Jonckheere Double Star Photometry - Part VII: Aquarius

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Abstract: If any double star discoverer is in urgent need of photometry then it is Jonckheere. There are over 3000 Jonckheere objects listed in the WDS catalog and a good part of them with magnitudes obviously far too bright. This report covers the Jonckheere objects in the constellation Aquarius. One image per object was taken with V-filter to allow for visual magnitude measurement by differential photometry. All objects were additionally checked for common proper motion by comparing 2MASS to GAIA DR1 positions and a rather surprisingly large part of the objects qualify indeed as potential CPM pairs. For a few objects also WDS position errors were found.

Introduction

As follow up to the reports on Jonckheere objects (J -objects) I submitted so far, I selected this time all J-objects in Aquarius to be imaged with a remote telescope located in New Mexico. As several images were of low quality due to bad weather I had to take additional images with a telescope in Australia as a substitute. The single image random effects seem less significant for the measured magnitudes as a magnitude error of ~0.1 or even a bit larger seems negligible in comparison with the Jonckheere objects often given magnitude errors in the range of up to 2 magnitudes. While the astrometry results from single images are less reliable for good reasons, I found several J-objects in Aqr with wrong WDS RA/Dec coordinates despite recent precise measurements - counter-checks with 2MASS images and GAIA DR1 coordinates confirmed these obvious misplacements.

Results of photometry and catalog checking

For each of the selected J-objects one single image was taken with iTelescope iT24 with V-filter and 3s exposure time, plate solved with Astrometrica using the URAT1 catalog with reference stars in the Vmag range of 8.5 to 14.5 giving not only RA/Dec coordinates but also photometry results for all reference stars used including an average dVmag error. The J-objects were then located in the center of the image and astrometry/ photometry was then done by the rather comfortable Astrometrica procedure with point and click at the components delivering RA/Dec coordinates and Vmag measurements based on all reference stars used for plate solving. Weather was a bit difficult during the imaging sessions, so I had to take additional images with iT27 in Australia for several objects to get acceptable results. I compared further for all objects, the 2MASS positions with GAIA DR1 to identify potential common proper motion pairs - rather surprisingly about 15% of the J-objects in Aqr qualify as solid CPM candidates with another 15% being potential CPM pairs while the rest seem clearly optical.

The results are given in Table 1 below with the following structure:

- J# gives the number of the J-object
- RA/Dec gives the position in the HH:MM:SS/ DD:MM:SS format for both components
- dRA and dDEc give the average plate solving error for RA and Dec in arcseconds
- Sep gives separation in arcseconds in the data lines calculated as SQRT(((RA2-RA1)*cos(Dec1))^2+ (Dec2-Dec1)^2) in radians
- Err Sep gives the calculated error range for Sep as

SQRT(dRA^2+dDec^2)
- PA gives position angle in degrees in the data lines calculated as arctan((RA2-RA1)*cos(Dec1))/(Dec2 -Dec1)) in radians depending on quadrant
- Err_PA = position angle error estimation in degrees calculated as arctan (Err_Sep/Sep) assuming the worst case that Err_Sep points perpendicular to the separation vector
- Mag gives Vmag for both components according to plate solving
- Err_Mag = magnitude error estimation calculated as SQRT(dVmag^2+(2.5*LOG10(1+1/SNR))^2)
- SNR as signal to noise ratio for the given object
- dVmag as average magnitude plate solving error
- Date gives the Bessel observation epoch
- Notes indicate the telescope used, number of images with exposure time, catalog used for plate solving, a comment regarding CPM assessment, additional comments like for example RE/Dec issues

All objects in Table 1 were additionally checked for potential common proper motion by comparing 2MASS to GAIA DR1 positions. The results for objects with at least some CPM probability are given in Table 2 below with the following structure:
- J# gives the J-object number
- RA/Dec in decimal degrees with the catalog reference given in the Source/Notes column – in all but 2 cases GAIA DR1
- Sep gives separation in arcseconds in the data lines calculated as SQRT(((RA2-RA1)*cos(Dec1))^2+ (Dec2-Dec1)^2) in radians
- PA gives position angle in degrees in the data lines calculated as arctan((RA2-RA1)*cos(Dec1))/(Dec2 -Dec1)) in radians depending on quadrant
- G-band M1 and M2
- Proper motion data is calculated from comparison 2MASS to GAIA DR1 positions according to the formulae used for Sep and PA (see above) including pm error range
- Used Aperture and observation method code is given in the Ap and Me columns. As GAIA uses a rectangular aperture the value given in the Ap column is the calculated diameter for a corresponding circular surface
- CPM rating procedure according to Knapp and Nanson 2017 (see Appendix for description)
- Date gives the Bessel observation epoch
- Source/Notes indicate the source used with additional comments

Summary

A good part of the listed J-objects in Aqr shows the expected significant magnitude difference compared with the WDS catalog data. Further a surprisingly large part of these objects qualifies as solid or at least good CPM candidates by comparing 2MASS to GAIA DR1 positions. Finally a few objects were found to be listed in the WDS catalog with wrong coordinates.

Acknowledgements:

The following tools and resources have been used for this research:
- 2MASS catalog
- 2MASS images
- AAVSO APASS
- AAVSO VPhot
- Aladin Sky Atlas v9.0
- Astrometrica v4.10.0.427
- AstroPlanner v2.2
- iTelescope:
  - iT24: 610mm CDK with 3962mm focal length. Resolution 0.625 arcsec/pixel. V-filter. No transformation coefficients available. Located in Auberry, California. Elevation 1405m
  - iT27: 700mm CDK with 4531mm focal length. CCD: FLI PL09000. Resolution 0.53 arcsec/pixel. V-filter. Siding Spring, Australia. Elevation 1122m
- GAIA DR1 catalog
- MaxIm DL6 v6.08
- POSS images
- SDSS DR9 and DR7 catalogs
- SDSS images
- SIMBAD
- UCAC4 catalog
- URAT1 catalog
- VizieR
- Washington Double Star Catalog

References

Buchheim, Robert, 2008, "CCD Double-Star Measurements at Altimira Observatory in 2007", *Journal of Double Star Observations*, **4**, 27 - 31.

Knapp, Wilfried and Nanson, John, 2017, "A New Concept for Counter-Checking of Assumed CPM Pairs", *Journal of Double Star Observing*, **13**, 31 - 51.

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Table 1: Jonckheeree Objects in Aquarius

J#		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	Notes
163	A	21 36 27.819	00 31 18.86	0.12	0.10	4.554	0.156	306.204	1.964	10.104	0.071	109.47	0.07	2015.848	iT27 1x3s URAT1. Comparison 2MASS to GAIS DR1 suggests optical
	B	21 36 27.574	00 31 21.55							11.280	0.073	48.26			
291	A	22 33 21.098	-00 41 53.53	0.08	0.07	3.139	0.106	175.616	1.939	10.605	0.090	167.06	0.09	2016.579	iT24 1x3s URAT1. Touching star disks. Comparison 2MASS to GAIS DR1 suggests optical
	B	22 33 21.114	-00 41 56.66							11.791	0.091	71.71			
569	A	20 38 28.240	01 55 04.38	0.07	0.08	3.026	0.106	316.087	2.012	11.022	0.090	132.39	0.09	2016.579	iT24 1x3s URAT1. Touching star disks. No hint of CPM
	B	20 38 28.100	01 55 06.56							11.785	0.091	83.06			
615	A	21 46 37.700	-01 29 33.72	0.07	0.08	5.324	0.106	348.631	1.144	11.889	0.081	94.06	0.08	2016.579	iT24 1x3s URAT1. Good CPM candidate
	B	21 46 37.630	-01 29 28.50							14.288	0.096	19.97			
919	A	22 37 36.441	00 15 06.57	0.10	0.12	4.936	0.156	75.091	1.813	11.203	0.082	58.76	0.08	2015.881	iT27 1x3s URAT1. Solid CPM candidate
	B	22 37 36.759	00 15 07.84							12.368	0.086	35.03			
1040	A	22 02 50.307	01 06 12.67	0.08	0.07	1.689	0.106	188.680	3.601	10.450	0.111	83.47	0.11	2016.579	iT27 1x3s URAT1. Heavily overlapping star disks
	B	22 02 50.290	01 06 11.00							11.258	0.112	56.19			
1400	A	20 39 02.209	-09 42 15.89	0.10	0.08	4.628	0.128	21.359	1.585	11.645	0.071	85.68	0.07	2016.579	iT24 1x3s URAT1. Good CPM candidate
	B	20 39 02.323	-09 42 11.58							12.104	0.072	66.37			
1400	A	20 39 02.209	-09 42 15.89	0.10	0.08	12.401	0.128	231.676	0.592	11.645	0.071	85.68	0.07	2016.579	iT24 1x3s URAT1. Optical
	C	20 39 01.551	-09 42 23.58							13.397	0.076	36.53			
1401	A	20 47 34.465	-11 22 26.37	0.09	0.09	4.334	0.127	304.107	1.682	10.552	0.080	142.90	0.08	2016.579	iT24 1x3s URAT1. Weak CPM candidate with potential orbit
	B	20 47 34.221	-11 22 23.94							12.460	0.084	44.66			
1402	A	21 07 56.308	-01 03 27.13	0.07	0.08	3.104	0.106	146.903	1.962	10.227	0.100	128.08	0.10	2016.579	iT24 1x3s URAT1. Touching star disks. Solid CPM candidate
	B	21 07 56.421	-01 03 29.73							11.065	0.101	84.25			
1403	A	21 12 45.841	-00 45 04.47	0.08	0.07	3.878	0.106	343.599	1.570	10.379	0.080	139.17	0.08	2016.579	iT24 1x3s URAT1. Touching star disks. Optical
	B	21 12 45.768	-00 45 00.75							10.819	0.081	90.59			
1404	A	21 14 08.902	-10 32 39.76	0.09	0.07	6.876	0.114	237.445	0.950	12.560	0.083	53.10	0.08	2016.579	iT24 1x3s URAT1. Solid CPM candidate
	B	21 14 08.509	-10 32 43.46							12.561	0.083	52.20			
1408	A	21 41 01.702	-00 34 38.47	0.09	0.06	6.590	0.108	355.562	0.940	12.654	0.102	58.77	0.10	2016.579	iT24 1x3s URAT1. Weak CPM candidate
	B	21 41 01.668	-00 34 31.90							12.857	0.102	51.45			
1409	A	21 41 45.272	-00 35 49.54	0.07	0.08	3.828	0.106	326.996	1.591	11.558	0.101	92.73	0.10	2016.579	iT24 1x3s URAT1. Touching star disks. Optical
	B	21 41 45.133	-00 35 46.33							11.847	0.102	59.47			
1411	A	21 54 42.075	-05 26 50.39	0.16	0.17	6.469	0.233	59.430	2.067	10.433	0.091	71.75	0.09	2015.881	iT27 1x3s URAT1. Comparison 2MASS to URAT11 suggests weak CPM candidate with potential orbit
	B	21 54 42.448	-05 26 47.10							11.919	0.094	38.98			

Table 1 continues on next page.

Jonckheere Double Star Photometry - Part VII: Aquarius

Table 1 (continued): Jonckheeree Objects in Aquarius

J#		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	Notes
1416	A	22 46 30.940	-05 57 50.98	0.10	0.11	9.715	0.149	212.096	0.877	12.051	0.092	58.03	0.09	2015.881	iT27 1x3s URAT1. Optical
	B	22 46 30.594	-05 57 59.21							12.813	0.093	46.08			
1417	A	22 50 43.141	-07 14 20.17	0.12	0.12	3.616	0.170	109.549	2.687	12.350	0.083	47.22	0.08	2015.881	iT27 1x3s URAT1. WDS catalog position obviously wrong. Optical
	B	22 50 43.370	-07 14 21.38							12.573	0.085	35.99			
1420	A	23 07 46.834	-05 05 40.31	0.12	0.09	6.391	0.150	172.748	1.344	9.132	0.070	156.35	0.07	2015.881	iT27 1x3s URAT1. Optical
	B	23 07 46.888	-05 05 46.65							11.253	0.071	75.13			
1421	A	23 09 23.156	-08 27 11.03	0.08	0.10	6.063	0.128	16.931	1.210	12.305	0.074	47.43	0.07	2015.881	iT27 1x3s URAT1. Optical
	B	23 09 23.275	-08 27 05.23							13.069	0.075	40.02			
1422	A	23 22 50.474	-11 37 30.63	0.15	0.19	7.356	0.242	93.039	1.885	11.137	0.062	75.46	0.06	2015.881	iT27 1x3s UCAC4. Optical
	B	23 22 50.974	-11 37 31.02							12.523	0.064	45.89			
1423	A	23 25 56.062	-05 14 13.32	0.14	0.11	7.002	0.178	254.171	1.457	11.420	0.081	83.47	0.08	2015.881	iT27 1x3s URAT1. Solid CPM candidate
	B	23 25 55.611	-05 14 15.23							12.033	0.082	68.27			
1424	A	23 26 05.223	-07 08 14.69	0.08	0.08	6.392	0.113	140.185	1.014	9.863	0.110	127.30	0.11	2015.881	iT27 1x3s URAT1. Weak CPM candidate
	B	23 26 05.498	-07 08 19.60							10.688	0.111	93.25			
1427	A	23 52 29.921	-06 37 20.01	0.14	0.11	6.711	0.178	144.896	1.520	9.898	0.081	119.21	0.08	2015.881	iT27 1x3s URAT1. Optical
	B	23 52 30.180	-06 37 25.50							11.603	0.082	60.75			
1428	A	23 52 34.587	-06 38 53.35	0.07	0.08	8.965	0.106	221.923	0.679	11.529	0.071	88.98	0.07	2015.881	iT27 1x3s URAT1. Optical
	B	23 52 34.185	-06 39 00.02							13.355	0.076	36.01			
1430	A	23 55 02.054	-04 37 26.08	0.22	0.08	9.593	0.234	14.440	1.398	11.507	0.111	83.68	0.11	2016.579	iT24 1x3s URAT1. Solid CPM candidate
	B	23 55 02.214	-04 37 16.79							13.689	0.117	25.83			
1709	A	20 46 42.455	-04 15 23.32	0.07	0.08	8.091	0.106	214.970	0.753	11.827	0.071	83.41	0.07	2016.579	iT24 1x3s URAT1. Optical
	B	20 46 42.145	-04 15 29.95							12.971	0.075	41.05			
1710	A	20 47 58.842	-04 08 54.67	0.09	0.07	8.457	0.114	205.235	0.772	11.699	0.071	92.56	0.07	2016.579	iT24 1x3s URAT1. Optical
	B	20 47 58.601	-04 09 02.32							12.508	0.072	62.96			
1711	A	20 51 06.550	-00 36 16.79	0.07	0.07	8.431	0.099	222.258	0.673	11.814	0.071	96.55	0.07	2016.579	iT24 1x3s URAT1. Good CPM candidate
	B	20 51 06.172	-00 36 23.03							12.047	0.071	84.20			
1713	A	20 55 23.690	-02 50 38.75	0.08	0.10	8.692	0.128	326.288	0.844	10.584	0.080	135.28	0.08	2016.579	iT24 1x3s URAT1. Weak CPM candidate
	B	20 55 23.368	-02 50 31.52							12.525	0.082	54.69			
1714	A	20 57 50.402	-05 09 54.36	0.07	0.07	10.249	0.099	94.421	0.553	11.093	0.080	127.38	0.08	2016.579	iT24 1x3s URAT1. Optical
	B	20 57 51.086	-05 09 55.15							12.187	0.081	72.03			

Table 1 continues on next page.

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Table 1 (continued): Jonckheeree Objects in Aquarius

J#		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	Notes
1717	A	21 03 49.672	-02 58 02.48	0.07	0.08	2.980	0.106	179.712	2.043	11.161	0.071	112.36	0.07	2016.579	iT24 1x3s URAT1. Solid CPM candidate
	B	21 03 49.673	-02 58 05.46							11.181	0.071	102.49			
1719	A	21 18 11.991	-02 22 55.30	0.09	0.07	5.756	0.114	170.104	1.135	10.933	0.081	79.30	0.08	2016.582	iT24 1x3s URAT1. SNR B <20. WDS Dec position obviously wrong despite recent 2015 measurement. Optical
	B	21 18 12.057	-02 23 00.97							13.265	0.098	18.54			
1727	A	22 10 26.748	-01 05 52.85	0.07	0.12	4.009	0.139	156.636	1.985	12.017	0.110	23.58	0.10	2015.947	iT27 1x3s URAT1. SNR B <20. Image quality a bit questiona-ble. Optical
	B	22 10 26.854	-01 05 56.53							12.389	0.132	12.04			
1729	A	22 49 46.704	-02 24 42.75	0.14	0.14	5.355	0.198	158.147	2.118	12.569	0.115	11.44	0.07	2016.582	iT24 1x3s URAT1. Image quality questionable. SNR A <20 and B <10. Solid CPM candidate
	B	22 49 46.837	-02 24 47.72							13.143	0.140	8.50			
1776	A	20 38 28.236	01 55 04.49	0.08	0.08	2.903	0.113	316.621	2.232	10.943	0.091	108.62	0.09	2016.601	iT24 1x3s URAT1. Touching star disks. No CPM assessment due to lack of 2MASS data for B, but possible
	C	20 38 28.103	01 55 06.60							11.522	0.092	64.35			
1782	A	21 07 03.462	-08 55 48.58	0.12	0.08	5.148	0.144	192.805	1.605	12.338	0.082	59.57	0.08	2016.601	iT24 1x3s URAT1. Solid CPM candidate. WDS RA/Dec position meanwhile wrong
	B	21 07 03.385	-08 55 53.60							12.679	0.084	44.06			
1795	A	22 14 32.782	-00 13 01.24	0.10	0.10	7.848	0.141	101.317	1.032	12.440	0.092	58.56	0.09	2016.601	iT24 1x3s URAT1. Optical
	B	22 14 33.295	-00 13 02.78							13.321	0.095	34.27			
2318	A	20 38 27.702	00 00 44.41	0.09	0.09	5.628	0.127	149.927	1.296	12.379	0.092	62.35	0.09	2016.601	iT24 1x3s URAT1. Optical
	B	20 38 27.890	00 00 39.54							12.959	0.093	44.31			
2318	A	20 38 27.702	00 00 44.41	0.09	0.09	14.871	0.127	119.487	0.490	12.379	0.092	62.35	0.09	2016.601	iT24 1x3s URAT1. SNR C <20. Optical
	C	20 38 28.565	00 00 37.09							14.662	0.107	18.27			
2320	A	20 44 40.346	-08 53 22.98	0.08	0.10	3.367	0.128	135.227	2.178	13.133	0.028	38.47	0.08	2016.601	iT24 1x3s URAT1. SNR B <20. Optical
	B	20 44 40.506	-08 53 25.37							14.537	0.080	13.14			
2320	A	20 44 40.346	-08 53 22.98	0.08	0.10	10.478	0.128	53.723	0.700	13.133	0.028	38.47	0.08	2016.601	iT24 1x3s URAT1. Optical
	C	20 44 40.916	-08 53 16.78							13.728	0.040	26.92			
2322	A	20 49 54.086	-08 15 03.67	0.09	0.09	3.938	0.127	8.017	1.851	10.159	0.007	153.37	0.07	2016.601	iT24 1x3s URAT1. Optical
	B	20 49 54.123	-08 14 59.77							12.756	0.045	23.37			
2324	A	20 50 42.926	-11 34 01.37	0.08	0.07	27.103	0.106	192.112	0.225	9.994	0.080	150.56	0.08	2016.582	iT24 4x3s URAT1. Optical
	B	20 50 42.539	-11 34 27.87							11.185	0.081	77.53			
2324	A	20 50 42.926	-11 34 01.37	0.08	0.07	25.762	0.106	183.990	0.236	9.994	0.080	150.56	0.08	2016.582	iT24 4x3s URAT1. Optical
	C	20 50 42.804	-11 34 27.07							11.708	0.082	64.52			

Table 1 continues on next page.

Table 1 (continued): Jonckheeree Objects in Aquarius

J#		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	Notes
2324	B	20 50 42.539	-11 34 27.87	0.08	0.07	3.975	0.106	78.391	1.532	11.185	0.081	77.53	0.08	2016.582	iT24 4x3s URAT1. Good CPM candidate
	C	20 50 42.804	-11 34 27.07							11.708	0.082	64.52			
2326	A	20 53 07.333	-06 50 44.44	0.08	0.07	8.086	0.106	79.597	0.753	10.347	0.080	174.77	0.08	2016.601	iT24 1x3s URAT1. Optical
	B	20 53 07.867	-06 50 42.98							10.534	0.080	165.79			
2328	A	20 54 04.633	-00 34 17.00	0.08	0.07	3.179	0.106	351.042	1.915	13.507	0.080	27.85	0.07	2016.591	iT24 2x3s URAT1. SNR B <20. Optical
	B	20 54 04.600	-00 34 13.86							14.092	0.090	18.67			
2330	A	20 56 35.363	-05 59 50.29	0.07	0.08	6.319	0.106	113.997	0.964	12.233	0.072	70.91	0.07	2016.601	iT24 1x3s URAT1. Optical
	B	20 56 35.750	-05 59 52.86							12.674	0.073	53.72			
2330	A	20 56 35.363	-05 59 50.29	0.07	0.08	27.702	0.106	105.665	0.220	12.233	0.072	70.91	0.07	2016.601	iT24 1x3s URAT1. Optical
	C	20 56 37.151	-05 59 57.77							11.682	0.071	95.57			
2332	A	20 57 07.557	01 28 08.05	0.08	0.08	3.145	0.113	231.445	2.060	11.988	0.091	78.50	0.09	2016.601	iT24 1x3s URAT1. Optical
	B	20 57 07.393	01 28 06.09							12.615	0.093	49.06			
2340	A	21 11 21.755	-08 31 36.83	0.10	0.10	6.745	0.141	322.626	1.201	12.395	0.082	59.35	0.08	2016.601	iT24 1x3s URAT1. Optical
	B	21 11 21.479	-08 31 31.47							14.209	0.099	18.07			
2343	A	21 23 18.186	-11 21 37.15	0.09	0.09	7.541	0.127	172.717	0.967	12.441	0.092	64.36	0.09	2016.601	iT24 1x3s GAIA DR1/UCAC4. Optical
	B	21 23 18.251	-11 21 44.63							12.755	0.093	47.85			
2349	A	21 27 28.039	02 02 58.06	0.08	0.08	8.393	0.113	236.520	0.772	13.606	0.089	28.18	0.08	2016.601	iT24 1x3s URAT1. Optical
	B	21 27 27.572	02 02 53.43							13.736	0.089	26.56			
2353	A	21 35 35.826	-06 15 16.36	0.08	0.08	3.435	0.113	73.598	1.886	12.431	0.073	56.22	0.07	2016.601	iT24 1x3s URAT1. No CPM assessment due to lack of 2MASS data for B, but possible
	B	21 35 36.047	-06 15 15.39							13.188	0.079	29.83			
2359	A	21 52 59.216	-03 54 49.30	0.09	0.07	5.327	0.114	160.129	1.226	14.712	0.108	14.43	0.08	2016.601	iT24 1x3s URAT1. SNR A <20, SNR B <10. Probably optical
	B	21 52 59.337	-03 54 54.31							15.459	0.152	7.89			
2360	A	21 53 05.221	-03 56 05.79	0.17	0.27	5.918	0.319	151.284	3.086	11.880	0.143	39.90	0.14	2015.947	iT27 1x3s UCAC4. SNR B <20. Image quality very questionable. Optical
	B	21 53 05.411	-03 56 10.98							14.273	0.193	7.68			
2366	A	22 16 37.675	-08 22 15.75	0.17	0.10	7.035	0.197	32.398	1.606	10.761	0.122	46.69	0.12	2015.947	iT27 1x3s UCAC4. SNR B <20. Image quality a bit questionable. Solid CPM candidate
	B	22 16 37.929	-08 22 09.81							11.451	0.122	46.18			
2367	A	22 18 01.551	-11 08 57.54	0.17	0.14	7.767	0.220	33.723	1.624	11.939	0.092	60.80	0.09	2015.947	iT27 1x3s UCAC4. Image quality a bit questionable. Solid CPM candidate despite the rather large 2MASS position error
	B	22 18 01.844	-11 07 51.08							12.109	0.092	50.74			

Table 1 continues on next page.

Table 1 (conclusion): Jonckheeree Objects in Aquarius

J#		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	Notes
2368	A	22 18 01.368	-11 06 58.67	0.17	0.14	12.484	0.220	127.041	1.011	11.615	0.092	61.54	0.09	2015.947	iT27 1x3s UCAC4. Image quality a bit questionable. Weak CPM candidate
	B	22 18 02.045	-11 07 06.19							12.683	0.095	36.52			
2368	A	22 18 01.368	-11 06 58.67	0.17	0.14	18.144	0.220	69.278	0.695	11.615	0.092	61.54	0.09	2015.947	iT27 1x3s UCAC4. Image quality a bit questionable. Optical
	C	22 18 02.521	-11 06 52.25							12.874	0.096	31.77			
2370	A	22 29 50.497	-09 24 50.05	0.09	0.11	7.532	0.142	146.626	1.081	11.941	0.062	78.20	0.06	2016.601	iT24 1x3s URAT1. Solid CPM candidate
	B	22 29 50.777	-09 24 56.34							13.714	0.069	31.00			
3346	A	20 43 25.728	-00 09 50.10	0.07	0.08	1.799	0.106	106.470	3.382	11.984	0.081	81.21	0.08	2016.601	iT24 1x3s URAT1. Heavily overlapping star disks make measurement precision somewhat questionable. Weak CPM candidate. WDS position obviously in error, only single star. 2MASS and SDSS images show also only single star in the given position. But nearby double with similar parameters seems to be the correct match with J3346. Also confirmed by corresponding SDSS and GAIA DR1 objects with 2.465" at 110,557° from the latter
	B	20 43 25.843	-00 09 50.61							12.624	0.084	42.10			

Explanations Notes column:

- "iT24 1x3s URAT1" indicates the use of a single telescope iT24 image with 3s exposure time based URAT1 for plate solving
- "Touching star disks" indicates that the rims of the star disks are touching and that the measurement results might be a bit less precise than with clearly separated star disks
- "Touching/Overlapping star disks" indicates that the star disks overlap to the degree of an elongation and that the measurement results is probably less precise than with clearly separated star disks
- "SNR <20" indicates that the measurement result might be a bit less precise than desired due to a low SNR value but this is already included in the calculation of the magnitude error range estimation
- "SNR <10" indicates that the measurement result is probably a bit less precise than desired due to a very low SNR value but this is already included in the calculation of the magnitude error range estimation
- "Image quality questionable" or similar indicates rather large average errors for the reference stars used for plate solving for different reasons (mostly atmospheric influences). But this is at least to some degree already included in the calculation of the error range estimation

Table 2: J objects in Aqr being at least potentially CPM pairs

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
615	326.65706861	-1.4926818	5.39	348.4	11.58	13.51	13.24	-37.20	7.80	11.65	-35.66	7.80	0.96	Hg	2015.000	ABCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
919	339.40180969	0.2519325	4.99	77.2	10.75	11.80	-38.22	-203.60	6.90	-37.52	-205.33	6.90	0.96	Hg	2015.000	AAAA	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1400	309.75922688	-9.7044483	4.64	22.0	11.49	11.91	-0.53	-9.10	6.90	-0.39	-8.95	6.90	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1401	311.89361298	-11.3739903	4.42	304.4	10.40	12.05	5.66	-15.85	6.56	4.37	-13.05	6.56	0.96	Hg	2015.000	ACCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1402	316.9846097	-1.05749672	3.20	147.1	10.19	10.88	0.92	-35.25	7.01	0.06	-33.97	7.01	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1404	318.53698279	-10.5442603	6.93	237.3	12.21	12.27	4.91	-46.74	6.46	4.26	-48.76	6.46	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1408	325.25707448	-0.5773692	6.60	356.0	12.49	12.61	34.56	11.67	5.66	34.77	8.20	5.66	0.96	Hg	2015.000	BACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1411	328.67545350	-5.4473044	6.30	58.8	10.28		-22.94	1.93	6.52	-26.41	1.09	6.52	0.20	Eu	2012.868	ACCB	URAT1. M1 URAT1 Vmag. PM data calculated from position comparison with 2MASS
1423	351.48353957	-5.2370227	6.88	252.8	11.14	11.73	12.06	53.01	6.00	12.76	53.52	6.00	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1424	351.5218669	-7.137392441	6.50	141.0	9.55	10.50	-38.12	-33.16	7.52	-38.05	-29.73	7.52	0.96	Hg	2015.000	BACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1430	358.75853723	-4.6238774	9.72	15.7	11.40	13.33	62.48	-33.29	7.40	62.88	-33.02	7.40	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1711	312.77728746	-0.6046973	8.43	222.3	11.57	11.78	12.48	32.00	6.53	14.86	34.32	6.53	0.96	Hg	2015.000	ABCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1713	313.84873852	-2.8441137	9.02	326.5	10.51	12.16	-1.87	-11.43	5.21	-2.96	-15.46	5.21	0.96	Hg	2015.000	ACCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS

Table 2 concludes on next page.

Table 2 (conclusion): J objects in Aqr being at least potentially CPM pairs

J#	RA	Dec	Sep	PA	M1	M2	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPM Rat	Source/Notes
1717	315.95697384	-2.9673312	3.20	179.1	11.01	11.10	21.38	1.94	6.64	20.82	0.92	6.64	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1729	342.44454896	-2.4117936	5.98	154.0	12.42	13.17	-32.13	-34.52	5.68	-32.89	-34.88	5.66	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
1782	316.76435395	-8.9301166	5.12	191.5	12.10	12.42	26.48	-1.92	8.26	25.38	-1.16	8.26	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
2324BC	312.67726195	-11.5743847	4.04	78.6	10.99	11.49	-17.21	-26.83	5.24	-15.11	-24.88	5.24	0.96	Hg	2015.000	ABCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
2366	334.15709451	-8.3709075	6.90	32.1	10.70	11.38	25.39	0.33	12.16	26.09	1.10	12.16	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
2367	334.50649320	-11.1494267	7.46	33.9	11.73	11.96	14.65	-3.72	9.95	14.19	-3.75	9.95	0.96	Hg	2015.000	AACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
2368 AB	334.50567819	-11.1163464	12.70	125.4	11.41	12.39	-21.76	-25.42	9.95	-23.88	-23.42	9.95	0.96	Hg	2015.000	BACB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with 2MASS
2370	337.46040140	-9.4138289	7.61	146.6	11.82		-39.13	-104.70	5.71	-40.97	-103.39	5.71	0.20	Eu	2013.599	AABA	URAT1. M1 URAT1 Vmag. PM data calculated from position comparison with 2MASS
3346	310.85719409	-0.1639097	2.46	110.6	11.78	12.86	1.39	-23.90	6.32	0.31	-29.46	6.37	0.96	Hg	2015.000	ACCB	GAIA DR1. M1 and M2 are G-band. PM data calculated from position comparison with SDSS DR7

Appendix A

CPM rating scheme according to Knapp/Nanson 2017 with extensions

Four rating factors are used: Proper motion vector direction, proper motion vector length, size of position error in relation to proper motion vector length and relationship separation to average proper motion speed:

- Proper motion vector direction rating: "A" for within the error range identical direction, "B" for similar direction within the double error range and "C" for outside
- Proper motion vector length rating: "A" for within the error range identical length, "B" for similar length within the double error range and C for outside
- Error size rating: "A" for error size of less than 5% of the proper motion vector length, "B" for less than 10% and "C" for a larger error size
- Rating for relation separation to average proper motion speed: "A" for less than 100 years, "B" for 100 to 1000 years and "C" for above.

To compensate for (depending on the selected objects and available catalogs) excessively large position errors resulting an "A" rating despite rather high deviations absolute upper limits are applied regardless of calculated error size:

- Proper motion vector direction: Max. 2.86° difference for an "A" and 5.72° for a "B"
- Proper motion vector length: Max. 5% difference for an "A" and 10% for a "B"

Modification for cases of very small position errors (when for example using SDSS9 instead of 2MASS) with the consequence that the requirements to get an A or even B CPM rating get unreasonably hard:

- The error estimation for proper motion vector direction and length is, in this case, calculated as root mean square from both position errors (instead of only the larger 2MASS one)
- If the PM vector direction difference is larger than this calculated "allowed" error but still less than 0.5° then an "A" is given, a "B" is given for larger than 0.5 but less than 1 degree, and a "C" is given if above
- If the PM vector length difference is larger than this calculated "allowed" error but still less than 0.5% then an "A" is given, a "B" is given for larger than 0.5 but less than 1 percent, and a "C" is given if above.