Observations of Epsilon Lyrae by the Video Drift Method

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Abstract: The major components of the famous "double-double" star Epsilon Lyrae, STF2382AB and STF2383CD, were measured by the Video Team at the Apple Valley Double Star Workshop in 2013, using the Video Drift Method. The results are in reasonable agreement with other recent measures and predictions of the latest orbital solutions.

Introduction

The Apple Valley Double Star Workshop (Brewer, et al, 2014) brought together students, teachers and amateur astronomers, to learn about and practice measuring double stars by several different methods. The workshop was held at the Lewis Center for Educational Research in Apple Valley, California in July, 2013.

The "Video Drift Team," consisting of authors Wasson, Wilson and Buehlman, who carried out the observations. Authors Nelson and Zapata joined the team after the workshop, reducing portions of the data and contributing to this written paper. The major components of the famous double star Epsilon Lyrae, STF2382AB and STF2383CD, were measured and compared with the projected orbits and other recent measures.

Equipment

The equipment used was described by Wasson (2014). The telescope was a portable Orion 12-inch f/4.9 "Go-To" Dobsonian (alt-az mount). The camera used in place of a 1¼" eyepiece was a PC-164c low-light surveillance CCD video camera, providing 30 frames/second NTSC digital video images. The chip contains 510(H) x 492(V) rectangular pixels (9.6μ x 7.5 μ) for an overall detector size of 4.9mm(H) x 3.7mm (V). H and V indicate horizontal and vertical video frame dimensions, respectively. The observations of Epsilon Lyrae were made with a 3X Barlow lens, for higher magnification to separate the close pairs.

A "Kiwi" GPS time inserter, originally intended for accurate timing of asteroid occultations, added a GPS time display to each video frame. A Canon ZR-200 mini DV camcorder was used to record the video stream on cassette tape.

The bright stars of Epsilon Lyrae (magnitudes 5-6) initially produced slightly over-exposed images and the stars were not easily split on the camcorder monitor. Therefore, a 13% neutral density ("moon") filter was installed to reduce the light intensity, avoid over-exposure and improve video image quality. A color filter would have been preferable, because limiting the wavelength tends to sharpen the star images, but unfortunately, none was available.

Observing Procedure

All observations were made using the video drift method (Nugent & Iverson, 2011), as adapted by Wasson (2014) for a Dobsonian telescope. In this technique, the video camera was first rotated until the frame was roughly aligned east-west horizontally, to match

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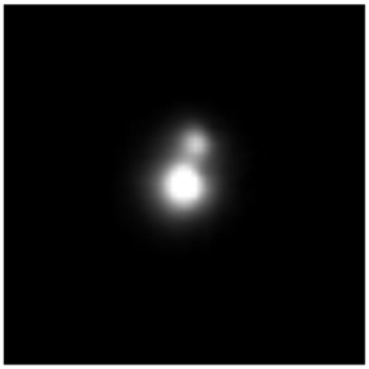

Figure 1. Epsilon Lyrae north-west pair, STF2382AB. REDUC Shift & Add image of best 117 (25%) of 473 frames from drift "a." North is up, east at left in Figures 1-3.

Figure 2. Epsilon Lyrae south-east pair, STF2383CD. REDUC Shift & Add image of best 42 (8%) of 495 frames from drift "a."

the sidereal motion. To make an observation, the target stars were moved slightly out of the field eastward, the telescope drive was turned off, and a video recording was made as the stars drifted across the field. The recording was stopped once the stars drifted completely out of the field, and the tracking motors were turned back on to avoid losing the stars. This process was repeated for a total of 14 "drifts" for each target double star. To insure that video runs were not confused later during data reduction, one of the team members kept a hand-written log sheet, labeling the drifts a, b, c, etc., and recording the drift letter and approximate time of each drift.

The motor-driven alt-az mount of the Dobsonian telescope was capable of tracking the stars, but continuous field rotation presents a challenge for calibration and measurement of Position Angle. However, in the video drift method, each video drift sequence is a stand-alone package of information which contains data for calibration of pixel scale and sky orientation, by using the known sidereal drift rate coupled with accurate GPS time for each frame. Of course, the video sequence also contains many image samples (frames) used for double star measurement. No other calibration observations were made.

For the telescope focal length of 1500mm, the field of view is small: about 11.2 x 8.5 arc minutes. With the 3x Barlow, the field is three times smaller, but typical drift times for Epsilon Lyrae were still over 15 seconds, providing about 500 video frames for each drift.

Stars Observed

On the first night of the workshop, 13 July 2013, the famous, bright "double-double" star Epsilon Lyrae was chosen as a convenient yet challenging target for the video drift method. The two main pairs, shown in Figures 1 and 2, were first noted as double by William Hershel in 1779, but not measured until 1831 by F.W. Struve. The Washington Double Star Catalog (WDS) designation is 18443+3940. Since the separation of each pair is only about 2", neither pair could be cleanly split on the video monitor, so a 3x Barlow lens was used to increase magnification.

The north-west pair is STF2382AB. The WDS provides the following data: precise coordinates RA 18h 44' 20.34" and Dec +39° 40' 12.4"; magnitudes 5.15 and 6.10; spectral types A4V and F1V; PA 346° and separation 2.2" as of 2010. A "premature" orbit, provided in the 6th Orbit Catalog of the WDS, has been estimated with a period of 1725 years.

The south-east pair is STF2383CD. The WDS provides the following data: precise coordinates RA 18h 44' 22.78" and Dec +39° 36' 45.8"; magnitudes 5.25 and 5.38; spectral types A8Vn and F0Vn; PA 79° and separation 2.3" as of 2010. The WDS 6th Orbit Catalog gives a preliminary orbit for this pair, with an estimated period of 724 years.

On the night of 14 July 2013, several wider but fainter doubles were observed, so no Barlow lens was required and no "moon" filter was used. The multiple star WDS 19448-2029 HJ2890 was observed and components AC, AD and AE were measured. The faint component B, only about 3" from A at magnitude 13.9, was not visible. Unfortunately, as can be seen in the misshapen star images of Figure 3, the telescope was not well collimated, which must tend to bias the measures of PA and Separation. In addition, the seeing was poor due to hot, windy conditions, and the target stars were quite low in the south. Therefore, the quality of those observations was poor, much worse than typically achieved with the video drift method; the measures are not considered reliable, and are not reported here.

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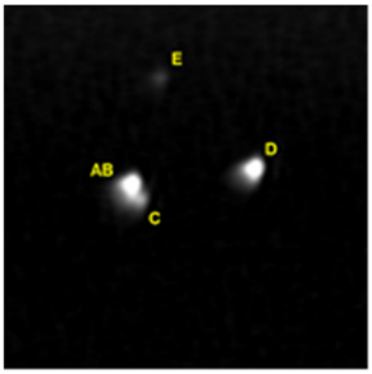

Figure 3. The field of WDS 19448-2029 components. Flared distortion of star images was caused by poor telescope collimation.

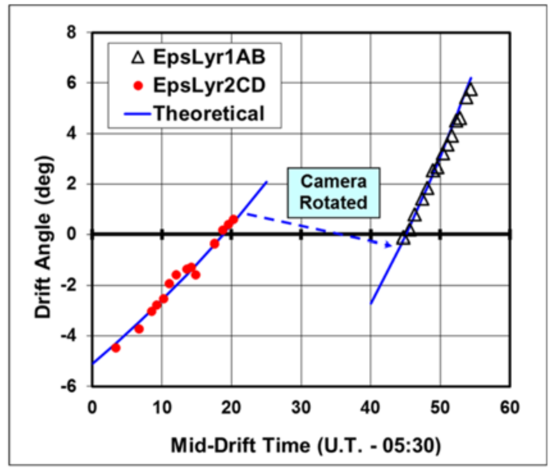

Figure 4. Change in Drift Angle during observations, caused by alt-az mount field rotation.

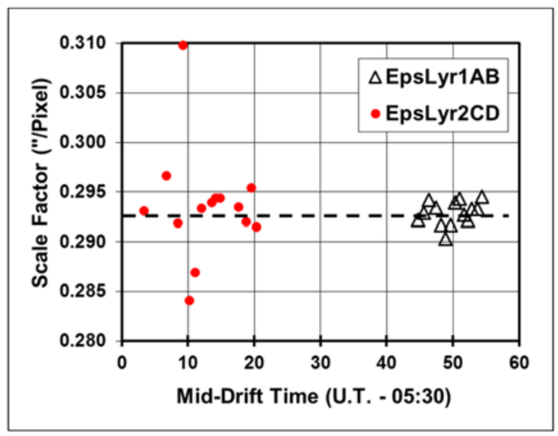

Figure 5. Scale Factor measured for each drift.

Data Reduction

Data processing of drift videos involves use of several software programs, available free on-line. These programs, as well as the uploaded digitized video files and a set of tutorial instructions, were provided to each team member by the team leader (Wasson). A common drift ("a") was assigned to be processed by all members, so that results could be compared.

Unfortunately, sufficient time and a suitable computer were not available during the Workshop for a hands-on demonstration and team practice with the software. Therefore, all the data reduction was done after the Workshop, with communication only by email or phone, leading to a rather long "learning curve" and final reduction.

VidPro Calibration

Calibration of Drift Angle (camera orientation to the sky) and image scale (arc-seconds per pixel) for each recorded video "drift" made use of the "VidPro" spreadsheets of Nugent & Iverson, 2011. The spreadsheets, adapted for close doubles as described by Wasson, 2014, were used for calibration. However, they could not be used for measurement because the stars were too close together; the "LiMovie" program (Miyashita, 2008), which provides input data to the VidPro spreadsheets, could not track the stars separately across an entire drift.

Figure 4 shows the Drift Angle calibration data calculated by the VidPro spreadsheets, where each point represents one drift. The non-linearity of the Alt-Az mount field rotation is very noticeable, becoming faster as the high-overhead stars approached the meridian; field rotation rate actually approaches infinity if a star passes through the zenith point.

The "theoretical" lines were calculated according to the method outlined by Wasson, 2014; the curvature of the lines is caused by the accelerating rotation rate, but the absolute level of Drift Angle depends on the orientation of the camera, so it was adjusted to match the level of the points of each series of drifts. Between the two drift series (for the two pairs observed), the video camera was re-oriented in the telescope to make the stars drift roughly horizontally across the frame once again.

Figure 5 shows the Scale Factor calibration points for each drift, calculated by the VidPro spreadsheets. Three drifts (d, e, and f) for the CD pair had unusually large variations: 2% to 6%. Extra effort was made in re-reducing and double checking these drifts, but no clear explanation was found; however, in drift "d" (the highest), the stars did show considerable "bouncing" due to wind gusts. Using the 3x Barlow, the average scale factor was 0.2933 arc-sec/pixel.

REDUC Analysis

The REDUC freeware program (Losse, 2011) was used to measure Position Angle (PA) and Separation for each video drift. REDUC capabilities, as applied to the Video Drift Method, were described by Wasson, 2014.

Analysis was typically done according to the following pattern. All the frames in a drift were sorted, using the "Best of - Max" option. A group of frames was then selected from the best frames in the drift (e.g., best 10%), and were analyzed in the "Auto" mode. Next, those same frames were Shifted & Added (registered and stacked) to produce a single frame of higher quality, and measured again. Finally, this frame was measured once more, using the "Surface" method within REDUC that is capable of modeling overlapping point spread functions.

After all the drifts had been analyzed, it was discovered that all the frames had been "stretched" 12.5% horizontally while editing each drift in the "VirtualDub" program (Lee, 2010). This spacial distortion invalidated the calibration data as well as the measurements. The source of the "stretch" problem was briefly described by Wasson, 2014.

Rather than re-reduce all the data, corrections were derived for the calibration quantities (Drift Angle and Scale Factor) as well as for the measurement quantities (PA and Separation). Although there may be some approximations in the correction equations, it is believed that they fix most of the distortion errors.

After correcting the data for all drifts, a simple way to avoid the "stretch" problem was discovered, utilizing the tools already in the VirtualDub program. As a spot check on the corrections, one drift for each pair was re-analyzed, starting with the original video clips. The results compared closely (within ~0.6^o PA, ~0.05" Sep) with the "corrected" data, validating the corrections.

PA and Separation Measures

Results of measurements of the two close pairs are summarized in Table 1. The data columns are: Discovery designation, WDS designation, WDS magnitudes, measured Position Angle (PA), standard deviation of PA, measured Separation, standard deviation of Separation, number of drifts recorded, and total number of measurements for all drifts combined.

As described above, the measures were made using three methods within REDUC: Auto, Shift&Add/Auto, and Shift&Add/Model. Each method was typically rerun using two or three different samples of the "best" frames (e.g., the best 25%, 10% and 5% of the total number of frames in a drift). In this way, four to eight measures were made for each drift, and the total number of measures far exceeded the number of drifts. The average and σ values of all measures (# Meas.) are given in Table 1. Each drift used its calibration data point shown in Figures 4 and 5. All measures include correction of the frame horizontal "stretch" problem discussed above.

For the CD pair, in which the stars have very similar magnitudes, only frames where REDUC found the correct (western) star as the primary (brightest) were used for measurement. This process discarded about a quarter of the frames, in which the secondary appeared brighter, thereby excluding frames having a 180 degree PA error.

Comparison with Other Observations

Comparisons with measures of STF2382AB made over the last ten years, including modern techniques (e.g. speckle interferometry and CCD astrometry), are shown in Figure 6. The "Orbit" lines are yearly predicted points in the WDS 6th Orbit Catalog for the orbits of Mason, et al., 2004 and Novakovic & Todorovic, 2006. PA predictions are virtually identical for both orbits.

Similar comparisons for STF2383CD are shown in Figure 7, where the orbit solution is that of Docobo and Costa, 1984.

Table 2 shows the Delta (difference) between the PA and Separation measured by the Video Drift Team and the PA and Separation of the Orbital Ephemerides (for date of observation) from WDS for STF2382AB and STF2383CD. The WDS data for STF2382AB is the predicted orbit of Novakovic & Todorovic, 2006. The WDS data for STF2383CD is from the orbit solution of Docobo and Costa, 1984. The overall Video Team results are reasonably good, generally comparable with the widely used CCD astrometry method.

(Continued on page 41)

Table 1. Video Drift measures of Epsilon Lyrae with a 12-inch telescope on Besselian date 2013.529.

Name	WDS	Magnitude	PA	σ PA	Sep.	σ Sep.	# Drifts	# Meas.
STF2382AB	18443+3940	5.15, 6.10	346.6	1.0	2.41	0.12	14	62
STF2383CD	18443+3940	5.25, 5.38	77.4	0.8	2.42	0.09	14	108

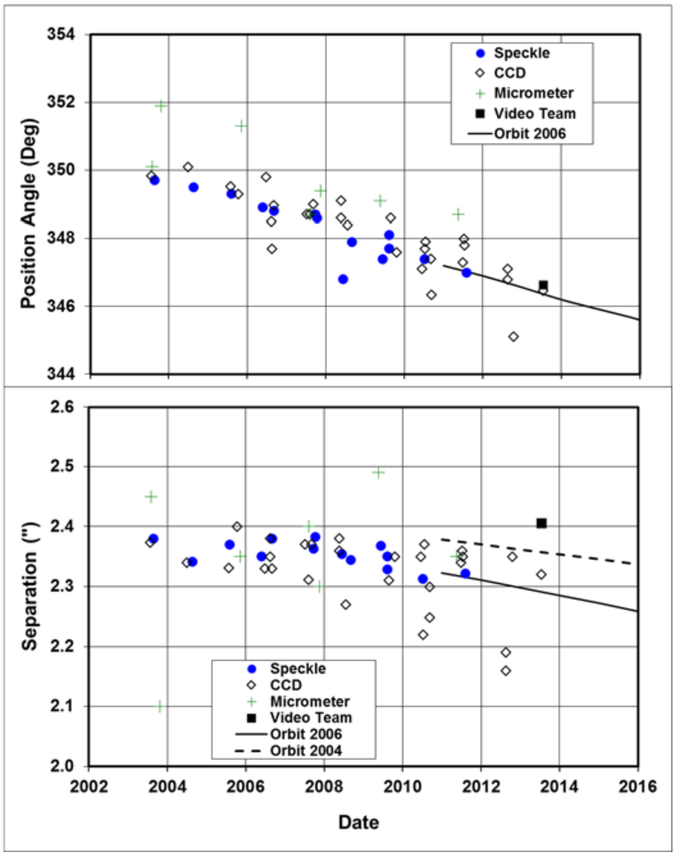

Figure 6. STF2382AB comparison of the Video Team measures with recent measures and predicted orbits.

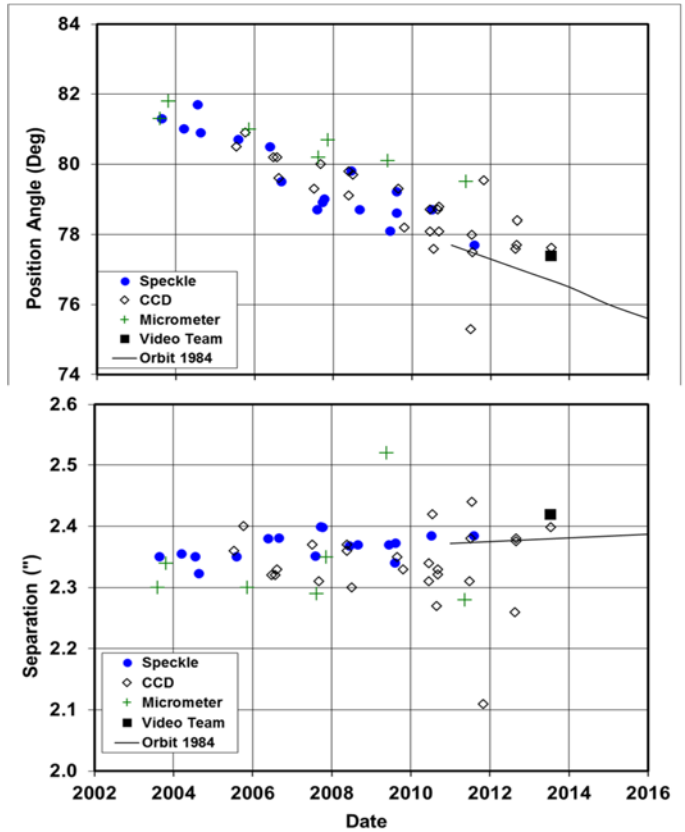

Figure 7. STF2383CD comparison of the Video Team measures with recent measures and predicted orbit.

Table 2. Video Team Comparison with WDS Orbit Predicted Values

Name	WDS	PA Obs (deg)	PA WDS (deg)	Delta (deg)	Sep Obs (arc sec)	Sep WDS (arc sec)	Delta (arc sec)
STF2382AB	18443+3940	346.6	346.4	0.2	2.41	2.292	0.12
STF2383CD	18443+3940	77.4	76.7	0.7	2.42	2.380	0.04

Observations of Epsilon Lyrae by the Video Drift Method

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Deanna Zapata studies Physics at UCLA and enjoys amateur astronomy in her free time.