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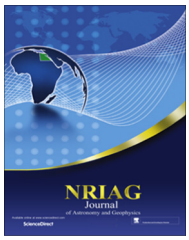

First CCD photometric observation of the W-UMa eclipsing binary system 1SWASP J064501.21 + 342154.9

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Abstract New *BVRI* light curves of the eclipsing binary system 1SWASP J064501.21 + 342154.9 (J0645) have been constructed based on CCD observations that were obtained by using the 1.88-m telescope of Kottamia Astronomical Observatory (KAO), Egypt on January and February, 2013. New times of minima and new ephemeris have been determined from these light curves. Using the Binary Maker 3.0 (BM3) package, a preliminary determination of the geometric and photometric element parameters of the system J0645 is derived.

1. Introduction

The eclipsing binary system 1SWASP J064501.21 + 342154.9 (α_{2000} = 06^h 45^m 1.21^s, δ_{2000} = +34° 21′ 54.9″) was discovered as a variable star by Norton et al. (2011) during the analysis of the data from Super WASP project with the aim of searching for transiting extra-solar planets. They published a list of 53 candidates for short period eclipsing binary stars observed by SuperWASP. The list includes 48 newly identified objects with periods $< 2 \times 10^4$ s ($\sim$0.23^d).

Norton et al. (2011) reported that the orbital period of the system J0645 is 0.22105^d with maximum V_{mag} = 14.11, and amplitude of 0.35 mag for the primary and secondary depths.

Lohr et al. (2012) give a short name for the system as J0645 and they have made more precise study for the orbital periods of Norton's list where they found that the orbital period of the system J0645 is 0.24862^d, a bit longer than that the previously estimated by Norton et al. (2011).

Searching by coordinates for the system J0645 in VizieR data base web site (http://vizier.u-strasbg.fr/viz-bin/VizieR), we found different names in different catalogs (see Table 1).

Until now there is no information about the spectral type of the system J0645.

2. Observations and data reduction

Photometric observations of the eclipsing binary system J0645 have been obtained in *B*, *V*, *R* and *I* wide pass-band filters (closely match to those of the standard Jonson system) through four nights, 4th, 5th of January and 7th, 8th of February, 2013, using EEV CCD 42–40 camera with a format of 2048*2048 pixels,

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Table 1 Different names of the system J0645 in different catalogs.

Catalog	Other name of J0645
USNO-A2.0 catalog, Monet (1998)	USNO-A2.0 1200-05105590
GSC 2.2 catalog, STScI (2001)	GSC2.2 N222313213818
USNO-B1.0 catalog, Monet (2002)	USNO-B1.0 1243-0137217
2MASS All-Sky catalog, Cutri (2003)	2MASS 06450122 + 3421546
UCAC2 catalog, Zacharias (2004)	2UCAC 43776205
NOMAD catalog, Zacharias (2005)	NOMAD1 1243-0140899
Carlsberg meridian catalog 14, CMC (2006)	CMC14 064501.2 + 342154
Guide star catalog, version 2.3.2, STScI (2007)	GSC2.3 N8GU013818
PPMXL catalog, Roeeser (2010)	PPMXL 3331592793753944658
UCAC4 catalog, Zacharias (2012)	UCAC4 622-035881
WISE All-Sky data release, Cutri (2012)	WISE J064501.22 + 342154.5
AAVSO International VSX, Watson (2013)	NSVS 7178717

Table 2 ID, coordinates, and Mag. of variable, comparison, and check stars.

Star	ID	RAJ2000"h:m:s"	DEJ2000"d:m:s"	V_{mag}	B_{mag}
Variable	1SWASP J064501.21 + 342154.9	06:45:01.21	+ 34:21:54.9	14.217	15.298
Comparison	USNO-A2.0 1200-05104801	06:44:58.05	+ 34:23:52.8	14.037	14.685
Check	USNO-A2.0 1200-05103968	06:44:54.65	+ 34:24:09.6	13.564	14.277

cooled by liquid nitrogen to −125 °C attached to the Newtonian focus of the 1.88-m reflector telescope of Kottamia Astronomical Observatory (KAO), Egypt. The field of view equals 10 arcmin and the exposure times equal 180^s, 60^s, 20^s, and 10^s for *BVRI* filter, respectively. The *BRI* light curves for the system J0645 are presented here for the first time. For more details about KAO see Azzam et al., 2007.

The basic data reduction of the raw CCD images was performed according to the standard method as specified by the following formula:

$$\text{REDUCED} = [(\text{Object Frames}) - (\text{Master Bias})]/(\text{Master Flat}).$$

where Master Flat = (Flat-Master Bias)

Differential photometry was performed with respect to USNO-A2.0 1200-05104801 and USNO-A2.0 1200-05103968 as a comparison and check stars, respectively.

The basic information of the variable, comparison, and check stars are obtained from the AAVSO Photometric All-Sky Survey (APASS) (http://www.aavso.org/apass) and listed in Table 2. The variable (V), comparison (C), and check (K) stars are shown in one of the *V*-band frames of our observations (see Fig. 1). All times were converted to HJD.

The complete light curves in *VRI* and *B* bands are obtained in the nights of 7th and 8th February, 2013, respectively. These light curves are shown in Fig. 2 and their data listed in Table A1 of Appendix A.

It is noticed that there is a slight phase shift about −0.003 in the *B* light curve in comparison to that of the *VRI* light curves. This may lead us to conclude that the system J0645 has a variation from cycle to cycle.

3. Epochs of photometric minima

New six times of minima of the system J0645 (two primary and four secondary) are derived from the present photometry. The moments of these minima were calculated using the software package AVE Barbera (1996), that employs the method of

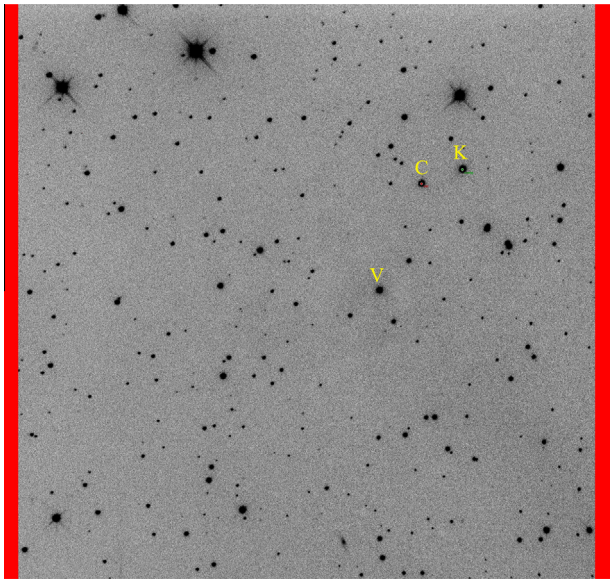

Fig. 1 One of the *V*-band CCD images of J0645V, C, and K in the image refer to the variable, comparison, and check stars respectively.

Kwee and van Woerden (1956). Table 3 gives the following parameters: date of observation, the deduced heliocentric time of minima, the probable error in the heliocentric time of minima (P.E.), and type of minima (Min.) respectively. We used the new times of minima to construct a new ephemeris as follows:

$$\text{JD}(\text{Min}I, \text{Hel}) = 2456331.2694707(\pm 0.000084) + 0.24862(\pm 0.0031) * \text{E},$$

where *E* is the integer cycle.

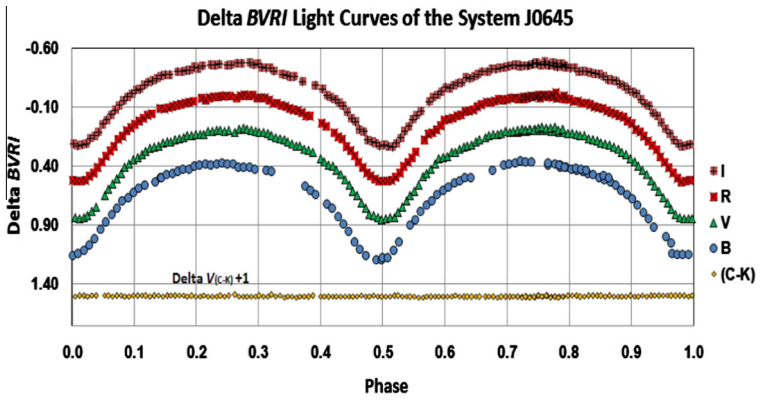

Fig. 2 *BVRI* light curves of the system J0645 in 7th, and 8th of February, 2013, with delta $V(c-k)+1$ that approximately shows a constant value.

Table 3 Epoch's minimum light of the system J0645.

Date of observations	Hel. time of min.	P.E.	Min.
4 Jan. 2013	2456297.582526	0.000243	II
5 Jan. 2013	2456298.328348	0.000163	II
7 Feb. 2013	2456331.269471	0.000084	I
7 Feb. 2013	2456331.394084	0.000153	II
8 Feb. 2013	2456332.262074	0.000322	I
8 Feb. 2013	2456332.386104	0.000323	II

4. Preliminary photometric data analysis

The software Binary Maker 3 (Bradstreet et al., 2005, hereafter BM3) has been used to construct the theoretical light curve of the system J0645. The software requires input data as *Phase-Flux* pair data or *HJD-Mag*. To construct any model of eclipsing binary system accurately, we need both light curve and radial velocity curve. In our case and due to the lacking of the radial velocity curve for the system J0645, we construct only a theoretical photometric model for the light curves of the *BVRI* pass bands.

From Table 2 the (B–V) color index of the system J0645 equals 1.081, which corresponding to effective temperature of the hot component (T_h) equals 4694 K° (see Popper, 1980).

The light curves of the system J0645 in Fig. 1 reflect the occurring of a total eclipse event in the primary minimum which enables us to conclude that the system is highly inclined. The various parameters are then tweaked until the theoretical light curves perfectly match the observed ones.

The BM3 output parameters of the system are listed in Table 4 for the B, V, R and I filters. The observed light curves are fitted using BM3 and presented with their residuals in Figs. 3, 4, 5, and 6 for the B, V, R, and I bands, respectively. We used the geometrical and photometric parameters in the V band (Table 4) to produce the Roche geometry (surface outline) of the system J0645. This result is illustrated in Fig. 7, and shown the degree of over contact 24% of the system. The same parameters in Table 4 have been employed to display the system configuration at different phases (0.25, 0.5, 0.75 and 1.0) in Fig. 8.

Table 4 BM3 parameters of the system J0645.

Parameter	Value
Phase shift = (φ_0) (B-band)	−0.0031
Inclination, I	86.98°
Temperature, T_1 (K)	4675
Temperature, T_2 (K)	4800
Gravity Exponent, ($g_1 = g_2$)	0.32
Reflection, ($A_1 = A_2$)	0.5
Surface potential, $\Omega_1 = \Omega_2$	5.270379
Overcontact	24%
Mass ratio, $q = M_2/M_1$	2.115
Luminosity, $L_1/(L_1+L_2)$ (B-band)	0.6176
Luminosity, $L_1/(L_1+L_2)$(V-band)	0.6213
Luminosity, $L_1/(L_1+L_2)$ (R-band)	0.6259
Luminosity, $L_1/(L_1+L_2)$(I-band)	0.6373
r_1 (vol.)	0.459531
r_1 (pole)	0.430799
r_1 (side)	0.460901
r_1 (back)	0.493533
r_2 (vol.)	0.329499
r_2 (pole)	0.307791
r_2 (side)	0.323077
r_2 (back)	0.364679
Spot co-latitude(°)	90.0
Spot longitude (°)	200
Spot radius (°)	6.00
Spot factor	0.75

5. Conclusions and future remarks

The B, R and I light curves of the system J0645 have been presented here for the first time, while our V light curve is the secondary after that of the SuperWasp.

All observed light curves exhibit a total eclipse in the primary minima, so we estimate the value of the inclination to be 86.98°.

New six times of minima of the system (two primary and four secondary) have been derived from the present observations.

The new linear ephemeris has been determined.

The solution reveals that the system J0645 is an over contact binary system by 24% and follows the spot model.

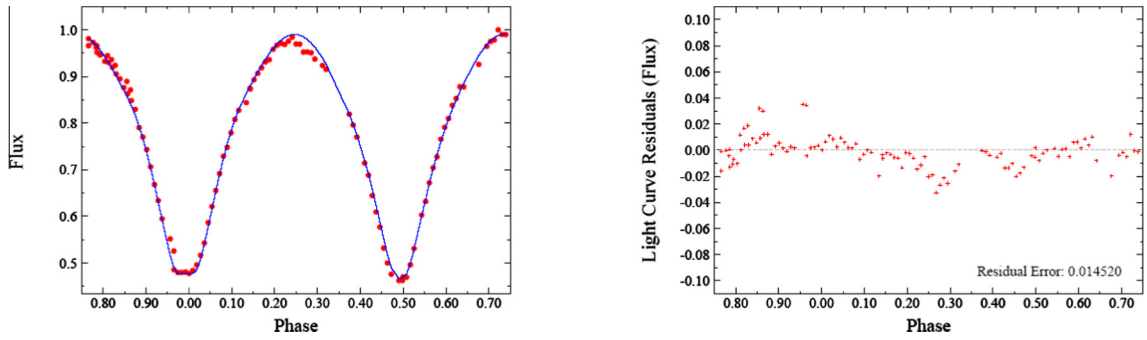

Fig. 3 In the lift panel, the *B* observed light curve of the system J0645 (dot points) overlaid with the theoretical light curve (solid curve). The right panel is LC residual.

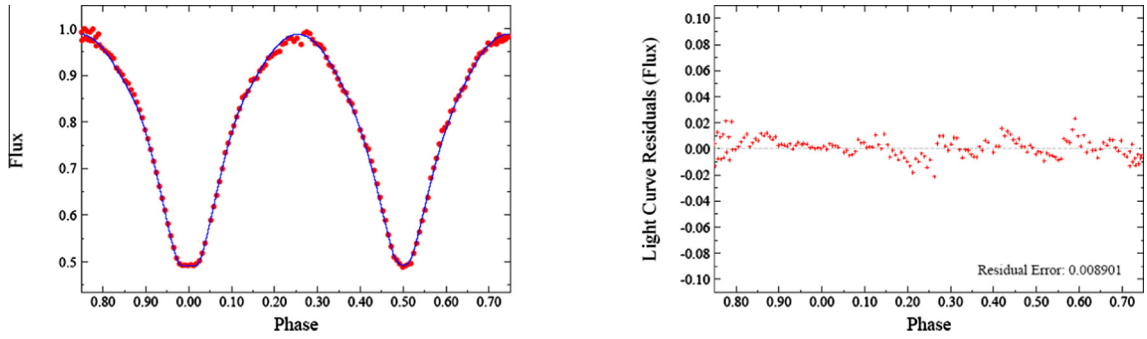

Fig. 4 The same as Fig. 3, but in the *V*-band.

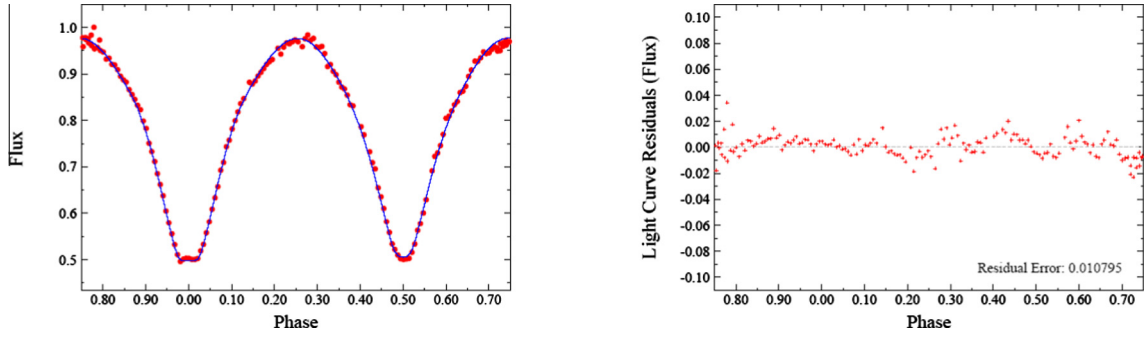

Fig. 5 The same as Fig. 3, but in the *R*-band.

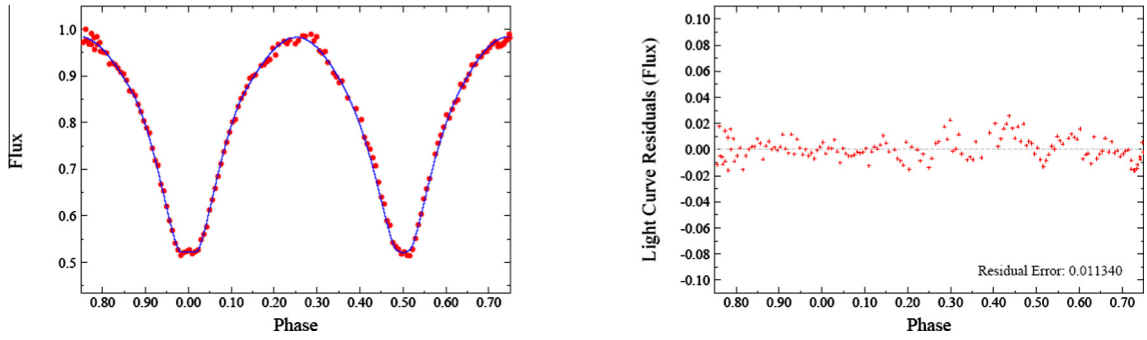

Fig. 6 The same as Fig. 3, but in the *I*-band.

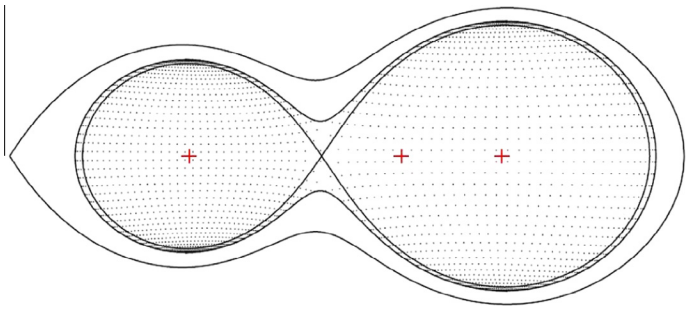

Fig. 7 The surface outline of the system J0645.

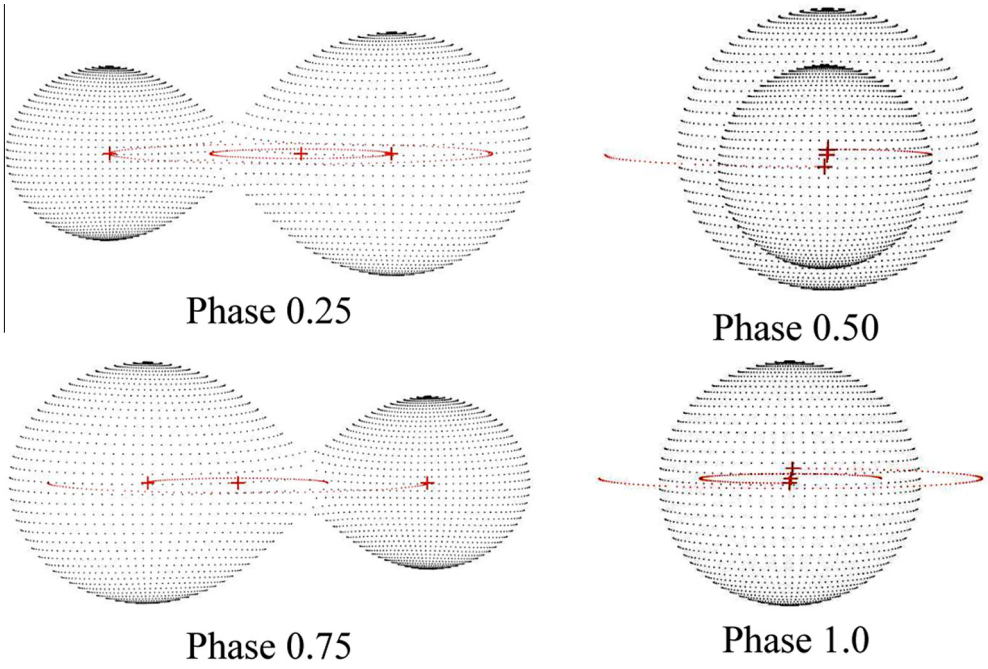

Fig. 8 3D model of the system J0645 at different phases (0.25, 0.5, 0.75, and 1.0).

For the contact binary system J0645 the categorization of the system may like to be a W- subtype of W-UMa system, where the secondary component star is the hotter and less massive one.

The *B* light curve in the 8th of February, 2013 has a slight shift in phase (−0.0031) comparing to the *VRI* light curves in 7th of February, 2013.

The system J0645 may have a variation from cycle to cycle due to some chromospheric activity.

Appendix A.

See (Table A1)

Table A1 Instrumental differential mag. ΔB, ΔV, ΔR, and ΔI of the system J0645.

HJD = 2456000+	Phase	ΔB	SD	HJD = 2456000+	Phase	ΔV	SD	HJD = 2456000+	Phase	ΔR	SD	HJD = 2456000+	Phase	ΔI	SD
332.2058	0.7660	0.3918	0.0067	331.1992	0.7172	0.1121	0.0036	331.1998	0.7198	−0.1723	0.0048	331.2002	0.7212	−0.4501	0.0071
332.2085	0.7769	0.3837	0.0065	331.2009	0.7244	0.1043	0.0036	331.2016	0.7270	−0.1831	0.0048	331.2020	0.7284	−0.4450	0.0069
332.2106	0.7852	0.3918	0.0065	331.2026	0.7310	0.1043	0.0036	331.2033	0.7337	−0.1850	0.0048	331.2036	0.7352	−0.4520	0.0069
332.2107	0.7859	0.4079	0.0066	331.2044	0.7381	0.1010	0.0036	331.2050	0.7406	−0.1796	0.0048	331.2053	0.7421	−0.4580	0.0070
332.2129	0.7948	0.4129	0.0067	331.2060	0.7447	0.0933	0.0036	331.2066	0.7473	−0.1880	0.0048	331.2070	0.7487	−0.4640	0.0070
332.2151	0.8037	0.4299	0.0066	331.2076	0.7513	0.1026	0.0036	331.2083	0.7539	−0.1752	0.0048	331.2087	0.7554	−0.4530	0.0070
332.2174	0.8126	0.4330	0.0067	331.2093	0.7579	0.0980	0.0036	331.2099	0.7605	−0.1928	0.0049	331.2103	0.7619	−0.4584	0.0070
332.2196	0.8216	0.4448	0.0066	331.2109	0.7645	0.1010	0.0036	331.2116	0.7671	−0.1843	0.0048	331.2119	0.7686	−0.4489	0.0070
332.2218	0.8304	0.4619	0.0067	331.2126	0.7711	0.1033	0.0036	331.2132	0.7738	−0.1779	0.0047	331.2136	0.7752	−0.4478	0.0070
332.2240	0.8393	0.4745	0.0068	331.2142	0.7779	0.1035	0.0035	331.2149	0.7805	−0.1701	0.0047	331.2153	0.7819	−0.4354	0.0070
332.2262	0.8482	0.4977	0.0067	331.2159	0.7845	0.1158	0.0035	331.2166	0.7872	−0.1737	0.0047	331.2169	0.7886	−0.4478	0.0069
332.2284	0.8571	0.5138	0.0068	331.2176	0.7913	0.1138	0.0035	331.2182	0.7940	−0.1659	0.0047	331.2186	0.7954	−0.4313	0.0069
332.2306	0.8660	0.5326	0.0069	331.2192	0.7979	0.1213	0.0035	331.2199	0.8006	−0.1622	0.0047	331.2203	0.8021	−0.4288	0.0068
332.2328	0.8749	0.5573	0.0067	331.2210	0.8051	0.1283	0.0034	331.2217	0.8077	−0.1450	0.0046	331.2220	0.8091	−0.4276	0.0068
332.2350	0.8837	0.6097	0.0071	331.2227	0.8117	0.1334	0.0034	331.2233	0.8143	−0.1472	0.0046	331.2237	0.8157	−0.3996	0.0068
332.2373	0.8926	0.6379	0.0070	331.2243	0.8183	0.1394	0.0035	331.2249	0.8209	−0.1317	0.0047	331.2253	0.8223	−0.4025	0.0069
332.2395	0.9015	0.6762	0.0072	331.2259	0.8249	0.1471	0.0035	331.2266	0.8276	−0.1300	0.0047	331.2270	0.8290	−0.3980	0.0068
332.2417	0.9104	0.7313	0.0073	331.2276	0.8317	0.1706	0.0035	331.2283	0.8343	−0.1178	0.0046	331.2287	0.8359	−0.3894	0.0070
332.2439	0.9193	0.7913	0.0077	331.2293	0.8385	0.1796	0.0035	331.2300	0.8411	−0.1012	0.0047	331.2303	0.8425	−0.3788	0.0069
332.2461	0.9282	0.8487	0.0080	331.2310	0.8451	0.1885	0.0035	331.2316	0.8477	−0.0915	0.0046	331.2320	0.8491	−0.3744	0.0069
332.2483	0.9371	0.9185	0.0085	331.2326	0.8517	0.2035	0.0035	331.2333	0.8544	−0.0854	0.0047	331.2336	0.8558	−0.3581	0.0067
332.2530	0.9561	1.0001	0.0088	331.2343	0.8586	0.2109	0.0035	331.2350	0.8612	−0.0657	0.0047	331.2353	0.8627	−0.3299	0.0068
332.2551	0.9645	1.0523	0.0092	331.2360	0.8653	0.2276	0.0036	331.2366	0.8679	−0.0523	0.0046	331.2370	0.8694	−0.3283	0.0067
332.2553	0.9651	1.1384	0.0098	331.2376	0.8719	0.2412	0.0036	331.2383	0.8745	−0.0391	0.0047	331.2386	0.8760	−0.3176	0.0069
332.2575	0.9741	1.1512	0.0099	331.2393	0.8785	0.2619	0.0035	331.2399	0.8811	−0.0228	0.0047	331.2403	0.8826	−0.2928	0.0067
332.2597	0.9830	1.1514	0.0097	331.2409	0.8851	0.2833	0.0036	331.2416	0.8877	−0.0102	0.0047	331.2419	0.8893	−0.2723	0.0068
332.2619	0.9919	1.1494	0.0100	331.2426	0.8918	0.3056	0.0036	331.2432	0.8944	0.0226	0.0048	331.2436	0.8959	−0.2460	0.0069
332.2641	0.0007	1.1567	0.0098	331.2442	0.8984	0.3409	0.0037	331.2449	0.9011	0.0449	0.0048	331.2452	0.9025	−0.2251	0.0070
332.2663	0.0096	1.1413	0.0099	331.2459	0.9050	0.3681	0.0037	331.2465	0.9077	0.0900	0.0049	331.2469	0.9091	−0.2107	0.0070
332.2686	0.0185	1.1150	0.0095	331.2475	0.9117	0.4013	0.0037	331.2482	0.9143	0.1166	0.0049	331.2485	0.9158	−0.1636	0.0070
332.2708	0.0274	1.0716	0.0091	331.2492	0.9184	0.4389	0.0038	331.2498	0.9210	0.1482	0.0051	331.2502	0.9224	−0.1244	0.0072
332.2730	0.0363	1.0175	0.0088	331.2508	0.9250	0.4753	0.0038	331.2515	0.9276	0.1891	0.0051	331.2518	0.9290	−0.1095	0.0073
332.2752	0.0452	0.9334	0.0084	331.2525	0.9316	0.5240	0.0039	331.2531	0.9342	0.2267	0.0052	331.2535	0.9357	−0.0452	0.0073
332.2774	0.0541	0.8705	0.0078	331.2541	0.9383	0.5664	0.0040	331.2548	0.9408	0.2668	0.0053	331.2551	0.9423	−0.0220	0.0074
332.2796	0.0630	0.8126	0.0078	331.2558	0.9449	0.6112	0.0041	331.2564	0.9475	0.3242	0.0053	331.2568	0.9490	0.0347	0.0077
332.2818	0.0719	0.7537	0.0074	331.2574	0.9516	0.6643	0.0041	331.2581	0.9541	0.3710	0.0054	331.2584	0.9556	0.0898	0.0076
332.2840	0.0807	0.6972	0.0071	331.2591	0.9582	0.7138	0.0042	331.2597	0.9609	0.4163	0.0055	331.2601	0.9623	0.1288	0.0076
332.2862	0.0896	0.6694	0.0070	331.2608	0.9650	0.7635	0.0043	331.2614	0.9676	0.4627	0.0055	331.2618	0.9691	0.1821	0.0078
332.2884	0.0985	0.6251	0.0080	331.2624	0.9717	0.8109	0.0044	331.2631	0.9743	0.5077	0.0056	331.2634	0.9757	0.2122	0.0080
332.2907	0.1074	0.5862	0.0068	331.2641	0.9783	0.8374	0.0044	331.2647	0.9809	0.5393	0.0057	331.2651	0.9823	0.2363	0.0081
332.2929	0.1163	0.5602	0.0064	331.2657	0.9849	0.8451	0.0044	331.2664	0.9875	0.5287	0.0057	331.2667	0.9889	0.2236	0.0079
332.2973	0.1340	0.5384	0.0064	331.2674	0.9916	0.8439	0.0044	331.2680	0.9942	0.5244	0.0056	331.2684	0.9958	0.2185	0.0079
332.2994	0.1424	0.4991	0.0063	331.2691	0.9983	0.8457	0.0044	331.2697	0.0010	0.5248	0.0057	331.2701	0.0024	0.2114	0.0078
332.2995	0.1431	0.5012	0.0062	331.2707	0.0049	0.8416	0.0044	331.2714	0.0076	0.5295	0.0056	331.2717	0.0090	0.2291	0.0079

(*continued on next page*)

Table A1 (*continued*)

HJD = 2456000+	Phase	ΔB	SD	HJD = 2456000+	Phase	ΔV	SD	HJD = 2456000+	Phase	ΔR	SD	HJD = 2456000+	Phase	ΔI	SD
332.3017	0.1520	0.4768	0.0062	331.2724	0.0117	0.8464	0.0044	331.2730	0.0144	0.5300	0.0056	331.2734	0.0158	0.2195	0.0079
332.3039	0.1608	0.4601	0.0060	331.2740	0.0183	0.8364	0.0043	331.2747	0.0210	0.5250	0.0056	331.2751	0.0225	0.2121	0.0077
332.3062	0.1697	0.4461	0.0060	331.2757	0.0251	0.8232	0.0043	331.2764	0.0277	0.4904	0.0056	331.2767	0.0292	0.1676	0.0077
332.3084	0.1786	0.4313	0.0059	331.2774	0.0317	0.7880	0.0042	331.2780	0.0343	0.4617	0.0054	331.2784	0.0358	0.1448	0.0075
332.3106	0.1875	0.4259	0.0061	331.2790	0.0383	0.7449	0.0042	331.2797	0.0410	0.4119	0.0054	331.2800	0.0425	0.1148	0.0074
332.3128	0.1964	0.4004	0.0059	331.2823	0.0518	0.6496	0.0040	331.2813	0.0478	0.3668	0.0054	331.2817	0.0492	0.0483	0.0073
332.3150	0.2053	0.3907	0.0058	331.2840	0.0584	0.5972	0.0039	331.2830	0.0544	0.3170	0.0052	331.2833	0.0558	0.0098	0.0072
332.3172	0.2142	0.3860	0.0059	331.2856	0.0650	0.5557	0.0038	331.2846	0.0610	0.2743	0.0050	331.2850	0.0625	−0.0312	0.0070
332.3194	0.2231	0.3889	0.0059	331.2873	0.0719	0.5076	0.0038	331.2863	0.0677	0.2337	0.0049	331.2867	0.0692	−0.0726	0.0069
332.3216	0.2320	0.3806	0.0059	331.2890	0.0785	0.4632	0.0037	331.2880	0.0745	0.1776	0.0049	331.2884	0.0760	−0.1137	0.0069
332.3238	0.2409	0.3711	0.0058	331.2906	0.0851	0.4113	0.0036	331.2896	0.0812	0.1512	0.0049	331.2900	0.0826	−0.1523	0.0068
332.3261	0.2498	0.3875	0.0058	331.2923	0.0917	0.3817	0.0035	331.2913	0.0877	0.1006	0.0047	331.2916	0.0892	−0.1821	0.0068
332.3283	0.2587	0.3879	0.0059	331.2940	0.0986	0.3505	0.0036	331.2930	0.0945	0.0808	0.0047	331.2933	0.0959	−0.2127	0.0068
332.3305	0.2676	0.4072	0.0058	331.2956	0.1053	0.3286	0.0035	331.2946	0.1012	0.0464	0.0047	331.2950	0.1027	−0.2431	0.0068
332.3327	0.2764	0.4067	0.0060	331.2973	0.1119	0.3033	0.0035	331.2963	0.1079	0.0217	0.0047	331.2967	0.1094	−0.2501	0.0067
332.3349	0.2853	0.4089	0.0059	331.2989	0.1185	0.2801	0.0035	331.2979	0.1145	−0.0036	0.0046	331.2983	0.1160	−0.2869	0.0066
332.3371	0.2942	0.4241	0.0059	331.3007	0.1256	0.2491	0.0035	331.2996	0.1211	−0.0273	0.0046	331.2999	0.1226	−0.3092	0.0066
332.3415	0.3119	0.4404	0.0061	331.3023	0.1322	0.2427	0.0034	331.3013	0.1282	−0.0409	0.0047	331.3017	0.1297	−0.3232	0.0066
332.3436	0.3203	0.4500	0.0063	331.3040	0.1388	0.2311	0.0035	331.3047	0.1415	−0.0852	0.0051	331.3033	0.1363	−0.3412	0.0065
332.3570	0.3743	0.5709	0.0066	331.3057	0.1457	0.2026	0.0036	331.3064	0.1484	−0.0808	0.0047	331.3050	0.1430	−0.3628	0.0070
332.3592	0.3832	0.6020	0.0067	331.3074	0.1525	0.1990	0.0036	331.3080	0.1551	−0.0886	0.0046	331.3067	0.1499	−0.3686	0.0069
332.3614	0.3921	0.6380	0.0069	331.3090	0.1591	0.1974	0.0034	331.3097	0.1616	−0.1017	0.0046	331.3084	0.1565	−0.3721	0.0066
332.3659	0.4099	0.7197	0.0073	331.3106	0.1656	0.1787	0.0034	331.3113	0.1683	−0.1109	0.0046	331.3117	0.1697	−0.3957	0.0065
332.3681	0.4188	0.7596	0.0076	331.3123	0.1724	0.1705	0.0033	331.3130	0.1750	−0.1209	0.0045	331.3133	0.1764	−0.3979	0.0064
332.3703	0.4277	0.8306	0.0078	331.3140	0.1791	0.1635	0.0033	331.3146	0.1817	−0.1317	0.0045	331.3150	0.1831	−0.4056	0.0065
332.3725	0.4366	0.8919	0.0082	331.3156	0.1857	0.1464	0.0033	331.3163	0.1883	−0.1384	0.0045	331.3166	0.1898	−0.4108	0.0063
332.3747	0.4455	0.9512	0.0086	331.3173	0.1923	0.1413	0.0033	331.3180	0.1950	−0.1439	0.0045	331.3183	0.1965	−0.4389	0.0064
332.3769	0.4544	1.0396	0.0091	331.3190	0.1991	0.1357	0.0034	331.3212	0.2082	−0.1717	0.0045	331.3200	0.2031	−0.4224	0.0064
332.3791	0.4633	1.1066	0.0096	331.3206	0.2056	0.1316	0.0033	331.3229	0.2148	−0.1570	0.0045	331.3216	0.2097	−0.4482	0.0064
332.3813	0.4722	1.1600	0.0099	331.3222	0.2122	0.1300	0.0033	331.3245	0.2214	−0.1743	0.0044	331.3249	0.2228	−0.4557	0.0064
332.3858	0.4899	1.1912	0.0100	331.3238	0.2187	0.1121	0.0033	331.3262	0.2282	−0.1844	0.0045	331.3266	0.2296	−0.4498	0.0064
332.3878	0.4983	1.1911	0.0105	331.3255	0.2255	0.1091	0.0033	331.3278	0.2348	−0.1824	0.0045	331.3282	0.2362	−0.4585	0.0063
332.3880	0.4990	1.1734	0.0104	331.3272	0.2321	0.0982	0.0033	331.3295	0.2414	−0.1871	0.0045	331.3315	0.2494	−0.4495	0.0063
332.3902	0.5079	1.1746	0.0107	331.3288	0.2388	0.0975	0.0033	331.3311	0.2480	−0.1917	0.0044	331.3332	0.2563	−0.4575	0.0062
332.3924	0.5168	1.1150	0.0099	331.3305	0.2453	0.1048	0.0033	331.3328	0.2549	−0.1872	0.0044	331.3356	0.2662	−0.4684	0.0062
332.3946	0.5257	1.0421	0.0096	331.3322	0.2522	0.0975	0.0033	331.3353	0.2648	−0.1753	0.0044	331.3373	0.2726	−0.4672	0.0063
332.3991	0.5435	0.9034	0.0084	331.3347	0.2622	0.1127	0.0033	331.3369	0.2713	−0.1947	0.0044	331.3406	0.2859	−0.4720	0.0062
332.4013	0.5524	0.8520	0.0082	331.3363	0.2687	0.0864	0.0032	331.3385	0.2778	−0.2038	0.0044	331.3422	0.2926	−0.4562	0.0063
332.4035	0.5612	0.7853	0.0078	331.3379	0.2752	0.0829	0.0033	331.3402	0.2845	−0.1909	0.0044	331.3438	0.2991	−0.4664	0.0064
332.4057	0.5701	0.7349	0.0078	331.3396	0.2820	0.0870	0.0032	331.3418	0.2910	−0.1955	0.0045	331.3454	0.3056	−0.4324	0.0063
332.4079	0.5790	0.6992	0.0075	331.3412	0.2884	0.1006	0.0033	331.3435	0.2977	−0.1747	0.0044	331.3471	0.3121	−0.4269	0.0063
332.4101	0.5879	0.6440	0.0074	331.3428	0.2951	0.1105	0.0033	331.3451	0.3041	−0.1735	0.0044	331.3487	0.3187	−0.4305	0.0064
332.4123	0.5968	0.6088	0.0072	331.3444	0.3016	0.1122	0.0033	331.3467	0.3107	−0.1763	0.0045	331.3503	0.3252	−0.4037	0.0063
332.4145	0.6057	0.5833	0.0072	331.3461	0.3081	0.1149	0.0033	331.3483	0.3172	−0.1585	0.0044	331.3536	0.3382	−0.3769	0.0063

332.4167	0.6146	0.5455	0.0070	331.3477	0.3147	0.1243	0.0033	331.3500	0.3237	−0.1259	0.0044	331.3552	0.3450	−0.3670	0.0065
332.4190	0.6235	0.5265	0.0070	331.3493	0.3211	0.1443	0.0033	331.3516	0.3303	−0.1312	0.0044	331.3569	0.3516	−0.3522	0.0067
332.4212	0.6323	0.4952	0.0070	331.3509	0.3277	0.1627	0.0033	331.3532	0.3368	−0.1139	0.0045	331.3585	0.3581	−0.3561	0.0067
332.4234	0.6413	0.4956	0.0069	331.3526	0.3342	0.1673	0.0033	331.3549	0.3436	−0.1051	0.0046	331.3618	0.3713	−0.3113	0.0066
332.4321	0.6763	0.4375	0.0067	331.3542	0.3410	0.1813	0.0034	331.3565	0.3501	−0.0856	0.0047	331.3667	0.3911	−0.2813	0.0067
332.4367	0.6947	0.3932	0.0068	331.3559	0.3475	0.1988	0.0035	331.3582	0.3567	−0.0726	0.0048	331.3698	0.4036	−0.2497	0.0068
332.4389	0.7036	0.3815	0.0067	331.3575	0.3542	0.2156	0.0035	331.3598	0.3632	−0.0675	0.0049	331.3715	0.4103	−0.1976	0.0068
332.4411	0.7125	0.3781	0.0067	331.3591	0.3606	0.2306	0.0036	331.3614	0.3699	−0.0507	0.0049	331.3731	0.4169	−0.1777	0.0068
332.4433	0.7214	0.3543	0.0067	331.3607	0.3671	0.2366	0.0036	331.3631	0.3766	−0.0244	0.0048	331.3747	0.4234	−0.1607	0.0069
332.4455	0.7303	0.3649	0.0065	331.3624	0.3740	0.2581	0.0036	331.3647	0.3831	−0.0208	0.0050	331.3763	0.4299	−0.1338	0.0070
332.4477	0.7392	0.3653	0.0067	331.3641	0.3805	0.2661	0.0036	331.3695	0.4022	0.0400	0.0048	331.3780	0.4364	−0.1077	0.0078
332.4544	0.7659	0.3750	0.0069	331.3657	0.3871	0.2886	0.0036	331.3711	0.4089	0.0641	0.0049	331.3797	0.4434	−0.0527	0.0073
332.4588	0.7837	0.3957	0.0072	331.3688	0.3995	0.3409	0.0036	331.3744	0.4220	0.1169	0.0049	331.3813	0.4500	0.0004	0.0073
332.4610	0.7925	0.4141	0.0072	331.3705	0.4063	0.3627	0.0036	331.3760	0.4285	0.1523	0.0051	331.3830	0.4564	0.0259	0.0075
332.4654	0.8103	0.4156	0.0074	331.3721	0.4128	0.3887	0.0037	331.3776	0.4350	0.1731	0.0053	331.3846	0.4629	0.0899	0.0076
332.4677	0.8193	0.4255	0.0074	331.3738	0.4194	0.4001	0.0037	331.3794	0.4420	0.2377	0.0052	331.3862	0.4695	0.1078	0.0078
332.4698	0.8281	0.4400	0.0075	331.3754	0.4259	0.4390	0.0038	331.3810	0.4485	0.2709	0.0053	331.3878	0.4761	0.1794	0.0080
332.4765	0.8551	0.4808	0.0080	331.3770	0.4324	0.4684	0.0039	331.3826	0.4550	0.3143	0.0053	331.3895	0.4826	0.1960	0.0079
332.4786	0.8635	0.5035	0.0080	331.3787	0.4394	0.5153	0.0042	331.3842	0.4615	0.3664	0.0055	331.3911	0.4891	0.2086	0.0079
				331.3803	0.4459	0.5632	0.0041	331.3858	0.4681	0.4110	0.0055	331.3927	0.4958	0.2301	0.0079
				331.3820	0.4525	0.6131	0.0041	331.3875	0.4747	0.4599	0.0056	331.3944	0.5025	0.2208	0.0080
				331.3836	0.4589	0.6506	0.0042	331.3891	0.4811	0.4846	0.0057	331.3960	0.5091	0.2361	0.0082
				331.3852	0.4654	0.7098	0.0044	331.3907	0.4878	0.5097	0.0058	331.3977	0.5156	0.2379	0.0080
				331.3869	0.4721	0.7591	0.0044	331.3924	0.4943	0.5262	0.0059	331.3993	0.5222	0.2096	0.0079
				331.3885	0.4786	0.8066	0.0046	331.3940	0.5010	0.5298	0.0059	331.4009	0.5287	0.1629	0.0078
				331.3901	0.4852	0.8202	0.0045	331.3957	0.5077	0.5282	0.0058	331.4026	0.5354	0.1060	0.0076
				331.3917	0.4917	0.8374	0.0047	331.3973	0.5142	0.5249	0.0059	331.4042	0.5420	0.0641	0.0076
				331.3934	0.4985	0.8534	0.0047	331.3989	0.5207	0.4973	0.0058	331.4058	0.5484	0.0067	0.0075
				331.3950	0.5051	0.8471	0.0047	331.4006	0.5274	0.4603	0.0057	331.4074	0.5549	−0.0296	0.0072
				331.3967	0.5116	0.8396	0.0048	331.4022	0.5340	0.4021	0.0056	331.4091	0.5615	−0.0648	0.0072
				331.3983	0.5182	0.8353	0.0046	331.4039	0.5405	0.3744	0.0055	331.4124	0.5750	−0.1451	0.0070
				331.3999	0.5247	0.7890	0.0045	331.4055	0.5470	0.3317	0.0055	331.4141	0.5815	−0.1791	0.0070
				331.4016	0.5314	0.7452	0.0044	331.4071	0.5535	0.2815	0.0054	331.4157	0.5880	−0.2038	0.0069
				331.4032	0.5379	0.6982	0.0043	331.4105	0.5671	0.1793	0.0051	331.4173	0.5946	−0.2281	0.0069
				331.4048	0.5444	0.6522	0.0043	331.4121	0.5736	0.1317	0.0051	331.4190	0.6014	−0.2637	0.0070
				331.4064	0.5509	0.6108	0.0042	331.4137	0.5801	0.1206	0.0051	331.4206	0.6080	−0.2547	0.0069
				331.4081	0.5574	0.5644	0.0041	331.4153	0.5866	0.0972	0.0050	331.4222	0.6145	−0.2796	0.0069
				331.4098	0.5644	0.4948	0.0040	331.4169	0.5932	0.0627	0.0050	331.4238	0.6209	−0.2989	0.0068
				331.4114	0.5710	0.4606	0.0040	331.4186	0.5998	0.0142	0.0050	331.4255	0.6275	−0.3055	0.0069
				331.4131	0.5775	0.4290	0.0039	331.4203	0.6065	0.0083	0.0050	331.4272	0.6343	−0.3472	0.0068
				331.4147	0.5840	0.3845	0.0039	331.4219	0.6131	−0.0068	0.0049	331.4288	0.6409	−0.3408	0.0066
				331.4163	0.5905	0.3429	0.0039	331.4235	0.6195	−0.0240	0.0049	331.4304	0.6474	−0.3583	0.0066
				331.4180	0.5973	0.3340	0.0038	331.4251	0.6262	−0.0334	0.0049	331.4320	0.6538	−0.3736	0.0065
				331.4196	0.6039	0.3211	0.0038	331.4268	0.6329	−0.0576	0.0049	331.4337	0.6605	−0.3973	0.0066
				331.4213	0.6105	0.2869	0.0038	331.4285	0.6395	−0.0616	0.0048	331.4358	0.6688	−0.3990	0.0066

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Table A1 (*continued*)

HJD = 2456000+	Phase	ΔB	SD	HJD = 2456000+	Phase	ΔV	SD	HJD = 2456000+	Phase	ΔR	SD	HJD = 2456000+	Phase	ΔI	SD
				331.4229	0.6170	0.2836	0.0037	331.4301	0.6460	−0.0746	0.0047	331.4374	0.6754	−0.4184	0.0066
				331.4245	0.6235	0.2548	0.0038	331.4317	0.6525	−0.1007	0.0047	331.4390	0.6821	−0.4180	0.0066
				331.4262	0.6304	0.2445	0.0037	331.4333	0.6591	−0.1171	0.0047	331.4407	0.6887	−0.4287	0.0067
				331.4278	0.6369	0.2282	0.0037	331.4354	0.6674	−0.1395	0.0048	331.4423	0.6951	−0.4313	0.0067
				331.4294	0.6434	0.2201	0.0036	331.4370	0.6740	−0.1392	0.0048	331.4439	0.7017	−0.4405	0.0069
				331.4310	0.6499	0.1975	0.0036	331.4387	0.6807	−0.1483	0.0046	331.4455	0.7082	−0.4489	0.0067
				331.4327	0.6564	0.1777	0.0036	331.4403	0.6871	−0.1627	0.0047	331.4472	0.7148	−0.4550	0.0069
				331.4348	0.6649	0.1634	0.0036	331.4419	0.6937	−0.1585	0.0048	331.4488	0.7213	−0.4427	0.0067
				331.4364	0.6714	0.1466	0.0036	331.4436	0.7003	−0.1605	0.0048	331.4504	0.7278	−0.4448	0.0067
				331.4380	0.6781	0.1355	0.0036	331.4452	0.7068	−0.1686	0.0047	331.4520	0.7344	−0.4485	0.0068
				331.4397	0.6846	0.1322	0.0035	331.4468	0.7134	−0.1749	0.0048	331.4537	0.7411	−0.4596	0.0068
				331.4413	0.6912	0.1257	0.0036	331.4485	0.7199	−0.1647	0.0048	331.4553	0.7476	−0.4723	0.0068
				331.4429	0.6977	0.1089	0.0036	331.4501	0.7264	−0.1658	0.0048	331.4586	0.7608	−0.4837	0.0070
				331.4446	0.7042	0.1135	0.0036	331.4517	0.7330	−0.1765	0.0048	331.4603	0.7674	−0.4554	0.0090
				331.4462	0.7108	0.1093	0.0036	331.4534	0.7397	−0.1910	0.0048	331.4619	0.7741	−0.4741	0.0074
				331.4478	0.7174	0.0998	0.0036	331.4550	0.7461	−0.1870	0.0048	331.4635	0.7806	−0.4642	0.0074
				331.4494	0.7238	0.0897	0.0036	331.4566	0.7528	−0.1967	0.0048	331.4651	0.7871	−0.4664	0.0077
				331.4510	0.7303	0.0986	0.0036	331.4583	0.7594	−0.1974	0.0049	331.4668	0.7936	−0.4525	0.0074
				331.4527	0.7371	0.0934	0.0037	331.4599	0.7660	−0.1946	0.0051				
				331.4543	0.7436	0.0954	0.0036	331.4616	0.7727	−0.2031	0.0057				
				331.4560	0.7502	0.0835	0.0037	331.4632	0.7791	−0.2214	0.0061				
				331.4576	0.7568	0.0754	0.0036	331.4664	0.7922	−0.1914	0.0052				
				331.4593	0.7634	0.0819	0.0038								
				331.4609	0.7700	0.0830	0.0048								
				331.4625	0.7766	0.0760	0.0039								
				331.4642	0.7831	0.0952	0.0058								
				331.4658	0.7895	0.0879	0.0039								

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