Lunar Occultation Observations of Double Stars – Report #2

Brian Loader, Darfield, New Zealand (BL)
Royal Astronomical Society of New Zealand (RASNZ)
International Occultation Timing Association
J. Bradshaw, Yugar, Qld, Australia (JB)
D. Breit, Morgan Hill, California, USA (DB)
D. Gault, Hawkesbury Heights, NSW, Australia (DG)
T. George, Umatilla, Oregon, USA (TG)
D. Herald, Kambah, Canberra, Australia (DH)
E. Iverson, Lufkin, Texas, USA (EI)
M. Ishida, Moriyama, Shiga, Japan (MI)
H. Karasaki, Nerima, Tokyo, Japan (HK)
M. Kashiwagura, Oe, Yamagata, Japan (MK)
K. Kenmotsu, Soja, Oakyama, Japan (KK)
D. Lowe, Brisbane, Qld, Autsralia (DL)
J. Manek, Praha, Czech Republic (JM)
S. Messner, Northfield, Minnesota, USA (SM)
T. Oono, Kurashiki, Okayama, Japan (TO)
H. Tomioka, Hitachi, Ibaraki, Japan (HT)
H. Watanabe, Inabe, Mie, Japan (HW)

Email: palbrl@clear.net.nz

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 double stars discovered as a result of an occultation are included together with light curves for the event.

This paper continues the series of reports of double star measurements made during lunar occultations. The principle and general method of calculation is 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.

For most events, a light curve of the occultation has been obtained from an analysis of the video of the event, using the Limovie program developed by K. Miyashita. 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.

For each observation an estimate of the slope of the moon's limb at the point of occultation is 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.

Table 1 continues the series of measures of known double stars for which occultations have been observed from more than one locality. In some 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 4 continues the 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 4 all have an entry in the Interferometric Catalog.

There are 3 possible explanations of the failure to detect a companion star:

1. the vector separation was too small;
2. the magnitude difference is too large for the circumstances of the event;
3. the purported companion 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. The figures show light curves for lunar occultations of stars. The horizontal axes mostly show the frame number of the video while the vertical axes show the measured light intensity of the star in arbitrary units. In many cases measures have been made of the light intensity in each field of the video recording.

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

Table 1: Known double stars: PA and separation measured

WDS name	XZ	RA Dec	PA	+/-	Sep	+/-	Mag. diff	Date	Observers	Note
BU 867	1373	01014+1155	359.3	1.7	0.61	0.02	0.8	2008.039 2008.562 2009.087 2009.910	BL DH DB MI	1
BU 536AB	4871	03463+2411	174.4	2.7	1.01	0.03	1.25	2009.619 2010.069	SM HK,HW,KK,MI	2
BU 1105	4943	03486+2411	114.4	3.2	0.23	0.03	1	2010.069	HK,HT,TO	
BOV 24	67460	03494+2456	181.1	2.0	0.27	0.025	0.33	2007.673 2009.096	SM SM	3
STF 499AB	5405	04101+2407	83.9	1.7	1.91	0.04	0.4	2010.219	HK,KK	
A1843 AC (CHR 127AB)	6268	04536+2522	348.4	2.4	0.22	0.02	1.7	2009.896 2010.072	SM KK,MI,HK	4
BU 225BC	20283	14255-1958	90.6	2.0	1.19	0.07	0.9	2008.603	DG,DH	

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Table 2: Occultation Discoveries: PA and separation measured

Star Name	XZ	RA Dec	PA	+/-	Sep	+/-	Mag. diff	Date	Observ-ers	Figure & Note
TYC 1210-01605-1	2922	02071+1756	276.4	3.8	0.028	0.013	0.2	2009.016 2009.540	SM	Fig. 1
TYC 1229-00832-1	63362	02463+2105	301.5	1.2	0.48	0.02	0.7 0.1	2009.090 2010.066	SM HK	Fig. 2
TYC 1803-00944-1	67175	03457+2454	174.0	4.0	0.16	0.01	0.1	2009.096	EI, SM	Fig. 3
HD 23763	4940	03485+2421	239.4	1.6	0.19	0.02	1.3	2010.693	KK, MI	Fig. 4 Note 5
HD 283433	69104	04100+2406	42	8	0.44	0.16	1	2010.219	HK, KK	Fig. 5
SAO 79418	11145	07287+2151	314	10	0.25	0.05	1.3	2009.853	HK, MI	Fig. 6
SAO 138935	18731	12438-0946	140.5	5	0.08	0.01	1.9	2009.570 2010.468	BL DG	Fig. 7

Table 3: Occultation Discoveries: Vector separation only measured

Star name	XZ	RA Dec	Vector Angle	Vector Sepn.	Mag. Diff	Date	Oberver	Figure & Note
TYC 1206-00659-1	60404	01567+1550	49.025	0.056″	0.25	2007.143	SM	Fig. 8
TYC 1210-00178-1	61120	02077+1737	219.770	0.593″	0.5	2009.541	SM	Fig. 9
TYC 1819-00838-1	5484	04139+2546	78.264	0.033″	0.18	2006.700	SM	Fig. 10
TYC 1874-00731-1	78191	05486+2813	114.420	0.39″	2	2006.256	SM	Fig. 11
TYC 1877-00386-1	84154	06110+2420	326.738	0.62″	0.5	2010.150	SM	Fig. 12 Note 6
TYC 1901-01063-1	93442	06487+2749	98.238	0.037″	0.65	2006.258	SM	Fig. 13
TYC 1910-00444-1	101628	07274+2306	244.628	0.61″	0.7	2009.254	SM	Fig. 14
TYC 1916-00120-1	103887	07410+2526	66.209	0.174″	0.67	2007.234	SM	Fig. 15
TYC 1374-00886-1	104479	07450+2214	93.749	0.135″	1.3	2009.181	SM	Fig. 16
TYC 1928-00381-1	108624	08181+2344	116.699	0.15″	1.4	2006.339	SM	Fig. 17
SAO 98681	14557	09380+1650	299.638	0.107″	0.9	2006.418	SM	Fig. 18
TYC 1412-01367-1	117172	10065+1545	77.946	0.28″	0.2	2006.345	DG	Fig. 19
SAO 99198	15876	10366+1137	102.545	0.61″	3.3	2006.421	DG	Fig. 20
SAO 158101	19630	13423-1409	106.095	0.039″	0.25	2006.508	SM	Fig. 21
SAO 186227	24532	18046-2420	28.770	0.062″	0.6	2010.334	BL	Fig. 22
SAO 163107	27732	19554-1918	250.927	0.041″	0.2	2010.340	BL	Fig. 23
SAO 165197	30841	22371-1254	245.962	0.63″	1.5	2005.786	SM	Fig. 24
SAO 146406	31127	22576-0311	274.843	0.037″	1.5	2009.528	SM	Fig. 25

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Table 4: Companion not observed (possible double star)

Star Name	XZ	RA Dec	Vector Angle	Resolution Limit	Limiting Mag. Diff	Date	Observer	Note
BD+10 115	1369	01012+1111	190° 232° 77°	0.019″ 0.031″ 0.029″	2.5 2.3 2.7	2009.611 2009.685 2009.835	SM MI DB	
BD+13 240	2221	01358+1440	119° 237°	0.019″ 0.022″	2.7 2.9	2009.987 2010.734	JM MI	
BD+16 225	2741	01581+1732	38° 28°	0.023″ 0.021″	2.8 2.0	2010.063 2010.063	MI HT	
HD 23302	4818	03449+2407	34° 18°	0.034″ 0.013″	2.5 2.5	2006.924 2010.069	SM HK	
BD+24 587	5035	03522+2510	133° 253°	0.013″ 0.028″	3.0 3.5	2006.101 2007.673	DG SM	
HD 58364	11073	07261+2153	248° 235°	0.022″ 0.018″	1.0 2.3	2009.853 2009.853	MK HK	
HD 64648	11900	07557+1953	57° 159°	0.022″ 0.030″	2.5 2.7	2010.100 2010.304	JM DG	7
BD+17 1871	12951	08344+1653	254° 152°	0.028″ 0.031″	2.5 3.8	2010.006 2010.352	HK DH	
BD-08 3366	18537	12314-0911	183° 170° 140° 140°	0.015″ 0.022″ 0.033″ 0.032″	3.8 3.8 2.7 2.7	2010.542 2010.542 2010.542 2010.542	DH DG JB DL	
BD-16 3760	19811	13544-1711	135° 146°	0.027″ 0.022″	2.9 3.0	2009.499 2009.499	DG BL	
HD 144844	22084	16087-2341	261° 17° 17°	0.030″ 0.001″ 0.001″	2.3 2.9 2.9	2010.329 2010.553 2010.553	BL DG DH	 8 8
BD-12 6088	30049	21467-1142	42° 32°	0.022″ 0.022″	2.1 2.3	2009.671 2009.671	DB TG	
HD 220035	31496	23207-0554	236° 282°	0.023″ 0.026″	0.8 3.3	2009.009 2010.354	BL DH	

[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.]

Notes to Tables.

1. Expected change from 2008.0 to 2009.9: PA -0.74°, separation +0.004"
2. Expected rate of change: PA ca -0.09°/yr, separation +0.005"/yr
3. Expected change from 2007.7 to 2009.1: PA +0.1°, separation -0.01"
4. A1843 AC expected rate of change: PA ca 0.15°/yr, separation nil. There appears to be possible confusion with CHR 127AB . The solution for the PA and separation fits A1843 AC, the observed magnitude difference is closer to CHR 127AB.
5. HD 23763 was reported as double as a result of a lunar occultation observation by J Bourgeois, 1988 August 6 and has an entry in the Interferometric Catalog. The star is the primary component of HL 26.
6. TYC 1877-00386-1 is the primary component of POU1110, an 8.8" double.
7. HD 64648 = 85 Geminorum. The Interferometric Catalog shows a reported double as a result of an occultation observation by A. Richichi, 2000.203.
8. Observed by DG and DH at a grazing occultation. The resolution limit is nominal.

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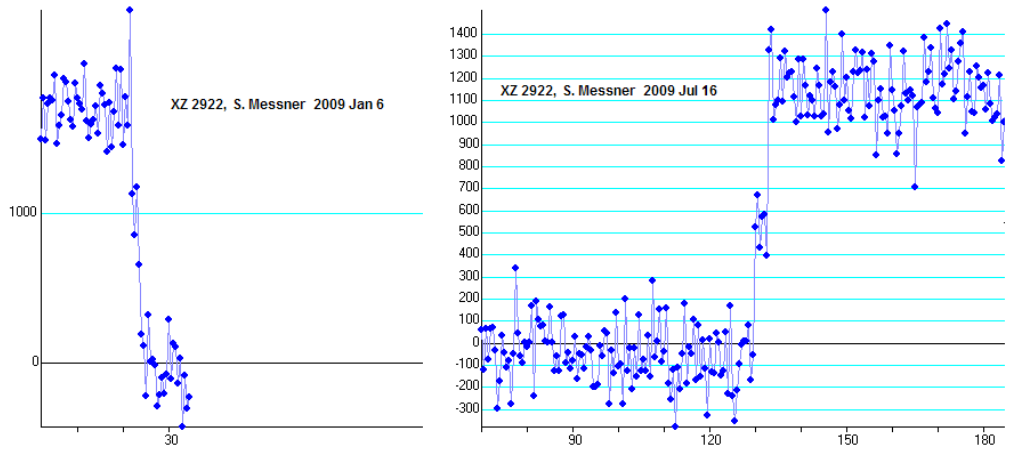

Figure1: Light curves obtained by S. Messner for lunar occultations of XZ 2922. Intensity measures were made on each field of the video, that is 60 fields per second. The step for the disappearance lasts for 4 fields, 0.07 second, that for the reappearance lasts for 6 fields, 0.10 seconds. The vertical heights of the steps suggest a magnitude difference of about 0.15 with the fainter star being occulted first.

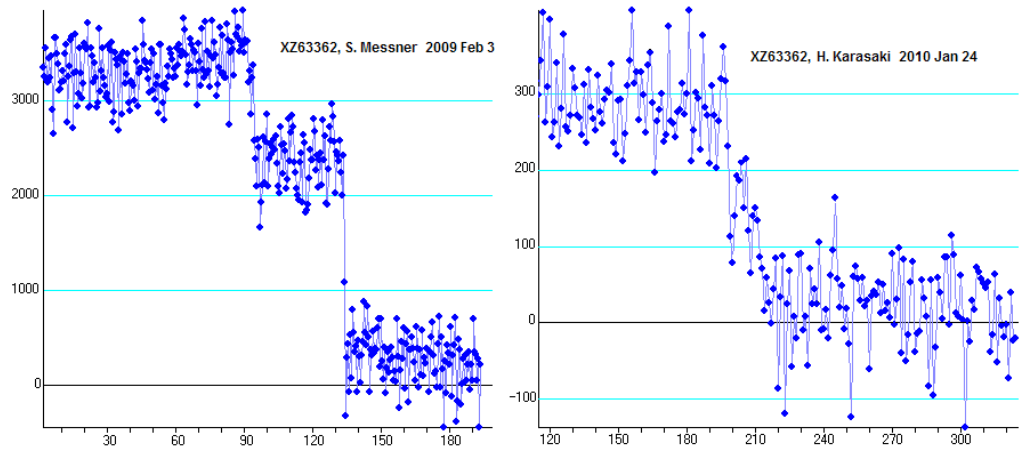

Figure 2: Light curves for occultations of XZ 63362 obtained by S. Messner and H. Karasaki. Messner's curve has measures for each field with a step lasting 1.32 seconds. Karasaki's curve has measures for each frame with a step lasting 0.43 second.

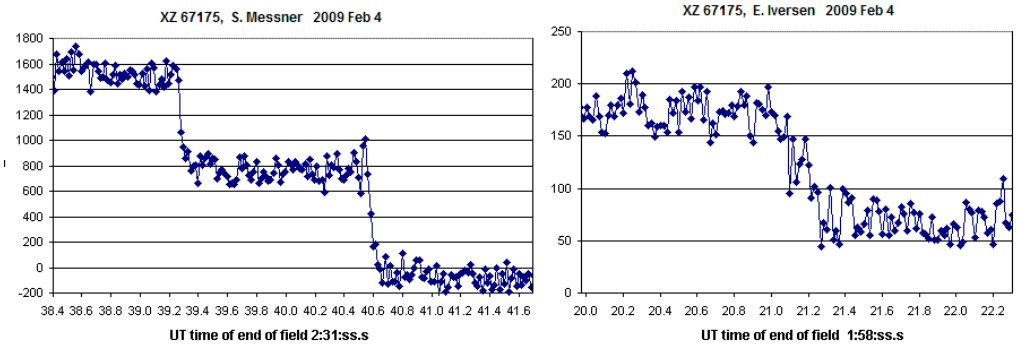

Figure 3: Light curves for the lunar occultation of XZ 67175 obtained by S. Messner and E. Iversen, 2009 February 4. The horizontal axes show the UT time in seconds of the video fields. The position angles of the occultations on the moon's limb were 4° and 69° respectively, resulting in the different step lengths: Messner's step lasts 1.30 seconds, Iversen's 0.14 seconds.

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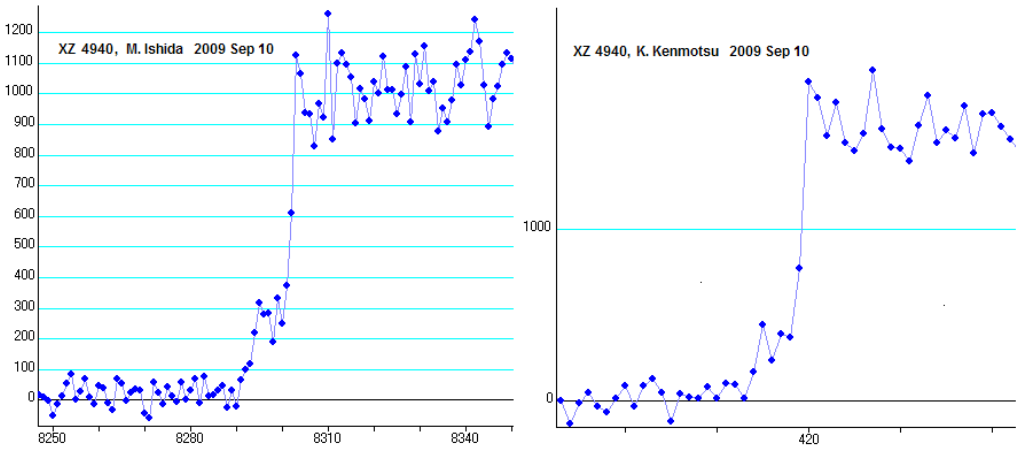

Figure 4: Light curves for the occultation reappearance of XZ 4940 obtained by M. Ishida and K. Kenmotsu, 2009 September 10. Measures have been taken each frame, Ishida's step lasting for 0.30 second, Kenmotsu's 0.11 second.

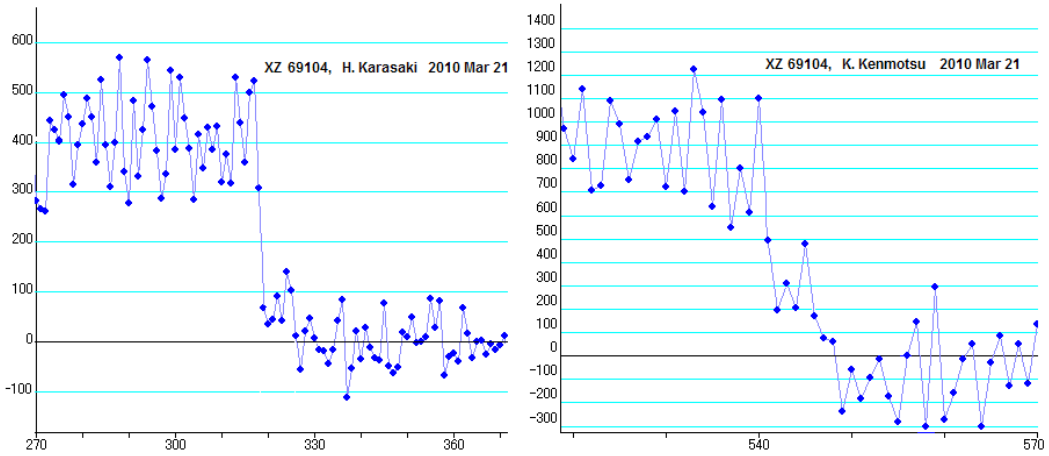

Figure 5: Light curves for the occultation of XZ 69104 obtained by H. Karasaki and K. Kenmotsu, 2010 March 21. Measures have been taken each frame, Karasaki's step lasting for 0.25 second, Kenmotsu's 0.17 second. There is a noticeable discrepancy in the apparent magnitude differences, 1.6 for Karasaki and 0.7 for Kenmotsu.

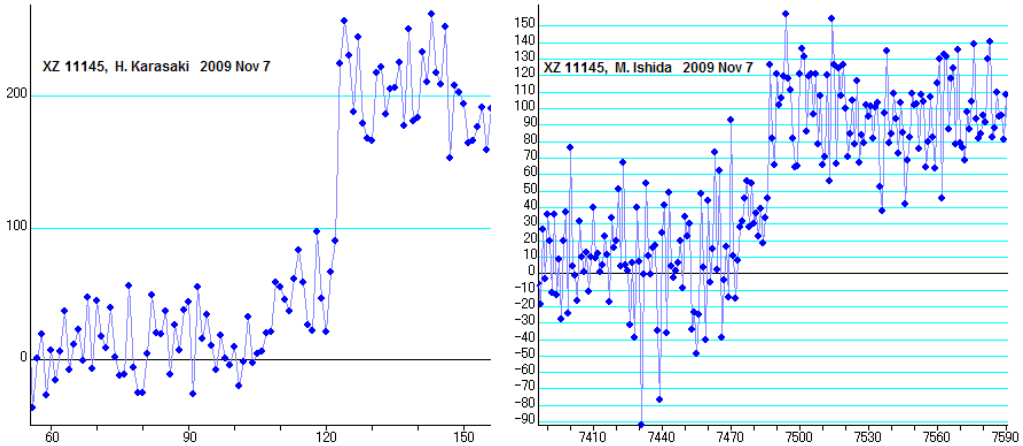

Figure 6: Light curves for the occultation reappearance of XZ 11145 obtained by H. Karasaki and M. Ishida, 2009 November 7. Karasaki's step lasts for 0.47 second, Ishida's 0.43 second.

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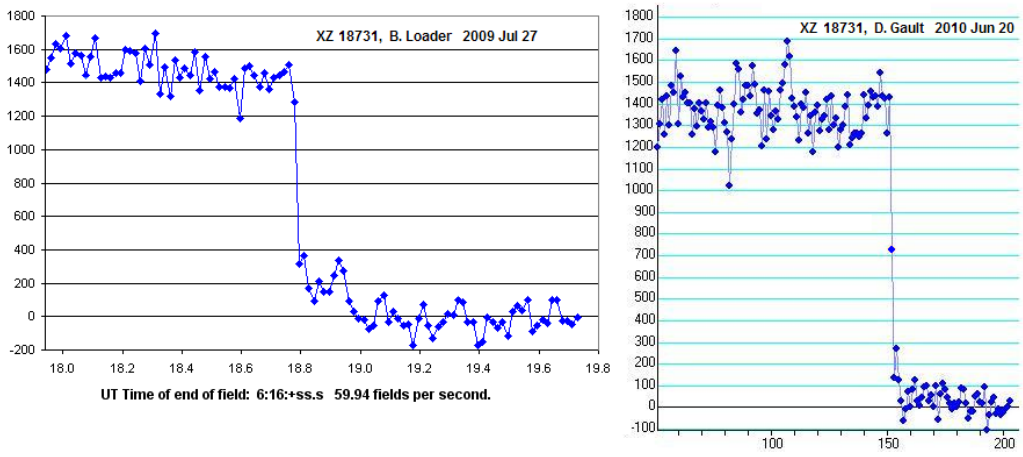

Figure 7: Light curves for occultations of XZ 18731 obtained by B. Loader, 2009 July 27 and D. Gault, 2010 June 20. Loader's step lasts 0.17 seconds, Gault's 0.12 seconds, with measures made each frame.

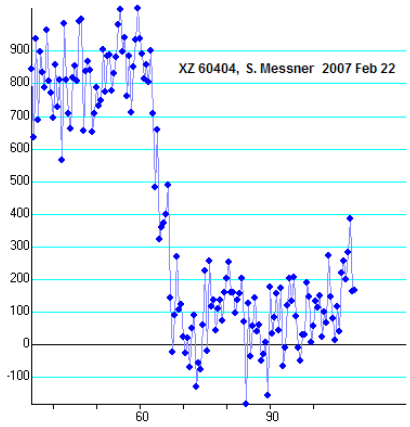

Figure 8: Light curve for occultation of XZ 60404 obtained by S. Messner, 2007 February 22. The step lasts 0.12 second with measures taken each video field.

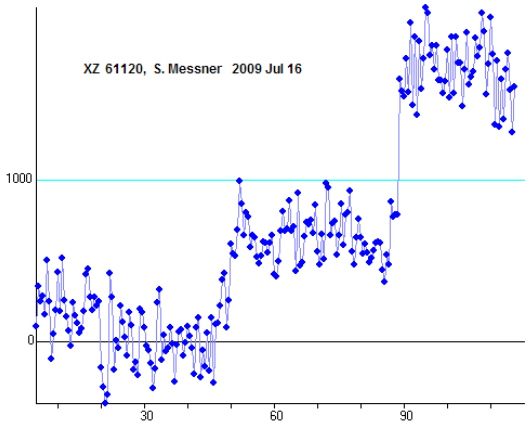

Figure 9: Light curve for occultation reappearance of XZ 61120 obtained by S. Messner, 2009 July 16. The step lasts 1.30 seconds with measures taken each video field.

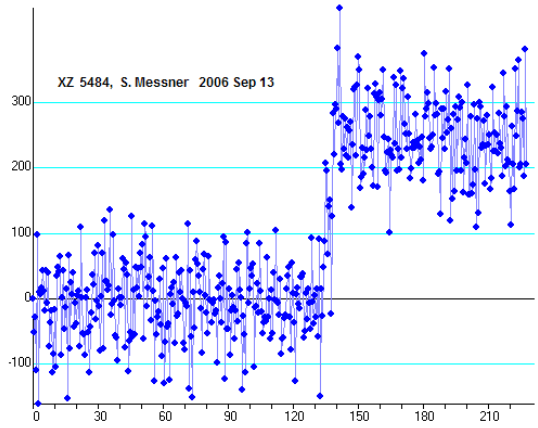

Figure 10: Light curve for occultation reappearance of XZ 5484 obtained by S. Messner, 2006 September 13. The step lasts 0.15 second with measures taken each video field.

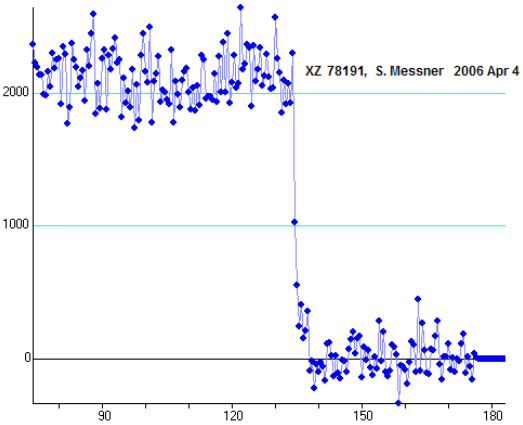

Figure 11: Light curve for occultation of XZ 78191 obtained by S. Messner, 2006 April 4. The step lasts 0.10 second with measures taken each video field.

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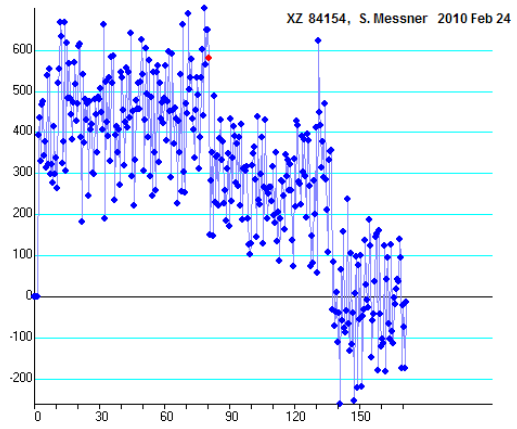

Figure 12: Light curve for occultation of XZ 84154 obtained by S. Messner, 2010 February 24. The step lasts 1.89 seconds with measures taken each video field.

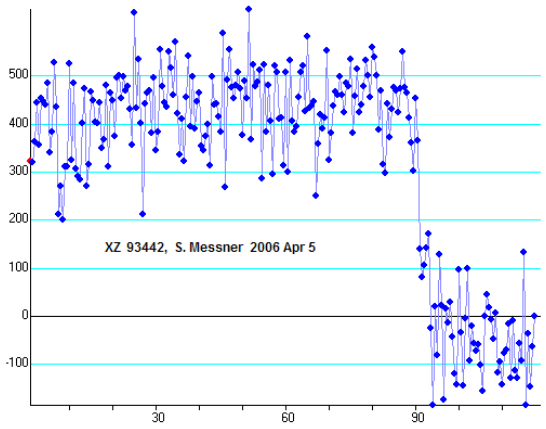

Figure 13: Light curve for occultation of XZ 93442 obtained by S. Messner, 2006 April 5. The step lasts 0.09 second with measures taken each video field.

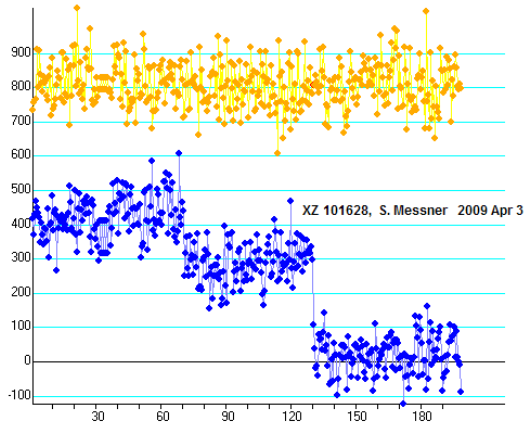

Figure 14: Light curve for occultation of XZ 101628 obtained by S. Messner, 2009 April 3. The step lasts 1.98 seconds with measures taken each video field. A second star was visible on the field and was used as a check.

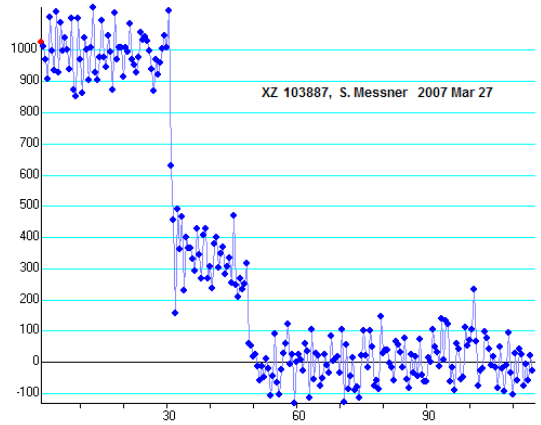

Figure 15: Light curve for occultation of XZ 103887 obtained by S. Messner, 2007 March 27. The step lasts 0.63 second with measures taken each video field.

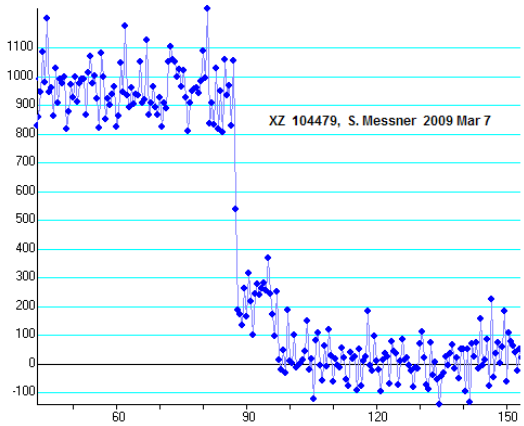

Figure 16: Light curve for occultation of XZ 104479 obtained by S. Messner, 2009 March 7. The step lasts 0.32 second with measures taken each video field.

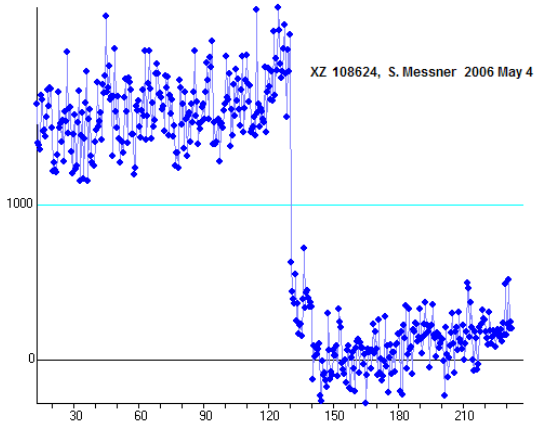

Figure 17: Light curve for occultation of XZ 108624 obtained by S. Messner, 2006 May 4. The step lasts 0.34 second with measures taken each video field.

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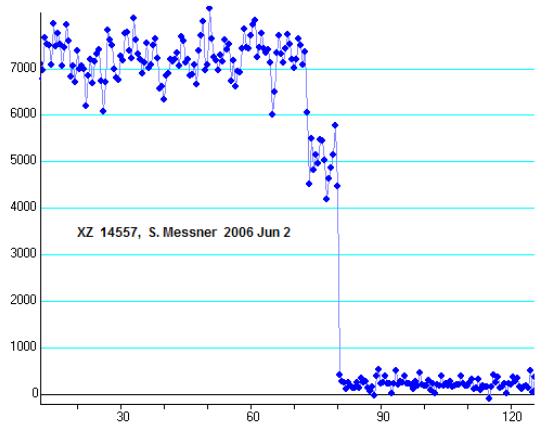

Figure 18: Light curve for occultation of XZ 14557 obtained by S. Messner, 2006 June 2. The step lasts 0.24 second with measures taken each video field.

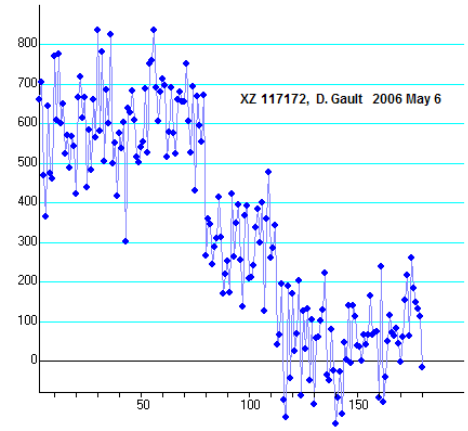

Figure 19: Light curve for occultation of XZ 117172 obtained by D. Gault, 2006 May 6. The step lasts 1.32 seconds with measures taken each video frame.

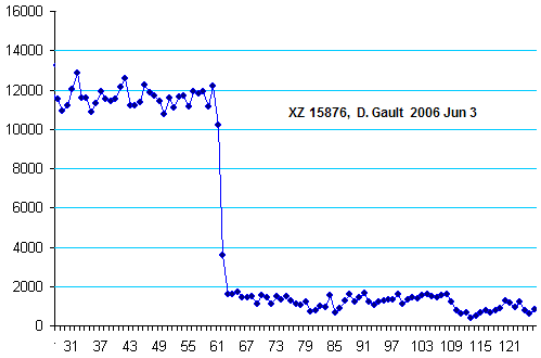

Figure 20: Light curve for occultation of XZ 15876 obtained by D. Gault, 2006 June 3. The step lasts 1.88 seconds with measures taken each video frame.

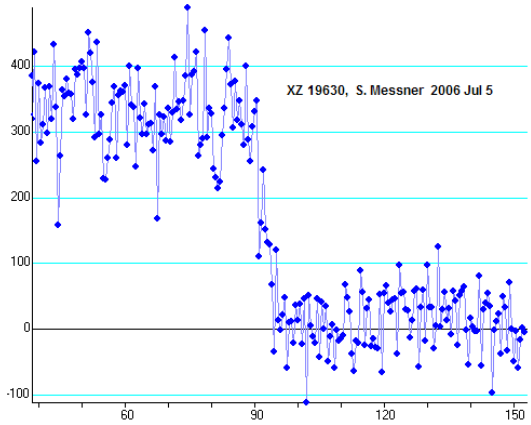

Figure 21: Light curve for occultation of XZ 19630 obtained by S. Messner, 2006 July 5. The step lasts 0.11 second with measures taken each video field.

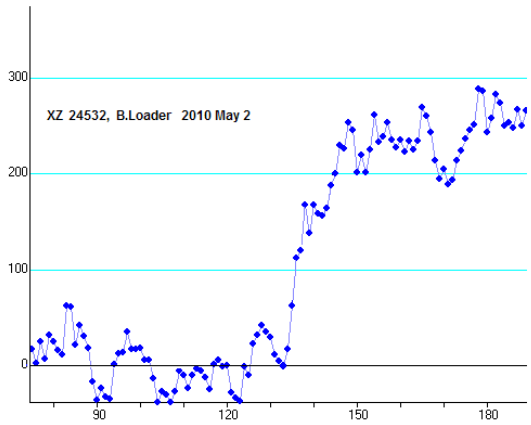

Figure 22: Light curve for occultation of XZ 24532 obtained by B. Loader, 2010 May 2. The step lasts 0.30 second with measures taken each video frame.

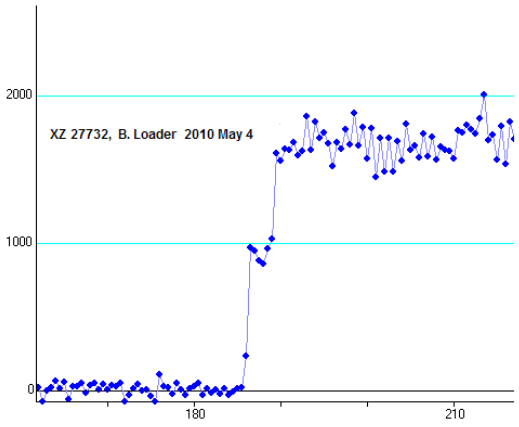

Figure 23: Light curve for occultation of XZ 27732 obtained by B. Loader, 2010 May 4. The step lasts 0.11 second with measures taken each video field.

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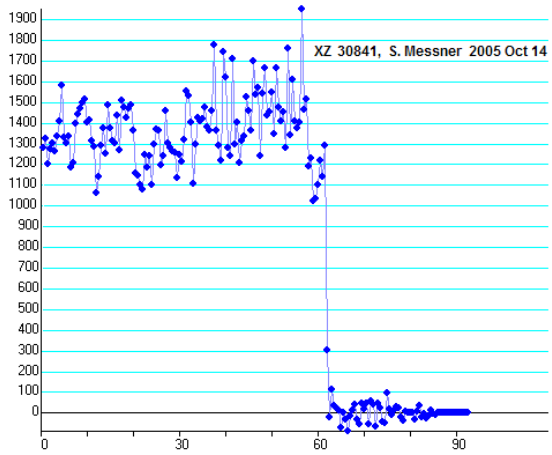

Figure 24: Light curve for occultation of XZ 30841 obtained by S. Messner, 2005 October 14. The step lasts 0.14 second with measures taken each video field.

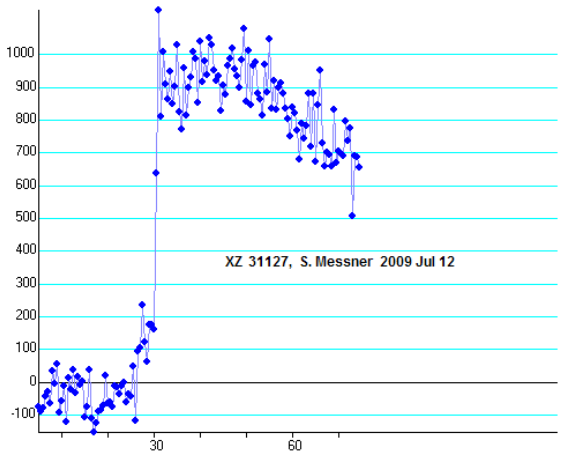

Figure 25: Light curve for occultation of XZ 31127 obtained by S. Messner, 2009 July 12. The step lasts 0.14 second with measures taken each video field.