The New RS CVn Binary V1034 Her Revisited and the orbital period - Activity relation of Short-period RS CVn binaries using photometric distortion amplitude

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Abstract This paper presents new CCD $BVRI$ light curves of the newly discovered RS CVn eclipsing binary V1034 Her in 2009 and 2010, which shapes are different from the previous published results. They show asymmetric outside eclipse and we try to use a spot model to explain the phenomena. Using the Wilson-Devinney program with one-spot or two-spots model, photometric solutions of the system and starspot parameters were derived. Comparing the two results, it shows that the case of two spots is better successful in reproducing the light-curve distortions. For all the spot longitudes, it suggests that the trend towards active longitude belts and each active longitude belts might be switch. Comparing the light curves of 2009 and 2010, it indicates that the light curve changes on a long time scale of one year, especially in phase 0.25. In addition, we also collected the values of the maximum amplitudes of photometric distortion of the short-period RS CVn binary. We found for the first time that there is a trend of increasing activity with decreasing the orbital period. Finally, fitting all available light minimum times including our newly obtained ones with polynomial function confirmed that the orbital period of V1034 underwent up increase.

Key words: stars: binaries: late-type — stars: binaries: eclipsing — stars: individuals (V1034 Her) — stars: spots

1 INTRODUCTION

For V1034 Her (GSC 0983.1044, ROTSE 1 J165241.80+124905.2), it is a newly identified RS CVn-type eclipsing binary, which is also characterized by the light-curve asymmetries (Kaiser et al. 2002; Doğru et al. 2009; Ordway & Van Hamme 2004). Therefore, it is a very intriguing object to study stellar magnetic activity and test the effect of magnetic braking. However, it is poorly studied by astronomers, so we re-observed it in two different seasons to discuss starspot activity.

V1034 Her was discovered by Akerlof et al. (2000) as a 13th mag eclipsing binary with a period of 0.40763 day and an amplitude of 1.022 mag from the ROTSE 1 sky survey. Later, Kaiser et al. (2002) revised the standard magnitude $V = 12.90$, and color indices $B - V = 0.78$. They also derived the linear ephemeris of the system with the period of 0.8153 day and suggested that V1034 Her is a RS CVn type eclipsing detached binary due to the light-curves variations, which were explained using two-spots model on the secondary component. Later, Ordway and Van Hamme (2004) also obtained
the $BVRi$ light curves of the system and analyzed them using Wilson-Devinney program with the spot model. Recently, Doğru et al. (2009) revised the ephemeris and considered firstly the possibility orbital period variation. The O-C diagram shows an upward parabola, which indicates a secular increase in the orbital period of the system. They also confirmed it the characters of RS CVn type and explained them in terms of two large dark starspots on the primary component.

As our on-going program of the study of RS CVn binary with multi-color photometry and high-resolution spectra (Gu et al. 2002, Zhang & Gu 2007, Zhang & Gu 2008, Zhang et al. 2010a, etc), we present new $B, V, R,$ and $I$ CCD light curves of V1034 Her in two different seasons and analyze them to study the properties of active regions using the version 2003 of Wilson-Devinney code. In addition, we accumulated the maximum amplitudes of photometric distortions of short-period RS CVn binary from the literatures to discuss the relation between the photospheric starspot activity and the orbital period.

2 OBSERVATIONS

The new photometric observations were made on seven nights (2009 March 22, 24, 25, 26, 30, and 31, and April 1) and two nights ( 2010 March 26 and 27) with the 85-cm telescope of Xinglong station of the National Astronomical Observatories of China. The camera was equipped with a $1024 \times 1024$ pixel CCD and the standard Johnson-Cousin-Bessell $BVRi$ filters (Zhou et al. 2009). Our observations of V1034 Her was made in $B$, $V$, $R$, and $I$ bands. All observed CCD images were reduced using the Apphot sub-package of IRAF in the standard fashion (including image trimming, bias subtraction, flat-field division, cosmic ray removal, and aperture photometry). The comparison star GSC0983-566 and the check star ($\alpha_{2000}=16^{h}52^{m}19^{s}.07$; $\delta_{2000}=12^{\circ}50^{\prime}43^{\prime\prime}.9$) were chosen near target. The LCs of V1034 Her are plotted in Figure. 1, where circles(○) indicate Mar. 26 - Apr. 1 2009, squares(□) - Mar. 26-27 2010. The errors of individual points are better than 0.01 mag in all bands.

From our observations, two primary minimum times (2454916.3181±0.0044; 2454921.2101±0.0010) and one secondary minima (2454923.2477±0.0003) were obtained using the method of Kwee and van Woerden (1956). To calculate an update ephemeris and period variation, all published minimum times were collected from the literatures (Table.1). Using the CCD minima times, an updated linear ephemeris formula was obtained as follows:

$$Min.I = HJD2451767.6630(\pm0.0003) + 0d.8152912(\pm0.0000001)daysE. \quad (1)$$

For our new observations, the phases of data points are calculated using the above equation (1).

Doğru et al. (2009) found the (O-C) (observational times of light minimum calculational times of light minimum) diagram shows an upward parabola. To revise the period change, we reanalyzed them with our new minimum. During the analysis, the weights 0, 1 and 5 were given to visual, photographic and CCD observations. The two CCD minimum times (deviating too much) whose $O-C$ values are higher than 0.0070 were omitted because they might be influenced by spots and shifted. They are listed under the line at the end of Table.1. Then, with the least-square method, the following quadratic ephemeris was obtained.

$$Min.I = JD(HeI.)2451767.6632(\pm0.0008) + 0d.81529075(\pm0.00000004)E + 1d.38(\pm0.08) \times 10^{-10} \times E^2. \quad (2)$$

It indicates that the orbital period shows a continuous secular increase of the period at a rate of $dp/dt=1.24(\pm0.07) \times 10^{-7}$ $dyr^{-1}$ (or $0.0107(\pm0.0006)$ second per year). The $O-C$ values are listed in the third column of Table 1 and plotted in Figure 2.

3 PHOTOMETRIC ANALYSIS OF V1034 HER

Because our data have high time-resolution and full phase coverage in 2009, we might re-obtained the photometric solution of V1034 Her using the 2003 version of the Wilson-Devinney program (Wilson &
Table 1  The minimum times of V1034 Her.

| JD(Hel.)   | Cycle | (O-C)   | Method | Reference                  |
|------------|-------|---------|--------|----------------------------|
| 2455901.652| −7195.0−0.0043| pg      | Kaiser et al. (2002)          |
| 2446116.891| −6931.0−0.0066| pg      | Kaiser et al. (2002)          |
| 2451738.7197| −35.5−0.0016 | CCD    | Kaiser et al. (2002)          |
| 2451740.7594| −33.0−0.0001 | CCD    | Kaiser et al. (2002)          |
| 2451747.6883| 24.5−0.0012 | CCD    | Kaiser et al. (2002)          |
| 2451753.8028| −17.0−0.0014 | CCD    | Kaiser et al. (2002)          |
| 2451767.6641| 0.0−0.0002  | CCD    | Kaiser et al. (2002)          |
| 2452084.8118| 389.0−0.0004 | CCD    | Kaiser et al. (2002)          |
| 2452873.1962| 1356.5−0.0011 | CCD    | Kaiser et al. (2002)          |
| 2453130.4213| 1671.5−0.0012 | CCD    | Kaiser et al. (2002)          |
| 2453518.5010| 2147.5−0.0001 | CCD    | Hübischer et al. (2006)       |
| 2453596.3613| 2243.0−0.0002 | CCD    | Bakis et al. (2005)           |
| 2453872.3376| 2581.5−0.0006 | CCD    | Doğru (2009)                  |
| 2453874.3761| 2584.0−0.0008 | CCD    | Doğru (2009)                  |
| 2453921.2477| 2643.0−0.0002 | CCD    | Doğru (2009)                  |
| 2454096.4198| 2984.0−0.0003 | CCD    | Hübischer (2007)              |
| 2454921.2101| 3862.0−0.0013 | CCD    | present paper                 |
| 2454923.2477| 3868.0−0.0016 | CCD    | present paper                 |
| 2455396.3613| 3870.5−0.0010 | CCD    | present paper                 |

**Fig. 1** B, V, R, and I observations of V1034 Her in 2009 and 2010 at Xinglong station. Circles(○) indicate Mar. 22 - Apr. 1 2009, squares(□) - Mar. 26 - 27 2010.

Due to the asymmetric light curves outside the primary eclipse, there is at least a large distortion in the phase range 0.1-0.3 (spot1). From a comparison between the observational light curves and the clean theoretical ones (the system parameters with less distortional effect are taken from the papers of Kaiser et al. (2002) and Doğru et al. (2009)), it indicates that there might be a depression around 0.9 (spot2). Hence, we are not able to tell whether there are one spot or two spots. Moreover, because of having no spectroscopic observation, it is very difficult to tell whether the spots are located on the
primary or secondary components, especially spot on the quadratures. Therefore, we performed two solutions (one is one-spot model on the primary, the other is two-spots model on the primary) to search the final result. The details of the procedure of photometric solution are similar to those of our previous works of RT And (Zhang & Gu 2007), DV Psc (Zhang et al. 2010a), GSC 3576-0170(Zhang et al. 2010b) and KQ Gem (Zhang 2010).

All BVRI light curves are analyzed simultaneously. In computing the photometric solutions, mode 2 of Wilson-Devinney code (appropriate for detached binaries) is employed with the synchronous rotation and zero eccentricity. Simple treatment is used to compute the reflect effect, and the linear limb-darkening law is used to compute the limb-darkening effect. The bolometric albedo $A_1=A_2=0.5$ (Rucindki 1973), the limb-darkening coefficients $x_{1B} = 0.819 \quad x_{2B} = 0.906$, $x_{1V} = 0.686 \quad x_{2V} = 0.763$, $x_{1R} = 0.568 \quad x_{2R} = 0.629$, $x_{1I} = 0.467 \quad x_{2I} = 0.512$ from Van Hamme (1993) and the gravity-darkening coefficients $g_1 = g_2 = 0.32$ for convective envelopes (Lucy 1967) are set for the primary and the secondary, as usual. According to the color index of $B-V = 0.78$ obtained by Kaiser et al. (2002), the effective temperature of the primary is $T_1 = 5360$ K from Budding & Demircan (2007) (see Doğru et al. 2009).

We have performed two solutions: one-spot model and two-spots model on the primary. The preliminary values of the orbital parameters are taken from the prior photometric solutions derived by Kaiser et al. (2002) and Doğru et al. (2009). We separately adjusted the orbital parameters and spot parameters until the theoretical curves fit the observed ones well. For the two-spots model, we fixed the spot latitude and temperature to avoid correlation among the spot latitude, temperature and radius. According to the temperature relation of the starspot and its located photosphere for active stars (Berdyugina 2005), we could determined that the starspot temperature is about 1500 K below the photosphere of the primary for V1034 Her. Therefore, the temperature factor is assumed to be 0.75. The preliminary latitude was set at the intermediate latitude $50^\circ$ based on the prior result for the RS CVn binary. After a lot of runs, two photometric solutions of V1034 Her are derived and listed in Table 2. While, the weighted sum of squares of residuals of two-spots model is smaller than that of one-spot model, so we concluded that the two-spots model being on the primary is better successful for describing the LCs of V1034 Her. The theoretical light curves for the spotted solutions and the observed light curves are shown in Figure. 3. Corresponding configurations for V1034 Her in phases 0.0, 0.25, 0.5 and 0.75 are shown in Figure. 4.

As can be seen from Fig. 1, the LCs do not have full phase coverage in 2010 due to weather condi-

Fig. 2 (O-C) diagram for the minimum times of V1034 Her. The solid line represents the quadratic fitting and show a period increase.
Table 2 Photometric solutions for V1034 Her.

| Parameters                  | Values (one spot) | Values (two spots) |
|-----------------------------|-------------------|--------------------|
| $T_1$ (K)                   | 5360              | 5360               |
| $T_2$ (K)                   | 4823 ± 5          | 4857 ± 4           |
| $i$ (deg)                   | 87.57 ± 0.08      | 88.50 ± 0.09       |
| $q$                         | 1.006 ± 0.007     | 0.98 ± 0.01        |
| $\Omega_1$                 | 5.825 ± 0.040     | 5.560 ± 0.024      |
| $\Omega_2$                 | 5.681 ± 0.042     | 5.583 ± 0.047      |
| $L_1/(L_1 + L_2)$ (B)       | 0.6688 ± 0.0017   | 0.7063 ± 0.0009    |
| $L_1/(L_1 + L_2)$ (V)       | 0.6291 ± 0.0020   | 0.6716 ± 0.0011    |
| $L_1/(L_1 + L_2)$ (R)       | 0.6005 ± 0.0022   | 0.6462 ± 0.0012    |
| $L_1/(L_1 + L_2)$ (I)       | 0.5795 ± 0.0023   | 0.6275 ± 0.0013    |
| $r_1$ (pole)                | 0.2066 ± 0.0017   | 0.2174 ± 0.0012    |
| $r_1$ (point)               | 0.2120 ± 0.0019   | 0.2240 ± 0.0014    |
| $r_1$ (side)                | 0.2085 ± 0.0018   | 0.2197 ± 0.0013    |
| $r_1$ (back)                | 0.2111 ± 0.0019   | 0.2228 ± 0.0014    |
| $r_2$ (pole)                | 0.2138 ± 0.0019   | 0.2015 ± 0.0020    |
| $r_2$ (point)               | 0.2200 ± 0.0022   | 0.2064 ± 0.0022    |
| $r_2$ (side)                | 0.2159 ± 0.0020   | 0.2031 ± 0.0020    |
| $r_2$ (back)                | 0.2189 ± 0.0021   | 0.2055 ± 0.0021    |
| $\text{latitude}_{\text{spot}1}$ (deg) | 50 ± 12.0        | 50°                |
| $\text{longitude}_{\text{spot}1}$ (deg) | 68.1 ± 5.1       | 70.2 ± 5.1         |
| $\text{radius}_{\text{spot}1}$ (deg) | 14.6 ± 5.1       | 15.3 ± 0.4         |
| $\text{temperature}_{\text{spot}1}$ | 0.82 ± 0.09      | 0.75°              |
| $\text{latitude}_{\text{spot}2}$ (deg) | -               | 50°                |
| $\text{longitude}_{\text{spot}2}$ (deg) | -               | 333.9 ± 2.6        |
| $\text{radius}_{\text{spot}2}$ (deg) | -               | 10.9 ± 1.6         |
| $\text{temperature}_{\text{spot}2}$ | -               | 0.75°              |
| $\sum_i (O - C)_i^2$        | 0.2862            | 0.2238             |

Parameters not adjusted in the solution are denoted by a mark "a".

4 DISCUSSION AND CONCLUSION

In this paper, our new light curves in BVRI bands were analyzed using the 2003 version of the Wilson-Devinney code with a spot model. New absolute physical parameters and starspot parameters were obtained. Secondly, we discussed the relation between photospheric starspot activity and the orbital period for the short-period RS CVn binary. Finally, the variation of the orbital period of V1034 Her were reanalyzed.

4.1 Photometric solution and starspot activity of V1034 Her

The marked asymmetry of the light curves of V1034 Her might suggest high-level surface activity, which was explained by starspot. From our results, we derived that the case of two-spots model being on the primary star is better successful in representing the distortions of the light curves. For the orbital parameters, the contribution of the primary component of V1034 Her to the total light is 0.71 in $B$, 0.67 in $V$, 0.65 in $R$, and 0.63 in $I$ band. Our new orbital parameters of luminosity ratios, the temperature of the secondary, and the orbital inclination are similar to those derived by Kaiser et al. (2002) and Doğru et al. (2009). However, the dimensionless potentials of the primary and secondary components $\Omega_1$ and
Fig. 3 The observational and theoretical light curves of V1034 Her in 2009. The circles and solid lines represent the observational and theoretical light curves, respectively.

Fig. 4 The configurations of V1034 Her in phases 0.0, 0.25, 0.5 and 0.75.

$\Omega_2$ are a bit smaller than the results derived by Kaiser et al. (2002) and Doğru et al. (2009). These may be affected by the starspot.

It is well known that active-region longitude is the most reliable spot parameters determined by the traditional Light-curve method. For the result derived by Kaiser et al. (2002), the longitudes of two spots in 2001 are about $118^\circ$ and $335^\circ$, respectively. The spot longitude was transformed to the binary orbital motion system. Later, Doğru et al. (2009) derived that the longitudes of the two cool spots were $135^\circ$ and $239^\circ$ in 2006, respectively. For our starspot parameters, the longitude of the spot1 is $70^\circ$.
Fig. 5 The spot longitudes from 2000 to 2009.

and the spot2 is about 334°. Therefore, it suggested that active regions tend to appear in two active longitude belts 90° and 270°, and each active longitude might be migrate in the orbital reference frame (see Fig.5). The active longitude phenomenon have also been found using photometry on many other active RS CVn binary systems, such as EI Eri (Berdyugina & Tuominen 1998), σ Gem (Henry et al. 1995), HK Lac (Olah Hall & Henry 1991), DV Psc (Zhang et al. 2010a) SV Cam (Zeilik et al. 1988) and RT And (Pribulla et al. 2000, Zeilik et al. 1989, Zhang & Gu 2007).

Comparasion of the LCs of 2009 and 2010, it indicates the spot1 becomes weaker at phase 0.2 and the spot2 becomes a bit stronger at phase 0.8 in 2010. Therefore, the spot activity changed on long time scale of one year. Indeed, Kaiser et al. (2002) also found the light curves differ on the order of 0.04 magnitudes at phase 0.9 during their observations in 2000 and 2001. These indicates starspot variation on a time scale of one year.

4.2 The orbital period - Activity relation for the short period RS CVn binary

For our observational light curves of V1034 Her, Max.II is around 0.04 mag in B, 0.07 mag in V, 0.06 mag in R and 0.04 mag in the I band brighter than Max.I, respectively. As you know, the light curve distortions are caused by dark photospheric spots for RS CVn stars. In order to detect the relation of the orbital period and the photospheric activity, we have also collected the values of the maximum amplitude of photometric distortions of other short-period RS CVn binary (Strassmeier et al. 1993; Eker et al. 2008). The values are listed in Table 3, which includes the object name, spectral type, the orbital period, the maximum distortion amplitudes in BVRI bands. For these values, the number of BV bands values are more than the RI bands. To detect the amplitude variation with the orbital period, they are plotted in Figure.6. As can be seen from Fig.6, there is a trend of increasing activity with decreasing the orbital period, and the trend are basically consistent with each other in the B and V bands (see Fig.6). To clarify the change, we also used the linear least-squares method to fit, and the linear formulas were
Table 3  The maximum distortion amplitudes of short-period RS CVn binary in B, V, R and I bands.

| Object      | Spectral type | Period (days) | The distortion amplitude (mag) | Reference                                      |
|-------------|---------------|---------------|--------------------------------|------------------------------------------------|
| RT And      | F8-G0V+K1-3V  | 0.629         | B 0.095 V 0.075 R 0.06 I 0.03 | Pribulla et al., 2000; Zhang & Gu 2007         |
| V1034 Her   | G5-9V+K1-4V   | 0.815         | B 0.040 V 0.070 R 0.06 I 0.04 | Kaiser et al., 2002; Dojrun et al., 2009; my paper |
| DV Psc      | K4V           | 0.309         | B 0.122 V 0.109 R 0.09 I 0.06 | Zhang & Zhang 2007; Zhang et al., 2010a        |
| XY Uma      | G2-5V+K5V     | 0.479         | B 0.292 V 0.251 R 0.12 I 0.10 | Pribulla et al., 2001; Yuan 2010               |
| CG Cyg      | G0V+K3V       | 0.631         | B 0.170 V 0.140 R 0.05 I 0.05 | Heckert 1996; Afaj et al., 2004; Kozhevnikova et al., 2007a |
| BH Vir      | F8V+G5V-M2V   | 0.817         | B 0.030 V 0.100 R 0.04 I 0.04 | Xiang et al., 2000; Kozhevnikova et al., 2007b |
| WY Cnc      | G5V+K7V       | 0.830         | B 0.100 V 0.110 R 0.06 I 0.04 | Koff et al., 2005; Terrell et al., 2005        |
| GSC03377-0296 | K3+            | 0.422         | B 0.140 V 0.120 R 0.10 I 0.10 | Lloyd et al., 2007                            |
| DK CVn      | K7V+M         | 0.495         | B 0.159a V 0.117a R 0.10a I 0.08a | Koff et al., 2005; Terrell et al., 2005        |
| SY Can      | G0-G5V+K4V    | 0.593         | B 0.150a V 0.150a R 0.10a I 0.10a | Koff et al., 2005; Terrell et al., 2005        |
| UCA3 295-68871 | G6-9+K1-3      | 0.495         | B 0.090 V 0.070 R 0.06 I 0.06 | Bernhard & Frank 2006                         |
| GSC 2038.0293 | G5V+K2-3V      | 0.861         | B 0.094 V 0.100 R 0.06 I 0.06 | Akan et al., 1988; Kjurkchieva et al., 2005   |
| ER Vul      | G0V+G5V       | 0.698         | B 0.080a V 0.050 R 0.05 I 0.05 | Heckert 1991; Qan 2001; Pribulla et al., 2003 |
| BB Scy      | K3-5V+K4V     | 0.477         | B 0.070 V 0.070 R 0.05 I 0.05 | Bromage & Buchley 1996; Watson et al., 2001    |
| UV Leo      | G0V+G2V       | 0.600         | B 0.050 V 0.050 R 0.05 I 0.05 | Kjurkchieva & Marchev 2007                    |
| BC Psc      | G5-4V+K3-5V   | 0.649         | B 0.170 V 0.170 R 0.10 I 0.10 | Cutispoto 1995                                |

The values are denoted by a mark “a”, which are approximately calculated by the light curves of the literatures.

obtained for B and V bands as follows:

\[
\text{The } B \text{ amplitude}(\text{mag}) = 0.257(\pm0.067) - 0.223(\pm0.106) \times P.
\]

\[
\text{The } V \text{ amplitude}(\text{mag}) = 0.151(\pm0.052) - 0.068(\pm0.083) \times P.
\]

These fits are also plotted in figure 6 with solid line. They are consistent with the rotation-activity correlation of RS CVn binaries by using chromospheric activity indicators (Montes et al. 1995; Montes et al. 1996), the radio luminosity (Gunn 1998), the extreme ultraviolet emission (Mitrou et al. 1997).

4.3 The period variation of V1034 Her

The variation of the orbital period of V1034 was reanalyzed on the basis of our new minimum times and those collected from the literatures. The quadratic term indicates that the orbital period of V1034 Her shows a continuous increase at a rate of 0.0107(±0.0006) second yr\(^{-1}\). The rate is similar to the result derived by Dojrun et al. (2009). Since V1034 Her is a detached system, it is impossible that the mass transfer directly from the less massive component to the larger massive primary. So it is probable that the coronal mass flow from the less massive component to the large massive component by stellar wind (Gálvez et al., 2007). Because the photometric mass ratio is about 1, so it is difficult to tell the massive component is the primary star or the secondary component. Because the time range of (O-C) information is rather short - about 25 years, it is too early to decide about the character of the period variation. The upward parabola maybe a part of long periodic oscillation cause by a presumed third component or by magnetic activity cycle (Applegate 1992; Lanza et al. 1998). More new observations are needed to confirm it in the next 20-30 year.

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**Fig. 6** The relations between the orbital period and photometric distortion amplitudes in the B and V bands.

**References**

Afsar, M., Heckert, P. A., Ibanoğlu, C., 2004, A&A, 420, 595
Akan, M. C., 1988, Ap&SS, 143, 367
Akerlof, C., Amrose, S., Balsano, R., et al., 2000, AJ, 119, 1901
Applegate, J. H. 1992, ApJ, 385, 621
Bakis, V., Doğru, S. S., H., Doğru, D., et al., 2005, IBVS, 5662
Berdyugina, S. V., & Tuominen, I. 1998, A&A, 336, 25
Berdyugina, S. V. 2005, living Rev. Solar Phys., 2, (2005), 8. [Online Article]
Bernhard, K., & Frank, P., 2006, IBVS, 5719
Bromage, G. E., & Buchley, D. A. H., 1996, IBVS, 4400, 1B
Budding, E., Demircan, O. 2007, Introduction to Astronomical Photometry, seconded. Cambridge University Press
Cutispoto, G., 1995, A&AS, 111, 507
Diethelm, R., 2001, IBVS, 5060
Diethelm, R., 2003, IBVS, 5438
Diethelm, R., 2004, IBVS, 5543
Doğru, D., Erdem, A., & Doğru, S. S. 2009, NewA, 14, 711
Eker, Z., Filiz, Ak N., Bilir, S., et al., 2008, MNRAS, 389, 1722
Gu, S. H., Tan, H. S., Shan, H. G., et al. 2002, A&A, 388, 889
Gunn, A. G., 1998, IrafJ, 25, 33
Gulvez M. C., Montes D., Fernández-Figueroa, M. J., et al., 2007, A&A, 472, 587
Heckert, P. A., 1996, IBVS, 4371
Heckert, P. A., & Zeilik, M., 1991, IBVS, 3636
Henry, G. W., Eaton, J. A., Hamer, J., et al. 1995, ApJs, 97, 513
Höbscher, J., 2007, IBVS, 5802
Höbscher, J., Paschke, A., Walter F., 2006, IBVS, 5731
Kaiser, D. H., Pullen, A. C., Henden, A. A., et al., 2002, IBVS, 5231
Kjurkchieva, D. P., Marchev, D. V., Heckert, P. A., et al., 2005, AJ, 129, 1084
Kjurkchieva D. P., & Marchev D. V., 2007, MN, 381, 663
Koff, R. A., Terrell, D., Henden, A. A., et al., 2005, SASS, 24, 17
Kozhevnikova, A. V., Alekseev, I. Yu., Heckert, P. A., et al., 2007a, AAT, 26, 111
Kozhevnikova, A. V., Alekseev, I. Yu., Heckert, P. A., et al., 2007b, ARep, 51, 932
Krajci, T, 2005, IBVS, 5592
Kwee, K. K., van Woerden, H., 1956, BAN, 12, 327
Lanza, A. F., Rodonò, M., Rosnor, R., 1998, MNRAS, 296, 893
Locher, K., 2005, OEJv, 3
Lucy, L. B. 1967, Z.Astrophys, 65, 89
Lloyd, C., Bernhard, K., Monninger, G., 2007, IBVS, 5772
Mitrou, C. K., Mathioudakis, M., Doyle, J. G., et al., 1997, A&A, 317, 776
Montes, D., Fernández-Figueroa, M. J., De Castro, E., Cornide, M., 1995, A&A, 294, 165
Montes, D., Fernández-Figueroa, M. J., Cornide, M., De Castro, E., 1996, A&A, 312, 221
Olah, K., Hall, D. S., & Henry, G. W. 1991, A&A, 251, 531
Ordway, J., & Van Hamme, W. 2004, AAS, 36, 1370
Pribulla, T., Chochol, D., Milano, L. et al. 2000, A&A, 362, 169
Pribulla, T., Chochol, D., Heckert, P. A., et al., 2001, A&A, 371, 997
Pribulla, T., Chochol, D., & Vittone, A. A., 2003, Chin. J. Astron. Astrophys, Suppl. 361-366
Qian, S. B., 2001, IAUS, 203, 437Q
Rucinski, S. M., 1973, Acta Astron, 23, 79
Strassmeier, K. G., Hall, D. S., Fekel, F. C., & Scheck M., 1993, A&AS, 100, 173
Solovyov, V., Samokhvalov, A., Satovskiy, B., 2011, IBVS, 5961
Terrell, D., Koff R. A., Henden A. A., et al., 2005, IBVS, 5642
Van Hamme, W. 1993, AJ, 106, 2096
Watson, L. C., Pritchard, J. D., Hearnshaw, J. B., et al., 2001, MNRAS, 325, 143
Wilson, R. E. 1979, ApJ, 234, 1054
Wilson, R. E. 1990, ApJ, 356, 613
Wilson, R. E. 1994, PASP, 106, 921
Wilson, R. E., & Devinney, E. J. 1971, ApJ, 166, 605
Wilson, R. E., & Van Hamme, W. 2004, Computing Binary Star Observables, privately circulated monograph
Xiang, F. Y., Deng, S. F., Liu, Q. Y., 2000, A&AS, 146, 7
Yuan, J. Z., 2010, AJ, 139, 1801
Zeilik, M., Cox D. A., De Blasi, C. et al., 1989, ApJ, 345, 991
Zeilik, M., De Blasi, C., Rhodes M. et al. 1988, ApJ, 332, 293
Zhang, L. Y., & Gu, S. H. 2007, A&A, 471, 219
Zhang, L. Y., & Gu, S. H. 2008, A&A, 487, 709
Zhang, L. Y., Zhang, X. L., & Zhu, Z. Z. 2010a, NewA, 15, 362
Zhang, L. Y., 2010, PASP, 122, 309
Zhang, L. Y., Jing J H., Tang, Y. K., & Zhang, X. L., 2010b, NewA, 15, 653
Zhang, X. B., & Zhang, R. X., 2007, MNRAS, 382, 1133
Zhou, A. Y., Jiang, X. J., Zhang Y. P., et al., 2009, RAA, 9, 349