

CCD Measurements of Star Systems 00152+2722 J 868 and 05413+5329 BUP 82AD

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Abstract: Position angle (Theta) and separation (Rho) measurements were acquired through images of WDS 00152+2722 (J 868) and WDS 05413+5329 (BUP 82AD) using T7, a 17-inch telescope in Nerpio, Spain, through the iTelescope network, and a 10-inch telescope near San Diego, California. Image data was analyzed using MaxIm DL Pro 6 and Mira Pro x64 software tools. J 868 has an angle of 231.158 degrees and a separation of 6.205 arcseconds. BUP 82AD has an angle of 283.404 degrees and a separation of 699.842 arcseconds. Measurements of J 868 follow its proposed orbit, but it is likely the two stars are not gravitationally bound. Measurements on BUP 82AD suggest this pair is an optical binary.

Introduction

Double Star systems 00152+2722 J 868 and 05413+5329 BUP 82 were imaged using telescopes equipped with CCD cameras to measure the separation and angle between them. Measurements were then compared against historical data obtained from the Washington Double Star catalog (WDS).

To select possible candidate pairs for research, many different catalogs were used to identify stars that fit the following criteria: separation greater than four arcseconds, delta magnitude less than 3, no recent recorded measurements, an observable amount of change in theta and/or rho from the first to the last measurements, no calculated orbit ranked by the 6th Orbital Catalog as three or better. The Washington Double Star Catalog (WDS), the Sixth Catalog of Orbits of Visual Binary Stars (Orb6), and Stelle Doppie – an online catalog of stellar data and references – were consulted to help in finding pairs based on these criteria.

Double Stars from the Washington Double Star Catalog (WDS) were filtered based on the criteria above, revealing four possible candidates: WDS 00152+2722, 02442+4914, 00002-0021, and 05413+5329. After an initial imaging session, two candidates were excluded due to low separation, which made imaging difficult. The resulting double star pairs, WDS 00152+2722 and 05413+5329, remained the focus of the research.

Star system 05413+5329, also known by its discover code, BUP 82, consists of 5 stars. The focus is the AD pair due to the difference in brightness between the primary star and the other stars was larger than the established criteria for being able to image the systems. While it would have been possible to take additional images and compile data on the other stars in this system, limited time, ability, and resources meant that the study was limited to only the AD pair.

WDS 00152+2722, J 868, Figure 1, was discovered by Robert Jonckhère, a French astronomer who discovered over 3,350 double star pairs. For this and other work, Jonckhère received an award from the French Academy of Sciences in 1943. BUP 82AD was originally published by S. W. Burnham in 1906 in a large catalog of various stars, titled "A General Catalogue of Double Stars within 121° of the North Pole."

Equipment

Images of both star systems of interest were acquired with two different telescopes: T7 and an RC10C. Telescope T7 is located in Nerpio, Spain and is a 17" platform with a large format STL11000 CCD camera with a combined resolution of 0.63 arcseconds/pixel at an aperture of 431mm. T7, a deep field telescope part of the iTelescope network, was chosen because of its location in the northern hemisphere and its resolution that enabled accurate images of the double star pairs, some of which had a very tight separation.

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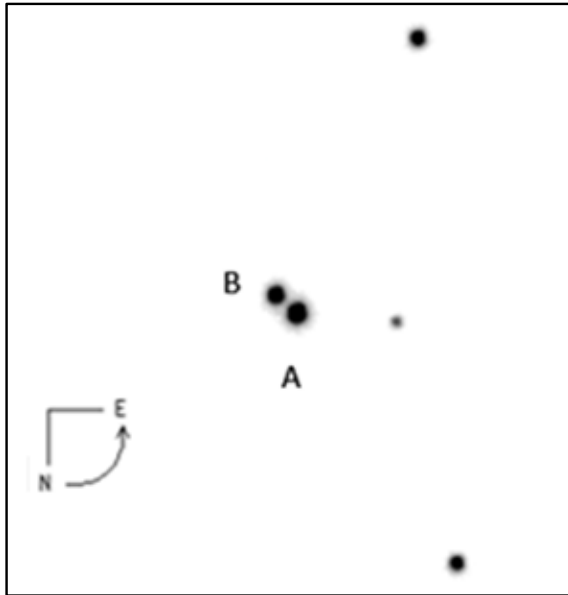


Figure 1. Sample Image of J 868 with Stars Labeled

Additionally, images were acquired through a 10 inch TrueRC RC10C telescope from Deep Sky Instruments, owned by Mike Chasin, President of the San Diego Astronomy Association. This telescope is a 10 inch Ritchey-Chretien telescope from Deep Sky Instruments. It is equipped with a QSI 683WSG 8.3MPixel camera, resulting in a resolution of 0.61 arcseconds per pixel. This telescope was chosen to provide additional images on a different night of observing and with a different optical train to cancel out any systematic errors in the measurements which might be caused by such factors.

Image calibration, specifically Dark, Flat, and Bias reduction, were provided by the iTelescope network for the images taken with T7. The images taken with the RC10C telescope were not calibrated. Further image processing, measuring, and calibration for images from both telescopes occurred through a remote server hosting programs such as MaximDL and MiraPro. These programs used internal and online databases for star field comparison and measurements.

Procedures and Methods

Imaging the Stars

Images were remotely ordered from telescope T7 on the iTelescope network, specifying different exposure lengths and filter types, in the event one filter and exposure time did not yield measurable results. Then the images were delivered to the Boyce Astro Research Computer (BARC), for processing.

Processing and Measuring the Stars

Once the images were obtained, they were reviewed for image quality and measured using MaximDL and MiraPro. Each image had to be plate-solved to determine the camera's orientation and pixel scale to assist in accurate measurements of Theta and Rho. For this process, the program PinPoint Astrometry was used, embedded in the software MaxIm DL Pro 6.

The plate-solved images were imported into Mira Pro x64. This program considers the pixel scale and orientation of the picture from MaxIm DL as well as the Analog to Digital Unit (ADU) light count in each pixel to calculate the centroid of the stars. This provided an accurate calculation of the distance and angle between the stellar components. All images were measured in this manner.

The results from Mira were copied into an Excel spreadsheet for statistical analysis: calculating the mean, standard deviation, standard error, and the standard error percent (the standard error divided by the mean) of all images for each star. The values of the angle and separation of the stars were graphed to find outliers. No strong outliers were found, so all measurements were used in calculating the statistics. The separate measurements were condensed into one figure by finding their mean. That mean is the 2016 data in this paper that will be compared to and analyzed in graphical form with the historical data, obtained from the WDS.

00152+2722 J 868

Background

As reported in the Washington Double Star Catalog, J 868, shown in Figure 1, has high relative proper motion (rPM) at 1.58. The rPM is the ratio of the proper motion of the stars in the pair. Stars that are gravitationally bound move through space together and should, therefore, have similar proper motion vectors. Harshaw (2016) provides classification guidelines by which one can estimate the likelihood of a pair being a physical binary. A high rPM would suggest that this pair is not a physical binary. Despite this, however, J 868 does have a proposed orbit given in the Sixth Catalog of Orbits of Visual Binary Stars. This seemingly inconsistent result was intriguing and this system was measured to contribute to the available data and, in so doing, perhaps add to the validity of the orbital solution.

Results

A total of 8 images were used in the measurement of J 868. The details about filters and exposure times are shown in Table 1. The results of the measurements are shown in Table 2.

In the graph of Figure 2, historical data points were

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Table 1. Imaging Information about J 868.

Date	# of Images	Telescope	Filter	Exposure Time (s)
2016.83	2	T7	Luminance	120
2016.83	2	T7	Luminance	180
2016.83	2	T7	Ha	180
2016.83	2	T7	Ha	240

plotted for the position of the secondary star along with the 2016 measured data point on a Cartesian graph. In this graph, the primary star is located at coordinate (0,0) in the lower right corner. Following the progression of time, the star moves from right to left as indicated by the labels showing the epoch for some of the data points. The data point shown in red on the left edge of the chart is the result our team is reporting in this paper. Figure 3 shows the orbital solution proposed by Novakovic (2007).

Discussion

The measurement reported herein agrees favorably with previous measurements of this pair with the secondary star appearing to be continuing the same type of motion as indicated by the data points in the historical record. This supports the proposed orbit, showing a curving of the motion of the star, but is not yet enough to determine that this is in fact an orbit. As mentioned earlier, this pair has a high relative proper motion bringing into doubt whether there truly is an orbit. In addition, looking at the plotted data points on the Cartesian graph, the apparent curvature in the motion of the secondary star is only attributed to the data points from the early 1900's. For the more recent measurements, the path appears less curved and more linear which would lead one to assume that the secondary star is not, in fact, orbiting the primary.

Rica (2014) discusses this system in depth, and concludes that this system is indeed only an optical pair. Rica states that “the photometric distances are barely compatible,” meaning that the two measured distances from Earth to each star are so different that it is unlikely they are close enough to be gravitationally

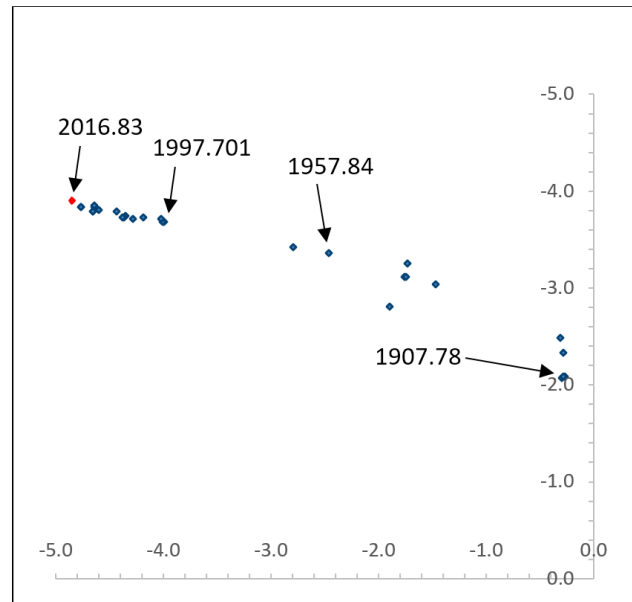


Figure 2. Graph of the Historical Data of J 868 Pair with the New Data Point Added

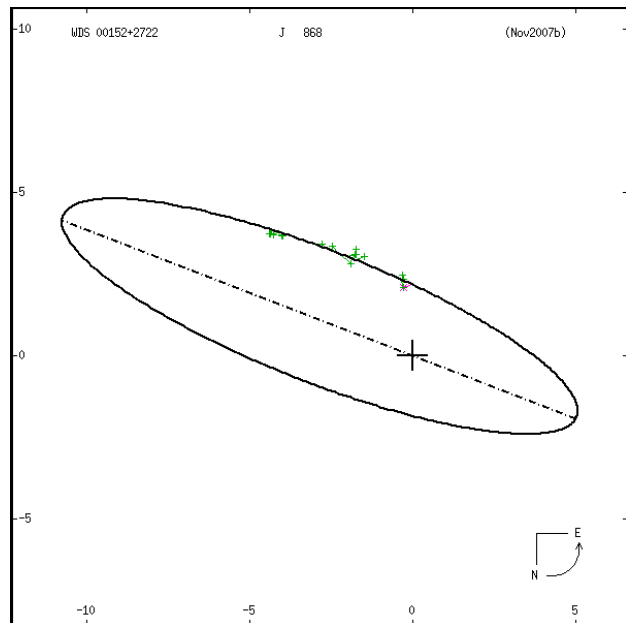


Figure 3. Proposed Orbit of Pair J 868

Table 2. Results and Statistics for J 868.

WDS No.	ID	Date		PA	Separation
00152+2722	J868	2016.83	Mean	231.158	6.205
			Std Dev	0.184	0.03
			Std Error	0.065	0.011

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Table 3. Imaging Information about BUP 82AD.

Date	# of Images	Telescope	Filter	Exposure Time (s)
2016.83	2	T7	Luminance	120
2016.83	2	T7	Luminance	180
2016.83	2	T7	Ha	120
2016.83	2	T7	Ha	180
2016.93	2	RC10C	Luminance	200
2016.93	3	RC10C	Luminance	300
2016.93	2	RC10C	Ha	200
2016.93	2	RC10C	Ha	300

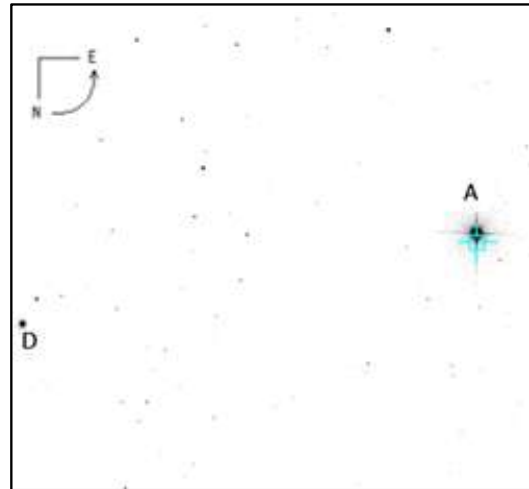


Figure 4. Sample Image of BUP 82 with the A and D Stars Labeled

bound. Furthermore, Rica states that he “compared the relative velocity with the escape velocity to confirm the non-gravitationally bound nature.” In other words, the velocity of the secondary star exceeds the escape velocity for this system, which also indicates that this pair is an optical binary and not actually gravitationally bound. Our team has concluded that it is unlikely that there is any gravitational interaction between these stars.

05431+5329 BUP 82 AD

Background

This star pair was last observed in 2003, more than 13 years ago, and has been listed as a neglected double in the Washington Double Star Catalog. As mentioned earlier, our research is specifically seeking information about the AD pair of this star system due to the similarity of the brightness of the primary and secondary star. This pair has only been measured five times, the last being in 2003. Figure 4 is a sample image of this pair.

Procedure and Results

Similar to the other star system reported in this paper, Luminance and Ha filters were used when taking images of this system. A total of 8 images were acquired using the iTelescope T7 telescope. Nine images were also taken by Mike Chasin using the telescope mentioned above in the equipment section. See Table 3 for detailed information on what filters and exposure

times were used. Measuring the star positions in these images resulted in the data shown below in Table 4. This star was observed on two different days – 2016.83 and 2016.93 – by T7 and the RC10C respectively. The date reported in Table 4 is an average of those two dates.

Figure 5 provides a graph of the historical data of all recorded measurements, plus the measurement we are reporting. The data point at the bottom is from 1874, and this paper’s measurement, in 2016, is at the top, indicated in red. These data indicate a linear motion of the secondary star of this system.

Conclusion

The first star system measured, 00152+2722 J 868, was determined to be an optical binary despite continued measurements indicating sufficient gravitational attraction and an orbit. This was shown through previous conclusions by Rica (2014), where the total relative velocity of the system is greater than the escape velocity. The second system was also concluded to be an optical binary by comparing past measurements to the point measured in this paper. The motion of the D star in the pair has linear motion instead of the necessary curved relative motion for the pair to be a double star pair.

Table 4. Results and Statistics for BUP 82AD.

WDS No.	ID	Date	PA	Separation	
05431+5329	BUP 82AD	2016.88	Mean	283.404	699.842
			Std Dev	0.021	0.492
			Std Error	0.005	0.119

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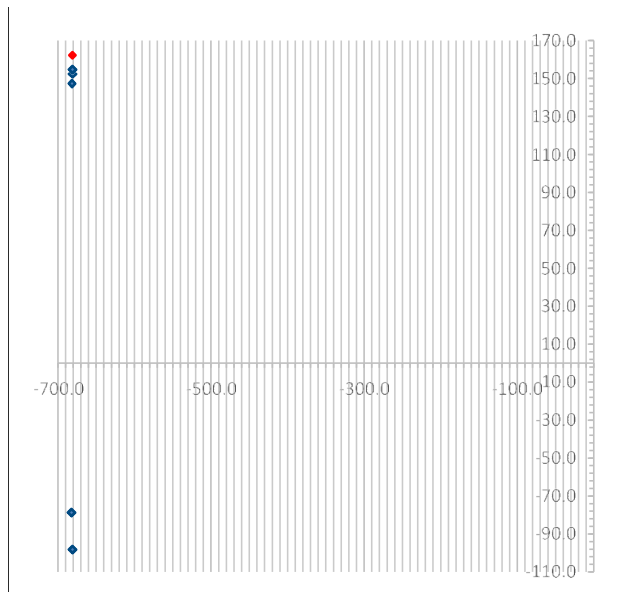


Figure 5. Graph of the Historical Data of BUP 82AD Pair with the New Data Point Added

Hartkopf, W.I., Mason, B.D, 2006, “Sixth Catalog of Orbits of Visual Binary Stars”, US Naval Observatory, Washington. <http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/orb6>

Mason, B. and Hartkopf, W., “USNO CCD Astrograph Catalog (UCAC)”, 2011. Astrometry Department, U.S. Naval Observatory, <http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/ucac>

Novakovic, B., Baltic, 2007, *Astron.*, **16**, 435.

Rica, Francisco, 2014, “The System J 868 = 00152+2722 – A New Optical Double Star with Optical Parameters”, *Webb Society Double Star Circ.* **22**.

SIMBAD, <http://simbad.u-strasbg.fr/simbad/>.

Therefore, the pair is merely an optical binary and is not gravitationally bound.

Acknowledgments

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References

- Burnham, S.W., Hussey, W. J., 1907, “A General Catalogue of Double Stars within 121° of the North Pole”, *Astrophysical Journal*, **26**, 195.
- Genet, R. M., Johnson, J. M., Buchheim, R., and Harshaw, R., 2015, *Small Telescope Astronomical Research Handbook*.
- Harshaw, R. W., 2016, “CCD Measurements of 141 Proper Motion Stars: The Autumn 2015 Observing Program at the Brilliant Sky Observatory, Part 3”, *Journal of Double Star Observations*, **12**, 394-399.