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A Photometric Study of the Near Contact Binary UU Lyncis *

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Abstract The near-contact binary UU Lyn with an F3V-type primary was observed in 2005 and 2006. With the latest version of the Wilson-Devinney code, the photometric elements were computed. The results reveal that UU Lyn is a marginal contact system with a large temperature difference of about 1900 K between the primary and secondary components. All available eclipse times, including new ones, were used in the analysis. The results show that the orbital period of this system undergoes a continuous decrease at a rate of $dP/dt = -1.84 \times 10^{-8}\,\mathrm{d\,yr^{-1}}$. With the period decrease, UU Lyn may evolve from the present short-period marginal contact system into a contact system with true thermal contact. This target might just be undergoing the cycles predicted by the theory of thermal relaxation oscillations (TRO). It is an interesting example resembling BL And, GW Tau, ZZ Aur, KQ Gem, CN And and AD Cnc, that lie in the key evolutionary stage.

Key words: techniques: photometric — binaries: eclipsing — stars: individual: UU Lyncis

1 INTRODUCTION

Light variation in the eclipsing binary system UU Lyn was discovered by Geyer et al. (1955). In 1963, Strohmeier et al. obtained a complete photographic light curve and derived its period of 0.468461 days. The spectral type of this system was determined to be A4 by Götz & Wenzel (1962). However, when Yamasaki et al. (1983) published its first photometric light curves and radial velocity curve, it was suggested that its spectral type should be F3V. With a modern method of light-curve synthesis of Yamasaki (1981), they found that the components of UU Lyn are nearly filling their critical Roche lobes. A long-term period decrease at the rate of $dP/dt = -1.01 \times 10^{-7}\,\mathrm{d\,yr^{-1}}$ for this system was suggested by Qian (2002). Since that, some new photoelectric and CCD epochs of minimum light were published, which can be used to further period analysis.

In this paper, combining the light curve analysis with the period study, we investigate this short-period close binary system and discuss the possible structure and evolutionary state of this system.

2 PHOTOMETRIC OBSERVATIONS

UU Lyn (α_{2000}=09:15:31, δ_{2000}=42:42.2) was observed on 2005 April 1, 13, 15, May 4, and 2006 Mar 2, with the PI1024 TKB CCD photometric system attached to the 1.0-meter Cassegrain reflecting telescope at the Yunnan Observatory, China. Its effective field of view at the Cassegrain focus is about 6.5×6.5 square arc min. The integration time for each image was 150 s, and an R filter close to Johnson UBVRI

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system was used (Yang & Li 1999). The image reductions were done with the IRAF package, and the observed data are listed in Table 1 and plotted in Figure 1. Comparison star N2331230381 (α_{2000}=09:15:44.8, δ_{2000}=42:43:15.8) and check star N2331222476 (α_{2000}=09:15:36.4, δ_{2000}=42:38:41.1) were chosen from the same field as the target. As shown in Figure 1, this system exhibits a typical β Lyr type light variation and undergoes total eclipse.

Table 1 R-band CCD Observations of UU Lyn

JD (Hel.) +2453000	$\Delta(m)$	JD (Hel.) +2453000	$\Delta(m)$	JD(Hel.) +2453000	$\Delta(m)$	JD (Hel.) +2453000	$\Delta(m)$	JD (Hel.) +2453000	$\Delta(m)$	JD (Hel.) +2453000	$\Delta(m)$
462.0141	–1.580	462.0207	–1.547	462.0704	–1.514	462.0800	–1.484	462.0866	–1.425	462.0932	–1.390
462.0998	–1.390	462.1063	–1.374	462.1129	–1.358	462.1195	–1.353	462.1261	–1.344	462.1328	–1.365
462.1394	–1.400	474.0156	–1.447	474.0201	–1.436	474.0244	–1.387	474.0287	–1.330	474.0330	–1.302
474.0373	–1.234	474.0417	–1.172	474.0461	–1.101	474.0505	–1.027	474.0548	–0.993	474.0592	–0.997
474.0635	–0.973	474.0678	–0.961	474.0721	–0.977	474.0765	–0.990	474.0808	–0.985	474.0852	–1.074
474.0896	–1.146	474.0939	–1.179	474.0982	–1.252	474.1026	–1.287	474.1068	–1.353	474.1111	–1.403
474.1155	–1.413	474.1198	–1.427	474.1241	–1.506	474.1284	–1.464	474.1328	–1.517	476.0126	–1.527
476.0169	–1.560	476.0212	–1.550	476.0255	–1.568	476.0299	–1.571	476.0342	–1.589	476.0386	–1.574
476.0429	–1.583	476.0472	–1.588	476.0515	–1.592	476.0558	–1.594	476.0602	–1.590	476.0648	–1.602
476.0691	–1.595	476.0735	–1.584	476.0778	–1.605	476.0822	–1.576	476.0866	–1.583	476.0910	–1.553
476.0953	–1.540	476.0997	–1.561	476.1041	–1.542	476.1085	–1.504	476.1129	–1.558	476.1173	–1.527
476.1218	–1.507	476.1262	–1.467	476.1306	–1.502	476.1350	–1.471	476.1395	–1.420	476.1440	–1.421
476.1488	–1.394	476.1533	–1.346	476.1577	–1.389	476.1621	–1.395	476.1666	–1.371	476.1711	–1.387
476.1756	–1.379	476.1801	–1.368	476.1847	–1.351	476.1891	–1.355	476.1937	–1.332	476.1982	–1.375
476.2032	–1.354	476.2077	–1.413	476.2124	–1.455	476.2169	–1.458	476.2214	–1.456	495.0171	–1.571
495.0215	–1.598	495.0258	–1.596	495.0301	–1.594	495.0346	–1.583	495.0390	–1.583	495.0434	–1.585
495.0478	–1.574	495.0522	–1.574	495.0565	–1.568	495.0609	–1.567	495.0655	–1.548	495.0699	–1.551
495.0745	–1.525	495.0790	–1.518	495.0834	–1.503	495.0879	–1.486	495.0924	–1.472	797.0162	–1.543
797.0219	–1.509	797.0278	–1.500	797.0338	–1.508	797.0392	–1.468	797.0447	–1.471	797.0502	–1.410
797.0557	–1.398	797.0611	–1.373	797.0666	–1.405	797.0721	–1.399	797.0776	–1.376	797.0831	–1.377
797.0886	–1.382	797.0941	–1.413	797.0995	–1.442	797.1050	–1.429	797.1105	–1.494	797.1160	–1.484
797.1215	–1.511	797.1270	–1.516	797.1326	–1.530	797.1381	–1.570	797.1437	–1.561	797.1512	–1.589
797.1567	–1.575	797.1622	–1.606	797.1678	–1.613	797.1734	–1.594	797.1789	–1.594	797.1844	–1.597
797.1899	–1.605	797.1954	–1.615								

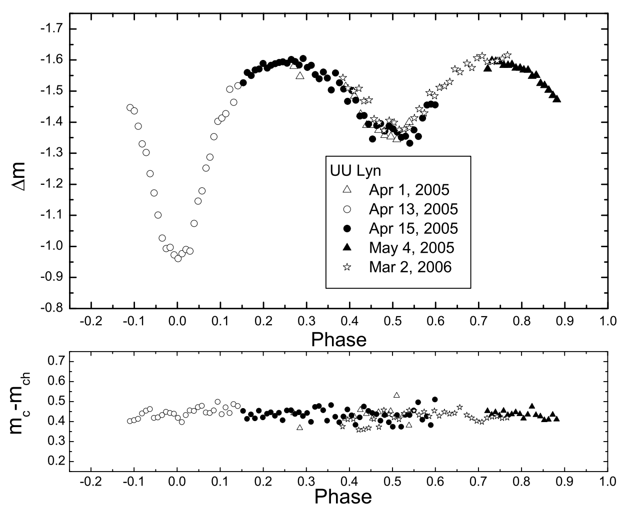

Fig. 1 Observed light curve of UU Lyn. Photometric phase is calculated from the ephemeris HJD 2453474.0674 + 0.468460154E. The lower panel shows the magnitude differences between the comparison and check stars.

3 ORBITAL PERIOD VARIATIONS

Kreiner et al. (2000) compiled 92 times of light minimum of UU Lyn. With our new ones, all available minima are listed in Table 2. Using the linear ephemeris given by Kreiner et al. (2000),

$$\mathrm{Min.I} = \mathrm{HJD}2425687.361 + 0.468460154 \times E, \quad (1)$$

we compute the $O - C$ values for these times and plot them in Figure 2. We discarded one photographic time of light minimum (2429195.656) because it deviated greatly from the general $(O - C)$ trend defined by the other points. We assigned weight 1 to photographic and visual observations, 10 to photoelectric and CCD observations. Then, with the least-square method, the following second-order ephemeris was obtained

$$\begin{aligned}\mathrm{Min.I} \; = \; & \mathrm{HJD}2453474.0620(7) + 0.468460795(5) \times E \\ & -1.178(\pm 0.009) \times 10^{-11} \times E^2. \end{aligned} \quad (2)$$

This ephemeris suggested a continuous secular decrease of the period at a rate of $dP/dt = -1.84 \times 10^{-8}\,\mathrm{d\,yr^{-1}}$. This revised value is smaller than the value ($dP/dt = -1.01 \times 10^{-7}\,\mathrm{d\,yr^{-1}}$) obtained by Qian (2002). Of course, the secular decrease may just be a part of a periodic variation with a longer period, but this needs further checking with more precise photometric minima.

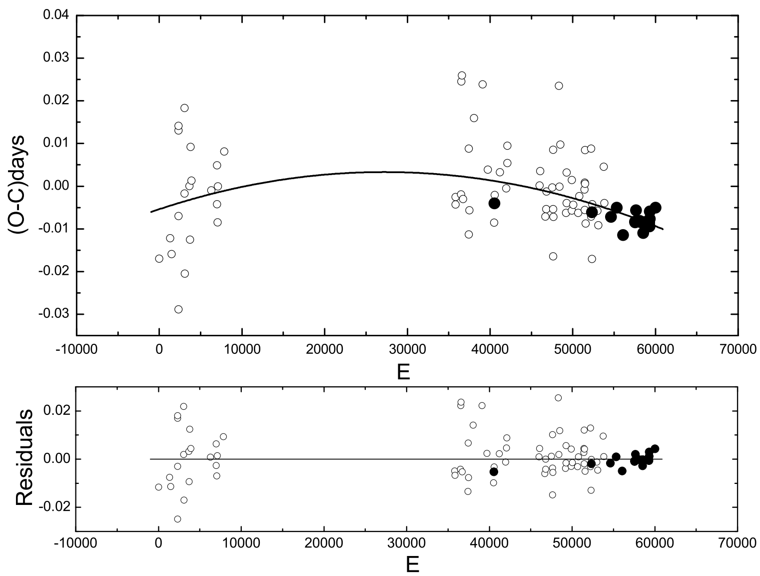

Fig. 2 $O - C$ diagram of UU Lyn constructed using the ephemeris (1). The solid line in the upper panel indicates the quadratic fit. The corresponding residuals are plotted in the bottom panel. Open circles represent epochs determined from photographic and visual observations, dots, from photoelectric and CCD observations.

4 PHOTOMETRIC SOLUTIONS

A complete R Band CCD light curve of UU Lyn including 140 points was analyzed with the latest Wilson-Van Hamme code (Wilson & Devinney 1971; Wilson 1979, 1990, 1994; Wilson & Van Hamme 2003). We assumed an effective temperature of $T_1 = 6\,700\,\mathrm{K}$ for the primary (the star eclipsed at primary minimum) according to its $B-V = 0.41$ (Yamasaki 1983). The gravity-darkening coefficients, g_1, g_2, and values of the bolometric albedo, A_1, A_2, were chosen corresponding to the convective envelopes. Bolometric and band-pass square-root limb-darkening parameters were taken from Van Hamme (1993) and are listed in Table 3. The adjustable parameters are: the inclination i, the mean temperature of star 2, T_2, the monochromatic luminosity of star 1, $L_{1\mathrm{R}}$, the dimensionless potentials of stars 1 and 2, Ω_1 and Ω_2.

To acquire a reliable mass ratio, q, the solutions for several assumed values (q=0.3, 0.35, 0.4, 0.45, 0.5, 0.6 and 0.7) were obtained. For each assumed q the calculation started at mode 2 (the detached mode). The sums of weighted square deviations $\Sigma W_i(O-C)_i^2$ for all assumed values of q are shown in Figure 3. The minimum value of Σ occurs at $q = 0.35$. Then, choosing $q = 0.35$ as the initial value and making q an adjustable parameter, we made differential corrections until convergence. The derived photometric

Table 2 Times of Light Minimum of UU Lyn

JD (Hel.) +2400000	Error	Min.	Meth.	E	$(O-C)$	Ref.	JD (Hel.) +2400000	Error	Min.	Meth.	E	$(O-C)$	Ref.
25687.344		I	p	0.0	–0.01700	(1)	48003.392		I	v	47637.0	–0.00536	(1)
26308.527		I	p	1326.0	–0.01216	(1)	48017.444		I	v	47667.0	–0.00716	(1)
26382.540		I	p	1484.0	–0.01587	(1)	48331.343		I	v	48337.5	0.02354	(1)
26769.497		I	p	2310.0	–0.00696	(1)	48359.427		I	v	48397.0	–0.00007	(1)
26769.517		I	p	2310.0	0.01304	(1)	48404.409	0.004	I	v	48493.0	0.00975	(1)
26770.412		I	p	2312.0	–0.02888	(1)	48739.342	0.005	I	v	49208.0	–0.00626	(1)
26770.455		I	p	2312.0	0.01412	(1)	48760.425	0.007	I	v	49253.0	–0.00396	(1)
27119.442		I	p	3057.0	–0.00169	(1)	48768.396	0.007	I	v	49270.0	0.00321	(1)
27119.462		I	p	3057.0	0.01831	(1)	49057.427	0.006	I	v	49887.0	–0.00570	(1)
27133.477		I	p	3087.0	–0.02050	(1)	49065.398	0.005	I	v	49904.0	0.00147	(1)
27398.646		I	p	3653.0	0.00006	(1)	49132.382	0.006	I	v	50047.0	–0.00433	(1)
27421.588		I	p	3702.0	–0.01249	(1)	49421.420	0.005	I	v	50664.0	–0.00624	(1)
27459.555		I	p	3783.0	0.00924	(1)	49473.423	0.006	I	v	50775.0	–0.00232	(1)
27513.420		I	p	3898.0	0.00132	(1)	49779.329	0.004	I	v	51428.0	–0.00080	(1)
28626.479		I	p	6274.0	–0.00101	(1)	49785.4206		I	v	51441.0	0.00082	(1)
28953.461		I	p	6972.0	–0.00419	(1)	49793.378	0.005	I	v	51458.0	–0.00560	(1)
28954.407		I	p	6974.0	0.00489	(1)	49800.419		I	v	51473.0	0.00849	(1)
28991.402		I	p	7053.0	–0.00847	(1)	49807.438		I	v	51488.0	0.00059	(1)
29014.365		I	p	7102.0	–0.00001	(1)	49844.437	0.005	I	v	51567.0	–0.00876	(1)
29159.656		I	p	7412.0	0.06834	(1)	50151.296	0.005	I	v	52222.0	0.00884	(1)
29363.376		I	p	7847.0	0.00817	(1)	50157.370		I	v	52235.0	–0.00714	(1)
42464.322		I	v	35813.0	–0.00250	(1)	50179.389	0.005	I	v	52282.0	–0.00577	(1)
42478.374		I	v	35843.0	–0.00430	(1)	50192.4946		I	v	52310.0	–0.01706	(1)
42782.407		I	v	36492.0	–0.00194	(1)	50194.3794	0.002	I	CCD	52314.0	–0.00610	(1)
42805.388		I	p	36541.5	0.02451	(1)	50209.372	0.005	I	v	52346.0	–0.00422	(1)
42828.344		I	p	36590.5	0.02597	(1)	50514.338	0.005	I	v	52997.0	–0.00578	(1)
42887.341		I	v	36716.0	–0.00301	(1)	50557.433	0.005	I	v	53089.0	–0.00912	(1)
43213.381		I	v	37412.0	–0.01128	(1)	50871.315	0.006	I	v	53759.0	0.00458	(1)
43220.428		I	v	37427.0	0.00882	(1)	50900.351	0.007	I	v	53821.0	–0.00395	(1)
43250.395		I	v	37491.0	–0.00563	(1)	51270.4313	0.0004	I	CCD	54611.0	–0.00717	(3)
43510.412		I	v	38046.0	0.01598	(1)	51596.4817	0.0026	I	CCD	55307.0	–0.00504	(1)
44008.393		I	v	39109.5	0.02384	(1)	51952.505	0.006	I	CCD	56067.0	–0.01145	(1)
44291.323		I	v	39713.0	0.00390	(1)	52644.8921	0.0003	I	CCD	57545.0	–0.00846	(4)
44662.331		I	v	40505.0	–0.00854	(1)	52644.8922	0.0001	I	CCD	57545.0	–0.00836	(5)
44674.0470		I	pe	40530.0	–0.00404	(2)	52646.2977		I	CCD	57548.0	–0.00824	(1)
44691.382		I	v	40567.0	–0.00207	(1)	52691.2725	0.0010	I	CCD	57644.0	–0.00562	(6)
44989.328		I	p	41203.0	0.00327	(1)	52901.6086	0.0002	I	pe	58093.0	–0.00813	(7)
45347.462		II	p	41967.5	–0.00051	(1)	52989.2103		I	CCD	58280.0	–0.00848	(1)
45402.512		I	p	42085.0	0.00542	(1)	53081.4970	0.0002	I	pe	58477.0	–0.00843	(8)
45406.498		II	p	42093.5	0.00951	(1)	53105.3859	0.0031	I	pe	58528.0	–0.01099	(7)
47239.339		I	v	46006.0	0.00016	(1)	53123.1899	0.0002	I	pe	58566.0	–0.00848	(9)
47267.450		I	v	46066.0	0.00355	(1)	53407.5450	0.0041	I	pe	59173.0	–0.00869	(8)
47565.380		I	p	46702.0	–0.00711	(1)	53439.8689	0.0001	I	CCD	59242.0	–0.00854	(10)
47609.417		I	v	46796.0	–0.00537	(1)	53462.3541	0.0048	I	pe	59290.0	–0.00943	(8)
47616.448		I	v	46811.0	–0.00127	(1)	53474.0674	0.0004	I	CCD	59315.0	–0.00763	(11)
47945.308		I	v	47513.0	–0.00030	(1)	53476.1772	0.0017	II	CCD	59319.5	–0.00591	(11)
47996.379		I	v	47622.0	0.00855	(1)	53797.0733	0.0014	II	CCD	60004.5	–0.00501	(11)
48002.444		I	v	47635.0	–0.01644	(1)							

References: (1) Kreiner et al. (2000); (2) Yamasaki et al. (1983); (3) Van Cauteren & Wils (2000); (4) Dvorak (2004); (5) Nelson (2004); (6) Diethelm (2003); (7) Hubscher (2005); (8) Hubscher et al. (2005); (9) Krajci (2005); (10) Nelson (2006); (11) This paper.

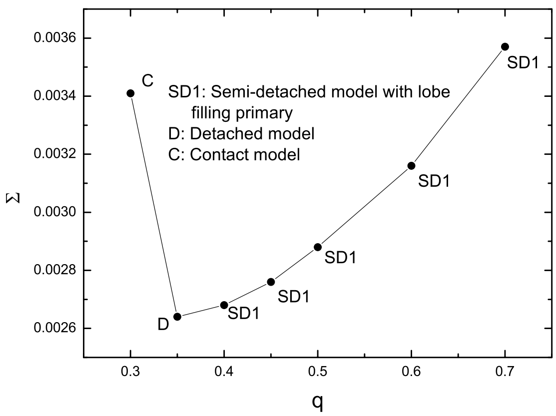

Fig. 3 Σ-q curve for UU Lyn.

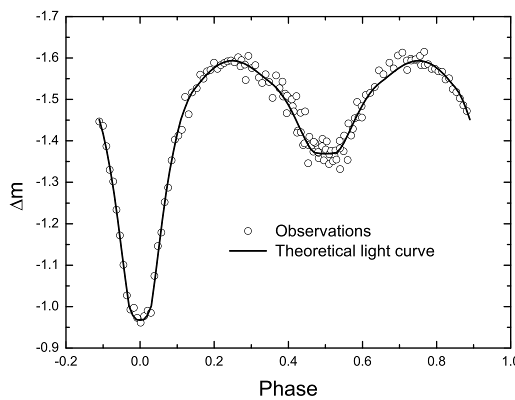

Fig. 4 Theoretical light curve of UU Lyn.

parameters are listed in Table 3 (Col. 2). Figure 4 shows the synthetic light curve (solid line) computed with these parameters. Our solution indicates that both components of UU Lyn have filled their lobes up to the parameter uncertainties, even though the photometric solutions converged to mode 2 (detached model, D). Our results agree well with that calculated by Yamasaki et al. (1983). Furthermore, as it is known that a third body may exist in many close binary systems, e.g., HL Aur (Gray et al. 1997; Qian et al. 2006), V502 Oph (Liu & Yang 2006), IR Cas (Zhu et al. 2004) and BF Vir (Qian 2000), we tested for a third light (l_3) in UU Lyn and it converged quickly in mode 3. The corresponding solution is given in Col. 3 of Table 3.

5 DISCUSSION AND CONCLUSIONS

The photometric solutions obtained by the latest Wilson-Van Hamme code show that UU Lyn is a marginal-contact binary with poor thermal contact just like some other near-contact binaries, such as ZZ Aur (Oh et al. 2006), GW Tau (Zhu & Qian 2006), CN And (Çiçek et al. 2005) and AD Cnc (Yang & Liu 2002). This result is well consistent with the conclusion by Yamasaki et al.(1983). Based on the results of period analysis, we find that the period of this system shows a long-term decrease at a rate of $dP/dt = -1.84 \times 10^{-8}\,\mathrm{d\,yr^{-1}}$, which implies that the mass will transfer from the primary to the secondary at the rate of $dM/dt = 1.5 \times 10^{-8}\,M_{\odot}\,\mathrm{yr}^{-1}$ under conservative mass transfer. Of course, the components of this target are rapid-rotation late-type stars and magnetic stellar wind will lead to angular momentum loss (AML). Therefore, the secular decrease of the period may result from a combined effect of mass transfer from the

Table 3 Photometric Solutions of UU Lyn

Parameter	Values without l_3	Values with l_3
$g_1 = g_2$	0.32	0.32
$A_1 = A_2$	0.5	0.5
$x_{1\mathrm{bol}}$	0.108	0.108
$x_{2\mathrm{bol}}$	0.313	0.313
$y_{1\mathrm{bol}}$	0.615	0.615
$y_{2\mathrm{bol}}$	0.366	0.366
$x_{1\mathrm{V}}$	−0.002	−0.002
$x_{2\mathrm{V}}$	0.545	0.545
$y_{1\mathrm{V}}$	0.732	0.732
$y_{2\mathrm{V}}$	0.240	0.240
i (deg)	86.6(2.6)	89.2(5.9)
T_1 (K)	6 700	6 700
T_2 (K)	4 804(50)	4 791(55)
q	0.35(1)	0.39(2)
Ω_{in}	2.5743	2.6529
Ω_{out}	2.3584	2.4158
Ω_1	2.5859(311)	2.6475(301)
Ω_2	2.5956(542)	2.6475(301)
$L_{1\mathrm{R}}/(L_{1R} + L_{2R})$	0.9170(4)	
$L_{1\mathrm{R}}/(L_{1R} + L_{2R} + L_{3V})$		0.9009(46)
r_1(pole)	0.4414(63)	0.4363(62)
r_1(side)	0.4719(84)	0.4661(83)
r_1(back)	0.4931(109)	0.4972(111)
r_2(pole)	0.2683(125)	0.2812(94)
r_2(side)	0.2789(147)	0.2932(113)
r_2(back)	0.3088(235)	0.3267(195)
The degree of overcontact*		2.3 %
Σ	0.00265	0.00268

$*$ The degree of overcontact $= (\Omega_{\mathrm{in}} - \Omega)/(\Omega_{\mathrm{in}} - \Omega_{\mathrm{out}})$

Table 4 Estimated Absolute Parameters of UU Lyn

	without l_3		with l_3	
	primary	secondary	primary	secondary
Mass ($M_\odot$)	2.1 (0.1)	0.74 (0.05)	1.6 (0.1)	0.62 (0.05)
Radius ($R_\odot$)	1.69 (0.06)	1.02 (0.11)	1.54 (0.06)	0.99 (0.08)
Luminosity ($L_\odot$)	5.16 (0.37)	0.50 (0.11)	4.28 (0.33)	0.46 (0.08)
Separation ($R_\odot$)	3.59 (0.05)		3.31 (0.06)	

primary component to the secondary and angular momentum loss of the system. Note, also, that this secular decrease may just be a part of a periodic variation. Our photometric solution in Section 4 suggests the possibility of a third light, and thus the periodic light variation in the O-C residuals due to light-time effect might exist. This needs further checking by more precise photometric minima.

Combining our derived photometric solution with the mass function ($f = 0.0496\,M_\odot$) given by Yamasaki et al. (1983), we calculated the absolute elements shown in Table 4. One can see in Table 4 that the primary component of this system is a main-sequence star according to Cox (2000), while the radius of the secondary seems to be a little larger than that of a main-sequence star with the same mass. With the period decrease, the mass ratio of this system increases and the separation between components decreases. UU Lyn will evolve from the present marginal contact phase to normal contact phase. Therefore, it may be a progenitor of contact binary with true thermal contact. On the other hand, as predicted by the theory of thermal relaxation oscillations (TRO, e.g., Lucy 1976; Flannery 1976; Robertson & Eggleton 1977; Lucy & Wilson 1979), W UMa systems must undergo oscillations around the state of marginal contact as a result of being unable to achieve thermal equilibrium. Thus UU Lyn might be such a system at the beginning of contact phase. It resembles some other systems, such as BL And, GW Tau (Zhu & Qian 2006), ZZ Aur (Oh et al. 2006), KQ Gem (Hilditch et al. 1998), CN And (Çiçek et al. 2005) and AD Cnc (Yang & Liu 2002), which lie in the key evolutionary phases. They are interesting targets for understanding the evolution of close binaries.

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References

Çiçek C., Erdem A., Soydugan F., 2005, AN, 326, 127
Cox A. N., 2000, Allen's Astrophysical Quantities (4th ed.; New York: Springer)
Diethelm, R., 2003, Inf. Bull. Variable Stars, 5438
Dvorak S. W., 2004, Inf. Bull. Variable Stars, 5502
Flannery B. P., 1976, ApJ, 205, 217
Gray J. D., Samec R. G., Carrigan B. J., 1997, AJ, 113, 2270
Geyer E., Kippenhahn R., Strohmeier W., 1955, Kleine Veröff. Remeis-Sternw. Bamberg, No. 11.
Götz W., Wenzel W., 1962, Mitt Veränderl. Sterne, No. 702
Hilditch R. W., Bell S. A., Hill G. et al., 1998, MNRAS, 296, 100
Hubscher J., 2005, Inf. Bull. Variable Stars, 5643
Hubscher J., Paschke A., Walter F., 2005, Inf. Bull. Variable Stars, 5657
Krajci T., 2005, Inf. Bull. Variable Stars, 5592
Kreiner J. M., Kim C. H., Nha I. S., 2000, An Altas of O-C Diagrams of Eclipsing Binary Stars, Wydawnictwo Naukowe Akademii Pedagogicznej, Cracow, Poland
Liu Q. Y., Yang Y. L., 2006, Chin. J. Astron. Astrophys. (ChJAA), 6, 331
Lucy L. B., 1976, ApJ, 205, 208
Lucy L. B., Wilson R. E., 1979, ApJ, 231, 502
Nelson R. H., 2004, Inf. Bull. Variable Stars, 5493
Nelson R. H., 2006, Inf. Bull. Variable Stars, 5672
Oh K. D., Kim C. H., Lee W. B. et al., 2006, MNRAS, 366, 1243
Qian S. B., Liu Q. Y., Yang Y. L. et al., 2000, AcASn, 41, 36
Qian S. B., 2002, MNRAS, 336, 1247
Qian S. B., Zhu L. Y., Boonruksar S., 2006, NewA, 11, 503
Robertson J. A., Eggleton P. P., 1977, MNRAS, 179, 359
Strohmeier W., Knigge R., Ott H., 1963, Kleine Veröff. Remeis-Sternw. Bamberg, No. 16.
Van Cauteren P., Wils P., 2000, Inf. Bull. Variable Stars, 4872
Van Hamme W., 1993, AJ, 106, 2096
Wilson R. E., Devinney E. J., 1971, ApJ, 166, 605
Wilson R. E., 1979, ApJ, 234, 1054
Wilson R. E., 1990, ApJ, 356, 613
Wilson R. E., 1994, PASP, 106, 921
Wilson R. E., Van Hamme W., 2003, Computing Binary Stars Observables, the 4th edition of the W-D program., Ftp: astro. ufl. edu, directory pub /wilson/lcdc2003
Yamasaki A., 1981, Ap&SS, 77, 75
Yamasaki A., Okazaki A., Kitamura M., 1983, PASJ, 35, 131
Yang Y. L., Li L. F., 1999, Publications of Yunnan Observatory, No. 1, 32
Yang Y. L., Liu Q. Y., 2002, Chin. J. Astron. Astrophys. (ChJAA), 2, 369
Zhu L. Y., Qian S. B., Xiang F. Y., 2004, PASJ, 56, 809
Zhu L. Y., Qian S. B., 2006, MNRAS, 367, 423