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Six new W UMa type eclipsing binaries in the field of DE Lac

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Abstract: *USNO-B1.0 1307-0466878, 1304-0469894, 1303-0467062, 1308-0467803, 1310-0458562 and 1313-0462253 were identified as eclipsing binaries for the first time. The shape and amplitude of the light curve and the period implies that all new variables are short-period W UMa type eclipsing binaries.*

Introduction

During photometric imaging observations of DE Lac, a high-amplitude Delta Scuti star, USNO-B1.0 1307-0466878, 1304-0469894, 1303-0467062, 1308-0467803, 1310-0458562 and 1313-0462253 were within the field of view. Closer studies of the images revealed that these stars were variable. Follow-up observations in 2008 provided first indications on the type of light curve morphology.

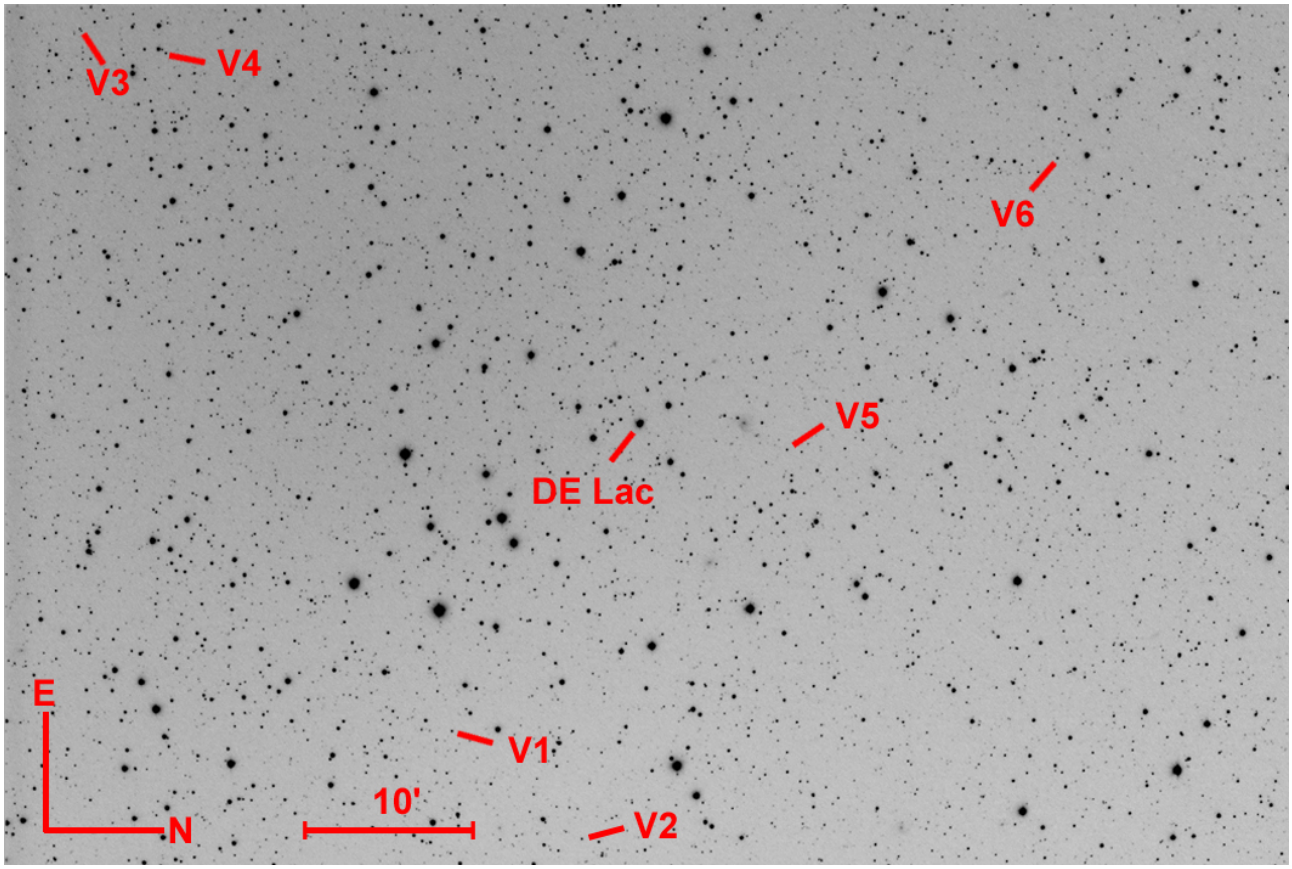

Figure 1. Typical IR cut-off filter frame of the DE Lac field and six new variables. The field of view is about 73'x 49'.

First photometric observations of the eclipsing binaries were carried out over two nights in 2008 with an SBIG ST10XME CCD camera and IR cut-off filter attached to a 60 mm (2.4 inch) f/11.7 refractor in Gemmingen (Germany). The effective field of view of the CCD photometric system is about 73'x 49' and the size of each pixel is 2.0"x 2.0". The exposure times were set to 300 seconds for each CCD image.

Further time-series CCD photometry was obtained between 2009 and 2016 using a 14 inch Cassegrain telescope at f/6 equipped with a CCD SBIG ST10XME and V filter. The CCD was configured in a 3x3 binning mode resulting in an angular resolution of 2.1"/pixel (the field of view is 24'x16'). Due to the low brightness of the variable stars, the exposure time was set to a range of 110 to 300 seconds.

Data analysis

The CCD images were reduced with standard procedures in Mira AP[1]. The flat-field correction utilized sky-flat images taken during the morning twilight. Aperture photometry was also performed in Mira AP and differential magnitudes were calculated. The instrumental magnitudes given were calculated on the basis of the magnitudes in the V photographic band for the comparison stars listed in the Guide Star Catalogue (GSC 2.3).

The times of primary and secondary minima were determined using the Kwee and Van Woerden method (Kwee et al. (1956)). A linear fit to the times of primary minima provides the specified ephemeris.

To estimate the observed maxima and eclipse depths, polynomial fits of fourth degree were applied to the primary and secondary maximum and minimum of the complete data set. Finally, the mean instrumental magnitudes were calculated.

Results

The main result of the observations is summarized in Table 1. Except for USNO-B1.0 1308-0467803 and 1303-0467062 there is an obvious difference between the two out-of-eclipse maxima in the light curves, a phenomenon which is called the O'Connell effect (Milone (1968)). The size of the asymmetry is usually designated Δm. Following O'Connell's convention, Δm is the magnitude of the maximum after primary minimum subtracted from the magnitude of the maximum after secondary minimum.

No.	USNO-B1.0	HJD Min I (E_0)	Period [d]	Max I	Max II	Min I	Min II	O'Connell
V1	1307-0466878	2457626.3747	0.27678383	14.49	14.50	14.84	14.78	> 0
V2	1308-0467803	2457624.4464	0.4138453	14.77	14.77	15.37	15.35	-
V3	1303-0467062	2455397.4875	0.315522	15.67	15.67	15.85	15.82	-
V4	1304-0469894	2455481.4069	0.340253	14.86	14.89	15.37	15.25	> 0
V5	1310-0458562	2455836.4666	0.3670230	14.60	14.62	14.85	14.83	> 0
V6	1313-0462253	2457639.5280	0.3070425	14.39	14.42	14.63	14.57	< 0

Table 1: Summary of the discovered variables in the field of DE Lac with USNO-B1.0 identification number, new light elements and V instrumental magnitudes of the maxima and minima, respectively.

In the following section a detailed description of the new variables is given with all the new times of primary (I) and secondary (II) minima and phased light curves. In the finding charts the new variable star is labelled as star V, stars C and K are the selected comparison and check stars.

[1] Mira AP software by Mirametrics, Inc. (USA)

V1 = USNO-B1.0 1307-0466878

$\alpha_{2000}=22^h08^m34.8^s$ $\delta_{2000}=+40°45'14.5''$

V_{mag}(instr.): Max I: 14.49 Max II: 14.50 Min I: 14.84 Min II:14.78

Remark:
W UMa type eclipsing binary. The system shows an O'Connell effect $\Delta m>0$.

Comparison star C
USNO-B1.0 1306-0468645
V_{mag}= 13.69 ± 0.28 (GSC 2.3)

Check star K
USNO-B1.0 1306-0468375
V_{mag}= 13.67 ± 0.27 (GSC 2.3)

HJD	±	type	E	O-C [d]	filter	exposure time
2455039.4156	0.0004	II	-9346.5	0.0009	V	300s
2455041.4916	0.0005	I	-9339	0.0011	V	300s
2455075.3966	0.0002	II	-9216.5	0.0001	V	300s
2455083.4233	0.0004	II	-9187.5	0.0000	V	300s
2455100.3080	0.0005	II	-9126.5	0.0009	V	300s
2455100.4456	0.0007	I	-9126	0.0002	V	300s
2455380.5501	0.0003	I	-8114	-0.0006	V	300s
2455385.3936	0.0005	II	-8096.5	-0.0009	V	300s
2455385.5327	0.0003	I	-8096	-0.0001	V	300s
2455386.5020	0.0007	II	-8092.5	0.0004	V	300s
2455391.4809	0.0005	II	-8074.5	-0.0028	V	300s
2457210.5090	0.0006	II	-1502.5	0.0020	V	180s
2457214.5220	0.0004	I	-1488	0.0017	V	180s
2457225.4541	0.0004	II	-1448.5	0.0008	V	180s
2457623.4680	0.0003	II	-10.5	-0.0005	V	180s
2457624.4351	0.0003	I	-7	-0.0021	V	180s
2457624.5771	0.0004	II	-6.5	0.0014	V	180s
2457626.3738	0.0001	I	0	-0.0009	V	180s
2457626.5121	0.0005	II	0.5	-0.0010	V	180s
2457627.3447	0.0004	II	3.5	0.0013	V	180s
2457627.4807	0.0002	I	4	-0.0012	V	180s

Table 2: New times of primary (I) and secondary (II) minima of USNO-B1.0 1307-0466878.

A linear fit to the 8 times of primary minima provides the following ephemeris:

$$HJD_{Min\ I} = 2457626.3747 + 0.27678383*E$$
$$\pm 0.0004 \quad \pm 0.00000007$$

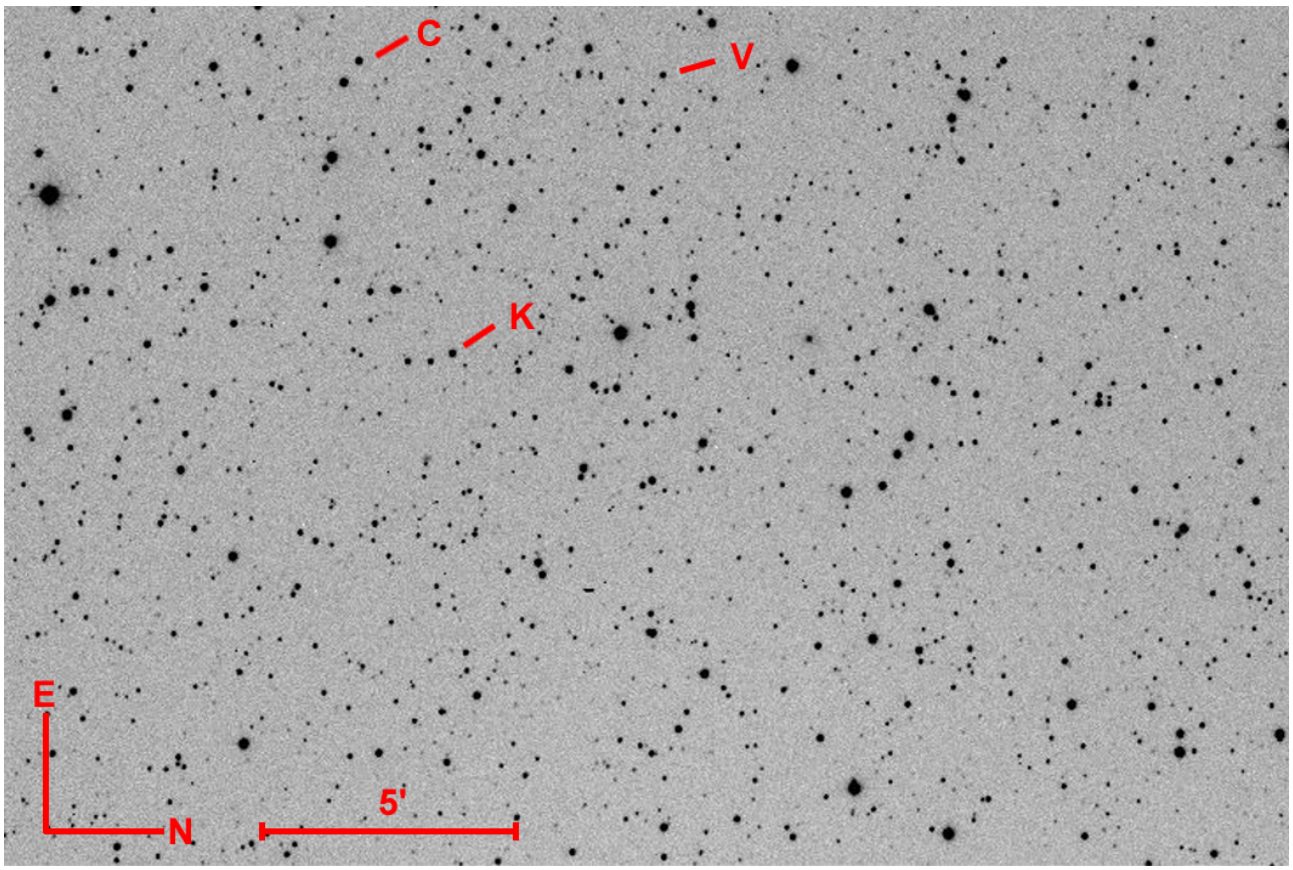

Figure 2: Typical frame of the USNO-B1.0 1307-0466878 field.

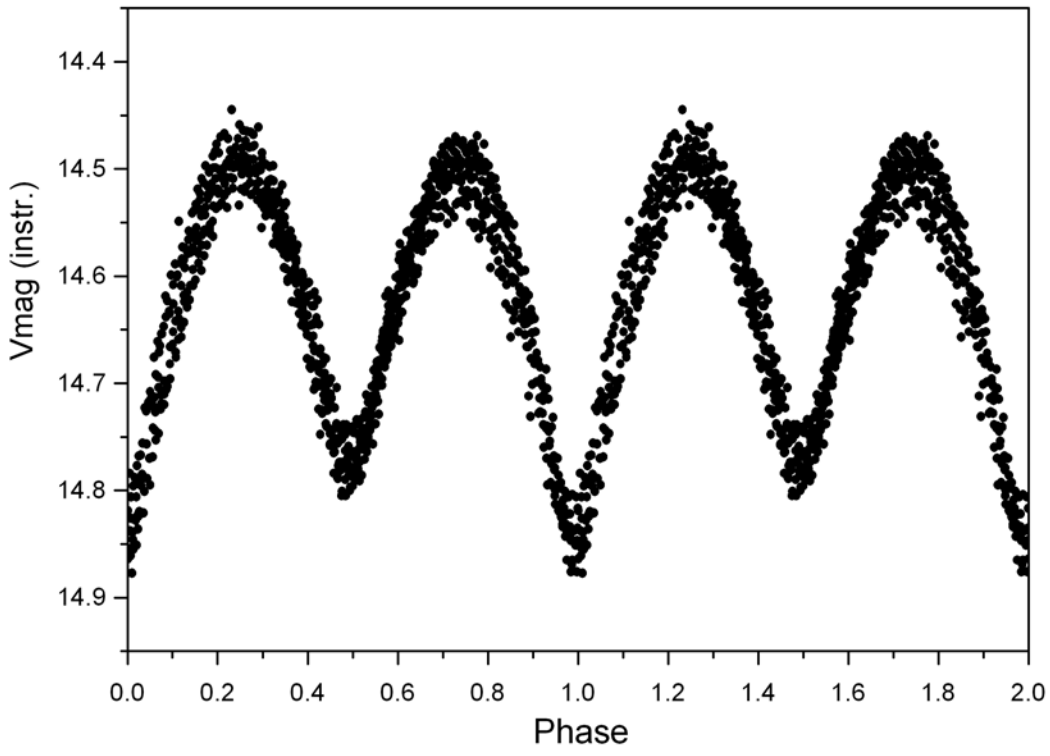

Figure 3: Phased light curve for USNO-B1.0 1307-0466878 calculated with E_0 = 2457626.3747 and P = 0.27678383^d (instrumental magnitudes with respect to USNO-B1.0 1306-0468645).

V2 = USNO-B1.0 1308-0467803
$\alpha_{2000}=22^h08^m04.1^s$ $\delta_{2000}=+40°52'43.9''$

V_{mag}(instr.): Max I: 14.77 Max II: 14.77 Min I: 15.37 Min II:15.35

Remark:
W UMa type eclipsing binary.

Comparison star C
GSC 3202-00171
V_{mag}= 13.67 ± 0.26 (GSC 2.3)

Check star K
GSC 3202-00001
V_{mag}= 13.13 ± 0.26 (GSC 2.3)

HJD	±	type	E	O-C [d]	filter	exposure time
2455041.4317	0.0002	II	-6241.5	0.0026	V	300s
2455075.3647	0.0005	II	-6159.5	0.0026	V	300s
2455100.4030	0.0003	I	-6099	0.0026	V	300s
2455385.5433	0.0002	I	-5410	0.0024	V	300s
2455391.5444	0.0005	II	-5395.5	0.0023	V	300s
2457225.5008	0.0002	I	-964	0.0008	V	180s
2457623.4112	0.0003	II	-2.5	0.0005	V	180s
2457624.4468	0.0002	I	0	0.0005	V	180s
2457626.5168	0.0003	I	5	0.0005	V	180s
2457627.3410	0.0002	I	7	0.0005	V	180s
2457627.5472	0.0002	II	7.5	0.0005	V	180s

Table 3: New times of primary (I) and secondary (II) minima of USNO-B1.0 1308-0467803.

A linear fit to the 6 times of primary minima provides the following ephemeris:

$$HJD_{Min\ I} = 2457624.4464 + 0.4138453*E$$
$$\pm 0.0008 \quad \pm 0.0000003$$

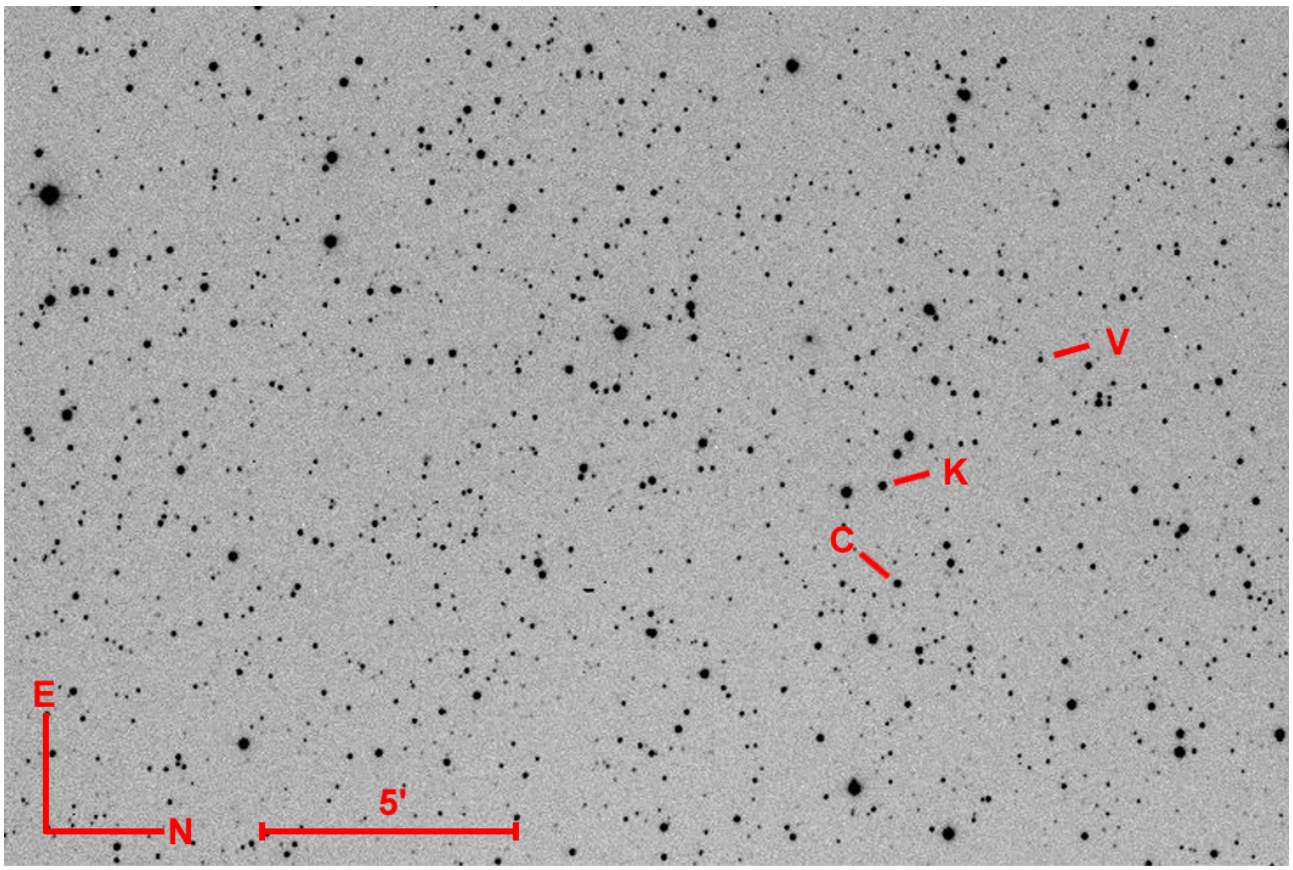

Figure 4: Typical frame of the USNO-B1.0 1308-0467803 field.

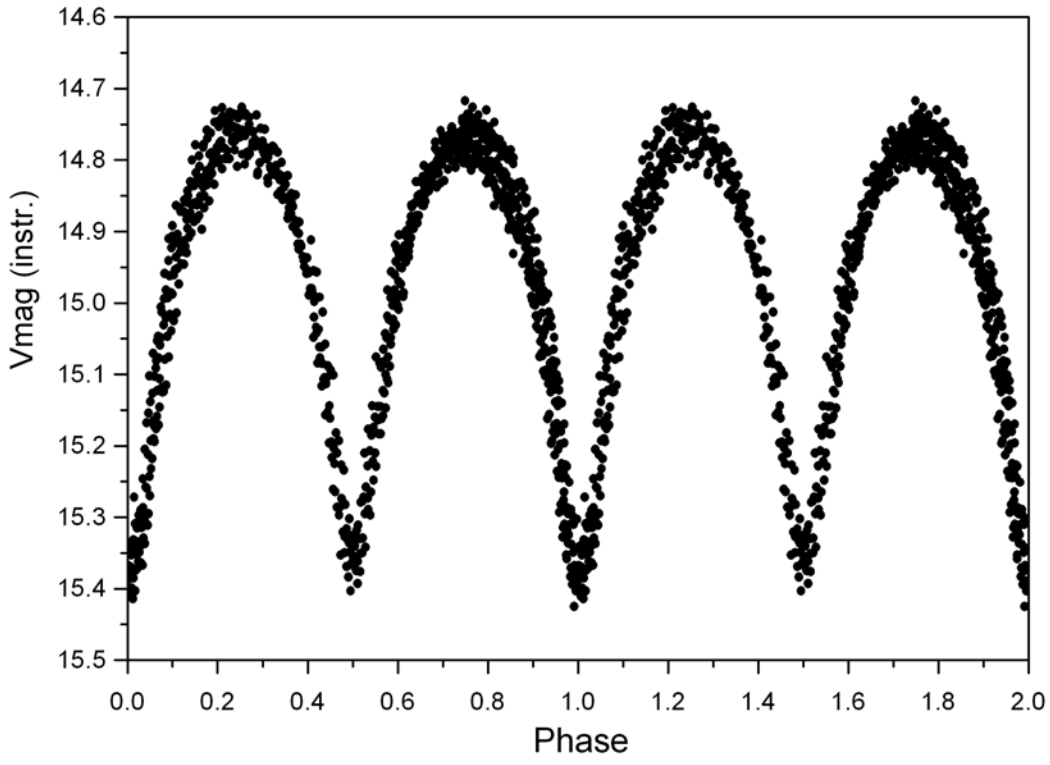

Figure 5: Phased light curve for USNO-B1.0 1308-0467803 calculated with E_0 = 2457624.4464 and P = 0.4138453^d (instrumental magnitudes with respect to GSC 3202-00171).

V3 = USNO-B1.0 1303-0467062
α_{2000}=22^{h}11^{m}57.2^s δ_{2000}=+40°22'57.8''

V_{mag}(Instr.): Max I: 15.67 Max II: 15.67 Min I: 15.85 Min II:15.82

Remark:
W UMa type eclipsing binary.

Comparison star C
GSC 3203-01775
V_{mag}= 13.42 ± 0.30 (GSC 2.3)

Check star K
GSC 3203-01824
V_{mag}= 12.90 ± 0.30 (GSC 2.3)

HJD	±	type	E	O-C [d]	filter	exposure time
2455397.4925	0.0010	I	0	0.0050	V	300s
2455408.3796	0.0007	II	34.5	0.0066	V	300s
2455408.5252	0.0009	I	35	-0.0056	V	300s
2455460.4437	0.0016	II	199.5	0.0095	V	300s
2455481.4178	0.0008	I	266	0.0014	V	300s
2456188.3508	0.0012	II	2506.5	0.0074	V	180s
2456188.4934	0.0007	I	2507	-0.0078	V	180s
2456190.3988	0.0005	I	2513	0.0045	V	180s
2456190.5553	0.0004	II	2513.5	0.0033	V	180s

Table 4: New times of primary (I) and secondary (II) minima of USNO-B1.0 1303-0467062.

A linear fit to the 5 times of primary minima provides the following ephemeris:

$$HJD_{Min\ I} = 2455397.4875 + 0.315522*E$$
$$\pm 0.0051 \quad \pm 0.000003$$

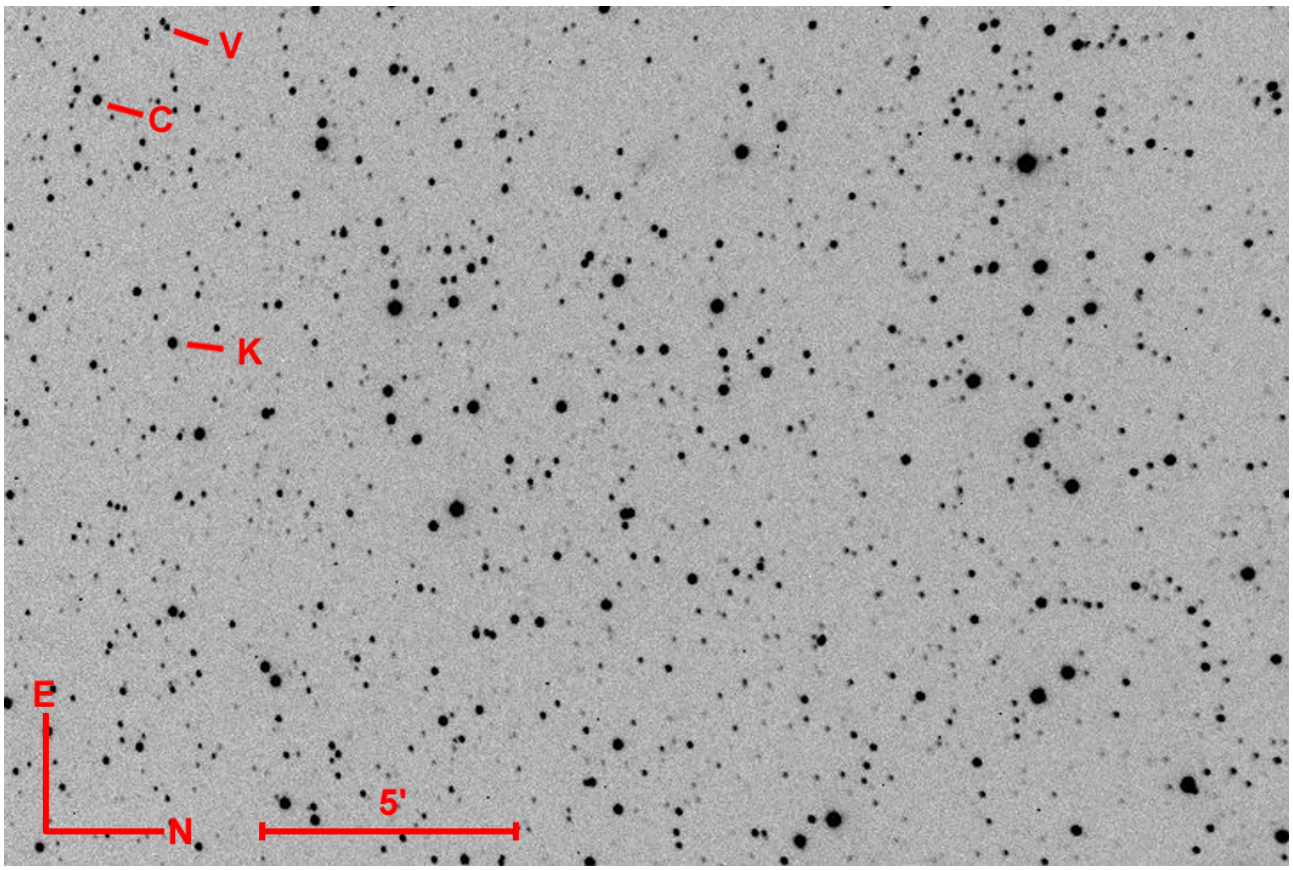

Figure 6: Typical frame of the USNO-B1.0 1303-0467062 field.

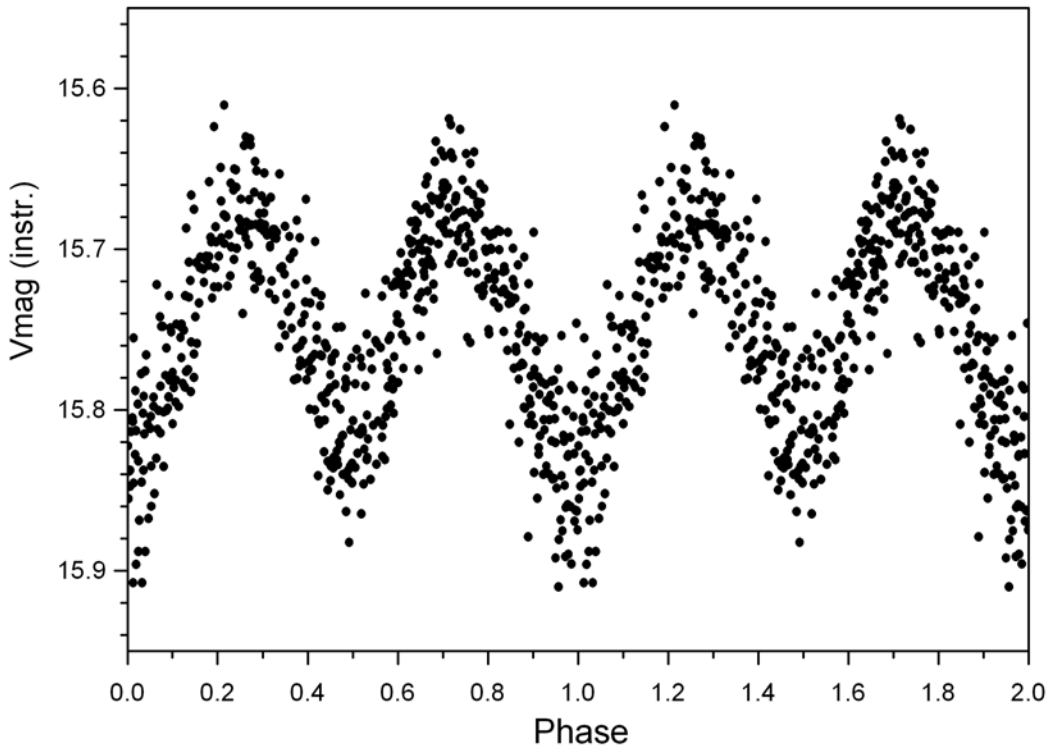

Figure 7: Phased light curve for USNO-B1.0 1303-0467062 calculated with E_0 = 2455397.4875 and P = 0.315522^d (instrumental magnitudes with respect to GSC 3203-01775).

V4 = USNO-B1.0 1304-0469894
$\alpha_{2000}=22^h11^m51.8^s$ $\delta_{2000}=+40°27'44.9''$

V_{mag}(Instr.): Max I: 14.86 Max II: 14.89 Min I: 15.37 Min II:15.25

Remark:
W UMa type eclipsing binary. The system shows clearly an O'Connell effect $\Delta m>0$.

Comparison star C
USNO-B1.0 1304-0469896
V_{mag}= 14.20 ± 0.30 (GSC 2.3)

Check star K
USNO-B1.0 1304-0469838
V_{mag}= 14.26 ± 0.30 (GSC 2.3)

HJD	±	type	E	O-C [d]	filter	exposure time
2455397.5361	0.0003	II	-246.5	0.0016	V	300s
2455408.4249	0.0006	II	-214.5	0.0023	V	300s
2455408.5915	0.0007	I	-214	-0.0012	V	300s
2455409.4443	0.0006	II	-211.5	0.0009	V	300s
2455481.4054	0.0003	I	0	-0.0015	V	300s
2455499.2675	0.0009	II	52.5	-0.0026	V	300s
2455758.5450	0.0010	II	814.5	0.0022	V	300s
2455761.4397	0.0007	I	823	0.0048	V	300s
2456188.4511	0.0003	I	2078	-0.0011	V	180s
2456190.4928	0.0003	I	2084	-0.0009	V	180s

Table 5: New times of primary (I) and secondary (II) minima of USNO-B1.0 1304-0469894.

A linear fit to the 5 times of primary minima provides the following ephemeris:

$$HJD_{Min\ I} = 2455481.4069 + 0.340253*E$$
$$\pm 0.0019 \quad \pm 0.000001$$

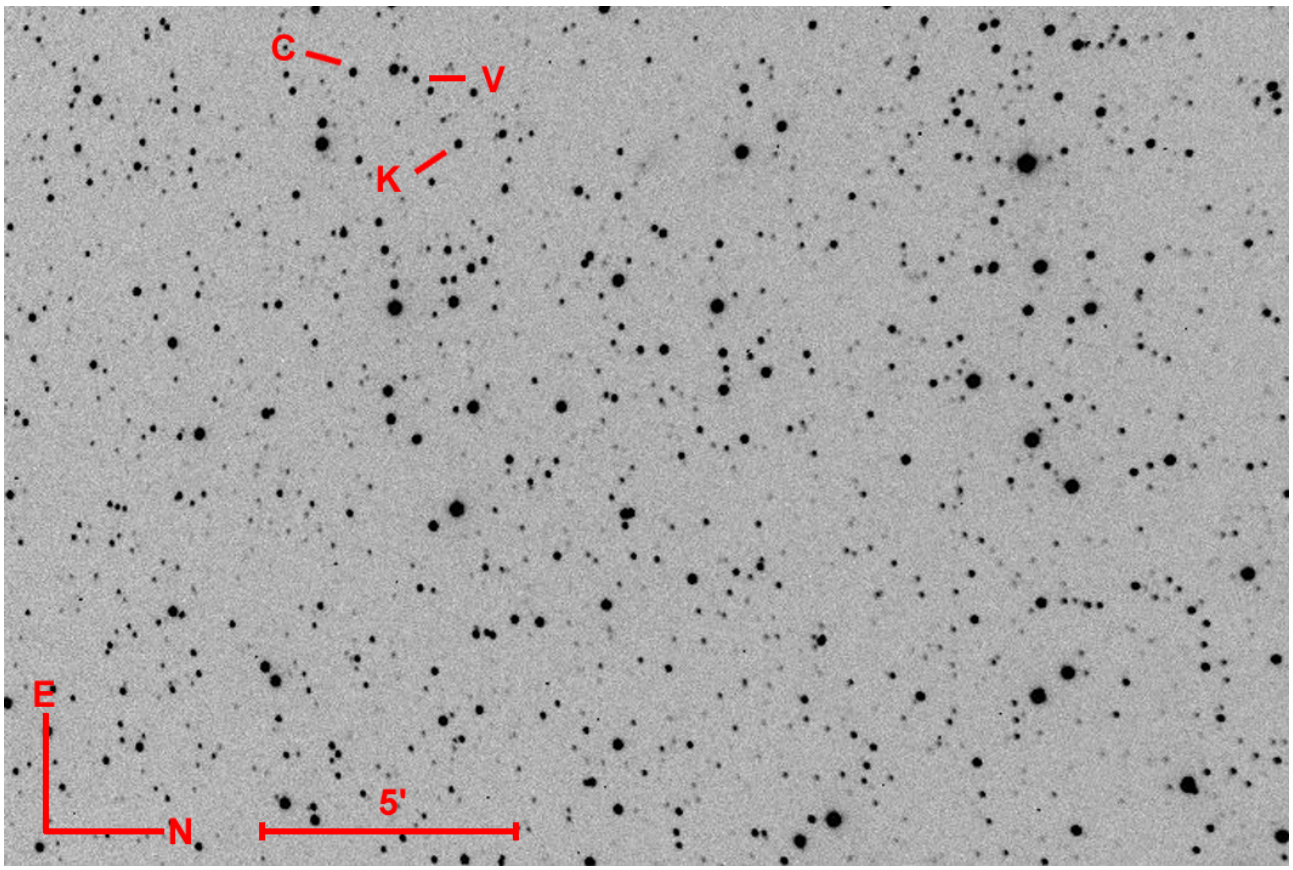

Figure 8: Typical frame of the USNO-B1.0 1304-0469894 field.

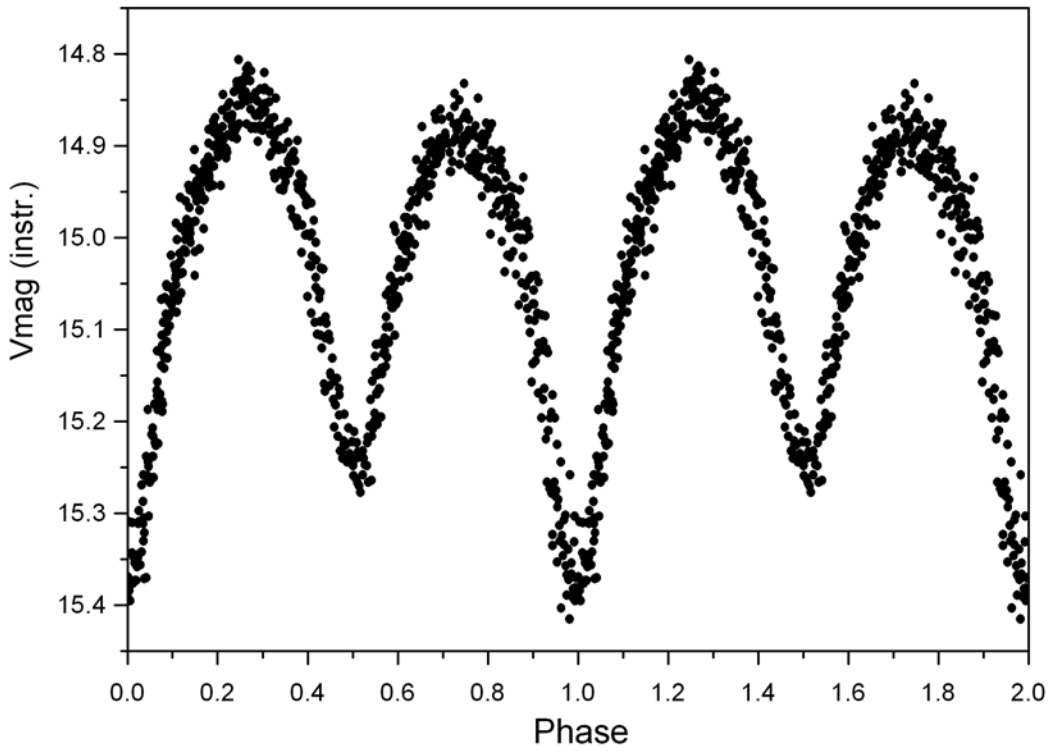

Figure 9: Phased light curve for USNO-B1.0 1304-0469894 calculated with E_0 = 2455481.4069 and P = 0.340253^d (instrumental magnitudes with respect to USNO-B1.0 1304-0469896).

V5 = USNO-B1.0 1310-0458562
$\alpha_{2000}=22^h10^m02.1^s$ $\delta_{2000}=+41°03'32.4''$

V_{mag}(Instr.): Max I: 14.60 Max II: 14.62 Min I: 14.85 Min II:14.83

Remark:
W UMa type eclipsing binary. The system shows clearly an O'Connell effect $\Delta m>0$.

Comparison star C
GSC 3203-00971
V_{mag}= 12.40 ± 0.27 (GSC 2.3)

Check star K
GSC 3203-00327
V_{mag}= 12.63 ± 0.27 (GSC 2.3)

HJD	±	type	E	O-C [d]	filter	exposure time
2455372.5477	0.0005	I	-1264	-0.0018	V	270s
2455740.4914	0.0006	II	-261.5	0.0014	V	180s
2455747.4678	0.0005	II	-242.5	0.0043	V	180s
2455754.4376	0.0004	II	-223.5	0.0007	V	180s
2455815.5450	0.0010	I	-57	-0.0013	V	240s
2455829.3109	0.0044	II	-19.5	0.0013	V	180s
2455831.3288	0.0014	I	-14	0.0006	V	180s
2455835.3622	0.0005	I	-3	-0.0033	V	180s
2455836.2812	0.0006	II	-0.5	-0.0019	V	180s
2455836.4658	0.0005	I	0	-0.0007	V	180s
2455837.3869	0.0006	II	2.5	0.0028	V	180s
2455849.3136	0.0009	I	35	0.0013	V	180s
2456131.5525	0.0006	I	804	-0.0006	V	180s
2456525.5499	0.0060	II	1877.5	-0.0024	V	180s
2456835.5021	0.0004	I	2722	-0.0011	V	180s
2456856.4180	0.0006	I	2779	-0.0055	V	180s
2456857.5248	0.0004	I	2782	0.0002	V	180s
2457205.4630	0.0015	I	3730	0.0007	V	180s
2457207.4834	0.0007	II	3735.5	0.0024	V	180s
2457588.4506	0.0009	II	4773.5	-0.0003	V	180s
2457589.5550	0.0006	II	4776.5	0.0030	V	110s

Table 6: New times of primary (I) and secondary (II) minima of USNO-B1.0 1310-0458562.

A linear fit to the 11 times of primary minima provides the following ephemeris:

$$HJD_{Min\ I} = 2455836.4666 + 0.3670230*E$$
$$\pm 0.0006 \quad \pm 0.0000003$$

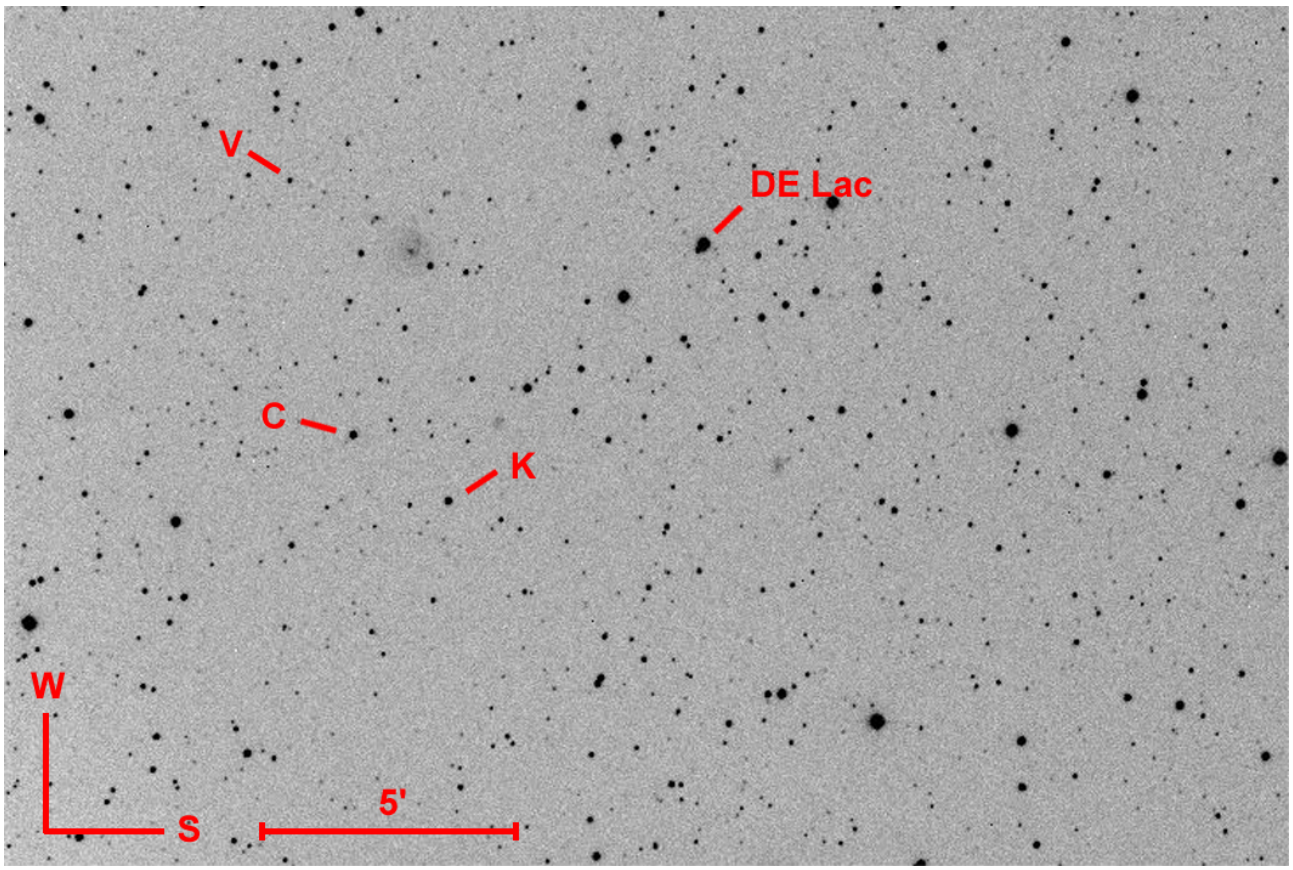

Figure 10: Typical frame of the USNO-B1.0 1310-0458562 field.

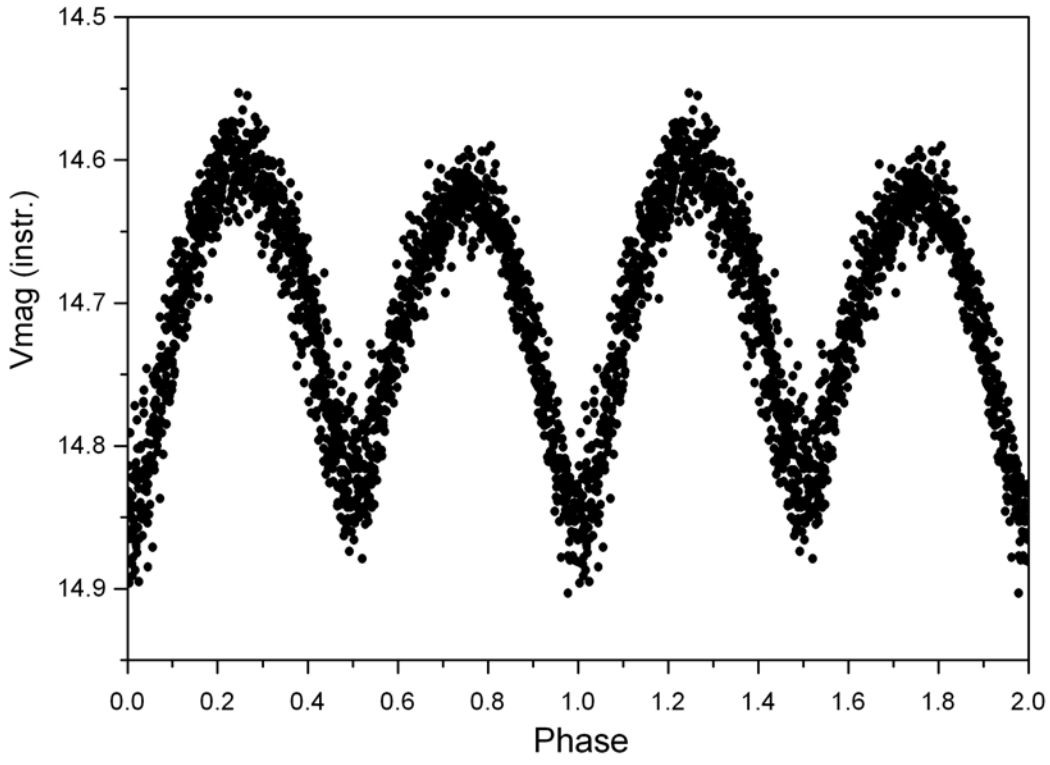

Figure 11: Phased light curve for USNO-B1.0 1310-0458562 calculated with E_0 = 2455836.4666 and P = 0.3670230^d (instrumental magnitudes with respect to GSC 3203-00971).

V6 = USNO-B1.0 1313-0462253
$\alpha_{2000}=22^h11^m31.8^s$ $\delta_{2000}=+41°18'00.1''$

V_{mag}(Instr.): Max I: 14.39 Max II: 14.42 Min I: 14.63 Min II:14.57

Remark:
W UMa type eclipsing binary. The system shows clearly an O'Connell effect $\Delta m<0$.

Comparison star C
GSC 3207-00826
V_{mag}= 12.51 ± 0.27 (GSC 2.3)

Check star K
GSC 3207-01062
V_{mag}= 12.41 ± 0.15 (GSC 2.3)

HJD	±	type	E	O-C [d]	filter	exposure time
2456133.4753	0.0006	I	-4905.0	-0.0092	V	180s
2456167.4149	0.0005	II	-4794.5	0.0021	V	180s
2456167.5683	0.0012	I	-4794.0	0.0020	V	180s
2456177.3956	0.0004	I	-4762.0	0.0039	V	180s
2456178.4729	0.0004	II	-4758.5	0.0066	V	180s
2456179.3940	0.0004	II	-4755.5	0.0065	V	180s
2457638.4484	0.0009	II	-3.5	-0.0050	V	120s
2457639.3714	0.0010	II	-0.5	-0.0030	V	120s
2457639.5269	0.0003	I	0.0	-0.0011	V	120s
2457640.4497	0.0002	I	3.0	0.0006	V	120s
2457641.3689	0.0003	I	6.0	-0.0014	V	120s
2457641.5200	0.0005	II	6.5	-0.0038	V	120s
2457642.4424	0.0006	II	9.5	-0.0026	V	120s
2457644.4416	0.0003	I	16.0	0.0010	V	120s

Table 7: New times of primary (I) and secondary (II) minima of USNO-B1.0 1313-0462253.

A linear fit to the 7 times of primary minima provides the following ephemeris:

$$HJD_{Min\ I} = 2457639.5280 + 0.3070425*E$$
$$\pm 0.0012 \quad \pm 0.0000006$$

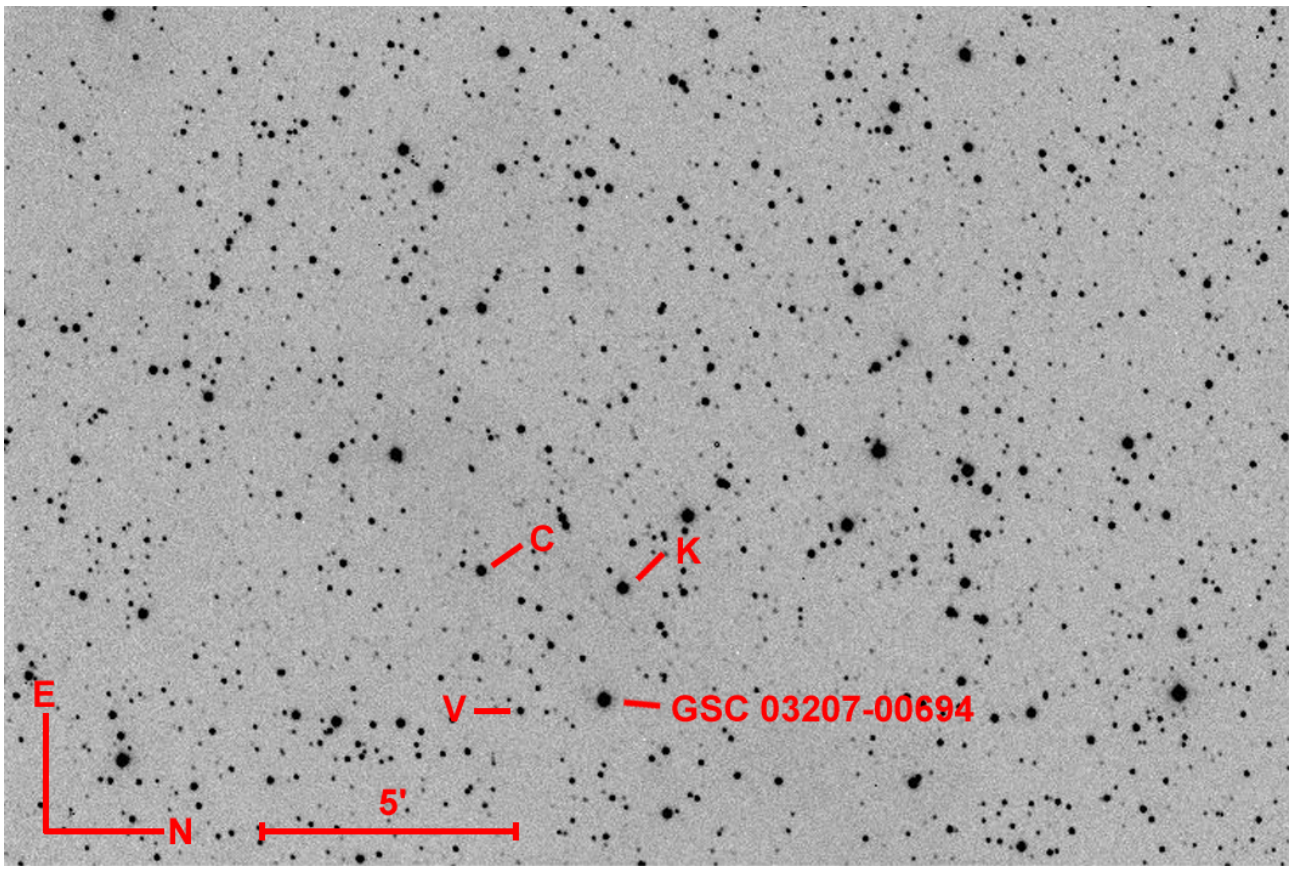

Figure 12: Typical frame of the USNO-B1.0 1313-0462253 field.

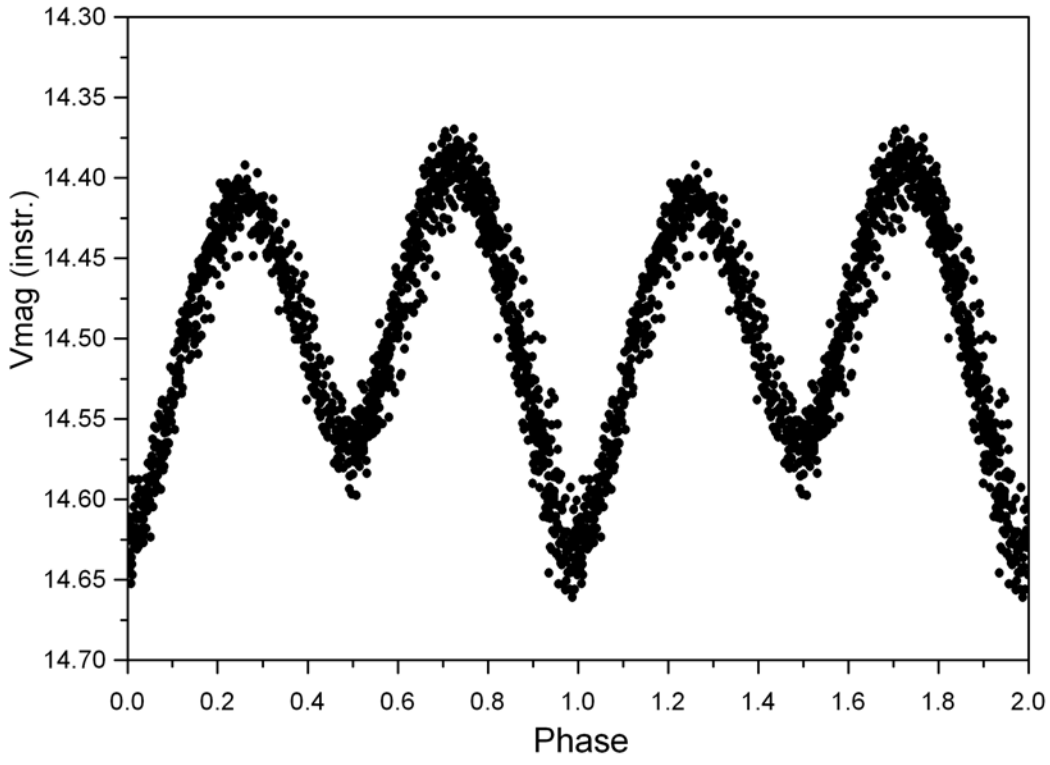

Figure 13: Phased light curve for USNO-B1.0 1313-0462253 calculated with E_0 = 2457639.5280 and P = 0.3070425^d (instrumental magnitudes with respect to GSC 3207-00826).

Acknowledgements

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