Counter-Check of Reported Common Origin Pairs

Wilfried R.A. Knapp
Vienna, Austria
wilfried.knapp@gmail.com

Abstract: All stars are born in molecular clouds most likely together with other stars nearby in the same cloud but most such systems are separated over time by the tidal forces of the galaxy. Kamdar et al. 2019 report the detection of 111 pairs of co-moving stars with similar metallicity assumed to be born together but separated later on.

This report counter-checks this proposition by cross-matching the listed objects with the GAIA DR2 catalog and using the found data to calculate the spatial distance between the components as well as spatial velocity speed and direction. The results confirm with some caveats the data given in the Kamdar et al. 2019 paper but do not necessarily confirm the conclusion that all reported pairs have to be indeed of common origin.

Finally all WDS pairs listed as common proper motion pairs (note code "V") but with spatial separation likely too large for gravitational relationship are checked for common origin.

1. Introduction

Kamdar et al. 2019 report 111 co-moving pairs in the solar neighborhood (which means up to 1kpc distance from the Sun) with distances between the components too large to allow for gravitational relationship but assumed to be of common origin. This report counter-checks this proposition using astrometric data from GAIA DR2 and metallicity data from the GAIA DR2 StarHorse catalog.

2. Cross-Match of WDS FAR Objects with Gaia DR2

The number of KMD objects (for objects reported in Kamdar et al. 2019) is small enough to access the GAIA DR2 data for the counter-check manually by entering the positions of the components directly into Aladin and load the GAIA DR2 data over the default DSS images. The GAIA DR2 data is then copied into a spreadsheet checking for common proper motion and potential gravitational relationship based on Monte Carlo simulation for the distance between the components with a sample size of 120,000 which means a margin of error of 0.37% at 99% confidence. The resulting data is then copied again in another spreadsheet created specifically for this purpose calculating spatial velocity speed and direction. The results are given in table 1 below and confirm the values given in the Kamdar et al. 2019 paper for all objects with a few minor exceptions. The additional information from the LAMOST DR4 catalog suggesting similar metallicities giving additional support for the proposition that these pairs are indeed most likely of common origin are counter-checked by comparison with GAIA DR2 StarHorse metallicity data (Anders et al. 2019).

Table 1 lists the cross-matching results with the following structure:

- Obj = Running object number
- Disc = WDS discoverer code in case of components (mostly A) overlapping with existing WDS objects
- No = Number of additional GAIA DR2 objects with similar values for proper motion, parallax and radial velocity but mostly with spatial velocity not similar enough to be considered also co-moving
- CPMS = Common proper motion score (see Appendix)
- Plx1 = Parallax 1 in mas
- e_Plx1 = Error parallax 1
- Plx2 = Parallax 2 in mas
- e_Plx2 = Error parallax 2
- Min_D_AU = Minimum spatial distance in AU

between components (see Appendix)
- Med_D_AU = Median spatial distance in AU between components (see Appendix)
- Max_D_AU = Maximum spatial distance in AU between components (see Appendix)
- LPGR = Likelihood of potential gravitational relationship (see Appendix)
- V1 = Spatial velocity 1 in km/s
- V2 = Spatial velocity 2 in km/s
- DV1 = Direction of spatial velocity 1 in degrees
- DV2 = Direction of spatial velocity 2 in degrees
- AV1 = Angle between spatial and radial velocity 1 in degrees (<0-45° more radial, >45-90° more tangential)
- AV2 = Angle between spatial and radial velocity 2 in degrees (<0-45° more radial, >45-90° more tangential)

The proper motion vector direction and length for 31 of the listed objects is similar enough to consider these objects as common proper motion pairs.

15 objects have parallax values similar enough to give a likelihood larger than 5% for a spatial distance between the components smaller than 200,000 AU suggesting potential gravitational relationship. The postulated non-existence of a gravitational relationship is therefore not completely ensured for all listed objects.

Four objects have a difference in spatial velocity larger than 10% of the average speed of the components (values given in red type), speaking against common movement. Six objects have differences in the direction of the spatial velocity larger than 10° (values given in red type), also speaking against common movement. Seven objects have a difference in the angle between radial and spatial velocity larger than 5° (values given in red type), also speaking against common movement.

Combining these factors (with the exception of common proper motion) results in 28 objects showing rather not common movement or with a small likelihood potential gravitational relationship.

3. Comparison of LAMOST Effective Temperature and Metallicity Values with data from the Gaia DR2 StarHorse Catalog

As additional information for the listed objects, I selected the median mass values from the Gaia DR2 StarHorse catalog (Anders et al. 2019) as well as the median effective temperature data given there listed in Table 2 below.

- Obj = Running KMD object number
- Source_ID1 = GAIA DR2 source ID
- mass50_1 = Median GAIA DR2 StarHorse Sun mass for the primary
- teff50_1 = Median GAIA DR2 StarHorse effective temperature for the primary
- dTeff_1 = Difference effective temperature between LAMOST and GAIA DR2 StarHorse catalog for the primary
- X-out_1 = LAMOST effective temperature outside percentile 16 to 84 GAIA DR2 StarHorse values for the primary
- Source_ID2 = GAIA DR2 source ID
- mass50_2 = Median GAIA DR2 StarHorse Sun mass for the secondary
- teff50_2 = Median GAIA DR2 StarHorse effective temperature for the secondary
- dTeff_2 = Difference effective temperature between LAMOST and GAIA DR2 StarHorse catalog for the secondary
- X-out_2 = LAMOST effective temperature outside percentile 16 to 84 GAIA DR2 StarHorse values for the secondary
- dmass = Difference in GAIA DR2 StarHorse mass between primary and secondary

Most interesting are the differences between the LAMOST effective temperature values (as given in the Kamdar et al. 2019 report) and the corresponding values in the Gaia DR2 StarHorse catalog with a mean value of 183.512 (which means that the Gaia DR2 StarHorse values are generally somewhat higher) and a standard deviation of 328.036 with a few outliers as for example object 20 and 58. The error range of the given LAMOST values is below 40 while the spread between the 16 and the 84 percentile values is close to 700. Yet about 30% of the LAMOST values are outside of the corresponding 16 and 84 percentile values, but this does not allow for any conclusions as such a percentage is by definition to expect from such percentile values.

On average the median Gaia DR2 StarHorse masses for the 111 pairs are quite similar with an average difference of 0.094 with a standard deviation of 0.117 with a few outliers, especially objects 20, 70 and 85. Same origin should mean same age and same composition, so different mass should account for different effective temperature – this conclusion is not fully confirmed by the listed data as two of the pairs with the largest differences in mass are listed with rather similar effective temperatures.

The comparison of differences in mass with differences in Teff shows. with the exception of a few outliers, a good relationship between the values of the Gaia DR2 StarHorse catalog (see Figure 1).

Completely different impression when compar-

(Text continues on page 56)

Obj	Disc	No	CPMS	Plx1	e_Plx1	Plx2	e_Plx2	Min_D_AU	Med_D_AU	Max_D_AU	LPGR	V1	V2	DV1	DV2	AV1	AV2
1		2	4	6.1510	0.0420	6.2039	0.0423	2490518	2562572	3084989	0.00	26.72617	25.95566	119.28	117.61	64.64	63.52
2		2	0	5.9359	0.0418	5.6563	0.0351	1340812	2168992	3584779	0.00	6.41619	7.57869	327.67	301.54	14.17	15.31
3		2	59	6.5862	0.0586	6.6346	0.0483	2255418	2327511	2898098	0.00	34.62374	34.44556	132.68	134.04	69.89	67.52
4		3	5	2.9011	0.0248	2.8558	0.1259	1819541	2950889	18609962	0.00	27.10355	26.32522	170.73	170.68	46.27	43.75
5		5	5	8.7257	0.0486	10.0437	0.0617	3344882	3994724	4599410	0.00	52.92963	52.32685	140.99	140.55	30.02	36.21
6		2	15	7.9693	0.0409	8.0168	0.0565	3174971	3239318	3423317	0.00	21.55138	21.05706	-227.22	-229.32	89.37	87.08
7		2	0	4.7087	0.0529	4.5288	0.0494	2588252	3170787	5566692	0.00	20.12437	19.62902	143.27	149.69	60.49	60.98
8		2	95	2.5524	0.0369	2.5066	0.0351	25185	1601611	8772892	6.40	38.75502	39.67870	101.69	101.41	89.03	87.86
9		2	0	8.0198	0.0834	8.3657	0.0426	3364319	3603404	4173810	0.00	12.45912	12.26464	-248.76	-244.17	40.13	52.69
10	SMA 39	2	62	2.4601	0.0428	2.4956	0.0371	4441	1552725	9550162	6.87	44.63466	45.33590	153.93	154.95	56.28	55.42
11		2	1	2.6953	0.0408	2.6380	0.0395	794142	1932572	8960889	0.00	29.54426	27.46444	141.54	144.34	22.62	23.53
12		2	18	2.5369	0.0431	2.5306	0.0361	2297731	2696252	8745762	0.00	19.56407	20.59840	143.63	140.70	33.78	31.90
13		2	95	2.7248	0.0393	2.7821	0.0411	12630	1637446	8280270	6.12	37.57576	36.72981	-255.92	-255.52	41.68	41.87
14		3	0	1.5758	0.0412	1.5849	0.0435	3242973	4819195	23286169	0.00	21.00581	21.58346	183.80	188.76	55.20	54.38
15		2	0	4.3440	0.0453	4.5413	0.0479	2504468	3286001	5916375	0.00	23.62195	23.87626	236.29	232.53	59.37	56.27
16	BVD 36	2	78	5.9611	0.0352	6.0729	0.0365	6448	635697	1973643	6.46	35.66566	35.09343	175.97	177.70	61.63	61.84
17		3	0	2.5724	0.0429	2.6205	0.0334	3255361	3738475	10439137	0.00	30.23736	30.38125	114.67	123.03	4.55	2.86
18		2	7	5.6230	0.0319	5.7776	0.0389	1216456	1569028	2653799	0.00	39.06484	38.14419	137.89	139.98	47.38	49.07
19		6	1	2.8574	0.0566	2.7725	0.0382	2902826	3749319	9867425	0.00	40.64690	41.62320	136.10	131.98	73.31	75.83
20		2	0	1.1505	0.1346	1.1415	0.0349	3582010	15419254	197262875	0.00	29.79526	30.02603	-328.22	-323.20	15.32	16.44
21	DAM1028	20	78	3.1956	0.0528	3.1507	0.0440	3974	1161257	6686862	9.03	42.50810	42.12051	174.20	174.72	56.49	57.66
22		2	74	1.5443	0.0391	1.5444	0.0438	2773325	4510029	23695340	0.00	76.70089	77.43085	-186.76	-185.11	30.32	30.27
23		47	92	2.1530	0.0408	2.0931	0.0421	2595031	3968481	14661876	0.00	17.42199	16.29870	-173.16	-172.21	39.08	43.95
24		16	4	1.9251	0.0360	1.8903	0.0645	2872334	4389400	23917932	0.00	23.26423	24.04781	-280.27	-281.29	46.48	50.14
25		7	4	4.7728	0.0444	5.0092	0.0419	425854	2081281	4429465	0.00	35.88259	36.73337	101.41	100.24	78.36	77.79
26		8	0	3.9337	0.0366	3.8958	0.0434	2917160	3067307	4700177	0.00	14.59396	15.31586	282.87	286.58	82.61	84.24
27		6	92	1.6805	0.0407	1.6772	0.0516	763969	3359673	22136607	0.00	24.44049	23.99614	-232.58	-231.97	69.52	72.19
28		2	5	1.8477	0.0363	1.8721	0.0356	2512153	3504031	14852686	0.00	16.18745	16.92244	-110.79	-109.88	54.06	56.86
29		5	0	1.4043	0.0401	1.3897	0.0460	3233182	5676292	33276142	0.00	14.87956	14.03716	-250.25	-254.90	60.84	60.52
30		2	74	3.7426	0.0423	3.8179	0.0347	3577907	3843701	5766522	0.00	29.32221	29.10828	131.96	132.51	81.29	81.25
31		3	1	3.0996	0.2180	3.1114	0.0203	2800834	4263671	30062404	0.00	36.81569	37.07512	-153.39	-149.85	29.95	28.99
32		2	1	1.9149	0.0276	1.9350	0.0169	609605	1590269	10711428	0.00	32.97147	33.13897	-175.47	-177.58	37.84	39.34
33		2	56	2.6906	0.0313	2.5880	0.1371	2148113	4220370	26774866	0.00	17.98388	18.26202	-267.91	-266.38	32.48	33.77
34		2	37	3.0828	0.0377	3.2584	0.0371	511230	3635068	8412399	0.00	51.92573	50.85835	271.59	270.87	60.32	59.44
35	A 2135	2	0	3.3147	0.0649	3.4052	0.0498	26470	1698536	8182503	5.73	21.61542	20.54833	202.09	196.13	28.16	28.20
36		2	95	4.4173	0.0470	4.3372	0.0447	18051	877172	3988092	10.65	59.31021	59.97372	-191.38	-191.44	46.55	47.32
37	HJ 91	2	95	1.7665	0.0758	1.7476	0.0529	11063	4263607	31987814	2.49	17.62868	17.59778	223.21	223.01	79.67	82.52
38		2	74	2.6756	0.0425	2.7783	0.0675	1385082	3223549	12327833	0.00	36.31997	35.53158	205.63	205.63	41.36	41.36
39		2	37	3.8017	0.0408	3.6788	0.0509	282998	1842958	6083579	0.00	36.79865	36.55879	209.33	208.92	41.27	42.19
40		2	5	5.4762	0.1673	5.2636	0.0748	1255648	2027303	6789692	0.00	47.99150	47.43376	245.19	244.57	42.07	41.42
41		2	0	8.6380	0.0704	7.6073	0.0402	2624528	3588373	4504860	0.00	65.33412	64.62761	216.99	212.96	52.83	52.28

Table 1: List of Kamdar et al. 2019 objects with spatial movement values derived from GAIA DR2 data

Table continues on the next page.

Obj	Disc	No	CPMS	Plx1	e_Plx1	Plx2	e_Plx2	Min_D_AU	Med_D_AU	Max_D_AU	LPGR	V1	V2	DV1	DV2	AV1	AV2
42	GRV 805	2	76	3.0532	0.0484	2.9928	0.0509	11974	1498745	7820905	6.95	34.49595	35.09479	-143.82	-142.72	61.45	61.00
43		2	5	3.1851	0.0616	3.3693	0.0514	1518923	3880802	10761995	0.00	34.53613	35.11742	247.81	248.33	75.29	72.82
44		3	4	3.8092	0.0552	3.9904	0.0487	2895833	3883863	7367667	0.00	37.80677	37.62482	251.15	249.57	88.44	84.68
45		2	0	3.4292	0.0547	3.5960	0.0387	271357	2801455	8364659	0.00	18.94977	17.73630	-293.96	-298.45	3.21	3.12
46		3	1	6.5159	0.0476	6.8929	0.0385	3354390	3784177	4575766	0.00	11.79206	11.51175	-223.40	-229.30	78.87	74.10
47		2	0	9.2591	0.0402	9.3571	0.0501	1497854	1534555	1747949	0.00	33.43232	33.09230	219.67	228.38	37.82	40.18
48		3	1	2.1520	0.0513	2.1954	0.0456	1836787	3122694	16885450	0.00	42.30440	42.43229	197.44	199.52	33.36	35.53
49		2	1	4.9194	0.0448	4.6273	0.0445	2933304	3957858	6049743	0.00	41.58095	42.57121	208.50	211.16	29.29	26.39
50		2	92	3.0131	0.0343	3.0486	0.0372	2673196	2921597	6322768	0.00	28.71449	28.43545	131.91	131.14	77.03	75.26
51	KPP2169	2	1	6.2609	0.0383	5.9648	0.0369	3151730	3543851	4392069	0.00	56.74280	56.35038	-158.12	-154.71	39.31	41.46
52		2	1	6.2478	0.0457	6.5193	0.0388	369384	1419190	2757076	0.00	20.92264	21.85981	-253.24	-255.50	28.62	28.42
53		2	1	3.0357	0.0499	2.9417	0.0486	2062801	3062672	9082849	0.00	26.00852	25.86391	-211.88	-208.90	43.82	43.48
54		2	0	2.8376	0.0363	2.9499	0.0653	2853212	4031268	10739274	0.00	12.75264	11.63919	209.79	215.13	54.53	51.31
55		2	29	2.2583	0.0286	2.2160	0.0579	2945075	3775205	15069757	0.00	17.11587	16.97311	216.91	215.29	77.76	79.82
56		2	0	1.7065	0.0427	1.6929	0.0422	1162845	3212767	19918679	0.00	20.39381	19.79175	-190.34	-199.33	15.80	17.84
57		2	1	3.9322	0.1212	3.9957	0.0508	1346499	1915504	9381293	0.00	14.60067	14.12095	-279.77	-282.79	66.59	67.99
58	DJU 3	2	0	9.1826	0.0468	8.5682	0.0454	3125445	3396053	3861949	0.00	34.57088	33.82232	-301.57	-292.73	39.11	39.94
59		2	4	8.7676	0.0238	8.5874	0.0353	3162403	3226525	3355315	0.00	50.80591	51.12598	-306.43	-307.56	63.37	56.79
60		2	15	4.1098	0.0463	4.2631	0.0322	2776957	3365251	5786600	0.00	65.35614	65.16584	-262.13	-264.33	62.91	60.93
61		2	0	7.4659	0.0503	6.9625	0.0483	2268995	2901133	3879576	0.00	16.74321	16.95336	-154.37	-158.97	34.05	28.93
62	SEI 537	2	97	4.8101	0.0368	4.9042	0.0440	1463	823442	3496196	8.71	68.29955	67.16688	-135.71	-135.45	79.21	79.45
63		2	95	3.0739	0.0272	3.0919	0.0273	29364	630767	4739515	16.83	50.02468	49.87565	-221.63	-221.77	87.78	88.08
64		4	0	5.8600	1.1521	6.2855	0.0270	2038330	4903603	158568938	0.00	32.15929	31.13647	-42.08	-52.11	17.53	21.58
65		2	0	4.0196	0.0231	3.7978	0.0193	1959842	3388930	5018626	0.00	22.54966	23.53348	-261.74	-257.88	35.17	37.25
66		2	5	7.7009	0.0343	7.2244	0.0327	1095145	1817946	2587273	0.00	32.23475	32.78033	-250.40	-251.16	72.16	71.06
67		2	1	1.9542	0.0360	1.9227	0.0295	17560	2147937	13629208	4.98	30.94525	30.40673	254.26	256.45	59.48	58.31
68		2	76	4.3955	0.0246	4.4926	0.0335	18329	1014558	2938270	2.77	21.12998	21.20677	-242.61	-244.25	52.22	50.35
69		2	0	7.4806	0.0259	7.1392	0.0211	2815019	3000490	3293342	0.00	16.84239	16.50907	-347.91	-352.21	79.09	83.37
70		2	37	1.8922	0.0549	1.9337	0.0199	524939	2858863	18321698	0.00	44.42350	45.00879	-343.69	-344.43	67.75	66.31
71		2	59	2.3846	0.0218	2.4707	0.0225	192086	3016066	7528636	0.06	15.52448	15.16066	-346.09	-345.06	39.69	38.34
72	GRV 503	2	97	2.7852	0.0315	2.7492	0.0322	7272	1108984	6511569	9.46	57.20110	58.01430	-224.14	-224.35	72.19	73.36
73		3	0	2.9543	0.0464	2.9732	0.0289	3943691	4197092	8320601	0.00	11.67337	10.50429	-99.51	-103.64	53.38	53.85
74		2	0	3.9800	0.0257	3.7682	0.0307	1270802	3123738	5511708	0.00	15.44167	15.89318	-207.86	-203.25	69.03	67.20
75		2	1	2.7516	0.0334	2.8026	0.0296	1830712	2342581	7312536	0.00	30.88683	31.02633	-59.62	-54.89	70.52	69.83
76		2	59	3.9413	0.0423	3.9043	0.0312	200176	636255	3556104	0.00	38.84212	38.95838	-179.53	-178.14	17.90	18.26
77		2	0	3.2180	0.0206	3.3151	0.0233	2442620	3101555	4986031	0.00	29.51920	29.07355	-39.67	-43.87	9.71	9.06
78		2	0	5.6869	0.0286	5.4580	0.0234	3636326	3915398	4394465	0.00	30.63439	29.64318	-335.49	-2.21	15.62	18.74

Table 1 (continued): List of Kamdar et al. 2019 objects with spatial movement values derived from GAIA DR2 data

Table continues on the next page.

Obj	Disc	No	CPMS	Plx1	e_Plx1	Plx2	e_Plx2	Min_D_AU	Med_D_AU	Max_D_AU	LPGR	V1	V2	DV1	DV2	AV1	AV2
79	JKA 38	2	61	4.5741	0.0440	4.4603	0.0248	9115	1151136	3206072	2.64	42.85531	43.28074	223.95	225.09	84.75	85.21
80		2	1	3.7251	0.0642	3.8046	0.0481	25475	1213668	6157484	8.29	11.13034	11.13011	134.95	131.33	65.45	62.46
81		2	92	4.2514	0.0480	4.3513	0.0445	626333	1288527	4498854	0.00	31.34605	30.59609	-75.96	-76.50	23.01	23.14
82		2	4	4.4322	0.0481	4.2183	0.0420	2812066	3708493	6041561	0.00	77.30732	76.74319	-115.35	-116.36	69.65	73.33
83		2	0	10.0574	0.0429	10.6727	0.0500	2677134	2856400	3182981	0.00	9.33643	9.32304	-215.76	-221.82	70.12	69.61
84		2	0	3.3580	0.0391	3.2911	0.0435	123047	1278071	6160050	5.93	25.52551	26.30788	96.55	126.59	3.31	2.46
85		2	74	2.0157	0.0572	2.0255	0.0543	2293818	3664915	19117330	0.00	38.40677	37.65036	-221.13	-222.31	64.69	67.11
86		2	92	1.5416	0.0539	1.5770	0.0447	2070376	5059125	30558049	0.00	55.63124	54.84386	-205.83	-205.32	71.09	70.30
87		2	4	4.7232	0.0389	4.6175	0.0602	3856889	4102796	5648319	0.00	12.52043	12.83181	-112.90	-114.69	69.96	79.36
88		2	0	3.8213	0.4089	3.7524	0.0440	3625316	5540898	42427719	0.00	2.35068	1.89124	-333.29	-341.50	27.25	50.78
89		3	74	1.5286	0.0356	1.5624	0.0510	2498159	4989652	24348508	0.00	47.26016	47.00574	171.63	173.26	48.33	47.91
90		2	1	2.6269	0.0666	2.6303	0.0360	2010175	2590409	11625531	0.00	23.40648	23.99154	240.98	235.68	35.64	34.52
91		2	0	2.7503	0.0334	2.8027	0.0511	726009	1718300	7890262	0.00	30.35580	29.80785	300.87	297.08	17.48	15.93
92		2	29	1.6827	0.0433	1.6928	0.0378	3078837	4350870	20061718	0.00	17.89027	18.28188	256.32	258.14	48.49	48.16
93		2	1	4.3523	0.0448	4.1319	0.0377	2496333	3579762	5869745	0.00	44.43198	45.28878	303.74	305.80	28.95	31.08
94		2	1	3.2720	0.0522	3.1259	0.0392	1939965	3545823	9133646	0.00	30.97192	32.52542	236.90	239.29	16.89	15.14
95		3	4	3.1737	0.0342	3.0038	0.0361	1425574	3949352	8532474	0.00	51.90413	51.57890	270.97	269.03	14.14	12.18
96	BAL1009	2	0	3.0520	0.0377	2.9927	0.0380	2317146	2766935	6930527	0.00	21.30947	21.76326	228.77	232.55	42.81	44.20
97		2	0	2.0420	0.0445	2.0526	0.0339	2891833	3578525	13510016	0.00	52.14251	51.47288	206.56	215.05	11.11	13.38
98		2	29	2.5389	0.0466	2.4340	0.0461	41732	3511901	13306164	1.97	14.89771	15.18480	-56.70	-58.40	76.27	76.08
99		2	92	2.4354	0.0413	2.5142	0.0398	100382	2671292	11465344	2.86	30.89535	29.96532	295.55	296.04	44.76	44.96
100		2	78	6.3615	0.0247	6.2043	0.0223	31501	821115	1610580	0.02	35.38354	36.51072	265.18	265.36	69.13	70.09
101		2	95	3.2150	0.0315	3.1916	0.0366	91998	741831	4663196	12.63	51.51236	51.36674	303.36	303.38	61.69	62.30
102		2	18	5.5254	0.0413	5.5616	0.1643	2886504	3056252	5855040	0.00	31.87713	31.64854	142.86	145.41	89.40	88.50
103	POU1965	3	0	3.6153	0.0424	3.5810	0.0395	3586803	3778767	5663911	0.00	27.81814	28.75788	252.02	257.80	52.44	52.73
104		3	5	3.7680	0.0618	3.9891	0.0797	1374830	3344369	9041317	0.00	45.33209	45.13291	206.30	205.37	29.01	30.48
105		2	0	2.7944	0.0457	2.8621	0.0467	11022	1809283	10737882	5.52	22.35477	22.58473	-299.69	-306.34	30.24	31.44
106		2	15	4.8247	0.0464	4.7717	0.1916	2852472	3215611	9987385	0.00	48.20887	49.10296	-277.99	-275.97	56.72	54.61
107		2	0	8.1079	0.0377	7.8150	0.1058	3427193	3645347	4492516	0.00	42.80824	43.48761	277.18	273.80	73.49	69.01
108		2	0	3.6353	0.0475	3.5082	0.0397	2937821	3647229	7049365	0.00	13.89587	13.21841	-135.11	-124.56	28.04	32.15
109	BAL1482	2	0	4.1091	0.0491	3.8086	0.0488	341875	3971457	7915626	0.00	6.59040	5.40833	-33.85	27.19	88.99	86.98
110		2	5	5.3893	0.0372	5.5387	0.0505	3293697	3494539	4369676	0.00	35.26461	35.38239	-275.91	-276.17	54.73	60.10
111		2	59	1.4992	0.0285	1.5022	0.0338	3369892	4476561	20937110	0.00	80.32007	80.12464	-311.85	-313.20	36.74	37.36

Table 1 (conclusion): List of Kamdar et al. 2019 objects with spatial movement values derived from GAIA DR2 data

Obj	Source_ID1	mass50_1	teff50_1	dTeff_1	X-out_1	Source_ID2	mass50_2	teff50_2	dTeff_2	X-out_2	dmass
1	1122704451665024	0.82354641	5498.7480	146.1880	0	3265589567885580928	0.83603233	5604.88818	336.1582	1	0.012
2	7692256363002240	0.84840083	5408.1909	-34.0991	0	20971947349799552	0.85241753	5559.36133	-11.8789	0	0.004
3	16154437152168832	0.79902482	5284.1997	128.2896	0	9880902977577984	0.84556007	5420.12451	84.9746	0	0.047
4	42551825846558592	0.88936770	5797.2202	147.4404	0	42084395964513792	0.91640741	5980.22461	162.9248	0	0.027
5	47857587925189120	0.64921528	4059.8782	158.0081	1	53789109561985664	0.65013093	4077.20435	153.0745	1	0.001
6	111189457686432768	0.82186818	5395.5186	-109.5015	0	64763987951737728	0.85051018	5640.72656	44.3364	0	0.029
7	119917449706594048	0.93315661	5864.3799	85.1597	0	167938413891896320	0.96537900	6005.25098	267.4912	0	0.032
8	123121907625515264	1.26741958	6491.2031	99.0132	0	123122109487531392	1.24347806	6853.45947	390.8696	0	0.024
9	125696203647091968	0.98452550	6015.6221	76.4819	0	130090337447459456	0.96829951	5948.62891	91.6890	0	0.016
10	169924131895224576	1.28370500	6755.4702	-26.2397	0	169924338053653888	1.16347039	6437.42139	-196.8584	0	0.120
11	170420595752139136	1.04931045	6444.7534	274.9937	0	218583323918729344	1.01199782	6374.47900	313.9390	1	0.037
12	218585080564110720	1.04612553	6005.7607	309.0010	0	219558079636107904	0.96354043	5711.76318	93.7334	0	0.083
13	219306463271848960	1.05499613	6258.9482	12.6782	0	219306669430278528	0.99368417	6164.08740	105.5674	0	0.061
14	231950159800091136	1.33756506	7054.1221	453.0620	0	227143507276539776	1.71516764	6390.08984	-224.0200	0	0.378
15	232399379018288000	0.97196430	6011.7480	495.8979	1	243874294680919040	0.98462313	5817.71680	259.0269	1	0.013
16	238163534366737792	1.16875386	6421.9092	440.0693	1	238164255921243776	1.06772888	6172.66309	225.8433	0	0.101
17	246940626453544448	0.95937753	6067.3677	41.1675	0	247256285068674688	1.04637659	6385.91016	248.0503	0	0.087
18	441835346009033984	0.88860452	5651.0308	122.6509	0	249672122574436096	0.91421098	5921.97021	213.1802	0	0.026
19	250841487549136384	1.09061027	6330.7832	25.5132	0	251596813379978752	1.06547701	6300.90723	151.0771	0	0.025
20	251334240556370688	2.30334878	10220.6240	2644.8643	0	443759220778884224	1.77058589	7417.18799	-161.9619	0	0.533
21	261380718817244160	1.03973842	6310.4351	-90.9351	0	261380718817241088	1.03881931	6374.73389	131.6240	0	0.001
22	324809272581952000	1.41529906	6508.9897	238.0298	0	324514710840745856	1.31336868	6583.26660	119.8267	0	0.102
23	341881492706662144	1.03255880	6162.2339	-371.4561	0	341622798236732544	1.19063318	6680.63037	91.4902	0	0.158
24	4549479498839075 84	1.03670335	6178.4028	-220.7974	0	359930701929480576	1.15079343	6465.92969	-40.6401	0	0.114
25	375862311879284608	1.08074927	6232.2070	-85.0332	0	375470099761825152	1.07294464	6282.23291	-36.3770	0	0.008
26	378396823620082176	0.94099438	6020.3726	436.8325	1	2863674156188051968	0.91534865	5677.97119	182.8911	0	0.026
27	391987680693489152	1.15636611	6586.3306	106.4604	0	392030252409329152	1.22869611	6651.58447	28.3442	0	0.072
28	393820124202543744	1.23344064	6665.6909	-388.7593	0	393318025340738304	1.21399820	6684.61377	-568.1265	1	0.019
29	404970954514021248	1.48430407	6280.6831	302.7930	0	410369144287662848	1.21617508	6302.15381	308.1440	0	0.268
30	435642209326124672	0.94299531	6133.8262	257.5859	1	443414833121045376	0.97542882	6002.25684	138.7769	0	0.032
31	447513503231078400	0.94598198	5827.5762	109.3662	0	449590205816652416	0.92190880	5734.71973	89.9600	0	0.024
32	448952656574582912	1.38989246	6607.0918	116.6519	0	448597243738258176	1.28586125	6382.28662	63.4365	0	0.104
33	454335594920988288	1.25482953	6569.2393	193.8193	0	454131631217853312	1.09048426	6290.67480	-221.4053	0	0.164
34	584181183652059520	0.93888760	5719.1206	38.3804	0	584164828416571264	0.86158121	5671.30811	40.8682	0	0.077
35	636738934675606784	1.59599984	6871.2813	419.4414	0	636739179489212032	1.51452315	6928.14258	381.5127	0	0.081
36	646124645103549312	1.33366895	6781.7344	713.8545	1	646125297938578944	1.40570605	6345.96826	374.5581	0	0.072
37	649308177943887744	1.28194988	6899.8096	189.4697	0	649308177943888256	1.41994059	7520.42529	811.9053	1	0.138
38	649872875947754368	0.96449602	5945.3491	145.4990	0	649658509835641984	1.07643330	6166.14893	355.1890	1	0.112
39	681387387460651392	0.98258853	6012.6191	211.1489	0	681308634941086592	1.01606786	6052.39746	381.5474	1	0.033
40	694859604653048320	0.84657586	5395.4961	202.0361	1	698203249576119424	0.85109192	5306.54736	-60.4028	0	0.005

Table 2. List of Kamdar et al. 2019 objects with masses and comparison of effective temperature values

Table 2 continues on the next page.

Counter-Check of Reported Common Origin Pairs

Obj	Source_ID1	mass50_1	teff50_1	dTeff_1	X-out_1	Source_ID2	mass50_2	teff50_2	dTeff_2	X-out_2	dmass
41	700628394269760384	0.64959866	4521.0425	58.2227	0	712157155941158528	0.71526599	4770.91699	162.7471	1	0.066
42	743956681482125696	1.35093105	7145.5308	492.9507	0	743944930451603584	1.28289664	6508.82422	-37.8960	0	0.068
43	759993226077119744	0.92548752	5661.4824	117.1826	0	757566711288894336	0.93561995	5696.64600	-17.2842	0	0.010
44	772021200385350656	0.94391233	5885.9219	-32.8979	0	771335483086516608	0.96646762	5955.19873	81.3989	0	0.023
45	809876320578914560	1.00969779	6152.6660	-66.9941	0	809892916332505344	1.08645821	6430.24365	86.2036	0	0.077
46	1013151556420133760	0.83115226	5402.2441	25.8843	0	824940179634765184	0.88349777	5802.80078	263.2910	1	0.052
47	893835131555196928	0.85144681	5394.0493	134.2896	0	881823826013408384	0.84755492	5226.06641	43.5264	0	0.004
48	887350001520664320	1.20806801	6746.3696	584.7896	1	887785476843657216	1.15230465	6536.98242	208.5625	0	0.056
49	888398321434606336	0.82226795	5353.3774	312.4175	1	3384590875297070336	0.83390433	5264.92578	33.2856	0	0.012
50	895244705461615360	0.95762074	6122.1138	49.6538	0	892704932384262016	1.01139796	6248.44238	210.2822	0	0.054
51	905618632028815488	0.69929254	4690.4795	260.2393	1	903078893312116992	0.69810742	4732.06543	181.3057	1	0.001
52	946471222781159040	0.86123198	5442.1948	473.0249	1	946435007617437056	0.72477883	4874.40039	-26.6694	0	0.136
53	951384665369338496	1.12926197	6488.9829	22.1230	0	953385505948551424	1.35763168	6965.49268	310.9727	0	0.228
54	964632547829087104	1.58103168	7173.2129	500.7930	0	951885909527428608	1.19650888	6701.50928	132.5293	0	0.385
55	990900426075527552	0.96854061	6052.1865	12.0967	0	966619154885685632	0.99235028	6185.04346	49.8232	0	0.024
56	984419320425738368	1.32092071	6754.4351	253.7949	0	985206124075128832	1.29392290	6448.38721	-41.2529	0	0.027
57	1001366818996615808	0.93009263	5673.2266	649.2266	1	1000361659209075584	0.86338896	5387.76367	251.0737	1	0.067
58	1168180153315910016	0.90105122	5431.5835	1068.2734	1	1154953573894521856	0.70068246	4587.10938	411.7495	1	0.200
59	1224871213362969088	0.99256539	6029.8086	321.9087	1	1206701371397064320	0.92105979	5934.45117	341.0713	1	0.072
60	1257207742959979776	0.89396465	5688.6553	116.6055	0	1259706146911669376	1.07587135	6237.99756	562.0874	1	0.182
61	1281094087612638976	0.85173374	5623.3350	234.4048	1	1286716440326271616	0.87724942	5394.81543	-71.8848	0	0.026
62	1283252566380133888	1.03986490	6129.4985	348.1587	1	1283252566380134016	0.94234687	5829.38037	170.2305	0	0.098
63	1291119606434912384	1.07280505	6159.2847	170.4448	0	1291120362349158016	1.16432071	6317.44287	359.1631	0	0.092
64	1304112397900299648	0.90432316	5936.0337	268.3335	0	1301234048257809664	0.88407356	5664.48730	6.5674	0	0.020
65	1312512490643339264	0.97247839	6060.1050	153.4448	0	1312257786198974208	0.94912940	6049.83057	275.2808	1	0.023
66	1536912922562394880	0.70140457	4537.9131	299.4429	1	1537081560158538240	0.69993162	4644.82275	337.4028	1	0.001
67	1541225138449580928	1.22434998	6302.2651	1.3452	0	1541225310245728640	1.41579914	6200.96045	-116.6597	0	0.191
68	1574123282265128576	0.95434684	5973.5825	23.6123	0	1574123454063820928	0.93853801	6068.65332	169.0034	0	0.016
69	1586864388649398656	0.80125594	5315.1611	63.4312	0	1589711432272952448	0.78449023	5184.50781	113.3677	0	0.017
70	1588873265111172992	1.36576605	6336.8926	202.9224	0	1589069356138116608	0.97696918	6270.41016	40.2002	0	0.389
71	1594637248661284864	1.10911000	6627.0273	353.5674	1	1594612952030474496	1.00242877	6135.75049	-141.3794	0	0.107
72	1897440689367972096	1.20438313	6194.0449	18.4751	0	1897440689367972736	1.18771827	6351.32617	140.3560	0	0.017
73	1935112912675231360	1.24469006	6474.5093	275.2495	0	1924718984440067584	1.03835642	6198.70264	128.4824	0	0.206
74	1931948690008232960	0.97435808	6004.8057	-19.1143	0	1935115386576401152	1.03344274	6228.21582	123.1060	0	0.059
75	1998564659266179840	1.05144942	6141.1816	-17.1182	0	1997199585521495808	1.14105678	6298.01709	134.4170	0	0.090
76	2052491723180057856	1.26357603	6604.1338	728.7339	1	2076462137513753600	0.97298032	6050.66162	241.1118	1	0.291
77	2080536931908027392	1.20488608	6633.3350	98.9048	0	2128080536248155776	1.26988995	7061.06836	485.2886	0	0.065
78	2130506398193844352	0.79537481	5315.3970	63.9067	0	2128941861868381952	0.78793889	5170.17480	15.2646	0	0.007
79	2130775885920987520	0.92900294	5973.7861	51.5264	0	2130775782841768192	0.98768097	6097.32520	66.9951	0	0.059
80	2663390691484861440	1.02303529	6195.1787	-52.2515	0	2663390485326432000	1.40682697	6382.39063	133.0806	0	0.384

Table 2 (continued). List of Kamdar et al. 2019 objects with masses and comparison of effective temperature values

Table 2 concludes on the next page.

Counter-Check of Reported Common Origin Pairs

Obj	Source_ID1	mass50_1	teff50_1	dTeff_1	X-out_1	Source_ID2	mass50_2	teff50_2	dTeff_2	X-out_2	dmass
81	2735779131148531840	0.83648479	5244.3921	154.3320	0	2735476215694707072	0.88949895	5489.33643	287.7563	1	0.053
82	2810800188196233344	0.85231125	5375.4116	323.9214	1	2762037775217685888	0.85252297	5382.29736	232.8071	1	0.000
83	2803106080703163264	0.73399782	4961.4956	182.1558	1	2783778556072274432	0.74062973	5241.76709	400.8770	1	0.007
84	2785776059462243200	0.83328438	5540.5679	36.9678	0	2784261344756137984	0.85572886	5721.98486	123.0947	0	0.022
85	2807938777904465792	1.03713477	6369.8535	56.1235	0	2807428329631314048	1.66207433	6449.70801	33.9380	0	0.625
86	2837284227854578432	1.23242128	6226.0879	268.9277	0	2825213239449531008	1.23556089	6550.00684	403.7769	1	0.003
87	2878471795992127232	0.96573788	5989.6182	-22.0918	0	2861383426791456640	0.96537614	6192.89355	270.4136	1	0.000
88	3007597685645337472	0.77373809	5442.5234	-210.8467	0	3019102494281388288	1.30822289	6043.48047	304.4307	0	0.534
89	3021022993201243264	1.06230366	6274.8755	-33.8745	0	3021430087381710464	1.14204693	6505.12793	62.9180	0	0.080
90	3021426342170234624	0.93413943	5867.9731	55.0029	0	3024359809129971584	0.96781063	6036.91113	132.9912	0	0.034
91	3022721326349517696	0.94521022	6139.9404	211.5503	0	3022981567008196864	0.92936379	6177.56445	384.9243	1	0.016
92	3109969433741698560	1.28052187	6743.5186	-530.3613	1	3061624869539761664	1.37799323	7044.90381	-121.7261	0	0.097
93	3080846875411001728	1.29392874	7131.1445	728.8545	1	3068202869648745472	1.18023348	6685.26563	133.8154	0	0.114
94	3082939177319324160	1.03866470	6166.2568	344.2070	1	3081181470543888128	0.92971134	5934.84961	118.5098	0	0.109
95	3095492782609237376	0.89617717	5561.5698	-65.8403	0	3143607686319804544	1.18344760	6440.63379	647.0937	1	0.287
96	3124167496106659584	1.09877348	6461.3291	86.6489	0	3120372630506706432	1.03270340	6174.51709	-162.3428	0	0.066
97	3124120350247568000	1.15627027	6534.2935	173.9033	0	3130078745494663680	1.01909208	6223.10791	8.4678	0	0.137
98	3130844997721522944	1.38587451	6861.1143	330.5044	0	3130845723576534016	1.41342878	6912.54248	330.6924	0	0.028
99	3132274672076250624	1.07736921	6378.1455	9.5957	0	3132273508145500032	0.99969578	6289.34033	-84.9697	0	0.078
100	3133697444423385984	0.64873683	4368.1567	15.3667	0	3133697444423388288	0.73728192	5267.02051	1090.2905	1	0.089
101	3210885119193585536	1.12358272	6467.6489	69.3091	0	3210886042610196480	1.16674078	6493.28027	174.4204	0	0.043
102	3366175910957358080	0.89170694	5734.9111	145.4409	0	3367337441911377920	0.92681462	6058.41797	472.3481	1	0.035
103	3385798109000950144	1.06518805	6082.3159	169.1357	0	3379735706825164544	0.91416997	5829.45508	72.8853	0	0.151
104	3385278383597632896	1.48119915	7691.0225	416.0127	0	3386349479721943040	1.68937874	7654.55762	469.3975	0	0.208
105	3413324584462632576	1.03972507	6285.7153	-96.1846	0	3413324657478444160	1.04975462	6355.91650	-84.7334	0	0.010
106	3672044382058159488	0.80100942	5099.9419	329.8818	1	3661316962501936512	0.77204216	5242.91650	323.8867	1	0.029
107	3795747411642295168	0.69937313	4158.0396	219.3896	1	3813985006717191936	0.76842570	5167.81104	1152.3911	1	0.069
108	3992114209767880960	1.03982913	6267.6538	21.8638	0	3994508877374172160	0.96582818	5924.03271	-165.6973	0	0.074
109	4381826932186259712	1.06430030	6330.2222	177.1821	0	4381843046903618688	1.21808851	6369.93994	164.9800	0	0.154
110	4403568262795516032	0.92257452	5780.6030	163.4331	0	4417843806373635840	1.01630294	6132.86914	336.4990	1	0.094
111	4444214630694301696	1.09055841	4855.4824	3.2524	0	4444406254955951488	1.11599422	4630.28662	-172.0034	1	0.025
	Mean value	183.5117							164.6727		0.094
	Standard deviation	328.0360							237.0024		0.117
	Maximum value	2644.8643							1152.3911		0.625

Table 2 (conclusion). List of Kamdar et al. 2019 objects with masses and comparison of effective temperature values

Counter-Check of Reported Common Origin Pairs

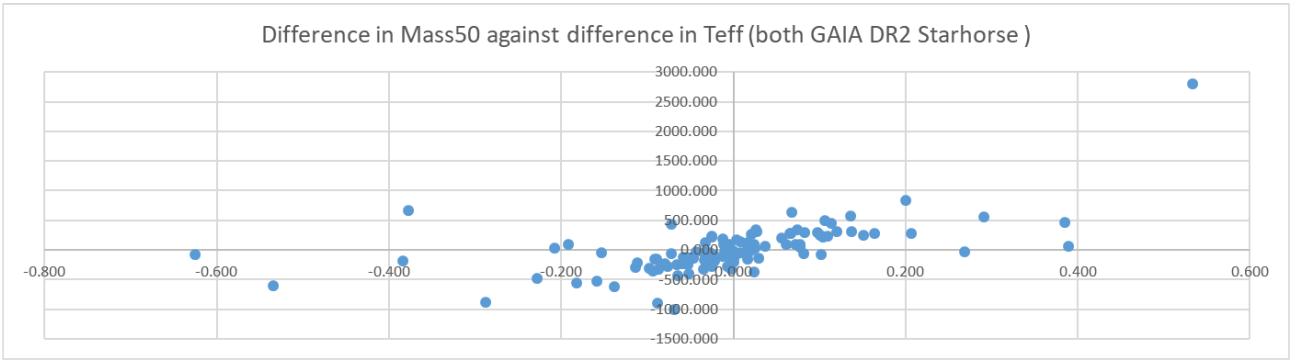


Figure 1: Relationship difference Mass50/Teff for GAIA DR2 StarHorse

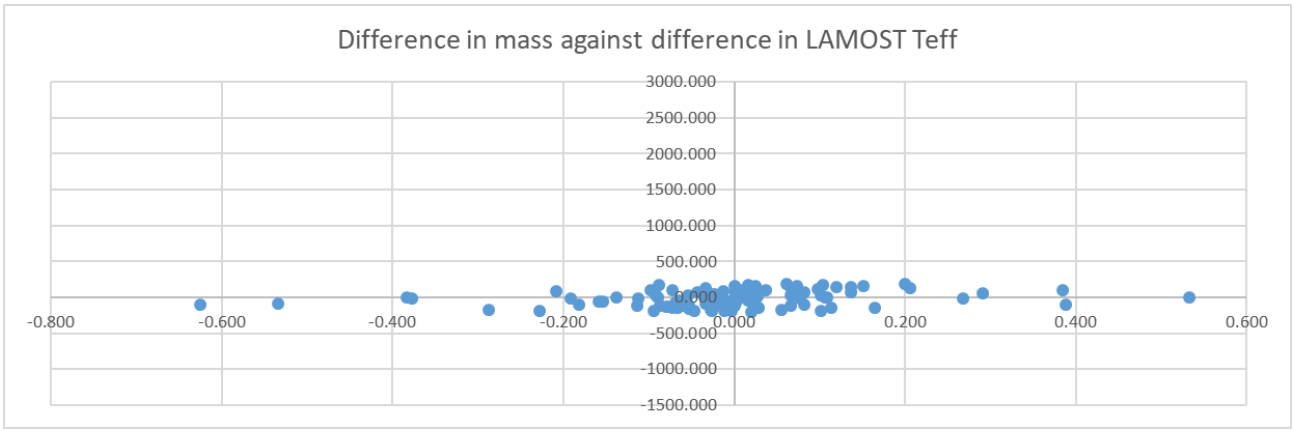


Figure 2: Relationship difference GAIA DR2 StarHorse Mass50/LAMOST Teff

(Continued from page 49)

ing GAIA DR2 StarHorse Mass50 differences to LAMOST Teff differences (see Figure 2) – no relationship between MASS50 and Teff to be explained by the dTeff<200 cut applied by Kamdar et al. 2019.

GAIA DR2 StarHorse provides also metallicity data – this time the relationship with LAMOST data is somewhat different as 48% of the LAMOST values are outside the StarHorse 16 and 84 percentile values which can no longer to be explained by statistical means. Table 3 gives the GAIA DR2 StarHorse metallicity values with the LAMOST metallicity values for comparison:

Content description:

- Obj = KMD object number
- met16_1 = GAIA DR2 StarHorse percentile 16 metallicity value primary
- met50_1 = GAIA DR2 StarHorse percentile 50 metallicity value primary
- met84_1 = GAIA DR2 StarHorse percentile 84 metallicity value primary
- [Fe/H]_1 = LAMOST metallicity value primary
- e_[Fe/H]_1 = LAMOST metallicity value error primary
- met16_2 = GAIA DR2 StarHorse percentile 16 metallicity value secondary
- met50_2 = GAIA DR2 StarHorse percentile 50 metallicity value secondary
- met84_2 =
- GAIA DR2 StarHorse percentile 84 metallicity value secondary
- [Fe/H]_2 = LAMOST metallicity value secondary
- e_[Fe/H]_2 = LAMOST metallicity value error secondary

With few exceptions the LAMOST [Fe/H] are rather high near the StarHorse met84 values indicating a regular pattern towards higher metallicity values.

(Text continues on page 60)

Counter-Check of Reported Common Origin Pairs

Obj	met16_1	met50_1	met84_1	[Fe/H]_1	e_[Fe/H]_1	met16_2	met50_2	met84_2	[Fe/H]_2	e_[Fe/H]_2
1	-0.504730	-0.214799	0.018472	0.174	0.024	-0.533411	-0.287828	-0.026535	0.135	0.027
2	-0.329780	-0.072325	0.127610	0.068	0.027	-0.419454	-0.170029	0.090333	-0.058	0.026
3	-0.336304	-0.158173	0.037918	0.212	0.036	-0.339459	-0.116237	0.117755	0.141	0.029
4	-0.486111	-0.218653	0.024346	0.112	0.032	-0.617031	-0.254580	0.031695	0.012	0.033
5	-0.034633	0.111280	0.238216	-0.255	0.064	-0.015918	0.109144	0.220651	-0.099	0.055
6	-0.411372	-0.189868	0.032739	-0.159	0.026	-0.491621	-0.236863	-0.005390	-0.100	0.017
7	-0.465934	-0.170349	0.050404	0.172	0.016	-0.543610	-0.257203	0.000011	0.110	0.026
8	-0.478800	-0.245652	0.029777	-0.264	0.013	-0.591997	-0.303373	-0.021739	-0.350	0.011
9	-0.538603	-0.213167	0.067907	0.115	0.019	-0.497312	-0.145970	0.123018	0.028	0.019
10	-0.571332	-0.263635	0.009952	0.016	0.013	-0.461071	-0.172921	0.108874	0.045	0.063
11	-0.684599	-0.375784	-0.149648	-0.017	0.018	-0.705887	-0.410444	-0.146290	0.096	0.027
12	-0.604344	-0.310685	-0.009425	0.140	0.024	-0.735991	-0.394119	-0.045994	0.142	0.025
13	-0.478824	-0.221713	0.021298	0.006	0.015	-0.554977	-0.251318	-0.014994	0.035	0.019
14	-0.486413	-0.235910	0.000006	-0.056	0.036	-0.220633	0.054005	0.296181	0.031	0.032
15	-0.454740	-0.127553	0.103158	0.173	0.026	-0.223838	0.082330	0.282742	0.291	0.029
16	-0.490128	-0.185930	0.080898	0.186	0.012	-0.444843	-0.162316	0.136129	0.108	0.009
17	-0.567472	-0.274933	-0.010450	-0.168	0.033	-0.678518	-0.344229	-0.070892	-0.467	0.048
18	-0.373046	-0.129227	0.080382	0.113	0.017	-0.520404	-0.217929	0.036367	0.249	0.021
19	-0.552573	-0.229601	0.032306	-0.058	0.015	-0.553500	-0.251073	0.011146	0.188	0.063
20	-0.445734	-0.176862	0.100036	-0.124	0.084	-0.475487	-0.190004	0.140063	-0.075	0.032
21	-0.591864	-0.298452	-0.023195	-0.017	0.030	-0.668509	-0.338875	-0.095745	-0.038	0.037
22	-0.460254	-0.190557	0.058184	0.107	0.014	-0.536076	-0.126156	0.117013	0.087	0.016
23	-0.492197	-0.236133	0.012984	-0.013	0.021	-0.580382	-0.295423	-0.035518	-0.044	0.011
24	-0.417558	-0.182820	0.092814	0.089	0.025	-0.496123	-0.192172	0.060389	0.006	0.012
25	-0.411062	-0.132018	0.170217	0.204	0.015	-0.504694	-0.200349	0.065168	0.076	0.014
26	-0.528237	-0.259098	-0.001440	0.152	0.027	-0.336341	-0.056597	0.168923	0.287	0.042
27	-0.571472	-0.263488	-0.000101	-0.111	0.044	-0.494434	-0.193868	0.023416	-0.047	0.019
28	-0.545967	-0.225304	0.003052	-0.112	0.011	-0.631137	-0.283507	-0.027862	-0.144	0.023
29	-0.446516	-0.131022	0.131600	-0.300	0.084	-0.420453	-0.162598	0.092312	0.135	0.021
30	-0.654620	-0.356302	-0.108279	0.095	0.028	-0.522167	-0.228267	0.030653	0.121	0.034
31	-0.394132	-0.108565	0.116114	-0.138	0.088	-0.317991	-0.041902	0.167132	0.182	0.046
32	-0.347239	-0.034190	0.273158	0.043	0.029	-0.269190	0.046649	0.363325	0.090	0.079
33	-0.464321	-0.135290	0.105043	-0.007	0.020	-0.462254	-0.177135	0.073527	-0.048	0.046
34	-0.316906	-0.030815	0.206894	0.069	0.038	-0.504110	-0.252154	-0.020714	-0.073	0.017
35	-0.516252	-0.210490	0.014526	-0.148	0.011	-0.520692	-0.238573	0.079828	-0.280	0.009
36	-0.417207	-0.126166	0.144058	0.331	0.034	-0.323733	-0.074603	0.218316	0.316	0.035
37	-0.603742	-0.284685	0.027087	-0.169	0.012	-0.686952	-0.333572	-0.026532	-0.139	0.010
38	-0.392878	-0.162378	0.102092	0.142	0.072	-0.420150	-0.128506	0.191816	0.101	0.014
39	-0.467818	-0.167664	0.074249	0.164	0.023	-0.416215	-0.113584	0.130606	0.251	0.025
40	-0.291330	-0.044508	0.152809	0.007	0.025	-0.188218	0.008024	0.234578	0.090	0.035

Table 3: Comparison metallicity values GAIA DR2 StarHorse and LAMOST index

Table 3 continues on the next page.

Counter-Check of Reported Common Origin Pairs

Obj	met16_1	met50_1	met84_1	[Fe/H]_1	e_[Fe/H]_1	met16_2	met50_2	met84_2	[Fe/H]_2	e_[Fe/H]_2
41	-0.467962	-0.310881	-0.149665	-0.490	0.024	-0.326669	-0.110265	0.023105	-0.530	0.037
42	-0.576009	-0.223598	-0.004569	-0.173	0.009	-0.530385	-0.234885	0.048425	-0.157	0.014
43	-0.156943	0.019955	0.228716	0.241	0.057	-0.317150	-0.034048	0.188641	0.207	0.032
44	-0.426928	-0.115645	0.118799	-0.009	0.013	-0.442575	-0.156124	0.118844	0.368	0.026
45	-0.482139	-0.168969	0.099184	-0.116	0.016	-0.590733	-0.303078	-0.012615	0.034	0.012
46	-0.403086	-0.174252	0.037731	0.080	0.025	-0.610894	-0.323304	-0.072447	0.013	0.020
47	-0.311652	-0.074635	0.173896	0.344	0.039	-0.161045	0.027214	0.251074	0.403	0.090
48	-0.576217	-0.269161	-0.023067	0.009	0.054	-0.574138	-0.254205	0.033766	0.257	0.016
49	-0.337515	-0.154410	0.075029	0.092	0.088	-0.283678	-0.025871	0.190184	0.222	0.030
50	-0.539819	-0.297980	-0.016171	-0.645	0.015	-0.627590	-0.314466	-0.064572	-0.493	0.045
51	-0.351187	-0.162341	0.083178	-0.158	0.036	-0.411089	-0.250350	-0.051253	-0.477	0.042
52	-0.285749	-0.019436	0.192397	0.397	0.056	-0.327668	-0.174744	-0.012329	-0.233	0.265
53	-0.558527	-0.265057	-0.011548	-0.045	0.019	-0.418650	-0.162158	0.072589	0.006	0.016
54	-0.405367	-0.131515	0.128203	-0.251	0.009	-0.580979	-0.254307	-0.022309	-0.056	0.030
55	-0.597362	-0.273575	-0.004613	0.066	0.046	-0.613184	-0.317751	-0.029745	-0.131	0.032
56	-0.488602	-0.144363	0.132350	0.061	0.013	-0.474647	-0.177635	0.108953	0.073	0.012
57	-0.203543	0.033767	0.279636	0.079	0.137	-0.252783	-0.023820	0.210767	0.257	0.074
58	-0.033633	0.203981	0.348046	-0.205	0.032	-0.244737	-0.025005	0.242549	-0.149	0.050
59	-0.467855	-0.161181	0.103636	0.198	0.021	-0.574943	-0.269228	-0.011852	0.189	0.028
60	-0.397423	-0.134122	0.060205	0.158	0.031	-0.427342	-0.128383	0.134354	0.408	0.021
61	-0.494288	-0.248751	-0.007749	0.109	0.020	-0.227273	0.010158	0.272978	0.172	0.018
62	-0.464254	-0.137565	0.143238	-0.069	0.024	-0.382538	-0.070400	0.158991	-0.071	0.031
63	-0.426165	-0.124629	0.170746	0.183	0.024	-0.461149	-0.136512	0.149124	0.306	0.020
64	-0.653075	-0.323214	-0.060079	0.466	0.022	-0.431629	-0.210161	0.040055	-0.002	0.126
65	-0.517179	-0.217378	0.069149	0.062	0.014	-0.620444	-0.314410	-0.029756	0.236	0.019
66	-0.105293	0.071622	0.275868	-0.072	0.044	-0.332103	-0.106805	0.169103	-0.093	0.052
67	-0.500502	-0.211273	0.055008	-0.181	0.015	-0.495982	-0.161934	0.070655	-0.223	0.009
68	-0.544916	-0.209462	0.032198	-0.089	0.019	-0.598782	-0.318575	-0.051733	-0.030	0.017
69	-0.411865	-0.195246	-0.003980	-0.030	0.024	-0.407800	-0.211744	-0.017349	-0.062	0.102
70	-0.556978	-0.254612	0.043373	-0.038	0.014	-0.744829	-0.368586	-0.125936	-0.630	0.144
71	-0.847239	-0.435922	-0.103198	-0.053	0.011	-0.514046	-0.178073	0.086689	-0.123	0.169
72	-0.393255	-0.106633	0.192288	0.158	0.011	-0.403667	-0.096065	0.126546	0.098	0.011
73	-0.427884	-0.105269	0.157445	-0.006	0.021	-0.598389	-0.247903	0.026764	0.028	0.075
74	-0.446517	-0.114970	0.126011	-0.100	0.266	-0.519610	-0.251212	0.029192	-0.344	0.191
75	-0.385577	-0.089389	0.164477	0.072	0.016	-0.406135	-0.139310	0.111336	0.034	0.025
76	-0.417588	-0.114350	0.145133	-0.041	0.013	-0.476157	-0.191820	0.009347	-0.013	0.016
77	-0.517962	-0.206479	0.027314	0.156	0.012	-0.619084	-0.324270	-0.124792	-0.043	0.007
78	-0.455724	-0.207887	-0.022782	0.147	0.028	-0.347699	-0.161017	0.028828	0.104	0.039
79	-0.597275	-0.287297	-0.023274	-0.401	0.015	-0.582232	-0.287810	-0.013766	-0.362	0.010
80	-0.516644	-0.232680	0.013543	-0.115	0.020	-0.497026	-0.163418	0.105706	-0.101	0.012

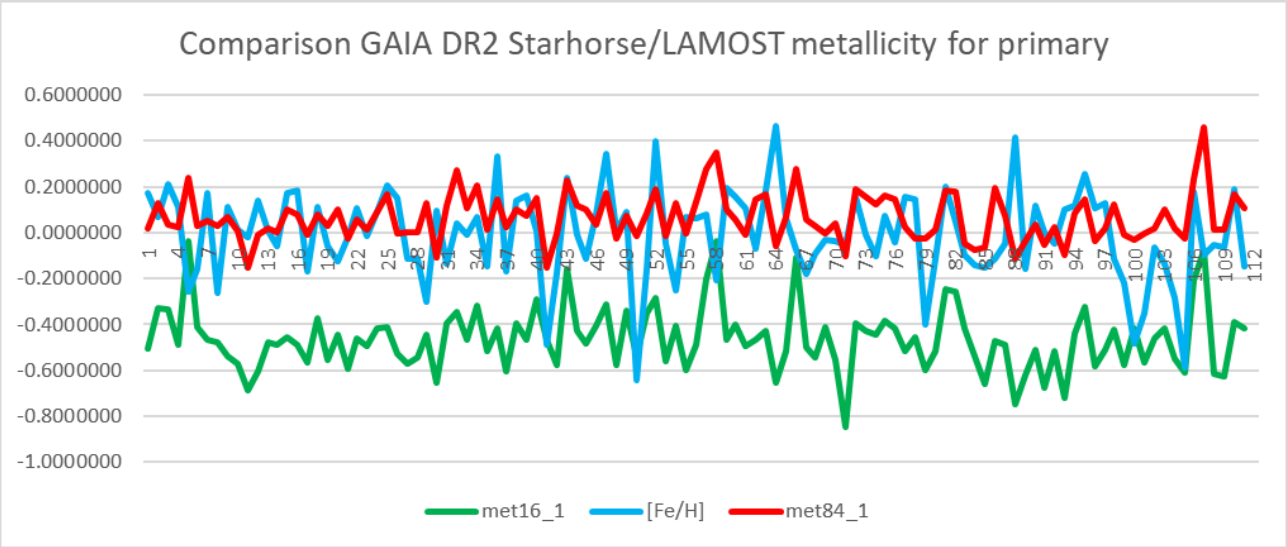
Table 3: Comparison metallicity values GAIA DR2 StarHorse and LAMOST index

Table 3 concludes on the next page.

Counter-Check of Reported Common Origin Pairs

Obj	met16_1	met50_1	met84_1	[Fe/H]_1	e_[Fe/H]_1	met16_2	met50_2	met84_2	[Fe/H]_2	e_[Fe/H]_2
81	-0.245099	-0.025589	0.182754	0.200	0.038	-0.274318	-0.052505	0.204684	0.289	0.030
82	-0.255055	-0.047360	0.178653	0.045	0.098	-0.250551	-0.028803	0.210143	0.069	0.026
83	-0.415291	-0.221541	-0.049659	-0.097	0.031	-0.585354	-0.360555	-0.161202	-0.008	0.040
84	-0.539896	-0.302899	-0.074394	-0.139	0.052	-0.560185	-0.302825	-0.038305	-0.104	0.036
85	-0.661037	-0.357688	-0.063986	-0.150	0.050	-0.293320	0.013868	0.266422	0.139	0.065
86	-0.472739	-0.113192	0.196950	-0.114	0.014	-0.495787	-0.235061	0.079860	-0.051	0.017
87	-0.491012	-0.194485	0.076004	-0.048	0.012	-0.710104	-0.386832	-0.151339	0.072	0.014
88	-0.745131	-0.381134	-0.115921	0.414	0.034	-0.428539	-0.170137	0.144898	0.026	0.014
89	-0.620113	-0.321608	-0.035361	-0.157	0.020	-0.574907	-0.236641	0.011743	-0.175	0.088
90	-0.508143	-0.181210	0.033789	0.119	0.046	-0.513228	-0.234314	-0.013196	0.109	0.017
91	-0.675210	-0.348837	-0.053654	0.005	0.029	-0.695992	-0.451026	-0.187099	0.209	0.039
92	-0.513469	-0.229146	0.026655	-0.049	0.012	-0.546004	-0.231167	0.047707	-0.052	0.014
93	-0.722804	-0.384410	-0.099262	0.103	0.010	-0.624944	-0.336379	-0.071526	-0.183	0.163
94	-0.438684	-0.191086	0.085585	0.120	0.035	-0.544101	-0.278767	-0.005878	0.157	0.051
95	-0.324121	-0.087987	0.146839	0.256	0.096	-0.400773	-0.133940	0.161750	0.272	0.036
96	-0.579761	-0.314241	-0.033525	0.107	0.019	-0.490528	-0.190337	0.091962	-0.120	0.012
97	-0.508968	-0.246256	0.019071	0.131	0.073	-0.612042	-0.301296	-0.022261	-0.042	0.052
98	-0.421883	-0.178091	0.124905	-0.112	0.019	-0.498384	-0.193039	0.097248	-0.118	0.016
99	-0.576596	-0.299978	-0.010733	-0.219	0.024	-0.613788	-0.328775	-0.082957	-0.211	0.028
100	-0.415308	-0.186204	-0.030741	-0.485	0.148	-0.657282	-0.416836	-0.235046	-0.656	0.176
101	-0.565219	-0.262246	-0.003038	-0.348	0.011	-0.539020	-0.216841	0.029790	-0.328	0.010
102	-0.461958	-0.213569	0.016547	-0.063	0.035	-0.603614	-0.312158	-0.029837	0.179	0.015
103	-0.417991	-0.149785	0.102371	-0.137	0.016	-0.471003	-0.210515	0.032888	0.086	0.030
104	-0.551161	-0.244398	0.020161	-0.285	0.009	-0.487894	-0.149511	0.123009	0.594	0.024
105	-0.610076	-0.316874	-0.027733	-0.585	0.017	-0.601856	-0.312392	-0.053280	-0.595	0.018
106	-0.207767	0.002264	0.233144	0.180	0.051	-0.467373	-0.268151	-0.033045	0.118	0.072
107	-0.075377	0.299468	0.457746	-0.099	0.152	-0.401706	-0.243814	-0.028263	-0.017	0.043
108	-0.615981	-0.264281	0.014048	-0.053	0.031	-0.411049	-0.121928	0.115080	-0.046	0.215
109	-0.628613	-0.284778	0.011912	-0.061	0.090	-0.504638	-0.186563	0.100059	0.017	0.072
110	-0.388020	-0.093996	0.170338	0.188	0.054	-0.430975	-0.143925	0.115032	-0.001	0.015
111	-0.417117	-0.176035	0.106590	-0.146	0.023	-0.278125	-0.030774	0.211766	-0.363	0.015

Table 3 (conclusion) Comparison metallicity values GAIA DR2 StarHorse and LAMOST index



Graph 3: Comparison GAIA DR2 StarHorse metallicity (met16 and met84) with LAMOST [Fe/H] for the primary

(Continued from page 56)

These noticeable differences between GAIA DR2 StarHorse and LAMOST metallicity values remain in this context without explanation but comparing the StarHorse met50 values for primary and secondary shows in ~67% a difference of less than 0.1 indicating similar metallicity also with StarHorse catalog values.

4. Discussion

The question how stars are born and how they move over time is certainly fascinating. A star with a moderate fast spatial velocity of 20km/s needs only 150 million years to change is position relative to our Solar system by ~10 lightyears. Taking the age of the Sun with ~4.6 billion years this makes then about 300 lightyears or nearly 100 parsecs. As the speed and direction of the movement of stars is quite diverse this means that the neighborhood of a star might change significantly over its lifetime.

This report basically confirms with some caveats the data given in the Kamdar et al. 2019 paper but does not necessarily confirm the conclusion that the reported pairs have to be indeed of common origin due to the following reasons:

- Several seemingly co-moving pairs are despite very similar data values for parallax, proper motion and radial as well as spatial velolicty moving in directions different enough to question the "co-moving" property (see comments below Table 1). With a bit more restrictive thresholds for the direction of the spatial velocity even most of the listed KMD objects would not be assessed as co-moving
- Several KMD objects might if with a small likelihood be very well bound by gravitation according to a Monte Carlo simulation with a sample size of 120,000 using GAIA DR2 data for RA/Dec and Plx with the given error range used as standard deviation
- The KMD objects are listed as pairs and with few exceptions most are confirmed as such as no other objects with similar parameters are to be found in GAIA DR2. In a few cases such additional objects were found but could not be identified as co-moving members. This confirms the proposition that the listed pairs are most likely no longer part of a cluster – on the other side it seems a bit surprising that the "common origin" property should be restricted to pairs
- More or less all KMD objects come with parallax error values larger than 0.5% which means that at least for this parameter the data quality for the selected objects might be questionable. As the derived values like the spatial velocity are directly depending on the parallax data this casts a shadow at the final assessment of these objects
- With distances between the components of in average 40 light years the tidal forces of the Galaxy are no longer identical and such differences would over time counter-act against co-movement questioning the overall setup of the Kamdar et al. 2019 paper

- The total number of GAIA DR2 objects with parallax >1 and existing radial velocity data is 3,129,408 suggesting some likelidhood for pairs to have by chance similar values for parallax, proper motion and radial velocity – so it seems possible that the presented pairs are just random even if the additional criteria "metallicity" is considered
- Several KMD objects are already known double stars listed in the WDS catalog rendering these WDS pairs as likely opticals.

5. Common Origin/Common Movement Pairs in the WDS

The WDS catalog contains per June 2019 about 25,000 objects with code "V" for common proper motion. These objects offer a good chance to detect stars born together without being close enough for gravitational relationship by differentiating three szenarios:

- Doubles with a high likelihood for a spatial distance between components smaller than 1 parsec allowing for potential gravitational relationship - binaries
- Doubles with proper motion values by chance similar but with parallaxes and radial velocities and as a result spatial velocity far too different to be born together - opticals
- Doubles with all parameters similar enough to be considered to be born together but with parallaxes different enough make potential gravitational relationship rather unlikely either from the very beginning or by splitting up wide binaries later on – common origin.

After eliminating all pairs with separation less than 0.4" or more than 9999.9" plus the objects with insufficient RA/Dec data 24,635 objects remained for cross matching with GAIA DR2. The first X-match run with 5" radius around the primary position yielded 33,232 matches. The second X-match run with calculated J2000 positions for these objects and again 5" search radius yielded 55,882 objects with the unavoidable self matches and double matches for doubles with a separation smaller than 5". After eliminating all self-matches and likely wrong matches with delta in separation larger than 20%, delta in position angle larger than 15°, delta in M1 and M2 larger than 4 and eliminating the remaining multiple matches due to dense star fields 23,476 objects remained considered as likely correct cross-matches.

To be able to calculate spatial velocity all objects with missing parallax data or values below 1 mas or missing radial velocity values were eliminated as well reducing the object count drastically to 2,654. From these 2,203 objects have similar spatial movement (spatial velocity delta below 10% of the mean spatial velocity of both components and less than 10° delta in spatial movement direction – this allows for a few pairs a larger delta in spatial velocity than the 1.5km/s cut used by Kamdar et al. 2019 but the additional cut with the direction of the spatial velocity should overcompensate this generosity) and from these 1,030 have a spatial distance between the components (calculated with the given parallax values and the angular separation) of less than 1 parsec considered as threshold for potential gravitational relationship. From the remaining 1,173 objects a few with a spatial distance larger than 100 lightyears as threshold for the diameter of star forming molecular clouds had to be eliminated leaving 1,137 objects.

This selection of WDS objects is based only on the available astrometric data. An attempt to check the aspect of similar metallicity with LAMOST was not very successful due to the limited LAMOST DR4 coverage – only 32 pairs have [Fe/H] values for both components with 25 of them up to a delta of 0.1 meeting the cut applied by Kamdar et al. 2019.

The GAIA DR2 StarHorse catalog offers ~98% coverage but the spread of the given metallicity values indicated by the percentile 16 and 84 data is significantly larger than the spread of the [Fe/H] values in LAMOST. With a doubled cut value of 0.2 applied on the GAIA DR2 StarHorse median metallicity value 904 of the listed WDS code "V" objects qualify for similar metallicity and 233 pairs are despite common movement most likely not of common origin due to different metallicities including some outliers with large differences up to 1.96.

This means that out from the sample of V-coded WDS objects with data available for assessment 44% show common spatial movement and 34% have additionally similar metallicity suggesting common origin. It might make sense to add an additional WDS notes code for such objects – for example "G" for "proper motion, parallax and radial velocity suggest common origin and common movement".

Table 4 lists 20 such objects as stub with the full table available as flat text file "WDS V common origin and movement" for download.

- WDS = WDS ID
- Disc = Discoverer ID
- *C = Components (AB if blank, in Table 2 all AB)
- PA = Position angle from GAIA DR2 positions
- *e_PA = Error position angle

(Text continues on page 63)

WDS	Disc	C	PA	Sep	Plx1	pmra1	pmdec1	rV1	Plx2	pmra2	pmdec2	rV2	V1	V1D	V2	V2D	D_1-2
00013+0504	UC 304		53.647	15.33981	8.2162	-56.863	-23.221	12.43	8.3387	-57.641	-28.541	14.57	37.55	247.79	39.36	243.66	5.832
00061+2649	GRV 4		19.102	7.27753	2.6503	18.946	-8.057	-51.42	2.6719	19.038	-8.275	-44.36	63.24	113.04	57.65	113.49	9.949
00093+2517	GIC 2	AB	237.130	29.61193	24.8900	175.348	-158.970	0.67	22.4794	171.422	-145.634	4.71	45.08	132.20	47.66	130.35	14.052
00094-3321	TDS1322		277.574	9.46621	7.0201	167.998	-20.353	2.82	7.1058	167.660	-21.768	3.42	114.30	96.91	112.83	97.40	5.604
00102+0417	GRV 12		174.406	45.84872	4.7830	42.249	-25.818	-0.02	4.5758	42.832	-26.555	-1.77	49.07	121.43	52.23	121.80	30.879
00110-6309	UC 331		311.131	35.11078	3.7097	51.032	20.737	-25.51	3.7404	51.617	21.094	-25.32	74.86	67.89	75.06	67.77	7.218
00141-0602	KPP 52		196.820	3.50176	2.4400	2.805	-14.824	-57.53	2.4279	3.351	-14.913	-59.73	64.57	169.29	66.77	167.34	6.662
00159+1706	GRV 18		359.979	16.09166	4.2445	25.805	-30.356	-38.99	4.2743	25.842	-30.438	-37.03	59.16	139.63	57.72	139.67	5.358
00174+0221	STF 21		51.638	7.65779	5.6454	12.511	51.421	-61.17	5.6817	13.230	50.902	-60.20	75.61	13.67	74.49	14.57	3.691
00175-6142	KPP1737		130.295	13.40715	3.0868	40.117	7.579	-1.60	3.0467	40.374	7.870	-1.78	62.71	79.30	64.02	78.97	13.907
00185-3005	KPP1566		335.377	11.81386	2.6561	-9.674	-31.869	-2.41	2.6430	-8.606	-31.498	-3.69	59.48	196.89	58.68	195.28	6.087
00185-5325	UC 351		223.453	28.96995	7.4621	47.531	-24.364	-10.30	7.5238	46.284	-22.534	-11.19	35.46	117.14	34.31	115.96	3.585
00196+6457	CBL 568		12.476	24.68793	4.6139	73.984	19.281	-14.47	4.6375	73.907	18.312	-12.28	79.87	75.39	78.79	76.08	3.598
00211+5447	CBL 3		332.118	18.03992	5.7191	75.425	8.714	8.82	5.6807	75.713	8.555	10.43	63.54	83.41	64.43	83.55	3.855
00215-6744	HJ 3361	AB	293.406	5.06627	4.4129	-53.342	-20.102	17.27	4.3495	-52.848	-21.031	16.94	63.62	249.35	64.26	248.30	10.774
00248+5030	KPP1866		211.506	14.46339	3.4277	40.495	-16.087	1.67	3.4742	40.499	-16.434	1.16	60.28	111.67	59.64	112.09	12.736
00250-5904	SPM 2		3.943	24.51298	5.8662	82.091	66.293	17.47	5.9561	82.592	67.876	20.27	87.03	51.08	87.46	50.59	8.392
00276+1616	GWP 52		73.467	19.52921	2.5648	50.140	-4.752	-0.67	2.6465	50.352	-4.498	0.32	93.08	95.41	90.54	95.10	39.258
00280-3051	UC 375		335.925	39.77174	4.4577	-30.718	-44.846	-3.77	4.5852	-28.046	-44.646	-3.86	57.92	214.41	54.64	212.14	20.346
00298+0727	LOC 1		77.057	9.27217	3.4029	-15.519	-30.537	-7.81	3.4884	-16.535	-31.076	-7.98	48.35	206.94	48.49	208.02	23.492

Table 4. WDS pairs assumed to be of common origin

(Continued from page 61)

- Sep = Separation from GAIA DR2 positions in arcseconds
- *e_Sep = Error separation
- *Vest1 = Vmag1 estiamted from GAIA DR2 G/B/R-mags
- *Vest2 = Vmag2 estiamted from GAIA DR2 G/B/R-mags
- Plx1 = Parallax 1 in mas
- pmra1 = Proper motion RA 1 in mas/yr
- pmdec1 = Proper motion Dec 1 in mas/yr
- rV1 = Radial velocity 1 in km/s
- Plx2 = Parallax 2 in mas
- pmra2 = Proper motion RA 2 in mas/yr
- pmdec2 = Proper motion Dec 2 in mas/yr
- rV2 = Radial velocity 2 in km/s
- *Vt1 = Transverse velocity 1 in km/s
- V1 = Spatial velocity 1 in km/s
- V1D = Velocity 1 direction
- *Vt2 = Transverse velocity 2 in km/s
- V2 = Spatial velocity 2 in km/s
- V2D = Velocity 2 direction
- D_1-2 = Spatial Distance between the components in lightyears calculated by inverting the given parallaxes
- *met50_1 = GAIA DR2 StarHorse median metallicity 1 in dex
- *met50_2 = GAIA DR2 StarHorse median metallicity 2 in dex
- *dmet50 = Metallicity difference between the components

* = Data given only in download file

A side result of this matching process is that WDS objects BPM 489/490/491/492/493/494 have an identical primary.

6. Acknowledgements

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

- DSS2 images
- Aladin Sky Atlas v10.0
- GAIA DR2 catalog
- LAMOST DR4 catalog
- GAIA DR2 StarHorse catalog
- Washington Double Star Catalog
- CDS VizieR
- GAIA Archive (ADQL Search)
- Gaia@AIP Services hosted by the Leibniz-Institute for Astrophysics Potsdam (AIP)

7. References

Anders, F., et al., 2019, "Photo-astrometric distances, extinctions, and astrophysical parameters for Gaia DR2 stars brighter than G = 18", *Astronomy & Astrophysics*, 10.1051/0004-6361/201935765.

Harshil Kamdar, et al., 2019, "Stars that Move Together Were Born Together", arXiv:1904.02159 [astro-ph.GA]. Submitted to ApJL

Knapp, Wilfried R. A., 2018, "A New Concept for Counter-Checking of Assumed Binaries", *Journal of Double Star Observations*, **14** (3), 487.

Appendix

Description of the PGR assessment procedure (according to Knapp 2018)

GAIA DR2 data for RA/Dec and Plx are used for a Monte Carlo simulation assuming a normal distribution for these parameters with the given error range as standard deviation. The distance between the components is calculated from the inverted simulated parallax data and the simulated angular separation using the law of cosines

$$\sqrt{a^2 - 2ab\cos\gamma + b^2}$$

with a and b = distance vectors for the stars A and B in lightyears calculated as (1000/Plx)*3.261631 and γ = angular separation in degrees calculated as

$$\gamma = \arccos\left[\sin(DE1)\sin(DE2) + \cos(DE1)\cos(DE2)\cos(|RA1 - RA2|)\right]$$

The likelihood for potential gravitational relationship (LPGR) is the percentage of simulation results <200,000 AU (~1 parsec) out of the simulation sample with a size of 120,000 corresponding with the likelihood that the real distance is smaller than 200,000 AU with an margin of error of 0.37% at 99% confidence.

The smallest, median and largest distance is the smallest, median and largest result of the simulation sample.