CCD Astrometric Measurements of Double Stars BAL 746, BPM 342, KU 92, and STF 897

Schuyler Smith

Mt. Everest Academy, San Diego CA

Abstract: Double stars WDS 06589-0106 (BAL 746), WDS 06579+1430 (BPM 342), WDS 07006+0921 (KU 92), and WDS 06224+2640 (STF 897) were measured as part of a science fair project for the 2016 Greater San Diego Science and Engineering Fair. The goal was to measure the separation and position angles of stars by using a telescope with a charge-coupled device (CCD) on the iTelescope network. Five images were taken of each of the stars. These images were plate solved with Visual PinPoint and measured using Aladin Sky Atlas. Measurements for all five doubles compare well to the more recent values in the Washington Double Star Catalog.

Introduction

Double stars WDS 06589-0106 (BAL 746), WDS 06579+1430 (BPM 342), WDS 07006+0921 (KU 92), and WDS 06224+2640 (STF 897) were imaged with a charge-coupled device (CCD) in November and December of 2015 as part of a project for the 2016 Greater San Diego Science and Engineering Fair. These star systems were selected because they had separation angles greater than 10 arcseconds and the magnitudes of both components were between 8 and 10. STF 897 was specifically chosen as a test case to attempt to duplicate recent measurements (AlZaben, et al. 2016).

Equipment and Procedures

The iTelescope network was used to image the double star systems. iTelescope has telescopes of various focal lengths and apertures with charge-coupled device (CCD) cameras of various resolutions in four locations: seven in the U.S. (six in New Mexico and one in California), three in Spain, and nine in Australia. At least one set of telescopes is open at any time of the day, weather permitting. Spain had the most convenient times and best weather for imaging, so all images used in this project were taken using the T18 telescope in Spain. T18 is a PlaneWave Corrected Dall-Kirkham (CDK) 318mm aperture imaging platform and uses an STXL-6303E CCD camera from SBIG Imaging Systems with a resolution of 0.73 arcsecond/pixel and the field of view is 37.41 x 24.94 arcminutes.

A hydrogen-alpha (Hα) filter was used for all images. This filter shows light emitted by hydrogen, the most common element in stars. It is a "narrowband filter," meaning that it transmits a very specific, or narrow, wavelength of light. This filter was used in the hope that it would decrease the amount of ambient light from the moon, since many images were taken during a gibbous or full moon.

Visual PinPoint astrometric engine and the Fourth U.S. Naval Observatory CCD Astrograph Catalog (UCAC4) were used to plate solve the images. Aladin Desktop, an interactive sky atlas available from the Strasbourg Astronomical Data Center (CDS) was used to analyze the images and measure the position and separation angle of the doubles using its photometry "phot" and "Auto-distance measurer" tools.

Methods and Procedures

Imaging plans were scheduled with iTelescope.net. Weather often interfered with the scheduled imaging plans as the observations were done during the winter. Consequently, most images were taken in real time using the "Single Image" feature on iTelescope.com. The Single Image button immediately begins the imaging procedures when you confirm the settings, such as coordinates and filter, without having to reserve the system if the telescope is not in use. All doubles were imaged over two nights; consecutive nights for one double, and up to two weeks apart for two of the doubles.

Eventually, 5 FITS images were taken of each of the 4 double stars. This format allows extra data such as the coordinates of the stars and the arcsecond/pixel

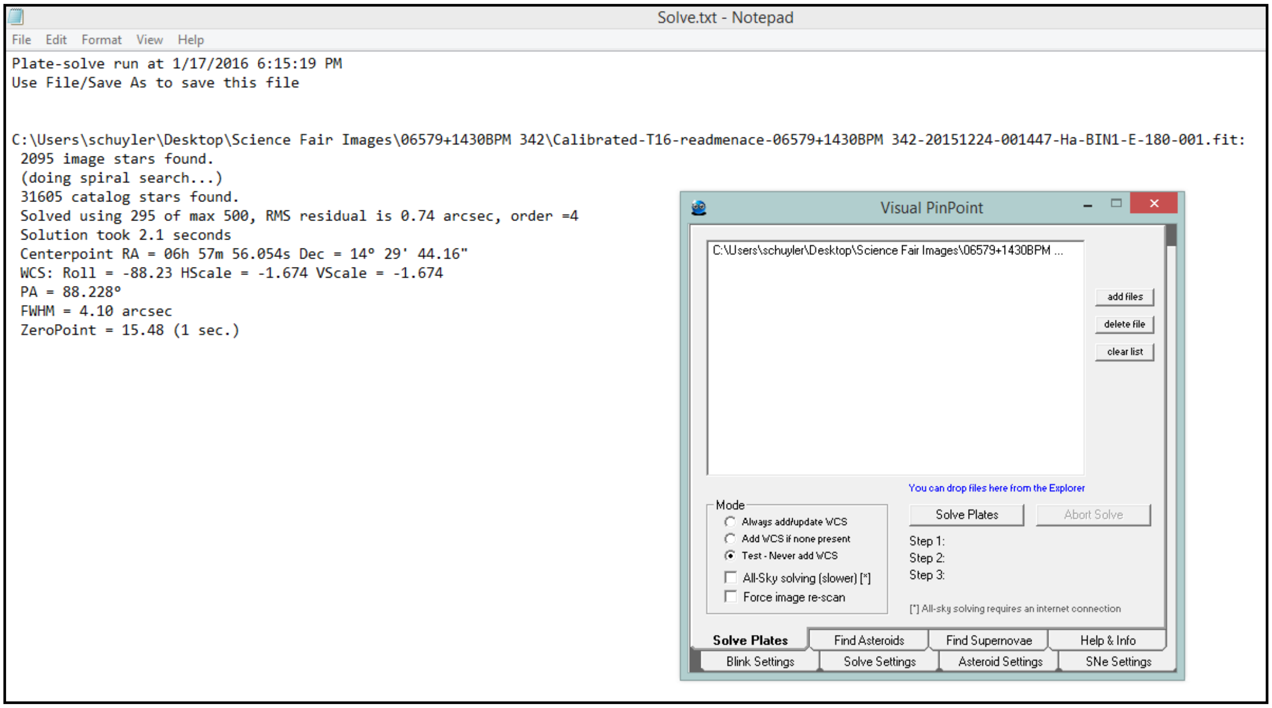

Figure 1. Visual PinPoint plate solving an image of BPM 342 using 295 stars.

scale to be added to the image file's header. To add this data, the images were plate solved using Visual PinPoint (Figure 1). To plate solve, Visual PinPoint required the UCAC4 star catalog so it could check to see if any stars in the image match stars in the catalog. When it determines where the image is in the sky, it adds coordinate information to the FITS header.

After the images were plate solved, they were imported into the free software Aladin Sky Atlas. Using Aladin's photometry "phot" tool, the separation between two objects can be calculated. In the "Tool" menu, the "Auto-distance measurer" option must be enabled and the "phot" tool button must be clicked. To measure the double, first the B component is clicked on, which finds its centroid. Next, the same is done with the A component. Finally, by clicking between the two components, Aladin will draw a line between them and calculate the position and separation angle of the two stars (Figure 2). This was repeated for each of the twenty images and the results were recorded in a Google Sheet spreadsheet. Statistics were calculated for all data, and Besselian epochs were calculated from the Julian dates of each image using the following formula: (Greaney 2012):

$$BesselianEpoch = B1900 + \frac{JulianDate - 2415020.31352}{365.242198781}$$

The epoch of each image was averaged and rounded to four decimal places to obtain an epoch for each mean measurement.

Results

Table 1 shows the mean of the measurements, the standard deviation (SD), and the standard error of the mean (SEM) for separation in arcseconds and position angles in degrees of the primary and secondary components of each double star system. Table 2 shows comparisons between these measurements and the most recent published measurements in the Washington Double Star Catalog (WDS).

Discussion

STF 897 was chosen as the first of the four stars to measure in this project because it was recently measured by a team of astronomers at the Army and Navy Academy in Carlsbad, California (AlZaben et al., 2015). After an early draft of their paper was read it was decided to attempt to duplicate their measurements first as a test. Instead of a separation of 18.3 arcseconds - the value listed in the WDS at the time - this project measured a separation of 17.99 arcseconds. AlZaben et al. measured a separation of 18.00 arcseconds, only .01 arcseconds off this project's measurements. The posi-

(Text continues on page 418)

CCD Astrometric Measurements of Double Stars BAL 746, BPM 342, KU 92, and STF 897

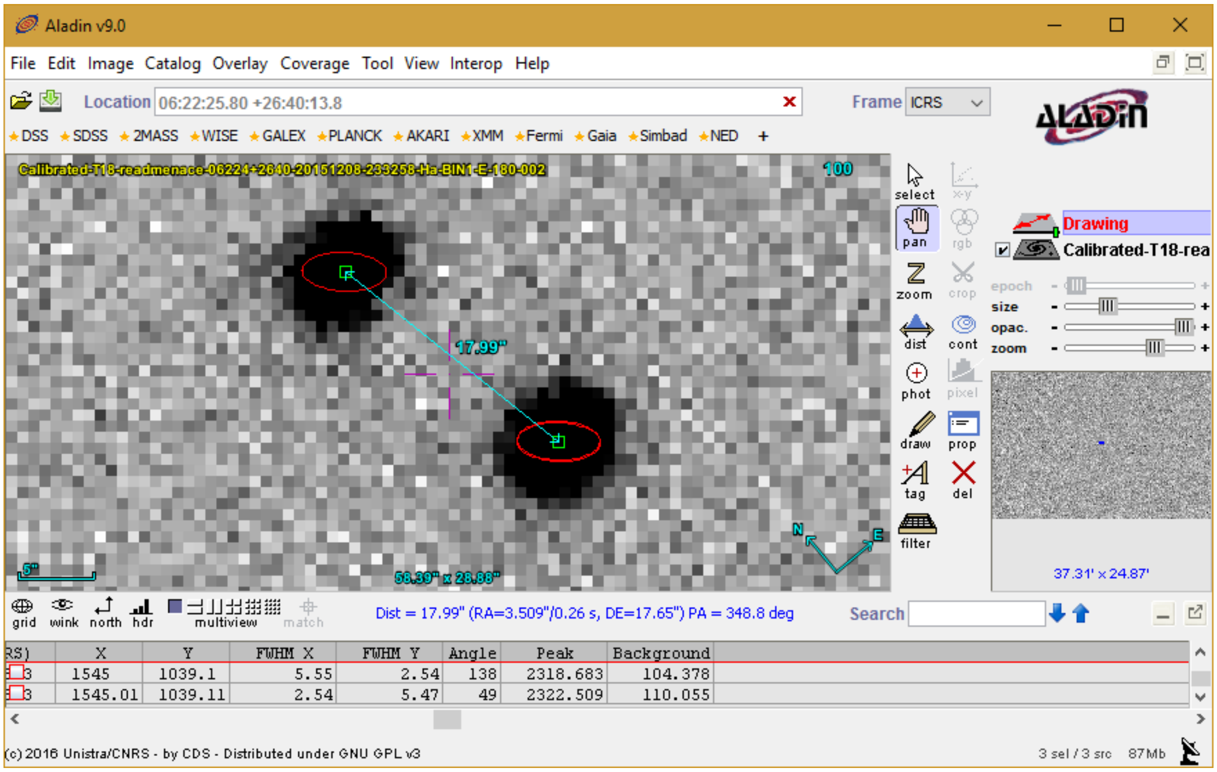

Figure 2. Measuring an image of STF 897 in Aladin Astrometry Software

Table 1. Measurements of the Pairs

Discoverer Code	WDS ID	Besselian Epoch	Total # of Exposures	Nights		Theta	Rho
STF 897	06224+2640	B2015.9306	5	2	Mean	348.58	17.99
					SD	0.28	0.037
					SEM	0.124	0.016
BPM 342	06579+1430	B2015.9724	5	2	Mean	223.26	26.83
					SD	0.05	0.074
					SEM	0.024	0.033
KU 92	07006+0921	B2015.9725	5	2	Mean	321.64	46.17
					SD	0.05	0.017
					SEM	0.024	0.008
BAL 746	06589-0106	B2015.9894	5	2	Mean	289.84	14.12
					SD	0.57	0.060
					SEM	0.256	0.027

Table 2. Comparison of Last and New Measurements

Discoverer Code	Last Historical WDS Measurements			New Measurements			Residuals	
	Date	Theta	Rho	Date	Theta	Rho	Theta	Rho
STF 897	2015.249	348.58	18.00	B2015.9306	348.58	17.99	0.00	-0.01
BPM 342	2001.01	223.4	26.802	B2015.9724	223.26	26.82	-0.14	0.016
KU 92	2004.967	321.1	46.41	B2015.9725	321.64	46.17	-0.46	-0.24
BAL 746	2010.5	290	14.06	B2015.9894	289.84	14.12	-0.16	0.06

CCD Astrometric Measurements of Double Stars BAL 746, BPM 342, KU 92, and STF 897

(Continued from page 416)

tion angles measured were the same - both projects measured 348.58° as opposed to the WDS's most recent listed value of 348°. Even though AlZaben et al. used a different combination of telescopes (iTelescope's T3, T18, and T11), different CCD cameras, and different software (Mira Pro x64) to perform measurements of STF 897, the results were almost identical, so the first attempt was considered a success. Eventually, AlZaben et al.'s measurement was recorded as the most recent measurement in the WDS.

All separation measurements were within ±0.25 arcseconds of the previous WDS value and all position angle measurements were within ±0.5 degrees of the listed value. STF 897 was most recently measured in 2015, BPM 342 in 2001, BAL 746 in 2010, and KU 92 in 2004. Hopefully these new measurements will help to determine their classifications as physical or optical doubles.

The standard deviation and standard error of the mean for the theta measurements of the stars STF 897 and BAL 746 were larger than expected. There was a single measurement for each star that strayed from the values of the other measurements, but not enough to be considered an outlier. Despite the fact that the theta result for STF 897 had a high SD and SEM, the mean of the measurements was identical to the most recent value in the WDS reported by AlZaben et al.

Acknowledgements

The author thanks Kent Smith for making iTelescope.net available for use, editorial help, and general guidance and encouragement with this paper. Thanks to Grady Boyce for feedback and encouragement. Thanks to Boyce Research Initiatives & Education Foundation (http://www.boyce-astro.org) and Pat Boyce for the introduction to double star astrometry. Thanks to Dr. Russell Genet, Richard Harshaw, and Dr. Vera Wallen for reviewing this paper. This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. This research has made use of "Aladin sky atlas" and the SIMBAD database, both developed and operated at CDS, Strasbourg Observatory, France.

References

AlZaben, F., Li, D., Li, Y., Dennis, A., Fene, M., Boyce, G., and Boyce, P. 2016. CCD Astrometry with Robotic Telescopes. *Journal of Double Star Observations.* Vol. 12 No. 1.

Genet, R. M., Johnson, J. M., Buchheim, R., and Harshaw, R. 2015. Small Telescope Astronomical Research Handbook. Santa Margarita, CA: Collins Foundation Press.

Greaney, M. 2012. Some Useful Formulae. In *Observing and Measuring Visual Double Stars,* 2nd ed. Argyle, R. W. editor. New York: Springer.

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

Schuyler Smith (Figure 3) attends Mt. Everest Academy, a K-12 Independent Study school in San Diego, CA. At the time of writing this paper, she was in the 8th grade. This research was part of a science fair project that was awarded sweepstakes in the Junior Division of the 2016 Greater San Diego Science and Engineering Fair and 2nd Place in the Junior Division Physics & Astronomy category at the 2016 California State Science Fair. Ms. Smith is also a member of the San Diego Astronomy Association and volunteers at school star parties around San Diego.

Figure 3. Schuyler Smith measuring double stars through her Orion SkyQuest XT8.