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RT Leonis Minoris: an Unstable W Ursae Majoris System with a Spotted Component *

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Abstract Complete BV light curves of the W UMa type binary RT LMi are presented. From the observations, four times of minimum light were determined. Based on the new times of minimum light and those collected from the literature, changes in the orbital period of the system were found and analyzed with Kalimeris et al.'s method. The result shows that the orbital period possibly oscillates with a cycle of about 64 years and an amplitude of 1.2×10^{-6} days. The present CCD photometric observations reveal that the light curves are obviously asymmetrical, and show a positive O'Connell effect, while the light curves obtained in 1982 exhibit a negative O'Connell effect. The present light curves were analyzed by means of the latest version of the Wilson-Devinney code, which was also used to correct the photometric effects, including the distortion on the radial-velocity curves obtained by Rucinski et al. The following absolute dimensions have been derived: $M_1 = 1.28 \pm 0.08\ M_\odot$, $M_2 = 0.48 \pm 0.06\ M_\odot$, $R_1 = 1.28 \pm 0.06\ R_\odot$, $R_2 = 0.83 \pm 0.05\ R_\odot$, $L_1 = 1.88 \pm 0.12\ L_\odot$, $L_2 = 0.77 \pm 0.08\ L_\odot$, and $A = 2.64 \pm 0.02\ R_\odot$. The asymmetry of the light curves can be explained by a model with a cool spot on the secondary component. The orbital period modulation can be reproduced by a magnetic activity cycle model of the secondary component with $\Delta J = 5.6 \times 10^{46}$ g cm^2 s^{-1}, $\Delta\Omega/\Omega = 8.8 \times 10^{-4}$, and $B = 5.1 \times 10^3$ G.

Key words: star: contact binary — star: individuals: RT LMi – star: magnetic activity

1 INTRODUCTION

The variable RT LMi was discovered by Hoffmeister (1949) as Sonneberg variable No.4759. The 4th edition of the GCVS listed RT LMi as a W UMa-type eclipsing binary. Meinunger (1961) estimated a preliminary period of 0.374 days from observations since 1936. The first light ephemeris was derived by Hoffmann & Meinunger (1983) from two photoelectric minima

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and 72 photographic ones over the years 1957–1982. After 1982, some photoelectric epochs of light minimum were published by Hoffmann (1983) and Agerer & Hübscher (1996, 1997, 1999), but no changes in period could be recognized. Only photoelectric light curves in the BV bands were published by Hoffmann (1984). Niarchos et al. (1994) analyzed Hoffmann's (1984) observations with the Wilson-Devinney code and found that RT LMi is a W-type system with spotted components. A radial velocity curve and spectroscopic orbital elements of the system were published by Rucinski et al.(2000).

In order to investigate the stability in light curves and the orbital period change of the system, RT LMi was included in a program of observations of short period variables using the 100-cm Reflecting Telescope of the Yunnan Observatory, equipped with a CCD photometric system.

2 OBSERVATION

The observations in B and V bands for RT LMi were carried out on March 1, 2 and 3, 2003, with the PI1024 TKB CCD photometric system attached to the 100-cm Reflecting Telescope at the Yunnan Observatory. The effective field of view of the photometric system is 6.5 square arc minutes at the Cassegrain focus and the size of each pixel is 0.38 arcsec. The BV color system approximates the standard Johnson's BV photometric system (Yang & Li 1999). The comparison and check stars used are so close to the variable that they are in the same field of observation. The coordinates of the variable, comparison and check star are given in Table 1.

Table 1 Coordinates of the Variable, Comparison and Check Stars

Star	R. A. (2000.0)	Dec. (2000.0)	mag (V)
Variable	$09^h50^m00^s$	$34°26'\ 23''$	11.4–12.0
Comparison	$09^h50^m02^s$	$34°24'\ 12''$	12.8
Check	$09^h50^m24^s$	$34°24'\ 05''$	13.7

The integration time for each image was 200 seconds. A total of 137 images in V and 139 images in B were obtained on three nights. The aperture photometry package of the IRAF was used to reduce the images. The reduced results show that the difference between the magnitude of the check star and that of the comparison star is constant within a standard error of ± 0.008 magnitude in V and ± 0.009 magnitude in B. Extinction correction was not made as the comparison star is very close to the variable so that the range of air-mass difference between them is very small (maximum value of 0.0007) during the observations.

From the observations, two primary and two secondary times of minimum light were derived by parabolic fitting. The new times of minimum light together with those collected from the references are listed in Table 2, in which the $O-C$ values are calculated by means of the improved light elements, namely,

$$\text{Min.I} = \text{HJD}2452702.2869(3) + 0.^{\text{d}}37491717(4)E. \quad (1)$$

This ephemeris was used to compute the phases of present observations. The $O-C$ values against the cycles are plotted in Fig. 1. This diagram shows that the orbital period of RT LMi may be changing in a cyclical way.

Table 2 Times of Minimum Light of RT LMi

HJD 2400000+	way	E	$O-C$	References
35868.477	ph	−44900	−0.0290	Hoffmann & Meinunger (1983)
44988.3555	pe	−20575	−0.0106	Hoffmann (1983)
45002.4147	pe	−20537.5	−0.0108	Hoffmann (1983)
49786.3694	pe	−7777.5	0.0008	Agerer & Hübscher (1996)
49788.4303	pe	−7772	−0.0004	Agerer & Hübscher (1996)
49796.3028	pe	−7751	−0.0011	Agerer & Hübscher (1996)
50080.6786	pe	−6992.5	0.0000	Agerer & Hübscher (1996)
50154.3495	pe	−6796	−0.0003	Agerer & Hübscher (1997)
50898.3730	pe	−4811.5	0.0001	Agerer & Hübscher (1999)
52700.2250	pe	−5.5	0.0001	this paper
52701.1620	pe	−3	−0.0001	this paper
52702.0994	pe	−0.5	−0.0000	this paper
52702.2868	pe	0	−0.0001	this paper

pe: photoelectric method;
ph: a mean epoch from 72 photographic minima between JD 2435868.483 and JD 2445002.4147.

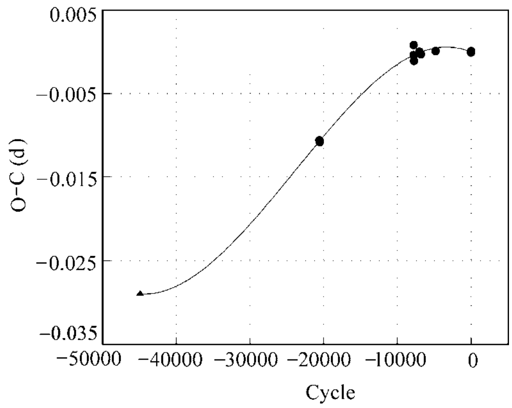

Fig. 1 $O-C$ diagram of the period change in RT LMi. The filled circles are the photoelectric minima; the triangle represents an epoch obtained from 72 photographic times of minimum light; the curve is fitted to the observations.

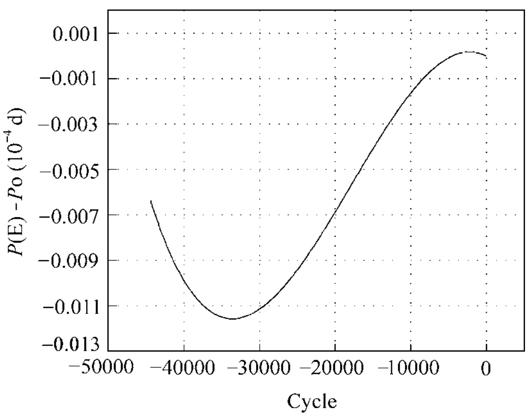

Fig. 2 $P(E)-P_0$ as a function of time.

Table 3 CCD Observations in V Band for RT LMi

HJD 2452700+	Δm	HJD 2452700+	Δm	HJD 2452700+	Δm	HJD 2452700+	Δm	HJD 2452700+	Δm
0.1209	−1.839	0.2892	−1.789	1.2094	−1.686	2.0443	−1.726	2.1995	−1.829
0.1317	−1.863	0.2947	−1.808	1.2150	−1.716	2.0497	−1.693	2.2049	−1.821
0.1378	−1.848	0.3004	−1.829	1.2208	−1.760	2.0552	−1.654	2.2109	−1.801
0.1433	-1.851	0.3060	-1.830	1.2265	-1.780	2.0607	−1.610	2.2163	-1.798
0.1490	−1.826	0.3116	−1.843	1.2336	−1.800	2.0662	−1.569	2.2222	-1.777
0.1545	−1.820	0.3172	−1.847	1.2393	−1.829	2.0718	−1.502	2.2280	−1.738
0.1602	−1.791	0.3229	−1.836	1.2469	−1.822	2.0772	−1.420	2.2341	−1.710
0.1657	−1.767	0.3344	−1.809	1.2525	−1.846	2.0829	−1.348	2.2402	−1.677
0.1712	−1.742	0.3461	−1.773	1.2578	−1.844	2.0883	−1.267	2.2478	−1.623
0.1767	−1.703	0.3519	−1.750	1.2632	−1.844	2.0937	−1.247	2.2532	−1.568
0.1822	−1.681	0.3575	−1.718	1.2689	−1.826	2.0991	−1.243	2.2586	−1.536
0.1877	−1.633	0.3630	−1.673	1.2743	−1.808	2.1046	−1.249	2.2641	−1.434
0.1935	−1.576	0.3688	−1.648	1.2800	−1.804	2.1100	−1.258	2.2697	−1.348
0.1992	−1.490	0.3754	−1.593	1.2855	−1.771	2.1154	−1.319	2.2754	−1.264
0.2047	−1.416	0.3809	−1.570	1.2909	−1.758	2.1210	−1.400	2.2808	−1.224
0.2102	−1.339	1.1259	−1.862	1.2964	−1.716	2.1265	−1.494	2.2864	−1.221
0.2157	−1.276	1.1430	−1.378	1.3021	−1.683	2.1319	−1.557	2.2922	−1.231
0.2212	−1.261	1.1485	−1.286	1.3078	−1.644	2.1373	−1.619	2.2976	−1.255
0.2256	−1.265	1.1543	−1.220	1.3139	−1.611	2.1427	−1.654	2.3037	−1.349
0.2367	−1.286	1.1600	−1.208	1.3196	−1.542	2.1482	−1.699	2.3091	−1.436
0.2423	−1.369	1.1656	−1.209	1.3255	−1.465	2.1542	−1.725	2.3145	−1.514
0.2482	−1.452	1.1710	−1.231	1.3315	−1.371	2.1604	−1.752	2.3202	−1.579
0.2555	−1.560	1.1766	−1.299	1.3371	−1.294	2.1658	−1.772	2.3258	−1.634
0.2615	−1.613	1.1823	−1.394	1.3427	−1.231	2.1712	−1.798	2.3313	−1.683
0.2669	−1.672	1.1877	−1.505	1.3485	−1.249	2.1766	−1.809	2.3369	−1.714
0.2725	−1.710	1.1931	−1.543	2.0260	−1.825	2.1824	−1.820		
0.2781	−1.745	1.1985	−1.601	2.0330	−1.800	2.1879	−1.835		
0.2835	−1.754	1.2038	−1.649	2.0388	−1.750	2.1941	−1.831		

With the method of Kalimeris et al. (1994), the $O-C$ curve was analyzed and described by higher order least squares polynomials with different weights according to the quality of the data point. The same weight was used for both the photoelectric and photographic minima, since the photographic epoch of minimum light was the mean value from 72 photographic minima over the years 1957–1982 (Hoffmann & Meinunger 1983). We found that a single polynomial of third order fitted the observed times of minimum light well (solid line in Fig. 1). The semi-amplitude of the curve in the $O-C$ diagram is 0.0148 days and the modulation period is about 64 years. Using the equations given by Kalimeris et al. (1994), we calculated the real period $P(E)$. The result is shown in Fig. 2, in which we plot the difference between the real period $P(E)$ and the ephemeris period P_o in units of 10^{-4} days. As plotted in Fig. 2, the orbital period of RT LMi shows a wave-like variation. It can be inferred that the change in the orbital period of RT LMi has a periodicity of about 64 years and an amplitude of $\Delta P = 1.2 \times 10^{-6}$ days.

As mentioned previously, 137 individual observations in the V band and 139 individual observations in the B band were secured. The magnitude differences in the sense of the variable minus the comparison star together with their heliocentric Julian dates are listed in Table 3 for V and Table 4 for B. The light curves are shown by the filled circles in Fig. 3. They appear to exhibit a typical O'Connell effect, with Maximum I being brighter than Maximum II by 0.014 mag for V and 0.017 mag for B. This asymmetry is common in many W UMa binaries. In order to investigate variations in the shape of the light curve, the characteristic parameters of the light curves obtained in this paper and Hoffmann (1984) are listed in Table 5. The data show that the shape of the light curve of RT LMi may be unstable. The light curves obtained by Hoffmann (1984) in 1982 appear to exhibit a negative O'Connell effect (Max.I is fainter than Max.II), while the present light curves show a positive O'Connell effect (Max.I is brighter than Max.II). In addition, the difference between the depths of the primary and secondary eclipses is also variable.

Table 4 CCD observations of RT LMi in the B band

HJD 2452700+	Δm	HJD 2452700+	Δm	HJD 2452700+	Δm	HJD 2452700+	Δm	HJD 2452700+	Δm
0.1230	−2.197	0.2864	−2.102	1.2011	−1.986	2.0360	−2.116	2.1905	−2.182
0.1287	−2.206	0.2920	−2.136	1.2067	−2.038	2.0415	−2.084	2.1968	−2.180
0.1347	−2.201	0.2975	−2.153	1.2122	−2.080	2.0469	−2.053	2.2022	−2.198
0.1405	−2.212	0.3032	−2.155	1.2176	−2.096	2.0524	−2.011	2.2082	−2.181
0.1462	−2.190	0.3088	−2.159	1.2235	−2.130	2.0579	−1.995	2.2136	−2.163
0.1517	−2.165	0.3144	−2.197	1.2309	−2.164	2.0634	−1.943	2.2194	−2.151
0.1573	−2.145	0.3200	−2.176	1.2362	−2.197	2.0688	−1.901	2.2249	−2.123
0.1630	−2.139	0.3257	−2.160	1.2420	−2.195	2.0745	−1.808	2.2307	−2.097
0.1684	−2.101	0.3315	−2.165	1.2498	−2.205	2.0799	−1.734	2.2369	−2.062
0.1739	−2.085	0.3372	−2.170	1.2551	−2.209	2.0856	−1.659	2.2429	−2.003
0.1794	−2.040	0.3430	−2.124	1.2605	−2.187	2.0910	−1.621	2.2505	−1.963
0.1850	−1.996	0.3490	−2.111	1.2661	−2.192	2.0964	−1.605	2.2559	−1.895
0.1905	−1.945	0.3547	−2.070	1.2716	−2.176	2.1017	−1.595	2.2614	−1.779
0.1964	−1.879	0.3603	−2.047	1.2770	−2.165	2.1072	−1.599	2.2668	−1.738
0.2019	−1.788	0.3658	−2.019	1.2828	−2.135	2.1127	−1.634	2.2724	−1.641
0.2074	−1.710	0.3716	−1.906	1.2882	−2.123	2.1180	−1.729	2.2781	−1.573
0.2129	−1.632	0.3782	−1.926	1.2937	−2.093	2.1237	−1.820	2.2834	−1.551
0.2184	−1.593	0.3837	−1.857	1.2991	−2.073	2.1292	−1.884	2.2894	−1.548
0.2305	−1.586	1.1458	−1.670	1.3050	−2.046	2.1346	−1.933	2.2949	−1.592
0.2340	−1.582	1.1513	−1.600	1.3108	−1.981	2.1400	−1.986	2.3005	−1.659
0.2395	−1.641	1.1570	−1.550	1.3166	−1.902	2.1454	−2.050	2.3063	−1.759
0.2451	−1.734	1.1626	−1.550	1.3226	−1.863	2.1509	−2.064	2.3118	−1.827
0.2528	−1.845	1.1683	−1.559	1.3283	−1.765	2.1570	−2.096	2.3172	−1.911
0.2586	−1.929	1.1739	−1.614	1.3343	−1.676	2.1630	−2.119	2.3230	−1.947
0.2642	−1.973	1.1793	−1.701	1.3399	−1.621	2.1684	−2.148	2.3286	−2.016
0.2697	−2.023	1.1849	−1.795	1.3455	−1.585	2.1739	−2.167	2.3341	−2.056
0.2753	−2.060	1.1904	−1.867	1.3515	−1.595	2.1796	−2.157	2.3398	−2.073
0.2808	−2.072	1.1958	−1.943	2.0297	−2.154	2.1851	−2.192		

Table 5 Characteristic Parameters of the Light Curves of RT LMi

Observer (Date)	Hoffmann (1982)		Yang & Liu (2003)	
Color	V	B	V	B
Max.I − Min.I	−0.613	−0.664	−0.637	−0.677
Max.I − Min.II	−0.540	−0.639	−0.594	−0.619
Max.II − Min.I	−0.628	−0.681	−0.623	−0.660
Max.II − Min.II	−0.555	−0.656	−0.580	−0.602
Max.II − Max.I	−0.015	−0.017	0.014	0.017
Min.I − Min.II	0.073	0.025	0.043	0.058

3 ROCHE MODEL SOLUTION

Photometric and spectroscopic solutions were obtained by means of the WD program which includes the new reflection treatment, the options to use non-linear limb-darkening laws and to adjust spot parameters. In the photometric solution, all the present observations were used and several parameters were fixed as follows: a temperature of 6000 K for star 1, which corresponds to a spectral type G0V (Götz & Wenzel 1961); Claret & Gimenez's (1990) values of the limb darkening coefficient ($x_1 = x_2 = 0.620$ for V band and 0.750 for B band); Lucy's (1967) values of the gravity darkening coefficient ($g_1 = g_2 = 0.320$); and Rucinski's (1969) values of the albedo ($A_1 = A_2 = 0.500$). The adjustable parameters are the orbital inclination i; the mean temperature of star 2 T_2; the potential of the components Ω_1 and Ω_2; the monochromatic luminosity of star 1 L_1 (the Planck function was used to compute the luminosity); the phase shift ϕ_0; and third light l_3. The convergence of the minimization procedure was obtained by means of the method of multiple subsets (Wilson & Biermann 1976). In the radial-velocity solution, DDO observations of RT LMi obtained by Rucinski, Lu & Mochnacki (2000) were used and the phases of the radial-velocity curves were re-computed with the ephemeris (1). The adjustable parameters are the separation between the two components, A; the mass ratio, q, and the radial-velocity of the mass centre of the system, V_o.

Table 6 Roche Model Solution of RT LMi

Parameters	Photometric sol.	Spectroscopic sol.
$A(R_\odot)$	–	2.642 ± 0.020
ϕ_0	0.0006 ± 0.0002	0.0008 ± 0.0003
V_o (km s^{-1})	–	-10.1 ± 1.3
$q(m_2/m_1)$	0.376	0.376 ± 0.007
i (°)	83.7 ± 0.3	83.7
$g_1 = g_2$	0.32*	0.32*
$A_1 = A_2$	0.50*	0.50*
$X_{1v} = X_{2v}$	0.61*	0.68*
$X_{1B} = X_{2B}$	0.74*	
$\Omega_1 = \Omega_2$	2.5628 ± 0.0022	2.5628
f	0.28	
T_1 (k)	6000*	6000*
T_2 (k)	5972 ± 6	5972*
$L_2/(L_1 + L_2)V$	0.3005 ± 0.0009	
$L_2/(L_1 + L_2)B$	0.3017 ± 0.0011	
r_1(pole)	0.4504 ± 0.0004	
r_1(side)	0.4847 ± 0.0006	
r_1(back)	0.5159 ± 0.0008	
r_2(pole)	0.2910 ± 0.0005	
r_2(side)	0.3053 ± 0.0007	
r_2(back)	0.3488 ± 0.0010	
Σ	0.00632	0.00243

* values assumed.

The Wilson-Devinney code was used in contact mode 3 as the contact configuration of RT LMi is known (Niarchos et al. 1994). To avoid the difficulty of assigning relative weights to the light and velocity measurements, the two kinds of observations were not analyzed simultaneously. First, a solution was carried out for the B and V light curves together to obtain the photometric elements, with the mass-ratio fixed at the value derived by Rucinski, Lu & Mochnacki (2000) from the radial-velocity curves. When the solution converged, the same model was used to solve the velocity curves for the spectroscopic elements, with the physical quantities fixed at the values just obtained in the photometric solution, to derive a new spectroscopic mass ratio. The next step was to solve the light curves once again, with the mass ratio fixed at this new value. The final step was to make one more solution of the velocity curves, with the parameters fixed at the values obtained in the final photometric solution. In this way (after 12 iterations to acquire a convergent result), the photometric solution and spectroscopic orbital elements, corrected for the photometric effects of reflection, and tidal and rotational distortion, were obtained. The results are given in Table 6, in which ϕ_0 denotes the phase shift and the other symbols have their usual meaning. In the final photometric solution, the third light was found to be a very small negative value, which indicates that there is no third light in the system. The observed and computed light curves are compared in Fig. 3. The radial-velocity curves computed from the Roche model are shown in Fig. 4.

However, although the overall fit of the computed light curves to the observations is quite satisfactory, Fig. 3 shows an obvious distortion in the observed light curves, which seems to be due to surface inhomogeneities on the components. Unequal quadrature light level, known as the O'Connell effect, is known in many eclipsing binaries and several suggestions have been made by various authors to explain this effect. For RT LMi, the observed distortion, with Maximum II being fainter than Maximum I, may result from a cool region or a hot region on either component. We tried assuming one more dark or hot spots either on star 1 or on star 2, and we found that a hot spot or hot spots could not give a convergent solution, but that the best fit to the observed light curves was given by one dark spot on star 2 (the secondary). The parameters of the dark spot are: co-latitude $\phi = 104.7$, longitude $\theta = 253.2$, angular radius $\gamma = 16.06$, (all in degrees), and temperature factor $T_s/T_* = 0.81$ (see Fig. 5).

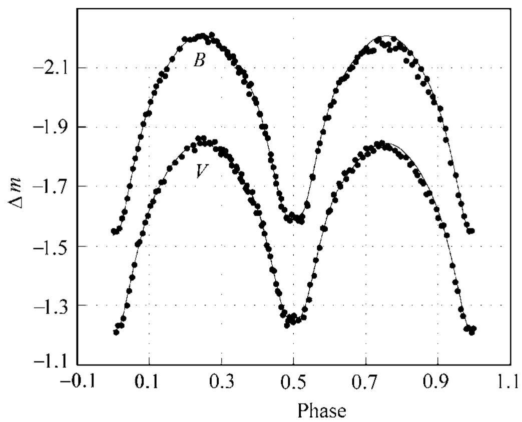

Fig. 3 Light curves of RT LMi. The dots indicate the observational data and the curves correspond to the computed light curves with the solution listed in Table 6.

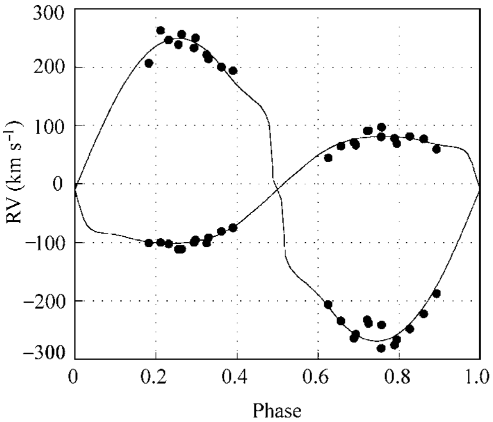

Fig. 4 Radial-velocity curves of RT LMi. Solid curves are computed from the Roche model and filled circles are the observational data.

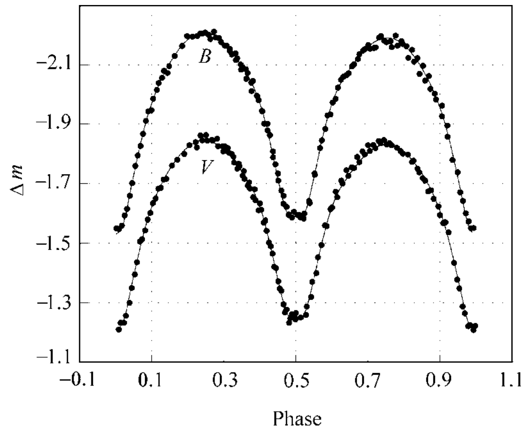

Fig. 5 As Fig. 3, but the lines were derived from the model with a dark spot on the secondary component.

Table 7 Orbital Period Modulation Parameters of Close Binaries

Star name	$\Delta P/P$	$P_{\rm mod}$ (yr)	ΔJ(g cm^2 s^{-1})	$\Delta\Omega_{\rm out}/\Omega_s$	B (kG)
Algol	1.6×10^{-5}	32	2.8×10^{48}	14×10^{-3}	5.5
SS Com	3.0×10^{-5}	55	1.32×10^{49}	12×10^{-3}	3.5
SV Cam	3.0×10^{-6}	82	2.0×10^{47}	3.9×10^{-3}	9.0
V471 Tau	2.0×10^{-6}	20	1.0×10^{47}	3.2×10^{-3}	11
RS CVn	2.0×10^{-5}	68	2.4×10^{49}	36×10^{-3}	13
EQ Tau	2.5×10^{-6}	23	0.6×10^{47}	4.4×10^{-4}	9.2
CC Com	1.3×10^{-6}	16	1.4×10^{46}	3.6×10^{-4}	9.8
RW Com	2.3×10^{-6}	14	1.9×10^{46}	7.8×10^{-4}	13
RT LMi	3.1×10^{-6}	64	5.6×10^{46}	8.8×10^{-4}	5.1

4 DISCUSSION

From the results given in Table 6, the following set of basic parameters was found: $M_1 = 1.28(8)\ M_\odot$ and $M_2 = 0.48(6)\ M_\odot$, $R_1 = 1.28(6)\ R_\odot$, $R_2 = 0.83(5)\ R_\odot$, $L_1 = 1.88(12)\ L_\odot$ and $L_2 = 0.77(8)\ L_\odot$. The relative radius of each component is defined as the cube root of the product $r_{\rm pole}\times r_{\rm side}\times r_{\rm back}$. The luminosities were derived by adopting $T_{\rm eff\odot} = 5780\,$K.

The asymmetry and variation of the light curves of RT LMi suggest that magnetic activity may be occurring on its secondary component. The positive O'Connell effect of the present light curves can be explained by the model with a cool star spot on the secondary component, while the negative O'Connell effect of the light curves observed by Hoffmann (1984) was simulated by Niarchos et al. (1994) with a hot spot on the primary and two cool spots on the secondary.

It has been found that the orbital period of RT LMi may have changed in a cyclical way. In general, a sinusoidal variation in the period of an eclipsing binary can be explained in either of two ways: a light-time effect caused by a third body or a magnetic cycle mechanism. For RT

LMi, if there is a third body orbiting the system, then from the semi-amplitude in the $O-C$ diagram and the modulation period, a minimum mass of the third body can be estimated to be $M_3 = 0.27M_{\odot}$, and then the light from the third body should be included in the light curves of the system. In fact, no third light was found in the analysis of the light curves. This suggests that the wave-like change in the period may not have resulted from a third body.

We now propose another explanation for the variation. According to Matese & Whitmire (1983), Applegate & Patterson (1987), Hall (1990), Applegate (1992) , and Lanza et al. (1998), a quasi-period change of orbital periods in binaries containing a convective star may be a consequence of possible magnetic activity cycles. According to their model, as the star goes through its magnetic activity cycle, a certain amount of angular momentum is periodically exchanged between the inner and outer parts of the convection zone, and therefore the rotational oblateness of the star will also change. This change of rotational oblateness will be transferred to the orbital movement by gravity and therefore the period will change. For RT LMi, according to the $P(E)$ function, the value ΔP of the amplitude of the orbital period modulation is 1.2×10^{-6} days, while the periodicity of the modulation is $P_{\rm mod} = 64$ years. We consider the secondary component is capable of supporting a magnetic activity cycle model, since it is a late-type star with a small mass. In order to reproduce the orbital period change $\Delta P = 1.2 \times 10^{-6}$ days, the required angular momentum transfer is $\Delta J = 5.6 \times 10^{46}$ g cm^2 s^{-1}. The modulation period of $P_{\rm mod} = 64$ years implies a variable differential rotation of $\Delta\Omega/\Omega = 8.8 \times 10^{-4}$, where Ω is the rotation angular velocity of the secondary component and $\Delta\Omega$ is the increase of the angular velocity of the shell due to the transfer of ΔJ to the outer shell. If the period change is caused by the action of a magnetic activity cycle in the secondary component, the needed mean subsurface magnetic field will be 5.1×10^3 G. These results, together with those for Algol, SS Com, SV Cam, V471 Tau, and RS CVn studied by Applegate (1992), EQ Tau (Yang & Liu 2002), CC Com and RW Com (Yang & Liu 2003), are listed in Table 7. Comparing with the other systems listed, it seems probable that the orbital period modulation in RT LMi is caused by a magnetic activity cycle mechanism such as suggested by Applegate (1992).

The analysis shows that the orbital period of RT LMi reached a minimum in 1967 and a maximum in 1999. Hoffmann's observations in 1982 were in the increasing part of the orbital period change and his light curves showed a negative O'Connell effect. The present observations in 2003 were in the decreasing part and our light curves showed a positive O'Connell effect. This phenomenon is very interesting. We hope to investigate the relation between the phenomenon and the magnetic cycle further when more data become available.

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