

Astrometry Observations of STF 1321AB

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Abstract: The double star STF 1321AB (WDS 09144+5241) was observed April 12th, 2017 using a CDK-17 robotic telescope at Sierra Remote Observatories (SRO). Through the use of Astro Image J astrometry software, we determined an average arclength of 17.17" (arc seconds) with a position angle of 98.17° (degrees). Our measurements from this observation showed a statistically significant deviation from the projected orbital motion of this binary.

Introduction

Astrometry is an important part of astronomy. Its focus is the measurement of positions and movements of stars and other celestial bodies. The data obtained through astrometry is essential to the study of astronomy because these positional measurements allow us to determine the orbital movement of stars, and therefore calculate stellar masses. Stellar mass allows scientists to substantiate and confirm theories of origin and evolution of the celestial bodies in our universe (Seeds & Backman, 2014).

The discipline of astrometry has an extensive history. It is thought to have begun with Hipparchus in 190 BC, who used astrometry to realize the precession of the Earth's poles (Lankford, 1997). The precision with which astrometry is conducted has increased due to the evolution of technology. As the instrumentation utilized in astrometry gets more complex and more accurate, the data obtained by these instruments prove to be more and more useful to astrometry and astronomy as a whole. In many ways, CCD imagers have improved astronomical observing. CCD imaging is an efficient way to accurately measure the separations and position angles of double stars (Genet et al. 2016).

The first recorded observation of the double, STF 1321AB, was made in 1821 by Friedrich Georg Wilhelm von Struve. Von Struve, a German/Russian astronomer who was one of the founders of the modern study of binary stars (Encyclopaedia Britannica, 2009),

made the first measurement of this particular pair and published his findings in *Description de L'Observatoire Astronomique Central de Poulkova* in 1837.

Over the next century, there were more than one hundred visual observations of this binary, and as technology advanced so did the precision of the observations. Photographic observations began in 1903 with the astrograph (Urban et al., 2000) with much of the work being done by the Pulkovo Observatory in St. Petersburg, Russia since the 1950s, as well as the United States Naval Observatory (USNO) beginning in the 1960s. In 1991 Hipparcos, the European Space Agency's scientific satellite, made an observation of STF 1321AB from space. More recently, there have been two reductions using speckle interferometry. In 2007 the USNO used speckle-style reduction of the binary pair (Mason, Hartkopf, and Wycoff, 2008) with the last data recorded in 2016 (Locatelli, 2016).

The primary goals of this paper were to contribute the most recent position angle and separation to the published observations of STF 1321AB, and to demonstrate the practicality and accessibility of astrometry through the use of small telescopes, and open-source astrometry software.

Procedures

Instrumentation

Telescope: CDK-17 OTA

The CDK-17 telescope, as described by PlaneWave

Astrometry Observations of STF 1321AB



Figure 1. A photograph taken of 17-inch PlaneWave Telescope CDK-17.

Instruments (2017), is a 17-inch (0.43 m) f/6.8 Corrected Dall-Kirkham Astrograph telescope (Figure 1). It is equipped with a dual carbon-fiber truss design, three cooling fans ejecting air from the back of the telescope, and four fans blowing across the boundary layer of the mirror's surface. The telescope covers a 70-mm field of view that provides an image without any field curvature, off-axis coma, or astigmatism (PlaneWave Instruments, 2017).

Camera: Apogee F16M KAF-16803 based camera with filter wheel

The camera, also provided by PlaneWave Instruments, is an Apogee Alta F16M CCD Camera which utilizes a Kodak KAF-16803 full frame sensor with microlensing and anti-blooming gates that provides the resolution, contrast, and sensitivity essential for high quality radiographs (PlaneWave Instruments, 2017).

Observations

Ten images were obtained remotely with PlaneWave's CDK-17 robotic telescope and camera. These observations were collected remotely from the Sierra Remote Observatories (SRO) in California on the night of April 12th, 2017. The observations were made without a filter and found with an integration time that did not saturate the primary star. This provided a sufficient number of other stars in the image, allowing for a plate solution for analysis. The ten consecutive images allowed us to obtain more precise mean position angles and separations.

SRO maintains an observing complex in Auberry, California which is located in the foothills of the Sierra Nevada mountain range (Figure 2). Located near Fresno, SRO provides a unique combination of excellent



Figure 2. Aerial view of the Sierra Remote Observatories.

observing conditions and accessibility. This allows for optimum performance of state of the art equipment that can be regularly maintained (<http://www.sierra-remote.com>).

Methods

The images were analyzed through open source software, AstroImageJ (AIJ) using a plate solution obtained from nova.astrometry.net (Bush and Freed, 2017). A screenshot from nova.astrometry.net is shown in Figure 3.

AIJ software was used to measure the separation and position angle. This was done by moving the cursor very close to the center of one of the stars and center clicking with the mouse wheel and holding it down. While the click was held down, the cursor was dragged over to the center of the other star and let go of the mouse wheel. At this point the program calculated the

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Astrometry.net

Home Explore Upload API Support Search

Images > STF1321AB_1sec_Lumina...0.FITS

Submitted by anonymous (1) on 2017-04-14T16:43:29Z as * STF 1321AB_1sec_Lumina_0.FITS * (Submission 1537237) under Attribution 3.0 Unported

Job Status

Job 2030464: **Success**

Calibration

Center (RA, Dec):	(138.620, 52.704)
Center (RA, hms):	09 ^h 14 ^m 28.822 ^s
Center (Dec, dms):	+52° 42' 15.025"
Size:	23.7 x 23.7 arcmin
Radius:	0.280 deg
Pixel scale:	0.635 arcsec/pixel
Orientation:	Up is 6.73 degrees E of N
WCS file:	wcs.fits
New FITS image:	new-image.fits
Reference stars nearby (RA, Dec table):	rdts.fits
Stars detected in your images (xy table):	axy.fits
Correspondences between image and reference stars (table):	corr.fits
KMZ (Google Sky):	image.kmz

Figure 3. Image of the binary pair STF 1321AB using astrometry.net.

Astrometry Observations of STF 1321AB

Table 1: Positional data for STF 1321AB.

Observation #	Arclength (")	Position Angle (°)
1	17.11	97.66
2	17.08	97.38
3	17.11	98.08
4	17.20	98.26
5	17.12	98.63
6	17.08	97.99
7	17.25	98.47
8	17.22	98.71
9	17.23	97.78
10	17.28	98.72
Average	17.17	98.17
Stand. Dev.	0.076	0.48
Standard Error	0.024	0.15

arc length (in arc seconds) and position angle (in degrees).

Results

Ten images were taken of STF 1321AB and the arc length and position angle were measured for each image. With these measurements, we calculated an average arclength of 17.17" with an average position angle of 98.17°, as shown in Table 1.

Discussion

Our recorded position angle and separation of the secondary star relative to the primary star, as can be seen in Figure 4 (the blue cross near the top of image), deviated from the projected orbit. With our double star's projected orbit being 975 years long (Chang 1972), it should not have differed much from the last observation, given that it was recorded only a year ago (Locatelli 2016). Starting at the bottom of the image

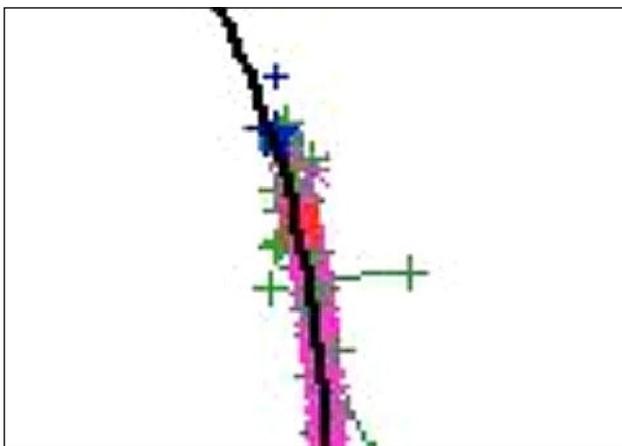


Figure 4. Close-up view of the orbital plot from Figure 5 (right) shows recent observational data for STF 1321AB plotted along its presumed binary orbital motion.

we have pink photographic (film camera) observations which are fairly well centered on the black orbit line. However, as we move up, note that the red Hipparcos and Tyco observations from the space telescope are off a bit to the right of the line. There are then some green, visual observations a bit to the right, and some blue speckle observations just slightly to the right of the orbit line. Our observation is also off to the right, suggesting this recent trend to the right of the orbit plot is continuing and that the orbit is off a bit.

To check if the deviation of our observation was statistically significant, we went to the Sixth Catalog of Orbits of Visual Binary Stars and looked up STF 1321AB (WDS 09144+5241) and clicked on the Ephemerides. These give the position angles (theta) and separations (rho) for Jan 0 (start of the year) for 2016, 2017, etc. We recorded the 2017 and 2018 values (theta, rho) as 98.5/16.829 and 98.8/16.807. To find the predicted positions we have to take into account the fraction of the year since Jan 0 2017. Our observation date was April 12 and it was not a leap year. According to the Julian Calendar, this would have been day 102 of the year, so the fraction of a year is 102/365 which, rounded off slightly is 0.28.

We then took the difference in theta for the two years (0.3) and multiplied by the fraction of the year (0.28) and rounded it off to 0.1. Adding this to 98.5 gives us 98.6 degrees as the predicted theta for the orbit for the night of our observation. Doing the same for

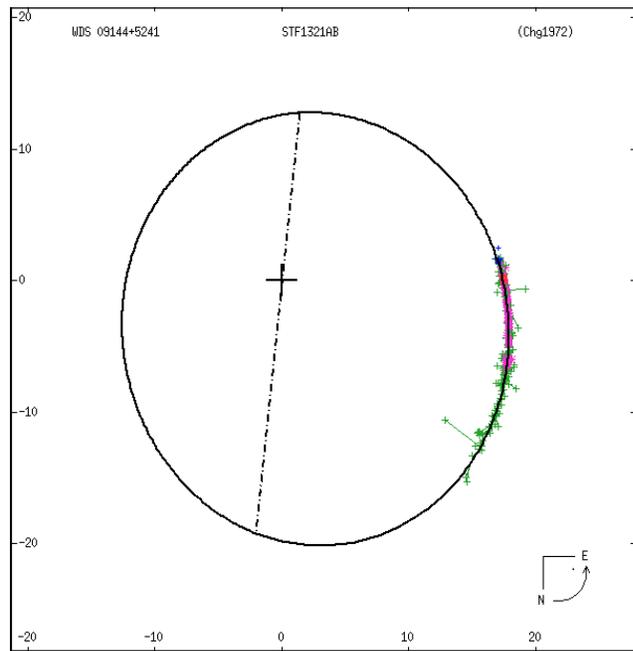


Figure 5. All known positional data for STF 1321AB plotted along its presumed binary orbital motion (obtained from the U.S. Naval Observatory, 2016).

Astrometry Observations of STF 1321AB

separation gives $0.22 \times 0.28 = 0.062$ and subtracting this time gives 16.767 arc seconds.

The predicted theta is 98.6, our observation is 98.17, a difference of about 0.4 degrees. The standard error of our ten observations of theta was 0.02, indicating a 20 sigma difference. For rho, the difference is 0.41, while our standard error is 0.13, a bit over 3 sigma, yet still significantly different.

Thus, the visual inspection of the magnified orbital plot suggests that our observation is continuing a trend to the right, while some simple analysis suggests that our observation off to the right of the orbit is not due to some random error but is statistically significant.

The preliminary orbit was calculated by Kyongae Chang in 1972 (Chang 1972). Since the first observation, 1321AB has been recorded to have completed 20% or 72.4 degrees of its projected orbit. Our measurements, as well as the plotted observations over the past 25 years, appear to be consistently placed on the outer edge of this projected orbit. This may suggest that the actual orbit may be of a longer period than originally predicted. It may be necessary to determine a new orbit, using the extensive data gathered since the preliminary orbit was made in 1972.

The extensive observational data also shows us how the tools used to observe double stars have changed over time. It can be noted that the original observations of this particular star system were made with micrometers that utilized either a refractor or reflector. This technology was not readily available except to professional astronomers who were employed by government or to those of a social class that allowed them to afford such instrumentation (Brooks 1991). Using micrometers involves manual adjustments and sensitive calibration. Measurements are taken by calculating parallax and other advanced mathematical procedures, making its execution possible by only those with highly specialized and extensive experience (Brooks 1991).

These observations, which are displayed with the green markers on the orbit plot, have a far higher rate of deviation. The relative inaccuracy becomes apparent when compared to modernized techniques. The consistency of observational data taken with telescopic (film) photography (pink), Hipparcos or Tycho space telescopes (red), and interferometric techniques (blue), cannot be ignored.

The accessibility to high quality observation with remote telescopes and simple and accurate analyses can be completed by nearly anyone, including high school and college students, to junior astronomers, to basically anyone with a computer connected to the internet. With the developments in remote observation and the availability of free software like AstroImageJ and astrono-

my.net, more star data can be compiled and shared than ever before.

Conclusion

By obtaining observational data of STF 1321AB, we accomplished the goals set at the project's outset. We added another set of measurements to the pool of double star data. Its position did not confirm the projected orbital motion, as we had thought it would at the project's beginning. Instead, a visual inspection of a magnified orbital plot suggested that our observation is continuing a trend to the right, and analysis suggests that our observation off to the right of the orbit is not due to some random error but is statistically significant.

We confirmed the practicality, accessibility, and accuracy of the online tools AstroImageJ and astrometry.net for double star astrometry. The execution of our project highlights how modern resources allow astrometric observations and data analyses to be endeavored by anyone, anywhere.

Acknowledgements

Thanks to PlaneWave Instruments and their CDK-17 robotic telescope at Sierra Remote Observatories (SRO). We thank Brian Mason for providing past observations of STF 1321 from the Double Star data bank at United States Naval Observatory in Washington (Mason, 2017). We thank Dr. Vera Wallen for her review of the paper.

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Astrometry Observations of STF 1321AB

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