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The multi-band CCD photometric investigation of short-period eclipsing binary V1044 Her

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HIGHLIGHTS

- We observed the new VR bands of V1044 Her on May 22, 23 and 24, 2015.
- Photometric orbital parameters and starspot parameters of V1044 Her are derived.
- The orbital period of V1044 Her exists a cyclic variation.
- The cyclic variation of V1044 Her can caused by LITF or magnetic cyclic

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ABSTRACT

We present new CCD photometric observations of V1044 Her obtained on May 22, 23 and 24, 2015. From our data, we derived five new light curve minimum times. Combining our new results with previously available CCD light minimum times, we derived an updated ephemeris and discovered that the period of this binary system exhibits an oscillation. The cyclic variation may be caused by the light-time effect via the presence of a third body or magnetic activity cycle. We calculated the corresponding period of the third body to be 14.1 ± 1.4 years or magnetic cycle to be 12.2 ± 0.7 years. We analyzed our new asymmetric light curves to obtain photometric solutions and starspot parameters using the Wilson and Devinney program. The final results show that V1044 Her is a contact binary system with a degree of contact factor $f = 3.220(\pm 0.002)\%$.

1. Introduction

Photometric investigation of contact eclipsing binaries provide key information at an important stellar evolutionary stage (Robertson and Eggleton, 1977; Kaluzny, 1985; Hilditch et al., 1988; Shaw, 1994; Zhu and Qian, 2006; Yang and Qian, 2015, etc.). By analyzing photometric light curves (LCs), we can obtain orbital parameters of eclipsing binaries and photospheric starspot parameters. Many eclipsing binaries display a periodic variation of orbital period (Qian et al., 2014a; Xiang et al., 2015a, etc.). The explanation for the periodic change might be a third body or a magnetic cycle (Applegate, 1992; Lanza et al., 1998; Hoffman et al., 2006, etc.).

The eclipsing binary star V1044 Her (GSC 03073-00837) was first discovered as a variable object by Akerlof et al. (2000). Its first unfiltered light curve was obtained by Blattler and Diethelm (2001) and displayed an apparent asymmetry. According to the 77th name-list of variable stars (Kazarovets et al., 2003), it was classified as an EW-type eclipsing binary. Bradstreet et al. (2009) analyzed the light curve of V1044 Her and derived preliminary orbital parameters.

V1044 Her is an intriguing star for studying period variation, LCs evolution and the possible presence of a third body. In this paper, we present our new light curves (LCs) in V and R bands for V1044 Her and our analyses using the updated version of Wilson–Devinney (WD) program (Wilson and Devinney, 1971; Wilson, 1979; 1990; 1994). We also present our analyses on its period variation for the first time.

2. New CCD photometric observations

V1044 Her was observed in the *VR* bands on May 22, 23 and 24, 2015 using the 60-cm reflecting telescope at Xinglong Station of the National Astronomical Observatories of China (NAOC). This telescope was equipped with a 1024 × 1024 pixel CCD and the standard Johnson UBVRI filters. The field of view of the system is 17 × 17 square arcmin Xiang et al. (2015a). The exposure times are 40–60 s and 40–50 s in V and R bands, respectively. We chose

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Table 1
Magnitudes and coordinates of V1044 Her, comparison and check stars.

Targets	Name	Coordinates (Ra;Dec 2000)	*Mag_J*	*Mag_H*	*Mag_K*	Reference
Variable	V1044 Her	17:10:17.90;+38:26:41.5	10.631	10.213	10.055	[1],[2]
Comparison	2mass J17104747+3824556	17:10:47.47;+38:24:55.6	11.098	10.555	10.425	[1],[2]
Check 1	2mass J17094676+3832217	17:09:46.76;+38:32:21.7	11.883	11.590	11.523	[1],[2]
Check 2	2mass J17101718+3822295	17:10:17.18;+38:22:29.5	12.461	12.183	12.117	[1],[2]

References. [1] Cutri et al. (2003); [2] Morrison et al. (2001).

Table 2
Photometric data of V1044 Her in V and R bands.

V band (May 22, 2015)		R band (May 23, 2015)		R band (May 24, 2015)	
HJD	Δ Mag	HJD	Δ Mag	HJD	Δ Mag
2457165.0669	0.058	2457166.1594	−0.036	2457167.0396	0.046
2457165.0676	0.066	2457166.1602	−0.041	2457167.0404	0.026
2457165.0683	0.054	2457166.1609	−0.041	2457167.0411	0.039
2457165.0691	0.060	2457166.1616	−0.044	2457167.0418	0.041
2457165.0698	0.053	2457166.1623	−0.051	2457167.0425	0.047
2457165.0705	0.037	2457166.1631	−0.049	2457167.0433	0.057
–	–	–	–	–	–
2457165.3253	−0.017	2457166.3165	0.036	2457167.3172	0.694
2457165.3262	−0.019	2457166.3172	0.041	2457167.3179	0.727
2457165.3272	−0.035	2457166.3180	0.032	2457167.3186	0.717
2457165.3282	−0.021	2457166.3187	0.053	2457167.3193	0.715
2457165.3291	0.003	2457166.3194	0.057	2457167.3201	0.718
2457165.3301	−0.033	2457166.3201	0.080	2457167.3208	0.691
2457165.3310	−0.029	2457166.3208	0.059	2457167.3215	0.706
2457165.3320	−0.003	2457166.3216	0.063	2457167.3222	0.706

This table is available in its entirety in machine-readable and Virtual Observatory (VO) forms in the online journal. A portion is shown here for guidance regarding its form and content.

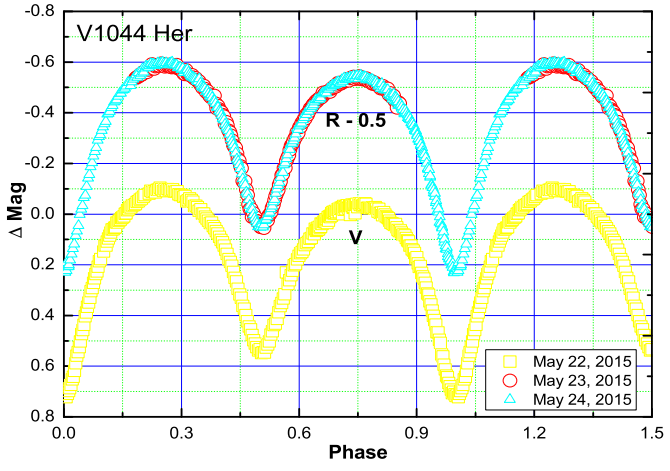

Fig. 1. Light curves of V1044 Her for VR bands, with squares (□) for the May 22, 2015 data, circles (○) for the May 23, 2015 data and triangles (△) for the May 24, 2015 data.

comparison and check stars around V1044 Her, which are listed in Table 1. All magnitudes are measured by using the IRAF package in standard fashion, including trimming, bias-substraction, flat-field correction, cosmic-rays removal, and aperture photometry. We plotted the VR CCD light curves of V1044 Her in Fig. 1. We can clearly see that our LCs also exhibit the so-called O'Connell effect, the primary maxima of the light curves being higher than the secondary ones. We provide the original photometric data in Table 2 by listing the HJD and VR magnitude difference between V1044 Her and its comparison star.

Table 3
New minima times of V1044 Her in VR bands.

HJD (2,457,000+)	Uncertainty	Filter	Type
165.15328	0.00003	V	Primary
167.07851	0.00002	R	Primary
165.27466	0.00012	V	Secondary
166.23680	0.00011	R	Secondary
167.19970	0.00007	R	Secondary

3. Period analyses

We fit our VR LCs using the polynomial fitting method of Kwee and van Woerden (1956), and obtained five new light minimum times and their uncertainties. The fitting program was developed by Nelson (2007). We listed the new minima in Table 3. In order to analyze the period variation for V1044 Her, we need as many light minimum times as possible covering a time period for as long as possible. Therefore, in addition to the five new minimum times, we collected all the available CCD minima times from the Eclipsing Binaries Minima Database (Paschke and Brát, 2006). The results are listed in Table 4, including the corresponding HJD of minima (column (1)), their uncertainties (column (2)), cycles (column (3)) that were based on the previous linear ephemeris JD(min, hel) = 2452065.5005+0.240641∗E (Blattler and Diethelm, 2001), and the type of the minima (column (4)). Combining our new minimum times with the CCD minima collected, we derived a new linear ephemeris as follows:

$$\begin{aligned}\mathrm{Min}.I = {} & HJD2452065.5003(\pm 0.0005) \\ & + 0^d.24064058(\pm 0.00000004)E \end{aligned} \quad (1)$$

where 2452065.5003 is the initial epoch and 0.24064058 days is the orbital period. We computed the values of (O-C)I (residuals of the linear fit), which are listed in column (5) of Table 4 and plotted