%) and within the B range for the secondary (9.5%). Both Halbwachs and Simbad shows each star with a spectral class of F8.
ES 149AB (HJL 320)	85.38	81.55	2.860	1,233.0	1,187.6	60.515	B	A	C	VD	Picked at random from Halbwachs, 1986. Check CPM results show the pair is within the 2x error range for vector direction and within the error range for vector length; position error in relation to PM vector length is a bit outside the B range for the A component (13.2%) and within the B range for the secondary (8.4%). Both Halbwachs and Simbad shows A with an F8 spectral class, but neither shows a class for B. The URAT1 PM numbers (+088.8 +007.2 and +083.6 +012.5) are very different from the PM numbers shown in the WDS (+057 +026 and +089 +005). The Simbad numbers also differ (+090.1 +008.6 and +088.9 +004.9).
GIC 168	46.84	47.63	2.696	2,513.6	2,548.4	120.000	A	A	A	V	Selected by random from the WDS catalog as V-coded object. Solid triple AAA CPM result.
GIC 24	91.64	91.71	2.014	3,981.1	3,905.7	140.000	A	A	A	V	Selected by random from the WDS catalog as V-coded object. Solid triple AAA CPM result.
GMC 13DE	106.77	219.17	2.860	131.0	75.7	5.168	C	C	C	V	Selected by random from the WDS catalog as V-coded object. Interesting idea that this should be a CPM pair. Difficult to detect any change in position in the primary when blinking POSSI (1954) and POSSII (1998) images; slight change toward the south is noticeable in the secondary. Rate of PM has lessened noticeably starting with NOMAD1 data and moving to UCAC4 and then to URAT1, which currently shows rates of +009.1 -002.7 for the primary and -003.5 and -004.2 for the secondary. Based on the URAT1 data, motion in the primary should be more obvious than in the secondary.

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
GRV 840	244.30	244.38	2.860	1,509.1	1,509.4	75.463	A	A	B	-	Picked at random from Benavides, et al, 2010. Check CPM results show the pair is within the error range for vector direction and length; position error in relation to PM vector length is in the middle of the B range (7.0% for both components). Simbad shows A with a spectral class of G7 and B as K1.
GRV 589	212.67	209.26	2.860	1,524.2	1,600.2	78.112	B	A	B	V	Selected by random from the WDS catalog as V-coded object. PM direction slightly larger than 2.86° and position error slightly larger than 5% of the proper motion vector, potential CPM result, but far from perfect.
GRV 862	285.50	283.37	2.860	1,396.0	1,367.1	69.079	A	A	B	V	Selected by random from the WDS catalog as V-coded object. Position error near 10% of the proper motion vector, border case of plausible CPM result.
GWP 117	225.45	223.20	2.860	843.2	893.3	43.413	A	B	C	V	Selected by random from the WDS catalog as V-coded object. Position error in relation to proper motion vector length too large to be considered as confirmed CPM pair; also pm vector length delta a bit too large.
GWP 52	88.47	86.85	2.860	823.5	832.8	41.407	A	A	C	V	Selected by random from the WDS catalog as V-coded object. Position error in relation to proper motion vector length too large to be considered as reliable confirmed CPM pair.
GWP 964	180.95	181.85	2.860	1,808.9	1,740.8	88.742	A	A	A	V	Selected by random from the WDS catalog as V-coded object. Solid triple AAA CPM rating.
HAU 10	112.20	111.95	2.860	1,839.6	1,827.8	91.685	A	A	A	V	Selected by random from the WDS catalog as V-coded object. Solid triple AAA CPM confirmation.
HDS 2093	267.38	269.53	2.860	2,202.5	2,121.1	108.091	A	A	A	V	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). PM direction and speed quite similar and position error below 5%. Solid triple AAA CPM confirmation. Listed also in VizieR I/330 as MPN 5211 as "new discovery 2015."
HJ 1267 (HJL 211)	252.23	259.13	2.860	935.5	882.1	45.439	C	B	C	V	Picked at random from Halbwachs, 1986. Check CPM results show the pair is outside the 2x error range for vector direction and within the 2x error range for vector length; position error in relation to PM vector length is just outside the B range for both components (11.4% for A and 12.1% for B). Halbwachs and Simbad show A with a spectral class of G5 but neither list a class for the B component. Mosaic and blinking of POSS images did not show anything conclusive - roughly similar direction and speed. The pm numbers in UCAC4 and URAT1 are rather different and do both not suggest CPM.
HJ 1930	229.38	234.90	2.860	80.2	87.0	4.180	B	B	C	-	Picked at random from Harshaw, 2016, where the results categorize HJ 1930 as CPM. Check CPM results show vector direction and length in the 2x range; the position error in relation to PM vector length is far outside the 10% cutoff for both stars. Simbad shows the two stars with spectral classes of B1.5 and B1.
HJ 547	209.99	213.39	2.860	1,322.2	1,293.5	65.392	B	A	B	-	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). PM direction and speed not this close and position error far above 5%, looks like a not solid CPM confirmation. Listed also in VizieR I/330 as MPN 4983 as "new discovery 2015."
HJL 1	98.07	99.69	2.860	1,021.2	971.0	49.805	A	B	B	V	Picked at random from Halbwachs, 1986. Check CPM results show the pair is within the error range for vector direction and in the 2x error range for vector length; position error in relation to PM vector length is at the outer edge of the B range (9.0% for A and 9.5% for B). Simbad shows A with a spectral class of F6 and B as G1.

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
HJL1019 AB	103.31	102.42	2.860	1,355.6	1,351.0	67.666	A	A	B	-	Picked at random from Halbwachs, 1986. Check CPM results show the pair is within the error range for vector direction and vector length; position error in relation to PM vector length is a bit inside the B range (6.8% for both A and B). Halbwachs shows A with a spectral class of A5m and B as F8.
HJL1020 (53 Ari)	314.82	158.79	2.860	133.3	307.8	11.027	C	C	C	-	Picked at random from Halbwachs, 1986. Check CPM results show the pair is well outside the 2x error range for both vector direction and vector length; position error in relation to PM vector length is well beyond the B range for both the A component (75.0%) and the B component (32.5%). Both Halbwachs and Simbad show A with a spectral class of B1.5 and B as G5. URAT1 PM's (-006.7 +006.7 and -008.1 -021.0) differ considerably from WDS PM's (-024 +008 and +001 -026). Simbad shows a PM for A of -024.3 +007.5 and for B of -001.1 -028.2.
HJL 54	314.03	315.68	2.860	943.2	921.8	46.624	A	A	B	V	Picked at random from Benavides, et al, 2010. Check CPM results good for vector direction and length; position error in relation to PM vector length is right at the edge of the cutoff for a B rating (9.0% for A, 9.2% for B). Simbad shows the primary with a spectral class of F6 and the secondary as F8.
HJL 234	202.39	200.45	2.860	788.8	814.5	40.084	A	A	C	V	Selected by random from the WDS catalog as V-coded object. Position error in relation to proper motion vector length too large to allow a fully reliable positive CPM result.
J0526 +6810N	159.84	160.82	2.860	2,407.5	2,355.9	119.085	A	A	A	n.a.	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. No WDS catalog object. URAT1 791-095367 and 791-095369 objects with separation 14.070" and PA 28.257°. Solid triple AAA CPM rating. Also included in the VizieR I/330 catalog as MPN 1233 as "newly discovered 2015". Positive counter-checked by blinking POSS images.
J1047 +2117	256.58	257.22	2.860	2,665.6	2,591.5	131.427	A	A	B	n.a.	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. No WDS catalog object. URAT1 557-171485 and 557-171484 objects with separation 21.457" and PA 359.171°. PM direction and speed very close, position error slightly outside 5% of the pm vector length - solid triple AAB CPM rating. Also included in the VizieR I/330 catalog as MPN 3088 as "newly discovered 2015". Positive counter-checked by blinking POSS images.
J 1369	138.28	138.73	2.860	2,566.5	2,592.5	128.975	A	A	A	V	Selected from the WDS catalog as J-object with code V - fully confirmed with triple AAA. Listed also in VizieR I/330 as MPN 3042 as "new discovery 2015."
J1522 +5942E	179.42	178.60	2.860	2,512.6	2,360.9	121.836	A	B	A	n.a.	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. No WDS catalog object. Very faint ~15mag URAT1 749-239708 and 749-239711 objects with separation 14.454" and PA 113.978°. PM direction very similar, speed rather similar, position error less than 5% of the pm vector length - solid triple ABA CPM rating. Also included in the VizieR I/330 catalog as MPN 5479 as "newly discovered 2015."
J1523 +1613N	281.31	281.07	2.860	2,611.0	2,562.3	129.331	A	A	A	n.a.	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. No WDS catalog object. URAT1 532-189347 and 532-189351 objects with separation 17.223" and PA 44.257°. Solid triple AAA CPM rating. Also included in the VizieR I/330 catalog as MPN 5480 as "newly discovered 2015". Positive counter-checked by blinking POSS images.
J1650 +2747N	313.04	312.81	2.860	2,436.5	2,335.1	119.291	A	A	A	n.a.	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. No WDS catalog object. URAT1 589-215144 and 589-215148 objects with separation 20.999" and PA 44.450°. Solid triple AAA CPM rating. Also included in the VizieR I/330 catalog as MPN 6093 as "newly discovered 2015". Positive counter-checked by blinking POSS images.
J 1804	237.76	243.74	2.860	367.1	380.8	18.698	C	A	C	-	Selected as potential CPM pair with a Jonckheere designation well aware that the pm numbers are too small to be significant - position error in relation to the pm vector length far too large to allow any reliable positive conclusion. PM direction seems too different to suggest CPM.

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
J1945 +3140E	356.50	355.79	2.855	2,406.4	2,365.5	119.297	A	A	A	n.a.	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. No WDS catalog object. URAT1 609-386641 and 609-386725 objects with separation 19.850" and PA 122.948°. Solid triple AAA CPM rating. Surprisingly no entry in the VizieR I/330 catalog.
J1949 +1010E	53.02	51.80	2.860	2,217.4	2,228.9	111.156	A	A	A	n.a.	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. No WDS catalog object. Very faint ~15mag URAT1 501-556660 and 501-556606 objects with separation 24.704" and PA 246.233°. Solid triple AAA CPM rating. Also included in the VizieR I/330 catalog as MPN 7870 as "newly discovered 2015."
J2026 +3156E	46.74	46.12	2.860	2,141.1	2,204.2	108.632	A	A	A	n.a.	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. No WDS catalog object. URAT1 610-486991 and 610-487036 objects with separation 17.215" and PA 60,071°. Solid triple AAA CPM rating. Also included in the VizieR I/330 catalog as MPN 8144 as "newly discovered 2015." Positive counter-checked by blinking POSS images.
J2219 +6640	61.41	61.76	2.860	2,352.8	2,402.2	118.874	A	A	A	n.a.	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. No WDS catalog object, may be ident with LDS 4958 but parameters besides PA do not match very well - and even for PA you have to switch the components for the fainter being A. Very faint ~16mag URAT1 784-195874 and 784-195879 objects with separation 20.668" and PA 13.815°. Solid triple AAA CPM rating. Also included in the VizieR I/330 catalog as MPN 8887 as "newly discovered 2015."
KU 53	173.25	175.37	2.860	1,509.5	1,628.6	78.452	A	B	B	V	V-coded object selected by random from the WDS catalog. PM direction very close and speed rather similar, position error in relation to the pm vector less than 10% - medium solid ABB CPM rating.
LDS2931	210.78	211.92	1.509	4,554.4	4,397.7	120.000	A	B	A	V	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. PM direction very close, speed only slightly outside the error estimation allowed for an A, position error less than 5% of the pm vector length - solid triple ABA CPM rating.
LDS3127	82.49	82.93	2.860	2,387.3	2,387.0	119.356	A	A	A	-	Selected from Kirkpatrick et al 2016, Table 11, Sys. No. 7 as northern sky object with separation <30". Solid triple AAA CPM rating, yet not WDS V-coded.
LDS3131	96.19	96.39	2.860	2,284.5	2,321.5	115.152	A	A	C	V	Selected from Kirkpatrick et al 2016, Table 11, Sys. No. 9 as northern sky object with separation <30". Solid triple AAC CPM rating with a rather large 2MASS position error giving a C in the third position.
LDS4537	192.75	194.23	2.860	1,595.6	1,605.9	80.038	A	A	C	-	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). PM direction and speed quite similar but large position error makes this a bit unreliable - yet CPM rather confirmed. Listed also in VizieR I/330 as MPN 5399 as "new discovery 2015."
LDS4803	212.99	204.87	2.860	218.0	279.7	12.444	C	C	C	-	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. WDS object but without V-code and otherwise rather suspect parameters. URAT1 666-284685 and 666-284691 objects with separation 7.820" and PA 23.075°. This is certainly no CPM pair and the data suggests LDS 4803 being rather bogus or this is a mismatch.
LDS6302	126.37	125.84	2.860	4,090.1	4,129.5	205.490	A	A	A	I	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. Solid triple AAA CPM rating.
LDS 883AC	128.46	122.45	1.604	5,369.5	5,115.3	150.333	C	B	A	V	Selected STF 326 from Wiley 2015 but URAT1 did not provide an object for the B component, so component C (WDS V-coded as LDS 883 AC) was taken as substitute. Similar pm direction and speed but not close enough to qualify for CPM. Comparison of POSS I and POSS II images confirmed similar pm for component B. Mosaic and blinking of POSS images suggests very similar pm in direction as well in speed. Comparison of UCAC4 and URAT1 pm data is not possible as URAT1 does not offer pm data for this object; however the position data from 2MASS and URAT1 suggests not CPM for this one. A reason for this might very well be a parabolic orbit suggested for STF 326 AB.

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
LDS 969	244.89	244.76	2.860	2,393.8	2,403.2	119.925	A	A	B	-	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). PM direction and speed quite similar and position error only slightly above 5%, looks like a solid CPM confirmation. Listed also in VizieR I/330 as MPN 5229 as "new discovery 2015."
LDS 972	314.45	315.20	6.141	1,397.2	1,393.3	150.333	A	A	B	-	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). PM direction and speed quite similar but position error makes this result somewhat unreliable. Listed also in VizieR I/330 as MPN 5368 as "new discovery 2015."
LEP 1AD (STF 3060)	202.93	226.96	2.860	2,955.4	2,653.1	140.213	C	C	A	V	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) as substitute for AB because URAT1 missed an object for the B component. WDS notes regarding AD mention: "the visual binary at 573" is co-moving, same parallax. The D component is ~1.3m below the main sequence in the (K, V-K) color- magnitude diagram." Whatever this means, this is most certainly no CPM. Mosaic and blinking of POSS images did not show anything conclusive - roughly similar pm speed and slightly different pm direction. The pm numbers from UCAC4 to URAT1 for the B component are rather different and at least the latter do not suggest CPM.
LEP 2	93.59	94.83	2.860	2,393.0	2,420.0	120.326	A	A	A	V	Selected from Kirkpatrick et al 2016, Table 11, Sys. No. 11 as northern sky object with separation <30". Solid triple AAA CPM.
MLB 277	263.81	258.61	2.860	370.7	361.0	18.293	B	A	C	-	Picked at random from Harshaw, 2016. His results for MBL 277 were inconclusive (in the form of "???"). Check CPM results good for vector direction in the 2x range, while the vector length is within the error range. The position error in relation to PM vector length is outside the 10% cutoff for a B rating (22.9% for A, 23.5% for B). No spectral class for either star is shown in Simbad.
MLB 441AB	53.24	55.57	2.860	717.0	808.1	38.126	A	C	C	D	Picked at random from Harshaw, 2016. His results categorize MLB 441 as CPM. Check CPM results good for vector direction but vector length is outside the 2x range; the position error in relation to PM vector length is just beyond the 10% cutoff for a B rating (14.8% for A, 13.2% for B). Simbad shows A with a stellar class of G1, none listed for B.
MPN 115	182.34	174.51	2.860	931.7	966.0	47.443	C	A	C	n.a.	Selected by random from the VizieR I/330 catalog after applying the Halbwachs 1986 distinction criterion with negative result. Due to the in relation to the proper motion vector length far too large position error the "similar" direction and speed of proper motion is highly questionable - rather unlikely CPM.
MPN 4	77.86	82.68	2.860	1,261.7	1,302.5	64.105	B	A	C	n.a.	Selected by random from the VizieR I/330 catalog after applying the Halbwachs 1986 distinction criterion with negative result. Due to the in relation to the proper motion vector length far too large position error (~20%) the seemingly "similar" direction and speed of proper motion is a bit questionable. URAT1 gives here an e_pm of 6.5 and 6.6mas - far too optimistic with the given large 2MASS position error. Yet CPM not unreasonable.
MPN 49	77.94	87.55	2.860	975.2	1,003.5	49.466	C	A	C	n.a.	Selected by random from the VizieR I/330 catalog after applying the Halbwachs 1986 distinction criterion with negative result. Due to the in relation to the proper motion vector length far too large position error (~16%) the seemingly "similar" direction and speed of proper motion is highly questionable - rather unlikely CPM.
MPN 50	88.54	80.51	2.860	891.9	877.5	44.235	C	A	C	n.a.	Selected by random from the VizieR I/330 catalog after applying the Halbwachs 1986 distinction criterion with negative result. Due to the in relation to the proper motion vector length far too large position error the "similar" direction and speed of proper motion is highly questionable - rather unlikely CPM.

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
PKO 5	67.83	52.51	2.860	53.4	26.6	2.001	C	C	C	V	Selected by random from the WDS catalog as V-coded object. There must be a special reason to list this object as physical - it cannot be proper motion as the position error is far larger than the proper motion vector length. Impossible to detect any significant change in position when blinking 1953 POSSI and 1995 POSSII images, which isn't surprising given the minimal rate of PM per URAT1 (+003.7 +001.5 and +001.6 +001.3).
PNT 2	159.97	159.93	2.860	1,042.2	1,060.1	52.558	A	A	B	V	V-coded object selected by random from the WDS catalog. At the time we first came across this pair, the PA and separation data had been reversed in the WDS listing, resulting in our identifying a companion with no shared CPM. Correspondence with Bill Hartkopf identified the problem. With the correct companion identified, the results show vector direction and length well within the error tolerance, while the position error in relation to the PM vector length is at the outer edge of the 10% cutoff (9.6% for the primary, 9.4% for the secondary). No spectral class for either of the correct components is shown in Simbad. Blinking of POSSI and POSSII images confirms direction of PM.
SEI 220	174.32	179.54	2.860	996.7	1,003.4	50.001	B	A	B	V	V-coded object selected by random from the WDS catalog. Rather similar pm direction, very similar pm speed and rather large position error in relation to the pm vector length - CPM possible but not very convincing.
SHJ 223AC	120.72	122.65	2.860	431.9	250.9	17.071	A	C	C	-	Selected by random from the WDS catalog for very similar pm direction. PM speed very different far outside any error estimation and position error in relation to the pm vector length far above 10%. Obviously not CPM.
SHY 227 (γ UMa)	71.16	89.87	2.860	1,503.1	1,420.7	73.095	C	B	C	V	Pair separated by 5.6 degrees. Selected from Wielen et al 1999 as example of one of the very wide pairs. Wielen argues this a binary pair, while the WDS catalog classifies the pair as physical based on proper motion per findings of Shaya and Olling, 2011. Proper motion direction is rather different as illustrated by the Check CPM results, which show vector direction is also well outside the 2x range; however this may be a side result of the very large 2MASS position error for the primary. The Check CPM results show the vector length is within 2x range; and finally the position error in relation to PM vector length is beyond the 10% cutoff for the primary (28.2%) and the secondary is just within the 10% cutoff (9.6%), so the CPM probability seems quite low. Simbad shows the primary (HIP 58001) with a spectral class of A0 and the secondary (HIP 61100)as K2. Very large and saturated star disks for both components - POSS images of no use for determining proper motion. Checking the pm data from UCAC4 and comparing with URAT1 provides a possible explanation for an earlier CPM assessment: UCAC4 suggests rather similar direction while URAT1 is identical with our calculation and shows completely different directions.
SHY 378 (HIP 201)	324.38	311.46	2.860	367.1	449.7	20.420	C	C	C	V	Selected from Shaya and Olling 2011. Slightly similar pm direction and speed, large position error - not a good CPM candidate. No obvious change in position seen when blinking POSSI (1954) and POSSII (1994) images. Slight change in PM data from UCAC4 (-017.6 +018.6 and -017.8 +019.2) to URAT1 (-014.4 +020.1 and -022.7 +020.1) indicates a greater disparity in RA motion with the URAT1 numbers.
SHY 569	236.70	240.72	2.860	1,062.9	940.1	50.075	B	C	C	V	Selected from the WDS catalog as one of the infamous 999.9" separation objects - this one is over 4° separated. The position error relation to the pm vector length renders this object as a rather questionable CPM object.
SKF1186	75.25	75.25	2.860	1,232.7	1,193.3	60.650	A	A	B	V	V-coded object selected by random from the WDS catalog. Very solid AAB CPM rating. Listed also in VizieR I/330 as MPN 9251 as "new discovery 2015."

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
SKF 12	208.96	209.21	2.860	2,328.4	2,254.9	114.584	A	A	B	V	V-coded object selected by random from the WDS catalog. Very solid AAB CPM rating. Listed also in VizieR I/330 as MPN 5939 as "new discovery 2015."
SKF 179BC	1.66	5.13	2.860	350.1	364.0	17.851	B	A	C	V	Selected by random from the WDS catalog as V-coded object. Position error in relation to proper motion vector length too large to allow a reliable positive CPM result. PM direction also rather different. Component A of STI 1195 is obviously only optical.
SKF1840	219.99	223.56	2.860	256.1	208.6	11.618	B	C	C	V	Selected from Knapp 2016 (Measurement of some SKF objects) - proper motion vector far too short to allow a reasonable positive CPM result. 2MASS position error is average ~40% of the proper motion vector. PM direction indicates rather not CPM.
SKF 229CD	230.33	230.65	2.425	1,977.6	2,004.6	120.000	A	A	A	-	Object selected by random from Skiff 2016. Prime example for UCAC4 and IGSL errors and gaps. IGSL positon error for component C results in a CCC rating and UCAC4 does not allow any check as this object is simply missing. Check with 2MASS results in a plan triple AAA rating. Counter-check with POSS I and POSS II images shows also very clearly common proper motion. Notes from Skiff 2016: "I previously thought the proper motion of this pair was quite small, since the nearby fast-moving AB components are moving in the opposite direction. But in fact this pair has substantial motion itself, now shown correctly in the WDS."
SKF2325	288.80	282.75	2.860	316.2	357.3	16.837	C	C	C	V	Selected by random from the WDS catalog as V-coded object. Position error in relation to proper motion vector length far too large to allow a reliable positive CPM result. Delta in direction and speed too large to be considered CPM. Blinking of POSSI (1953) and POSSI (1998) images shows parallel motion to the northeast, which matches URAT1 PM data. URAT1 PM data (-020.7 +007.1 and -024.1 +005.5) shows and more disparity in RA motion in the primary than is shown in the UCAC4 PM data (-019 +003.8 and -017.1 +004.7).
SKF2460AB	279.85	283.01	2.860	191.5	199.9	9.786	B	A	C	V	Object selected by random from the WDS catalog. Check CPM result shows a rather small if similar proper motion speed combined with a too large PMVL error rendering "similar direction and similar speed" results a bit questionable - there have to be very good other arguments to consider this a CPM pair.
SKF2600	253.82	251.79	2.860	369.4	427.4	19.920	A	C	C	V	Selected by random from Skiff 2016. PM direction is quite similar but pm vector length seems rather different and the position error is about 30% of the pm vector length - not a good CPM candidate.
SKF 8	273.98	274.02	2.860	3,273.4	3,368.7	166.052	A	A	A	V	V-coded object selected by random from the WDS catalog. Very solid triple AAA CPM rating.
SMA 1	325.68	274.10	2.860	93.3	15.1	2.710	C	C	C	-	Picked at random from Harshaw, 2016. His results categorize SMA 1 as CPM. Check CPM results show vector length and direction well outside the 2x error range; position error in relation to PM vector length is far outside the error ranges for both components. Simbad shows the primary with a spectral class of A5, none listed for the secondary.
SMR 16 AC	91.82	131.87	2.860	238.3	136.5	9.368	C	C	C	V	Selected from WDS as SMR object with code V. Solid triple CCC rating, it remains unclear, why this object should be considered CPM. Blinking of POSSI (1953) and POSSII (1996) images shows no detectable motion. There's a significant change in PM data from UCAC4 (+003.8 -007 and +005.4 -007.4) to URAT1 (+014.8 -000.4 and +006.4 -005.7), which argues against there being shared proper motion between the A and C components.
SMR 48	267.10	316.88	2.860	21.4	38.5	1.496	C	C	C	-	Selected from Schlimmer 2013. Classic triple CCC - definitely not CPM. Schlimmer applied only the sep/pm<1000 Halbwachs1986 criterion for his CPM check, so this result was to be expected as the relationship of the position error to proper motion vector length makes given pm data completely unreliable.

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
SMR 56	187.16	158.90	2.860	143.7	134.3	6.949	C	B	C	-	Selected from Schlimmer 2013. Classic triple CCC - very probably not CPM. Schlimmer applied only the sep/pm<1000 Halbwachs1986 criterion for his CPM check, so this result was to be expected as the relationship of the position error to proper motion vector length makes given pm data completely unreliable.
SMR 65	336.65	248.72	2.860	192.9	196.4	9.734	C	A	C	V	Selected from Schlimmer 2015. PM direction delta renders CPM negative. Schlimmer applied only the sep/pm<1000 Halbwachs1986 criterion for his CPM check, so this result was to be expected as the relationship of the position error to proper motion vector length makes given pm data completely unreliable. No suitable 1.1" POSS I image for blinking available; blinking with second choice POSS I 1.7" image suggests some noticeable pm of nearby UCAC4-503-061608 but not so for SMR65. UCAC4 offers pm data only for one component but URAT1 has data for both with quite different pm direction - so this object cannot be considered CPM.
SMR 66	92.04	245.36	2.860	80.7	133.0	5.342	C	C	C	V	Selected from Schlimmer 2015. Classic triple CCC - definitely not CPM. Schlimmer applied only the sep/pm<1000 Halbwachs1986 criterion for his CPM check, so this result was to be expected as the relationship of the position error to proper motion vector length makes given pm data completely unreliable. Blinking of POSSI and POSSII images inconclusive. No UCAC4 PM data exist for the secondary, but the primary shows data of +013 -015.5; URAT1 PM data (+006.1 -000.2 and -008.8 -004) shows significantly less motion for the primary.
SMR 67	201.90	176.97	2.860	350.0	237.2	14.680	C	C	C	V	Selected from Schlimmer 2015. Classic triple CCC - definitely not CPM. Schlimmer applied only the sep/pm<1000 Halbwachs1986 criterion for his CPM check, so this result was to be expected as the relationship of the position error to proper motion vector length makes given pm data completely unreliable. Blinking of POSSI (1954) and POSSII (1990) images shows slight southwesterly motion for the primary and due south motion for the secondary. Comparison of UCAC4 PM data (-012.4 -23.1 and -014.9 -018.8) with URAT1 PM data (-009.8 -024.3 and +001 -017.8) shows a significant change in speed and direction for the secondary which argues against shared proper motion.
SOZ 17 (HD 155060)	255.25	252.08	2.424	2,621.4	2,834.4	120.000	B	B	A	VK	Selected from Scholz 2016. Similar pm direction, rather high speed with a delta less than 10% - looks like a potential CPM candidate.
SO 8 (HD 18404)	96.70	94.23	2.511	3,487.8	3,291.4	152.971	A	B	A	VK	Selected from Scholz 2016. Very similar pm direction, rather high speed with only slightly larger delta than 5% - looks like a very good CPM candidate.
SRT 1	167.06	166.85	2.819	2,437.2	2,409.6	120.000	A	A	A	-	Picked at random from Benavides, et al, 2010. Meets all three Check CPM criteria for CPM. Simbad shows the primary with a spectral class of G5 and the secondary as G7.
STF1309 (HJL 104)	315.15	311.78	2.860	913.6	937.9	46.287	B	A	C	VDZ	Picked at random from Halbwachs, 1986. Check CPM results show the pair is within the 2x error range for vector direction and within the error range for vector length; position error in relation to PM vector length is just outside the B range for the A component (10.1%) and at the outer edge of the B range for the secondary (9.8%). Both Halbwachs and Simbad show the two components with an F5 spectral class.
STF1719	222.16	217.29	2.860	1,955.1	2,236.3	104.785	B	C	B	VD	The AB pair to TOK 155 AC being thought to form a CPM triple by Tokovinin - does not look good for either AB or for AC.
STF1927	301.88	302.60	2.826	2,641.1	2,593.9	130.384	A	A	A	VDZ	Selected by random from the WDS catalog as code V object. Solid CPM triple AAA rating.

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
STF 289 (HJL 41)	103.34	112.03	2.860	1,169.0	1,075.1	56.102	C	B	B	VD	Picked at random from Halbwachs, 1986. Check CPM results show the pair is outside the 2x error range for vector direction and within the 2x error range for vector length; position error in relation to PM vector length is at the outer edge of the B range for the A component (9.1%) and in the middle of the B range for the secondary (7.9%). Halbwachs shows A with an A3 spectral class and B as A2. The POSS I images are overexposed for the A component so blinking and mosaic image show nothing of interest. The pm numbers from UCAC4 to URAT1 have changed and at least the latter do not suggest CPM .
STF 77	19.26	16.40	2.860	382.5	476.2	21.468	A	C	C	D	Picked at random from Harshaw, 2016, where the results categorize STF 77 as CPM. Check CPM results good for vector direction, while vector length is well outside the 2x range; position error in relation to PM vector length is beyond the 10% cutoff for a B rating (29.8% for A, 23.9% for B). Simbad shows both stars with a G0 spectral class.
STI 117	229.06	212.56	2.860	118.7	190.9	7.740	C	C	C	V	Selected by random from the WDS catalog as V-coded object. Besides significant pm direction and speed deltas, the position error in relation to proper motion vector length far too large to be considered as CPM pair. Blurring of the primary and secondary make it impossible to detect individual motion in the POSSI and POSSI images. Considerable change exists in PM data from UCAC4 (-020 -014 -012.8 -006.4) and URAT1 (-006.5 -005.6 and -007.5 -011.8).
STI1248	60.36	55.01	2.860	257.0	347.8	15.120	B	C	C	-	Picked at random from Harshaw, 2016, where the results categorize STI 1248 as CPM. Check CPM results show vector direction in the 2x range and vector length outside the 2x range; the position error in relation to PM vector length is well outside the 10% cutoff for a B rating (44.4% for A, 32.8% for B). Simbad shows both stars with a spectral class of K.
STI1560	192.94	244.93	2.860	5.9	49.3	1.380	C	C	C	-	Picked at random from Harshaw, 2016, where the results categorize STI 1560 as CPM. Check CPM results show vector direction and length well outside the 2x error range; the position error in relation to PM vector is far beyond the 10% cutoff. Simbad shows the primary with a spectral class of B1, none listed for the secondary.
STT 276AB-C	122.91	122.13	2.860	406.8	414.2	20.526	A	A	C	-	Picked at random from a list of STT pairs in Bootes. Check CPM results good for vector direction and length; position error in relation to PM vector length is slightly outside the 10% cutoff for a B rating (20.9% for AB, 20.5% for C). Simbad shows A with a G4 spectral class but has no classification for C.
STT 30AC	110.83	108.50	2.531	2,681.0	2,715.0	120.000	A	A	A	VDZ	Just another prime example for the bad data quality of the IGSL catalog at least for some objects - due to the given unreasonable small position error for B the Check CPM rating would be ACA. With 2MASS as reference catalog STT 30 AC gets a clear triple AAA rating confirmed by blinking of POSS images.
STT 547AB	99.38	99.73	0.674	13,601.2	12,955.3	160.000	A	C	A	ODZ	Found by random as very large proper motion pair during another research project. Nearly identical pm direction and rather similar pm vector length but clearly outside position error, the latter less than 1% of the pm vector length. This seems to be a pattern for very fast pairs: speed difference outside the position error range.
STT 547AF	99.38	99.08	0.596	13,601.2	13,164.1	141.421	A	C	A	VO	Similar to even better values for STT547AF - so this is obviously a common motion triple.
STTA 61AB (HJL 1040)	90.58	84.40	2.860	1,059.7	1,121.0	54.519	C	B	B	V	Picked at random from Halbwachs, 1986. Check CPM results show the pair is just outside the 2x error range for vector direction and within the 2x error range for vector length; position error in relation to PM vector length is in the middle of the B range for the A component (8.0%) and the B component (8.2%). Both Halbwachs and Simbad show A with a spectral class of F8 and B as G0. Blinking POSS images shows roughly similar pm direction and speed. PM values have changed from UCAC4 to URAT1 and at least the latter do not suggest CPM.

Table 2 continues on next page.

A New Concept for Counter-Checking of Assumed CPM Pairs

Table 2 (continued). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
TOK 155AC	222.16	217.01	2.860	1,955.1	1,797.8	93.823	B	B	B	V	Selected from the WDS catalog as one of the infamous 999.9" separation objects - obviously does not fulfill the numeric requirements for a CPM pair. Attention: URAT1 shows two objects for TOK 155 A, one of them with wrong pm data.
UC 193	202.90	201.90	2.860	1,058.3	1,068.1	53.161	A	A	B	V	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). PM direction and speed very similar - position error in relation to the pm vector length a bit too large for a fully reliable result. Listed also in VizieR I/330 as MPN 4986 as "new discovery 2015."
UC 203	228.11	228.47	2.860	1,447.1	1,469.3	72.911	A	A	B	V	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). PM direction and speed very similar - position error in relation to the pm vector length a bit large - yet good CPM candidate. Listed also in VizieR I/330 as MPN 5447 as "new discovery 2015."
UC 2692	296.48	295.61	2.860	2,135.5	2,126.0	106.536	A	A	B	V	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). PM direction and speed very similar - position error in relation to the pm vector length a bit too large for a triple AAA, else solid. Listed also in VizieR I/330 as MPN 4868 as "new discovery 2015."
UC 2840	192.20	192.56	2.860	2,385.2	2,362.7	118.698	A	A	B	V	Selected by random with own research in the LSPM catalog (Lepine and Shara 2005) for close objects. PM direction and speed very close, position error slightly outside 5% of the pm vector length - solid triple AAB CPM rating. Also included in the VizieR I/330 catalog as MPN 5196 as "newly discovered 2015."
UC 2988	308.87	308.19	2.860	1,331.5	1,332.1	66.591	A	A	B	V	Cross reference object from Knapp 2016 (Measurements of some VizieR I/330 objects). PM direction and speed very similar - position error in relation to the pm vector length a bit large - yet good CPM rating. Listed also in VizieR I/330 as MPN 5467 as "new discovery 2015."
UC 302	74.30	86.55	2.860	729.1	633.6	34.068	C	C	C	V	Taken from Table 4 in Hartkopf, et al, 2013. Check CPM results show the pair is well outside the 2x error range for both vector direction and vector length; position error in relation to PM vector length is outside the B range for both the A component (23.3%) and the B component (14.6%). A is a class K2 star, no spectral class listed in Simbad for B. This is most probably no CPM pair. There's a significant change in PM data from UCAC4 (+061.1 -000.2 and +-056.2 -003.9) to URAT1 (+053 +015 and -051.2 +003.2) which shows an increase in northward motion of the primary. Surprisingly, blinking of POSSI (1955) and POSSII (12-1991) images shows a distinct eastward parallel motion for both primary and secondary.
UC 303	81.29	79.36	2.860	943.6	932.3	46.898	A	A	B	V	Taken from Table 4 in Hartkopf, et al, 2013. Check CPM results show the pair is within the error range for both vector direction and vector length; position error in relation to PM vector length is at the outer edge of the B range for both the A component (9.0%) and the B component (9.1%). No spectral class is shown for either star in Simbad.
UC 304	245.16	240.11	2.860	792.7	788.8	39.536	B	A	C	V	Taken from Table 4 in Hartkopf, et al, 2013. Check CPM results show the pairs is in the 2x error range for vector direction and within the range for vector length; position error in relation to PM vector length is just outside the B range for both the A component (10.7%) and the B component (10.8%). No spectral class is shown for either star in Simbad.

Table 2 concludes on next page.

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Table 2 (conclusion). CPM Check results for the selected objects. Explanation of the content: Object = discoverer or catalog ID (in case of LSPM objects only for one of the components). PMVD A = proper motion vector direction in degrees for component A. PMVD B = proper motion vector direction in degrees for component B. e_PMVD = error estimation for the pm vector direction according to the given 2MASS position error. PMVL A mas = proper motion vector length of component A in mas. PMVL B mas = proper motion vector length of component B in mas. e_PMVL mas = error estimation for the pm vector length according to the given 2MASS position error. PMVD Δ = rating for the resulting proper motion vector direction delta between the components. PMVL Δ = rating for the resulting proper motion vector length delta between the components. e_PMVL = rating for the relation of the 2MASS position error to the proper motion vector length.

Object	PMVD A	PMVD B	e_PMVD	PMVL A mas	PMVL B mas	e_PMVL mas	PMVD Δ	PMVL Δ	e_PMVL	WDS Code	Notes
UC 306	86.11	105.00	2.860	1,038.8	863.7	47.562	C	C	C	VU	Taken from Table 4 in Hartkopf, et al, 2013. Check CPM results show the pair is well outside the 2x error range for both vector direction and vector length; position error in relation to PM vector length is outside the B range for both the A component (12.1%) and the B component (14.5%). Simbad shows no spectral class for either of the two stars. Blinking of POSSI (1954) and POSSII (1995) images shows distinct eastward motion of primary and distinct eastward motion with a slight southern component for the secondary. There's a significant change in PM data from UCAC4 (+071.2 -004.3 and +051.8 -022.5) to URAT1 (+075.8 +005.2 and +061.1 -016.3) which shows motion in declination of the primary changing from south to north, which wasn't detectable in the POSS images.
UC 309	156.40	114.89	2.860	739.0	766.4	37.634	C	A	C	VU	Taken from Table 4 in Hartkopf, et al, 2013. Check CPM results show the pairs is well outside the 2x error range for vector direction and within the range for vector length; position error in relation to PM vector length is outside the B range for both the A component (14.4%) and the B component (12.0%). No spectral class is shown for either star in Simbad. Mosaic and blinking of POSS images suggest roughly similar pm speed but slightly different direction. Comparison of pm data from UCAC4 to URAT1 shows significant changes, especially in direction; the URAT1 data does not suggest CPM at all.
UC 310	80.55	94.12	2.860	1,000.1	938.0	48.454	C	B	B	VU	Taken from Table 4 in Hartkopf, et al, 2013. Check CPM results show the pairs is outside the 2x error range for vector direction and within the range for vector length; position error in relation to PM vector length is in the B range for both the A component (8.5%) and the B component (9.1%). No spectral class is shown for either star in Simbad. Notable difference in PM numbers between URAT1 (+067.4 +011.3 and +063.9 -004.6) and WDS (+066 +020 and +071 +006). Mosaic and blinking of POSS images did not show anything conclusive - roughly similar speed and slightly different direction. The pm numbers from UCAC4 to URAT1 are rather different and at least the latter do not suggest CPM at all.
UC 3111	144.14	144.34	2.860	863.5	878.1	43.542	A	A	C	V	V-coded object selected by random from the WDS catalog. PM direction and speed very close, position error in relation to the pm vector length a bit large - yet rather solid AAC CPM rating.
UC 319	54.27	51.57	2.860	929.6	946.4	46.900	A	A	C	V	Selected by random from Hartkopf et al 2013. Very similar pm direction and speed but large position error in relation to pm vector length, yet very solid CPM rating.
UC 4962	126.77	122.61	2.860	882.3	917.1	44.984	B	A	C	V	Selected by random from Hartkopf et al 2013. Similar pm direction and very similar pm speed but large position error in relation to pm vector length.
UC 696	150.82	153.04	2.860	961.9	951.6	47.838	A	A	B	V	Selected by random from Hartkopf et al 2013. Very similar pm direction and speed and moderate large position error in relation to pm vector length gives a very solid CPM rating.
UC 715	233.35	237.83	2.860	770.7	791.7	39.059	B	A	C	V	Selected by random from Hartkopf et al 2013. Similar pm direction and very similar pm speed but large position error in relation to pm vector length gives in total a mediocre CPM rating.
UC 84	179.84	179.61	2.860	739.1	782.3	38.035	A	B	C	V	V-coded object selected by random from the WDS catalog. Similar pm direction, not this similar pm speed and rather large position error in relation to the pm vector length.
UCAC4-754-014689	133.36	135.03	2.860	443.6	437.1	22.017	A	A	C	n.a.	Found by chance by checking UCAC4 proper motion vectors in Aladin for another object. Very solid CPM AAC rating with only the position error a bit large in relation to the pm vector length but pm direction and speed very close. No WDS object so far - UCAC4 objects 754-014689 and 754-014693 with separation 12.557" and PA 126.64°.
UR 2	167.03	170.65	2.860	1,118.2	1,061.0	54.480	B	B	C	V	Selected by random from Skiff 2016. PM direction is nearly similar, pm vector length seems also nearly similar and the position error is about 12% of the pm vector length - not a perfect but possible CPM candidate.

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(Continued from page 35)

~93,800mas in 17.9 years with a delta of less than 2%. This would very well deserve a triple AAA rating but due to the huge vector length the “allowed” deltas are far smaller so the rating is only a BCA. This means that our spreadsheet imposes for high speed objects a precision requirement hard to meet with the current available data.

- A similar lack of URAT1 objects is usually also given for Δμ Binaries (M dwarfs and white dwarf pairs) as for example reported by Khovritchev and Kulikova 2016.
- High proper motion pairs with an assumed orbit might get a C rating for different proper motion vector length as was for example the case for STT 547 AB (see table 2). The 6th Orbit catalog shows here 2 calculated orbits. The orbit calculation with Kiy2001 allows for ~0.65" difference in pm vector length between 1998 and 2013 - a good explanation for the measured pm vector length difference between 1998 and 2013. With Pop1996b we get ~0.5" - not such a good match but still large enough to be also a good explanation for the measured difference in pm vector length. When comparing the orbit calculations for 2016 with our current astrometry measurements then both orbits differ somewhat with Kiy2001 the better match with 6" and 188,53° compared to measured 6.085" and 188.22.
- According to the preliminary character of URAT1 some objects are listed with obvious errors as for example for the WDS V-coded CPM pair HZG7 – usually such errors are instantly recognizable due to inconsistent data.
- In many cases (of mostly rather close CPM pairs) like for example STF4 and STF326 (both highly interesting objects according to Wiley 2015) but also SOZ4AB,D, SMR44, MLB247, GIC17, FMR208, SKF269 or FMR192, URAT1 provides no object for at least one component with the consequence that no position comparison with 2MASS is possible.
- In a few cases like for example MLB203 the URAT1 data is simply off – usually easily to recognize by significant differences of the pm data in comparison with UCAC4. Such cases make clear why URAT1 is considered preliminary.
- 2MASS provides a time frame of about 15 years up to URAT1 and is obviously based on reliable observation epoch data of good use for proper motion calculations.
- This means that while a false positive CPM confirmation with our Check CPM spreadsheet might be highly unlikely an unexpected negative result needs an additional countercheck (for example by comparing 2MASS data with UCAC4 or visual comparison of POSS I and POSS II images) to make sure that this is not a case of faulty 2MASS data .
- Even a triple AAA result with our Check CPM spreadsheet is still no “proof” that this is actually a physical pair but can be considered as additional confirmation that the numbers suggest common proper motion. Yet it might still very well be a random fellow traveller pair – a check for being a physical pair was not our intention from the very beginning and would need checking of additional data.
- In the current version this check has to be done object by object and is not available as algorithm to be applied on a set of objects – but it should be possible to make software to do exactly this.
- A solid ACA result combined with a rather large pm value might not necessarily mean a falsification of a CPM assumption due to different pm speed but be a serious hint for an orbit as is shown by the example of STT 547 AB.
- Odd results for WDS V-coded objects suggest the need for further investigation – the WDS catalog has its fair share of errors starting with simple typos like for PNT 2 up to misidentification of components like for CLL 21 AC.

Acknowledgements

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

- Washington Double Star catalog
- 2MASS All Sky catalog
- AAVSO APASS
- UCAC4 catalog
- URAT1 catalog
- IGSL catalog
- LSPM catalog
- Vizier I/330 catalog
- Aladin Sky Atlas v9.0
- SIMBAD, VizieR
- AstroPlanner V2.2

Special thanks to Brian Skiff, Bill Hartkopf and Norbert Zacharias for their useful advice during developing this concept.

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