CCD Astrometry of the AB and AC Components of WDS 00052+4514

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Abstract: Measurements of position angles and separation of the multiple star system WDS 00052+4514 (containing ES 9001AB and BU 9001AC) obtained from new CCD images are reported. The measurements follow the trends of the historical data that indicate movement of the AB pair and no change in theta and rho for the AC. Analysis of BU 9001AC's proper motions suggest that it is likely a Common Motion Pair.

Introduction

Triple star system WDS 00052+4514 contains double stars ES 9001AB and BU 9001AC. Both systems were CCD imaged and their position angle and separation measured as part of an astronomy research seminar at Mt. Everest Academy in San Diego in conjunction with a course taught at Cuesta College, San Luis Obispo.

The term "double star" is often used in a casual fashion to describe two subsets: optical doubles and binary stars. There is an important distinction between the two terms. An optical double is a grouping of two stars that are not in orbit around each other, but by circumstances of their alignment in space are perceived from Earth to appear near each other. A binary star is two stars that have been determined to be gravitationally bound to each other. This is determined by repeated observation, measurement, and plotting—over years and sometimes decades, centuries, or millennia—of the position angles and separations of the pair. In the case of physically connected pairs, a curve and eventually an ellipse will be apparent.

From studying binary stars, astronomers can determine stellar mass for each component from computed orbits. Stellar mass is significant in the determination and confirmation of theories that describe the life cycles of stars. The intention behind this paper is to contribute to science by measuring the position angle (θ) and separation (ρ) for 00052+4514. The criteria for selection of a double star system for research were systems that were not definitively classified as a binary or optical pair, and systems that had not been measured in the past 20 years. WDS 00052+4514 met those criteria.

WDS 00052+4514 is a triple star system with components A, B, and C, Figure 1, in the constellation Andromeda. Parallax data for the A component gives a distance of 170 parsecs from earth; no parallax data for

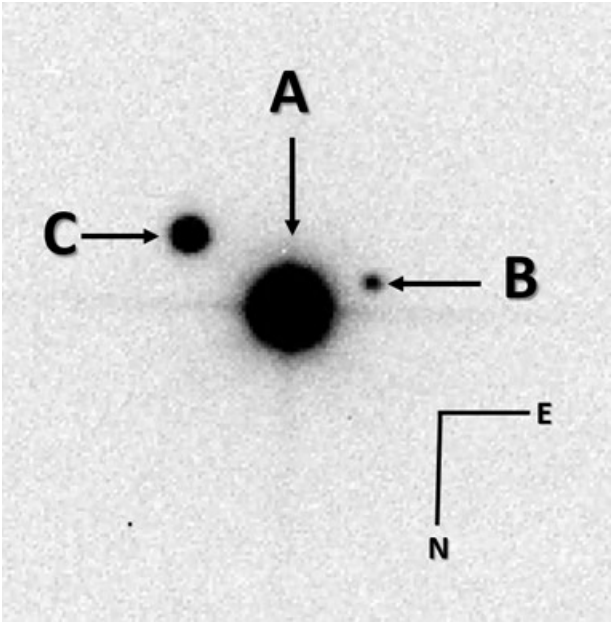

Figure 1. WDS 00052+4514 A, B, and C components.

the B and C components is available. The AB pair was first measured in 1915 and last measured in 2005. The first measurement of the AC pair was made in 1893 with the last reported measurement in 2008. This research project focused on gathering new data and then determining whether current measurements of theta and rho would support, or deviate from, the historical trend of the AB and AC pairs from the data files contained in the WDS.

Materials and Methods

Photographic CCD images were obtained via the iTelescope network using a 17" Corrected Dall-Kirkham (CDK) Astrograph Refractor located in Spain identified as T7. This telescope is remotely controlled and allowed scheduling of six images, using various filters, to be acquired on the eighth of November, 2016. The resolution of each image was 0.63 arcseconds/pixel allowing for the measurement of closely spaced double star components.

After each image was acquired, the iTelescope system provided post processing by dark, bias, and flat field subtraction from each scientific image. This post processing technique is used to remove image imperfections and possible erroneous data introduced by the nature of electronic imaging through a telescope and CCD camera.

The post processed images were downloaded and opened in MaximDL to be inspected individually for quality. Of the six total images, two did not contain enough information for an accurate depiction of the B component of the AB pair.

Stellar coordinates of each image center (right ascension and declination) are in the image header file. From this data, MaximDL and its plugin, PinPoint Astrometry, were used to embed the World Coordinate System (WCS) Right Ascension and Declination data into each pixel of the image file. This allows for accurate measurement of the position angle and separation in the next step of this process.

The WCS calibrated images were then opened in Mirametrics Mira Pro x64 software to obtain the theta and rho measurement for the AB and AC pair of WDS 00052+4514. To help ensure accurate measurement from and to the center of each stellar component, Mira's centroid function was used to locate the centroid of each star on the image. If care is not taken to ensure accurate placement of this center point, both theta and rho can be negatively biased and provide inaccurate measurements. With the centroid confirmed on each component, the resultant theta and rho were copied into data tables.

Final measurements were imported into Excel to record, measure, graph, and determine the mean, standard deviations, and standard errors of the mean. The final data was compared to the data from the USNO's WDS catalogue and used to determine the motion of the two stars as well as to graph them.

Data and Results

Tables 1 and 2 outline each measurement by providing each image name with the corresponding filter used. As noted above, the image center of the B component was not able to be accurately located in two images. These are highlighted in Table 1 and the deviation from the theta and rho of those images where the centroid could be determined can be noted. These two images were not included in the final data assessment for the AB pair.

Table 1. Theta and Rho measurements for the AB Pair of WDS 00052+4514.
**Luminance 60 Seconds-002 and Hydrogen Alpha (Ha) 120 Seconds-001 were excluded from the Average, Standard Deviation, and Standard Deviation of the Mean as the image quality for the B component was not sufficient to allow an accurate measurement.*

Image Name and Filter Used	Position Angle (degrees)	Separation (arc seconds)
Red 120 Seconds-002	107.321	16.3849
Red 120 Seconds -001	107.317	16.2286
Luminance 60 Seconds-002*	109.94	14.7125
Luminance 60 Seconds-001	107.659	15.5796
Hydrogen Alpha (Ha) 120 Seconds-002	107.386	15.7781
Hydrogen Alpha (Ha) 120 Seconds-001*	110.576	14.9016
Average:	**107.42**	**15.99**
Standard Deviation:	**0.16**	**0.38**
Standard Deviation of the Mean:	**0.040**	**0.094**

Table 2. Theta and Rho measurements for the AC Pair of WDS 00052+4514.

Image Name and Filter Used	Position Angle (degrees)	Separation (arc seconds)
Red 120 Seconds-002	233.438	20.2820
Red 120 Seconds -001	233.724	20.3668
Luminance 60 Seconds-002	235.695	21.8474
Luminance 60 Seconds-001	234.802	20.8611
Hydrogen Alpha (Ha) 120 Seconds-002	235.618	21.3773
Hydrogen Alpha (Ha) 120 Seconds-001	235.759	21.3989
Average:	**234.84**	**21.02**
Standard Deviation:	**1.04**	**0.62**
Standard Deviation of the Mean:	**0.173**	**0.104**

Discussion

ES 9001AB

The historical measurements for the AB components are comprised of six recorded observations dating from 1914 to 2005. Our 2016 measurement is included with this historical data in Table 3. Through this period there is a noted change in Theta from 119.8° in 1914 to 110.2° in 2005. Over the same period, separation has displayed an increasing trend.

All measurements were imported into Excel for a graphical depiction, Figure 2. The star system with proper motion vectors (obtained from the UCAC5 catalog) is shown in Figure 3. These proper motion vectors show B moving away from A.

Historical measurements and the 2016 measurement of the AB pair show a changing trend in both position and separation that suggests a linear motion. It cannot be determined yet whether this trend is indicative of an elongated elliptical orbit, or is due to unrelated motions and coincidental positions of the stars.

BU 9001AC

The historical measurements for the AC component are comprised of twenty-three recorded observations dating from 1893 to 2008, shown in Table 4, with the new 2016 measurement included. Through this period there is no noted change in theta and rho. All position and separation data including our 2016 measurement were imported into Excel and plotted, Figure 4.

The AC pair has not historically demonstrated any significant change in theta or rho. The mean of the historical separation measurements of the A and C components is 21.022", differing from the lowest historical measurement by 0.663" and from the largest by 0.867", a change that does not exceed a 3% difference.

As seen in Figure 3, the proper motion vectors of the AC components are visibly similar, suggesting that BU 9001AC could be a common proper motion pair. Harshaw (2016) provides three types of proper motions

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Table 3. Historical and 2016 Theta and Rho measurements for the AB components of WDS 00052+4514.

Epoch	Theta	Rho
1914.99	119.8	13.32
1925.06	121.4	12.79
1989.674	112.0	14.1
1998.84	110.3	14.71
2002.758	110.9	14.92
2005.951	110.2	14.62
2016.8514	107.42	15.99

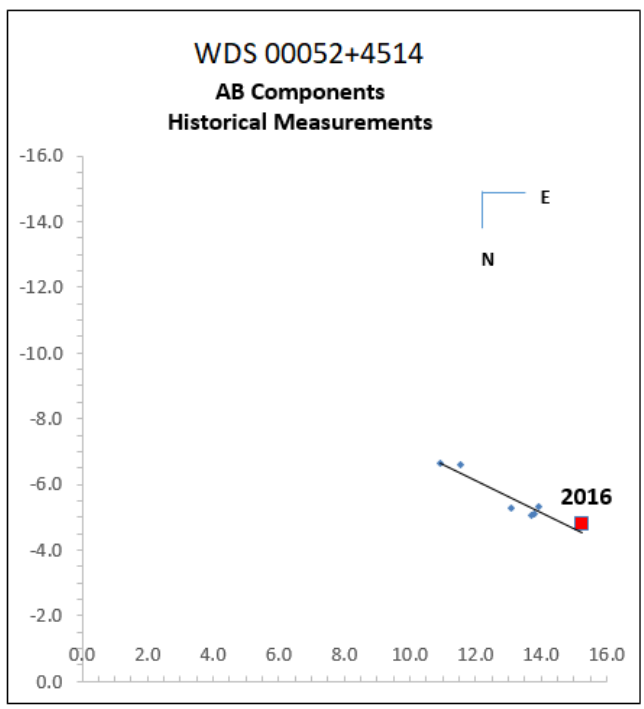

Figure 2. Plot of the historical and 2016 measurements for the AB pair. A is located at (0,0).

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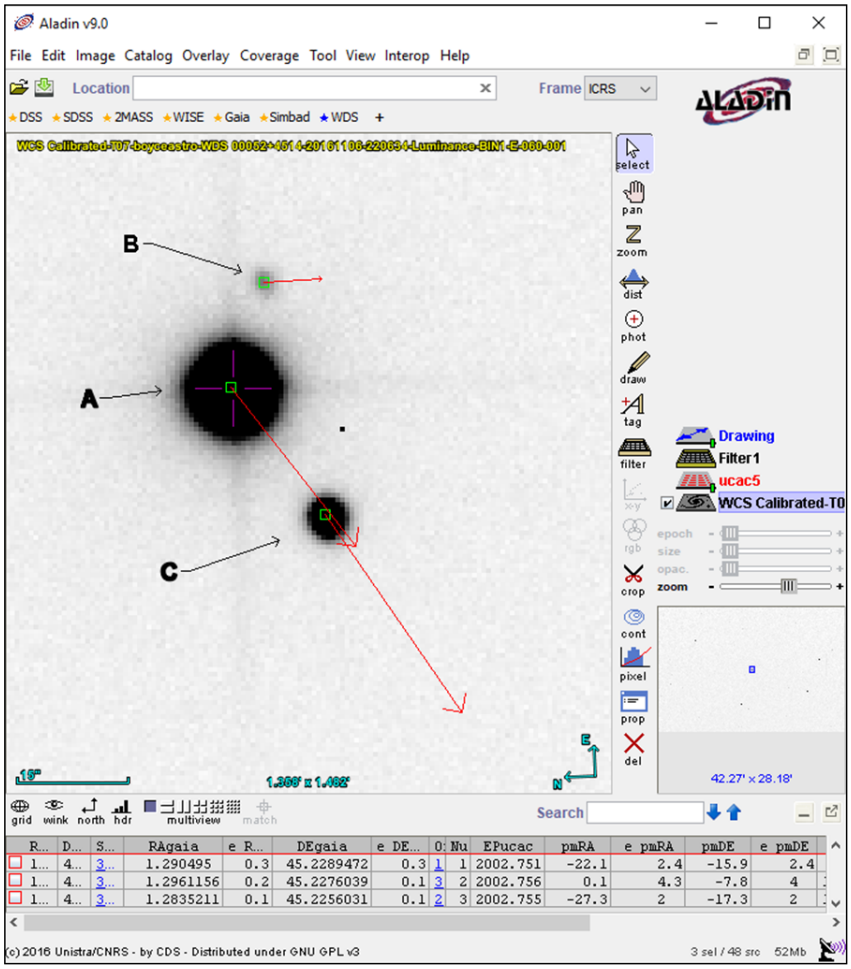

Figure 3. Proper motions vectors (red) of WDS 00052+4514 ABC obtained from the UCAC5 catalog.

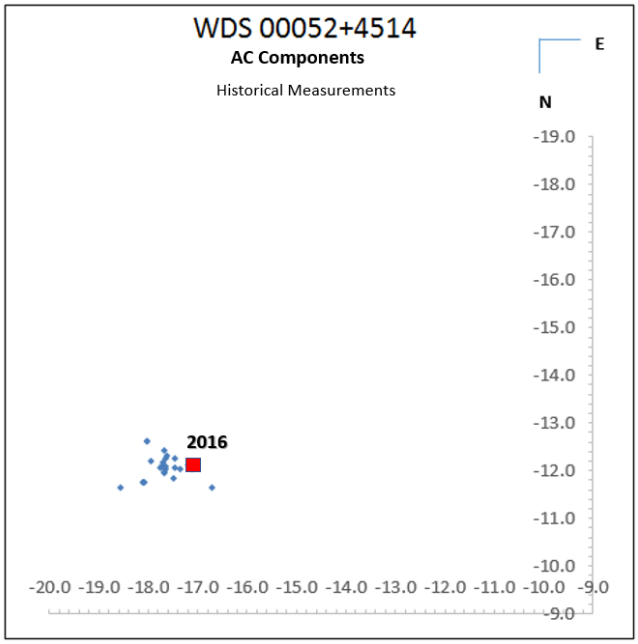

Figure 4. Plot of the historical and 2016 measurements for the AC pair with A at (0,0).

Table 4. Historical and 2016 Theta and Rho measurements for the AC components of WDS 00052+4514.

Epoch	Theta	Rho
1893.83	235.7	21.38
1893.83	235.9	21.12
1894.81	237.0	21.57
1906.08	235.5	21.49
1907.84	234.9	21.59
1914.99	235.1	20.37
1925.06	234.9	20.93
1933.91	235.8	21.46
1934.05	234.9	21.33
1973.000	235.0	22.00
1980.000	235.0	22.00
1991.25	235.1	21.50
1991.48	235.6	21.39
1998.84	235.7	21.46
2001.76	235.9	21.34
2002.756	235.2	21.49
2002.900	235.4	21.22
2003.766	235.3	21.12
2003.79	237.	21.6
2003.802	237.	21.6
2005.951	235.9	21.36
2007.715	237.9	21.9
2008.735	235.75	21.7
2016.8514	234.84	21.02

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classes for double stars, and a method to determine them, based on the relative differences of their proper motions:

> *"The proper motion of a star can be depicted as a vector. When the resultant of the two vectors is divided by the largest vector, the result will either be zero (or very near it) if the proper motions are identical, somewhere between 20% and 60% of the resultant of the vectors, or over 60% of the resultant. Pairs in the first category are classed as Common Proper Motion pairs, or CPM. Pairs in the second category are classed as Similar Proper Motion pairs (SPM), and those in the third category are classed as Different Proper Motion* pairs (DPM)."

The proper motion vector for each star is found by:

$$V = \sqrt{pmRA^2 + pmDE^2}$$

The resultant (R) is found by:

$$R = \sqrt{(pmRA_a - pmRA_b)^2 + (pmDE_a - pmDE_b)^2}$$

The proper motions (obtained from the UCAC5), vectors, residual, and ratio of residual to the larger of the two proper motion vectors for BU 9001AC, are shown in Table 5.

For BU 9001AC the resultant (5.4) divided by the largest vector (32.3) = 17%. Consequently, BU 9001AC can be classed as a CPM.

Table 5. BU 9001AC proper motion comparison. (All values in milliarcseconds.)

Component	pmRA	e_pmRA	PmDE	e_pmRA	PM Vector
A	-22.1	2.4	-15.9	2.4	27.2
C	-27.3	2	-17.3	2	32.3
Resultant	5.4				
Resultant/Largest PM vector = 5.4/32.3 = 17%					

Conclusion

WDS 00052+4514 is a triple star system with the first measurement in 1893 for the AC, and 1915 for the AB. The 2016 measurements follow the trends of the historical data that indicate linear movement of the AB pair and no change in theta and rho for the AC. Analysis of BU 9001AC's proper motions suggest that it is a Common Motion Pair.

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Galileo Resca and Nathan Hurdich are seniors at Mt. Everest Academy, a K-12 independent study school in San Diego, CA. Galileo Resca has an interest in astrophysics, materials science, and engineering. He hopes to pursue the latter as a major in college while still pursuing his interest in astrophysics. Nathan Hurdich desires to graduate college with a major in astrophysics.