CCD Astrometry of the Four Components of STF 1088

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Abstract Fifty CCD astrometric measurements were made of the separations and position angles of the AB, AC, AD, and AE components of STF 1088. Longer integration times provided more stars in the astrometric solution which may have significantly improved the precision of the measurements. The precision of the measurements did not appear to be a function of component separation, although the smallest separation (that of STF 1088 AB) was only 11″.

Introduction

Students at Leeward Community College and Waipahu High School on the island of Oahu, Hawaii took an astronomy research seminar offered by Cuesta College in San Luis Obispo, California. Several research topics were initially considered for our team's project, but we decided to make CCD astrometric measurements of a neglected double star system. A neglected double star is one that has not been observed for some time. The neglected double star system STF 1088 (WDS 07260+1406) was chosen because it was close to the zenith for optimal seeing during the evening and the brightness of the member stars were suitable for the instrumentation used.

Figure 1: Leeward team students (left to right) Stuart Martin (Leeward Community College), Diana Castaneda, Cathrina Ramos, and Linsey Daclison (Waipahu High School). Not shown are team members Kakkala Mohanan (Leeward Community College instructor), Russell Genet (Cuesta College instructor), and Joseph Carro (seminar advisor).

Our research project had four specific objectives: (1) measure and report the position angles and separations of the system's components; (2) determine if the number of stars included in the astrometric solution—a result of longer integrations—significantly affected the precision of the measurements; (3) determine if the separation of the components affected the precision of the measurements; and (4) check for any systematic differences between our observations and past observations.

STF 1088 AB was discovered in the summer of 1828 by Friedrich Georg Wilhelm von Struve at the Tartu Observatory in Estonia (Struve 1837), see Figure 2. Observations were made with a filar micrometer mounted on a 9-inch, equatorially-mounted refractor equipped with a precision clock drive. The micrometer and telescope were purchased by the Tartu Observatory from the firm, Utzschneider and Fraunhofer, in Munich, Germany. Joseph von Fraunhofer was the optical and mechanical genius behind this "Dorpat" refractor, often credited with being the first German equatorial mount (GEM).

Figure 2: STF1088AB was discovered by Struve using a 9-inch refractor at the Tartu Observatory.

A year and a half later, Sir John Herschel confirmed Struve's discovery (Herschel 1836). He used another famous telescope, the "20-foot" telescope built by his father, William Hershel (Figure 3). This telescope, built in England, was disassembled, shipped to South Africa, and then reassembled at the Cape Town Observatory.

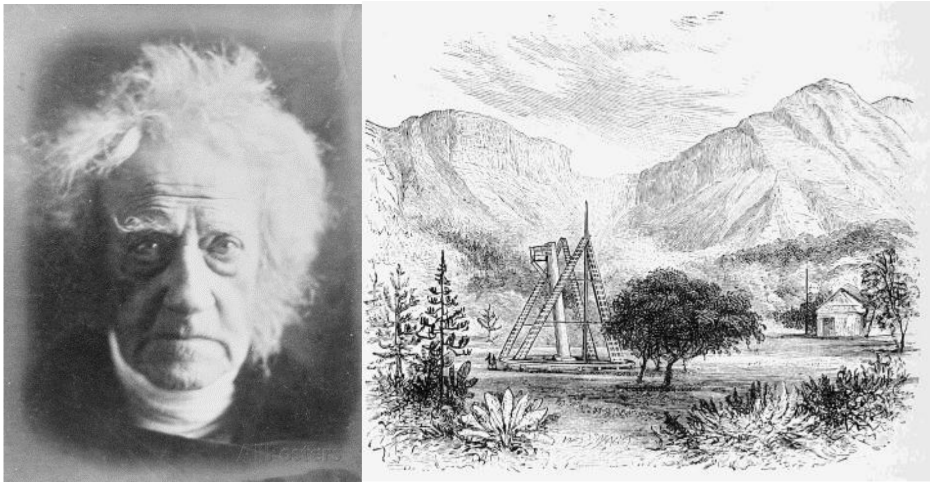

Figure 3: Sir John Herschel made the second observation of STF 1088 AB with his father's 20-foot telescope at the Cape Town Observatory in South Africa.

Prior to our observation of STF 1088 AB, there had been 26 published values for position angles and separations. The last observation, made in the summer of 2012, was by Robert Argyle (2013).

STF 1088 AC was also discovered by Struve (1837), using Fraunhofer's micrometer and refractor at the Tartu Observatory in the summer of 1829. Prior to our observation of the AC component, there had been 27 published values for position angles and separations. The last observation of the AC component was also made by Robert Argyle (2013) in 2012 on the same night he observed the AB component.

Both the AD and AE components were discovered in 1984 by French astronomer G. Soulie (1986). Additional observations of both components were made during the Two Micron All Sky Survey in 1997 (TMA 2003) and in 2000 (Hartkopf et al. 2000). In addition to these three past observations, the AE component was observed in early 2011 by students at Estrella Mountain Community College as a research project in a course taught by Douglas Walker (Darling et al. 2012). Thus, prior to our observation, there had been three published values for the AD component and four for the AE component.

Methods

The Kilo Hoku Observatory at Leeward Community College is equipped with a 0.5 meter telescope built by Optical Guidance Systems. An unfiltered Apogee Alta U6 camera with 24 micron pixels was used for all observations. The telescope was controlled with TheSky 6, and CCD images were acquired with CCDSoft.

Figure 4: Kilo Hoku Observatory located near Pearl Harbor, Oahu, Hawaii.

The first twenty frames at 0.5 seconds were obtained during the evening of February 6, 2015. On the evening of February 21, 2015, further observations were conducted with ten frames at 5 seconds and twenty frames at ten seconds.

After dark subtraction, but not flat fielding, the images were analyzed using CCDSoft and TheSky 6 to obtain astrometric solutions. While care was taken to avoid saturation, there was no attempt in the reduction to account for any bridged light between the two components. The plate solutions were used to find the separations and position angles for all four component pairs, AB, AC, AD, and AE. The plate solutions also provided the camera angle of 5.37° east and the image scale of 1.206″/pixel.

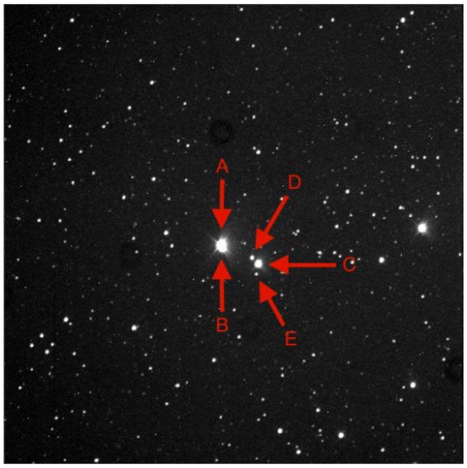

Figure 5: The components of the STF 1088 system from a ten second exposure.

Results

Tables 1-4 show the observational results for pairs AB, AC, AD, and AE, respectively. The position angle and separation values from each frame were entered on a spreadsheet to obtain the averages, standard deviations, and standard errors of the means. In all four tables, the set refers to: 1) the evening of February 6, 2015; 2) 5 second exposures on the evening of February 21, 2015; and 3) 10 second exposures on the evening of February 21, 2015. "No. Stars" is the number of stars in the astrometric plate solution.

et	Frames	No. Stars	Av. θ (°)	θ StD (°)	θ SEM (°)	Av.ρ (″)	ρ StDev (″)	ρ SEM (″)
	20	16	194.36	0.74	0.18	11.91	0.25	0.06
	10	164	194.76	0.43	0.14	11.31	0.07	0.02
	20	170	195.05	0.65	0.14	10.93	0.17	0.04

Table 1: Pair AB, primary magnitude = 7.38, secondary magnitude = 9.37

et	Frames	No. Stars	Av. θ (°)	θ StD (°)	θ SEM (°)	Av.ρ (″)	ρ StDev (″)	ρ SEM (″)
	20	16	238.02	0.12	0.03	112.82	0.39	0.09
	10	164	237.98	0.04	0.01	112.90	0.09	0.03
	20	170	238.16	0.06	0.01	112.75	0.11	0.02

Table 2: Pair AC, primary magnitude = 7.38, secondary magnitude = 8.71

et	Frames	No. Stars	Av. θ (°)	θ StD (°)	θ SEM (°)	Av.ρ (″)	ρ StDev (″)	ρ SEM (″)
	20	16	242.82	0.18	0.04	91.39	0.36	0.09
	10	164	242.82	0.04	0.01	91.40	0.12	0.04
	20	170	243.01	0.08	0.02	91.24	0.11	0.02

Table 3: Pair AD, primary magnitude = 7.38, secondary magnitude = 11.77

et	Frames	No. Stars	Av. θ (°)	θ StD (°)	θ SEM (°)	Av.ρ (″)	ρ StDev (″)	ρ SEM (″)
	20	16	NA	-	-	NA	-	-
	10	164	225.67	0.05	0.02	123.82	0.14	0.04
	20	170	225.78	0.07	0.02	123.55	0.15	0.03

Table 4: Pair AE, primary magnitude = 7.38, secondary magnitude = 9.00

Discussion

An examination of Tables 1-3 reveals that the standard error of the mean for both the position angle and separation are 2 to 3 times greater for set 1. This is likely due to the smaller number of solution stars (16) as compared to sets 2 and 3 (164 and 170, respectively). Thus it seems likely that the number of stars included in the astrometric solution does significantly affect the precision of the results. However, there are at least two alternative explanations. First, it could have been that it was longer integration times alone, not the number of stars in the solution that increased the precision. The exposure time has a direct relationship to the number of solution stars identified. Second, it could have been that the night that set 1 was observed was of significantly poorer seeing than the night when both sets 2 and 3 were observed. No quantitative assessment of the seeing each night was made.

An examination of Tables 1-3 also reveals that the AB component on all three sets of observations is between 3 and 18 times greater than that of the AC or AD components. Yet, counterintuitively, the standard error of the mean of the separation is comparable for AB, AC, and AD. This suggests that there is something unusual with respect to the determination of the position angle of the close AB pair as compared with the other three much wider pairs.

A likely explanation for this difference is that, for CCD observations, as the separation gets smaller, the θ precision falls off while the ρ error remains constant (Naipier-Munn and Jenkinson 2014). This is a simple geometric result of providing measurements in polar as opposed to rectangular coordinates. If, instead of position angle and separation between the primary and secondary star (polar coordinates), the measurements were given in x/y displacements in arc seconds, then the precision would have been similar for the system's components.

Richard Harshaw noted that since the resolution is 1.206″/pixel and the AB separation is 11.08″, the pixel span is only 9.19 pixels. A centroid variance of even half a pixel would offset the position angle by much more than a degree. Robert Buchhein pointed out that as integration times increased, the measured separation of the AB pair decreased.

The large number of past AB and AC observations (26 and 27, respectively), allowed statistical summaries of these two pairs to be calculated as shown in Table 5. Given the large number of past observations and apparent lack of movement, we assumed that the past observations of these two components could be used as "standards" to draw conclusions with respect to the accuracy of our current observations. "Current observations" refers to the average of all observations that we made on the two nights reported in this paper, while "past observations" refers to the average of all previous observations reported in the Washington Double Star data base as supplied by Brian Mason.

Comp.	When	No. Obs.	Av. θ (°)	θ StD (°)	θ SEM (°)	Av. ρ (″)	ρ StDev (″)	ρ SEM (″)
AB	Past	26	196.20	0.97	0.19	11.08	0.33	0.64
AB	Current	50	194.72	0.60	0.15	11.38	0.16	0.04
AC	Past	27	238.17	0.26	0.05	112.53	0.78	0.15
AC	Current	50	238.05	0.07	0.02	112.82	0.19	0.05

Table 5: Statistical summary of past AB and AC position angles and separations compared the current study.

An examination of Table 5 suggests that all of the observations are comparable and could have been part of the same population *except* for the current observations of the AB position angle. The position angle difference between the past and current observations of the AB stars (196.20° and 194.72°, respectively) is 1.48°. This is 8.7 times the average of the past and current standard errors of the means for position angle (0.17) and therefore of statistical significance.

While the precision of AB measurements was lower, it seemed reasonable to assume that these variations would be random and not produce any systematic error. It should be noted that there did not appear to be any systematic error in either the position angle or separation of the AB component. Further, there were no obvious systematic errors in the AD or AE components (though their numbers of past observations were small).

With a plate scale of 1.206″/pixel, the separation is just 9.19 pixels, and assuming a centroid accuracy of 0.1 pixels, a potential digitization error of 1 part in 90 can be calculated. Any bias in the centroiding process that favored some particular direction when the two stars are close together could produce a systematic error and could be addressed via mathematical deconvolution. The tails of the point spread functions of the two close components may have had significant overlap in the middle, causing such directionality in centroid error. This might be one possible explanation for what appears to be a systematic error in the position angle of the AB component.

If this conjecture is correct, then introducing some magnification (such as a Barlow lens) into the optical train before the CCD camera could reduce this error. Such an adjustment would come at the expense of a smaller field-of-view and hence fewer stars included in the astrometric plate solution. Fewer solution stars, as discussed earlier, may yield higher uncertainties.

Conclusions

It seems likely that the number of stars included in the astrometric solution—a result of longer integrations—did significantly affect the precision of the results. While the precision of the separation measurements was the same for all components, wide or close, the precision of the position angle of the closest component appeared, somewhat counterintuitively, to be much less than for the wider components. This, however, is probably just a geometric effect of providing results in polar as opposed to Cartesian coordinates.

There appeared to be a large systematic error in our measurement of the position angle of the component with the smallest separation, but not in its separation. This error does not appear in the other components measured from the same observations. Accurate measurements of close components with this camera and telescope may benefit from increased magnification to decrease the plate scale and from mathematical deconvolution techniques during reduction.

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