Measures in 2015 Using a DSLR and Video Lucky Imaging

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Abstract: Measures of 31 pairs taken in 2015 are reported. A 202mm, f/15 Maksutov-Cassegrain and a DSLR in video crop mode were used for the acquisition of "lucky images". Calibration was via essentially stationary wider pairs, as analyzed and discussed.

Introduction

The measurements were taken on several evenings in 2015, at the Winter Star Party in February and at the Okie-Tex Star Party in September, with a total of 31 pairs measured. The pairs selected for measurement were based upon two criteria: either the most recent published measure in the WDS was more than 10 years ago or the pair had fewer than 10 measures since discovery. Calibration was done by utilizing wide pairs exhibiting little or no orbital motion.

Image Acquisition

The telescope used was a 202mm diameter, f/15.5 Maksutov-Cassegrain made by the Telescope Engineering Company. Its nominal focal length was 3131mm. A Canon 60 Da DSLR was used in its 'Video Crop' mode which gave frame dimensions of 640 x 480 pixels and a field of view of 3' x 2.25'. The imaging system was mounted on an Astro Physics Mach 1 equatorial mount.

The camera operates at a set frame rate of 60 f.p.s. so that the maximum frame exposure was 1/60 second. The gain of the system was varied by adjusting the ISO value so as to avoid saturating the image. At the maximum ISO of 6400 the system could record useful video of stars as faint as 9.5 magnitude. The maximum magnitude difference between components which gave a useable image of the secondary component while not saturating the primary was about 2.0 magnitudes.

Focusing was done using a Bahtinov mask. The focuser was locked to prevent any change once set.

Videos of 30 seconds provided 1800 frames for processing. For most observing runs three videos were made of each pair on the same night to provide three 'measures' which could be averaged. On one night, 2015.134, the measurement runs were curtailed by cloud so that only two measures were available for averaging.

Calibration

Since the measurement runs were done at remote locations, the focus position of the telescope and the camera angle could not be reliably repeated. The catadioptric design of the telescope means that the working focal length changes with focus position due to movement of the primary mirror. For each run the camera cannot be placed in the focuser with any accurate idea of its orientation to the sky. Images of pairs of known separation and position angle would be needed for calibration. The WDS 6th Catalog has extensive lists of 'Calibration Pairs' with detailed ephemerides but a great deal of searching turned up virtually no pairs, with the exception of 70 Ophiuchi (STF 2272), which had definitive grade 1 orbits as well as being wide enough, bright enough, and with a delta magnitude as required by my imaging system's capabilities. There was a need to find a list of pairs for calibration that could be confidently used and which were well spread around the sky for use in all seasons.

A list of calibration pairs was obtained from the Washington Double Star Catalog by requesting an observing list of pairs whose Rho and Theta values had not changed at all or only very slightly since their discovery. Additionally criteria were: north of Declination 0, the primary brighter than 8.5 magnitude, the delta magnitude 2.0 or less, and separation between 3.0" and 90.0". Thirteen pairs were found to be suitable and are listed in Table 1 with their WDS identifier, magnitudes, and most recent Theta and Rho. For all runs, three calibration pairs were used, each imaged three times in succession.

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Table 1. These 13 pairs have exhibited very little relative motion since their discovery and are useable as calibration pairs for both theta and Rho. None show any appreciable change in Rho and change in Theta is minimal as well. The faintest individual component is 9.53 magnitude and the maximum delta magnitude is 1.83.

WDS ID	NAME	MAGNITUDES	YEARS	THETA FIRST	THETA MOST RECENT	RHO FIRST	RHO MOST RECENT
01101+5145	STT 23AB	8.14, 8.59	1845-2011	191	191	14.3	14.3
03009+5940	STTA 31	7.33, 8.03	1875-2008	229	230	73.6	73.6
02476+5357	STF 301	7.85, 8.70	1830-2011	17	17	8.2	8.2
05092+1130	BVD 50	8.35, 8.49	1900-2011	103	104	30.9	30.9
06317+0546	STF 926AB	7.23, 8.62	1829-2013	287	288	10.7	10.7
08404+1940	STF1254AC	6.52, 7.61	1863-2012	342	343	63.4	63.4
08467+2846	STF1268	4.13, 5.99	1777-2013	302	305	31	31
11560+2159	STF1582	8.09, 9.53	1827-2013	77	75	12	12
12519+1910	STF1685AB	7.31, 7.78	1783-2012	202	201	15.9	15.9
14083+2112	STF1804	8.17, 9.28	1825-2009	20	14	4.9	4.9
16362+5255	STFA 30AC	6.42, 5.50	1832-2004	17	15	89.9	89.9
17512+4454	STF2242	8.14, 8.28	1830-2010	327	326	3.5	3.5
19200+0535	STF2497	7.73, 8.49	1794-2013	0	356	30	30

Data Reduction

The 1800 frame videos were stacked in Lynkeos software by first selecting the best 200 frames as determined by the software. These frames were stacked and the image saved as a FITS file. The FITS image was placed in AstroimageJ software which found the centroids of the stellar images to sub pixel accuracy as (x , y) coordinates in pixel units. The centroid coordinates were then subjected to Pythagorean and Trigonometric mathematics to find the separation of the components in pixels and the position angle in degrees relative to the camera frame.

The calibration pairs were imaged at the beginning or end of each run in order to have the plate scale and camera angle data that would be applied to the measured pairs. The Theta and Rho of the three calibration images of each of the three calibration pairs were compared to the actual values of the pairs as determined above and the resulting nine values each of plate scale and camera angle were averaged to give the values for that run.

The images of the measurement pairs were analyzed the same way as the calibration pairs, in Lynkeos and then AstroimageJ. The calibrated plate scale was applied to the pixel separation of the components to give the Rho value and the calibrated camera angle correction was applied to give the reported Theta value.

Discussion and Results

The historical measures for the 13 calibration pairs were requested from the WDS. For each pair a scatter graph of Rho versus year and Theta versus year were made and in each case a regression line of best fit was generated by the graphing software. It was immediately apparent that there was some variation in the historical measures, a few being obviously very much in error. A typical case was STF 1268 (Iota Cancri). Figure 1 shows all of the historical measures for this pair.

It is clear that the vast majority of the Rho measures for STF 1268 cluster very closely to a value of about 30.5". However there are three or four measures that are slightly more than 1 Standard Deviation in error and two measures of 40" which were several S.D.'s in error. It was decided to reject measures

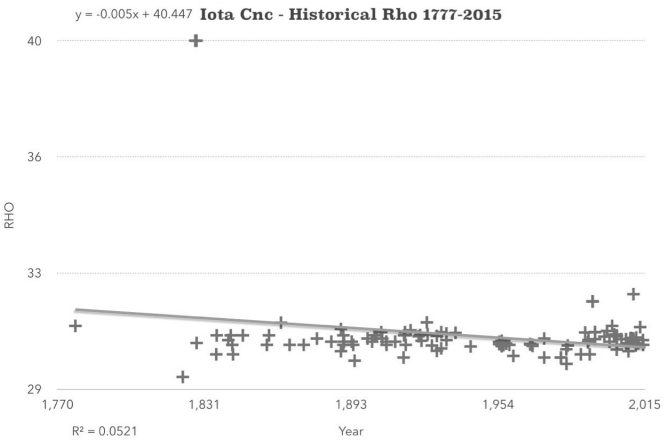

Figure 1. This graph shows all published measures for STF 1268, iota Cancri, from its discovery in 1777 to the most recent measure of 2015. The regression equation for the line of best fit is in the upper left corner, where x is the year and y is Rho. The outlying measures are clearly seen.

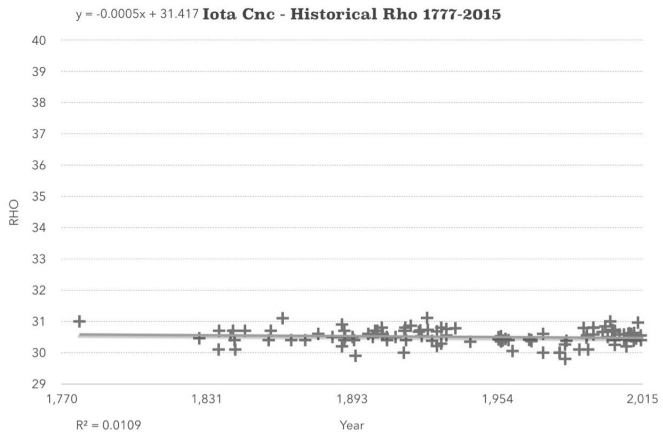

Figure 2. Once the outlying measures are removed the regression line becomes essentially flat with a slope of only -0.0005, indicating an annual delta Rho of only 0.5 milliarcseconds.

that were more than 1 S.D. away from the line of best fit. The resulting graph (Figure 2) shows that the Rho value of STF 1268 has changed by an extremely small amount over the 240 years since its discovery.

After removal of the erroneous measures, the regression equation for the second scatter plot of Rho for STF 1268 is given by Rho = -0.0001x + 30.791 where x is the year of the measure and Rho is in arc seconds. The separation for the dates at the time of the measurement runs were found by entering the year in the regression equation.

For calibration of the camera angle relative to the cardinal directions of the sky a correction angle was generated by comparing the observed Theta of the calibration pair to the actual Theta of the calibration pair. Just as with the Rho values there was a good deal of variation among the historical Theta measures and, once the measures more than 1 S.D. from the regression line were removed, there resulted a regression equation showing very little change over the measurement history of the pair. The measurement run date was then entered in the regression equation to determine the Theta value for that date. The list of calibration pairs and the regression equations used for Theta and Rho of each pair appear in Table 2.

Table 3 gives the resulting measures of the 31 pairs measured in 2015.

Acknowledgements

I would like to thank the United States Naval Observatory for providing vital calibration data from the Washington Double Star Catalog which were used in this article. Thanks also to Ed Wiley for his advice and suggestions.

Table 2. The regression equations for the lines of best fit, after removal of outlying data, for Theta and Rho are given for the 13 calibration stars. For these equations the y-value is either Theta or Rho and the x-value is the year.

PAIR	Theta Regression	Rho Regression
BVD 50	y = 0.0022x + 99.4700	y = 0.0016x + 27.789
STF 301	y = 0.0057x + 5.5468	y = 0.0003x + 7.6137
STF 926AB	y = 0.0057x + 276.7700	y = 0.0021x + 6.8257
STF1254AC	y = 0.0039x + 334.7300	y = 0.0011x + 61.0310
STF1268	y = -0.0015x + 310.23	y = -0.0001x + 30.791
STF1582	y = -0.0049x + 85.014	y = 0.0002x + 11.708
STF1685AB	y = 0.0005x + 200.47	y = -0.0005x + 16.859
STF1804	y = -0.0367x + 87.747	y = 0.0018x + 1.2395
STF2242	y = -0.0035x + 333.07	y = -0.0012x + 5.7712
STF2497	y = -0.0064x + 369.20	y = -0.0009x + 31.903
STFA 30AC	y = -0.0067x + 206.79	y = -0.0017x + 93.561
STT 23AB	y = -0.0035x + 198.28	y = -0.0005x + 15.642
STTA 31	y = 0.0074x + 215.46	y = 0.0009x + 71.804
STF1685AB	y = 0.0005x + 200.47	y = -0.0005x + 16.859

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Table 3. The measures of 31 pairs are shown. The information from the first three columns is from the Washington Double Star Catalog 'Last Precise Measure' list. The date of the measure is the mean of the dates when measures were taken. The last column gives the number of measures that were averaged to give the listed measure.

Pair	WDS	Magnitudes	theta	rho	Date	n	Notes
STF 16	00167+5439	7.68, 8.78	38.9	5.93	2015.707	3	
ES 42	00229+5420	8.35, 9.40	208.1	6.91	2015.707	3	
STF 60AB	00491+5749	3.52, 7.36	323.8	13.18	2015.707	3	
ARG 6AB	01527+5717	8.15, 9.96	136.3	15.13	2015.707	3	
WAL 14AC	01527+5717	8.15, 9.70	102.3	66.65	2015.707	3	
STF 222	02109+3902	6.05, 6.71	35.3	16.69	2015.707	3	59 And
STF 227	02124+3018	5.26, 6.67	65.8	3.76	2015.707	3	6 Tri
STF 249	02216+4436	7.21, 8.99	195.8	2.32	2015.707	3	
STF 576AB	04380-1302	7.33, 7.85	172.2	12	2015.134	2	
STF 631	05007-1330	7.49, 8.77	106.7	5.93	2015.134	2	
BVD 51	05154-0322	7.76, 9.56	317.7	44.95	2015.134	2	
STF 751	05358-0059	8.02, 8.96	123.2	15.09	2015.134	2	
STF 758AC	05381-0011	7.96, 8.69	87.7	51.36	2015.134	2	
STF 758AD	05381-0011	7.96, 8.52	79.6	41.65	2015.134	2	
SKI 2	06041-1541	8.04, 9.96	173.2	5.04	2015.134	2	
STF 844AB	06083+1400	8.49, 9.29	9.5	23.32	2015.134	2	
STF 848AB	06085+1358	7.28, 8.15	112.2	2.614	2015.134	2	
STF 848AD	06085+1358	7.28. 8.31	122.2	28.2	2015.134	2	
STF 848AE	06085+1358	7.28, 9.01	184	43.84	2015.134	2	
STF 869	06107-0951	8.18, 9.09	280.1	24.36	2015.134	2	
STF 877	06147+1435	7.55, 7.96	263.8	5.65	2015.134	2	
STF1010AC	07015-0307	7.68, 8.77	6.8	22.21	2015.134	2	
STTA 86	07292+1421	7.17, 8.24	348.8	56.18	2015.134	2	
BGH 3	07400-0336	7.30, 9.01	112.8	58.53	2015.134	2	
STF1132	07422-0331	8.13, 8.49	234.1	19.76	2015.134	2	
STF1149	07495+0313	7.81, 9.19	41.2	21.45	2015.134	2	
STTA163AB	17563+6237	7.77, 7.59	52.8	54.76	2015.707	3	
HJ 606	20084+3808	7.98, 8.12	228.2	44.66	2015.707	3	
STF2733	20527+0720	8.39, 8.58	144.5	40.21	2015.707	3	
ES 825AC	21399+4908	7.25, 9.56	284.9	57.42	2015.707	3	
STF2953	22527+6055	7.63, 9.52	138.9	7.79	2015.707	3	