Jonckheere Double Star Photometry – Part V: Cancer

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

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 have magnitudes which are obviously far too bright. This report covers the Jonckheere objects in the constellation Cancer. Only one image per object was taken as despite the risk of random effects even a single measurement is better than the currently usually given estimation, although the J-objects in this constellation seem with some exceptions better covered with observations as usual for Jonckheere doubles.

Introduction
The degree of contamination of the WDS catalog with wrong magnitude data is rather high – this might very well be a side effect of magnitudes considered being not as important as the basic double star parameters separation and position angle. Measurements of magnitudes without these basic parameters are not even counted as observations in the WDS catalog. As follow up to the report on J-objects so far, I selected this time all J-objects in Cancer to be imaged for measurements with a remote telescope located in Spain. To counter the single image random effects especially for the astrometry results, I checked catalogs like SDSS, URAT1 and GAIA DR1 with recent position data. 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 magnitude errors in the range of up to 2 magnitudes for Jonckheere objects.

Results of photometry and catalog checking
For each of the selected J-objects, one single image was taken with iTelescope iT18 with V-filter and 3s exposure time and plate solved with Astrometrica, using the URAT1 catalog with reference stars in the Vmag range of 8.5 to 14.5 and 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. As the companion of one double star was too faint to be resolved in the iT18 image, I took for this object additional images with iT24 for a stack.

The results are given in table 1 below with the following structure:
- The header line gives the WDS catalog data for each object per 08/2016 with RA/Dec in the HH:MM:SS/DD:MM:SS format with Date giving the year of the last observation
- The following rows give the data for the object in existing catalogs as far as available with RA/Dec in decimal degrees with the catalog reference given in the Source/Notes column
- Estimated visual M1 and M2 for 2MASS objects calculated from J- and K-band magnitudes if available
- Visual M1 and M2 for URAT1 objects if available
- 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
- Date gives the Bessel observation epoch
If 2MASS (or in some cases SDSS9) and GAIA DR1 positions are available then also proper motion data is calculated (using the formulas provided by Buchheim – 2008 to determine proper motion vector direction and proper motion vector length) and checked for potential common proper motion with the CPM rating procedure according to Knapp and Nanson 2016.

- The last row gives then the measurements based on the iT18 images
  - RA/Dec in decimal degrees from plate solving
  - Sep gives separation in arcseconds in the data lines calculated as \( \sqrt{(\text{RA}2-\text{RA}1)^2+(\text{Dec}2-\text{Dec}1)^2} \) in radians
  - PA gives position angle in degrees in the data lines calculated as \( \arctan((\text{RA}2-\text{RA}1)/(\text{Dec}2-\text{Dec}1)) \) in radians depending on quadrant
  - Visual magnitudes M1 and M2 based on the plate solving results
  - Measurement error estimations calculated on base of the average plate solving errors are given in a separate table in the appendix.

**Summary**

Table 1 shows with few exceptions significant differences for the magnitudes compared with the WDS data even if the J-objects in Cancer seem rather well researched in comparison with other northern constellations. A small part of the objects qualify as CPM pairs based on calculations with the now available GAIA DR1 data.

**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:
  - iT18: 318mm CDK with 2541mm focal length. CCD: SBIG-STXL-6303E. Resolution 0.73 arcsec/pixel. V-filter. Located in Nerpio, Spain. Elevation 1650m
  - iT24: 610mm CDK with 3962mm focal length. Resolution 0.625 arcsec/pixel. V-filter. No transformation coefficients available. Located in Auberry, California. Elevation 1405m
- 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**


Table 1. J objects in Cancer

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No resolution in any available image, not even an elongation. WDS PM values suggest CPM - but POSS I to II images do not show significant proper motion.
Table 1 (continued). J objects in Cancer

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Table 1 (continued).  J objects in Cancer

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Table 1 (continued) on next page.
Table 1 (continued). J objects in Cancer

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Table 1 (continued).  J objects in Cancer

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Table 1 (conclusion). $J$ objects in Cancer

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<td>2MASS. M1 and M2 estimated from J- and K-band</td>
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<td>5.70</td>
<td>0.96</td>
<td>Hg</td>
<td>2015</td>
<td>ACB</td>
<td>GAIA DR1. PM data calculated from position comparison with 2MASS - PM values too small to be significant, but CPM possible, potentially with orbit</td>
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<th>Sep*°</th>
<th>PA*°</th>
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<th>M2</th>
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<th>pmDec1</th>
<th>e_pm1</th>
<th>pmRA2</th>
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<th>Date</th>
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<td>12.87</td>
<td>-1</td>
<td>-3</td>
<td>3</td>
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<td>2015</td>
<td>WDS0910D+0849 values per 08/2016</td>
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<td>2.08</td>
<td>67.29</td>
<td>6.66</td>
<td>0.96</td>
<td>Hg</td>
<td>2015</td>
<td>COCB</td>
<td>GAIA DR1. PM data calculated from position comparison with 2MASS - obviously no CPM</td>
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Explanations Notes column:
- “IT28 1x3s” indicates the use of telescope iT18 images with 3s exposure time and use of URAT1 for plate solving
- “IT24 5x3s” indicates the use of stacked telescope iT24 images with 3s exposure time and use of 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 (one of them might be objects with fast proper motion not or wrong given in URAT1). But this is already included in the calculation of the error range estimation
Appendix A

Table 2 gives the plate solving errors for the used images and error information derived from the measurements reported in Table 1 and also the measured positions for both components.

Table 2: Error estimations for the in table 1 provided measurements for the given objects:

<table>
<thead>
<tr>
<th>Name</th>
<th>RA</th>
<th>Dec</th>
<th>dRA</th>
<th>dDec</th>
<th>Err_Sep</th>
<th>Err_PA</th>
<th>Err_Mag</th>
<th>SNR</th>
<th>dVmag</th>
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<td>07 49 08.50</td>
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<td>1.217</td>
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<td>12 12 27.41</td>
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<td>0.10</td>
<td>0.117</td>
<td>0.696</td>
<td>0.096</td>
<td>30.88</td>
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<tr>
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<td>12 12 27.41</td>
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</table>

- dRA and dDec = average RA and Dec plate solving errors in arcseconds
- Err_Sep = separation error estimation in arcseconds calculated as SQRT(dRA^2+dDec^2)
- 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
- dVmag as average mag plate solving error (Vmag for images with made V-filter and Imag for images made with I-filter)
- 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
Appendix B

*CPM rating scheme according to Knapp/Nanson 2016 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 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 pf 2MASS) with the consequence that the requirements to get an A or even B CPM rating get unreasonably 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.