Astrometry Observations of Six Uncertain Double Stars

Cooper Howlett¹, Erin Pickering¹, Joshua Breman², Malia Barker³

¹. University of Hawaii Maui College, Kahului, Hawaii, USA
². Haleakala Waldorf High School, Makawao, Hawaii, USA
³. Kihei Charter High School, Kihei, Hawaii, USA

Abstract: Double-star systems HJ3231AC, BU1341AB, STI1656, HJ1002, STI110, STF3041AB, DAM622, STF2796, and ES1865AB were observed by the Las Cumbres Telescope network at the Teide Observatory. Average separations (ρ) and position angles (θ) were determined through AstroImageJ software and compared against pre-existing data in the Stelle Doppie database. The concluded data is checked for accuracy by comparing to two reference targets and ultimately contributes to database observations for each target. Three outliers were discovered: STI1656, a possible triple star system; DAM622, where we found a nearby quintuple system; and STI110.

Introduction

In this paper, we seek to update several double-star systems with new data, while also demonstrating the accuracy of our methods by comparing our results with two well-known double-star systems acting as reference targets. This research project was a part of an Astronomy Research Seminar offered by the University of Hawaii Maui College, instructed by Hsin-Yi Shih. The team members participating in this seminar can be found above, in Figure 1.

Targets were selected from the Stelle Doppie database, and was recorded by the Washington Double Star Catalog. The database has a wide variety of attributes to sort by, including position, magnitude, and amount of stars within a system (Stelle Doppie). Preference was given to uncertain doubles: double-star systems with a low enough amount of observations to merit uncertainty regarding their binary nature. We searched for uncertain doubles, keeping in mind the low number of observations and observations made within the past 15 years. The targets were also selected with proximity to 0h Right Ascension, in order to ensure night time visibility during the fall season (Chaisson & McMillan). The reference targets were selected for their large number of observations, in order to identify and minimize procedure error. The selected targets and more information can be found in Table 1.

During analysis of the system DAM 622, a quintuple star system was unintentionally observed: ES1865AB. We later included this system as a target. The properties of this system are described in Table 2.

Procedures

Observations were made by the Las Cumbres Telescope network, or LCO. This network consists of twenty-one robotic telescopes located in eight sites based around the world. They are all centrally connected over
the internet and have the ability to observe an object from any time zone, using a method called time domain astronomy. Multiple analyses of factors like similar requests, weather conditions, and target locations are automatically taken into account by LCO to best determine when observations will be taken. The availability of certain telescopes to observe a specific target can also be checked using the LCO Visibility Tool. This is done by entering the RA and Declination of the target (LCO, Visibility Tool). When best conditions have been found for each request, they are submitted to their respective telescopes and observed. The resulting data is then uploaded, and made available for download online.

**Instrumentation**

For each double star, fifteen to twenty observations were taken at Teide Observatory, located in the Canary Islands, Spain (LCO, Teide). The observatory rests at an elevation of 2,390 meters (AEMET). Observations were taken using a 0.4-meter telescope supported by a C-ring Equatorial mount, as well as an SBIG STX 6303 Charge Coupled Device, or CCD camera, mounted at the Cassegrain focus (LCO, 0.4 Meter). It has a pixel scale of .59 arcseconds / pixel, and a field of view of 2K x 3K pixels. This is equivalent to a 19 x 29 arcminute field of view. The telescope was built by the Las Cumbres Observatory, similar to the equipment in Figure 2. Several different filters were used, depending on the target. Targets HJ3231AC, HJ1002, STI110, DAM622, and STF2796 were observed with the GP

Astrometry Observations of Six Uncertain Double Stars

Table 1. A summary of historical measurements for the double stars observed in this project. All targets are uncertain doubles, except for those marked by an asterisk (*). Asterisk indicates a reference target.

<table>
<thead>
<tr>
<th>Name</th>
<th>Recorded ρ</th>
<th>Recorded Position Angle</th>
<th>Number of Observations</th>
<th>Last Recorded Observation</th>
<th>First Recorded Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HJ 3231AC</td>
<td>44.7&quot;</td>
<td>296°</td>
<td>9</td>
<td>2012</td>
<td>1831</td>
</tr>
<tr>
<td>BU 1341AB</td>
<td>20.3&quot;</td>
<td>319°</td>
<td>11</td>
<td>2015</td>
<td>1903</td>
</tr>
<tr>
<td>STI1656</td>
<td>13&quot;</td>
<td>81°</td>
<td>4</td>
<td>2003</td>
<td>1917</td>
</tr>
<tr>
<td>HJ 1002</td>
<td>27.2&quot;</td>
<td>26°</td>
<td>6</td>
<td>2010</td>
<td>1909</td>
</tr>
<tr>
<td>STI 110</td>
<td>7.3&quot;</td>
<td>5°</td>
<td>7</td>
<td>2012</td>
<td>1908</td>
</tr>
<tr>
<td>DAM 622</td>
<td>6.9&quot;</td>
<td>48°</td>
<td>3</td>
<td>2010</td>
<td>1999</td>
</tr>
<tr>
<td>STF3041AB*</td>
<td>56.4&quot;</td>
<td>358°</td>
<td>42</td>
<td>2016</td>
<td>1891</td>
</tr>
<tr>
<td>STF 2796*</td>
<td>26.4&quot;</td>
<td>42°</td>
<td>44</td>
<td>2010</td>
<td>1782</td>
</tr>
</tbody>
</table>

Table 2. Summary of data from the quintuple system ES 1865

<table>
<thead>
<tr>
<th>Name</th>
<th>Recorded ρ</th>
<th>Recorded Position Angle</th>
<th>Number of Observations</th>
<th>Last Recorded Observation</th>
<th>First Recorded Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES 1865AB</td>
<td>23.7&quot;</td>
<td>123°</td>
<td>13</td>
<td>2015</td>
<td>1913</td>
</tr>
<tr>
<td>ES 1865AD</td>
<td>77&quot;</td>
<td>37.3°</td>
<td>5</td>
<td>2012</td>
<td>1971</td>
</tr>
<tr>
<td>ES 1865BC</td>
<td>3.7&quot;</td>
<td>180°</td>
<td>8</td>
<td>2012</td>
<td>1913</td>
</tr>
<tr>
<td>ES 1865AE(^1)</td>
<td>33.2&quot;</td>
<td>330°</td>
<td>3</td>
<td>2013</td>
<td>1999</td>
</tr>
<tr>
<td>ES 1865AC(^2)</td>
<td>N/A</td>
<td>N/A</td>
<td>0</td>
<td>2018</td>
<td>2018</td>
</tr>
</tbody>
</table>

Table 2 Notes
1. Also referred to as FYM204 in Stelle Doppie catalog.
2. No previous measurements.
Astrometry Observations of Six Uncertain Double Stars

Methods of Data Collection

As students of the University of Hawaii, the Institute for Astronomy (IfA) has granted us a certain amount of time to access the LCO telescopes in order to obtain data for educational purposes. To request imaging from the Las Cumbres Telescopes, we needed to predetermine exposure information using the 0.4-meter telescope's exposure calculator. This included exposure time, the signal to noise ratio, and the peak photon count for the primary and secondary magnitude stars in each target (LCO, Exposure Time Calculator). We also noted the targets’ previously recorded coordinates, separations, and magnitudes from the Stelle Doppie catalog. We initially requested data on 12 targets. However, after analyzing the received data we narrowed down our selection to the eight targets - as noted in Table 3 - based on image quality and clarity of the target star system.

Before the observations were analyzed by our team, they were subject to the LCO “BANZAI” data reduction pipeline. The automatic processes used were bias and dark subtraction, bad pixel masking, flat field correction, source extraction, and astrometric solution using Astrometry.net (LCO, Data Pipeline). These processes are explained below.

Data Processing

Images were received in FITS files and previously processed by the Las Cumbres Telescope’s BANZAI data processing pipeline. Our observations were created with a 2x2 binning mode, with readout times averaging less than 6 seconds. A variety of data processes were used by the pipeline to create optimal observations for analysis. An explanation of these methods can be found below.

Bad pixel masking: This flags any pixels in the detector array that are not in working observational condition; such as pixels with excessive noise or potential outliers. The bad pixels are then set to zero, removing them from the processed image and data analysis.

Bias Subtraction: This eliminates the readout signal from the CCD.

Dark subtraction: This eliminates the dark noise, created by accumulated electrons in the CCD (Nass, P).

Flat Field correction: This checks for sensitivities in different locations on the CCD (Hainaut, O.). The inaccuracies are then corrected by taking several observations of uniform light, and using the resulting average to identify locations of variable sensitivity. The sensitivity map that results can then be used to correct the light readings of observation.

Astrometric solution: Astrometry.net uses calibration meta-data and known celestial objects to calibrate the observed images to the correct coordinates in the sky. This includes the Right Ascension and Declination data for each image.

We then downloaded the processed data from the LCO web server and began to perform our own analyses.

Methods of Analysis

To analyze and view the observations, we used AstroImageJ, a FITS file reader and analysis application (AIJ). The correct view used within AstroImageJ to perform analyses can be seen in Figure 3. We first identified each uncertain double by its proximity to the center of the image and how much it visually resembled a double-star system. We then confirmed our predicted target by finding the Right Ascension and Declination of the primary star in AstroImageJ, then comparing this data to the Stelle Doppie catalog values.

To find the separation and position angles of the target system, their apertures must be plotted. This was done by setting the aperture radius to the size of the primary star and plotting it with respect to the aperture.
Astrometry Observations of Six Uncertain Double Stars

radius of the second star. The resulting separation and position angles are generated from the plot by AstrolmageJ. Record this data, and repeat the steps outlined in this paragraph with ten to fifteen more observations in the same filter, per target. If more observations are available, include them.

After the above steps, a data set of the observed separation and position angle values are created. From this data set, the average separation and position angles for each target can be found. A standard deviation can also be derived from each observed value, from which an average of standard deviation can be found per target. Our results using these analyses are stated below in Table 3 for all six chosen targets, with Table 4 stating our results for the quintuple system ES1865.

Discussion

**HJ3231AC**

The data collected on the double-star HJ3231AC regarding position angle and separation is the closest alignment we found when compared to previously recorded data of the system. Our method used to measure this system proved accurate, without a change in position angle, and a very slight change (less than 0.40%) in separation angle.

**BU1341AB**

The data collected on this binary system matched the last recorded data from 2015. There is no difference in position angle. However, a slight separation angle difference of 0.98% is presented.

**STI1656**

Compared to previously recorded data in Stelle Doppie, there is a slight difference in separation angle, 0.7%, and an even smaller difference in position angle, 0.14%. This is still closely consistent with the last recorded data in 2003. However, there is a dim nearby star extending from the primary magnitude star that has no previously observed data. See Figure 4. Data obtained from this star is as follows: \( \rho = 4.52'' \) (arc seconds), Position Angle = 102.78° (degrees). This suggests a possible triple star system.

**HJ1002**

For this binary system, our data showed a decrease in both separation angle and position angle. A 0.37% decrease in separation angle and a 6.61% decrease in position angle were presented among the data for this target.

**STI110**

For this system, our method proved accurate in finding the separation angle. However, for the position angle, there was a percentage difference of 14.8%, which is far outside the standard deviation of percent differences across all targets (4.57%). This difference presented as a consistent difference in our measurement against the previous record, especially considering the accuracy of the target’s separation measurements and that of our other targets. To check the significance of this difference, we re-measured the position angle and...
Astrometry Observations of Six Uncertain Double Stars

separation of the system using fifteen images and calculated the average and standard deviation of each. What we calculated was \(7.31''\pm0.05''\) for the separation and \(5.74°\pm0.36°\) for the position angle. This result further indicates the significance of the difference between the previously recorded position angle and our observed position angle.

One possible reason for this deviation is that STI110 may be orbiting and that would present as an evolving position angle with a relatively constant separation. This hypothesis is supported by the differences in previous observations from Stelle Doppie. The first observation in 1908 recorded the position angle as \(354°\), but observations in 2001, 2003, and 2012 recorded \(5°\), \(4°\), and \(5°\), respectively, indicating a significant change, or at least inconsistent observation, in the system’s position angle over the past century.

For binary system DAM 622, we were able to contribute data to its previous record of only three observations. We found that there was quite a slight increase in separation angle, with a difference of \(1.38\%\) than its last recorded observation in 2010. Upon further observation of this double star, we came across the quintuple system, ES1865, as pictured in Figure 5. Since all the images we gathered of DAM622 provided a clear view of ES1865, we decided to go ahead and record data for that system as well, recorded in Table 4.

This system served as an excellent reference, as it had been observed 44 times - giving us a good platform to test the precision of our methods. The data we had collected for this system matched previously recorded data - with only a difference in \(\rho\) of \(0.95\%\), and a difference in \(\theta\) of \(0.98\%). This is a sufficient difference to

Table 3. Summary of observation data and its comparison to previously recorded data. An asterisk (*) indicates reference targets. Uncertainties are standard deviation.

<table>
<thead>
<tr>
<th>Name</th>
<th>Observed (\rho) (Average of 10 to 15 images)</th>
<th>Recorded (\rho)</th>
<th>(\rho) Percentage Difference</th>
<th>Observed Position Angle (Average of 10 to 15 images)</th>
<th>Recorded Position Angle</th>
<th>Position Angle Percentage Difference</th>
<th>Filter</th>
<th>Julian Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>HJ3231AC</td>
<td>44.87''±0.36''</td>
<td>44.7''</td>
<td>0.38%</td>
<td>295.99''±0.09''</td>
<td>296°</td>
<td>0%</td>
<td>gp</td>
<td>2458373</td>
</tr>
<tr>
<td>BU1341AB</td>
<td>20.50''±0.07''</td>
<td>20.3''</td>
<td>0.98%</td>
<td>319°±0.1''</td>
<td>319°</td>
<td>0%</td>
<td>rp</td>
<td>2458368</td>
</tr>
<tr>
<td>STI1656</td>
<td>13.09''±0.08''</td>
<td>13''</td>
<td>0.7%</td>
<td>80.96°±0.17''</td>
<td>81°</td>
<td>0.14%</td>
<td>rp</td>
<td>2458361</td>
</tr>
<tr>
<td>HJ1002</td>
<td>27.30''±0.33''</td>
<td>27.2''</td>
<td>0.37%</td>
<td>54.2°±0.98''</td>
<td>5°</td>
<td>6.61%</td>
<td>gp</td>
<td>2458368</td>
</tr>
<tr>
<td>STI110</td>
<td>7.31''±0.05''</td>
<td>7.3''</td>
<td>0.14%</td>
<td>5.74°±0.36°</td>
<td>5°</td>
<td>14.8%</td>
<td>gp</td>
<td>2458368</td>
</tr>
<tr>
<td>DAM622</td>
<td>7.04''±0.32''</td>
<td>6.9''</td>
<td>2.2%</td>
<td>46.9°±1.78°</td>
<td>48°</td>
<td>1.38%</td>
<td>gp</td>
<td>2458369</td>
</tr>
<tr>
<td>STF3041AB*</td>
<td>57.92''±1.4''</td>
<td>56.4''</td>
<td>0.23%</td>
<td>358.13°±0.15°</td>
<td>358°</td>
<td>0%</td>
<td>rp</td>
<td>2458368</td>
</tr>
<tr>
<td>STF2796*</td>
<td>26.65''±0.6''</td>
<td>26.4''</td>
<td>0.95%</td>
<td>41.59°±1.16°</td>
<td>42°</td>
<td>0.98%</td>
<td>gp</td>
<td>2458381</td>
</tr>
</tbody>
</table>

Table 4. Summary of observation data collected for quintuplet system ES1865, and its comparison to previously recorded data. ± indicates average standard deviation.

<table>
<thead>
<tr>
<th>Name</th>
<th>Observed (\rho) (Average of 10 to 15 images)</th>
<th>Recorded (\rho)</th>
<th>(\rho) Percentage Difference</th>
<th>Observed Position Angle (Average of 10 to 15 images)</th>
<th>Recorded Position Angle</th>
<th>Position Angle Percentage Difference</th>
<th>Filter</th>
<th>Julian Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES1865AB</td>
<td>23.92''±0.5''</td>
<td>23.7''</td>
<td>0.93%</td>
<td>122.25°±0.6°</td>
<td>123°</td>
<td>0.61%</td>
<td>gp</td>
<td>2458361</td>
</tr>
<tr>
<td>ES1865AC*</td>
<td>25.37''±0.5''</td>
<td>N/A</td>
<td>N/A</td>
<td>129.73°±0.6°</td>
<td>N/A</td>
<td>N/A</td>
<td>gp</td>
<td>2458361</td>
</tr>
<tr>
<td>ES1865AD</td>
<td>37.25''±0.6''</td>
<td>37.3''</td>
<td>0.13%</td>
<td>76.52°±0.4°</td>
<td>77°</td>
<td>0.62%</td>
<td>gp</td>
<td>2458361</td>
</tr>
<tr>
<td>ES1865AE</td>
<td>33.48''±0.2''</td>
<td>33.2''</td>
<td>0.84%</td>
<td>329.75°±0.8°</td>
<td>330°</td>
<td>0.08%</td>
<td>gp</td>
<td>2458361</td>
</tr>
</tbody>
</table>

1. N/A indicates no previous measurements
validate that the methods we used were accurate.

Our method of finding the separation and position angles of our targeted binary systems, in general, proved to be precise. With an overall standard deviation of \( \rho \) to be \( \pm 0.6" \), and standard deviation of \( \theta \) to be \( \pm 1.16^\circ \), it’s safe to say the data that we contributed to these double-star systems are accurate. There are, however, two that stood out in our findings, one being our unexpected observation of the quintuple system ES1865AB. Another thing that stood out in our findings was the large percentage difference found in system STI110’s position angle.

**STF3041AB (reference)**

Binary system STF3041AB was used as our reference target, as it has been observed 42 times in the last 125 years. We were able to validate our method’s accuracy with this binary system, as our results correlated closely with the data that has been previously recorded for this double star.

**ES1865**

This system was sort of a “bonus system” as it wasn’t necessarily a hand-picked target, rather we unexpectedly came across it in images of DAM622 (a target that was originally chosen to be observed). Upon analyzing this system, we found out that it is known as a quintuple system, as there are five visible stars in this system, that we referenced as: A (primary star), B, C, D, E, as depicted in Figure 6. Although the relations between AB, AD, and AE were observed with an accumulation of 24 times, we weren’t able to find any recorded data on ES1865AC (data of the primary star, “A”, to star “C”), so we proceeded to record the first documented data of this relation.

**Conclusion**

Our initial goal was met, as we updated the data for the small number of observations on these six double-star systems with our own data sets. The method of data collection used proved successful, as we recorded an average of a 0.71% difference for separation angle and an average of 2.29% difference for position angle.

We updated information on targets STI110, HJ1002, HJ3231AC, and BU1341AB. We found unexpected results among STTI1656 and DAM662.

Further research into double-star system STI1656 could reveal more information on the background star behind the primary magnitude star, possibly identifying this target as a triple star system. The magnitude of the background star would have to be determined, then observations need to be made in a filter allowing both the primary and background stars to be visible.

Because our measurements proved to be accurate, it is logical to reason that the large percent difference in position angle for target STI110 could reflect a natural change in position, like an orbit. Previous measurements support the theory, as explained in the discussion section. Further observations may or may not confirm the orbital nature of this target.

Additional research can be pursued with these targets, through photometry. It is possible to observe the ten available targets with different color filters. This could lead to updating magnitude data sets in Stelle Doppie.

**Acknowledgments**

We want to thank our instructor, Hsin-Yi Shih, for guiding us through the research paper process, answering all questions along the way, and reviewing the paper. Additionally, we thank the Las Cumbres Observatory for our target images, the Stelle Doppie catalogue for the recorded data, the Simbad catalogue for additional reference, and the University of Hawaii Maui College, for utilization of the computer lab and overall enriching learning opportunity. We would also like to thank Russ Genet and Vera Wallen, for contributing...
Astrometry Observations of Six Uncertain Double Stars

their expertise and time to review this paper. This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

References


Las Cumbres Observatory. (2018). 0.4-meter. Retrieved from https://lco.global/observatory/0.4m/


