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RZ Pyx: A Special Short Period Detached Massive Binary with Two Cool Stellar Companions in a Quadruple System

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Abstract

RZ Pyx is one of a small group of short-period B-type eclipsing binaries with an orbital period of 0.656 days. Several new CCD times of light minimum of RZ Pyx were obtained. Together with all available photoelectric and CCD times of light minimum, the changes of the orbital period are investigated for the first time. Meanwhile, previously published light curves are reanalyzed with the Wilson–Devinney code. Based on the analysis of the O–C diagram, two cyclic variations with periods of 37.1 years and 9.7 years are discovered superimposed on a continuous increase at a rate of $dP/dt = +0.32 \times 10^{-7}$ day yr^{-1}. The light curve solutions suggest that RZ Pyx is a marginal detached binary system where both components do not overfill their respective Roche lobes. The fill-out factors of the primary and the secondary component are 95.5($\pm$0.8)% and 99.1($\pm$1.9)%, respectively, revealing that the secondary is nearly filling its Roche lobe. This may indicate that RZ Pyx has undergone a mass-transferring evolutionary stage and it is on the marginal detached stage temporarily. The long-term increase in the orbital period could be explained by the enhanced mass loss by stellar winds of the two detached massive components. Since the two binary components are early-type stars, the two cyclic oscillations could be plausibly interpreted as the results of the light travel-time effect caused by the presence of two additional companions. It is estimated that the masses of the two additional bodies are no less than 0.36 $M_\odot$ and 0.21 $M_\odot$, respectively. The two cool stellar companions are orbiting the central binary at orbital separations of 23.1 and 9.5 au in a quadruple stellar system. Both the marginal detached configuration and the presence of two cool stellar companions make RZ Pyx a very interesting binary system for further investigations.

Key words: binaries: eclipsing – binaries (including multiple): close – stars: evolution – stars: individual (..., ...)

Online material: color figure

1. Introduction

RZ Pyx (HD 75920, CPD $-27°3452$, CoD $-27°6009$) was found to be a short-period variable star by Hoffmeister (1936). Subsequently, Kaho (1937) found that this star was an RR Lyrae variable with a period of 0.4888 days from visual observations. However, photoelectric data were made by Kinman (1960) who pointed out that the spectral type was B7 and it was not an RR Lyrae variable and the author detected that RZ Pyx was an eclipsing binary system with a period of 0.65627 days. Breger (1968) made photoelectric observations and found that the light curve shows small asymmetry, which may be caused by the small systematic magnitude differences. About two decades later, the first modern photometric and spectroscopic study of RZ Pyx was carried out by Bell & Malcolm (1987a). The solutions, obtained by using the code LIGHT, suggested that the system was in a marginal contact configuration with components on the zero-age main sequence and the spectral type of the primary component may be in the range B3-4. The masses and radii of these two components were determined to be 5.3 $M_\odot$ and 4.3 $M_\odot$ and 2.61 $R_\odot$ and 2.44 $R_\odot$, respectively. The authors concluded that the age of the system was less then 2×10^6 years.

RZ Pyx belongs to a small group of early-type close binaries with periods shorter than one day. Some similar systems include V701 Sco (Bell & Malcolm 1987b), CT Tau (Plewa & Wlodarczyk 1993), BH Cen (Zhao et al. 2018), V593 Cen (Lanza et al. 1998), V758 Cen Cen (Lipari & Sistero 1984) and GU Mon (Lorenzo et al. 2016). Although some times of light minimum were published before, RZ Pyx has been neglected in period investigation so far. A period change analysis of RZ Pyx would provide valuable information on the evolutionary state of this short-period binary system. In this paper, by using a combination of our observations and previously published ones, the orbital period variation of the system RZ Pyx was

Table 1
Epochs and Orbital Periods of RZ Pyx

Epoch	Orbital Period	References
2428548.162	0.4888	Kaho (1937)
2436589.809	0.65627	Kinman (1960)
2438431.474	0.656273	Breger (1968)
2446522.33949	0.65627334	Bell & Malcolm (1987a)

studied. Based on the period change analysis, the formation and evolutionary state of the binary were investigated.

2. Orbital Period Variation of RZ Pyx

Epochs and periods of RZ Pyx had been given by several authors (e.g., Breger 1968; Bell & Malcolm 1987a) and are listed in Table 1. Since the time when Bell & Malcolm (1987a) pointed out that no evidence had been found for any period change, thirty years have passed. In order to analyze the period changes of this binary star, we observed the light minimum of RZ Pyx several times during the time interval from 2008 January to 2017 March. The telescopes used are the 1 m and the 60 cm telescope of Yunnan Observatories at Kunming, China (shorted as YNOs 1 m and YNOs 60 cm), the Sino-Thai 70 cm telescope in Lijiang station of Yunnan Observatories (YNOs 70 cm) and HSH 0.6 m telescope at Casleo in Argentina (HSH 60 cm). During those observations, the nearly standard Johnson-Bessel filter system was used. All the new minima are listed in Table 2 and some examples of minima are shown in Figure 1. All of the available photoelectric and CCD times of light minimum were collected and listed in Table 3. The third column of Table 3 shows the observational methods, where "Pe" refers to photoelectric, and "CCD" to charge-coupled device.

The $(O–C)_1$ curve of RZ Pyx was calculated using the linear ephemeris from Breger (1968),

$$\mathrm{Min}\, I = 2438431.471 + 0\overset{\mathrm{d}}{.}656273 \times E. \tag{1}$$

The $(O–C)_1$ value is shown in the sixth column of Table 3 and the corresponding $(O–C)_1$ diagram is plotted against the epoch number in the top panel of Figure 2. It is obvious that the orbital period of RZ Pyx is variable. As shown in the top panel of Figure 2, the general trend of the $(O–C)_1$ shows an upward parabolic change (dashed line in Figure 2) indicating a continuously increasing period. However, after the long-term continuous increase is removed from the $(O–C)_1$ curve, we find a cyclic oscillation in the residuals. Therefore, a cyclic term is added to the quadratic ephemeris to fit the observations (solid line in the Figure 2). A least-square solution leads to the following quadratic ephemeris,

Table 2
New Times of Light Minimum

Minmun (2400000+)	Err (days)	Band	Telescope
54483.5975	0.0005	V	HSH 60 cm
56340.19970	0.00029	B	YNOs 1 m
56340.19982	0.00027	Ic	YNOs 1 m
56340.19943	0.00026	No filter	YNOs 1 m
56340.19984	0.00030	Rc	YNOs 1 m
56340.19956	0.00025	V	YNOs 1 m
56673.25902	0.00010	B	YNOs 60 cm
56673.25895	0.00024	V	YNOs 60 cm
56673.25891	0.00012	Rc	YNOs 60 cm
56673.25928	0.00021	Ic	YNOs 60 cm
56673.25928	0.00018	No filter	YNOs 60 cm
57815.17674	0.00041	B	YNOs 70 cm
57815.17667	0.00039	V	YNOs 70 cm
57815.17663	0.00041	Rc	YNOs 70 cm
57815.17699	0.00040	Ic	YNOs 70 cm

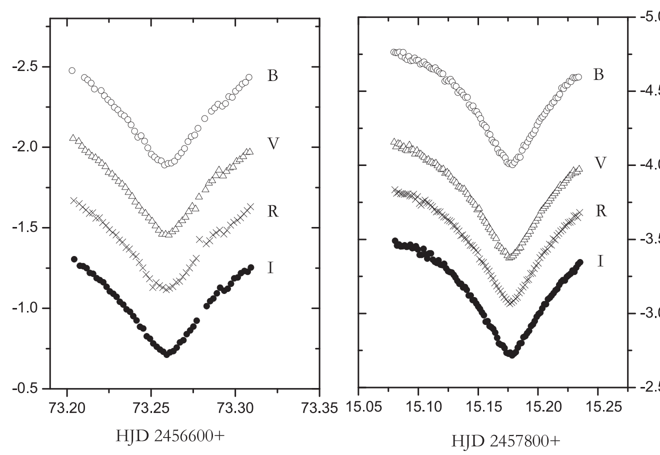

Figure 1. Two examples of minimum for RZ Pyx by using telescopes of YNOs.

$$\begin{aligned}\mathrm{Min}\, I = {} & 2438431.4706 + 0.6562732 \times E\\ & + 2.98 \times 10^{11} \times E^2\\ & + 0.00384 \sin[0\overset{\circ}{.}0175 \times E + 150\overset{\circ}{.}7].\end{aligned} \tag{2}$$

The fitting residual data of Equation (2) show another cyclic oscillation (listed in the bottom panel of Figure 2) by Fourier analysis of the residuals. Finally, a parabolic with two cyclic oscillations was used to fit the $(O–C)_1$ very well (shown in

Table 3
Photoelectric and CCD Times of Light Minimum of RZ Pyx

JD.Hel. 2400000+	Errors (days)	Method	Min.	E	$(O–C)_1$ (days)	Residuals (days)
36589.973		Pe	I	−2806	0.0040	0.0007
37006.3757	±0.0005	Pe	II	−2171.5	0.0015	−0.0009
37028.3618	±0.0004	Pe	I	−2138	0.0024	0.0001
38431.4739		Pe	I	0	0.0029	0.0002
44245.7195		Pe	II	8859.5	−0.0021	0.0002
46141.37207	±0.00008	Pe	I	11748	0.0059	−0.00001
46142.35512	±0.00012	Pe	II	11749.5	0.0045	−0.00137
46144.32599	±0.00008	Pe	II	11752.5	0.0066	0.00067
46493.46475	±0.00012	Pe	II	12284.5	0.0081	0.00109
46502.32279	±0.00022	Pe	I	12298	0.0064	−0.00057
46503.30816	±0.00010	Pe	II	12299.5	0.0074	0.00038
46521.35498	±0.00011	Pe	I	12327	0.0067	−0.00034
46522.33949	±0.00006	Pe	II	12328.5	0.0068	−0.00025
46523.32413	±0.00008	Pe	I	12330	0.0070	−0.00002
48333.0016	±0.0004	CCD	II	15087.5	0.0117	0.00064
48466.5529	±0.0005	CCD	I	15291	0.0114	−0.00025
51993.3697	±0.0003	CCD	I	20665	0.0172	0.00042
52001.5725	±0.0005	CCD	II	20677.5	0.0165	−0.00021
52075.4034	±0.0007	CCD	I	20790	0.0167	−0.00018
52097.3883	±0.0004	CCD	II	20823.5	0.0165	−0.00048
52636.1904	±0.0006	CCD	II	21644.5	0.0185	0.00019
52647.6752	±0.0003	CCD	I	21662	0.0185	0.00019
52660.8009	±0.0008	CCD	I	21682	0.0187	0.00041
52963.6704	±0.0005	CCD	II	22143.5	0.0182	−0.00058
53031.5951	±0.0004	CCD	I	22247	0.0187	−0.00020
53044.3928	±0.0003	CCD	II	22266.5	0.0190	0.00017
53055.2205	±0.0003	CCD	I	22283	0.0182	−0.00065
53378.7646	±0.0003	CCD	I	22776	0.0198	0.00084
54483.5975	±0.0005	CCD	II	24459.5	0.0171	−0.00010
56340.19967	±0.00037	CCD	II	27288.5	0.0229	0.00041
56673.25902	±0.00010	CCD	I	27796	0.02371	−0.00013
56673.25895	±0.00024	CCD	I	27796	0.02364	−0.00020
56673.25891	±0.00012	CCD	I	27796	0.02360	−0.00024
56673.25928	±0.00021	CCD	I	27796	0.02397	0.00013
56673.25928	±0.00018	CCD	I	27796	0.02397	0.00013
57815.17676	±0.00040	CCD	I	29536	0.02643	−0.00004

Figure 3). The solutions are

$$\begin{aligned}\mathrm{Min}\,I = {} & 2438431.470(\pm 0.001)\\ & + 0^{\mathrm{d}}.6562732(\pm 0.0000002) \times E\\ & + 2.9(\pm 0.9) \times 10^{-11} \times E^2\\ & + 0.00497(\pm 0.00132)\sin[0^{\circ}.0175(\pm 0.0034) \times E\\ & + 148^{\circ}.6(\pm 48^{\circ}.6)]\\ & + 0.00125(\pm 0.00021)\sin[0^{\circ}.0669(\pm 0.0045) \times E\\ & + 15^{\circ}.3(\pm 5^{\circ}.3)].\end{aligned} \tag{3}$$

The quadratic term in the ephemeris (dashed line in Figure 2) suggests a continuous period increase at a rate of $dP/dt = 0.32 \times 10^{-7}$ day yr^{-1}, which corresponds to a period increase of 0.27s per century. The residuals from the equation are displayed in the bottom panel of Figure 3.

The sinusoidal term in Equation (3) reveals two periodic change, where the first period is $P_3 = 37.1$ years with an amplitude of $A_3 = 0.00497$ days and the second period is $P_4 = 9.7$ years with $A_4 = 0.00125$ days, which are more easily seen in Figure 4 .

3. Photometric Solutions

The photometric light curves for RZ Pyx in *UBV* bands were first presented and analyzed by Bell & Malcolm (1987a) using the code LIGHT. The basis of LIGHT is the Roche geometry combined with Wood's (1971) elegant Gauss–Legendre quadrature scheme. The real limitation is that it would become very difficult when over-contact systems or spotted stars are modeled. During recent decades, the Wilson–Devinney Codes (W–D) are more and more popular to get solutions from light curves (Wilson & Devinney 1971; Wilson 1990, 1994;

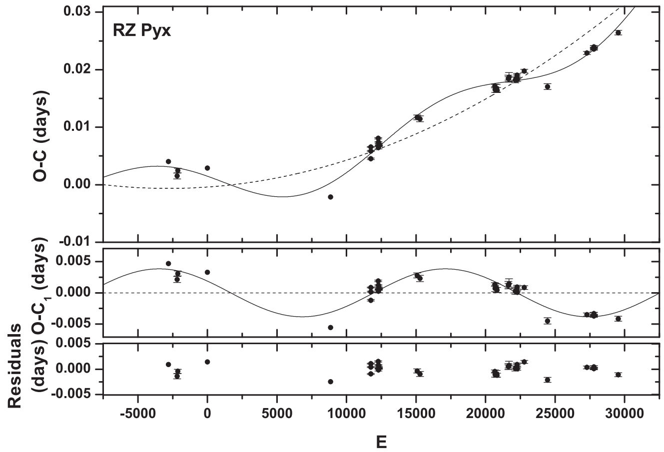

Figure 2. (O–C)$_1$ curve of RZ Pyx. Top panel: the solid line refers to a combination of a continuous period increase and a cyclic period variation, while the dashed line represents the long-term period increase. Bottom panel: the residual from Equation (2).

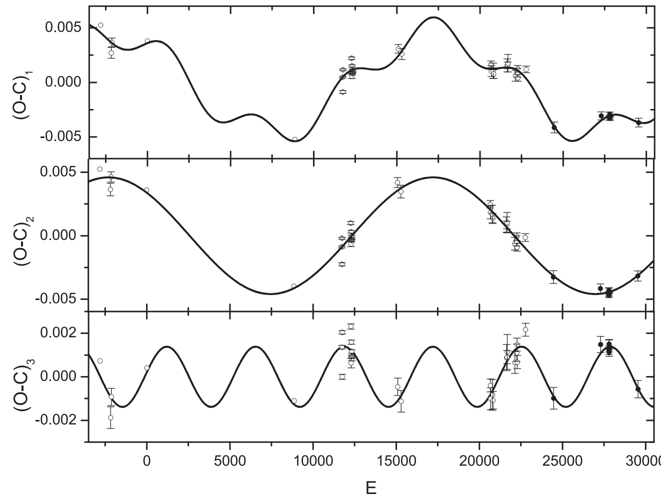

Figure 4. Two cyclic variations by removing the long-period continuous change from top panel of Figure 3. The open circles and black dots are the same as in Figure 3.

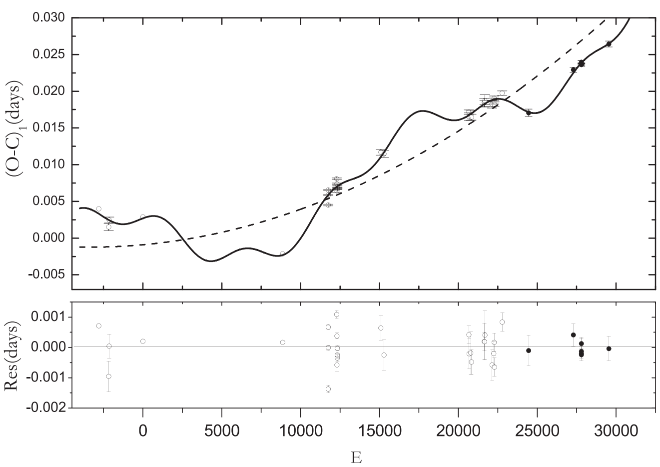

Figure 3. (O–C)$_1$ curve of RZ Pyx with a continuous period increase and two cyclic period variations. The solid line refers to a combination of a continuous period increase and two cyclic period variation while the red dashed line represents the long-term period increase in the top panel. The residuals from Equation (3) are displayed in the bottom panel. The open circles represent minima from literature and the black dots are observed by authors.

Van Hamme & Wilson 2003; Wilson 2012 and so on). While LIGHT had changed the light curve solver from simple differential corrections to the more sophisticated Marquardt algorithm, W–D Code uses the classical method of differential corrections with simplex algorithm to optimize light curve solutions, which belongs to a classic Newton-type method without second derivatives. As mentioned by Bell & Malcolm (1987a) and above, LIGHT is not well suited to the analysis of over-contact configuration and the solutions in different bands from LIGHT are independent. We have thus chosen to reanalyze the same light curves with the W–D code, as it is better at the analysis of multi-band synthesis light curves and can be used for all different binary models—detached, semi-detached and contact.

Because the mass-ratio has been obtained by Bell & Malcolm (1987a) from the spectroscopic study, we fix the mass-ratio at 0.82 in W–D. We adopt the same temperature of 17000 K for the primary component as Bell & Malcolm (1987a). Since the system is in a marginal contact configuration from the analysis by Bell & Malcolm (1987a), we have tried all possible models (detached, contact, semi-detached with primary or secondary filling out its Roche lobe) to fit the light curves. In all solutions, the gravity-darkening coefficient, $g_1 = g_1 = 1.0$ (Lucy 1967) and the bolometric albedo, $A_1 = A_2 = 1.0$ (Ruciński 1969), were adopted. Bolometric and bandpass limb-darkening coefficients are taken from Van Hamme (1993). The adjustable parameters are: the inclination (i), the mean temperature of star 2 (T_2), the monochromatic luminosity of star 1 (L_{1U}, L_{1B}, L_{1B}) and the dimensionless potentials of two components (Ω_1 or Ω_2). All different model solutions are listed in Table 4. According to the $\sum(\text{O–C})_i^2$, we can see that detached model has the lowest value. Therefore, we adopt model 2 as the best fitting model and plot it in Figure 5. The structure in phase 0.0, 0.25, 0.50 and 0.75 are plotted in Figure 6. From the parameters of model 2, we calculate the Roche lobe filling factors of the primary and secondary component as 95.5($\pm$0.8)% and 99.1($\pm$1.9)%, which means the secondary is nearly filling its Roche lobe. The parameter uncertainties stated in Table 4 are calculated from standard error estimates and obtained directly from the W–D code (Van Hamme & Wilson 2003). We leave them unchanged, however, it can be seen that they are clearly underestimated from the analysis of light curves in different

Table 4
The Solutions of RZ Pyx using WD Code

Parameters	Model 2	Model 3	Model 4	Model 5
g_1(fix)	1.0	1.0	1.0	1.0
g_2(fix)	1.0	1.0	1.0	1.0
A_1(fix)	1.0	1.0	1.0	1.0
A_2(fix)	1.0	1.0	1.0	1.0
q(M_2/M_1)(fix)	0.82	0.82	0.82	0.82
T_1(K)(fix)	17000	17000	17000	17000
T_2(K)	16526 ± 30	16483 ± 30	16472 ± 30	16537 ± 29
i (°)	88.7 ± 0.5	88.4 ± 1.0	88.9 ± 0.6	88.3 ± 0.2
$L_1/(L_1+L_2)_U$	0.5564 ± 0.0021	0.5649 ± 0.0005	0.5699 ± 0.0009	0.5513 ± 0.0012
$L_1/(L_1+L_2)_B$	0.5516 ± 0.0021	0.5596 ± 0.0005	0.5643 ± 0.0009	0.5467 ± 0.0012
$L_1/(L_1+L_2)_V$	0.5503 ± 0.0021	0.5582 ± 0.0005	0.5629 ± 0.0009	0.5456 ± 0.0013
Ω_1	3.49150	3.45107	3.45107	3.50090
Ω_2	3.46020	3.45107	3.46800	3.45107
Ω_{in}	3.45107	3.45107	3.45107	3.45107
Ω_{out}	2.991107	2.991107	2.991107	2.991107
r_1/a(pole)	0.3667 ± 0.0013	0.3728 ± 0.0026	0.3728 ± 0.0026	0.3656 ± 0.0011
r_1/a(side)	0.3851 ± 0.0029	0.3925 ± 0.0029	0.3925 ± 0.0029	0.3838 ± 0.0013
r_1/a(back)	0.4127 ± 0.0029	0.4228 ± 0.0029	0.4228 ± 0.0029	0.4110 ± 0.0018
r_2/a(pole)	0.3388 ± 0.0012	0.3397 ± 0.0042	0.3373 ± 0.0008	0.3397 ± 0.0013
r_2/a(side)	0.3549 ± 0.0014	0.3560 ± 0.0044	0.3531 ± 0.0011	0.3560 ± 0.0015
r_2/a(back)	0.3860 ± 0.0020	0.3875 ± 0.0045	0.3834 ± 0.0014	0.3874 ± 0.0019
filling(p,s)(%)	95.5(8), 99.1(1.9)	−, −	−,97.9(9)	94.3(7),−
$\sum(\text{O–C})_i^2(\times10^{-4})$	1.7972	2.1341	1.9620	1.9225

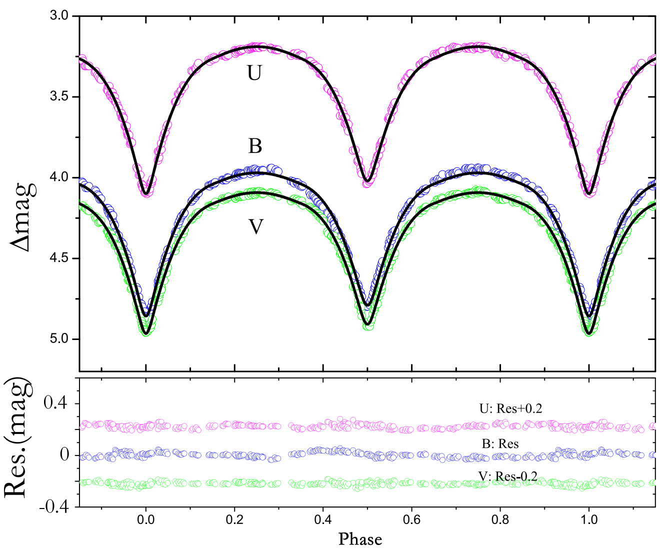

Figure 5. Theoretical light curve (solid lines) calculated by using the W–D code. The bottom panel shows the residuals obtained by removing the theoretical light curves.
(A color version of this figure is available in the online journal.)

bands. For example, the temperature of the secondary is 16543 K in the U-band, 16456 K in the B-band and 16465 K in the V-band, the range of temperatures which is clearly larger than the parameter error in Table 4. Among three bands, we could see that the error should be nearly 90 K, but that is only 30 K in Table 4 (Prša & Zwitter 2005).

4. Discussion and Conclusion

Photometric solutions derived by Bell & Malcolm (1987a) suggested that RZ Pyx was in a marginal contact configuration, but they did not pointed out which one fills out its Roche lobe. According to their solutions, the system was not a contact binary from the U-band and V-band observations, but the B-band solution suggested a marginal contact configuration. Using four models (detached, semi-detached with primary star filling out its Roche-lobe or secondary filling out its Roche-lobe and contact structure) to fit the light curves, we find the detached model has the best fitting, indicating this system is more likely a nearly contact binary with both components not filling their Roche-lobe. In this configuration, the secular period increase could not be interpreted by the mass transfer between components; instead, it may be due to the enhanced mass-loss from stellar wind. Due to there being no spectral observation, we could not obtain the masses of primary and secondary. From its temperature, the mass of primary is estimated about 5.9 $M_\odot$ (Cox 2000), which is close to the corrected solutions from Bell & Malcolm (1987a), so we adopt the mass and radii 5.8 $M_\odot$ and 4.7 $M_\odot$, 2.72 and 2.43 $R_\odot$. A calculation with the

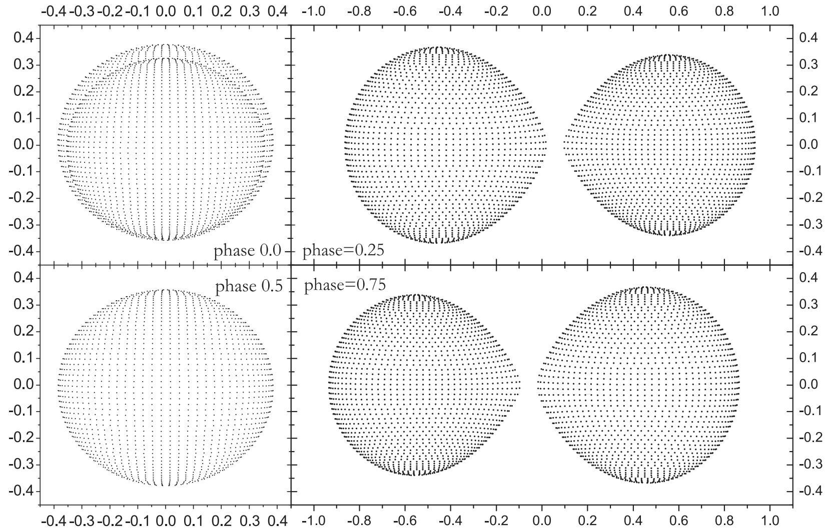

Figure 6. Geometrical structure of RZ Pyx at phases of 0.0, 0.25, 0.5, and 0.75, respectively.

formula proposed by Tout & Eggleton (1988) and Tout & Hall (1991),

$$\dot{M} = -4 \times 10^{-13} \frac{RL}{M} \left\{ 1 + 10^4 \left(\frac{R}{R_L} \right)^6 \right\}, \tag{4}$$

leads to the mass-loss rates by stellar wind for the primary and secondary component as, $\dot{M}_1 = 8.1 \times 10^{-7} M_\odot\,\text{year}^{-1}$ and $\dot{M}_2 = 9.5 \times 10^{-7} M_\odot\,\text{year}^{-1}$, respectively. With the well-known relationship (Hilditch 2001) between the orbital period change and mass loss rate,

$$\frac{\dot{P}}{P} = \frac{-2\dot{m}}{(m_1 + m_2)}, \tag{5}$$

it can be calculated that the orbital period is increasing at the rate of $\dot{P} = 2.4 \times 10^{-7}\,\text{day yr}^{-1}$ due to the stellar wind from primary and secondary. It appears that this is bigger than the period change obtained from the (O–C) diagram and they are not in the same order. Nevertheless, these differences probably arise from the complexity of stellar wind. Thus, it can not be denied that the period increase is due to the mass loss by stellar wind.

On the other hand, our photometric solutions indicate that the filling factor for the secondary is 99.1($\pm$1.9)%. This reveals that the secondary is nearly filling out its Roche-lobe within the error $\pm$1.9. With the error, it may fill out its Roche-lobe, and the long period change can be interpreted by the mass transfer from secondary component to primary on the thermodynamic timescale (τ_K) of the less massive component. The thermodynamic timescale is as follows,

$$\tau_K = 10^7 \times M_2^2/(R_2 L_2); \tag{6}$$

With the physical parameters determined by Bell & Malcolm (1987a), we can calculate that the thermodynamic timescale is about 1.8×10^5 years. So the rate of mass transfer could be estimated as $\dot{M}_2 = M_2/\tau_K = 2.4 \times 10^{-5} M_\odot\,\text{year}^{-1}$. A calculation with the following equation:

$$\frac{\dot{P}}{P} = 3\dot{M}_2 \left(\frac{1}{M_1} - \frac{1}{M_2} \right), \tag{7}$$

yields a period change of $2.1 \times 10^{-6}\,\text{day yr}^{-1}$. This is about two orders larger than the observed value ($dP/dt = 0.32 \times 10^{-7}\,\text{day yr}^{-1}$), revealing that the observed period change definitely can not be explained by thermodynamic mass transfer between the components. At the same time, we use this method to calculate the period change to be $5.0 \times 10^{-9}\,\text{day yr}^{-1}$ if it is the nuclear timescale. Therefore, it is possible that the marginal detached configuration of the system and the period increase is caused by the enhanced stellar wind.

To explain the evolutionary state of this binary, we try to propose an evolutionary scenario. The progenitor of RZ Pyx is a short-period detached binary system, and the present binary is formed from case A mass transfer as those observed for low-mass EWs (e.g., Qian et al. 2017, 2018). The more massive component evolved fast and filled out its Roche lobe first, so the mass transfer occurred from the more massive component to the less massive one. After the mass ratio reversed, the original more massive component becomes the less massive one and fills the critical Roche lobe. At the same time, the orbital period is increasing continuously, which causes the Roche lobe to expand. If the Roche lobe expands faster, the present less massive component may have detached from its Roche lobe temporarily and has a marginal-detached configuration. Both components are undergoing enhanced stellar winds that cause the period increase.

For the period analysis in Section 2, after removing the long term increase, there are also two cyclic oscillations, which are usually explained by magnetic activity (e.g., Applegate 1992; Lanza et al. 1998) or additional bodies (e.g., Irwin 1952; Liao & Qian 2010). RZ Pyx has two early-type component stars that presumably contain a convective core and a radiative envelope. This suggests that the small-amplitude period oscillation can not be explained by the magnetic activity cycle mechanism, which is usually proposed to explain the cycle period change of solar-type binary stars. Therefore, the light-travel time effect via the presence of a tertiary component is used to explain the periodic change of the orbital period (e.g., Chambliss 1992; Borkovits & Hegedüs 1996). Assuming that the third and fourth body are moving in circular orbits, the projected orbital radius of the eclipsing pair revolving around the whole system center can be calculated by the equation,

$$a'_{12}\sin i' = A_{3,4} \times c \tag{8}$$

where A_3 or A_4 are the amplitude of the O–C oscillations and c is the speed of light. Using the masses derived by Bell & Malcolm (1987a), a computation with the following equation,

$$f(m) = \frac{4\pi^2}{GP_{3,4}^2} \times (a'_{12}\sin i')^3, \tag{9}$$

leads to an extremely small mass functions of $f(m_3) = 0.00046\,M_\odot$ and $f(m_4) = 0.00011\,M_\odot$ for the additional bodies. G and $P_{3,4}$ in Equation (7) are the gravitational constant and the periods of the O–C oscillations. Finally, the values of the masses and the orbital radii of the additional components for different values of i' were estimated by the use of the following equation:

$$f(m) = \frac{(M_3\sin i')^3}{(M_1 + M_2 + M_3)^2}. \tag{10}$$

The minimum mass of the third and fourth companion are thus $0.36\,M_\odot$ and $0.21\,M_\odot$, which may be cool stars, and the separation between the binary and the additional companions are shorter than 23.0 au and 9.5 au with periods of 37.1 years and 9.7 years.

Based on the available photoelectric and CCD times of the light minimum, the orbital period of RZ Pyx is increasing at a rate of $dP/dt = 0.32 \times 10^{-7}$ day yr^{-1} and two cyclic period changes are discovered. Together with the detached configuration, it could be inferred that the period increase may be caused by the mass-loss from stellar wind. The fill-out factors of the two component may indicate that RZ Pyx may have undergone a mass-transferring evolutionary stage and it is on a special evolutionary stage where the less massive component is marginally detached from the Roche lobe temporarily. The orbital period shows two periodic oscillations with periods of 37.1 years and 9.7 years. We have shown that the mass of the two additional bodies are no less then $0.36\,M_\odot$ and $0.21\,M_\odot$, and the separation between the binary and the companions are 23.1 au and 9.5 au. That is similar to many other massive close binary stars, e.g., BH Cen, V701 Sco (Qian et al. 2006), V382 Cyg, TU Mus (Qian et al. 2007) and AI Cru (Zhao et al. 2010). Recently, more and more additional components are detected in binary systems and it is possible that the presence of additional bodies in binaries is a common phenomenon. To confirm this period increase and periodic oscillation, more data are required.

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