A New Video Method to Measure Double Stars

Richard L. Nugent
International Occultation Timing Association
Houston, Texas
rnugent@wt.net

Ernest W. Iverson
International Occultation Timing Association
Lufkin, Texas
ewiverson@consolidated.net

Abstract: A new video method is presented to measure double stars. The double star components are video recorded as they drift across the entire field of view from east to west with the telescope's motor drive turned off. Using the software program *LiMovie*, specifically written for analysis of occultation videos, (x,y) coordinates are extracted for each star for each video frame. An Excel program written by author RLN analyses the (x,y) positions output by *LiMovie* for determining position angle (PA), separation and other quantities. The duration of a typical video for an f/10 telescope system ranges between 20 sec – 1 minute; this along with a 30 frame/sec recording rate produces 100's to 1000's of (x,y) pairs for analysis. The orientation of the video chip and its deviation from the true east-west direction (drift angle) is computed simultaneously along with a scale factor for each video. This provides a calibration for each double star measured. This drift angle and scale factor are used with all (x,y) positions to generate a unique position angle and separation. Typical standard deviations for position angles ranged from 0.3° to 4°, and for separations 0.2" to 1.3". A comparison was made using this new method with the Washington Double Star catalog (WDS) entries that had little or no change in PA and separation for 120 + years. For these 13 doubles our PA's and separations differed by an average of 0.2 deg and 0.2". Position angles and separations are given for 88 additional stars. Sources of error are discussed along with tips to maximize the quality of the (x,y) data produced by *LiMovie*.

Introduction

With the emergence of low cost, higher sensitivity video cameras and digital video recorders (DVR's), video astronomy has reached new levels. This paper describes a new video method to measure separations and position angles of double stars. From a single 20-second to 60-second (or longer) video, this method will analyze thousands of (x,y) positions of the double star components and provide an accurate separation and position angle. The equipment needed to get started is the same as for modern occultation observations: A telescope (equatorial mounted motor driven preferred), an optional Global Positioning Satellite (GPS) time inserter, a video camera and a DVR. In lieu of a DVR, older camcorders can be used for the recordings however any videos acquired must be in AVI (Audio Video Interleave) format for analysis purposes.

The principle of this method is as follows: The double star components will drift in the east-west direction from one side of the field of view (FOV) to the other side with the telescope's motor drive turned off. The duration of a drift depends on the FOV of the video camera and focal length of the telescope system. No other stars need to be visible on the video except for the double star components.

A GPS time inserter will overlay on each video frame the current date and Universal Time (UT) accurate to 0.001 second. This information is used to identify the start time of the first video frame and the end time of the last video frame of the drift. These times are used to determine scale factors for the video system in arc-seconds/pixel which is crucial for calculating the separation of the components. In lieu of GPS time insertion, the number of video frames in the recording may be used (which will be converted into seconds of time) for each individual drift. This requires that the frame rate per second of the DVR be known precisely. With either of these timing methods, the total drift duration needs to be known to a precision to better than 0.1 second.

A freeware program, *LiMovie*, (Miyashita 2006) written and used for the analysis of occultation videos will output an (*x*,*y*) position for each star for each video frame from a 640 x 480 pixel size grid. This (*x*,*y*) position output feature from *LiMovie* was overlooked by it's author Miyashita and the occultation community, yet recognized by one of us (RLN) as a potential new method to measure double stars. At the NTSC (National Television System Committee) video rate of 30 frames per second (fps) of most DVR's, a 25-second video drift will produce 750 (*x*,*y*) positions for determining the position angle (θ) and separation (ρ), and a 70-second video drift will produce nearly 2,100 (*x*,*y*) positions.

LiMovie outputs the (*x*,*y*) pairs (with brightness and other data) to a comma separated value (CSV) Excel file. This CSV file is then input into an Excel program written by one of us (RLN) for immediate PA, separation plus statistical results. *LiMovie* accepts both NTSC and Phase Alternating Line (PAL) format videos. *LiMovie* will analyze frames at a 0.033 sec incremental rate for 30 fps NTSC videos and at 0.04 sec increments for 25 fps PAL format videos.

GPS time insertion is not mandatory for this method but is preferred for several reasons. Not all DVR's have a 30 fps recording rate so it is crucial to know the start and end times of the drift, which is used for determining the scale factor. With GPS millisecond timing overlaid on each video frame, the frame rate of the DVR can be determined and any dropped frames and other ambiguities associated with a video can be identified. It also simplifies identification of videos for record keeping purposes.

The video drift technique presented here is much simpler to utilize than CCD astrometric methods. Only the components of the double star need to be measured for (*x*,*y*) position (which is done automatically by *LiMovie*) as it is not necessary to have any other stars visible. Each video frame will provide a position angle and separation which is later averaged, thus this is not a video stacking method where the user must spend large amounts of time discarding bad frames. Nor is it a CCD astrometry method either, since no RA and DEC positions are calculated for the components. There is no classical least squares CCD image (plate) adjustment performed, thus no star catalog is required either, as no reference star positions are needed.

The authors typical drift durations range from 25 seconds with a Meade 14" (35cm) LX-200 to 75 seconds with a 3.5" (9cm) Questar. It is advised that no focal reducers or other optical components be placed between the telescope's objective and video camera as this method is astrometric in nature. Using additional optical components will potentially add unwanted distortions and aberrations. Investigators using this method that wish to resolve close pairs (under 6") may require the use of a barlow lens.

The minimum separation we method has resolved is 3.6 arc seconds (see Table 3). The minimum separation that can be resolved is highly dependant on the focal length of the telescope/video system. If the telescope/video camera can discern closer separations, then they should be able to be resolved with the program *LiMovie* as long as the star images are distinct and not merged. Background noise and atmospheric turbulence becomes an issue when resolving close doubles.

Experience shows that the method can handle double star systems that have a maximum 3 - 4 magnitude difference. A large magnitude difference with a small separation may cause the star images to merge in *LiMovie* even though they are visually distinct. Very bright stars will have large seeing disks making the centroid determination difficult. The basic rule of thumb in choosing systems to analyze, is that if you can't resolve the components on the video monitor, then they cannot be resolved by the software.

Acquisition of Data / Procedure

The telescope equipment used is summarized in Table 1.

Once setup with telescope, optional GPS time inserter, video camera and DVR, the observer will iden-

Table 1: Telescopes used in this research. Scale factors will vary slightly due to the declination of the doubles. Focal reducers (f6.3, f3.3) and barlows were sometimes used in acquiring videos.

TELESCOPE	APERTURE	FOCAL LENGTH	SCALE FACTOR
Meade LX-200	14" (35cm)	3550 mm f/10	0.6"/pixel
Meade LX-200	8" (20cm)	2000 mm f/10	1.1"/pixel
Questar	3.5" (9cm)	1299 mm f14.4	1.6"/pixel

tify a double star and place it in the video monitor ready for recording. As this is an astrometric method, a steady atmosphere and sharp focus is required to get good results. Investigators should strive to acquire videos when the targets are within 1 hour (15º) of the meridian to minimize the air mass starlight travels through.

The goal is to obtain video of the double stars drifting east-west across the entire FOV. The orientation of the top edge of the camera/video chip does not have to be precisely parallel with the east-west line, but should be within 5 degrees (see Figure 2). A few practice drifts will determine if the video camera needs to be rotated.

Place the double star system just outside the east edge of the video FOV. Start recording and turn off the telescope motor drive. When the double has drifted outside the opposite (west) side of the FOV, turn off the video recording and turn back on your motor drive. For users with computer controlled telescopes the Appendix offers procedures to turn off the motor drive without losing alignment.

The components should be easily resolved on your video monitor, otherwise *LiMovie* won't be able to resolve them either. If the secondary star does not have sufficient magnitude (brightness), *LiMovie* may not be able to detect it. *LiMovie* relies on stars having sufficient brightness levels against the background to be able to extract an (x,y) position. It is always desirable to use the entire video FOV for the drifts to maximize the no. of video frames used for analysis.

For investigators using GPS time insertion this requires specific hardware that lies in between the video camera and the DVR. More information on GPS time insertion can found from Nugent (2007) and Nugent (2010).

Figure 1 shows a screen shot of *LiMovie* and it's colored aperture rings wrapped around the double star components. As the stars drift, the (x,y) positions of the centroid of the aperture rings for each frame are stored. For any frame, the date and GPS time can be read off the bottom of the video.

LiMovie creates an Excel format CSV file containing the (x,y) data. General instructions for using *LiMovie* are found on its website (Miyashita 2006). Nugent (2010) gives specific instructions on how to use *LiMovie* for this double star method.

Analysis of Observations

Determining the orientation of the video chip offset from the true east-west direction is needed for each individual video. As shown in Figure 2, the drift angle α is the deviation of the camera chip and telescope orientation vs. the true east-west direction.

The drift angle α can be computed in one of two ways. From Figure 2, the triangle ABC is formed from the video chip orientation and the start/stop positions from one component. Using the (x,y) coordinates of these endpoints stored in *LiMovie's* CSV file, the drift angle α is calculated as follows:

$$\alpha = \arccos \frac{AB}{AC} \quad (1)$$

A triangle is formed for each double star component, hence two drift angles are computed. Averaging these provides the drift angle which will later be used as a correction to the position angle.

The second method to determine the drift angle uses a least squares adjustment from the relationship:

$$y_i = mx_i + b \quad (2)$$

where y_i and x_i are the tabular values for either component output by *LiMovie* into the CSV file. In this case the (x,y) data pairs for all video frames are used in the adjustment. The quantity m is the slope of the line AC, where $\tan(\alpha) = m$ and thus

$$\alpha = \arctan(m) \quad (3)$$

In the least squares calculation from equation (2), the quantity b is not needed and can be disregarded. Each double star component produces an independent drift angle from equation (2) and these are averaged

A New Video Method to Measure Double Stars

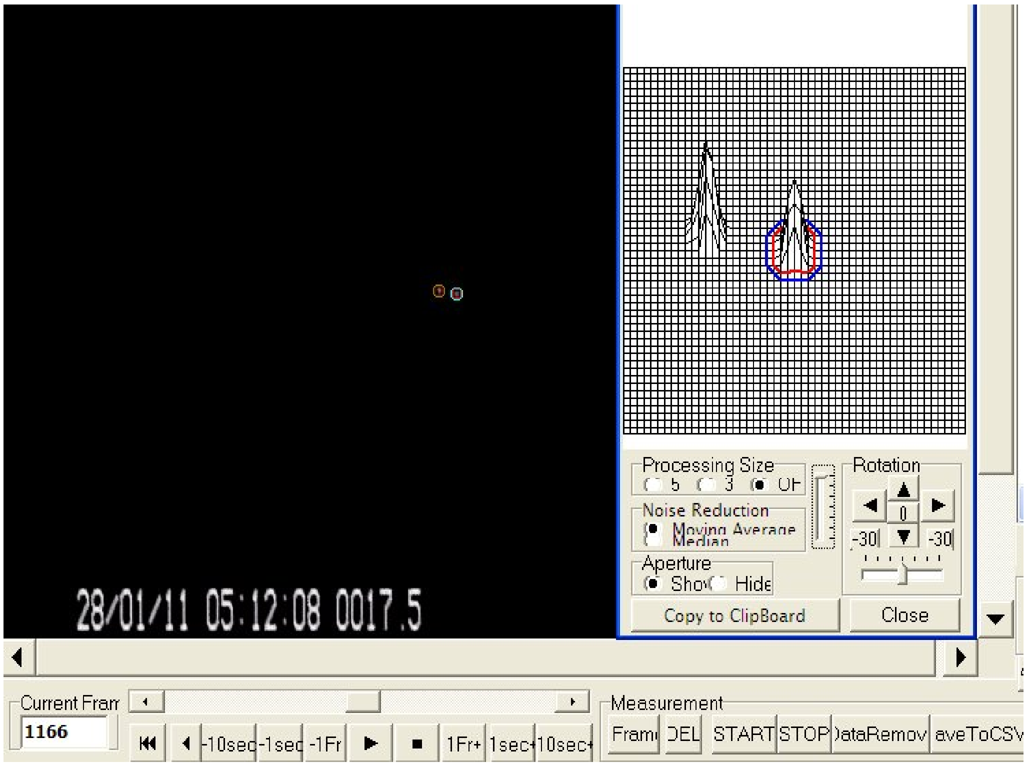

Figure 1. *LiMovie* screen shot. Colored rings are placed around both double star components by the user. A 3-D contour diagram at right shows the relative intensity of each component and its position on the 50-pixel square window grid. At extreme lower left is the video frame no. 1166. GPS time is on the bottom of the video and it reads: January 28, 2011 5h 12min 8.017sec.

for a final result. Thus each video provides a unique drift angle. The authors use the least squares method for all drift angle computations.

The position angle θ is computed using:

$$\theta = \arctan\left(\frac{x_p - x_s}{y_p - y_s}\right) \quad (4)$$

The primary is determined from the brightness comparison of the two stars. With the primary known, the position angle θ derived will then be corrected for proper quadrant.

For each video frame, the separation ρ is computed using the formula:

$$\rho = \left[\sqrt{\left(x_p - x_s\right)^2 + \left(y_p - y_s\right)^2}\cos\delta\right] \quad (5)$$

In equations (4) and (5) the quantities x_p, x_s, y_p

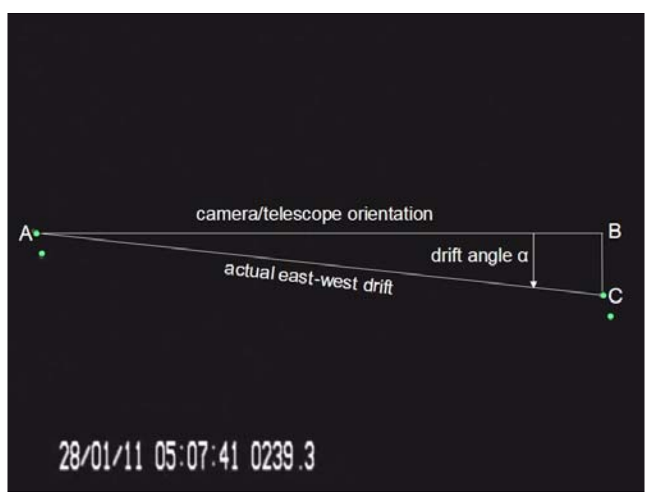

Figure 2: Drift angle determination. Double stars are green and points A, B and C are the vertices of a right triangle. Drift angle *a* is defined by BAC.

A New Video Method to Measure Double Stars

and y_s are the (x,y) positions for the primary and secondary star respectively. The declination of either double star is δ. The equation (5) for separation is not rigorous considering we are measuring the projection of a curved celestial sphere onto a flat video chip. However this formula suffices for small separations in double star astronomy.

The quantity ρ is formula (5) is in units of pixels. To convert it to arc-seconds multiply by a scale factor. The scale factor is calculated from:

$$scalefactor = \frac{(drifttime)15.041068}{\sqrt{\left(x_B - x_E\right)^2 + \left(y_B - y_E\right)^2}} \qquad (6)$$

In equation (6), x_B, x_E, y_B and y_E are the beginning and end points of the drift for a component and "*drifttime*" is the drift duration in units of seconds. The constant "15.041068" is the sidereal drift rate in arcseconds/second. The "*drifttime*" is calculated by knowing the precise start and end time of the drift or the total number of frames of the drift divided by the known frame rate (frames/sec) of the DVR. A scale factor is computed for each double star component and the result is averaged. The units of the scale factor from (6) will be arcseconds/pixel.

An Excel program is available that automatically computes the drift angle, scale factor, position angle and separations for all video frames from the output CSV file produced by *LiMovie*. This Excel program is available upon request from author RLN.

The position angles and separations computed are referred to the Epoch and Equator of date. To convert to a catalogued position (such as the Washington Double Star Catalog), the position angle needs to be precessed to the Equator of the catalogued position and then have proper motions applied. Except for stars with the largest proper motions and doubles close to the celestial pole, these corrections can generally be ignored.

Results and Discussion

Table 2 lists doubles from our data in which the WDS values showed little or no PA and separation movement (≤ 1° and ≤ 0.2") over long periods of time (120+ years). These were chosen to test the validity of this method. Many of these WDS test doubles had zero change in PA and separation over this 120+ year interval. The video drift method's average difference from the WDS values for PA's was 0.2° and for separations was 0.2". If multiple videos were used (N >1 from last Table column) then the values for our PA and separation are weighted averages.

As expected, double stars with larger separations have smaller standard deviations for position angle. Scale factors for videos changed slightly for each drift but remained in the range of 1.6"/pixel for the 9-cm (3.5-inch) Questar and 0.6"/pixel for the 35-cm Meade (14-inch) LX-200.

Table 3 shows the video drift method results for 88 additional double stars in WDS increasing order.

The standard deviations (σ's) of the PA and separations seem larger than those obtained by video stacking and CCD methods. In reality the σ's are a measure of the steadiness of the atmosphere. With a CCD camera that takes, for example, a 10 second exposure, the resultant star images are the sum total of all of the image motions and seeing effects due to the Earth's atmosphere. CCD measuring methods determine the centroid of the central pixel of a single star image. Every 0.033 second the video drift method computes a new PA and separation based on incremental changes of (x,y) positions due to atmospheric fluctuations and the drift. The final PA and separation are averages of all values for all frames during the drift. With this method no video frames are discarded.

For 101 double stars from Table's 2 and 3, Table 4 summarizes the σ's for the video drift method plus comparison summary of PA and separation to the WDS catalog.

The following subsections describe sources of error that should be considered when utilizing this technique.

Precession and Proper motions

To compare results with values from the WDS, one should apply the proper motions of the components and precess your RA, DEC positions to match the date of the published observation. Generally speaking, proper motions are very small and can be neglected and so can precession unless the double star system is close to one of the celestial poles. The vast majority of the entries in the WDS were made in the past 10 years, so precession and proper motions can usually be neglected.

Aberrations and distortions of the optical system

No optical system is perfect. All telescopes have at least some aberrations and distortions that will affect the position of the optical images. If we were seeking *absolute* RA, DEC positions of the target compared to a star catalog's reference frame, then we

(Continued on page 193)

Table 2: Comparison of video drift method to the WDS catalog. N is the number of separate video drifts used to obtain the result. If more than 1 video was used for the result (N>1), PA and separation values represent weighted averages from their individual standard deviations.

WDS	PA	σ-PA	WDS PA	Δ-PA (°)	SEP	σ-SEP	WDS SEP	Δ-SEP (")	DATE	No. video frames	N
00137+4934	165.2	0.9	165	0.2	20.2	0.22	20.2	0	2010.975	1093	1
02408+1500	312.2	1.1	312	0.2	22.5	0.49	22.7	0.2	2010.896	720	1
03021+0005	139.9	3.8	139	0.9	7.9	0.63	8	0.1	2010.896	701	1
03084-2410	217.7	1.3	218	0.3	25.8	0.56	25.7	0.1	2010.975	772	1
03311+2744	233	0.3	233	0	44.4	0.23	44	0.4	2010.998	1493	2
03313+2734	269	0.7	269	0	11.5	0.21	11.3	0.2	2010.992	1589	2
03383+4448	96	1.6	96	0	41.3	0.65	41	0.3	2011.085	2624	1
03425+0202	182.8	2.1	183	0.2	11.3	0.66	11.8	0.5	2011.003	706	1
04009+2312	127	2.3	127	0	7.4	0.31	7.4	0	2011.092	794	1
04380-1302	172.3	2	172	0.3	12.5	0.52	12.3	0.2	2011.104	740	1
05193-1831	18.5	1.3	19	0.5	39.4	0.93	39	0.4	2011.077	2052	1
06090+0230	114	1.8	114	0	29.2	0.98	29.1	0.1	2011.151	1941	1
08397+0546	30	0.8	30	0	26.3	0.39	25.9	0.4	2011.105	1961	2
AVERAGES		1.5		0.2		0.52		0.2			

Table 3: Results for 88 double stars using the video drift method.

WDS	Discoverer	magnitudes	PA°	σ-PA	Sep"	σ-Sep	date	# of video frames	N	Notes
00027+5958	ARG 47	9.49 10.3	290	3.9	9.9	0.35	2010.844	2356	1	
00080+3123	STTA256AB	7.1 7.3	113	0.2	111.4	0.32	2010.842	2827	2	
00116-0305	STF 8	7.84 9.26	292	2.7	8.4	0.39	2010.975	719	1	
00148+6250	STF 10AB	8.04 8.55	176	1.2	17.6	0.37	2010.975	1588	1	
00275+1602	STT 10AB	6.46 10.19	239	0.4	114.9	1.00	2010.847	2003	1	
00314+3335	HJ 5451	6.01 9.34	86	0.4	56.3	0.31	2010.842	3106	2	
00369+3343	H 5 17AB	4.36 7.08	175	0.6	37.2	0.34	2010.842	3219	2	
00403+2403	STF 47AB	7.25 8.82	205	2.5	17.0	0.65	2010.847	2255	1	
00405+5632	H 5 18AD	2.35 8.98	281	0.4	71.2	0.21	2010.840	3373	2	
00491+5749	STF 60AB	3.52 7.36	320	1.8	13.0	0.20	2010.840	3782	2	
01129+3205	STF 98AB	7.02, 8.14	249	1.0	19.9	0.35	2010.975	821	1	
01284+0758	S 398	6.34 8.02	100	0.3	68.7	0.28	2010.882	1244	2	
01332+6041	STF 131AB	7.3 9.9	144	2.5	14.0	0.31	2010.844	1566	1	
01374+5838	STT 33AB	7.26 8.96	77	1.4	26.9	0.33	2010.844	2697	1	
01423+5838	HJ 1088AB	6.34 9.79	169	1.9	20.3	0.32	2010.844	2609	1	

Table 3 continued on next page.

A New Video Method to Measure Double Stars

Table 3 (continued): Results for 88 double stars using the video drift method.

WDS	Discoverer	magnitudes		PA°	σ-PA	Sep"	σ-Sep	date	# of video frames	N	Notes
01513+6451	STF 163AB	6.8	9.13	37	0.6	34.8	0.22	2010.836	1581	1	
01535+1918	STF 180AB	4.52	4.58	2	0.5	7.5	0.16	2010.905	2775	2	
02038-0020	H 5 102AB	5.96	10.77	194	0.6	43.6	0.38	2010.882	1403	2	
02128-0224	STF 231AB	5.72	7.71	235	0.8	16.9	0.25	2010.883	1529	3	
02137-0302	H 6 110	7.36	10.38	142	0.3	79.8	0.37	2010.882	1492	2	
02162-2100	HJ 3491	9.43	9.97	288	3.1	6.8	0.40	2010.896	754	1	1
02174+2845	STF 239	7.09	7.83	212	1.0	14.0	0.26	2010.896	802	1	
02186+4017	STF 245AB	7.26	8.03	293	2.1	11.1	0.49	2010.896	907	1	
02193-0259	H 6 1AC	6.65	9.59	68	0.2	122.8	0.43	2010.868	627	1	
02268+1034	STTA 27AB	6.72	8.31	31	0.2	74.2	0.27	2010.882	1397	1	
02305+0504	PLQ 31	10.0	11.02	328	1.3	26.7	0.67	2010.896	685	1	
02315+0106	STF 274	7.52	7.62	220	0.7	13.6	0.18	2010.924	2743	3	
02359+0536	STF 281	4.97	9.08	80	2.2	7.3	0.34	2010.868	269	1	
02572-0034	STF 330	7.25	9.06	192	2.6	8.9	0.47	2010.868	684	1	
03030-0205	STF 341	7.57	9.97	222	1.8	8.9	0.27	2010.882	1474	2	
03066+2038	STF 350	8.81	10.5	120	2.0	16.4	0.70	2010.896	723	1	
03112+2225	H 5 117AB	8.58	10.59	321	0.9	33.8	0.53	2010.975	750	1	
03143+2257	STF 366AB	6.9	10.43	34	0.5	42.4	0.36	2010.937	2007	2	
03203+1944	STF 376	8.33	8.44	252	2.6	8.1	0.52	2010.975	416	1	
03322+1133	AG 68	6.79	9.87	248	1.7	16.9	0.65	2010.871	819	1	
03405+0508	STF 430AB	6.77	9.63	56	0.9	26.6	0.49	2010.871	764	1	
03412-0517	HJ 2201	8.32	10.70	41	1.3	38.3	0.77	2011.003	692	1	
03457-1320	STF 451	8.97	10.22	324	3.7	20.0	1.00	2010.899	753	1	
03483+1109	STF 452	5.06	9.77	59	2.3	9.0	0.46	2010.871	610	1	
03485+0136	STF 456	9.19	10.09	122	1.5	22.0	0.61	2011.003	704	1	
03495+1255	AG 74	9.72	10.80	197	4.0	11.1	0.80	2011.003	748	1	
04314+4000	STF 552	6.78	7.18	117	5.2	9.0	0.55	2011.085	2388	1	
04363+4722	S 451	7.59	7.91	202	0.5	55.7	0.42	2011.104	1009	1	
04436-0848	STF 590	6.74	6.78	318	3.0	9.2	0.66	2011.091	251	2	2
04549+1009	ENG 19AB	4.66	8.95	253	0.2	172.0	0.59	2010.942	1011	1	
04590+1433	SHJ 49AB	6.06	7.43	306	0.7	39.9	0.53	2011.091	680	2	
05006+0337	STF 627AB	6.59	6.95	261	1.1	21.4	0.46	2011.091	694	2	
05020+0137	STF 630A-BC	6.50	7.71	49	1.7	14.4	0.44	2011.104	711	1	
05296+0309	STF 721A-BC	7.09	9.14	149	1.3	25.7	0.59	2010.942	1208	1	
05364+2200	STF 742	7.09	7.47	275	1.9	4.1	0.22	2011.115	469	1	
05387-0236	STF 762AB	3.73	6.56	84	3.5	12.0	0.61	2011.074	1904	1	

Table 3 continued on next page.

A New Video Method to Measure Double Stars

Table 3 (concluded): Results for 88 double stars using the video drift method.

WDS	Discoverer	magnitudes		PA°	σ-PA	Sep"	σ-Sep	date	# of video frames	N	Notes
06156+3609	STF 872AB	6.89	7.38	216	4.7	11.4	0.83	2011.151	2305	1	
06238+0436	STF 900AB	4.42	6.64	31	3.7	12.3	0.84	2011.151	1978	1	
06323+1747	STF 924AB	6.31	6.88	211	0.8	20.2	0.28	2011.134	2616	2	
06341+2207	S 524AB	6.31	6.88	244	1.0	53.7	0.79	2011.153	2036	1	
06412-0759	S 532AC	6.31	6.88	189	6.2	11.1	1.34	2011.153	1837	1	
07120+2217	STF1035	8.09	8.38	41	5.8	8.9	0.85	2011.153	1295	1	1
07256+2030	STF1083	7.32	8.13	47	1.5	6.7	0.16	2011.114	1100	1	
07276-1830	S 550	6.89	7.63	116	1.5	39.7	1.06	2011.153	2002	1	
07277+2208	S 548AC	6.98	8.89	277	0.7	35.3	0.51	2011.112	1310	2	
07366-1429	STF 855AB	6.92	7.30	305	7.3	7.2	0.84	2011.170	690	1	
07444+2424	STT 179	3.70	8.20	243	2.2	7.9	0.38	2011.112	308	2	
07455-1441	STF1138AB	6.00	6.73	340	2.8	16.7	0.86	2011.170	2038	1	
07490+0040	STTA 88AB	7.48	8.90	5	0.6	57.6	0.65	2011.107	727	1	1
08056+2732	STF1177	6.69	7.41	350	3.4	3.6	0.24	2011.112	589	1	
08065-0915	STF1183AB	6.20	7.77	328	1.6	30.7	0.88	2011.170	1970	1	
08248+2009	STT 191	7.41	8.62	192	0.7	38.1	0.51	2011.115	1363	1	
08259+0734	H 5 109	5.22	10.23	345	1.7	30.0	0.80	2011.104	623	1	
08267+2432	STF1224A-BC	6.94	7.53	50	3.7	5.5	0.36	2011.099	295	1	
08358+0637	STF1245AB	6.20	7.77	24	2.5	10.2	0.46	2011.087	2768	2	
08399+1933	S 571AC	7.31	7.47	157	1.2	45.3	1.04	2011.170	2052	1	
08433+2128	ENG 38AB	4.65	10.2	66	0.2	115.4	0.34	2011.107	1724	2	
08520+2543	STTA 96AB	7.65	8.45	314	0.6	50.0	0.45	2011.115	1302	2	
08526+3228	S 583AC	5.66	10.2	24	0.3	77.6	0.40	2011.099	735	1	
08540+0825	STT 195	7.73	8.33	139	1.9	9.8	0.37	2011.134	2649	2	
09066+0249	STF1309	8.48	8.38	274	1.8	11.7	0.46	2011.107	726	1	
09285+0811	H 4 47	5.76	11.12	79	1.4	25.2	0.55	2011.104	1210	2	
09320+0943	SHJ 107	5.22	9.3	75	1.2	38.0	1.40	2011.104	1185	1	
09448+1940	HJ 470	10.2	10.33	212	1.9	22.8	0.64	2011.107	424	1	
18078+2606	STF2280AB	5.81	5.84	183	3.2	14.3	1.10	2010.767	2182	1	
18465-0057	STF2379AB	5.88	7.02	121	4.1	12.7	0.82	2010.767	1863	1	
19050-0402	SHJ 286	5.52	6.98	210	1.3	41.5	1.06	2010.756	1166	1	
19307+2758	STFA 43AB	3.19	4.68	54	1.4	34.8	0.71	2010.715	1298	1	
20467+1607	STF2727	4.36	5.03	266	4.8	8.7	1.02	2010.718	777	1	
21580+0556	STF2848	7.21	7.73	56	4.7	10.8	0.83	2010.825	1831	1	
23191-1328	STF2998AB	5.27	6.97	353	3.6	12.1	0.87	2010.825	2018	1	
23460-1841	H II 24	5.65	6.46	137	6.3	6.8	0.85	2010.825	2076	1	
23530+1155	STF3044	7.27	7.91	282	2.5	19.3	0.68	2010.847	2115	1	

Table 3 Notes:

1. very noisy video yet good result
2. only 8.3sec video clip usable

A New Video Method to Measure Double Stars

(Continued from page 189)

Table 4: Statistical results from Tables 2 and 3 and a comparison to the WDS catalog.

	Position angle (deg)	Separation (arc-second)
Average std. dev. using video drift method	1.74	0.54
Avg. difference from WDS catalog values	0.5	0.30

would have to model for distortions and aberrations since these would affect the actual positions of the stars. However we are only seeking *relative* quantities here, the separation between the stars and their relative position angle to each other. With the double star components so close to each other any such distortions/aberrations will affect both component images simultaneously and will generally cancel out.

Focal reducers/barlows

In certain circumstances focal reducers are useful in providing a wider FOV which allows a longer drift time, which provides more (*x*,*y*) data pairs to average into the results. A focal reducer increases the apparent brightness of stars to aid in measuring fainter doubles. A barlow lens may be necessary to resolve closer pairs. Focal reducers and barlows have the potential to add distortions and aberrations. Always opt for the least amount of glass between the double stars and your video camera if possible.

Gnomonic projection

The celestial sphere is curved and the video camera chip is flat. The projection of the curved sky FOV onto the flat video chip normally has a mathematical model to account for this. This is done for CCD astrometry but can be ignored here. The small separations for doubles stars (usually under 2 arc-minutes) can be approximated accurately by a flat (*x*,*y*) coordinate system on the surface of your video camera chip.

Scale Factor

A scale factor is computed for each run. It will be different from one drift run to another due to slight instrument/flexture changes, differential refraction and the declination of the components.

The video drift method's results are optimized when the telescope has reached thermal equilibrium and the components are within 1 hour (15°) of your local meridian. At or near the celestial meridian reduces the amount of air the starlight passes through.

Compared to CCD astrometry and other video methods for measuring double stars, the video drift method does not require any dark frames, flat fielding, or any positional information from reference stars from a star catalog. No special cooling or shielding of the video camera is required. There is no longer a need for a separate series of exposures to determine the drift angle orientation from the final measurement image. Investigators simply make a short video, then use the program *LiMovie* to extract the (*x*,*y*) positional information and with a few clicks copy this data into the Excel program for immediate results.

The video drift technique presented here has been shown to be a useful independent method for measuring double stars.

Acknowledgements

The authors would like to thank Kazuhisa Miyashita, *LiMovie's* author for helpful suggestions in the early part of this research. Mr. Miyashita even wrote a custom version of the program early on. This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

Appendix

Meade LX-200 users who wish to use this method need not shut down the telescope to stop/start the motor drive. Use these keystrokes:

-Setup
-Utilities
-Telescope
-Tracking Rate
-Custom
-Enter Rate Adj.

Under "Enter Rate Adj." input -999 to stop the motor drive and then +000 to restart it at the sidereal rate. Another function, "Sleep Scope", is a power saving feature and shuts down the Autostar and telescope (but keeps the internal clock running) without forgetting the alignment. Check the LX-200 user manuals for additional details.

NexStar users can use this keystroke method to turn the motor drive off and not have to re-align:

-NexStar Ready
Menu: Tracking
Tracking: Mode
Mode: Off

Press UNDO to return to tracking rates, Alt-Az, EQ North or EQ South.

References

Miyashita, K. 2006, *LiMovie, Light Measurement Tool for Occultation Observation Using Video Recorder*, http://www005.upp.so-net.ne.jp/k_miyash/occ02/limovie_en.html

Chasing the Shadow, The IOTA Occultation Observer's Manual, Nugent, R., ISBN 978-0-615-29124-6, International Occultation Timing Association, 2007, http://www.poyntsource.com/IOTAmanual/Preview.htm

Nugent, R., 2010, *A New Video Method to Measure Double Stars*, http://www.poyntsource.com/Richard/double_stars_video.htm

Ernest Iverson is a retired aerospace engineer and avid amateur astronomer. He has been interested in double stars for over 15 years.

Richard Nugent holds BS and MS degrees in astronomy from the University of South Florida, and since 1998 is the Executive Secretary of the International Occultation Timing Association.