Jonckheere Double Star Photometry – Part XIII: Peg

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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 Pegasus. At least one image per object was taken with V-filter to allow for visual magnitude measurement by differential photometry. All objects were additionally checked for potential gravitational relationship and 11 qualify indeed as potential physical pairs.

Preamble: This report in no way intends to belittle the work of Jonckheere – on the contrary: He was obviously a very dedicated and able double star observer fighting with a lot of obstacles including equipment destroyed in World War I. It seems that the basic double star parameters, RA/Dec coordinates and separation as well as position angle were his main concern and the estimation of magnitudes was rather a side aspect to him. The often crass over estimation of magnitudes may also be a side effect of his obviously extraordinary eyesight.

Introduction

As follow up to the reports on J-objects photometry beginning with Knapp/Nanson 2016 we selected this time the J-objects in Pegasus (Peg). 175 J-objects in Peg is quite a large number and weather conditions did often not allow for taking images of good quality so an unusual number of imaging sessions were required to get images of acceptable quality for photometry. But even images of good quality were often less than perfect for plate solving due to the lack of a sufficient population of well suited reference stars in some Peg areas. Due to these problems we did this time not look for other WDS objects in the existing image material.

Results of Photometry and Catalog Checking

With a few exceptions, for all selected J-objects one single image was taken with iTelescope iT24 with V-filter and 3s exposure. While for the mentioned image quality issues the astrometry results have to be taken with caution beyond the given error range the effects seem less significant for the V-filter measured magnitudes as a magnitude error of ~0.1 or even a bit larger seems negligible in comparison with those for the Jonckheere objects, which often have given magnitude errors in the range of up to 2 or more magnitudes. With the availability of precise GAIA positions for most of the listed components the value of astrometry results from processing of CCD images taken with traditional earth-bound telescopes seems anyway a bit questionable.

Several objects were too faint to be resolved with a 3s exposure time – additional images with longer exposure time were taken for these and stacked with AAVSO VPhot. The images were then 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.

A subset of the measurement results for the first 10 objects is given in table 1 below. The full data set including the parameters listed in parenthesis is available for download from the JDSO website as fixed format text file "Jonckheere Peg Results" with the following structure:

- First row gives the WDS data as of April 2018:
  - WDS ID
  - Comp gives the components
  - J gives the number of the J-object
  - RA/Dec gives the position in the HH:MM:SS/ DD:MM:SS format for the primary
  - Sep, PA, M1, M1, pmRA and pmDec give the WDS catalog data for this object
  - Date gives the year of the last observation
  - Notes gives additional comments listed below Table 1
- Data rows give data from GAIA DR2:
  - (RA and Dec give the J2015.5 coordinates in degrees for the primary)
  - Sep gives the calculated separation in arcseconds if coordinates for both components are available
  - (e_Sep gives the separation error)
  - PA gives the calculated position angle in degrees if coordinates for both components are available
  - (e_PA gives the position angle error)
  - M1 and M2 give GIA DR2 Gmags
  - (e_M1/2 give the magnitude error)
  - Plx1 and Plx2 give the parallax for both components if available
  - pmRA/pmDE give the proper motion data for both components if available
  - Ap and Me give aperture and used observation method
  - CPMR gives the common proper motion rating based on the available PM data according to the description in Appendix A
  - CPMS gives an estimated probability for being a physical pair based on proper motion data (see Appendix A)
  - PlxR gives the distance rating based on the available parallax data according to the description in Appendix A
  - PlxS gives an estimated probability for being a physical pair based on parallax (see Appendix A)
  - Notes gives additional comments listed below Table 1
- Measurement row gives the results from processing of own images:
  - (RA/Dec gives the position in degrees for the primary)
  - Sep gives the calculated separation in arcseconds for resolved pairs
  - (e_Sep gives the separation error)
  - PA gives the calculated position angle in degrees for resolved pairs
  - (e_PA gives the position angle error)
  - M1 and M1 give Vmags for both components measured by differential photometry
  - (e_M1/2 give the magnitude error)
  - Date gives the Julian observation epoch
  - Notes gives additional comments listed below Table 1

Summary

124 of the 175 J-objects in Peg show the expected magnitude difference larger than 0.5 compared with the WDS catalog data. Further about 39 of these objects qualify as solid or at least good CPM candidates based on a rating scheme using GAIA DR2 proper motion data if available for both components with the caveat of rather small proper motion values for a few of them. Further 11 objects have parallaxes and angular separations allowing for a higher than 50% likelihood for a distance between the components of less than 200,000 AU suggesting potential gravitational relationship between the components.

Acknowledgements

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

- Washington Double Star Catalog
- CDS VizieR and X-Match
- GAIA DR2 catalog
- 2MASS images
- DSS images
- Aladin Sky Atlas v10.0
- 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
- AAVSO VPhot
- Astrometrica v4.10.0.427
- URAT1 and UCAC4 catalog
- AstroPlanner v2.2
- MaxIm DL6 v6.08

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WDS	Comp	J	Sep	PA	M1	M2	Plx1	Plx2	pmRA1	pmDec1	pmRA2	pmDec2	Ap	Me	Date	CPMR	CPMS	PlxR	PlxS	Notes
21551+1908		2	3.5	36	11.5	11.5			8	-41					2015					
			3.46732	35.996	10.776	10.899	5.4202	5.3973	53.798	31.832	53.609	29.951	0.96	Hg	2015.50000	BBAA	64	BA	80	1)
			3.32774	33.028	10.626	10.875							0.62	C	2015.84310					2)3)
00060+1315		143	2.5	86	11.3	11.6			-76	-32	15	-25			2015					
			2.53563	85.983	10.932	11.557	3.9741	3.9645	-12.456	-27.592	-12.841	-27.450	0.96	Hg	2015.50000	AAAA	100	BA	80	1)
			2.16635	86.030	10.933	11.355							0.62	C	2015.84311					2)4)
21212+1841		160	3.2	290	12.2	12.4			-3	-8					2016					
			3.22270	289.774	11.546	11.400	0.6267	0.1919	-4.264	-6.690	-2.730	-7.015	0.96	Hg	2015.50000	DDAB	0	DC	1	1)
			3.14631	289.302	11.646	13.031							0.62	C	2015.91146					2)3)5)
21288+1341		162	2.7	59	10.9	12.2			28	-34					2015					
			2.68405	59.022	10.196	11.758	5.4086	5.7380	29.718	-31.125	32.081	-34.060	0.96	Hg	2015.50000	ADAA	5	DA	1	1)
			2.66294	58.029	10.363	11.279							0.62	C	2015.84313					2)4)
21458+1419		164	5.1	301	9.4	11.0			-4	-13					2017					
			5.05090	300.182	10.878	12.397	1.5347	1.7322	-8.235	-11.563	-9.697	-11.375	0.96	Hg	2015.50000	DDAB	0	DA	1	1)
			4.96115	299.195	10.937	12.620							0.62	C	2015.84314					2)
22379+1131		165	2.0	137	10.6	11.0			33	3	33	3			2001					
			2.06893	137.189	10.281	10.810	4.8313	4.9578	36.615	6.002	36.779	2.683	0.96	Hg	2015.50000	DAAA	1	CA	20	1)
			2.39318	142.554	10.148	10.627							0.62	C	2015.84314					2)4)
23282+1701		166	4.8	351	10.6	12.6			17	2	26	10			2015					
			4.79536	350.916	10.366	12.089	4.6133	4.5091	15.738	8.616	16.001	9.254	0.96	Hg	2015.50000	BCAB	31	CA	20	1)
			4.63804	350.926	10.483	12.165							0.62	C	2015.91148					2)
21309+1141		178	2.9	186	10.8	11.1			-12	-25					2015					
			2.86029	185.654	11.186	11.805	4.7304	4.7031	-14.144	-36.939	-13.601	-35.497	0.96	Hg	2015.50000	ADAA	5	CA	20	1)
			2.41541	183.836	11.185	11.276							0.62	C	2015.91148					2)3)
22193+0800		179	3.8	311	11.2	11.4			-25	-17	-64	1			2016					
			3.77917	311.437	10.404	11.840			-28.417	-11.819	-29.875	-11.676	0.96	Hg	2015.50000	BDAB	4			1)
			3.55072	311.872	10.565	12.047							0.62	C	2015.91149					2)3)
22282+0910	AB,C	180	5.8	308	9.6	12.3			3	-40	-27	-2			2010					
																				6)
			5.74549	308.415	9.968	12.745							0.62	C	2015.91149					2)

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Content of the Notes column:

1. Source GAIA DR2 catalog. M1 and M2 are GAIA DR2 Gmags
2. iT24 1x3s: Image taken with iTelescope T24 with V-filter and 3 seconds exposure time
3. 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
4. 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
5. Vmags confirmed by counter-checking with GAIA GBR-mags based estimation
6. AB resolved in GAIA DR2, for this reason no match with AB
7. iT24 5x3s: Five stacked images taken with iTelescope T24 with 5 filter and 3 seconds exposure time
8. No resolution
9. No Plx and PM listed in GAIA DR2 for secondary (or primary)
10. Image quality questionable: Rather large average errors for the reference stars used for plate solving and photometry for different reasons (mostly atmospheric influences). But this is at least to some degree already included in the calculation of the error range estimation
11. Small number of reference stars. Plate solved with UCAC4
12. 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
13. Source GAIA DR2 catalog. M1 is GAIA DR2 Gmag. No object at WDS location for C
14. No resolution of C, bogus assumed
15. Hint of elongation but no serious resolution. Combined magnitude suggests components about 0.4mag fainter than WDS
16. Hint of elongation but no serious resolution. Combined magnitude corresponds with WDS mags
17. SNR <10: Indicates that the measurement result might be much less precise than desired due to a low SNR value but this is at least to some degree already included in the calculation of the magnitude error range estimation
18. Hint of elongation but no resolution. Combined magnitude suggests fainter than WDS mags
19. B probably 0.5mag fainter
20. WDS position wrong. Correct position is 23:46:07.82 +30:26:25.4
21. Hint of elongation but no serious resolution. Combined magnitude suggests components being brighter than WDS listed
22. No resolution of A nor B. Both have to be fainter than 13.5mag
23. WDS J2000 position wrong. Correct position is 22 10 47.62 +21 52 41.7
24. iT24 5x4s: Five stacked images taken with iTelescope T24 with V filter and 4 seconds exposure time
25. iT24 5x6s: Five stacked images taken with iTelescope T24 with V filter and 6 seconds exposure time
26. PM for B is slightly different than above for the AB pair
27. B brighter than A
28. No object for the primary in GAIA DR2 although it exists in DR1
29. No secondary at this position. Wrong position or bogus
30. WDS J2000 position wrong. Correct coordinates are 22 34 58.65 +29 51 48.5
31. SNR <5: Indicates that the measurement result might indeed be much less precise than desired due to a low SNR value but this is at least to some degree already included in the calculation of the magnitude error range estimation
32. No such object at this position. WDS X-coded
33. iT24 1x4s: One image taken with iTelescope T24 with V filter and 4 seconds exposure time
34. WDS code “V” for common proper motion suggested
35. WDS code “T” for common parallax suggested

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References

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Appendix A

Description of the CPM rating procedure (according Knapp and Nanson 2017 and Knapp 2018):

- 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 relation separation to proper motion speed
- Proper motion vector direction ratings: "A" for within the error range of identical direction, "B" for similar direction within the double error range, "C" for direction within the triple error range and "D" for outside
- Proper motion vector length ratings: "A" for identical length within the error range, "B" for similar length within the double error range, "C" for length within the triple error range and "D" for outside
- Error size ratings: "A" for error size of less than 5% of the proper motion vector length, "B" for less than 10%, "C" for less than 15% and "D" for a larger error size
- Relation separation to proper motion speed: "A" for less than 100 years, "B" for less than 1000 years, "C" or less than 10000 years and "D" for above

To compensate for the extremely small proper motion GAIA DR2 errors resulting in a worse than "A" rating despite only very small deviations an absolute lower limit is applied regardless of calculated error size:

- \- Proper motion vector direction: Max. 1° difference for an "A"
- \- Proper motion vector length: Max. 1% difference for an "A"

The letter based scoring is then transformed into an estimated probability and a verbal assessment for being CPM

Description of the Plx rating procedure (according to Knapp 2018):

- Two rating factors are used: Distance between the components in AU and relationship Plx error to Plx value. The distance between the components is calculated from the inverted GAIA DR2 parallax data (if positive and Plx>3*e_Plx) and the angular separation using the law of cosine. Realistic case is based on the given Plx values and the best and worst case scenario uses the given e_Plx data on the Plx values to estimate a smallest and largest possible distance
- "A" for worst case distance, "B" for realistic case distance and "C" for best case distance less than 200,000 AU (means touching Oort clouds for two stars with Sun-like mass) and "D" for above
- "A" for Plx error less than 5% of Plx, "B" for less than 10%, "C" for less than 15% and "D" for above

The letter based scoring is then transformed into an estimated probability for being potentially gravitationally bound.