Jonckheere Double Star Photometry – Part VIII: Sextans

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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 Sextans. 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 and a good part of the objects qualify indeed as potential CPM pairs.

1. Introduction

As follow up to the report on J-objects I submitted so far I selected this time all J-objects in Sextans to be imaged with a remote telescope located in Siding Spring/Australia. The single image random effects seem less significant for the measured magnitudes as a magnitude error of about 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.

2. Results of Photometry and Catalog Checking

For each of the selected J-objects one single image was taken with iTelescope iT27 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. In a few cases I had to take additional images to avoid issues with image quality. In an additional step, I checked all objects for common proper motion by using the UCAC5 catalog if possible, otherwise I compared the 2MASS positions with GAIA DR1 or URAT1 with the result that a good part of the J-objects in Sextans qualify as solid CPM candidates. Rather surprisingly several objects were missing corresponding objects for the secondary in these catalogs so no CPM rating was possible in these cases.

The results are given in Table 1 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
- N gives the number of images used
- Notes indicate the telescope used, number of imag-

es 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 using UCAC5 data if available, or else by comparing 2MASS to GAIA DR1 (and in a few cases URAT1) positions. The results are given in Table 2 with the following structure:

- J# gives the J-object number
- RA/Dec in decimal degrees with the catalog reference indicated in the Source/Notes column (in case of UCAC5 the given GAIA DR1 coordinates are used)
- 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
- M1 and M2 give Gmags in case of UCAC5 or GAIA DR1 as data source and Vmags with URAT1
- Proper motion data is from UCAC5 if available, or else calculated from a comparison of 2MASS to GAIA DR1 or URAT1 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. For UCAC5 the GAIA DR1 aperture and observation method are given accordingly to the given coordinates
- CPMRat gives the common proper motion assessment according to Knapp and Nanson 2017 (see appendix for description)
- Date lists the observation epoch for the source used (with the exception of UCAC5 – here 2015.0 for GAIA DR1 is given. The UCAC5 observation epoch is given in the Source/Notes column as reference for the used proper motion data)
- Source/Notes indicate the source used with additional comments.

3. Summary

A good part of the listed J-objects in Sex shows the expected significant magnitude difference compared with the WDS catalog data. Further one third of these objects qualifies as solid or at least good CPM candidates based on a rating scheme using UCAC5 proper motion data or by comparing 2MASS to GAIA DR1 or URAT1 positions. Surprisingly about 20% of the objects are with at least one component not covered by the recently published extensive star catalogs like especially GAIA DR1.

Acknowledgements:

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- 2MASS catalog
- 2MASS images
- AAVSO APASS
- AAVSO VPhot
- Aladin Sky Atlas v9.0
- Astrometrica v4.10.0.427
- AstroPlanner v2.2
- iTelescope: 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
- UCAC5 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**(1), 27-31.

Knapp, Wilfried; Nanson, John, 2017, “A New Concept for Counter-Checking of Assumed CPM Pairs”, *Journal of Double Star Observations*, **13**(1), 31-51.

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Table 1. Measurement results for J objects in Sex

J#		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
83	A	09 50 30.023	03 37 02.02	0.08	0.09	2.008	0.120	231.507	3.431	10.376	0.082	58.41	0.08	2015.969	1	iT27 1x3s. Overlapping star disks
	B	09 50 29.918	03 37 00.77							10.574	0.084	44.10				
84	A	10 36 09.141	00 41 09.98	0.16	0.17	-	0.233	-	-	8.512	0.091	74.18	0.09	2016.106	1	iT27 1x3s. No resolution. Combined magnitude corresponds with WDS mags
	B										-					
88	A	10 38 11.883	-05 56 19.46	0.19	0.15	9.040	0.242	238.748	1.534	10.124	0.141	60.69	0.14	2015.969	1	iT27 1x3s. SNR B <20
	B	10 38 11.365	-05 56 24.15							13.174	0.151	18.67				
89	A	10 43 19.213	-03 52 51.83	0.13	0.18	4.229	0.222	83.892	3.005	10.149	0.121	72.89	0.12	2016.106	1	iT27 1x3s
	B	10 43 19.494	-03 52 51.38							11.424	0.123	37.80				
426	A	09 56 09.401	03 27 56.59	0.09	0.11	3.177	0.142	205.396	2.561	10.151	0.100	124.62	0.10	2016.106	1	iT27 1x3s
	B	09 56 09.310	03 27 53.72							10.157	0.100	124.63				
746	A	09 54 48.829	-07 56 54.59	0.15	0.08	2.352	0.170	296.243	4.134	9.802	0.071	85.12	0.07	2017.365	5	iT27 4x1s. Overlapping star disks
	B	09 54 48.687	-07 56 53.55							10.555	0.074	42.43				
747	A	10 29 03.341	-03 21 49.11	0.08	0.10	3.477	0.128	252.942	2.109	10.916	0.081	78.75	0.08	2016.106	1	iT27 1x3s. Touching star disks
	B	10 29 03.119	-03 21 50.13							11.997	0.084	44.29				
1010	A	10 23 39.489	00 20 35.35	0.17	0.20	3.733	0.262	308.037	4.022	9.551	0.081	82.45	0.08	2015.969	1	iT27 1x3s. Touching star disks
	B	10 23 39.293	00 20 37.65							11.302	0.084	43.64				
1369	A	10 41 02.163	03 35 44.84	0.12	0.17	7.410	0.208	118.979	1.609	10.015	0.100	159.49	0.10	2016.106	1	iT27 1x3s
	B	10 41 02.596	03 35 41.25							11.664	0.101	66.80				
1557	A	09 43 09.822	-07 41 47.42	0.13	0.12	5.112	0.177	169.105	1.982	11.072	0.061	95.87	0.06	2015.969	1	iT27 1x3s
	B	09 43 09.887	-07 41 52.44							12.165	0.064	51.27				
1558	A	09 46 35.432	-05 04 21.86	0.22	0.28	10.978	0.356	169.095	1.858	11.529	0.093	21.96	0.08	2015.969	1	iT27 1x3s. Image quality questionable
	B	09 46 35.571	-05 04 32.64							11.911	0.096	19.66				
1559	A	09 48 55.097	-10 43 53.97	0.11	0.18	6.132	0.211	120.909	1.970	10.552	0.082	59.98	0.08	2015.969	1	iT27 1x3s
	B	09 48 55.454	-10 43 57.12							11.235	0.083	47.46				

Table 1 concludes on next page.

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Table 1 (conclusion). Measurement results for J objects in Sex

J#		RA	Dec	dRA	dDec	Sep	Err Sep	PA	Err PA	Mag	Err Mag	SNR	dVmag	Date	N	Notes
1560	A	09 53 35.026	-06 43 23.83	0.11	0.09	10.125	0.142	303.309	0.804	11.125	0.091	71.95	0.09	2015.969	1	iT27 1x3s
	B	09 53 34.458	-06 43 18.27							13.039	0.097	28.72				
1563	A	10 14 59.133	-06 24 11.61	0.08	0.09	9.904	0.120	3.020	0.697	10.405	0.081	110.06	0.08	2015.969	1	iT27 1x3s
	B	10 14 59.168	-06 24 01.72							12.195	0.083	51.95				
1565	A	10 30 07.833	-04 57 08.90	0.08	0.08	19.947	0.113	11.451	0.325	11.399	0.110	105.81	0.11	2016.106	1	iT27 1x3s. SNR B <10
	B	10 30 08.098	-04 56 49.35							14.877	0.161	8.72				
1566	A	10 30 00.389	-02 52 12.74	0.10	0.11	12.285	0.149	269.720	0.693	10.968	0.120	104.05	0.12	2016.106	1	iT27 1x3s
	B	10 29 59.569	-02 52 12.80							13.488	0.124	35.43				
2073	A	10 05 41.193	-03 33 01.47	0.15	0.10	7.790	0.180	323.976	1.326	10.106	0.071	93.64	0.07	2015.969	1	iT27 1x3s. SNR B<20
	B	10 05 40.887	-03 32 55.17							14.874	0.114	11.61				
2075	A	10 37 25.187	-11 02 38.64	0.07	0.11	6.670	0.130	63.368	1.120	8.113	0.100	337.27	0.10	2016.106	1	iT27 1x3s
	B	10 37 25.592	-11 02 35.65							10.927	0.101	105.17				
2076	A	10 49 50.192	-08 54 21.07	0.10	0.12	2.182	0.156	66.497	4.096	10.896	0.082	61.97	0.08	2017.365	4	iT27 4x1s. Overlapping star disks
	B	10 49 50.327	-08 54 20.20							11.136	0.083	51.92				
2499	A	09 43 51.095	04 28 40.00	0.16	0.19	4.679	0.248	346.508	3.039	12.116	0.114	36.75	0.11	2015.969	1	iT27 1x3s
	B	09 43 51.022	04 28 44.55							12.546	0.115	30.95				
2500	A	09 49 13.120	02 43 54.02	0.13	0.11	6.093	0.170	284.348	1.601	12.829	0.091	93.50	0.09	2017.324	5	iT27 5x3s
	B	09 49 12.726	02 43 55.53							14.696	0.095	36.82				
3250	A	09 44 49.727	-07 44 44.19	0.10	0.10	4.142	0.141	4.322	1.956	13.022	0.099	25.84	0.09	2015.969	1	iT27 1x3s. UCAC4. SNR B<20
	B	09 44 49.748	-07 44 40.06							13.599	0.113	15.25				
3320	A	10 15 55.207	-06 24 32.98	0.07	0.09	6.151	0.114	108.190	1.062	12.221	0.081	89.24	0.08	2016.106	1	iT27 1x3s
	B	10 15 55.599	-06 24 34.90							13.315	0.083	48.93				
3340	A	10 27 42.722	-05 59 46.12	0.11	0.12	4.002	0.163	19.602	2.329	12.217	0.074	44.36	0.07	2015.969	1	iT27 1x3s
	B	10 27 42.812	-05 59 42.35							12.770	0.079	28.92				

Explanations Notes column:

1. "UCAC4" indicates the use of UCAC4 for plate solving, otherwise URAT1 was used
2. "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
3. "Touching/Overlapping star disks" indicates that the star disks overlap to the degree of an elongation and that the measurement results are probably less precise than with clearly separated star disks
4. "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
5. "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
6. "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

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Table 2. J objects in Sextans with Most Recent Catalog Coordinates and Check for being Potentially CPM Pairs

J#	RA	Dec	Sep"	PA°	M1(G)	M2(G)	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPMRat	Source/Notes
83	147.62516030	3.6172608	2.21	238.6	10.36	10.70	-55.50	-3.00	1.70	-57.80	-3.50	3.54	0.96	Hg	2015.000	AABA	UCAC5 2000.185. PM data from UCAC5 catalog. Solid CPM candidate
84																	Neither UCAC5 nor GAIA DR1 objects for A and B
88	159.54962970	-5.9388017	9.38	237.1	9.93	12.63	4.00	0.50	2.33	3.10	-0.60	2.05	0.96	Hg	2015.000	CCCC	UCAC5 2000.100. PM data from UCAC5 catalog. Optical
89																	Neither URAT1, UCAC5 nor GAIA DR1 objects for A and B
426	149.0391933	3.4656572	3.43	207.6	10.08	10.09	-64.00	-5.90	1.84	-64.80	-8.90	3.39	0.96	Hg	2015.000	AABA	UCAC5 2000.185. PM data from UCAC5 catalog. Solid CPM candidate
746																	Neither 2MASS, URAT1, UCAC5 nor GAIA DR1 objects for B
747	157.26394830	-3.3636461	3.66	252.7	10.72	11.75	12.00	-18.10	1.70	9.50	-16.90	1.84	0.96	Hg	2015.000	BCBB	UCAC5 2000.117. PM data from UCAC5 catalog. Rather optical
1010																	Neither URAT1, UCAC5 nor GAIA DR1 objects for B
1369	160.25895346	3.5957329	7.43	120.1	9.77	11.12	120.50	-135.63	7.60	120.56	-137.09	7.60	0.96	Hg	2015.000	AAAB	GAIA DR1. PM data calculated from position comparison with 2MASS. Solid CPM candidate. Already V-coded in WDS
1557	145.7908694	-7.6965183	5.2	165.2	10.98	11.89	-64.40	28.30	1.56	-42.90	26.60	1.70	0.96	Hg	2015.000	CCAA	UCAC5 2000.078. PM data from UCAC5 catalog. Optical
1558	146.64767140	-5.0725922	11.10	169.9	11.44	11.71	-25.20	3.40	1.84	-26.40	3.80	1.84	0.96	Hg	2015.000	AABB	UCAC5 2000.098. PM data from UCAC5 catalog. Solid CPM candidate
1559	147.22953530	-10.7318294	6.26	119.5	10.39	10.99	-3.50	-5.50	1.77	-3.30	-4.40	3.39	0.96	Hg	2015.000	BCCC	UCAC5 2000.043. PM data from UCAC5 catalog. Optical
1560	148.39601390	-6.7233189	10.05	301.8	10.86	12.74	5.50	-6.30	2.40	5.20	-6.30	2.19	0.96	Hg	2015.000	AACC	UCAC5 2000.086. PM data from UCAC5 catalog. Potential CPM but PM values too small to be significant

Table 2 concludes on next page.

Table 2(conclusion). J objects in Sextans with Most Recent Catalog Coordinates and Check for being Potentially CPM Pairs

J#	RA	Dec	Sep"	PA°	M1(G)	M2(G)	pmRA1	pmDec1	e_pm1	pmRA2	pmDec2	e_pm2	Ap	Me	Date	CPMRat	Source/Notes
1563	153.74635220	-6.4032664	9.96	4.2	10.23	11.88	6.70	7.00	1.84	6.40	7.50	1.91	0.96	Hg	2015.000	BACC	UCAC5 2000.091. PM data from UCAC5 catalog. Potential CPM but PM values too small to be significant
1565	157.53271030	-4.9525208	20.12	10.9	11.34	14.97	0.00	-8.30	1.70	-16.90	-21.40	2.90	0.96	Hg	2015.000	CCCC	UCAC5 2000.106. PM data from UCAC5 catalog. Optical
1566	157.50165640	-2.8701792	12.32	269.8	10.81	13.17	69.40	-48.60	1.70	15.80	-14.90	1.84	0.96	Hg	2015.000	CCBB	UCAC5 2000.121. PM data from UCAC5 catalog. Optical
2073	151.42160890	-3.5504203	7.79	320.0	10.06		-23.35	7.17	5.51	2.50	9.70	5.51	0.20	Eu	2014.137	CCCB	URAT1. Neither UCAC5 nor GAIA DR1 object for B. Data from URAT1. PM data calcu-lated from position comparison with 2MASS - optical
2075	159.35495470	-11.0440903	6.56	62.6	8.69		14.36	-0.54	5.50	-0.27	5.54	5.46	0.20	Eu	2014.217	CCCB	URAT1. Neither UCAC5 nor GAIA DR1 object for B. Data from URAT1. PM data calcu-lated from position comparison with 2MASS - optical
2076																	Neither 2MASS, UCAC5 nor GAIA DR1 object for B
2499	145.96281250	4.4776908	4.86	348.1	11.90	12.26	35.80	-20.40	1.84	35.00	-20.60	1.84	0.96	Hg	2015.000	AAAB	UCAC5 2000.192. PM data from UCAC5 catalog - solid CPM candidate
2500	147.30463250	2.7316778	6.15	284.3	12.64	14.35	-3.30	0.60	1.70	-3.10	-0.20	2.26	0.96	Hg	2015.000	CBCC	UCAC5 2000.171. PM data from UCAC5 catalog - rather optical
3250	146.20723280	-7.7456847	4.33	358.1	12.56	13.13	17.10	7.90	1.63	16.10	7.60	1.70	0.96	Hg	2015.000	ABBB	UCAC5 2000.079. PM data from UCAC5 catalog - good CPM candidate
3320	153.98001080	-6.4091756	6.12	106.7	11.91	12.95	-14.50	-29.50	1.84	-15.40	-30.70	1.98	0.96	Hg	2015.000	AABB	UCAC5 2000.091. PM data from UCAC5 catalog - solid CPM candidate
3340	156.92808830	-5.9962144	4.50	15.4	12.01	12.44	-19.80	-6.10	1.70	-20.30	-5.30	1.70	0.96	Hg	2015.000	AABB	UCAC5 2000.093. PM data from UCAC5 catalog - solid CPM candidate

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 or directly proper motion data from GAIA DR1 or UCAC5) with the consequence that the requirements to get an A or even B CPM rating get unreasonable hard:

- The from the position error resulting error estimation for proper motion vector direction and length is in this case calculated as root mean square from both position errors (instead of so far 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.