Lunar Occultation Observations of Double Stars – Report #3

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Abstract: Reports are presented of lunar occultations of close double stars observed using video including cases where a determination of the position angle and separation of the pair can be made and other cases where no duplicity has been observed. A number of double stars discovered as a result of an occultation are included together with light curves for the events.

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This paper continues the series of reports of double star measurements made during lunar occultations. The principle and general method of calculation are explained in Herald (2009) and Loader (2010).

All occultations used for this paper have been observed using video cameras, with either 25 frames (50 fields) per second (Australasia and Europe) or 30 frames (60 fields) per second (USA and Japan). The start and end times of each field of the videos were time stamped to milli-second accuracy. The limit of timing accuracy is usually about ±0.02 seconds where analysis has been carried out using video frame measures and ±0.01 seconds using field measures. An error of 0.01 seconds in time will typically translate to an angular error of 4 milli-arcseconds.

All events have been analyzed using the Limovie program developed by K. Miyashita and a light curve of the occultation has been generated. From this analysis an estimate of both the time interval between the occultations of the pair of stars and the relative brightness of the stars has been obtained.

Occultations of double stars result in a stepped light curve, see Herald (2009). The relative size of the step enables an estimate of the magnitude difference of the two stars to be made. Observations are normally made with an unfiltered camera.

Normally the separate occultations of the two stars of a pair will take place at slightly different points on the moon's limb. An angular separation of 1" at the mean distance of the moon is about 1.86 km. The heights of the moon's limb at the two points of occultation may differ. Any difference will have an effect on the interval between the two events.

For each observation an estimate of the effective slope of the moon's limb between the two points of occultation is therefore needed for calculations of the position angle and separation angle of a pair of stars. For this paper use has been made of the Kaguya satellite data. Whilst this gives a more detailed view of the moon's limb than the Watt's corrections, some uncertainty remains. An estimate of these has been built into the uncertainty of the resulting PA and separation.

The Observations Reported

Table 1 continues the series of measures of known double stars for which occultations have been observed from more than one locality. In most cases the occultation observations have been made on different dates, with an interval between them sufficiently short for any change in relative position of the pair of stars to be small. An estimate of the change, derived from WDS data, is given in the notes.

Table 2 gives details of similar observations, but of previously unknown double stars discovered as a result of stepped lunar occultations. Two or more observations of the same star enables a determination of the position angle and separation of the pair to be made. In some cases the star had been previously reported as double as a result of a visual observation of an apparently prolonged occultation event.

Table 3 presents a further series of discoveries for which only one observation has been made. In this case only a vector separation can be determined along with an estimate of magnitude difference. Only cases where the resulting light curve shows a clearly defined step have been included.

Table 4a continues a series of observations of stars which are listed in the WDS, but where the double nature has not been detected at lunar occultations. Only cases where at least two such observations have been made are included.

The most likely reasons for the failure to detect a companion star are:

- the vector separation was too small so that the interval between the two events was too short to detect;
- the magnitude difference of the two stars is too large for the circumstances of the event.

Table 4b continues a similar series of observations of stars which have been reported as possibly double as a result of visual occultation observations, but which subsequently have shown no sign of being double as a result of the observation of occultations using a video system. Only cases with two or more observations with event PAs (the vector angle) separated by at least 10° have been included. The stars in table 4b all have an entry in the Interferometric Catalog, but are not listed in the WDS.

In addition to the possible reasons for not observing a companion star given above, in this case there is a strong probability that the purported companion simply does not exist.

Names of observers are listed at the head of this paper and are referred to by the two letter code in the table.

Light curves, are presented for events involving the discovery of a double star presented in tables 2 or 3.

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Table 1: Known double stars: PA and separation measured

WDS name	XZ	RA Dec	PA	+/-	Sep.	+/-	Mag. diff.	Date	Observers	Note
STF 333AB	3943	02592+2120	195.6	4.5	1.48	0.05		2010.141 2011.188	JM PG	1
CHR 11Aa,Ab	4786	03437+2339	222.0	2.3	0.045	0.003		2009.694 2009.918 2010.068	HK, MI HK HK, HT	
WSI 52Da,Db	4895	03473+2408	112.5	7.8	0.33	0.08	1.1	2010.068	HK,KK,TO	2
STF 520	5566	04182+2248	86.4	1.8	0.608	0.008	0.18 n/a	2011.192 2011.267	VT EI	
STT 139	9016	06256+2227	257.0	1.7	0.736	0.02	Mean 1.7 ±0.1	2010.898 2011.048 2011.198	HK TG AS	3
COU 925	10639	07118+1953	65.31	3.08	0.508	0.015		2011.350	HK,HW,HY, KK,YA,MI	
A 2874	11387	07362+1815	49.65	1.23	0.275	0.007	0.9	2011.351 2011.650	VP,JM,JF JM	4
HO 247	11655	07491+2107	247.3	2.8	0.531	0.032		2009.779 2010.303	MI BL	5
A 2546	13255	08437+1654	215.5	1.3	1.70	0.15	0.7	2009.782 2010.306	MI BL	6
STF1426AB	15514	10205+0626	311.39	0.90	0.935	0.010	0.7 0.64	2009.487 2010.386	EI DH	7
BU 1117	22820	16568-2309	304.7	2.0	1.013	0.01	0.3	2011.528	JB,DL,BL	
B 351	23758	17383-2312	251.6	3.0	0.665	0.019		2011.230	DH,BL	
OCC9022	24055	17504-2704	190.6	2.4	0.086	0.012	0.5 0.3	2008.390 2009.511 2009.586 2009.660	DH JM RS, SM HTg, MK	8
BU 172AB	30645	22241-0450	38.48	2.07	0.427	0.009	0.38	2011.769	MI,KM,YA,HW	
A 2100	32105	23568+0444	260.67	1.42	0.366	0.010	1±0.3	2011.849 2011.924	AP DB	9

Notes

1. Expected change from 2010.1 to 2011.2: PA +0.08°, separation 0.006”
2. PA on the moon’s limb of the three occultations were close resulting in a relatively poor solution
3. Expected change from 2010.9 to 2011.2: PA +0.05°, separation +0.001”
4. Expected change from May to August 2011: PA ca -0.03°, separation -0.000”
5. Expected change from 2009.8 to 2010.3: PA +0.39°, separation +0.003”
6. Expected change from 2009.8 to 2010.3: PA +0.02°, separation +0.003”
7. Expected change from 2009.5 to 2010.4: PA +0.25°, separation -0.001”
8. OCC9022 originally discovered by RS at occultations in 2003.
9. Expected change from 2011.85 to 2011.93: PA -0.10°, separation +0.001”

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WDS refers to the Washington Double Star Catalog and IF to the Interferometric Catalog both published by United States Naval Observatory, Washington. XZ refers to the XZ80 catalog originally published by the USNO. It includes all stars to magnitude 12.5 within 6°40' of the ecliptic, that is all stars which can be occulted by the moon.

References

Herald, D. "SAO97883 – a new double star", JDSO, Vol 5, No 4, 2009.

Loader B. "Lunar Occultations of Known Double Stars – Report #1", JDSO, Vol 6, No 3, 2010

Loader B. "Lunar Occultations of Double Stars – Report #2", JDSO, Vol 7, No 3, July 2011

The program "Limovie" by K. Miyashita can be downloaded from: http://astro-limovie.info/limovie/limovie_en.html

Table 2: Occultation Discoveries: PA and separation measured

Star Name	XZ	RA Dec	PA	+/-	Sep.	+/-	Mag. diff.	Date	Observers	Figure & Note
SAO 77358	7286	05395+2146	184.2	7.2	0.094	0.038	0.8 0.6	2011.869 2012.091	JM JM	Fig. 1 10
SAO 183650	21531	15386-2136	31.3	3.5	0.083	0.013	0.2	2011.225 2011.599	DG DH, JB	Fig. 2 11

Notes

10. SAO 77358 was originally reported as double 1926 March 20 by E I Johnson as a result of an occultation observation.
11. 11. SAO 183650 was also observed again by DG on 2011 August 7. The light curve is inconclusive due to variable amounts of cloud.

Table 3: Occultation Discoveries: Vector separation only measured

Star name	XZ	RA Dec	Vector Angle	Vector Sep.	Mag. diff.	Date	Observer	Figure
SAO 93224	3948	02595+2004	98.60	0.022″	n/a	2012.010	DH	Fig. 3
TYC 1279-00730-1	6134	04469+2226	65.20	0.082″	0.1	2011.642	JM	Fig. 4
TYC 1863-01688-1	79015	05519+2303	114.47	0.345″	0.34	2011.197	HK	Fig. 5
TYC 1877-00575-1	83756	06095+2236	86.18	0.092″	ca 0.2	2011.272	EI	Fig. 6
TYC 1879-00217-1	88015	06267+2258	300.66	0.188″	0.2	2011.273	DH	Fig. 7
SAO 78416	9140	06288+2325	138.73	0.121″	1.65	2010.674	MI	Fig. 8
TYC 1392 01057-1	111160	08423+1506	47.85	0.015″	1.5	2011.429	DH	Fig. 9
SAO 118501	16193	10481-0218	182.79	0.109″	0.6	2011.585	BL	Fig. 10
SAO 183232	20996	15098-2031	328.08	0.060″	1.24	2011.448	BL	Fig. 11
SAO 164563	29940	21402-0948	132.12	0.037″	0.54	2011.392	JM	Fig. 12

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Table 4a: Companion not observed (definite double star, listed in WDS)

Star name	XZ	RA Dec	Vector angle	Resolution limit	Limiting Mag. diff.	Date	Observer
STF 453Aa,Ab	4957	03492+2403	51.6° 78.2° 82.2° 267.6°	0.025″ 0.027″ 0.026″ 0.035″	- 3.0 2.5 2.3	2009.611 2010.069 2010.069 2010.592	BH SU MI DL
CHR 125Aa,Ab	4958	03492+2408	60.0° 56.6°	0.025″ 0.024″	2.8 3.2	2010.067 2010.067	SU HT
HDS 541	5514	04154+2405	115.3° 46.6° 111.6°	0.035″ 0.030″ 0.025″	2.0 2.3 2.7	2010.219 2010.294 2011.117	HK JM JB
HEI 146	13271	08443+1428	132.1° 102.3°	0.036″ 0.036″	3.5 3.5	2010.322 2010.322	DH JB
A 2975	14121	09190+1057	104.7° 86.3°	0.026″ 0.023″	3.0 2.7	2011.281 2011.282	KK HT
MCA 36	17739	11510-0520	256.4° 173.9° 255.7°	0.026″ 0.024″ 0.022″	2.0 2.3 2.5	2010.166 2010.316 2010.989	JM JM HK
LAB 3	21917	16003-2237	294.9° 317.2°	0.032″ 0.028″	3.5 3.5	2011.151 2011.151	DG DL
CHR 182	23426	17220-2500	230.9° 234.9°	0.027″ 0.028″	3.5 3.5	2010.322 2010.322	DH DG

[The 'Resolution limit' is set at no less than two frame intervals [0.080s (PAL) or 0.067s (NTSC)] times the vector rate of motion.]

Table 4b: Companion not observed (possible double star, listed in Interferometric Cat.)

Star name	XZ	RA Dec	Vector angle	Resolution limit	Limiting Mag. diff.	Date	Observer
BD+13 207	1956	01243+1354	112.1° 82.9°	0.022″ 0.028″	2.6 2.6	2010.136 2012.004	SM DG
HD 93102	16106	10452+0229	121.5° 127.2° 130.9° 63.0° 178.8° 167.7°	0.032″ 0.032″ 0.030″ 0.019″ 0.020″ 0.024″	2.7 2.4 2.5 2.0 2.5 3.2	2010.313 2010.313 2010.313 2010.387 2011.361 2011.361	HK MI KK JM JB SK
BD-13 5904	29553	21193-1303	64.7° 263.7°	0.023″ 0.020″	3.2 3.2	2009.822 2010.420	BL MI

[The 'Resolution limit' is set at no less than two frame intervals [0.080s (PAL) or 0.067s (NTSC)] times the vector rate of motion.]

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The figures show light curves for lunar occultations of double stars. The horizontal axes, effectively time, show the frame number of the video. The vertical axes show the measured light intensity of the star in arbitrary units. Measures have been made of the light intensity for each frame of the video recording, unless otherwise stated.

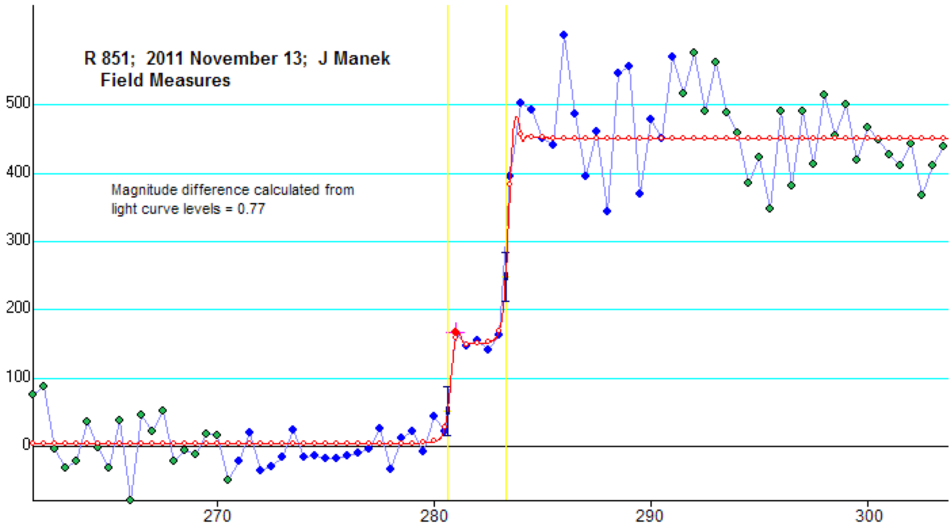

Figure 1: Light curve for the occultation of SAO 77358 obtained by J. Manek.. Intensity measures were made for each field of the video, giving a time resolution of 50 fields per second. The step lasts 0.11 seconds, between 5 and 6 fields. The vertical height of the steps suggests a 0.77 difference in magnitude for the two stars. At this event the fainter star was the first to reappear from occultation.

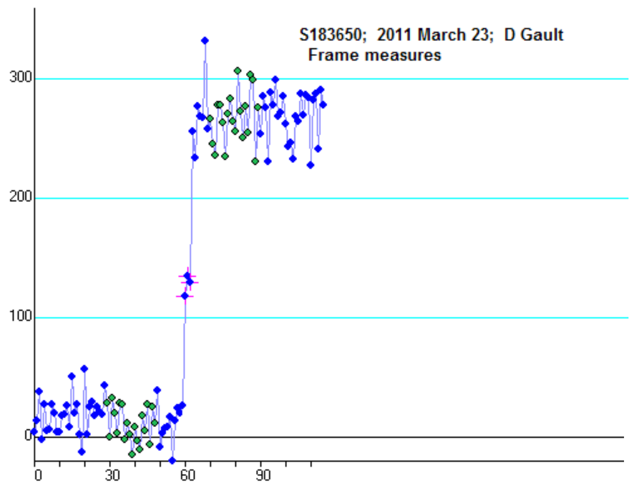

Figure 2: Light curve for the occultation of SAO 183650 obtained by D. Gault. The step lasts about 0.12 seconds, 3 frames. The height of the steps suggests a 0.2 difference in magnitude, with the fainter stars reappearing first.

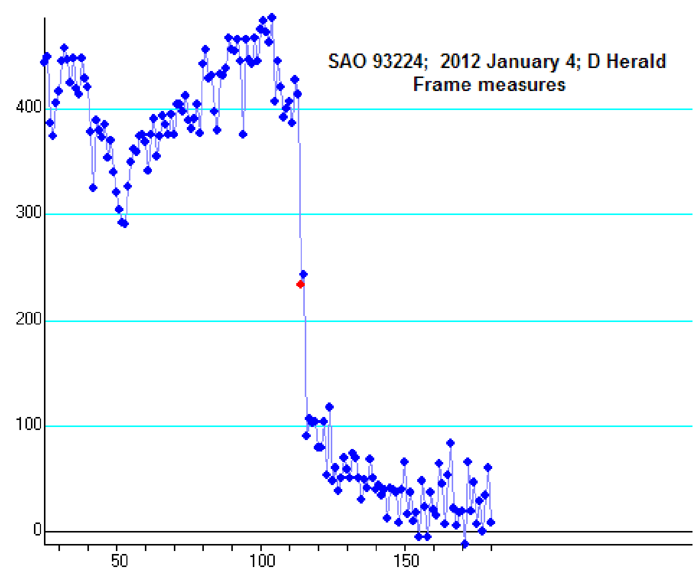

Figure 3: Light curve for the lunar occultation of SAO 93224 obtained by D. Herald, 2012 January 4. The two point step indicates a duration of 0.08 seconds, equivalent to a minimum separation of 22 arc-milliseconds for the components of the double star. The level of noise does not allow an accurate estimate of the magnitude difference.

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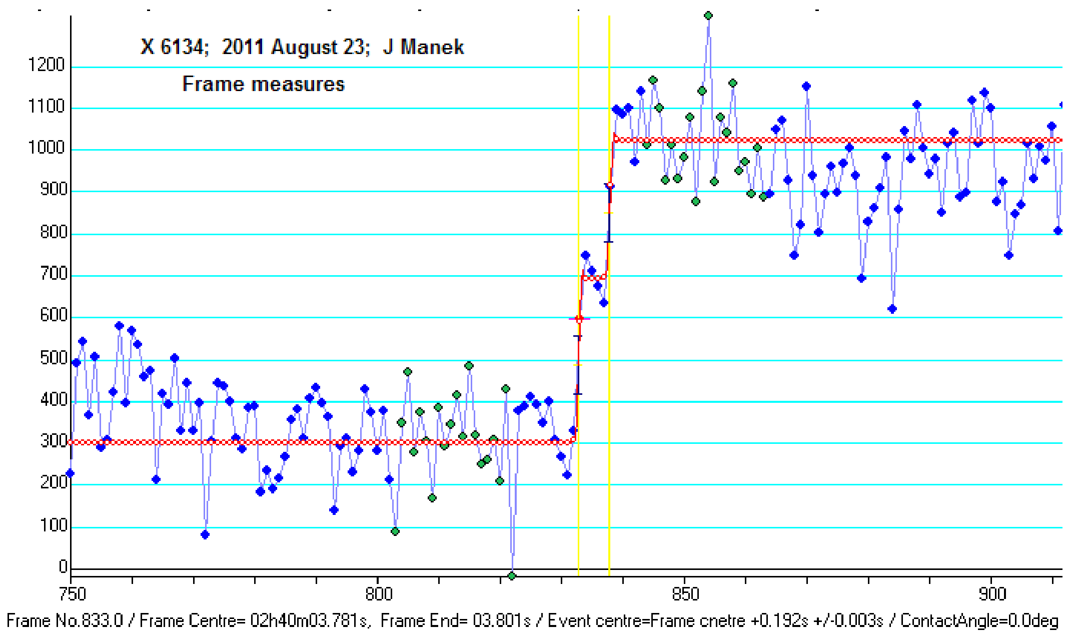

Figure 4: Light curve for the occultation reappearance of XZ 6134 obtained by J. Manek, 2011 August 23. The 0.20 second step equates to a minimum separation of 82 arc-milliseconds for the pair.

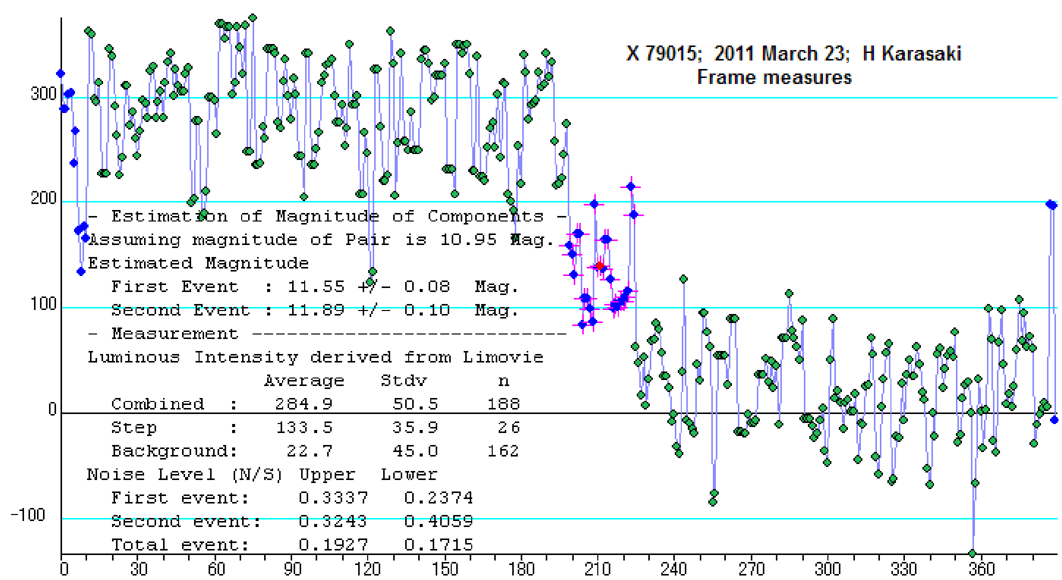

Figure 5: Light curve for the occultation disappearance of XZ 79015 obtained by H. Karasaki, 2011 March 23. The 0.87 second step equates to a minimum separation of 345 arc-milliseconds for the pair.

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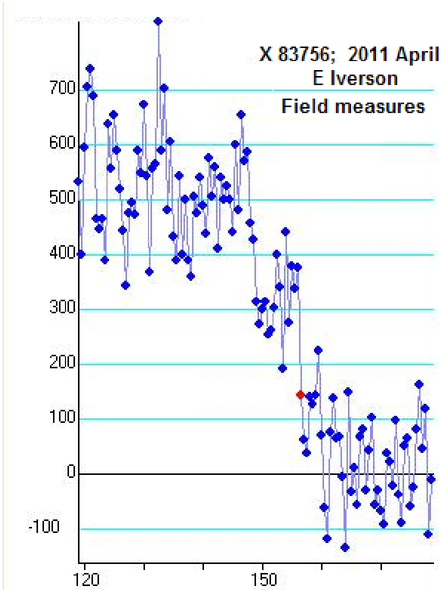

Figure 6: Light curve for the occultation disappearance of XZ 83756 obtained by E. Iverson, 2011 April 10. Light intensity measures have been made for each field (60 per second). The 0.25 second step is equivalent to a minimum separation of 92 arc-milliseconds.

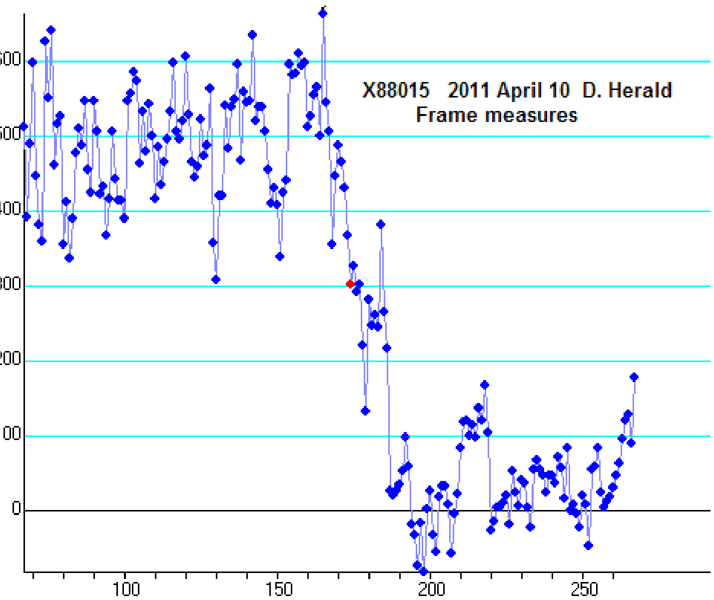

Figure 7: Light curve for the occultation disappearance of XZ 88015 obtained by D. Herald, 2011 April 10. The 0.52 second step equates to a minimum separation of 188 arc-milliseconds. The magnitude difference of the pair of stars appears to be about 0.2 with the fainter star occulted first.

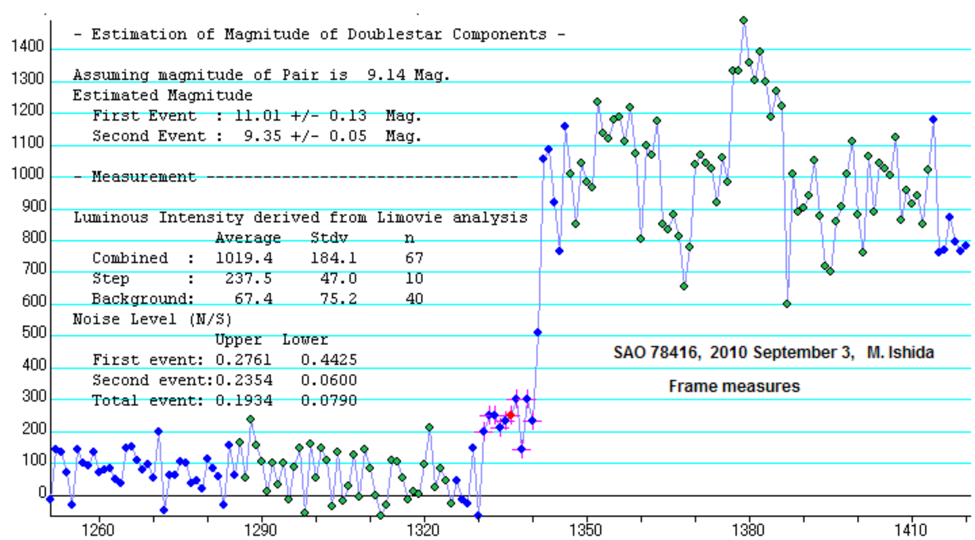

Figure 8: Light curve for the occultation reappearance of SAO 78416 obtained by M. Ishida, 2010 September 3. The 0.35 second step equates to a minimum separation of 121 arc-millisecond for the pair.

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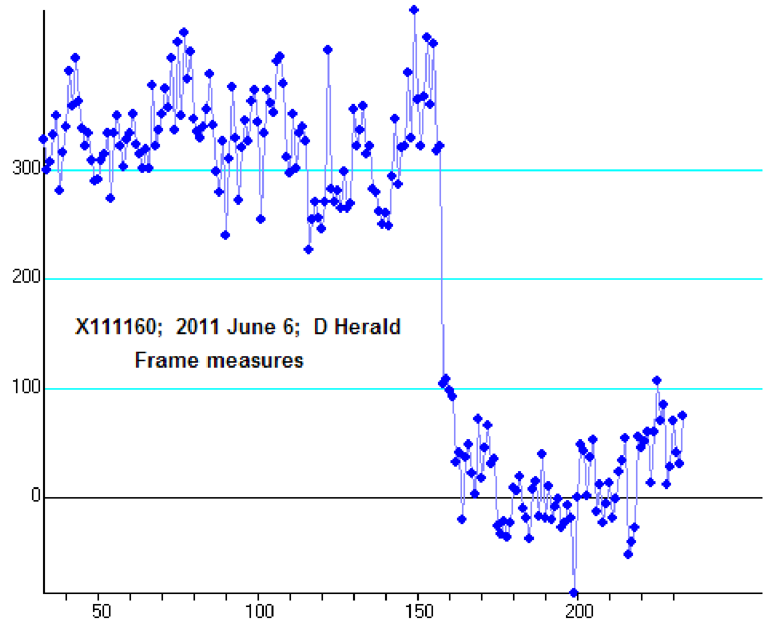

Figure 9: Light curve for the occultation disappearance of XZ 111160 obtained by D. Herald, 2011 June 6. Herald estimates the duration of the step to be 0.12 seconds which is equivalent to a minimum separation of 15 arc-milliseconds. The fainter star clearly was the second to be occulted, the estimated magnitude difference being 1.5

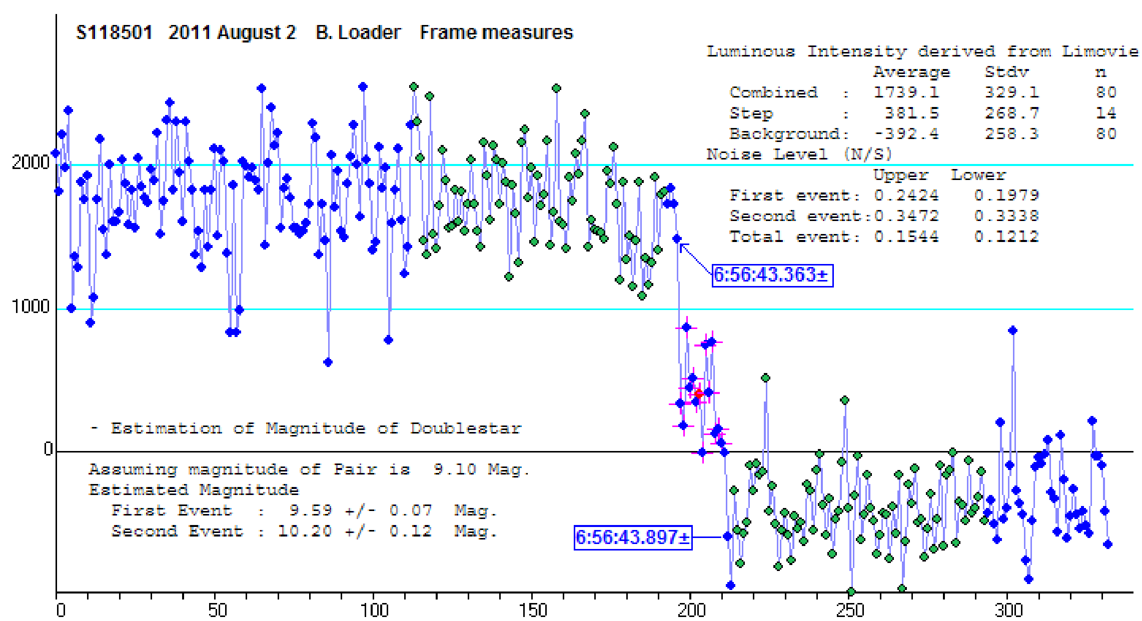

Figure 10: Light curve for the occultation disappearance of SAO 118501 obtained by B. Loader, 2011 August 2. The step lasts for 0.49 seconds which is equivalent to a minimum separation of 109 arc-milliseconds.

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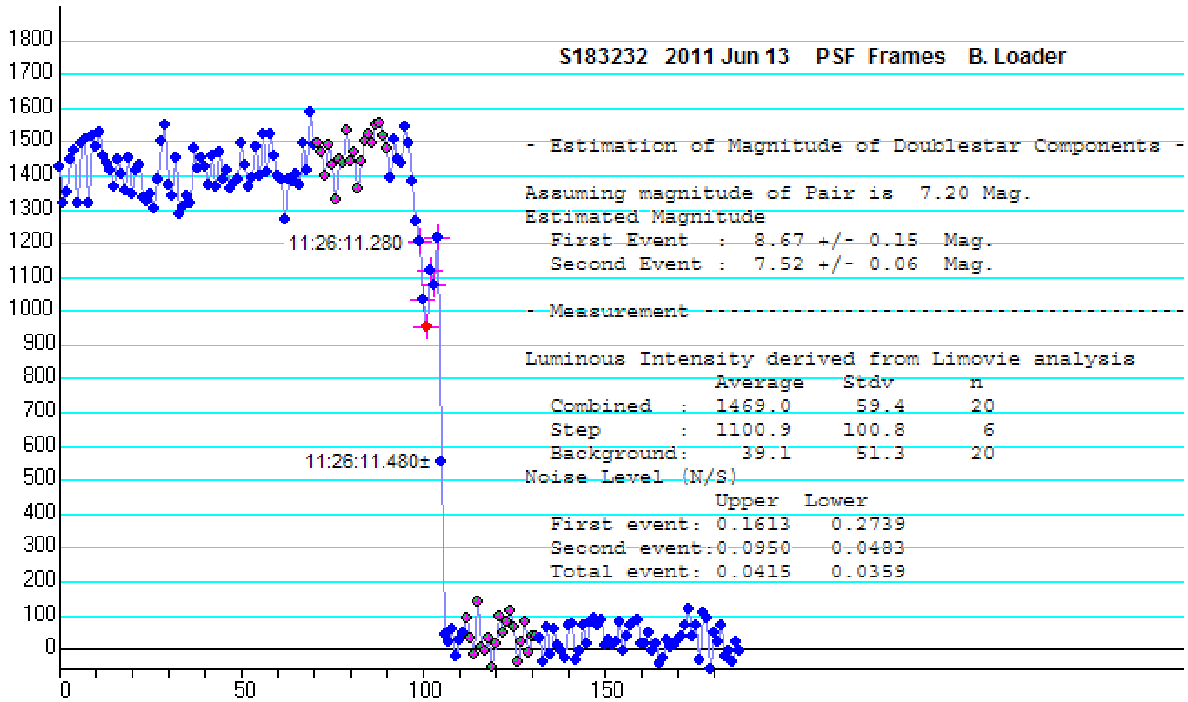

Figure 11: Light curve for the occultation disappearance of SAO 183232 obtained by B. Loader, 2011 June 13. The step lasts for 0.20 seconds which is equivalent to a minimum separation of 60 arc-milliseconds.

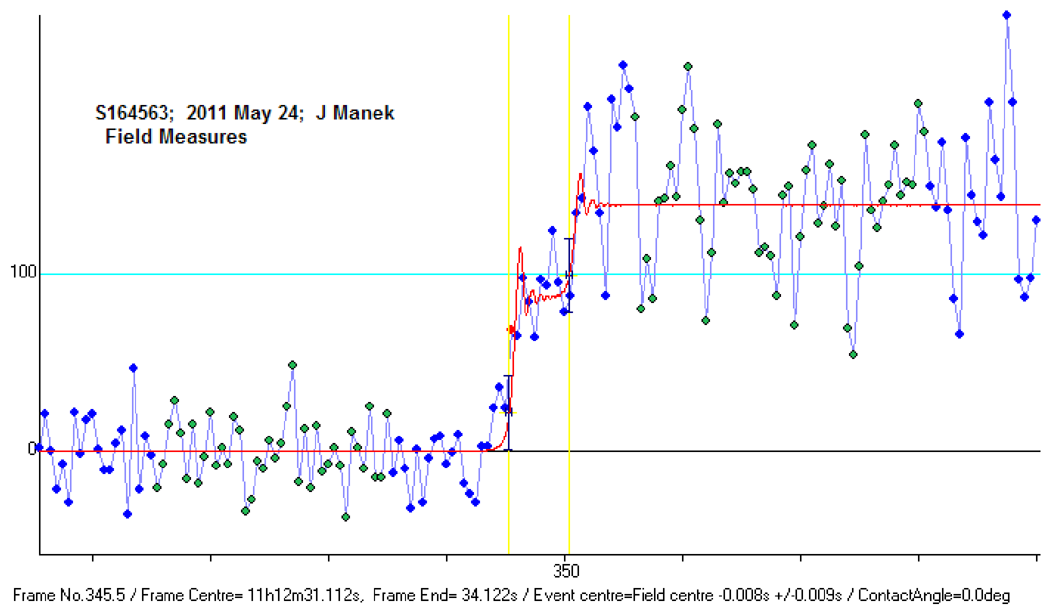

Figure 12: Light curve for occultation reappearance of SAO 164563 obtained by J. Manek, 2011 May 24. The step lasts 0.21 seconds with measures taken each video field and equates to a minimum separation of 37arc-milliseconds.