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# Rapid Light-curve Changes and Probable Flip-flop Activity of the W UMa-type Binary V410 Aur

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## Abstract

New photometric observations of a W UMa system, V410 Aur, were carried out over 10 nights from 2014 December 19 to 2015 February 8, from which four sets of light curves were obtained. The light curves show many unusual behavioral features, including changing occultation depths, transit minima, and asymmetric maxima. The four sets of light curves have been separately analyzed with the Wilson–Devinney method. The results suggest a totally eclipsing contact configuration for the system. Over a surprisingly short time span of only 52 days, the dominant spot distortion phase jumped twice between phases 0.0 and 0.5. The light-curve variations can be interpreted by the presence of two cool spots on the massive component. Based on our analysis, it is further suggested that the peculiar behavioral patterns are probably caused by the presence of two permanent, active large spots separated in longitude by about 180°, whose locations remain almost unchanged throughout. Our study demonstrates that the system has been undergoing typical flip-flop activity. We therefore conclude that V410 Aur is a W UMa-type system exhibiting flip-flop activity.

*Key words:* binaries: eclipsing – stars: individual (V410 Aur) – stars: late-type – stars: starspots

*Supporting material:* data behind figure

## 1. Introduction

As systems composed of two stars in a contact configuration and with a common envelope, W UMa-type binaries serve as laboratories for studying many aspects of the microphysics driving the evolution of interacting binary systems. They are widely observed in different environments in the Galaxy, and therefore, they play an important role among Galactic stellar populations (Rucinski 1998; Li et al. 2004a). These systems provide a unique opportunity to investigate a number of complex physical phenomena, such as mass and energy transfer (Shu & Lubow 1981), angular momentum loss (Li et al. 2004b), stellar magnetic activity (Applegate 1992), and binary mergers (Tylenda et al. 2011). Interacting binaries, including W UMa types, may be responsible for the formation of some special types of objects such as blue stragglers, red novae (Andronov et al. 2006), and subdwarf B stars (Han et al. 2002). However, their formation, evolution, and the final stage of their evolution remain to be studied, particularly in relation to some strange observational properties. For example, the O'Connell effect can directly affect the determination of the basic physical parameters of binary systems.

Many W UMa-type binaries exhibit asymmetric light curves, with unequal out-of-eclipse maxima. This is called the O'Connell effect (Milone 1968), and it is entirely unexpected in view of the side-by-side configuration of the components. This phenomenon seems to be a common feature among eclipsing binaries, but the detailed light-curve shapes are quite diverse. The shapes of the light curves of BX Dra (Park et al. 2013) and XZ Leo (Luo et al. 2015) appear to be relatively stable on long timescales. However, the O'Connell effect is known to be highly variable in other systems, for instance in V523 Cas (Zhang & Zhang 2004), CK Boo (Yang et al. 2012), and DZ Psc (Yang et al. 2013). Most interestingly, some W UMa systems exhibit considerable variation in the relative surface brightnesses of the two light maxima, as well as in the relative depths of the two light minima. For instance, the light curves of HH UMa show rapid changes between the two light maxima on the very short timescale of only 44 days (Wang et al. 2015b). The light curve of TZ Boo displays quasi-periodic changing occultation depths and transit minima (Hoffmann 1980; Christopoulou et al. 2011). Although these observational phenomena have been recognized for decades, the underlying cause has not been determined conclusively. In order to find a common denominator or any clues shedding light on these complicated light curves, we carried out a long-term multi-color photometric survey of several active contact binary systems, including V410 Aur.

The variability of V410 Aur was discovered by the *Hipparcos* mission. The object was classified as a W UMa-type binary with an orbital period of 0.36634 days. The first radial velocity study of V410 Aur was performed by Rucinski et al. (2003), who determined a spectroscopic mass ratio $q_{\rm sp} = 0.144 \pm 0.013$. V410 Aur is a triple system with a visual companion at a projected separation of $1\overset{''}{.}716 \pm 0.006$ (Rucinski et al. 2007). Photometric observations of the system were obtained by Yang et al. (2005), Gazeas et al. (2006), and Oh et al. (2007); their light curves showed obvious variations from one epoch to another. The light curves shown by Yang et al. (2005) did not display any obvious asymmetries, with nearly equal light maxima. The light-curve shape presented by Gazeas et al. (2006) exhibited a negative O'Connell effect, with the first light maximum at phase 0.25 being fainter than the second maximum at phase 0.75. The light curve of Oh et al. (2007), however, displayed a positive O'Connell effect, with the first maximum becoming brighter.

These prior studies clearly made V410 Aur a very interesting object in terms of its odd O'Connell effect. Long-term continuous photometric surveillance is needed to improve our understanding of the stellar activity in this system. In this

**Table 1**
Observation Log

| Date | Start (HJD 2457000+) | Length (hr) | Telescope | Filters | Frames |
|---|---|---|---|---|---|
| 2014 Dec 19 | 10.936 | 10.3 | 85 cm | *BVRI* | 566 |
| 2014 Dec 20 | 11.936 | 10.0 | 85 cm | *BVRI* | 549 |
| 2014 Dec 29 | 21.047 | 8.0 | 25 cm | *BVR* | 208 |
| 2014 Dec 30 | 22.027 | 9.1 | 25 cm | *BVR* | 229 |
| 2015 Jan 10 | 32.983 | 8.9 | 25 cm | *BVR* | 238 |
| 2015 Jan 11 | 33.982 | 9.1 | 25 cm | *BVR* | 244 |
| 2015 Jan 12 | 34.988 | 7.4 | 25 cm | *BVR* | 193 |
| 2015 Jan 13 | 35.999 | 8.6 | 25 cm | *BVR* | 233 |
| 2015 Feb 7 | 61.091 | 4.7 | 25 cm | *BVR* | 110 |
| 2015 Feb 8 | 61.991 | 7.1 | 25 cm | *BVR* | 186 |

**Table 2**
Basic Parameters of Variable, Comparison, and Reference Stars

| Star | Name | $\alpha_{2000}$ | $\delta_{2000}$ | $m_V$ | $B - V$ |
|---|---|---|---|---|---|
| Variable | V410 Aur | 05:01:10.833 | +34:30:26.53 | 10.215 | 0.686 |
| Comparison | UCAC4 623–019812 | 05:01:39.684 | +34:24:00.34 | 10.943 | 0.647 |
| Reference | UCAC4 623–019777 | 05:01:15.858 | +34:33:32.81 | 12.717 | 0.920 |

paper, we report time-series photometric results of the W UMa system V410 Aur.

## 2. Observations and Data Reduction

New CCD photometric observations of V410 Aur were carried out from 2014 December 19 to 2015 February 8. Two small telescopes, i.e., the ASA 25 cm telescope in Delingha and the 85 cm reflecting telescope at Xinglong Station, were used to monitor the star's light variations. The 85 cm telescope was equipped with an Andor iKon-L 936 2K × 2K CCD with an image scale of about $0.''97$ pixel$^{-1}$, providing a field of view of about $33' \times 33'$ (Zhang et al. 2015). The standard Johnson–Cousins–Bessell set of *BVRI* filters were alternately used on 2014 December 19 and 20. The 25 cm telescope, auxiliary equipment of the SONG China project (Deng et al. 2013; Wang et al. 2015a), was equipped with an SBIG ST-10 XME CCD camera with 2184 × 1472 pixels. The size of each pixel is about $1.''47$, resulting in a field of view of about $53.'5 \times 36.'1$. The standard Johnson–Cousins–Bessell set of *BVR* filters were alternately used on 2014 December 29–30, 2015 January 10–13, and 2015 February 7–8. A brief log of the observations is included in Table 1.

The standard IRAF/CCDPROC procedures were adopted to pre-process all of the data collected with both telescopes. Aperture photometry of all images was next carried out using the IRAF/PHOT package. The stars UCAC4 623–019812 and UCAC4 623–019777[4] were used as comparison and reference stars, respectively, given their similar colors and magnitudes as the target star's parameters. Their basic physical parameters, provided by Zacharias et al. (2013), are summarized in Table 2. The differential photometry technique was then applied to the target star to derive a $\Delta M$ time sequence, with the mid-exposure time of each image translated into heliocentric Julian days. By inspecting the temporal difference in magnitude between the comparison and

**Table 3**
New Times of Light Minima for V410 Aur

| HJD | Error | Type | Filter |
|---|---|---|---|
| 2457011.0091 | 0.0001 | I | *BVRI* |
| 2457011.1935 | 0.0001 | II | *BVRI* |
| 2457012.1083 | 0.0001 | I | *BVRI* |
| 2457012.2928 | 0.0001 | II | *BVRI* |
| 2457021.0850 | 0.0001 | II | *BVR* |
| 2457021.2677 | 0.0001 | I | *BVR* |
| 2457022.1849 | 0.0001 | II | *BVR* |
| 2457022.3664 | 0.0002 | I | *BVR* |
| 2457033.1753 | 0.0001 | II | *BVR* |
| 2457034.0924 | 0.0001 | I | *BVR* |
| 2457034.2729 | 0.0001 | II | *BVR* |
| 2457035.1914 | 0.0001 | I | *BVR* |
| 2457036.1053 | 0.0001 | II | *BVR* |
| 2457036.2904 | 0.0002 | I | *BVR* |
| 2457040.1360 | 0.0001 | II | *BVR* |
| 2457041.2340 | 0.0001 | II | *BVR* |
| 2457061.2022 | 0.0001 | I | *BVR* |
| 2457062.1170 | 0.0001 | II | *BVR* |

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[4] UCAC4 represents the fourth United States Naval Observatory (USNO) CCD Astrograph Catalog.

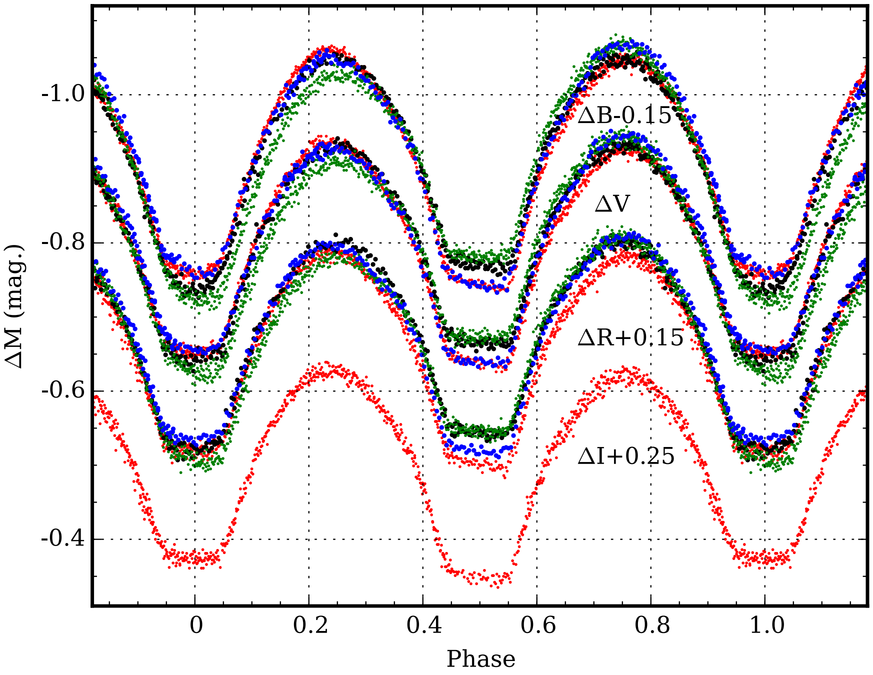

**Figure 1.** All measurements of V410 Aur. The red, black, green, and blue dots were observed on 2014 December 19–20, 2014 December 29–30, 2015 January 10–13, and 2015 February 7–8, respectively. The *B*-, *R*-, and *I*-band points have been shifted by −0.15 mag, +0.15 mag, and 0.25 mag, respectively, to separate the curves in the figure. The data used to create this figure are available.

reference stars, we obtained a photometric uncertainty better than 0.015 mag for our differential photometry.

## 3. Light-curve Analysis

Our observations covered a total of 18 eclipses of the V410 Aur binary system, including 8 primary eclipses and 10 secondary ones. The times of minimum light were calculated with the K–W method (Kwee & van Woerden 1956), and their mean *BVRI* magnitudes are given in Table 3. We also collected a total of 77 previous eclipse timings from the O–C gateway.[5] Based on these data, we derived a revised linear ephemeris for the eclipsing binary using the classical $O - C$ method. We can therefore compute the times of minimum light (Min.I) using

$$\text{Min.I} = 2457011.0101(2) + 0.36636259(4) \times E, \qquad (1)$$

where $E$ is the eclipse cycle number.

The phases of all observations were determined based on the orbital period and the reference epoch, which we obtained from the linear ephemeris derived above. All of our measurements are displayed in Figure 1 in the form of differential magnitude, $\Delta M$ (variable minus comparison star), versus orbital phase. The thickness of the light curves reveals marked asymmetries, which in turn imply rapid intrinsic variations during our observations. In order to distinguish the light-curve features, we folded the observations into four sets of phased light curves, as illustrated in Figure 2. This figure shows that V410 Aur is a fully eclipsing system and the total eclipse occurs during the second light minimum, with a totality duration of at least 45 minutes. Similar cases were also present in the light curves of Yang et al. (2005), Gazeas et al. (2006), and Oh et al. (2007). In addition, by comparing the radial velocity curves of Rucinski et al. (2003) with the newly derived ephemeris, we infer that the massive component is moving away from us and the less massive one is moving toward us after the second light minimum at phase 0.5. This means that the second minimum is due to occultation while the first one reflects a transit.

We discovered significant epoch-to-epoch variations in the light curves in our data set, showing changing depths of transit and occultation minima as a function of time. The occultation minima recorded on 2014 December 19 and 20 were fainter than the transit minima, in all filters. Just 10 days later, the shape of the light curves reversed to show a deeper transit minimum. The transit minima obtained on 2015 January 10–13 became fainter than the earlier minima. In 2015 February, however, the situation switched once again, when the shape of the light curves returned to showing a deeper occultation minimum. It is interesting that such drastic changes in the minimum depths in all bands (significantly larger than the photometric errors) are characterized by a full cycle timescale of only 52 days. The light intensity at minimum also varies. It seems that the minima at phase 0.5 are clearly sloping in the December measurements, while this sloping behavior is increasingly manifested in the minima at phase 0. The light curves of 2015 January showed a noticeable O'Connell effect, but at other times, the height difference between the two maxima was negligible. The main characteristic parameters of the light-curve shapes are summarized in Table 4.

To understand the underlying physics in such a system, careful fitting of all features in the light curves is needed. Any model that fails such a criterion should not be used, which includes the hot-spot hypothesis. Stellar surface activity usually has a cycle period of at least several years (Strassmeier 2009). The 52-day cycle observed for V410 Aur is too short, and this is surely a significant challenge to all theoretical models based spot migration. Alternatively, for the current case, one could adopt a decaying and emerging chain of a few consecutively appearing large spots. Although such large spots are consistent

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[5] http://var.astro.cz/ocgate/

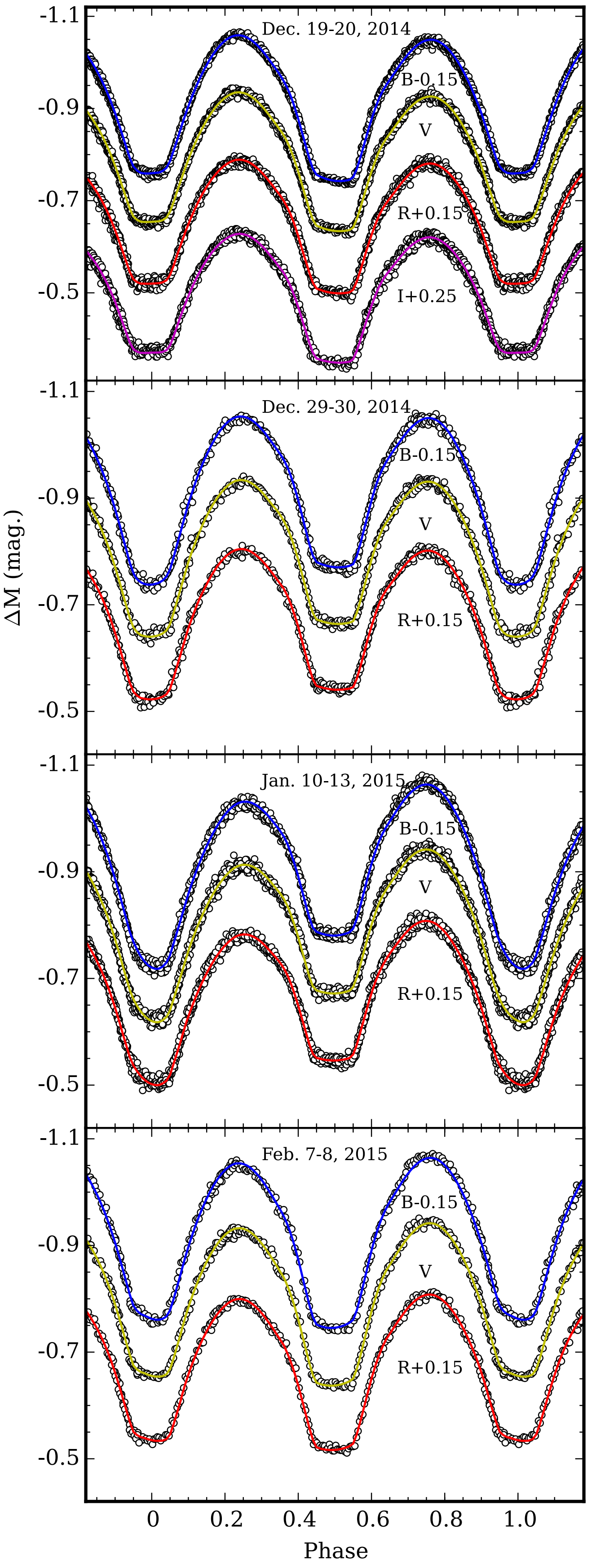

**Figure 2.** Observed *B*-, *V*-, *R*-, and *I*-band light curves of V410 Aur plotted along with their theoretical synthesis. The *B*-, *R*-, and *I*-band points have been shifted by −0.15 mag, +0.15 mag, and 0.25 mag, respectively, to separate the curves in the figure.

with the light-curve analysis of V410 Aur, the spot lifetimes related to their decay and emergence is still a serious problem for such a scenario to work. The light variations of V410 Aur from season to season closely resemble those of another W UMa system, HH UMa, whose light curves exhibit significant asymmetry and rapid changes between the light maxima twice in just six weeks (Wang et al. 2015b). The latter authors applied the flip-flop mechanism, defined as switching of the dominant activity between two opposite longitudes (Korhonen et al. 2001; Berdyugina 2005), to model the asymmetries in the HH UMa light curve and then argued that flip-flop activity seems a common pattern of stellar activity in W UMa systems, just like in RS CVn-type binaries, FK Com-type stars, and very active young solar analogs. We therefore propose to use the flip-flop mechanism to model the V410 Aur light-curve changes.

We analyzed the four sets of V410 Aur light curves separately, using the 2013 version of the Wilson–Devinney code, including Kurucz's stellar atmosphere models (Wilson & Devinney 1971; Wilson 1979, 1990, 2012). A circular orbit and synchronous rotation were adopted when considering the evolutionary status of W UMa stars. We define the massive primary component as star 1 and the less massive secondary as star 2, following Yang et al. (2005), Gazeas et al. (2006), and Oh et al. (2007). The mean temperature of star 1 and the stellar mass ratio were fixed at $T_1 = 5950$ K and $q = M_2/M_1 = 0.144$ (Rucinski et al. 2003), respectively. The corresponding bolometric and monochromatic limb-darkening coefficients were interpolated adopting a logarithmic law from van Hamme (1993)'s tables. The gravity-darkening coefficients and the bolometric albedos were set at $g_{1,2} = 0.32$ (Lucy 1967) and $A_{1,2} = 0.5$ (Ruciński 1969) in view of the convective atmospheres.

The adjustable parameters are the phase shift, the orbital inclination, $i$, the mean temperature of star 2, $T_2$, the surface potentials of both components ($\Omega_1$, $\Omega_2$), and the monochromatic luminosity of star 1, $L_1$. Third light, $L_3$, was also included, because the system is a spectroscopic triple system (Rucinski et al. 2003). Because the light intensity at minimum varies, especially around the flat occultation minimum where there is an obvious slope, the flip-flop mechanism was introduced to model the asymmetries and variations of the light curves. The presence of two cool spots was assumed for star 1, because the massive primary components are usually more active (Mullan 1975; Eaton et al. 1980. The spot parameters are their co-latitudes, longitudes, angular radii, and temperature factors.

The light curves obtained on 2014 December 29 and 30 were first analyzed. The DC program started from mode 2 (detached configuration) and rapidly converged to mode 3 (contact configuration) after several iterations. According to the spot distortion phases in the light curves, we estimated the initial approximate spot longitudes. The spot parameters, along with the free systematic parameters mentioned above, were then tuned. Based on many trials, we obtained a fair photometric solution that fits the observations very well. The other three sets of light curves were analyzed in the same way. Table 5 lists the results from the best-fitting solution. The theoretical light curves and geometric configurations of V410 Aur were calculated using these photometric solutions. The synthetic light curves are displayed in Figure 2, and the geometric configurations of the system, along with the spot distributions, are illustrated in Figure 3.

**Table 4**
Characteristic Light-curve Parameters

| Epoch | Filter | Min.I − Min.II | Max.II − Max.I | Min.I − Max.I | Min.II − Max.I |
|---|---|---|---|---|---|
| 2014 Dec 19–20 | $\Delta B$ | 0.015 | −0.012 | −0.300 | −0.315 |
| … | $\Delta V$ | 0.015 | −0.006 | −0.280 | −0.295 |
| … | $\Delta R$ | 0.021 | −0.004 | −0.265 | −0.285 |
| … | $\Delta I$ | 0.025 | −0.005 | −0.253 | −0.278 |
| 2014 Dec 29–30 | $\Delta B$ | −0.035 | −0.007 | −0.316 | −0.281 |
| … | $\Delta V$ | −0.022 | −0.002 | −0.290 | −0.267 |
| … | $\Delta R$ | −0.025 | 0.003 | −0.277 | −0.253 |
| 2015 Jan 10–13 | $\Delta B$ | −0.058 | 0.042 | −0.303 | −0.245 |
| … | $\Delta V$ | −0.048 | 0.031 | −0.288 | −0.239 |
| … | $\Delta R$ | −0.041 | 0.028 | −0.275 | −0.235 |
| 2015 Feb 7–8 | $\Delta B$ | 0.016 | 0.020 | −0.287 | −0.303 |
| … | $\Delta V$ | 0.015 | 0.013 | −0.271 | −0.287 |
| … | $\Delta R$ | 0.015 | 0.009 | −0.262 | −0.277 |

**Note.** Max.I, Max.II, Min.I, and Min.II represent the first light maximum at phase 0.25, the second light maximum at phase 0.5, the first light minimum at phase 0.0, and the second light minimum at phase 0.5, respectively.

## 4. Results and Discussion

Based on the analysis of our data and tuning all free parameters, the best-fitting photometric solutions were derived. We confirm that V410 Aur is a W UMa-type system with a fill-out factor of $f \sim 29\%$, and an orbital inclination of $82\overset{\circ}{.}2$. Its light curve reveals that it goes through total eclipses on account of the components' orbital motions. Putting together our photometric solutions and the spectroscopic results from the radial velocity measurements (Rucinski et al. 2003), the physical parameters of the binary system were calculated as follows: $M_1 = 1.27 \pm 0.05\,M_\odot$, $M_2 = 0.18 \pm 0.02\,M_\odot$, $R_1 = 1.37 \pm 0.02\,R_\odot$, $R_2 = 0.59 \pm 0.01\,R_\odot$, $L_1 = 2.10 \pm 0.07\,L_\odot$, and $L_2 = 0.37 \pm 0.01\,L_\odot$.

The shape of the V410 Aur light curve exhibits very large variations and many unknown features: the depths of transit and occultation minima vary from season to season; the light intensity at minimum is variable, strongly sloping with phase; the light maxima vary as well. All of the peculiar phenomena indicate that this binary is a very active W UMa system. The cyclic and sudden phase jumps, switching between A- and W-type light-curve types (Christopoulou et al. 2011), closely resemble flip-flop events where the more and less active longitudes are suddenly reverted (Berdyugina 2007; Oláh 2011). This led us to introduce the flip-flop mechanism to model the light-curve asymmetries and variations. Our analysis shows that, as displayed in Figure 2, the four sets of V410 Aur light curves are fairly well synthesized by adding two cool spots on the massive primary component. Figure 3 shows that the two spots have always been on the opposite hemispheres and that their locations remain almost unchanged, but they evolve in size and temperature. Similar cases have been observed using Doppler imaging in a number of active stars that show flip-flop behavior (see Berdyugina 2005, their Figure 15). This indicates that sudden changes in the depths of the minima could be attributed to a sudden switch of the dominant activity from one longitude to the opposite one. In addition, we also note that the geometric parameters generated from our four sets of light curves are almost identical, which in turn supports the flip-flop model. Therefore, we conclude that the unusual behavior seen in the V410 Aur light curve could be associated with flip-flop activity.

**Table 5**
Photometric Solutions for the V410 Aur Contact Binary

| Parameter | 2014 Dec 19–20 | 2014 Dec 29–30 | 2015 Jan 10–13 | 2015 Feb 7–8 |
|---|---|---|---|---|
| $q = M_2/M_1$ | 0.144 | 0.144 | 0.144 | 0.144 |
| $T_1$ (K) | 5950 | 5950 | 5950 | 5950 |
| $T_2$ (K) | 5893(4) | 5909(5) | 5913(8) | 5898(9) |
| $i$ (deg) | 81.8(1) | 82.5(2) | 82.4(2) | 81.9(2) |
| $\Omega_1 = \Omega_2$ | 2.057(1) | 2.061(2) | 2.057(1) | 2.062(2) |
| $l_{1B}$ | 0.829(4) | 0.830(5) | 0.814(5) | 0.827(7) |
| $l_{1V}$ | 0.831(4) | 0.831(5) | 0.817(4) | 0.830(7) |
| $l_{1R}$ | 0.832(3) | 0.833(4) | 0.820(4) | 0.832(6) |
| $l_{1I}$ | 0.832(3) | … | … | … |
| $l_{3B}$ | 0.017(3) | 0.017(4) | 0.023(4) | 0.018(5) |
| $l_{3V}$ | 0.017(2) | 0.016(4) | 0.022(3) | 0.017(5) |
| $l_{3R}$ | 0.016(3) | 0.015(3) | 0.021(3) | 0.016(4) |
| $l_{3I}$ | 0.016(3) | … | … | … |
| $\phi_1$ (deg) | 107.0(1.4) | 115.6(2.1) | 148.1(1.0) | 109.1(2.6) |
| $\theta_1$ (deg) | 0.5(2) | 0.7(3) | 338.5(5) | 356.8(3) |
| $\gamma_1$ (deg) | 21.3(2) | 22.2(4) | 46.4(3) | 24.0(3) |
| $T_{\rm spot\ 1}/T_1$ | 0.875(5) | 0.877(7) | 0.856(7) | 0.877(9) |
| $\phi_2$ (deg) | 150.7(1.0) | 144.9(2.4) | 121.4(2.4) | 144.9(2.8) |
| $\theta_2$ (deg) | 169.5(3) | 169.9(1.5) | 178.4(6) | 185.7(6) |
| $\gamma_2$ (deg) | 38.6(2) | 23.3(8) | 20.1(4) | 39.0(5) |
| $T_{\rm spot\ 2}/T_1$ | 0.830(9) | 0.846(12) | 0.840(14) | 0.868(16) |

**Note.** $l_1 = L_1/(L_1 + L_2 + L_3)$: fractional luminosity of the primary star; $l_3 = L_3/(L_1 + L_2 + L_3)$: fractional luminosity of the third light; $\phi$: spot latitude; $\theta$: spot longitude; $\gamma$: spot angular radius.

Flip-flops, switching of the dominant activity between opposite longitudes, are an important but unexplored phenomenon (Berdyugina 2005; Strassmeier 2009). Because this type of phenomenon was first seen in the light-curve phase jumps of the single, late-type giant FK Com (Jetsu et al. 1991), only about 10 stars are known to show this effect. With V410 Aur and HH UMa, we now have two convincing cases exhibiting this phenomenon in late-type W UMa systems. In addition, similarly changing depths of transit and occultation minima as the patterns observed for V410 Aur have already been observed for several active W UMa systems, including AC Boo

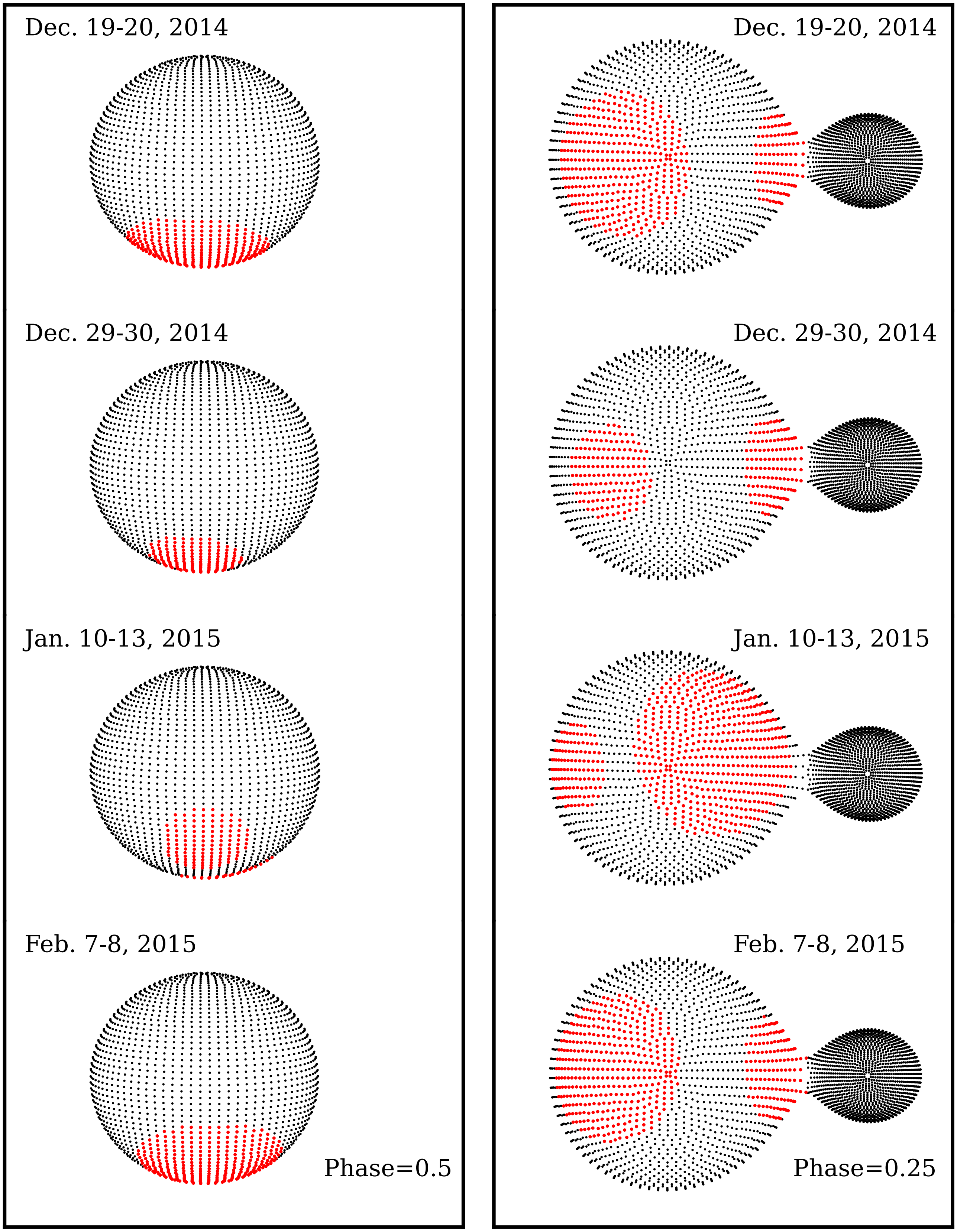

**Figure 3.** (Left): geometric configuration and spot distribution of V410 Aur at phase 0.5. (Right): south pole-on view of the component stars, selected to clarify the changes in the surface distribution of the two dark spots.

(Nelson 2010), AM Leo (Hiller et al. 2004), TY UMa (Kang et al. 2002), and TZ Boo (Hoffmann 1980), even before the term “flip-flop” was coined. The light maxima of some active W UMa systems also show similar behavior. For instance, the O’Connell effect observed for HH UMa (Wang et al. 2015b), CK Boo (Yang et al. 2012), FU Dra (Liu et al. 2012), and V523

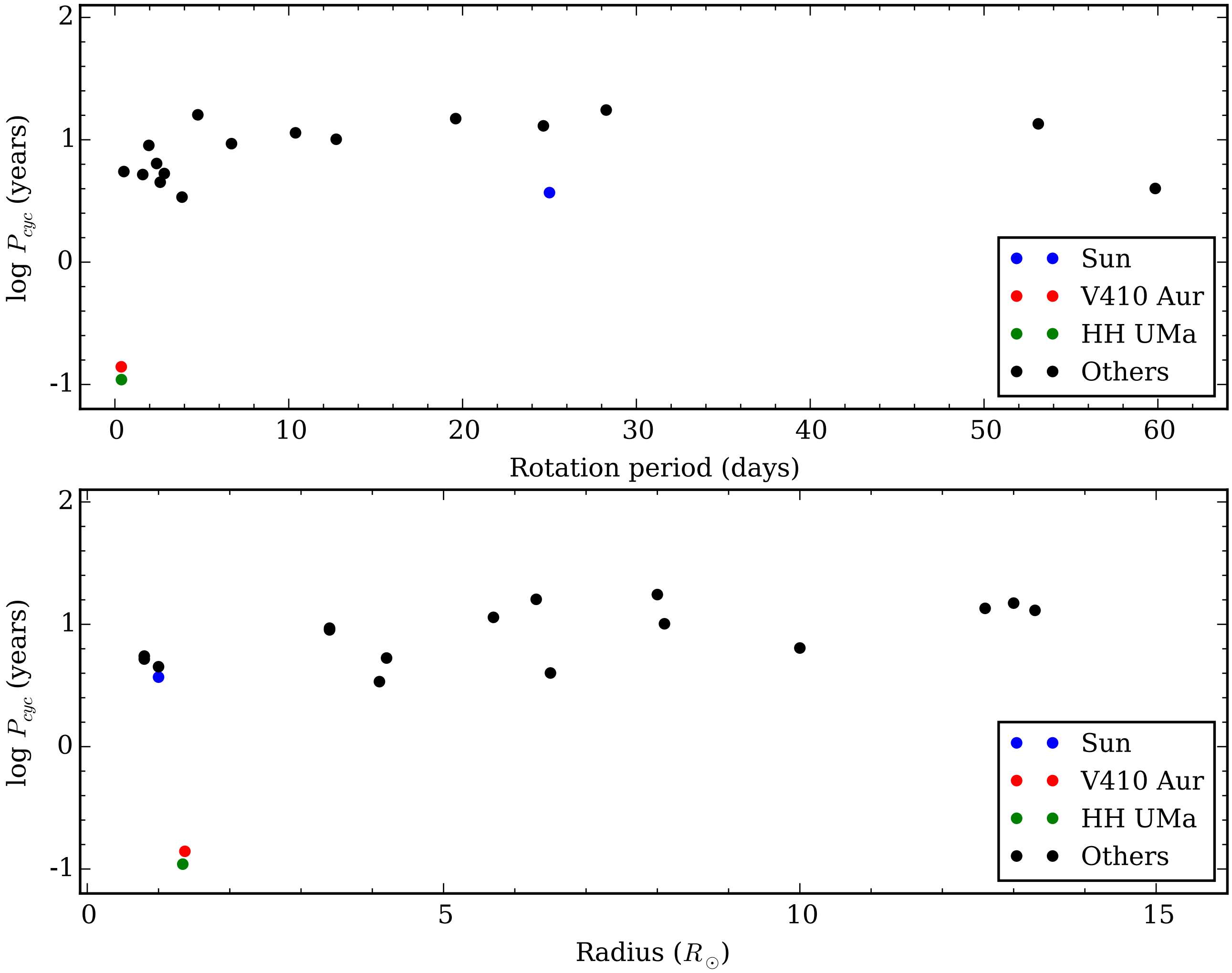

**Figure 4.** Stellar rotation period and radius plotted against the flip-flop cycle for previously known flip-flop stars and V410 Aur. Data were taken from Berdyugina (2005), Berdyugina & Henry (2007), Korhonen & Järvinen (2007), and Wang et al. (2015b).

Cas (Zhang & Zhang 2004) changed from positive to negative, and then back. Spots located at different active longitudes can result in the emergence of light-curve distortions at the corresponding phases, indicating that these peculiar light-curve features are probably caused by the presence of two persistent active longitudes and the flipping between them. Wang et al. (2015b) successfully synthesized three sets of HH UMa light curves. This system's O'Connell effect changed twice over a surprisingly short time span of only 44 days, assuming that the flip-flop mechanism was responsible for this observation. Because all active W UMa systems referred to above can be interpreted by assuming the flip-flop scenario, it appears that the flip-flop phenomenon is not a rare pattern of stellar activity in W UMa-type binary systems. Naturally, the light-curve asymmetries and variations of W UMa systems may be attributed to this phenomenon.

Owing to the short time baseline and duty cycle of the current observing runs, the photometric data set of V410 Aur is not sufficient to provide a precise flip-flop cycle period. However, based on the two changes in the brightness difference between the light minima, a rough estimate of 50 days can be inferred as an upper limit. This is almost the same as that for HH UMa, but it is shorter by orders of magnitude than those for other stars, whose timescales range from years to decades (Berdyugina & Tuominen 1998; Korhonen et al. 2002; Berdyugina & Järvinen 2005; Berdyugina & Henry 2007). In Figure 4, we plot V410 Aur and other stars with known flip-flop phenomenon on the same diagrams in the form of flip-flop period versus rotational period and stellar radius. V410 Aur and HH UMa have a very different flip-flop timescale from those of previously observed systems (Figure 4), yet the plots seem too sparsely populated to derive more detailed conclusions. In general, V410 is one of the most interesting W UMa-type systems. It deserves acquisition of more high-precision spectroscopy and photometry to verify the present results and reveal the true nature of this system.

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