Vol. 13 No. 3 July 1, 2017 Journal of Double Star Observations Page 401

CCD Astrometric Measurements of WDS 05247+3723

Mike Chasin[1], Matthew Adas[1], Naylynn Tañon[1], Grady Boyce[2], and Pat Boyce[2]

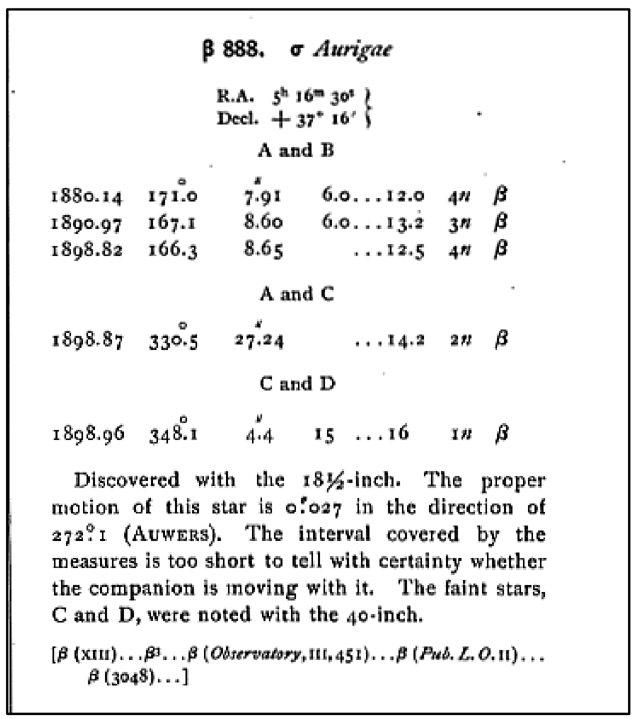
1. San Diego Astronomy Association
2. Boyce Research Initiatives and Educational Foundation

Abstract: Theta (θ) and rho (ρ) astrometric measurements were made of the double star system WDS 05247+3723 pairs AB, AC, and CD. These measurements compared favorably with the historic data from the Washington Double Star Catalog (WDS). We also measured the AD, BC, & BD pair relative astrometry.

Introduction

The goal of this project is to increase knowledge of WDS 05247+3723 by adding measurements and data to aid in a future determination as to whether WDS 05247+3723 is either an optical system or a gravitationally bound binary system.

The first recorded measurements of the AB pair were originally made by S. W. Burnham in 1880, with subsequent measurements made for the AC and CD pairs in 1898. He named this multi-star system "β 888 σ Aurigae" and published his findings of this system in various journals. Burnham, in 1880, Figure 1, recorded his findings on WDS 05247+3723 as: "Discovered with the 18 ½ inch. The proper motion of this star is 0.027 in the direction of 272.1 (AUWERS). The interval covered by the measure is too short to tell with certainty whether the companion is moving with it. The faint stars, C and D, were noted with the 40-inch" (Burnham, 1900).



β 888. σ *Aurigae*

R.A. 5h 16m 30s
Decl. +37° 16'

A and B

1880.14	171°.0	7″.91	6.0...12.0	4n	β
1890.97	167.1	8.60	6.0...13.2	3n	β
1898.82	166.3	8.65	...12.5	4n	β

A and C

1898.87	330°.5	27″.24	...14.2	2n	β

C and D

1898.96	348°.1	4″.4	15 ...16	1n	β

Discovered with the 18½-inch. The proper motion of this star is 0″.027 in the direction of 272°.1 (Auwers). The interval covered by the measures is too short to tell with certainty whether the companion is moving with it. The faint stars, C and D, were noted with the 40-inch.

[β (xiii)...β3...β (*Observatory*, iii, 451)...β (*Pub. L. O.* ii)... β (3048)...]

Figure 1. *Screenshot of Publications of Yerkes Observatory, seen on the upper right as being named by Burnham as "β 888 σ Aurigae":*

Equipment and Procedures

Two telescopes from the iTelescope network were used for data collection during this study: iTelescope 18 (T18), Figure 2, and iTelescope 21 (T21), Figure 3. The Telescope and CCD camera for T18 included a 0.32m Planewave CDK telescope, an SBIG STXL-6303 NABG CCD camera, Astrodon Series E LRGB filters, Astrodon 10nm hydrogen alpha, SII, OIII, and photometric V filters. T18 uses a Paramount ME Mount providing a system resolution is 0.73 arc-sec/pixel. The telescope and CCD camera for T21 included a 0.43m Planewave CDK telescope, a 0.66 focal reducer, an FLI-PL6303 NABG CCD camera, and a Paramount ME mount providing a system resolution of 0.96 arc-sec/pixel. The filter brand is not specified for T21. Thirty-six images were used in this study taken between 2016.80087-2016.86311.

Once the images were obtained from the iTelescope network, they were processed using MaxIm DL Pro 6

CCD Astrometric Measurements of WDS 05247+3723

Figure 2: iTelescope 18 (T18), located in Nerpio, Spain

Figure 3: iTelescope 21 (T21), located in Mayhill, New Mexico

to encode World Coordinate System (WCS) into each image. Mira Pro x64 was used to measure angles, theta (denoted as θ), and distances, rho (denoted as ρ), between stars in the images of WDS 05247+3723 to obtain an accurate mean measurement. Using the distance and angle tool, measurements were made and then copy/pasted into a spreadsheet containing all measurements by order of pair (i.e, AB, AC, CD, etc.) to be used for further analysis.

Results and Discussion

AB

Measuring the AB pair proved to be a moderate challenge during the research phase due to the differential magnitude, approximately 7, between the components. In the first set of images using the Hydrogen Alpha filter, the B component, with a last reported Rho of 8" was not located as the size of the A star disk on the image exceeded the 8". This filter was selected since the A component has a reported 5.16 magnitude, while the B component has a reported 12 magnitude. The selection of the Ha filter, one with a lower bandpass, was an effort to reduce the brightness of the A component while allowing the B component to be seen.

The first attempt to image/measure AB was attempted with a 45 second exposure, as seen in Figure 4. The B component is not visible. Additional attempts yielded the same result.

Another effort to measure AB was attempted with a 180 second exposure through a luminance filter to allow more photons to be captured for the fainter B component. Figure 5 displays the result. This effort failed and oversaturated the A component resulting in blooming while the B component remained undetected.

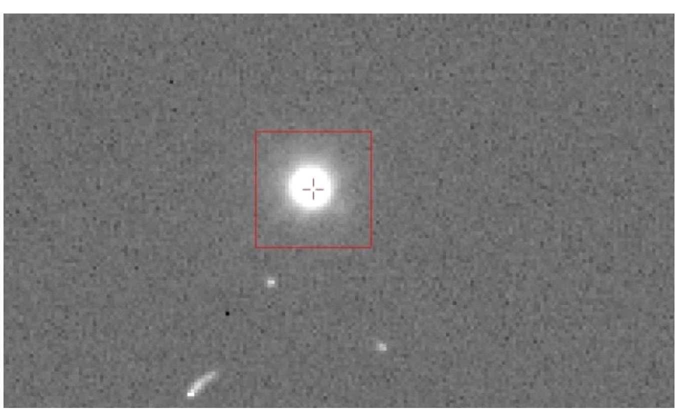


Figure 4. Initial image where the B component is obscured by the disk of A.

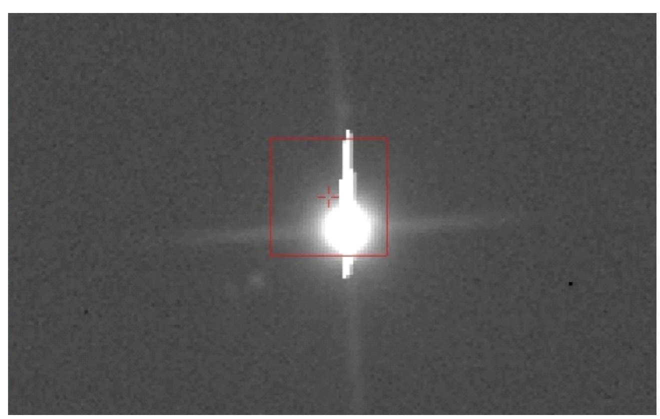


Figure 5. Image through a Luminance Filter.

CCD Astrometric Measurements of WDS 05247+3723

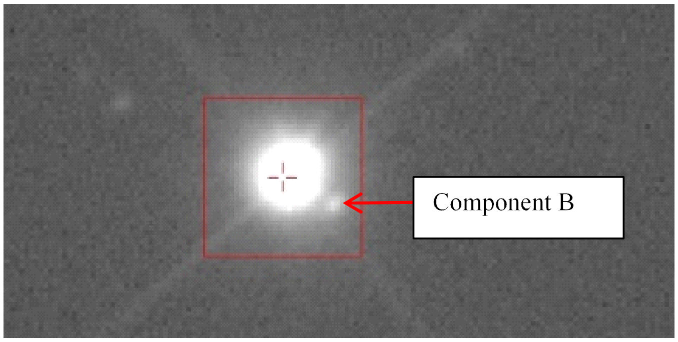


Figure 6. Image with B component visible after using B filter.

Using the internet resource, Stelle Doppie, the A component was listed with a spectral class of K3III. This spectral designation indicates that the A component is a cooler K class star that has left the main sequence of the Hertzsprung-Russell Diagram and evolved into a giant star. Applying Wien's Law, that a star's light curve (output) will peak at wavelengths inversely proportional to their temperature, we realized that since the K class star was emitting more light in the cooler red portion of the spectrum, the desired effect of filtering out some light with a red filter was counterintuitive. Therefore, in an application of the concept of Wien's Law, the third attempt used a blue filter where the A component would emit less light during the allotted exposure time. This application resulted in a clearly visible B component, seen in Figure 6 while reducing the size of the A disk on the image to 3.5".

The conclusion reached from this application was that spectral classes of the two components, if known, should be consulted for filter application in the case of closely spaced, high delta magnitude components. If not known, experimentation may be in order.

The method of displaying the data in these figures is noteworthy. The display data was "stretched" using Mirametrics Software function named "Vertical Transfer". Within the Vertical Transfer there are several settings available. The Min/Max setting was selected to apply a linear stretch using the minimum and maximum pixel values in the image. This creates an image that is brighter and has more contrast, producing the appearance of details that otherwise might have been missed. The gamma setting was also manipulated to adjust the degree of contrast of gray values. This also serves to brighten some details. It is worth noting that these changes affect the display of the image only leaving the subsequent centroid calculations, performed by the software, unaffected.

The sets of measurements taken from these images, along with other images from this epoch not shown in

Table 1. *Error statistics for AB.*

WDS 05247+3723 Astrometry (AB)				
Telescope	**Besselian Epoch**	**Measurement**	**θ (degrees)**	**ρ (arcseconds)**
T18: (4 images in Blue)	2016.83849	Mean	164.45	8.11
		Standard deviation	1.05	0.10
		Std. error of mean	0.42698	0.04267
	1922	Recorded Measurement	167.40	8.71

Table 2. *Historical measurement summary from WDS data.*

Date of Observation	Position angle (degrees)	Separation (arc seconds)
1880.14	171.0	7.91
1890.97	167.1	8.6.0
1898.82	166.3	8.65
1904.22	170.3	8.6.0
1908.83	166.0	8.55
1914.72	166.8	8.46
1922.073	167.4	8.71

this paper, were used in calculating averages. Looking at the results of our measurements in 2016, and comparing them with historical measurements, has led us to conclude that this is the closest the B component has been measured to come to A component since the first observation made in 1880, that first observation has the only closer measurement at 7.91″. The rest of the measurements from 1890 - 1922 display an arcsecond length ranging from 8.4 - 8.7 as seen in Table 2.

AC, CD, and AD

The AC, CD, and AD pairs were the most common measurements for the study. Since these pairs have the most numerous measurements, these averages are the most accurate of those documented by this research. The AC measurement results are displayed in Table 3, with the CD measurements in Table 4, and AD in Table 5.

The remainder of this research paper is measurements that haven't been documented previously, along with a description of the methods used to make these measurements. This section will provide even further data on this system than had already been published.

BC & BD

The BC and BD measurements, Table 6 and Table 7 respectively, were made with a process similar to the one described for the AB pair, taking the A component's KIII spectral type into account (Stella Doppie).

Conclusions

Imaging of binary stars with high delta magnitudes and close separations in arcseconds can be accomplished with a pragmatic approach that accounts for stellar spectral type and use of filters. In many cases, use of Ha and/or red filters is preferred as it may im-

(text continues on page 406)

Table 3. Measurements of the AC Components

WDS 05247+3723 Astrometry (AC)			
Telescope	**Besselian Epoch 2016.83849**	**θ (degrees)**	**ρ (arcseconds)**
T18: (Red - 2 images) (Luminance - 4 images) (Blue - 4 images) (Visual - 2 images) 12 images total	Mean	334.11	27.93
	Standard deviation	1.63	0.45
	Std. error of mean	0.383	0.106
	Besselian Epoch 2016.80087		
T21: (Red - 2 images) (Luminance - 2 images) (HA - 4 images) 8 images total	Mean	334.22	27.63
	Standard deviation	1.58	1.22
	Std. error of mean	0.43935	0.33796
	2014 measurement	335.68	26.789

Table 4. Measurements of the AD Components

WDS 05247+3723 Astrometry (CD)			
Telescope	**Besselian Epoch 2016.83569**	**θ (degrees)**	**ρ (arcseconds)**
T18: (Red-2 images) (Luminance-4 images) (Visual-2 images) (Blue-4 images) 12 images total	Mean	345.05	7.35
	Standard deviation	1.98	0.23
	Std. error of mean	0.481	0.055
	Besselian Epoch 2016.80087		
T21: (Red-2 images) (Luminance-2 images) (Hydrogen Alpha-4 images) 8 images total	Mean	344.40	7.30
	Standard deviation	3.18	0.65
	Std. error of mean	0.851	0.173
	2002 measurement	346.70	7.066

CCD Astrometric Measurements of WDS 05247+3723

Table 5. Measurements for AD Pair.

WDS 05247+3723 Astrometry (AD)			
Telescope	**Epoch 2016.83849**	**θ (degrees)**	**ρ (arcseconds)**
T18: (Red-2 images) (Luminance-4 images) (Visual-2 images) (Blue-4 images) 12 images total	Mean	335.93	35.20
	Standard deviation	1.65	0.57
	Std. error of mean	0.389	0.134
	Besselian Epoch 2016.80087		
T21: (Red-2 images) (Luminance-2 images) (Hydrogen Alpha-4 images) 8 images total	Mean	334.85	35.86
	Standard deviation	3.63	1.14
	Std. error of mean	1.093	0.343

Table 6. Measurements for BC Pair.

WDS 05247+3723 Astrometry (BC)			
Telescope	Besselian Epoch 2016.83569	θ (degrees)	ρ (arcsec)
T18: (Luminance-1 image) (Visual-1 image) (Blue-2 images) 4 images total	Mean	335.69	35.78
	Standard deviation	0.56	0.28
	Std. error of mean	0.278	0.141

Table 7. Measurements for BD Pair.

WDS 05247+3723 Astrometry (BD)			
Telescope	**Besselian Epoch 2016.83849**	**θ(degrees)**	**ρ (arcseconds)**
T18: (Luminance-1 image) (Visual-1 image) (Blue-2 images) 4 images total	Mean	337.55	43.07
	Standard deviation	0.06	0.23
	Std. error of mean	0.032	0.116

(Continued from page 404)

prove the signal to noise ratio. However, in certain spectral combinations, other filters may yield the desired results.

With some multiple stars that contain more than two components, measurements of each combination can assist in detecting stellar movement, especially in cases where parallax is not reported. Current CCD images can be combined with historical images such as the Palomar Sky Survey (I and II) and the 2Micron All-Sky Survey where needed. These additional measurements can be useful in a systemic analysis.

Acknowledgements

We thank the United States Naval Observatory for providing historical measurement data. We thank the Boyce Research Initiatives and Educational Foundation (B.R.I.E.F) for their mentorship as well as providing access to the iTelescope network.

References

Burnham, S. W. 1900. *A General Catalogue of the Double Stars discovered by S. W. Burnham from 1871 to 1899,* arranged in order of Right Ascension, Publications of the Yerkes Observatory, vol. 1, pp.1-271

Mason B. 2016. *The Washington Double Star Catalog,* Astrometry Department, U.S. Naval Observatory, http://ad.usno.navy.mil/wds/

Stella Doppie website. 2016. Reference WDS 05247+3723, http://stelledoppie.goaction.it/index2.php?iddoppia=19417