Double Star Measures Using the Video Drift Method - IV

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: Position angles and separations for 240 multiple star systems are presented using the video drift method. The drift method generates a Cartesian (x,y) coordinate pair for the primary and companion star for each video frame during the drift. Position angle and separation are calculated from these coordinates. Most doubles had multiple drifts observed over several nights resulting in 1,000's of (x,y) pairs analyzed per system. Several systems lacked measurements since the early 1900's or had less than 10 measurements since their discovery. The video drift method provides high systematic accuracy.

Introduction

In our first paper, Nugent and Iverson 2011, and subsequent papers, Nugent and Iverson 2012 and Nugent and Iverson 2013, (hereinafter called Papers I, II, and III) we described a new video method that computes both the position angle and separation for a double star. A short video clip of the multiple star system drifting across the field of view is used by the freeware program *Limovie* (Miyashita, 2006) to capture 100's to 1,000's of (x,y) positions for each component. Although *Limovie* was originally written to measure the change in light levels during an occultation, it also produces a table of Cartesian (x,y) coordinates for both components along with the brightness levels for each video frame. *VidPro*, an Excel program written by co-author RLN, reads the (x,y) coordinate data and computes a simultaneous solution for the position angle, separation and other statistical quantities for each double star system.

Paper I outlined the theory behind the video drift method and compared the results to several doubles that had no change in PA and separation for 120+ years. A significant advantage of this method is that data collection and subsequent data analysis is almost completely automated with little human interaction. Since the method does not rely on visual measurements, it is not plagued by personal bias/personal error, or optical axis problems with eyepieces. This includes aberrations and distortions from the edge to the center of the field of view found in some eyepieces and the misalignment of eyepieces with the optical axis of the telescope.

Unlike other video/CCD methods, no calibration doubles are needed to determine plate scale, no line is drawn to determine the east-west direction, no star catalog is needed since no "plate adjustment" is performed, and no video frames are discarded. Each double star drift is self calibrating (see discussion below on pre-calibration). The *VidPro* program computes a unique scale factor, an offset from the east- west direction compared to the camera's pixel array, and standard deviations for both position angle and separation for each drift. The offset of the pixel array alignment of the video camera's chip from the true east-west direction (drift angle) is calculated using the method of least squares to an accuracy of better than 0.02°. Paper II provided the formulas for determining a unique PA and separation from a simultaneous solution of all the (x,y) pairs obtained from all the video drift runs made for a particular double star system.

Methodology

Preference was given to multiple star systems where the WDS lacked measurements for at least the past 10 years and had less than 10 previous measurements. This criterion applies to many of the multiple star systems measured at the epoch of their measurement. In some cases, where one component of a complex system meets this requirement, all of the other components were also measured for completeness even though they had been well measured in the past. Eleven systems lacked measurement since 1899-1933. The faintest system measured had primary/secondary magnitudes of +13.2, +14.4.

Calibration

During the preparation of our previous papers (Papers I, II, and III) we noticed that the measured values of some widely separated doubles often had noticeable deviations from the WDS catalog value. If the deviation seemed unusual we held back that measurement pending further investigation and additional measurements. These differences were typically not noticeable for double stars with separations less than 100 arc seconds.

This issue lies largely with the recording system's storage/compression method into a memory card or to a computer's hard drive. The telescope camera system also introduces small optical effects (aberrations, distortions, gnomonic projection) into the field of view recorded. However, for determining relative positions between two stars and the small field of view associated with double stars these optical effects can generally be ignored.

Author Nugent uses a digital video recorder (DVR) that stores videos onto a memory card. Author Iverson uses an analog 8mm video tape recorder that exports the video via a fire wire port into a computer. The recording methods used by the authors (all recording methods will have these issues) skew the video format slightly as part of the compression scheme before copying the video into the storage medium. As a result, the field of view (image aspect ratio) is not a perfect match of the sky but slightly distorted.

To compensate for this we calibrated each recording system by adjusting the image aspect ratio until it matched the real sky. This was done forcing Limovie to open each video using an Avisynth video editor script (Rudiak-Gould, 2008) containing the filter "LanczosResize". Several long term stable WDS doubles (as verified by requesting the full observational catalog entry from the USNO) and from PA/Sep determined directly from RA, DEC coordinates in recent star catalogs from the VisieR database were used to determine the correct aspect ratio.

To do this we picked a convenient, standard video aspect ratio size of 640x480 pixels. Holding the horizontal scale (640 pixels) constant, we then varied the vertical scale to match the sky. Once determined, the aspect ratio was adjusted slightly by trial and error to give the best average data reduction performance. For our 14" SCT's the size that closely matched the sky was 640x510 for Nugent's system and 640x465 for Iverson's system. This calibration procedure only needs to be done once, and is valid until the hardware in the video path changes.

A common practice is to check the accuracy of new measurements by comparing them to the WDS summary catalog value. Unfortunately this is not a valid test of accuracy. The published WDS value is just the most recent value entered into the catalog. Although these measurements are typically very good, it should be pointed out that the last entry can have a significant error associated with it. False assumptions about the accuracy of a new measurement can also occur when the last catalog entry is several years old or the double star is undergoing rapid change.

The telescope equipment used and scale factors are summarized in Table 1. Results of the measurements made using the video drift method are given in Table 2.

(Continued on page 222)

Table 1. Telescopes used in this research. Scale factors vary slightly due to the declination of the doubles.

Telescope	Aperture	Focal Length	Scale Factor
Meade LX-200	14″ (35 cm)	3350mm f/10	0.6″/pixel
Questar	3.5″ (9 cm)	1299mm f/14.4	1.6″/pixel
Celestron Refractor	6″ (15.2 cm)	1220mm f/8	1.4″/pixel (barlow)

Double Star Measures Using the Video Drift Method - IV

Table 2. Results of 240 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	# x-y pairs	Mag Pri	Mag Sec	Drifts	Nights
00024+1047	BGH 1AB,C	300.6	0.1	63.2	0.1	2012.753	3653	8.80	8.55	6	2
00030+0723	HJ 3233AC	324.6	0.3	82.9	0.6	2014.008	1148	10.70	10.2	2	1
00031+0816	STF3054	181.5	0.2	33.5	0.1	2012.751	4226	8.13	9.05	6	2
00052+3020	STF3058	52.2	0.7	12.6	0.1	2012.858	2386	7.81	9.21	3	1
00150+0849	STF 12	147.0	0.6	11.3	0.1	2012.751	4180	6.06	7.51	6	2
00176+1300	HJ 3	262.1	0.6	12.1	0.1	2012.753	4201	9.97	10.24	6	2
00180+0931	AG 1	210.9	0.6	11.8	0.1	2012.753	4237	9.21	10.07	6	2
00239+2930	STF 28AB	224.3	0.2	32.9	0.1	2012.863	4452	8.32	8.55	6	2
00320+2831	S 386	17.7	0.2	43.1	0.1	2012.863	4618	8.92	8.94	6	2
00399+2126	STF 46	198.0	1.7	6.3	0.2	2012.841	2110	5.56	8.49	3	1
00477+1253	STTA 8AB	125.1	0.2	44.3	0.1	2012.753	3919	8.97	9.25	6	2
00499+3027	STTA 9AB	244.3	0.1	116.9	0.1	2012.863	3369	7.75	8.81	6	2
00531+6107	BU 497AB	169.6	0.1	144.6	0.1	2012.841	3655	4.85	9.79	3	1
00546+3910	STF 72	173.8	0.7	22.7	0.2	2012.863	2698	8.38	9.31	3	1
00556+3433	HJ 629AC	256.8	0.1	66.2	0.1	2012.863	4235	9.32	8.86	6	2
01438+5553	STT 35	92.1	0.8	14.4	0.1	2012.841	3379	6.98	10.81	3	1
01581+4123	S 404AB	82.7	0.5	28.9	0.2	2012.863	2569	7.64	9.74	3	1
01596+6437	HJ 1100	309.1	0.3	43.1	0.1	2012.841	4181	5.28	11.99	3	1
02103+3322	STF 219	184.6	1.0	11.4	0.2	2012.863	2499	8.03	8.89	3	1
02135-2546	HJ 2120	259.1	0.9	49.5	0.7	2014.008	1258	10.26	10.53	2	1
02157+1046	STF 237AB	237.2	0.9	14.5	0.2	2014.008	1300	9.54	9.94	2	1
02157+1046	STF 237AC	275.0	0.5	72.7	0.5	2014.008	972	9.54	11.87	1	1
02157+1046	HJL1014AE	4.9	0.2	167.4	0.5	2014.008	1263	9.54	10.81	2	1
02157+1046	HJL1013BE	8.7	0.1	176.6	0.5	2014.008	1280	9.94	10.81	2	1
02166-0516	A 445AC	131.5	0.7	69.1	0.9	2014.008	1111	9.95	11.31	2	1
02180+1958	GWP 294	7.2	0.9	74.9	0.9	2014.008	1372	11.2	11.4	2	1
02187+3429	STF 246	122.4	1.3	9.6	0.2	2012.863	2510	7.82	9.26	3	1
02371-1112	TOK 232AB	233.8	0.1	187.3	0.3	2014.019	907	8.11	11.84	2	1
02383+3744	BU 305AC	205.5	0.6	19.4	0.1	2013.882	1844	6.16	11.37	2	1
02383+3744	WAL 18AD	78.1	0.4	48.7	0.3	2013.882	1637	6.16	12.13	2	1
02389-2810	HJ 3518AB	15.8	1.1	13.3	0.3	2014.019	1683	9.38	11.20	2	1
02389-2810	HJ 3518AC	199.6	0.6	30.7	0.3	2014.019	1654	9.38	11.6	2	1
02407+2704	STF 289	0.3	0.3	28.4	0.2	2012.841	2239	5.30	9.56	3	1
02438-2754	BU 261AC	133.3	0.3	68.7	0.3	2014.019	1467	7.86	10.51	2	1
02439-2758	HDO 60	164.4	1.6	8.7	0.3	2014.019	1684	10.31	12.1	2	1
02501-0616	J 1453AB	200.8	1.7	9.2	0.3	2014.022	1499	11.1	10.7	2	1
02501-0616	J 1453AC	68.7	0.6	38.5	0.4	2014.022	1389	11.1	13.0	2	1
02508-1212	UC 826	163.5	0.7	28.7	0.4	2014.022	1517	11.8	12.9	2	1
02519+2835	AZC 27	16.4	0.9	27.5	0.4	2014.022	1685	11.3	14.0	2	1
02524-1546	LDS5398	105.0	0.3	114.8	0.6	2014.022	1103	12.8	13.94	2	1
02532-1007	GWP 385	22.2	0.7	31.3	0.3	2014.022	1471	10.5	12.4	2	1
02537-1421	GAL 80	154.7	3.1	5.6	0.4	2014.022	1537	11.18	11.87	2	1
02539-3220	PRO 11	168.2	1.9	6.5	0.2	2014.019	1770	10.15	11.68	2	1
02558-1606	GWP 398	56.2	0.3	81.4	0.4	2014.022	1274	12.0	13.8	2	1

Table 2 continues on next page.

Table 2 (continued). Results of 240 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	# x-y pairs	Mag Pri	Mag Sec	Drifts	Nights
02560-1607	ARA 16	232.9	2.8	7.9	0.4	2014.022	1535	13.1	13.4	2	1
02565+0039	BAL 960	215.5	2.6	8.6	0.4	2014.005	1483	12.57	12.57	2	1
02577-2858	HJ 3543AB	266.1	2.2	9.1	0.5	2014.022	1648	10.5	10.9	2	1
02577-2858	HJ 3543AC	65.0	1.8	17.1	0.4	2014.022	1617	10.5	12.3	2	1
02577-2858	ABH 17AD	263.6	0.4	84.8	0.6	2014.022	1296	10.5	13.7	2	1
03074+1753	HJL1020	358.8	0.3	104.2	0.6	2014.008	1348	6.10	10.42	2	1
03079-2813	LDS 86AB	208.3	0.4	66.3	0.5	2014.019	1556	10.45	12.63	2	1
03079-2813	HDS3408AC	96.3	0.6	37.4	0.4	2014.019	1525	10.45	11.68	2	1
03088+2339	POU 247	139.3	1.7	13.4	0.4	2014.019	1604	11.94	12.0	2	1
03093+2046	HJL1021	239.3	0.2	122.2	0.4	2014.008	1464	6.54	8.77	2	1
03107-2007	CBL 120	312.9	0.7	59.0	0.7	2014.008	1213	7.6	10.5	2	1
03125-3449	LDS 89	329.4	0.6	52.8	0.5	2014.019	1706	10.59	13.2	2	1
03163-2010	ARA 834	203.4	2.2	9.2	0.3	2014.022	1587	10.7	12.0	2	1
03168-1956	HJ 3561	152.2	1.0	25.7	0.4	2014.022	1548	10.10	13.9	2	1
03180-1744	ARA 321	67.4	3.2	8.0	0.5	2014.022	1524	13.0	13.0	2	1
03184-2734	BVD 33	301.0	0.7	24.6	0.3	2014.019	1610	10.33	11.18	2	1
03195-2815	UC 981	248.3	1.4	20.4	0.5	2014.019	1628	13.2	14.4	2	1
03207+1736	HJ 3246AB	193.6	0.2	158.7	0.6	2014.008	623	9.96	11.35	1	1
03220-3349	BVD 35	239.6	1.2	18.1	0.3	2014.019	1749	11.47	11.64	2	1
03222-0020	UC 993	304.6	0.6	45.0	0.5	2014.022	1359	10.8	13.6	2	1
03227-2258	UC 996	130.4	1.0	15.0	0.3	2014.022	1576	9.8	14.4	2	1
03234-2253	ARA1975	246.6	2.3	10.8	0.4	2014.022	1588	12.26	13.4	2	1
03240-2613	HJ 3572	94.4	1.5	20.8	0.6	2014.008	1368	8.24	8.53	2	1
03247-2131	HJ 3574	85.8	2.2	16.4	0.9	2014.022	727	11.76	14.4	1	1
03263-3057	LDS5426	36.2	0.8	32.1	0.4	2014.019	1661	11.83	13.7	2	1
03277-3215	HJ 3578	41.2	0.7	29.5	0.3	2014.019	1698	9.2	12.6	2	1
03282-1335	GAL 330	81.8	2.1	9.5	0.4	2014.019	1513	11.63	12.6	2	1
03305-1752	B 2517AB	176.1	1.2	25.1	0.6	2014.022	1568	9.74	12.9	2	1
03323-0705	STF 411AB	87.9	0.7	18.8	0.2	2014.019	1434	7.36	9.19	2	1
03323-0705	STF 411AC	31.4	0.4	44.2	0.3	2014.019	1354	7.36	11.2	2	1
03336-0725	CLL 2	138.9	0.2	66.3	0.3	2014.019	1317	7.61	7.96	2	1
03344-1940	GWP 480	1.3	0.7	36.2	0.7	2014.022	1564	12.2	13.6	2	1
03346-1613	GAL 332	235.2	1.0	20.9	0.4	2014.022	1506	10.68	11.99	2	1
03363-1020	UC 1032	84.5	1.1	29.1	0.6	2014.022	696	12.2	13.1	1	1
03459+2433	HJL1026AB	129.8	0.2	149.7	0.4	2013.121	5382	5.75	6.42	3	1
03484-2025	HJ 3594	114.2	1.1	9.7	0.3	2014.005	1545	9.1	14.5	2	1
03556+2419	POU 318	335.2	2.6	7.5	0.3	2014.005	1623	11.83	12.6	2	1
04072-3118	RSS 70	2.0	1.1	13.1	0.2	2014.019	1729	10.22	13.0	2	1
04157-3033	B 2568A,BC	219.2	0.3	105.1	0.7	2014.019	1421	8.93	13.74	2	1
04297-1043	GAL 134	210.6	1.5	14.3	0.4	2014.022	1479	9.77	12.3	2	1
04368-1736	ARA 154	304.5	3.2	5.0	0.4	2014.005	1554	11.98	14.4	2	1
04429+1843	LDS2266AB	102.8	0.1	142.3	0.3	2013.038	1853	7.18	10.20	4	1
04543+0722	STF 612AC	264.2	0.5	59.8	0.5	2014.005	1231	8.33	14.1	2	1
05210+3805	SEI 202	114.5	2.2	7.6	0.2	2013.199	2789	10.5	11.0	3	1

Table 2 continues on next page.

Double Star Measures Using the Video Drift Method - IV

Table 2 (continued). Results of 240 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	# x-y pairs	Mag Pri	Mag Sec	Drifts	Nights
05246+0149	S 479AB	220.6	0.9	46.2	0.8	2013.121	5132	8.30	8.94	3	1
05246+0149	S 479AC	36.3	0.2	157.5	0.5	2013.121	5003	8.30	4.84	3	1
05252-1119	STF 710AB	196.2	0.9	10.2	0.3	2013.200	3725	8.61	8.91	5	1
05309+0137	BAL1294AB	52.5	1.9	8.9	0.3	2013.036	718	8.79	10.69	1	1
05322+1703	STF 730	140.8	1.7	9.6	0.3	2013.121	3315	6.06	6.44	3	1
05353-0520	HJ 1157EF	305.8	3.7	8.5	0.6	2014.005	1232	12.8	12.8	2	1
05382+2429	POU 764	54.3	2.3	21.0	0.8	2014.005	1565	12.02	12.2	2	1
05404-2151	ARA1278	322.0	2.2	9.1	0.4	2014.005	1539	12.08	12.4	2	1
05410+3913	ALI1057	312.4	1.8	13.7	0.3	2014.005	1891	11.47	11.8	2	1
05429+0001	STF 782AB	305.3	0.2	47.1	0.1	2012.956	3718	8.60	8.83	6	2
05485-1322	STF 801A-BC	327.5	0.6	26.8	0.4	2013.037	2035	7.49	10.1	3	1
05506-0126	STF 809AC	91.3	0.3	24.3	0.1	2012.956	3865	8.08	9.15	6	2
05575+0024	BU 1189AB,C	194.8	0.1	55.4	0.1	2012.956	3943	8.01	8.32	6	2
06116-0046	STF 871	306.4	1.0	7.2	0.1	2012.956	3906	8.84	9.38	6	2
06137-0019	BAL 686	5.9	0.7	10.1	0.1	2012.956	4132	8.83	10.51	6	2
06212+2108	S 513AB	258.5	0.1	59.2	0.1	2013.049	3787	7.31	8.92	6	2
06267+0027	STF 910A,BC	151.5	0.1	66.0	0.2	2012.956	3782	6.99	8.11	6	2
06278+2047	SHJ 70AB	202.3	0.3	24.6	0.1	2013.121	4389	6.65	8.18	6	2
06290+2013	STTA 77AB	329.8	0.1	111.3	0.2	2013.159	3692	4.10	8.01	6	2
06321+0130	BAL1315	139.9	0.6	12.7	0.1	2012.956	4076	9.89	10.45	6	2
06478-1143	STF 970	128.4	0.4	20.1	0.1	2013.066	4107	9.11	9.67	6	2
06585-1126	STF1004	90.9	0.2	20.3	0.2	2013.066	2023	8.06	9.65	3	1
06594+2514	STF1000AB,C	67.7	0.3	22.2	0.1	2013.121	4388	8.09	9.02	6	2
07027+2249	POU2324	47.8	4.6	15.4	1.2	2013.200	773	14.3	15.6	1	1
07146-1018	STF1052	21.8	0.4	19.8	0.1	2013.066	4189	8.76	9.19	6	2
07201+2159	STF1066	229.9	1.3	5.6	0.1	2013.195	1228	3.55	8.18	3	1
07287+2439	STTA 85AB	20.0	0.1	64.0	0.1	2013.121	4276	7.65	8.95	6	2
07320-0841	STF1111	221.4	0.4	19.6	0.2	2013.066	4128	8.87	9.19	6	2
07410+2148	STF1124AB	325.8	0.4	19.2	0.1	2013.049	4425	9.11	9.28	6	2
07534+2050	HJ 432AB	277.0	0.5	14.9	0.1	2013.049	4355	9.86	9.98	6	2
07549+0039	BAL1122	89.1	1.5	10.7	0.5	2013.255	2184	10.8	10.9	3	1
08086-0259	STF1190AC	246.1	0.2	64.5	0.2	2013.159	1659	4.46	9.68	3	1
08102+2551	BUP 111AB	49.0	0.2	80.0	0.2	2013.159	1865	6.58	9.32	3	1
08122+1739	STF1196AB,C	67.7	1.7	6.1	0.2	2013.159	2833	4.92	5.85	4	1
08142+1741	H 6 78AC	299.8	0.2	62.8	0.2	2013.121	3716	6.40	9.2	6	2
08142+1741	STU 22AB,D	322.9	0.1	228.6	0.2	2013.123	2499	6.51	8.94	6	2
08202+0953	CHE 112AB	50.1	0.2	34.3	0.1	2013.159	3844	9.52	10.38	6	2
08230+0738	STF1219	82.5	0.6	12.2	0.1	2013.121	4075	9.24	9.26	6	2
08358+0637	STF1245AC	110.0	0.2	99.5	0.2	2013.121	1496	5.98	10.70	3	1
08358+0637	STF1245AE	206.6	0.1	113.4	0.2	2013.123	1767	5.98	9.60	3	1
08359+0955	STF1246	115.8	0.7	10.5	0.1	2013.159	4030	8.73	9.85	6	2
08362+1347	STTA 94	132.8	0.2	43.1	0.1	2013.159	3857	7.39	8.11	6	2

Table 2 continues on next page.

Double Star Measures Using the Video Drift Method - IV

Table 2 (continued). Results of 240 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	# x-y pairs	Mag Pri	Mag Sec	Drifts	Nights
08379-0648	HJ 99AB	175.2	0.2	60.5	0.2	2013.066	4147	6.82	8.27	6	2
08401+2000	ENG 37AD	111.0	0.1	134.9	0.3	2013.195	1316	6.47	8.79	2	1
08401+2000	ENG 37AB	151.6	0.1	148.9	0.3	2013.200	1643	6.47	6.58	2	1
08401+2000	ENG 37AC	309.3	0.2	134.2	0.4	2013.200	410	6.47	9.03	1	1
08441+1357	HEI 145A,BC	130.1	0.8	9.1	0.1	2013.159	4109	10.77	10.9	6	2
08453+1316	HJ 105	255.7	0.3	25.9	0.1	2013.159	3934	9.69	10.27	6	2
08472+1110	STF1276AB	353.5	0.6	12.4	0.1	2013.159	4116	8.32	8.56	6	2
09003+0332	HJ 2479	324.6	1.2	23.1	0.5	2011.104	1397	8.99	12.35	2	1
09018+2754	SHJ 101	330.0	0.2	109.6	0.4	2011.203	683	6.08	9.22	1	1
09185-2249	ARA1764	193.0	2.7	7.1	0.3	2013.260	1628	11.19	12.3	2	1
09233+0330	STF1347	311.5	0.3	21.1	0.1	2013.121	4000	7.33	8.26	6	2
09359+1423	H 5 58	80.3	0.3	41.1	0.2	2013.159	1866	6.31	9.39	3	1
10072+0117	BAL1436	229.0	3.1	11.0	0.6	2011.203	578	10.53	12.2	1	1
10232+0542	SHJ 115AB	13.3	0.2	63.7	0.3	2013.159	1939	6.57	10.45	3	1
10262+0356	BU 1280AB	190.6	0.1	115.5	0.1	2012.041	5780	6.68	9.43	9	3
10358+0233	STF1452A,BC	327.7	0.7	10.4	0.1	2013.123	4104	9.59	9.81	6	2
10383+0115	STF1456	45.4	0.5	13.6	0.1	2013.123	4041	8.24	9.75	6	2
10416-0016	STF1464AC	226.2	0.1	66.4	0.1	2013.123	3638	8.26	10.51	6	2
10457-0130	FIL 26	260.1	0.3	20.6	0.1	2013.123	3917	10.02	10.19	6	2
11075+2203	HDS1586	201.9	1.4	13.7	0.3	2013.258	1420	8.30	11.43	2	1
13176-1157	CBL 147	344.5	1.0	24.1	0.4	2013.359	1377	11.0	12.7	2	1
13190-2637	UPT 2	21.1	1.2	17.1	0.3	2013.359	1501	10.10	10.30	2	1
13229-1854	J 1585	51.7	3.1	5.9	0.3	2013.359	1416	10.70	11.3	2	1
13324-1240	SHJ 165	78.3	0.2	48.1	0.1	2013.458	3633	7.60	8.58	6	2
13343-0019	STF1757AC	135.3	0.4	56.3	0.4	2013.351	1194	7.82	11.7	2	1
13345-1326	S 650	125.5	0.1	56.9	0.1	2013.458	3610	8.24	9.04	6	2
13408-2815	HJ 4604AC	279.4	1.2	15.8	0.3	2013.359	1498	8.08	10.44	2	1
13433-2458	HJ 2671AB	66.8	0.7	27.4	0.4	2013.359	1402	8.90	9.81	2	1
14237-2622	B 2768AB	53.9	0.2	152.9	0.5	2013.529	1136	8.81	11.31	2	1
14237-2622	B 2768BC	137.3	2.8	7.7	0.4	2013.521	1467	11.31	11.5	2	1
14242+0549	HJL1086	273.6	0.1	158.9	0.3	2013.359	1108	5.11	7.32	3	1
14265+1914	HJL1087	253.9	0.1	224.4	0.3	2013.359	808	5.43	8.38	3	1
15275-1058	STF1939	130.4	1.1	9.5	0.2	2013.458	2048	8.22	9.32	3	1
15420-1108	STF1966	52.3	0.3	23.0	0.1	2013.458	3987	9.26	9.40	6	2
15568-4058	WFC 171	349.1	1.9	9.5	0.3	2011.507	2950	12.12	12.5	3	1
16054-1948	H 3 7AC	19.7	2.6	13.6	0.7	2012.553	1208	2.59	4.52	1	1
16120-1928	H 5 6AC	336.3	0.9	41.1	0.6	2012.553	2354	4.35	6.60	2	1
16143-1025	STF2019AB,C	152.6	0.4	22.5	0.2	2013.458	4046	7.38	9.84	6	2
16305-1433	STF3104AB	228.7	1.0	9.5	0.2	2013.449	1403	9.15	10.37	3	1
16305-1433	STF3104AC	82.4	0.1	111.0	0.2	2013.458	2878	9.15	9.97	6	2
16406+0413	STFA 31AB	229.7	0.7	69.8	1.3	2012.553	1038	5.76	6.92	1	1
16560+4643	KZA 122AB	261.6	0.1	79.9	0.1	2013.518	2321	10.14	11.44	3	1
16560+4643	KZA 122AC	239.1	0.1	141.9	0.2	2013.518	1891	10.14	11.93	3	1

Table 2 continues on next page.

Double Star Measures Using the Video Drift Method - IV

Table 2 (continued). Results of 240 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	# x-y pairs	Mag Pri	Mag Sec	Drifts	Nights
17004+3058	HLM 8	347.3	0.8	19.6	0.2	2013.510	2357	11.61	11.45	3	1
17050-0504	LDS 585AB	122.2	0.1	185.0	0.2	2013.521	1336	7.86	10.14	3	1
17068+3356	SLE 78AB	99.0	0.4	59.6	0.4	2011.507	735	7.96	11.27	1	1
17068+3356	SLE 78AC	114.0	0.8	58.2	0.6	2011.507	736	7.96	12.15	1	1
17068+3356	SLE 78BC	202.0	2.8	15.5	0.7	2011.507	858	11.27	12.15	1	1
17068+3356	SLE 78AB	98.7	0.2	59.6	0.2	2013.510	2033	7.96	11.27	3	1
17087+3407	KU 115	58.3	0.4	35.7	0.2	2013.510	2261	9.79	10.31	3	1
17418-2032	ARA1129	270.5	1.7	6.0	0.3	2013.523	1569	11.57	12.1	2	1
17507+0755	STF2230AB	86.7	0.2	46.7	0.2	2013.458	1815	9.21	9.85	3	1
17507+0755	STF2230AC	112.6	0.3	40.0	0.2	2013.458	1815	9.21	11.12	3	1
17520+1520	STT 338AC	200.9	0.8	32.8	0.3	2013.518	2006	7.21	13.6	3	1
17520+1520	STT 338AD	246.6	0.1	95.6	0.2	2013.518	1556	7.21	10.6	3	1
17534+1058	STTA160	190.9	0.1	101.0	0.2	2013.458	1971	8.36	9.64	3	1
17535-2231	ARA1828	94.8	2.0	6.7	0.3	2013.523	1612	11.31	12.3	2	1
18006+0256	H6 2AC	142.4	0.2	53.9	0.2	2012.848	2021	3.96	8.06	2	1
18032+0755	STTA164	359.7	0.1	50.3	0.2	2013.458	2071	8.26	9.28	3	1
18089+1802	BPM 729	91.7	0.6	23.3	0.3	2013.523	1489	10.71	11.84	2	1
18093+0909	RUC 24AC	35.4	0.7	22.2	0.3	2013.523	1462	9.0	13.0	2	1
18111+3258	ES 185	286.1	1.0	12.6	0.2	2013.510	2360	9.89	10.99	3	1
18117+4020	UC 3526	136.3	0.6	24.8	0.2	2013.523	1904	9.9	12.7	2	1
18118+3406	DAM 630	39.6	1.4	14.8	0.3	2013.523	1788	12.6	14.3	2	1
18143-1902	ARA 740	52.5	1.9	8.8	0.3	2013.521	1532	12.02	12.0	2	1
18597+1002	HJ 5506	60.5	1.4	12.9	0.3	2013.521	1465	10.95	11.9	2	1
19053-0610	BU 974AC	118.8	0.8	19.6	0.4	2013.521	1426	9.96	12.6	2	1
19079-2259	ARA2256	357.3	1.2	7.7	0.3	2013.521	1605	11.79	11.9	2	1
19260+3555	BU 1286AB	45.1	0.7	22.5	0.2	2013.521	1789	9.45	10.49	2	1
19278+3709	ALI 392	196.0	1.7	14.6	0.4	2013.521	1823	12.00	12.3	2	1
20060+3546	ES 25AF	329.0	0.1	95.5	0.1	2013.510	4267	7.89	6.78	6	2
20060+3546	SHJ 315AD	235.6	0.4	20.4	0.1	2013.510	4773	7.89	8.73	6	2
20060+3547	BU 429AC	31.8	1.2	11.8	0.2	2013.510	2368	6.78	11.0	3	1
20060+3547	BU 429AE	108.7	0.3	28.7	0.2	2013.510	4535	6.78	11.42	6	2
20060+3547	SHJ 314AD	297.4	1.2	10.8	0.2	2013.121	2459	6.78	9.49	3	1
20060+3547	SHJ 314AF	28.5	0.2	35.5	0.1	2013.510	4774	6.78	7.30	6	2
20140-0403	HJ 909	128.4	0.6	15.3	0.2	2012.712	4107	11.00	12.07	6	2
20152-0330	STF2654	232.7	0.5	14.4	0.1	2012.712	4159	6.96	8.14	6	2
20262+3547	SEI1125AB	248.4	0.7	19.3	0.2	2013.121	2250	8.7	11.5	3	1
20270+3329	HJ 1515	24.7	0.8	15.7	0.2	2013.121	2397	9.31	11.28	3	1
20302+1925	S 752AC	287.8	0.4	106.5	0.5	2012.685	3618	6.80	7.30	2	1
20431+1705	BLL 51	159.4	0.1	55.7	0.1	2012.745	4192	8.72	9.56	6	2
20469+3252	ARG 93	87.8	1.0	10.9	0.1	2012.688	2495	8.30	9.59	3	1
20493+3314	ES 31AB	236.8	0.9	13.7	0.2	2012.688	2508	9.62	10.92	3	1
20493+3314	ES 31AC	142.6	0.8	19.2	0.2	2012.712	2413	9.62	9.50	3	1
20598+1649	STTA213	36.6	0.1	70.5	0.1	2012.745	3794	6.66	9.22	6	2
21126+0149	BAL1583	5.7	1.0	8.2	0.2	2012.688	4221	10.17	10.45	6	2

Table 2 concludes on next page.

Double Star Measures Using the Video Drift Method - IV

Table 2 (conclusion). Results of 240 double stars using the video drift method.

WDS	Discoverer	PA°	σ-PA	Sep"	σ-Sep	Date	# x-y pairs	Mag Pri	Mag Sec	Drifts	Nights
21218+0202	STF2787AB	20.2	0.3	22.4	0.1	2012.688	4099	7.49	8.64	6	2
21218+0202	STF2787AC	94.1	0.1	70.7	0.2	2012.751	3366	7.49	11.41	6	2
21376+0643	STT 443AB	348.5	0.9	8.0	0.1	2012.751	4245	9.47	9.67	6	2
21377+0637	STFA 56AB	348.6	0.2	38.6	0.1	2012.751	4208	6.18	7.50	6	2
21420+1856	STF2818AB	24.6	0.3	26.3	0.1	2012.745	4295	7.38	10.24	6	2
21434+3817	S 799AB	60.2	0.3	149.7	0.6	2012.685	2066	5.69	7.00	1	1
21441+0709	STTA222	257.5	0.1	87.6	0.1	2012.712	3229	7.49	8.47	6	2
21543+1943	STF2841A,BC	109.6	0.3	22.4	0.1	2012.745	4165	6.45	7.99	6	2
21560+1948	ALL 4	208.7	0.4	19.0	0.1	2012.745	4347	9.31	9.77	6	2
22207+2457	STF2895AB	47.9	0.6	13.7	0.1	2012.753	4499	8.49	9.95	6	2
22269+4943	BU 380AB	323.6	1.0	24.1	0.3	2012.688	2980	8.15	11.29	3	1
22269+4943	STTA234AC	133.7	0.2	36.1	0.1	2012.688	6078	8.15	8.49	6	2
22301+4921	FRK 11	90.5	0.1	67.4	0.1	2012.688	5178	6.55	10.74	6	2
22586+1203	STTA241	160.6	0.1	84.0	0.1	2012.751	3971	8.28	8.37	6	2
23075+3250	STF2978	145.4	5.6	8.0	0.8	2010.767	2436	6.35	7.46	1	1
23100+1426	STF2986	269.3	0.2	31.1	0.1	2012.751	3970	6.61	8.88	6	2
23134+1104	STF2991	358.7	0.3	32.5	0.2	2012.745	2810	5.96	10.16	5	2
23283+0604	H 5 48	1.5	0.1	90.1	0.2	2012.712	2052	7.43	9.54	3	1
23283+2556	BUP 237AB	282.6	0.3	54.6	0.3	2013.882	1429	8.80	13.0	2	1
23283+2556	BUP 237AC	261.4	0.3	66.6	0.4	2013.882	1364	8.80	13.1	2	1
23307+0515	STF3019	184.4	0.9	10.7	0.2	2012.712	2115	7.77	8.37	3	1
23412+0616	STF3031	309.9	0.5	14.0	0.1	2012.712	4107	7.80	8.58	6	2
23549+2929	STTA252	144.3	0.2	110.8	0.4	2012.847	6030	6.77	8.37	3	1

Table 2 Notes

All magnitudes were taken from the WDS catalog. All position angle/separation measurements are of the Equator and Equinox of date.

Column titled "# **x-y pairs**" is the total combined no. of (*x*,*y*) pairs (video frames) from all drift runs. All video frames were used, none were discarded.

The column "**drifts**" is the number of separate drifts made. "**Nights**" is the number of successive nights drift runs were made for that system.

WDS 04368-1736 ARA 154 – Corrected RA, DEC coordinates are (J2000)
4h 36m 44.3s, -17° 35' 20.3"

WDS 05404-2151 ARA 1278 – Corrected RA, DEC coordinates are (J2000)
5h 40m 22.6s, -21° 51' 05.7"

WDS 17418-2032 ARA 1129 – Corrected RA, DEC coordinates are (J2000)
17h 41m 43.18sec, -20° 32' 21.4″, which is 1.8' different from the WDS catalog values.

This updated coordinate information was submitted to the USNO prior to publication.

(Continued from page 215)

Consistency of the Method

The video drift method maintains consistent results over multiple drifts and over several nights. The video drift method is ideally suited for high school and college students that are proficient with computers.

Acknowledgements

This research makes use of the Washington Double Star Catalog maintained at the US Naval Observatory. We also thank Dave Herald and Chris Peterson for helpful comments on video error sources and calibration procedures.

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

Nugent, R. and Iverson, E. 2011, *Journal of Double Star Observations*, 7, No. 3, 185-194 (Paper I)

Nugent, R. and Iverson, E. 2012, *Journal of Double Star Observations*, 8, No. 3, 213-222 (Paper II)

Nugent, R. and Iverson, E. 2013, *Journal of Double Star Observations*, 9, No. 2, 113-121 (Paper III)

Rudiak-Gould, Ben, 2008 http://neuron2.net/www.math.berkeley.edu/benrg/avisynth.html